COASTAL RESILIENCE CENTER
A U.S. Department of Homeland Security Center of Excellence

Coastal Resilience Center of Excellence
Research Lead

based at

The University of North Carolina at Chapel Hill

YEAR 1 ANNUAL REPORT

Reporting Period:
July 1, 2015 – June 30, 2016

Award Number 2015-ST-061-ND0001-01

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US Department of Homeland Security
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Theme 4: Education and Workforce Development

Annual Report Summary

This report, which covers July 1, 2015, to June 30, 2016, provides a description of the accomplishments of the Coastal Resilience Center's (referred to as the Center and CRC in this report) first year of operations. Funding for the Center, provided by the Department of Homeland Security's Office of University Programs, was awarded in April 2015, education projects began in August 2015 and research projects began in January 2016. The Center is a consortium of universities, private companies and government agencies focused on applied research, education and transition of research findings to practice addressing threats to coastal communities due to natural hazards. The CRC will also consider future climate trends and their impacts on coastal resilience. The CRC currently encompasses 22 projects at 21 academic institutions in 12 U.S. states and one U.S. territory.

The first section of the report focuses on a general overview of accomplishments by Center Principal Investigators (PIs). The second section focuses on additional projects undertaken beyond those paid for through a five-year Department of Homeland Security grant. Organizational tasks related to setting up the Center's structure and operations are covered in greater detail in the Appendix.

Between July 1, 2015, and June 30, 2016, PIs at Coastal Resilience Center of Excellence made steady progress on their projects and set the stage for larger accomplishments in Year 2. Among the highlights:

- PIs taught 25 courses to nearly 350 students across seven campuses.
- Students were involved in nearly 30 Homeland Security-related internships.
- Nine students received Homeland Security-related degrees.
- Nine student secured employment in Homeland Security-related fields.
- Nearly 20 journals articles were published.
- PIs gave more than 130 presentations on Center projects.
- Center partners reported more than $700,000 in leveraged support and more than $9 million of external funding.

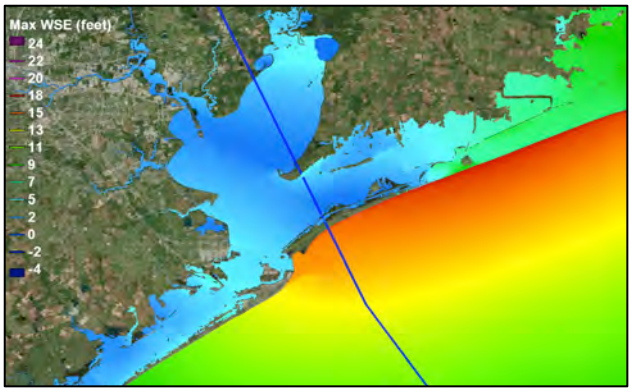
Highlights from this first year are included below. A full table of accomplishments can be found on page 13-14 of this report.

Research and Education Highlights

- PI Dr. Phil Berke was honored with his co-authors with an award for a paper assessing the degree to which the integration of plans of varied types support community resilience. Berke is first author of "Evaluation of Networks of Plans and Vulnerability to Hazards and Climate Change: A Resilience Scorecard," which was named Best Paper in Vol. 81, 2015, of the *Journal of the American Planning Association*.

- The University of North Carolina at Chapel Hill's Renaissance Computing Institute (RENCI) and the Georgia Institute of Technology are co-directing a national effort to develop a big data innovation hub serving 16 Southern states and the District of Columbia. The hub has locations in Atlanta and Chapel Hill. Three members of the Center - Lead Principal Investigator and UNC faculty member Rick Luettich; Principal Investigator and RENCI researcher Brian Blanton; and co-Principal Investigator and University of North Florida faculty member Stephen Medeiros – took part in a December 2015 meeting on the South Big Data Regional Innovation Hub at Georgia Tech.

- ADCIRC modeling data provided by co-PIs Bruce Ebersole of Jackson State University and Clint Dawson at the University of Texas-Austin were used in a multimedia report, "Hell and High Water," published by the website ProPublica and the Texas Tribune. The report looked at the multiple potential paths of 2008's Hurricane Ike, as calculated by ADCIRC, and the potential of another storm of that strength in the future. In a companion piece, the authors discussed how they used ADCIRC data to create the interactive piece.



Hurricane Ike storms path as displayed on the CERA website.

- PI Dr. Jen Horney had an article accepted for publication in the journal *Disasters*. The manuscript, titled "Developing indicators to measure post-disaster community recovery in the United States," was co-written by fellow CRC PIs Phil Berke and Gavin Smith.

- PI Ismael Pagan-Trinidad led a group of engineering students who recently took first prize in a regional competition to build the best concrete canoe and other designs. At the March 2016 American Society of Civil Engineers (ASCE) Southern Student Conference in Tuscaloosa, Ala., The University of Puerto Rico at Mayaguez (UPR-M) engineering students took overall first prize in a competition that judges all aspects of vessel design and use. While the University of Florida won the boat race, UPR-M won first prize in eight categories plus the overall prize. The team then picked up several top-5 awards at the American Society of Civil Engineers Concrete Canoe Championship, held in June 2016 in Tyler, Texas.

- The Center, in partnership with the Department of City and Regional Planning at the University of North Carolina at Chapel Hill (DCRP), co-sponsored a graduate certificate program in the study of Natural Hazards Resilience. As part of this effort, Director Gavin Smith taught a Natural Hazards Resilience Speaker Series seminar

Former Governors James B. Hunt, Jr. (NC) and Haley Barbour (MS) discuss state roles in recovery.

course that involved talks by internationally recognized scholars and policymakers during the Spring 2016 semester. Speakers included Dennis Wenger, former Program Director of Infrastructure Systems Management and Extreme Events at the National Science Foundation; and William H. Hooke, Associate Executive Director and Senior Policy Fellow at the American Meteorological Society, and FEMA Administrator Craig Fugate.

- In January, Lead Principal Investigator Rick Luettich was re-appointed by Louisiana Governor John Bel Edwards of the Southeast Louisiana Flood Protection Authority–East Board of Commissioners. The Authority covers three consolidated districts: East Jefferson Levee District, Orleans Levee District, and Lake Borgne Basin Levee District, and ensures the physical and operational integrity of the regional flood risk management system.

- **'**An instructional video and accompanying guide, "The Role of States in Disaster Recovery," created by Director Gavin Smith, has been completed and posted on the Coastal Resilience Center of Excellence website. The project was co-funded by the CRC and the Federal Emergency Management Agency (FEMA), and includes interviews with former Governors James Hunt and Haley Barbour along with other state-level officials who played an active role during initial recovery periods following hurricanes Floyd and Katrina. The film focuses on the unique role of states in preparing administrative and other infrastructure in advance of and after disasters. It can be viewed at http://coastalresiliencecenter.unc.edu/crc-projects/the-role-of-states-in-disaster-recovery.

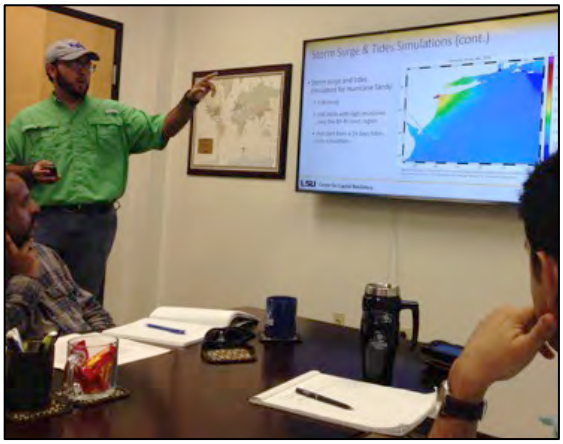
- **SUMREX**

In the first year of the project, the Center offered several opportunities for students at its partner schools. This included a popular and successful effort to match students at education partner institutions with experiences at research project institutions during the summer of 2016.

The Summer Research Experience (SUMREX) program provides students that are part of the CRC education partner-affiliated universities an opportunity to work with CRC research partners. The SUMREX program has three objectives:

- Provide meaningful summer research experiences with CRC research partners for students from CRC education partners.
- Foster collaboration and integration among CRC research and education projects.
- Encourage student/professor relationships that could lead to graduate studies at CRC research partners.

The SUMREX program has already proven to be highly successful, with seven students from Education Projects at the three CRC Minority Serving Institutions having initiated SUMREX internships at four CRC Research partner universities. Additionally, a student from the Education Project at LSU planned an internship during July and August with a Research University partner. These seven student internships are summarized below.



1. University of Puerto Rico, Mayaguez students (Mr. Diego Delgado Tamariz and Mr. Kevin Cueto Alvarado) to Oregon State University (Dr. Dan Cox, professor)
2. Tougaloo College students (Ms. Taralyn Rowell and Ms. Renia Ball) to University of Delaware (Dr. Rachel Davidson and Dr. Joseph Trainor, professors).
3. University Puerto Rico, Mayaguez student (Mr. Felix Santiago-Collazo) to Louisiana State University (Dr. Scott Hagen, professor) and to University of North Florida (Dr. Stephen Medeiros, professor) for 5 weeks each.
4. Jackson State University student (Mr. Xuesheng Qian) to University of Texas, Austin (Dr. Clint Dawson, professor)
5. Louisiana State University student (Mr. Rudy Bartles) to University of North Florida (Dr. Donald T. Resio, professor) during July and August.

A detailed report on these student internships, ending in August 2016, will be included in the Year 2 Report along with a description of the 2017 SUMREX internships underway. A summary of the summer 2016 activities is available at http://coastalresiliencecenter.unc.edu/students-reflect-on-summer-research-and-internships/.

The CRC also hosted a guest faculty member and student from Benedict College, in Columbia, S.C., at UNC-Chapel Hill as part of the DHS Summer Research Team Program for Minority Serving Institutions. Reinaldo Santiago, a rising senior at Benedict, worked with Dr. Anton Bezuglov and CRC PI Dr. Brian Blanton on testing artificial neural networks for applicability in storm surge modeling.

- *The Research Talk program, or RETALK*, involves research PIs delivering an in-person talk to students at a CRC education partner. The talk may be a lecture, seminar, or other type of presentation. Considering the breadth of coastal resilience, the CRC encourages research PI's to discuss research projects not only in disciplines similar or complementary to ones being taught by the education partner, but also those that may offer enrichment opportunities by exposing students to other scientific or

Dr. Wie Yusuf of Old Dominion University gave a lecture at Johnson C. Smith University as part of RETALK, which began in Year 1.

technical areas. The RETALK program has four objectives:

- Disseminate knowledge about CRC research partners and their activities to students from CRC education partners.
- Foster collaboration and integration among CRC research and education projects.
- Encourage interest among students from CRC education partners in graduate studies at CRC research partners.
- Strengthen the SUMREX program by enhancing relationships between CRC research and education Principal Investigators (PI's).

- *The Career Development Grant (CDG) and Science and Engineering Workforce Development (SEWD) Grant* program has funded four students at the University of North Carolina at Chapel Hill who are pursuing the 10-credit hour UNC-based Natural Hazards Resilience Certificate (which is one of the CRC education projects) and agree to work in the field upon graduation for not less than two years. Additional requirements include attending two professional conferences and interning over two summers in select organizations.

The first CDG student, and first recipient of the Natural Hazards Resilience Certificate, Lea Sabbag, graduated in the summer of 2016. During her time in the program she interned at the North Carolina Division of Emergency Management and Maui County Hawaii. Since graduation, Lea has accepted a position with North Carolina Division of Emergency Management, where she is coordinating housing-related policy issues following Hurricane Matthew. Ashton Rohmer, who is beginning her second year in the program interned this summer with the Department of the Interior in Washington, D.C. Two incoming students, Darien Williams and Colleen Durfee will begin the program in the Fall of 2016.

Students from UNC-Chapel Hill toured the North Carolina Emergency Management Emergency Operations Center as part of a spring 2016 class.

Jackson State University provided funding for two master's-level students beginning in the Spring 2016 semester, with a third being funding in the Summer of 2016. One graduate is a full-time employee in the greater Homeland Security Enterprise (U.S. Army Corps of Engineers, Vicksburg District). Two students had the unique internship experience of performing research in The Netherlands for two weeks with students from Texas A&M University, Galveston (TAMUG); Rice University; Texas A&M University, College Station; and the Technical University of Delft. The other student's summer research internship focused on tides in the Gulf of Mexico and characteristics of tidal propagation into rivers, bays and estuaries on the Gulf coast

Additional projects

DHS Flood Apex Program

The Department of Homeland Security Science and Technology Directorate (S&T) First Responder Group has initiated the Flood Apex program. The goal of this program is to save lives, reduce property loss, and enhance resilience to disruptive events through the creation and application of a decision support system-of-systems for community risk assessment and resilience planning. The community-centric resilience metrics and modeling capabilities enabled by the Flood Apex program will support the development of a National Flood Decision Support Tool (NFDST).
The CRC has been tasked with supporting the Flood Apex project by:

- Organizing and overseeing a Research Review Board for the current phase of the Flood Apex program
- Conducting an independent landscape review to provide background and scope for the development of the NFDST
- Framing, soliciting and conducting research projects as needed to support the development of the NFDST
- Providing academic and scientific expertise to the Flood Apex program

Storm Surge Protection for Houston Galveston Bay Area

Since 2013, the Center partners at Jackson State University (JSU) have been part of a multi-university international team, funded by local interests, that is investigating the technical and economic feasibility of a hurricane surge barrier to protect the area surrounding Galveston Bay in Texas. As part of this effort, they established a Cooperative Research and Development Agreement with the Engineer Research and Development Center to support JSU's application of the ADCIRC storm surge model and analysis of surge statistics generated for FEMA's Risk Map study of the area. During the period covered by this Annual Report, JSU's work was critical in establishing a broad consensus among government and business interests that the surge barrier should consist of a "coastal spine" that prevents hurricane surge from entering Galveston Bay. Their work also helped attract a 5-year, $3.6 million National Science Foundation PIRE (Partnerships for International Research and Education) grant to investigate integrated, multi-scale approaches to coastal flood risk reduction. In May, 2016, three JSU graduate students were part of a 12-student PIRE team led by Texas A&M University-Galveston that spent 2 weeks in The Netherlands working with students and experts there on various aspects of planning, designing, and implementing integrated flood risk reduction.

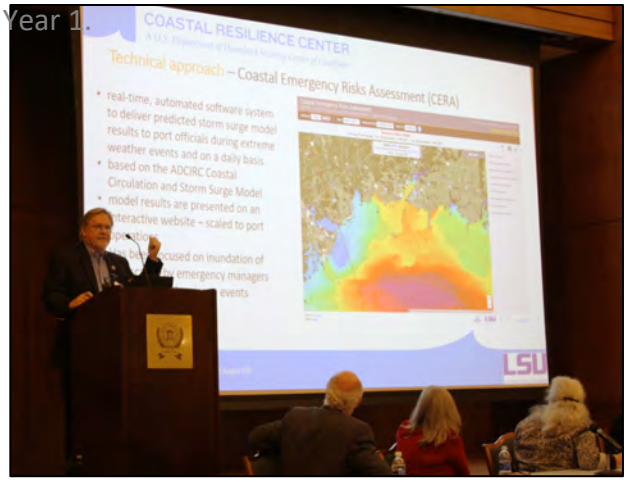
Maritime Risk Symposium

Invited university, governmental Federal, state, university and private sector officials will gather this fall to discuss the intersection of homeland maritime security and coastal resilience. The 7th Maritime Risk Symposium (MRS 2016) will be held on Nov. 14-15 at the University of North Carolina at Chapel Hill, hosted by the Department of Homeland Security's Coastal Resilience Center of Excellence.

The event brings together leading researchers and practitioners in the maritime and across multiple homeland security sectors to build networks, identify gaps in current capabilities and generate ideas for future research projects. The event will focus on "Integrating Maritime and Coastal Resilience." MRS 2016 will encourage practitioners to identify pressing needs in their fields and inspire researchers to think beyond their current focus. Working together, organizers seek to define a research horizon that will enhance maritime and coastal resilience to disturbances that are both natural and man-made.

While research projects were operating for about six months of the project reporting period, opportunities for transition and related plans will naturally expand in Year 2.

Dr. Robert Twilley speaks during the Maritime Risk Symposium, for which planning began in Year 1.



Partnerships

Below is a list of potential and developing partnerships begun during the first project year.

Potential new partner/customer	**How partnership was formed**	**Scope of potential partnership (if available)**
Environmental Protection Agency	Gavin Smith connected with Chris Weaver – Global Climate Research Program; Brendan Doyle/Shawn Ryan of National Homeland Security Research Center	Chris Weaver to speak in Spring Speaker Series Class at UNC-CH; Exploring linkage to EPA's work in the National Disaster Recovery Framework (see previously funded work with EPA and FEMA

National Governors' Association	Gavin Smith connected with Alicia Powell of NGA Center for Best Practices	CRC working with NGA to solicit funding to develop Governor's Policy Academy; drawing on previous work funded through BOA-Role of States in Recovery; expected start of project Spring 2017 (filmed interviews with Governors, advising Governors and their staff through training workshops)
Gulf Coast Community Design Studio	Gavin Smith connected with David Perkes	Disasters and Design student exchange and guest lectures (ongoing through Natural Hazards Certificate Program; invitation to CRC Disasters and Design project - start date October 2016.
Argonne National Lab	Discussions between Duane Verner and Leslie-Anne Levy of ANL and CRC leadership; scope of work has been submitted and CRC is awaiting confirmation	Work on impact of storm surge and climate change on infrastrcture in NY/NJ area
Bushfire and Natural Hazards CRC (Australia)	Gavin Smith connected with Michael Rumscewicz (Research Director) and Richard Thornton (Executive Director); spoke at international conference	Gavin Smith is part of International Science Panel, submitted LOI in October in partnership with Macquarie University to conduct international lesson drawing focused on catastrophic disaster planning. Bushfire Center and other Australia universities part of proposed international learning lab.
LSU Coastal Sustainability Studio	Gavin Smith connected with Jeff Carney	Jeff will speak in Spring Speaker Series (October) at UNC-CH; member of Disasters and Design Project expert panel (October start date)
DOI - National Park Service	Gavin Smith connected with Thomas Sheffer, Patrick Gregson	Possible training of NPS staff; CDG Student Ashton Rohmer interned there this summer-future internship location for Certificate students
American Shore and Beach Preservation Association	Tom Richardson connected with leadership	CRC is sponsor (non-monetary) of annual conference
American Planning Association	Gavin Smith is a member and founding member of the HMDR Planning Division	Development of Hazard Mitigation and Disaster Recovery Division with Jim Schwab-venue

		to transfer research findings to practice-particularly planning-related work which has been done re the Hazard Mitigation Planning and Disaster Recovery Planning Research; training venue for NDPTC Recovery Course developed by Smith.
American Institute of Architects	David Perkes AIA Leadership in Disaster Resilient Subcommittee	Involvement in Disasters and Design Project (October start date)
Housing and Urban Development	Gavin Smith connected with Kevin Bush (Resilience Team Lead), Scott Davis	Post-Doc opportunities; internship opportunities; Exploring grant opportunities
NOAA	Center has connections with Todd Davidson, Adam Stein, Margaret Davidson	Submitting proposal through CRC (October 2016) w Mai Nguyen DCRP at UNC-CH Faculty and CRC Associate
UNC-Ashville National Environmental Modeling and Analysis Center	Gavin Smith connected with Jim Fox	Jim Fox will write article in Carolina Planning Journal (UNC-CH) Special Edition on Resilience
WeatherFlow	Discussions of partnership within state of Texas	CRC has partnered with WeatherFlow on a proposal to the Texas Windstorm Insurance Association and are waiting to learn if our team is selected
	Discussion of partnership within state of Florida	CRC is discussing performing storm surge forecasts for the Florida Electric Utility Management Authority
EXPLORING OPTIONS		
Federal Emergency Management Agency	Gavin Smith connected with Thomas Muller, Professor in the Department of Earth Sciences at the California University of Pennsylvania; Shane Hubbard-formerly at Polis Center	Potential HAZUS Center of Excellence run in partnership with CRC; Reached out to John Pine for CRC Advisory Board insights (John is an expert in the use of HAZUS)
Sandia National Lab	Gavin Smith connected with Lori Parrott, Theresa Brown	
Sea Grant (NC, LA, MS, FLA, RI)	Center connecting through NC Sea Grant Director Susan White	
NC College of Design	Gavin Smith connected with Andy Fox and David Hill	Possible student exchange and involvement in UNC-CH graduate certificate; Involved in Disasters and Design Project (start date October 2016)

UNC Kenan-Flagler School of Business	CRC connected with Ted Zoller	Discussion of business plan for the Center through faculty-led program
DOI Southeast Climate Science Center	Gavin Smith connected with Gerrard McMahon (Director) and Ryan Boyles	Meeting with DOI SECC to explore opportunities; Ryan regular spaeaker in Certificate Program
Climate Central	Gavin Smith connected with Tim Grandia	Writing proposal to be run through CRC with Mai Nguyen, DCRP Faculty at UNC-CH and CRC Associate
South Florida Water Management District	Discussion between ADCIRC team and district	Potential transition of ADCIRC for their in-house use for performing storm surge forecasts. Team member Jason Fleming traveled to the SFWMD and provided a multi-day tutorial on the use of ADCIRC.

Administrative Activities

See the Appendix for more information on this section.

Performance metrics

CRC Performance Metrics				
Metric	**Research Project**	**Education Project**	**Center**	*Total*
Courses/certificates developed, taught, and/or modified		25		*25*
Enrollments in Center-supported courses/certificates		342		*342*
HS-related internships (number)		28		*28*

Undergraduates provided tuition/fee support (number)		1		*1*
Undergraduate students provided stipends (number)	1	52		*53*
Graduate students provided tuition/fee support (number)	16	11		*27*
Graduate students provided stipends (number)	15	10		*25*
Undergraduates who received HS-related degrees (number)		9		*9*
Graduate students who received HS-related degrees (number)		9		*9*
Certificates awarded (number)				
Graduates who obtained HS-related employment (number)	1	8 (2R, 6E)		*9*
SUMREX program students hosted (number)	4			*4*
Lectures/presentations/seminars at Center partners (number)	8	3		*11*
DHS MSI Summer Research Teams hosted (number)	2			*2*
Journal articles submitted (number)	5	5		*10*
Journal articles published (number)	11	8		*19*
Conference presentations made (number)	45	7		*52*
Other presentations, interviews, etc. (number)	37	46		*83*
Patent applications filed (number)				
Patents awarded (number)				
Trademarks/copyrights filed (number)				
Requests for assistance/advice from DHS agencies (number)	13	6		*19*
Requests for assistance/advice from other Federal agencies or state/local governments (number)	23	18		*41*
Total milestones for reporting period (number)	62	26		*88*
Accomplished fully (number)	39	21		*60*
Accomplished partially (number)	24	7		*31*
Not accomplished (number)	3			*3*
Product/s delivered to end-user/s (description and recipients)	See Table			
External funding received	$6,900,035.19	$2,455,591		*$9,355,626.19*
Leveraged support	$496,623.90	$230,916		*$727,539.90*
Articles on Center-related work published on website (number)			26	*26*
Coverage in media, blogs (number)			12	*12*
New social media followers (number)			283	*283*
Posts to social media accounts (number)			621	*621*
Events hosted (number)			30	*30*
Website hits (number)			5,866	5,866

Theme 1

Coastal Infrastructure Resilience

WALLACE, RPI

DHS Coastal Resilience Center

Research Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Community Supply Resiliency (COMSURE)

2. **Principal Investigator / Institution:** William A. Wallace, Yamada Corporation Professor, Industrial & Systems Engineering (ISE), Rensselaer Polytechnic Institute (RPI)

3. **Other Research Participants/Partners:** John Mitchell, Professor, Mathematical Sciences, RPI; Thomas Sharkey, Associate Professor, ISE, RPI; Richard Little, Research Scholar, ISE, RPI

4. **Short Project Description ("elevator speech"):** The resilience of a coastal community to an extreme event depends, to a large extent, on the degree to which critical services can be maintained during the event or restored in its aftermath. In addition to the utilities on which we rely such as power, water, and communications, there are critical commercial services such as banking and food, drug, and fuel distribution that are equally important to community resilience. COMSURE, Community Supply Resiliency, will improve our understanding of how the supply chains for these critical commercial services are impacted by extreme events so that they, and the communities they serve, can be restored quickly following such an event.

5. **Abstract:** The capability of communities to withstand and recover from the disruptions of extreme events will determine, to a large extent, the degree to which the social, economic, and psychological impacts of these events can be reduced. It is well recognized that civil infrastructures (e.g., transportation, power, water supply and sewerage, and communications) are critical to the wellbeing of a community; our past work has focused on these systems. However, it is the social infrastructures (e.g., emergency response, banking, and food, drug, and fuel distribution) that play a crucial role in societal functioning; the availability of these systems following an extreme event is a key element in determining the resilience of a community. Therefore, the objective of the proposed research is to better understand, describe, and portray the supply chains that provide the goods and services needed to respond to and recover from an extreme event, such as a hurricane impacting a coastal community. With this knowledge, models and algorithms will be developed to support emergency management in planning, community development, training and education, thereby enhancing community supply resiliency.

6. **End users:** The primary end users for our research will be local emergency managers and DHS analysts who can use the tool to improve policies that affect community resilience to extreme events. The tool will also be made available to private sector service providers interested in improving the resilience of their supply chains. Based on feedback from Federal reviewers

following the CRC Annual Meeting in March, we will also reach out to universities offering programs in emergency management to determine how best to incorporate the tool as a training aid into the curriculum. Our research continues to draw heavily upon our association with Warren Lee, Emergency Manager for New Hanover County, NC. We have collected data on the supply chains for the goods and services provided by the social infrastructures in this county, focusing particularly on end-point customer interactions. This information will ultimately be incorporated into CLARC, the artificial coastal community of 500,000 citizens created for our research and analyses. In addition to meetings with DHS's Office of Cyber & Infrastructure Analysis to present our decision support tool MUNICIPAL for their review, we also have had discussions with representatives of the food and drug sector in New Hanover County, and discussed the project at length with Healthcare Ready, a service organization dedicated to improving the resilience of pharmaceutical supply chains.

7. **Explanation of Changes:** At the request of DHS project management, the MUNICIPAL/COMSURE technology was highlighted at the DHS Technology Showcase on May 20, 2016 and exploratory efforts were undertaken with the Texas Department of Homeland Security and the City of Austin to determine if the MUNICIPAL/COMSURE technology was appropriate to the needs of Austin, TX.

8. **Unanticipated Problems:** No unanticipated problems have been encountered.

9. **Project Outcomes:** The primary objective of the research associated with COMSURE is to improve our understanding of how community resilience is affected by interdependent interactions of social and civil infrastructures during extreme events. This is to be accomplished by visualization and mathematical representations of the supply chains for critical commercial services (banking, food, fuel, and drugs). Research to date on infrastructure and resilience has focused primarily on utilities or civil infrastructure (water, power, communications, and transportation). The role of critical commercial services is largely unstudied and what work exists is anecdotal. This is particularly true for the end-of-chain customer interactions that directly affect people. A better understanding of these complex interactions will assist emergency managers, utility service providers, and other key decision makers in determining what assets should be hardened against damage and what should be the priorities for service restoration following an extreme event so that the most critical services are made available in the shortest possible time. A beta-level version of MUNICIPAL has already been assessed within New Hanover County and determined to have great potential as a planning and training tool. COMSURE, when incorporated into the existing MUNICIPAL architecture, will bring a powerful new capability to the emergency management community. If incorporated into university curricula for emergency management, it also has the potential to make the next generation of EM professionals more comfortable and conversant with computer-aided decision support tools for planning and training purposes.

10. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Data Collection	4/1/16	100%	The data collected were the locations of major groceries, pharmacies, banks, and convenience stores in New Hanover County. Street addresses were obtained from individual corporate websites and converted to GPS coordinates for use in the MUNICIPAL database.
Visualization of Supply Chains	5/1/16	80%	Visualization has not been completed because of technical issues in the software interface between the mapping software (ArcGIS) and the database (Access) formats. Anticipated completion date is 7/31/16.
Assessment	6/1/16	100%	The data collection effort was followed up by discussions with representatives of the food, pharmaceutical, fuel, and banking industries to review the research team's understanding of the individual supply chains, their dependence on civil infrastructures, and industry practice for preparedness, response, and recovery from extreme events. Based on the feedback to the proposed approach received in these discussions, normative rules for populating the artificial community CLARC with commercial services were developed and will be applied during testing of the updated software.
Research Milestone			

Report on results of data collection and visualization	6/30/16	60%	Data collection is completed but final report cannot be completed until visualizations are finalized. Anticipated completion date is 8/15/16.

11. Transition Activity and Milestone Progress:

No transition activities were proposed at this stage of the project. However, at the request of DHS project management, two activities were added; the DHS Technology Showcase in Washington, DC and exploratory efforts with the Texas Department of Homeland Security and the City of Austin to determine if the MUNICIPAL/COMSURE technology was appropriate to the needs of Austin, TX.

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
May 20 DHS Showcase in Washington, DC	5/20/16	100%	
Exploratory efforts with the Texas Department of Homeland Security and the City of Austin to determine if the MUNICIPAL/COMSURE technology was appropriate to the needs of Austin, TX.	4/30/16	100%	
Transition Milestone			
Participation in the DHS Technology Showcase	5/20/16	100%	
Phone conference with Texas DHS and the City of Austin	4/12/16	100%	Discussions were initiated with the Texas DHS and the City of Austin in late 2015 to determine if MUNICIPAL was a suitable tool for the Agency and City to use in a vulnerability and response and recovery exercise. Although it was agreed that MUNICIPAL was potentially useful in this capacity, modifications to incorporate the HSIP Gold dataset were necessary and no funding source to do this was identified. Negotiations concluded with the understanding that if the necessary modifications to MUNICIPAL were eventually completed, the potential for a

			working relationship would be revisited.

12. **Interactions with education projects:** There has been no involvement to date with the CRC's MSI education partners. However, based on feedback from Federal reviewers following the CRC Annual Meeting in March, we plan to reach out to the MSI education partners offering programs in emergency management to determine how COMSURE might best incorporated into the curriculum as a training aid.

13. **Publications:** No publications were anticipated at this stage of the project and none are currently underway.

14. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)	--		
Undergraduates provided tuition/fee support (number)	--		
Undergraduate students provided stipends (number)	--		
Graduate students provided tuition/fee support (number)	--		
Graduate students provided stipends (number)	1		
Undergraduates who received HS-related degrees (number)	--		
Graduate students who received HS-related degrees (number)	--		
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)	--		
SUMREX program students hosted (number)	--		
Lectures/presentations/seminars at Center partners (number)	1		
DHS MSI Summer Research Teams hosted (number)	--		
Journal articles submitted (number)	--		
Journal articles published (number)	--		
Conference presentations made (number)	--		
Other presentations, interviews, etc. (number)	2		
Patent applications filed (number)	--		
Patents awarded (number)	--		
Trademarks/copyrights filed (number)	--		
Requests for assistance/advice from DHS agencies (number)	1		
Requests for assistance/advice from other Federal agencies or	1		
Total milestones for reporting period (number)	3		
Accomplished fully (number)	2		
Accomplished partially (number)	1		
Not accomplished (number)	0		
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
N/A			

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
N/A			
Leveraged Support			
Description			Estimated Annual Value
Office Space			$8,000
6-week stipend for Graduate Student			$10,380
Visiting Research Scholar			$21,600

BENNETT, RPI

DHS Coastal Resilience Center

Research Project

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Establishment of a Remote Sensing Based Monitoring Program for Performance Health Assessment of the Sacramento Delta

2. **Principal Investigator / Institution:** Victoria Bennett, Rensselaer Polytechnic Institute

3. **Other Research Participants/Partners:**
   - Tarek Abdoun, RPI
   - Mourad Zeghal, RPI
   - Mohammed Gabr, NCSU
   - Brina Montoya, NCSU;
   - Cathleen Jones, NASA/Jet Propulsion Laboratory;
   - Joel Dudas, Department of Water Resources, Sacramento, CA;
   - Mike Sharp, USACE, Vicksburg, MS

4. **Short Project Description:**

   As climate change progresses in the form of continuous land subsidence and rising sea water level, the integrity and reliability of flood-control infrastructure become ever more essential components to homeland safety. This project will employ a sensor-based (remote sensing with in-ground instrumentation for validation) and model-aided approach to provide engineers and decision makers with systematic tools to assess the health and provide early warning of deteriorating levees in the Sacramento Delta. The modeling tool integrates the use of measured data with the concept of performance limit states to effectively achieve a performance-based, network-level health assessment of the levee system.

5. **Abstract:**

As climate change progresses in the form of continuous land subsidence and rising sea water level, the integrity and reliability of earthen dams and levees become increasingly essential components of homeland security. The failure of levees during Hurricane Katrina in 2005 is a highly illustrative example of the criticality of these systems. But this distributed system of national flood-control infrastructure is aging and its structural health is deteriorating. Assessing the health, predicting the failure and implementing countermeasures are challenging tasks for any civil infrastructure in view of the complexity of the associated processes of long-term environmental degradation and wear. To efficiently maintain this infrastructure, managing engineers should have access to fully automated programs to continuously monitor, assess the health and adaptively upgrade these systems. *A **validated** remote sensing-based (i.e., satellite or airborne radar) approach will be used to assess the health of this spatially distributed system in*

order to identify weak sections and impending failures that can be used to help prioritize maintenance and upgrade efforts. This project highlights the potential of a remote sensing-based monitoring system and health assessment tools that will enable early identification and warning of vulnerable levee or dam sections enabling prioritized repair work. This project will validate the use of satellite imagery to detect rate of deformation of a levee section on Sherman Island. Such data will be used and implemented in a numerical model for estimating the probability of exceeding a performance limit state. This probability will provide an indication of the likelihood of failure and the extent of damage from such failure.

6. End users:

The work in this project is focused on developing an innovative platform for monitoring and condition assessment of the California Delta levees. A levee on Sherman Island is used for this purpose. The proposed approach couples the concept of deformation-based limit states (LS) with data collection from frequently employed remote sensing efforts to identify the levees' weak sections and possible impending failure modes. The modeling of the levee sections will provide condition assessment of their current state and will provide the context through which the monitoring data will be viewed to discern gradual and abrupt condition changes. The end users include the following:

i. California's Department of Water Resources (DWR);
ii. US Army Corps of Engineers (USACE);
iii. Federal Emergency Management Agency (FEMA);
iv. US Bureau of Reclamation (USBR); and
v. Levee Safety Boards.

Joel Dudas, Senior Engineer with California's DWR FloodSAFE Environmental Stewardship and Statewide Resources Office, Mike Sharp, Technical Director of USACE Engineer Research and Development Center (ERDC), and Rich Varuso, Senior Program Manager at USACE – Risk Management Center, will consult with the research team throughout the two-year project and will serve as ambassadors for the transition to practice. Joel Dudas is also an incident responder with DWR. Joel McElroy, Superintendent with Reclamation District #341, is responsible for bimonthly levee inspections and is a first responder for levee breaches on Sherman Island. John Paasch, Program Manager for the Delta Flood Emergency Preparedness, Response and Recovery Program, will link our project to others in DWR Emergency Management and California Emergency Management Agency (CalEMA) (http://www.water.ca.gov/floodmgmt/hafoo/fob/dfeprrp/). Jim Murphy, Head of Levee Condition Assessment Division of Risk Assessment, Mapping and Planning Partners (RAMPP), will help bring the project outcomes from FEMA Region IX to other critical coastal areas such as Louisiana (Region VI) and New York / New Jersey (Region II).

Multiple meetings between the PI, Joel Dudas, and Joel McElroy have occurred in the first period of this project. The outcomes of these meetings included a review of GPS station locations by Joel Dudas and Joel McElroy, sharing of DWR's prior site investigation documents, e.g., boring logs and soil profiles along monitored section, and a DWR review of soil profile geometry incorporated into finite element model. The importance of this project to these individuals and agencies has escalated due to the appearance of surface cracks in the setback levee section on Sherman Island. These cracks appeared in March 2016. The California Department of Water

Resources and Reclamation District #341 is tasked with identifying improvement projects to the Sherman Island levee system that will protect public facilities and provide public benefits. Improved levees minimize the threat of levee failure, protect the Sacramento Delta water quality and protect the reliability of the State Water Project, Contra Costa Canal, and Central Valley Project. Due to the public benefit provided by Sherman Island levees and the valuable assets they protect, the Reclamation District and DWR gather a variety of technical information for analysis and use in assessing the status of the levee system, i.e., levee crown surveys, visual inspections, inclinometer monitoring, settlement plate monitoring, etc. All of these techniques require technical personnel to visit the site and manually collect data. The proposed UAVSAR and GPS/SAA monitoring of the Sherman Island levees will provide continuous deformation information that can be collected remotely. Currently, these agencies do not have a framework to prioritize their levee rehabilitation efforts. The outcomes of this project will be of direct benefit to Reclamation District #341, California's DWR, the Army Corps of Engineers, and FEMA. The end users will be the professional staff at these agencies that are in charge of monitoring and maintaining the Delta Levee system. The components of the monitoring/modeling framework in this project will be transferred to these agencies through Joel Dudas and Mike Sharp. This will be in the form of the instrumentation layout, frequency of data collection, algorithms to process the monitored data, and the numerical analyses model and the coupling of the monitoring and modeling to perform condition assessment of the levee section being investigated.

7. **Explanation of Changes:** Nothing to report.

8. **Unanticipated Problems:**

An unexpected policy from NASA's Jet Propulsion Lab resulted in a delay in establishing the subcontract. The contracts and grants office at JPL will not process paperwork for projects totaling less than $50,000. This has not resulted in any milestone delays in the first performance period because remote sensing validation was scheduled for the second performance period. Our plan to address this problem is to increase the JPL subcontract to $50,000 for performance periods 2 and 3. The money will come out of the equipment line item. The instrumentation equipment was purchased through other external funds (included in External Funding and Leveraged Support Table).

9. **Project Outcomes:**

The work in this project presents results of integrated and validated remote-sensing program and finite element modeling for a Sherman Island levee section. At this location, satellite images and in-ground GPS sensors are collecting displacement measurements. These measurements are used for the calibration of a numerical model using the finite element program PLAXIS 2D with mesh updating. The model is used to establish a deterministic performance response under rising water level loading and investigates the effect of the peat decomposition on the deformation response of the levee section.

The large deformation option in the finite element program PLAXIS 2D 2015 is used to model a levee section on Sherman Island, within the California Delta area. The section geometry was selected on the basis of the information presented by Jafari et al. (2016) as shown in Figure 1. The locations of Global Navigation Satellite System (GNSS) remote sensing recordings of

displacement (GNSS-1, 2 and 3) are shown in Figure 1. Points A and B along the levee landslide side slope are used to compare the numerical model displacement with monitored GNSS records. Different finite element mesh resolutions are investigated from coarse to fine to very fine mesh showed a slight increase in the displacement. A fine 15-node element mesh was used with the domain having 1961 elements and 15975 nodes. Flow and deformation boundary conditions were assigned appropriately.

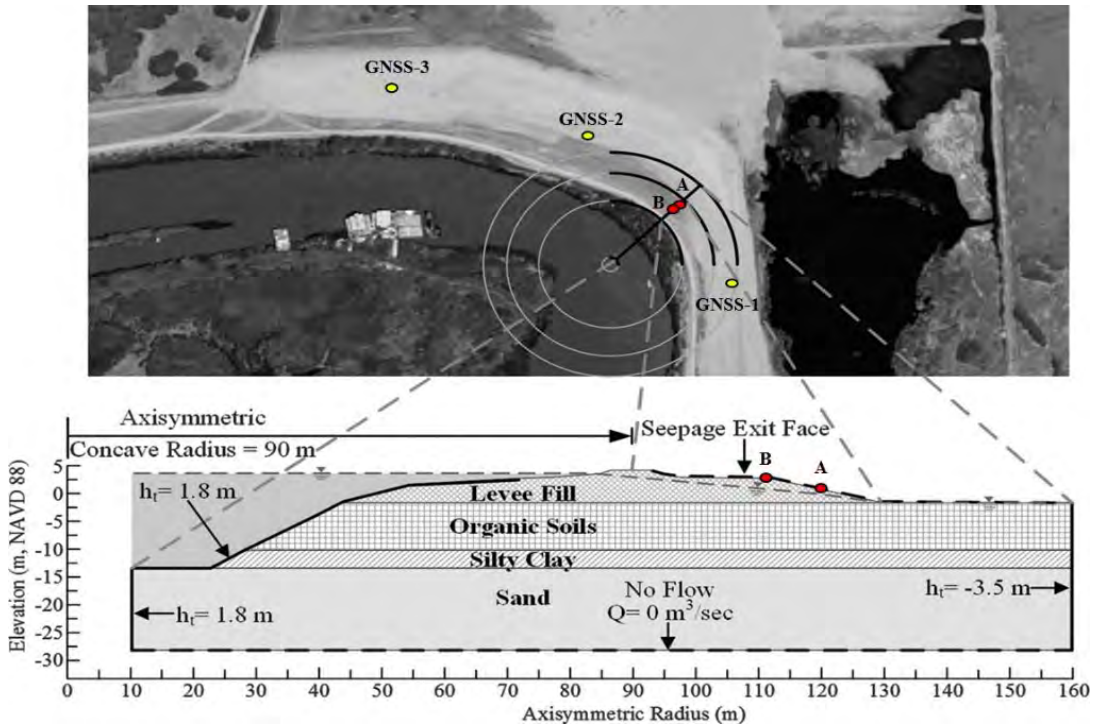


Figure 1.Model of Sherman Island proposed by Jafari et al. (2016).

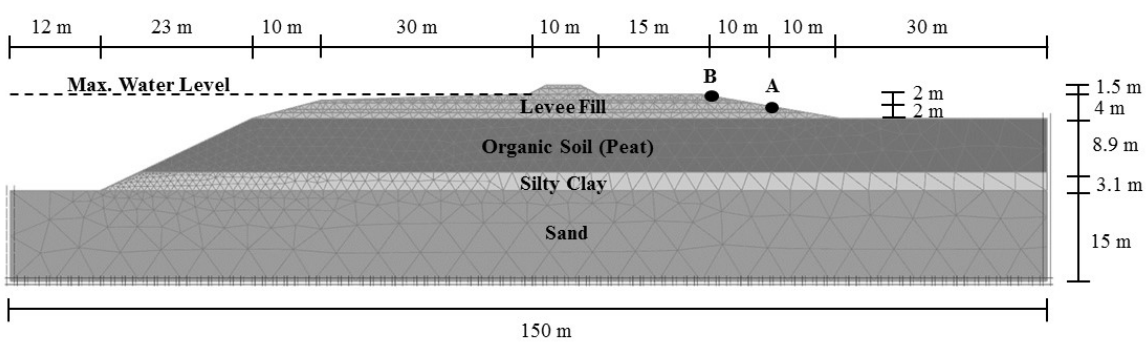


Figure 2. Finite element PLAXIS 2D levee mesh and boundary conditions

Soft Soil Creep Model (SSC) in PLAXIS is used to model to the peat layer to account for the viscous effects including creep and stress relaxation. This model takes into account secondary (time-dependent) compression (creep) and utilizes stress-dependent stiffness with the failure behavior conforming to the Mohr-Coulomb criterion. The input parameters for the soil model were assumed from the literature as limited data is available for the Sherman Island site. The levee is modeled using staged construction in 7 layers. Direct generation of initial effective

stresses, and pore pressures and state parameters in the foundation layers is performed before construction of the embankment. The initial groundwater level was assumed at the boundary between the fill layer and the peat layer.

Several points along the landslide side slope were chosen to investigate the displacement response given the change in the peat properties and place such a response within the context of limit states. Results for vertical displacement (Negative sign means settlement downwards) versus time for fibrous peat are shown in Figure 3 for points A and B (designated on Figure 1). These points were chosen to allow for the model calibration with the GNSS-1 and GNSS-2 remote sensing records available near these locations in the Sherman Island levee. These GNSS data are for a one-year period from 4/1/2015 up to 4/1/2016. In this case, the rates of deformation with time show a relatively close trend as the model results fall between the range of measured deformation at points A and B. The GNSS data showed an average of 0.13 m of deformation per year compared to the 0.095 per year computed for points A. The rates between the model results and point B were not in agreement but the monitored points are located on the landside side slope in locations consistent with "point A" as shown in Figure 1.

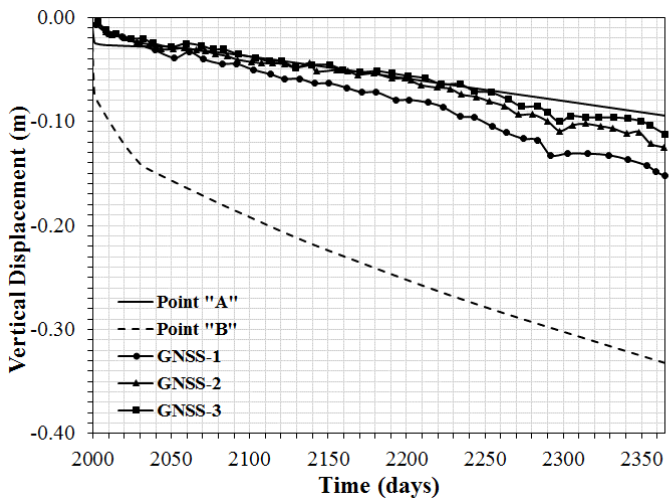


Figure 3. Displacement with time for fibrous peat versus measured data

Similar to the approach for model calibration, the levee is modeled using staged construction in 7 layers. Direct generation of initial effective stresses, and pore pressures and state parameters in the foundation layers is performed before construction of the embankment. The groundwater level was assumed at the boundary between the fill layer and the peat layer. The time interval for placing each layer was set to 1 day. In these phases, the displacement and strains are reset to zero before placement of the next layer and undrained behavior was ignored. Large deformation option was used (updated mesh technique) in all phases.

Water level was raised on two stages; first to reach its normal elevation (sunny day) of 1.5 m below crest. Second, a transit analysis is preformed where water level is raised with a rate of 0.08 m/hr to reach its max elevation (1 m below crest), then leaving it there for a week (7 days) while performing a consolidation analysis. Water level was then lowered with the same rate of 0.08 m/hr to the sunny day level of 1.5 m below crest. At such point, consolidation analysis of 1000 days was performed to capture the deformation profile with time. After the end of consolidation stage, another cycle of raising and lowering water level was performed with the exact same rate and stages as before. Then, a consolidation phase of another 1000 days was carried out. The

results of such analyses are shown in Figure 4. The displacement profiles at points A and B showed that the effect of the transient high water level loading on the displacement magnitude is insignificant compared to the secondary compression due to the presence of the peat layer. The assumption of having an amorphous peat layer leads to a lower settlement with time of the levee section compared to fibrous peat. The rate of deformation in the case of the amorphous peat increases with time, as shown in Figure 4, due to the smaller change in void ratio as compared to the amorphous peat, and therefore a larger secondary compressibility rate with time. As peat properties transition with time from fibrous to amorphous case, the vertical deformation will be bounded by the trend shown in Figure 4. Figure 5 shows the change in the deviatoric strain with time and the associated limit states on the basis of using the mean value of Cα/Cc=0.06 for assessment of deformation.

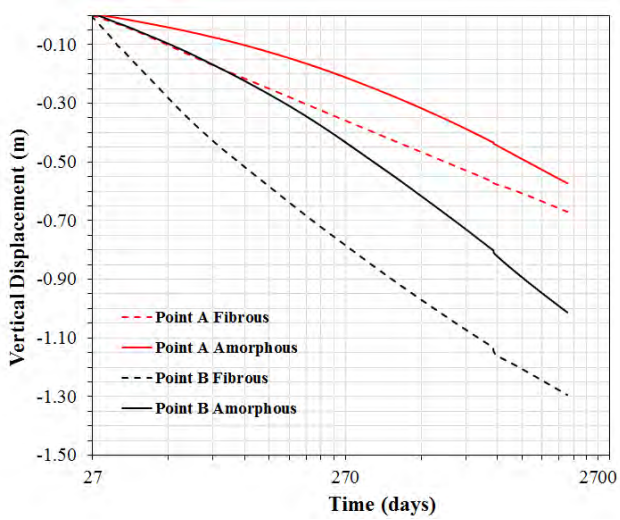


Figure 4. Vertical Displacement with time for fibrous and amorphous peat.

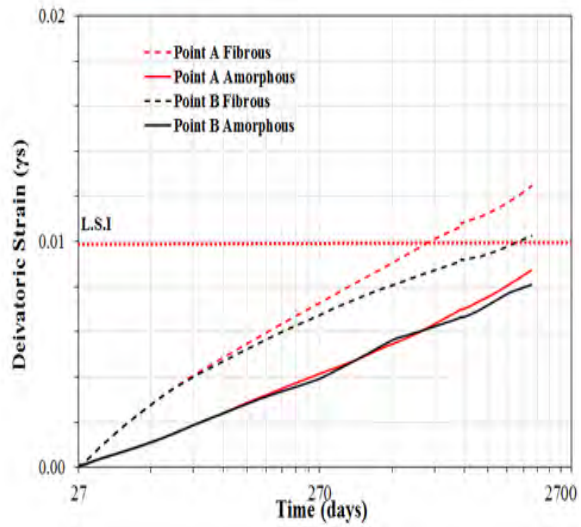


Figure 5. Total Deviatoric Strain (γ_s) with time and limit state criteria for mean value of C_α/C_c=0.06.

Based on the results in this work, the following conclusions are advanced:

1- Amorphous peat shows stiffer response and lower compressibility than fibrous peat, which agrees with literature (Mesri and Ajlouni, 2007). The assumption of amorphous peat led to lower computed displacements overall that ranged from 10 to 30% depending on the location within the domain.

2- The analyses indicated a relatively small mechanistic deformation induced by "extreme" water level under transient conditions. This is in comparison to the continuous and large deformation induced by the compression of the peat layer. The high-water level will however affect the exit hydraulic gradients and may lead to critical conditions as was discussed by Jafari et al (2016).

3- The variability in the reported values for compression coefficients (C_c and C_α) for fibrous and amorphous peat suggests these values need to be better defined as a function of fiber contents, state of decomposition, and water content. A parameter in terms of cellulose and lignin content can provide insight as to the chemical composition of the materials and the related shear strength with aging for more accurate performance assessment of the levee.

The analyses results indicated the exceedance of LS I in terms of deviatoric strain, with main driving factor being the compressibility of the peat layer. The deformation of the embankment levee is non-uniform due to stress variability with location. The continuous large deformation

can lead to compromising the levee hydraulic performance function and transitional sliding of the embankment as presented by Duncan and Houston (1983).

10. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Task a. Appropriate sensor selection and layout	2/15/2016	100%	
Task b. Deployment of field sensors in Sherman Island	6/30/2016	100%	
Task i. Site Data Collection	6/30/2016	100%	
Research Milestone			
Report on instrumented test site on Sherman Island	6/30/2016	100%	Upon completion of field instrumentation installation, Joel Dudas and Joel McElroy were briefed on setup and technology. Instrumentation cabinet access keys were provided to Bryan Brock of DWR (liaison between field site and Sacramento office).
Characterization of the subsurface properties and possible constitutive relationship to use in the modeling effort	6/30/2016	100%	Site investigations and boring logs provided by DWR were used by NCSU as input geometry for finite element model. Literature review and previous work by NCSU (as part of UNC-CH's Center of Excellence) used to evaluate available constitutive models for peat soils.

Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Present preliminary findings of Outcomes 1 and 3 at the CRC annual meeting	6/30/2016	100%	
Transition Milestone			
Report on subsurface properties of the Sherman Island Levee section to be studied reviewed by DWR	6/30/2016	100%	During a face-to-face meeting in June 2016, Joel Dudas of DWR provided previous site investigations and boring logs to PI Bennett. These documents were used to select input parameters and geometry for finite element model. Appropriateness of resulting model was reviewed and accepted by Joel Dudas.

11. Interactions with education projects:

The PIs engaged some CRC MSI education partners at the CRC Annual Meeting in March 2016. Unfortunately this was too late to make arrangements for the summer of 2016. We will start planning for the summer of 2017 now. While we have links to the University of Puerto Rico, Mayaguez through RPI graduate Ricardo Ramos, we do not have enough budget to fully host an intern from Puerto Rico for the summer. We will work with Robert Whalin to identify some domestic students that will be placed at RPI or NCSU in the summer of 2017 within an appropriate budget. If the intern is placed at RPI, undergraduate student activities in the Center for Earthquake Engineering Simulation (CEES) will be leveraged for this CRC intern as well.

12. Publications:

- "***Monitoring and Modeling of Peat Decomposition in Sacramento Delta Levees***" Amr Helal, Victoria Bennett, Mo Gabr, Roy Borden and Tarek Abdoun. Submitted to the Proceedings of Geotechnical Frontiers 2017, Orlando, Florida, March 12-17.
- ***"Deformation Monitoring for the Assessment of Sacramento Delta Levee Performance"*** Victoria Bennett, Mo Gabr, Amr Helal, Cathleen Jones, and Tarek Abdoun. Accepted abstract for Geo-Risk 2017 (Geotechnical risk from theory to practice), Denver, Colorado, June 4-7.

13. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)			
Undergraduates provided tuition/fee support (number)			
Undergraduate students provided stipends (number)			
Graduate students provided tuition/fee support (number)	2		
Graduate students provided stipends (number)	2		
Undergraduates who received HS-related degrees (number)			
Graduate students who received HS-related degrees (number)			
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)			
SUMREX program students hosted (number)			
Lectures/presentations/seminars at Center partners (number)			
DHS MSI Summer Research Teams hosted (number)			
Journal articles submitted (number)			
Journal articles published (number)			
Conference presentations made (number)	2		
Other presentations, interviews, etc. (number)	1		
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)			
Requests for assistance/advice from DHS agencies (number)			
Requests for assistance/advice from other Federal agencies or state/local	4		
Total milestones for reporting period (number)	3		
Accomplished fully (number)	3		
Accomplished partially (number)			
Not accomplished (number)			
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
REES "Risk Estimator for Embankment Structures"	Software	June 2017	Federal Agencies looking for an expedient means to assess performance of levees and earth dams

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
Establishment of Sensor Driven and Model Based Health Assessment for Flood Control Systems	Tarek Abdoun	$60,000	US Army Engineer Research Development Center
New Faculty Startup Funds	Victoria Bennett	$241,500	Rensselaer Polytechnic Institute

Leveraged Support	
Description	Estimated Annual Value
Spare GPS equipment available from JPL to maintain instrumentation installed in Sherman Island setback levee.	$34,500

References

Duncan, J. M., and Houston, W. N., (1983). "Estimating failure probabilities for California levees." *Journal of Geotechnical Engineering,* 109 (2): 260-268.

Jafari, N. H., Stark, T. D., Leopold, A. L., and Merry, S. M., (2016). "Three-dimensional levee and floodwall underseepage." *Canadian Geotechnical Journal*, 53:72-84, 10.1139/cgj-2014-0343.

Mesri, G. and Ajlouni, M. (2007). "Engineering Properties of Fibrous Peats." *J. Geotech. Geoenviron. Eng*., 10.1061/ (ASCE) 1090-0241(2007)133:7(850), 850-866.

COX, OSU and VAN DE LINDT, CSU

DHS Coastal Resilience Center

Research Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Experimental and Numerical Study to Improve Damage and Loss Estimation due to Overland Wave and Surge Hazards on Near-Coast Structures
2. **Principal Investigator / Institution:**
   Dr. Daniel Cox, (PI) Professor, Oregon State University
   Dr. John van de Lindt (co-PI), Professor, Colorado State University
3. **Other Research Participants/Partners:**
   - Bill Coulbourne, Applied Technology Council
   - Chris Jones, consulting coastal engineer; Chair, ASCE-7 Flood Loads
4. **Short Project Description ("elevator speech"):**

   This project will develop an accurate method to determine damage to buildings subjected to extreme surge/wave forces during hurricanes. The methodology will use large-scale hydraulic model testing combined with numerical simulations to improve existing risk software used by DHS/FEMA and to advance risk-based design methodologies to enhance coastal infrastructure resilience. The method will be consistent with other multi-hazard frameworks such as earthquake and wind engineering.
5. **Abstract:**

This project focuses on Theme 1 – Coastal Infrastructure Resilience; Topic 1a – Coastal Infrastructure Planning and Design. As building stakeholders seek to mitigate damage, risk to property and structure loss it is becoming apparent that exiting design methodologies such as those outlined in the FEMA Coastal Construction Manual are inadequate to incorporate the range of building types, storm conditions, and potential for resulting damage. More effective decision support tools such as FEMA's HAZUS-MH rely on a framework of multi-hazard fragility curves to relate the hazard and affected buildings to compute/predict an expected level of damage and subsequent losses. Although there have been significant advances in this correlation for wind and earthquake loading and some preliminary work for tsunamis, the coastal surge and wave response of structures remains poorly defined, primarily due to a lack of large-scale data and the complexity of the fluid/structure interaction modeling. This project will significantly improve HAZUS input fragilities for surge and wave through a robust experimental and numerical study of the interaction of surge and waves with near-coast structures. The overall goal of this project is to develop accurate fragilities for near-coastal structures against overland surge and wave forces for input to HAZUS-MH such that they can be used in a design framework consistent with the risk-based methods used in wind and earthquake engineering. We outline these specific objectives to be completed in two years in order to provide (1) improved accuracy for surge and wave analysis in HAZUS-MH; and (2) innovative advances in risk-informed design methodologies to enhance coastal infrastructure resilience:

- ***Objective 1:*** Quantify wave forces on near-coast structures for a range of surge levels based on a mid-scale hydraulic model test program, and develop new predictive equations for horizontal and vertical forces.
- ***Objective 2:*** Develop the conditional probabilities (fragilities) for exceeding key thresholds which will be linked to damage levels available in HAZUS-MH.
- ***Objective 3:*** Illustrate next-generation risk-informed design for near-coast structures that have been shown to be vulnerable to hurricane surge and waves using the fragilities developed in (2). This will improve the ability of building occupants to return following the hurricane thereby improving the resiliency of the community.

This project will have a direct impact on estimating probable damage and loss of existing coastal infrastructure by providing improved load-response relationships to HAZUS-MH for surge and wave and develop a risk-informed framework for future engineering design of near-coast structures. While beyond the scope of this study, the results could also help improve the potential designs associated with the retrofit of existing structures funded through FEMA hazard mitigation grant programs and the implementation of improved coastal building codes.

6. End users:

In addition to these Research Participants, we have contacted the following people to schedule a meeting in DC in January 2017 to begin the End-User Transition:

- Eric Berman, HAZUS Program Manager at FEMA HQ
- Ed Laatsch, FEMA Building Science Division

If an in-person meeting is not possible because of schedule constraints, then we will convene a video conference call prior to the February center meeting. At the February meeting we will be able to provide direct information on the end-user transition process.

Additional possible end-users include the USACE, FEMA, and ASFPM:

- Ty Wamsley, USACE-ERDC, Vicksburg, MS
- Marc Gravens, USACE-ERDC, Vicksburg, MS
- Julie Rosati, USACE-HQ, Washington, DC
- Christina Lindemer, Coastal Engineer, FEMA Risk Analysis Branch, Atlanta GA
- Chad Berginnis, ASFPM Executive Director and CRC Advisory Board Member

We have described our project to the end users during the CRC meetings in Washington DC (July 27, 2015) and at UNC (March 1, 2016). At the January, 2017 meeting with the end-users in Washington D.C. we will explain the benefits in a presentation and report back on end-user plans. The benefit of this project will show how HAZUS software can be improved using new fragility curves developed in this project.

7. **Explanation of Changes:**

   There have been no changes to the work plan. The hydraulic model tests (Task 1) are currently underway. Numerical modeling (Task 2) is also underway and limit states for failure of elevated buildings are being computed using detailed modeling approaches. Colorado State researcher Dr. Trung Do will be on site at Oregon State University to collaborate with Dr. Hyoungsu Park to work on integration of Task 1 and 2 from Aug 2 to Sept 2, 2016.

8. **Unanticipated Problems:**

   There have been no unanticipated problems.

9. **Project Outcomes:**

   There are two major limitations within HAZUS-MH when estimating damage and loss due to hurricanes that can be addressed in this study:

   (1) Characterizing the inland hazard with respect to wave climate. Currently, HAZUS-MH uses WHAFIS to characterize the wave climate inland. Although this model can calculate wave climate efficiently, it is formulated as a "transect model", meaning that the three dimensional effects (wave refraction, diffraction, reflection) are not included in the model. This is problematic for complex shorelines. Further, there has not been extensive validation of WHAFIS for overland surge/waves.

   (2) Improving hazard-damage relationships for structures. Although the existing practice is to use flood depth as the intensity measure, this project will develop improved intensity measures derived from the wave climate. One example would be the modification of Goda's formula which has been used successfully for wave loads on coastal structures and has been adopted by the USACE for breakwater design. A second example is the momentum flux which is a parameter used for tsunami-structure interaction and has also be used to predict runup and stability of coastal structures. Finally, fragility functions to relate the hazard intensity to building damage are limited in HAZUS-MH for coastal surge/wave loading.

Although direct implementation of the research outcomes into HAZUS is beyond the scope for this project (and would have to be directed by FEMA through their contract with a consultant), this project will make direct comparison between existing HAZUS methodology and improvements that can be gained by implementing the new methodology and communicate it effectively to FEMA contacts described earlier. We have initiated a request to meet with Eric Berman and Ed Laatsch, and we can report out on this after the meeting. The meeting will either be in-person (in DC in January 2017) or by video conference

10. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Experimental Design (OSU) – Task 1.1, develop wave/surge boundary conditions; bathymetry; specimen design and placement; test matrix and protocols.	3/31/2016	100%	
Physical Model Testing (OSU) – Task 1.2, conduct physical model tests in Directional Wave Basin at HWRL; test setup, data acquisition, demobilization; initial data QA/QC	6/30/2016	50%	Experiments are currently underway at Oregon State University. Experiment was extended so that additional tests could be performed to increase the wave and airgap conditions. Also, additional testing allowed us to include 2 SUMREX students on the project.
Numerical Model (CSU) – Task 2.1, develop numerical model of a building and calibrate with existing experimental data	3/31/2016	100%	The numerical model has been developed in ANSYS and calibration shown for a wall and bridge specimen using two existing data sets from past OSU experiments.
Fragility Formulation – Task 2.2, develop initial fragility limit states in cooperation with CRC, DHS/FEMA.	6/30/2016	50%	Under development; the structural models are being refined more than originally planned. Originally, the limit states for the fragility development was going to be force, but it was decided to move this to structural failure which requires a more detailed structural load-response model and is more time consuming. This type of models is more realistic and will improve accuracy for use in risk-based design and analyses.
Research Milestone			
Progress Report 1: Detailed experimental work plan summarizing experimental plan (Task 1.1). Work plan to be developed with input from project partners and end users (Item 8).	3/31/2016	90%	Draft experimental plan complete and will be finalized by Aug 31, 2016.

Progress Report 2: Physical Model Data Base Report summarizing completed experiment. To be reviewed by project partners and end users.	6/30/2016	10%	Daily logs are kept for experiment. 90% draft report to be completed by September 30, 2016.
Progress Report 3: Technical Brief summary of Task 2.1 calibration accuracy in a technical brief format and	3/31/2016	75%	A journal paper is underway and will be used as the outline to pull the brief from.
Progress Report 4: Summary of the fragility formulation methodology (Task 2.2) to be used within this project. To be reviewed by project partners and end users.	6/30/2016	50%	Limit states have not been finalized because structural model underway (see above). Once this is complete in approximately one month, the methodology will be summarized.

11. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
PI will attend 5th HAZUS conference in Atlanta, GA. Develop better understanding of HAZUS User Groups (HUGs).	Dec 9-11, 2015	0%	Did not have travel funds available to attend meeting. We can consider attending future HAZUS conference meeting pending discussion with HAZUS program manager Eric Berman.
Meeting with Ed Laatch (DHS/FEMA) and others listed in Item 8 prior to the start of testing phase to gather additional information on potential adoption of fragilities in HAZUS. Discussion of what building types are needed. Meeting to be held at FEMA HQ in Washington DC. Attended by Cox, van de Lindt, Jones and Coulbourne. USACE will be invited (Wamsley, Gravens, Rosati)	Feb 2016	10%	Met with Jones and Coulbourne in Ft. Collins at Colorado State Univ. to discuss project. Did not schedule DHS/FEMA meeting due to travel schedule conflicts. We have requested a meeting with Ed Laatsch and Eric Berman.
Live video feed of physical model testing at OSU with overview explanation to project team and end users. Followed by discussion. Entire CRC personnel will be able to view the tests. We will also invite/coordinate national/local media coverage for DHS outreach	May 2016	30%	Live video feed is operational as of July 25 2016. http://wave.oregonstate.edu/live-views The experiment is complete (100%).

Transition Milestone			
Meeting minutes with action items Feb meeting at FEMA HQ	2/29/2016	0%	No meeting occurred. We have requested a meeting with Ed Laatsch and Eri Berman. We will report on that meeting after it occurs.
Summary of live demo and discussion.	2/29/2016	0%	Testing is not completed Summary reports are in progress.

12. Interactions with education projects:

Currently, we are hosting two SUMREX students from the University of Puerto Rico Mayaguez, Diego Delgado and Kevin Cueto. Kevin and Diego were on the Oregon State University campus from June 18, 2016, to August 5, 2016. Both students participated in a summer research experience for undergraduates (REU) program with 9 other students and will complete a project report and presentation on August 4. Because of budgetary issues, both students are supported on grants from the National Science Foundation which were in place when the travel arrangements were being made.

Image of Diego Delgado (REU student, left), Tori Johnson (post doctoral scholar, center) and Kevin Cueto (REU student, right) during the setup of the hydraulic model tests.

13. Publications: *List all articles published, or submitted for publication. Include author name(s), title of article, title of journal, date of submission, and anticipated publication date.* ***Provide full citation in format appropriate for your discipline.***

No publications to report at this time

***14.* CRC Performance Metrics:** *Complete the following Metrics Table and attach to your progress report.*

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)			
Undergraduates provided tuition/fee support (number)	0		
Undergraduate students provided stipends (number)	0		
Graduate students provided tuition/fee support (number)	2		
Graduate students provided stipends (number)	0		
Undergraduates who received HS-related degrees (number)	0		
Graduate students who received HS-related degrees (number)	0		
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)	0		
SUMREX program students hosted (number)	0		
Lectures/presentations/seminars at Center partners (number)	0		
DHS MSI Summer Research Teams hosted (number)	2		
Journal articles submitted (number)	0		
Journal articles published (number)	0		
Conference presentations made (number)	0		
Other presentations, interviews, etc. (number)	0		
Patent applications filed (number)	0		
Patents awarded (number)	0		
Trademarks/copyrights filed (number)	0		
Requests for assistance/advice from DHS agencies (number)	0		
Requests for assistance/advice from other Federal agencies or	0		
Total milestones for reporting period (research activity/milestone)*			
Accomplished fully (research activity/milestone)	2/0		
Accomplished partially (research activity/milestone)	4/4		
Not accomplished (research activity/milestone)	1/2		
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

*Note: Table modified to report both research activities and milestones from Section 10 and 11.

Table for Documenting CRC Research Project Product Delivery

Nothing to report at this time

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
Collaborative Research: Fundamental Mechanics and Conditional Probabilities for Prediction of Hurricane Surge and Wave Loads on Elevated Coastal Structures	Cox	$215,000	NSF CMMI-1301016
Collaborative Research: Fundamental Mechanics and Conditional Probabilities for Prediction of Hurricane Surge and Wave Loads on Elevated Coastal Structures	Van de Lindt	$140,000	NSF CMMI-1266101
Leveraged Support			
Description			Estimated Annual Value

Theme 2

Building Resilient Communities

HORNEY, TEXAS A&M

DHS Coastal Resilience Center

Research Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Implementing the Disaster Recovery Tracking Tool

2. **Principal Investigator / Institution:** Jennifer Horney, Associate Professor, Texas A&M University Health Science Center School of Public Health, Department of Epidemiology and Biostatistics

3. **Other Research Participants/Partners:** Phil Berke, Professor, Texas A&M University, College of Architecture, Department of Landscape Architecture and Urban Planning

4. **Short Project Description:**

   Long-term, coordinated, systematically collected, and shared data on recovery is needed to effectively improve community resilience to future disasters. Tools are needed that can be used to measure disaster recovery at the local, regional, and state level so that best practices can be adopted. Valid and reliable quantitative and qualitative measures of community disaster recovery are needed in order to be able to track recovery in different geographic locations, from different types of disasters, and over time. The proposed research will transition the existing Disaster Recovery Tracking Tool into a widely adopted web-based tool for end users to track the progress and quality of post-disaster recovery by entering baseline and post-disaster data for up to 84 metrics with two pilot communities. Technical assistance and training will be provided for the two pilot communities. Lessons learned will be incorporated into final marketing materials, a training module, and a user guide for additional end users. Final materials will also be shared with appropriate Federal partners, including FEMA / EMI Emergency Management Higher Education Program as well as Texas A&M's Engineering Extension Service, which provides training in emergency management and homeland security.

