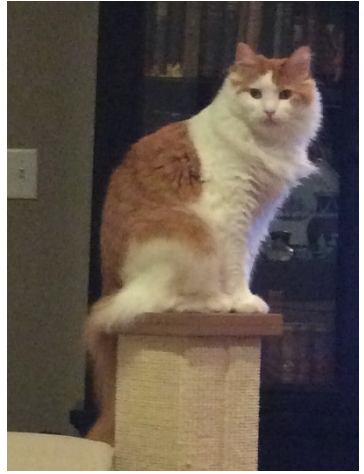
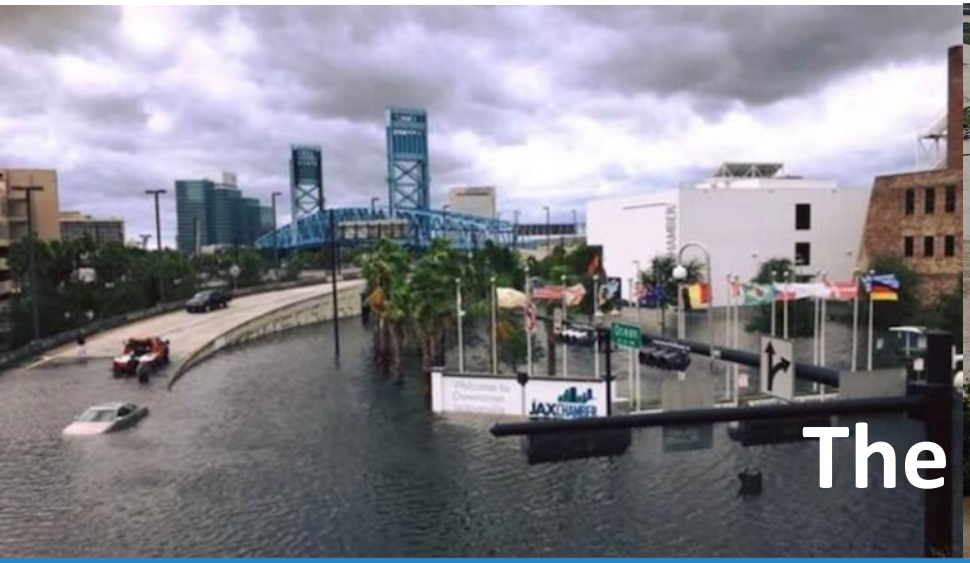
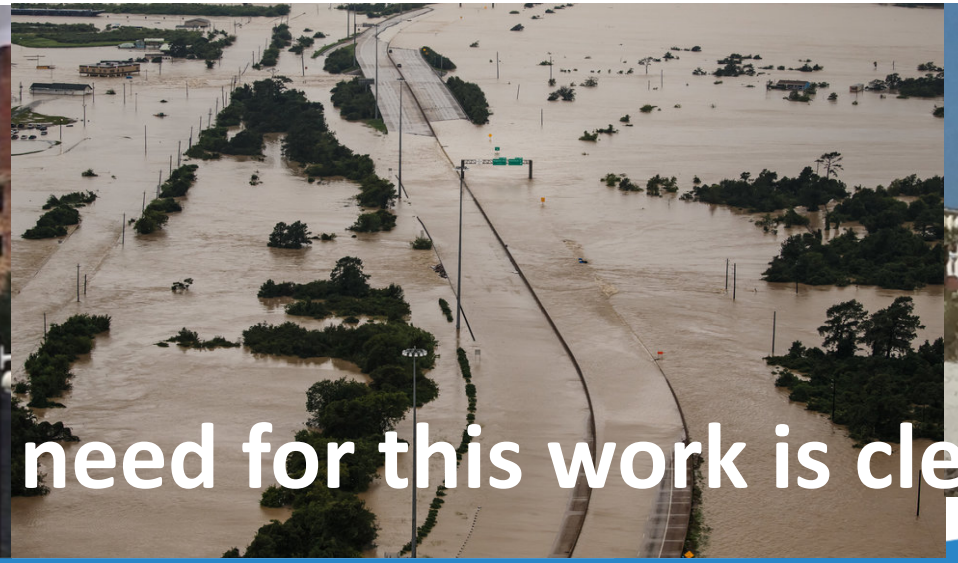


