Hurricanes and Climate: Our growing understanding

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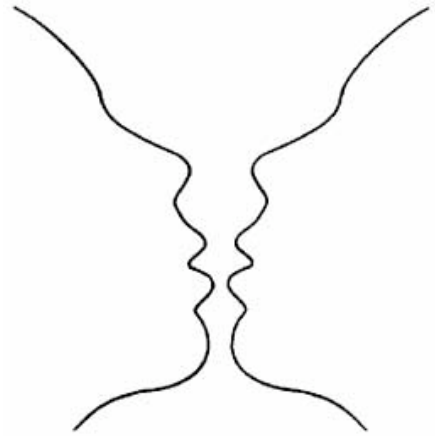
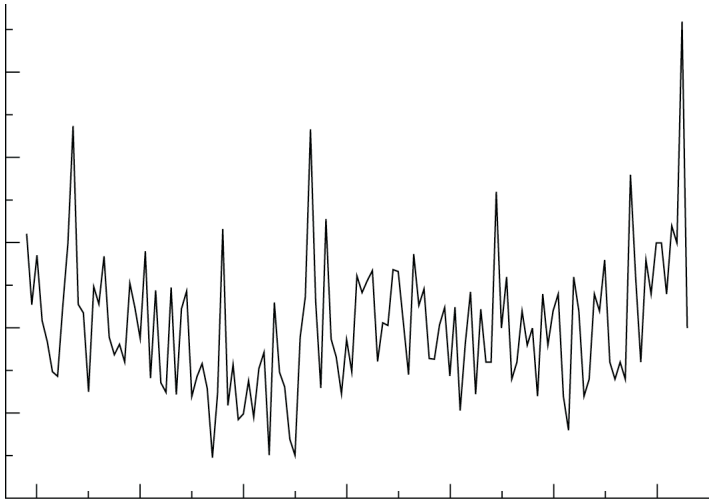


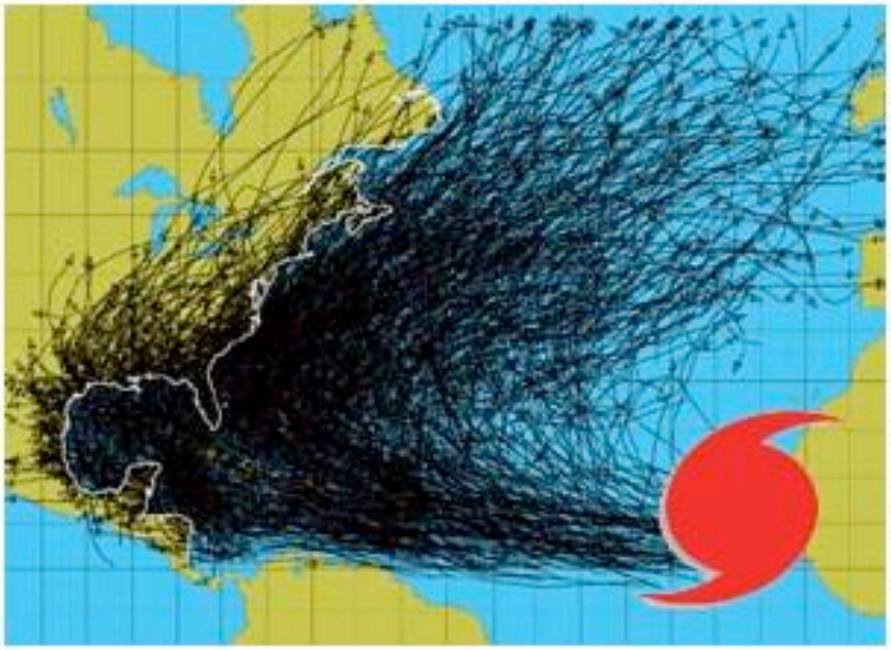


Key concepts

- Established vs. Developing understanding
  - Multiple factors impact hurricanes
  - Observational uncertainties
  - Pushing the limits of our theory and computers
- False choice: global warming **OR** climate variability
- Not about one storm or one season ("Katrina effect").
- How do we develop our understanding?
  - Observations
  - Theoretical understanding
  - Numerical Modeling
- As we learn more, interpretation of total evidence changes: this is how science works
- Interpretations of sum of evidence can differ between scientists: not a "debate" - an ongoing inquiry.

