Trends in the Character of Hurricanes and their Impact on Heavy Rainfall across the Carolinas

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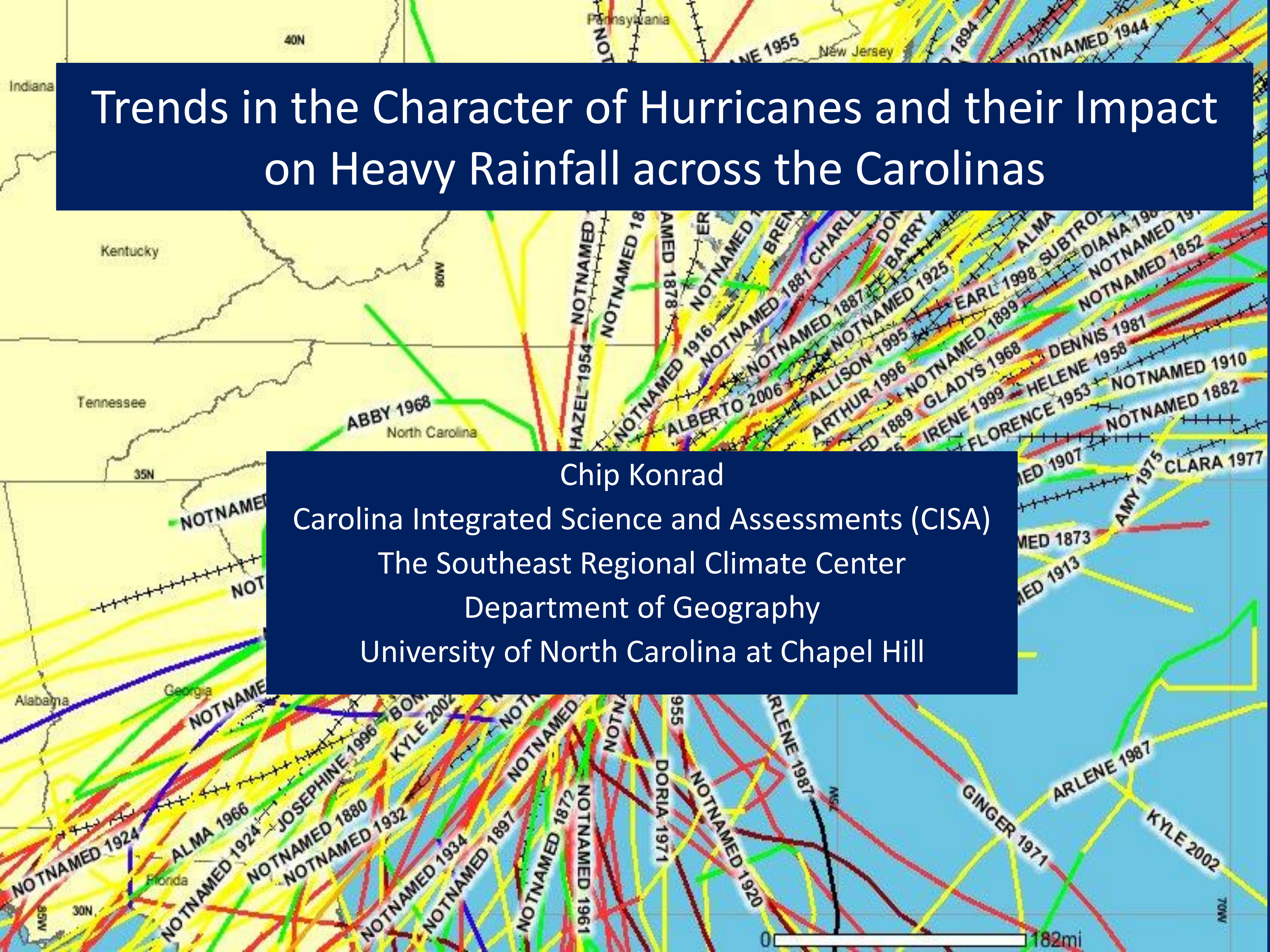


Outline

Hurricanes

1. Background

2. Trends in Character of Hurricanes & factors that control them

   - Character: frequency & intensity, translation speed
   - Controlling factors: Sea surface temperature, vertical wind shear, atmospheric dust, El Nino/La Nina

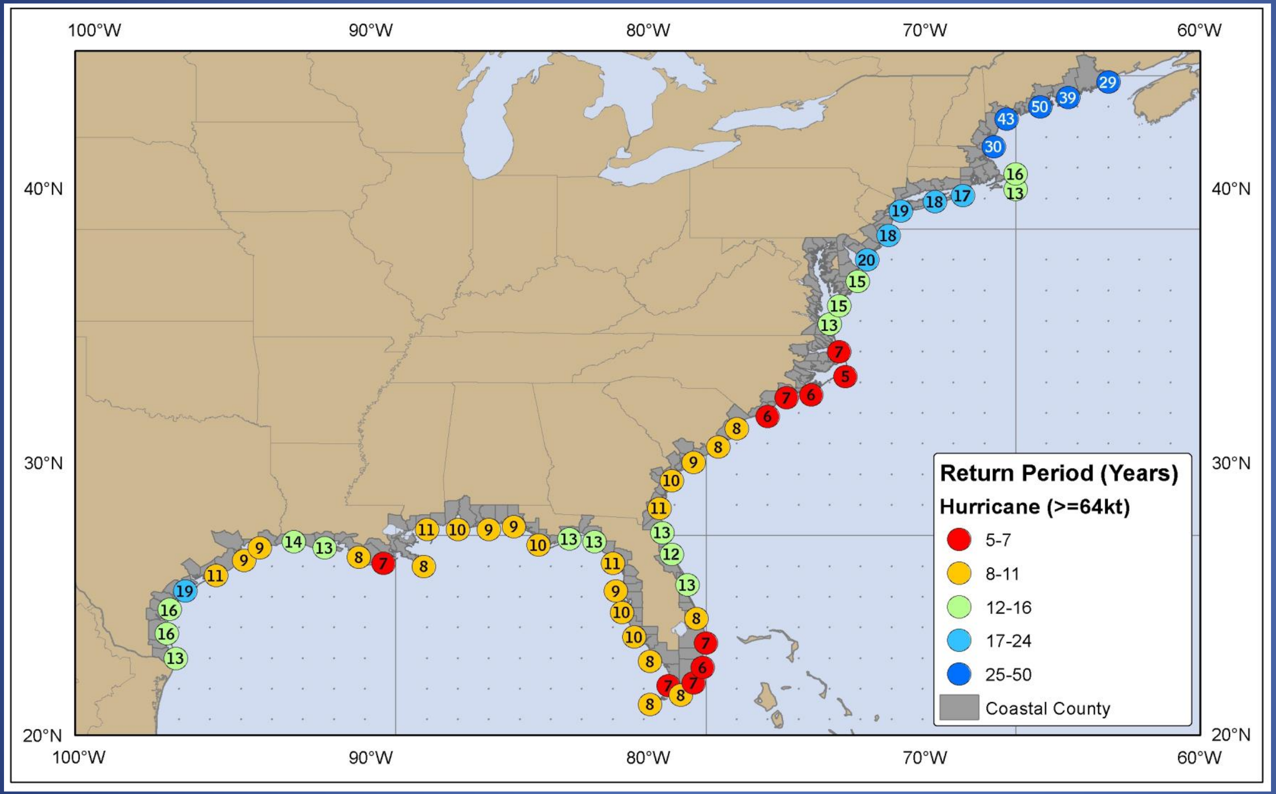
3. Influences on Heavy Rainfall and Flooding

   - Trends in hurricane translation speed
   - Examples: Oct 2015 SC event (Joaquin) & Hurricane Florence

