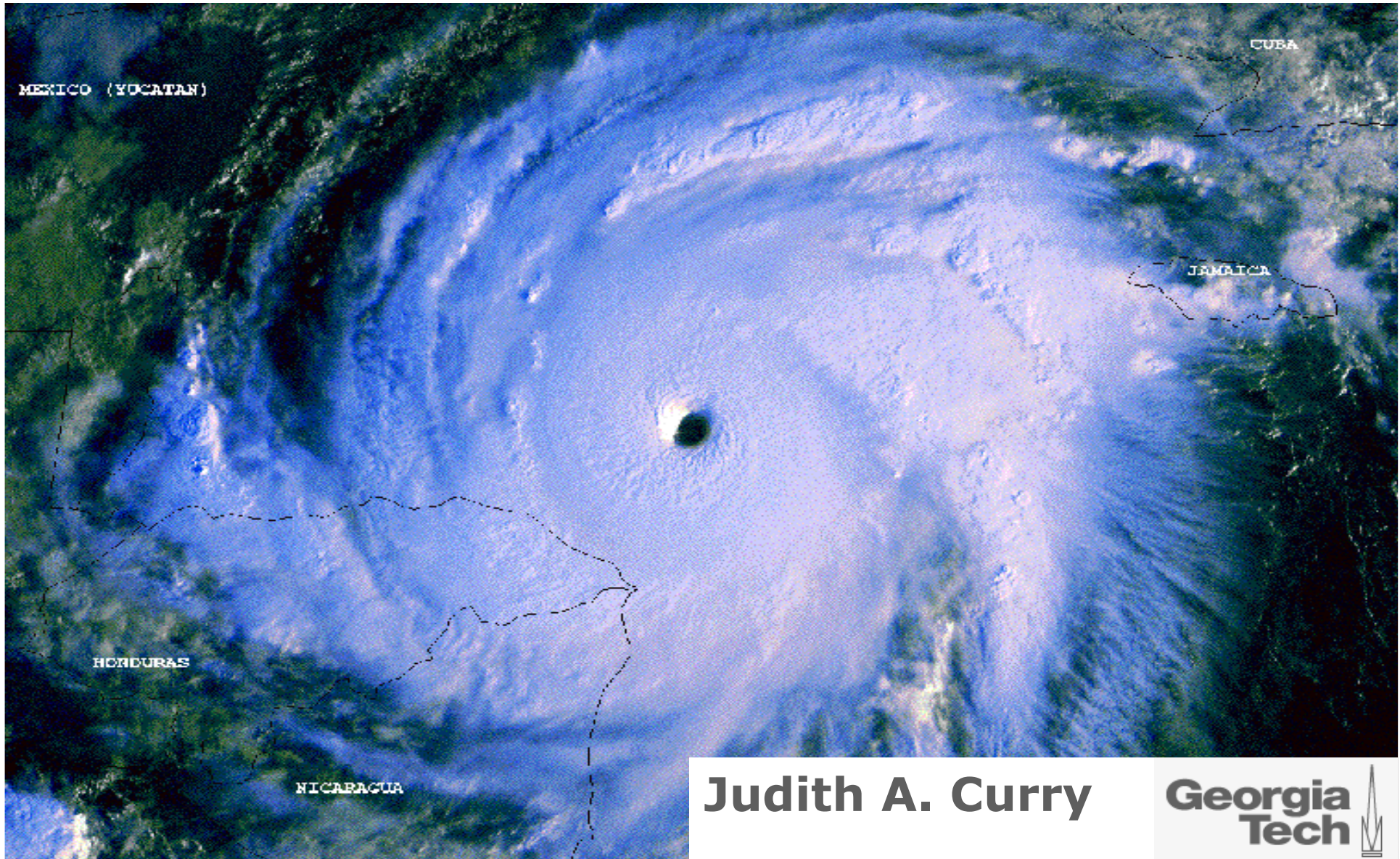


Global Climate Change and Hurricanes: the Science, the Controversy & the Risk



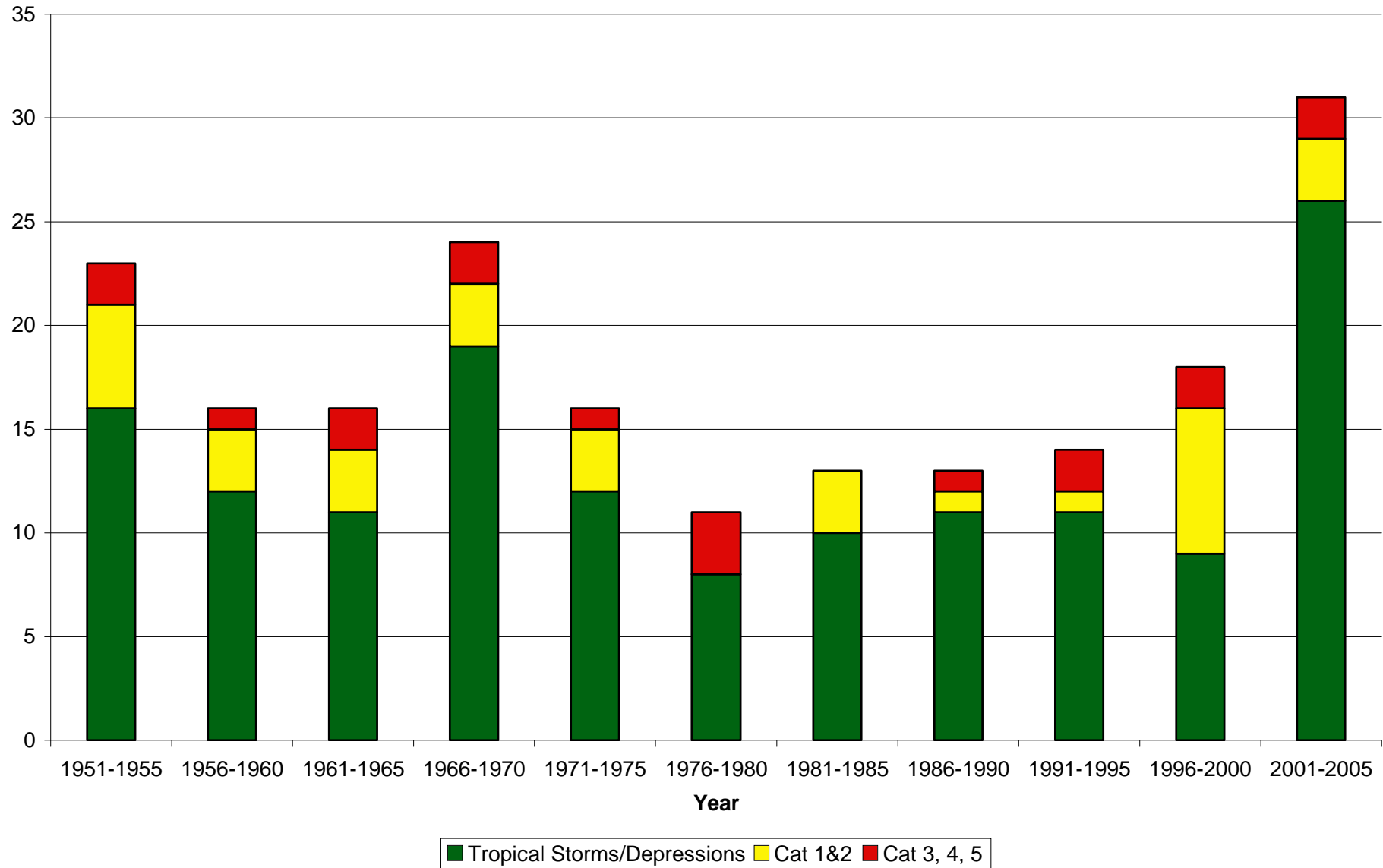
Judith A. Curry



Deadliest Hurricanes to Hit Central America and the Caribbean

Storm	Deaths	Locations Affected
Great Hurricane of 1780	>22,000	Barbados, Martinique
Hurricane Mitch (1998)	11,000 – 18,000	Honduras, Nicaragua
Hurricane Fifi (1974)	8,000 – 10,000	Belize, Guatemala, Honduras
Hurricane Flora (1963)	7,186 – 8,000	Tobago, Hispaniola, Cuba
1930 Dominican Republic Hurricane	2,000 – 8,000	Hispaniola, Cuba
Pointe-a-Pitre Bay Hurricane (1776)	>6,000	Martinique, Guadeloupe
San Ciriaco Hurricane (1899)	3,433	Puerto Rico
1932 Cuba Hurricane	3,033	Cuba, Bahamas
1934 Yucatan Hurricane	1,000 – 3,000	Belize, Guatemala, El Salvador, Honduras
1931 Belize Hurricane	2,500	Belize, Guatemala
Hurricane Stan (2005)	1,620	Guatemala, El Salvador, Nicaragua, Honduras, Costa Rica

Atlantic Landfalling Storms Striking Central America and the Caribbean



Are more hurricanes a harbinger of the Caribbean's future?