5. **Abstract:**

   Without monitoring recovery and comparing post-recovery status with pre-disaster benchmarks, it is difficult for communities to assess whether or not they are achieving a quality recovery, improving disaster resilience, or building back better. The Disaster Recovery Tracking Tool provides a framework for end users (e.g., planners, emergency managers, long-term recovery committees) to track progress on 84 metrics of disaster recovery. The 84 metrics were identified and content validated through a literature review, recovery plan review, case studies, focus groups, key informant interviews, and pilot tests with communities impacted by Hurricane Sandy. Practitioners using this tool can compare pre- and post-disaster status using baseline and current data. Reports generated by the tool can provide end users with a useful means of prioritizing recovery goals and activities and identifying elements important to

include in recovery planning, potentially making recovery more effective and efficient and communities more resilient.

6. **End users:**

The existing Disaster Recovery Tracking Tool currently has approximately 50 registered users were contacted to assess their interest in continuing to work with the project. These include Federal (EPA, FEMA, NOAA (ERMA), Small Business Administration, US Air Force Academy, Cooperation for National and Community Service); Regional (FEMA Regions 2, 6, and 8); Local Governments; Ga. Tech University; National Non-Profits (Red Cross, Natural Resources Defense Council); Other Non-Profits (SeaPlan.org); and private consultants. Additional new end users will include: 1) Municipal- and county-level planners, emergency managers, and members of long-term recovery committees (Additional municipal- and county-level partners will be engaged as the project starts); 2) FEMA national (Matt Campbell) and regional-level recovery division staff (Charlie Cook, Region 6; Marianne Luhrs, Region 2); 3) Department of Health and Human Services, Assistant Secretary for Preparedness, Office of Emergency Management, Recovery (Natalie Grant) 4) Texas A&M Hazard Reduction and Recovery faculty, staff and students and Texas Target Cities partner communities (John Cooper, Associate Professor of Practice and Jamie Masterson, Program Coordinator, Texas Target Cities will assist with identifying the two willing community partners). In addition, 67 federal, state, and local public health and emergency management staff attended a DEMO session of the Tool, called Can We Measure Successful Disaster Recovery? at the National Association of County and City Health Officials Annual Preparedness Summit in April, 2016.

Table of End Users:

Name	Agency / Contact Information	Interactions
Balsley, Alex	Project Manager Research and Development Center U.S. Coast Guard Email: Alexander.Balsley@uscg.mil	The USCG has expressed interest in linking the Disaster Recovery Tool to its oil spill impact forecasting.
Branch, Tom	Emergency Management Coordinator Office of Emergency Management Liberty County, Texas Phone: (936) 334-3219 Email: tom.branch@co.liberty.tx.us	Liberty County, TX has agreed to serve as a pilot community for the Disaster Recovery Tool. Current disaster response and recovery plans are being reviewed and recommendations for improvement will be provided.
Capasso III, Samuel	Regional Building Science Specialist Region II - Hazard Mitigation Division Phone: (212) 720-9517 Email: samuel.capasso@fema.dhs.gov	The Disaster Recovery Tool will be leveraged by FEMA to assess the impacts of and opportunity for mitigation efforts on community-level disaster recovery.
Chung, John	Emergency Planner, Recovery Office of Emergency Management Los Angeles County Chief Executive Office Phone: (323) 980-2294 Email: JChung@ceooem.lacounty.gov	The Disaster Recovery Tool metrics are being incorporated in the Los Angeles County Recovery Plan/Framework. The Emergency Planner has agreed to provide feedback and suggestions for improvement related to the metrics.
Graham, Larissa	Oil Spill Science Extension Specialist Mississippi-Alabama Sea Grant Consortium Phone: (251) 438-5690 Email: Larissa.Graham@auburn.edu	The Disaster Recovery Tool could be used by the Texas Sea Grant College Program to assess recovery progress in oil spill-affected communities.

Hale, Christine	Oil Spill Science Outreach Specialist Texas Sea Grant College Program Texas A&M University-Corpus Christi Phone: (361) 825-6215 Email: chris.hale@tamu.edu	The Disaster Recovery Tool could be used by the Texas Sea Grant College Program to assess recovery progress in oil spill-affected communities.
Lowe, Sheila	Executive Director Long Term Recovery Team Bastrop County, Texas Phone: (512) 521-3001 Email: ed@bcltrt.org	Bastrop County, TX has agreed to serve as a pilot community and provide feedback for the Disaster Recovery Tool.
Zwolinski, Mia	Research Coordinator Texas Sea Grant College Program Texas A&M University Phone: (979) 458-0449 Email: mzwolinski@tamu.edu	The Disaster Recovery Tool may be used by the Texas Sea Grant College Program to assess recovery progress in oil spill-affected communities.

7. Explanation of Changes:

No changes to the initially approved work plan have been made.

8. Unanticipated Problems:

No unanticipated problems have occurred.

9. Project Outcomes:

The primary outcome of the proposed project is the systematic measurement of the disaster recovery process in various locations, across events, and over time. Throughout the project period, metrics and analytic approaches will be refined based on feedback from end users from this and other leveraged research projects. For example, Samuel Capasso III, Building Science & Safety Team Lead in Hazard Mitigation at FEMA Region II, has been charged with leading resilience-building efforts in FEMA Region II. One component of this initiative is to assess the impacts of and opportunity for mitigation efforts on community-level disaster recovery. The community status tracking function of the Disaster Recovery Tracking Tool will be leveraged to quantify these impacts using publicly-available government datasets. To enhance the usefulness of the tool for local and federal end-users, the needs, insights, and expertise of FEMA partners will be incorporated throughout the decision-making process.
Results may also contribute to increases in the number and improvements in the quality of pre-disaster recovery plans. For example, one of the primary indicators of a high-quality plan is a strong community fact base. It often difficult for smaller communities with limited capacity for recovery planning to develop a robust fact base focused appropriately on high-priority issues. Data collected for the 84 recovery metrics may be used to guide the development of a recovery plan element as part of a larger plan, or the development of a stand-alone recovery plan. For this purpose, we will develop a checklist based on the metrics for practitioners that can be used to update plans or begin the process of developing a fact base for a pre-disaster recovery plan.

10. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Refine the metrics for tracking disaster recovery as necessary based on results of leveraged research projects	3/31/16	100	There are currently 84 metrics included in the Disaster Recovery Tracking Tool. In response to end-user feedback generated using surveys and key informant interviews, the number of metrics that are automatically populated from publically-available datasets has been increased from 17 to 39.
Recruit local partners	4/15/16	100	Partnerships have been secured with Bastrop County, Texas and Liberty County, Texas.
Secure commitment of at least one local partner to begin pilot on 7/1/16	6/1/16	100	Representatives of Bastrop County, Texas and Liberty County, Texas have agreed to serve as pilot communities to evaluate the Disaster Recovery Tracking Tool.
Research Milestone			Next key milestone is in future projectperiod

11. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Conduct horizon scan and explore the potential market for the Tool	6/30/16	100	A horizon scan of similar web-based tools dedicated to disaster recovery tracking and pre-disaster recovery planning revealed that this product is unique. Subsequent horizon scans were also performed by 3 undergraduate honors marketing teams. The searches conducted by these teams yielded no significant competitors.

Work with CHC / RENCI to research appropriate processes and actions for IP related to the web-based tool	4/1/16	100	Lisa Stillwell, a research software developer at RENCI, provided technical assistance during the development of the Disaster Recovery Tracking Tool. The results of this assistance include an improved user interface, the inclusion of additional tracking functions, and a greater number of automatically-populated metrics.
Transition Milestone			
Release open Beta version of the Disaster Recovery Tracking Tool website	6/30/16	100	
Place appropriate links to site on CHC website, as well as other virtual locations identified in horizon scan	5/31/16	100	The following organizations have placed the Disaster Recovery Tracking Tool link on their respective websites: Association of Schools and Programs of Public Health Coastal Resilience Center Environmental Grand Challenge at Texas A&M University Federal Emergency Management Agency (FEMA) North Carolina Planning Journal (article accepted for future publication) Office of the Assistant Secretary for Preparedness and Response (ASPR) Technical Resources, Assistance Center, and Information Exchange (TRACIE) – Technical Resources Texas A&M Foundation

12. Interactions with education projects:

We supported the successful application of Dr. Sonia Gilkey from Texas A&M Kingsville, a minority serving institute in Texas, to the U.S. Department of Homeland Security (DHS) Summer Research Team Program for Minority Serving Institutions. Although Dr. Gilkey and her student were selected to participate in the program, they subsequently declined to participate due to a scheduling conflict.

13. Publications:

Horney, J., Dwyer, C., Aminto, M., Berke, P., & Smith, G. (2016). Developing indicators to measure post-disaster community recovery in the United States. *Disasters.* Advance online publication. doi:10.1111/disa.12190

14. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)	0	0	
Undergraduates provided tuition/fee support (number)	0	0	
Undergraduate students provided stipends (number)	0	0	
Graduate students provided tuition/fee support (number)	0	0	
Graduate students provided stipends (number)	1	0	
Undergraduates who received HS-related degrees (number)	0	0	
Graduate students who received HS-related degrees (number)	0	0	
Certificates awarded (number)		0	
Graduates who obtained HS-related employment (number)	1	0	
SUMREX program students hosted (number)	0		
Lectures/presentations/seminars at Center partners (number)	0	0	0
DHS MSI Summer Research Teams hosted (number)	0	0	0
Journal articles submitted (number)	1	0	0
Journal articles published (number)	1	0	0
Conference presentations made (number)	3	0	0
Other presentations, interviews, etc. (number)	4	0	0
Patent applications filed (number)	0		
Patents awarded (number)	0		
Trademarks/copyrights filed (number)	0	0	
Requests for assistance/advice from DHS agencies (number)	1	0	0
Requests for assistance/advice from other Federal agencies or	3	0	0
Total milestones for reporting period (number)	3	0	0
Accomplished fully (number)	3	0	0
Accomplished partially (number)	0	0	0
Not accomplished (number)	0	0	0
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			0
Coverage in media, blogs (number)			0
Social media followers (number)			0
Posts to social media accounts (number)			0
Events hosted (number)			0
Website hits (number)			0

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
Trackyourrecovery.org	Conference DEMO Session	April 2016	Various; 67 attendees from federal, state, and local
Measuring successful disaster recovery: A case study of six communities in Texas.	Oral Presentation	April 2016	Texas Public Health Association Annual Conference Attendees
Measuring successful disaster recovery: A case study of six communities in Texas.	Poster Presentation	April 2016	Texas A&M Public Health Week Delta Omega Student Poster Contest (Awarded 2nd Place)

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
N/A			
Leveraged Support			
Description			Estimated Annual Value
N/A			

ATKINSON, ODU

DHS Coastal Resilience Center

Research Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** A Tool to Measure Community Stress to Support Disaster Resilience Planning

2. **Principal Investigator / Institution:** Larry Atkinson, Slover Professor and Eminent Scholar, Department of Ocean Earth & Atmospheric Sciences, College of Sciences

3. **Other Research Participants/Partners:**

   Old Dominion University Co-PIs:
   - Joshua Behr, Research Associate Professor, Virginia Modeling, Analysis, and Simulation Center (VMASC)
   - Michelle Covi, Assistant Professor of Practice, Department of Ocean Earth & Atmospheric Sciences, College of Sciences and Virginia Sea Grant Extension
   - Jose Padilla, Research Assistant Professor, Virginia Modeling, Analysis, and Simulation Center (VMASC)
   - Wie Yusuf, Associate Professor, School of Public Service, Strome College of Business

4. **Short Project Description:**

   This project will support at least two Coastal Resilience Center projects, building on project team's expertise in stakeholder engagement, leveraging information already collected from initial case studies, and utilizing existing connections to stakeholders and possible end users in Hampton Roads. Two projects that will be supported are: (1) Organizing a panel for the Maritime Risk Symposium that addresses "Integrating Maritime and Costal Resilience;" and (2) supporting stakeholder engagement and end user translation efforts of '*The Incorporation of Rainfall into Hazard Estimates for Improved Coastal Resiliency' project. The project team will remain engaged with the CRC and can assist with communications efforts and help provide linkages between research or education projects and Hampton Roads Resilience Initiatives.*

5. **Abstract:**

The original project involved development of a Hazards Stress Test Tool (HSTT) that supports coordinated actions in all risk management and mitigation phases involving collaboration between federal, state, local, tribal, and private sector partners. From our meetings with use case stakeholders, we found that the HSTT project, as originally proposed, did not meet end user needs and would not gain traction within the end user community as a decision support tool. We concluded that the project direction should be adjusted to produce a decision support framework that supports not only planning, but the integration of planning within a broader decision making context including implementation and funding. This revised project will support at least two Coastal Resilience Center projects, building on project team's expertise in stakeholder engagement, leveraging information already collected from initial case studies, and

utilizing existing connections to stakeholders and possible end users in Hampton Roads. Two project that will be supported are: (1) Organizing a panel highlighting Hampton Roads resilience projects, including the Intergovernmental Pilot Project, for the Maritime Risk Symposium that addresses "Integrating Maritime and Coastal Resilience;" and (2) supporting stakeholder engagement and end user translation efforts of '*The Incorporation of Rainfall into Hazard Estimates for Improved Coastal Resiliency' project.*

6. End users:

ODU has a long and successful track record of working closely with stakeholders in the co-design of research and the co-creation of practice-relevant knowledge. This "tried-and-true" approach will be used in the current project to engage stakeholders and potential end users.

Potential end users include:

- Hampton Roads Sea Level Rise Preparedness and Resilience Intergovernmental Planning Pilot Project which includes a range of federal agencies involved in a whole-of-community and whole-of-government approach to resilience.
- Hampton Roads Sea Level Rise/Flooding and Adaptation Forum organized by Michelle Covi, Larry Atkinson and the Hampton Roads Planning District Commission (HRPDC) provides quarterly stakeholder forums that engage government and private sector actors from planning, emergency management, public works, etc. Don Resio will be presenting his modeling work in the July 29, 2016 Adaptation Forum to this audience of end users.
- City of Norfolk, City of Portsmouth, Gloucester County are local governments that will be engaged
- Norfolk Emergency Preparedness and Response, City of Norfolk (linked to Rockefeller Foundation; Christine Morris): The project team will conduct interviews with planners to guide the development of the HSTT; data provision for validation and scenarios; participation in companion modeling.
- The project team also has connections to other organizations such as the US Coast Guard, Port of Virginia, City of Norfolk Department of Emergency Management, etc. These end users have been invited to participate in the Maritime Risk Symposium in November 2016.

7. Explanation of Changes:

Our project was revised in March 2016. The revised project would support at least two Coastal Resilience Center projects, building on project team's expertise in stakeholder engagement, leveraging information already collected from initial case studies, and utilizing existing connections to stakeholders and possible end users in Hampton Roads. Two project that were supported are: (1) Organizing a panel for the Maritime Risk Symposium that addresses "Integrating Maritime and Coastal Resilience;" and (2) supporting stakeholder engagement and end user translation efforts of '*The Incorporation of Rainfall into Hazard Estimates for Improved Coastal Resiliency' project.*

8. Unanticipated Problems:

The original project involved development of a Hazards Stress Test Tool (HSTT) that supports coordinated actions in all risk management and mitigation phases. However, our meetings with use case stakeholders identified that the project, as originally proposed, did not meet end user needs and would not gain traction within the end user community as a decision support tool. Following discussion with CRC program staff and the DHS Program Manager, we revised the project in March 2016. The revised project would support at least two Coastal Resilience Center projects, building on project team's expertise in stakeholder engagement, leveraging information already collected from initial case studies, and utilizing existing connections to stakeholders and possible end users in Hampton Roads. Two projects that were supported are: (1) Organizing a panel for the Maritime Risk Symposium that addresses "Integrating Maritime and Coastal Resilience;" and (2) supporting stakeholder engagement and end user translation efforts of '*The Incorporation of Rainfall into Hazard Estimates for Improved Coastal Resiliency' project.*

9. Project Outcomes:

Project outcomes:

(a) Connections to end users
Introduced port, maritime and emergency management stakeholders and end users into CRC activities via the Maritime Risk Symposium.
Invited Don Resio to present at the July 29, 2016 Hampton Roads Adaptation Forum with anticipated 80 end user attendees.

(b) Support of 2 Coastal Resilience Center projects.
Organized a panel for the Maritime Risk Symposium that addresses "Integrating Maritime and Costal Resilience" for November 2016.
Supported stakeholder engagement and end user translation efforts of '*The Incorporation of Rainfall into Hazard Estimates for Improved Coastal Resiliency' project through connecting Don Resio to the Hampton Roads Adaptation Forum.*

(c) Participate in Coastal Resilience Center activities and engage with CRC and projects.

10. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date
(expand cell size / add rows as needed)

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Meeting with potential use case stakeholders	March 2016	100%	Met with stakeholders from an urban area (City of Norfolk for long-term visioning/planning process); rural area (Gloucester County for disaster planning and

			emergency management); and regional organization (Hampton Roads All Hazards Advisory Committee and Hampton Roads Planning District Commission).
Finalize the identification of three use cases for HSTT	March 2016	100%	Identified regional, urban, and rural use cases for HSTT development.
Develop instruments for obtaining end user requirements and HSTT specification	March 2016	100%	Developed interview questions and user requirement survey to determine possible use of HSTT, tool input and output requirements, and systems requirements of end users.
Participation in CRC annual meeting	March 2016	100%	
Identify theme and potential maritime stakeholders as possible participants for the Maritime Risk Symposium panel	June 2016	100%	
Organize and submit Maritime Risk Symposium panel	June 2016	100%	
Agree (with rainfall project PI Don Resio) on stakeholder and end user engagement activities	May 2016	50%	Scheduled Don Resio to present his research and engage with stakeholders and end users on July 29, 2016 at the Hampton Roads Adaptation Forum.
Research Milestone			Next key milestone is in future project period

11. Transition Activity and Milestone Progress:

No transition activity associated with this project. This project serves as a testbed for other CRC projects and results will be reported through other projects.

12. Interactions with education projects:

None

13. Publications:

None

***14.* CRC Performance Metrics:**

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
N/A			

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
N/A			
Leveraged Support			
Description			Estimated Annual Value
N/A			

BERKE, TAMU

DHS Coastal Resilience Center

Research Project

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Local Planning Networks and Neighborhood Vulnerability Indicators

2. **Principal Investigator / Institution:** Philip Berke/Texas A&M University-College Station

3. **Other Research Participants/Partners:**

   -Galen Newman, Assistant Professor, Texas A&M; Supervise digital mapping, visualization.

   -Walter Peacock, Professor, Texas A&M; Develop indicators, analysis of indicator data, report research.

   -Texas Target Communities (John Cooper and Jaimie Masterson), Texas A&M University; lead and supervise all end user engagement activities.

4. **Short Project Description:**

   We developed a plan integration scorecard and user guidelines to assist local planners and emergency managers to improve integration of vulnerability reduction practices into different plans (land use, hazard mitigation, housing, transportation, economic development) that guide land use and urban development in hazardous areas. Communities often fail to coordinate networks of plans, which can significantly increase the vulnerability to coastal hazards and climate change. Development and validation of the tool requires testing the tool in six demonstration communities at risk to coastal hazards to determine how well networks of local plans integrate vulnerability reduction practices.

5. **Abstract:**

   Problem**.** Fragmentation and poor integration among the diverse range of sectors of planning has led to siloes in which mitigation planning is isolated from other planning. Hazard mitigation specialists have long been concerned about the lack of integration of mitigation across local planning sectors, which can significantly compound future vulnerability. Failure to coordinate multiple planning activities that govern land use in hazard areas has become a national policy concern. This was acknowledged by the FEMA director Craig Fugate's call for more integration of hazard mitigation efforts into all types of local planning and more cooperation between emergency managers and planners (Fugate 2010).

   Methods. We will initially review the literature in hazard mitigation planning to identify how mitigation can be supported by different local planning activities (economic development, land use, capital improvement programs, environment) that influence land use and development patterns. We then develop a conceptual framework to guide the creation of a scorecard that includes indicators that measure the variation of vulnerability within different geographic areas of a community, and that measure how well a local network of plans integrate vulnerability

reduction for each geographic area. Next, we apply the scorecard indicators to six demonstration coastal communities to test the applicability of the scorecard in determining how well the network of local plans support mitigation, and how well they are correlated with neighborhood vulnerability to coastal floods and projected sea level rise.

Fugate, W. C. 2010. "Integrating Hazards into Local Planning," Foreword to *Hazard Mitigation: Integrating Best Practices into Planning,* James Schwab, editor, PAS 560, American Planning Association, Chicago: iii-iv.

6. End users:

We are engaging end-users through creation of a National Advisory Committee, direct contact with FEMA officials, and involvement of local government staff in the demonstration communities.

We have recruited and convened a National Advisory Committee to strengthen partnerships and collaborations with the practice community and to ensure the applicability of the scorecard for mitigation practitioners. Members include key leaders in the practice community:

-Chad Berginnis, Director, Association of State Floodplain Managers
-Matt Campbell, Nat'l Coordinator for Community Recovery Planning & Branch Chief for Community Planning and Capacity Building of the Interagency Coord. Div.,FEMA
-Jennifer Ellison, Community Development Coordinator, City of Urbandale, Iowa
-Allison Hardin, Urban Planner, City of Myrtle Beach, SC
-Barry Hokanson, Director, Hazard Mitigation and Disaster Recovery Division of the American Planning Association & Mitigation Planner, PLN Associates
-Darrin Punchard, Mitigation Planner, Hawksley Consulting
-Gavin Smith, Exec. Director, Coastal Resilience Center, University North Carolina

The Committee meets about every 4-months via teleconference with project investigators. To date the Committee has met twice. Committee members offer guidance in the development of the plan integration scorecard tool, assist with dissemination of project results, and provide oversight and strategic advice to the research and translational activities. The Committee also serves to enhance communication between the project researchers and the practice community.

FEMA is the primary end user for this project. Our point of contacts are in the FEMA Risk Analysis Division, Assessment and Planning Branch, Mitigation Planning Program: Kathleen Smith, 202 646-4372, Kathlccn.W.Smith@fcma.dhs.gov; and Jenny Burmester, Jenny.Burmester@fema.dhs.gov. We informed Kathleen Smith of our progress last April during the Hazard Mitigation and Disaster Recovery Division meeting at the American Planning Association Conference in April 2016. In addition, Matt Campbell of FEMA serves on our National Advisory Committee. We also plan to keep in regular communication with our OUP Program Manager (Eleanore Hajian at 202 567-1525 or eleanore.hajian@hq.dhs.gov) about progress of this study through emails, conference calls, and preparation of a brief research summary report.

Finally, we have initiated preliminary engagement efforts with two demonstration communities in League City, Texas (Key contact: Marc Linenschmidt, Planning and Development Department) and Hampton, Virginia (Terry O'Neill, Community Development Department). It is the local community where all aspects of planning come together. We engage local agency staff and in some cases non-governmental actors charged with responsibilities for planning.

Local entities include, for example, emergency management, land use planning, housing, utilities, transportation, economic development, and environmental conservation. These end users are typically charged with preparing, updating and reviewing the diversity of local plans that influence land use and development in hazardous areas.

7. Explanation of Changes:

No significant changes.

8. Unanticipated Problems:

No unanticipated major problems.

9. Project Outcomes:

We will create an interactive web-based plan integration scorecard for community disaster resiliency derived from research in six demonstration communities. We will convert the research-driven scorecard to a user-friendly tool that will enable local decision makers to improve integration of mitigation into multiple planning activities, regulations, and public infrastructure investment decisions that influence land use and development patterns in hazard areas. A Practitioner's Guide and Scorecard will provide end users the opportunity to identify when and where their community plans are in conflict, as well as how well they target different geographic areas of the community that are most vulnerable. Armed with this new knowledge, planners can engage the whole community regarding 'missed opportunities' to strengthen local hazard mitigation planning, and leveraging the new knowledge to improve the integration, consistency, and responsiveness of their networks of plans.

The plan integration scorecard will be a web-based tool that adds new elements to a previous UNC CRC project by Berke, which yielded the "Beyond the Basics" website. The site is designed to help local governments prepare a new, or update an existing, hazard mitigation plan based on best practice standards and consistent with FEMA's Local Mitigation Planning Handbook. The core contribution of the plan integration scorecard is to help communities apply mitigation practices – development regulations, incentives and public spending – that are woven into all sectors of urban development management, rather than stand-alone and isolated efforts. Beyond the Basics" has recorded more than 13,000 hits over the last 12 months (7/15 to 7/16), with a steady growth in usage. Within the United States, California, Texas and New York, all high-population coastal states, are the source of most visitors.

10. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Draft plan integration assessment tool and user guidelines	2/28/16	100	The draft version of the tool was completed in response to reviews by our national advisory committee. (See below for discussion on importance of committee in assisting our efforts to translate our research to practice.)
Assess the physical and social vulnerability and apply the draft plan integration assessment tool to 2 demonstration communities.	6/30/16	100	We have engaged 2 demonstration cities: League City, TX and Norfolk, VA. We developed a vulnerability assessment for each city. We developed a 3-step process that led to selection of the 2 cities: 1) sent out request to 400 communities on HMDR's membership list; 2) candidate cities were asked to ensure participation by key local government agencies that influence development in hazard areas (planning, emergency management, housing, parks and rec., etc.); and 3) elected officials of selected cities express support for the project. We completed a social and physical vulnerability assessment and are training local officials in applying the plan integration tool in the 2 cities.
Research Milestone			
Complete data collection for social and physical vulnerability for the two demonstration communities.	6/30/16	100	

11. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Engage 2 partner communities willing to work with research team in the development of a draft plan integration assessment tool.	2/28/16	100	As noted, the draft version of the tool was completed with assistance from our national advisory committee. The committee plays a critical role in helping us ensure that the tool is relevant to hazard mitigation planning practice. The committee members include 8 highly qualified practitioners with experience in various aspects of planning that potentially influence land use and development in hazard areas. They are drawn from the leadership team of the Hazard Mitigation and Disaster Recovery Division (HMDR) of the American Planning Association. The tool has gone through 3 reviews by the advisory committee and been improved via multiple revisions. As indicated below, we are training local agency staff to self-evaluate the network of local plans by applying the plan integration assessment tool in League City and Norfolk. The results will identify degree of coordination (and conflict) among plans and the degree to which plans prioritize vulnerability reduction in different geographic areas. The cities are committed to use this information to update existing plans and guide creation of new plans deal with guiding public and private investments, regulations and revenue generation in hazard areas. Our ultimate goal is to translate the research (2015 Best Article Award, Journal of the American Planning Association) to a practice-based guidebook for application of the tool. We are working with HMDR at APA and the Rockefeller 100 Resilient Cities Program to help

			support widespread application of the tool. Of course, we aim to work with FEMA to achieve this goal. One of the members, Matt Campbell, on our National Advisory Committee is from FEMA.
Transition Milestone			
Conduct three workshops with key agency staff for each demonstration community. The purpose is to receive input on current mitigation practices and opportunities to improved coordinated integration among agencies.		80	We have engaged the communities and are currently working with them in assessing their networks of plans. We have not conducted three workshops in each community to date. The actual number of workshops needed per community may vary given the technical capacity and availability of local staff. We see 100% achievement of this milestone that will enable 100% achievement of the next milestone (draft user guidelines and assessment tool) on 9/30/16.

12. Interactions with education projects:

We supported the successful application of Dr. Sonia Gilkey from Texas A&M Kingsville that is a HSI (Hispanic serving institution) with Jen Horney (School of Public Health at Texas A&M University) to the DHS Summer Research Team Program for Minority Serving Institutions. Although Dr. Gilkey and her student were selected to participate in the program, they subsequently declined to participate due to a scheduling conflict.

13. Publications:

14. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)	0		
Undergraduates provided tuition/fee support (number)	0		
Undergraduate students provided stipends (number)	0		
Graduate students provided tuition/fee support (number)	2		
Graduate students provided stipends (number)	3		
Undergraduates who received HS-related degrees (number)	0		
Graduate students who received HS-related degrees (number)	0		
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)	0		
SUMREX program students hosted (number)	0		
Lectures/presentations/seminars at Center partners (number)	0		
DHS MSI Summer Research Teams hosted (number)	0		
Journal articles submitted (number)	0		
Journal articles published (number)	0		
Conference presentations made (number)	3 (Delft University, Holland; University of Kansas, University of Colorado)		
Other presentations, interviews, etc. (number)	1 (Hazard Mitigation Division, American Planning Assoc.)		
Patent applications filed (number)	0		
Patents awarded (number)	0		
Trademarks/copyrights filed (number)	0		
Requests for assistance/advice from DHS agencies (number)	0		
Requests for assistance/advice from other Federal agencies or state/local	0		
Total milestones for reporting period (number)			
Accomplished fully (number)			
Accomplished partially (number)			
Not accomplished (number)			
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support	See Table		

Articles on Center-related work published on website (number)			1
Coverage in media, blogs (number)			0
Social media followers (number)			0
Posts to social media accounts (number)			1
Events hosted (number)			0
Website hits (number)			0 (13,000

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
Plan Integration Scorecard for Community Disaster Resilience	Software and Hard Copy Products	November 2016	FEMA, Coastal Communities

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
Coastal Flood Risk Reduction Program: Integrated, Multi-scale Approaches for Understanding How to Reduce Vulnerability to Damaging Events	Berke	$200,000	NSF

Leveraged Support	
Description	Estimated Annual Value
Portion of university indirect returned to project	$2,000

DAVIDSON, UDEL

DHS Coastal Resilience Center

Research Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** An Interdisciplinary Approach to Household Strengthening and Insurance Decisions

2. **Principal Investigator / Institution:**

   Rachel Davidson, Professor, Civil Engineering, University of Delaware

3. **Other Research Participants/Partners:**

   - Jamie Kruse, Professor, Economics, East Carolina University
   - Linda Nozick, Professor, Civil Engineering, Cornell University
   - Joseph Trainor, Assistant Professor, Public Policy, University of Delaware

4. **Short Project Description:**

   This interdisciplinary project will improve a developing policy analysis tool to help agencies explore the potential effects of policies related to household hurricane risk reduction. The project specifically focuses on better understanding the factors that influence homeowner insurance purchase and retrofit decision-making.

5. **Abstract:**

   Two primary mechanisms to manage natural disaster risk— insurance and retrofit—are presently underutilized, suggesting a need to better understand how homeowners make retrofit and insurance purchase decisions. Future programs and policies intended to reduce coastal natural disaster risk will be more effective if designed to align with how homeowners actually make these choices.

   This project will advance understanding of (1) homeowner insurance purchase and retrofit decision-making and (2) the role it plays within the larger insurer-government-homeowner system of managing natural disaster risk. We will leverage two products from a NIST-funded research project we undertook recently—phone survey data and a holistic framework comprised of interacting mathematical models of hurricane risk, and homeowner and insurer decision-making that can help policy makers consider how specific policy alternatives might affect different stakeholder groups.

   In addition to advancing the scientific models and the broader mathematical framework, we expect four main near-term outcomes: (1) new discrete choice statistical models that describe

homeowner insurance and retrofit decisions; (2) a prototype computer-based decision tool that can predict the percentage of homeowners in a region that will buy insurance and/or retrofit under different circumstances and hypothesized government policy interventions; (3) a "system win-win" white paper that describes the larger mathematical framework this project contributes to, including the insights they produce when combined, and the value that the system will provide to practitioners; and (4) a series of short, accessible policy briefs on the impact of low cost loans, grants, and insurance premium reductions on homeowner retrofit decisions; insurance adoption decisions; and the impact of hurricane experience on insurance purchases.

6. End users:

Five primary end users are involved in this project, representing both the mitigation and preparedness directorates of FEMA, state floodplain managers, and the NIST Community Resilience group (Table 1). For all, their role is as members of a project Advisory Panel from with whom we get regular input and feedback through biannual group, web-based meetings as well as occasional one-on-one offline interactions. There were other communications before the project officially started and another one shortly after the end of this reporting period, but no group call other than the one listed during the 6 month period of Year 1. In addition, the co-PI Joe Trainor has been working with Jackie Snelling (below) on a different effort over the last year and they have spoken a great deal about this over that time as well.

Table 1. Primary end users involved in project

Name	Title	Organization	Role in project
Paul Huang	Acting Division Director	FEMA Federal Insurance and Mitigation Administration, Risk Analysis Division	Advisory Panel
Jacqueline Snelling	Senior Policy Advisor	FEMA Individual and Community Preparedness Division, National Preparedness Directorate	Advisory Panel
Chad Berginnis	Executive Director	Association of State Floodplain Managers (ASFPM)	Advisory Panel
Jennifer Helgeson	Research Economist	NIST Applied Economics Office/ Community Resilience Group	Advisory Panel
Steve Cauffman	Lead for Disaster Resilience	Materials and Structural Systems Division	Advisory Panel

Expected benefit to end users

The end users affiliated with this project are all charged with the management of national and local natural disaster risks. As part of their responsibilities, they must consider how to manage, improve, and incentivize risk reduction and loss management. Within this context, two main end user requirements have emerged that are particularly related to this project: (1) Motivating risk management actions among homeowners and other stakeholders, and (2) identifying win-win opportunities for risk reduction that engage multiple stakeholders.

First, a major part of being able to effectively manage risk is understanding how homeowners make insurance, retrofit, and other risk management decisions so that the government agencies can more effectively encourage and incentivize them to do so. These homeowner decisions are complex and depend on many factors, thus making it difficult to determine what combination of messages and incentives are most effective for different types of people experiencing different hazards under different community contexts and circumstances. In particular, the end users are interested in better understanding the likely effectiveness of different types of retrofit incentives, and how homeowner risk management decisions vary across hazards.

Another major challenge expressed by the end users is the need to identify and foster opportunities in which multiple stakeholders can be engaged in risk reduction and risk management activities in such a way that they all benefit and together help achieve community resilience. This "whole community" approach promoted by FEMA requires understanding both the decision-making drivers of each stakeholder, as well as how they interact. These questions are in line with those that our modeling framework intends to examine. As a result, the broader project vision provides a mental framework for end users to consider how risk management strategies and polices across stakeholders work together or against each other.

7. Explanation of Changes:

In response to a direct request from DHS in March/April, several changes were made to the original work plan for 2016. The changes were made to reflect incorporation of comments from DHS and to accommodate a substantial 25% Year 2 budget cut which forced us to reduce the student time working on the project. The primary changes are:

- Added development of a prototype computer-based decision tool (Transition Outcome #1)
- Removed task in which we would have replaced the current expected utility-based homeowner model in the modeling framework with the new discrete choice homeowner models and examined the effect on the overall system behavior. This was viewed as being of less interest to DHS and most of the end users than the other tasks.
- Added two policy briefs on insurance adoption and the impact of hurricane experience on homeowner protective action decision-making (in addition to the one already planned on incentives to encourage homeowner retrofit to mitigate hurricane damage).
- Moved development of the insurance purchase discrete choice model to occur before development of the retrofit decision discrete choice model.
- Added a second summer intern from Tougaloo College.

8. Unanticipated Problems:

None.

9. Project Outcomes:

The framework being developed in this project will advance understanding of what form of incentives to increase insurance and mitigation adoption will be the most impactful, cost effective, and effective at reducing overall risk for a region. It will improve the ability of emergency managers to predict how mitigation incentives and insurance premiums and deductibles impact homeowner risk reduction.

Research Outcomes.

- All of the work pushes the team further towards a policy analysis tool based on the larger holistic framework.
- Discrete choice household decision models that help users understand how homeowners make insurance purchase and retrofitting decisions.
- Analysis of the impact hurricane experiences have on risk mitigation/insurance decisions
- Research presentations and publications

End User / Transition Outcomes.

- *Prototype decision tool*. Based on the results we have generated from our Eastern North Carolina based dataset, we will develop a simple prototype decision tool (possibly in the form of an excel spreadsheet, for example) that will allow policy makers to see how this type of work might be used to predict how adjustments to policy (e.g., mitigation incentives or insurance premium changes) would affect homeowner risks within a region. The tool will be based on application of the discrete choice models to predict homeowner protective action behavior at the regional scale. While there are limits to the generalizability of the tool given the data source, it could allow users to adjust some fields and see what might happen. For example, we might include a place where the user could enter how many years since a major event and see what happens to risk reduction activity levels. End users will be able to adjust assumptions based on local data. The tool will include a user manual explaining how to use it, and a technical manual explaining the statistics behind it.

- *System win-win white paper.* This white paper will explain how the larger mathematical framework we are developing represents a new approach to thinking about risk reduction policies. It will discuss how this work along with other parallel projects and future envisioned efforts are the foundation for a new decision tool with the potential to fundamentally change the national system of incentives and regulations related to insurance and mitigation thereby reducing coastal risk. More specifically, it will help identify solutions that are better both for each stakeholder type individually and for society as a whole. By recognizing the stakeholders' different perspectives up front as an integral part of the analysis, the modeling framework may make it possible to identify those win-win system-wide solutions that are most likely to be effective and that are easier to build a coalition around instead of finding solutions that are theoretically best but practically unworkable. This approach complements the traditional approach of making incremental changes to the existing system and focusing on how to convince homeowners and other stakeholders to undertake actions considered desirable for community resilience. It can help the end users think about creative ways to make transformative changes in how disaster risk is managed in the United States by forcing us to think about how key stakeholder's interests interact.

- *Policy briefs*. We intend to produce a series of short policy briefs that translate the scientific analyses in this project into digestible results. The work will address incentives to encourage homeowner retrofit to mitigate hurricane damage (e.g., grant that does not

require repayment, reduction in insurance premium, or low interest loan), analysis of insurance adoption decisions, and analysis of the impact or hurricane experience on homeowner protective action decision-making. The briefs will directly address the end user interests in these scientific analyses and will translate the resulting insights into implications for practice and policy.

10. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Organize survey data and prepare software for statistical analysis	3/16	100%	
Formulate testable hypotheses based on end user interests and the protective action decision-making model (PADM). Our analysis will focus on the role of past hurricane experience on homeowner insurance purchase.	3/16	100%	We developed an analysis of how experience with hurricanes is linked to worry and fear. In addition we are analyzing the subsequent effects of these experiences and emotions on insurance purchase.
Begin fitting discrete choice models for decisions about insurance purchase.	6/16	100%	
Fit discrete choice models for decisions about insurance purchase.	8/16	100%	We were able to complete this ahead of schedule
Write journal paper about homeowner hurricane-related insurance decision-making	11/16	100%	We were able to complete this ahead of schedule
Begin fitting discrete choice models for decisions about homeowner hurricane-related retrofit decision-making, including consideration of incentives.	6/16	100%	
Begin testing hypotheses based on end user interests and PADM, specifically focused on hurricane experience and risk perception behavioral analysis.	6/16	100%	
Research Milestone			
Write journal paper about homeowner hurricane-related insurance decision-making	11/16	100%	We were able to complete this ahead of schedule. Some principal findings are included in footnote to this table.

* We found evidence that the following are all significant and associated with higher probability of purchasing insurance—lower premium, lower deductible, more recent previous hurricane experience, location in a floodplain or closer to the coast, higher income, and younger homeowners. However, demand is relatively inelastic with respect to premium and deductible, and the willingness to pay for a $1 reduction in deductible varies throughout the population with some willing to pay more than $1, a behavioral anomaly. The recency of the last hurricane experience is more influential for homeowners who experienced damage than for homeowners who did not. Importantly we present statistical models that can be used to predict insurance penetration rates for a region under different premium levels.

Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Group conference call with research team and all end user partners to describe and get additional input on proposed plan	1/16	100%	The entire group participated and their input focused on helping us understand what types of output would be useful for them. They are particularly interested in incentives to encourage retrofit.
Begin writing System win-win white paper	6/16	100%	
Transition Milestone			
Next key milestone is in future period.			

11. Interactions with education projects:

In the Summer of 2016, we are hosting two 8-week summer interns from our CRC partner, Tougaloo College, at the Disaster Research Center at the University of Delaware. The students are Irenia Ball and Taralyn Rowell, both African American Female Seniors. While at UD they are contributing to this project by reviewing extant insurance literature and developing an inventory of mitigation programs currently being offered by states. These students have also visited the Delaware Legislature and with a group of non-profit leaders in Wilmington. They have also been interacting more generally with UD social science and engineering students and faculty interested in disaster studies. We were able to bring the second student by identifying supplemental funds from the University of Delaware to support her.

12. Publications:

Wang, D., Davidson, R., Trainor, J., Nozick, L., and Kruse, J. Homeowner purchase of insurance for hurricane wind and flood protection. *Natural Hazards*, in review (submitted July 7, 2016). (Wang, D. is a Ph.D. student)

13. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research Project**	**Education Project**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)	0		
Undergraduates provided tuition/fee support (number)	0		
Undergraduate students provided stipends (number)	0		
Graduate students provided tuition/fee support (number)	2		
Graduate students provided stipends (number)	2		
Undergraduates who received HS-related degrees (number)	0		
Graduate students who received HS-related degrees (number)	0		
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)	0		
SUMREX program students hosted (number)	2		
Lectures/presentations/seminars at Center partners (number)	0		
DHS MSI Summer Research Teams hosted (number)	0		
Journal articles submitted (number)	1		
Journal articles published (number)	0		
Conference presentations made (number)	0		
Other presentations, interviews, etc. (number)	0		
Patent applications filed (number)	0		
Patents awarded (number)	0		
Trademarks/copyrights filed (number)	0		
Requests for assistance/advice from DHS agencies (number)	0		
Requests for assistance/advice from other Federal agencies or state/local governments (number)	0		
Total milestones for reporting period (number)	1		
Accomplished fully (number)	1		
Accomplished partially (number)	0		
Not accomplished (number)	0		
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
Insurance purchase paper	Journal paper	July 2016	Academic and professional

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
Collaborative Research: An Interdisciplinary Approach to Modeling Multiple Stakeholder Decision-making to Reduce Regional Natural Disaster Risk, National Science Foundation	Davidson	$306,555	NSF
Modeling natural disaster risk management: A stakeholder perspective	Davidson	$797,000	NIST

Leveraged Support	
Description	Estimated Annual Value
DRC support of interns	$1,000
UDEL School of Public Policy and Administration support of interns	$1,000
UDEL Vice Provost of Diversity support of interns	$3,000

PROCHASKA, URI

DHS Coastal Resilience Center

Research Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Communicating risk to motivate individual action

2. **Principal Investigator / Institution:** Dr. James O. Prochaska, Cancer Prevention Research Center (CPRC), URI

3. **Other Research Participants/Partners:** Additional Investigators: Dr. Andrea Paiva, CPRC, URI, Pam Rubinoff, CRC, URI.
    a. Significant partner: Pro-Change Behavior Systems, Inc.

4. **Short Project Description:** Communicates risk to motivate action by tailoring communication to diverse populations. Participants receive individualized feedback via online coaching based on their readiness to take action, thereby encouraging them to move forward in the behavior change process to prepare and mitigate impacts of coastal storms.

5. **Abstract:** Efforts to communicate disaster preparedness and risk messages lead to increased public awareness. However, FEMA surveys indicate that the public today is little more prepared to respond to a disaster than it was several years ago. This conundrum reflects the axiom in the science of behavior change that increasing awareness can start the change process, but cannot sustain it; reflecting a disconnect between theory and practice. Behavior change psychology indicates that: 1) the behavior targeted for change must be clearly defined and include specific achievable actions; and that 2) behavior change is a long process where each stage is a small step on the way to permanent behavior change. While efforts at linking behavior change and preparedness have been shown to be successful (Miletti and Darlington, 1995) it is not common place for most emergency managers, communicators and planners to incorporate behavior change psychology when communicating with the public.

    This intervention will be based on the Transtheoretical Model of Behavior Change (TTM), which has demonstrated with more than 50 risk behaviors that change unfolds over time and involves progress through a series of five stages. 1) Precontemplation (Not Ready): people do not intend to take action in the foreseeable future, usually measured as the next six months. 2) Contemplation (Getting Ready): the stage in which people intend to change in the next six months. 3) Preparation (Ready): people intend to take action in the immediate future, usually measured as the next month. Typically, they have already taken some significant action in the past year. 4) Action: people have made specific overt modifications in their lifestyles within the past six months. 5) Maintenance: the stage in which people have made specific overt modifications in their lifestyles more than 6 months ago. At each stage, different principles and processes of change need to be applied if populations are to take effective action and maintain that action. This project addresses key questions about what motivates individuals and groups to prepare for disasters before threats exist, when threats exist, and when a crisis is occurring.

Our project parallels FEMA's effective application of our TTM Model in the research reported in Preparedness in America.

This project builds upon state-of-the-art approaches to communications designed to reduce risks, which most recently were adapted for a pilot related to natural hazard preparedness. The primary focus of this project will be on preparedness, which will utilize computer tailored interventions (CTIs) which are online, user-friendly programs that ask a series of questions and provide immediate feedback tailored to the users' responses. The CTI's have the greatest impact across populations and problems. Such communications can produce interventions for entire populations that are fully tailored to each individual and those constructs that drive the most change (e.g. stages of change and pros/cons of changing). Statistical decision-making rules determine the best messages that should be sent and provide feedback on where participants are making their best efforts, where they need to improve, and where they are progressing. The secondary focus will be on mitigation behaviors designed to reduce damage from wind and flooding. These behaviors will be tailored only on the individual's stage of change. Previous research on health risk behaviors has demonstrated that applying CTIs that are fully tailored to a primary behavior (in this case preparedness), and stage tailored to secondary behaviors (in this case wind and flood) has had significant impacts on each behavior.

To evaluate the efficacy of communication interventions, longitudinal studies are necessary over a period of time, including reassessing participants after one and two-year periods to determine how behaviors change by movement through the five stages, and to adjust the individualized coaching accordingly. This is not common practice. This program promotes such an effort and is scalable to large populations to effectively communicate disaster preparedness and risk messages.

6. **End users:** The direct end users of this project are coastal residents in New England and Florida. However, to ensure the continued use of this research in practice, it will also target local, state, and Federal emergency managers, and coastal planners, who can help us identify ways to incorporate and/or adapt the research findings to their communication programs. We have reached out to the following individuals and received several commitments to engage in our end-user team:

   National – (1) Jacqueline Snelling from FEMA's Individual & Community Preparedness Program;

   (2) Mary Culver from NOAA's Office for Coastal Management; Chad Berginnis ASFPM Executive Director; Kim Smail the Federal Alliance for Safe Homes).

   We organized a meeting in Washington with her team and other stakeholders from NOAA, the National Weather Service, and our team, with the PI's presenting and other team members on teleconference. This half day meeting covered considerable ground including agreements that our team would be available to consult at no cost with the FEMA team and others. We also discussed an additional project targeting preparedness with high school teens serving as change agents guided by our Computer-Tailored Interventions and text message adaptation for teens and delivered in schools and homes. This proposal serves to support a way to disseminate our research via schools. Since that meeting, we have submitted a grant proposal for state funding aimed at reducing costly effects of coastal storms. As part of this project we received

commitment from Westerly, RI's school department and the Red Cross of RI who has been interested in such a school-based program for possible national dissemination. Since the meeting, we also collaborate with the FEMA team on their National Household Survey and consulted on measures and analyses in order to compare results across projects.

Regional - Mark Landry, Federal Federal Coordinating Officer and Disaster Recovery Manager for FEMA Region 1

Rhode Island – Jessica Stimson RI Emergency Management (to be confirmed); Igor Runge of the Rhode Island Floodplain Mitigation Association Board of Directors (Chapter of the ASFPM); Elizabeth Stone RI Department of Environmental Management and the RI Executive Climate Change Coordinating Council.

7. **Explanation of Changes:** No Changes

8. **Unanticipated Problems:** We have not experienced any unanticipated problems or challenges since the start of the project.

9. **Project Outcomes:** Previous research across a range of risk behaviors has identified four effects or drivers that predict successful behavior change at long-term follow-up. The first is the stage effect that generates the hypothesis that at-risk individuals who are in the preparation stage at baseline will have greater success in adapting preparedness behaviors that those in the contemplation stage who will have greater success than those in the Precontemplation stage. The effort effect generates the hypothesis that at-risk individuals making the best efforts at baseline (e.g., endorsing that they have more pros of changing and fewer cons of changing) will have higher percentages adopting preparedness behaviors than those with poorer efforts (endorsing a high number of cons of changing and few pros of changing). The severity effect generates the prediction that those who experience the more severe effects from storms (e.g., injuries, cost, and disruption) over the course of the project are most likely to take action and maintain a higher level of preparedness over time. Further, the team hypothesizes that the effects will continue to be seen at later time points with changes in the outcome measures increasing over time from the 12 to 24 month time points. We will also compare outcomes by demographic groups with special emphasis on comparing the 500 participants from the New England region to the 500 from Florida's coastal communities. The team would also seek to benchmark annual rates of increases in preparedness against FEMA surveys of increases in preparedness in coastal populations. The team hypothesizes that there will be increased action success rates (taking action by making changes) across five stages of change based on feedback and length of intervention. The major outcome metric will be comparable to that used in more than 25 population trials – the percentage who progress from "not prepared" to "prepared" for disasters. A revised Internet-based CTI together with ongoing coaching through individualized text messages to 1000 participants is expected to increase the efficacy of storm preparedness — the key behavior targeted. The project will assess participants every 12 months so the team can dynamically tailor the messages to their stage.

We expect an evidence based CTI and texting program that is highly portable and could be delivered by end-users like FEMA and the Red Cross. Technically our University will own Intellectual Property and will follow national guidelines on how to share the program with the funding agency and others implementation across states, regions, and others for maximum nationally.

10. **Research Activity and Milestone Progress:**

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Receive Human Subjects Institutional Review Board approval	1/31/16	100%	
Develop statistical decision rules for text-based CTIs	3/30/16	100%	
Update/customize Internet CTI for each region	6/30/16	100%	Based on discussions with end-users, like FEMA, the Red Cross and Smart Homes and based on our limited budget it was decided that the best customization for now would be bursts of texts that could be communicated at key times like prior to, and after, a severe storm in one of our target areas.
Research Milestone			
None for this period.			

11. **Transition Activity and Milestone Progress:**

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Ongoing collaborative conference calls with End-user Team	1/1/2016 – 6/30/2016	100%	
Build capacity of End-user team on TTM/CTI behavior change methods	1/1/2016 – 6/30/2016	100%	
Working with DHS & URI intellectual property offices to facilitate transition prior to making the purchase	1/1/2016 – 6/30/2016	100%	
Engage end users for collaborative input for tailored messages for texting	1/1/2016 – 6/30/2016	100%	
Transition Milestone			
Completed one collaborative conference call with End-user Team	6/30/16	100%	This was one of the collaborative calls with the FEMA team and their Gallop support team with 7 people participating. One key result of this meeting is that both teams modified their measures to make direct comparisons possible from national surveys and other regional sample assessments. We have agreed that our team would collaborate in 2017 on the national survey in order to include behavior change variables that can provide more sensitive measures of preparedness and progress and can be stronger drivers of such change.
Webinar-based presentation with End-user team on behavior change methods	6.30/16	100%	This was a presentation for a RI Task Force charged with protecting coastal properties, including government and private property. About 20 individuals representing about 12 groups participated. A key outcome was our team's commitment to show both our baseline and follow-up assessments to help guide the Task Force's work.

Participation of majority of targeted end-users on End-User Team for collaborative input for tailored messages for texting	6/30/16	100%	This was a half-day meeting in Washington with about 20 people participating, including those on the phone. As indicated in Section 6 above there was robust dialog, exchange of ideas, like a future school-based program and commitments to work closely with the FEMA team and other end-users that were there.
Developed plan with DHS and URI intellectual property offices if DHS or any community want to use project's intellectual property	6/30/16	100%	The plan was that DHS as the funding agency could apply our IP with any community it serves.

12. **Interactions with education projects:** Our project team has been involved in several meetings with key stakeholders and partners, the most recent of which was in April when we presented our project to the FEMA team most responsible for the Preparedness in America project. Stakeholders from the National Weather Service, Eleanore, our DHS project officer and others, like Dr. Andrea Paiva and Pam Rubinoff, participated via teleconferencing.

    - The URI research team held a meeting with Center PI Gavin Smith in Rhode Island on January 6th, 2016 to discuss our project's tasks, and to facilitate potential collaborations across the Center.
    - The URI research team initiated planning for summer interns. Lack of adequate funds proved to be a challenge to funding summer interns. We are coordinating with the URI Summer Undergraduate Research Opportunity program, funded by National Science Foundation, to help fund one or more summer interns to collaborate on URI research projects for 2017.
    - Project co-PI Dr. Austin Becker was invited to present for the education program "Expanding Coastal Resilience Education" at University of North Carolina. Date to be determined.
    - Project co-PI Pamela Rubinoff University presented for a class at the University of North Carolina education program "Expanding Coastal Resilience Education"
    - Project PI James Opaluch coordinated with CRC Team led by Dr. Rachel Davidson to facilitate collaborations among the two projects. We are now participating in periodic conference calls. The first joint call was held on Wednesday February 24th.
    - URI-hosted conference on Monday, June 13, 2016 on coastal storm modeling attended by Dr. Rich Luettich. Following the conference, the URI research team met with Dr. Luettich to discuss issues of mutual interest, and to facilitate collaborations, including collaborations with educational programs.

13. **Publications:** No publications have been submitted in this first 6 month period.

14. **CRC Performance Metrics:**

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)			
Undergraduates provided tuition/fee support (number)			
Undergraduate students provided stipends (number)			
Graduate students provided tuition/fee support (number)	1		
Graduate students provided stipends (number)			
Undergraduates who received HS-related degrees (number)			
Graduate students who received HS-related degrees (number)			
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)			
SUMREX program students hosted (number)			
Lectures/presentations/seminars at Center partners (number)	2		
DHS MSI Summer Research Teams hosted (number)			
Journal articles submitted (number)			
Journal articles published (number)			
Conference presentations made (number)			
Other presentations, interviews, etc. (number)			
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)			
Requests for assistance/advice from DHS agencies (number)	2		
Requests for assistance/advice from other Federal agencies or			
Total milestones for reporting period (number)	4		
Accomplished fully (number)	4		
Accomplished partially (number)	4		
Not accomplished (number)			
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
N/A			

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
N/A			

Leveraged Support	
Description	Estimated Annual Value
Returned Indirect Cost[1]	$4,948
Travel Support	$500

[1] The University of Rhode Island's Coastal Institute (CI) has generously agreed to return 66% of their share of indirect cost return back to the project. The CI obtains 17% of the indirect cost, so roughly 11.3% of indirect cost is being returned to the project.

OPALUCH, URI

DHS Coastal Resilience Center

Research Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title**. Overcoming Barriers to Motivate Community Action to Enhance Resilience

2. **Principal Investigator**. James Opaluch, Environmental and Natural Resource Economics, University of Rhode Island

3. **Other Research Participants/Partners**. Austin Becker, Marine Affairs, Univ. of Rhode Island, Dawn Kotowicz, Donald Robadue, and Pamela Rubinoff, Coastal Resources Center, Univ. of Rhode Island

4. **Short Project Description**.

To date there is little quantitative information on the ability of communities to adapt to the threat of coastal hazards (e.g., Corps of Engineers, 2012). This project will help increase community resilience by providing a better understanding of the barriers that communities face in adapting to coastal storm hazards, and by designing and testing interventions that can have the potential to overcome these barriers. We will combine individual interviews, group decision processes and policy simulation exercises to identify key barriers and to design interventions to overcome those barriers.

5. **Abstract**.

This research will help improve the resilience of communities that face risks from coastal storm hazards. We adopt insights from social science models of behavior change to develop programs to improve the adoption rates of actions that can reduce potential damages from major coastal storms. A principal finding of the literature on behavior change is that simply providing information is not generally sufficient to bring about changes in behavior (Scott 2002, Stern 2000). Rather, increasing the adoption rate of behaviors to mitigate storm effects is challenging (Kesete et al. 2014; Carson et al., 2013). Various theories of behavior change recognize that carefully planned and well-designed interventions can help to expedite change (e.g., Velicer et al. 1998; Moser and Ekstrom, 2014; Lindell and Perry, 2012).

This project focuses on improving the adoption rate of community-based and other collective actions, such as mitigating actions by groups of interacting stakeholders. We adopt a framework based on the insights from social science models of behavior change to identify barriers to adoption of mitigation actions by communities, and to develop measures that are designed specifically to overcome these barriers.

This research project is based on the hypothesis that there are multiple reasons for inadequate behavioral response to coastal storm hazards, and that the reasons vary across the types of

decisions, the prior experience with hazards, and characteristics of community decision-makers. As a consequence, building resilience requires a systematic research program to understand the resistance of the community to adopting new behaviors, to identify barriers to adoption of hazard mitigating strategies, and to design effective policy interventions to overcome barriers for different groups of individuals, businesses and communities.

We adopt the DHS "Whole Community Approach" (e.g., Department of Homeland Security, 2014) to identify the barriers faced in adopting damage mitigation measures, and to design and test interventions to overcome these barriers. Interventions to increase adoption rates may include information tools to deepen the understanding of causes and consequences; improved information on specific feasible protective actions; economic incentives for the adoption of protective actions; new and/or changes in existing policies; and other interventions designed to specifically overcome the barriers that we identify in working with communities. The model is implemented with targeted stakeholder groups to improve our understanding of how to overcome obstacles at the community level, and thereby help to build community resilience.

The focus of our behavioral research is also responsive to President Obama's September 15, 2015 Executive Order "Using Behavioral Science Insights to Better Serve the American People" (White House, 2015), which directs agencies to "develop strategies for applying behavioral science insights to programs and, where possible, rigorously test and evaluate the impact of these insights". The Executive Order goes on encourage agencies to conduct behavioral research to "… review elements of their policies and programs that are designed to encourage or make it easier for Americans to take specific actions …"

6. End users:

This project adopts the core guiding principles of the DHS "Whole Community Approach", and we will work cooperatively with as many community groups as feasible to ensure we understand the needs of the community, and that we engage and empower all community members. To do so, this project leverages ongoing efforts by co-PI Pamela Rubinoff and colleagues at the URI Coastal Resources Center/RI Sea Grant program to help communities prepare for sea level rise and coastal storm hazards. We also leverage workshops conducted by co-PI Dr. Austin Becker on Rhode Island port vulnerability. This project adds value to those ongoing efforts by applying social-science based models of behavior change, identifying barriers to change and designing interventions to overcome those barriers. Table 1 below contains a partial list of community groups that have participated in those efforts to build a more resilient coastal community. We anticipate continuing to work to meet the needs of these and other community groups.

Project personnel have participated in, facilitated and/or observed a total of 29 group decision processes with industry representatives and federal, state and local agencies. The dates, titles and purpose of these events are briefly summarized in Appendix A. These activities include both direct project-related efforts, and leveraged efforts of ongoing activities of co-PIs that the project capitalized upon. The meetings were used to assist private and public officials in planning for coastal storm hazards, and for the coordination of related actions. Simultaneously, we used the events to improve our understanding of the barriers to adaptation faced by members the private sector and government agencies, as well as the potential for various actions to overcome those barriers.

We will continue interact with other local officials as part of these ongoing efforts in order to obtain community perspectives on potential actions to make their community more resilient to coastal storm damages. Individuals at the municipal level with whom we are working include Pamela T. Nolan, Town Manager for Narragansett, City of Warwick Mayor Scott Avedisian, Warwick City Council Chair Donna Travis, Charlestown Town Council Member Virginia Lee, and Executive Director Daniel Beardsley of the Rhode Island League of Cities and Towns.

We have also tentatively identified the following end users who will be involved in the project:

- Tim Smail Federal Alliance for Safe Homes (FLASH)
- Jackie Snelling, FEMA HQ - ICPD - Individual & Community Preparedness.
- Michelle Burnett and Jessica Stimson, RI Emergency Management Agency
- Mary Culver, NOAA Office of Coastal Management
- Elizabeth Stone. Office of the Director, RI Department of Environmental Management
- Board of Directors of the Rhode Island Flood Mitigation Association
- Stephen Cauffman, National Institute of Science and Technology
- Natalie Grant U.S. Department of Health and Human Services

Phase I of the project focusses on a Rhode Island-specific application, but later phases of the research will extend the methods, results and outputs obtained in Rhode Island to other geographic contexts. In Phase I, we have budgeted for one regional trip to discuss the applicability of Rhode Island-specific results and outputs to another geographic location, to be determined. We currently anticipate meeting in Boston or New York/New Jersey area. As the research progresses, we will work in collaboration with DHS and regional contacts to identify the most appropriate location. We will also leverage a pilot study by co-PI Dr. Austin Becker on port resilience in the North Atlantic as a broader context within which to test insights obtained from our work in Rhode Island.

Table 1. End Users Participants in Group Decision Processes

Shoreline Change SAMP	Port Vulnerability Assessment
Private Sector Associations, Educational Institutions and Nonprofits:	
RI Realtors Association RI Builders Association Westerly Economic Development Committee RI Independent Insurers Association Save-the-Bay Homeowners Associations of Block Island and North Kingstown Salt Pond Coalition (Nonprofit Advocacy Group for RI Salt Ponds) RI Nursery and Landscape Association American Society of Civil Engineers Univ. of Albany	Quonset Development Corp ProvPort (Port Authority) Private firms on the waterfront FM Global (Global Provider of Commercial and Industrial Property Insurance) Save-the-Bay CommerceRI (State of RI Business Promotion Agency) RI Marine Trades Association, Newport Maritime Association. Private Marinas. RI Sea Grant/Coastal Resources Center
Federal/State/Local Government Agencies	
RI Department of Environmental Management RI Coastal Resources Management Council RI Division of Statewide Planning RI Flood Mitigation Association RI Emergency Management Agency. South County Communities (Town Representatives) RI Green Infrastructure Project: (Participating Towns: Warwick, No. Kingstown, Newport, & Aquidneck Island) US Army Corps of Engineers	RI Coastal Resources Management Council RI Division of Planning Providence Department of Planning RI Emergency Management Agency US Marine Administration (MARAD) US Coast Guard US Army Corps of Engineers

7. End user requirements or problems the project addresses.

As indicated above, coastal communities face large and increasing risks associated with coastal storm hazards. There are numerous protective actions that can be undertaken to substantially reduce potential storm damages (FEMA, 2011; FEMA 2104; Coastal Resources Center, 2014), but decision makers frequently do not invest in these measures (Kesete et al., 2014; Carson et al, 2013).

Decisions to carry out mitigation actions are complicated, and can depend on a variety of factors involving individuals or policies (e.g., Ge et al, 2014; Carson et al, 2013; Peacock, 2003). This contributes to the so-called "adaptation deficit" (e.g., Burton, 2009), whereby threatened communities often fail to take an appropriate level of actions to adapt to climate change threats, including sea level rise and coastal storm hazards.

This project will carry out a systematic research program to identify actions to mitigate risks from major coastal storms, identify barriers that are faced by communities in taking these actions, and design interventions to overcome these barriers. The information generated will improve our understanding of how to build community resilience. Consistent with the spirit of the DHS "Whole Community" approach, we will disseminate project-related information as widely as possible, and do not anticipate that any single end user will "own" the information we obtain. Information will be delivered in the form of reports, publications and less formal information sheets.

We will also transmit information to representatives of the private sector, and to federal, state, local government officials as part of ongoing planning activities in which we routinely participate as part of leveraged activities. Examples of these activities for September 2015 June 2016 are reported in the Appendix A. Additional ongoing and future activities include planning events led by Co-PI Austin Becker for US Atlantic ports, and efforts by co-PI Pamela Rubinoff for Rhode Island state agencies and coastal communities.

As indicated elsewhere, we are working with end users and other community groups on a continuing basis throughout the project to ensure our project outputs meet their needs. See the preceding section for more details.

8. Explanation of Changes:

We have adapted the schedule of our planned activities, so we focus more heavily than anticipated on facilitating, observing and participating in group decision process, and have pushed the one-on-one semi-structured interviews back to year 2. This is in part because we had identified more opportunities to participate in group decision processes than we previously anticipated, and we didn't want to miss those opportunities (See the Appendix for a list of group decision processes in which we participated, as of July 1). Also, in retrospect, we decided that we would use the group decision processes as an opportunity to obtain insights, formulate hypotheses and develop preliminary conclusions, and follow up on these in the one-on-one semi-structured interviews.

9. Unanticipated Problems:

None

10. Project Outcomes:

As indicated above, we are working closely with federal, state and local partners to increase the resilience of communities to coastal storm hazards. To do so, the project leverages ongoing efforts by project PIs Rubinoff and Becker, and adds value to those efforts by applying formal social science-based frameworks of behavior change, identifying barriers to adoption of protective actions and interventions that may help overcome those barriers. This work with stakeholder groups is in the spirit of the DHS "Whole Community Approach" to understand the needs of the community, and that we engage and empower all community members. (Department of Homeland Security, 2015), and the September 2015 Executive Order "Using Behavioral Science Insights to Better Serve the American People" (White House, 2015) which directs agencies to conduct behavioral

research to "… review elements of their policies and programs that are designed to encourage or make it easier for Americans to take specific actions …"

To date, we have facilitated, observed and/or participated in a total of 29 stakeholder meetings. From these meetings, we have developed a preliminary list of opportunities for making communities more resilient to coastal storms, barriers to adoption of protective actions to capitalize on these opportunities and interventions that can potentially help overcome those barriers.

Other outputs of the project to date include (1) an annotated bibliography of roughly 100 publications and reports directly germane to the project (Task 1), (2) 13 presentations at professional conferences, (3) two papers submitted to peer reviewed publications, (4) 2 presentations to date in webinars for FEMA Region 1 and one face-to-face meeting in Washington for FEMA.

The next step in this research will be to carry out a series of semi-structured interviews with stakeholders, working one-on-one or within small groups. This effort will follow up the observations and hypotheses generated during the group decision processes, and to validate and refine the preliminary list of opportunities, barriers and potential interventions. Simultaneously, we will be developing and refining preliminary Policy Simulation tools to be applied later in the project.

These Policy Simulation tools will be made available to facilitate planning by federal, state and local agencies. Many of these tools are being created by leveraged activities by project PIs, and used in ongoing planning activities. For example, Dr. Austin Becker is taking the lead to create visualizations of storm impacts, and we anticipate these visualizations will be integrated with "Storm Tools", a set of planning tools being created as part of the Rhode Island Shoreline Change Special Area Management Plan (see http://www.beachsamp.org/stormtools/). This is an effort led by the State of Rhode Island Coastal Resources Management Council, to help individuals, businesses and communities prepare for sea level rise and coastal storms. Other tools created for Policy Simulation activities will similarly be shared and used, as appropriate, for various planning activities. Project co-PI are actively involved in planning activities, and we anticipate that these tools will see wide use by end users.

11. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Task 1. Literature Review		100%	We have identified, reviewed and created an annotated bibliography of roughly 100 publications and reports. However, we will continue to update the literature review throughout the project as we identify additional literature.
Task 2. Group Decision Processes		100%	We have facilitated, observed and participated in a total of 29 group decision processes listed in the Appendix. However, in order to obtain additional insights and to maintain two-way communications with stakeholders, we will continue to participate in this activity as opportunities arise through the project.
Task 3. Individual Semi-Structured Interviews	2/28/17	0%	As discussed elsewhere, we have moved the timing of this task to Year 2, and instead focusses more than anticipated on Task 2 Group Decision Processes (see Section 8 above for the rationale). Carrying out and analyzing semi-structured interviews activity will be a primary focus of year 2. We anticipate completing interviews by Dec 31, 2016, and completing the coding interviews by Feb 28, 2017.
Task 4. Initial Draft Policy Simulation Tools	12/31/16	25%	This Task is on schedule to be completed by Dec 31, 2016, as proposed in the work plan.
Research Milestone			
Plan for Coordination with Davidson Research Team	3/1/2016	100%	We participate in periodic conference calls with the Davidson team
Updated Literature Review	3/1/2016	100%	As indicated above, we have written an annotated bibliography of a substantial literature. However, this activity will continue throughout the project as addition literature is identified.

Facilitate, Observe and Participate in Group Decision Processes		100%	This activity was moved forward to Year 1, as discussed elsewhere. We have facilitated, observed and participated in a total of 29 group decision processes, listed in the Appendix. However, in order to obtain additional insights and to maintain two-way communications with stakeholders, we will continue to participate in this activity as opportunities arise through the project.
Preliminary list of barriers and interventions	12/31/2016	33%	This activity is on schedule to be completed by Dec 31 2016, as initially planned. The initial list from Group Decision Processes will be validated and refined in the semi-structured interviews of Year 2.
Complete One-on-One Interviews	12/31/2016	0%	The timing of this activity was switched with group decision process, and consequently pushed back to 2016-7 as explained elsewhere in this progress report
Content Analysis of Interviews	2/28/2017	0%	See item above.

12. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Facilitated, Observed and/or Participated in 29 Group Decision Events		100%	We have completed a total of 29 group decision processes as of June 30, which is more than we anticipated. However, this activity will continue throughout the project, as it allows us to obtain additional insights and to maintain critical two-way communications with stakeholder groups.
Obtain input and feedback from an end-user workshop to support design of scenarios and products.	September 30, 2016	25%	Team changed strategy to engage end-users in different venues, rather than a single workshop, as individual have proven more effective. A meeting with USCG had been scheduled for June 12th, but unfortunately USCG had to postpone that meeting due to an

			unanticipated commitment. A meeting with RI Emergency Mgmt team will take place within next 6 weeks. A workshop at annual "Rhody Ready" event of local, state and regional emergency managers will include a presentations and discussions to gain input and feedback.
Transition Milestone			
Group decision processes	Dec 2017	100%	See attached list of events in the Appendix. We intend to continue this activity throughout the project to obtain additional insights and to maintain two-way communications with Stakeholder
Presented project goals and preliminary results in 3 FEMA meetings	June 2016	100%	These meetings were organized by CRC and DHS personnel, and were held in DHS headquarters in Washington DC and at the Univ of Rhode Island. Although we received considerable interest and positive feedback, no specific outcomes were achieved at this early stage of our research.
Presented for FEMA Region I Advisory Council	June 2016	100%	Project goals, objectives and preliminary results were presented for a conference call of regional DHS personnel. This conference call led to additional invitations to present our project at a future meetings of regional DHS officials.
Obtain input and feedback from the End-user workshop to support design of scenarios and products.	September 30, 2016	25%	See details above
Stakeholder Newsletter		100%	We anticipate continuing to release newsletters periodically throughout the project in order to keep stakeholders apprised of our research progress and results. Originally we planned to release monthly newsletters, but we felt this frequency reduced the effectiveness of this communication tool. Instead we believe that release of more substantive, but less frequent Newsletters will be more effective in gaining attention of Stakeholders

13. Interactions with education projects:

Below we summarize interactions with other Center Activities to date:

- The URI research team held a meeting with Center PI Gavin Smith in Rhode Island on January 6th, 2016 to discuss our project's tasks, and to facilitate potential collaborations across the Center.
- The URI research team initiated planning for summer interns. Lack of adequate funds proved to be a challenge to funding summer interns. We are coordinating with the URI Summer Undergraduate Research Opportunity program, funded by National Science Foundation, to help fund one or more summer interns to collaborate on URI research projects for 2017.
- Project co-PI Dr. Austin Becker was invited to present for the education program "Expanding Coastal Resilience Education" at University of North Carolina. Date to be determined.
- Project co-PI Pamela Rubinoff University presented for a class at the University of North Carolina education program "Expanding Coastal Resilience Education"
- Project PI James Opaluch coordinated with CRC Team led by Dr. Rachel Davidson to facilitate collaborations among the two project. We are now participating in periodic conference calls. The first joint call was held on Wednesday February 24th.
- URI-hosted conference on Monday, June 13, 2016 on coastal storm modeling attended by Dr. Rich Luettich. Following the conference, the URI research team met with Dr. Luettich to discuss issues of mutual interest, and to facilitate collaborations, including collaborations with educational programs.

14. Publications:

Touzinsky, K, Rosati, J., Fox-Lent, C., Becker, A., Luscher, A., 2016. "Advancing Coastal Systems Resilience Research: Improving Quantification Tools through Community Feedback" under review at *Shore and Beach*. Expected publication date 2017.
Zhang, H., Ng, A., Becker, A. 2016, "Institutional Barriers in Adaptation to Climate Change at Ports, Regions, and Supply Chains." under review at *North American Symposium on Climate Adaptation.*. Expected publication date 2017.

15. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)			
Undergraduates provided tuition/fee support (number)			
Undergraduate students provided stipends (number)			
Graduate students provided tuition/fee support (number)			
Graduate students provided stipends (number)			
Undergraduates who received HS-related degrees (number)			
Graduate students who received HS-related degrees (number)			
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)			
SUMREX program students hosted (number)			
Lectures/presentations/seminars at Center partners (number)	2		
DHS MSI Summer Research Teams hosted (number)			
Journal articles submitted (number)	2		
Journal articles published (number)			
Conference presentations made (number)	13		
Other presentations, interviews, etc. (number)	5		
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)			
Requests for assistance/advice from DHS agencies (number)	2		
Requests for assistance/advice from other Federal agencies or state/local governments (number)	5		
Total milestones for reporting period (number)	6		
Accomplished fully (number)	4		
Accomplished partially (number)			
Not accomplished (number)			
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
N/A			

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
Measuring Climate Risk to Inform Resilience: Pilot Study for North Atlantic Medium and High-Use Seaports	Dr. Austin Becker	$280,000	US Army Corps of Engineers
Climate Change Community Resilience[2]	co-PI Pamela Rubinoff	$47,625	RI Sea Grant
Leveraged Support			
Description			Estimated Annual Value
Returned Indirect Cost[3]			$4,174
Project Management and Coordination			$1,500

References

Burton I., 2009. "Climate Change and the Adaptation Deficit". *Earthscan Reader on Adaptation to Climate Change*, eds. Schipper ELF, Burton I (Earthscan, Sterling, VA), pp 89–95.

Carson, J., K. McCullough, and D. Pooser. 2013. "Deciding Whether to Invest in Mitigation Measures: Evidence from Florida". *The Journal of Risk and Insurance*. 80(2): 309-327.

Coastal Resources Center, 2014. "Catalog of Adaptation Techniques for Coastal and Waterfront Businesses: Options to Help Deal with the Impacts of Storms & Sea Level Rise" Available online at: http://www.beachsamp.org/wp-content/uploads/2015/05/adaptation_catalogue.pdf.

Department of Homeland Security, 2014. "The 2014 Quadrennial Homeland Security Review", available online at: http://www.dhs.gov/sites/default/files/publications/2014-qhsr-final-508.pdf. (Retrieved June 23, 2015).

[2] Our DHS project leverages ongoing efforts by co-PI Pamela Rubinoff and colleagues at the URI Coastal Resource Center to increase resilience of coastal communities in the face of climate change. Many of the group decision processes listed in the Appendix are organized by, or otherwise associated with this Sea Grant funded project. We add value to that effort by applying formal a social science based framework of behavior change, identifying barriers to adaptation and interventions to overcome those barriers.

[3] The University of Rhode Island's Coastal Institute (CI) has generously agreed to return 66% of their share of indirect cost return back to the project. The CI obtains 17% of the indirect cost, so roughly 11.3% of indirect cost is being returned to the project.

FEMA. 2011. Coastal Construction Manual: Principles and Practices of Planning, Siting, Designing, Constructing, and Maintaining Residential Buildings in Coastal Areas (4th ed.) FEMA P-55

FEMA, 2014. "Against the Wind: Protecting Your Home from Wind Hazards" available online at http://www.fema.gov/media-library-data/20130726-1505-20490-3483/agstwnd.pdf. Retrieved November 10, 2014.

Ge, Y., W. Peacock, and M. Lindell. 2011. Florida Households' Expected Responses to Hurricane Hazard Mitigation Incentives. Risk Analysis 31(10): 1676-1691.

Kesete, Y., J. Peng, Y. Gao, W. Shan, R. Davidson, L. Nozick, and J. Kruse. 2014. "Modeling Insurer-Homeowner Interactions in Managing Natural Disaster Risk". *Risk Analysis* Vol 34 No. 6, pp 1040-1055.

Lindell, Michael K. and Ronald W. Perry, 2012. "The Protective Action Decision Model: Theoretical Modifications and Additional Evidence" *Risk Analysis*, Risk Analysis, Vol. 32, No. 4, pp 616-632.

Moser, S. C. and J. A. Ekstrom, 2014. "A framework to diagnose barriers to climate change adaptation". *Proc. Natl. Acad. Sci.* **107**, 22026–22031(2014).

Peacock, W.G. 2003. Hurricane Mitigation Status and Factors Influencing Mitigation Status among Florida's Single-Family Homeowners. Natural Hazards Review 4:149-158.

Scott, W. 2002. "Editorial: Minds, Gaps, Models, and Behaviors." *Environmental Education Research* 8 (3): 237-38.

US Army Corps of Engineers, 2012. "The Quantification and Evolution of Resilience in Integrated Coastal Systems" ERDC TR-12-7 (August).

Velicer, W. F, Prochaska, J. O., Fava, J. L., Norman, G. J., & Redding, C. A. (1998). "Smoking Cessation and Stress Management: Applications of the Transtheoretical Model of Behavior Change". *Homeostasis*, Vol. 38, pp 216-233.

White House, 2015. "Executive Order—Using Behavioral Science Insights to Better Serve the American People". Available on-line at https://www.whitehouse.gov/the-press-office/2015/09/15/executive-order-using-behavioral-science-insights-better-serve-american. Retrieved October 20, 2015.

Appendix A. Summary of Group Decision Events

Rhode Island Legislative Commission on Economic Impacts of Sea Level Rise and Coastal Flooding. (September 24, 2015) Legislative Hearings on economic threats of sea level rise and coastal flooding.

Rhode Island Legislative Commission on Economic Impacts of Sea Level Rise and Coastal Flooding. (Oct 15, 2015) Legislative Hearings on economic threats of sea level rise and coastal flooding.

Municipal Adaptation Work Session, New Shoreham. (Oct 22, 2015). Purpose: Assist communities to understand exposure to coastal storm hazards, plan for action to reduce risk and implement plans. Increase awareness of tools, planning requirements and adaptation strategies.

Municipal Adaptation Work Session, Westerly. (Oct 29, 2015) Purpose: Assist communities to understand exposure to coastal storm hazards, plan for action to reduce risk and implement plans. Purpose: Assist communities to understand exposure to coastal storm hazards, plan for action to reduce risk and implement plans. Increase awareness of tools, planning requirements and adaptation strategies.

Municipal Adaptation Work Session, Charlestown. (Oct 29,2015) Purpose: Assist communities to understand exposure to coastal storm hazards, plan for action to reduce risk and implement plans. Purpose: Assist communities to understand exposure to coastal storm hazards, plan for action to reduce risk and implement plans. Increase awareness of tools, planning requirements and adaptation strategies.

Municipal Adaptation Work Session, North Kingstown. (Nov 11, 2015) Purpose: Assist communities to understand exposure to coastal storm hazards, plan for action to reduce risk and implement plans. Purpose: Assist communities to understand exposure to coastal storm hazards, plan for action to reduce risk and implement plans. Increase awareness of tools, planning requirements and adaptation strategies.

Rhode Island Legislative Commission on Economic Impacts of Sea Level Rise and Coastal Flooding (Nov 19, 2015) Legislative Hearings on economic threats of sea level rise and coastal flooding.

Rhode Island Legislative Commission on Economic Impacts of Sea Level Rise and Coastal Flooding. (December 17, 2015) Legislative Hearings on economic threats of sea level rise and coastal flooding.

Town of South Kingstown, Municipal Adaptation Work Session. (January 20, 2016) Purpose: Assist communities to understand exposure to coastal storm hazards, plan for action to reduce risk and implement plans. Increase awareness of tools, planning requirements and adaptation strategies.

Rhode Island Legislative Commission on Economic Impacts of Sea Level Rise and Coastal Flooding. (January 21, 2016) Legislative Hearings on economic threats of sea level rise and coastal flooding.

#ResilientPVD Community Workshop. A team of experts from around the country come to Providence for three days of charrettes, workshops, and community meetings to explore how Providence's infrastructure, buildings, and neighborhoods can prepare for the impacts climate change. (February 1- 3, 20016)

Beach SAMP meeting, Meeting of State and Town leaders to discuss adaptation to sea level rise and coastal flooding threats. (February 4, 2016)

Meeting of Community Leaders to discuss historic and potential future impacts of coastal flooding, and actions to mitigate impacts. (February 16, 2016)

Conference call with Davidson et al to coordinate efforts of the two Research Groups (February 24, 2016)

Rhode Island Legislative Commission on Economic Impacts of Sea Level Rise and Coastal Flooding. Legislative Hearings on economic threats of sea level rise and coastal flooding. (February 25 2016)

Preparedness Conference (CCRI) - Series of presentations, trainings, and exhibits. http://www.riema.ri.gov/resources/government/prepare/preparednessconference/index.php (March 1, 2016)

BeachSAMP meeting. Meeting of State and Town leaders to discuss adaptation to sea level rise and coastal flooding threats. (April 6, 2016)

ANNUAL RIFMA CONFERENCE - "Incentivizing Actionable Resilience to Flooding" - Floodplain management and hazard mitigation professionals explore tools and techniques to improve resiliency in the present and future. (April 7, 2016)

Keeping History Above Water Conference, Newport, RI. One of the first national conversations to focus on the increasing and varied risks posed by sea level rise to historic coastal communities and their built environments. This is a conference on what can be done to protect historic buildings, landscapes and neighborhoods from the increasing threat of coastal inundation. (April 10-13, 2016)

RI Silver Jackets (RIEMA, Cranston) - Meeting of Interagency coalition to reduce flood risk. State-led teams, implementation of USACE National Flood Risk Program (April 14, 2016)

DC DHS Presentation and discussion with DHS HQ and others on how to link with their efforts. (April 14, 2016)

RI Coastal Erosion Control Workshop (April 21, 2016) http://www.crmc.ri.gov/news/pdf/2016_0421_Workshop_Flyer.pdf

Meeting with and presentation by Chris Landsea, NOAA's Joint Hurricane Testbed Director/Science and Operations Officer at the National Hurricane Center. Discussion of all three URI projects funded by DHS, and lecture "Inside the Eye: Improving Hurricane Forecasts". (May 3, 2016)

BEACHSAMP Stakeholder Meeting with presentation from Michael Oppenheimer, speaking about climate change and the IPCC. (May 3, 2016)

BeachSAMP Modeling meeting, 4, May 2016, 2-4 pm & 6-8 PM

Report to FEMA Regional Advisory Council May 19th

New England Climate Adaptation, Preparedness, and Resilience seminar - Organized by DHS Infrastructure Protection, EPA, FEMA, NOAA, NH Department of Safety. First in a series of New England seminars. (May 24 – 25, 2016)

Estuarine and Coastal Modeling Conference (ECM14) at URI - Rick Luettich (UNC lead) will be a keynote, Meeting with Rick Luettich with our team and other key users, including Coast Guard, and other DHS leaders. (June 12-15, 2016)

Theme 3

Disaster Dynamics

RESIO, UNF

DHS Coastal Resilience Center

Research Project

Annual Project Performance Report

1. **Project Title:** The Incorporation of Rainfall into Hazard Estimates for Improved Coastal Resiliency

2. **Principal Investigator / Institution:** Don Resio / University of North Florida

3. **Other Research Participants/Partners:** ARCADIS, Jackson State University

4. **Short Project Description:** Rising sea level, climate variability, and growing coastal populations increasingly threaten immense investments in critical coastal infrastructure within the US. This threat greatly impacts the commercial and military value of coastal cities such as New York, New Orleans, Norfolk/Hampton Roads and many others. Natural coastal areas are also essential to maintaining healthy ecosystems and provide much needed food and recreation and can contribute nature-based coastal protection in many areas. Decisions affecting coastal utilization must be based on accurate quantification of factors affecting this balance to maximize coastal resilience. A well-known example of an inaccurate assumption is the treatment of coastal and inland/riverine flooding at though they do not interact. This project will develop a methodology for incorporating these interactions in a statistically and physically appropriate manner into FEMA's operational coastal modeling systems.

5. **Abstract:** This project will develop a method for including rainfall-runoff effects into FEMA-JPM studies, and evaluate the potential impacts of incorporating these effects into improved estimates of flooding hazards. There are two parallel efforts the project will be undertaking: 1) an improved understanding of the statistics of river/tributary discharges in terms of both antecedent conditions and the conditional probabilities of rainfall patterns and magnitudes given a tropical cyclone in a particular area and 2) a physics-based coupling of major tributaries into the ADCIRC model, including antecedent and rainfall effects during a surge event. The goal is to develop a model that is ready to be transitioned into realistic JPM applications in areas where rainfall, hydrologic flows and surges are expected to interact strongly.

6. **End users:** 1) FEMA Regions 2, 3, 4, 5 and 6 are contributing technical oversight and guidance on user needs related to Risk Map applications and expect to obtain more accurate actuarial representations of flooding risks. 2) USACE-ERDC is coordinating on the exploration of different approaches and which can be applied to planning and design of Corps projects in areas affected by combined hydrologic-coastal flooding. 3) NOAA is coordinating on hydrologic modeling and coupling with coastal surges which will enable improved predictions in areas affected by flooding from these combined mechanisms. 4) USGS has expressed an interest in using outputs from this to develop realistic scenarios for Coast Guard guidance during and after disasters. 5) NGA has expressed an interest in incorporating our research into their maritime mission. However, the USGS and Coast Guard contacts have not been involved in the project to date.

7. **Explanation of Changes:** The only change in our initial work plan is a minor 6 weeks slowdown in the production of a report on rainfall patterns associated with tropical events affecting the Norfolk areas. The radar data which was already available to us and was adequate for categorizing many hurricanes in the Gulf of Mexico did not include sufficient storms in the Norfolk/Hampton Roads area to provide a good characterization of rainfall patterns for tropical events at that site. We downloaded available National Weather Service station data for the area and have almost completed our analyses.

8. **Unanticipated Problems:** As noted above, we had a slight slowdown due to the lack of time coverage in our radar data and have addressed this problem.

9. **Project Outcomes:** This project will play a significant role in meeting DHS Goal 1.3: Manage Risks to Critical Infrastructure, Key Leaders and Events," with its emphasis on the first of these, *critical infrastructure.* In particular, the need to understand and prioritize risks to critical infrastructure, i.e. to ensure critical infrastructure resilience needs to understand the areas most threatened in various hazard scenarios will be of great concern in coastal areas in the future. Many hurricanes have wreaked havoc on inland areas far beyond either the effects of coastal flooding or inland flooding considered independently. Improved tools provided by this project will significantly reduce the existing information gap with regard to the coupled flooding of mechanisms combined. Under DHS Goal 5.1: Mitigate Hazards, this project will work with multidisciplinary teams to prepare for, protect against, respond to and mitigate a natural disaster in coastal areas. We plan to transition our modeling system to operational applications and utilize students in exercises to examine the impacts of these new results in areas within the selected test area, Norfolk/Hampton Roads. These exercises will help convert our understanding of increased hazards related to combined hydrologic and coastal flooding to improved quantification of risks in these areas along with potential impacts on societal functions and ecosystems. Such conceptual development will help planners properly locate critical infrastructure to avoid serious flooding. Since lost infrastructure is a major problem in post-disaster recovery, exploitation of such information is expected to reduce post storm recovery time (DHS Goal 5.4).

10. **Research Activity and Milestone Progress:**

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Obtain radar rainfall data set for statistical analysis of patterns of rainfall relative to hurricane tracks and other parameters	June 2016	90%	We found out we needed a longer period of data and are still downloading some of the NWS

			hourly rainfall data. Completion is expected by August 2016
Develop and test initial methodology for coupling rivers/tributaries and rainfall into ADCIRC in different characteristic geographic areas.	June 2016	30%	Several conference calls and one on-site meeting have been completed. This effort will still be completed by the due date for the report on this topic.
Interaction with JSU and user groups to develop a firm framework for effective user review of project accomplishments and future directions.	June 2016	40%	We have identified end users groups in FEMA HQ (incl the Coastal Working Group of private sector flood risk practitioners they engage with), in FEMA Regions I, II, II, IV and VI where risk of combined tropical/hurricane storm surge and precipitation is major element of flood risk assessments. User groups in US Coast Guard, USACE, NOAA and NGA also have been identified. Work is underway to identify and enlist an individual in each of these groups to comprise an end-user group that we will interact with. Completion of this activity is expected by 31 Aug.
Research Milestone			
Provide brief report on preliminary analyses of rainfall patterns in hurricanes.	June 2016	90%	We had to revise the length of record that we were examining and will complete this report by 15 August.
Progress reports on research activities 2 and 3.	June 2016	10%	Progress report on standing-up of and composition of the end user group, and initial engagement activities with them, including distribution of project reports is expected for Sep 30.

11. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Establishment of effective coordination between the project team and end users involved in this project.	June 2016	75%	A 4-person standing committee has been identified, comprised of the FEMA HQ lead for the FEMA Coastal Working Group (which reflects an end user community), two project team members who are former USACE employees and both have extensive flood risk experience and experience working with FEMA on flood risk studies, and a fourth member who is a current USACE employee who works in coastal flood risk research and applications community and who represents USACE end user groups. Formalization of the committee is underway. Expect to complete formalization by 15 Aug. Coordination will commence at that time.
Transition Milestone			
Establish a standing committee for coordination between the project team and end users involved in this project.	June 2016	75%	Expect to complete formalization of the standing committee by 15 Aug.

12. Interactions with education projects: Amanda Tritinger, a UNF PhD student funded under this project, attended the CES in Los Vegas and participated in the pre- and post-conference meetings to document her experience and how she benefited from it. The project PI (Don Resio) travelled to Mississippi in April to meet with the JSU Educational Project leaders on this project Robert Whalin, Tom Richardson and Bruce Ebersole. UNF also coordinated a SUMREX visit from a LSU PhD candidate, Rudy Bartels, to come to Jacksonville and work on an internship with Dr. Resio starting in July 2016.

13. Publications:

1. Irish, J.L., Weiss, R. and D.T. Resio," Physical Characteristics of Coastal Hazards and Risks", Chapter 25, Springer Handbook of Ocean Engineering, Springer Dordrecht Heidelberg London New York, M. Dhanak and N. Xiros (Eds.), 549 – 562.

2. Resio, D.T., Tumeo, M.A., and J.L. Irish, "Statistical Characterization of Hazards and Risk in Coastal Areas," Chapter 26, Springer Handbook of Ocean Engineering, Springer Dordrecht Heidelberg London New York, M. Dhanak and N. Xiros (Eds.), 567 – 593.

A. Progress Report: Obtain radar rainfall data set for statistical analysis of patterns of rainfall relative to hurricane tracks and other parameters and preliminary analysis of patterns

All of hourly rainfall data for sites in Virginia and North Carolina have been downloaded for the period 1951-2015 for 11 stations, with most stations reasonably complete over this entire interval. Hurricane track information from HURDAT is also available over this interval through 2013. Norfolk and Elizabeth City are being used as the two selected sites to develop analytical methods for describing the temporal rainfall patterns relative to the hurricane location. Preliminary analysis of these stations shows a clear tendency for rainfall to precede the passage of the hurricane eye and suggest that hurricane size is an important parameter to consider in estimates of hurricane-related rainfall.

Very fine scale radar data has been downloaded and is available for detailed analysis from 2000 – 2009. Along the US Gulf coast these data indicate a rain-shield pattern that occurs before the storm crosses the coast with rainfall diminishing after landfall; however significant exceptions occur in cases where storms slow down at the coast and/or move parallel to the coast west-to-east after landfall. The radar information shows that the rainfall pattern varies substantially from storm to storm, but the slower moving larger storms produce more rainfall than moderate-speed and fast-moving storms.

A hopeful development is the potential for collaboration found in a May 18-19 meeting at the NOAA National Water Center (NWC) in Tuscaloosa, Alabama, where a new initiative was announced, centered on integrated water prediction and the development of a new National Water Model (NWM) at the NWC. This model was described as being "open-source" and a general finite-difference code which could be made available to collaborating groups. Such a model could offer substantial benefits over the presently available "closed-source" HEC models which are being considered for application in the coupled surge-stream flow modeling system on this project.

B. Progress Report: Test methodology for including a range of riverine flows within ADCIRC surge simulations.

A common tool for simulating storm surge in probabilistic flood studies is the ADCIRC model. For ADCIRC models that include rivers, the probabilistic studies (such as JPM-OS used by FEMA) have included a single riverine flow rate for all hurricane surge simulations. Typically, an average

value observed during hurricane season is used. Regardless, it is known that the magnitude of the downstream discharge and the stage of the river vary significantly through hurricane season. Moreover, the stage and discharge have meaningful impact on the propagation of surge up river and the extent of inundation adjacent to the river during a hurricane event. The additional water mass associated with the river's discharge can also increase surge and flooding within coastal bays. Thus, it is important to understand the degree of this interaction and the spatial extent to which it occurs both above and below the river mouth. Specifically, this study will quantify the interaction and test several methodologies to include the effect within future probabilistic studies, and identify hurdles to implementation and guidance for deploying an operational approach.

In an operational setting, ADCIRC is considered too expensive to run each JPM-OS synthetic storm multiple times for different antecedent river flows. Thus, a method is required to include the effect of the river either empirically or with use of a more efficient model such as HEC-RAS to evaluate the flooding potential up riverine regions. To this end, we are using an ADCIRC model and a HEC-RAS model to experiment with coupling.

The geographic location selected for testing is the Neches River in eastern Texas. Both a HEC-RAS model and an ADCIRC mesh of the region already exists and flow rate data is available. The Neches River drains into Lake Sabine at the border between Texas and Louisiana. Surge enters Lake Sabine through Sabine Inlet and can propagate some distance up the river. The distance of propagation up river depends upon the magnitude of the surge, the directionality of wind and wave setup within Lake Sabine, and on the magnitude of the discharge flowing down the Neches. The ADCIRC mesh has been modified to include a larger reach of the Neches River which required significant additional resolution. The mesh resolution has been increased to allow for three "wet" elements across the channel which required elements as small as 20m for a long distance inland. Figure 1 and Figure 2 demonstrate the original and modified geometry in the ADCIRC model and Figure 3 and Figure 4 demonstrate the level of mesh resolution in the two models.

We are using a range of flow conditions to determine the sensitivity of surge and flooding to the flow in the river. The flow scenarios are no flow, the 2 year flow, the 25 year flow, and the 100 year flow. The hurricane scenarios are representative 100-yr synthetic storms from the FEMA storm suites for Texas and Louisiana and Hurricane Ike. Figure 5 indicates seven synthetic storms that generate the 100 year surge at the mouth of the Neches. Of these storms, LA-218, TX-151, and TX-128 were chosen because they span a range of storm track angles and landfall locations. For simulations of the synthetic storms, no tidal forcing is included (as consistent with FEMA operational methodology in Texas). For the Hurricane Ike simulations, a 36 day tidal spin up is included using the eight most dominant tidal constituents. Figure 6 and Figure 7 provide contour plots of maximum surge elevation for the no river flow and 100-year river flow respectively using synthetic storm LA-218. Figure 8 is a contour plot of the difference between the two scenarios from which the spatial extent of the river's influence on surge can be clearly identified.

The coupling between models has been limited to sharing results from one model as a boundary condition in the other. ADCIRC simulations use a flow boundary at the upper end of the Neches

River while HEC-RAS simulations are being performed using the surge from the ADCIRC model to supply a downstream stage boundary condition. Testing is underway to identify the appropriate location for establishing the lower boundary in HEC-RAS and the upper boundary in ADCIRC.

Summary of Lessons Learned to Date

General

- Surge can propagate very far upstream, on the order of miles.
- Inclusion of riverine flow can increase stage in the river by several feet.
- Details of surge/river interaction learned from testing at the Neches may not apply to all river systems. Presence of hydraulic features such as salinity barriers and flood control dams will need to be considered for some rivers.
- Coastal morphology at the river mouth (barrier islands, back bay, delta, or open coast) will alter the surge response.
- Spatial extent and magnitude of surge/river interaction will be specific to each river bathy/topo.
- Guidance is to perform sensitivity testing at each river location of interest to evaluate.
- Operational methodology will need to be tailored to each river location.

ADCIRC

- In an operational mode, it will be challenging to provide adequate resolution in the ADCIRC mesh to capture smaller river systems. As the finite element size is reduced, the time step also must decrease to maintain numerical stability which can become impractical. Node spacing of 20m is a practical lower limit, which results in a crude representation of the river bathymetry.
- It will be important to limit the upstream extent of river representation in ADCIRC. Site specific empiricism for estimating the surge/river interaction or reliance on HEC-RAS are recommended.
- Setting the initial condition for a sloping water surface up a river can be challenging and can induce instability if done poorly. Several approaches are being explored to solve this issue and create a robust operational method.

HEC-RAS

- While HEC-RAS is a well-used model, the source code is not available. This limits true coupling in the sense that HEC-RAS must be operated through its stand-alone GUI.
- It may be worth considering an alternative to HEC-RAS such as the open source hydrology/routing model being developed at Sandia Labs. Access to source code would allow for dynamic coupling with ADCIRC (following the SWAN paradigm).
- Alternately, future research may be pursued to define one-dimensional flow elements within ADCIRC to get around the resolution limitation mentioned above.

- HEC-RAS does allow for batch processing, which will be efficient during operational mode as long as all of the ADCIRC surge results are pre-processed and available as input to HEC-RAS.

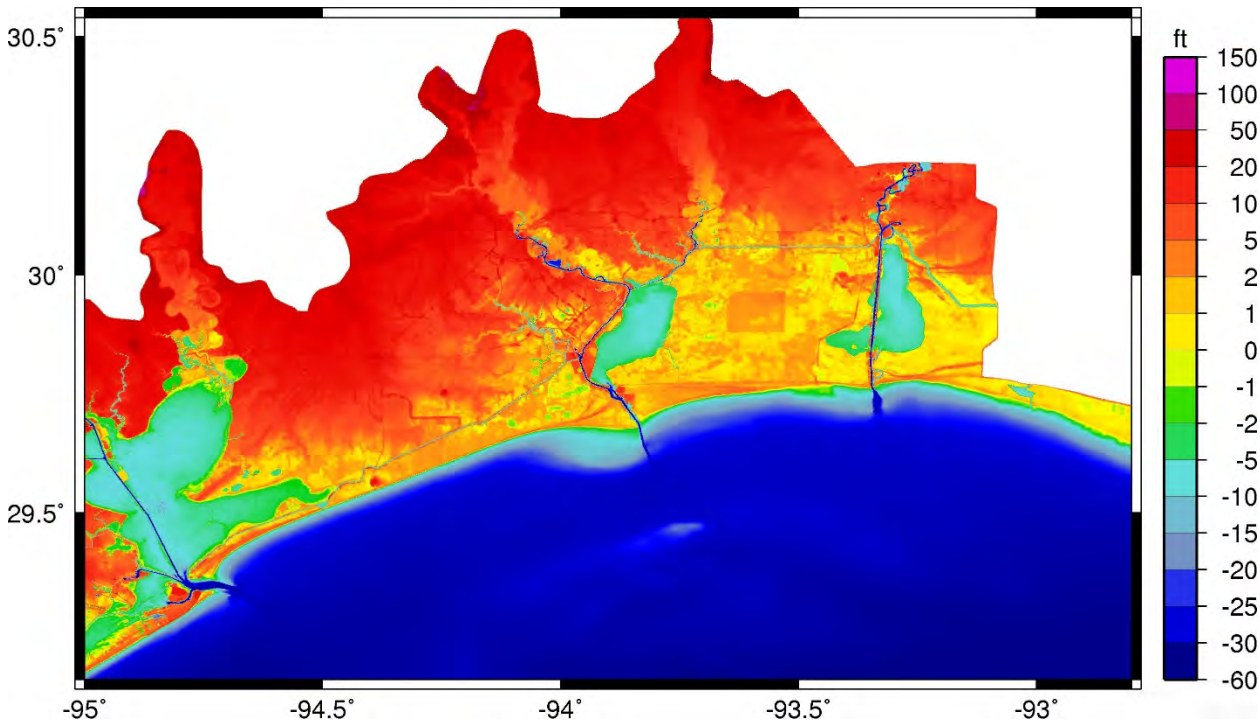


Figure 1. Modified ADCIRC mesh of Texas including expanded Neches River.

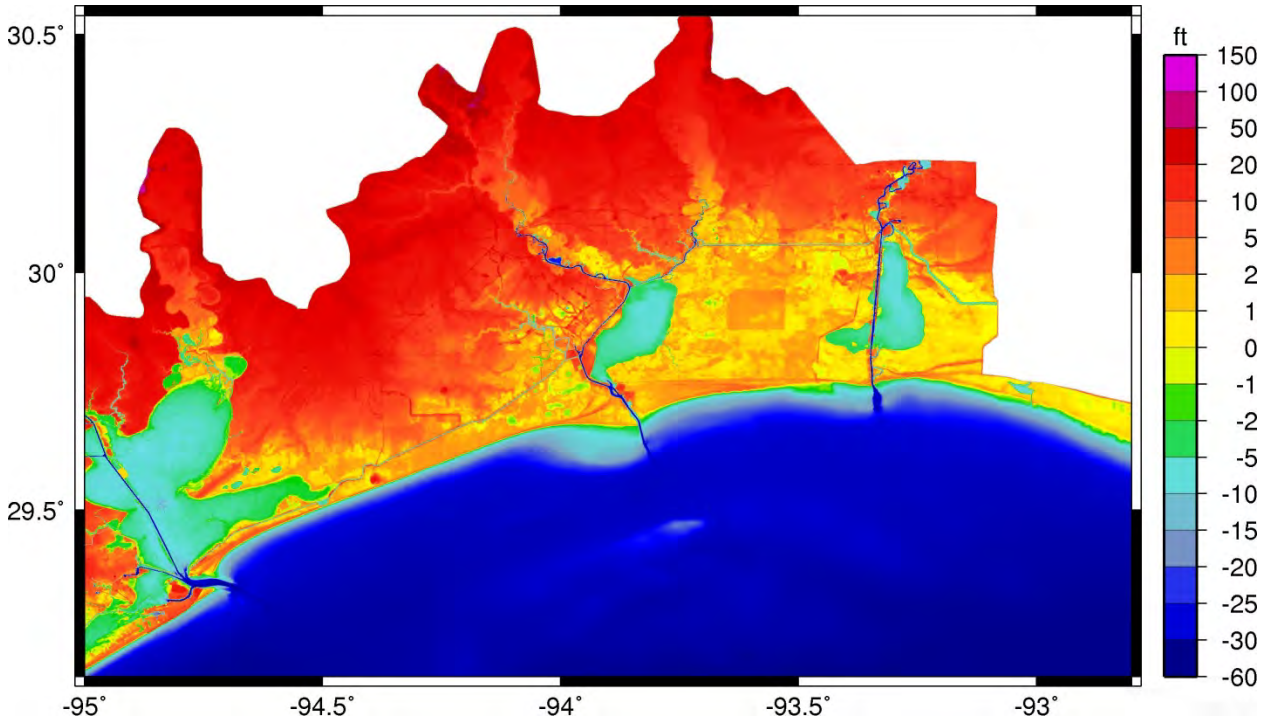


Figure 2. Original ADCIRC Mesh of Texas

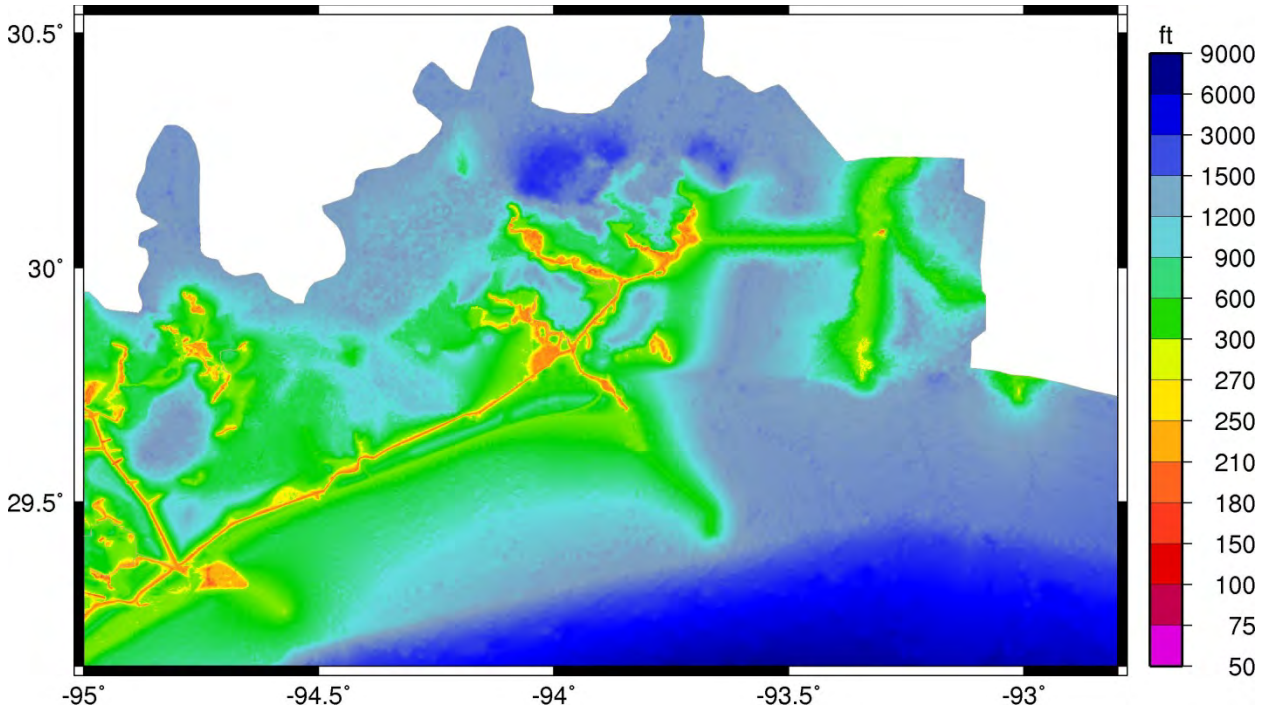


Figure 3. Resolution in the original ADCIRC mesh.

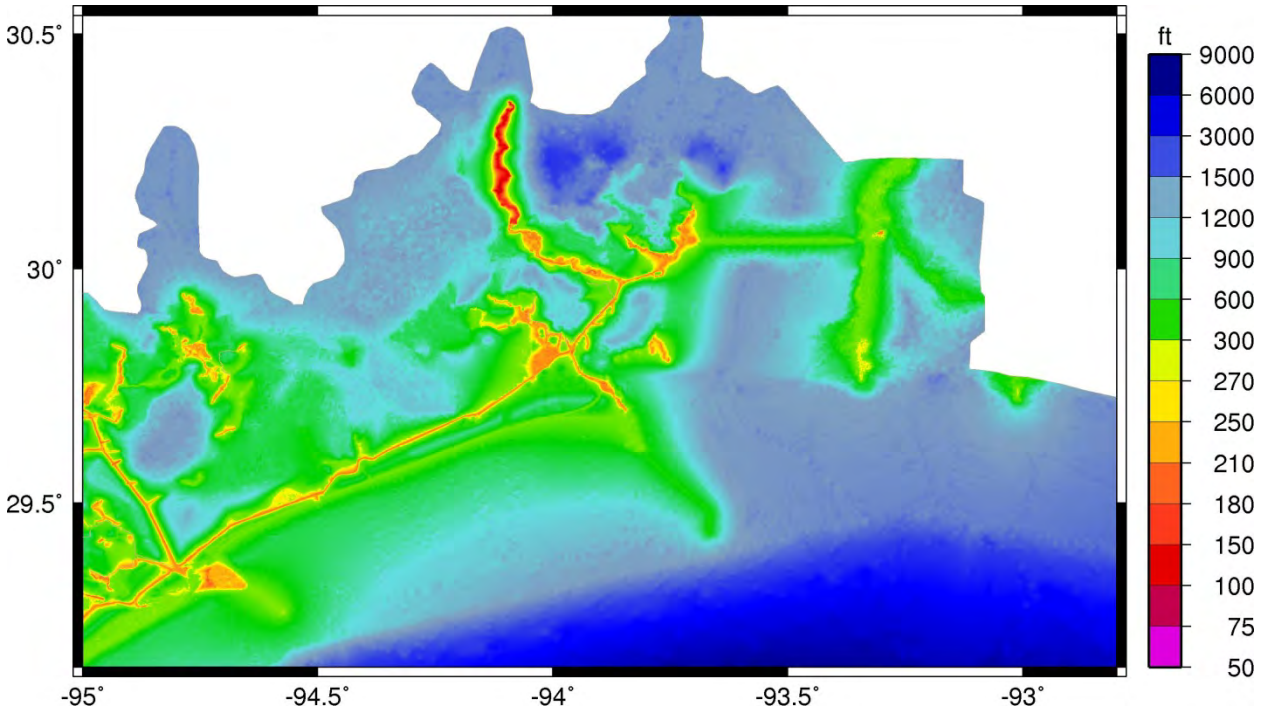


Figure 4. Resolution in the updated ADCIRC mesh.

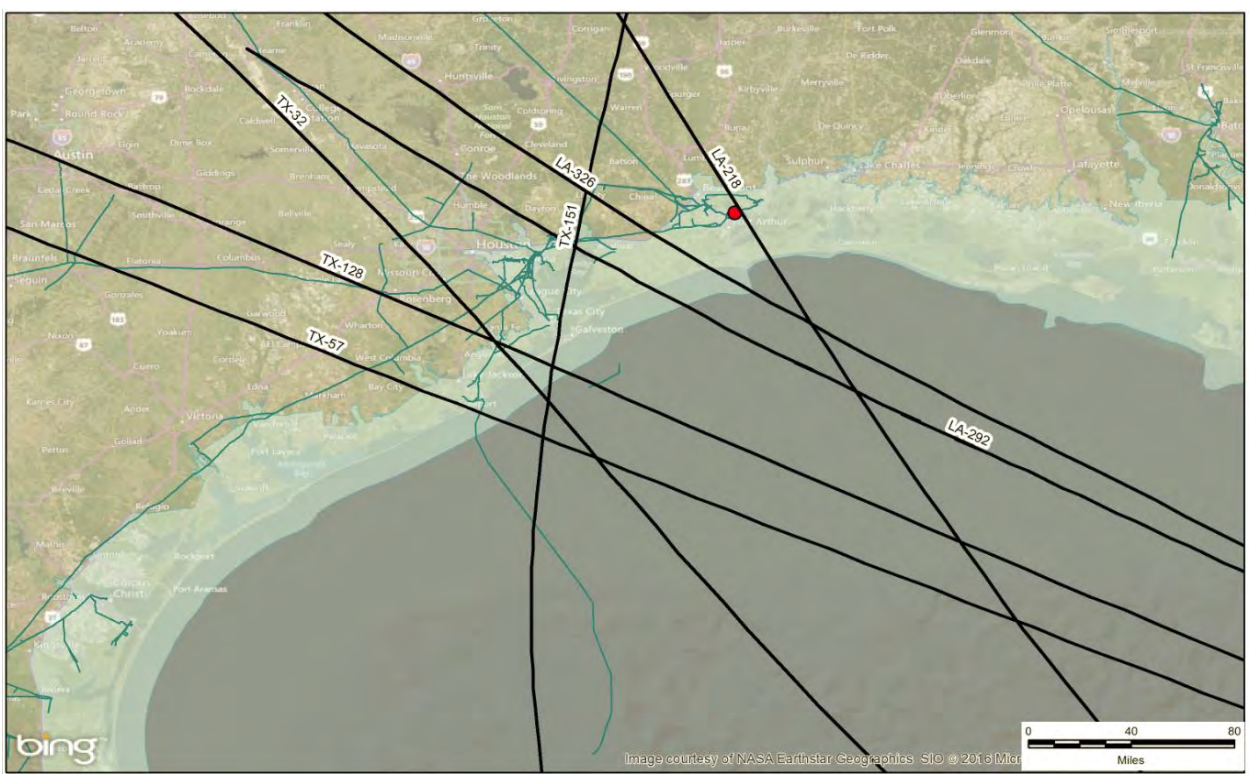


Figure 5. Storms from the synthetic storm suite that generate the 100-yr surge at the mouth of the Neches River.

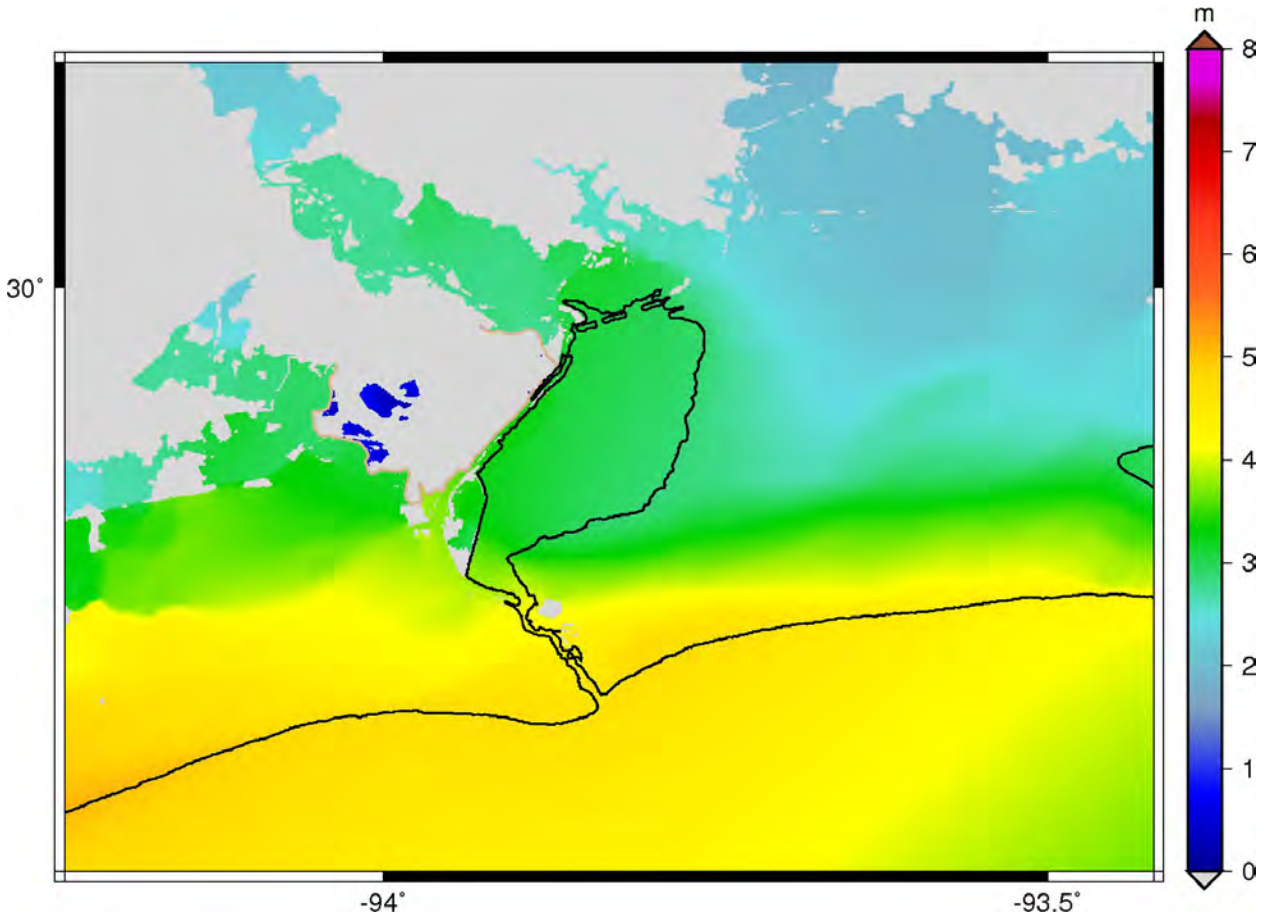


Figure 6. Contours of maximum surge elevation with zero river flow.

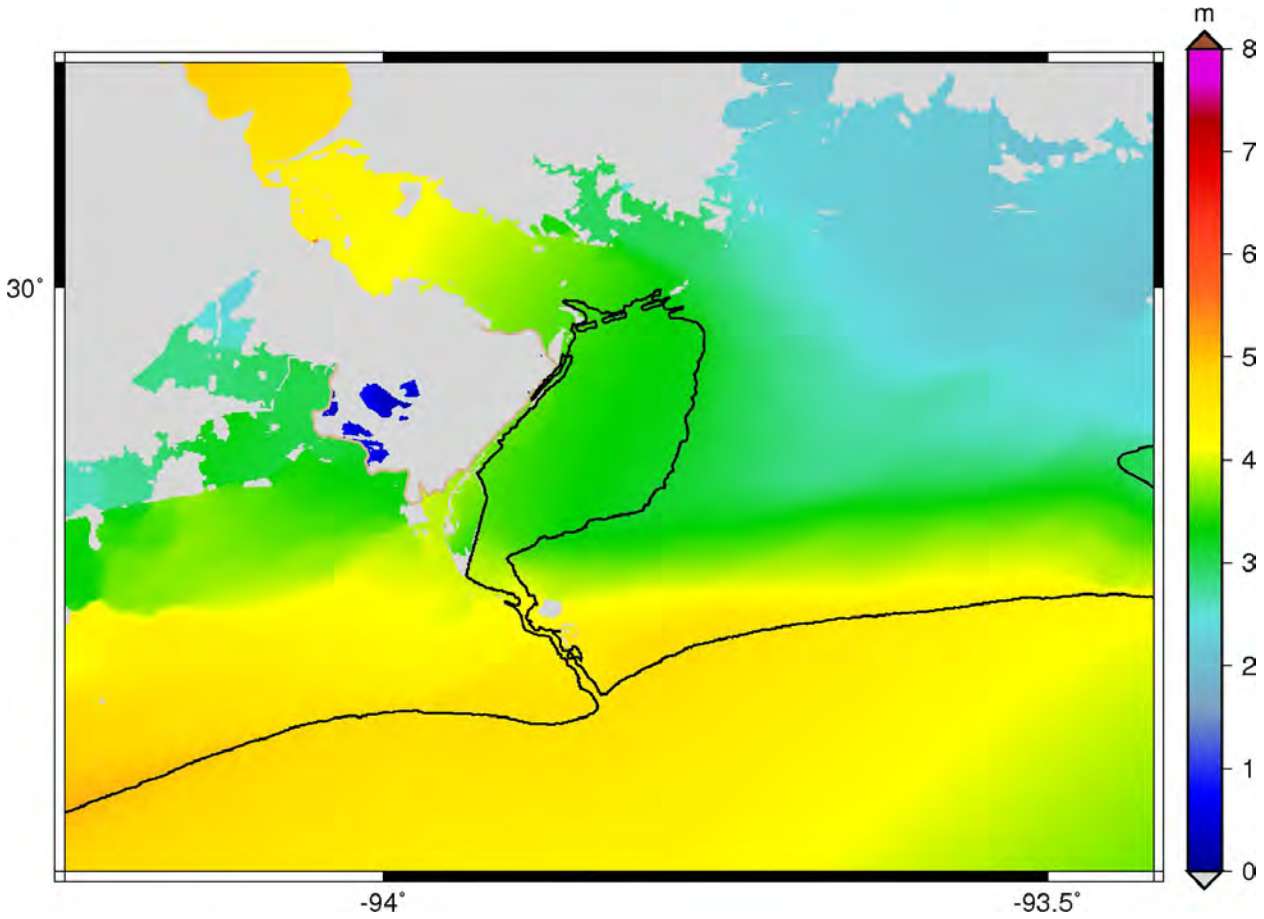


Figure 7. Contours of maximum surge elevation with the 100-year riverine flow (91,000 cfs).

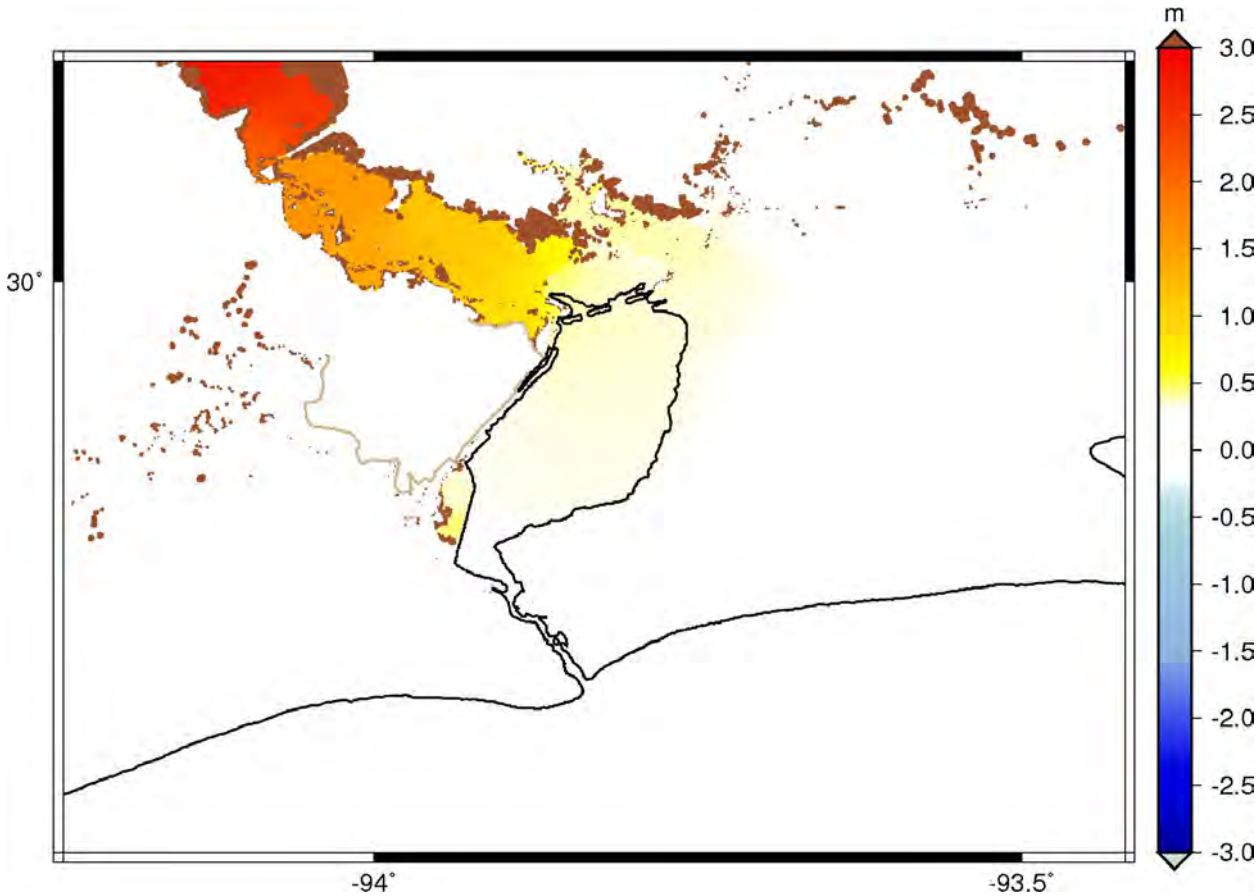


Figure 8. Contours of the surge difference between no riverine flow and the 100-year riverine flow.

14. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)			
Undergraduates provided tuition/fee support (number)			
Undergraduate students provided stipends (number)			
Graduate students provided tuition/fee support (number)	1		
Graduate students provided stipends (number)	1		
Undergraduates who received HS-related degrees (number)			
Graduate students who received HS-related degrees (number)			
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)		2	
SUMREX program students hosted (number)			
Lectures/presentations/seminars at Center partners (number)			
DHS MSI Summer Research Teams hosted (number)			
Journal articles submitted (number)			
Journal articles published and Book Chapters (number)	2		
Conference presentations made (number)			
Other presentations, interviews, etc. (number)	1		
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)			
Requests for assistance/advice from DHS agencies (number)			
Requests for assistance/advice from other Federal agencies or			
Total milestones for reporting period (number)	3		
Accomplished fully (number)	1		
Accomplished partially (number)	2		
Not accomplished (number)			
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
None			

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
Coupled Rainfall-Surge Modeling for the Upper Barataria Basin	Resio	$40,000	Louisiana Water Institute of the Gulf

Leveraged Support	
Description	Estimated Annual Value
Free office space	$2,000
Portion of university indirect returned to project	$15,000
Reduced rates on high performance computer	$20,000

BLANTON, UNC

DHS Coastal Resilience Center

Research Project

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** A multi-tiered ADCIRC-based storm surge and wave prediction system

2. **Principal Investigator / Institution:** Brian Blanton, Renaissance Computing Institute, UNC-Chapel Hill

3. **Other Research Participants/Partners:**
   - Rick Luettich, Institute of Marine Sciences, UNC-Chapel Hill, co-PI
   - Chris Calloway, Renaissance Computing Institute, UNC-Chapel Hill, software engineer
   - Jason Fleming, Seahorse Coastal Consulting, ASGS developer, ADCIRC Bootcamp organizer
   - Crystal Fulcher, Institute of Marine Sciences, UNC-Chapel Hill, ADCIRC grid development
   - Jess Smith, Masters student, UNC-Chapel Hill, Department of Marine Sciences. (50%, as of Aug 1, 2016)

4. **Short Project Description:** Decision makers need critical and helpful information delivered on time and in formats that are easily understandable. This is particularly true with dangerous and destructive natural hazards such as hurricanes and the resulting wind, storm surge, and wave impacts. Late and/or incomprehensible information is useless. This DHS CRC project is about reducing the time needed to deliver hazard information to end users by using advanced models for storm surge, very high performance computing resources, and statistical methods that can provide early guidance information in a matter of minutes as opposed to hours.

5. **Abstract:** We will enhance and extend a multi-tiered, ADCIRC-based storm surge and wave prediction system covering the US East Coast with highest resolution in North Carolina (NC) and southern Chesapeake Bay coastal waters. The system has two main components: (i) the ADCIRC Surge Guidance System (ASGS) that provides fully dynamic, deterministic, highly accurate ADCIRC-based storm surge and wave predictions ~1-2 hrs following the release of meteorological forecasts and (ii) ADCIRC-Lite, which utilizes a response surface method (Taflanidis et al, 2013, Rapid assessment of wave and surge risk during landfalling hurricanes: Probabilistic approach, Journal of Waterway, Port, Coastal, and Ocean Engineering, 139**,** 171–182.) with a pre-computed database of ADCIRC surge and wave solutions to provide rapid (e.g., within minutes) probabilistic or deterministic surge and wave predictions for hurricanes using either forecast meteorological input or end user specified storm parameters. A graphical interface will facilitate user interaction and provide an important tool for risk assessment, education and outreach.

6. **End users:**

Dr. Joe DiRenzio, LCDR B. Sweigart, US Coast Guard, will provide essential usability feedback on project outcomes. USCG uses ADCIRC-based information routinely, but generally does not have the resources to either run the model or create derived products themselves. Instead, they rely on the products generated by ASGS and accessed through the nc-cera.renci.org website, not the ASGS output itself. They are thus perhaps our most critical end user and have previously provided essential feedback on ADCIRC products, including ADCIRC-Lite-NC. We will hold several WebEx meetings with USCG to demonstrate the project activities, particularly for ADCIRC_Lite. We will specifically request feedback as to the user interface and general functionality. We will then update the application.

Tucker Mahoney, *Jonathan Westcott,* FEMA HQ, advisors on federal level coastal hazards and risk. Both Westcott and Mahoney are acquainted with ADCIRC, primarily from the federal NFIP perspective. Mahoney was previously in Region 4, and oversaw most of the technical aspects of the recent coastal Flood Insurance Study that RENCI conducted (with the State, Dewberry and Davis, Applied Research Associates, and US ACE). With our FEMA end users, we will be particularly interested in how they view ADCIRC_Lite as a potential outreach and education tool. Thus, being able to extend ADCIRC_Lite to more areas will be critical. We will invite FEMA to participate in the WebEx meetings to get a "multi-user" perspective on our project.

Christina Lindamer, Coastal Engineer, FEMA Region 4, Atlanta, GA, is knowledgeable of ADCIRC, having previously been a coastal engineer for Dewberry and Davis. Dewberry is the prime contractor for FEMA-related activities for the State of North Carolina, and Lindamer worked extensively on the coastal extra-tropical statistical problem for the comprehensive sea level rise impacts study recently completed. See above.

Maxwell Agnew, USACE, MVN District, user of ADCIRC products for operational decision making for New Orleans area. Agnew is well acquainted with ADCIRC and ASGS, and will provide end-user critiques of product usefulness, accessibility, and confidence. *Agnew typically engages with the UNC ADCIRC group during active tropical events that pose a threat to the New Orleans region. During those periods, we work extensively with him to ensure that the ASGS systems are producing needed output in a timely manner. Agnew frequently advises us as to functionality feedback, and we expect this to continue over the next Atlantic hurricane seasons, as well as interactions during the ADCIRC users group meetings.*

Max Agnew attended the 2016 ADCIRC Meeting and Boot Camp and is now working with ASGS and related software to develop customized capabilities for the USACE to leverage ASGS code, interface, and results. Boot Camp information was essential for Agnew to embark on this activity.

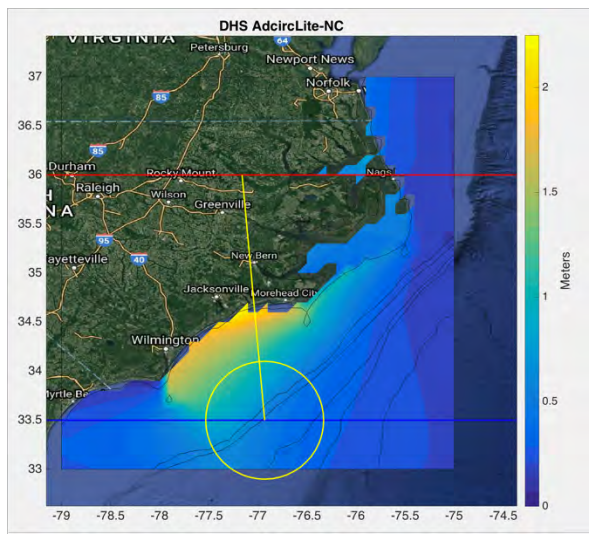
NOAA: We note that Dr. Jesse Feyen has taken a new position at NOAA and is no longer in the Coast Survey Development Laboratory. We have several possible "replacements" and will attempt to fill this void prior to the next CRC Annual Meeting. Feyen's replacement at CSDL, Dr. Sergey Vinogradov, has expressed substantial interest in this project, ranging from ASGS operations and the statistical prediction approach, and he has agreed to provide end-user

feedback on both aspects.

ADCIRC/ASGS Users: While not a specific individual, the collection of ADCIRC/ASGS users is an important end-user group, as they are the first point of transition/translation of research and applications results to the science and engineering communities. In addition to frequent concalls and impromptu gatherings at professional events, the primary organized contact is at the Annual ADCIRC Meeting and Boot Camp. Attendees to these events span from academic institutions, government agencies, and the commercial sector.

7. Explanation of Changes:

The response surface method is fundamentally an interpolation method, and as such the results are very sensitive to the input data (in our case, the FEMA NC storm surge simulation database). While the statistical distributions of dynamic hurricane parameters (radius to maximum winds, central pressure, etc) are evenly sampled, the landfalling location is randomly drawn from a uniform distribution. For the intended purposes of the FEMA coastal flood insurance study, this is appropriate because, for larger storms that contribute more to low-frequency water levels (such as the 1% or 0.5% annual exceedance levels), the storms' radii are large enough to fill in unevenness in landfall location. However, for general interpolation problems, where it is necessary to compute a weighted response from a set of "nearest" neighbors, the interpolated results can be unexpected. For example, if the nearest neighbor set contains storms whose landfall location is to the left of the storm being predicted, the resulting water level will have unphysical higher water to the left of the storm. An example of this behavior is shown in the figure to the right. The majority of the high water is to the left of the track (yellow line), which is not expected.



The implications of this behavior are that it may be necessary to enforce even sampling of the landfalling location, with the set of dynamic parameters being repeated for each landfall location. While this does not eliminate the above-mentioned issue, it will mitigate it to a large extent. We are planning on computing a different dataset where all parameters are evenly sampled. This will require many more storm simulations, but we will do this on a coarse ADCIRC grid for demonstration purposes.

This behavior also implies that the Region 3 area will exhibit the same issue, but with perhaps an even larger extent because there are fewer storms (189) covering a larger coastline, with less storms making actual landfall (as opposed to bypassing the coastline). Instead of pursuing the Region 3 activities, we will compute a better-resolved North Carolina dataset as noted above, with a coarse ADCIRC grid.

Finally, we note that this behavior may not be specific to response surfaces, or our specific

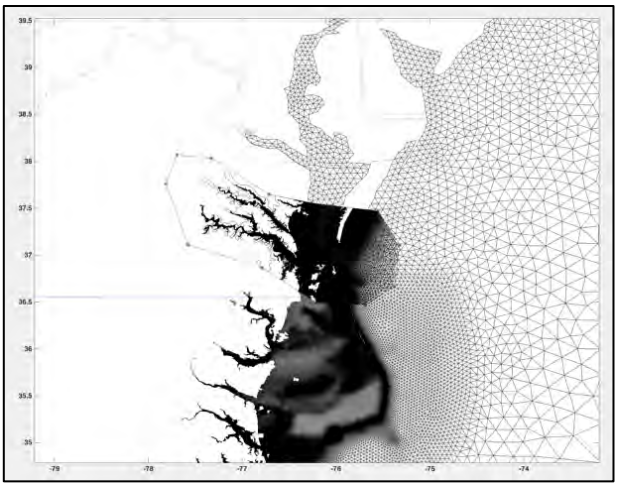
implementation of Taflanidis et al. It seems likely that any interpolation method will exhibit this characteristic. It may not have been noticed in prior studies since most of those are focused on wind-wave heights on relatively narrow continental shelves (e.g., Hawaii). Waves generated in deep water naturally spread out and may mask this behavior to a large extent. We are planning to discuss this with Taflanidis and Kennedy at Notre Dame in the immediate future.

8. Unanticipated Problems:

The main challenge that has occurred is in developing a web-based interface to ADCIRC_Lite. The primary complication has been in trying to use standard web page programming to build a graphical user interface similar to what was done in MATLAB for the current desktop version.

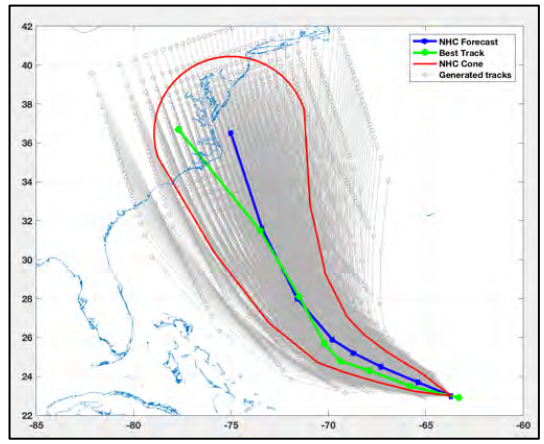
This has proved more difficult than anticipated, and we thus took a different approach. The Python community has developed a concept called notebooks which allow Python code to be easily shared. The notebooks can be put onto a stand-alone server so that users of the notebook do not need to install any software (other than a web browser). In addition, "dashboards" have become a common way of providing data analysis functionality in a web page, and the Python community has been central in developing the dashboard mechanics. So, we ported (into Python) the parts of ADCIRC_Lite that evaluate storm surge given a set of hurricane parameters and used the notebook, dashboard, and dashboard widgets to put ADCIRC_Lite on a webpage. See below for the webpage dashboard for ADCIRC_Lite.

9. Project Outcomes:

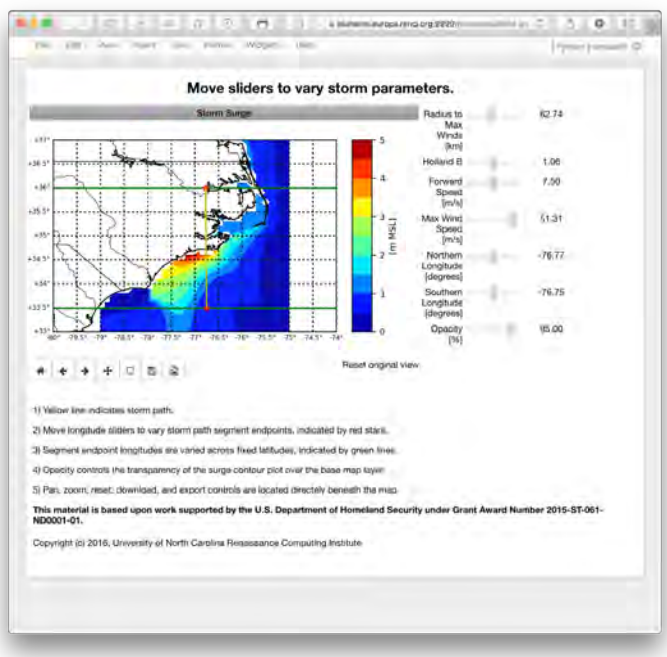


- The new ADCIRC grid that extends the current coastal North Carolina coverage into the lower Chesapeake Bay is progressing. The lower Chesapeake Bay area in the FEMA Region 3 ADCIRC grid has been extracted and inserted into the North Carolina grid. This is shown in the figure to the right, where the grid part in the red polygon is from the Region 3 grid. Grid nodes above the 5 m elevation (land) have also been eliminated to reduce the overall gridsize. It is important to keep the grid at or below about 750K nodes so as not to impact computation time for forecasts. Currently, we are smoothing out the transition between the different resolutions. We anticipate beginning tests on this new grid in mid-October 2016.

