GINIS, URI

DHS Coastal Resilience Center

Research Project:

Annual Project Performance Report

Covers reporting period July 1, 2016 – June 30, 2017

1. **Project Title:**

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

2. **Principal Investigator / Institution:**

PI: Isaac Ginis, University of Rhode Island
Professor 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
- Wenrui Huang, Florida State University, Professor

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

- Kevin Rosa, URI/GSO, Graduate Student
- Xuanyu Chen, URI/GSO, Graduate Student
- Xiaohui Zhou, URI/GSO, Graduate Student
- Pam Rubinoff, URI/CRC, Senior Coastal Manager
- Austin Becker, URI/Marine Affairs, Assistant Professor
- Peter Stempel, URI/Marine Affairs, Architect, Graduate Student
- Robert Witkop, URI/Marine Affairs, Graduate Student
- M Reza Hashemi, URI/Ocean Engineering, Assistant Professor

Key Partners:

- NOAA/NWS/NCEP Environmental Modeling Center (EMC), Marine Modeling Branch
- NOAA Northeast River Forecast Center (NERFC), Director
- NOAA NWS, Taunton, MA, Meteorologist-in-Charge
- NOAA NWS, Taunton, MA, Hurricane Program Leader
- FEMA Region 1, Hurricane Program Manager
- RIEMA, Stephen Conard, Training & Exercise Specialist
- DHS Office of Cyber and Infrastructure Analysis, Senior Analyst

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

This project will advance 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 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 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) Create physically consistent, hypothetical high-impact scenarios that combine widespread, multiple hazard impacts (e.g. storm surge and rainfall-induced flooding); 2) use a multi-model ensemble approach to integrate 2D and 3D coastal models with watershed and 1D river models to provide the best possible coastal and inland flood guidance; 3) implement the URI air-sea coupling module, developed for NOAA operational hurricane models, for coupling storm surge/wave models; 4) provide hazard model output in a format suitable for HAZUS, HURREVAC or other risk modeling software and decision support tools used by DHS and other agencies; and 5) utilize the most advanced tools for sharing, visualizing and communicating the hazard model simulations with end users.

6. **End users:**

Rhode Island Emergency Management Agency (RIEMA)

Emergency Management Institute (EMI)

The URI team provided modeling products and collaborated with Rhode Island Emergency Management Agency (RIEMA) and the Emergency Management Institute (EMI) to conduct an Integrated Emergency Management Course (IEMC) as part of a statewide preparedness exercise on June 19 – 22, 2017. The four-day exercise focuses on the response to hurricane scenarios while identifying key actions taken before, during, and after a hurricane. The modeling team developed scenarios and impact visualizations of a high-impact hurricane (Hurricane Rhody) for use in the exercise. Outcomes from the course will provide RIEMA with an opportunity to enhance overall preparedness, while actively testing modeling outputs during various parts of the course.

In this effort, the URI team worked closely with Stephen Conard at RIEMA, Douglas Kahn and Sabrina Bateman at EMI, and the DHS Office of Cyber and Infrastructure Analysis in developing the impact analysis on critical infrastructures in Rhode Island.

Stephen Conard, Training & Exercise Specialist, stated: "The information and modeling provided by URI will be used within RIEMA sponsored trainings and exercises to update the scientific data and modeling used. Also, RIEMA can use this information within the State Emergency Operations Center for catastrophic planning. The information given from URI can also be used in long-term planning to deal with the effects that sea level rise plays on 21 of RI's 39 communities."

This provides an opportunity to share this type of capability and products to FEMA Region 1, for application on a broader scale. It also provides an opportunity to see if the EMI training can incorporate these types of models into exercises in other regions.

FEMA Region 1

Paul Morey, Hurricane Program Manager, implemented the Hurricane Rhody scenario into HVX decision support tool administered by FEMA for the Integrated Emergency Management Course on June 19 – 22, 2017.

NOAA NWS, Taunton, MA

Meteorologist-in-Charge and Hurricane Program Leader developed tropical storm advisories and hazard graphics for the weather briefings during the Integrated Emergency Management Course based on the Hurricane Rhody scenario and output from the URI HBL model wind simulations.

