HAGEN, LSU

DHS Coastal Resilience Center

Research Project:

Annual Project Performance Report

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

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.

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 ("elevator speech"):**

   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 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. 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 are also having this years SUMREX students run through the tutorial and provide feedback as well. We will assimilate all feedback and produce a revised tutorial in 2017. 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 rthis stakeholder 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 during Performance Period 3) to the NGOM SSC as well as their invitees.

7. Unanticipated Problems:

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.

8. Project Impact:

Our project will produce 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 ASGS 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 methods 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 is also the best, most readily adoptable means for conveying the model results to the public in a meaningful way.

Our project will also train multiple end users (NWFWMD, NGOM SSC, possibly FDOT, FDEM and FEMA) in the use of CERA to receive updated surge forecasts. We are also coordinating with NWFWMD regarding the incorporation of CERA into an emergency management exercise (i.e. a table-top evacuation plan), although correspondence to date has indicated that they are less receptive to this; the CERA tutorial has gotten more traction with this end user.

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.

9. Research Activity and Milestone Progress:

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
Develop scalable data processing pipeline for lidar-based surface roughness parameterization	06/30/2016	75%	Issues with magnitude of data, explained above in Section 7. Expect completion by 06/30/2018
Phase 2 of optimization procedure: Enforce stricter inclusion criteria for vertical features and document incremental performance improvements	10/31/2016	100%	
Phase 3 of optimization procedure: Accelerate relaxation criteria moving away from vertical features and document incremental performance improvements	12/31/2016	100%	
Research Milestone			
Submit a manuscript on Regional Scale Lidar Surface Roughness	06/30/2016	60%	Issues with magnitude of data, explained above in Section 7. Targeted journal will be PE&RS due to industry reach. Expect completion by 06/30/2018
Presentation of Mesh Optimization Progress at ADCIRC Workshop	04/30/2017	100%	Completed by Dr. Bilskie
Submit manuscript on mesh optimization	6/30/2017	25%	Currently spending time and effort to finalize the new forecast-grade optimized mesh for the 2017 hurricane system and its implementation into ASGS/CERA. Once the model is ready effort will then be put forth towards manuscript preparation. Expected Completion June 2018.

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
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	100%	
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	90%	This activity is nearly complete and is reliant on completion of the first version of the optimized forecast grade model. Expected Completion is 7/31/2017.
Participate in workshop (in-person or virtual) to discuss possible improvements to the interface at http://cera.cct.lsu.edu to facilitate both end-user experience and model output integration pipeline	03/31/2017	50%	Made decision to have students conduct preliminary assessment of tutorial prior to presentation to end users. Expect Completion by 12/31/2017
Transition Milestone			
Prototype integration of NGOM ADCIRC model output into CERA	06/30/2016	50%	This activity is nearly complete and is awaiting mock model run results for testing on the CERA platform. In-person meetings have been conducted between model developers and CERA technical personnel. Expected Completion is 7/31/2017.
Refined transition goals and plan with end user input	06/30/2016	75%	Consultations with end users are ongoing. We expect to keep an open dialogue with end users until end of project.
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	08/31/2016	25%	This activity is reliant on completion of the first version of the optimized forecast grade model. Expected Completion is 8/31/2017.

of our optimized NGOM model using latest NHC storm tracks.			
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	25%	This activity is reliant on completion of the first version of the optimized forecast grade model. Expected Completion is 8/31/2017. This activity will be released on the CERA development site and will not be a full release until the 2018 hurricane season to ensure a robust implementation of the optimized model into the ASGS/CERA framework.

11. Interactions with education projects:

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

At UCF, the students begin with a pre-test consisting of 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, 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 WANT 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 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 (underway at the time of this writing), 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 will attend 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 will also simulate several hurricanes using a coarse ADCIRC model on both their workstations and on the LSU HPC and document the difference in run-time. They will also learn 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). This experience is still underway and we look forward to Sabrina and Diego's final presentations.

12. Publications:

Tahsin, S., **S.C. Medeiros**, A. Singh, M. Hooshyar (2017), "Optical Cloud Pixel Recovery via Machine Learning", *Remote Sensing*, Accepted.

13. Tables:

Table 1: Documenting CRC Research Project Product Delivery

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
Lidar to Surface Roughness Processing Script	Software Code made available on Github	June 2018	The general coastal modeling community
CERA Tutorial for Coastal Stakeholders	Guidance	December 2017	NWFWMD, NGOM SSC, FDOT, FDEM, FEMA, Coastal Communities
ASGS NGOM Forecasts	Web Application	June 2018	NGOM SSC, NWFWMD, General Public
Lidar to Surface roughness processing paper	Journal Paper PE & RS	June 2018	General coastal resilience, remote sensing, and geospatial big data community
Paper on mesh optimization	Journal Paper Advances in Water Resources	June 2018	General coastal resilience and hydrodynamic modeling community
Paper comparing tide and surge results from mesh with standard (land cover) versus lidar based surface roughness parameterization	Journal paper Coastal Engineering	June 2018	General coastal resilience and hydrodynamic modeling community

