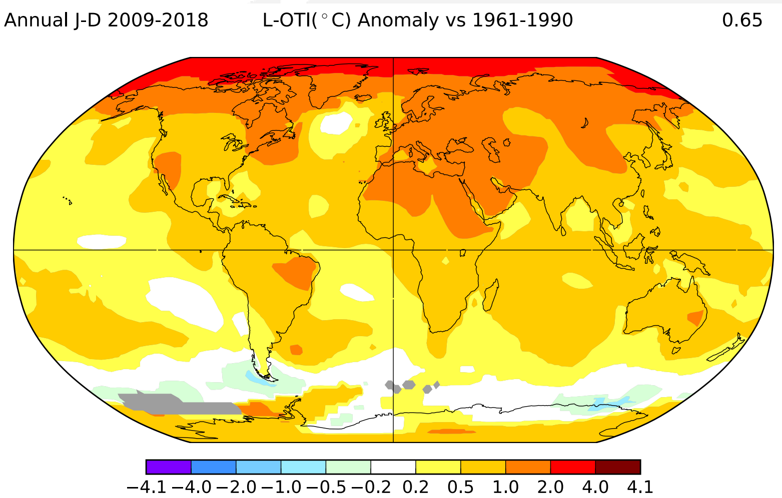
Climate change: what we know (what we don't know) & why it matters

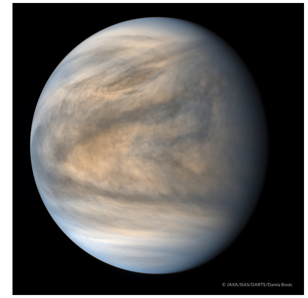
Walt Robinson, PhD: Interim Director, NC State Climate Office



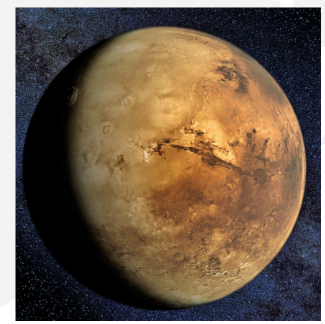
https://data.giss.nasa.gov/gistemp/

Annual Erosion and Sediment Control Local Programs Workshop
Wake Forest – April 23, 2019

What *do* we know?

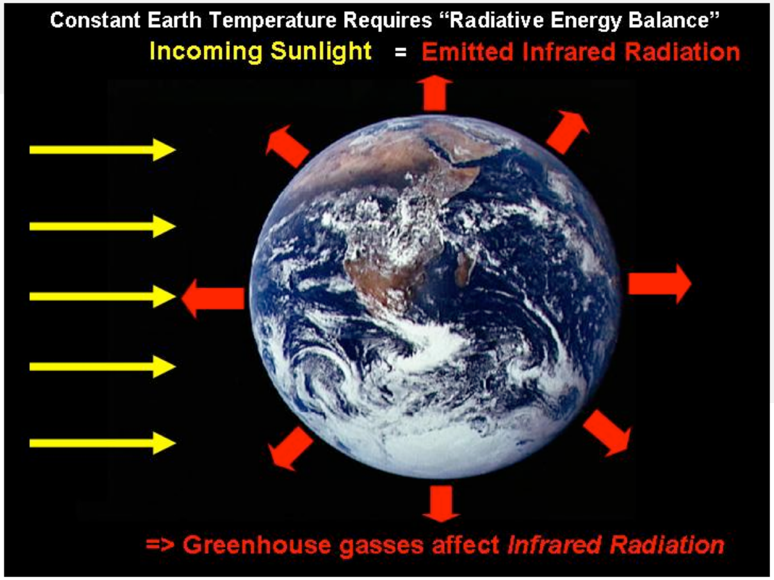


- What controls the temperature of any planet
  - the role of the “greenhouse effect”
- We are adding heat-trapping gases to Earth’s atmosphere
- Earth is warming as expected
- Warming will continue for foreseeable future
- Heavier flooding rains expected
  - Happening *now* in extreme events



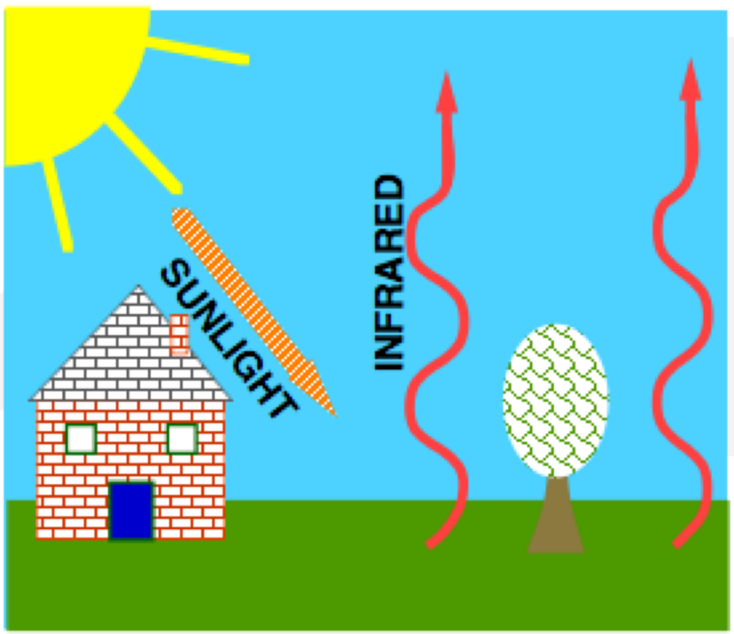
Earth energy balance

- 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

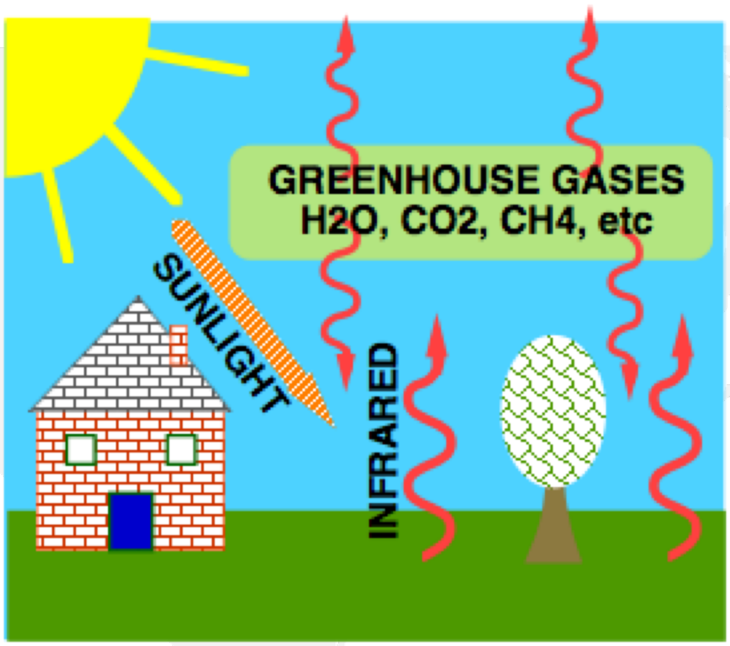


The greenhouse effect is good!

