RESIO, UNF
DHS COASTAL RESILIENCE CENTER
ADCIRC PROJECT
YEAR 5 PROGRESS REPORT
July 1, 2019 – June 30, 2020

I. INTRODUCTION

Project Title: Development and Validation of Efficient and Accurate Methods for Coupling ADCIRC to Hydrologic Models

Principal Investigator Name/Institution: Donald Resio, Professor, University of North Florida

Additional Research Participants/Partners: John Atkinson, ARCADIS

Short Project Description ("elevator speech"):

Today, the ability of coastal communities to sustain health and prosperity is being threatened by rising sea level and increased development in areas vulnerable to flooding. Recent storms such as Isaac, Harvey, and Irma have shown that a somewhat previously overlooked threat, the omission of hydrologic contributions (rainfall, runoff, and river flow) during storm surge events, can produce significant under-predicted flood risks in coastal areas. This project will develop and evaluate methods to couple hydrologic and surge models for the quantification of flood risk. In terms of coastal resilience, this change is critical to the accurate estimates of flooding for real-time evacuation planning, supporting long-term resiliency planning, as well as accurate hazard predictions in coastal areas. Products derived from this research mission will be of immediate utility to DHS and their mission to define existing risk and proposed risk reduction activities for United States coastal communities. The project will also develop a set of metrics that include accuracy, computer resource requirements (primarily execution time) and the flexibility of the system to function effectively and accurately over a range of conditions.

II. PROJECT NARRATIVE

1. Project overview:
    a) Year 5 research focused on the evaluation of three methods for estimating the computational feasibility and system accuracy of three different methods for calculating inland flood stages due to combined storm surge and storm-related hydrologic processes that lead to increased flooding in the Lower Saint Johns River Basin. It also investigated various means to convert the prediction system from execution in a deterministic mode to execution in a probabilistic mode, i.e. a Joint-Probability-Method – Optimal- Sampling (JPM-OS) execution. This is an important initial step toward developing a methodology that can be used by FEMA to quantify hazards and risks in coastal areas around the United Stated in order to improve coastal resilience. This information is also key to enabling local and state governments to recognize additional threats to their lives and livelihood that have been previously neglected.

2. Results:
    a) In year 5, the UNF team re-formulated response functions for flooding along open coasts and in estuarine and riverine environments where hydrologic forcing is also important. This new methodology allows us to quantify the potential effects of local and broad-scale variations in coastal/riverine configuration.
    b) We also found that the degrees in freedom needed to include at least the discharge at the upper boundary (or boundaries) of the modeled area and sufficient parameters to describe the space-time varying rainfall over the entire modeled area is quite large However, discharge at the downstream location of these systems did not significantly affect water levels at points slightly removed (offshore), allowing a de-coupling of the surge models from the discharge rate.
    c) Treatment of input from small tributaries into a main channel can be represented for all basins along the St Johns River within a parametric model that includes rainfall, backwater effects, and drainage rates will be explained in the final report.
    d) Rainfall rates within the ADCIRC model can be estimated by the IPET extension of the Parametric Hurricane Rainfall Model (PHRAM) (IPET, 2008), with some regional empirical adjustments.
    e) It was also determined, consistent with previous JPM effort, that it is essential to include organized deviations from the mean rain field and uncertainty in all factors involved in probabilistic model outputs.
    f) It was determined that about 350 discharge-rainfall variations will be needed to estimate the hydrologic runoff/backwater flooding effects in a study area such as the Lower St Johns River Basin.
    g) Three options have been evaluated as part of this effort:
        i. Execution of a single pass ADCIRC model to all combinations of forcing;
        ii. Executing independent ADCIRC simulations using a "slightly off-coast water level boundary at one end and the discharge boundary at the upstream end of the model domain;
        iii. Executing a simple one-dimensional finite-difference model using similar boundary conditions as those described in ii (the ADCIRC independent executions).
    h) Option "i" would require an increase of over two orders of magnitude in run-time for the JPM-OS simulations, so it does not appear feasible in a JPM-type application.
    i) Option "ii" appears to be the most advantageous, since it is already used in FEMA studies and training in the use of an ADCIRC river model to an ADCIRC surge model should build on existing capabilities.
    j) Option "iii" would require new training tools, testing, and would not initially include be able to include wind and wave forcing in areas where they might be important.
    k) Choice for final coupled system St Johns River testing:
        i. Option 2 is now in its stage of beginning production runs for option 2 as part of the Arcadis effort
        ii. The Arcadis and UNF groups have jointly developed the methodology for combining small-basin drainage and rainfall into the ADIRC model to retain stability.

