Hot Science Cool Talks

UT Environmental Science Institute

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Is Climate Change Increasing Hurricane Activity?

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Is Climate Change Increasing Hurricane Activity?

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Two Key Issues:

- How does climate change affect hurricane activity?
- Do hurricanes respond passively to climate change or do they play an active role in regulating climate?

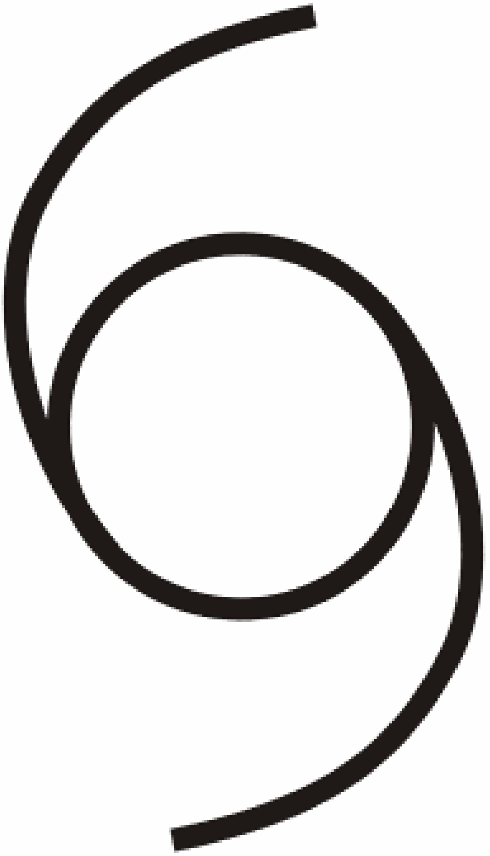
What is a Hurricane?

Formal definition:

A *tropical cyclone* with 1-minute average winds at an altitude of 10 meters in excess of 32 meters/second (64 knots or 74 mph) located over the North Atlantic or eastern North Pacific

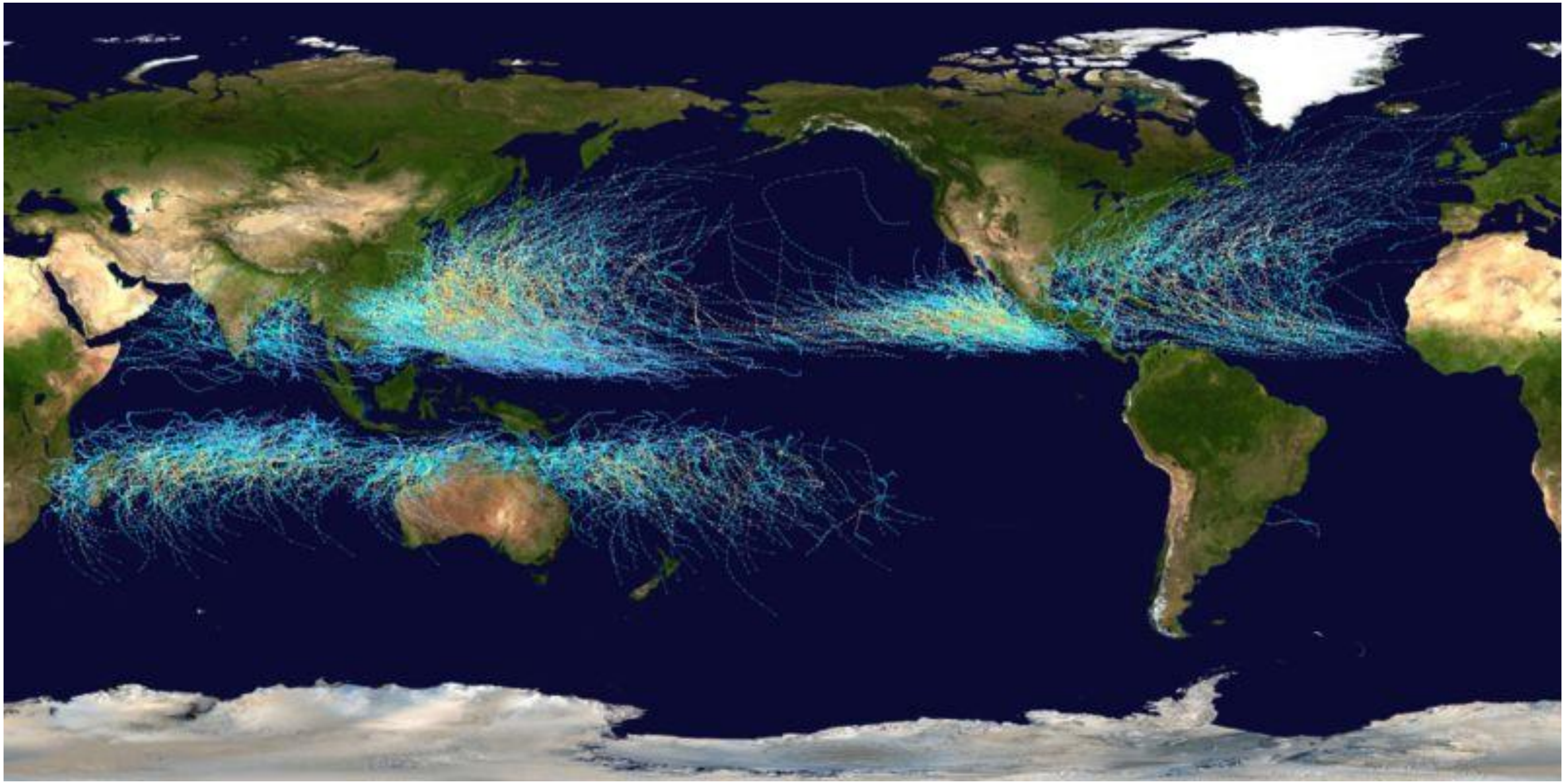
Universal Symbol of a Tropical Cyclone

The word ***Hurricane*** is derived from the Mayan word ***Hunraken*** and the Taino and Carib word ***Huracan***, a terrible God of Evil, and was brought to the West by Spanish explorers

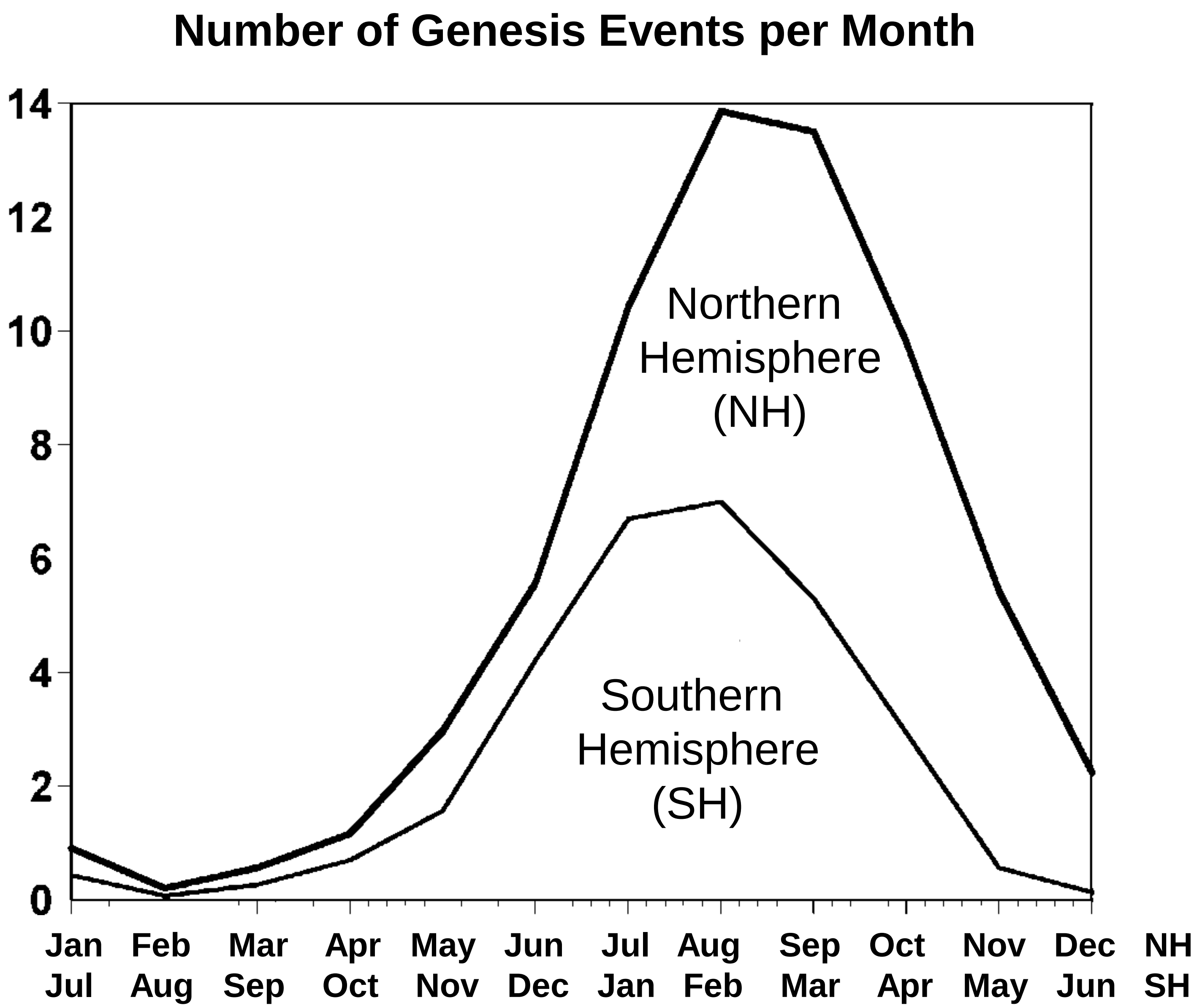


Where and When do Tropical Cyclones Occur?

Global Tropical Cyclones:
20 Years of Tracks (1985 – 2005)

