The Climate of the Carolinas: Past, Present, and Future

- Results from the National Climate Assessment

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The Southeast National Climate Assessment (SE NCA)

- Carried out through the US Global Change Research Program (USGCRP) and required with the implementation of the Global Change Research Act 1990
- Most comprehensive look to date at the effects of climate change on the Southeastern US.
- More than 100 contributors across the region
- Publication of "*Climate of the Southeast United States: Variability, Change, Impacts, and Vulnerability*" by Island Press
  http://www.sercc.com/ClimateoftheSoutheastUnitedStates.pdf

Describe the latest in climate science through an examination of weather and climate extremes and their impacts:

1. Geographic pattern of occurrence across the region.

2. Variability and trends over last 50-100 yrs.

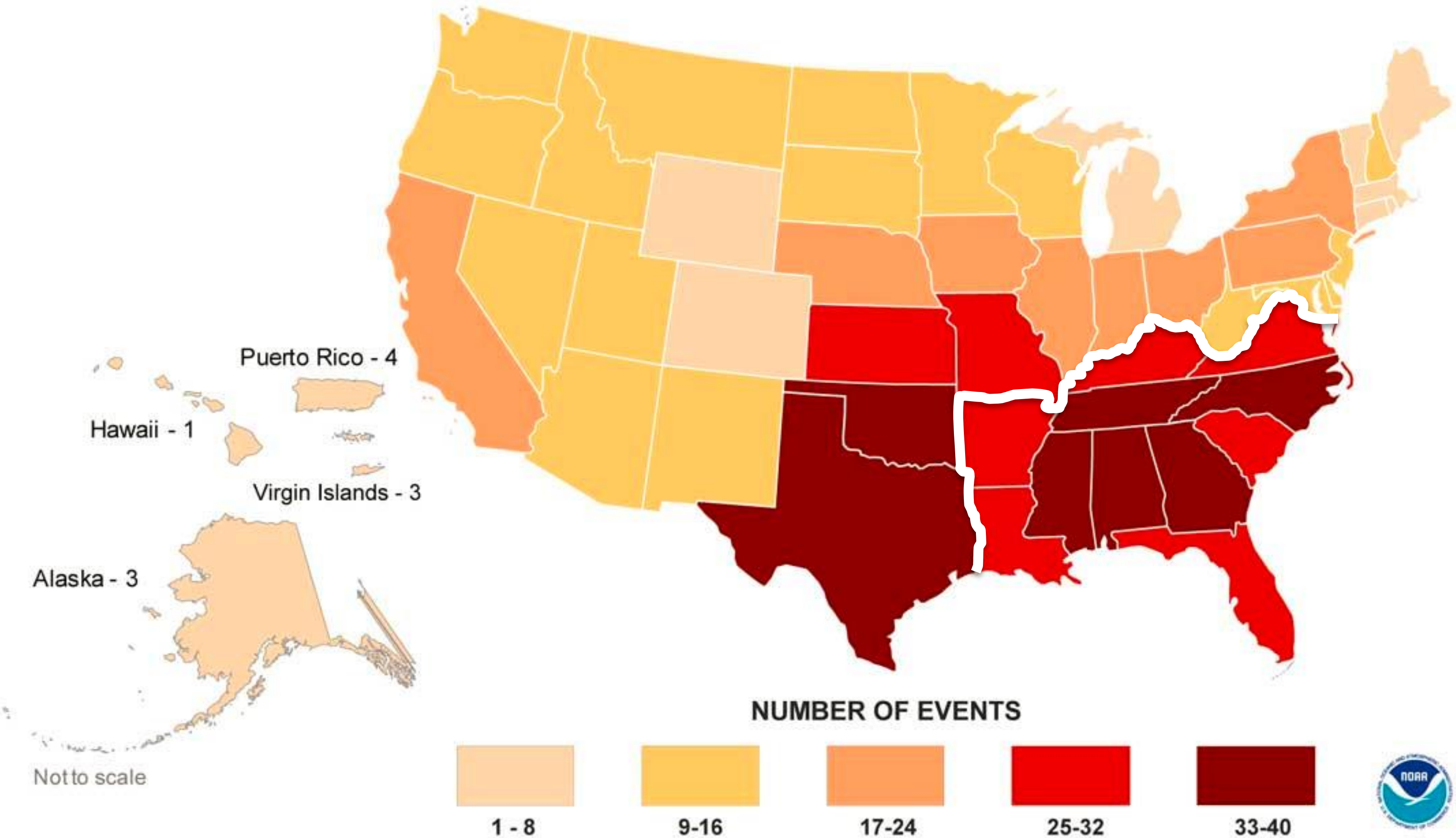
3. Future projections and uncertainties

Weather and climate extremes plus sea level rise

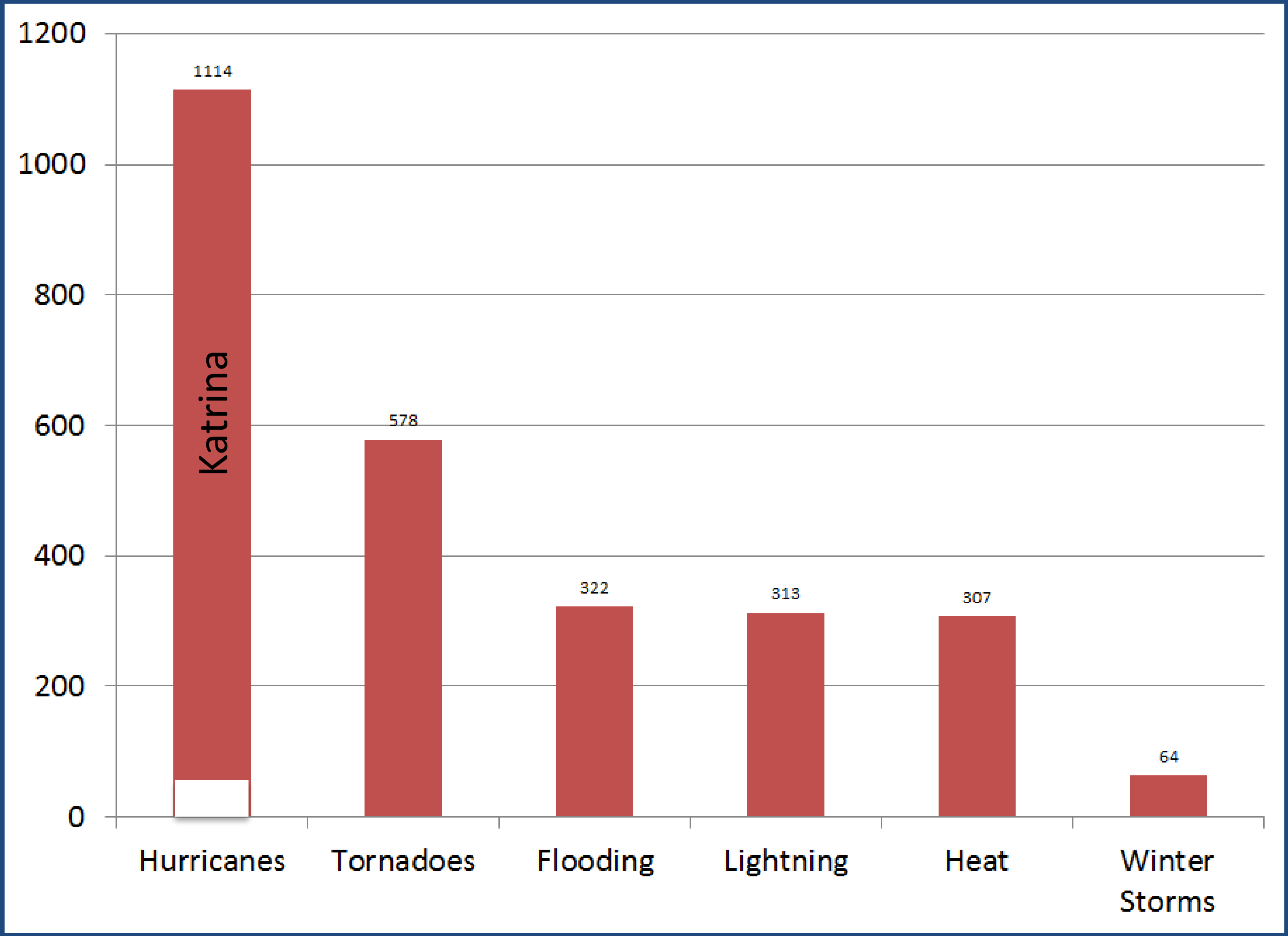
1. Heavy Rain/Flooding
2. Droughts
3. Heat waves
4. Cold Outbreaks
5. Hurricanes
6. Tornadoes/Thunderstorms
7. Sea level rise

Billion Dollar Weather/Climate Disasters

1980 - August 2011



Fatalities Due to Extreme Events in the Southeast (1995-2010)



