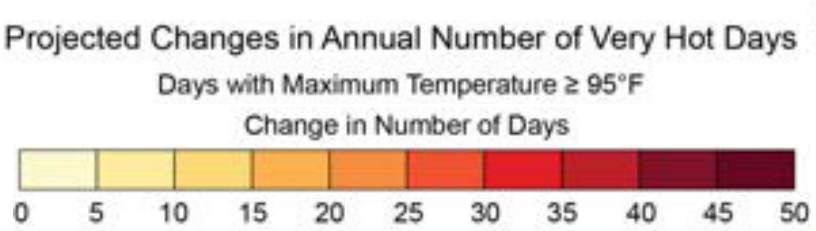
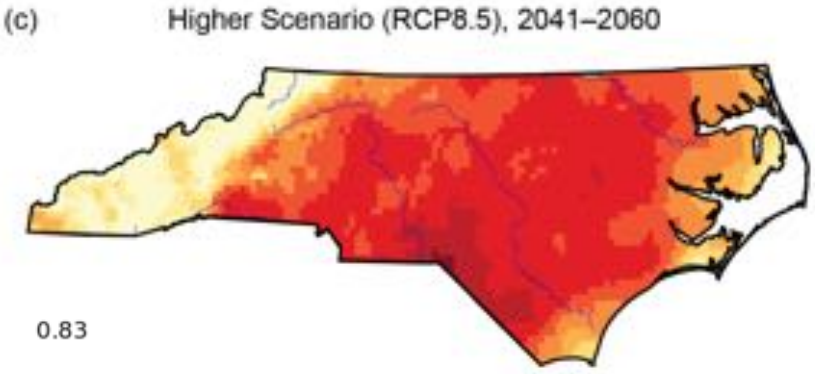
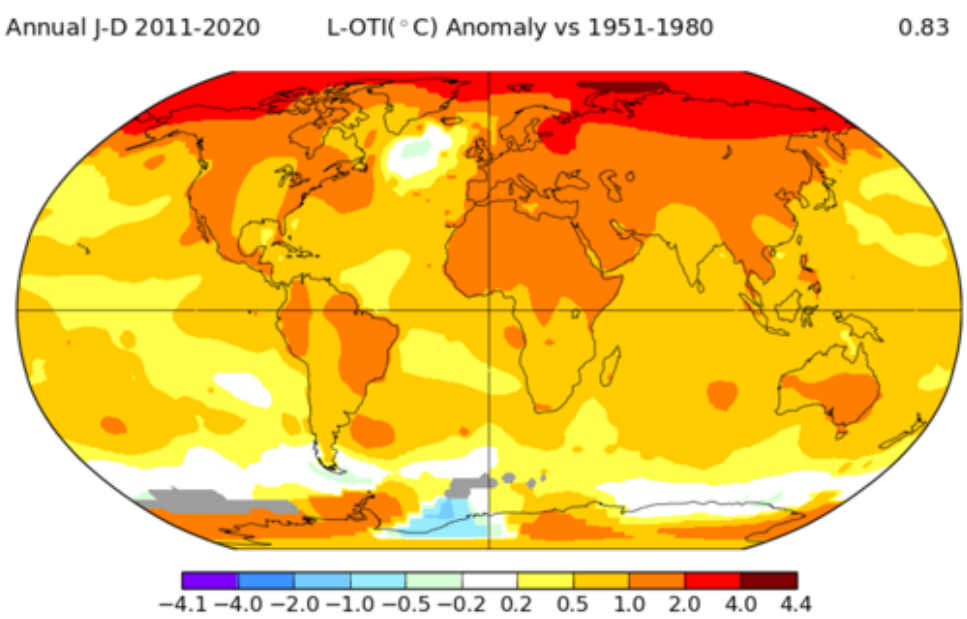
Climate change: what's happening & why it matters for NC nature







Walt Robinson, PhD
NC State University

https://ncics.org/programs/nccsr/

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

Carolina Backyard Naturalist
December 8, 2021

BACKYARD NATURALIST PROGRAM

4 excellent references

North Carolina
Climate Science Report

Authors

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March 2020

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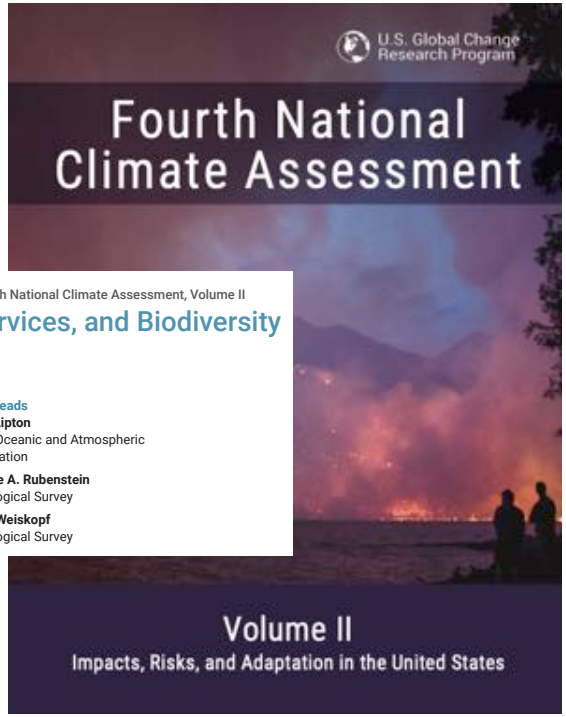
Subject to final copyedit and layout.

Plan language summary here



Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II

7 Ecosystems, Ecosystem Services, and Biodiversity

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U.S. Geological Survey

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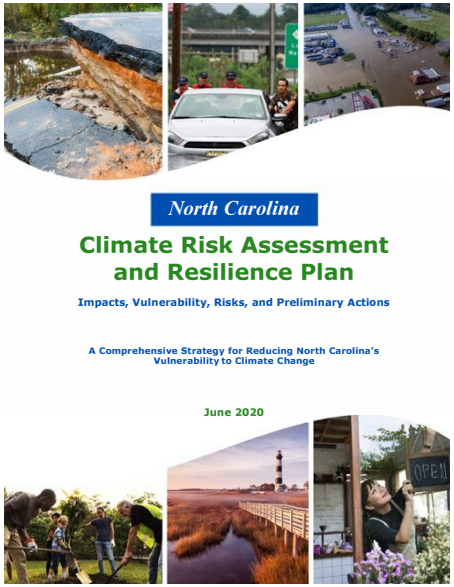
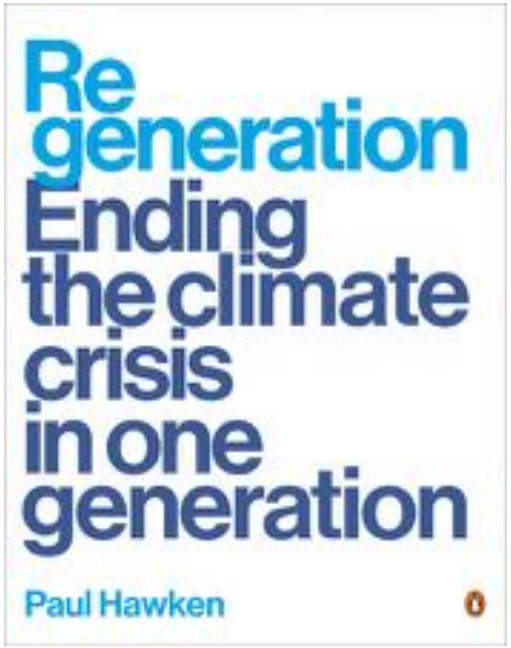
U.S. Geological Survey

https://nca2018.globalchange.gov/chapter/7/

Plan is here; sections 5F & 6 are most relevant to NC nature

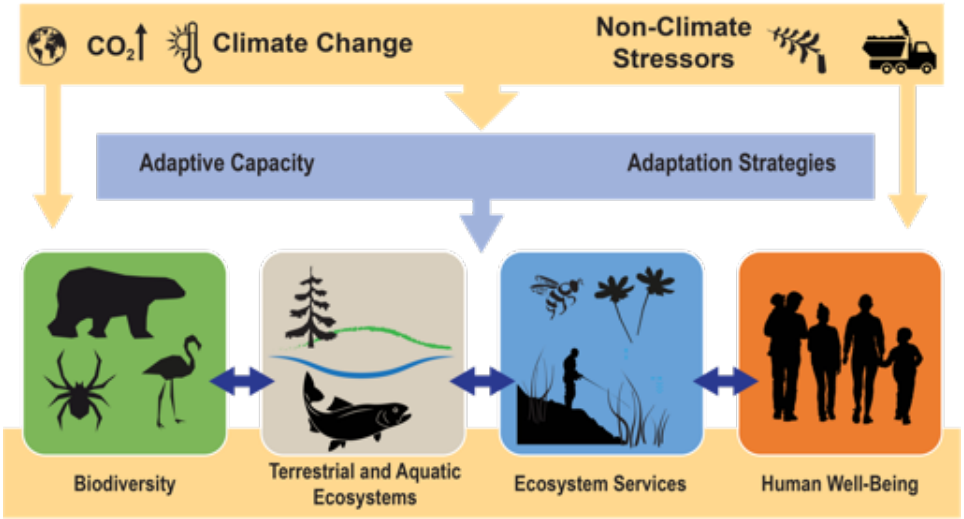


https://regeneration.org/home



This evening …

- Climate change basics
- What's happened/what's expected
- Impacts on nature
- Nature as a (partial) solution
- Wrap up & conversation (Qs anytime in chat)



Basics: Earth energy

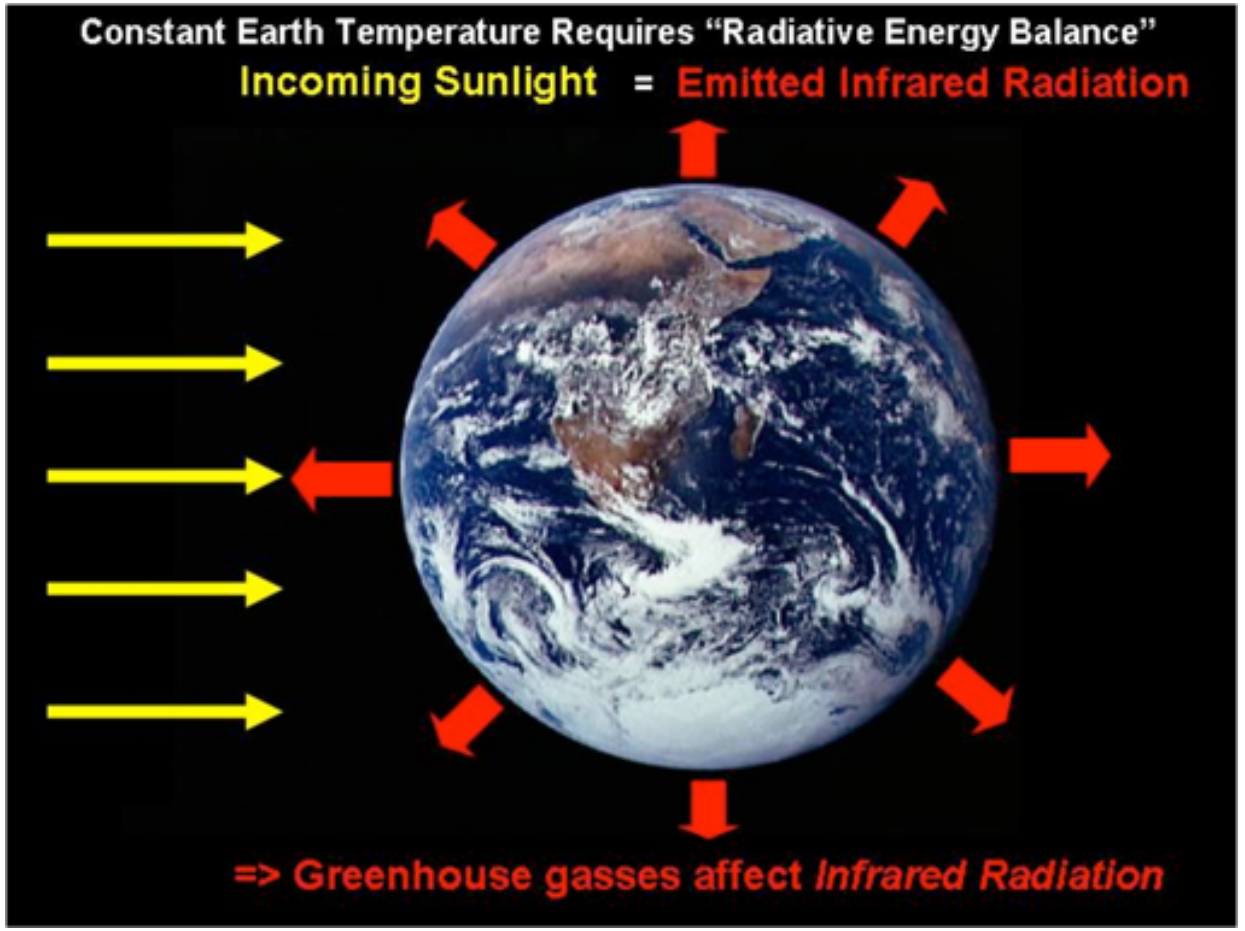
- Earth

  gets energy from the sun

  loses energy as infrared radiation (IR)

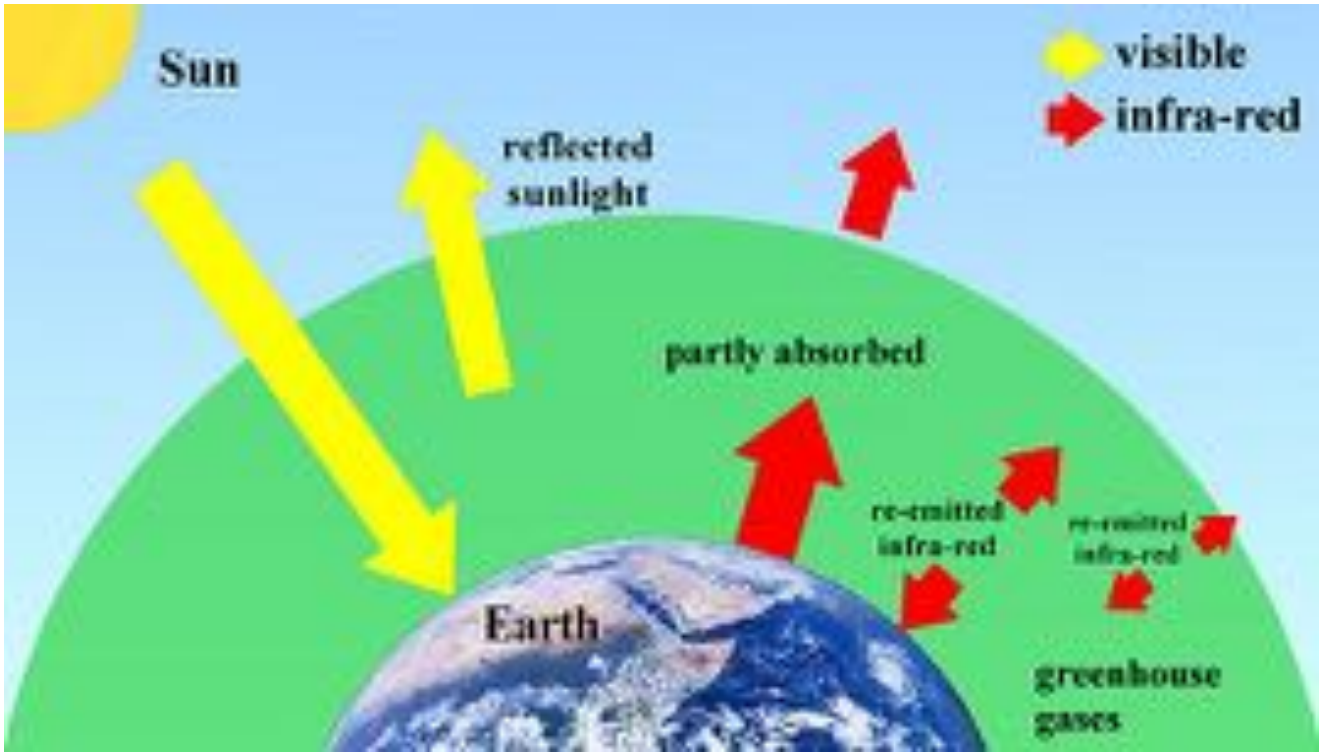
- This balance sets global temperature

  (as measured by an astronomer on Mars)