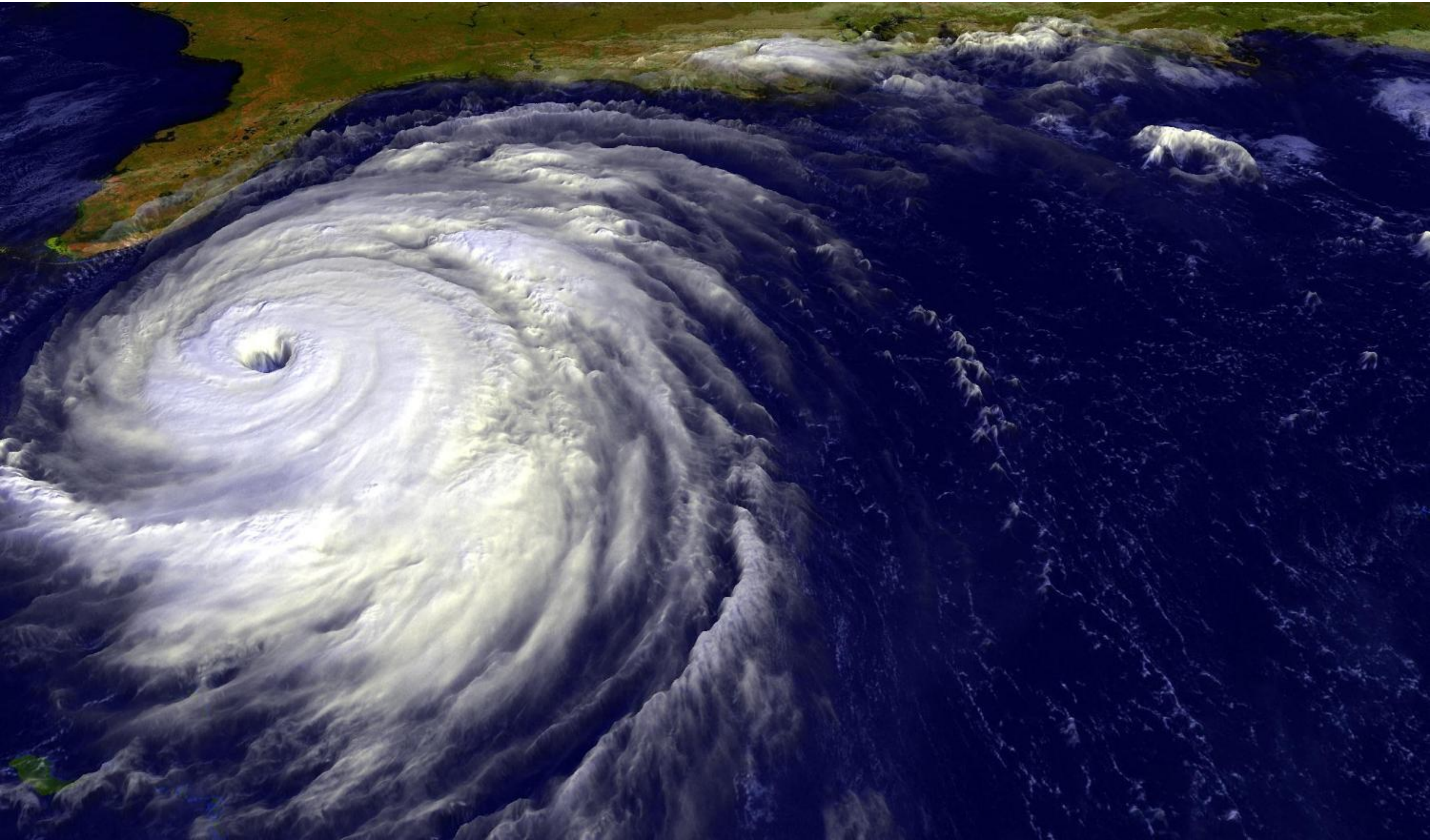


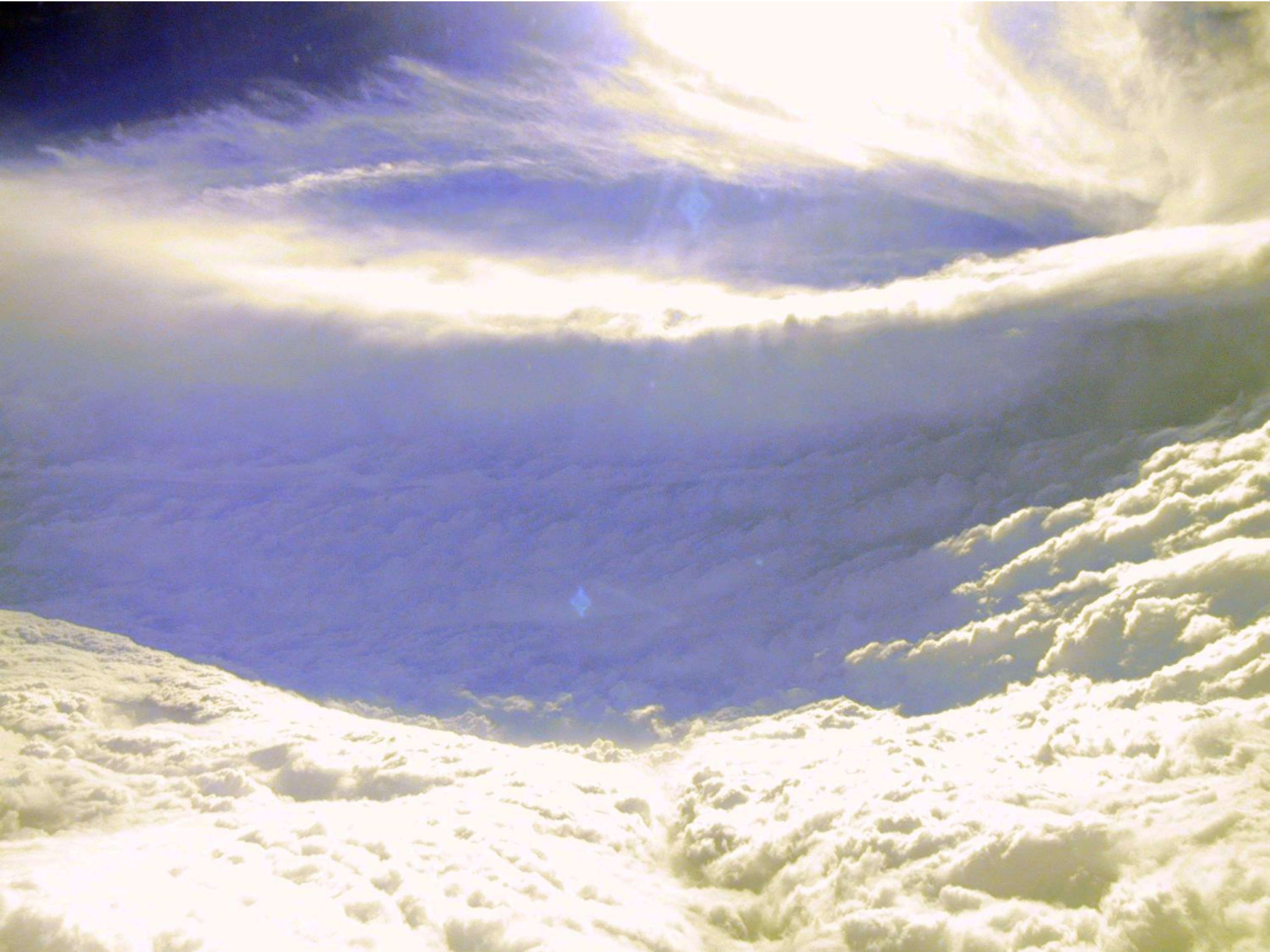
Annual Cycle of Tropical Cyclones



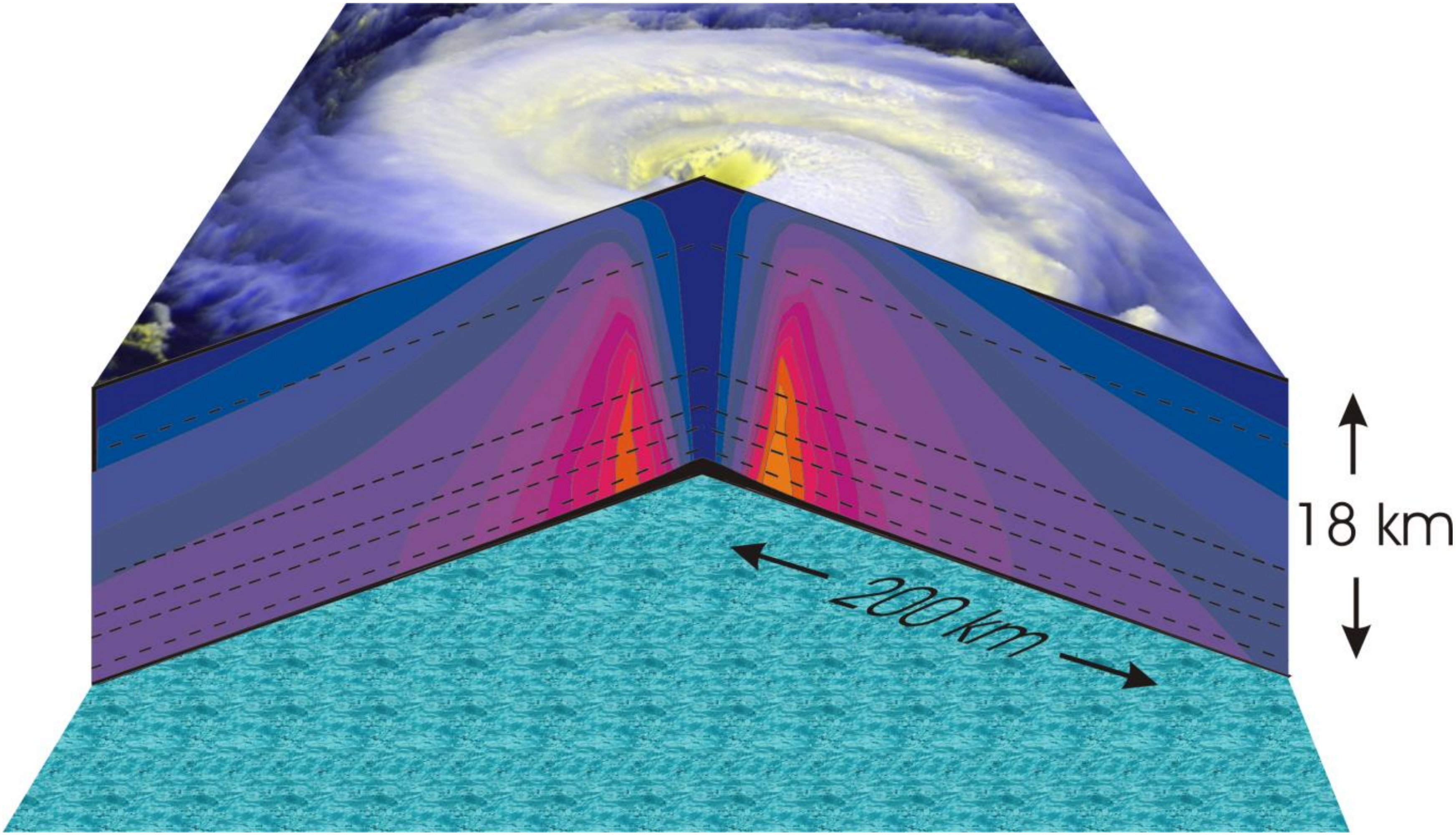
Hurricane Structure

The View from Space





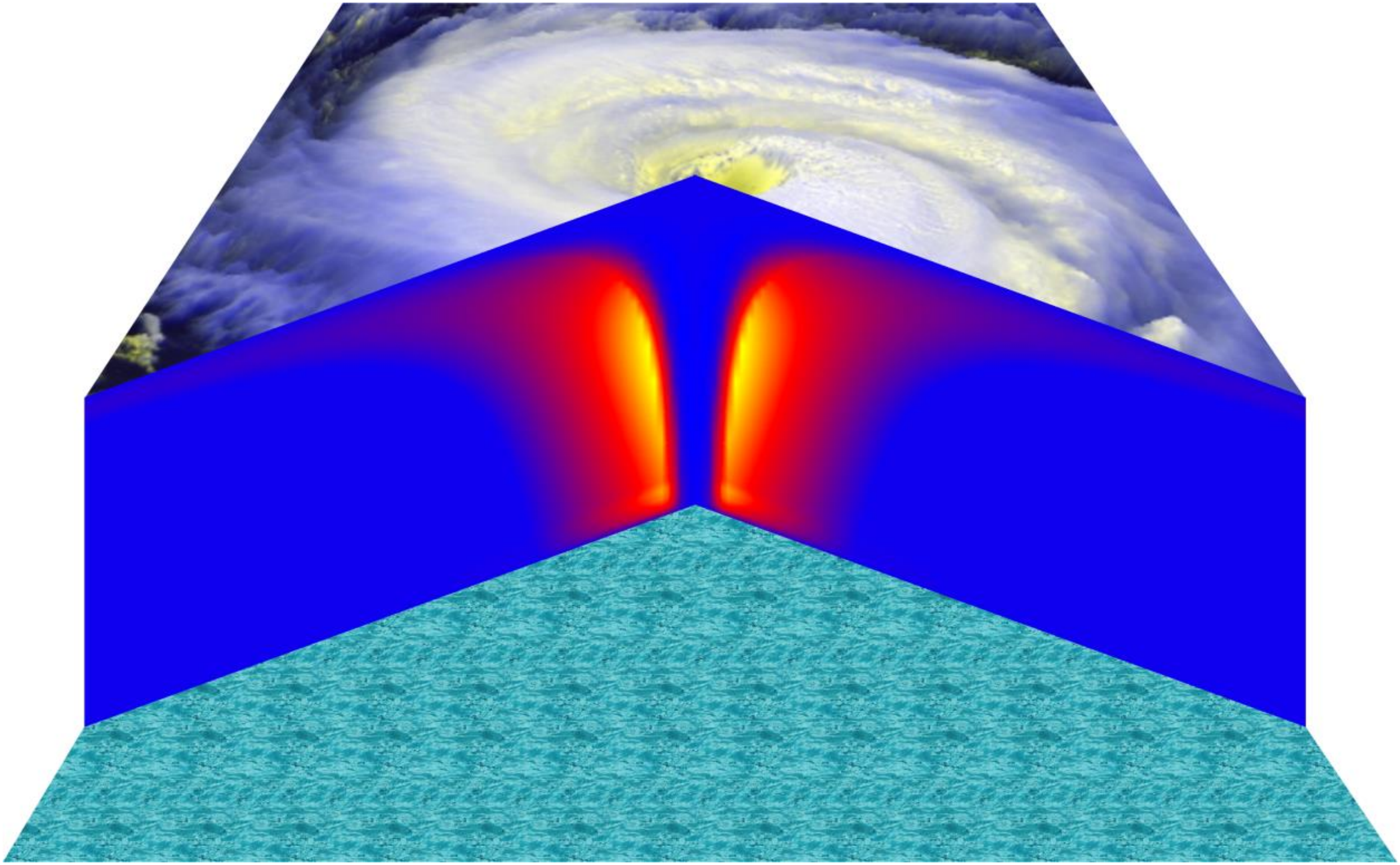
Hurricane Structure: Wind Speed



Azimuthal component of wind

< 11 mph - > 145 mph

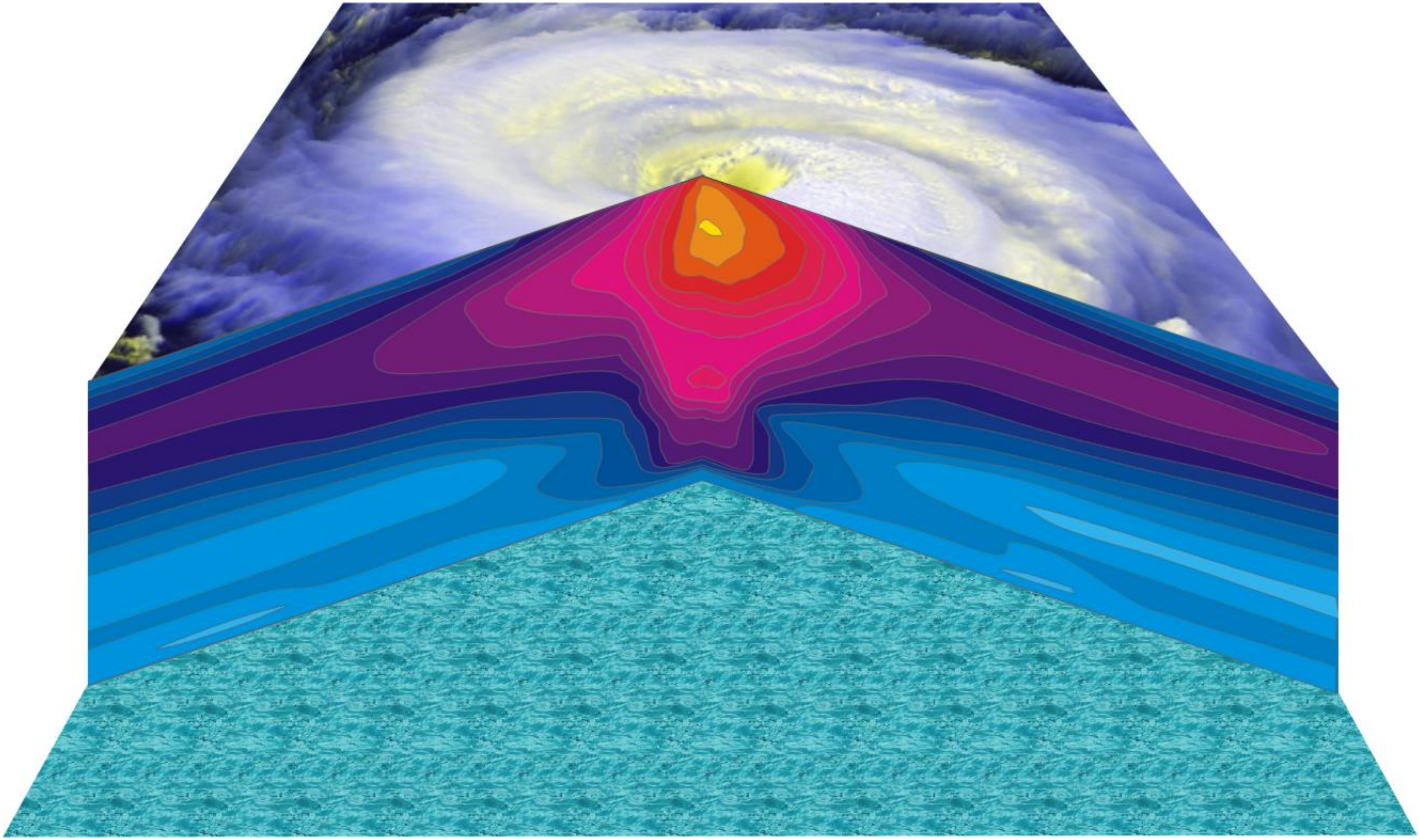
Vertical Air Motion



Updraft Speed

Strong upward motion in the eyewall

Hurricane Temperature

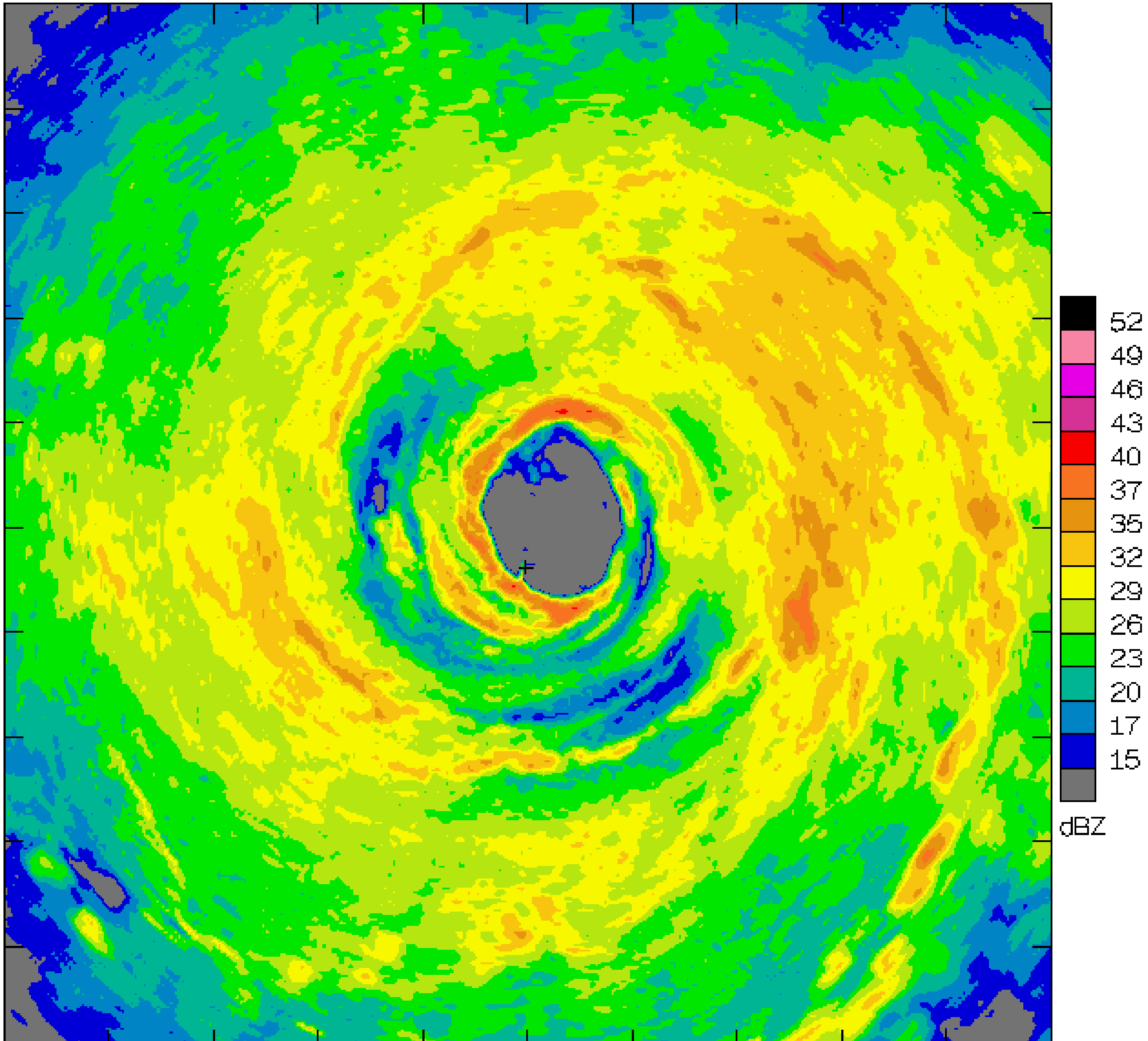


Temperature perturbation

