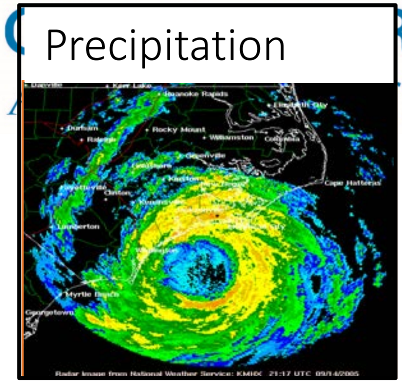
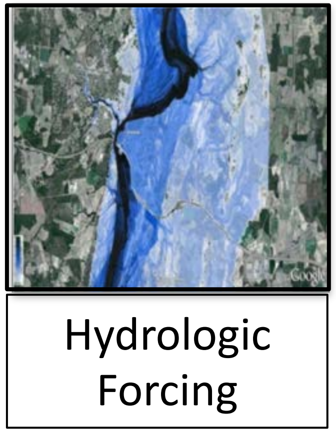
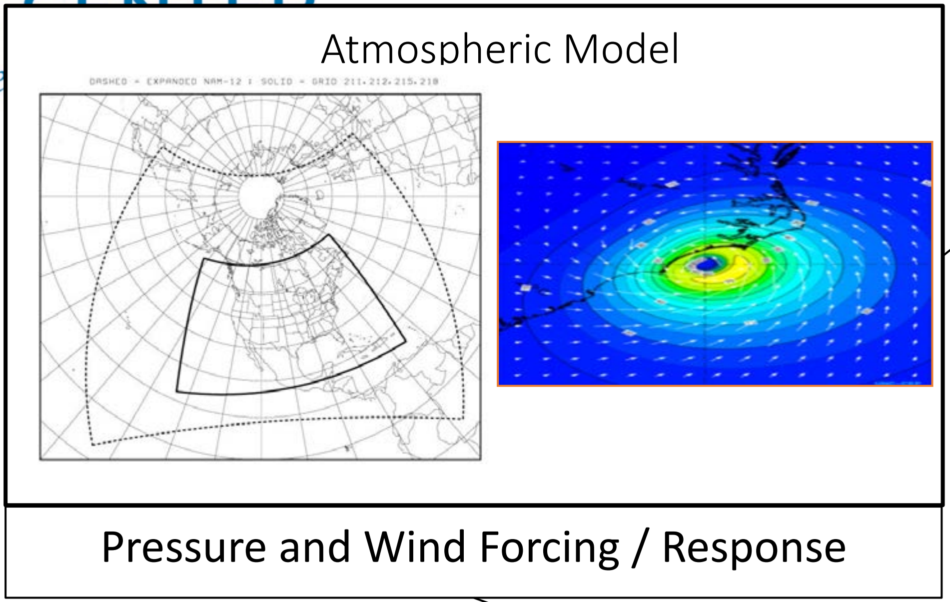
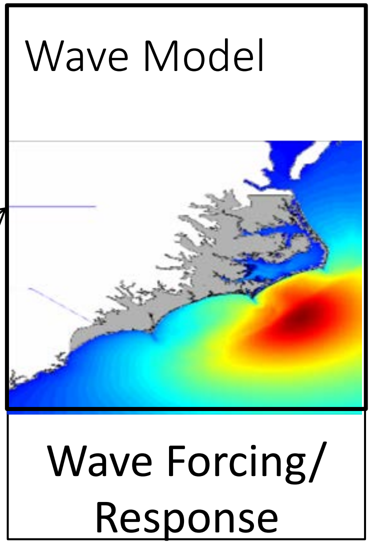
Development and Validation of Efficient and Accurate Methods for Coupling ADCIRC to Hydrologic Models

Don Resio University of North Florida
John Atkinson Arcadis-US
Zach Cobell The Water Institute of the Gulf

