

# Deltas: Climate and Hurricane Risks

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## Potential Impacts on Deltas

Sea-Level Rise, Flooding,  
Storm Surge, Waves

**Possible Climatic Changes**  
*(Emphasis is on North Atlantic)*

**Rita**  
23 September

**Katrina**  
28 August

**Wilma**  
21 October

**Emily**  
17 July



# Hurricane Impacts on Deltas

**Winds:**

**Storm Surge**

**Wave Action**

**Rainfall and Fresh Water Flooding**



# Storm Surge



- Comprised of lifting of ocean over a large area, plus “set up” in coastal zones from breaking waves;
- Over 30 ft !!! And that does not include waves
- Allows breaking waves to move inland;
- Very dangerous;
- Responsible for ~1 million deaths in the last 50 years, mostly in Delta regions.



# Past Hurricane Climate Changes

## Summary:

- **Frequency:** has increased in North Atlantic, ambiguous elsewhere, with global total roughly constant;
- **Intensity:** has not experienced any sustained long-period change, but increased major hurricanes in last few decades;
- **Rainfall:** has probably increased, unable to rigorously confirm.
- **Distributions:** possible increase in near equatorial (especially for major hurricanes), and subtropical activity



# Potential Future Hurricane Changes

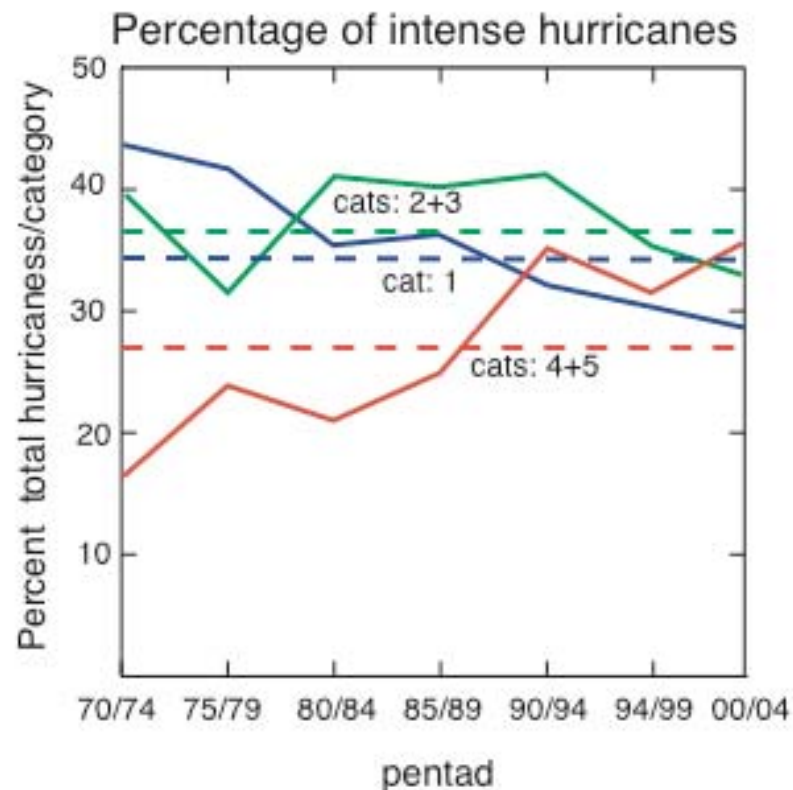
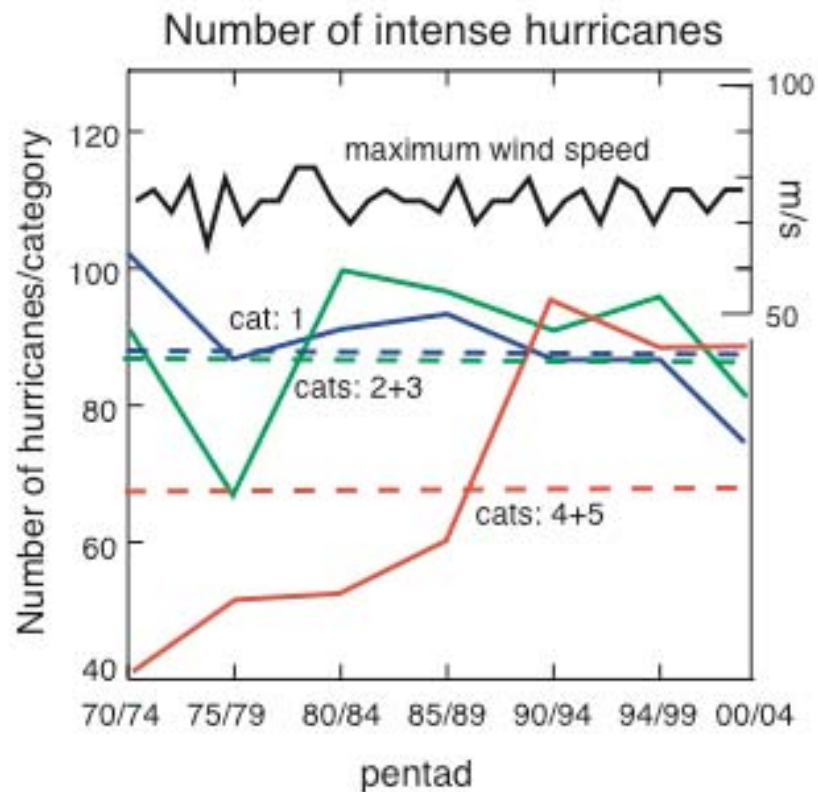
## Summary

- **Frequency:** likely global decrease, regional effects poorly known;
- **Intensity:** poorly handled by current models; 5-10% increase in maximum for each 1°C SST increase, possible distribution shift towards more intense systems;
- **Rainfall:** Increase of ~7% for each 1°C SST increase, reasonably firm result;
- **Distributions:** No idea.