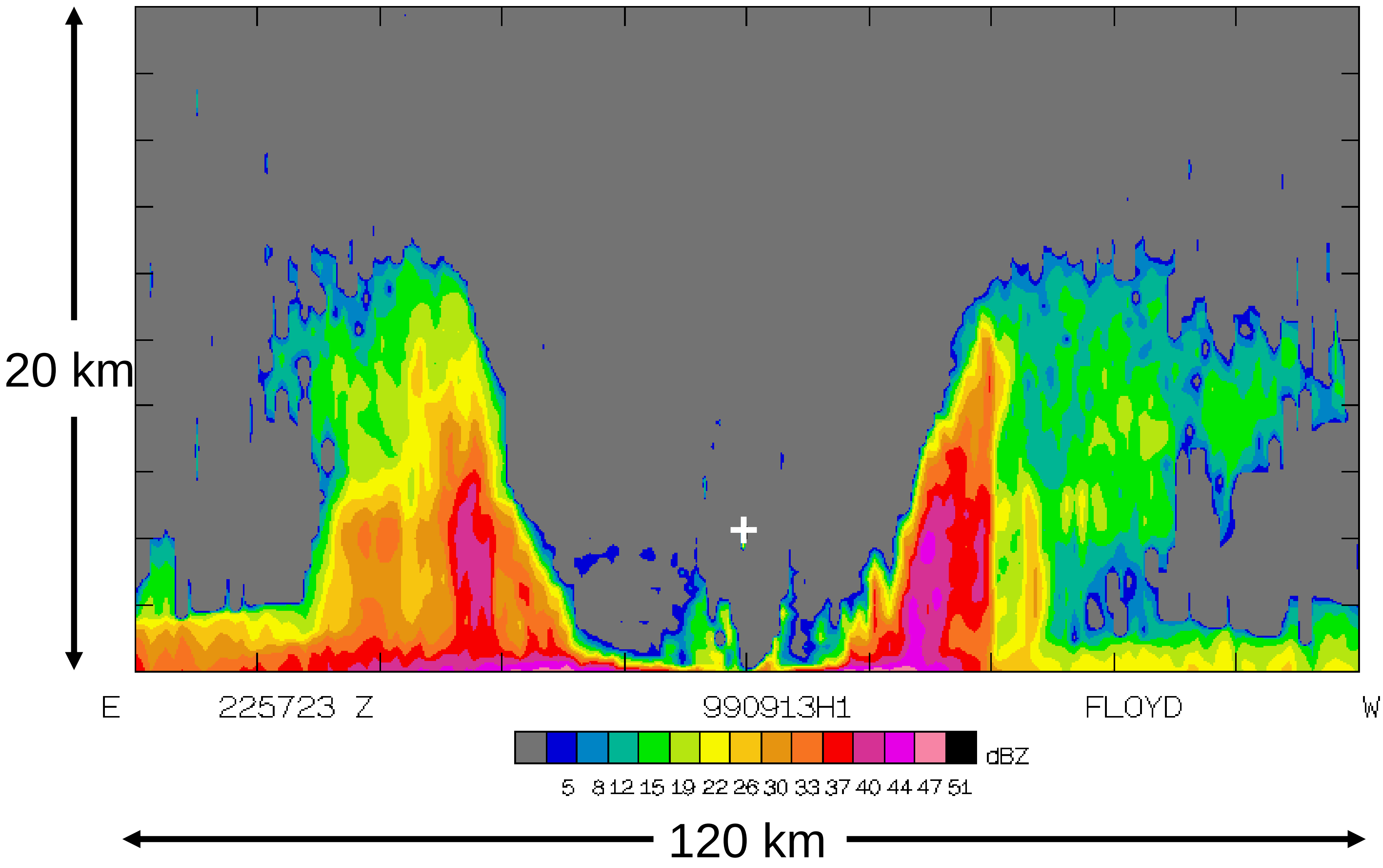
No temperature difference - > 16°C (29°F) warmer

Airborne Radar

360 km



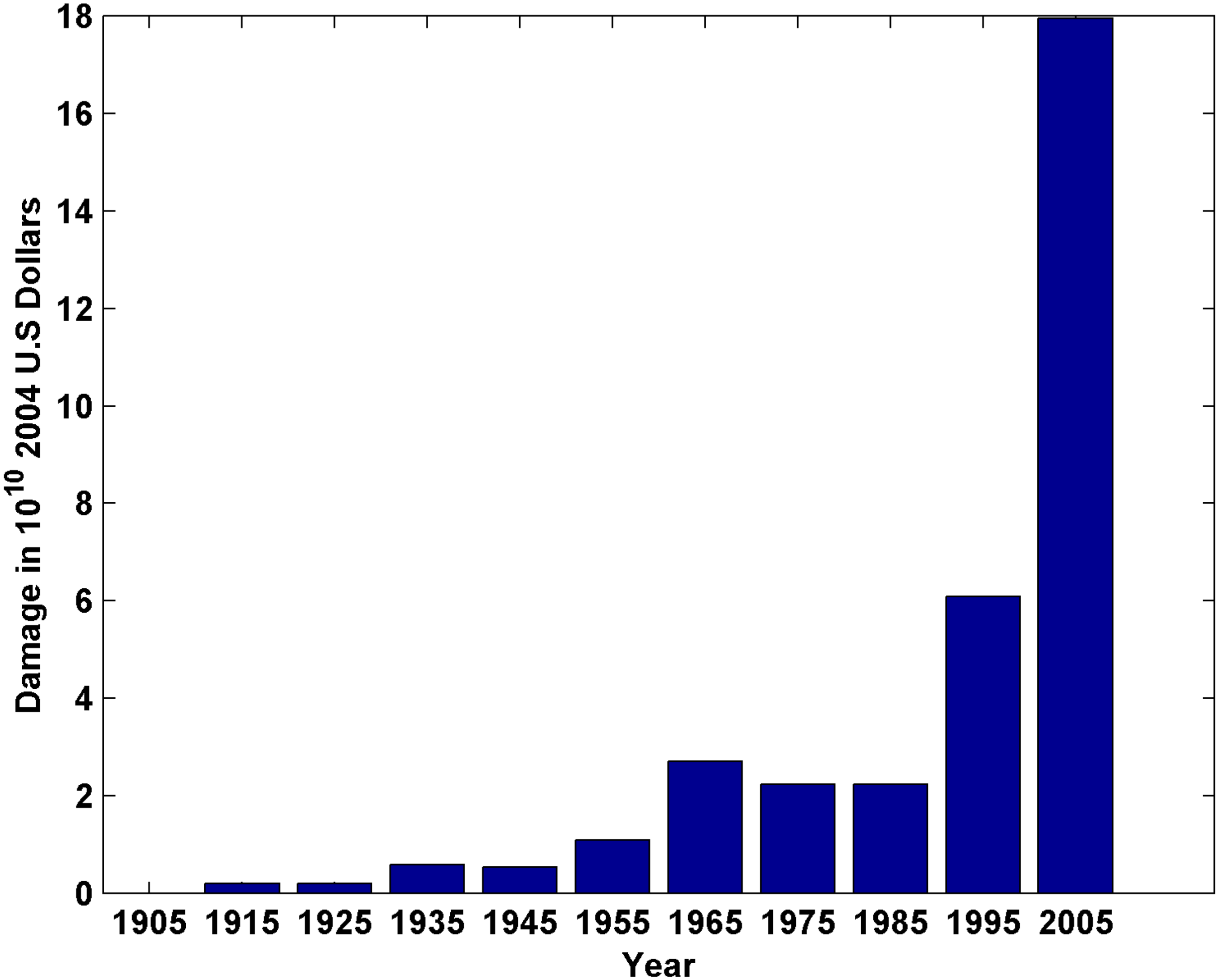
Cross-section of Radar Reflectivity



Hurricane Risk

- Tropical cyclones account for the bulk of natural catastrophe U.S. insurance losses
- Risk assessment is vital to the insurance industry and to government disaster preparedness programs
- Losses vary roughly as the cube of the maximum wind speed
- Katrina caused > 1300 deaths and > $130 billion in damage