To assess the Caribbean's risk from landfalling hurricanes in the coming decades, we must understand:

- Impact of global warming on hurricane activity
- Natural variability in the Atlantic Ocean
- Nature of local risks





INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

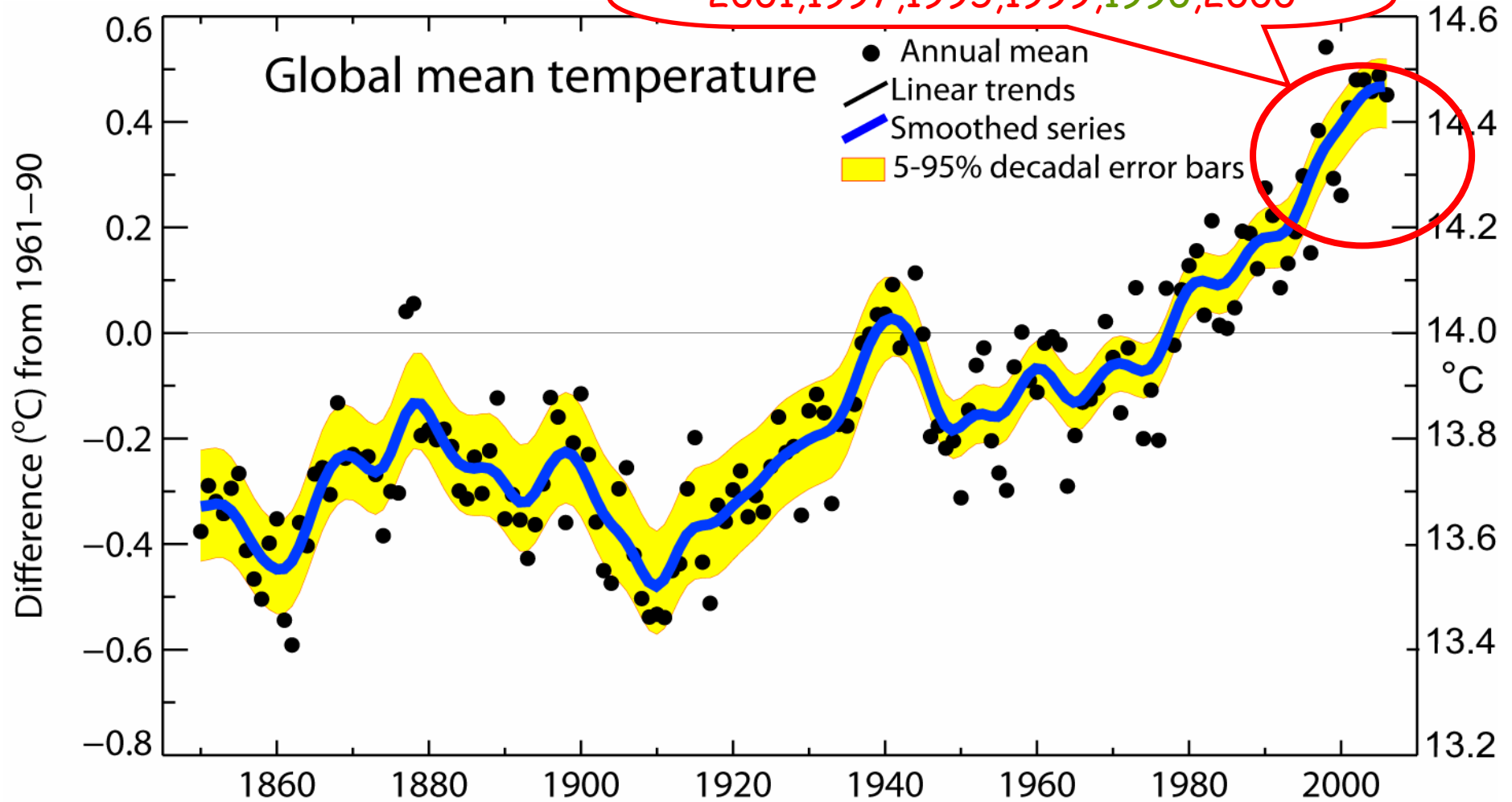


4th Assessment Report Summary for Policy Makers

“Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.”

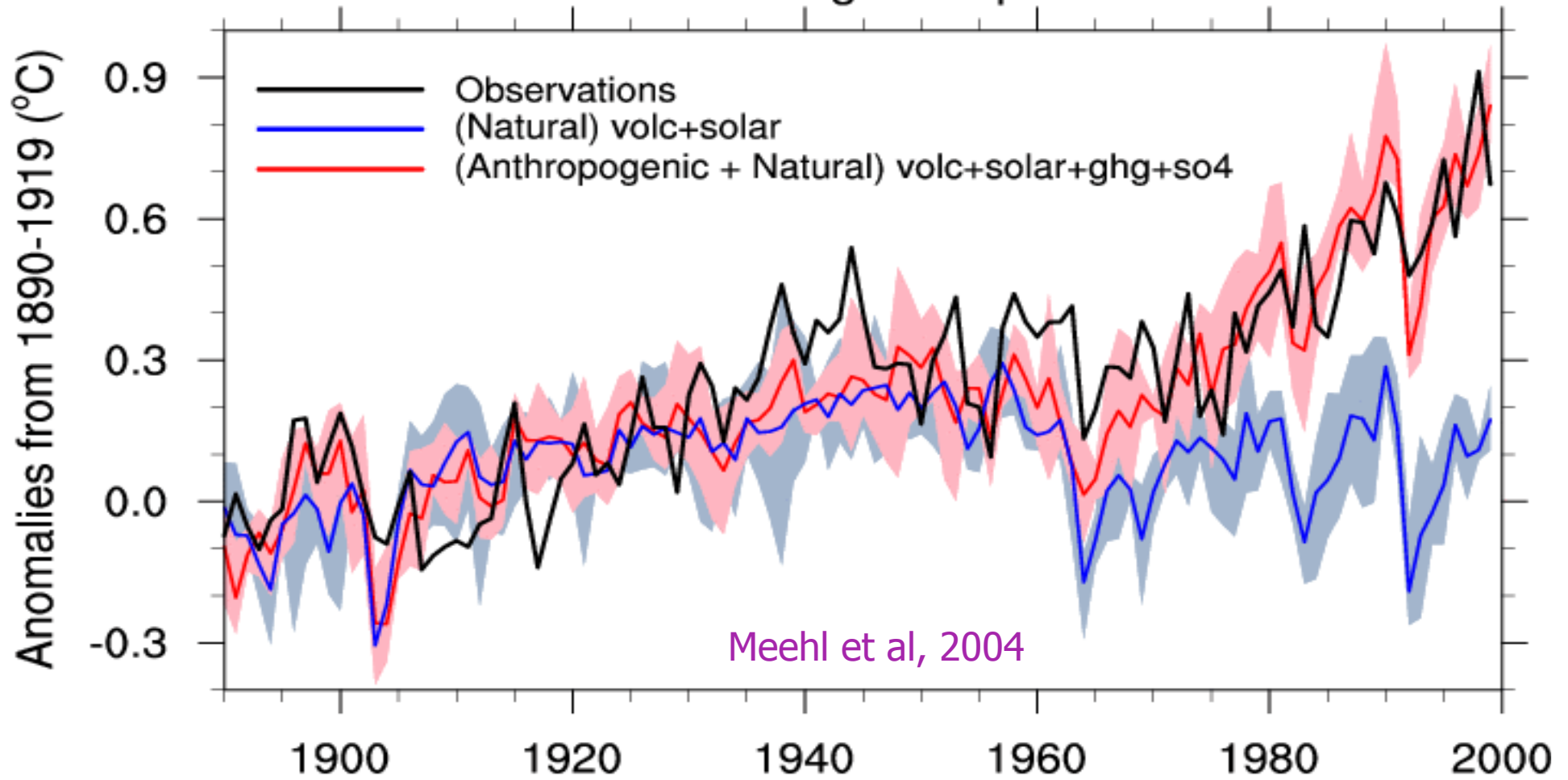
“Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely [$>90\%$] due to the observed increase in anthropogenic greenhouse gas concentrations.”