The Incorporation of Rainfall into Hazard Estimates for Improved Coastal Resiliency

- Don Resio – University of North Florida
- John Atkinson – Arcadis
- Bruce Ebersole – Jackson State University
- Amanda Tritinger – PhD Candidate University of Florida & University of North Florida



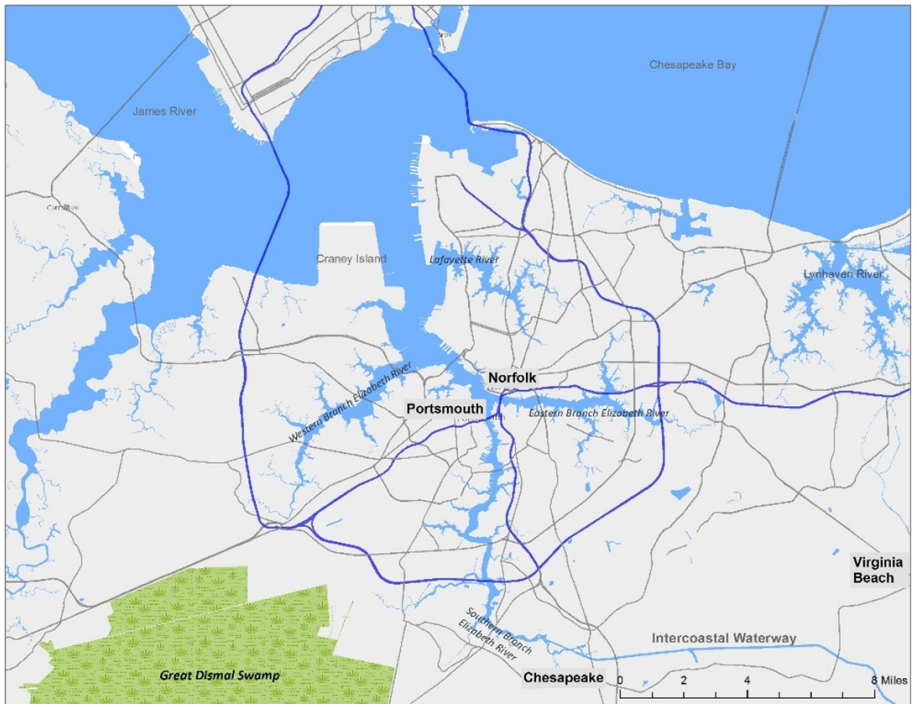


The need for this work is clear

Research Work and Accomplishments

PLANNED APPROACH
LIST FROM LAST YEAR'S MEETING

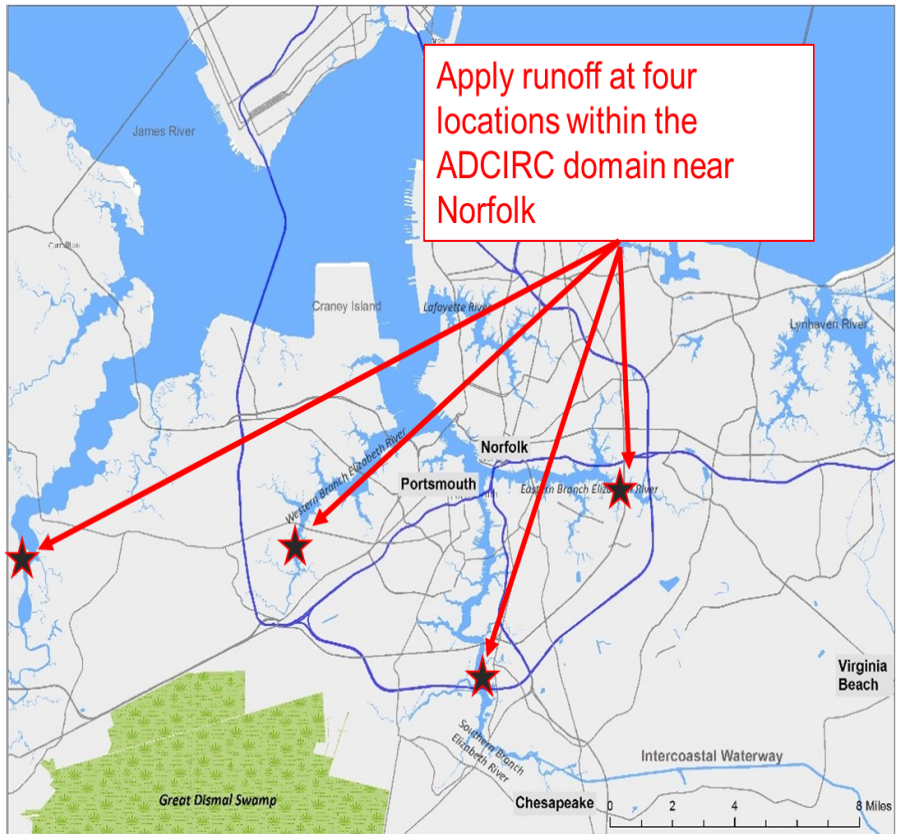
- **Develop and test a statistical and modeling framework over the expected range of forcing.**
- **Delineate magnitudes and areas of significant differences and investigate impacts on inundation probabilities**
- **Develop objective methodology for SRF approach to storm selection that includes rainfall, hydrologic inputs, and antecedent conditions.**
- **Evaluate performance of the newly released 2D version of HEC-RAS**
- **Compare 2D HEC-RAS performance with SOBEK and/or SWAT for ADCIRC coupling**
- **Deploy coupled system on different river system to see if conclusions are general (possibly lower James River area)**
- **Include precipitation in surge model**
- **Define a "flashiness" parameter for river basins to identify where coupling is more important during surge-precipitation events**



Overall Plan of Development

Establish Overarching Modeling and Statistical Concepts

- Fit our methodology to meet existing needs of for FEMA's Flood Studies.
- Recognize that bad statistical approximations, bad modeling approximations and excessive computer requirements can all unusable system
- Make our statistical and modeling approach as generalizable to get the job done
