Combining Atmospheric and Hydrodynamic Modeling to Identify Future Changes to Hurricane Flood Hazard in North Carolina

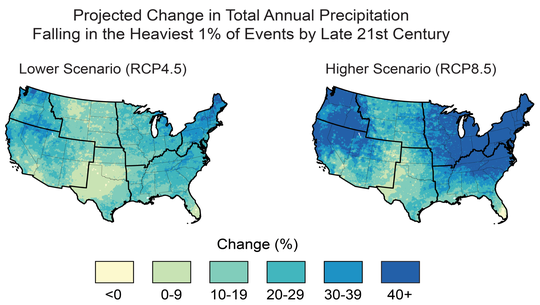
Katy Hollinger[1], Antonia Sebastian[2], and Gary Lackmann[1]

[1]Department of Marine, Earth, and Atmospheric Sciences, North Carolina State University, Raleigh, NC

[2]Department of Earth, Marine, and Environmental Sciences, University of North Carolina, Chapel Hill, NC

1. Background: Hurricane Rainfall, Flooding, and Climate Change

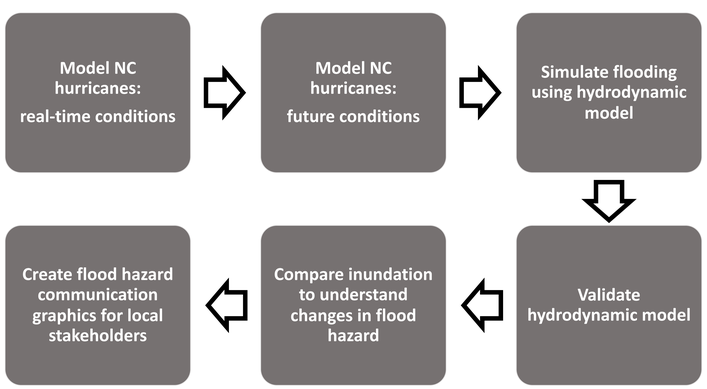
- North Carolina experienced multiple high impact hurricanes over the last few decades
  - Ex) Hurricanes Floyd (1999), Matthew (2016), and Florence (2018).
  - Brought double-digit rainfall, flooded interstates and communities, and multiple flood-related fatalities to central and eastern NC
- **High confidence hurricane rainfall will continue to increase as climate warms**
  - **How much will rainfall increase by end-of-century due to climate change?**
  - **How will associated flooding change as a result?**



Projections of changes in heavy precipitation events by the end of the century under CMIP5 RCP4.5 and RCP8.5. [2]

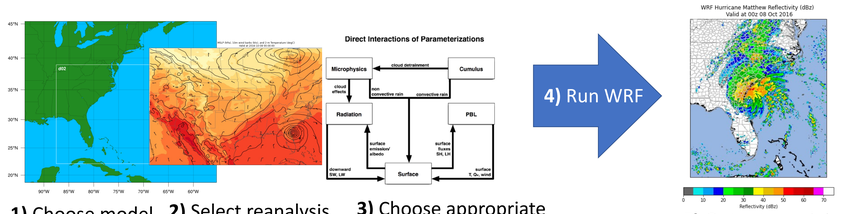
- Atmospheric and climate models can give good projections for rainfall, but what about flooding?
  - Communicating flood risk requires more than just rainfall data
  - Evaluate flood piece by combining atmospheric with hydrodynamic models to understand hazards
- Why do we need future hazard information?
  - Need to translate large-scale climate information into actionable information at the local level
    - Help with decision making and planning

2. General Workflow



3. Atmospheric Modeling

- Weather Research and Forecasting (WRF) model enables simulation of modern-day, high-impact hurricanes in future climate



1) Choose model domain

2) Select reanalysis data for event

3) Choose appropriate physics parameterizations [1]

5) Output: model representation of event

Future-climate runs:

2.5) Adjust model temperature to represent end-of-century under RCP8.5

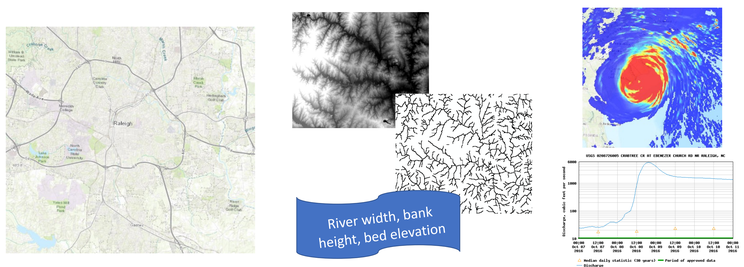
6) Adjust physics settings and re-run to account for variability

Hurricane Matthew Case Study: Climate Change Influences Rainfall Amount and Distribution

Total accumulated precipitation produced by the model simulations of Hurricane Matthew under present-day conditions (left) and future, end-of-century RCP8.5 conditions (right)

4. Hydrodynamic Modeling

- LISFLOOD-FP hydrodynamic model allows for simulation of streamflow and inundation from hurricanes
  - Choose subset of atmospheric model domain to model in higher resolution with LISFLOOD-FP
- Combine elevation model, channel locations, channel dimensions, channel hydrographs, and spatially varying precipitation data over chosen domain



1) Choose model domain

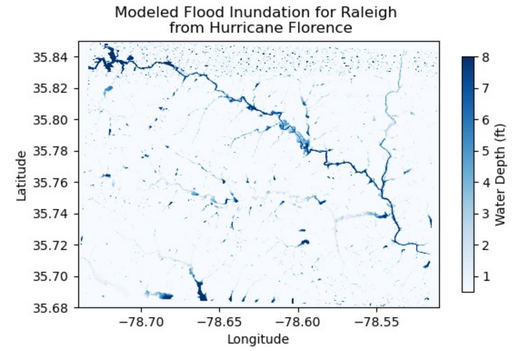
2) Get topography, stream location, stream characteristics data

3) Get storm-specific data: rain rates and hydrograph

- Validate model using hydrographs from river gauges inside of domain and high-water marks from storm to confirm accurate representation of storm flooding

5. Result: Example Inundation Maps

- LISFLOOD-FP model outputs water depth at every cell location in the model domain at the end of the run
- Max water depth at each location for whole simulation represents flood inundation from modeled event from combination of streamflow and precipitation



Sample inundation map for Crabtree Creek in Raleigh, NC (box encompassing -78.74 to -78.51 longitude and 35.68 to 35.85 latitude) with precipitation and streamflow information from Hurricane Florence (2018).

- End goal is to simulate hurricanes Florence, Matthew, and Floyd for larger Triangle domain

6. Communicating Future Hazards

- Compare inundation maps from future storm simulations and present-day storm simulations to identify future changes in inundation and affected buildings associated with climate change
- Change in flood hazard is important to communicate to city planners and policy makers to help inform future building decisions
- **Challenges with communicating:**
  - How to include some measure of uncertainty/error
  - What types of impacts to include (i.e., homes impacted, area inundated, number of roads underwater)
  - How to combine with existing risk metrics
  - How to distribute information to those that need it
  - Should we standardize flood hazard to scale (i.e., 1-10 for hazard)

7. References

1. Dudhia, J., 2014: A history of mesoscale model development. *Asia Pac J Atmos Sci*, **50**, 121–131, https://doi.org/10.1007/s13143-014-0031-8.
2. Reidmiller, D. R., C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, and B. C. Stewart, eds., 2018: *Impacts, Risks, and Adaptation in the United States: The Fourth National Climate Assessment, Volume II*.