HAGEN, LSU
MEDEIROS, UCF
DHS COASTAL RESILIENCE CENTER
RESEARCH PROJECT
YEAR 3 PERFORMANCE REPORT
AND
FINAL PROJECT REPORT

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.

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

Co-Principal Investigators and Other Partners/Institutions: Stephen C. Medeiros, Research Assistant Professor. University of Central Florida, Civil, Environmental & Construction Engineering Department.

Project Start and End Dates: 1/1/2016 – 6/30/2018

Short Project Description ("elevator speech"):

This study developed a semi-automated mesh de-refinement method designed to optimize a research grade tide, wind-wave, and hurricane storm surge model for use in real-time surge guidance operations. The resulting model includes advanced terrain characterization and is capable of producing accurate predictions within the ADCIRC Surge Guidance System (ASGS) forecast time frames.

Summary Abstract:

This project advanced 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 were 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 used 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 emphasized the accurate capture of the timing and magnitude of maximum water levels. This was 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 were 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. In addition, this high resolution

ADCIRC+SWAN model can serve as a benchmark for validating future versions that may incorporate less resolution or smaller regional focus.

1. Research Need:

This project is directly relevant to the Homeland Security Enterprise, in particular the stated mission to "Strengthen National Preparedness and Resilience." In the 2014 Quadrennial Homeland Security Review, two out of the three examples used to illustrate evolving threats and hazards since the 2010 review are directly related to this project. The Deepwater Horizon Oil Spill is relevant both scientifically and geographically; the end result of this project will be an immediately applicable tool if such an event were to occur in the future.

Furthermore, Hurricane Sandy is exactly the type of hazard scenario the ASGS and the NGOM model is designed to simulate. Our project enables DHS / FEMA to determine hazard risk by simulating the effects of synthetic or historic storms under various scenarios such as including existing conditions, infrastructure enhancements/degradations and sea level rise. This directly impacts the resiliency of the United States by enabling government agencies to develop planned mitigation strategies, adopt relevant disaster-resistant building codes and educate their citizens on the specific preparedness measures necessary for the storm surge hazard. In addition, this project contributes to near real-time storm surge hazard impact forecasts for storms in progress that inform communities in the impact zone. This directly enhances the preparedness of the United States by enabling the pre-staging of required life-sustaining commodities for post-storm delivery into affected areas, assembly of incident response teams including the incident command hierarchy as well as search and rescue teams for deployment within the stated goal of 12 hours post-storm.

2. Project History:

This project proceeded more or less as planned with some unforeseen administrative delays. The development of the NGOM forecast grade model proceeded according to schedule with the model becoming active for the 2018 hurricane season. All that remains is full integration of its results into CERA.

The expansion of the lidar-based surface roughness to the regional scale was hampered by the amount of data to process. The problems scaling the surface roughness parameter computations to model scale proved to be difficult on many fronts (compute, storage, spatial registration of results). To address this problem, Dr. Medeiros invested in lidar processing software (LAStools) in order to use its tools on some of the more routine lidar data processing tasks such as projecting, clipping, tiling, boundary shapefile production and point height computations. This has greatly sped up the progress of this aspect of the work. Dr. Medeiros also hired an established undergraduate research assistant, Alex Rodriguez, to work on the lidar data processing pipeline for 30 hours per week during the summer semester and plans to continue through Performance Period 3. To date, this has already accelerated the progress of the work. Lastly, Dr. Medeiros is planning to invest in additional compute allocation from the STOKES HPC at UCF in order to speed up the production of surface roughness parameters for the model domain.

One of the major successes of the project was the SUMREX program. In the summers of 2016 and 2017 we were able to host 3 students (two from UPRM and one from Jackson State). The students benefitted significantly from the experience and the student from 2016 earned an NSF Graduate Research Fellowship and is currently pursuing his PhD at LSU under the direction of Dr. Hagen. The administrative tasks associated with implementing 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 were resolved and we expect the process to go much smoother in summer 2019 and onward.

3. Results:

The project achieved its primary goal of creating a forecast grade surge and wave model of the Northern Gulf of Mexico, specifically the Florida panhandle, Mississippi, and Alabama. The primary driver of this was the ability to modify what is recognized as the best research grade ADCIRC+SWAN model of the region to optimize run times. As of 2018, the model is running in an ASGS instance producing results automatically each time a relevant storm advisory is issued.

This project also significantly advanced the parameterization of surface roughness using lidar data. Future storm surge modeling efforts nationwide will be enhanced by the big data methods and workflows developed during this project.