NOAA Magazine || NOAA Home Page Commerce Dept.

NOAA ATTRIBUTES RECENT INCREASE IN HURRICANE ACTIVITY TO NATURALLY OCCURRING MULTI-DECADAL CLIMATE VARIABILITY *



Nov. 29, 2005 — The nation is now wrapping up the 11th year of a new era of heightened Atlantic hurricane activity. This era has been unfolding in the Atlantic since 1995, and is expected to continue for the next decade or perhaps longer. NOAA attributes this increased activity to natural occurring cycles in tropical climate patterns near the equator. These cycles, called "the tropical multi-decadal signal," typically last several decades (20 to 30 years or even longer). As a result, the North Atlantic experiences alternating decades long (20 to 30 year periods or even longer) of above normal or below normal hurricane seasons. NOAA research shows that the tropical multi-decadal signal is causing the increased Atlantic hurricane activity since 1995, and is not related to greenhouse warming. **(Click NOAA**

Research by NOAA scientists [..] and [..], currently in press with the *Journal of Climate*, describes the tropical multi-decadal signal and shows that it accounts for the entire inter-related set of conditions that controls hurricane activity for decades at a time."

*EDITOR'S NOTE: This consensus in this on-line magazine story represents the views of some NOAA hurricane researchers and forecasters, but does not necessarily represent the views of all NOAA scientists. It was not the intention of this article to discount the presence of a human-induced global warming element or to attempt to claim that such an element is not present. There is a robust, on-going discussion on hurricanes and climate change within NOAA and the scientific community.