- Without it Earth would be too cold for most life



No heat trapping gases: T below 0°F

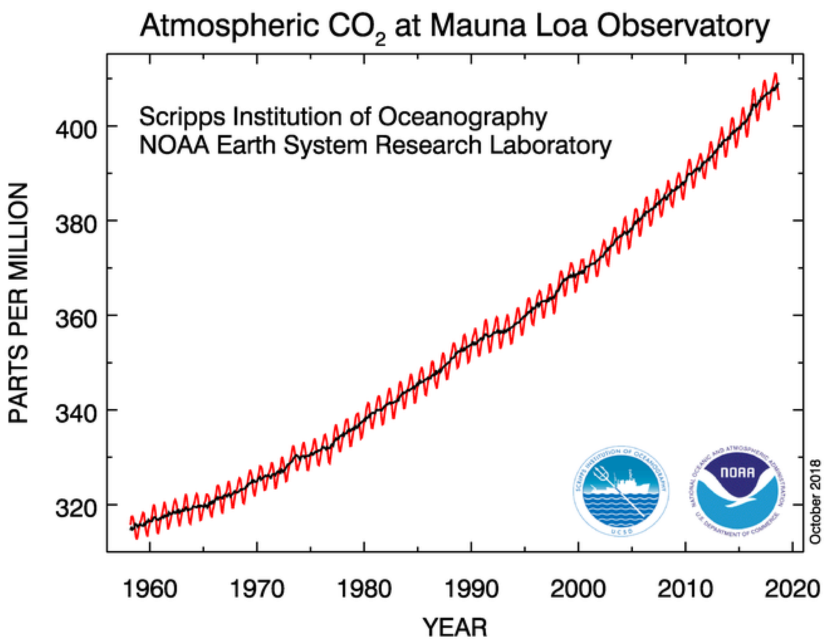


Natural heat trapping gases: T ~ 56 °F

Global warming comes from *added* heat-trapping gases

- CO_2 up nearly 50% since 1800
  - – Burning coal, oil , & gas; clearing forests & prairies
- Double CO_2: expect 3 - 8 °F warming
  - – Svante Arrhenius: 1896
  - – *Not* a new idea

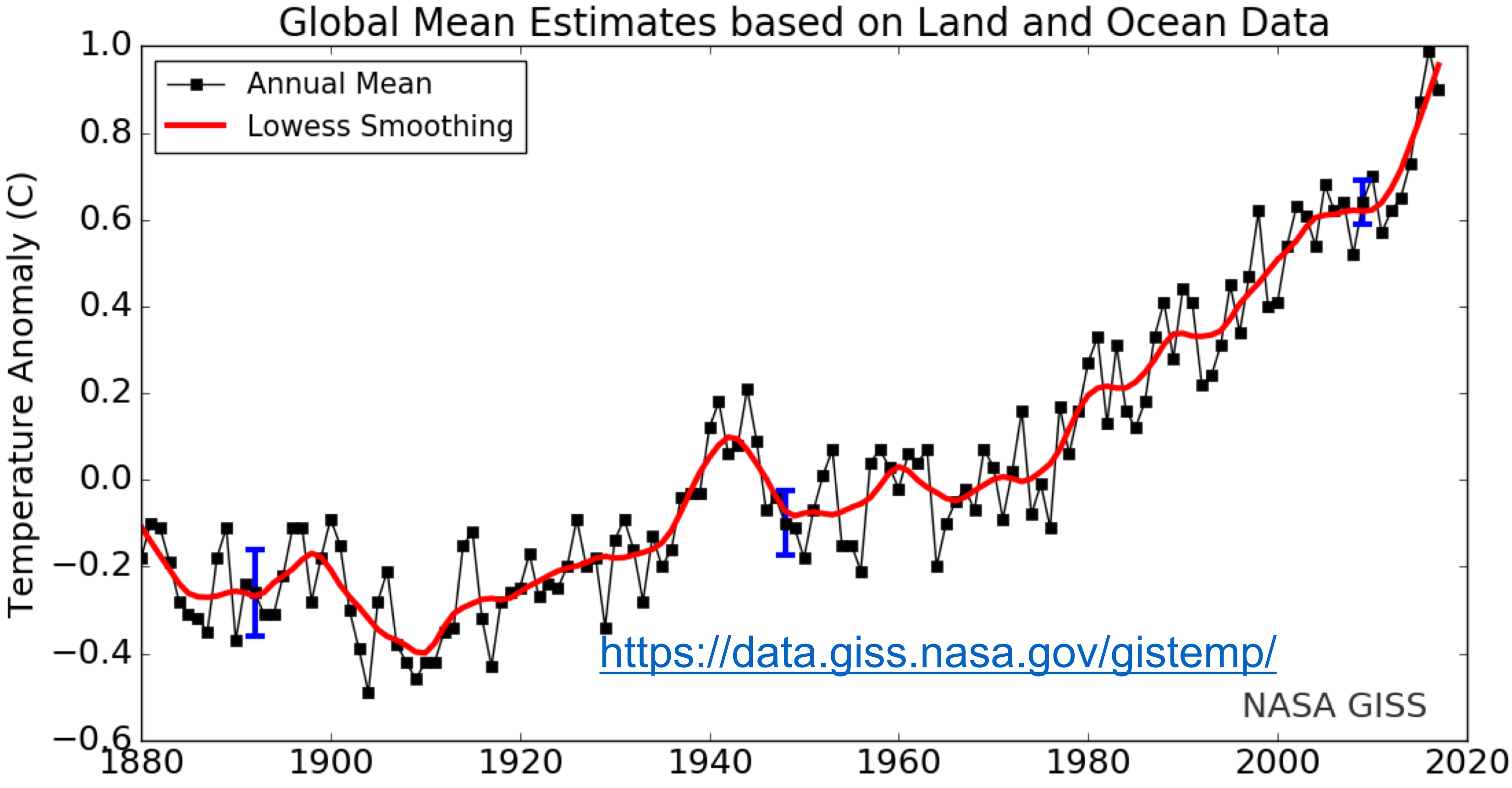
  at current pace, CO_2 will double its preindustrial level in ~50 years