4. What about the future?

Background on Hurricanes

North Carolina is especially vulnerable

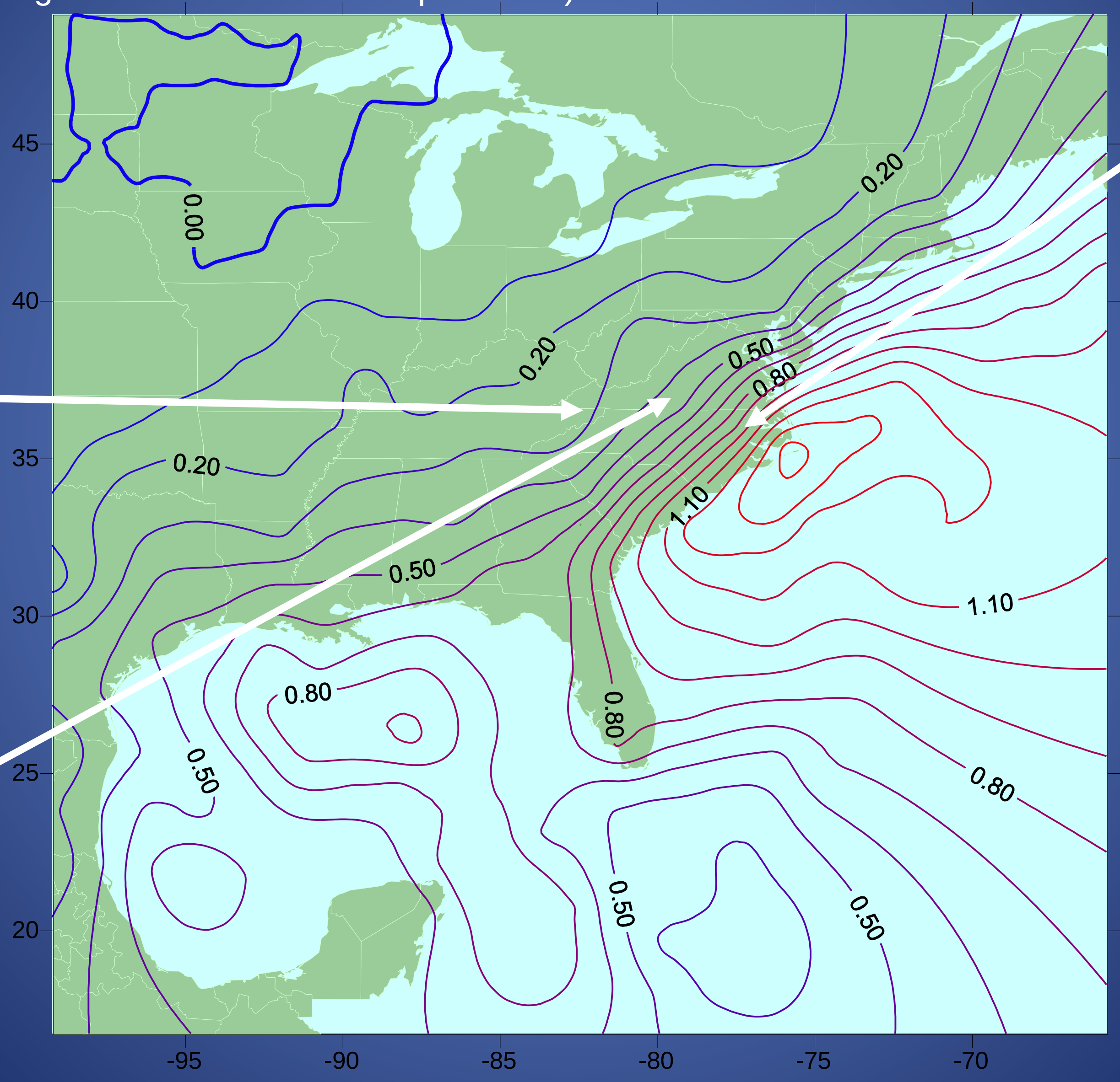


Estimated return period in years for hurricanes passing within 50 nautical miles of various locations on the U.S. Coast in the last 100 years (from the National Hurricane Center)

Background on Hurricanes

Annual Frequencies of Tropical Cyclones and Their Remnants

(Passage within 124 miles of map location)



Mtns

0.32/year

Once every 3 yrs

Piedmont

0.60/year

Once every 1.5 yrs

Coastal Plain

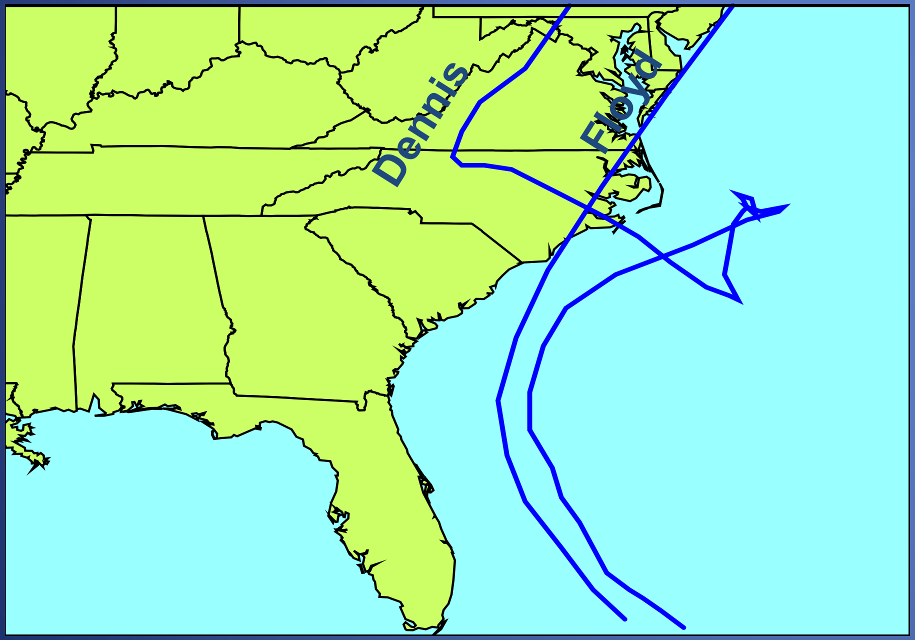
1.1/year

Once a year

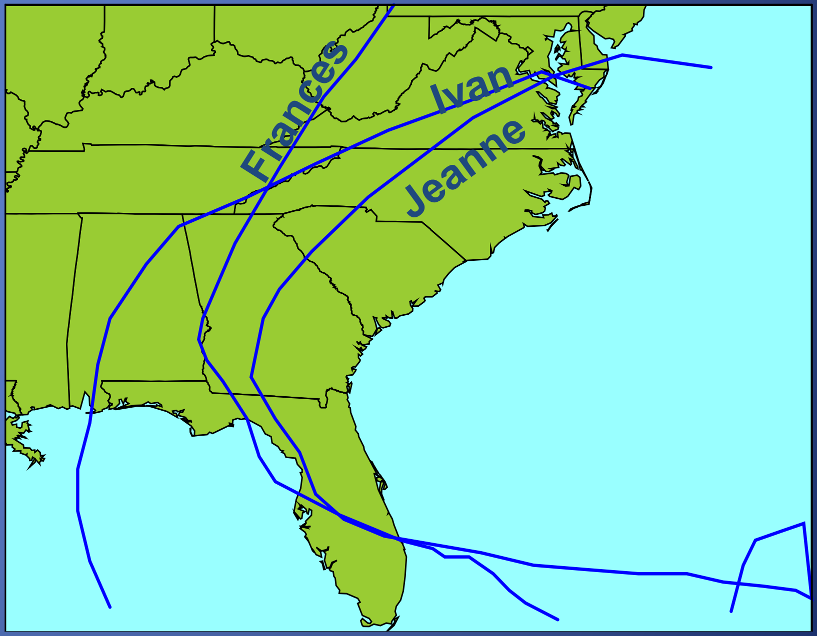
Background on Hurricanes

Hurricanes often cluster together in time:

Sept 1999: 2 in 3 weeks



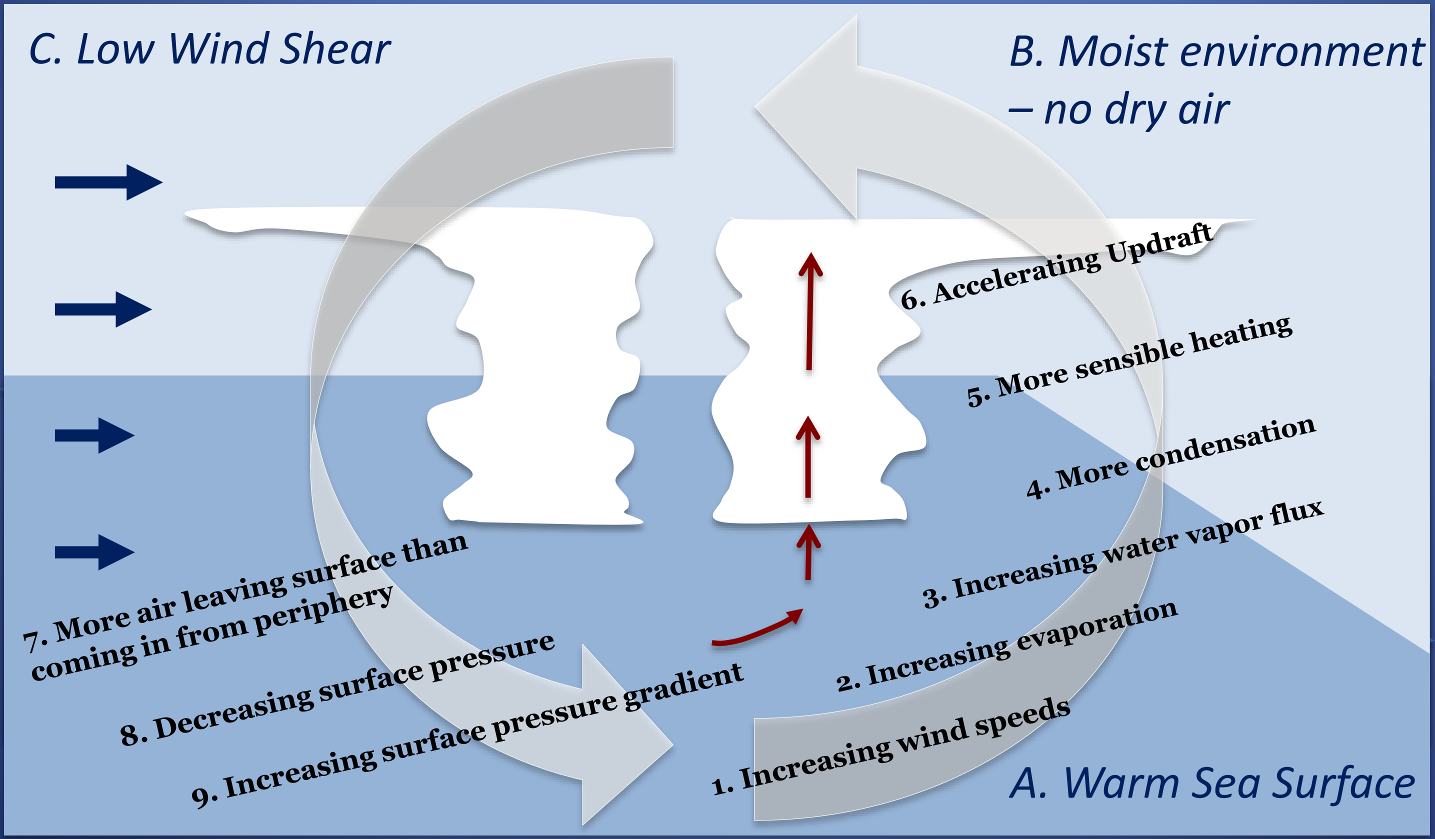
Sept. 2004: 3 in less than 3 weeks



Background on Hurricanes

Hurricanes driven by heat in ocean

Factors that control frequency of hurricanes and their strength



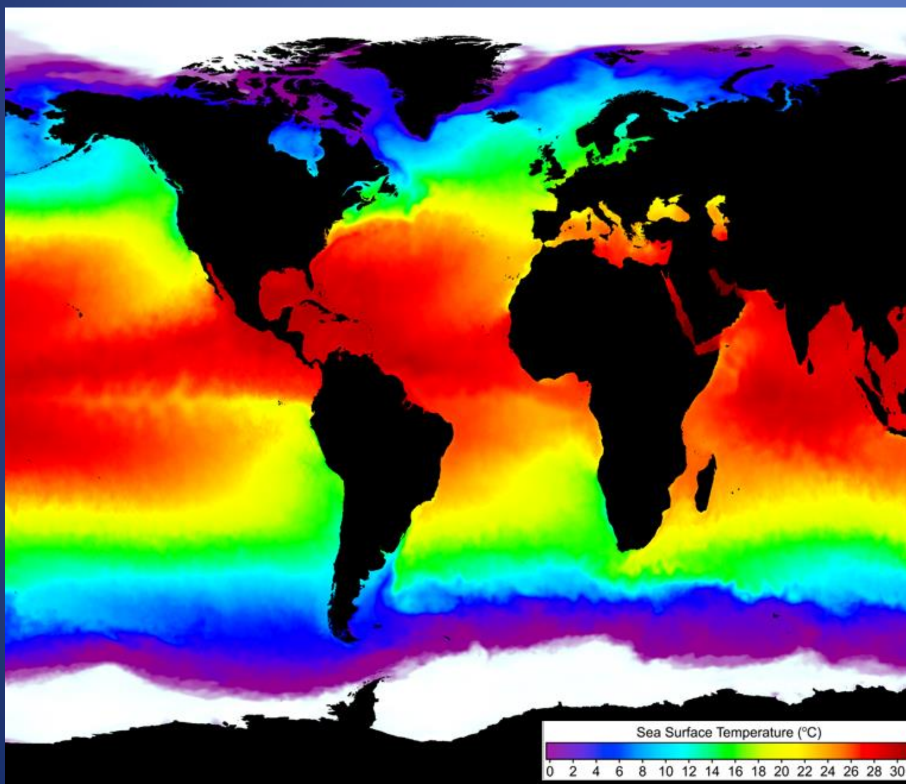
Background on Hurricanes

https://www.wunderground.com/blog/JeffMasters/dry-air-dominates-the-atlantic

Trends in Factors that control frequency and strength

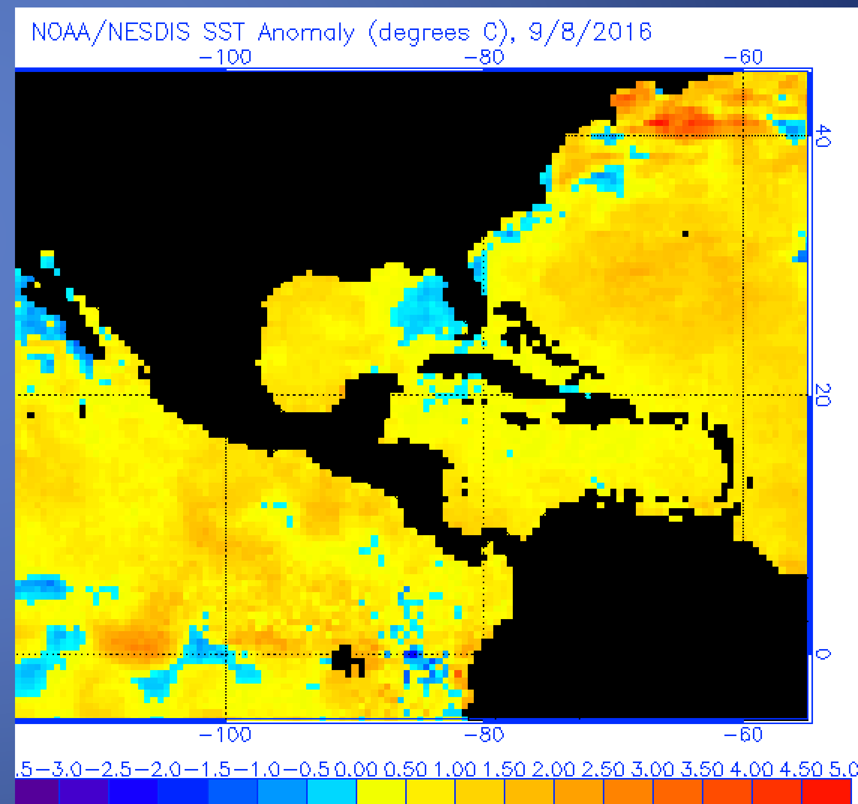
A. Sea Surface Temperature

Average SST temperatures in September



