Modeling Community Resilience Under Climate Change: Hazard Model Development

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3rd International Workshop on Waves, Storm Surges, and Coastal Hazards

University of Notre Dame
October 1-6, 2023

- Geoghegan, K., Fitzpatrick, P., Kolar, R., Dresback, K. "Evaluation of a Synthetic Rainfall Model, P-CLIPER, for Use in Coastal Flood Modeling" *Natural Hazards*, DOI: 10.1007/s11069-018-3220-4.
- Dresback, K.M., Szpilka, C.M., et al., Steps Towards Modeling Community Resilience Under Climate Change: Hazard Model Development, *Journal of Marine Science and Engineering*, DOI: 10.3390/jsme707022 .

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NIST COE Project Objectives

- Modeling tool for use with risk-based coastal community resilience planning under a changing climate.
- Hazard Model Features
  - Total water level (tides + surge + waves + inland runoff)
  - Future climate + Relative SLR
  - Need time series probability of occurrence for resilience assessment
  - Community and regional scales (NC case study)
  - Modular
    - Different model components
    - Different sources of input data

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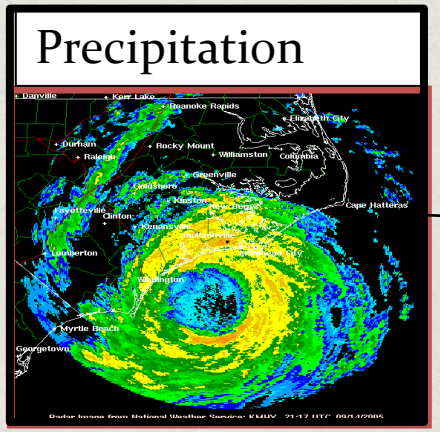
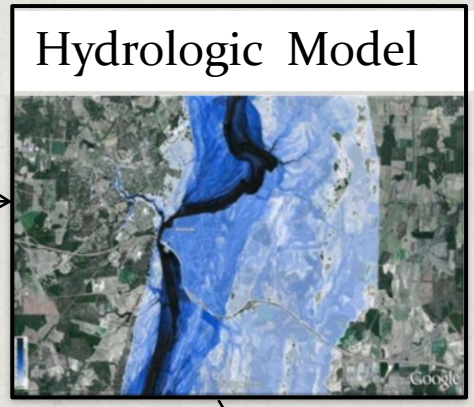
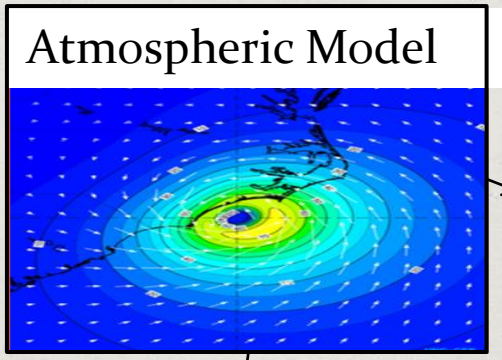
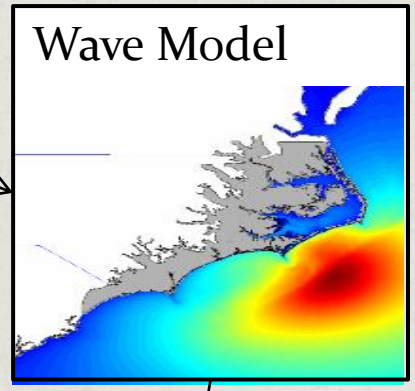
Modeling Approach