https://www.esrl.noaa.gov/gmd/ccgg/trends/full.html

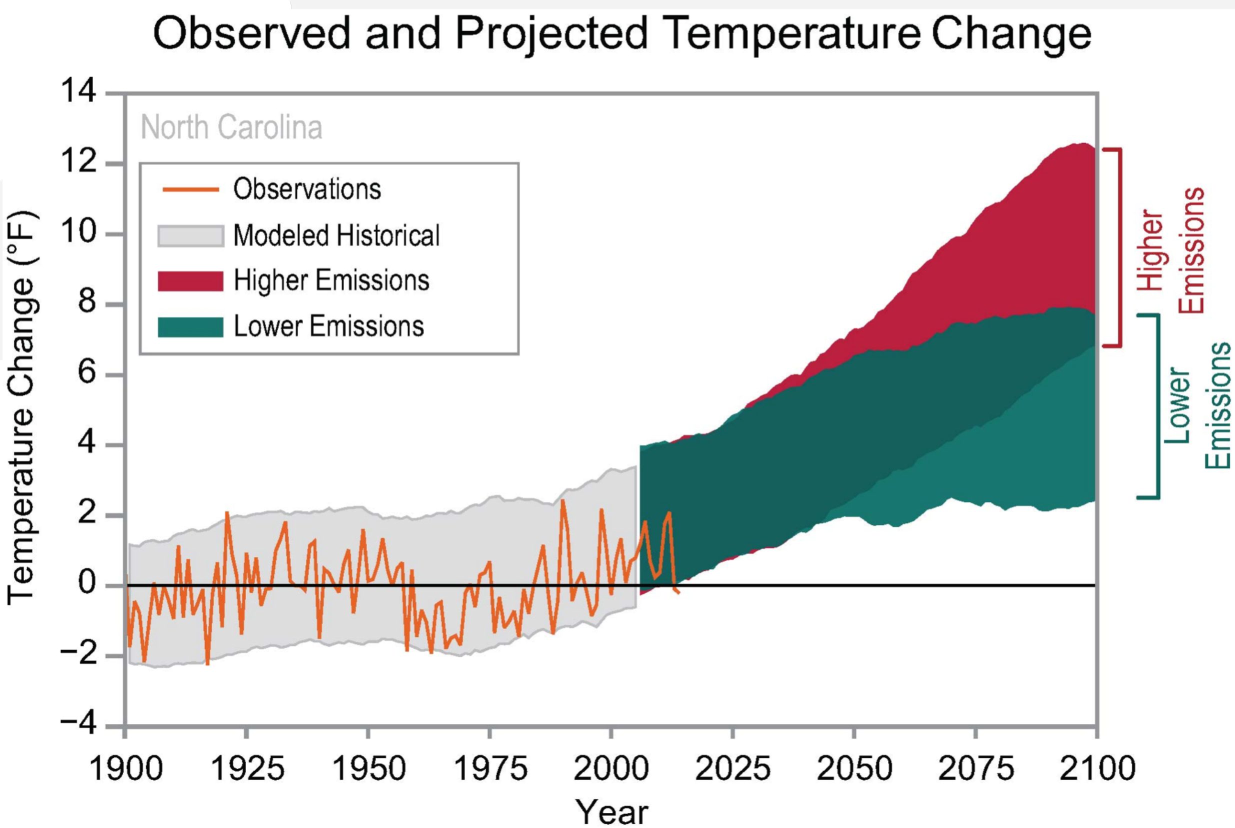
Earth has warmed as expected

- About 1.8 °F (1 °C) since 1900



What about NC?