Table 2: Documenting External Funding and Leveraged Support

External Funding			
Title	PI	Total Amount	Source
NA			
Leveraged Support			
Description			Estimated Annual Value
XSEDE High Performance Computing Allocation (Stampede) – Est. 13% of award to be used on this project (400,000 CPU hours)			$13,946.23
STOKES HPC at UCF – Est. 50% of Dr. Medeiros base monthly allocation equal to 40,000 CPU hours per month			$1,394.00
LSU/LONI High Performance Computing Allocation – 200,000 CPU hours			$6,973.11

14. Metrics:

Metric	**Year 1** (1/1/16 – 6/30/16)	**Year 2** (7/1/16 – 6/30/17)
HS-related internships (number)		
Undergraduates provided tuition/fee support (number)		
Undergraduate students provided stipends (number)		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)		
Other presentations, interviews, etc. (number)	8	10
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 (number)		2
Total milestones for reporting period (number)	3	4
Accomplished fully (number)	0	5*
Accomplished partially (number)	3	2
Not accomplished (number)	0	

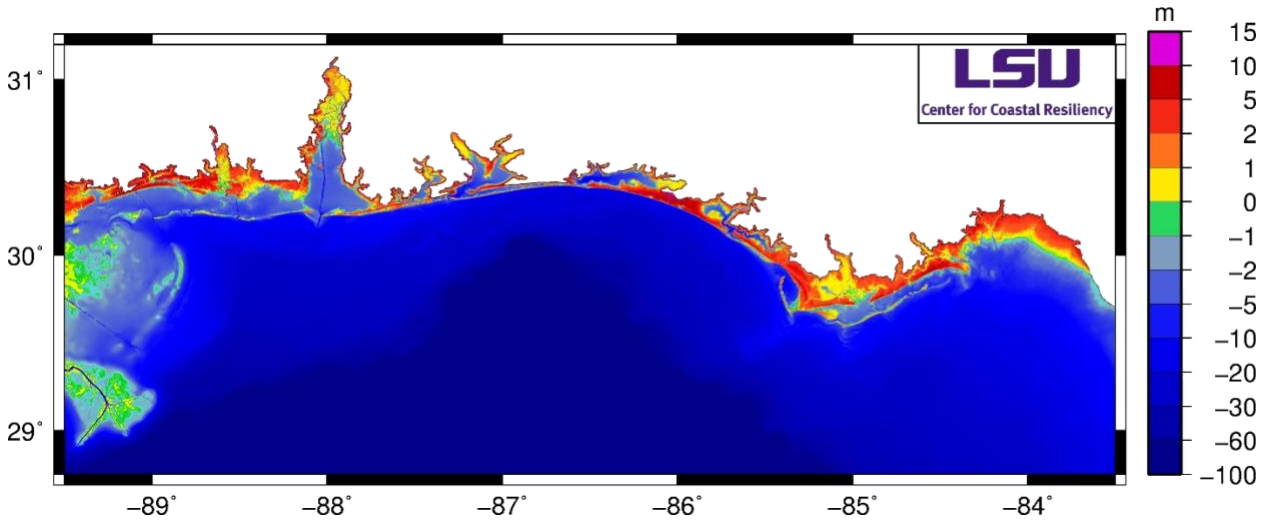

Figure: NGOM3 Mesh Elevations

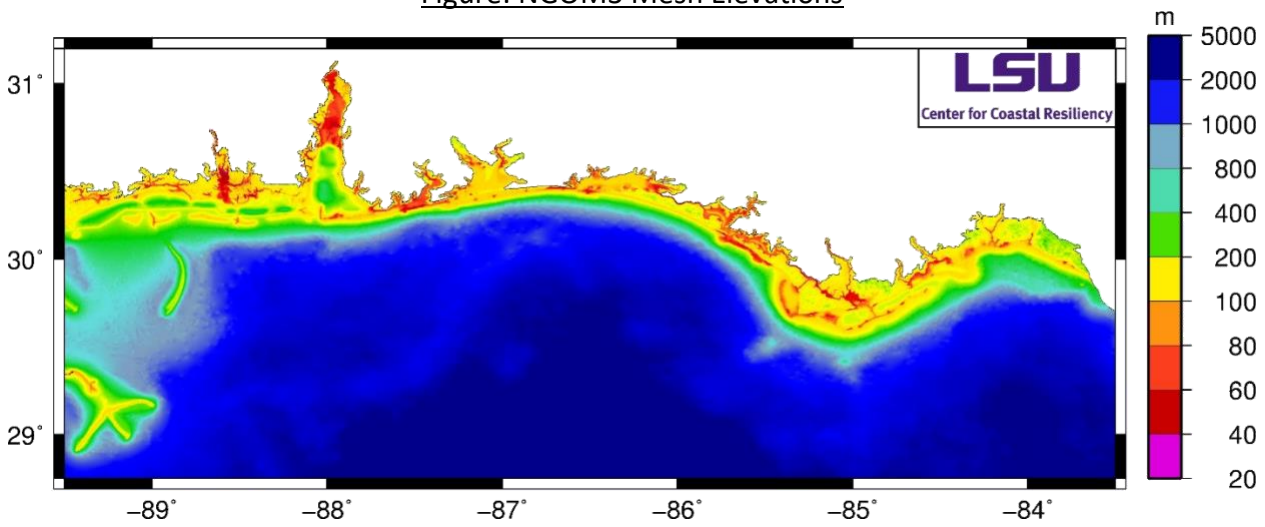

Figure: NGOM3 Mesh Resolution (Element Size)