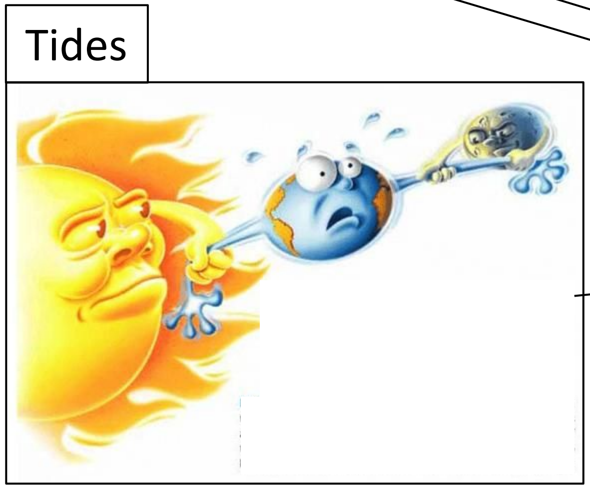


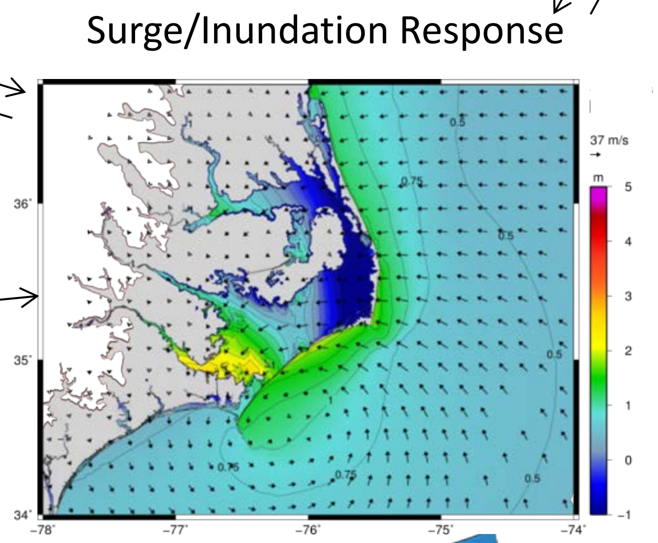






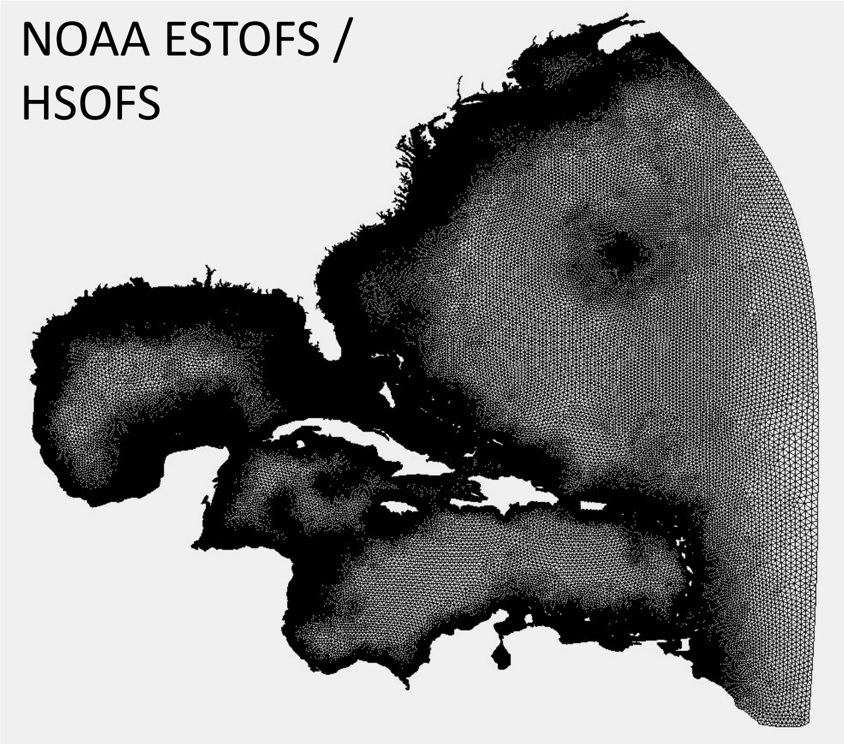
ADCIRC Prediction System

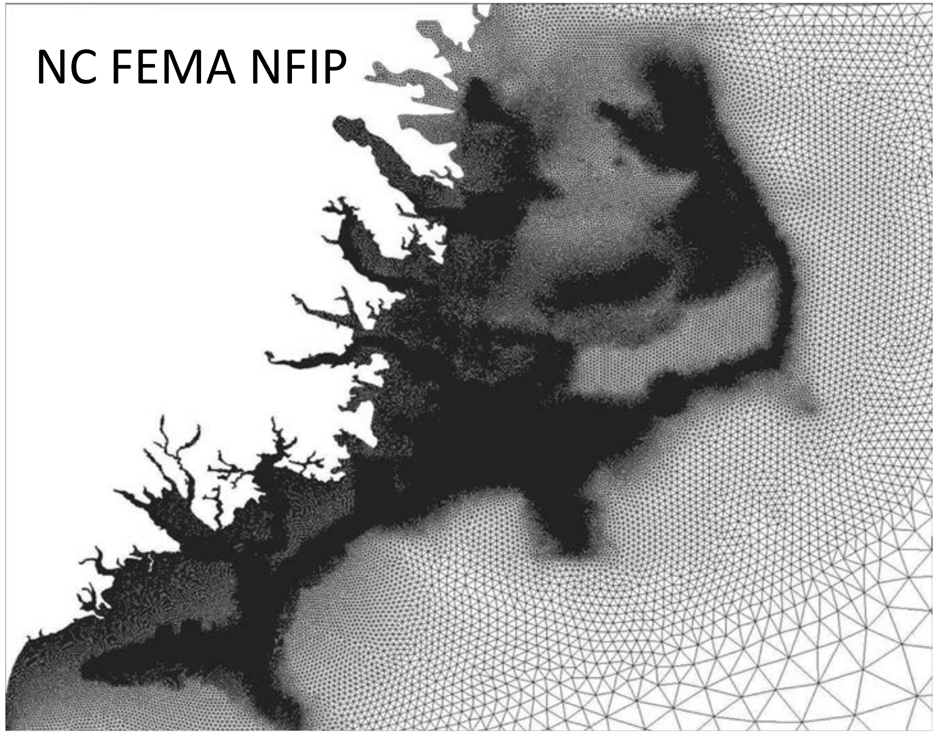




Typical Grids for ADCIRC Applications

National vs Local





1.8 M nodes, nearshore resolution ~500m

0.5 M nodes, nearshore resolution ~20m

Logic suggests that the best physics should be applied to all problems

- This argument leads to an obvious conclusion that ADCIRC should be used to the maximum extent possible; however, how do we deal with:

✓Major Rivers

✓Tributaries

✓Dams and hydraulic structures ?

✓Infiltration and groundwater movement?

- **We need clear metrics to guide these decisions**

1. Physics Based Models?

- ADCIRC – tides, surge, inundation
- SWAN – waves (WWIII – NOAA, STWAVE – USACE)
- Hydrological models

Increasing amount of empiricism imbedded within the models

Logic suggests that the best physics should be applied to all problems

- This argument leads to an obvious conclusion that ADCIRC should be used to the maximum extent possible

✓Major Rivers

✓Tributaries

✓Dams and hydraulic structures ?

✓Infiltration and groundwater movement (possibly not)

- **We need clear metrics to guide these decisions**

- *Large Sample Basin Experiments for Hydrological Model Parameterization: Results of the Model Parameter*
- *Experiment–MOPEX*. IAHS Publ. 307, 2006.

- **Has basin-scale modelling advanced beyond**
- **empiricism?**

- **C. MICHEL**[1]**, C. PERRIN**[1]**, V. ANDRÉASSIAN**[1]**, L. OUDIN**[2]
- **& T. MATHEVET**[1]
- 1 *Cemagref, Hydrosystems and Bioprocesses Research Unit, Parc de Tourvoie, BP 44,*
- *92163 Antony cedex, France*
- claude.michel@cemagref.fr
- *2 Université Pierre-et-Marie Curie, UMR SISYPHE, 4 place Jussieu, 75252 Paris cedex 05, France*

Typically the answer to this is still “no,” due to the number of degrees of freedom in this problem, requiring $250,000 to calibrate a basin (SJWMD)

Fluid motions in coastal areas follow well-known equations that are approximated in finite element, volume and difference formulations.
Is this true for water transport through arbitrary vegetation and under the ground in variable porosity?