NOAA/NWS/NCEP Environmental Modeling Center

The URI team conducted an evaluation of the new operational (ST4) version of the WAVEWATCH 3 wave model in hurricane conditions and communicated the results to the NCEP wave modeling group and via conference calls and WW3 developer meetings (Jessica Meixner), providing recommendations to adjust/recalibrate the source term in WW3 in high wind conditions. Our team will conduct this effort with potential transition to operations at NCEP.

RI Flood Mitigation Association

Participated in the RI Flood Mitigation Association Annual Meeting to network with state emergency managers. Presentation of initial model outputs provided our team with feedback from local end users. These inputs have been incorporated into the model and outputs as feasible.

RI Coastal and Resources Management Council

Coordinated with this state regulatory agency on modeling and visualizations as a tool for planning, response and permitting. Discussions on integrating the models and programs (i.e. Shoreline Change Special Area Management Plan) is underway. This coordination also provides an example of how to link with 33 coastal states as well as NOAA's Office of Coastal Resources Management.

Rhode Island Environmental Management Agencies

Significant efforts have been made to transfer technological advances and multi-modeling tools to those relevant RI management agencies that are tasked with protecting RI marine

resources. Organized a meeting/workshop that included DHS team members Chris Kincaid, David Ullman and Lew Rothstein, along with Jim Boyd, (Coastal Policy Analyst, RI CRMC), David Beutel, (Aquaculture Coordinator, RI CRMC) and Conor McManus (RI DEM, Fisheries Management Section). Also present were Professors Dale Levitt and Scott Rutherford, researchers from Roger Williams University with extensive experience with RI Shellfishing activities, communities, outreach, and research. Grover Fugate (Head of RI CRMC) and Jason McNamee (Chief of RIDEM Marine Resource Management) were copied on all emails where DHS-supported research was summarized and the workshop agenda was set, but could not attend. They were briefed by their representatives. The outcome of the meeting was the consensus agreement that our DHS-funded modeling tools on the mobilization and transport of hazardous materials from the urban source regions in the north, through the sensitive and valuable fisheries resource regions of the mid-lower estuary, should be developed into planning and training activities similar to the IEMC.

7. **Unanticipated Problems:**

None.

8. **Project Impact:**

- The project advanced current technologies and capabilities by developing end-to-end model simulations capable of representing extreme hurricane events from the open ocean, onto the shelf, through coastal estuaries and tributaries, and into coastal watersheds based on multiple, independent models that contributed to an ensemble of model solutions for DHS stakeholders in the Rhode Island region.

- The project conducted detailed assessment of the performance of state-of-the-art coastal circulation, watershed rainfall and river flood models in representing the hurricane and other extreme weather hazards in the RI region.

- The project conducted detailed assessment of the performance of two ocean surface wave models under hurricane forcing and communicated the results to operational wave modeling centers.

- The project created reasonable hypothetical worst case scenarios (low probability, high impact) by combining multiple hazard impacts, including coastal flooding due to storm surge and inland flooding due to rainfall, based on a combination of historical storm elements.

- The project developed multi-model strategies and methodologies for testing the benefits and unintended consequences of utilizing engineered structures (hurricane barriers) under a range of storm characteristics, and conducted detailed evaluations of the Fox Point Hurricane Barrier in Rhode Island.

- The project transitioned the results from the physical modeling scenarios to DHS end users that helped to inform the impact on infrastructure and losses and the associated

challenges in managing multiple threats with limited resources, and used this as a pilot for other emergency preparedness and response trainings.

- The project designed a computationally efficient framework that combined multi-model ensemble output with interactive 3D visualization tools for training and real-time hazard impact analyses. These products are a substantial advancement of the existing tools that will maximize the utility of outputs from complex numerical models. They are produced in forms that are most useful for emergency managers, first responders, and other professionals from all levels of government and the private sector.

- By contributing models and outputs (visualizations and impact scenarios) to RIEMA/FEMA training for their Integrated Emergency Management Course (EMI-IEMC), the trainees of the statewide preparedness exercise are able to envision (and practice) and respond to "exercises that update our materials to current threat standards, instead of slightly outdated, unrealistic thresholds that growth has easily surpassed." (Stephen Conard, RIEMA). These materials are already being considered for more trainings and exercises in the state and the Northeast region.