Basics: greenhouse effect

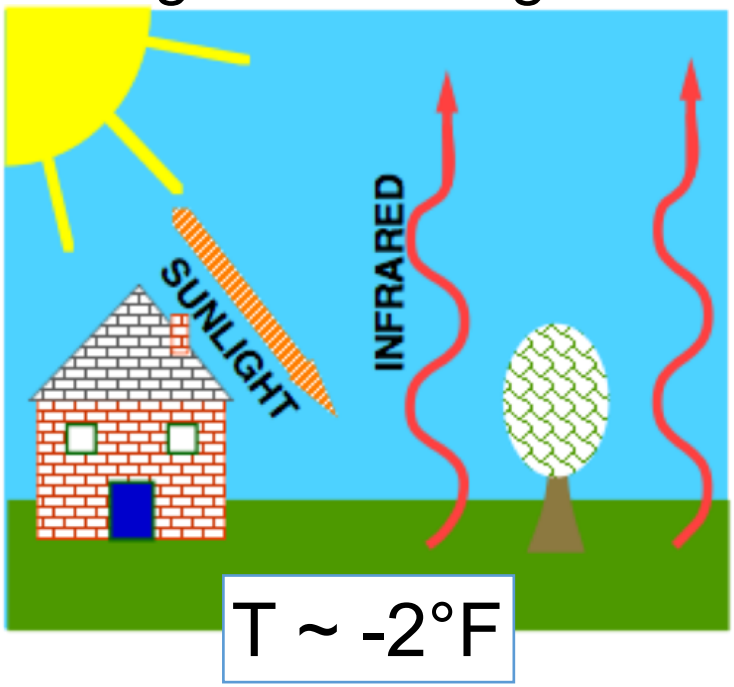
Greenhouse gases absorb outgoing IR & emit IR (Kirchoff's law) warming Earth's surface



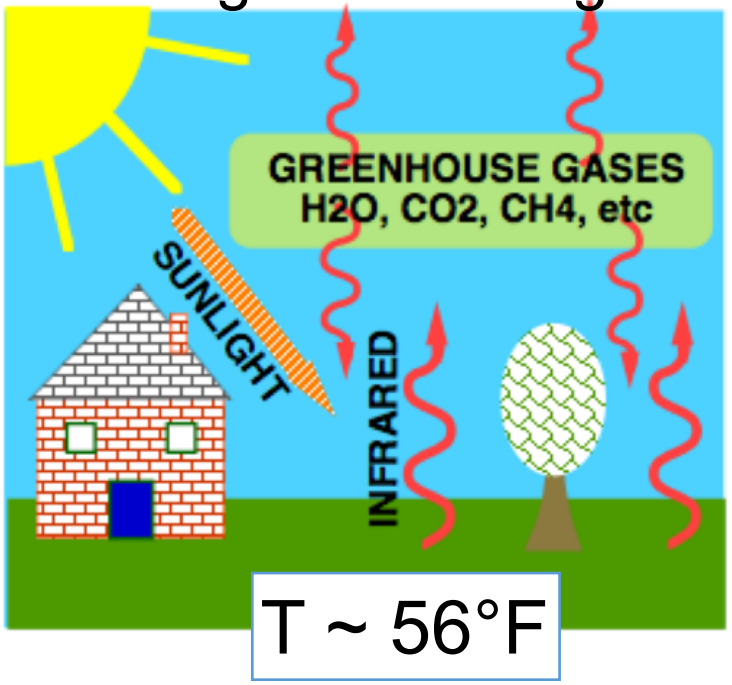
Gustav Kirchhoff

Basics: the greenhouse effect & Earth's temperature

No greenhouse gases



Natural greenhouse gases



Without greenhouse Earth is too cold for life

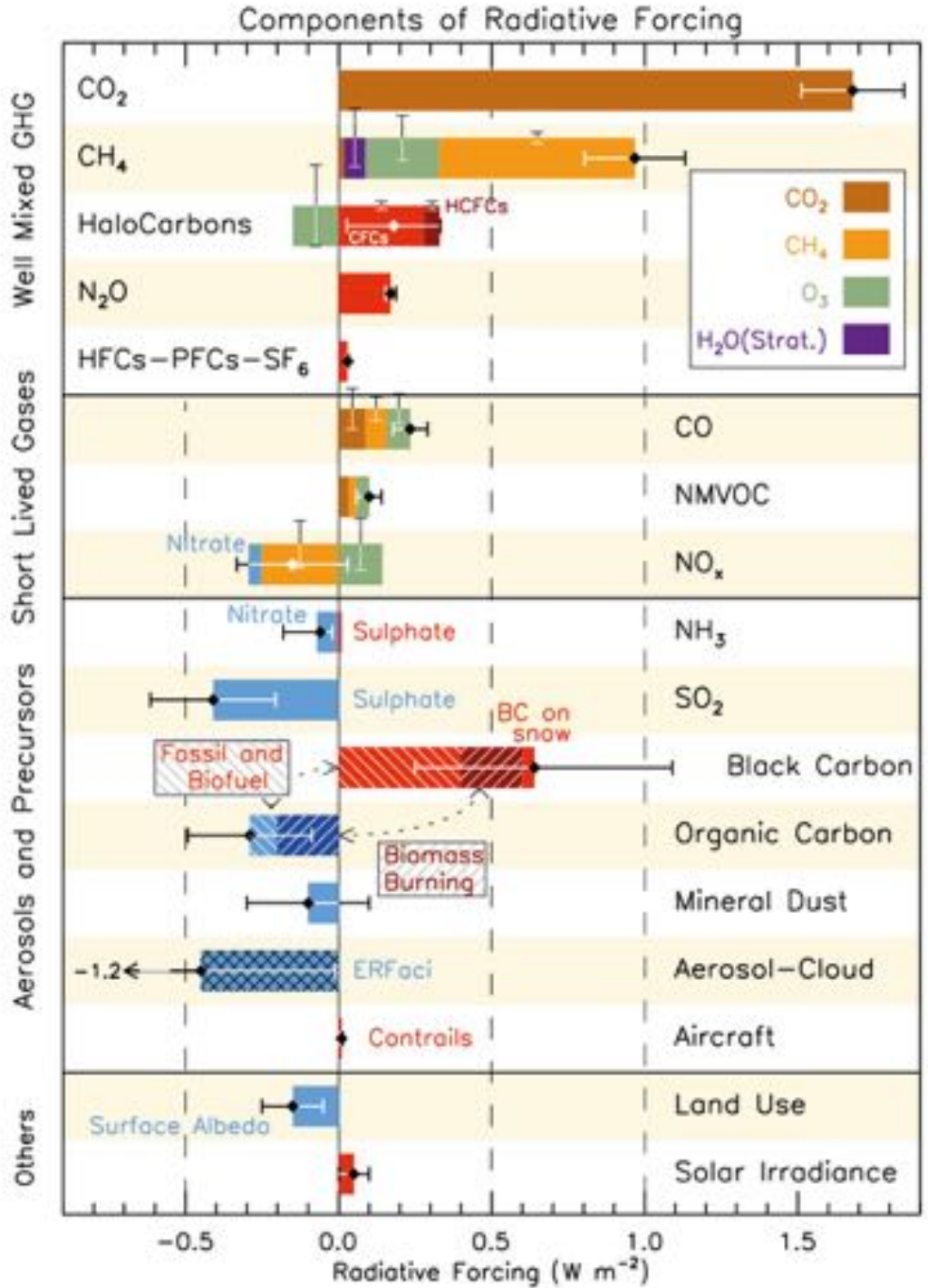
Basics: greenhouse gases

- Water vapor
  - Controlled by weather & climate
- Carbon dioxide
  - From burning coal, oil, & gas
  - Clearing forests

- Methane
  - Livestock
  - Rice paddies
  - Shale-gas production
  - Landfills

- Nitrous oxide
  - Denitrification (e.g. of fertilizer)

Anthropogenic radiative forcing



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

Basics: expected warming

CO_2 up nearly 50% since 1800

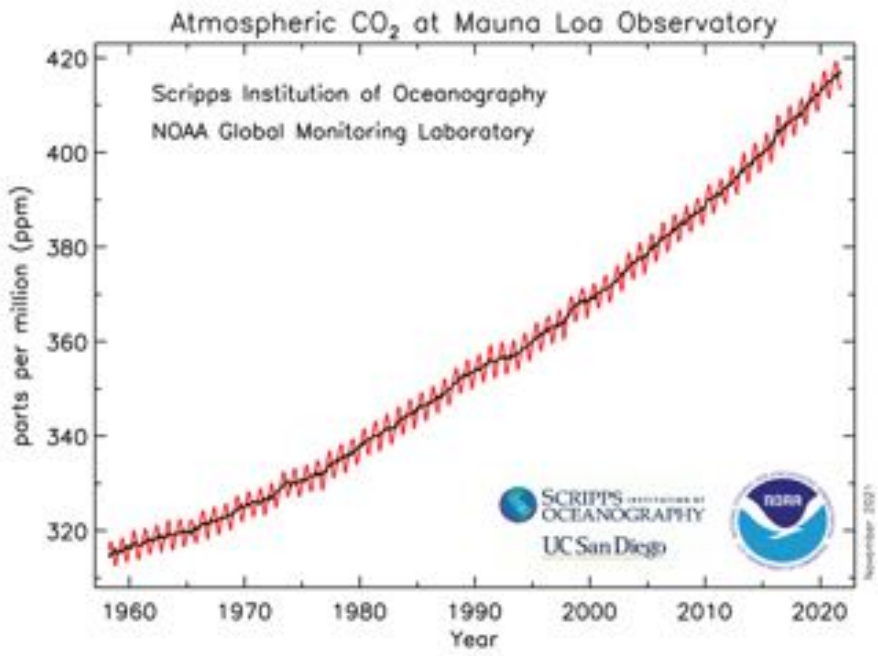
- burning coal, oil, gas
- clearing forests & prairies

For 2xCO_2

- expect 3 - 8 °F warming
- Svante Arrhenius (1896)

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

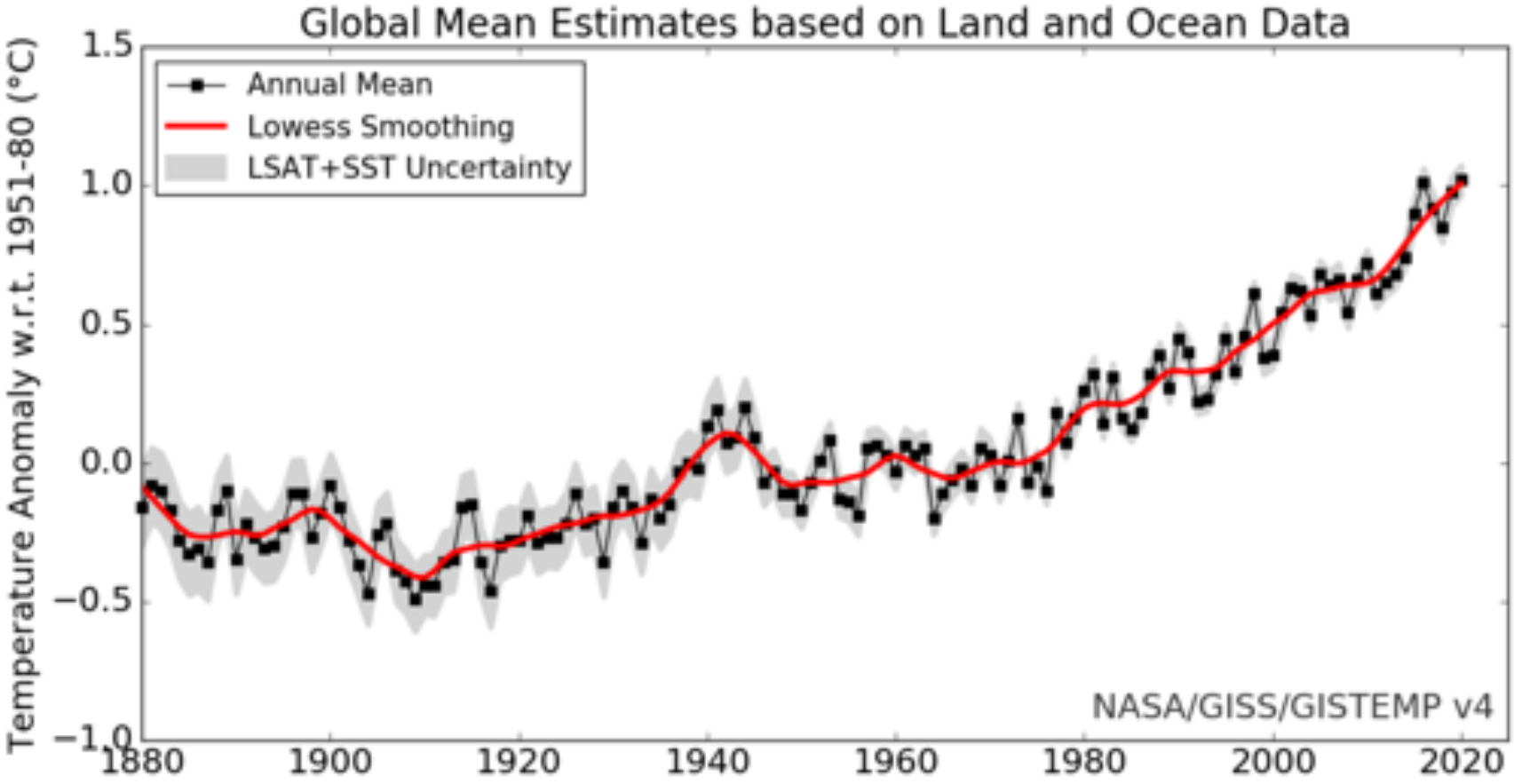
"Suki" Manabe
2021 Nobel Prize in Physics



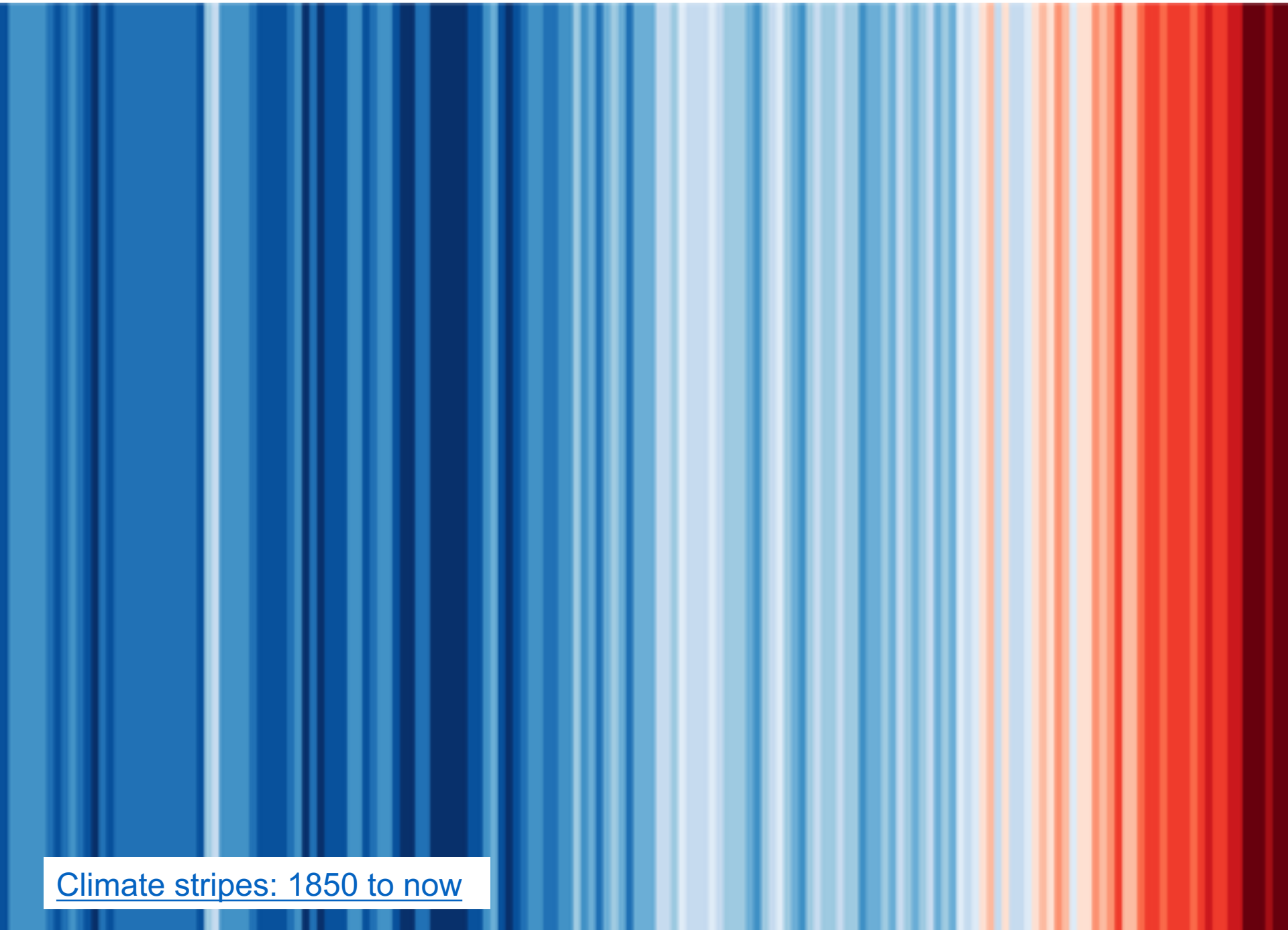
https://www.esrl.noaa.gov/gmd/ccgg/trends/