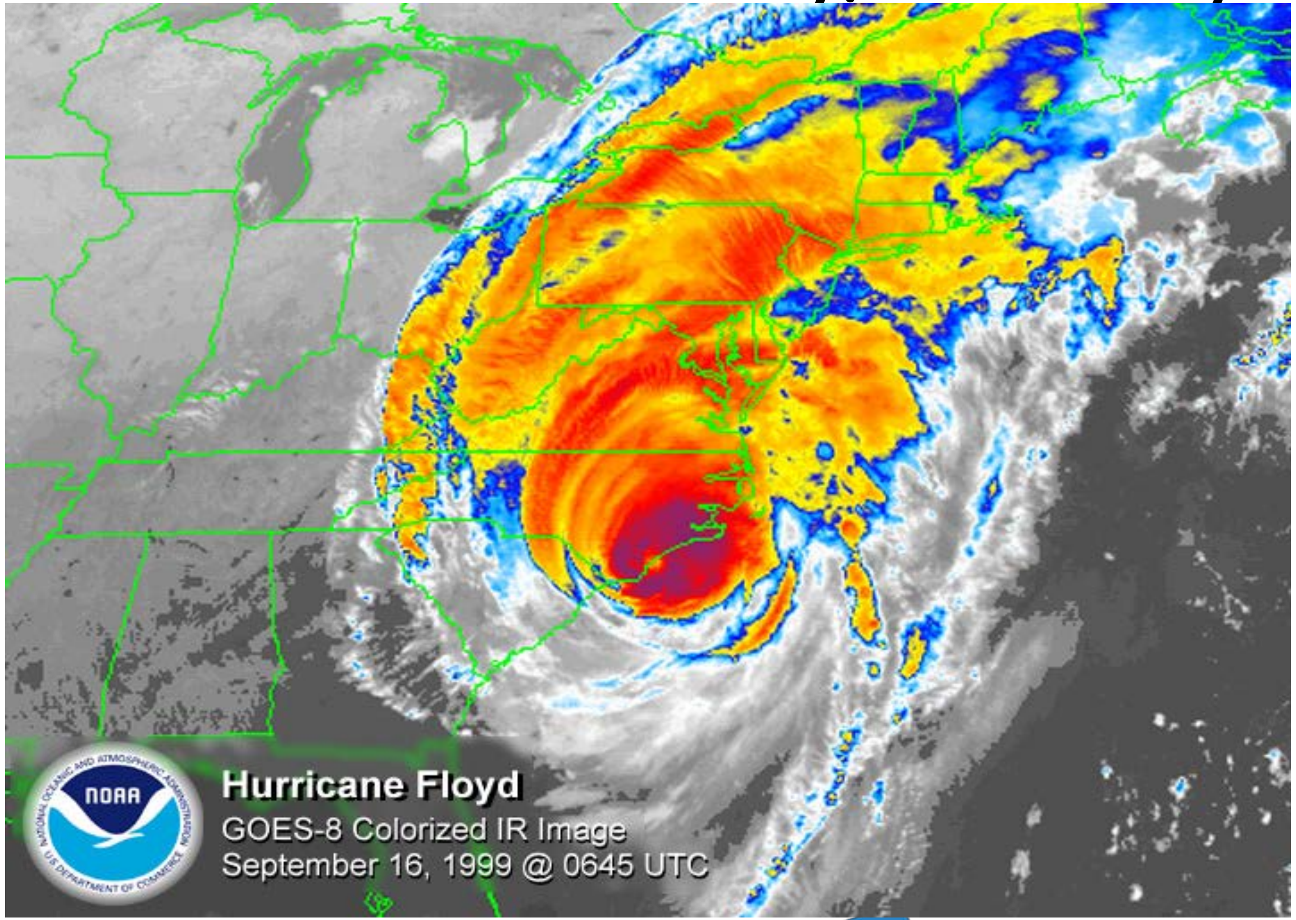
No, too many unknowns in the equations…..