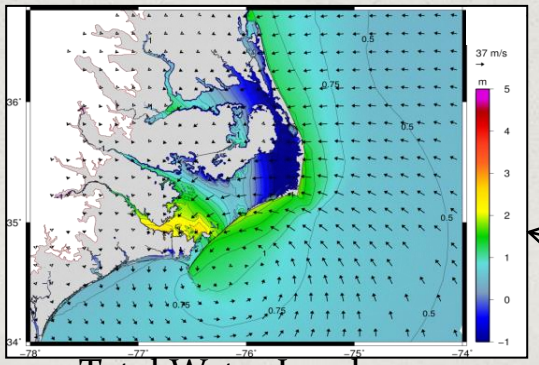




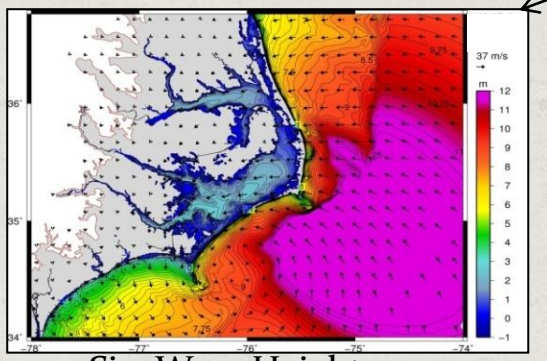
River BCs
Discharge

Surface BCs
Pressure
Wind Forcing

Surface BCs
Wave Forcing


Total Water Levels

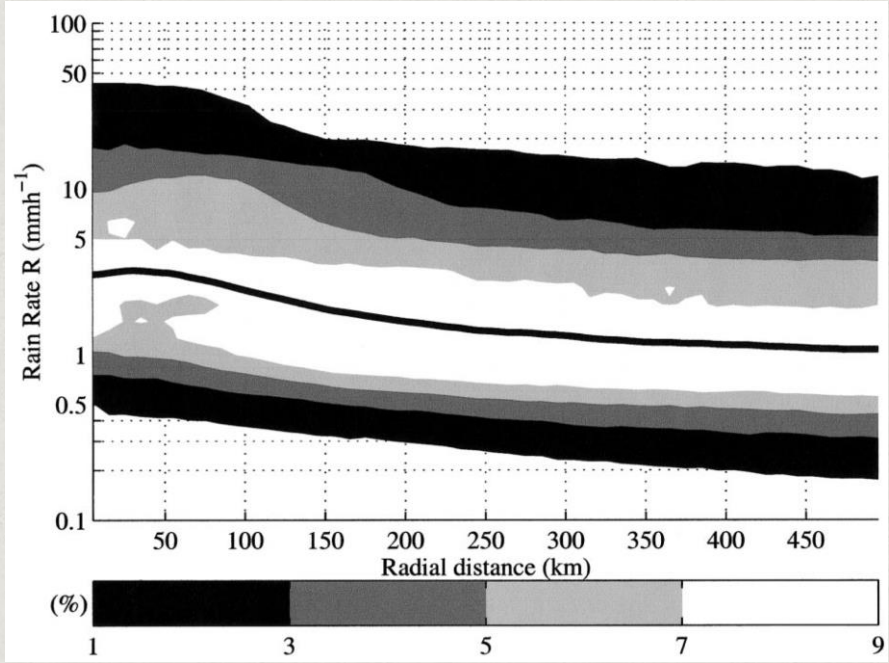
Hydrodynamic Model (ADCIRC)


Sig. Wave Heights

Atmospheric Model: OWI or NHC track/parametric
Precipitation Source: QPE/QPF or parametric model
Hydrologic Model: HL-RDHM or CREST (part of EF5)
Wave Model: unstructured SWAN
Future Climate: Downscaled GCM (Emanuel 2006, 08, 10)

Background on Probabilistic Rainfall Model, R-CLIPER

- Rain CLImatology and PERsistence model (R-CLIPER, Lonfat et al., 2004)
  - Created for idealized studies and tropical cyclone (TC) QPF benchmark
  - Data from Tropical Rainfall Measuring Mission (TRMM)
  - 260 TCs, 2121 instantaneous observations
  - Flexible approach – equations with probability distribution functions (PDFs)



Radial distribution of rainfall PDF; gray scale indicates frequency of occurrence

