RESIO – UNF

DHS COASTAL RESILIENCE CENTER
RESEARCH PROJECT
YEAR 3 PERFORMANCE REPORT
AND
FINAL PROJECT REPORT

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

Principal Investigator Name/Institution: Donald T. Resio, Ph.D., University of North Florida

Co-Principal Investigators and Other Partners/Institutions: Dr. John Atkinson, ARCADIS, and Bruce Ebersole, Jackson State University.

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

Short Project Description: Rising sea level and growing coastal populations increasingly threaten lives and livelihood of those living along coasts and the environment in which they live. Planning decisions for a range of timescales must be based on accurate information on hazards and risks; however, the present state of the art does not include critically important combined hydrologic-surge sources of flooding. This project will focus on the development of a methodology for incorporating these interactions in a statistically and physically appropriate manner into FEMA's operational coastal modeling systems.

Summary Abstract: The primary objectives of this project have been 1) to develop a statistical method for including rainfall-runoff effects into FEMA-JPM studies and 2) to develop a stable, adaptable numerical scheme to combine hydrologic and surge models into a common executable system, and 3) to produce a preliminary evaluation of the impacts of combining these effects into improved estimates of flooding hazards. Ancillary goals that were important to work on this project were 1) to ensure involvement of students into studies of coastal resilience and 2) to coordinate our work with potential end-users and collaborators. Some primary accomplishments on this project include an improved understanding of the role of natural structure in flooding hazards and the identification/development of analysis tools to utilize this information in combined hydrologic-surge flooding. Also, during this project, all graduate students in the Coastal Program at UNF participated in a forensics study of the impact of Hurricane Matthew, which provided an excellent motivation for students to understand the importance of hurricane impacts in terms of dune breaching relative to their location within a half-completed beach-fill project in Jax Beach. The final report accompanying this Year 3 Performance Report provides information on changes in flooding patterns and depths for a range of storm tracks and rainfall rates, along with conclusions concerning a statistical approach that appears to offer a flexible basis for conducting FEMA RiskMap studies within reasonable computer resources.

PROJECT NARRATIVE:

1. Research Need: Rainfall and coastal tributaries/rivers greatly affect inundation patterns and levels throughout the U.S. East and Gulf coasts. Present coastal flood maps neglect hydrologic-surge interactions, significantly underestimating the extent and magnitude of hazards and risks in essentially all major urbanized areas and underestimating actuarial insurance costs; therefore, improved quantification of this compound flooding is essential to establishing clear guidelines for coastal resilience. The research needed to accomplish this task consists of two major elements 1) improving the statistical treatment of combined hydrologic-surge flooding and 2) developing stable, efficient and accurate numerical methods for coupling hydrologic and surge models into a common numerical framework. The fundamental problem in achieving this goal is to retain accuracy and stability in the numerical code while still allowing all necessary computer simulations to be completed within an acceptable level of computer resources. It is well recognized that existing RiskMap studies require many extensive, time-consuming model simulations in order to obtain estimates of flooding hazards in coastal areas. The number of simulations needed for this purpose has been shown to be directly related to the number of different parameters required to represent the phenomena responsible for causing the flooding. If rainfall, antecedent conditions, and river/tributary discharges were added to this list in a fashion that required execution of both the surge model and coupled hydrologic model in a simplistic manner, this could increase the number of simulations needed by more than an order of magnitude. The results shown in the accompanying report suggest that this may not be necessary.

1. History:
    - primary steps taken to carry out the project

        Year 1

        i. obtain river discharge and rainfall data for statistical analysis
        ii. form user group for project communication
        iii. obtain gridded bathymetry-topography of study area for ADCIRC model, wind fields for simulations for the study area
        iv. obtain hydrologic models (HEC-RAS and SWAT) for hydrologic testing

        Year 2

        v. Develop statistical characterization of rainfall patterns relative to the deterministic PHRaM algorithm
        vi. Perform sequence of tests of different methods of coupling a modified SWAT model to the ADCIRC model
        vii. Characterize the rainfall and James River discharge statistics

        Year 3

        viii. Choose a set of storm tracks and rainfall patterns to test sensitivity of response to variations in the hydrologic variables and utilize a response function to examine the sensitivity of flood levels to these variations
        ix. Provide skype briefing on statistical methods to user group
        x. Write final report
    - major project milestones
        i. Data acquisition
        ii. Statistical characterization of rainfall patterns, amounts and variability
        iii. Three stages of model coupling tests

iv. Definition of test cases for demonstration of modeling system and sensitivities to rainfall and James River discharge
v. Presentation to user group and obtain feedback