4. End Users and Transition Partners:

- Jerrick Saquibal, Northwest Florida Water Management District. Dr. Medeiros contacted him prior to CAT 1 Hurricane Hermine Landfall. Provided link to CERA and sample images from NGOM3 via email. Received positive feedback on the CERA product. Dr. Medeiros followed up with him regarding a possible CERA tutorial for NWFWMD staff. Mr. Saquibal was interested and also suggested two people from FDEM and FDOT that might be interested as well. To help facilitate this, Dr. Medeiros has tested the existing CERA tutorial on the CERA website by having 2 undergraduate research assistants go through it and provide feedback. We also had the 2017 SUMREX students run through the tutorial and provide feedback as well. We assimilated all feedback and produced a revised tutorial in early 2018. Mr. Saquibal continues to look forward to high resolution surge forecasts for the Florida Panhandle and Big Bend regions, as well as the value-added lidar products.
- NOAA Northern Gulf of Mexico Sentinel Site Cooperative (NGOM SSC). Team has remained in constant contact with Mr. Kidwell and Renee Collini of NGOM SSC regarding the value of accurate coastal hydrodynamic modeling to the NGOM SSC mission. This partnership had been leveraged into a funded NOAA project. We anticipate presenting the CERA tutorial (once finalized in conjunction with Carola Kaiser) to the NGOM SSC as well as their invitees.

5. Project Impact:

Our project produced an accurate, optimized hurricane storm surge model of the NGOM that is suitable for use with the ASGS and CERA. This will enable ASGS and CERA to provide emergency management personnel in the region with the highest resolution, most accurate storm surge forecasts for real-time tropical cyclones as they approach. In turn, this will facilitate more efficient evacuation and better prediction of post-storm emergency resource needs.

The submission and subsequent publication of the surface roughness parameterization and mesh optimization method papers (in preparation) in high-impact journals will 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 provided a major advance towards a readily adoptable means for conveying the model results to the public in a meaningful way (CERA).

Lastly, the impact of the SUMREX program needs little explanation other than stating the facts. Our pilot program in the summer of 2016 was a resounding success as the student, Felix Santiago of UPRM, had an outstanding experience and was able to leverage his participation into a PhD opportunity at LSU, which will be funded in part by an NSF Graduate Research Fellowship award (Drs. Hagen and Medeiros both provided letters of recommendation). Furthermore, the program was expanded to two students in 2017: Sabrina Welch of Jackson State University and Diego Delgado of UPRM. This impact of this program will be qualified, talented, and motivated students that will remain in this field either through advanced study or industry practice.

6. Student involvement and awards:

Alex Rodriguez, UCF Undergraduate Research Assistant. Major: Industrial Engineering and Management Systems. Presented poster at UCF Showcase of Undergraduate Research regarding the lidar data processing for surface roughness parameters. Co-Author on peer-reviewed IEEE paper (in preparation.)

7. Interactions with education projects:

This reporting period contains the 2016 (student: Felix Santiago, UPRM) and the 2017 SUMREX (students: Sabrina Welch, Jackson State University and Diego Delgado, UPRM). The students spent the first 3 weeks at UCF and the second 3 weeks at LSU.

At UCF, the students began with a pre-test consisting of basic linear algebra and numerical methods problems designed to assess their level of competence in these topics and gage the need for further explanation on these topics. During the experience, the students engaged with Dr. Talea Mayo for assistance with the mathematical aspects of the pre-test. The pre-test also required the students to read a research paper in JGR-Oceans written by the LSU-UCF team, highlighting both concepts they did not understand as well as concepts that they were interested

in. For the remainder of the UCF phase of the SUMREX, the students worked closely with Dr. Medeiros to learn the SMS software for ADCIRC mesh development (temporary software licenses provided at no cost by Alan Zundel of Aquaveo). They went through tutorials from past ADCIRC boot camps, working through the examples. They then used their knowledge to implement and run desktop ADCIRC tide simulations on an existing WNAT mesh in SMS. Dr. Medeiros also took the students into the field on the UCF campus where they learned the basics of RTK-GPS topographic surveying, field methods for determining Manning's n bottom friction coefficients and effective aerodynamic roughness length by measuring the height, canopy width and other dimensions of trees and above-ground obstructions. Lastly, the 2017 students engaged with Dr. Thomas Wahl to discuss sea level rise, appropriate model scales, and how ADCIRC (or surge model output in general) is used by downstream researchers and policy makers. The students were given 3 questions to ponder after Dr. Wahl's presentation and given three days to develop responses.

- How can ADCIRC be used to identify and quantify non-linear interaction between different sea level components?
- How could you implement sea level rise in an ADCIRC model? Be specific.
- For which spatial scales is ADCIRC most suitable and why?