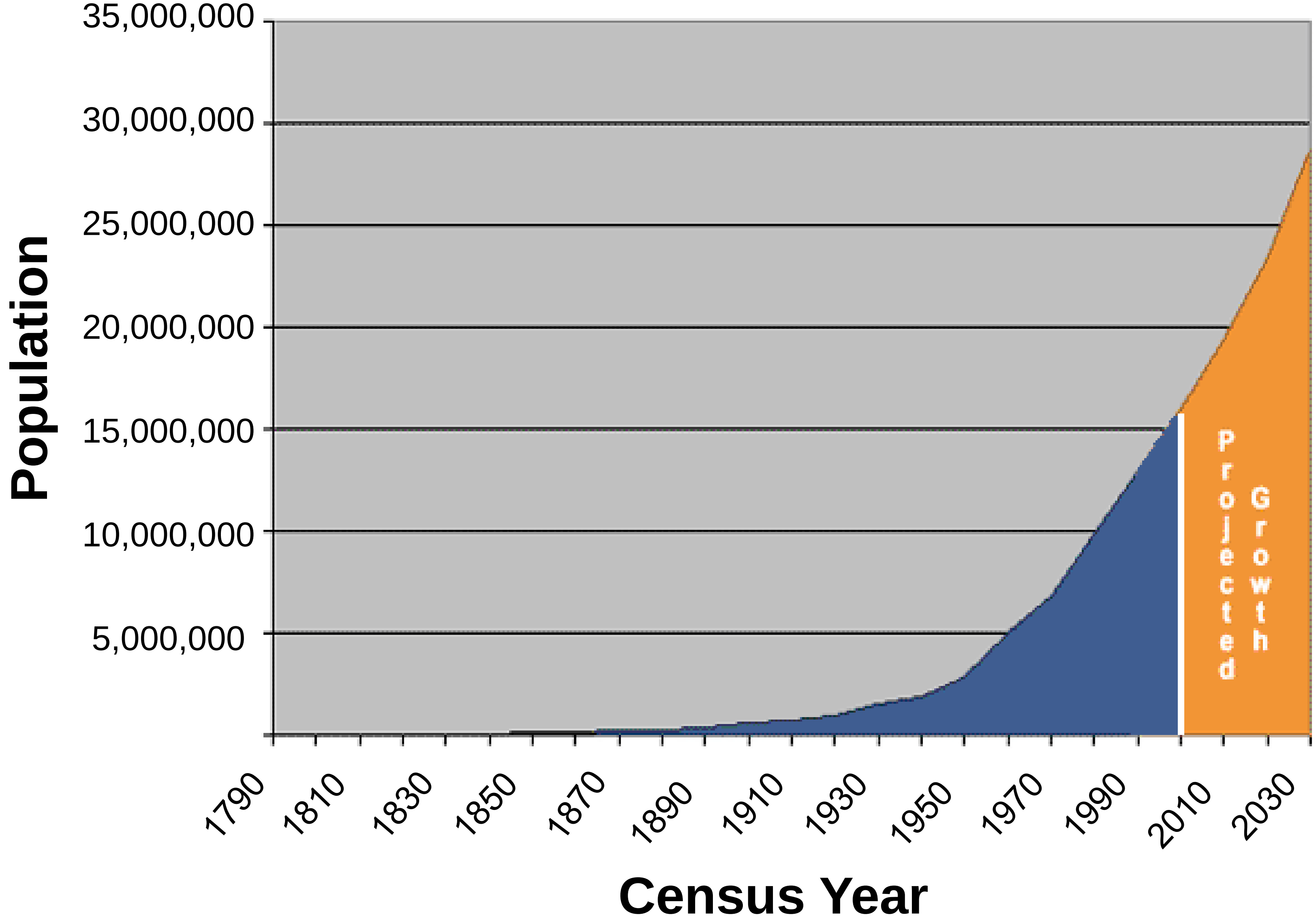
Total U.S. Hurricane Damage
by Decade



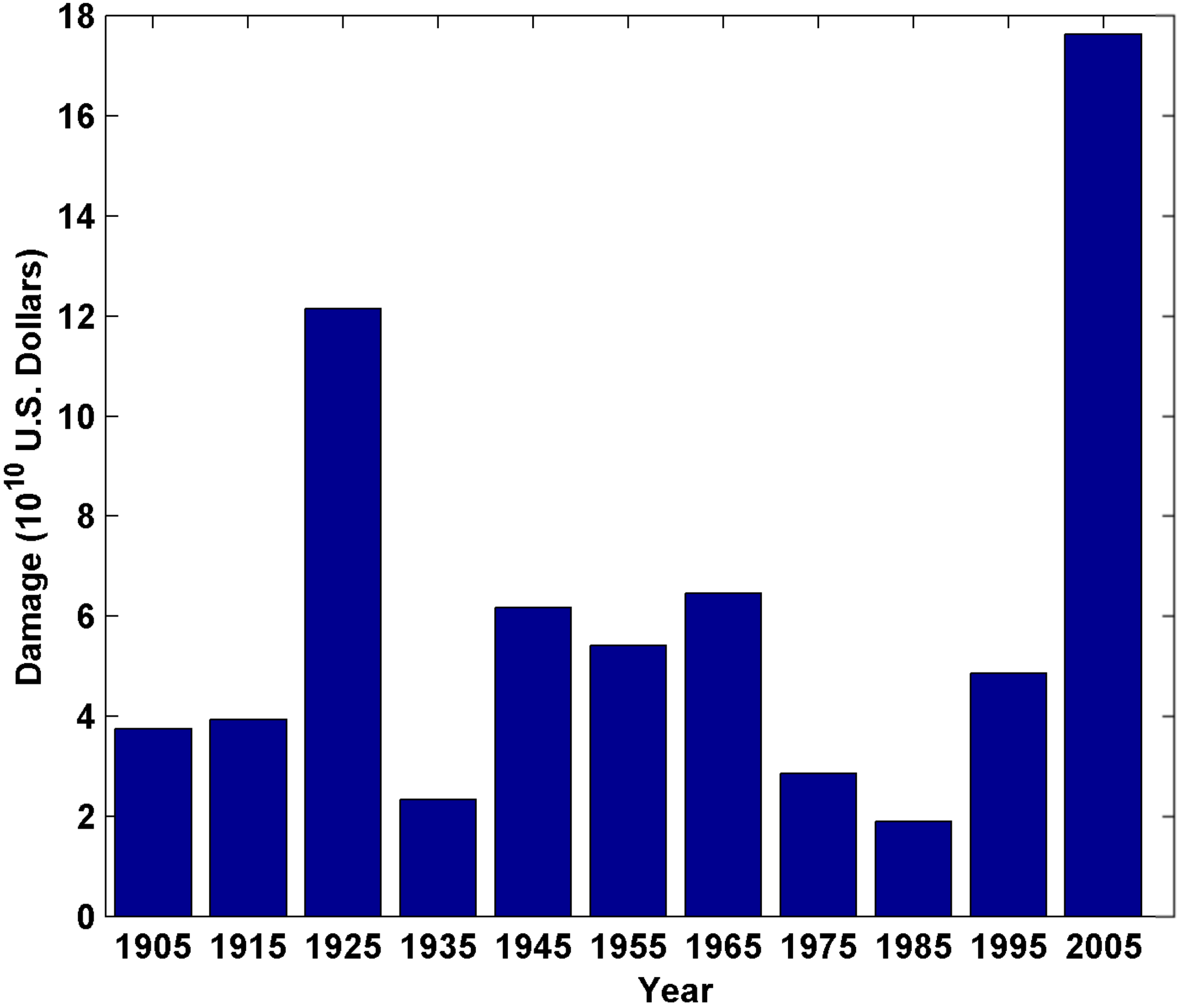
10^{10} = 10 billion

Source: Roger Pielke, Jr.

Florida Population



Total Adjusted Damage in 2004



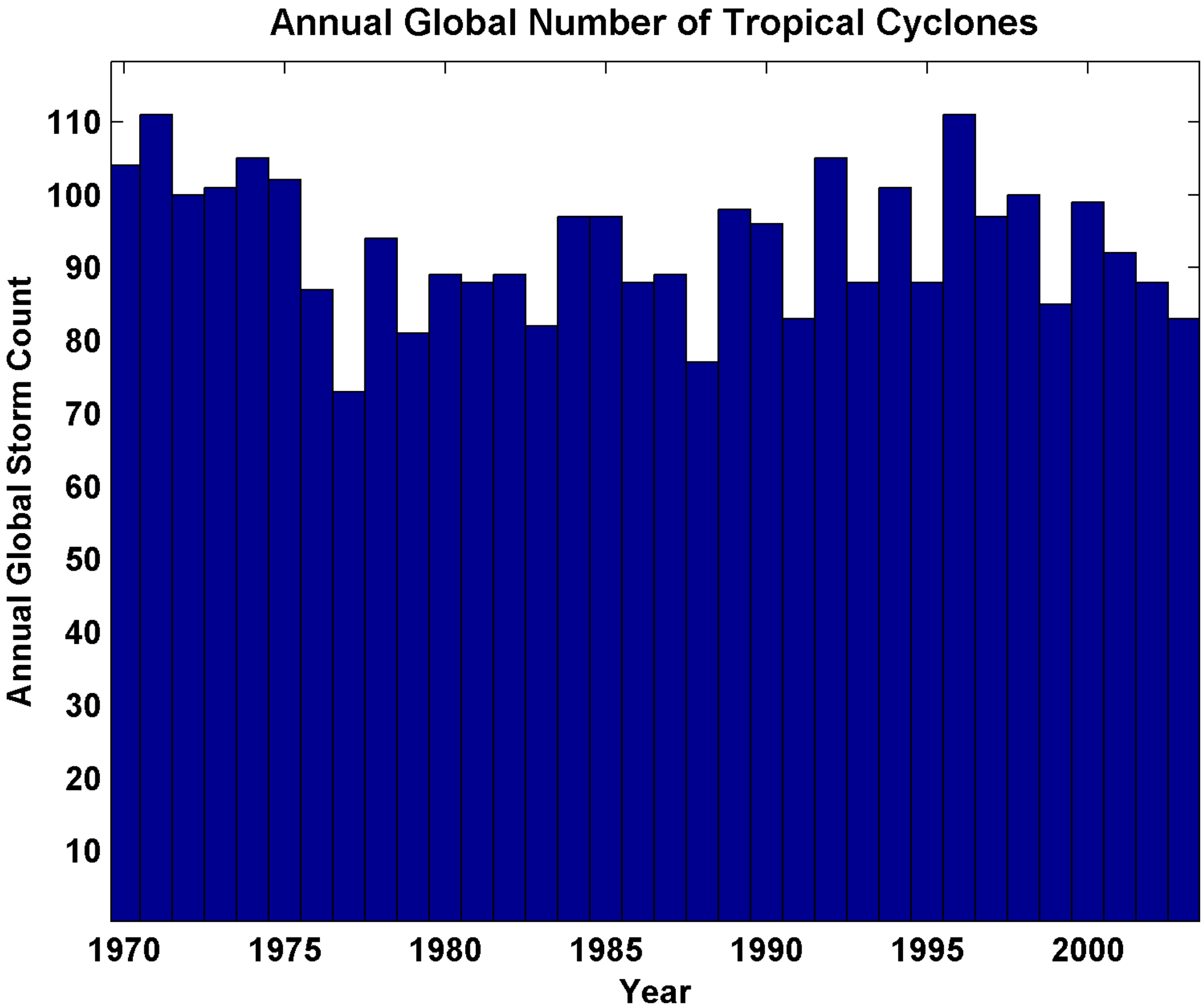
Source: Roger Pielke, Jr.