- No new hydrologic model development for coupling, instead utilize idealized mass-conserving aspects of the coupled system to examine the zone where inundation is moved farther inland. Hydrologic models can use this point to estimate a time-varying boundary along a fixed line for backwater heights (Gradually Varied Flow assumption). **Assumes mass balance not momentum balance is the dominant factor in coupling.**
- Adaptation of our work to specific hydrologic models should be relatively straightforward.



Accomplishments

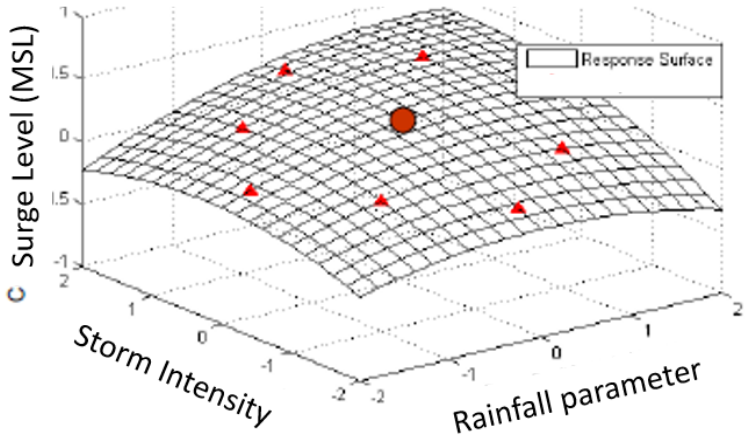
Statistics

- Model accuracy metrics should always be considered relative to uncertainties in their forcing functions
  - For predictions, uncertainties are large (evacuations) (Resio et al., 2017)
  - For parameterized storms, they are larger! (Flood maps)
- Risk related estimation recovers the uncertainty in the JPM integral
- The choice of modeling tools should be based on the ability to estimate unbiased values
- The multivariate analysis of river flows, antecedent conditions, storm surges and even tides can be accomplished with reasonable accuracy using existing tools.
- Developed a Modified Surface Response Function that provides an important capability for estimating continuous pdfs

Accomplishments

Statistics

RSFs (Response Surface Functions) use physical relationships to define a surface in any number of directions. The equations for these surfaces allow the interpolation within the discrete points obtained by simulations. The interpolations functions can be a combination of empirical and physics-base equations and allow for a much finer resolution than the simulation basis.