- Three students from Tougaloo College are actively working with researchers to advance and apply their knowledge in natural and social science.

9. **Research Activity and Milestone Progress:** Details of the project activities and main accomplishments are provided in Appendix, which includes 8 chapters:

   1. Hurricane Boundary Layer Model

   2. R-CLIPER Hurricane Rainfall Model

   3. Hurricane Rhody

   4. ADCIRC Storm Surge Simulations

   5. Multi-model Storm Surge and Post-Hurricane Environmental Impact Simulations: ROMS vs. ADCIRC and 2D vs. 3D

   6. Wave Modeling Under Hurricanes in Coastal Regions

   7. Rainfall Runoff and Coupled Inland/Coastal Flood Simulations in Woonasquatucket and Pawtuxet River Basins

   8. Developing 3D Visualization and Impact Analysis Methods and Tools

Research Activities and Milestones: Progress to Date

Reporting Period 7/1/2016 – 6/30/2017			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Configure and implement high-resolution ADCIRC in Narragansett Bay and Rhode Island coastal waters.	11/30/2016	100%	This activity was expanded, after the previous report, to include the uniform refinement of the ADCIRC mesh (minimum mesh size 30 m) within Narragansett Bay and Southern New England coastal waters. Summary is provided in Appendix
Configure and implement high-resolution WAVEWATCH III and SWAN wave models in Narragansett Bay and Rhode Island coastal waters.	11/30/2016	100%	This activity was expanded to include the investigation of the wave model performance under hurricanes, and the investigation of the model sensitivity to spatial resolutions. Summary is provided in Appendix
Calibrate and verify ROMS, ADCIRC, HEC-HMS and HEC-RAS models for selected historic hurricane events.	11/30/2016	100%	Summary is provided in Appendix
Conduct initial simulations of Hurricanes Bob (1991), Floyd (1999), and Carol (1954).	11/30/2016	100%	Summary is provided in Appendix
Implement the URI air-sea coupling module (ASCM) into the ADCIRC/SWAN and ROMS/SWAN models coupled with the new, unstructured grid version of WAVEWATCH III.	6/30/2017	70%	Implementation of ASCM into ROMS has been postponed. Instead, sea state dependent drag coefficient was investigated.
Simulate the impact of hypothetical Hurricane ‘Rhody’ on coastal and inland flooding and compare it to the historical events.	12/31/2017	100%	This activity is accomplished ahead of schedule. Summary is provided in Appendix

Develop a new Hurricane Boundary Layer model	6/30/2017	100%	This activity has been added in the course of the project. Summary is provided in Appendix
Implement the R-CLIPER rainfall model for hurricane rainfalls	6/30/2017	100%	This activity has been added in the course of the project. Summary is provided in Appendix
Refined ADCIRC mesh to provide uniformly high resolution (30 m minimum cell size) over Narragansett Bay and the adjacent southern New England shelf	6/30/2017	90%	Summary is provided in Appendix (work continues to further refine the mesh to better resolve very narrow inlets between RI coastal ponds and the ocean).
Perform ADCIRC simulations of Hurricanes Bob (1991) and Carol (1954) on refined and prior meshes and compared with observations.	6/30/2017	100%	Summary is provided in Appendix
Perform ADCIRC simulations of Hurricane Rhody on refined mesh with and without the presence of the (closed) Providence Hurricane Barrier and with and without the inclusion of river inflows north of Providence.	6/30/2017	100%	Summary is provided in Appendix
Run ADCIRC in idealized experiments to begin to determine the impact of dunes on coastal and inland flooding.	6/30/2017	100%	Summary is provided in Appendix
Setup and calibrate rainfall runoff model for Woonasquatucket River Basin and Moshassuck River Basins. Modify HEC-RAS model for unsteady model simulations in Woonasquatucket River.	6/30/2017	100%	Summary is provided in Appendix
Perform rainfall-runoff and river flood simulations caused by 2010 storm and Hurricane Carol (1954) events under hurricane barrier open and close conditions.	6/30/2017	100%	Summary is provided in Appendix