Warmest 12 years:
1998, 2005, 2003, 2002, 2004, 2006,
2001, 1997, 1995, 1999, 1990, 2000



Global surface temperature has increased 0.74°C since 1906

Global Average Temperature



Increased global temperatures since 1970 is attributed to greenhouse warming



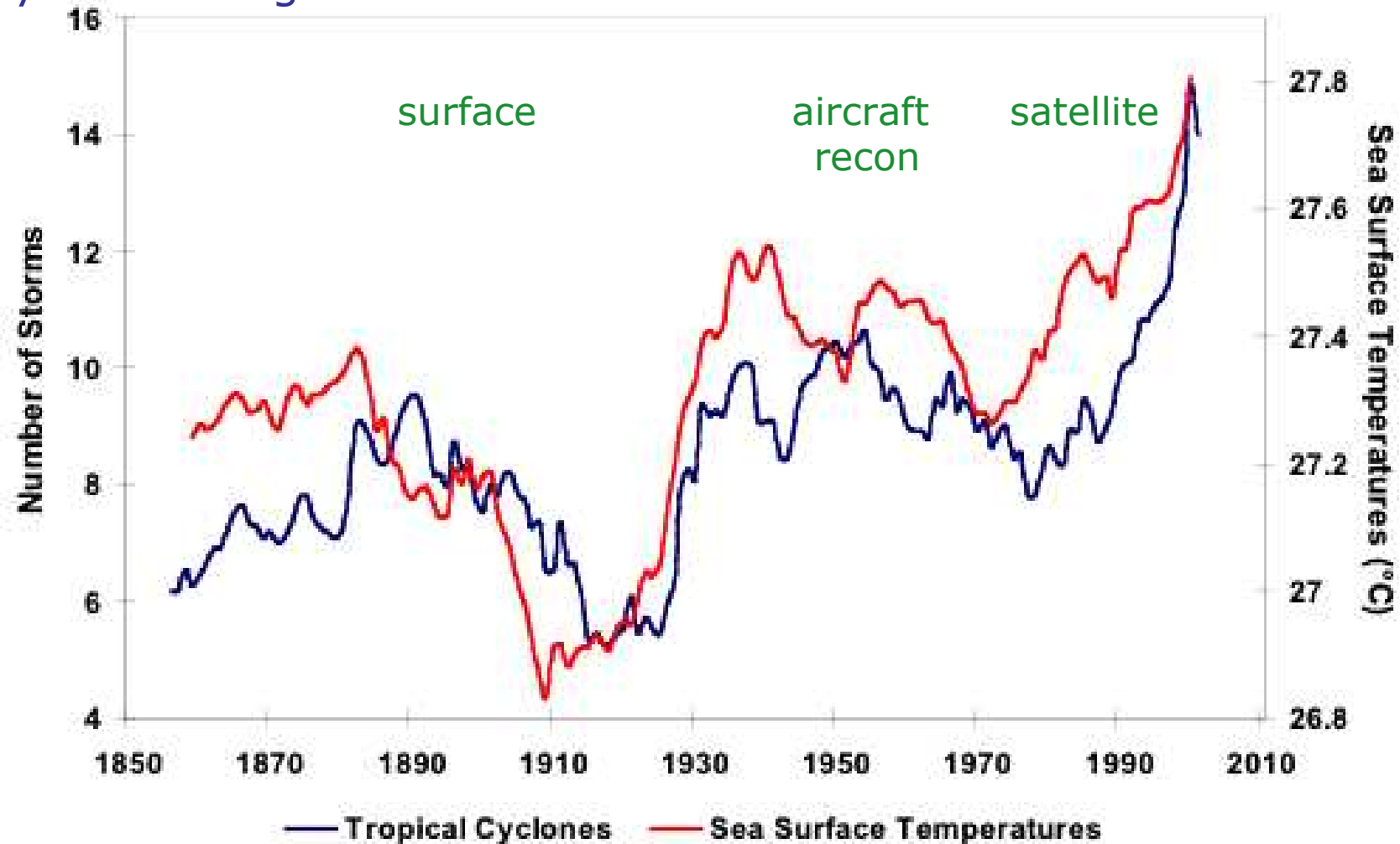
IPCC AR4: Hurricanes Detection of Change



- There is observational evidence for an increase of intense tropical cyclone activity in the North Atlantic since about 1970, correlated with increases of tropical sea surface temperatures
- There are suggestions of increased intense tropical cyclone activity in other regions where concerns over data quality are greater
- Multi-decadal variability and the quality of the tropical cyclone records prior to 1970 complicate the detection of long-term trends in tropical cyclone activity

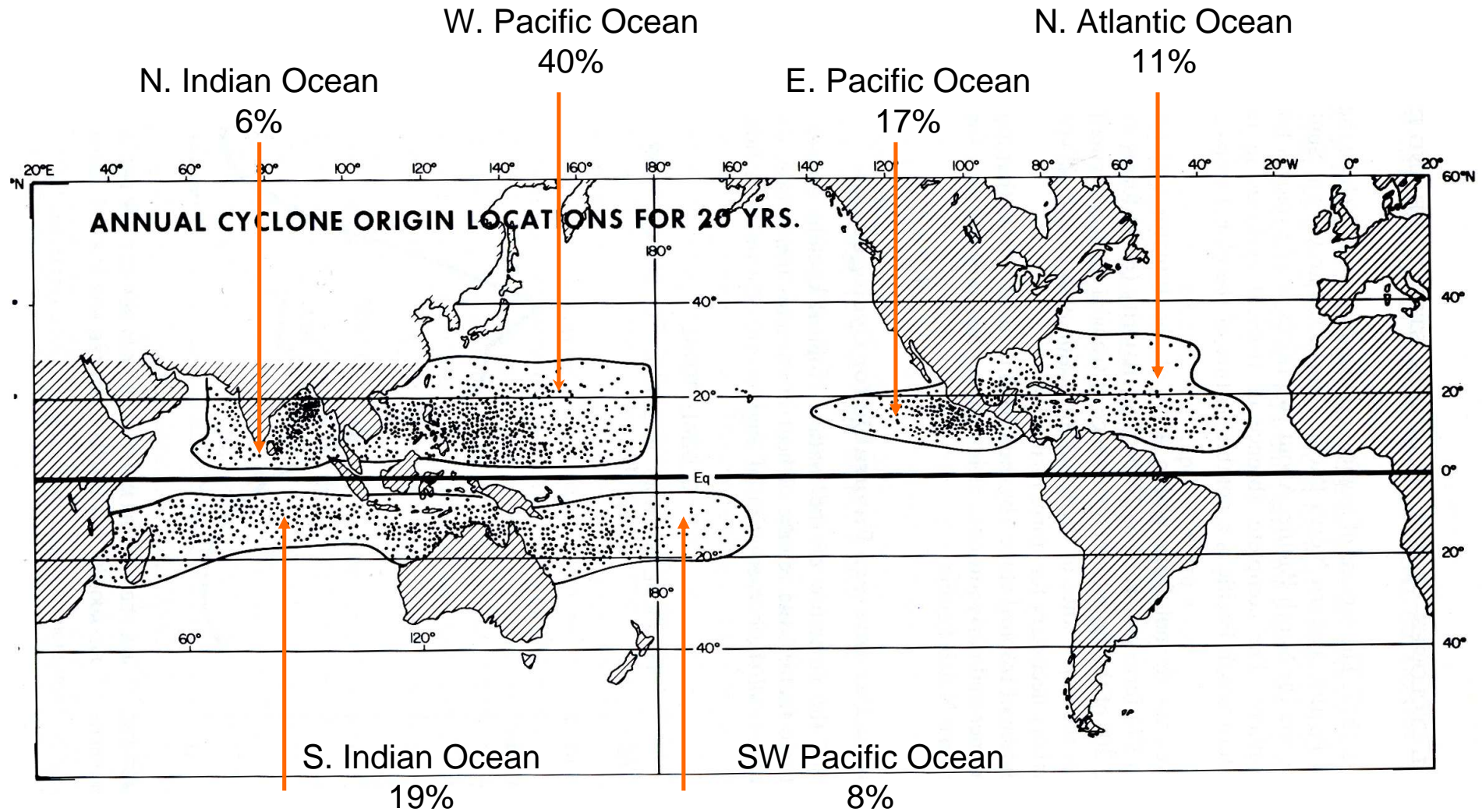
North Atlantic Tropical Cyclones and SST

11 year running mean



Increased tropical cyclone activity since 1970,
correlated with increasing sea surface temperatures