Summary of U.S. Hurricane Damage Statistics

- >50% of all damage was caused by the top 5 events, all category 4 and 5 storms
- >90% of all damage caused by storms of category 3 and greater
- Category 3, 4 and 5 storms are only 13% of the total landfalling events; only 30 since 1870
- ∴ ***Landfalling storm statistics are grossly inadequate for assessing hurricane risk***

Observations of Changing Hurricane Activity

No Long-Term Trend in Frequency

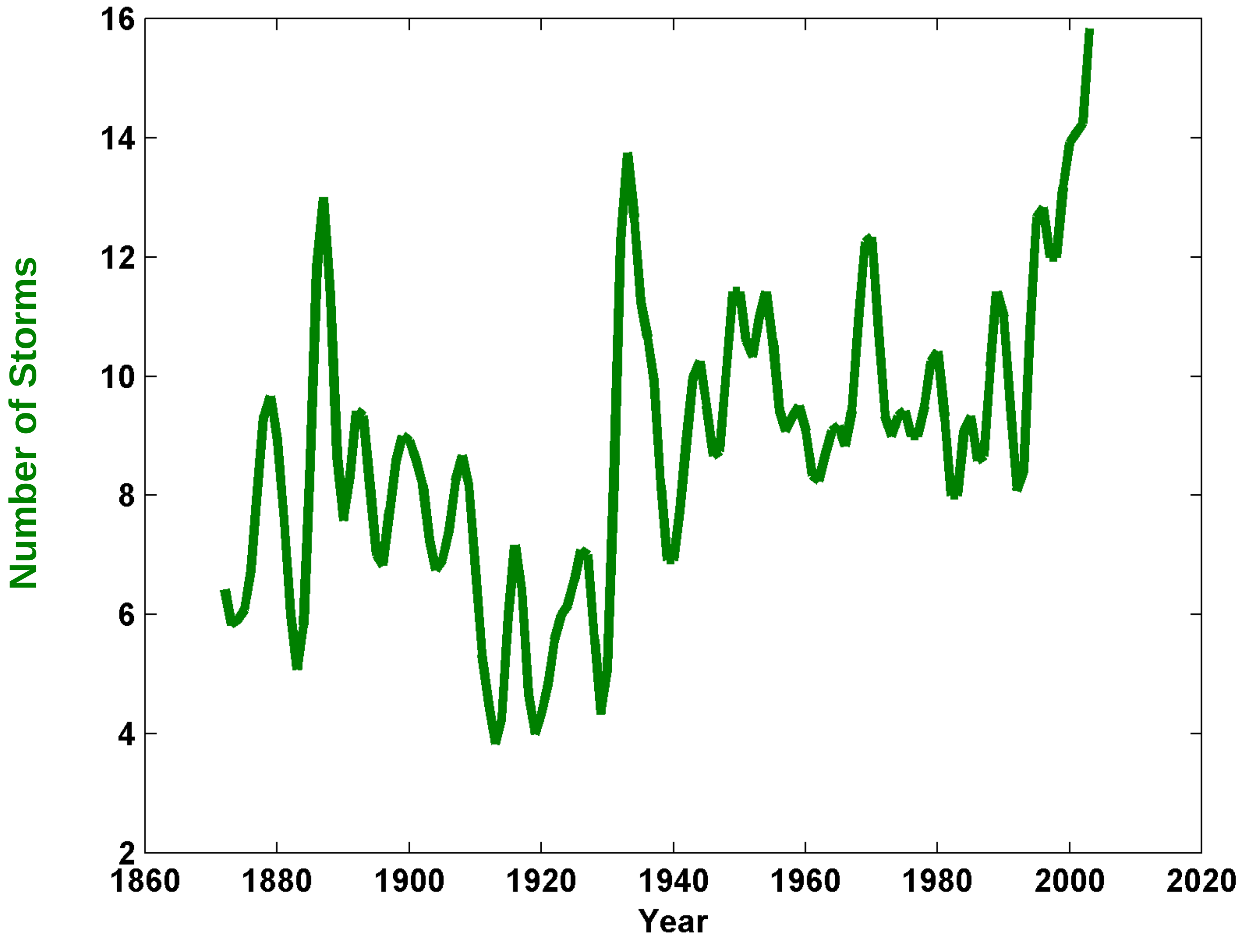


Observed Variability and Trends in Atlantic Hurricanes

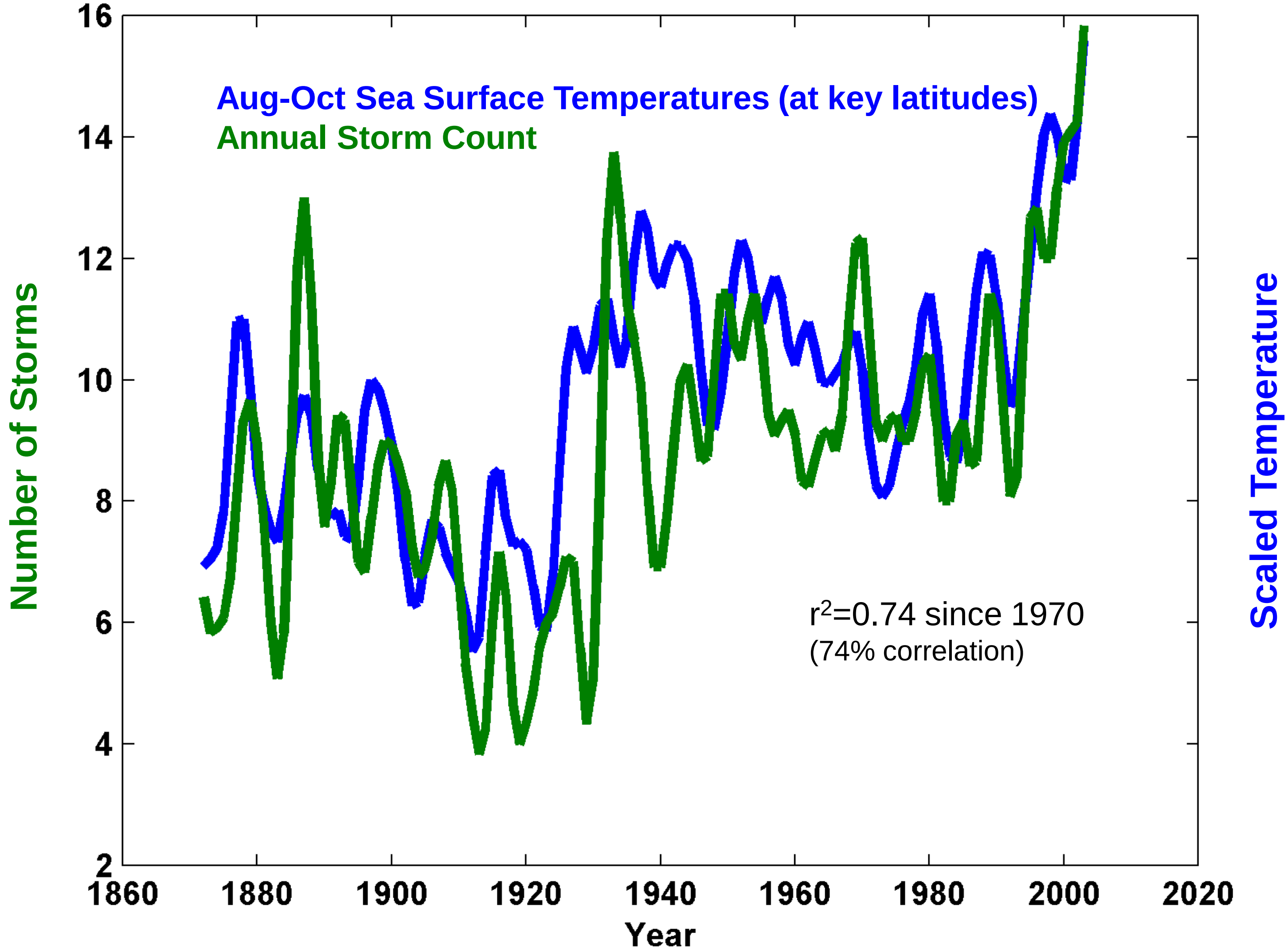
Note: Atlantic storms constitute only 11% of global tropical cyclone activity

Annual Atlantic Storm Count

(Smoothed with a weighted filter)



In Atlantic, the Frequency of Storms is Well Correlated with Tropical Atlantic Sea Surface Temperatures



Two Ways to Compare Hurricane Intensity

1. Power Dissipation Index: $$PDI \equiv \int_0^{\tau} V_{max}^3 dt$$

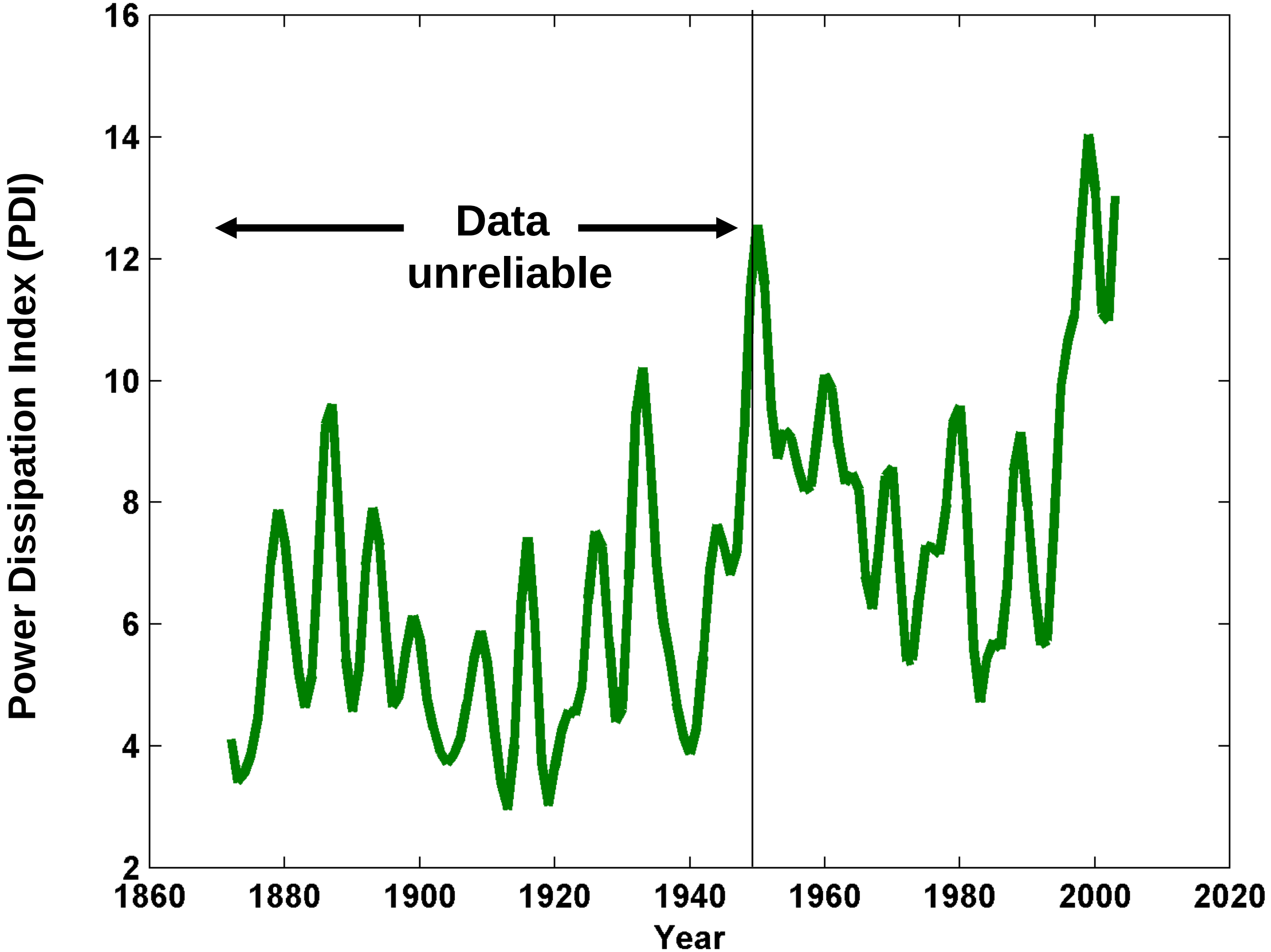
This is the estimated power produced by a hurricane

2. Storm Maximum Power Dissipation Index: $$SPDI \equiv \mathbf{MAX}\left(V_{max}^3\right)$$

This is the cube of the peak wind speed

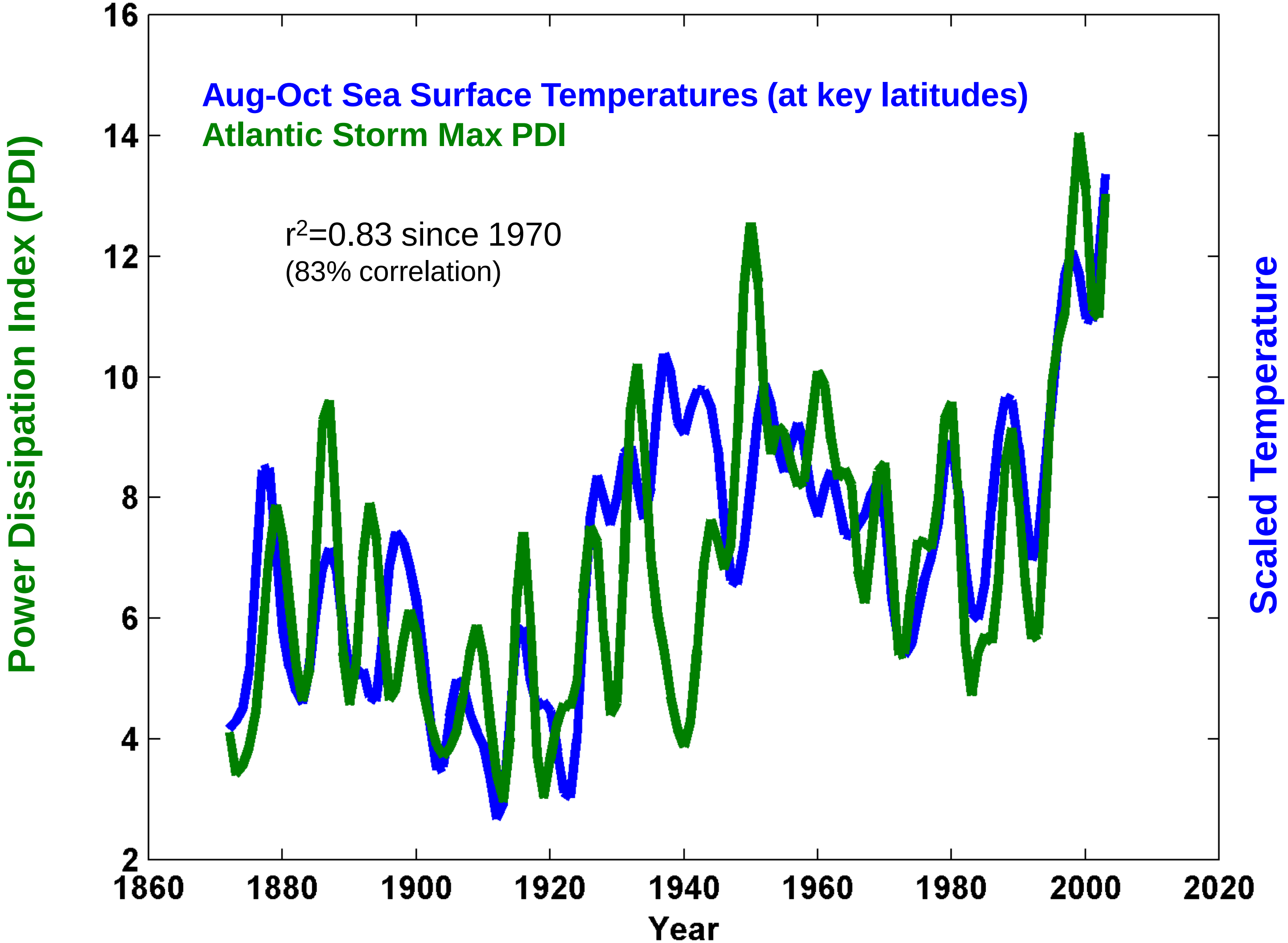
Change of Hurricane Intensity in the 20th Century