- Problems or challenges that arose, how they impacted progress, and the action taken to address them.
    i. Insufficient radar data available for entire study time period forced a greater reliance on meteorological station data and multivariate analyses of the intrinsic rainfall patterns in time and space.
    ii. The lack of readily available open-source hydrologic models for the area of application made it necessary to borrow parts of the SWAT model approach (basin-scale) and implement a gradually varied flow (GVF) approximation on the hydrologic-surge model interface. This did not affect water levels much on the surge side in areas which opened into broad, deep water bodies but definitely had important effects in rivers and on the hydrologic side of the boundary in our model tests.
    iii. A problem that emerged during our interactions with hydrologic groups is the tremendous inertia in the hydrologic modeling systems. The amount of site-specific tuning and event specific tuning makes the users very reluctant to consider changing to a different model than the one they are presently using. This issue was beyond the scope of our project but definitely will need to be solved either by making a "universal" coupling system or by choosing a "universal" hydrologic model to couple with ADCIRC. Clearly, the latter of these two choices is preferred for RiskMap applications.

2. Results:
    i. Our final results suggest that it is indeed possible to avoid an overly large increase in the number of computer simulations using methods investigated during this project; however, these findings could be site specific and additional tests at other sites are recommended.
    ii. The characterization of rainfall characteristics in terms of mean function have only begun to receive the level of analysis and local modification needed to ensure that they can be used along all East and Gulf Coast areas to set insurance rates in this area.
    iii. Given the results of our set of simulations, it is very appropriate that the continuation of this effort with focus on different accuracies of hydrologic model combinations with ADCIRC, using different types of boundary conditions at their intersection.
    iv. An important part of the work involved in the investigation into different types of statistical techniques that could be considered for RiskMap applications. In particular, Resio et al. (2017) showed the importance of allowing the physical influence of natural structure to influence statistical analyses.

3. End Users and Transition Partners:
    i. Coastal communities that need accurate information for their planning
    ii. FEMA managers since they can justify raising rates to cover costs. Since the estimated risk, with combined effects neglected, greatly underestimates the rates and the distribution of flooding problems over the entire flooding range from nuisance to extreme disasters.
    iii. Coast Guard, USACE and other first responders who could obtain improved estimates of expected locations of flooding and preposition materials that have a high likelihood of being needed in the immediate, critical post-storm interval.

- List of organizations/agencies or other partners that participated in transition planning and implementation and the role they played.
    i. Agency

        FEMA HQ
        FEMA Region I
        FEMA Region II
        FEMA Region III
        FEMA Region IV
        FEMA Region VI
        US Coast Guard
        USACE
        NOAA

    ii. These individuals were assembled into a review team by Mr. Ebersole (JSU) and interacted with him to provide feedback to the overall team.
    iii. A number of collaborators such as Larry Atkinson and Michelle Covey from Old Dominion University worked with us to appreciate special considerations for the study area.
- How did you transition your results?
    i. Via the final report accompanying the Performance Report and from the journal publication on the role of natural structure in statistics.
- Describe how end-users are using the results
    i. Presently used only as a building block to move to a more formalized system for coupling surges and hydrologic flooding into a unified statistical analysis. The current coupling method should be adaptable to any hydrologic model linked with the ADCIRC model; however, the applications in developing a production version for a hydrologic-surge system is not complete.
    ii. Concepts from the statistical methods developed as part of this study are currently being adapted to the application of coupled tide-surge statistics in the New York City appeal to FEMA. This is potentially an important adaptation to the previously proposed method that provides both reduced numbers of simulations required and more accurate results.

4. Project Impact:
    - The overall impact is the enhanced ability to analyze the structure of coupled interactions in numerical modeling systems which could become an enabler for the production of significantly more accurate hazard and risk estimates in coastal areas. This is a necessary step toward making the risks represent the actual expected economic losses in coastal areas.

5. Student involvement and awards:
    - Discuss how you involved students in your research, including research assistants or other student participants.
        i. A mandatory class for all graduate and selected undergraduate students on the topic of damages caused by Hurricane Matthew along the coast in the three coastal counties in the vicinity of Jacksonville. The class covered all aspects of flooding and wave induced damage in this tri-county area and presented their findings at a special, well attended, session at the annual American Shore and Beach Preservation Association in Ft Lauderdale in 2017. We have also designed a special Risk Assessment course to teach students new statistical tools that are needed for quantifying coastal resilience.
        ii. Amanda Tritinger is working on a new class of model which incorporates the vertical structure of currents into a model such as ADCIRC. She is the first author on a recently submitted manuscript on this topic to the Journal of Geophysical Research (JGR).
    - List degrees attained by students supported through your project. Include student name and degree (Bachelors, Masters, Ph.D.) and field
        i. Nikole Ward who was funded for one semester under this DHS project was awarded her MS in Civil Engineering and is now in the UNF-UF Ph.D. program working on the topic of an improved representation of beach recovery following storm.
    - List student awards, publications, posters, presentations, etc.
        i. Amanda Tritinger gave a presentation in Liverpool, England in September 2017 on the topic of her recently submitted JGR paper.
        ii. Amanda Tritinger received the Coasts Oceans Ports and Rivers Institute (COPRI) award for the best student poster at the 2017 national convention.
        iii. Nikole Ward received the COPRI award for best student poster at the 2018 national convention.