Hydrologic models have to be carefully tuned locally

- The best source of this information is local hydrologists and water resource managers.
- Such tuning is typically the venue of water management districts and is performed on a basin by basin basis.
- Empirical coefficients are adjusted to approximate stage and discharge information, often from short-term, site-specific field studies
- Little or no agreement on a “universal” model

Different Scales and Processes Complicate the Development of Model Metrics for Efficiency/Accuracy

- Processes:
  - Prior rainfall and groundwater
  - Prior stages of "larger" rivers and tributaries
  - Rainfall during event (time-space distribution)
  - Interaction with tides and surges



Isaac, Harvey, Florence, Irma have shown that the neglect of hydrologic contributions in many situations is critical

- Historic in flooding in Jacksonville was caused by combination of surge, tides and hydrologic inputs

Problem with computer run time in compound flooding!!

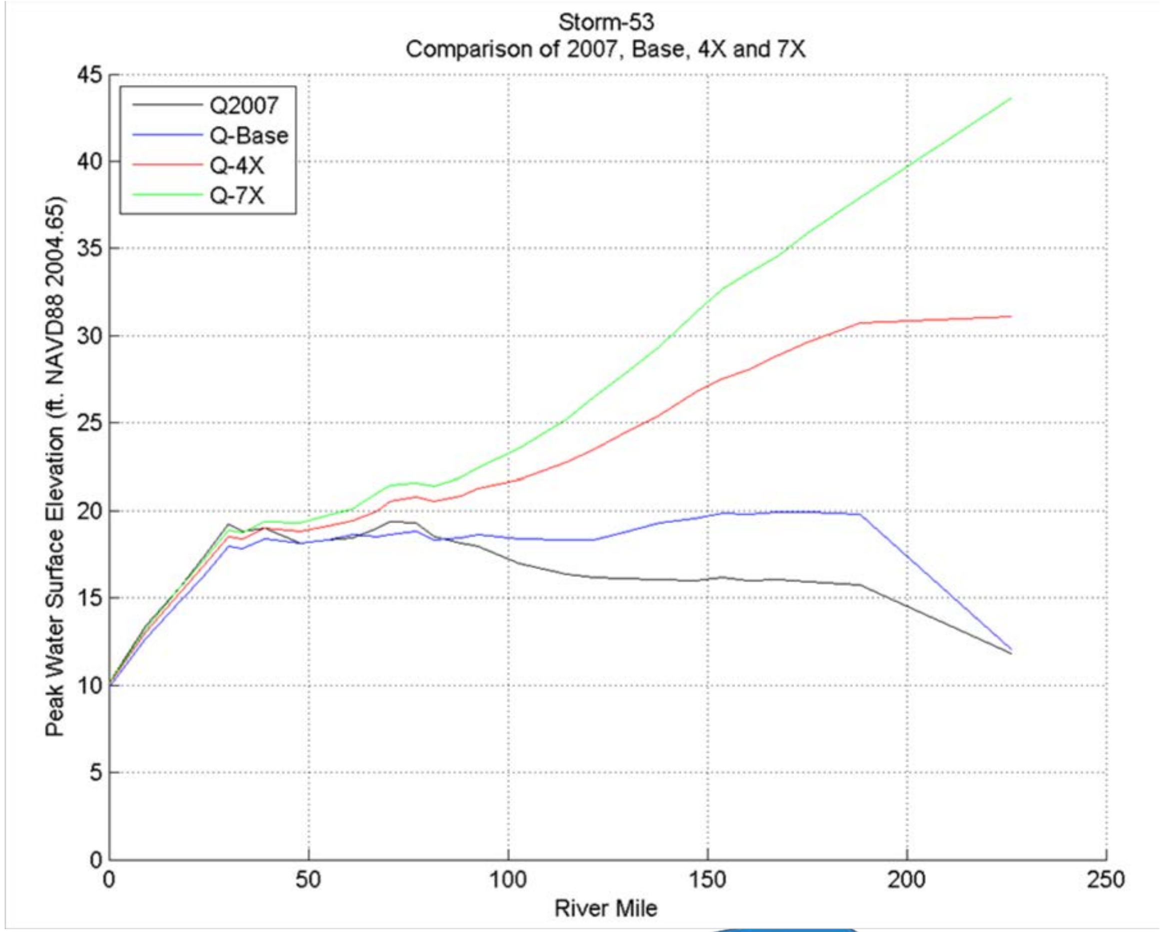
- Potentially, there are up to three new basic dimensions of variability that have to be considered on top factors already considered
  - River/stream discharge
  - Rainfall (spatial-temporal distribution)
  - Antecedent conditions
- Additionally, there are temporal and spatial variations that must be investigated via simulations with the coupled system
- This can be done relatively quickly using temporally varying parametric fields of rainfall and water levels within the existing system → **However, the number of runs increased dramatically, for example 6 different event rainfalls, 5 antecedent discharges, 3 different initial antecedent groundwater condition, etc. (x 90)**