Source: National Weather Service

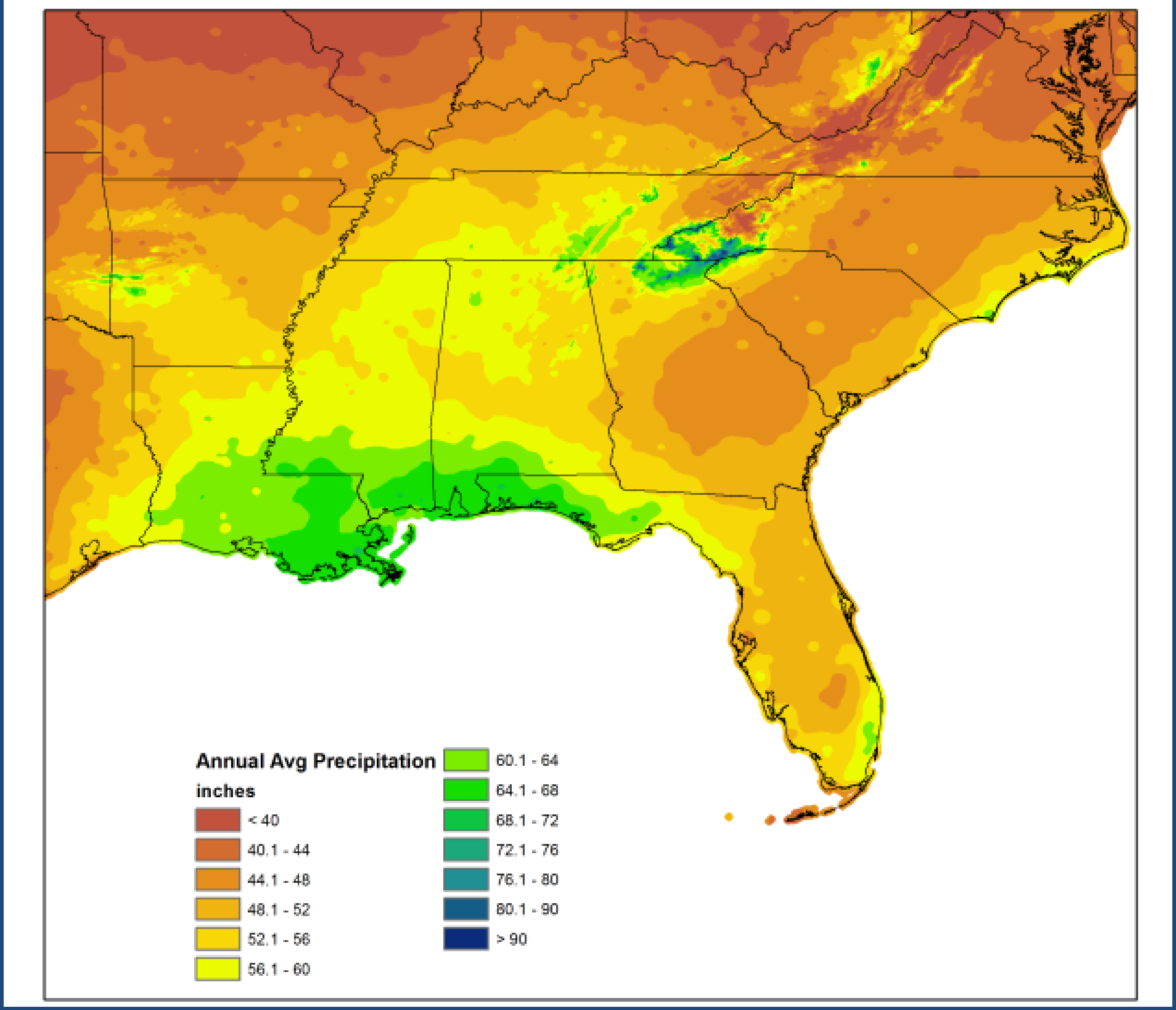
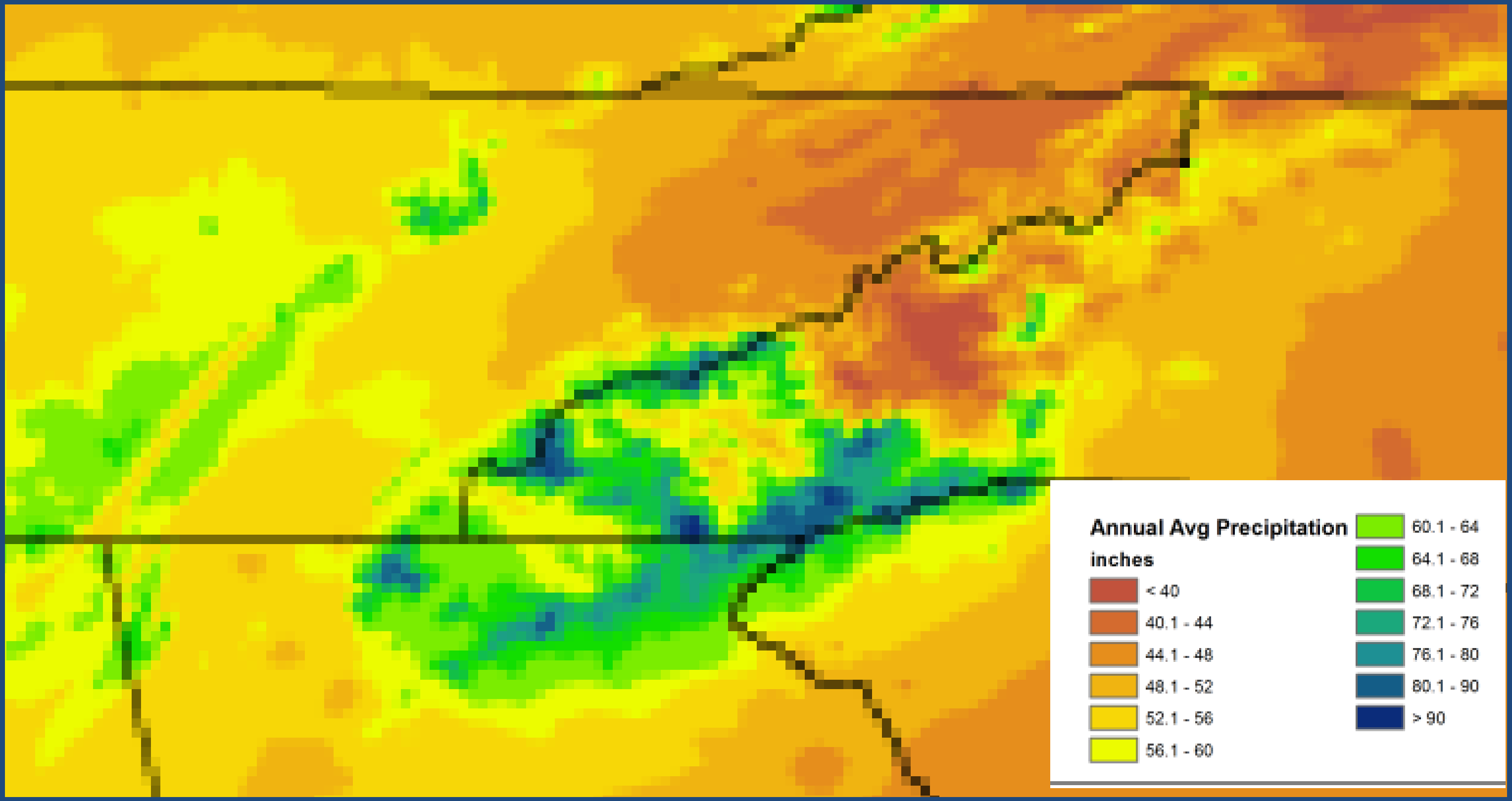
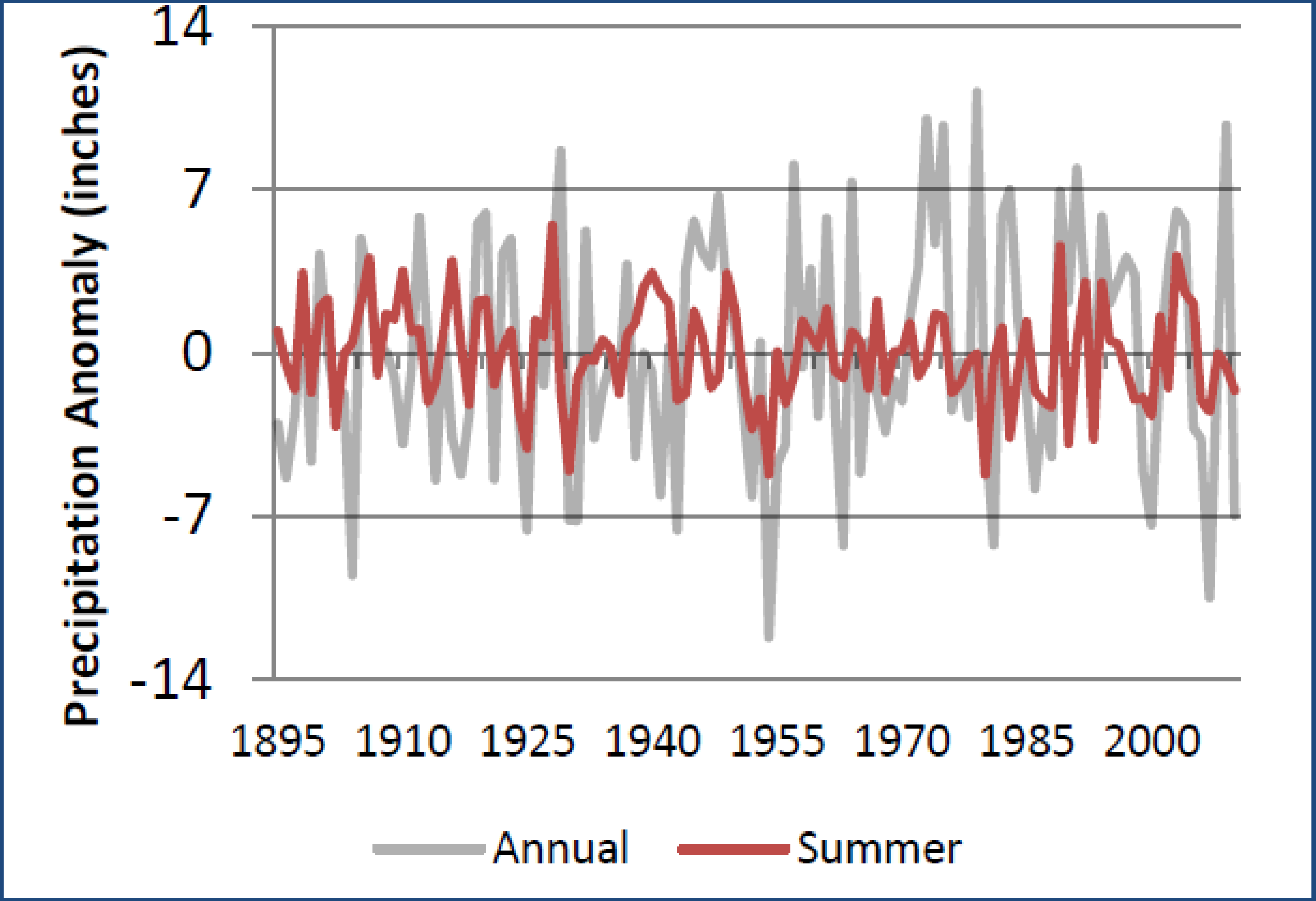


Figure 2.3. Map of annual average precipitation (from PRISM)



Annual average precipitation for Western NC (from PRISM)

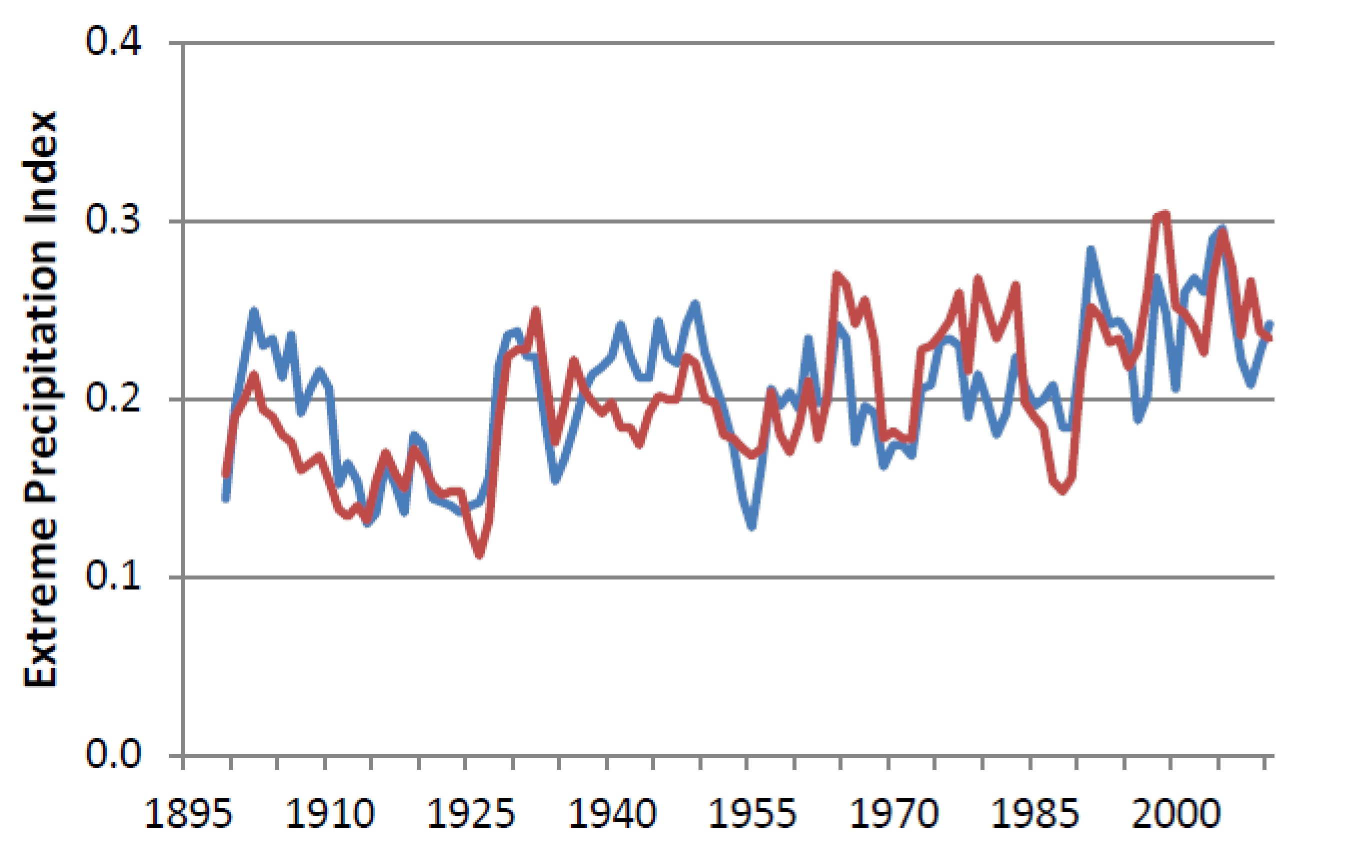
Precipitation



Much inter- annual variability

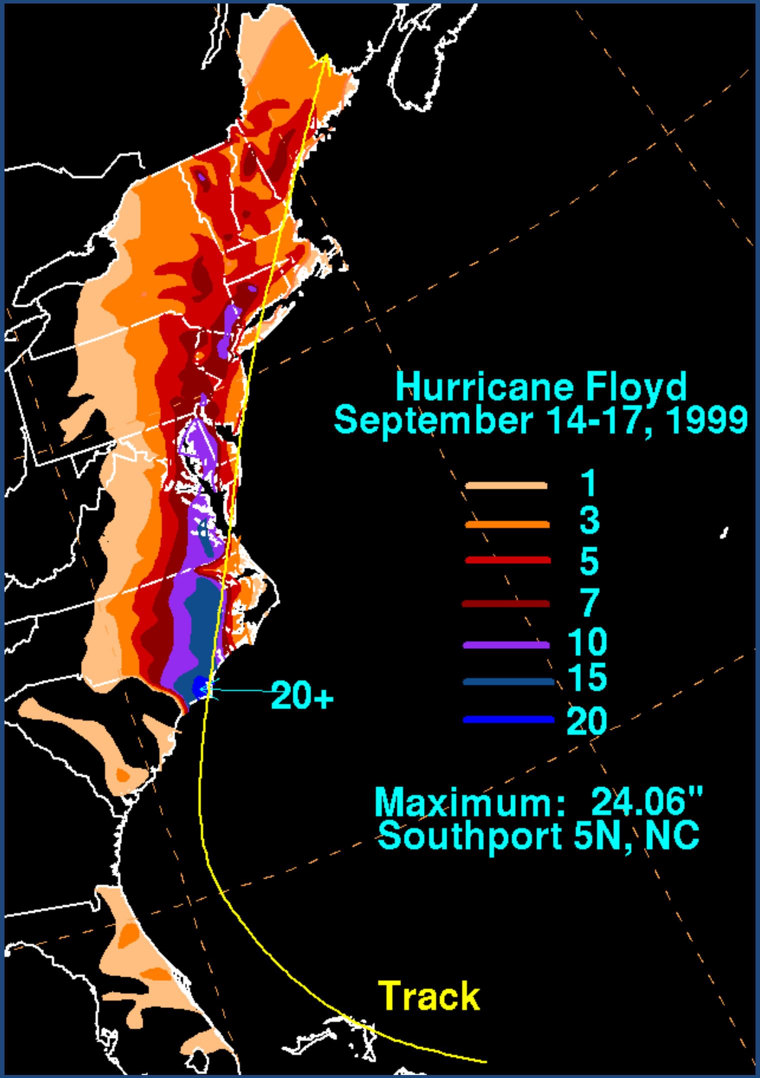
Precipitation Extremes

High rainfall rates → Flash flooding: Property damage and loss of life
Broad scale heavy rainfall → High surface runoff, river flooding: disease and poor water quality