**Ancillary Impact: Sea Level Rise of >1m**



# Past Global Changes

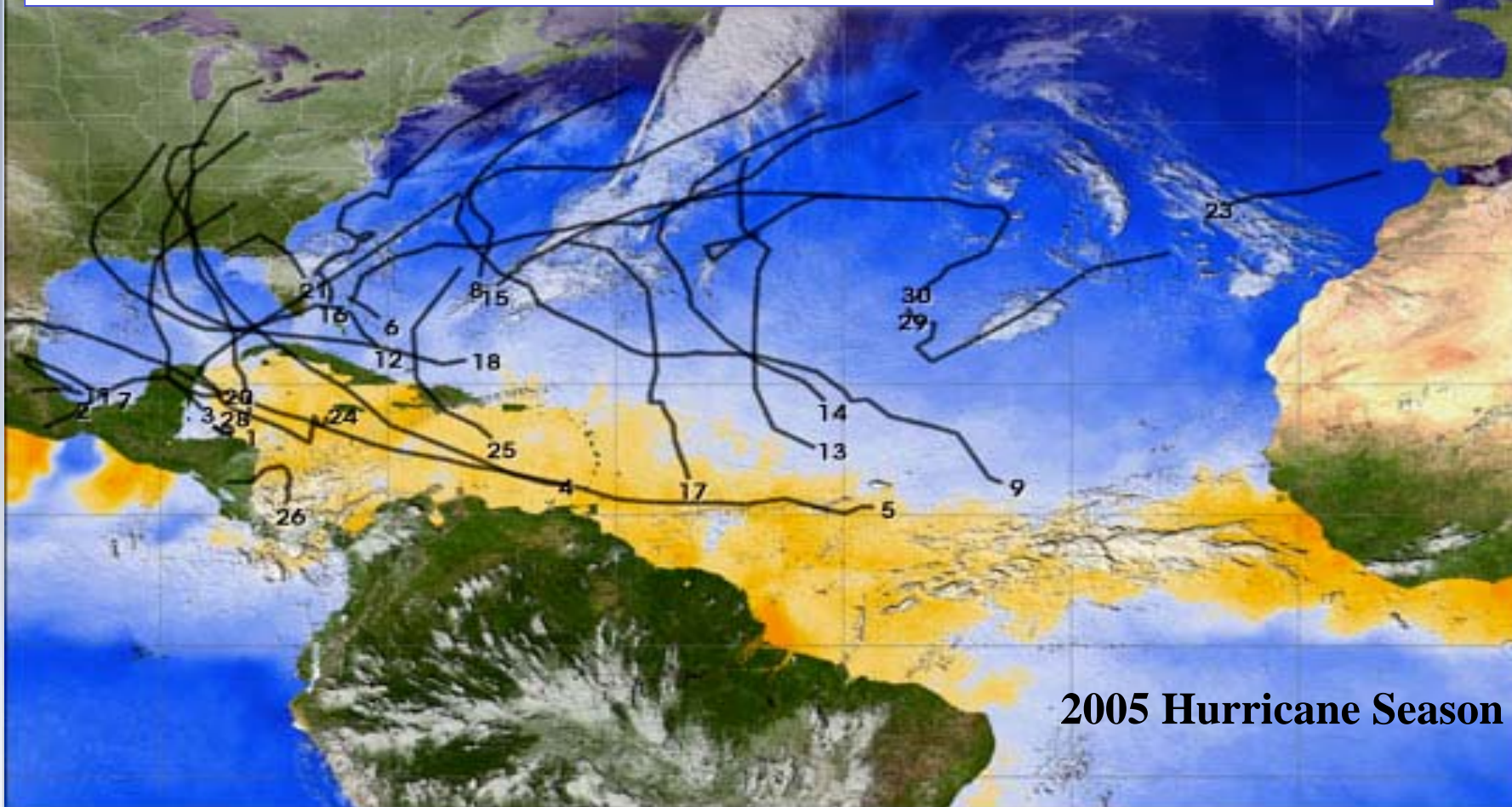


Webster et al 2005



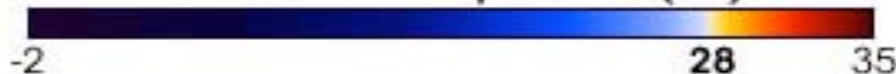
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# North Atlantic Changes



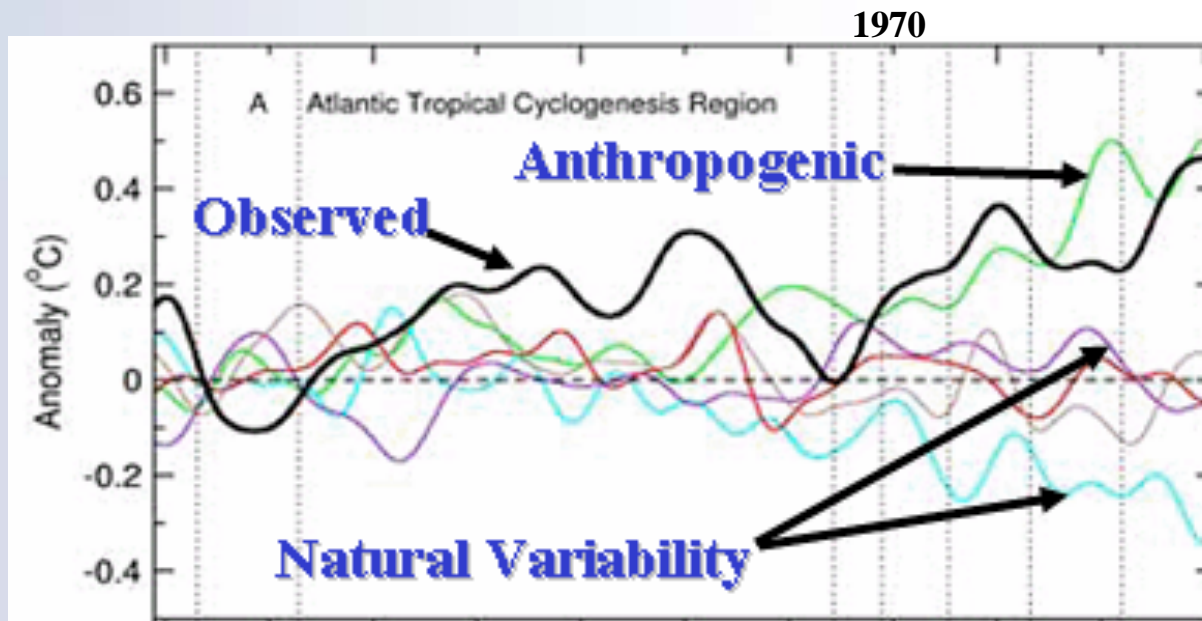
2005 Hurricane Season

sea surface temperature (°C)