Background on Probabilistic Rainfall Model, P-CLIPER

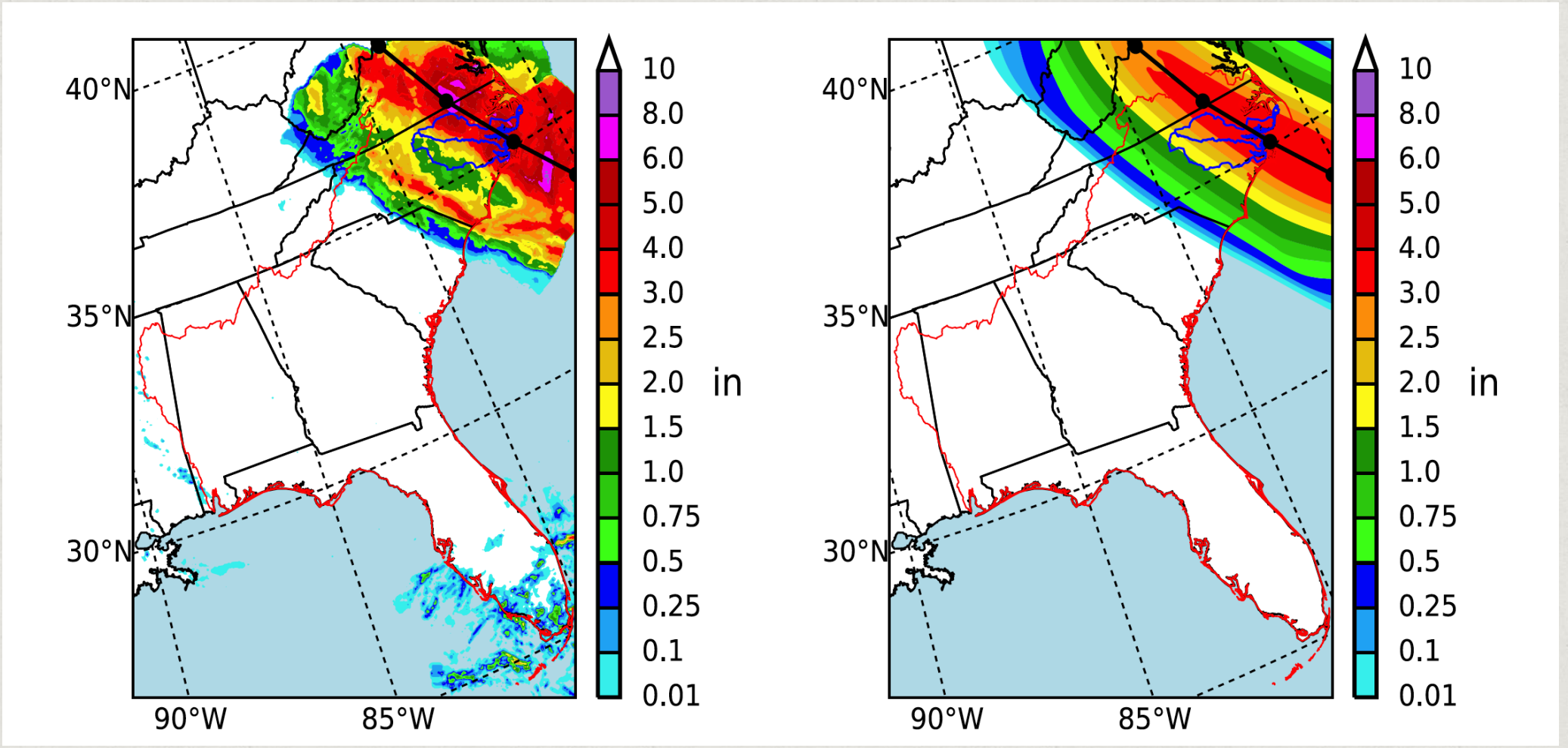
- Extension of Lonfat et al.:
  - Parametric equations developed for three intensities: TS, CAT12, CAT345
  - Describes TC rain rate, *R*, as function of:
    - Radial distance from storm center, *r*
    - Frequency, *f* (percent from class average)
- Hourly rainfall obtained along NHC best track
- Integration along path for storm-total rainfall accumulation
- Calibrate against historical storms

Functional form of equations (CAT classes):

$$R(r,f) = A\, e^{Bf} \text{ x } r/30 \text{ ; } r <= 30 \text{ km}$$

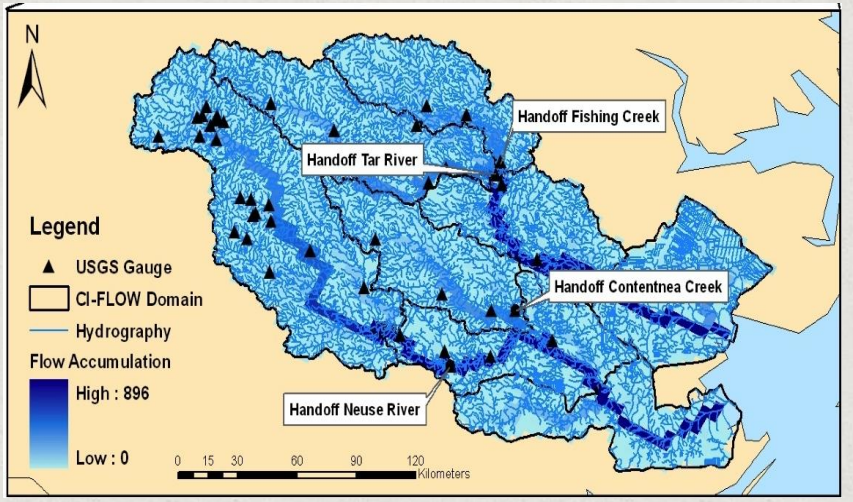
$$R(r,f) = p(r) \text{ x } e^{Bf} \text{ ; } r > 30 \text{ km}$$