For the second three weeks, the students transitioned to LSU and began working with Dr. Matthew Bilskie to build on their ADCIRC knowledge by conducting storm surge simulations. The students 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. They also simulated several hurricanes using a coarse ADCIRC model on both their workstations and on the LSU HPC and document the difference in run-time. They 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). On the last day of the program each student gave a presentation outlining their overall summer research tasks and experience with SUMREX.

8. Publications.

Tahsin, S., S.C. Medeiros, A. Singh, M. Hooshyar (2017), "Optical Cloud Pixel Recovery via Machine Learning", *Remote Sensing*, Vol. 9 (6), doi:10.3390/rs9060527..

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.

9. Tables:

Table 1: Documenting CRC Research Project Product Delivery

Product Name	**Product Type** (e.g., software, guidance document)	**Delivery Date**	**Recipient or End User**
CERA Video Tutorial	YouTube Video	02/28/2018	We were asked to withhold public release pending an upgrade to CERA

Table 2A: Documenting External Funding

Title	**PI**	**Total Amount**	**Source**

Table 2B: Documenting Leveraged Support

Description	**Estimated Total Value**
STOKES HPC at UCF	**$10,000**
Queenbee2 HPC at LONI	**$50,000**
Stampede2 at TACC (via XSEDE)	**$25,000**

Table 3: Performance Metrics:

HAGEN-MEDEIROS PERFORMANCE METRICS

Metric	Year 1 (1/1/16 – 6/30/16)	Year 2 (7/1/16 – 6/30/17)	Year 3 (7/1/17-6/30/18)
HS-related internships (number)			
Undergraduates provided tuition/fee support (number)			
Undergraduate students provided stipends (number)		1	1
Graduate students provided tuition/fee support (number)	1	1	
Graduate students provided stipends (number)	1	1	
Undergraduates who received HS-related degrees (number)			
Graduate students who received HS-related degrees (number)			
Graduates who obtained HS-related employment (number)			
SUMREX program students hosted (number)	1	2	
Lectures/presentations/seminars at Center partners (number)			
DHS MSI Summer Research Teams hosted (number)			
Journal articles submitted (number)			
Journal articles published (number)	1	1	
Conference presentations made (number)			1
Other presentations, interviews, etc. (number)	8	10	1
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 agencies or governments		2	
Total milestones for reporting period (number)	3	4	
Accomplished fully (number)	0	5*	3
Accomplished partially (number)	3	2	3
Not accomplished (number)	0		

10. Year 3 Research Activity and Milestone Achievement:

Research Activities and Milestones: Final Status as of 2018
Reporting Period 7/1/2017 – 6/30/2018

Research Activities	Proposed Completion Date	% Completed	Explanation of why activity/ milestone was not reached
Develop scalable data processing pipeline for lidar-based surface roughness parameterization	06/30/2016	100%	
Finalize, validate and test NGOM forecast grade model and get running inside of ASGS	06/20/2018	100%	
Research Milestones			
Submit a manuscript on Regional Scale Lidar Surface Roughness	06/30/2016	80%	Efforts directed towards engaging with end users regarding NGOM model's integration into ASGS and CERA. Expect completion by 12/31/2018.
Submit manuscript on mesh optimization	6/30/2017	60%	Efforts were directed towards getting model for hurricane season 2018. Expected Completion 12/31/2018.

11. Year 3 Transition Activity and Milestone Status:

Transition Activities and Milestones: Final Status as of 2018
Reporting Period 7/1/2017 – 6/30/2018

Transition Activities	Proposed completion date	% completed	Explanation of why activity / milestone was not reached
Develop transfer protocol for NGOM model to ASGS including file naming convention, file compression, security keys, model update schedule, ADCIRC version control, etc.	07/31/2016	100%	
Participate in workshop (in-person or virtual) to discuss possible improvements to the interface at http://cera.cct.lsu.edu to facilitate both	03/31/2017	100%	

end-user experience and model output integration pipeline			
Transition Milestone			
Prototype integration of NGOM ADCIRC model output into CERA	06/30/2016	100%	
Refined transition goals and plan with end user input	06/30/2016	100%	
Implementation of preliminary optimized NGOM model in ASGS. Enables us to deliver surge imagery to NGOM Sentinel Site Cooperative and NWFWMD via email. This preliminary implementation sets up ASGS to automatically execute simulations of our optimized NGOM model using latest NHC storm tracks.	08/31/2016	100%	.
Full integration of NGOM ADCIRC model output into CERA. Enables NGOM Sentinel Site Cooperative and NWFWMD to view current surge forecasts on CERA. These surge forecasts will be generated by ASGS using the preliminary optimized NGOM ADCIRC model and latest NHC storm tracks.	05/31/2017	95%	Technical difficulties, high demand, and security issues at CERA have prevented full scale testing of automatic output integration of our results.