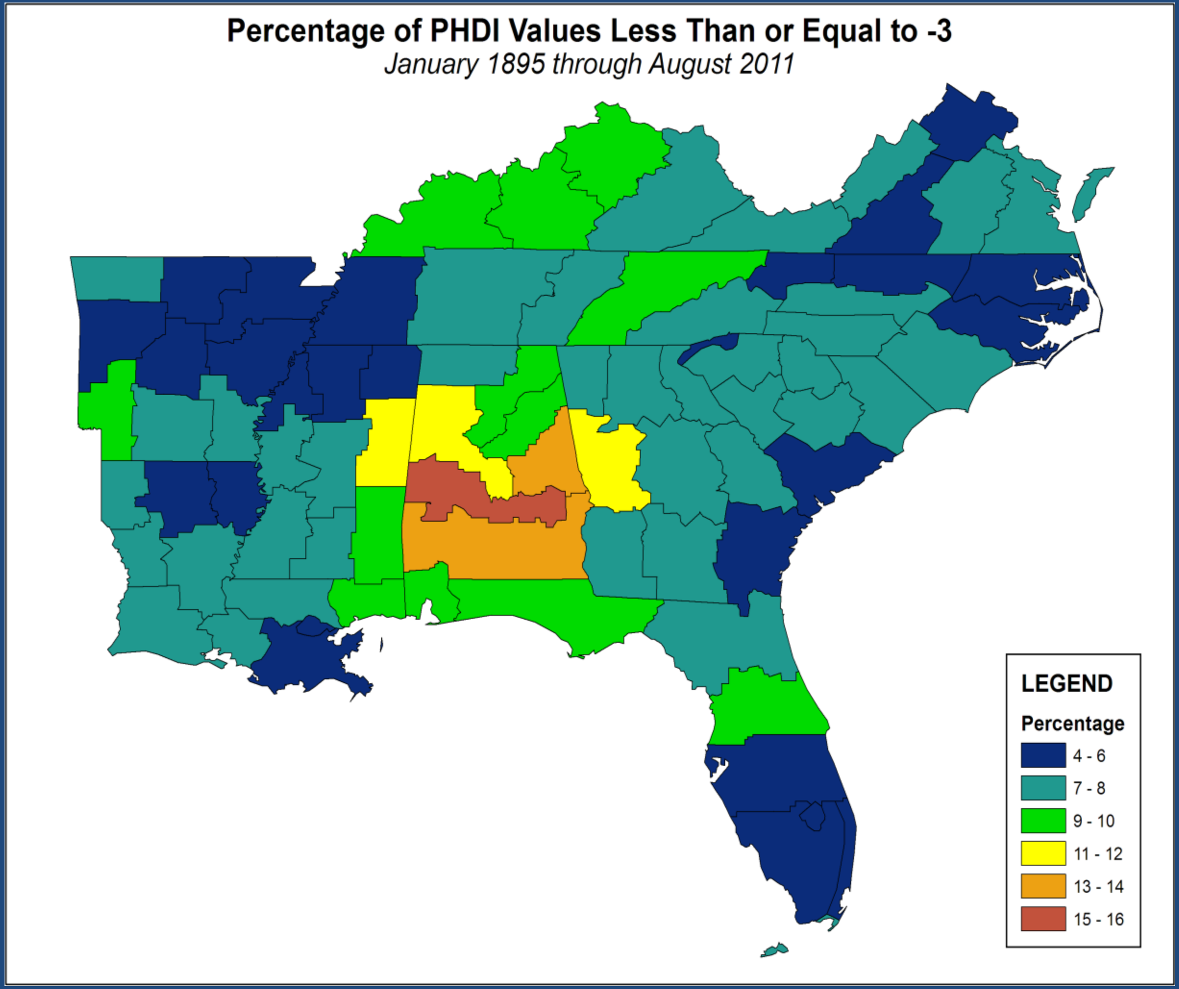
5-yr running mean of extreme precipitation index for SE region.
1 day 1 in 5-yr events. 5 day 1 in 5-yr events Constructed by K. Kunkel

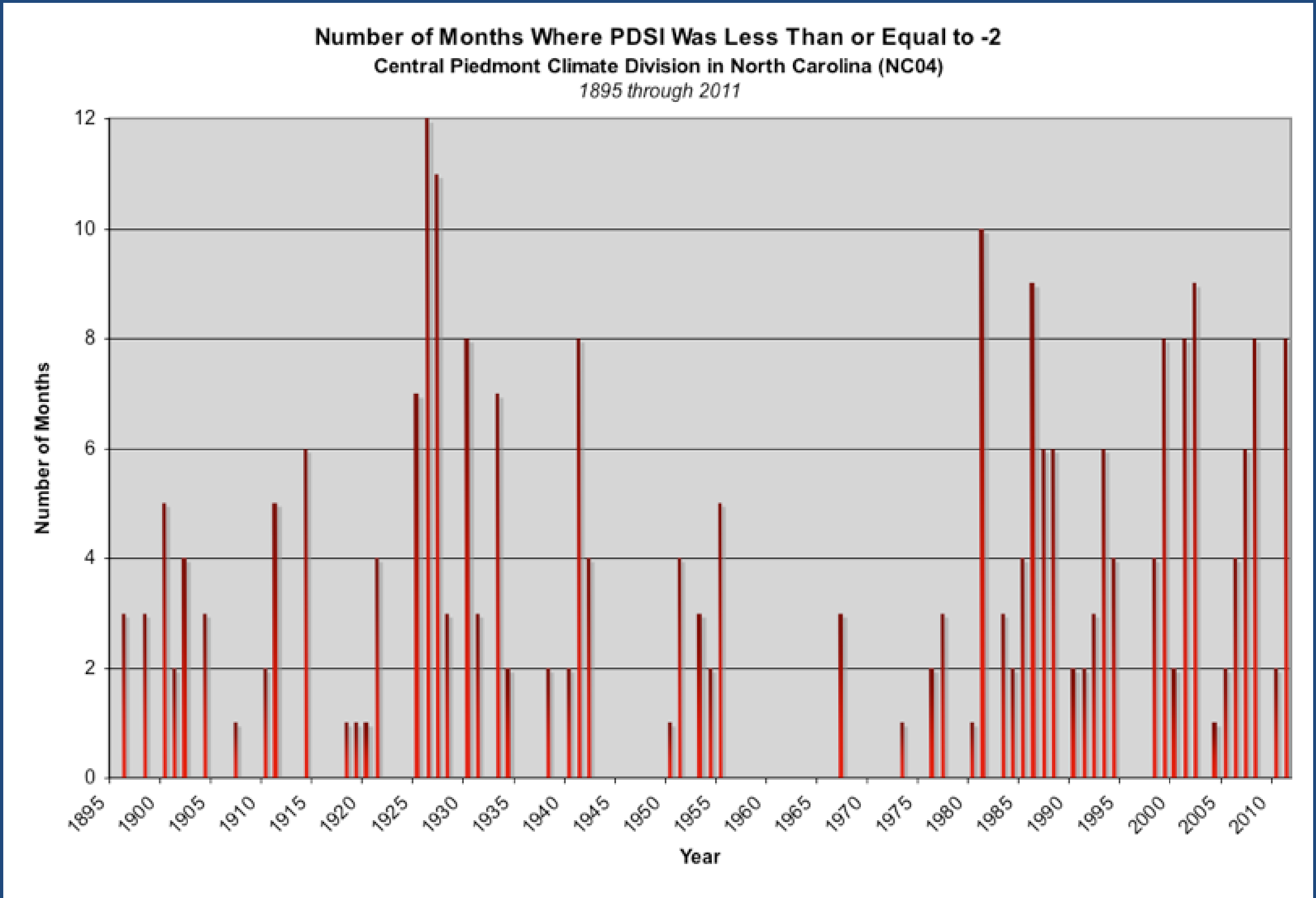
Heavy rain with Hurricane Floyd caused major flooding and over $8 billion in damage across eastern NC, VA and portions of the NE U.S.



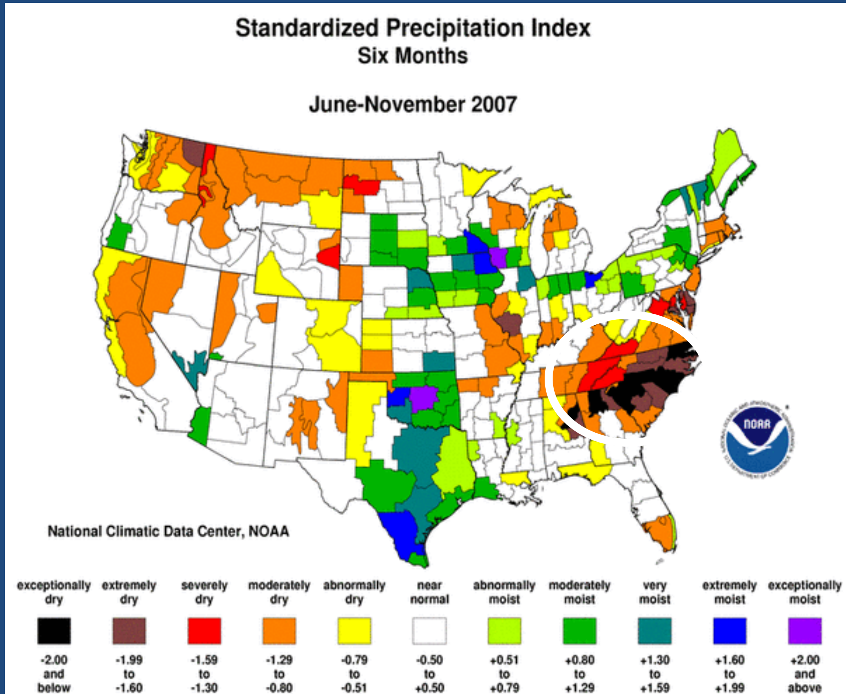
The most extreme events are responsible for a disproportionate of damages.

Hydrological droughts – reduced municipal water supplies dried up wells in rural areas, poor water quality, algal blooms etc.