- We have also made progress on a hurricane track generator that uses the NHC's published forecast error database. An example of the track generator output is shown in the next figure. This shows NHC Forecast Advisory #23 for Hurricane Isabel (2003) and 729 probabilistic tracks (gray). The red polygon is the NHC's forecast probability cone, which contains 67% of the probabilistic tracks. The green line is the best-track (observed) for Isabel, for reference.



- The web-based interface to ADCIRC_Lite has finally reached a state where it is available in "beta" mode. The webpage is shown in the figure below. The webpage can be found at: https://bluheron.europa.renci.org:9999/notebooks/RSM-ipympl-basemap.ipynb?dashboard. This requires a password ("stormsurge").



- The 2016 ADCIRC Annual Meeting and Boot Camp events were co-organized with Chris Massey and Mary Cialone at the host site, the US Army Engineer Research and Development Center (ERDC) Coastal and Hydraulics Lab (CHL) in Vicksburg, Mississippi. They were held 5-6 May and 2-4 May 2016, respectively. The Boot Camp included sessions on grid development with SMS, ADCIRC setup, simulations, and diagnostics, and deploying the ASGS for forecasting applications. In attendance were:
    - 50+ in-person and 7 virtual via webinar
    - 8 students attended the ADCIRC Boot Camp, with the following organizational affiliations:
        - North Carolina State University x2

        - University of Central Florida
        - Kunsan University (Korea) x4
        - RPS Group
    - 9 professionals attended the ADCIRC Boot Camp, with the following organizational affiliations:
        - Stantec x3
        - Taylor Engineering
        - Woods Hole Group
        - Florida Department of Environmental Protection
        - Applied Technology & Management
        - Ransom Environmental
        - USACE ERDC CHL

- Several storm events occurred in this period. Most notably, historic flooding of the Sabine River in Louisiana and the flooding of the Pearl River in Mississippi occurred as a result of high rainfall in the mid-US. We we were contacted by Derek Giardino (Senior Hydrologist at the West Gulf River Forecast Center, derek.giardino@noaa.gov) with the following request:

  > "*As this flood approaches the Gulf in East Texas, its [sic] getting out of our domain. As well as significant impacts happening in Orange Texas that have no real modeling available and really should be performed by a coastal model. Is [sic]there any thoughts or plans or possibly any completed runs that can be performed in ADCIRC?"*

  We were able to provide guidance information from ASGS running on the Gulf of Mexico to "unanticipated" end-users.

- During the reporting period, we provided transition support to Yuji Funakoshi, Ph.D. in the NOAA Coast Survey Development Laboratory (CSDL). The CSDL has developed a Hurricane Surge On-demand Forecast System (HSOFS) using ADCIRC and the ASGS running on the National Centers for Environmental Prediction (NCEP) Central Operations (NCO) Weather and Climate Operational Supercomputing System (WCOSS). We were able to provide provenance information for the code in the ASGS to facilitate technical support within the NCEP Central Operations, and we will continue to support the transition of our technology into operations.

- <u>Professionals with other NOAA offices have also sought collaboration with our efforts, including Greg Dusek, Ph.D., Senior Scientist with NOAA/National Ocean Service, Center for Operational Oceanographic Products and Services. He is specifically interested in including the effect of sea level anomaly in forecast products:</u>

  > <u>*"If you are looking for any further collaboration on this for the observational side of things, definitely let us know. And regardless, will be interested to hearing more about how your assimilation approach comes together, so stay in touch. "*</u>

We are addressing the incorporation of sea level anomaly using a new ADCIRC nodal attribute that will be transitioned into practice with the next major version release of ADCIRC.

10. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Develop ADCIRC grid for NC and lower Chesapeake Bay by merging existing NC grid with portions of the existing FEMA Region III grid	03/30/2016	50	The two grids being worked with (the FEMA grids for Region 3 and NC) are large, and it is requiring a bit more attention than expected. However, we expect a testable grid by the end of September 2016.
Test early grids with historical storms and in the ASGS	05/31/2016	0	A draft grid is not yet ready for testing. We expect a testable grid by the end of September 2016 and ASGS testing in mid-October 2016.
Review existing literature on probabilistic hurricane track generation	05/31/2016	50	We have compiled a list of relevant publications on statistical models for hurricane tracks. A literature review document will be ready in mid November 2016.
Continue operation of ASGS at RENCI	Ongoing	100	RENCI continues to support the ASGS by providing computational resources to ASGS.
Research Milestone			
Presentation on project's ASGS activities to ADCIRC Annual Meeting	May 5-6 2016	100	Jason Fleming gave an overview on ASGS to attendees at the ADCIRC Annual Meeting held U.S. Army Corps of Engineer's Coastal and Hydraulics Laboratory in Vicksburg, Mississippi. Please see Project Outcomes for more details.
Status report on ASGS system upgrades and initial tests with new grid	05/31/2016	25	We have not yet started testing the new ADCIRC grid. The grid is still under development. We expect to start testing in mid-October 2016.

Draft ADCIRC grid for NC and lower Chesapeake Bay	05/31/2016	50	The grid is still under development. We expect to start testing in mid-October 2016.
Literature review of current track generation methods and implementation plan for project's ensemble generator	06/15/2016	50	The literature review is part of track generator activities, being done concurrently with other CRC project activities. The track generator itself is about 90% complete.

11. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Develop report on ASGS enhancements and status to ADCIRC user community	03/31/2016	100	J. Fleming presented details of enhancements and updates to both ADCIRC and the ASGS system at the 2016 ADCIRC Annual Meeting in Vicksburg MS. It was also presented and discussed at the ADCIRC Annual Meeting and Boot Camp. Additional information is included at the end of this document.
Prepare new version and documentation of ADCIRC-Lite for USCG	4/30/2016	50	This has been delayed by the web development issues noted above. Understanding the "interpolation" issue noted above has also slowed this down a bit. However, the new dashboard/web version of ADCIRC_Lite is the best way to deploy applications, so we anticipate completing this activity by mid-October 2016.
Transition Milestone			
Provide update on ASGS status and enhancements at Annual ADCIRC Users Meeting and Bootcamp	May 2016	100	J. Fleming reported on ASGS status and upgrades at the 2016 ADCIRC Annual Meeting and Boot Camp in Vicksburg MS.
Deliver ADCIRC_Lite to USCG and FEMA. Delivery will be in the form of a downloadable application that does NOT require a MATLAB license.	4/31/2016	0	The downloadable application has proven to be a technical burden, and the dashboard approach to deployment is substantially simpler. Since we have recently worked out

			the latter, we anticipate completing this milestone by mid-October 2016.
Host a WebEx to demonstrate ADCIRC_Lite operations and features	5/31/2016	0	We will host this WebEx in mid-November 2016.

12. Interactions with education projects:

DHS SRT researchers in residence at RENCI, a collaborator with the CRC. Mr. R. Santiago (left) and Prof. A. Bezuglov (Right).

While not a CRC education project interaction, we note the following. During the 2016 summer, the CRC hosted Anton Bezugloz (Associate Professor of Computer Science) and Reinaldo Santiago (rising senior in Computer Engineering) from Benedict College in Columbia South Carolina. This was through the DHS Summer Research Team for Minority Serving Institutions (SRT MSI). Bezuglov and Santiago were in residence at RENCI, where they developed an artificial neural network that uses hurricane parameters and storm surge responses from our FEMA North Carolina coastal flood insurance study to simulate storm surges at coastal locations. The network is an accurate and fast method and is a strong complement to ongoing CRC-funded research at RENCI on response surface methods for storm surge prediction. A manuscript describing the research and results is in preparation for submission to the Journal of Expert Systems and Applications.

This summer research has led to a recently submitted follow-on proposal to the DHS SRT MSI program, where different neural network methods will be developed and applied to the same prediction problem. If funded, this research will occur at Benedict College under the direction of Prof. Bezuglov with support from the CRC through RENCI's computing resources.

13. Publications:

None.

14. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research Project**	**Education Project**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)	0		
Undergraduates provided tuition/fee support (number)	0		
Undergraduate students provided stipends (number)	0		
Graduate students provided tuition/fee support (number)	0		
Graduate students provided stipends (number)	0		
Undergraduates who received HS-related degrees (number)	0		
Graduate students who received HS-related degrees (number)	0		
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)	0		
SUMREX program students hosted (number)	0		
Lectures/presentations/seminars at Center partners (number)	1		
DHS MSI Summer Research Teams hosted (number)	1		
Journal articles submitted (number)	0		
Journal articles published (number)	0		
Conference presentations made (number)	2		
Other presentations, interviews, etc. (number)	0		
Patent applications filed (number)	0		
Patents awarded (number)	0		
Trademarks/copyrights filed (number)	0		
Requests for assistance/advice from DHS agencies (number)	0		
Requests for assistance/advice from other Federal agencies or	0		
Total milestones for reporting period (number)	7		
Accomplished fully (number)	2		
Accomplished partially (number)	3		
Not accomplished (number)	2		
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery	Recipient or Anticipated End Users
ADCIRC_Lite-NC	Webpage/dashboard	November 2016	USCG, FEMA

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
N/A			
Leveraged Support			
Description			Estimated Annual Value
RENCI Computing Resources for ASGS			30,000

Multi-tiered ADCIRC-based Storm Surge and Wave Prediction System
Seahorse Coastal Consulting, LLC
Detailed Reporting Period Activities.

Introduction

Continuous delivery of model guidance from the multi-tiered ADCIRC-based storm surge and wave prediction system provides key authorities and decision makers with actionable information on coastal hazards on a daily basis. The U.S. Coast Guard as well as NOAA offices including local Weather Forecast Offices (WFOs) and River Forecast Centers (RFCs) use these results routinely, and have expressed a strong interest in expanded capabilities. This report describes progress and achievements that were delivered during this reporting period.

Capability

In previous years, the North Carolina v6c ADCIRC mesh has been used to produce real time storm surge guidance. However, a newer mesh for North Carolina has been developed (the v9.99 mesh) and used in offline risk and design studies. After an extended period of experimentation, we used the ASGS to redeploy the NC v9.99 mesh on the Hatteras HPC machine at RENCI. Our technology roadmap includes a full transition to the higher resolution mesh in time for hurricane season 2016. The improved capabilities of this new mesh are illustrated in the figures below.

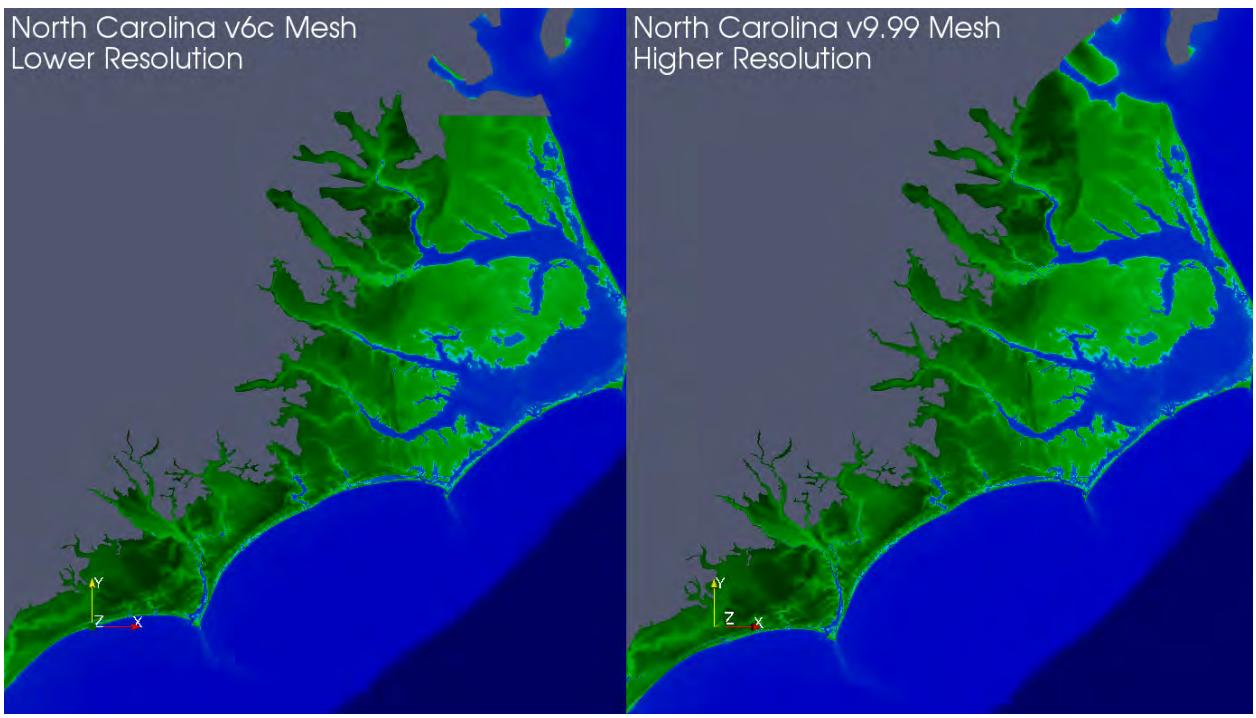


Figure 1: The new NCv9.99 ADCIRC mesh (on the right) extends farther north, into the lower Chesapeake, and includes higher resolution, particularly in the southern half of the North Carolina coast.

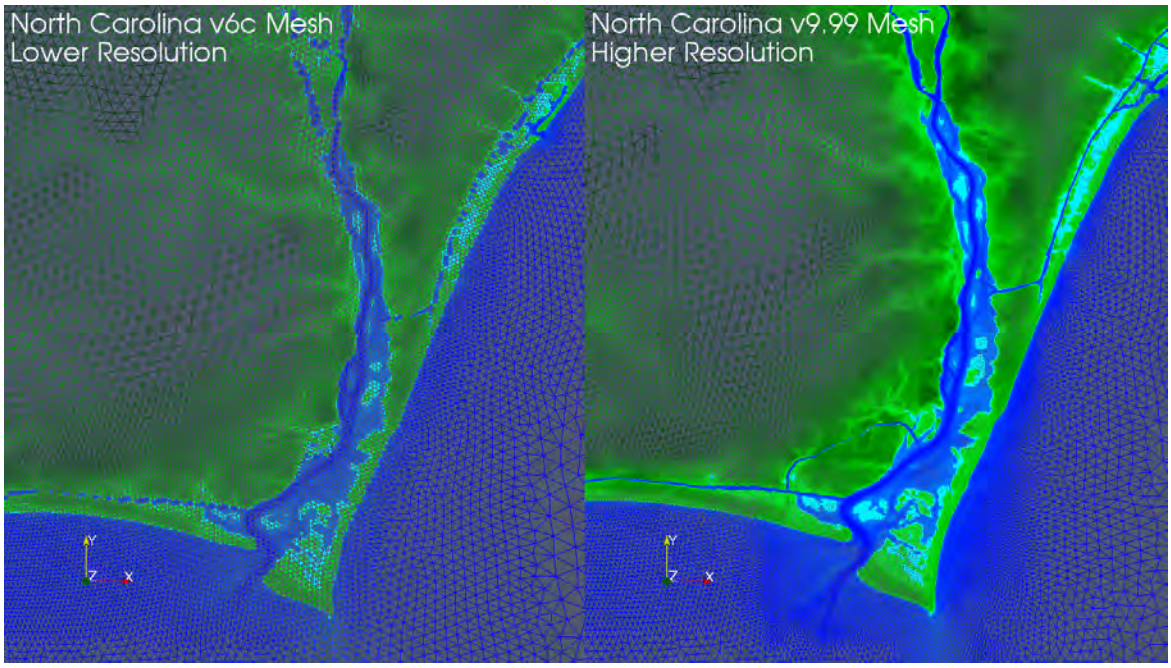


Figure 2: The NCv9.99 ADCIRC mesh (on the right) represents a significant improvement in the accuracy of representation in the upper Cape Fear River as well as the intracoastal waterway in the southern half of the North Carolina coast, in comparison with the older NCv6c mesh on the left.

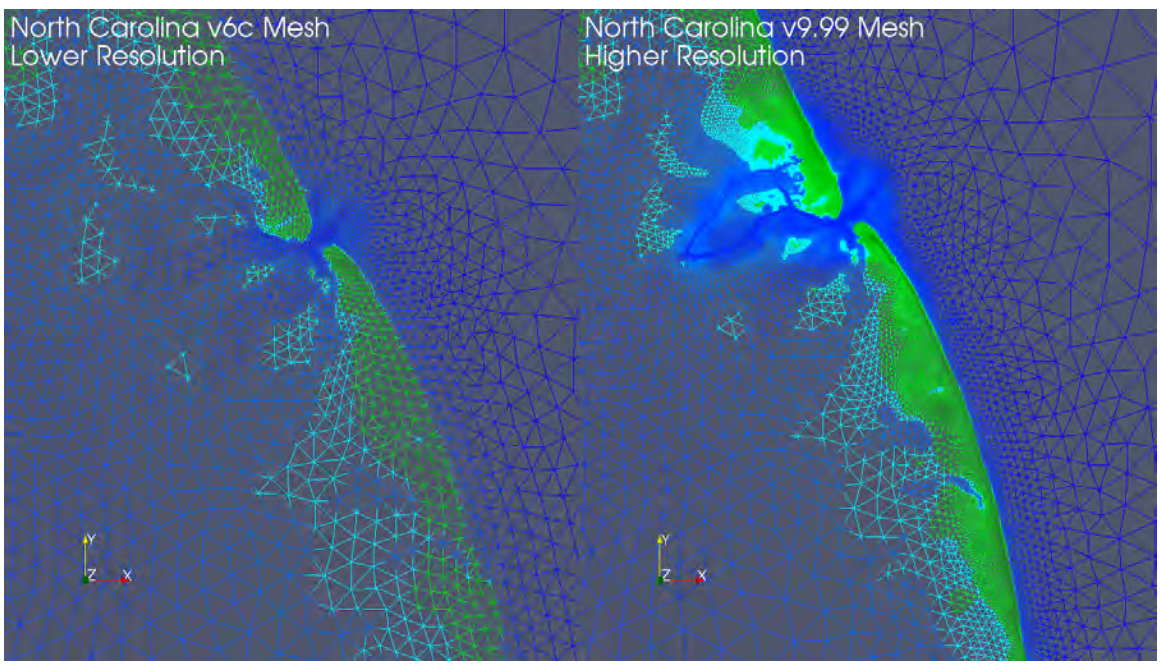


Figure 3: The new NCv9.99 ADCIRC mesh substantially improves the resolution and accuracy of the Oregon Inlet representation. Oregon Inlet is a key maritime connection between Pamlico Sound and the Atlantic Ocean, and is the site of the Oregon Inlet Coast Guard station as well as the Bonner Bridge, a high volume and at-risk link in the coastal transportation infrastructure.

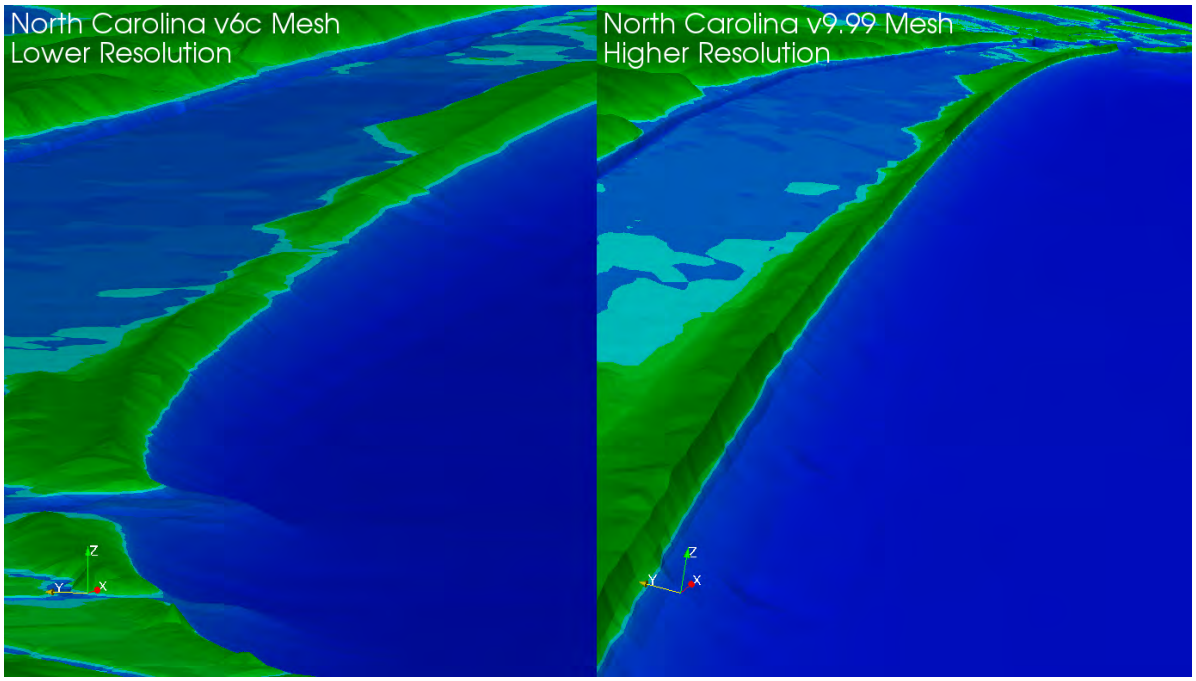


Figure 4: The functional representation of the dune line has improved in the new mesh, allowing it to represent the storm surge inundation reduction performed by coastal dunes more accurately.

Transition

Transition activities in the reporting period include (1) the continuous presentation of the latest high resolution results to end users via the Coastal Emergency Risks Assessment (CERA) application; (2) organization, preparation, and execution for the 2016 ADCIRC Boot Camp; and (3) support for transitioning ASGS technologies into the Hurricane Surge On-demand Forecast System (HSOFS) at NOAA.

High Resolution Results

The new high resolution results produced by the ASGS at RENCI are being provided to decision makers continuously via the Coastal Emergency Risks Assessment web application as shown in the following figures. In addition to improved accuracy, the higher mesh resolution resolves some visual artifacts that may have been confusing for emergency managers that use the web application to make decisions.

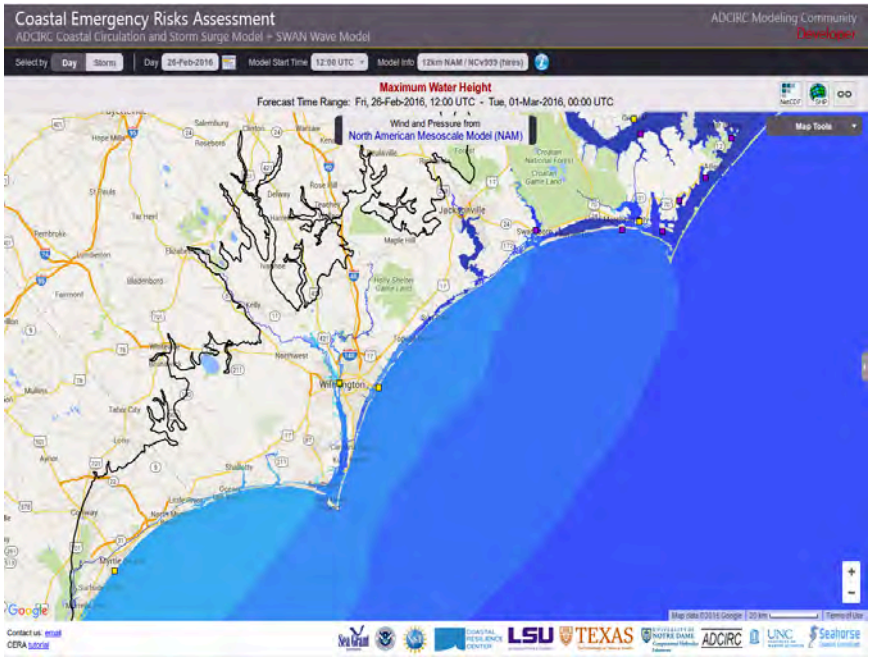


Figure 6: The transition of the results on the high resolution v9.99 ADCIRC mesh to decision makers and emergency managers is being achieved via the Coastal Emergency Risks Assessment (CERA) site.

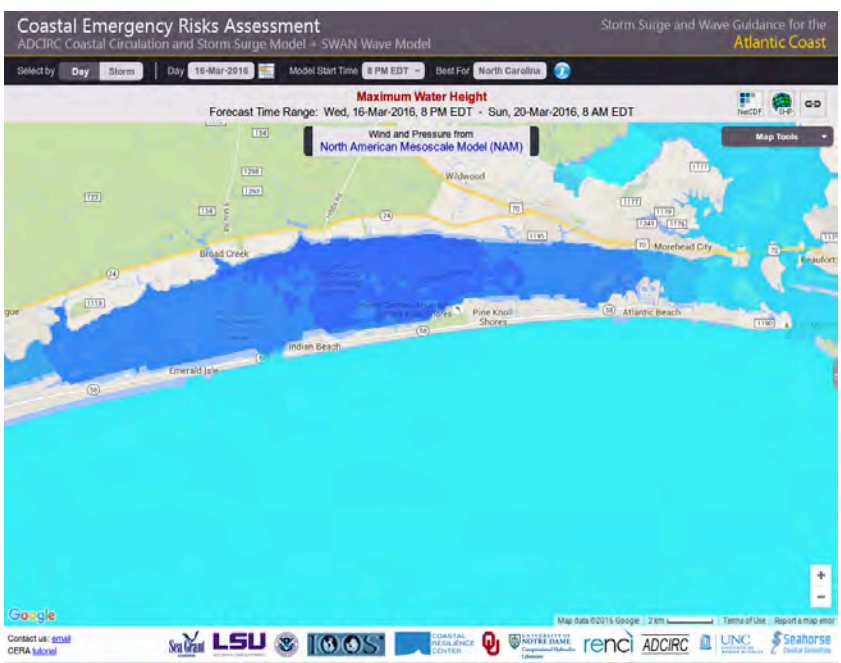


Figure 7: The bathymetric representation of the lower resolution mesh was causing visual artifacts in the presentation web site. This example shows what looks like a false inlet Near Indian Beach on Bogue Banks.

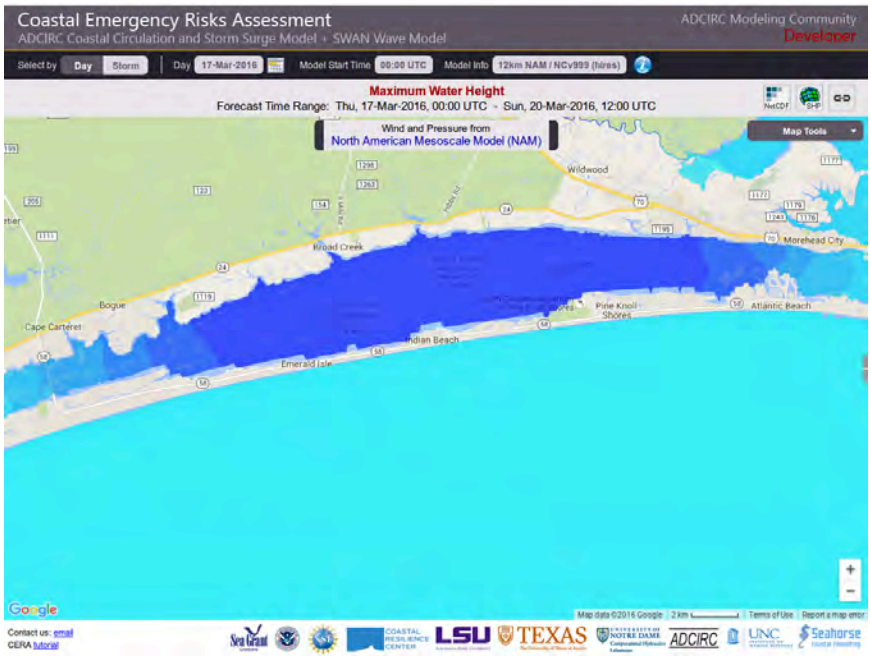


Figure 8: The improved bathymetric representation of the higher resolution v9.99 ADCIRC mesh provides correct visual representation to decision makers when presented with the CERA web application.

ADCIRC Boot Camp

The annual ADCIRC Boot Camp event is a key vector supporting the transition of research results to the science and engineering communities of practice. Over the course of the 2016 reporting period, we developed the registration website for the 2016 ADCIRC Boot Camp, a portion of which is shown in the following figure.

The ADCIRC Boot Camp event is used to provide training for the ADCIRC model including the latest features produced by the research community. It also provides an opportunity to transition the tech- nologies of the ASGS to public, private, and university scientists and engineers. During the reporting period we co-organized the event in collaboration with Chris Massey and Mary Cialone at the host site, the US Army Engineer Research and Development Center (ERDC) Coastal and Hydraulics Lab (CHL) in Vicksburg, Mississippi.

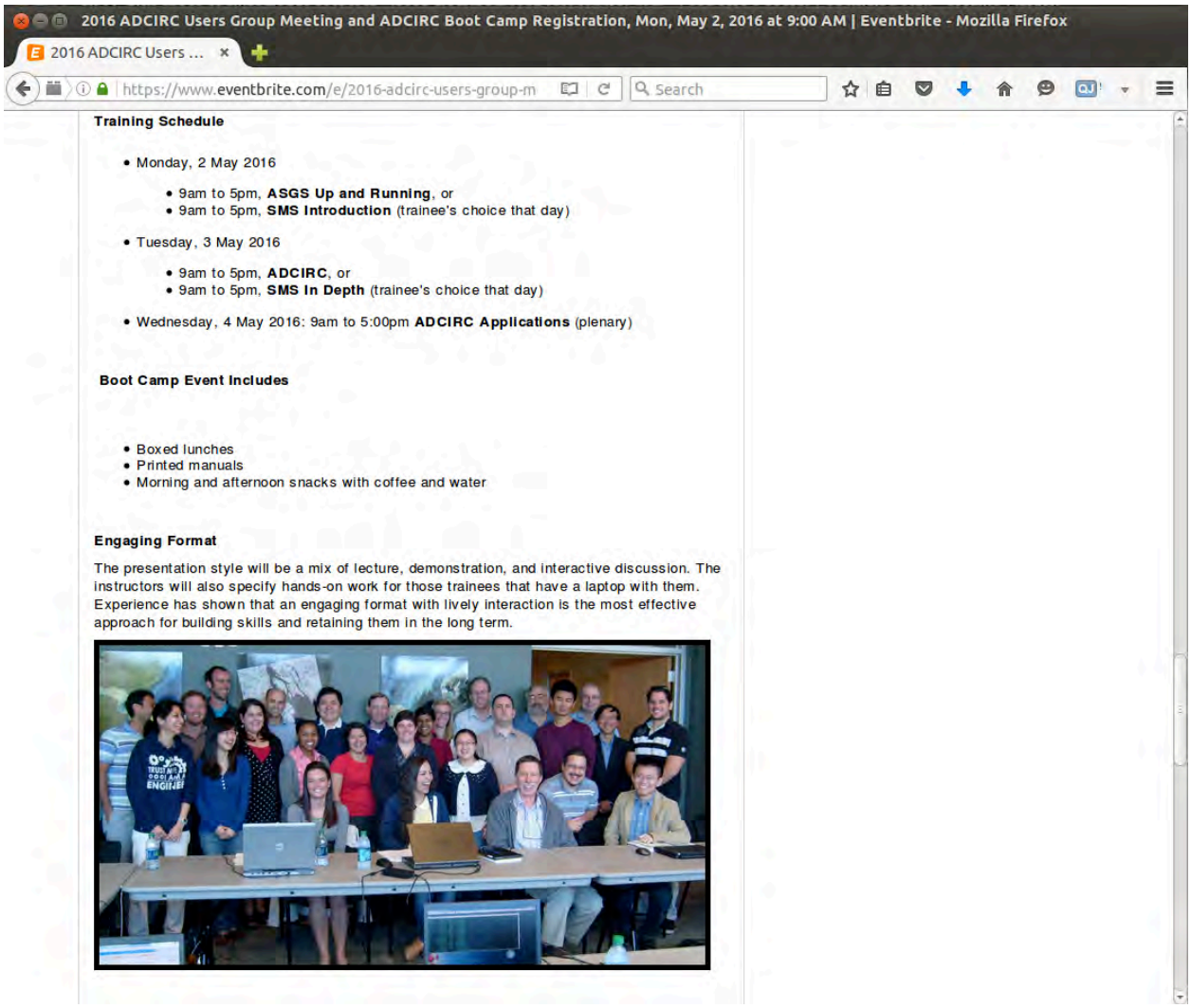


Figure 9: The ADCIRC Boot Camp Registration site for 2016 provides visibility for training activities as well as practical support for managing the event and its participants.

Continuity of Operations

In this reporting period, four service outages and two instances of solution degradation occurred with the NCFS which required attention, determination of root cause, and corresponding correction in order to maintain continuity of operations. Three examples of these outages, their root causes, and the corresponding corrective action that we took to resolve them are described below:

1. During a severe coastal storm event, on 8 February, Rick Luettich reported good accuracy along the coast but expressed concern about predictions further inland along the Neuse River. We determined that the root cause was an outage of the Local Data Manager (LDM) server at RENCI. This server downloads real time river flow prediction data from our partners at the NOAA National Severe Storms Lab (NSSL). I restarted the LDM server and the acquisition of boundary condition data for rivers from our collaborators resumed successfully.

2. On 23 February, all the computational jobs submitted by the NCFS suddenly started to fail. During the root cause analysis, it was found that these jobs were executing much more slowly than usual, and were not able to complete within the 5 hour wall clock time window as

expected (typical run times are less than one hour). There were no error messages present, and the numerical results up to the point where the jobs were killed by the queueing system all appeared stable. We notified the sysadmins on Hatteras and were informed that the issue was likely a result of a system change made in the resource allocation on Hatteras, and we were advised to modify the configuration of the queue scripts produced by the NCFS on Hatteras. We did so and the issue was resolved.

3. On 29 February, it was found that the NCFS was running as expected, but was not able to produce results because it had exhausted its disk storage quota. The RENCI systems administrators increased our quota enough for the NCFS to resume production and suggested that we reduce our use of disk storage. We complied, finding and deleting old model results that appeared to no longer be of interest. However, we were contacted by our collaborators at NC State (Casey Dietrich) about restoration of a range of files that were the subject of current re- search. We started a restoration operation for the deleted files in cooperation with RENCI systems administrators and our collaborators, and quantified future storage needs and requested automated mechanisms for anticipating and avoiding outages resulting from exhausted disk storage quotas in the future.

HAGEN, LSU

DHS Coastal Resilience Center

Research Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Development of an optimized tide and hurricane storm surge model for the northern Gulf of Mexico (MS, AL, FL) for use with the ADCIRC Surge Guidance System.

2. **Principal Investigator / Institution:** Scott C. Hagen, Professor. Louisiana State University, Department of Civil & Environmental Engineering / Center for Computation & Technology / Center for Coastal Resiliency.

3. **Other Research Participants/Partners:** Stephen C. Medeiros, Research Assistant Professor. University of Central Florida, Civil, Environmental & Construction Engineering Department, Coastal Hydroscience, Analysis, Modeling and Predictive Simulations Lab.

4. **Short Project Description:** This study will develop a semi-automated mesh de-refinement method designed to optimize a research grade tide, wind-wave, and hurricane storm surge model so that it can be used in real-time surge guidance operations. The resulting model will be capable of producing accurate predictions within the ADCIRC Surge Guidance System (ASGS) forecast time frames and will include advanced terrain analysis and lidar-based surface roughness parameterizations.

5. **Abstract:** This project will advance state-of-the-art model development by introducing novel terrain analysis techniques and lidar-based surface roughness parameterization at the regional scale. These advanced techniques will also be used to develop intelligent, stable, and semi-automated mesh de-refinement methods for optimizing a research grade (i.e., high resolution) storm surge model to reduce computational time to the point where it can be run within reasonable real-time forecast time frames (e.g., ~1-2 hrs). We will use a protocol based on emphasizing hydraulically significant embankment or valley features to optimize a research grade model of the MS, AL, and FL Panhandle. Since the purpose of ASGS is the provision of real-time hazard guidance, we will emphasize the accurate capture of the timing and magnitude of maximum water levels. This will be achieved by employing mesh development techniques such as: running preliminary simulations to define active floodplain and removing unnecessary elements (relevant because the research grade model was developed to accommodate up to two meters of sea level rise); employing accelerated element relaxation moving outward from significant vertical features; and enforcing stricter criteria for vertical feature inclusion (especially for channels). Objective error metrics will be used to assess model performance. The final outcome/deliverable will be an accurate, optimized hurricane storm surge model of the northern Gulf of Mexico (MS, AL, & FL Panhandle) that is suitable for use with the ASGS including improved surface roughness parameterization from our lidar-based technique. In

addition, this high resolution ADCIRC+SWAN model will serve as a benchmark for validating future versions that may incorporate less resolution or smaller regional focus.

6. End users:

- Jerrick Saquibal, Northwest Florida Water Management District. Provided preliminary guidance as to the needs of his district during kick-off phone call with Dr. Medeiros. Follow up call to show preliminary model results to be scheduled in performance period 2. Expects high resolution surge forecasts for the Florida Panhandle and Big Bend regions, and looks forward to value-added lidar products.
- David Kidwell, NOAA Gulf of Mexico Sentinel Site Cooperative (GOMSSC). Provided preliminary guidance on role of surge forecasts in GOMSSC mission. Facilitated Dr. Medeiros presentation on topographic characterization of coastal salt marshes at GOMSSC monthly conference call. Expects to invite LSU-UCF personnel to demonstrate surge modeling and value-added lidar products at future GOMSSC workshops and meetings. We plan to elevate the role of the GOMSSC as an end-user as a result of our successful initial engagements.

7. Explanation of Changes:

There have been no major changes to the approved workplan. Minor changes to increase end-user engagement, and documentation thereof, were implemented as a result of DHS comments.

8. Unanticipated Problems:

The administrative tasks associated with implementing the SUMREX program were much more complex than anticipated. Issues regarding payment of travel funds and stipend resulted in Dr. Medeiros spending an inordinate amount of time on this, thus delaying the research milestone associated with submission of a journal paper on the lidar surface roughness parameterization. Also, due to delays in the issuance of Performance Period 2 funds, Dr. Medeiros temporarily funded the SUMREX program from his research balance account in order to mitigate the financial burden on the student from UPRM. All issues are now resolved and we expect the process to go much smoother in summer 2017.

9. Project Outcomes:

Our primary goal is to develop an accurate, optimized hurricane storm surge model of the NGOM that is suitable for use with the ASGS and CERA that includes improved surface roughness parameterization from our lidar-based evaluation technique. This will enable the ASGS to provide emergency management personnel in the region with the highest resolution, most accurate real-time storm surge forecasts for threatening tropical cyclones. In turn, this will facilitate more efficient evacuation and better prediction of post-storm emergency resource needs. These research outcomes have corresponding Research Milestones shown in the table below. The submission and subsequent publication of the surface roughness parameterization and mesh optimization methods in high-impact journals serve to validate the research pathways

and document their acceptance by successful peer review. By achieving these milestones, the incorporation of this optimized model into ASGS will be justifiable by any measure and DHS S&T will have independent documentation in support of it. The incorporation of the optimized model into ASGS is also the best, most readily adoptable means for conveying the model results to the public in a meaningful way. The following sections details the progress we have made towards achieving these outcomes.

The most progress has been made on Phase 1 of the effort to transform a research grade ADCIRC model to one that is optimized for runtime. To examine the potential reduction in wall-clock time two Hurricane Katrina simulations were performed using the two-dimensional depth-integrated version of ADCIRC [*Luettich and Westerink*, 2004]. The first simulation employs the original *NGOM3* unstructured mesh that contains 5,492,562 computational nodes. Details on the development and validation of the *NGOM3* model can be found in *Bilskie et al*. [2016]. The bathymetry and topography of the *NGOM3* mesh for the northern Gulf of Mexico (NGOM) is shown in Figure 1A.

The *NGOM3_FPL* unstructured mesh was employed for the second simulation. This mesh contains 4,441,392 computational nodes, a reduction of 1,051,170 nodes (19%). The *NGOM3_FPL* mesh was generated by removing mesh nodes and elements at the northern and most upland areas across Louisiana, Mississippi, Alabama, and Florida. The maximum envelope of water (MEOW) derived from 86 synthetic storm forced simulations using the *NGOM3* model under 2 m of sea level rise was utilized. Mesh nodes that were outside the computed MEOW were removed as well as their respective elements. The model boundary and topography and bathymetry of the *NGOM3_FPL* mesh is shown in Figure 1B.

The *NGOM3* and *NGOM3_FPL* unstructured meshes were employed in a simulation forced by Hurricane Katrina wind and pressure. The simulations were performed on the LONI Queenbee2 HPC across 400 computational cores (includes 2 dedicated writer cores). The Hurricane Katrina model was setup to run for 5.0 days with a 0.5 day ramp using a time step of 1.0 seconds (implicit mode). The maximum simulated water surface from the *NGOM3* and *NGOM3*_FPL simulation is shown in Figure 2A and B, respectively. Both simulations resulted in an equivalent solution.

The *NGOM3* Katrina model simulation resulted in a wall clock of 288 min (57.6 min/day of simulation) and the *NGOM3_FPL* resulted in 232 min (46.4 min/day of simulation), a reduction of 56 min (19.4%) in wall clock (Table 1). For this example, the reduction in wall clock scales linearly with the reduction in computational nodes. This is because the nodes that were removed were generally never wetted; however, more research is required to understand the reduction in wall clock given a reduction in computational nodes.
This initial model comparison yields promising results and will assist in the further development of a forecast-grade model for the NGOM coast. Of course, more research and experimentation is necessary to transition the *NGOM3* unstructured mesh to a forecast-grade model.

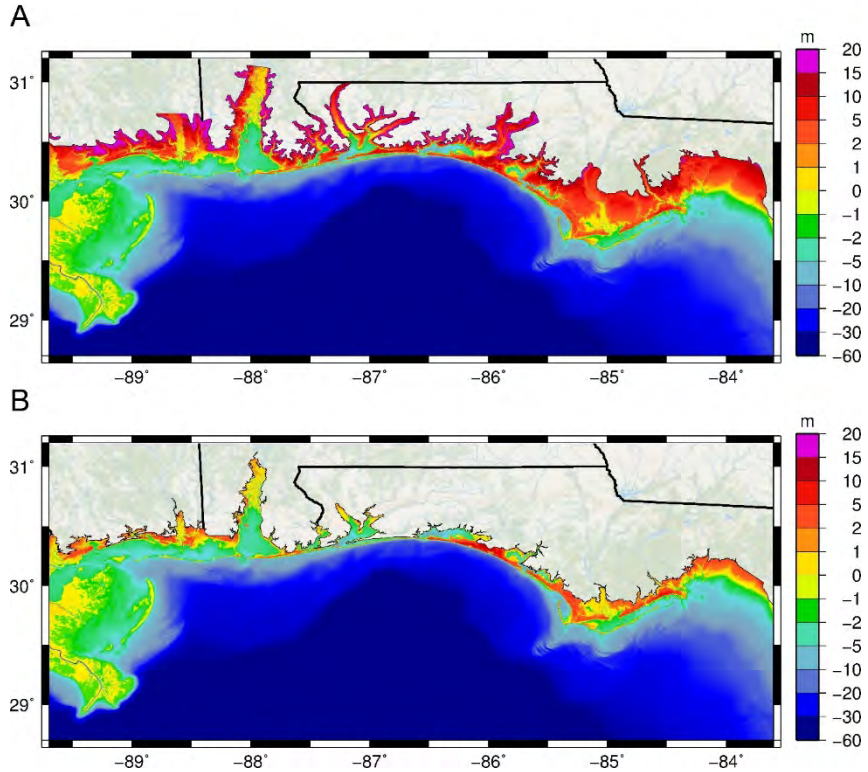


Figure 1. Research-grade NGOM3 model topography and bathymetry (m, NAVD88) for the (A) original model and (B) the *NGOM3_FPL* mesh.

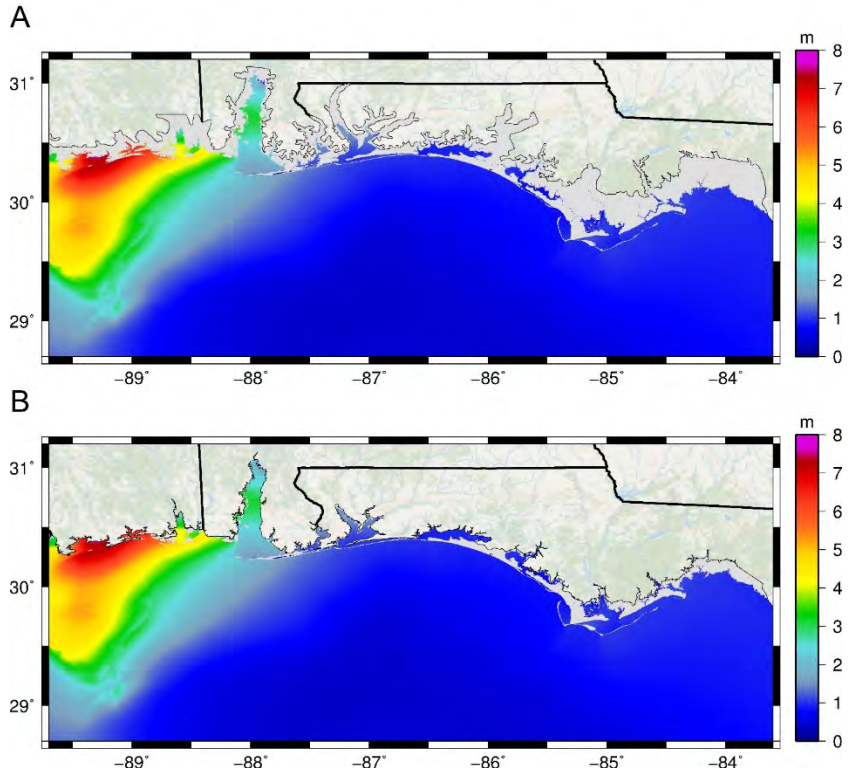


Figure 2. Research-grade NGOM3 simulated maximum water surface elevation from Hurricane Katrina (m, NAVD88) for the (A) original model and (B) the *NGOM3_FPL* mesh.

Table 1. Node count and wall-clock (min) for the full research-grade NGOM3 model and the NGOM3 model with additional floodplain removed.

Model	Node Count	Total Wall Clock (min)	Wall Clock (min) per day of simulation
NGOM3	5492562	288	57.6
NGOM3_FPL	4441392	232	46.4

References

Bilskie, M. V., S. C. Hagen, S. C. Medeiros, A. T. Cox, M. Salisbury, and D. Coggin (2016), Data and numerical analysis of astronomic tides, wind-waves, and hurricane storm surge along the northern Gulf of Mexico, *Journal of Geophysical Research: Oceans*, *121*(5), 3625-3658.

Luettich, R. A., and J. J. Westerink (2004), Formulation and numerical implementations of the 2D/3D ADCIRC finite element model version 44.XX*Rep*., 12/08/2004.

10. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Establish baseline metrics for research grade model performance (accuracy at stations, run time, etc.)	03/31/2016	75%	Diverted resources towards Phase 1 optimization task, Completion expected 09/30/2016
Develop scalable data processing pipeline for lidar-based surface roughness parameterization	06/30/2016	25%	Time devoted to SUMREX startup issues, expected completion 12/31/2016
Phase 1 of optimization procedure: Remove unnecessary floodplain elements and document incremental performance improvements	06/30/2016	100%	Phase 1 reduced 17% of the unnecessary floodplain nodes and resulted in a 25% reduction in wall-clock time on 480 HPC cores. Complete.
Research Milestone			
Submit a manuscript on Regional Scale Lidar Surface Roughness	06/30/2016	50%	Time devoted to SUMREX startup issues, expected completion 12/31/2016

11. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Meet (in-person or virtual) with technical team from Coastal Emergency Risks Assessment (CERA) to establish file format, tiling scheme, and transfer protocols for displaying model results on http://cera.cct.lsu.edu/	03/30/2016	40%	Effort directed at Phase 1 optimization task, the results of which will form the basis for this activity, expect to be complete by 12/31/2016
Coordinate with end users to determine transition goals and plan	03/01/2016	100%	End Users (D. Kidwell & R. Collini, NGOM Sentinel Site Cooperative; Tucker Mahoney, FEMA; Jerrick Saquibal, NWFWMD) were briefed on project and all requested to be kept informed. CERA interface presented and all users responded positively. All users responded positively to research grade model being evolved into usable product.
Transition Milestone			
Prototype integration of NGOM ADCIRC model output into CERA	06/30/2016	25%	Delays in funding delivery and actual project start, expect to be complete by 12/31/2016
Refined transition goals and plan with end user input	06/30/2016	50%	Initial conversations complete, pivoting to give NGOM SSC greater role, expect to be complete by 12/31/2016

12. Interactions with education projects:

The LSU-UCF Summer Research Experience (SUMREX) was a resounding success. Felix Santiago from UPRM was selected from the applicant pool to participate in the 2016 program. He arrived at UCF on Monday June 13, 2016 and checked into his on-campus apartment (paid for by the project).

Starting Tuesday, June 14, he began his SUMREX program with a pre-test consisting of some basic linear algebra and numerical methods problems designed to assess his level of competence in these topics and gage the need for further explanation on these topics. During the pre-test, he engaged daily with Dr. Talea Mayo for assistance with the mathematical aspects

of the pre-test. The pre-test also required Felix to read a research paper in JGR-Oceans written by the LSU-UCF team, highlighting both concepts he did not understand, as well as concepts that he was interested in. For the remainder of the UCF phase of the SUMREX, Felix worked closely with Dr. Medeiros and his graduate students to learn the SMS software for ADCIRC mesh development. He went through tutorials from past ADCIRC boot camps, working through the examples. He then used that knowledge to expand and add resolution to an existing mesh and run desktop ADCIRC tide simulations in SMS. Also, Dr. Medeiros took Felix into the field at the Merritt Island National Wildlife Refuge to determine Manning's *n* bottom friction coefficients. Dr. Medeiros also taught Felix the method for determining the effective aerodynamic roughness length in the field by measuring the height, canopy width and other dimensions of trees and above-ground obstructions.

On July 5, Felix transitioned to LSU and checked into his project provided housing. He immediately began working with Dr. Hagen's student Matt Bilskie to build on his ADCIRC knowledge by conducting storm surge simulations. Felix attended three virtual trainings entitled "Introduction to Linux" and High Performance Computer (HPC) User Environment Part 1 and Part 2". These trainings were provided by LSU HPC. He simulated several hurricanes using a coarse ADCIRC model on his workstation and on the LSU HPC and documented the difference in run-time. He also learned how to generate presentation and publication quality graphics of storm surge model output using the FigureGen software program (developed by J. Casey Dietrich, NC State University, CRC PI). His work continued by simulating Hurricane Dennis using a high-resolution model of the Florida panhandle and compared the peak storm surge using two different wind-vortex models. He also learned how to spin-up a model in order to hot-start a storm surge simulation. During his final week at LSU, Felix employed the modified mesh he developed at UCF and simulated astronomic tides and hurricane storm surge from Hurricane Sandy. He then compared storm surge results among his modified mesh and the original, pre-modified, mesh. This experience is still underway and we look forward to Felix's final presentation.

13. Publications:

Tahsin, S., **S.C. Medeiros**, A. Singh (2016). "Resilience of coastal wetlands to extreme hydrologic events in Apalachicola Bay." *Geophysical Research Letters*, Vol. 43, doi: 10.1002/2016GL069594.

14. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)			
Undergraduates provided tuition/fee support (number)			
Undergraduate students provided stipends (number)			
Graduate students provided tuition/fee support (number)			
Graduate students provided stipends (number)			
Undergraduates who received HS-related degrees (number)			
Graduate students who received HS-related degrees (number)			
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)			
SUMREX program students hosted (number)	1		
Lectures/presentations/seminars at Center partners (number)			
DHS MSI Summer Research Teams hosted (number)			
Journal articles submitted (number)			
Journal articles published (number)	1		
Conference presentations made (number)			
Other presentations, interviews, etc. (number)	8		
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)			
Requests for assistance/advice from DHS agencies (number)			
Requests for assistance/advice from other Federal agencies or			
Total milestones for reporting period (number)	3		
Accomplished fully (number)	0		
Accomplished partially (number)	3		
Not accomplished (number)	0		
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
ASGS NGOM Forecasts	Web Application	12/31/2017	NGOM SSC, NWFWMD, General Public

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
N/A			

Leveraged Support	
Description	Estimated Annual Value
XSEDE High Performance Computing Allocation (Stampede) – Est. 30% of award to be used on this project	$32,014.40

DIETRICH, NCSU

DHS Coastal Resilience Center

Research Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:**

   Improving the Efficiency of Wave and Surge Models via Adaptive Mesh Resolution

2. **Principal Investigator / Institution:**

   Joel Casey Dietrich, Assistant Professor, North Carolina State University

3. **Other Research Participants/Partners:**

   Clint Dawson, Professor, University of Texas at Austin

4. **Short Project Description:**

   Coastal communities rely on predictions of waves and flooding caused by storms. These predictions are used during the storm to make decisions about resource deployment and evacuation, and these predictions are also used between storms for design and to establish insurance rates for local homeowners. Computational models are essential for making these predictions, but they can be costly. A typical prediction can require hundreds or even thousands of computational cores in a supercomputer, and several hours of wall-clock time. In this project, we will improve the performance of a widely-used, predictive model. Its representation of the coastal environment will adapt during the storm, to better utilize the computing resources and ultimately provide a faster prediction. This speed-up will benefit coastal communities, including emergency management personnel, who will have more time to make decisions during the storm event. It will also benefit long-range planners, such as flood mappers, who will be able to consider larger, more-accurate models in the same amount of time.

5. **Abstract:**

   Storm-induced waves and flooding can be predicted using computational models such as the ADCIRC+SWAN modeling system, which has been used by DHS and its constituent agencies for mapping of floodplain flood risk and forecasting of storm surge and inundation. This modeling system has been shown to be efficient in parallel computing environments. It is implemented on static meshes and with a static parallelization, and thus it does not evolve as a storm approaches and inundates a coastal region. This implementation can be suboptimal when large portions of the mesh remain dry during the simulation.

   In this project, we will optimize the parallel implementation of ADCIRC by using a large-scale adaptivity, in which a mesh will be refined by incorporating entire portions of another, higher-resolution mesh. Instead of subdividing an individual element, we will increase resolution by

adding elements from a pre-existing mesh that has been well-validated. This procedure will leverage the existing suites of meshes for the same geographic region. The adapted mesh will be rebalanced among the computational cores so that geographic regions with increased resolution will not be concentrated on a disproportionally-small number of cores, and so that the time spent on inactive regions is minimized. These technologies will decrease the computational cost and better utilize the available resources.

This project will develop technologies to improve the efficiency of ADCIRC+SWAN simulations, thus allowing for more model runs in ensemble-based design applications, and for faster simulations in time-sensitive applications such as operational forecasting. These outcomes will increase the accuracy of flood risk products used in building design and the establishment of flood insurance rates, and thus lessen the impact of a disaster. These outcomes will also improve the communication and understanding of potential hazards.

6. **End users:**

The proposed enhancements to efficiency will benefit all model users, including several DHS agencies with missions related to coastal flooding. In its development of Flood Insurance Rate Maps (FIRMs), FEMA will benefit because the probabilistic guidance requires a large number of deterministic simulations, and the approach described in this project will require fewer computational resources. For example, if a flood mapping study would see an efficiency gain of, say, 10 percent, then the study could be completed in a shorter time. Alternatively, that efficiency gain could be reinvested into increasing the mesh resolution and/or considering a larger suite of storms, and thus increasing the accuracy of the model results. At FEMA, **Jon Westcott, Tucker Mahoney** and **Christina Lindemer** have agreed to participate as transition partners. The project will also help to speed the delivery of projected flood inundation levels associated with coastal storms, thereby assisting FEMA as well as state and local emergency managers to plan for coastal evacuations and deployment of resources and personnel. In addition, the Coast Guard will benefit from faster guidance about waves and surge and therefore can make operational decisions about the possible relocation of assets in advance of an oncoming storm. The project personnel will continue to work with the transition team to identify additional end-users in these and other DHS constituent agencies.

With the Texas State Operations Center, the project personnel will work with **Gordon Wells** and **Teresa Howard** to transition the analysis products that are used for guidance by the emergency management leadership. They have worked with forecast guidance for the Texas coastline in previous seasons, and are supportive of the proposed work to improve the speed of the forecasts. This partnership is important because it will connect the products with end users at the state and local levels.

The proposed work will also benefit ADCIRC model users at other federal agencies. With the USACE Engineer Research and Development Center, **Ty Wamsley** and **Mary Cialone**, with the NOAA NCEP, **Andre van der Westhuysen**, and with the NOAA West Gulf River Forecast Center, **Derek Giardino,** have agreed to participate as transition partners. In some cases, and especially for partners who are focused on operational modeling with ADCIRC, these activities will take the form of guidance about development with the goal of transitioning products to their work in the long term.

The project personnel will also work closely to transition the project outcomes to the ADCIRC

modeling community. These transition activities will connect with **Jason Fleming** and **Carola Kaiser**, who are key members of the Coastal Emergency Risks Assessment (CERA) group. They operate the forecasting systems for regions along the U.S. Gulf and Atlantic coasts, and they visualize and communicate the forecast guidance via a Google Maps application. Dr. Fleming also manages the software repository for the development of ADCIRC. The project personnel will work with these partners to ensure that the new modeling technologies can be incorporated within the forecasting system and the release version of ADCIRC.

The PIs have scheduled for quarterly videoconferences with the end users identified above. We held our first videoconference on Wednesday, 30 March 2016, and we shared our preliminary results for the static load balancing, which has improved the speed of ADCIRC by about 20 percent in our initial tests. That videoconference resulted in the following action items:

- Work with Jason Fleming (Seahorse Coastal Consulting) to push our preliminary code changes into the ADCIRC code repository, for use in testing for the upcoming season.
- Mary Cialone (USACE ERDC) was concerned about how the additional cuts in the subdomains and how this will work for finer resolution meshes. This comment will lead to future research on how to optimize the domain decomposition.
- Jesse Feyen (NOAA) noted that the research will have a clear benefit to NOAA operational forecasting. Later that morning, he shared an unstructured mesh with floodplain coverage from Texas through Maine, which we will use for initial testing of the adaptive meshing.
- Teresa Howard and Gordon Wells (Texas State Operations Center) asked about connections of the dynamic adaptivity with the web mapping tools that they use, which may lead to future research directions. They also suggested a connection with Derek Giardino (NOAA West Gulf River Forecast Center); he has since agreed to be an end user for this project.

Thus we are already working with our transition partners, and information is flowing in both directions. They have identified some future directions for our research, and we are sharing our technologies with them. The project technologies will be shared as they become available, and our transition partners will be trained and then test the technologies for applications ranging from operational forecasting to engineering design. The technologies developed in this project will also be released to the ADCIRC modeling community. This work will require the development of extensive documentation and example files, which will be hosted online, and the integration of the software into the release version of ADCIRC.

7. Explanation of Changes:

This project has not had any changes to its approved workplan.

8. Unanticipated Problems:

This project has not had any unanticipated problems or challenges.

9. Project Outcomes:

This project will develop technologies to improve the efficiencies of the ADCIRC+SWAN modeling system in parallel computing environments. It will develop automated routines for an

adaptive, multi-resolution approach to employ high-resolution, unstructured meshes for storm surge applications, and it will develop automated routines for the efficient re-balancing of the computational workload via parallelized domain decomposition. These routines will better utilize the available computing resources by ensuring that every core is busy during the entire simulation. These routines will be shared (with extensive documentation and examples) with the ADCIRC modeling community, including the ASGS for operational forecasting.

These technologies will decrease the time required for an ADCIRC simulation, thus allowing for more model simulations in ensemble-based design applications, and for faster simulations in time-sensitive applications such as operational forecasting. These outcomes will increase the accuracy of flood risk products used in building design, land use planning and the establishment of flood insurance rates, and thus lessen the impact of a disaster. These outcomes will also improve the communication and understanding of potential hazards to individuals, community officials, the insurance industry, and government agencies.

The project has made a lot of progress in the first six months, in three key areas. First, we have focused on code modifications to ADCIRC to improve its load balancing. The pre-processor was rewritten to improve its decomposition of the domain for use on a parallel computer. Before, all regions were treated equally, regardless of whether they were in the open ocean or far into the floodplain, and the result was that the overall workload was not distributed evenly across the cores in the parallel computer. Some cores were working much harder than others. Now, the domain is decomposed twice; the wet regions are split evenly among the cores, and then the dry regions are split evenly among the cores. All cores are contributing equally to the overall workload at the start of the simulation. This is the first step toward a dynamic rebalancing, in which the domain will be decomposed periodically during the simulation to optimize efficiency, and which is a necessary step toward the adaptivity in the third part of this project. Preliminary results are promising. In a hindcast of Hurricane Irene (2011) using the state-of-the-art ADCIRC model for North Carolina, the improved load balancing caused a speed-up of about 20 percent for simulations of tides, winds, and coastal flooding. This 20-percent speed-up is significant because it will lead to shorter simulations in real-time forecasting, and thus more time for the guidance in each forecast cycle to be interpreted by end users.

Second, we are exploring methods to optimize the design of unstructured meshes in coastal regions. ADCIRC uses unstructured meshes because it allows for increased resolution to represent small-scale flows in inlets, near barrier islands, within bays and estuaries, and over floodplains. The ADCIRC community has become smarter about how to design meshes and where to increase the resolution, but these methods are still *ad hoc*. The mesh designer has to make an educated guess about where the resolution will be needed, based on previous experiences. This project is developing techniques to quantify the mesh-related errors in the ADCIRC simulation, and then use those errors to design better meshes. The error measures are localized, related to mass balance and solution convergence, and can be used to show how regions within the mesh will perform relative to each other. If one region has lower errors but another region has higher errors, then resolution could be moved between regions to better

distribute the errors in the solution. This is another step toward the adaptivity in the third part of this project. Initial results are promising. In hindcasts of Irene (2011) and Isabel (2003), we are quantifying the errors and examining their spatial distributions. Then we will redesign the mesh to better distribute the errors, and ultimately improve the accuracy of the simulation.

Third, we are developing techniques to map solutions between meshes with varying levels of resolution. By using the interpolation techniques within the Earth System Modeling Framework (ESMF), the solution from one mesh (e.g. a coarser mesh) is mapped onto a different (e.g. finer) mesh, in a way that is fast and conservative. The simulation may start with the coarser mesh, then add resolution in regions near where the storm is projected to make landfall, and then continue on this finer mesh until new information becomes available. The results from the coarser mesh will be used to hot-start the continued simulation on the finer mesh. We have a prototype framework working already, and initial results are promising. We have developed an automated tool called the ADCIrpolate to map the results between meshes, and we have performed initial testing of the system by using results from a coarser mesh to hot-start a simulation on a finer mesh of the East Coast of the U.S. The comparison of the results has shown a near-identical match between simulations on coarse-only, coarse-then-fine, and fine-only meshes. This is a necessary step toward a multi-resolution adaptivity during storm forecasts.

10. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Additional information about activity / milestone
Parallelization of ADCIRC domain decomposition	06/2016	100	Described above
Interpolation of ADCIRC results from coarse to fine meshes	06/2016	100	Described above
Research Milestone			
Presentation at ADCIRC workshop	04/2016	100	This workshop was held at USACE ERDC on 5-6 May 2016, and is attended by users and developers of the ADCIRC modeling system. We presented preliminary results about the optimization of unstructured mesh construction, described above.

11. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Additional information about activity / milestone
Developmental ASGS instances at NCSU and UT-Austin	03/2016	100	These are research-grade versions of the forecasting systems used elsewhere for real-time guidance during storms. Our local versions are not run daily, but they can be started as necessary. In previous years, we have used an instance at UT-Austin to provide guidance directly to partners at the Texas State Operations Center. These instances will allow us to test our research products before passing them to the community.
Transition Milestone			
Quarterly progress updates, feedback from transition partners	03/2016 06/2016	100 100	We received feedback from Jason Fleming, Mary Cialone, Jesse Feyen, Teresa Howard, and Gordon Wells, on topics ranging from test cases to consider, to ways to transfer information to the community, to additional partners to include. Please see the discussion in Section 6 above.
Sharing of developmental forecast guidance with G Wells, T Howard	05/2016	100	As noted above, in previous years, we have used a research-grade version of the forecasting system at UT-Austin to provide guidance directly to these partners at the Texas State Operations Center. This instance was in place for the 2016 hurricane season.

12. Interactions with education projects:

This project has initiated involvement with the CRC's MSI education partners in two ways. First, PI Dietrich visited Jackson State University (JSU) in early May and presented a seminar about current research in storm surge modeling and forecasting. The seminar was on 4 May 2016, and it was attended by a combination of graduate students and faculty members from JSU. The first half of the seminar was a summary of the last decade of PI Dietrich's research, with a focus on storm surge modeling along the northern Gulf coast, and with an emphasis on experiences in

graduate school and beyond. The second half of the seminar was an introduction to and preliminary results from this CRC project. The seminar was well-received with many questions from the audience. The presentation has been archived on PI Dietrich's institutional web site, and notice of the seminar was shared with CRC leadership.

Second, Co-PI Dawson is hosting a PhD student from JSU at UT-Austin during this summer under the CRC SUMREX program. Xuesheng Qian is a PhD candidate in coastal engineering, and is visiting UT-Austin to learn the SWAN+ADCIRC wave and surge models. Qian has learned how to run the model on the HPC machines at UT Austin, how to use the Surface Water Modeling System to generate/modify finite element meshes and data used in the models, how wind files are generated and used, and has been working with Dawson and JSU researcher Bruce Ebersole to run the model for storms in the Texas Gulf Coast area. With this training, Qian will be able to teach other researchers at JSU how to run the model.

13. Publications:

This project does not yet have any articles submitted for publication.

14. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)	0		
Undergraduates provided tuition/fee support (number)	0		
Undergraduate students provided stipends (number)	0		
Graduate students provided tuition/fee support (number)	3		
Graduate students provided stipends (number)	3		
Undergraduates who received HS-related degrees (number)	0		
Graduate students who received HS-related degrees (number)	0		
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)	0		
SUMREX program students hosted (number)	1		
Lectures/presentations/seminars at Center partners (number)	1		
DHS MSI Summer Research Teams hosted (number)	0		
Journal articles submitted (number)	0		
Journal articles published (number)	0		
Conference presentations made (number)	2		
Other presentations, interviews, etc. (number)	1		
Patent applications filed (number)	0		
Patents awarded (number)	0		
Trademarks/copyrights filed (number)	0		
Requests for assistance/advice from DHS agencies (number)	0		
Requests for assistance/advice from other Federal agencies or	0		
Total milestones for reporting period (number)	6		
Accomplished fully (number)	6		
Accomplished partially (number)	0		
Not accomplished (number)	0		
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
ADCIRC forecast guidance	Guidance	June-Nov 2016	G Wells and T Howard, Texas State

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
Travel funds to Computational Methods in Water Resources Conference to present research findings	Dietrich	$1,112.19	NCSU CCEE Department
Leveraged Support			
Description			Estimated Annual Value
NSF XSEDE allocation of 5.7M CPU-hours combined for supercomputers at UT-Austin, NICS and SDSC			$199,767.50

TWILLEY, LSU

DHS Coastal Resilience Center

Research Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Integrated Modeling Approaches with Application to Pre- and Post-disaster Planning for Creating More Resilient Communities

2. **Principal Investigator / Institution:** Robert R. Twilley, Louisiana Sea Grant/Oceanography & Coastal Science, LSU

3. **Other Research Participants/Partners:**

   Jeff Carney, Coastal Sustainability Studio, LSU
   Traci Birch, Coastal Sustainability Studio, LSU
   Carola Kaiser, Center for Computation and Technology (CCT), LSU
   Brant Mitchell, Stephenson Disaster Management Institute (SDMI), LSU

4. **Short Project Description ("elevator speech):**

   We propose to develop pre- and post-disaster planning and adaptation tools for coastal communities to increase resilience. These efforts will enable vulnerable communities to plan, react, and recover more quickly and effectively in areas facing repetitive disturbance. The goals of the program are to improve emergency response with regard to protecting vulnerable infrastructure and populations, and to reduce repetitive loss by providing accurate impact data to community planners in the immediate aftermath of an event.