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# SST Changes in the eastern North Atlantic



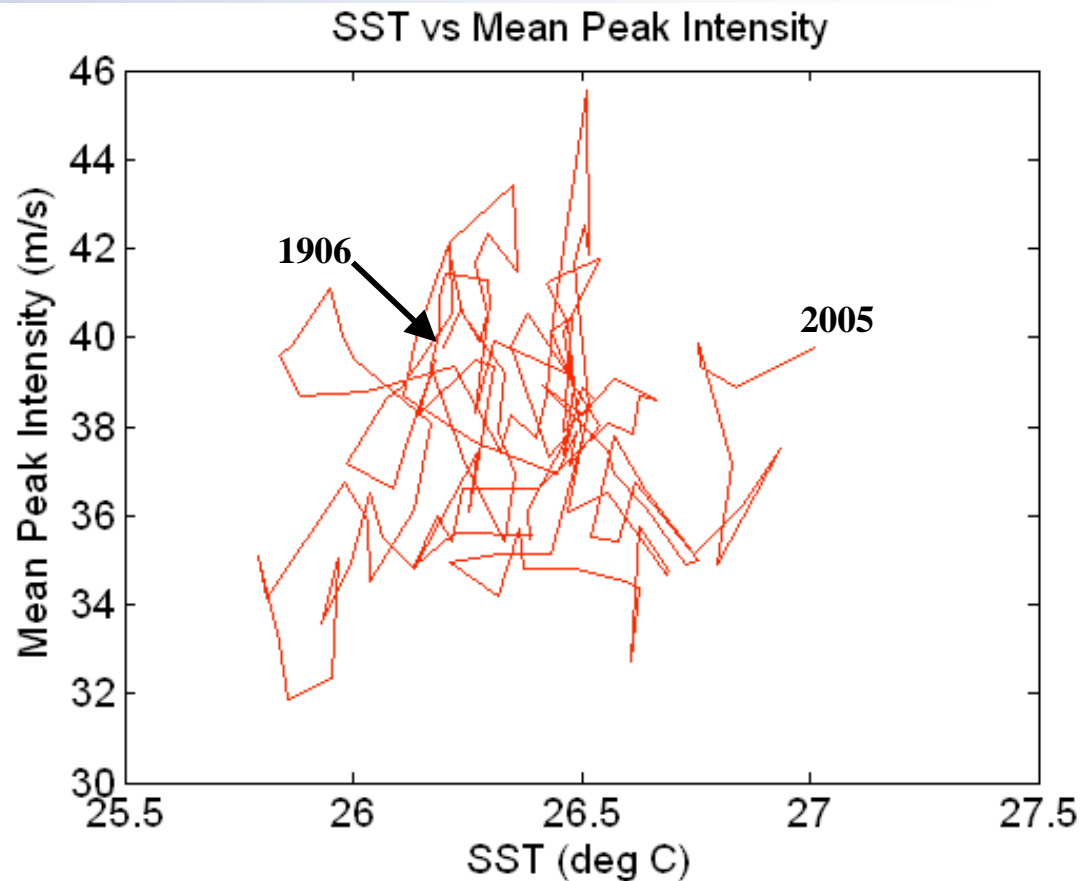
Santer et al (2006) clearly confirmed that the Meehl et al (2006) results for the globe are also applicable to the cyclone development regions.

The bulk of the warming since 1970 is due to anthropogenic effects.





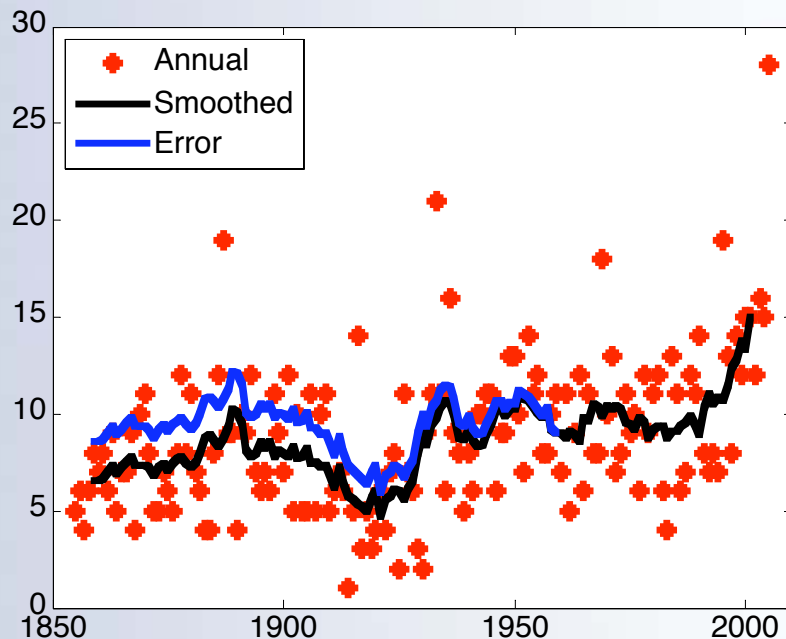
# Mean Peak Intensity



**No real change in peak intensity since 1906 as SST has increased, as predicted by earlier studies (e.g. Henderson-Sellers et al 1998)**



# North Atlantic Data: Frequency



## Missing Tropical Cyclones:

- Nybourg et al (2007): ~8-10 before 1945
- Landsea et al (2004): 0-6 before 1900, 0-4 up to 1945
- Landsea (2007): 2-4 before 1960
- Chang and Guo (2007): 1-2 before 1920 dropping to 0 by 1960
- Vecchi and Knutson (2007): 2.5 around 1900 dropping to 0 by 1960
- Holland (2007): <2 before 1900 dropping to 0 by 1950.
- Neumann (1999): 1 in early years
- Mann et al (2007): 1 around 1920 dropping to 0 by 1950