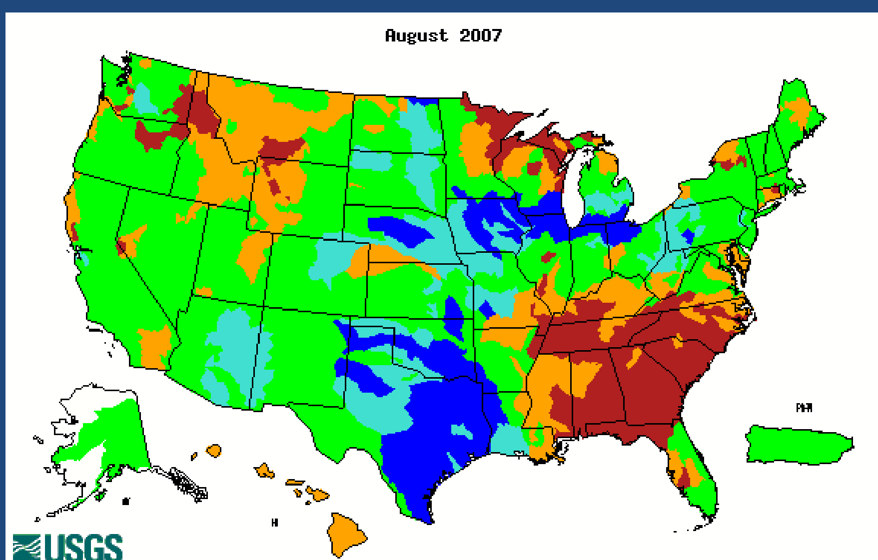




Palmer Drought Severity Index (PDSI) North Carolina CD 4
- No long term trend

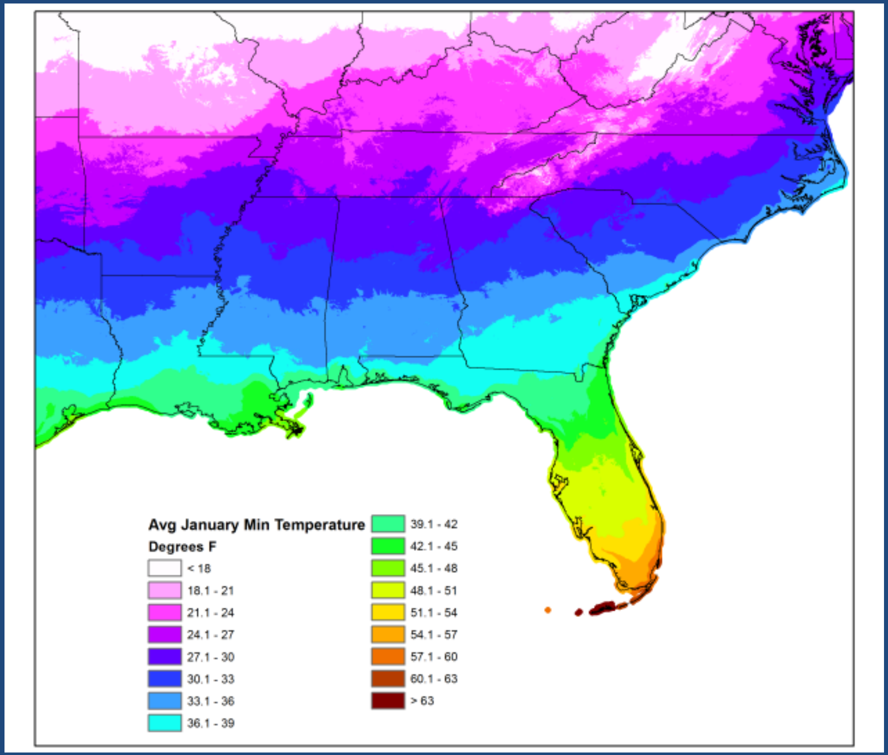


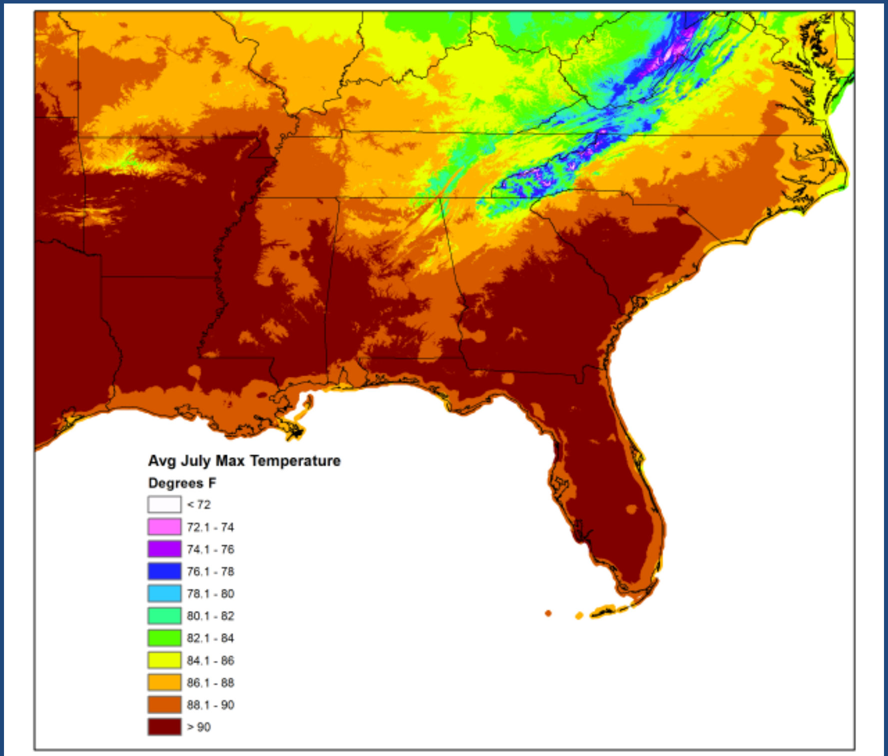
Stream flow (red = <10th percentile)