Derived Benefits to Resilience Depends on Application Scale

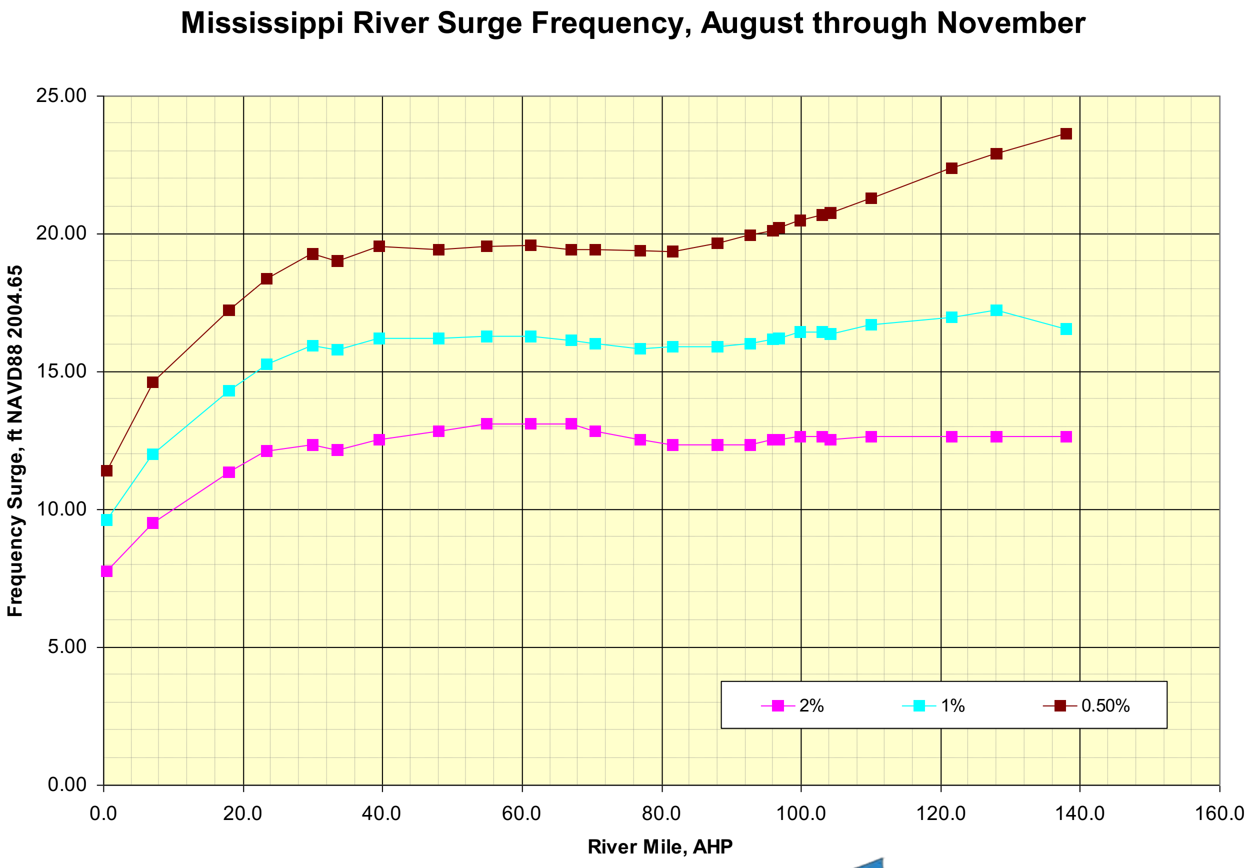
- For small sets of runs in synoptic-scale forecasting, model inter-comparisons, etc., this does not create any problem with execution time and running entire solutions in a single simulation will greatly benefit evacuation planning and potentially reduce loss of life; but will likely only minimally affect damages and post-event recovery time
- For Planning scale decision-making, a large increase in simulation time would be expected in the surge and hydrologic components are tightly or even loosely coupled. However benefits are extremely large in coastal plain areas along most of the Gulf and Atlantic coasts.