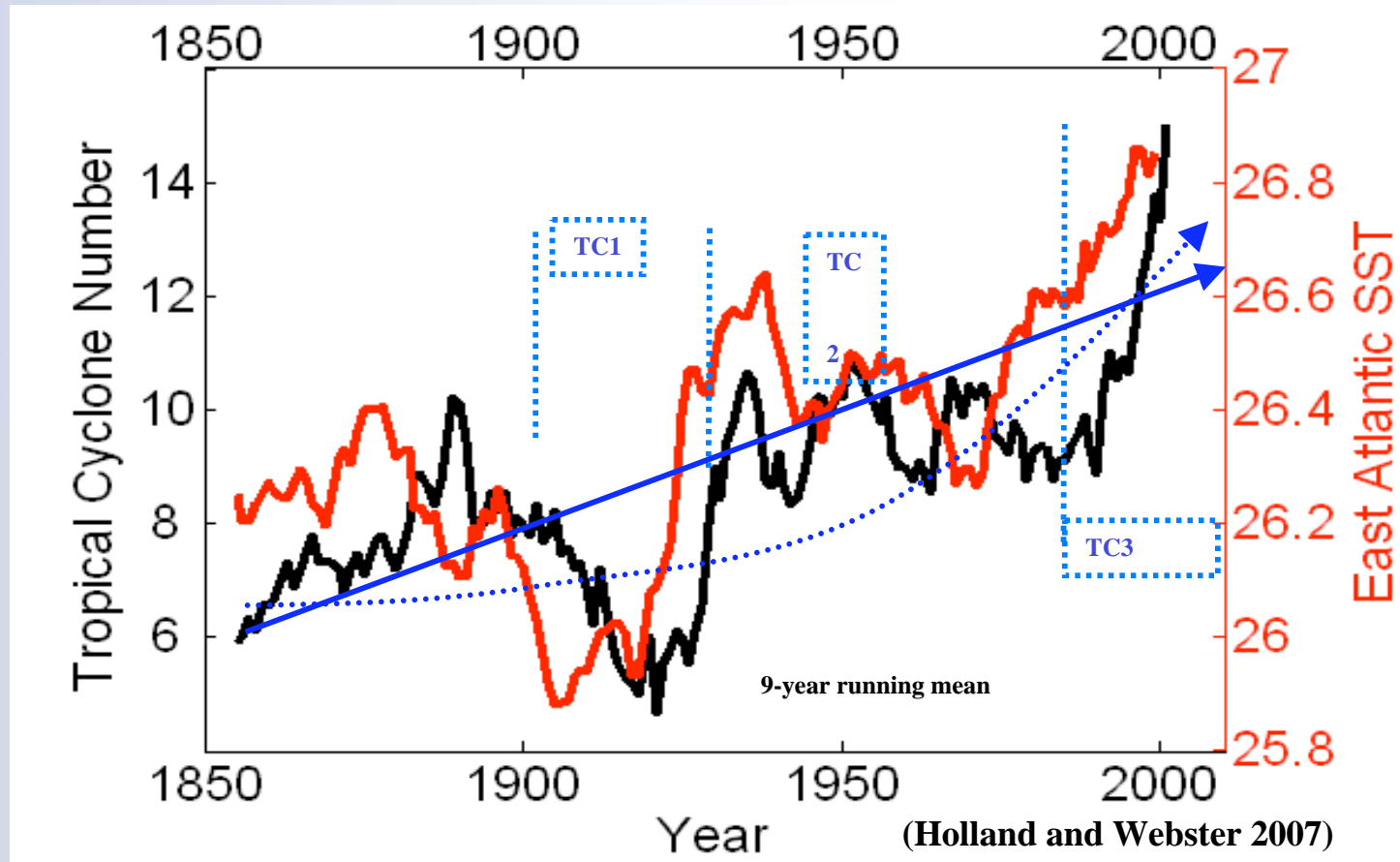
**Conclusion:** 1-2 cyclones per year missed in the early 1900s, perhaps up to 3 in late 1800s.

Anything < 2 leaves a significant linear upward trend since the late 1850s

Anything < 3 leaves a significant upward linear trend since 1905



# Past North Atlantic Changes

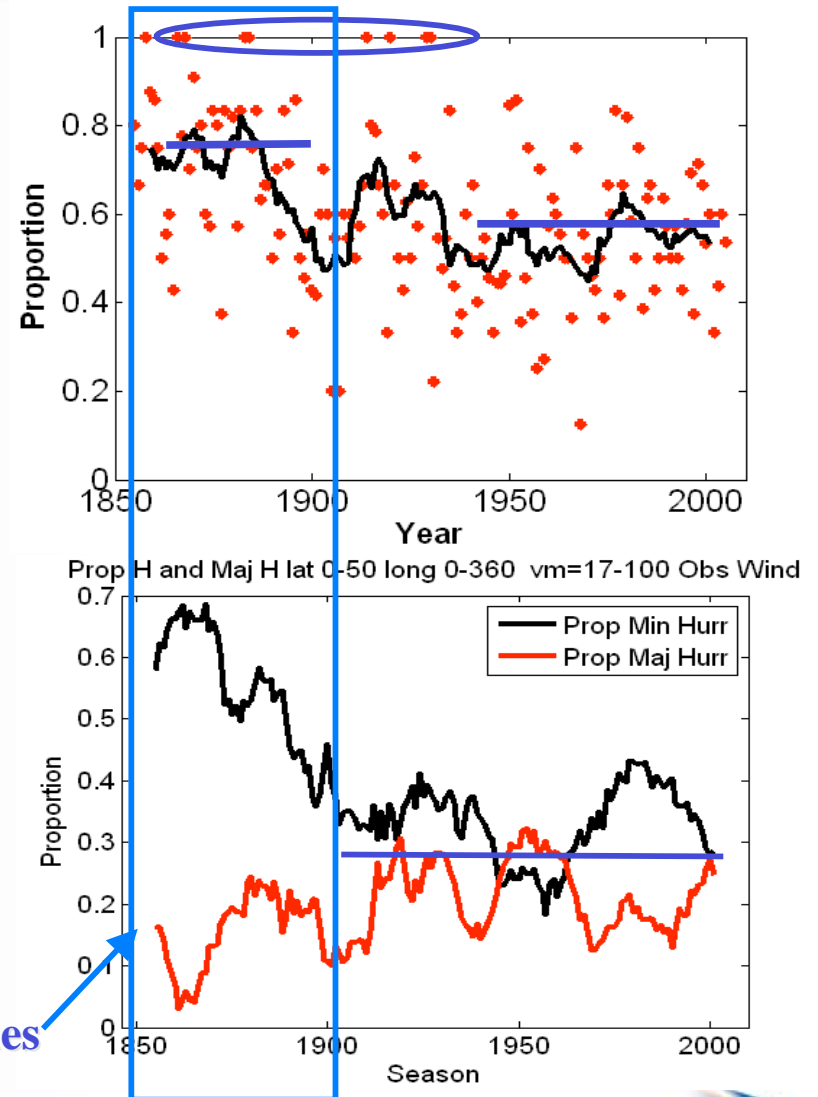


Based on the archived data an accelerating upward trend is one logical choice, though a series of steps is a more logical choice (both TCs and SSTs)