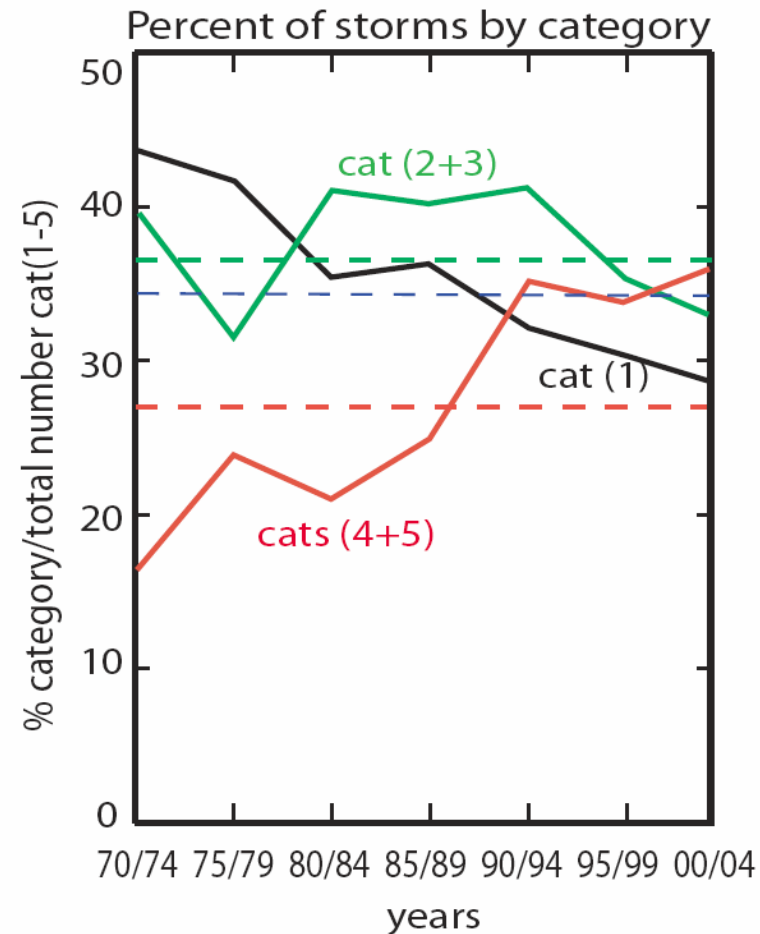
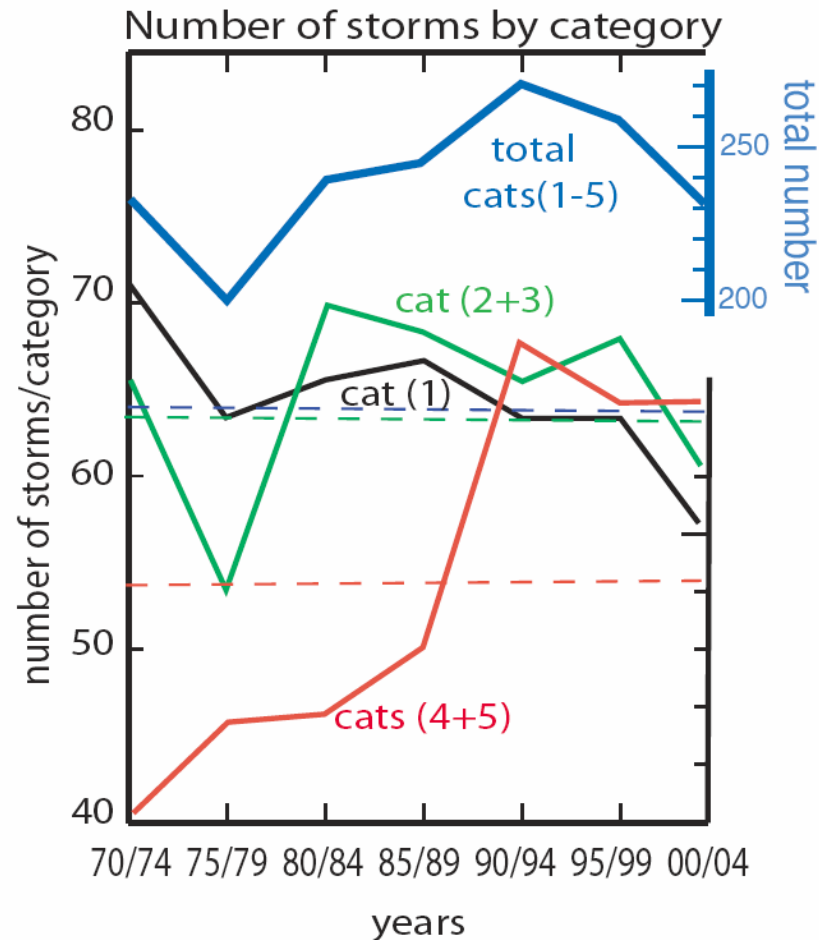
Global View of Tropical Cyclones



Each year there are about 85-90 tropical cyclones globally

Global tropical cyclone intensity

Webster, Holland, Curry, Chang (2005) *Science*



of cat 4+5 hurricanes has doubled globally since 1970
Data quality questioned in the Indian Ocean, Pacific Ocean

Wall Street Journal

February 2, 2006

Cold Front

Debate Shatters Civility of Weather Science

Hurricanes Worsened by Global Warming?

Spats are so tempestuous,
sides are barely talking

Charge of “brain fossilization”

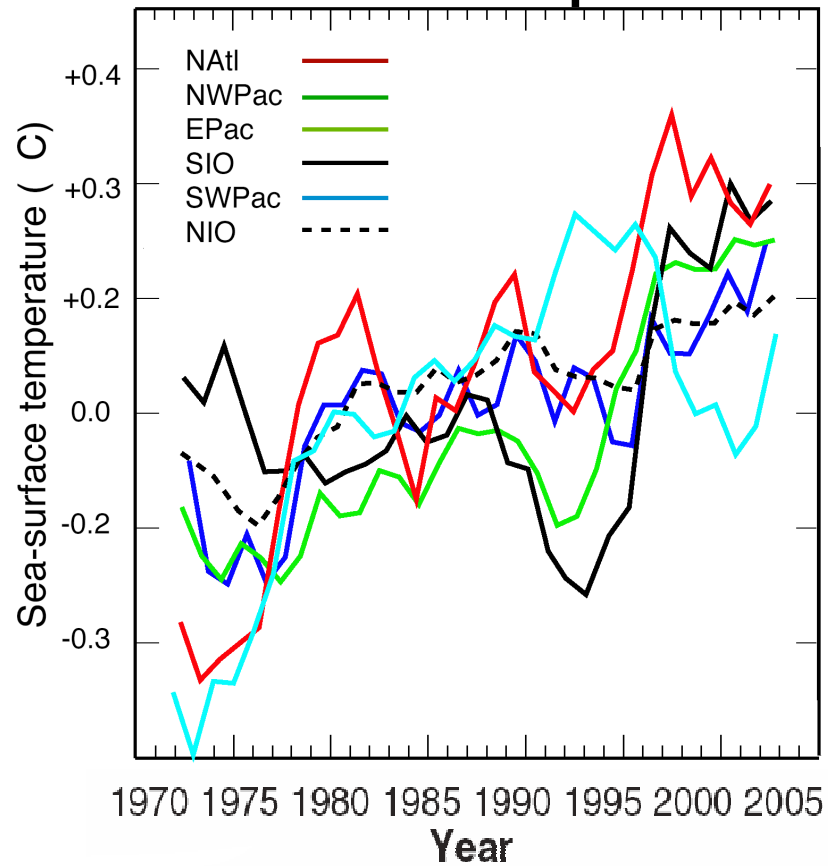
Tropical cyclone genesis/intensification factors

- ❑ **Sea water temperature > 26.5°C.
Major hurricanes >28.5°C**
- ❑ **Small vertical shear (minimal variation of
wind with height)**
- ❑ Moist mid-troposphere & convective instability
- ❑ Pre-existing weather disturbance
- ❑ Not too close to the equator

→ These factors change both with natural climate variability (e.g., El Nino) and global warming

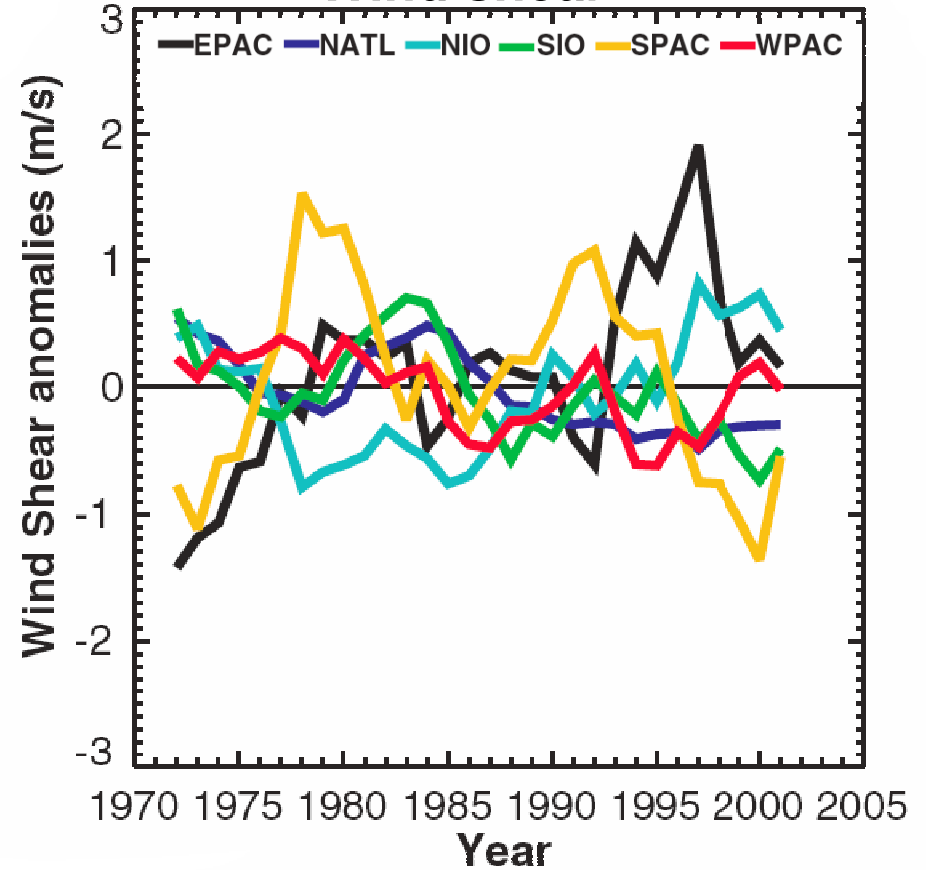
Global trends in the tropics since 1970

Sea surface temperature



0.5°C (1°F) increase

Wind shear



no trend



IPCC AR4: Hurricanes Projections of Future Change



- It is likely [$>66\%$] that future tropical cyclones will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical SSTs
- The apparent increase in the proportion of very intense storms since 1970 in some regions is much larger than simulated by current models for that period