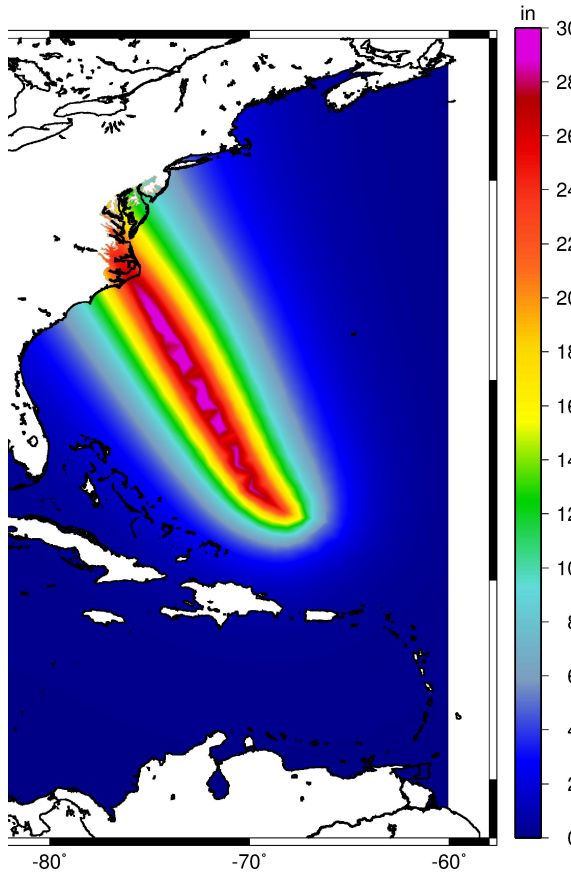
Response Surface Function example in 2 dimensions

- Completed an analysis of rainfall SRFs
- Sensitive to track and track angle along the coast, which are linked to hurricane parameter set
- SRF are not intended to be treated as probability masses – they provide much higher resolution of results that PMs

Accomplishments

Rainfall Modeling

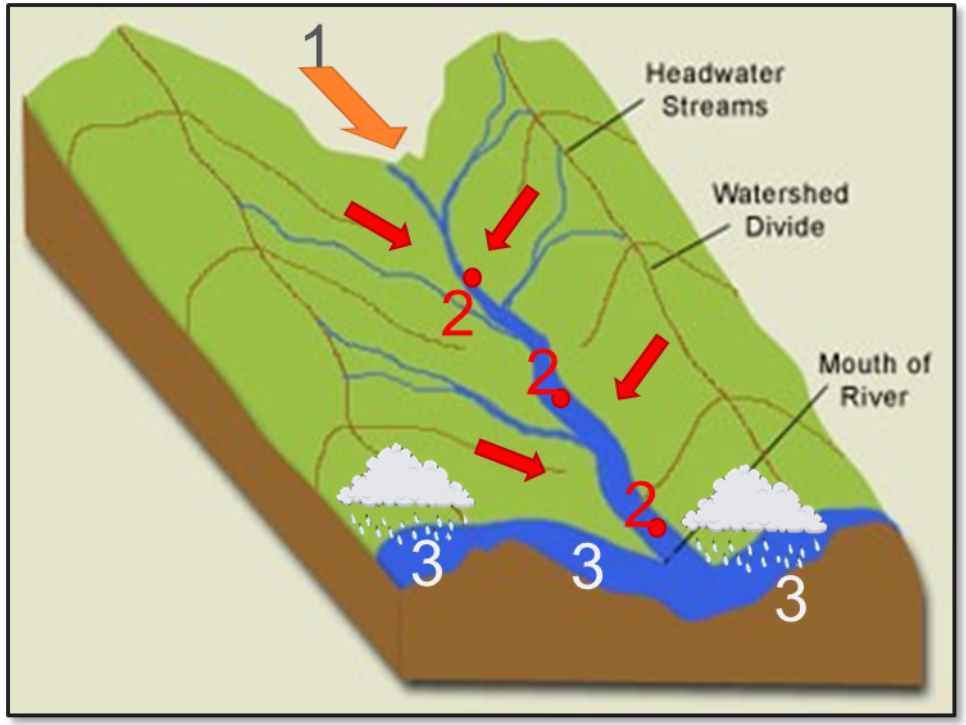
- Rainfall location, rates and timing in the Norfolk – Hampton Roads area are consistent with the PHRaM parametric representation; however, the sample size is much smaller than that of the PHRam study.
    - Two of the PHRam inputs (storm intensity and track proximity) are inherent in the storm parameters already used, but one parameter (shear) introduces a new term which can be evaluated in term of a local mean and variability around the mean (important to Matthew)
- PHRaM is coded inside the ADCIRC model for applications
- The number of additional simulations should be increased by less than a factor or 2, but additional work on combining surges and tides should keep the number of simulations about the same