# Past Hurricane Proportions

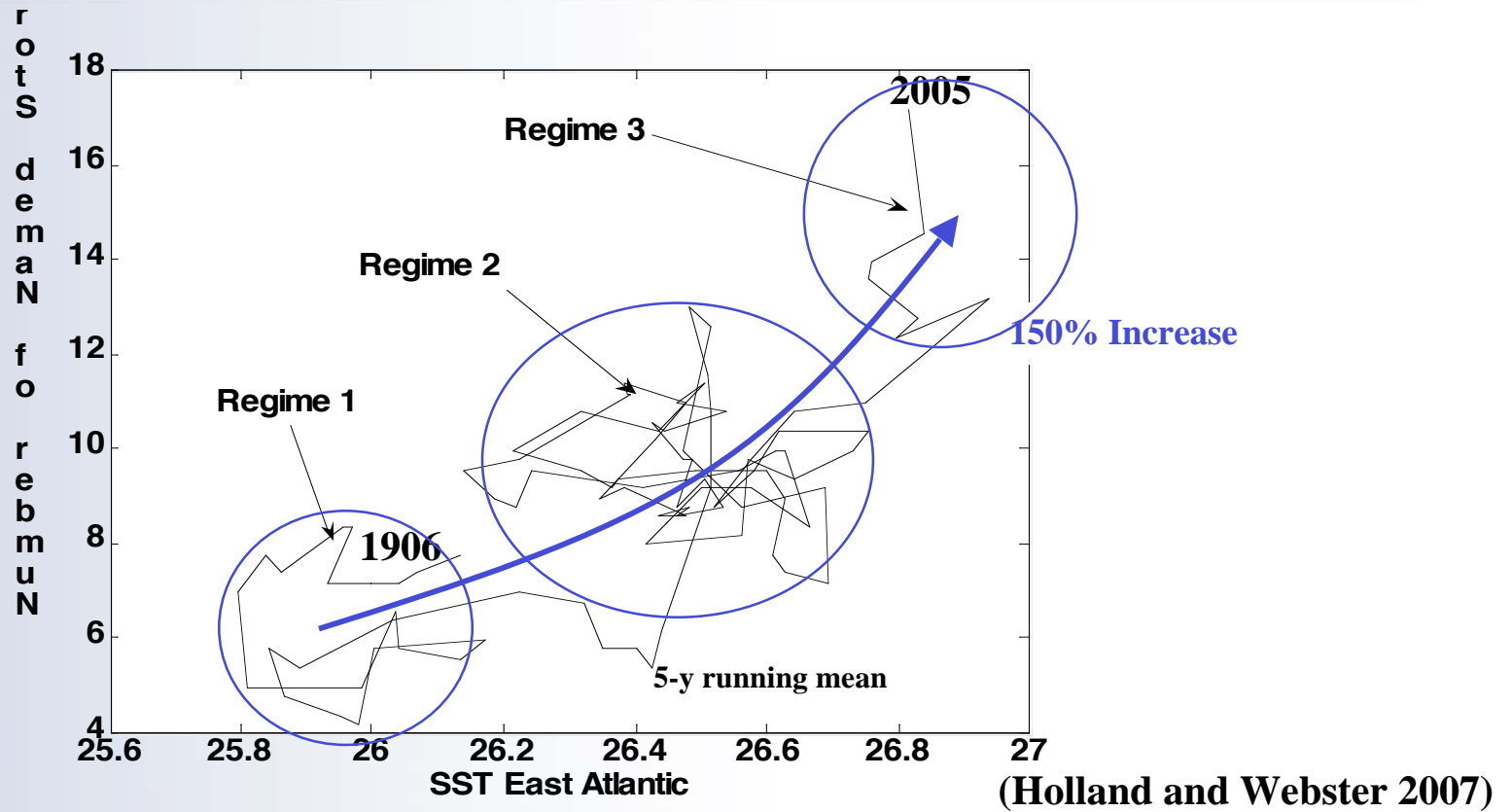
- **Stable proportions of hurricanes to all tropical cyclones over the past 50-100 years (the higher earlier proportions are considered due to analysis errors);**
- **Stable major hurricane proportions but with a marked, multi-decadal oscillation (peaks associated with equatorial developments and expansion of the warm pool).**