What's happened: globally

- About 1°C (1.8°F) warming since 1900

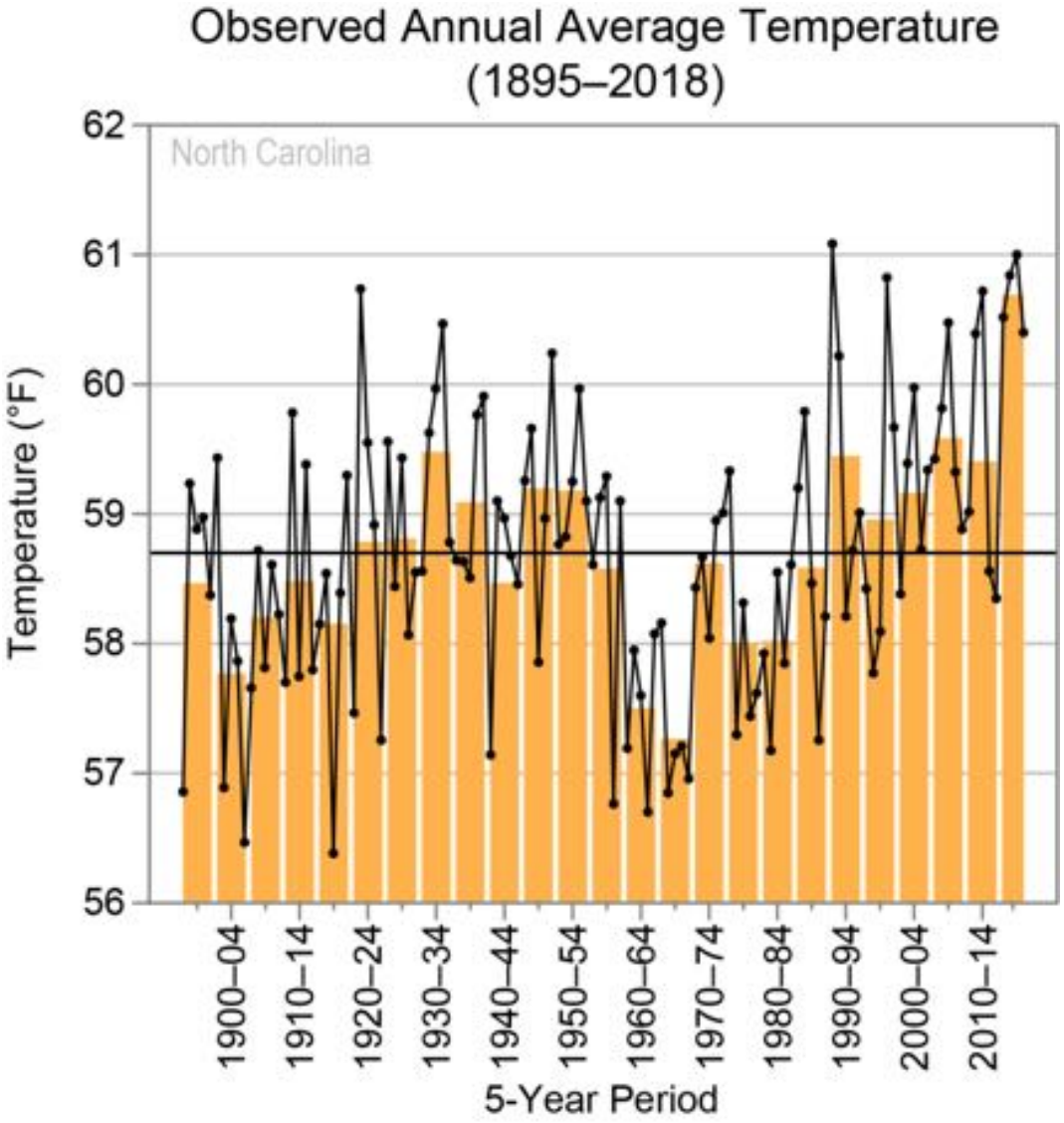


https://data.giss.nasa.gov/gistemp/


Climate stripes: 1850 to now

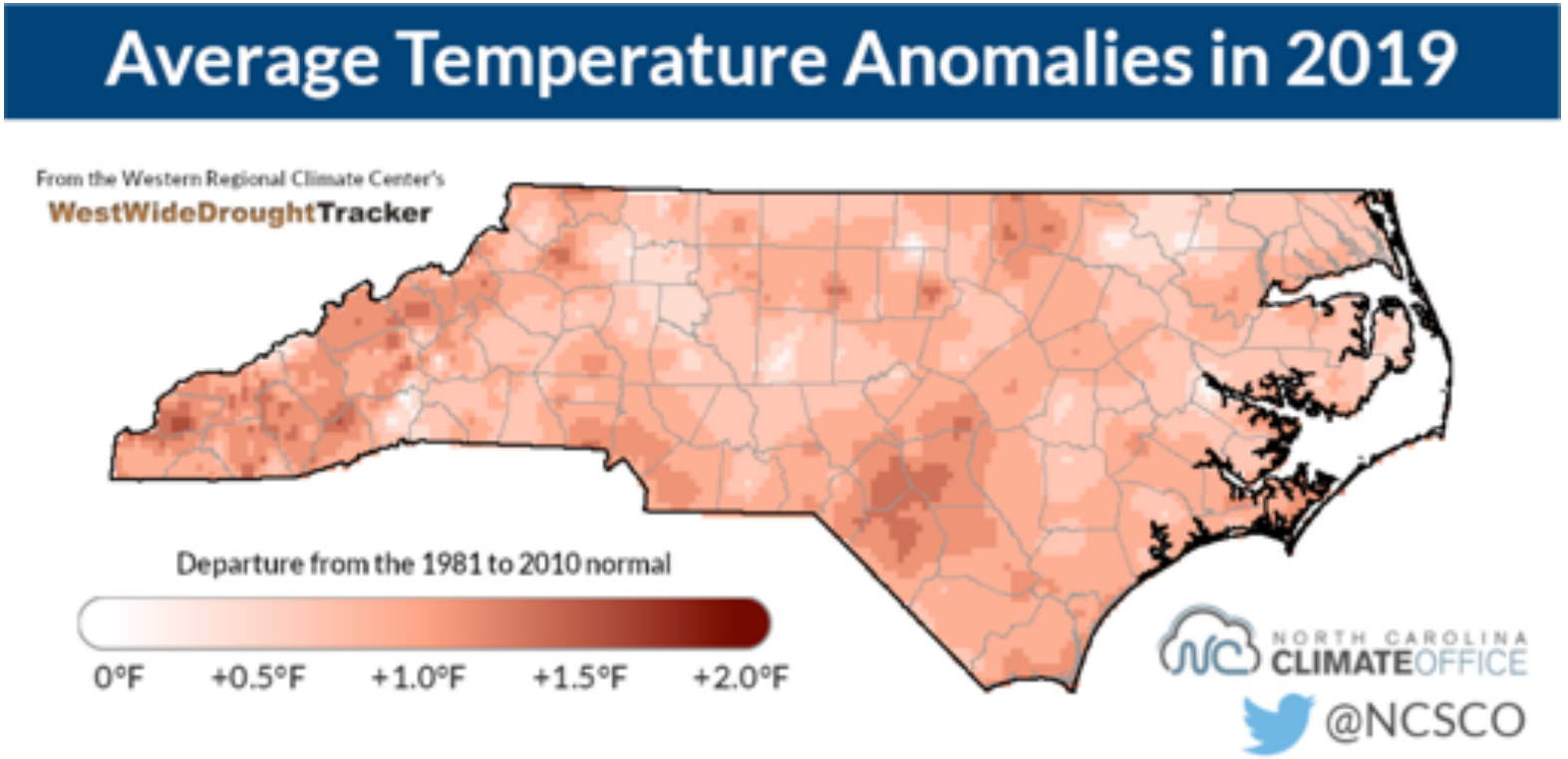
What's happened: NC

- Strong warming since 1960s
  - – early 20th Century was warm



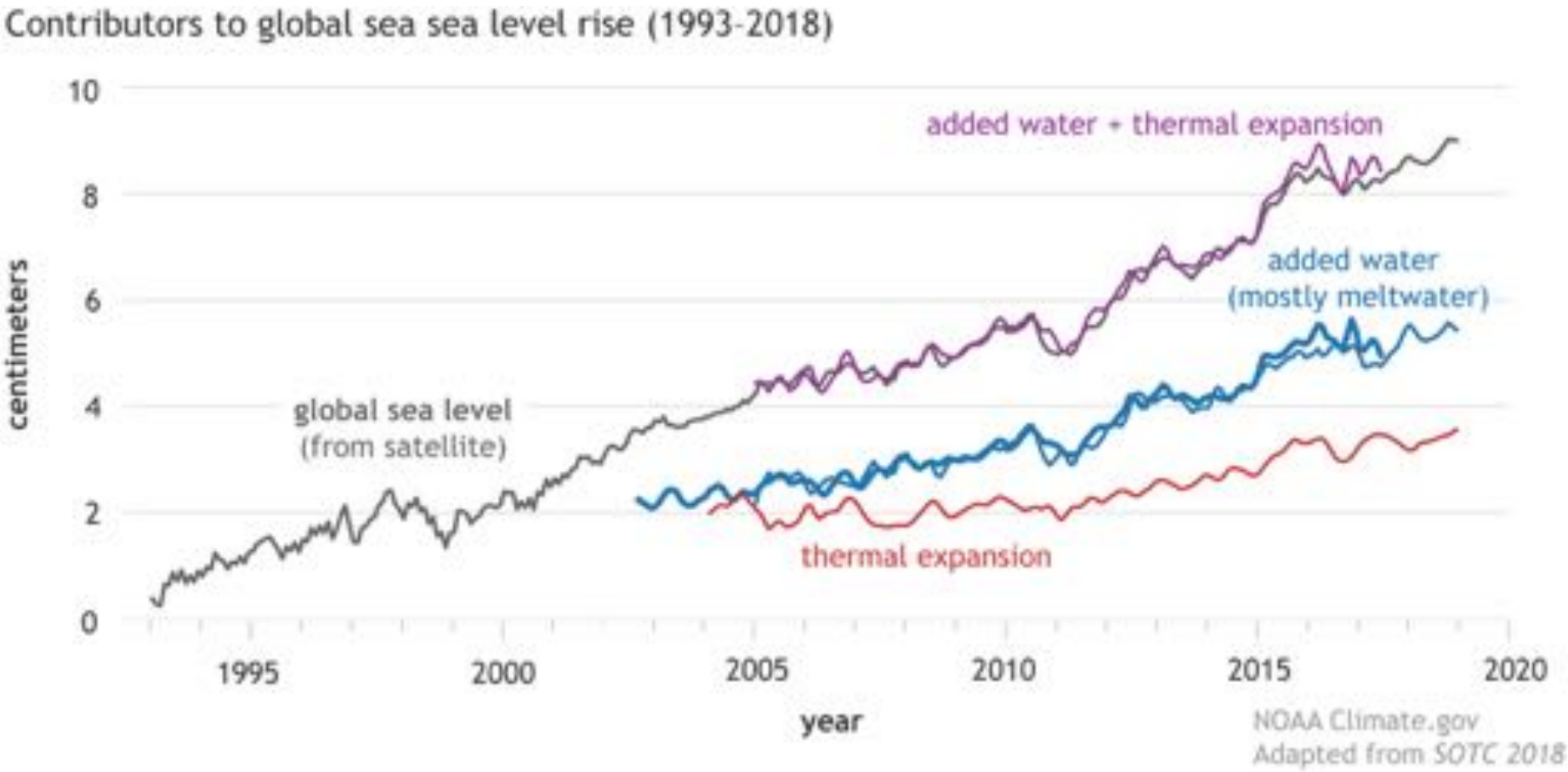
NCCSR

What's happened: 2019 warmest year for NC



https://climate.ncsu.edu/climateblog?id=308

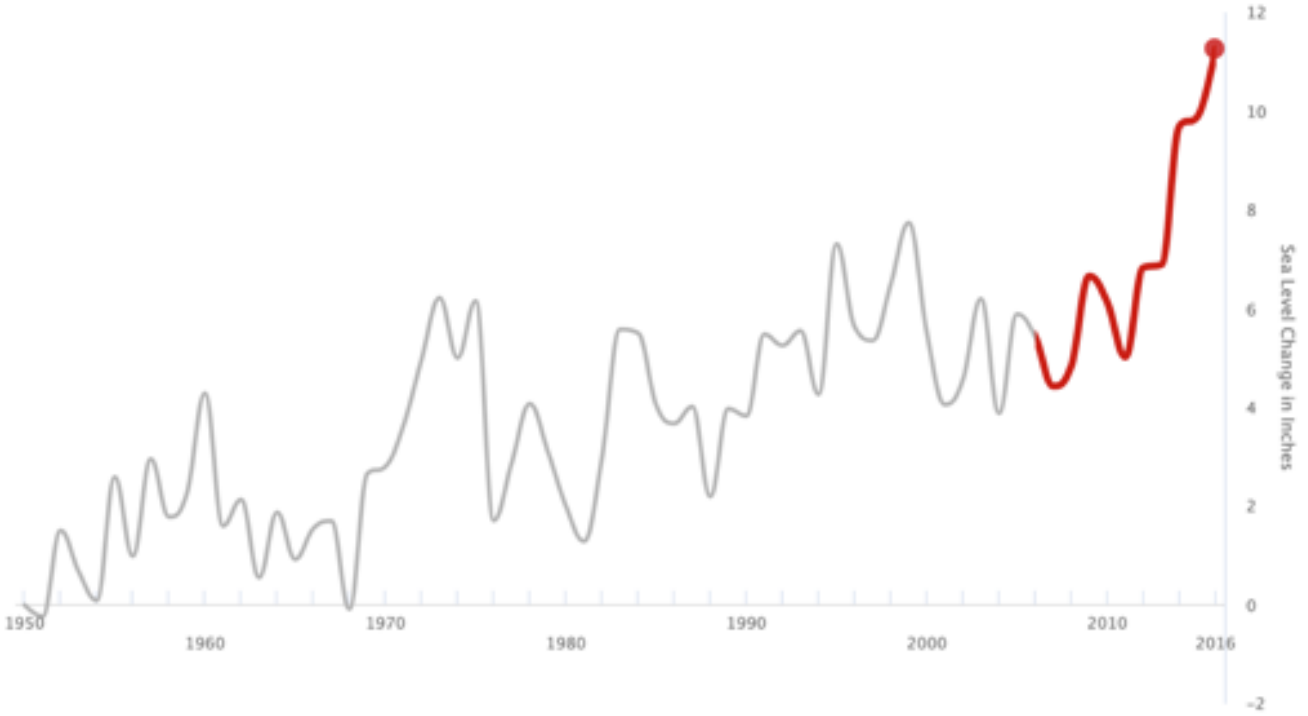
What's happened: sea level



https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level

What's happened: NC sea level

Wilmington tide gauge



https://sealevelrise.org/states/north-carolina/

∆ local sea level = ∆ global sea level + ∆ ocean circulation + sinking

coastal flood = local sea level + tide + storm surge

chronic ***episodic***

What's happening: saltwater intrusion

- Chronic sea-level rise drives intrusion into aquifers
- Floods bring salt water from drainage channels over the surface
- Salinization threatens natural ecosystems & agriculture

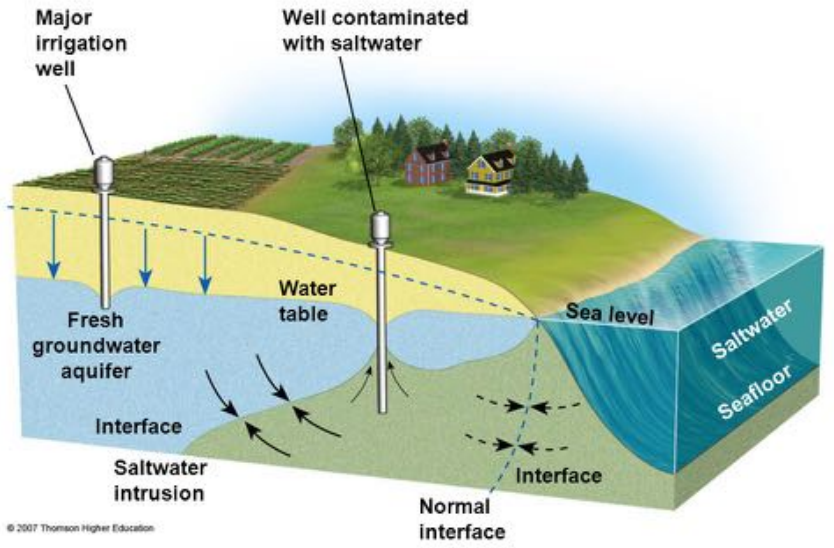


Fig. 14-11, p. 315

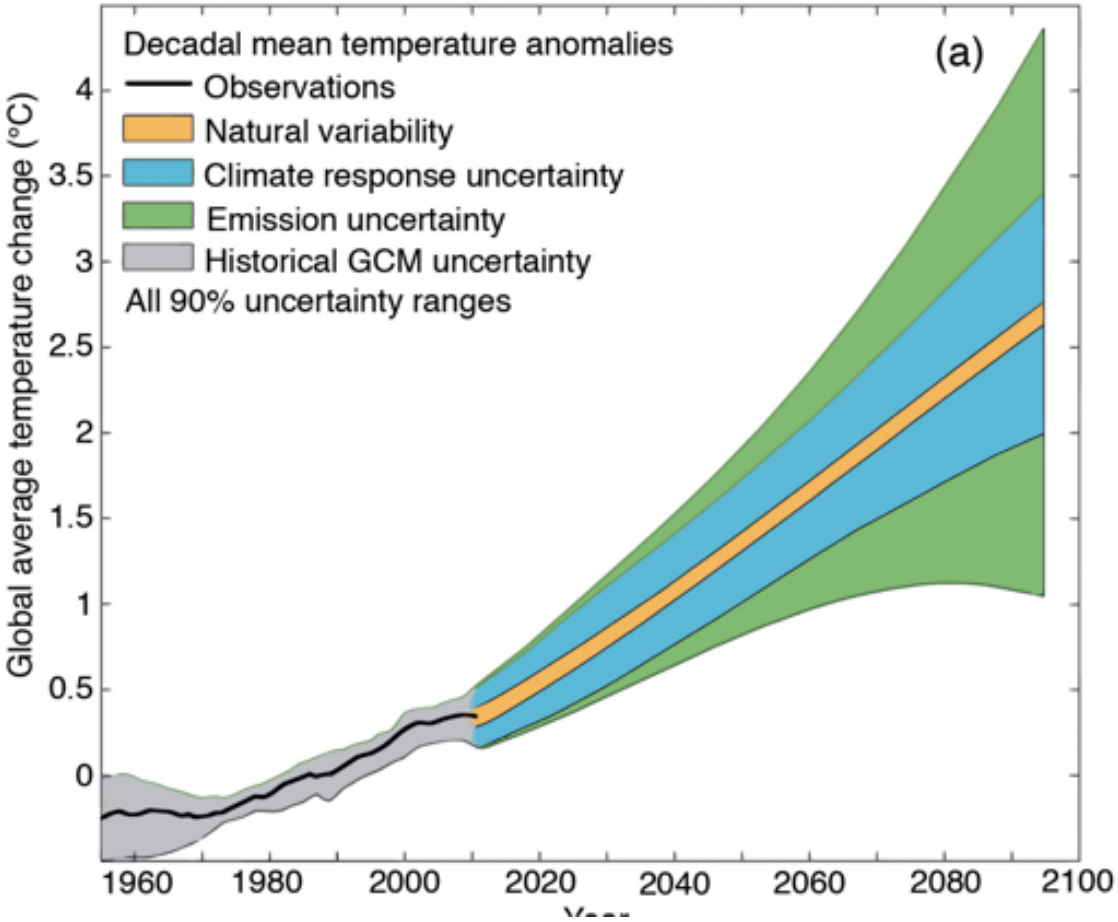
Hyde County field flooded by Florence
https://www.wwno.org/post/florences-impact-will-last-years-farm-crisis-advocate-says