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

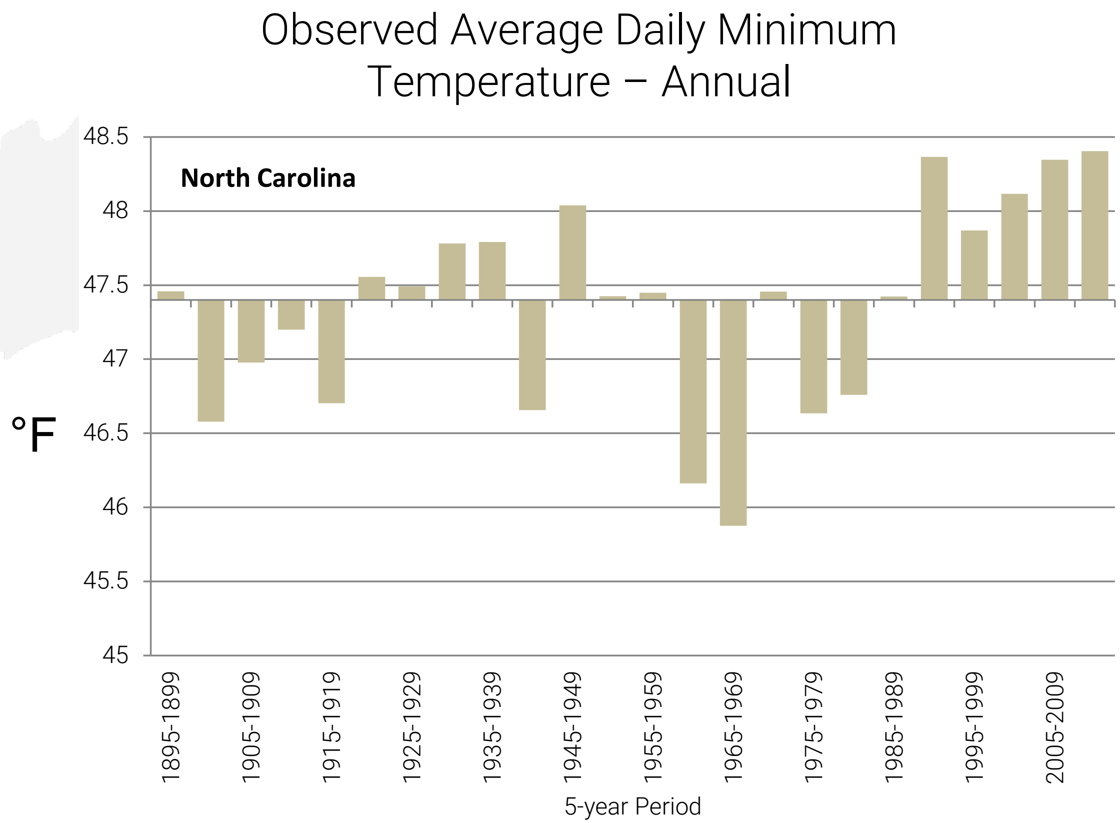


https://statesummaries.ncics.org/

NORTH CAROLINA CLIMATE OFFICE

Nighttime lows have warmed most

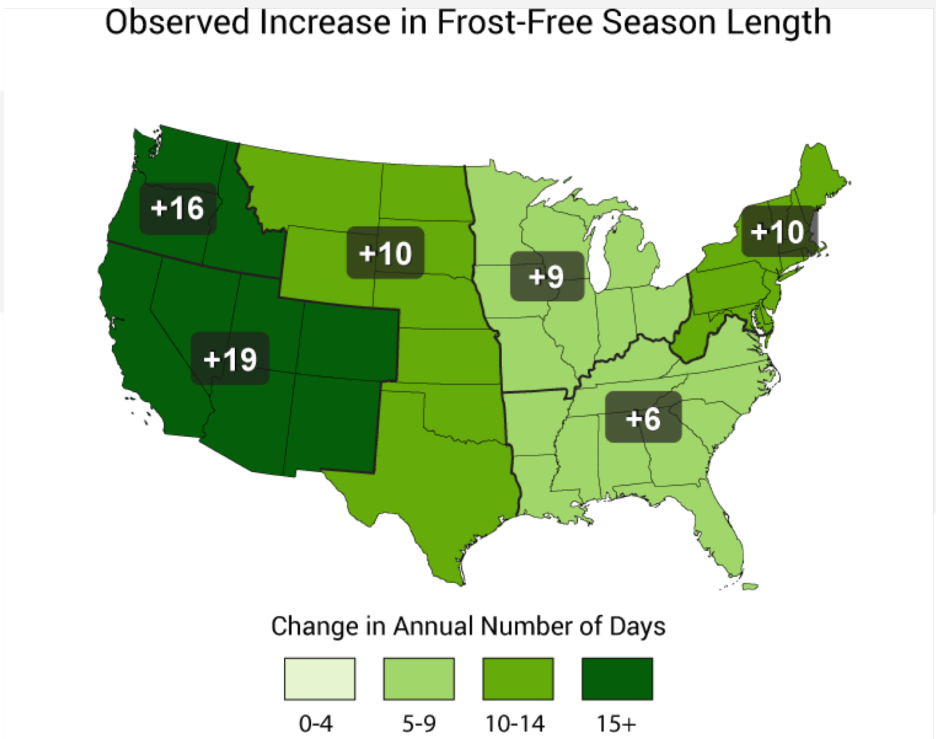
- Enhanced greenhouse limits overnight cooling