http://www.euroargo-edu.org/argoeu_4.php

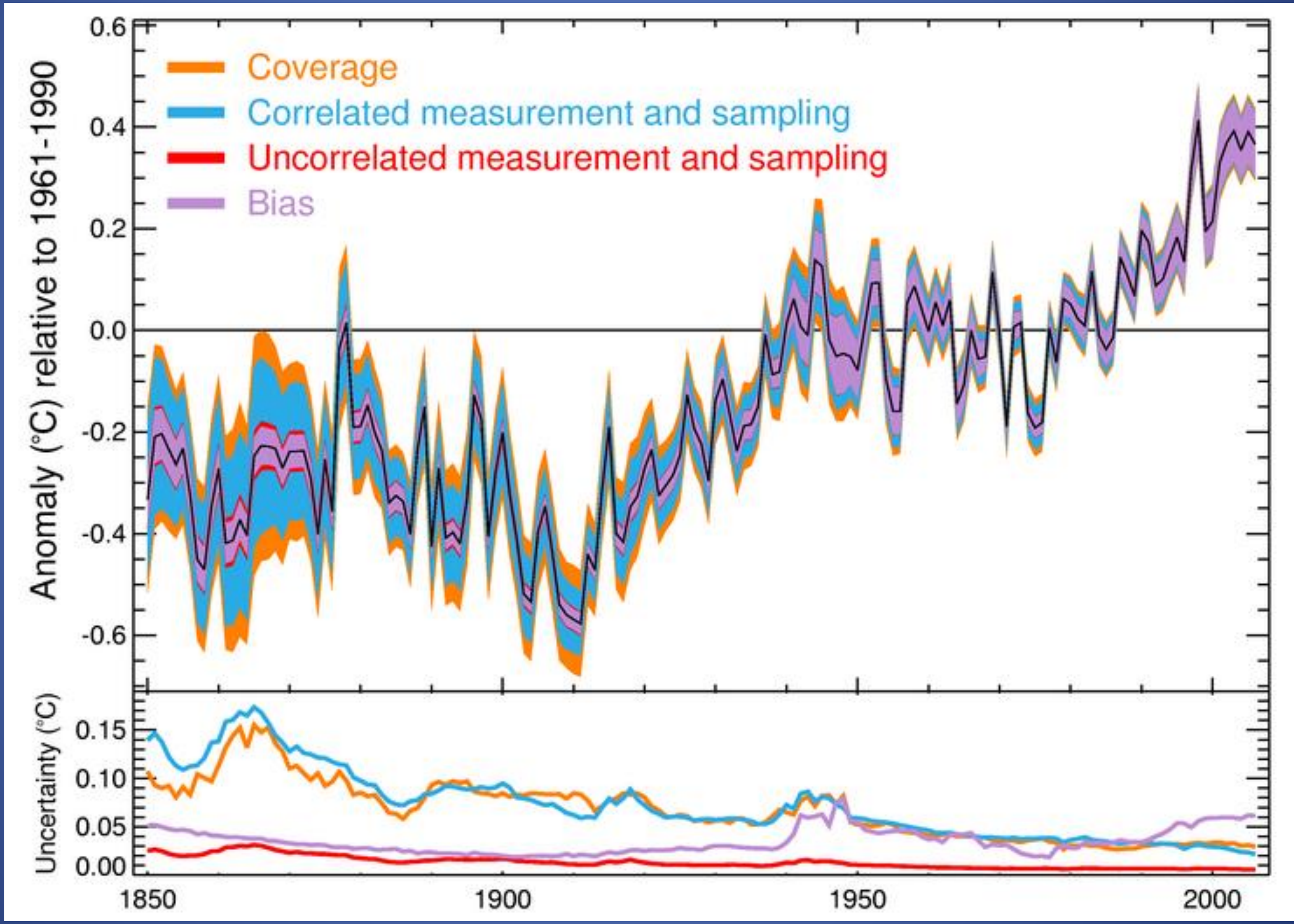
SSTs are above normal much of time now



http://www.ospo.noaa.gov/Products/ocean/sst/anomaly/

Trends in Factors that control frequency and strength

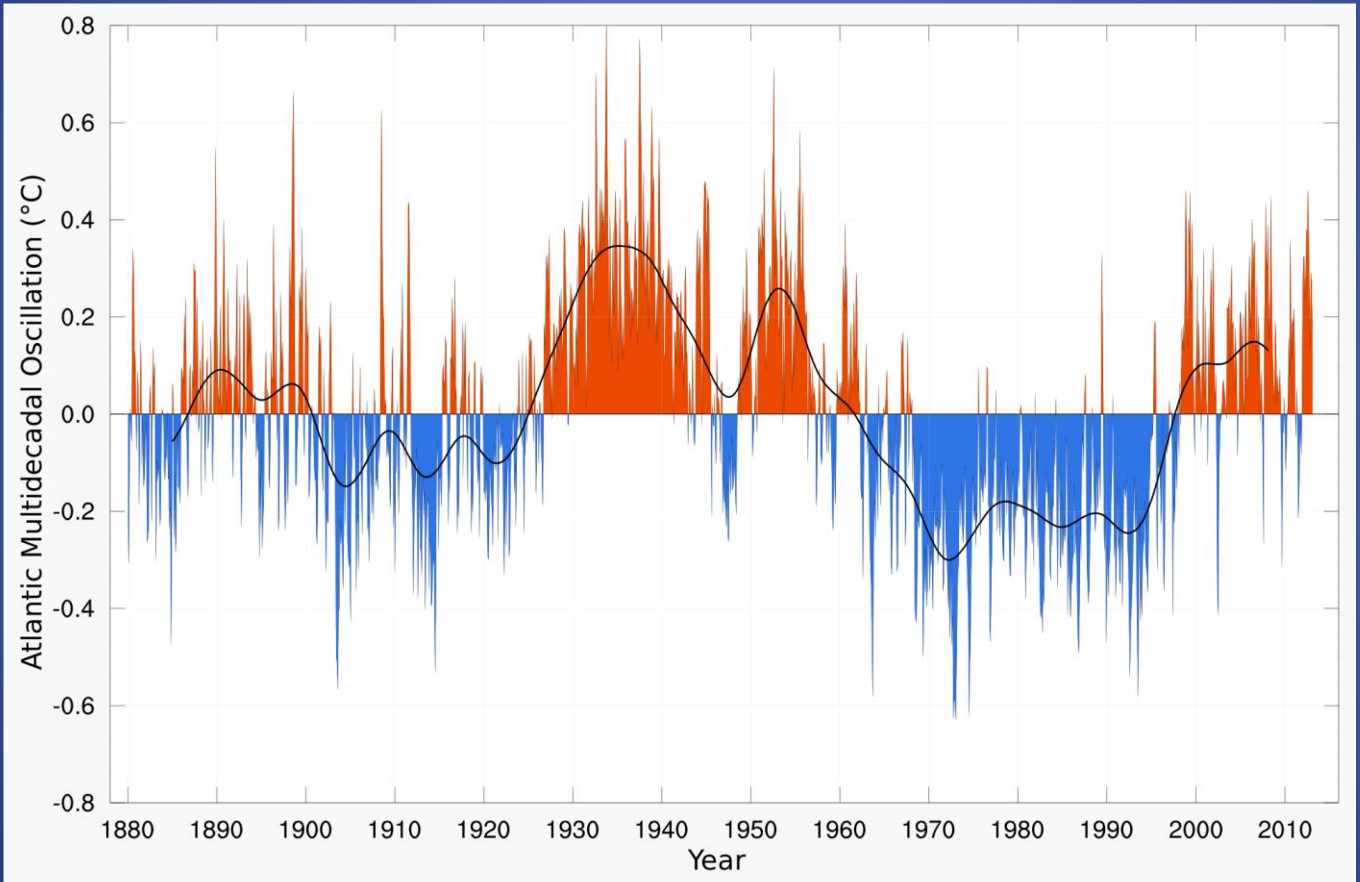
Global Sea Surface Temperature Anomaly



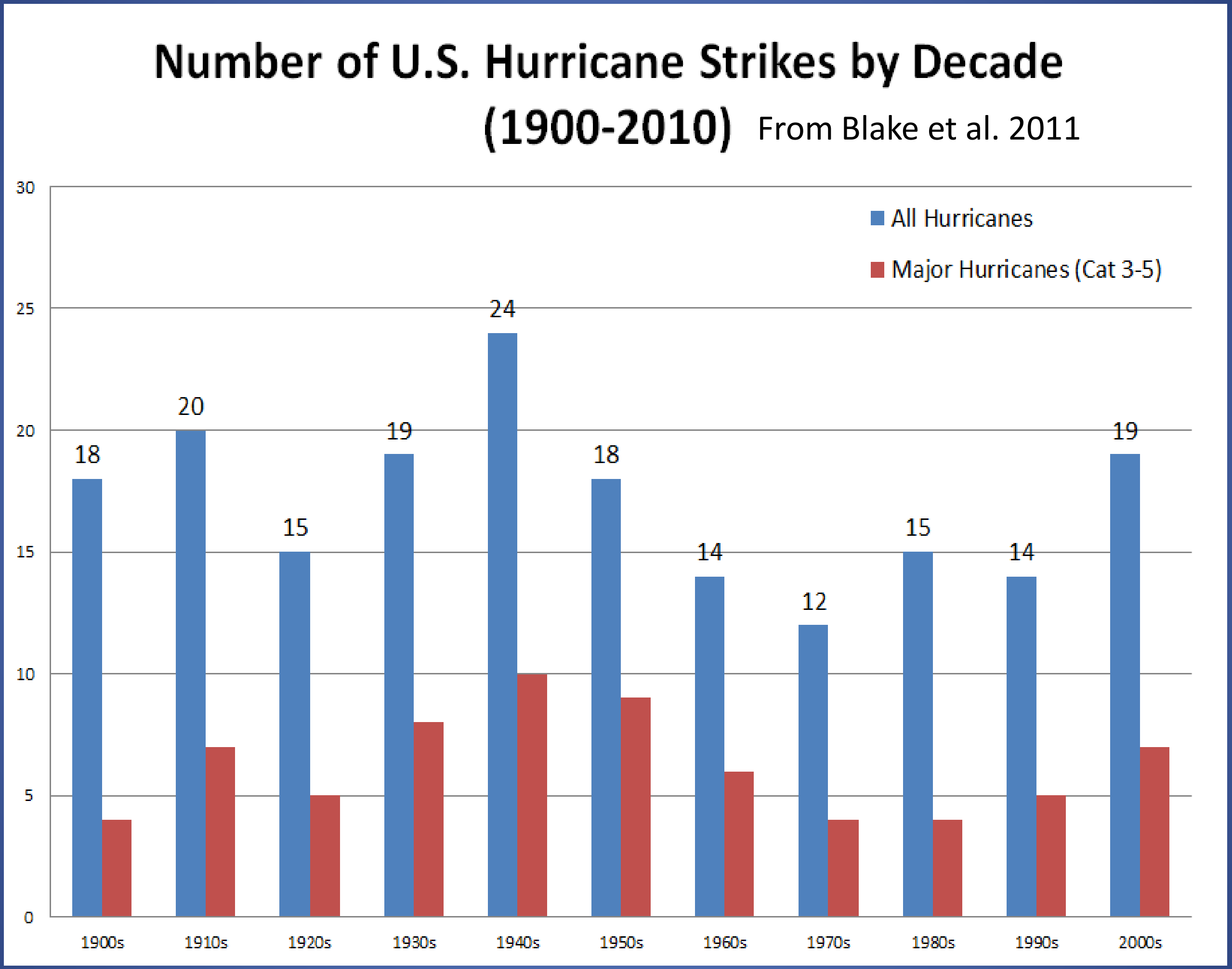
http://www.realclimate.org/index.php/archives/2011/07/revisiting-historical-ocean-surface-temperatures/

Trends in Factors that control frequency and strength

Atlantic Multi-decadal Oscillation (AMO)