http://ncsu-salt.weebly.com/freshwater-resources.html

Alligator River NWR

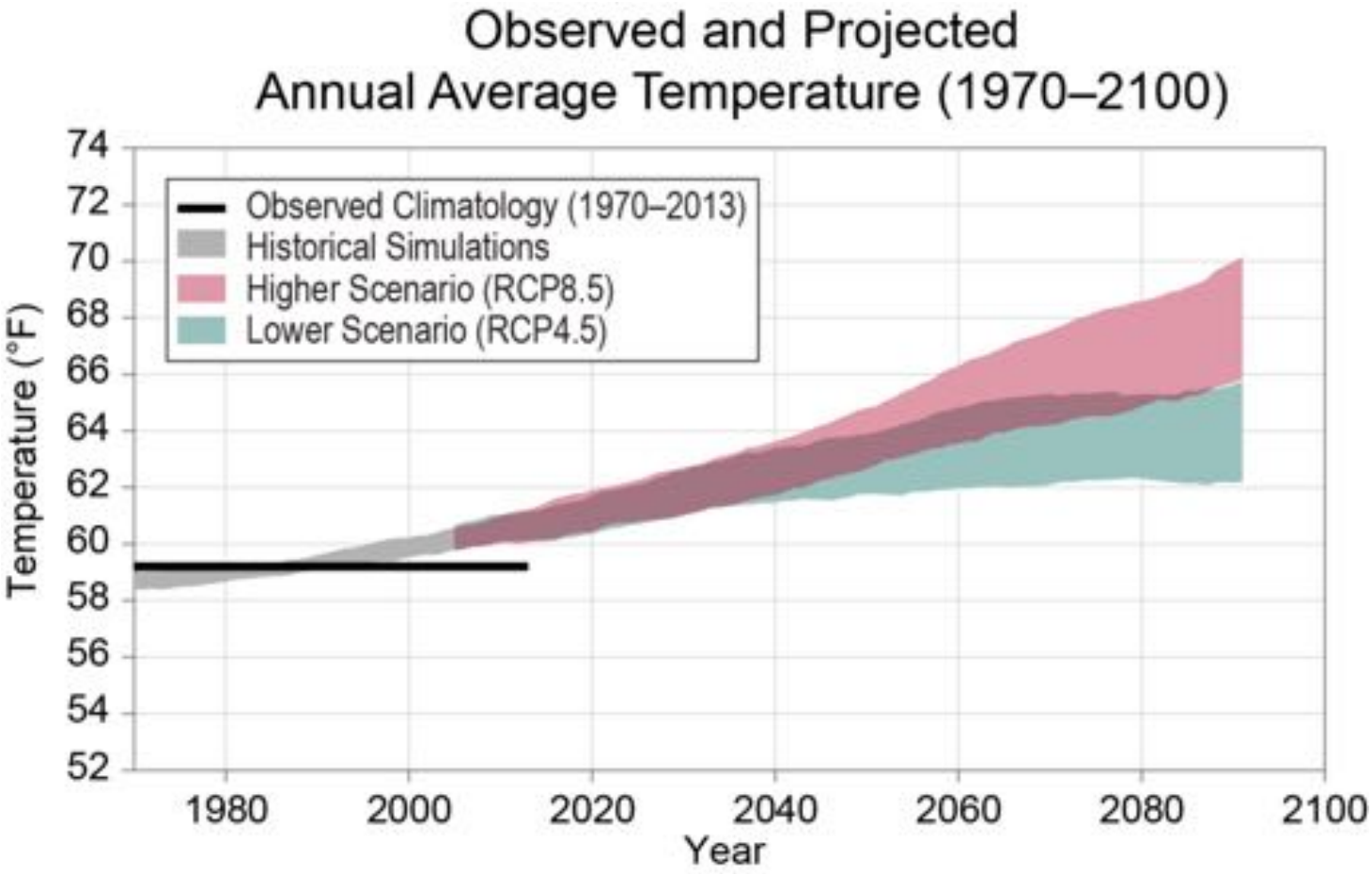
What's expected: more global warming

- Continued warming is "baked in": 1°F by 2100
- Large range due to unknown future emissions



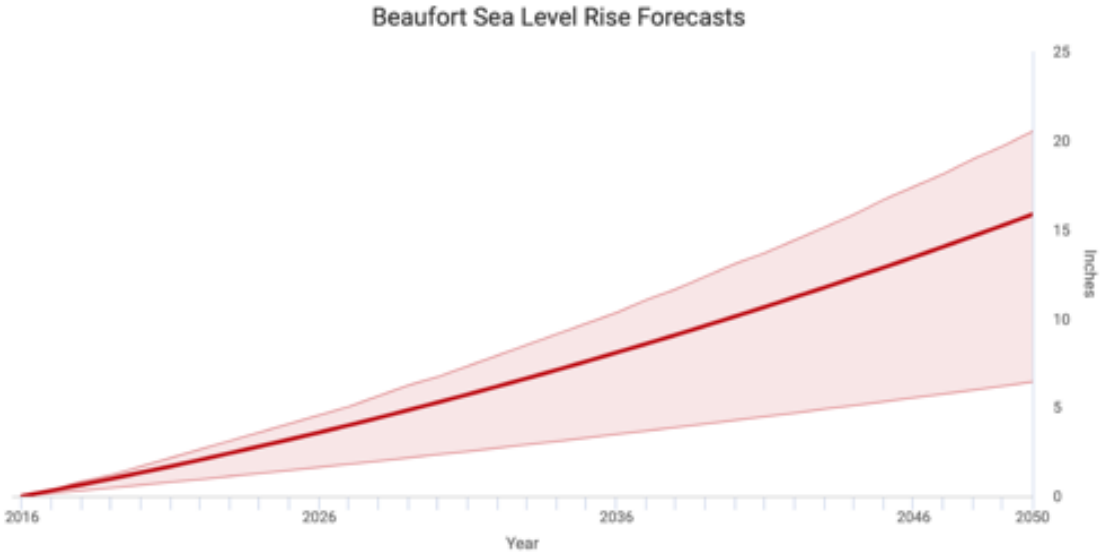
https://www.ipcc.ch/report/ar5/wg1/

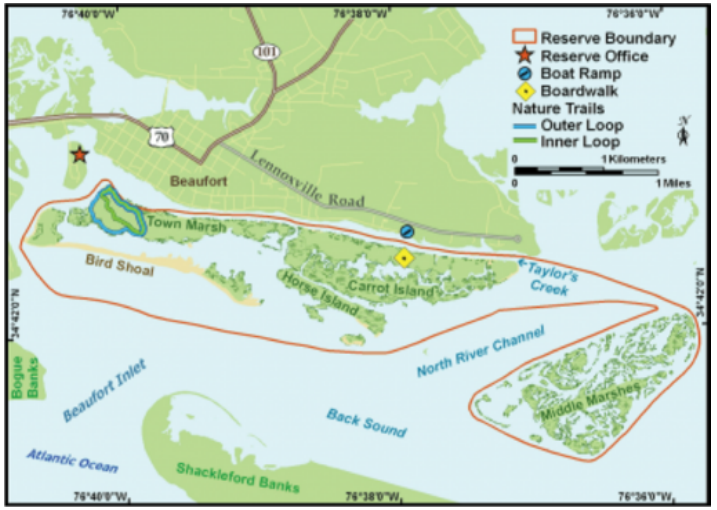
What's expected: NC



NCCSR

What's expected: NC sea level





https://sealevelrise.org/states/north-carolina/

Front St., Beaufort
November 2021

Impacts on nature

Digression: what is natural?

- NC never “pristine”
- Indigenous peoples here for ~12,000 years
  - Burned landscape to improve hunting & facilitate travel
  - Since 1,500 BP for cultivation (cf. Barden*)
- Implications for wildfire on unmanaged landscapes
  - With accelerated drying & prolonged drying season

*Barden, Lawrence S., 1997: Historic Prairies in the Piedmont of North and South Carolina, USA. *Natural Areas Journal*, **17**, 149-152

Species viability – 3 R's

- Representation

  breadth of genetic and environmental diversity within and among populations

- Resiliency

  ability to withstand stochastic disturbance; increases with population size, growth rate, & connectivity among populations

- Redundancy

  ability to withstand catastrophic events by spreading risk among multiple populations or across a large area

Smith *et al.* 2017

Climate change & the 3 R's

- Representation

  Reduced genetic diversity – subpopulations poorly adapted to new conditions removed

  Reduced environmental diversity as some habitats cross thresholds (temperature, etc.) of viability

- Resiliency

  More frequent & severe extreme events increase strengths of stochastic disturbances

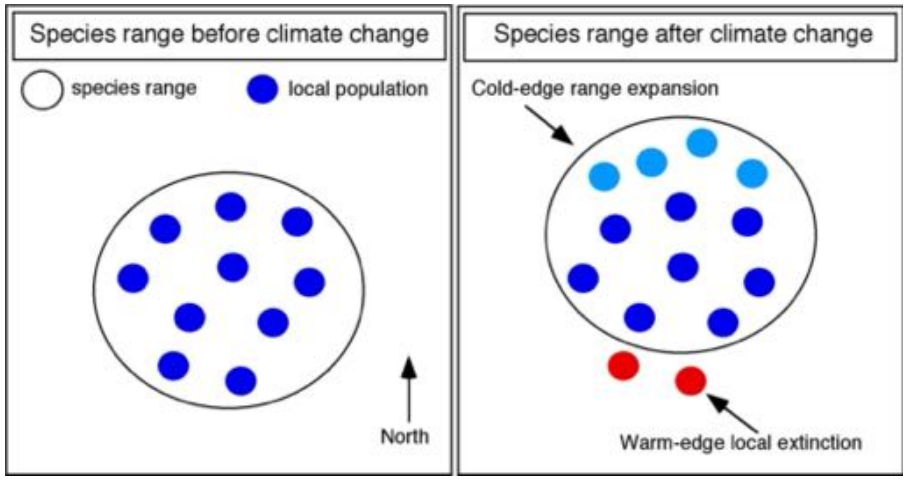
- Redundancy

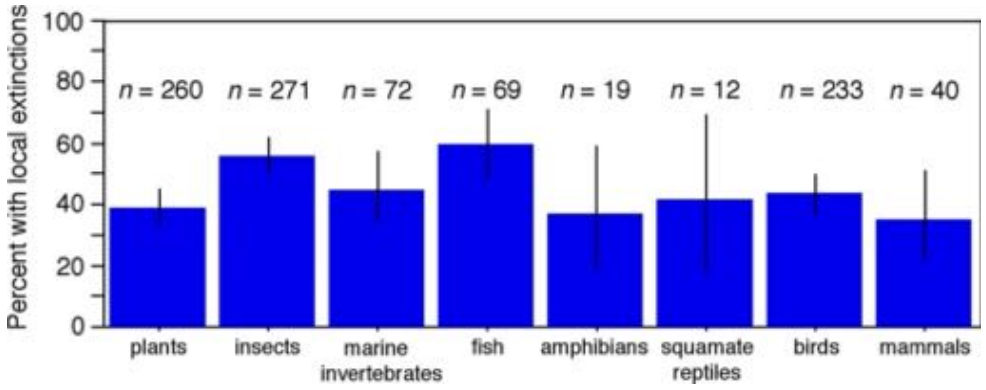
  Reduced, if range contracts

Exacerbated by other human influences: habitat destruction, introduction of invasive species, pollution, etc.


ANIMALS & PLANTS FLEEING CLIMATE CHANGE ARE MIGRATING TOWARD THE POLES AT 20 CM PER HOUR.
Dad, when will we get to Canada?
This is Canada.
©2011 S. McMILLAN

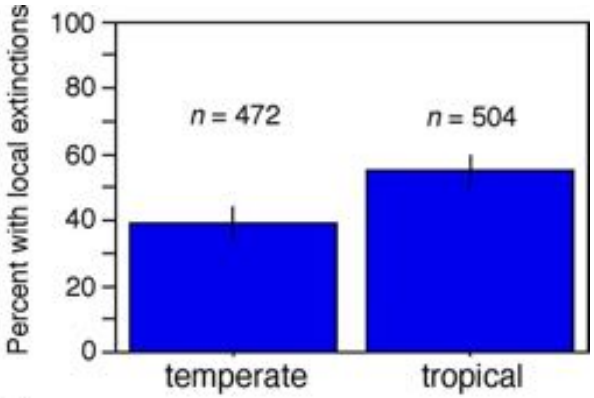
Range shifts & local extinctions reduce redundancy

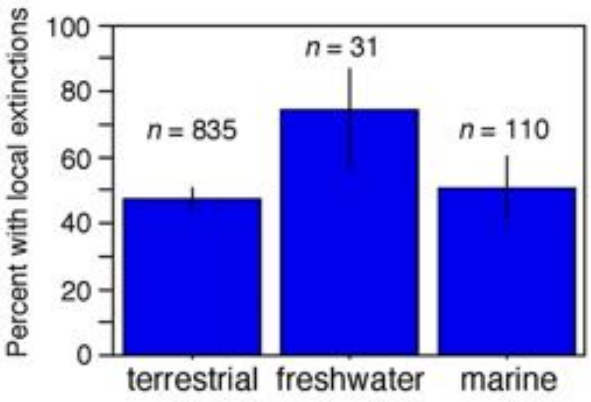


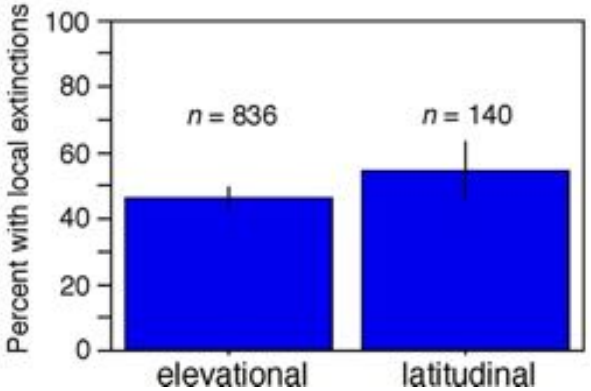


Climate-Related Local Extinctions Are Already Widespread among Plant and Animal Species