Perform rainfall-runoff and river flood simulations caused by Hurricane Rhody with hurricane barrier closed.	6/30/2017	100%	Summary is provided in Appendix
Perform rainfall runoff simulations of Hurricane Rhody in the Pawtuxet River Basin	6/30/2017	100%	This activity has been conducted by our URI partners sponsored by RI Coastal Resources Management Council. Summary is provided in Appendix
Refine ROMS mesh for Narragansett Bay to better include primary tributary, Seekonk/Blackstone Rivers.	6/30/2017	100%	Summary provided in Appendix
Perform simulations of Hurricanes Bob, Carol, Floyd and Rhody on refined ROMS mesh for both ROMS 3D and ROMS 2D. Compare solutions to all available data, and ADCIRC model runs.	6/30/2017	100%	Summary provided in Appendix
Initiate tests of mesh nesting capabilities in ROMS, for use in DHS simulations. Focus on defining benefits of enhanced resolution in the most sensitive regions of the estuary (e.g. Port of Providence, Fox Point Hurricane Barrier, etc.).	6/30/2017	80%	Summary provided in Appendix
Developing total storm impacts through multi-model approach: preliminary simulations of after hurricane environmental impacts. Fate/impacts of a) chemical releases from Port of b) mobilized debris.	6/30/2017	a. 25% b. 25%	This activity has been added in the course of the project based on feedback from end users. Summary provided in Appendix
Run ROMS tests of key differences in 2D versus 3D predictions for transport of chemical fields and debris for Hurricanes Carol and Bob.	6/30/2017	80%	Summary provided in Appendix

Research Milestone			
Applied the Hurricane Boundary Layer Model and R-CLIPER rainfall model for the ADCIRC, ROMS and hydrological models simulations.			Summary is provided in Appendix
Presented the results of the wave modeling studies at the NOAA/NWS/NCEP Environmental Modeling Center, July 2016, and at the WW3 Developers Meeting, February 2017.			Summary is provided in Appendix
Completed all planned ADCIRC and ROMS simulations of Hurricanes Bob and Carol and hypothetical Hurricane Rhody.			Summary is provided in Appendix
Completed all planned hydrological simulations for Woonasquatucket River Basin and Moshassuck River Basins of Hurricane Carol and hypothetical Hurricane Rhody.			Summary is provided in Appendix
Completed all necessary ROMS mesh upgrades and re-runs of all 2D/3D ROMS simulations for each Hurricane case (Bob, Carol, Floyd, Rhody).			Summary is provided in Appendix.

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

Transition Activities and Milestones: Progress to Date

Reporting Period 7/1/2016 – 6/30/2017			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity / milestone was not reached, and when completion is expected
Developed tools and products for Statewide preparedness exercise in coordination with RIEMA, FEMA's National Emergency Training Center, and the Emergency Management Institute to conduct an Integrated Emergency Management Course (EMI-IEMC)	6/30/2017	100%	Summary is provided in Appendix
Identified points of concern for facilities and communities through semi-structured interviews in person, over the phone, and through email with emergency and facility managers from Coventry, Providence, Westerly, Pawtucket and Middleton, RI	6/30/2017	100%	Summary is provided in Appendix
Developed new methods to create engaging 3d visualizations of storm impacts based on hurricane hazard modeling	6/30/2017	100%	Summary is provided in Appendix
Engaged with NOAA National Weather Service to share models and model results.	6/30/2017	100%	
Engaged with and initiated response plan for points of concern from Waste Water Treatment Facility managers through 2016 Silverjackets meeting and 2017 briefing workshop to the Narragansett Bay Commission.	6/30/2017	100%	
Held workshop to educate RI management agencies RI-DEM and RI-CRMC on potential applications of	6/30/2017	100%	