5. **Abstract:**

We propose that an integration of coastal modeling tools linked to innovative design/planning approaches, together with effective outreach to both emergency managers and land use planners, is needed to provide crucial community-level data for effective pre- and post-disaster planning. Beyond large-scale models or those that only demonstrate one aspect of hazard impact (e.g. storm surge), communities need clear guidance on exactly which vulnerable infrastructure and populations may be threatened and/or protected (pre-disaster planning and rapid response), and accurate post-event impact to make crucial land use and redevelopment decisions quickly. The ability to leverage this type of community-specific data provides the opportunity to avoid loss and rebuild for maximum future risk reduction. We will incorporate established modeling outputs into a new consequence model showing how flood risk (both from storms and SLR) will impact people, industry, and infrastructure. Together this group will provide (1) planning tools that visualize aggregated risks to include hurricane force winds, storm surge, and inland flooding along with vulnerable populations based on socio-economic status; (2) modeling and visualization tools to communicate flood risks during a tropical cyclone event by identifying vulnerable populations and structures that are susceptible to storm surge; (3) post-landfall search and rescue grid system with prioritization based on socio-

economic vulnerabilities; (4) methodology for helping community planning departments and recovery planning teams effectively utilize and implement changes to their built environment through effective resilience based planning. Louisiana Sea Grant and CSS will engage federal, state and local planners and emergency managers to incorporate these products into planning efforts.

6. End users:

This project, starting with the establishment of a focus group of federal, state and local planners and emergency managers, will determine what variables should be tracked in terms of consequences of storm surge to people, homes, and infrastructure to assist them in making critical decisions during and immediately following storm events. End users involved in this process will include:

- Federal Emergency Management Agency (FEMA) - Randy Meshell, Federal Preparedness Coordinator
- Department of Homeland Security (DHS) Federal Protective Services - Philip Constantin, Protective Service Advisor
- National Weather Service (NWS) – Ken Graham, Slidell/New Orleans Forecasting Office
- Louisiana Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP) – Christopher Guilbeaux, Deputy Director for Preparedness, Response and Interoperability-
- Louisiana Coastal Protection and Restoration Authority (CPRA) – Chris Ellis, Director
- Louisiana Department of Wildlife and Fisheries (LDWF) – Patrick Banks, Deputy Director
- Louisiana Office of Community Development (OCD) – Pat Forbes, Secretary
- Louisiana National Guard, - MAJ Robert Fudge
- US Coast Guard – Sector New Orleans - Roy Ford, Port Security Specialist
- Local Planners –

  Bob Rivers, Planning Director – City of New Orleans

  Louisette Scott, Planning Director – City of Mandeville, LA

  Chris Pulaski, Planning Director – Terrebonne Parish, LA

  Doug Burguires, Assistant Planning Director, Lake Charles, LA

  Jennifer Gerbasi, Terrebonne Parish Recovery Planner

  Dexter Accardo, Director - St. Tammany Parish OHSEP
- Emergency Managers –

  John Rahaim, Director – St. Bernard Parish

  Earl Eues, Director, Terrebonne Parish
- Sea Grant Agent - Kevin Savoie, Camaron Parish

Each of the agencies described above have already been involved in the development of CERA and its use during several recent hurricane events, such as Hurricane Isaac. These agencies have made commitments through attendance at workshops dedicated to training on CERA products, and technology updates prior to hurricane season, that demonstrate the partnerships that exist to the project proposed. In addition, SDMI has established relationships with local

partner communities in Vermilion Parish, such as Abbeville, that will serve as case studies for the Consequence Model production and targeted planning efforts.

7. Explanation of Changes:

The Focus Group was originally scheduled to be held in June 2016. Due to an unavoidable conflict, the Focus Group has been rescheduled to take place in September 2016. The rescheduling of the Focus Group will not have any detrimental impact to the original timeline and milestones of this project.

8. Unanticipated Problems:

The Focus Group had to be rescheduled as the original time line called for the Focus Group to meet in June 2016. During the only week that was available to all the PI's for this project, there was a conference that would have prevented local planners from participating in the Focus Group. While the team discussed meeting with them separately, a major outcome of this project is to ensure planners and emergency managers are communicating with one another so each can offer input into planning, response and recover processes. Having the cross dialogue was deemed more important than meeting the initial timeline. The Focus Group has now been rescheduled to take place on September 21, 2016.

9. Project Outcomes:

A major outcome of this project for Year 1 was an aggressive outreach component to ensure local, state and federal planners and emergency mangers were aware of this project and its potential to influence their decision-making and planning processes. The project team has completed several outreach opportunities that include the State of Louisiana American Planning Association and the Louisiana Emergency Preparedness Association's general sessions. In addition, direct outreach with several federal agencies to include FEMA Region VI, U.S. Coast Guard, DHS Protective Services and the National Communication Center have also taken place.

10. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Initiate plans to develop the CERA Consequence Model to capture the diversity of coastal infrastructure and assets in the MRDP.	June 2016	100%	
Conduct preliminary analysis of hurricane impact scenarios to capture the diversity of recovery and adaptation needs in the MRDP.	June 2016	100%	The State currently has an infrastructure database which serves as a basis for the consequence model. Additional

			work is being performed with individual agencies such as DHS Protective Service and USCG District 8 on refining additional infrastructure requirements. SLOSH Maxim of Maximums (MOMs) that were recently updated by NOAA and offer higher resolution have been identified to replace the older lower resolution SLOSH MOMs to determine hurricane impacts for planning purposes.
Determine available data to be used in building the Consequence Model. Collect information to integrate in the development of pilot parish(es) for SSVI.	June 2016	100%	The LSU team worked with the State to select the state's 144k point infrastructure database as the basis on which to build the consequence model.
Research Milestone			
With assistance of focus group, determine data not already available that would assist in determining consequences of storm surge.	June 2016	80%	Coordination and planning for the Focus Group has been completed. The Focus Group has been rescheduled to take place on September 20, 2016 due to a scheduling conflict. [Note – Focus group recommended that available parcel data and building footprints data be added to the consequence model.]
Have data sets compiled that reflect the information required to build SSVI.	June 2016	90%	Focus Group to determine how to prioritize inputs and determine which inputs should be included in the SSVI [Note – The focus group agreed with the initial metrics established by LSU-SDMI for the SSVI]
With assistance of focus group, determine sectors not already involved in process and engage in model and planning process development.	June 2016	80%	All known available data sets have been identified. Once the Focus Group has been completed, any gaps identified in data will be addressed, if feasible. [Note – The focus group agreed with the initial data sets that were identified by LSU-SDMI. They also emphasized that critical to the locals would be the status of water utilities, sewer treatment plants and any surge that would disrupt their operations. Without the ability to provide potable water their ability to

			recover and sustain their populations would be greatly decreased.]

11. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Develop a Focus Group to determine desired variables to assist decision makers in analyzing consequences of storm surge. Determine the most effective means to display results of consequence model. Participants at a minimum will include – The Louisiana Governor's Office of Homeland Security and Emergency Preparedness, Louisiana National Guard, U.S. Coast Guard – 8th District, Louisiana Department of Wildlife and Fisheries, Federal Emergency Management Agency, DHS Protective Services, local Emergency Managers.	June, 2016	80%	NOTE: SDMI is complete – members include GOHSEP Deputy Director, FEMA RVI National Preparedness Officer, Terrebonne Parish EM, St. Bernard Parish EM, DHS Protective Services Officer, and USCG – Sector New Orleans – Port Security Specialist, planners from across the state have been identified and invited. Communities approached include Orleans Parish (City of New Orleans), Terrebonne Parish, St, Tammany Parish, and Calcasieu Parish (City of Lake Charles). Expected completion August 2016.
Develop contacts with various federal, state and local and professional organizations to establish connections that enhance the utility of products developed in this project. Examples include American Planning Association, Association of State Floodplain Managers Association, FEMA National Preparednesss office, and FEMA MT. Continued effort to work with NOAA NWS office in Slidell (WFO and MRFO) and other regional networks to demonstrate utilty to NOAA forecasting capabilities. Connect with parish emergency managers and CIO of New Orleans to demonstrate utility of products at more local level. Participate in the annual Louisiana Emergency Preparedness Association meeting with project presentation.	June 2016	100%	Outreach to various personnel and organizations has been completed; however, the initial focus has been towards Louisiana and Region VI. We will continue to expand the national relevance of this project by bringing in additional users such as the National Communications Center which is responsible for providing situational awareness for all communications infrastructure during tropical cyclones and U.S. Coast Guard – Sector New Orleans. While this task has been marked complete as we have met our original intent, this milestone will be ongoing throughout the duration of the project.

Transition Milestone			
Execute a workshop of the Consequence Modeling focus group.	June 2016	80%	Coordination and planning for the Focus Group has been completed. The Focus Group has been rescheduled to take place on September 21, 2016 due to a scheduling conflict.

12. Interactions with education projects: N/A

13. Publications: N/A

14. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)			
Undergraduates provided tuition/fee support (number)			
Undergraduate students provided stipends (number)	1		
Graduate students provided tuition/fee support (number)	1		
Graduate students provided stipends (number)			
Undergraduates who received HS-related degrees (number)			
Graduate students who received HS-related degrees (number)			
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)			
SUMREX program students hosted (number)			
Lectures/presentations/seminars at Center partners (number)			
DHS MSI Summer Research Teams hosted (number)			
Journal articles submitted (number)			
Journal articles published (number)			
Conference presentations made (number)	5 (APA,		
Other presentations, interviews, etc. (number)	6 (FEMA		
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)			
Requests for assistance/advice from DHS agencies (number)	7 (Includes		
Requests for assistance/advice from other Federal agencies or	5 (GOHSEP,		
Total milestones for reporting period (number)	8		
Accomplished fully (number)	3		
Accomplished partially (number)	5		
Not accomplished (number)	0		
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
CERA	Software	June 2017	See list of users in item #6 above
Consequence Model	Software addition	December 2017	See list of users in item #6 above

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
Improved Algorithms for Computing Storm Surge (STORM)	Twilley, co-PI	$206,560	NSF
Coastal SEES Project on Accelerated Flood Risk with Delta Degradation	Twilley, PI	$298,683	NSF
Cyber SEES – Simulation Management System for Flood Modeling	Twilley, co-PI	$75,000	NSF
Port Resilience Index	Twilley, PI	$20,000	NOAA
Louisiana Community Resilience Institute	Carney, PI Birch, Co-PI	$50,000	Kresge, Sea Grant

Leveraged Support	
Description	Estimated Annual Value
Free office space	$14,000
Portion of university indirect returned to project	$13,240
Reduced rates on high performance computer	$25,000
Support for ASGS development by Louisiana Sea Grant	$25,000

GINIS, URI

DHS Coastal Resilience Center

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:**

   Modeling the combined coastal and inland hazards from high-impact hypothetical hurricanes

2. **Principal Investigator / Institution:**

   Isaac Ginis, University of Rhode Island, Professor

3. **Other Research Participants/Partners:**

   Co-PIs:
   - Chris Kincaid, University of Rhode Island, Professor
   - Tetsu Hara, University of Rhode Island, Professor
   - Lewis Rothstein, University of Rhode Island, Professor
   - David Ullman, University of Rhode Island, Marine Research Scientist
   - Pam Rubinoff, University of Rhode Island, Senior Coastal Manager
   - Wenrui Huang, Florida State University, Professor

   Key Partners:
   - Arun Chawla, NOAA/NWS/NCEP Environmental Modeling Center
   - David Vallee, NOAA/NWS Northeast River Forecast Center
   - NOAA/OAR Geophysical Fluid Dynamics Laboratory
   - Rick Luettich and Brian Blanton, University of North Carolina at Chapel Hill
   - Chris Massey, U.S. Army Corps of Engineers
   - Daniel Cox, Oregon State University

4. **Short Project Description:**

   This project advances modeling capabilities for assessing the potential impacts of landfalling hurricanes on critical infrastructure and communities, exacerbated by the effects of climate change. The primary focus is on extreme real and hypothetical, yet plausible high-impact hurricane scenarios in the Northeastern United States by combining multiple hazard impacts, including coastal flooding due to storm surge and inland flooding due to rainfall. This project will allow DHS and other agencies to better understand the consequences of coastal and inland hazards associated with extreme high-impact landfalling hurricanes in specific regions and to better prepare the coastal communities for future risks.

5. **Abstract:**

   The major goal of this project is to comprehensively investigate the hazards in the focus region using the most advanced coupled hurricane-ocean prediction, coastal ocean circulation/storm surge, wave, climate, and hydrological models. To attain this goal, the following specific tasks

will be accomplished: 1) Creating physically consistent, hypothetical high-impact scenarios that combine widespread, multiple hazard impacts (e.g. storm surge and rainfall-induced flooding); 2) using a multi-model ensemble approach to integrate 2-3D coastal models with watershed and 1D river models to provide the best possible coastal and inland flood guidance; 3) implementing the URI air-sea coupling module developed for NOAA operational hurricane models to coupling storm surge/wave models; 4) providing hazard model output in format suitable for HAZUS or other risk modeling software and tools used by DHS and other agencies; 5) utilizing the most advanced tools for sharing, visualizing and communicating the hazard model simulations with end users; and 6) account for the impacts of natural and anthropogenic stressors, including climate change, on the focus region by using nested-grid regional 'down-scaling techniques.

6. **End users:**

- NOAA/NWS Northeast River Forecast Center (NERFC), David Vallee, Director, Provided data for historic hurricanes in RI for model validation and will participate in the analysis and adoption of model results and implementing the improved model capabilities into operations at NERFC.
- NOAA/NWS/NCEP Environmental Modeling Center (EMC), Arun Chawla, Head of Marine Modeling and Analysis Branch.
  Assisted in the implementation of the WAVEWATCH 3 wave model in Narragansett Bay and Rhode Island coastal waters and will participate in the analysis and adoption of model results and implementing the improved model capabilities into operations at NCEP.
- US. Coast Guard, R&D Center, Alexander Balsley, Project Manager, Bert Macesker (Technical Director), Joe DiRenzo (Partnership Development Director), CDR Erich Stein (Program Manager): Met and provided briefing of the Disaster Dynamics project and explored potential intersections with Coast Guard Missions. Specific discussion focused on end-user interest in enhanced hurricane modeling and the benefits for Coast Guard decision making - specific reference was made to the use of ADCIRC by Coast Guard Atlantic Area a critical element of their decision matrix that led to relocating the Atlantic Area Command & Control to St. Louis ahead of an approaching hurricane. So continued improvement of the hurricane prediction tools was well received. Additionally, the R&D Center team was interested in the wind, wave and storm surge modeling and prediction aspects associated with this work and how it could support improved Search and Rescue Modeling/Prediction (specific reference made to the cargo ship El Faro case noting that the influence of wind and waves on the current and subsequent drift predictions would have helped locate the vessel more quickly), hind-casting storm impacts after hurricane landfall to assist with resource deployment (pollution response, assistance, etc.) as well as helping NOAA's Navigation Response Teams and USCG in reconstituting operation of key/priority waterways.
- Rhode Island Emergency Management Agency (RIEMA), Jessica Stimson, State Hazard Mitigation Officer and Stephen Conard, Training Exercise Coordinator
  Updates of this project are provided at quarterly meetings of State Hazard Mitigation Planning and Silver Jackets meetings. The research will provide input to their planning efforts, and training exercises, planned for FY2017.
- RI Flood Mitigation Association (RIFMA)

As a state association of floodplain managers, they have been briefed on the project and will track the outcomes so that they can collaborate on outreach and training as appropriate

- FEMA Region 1, Mark Landry Federal Federal Coordinating Officer and Disaster Recovery Manager: Provided verbal overview of the Disaster Dynamics project and had initial discussions about how best to integrate FEMA Coordinating Officer and Disaster Recovery Managers into the discussion and how these modeling and predication capabilities could be used to benefit FEMA's efforts. Landry was going to see if he was the right person to be involved, or to identify an alternate contact. Although not discussed, it follows from the US Coast Guard end-user discussions that both improved forecasting and hind-casting capabilities would add another key element to FEMA's decision matrix for resource deployment strategies ahead of and after hurricane landfall. More discussion will follow.
- Narragansett Bay Commission, Tom Uva, Director of Planning, Policy and Regulation: Chris Kincaid, Co-PI met with members of the Narragansett Bay Commission's (NBC's) Environmental Monitoring Division, and presented research goals of the project at the annual NBC board meeting. Based on discussions with NBC staff one potential benefit to their planning strategies that our modeling could impact was the effect on surge levels that could be expected at their campus (just south of the Fox Pt. Hurricane Barrier) given different storms and management responses. As an initial test, the ROMS model, with wetting and drying capabilities turned on, was run with and without the hurricane barrier closed for Hurricane Bob conditions. Results were presented at a professional meeting and will be shared at a meeting with NBC officials in Fall, 2016.
- Port of Providence, Stephen Curtis, Facility Manager - FY2017 participation anticipated
- Association of State Flood Managers, Chad Berginnis, Executive Director- FY2017 participation anticipated

7. Explanation of Changes:

As the research component of this project progressed some adjustments were made to the work plan, primarily to accelerate the implementation of the ADCIRC storm surge model in Narragansett Bay and Rhode Island coastal waters. The effort was facilitated by our UNC partners and led by Rick Luettich. In addition, we accelerated the implementation of the WAVEWATCH 3 wave model due to the assistance we received from our NOAA/NWS/NCEP/EMC partners led by Arun Chawla.

Given the multiple activities occurring in Rhode Island, the team modified our strategy to engage end-users in different venues, rather than one workshop as initially planned. This is reflected in the table and milestones below with activities planned in the coming months.

8. Unanticipated Problems:

N/A

9. Project Outcomes:

This project will deliver physically consistent, yet plausible high-impact hurricane scenarios for RI and Southern New England areas and a comprehensive multi- model analysis of the coastal and inland hazards. A new air-sea coupling module (ASCM) for coupling storm surge/wave models will be implemented into ADCIRC and the Regional Ocean Modeling System (ROMS). ASCM will be transitioned to NOAA's Environmental Modeling Center (EMC) for possible implementation into the operational hurricane prediction models and U.S. Army Corps of Engineers to improve their storm surge prediction models. We will take advantage of our multi-year collaboration with EMC to facilitate this transition. In addition, detailed mapping and analysis of the inland and coastal flooding from different hurricane scenarios will be generated and provided to NOAA NWS Forecast Office in Taunton, MA and DHS regional stakeholders.

We held a meeting at URI with Marilee Orr and Craig Gordon of the DHS Office of Cyber and Infrastructure Analysis and several scientists supported by DHS/OCIA to discuss how the coastal and inland hazard modeling results of this project may be applied for simulating the impact on critical infrastructure and developing risk analysis for decision-makers. Based on these discussions, we are currently developing a coordinated work plan that will include ingesting the URI hazard analysis (wind fields, inundation, and other storm parameters at landfall) into infrastructure impact models. The outcome of this effort could take several forms, depending on what kind of final product we intend to produce (e.g., text-based reports, graphical products, presentations).

We will collaborate with Prof. Dan Cox (OSU). Initially, this will involve a series of Skype/WebEx sessions to discuss how to efficiently combine our expertise into a next round of work, where a nested-grid modeling approach will link models of flow/surge energy in our simulated storms to Professor Cox's models on the response of critical infrastructure. In this second stage, our two groups will join efforts on establishing linkages from the large-scale circulation modeling at URI to the fluid-structure work at OSU.

10. Research Activity and Milestone Progress:

Research Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Simulate historic storms and generate *Hurricane Rhody* scenario using the HWRF and GFDL hurricane models.	5/30/2016	50%	This activity will be completed during the period 7/01/16-12/31/16. Instead, we prioritized implementation of the WAVEWATCH III wave model and ADCIRC storm surge model during this time period (see below)
Configure ROMS with wetting/drying (4/30) and increased model spatial resolution (2/29), coastline and bathymetry. Initial model validation.	6/30/2016	100%	
Initial set up of the HEC-HMS and HEC-RAS for Narragansett Bay and Wood-Pawcatuck River Watersheds, collecting and processing hydrological, soil, land cover data,	6/30/2016	100%	
Implement and configure high-resolution WAVEWATCH III wave model in Narragansett Bay and Rhode Island coastal waters.	11/30/16	100%	This activity is accomplished ahead of schedule
Implement and configure high-resolution ADCIRC in Narragansett Bay and Rhode Island coastal waters.	11/30/16	100%	This activity is accomplished ahead of schedule
Research Milestone			
Simulation of historic storms and generation of *Hurricane Rhody* hypothetical storm scenario	50%		Summary is provided in Appendix

Implemented and configured ADCIRC and ROMS storm surge models in Narragansett Bay and Rhode Island coastal waters	100%		Summary is provided in Appendix
Implemented and configured WAVEWATCH III wave model in Narragansett Bay and Rhode Island coastal waters	100%		Summary is provided in Appendix
Initial validation and calibration of the storm surge and wave models was done for Hurricane Bob (1991)	100%		Summary is provided in Appendix
Implemented and configured in Taunton River Basin two hydrological models HEC-HMS and PRMS and tested and compared the model performance against available observations.	100%		Summary is provided in Appendix
Implementation of HEC-RAS and HEC-HMS models and inland flood modeling in the area of Taunton City for the 2010 flood event	100%		Summary is provided in Appendix

11. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Organize a workshop with end users to discuss the objectives and outcome of this project and to determine what types and forms of products are most useful for meeting their short and long term oals.	3/31/16	50%	Team changed strategy to engage end-users in different venues, rather than one workshop. Meeting with RI Emergency Mgmt team will take place within next 6 weeks. Implementation of a break-out workshop at annual RI EMA sponsored "Rhody Ready" event of local, state and regional emergency managers will highlight the research and

			applications, together with a facilitated discussion with end-users to gain input and feedback. Meetings with USCG, RI Silver Jackets (Fed-state partnership with RIEMA, FEMA, USACE etc), and others individually have been most effective.
Transition Milestones			
Meetings with USCG, RI Silver Jackets (Fed-state partnership with RIEMA, FEMA, USACE etc),	4/13/16	100%	Learned of advances by RI-DEM and RIEMA in mapping pollution hotspots within the flood zones of Narragansett Bay and major RI Rivers. Developed plan for model simulations of risk analysis during extreme storm events. Pam Rubinoff joined the Board of the RI Silver Jackets. USCG has informed us that they specifically need early reads on predicted storm impacts in order to choose response/staging sites that enable resources to be close to the storm for fast deployment, but not so close as to suffer damage.
Meeting with Dr. Chris Landsea, National Hurricane Center	5/4/16	100%	Informed NHC about the scope and ongoing efforts of this project and discussed potential applications for improving hurricane coastal impact forecasting
Meeting with David Vallee, NOAA/NWS Northeast River Forecast Center, Taunton, MA Robert Thompson, NWS Weather Forecast Office, Taunton, MA	5/4/16	100%	Informed NOAA/NWS Northeast forecast center about the scope and ongoing efforts of this project and discussed potential applications for improving regional forecasts of coastal and inland flooding

Narragansett Bay Commission Board meeting	3/15/16	100%	Identified a need to investigate potential hazards associated with co-location of floating objects and holding tanks of environmentally sensitive fluids (oil, LNG, etc) within the flood zone of the primary waste water treatment plant at the Port of Providence and developed a plan to conduct a number of process simulations for various combinations of storm parameters
The PI has joined the RI Scientific Support for Environmental Emergency Response (SSEER) Team.	5/1/16	100%	The DHS URI team will be available to provide scientific support for environmental emergency response to the Department of Environmental Management

12. Interactions with education projects:

Pam Rubinoff, Co-PI, presented for the Natural Hazards Resilience UNC's graduate certificate program, as well as a public lecture on March 30, 2016. Both presentations provided an overview of resilience practice (RI, US, and International), tools, and lessons learned in a talk *Natural Hazards Risk Management: Outreach & Extension*. The presentation elicited rich discussion between students and the speaker related to practitioner experiences from the 2 decades in this field.

Chris Kincaid, Co-PI delivered a lecture on DHS Project Science as part of OCG 110 – The Ocean Planet, URI General Education Oceanography Course.

13. Publications:

Gao, K. and I. Ginis, 2016: On the equilibrium-state roll vortices and their effect in the hurricane boundary layer. *J. Atmos. Sci.*, 1205- 1222.
Gao, K., I. Ginis, J.D. Doyle, Y. Jin, 2016: Effect of boundary layer roll vortices on the development of the axisymmetric tropical cyclone *J. Atmos. Sci.*, submitted, June 2016.
Huang, W., F. Feng, and I. Ginis, 2016: Evaluations of two hydrological models for storm runoff modeling in Taunton River Basin, *Natural Hazards*, to be submitted in September 2016.
Liu, Q., L. M. Rothstein, Y. Luo, D. S. Ullman, and D. L. Codiga, 2016. Dynamics of the periphery current in Rhode Island Sound, *Ocean Modelling*, 105, 13-24.
Liu, Q., L. Rothstein, and Y. Luo, 2016. Dynamics of the Block Island Sound estuarine plume. J. Phys. Ocean., Accepted for publication.
Reichl, B. G, D. Wang, T. Hara, I. Ginis,, T. Kukulka, 2016: Langmuir turbulence parameterization in tropical cyclone conditions. *J. Phys. Oceanogr.,* 46, 863-886.
Reichl, B. G., I. Ginis, T. Hara, B, Thomas, T. Kukulka, and D. Wang, 2016: Impact of sea-state dependent Langmuir turbulence of the ocean response to a tropical cyclone, *Mon. Wea. Rev*, (in press).

Sun, Y., C. Chen, R. C. Beardsley, D. Ullman, B. Butman, and H. Lin, 2016. Surface Circulation in Block Island Sound and Adjacent Coastal and Shelf Regions: A FVCOM-CODAR comparison, *Progress in Oceanography*, 143, 26-45.
Whitney, M. M., D. S. Ullman, and D. L. Codiga, 2016. Subtidal Exchange in Eastern Long Island Sound, . *J. Phys. Oceanogr*. (in press).

14. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)	0		
Undergraduates provided tuition/fee support (number)	0		
Undergraduate students provided stipends (number)	0		
Graduate students provided tuition/fee support (number)	2		
Graduate students provided stipends (number)	2		
Undergraduates who received HS-related degrees (number)	0		
Graduate students who received HS-related degrees (number)	0		
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)	0		
SUMREX program students hosted (number)	0		
Lectures/presentations/seminars at Center partners (number)	1		
DHS MSI Summer Research Teams hosted (number)	0		
Journal articles submitted (number)	2		
Journal articles published (number)	7		
Conference presentations made (number)	15		
Other presentations, interviews, etc. (number)	12		
Patent applications filed (number)	0		
Patents awarded (number)	0		
Trademarks/copyrights filed (number)	0		
Requests for assistance/advice from DHS agencies (number)	0		
Requests for assistance/advice from other Federal agencies or	5		
Total milestones for reporting period (number)	11		
Accomplished fully (number)	9		
Accomplished partially (number)	2		
Not accomplished (number)	0		
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
Improving NOAA's HWRF Prediction System through New Advancements in the Ocean Model Component and Air-Sea-Wave Coupling	Ginis	$260,000	NOAA
GFDN operational tropical cyclone model maintenance and support	Ginis	$134,000	Navy
Advancing tropical cyclone models through explicit representation of boundary layer roll vortices	Ginis	$260,000	ONR-Navy
Langmuir turbulence under tropical cyclones	Hara, Ginis	$376,000	NSF
Airflow separations over wind waves and their impact on air-sea momentum flux	Hara	$355,000	NSF
4D physical models of migrating mid-ocean ridges: Implications for shallow mantle flow	Kincaid	357,000	NSF
Collaborative Research: 3D Dynamics of buoyant diapirs in subduction zones	Kincaid	442,000	NSF
NOAA/RISG: Quahog Larval Dispersion and Settlement in Narragansett Bay	Kincaid Ullman	199,000	RI Sea Grant/NOAA
Authentic Data and Visualization Experiences and Necessary Training (ADVENT): An undergraduate model for recruiting students to STEM careers in the U.S. Navy	Pockalny Kincaid	750,000	ONR-Navy
Numerical Circulation Modeling in Support of Hypoxia Studies in Narragansett Bay	Ullman	60,000	RI DEM
Pushing to New Limits for Models of Rhode Island Bays and Sounds	Ullman Kincaid Rothstein	68,000	Rhode Island Science and Technology Advisory Council
CHRP: Observations and Modeling of Narragansett Bay Hypoxia and its Response to Nutrient Management	Ullman and Co-PIs	660,00	NOAA

Leveraged Support	
Description	Estimated Annual Value
Returned Indirect Cost [1]	$10,000
Graduate Student tuition	$15,000
Project Coordination and Management (Thomas Miller)	$3,000

[1] The University of Rhode Island's Coastal Institute (CI) has generously agreed to return 66% of their share of indirect cost return back to the project. The CI obtains 17% of the indirect cost, so roughly 11.3% of indirect cost is being returned to the project.

DHS Coastal Resilience Center

Annual Project Performance Report

Project Title: Modeling the combined coastal and inland hazards from high-impact hypothetical hurricanes

Covers reporting period January 1, 2016 – June 30, 2016

Appendix

In this Appendix we provide some details of the project main accomplishments during this time period.

1. Implementing high-resolution ADCIRC-SWAN coupled system in Narragansett Bay and Rhode Island coastal waters

During the first 6 months of the project, we have run storm surge and wave simulations using ADCIRC-SWAN for several historical storms that impacted Rhode Island. These include hurricanes Carol (1954), Bob (1991), and Floyd (1999). The objective was to evaluate, using observational data, the various choices that need to be made when performing numerical simulations of storm surge. These simulations, forced with several different wind products, were compared with available observations of water level, wind, and waves to assess the skill of the model simulations. Because the modeled storm surge is quite sensitive to the magnitude of the surface drag coefficient used, we compared the model results using several different parameterizations for the surface drag coefficient.

Model setup and historical storm simulations

The ADCIRC/SWAN storm surge/wave modeling efforts were greatly facilitated by the provision by our UNC partners (R. Luettich and colleagues) of a basic finite element model grid. This grid covers the North Atlantic west of longitude 60° W and features fine resolution (of order 50-100 m) within Narragansett Bay. The advantage of this grid is that the open boundary is sufficiently far from the region of interest such that at these boundaries one need only apply tidal forcing which is obtained from a data assimilating global tidal model (the tides must be correctly simulated since the water levels during a storm are a superposition of the tidal and storm effects). The storm surge is a local effect in this grid, requiring no open boundary forcing. The model is run in 2-dimensional, depth-averaged mode, with wetting and drying of elements enabled, allowing simulation, not only of water elevation, but also of inundation of the land surface in the hurricane impact region.

Two types of wind forcing were used for the historical simulations. The first, used for all the storms, was a time series of parameterized wind fields at 10 m height, generated using the Best Track hurricane data (e.g. location of eye, minimum central pressure, radius of maximum winds). The second type of wind forcing, produced for Hurricane Bob only, was derived from a high-resolution dynamic model of the hurricane surface boundary layer forced by parameterized winds at the top of the boundary layer (3 km height). The hurricane wind fields produced by this model include the effects of land, which become important as hurricanes near landfall.

Comparison of model water levels with observations from long-term NOAA tide gauges at Newport and Providence was performed to evaluate model fidelity in simulating storm surges in Narragansett Bay. Observations from both stations were available for hurricanes Bob and Floyd, while for hurricane Carol only observations at Newport were available. Comparison of the predictions of the SWAN wave model, which is coupled to ADCIRC, with observations was performed at 3 National Data Buoy Center buoys in the mid-Atlantic Bight. These sites are not in the immediate vicinity of Narragansett Bay, but they do provide a check on the wave predictions under tropical storm conditions.

Evaluation of surface drag coefficient parameterizations

A key element of a storm surge/wave model when simulating the effects of hurricanes is the parameterization of the surface drag coefficient. The ADCIRC default parameterization is the linear function of 10-meter wind speed described by Garratt (1977), but with a limit on the drag coefficient magnitude of 3.5×10^{-3}. We tested an alternative formulation in which the limit was set at 2.0×10^{-3} as well as a different parameterization that is used by the Ginis group for their hurricane forecasts. The drag coefficient using this formulation initially rises with wind speed, but then peaks and drops off a moderately high wind speeds (see Figure 1.1). Comparisons of storm surge simulations using these parameterizations with observations from Hurricane Bob indicate that the default ADCIRC formulation results in a severe over-prediction (by about 1 m) of the surge magnitude (Figure 1.2). For Hurricane Bob, the Garratt formulation with the 2.0×10^{-3} limit produced the lowest surge in Narragansett Bay, with the Ginis parameterization producing a surge intermediate in height, but both were high relative to the observations. Because we could not rule out the fact that overestimation of the hurricane winds could produce a surge that is too high, we decided to use the Ginis parameterization going forward, since that formulation produces optimum hurricane track and intensity forecasts.

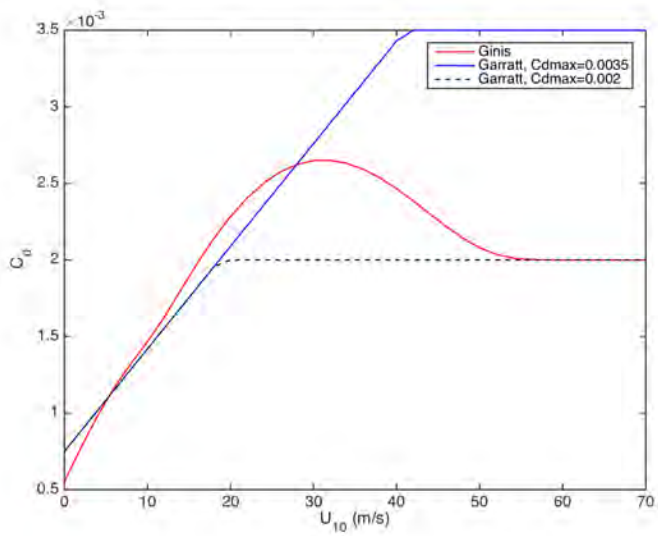


Figure 1.1. Surface drag coefficient parameterizations as functions of 10-meter wind speed.

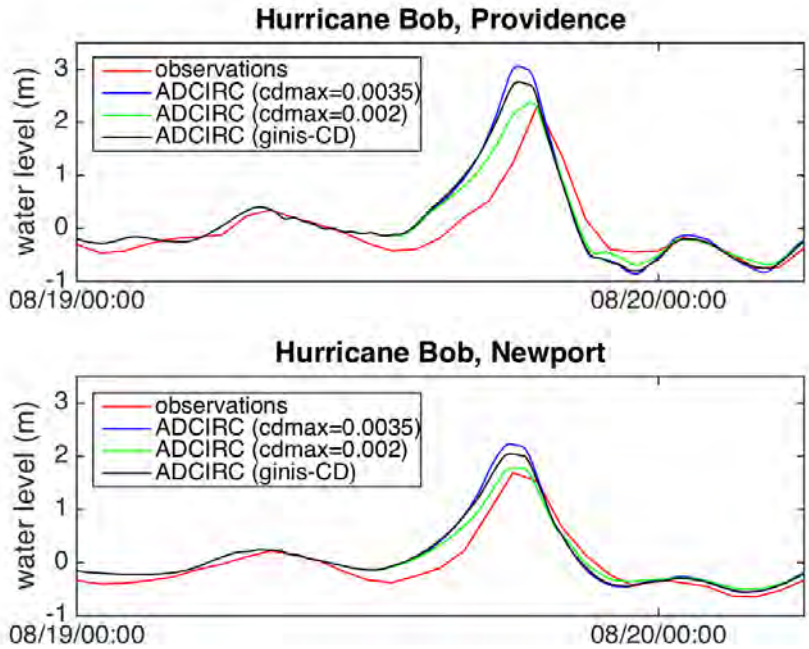


Figure 1.2. Comparison of water level observations with model predictions at Newport (bottom) and Providence (top) for Hurricane Bob. The blue and green lines show respectively the model water level time series using the Garratt drag coefficient parameterization with a limit of 3.5×10^{-3} and 2.0×10^{-3}. The black line shows the model response using the Ginis parameterization.

Effect of waves

Shoaling surface gravity waves can induce a change in the water surface elevation from so-called wave radiation stresses. The coupling of the ADCIRC circulation model and the SWAN wave model occurs via the radiation stresses (as well as the coupling of the wave field to the circulation field via the instantaneous water depth and currents). For Bob, the comparison of simulated significant wave height with observations yielded the conclusion that waves were over-predicted in height at locations to the left of the eye, while they were correctly predicted at the (one) station to the right of the eye (Figures 1.3 and 1.4). The reason for this discrepancy is still under investigation by the project team. Comparison of the storm surge with wave effects (coupled ADCIRC-SWAN) with the ADCIRC-only simulation indicates that for Bob, the presence of waves adds approximately 0.5 m to the predicted storm surge (Figure 1.5).

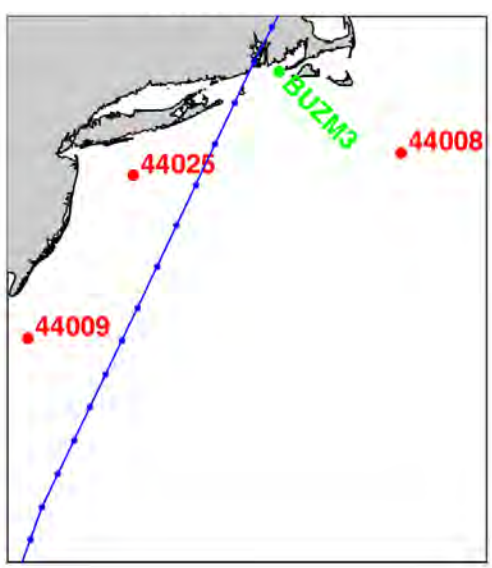


Figure 1.3. Track of Hurricane Bob (blue) in relation to the NDBC buoys with observations of wind and waves (red) and wind only (green).

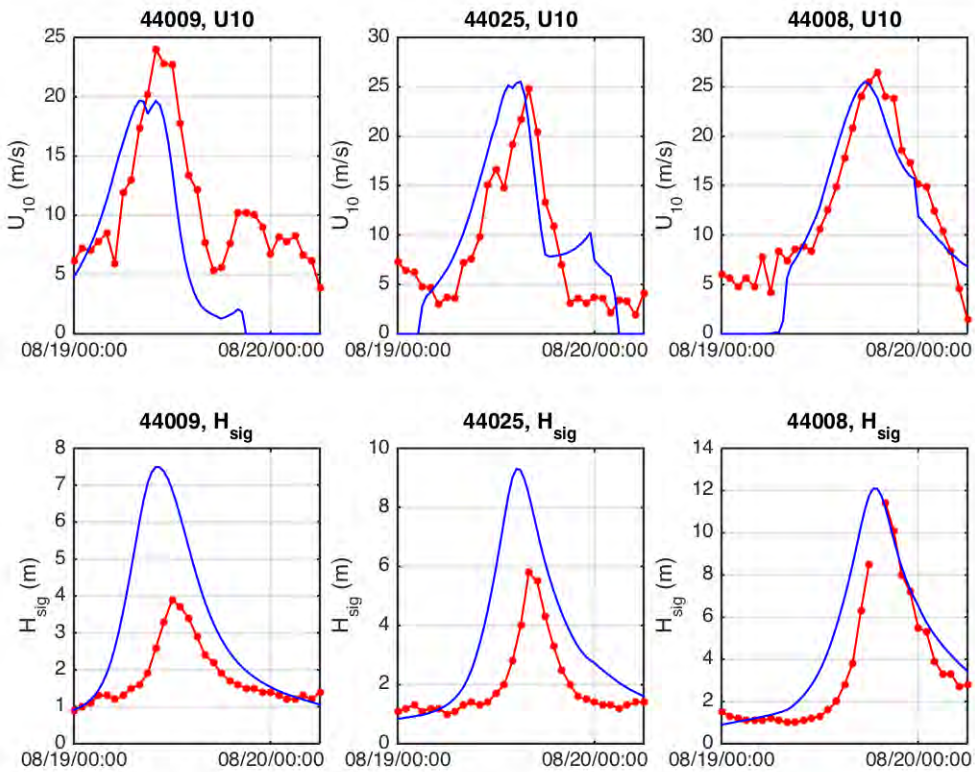


Figure 1.4. Comparison of observed wind speed at 10 m height (top) and significant wave height (bottom) with coupled ADCIRC/SWAN model predictions at the three buoy locations shown in Figure 3. Observations are in red and model predictions are in blue.

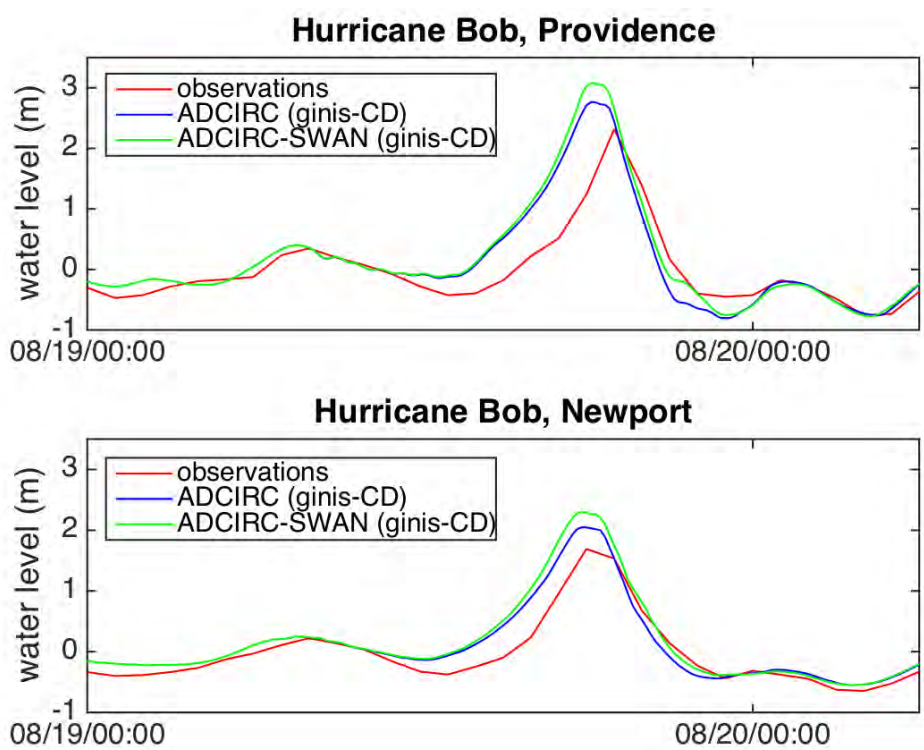


Figure 1.5. Comparison of water level observations with model predictions at Newport (bottom) and Providence (top) for Hurricane Bob, showing the effect of waves on the storm surge. The red line is the observations, the blue line is the ADCIRC simulation without waves, and the green line is the coupled ADCIRC/SWAN simulation.

Effect of different wind forcing fields

We compared the predicted (coupled ADCIRC-SWAN) storm surge with observations at the Narragansett Bay tide gauges using a number of wind forcing products. The first wind product, which was used for the results described above was the simple vortex parameterization of 10-meter wind based on hurricane best track information (blue line in Figure 1.6). The other wind fields were produced by the hurricane boundary layer model (with different assumptions about the wind at the top of the surface boundary layer). In general, the over-prediction of storm surge during Bob persists regardless of the wind product used (figure 6). However, the timing of the surge is better simulated using the boundary layer model winds. The range of variability in the maximum storm surge elevation arising from the uncertainty in the wind field is approximately 0.5 m for Hurricane Bob (Figure 1.6).

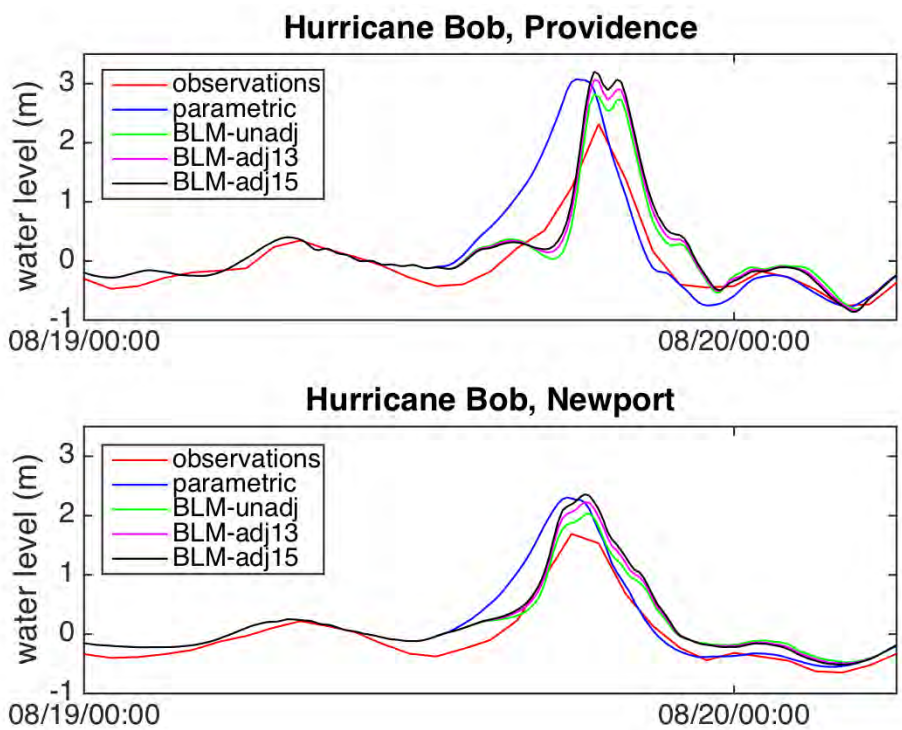


Figure 1.6. Comparison of water level observations with model predictions at Newport (bottom) and Providence (top) for Hurricane Bob, showing the effect of different wind forcing products. The red lines show the observed water levels while the blue, green, magenta, and black lines show respectively the model (ADCIRC/SWAN) water levels using the parametric wind model and the BLM for 3 different parameterizations of the winds at 3 km height.

Visualization of results

In order to provide compelling visualization of our storm surge simulations to potential stakeholders, we have been working with several groups to improve the presentation of results. We have provided sample output from Hurricane Bob to Carola Kaiser (Louisiana State University) for inclusion into her web-based ADCIRC visualization tool. We have also shared our results for Hurricane Carol with Peter Stempel (URI Marine Affairs graduate student) who will perform visualizations of infrastructure impacts from this storm.

2. Implementing high-resolution ROMS model in Narragansett Bay and Rhode Island coastal waters

The Regional Ocean Modeling System (ROMS) is a free-surface, terrain-following, primitive equation solver used to study the effect of storm surge in Narragansett Bay and surrounding areas. The ROMS model is used with wetting and drying scheme having a critical depth value of 0.1 meter. This allows for the inundation of normally dry areas under storm surge conditions.

Our study area covers Narragansett Bay and extends into Rhode Island Sound (Fig. 2.1). We use a numerical grid containing 750 by 900 by 7 nodes. The grid is curvilinear with increasing grid spacing to the south. The resulting resolution is highest at the head of Narragansett, Bay around 30 m and lowest in Rhode Island Sound around 150 m. Bounded on the east by the mouth of Buzzards Bay and extends south of Martha's Vineyard. To the west the grid extends into Long Island Sound and as far south as Montauk, NY.

The bathymetry is interpolated from three elevation and bathymetry data sets. For inside Narragansett Bay we use NOAA 30 meter resolution bathymetry obtained from hydrographic soundings. The datum is mean lower low water and is adjusted to mean sea level (MSL). For bathymetry outside of Narragansett Bay we use NOAA Coastal Relief model with resolution of 90 meters. Elevation was interpolated from USGS National Elevation Dataset with resolution of 30 meters. Both the 90 m bathymetry and 30 m elevations used a NAVD 88 datum. Once the three data sets were sampled at the grid locations, we use a Shapiro filter to smooth data and remove any jumps created by adjoining different data sets.

To study the effect of storm surge we have to include many forcing conditions. The two most important are meteorological forcing and boundary conditions. Initially we focus on modeling the effect of hurricane Bob, as there are observations to compare with. For hurricane winds we apply parametric winds at 10 meters every 15 minutes. This dataset was developed from URI/GSO hurricane Bob simulations. Other meteorological forcing include long wavelength radiation, solar shortwave radiation, surface relative humidity are based on normal year of the Weather Research & Forecasting Model (WRF) in the model area. Air temperature, precipitation and air pressure were obtained from atmospheric station USC00370218 in Adamsville, RI recorded daily during hurricane Bob. All meteorological time series were applied uniformly to the entire grid, expect for winds. Winds are applied on a course grid and vary spatially.

Due to the small spatial extent of the model, boundary conditions are very influential in terms of storm surge. We use surface elevations as well as barotropic estimates of flow interpolated from a Regional Advanced Circulation Model (ADCIRC). This model covers the majority of the United States East Coast and is run by URI/GSO team for hurricane Bob and includes. The boundaries of our ROMS model are forced every half hour.

To verify our model we use available hourly observations at NOAA tide gauges located at Newport, RI and Providence, RI (Fig. 1). Specifically, we use the Willmott skill to quantify our comparison (Willmott, 1982) :

$$\text{Willmott skill} = 1 - \frac{\frac{1}{N}\sum_{i=1}^{i=N}(m_i - o_i)^2}{\frac{1}{N}\sum_{i=1}^{i=N}(|m_i - \bar{o}| - |o_i - \bar{o}|)^2},$$

where o_i is an observation, m_i is a model observation and N is the total number of observations.

A value of 1 would be a perfect score and the model would completely reproduce the data. We compute the skill for both time periods before the storm, to obtain validity of tidal estimations, and during the storm. The skills are 0.95 and 0.96 for the tidal component and storm surge respectively. Time series of sea level are plotted in Figure 2. Output from the model is output every 3 minutes at a higher temporal resolution than the hourly tide gauges. The peak amplitude corresponds well with the timing of the observed peak but the model over estimated surge at both Providence and Newport (Fig. 2.2). The maximum surge at Providence tide gauge was 2.3 m and 3.0 m for observations and the model results respectively. The maximum surge at Newport tide gauge was 1.6 m and 2.0 m for observations and the model results respectively. In general with a high overall skill, the storm surge appears to be well modeled but the response after the hurricane has passed on August 20th is only moderately well predicted. Spatially, the maximum observed surge was around 3 m over MSL in the Providence area. A map of the maximum observed surge is displayed in Fig. 2.3.

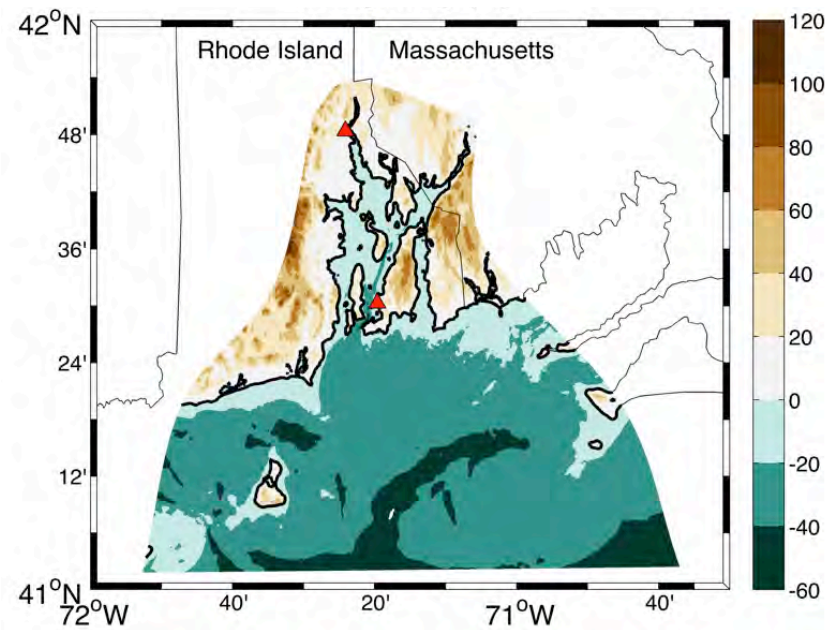


Figure 2.1: Map of ROMS domain. Color bar indicates elevation in meters. Red triangles indicate locations of Providence (north) and Newport (south) tide gauges. Mean sea level denoted with black line.

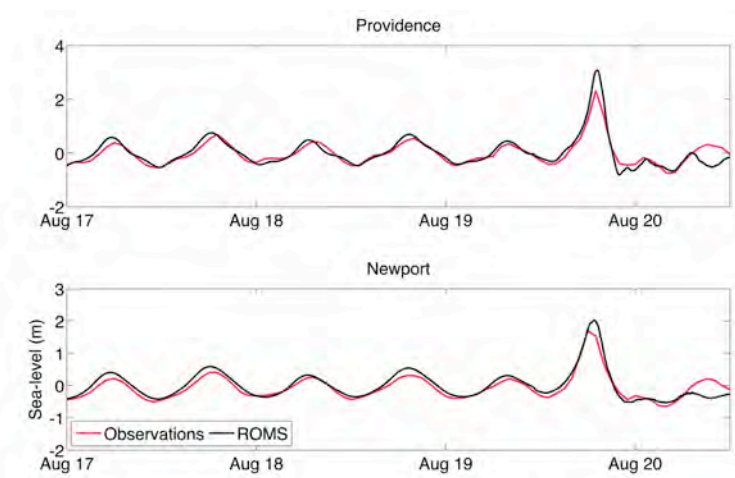


Figure 2.2: Sea-level observations (red) and modeled estimations (black) are displayed for Providence, RI (above) and Newport, RI (below).

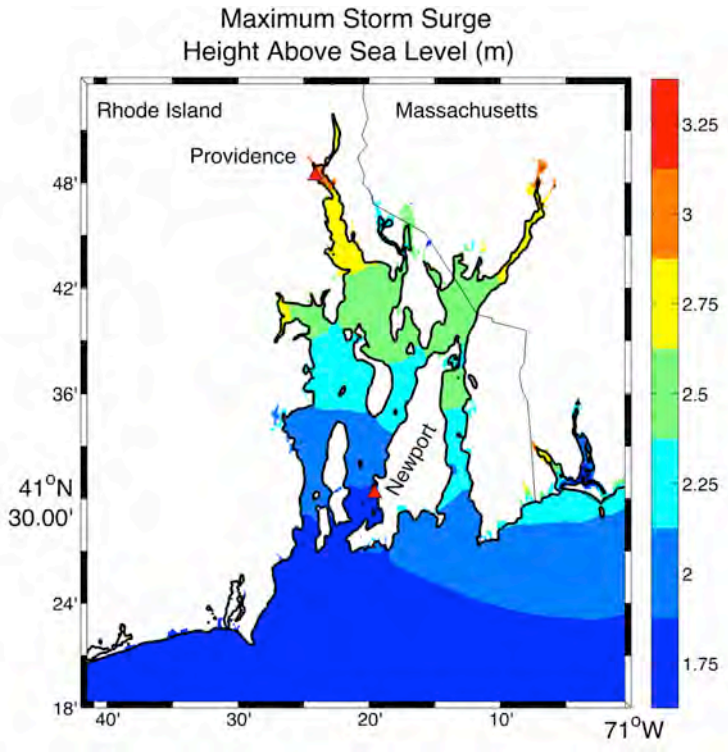


Figure 2.3: Maximum estimated storm surge in meters above mean sea level modeled by ROMS. Black line indicates mean sea level in the model. Tide gauge locations marked by red triangles.

3. Validation of wave models under hurricanes in coastal regions.

One of the main objectives of this project is to couple ocean wave models and storm surge models in order to properly account for the surface wave impacts on storm surge. We employ multi-model (ensemble) approaches by combining different wave models (WAVEWATCH III, SWAN, STWAVE) and different storm surge models (ADCIRC, ROMS).

During this report period, we carried out a validation study of the three wave models in coastal regions. First, we simulated the surface wave field under Hurricane Bob (1991) using both WAVEWATCH III and SWAN, forced by parametric wind field generated from the TCvital (Figure 3.1). In both models the drag coefficient was capped at 2.5×10^{-3} for high wind speeds (exceeding 25 m/s). The figure shows that SWAN predicts higher significant wave height than WAVEWATCH III when the same wind forcing is applied.

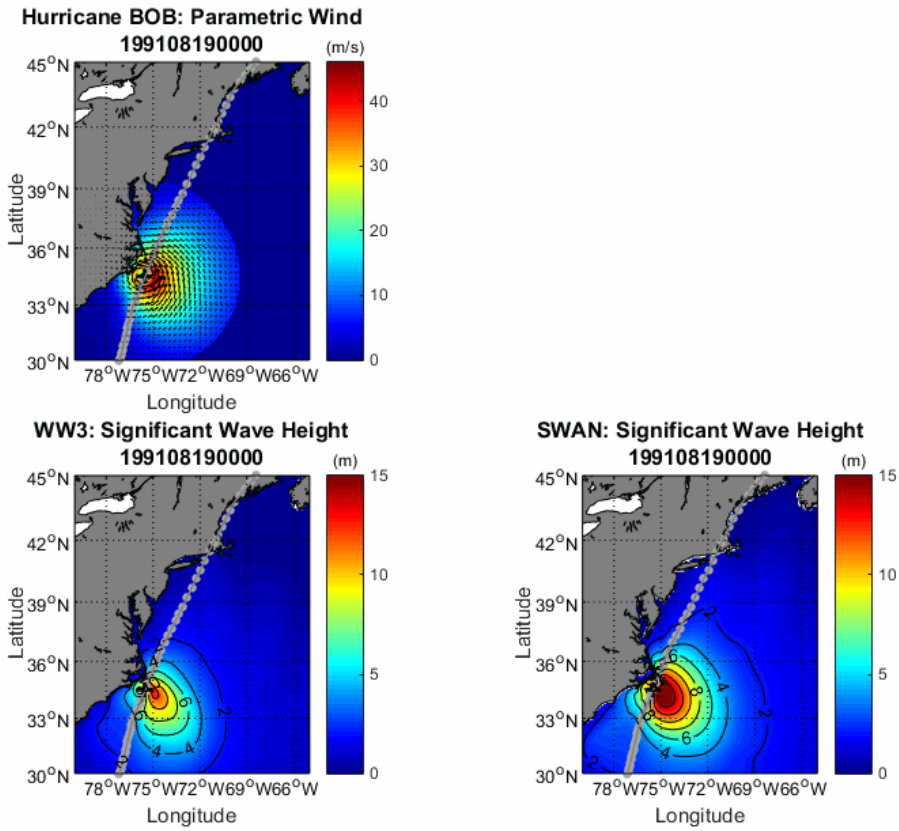


Figure 3.1. Top panel shows the parametric wind field. The bottom panels show the significant wave height simulated by WAVEWATCH III (left) and SWAN(right).

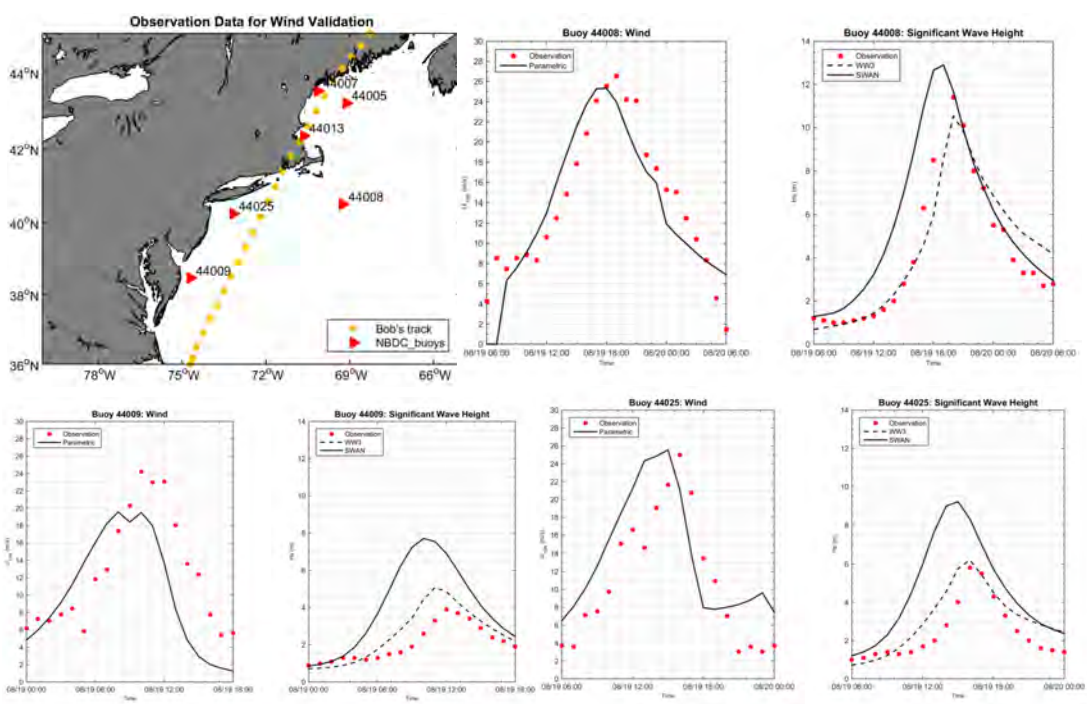


Figure 3.2. Comparison of predicted and observed wind speed and significant wave height at

The parametric wind and wave simulation results were compared against observations from three coastal buoys (Figure 3.2). The wind speed compaison shows that the parametric wind speed is consistent with the observation at the offshore location (44008), but it is not as consistent with the observaition near the coast (44009 and 44025). This is possibly because the real wind field becomes more complex as a hurricane approaches a coast and the simple parametric wind field becomes less accurate.

The significant wave height comparison shows that the WAVEWATCH III results (dashed lines) generally agree with the observation. This is consistent with our earlier finding (Fan et al. 2010) that the WAVEWATCH III is skillful in predicting the hurricane wave field if the drag coefficient is capped at high wind speeds. The SWAN results (solid lines), however, always overestimate the significant wave height, suggesting that the forcing terms (wind input and/or dissipation) of the model need to be adjusted before the model is coupled with the storm surge models.

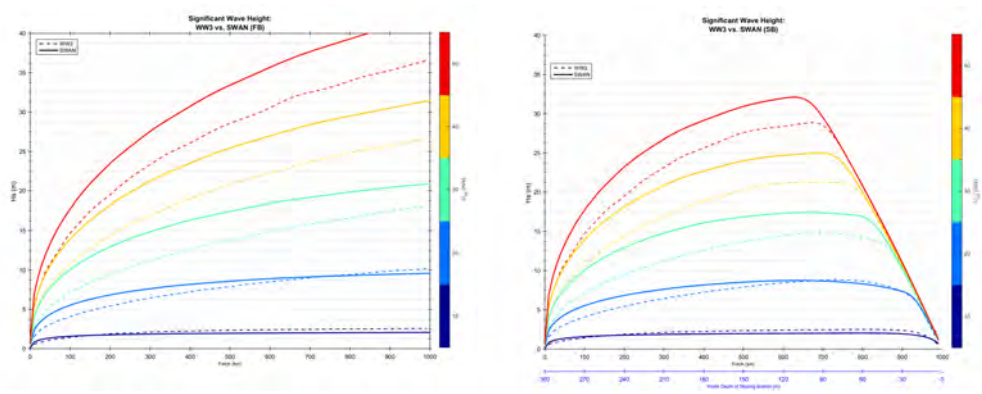


Figure 3.3. Fetch dependent wave field (significant wave height) under constant wind speeds (10, 20, 30, 40, and 50 m/s). Left panel shows results in deep water. Right panel shows results with shoaling (depth decreasing with fetch).

Next, we investigated the wave field in shallow water, where bottom dissipation and breaking reduce the significant wave height, using idealized experiments of steady state (fetch dependent) wave fields under constant wind speeds (Fig. 3.3). The deep water results show that both WAVEWATCH III (dashed line) and SWAN (solid line) produce similar wave fields at 10 m/s wind speed, but the results diverge (SWAN predicts higher waves) as the wind speed increases. When the wave field encounters decreasing depth, both models predict almost identical reduction of the significant wave height. We also investigated the reduction of the significant wave height due to decreasing depth using the STWAVE. The STWAVE result is consistent with the WAVEWATCH III and SWAN results at 10 m/s wind speed. However, as the wind speed increases, the STWAVE results deviate from the other two model results.

In summary:

1. WAVEWATCH III is skillful in hurricane conditions in deep and intermediate waters. (We need to validate WAVEWATCH III results in shallow waters.)
2. SWAN results are not as consistent with observations as WAVEWATCH III results, if wind forcing (drag coefficient) and bottom dissipation are identical. Forcing terms of SWAN need to be retuned in order to achieve a comparable skill as WAVEWATCH III.
3. With constant wind speed SWAN waves grow faster at high wind speeds.

4. SWAN and WW3 WAVEWATCH III behave similarly in shoaling regions but STWAVE results differ at high wind speeds.

4. Rainfall runoff and river flood modeling in Taunton River Basin

Taunton River Watershed

The Taunton River Watershed is one of the sub-basin of the Narragansett Basin (Fig. 4.1). It is the second largest watershed in the state of MA at 562 square miles and contains 94 square miles of wetlands and 221 lakes or ponds. 700,000 people call the watershed home. The Taunton River starts in the Town of Bridgewater and receives discharge waters from 18 river systems as it courses through ten communities before ending at the State of Rhode Island's Mount Hope Bay, which is part of Narragansett Bay. Tidal influences reach 18.0 miles inland and a salt-water intrusion reaches 12.6 miles inland, providing unique habitat for fresh and salt-water aquatic, terrestrial, and biological species. The river systems support the most productive river herring spawning grounds in the Commonwealth.

Figure 4.1. Taunton River Basin.

2010 Storm and flood Event in Taunton River Basin

The widespread flooding that occurred in central and eastern Massachusetts during mid to late March 2010 was caused by a series of moderate to heavy rainfall events over a 5-week period which started in late February. The successive and unrelenting nature of these moderate to heavy rainfall events saturated soils and limited opportunities for rivers and streams to recede, making the state vulnerable to flooding. The first major flood event in March occurred during the 13th to the 15th. Low pressure systems over the Gulf Coast and Midwest combined to form a potent, slow moving low pressure system that slowly tracked from Virginia to south of Long Island. A deep plume of tropical moisture fed into the system. Heavy rains affected a large portion of the Northeast but the heaviest precipitation fell over eastern portions of southern New England. With the mid-March event, a swath of 7 to 10 inch rains fell across east coastal Massachusetts from Methuen and Gloucester southward through Plymouth and Brockton. Totals of 4 to 6 inches fell

just to the west, generally in the vicinity of the I-495 corridor and west into the Worcester Hills. Notably lower totals occurred over the Connecticut River Valley area of Massachusetts, where totals ranged from 2 to 3 inches. Flood impacts were minimal in this area. Widespread flooding occurred along the eastern half of Massachusetts in mid-March. These sites included the Concord River at Lowell, the Taunton River at Bridgewater, the Shawsheen River at Wilmington, and the Charles River at Waltham. Impacts were severe. This rain event produced widespread flooding along numerous rivers and streams in eastern Massachusetts. Basement flooding was rampant. The Taunton River at Bridgewater, which had broken its record flood crest only 2 weeks prior, set a new record flood crest with the late March event. An unusual aspect of the late March floods was the lake flooding that occurred in southeast Massachusetts. Some of this lake flooding extended well into April 2010. Locations affected by lake flooding included Norton Reservoir and Lake Winnecunnet in Norton; West Pond, Big Sandy Pond and Kings Pond in Plymouth; Assawompset Pond in Lakeville; Long Pond in Freetown and Lakeville; Forge Pond in Freetown; and South Wattupa Pond in Westport. In total, 8 of the 30 long term United States Geological Survey network gages in Massachusetts broke previous record crests during the period of March to early April 2010. Monthly rainfall records also were exceeded for March.

Figure 4.2. Floodwaters from the Taunton River flood in Taunton during 2010 flood event: source, NWS.