TC intensity - SST link

Hurricane intensity change scaled for a 0.5°C SST increase:

Webster et al. obs: +6.0%

Climate models:

Knutsen/Tuleya (2004): +2.0%

Oouchi et al. (2006): +2.1%

Potential intensity theory:

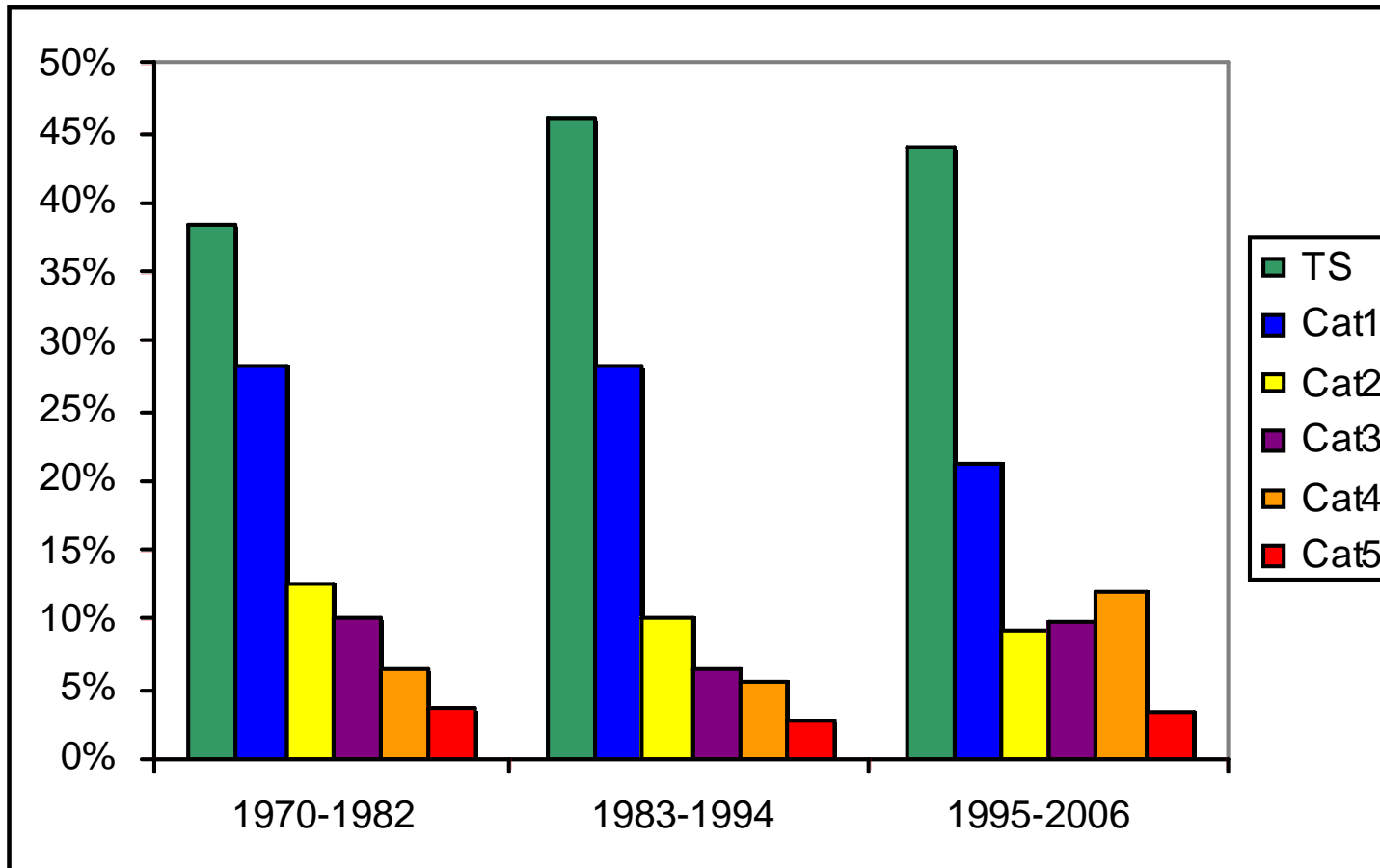
Emanuel +2.7%

Holland +5.3%



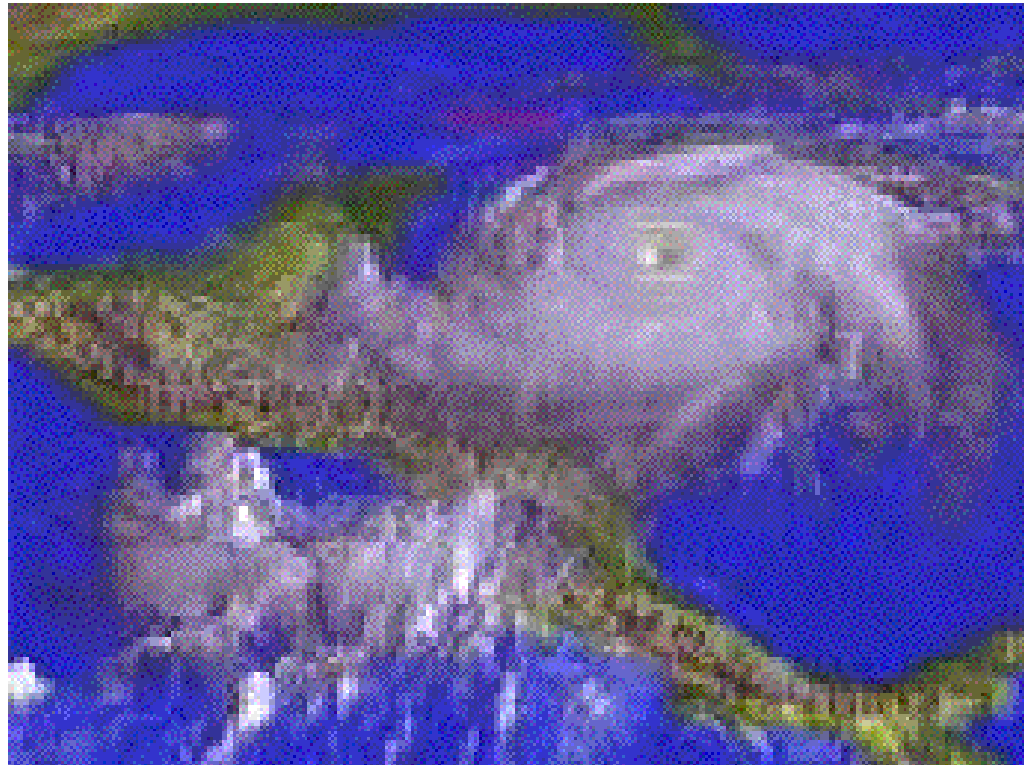
3-legged stool analogy: Observations, theory, and climate models agree that hurricane intensity should increase; they disagree on the magnitude of the increase. The stool stands.