DHS multi-model tools for planning and response actions related to assessing hurricane generated impacts to estuarine-based natural resources.			
Transition Milestone			
Organized a breakout session at RI Preparedness Conference, for local and state emergency managers, to get input and validate model. August, 2016.			
Transitioned tools and products to RIEMA, FEMA's National Emergency Training Center, and the Emergency Management Institute for an Integrated Emergency Management Course (EMI-IEMC)			
Participated in training, with modeling products, sponsored by the National Emergency Training Center, and the Emergency Management Institute to conduct an Integrated Emergency Management Course (EMI-IEMC) as part of a statewide preparedness exercise on June 19 – 22, 2017.			
Organized a meeting/workshop with RI CRMC and RIDEM, presented DHS-funded modeling tools for mobilization and transport of hazardous materials from the urban source regions into sensitive and valuable fisheries resource regions of the estuary, March, 2017.			
Provided the Hurricane Rhody scenario to FEMA Region 1 for implementation into the HVX decision support tool. May, 2017.			
Provided the Hurricane Rhody scenario to NOAA NWS for developing hurricane advisory for the Integrated Emergency Management Course, May 2017.			

Provided model output from Hurricane Rhody simulations to DHS Office of Cyber and Infrastructure Analysis for infrastructure impact analysis in Rhode Island			
Participated in the RI Flood Mitigation Association Annual Meeting network with state emergency managers, April 2017			
Met with Narragansett Bay Commission (NBC) to brief them on DHS modeling advancements, including Hurricane Rhody, effects of Hurricane Barrier open/closed for flooding at their site and ROMS simulations of long term transport of chemicals, including nutrients from their plant. Discussed organizing a workshop for linking DHS modeling tools to planning activities that involved all Narragansett Bay waste water treatment facilities/managers, April, 2017.			

11. **Interactions With Education Projects:**

URI has 3 undergraduate summer interns from Tougaloo College. The URI team took advantage of an opportunity presented when Tougaloo College approached us with the need to place students. We identified one project, under PI Jim Opaluch, to fund and work with his team's project related to Obstacles and Barriers to Adaptation.

Beyond this, PIs Ginis and Rubinoff, coordinated with the long-time program at the URI Graduate School of Oceanography's (URI-GSO) Summer Undergraduate Fellowship in Oceanography (SURFO), a partnership of URI and the National Science Foundation. This supported two additional students from Tougaloo College to become a new model for incorporating diversity in the SURFO program, that of cultural and racial diversity, as well as natural and social science integration.

Visualizations have been supported by a URI PhD candidate and a Masters student, working under the leadership of Dr. Austin Becker and the Marine Affairs Visualization Lab. The work on visualizations has been beneficial as an educational approach, as well as a true contribution to the project.

This project motivated a new URI-GSO minor (PODS-Proficiency in Ocean Data Science), a 4 course sequence with a capstone internship. The program involves all DHS Faculty PI's, with the fourth, or capstone course covering the multi-model hurricane-surge approach developed on this project. All courses and the PODS minor approved by general education and curriculum affairs committees and URI Faculty Senate.

Results from this research project have been used in class teaching and student's course projects at FSU: CWR4201, Hydraulic Engineering I, Fall, 2016, 20 students and a course project for CWR4201, Hydraulic Engineering I, Spring, 2017, 23 students

Results from this research project have been used in class teaching and student's course projects in URI's large general education course, The Ocean Planet, OCG 110, Fall, 2016.

12. Publications:

Blair, A., I. Ginis, T. Hara, and E. Ulhorn, 2017: Impact of Langmuir Turbulence on Upper Ocean Response to Hurricane Edouard: Model and Observations, submitted, April 2017.

Chen, X, I. Ginis, and T. Hara, 2017: Ocean surface wave modeling under tropical cyclones: sensitivity to spatial resolutions, *Ocean modelling,* to be submitted in August 2017.

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, 2017: Effect of boundary layer roll vortices on the development of the axisymmetric tropical cyclone *J. Atmos. Sci.*, in press.

Fei ,T., W. Huang, I. Ginis, Y. Cai, 2016. Characteristics of River Flood and Storm Surge Interactions in a Tidal River in Rhode Island, USA. Proceeding of IUTAM Symposium on Storm Surge Modelling and Forecasting, Oct 17-19, 2016, Shanghai, China

Fei T., W. Huang, I. Ginis, Y. Cai, 2017. Hydrological modeling of storm-induced runoff and snowmelt in Taunton River Basin. Submitted for review to the journal of Natural Hazards.