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ROSS GELBSPAN

The Boston Globe

Katrina's real name

By Ross Gelbspan | August 30, 2005

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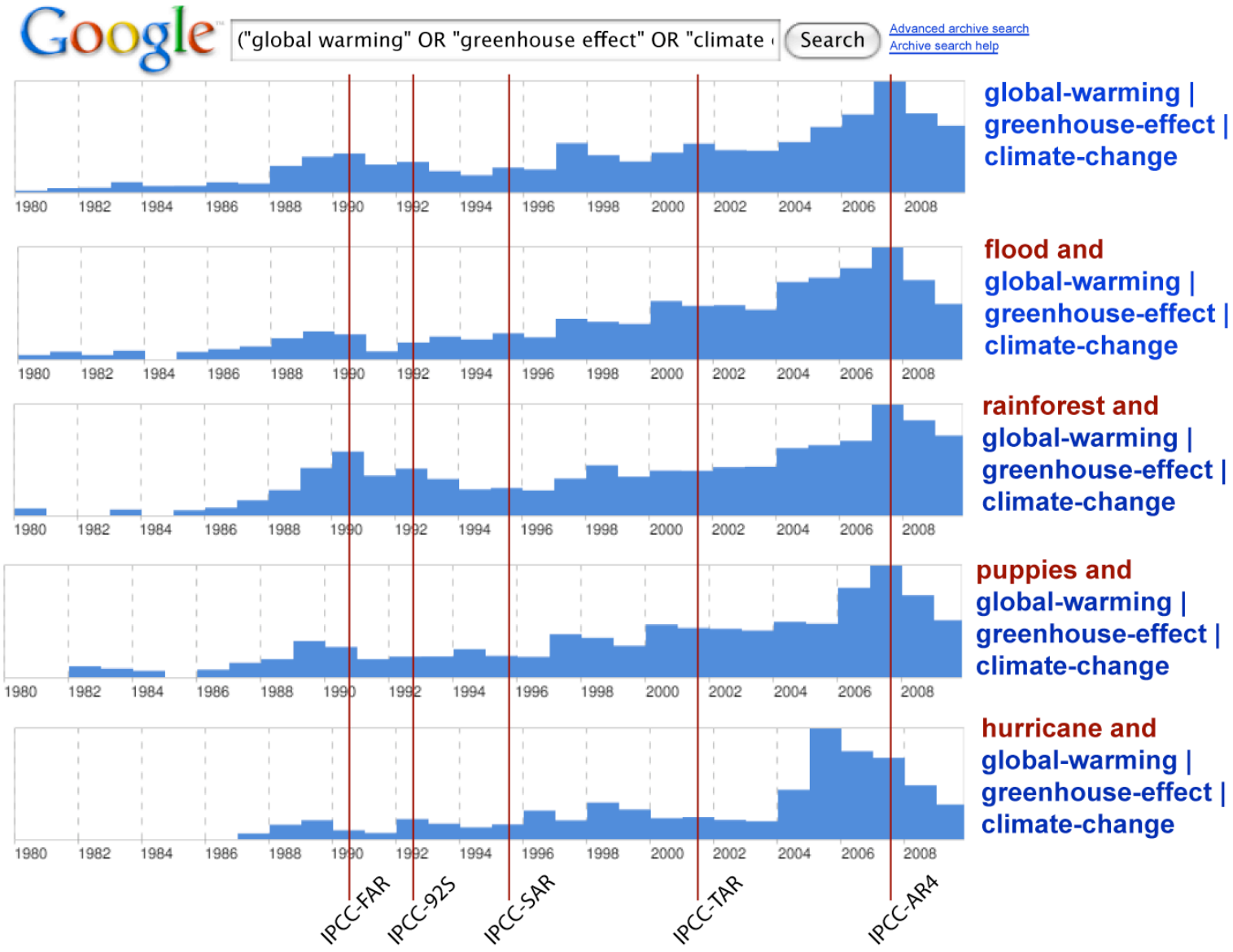
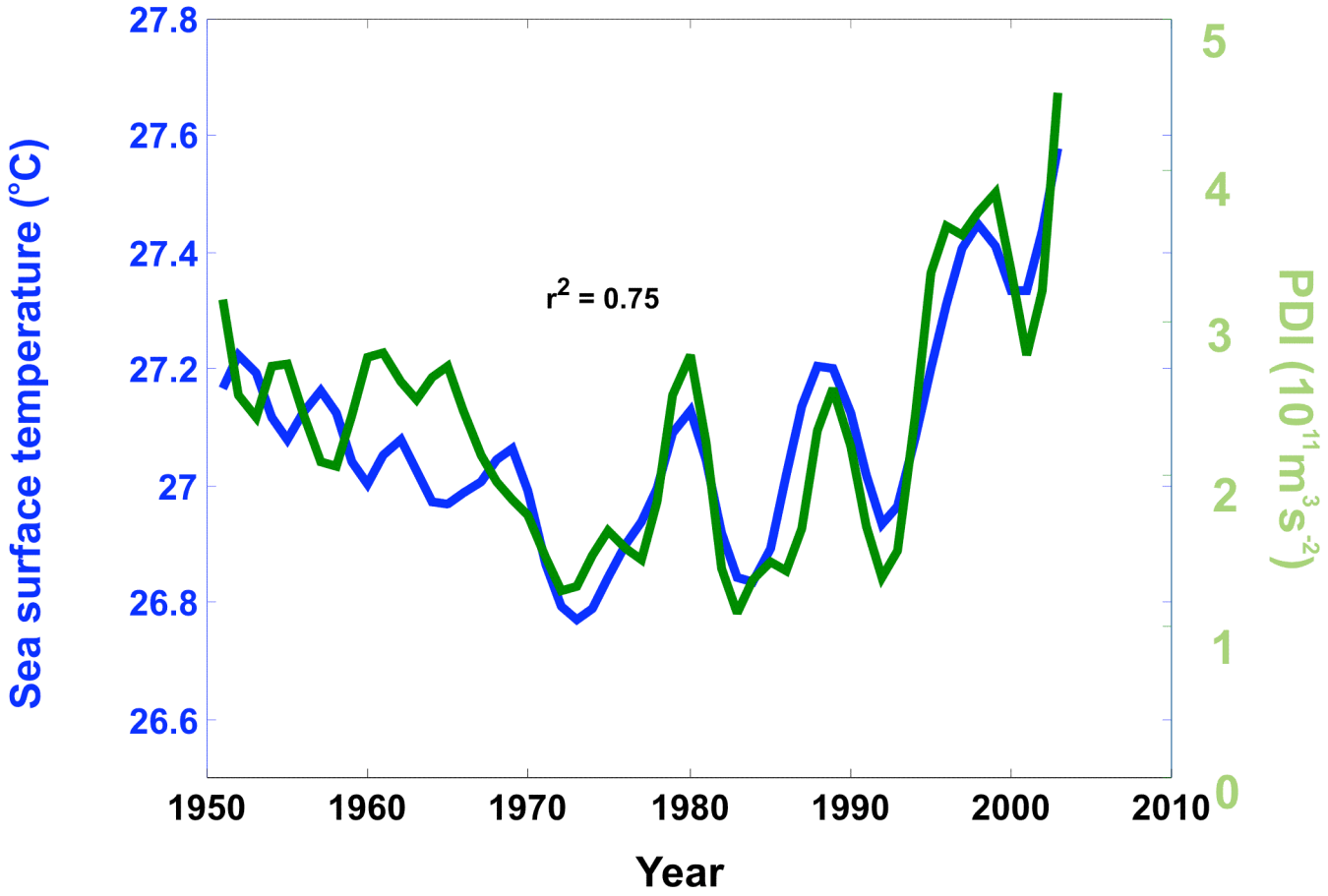
What about 1947 Hurricane and Betsy (1965)…oh and Camille (1969)? Focus on long-term, not events.