https://statesummaries.ncics.org/

Longer frost-free season

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

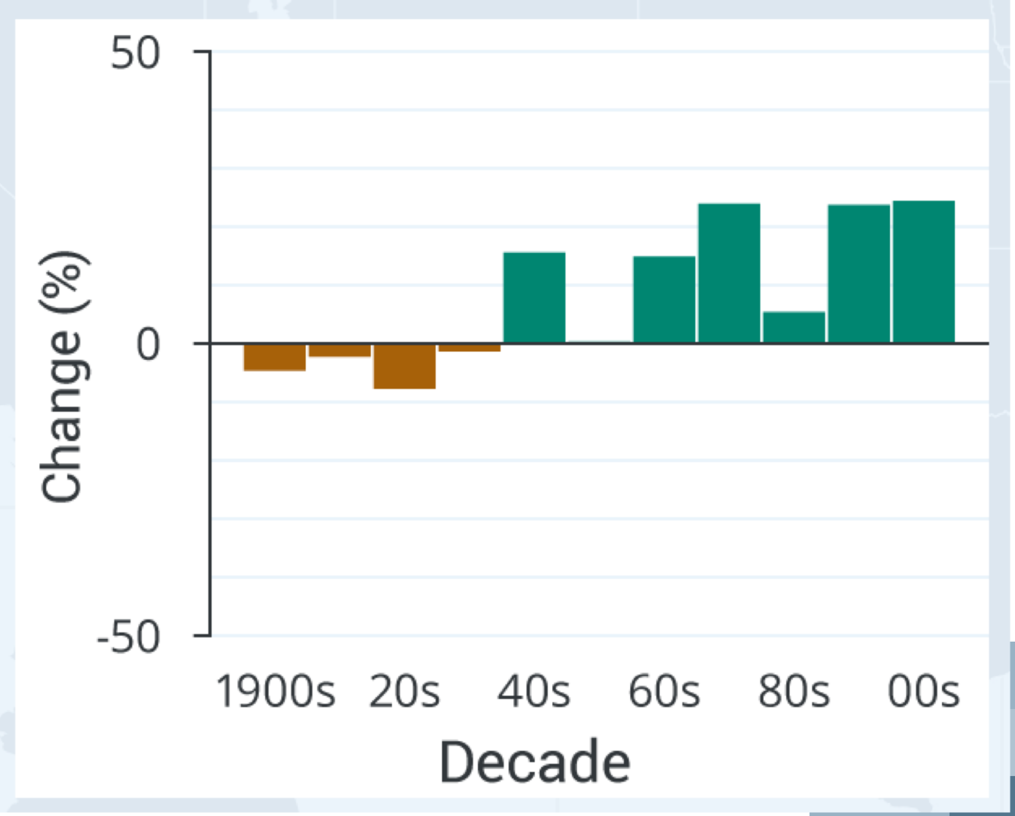


https://nca2014.globalchange.gov/

More intense rain

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

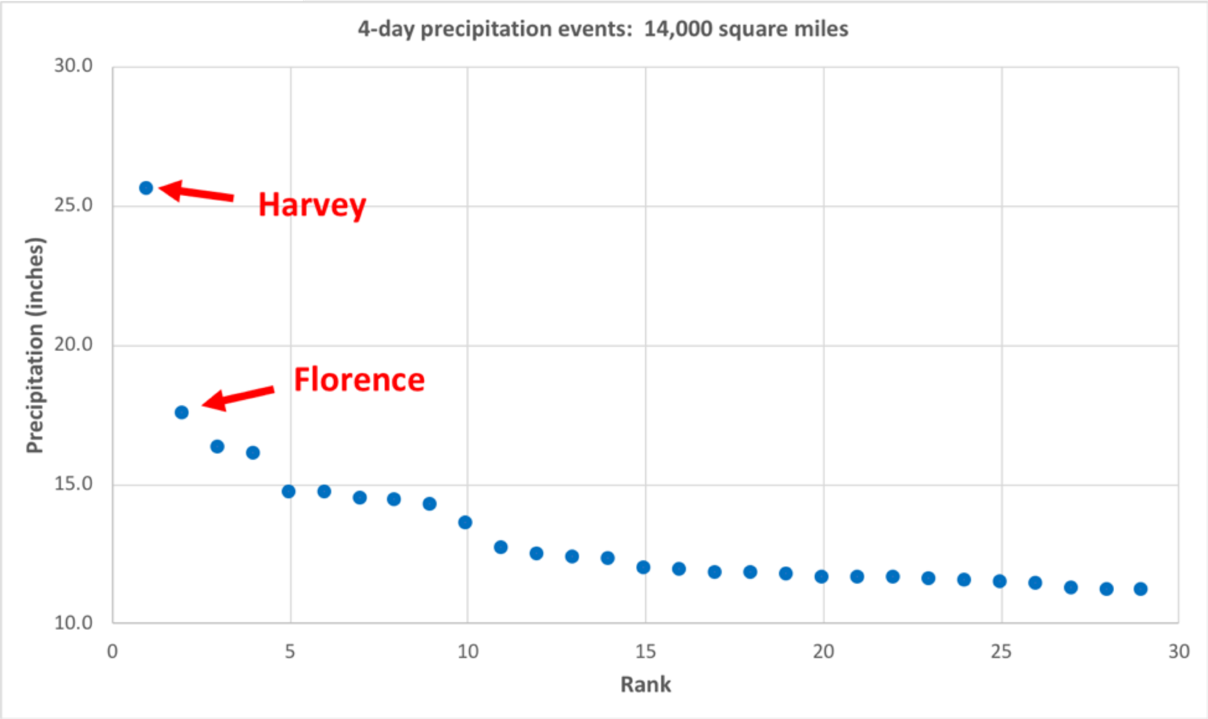
US Southeast – change (%) in amount of rain in top 1% of rain events



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

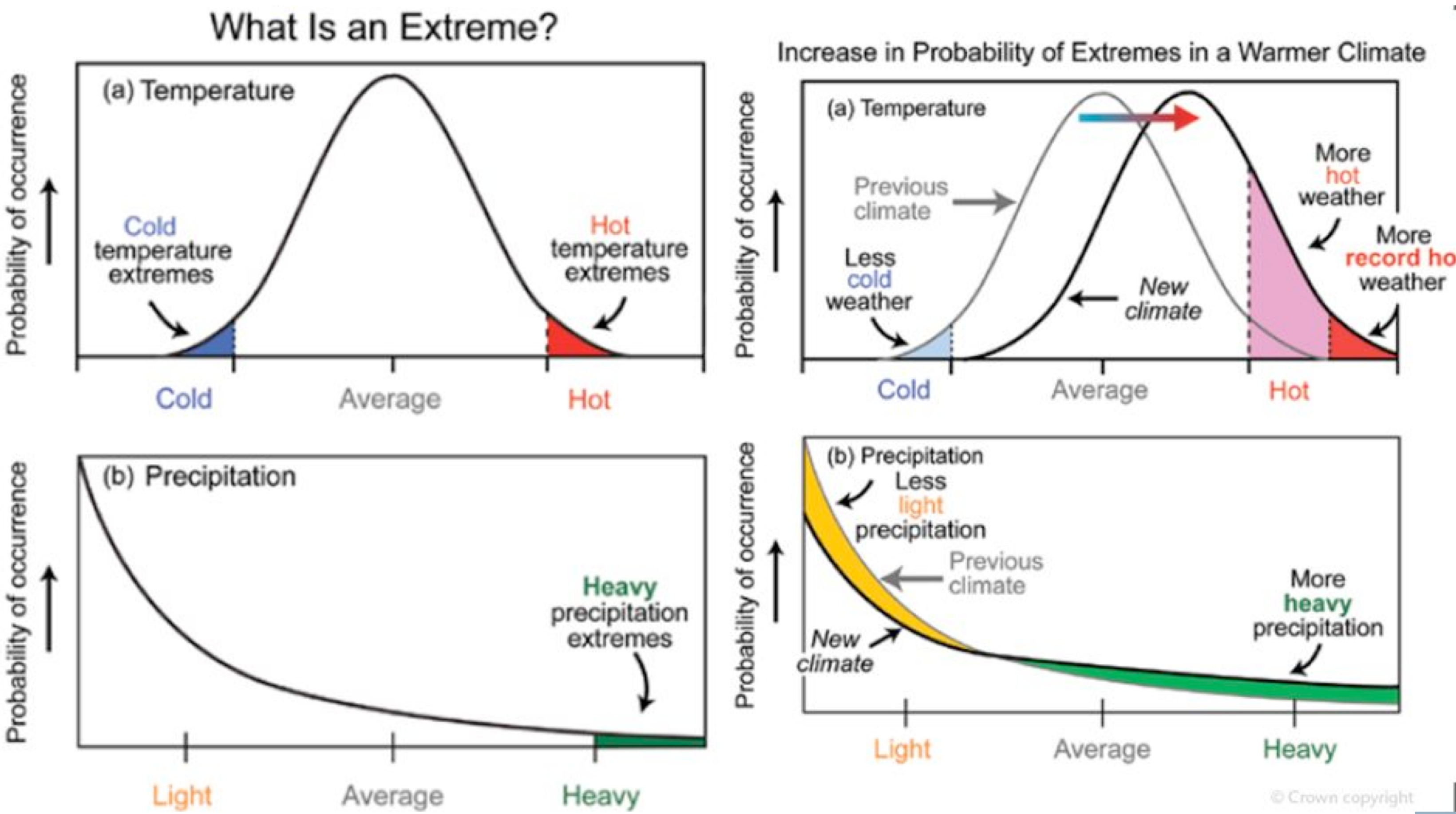


Ken Kunkel
NC State/NCICS

https://ncics.org/cics-news/putting-hurricane-florence-into-historical-perspective/