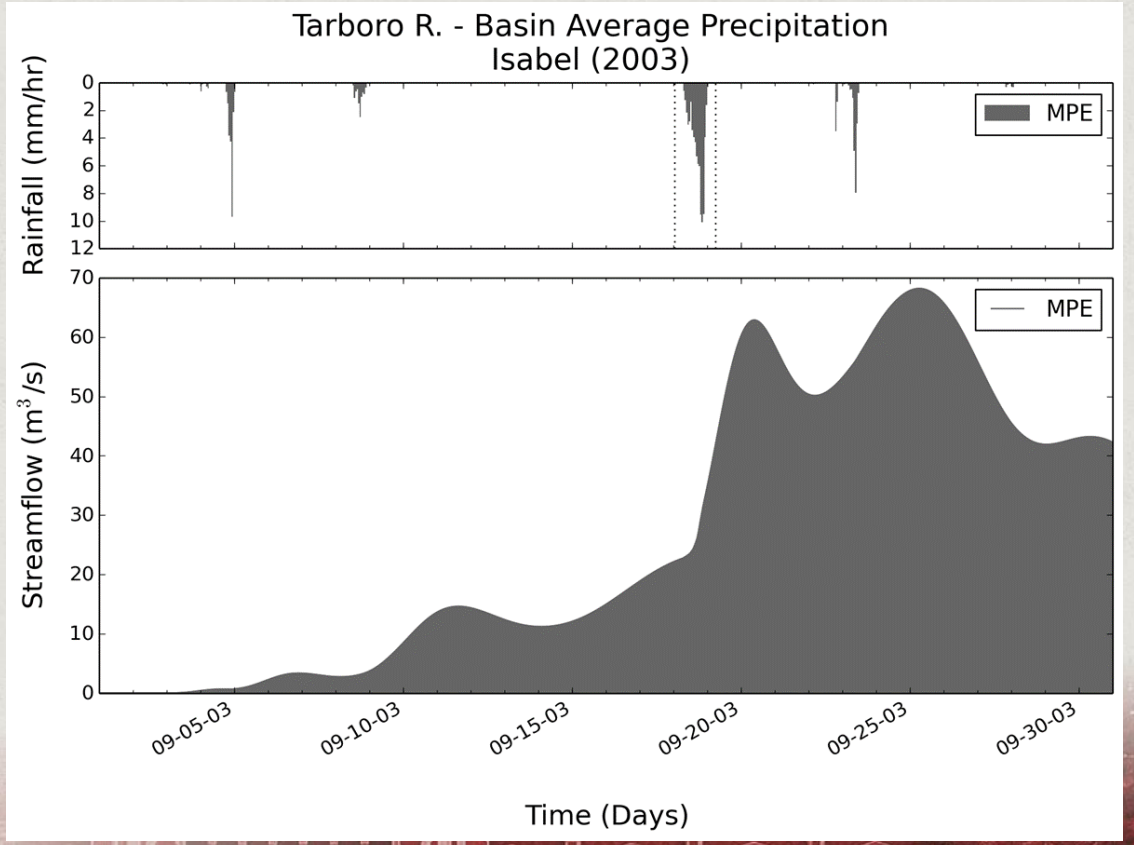
Performance - Hurricane Isabel (2003)



Hydrological Response for Rainfall

- North Carolina area used as application – significant data available for riverine areas
- Calibration using Observed NWS Stage IV radar rainfall for past hurricanes
- Ensemble of hydrographs using P-CLIPER output with variable *f*
- Nash-Sutcliffe Coefficient of Efficiency (NSCE) used as quantitative metric