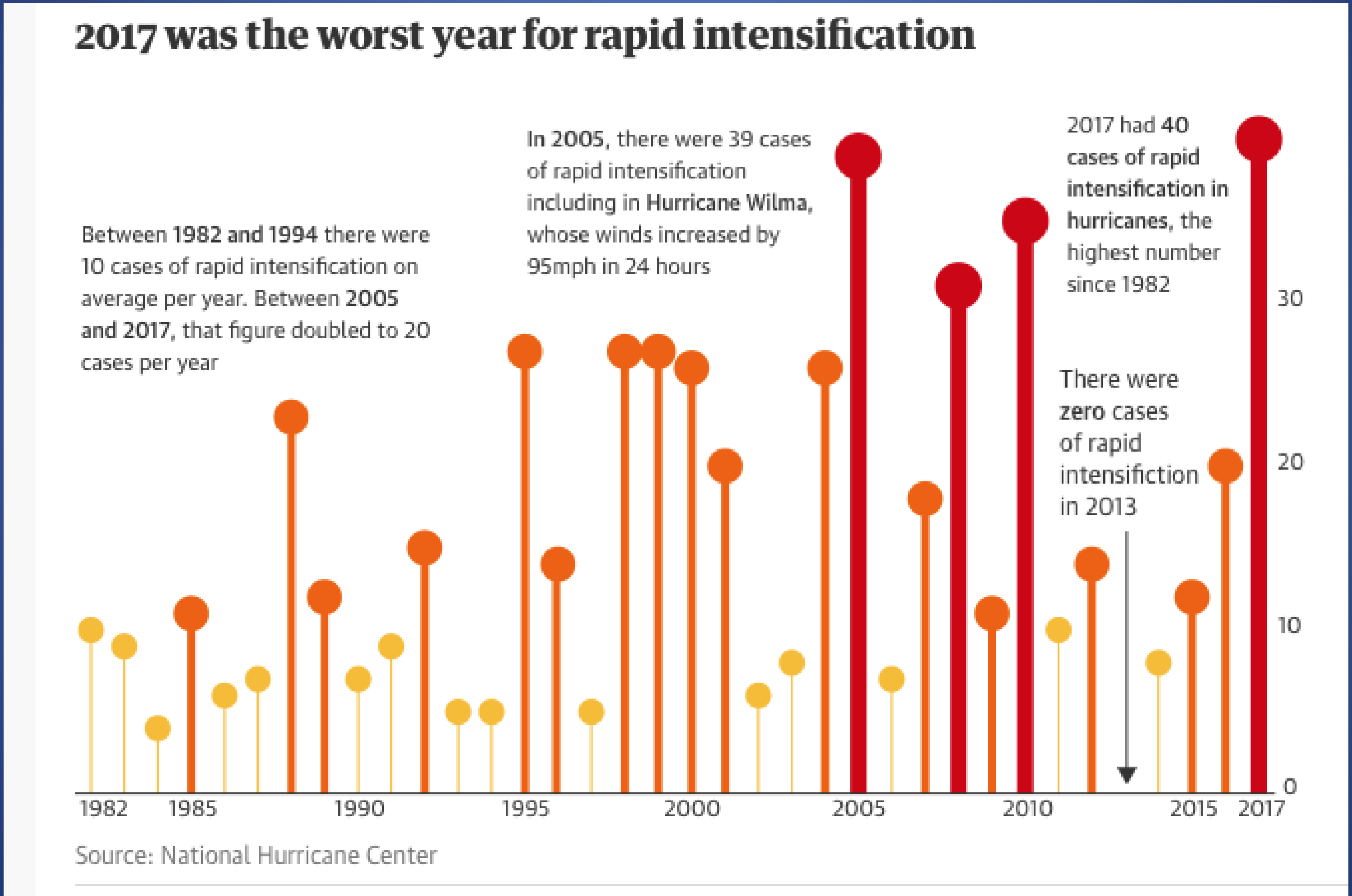


Trends in Factors that control frequency and strength



Trends in Factors that control frequency and strength

- **Increase in cases of rapid intensification**



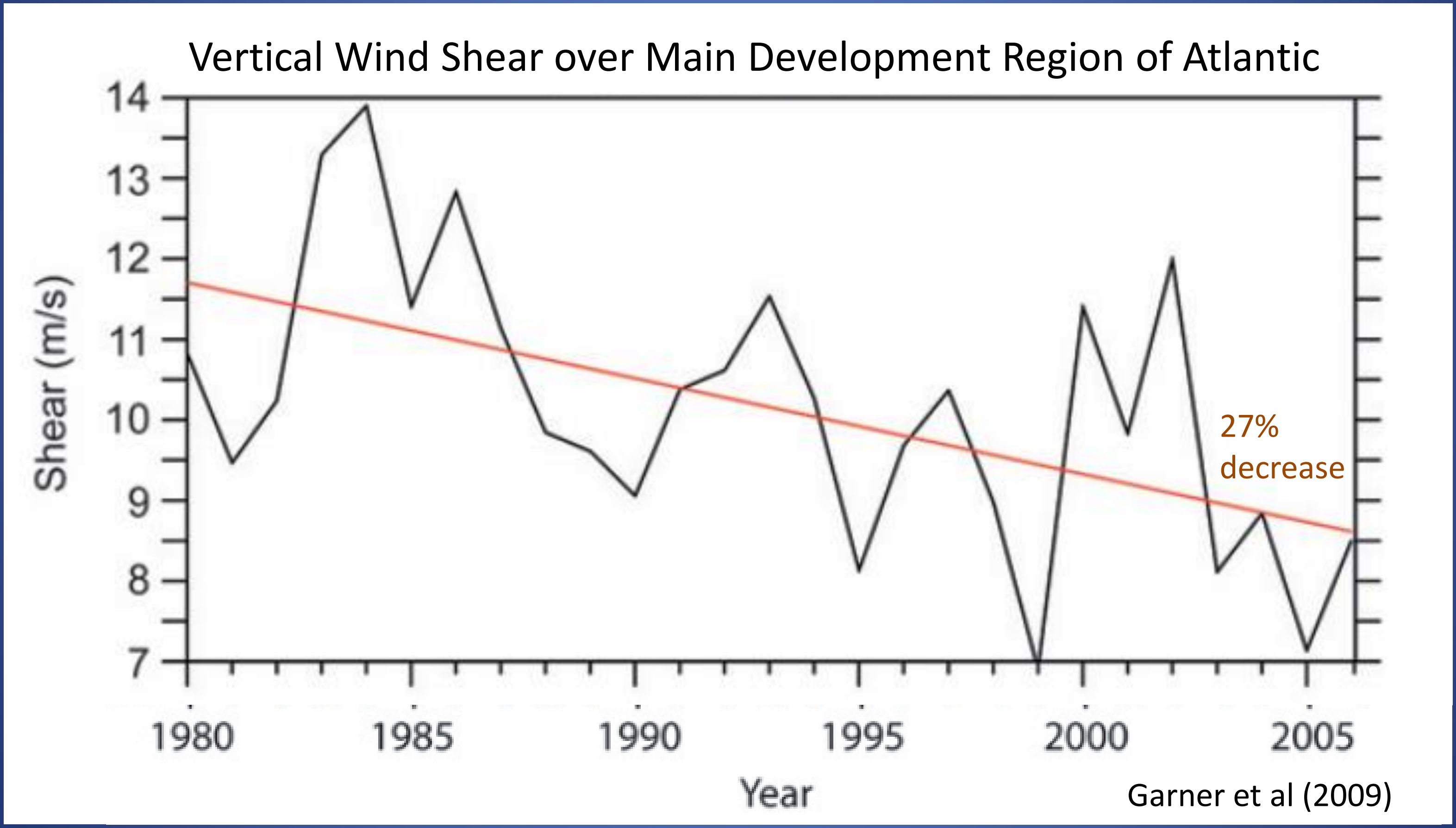
Note that both Michael and Florence intensified rapidly

Trends in Factors that control frequency and strength

Vertical Wind Shear

Trends in Factors that control frequency and strength

Vertical Wind Shear

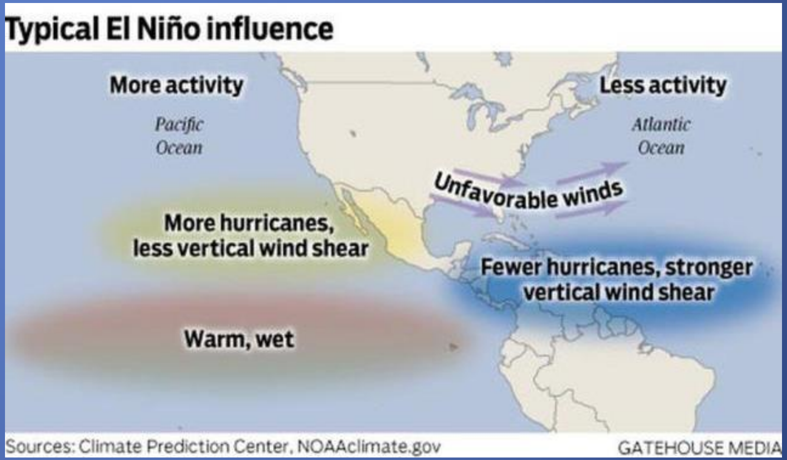


Trends in Factors that control frequency and strength

El Nino and La Nina events affect vertical wind shear and tropical cyclone tracking.