2007 "Flash Drought" in the Southeast

Temperature

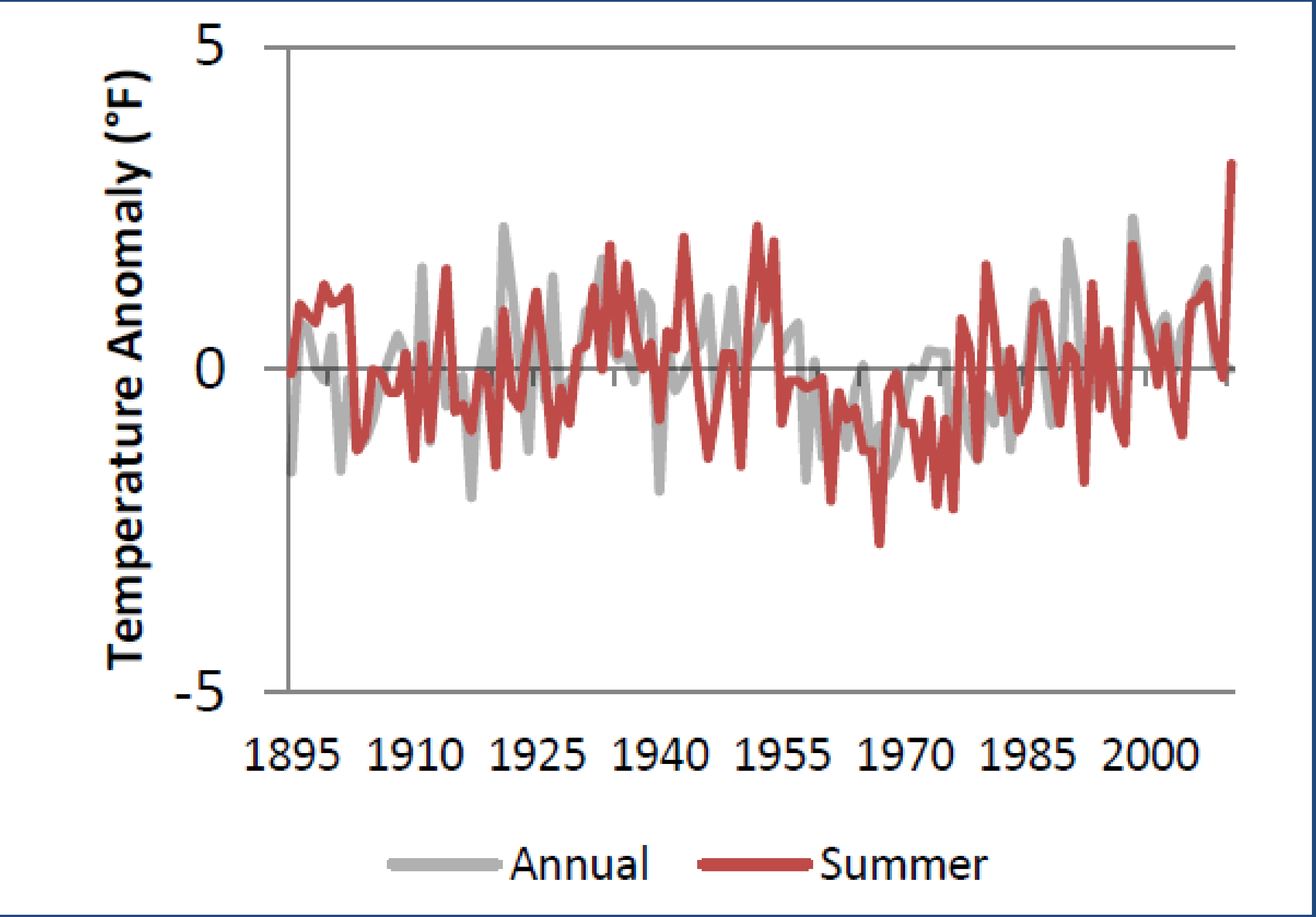




Mean January Minimum Temperature

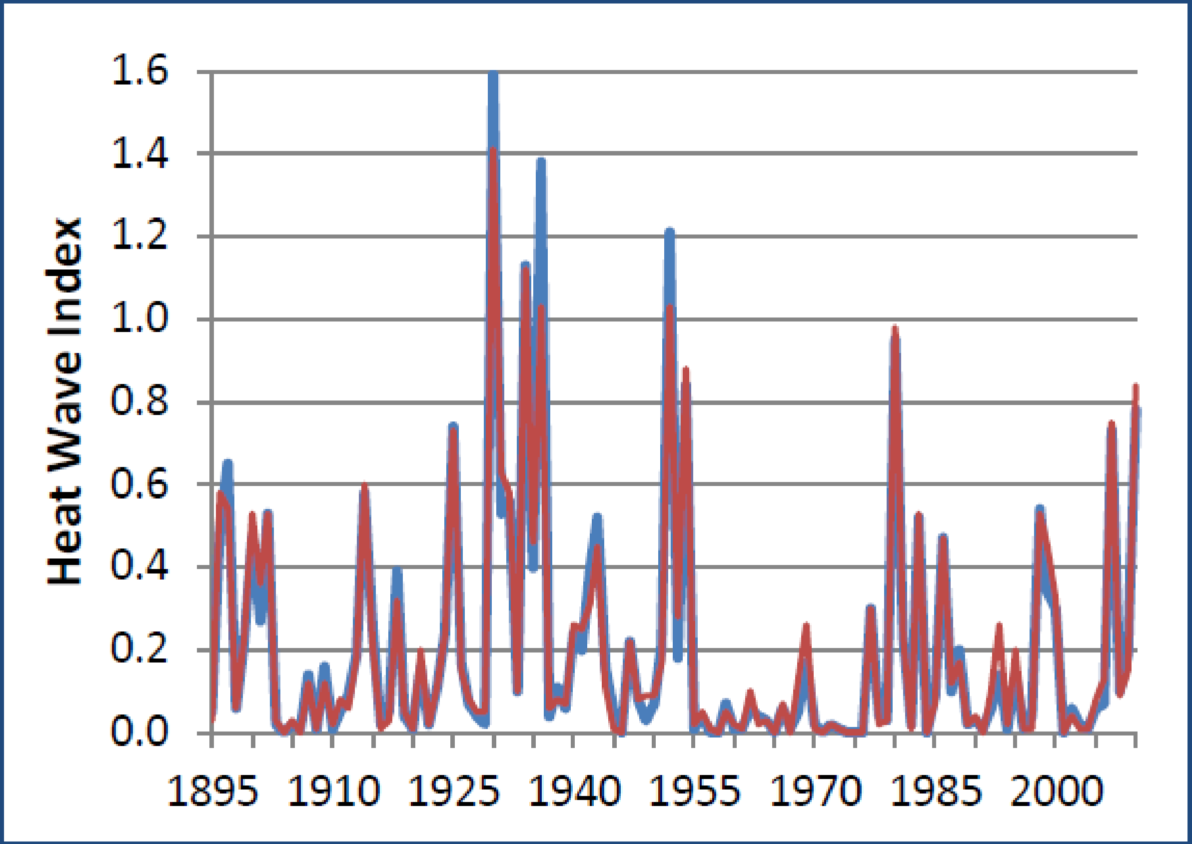
Mean July Maximum Temperature

Temperature anomalies across the SE region



- No long term trend, but warming since the 1970's

Heat Waves



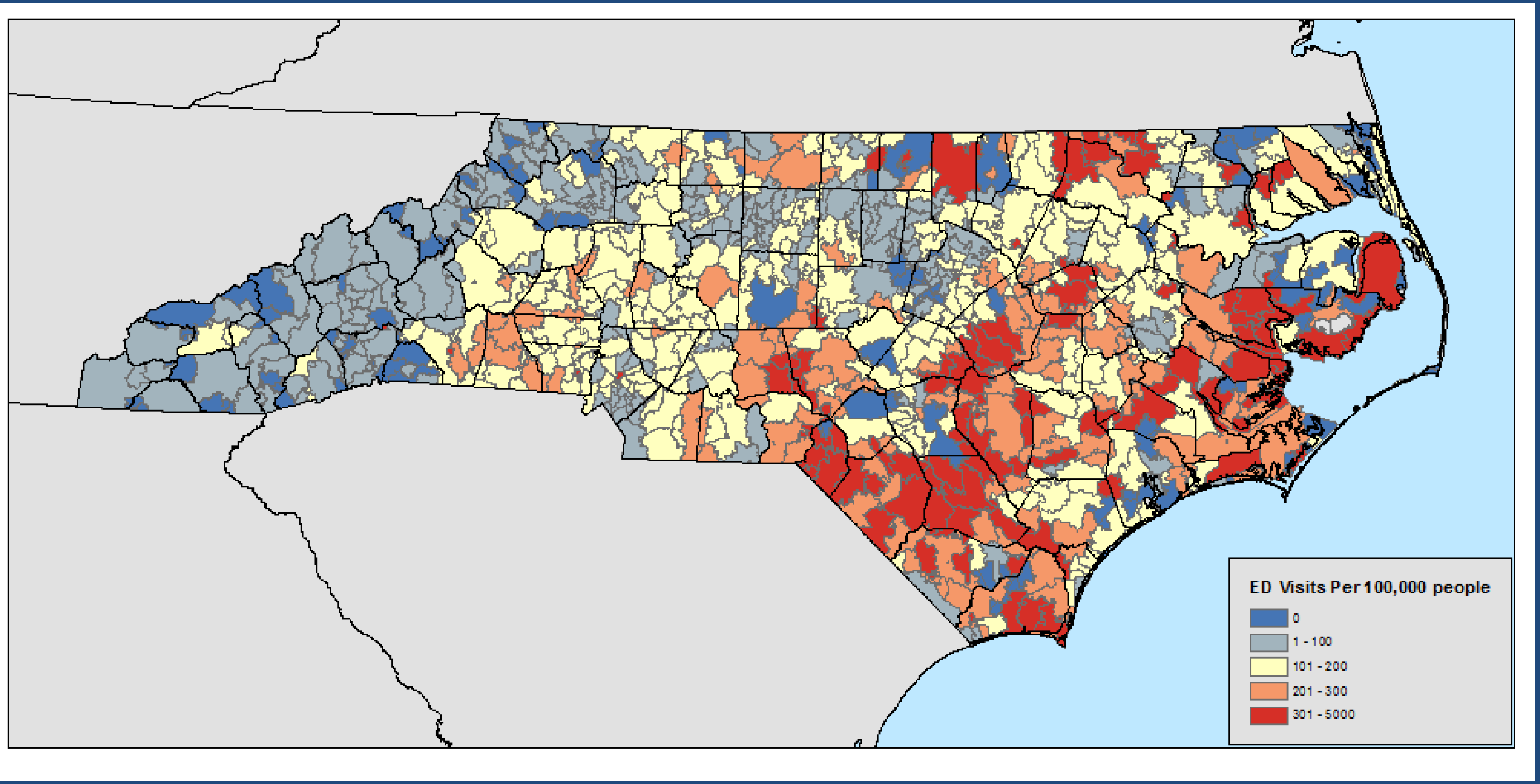
Time series of an index for the occurrence of heat waves defined as 4-day periods (blue) and 7-day periods (red) that are hotter than the threshold for a 1-in-5 year recurrence.

Heat Waves

→ Heat morbidity/mortality
→ High energy cost

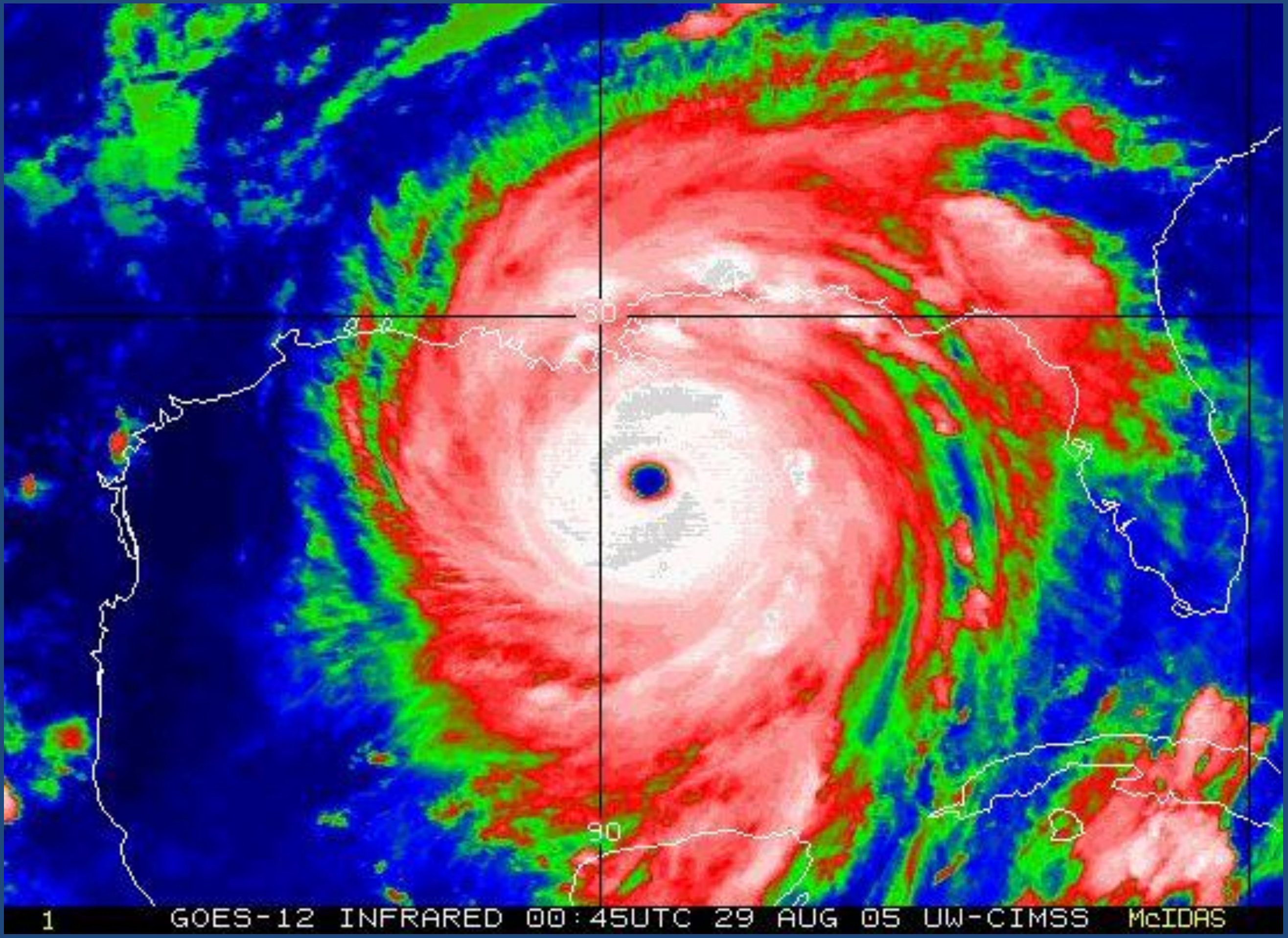
<u>**ED visits age standardized by population:**</u>

Urban **135 per 100,000 people**
Rural **150 (+15) per 100,000 people**

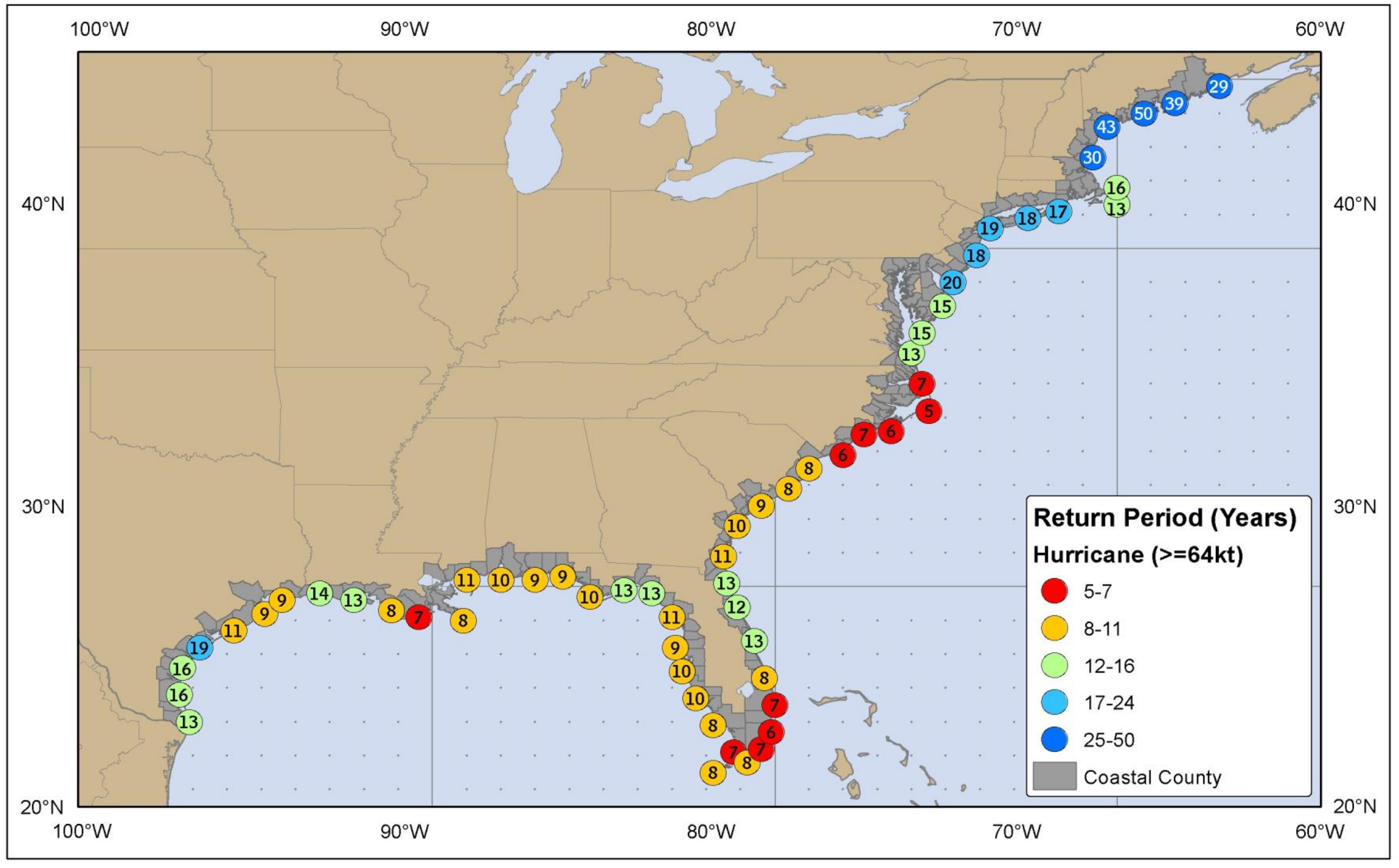


Hurricanes

Storm surge → coastal flooding
Strong winds → structural damage, downed trees, power outages, especially inland
Heavy rainfall → Inland flooding → structural damage and drowning fatalities