Rainfall Runoff Modeling

Hydrological rainfall-runoff modeling studies were conducted to simulate rainfall runoff in Taunton River Basin for the storm event in 2010. Two hydrological models, HEC-HMS and PRMS, were used in this study to evaluate their performance for rainfall runoff modeling. HEC-HMS (Hydrologic Modeling System) is a watershed hydrological model developed by Hydrologic Engineering Center, US Army Corp of Engineers (USACE). The HEC-HMS model has been widely used and tested worldwide. The program is a generalized modeling system capable of representing many different watersheds. Hydrologic elements are connected in a network to simulate a rainfall runoff process. Available elements are sub-basin, reach, junction, reservoir, diversion, sources and sinks. Computation proceeds from upstream elements to the downstream direction. A classification of different methods is available to simulate infiltration losses. Options for event modeling include SCS curve number, Gridded SCS curve number, Exponential, Green Ampt, and Smith Parlange. The one-layer deficit constant method can be used for simple continuous modeling. The five-layer soil moisture accounting method can be used for simple continuous modeling of complex infiltration and evapotranspiration environments. Unit hydrograph method includes the Clark, Synder, and SCS techniques. The modified Clark method, ModClark, is a linear quasi-distributed unit hydrograph method that can be used with gridded meteorological data. An implementation of kinematic wave method with multiple planes and channels is also included. Another popular hydrological model, the

Precipitation-Runoff Modeling System (PRMS), is a deterministic, distributed-parameter, physical process based modeling system developed by USGS to evaluate the response of various combinations of climate and land use on streamflow and general watershed hydrology.

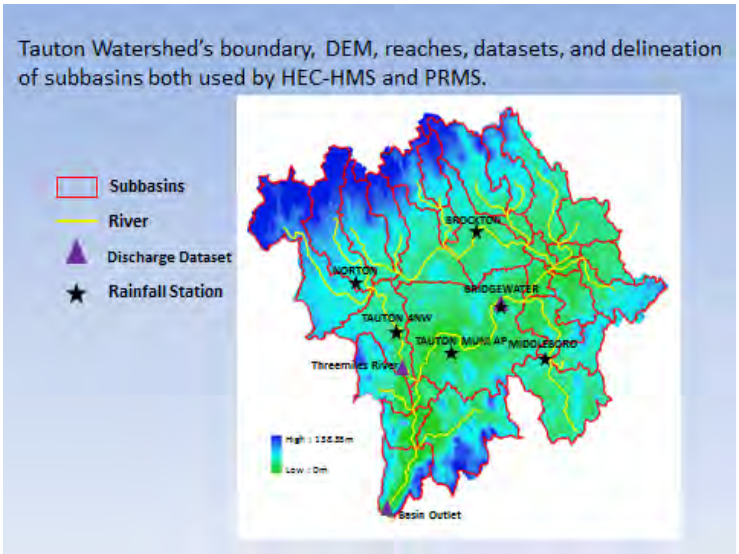
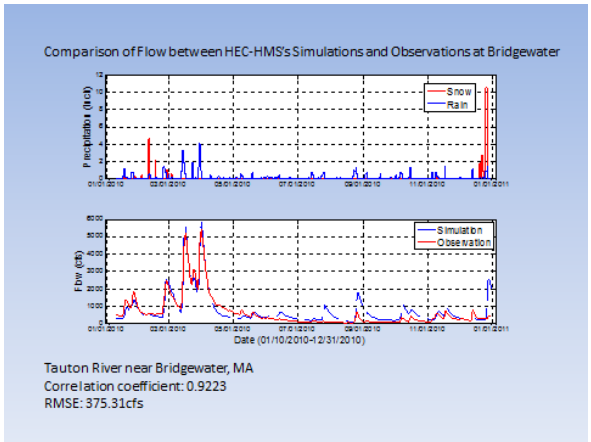


Figure 4.3. Watershed elevations, sub-basins, and data station locations.

Results of model simulated rainfall runoff by HEC-HMS model

Rainfall runoff modeling by using HEC-HMS for the year of 2010 are given in Fig. 4.4 a,b. Results indicate that the model is able to provide reasonable predictions of storm-induced runoff. However, over a year period, there are some errors for the period between July and September. In addition, for snow condition, the HEC-HMS model seems over estimates runoff.



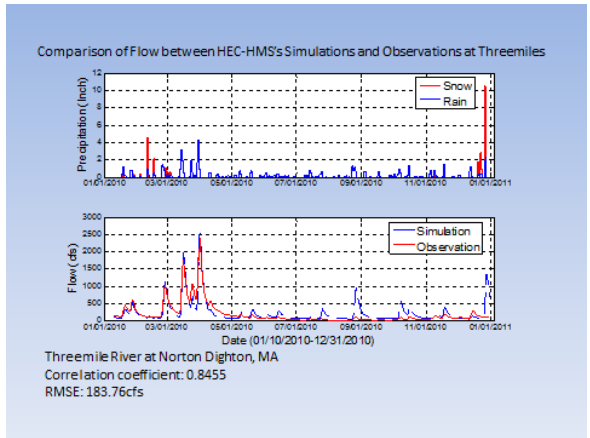


Figure 4.4. Comparison between HEC-HMS model simulated and observed flows at USGS gages.

Results of model simulated rainfall runoff by PRMS model

Rainfall runoff modeling by using PRMS was conducted. Comparison between PRMS model simulated and observed flow at USGS gages are presented in Fig. 4.5. Results indicated that PRMS can handle well for not only rainfall runoff in March and April but also the snowfall event in December.

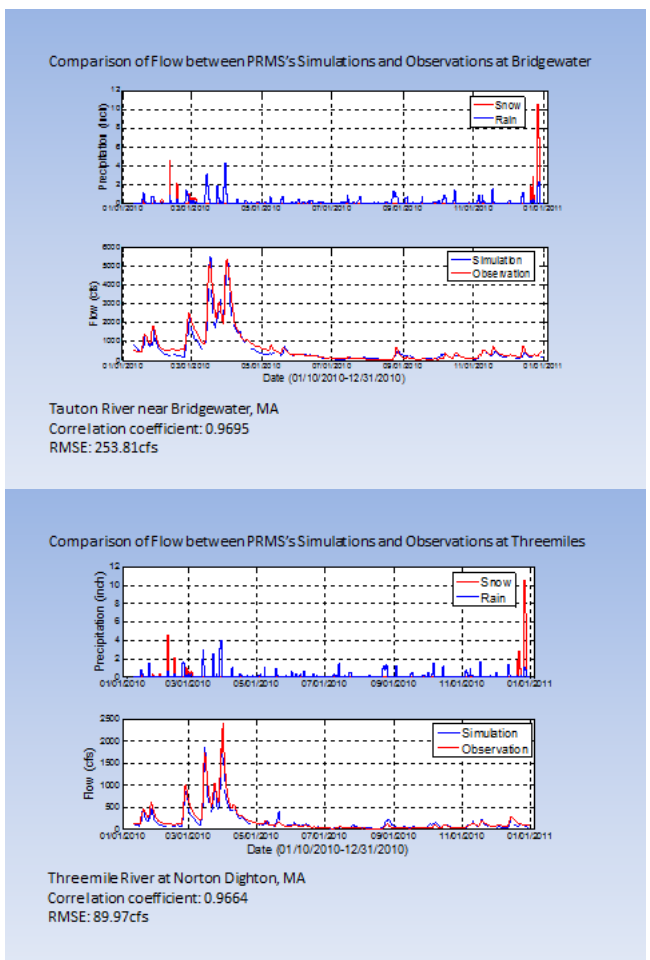


Figure 4.5. Comparison between PRMS model simulated and observed flows at USGS gages.

Comparison of performance between HEC-HMS model and PRMS model

Statistical comparison between hydrological model simulations and observations for 2010 are given in Table 1. Results indicated that, over a year period, HEC-HMS model show correlation values of 0.89 at Bridgewater and 0.85 at Threemiles Stations, and PRMS model show correlation values of 0.96 at Bridgewater and 0.96 at Threemiles Stations. At both stations, PRMS model show lower root-mean-square errors. The satisfactory calibrations of hydrological models for Taunton River Basin provide a very good reference for studies in the remaining sub-basins in Narragansett Watershed.

Table 1. Statistics between model simulations and observations

Comparisons between observations and simulations by HEC-HMS and PRMS

Data Set	Model	Peak Runoff (Simulation) cfs	Peak Runoff (Observation) cfs	Error of Peak Discharge (%)	Correlation coefficient	RMSE cfs
Bridgewater	HEC-HMS	5904.59	5388.69	9.57	0.8929	860.43
	PRMS	5503.92	5388.69	2.13	0.9695	253.81
Threemiles	HEC-HMS	2537.10	2399.29	5.74	0.8455	183.76
	PRMS	2354.11	2399.29	1.88	0.9664	89.97

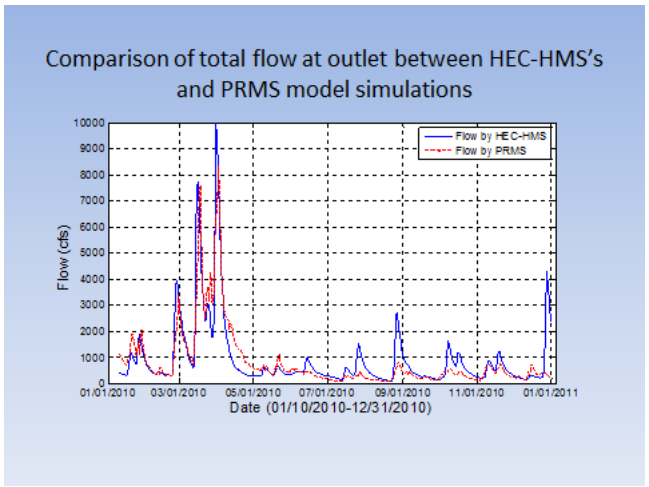


Figure 4.6. Comparison between rainfall runoff predicted by HEC-HMS and PRMS

River Flood Modeling in the Area near Taunton City

River flood modeling by using HEC-RAS model was conducted in the area of Taunton. HEC-RAS is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. The HEC-RAS system contains four one-dimensional river analysis components for: (1) steady flow water surface profile computations; (2) unsteady flow simulation; (3) movable boundary sediment transport computations; and (4) water quality analysis. A key element is that all four components use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the four river analysis components, the system contains several hydraulic design and analysis features that can be invoked for evaluations of hurricane impacts such as breaks, sediment scour around bridge piers

and abutments, backwater flood caused by culverts and bridge causeways; and effects of storage area such as detention ponds and lakes on flood mitigations. Based on the topo map and literature review, river cross sections were obtained in the selected river locations as shown in Fig. 4.7. Manning coefficient was selected based on the general range of values for open channels. For the rain storm event in 2010, upstream river inflow was specified from hydrological model simulations by PRMS model as shown in Fig. 4.8. Downstream boundary condition was specified as normal slope.

Figure 4.7. Area map and river cross-section locations for HEC-RAS model near Taunton City.

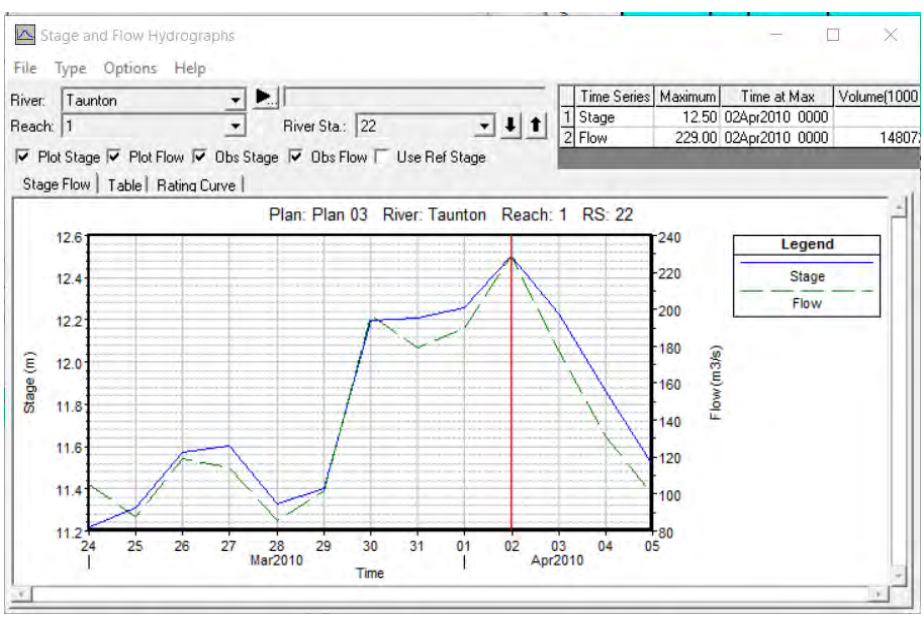


Figure 4.8. Upstream inflow predicted by hydrological model

Hydrodynamic modeling was conducted for the flood event from March 24- April 05, 2010. For the peak flow condition, flood area is shown in Fig. 4.9 in the HEC-RAS model plot. For convenience view, flood area has been mapped to the topo map as shown in Fig. 4.10.

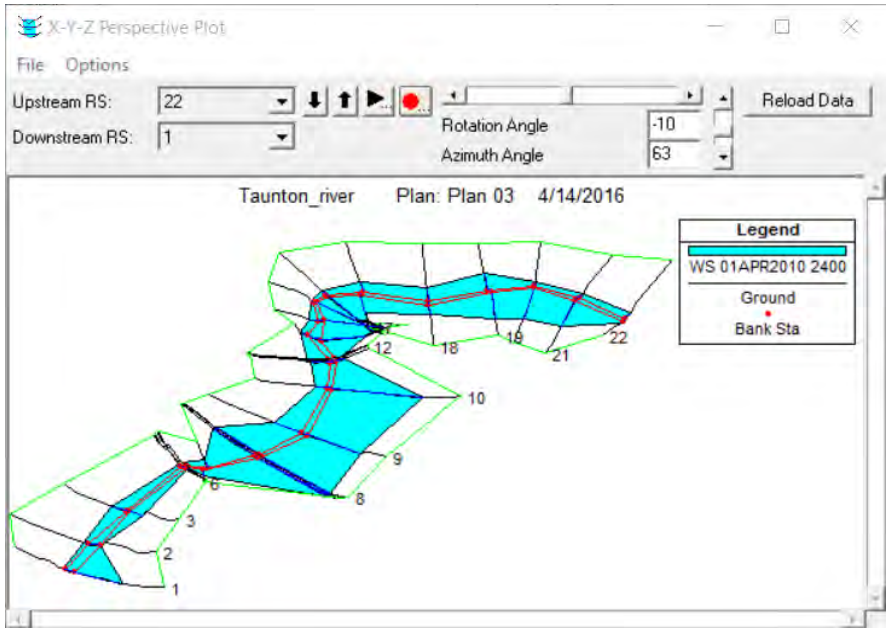


Figure 4.9. HEC-RAS model simulated flood at peak flow.

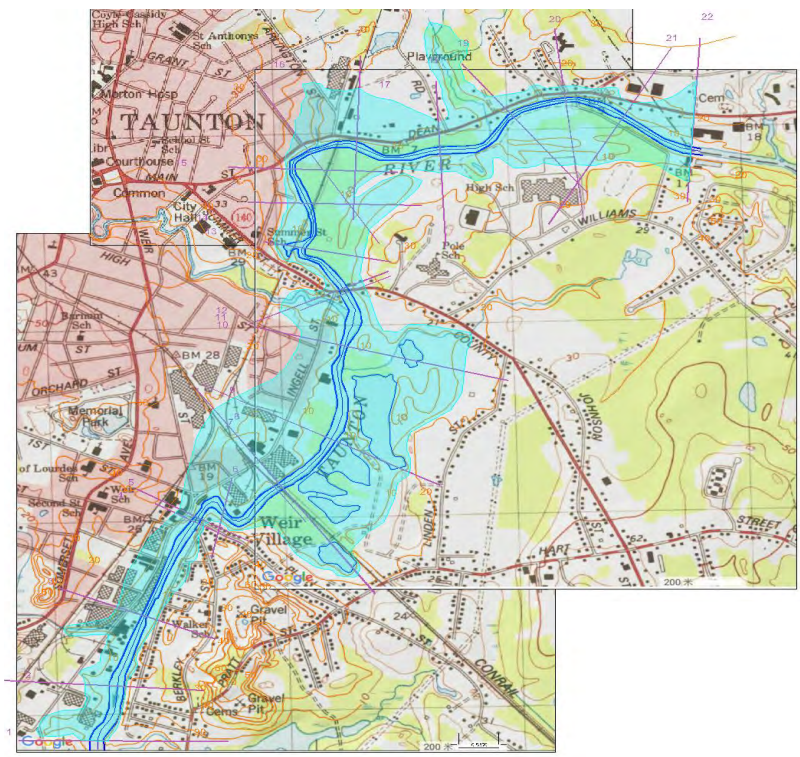


Figure 4.10. Flood area on top map as predicted by HEC-RAS model

References:

Garratt, J. R., 1977. Review of drag coefficients over oceans and continents, Monthly Weather Review, 105, 915-929.

National Geophysical Data Center (1999), U.S. Coastal Relief Model, Northeast Atlantic. National Geophysical Data Center, NOAA. doi:10.7289/V5MS3QNZ *http://www.ngdc.noaa.gov/mgg/coastal/crm.html*

NOAA (1998), Raster Digital Data, Narraganset, RI (M020) Bathymetry Digitial Elevation Model (30 meter resolution) Derived From Source Hydrographic Survey Soundings, NOAA's Ocean Service, Special Projects (SP), Silver Spring, MD. <http://estuarinebathymetry.noaa.gov>

U.S. Department of Commerce, (1991). Record of Climatological Observations- GHCND: USC00370218, NOAA/NCEI/NESDIS, Asheville, NC.

U.S. Geological Survey (2015), USGS NED 1/3 arc-second n42w072 1 x 1 degree ArcGrid 2015: U.S. Geological Survey: Reston, VA, http://ned.usgs.gov/, http://nationalmap.gov/viewer.html.

Willmott, C.J., 1982. Some Comments on the Evaluation of Model Performance. Bull. Am. Meteorol. Soc. 63, 1309–1313. doi:10.1175/1520-0477(1982)063<1309:SCOTEO>2.0.CO;2

Theme 4

Education and Workforce Development

WHALIN, JSU

DHS Coastal Resilience Center

Education Project

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** PhD in Engineering (Coastal Engineering and Computational Engineering concentrations) at an HBCU.

2. **Principal Investigator / Institution:** Robert W. Whalin, Ph.D., P.E., D.CE; Professor of Civil Engineering; Education Director, Coastal Resilience Center of Excellence, Jackson State University

3. **Other Education Participants/Partners:** US Army Engineer Research and Development Center, University of North Florida and Texas A&M University at Galveston

4. **Short Project Description ("elevator speech):** This project establishes the first HBCU PhD in engineering degree with concentrations focusing on coastal natural disasters. It will help increase workforce diversity (over 80% of students are minorities) in the Homeland Security enterprise. The PhD Engineering degree will have two coastal natural disaster related concentrations: Coastal Engineering (focusing on hurricanes and floods) and Computational Engineering (focusing on computational fluid dynamics) and continues to nurture the BS/MS education programs resulting from the Coastal Hazards Center of Excellence (July 1, 2008-June 30, 2016). End user (employer) relationships with ERDC, MDOT, Corps of Engineers Districts, MEMA and local emergency management offices across the southeastern US are promulgated.

5. **Abstract:** This project will formulate and implement a concentration in Coastal Engineering for the PhD Engineering degree and will promote the approved Computational Engineering concentration. These two PhD concentrations have a pipeline of BS Civil Engineering (Coastal Engineering Track) and MS Engineering (Coastal Engineering and Computational Engineering concentrations) graduates plus government and industry employees within the commuting area as a steady source of students. The BS and MS programs were formulated and implemented during the DHS Coastal Hazards Center of Excellence (July 1, 2008-June 30, 2016) at Jackson State University and form an academic foundation for the CRC. These are the only natural disaster focused coastal engineering and computational engineering graduate (or undergraduate) programs at an HBCU and are a direct result of DHS Office of University programs support for Centers of Excellence. Jackson State University has a minority student population exceeding 80% which directly supports the DHS Strategic Plan Goal to Enhance the DHS Workforce, especially the Objective to Increase Workforce Diversity and Priority Goal 3 to Enhance Resilience to Disasters. Leverage of federal assets is assured by the Education Partnership Agreement (authorized by Public Law) between the Engineer Research and Development Center and Jackson State University that facilitates ERDC engineers serving as Adjunct Faculty, providing student internships and potential use of ERDC experimental and computational facilities for graduate research. An outstanding record of DHS End User involvement and transition of graduates to end users was established during the eight years of the Coastal Hazards Center of Excellence at Jackson

State University and will be strengthened by the five-year Coastal Resilience Center. Research staff and graduate students have direct participation in hurricane barrier projects including the Ike Dike concept for protecting Galveston Island and the greater Houston metropolitan area from devastating, hurricane surges. Coastal Engineering programs nationwide have been on a decline for the past two decades and United States leadership in the coastal engineering profession has declined relative to other nations. This project will help ameliorate the trend while increasing the supply of minority coastal and computational graduate level engineers.

6. **End users:** The following table is a partial list of end users and their role in this education project: The only change from the original submission is the last line (an addition).

End User	Agency/Employer	Project Role
Emergency Management Institute (EMI)	DHS	Potential user of CRC education project courses for first responders and others.
Staff	FEMA Region IV	Transition, employer
Leaders Mississippi Emergency Management Agency	MEMA	Transition, potential employer of graduates, collaborator; a source for graduate students.
Free Flow Power Development, LLC	Free Flow Power	Collaborator (guest lecturer), Transition (helps students with internships/employment).
GIS Specialist	MEMA	Collaborator, Transition (employer and co-author).
Assistant Professor USCG Academy	USCG Academy	Collaborator, potential co-author & intern employer
Branch Chief, MVX Vicksburg District	USACE	Transition (employer)
Senior Association Coordinator	Louisiana Emergency Preparedness Association	Collaborator (potential employer).
Vice President	SDW	Transition employer
Commander Vice Commandant Office	USCG	Collaborator, coordinator with Commandant Office
President	Pritchett Engineering and Planning, LLC	Transition, employer of interns and graduates.
	Neel-Shafer, Inc.	Transition, employ student interns and graduates.
Leadership Team Member	Director, ERDC	Transition, signatory for ERDC Education Partnership Agreement with Jackson State University
Director Emeritus, ERDC	Retired, ERDC	Member of CRC Advisory Board and Collaborator.
Director, Coastal and Hydraulics Laboratory (CHL)	ERDC	Transition; CHL is employer of interns and graduates. CHL is source of Adjunct faculty & graduate students
Director, Information Technology Laboratory (ITL)	ERDC	Transition; ITL employs interns & graduates. Approver for Computational assets/use
Director, Geotechnical and Structures Laboratory (GSL)	ERDC	Transition; GSL employs interns & graduates.
Director of Human Capital	ERDC	Transition, Key person in strategic recruitment
Research Engineer, CHL	ERDC	Adjunct Professor, graduate Coastal Engineering courses.
Research Scientist, CHL	ERDC	Undergraduate Adjunct Professor.

Division Chief, CHL	ERDC	Collaboration/advisor & transition employer
Technical Director, CHL	ERDC	Guest lecturer (graduate)

7. **Explanation of Changes:** There are no Year 2 activity or milestone changes from the original approved workplan.

8. **Unanticipated Problems:** No challenges were encountered that impacted progress or Year 2 activities or milestones

9. **Project Outcomes:** End User/Transition Outcomes - Specific end-user outcomes from this new PhD Engineering program (Coastal Engineering concentration) are graduates available for employment in the greater Homeland Security enterprise. Graduation from a PhD program is nominally four to five years and at best some three to four years after completion of MS degree requirements. It requires approximately twelve to eighteen months for program approval within the university, consequently the first graduates from this program are expected at or near the end of year five with an established pipeline of 1-3 PhD graduates per year anticipated. The second end-user outcome is to continue to produce BS/MS coastal and computational engineering graduates resulting from Program 1 of the CHC. These Coastal and Computational Engineering programs are unique to the HBCU academic community. Transition Activities and Milestone progress are documented in item 11 of this progress report. All original Year 2 and beyond milestones are intact as originally scheduled.

1/1/2016-6/30/2016	
Transition Activity	Completion Date
1. Continued enrollment of students in BS/MS programs	06/30/2016
Transition Milestone	
1. Graduation of BS/MS students and employment in greater HS enterprise or continued graduate school enrollment.	06/30/2016
7/1/2016-6/30/2017	
Transition Activity	Completion Date
1. Continued enrollment of students in BS/MS programs	06/30/2017
Transition Milestone	
1. Graduation of BS/MS students and employment in greater HS enterprise or continued graduate school enrollment	06/30/2017
7/1/2017-6/30/2018	
Transition Activity	Completion Date
1. Continued enrollment of students in BS/MS programs	06/30/2018
2. Enrollment of students in approved PhD concentration	06/30/2018

Transition Milestone	
1. Graduation of BS/MS students and employment in the greater HS enterprise or continued graduate school enrollment.	06/30/2018

Progress toward the outcomes was steady and consistent. Two May 2016 BS graduates (who had taken undergraduate coastal engineering courses) and one May 2015 BS graduate applied for acceptance to graduate school, were accepted and are enrolled in courses for fall 2016 (Year 2). I am their advisor and they are committed to the Coastal Engineering concentration of the MS Engineering degree program (one with plans to enroll in the PhD Engineering degree program upon approval of the Coastal Engineering concentration. Three other graduate students continued progress toward a MS Engineering degree with a Coastal Engineering concentration (two are projected to graduate during Year 2 and one is projected to graduate during Year 3. The two students projected to graduate during Year 2 with MS degrees have expressed a desire to enroll in the PhD Engineering degree program (upon approval of the Coastal Engineering concentration). The PI is very pleased with the Year 1 Transition Activity and Milestone accomplishments described in item 11.

10. **Education Activity and Milestone Progress:** Formulation (draft) of the PhD Engineering program was completed and it is undergoing peer review and will continue to do so until the documentation is formally submitted for approval (scheduled 12/30/16). Recruitment of Adjunct Professors is a continuous process. Verbal commitments were received from two potential PhD adjunct professors and others have indicated a definite interest in completing the application package to be considered. During the reporting period a robust number of graduate courses were taught (three regular graduate courses and four different Independent Study courses. Two BS degrees were awarded and two MS degrees are scheduled Year 2.

Education Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Education Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached
Formulate Coastal Engineering concentration	4/30/16	100%	-
Continue to Recruit Adjunct Professors	5/30/16	100%	*This activity should have been worded as continue to…. Since it is a continuous activity. When correctly worded, as modified; it was 100% completed.*
Seek peer review of PhD program formulation	6/30/16 *12/20/16* *New completion date*	90%	Upon assessment of this activity, it was decided it was more beneficial to continue peer review until completion of preparation of Coastal Engineering concentration documentation scheduled for 12/30/16 since peer review could be incorporated into program formulation until it is submitted for approval. This activity completion date change has no impact on completion of original Year 2 activities or milestones.
Continue to teach BS/MS classes	6/30/16	100%	-
Education Milestone			
Continue to graduate students enrolling in BS/MS Coastal Engineering	5/30/16	100%	-
Submit Adjunct Professor documentation for approval	6/30/16 *10/30/16* *New completion date*	60%	Additional adjunct professors, based on the original schedule, are not needed until Fall 2017 (Year 3), at the earliest, therefore it was decided to modify this milestone completion date to 10/30/16 in order to collect as many potential adjunct professor applications as possible. A seminar was scheduled at ERDC for July 2016 to present the draft PhD program formulation and to seek additional adjunct professors. Expectations are that at least three PhD research engineers will express an interest and submit an application to be an Adjunct Professor. This 4 month milestone increase has no impact on completion of the original Year 2 Activities and Milestones.

11. Transition Activity and Milestone Progress:
Enrollment of students the BS/MS coastal engineering related courses continued. Two enrolled BS students graduated and two of three enrolled MS students are scheduled to graduate during Year 2 (Dec. 2016 and May 2017). The two BS graduates are both enrolled in graduate school for Fall 2016. One has a summer 2016 internship at University of Indiana and the other has an internship in private industry in Homeland Security enterprise firm.

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached
Continued enrollment of students in BS/MS program	6/30/16	100%	
Transition Milestone			
Graduation of BS/MS students and employment in the greater HS enterprise continued graduate school enrollment	6/30/16	100%	

12. Interactions with research projects: Planning and coordination discussions were held in Vicksburg, MS with Dr. Don Resio, University of North Florida and one of his graduate students relative to JSU participation/in his research project. Dr. Casey Dietrich, North Carolina State University gave an outstanding seminar, "Hurricane Wave and Storm Surge Forecasting for the North Carolina Coast" on May 4, 2016 attended by about 30 professors and students.

13. Publications: The first publication below was Co-authored by another CRC PI (Professor Ismael Pagan) and by two of our ERDC partners. Professor Pagan participated in presentation of the paper with me at the ASEE Annual Conference.

Whalin, Robert, W.; *Trinidad, Ismael Pagan*; Villanueva, Evelyn; and Pittman, David, "A Quarter Century of Resounding Success for a University/Federal Laboratory Partnership", ASEE 123rd Annual Conference and Exposition, New Orleans, LA, June 26, 2016

Whalin, Robert, W., "HBCU Engineering Faculty and Graduates: Implications for Race, Retention and Graduation Linkages", NAAAS & Affiliates 2016 National Conference, Baton, Rouge, LA, February 2016

14. Leveraged resources: Leveraged resources from Texas A&M University, Galveston NSF PIRE Project entitled, "Coastal Flood Risk Reduction Program" ($71,914) year one funding of $71,914. These funds provided monthly stipends for graduate students and the project enabled them to travel to The Netherlands for ten days in late May 2016 to gather data, view flood protection projects and speak extensively with Dutch professors and graduate students about individual research project information to comprise the basis for 3 semester hour summer Independent Research Projects under my direction. This was an outstanding and highly unusual international research experience for the students. The CRC staff also are performing research for this TAMU,G PIRE project with ERDC partners and have benefitted

by nominally 600,000 cpu hours of supercomputer usage that has an estimated leveraged value of about $ 36,000 [@ $0.06/hour].

15. **Anticipated / proposed future work**: This PhD in Engineering (Coastal Engineering and Computational Engineering concentrations) at an HBCU cannot realize its proposed output unless extended thru the five years of the CRC as awarded. PhD programs nominally take 4 to 5 years of graduate work and research to produce a PhD. The first PhD graduate is expected at or near the end of CRC Year 5 with an established pipeline of 1-3 PhD graduate yearly as originally proposed. Education projects nominally require at least five years to realize institutionalized productivity. We fully expect to realize the productivity proposed and are on schedule to do so.

16. CRC Performance Metrics: The following two pages contain performance metrics.

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)		5	
Undergraduates provided tuition/fee support (number)		1	
Undergraduate students provided stipends (number)		0	
Graduate students provided tuition/fee support (number)		4	
Graduate students provided stipends (number)		2	
Undergraduates who received HS-related degrees (number)		2	
Graduate students who received HS-related degrees (number)		0	
Certificates awarded (number)		0	
Graduates who obtained HS-related employment (number)		1	
SUMREX program students hosted (number)			
Lectures/presentations/seminars at Center partners (number)		1	
DHS MSI Summer Research Teams hosted (number)		0	
Journal articles submitted (number) (includes peer reviewed conference proceeding)		2	
Journal articles published (number) (includes peer reviewed conference proceeding)		2	
Conference presentations made (number)		2	
Other presentations, interviews, etc. (number)		5	
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)		0	
Requests for assistance/advice from DHS agencies (number)		0	
Requests for assistance/advice from other Federal agencies or state/local governments (number)		0	
Total milestones for reporting period (number)		3	
Accomplished fully (number)		2	
Accomplished partially (number)		1	
Not accomplished (number)		0	
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Courses Developed and Taught by Jackson State University under Project PhD in Engineering (Coastal Engineering and Computational Engineering concentration) at an HBCU						
Course		Developed (D), Revised (R), and/or Taught (T), by Project Year				
Number	Title	1	2	3	4	5
CIV631	Linear Theory of Ocean Waves	T				
	Offering: Elective (E), Concentration (C), Minor (M)	C				
	Enrollment	6				
CIV637	Advanced Design for Breakwater Rehabilitation	T				
	Offering: Elective (E), Concentration (C), Minor (M)	C				
	Enrollment	3				
CIV642	Prestressed Concrete Design	T				
	Offering: Elective (E), Concentration (C), Minor (M)	E				
	Enrollment	4				
CIV698	Independent Study (4 separate courses)	R/T				
	Offering: Elective (E), Concentration (C), Minor (M)	C				
	Enrollment	1				
Graduate courses are 500 and 600 level						

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
Coastal Flood Risk Reduction Program	Robert W. Whalin	$71,914	Texas A&M University, Galveston (NSF PIRE)
Leveraged Support			
Description			Estimated Year 1 Value
High Performance Computer use (at ERDC partner)			$36,000

CHEN, JCSU

DHS Coastal Resilience Center

Education Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Preparing Tomorrow's Minority Task Force in Coastal Resilience through Interdisciplinary Education, Research, and Curriculum Development

2. **Principal Investigator / Institution:** PI, Dr. Hang Chen, Johnson C. Smith University

   Other Education Participants/Partners: UNC-Chapel Hill, UNC-Charlotte, and Jackson State University (major partners)

3. **Short Project Description:** We focus on the integrative, interdisciplinary nature of real-world problems and strive to bridge traditional academic programs to develop solutions to coastal resilience and its related problems facing our nation. The proposed program will build an undergraduate education framework to prepare tomorrow's minority task force in coastal resilience (approximately 80% of students are minorities), which presents tailored courses in coastal resilience, applied research experience, knowledge transfer activities, scientific seminars, and summer camps.

4. **Abstract:**

Given the national need to prepare future coastal resilience professionals with educational and research experience, this proposed program supports a critical mission. Most existing coastal resilience related curricula currently either target graduate programs or vocational education. We will develop an undergraduate education framework that meets the needs and standards for excellence in undergraduate education.

The project is designed around the following aims:

1) **Aim 1**: Develop a curriculum to prepare undergraduate students for careers in coastal resilience;
2) **Aim 2**: Create partnerships to conduct applied research in the area of coastal resilience;
3) **Aim 3**: Create ongoing opportunities for the transfer of skills, knowledge, people and ideas between JCSU and the community at large.

To help reach these goals, we define the following objectives:

1) **Objective 1**: Develop four new courses to educate students with demonstrated interests and aptitudes in the area of coastal resilience study;
2) **Objective 2**: Design and deploy an interdisciplinary coastal resilience seminar series;
3) **Objective 3**: Establish and develop Faculty/Student research collaborations in coastal resilience;
4) **Objective 4**: Design and offer a summer camp to expose and increase the awareness of undergraduate students in coastal resilience study.

5. **End users:**

End User	Agency/Employer	Project Role
Dr. Rick Luettich	Principal Investigator & Director, the U.S. Department of Homeland Security's Coastal Resilience Center of Excellence UNC-Chapel Hill	External Advisor
Dr. Gavin Smith	Director, the U.S. Department of Homeland Security's Coastal Resilience Center of Excellence UNC-Chapel Hill	Collaborator (guest lecturer); Transition (helps students with internships/employment).
Dr. Robert W. Whalin Thomas Richardson	Jackson State University	Collaborator; Transition (Graduate study pipeline)
Kay Read	**IT-oLogy**	Transition (helps students with internships/employment).
Dr. Yufeng Wu	*University of Missouri-St. Louis*	Collaborator (guest lecturer, research project supervisor); Transition (Graduate study pipeline).
Elizabeth Austin	Society for Information Management-Charlotte region Chapter	Transition (helps students with internships/employment).
Dr. Mohamed Shehab	UNC Charlotte	Collaborator (guest lecturer, research projects supervisor); Transition (Graduate study pipeline).
Dr. Bei-Tseng Chu	UNC Charlotte	Transition (Graduate study pipeline).
Robert Lowe DHS/FEMA Region IV/Mitigation Risk Analysis Branch Chief	DHS/FEMA	Collaborator (guest speakers); Transition (helps students with internships/employment).
Jeff Stovall Chief Information Officer at City of Charlotte	City of Charlotte	Collaborator (guest speakers); Transition (helps students with internships/employment).

6. **Explanation of Changes:**

None.

7. **Unanticipated Problems:**

None.

8. **Project Outcomes:**

There are numerous jobs in the DHS enterprise available for qualified candidates who majored in Computer Science and Engineering. Nearly 70% of graduates with a master's degree in computer science are international students. Due to the fact that candidates must be U.S. citizens to fulfill federal government jobs, many employers are facing a serious shortage of computer science and engineering professionals. Moreover, according to the data reported by the Computing Research Association, only 4.5% of all new recipients of bachelor's degrees in computer science or computer engineering are African American. It is critical to recruit and retain more underrepresented minority students into the STEM pipeline

All DHS end users who hire engineers, regardless of degree level, need engineers to have as much knowledge of coastal natural disasters as possible. However, most existing coastal resilience related curricula either target graduate programs or vocational education. No other computer science and engineering undergraduate program in the U.S. offers courses which focus on natural disaster resilience.

The education program we propose meets the needs and standards for excellence in undergraduate education. The curriculum and research experience will provide students a solid knowledge foundation and skills to conduct coastal resilience research. JCSU is an HBCU with an approximately 80% minority population. Studies suggest that building partnerships between research-intensive universities and undergraduate-focused, minority-serving institutions can go beyond merely supplying the pipeline. We work with partner ins to identify gaps in the undergraduate training of coastal resilience for DHS and other agencies to ensure their success in graduate school and future careers.

Year 1 (January 1, 2016 to June 30, 2016) Outcome highlights:

1. Eight students conducted coastal resilience undergraduate research in spring 2016 semester.
2. Twenty students participated in coastal resilience one-week summer camp (May 9 to 13, 2016.
3. Nine students conducted four-week summer undergraduate research. (May 16 to June 11).
4. Nine students who participated in DHS CRC research graduated in May 2016.
   Two students were awarded scholarships to attend graduate programs at University of Cincinnati and University of North Carolina, Charlotte.
5. Graduates placements include: Army National Guard 35T military Intelligence Systems Maintainer/Integrator, FBI, US Department of Justice, United Technologies Corporation.

9. **Education Activity and Milestone Progress:**

Education Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Education Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Develop one new course.	04/30/2016	100%	
Host Three Seminars.	04/30/2016	100%	Completed by 05/11
Select eight students to conduct research projects	01/30/2016	100%	
Design a one-week summer camp focused on Coastal Resilience	05/01/2016	100%	
Select nine students and three faculty to form the summer research teams.	05/01/2016	100%	
Education Milestone			
New course will be offered for fall semester.	05/01/2016	100%	
Eight students completed the spring research project.	05/01/2016	100%	
Twenty Students complete the one-week summer camp.	05/30/2016	100%	
Nine students complete the four-week summer research projects.	06/30/2016	100%	

10. **Transition Activity and Milestone Progress:**

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
The students who participated in the research projects will be available for employment in the greater Homeland Security enterprise.	06/30/2016	100%	
Dissemination of the undergraduate education and research education framework and results.	06/30/2017	On schedule	
Develop the collaboration with research partners.	06/30/2017	On schedule	
Transition Milestone			
Graduates are employed in greater HS enterprise or continued graduate school enrollment	06/30/2017	On schedule	
Conference presentation and publications of the project results.	06/30/2017	On schedule	
Students present research finding at regional and national conferences.	06/30/2017	On schedule	

11. **Interactions with research projects:**
    1. Worked with the CRC Education Director and the Transition Director to place students in the CRC SUMREX programs. Since we started the process in February, most of our high potential computer science and engineering students had secured their summer internships. We will plan the selection process earlier in Year 2.
    2. Worked with the CRC Director to connect with end users and research partners. We will invite research partners to give seminars in fall 2016-2017 semester.

12. **Publications:**

Ying Bai, Hang Chen, "Build a Real Time Optimal Evacuation Contraflow Model for Natural Disasters by Using a Fuzzy Inference System," 2016 IEEE Symposium Series on Computational Intelligence (IEEE SSCI 2016). (Submitted on May 20th, 2016)
Ying Bai, Hang Chen, "Build a Real Time Optimal Evacuation Contraflow Model for Natural Disasters by Using a Fuzzy Inference System," Natural Hazards Review. (Submitted on June 13rd, 2016)
Students completed their research projects in summer 2016. Abstracts will be submitted in fall 2016 to 2017 National Undergraduate Research Conference.

Cody Byrd, Jean-Marie Nshimiyimana, Ehije Idehenre, Hang Chen (Faculty Advisor), "Data Analysis of Haiti's Resiliency Post-2010 Earthquake".

Shania Knight, Christian Fair, Ramoya Grandison, Ying Bai (Faculty Advisor) "Using Fuzzy Interference System to Build Real Time Optimal Evacuation Contraflow Model".

NyJae Dickerson, Adonis Tillman, Desmond Taylor, Awatif Amin (Faculty Advisor) "Using Data Mining to analyze Natural Disasters at 10 countries".

14. **CRC Performance Metrics:**

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)		1	
Undergraduates provided tuition/fee support (number)		0	
Undergraduate students provided stipends (number)		37	
Graduate students provided tuition/fee support (number)		0	
Graduate students provided stipends (number)		0	
Undergraduates who received HS-related degrees (number)		9	
Graduate students who received HS-related degrees (number)		0	
Certificates awarded (number)		0	
Graduates who obtained HS-related employment (number)		3	
SUMREX program students hosted (number)			
Lectures/presentations/seminars at Center partners (number)		0	
DHS MSI Summer Research Teams hosted (number)		0	
Journal articles submitted (number)		1	
Journal articles published (number)		0	
Conference presentations made (number)		0	
Other presentations, interviews, etc. (number)		0	
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)		0	
Requests for assistance/advice from DHS agencies (number)		0	
Requests for assistance/advice from other Federal agencies or		0	
Total milestones for reporting period (number)		7	
Accomplished fully (number)		4	
Accomplished partially (number)		3	
Not accomplished (number)		0	
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Education Project Courses and Enrollments

Courses Developed by Johnson C. Smith University under Project Preparing Tomorrow's Minority Task Force in						
Course		Developed (D), Revised (R), and/or Taught				
Number	Title	1	2	3	4	5
CSE439	**Technology in Emergency Management**	D				
	Offering: Elective (E), Concentration (C), Minor (M)	-				
	Enrollment	-				
	Community Resilience Summer Camp	D	T			
	Offering: Elective (E), Concentration (C), Minor (M)	-	N/A			
	Enrollment	-	20			

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
STEM Innovation Center	Carter, Ronald L.(President of JCSU)	$1.655 Million. We utilized the fund ($4,500) to support 5 faculty to develop community resilience seminars.	Kenan Charitable Trust
Carolina Cyber Defense Scholarship	Hang Chen	$262,917 We utilized the fund to support undergraduate tuition and travel.	NSF
Leveraged Support			
Description			Estimated Annual
Reduced indirect cost of 8% (DHS negotiated rate of 34.4%)			$20,188
In-kind faculty time to supervise Summer Research for 4-weeks ($3,000 stipend)			$25,000

LAIJU, TOUGALOO

DHS Coastal Resilience Center

Education Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Institutionalization, Expansion, and Enhancement of Interdisciplinary Minor: Disaster and Coastal Studies

2. **Principal Investigator / Institution:** Meherun Laiju, Ph. D. Associate Professor and Chair of Sociology Department; Tougaloo College

3. **Other Education Participants/Partners:** Interdisciplinary collaboration within Tougaloo College (Sociology, Psychology, Physics and Political Science Departments faculty members, of Tougaloo College)

4. **Short Project Description:** Through this project we will remodel the curriculum at Tougaloo College, making it more relevant to education and workforce development in homeland security operations. We plan to achieve this through institutionalization, expansion, and enhancement of the Interdisciplinary Minor in Disaster and Coastal Studies (DCS). Our goals are two-fold (i) train undergraduate students in interdisciplinary skills necessary to mitigate natural and man-made coastal hazards through research, training and coursework and (ii) create a certificate program to educate and prepare future community leaders, first responders, and citizens in planning and implementing disaster strategies to build an effective path towards societal resilience and safety.

5. **Abstract:** This project will expand/enhance the Interdisciplinary Minor: Disaster and Coastal Studies implemented during the Coastal Hazards Center of Excellence-Education (2008-2015). Interdisciplinary collaboration will be enhanced to embrace the Psychology and Physics Departments by adding GIS based courses to the Minor. Undergraduate research in the hazard mitigation area will be expanded to include a community preparedness focus to enhance community resilience. A certificate program will offer continuing education opportunities for first responders, community leaders and interested citizens in preparing resilient communities.

6. **End users:** This is an interdisciplinary project within the college. Faculty members from Physics, Sociology Psychology, and Political Science Departments will be collaboratively involved in student training (disaster related research) course modification or development and creating a certificate program for the community at large.

   Certification Program: A certification program will be designed for businesses, faith-based & community organizations, schools & academia, nonprofit support groups, and citizens. During the Spring 2016 academic session an advisory committee was put together. The committee members are assisting in the designing the program. The committee members met

on March 31st and May 16th and started the preliminary work. The participants and their roles are included in the following table:

End User	Agency/Employer	Project Role
Dr. Nicole Cathy	Political Science; TC	Coordinator
Dr. George Humphrey, CFM	Director (grants)MEMA	DCS Instructor, Place Intern
Mr. John Brown	Regional Manager; Red Cross	Serve on panel
Ms. Jana Henderson	Mitigation Office Director, MEMA	Serve on panel
Marsha Mannuel	Grant Director, MS office of Homeland Security	Serve on panel, Intern placement
Colonel Donnell Berry	MS State Trooper	Serve on panel
Mr. Ricky Moore	Director, Hinds County Emergency Management	Serve on Panel
Mr. Warren D. Miller	President, Mississippi Voluntary Organizations Active in Disaster (VOAD)	Serve on Panel
Mr. Anderson	Pastor, United Methodist Church	Serve on Panel
Dr. Shaila Khan	Psychology Department, TC	Mentor student research
Dr. Santanu Banerjee	Physics Department, TC	Mentor student research

7. **Explanation of Changes:** The delivery method has been changed for the certificate program. Initially the certificate program was planned to be part of the Tougaloo College Continuing Education Program. In January of 2016 the administration decided to phase out the Continuing Education Department. I have discussed the situation with the CRC Education Director and informed him of the alternative plan.

8. **Unanticipated Problems:** The closing of the Continuing Education Program put us slightly behind schedule to develop and launch the non-credit bearing certificate program. The program was regrouped by March and it was decided that the certificate program will be offered by the Sociology Department in collaboration with the Political Science Department. Dr. Nicole Cathy, assistant professor in the Political Science Department, is assigned as a coordinator. We have contacted local emergency management agencies and set up an advisory board to assist us in designing the certificate program.

9. **Project Outcomes:** Tougaloo College is a private Historically Black College which offers undergraduate degrees. The majority of the student body is comprised of first-generation college students. The main mission of the College is to prepare students for graduate school. The current project addresses the acute underrepresentation of minorities in the science, technology, engineering and mathematics areas (STEM). The project plans to diversify the future DHS and S&T workforce by training underrepresented minorities, mirroring some of the more vulnerable populations impacted by disaster scenarios. Through internship placement, students have an exposure to emergency management organizations. Students pursuing the minor have the opportunity to be trained in interdisciplinary fields across academic divisions (Natural & Social Science, so that other institutions may recruit graduate

students who have a background in disaster related curricula.

10. **Education Activity and Milestone Progress:**

Education Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Education Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Offer 3 courses for DCS minor	January 2016	100%	
Select students for research and training (GIS & Survey)	January 2016	100%	
Form Advisory Committee for certificate program	February 2016	100%	
Intern placement to end user setting	February 2016	100%	
Create a project charter and Gaant chart of GIS subproject for first 3 years	February 2016	30%	Delayed due to shortened period in the starting year.
Students complete literature review to help frame the questionnaires	March 2016	70%	First draft has been submitted on May 13th
Design questionnaires to evaluate: effectiveness of risk awareness program	April 2016	0%	Students are working during summer, expected draft on August
DCS Research Symposium	April 2016	100%	

Education Milestone			
Inter and DCS minor students present at DCS Research Symposium	April 2016	100%	
Invite CRC partners & end-user agency personnel as guest speaker and students from partnering institute to present at DCS Symposium	April 2016	100%	
Expecting 1-2 graduate with DCS minor. Encourage graduates to attend graduate program at CRC Institution and potentially seek employment at hosting agencies	May 2016	100%	
Application of GIS to a project	June 2016	60%	In progress
Project charter and Gantt chart milestone completion for the advisory committee	June 2016	40%	In progress
DCS Course evaluation for the certificate program	June 2016	10%	In progress
Send 1-2 students to CRC partner institution for summer internship	June 2016	100%	

11. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Advertise and promote the Certificate Program/Continuing Education Program	June 2016	0%	Delay due to phase out of the Continuing Education Program and developing an alternative administrative structure.
Recruit end-user organizations to participate in Certificate Program	June 2016	70%	Program planning in progress and working currently with five end user organizations.

Transition Milestone			
Approved end-user transition plan	February 2016	100%	
Develop end-user agreements to participate in Certificate Program	June 2016	100%	
DCS Students engaged in internships at end-user organizations	June 2016	100%	

12. Interactions with research projects: A collaborative working partnership has been developed with the University of Delaware's Disaster Research Center. Under the CRC's SUMREX Program, Taralyn Rowell and Irenia Ball were selected to participate in a summer internship (June 6th to August 1st) at the Center. Students will work under the guidance of Dr. Joseph Trainor. Taralyn Rowell, a Psychology major, graduated with a Disaster Coastal Studies (DCS) minor in May, and is interested in pursuing a graduate program related to Disaster Management. The summer internship experience is expected to solidify her field of study. Irenia Ball is a rising senior Sociology major with the DCS minor. Last year Irenia worked as an intern at the Mississippi Department of Homeland Security and plans to continue this internship in the fall. Irenia's SUMREX internship may be used for her senior paper requirement.

13. Publications: Laiju, M. (20016) *A Global Issue: Natural Disaster and Child trafficking,* proposal to write a paper was funded by Andrew W. Melon Foundation, the completion and submission date is May 2017.

14. CRC Performance Metrics:

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)		7	
Undergraduates provided tuition/fee support (number)			
Undergraduate students provided stipends (number)		15	
Graduate students provided tuition/fee support (number)		NA	
Graduate students provided stipends (number)		NA	
Undergraduates who received HS-related degrees (number)		3	
Graduate students who received HS-related degrees (number)		NA	
Certificates awarded (number)		NA	
Graduates who obtained HS-related employment (number)			
SUMREX program students hosted (number)			
Lectures/presentations/seminars at Center partners (number)		1	
DHS MSI Summer Research Teams hosted (number)		0	
Journal articles submitted (number)		0	
Journal articles published (number)		0	
Conference presentations made (number)		1	
Other presentations, interviews, etc. (number)		10	
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)		0	
Requests for assistance/advice from DHS agencies (number)		2	
Requests for assistance/advice from other Federal agencies or		5	
Total milestones for reporting period (number)		7	
Accomplished fully (number)		4	
Accomplished partially (number)		3	
Not accomplished (number)		-	
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Education Project Courses and Enrollments

Courses Developed and Taught by Tougaloo College under Project Title						
Course		Developed (D), Revised (R), and/or Taught				
Number	Title	1	2	3	4	5
DCS 301	Political & Legal Issues in Disaster Preparedness	T				
	Offering: Elective (E), Concentration (C), Minor (M)	C				
	Enrollment	14				
DCS 320	Emergency Preparedness Response & Planning.	T				
	Offering: Elective (E), Concentration (C), Minor (M)	C				
	Enrollment	16				
DCS 400	Internship	T				
	Offering: Elective (E), Concentration (C), Minor (M)	C				
	Enrollment	7				
DCS 211	Public Health Issues in Disaster Preparedness	T				
	Offering: Elective (E), Concentration (C), Minor (M)	C				
	Enrollment	1				

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
A Global Issue: Natural Disaster and Child trafficking	Meherun Laiju	$8,000	W. Andrew Melon Foundation
Using Geographical Information System (GIS) to Map Modern Day Slavery	Santanu Banerjee	$4,000	W. Andrew Melon Foundation

Leveraged Support	
Description	Estimated Annual Value
Class room space and computer lab for GIS Training	$15,000
Portion of university indirect returned to project	$15,000
25% release time for PI	$11,000

PAGAN, UPRM

DHS Coastal Resilience Center

Education Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Education for Improving Resiliency of Coastal Infrastructure

2. **Principal Investigator / Institution:** Ismael Pagán-Trinidad (PI), Ricardo R. López (Co-PI), University of Puerto Rico at Mayagüez

3. **Other Education Participants/Partners:** ERDC-US Army Corps of Engineers; Puerto Rico (PR) Emergency Management Agency; FEMA, PR Department of Natural and Environmental Resources (Coastal Management Program); Association of Professional Engineers of PR, UPRM partners (Marine Science Department, Sea Grant Program, CariCOOS NOAA project); NOAA (National Weather Service); PR Climate Change Council (PRCCC)

4. **Short Project Description:**

   This project will help educate the community by transferring state of practice knowledge on resiliency of coastal infrastructure (RCI) to stakeholders (students, faculty, professionals, first responders, and work force) through formal (curriculum, internships, student projects) and informal (workshops, seminars, lectures, short courses, webinars) learning experiences. It will serve as a vehicle to engage the community as a whole to understand and learn its members' roles and responsibilities in providing resilient coastal infrastructure systems. The project will help the community understand better various stages in coastal infrastructure hazard prevention, preparedness, response, recovery, and mitigation. It will also help create pipelines of students and professionals into RCI careers and practice.

5. **Abstract:**

The goal of this project is to develop and offer formal and informal education through courses, workshops, seminars, lectures, and other educational means to advance knowledge on the state of practice on RCI (built and natural). This initiative aims at creating a **Certificate in RCI.** The focus of the project is to provide students and faculty, professionals and homeland security personnel, and affected citizens with capabilities to assess the effects of natural hazards on coastal infrastructure, the conditions of existing structures, and rehabilitation alternatives to mitigate future damage and potential risks. New courses and existing course revisions will be evaluated in Civil Engineering and related disciplines dealing with estimates of causes and effects of coastal flooding, storm surge, ocean waves, tsunami loads, earthquake effects, and strong winds on infrastructure. Experts will be invited as lecturers. State of practice will be a priority. Results of recent research work will be incorporated. Being a small and fully developed island, Puerto Rico offers the ideal setting to assess lessons learned of the effect of natural hazards on built and natural infrastructure including housing, commercial, industrial, institutional, transportation, communication systems, and others. This program will facilitate participation in internships at CRC partner universities, government agencies, and industry dealing with coastal hazards. As a Minority Serving Institution (MSI) with a high female

enrollment (near ⅓ in Civil Engineering) it is also our goal to provide an up to date level of RCI competency in the Hispanic community.

6. End users:

End Users*	**Role of Participation in the Project**
Students:	Trainee; Interns; Undergrad/grad research experiences on RCI topics • Kevin Cueto, MSCE (Struct) Oregon State Univ., Intern • Diego Delgado, BSCE, Oregon State Univ., Intern • Felix Santiago, MSCE (Env), Univ. of Central Florida, Intern • Efrain Ramos, MSCE (Env), ERDC-US Army CoE, Intern • Jaime Calzada, PHD (Marine Sc.), ERDC-US Army CoE, Intern • Gabriela Salgado, MSCE(Environ), ERDC-US Army CoE, Intern • Jesús Otero, BSCE, ERDC-US Army CoE, Intern • Stefanía Quiñones, MSMS, ERDC-US Army CoE, Intern • Gabriela Buono, BSCE, UPRM, Undergraduate Research • Ángel Alicea, PhD, UPRM, Research Assistant in the project
Faculty	Trainers/Teachers in courses, seminars, workshops; CRI leaders; Project Advisors; Course content evaluators; • A.Saffar-Coastal Resilient Structures (3 credits) • A.Morales- Introduction to Marine Geomechanics (3 credits) • R.López & I.Pagán-Natural Hazards in Coastal Zones (3 credits) • R.Ramos Geotechnical Analysis of Coastal Structures (1 credit) • J.Muñoz-Remote Sensing in Coastal Erosion • L.Aponte-Wind Engineering for Coastal Applications
Professionals	Trainee; Trainers; Advisors; Providers of lessons learned; Survey responders for priority needs • 26 trainees and surveyed individuals, 3 trainers (Matt Pendleton, Billy Brooks, Doug Marcy from NOAA) @ Coastal Flood Workshop, June 6 and 7, 2016, Dept. of Civil/Surveying Dept. (in partnership with UPRM Sea Grant Program • 7 mentors and 5 mentees at Summer Research Internship program at Engineer Research and Development Center of the US Army Corp of Engineers • 4 mentors and 3 mentees at OSU, UCF, and LSU SUMREX Other professionals participated at these activities: • Over 60 people participated at CARICOOS Annual Conference at San Juan PR where the CRC Center project was formally presented and advertised. First and other responders participated and exchange views and ideas. All were surveyed. Survey results are pending.
Researchers from CRC	Advisors on course/seminar/workshop contents (breadth and depth); providers of internship opportunities; recruiters of students for graduate school; Trainers/lecturers; advisors • Dr. Dan Cox, Oregon State University-Mentor Internship • Dr. John van de Lindt, Colorado State University, Mentor, Internship • Dr. Stephen Medeiros, University of Central Florida, Mentor, Internship • Dr. Scott Hagen, Louisiana State University, Mentor, Internship • Dr. Robert Whalin, Jackson State University, Article coauthors and project Advisor
First responders (HLS Partners)	Trainee; Trainers/Lecturers; Survey responders of priority needs • 18/26 participants in the Coastal Inundation Workshop by NOAA identified or related to first responders. All 26 were surveyed.

	• 30 participants, including first and other responders, participated at Hurriplan Workshop sponsored by PR Sea Grant Program, one of our UPRM partners, and presented by National Disaster Preparedness Training Center (NDPTC) and the University of Hawaii Surveyed collaborated by PR Sea Grant program. Project PI and Co-PI participated in the training and had the opportunity to announce and advertise the CRC project. • Over 60 people participated at CARICOOS Annual Conference at San Juan PR where the CRC Center project was formally presented and advertised. First and other responders participated and exchange views and ideas. All were surveyed. Survey results are pending.
General Responders	**Trainee; Trainers; Survey responders on priority needs**; • See previous section, included in the discussion.
<u>UPRM Partners</u>	**Leverage; Support; Trainers; Collaboration** • Ruperto Chaparro, Sea Grant Director • Julio Morel, CariCOOS Director • Aurelio Mercado, Marine Sciences Researcher • Miguel Canals, Ocean Engineering Research Centre Director and Researcher • Sylvia Rodríguez, Materials Science and Engineering Researcher • Cecilio Ortiz, Social Science Research Center, Researcher • David Sotomayor, Agricultural Science Researcher • Raul Zapata, Assistant to Chancellor • Various faculties • Various technical personnel
Government Executive and Legislative branches	Leverage; Support; Advice • PR Senate: Written and oral position hearing on behalf of Chancellor at the PR Senate Special Commission on Climate Change. Interviewed with legislators on climate change and its effects in coastal environments in PR and the Caribbean were discussed. Follow up on the initiative after the hearing was incorporated as part of the activities of the project. • Ernesto Diaz, Director of Coastal Management Zone, Dept. of Natural and Environmental Resources and Director of the PR Climate Change Council. • José Sánchez, Director, Coastal and Hydraulics Laboratory, ERDC – US Army CoE

7. Explanation of Changes:

No changes from initially approved work plan.

8. Unanticipated Problems:

The unanticipated challenges have been mostly difficulties in coordination of meetings with intended end users. These have been resolved. The meetings occurred in July and the several seminars and conferences are being scheduled in coordination with partners.

9. Project Outcomes:

- **Students: Training /Education through curriculum research and learning**
  - Formal undergraduate and graduate research work experience (experimentation, modeling, simulation, programming, and analysis)
  - Improve communications skills (oral, written, graphical, media) on RCI topics and literature
  - Provide knowledge and tools on coastal hazards and its impact on coastal infrastructure
  - Attract and motivate candidates into HS career with emphasis in RCI
  - Provide access to state of the arts and practice in RCI
  - Provide access to experts with RCI expertise
  - Create a pipeline towards advance degrees or work force on RCI and DHS priority job opportunities
  - Develop maturity, confidence, satisfaction and expertise on new advances in RCI topics
  - Support work force through internships and summer jobs

- **Agencies: Trained, guided, and motivated work force**
  - Vision to new worldwide RCI challenges
  - Provide human resources for work force
  - Upgrade human capital capabilities
  - Trained professional with better capabilities to face new challenges in RCI
  - Increase institutional expertise
  - Provide continuing education on state of art and practice
  - Facilitate institutional networking and collaboration
  - Consultant to help regular work forces and advisors

- **Constituents: Continuing education RCI and HS advancements**
  - Provide state of practice resources and tools, for example literature, software (GIS), data bases (geospatial), guidelines, case studies, and examples that can be applied in their jobs.
  - Advance expertise and confidence which help in career development and better opportunities.
  - Orient and persuade potential professional to follow HS careers.
  - Provide networking opportunities to engage in team work consultation and collaboration.
  - Gain hands-on experience on new technologies.
  - Become educators for other professionals in resilience topics.

- **Faculty: Scholar professional development**
  - Provide scope of opportunities on Coastal Infrastructure Research to create new knowledge.
  - Provide resources and expertise to be incorporated into formal curricula.
  - Expand opportunities to team building and collaboration with scholars in the resiliency of coastal infrastructure.
  - Advise on funding opportunities and funding agencies.
  - Create opportunity for publishing.
  - Expand the scope of expertise.
  - Expand, update and upgrade existing programs on RCI.

10. **Education Activity and Milestone Progress:**

Education Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Education Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Training: "Beyond Academia: Maximizing Research Impact" – UPRM R&D Center	Feb 2016	100	
Collaboration Agreements UPRM - Univ. of Hawaii NDPTC, and Sea Grant Program	Feb 2016	100	
Participated in workshop: PER-306 HURRIPLAN Resilient Building Design for Coastal Communities	March 2016	100	
Kick-off meetings to launch the program, gather constituents	March 2016	75	Project development has taken place by participating in various separate meeting and activities with constituents. A strategic partners' group meeting is scheduled for August 2, 2016 to plan and program various joint activities and join initiatives within and outside the university. Preliminary activities confirmed the opportunity of developing Center partnership with other internal and external partners to align and strengthen effectiveness of Center activities.
Preliminary course design: UPRM faculty • Coastal Resilient Structures (3 credits)– Saffar • Introduction to Marine Geomechanics (3 credits)– Morales • Natural Hazards in Coastal Zones (3 credits) – López & Pagán • Geotechnical Analysis of Coastal Structures (1 credit) – Ramos • Remote Sensing for Assessment of Coastal Erosion- Muñoz • Wind Engineering for Coastal Applications-Aponte	June 2016	60 (average)	Each initiative is at a different stage. Most of these formal and informal course designs by faculty were not foreseen at the beginning of the project. However, a group of faculty has been enthusiastic and motivated to be involved in course revisions and development. Although faculty are working by themselves and we cannot guarantee final faculty deployment of the proposed courses, interesting initiatives are under development at different stages at the present time. Preliminary concepts are well defined.
UPRM Funding: Perspectives of Climate Change in the Caribbean – Dec 2016 Initial coordination by June; Conference by Dec 2016	June 2016	100	Progress on schedule
Allocate Students in Summer Internships: SUMREX, ERIP-ERDC, UPRM	June 2016	100	Allocated 10 students. Three with SUMREX and 6 in Center topics with ERDC, and 1 at UPRM

Planning short course	June 2016	75	Course scheduled for late September 2016/Early October
Identify, meet, and survey the HS constituents to establish CRI educational priorities	June 2016	80	Have met constituents individually. Gathered results of surveys conducted by Sea Grant, CariCOOS, Dept Natural Resources, and ourselves.
Offer first series of seminars and lectures on RCI	June 2016	100	First workshop was offered in June 2016 on Coastal Inundation in collaboration with NOAA and PR Sea Grant Program. Technical presentation was given at the CariCOOS
Education Milestone			
Create the constituents network and identify educational priorities on RCI based on the constituents needs (Metric: No. of constituents participating; list of educational priorities)	June 2016	100	The constituents have been identified and individual meetings have been held. This is a continuous activity. A strategic group meeting is scheduled for August. A list of educational priorities is being compiled and it will serve as a guide for educational programming.

11. **Transition Activity and Milestone Progress:**

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
First Series of seminar and lectures	June 2016	100	First short course was offered. Seminars and courses are being scheduled for Fall 2016 and Spring 2017 semesters
Transition Milestone			
Reach and engage first class of students, professionals, and faculty on RCI education. (Metric: Number of participants; Contents learned)	June 2016	100	**26 participants, Three days of instructions and laboratory work on fundamentals, theory, modeling, and simulations of coastal inundation using GIS tools**: Taught by NOAA personnel at the Computer Aided Instruction and Research Laboratory in the Department of Civil Engineering and surveying at UPRM. The first short course was offered with a diverse audience including Municipal, State and Federal Government officials, Consultants, Community officials, Educators, students, and general public. Final Evaluation of the short course given. Participants were surveyed on their needs and priorities. **Engaged 10 graduate and undergraduate students in summer research experiences at four different institutions.** Six of ten students were registered in formal undergraduate and graduate courses for three credit –hours at UPRM. These students developed formal proposals, progress reports, and a formal technical paper, and will present their findings orally at the end of the summer. They will also submit an abstract to a conference to participate in a Summer Research Internship Conference. **Seven faculties motivated and engaged in formal and informal course/seminars design:** Faculties were invited, oriented and motivated to get engaged in RCI education and research activities.

12. Interactions with research projects:

- **SUMREX** opportunities were communicated by researchers from three institutions, of which two were able to complete the process. Oregon State University (Dr. Dan Cox and Dr. John van de Lindt – two opportunities), and University of Central Florida/Louisiana State University (Dr. Stephen Medeiros/Dr. Scott Hagen- one opportunity). These initiatives were coordinated with Researchers during CRC meetings. Advertisements were posted including all requirements at the university. Interested students presented their credentials and we evaluated if students qualified. Students who qualified were advised to apply and referred directly to Research PI's for their evaluation. Two students were admitted at OSU (working at the O.H. Hinsdale Wave Research Laboratory (HWRL) on a research project related to hurricane wave and surge loads on coastal structures) and one student was admitted to UCF/LSU (working on the ADCIRC model (setup and parameterization) and how to run simulations on a high-performance computing cluster).

- Further interactions have taken place with other CRC research and educational PI's but most of pending actions are focused on Year 2 activities.

13. **Publications:**

- Robert W. Whalin of Jackson State University and Ismael Pagán-Trinidad of the University of Puerto Rico at Mayagüez, along with co-authors Evelyn Villanueva and David Pittman from the US Army Engineer Research and Development Center (ERDC), presented a paper entitled "A Quarter Century of Resounding Success for a University/Federal Laboratory Partnership" at the Minorities in Engineering Division Technical Session on June 27. The paper is to be published in the Conference Proceedings. Dr. Pittman is Deputy Director at ERDC, and Ms. Villanueva is ERDC's partnership coordinator. Submitted April 2016.