Intensity Distribution of North Atlantic Tropical Cyclones



Since 1995, there has been a shift in the intensity distribution towards more major hurricanes

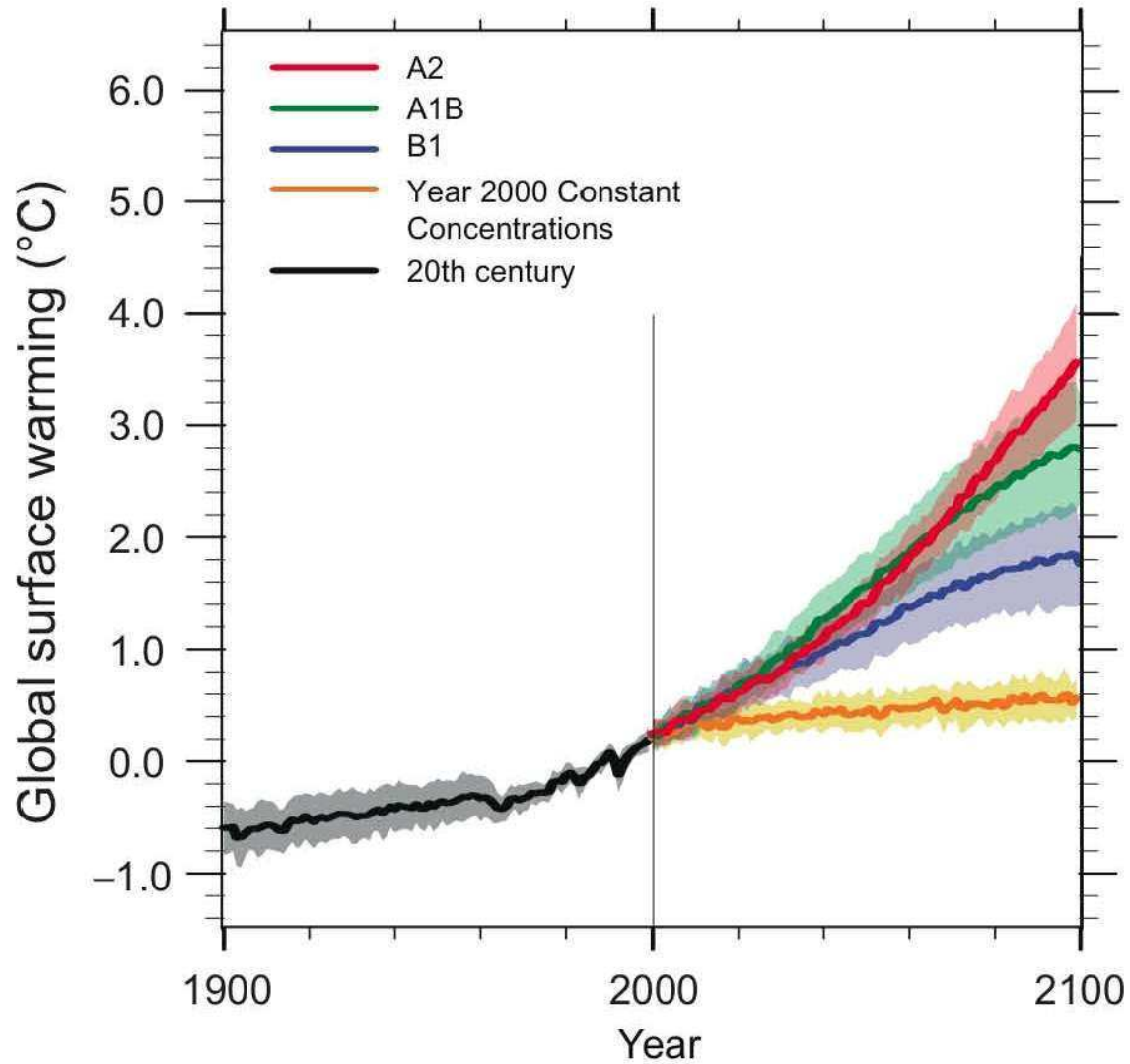
What does the future hold for hurricane activity in the North Atlantic?



Combined impacts of greenhouse warming and natural variability



Climate Model Projections

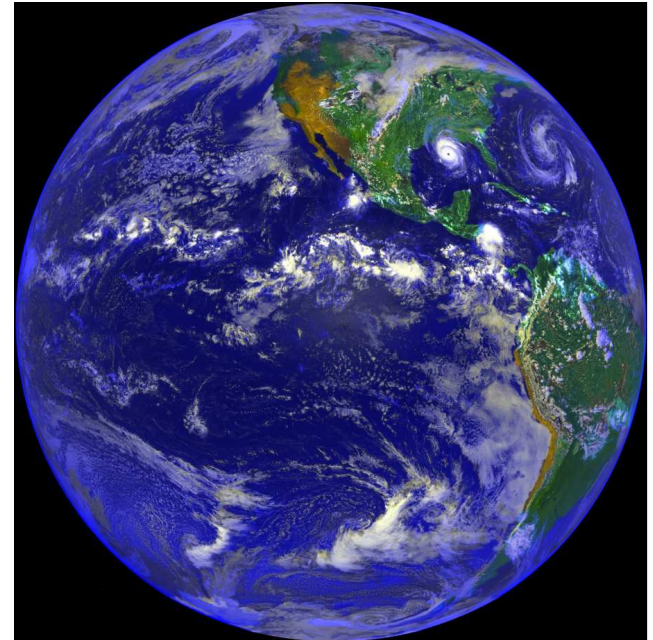


Scenario simulations indicate 1.8-4.0°C temperature increase by 2100

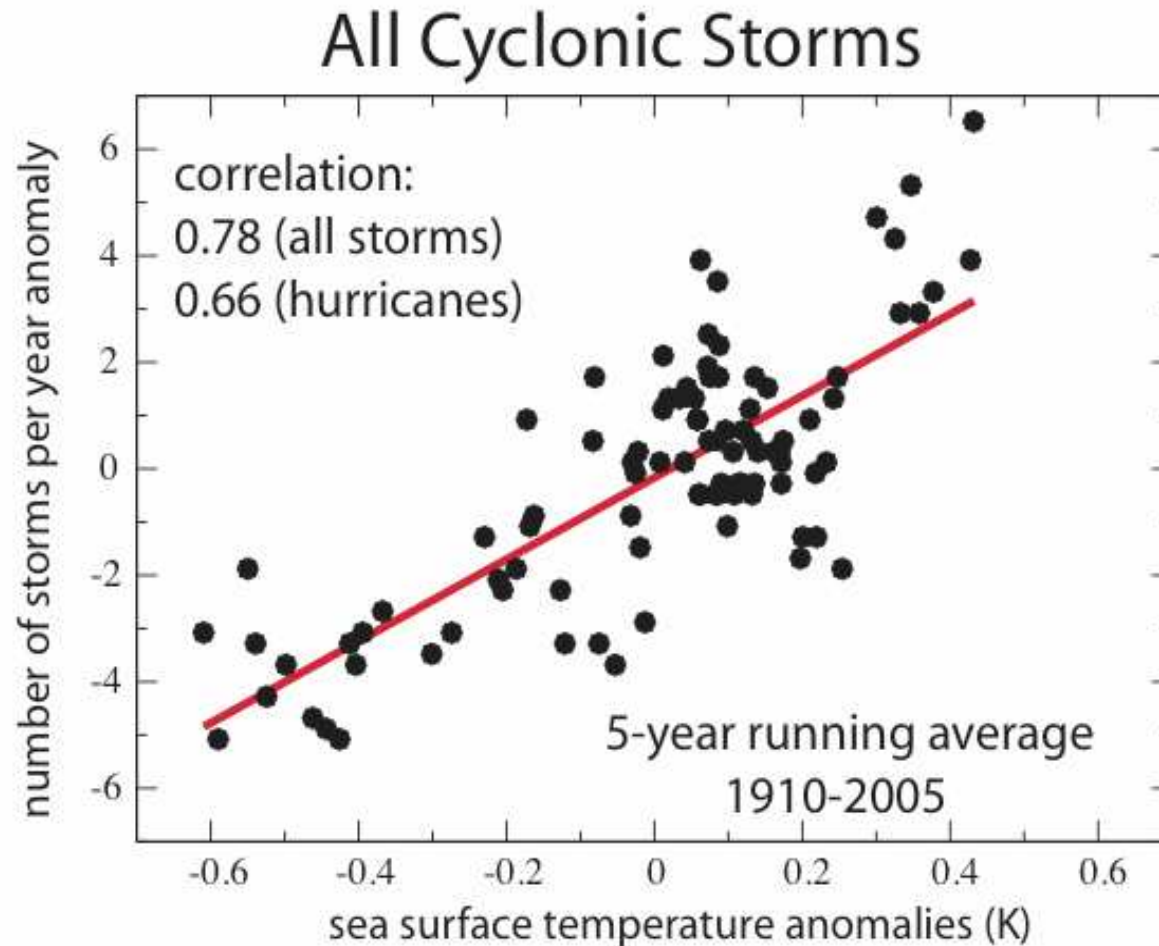
Climate model projections of future hurricane activity

For a 2.5°C temperature increase:

- up to 30% increase in number of N. Atlantic tropical cyclones (no increase or slight decrease in global numbers)
- 10% increase in tropical cyclone intensity
- 30% increase in the number of major hurricanes