Wiens, 2016

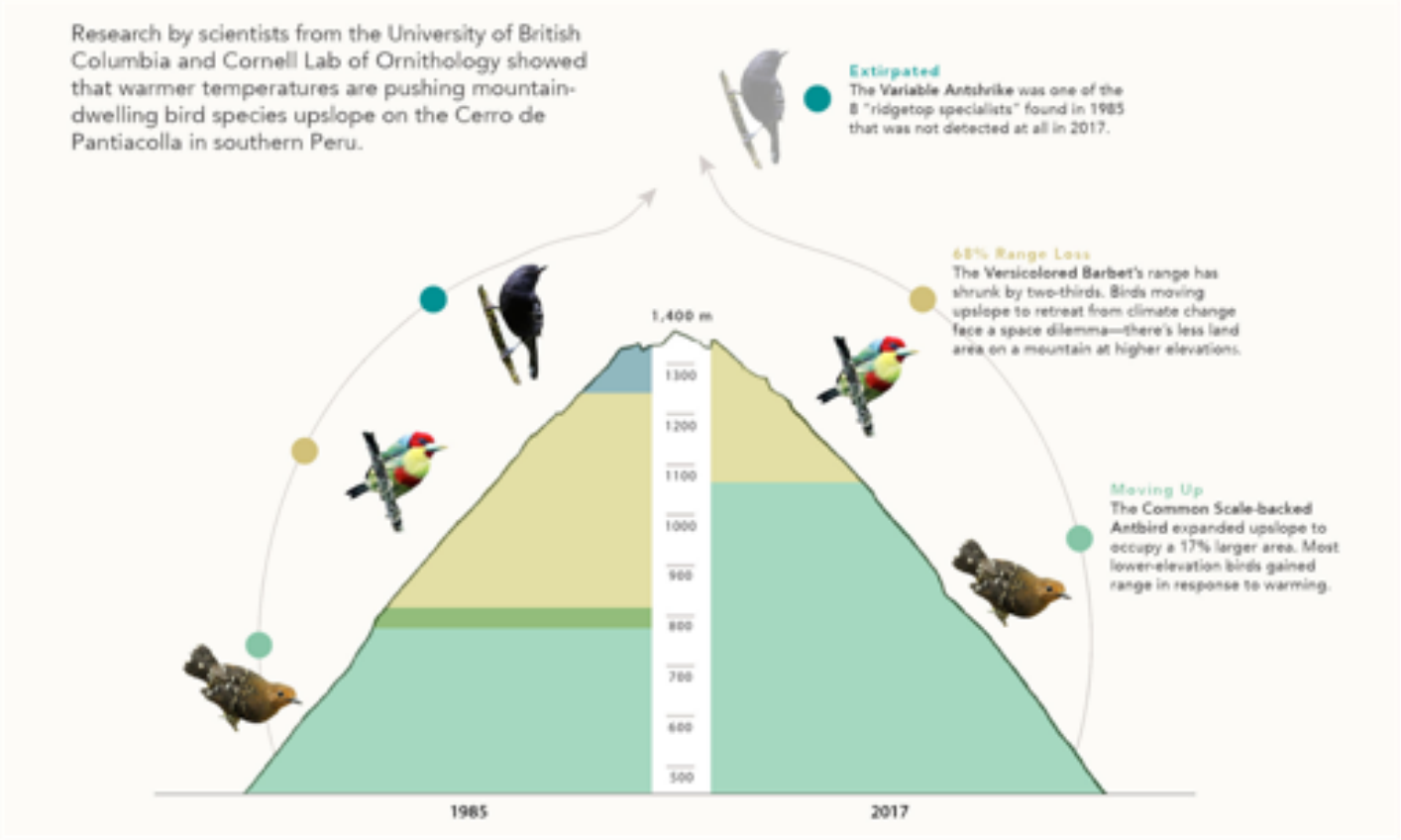






Range expansion may be blocked

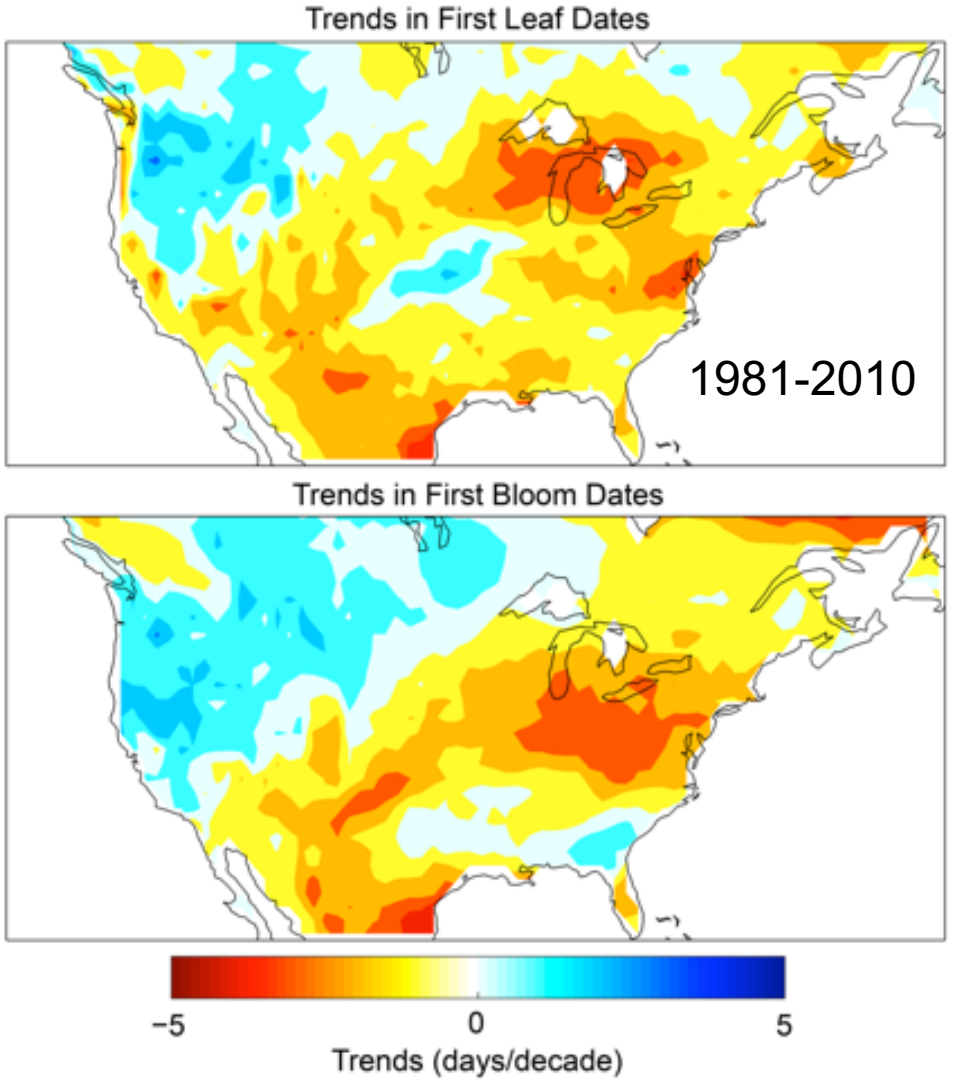
- "Escalator to extinction"



Development & agriculture can block northward & upward range expansions

Phenology

- Advance of spring
- But “rate of phenological change varies across trophic levels”
- Migratory species at risk if they arrive at the “wrong” time

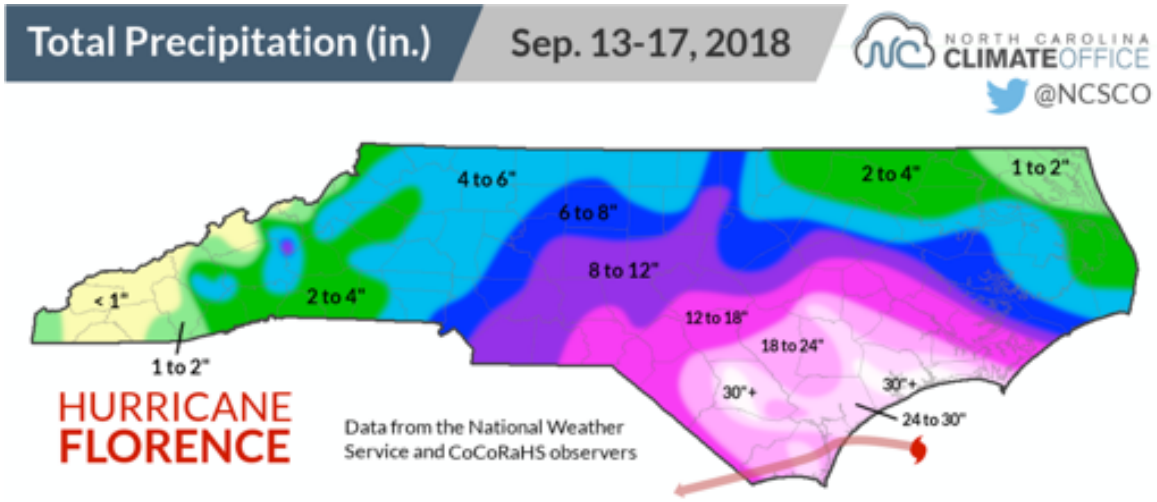


NCA

Extremes (disturbances) increase with climate change

- New temperature extremes
- New hydrologic extremes (wet & dry)

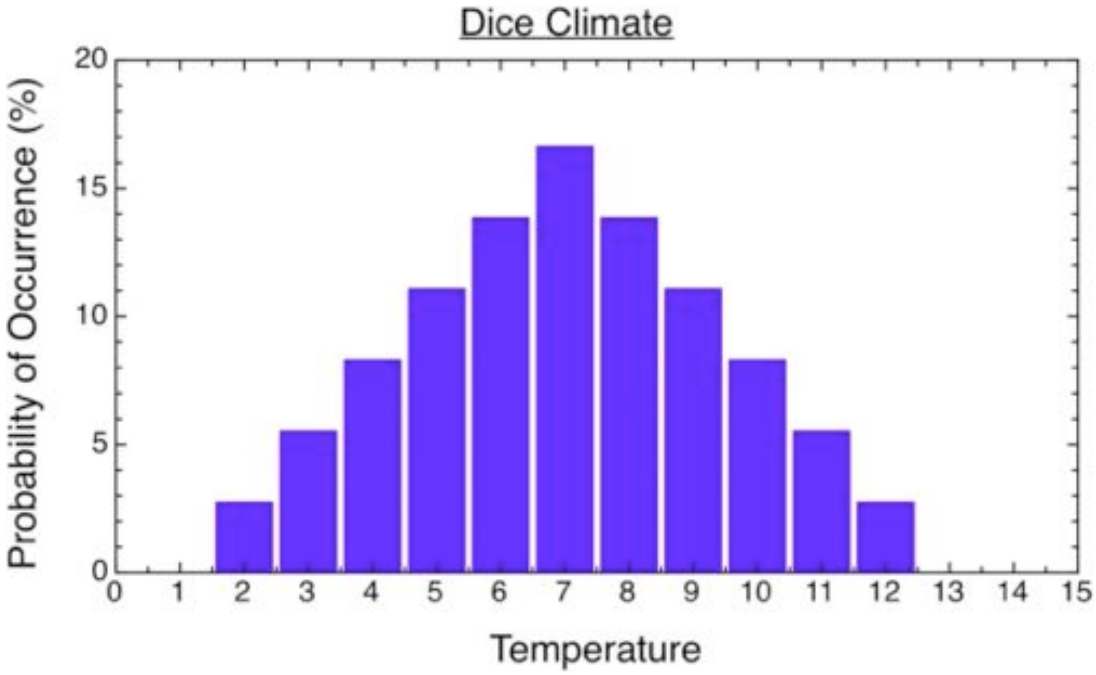
These changes arise from fundamental statistics & physics



Dice metaphor

- Think of the weather on a day as a roll of dice
- Dice “weather”: the number from a single roll
- Dice “climate”: the statistics accumulated over many rolls
  – Average roll = 7

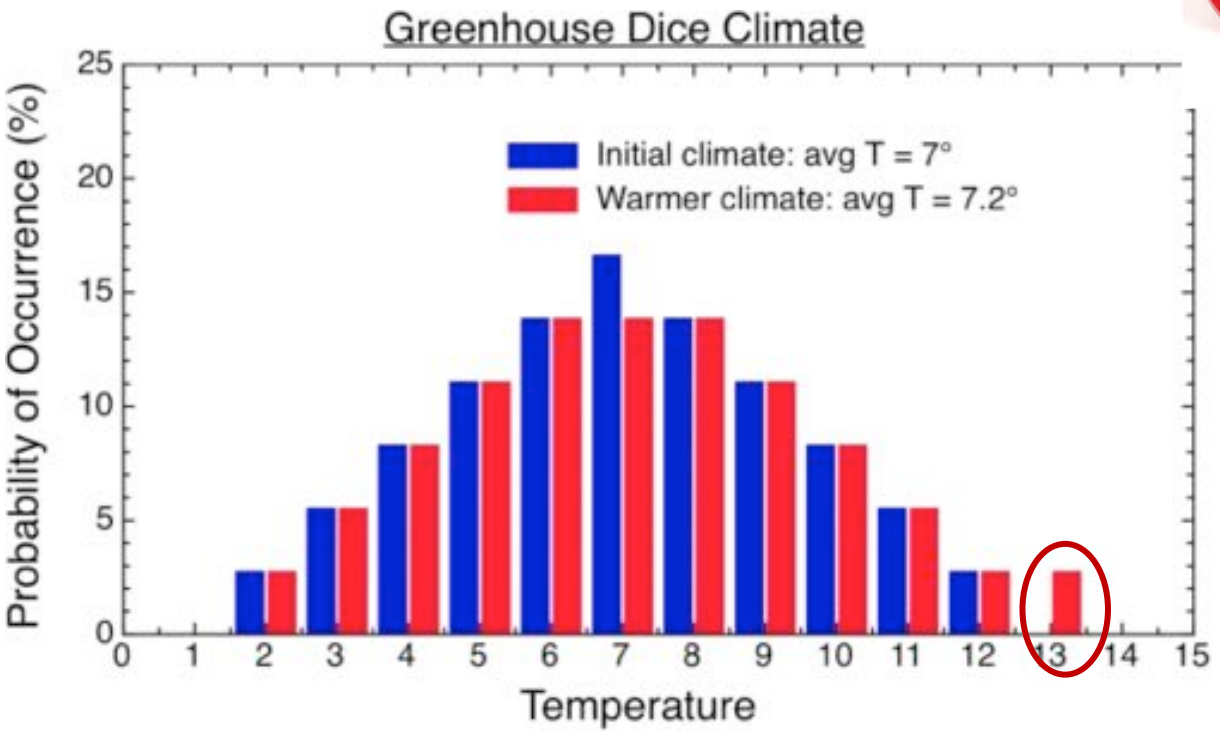
Chances of rolls:



Greenhouse dice

(Courtesy Jim Hansen)

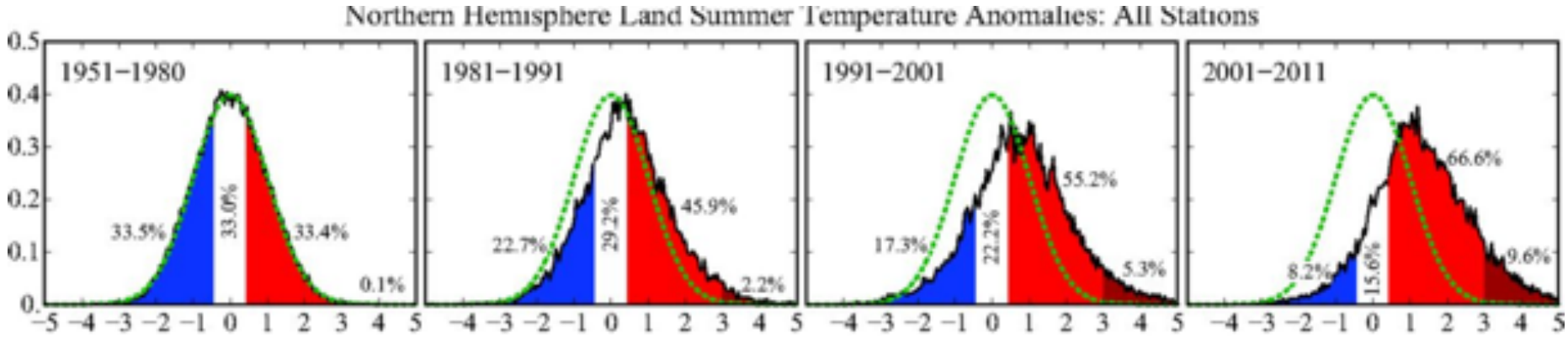
- "Greenhouse dice": add a dot to the 6 on one die
- Average climate changes a little (7 to 7.17)
- *But …* 13s!