14. **CRC Performance Metrics:**

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)		10	
Undergraduates provided tuition/fee support (number)			
Undergraduate students provided stipends (number)			
Graduate students provided tuition/fee support (number)		5	
Graduate students provided stipends (number)		6	
Undergraduates who received HS-related degrees (number)			
Graduate students who received HS-related degrees (number)			
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)			
SUMREX program students hosted (number)			
Lectures/presentations/seminars at Center partners (number)			
DHS MSI Summer Research Teams hosted (number)			
Journal articles submitted (number)		1 (2016	
Journal articles published (number)		1 (to be	
Conference presentations made (number)		2	
Other presentations, interviews, etc. (number)		2	
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)			
Requests for assistance/advice from DHS agencies (number)			
Requests for assistance/advice from other Federal agencies or		5	
Total milestones for reporting period (number)			
Accomplished fully (number)		2	
Accomplished partially (number)			
Not accomplished (number)			
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Education Project Courses and Enrollments

Courses Developed and Taught by **University of Puerto Rico at Mayaguez** under Project **Education for Improving Resiliency of Coastal Infrastructure (RCI)**						
Course		Developed (D), Revised (R), and/or Taught (T), by Project Year				
Number	Title	1	2	3	4	5
INCI6XXX INCI5XXX	***"Coastal Resilient Structures (under development)"***- Dual codes for undergraduates and graduates	D				
	Offering: Elective (E), Concentration (C), Minor (M)	E				
	Enrollment	-				
CMOF8990	Special Problems in Physical Oceanography (Graduate): • ***"FUNWAVE Test Bed"*** • ***"Wave Energy Dissipation Derived from Video Imagery"***	T				
	Offering: Elective (E), Concentration (C), Minor (M)	E				
	Enrollment	2				
INCI6995	CE Special Problems (Graduate): • ***"A Novel Boussinesq -Type Numerical Wave Model Development"*** • ***"Stochastic Simulation of Tropical Cyclones for the Quantification of Uncertainty Associated with Storm Recurrence and Intensity: Phase II"*** • ***"Analysis of a Ring Levee Breach Using Adaptive Hydraulic"***	T				
	Offering: Elective (E), Concentration (C), Minor (M)	E				
	Enrollment	3				
INCI 5996	CE Special Problems (Undergraduate) • ***"Impact of Projected Sea Water Rise on Coastal Infrastructures"***	T				
	Offering: Elective (E), Concentration (C), Minor (M)	E				
	Enrollment	1				

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
ERIP Summer Research Internship Program (BAA Grant) – ERDC Students paid under RA support	Pagan	$95,760	ERDC-US Army Corp of Engineers
Leveraged Support			
Description			Estimated Annual Value
Release time for PI			$9,845

Release time for CoPI	$11,019
Climate Change Conference-Pagan & Lopez	$25,000

KEIM, LSU

DHS Coastal Resilience Center

Education Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Disaster Science and Management Program at LSU

2. **Principal Investigator / Institution:** Barry D. Keim, Professor in the Department of Geography and Anthropology and Louisiana State Climatologist.

3. **Other Education Participants/Partners:**
   - Baton Rouge Community College (BRCC)
   - NOAA's Southern Climate Impacts Planning Program.

4. **Short Project Description:**

   The Disaster Science and Management (DSM) Program at LSU was originally within the College of Humanities and Social Sciences (for 7 years), however, the educational structure of the program took place outside of any single Department. This Coastal Resilience Center of Excellence project builds a home for the DSM program at Louisiana State University by making it an integral part of the Geography degree program. We are making DSM a concentration available within both the BA and BS degrees in Geography, and as a minor to students with majors in other Departments. We will enhance relationships with the Emergency Management Program at BRCC to partner with them in program development and foster ease of credit transfer to LSU for those that want to continue to a Baccalaureate degree. Additionally, we will continue fostering internships within the Emergency Management community.

5. **Abstract:**

Louisiana's propensity for natural disasters (e.g., Hurricanes Katrina, Rita, Gustav, Ike, and Isaac) demonstrates a clear need for a robust Disaster Science and Management Program in the region. We are building on past successes, while providing a solid platform for the DSM program to thrive by formally bringing it into the Department of Geography and Anthropology. The Program will begin in the Fall 2016 as a concentration within the Geography undergraduate curriculum, whereas students can obtain either a BA or BS in Geography, with a DSM concentration, in addition to making the program available as a minor. A revised curriculum was developed for the Program, including both on-campus, and on-line courses, and it will build on past successes of the student internship program.

6. End users:

End User/Agency	Project Role	Expected Return/Benefit
Ms. Joanne Moreau, Director Mayor's Office of Homeland Security and Emergency Preparedness	• Provided internship for DSM student during Spring 2016 semester. • Hired DSM student as a student worker.	Student gained real-world experience with employment in a Homeland Security Enterprise position.
Ms. Amy Pinero, Chair Department of Social Sciences and History Baton Rouge Community College	• Build curriculum at BRCC	DSM PhD alum employed by BRCC to teach Fall 2016. Curriculum at BRCC serves as a potential gateway from the community college to the LSU DSM program. Increase student diversity at LSU as BRCC maintains a higher percentage of minorities vs LSU (45% at BRCC vs. 25% at LSU).
Mr. Garrett J. Romagossa, Disaster Program Manager American Red Cross, Baton Rouge Chapter	• Provided internship for DSM student during Spring 2016 semester. • Provided volunteer opportunities for DSM class	Student gained real-world experience with employment in a Homeland Security Enterprise position.
Rick Weber, Director Ascension Parish Emergency Management Offices	• Provided internship for DSM student during Spring 2016 semester.	Student gained real-world experience with employment in a Homeland Security Enterprise position.
Mr. Christopher Gilbeaux Deputy Director Louisiana Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP)	• Provided internship for DSM student during Spring 2016 semester. • Hired DSM student as a student worker. • Hired DSM graduate as a full-time employee.	Student gained real-world experience with employment in a Homeland Security Enterprise position.

7. Explanation of Changes:

No changes were made.

8. Unanticipated Problems:

The DSM program underwent structural changes within the university which involved over 20 forms that required department, college, and university approval. This process was much more tedious than anticipated, but was successful.

There was also vigorous debate regarding a name change to the LSU DSM program. Ultimately, the department retained the original name.

9. Project Outcomes:

This program will officially commence in Fall 2016, though we have maintained the curriculum to grandfather students through the original college-managed DSM program. The majority of the groundwork for the transition from the College of Humanities and Social Sciences to the Department of Geography and Anthropology was completed during the reporting timeframe.

<u>Certificate Program.</u> The DSM certificate/concentration program targets current LSU students and professionals interested in the field of Emergency Management (EM). The program appeals to working professionals in the EM area as well as others who desire to increase their skill set to include EM. Homeland Security Enterprises, including the Red Cross, GOHSEP, LSU Police, etc. were places for students to further their experiences.

Degree Program. We completed the process of developing the DSM concentration in the Department of Geography and Anthropology which will begin officially in Fall 2016. All current DSM courses have been reconstituted under the GEOG (Geography) rubric. These courses will be available to students in either the BA or the BS degree programs in Geography, whereby if they take the requisite core DSM courses, the student would be awarded a concentration in DSM along with their Geography degree. We will also host a minor degree program through the Department. This concentration should be of interest to employers in the Homeland Security Enterprise, both locally (i.e., MOHSEP - the Mayor's Office of Homeland Security and Emergency Preparedness), regionally (i.e., the Louisiana Department of Environmental Quality), and nationally (i.e., FEMA). Depending on the success of the program, a Graduate-level certificate in DSM may be developed in future years.

10. Education Activity and Milestone Progress:

Education Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Education Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
1. Continue to deliver DSM courses while formulate concentration in BA/BS DSM concentration to be moved into the school of Geography and Anthropology.	1/29/2016	100%	
2. Formulate draft of Certification Program.	2/29/2016	100%	
3. Partner with Baton Rouge Community College (BRCC) to develop BRCC DSM curriculum.	1/29/2016	100%	
Education Milestone			
1. Deliver at least three (3) DSM courses during the Spring 2016 semester. Submit documentation for DSM concentration in BS/BA DSM to the Department of Anthropology and Geography for approval	2/29/2016	100%	
2. Submit documentation for DSM certificate to the Department of Anthropology and Geography for approval	3/31/2016	100%	
3. Complete one (1) or more course curricula for Baton Rouge Community College (BRCC) DSM.	6/30/2016	100%	

11. **Transition Activity and Milestone Progress:**

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
1. Develop DSM Student Post-Graduation tracking method in order to document post-graduation activities.	1/29/2016	100%	
2. Partner with the American Red Cross Baton Rouge Chapter to offer service learning project for DSM 2010 course and DSMA student association.	1/29/2016	100%	
3. Develop a working document detailing end users in the HSE to include name, agency, contact information, etc.	1/29/2016	100%	
Transition Milestone			
1. Implement DSM Student Post-Graduation tracking method and document post-graduation activities in Homeland Security enterprises or continued grad school of 50-60% of Spring 2016 students.	5/31/2016	100%	
2. Through the partnership with the ARC, 60-75% students completing Spring 2016 DSM 2010 Fundamentals of Emergency Management will complete the service learning portion of that class.	5/31/2016	100%	
3. Input data into the working document that contains the contact information of at least fifteen (15) end users in the HSE.	4/29/2016	100%	

11. Interactions with research projects:

Rudy Bartels, PhD candidate and DSM instructor at LSU, participated in an internship through the CRC SUMREX program. He was hosted by Dr. Don Resio at the University of Northern Florida. He collaborated on research projects involving rainfall across the United States.

Dr. Barry Keim, Principal Investigator on this project, was invited by Gavin Smith to give a lecture for a course via Skype at the University of North Carolina Chapel Hill. The course was part of the Graduate Certificate program in Natural Hazards Resilience sponsored by the CRC.

Dr. Barry Keim gave a presentation at the Louisiana Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP) to researchers from South American countries as part of the USAID program which was hosted by Brant Mitchell from the Stephenson Disaster Management Institute (SDMI) and is a part of the CRC Research Project spearheaded by Dr. Robert Twilley (*Integrated Modeling Approaches ….for Creating More Resilient Communities*).

12. Publications:

Gilliand, J., and B.D. Keim. Submitted. Surface Wind Speed Trend Climatology of Brazil from 1980-2014. *Journal of Climate*.

Allard, J.M., J.V. Clarke, and B.D. Keim. In Press. Spatial and Temporal Patterns of In Situ Sea Surface Temperatures within the Gulf of Mexico (GoM), 1901–2010. *American Journal of Climate Change*.

Shao, W., S. Xian, B. Keim, K. Goidel, N. Lin. In Press. Understanding Perceptions of Changing Hurricane Strength Along the U.S. Gulf Coast. *International Journal of Climatology*.

Shao, W., J.C. Garand, B.D. Keim, and L.C. Hamilton. In Press. Science, Scientists, and Local Weather: Understanding Mass Perceptions of Global Warming. *Social Science Quarterly*. DOI: 10.1111/ssqu.12317

Hamilton, L.C, J. Hartter, B.D. Keim, A.E. Boag, M.W. Palace, F.R. Stevens, M.J. Ducey. In Press. Wildfire, Climate and Perceptions in Northeast Oregon. *Regional Environmental Change* 16(6):1819-1832. DOI: 10.1007/s10113-015-0914-y

Shankman, D., and B.D. Keim. 2016. Flood Risk Forecast for China's Poyang Lake Region. *Physical Geography* 37(1):88-91.

14. **CRC Performance Metrics:**

CRC Performance Metrics			
Metric	**Research Project**	**Education Project**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)		5	
Undergraduates provided tuition/fee support (number)		0	
Undergraduate students provided stipends (number)		0	
Graduate students provided tuition/fee support (number)		2	
Graduate students provided stipends (number)		2	
Undergraduates who received HS-related degrees (number)		4	
Graduate students who received HS-related degrees (number)		0	
Certificates awarded (number)		0	
Graduates who obtained HS-related employment (number)		2	
SUMREX program students hosted (number)			
Lectures/presentations/seminars at Center partners (number)		1	
DHS MSI Summer Research Teams hosted (number)		0	
Journal articles submitted (number)		1	
Journal articles published (number)		5	
Conference presentations made (number)		2	
Other presentations, interviews, etc. (number)		4	
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)		0	
Requests for assistance/advice from DHS agencies (number)		2	
Requests for assistance/advice from other Federal agencies or state/local governments (number)		5	
Total milestones for reporting period (number)		6	
Accomplished fully (number)		6	
Accomplished partially (number)		0	
Not accomplished (number)		0	
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Education Project Courses and Enrollments

Courses Developed and Taught by Louisiana State University under Project Disaster Science and Management						
Course		Developed (D), Revised (R), and/or Taught				
Number	Title	1	2	3	4	5
DSM 2000	**Hazards, Disasters, and the Environment**	T				
	Offering: Elective (E), Concentration (C), Minor (M)	C				
	Enrollment	150				
DSM 2010	**Fundamentals of Emergency Management**	T				
	Offering: Elective (E), Concentration (C), Minor (M)	C				
	Enrollment	54				
DSM 3910	**Hazards Seminar**	T				
	Offering: Elective (E), Concentration (C), Minor (M)	C				
	Enrollment	10				
DSM	**Practicum in Disaster Science and Management**	T				
	Offering: Elective (E), Concentration (C), Minor (M)	C				
	Enrollment	5				
DSM	**Crisis Management**	T				
	Offering: Elective (E), Concentration (C), Minor (M)	C				
	Enrollment	8				

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
Southern Climate Impacts Planning Program (SCIPP)	Keim	$358,000	NOAA

Leveraged Support	
Description	Estimated Annual Value
Salary for DSM instructor from LSU Deans Office: DSM 2200 Hazards, Disasters, and the Environment	$4,000
LSU salary for Geog-DSM Professor to teach one (1) course: DSM 4600 Crisis Management	$13,000

SMITH, UNC

DHS Coastal Resilience Center

Education Project:

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Expanding Coastal Resilience Education at UNC

2. **Principal Investigator / Institution:** Gavin Smith, Director, Coastal Resilience Center of Excellence; Research Professor, Department of City and Regional Planning. Rick Luettich, Professor, Department of Marine Sciences, University of North Carolina at Chapel Hill.

3. **Other Education Participants/Partners:** UNC Departments of Marine Sciences, City and Regional Planning, Geological Sciences, Law School, Center for Public Service

4. **Short Project Description:**

   UNC has significantly expand its capabilities in Coastal Resilience by developing a graduate certificate program in Natural Hazards Resilience and by hiring a tenure track faculty member (trained in physical science and/or engineering) in the area of Coastal Natural Hazards and Climate Science. The Certificate program, which started in the Fall of 2015, focuses on the nexus between the physical science underlying natural hazards phenomena and the policies, programs, and plans needed to help societies manage their effects and increase resilience. The faculty position will initially be 2/3 funded by UNC and 1/3 by the CRC. At the end of the CRC's fifth year, the faculty position will become fully funded by UNC to provide a long-term programmatic contribution to the Homeland Security enterprise.

5. **Abstract:**

   The 10-hour credit Natural Hazards Resilience certificate program focuses on the nexus between the threats and impacts of natural hazards and disasters on human settlements, including those exacerbated by climate change, and how individuals, organizations, communities, and larger systems of governance prepare for, respond to, mitigate against, recover from, and adapt to these events. Emphasis is placed on the concept of disaster resilience, or "the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events" (National Research Council 2012). The curriculum provides students with an academic and practice-based exposure to the science underlying our understanding of natural hazards phenomena and a critical analysis of the policies, programs, and plans in place that are intended to help societies manage the effects of natural hazards and disasters, to include a discussion of those actions that effect disaster resilience. The certificate program is designed to serve enrolled graduate students and is not available to practicing professionals located outside the university. Based on the high demand among employers for recent graduates who have studied with faculty associated with the former Coastal Hazards Center, we believe the certificate program will provide a significant enhancement to participating students' graduate education and competitiveness in the job market.

6. **End users:**

Key "end users" of the program are our students. The certificate program is open to master's and Ph.D. students from all departments at UNC-CH that have identified an advisor in their home department that is willing to work with the head of the certificate program or an advisor that is actively participating in the certificate program. A Program Director (Gavin Smith) and Certificate Coordinating Committee - comprised of one representative from the Department of City and Regional Planning (Nikhil Kaza), the CRC (Rick Luettich); the Law School (Don Hornstein); The Department of Public Policy (Pam Jagger), the Department of Marine Sciences (to be determined), the Department of Geological Sciences (Laura Moore); Carolina Center for Public Service (Lynn Blanchard); a student representative currently enrolled in the program (to be determined on a bi-annual basis); and one non-UNC-CH hazards scholar will review applications for admission. The Program Director and Certificate Coordinating Committee will also be responsible for assessing other certificate compliance issues, such as course credits, the transfer of courses from other universities (if applicable), the appropriateness of fieldwork or student internships, the possible creation of on-line courses, or other issues that may arise. In addition, students will create a student group in the Fall of the second year of the Certificate Program. This will allow for additional connectivity with practitioners through field trips, invited guest speakers, and assisting with post-disaster recovery efforts.

Additional end users are those that stand to gain from a trained pool of graduates. DHS constituent agency representatives (e.g., FEMA, US Coast Guard) other federal agencies (e.g., NOAA, US Army Corps of Engineers, US Geological Survey), professional associations (e.g., American Planning Association, Association of State Floodplain Manager's) and CRC Advisory Board members play an important role in the certificate program in a number of ways, including: 1) serving as invited guest speakers in courses, 2) hosting student interns as identified, 3) providing feedback on course content, and 4) notifying the Program Director of available job postings. Given the certificate's focus on disaster recovery and hazard mitigation, Matt Campbell (FEMA Disaster Recovery - Community Planning and Capacity Building) and Kathleen Smith (FEMA Hazard Mitigation – Planning Lead) will serve as federal agency end user contacts. They will advise on course content, conduct class lectures, and assist in the identification of internship and job opportunities). Both have served in this capacity for the last two years prior to the official start of the certificate program in the Fall of 2015.

End users have played a major role by serving as lecturer's in all classes. This is particularly the case in the certificate's speaker series course. The list of Spring speakers include:

1) William H. Hooke – Associate Executive Director and Senior Policy Fellow, American Meteorological Society. Author of Living on the Real World: How Thinking and Acting Like Meteorologists Will Help Save the Planet (CRC Advisory Board).
2) Tom Birkland – William T. Kretzer Professor of Public Policy, School of Public and International Affairs, North Carolina State University.
3) Barry Keim (via Skype) – Richard J. Russell Professor, Louisiana State University, State Climatologist (CRC PI).
4) Craig Fugate - W. Craig Fugate Administrator of the Federal Emergency Management Agency (FEMA).
5) David Perkes – Gulf Coast Community Design Studio, Professor Mississippi State University of Art + Architecture. David Perkes is an architect and Associate Professor at Mississippi State University. He is the founding director of the Gulf Coast Community

Design Studio, a professional outreach program of the College of Architecture, Art + Design.

6) Carl Bruch, Senior Attorney; Co-Director, International Programs, Environmental Law Institute.
7) Pam Rubinoff is a Senior Coastal Manager at the Coastal Resources Center where she works with U.S. and international partners to build capacity, create policy and provide technical assistance in Latin America, Southeast Asia, the Marshall Islands and Rhode Island (CRC researcher).
8) Dennis Wenger – Former Program Director, Infrastructure Systems Management and Extreme Events, National Science Foundation.
9) Gerald E. Galloway - is a Glenn L. Martin Institute Professor of Engineering with the Department of Civil and Environmental Engineering and an Affiliate Professor in the School of Public Policy, at the University of Maryland.

***7.* Explanation of Changes:**

The changes noted here are more accurately characterized as the natural expansion of the Natural Hazards Resilience Certificate Program and are indicative of how the certificate is being used to leverage other ideas and resources.

Students have suggested that the Lecture Series course, which is currently a 1 credit hour course, should be expanded to two hours in order to provide additional time for speakers and students to interact. This is a good development in that students see the merits of lengthening the course. The Lecture Series course may be expanded to 2 hours in the future.

The Career Development Grant (CDG), now called the Career and Workforce Development Grant (CWFDG) has been more closely linked to the Certificate in that students receiving the grant agree to pursue the certificate. This was not explicitly stated in the original workplan. Both 2016 recipients of the CWFDG are pursuing the certificate (as are/did the CDG grant recipients).

Students have developed a listserv called triangle resilience as a means to keep students and researchers interested in natural hazards resilience abreast of relevant activities in the region and beyond. Starting in the Fall of 2016, students are using the listserv as a catalyst for the creation of a student group. Activities being considered include hosting nationally recognized speakers, conducting post-disaster community service, conducting field trips or other activities as identified.

Classes have been supplemented by field trips, including one to Kinston, NC (Spring 2016) and Charlotte NC (Fall 2016). This is planned to be a regular occurrence in future classes.

Additional Leveraged Activities: Two activities have evolved as a result of the Certificate.

I. Additional classes taught during the workplan timeframe:

1) Independent Study: *The Role of States in Disaster Recovery* (3 hours) – (Spring 2016)
2) Independent Study: *Building Resilience to Coastal Hazards in Hawai'i: Strengthening the Post-Disaster Recovery Process* (2.5 hours) – (Summer 2016)
3) Venice International University in Partnership with Duke University. *Environmental Management in a Changing World: Coping with Sea Level Rise* (Summer 2016 – one-week summer course in Venice, Italy).

II. International Learning Laboratory Concept: The field trip to Kinston has led to the possible creation of a "learning laboratory" in eastern North Carolina where faculty and students can come to study and learn from the many unique features found here including

large-scale investments in hazard mitigation, the implementation of major disaster recovery projects and the inherent dynamism of the region, including its barrier islands. This concept has fostered a larger effort to develop other learning laboratories overseas. Potential areas include: 1) Australia (the CRC Director will visit Australia in August 2016 to discuss this concept and build on partnerships with the Natural Hazards Resilience and Bushfire CRC and other universities in Australia, namely RMIT and Macquarie University), 2) Vietnam (The CRC Director may visit Vietnam in December 2016 to discuss this concept and build on this concept with UNC colleague Dr. Mai Nguyen who has already established a two-year agreement with Vietnamese universities and the national government), and 3) Venice, Italy (building on partnerships established this summer while teaching at Venice International University).

8. Unanticipated Problems:

A primary challenge includes identifying appropriate supporting faculty and staff to assist with student mentoring, the co-funding of invited speakers, and the teaching of certificate classes. Given that the PI of this project is assuming the majority of getting the certificate established, this has been extremely time consuming.

The administrative challenges are being addressed by: 1) the hiring of a new faculty position who will assist in the teaching of certificate classes, 2) reaching out to DCRP faculty that can mentor or co-mentor students who are interested in studying natural hazards resilience-related topics and are pursuing the certificate, and 3) working more closely with certificate committee members to include getting them to support incoming speakers, conduct guest lectures, and teach certificate elective courses. Specific faculty members who are assisting in these efforts include Don Hornstein and Laura Moore (conducting class lectures), Mai Nguyen (co-mentoring certificate students), and Laura Moore (teaching certificate electives), and Danielle Spurlock (co-teaching Independent Study with student pursuing certificate). These challenges will be addressed through the development of a Faculty Fellows program that is scheduled to begin in the Winter of 2016.

9. Project Outcomes:

The project has accomplished the following: 1) created an Advisory Committee; 2) Received Certificate approval by the University Administration; 3) Developed and delivered all three courses scheduled (e.g., Planning for Natural Hazards and Climate Change Adaptation, Survey of Natural Hazards and Disasters, and the Lecture Series plus an Independent Study course); 3) Recruited and hired a new faculty member; 4) assisted three students obtain summer internships; 4) recruited seven new students to the Certificate Program, and 5) initiated the development of a Natural Hazards Resilience Student Group. Each of these accomplishments are necessary foundational elements that will help build a program that will graduate well educated students.

Our first Certificate recipient graduated this summer and is in the process of seeking employment (she was hired by the North Carolina Division of Emergency Management to assist with housing recovery following Hurricane Matthew after the close of the CRC reporting period). This follows her summer internship with the Maui County, Hawaii and Hawaii Sea Grant. Two other students participating in the certificate program had summer internships, including one with the US Department of the Interior and one with a private sector firm. The latter example was offered a part-time job with the firm in which she interned while she completes he master's degree.

The Certificate has gained increased recognition at UNC, particularly among prospective and incoming students in the Department of City and Regional Planning. Six new students stated in

their application that the reason they wanted to come to UNC was to study natural hazards and disasters and pursue the Graduate Certificate in Natural Hazards Resilience (two additional students from Duke University have applied as well). This is a significant achievement as the certificate is now widely recognized by students applying to one of the most prestigious planning programs in the country. As part of the Certificate Program, guest speakers are invited to discuss key topical areas and discuss career opportunities and those skills that appeal to them when they recruit new hires. This interaction between students and practitioners is a regular part of the program and provides a unique opportunity for students to query those that are looking for new graduates. As mentioned earlier, Matt Campbell and Kathleen Smith from FEMA, as well as a number of other practitioners have agreed to assist in the identification of job openings and their feedback on class materials helps to educate students on those aspects of resilience that are important in the marketplace. Both officials regularly provide notice of job positions as they are posted.

Additional evidence of the certificate's growing maturity is the formation of a student group, scheduled to begin in the Fall of 2016. This group will bring in additional speakers and may include: 1) hosting of job fairs for those who seek new graduates in this rapidly growing field, 2) hosting guest speakers, 3) participating in post-disaster assistance activities, and 4) the creation of a student-led workshop where students will present the research they are engaged in with the CRC and other organizations.

10. Education Activity and Milestone Progress:

Education Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Education Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Recruit tenure track faculty member (trained in physical science and/or engineering) in the area of Coastal Natural Hazards and Climate Science	January 2016	100%	
Recruit students into certificate program	June 2016	100%	
Teach two Spring semester core courses	June 2016	100+% (Taught 3 Spring semester classes, including two core and one Independent Study)	
Education Milestone			
Tenure track faculty member hired	June 2016	100%	

Six students admitted to certificate program	June 2016	70%	Four new certificate program applicants have applied and will be vetted by the Certificate Review Committee in the Fall of 2016. Others beginning in the Fall of 2016 will be encouraged to apply as they noted this on their application to UNC's Department of City and Regional Planning. At this point it appears that 3 or more additional students are going to apply for the certificate following Fall orientation which was held in August 2016. Note: 7 students applied during Fall 2016 term.
Survey of Natural Hazards and Disasters and Lecture Series courses taught	June 2016	100%	
Track student performance (including first graduate(s)) – some students will have completed required coursework as 2 core courses were offered before certificate was approved.	June 2016	100% (First certificate program student graduated in the summer of 2016)	

11. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Promote internship opportunities for students/recruit end users to host students	January 2016	100% (2016 Summer internships included Maui County Hawaii and HI Sea Grant; US Department of the Interior; AMEC Consulting. Internship opportunities posted on triangle resilience listserv.	

Promote certificate program graduates to potential employers	June 2016	100% (Promotion strategy includes inviting prospective employers to serve as class lecturers)	
Transition Milestone			
Establish a list of potential employers and secure commitments from them to support internships	June 2016	100% List of employers is an ongoing process and represents employers in the public (FEMA, NOAA, USACE), private (URS, AECOM, etc.), and others as identified.	

12. Interactions with research projects:

The following CRC PI's have lectured or will lecture in certificate classes: 1) Barry Keim – Spring 2016; 2) Brian Blanton Spring 2016, 3) Pam Rubinoff (Spring 2016), 4) Jeff Carney Fall 2016.

Note: the following CRC Advisory Board Members have lectured in certificate classes: 1) Ellis Stanley (Spring 2016), 2) William Hooke (Spring 2016). The following Certificate Committee Members have lectured in certificate classes: 1) Don Hornstein (Spring 2016), 2) Laura Moore (Spring 2016).

Research findings associated with the CRC- and FEMA-funded Role of States in Recovery project has been incorporated into class lectures to include the use of a training video on this topic. Research findings tied to the national evaluation of hazard mitigation plans (funded through the Coastal Hazards Center) has also been incorporated into classroom lectures. Research findings of other CRC PI's have been presented-see Keim, Blanton, Rubinoff, and Carney.

13. Publications (including journal article, training guide and training video):

Gavin Smith, Lea Sabbag and Ashton Rohmer. A Comparative Analysis of the Roles Governors Play in Disaster Recovery (submitted for review-Spring 2016).

Smith, Gavin, Lea Sabbag, Ashton Rohmer. Role of States in Recovery Video Training Guide. March 2016. Chapel Hill, North Carolina: Department of Homeland Security, Coastal Resilience Center of Excellence.

Smith, Gavin. March 2016. Role of States in Disaster Recovery Video. Produced by Horizon Video Productions, Durham North Carolina. (30 minutes).

14. **CRC Performance Metrics:**

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)		2	
Undergraduates provided tuition/fee support (number)			
Undergraduate students provided stipends (number)			
Graduate students provided tuition/fee support (number)		2	
Graduate students provided stipends (number)			
Undergraduates who received HS-related degrees (number)			
Graduate students who received HS-related degrees (number)			
Certificates awarded (number)		1	
Graduates who obtained HS-related employment (number)		1	
SUMREX program students hosted (number)			
Lectures/presentations/seminars at Center partners (number)			
DHS MSI Summer Research Teams hosted (number)			
Journal articles submitted (number)		1	
Journal articles published (number)			
Conference presentations made (number)		6	
Other presentations, interviews, etc. (number)			
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)			
Requests for assistance/advice from DHS agencies (number)			
Requests for assistance/advice from other international, Federal or state agencies state/local governments (number)			4
Total milestones for reporting period (number)			
Accomplished fully (number)		9	
Accomplished partially (number)		1 (see above)	
Not accomplished (number)			
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

Table for Documenting CRC Education Project Courses and Enrollments

Courses Developed and Taught by University of North Carolina at Chapel Hill under Project Natural Hazards						
Course		Developed (D), Revised (R), and/or Taught				
Number	Title	1	2	3	4	5
PLAN 754	Natural Hazards Resilience Speaker Series	D/T				
	Offering: Elective (E), Certificate (C), Minor (M)	C				
	Enrollment	15				
PLAN 756	Survey of Natural Hazards and Disasters	D/T				
	Offering: Elective (E), Certificate (C), Minor (M)	C				
	Enrollment	14				
PLAN	Independent Study: The Role of States in Disaster	D/T				
	Offering: Elective (E), Certificate (C), Minor (M)	C				
	Enrollment	1				
PLAN	Independent Study: Building Resilience to Coastal					
	Offering: Elective (E), Certificate (C), Minor (M)	C				
	Enrollment	1				

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
N/A			
Leveraged Support			
Description			Estimated Annual Value
N/A			

KNIGHT, UMD

DHS Coastal Resilience Center

Education Project

Annual Project Performance Report

Covers reporting period January 1, 2016 – June 30, 2016

1. **Project Title:** Development and Testing of a Project Management Curriculum for Emergency Managers

2. **Principal Investigator:** Sandra K. Knight, PhD, PE, D.WRE, D.NE, Senior Research Engineer, Department of Civil and Environmental Engineering, University of Maryland, College Park. Lead investigator for research and key advisor for emergency management training and curricula content.

   Co-Principal Investigator: John Hart Cable, Director, Project Management Program, A. James Clark School of Engineering, University of Maryland. Lead advisor for Project Management curricula and certification.

3. **Other Education Participants/Partners:**
   - Gerald E. Galloway, PhD, PE, NAE, Glenn L. Martin Institute Professor of Engineering, Department of Civil and Environmental Engineering, University of Maryland
   - Lewis E. Link, PhD, Senior Research Engineer, Department of Civil and Environmental Engineering, University of Maryland
   - Gregory Baecher, PhD, PE, Glenn L. Martin Institute Professor of Engineering, Department of Civil and Environmental Engineering, University of Maryland

4. **Short Project Description:**

   The goal of this educational work plan is to develop and test an educational and training curriculum that prepares professionals to manage and deliver disaster-related project(s), by merging the unique challenges of emergency management with the capabilities and technologies introduced by applying project management processes. By incorporating modern project management organizational processes, technologies, and skills, emergency managers will be able to manage and execute disaster-related projects and meet resilience goals more effectively and efficiently. By building disaster resilient concepts and emergency protocols and goals into project management processes, project managers will be equipped to contribute to a more sustainable and disaster-resilience future.

5. **Abstract:**

Emergency managers are often assigned to lead many of the emergency activities and oversee the execution of large programs in the wake of disaster that are funded through federal and state programs. Also agencies and organizations (federal, state and local governments, utilities, non-profits, private industry, etc.) with a strong reliance on contract support and expertise, may be responsible for the response and recovery for sector-specific projects or program execution (marine transportation, healthcare, supply chain, utilities, etc.). Therefore, it is imperative, in this often urgent environment, that project and emergency

managers have the right training and educational skills to effectively deliver projects on-time and on-budget while being considerate of the needs of the community and planning for a resilient future.

There does not currently exist an explicit program that merges emergency management and project management curriculum for the purposes of advanced learning or certification for practitioners. This research will aim to support existing certifications, and both degree and non-degree programs. Practitioners in emergency management and project managers who carry out emergency management activities will have the opportunity to hone their knowledge and skills through a set of courses that will be offered through the existing UMD Project Management Program. Additionally, through collaboration and coordination with existing accreditation programs, specific emergency training institutes (like the Emergency Management Institute), other academic institutes of higher learning and DHS supported programs, targeted training materials and short-courses will be developed and opportunities identified for providing the broadest access possible for practitioners.

The proposed research comprises three distinct phases: 1) understanding the requirements and needs of practitioners and developing a disaster-focused project management curriculum to be offered within the UMD Project Management program, 2) developing training and short course curriculum that align with existing certification programs, and 3) executing initial course offerings and/or training programs for delivering the developed approaches and technologies to practitioners.

6. **End users:**

The following partners, collaborators and potential end-users have or will be contacted to participate in a needs interview, provide guidance and direction on existing certification requirements, collaborate on and/or review course curriculum development and either enroll or offer courses and training developed from this education research.

Initial contact and discussions have been carried out with a number of the people/Institutes identified below. Interviews were conducted the last week of July, 2016 and first week of August, 2016 with 20 experts. Names of some are below, but others identified in the consulting fields and with other related organizations were also included. Further, at each phase of the project, organizations and individuals will be asked to provide feedback and confirmation on products.

- Project Management Institute (PMI), John Hart Cable, Director PMP, UMD is coordinating this effort through the existing collaboration UMD has with PMI.
    - Role: PMI provides three certifications in project management. Working with both PMI and IAEM, this project will attempt to establish training and curricula that satisfies certifications and could potentially be accredited by both. Additionally, because of the close relationship UMD has with PMI, opportunities will be sought to collaborate and leverage resources to make the effort a success.
- International Association of Emergency Management (IAEM), IAEM Certification Coordinator, Daryl Spiewak.
    - Role of IAEM: IAEM provides two certifications in emergency management. Working with both PMI and IAEM this project will attempt to establish a connection between these two programs and identify curriculum that could be accredited by both.

- FEMA Federal Coordinating Officers, Director, TBD
    - Role: Identify requirements for federal and state coordinating officers in executing disaster programs and create training and curriculum that would support those needs. Use office as an opportunity to transition PM training into the FCO training and identify professionals interested in program.
    - Currently 3 current or former FCO's have been identified to participate in a needs survey: Libby Turner, Gracia Szczech, Tony Russell
- DHS Center for Domestic Preparedness, Anniston, AL, TBD
    - Role: establish training and curriculum needs, leveraging opportunities and resources and establishing opportunity to transition training products to their organization.
- DHS Emergency Management Institute (EMI), Emmitsburg, MD. Supervisor, Tony Russell, and Lillian Virgil, Chief Mitigation Branch
    - Role: establishing training and curriculum needs, leveraging opportunities and resources and establishing opportunity to transition training products to their organization.
- DHS FEMA Recovery Directorate, Matt Campbell, Branch Chief, National Coordinator Community Planning and Capacity Building
    - Role: serve as key sponsor to help identify best recovery program training opportunities and develop content. Opportunities to support the National Disaster Recovery Framework and leverage resources will be sought with this organization.
- FEMA Emergency Management Higher Education Program, Wendy Walsh, Program Manager
    - Role: learn how UMD can interface with this program and establish an opportunity to contribute to the Higher Education Program
- FEMA Director, National Training and Education System, Gerald White
    - Role: Along with EMI the development of the education program and course offerings will be closely coordinated with the EMHEP and NTES at FEMA. Opportunities to obtain financial or in kind support will be sought through their programs to leverage grant resources funded under this plan.
- National Emergency Managers Association, Paul Hogue
    - Role: NEMA could provide an opportunity to advertise the course offerings to its members which cover all the state emergency management agencies and FEMA and provide critical input to program development
- District of Columbia Homeland Security Emergency Management Agency, State Hazard Mitigation Officer, Donte Lucas
    - Role: HSEMA will be used to identify practitioners to help develop and test the course curriculum.
- Maryland Emergency Management Agency, TBD
    - Role: NEMA and connections to State emergency management agencies will be used to identify practitioners to help develop and test the course curriculum
- Jackson State University, DHS Coastal Resilience Center of Excellence, Tom Richardson
    - Role: As education partner lead for the CRC, UMD will coordinate and seek advice for improving and enhancing the work plan
- National Center for Security and Preparedness, Director Rick Mathews
    - Role: Can provide lessons learned and identify potential partners form their experiences as a COE
- State University of New York, David Rousseau, Dean College of Emergency Preparedness, Homeland Security and Cyber Security

    - Role: Can provide lessons learned in establishing their new college in emergency management
- National Consortium for the Study of Terrorism and Responses to Terrorism (START), UMD, Holly Roberts and Michael Egnoto
    - Role: potential on campus partner to mutually support, promote and leverage programs as well as provide critical input into needs and curriculum development
- University of Maryland University College, Emergency Management curriculum faculty adjunct, Cliff Oliver
    - Role: Advisor on curriculum and point of contact with UMUC and potential guest lecturer at UMD
- University of the District of Columbia, Chair Civil Engineering, Pradeep Behera
    - Role: Partnerships and collaboration with other academic institutes including but not limited to these will be used to 1) improve curriculum development, 2) collaborate on projects, symposia and training, 3) identify students that could participate with the PIs and interface with practitioners to validate content and usefulness of curriculum.
- National Disaster Preparedness Training Center (NDPTC) at University of Hawaii, Tim Manning, Deputy Administrator for Preparedness, FEMA and Karl Kim, Director NDPTC
    - Role: Consider as potential training deliverer and partner to develop a course or courses to be offered through their program.

7. Explanation of Changes:

The Year 2 Workplan updates provided to the CRC on April 22, 2016 reflected and explained all modifications in Year 1 and beyond from the original work plan submitted August 2015 prior to DHS S&T approval and funding in January 2016. Since award, there were some minor shifts in funding. One modification resulted from an unnecessary requirement to support an intern in the SUMREX program. In discussions with the CRC Education Director at the March 2016 PI meeting, this project does not lend itself to supporting an intern. Therefore, budgets were modified to reflect that change. RETALK can be considered in Year 2 or Year 3 to replace the SUMREX activity. Further, by the time funding arrived in January 2016, it was too late to identify and hire a graduate student. These funds were shifted to contract support. Delays in contracting and some shifts in travel funding required a carryover of funds which was requested by the PI to CRC on June 2, 2016.

There were only shifts to two milestones and one related transition milestone (all documented in the Year 2 work plan updates under review). These shifts were in part due to receipt of final approval and funding by UMD, but also due to 1) administrative delays at UMD of putting a sole-source contract in place to conduct a needs assessment and 2) adding attendance of an EMI higher education summer symposium in June. Both of these efforts will contribute to a better product. This should not impact overall effort. Other activities can be completed as scheduled.

8. Unanticipated Problems:

There were no real problems of concern. The biggest challenge was just getting things in place in January to get started and dealing with the unexpected challenge by the PI of putting sub-contracts in place at UMD. This has been resolved and processes should be better

understood moving forward.

9. Project Outcomes:

Natural Disasters between 2003 and 2012 resulted in estimated global average annual economic losses of $156.7 billion and average annual deaths of 106,654[4]. Following the tremendous losses that come with these disasters, come billions of dollars for emergency management activities that must be managed by federal, state and local agencies and/or organizations. For instance, the federal disaster appropriations following Hurricane Sandy were approximately $58 billion[5] and were dispersed via many programs and agencies with specific regulatory or policy requirements for execution. Disaster relief funds such as these are spent to get communities back on their feet by replacing or rebuilding critical infrastructure, key facilities, businesses and homes. Further, the organized response to a disaster shares all the characteristics and has all the organizational needs of a built project. It is also well understood that building resilience into our built, social and environmental systems prior to an event has recurring benefits to disaster losses. Therefore, resources are often allocated for mitigation following a disaster as well as on "sunny days."

Project outcomes:

- Help professionals, whether emergency managers or project managers, more effectively and efficiently deliver projects and programs to provide for a disaster resilient future.
    - Broaden and/or improve the skills and capabilities of emergency management workforce professionals
    - Educate program and project delivery professionals on the complexities and unique requirements that arise in the face of disaster
- Identify and link the best practices and lexicons of emergency management and project management
- Develop test courses/training/curriculum that can be easily adapted and used by other institutes of learning

[4] Guha-Sapir D, Hyois Ph., Below R. *Annual Disaster Statistical Review 2013: The Numbers and Trends.* Brussels: Center for Research on the Epidemiology of Disaster (CRED): 2014

[5] https://www.congress.gov/113/plaws/publ2/PLAW-113publ2.pdf

10. Education Activity and Milestone Progress:

Education Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Education Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Next key milestone is in future period.			
Education Milestone			
Needs assessment: to include review of literature and existing academic and accreditation programs, interviews with subject matter experts, case history review. (Needs assessment report)	07/31/16*	85%	A shift was requested from a completion date of 05/30/16 to 07/31/16 in the YR2 work plan update due to expected time needed to put a contract in place and to attend EMI higher education symposium. Due to delays at UMD the actual contract did not get into place for the needs assessment until June 6, 2016. Expected completion is now August 30, 2016
Top Priority Course Curriculum Offerings Descriptions: completion of 3 introductory course prospectus and targeted scheduling for initial delivery in year 2 and/or year 3 (depending upon university capacity): Course Prospectus and University Approval	08/30/16*	20%	A shift was requested from a completion date of 06/30/16 to 08/30/16 in the YR2 work plan update to be able to incorporate ideas that might come from needs assessment. Some concepts for courses have been collected and prospectus begun. However, the expected completion is now September 30, 2016.
*reporting these milestones as they were originally scheduled in Year 1 but were requested to be shifted to Year 2 and April, 2016 and have not received feedback.			

11. Transition Activity and Milestone Progress:

Transition Activities and Milestones: Progress to Date

Reporting Period 1/1/2016 – 6/30/2016			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Transition Milestone			
Collaboration and Communication with Emergency Management training professionals in development of curricula requirements. Key contacts will be made and contracting support, if needed, will be identified. The effort will be continuous throughout program.	04/30/2016	100	As noted in milestones, contracting support was delayed. However, numerous contacts have been identified and many called or consulted in development of this work plan. A list of 20 individuals were identified for interviews for the needs report and many more for future collaborative efforts. The higher education symposium offered a wide opportunity for the PI to make contacts and discuss her efforts with other professionals. This type of collaboration will continue throughout the project.
Collaboration and Communication with certification program officials for accreditation of project management training. Key contacts at potential certifying organizations will be made early, but effort will be continuous throughout program.	04/30/2016	100	Key contacts were identified and initial discussions were held with IAEM and PMI certification officials regarding requirements for certification. This will be continuous and as curriculum is developed, these organizations will be included in review.
Distribute Needs Assessment report	07/31/16*	20	A shift was requested 06/30/16 to 07/31/16 in the YR2 work plan update to put a contract in place. This cannot be completed until contractor provides report (see milestone above). However, a list of organizations and individuals are identified to provide feedback. Expected completion 9/30/2016
Site visits and other correspondence to FEMA Headquarters, EMI, CDP and/or others in development of needs. (This will continue throughout project)	06/30/16	100	Contacts have been made and interviews scheduled with FEMA, EMI staff and others. Additionally, PI attended a 4-day symposium on higher education at EMI. This continues throughout project.
*reporting these milestones as they were originally scheduled in Year 1 but were			

requested to be shifted to Year 2 and April, 2016 and have not received feedback.			

12. Interactions with research projects: None to date

13. Publications: None to date

14. **CRC Performance Metrics:**

CRC Performance Metrics			
Metric	**Research**	**Education**	**Center**
Courses/certificates developed, taught, and/or modified		See Table	
Enrollments in Center-supported courses/certificates			
HS-related internships (number)			
Undergraduates provided tuition/fee support (number)			
Undergraduate students provided stipends (number)			
Graduate students provided tuition/fee support (number)			
Graduate students provided stipends (number)			
Undergraduates who received HS-related degrees (number)			
Graduate students who received HS-related degrees (number)			
Certificates awarded (number)			
Graduates who obtained HS-related employment (number)			
SUMREX program students hosted (number)			
Lectures/presentations/seminars at Center partners (number)			
DHS MSI Summer Research Teams hosted (number)			
Journal articles submitted (number)			
Journal articles published (number)			
Conference presentations made (number)			
Other presentations, interviews, etc. (number)		25	
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)			
Requests for assistance/advice from DHS agencies (number)		2	
Requests for assistance/advice from other Federal agencies or		3	
Total milestones for reporting period (number)**		3	
Accomplished fully (number)		3	
Accomplished partially (number)			
Not accomplished (number)			
Product/s delivered to end-user/s (description and recipients)	See Table		
External funding received	See Table		
Leveraged support			
Articles on Center-related work published on website (number)			
Coverage in media, blogs (number)			
Social media followers (number)			
Posts to social media accounts (number)			
Events hosted (number)			
Website hits (number)			

*Interviews for needs assessment included federal and state governments, primarily DHS, FEMA and DC HSEMA
**This number reflects total (education and transition milestones) due by 06/31/2016 based on updated YR2 Workplan submitted in April.

Table for Documenting CRC Education Project Courses and Enrollments (**N/A)**

Courses Developed and Taught by Name of University under Project Title						
Course		Developed (D), Revised (R), and/or Taught				
Number	Title	1	2	3	4	5
N/AN/A						
Offering: Elective (E), Concentration (C), Minor (M)						
Enrollment						

Table for Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
N/A			
Leveraged Support			
Description			Estimated Annual Value
N/A			

COASTAL RESILIENCE CENTER
A U.S. Department of Homeland Security Center of Excellence

Appendix A: Administrative and Management Report

ANNUAL PERFORMANCE REPORT
April, 2015 – June 30, 2016

This report, which covers April 2015 to June 30, 2016, represents a description of the accomplishments of the Coastal Resilience Center's first year of operations. The first section of the report focuses on a general overview, including a number of key tasks associated with standing up the center. Specific areas covered include: 1) the Coastal Resilience Center's organizational structure, administration and management; 2) CRC Research focus areas and projects; 3) Education and workforce development projects and activities; 4) Development of CRC administrative documents; 4) Transition of research to practice; 5) Activities and accomplishments; and 6) Next steps. The remainder of the document describes in detail the research and education projects that are currently funded through the CRC.

Organizational Structure, Administration and Management

The activities of the CRC are guided by the following vision, mission and strategic objectives.
Vision: The Coastal Resilience Center of Excellence (CRC) will be the premier university-based facility in the United States focused on research, education and workforce development, and transition to advance coastal resilience.
Mission: The CRC will conduct research and education to enhance the resilience of the Nation's people, infrastructure, economies, and the natural environment to the impacts of coastal hazards such as floods and hurricanes, explicitly including the effects of climate change.
Strategic Objectives:

- Expand our understanding of coastal resilience through rigorous, integrated, interdisciplinary, and actionable research.
- Develop new tools and methods to assess and enhance physical, social, economic, environmental, and institutional resilience.
- Transfer the resulting knowledge, tools, and methods into widespread practice.
- Educate and train the next generation of scholars and practitioners

Coastal Resilience Center Administration and Management

The CRC is overseen by the Principal Investigator and administered by a management team led by the full-time Director. Other members of the management team include the Director of Education /Workforce Development and the Transition Director. Administrative support is provided by the Communications Coordinator, the Program Manager, and a shared Unified Business Center. Guidance for Center policies and activities is provided by the CRC Advisory Board (Figure 1).

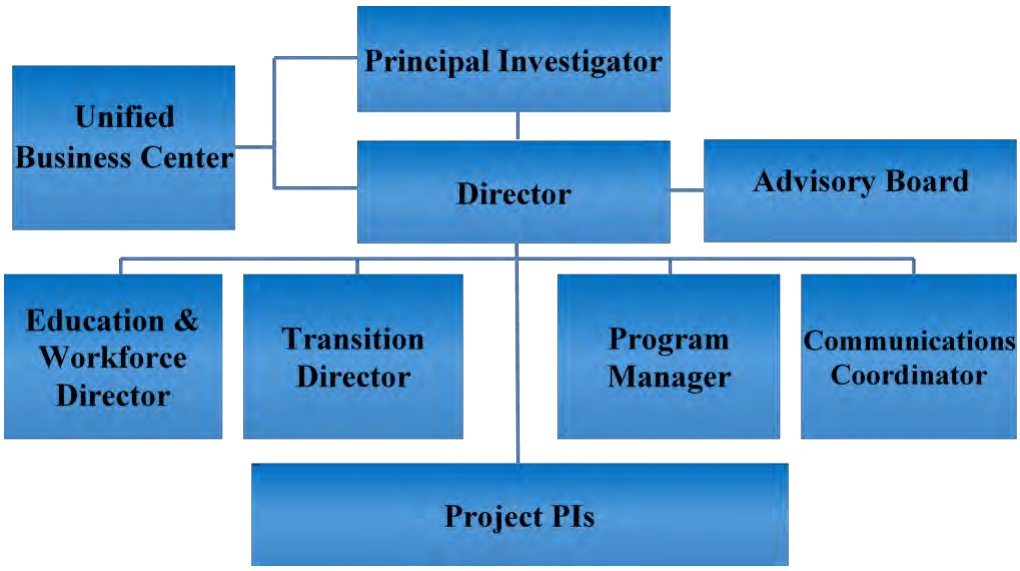


Figure 1. Coastal Resilience Center Organization Chart

CRC Advisory Board

The CRC Advisory Board is comprised of recognized experts in coastal resilience spanning, research, policy, and education. The primary roles of the Advisory Board include: 1) review and provide feedback on overall Center activities, 2) review and help evaluate Center projects, 3) help identify transition partners, 4) serve as subject matter experts as needed, and 5) provide support for CRC's education and workforce development program. Current membership of the CRC Advisory Board is shown in Appendix _.

Table 1. CRC Advisory Board Members

- Doug Bellomo, Engineer, Flood Risk Management Program, US Army Corps of Engineers / Institute for Water Resources
- Chad Berginnis, Executive Director, Association of State Floodplain Managers
- Dr. Curtis B. Charles, Vice President, Research, Development & Innovation RLM Communications, Inc.
- Dr. John Cooper, Associate Professor of Practice, Texas Target Communities Director, Texas A&M University
- Todd Davison, Manager, NOAA's Gulf Coast Services Center
- Dr. Reginald DesRoches, Dean's Professor and Chair, Civil and Environmental Engineering, Georgia Institute of Technology
- Dr. David Godschalk, Stephen Baxter Professor Emeritus, Department of City and Regional Planning, University of North Carolina at Chapel Hill
- Dr. Gerry Galloway, Glenn L. Martin Institute Professor of Engineering, University of Maryland
- Dr. Diana Harrington, Distinguished Professor of Finance, Babson College
- Jeffery Holland, Director, Engineer Research and Development Center, US Army Corps of Engineers
- Dr. William Hooke, Senior Policy Fellow and Director of Policy Program, American Meteorological Society
- Dr. James Houston, Director Emeritus, Engineer Research and Development Center
- Dr. Gary LaFree, Director, National Consortium for the Study of Terrorism and Responses to Terrorism (START)
- Dr. James R. Martin, Professor and Chair of Civil Engineering, Clemson University
- Dr. Jae Park, Recovery and Hazard Mitigation, AECOM

- Dr. John Pine, Director, Research Institute for Environment, Energy & Economics, Appalachian State University
- Anthony Pratt, Shoreline and Waterway Administrator, State of Delaware
- Dr. Linda Rimer, Environmental Protection Agency Region 4 Liaison for Climate Resilience
- Ellis Stanley, Executive Vice President, Hammerman & Gainer International and former General Manager, City of Los Angeles Emergency Preparedness Department
- Dr. Lee Weishar, Senior Scientist, Woods Hole Group, Inc.

Special Advisory Board Liaison to the US Coast Guard:

- Dr. Joe DiRenzo, Senior Advisor for Science, Technology and Innovation, US Coast Guard, Atlantic Area Command.

CRC Research Focus Areas and Projects

The CRC research portfolio addresses resilience via a suite of projects spanning three research themes. ***Building Resilient Communities*** involves a focus on decision-making processes, to include evaluating insurance; planning for hazard mitigation, disaster recovery, and climate change adaptation; developing indicators and metrics to measure disaster recovery outcomes; and creating tools to convey findings. ***Disaster Dynamics*** emphasizes advancing computer modeling capabilities for predicting storm surge, waves, and flooding associated with severe weather events along the U.S. East and Gulf Coasts and communicating the results of these predictions to improve coastal resilience. ***Coastal Infrastructure Resilience*** is analyzed in the context of physical, economic, environmental and social infrastructures and the degree to which they are interdependent. This provides a way to assess vulnerability and robustness and develop tools to assist practitioners. Table 1 lists the current CRC research projects, PI's, and their institutions.

Table 1 - CRC Research Projects

Research Theme 1: Coastal Infrastructure Resilience	
1	Decision Technologies to Support Coastal Infrastructure Resilience (A. Wallace, RPI)
2	Establishment Of A Remote Sensing Based Monitoring Program For Performance Health Assessment Of The Sacramento Delta (Bennett, RPI)
3	Experimental And Numerical Study To Improve Damage And Loss Estimation Due To Overland Wave And Surge Hazards On Near-Coast Structures -- (D. Cox, OSU)
Research Theme 2: Building Resilient Communities	
4	Implementing The Disaster Recovery Tracking Tool (J. Horney, Texas A&M)
5	A Framework For The Conceptualization Of Resiliency: Prioritization And Alignment Of Mitigation Strategies (L. Atkinson, ODU)
6	Local Planning Networks And Neighborhood Vulnerability Indicators (P. Berke, Texas A&M)
7	An Interdisciplinary Approach To Household Strengthening And Insurance Decisions (R. Davidson, U Of Delaware)
8	Communicating Risk To Motivate Individual Action (J. Prochaska, CPRC, URI)

9	Overcoming Barriers To Motivate Community Action To Enhance Resilience (J. Opaluch, URI)
Research Theme 3: Disaster Dynamics	
10	The Incorporation Of Rainfall Into Hazard Estimates For Improved Coastal Resiliency (D. Resio, UNF)
11	A Multi-Tiered ADCIRC-Based Storm Surge And Wave Prediction System (B. Blanton, UNC)
12	Development Of An Optimized Hurricane Storm Surge - Wave Model For The Northern Gulf Of Mexico For Use With The ADCIRC Surge Guidance System (S. Hagen, LSU)
13	Improving The Efficiency Of Wave And Surge Models Via Adaptive Mesh Resolution (J. Dietrich, NCSU)
14	Modeling The Combined Coastal And Inland Hazards From High-Impact Hypothetical Hurricanes (C. Kincaid; I. Ginis, URI)
15	Integrated Approaches To Creating Community Resilience Designs In A Changing Climate (R. Twilley, LSU)

Education and Workforce Development Projects and Activities

The CRC addresses education and workforce development by formulating and delivering resilience-oriented undergraduate and graduate courses, concentrations, minors, certificates, and training, with strong emphasis on Minority Serving Institutions (MSIs). Focus areas include coastal and computational engineering, computer science and engineering, social science, coastal infrastructure, disaster science, natural hazards resilience, and project management for emergency managers. CRC education and workforce development projects integrate with CRC research projects through seminars, workshops, and faculty/student summer internships. Table 2 lists the current CRC education and workforce development projects, PIs, and their institutions. Figure 2 shows the geographic distribution of all current CRC projects.

Table 2 - CRC Education and Workforce Development Projects	
1	PhD In Engineering (Coastal/Computational) At An HBCU - Jackson State University (R. Whalin, JSU)
2	Preparing Tomorrow's Minority Task Force In Coastal Resilience Through Interdisciplinary Education, Research, And Curriculum Development (H. Chen, JCSU)
3	Institutionalization, Expansion, And Enhancement Of Interdisciplinary Minor: Disaster And Coastal Studies (M. Laiju, TC)
4	Education For Improving Resiliency Of Coastal Infrastructure (I. Pagan-Trinidad, UPRM)
5	Disaster Science And Management Program At LSU (B. Keim, LSU)
6	Development And Testing Of A Project Management Curriculum For Emergency Managers -- (S. Knight, UMD)
7	Expanding Coastal Resilience Education At UNC - University Of North Carolina (G. Smith, UNC)

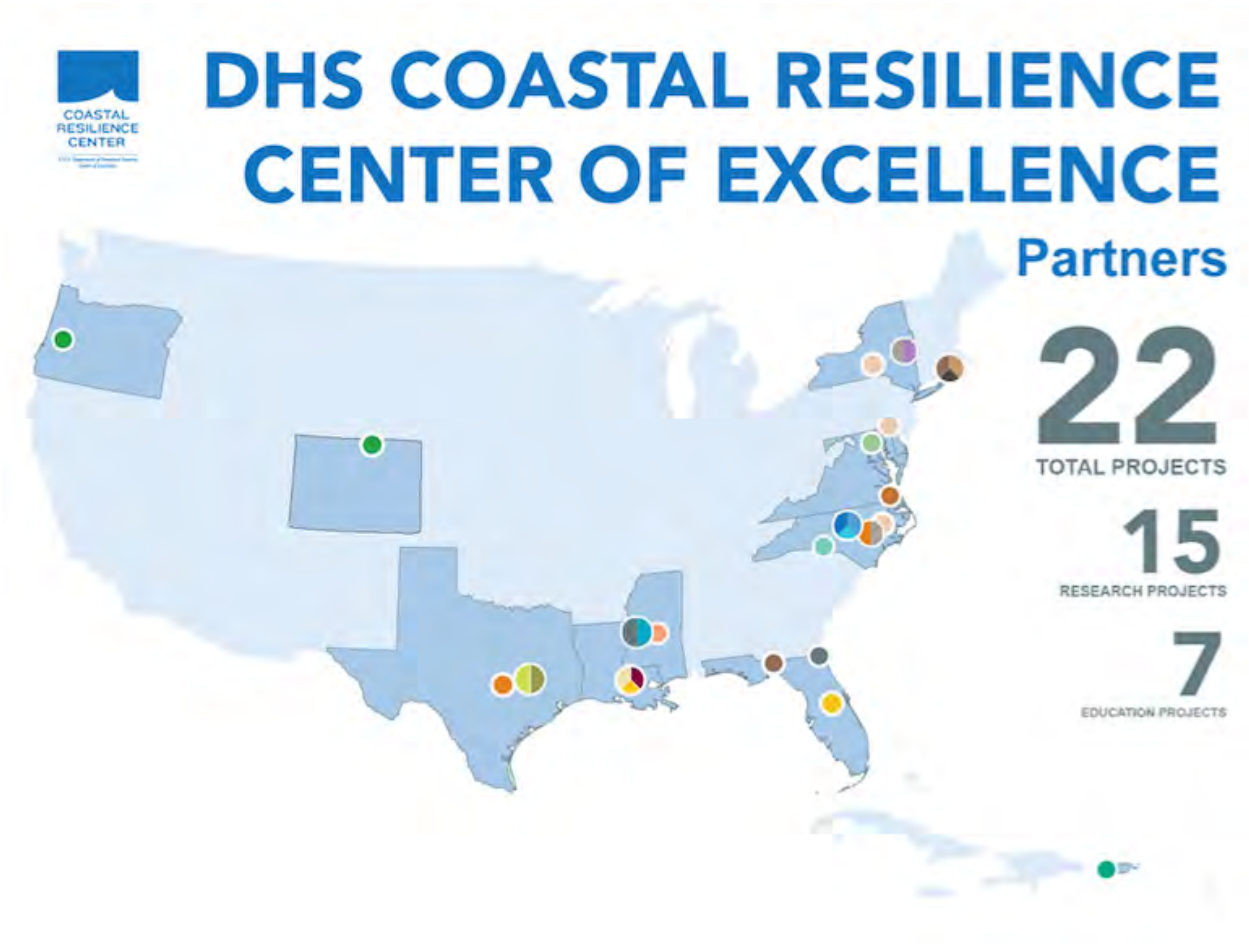


Figure 2. Locations of CRC Projects

The Summer Research Experience (SUMREX) program provides summer research experiences with CRC research partners for students from CRC education partners. The SUMREX program has three objectives:

- Provide meaningful summer research experiences with CRC research partners for students from CRC education partners.
- Foster collaboration and integration among CRC research and education projects.
- Encourage student/professor relationships that could lead to graduate studies at CRC research partners.

The Research Talk program, or RETALK, involves research PI's delivering an in-person talk to students at a CRC education partner. The talk may be a lecture, seminar, or other type of presentation. Considering the breadth of coastal resilience, the CRC encourages research PI's to discuss research projects not only in disciplines similar or complementary to ones being taught by the education partner, but also those that may offer enrichment opportunities by exposing students to other scientific or technical areas. The RETALK program has four objectives:

- Disseminate knowledge about CRC research partners and their activities to students from CRC education partners.
- Foster collaboration and integration among CRC research and education projects.
- Encourage interest among students from CRC education partners in graduate studies at CRC research partners.

- Strengthen the SUMREX program by enhancing relationships between CRC research and education Principal Investigators (PI's).

The Career Development Grant (CDG) and Science and Engineering Workforce Development (EWD) Grant program has funded four students at the University of North Carolina at Chapel Hill who are pursuing the 10-credit hour UNC-based Natural Hazards Resilience Certificate (which is one of the CRC education projects) and agree to work in the field upon graduation for not less than two years. Additional requirements include attending two professional conferences and interning over two summers in select organizations. The first CDG student, Lea Sabbag, graduated in the summer of 2016. During her time in the program she interned at the North Carolina Division of Emergency Management and Maui County Hawaii. Ashton Rohmer, who is beginning her second year in the program interned this summer with the Department of the Interior in Washington, D.C. Two incoming students, Darien Williams and Colleen Durfee will begin the program in the Fall of 2016.

Development of CRC Administrative Documents

During the first year of the CRC's existence the management team focused on the creation of several documents intended to guide center activities and provide direction to PI's, assist in the measurement of success, convey accomplishments and keep end-users and others abreast of our activities, including key Center objectives. These documents include our:

- Strategic Plan
- Communications and Branding Plan
- Research Safety Plan
- Data Acquisition Management Plan
- Sensitive Information Protection Plan

The Strategic Plan describes our Center's vision and mission, as well as key objectives used to help guide broader management and administrative initiatives and the three central aspects of the center, including research, education and workforce development and the transition of research findings to practice.

The Communications and Branding Plan defines who we are as a Center, what makes us unique (i.e., our brand), our target audience and how we can most effectively use the latest tools and approaches to communicate with them.

Data Acquisition and Management, Research Safety, and Sensitive Information Protection Plans are required of the Center as a whole and each research and education project. These plans ensure that those affiliated with the CRC adhere to recognized standards associated with the manner in which data is collected, managed and stored; comply with sensitive information; and comply with established safety standards.

Workplan Templates, Annual Report Templates and Powerpoint Templates have been developed by Center management. Workplan templates are used to describe each project and track progress over time through the use of established metrics. Annual report templates help to distill research and educational project work, including progress made to date. Powerpoint templates are provided to PI's for use during CRC Annual meetings in order to facilitate standardized presentations and succinctly apprise the DHS Review, CRC Advisory Board and others in attendance as to the nature of the work and progress made on their respective projects.

Transition

The CRC approach to transition has five principal elements: 1) an end-user-driven philosophy of transition; 2) a detailed CRC Transition Plan; 3) using existing product delivery systems for

transition where possible; 4) expanding our extensive network of transition partners, and 5) a coordinated approach to identifying and protecting intellectual property. Strategic CRC transition goals are:

- Transition research findings to practice through strategic alignments with identified and emerging training venues delivered by CRC partners.
- Ensure the inclusion of end-users in the development and implementation of CRC research projects.
- Coordinate intellectual property identification and registration of CRC PI's.
- Develop and implement transition plan.

Activities and Accomplishments

The CRC has achieved a number of important activities associated with the standing up of the Center which have been described above. Additional activities included a Workplan Development Workshop and the first CRC Annual Meeting. The CRC has also initiated a number of additional projects in its first year. These include the Flood Apex project, the Storm Surge Protection Project for the Houston Galveston Bay Area, and the Maritime Risk Symposium.

Workplan Development Workshop

This event, held in Washington, DC, on July 28-29, 2015, was organized by the DHS S&T Office of University Programs. It provided an opportunity for Center PI's to hear from DHS leadership, interact with each other and potential project end users in facilitated breakout groups, and incorporate the results of those presentations and discussions into the final versions of their project workplans.

CRC Annual Meeting

The first CRC Annual Meeting was held in Chapel Hill, NC, on March 2-3, 2016, approximately two months after the Center's projects commenced. The meeting was attended by the Center PI's, Center and DHS management, members of the Center's Advisory Board and Federal Coordinating Committee, and a number of students.

DHS Flood Apex Program

The Department of Homeland Security Science and Technology Directorate (S&T) First Responder Group has initiated the Flood Apex program. The goal of this program is to save lives, reduce property loss, and enhance resilience to disruptive events through the creation and application of a decision support system-of-systems for community risk assessment and resilience planning. The community-centric resilience metrics and modeling capabilities enabled by the Flood Apex program will support the development of a National Flood Decision Support Tool (NFDST).

The CRC has been tasked with supporting the Flood Apex project by:

- Organizing and overseeing a Research Review Board for the current phase of the RAPID Apex program
- Conducting an independent landscape review to provide background and scope for the development of the NFDST
- Framing, soliciting and conducting research projects as needed to support the development of the NFDST
- Providing general advice and guidance to the Flood Apex program

Storm Surge Protection for Houston Galveston Bay Area

Since 2013, the Center partners at Jackson State University (JSU) have been part of a multi-university international team, funded by local interests, that is investigating the technical and

economic feasibility of a hurricane surge barrier to protect the area surrounding Galveston Bay in Texas. As part of this effort, they established a Cooperative Research and Development Agreement with the Engineer Research and Development Center to support JSU's application of the ADCIRC storm surge model and analysis of surge statistics generated for FEMA's Risk MAP study of the area. During the period covered by this Annual Report, JSU's work was critical in establishing a broad consensus among government and business interests that the surge barrier should consist of a "coastal spine" that prevents hurricane surge from entering Galveston Bay. Their work also helped attract a 5-year, $3.6 million National Science Foundation PIRE (Partnerships for International Research and Education) grant to investigate integrated, multi-scale approaches to coastal flood risk reduction. In May, 2016, three JSU graduate students were part of a 12-student PIRE team led by Texas A&M University-Galveston that spent 2 weeks in The Netherlands working with students and experts there on various aspects of planning, designing, and implementing integrated flood risk reduction.

Maritime Risk Symposium

Invited university, governmental Federal, state, university and private sector officials will gather this fall to discuss the intersection of homeland maritime security and coastal resilience. The 7th Maritime Risk Symposium (MRS 2016) will be held on Nov. 14-15 at the University of North Carolina at Chapel Hill, hosted by the Department of Homeland Security's Coastal Resilience Center of Excellence.

The event brings together leading researchers and practitioners in the maritime and across multiple homeland security sectors to build networks, identify gaps in current capabilities and generate ideas for future research projects. The event will focus on "Integrating Maritime and Coastal Resilience." MRS 2016 will encourage practitioners to identify pressing needs in their fields and inspire researchers to think beyond their current focus. Working together, organizers seek to define a research horizon that will enhance maritime and coastal resilience to disturbances that are both natural and man-made.

Next Steps

The CRC is in the process of moving forward with a number of initiatives tied to general center management and the exploration of new and emerging opportunities. These include preparing for our Center's biennial review process, the identification of existing high performing projects worthy of continued funding as well as the review of new research proposals, and continued expansion of Center partnerships to include the development of a plan to become fully funded by non-DHS sources at the end of the 5-year funding provided by the Department of Homeland Security.

Center Biennial Review Preparation

Center management is in the process of preparing for the biennial review of all Center activities as required under the terms of our 5-year agreement. During the biennial review, the CRC will present detailed reports on the status of the Center, including individual projects and center administration and management to the DHS Office of Science and Technology as well as the Federal Coordination Committee, which is comprised of federal agency officials involved in work associated with coastal resilience. The results of this review will be used to inform Center activities and future directions.

Out year Project Identification and Development

In addition to the ongoing review of current Center projects, the CRC is also in the process of developing a means to identify future projects to include the continuation of high performing work and the selection process by which new projects will be funded. This will involve a national competition driven by a widely disseminated solicitation process. Potential new

projects will also reflect what the Center sees as innovative research, in many cases addressing emerging issues. Examples may include work tied to climate change phenomena, such as how changing climate models can inform ongoing coastal hazards modeling efforts and the study of climate change adaptation measures that draw from lessons found in hazard mitigation and disaster recovery research.