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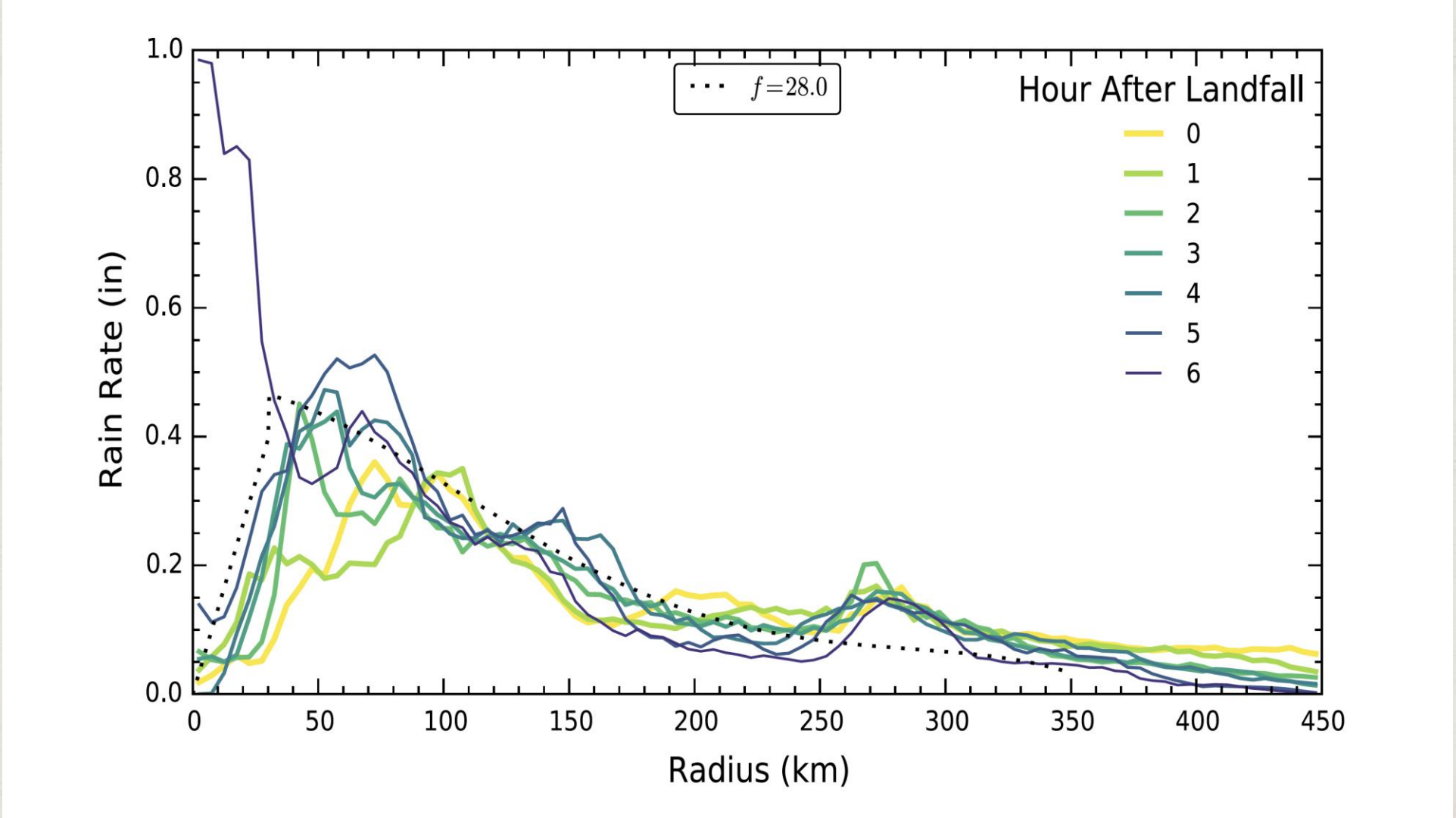