News search on global warming and impacts



There is some recent evidence that overall Atlantic hurricane activity may have increased since in the 1950s and 60s in association with increasing sea surface temperatures…

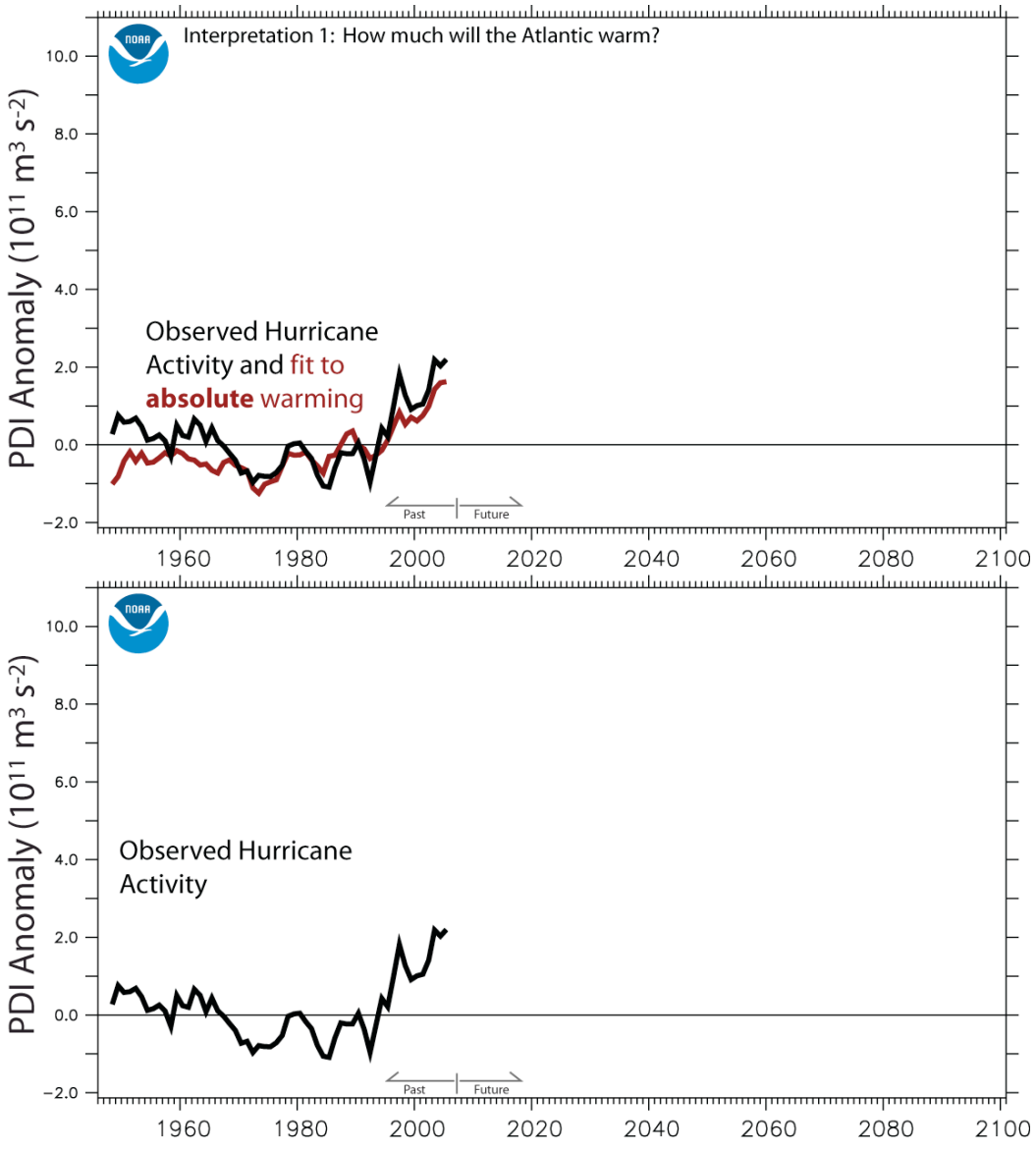


PDI is proportional to the time integral of the cube of the surface