El Nino – Westerly upper level winds over subtropical Atlantic

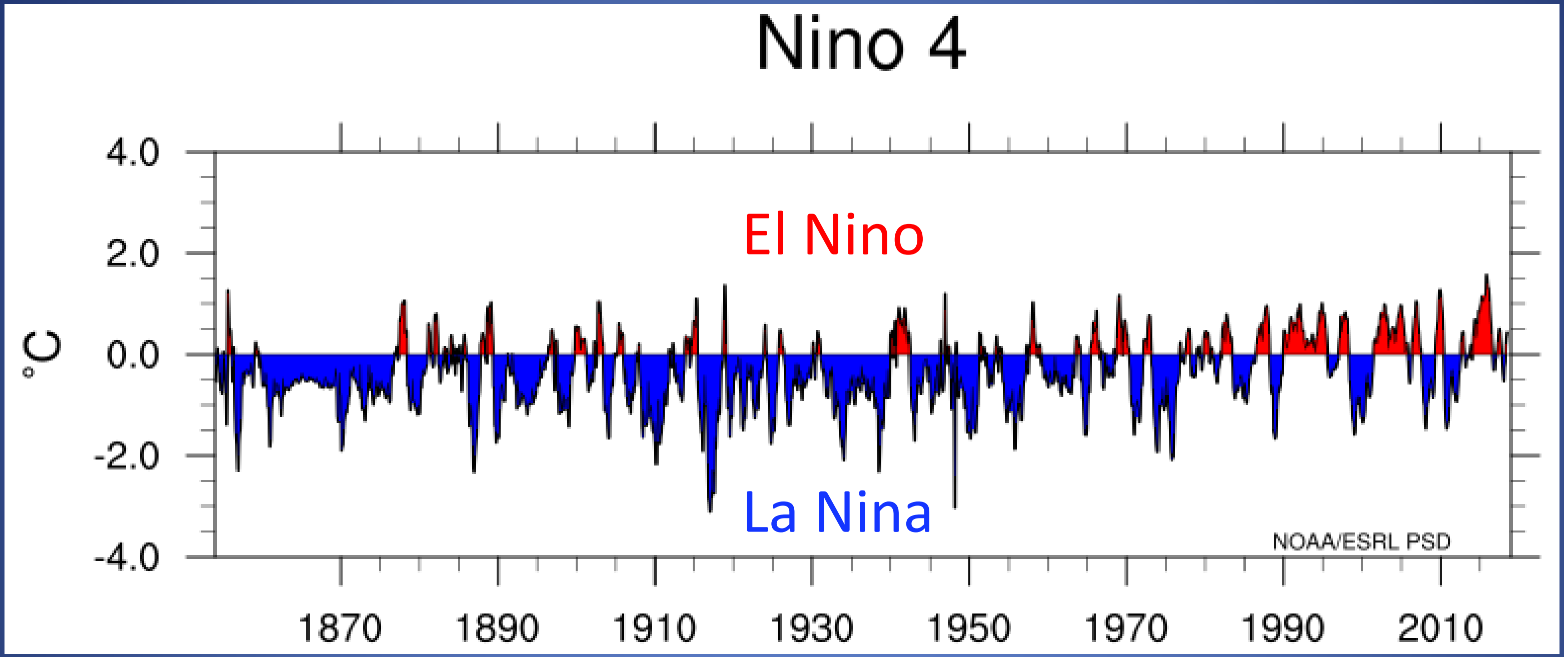
- More vertical wind shear, less hurricanes, & steering of hurricanes away from coast



La Nina – Easterly upper level winds over subtropical Atlantic

- Less vertical wind shear, more hurricanes, more steered towards U.S. coast

Trends in Factors that control frequency and strength

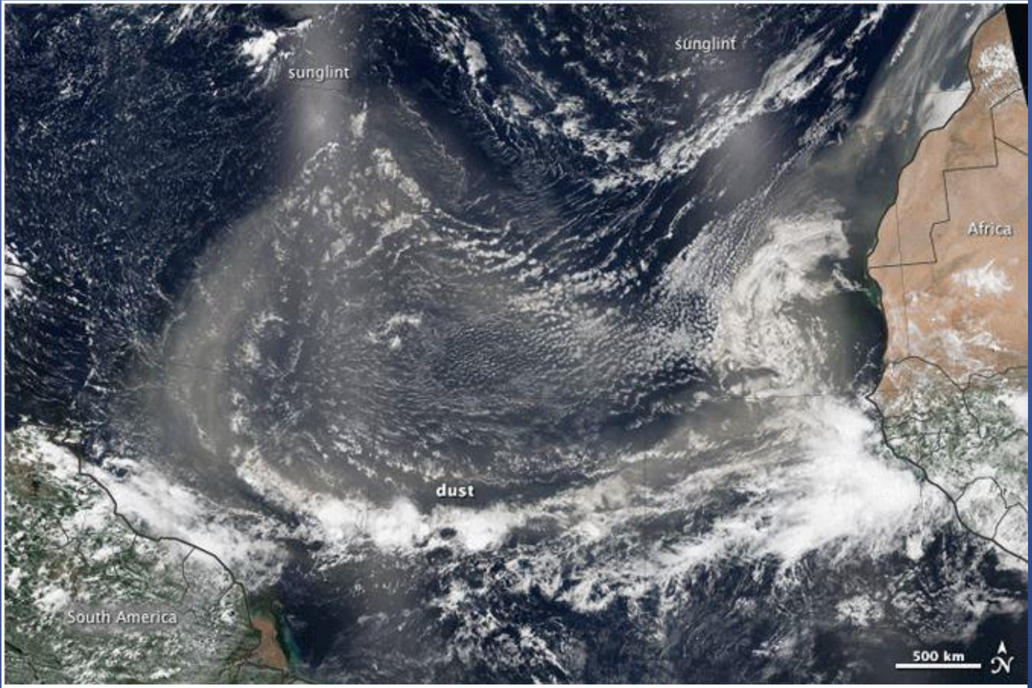


El Nino events have increased in frequency
La Nina events have decreased in frequency

Trends in Factors that control frequency and strength

Atmospheric dust

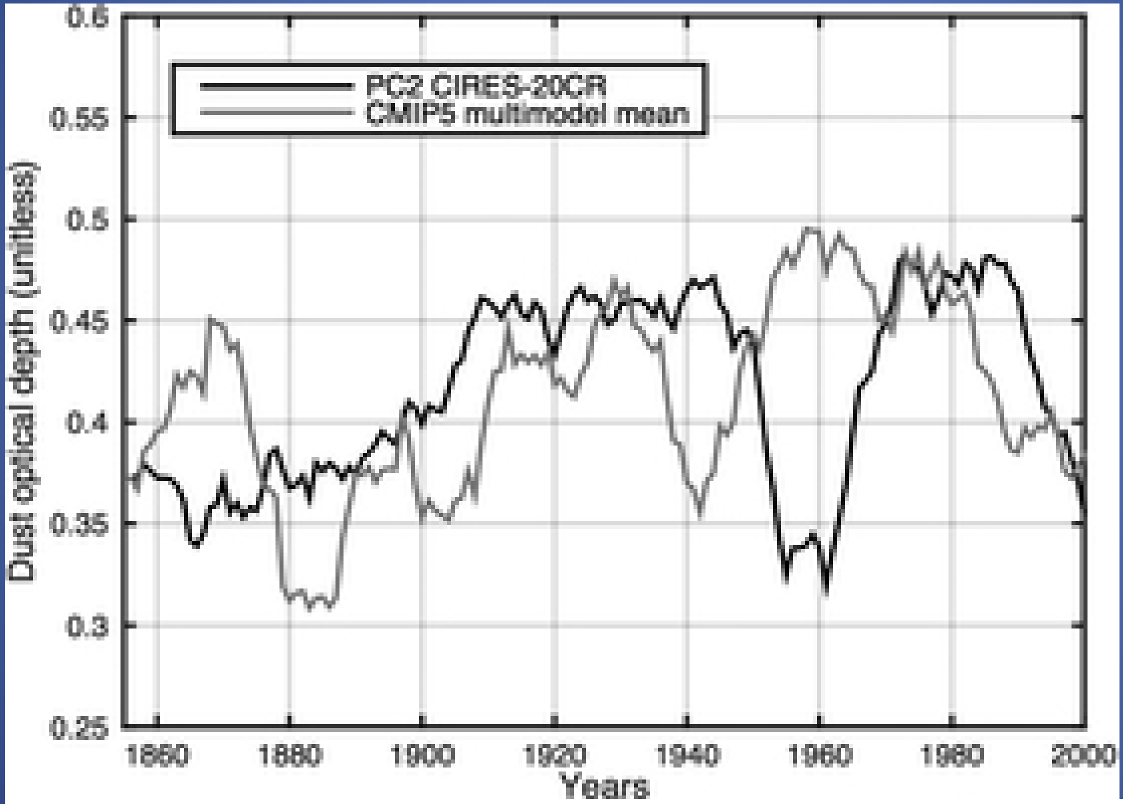
- Dust reflects incoming sunlight → cooler SSTs over periods of weeks/months



http://www.accuweather.com/en/weather-glossary/saharan-dust-how-does-it-devel-1/14307927

Trends in Factors that control frequency and strength

- Saharan dust concentrations affected by many factors



http://www.nature.com/nature/journal/v531/n7595/abs/nature17149.html

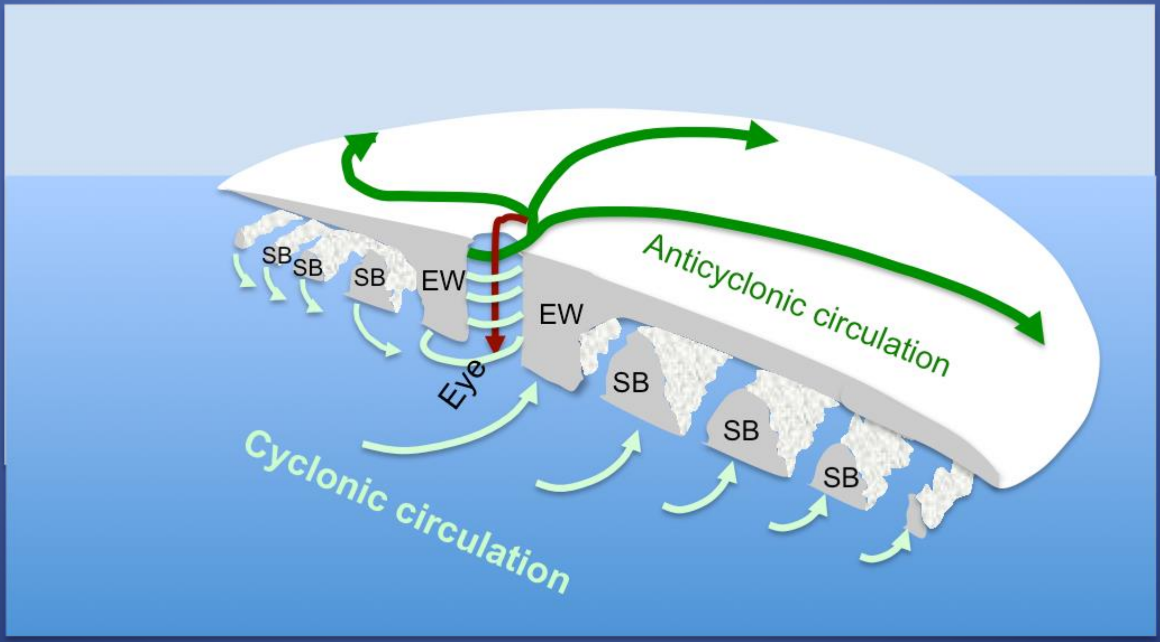
- No significant trend over time

Influences on Heavy Rainfall and Flooding

- Warmer atmosphere can hold more water vapor
  1°C temperature increase = 7% increase in moisture atmosphere can hold

- Warmer Sea Surface Temperature → Greater evaporation rate → More water vapor → Higher rates of precipitation.