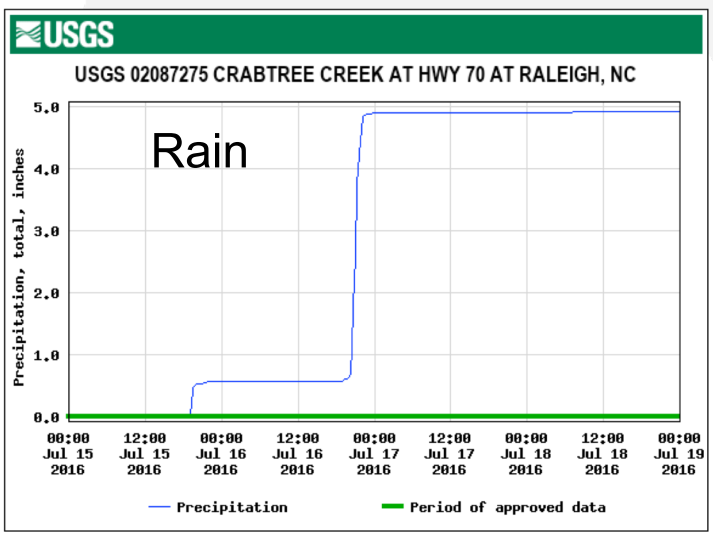
Changes in extremes appear first

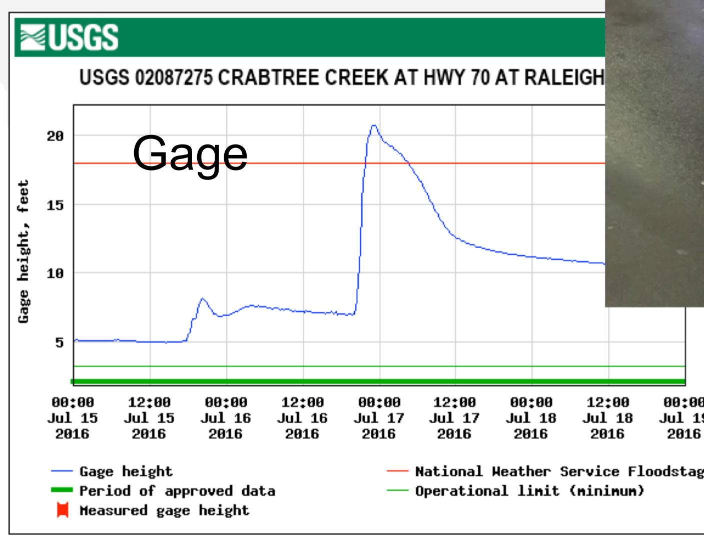
- Small changes => big changes in frequency of extremes



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



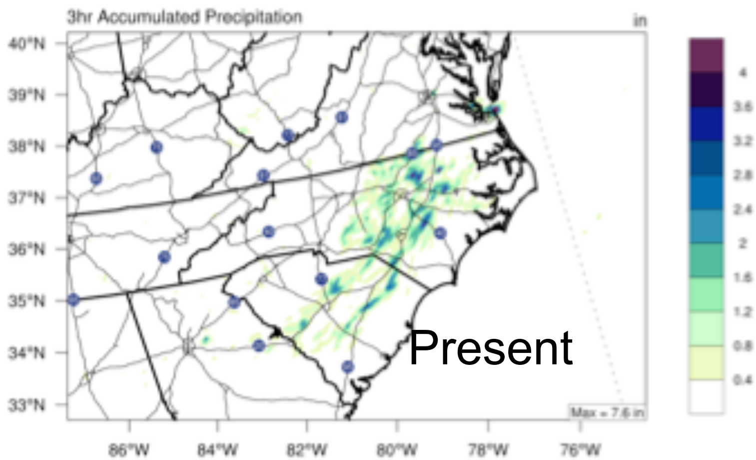


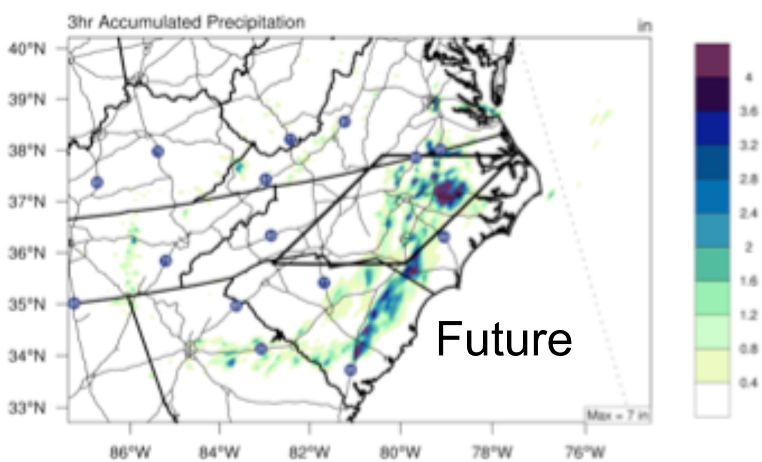
Flooded garage at Crabtree

Raleigh July 2016 flood *simulated*: now & in the future

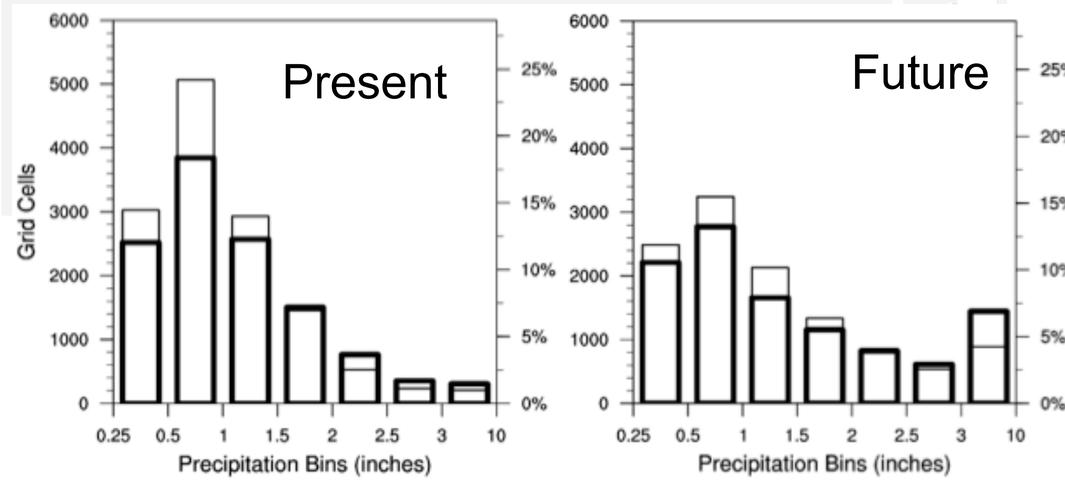
- WRF model – 4 km grid
- Climate change in 2090s
  - – from IPCC GCMs
- Future runs show *large* increases in heaviest rain