Real-world greenhouse dice

Northern Hemisphere summer temperatures (land stations)

- Once a century (or rarer) summer heat now once a decade



Hansen *et al.* 2013

13s

- As Earth heats up, hottest temperatures, heaviest rains, driest droughts worse than we've ever seen
- *Happening now*

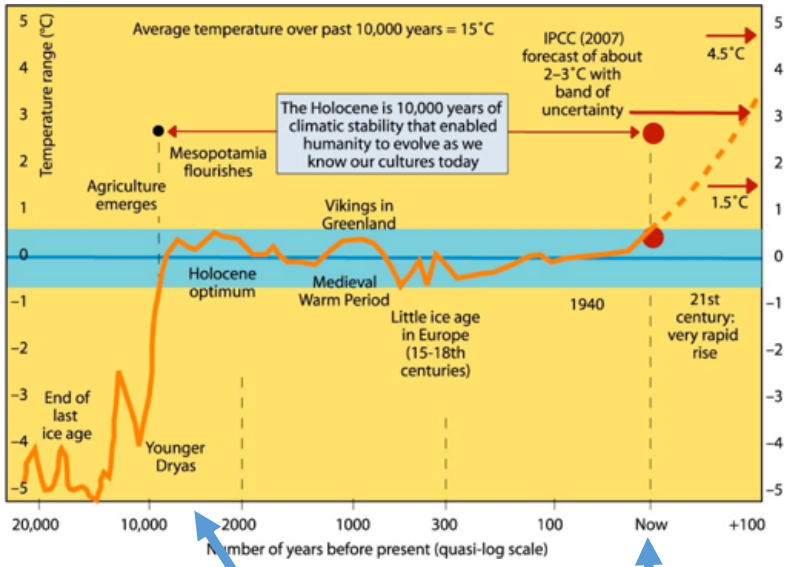
2021 Pacific NW heatwave

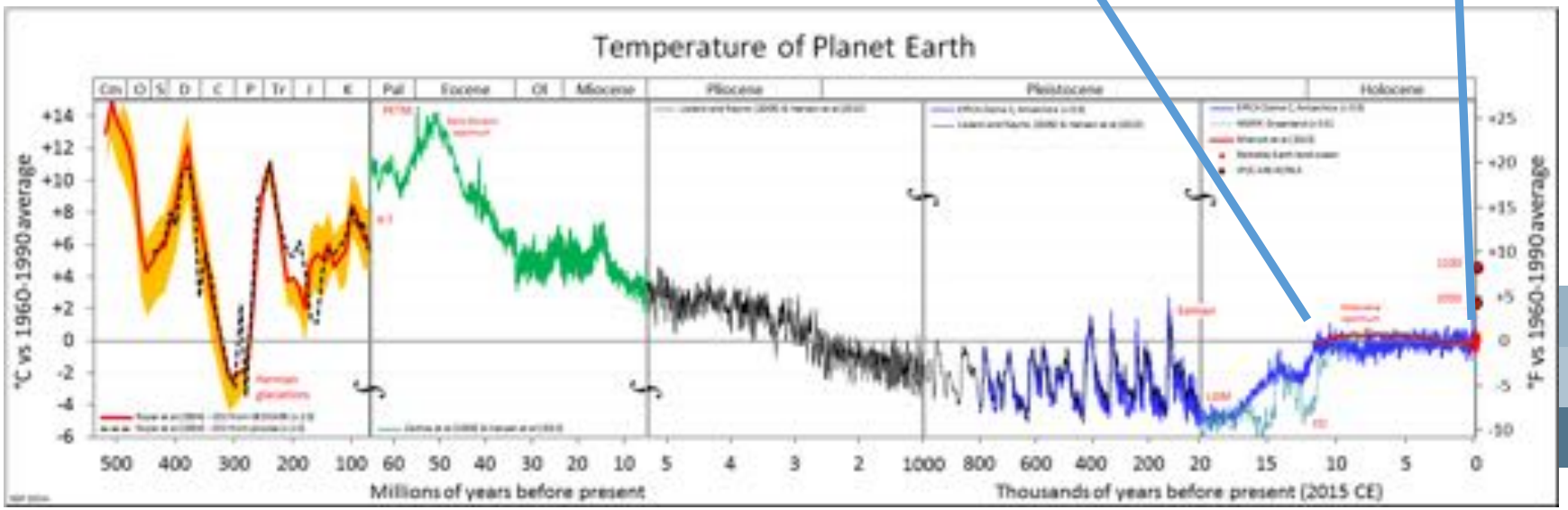
British Columbia mudslides – 11/14/2021

Pilot Mtn NC fire – 11/29/2021

Climate variations over Earth history

- Today's ecosystems developed during 10,000 years of stable climate
- *Not ready for 13s*





Hydrologic extremes

Water saturation vapor pressure rises exponentially with temperature

- nearly 7% for 1 °C warming

What does this mean?

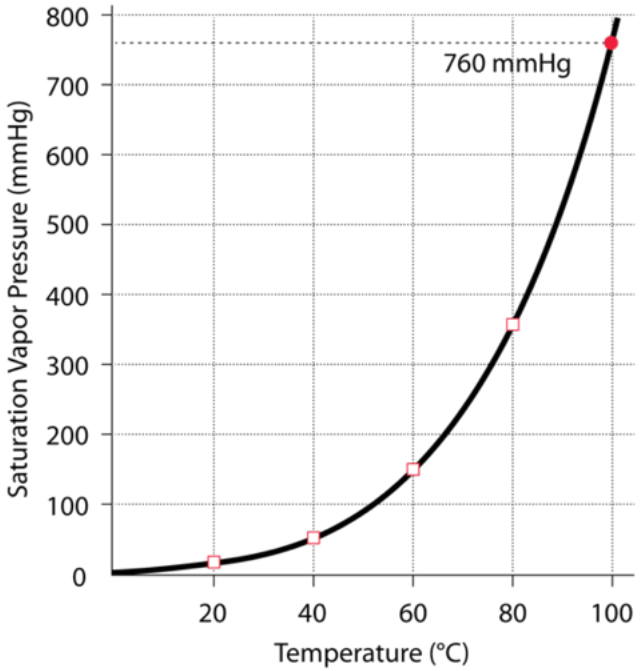
- Air "holds" more water vapor at higher temperatures

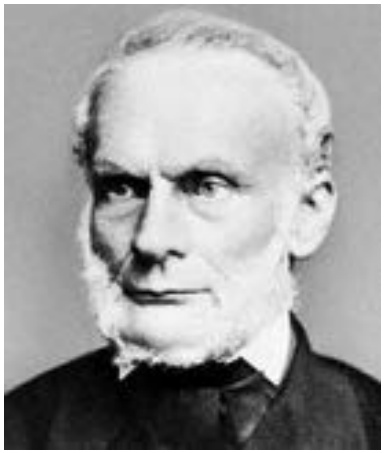
  Heavier rains

- Air "demands" more water at higher temperature

  Increased potential evapotranspiration

  Faster, more intense drought



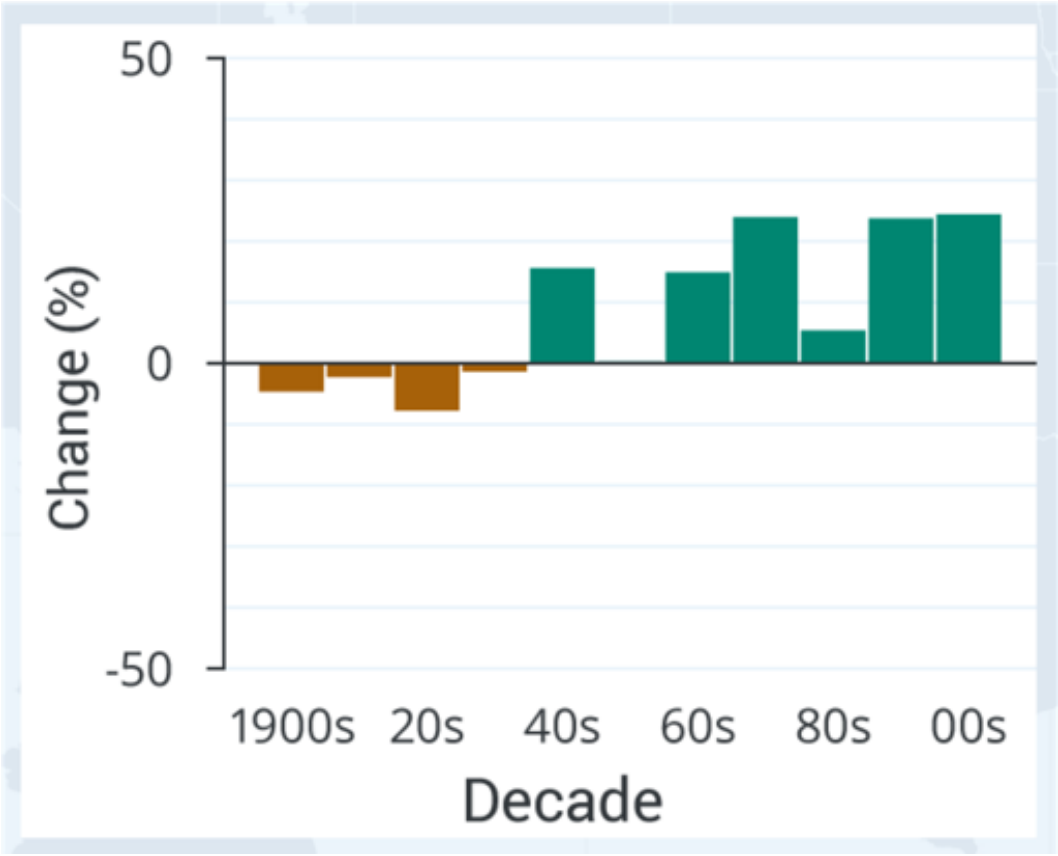


Rudolf Clausius
1822-1888

Benoit Clapeyron
1799-1864

More intense rain - observed

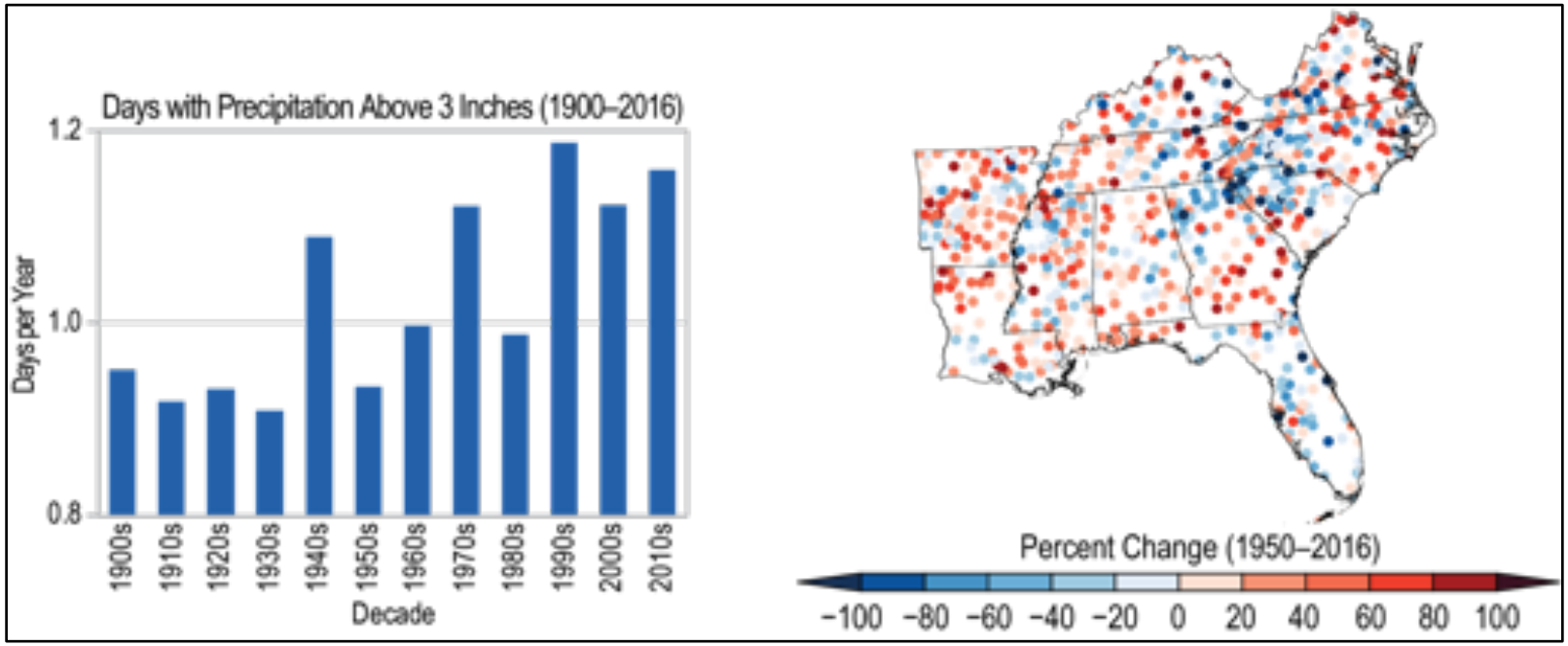
US Southeast – change (%) in amount of rain in top 1% of rain events



https://nca2014.globalchange.gov/

More frequent heavy rain

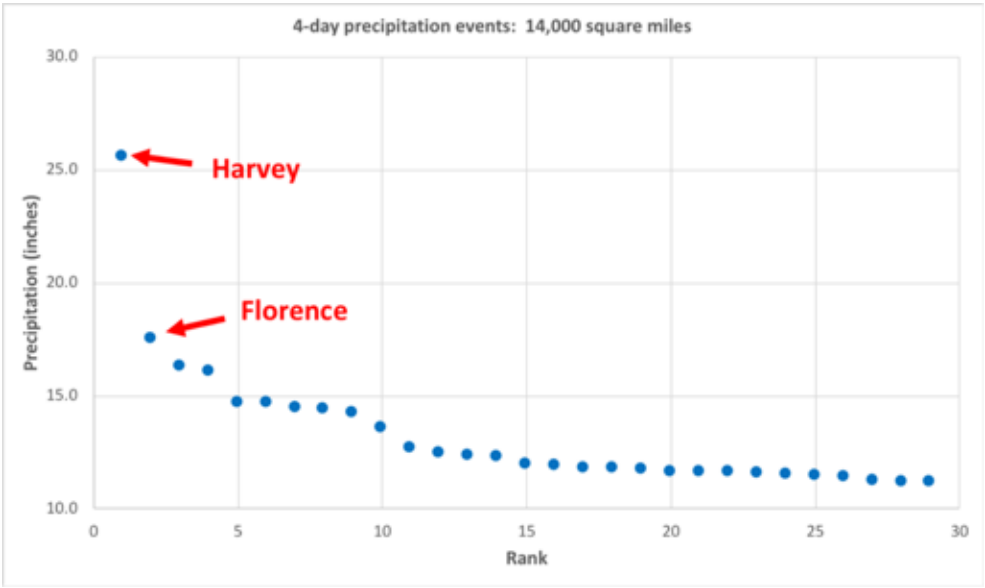
US Southeast – days with rain above 3”



More 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



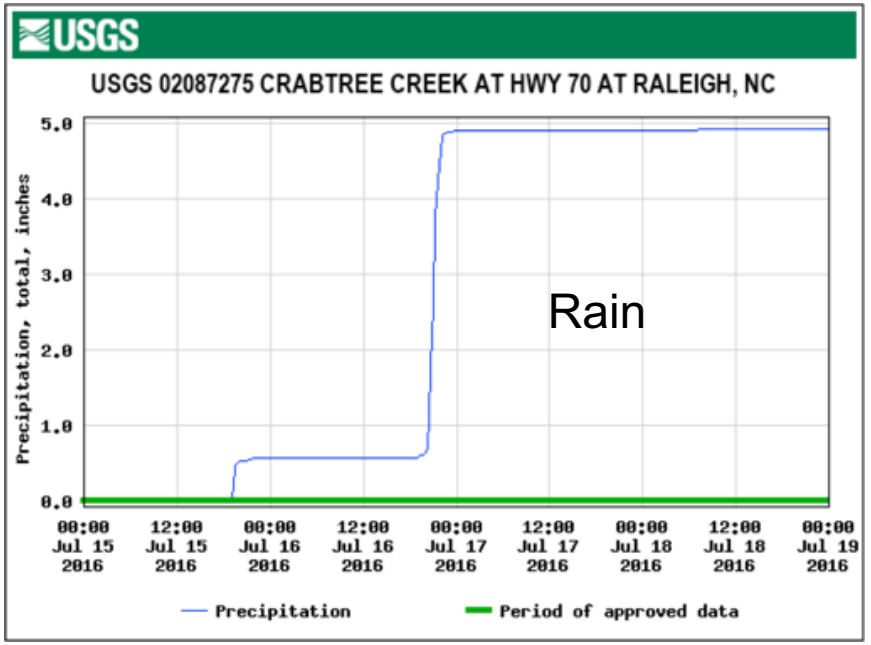
- Flooding events threaten aquatic/riparian species
  - – Scouring; bank failure & erosion
  - – Periods of high turbidity
  - – Pollutants flushed into streams & rivers (hog waste)
- Intervening low-flow periods also more intense

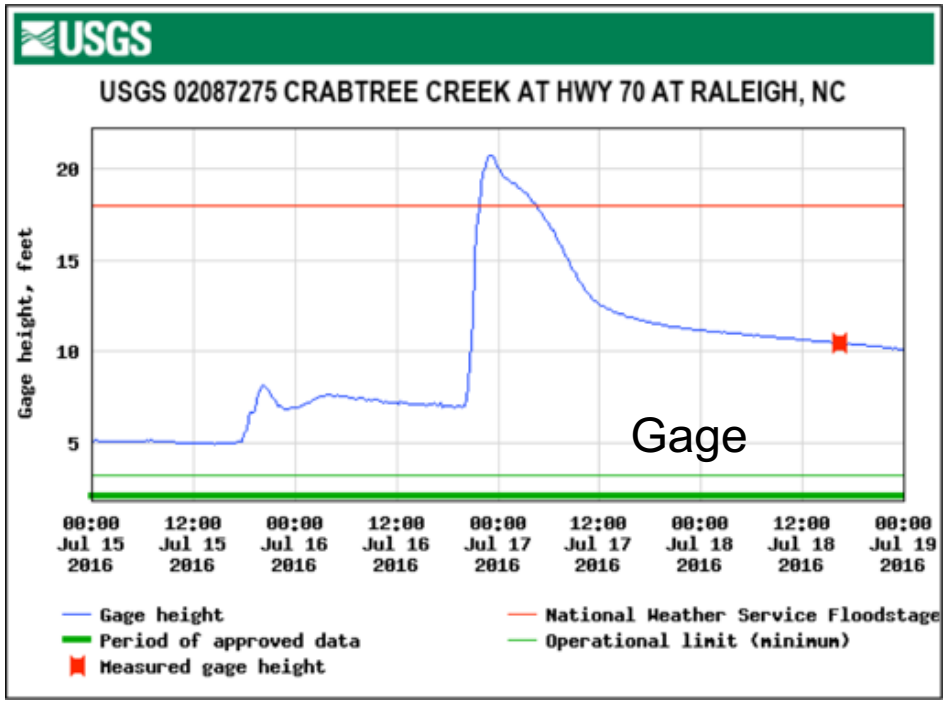
https://ncics.org/cics-news/putting-hurricane-florence-into-historical-perspective/

