Climate change: what we know (what we don’t know) & why it matters

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https://data.giss.nasa.gov/gistemp/

Annual Erosion and Sediment Control Local Programs Workshop
Wake Forest – April 23, 2019
What do we know?

- What controls the temperature of any planet
  - the role of the “greenhouse effect”
- We are adding heat-trapping gases to Earth’s atmosphere
- Earth is warming as expected
- Warming will continue for foreseeable future
- Heavier flooding rains expected
  - Happening now in extreme events
Earth energy balance

- Earth: warmed by the sun, cooled by the infrared light it gives off
- Heat-trapping gases (water vapor, carbon dioxide, ...) partially block outgoing infrared light, warming Earth
The greenhouse effect is good!

- Without it Earth would be too cold for most life

No heat trapping gases: T below 0°F
Natural heat trapping gases: T ~ 56°F
Global warming comes from *added* heat-trapping gases

- CO₂ up nearly 50% since 1800
  - Burning coal, oil, & gas; clearing forests & prairies
- Double CO₂: expect 3 - 8 °F warming
  - Svante Arrhenius: 1896
  - *Not* a new idea
  - *at current pace, CO₂ will double its preindustrial level in ~50 years*
Earth has warmed as expected

• About 1.8 °F (1 °C) since 1900

https://data.giss.nasa.gov/gistemp/
What about NC?

• Muted warming so far (first half of the 20th Century was warm in NC)

https://statesummaries.ncics.org/
Nighttime lows have warmed most

- Enhanced greenhouse limits overnight cooling

Observed Average Daily Minimum Temperature – Annual

North Carolina

°F

https://statesummaries.ncics.org/

5-year Period
Longer frost-free season

- 1991-2012 compared to 1901-1960
  Temperature above 32 °F

https://nca2014.globalchange.gov/
More intense rain

- A warmer atmosphere “holds” more water vapor
  - 4% more for each 1 °F warming

US Southeast – change (%) in amount of rain in top 1% of rain events

https://nca2014.globalchange.gov/
Increasing rain from hurricanes

- Biggest US storms in volume of rain since 1949:
  #1: Harvey in 2017
  #2: Florence in 2018

https://ncics.org/cics-news/putting-hurricane-florence-into-historical-perspective/
Changes in extremes appear first

- Small changes => big changes in frequency of extremes
Projecting future storms

• Hard! Climate models don’t resolve storms
• Simulate storms in storm-scale models in current & future climate conditions
  – Get future climate from climate model
• Example: July 2016 Raleigh rain storm
  – Unexceptional summer storm (“weakly forced”)
  – $400k damage, nuisance flooding, water rescues
Raleigh July 2016 flood *simulated*: now & in the future

- WRF model – 4 km grid
- Climate change in 2090s – from IPCC GCMs
- Future runs show *large* increases in heaviest rain

Rainfall (3 hr at peak)

Accumulated rainfall distribution

Present

Future

PhD work of J. Mike Madden
Uncertainties

- Method assumes future large-scale weather systems won’t change
  - Conservative assumption, but probably wrong
- Even high-resolution models of storms are imperfect
  - many processes parameterized
- More moisture $\Rightarrow$ more rain is reliable; changes that depend on detailed storm dynamics are not
What *do* we know?

- Warmer
- Heaviest rains will be heavier

What *don’t* we know?

- How much warmer (globally & regionally)
- How much heavier rains
- Changes in regional storm occurrence (e.g. hurricanes)
- Changes in drought frequency
### IPCC’s view