Hurricanes



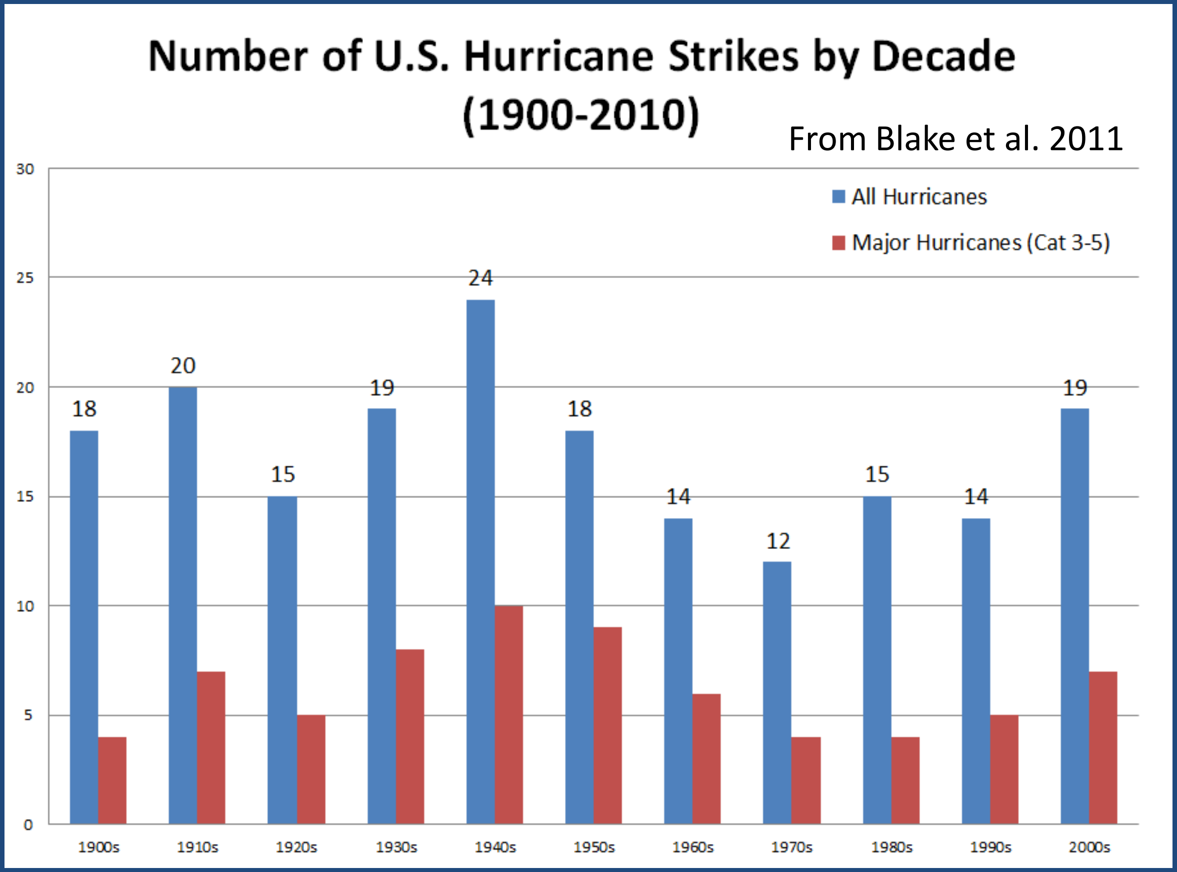
Estimated return period in years for hurricanes passing within 50 nautical miles of various locations on the U.S. Coast in the last 100 years (from the National Hurricane Center)

The costliest hurricanes to affect the United States (1900-2010)

6 of the 7 $10 billion+ hurricanes have occurred in the past 7 years, all impacting the Southeast region

RANK	TROPICAL CYCLONE	YEAR	CATEGORY	DAMAGE (U.S.)
1	*KATRINA* (SE FL, LA, MS)	2005	3	$108,000,000,000
2	*IKE (TX, LA)*	2008	2	29,520,000,000
3	*ANDREW* (SE FL/LA)	1992	5	26,500,000,000
4	*WILMA* (S FL)	2005	3	21,007,000,000
5	*IVAN* (AL/NW FL)	2004	3	18,820,000,000
6	*CHARLEY* (SW FL)	2004	4	15,113,000,000
7	*RITA* (SW LA, N TX)	2005	3	12,037,000,000
8	*FRANCES* (FL)	2004	2	9,507,000,000
9	*ALLISON* (N TX)	2001	TS	9,000,000,000
10	*JEANNE* (FL)	2004	3	7,660,000,000
11	*HUGO* (SC)	1989	4	7,000,000,000
12	*FLOYD* (Mid-Atlantic & NE U.S.)	1999	2	6,900,000,000
13	*ISABEL* (Mid-Atlantic)	2003	2	5,370,000,000
14	*OPAL* (NW FL/AL)	1995	3	5,142,000,000
15	*GUSTAV* (LA)	2008	2	4,618,000,000
16	*FRAN* (NC)	1996	3	4,160,000,000
17	*GEORGES* (FL Keys, MS, AL)	1998	2	2,765,000,000
18	*DENNIS (NW FL)*	2005	3	2,545,000,000
19	*FREDERIC (AL/MS)*	1979	3	2,300,000,000
20	*AGNES (FL/NE U.S.)*	1972	1	2,100,000,000

Data from Blake et al. 2011



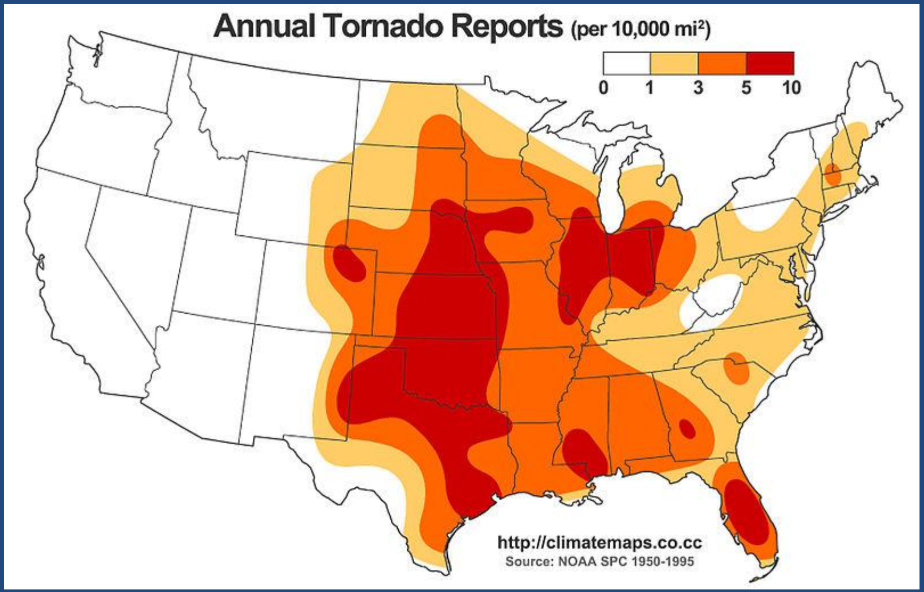
Complicated relationship between ocean/atmosphere and hurricanes

- Increase in sea surface temperatures ↑ hurricanes
- Stronger winds aloft ↓ hurricanes

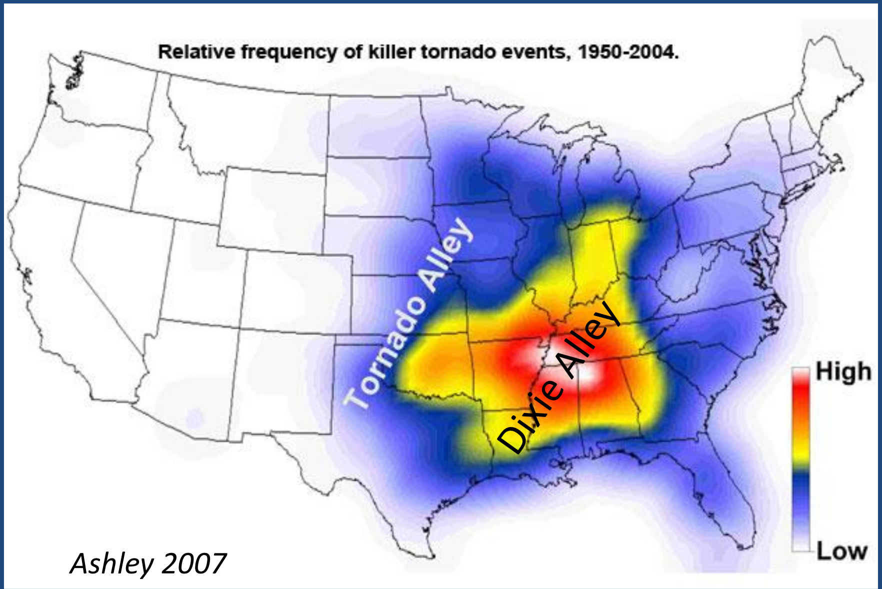
- El Nino ↓ hurricanes
- La Nina ↑ hurricanes