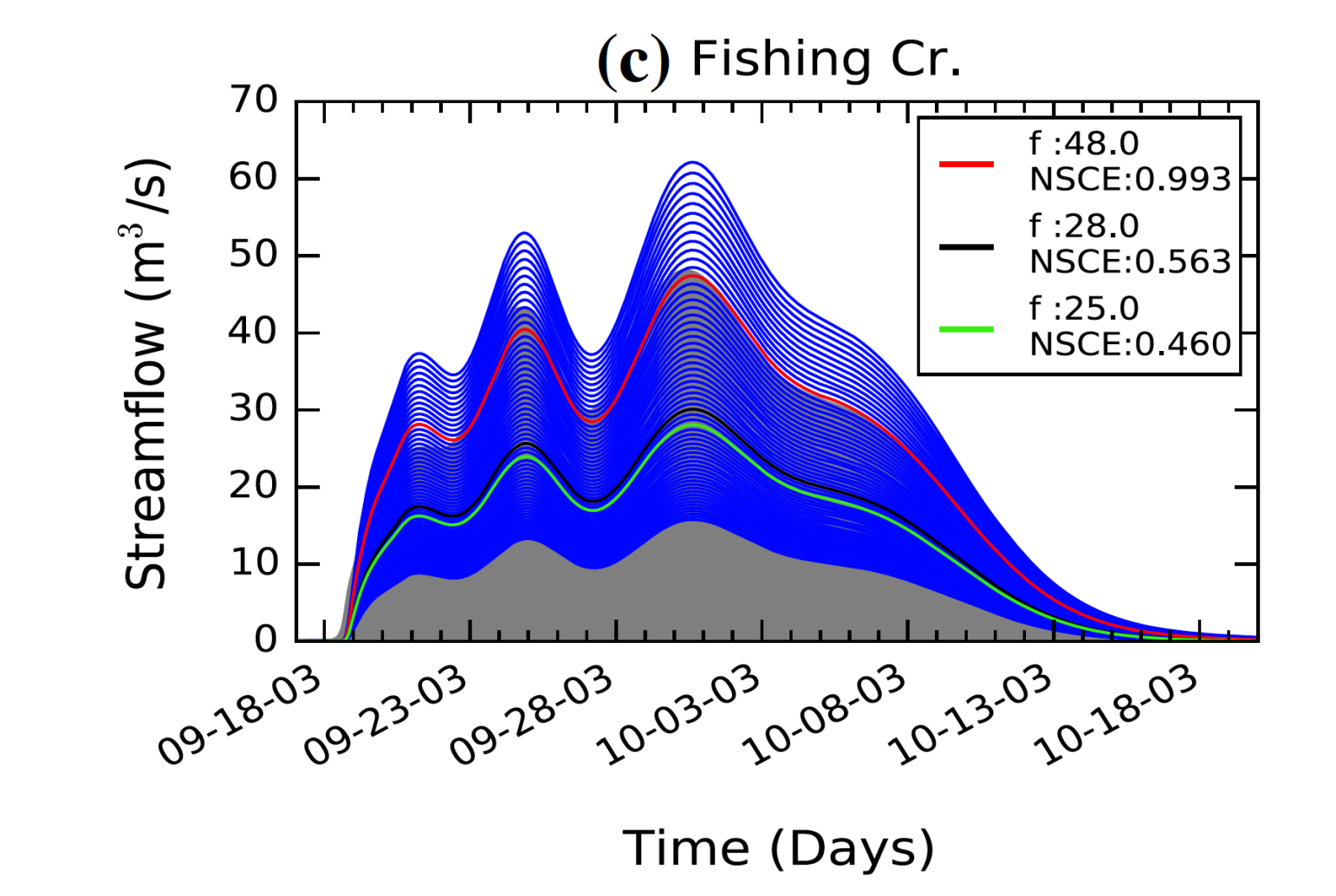
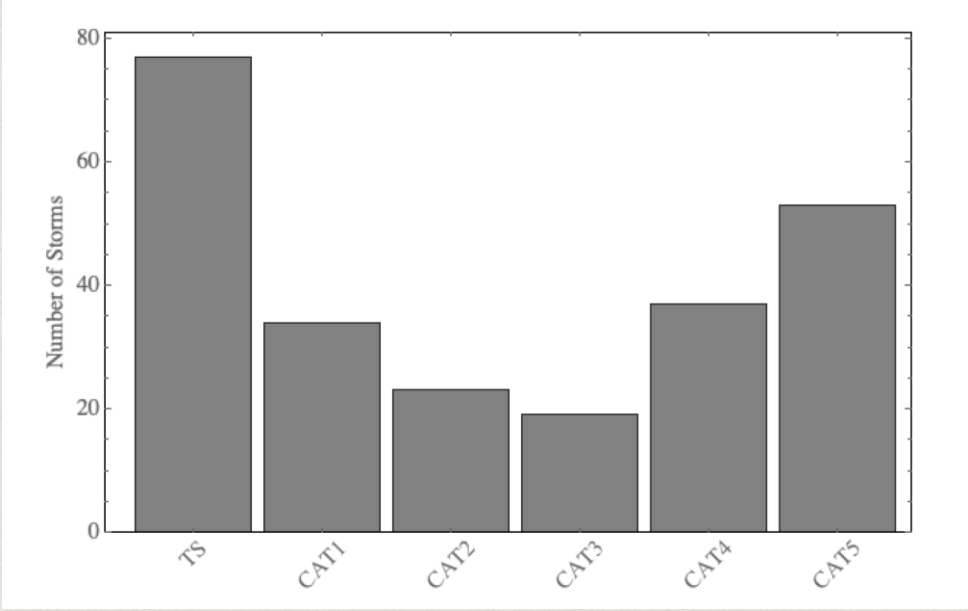