“Everyday” cloudbursts are bigger

July 2016 Raleigh rainstorm

- Unexceptional summer storm
- Crabtree Creek rose 14’ in minutes
- 12X increase in discharge

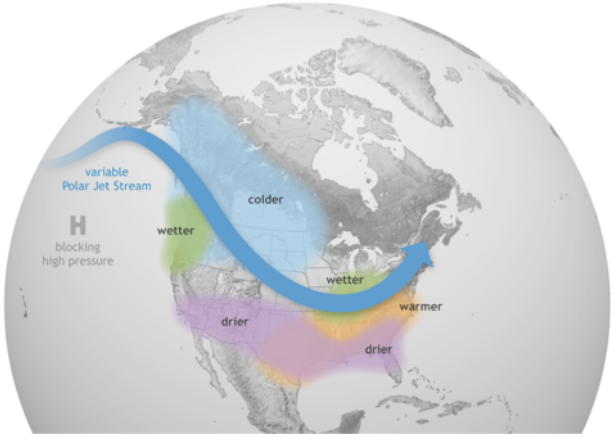




- Developed watershed
- Scouring
- Damage to greenway

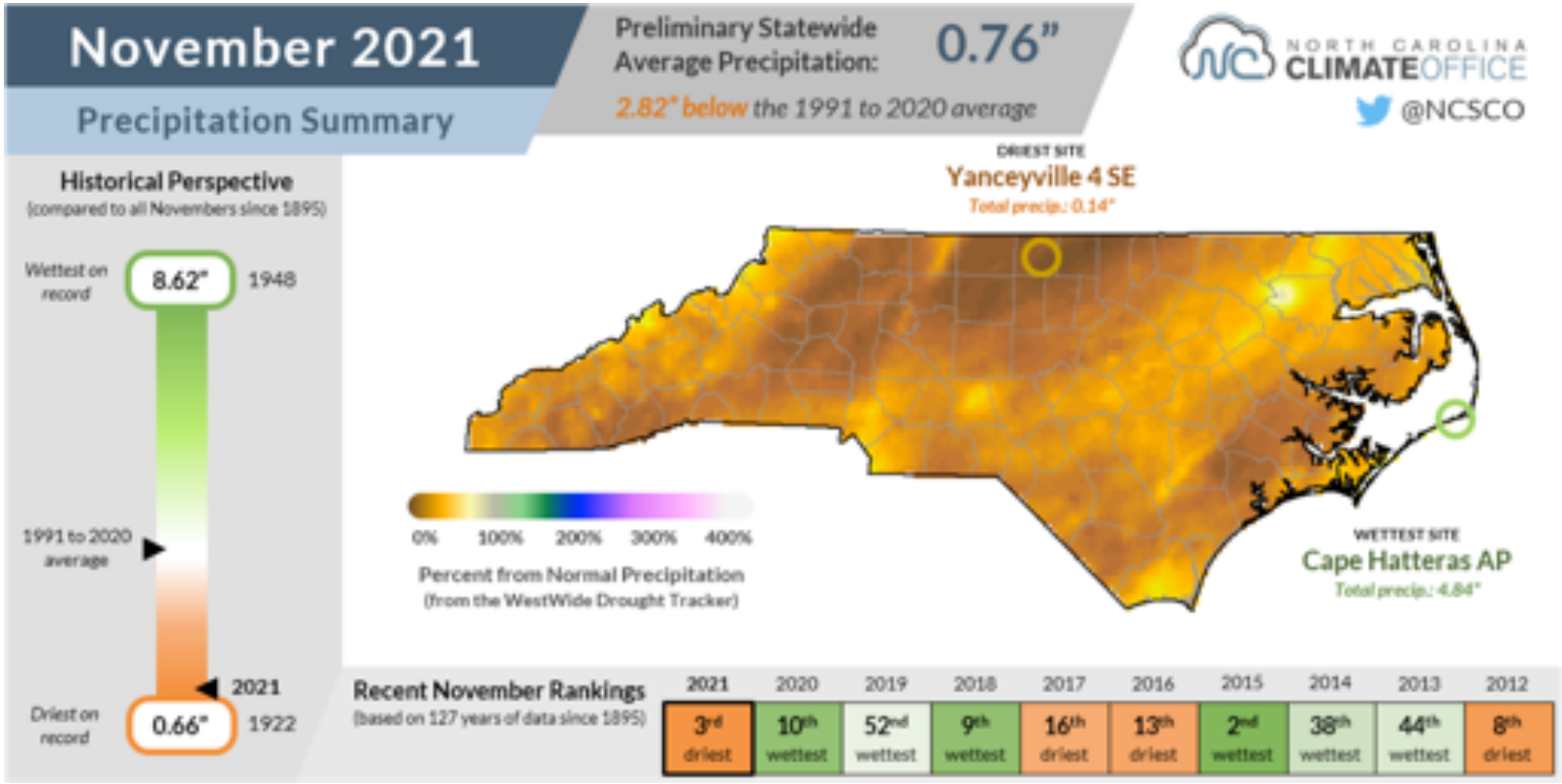
  Floodplain greenways are not sustainable under climate change

Dry November (la niña)

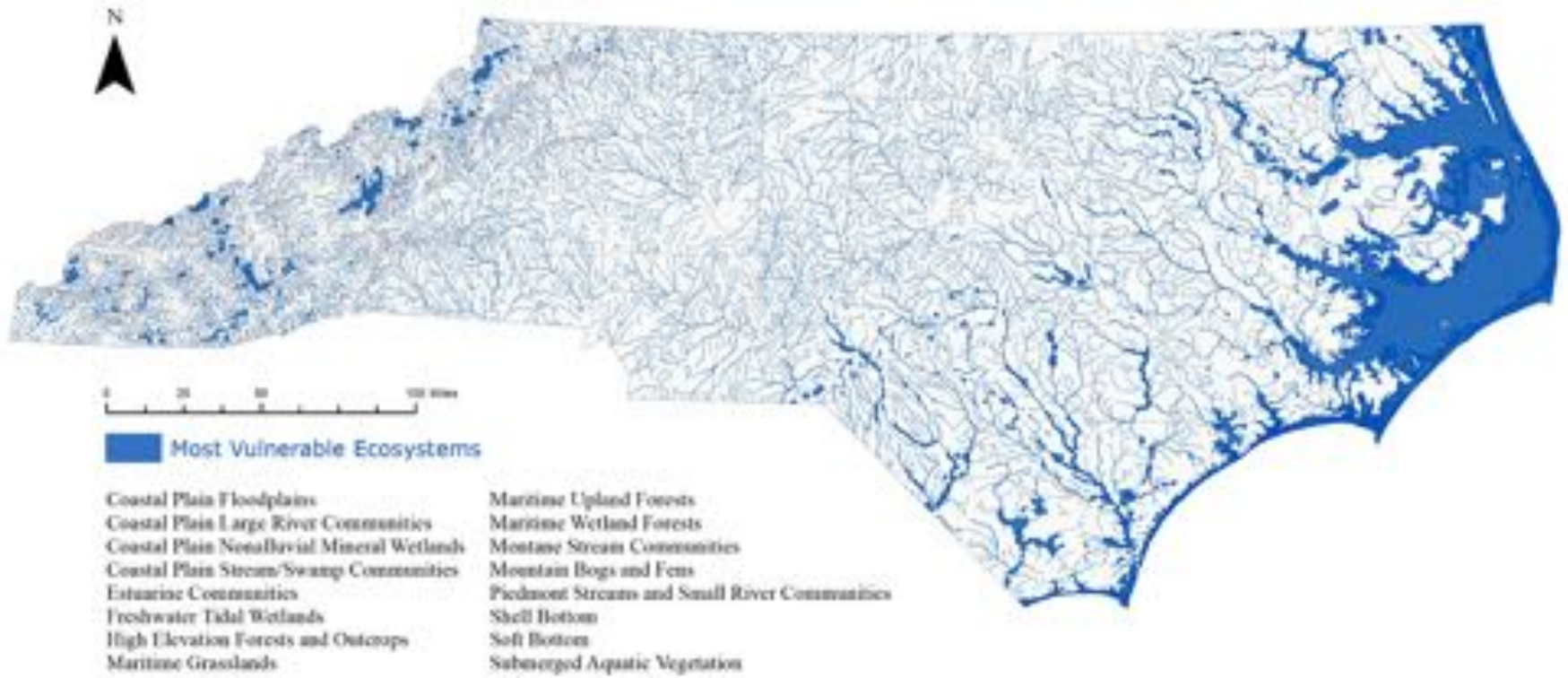


- Warming amplifies drying during droughts

  Increases fire danger



Vulnerable NC ecosystems



NCCRARP

Ecosystems at risk

Most impacts are from extreme events

Most Vulnerable Ecosystem Types	Change in Seasons	Coastal Erosion	Dam Failure	Extreme Heat	Flooding	Inundation due to Sea Level Rise	Landslides	Saltwater Intrusion	Severe Winter Weather	Storm Surge	Tidal Flooding	Water Shortage due to Drought	Wildfire	Wind
Coastal Plain Floodplains	*		*		*			*	*	*	*			*
Coastal Plain Large River Communities				*	*			*		*	*	*		
Coastal Plain Nonalluvial Mineral Wetlands								*		*	*		*	
Coastal Plain Stream/Swamp Communities			*	*	*			*		*	*	*		
Estuarine Communities	*	*				*		*		*	*			
Freshwater Tidal Wetlands	*	*				*		*		*	*			
High Elevation Forests and Outcrops	*			*					*			*	*	*
Maritime Grasslands	*	*		*		*		*		*	*	*		
Maritime Upland Forests		*								*	*			*
Maritime Wetland Forests		*				*		*		*	*			*
Mountain Streams	*		*	*	*		*					*	*	
Mountain Bogs and Fens	*			*	*							*		
Piedmont Streams and Small Rivers			*	*	*							*		
Shell Bottom (estuarine)	*					*		*		*	*			
Soft Bottom (estuarine)	*					*		*		*	*			
Submerged Aquatic Vegetation (Seagrass)	*					*		*		*	*			

NCCRARP

Nature as a solution

North Carolina Natural & Working Lands Action Plan

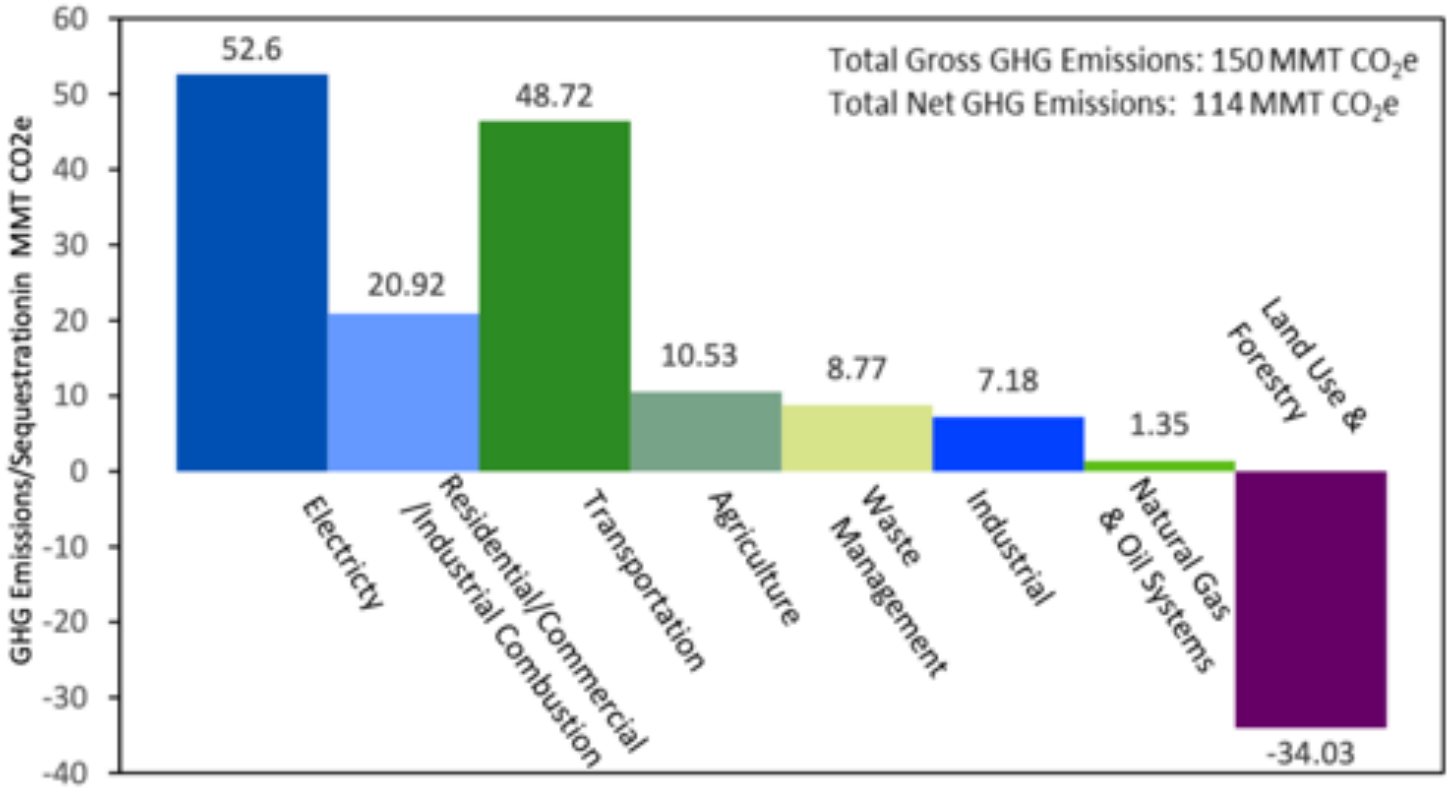
NC matters!

- NC annual emissions: 150 Mt CO_2e
  https://deq.nc.gov/energy-climate/climate-change/greenhouse-gas-inventory
- Global annual emissions: 36.6 Gt CO_2e
  https://www.globalcarbonproject.org/carbonbudget/19/highlights.htm