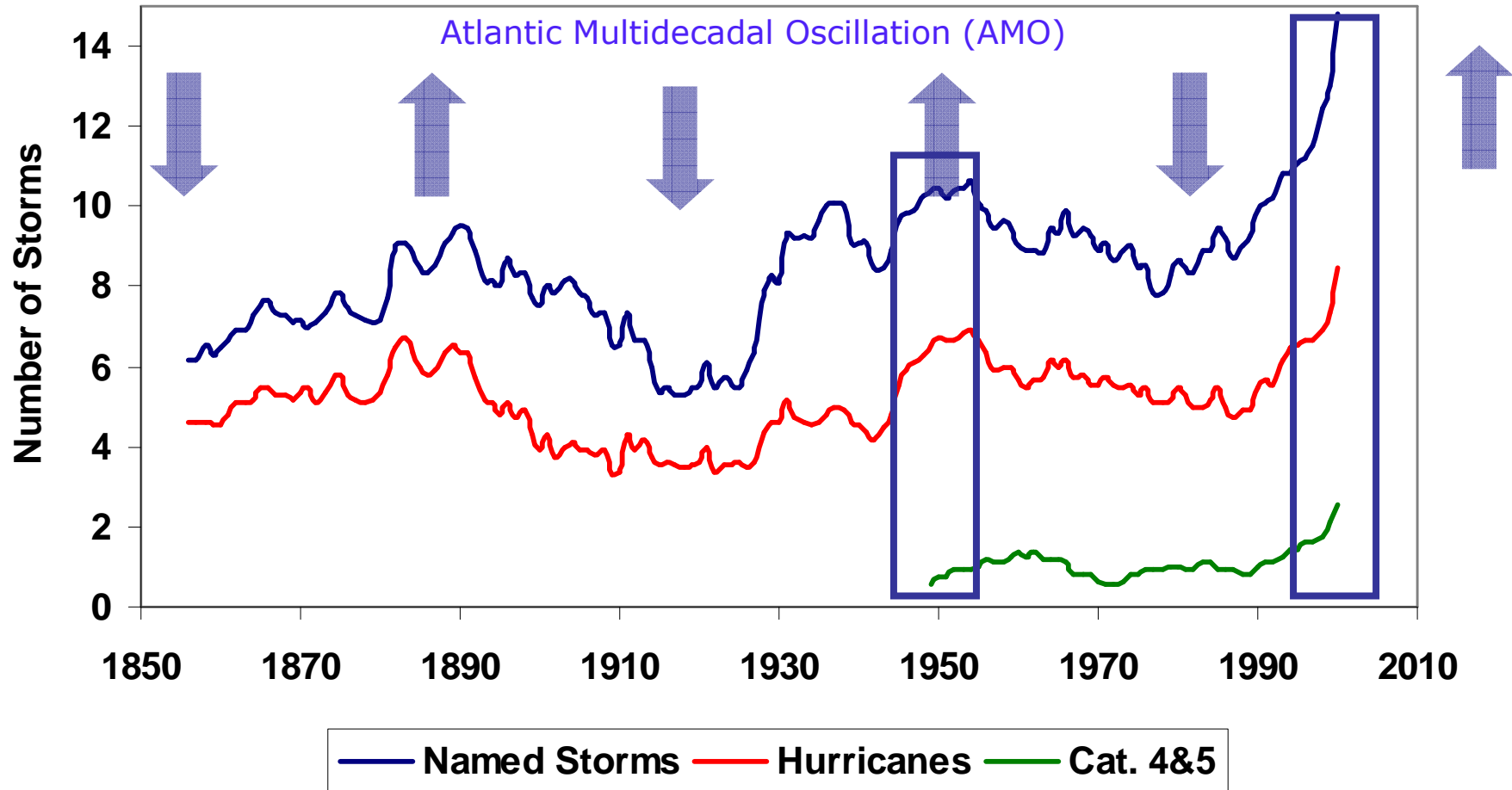
Relationship between # of Atlantic storms and sea-surface temperature



Obs: 1°F increase in SST --> +5 storms/year
Model: 1°F increase in SST --> +1 storm /year

North Atlantic Ocean

11 year centered running mean



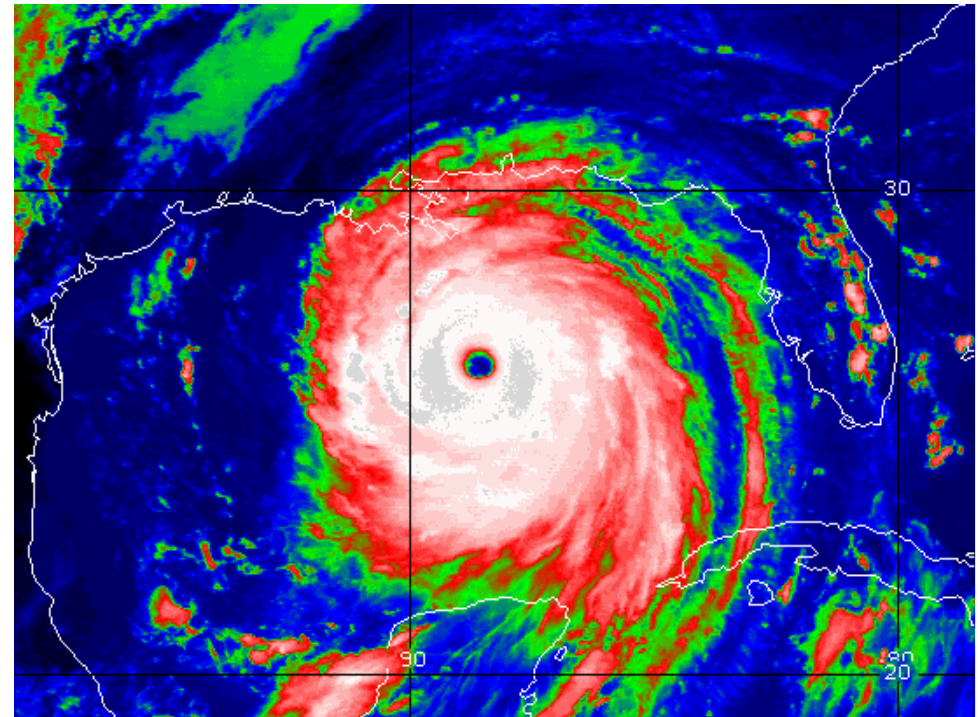
Since 1995, there has been 40-50% greater activity than the previous peak period ca. 1950

Projections for the average number of NATL tropical cyclones for 2025 (0.5°C warming)

of Tropical Cyclones:

- Avg for last 50 yrs: 10
- Avg last decade: 14
- **Avg ca. 2025: 15-20**
category 4+5 3-4

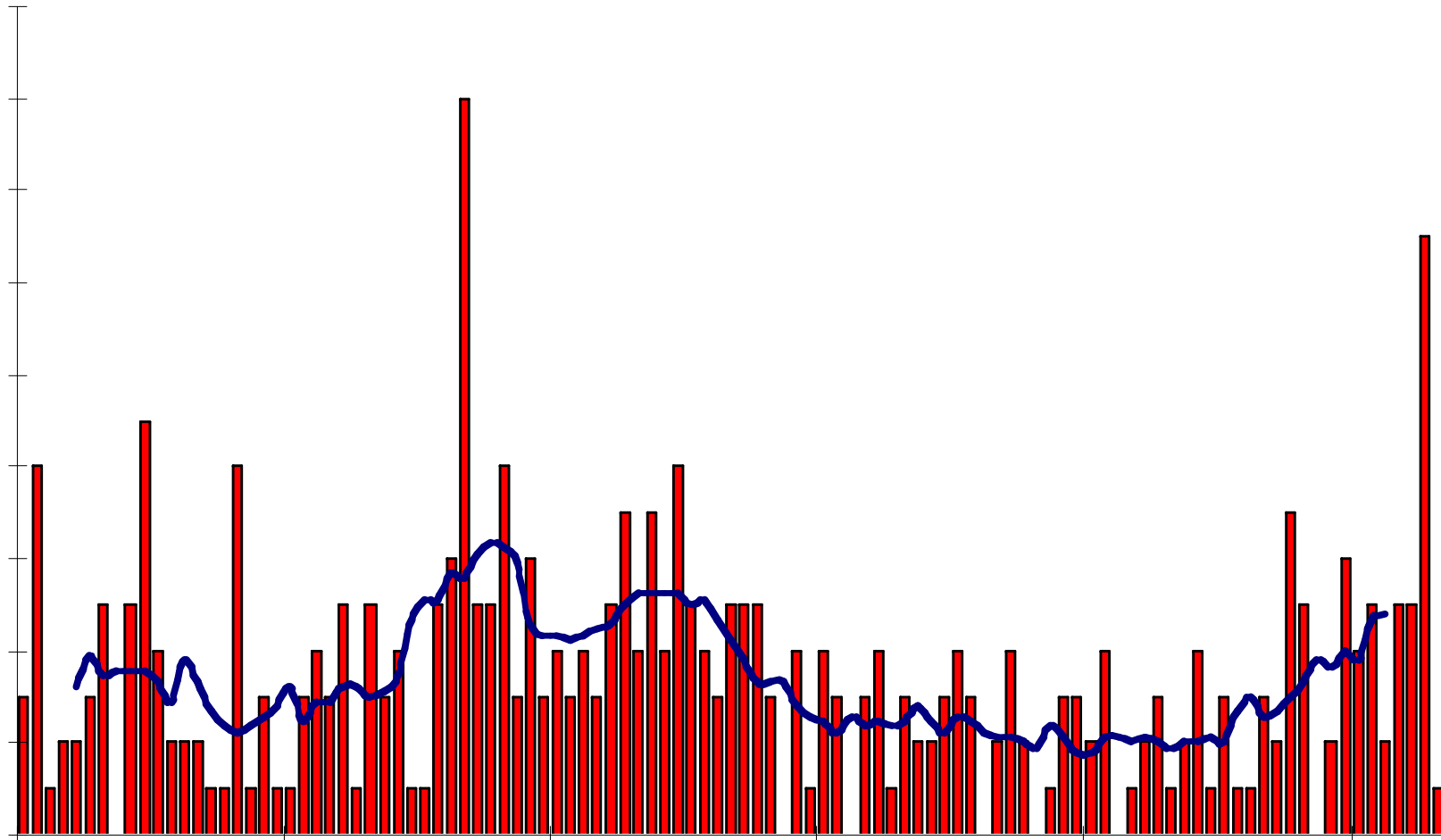
The combination of greenhouse warming and natural variability will produce unprecedented tropical cyclone activity in the coming decades