Hydrologic Calibration – MRMS vs. P-CLIPER Hydrographs



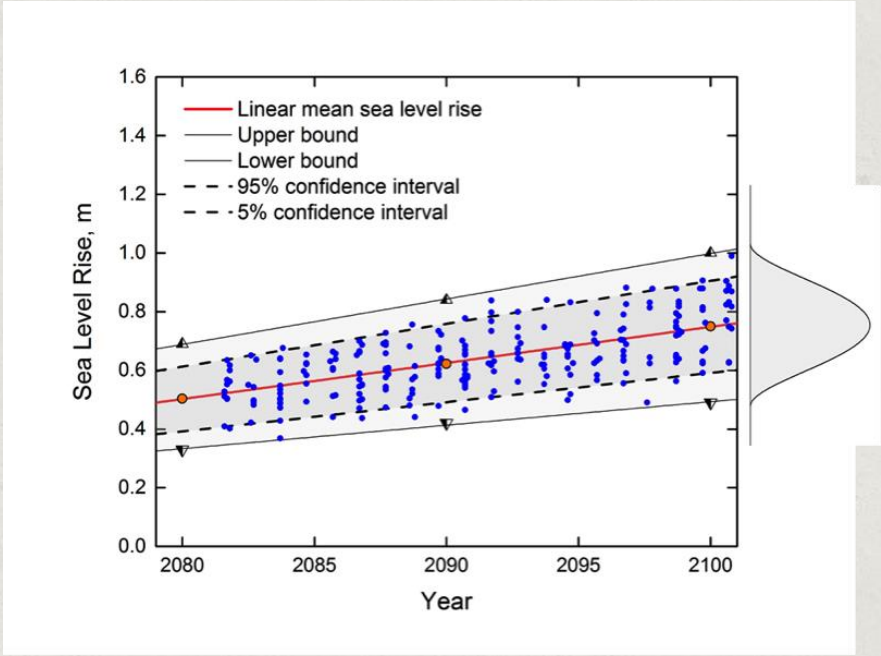
Future Climate (2080 – 2010)

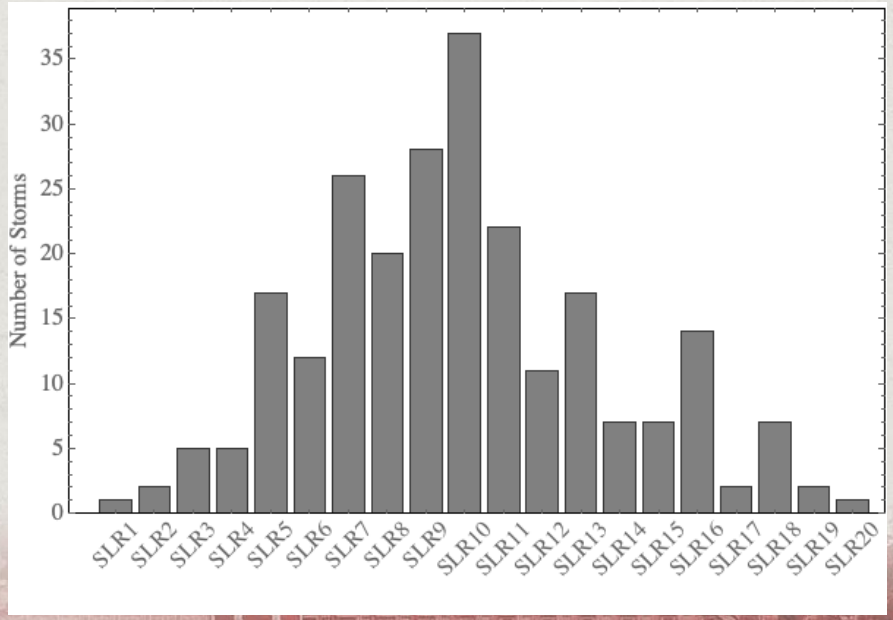
- RCP 8.5 Scenario
- Tracks provided by Emanuel
  - 5000 in data base made landfall near the study area
  - Reduction by binning into 243 Latin hypercubes such that each bin had 20 or 21 tracks
  - Five-dimensional binning: (at landfall) longitude, angle, pressure deficit, radius to maximum wind, and forward speed
  - Randomly select one storm from each hypercube (checked for bias)