3. End users:
    a) FEMA State Emergency Management, in conjunction with Florida Atlantic University are working on a statewide plan to evaluated coastal and inland hazards. Other universities are expected to join this team later.
    b) Discussions with City of St. Augustine on coastal and hydrologic hazards facing the city and threats to its historic landmarks and economic losses to flooding ranging from "nuisance-flooding" to major surge events in underway.

4. Transition:
    a) At this point, our emphasis has been on minimizing impacts on FEMA FloodMap operational methods, while still enabling the incorporation of combined hydrologic effects into the results used for the mapping.
    b) We believe the system developed through this effort will not significantly impact the overall time of computing in these studies, so their adoption would be very straightforward.

5. Project Impact:
    a) Since inland flooding in tropical cyclones is a major contributor to loss of life, damages and societal impact in many previous cases within the United States, the ability to include all major processes that contribute to risks in these areas, the incorporation of inland rainfall and rain fall in an accurate, efficient manner is essential to reaching this goal.
    b) The new system should very minimally affect the current computational burdens in FEMA studies in two fundamental ways:
        i. The hydrologic component of the computations is developed to be applied in a statistical context. This allows random errors to be included within a joint probability integral, which can be incorporated into the results within a context that does not require that details of every reach within the stream network be modeled exactly. Inside the integral this uncertainty is included via error term (typically Normally distributed around any bias).
        ii. In recent testing, many instabilities within ADCIRC ocean-to-river modeling system have arisen. By separating the ADCIRC runs into two components 1) computationally expensive offshore/nearshore regions and 2) computationally inexpensive hydrologic simulations of ADCIRC, coupled with a simple runoff model and rainfall over this area, by separating these two components in ADCIRC executions, problems with stability should be minimized.
        iii. Since our results suggest that there will be as many degrees of freedom in the hydrologic region as there are in the surge-modeling region, run time required for simulations in that form would increase the computational burdens by at least at factor of 300, since these degrees of freedom control the number of computer runs necessary for FEMA RiskMap studies)

6. Unanticipated Problems:

    a) Problems in the coupling of ADCIRC and hydrologic simulations were encountered in terms of instabilities in the ADCIRC model. The Arcadis group has made great progress in solving these problems, so we are now almost ready to begin some final runs in full system.

    b) The analysis of rainfall patterns coincident with hurricanes was much more difficult that the UNF group thought it would be; however, we have finalized our methodology and will present it in our final report.

7. Student Involvement and Awards:

    a. Students involved in research

    a) William (Paul) Chilton (MS Student) has been instrumental in developing new techniques for quantifying coastal surge response, both along the coast and inland, and for the objective quantification of potential errors in interpolations between points in the JPM-OS matrix. Paul has been accepted at Virginia Tech into their Coastal Resilience Program as a PhD student.

    b) Student Demographics

    b) Paul Chilton (male, Caucasian) was funded by this program for two years.

    a. Degrees Attained

    c) Paul Chilton will receive a M.S. degree at the end of June.

d) Student Awards

    d) Paul Chilton received the Ditzenberger Scholarship from the Ditznberger Foundation in Year 5.

8. Interactions with CRC education projects:

    N/A

III. RESEARCH ACTIVITIES AND TRANSITION MILESTONES

1. Year 5 Research Activities and Milestone Achievements:

Year 5 Research Activities and Milestones: Status as of 6/30/2020			
Research Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Finalize ADCIRC-Hydrologic grids	May 2020	100%	
Down-select models for final testing, based on metrics (such as computational efficiency and overall accuracy) that will be developed in year one of the project.	May 2020	100%	
Research Milestone			
Documentation of performance and computational costs for final options tested. For top performing hydrologic + ADCIRC model combinations, we will document the performance (i.e., run time, accuracy) and computational costs (i.e., number of HPC units required).	June 3, 2020	60%	Due to medical problems from Jun through early December of this year, this task will be finished in January

2. **Year 5 Transition Activities and Milestone Achievements**:

Year 5 Transition Activities and Milestones: Status as of 6/30/2020			
Transition Activity	Proposed Completion Date	% Complete	Explanation of why activity/milestone was not completed
Meetings with local officials to hold discussions on 1) the distributions of the flooding during Irma compared to previous flooding events and 2) provide information of the degree of potentially critical differences to the likelihood to flooding in areas along the St Johns River.	June 2020	80%	We have met with several groups but are waiting until we have our final results to give a full presentation to Jacksonville and St. Augustine. Due to medical issues this has been delayed until Febuary.
Cooperative efforts with other CRC groups to determine how to best transition emerging capabilities to planning agencies with the City of Jacksonville. It is expected that the City will	June 2020	80%	This will be completed in Febuary.

consider developing a commercial application of this system for urban planning along the River corridor.			
Transition Milestone			
Demonstration of system capabilities using different options for Hurricanes Matthew and Irma to federal (NOAA, USACE, FEMA), state (Florida Department of Environmental Protection, Water Management Districts) and local (Jacksonville Planning Commission). These demonstrations provide critical information on value of the improvements in prediction capabilities related to the need coupled system for end users and internal staff. The end-users could be motivated to ingest this information into their planning and the internal staff can identify the potential value of additional research in specific modeling components.	June 2020	80%	We have only completed Irma simulations to date, but will finish Matthew for our final report in February.
Report on "final" system capabilities and preliminary results of model boundary placement as a function of distance up the river (for example: at the river mouth or upriver).and implementation of different systems in conjunction with ADCIRC. This information could be of extreme value to FEMA RiskMap applications and to USACE design and planning applications, since such applications always involve decisions related to the value of different methodologies verses the cost of their application.	June 2020	50%	We have part of the report completed on our model selection; however, the "final" system is just coming online now. We expect to finish the final report in February.

3. **Research Project Product Delivery.**

Table: Research Project Product Delivery

Product Name and Function .	**Brief Product Description, including type** (e.g., software, algorithm, guidance document, knowledge product)	**Date Delivered** (or projected date of delivery)	**Recipient or End User(s)**
System for full JPM modeling of combined surge-hydrologic modeling	Set of software codes that allow Joint Probability Model applications to areas where this is a	June 30	Possible End Users for part or all of the system: FEMA USACE State of Florida

	discernible issue in flood levels.		
Documentation of model and system application	Use guides for applying models and utilizing outputs in JPM type studies	June 30	Potential User Groups: FEMA USACE State of Florida
Journal Article describing the system, its application in studies, its accuracy in the two storms simulated and suggestions for future improvements'	Published article will provide a good peer review of the methodology and its suitability to real-world studies.		Universities and other educations groups.

IV. PUBLICATIONS AND METRICS

1. <u>Publications:</u>

Student Theses and Dissertations

a) A dissertation by Amanda Tritinger was completed last June. She was supported by CRC funding for her entire dissertation and is now employed at the USACE ERDC. Her dissertation title is: The Influence of Vertical Structure on Open-Coast Surges and its Incorporation into Depth Averaged Models.

2. Performance Metrics

Resio 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)	Year 4 (7/1/18-6/30/19)	Year 5 (7/1/19-6/30/20)
HS-related internships (number)					
Undergraduates provided tuition/fee support (number)				2	1
Undergraduate students provided stipends (number)					1
Graduate students provided tuition/fee support (number)	1			1	1
Graduate students provided stipends (number)	1	2	1		1
Undergraduates who received HS-related degrees (number)					
Graduate students who received HS-related degrees (number)				1	1
Graduates who obtained HS-related employment (number)	2			1	
SUMREX program students hosted (number)		1			
Lectures/presentations/seminars at Center partners (number)	1	1	1		2
DHS MSI Summer Research Teams hosted (number)					
Journal articles submitted (number)	1	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		1
Patent applications filed (number)					
Patents awarded (number)					
Trademarks/copyrights filed (number)					
Requests for assistance/advice from DHS agencies (number)	1	1		1	
Requests for assistance/advice from other agencies or governments (number)	1	1		2	1
Dollar amount of external funding	$40,000	$187,000	$150,000	$125,000	$75,000
Total milestones for reporting period (number)	3	2	2	7	7
Accomplished fully (number)	1	5	1	2	2
Accomplished partially (number)	2	6	1	5	5
Not accomplished (number)					0