wind speeds accumulated across all storms over their entire life cycles.

Source: Emanuel (2007)

Gabriel Vecchi, NOAA/GFDL, Princeton, NJ

One Temperature Predictor of Atlantic Hurricane Activity

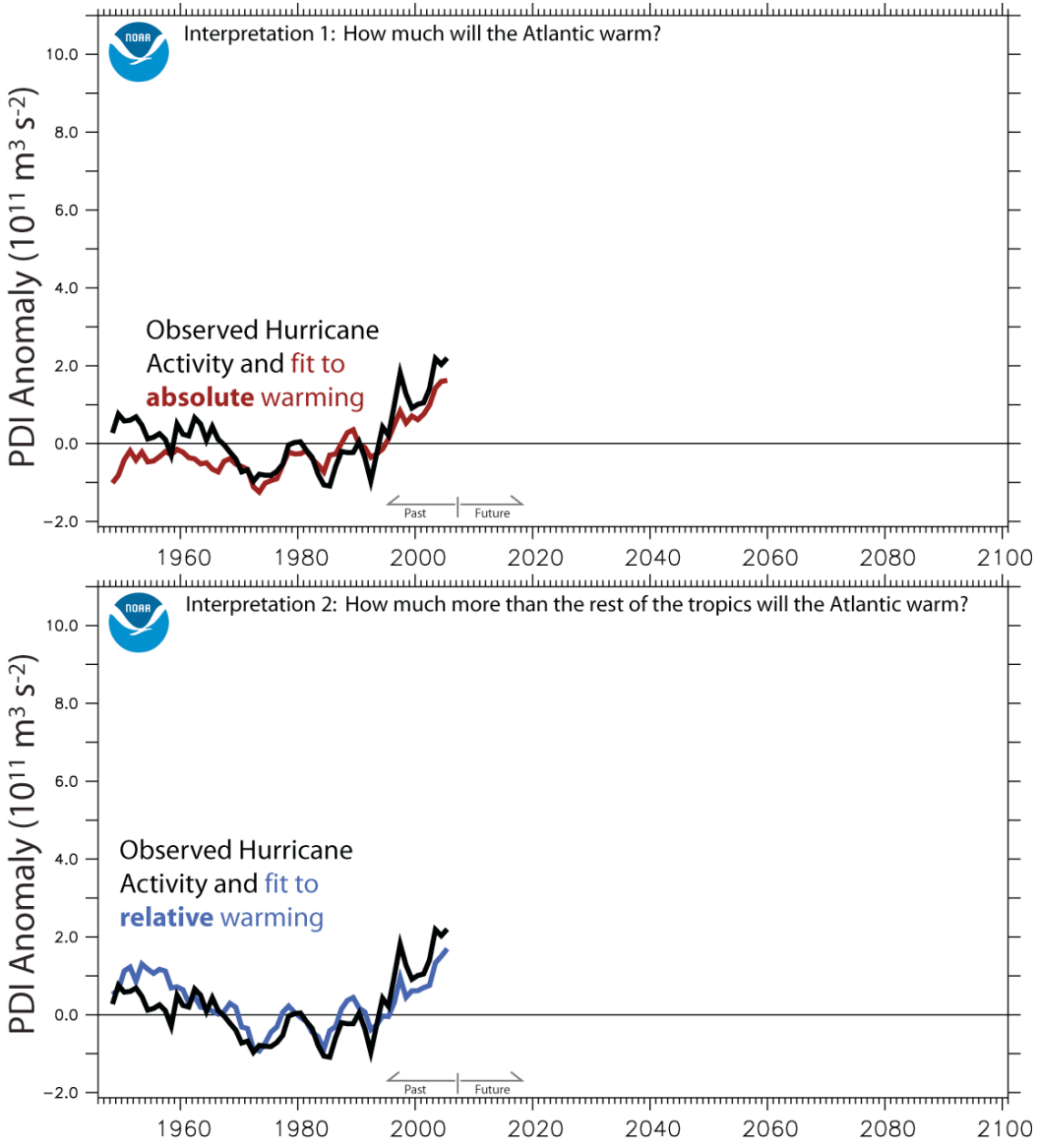


Observed Activity

Absolute Atlantic Temperature

Vecchi, Swanson and Soden (2008, Science)