Relative Sea Level Rise

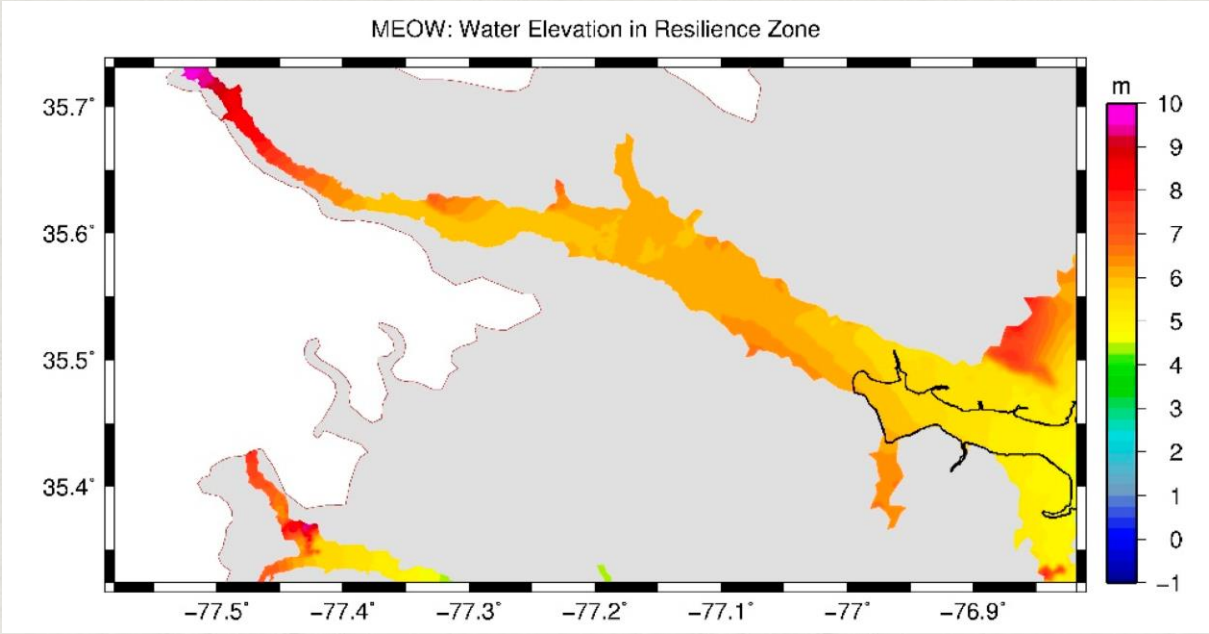
- N.C. Coastal Resources Commission Science Panel publishes R-SLR as a function of year, location
- Assume sea level rise in a given year follows a beta distribution
- Select 243 random samples from this space
- Group into 20 bins (to limit the computational cost); range 0.37 m to 0.99 m



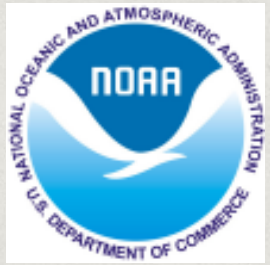


Probabilistic Output

- Created 243-member ensemble
- For each track, randomly assign:
  - Rainfall frequency factor from range found during calibration
  - Relative sea level rise from beta distribution sampling (assigned to nearest bin)
- Products for infrastructure group
  - Probability that a location is flooded
  - Spatial correlation
  - Max inundation



We appreciate the support of:



Questions?