<table>
<thead>
<tr>
<th>Phenomenon and direction of trend</th>
<th>Assessment that changes occurred (typically since 1950 unless otherwise indicated)</th>
<th>Assessment of a human contribution to observed changes</th>
<th>Likelihood of further changes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Early 21st century</td>
</tr>
<tr>
<td><strong>Warmer and/or fewer cold days and nights over most land areas</strong></td>
<td>Very likely</td>
<td>Very likely</td>
<td>Likely (11.3)</td>
</tr>
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<td></td>
<td>Very likely</td>
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<td></td>
<td>Very likely</td>
<td>Likely (nights only)</td>
<td></td>
</tr>
<tr>
<td><strong>Warmer and/or more frequent hot days and nights over most land areas</strong></td>
<td>Very likely</td>
<td>Very likely</td>
<td>Likely (11.3)</td>
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<td>Likely (nights only)</td>
<td></td>
</tr>
<tr>
<td><strong>Warm spells/heat waves. Frequency and/or duration increases over most land areas</strong></td>
<td>Medium confidence</td>
<td>Likely* (2.6)</td>
<td>Not formally assessed (11.3)</td>
</tr>
<tr>
<td>Medium confidence on a global scale</td>
<td>Likely</td>
<td>(2.6)</td>
<td></td>
</tr>
<tr>
<td>Likely in large parts of Europe, Asia and Australia</td>
<td>Medium confidence in many (but not all) regions</td>
<td>Likely</td>
<td></td>
</tr>
<tr>
<td>Medium confidence in many (but not all) regions</td>
<td>Likely</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Heavy precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation</strong></td>
<td>Likely more land areas with increases than decreases</td>
<td>Medium confidence (7.6, 10.6)</td>
<td>Likely over many land areas</td>
</tr>
<tr>
<td></td>
<td>Likely more land areas with increases than decreases</td>
<td>Medium confidence</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Likely over most land areas</td>
<td>More likely than not</td>
<td></td>
</tr>
<tr>
<td><strong>Increases in intensity and/or duration of drought</strong></td>
<td>Low confidence on a global scale</td>
<td>Low confidence (10.6)</td>
<td>Low confidence (11.3)</td>
</tr>
<tr>
<td></td>
<td>Likely changes in some regions</td>
<td>Low confidence</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium confidence in some regions</td>
<td>Medium confidence</td>
<td></td>
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<tr>
<td></td>
<td>Likely in many regions, since 1970</td>
<td>Medium confidence</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Likely in many regions, since 1970</td>
<td>More likely than not</td>
<td></td>
</tr>
<tr>
<td><strong>Increases in intense tropical cyclone activity</strong></td>
<td>Low confidence in long term (centennial) changes</td>
<td>Low confidence (10.6)</td>
<td>Low confidence (11.3)</td>
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<tr>
<td></td>
<td>Virtually certain in North Atlantic since 1970</td>
<td>Low confidence</td>
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<tr>
<td></td>
<td>Low confidence</td>
<td>Low confidence</td>
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<td></td>
<td>Likely in some regions, since 1970</td>
<td>More likely than not</td>
<td></td>
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<tr>
<td><strong>Increased incidence and/or magnitude of extreme high sea level</strong></td>
<td>Likely (since 1970)</td>
<td>Likely* (3.7)</td>
<td>Likely (13.7)</td>
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<td></td>
<td>Likely (late 20th century)</td>
<td>Likely</td>
<td></td>
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<tr>
<td></td>
<td>Likely</td>
<td>More likely than not</td>
<td></td>
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</tbody>
</table>

*Notes:*

- Bold indicates where the AR5 (black) provides a revised global-scale assessment from the SREX (blue) or AR4 (red).
- Projections for early 21st century were not provided in previous assessment reports.
- Projections in the AR5 are relative to Table SPM.1.

**Summary for Policymakers**

- High confidence that there have been increases in central tropical sea surface temperatures since the mid-1970s.
- Likely that sea level has risen globally by about 19cm, mainly since 1900.
- Likelihood of further changes is estimated based on assessment of projections which use an SRES A1B (or similar) scenario.
- Attribution is based on the close relationship between observed changes in extreme and mean sea level.
Why don’t we know?

- **Human behavior**: future emissions?
- **Computing power**: global models don’t resolve key processes that matter for storms & other extreme events
  - Compute time scales like model resolution cubed
- **Science**: imperfect understanding of weather/climate processes

Reducing emissions reduces risks

- *Big* reductions in US projected costs from lower emissions

https://nca2018.globalchange.gov/
Take-aways

• Warming & heavier rains are highly confident projections
  – From basic physics – don’t depend on complex models
• Plan for more intense rain events
  – Happening now
  – Don’t wait for numbers – reliable ones are not coming soon
• *Any* reduction in emissions of heat-trapping gasses is an unalloyed good, lessening the risk of bad outcomes
Hurricane Florence flooding in Lumberton

Questions?