Two Temperature Predictors of Atlantic Hurricane Activity



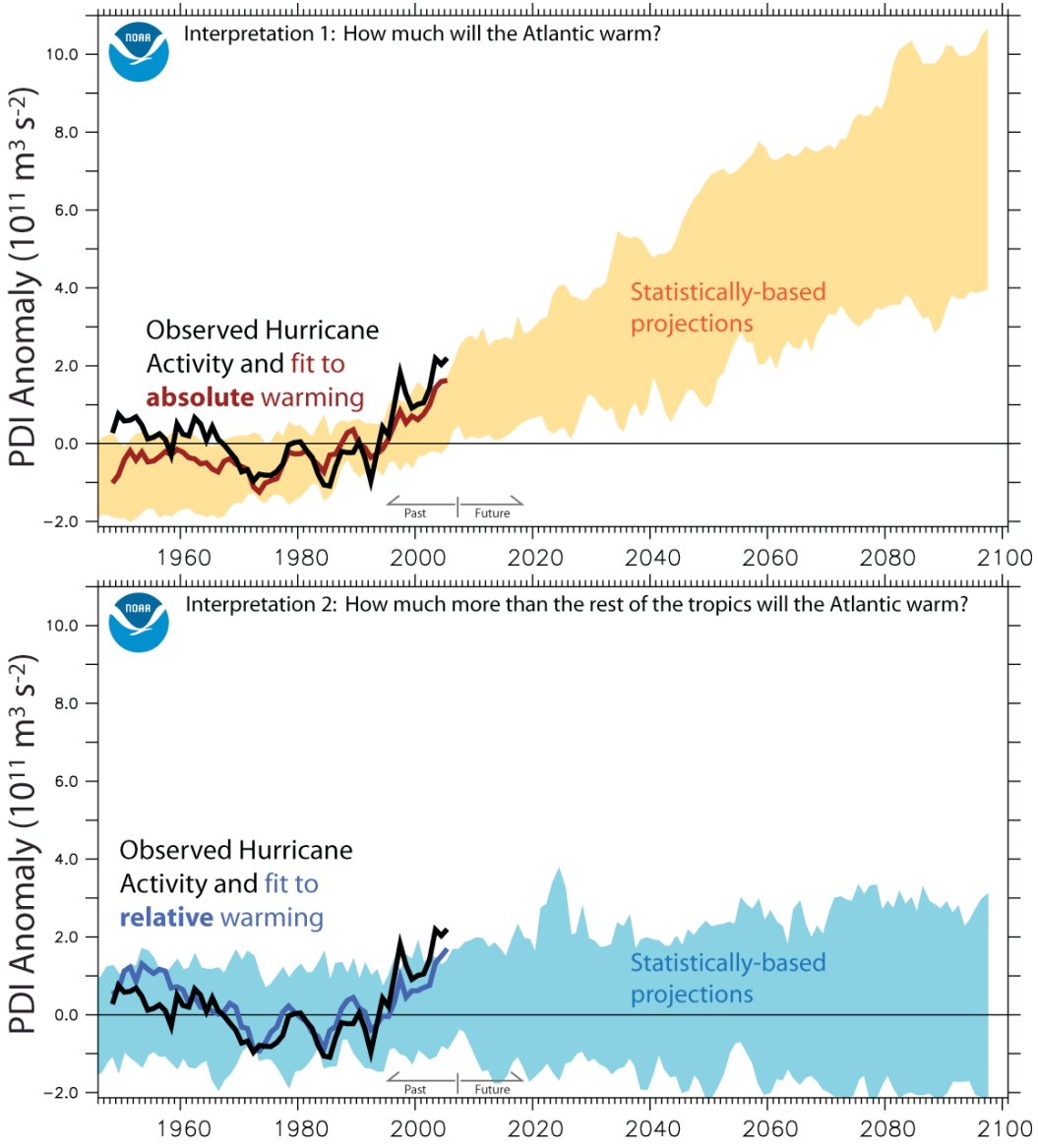
Observed Activity
Absolute Atlantic Temperature