Atlantic Multi-decadal Oscillation

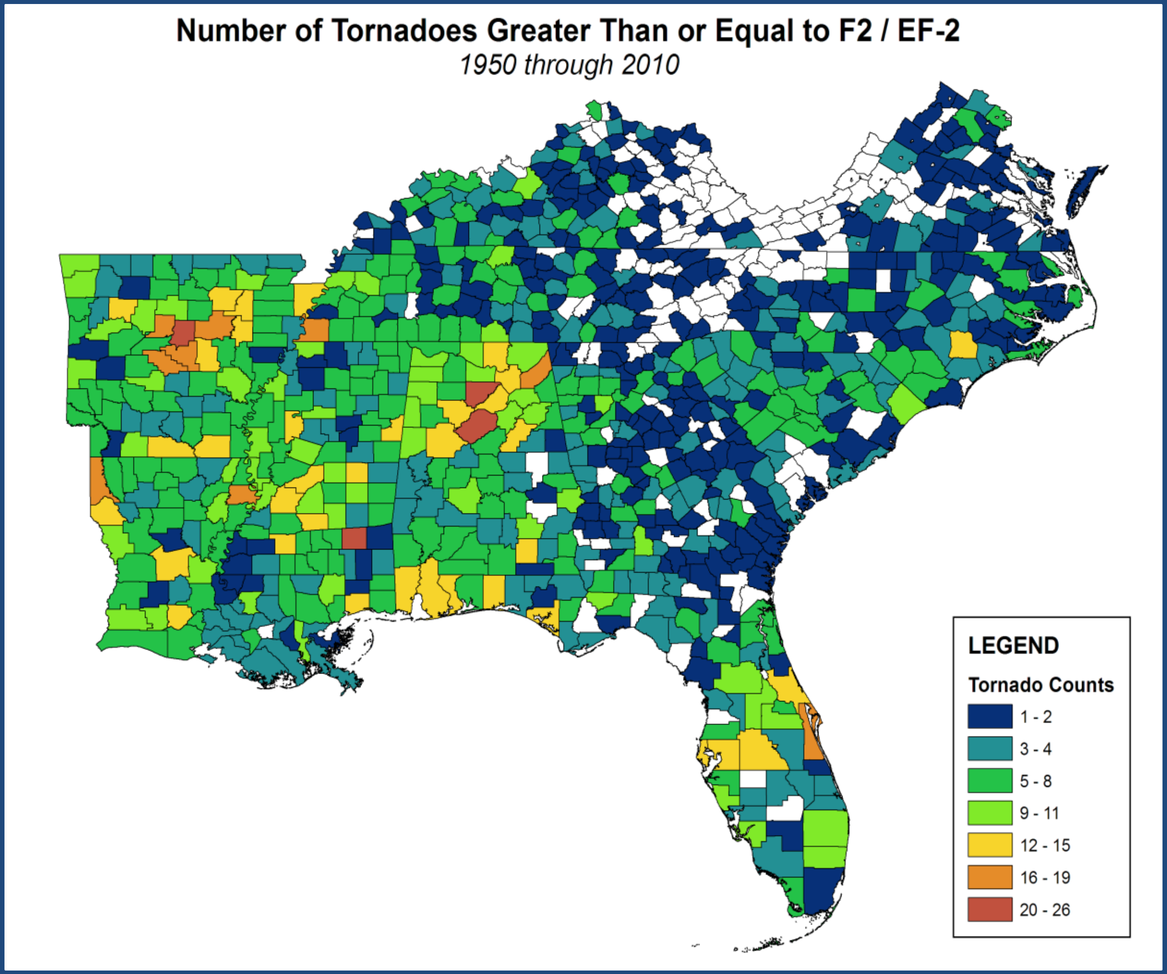
Tornadoes



Annual Tornado Reports



Number of Killer Tornado Events

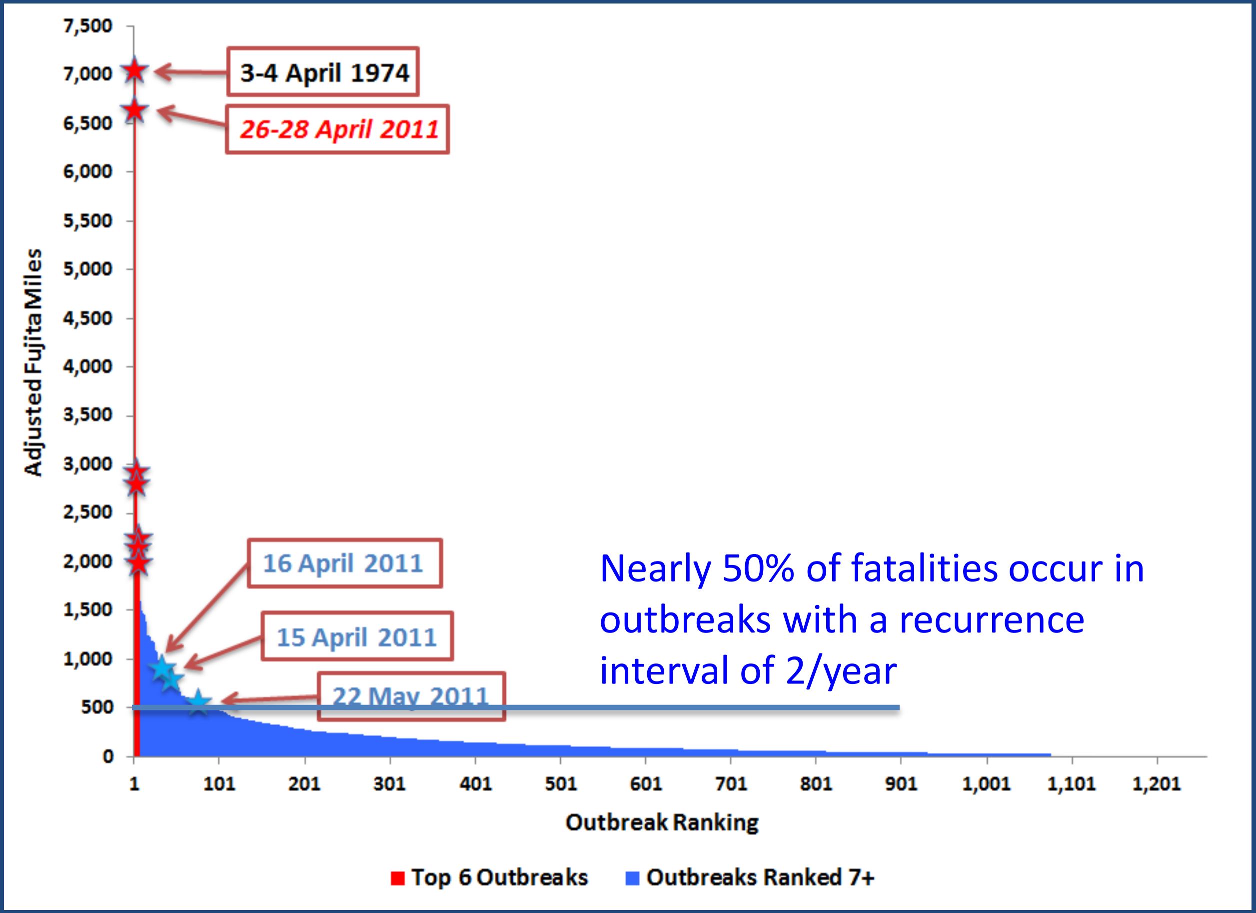


1. Much sub-standard housing (e.g. mobile homes).

2. Many trees and building materials hurled through the air.

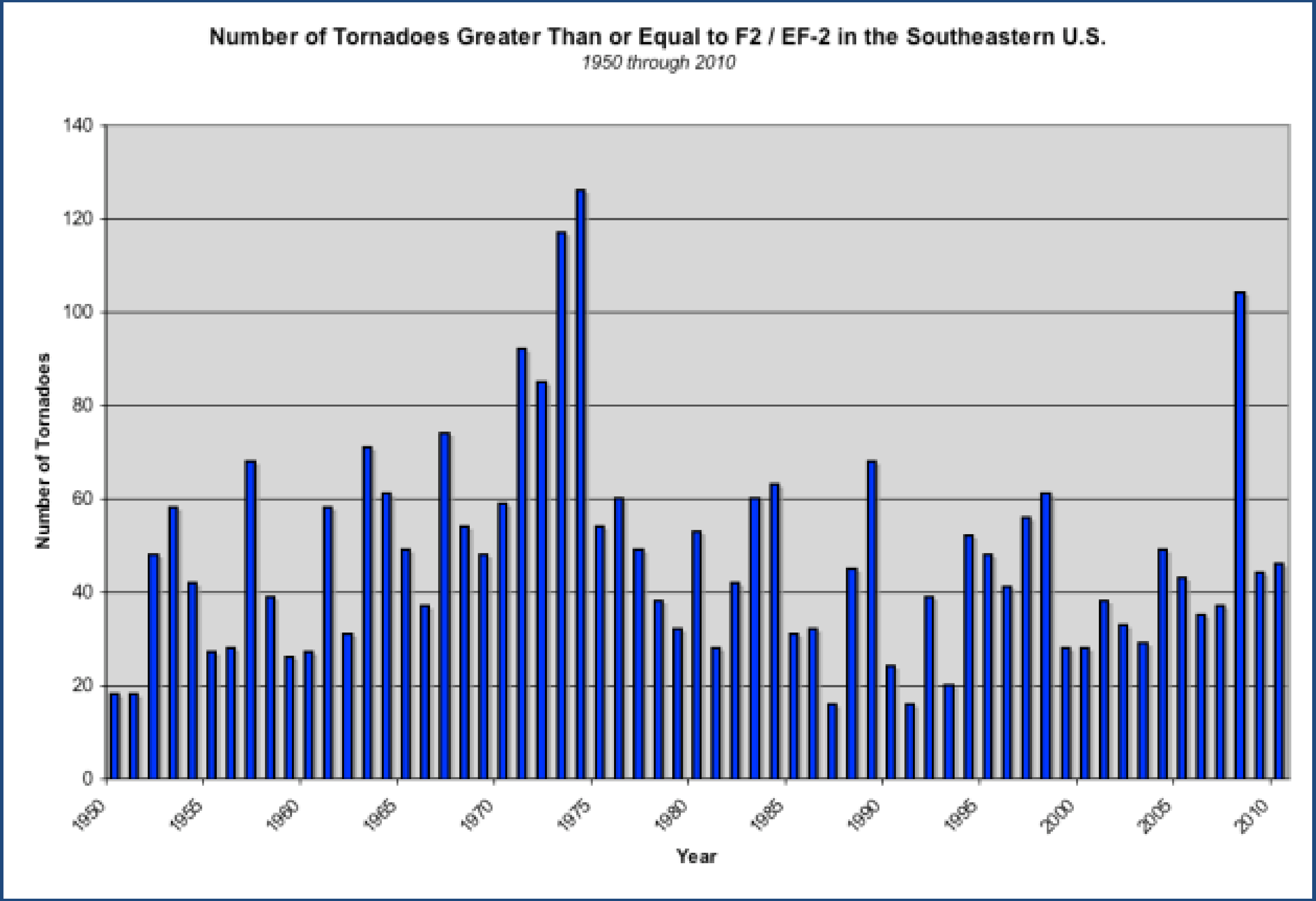
3. Poor visibility – many trees, low clouds, and precipitation.

Deadly tornadoes mostly occur in large tornado outbreaks



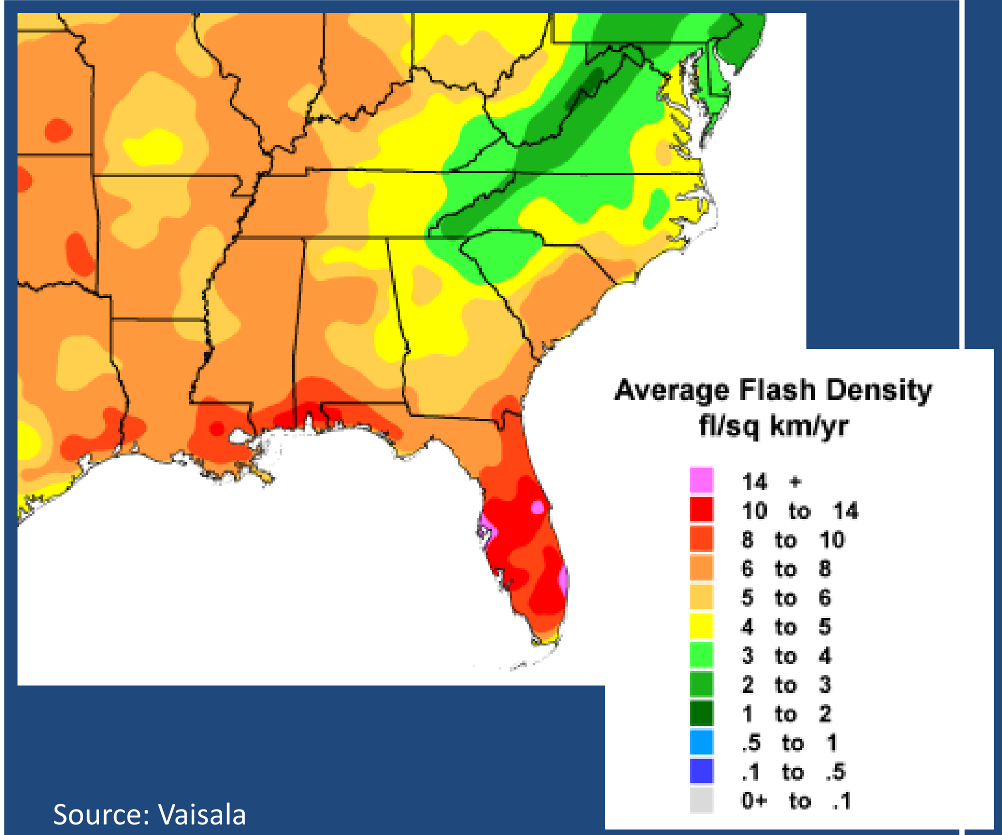
Fuhrmann, C.M., **C.E. Konrad**, M.M Kovach, J.T. McLeod, W.G. Schmitz, and P.G. Dixon: Ranking of tornado outbreaks in the United States and their climatological characteristics. *Weather and Forecasting*, in press. http://dx.doi.org/10.1175/WAF-D-13-00128.1

Tornadoes: Historical patterns



Lightning - property damage and loss of life

Rank	State	Death rate per million people 1959–2003
1.	New Mexico	1.48
2.	Wyoming	1.44
3.	Arkansas	1.18
4.	Colorado	0.95
5.	Florida	0.94
6.	Mississippi	0.87
7.	Montana	0.75
7.	Oklahoma	0.75
9.	Louisiana	0.74
10.	South Dakota	0.73
11.	Utah	0.71
12.	North Carolina	0.67
13.	Tennessee	0.65
14.	Maryland	0.64
15.	Nebraska	0.63
15.	South Carolina	0.63
17.	Idaho	0.62
17.	Vermont	0.62
19.	Alabama	0.59



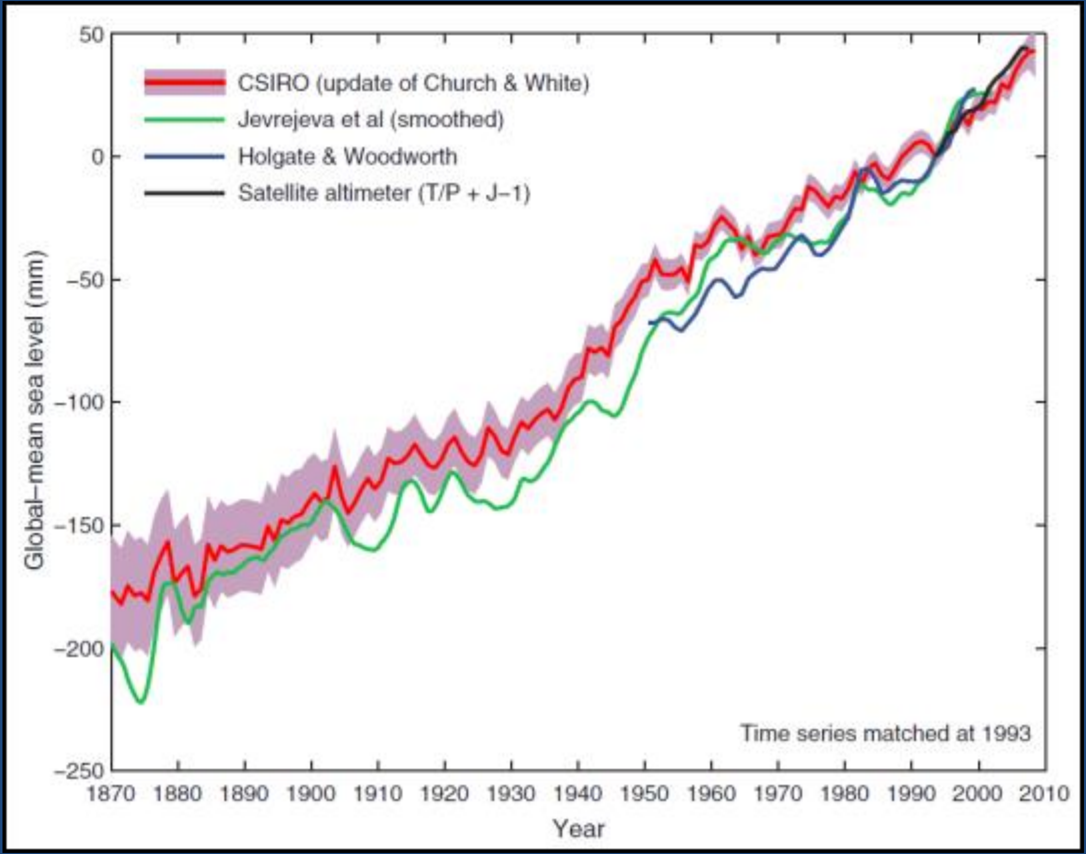
Source: Vaisala

Global Trend in sea level

- **Local and regional trends depart slightly due to different rates of subsidence and wind influences**

17 mm/decade
(~ 7’’ last 100 yrs)

Satellite estimate
33 mm/decade
btwn. 1990-2009



How does recent climate variability inform future climate projections?