NC produces 1 part in 244 of global emissions

- With 1 in 738 of Earth's people

NC greenhouse gas emissions

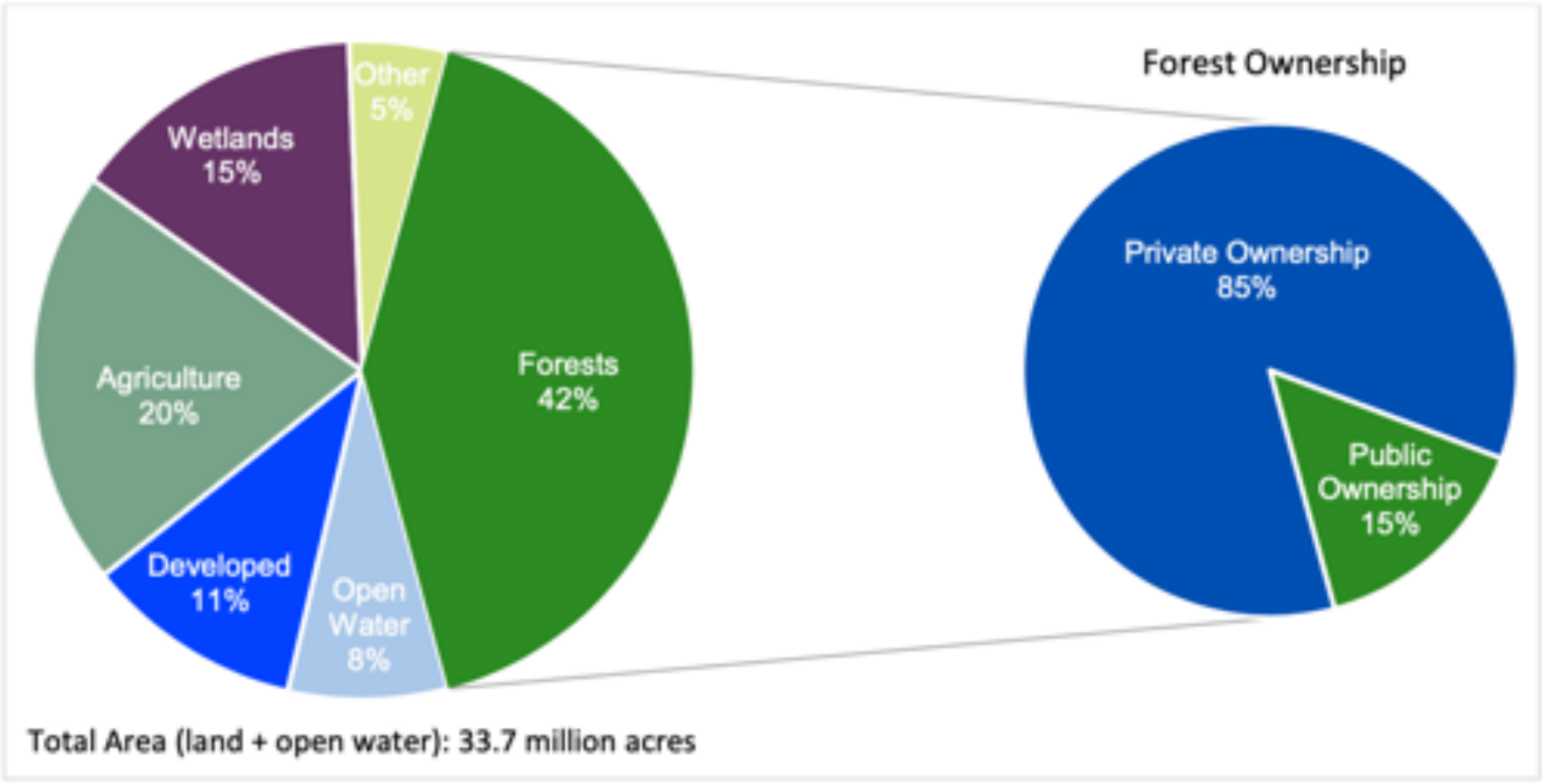


Land already mitigates 23% of NC emissions

NWL Action Plan

NC: land of (mitigation) opportunity

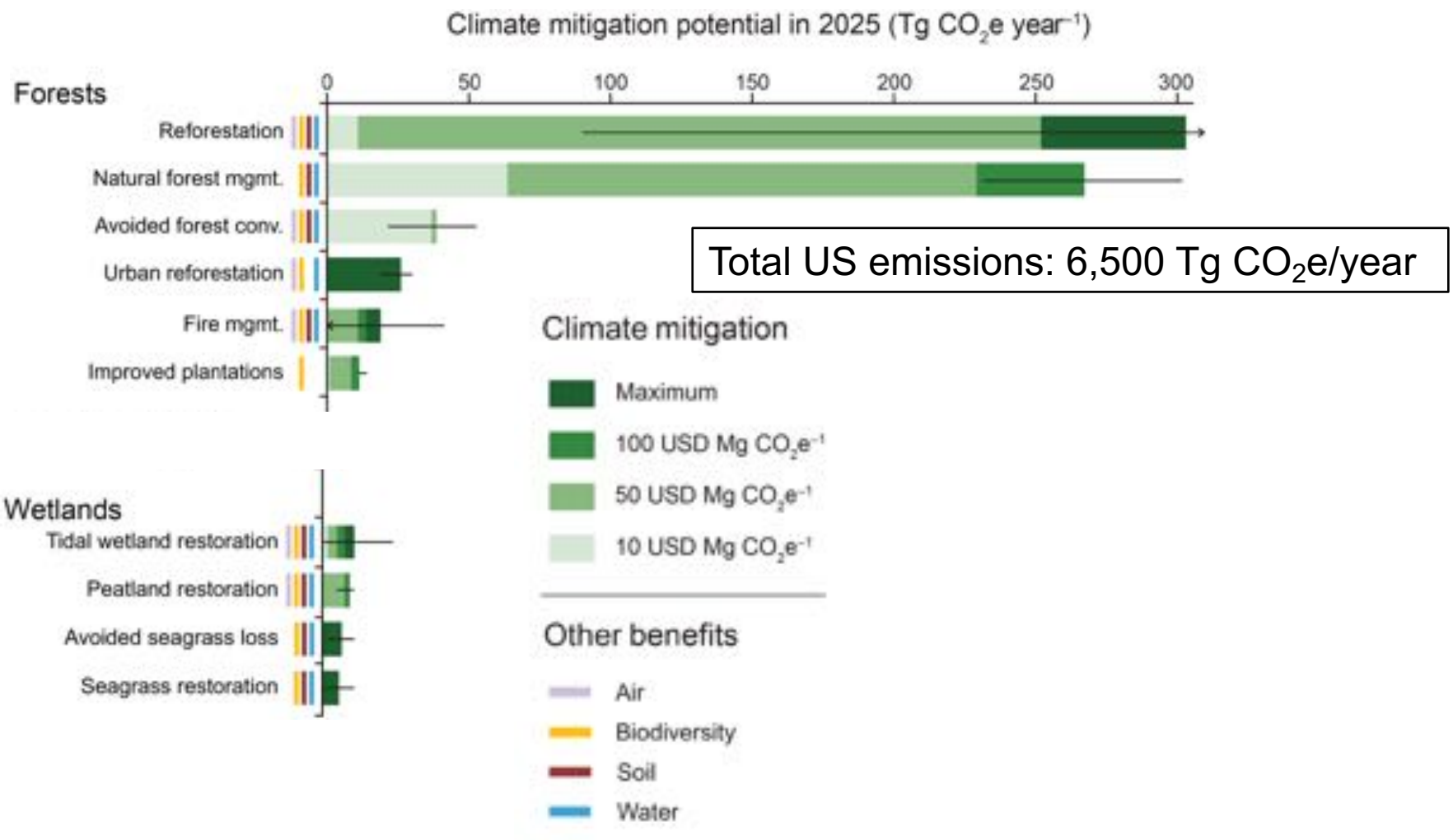
Figure 2-1: North Carolina Land Cover Types by Area in 2016



Plenty of undeveloped land, mostly private
=> mitigation must be incentivized

NWL Action Plan

US natural climate solutions

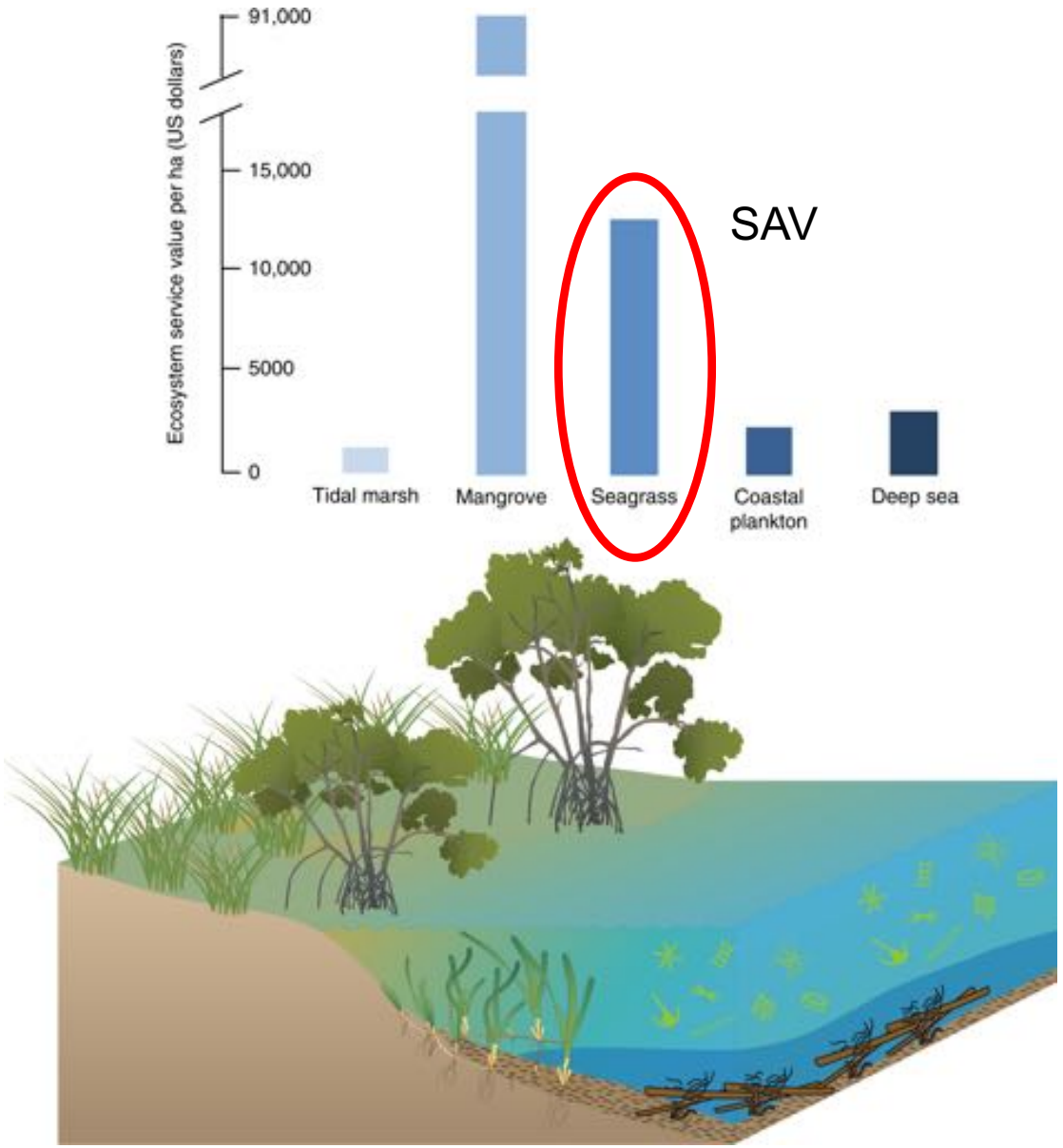


Total US emissions: 6,500 Tg CO_2e/year

https://advances.sciencemag.org/content/4/11/eaat1869

Growing interest in “blue” carbon

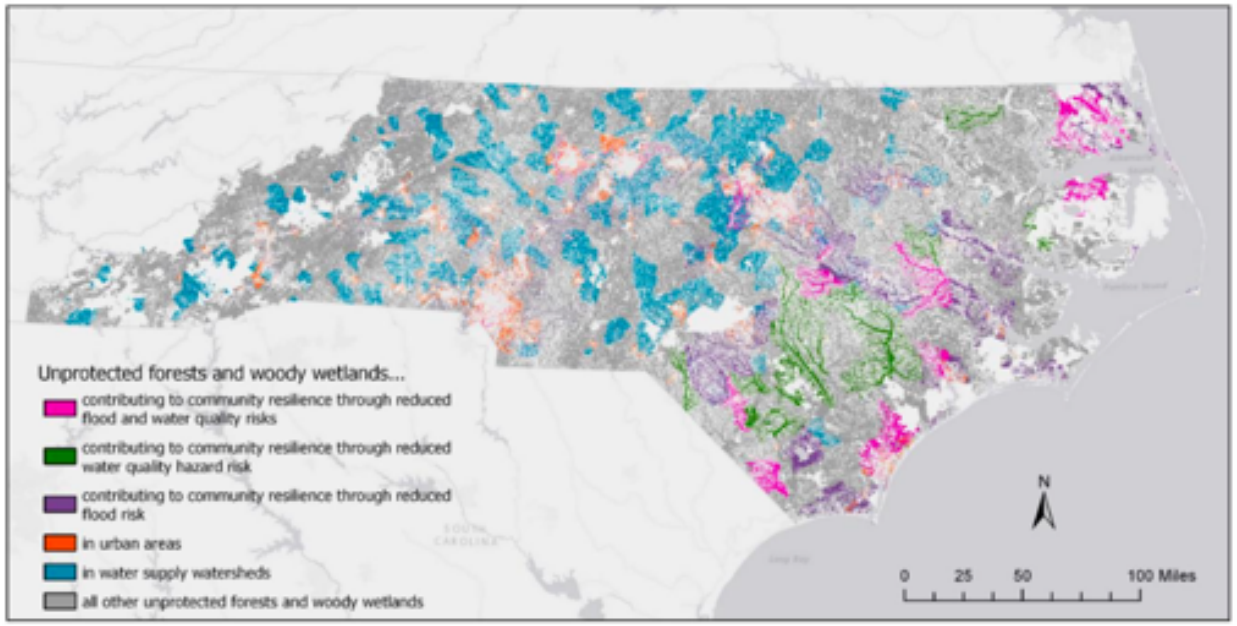
- C captured & stored by coastal ecosystems
- Now included in US green-house gas inventories

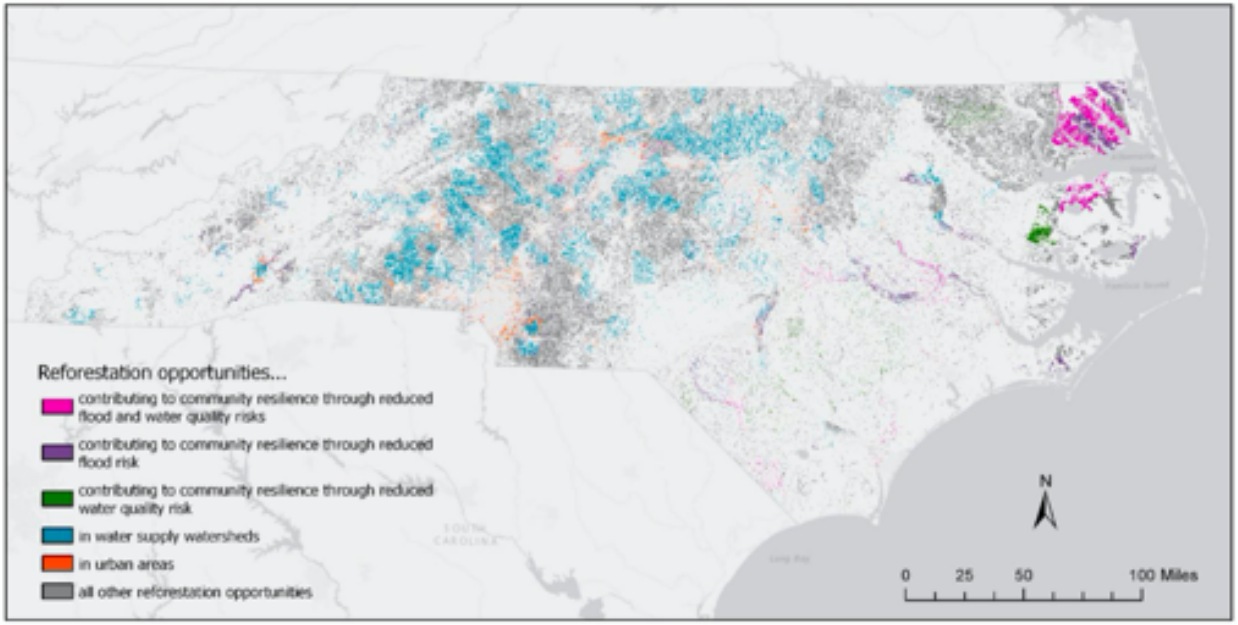


https://www.nature.com/articles/s41467-019-11693-w

Forest C sequestration: collateral benefits

Protection of extant forests





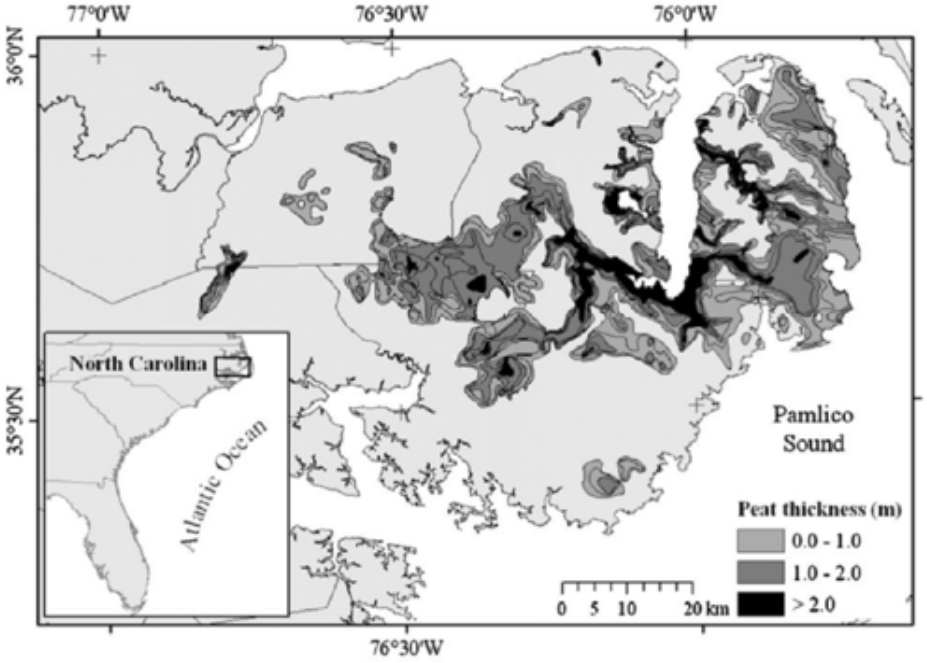
Possible reforestation

NWL Action Plan

Pocosins

- Peatland pocosins sequester C
- Accreting – keeping up with rising sea level
- Threatened by salt-water intrusion

Peat depth (m)



Degraded pocosins can (will) burn

- Release copious amounts of stored C

2008 Evans Road fire in Pocosin Lakes NWR

Double edged sword

- Ecosystems with potential to mitigate emissions become sources when mismanaged or abused

NC clear cut

https://cleanaircarolina.org/2019/06/our-clear-cut-problem/

Wrapping up

Global warming is …

- expected from basic physics
- happening as expected

NC nature is vulnerable to climate change

- Mostly from extremes: heat, drought, floods …

Natural systems must be part of the solution

- NC is rich in such opportunities
- *Thriving* ecosystems store Carbon

  & bring collateral benefits,

  but they can be squandered

Questions/Conversation?

https://indyweek.com/news/wake/neuse-river-waterdog-under-threat-from-development/