Continued Expansion of Center Partnerships

The CRC is continually reaching out to new partners that advance the central vision of the Center, while exploring new research, education and translational opportunities that serve to ensure that the Center endures after the completion of the 5-year DHS grant. Areas being explored by the CRC include placing increased emphasis on the natural hazards influenced by climate change (e.g., sea level rise, more intense coastal storms, flooding), international partnerships in disaster management and climate change adaptation, and the development of education and training initiatives for diverse audiences including university students, US-based practitioners, and overseas government officials. Opportunities associated with the Center and climate change may include linking coastal models with climate change models, downscaling climate change to conduct local risk assessment and the identification of associated hazard mitigation/adaptation strategies, and the integration of climate change research into class curricula. International partnerships include continuing to work with New Zealand colleagues as well as emerging partnerships in Australia through the Bushfire and Natural Hazards CRC, Italy and more specifically, working relationships begun in the Summer of 2016 teaching in Venice, and in Vietnam through the dean and department head in the School of Architecture of planning at National University of Civil Engineering (NUCE) in Hanoi, Vietnam. Since 1966, NUCE has trained more than 60,000 technical experts, including engineers, architects, and urban planners, in Vietnam. This work is supported by the Vietnamese national government through the Ministry of Construction.

COASTAL RESILIENCE CENTER
A U.S. Department of Homeland Security Center of Excellence

Appendix B: Coastal Resilience Center Student Activity

Career Development Grant
Student Annual Performance Report
2015-2016 academic year

(Written by Ashton Rohmer)

1) Name: Department, University: Ashton Rohmer, Department of City and Regional Planning, University of North Carolina-Chapel Hill

2) Expected degree and year: Master's of City and Regional Planning, 2017

3) Relevant Courses Taken while a CDG Student: Planning for Natural Hazards and Climate Change Adaptation (PLAN755), Survey of Natural Hazards (PLAN756), Natural Hazards Resilience Speaker Series Seminar (PLAN754); while these courses do not relate perfectly to my study of natural hazards, they will likely be helpful in informing my Master's Project: Land Use and Environmental Planning PLAN741), Land Use and Environmental Policy (PLAN740), Development and Environmental Management (PLAN744)

4) Research Project Title: Disaster Recovery: A Comparative Analysis of Gubernatorial Leadership, Collaboration, and Capacity Building

5) Principal Investigator and Mentor: Gavin Smith

6) Research Project Abstract:
This paper explores the roles of states and governors in the disaster recovery process following two historic events: Hurricane Floyd in North Carolina in 1999 (under Governor Hunt) and Hurricane Katrina in Mississippi in 2005 (under Governor Barbour). In both cases, these disasters were the worst events either state had ever experienced, and highlight the varying roles that governors can play following a disaster (e.g., creating commissions, lobbying for funds, coordinating state agency recovery efforts, etc.). They provide rich case studies from which to analyze recovery efforts at the state level through the lens of three overarching themes: understanding local needs, timing of assistance, and vertical and horizontal integration. From the interviews, we develop a set of policy recommendations based on lessons learned and provide areas for future study.

7) Background:
This past academic year, I mostly contributed to the draft of the article Gavin submitted to a peer-reviewed publication examining what role states generally and governors specifically

play in disaster recovery; I helped draft the overview of Hurricane Katrina, during which Mississippi Governor Haley Barbour coordinated state level recovery efforts. Gubernatorial leadership in disaster recovery is not a topic that has been widely researched or written about in the literature, neither in academic literature nor outside of peer review publications. To support the drafting of the Hurricane Katrina segment and to ensure we had taken into account all of the relevant literature, I explored the existing literature to determine what resources had not yet been captured in the literature review that had been conducted in the previous year by Gavin and fellow CDG student Lea Sabbag. I also proofread the final draft and brainstormed how the article could be further enhanced by providing comments and discussing items with Gavin and Lea. This article is part of a larger research project analyzing the disaster recovery phase of the emergency management cycle and the role that states play in that. While gubernatorial leadership is certainly not widely researched in the literature, disaster recovery is likely the least understood of the four traditional phases of emergency management, and even when considering much more thoroughly researched ones like emergency response, the state's role is often left out; rather, the research mainly focuses on the role that the federal government plays or that local communities (counties, cities, etc.) play.

This project certainly contributed to my understanding of the topic. Previously, I only studied disaster recovery broadly (and indeed was more familiar with disaster response efforts); however, by focusing on the state level, and governors in particular, I became more knowledgeable about disaster recovery at the state level and how it differs from federal or local recovery processes. For example, it was enlightening to learn about Governor Barbour's work to improve disaster housing options through the Alternative Housing Program, a project borne out of the Governor's Commission on Recovery, Rebuilding, and Renewal. This project led to the creation of an improved alternative to the housing typically provided by FEMA (trailers in many cases, meant to only be used temporarily and often discarded after one use). With this particular project, the resulting units were meant to be used more than once to increase their financial feasibility, and were designed to accommodate longer stays (an important feature given that many families inhabit "temporary" housing for many months - perhaps even years - following a disaster).

Similarly, learning about Governor Hunt's initiative in North Carolina following Hurricane Floyd to provide up to $75,000 in addition to federal buyout funding was eye-opening. This action was necessary because many of the housing structures that were damaged or destroyed during Hurricane Floyd were occupied by low-income tenants who were not likely to be able to relocate to a reasonable alternative if only given enough funds equal to the pre-event value of their homes (in some cases, under $30,000). My previous knowledge of disaster recovery was mainly limited to the types of actions taken by federal entities such as FEMA; learning about how active governors can influence the process was a fascinating lesson that I hope to be able to leverage if I am ever in a position to contribute to state-level disaster recovery policies.

8) <u>Relevance to Homeland Security</u>:

The disaster recovery process presents a unique opportunity to integrate hazard mitigation and climate change adaptation policies and actions - in particular, states are in a unique position following a disaster to take advantage of increased funding (both from donations - from individuals, foundations, etc. - and the federal government), resources (staff,

expertise, etc.), and heightened attention (from Washington to local municipalities to private foundations and organizations) to get things done. Without sufficiently understanding the full extent of the tremendous opportunity that is available to governors and states in such situations, these opportunities to make our communities more resilient may be squandered. For example, by highlighting the proactive efforts by state-level officials to help get funding applications prepared before Hurricane Floyd hit, North Carolina was able to take advantage of available buyout funds to move houses out of the floodplain. Moreover, following Hurricane Katrina, Governor Barbour was able to appeal to political leadership and secure more funding for housing initiatives in Mississippi using data available about the needs at the local level.

Because climate change will likely increase either the frequency or intensity of coastal storms and will contribute to a rapidly rising sea level, and because coastal areas are attracting more and more residents, a larger proportion of communities will be in harm's way. By examining how states and governors can participate in thoughtful pre-disaster recovery planning and effective post-disaster recovery efforts, we will be able to improve our nation's resilience to coastal hazards.

9) Methods:

Given Gavin's high-level experience both in North Carolina following Hurricane Floyd and in Mississippi following Hurricane Katrina, we had unparalleled access to key decision makers and intimate knowledge of the processes and policies that were carried about in both Governors Hunt and Barbour's administrations to support disaster recovery efforts. This assisted in the selection of cases for this particular research project, and also facilitated the interviews used to collect qualitative data to be analyzed - these interviews were conducted last year with Gavin and fellow CDG student Lea Sabbag. Additionally, we utilized academic and gray literature to supplement our understanding of leadership, disaster recovery, the state's role in disaster recovery, among the governor's role in disaster recovery, and other more broad and specific topics; however, this literature is rather thin so the interviews and first-hand experience provided much of the context for our qualitative analysis. Once we had the interviews in hand and they were transcribed for careful analysis, we were able to sort through the answers provided by the interviewees (both state staffers at the time for each disaster and the governors themselves) to find trends, lessons learned, and key pieces of information that helped us to understand the decision making processes that led to the programs developed and implemented.

10) Expected Results/Outcomes:

We are hoping that the article will be accepted by a peer-reviewed journal. The article we produced is closely related to the 30 minute documentary that Gavin developed that will be used as a training material for state level officials who may become involved in disaster recovery efforts. This article may also eventually be incorporated into a book that looks at broader issues related to disaster recovery and the state's role in that process. The results from Gavin's larger work on states and disaster recovery was that it was important to focus on three things: understanding local needs and resources, having strong vertical and horizontal integration, and coordinating the timing of assistance.

11) Next Steps:
Now that we have gathered all the relevant literature (although will likely continue to seek out new materials as articles get published and may further inform our study), we are hoping to continue with our case study analysis methodology and identify additional case studies. Case studies that are being explored include governors who were active in the Hurricane Sandy recovery process (including New Jersey governor Chris Christie and New York governor Andrew Cuomo), and the 2013 Colorado floods (under Governor John Hickenlooper). These case studies would provide interesting similarities and differences (party affiliations, size of disaster, etc.) by which to analyze the role of the state and the governors, and would also provide more data from which to derive lessons learned. Additionally, these are would be fascinating case studies to examine due to the time that has passed since both Hurricanes Floyd and Katrina - it would be informative to see if governors in these more recent events had different experiences, particularly given the highly charged political atmosphere we are in now and the financial state of the federal government. Hopefully, these interviews could be added to the current 30-minute documentary to provide more context in addition to informing additional written case studies.

12) Personal Reflection:
Throughout the year, I was blown away by the fantastic mentoring offered by Gavin, and the tremendous opportunities to connect with leaders in the field through classes, field trips, speaker presentations, attending the annual meeting, and Gavin's willingness to put me in touch with practitioners. For example, Gavin introduced me to one of our class speakers, Matt Campbell, who works on long-term community planning and recovery within FEMA. Since meeting with Matt, he has been a supportive and enthusiastic connection who has shown an interest in my proposed Master's Project research topic and has actively connected me with other professionals who might be able to inform my project. The sum of all that exposure, research, classroom work, and engaging discussions with professionals and students alike has been a fulfilling and enriching personal experience - one that I'm extremely grateful for. In that way, my first year studying hazards has exceeded my expectations and I feel it prepared me really well for my summer internship.

My knowledge of the field grew exponentially over the course of the year. My favorite class (of all the classes I took during my first year) was Gavin's fall course, Planning for Natural Hazards and Climate Change Adaptation. We looked at hazard mitigation plans, disaster recovery plans, and climate change adaptation plans, and were armed with tools to thoughtfully analyze them. In course lectures, discussions, and readings, I especially appreciated the attention focused on equity and international cases; all too often I found these issues overlooked in other planning classes despite their extraordinary importance in fully understanding the planning profession and the challenges we face.

One particularly satisfying experience I had this year was creating and managing the Triangle Resilience listserv. Even though it is only a humble email distribution list, I thoroughly enjoyed actively seeking out new members with similar interests in hazards, sharing interesting events and articles with fellow listserv members, being even more knowledgeable about the field, and leading an effort almost entirely on my own. Hopefully this will lay the groundwork for a student group, as next year there will be several students that share an interest in hazards and resilience. The listserv can serve as a way to further

inform our experience through relevant articles, speakers, and extracurricular opportunities.

I have learned about myself over the past year, particularly as I have thought more about what career path I might follow upon obtaining my degree. I think the most impactful experience I had was in talking with David Perkes, who has done incredible work along coastal Mississippi following Hurricane Katrina. His passion for positive change was clear, and it seemed he was engaged in the type of work I hope to one day be lucky enough to take on: leading a thoughtful team that is dedicated to creatively solving difficult problems, working closely with local partners to make communities better, and contributing his skills in a unique way that meets a need while giving him the opportunity to be challenged and grow as a professional.

13) Summer Internship:

This summer, I'm interning with the National Park Service; I was selected from a competitive application process to participate in the George Melendez Wright Young Leaders in Climate Change Initiative. I'm working in the Washington support office in the Park Planning and Special Studies division to support climate change adaptation planning in coastal parks. Specifically, at this point the projects that have been proposed include:

- Exploring how to best integrate climate change adaptation into current planning processes at Cape Lookout National Seashore
- Conducting a case study of Cape Lookout National Seashore following Hurricane Irene to help create guidance for pre-disaster recovery planning at the park level
- Examining lessons learned from climate change adaptation efforts for facilities, cultural and historic resources, and natural resources at Assateague National Seashore (and perhaps other parks impacted by Hurricane Sandy)
- Compilation and distillation of a wide array of federal documents (policy memoranda, directives, plans, etc.) related to climate change considerations in park planning
- Distributing a survey to park superintendents to learn about the extent to which they plan for climate change impacts and what challenges they face during the planning process
- Engaging with park planning staff at the federal, regional, and local level to determine the extent to which climate change adaptation is integrated into the suite of products and services that are offered to parks (especially because the Department of the Interior has stated that climate change considerations should be mainstreamed into all planning processes rather than used as a standalone plan or strategy) and the extent to which climate change considerations are incorporated into small “P” planning

In terms of how this internship fits with my education, it is giving me a unique opportunity to learn about a specific application of climate change adaptation practices. In Gavin’s classes we analyzed a lot of plans and looked at a lot of case studies, but becoming familiar with how adaptation is applied in real life will be a fantastic learning experience. This is especially true because the efforts are happening in such a focused way - it is eye-opening to see how climate change adaptation considerations can be such an important factor within parks, as it seems a lot of the examples we have examined are in large, dense cities. Furthermore, it is interesting to see how climate change adaptation is being conducted

within a federal agency, and the challenges and opportunities that come from operating within such a large bureaucracy.

As my internship relates to my professional goals, it is neat to work in a planning context that seems quite different from traditional land use planning - an experience I value as I was hoping to get exposure to different types of jobs. I think my internship will be an interesting way to determine if working in the federal government is a good fit for my professional aspirations, and if the National Park Service is an agency within which I can have an impact. Specifically, completing this internship will give me two years (post-graduation) of non-competitive hire status within a few bureaus of the Department of the Interior; I hope this summer to get exposure to the different types of positions that might be available within DOI that are dedicated to building the nation's resilience, whether it's to climate change or hazards in general.

14) Other Relevant Information:

There were a lot of meaningful experiences that made my first year at UNC and in the hazards certificate program a worthwhile one, but I think one of those most influential was the trip our class took to Kinston, NC. Kinston was hit hard by flooding during Hurricane Floyd, and as part of the recovery process the town executed a robust buyout program, removing hundreds of homes and other properties from the floodplain. More than 15 years later, the land that was acquired is still vacant, and an ambitious green infrastructure plan has failed to be implemented past the creation of a dog park. While we had discussed Kinston in class, I was completely struck when seeing the reality of the situation, so much so that it will hopefully inform my Master's Project (MP).

Early in the year, I had pitched an idea to Gavin about developing a disaster recovery exercise as part of my MP, because there are so few out there despite how important getting recovery right is (most are focused on response). I also wanted to include issues that concerned land use planners, because they are so often not involved in these discussions even though they should play a large role. When I saw how the buyout process had played out in Kinston, it gave me an idea: to conduct some case studies of buyouts that have occurred to draw lessons learned, and then apply those lessons to a disaster recovery exercise using a land buyout as the focused topic. Based on the preliminary research I have done, it seems like buyouts incorporate so many key issues to think about in recovery: housing, land use, equity, etc. By analyzing the process in Kinston and other case studies, I'm hoping to create an MP that has a positive impact by helping other municipalities be better prepared to pursue a buyout initiative, which in turn will lead to better outcomes for communities that have been affected and make our neighborhoods more resilient.

Career Development Grant
Final Performance Report
Reporting Period: 2015-2016 academic year
(Written by Lea Sabbag)

Lea E. Sabbag
Master's Degree in City and Regional Planning
The University of North Carolina at Chapel Hill
Certificate in Natural Hazards Resilience
Date of graduation: August 2, 2016

Overview

This annual performance report summarizes the research, educational, and other relevant activities that I performed over the 2015-2016 academic year as a graduate student in the Department of Homeland Security's (DHS) Career Development Grant program. These experiences helped establish a conceptual and practical understanding of the complexity and challenges of land use and disaster management, as well as both adaptive and maladaptive approaches intended to build foster urban resilience. I am confident my academic curriculum, research assistantship with Professor Gavin Smith, summer internship experiences, and additional activities have provided a comprehensive foundation for a future career in natural hazards risk management and community sustainability.

Relevant Courses Taken

As a soon to be graduate from the Department of City and Regional Planning (DCRP) at the University of North Carolina at Chapel Hill, I feel fortunate to have attended not only one of the best planning programs in the country, but one that has also produce an extensive amount of research on natural hazards and community resilience. Because I completed the majority of my core requirements during the 2014-2015 academic year, this year I had more flexibility and was able to enroll in a wide range of elective courses, some of which were even in other graduate departments and at a different university. Select course topics, such as systems modeling and geographic information systems, provided a background to not only the complexity of system dynamics, but also the extensive ways in which networks and large datasets can be analyzed and spatially displayed. In order to fulfill the Department's law requirement, I enrolled in an ocean and Coastal law and policy course offered at Duke University. Not only did I gain a deeper understand of marine and coastal resource management and environmental protection, but the course also provided a unique learning environment in that many of my peers did not have a planning background, and were pursuing degrees in environmental science, marine biology, and law. The second course I took outside of Department of City and Regional Planning was in UNC's School of Public Health. As part of the Health Policy and Management department, the course explored analytical methods in emergency management, and addressed issues of environmental health surveillance systems, program evaluation and cost benefit analysis, and emergency management ethics, law, and liability.

In addition to these courses, I am currently finalizing my capstone master's project, which will draw on planning theory and lessons derived from conceptual and practical knowledge. In it, I investigate the interface between local governments' understanding of risk to coastal storms and sea level rise in the Outer Banks of North Carolina, their potential adoption of land use measures to effectively confront and adapt to these threats, and the need to explore why leadership and policy changes are needed. In doing so, I discuss the current legal and regulatory frameworks in place, including various incentives and policy measures that perpetuate vulnerability and maladaptive behavior, as well as policy recommendations to better inform sustainable management practices in these inherently dynamic environments.

As a graduate student specializing in Land Use and Environment Planning, I selected the Hazards track in order to augment my core and elective curriculum. With this, I also pursued the Natural Hazards Resilience Certificate program, and will be the first candidate to receive this award upon graduation. This 10 credit hour certificate program focuses on disaster resilience frameworks, avenues for climate change adaptation, and various dimensions of social vulnerability and disaster recovery. Part of this certificate program entails a speaker series seminar, where high caliber researchers and practitioners discuss topics related to their own work and experiences. Invited guests who shared their expertise included: Craig Fugate, Administrator of the Federal Emergency Management Agency (FEMA); Samantha Medlock, Deputy Director of Climate Preparedness at the White House Council on Environmental Quality; Dennis Wenger, former Program Director and the National Science Foundation; and Carl Bruch at the Environmental Law Institute.
In addition to class lectures, the Natural Hazards Resilience speaker series, and my Master's Project, key insight and lessons learned were derived from site visits and panel discussions. I was able to attend the 1st Department of Homeland Security Coastal Resilience Center of Excellence Annual meeting where I not only presented a poster on the ongoing research that I am doing with Professor Gavin Smith, but also gained valuable information from project presentations. Specific discussions covered coastal infrastructure resilience, hazard modeling, and methods and tools for building community resilience. In addition to the Coastal Resilience Center's Annual meeting, were also a valuable part of my educational experience. During the Spring semester, I participated in a field trip to Kinston, North Carolina in order to better understand the successes and challenges of long-term recovery efforts following Hurricane Floyd in 1999. Discussions with Kinston officials and a State mitigation officer centered on pre-event conditions, impacts and damage assessments, home and junkyard acquisition programs, and planning linkages to hazard mitigation, recovery, and capital improvement plans.

Below is a complete list of my graduate courses for 2015-2016 academic year.

<u>Fall 2015</u>
PL 591: Advanced GIS
PL 641: Ecology and Land Use Planning
PL 740: Land Use and Environmental Policy
ENV 775: Ocean and Coastal Law and Policy (taken at Duke University)
HPM 422: Emergency Management I – Analytic Methods

Spring 2016
PL 722: Systems Thinking and Modeling
PL 744: Development and Environmental Management
PL 754: Natural Hazards Resilience Speaker Series
PL 823: Planning Workshop: Community Food Systems
PL 896: Independent Study: Disaster Recovery and Role of the State

Summer 2016
PL 896: Independent Study: Building Resilience to Coastal Hazards in Hawai'i: Strengthen the Post-Disaster Recovery Process
PL 992: Master's Project

Research Project

Project Title: The Role of the State in Disaster Recovery: A Comparative Analysis of Gubernatorial Leadership and State Agency Official Engagement, Collaboration and Capacity Building
Principal Investigator: Gavin Smith
Research Assistants: Lea Sabbag and Ashton Rohmer

For the past two years, I have had the opportunity to apply the theoretical planning frameworks that I have learned in graduate school and apply them to my research assistantship with the Coastal Hazards Center of Excellence. Myself, and another graduate student Ashton Rohmer, are supporting Professor Gavin Smith on his research surrounding the role of governors and state agencies in disaster recovery. From the data collected over the past two years, we are investigating influential recovery strategies, and the ways in which gubernatorial leadership impacted short- and long-term disaster recovery processes. We used a comparative case study approach to analyze the past disaster events of Hurricane Floyd in North Carolina (1999) and Hurricane Katrina in Mississippi (2005). In each case study, we are exploring how state actors influence key dimensions of the recovery process, including: how resources address local needs, the timing of assistance, and horizontal and vertical coordination. In addition, we highlight the role that pre-event planning has on state-level recovery processes and its influence on improving state capacity and commitment. The information gathered and lessons learned from this analysis are intended to inform future recovery outcomes and policies, and the knowledge gathered will be widely disseminated to both researchers and practitioners.

I have had the opportunity of presenting our research findings at several events. This past July, I attended the 40th Annual Natural Hazards Research and Applications Workshop in Broomfield, Colorado. While there, I not only gave a poster presentation on the preliminary findings of our research to date, but also had the opportunity to participate a variety of panel presentations on various dimensions of disaster management, community resilience, and risk reduction. Similarly, I presented a poster of our research findings at the Climate Change Symposium at the University of North Carolina at Chapel Hill in April, as well as at the Coastal Resilience Center of Excellence's 1st Annual Meeting held March 2-3.

Background

There currently exists limited research on the process of disaster recovery, particularly at the state level. The research carried out by Professor Smith, Ashton Rohmer, and myself attempts to partially fill this gap. Exploring the larger governance network will help synthesize lessons learned and enhance disaster recovery knowledge for governors and state officials. The findings are intended to build capacity and advance the knowledge of states' roles in disaster recovery by transferring these lessons to practitioners.

Three research questions guide our overall approach. These include:

1) What are the roles of state agencies in disaster recovery?
2) What are the roles of governors in disaster recovery?
3) How do these roles influence disaster recovery outcomes?

Relevance to Homeland Security

Addressing the gap in literature regarding the role of states in disaster recovery is critical. Not only will our research attempt to capture lessons learned from past disasters, but in an era of climate change, traditional practices of disaster management and natural hazards planning are no longer adequate and, thus, requires a reexamination of future recovery initiatives. Increased threats due to sea level rise, severe storms, and drought and extreme temperatures, compounded by existing decrepit infrastructure and increased disaster losses, will further strain our ability to recover from future disasters. Because states play an essential role in shaping recovery outcomes, expanding research on effective strategies for recovery officials is crucial. By focusing on the role of states in recovery, we will analyze the complex responsibilities of governors and their cabinet members who are often tasked as liaisons between local and federal governments. Their position provides a unique opportunity to build the capacity of recovery officials and local communities. In addition, states provide assistance to local governments by securing and allocating necessary funding. Finally, they often set the path for recovery through state policies and plans, and therefore, can significantly contribute to our nation's resilience to coastal hazards.

Methods

Our research uses a comparative case study approach to analyze recovery outcomes following Hurricane Katrina and Hurricane Floyd, which devastated parts of Mississippi and North Carolina. The unit of analysis for this project includes organizations (e.g. state agencies) and individuals (e.g. governors). The selected research methods for our analysis included reviews of academic literature, congressional testimony, and governmental reports. In addition, we employed direct and participant observation as well as conducted personal interviews with governors and state agency officials involved in the recovery of these two hurricanes. We framed the selected research questions by addressing three key dimensions of disaster recovery, e.g., the rules governing post disaster assistance and the degree to which resources address local needs; the timing of assistance; and, the level of horizontal and vertical integration across the disaster recovery framework.

Expected Outcomes

Expected outcomes of this research project are to expand on existing recovery literature by disseminating a wide range of documents, including journal articles, a textbook, and training modules that can better inform researchers, practitioners, and governmental officials. This past April, Gavin, Ashton, and myself submitted our first article for review to the *International Journal of Mass Emergencies and Disasters*. Drawing from personal interviews with former Governors James B. Hunt, Jr. (North Carolina) and Haley Barbour (Mississippi), our article explores specific gubernatorial roles and leadership styles in disaster recovery, along with policy recommendations, next steps, and future areas of study. We are currently waiting for comments and feedback from those reviewing our draft. For more information on this project, including a 30-minute video produced by the Coastal Resilience Center, please refer to the following website: http://coastalresiliencecenter.unc.edu/crc-projects/the-role-of-states-in-disaster-recovery/

Next Steps

Next steps for the Career Development Grant Program include finalizing tasks for the ongoing research project. Regarding the ongoing research with Professor Smith and Ashton Rohmer, we believe that the best course of action may be to expand the number of case studies in our analysis to include additional states and governors. For example, potential cases could include Governor Hickenlooper and the 2013 Colorado floods, Governor Culver and the 2008 Iowa Floods, and Vermont's Governor Shumlin during Tropical Storm Irene in 2011. Similar to the comparative analysis performed for North Carolina and Mississippi, the research team will conduct personal interviews with chosen governors and agency officials in the selected states.

Summer Internship

The Career Development Grant program stipulates that I complete two 10-week internships. Last summer I interned at North Carolina's Division of Emergency Management (NCEM) in the Recovery Section. I had the unique opportunity to assist the Hazard Mitigation Branch in developing a proposal for the National Disaster Resilience Competition (NDRC) funded by the Department of Housing and Urban Development. NCEM framed their proposal on mitigation measures targeted toward vulnerable and distressed populations affected by Hurricane Irene that struck North Carolina in 2011. Specific strategies focused on elevating or relocating flood-prone structures primarily in rural areas.

Despite finding out that North Carolina did not advance to Phase II of the NDRC competition, the Hazard Mitigation Branch was determined to leverage the data collected from Phase I and reprogram it in a way that would impact those with unmet recovery needs. In order to better understand why we were not shortlisted for the NDRC grant, I was tasked with reviewing applications of those states that did advance to Phase II to determine where our application fell short. General patterns that emerged in my analysis included rural vs. urban target areas, timing of the qualifying disaster, diminished capacity at the local level, and the degree to which applications promoted robust resilience strategies. In addition to this comparative summary, I created a document that outlined potential contingency plans that could be pursued for securing additional funding.

For the summer of 2016, I had the privilege of pursuing a dual internship program through the University of Hawai'i Sea Grant College Program and the County of Maui's Department of Planning. While there, I gained valuable knowledge on the regulatory framework in Hawai'i and coastal management issues faced by communities on the island. For example, approximately 85% of Maui's beaches are currently threatened by erosion. Understanding the implications of this and its relationship to land use practices is crucial to long-term planning processes and protecting the health and welfare of communities.

Because the internship with Maui's Department of Planning was unpaid, I successfully secured funding through the Peter J. Rappa Sustainable Coastal Development Internship. This University of Hawai'i Sea Grant fellowship provided a unique opportunity to extensively explore resilient community frameworks and potential avenues for climate change adaptation and disaster recovery. My role, as both a Maui County Department of Planning intern and a Sea Grant Fellow, was to support a NOAA funded Regional Coastal Resilience grant titled, "Building Resilience to Coastal Hazards and Climate Change in Hawai'i and the Pacific." My scope of work entailed a support function for the initiation of a pre-disaster planning process that built on previous work completed by Maui County, including their "Post-Disaster Reconstruction Guidelines and Protocols for the Conservation of Coastal Resources and Protection of Coastal Communities, Maui County." In addition, the fellowship covered expenses for site visits to Oahu and Kauai where I was introduced to other Hawai'i Sea Grant fellows to better understand overlapping issues across the islands.

This internship exposed me to Hawaii's coastal management legal framework and areas where there are significant unmet needs. The focus of my research and exploration centered around three elements: (1) Hawaii's existing emergency proclamation process and the unintended consequences of suspending certain laws and regulations; (2) the applicability of a draft reconstruction ordinance with emphasis on repairing and rebuilding private property (home, condos, hotels); and (3) key elements of pre-event planning for post-disaster recovery for statewide reference and use. In order to gain a comprehensive understanding of coastal risk management issues faced throughout Maui County, I applied a variety of techniques, such as a review of existing practice-based and academic literature as well as direct observation and site visits. In addition, I participated in a number of personal interviews and in-depth discussions with a broad range of stakeholders. These included academic scholars, County officials, condominium developers, coastal scientists, property owners, and other members of the community.

As Hawaii's coastal communities attempt to balance environmental sustainability with development pressures, it remains imperative that county and state level officials explore alternative notions of growth management that promote local capacity building and equitable smart growth practices. I believe that my internship experience highlighted the importance of intergovernmental coordination and enhanced my understanding of both complex ecological and coastal development processes surrounding natural hazards risk management.

Personal Reflection and Other Relevant Information

As I reflect on my second and final year as a graduate student, I am confident that the opportunities awarded to me through the Department of Homeland Security's Career

Development Grant will have an immense impact on my future success as a natural hazards planner. Not only has my academic experience equipped me with theoretical foundations and necessary development management tools, but the guidance and exposure provided by Professor Gavin Smith has been truly remarkable. He has been an invaluable mentor who has gone above and beyond any expectations I had for a professor or research supervisor. His insight and encouragement has had a significant contribution on my professional growth in the field of natural hazards resilience. I am eager to apply the skillset and lessons learned to my future endeavors in risk reduction and sustainable planning.

Post-Graduation Employment

In the Fall following graduation, I was hired by the North Carolina Division of Emergency Management to support recovery operations following Hurricane Matthew, which left thousands of households across the state needing some form of housing assistance. As the State's Disaster Housing Coordinator, I am tasked with coordinating housing operations across a spectrum of solutions that range from initial displacement and sheltering needs, to intermediate assistance and temporary housing, to more resilient forms of permanent living. In addition to acting as one of the state's liaisons for federally administered programs in Individual Assistance, including Direct Housing Mission and Transitional Sheltering Assistance, I also lead a housing strike team that is responsible for tracking individual cases among, and identifying interdependencies between, thirteen housing programs. Although the majority of my responsibilities are carried out at the Joint Field Office located in Durham, NC, I perform field visits and attend town meetings in the affected areas on a weekly basis.

This position will be instrumental in not only strengthening my skills as a natural hazards planner, but it also provides a truly unique opportunity to utilize the breadth of knowledge that I acquired at UNC-Chapel Hill and apply it to recovery operations across the state. Specific examples include best management practices for administering acquisition and relocation programs, as well as lessons learned from past disasters regarding the timing of assistance and mechanisms for building capacity and fostering inter-organizational coordination. I look forward to my role of making North Carolina more resilient to hazards, and grateful for the mentorship and financial support that helped guide me to where I am today.

Relevant Photos Documenting Lea Sabbag Graduate School Experience

Figure 1: Photo taken with former Governor James B. Hunt, Jr., Professor Gavin Smith, and Lea Sabbag. The 1.5-hour interview conducted with Governor Hunt had a significant impact on the research on the role that state's play in disaster recovery. Photo taken April 13, 2015.

Figure 2: Attending the 1st Coastal Resilience Center of Excellences Annual Meeting. It was held March 2-3, 2016 in Chapel Hill, North Carolina. Photo taken March 2, 2016.

Figure 3: Lea Sabbag and fellow graduates specializing in Land Use and Environmental Planning in the Department of City and Regional Planning at the University of North Carolina at Chapel Hill. Photo taken May 6, 2016.

Figure 4: Lea Sabbag at the Department Commencement Ceremony. Photo taken May 6, 2016.

Figure 5: As part of her 2016 summer internship with University of Hawai'i Sea Grant and Maui County's Department of Planning, Sabbag participated in a charted excursion with policy and decision makers in an effort to gain awareness on the degradation of Maui's coral reefs. Photo taken June 3, 2016.

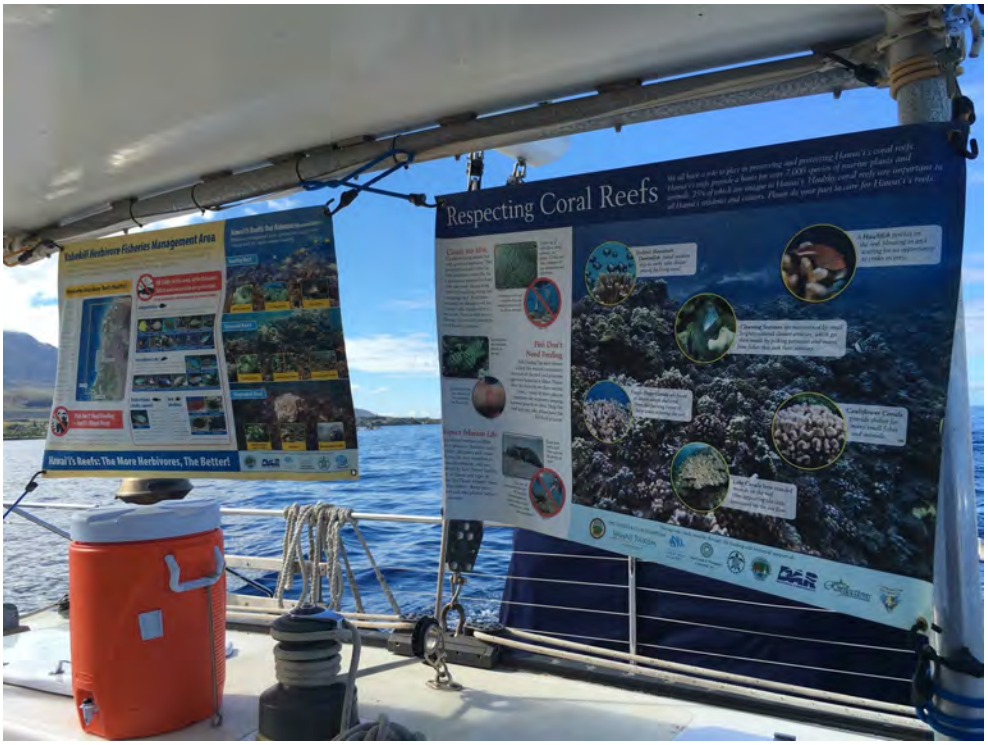


Figure 6: In addition to snorkeling on the reef and witnessing first hand coral bleaching, experts in the field gave presentations and discussed the social-ecological processes of the area. Photo take June 3, 2016.

CES Technology Evaluations

Amanda Tritinger
Consumer Electronics Showcase 2016

Coastal Resilience

The coastal environment has played a critical role in the development of America since early colonial days. Today, U.S. coastal areas serve as key infrastructure hubs and continue to become increasingly urbanized. Although only 8% of America's counties are located along the coast, they make up 29% of the total population (Wilson and Fischetti 2010). In 2008, 96% of the population lived in areas classified as predominantly metropolitan, up from 87% in 1960. Florida's coastal population alone has increased by 1.6 million since 2000. Americans are choosing to live near the coast for its economic opportunities, its environment and its rich cultural heritage; but coastal areas also represent areas where natural hazards have caused massive economic devastation and loss of life in recent decades. Given this pattern of growth and the overlap of coastal hazards into vulnerable urbanized areas, it is critical that we protect our coastal residents by building resilient and forward-thinking communities.

The acceleration of sea-level rise and possible climatic variations in the frequency, intensity, timing and distribution of tropical storms and hurricanes are anticipated to have substantial impacts on coasts during the 21st century. As of 2013, the Intergovernmental Panel on Climate Change (IPCC) estimated that the global mean sea-level will rise somewhere between 0.3-1.0 meter in the next century (Stocker, 2014). Presently, global mean sea-level rise is increasing by millimeters a year. Intensifying storms are expected to result in more frequent hazardous conditions for our coastlines, making planning for resilient coasts a high national priority. Information and technology are expected to play key roles in meeting this priority, via the collection of more data throughout our coastlines and wetlands, the deployment of more effective means of communication in coastal communities, and development of a tool that puts information into the hands of decision-makers more quickly and effectively.

With this in mind, I attended the Consumer Electronics Showcase (CES), hoping to find a tool to aid the goal of more resilient coastal communities. My motivation for attending this meeting was to find a technology that could be used to adapt existing devices to create a new, more capable network for delivering and sharing coastline historical and current data as well as possible risk factors; or to find a new technology that could be applied to accomplish these goals. Ideally, this new technology would help the populations that live in the communities at risk from coastal hazards to make an informed decision on an appropriate plan of action.

Often people do not evacuate based on the forecast information they are given, sometimes because they doubt its accuracy but probably more often because they do not understand the potential specific impact on them. This in turn leads to preventable injuries and fatalities. Typically this occurs because citizens receive the same type of warning for significant storm events that they do for other events that do not have the same level of threat. When residents evacuate at significant cost and then learn that they would have been fine, they are less likely to evacuate the next time they receive the same warning. If there were a more reliable way to share information, evacuation plans could change and adapt to save communities and lives.

We need better ways of collecting data from which we could create more effective models for predicting the specific consequences of coastal storms in terms that individuals can trust and understand. We also need more information and analyses to warn the public of potential dangers to enable educated decisions about their coastal lifestyles and to help develop more informed decisions by coastal leadership (i.e. what sort of protection is necessary for their community's stretch of beach or what building codes must be met for a home on the coast).

Lastly, if this "better data" were available through improved communication, more informed decisions could be made before, during and after major storm events, assisting in all phases of hazards: 1) long-term planning, 2) pre-event preparation and 3) post-event recovery. The time before a storm is when the public turns toward the emergency broadcast system, where they are informed what to do with information that can be based on an entire city's data. Perhaps this information could be more specifically delineated. Instead of telling the average person what they need to do, a community could tell specific individuals what they need to do.

Coastal hazards and natural disasters are chaotic events. Communication during a storm event can be just as chaotic and confusing. Finding a way to communicate information about the exact location of citizens and "real-time," on-the-ground data, could help authorities provide clarity in times of disarray. There will always be confusion during an event, but every moment spent making collaborative decisions helps bring down injury and fatality rates. The same goes for improvement of post-storm decision-making. Knowing exactly where citizens are, and what is happening throughout a city, can help save lives even after the storm has passed.

CES Attendance

Prior to attending CES, I identified and researched several enterprises, three of which emerged as likely candidates to positively impact the work done within the Coastal Resilience Center of Excellence (CRC). I approached these companies during CES, and supplemented those with a few others found during the showcase. I visited each company's booth and began a discussion of their products. Most of these discussions were extremely enlightening, with both sides prompting new possible applications for the technologies. Some of the discussions, however, ended with the conclusion that the product in question might not be a good fit for the needs of the CRC.

At CES, my goal was to find a technology that would help the resilience of America's coastal, urban areas. The focus was to find technologies that could collect new data, which could in turn help scientists understand critical aspects of our shorelines and coastal communities that could aid decision-makers and create more resilient communities. There was also motivation to find technologies that would allow better communications between first responders and citizens in coastal communities during and after major storm events and natural disasters.

While at CES I planned to talk with Mutualink, Oledcomm and ARRIS. Oledcomm and ARRIS were not good fits for my objectives. They both marketed very specific technologies intended for use by specific consumers and did not seem interested in adapting their technologies.

Mutualink did not attend at CES, but were willing to be a part of a webinar to share their ideas and innovative processes, and to answer questions. Their feedback was very positive.
After some on-site research, I discovered two more companies to work with: Revolutionary Design Products L.L.C., and RAPIDSOS. This report will identify the value proposition and rough order estimate of benefit of acquiring the technologies offered by:

- Mutualink
- Revolutionary Design Products L.L.C.
- RAPIDSOS

While at the Consumer Electronics Showcase (CES), the following objectives were achieved:

1) A better understanding of how a single group develops and brings new technologies to market.
2) An overall impression of the current techno-climate (i.e. "what is hot and what is not").
3) Increased ability to discuss products with a distributor/inventor.
4) A better idea about how high-tech items could be used in unanticipated systems, specifically within the Coastal Resilience Center of Excellence (CRC).
5) Experience on how to ask the "right questions" during a standard industry evaluation.

The discussion typically followed the format of the template that can be found on the next page.

• CES 2016 Industry Questionnaire Template

Company Name:		Product:		Booth:	

Our goal:	***Coastal Resilience.***

Communication of information during major coastal destruction event. Pre- and post-event data collection, and distribution.

Tell me about your company, what makes your company unique? What's your line of business?
What does your product do? What distinguishes this new product from others?
Where is your current product emphasis? What's important to this company?
How does your product distribution work? Will this product be direct to consumer?
How do you adapt your products/services to your customer's needs?
What is your outlook for next year? What is your direction?
Why your product is the best value for your customers/why are you the best choice for us?
How does your product/service enhance your customer's ability to achieve their goals?

Would you be willing to keep in touch and further adapt your product?	Y or N
Any Other Notes:	
Is this product an information generator, or an information sender/receiver?	

Take photo of both.	Y or N	**Social media photo.**	Y or N

RAPIDSOS

RAPIDSOS (rapidsos.com) is a startup company, with its origins at the Massachusetts Institute of Technology. The company will launch a one-touch 911 app that will connect users and dispatchers instantly. The Federal Communications Commission (FCC) reports that more than 70% of 911 calls are made with cell phones. However, most dispatchers are using landline systems. This system can fail in pinpointing the exact location of a caller in a prompt manner.

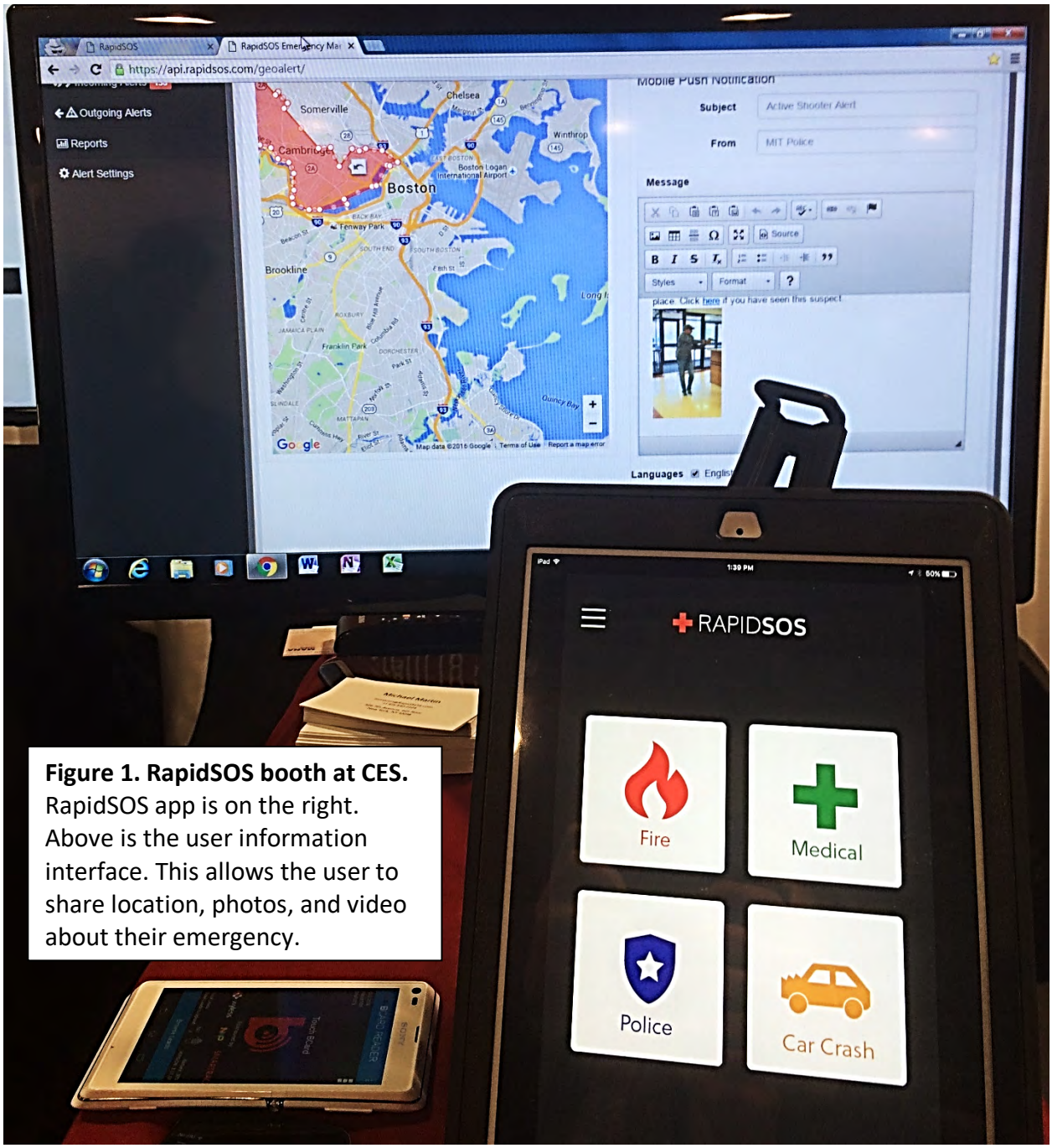


Figure 1. RapidSOS booth at CES. RapidSOS app is on the right. Above is the user information interface. This allows the user to share location, photos, and video about their emergency.

RAPIDSOS provides a service to communicate information to any three-digit emergency number globally through phones or wearables. RapidSOS can transmit key information, (for example, X, Y, Z and civic street address location, video feedback, medical and demographic data), with one touch. During natural disasters information can be sent in two directions.

No training, equipment or cost to the dispatch system is necessary. The technology is 100% interoperable with current dispatch systems. Most dispatch units are using location computer dispatch systems (known as CADS) to triangulate locations off of cell towers. This leads to less accurate location identification, or no identification if a tower is down or if the call is dropped before the system gets fixed coordinates.

RapidSOS utilizes every location sensor a cell phone has at its disposal (i.e. Bluetooth, GPS, personal hot spots and barometric sensors that measure altitude). This quickly secures a more accurate location of the user. This information works with the currently used CAD software. RapidSOS will pop the information up on the screen the same way an incoming call would. It is expected that emergency dispatchers could not tell the difference.

Individuals will be able to personally download this app onto their phone. The app will deliver location of the user and any medical information presently available to RapidSOS servers. The servers then patch it through to the dispatch center nearest to the individual. This is unique, because emergency phone calls are typically transferred to centers designated to callers prior to their emergency.

RapidSOS is working in partnership with the 911 community globally. The app has been tested in a few cities before its launch. The outcome of RapidSOS is reported to be a reduced loss of life of 10%, healthcare costs reduced by 6.9%, and building damage from structural fire by 20%. They are working towards helping to predict emergencies given set data, and then warn the people who are in harm's way. If this technology is geared toward coastal hazards, faith in the emergency broadcast system could be restored.

RapidSOS Future Direction

RapidSOS is launching an app called "Haven," a universal mobile safety and security system that shares your personal location and medical information with dispatchers. The app also features options for reporting fires, medical emergencies, car crashes and a need for the police. These functions connect the user with an option to include information, photos and video reporting. It will also alert family members and loved ones of the emergency and instantly share information with the designated emergency contacts on your phone.

RapidSOS Case Use

People who have lived in coastal communities have seen many storms come their way, and for this reason, experience is not the best teacher. They often stay in their homes, ignoring warnings telling them to leave, because last year they heard the same warning and were fine. This product has the ability to reach out to each person, and based on their geographic location, tell them why they personally need to leave, or what they need to do post-storm event.

Currently the RapidSOS Haven system is designed for four emergency types; medical, police, fire and car crash. During a coastal disaster these would all come in handy to emergency responders. The ability to learn where people are, exactly, during an event would help them

Figure 2. RapidSOS App
This is what the user sees when they open the app. They are given the choice on reporting four different emergency scenarios (Photo credit; http://www.popularmechanics.com/technology/apps/a15631/rapidsos-911-app/)

plan a more effective protocol. The information reporting tool could provide eyes on the

ground to the people who need to make evacuation decisions. Overall this device could provide more accurate information during devastating natural disaster and hazardous events.

Furthermore, RapidSOS could add one more type of emergency to their app - weather. If an option to report a weather event were available on the app, then the user could be delivered proper questions that could provide even more useful information to responders. For example the app could request video of flood levels on the street a user is on. This could help a responder prepare for the situation they will be coming into, instead of reacting when they get there. This preparation could increase the safety of users and responders.

This app could help the user provide information to decision-makers, so that they can make the best evacuation plans for themselves and their community. Then, these plans could be transmitted to users back through the app that was utilized to assemble the information behind the plan in the first place. The app would report location-based evacuation plans to users, providing maps and instructions that are unique to the user's location. They could even send out a public broadcast via the video option on the app. A message unique to a city, which is usually dependent on everyone watching their televisions at the same time and if the cable/satellite is working, could be sent in text form to an entire community instantly and be unique to an individual.

Figure 3 shows the multiple-platform RapidSOS currently uses to report and share information. A citizen can call 911 with one touch on their phone, and not have to rely on landlines or cell towers to connect and share their information with dispatchers. This provides more accurate information with more availability. During storm events this is necessary, due to the likelihood of downed cell towers.

The geotagged photos would get information about what is happening and exactly where it is happening to those in charge of deciding how to react, or plan for an approaching storm event. Understanding how far a flood has moved, or how a hurricane is affecting a given location, can help researchers predict what will happen next during a disaster. This could then be displayed using the emergency predictive analysis technology provided by RapidSOS. This could all be in the hands of coastal community citizens.

Figure 3. RapidSOS App Communication Platforms
RapidSOS uses multiple forms of data collection, and sharing to provide information to dispatchers.
(Photo credit; https://quoted.thezebra.com/wp-content/uploads/2015/04/rapidsos_tech.png)

After a coastal disaster has passed, RapidSOS would have an incredible amount of data on their servers. This data could be used to help understand storms and coastal natural disasters after they have passed. This information could be used to help modify and validate storm surge models. These models would then be more accurate and reliable. As a result, we would have better models for predicting future storm events and outcomes. This would lead to better planning of coastal cities, and an overall better understanding of the coastal risk of a community.

This data would also put a human touch on the data-fed models we use in coastal engineering today. Geotagged photos would help not only scientists, but citizens, in a community better understand what a 2-meter water-level rise along a given coastline means to them. This data will help communicate data-driven ideas to everyone. Reaction to a storm is important to a coastal community, how we plan for the next one should be equally as imperative.

After these events come through a community, there is a rebuilding period. The data collected in the RapidSOS servers would help community leaders, architects, city planners, etc. make the decisions they have to in order to make their city more resilient. This information could be shared with those decision-makers to put policies in place and help communicate why the protection policies are so important. The data would help a community not just rebuild, but possibly redesign for a more flexible and prepared coastal community.

If RapidSOS were used in this way, lives would be saved during coastal disaster events. Information could be shared with all citizens, in a form they are most familiar with: through their phones. The best decisions could be made by individuals and coastal community responders, because they are both receiving the best information available. RapidSOS and their Haven app could help make coastal communities more resilient without the cost of construction or even additional technologies in dispatch centers, through this proposal in technology integration.

RapidSOS Conclusion

RapidSOS has technology that can dramatically improve the outcome of medical, police, fire and car crash emergencies. If they included weather emergencies, the coastal community would greatly benefit. RapidSOS would have to be willing to work to add this capability to their app. At CES they seemed excited and very willing to do so. Representatives filled out the template and shared information, and contact information was exchanged with promise of a follow-up.

After CES, communication has been slow from RapidSOS. They are willing to work with me; however, as most companies that attended CES, they were much quicker to answer my questions in person than the weeks that followed. This is an important note. I suggest that next year, students attending CES through this program set up a meeting time during the week of CES with their prospective technology companies. Most of the information I received from RapidSOS, I got in person the one day I worked with them. The template (page 5) proved very helpful in that moment, as I had a clear set of questions for them at that time. I suggest a lengthier template be brought next time, for a longer meeting that will be later suggested.

Revolutionary Design Products L.L.C.

Revolutionary Design Products L.L.C. brought the PURI Engine to CES. This is a hybrid metal fuel cell/battery combination that uses magnesium and aluminum to fuel and charge the cell. Magnesium and aluminum are much more readily available fuel types than lithium, and come together to create a lower-cost battery: 4 cents on the dollar when compared to their lithium counterpart. The batteries are about 30 times longer-lasting, and can be set up to recharge when saltwater is available. They have 1,000 ma/cm^2 charge density, with 1.5 volts per cell, and are much lighter than lithium batteries. They can also be re-fueled instantly and easily.

Figure 4. Revolutionary Design Products L.L.C.
The technology was explained in detail during CES at the Revolutionary Design Products L.L.C. booth.

The PURI Engine technology was originally developed for hydroponic farming on off-grid locations. It had to be high-quality that was at the lowest cost possible for operating, maintenance and cost to purchase, keeping in mind there could be no hazardous materials used, and little to no field repair available. The result was metal fuels that are easily obtained that include a low-cost recycling procedure using solar or wind energy.

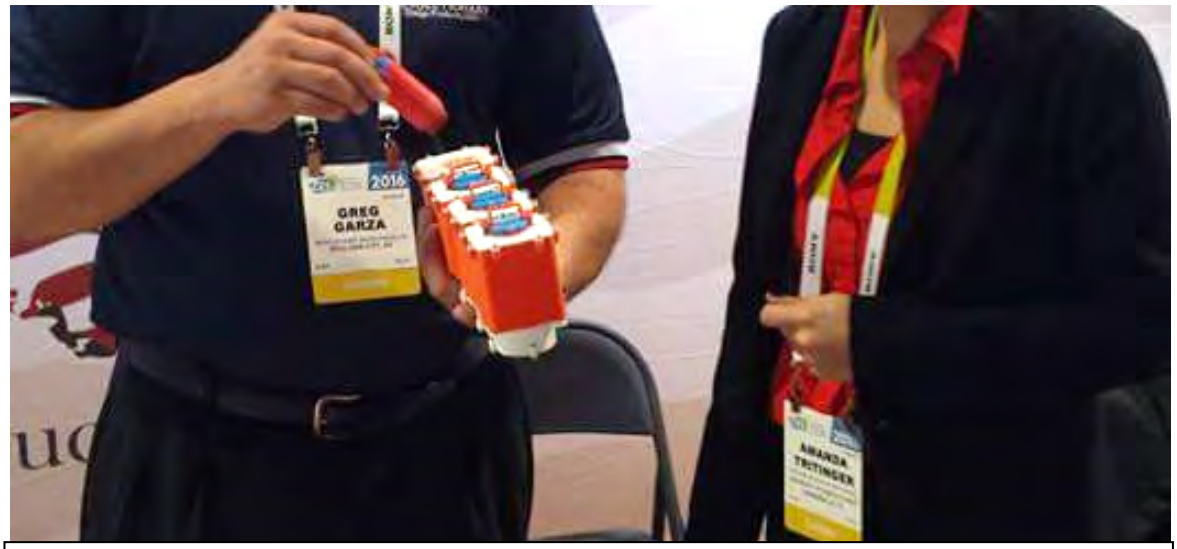


Figure 5. Revolutionary Design Products L.L.C. PURI Engine Cartridge Demonstration
The cartridges used in a PURI Engine cell can be changed out quickly. They are cheap to purchase, and light to carry. They can also be recycled.

The PURI Engine is designed to replace any battery source. This technology is used as a power source similar to any other battery for fuel cell, providing DC power. This means there is currently no cost to adapt the PURI Engine to fit its replacement. Preferably, the sources it replaces will be located near or in saltwater sites. Operating in saltwater is ideal for two reasons: The first is that the technology uses NaCl (sodium chloride) salts on the magnesium side as part of the electrolyte. In other words, the salt is being used in the chemical reaction that generates energy. The second is that sea water is on average 0.16% Magnesium Chloride (MgCl), which the technology can use to extract magnesium. These conditions are Revolutionary Design Products L.L.C. has primarily focused on.

One of the main advantages of using the PURI Engine, versus other battery technologies (i.e. lithium) is cost. The PURI Engine can produce power for $0.03/kW-hr. That is the rock-bottom cost in which the technology was designed for from the beginning of its conception. This technology has 25% more power, and thus will last longer than the competition. This means

fewer resources are spent replacing batteries, and instead are focused on job completion. The PURI Engine is smaller in size and weight compared to Lithium-Ion batteries. This means easier install for the user, and less time and space spent on lugging around heavier battery packs. Where Lithium-Ion battery cost is about $200/kW to purchase, the PURI Engine is around $80/kW to buy in large volume.

Another advantage is replacement. The PURI Engine is cartridge-based. When replacing the battery source, cartridges can be removed and replaced without any tools. The cartridges are lightweight and snap into place in less than one minute. The cartridges are 100% recyclable.

Revolutionary Design Products L.L.C. Future Direction

Currently PURI Engines have mostly been used in hydroponic farms, and in sea/brackish water. Their focus has been shifting to powering devises throughout the open channels off the coast. PURI is presently working on a project that could help power barges that are up to 50 meters long. They are primarily focusing on the saltwater locations and applications that are uniquely ideal for PURI. At the moment, Revolutionary Design Products L.L.C. is gearing up for production and custom orders this year. They currently have test lab reports that will be available later this year, as well as MIL-SPEC compliance reports that will follow.

PURI Engine Case Use

This battery design is important, because when coastal engineers design their fieldwork outings, they are typically designed around the constraint of battery life. Bulky battery packs are designed to be attached to gauges, and must be changed out typically every 3 weeks (depending on the frequency and resolution of data collection). When batteries die, this often leads to missing vital data that could have been collected by water gauges during storm events. The PURI Engine technology could extend the collection period of data gathering, as well as reduce the overall cost of collection. This would lead to a greater understanding of a coastal community's surroundings and more knowledge would lead to increasingly resilient coastal community designing (i.e. less destruction, flooding, mortality, etc. in the long run).

The PURI Engine process is simple, it is scalable and the fuel is not geography-dependent (components needed are available everywhere) and can be stored indefinitely. Scalability is incredibly helpful when engineers are designing a field data collection project. Water gauges require constant energy. If a gauge is collecting at a higher frequency (necessary for collecting wave data) this uses the battery faster. If we are interested in more complete data sets for our coastal communities, we need to collect more complete sets of water information. The scalability of the PURI Engine could create flexibility in fieldwork projects that would ultimately lead to understanding more about our coastlines and the environments that surround coastal cities.

Because the fuel source is not geography-dependent, cost will not suffer depending on deployment location. Magnesium and aluminum can be available at any given site. The ability to store these fuel cells indefinitely will help lower the cost of collection as well. Extra batteries are often thrown out after field assignments. These batteries could be placed in the same location as the gauges themselves while not in use.

Due to the process of collecting water data from coastal communities, water gauges are always located in water with salinity content. The proposed adaptation is to create a device that helps regenerate the PURI Engine fuel using the saltwater that surrounds it. As much as the PURI Engine already outlasts the typical battery pack used for data collection, this regeneration could keep a water gauge out on the water for almost two months. Many resources could be saved with the adaption of this device for this purpose, and much continuous data could be store and analyzed.

This uninterrupted data that is generated could be analyzed to find correlations between certain storm types and what occurred before and after the storm. The data would help us understand our past, in order to better predict the future. Uninterrupted data could be used to develop models that help us hindcast storms more effectively. These models would then lead to more accurate predictions of oncoming storms, and a better plan for evacuation and the overall design of more resilient coastal communities.

PURI Engine Conclusion

Revolutionary Design L.L.C has been in constant communication with us. The case study above has been pitched, and they are interested in adapting it. They proposed a way that the PURI Engine can store energy from solar during the day and then have a regular supply built in to operate at night or in bad weather without refueling.

In order to continue, Revolutionary Design Products L.L.C. only needs the specifications of our water gauges, to be sure everything will operate as needed. If needed, the system can still be refueled and field-repaired/serviced. The technology is more of a mechanical device than electrical, so the possibilities of adaptation are extensive. Again, this is ideal for the design of water gauges that are currently using lithium battery packs. For example, you can't take a lithium battery apart and replace the cells inside. In the case of the PURI Engine, however, you can; that is why it's called a PURI Engine and not a fuel cell or battery.

Mutualink

Mutualink is focused on the real-time connection of people and information. The products Mutualink (http://www.mutualink.net/Our-Solution.asp) is working on connect the industries and responders with information that is vital to them making the best decisions and ultimately protecting lives and coastal infrastructure.

The interface uses one screen to share interoperable systems with organizations connected through Mutualink. It uses small affordable technologies, so that subscribers do not pay a high cost. Subscribers can communicate using video, imaging, radio and other tech platforms. This device provides a connection between the internet of things and those looking to take advantage of them. The main technology running most of the devices on the ground that can communicate with the interface are being designed using the Edison chip (Figure 7).

Figure 6. Mutualink Product Interface
Mutualink provides clear communication on multiple devices with an understandable interface.
(Photo credit; www.mutualink.net_Our-Products)

The devices that are on the ground have the ability to report back to the Mutualink system. They also can communicate with each other. The advantage of this is that the devices can "ping" off of each other until one of them finds a working cell tower and Wi-Fi connection. This can come in handy during storm scenarios where cell towers have been brought down and Wi-Fi connectivity locations are scarce. This is also helpful when the systems need to be located far away from civilization (i.e. down streams or rivers, out in the ocean, or along the intercoastal region).

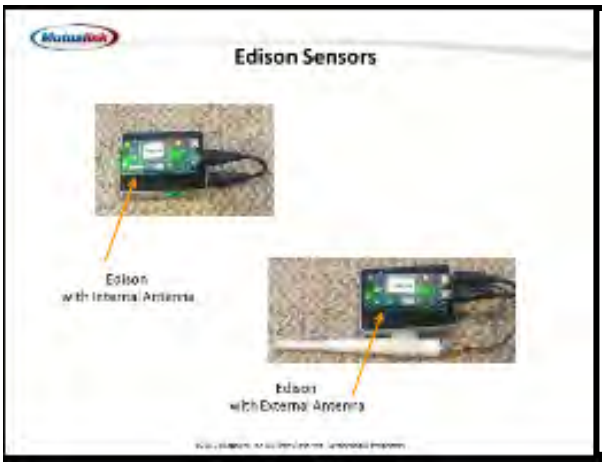


Figure 7. Mutualink Edison Sensors
Mutualink uses the processing speed of the Edison chip attached to sensors to communicate over Wi-Fi networks.

Figure 8 shows an example of how many devices can be used during a Mutualink session. If a decision is being made, perhaps on how to evacuate a city, Mutualink connects the user with emergency responders, video captured on local infrastructure, satellite and more. An entire city can be connected to one system, providing the maximum information to the user so that they can make the smartest and safest decision.

Mutualink uses an Internet Protocol (IP) Network. This eliminates single points of failure or the need to have a central server or "switch." Subscribers using the system have the choice to allow or deny invitations to communicate over resources. When they choose to connect, the communication is instantly established and then modified to meet the needs of the discussion. Mutualink provides this control so that government agencies and those with classified information need not worry about this intelligence being compromised.

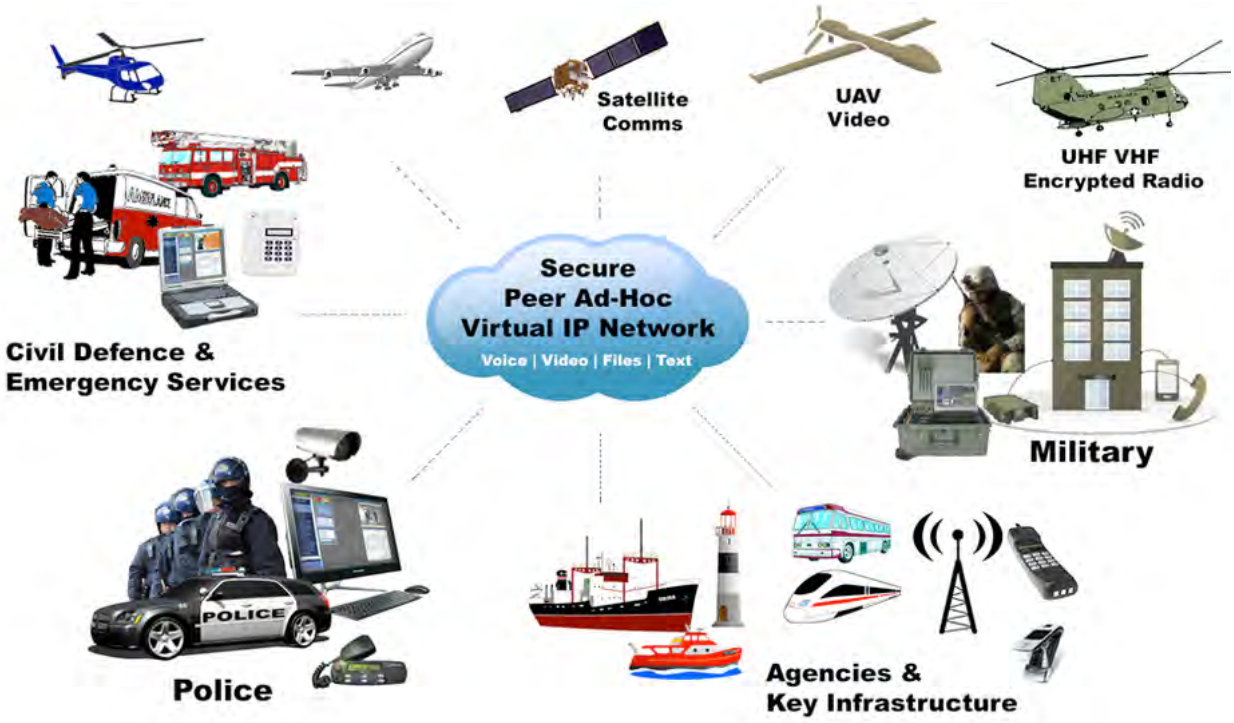


Figure 8

Mutualink Future Direction

Mutualink has worked with authorities primarily in New Jersey and a few other locations. They have worked with emergency responders and law enforcement agencies to help use all of the statewide platforms (Figure 8) and better understand what is going on in their city. Mutualink is currently working with New Jersey to get this technology in schools statewide in an effort to protect schools from mass shootings. More recently, authorities used Mutualink at Super Bowl 50 in California, in order to keep fans safe throughout the stadium.

Mutualink is also focusing on a branch of wearable technology. These devices could be worn by responders or data collectors. They would be located on-person and possibly relay sound and video back to command central. The wearables would come with GPS. While the viewer watches video from the command center, they can also get a map display of the user's location.

Information on current devices being used can be found at http://mutualink.net/Internet-of-public-safety-things-project-wins-2016-IJIS-Institute -Innovation-Award.asp.

Mutualink Case Use

Every coastal community has organizations that are working towards better understanding the trends of both nature and of the people living in that community. Communication is the key to preparing for, reacting during and recovering/rebuilding after a natural disaster. This system would help with the data collection process, so that a team on the coastline can communicate with each other, even when out of range of their local cell towers. During storm events, emergency networks can communicate across entire coastal city limits. If diverse groups of emergency responders are all working towards one plan, the mass confusion that typically stems from these events can be reduced or avoided. Lastly, when working toward evacuating or rebuilding after natural disaster events, the coastal communities can all work together to make the best resilient design decisions.

A more focused case scenario is water-level sensing use during a flood. Mutualink can provide the interconnecting network between water-level sensors throughout a community. If cost-effective sensors were located along streets that are near rivers and the coastline, they could use the Mutualink system to communicate the water level at their location every few minutes.

The Mutualink technology combined with the Edison sensors would then create a grid the size of a coastal community. The grid would have three points of information at each node: 1) longitude, 2) latitude and 3) water level, and Mutualink could store this information. The next step is creating an app, or in-home device that connects to this information, which could inform its user if a flood is likely, or incoming. The device could even be connected to shutters in a home or some protective device that would act after being prompted by the "internet of flood things" that Mutualink has created.

This data could save lives in real-time flood events. It could save infrastructure in the long run. Also, the data collected during a flood could be stored and analyzed later to better understand a city's flood risk. This could ultimately lead to that city developing a better plan of evacuation in the future, or even a more resilient city design plan. When living on the coast the risk of flood

is always looming. This technology adaptation could help us better understand it, react to it, and create a safer community in the future.

Mutualink Conclusion

Mutualink has been very helpful in providing information that has moved us toward the possibility of this case use. They have conducted webinars to showcase their product, and taken part in multiple phone calls and email conversations. Mutualink seems very willing to work on this possible adaptation of their product.

The next step is analyzing possible water depth sensors that could work in conjunction with the Mutualink technology. Swiss Watches currently sells one that is pressure-based, and provides up to 2 millimeters worth of resolution, for $15. There are many other options available for water-level sensing that will need to be considered as well. Mutualink appears to be the ideal technology group to work with on this project.

References

Stocker, T. F. (Ed.). (2014). Climate change 2013: the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Wilson, S. G., & Fischetti, T. R. (2010). Coastline population trends in the United States: 1960 to 2008. US Department of Commerce, Economics and Statistics Administration, US Census Bureau.