How Much of a Difference is Expected

- Mississippi River -Sample large storm up-river surge behavior as a function of flow rate, relative to base flow
- There is no single discharge that is the “right” discharge for a 100-year event



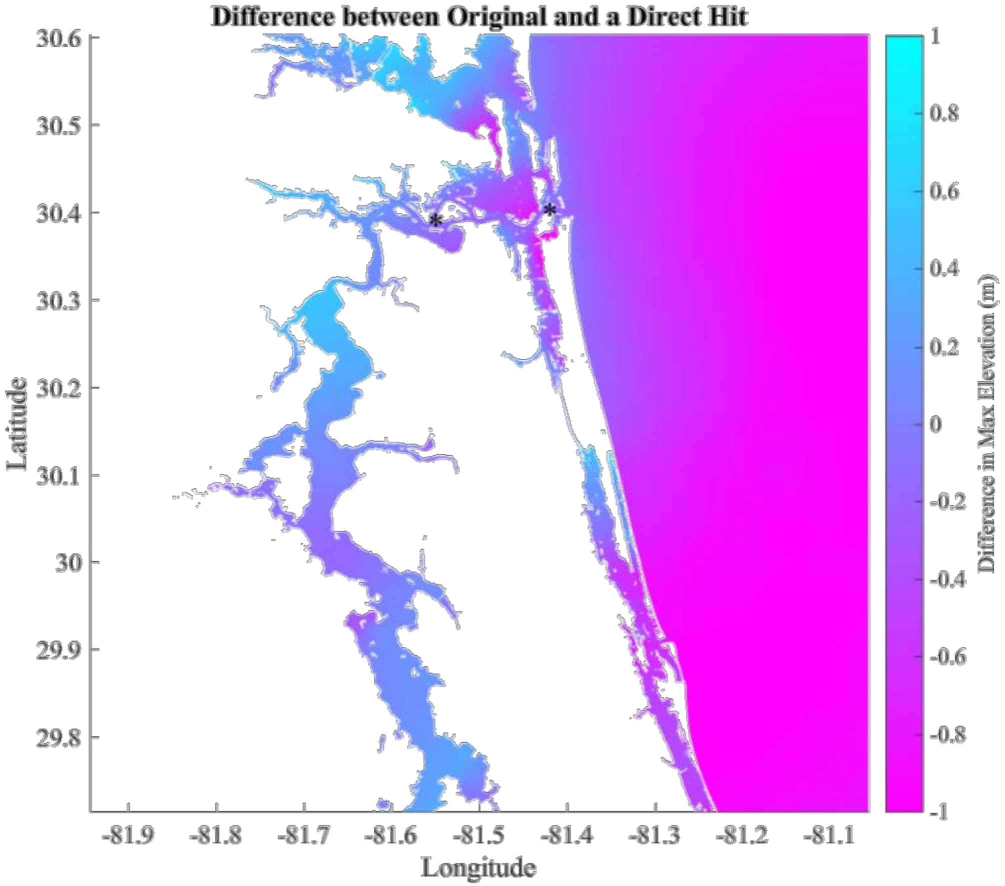
- Given that there is no single discharge that is the "right" discharge for a 100-year event…
- It has to be obtained by JPM-variant – not a surrogate event!
- Results will greatly affect damages and indirectly loss of life