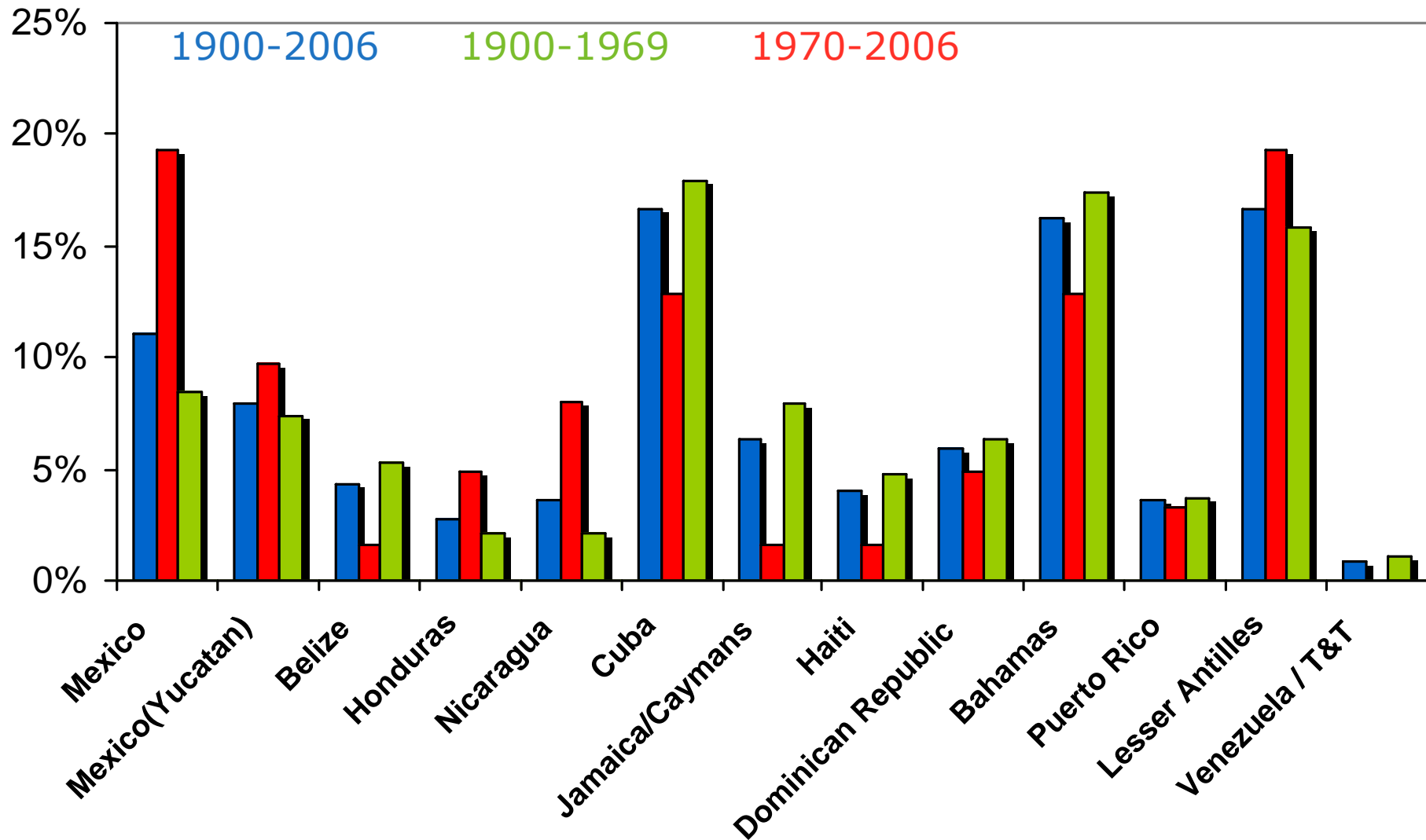
What does the increase in North Atlantic hurricane activity mean for the Caribbean?



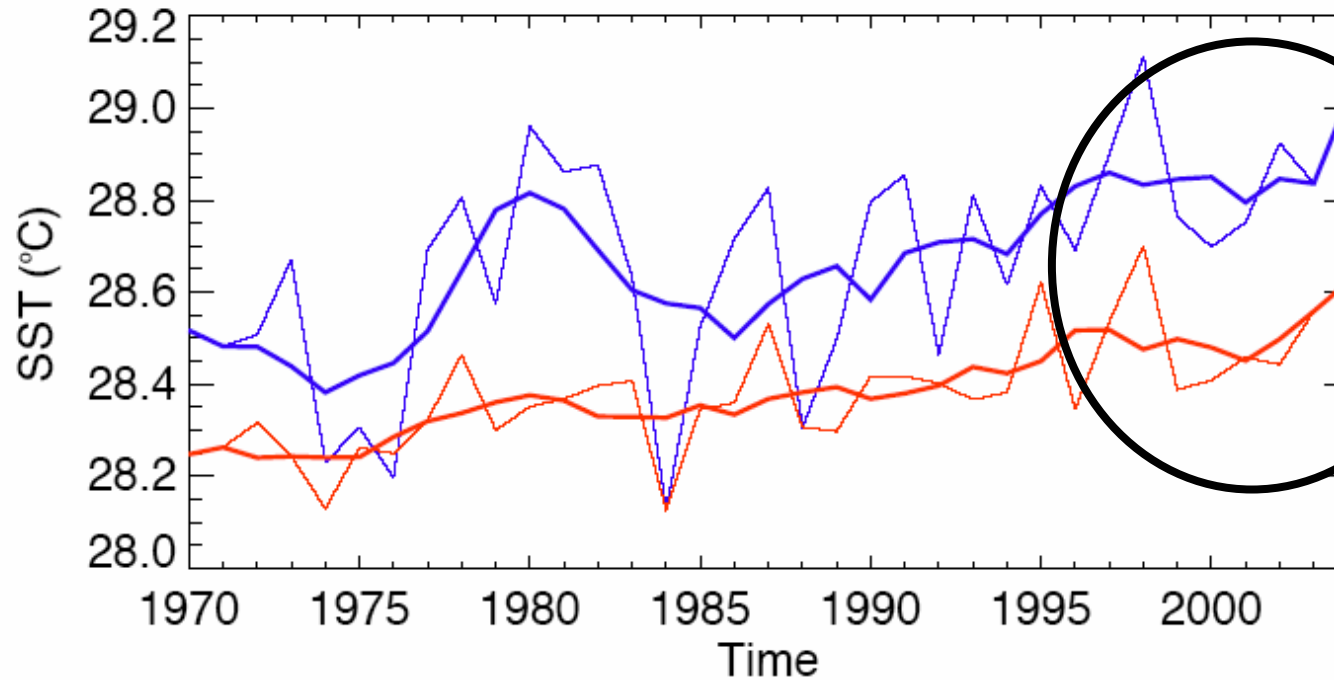
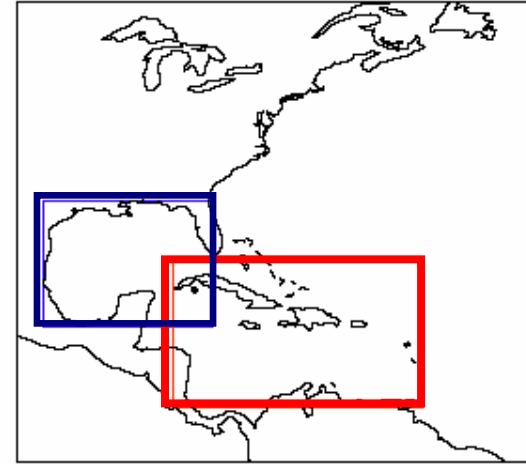
Landfalling tropical cyclones striking the Caribbean and Central America



Hurricane Landfall Location



SST Changes: Gulf of Mexico and Caribbean



Warmest
decade

Summary: Projection for next two decades

- The number of North Atlantic tropical cyclones most likely will increase in coming decades and intensity is expected to continue to increase
- The number of Caribbean landfalls will most likely continue to increase