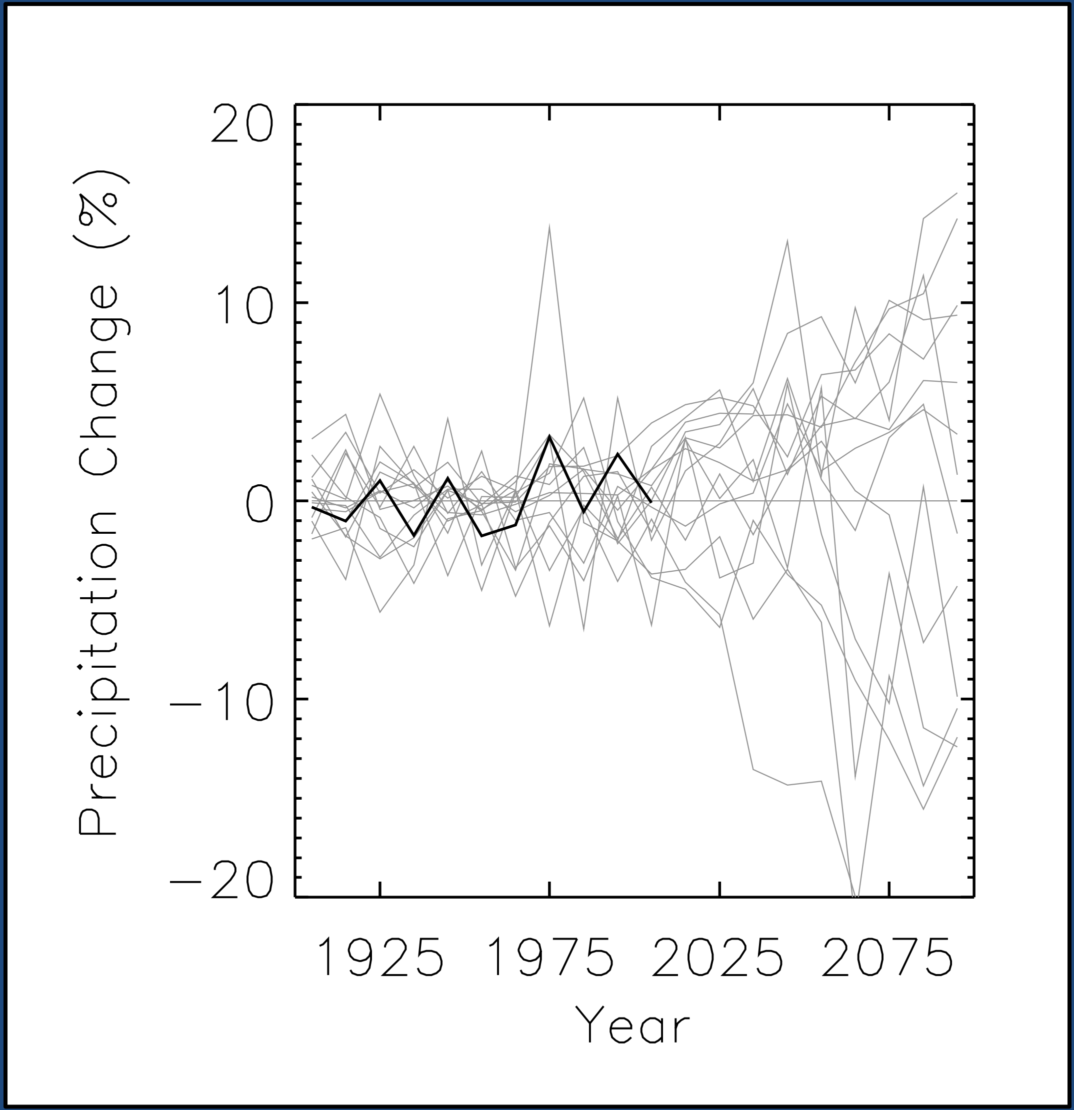


Figure 45. Observed decadal mean annual precipitation change (deviations from the 1901-2000 average, %) for the Southeast U.S. (black line). Based on a new gridded data set from NCDC for the NWS Cooperative Observer Network (R. Vose, personal communication). Gray lines indicate the 20th and 21st century simulations from 15 CMIP3 models, for the high (A2) emissions scenario. Observed precipitation variations are within the model simulations.

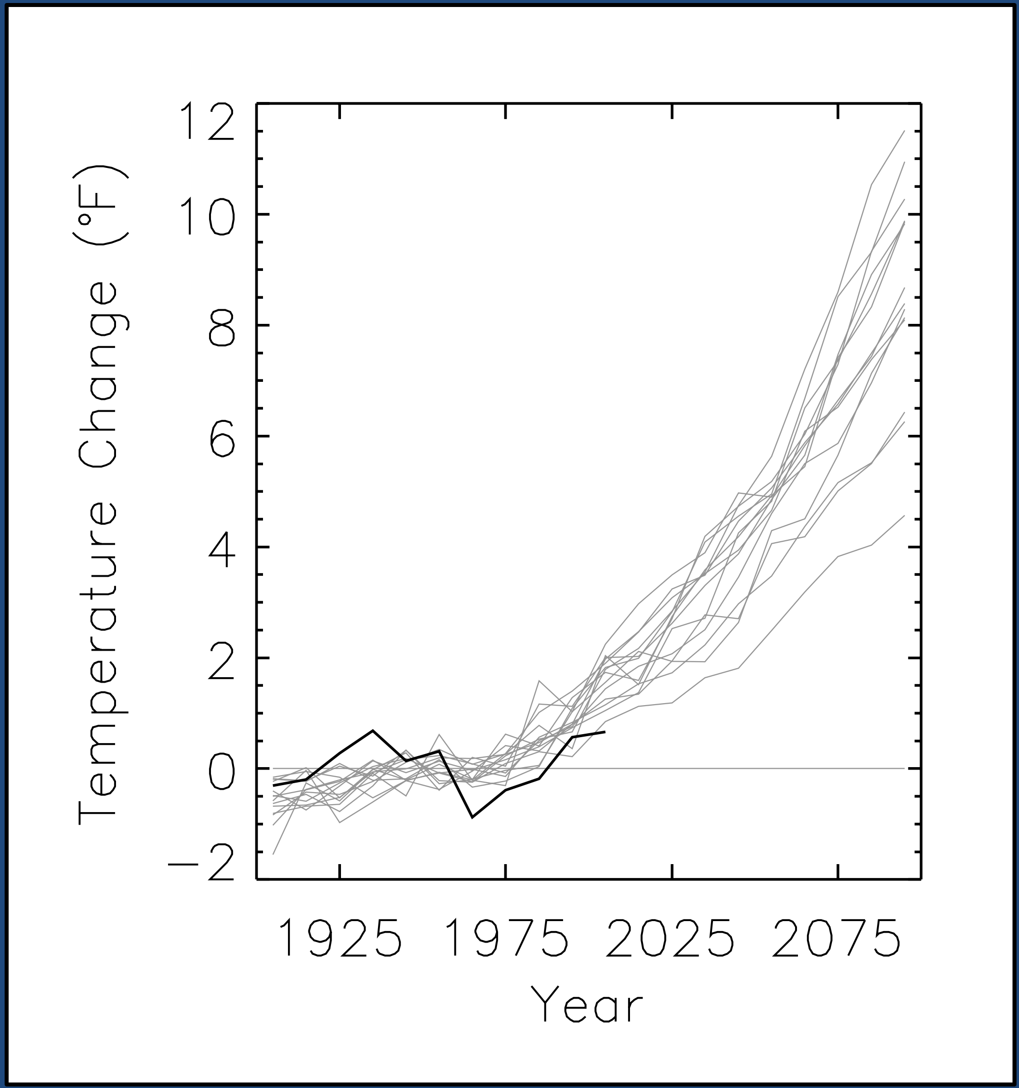


Figure 43. Observed decadal mean annual temperature change (deviations from the 1901-2000 average, °F) for the Southeast U.S. (black line). Based on a new gridded data set from NCDC for the NWS Cooperative Observer Network (R. Vose, personal communication). Gray lines indicate the 20th and 21st century simulations from 15 CMIP3 models, for the high (A2) emissions scenario. The early 20th century rate of warming and the mid-century rate of cooling are not simulated by the models, but the late-century rate of warming is similar to the rate of warming in the models.

Much variation in future projection of hurricanes

→ Modeling challenge: Hurricanes are smaller than the grid size of GCMs

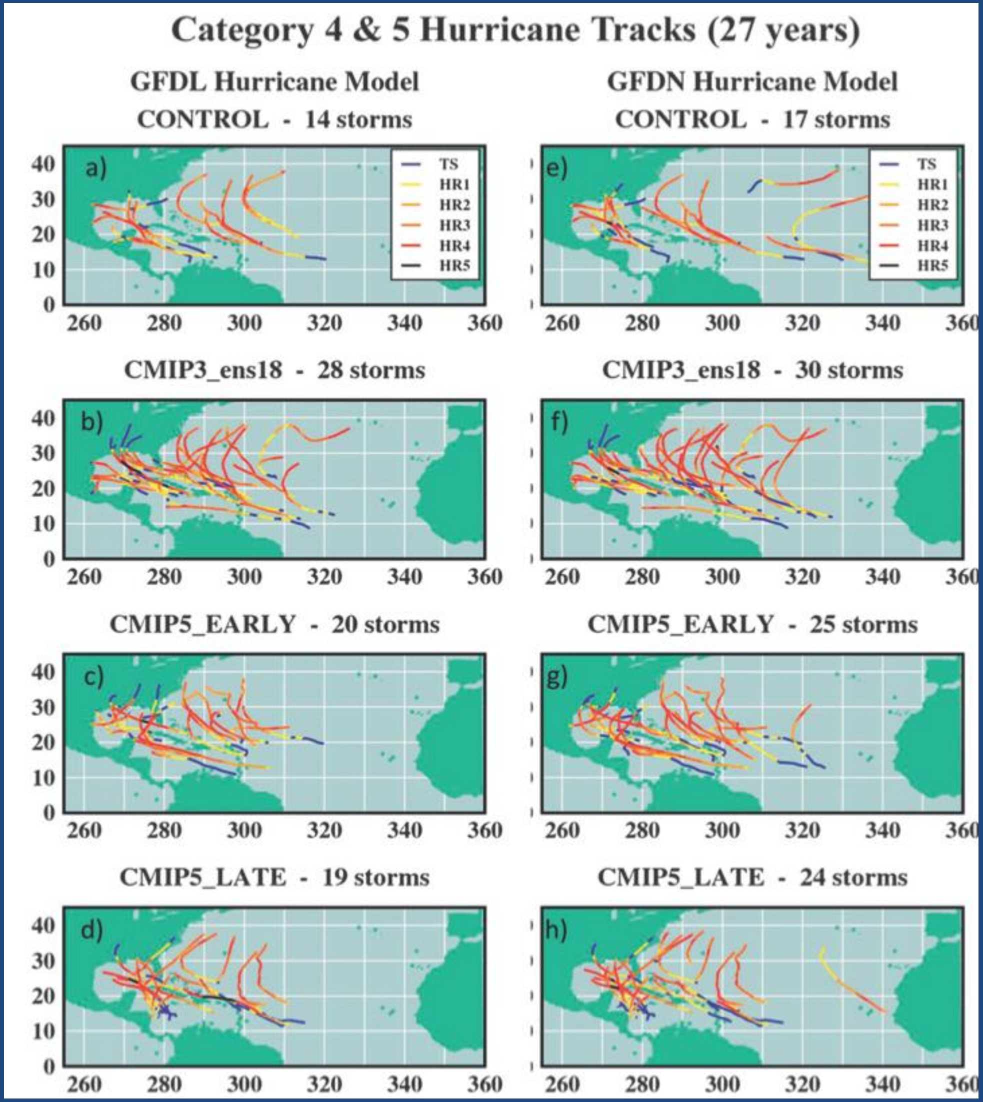
- Slight decrease in tropical cyclones and weak hurricanes
- Increase in strong hurricanes

Control climate
14 -17 storms/27 years

CMIP3
28-30 storms/27 years

CMIP5 early 21st century
20-25 storms/27 years

CMIP5 late 21st century
19-24 storms/27 years



Knutson, T.R. and others. 2013: Dynamical downscaling projections of twenty-first-century Atlantic hurricane activity: CMIP3 and CMIP5 model-based scenarios. Journal of Climate, 26

Acknowledgements:

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- Ryan Boyles and Ashley Fraser from the NC State Climate Office

Thank You!