Data Issues



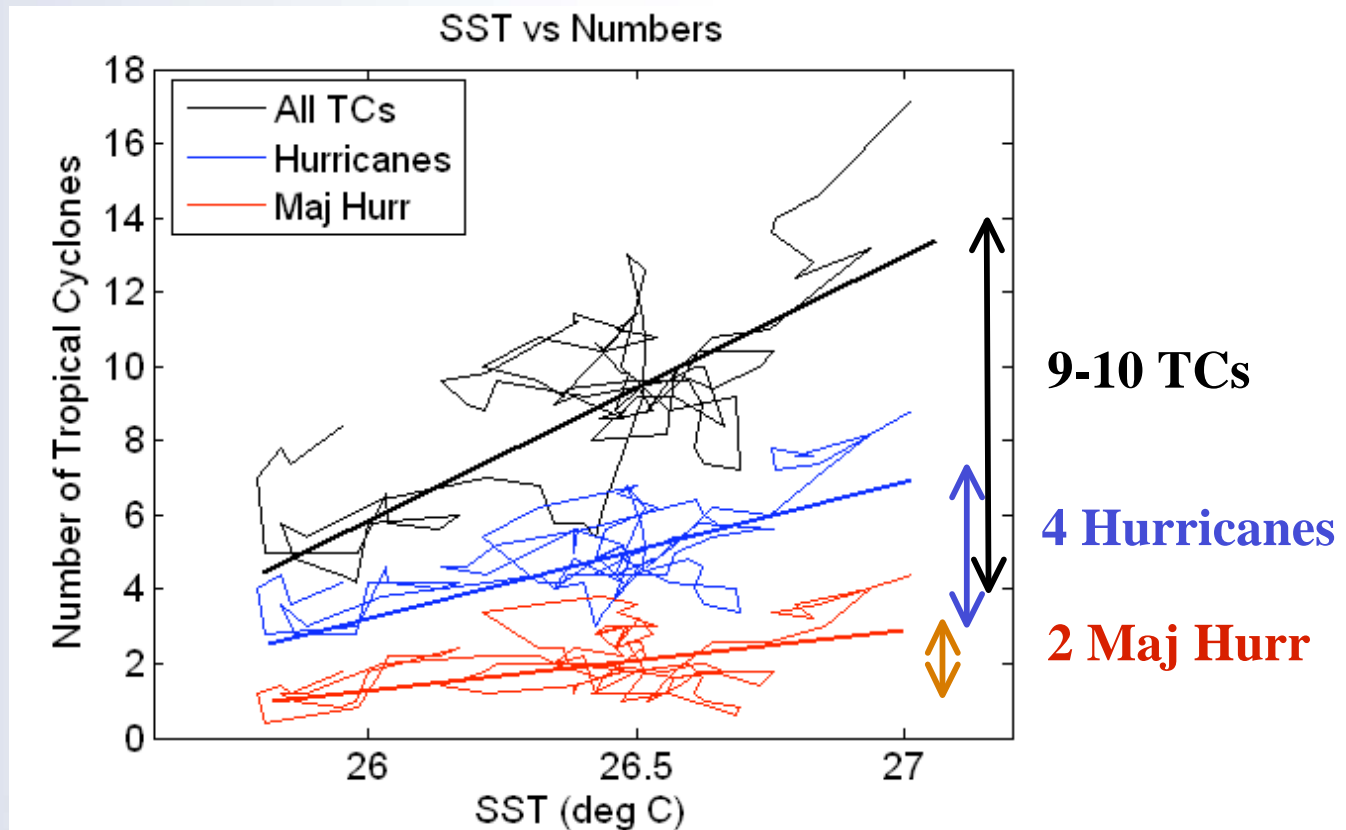
# The SST/Tropical Cyclone Relationship



*We emphasize that the SST-TC relationship is not entirely direct, but also arises from related atmospheric environmental changes (e.g. Goldenberg et al 2001; Delworth 2006; Kossin and Vimont 2007; Holland and Webster 2007b).*



# The SST/TC, Hurr, Maj Hurr Relationship

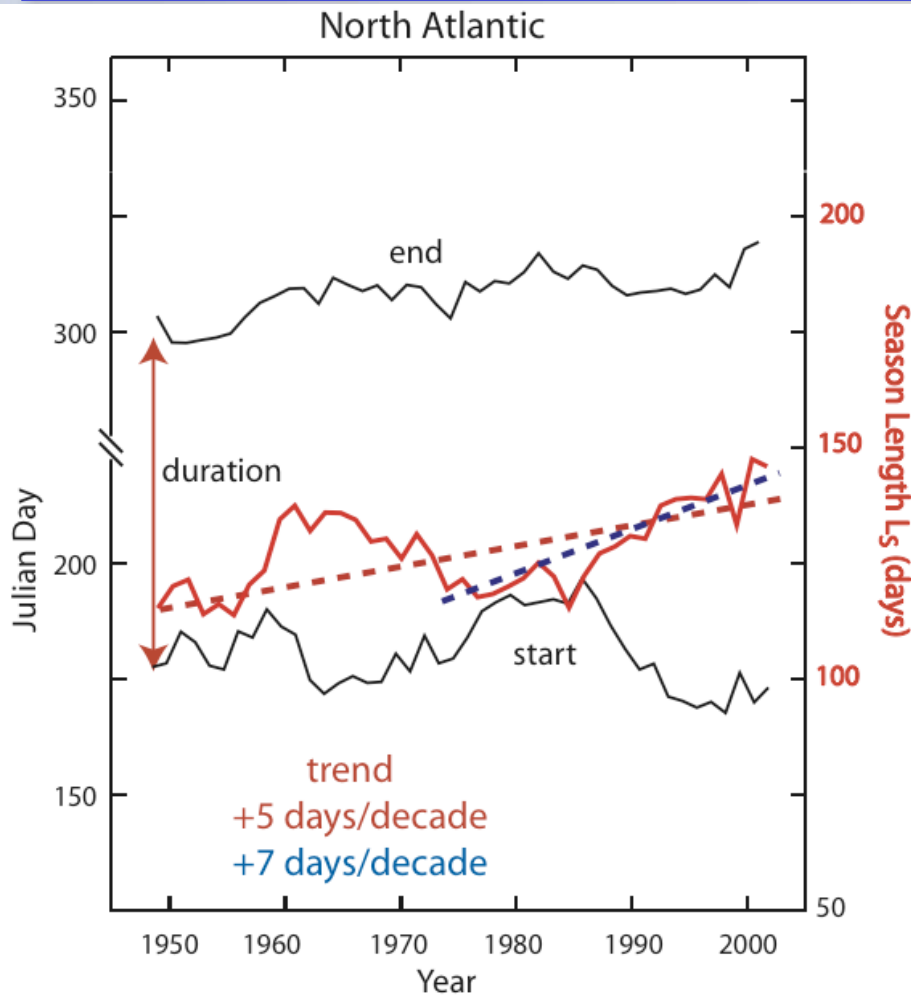


- 1 TC for each 0.1°C increase in SST**
- 1 Hurricane for each 0.2°C increase in SST**
- 1 Major Hurricane for each 0.3°C increase in SST**