Fei T., W. Huang, I. Ginis, D. Ullman, Y. Cai, 2017. Integrated rainfall runoff and river hydrodynamic modeling for flood analysis in Woonasquatucket river basin. In preparation for submission the journal of Frontiers of Civil and Structure Engineering.

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).

Rosa, K., and C. Kincaid, 2017: Modeling and observations of mixing, circulation and exchange in Narragansett Bay and Rhode Island Sound during Hurricane Floyd, manuscript in preparation for submission to J. Geophys. Res.

Rosa, K., C. Kincaid and D. Ullman. Comparing 2D and 3D ROMS models of historical and hypothetical hurricanes storm surge in Narragansett Bay, manuscript in preparation for submission to J. Geophys. Res.

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.

Ullman, D. S. I. Ginis, B. Thomas, X. Chen, and W. Hwang, 2017. Storm Surge/Rainfall Impacts of a Major Hurricane in Southern New England (Rhode Island), in preparation for submission to Natural Hazards.

Whitney, M. M., D. S. Ullman, and D. L. Codiga, 2016. Subtidal Exchange in Eastern Long Island Sound, . *J. Phys. Oceanogr*. 46, 2351-2371.

13. Tables:

Table 1: Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
Hurricane Rhody scenario	Digital track files and model output	May 2017	NOAA NWS, Taunton FEMA Region 1, Boston
WAVEWATCH III	Hurricane Evaluation Analysis	July 2016	NOAA NCEP
Hurricane Rhody impact analysis	Damage spread sheets	April 2016	EMI, RIEMA
Hurricane Rhody visualizations	3D graphics	May 2017	EMI, RIEMA
Hurricane Rhody Master Scenario List (MSEL)	Digital tables aligning with storm timing	June 2017	EMI, RIEMA

WAVEWATCH III	Analysis of hurricane waves	February 2017	NOAA NCEP

Table 2: 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

Rhode Island Sound as a Potential Source of HAB Toxins for Narragansett Bay	Ullman	$140,000	RI Sea Grant
MARACOOS: Preparing for a Changing Mid-Atlantic	Ullman	$75,000	NOAA, Rutgers Subcontract
Optimizing Seaweed and Shellfish Integrated Multi-Trophic Aquaculture: Developing a Spatially Explicit Ecosystem Model	Humphries, Ullman, Kincaid, Thornber	$300,000	NOAA
Summer Undergraduate Research Fellowship in Oceanography (2 students from Tougaloo)	Rubinoff	$12,000	NSF

Leveraged Support

Description	Estimated Annual Value
Returned Indirect Cost [1]	$10,000
Graduate Student tuition	$15,000
Microsoft Azure Research Award, a one-year grant that allows our project to utilize cloud computing technology.	$20,000
Support for graduate students Peter Stempel and Robert Witkop from URI Coastal Institute and RI Sea Grant	$40,000
Support for graduate students Kevin Rosa and Christina Wertman from State Funded TA's.	$40,000

[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.

14. Metrics:

Metric	**Year 1** (1/1/16 – 6/30/16)	**Year 2** (7/1/16 – 6/30/17)
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)	2	3
Graduate students provided stipends (number)	2	3
Undergraduates who received HS-related degrees (number)	0	0
Graduate students who received HS-related degrees (number)	0	0
Graduates who obtained HS-related employment (number)	0	0
SUMREX program students hosted (number)	0	2
Lectures/presentations/seminars at Center partners (number)	1	3
DHS MSI Summer Research Teams hosted (number)	0	0
Journal articles submitted (number)	2	7
Journal articles published (number)	7	8
Conference presentations made (number)	15	14
Other presentations, interviews, etc. (number)	12	22
Patent applications filed (number)	0	0
Patents awarded (number)	0	0
Trademarks/copyrights filed (number)	0	0
Requests for assistance/advice from DHS agencies (number)	0	3
Requests for assistance/advice from other agencies or governments (number)	5	13
Total milestones for reporting period (number)	11	21
Accomplished fully (number)	9	17
Accomplished partially (number)	2	4
Not accomplished (number)	0	0