Extreme Rainfall and Future Flooding
A Growing Risk? Why?

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Coastal Resilience Workshop
Wilmington, NC
May 14, 2019
Wet April for much of NC
Antecedent Conditions A Concern
Percent of Normal Precipitation (%)
Hurricane Dennis
Then Floyd

Took 6 years to remove Tarrytown Mall
What We Know:
Detectable Changes in Extreme Precipitation

- Precipitation intensity and frequency are increasing, especially east of the Rockies,
- Seasonality is important for Southeast US.
  - Fall (Sept., Oct., Nov.)
  - Winter (Dec., Jan. Feb.)
What we Know:
Rainfall Intensity Increases
(max. daily precip.)
August, September, October

Elizabeth City

Sept. 2010 – Remnants of Tropical Storm Nicole moisture w/ frontal system
Oct. 2016 - Matthew

Rocky Mount

Sept. 1999 - Floyd
Oct. 2016 - Matthew

Lumberton

Sept. 2018 - Florence
Oct. 2016 – Matthew
Sept. 1999 – Floyd
What We Know:
100-year storms are becoming more frequent

Wilmington, NC (1950–2013)

- Floyd
- Florence
What We Know:
Storm Characteristics are Changing

• Slower moving tropical storms (hurricanes)

Kossin et al., 2018. Nature

Hurricane Florence stalled
3 day event
https://www.nhc.noaa.gov/
What We Know:
Extreme rainfall scales with atmospheric temperature

Clausius-Clapeyron Equation
\[
\frac{1}{e_s} \frac{de_s}{dT} = \frac{L_v}{R_v T^2}
\]
What might we anticipate in the future (30-100 years)?

UNDERSTANDING CLIMATE CHANGE USING CLIMATE MODELS
What will our energy mix look like in the future?
The modeling experiment

The diagram shows the primary energy use (EJ) from 2000 to 2100 across different scenarios.

- **Low Emission Scenario**
  - RCP2.6
  - RCP4.5
  - RCP6
  - RCP8.5

- **High Emission Scenario**
  - Solar/wind/geothermal
  - Hydro
  - Bio-energy
  - Nuclear
  - Nat.gas
  - Oil
  - Coal

The chart also illustrates the net CO₂ emissions (Gt CO₂ yr⁻¹) from 1980 to 2100, with different scenarios and their respective temperature changes relative to 1850-1900 (RCP8.5: 3.2-5.4 °C, RCP6: 2.0-3.7 °C, RCP4.5: 1.7-3.2 °C, RCP2.6: 0.9-2.3 °C).

- **Historical emissions**
- **2014 estimate**: 37.1 in 2018
- **Net-negative global emissions**
Model changes to the rainfall frequency by end of century under a high scenario

USCRP, 2017: Climate Science Special Report

Model changes to the 1000 year event as global temperatures increase

Sanderson et al. 2019: Geophysical Research Letters
Future flooding: An engineering perspective from high-resolution climate change models (Ongoing Research)

IDF curves for Wilmington, NC

<table>
<thead>
<tr>
<th></th>
<th>Value for 24h 25 year rain (mm)</th>
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</thead>
<tbody>
<tr>
<td>NOAA</td>
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<tr>
<td>Atlas 2008</td>
<td>240</td>
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<tr>
<td>Our Study</td>
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<td>1952-2013</td>
<td>241</td>
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<td>1994-2013</td>
<td>346</td>
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</tbody>
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Ongoing research with EPA-USGS
Tanya Spero, Anna Jalowska, Adam Terando
What are some of the underlying changes in the atmosphere that would favor an increase extreme precipitation and flooding for eastern NC?

Bermuda High (Summer/Fall)

Tropical Storms (Hurricanes)

Weather Patterns
Warm/Cold Fronts (Fall/Winter/Spring)

Spring Storm and flooding on April 25, 2017
Bermuda High:
models show intensity to increase and westward shift
more variable precipitation in a warmer climate (wet and dry)
SPRING AND SUMMER SEASONS

Changes to deep moisture from the Gulf of Mexico
Can support: “Stronger thunderstorms”

Li et al. 2013, JGR Atmospheres
Tropical Cyclones (Hurricanes): models show frequency of high intensity storms to increase (Cat. 4 & 5); more rainfall associated with a future storm.

USCRP, 2017: Climate Science Special Report
Arctic amplification
Changing weather extremes
with loss of arctic sea ice and surface air temperature warming in the Arctic

Sea ice extent in September (million km²)

Wavier weather pattern favors more extreme weather

Dethloff et al, 2019; NY Academy of Sciences
Take-Away: Our climate is not stationary and is changing as we continue to increase greenhouse gases. Scientific studies depict a future with more extreme weather events that increases the risk of flooding.