(Smoothed with a weighted filter)



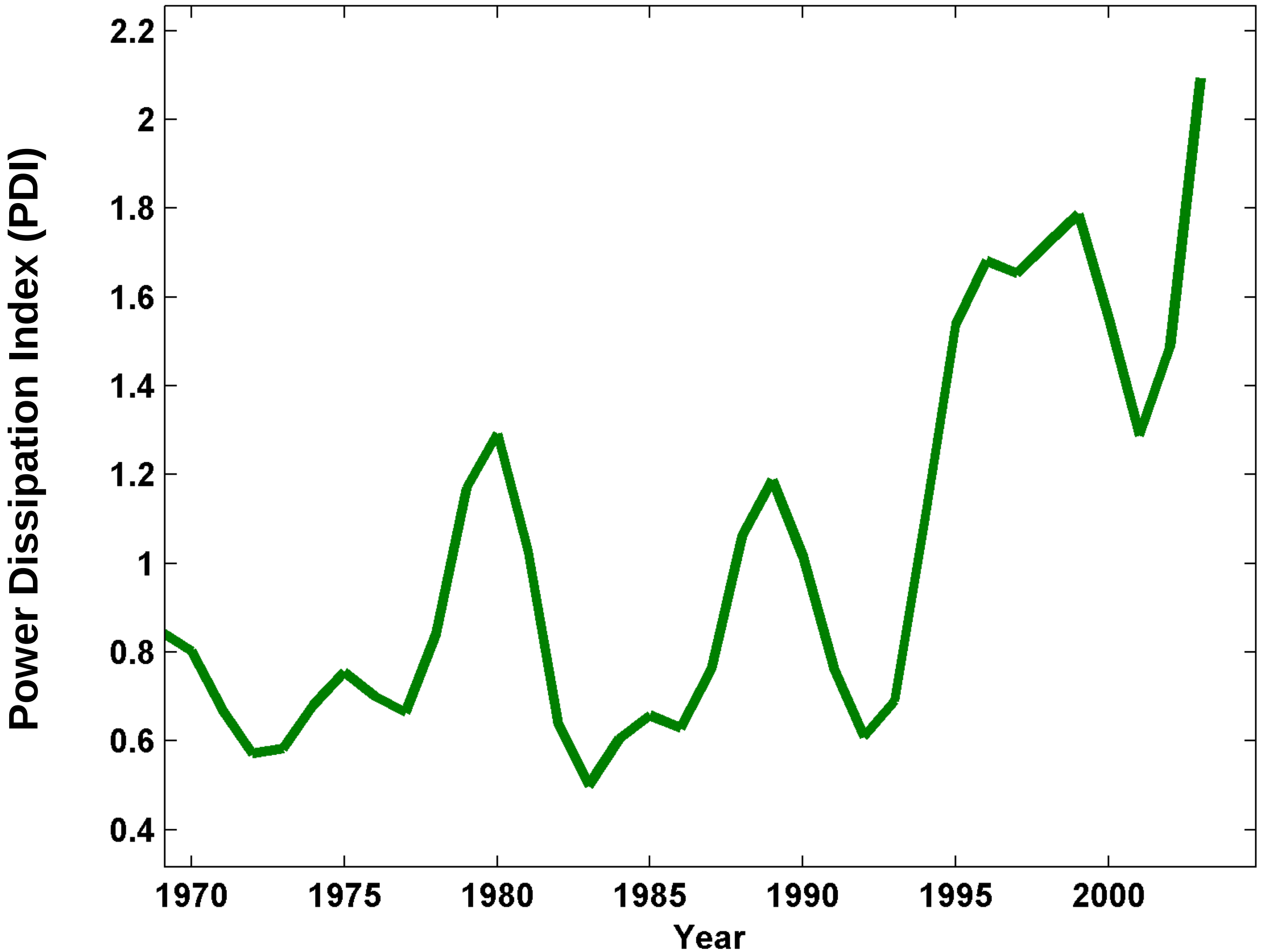
Atlantic Sea Surface Temperatures and Storm Max PDI

(Smoothed with a weighted filter)



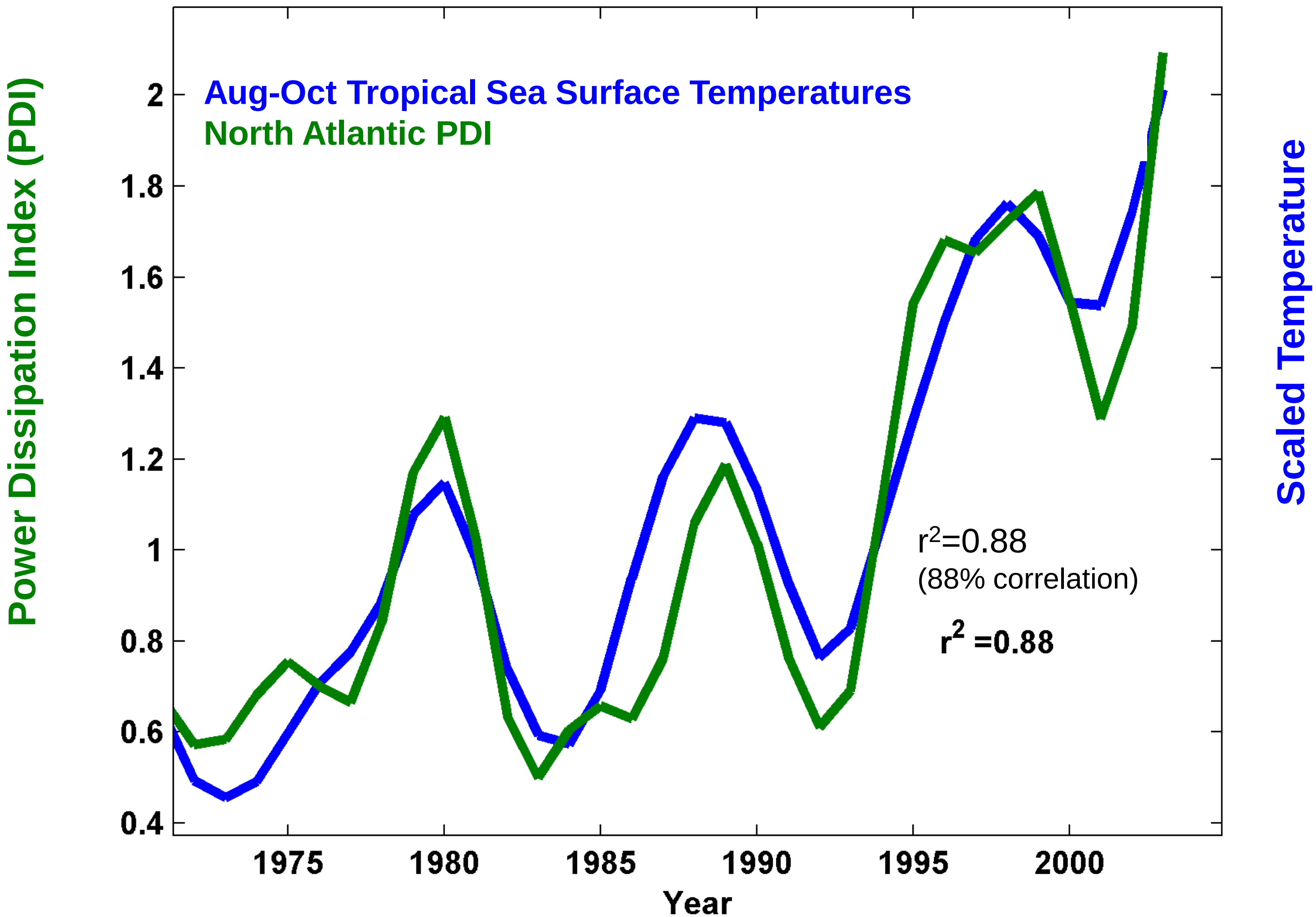
Atlantic PDI

(Smoothed with a weighted filter)



North Atlantic PDI and Sea Surface Temperatures

(Smoothed with a weighted filter)

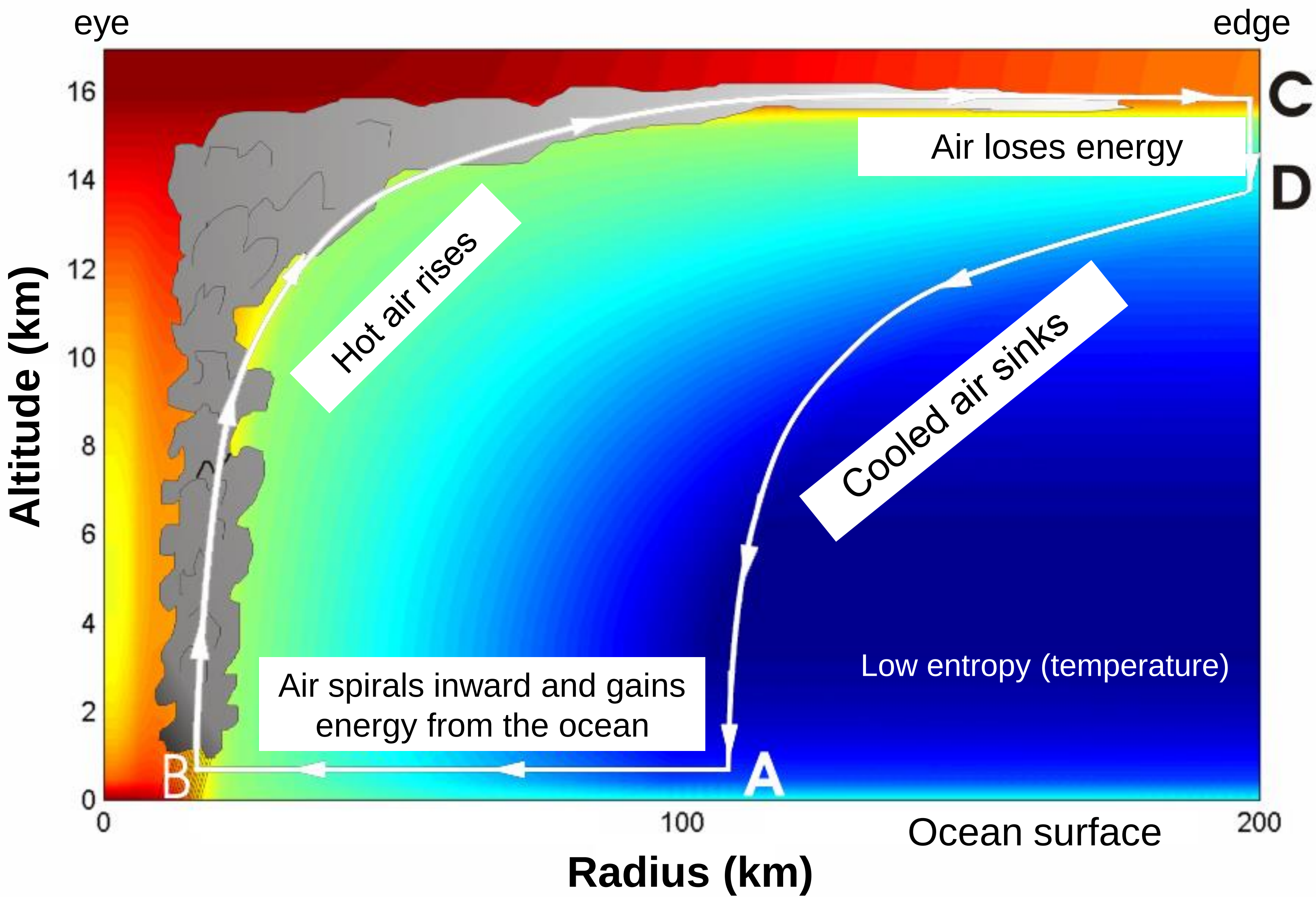


Why is Global Hurricane Activity Changing?