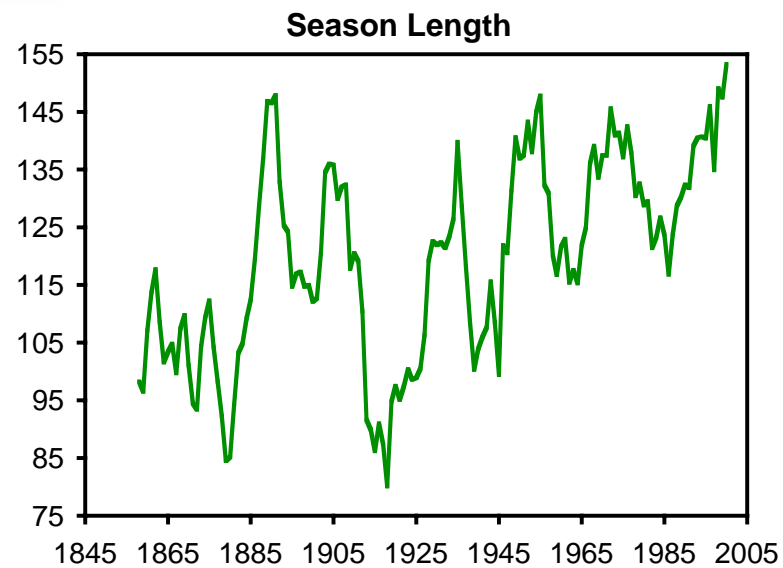
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# Length of Season Increase



Peter Webster 2007

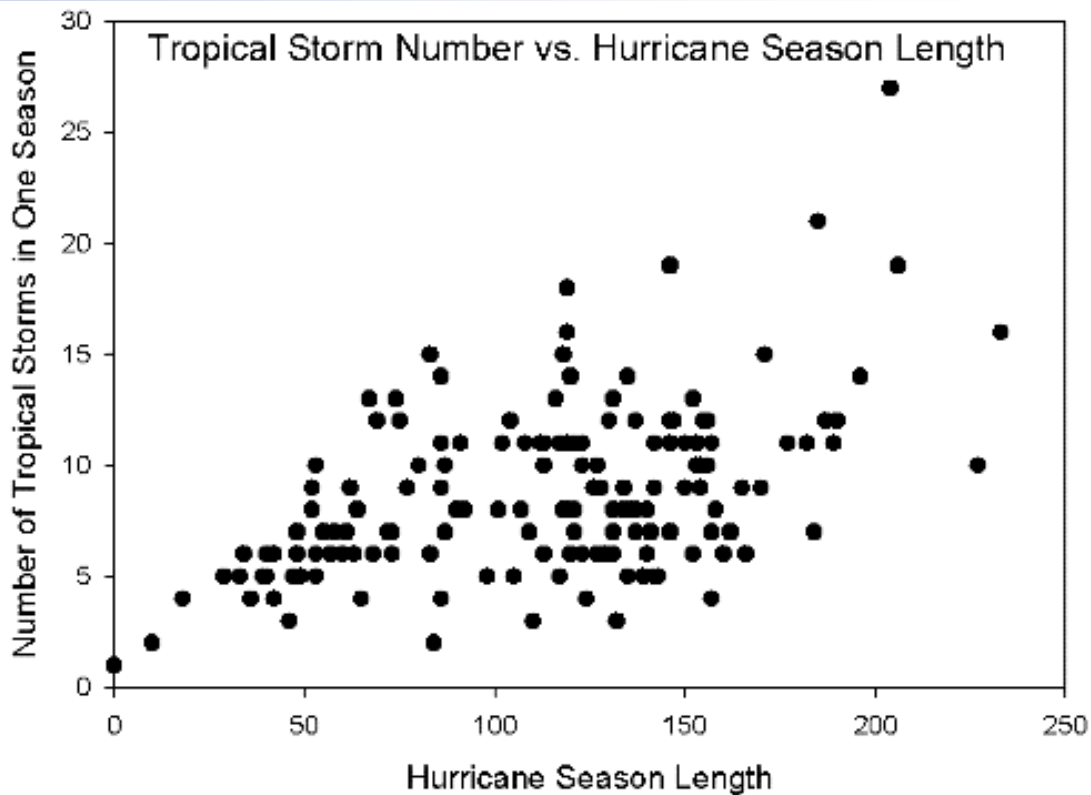
- The North Atlantic Season has grown by ~5 days per decade.