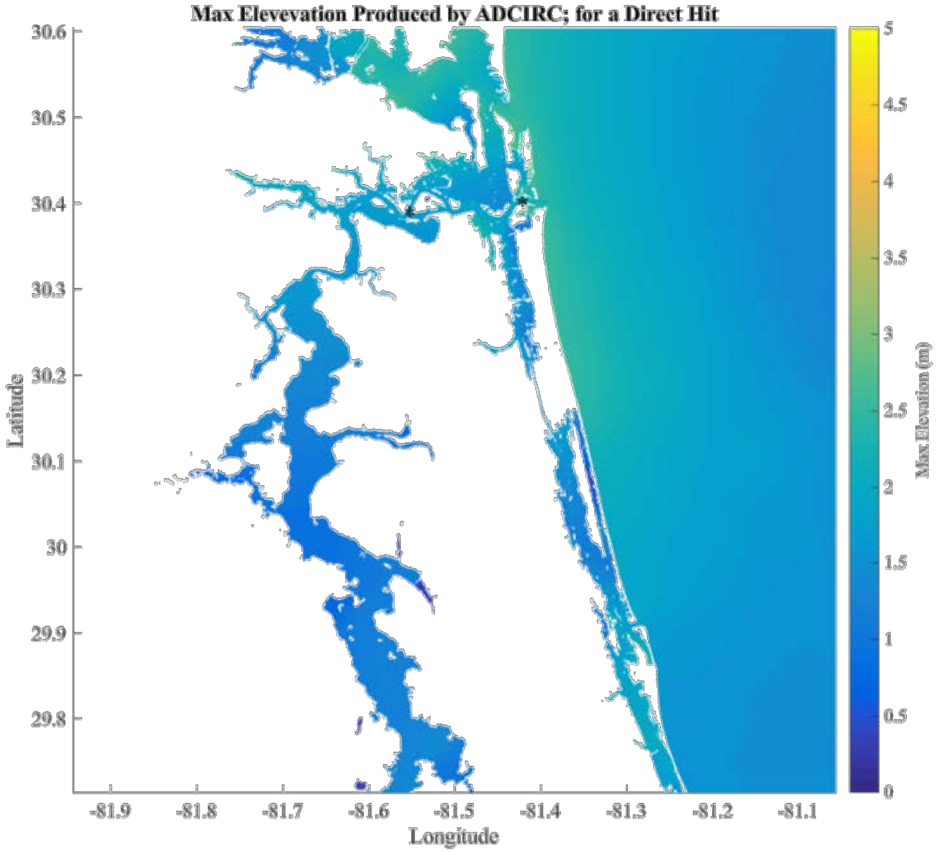


- **But left open are important questions for planning-scale resilience:**

"Where should the boundaries be placed and what type of interaction is most appropriate in terms of maintaining both reasonable accuracy and an acceptable run time for RiskMap type applications?"

Neglecting the Moderate River Discharge at the time of Matthew → No flooding downtown





Overall Approach to Project Investigation

1. In single-run cases covering a range of possible antecedent discharge and during-event rainfalls, Execute ADCIRC upriver to a point where the surge effects are negligible (TBD)
2. Calibrate model system to match results over this range of forcing related to storm, antecedent conditions, and during-event rainfall
3. Determine Appropriate Execution Time and Accuracy Metrics and compute these for selected hydrologic models in basins not within the ADCIRC model domain using different types of coupling
4. In different modes of coupling run a range of conditions which would typify a study for defining resilience for different applications

Overall Approach to Project Implementation

5. Develop Evaluation Matrix for different coupled models and coupling method accuracies, including the Gradually Varied Flow 1D model for the time-wise development of ‘backwater curves” (match model results in most large rivers)
6. Develop Evaluation Matrix for different coupled models and coupling method execution times
7. Discuss results with local and State user groups and with DHS Steering Group
8. Develop preliminary guidance for compound flooding modeling which may be different for forecasts and planning applications.

Additional Issues to Investigate

- Investigate methods for reducing the number of runs while maintaining maximum accuracy (sensitivity runs combined with space-time rainfall and discharge series).
- PHRAM is presently the “status quo” for modeling rainfall, but its universal form is not locally calibrated and has not measure of uncertainty associated with it, this will be addressed in year 1
- Model simulations with boundary at river mouth (most logical since this is where the interaction is primarily in one direction); Model simulations

Synergistic Ongoing R&D/Applications at UNF/Arcardis

- Developed and in testing mode of coupled prediction system for inclusion into NOAA's SLOSH model. (UNF)
- Working with RESTORE program to investigate a suite of coupled models, rainfall (space-time) probabilities. (UNF & Arcadis)
- Working on a major statewide program to improve resilience in Florida – integrating different hydrologic models, surge models, rainfall rates into recommendations for local applications. (UNF)
- Outreach to all Florida Water Management Districts and counties for interactions and feedback on results. (UNF)

QUESTIONS