- Global frequency of events constant, but
- Intensity is increasing
- Duration is increasing
- Frequency is increasing in the Atlantic (11% of global total)

First Need to Know How Hurricanes Work

Cross-section through a Hurricane & Energy Production



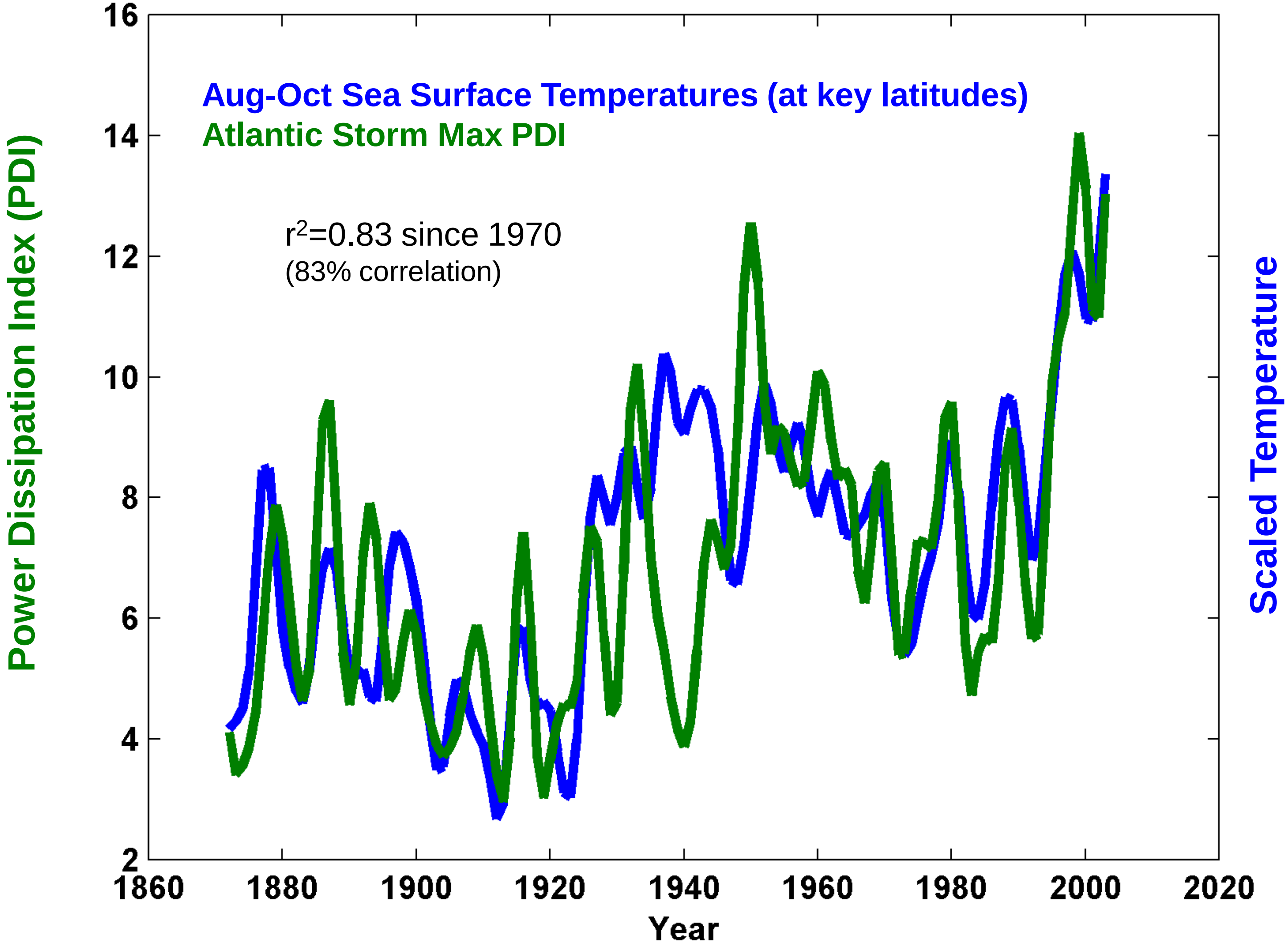
Energy Cycle gives Maximum Wind Speed that can be Sustained in Hurricanes

This depends on:

- Magnitude of the greenhouse effect
- Sea surface temperature
- Temperature in the lower stratosphere
- Average speed of the trade winds within which hurricanes form

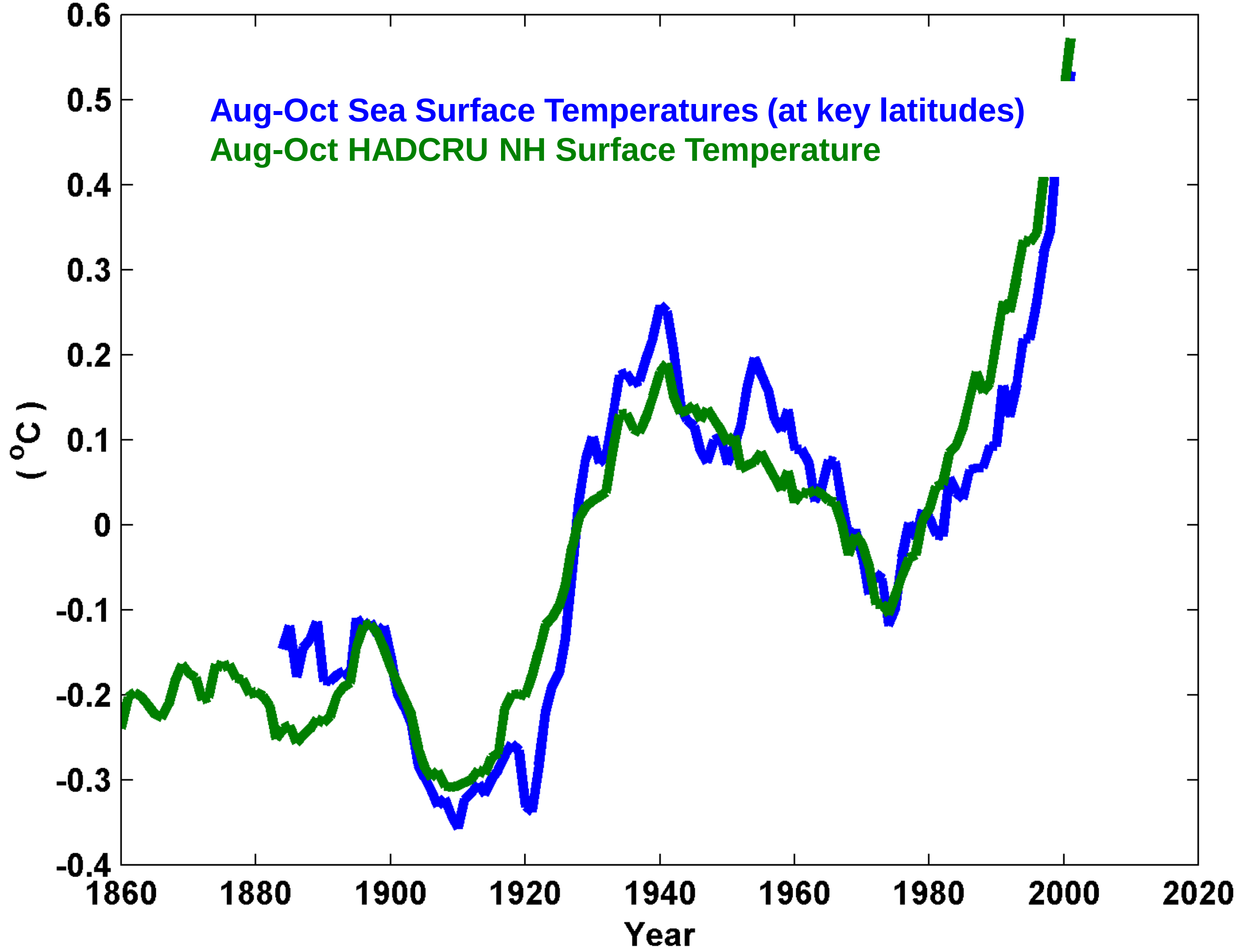
Atlantic Sea Surface Temperatures and Storm Max PDI

(Smoothed with a weighted filter)



What is Causing Changes in the Tropical Sea Surface Temperature?

Atlantic Sea Surface Temperatures and Surface Temperature



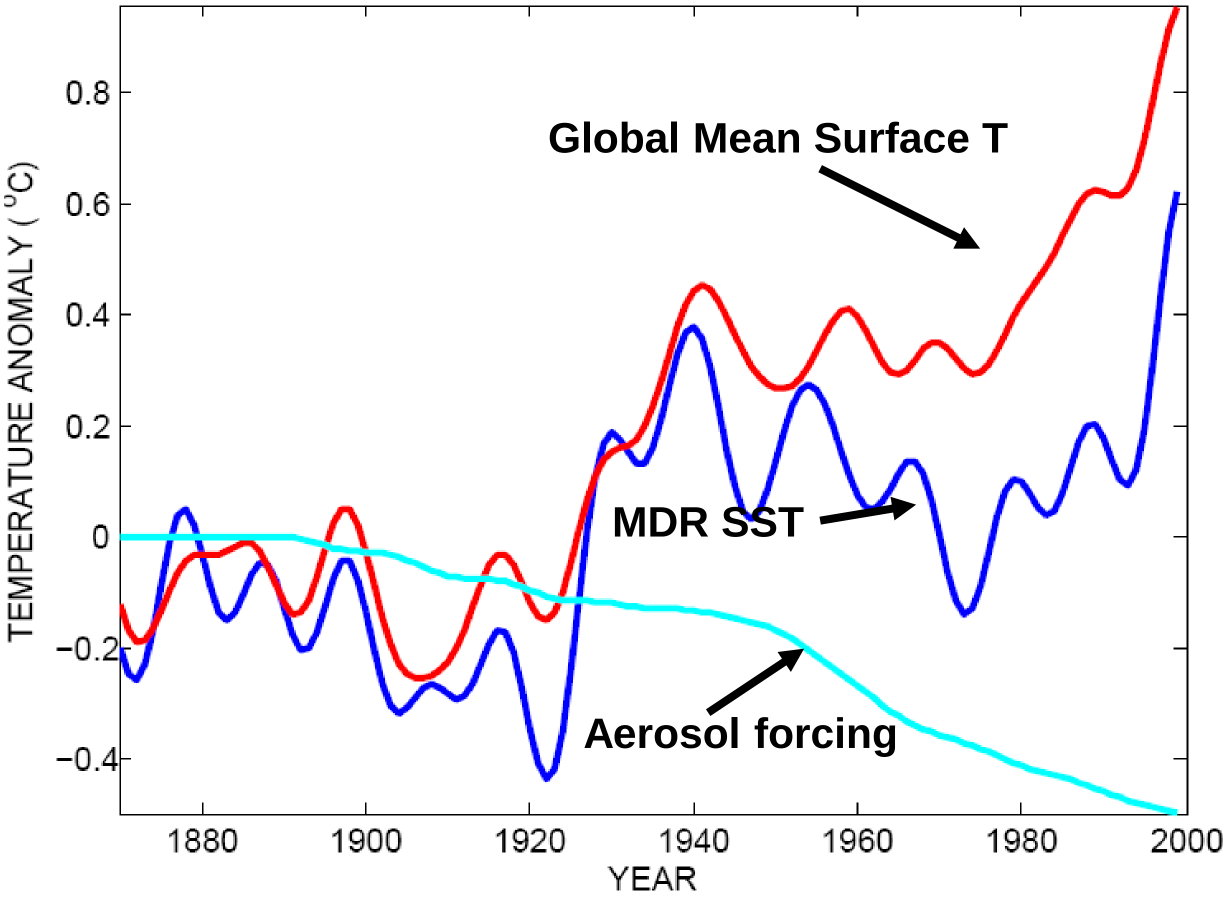
What is Controlling Northern Hemisphere Surface Temperature?