Jay Gullede 2007



# Length of Season and Numbers

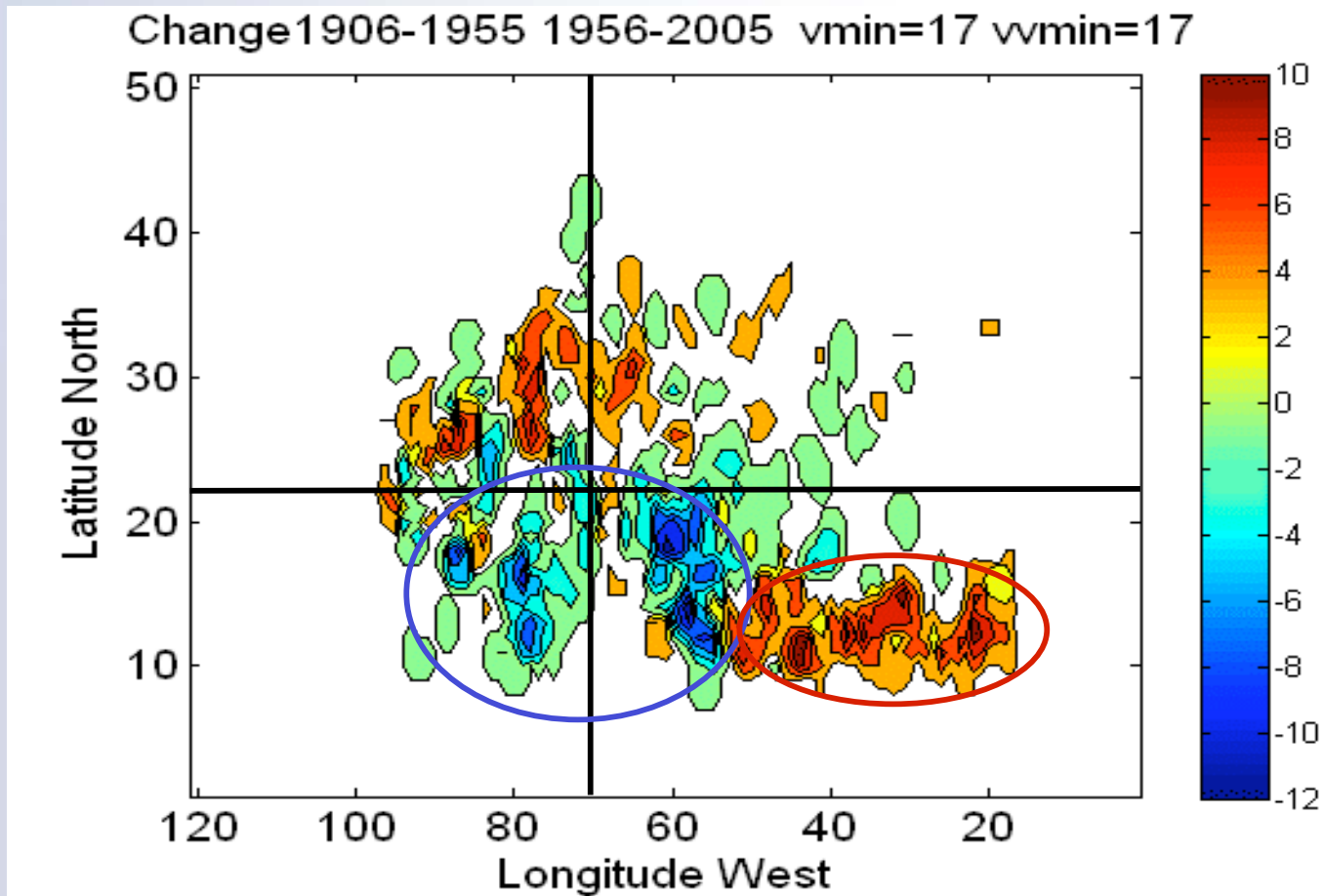


**Length of hurricane season correlates with number of storms in NATL**



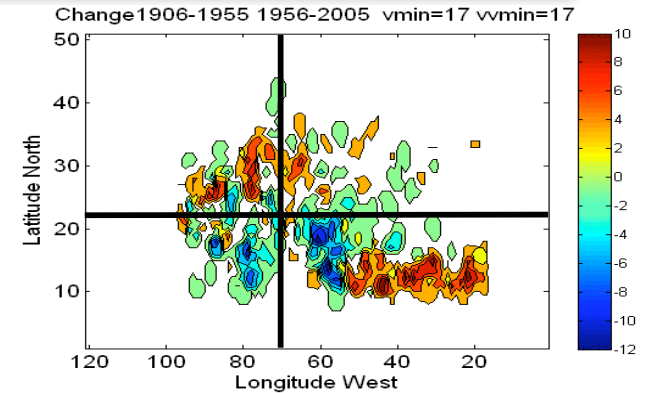
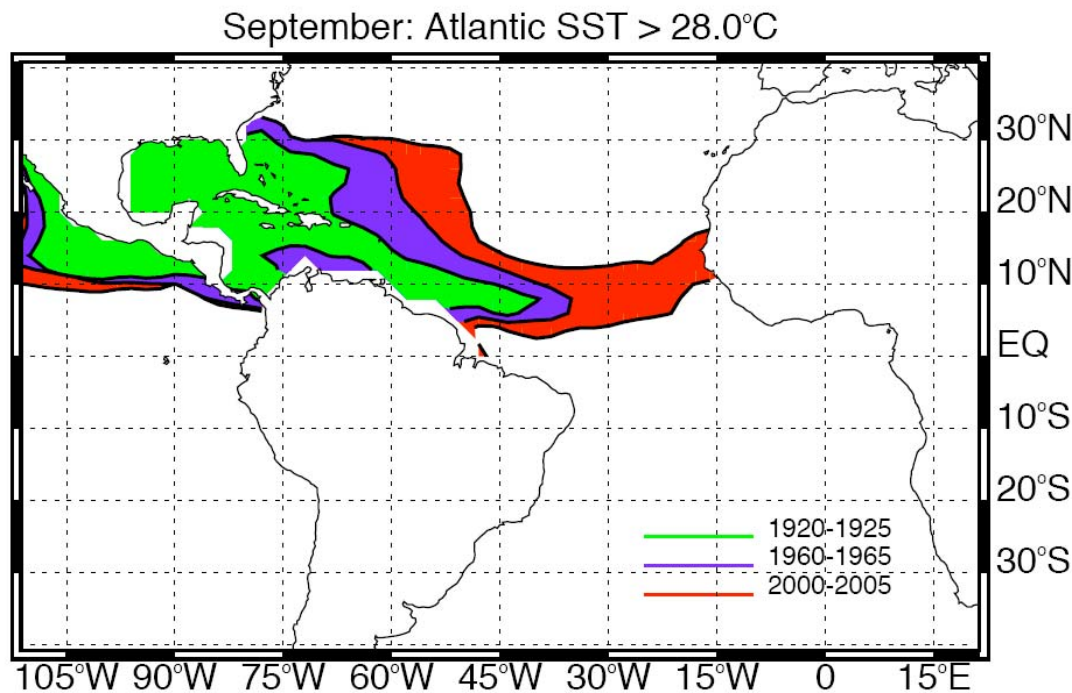


# Eastward Expansion



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# Eastward Expansion of the Warm Pool



- East Atlantic formations are consistent with the expansion of the North Atlantic Warm Pool;
- Similar changes in all other warm pools around the globe.

Hoyos and Webster (2007)

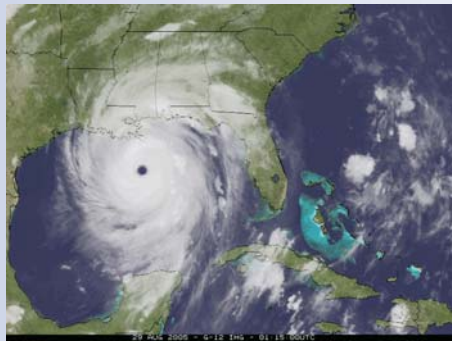


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# Summary



**Past: Anthropogenic Climate Change is substantially influencing the characteristics of North Atlantic tropical cyclones through complex ocean-atmosphere connections and may be influencing other regions.**



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**Future:**

**Good evidence for increased rainfall, moderate intensity increase, sea-level rise, decreased global frequency;  
Some evidence for substantial increase in major hurricanes;  
No real idea on distributions**



# The US National Hurricane Research Initiative

- Arose from National Science Board, plus community groups;
- With Congress and Senate;
- \$435 million per year for a decade, administered through NSF and NOAA;
- **All aspects of Hurricane Impacts:**
  - *Forecasting*
  - *Climate Projections*
  - *Community Response*
  - *Engineering Design and Planning*
  - *Coastal Eco-Systems*

**Please help us get this established**