Rainfall (3 hr at peak)





Accumulated rainfall distribution

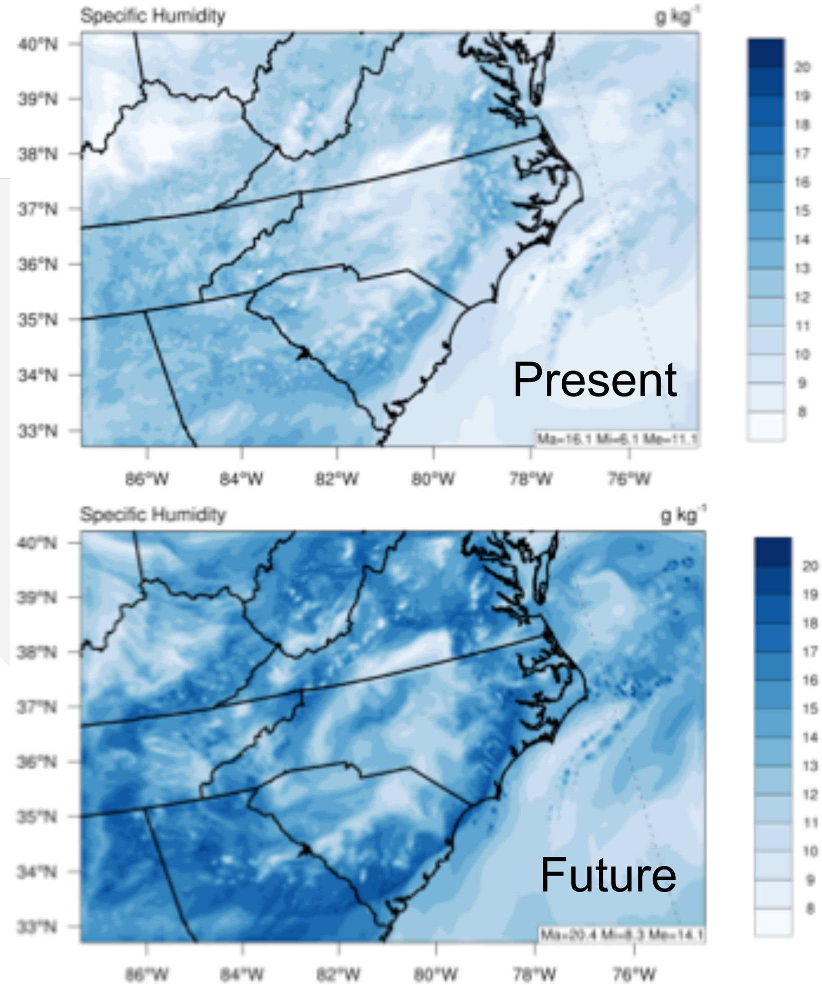


PhD work of J. Mike Madden

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 => more rain is reliable; changes that depend on detailed storm dynamics are not

Specific humidity



What *do* we know?

- Warmer
- Heaviest rains will be heavier

What *don't* we know?

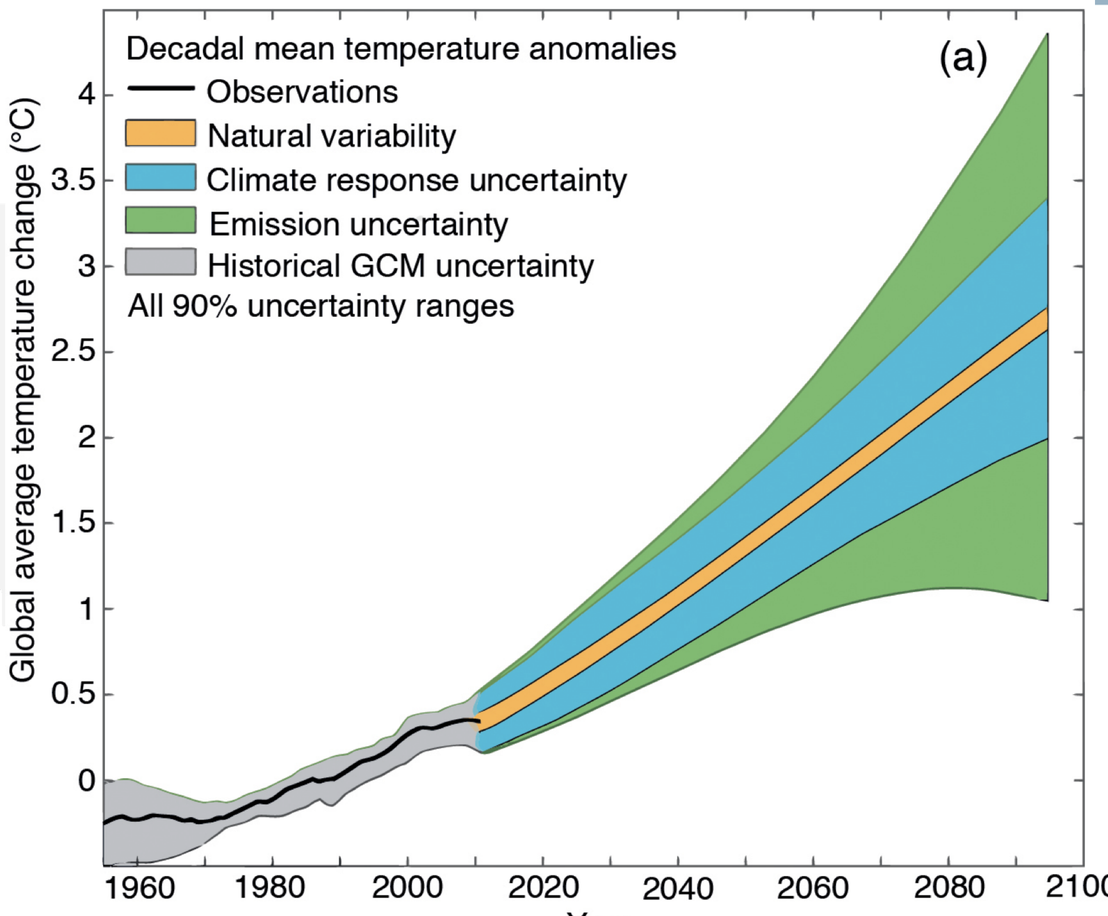
- How much warmer (globally & regionally)
- How much heavier rains
- Changes in regional storm occurrence (e.g. hurricanes)
- Changes in drought frequency