Hypothesis about Why the Northern Hemisphere Differs from the Globe:

Northern hemisphere surface temperature (and late summer-early fall tropical Atlantic sea surface temperature) represents a linear combination of global warming and aerosol cooling

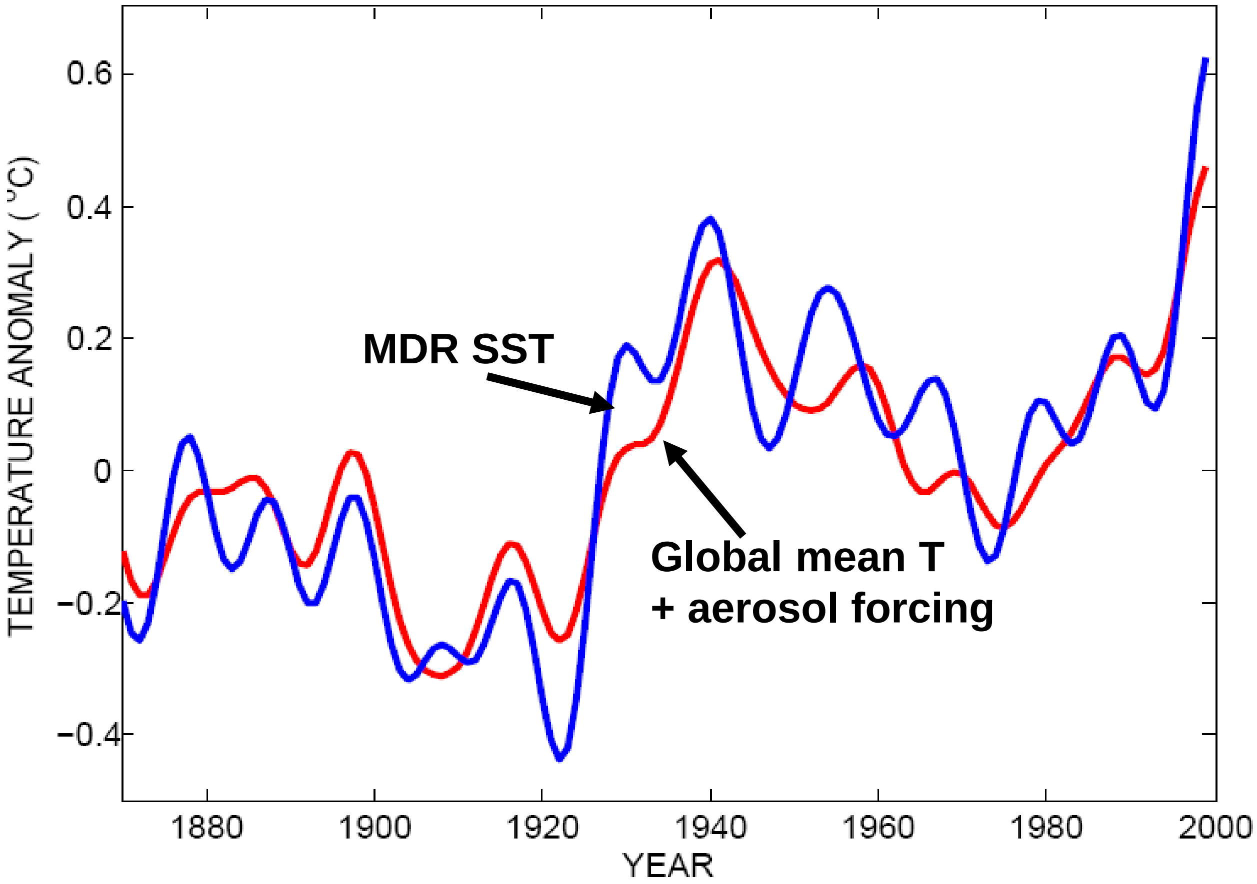
Mann and Emanuel 2006

Tropical Atlantic SST(blue), Global Mean Surface Temperature (red), Aerosol Forcing (aqua)



Mann, M. E., and K. A. Emanuel, 2006. Atlantic hurricane trends linked to climate change. EOS, 87, 233-244.

Best Fit Linear Combination of Global Warming and Aerosol Forcing (red) versus Tropical Atlantic SST (blue)

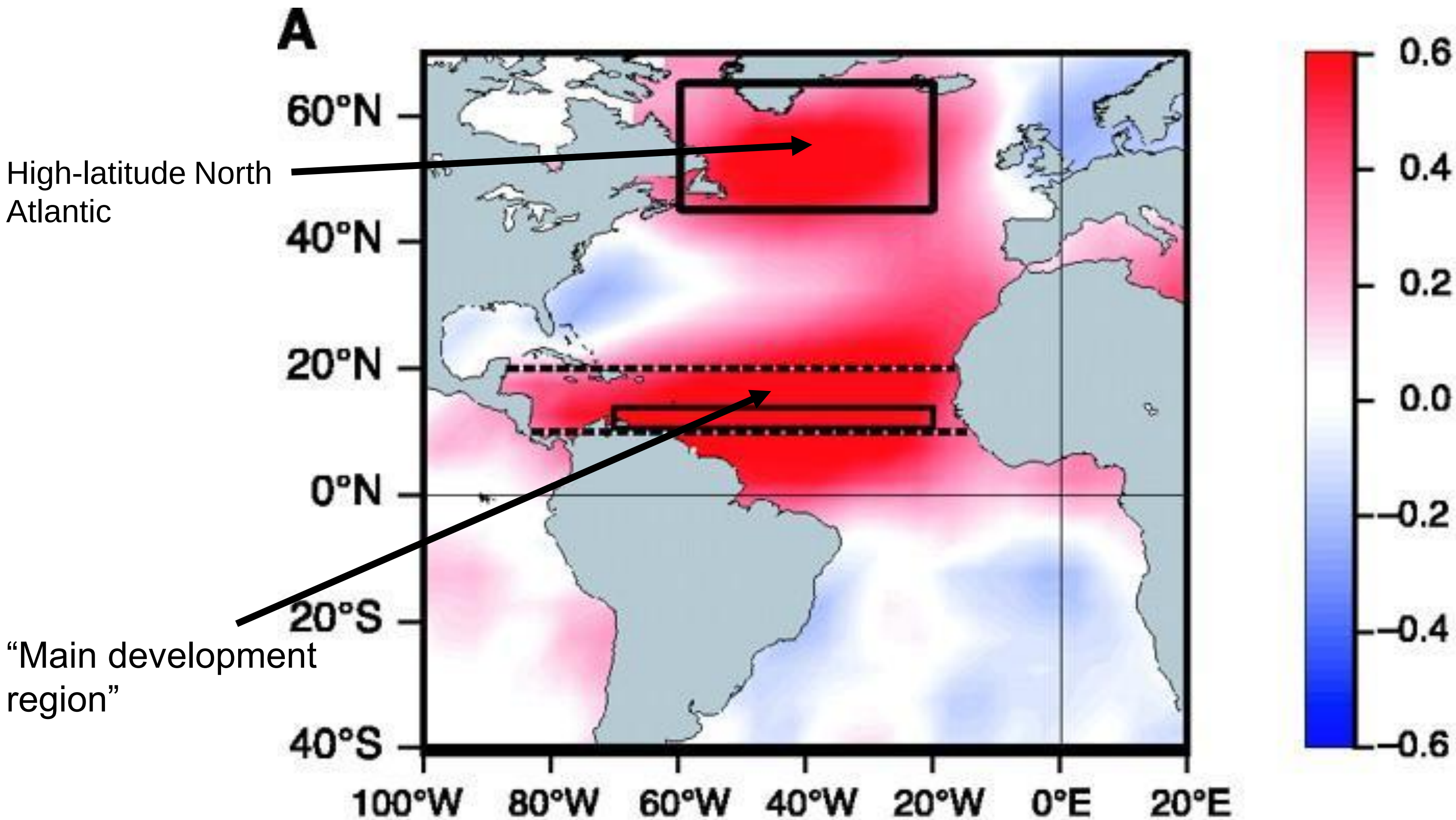


Mann, M. E., and K. A. Emanuel, 2006. Atlantic hurricane trends linked to climate change. EOS, 87, 233-244.

Scientific Basis of the "Natural Cycles" Story

The Atlantic Multi-Decadal Oscillation (AMO)

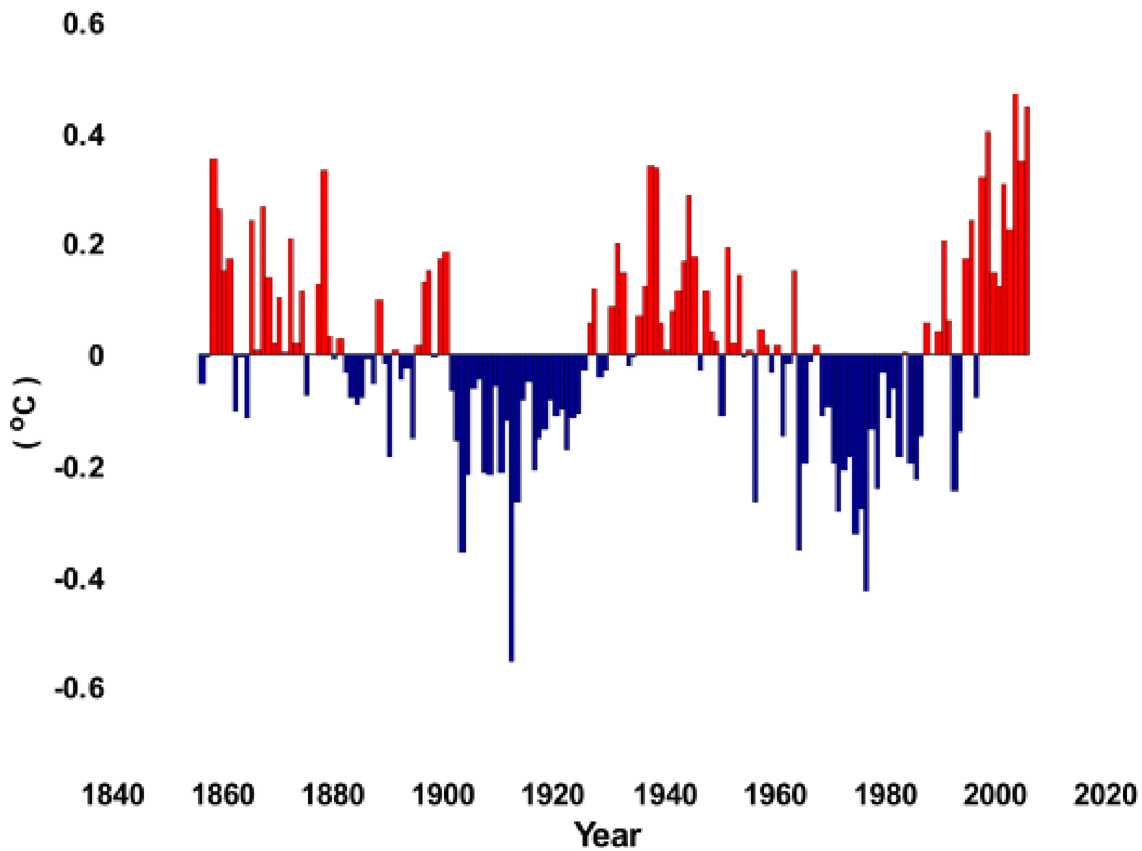
The AMO is a Pattern of Sea Surface Temperature



S. B. Goldenberg et al., 2001. Science, 293, 474-479

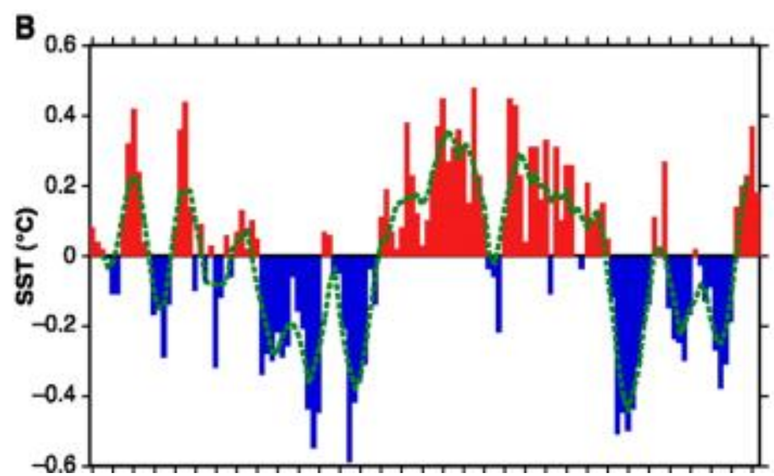
De-trended Aug-Oct Northern Hemisphere Surface Temperature

(Hadley Centre Global Surface Temperature Data)



Variation with Time of the Strength of the AMO

(Goldenberg et al. 2001)



Summary

- Hurricanes are the worst natural disasters that affect the U.S.
- Hurricanes are almost perfect Carnot heat engines that make use of the thermodynamic disequilibrium between the tropical ocean and atmosphere, caused by the greenhouse effect
- Tropical cyclone intensity and duration are increasing worldwide, in concert with tropical ocean temperature

Summary (contd.)

- In the Atlantic, the frequency, intensity and duration of events are all increasing in concert with tropical ocean temperature
- No evidence for natural multi-decadal “cycles” in late summer-early fall Tropical Atlantic SST or Atlantic TC activity; long-term trends and variability likely have arisen from forced climate change
- Changing tropical cyclone activity may eventually affect the ocean’s thermohaline circulation, moderating tropical warming but accelerating high latitude warming

Dr. Kerry A. Emanuel

Professor of Atmospheric Science, Massachusetts Institute of Technology

Dr. Kerry A. Emanuel is one of the world's leading authorities on hurricanes. He is a professor in the Program in Atmospheres, Oceans, and Climate in the Department of Earth, Atmospheric, and Planetary Sciences at the Massachusetts Institute of Technology (MIT), where he received his Ph.D. degree in Meteorology. He became a member of the MIT faculty in 1981 after 3 years at the University of California, Los Angeles (UCLA). He is a fellow of the American Meteorological Society and a member of the National Research Council's Board on Atmospheric Sciences and Climate. His research focuses on tropical meteorology and climate, with a specialty in hurricane physics. His work in air-sea interaction in tropical cyclones is well regarded among the meteorological community.

Dr. Emanuel has an extensive list of publications that include two books and more than 100 peer-reviewed scientific papers. His new book, Divine Wind: The History and Science of Hurricanes, was named one of the top twenty science books of 2005 by Discover magazine. In this book, he explains how tropical climates give rise to the most powerful storms in the world. TIME magazine named Dr. Emanuel one of the 100 most influential people for 2006 for his latest research, published in a recent issue of the journal Nature, which correlates the greater increasing hurricane intensity with human-induced global warming.