Accomplishments

Coupled Hydrologic - Surge Modeling

- Boundary Condition is simply exchange of mass using GVF concepts
- Simulations can be executed in either 1-way or 2-way coupling
  - Antecedent river flow (normal ADCIRC boundary condition)
  - Local watershed routing (from hydrologic model)
  - Direct precipitation
- Simple model tested used basin estimates of precipitation lag time and include all sources of hydrologic mass inputs
- Can be adapted to a broad range of models –
  - But recall the uncertainty in forcing when doing this



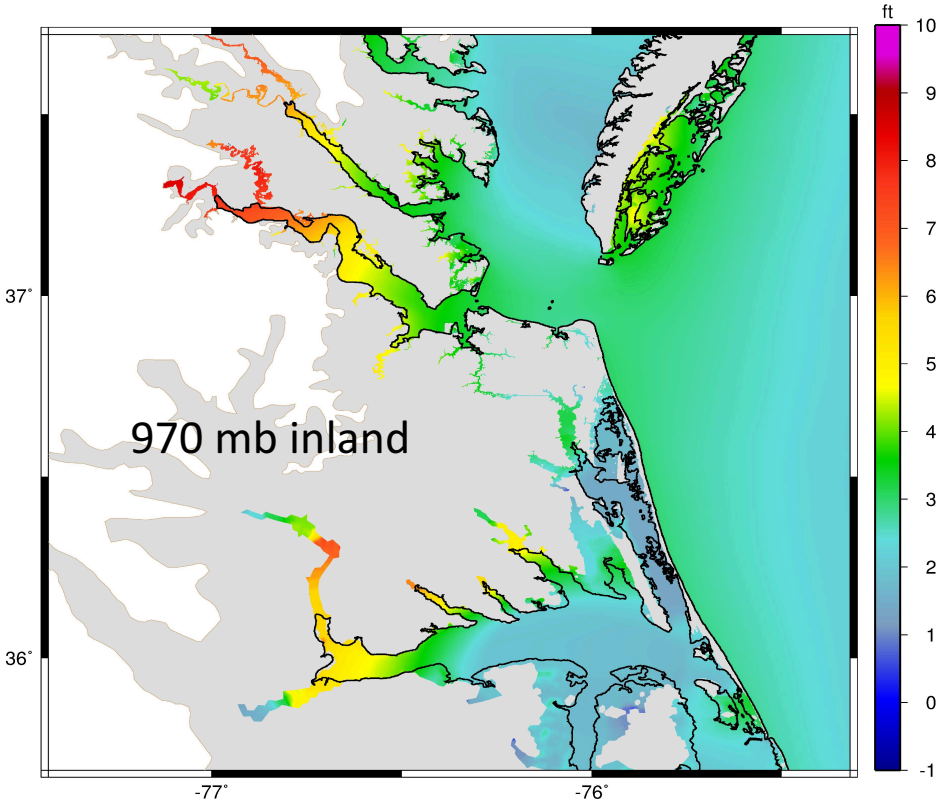
2-way Coupling System Examples

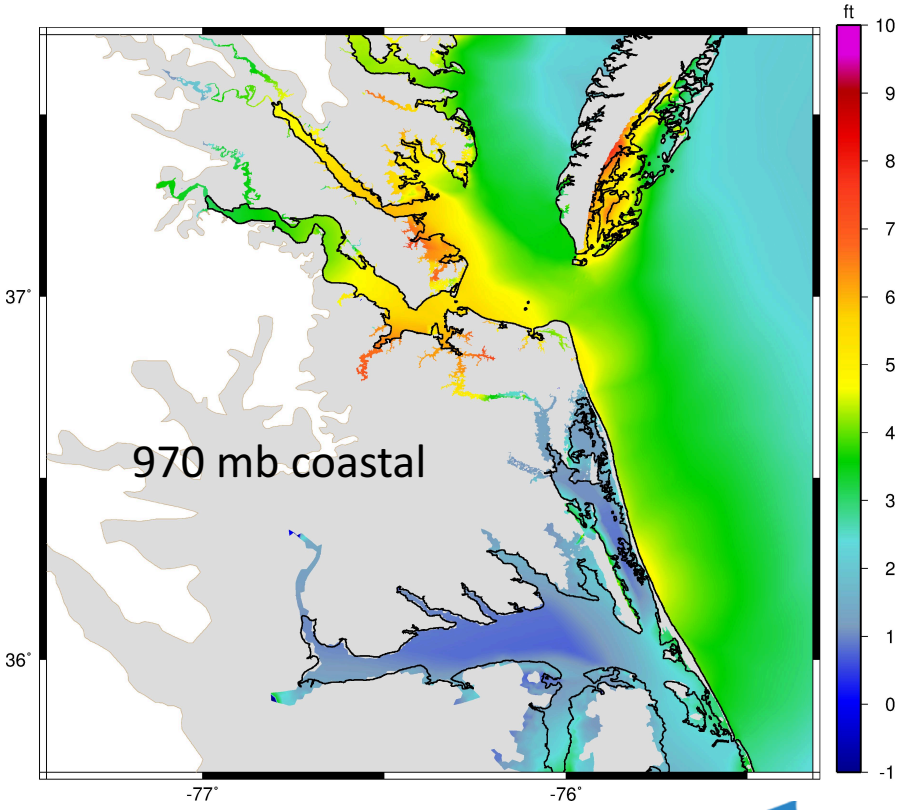
Storms selected from the FEMA Region III suite

One storm inland, one storm with eye at the coast, one storm offshore

Precipitation scaled for small rainfall event and large rainfall event

Essentially no significant extra simulation time – Boundary Condition can be used to drive local hydrologic model





Differences in peak water levels with and without hydrologic coupling

End User Engagement

- Primary End Users
  - FEMA HQ
  - Local Groups in Norfolk, Hampton Roads, Virginia Beach
    - Michelle Covey
    - Larry Atkinson
- Roles in project
  - Guidance and Assessment of Methods
- Specific interactions to date
  - On-site presentations, WEBEX and emails
- Advice on how to proceed

Transition

- We feel that this work is ready to be transitioned to testing for an improved FEMA Flood Mapping System on a test basis in its present form.

Anticipated Project Impact

The impact of hydrologic coupling into surge models has be demonstrated time and time again in recent years. The major impacts from such a transition would be:

- An improved assessment of potential risks which should be include in FEMA's insurance rates
- A more equitable distribution of flood insurance payments
- **Improved Resilience in planning for the future in coastal communities**

Proposed Follow-on Work

If the project were continued for an additional 2 years, the project team would:

- Perform a proof of concept test of our work in the Norfolk – Hampton Roads area, including validation of the coupling methodology in Hurricane Irma in Jacksonville – including tides, river flow, surge and rainfall
- Subject results to careful review by FEMA and other reviewers
- Meet on a regular basis to see how local communities could link our results to their own very-fine detail urban drainage models
- Provide presentations to communities on how to utilize these new tools and method and encourage them to do so
- Iterate on improving the methodology where needed
- Work with FEMA and other agencies to make maximum use of the new risk information provided which should help minimize future FEMA deficits