IPCC's view

Phenomenon and direction of trend	Assessment that changes occurred (typically since 1950 unless otherwise indicated)	Assessment of a human contribution to observed changes	Likelihood of further changes	
			Early 21st century	Late 21st century
Warmer and/or fewer cold days and nights over most land areas	*Very likely* {2.6} *Very likely* *Very likely*	***Very likely*** {10.6} *Likely* *Likely*	*Likely* {11.3}	*Virtually certain* {12.4} *Virtually certain* *Virtually certain*
Warmer and/or more frequent hot days and nights over most land areas	*Very likely* {2.6} *Very likely* *Very likely*	***Very likely*** {10.6} *Likely* *Likely* (nights only)	*Likely* {11.3}	*Virtually certain* {12.4} *Virtually certain* *Virtually certain*
Warm spells/heat waves. Frequency and/or duration increases over most land areas	***Medium confidence*** on a global scale *Likely* in large parts of Europe, Asia and Australia {2.6} *Medium confidence* in many (but not all) regions *Likely*	***Likely***[a] {10.6} Not formally assessed *More likely than not*	Not formally assessed[b] {11.3}	*Very likely* {12.4} *Very likely* *Very likely*
Heavy precipitation events. Increase in the frequency, intensity, and/or amount of heavy precipitation	*Likely* more land areas with increases than decreases[c] {2.6} *Likely* more land areas with increases than decreases *Likely* over most land areas	***Medium confidence*** {7.6, 10.6} *Medium confidence* *More likely than not*	*Likely* over many land areas {11.3}	***Very likely*** over most of the mid-latitude land masses and over wet tropical regions {12.4} *Likely* over many areas *Very likely* over most land areas
Increases in intensity and/or duration of drought	***Low confidence*** on a global scale *Likely* changes in some regions[d] {2.6} *Medium confidence* in some regions *Likely* in many regions, since 1970[e]	***Low confidence*** {10.6} *Medium confidence*[f] *More likely than not*	*Low confidence*[g] {11.3}	***Likely*** *(medium confidence)* on a regional to global scale[h] {12.4} *Medium confidence* in some regions *Likely*[e]
Increases in intense tropical cyclone activity	***Low confidence*** in long term (centennial) changes *Virtually certain* in North Atlantic since 1970 {2.6} *Low confidence* *Likely* in some regions, since 1970	***Low confidence***[i] {10.6} *Low confidence* *More likely than not*	*Low confidence* {11.3}	***More likely than not*** in the Western North Pacific and North Atlantic[j] {14.6} *More likely than not* in some basins *Likely*
Increased incidence and/or magnitude of extreme high sea level	*Likely* (since 1970) {3.7} *Likely* (late 20th century) *Likely*	***Likely***[k] {3.7} *Likely*[k] *More likely than not*[k]	*Likely*[l] {13.7}	***Very likely***[l] {13.7} *Very likely*[m] *Likely*

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

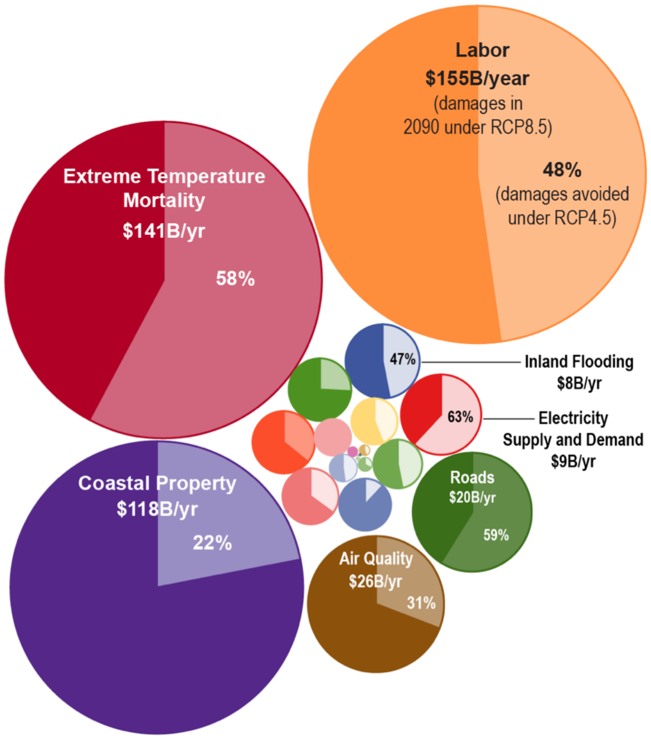


https://www.ipcc.ch/report/ar5/wg1/

Reducing emissions reduces risks

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

https://nca2018.globalchange.gov/



Annual Economic Damages in 2090		
Sector	Annual damages under RCP8.5	Damages avoided under RCP4.5
Labor	$155B	48%
Extreme Temperature Mortality◊	$141B	58%
Coastal Property◊	$118B	22%
Air Quality	$26B	31%
Roads◊	$20B	59%
Electricity Supply and Demand	$9B	63%
Inland Flooding	$8B	47%
Urban Drainage	$6B	26%
Rail◊	$6B	36%
Water Quality	$5B	35%
Coral Reefs	$4B	12%
West Nile Virus	$3B	47%
Freshwater Fish	$3B	44%
Winter Recreation	$2B	107%
Bridges	$1B	48%
Munic. and Industrial Water Supply	$316M	33%
Harmful Algal Blooms	$199M	45%
Alaska Infrastructure◊	$174M	53%
Shellfish*	$23M	57%
Agriculture*	$12M	11%
Aeroallergens*	$1M	57%
Wildfire	–$106M	–134%

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