6. Interactions with education projects:
        i. Rudy Bartels, Ph.D. candidate at LSU, spent 4 weeks at UNF working with Dr. Resio on multivariate analyses of climate data.
        ii. Dr. Resio gave a lecture in 2017 on “The Effect of Natural Structure on Storm Surge Probabilities” at LSU.

7. Publications

- Resio, D.T., T.G. Asher, J.L Irish, 2017. The Effects of Natural Structure on estimated tropical cyclone surge extremes. *Nat Hazards,* **88,** 1609-1637.

8. Tables:

Table 1: Documenting CRC Research Project Product Delivery

Product Name	**Product Type** (e.g., software, guidance document)	**Delivery Date**	**Recipient or End User**
Analysis of effects of natural structure on coastal flooding hazards	Journal Publication	3/2017	Scientific community and users of hazard information in coastal areas
Two-way coupling method for hydrologic-surge modeling	Software	10/2017	Modelers and developers of the next-generation modeling system
Integration of hydrologic and surge modeling and preliminary assessment of options	Report	7/2018	DHS and all agencies involved in CRC activities

Table 2A: Documenting External Funding

Title	PI	Total Amount	Source
Coupled Rain-Surge Flooding in the Upper Barataria Basin	Resio	$60,000	Louisiana Water Institute
Guidelines to Electric Power Research Institute for	Resio	$30,000	EPRI
Development of Combined Storm Surge and Rainfall-Hydrologic Modeling for the coast of Louisiana	Resio	$60,000	Louisiana RESTORE funding

Table 2B: Documenting Leveraged Support

Description (e.g., free office space; portion of university indirects returned to project; university-provided student support)	Estimated Total Value
UNF student support for Matthew forensics study	$30,000
UNF Taylor Engineering Research Institute contribution to project	$50,000

Table 3: Performance Metrics:

RESIO PERFORMANCE METRICS1

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)			
Graduate students provided tuition/fee support (number)	1		
Graduate students provided stipends (number)	1	2	1
Undergraduates who received HS-related degrees (number)			
Graduate students who received HS-related degrees (number)			
Graduates who obtained HS-related employment (number)	2		
SUMREX program students hosted (number)		1	
Lectures/presentations/seminars at Center partners (number)	1	1	1
DHS MSI Summer Research Teams hosted (number)			
Journal articles submitted (number)	1	1	1
Journal articles published and Book Chapters (number)	1	1	
Conference presentations made (number)		1	1
Other presentations, interviews, etc. (number)	1		1
Patent applications filed (number)			
Patents awarded (number)			
Trademarks/copyrights filed (number)			
Requests for assistance/advice from DHS agencies (number)	1	1	
Requests for assistance/advice from other agencies or governments	1	1	
Total milestones for reporting period (number)	3	2	2
Accomplished fully (number)	1	5	1
Accomplished partially (number)	2	6	1
Not accomplished (number)			

9. 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
Analysis of Coupled Flooding Statistics and Modeling Boundary Conditions	7/2018	100%	Rainfall report was included within the final report
Research into the effects of natural structure on statistical processes critical to coastal hazards	12/2016	100%	Published in 2017
Research Milestones			
Rainfall-Hydrology-Statistics and Modeling Integration Report	2/2017	100% (7/2017)	It was late but was reached
Journal Publication	12/2016	100%	Accepted before12/2016 but published in early 2017

10. 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
Presentation of teleconference to collaborators and end-users	2017	100%	
Final report on statistical-modeling approach to combining hydrologic and surge driven flooding in the Tidewater Virginia area	2017	100%	
Technical Guidelines for FEMA application of coupled hydrologic-surge modeling for coastal flooding hazards	No date proposed		This was intended as an ultimate goal but was not given a completion date, since it depended on many factors that had to be better understood during the research
Transition Milestones			
Application of Methodology to an area of interest	No date proposed	100%	An application of the modeling system to show statistically relevant impacts which could be quantified was completed as intended; however, a complete JPM study is well beyond the scope and resources of the current project, so this should be recognized as a demonstration of what can be done, not a full JPM application.