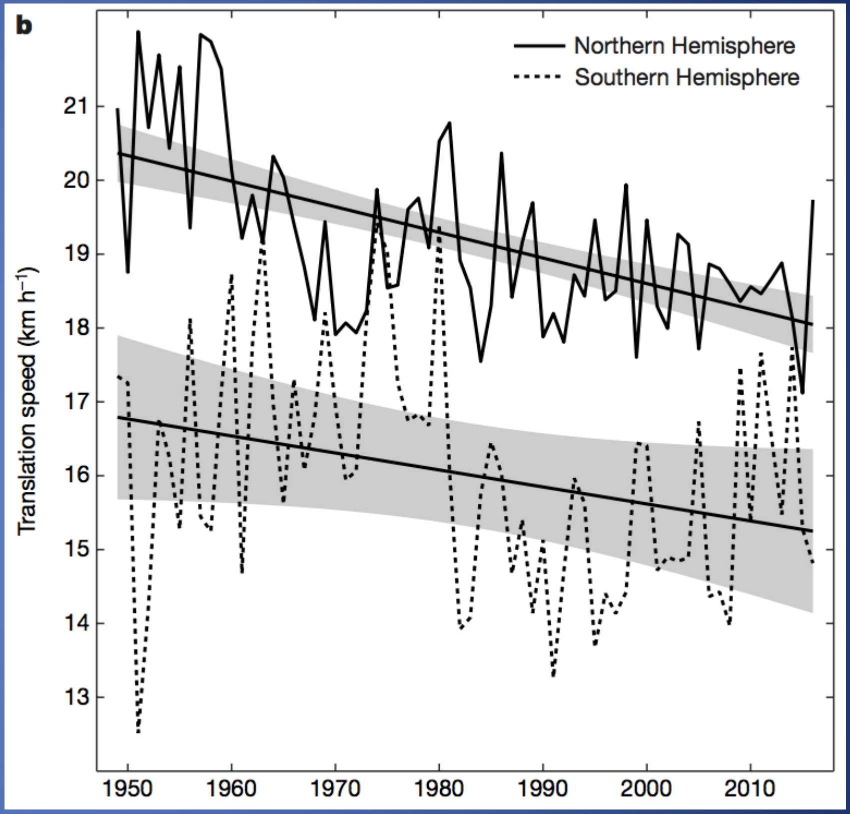
- Hurricanes and tropical storms can therefore produce higher rainfall rates



Influences on Heavy Rainfall and Flooding

Decreases in Tropical Cyclone Translation Speed

-10.0% Globally
-12.2% Northern Hemisphere
-20.0% Land areas around Atlantic Basin

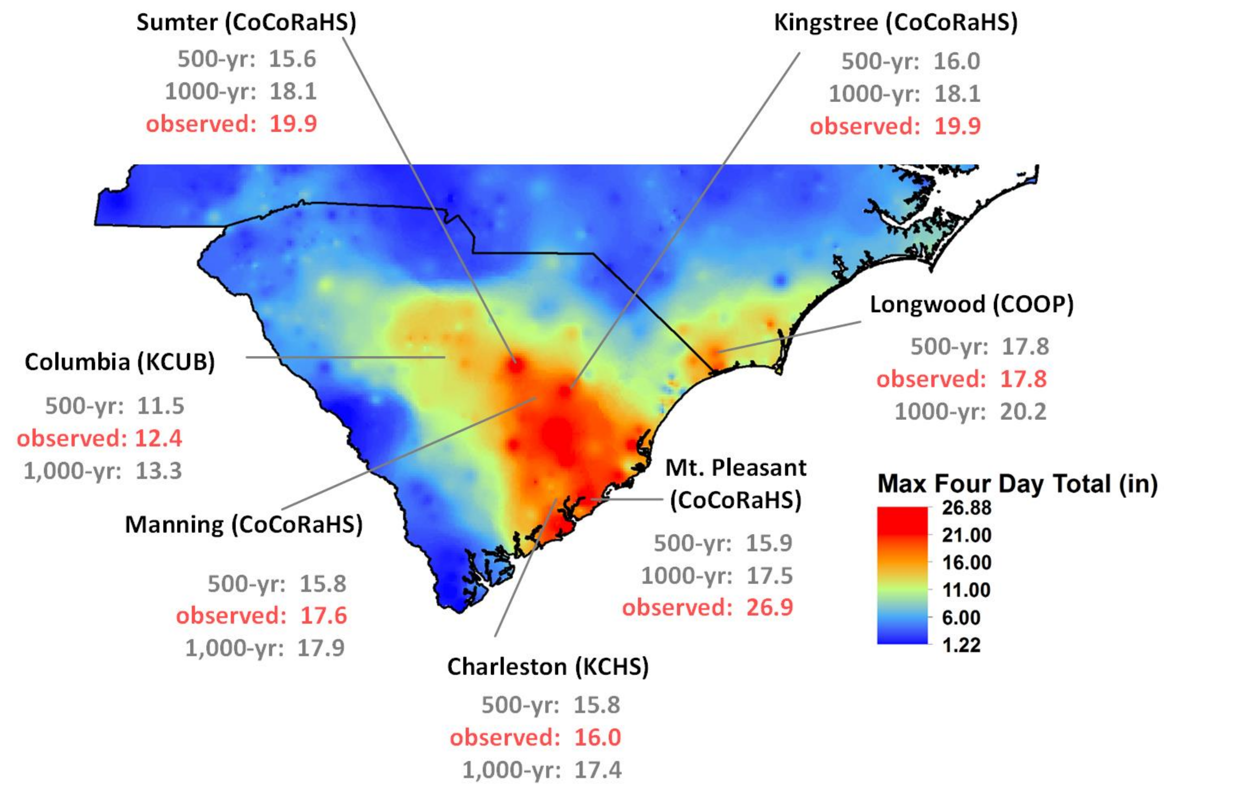


Kossin, James P **Nature (2017)**

More wetter & slower hurricanes → Heavier rainfall rates over a longer duration

Influences on Heavy Rainfall and Flooding

Example: Extreme Precipitation & Flooding Event in October 2015



From Carolinas Integrated Science & Assessment (CISA) report
http://www.cisa.sc.edu/PDFs/October%202015%20Flood%20Event%204%20Pager.pdf

Influences on Heavy Rainfall and Flooding

Example: Extreme Precipitation & Flooding Event in October 2015

Factors contributing to the heavy rainfall: The meteorology

A. Nearly stationary upper level low with persistent lifting across SC

B. Coastal front and low-level jet providing moisture

C. Additional moisture contribution from Hurricane Joaquin

D. Sea surface temperatures much above normal

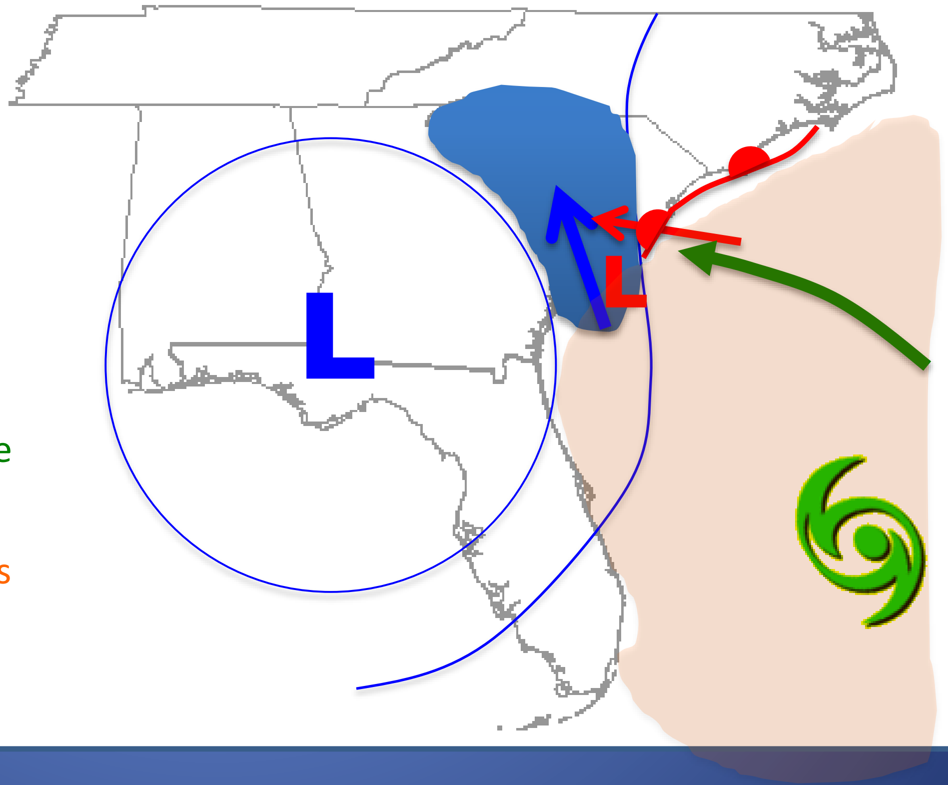
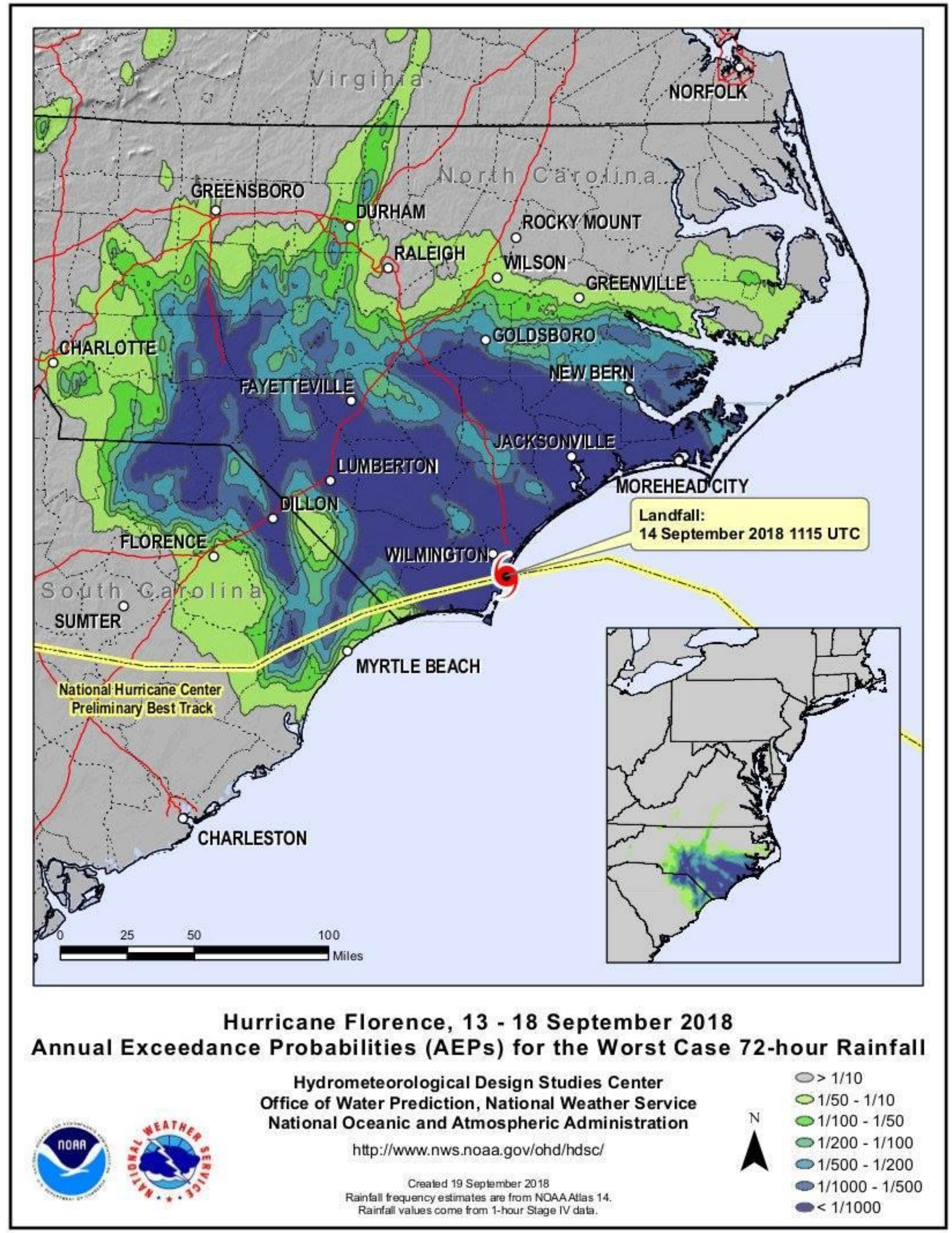


Illustration developed by C.E. Konrad SERCC

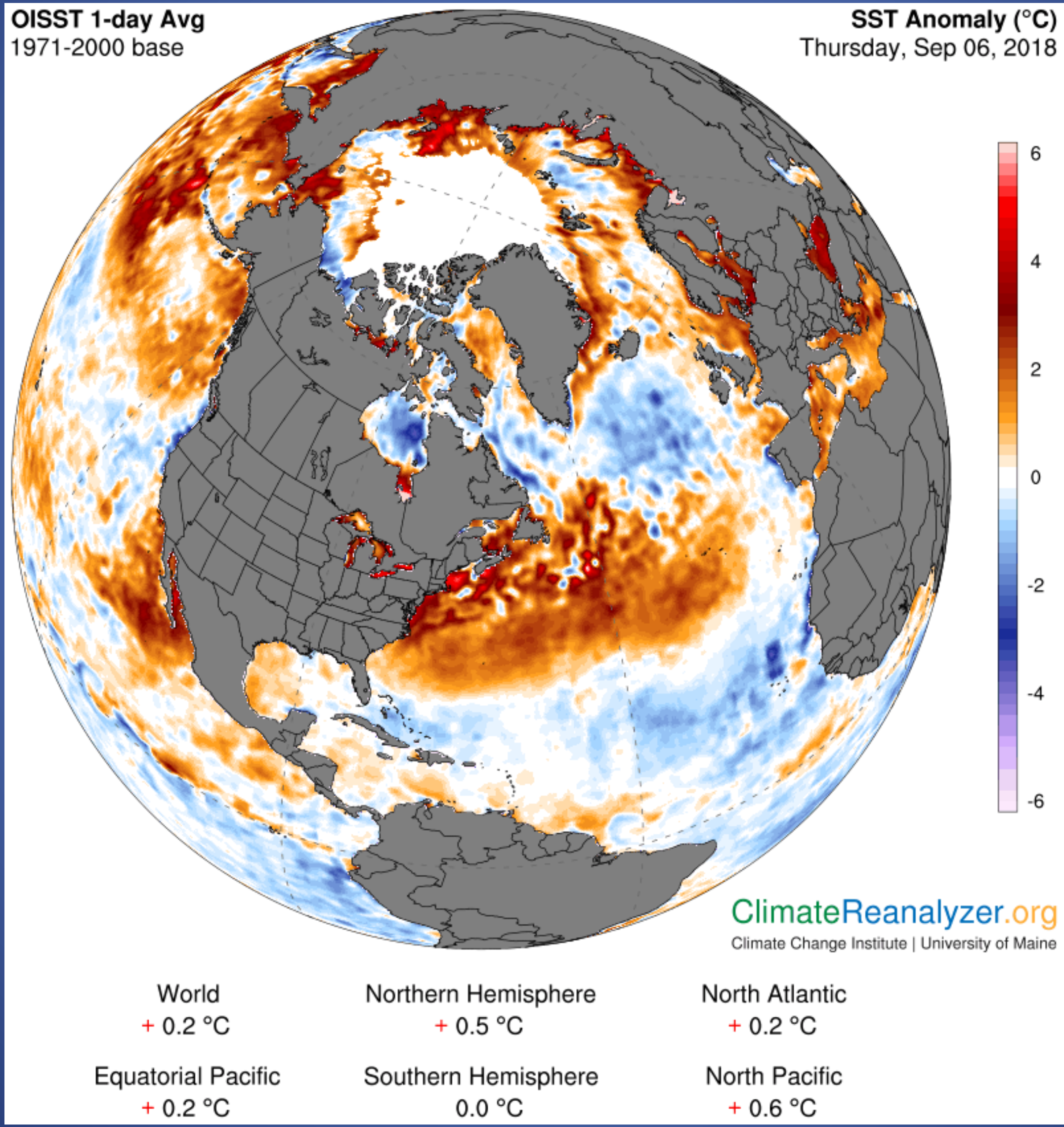
Example: Hurricane Florence

Many areas experienced the 1000 year and longer heavy rain event over a 3 day period



Example: Hurricane Florence

Sea Surface Temperatures above normal



What about the Future?

Model projections

a. All models project increases in sea surface temperatures (SSTs): Hurricanes ↑

b. Many models project increases in wind shear: Hurricanes ↓

c. Many models project decreases in Saharan dust: Hurricanes ↑

Various questions remain:

e.g. What about future frequencies of El Nino and La Nina events?

- No change to slight decrease in tropical cyclones and weak hurricanes
- Increase in strong hurricanes

What about the future?

Stronger & wetter hurricanes coupled with sea level rise and coastal development & population growth → Big increase in extreme flooding.

The costliest hurricanes to affect the United States (1900-2017)

Name	Damage	Year	Category (at US Landfall)
Katrina	$160bn	2005	3
Harvey	$125bn	2017	4
Maria	$90bn	2017	4
Sandy	$70.2bn	2012	1
Irma	$50bn	2017	4
Andrew	$47.79bn	1992	5
Ike	$34.8bn	2008	2
Ivan	$27.06bn	2004	3
Wilma	$24.32bn	2005	3
Rita	$23.68bn	2005	3

THANK YOU

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