Observed Activity
Relative Atlantic Temperature

Vecchi, Swanson and Soden (2008, Science)

Gabriel Vecchi, NOAA/GFDL, Princeton, NJ

Two Statistical Projections of Atlantic Hurricane Activity



Observed Activity
Absolute Atlantic Temperature

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Vecchi, Swanson and Soden (2008, Science)

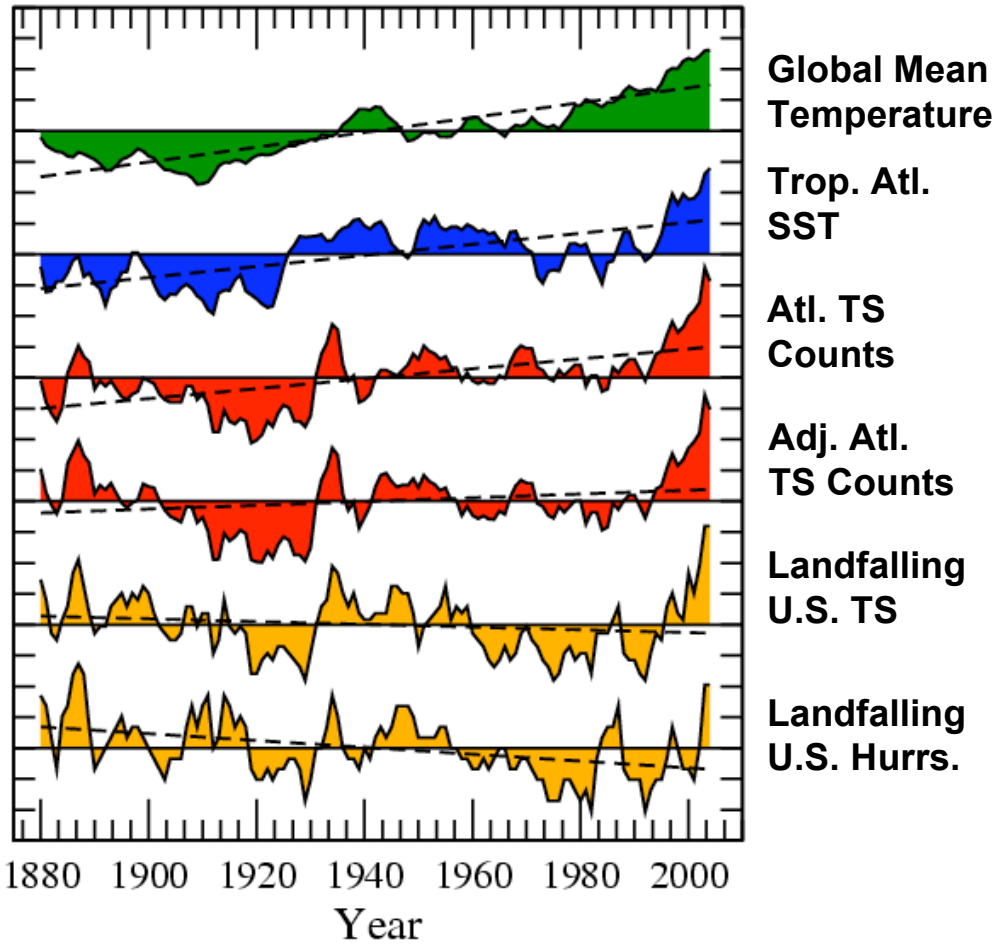
Requirements for understanding the hurricane-climate connection

Interconnected, complement/limit each other.

- Well-defined measure of hurricane activity
- Observations:
  - As homogeneous as possible
  - Uncertainty assessment
- Comprehensive dynamical models
- Theory:
  - Theories exist for intensity
  - Theory for cyclone frequency still lacking

Measure of Activity

- Which measure?
  - Hurricane count
  - Landfalling storm count
  - Extremes in intensity
  - Shifts in mean intensity
  - Integrated intensity
- Must balance demand with current understanding
  - Obs, models and theory limit.
- Differences must be communicated.



Vecchi and Knutson (2008, J. Clim.)

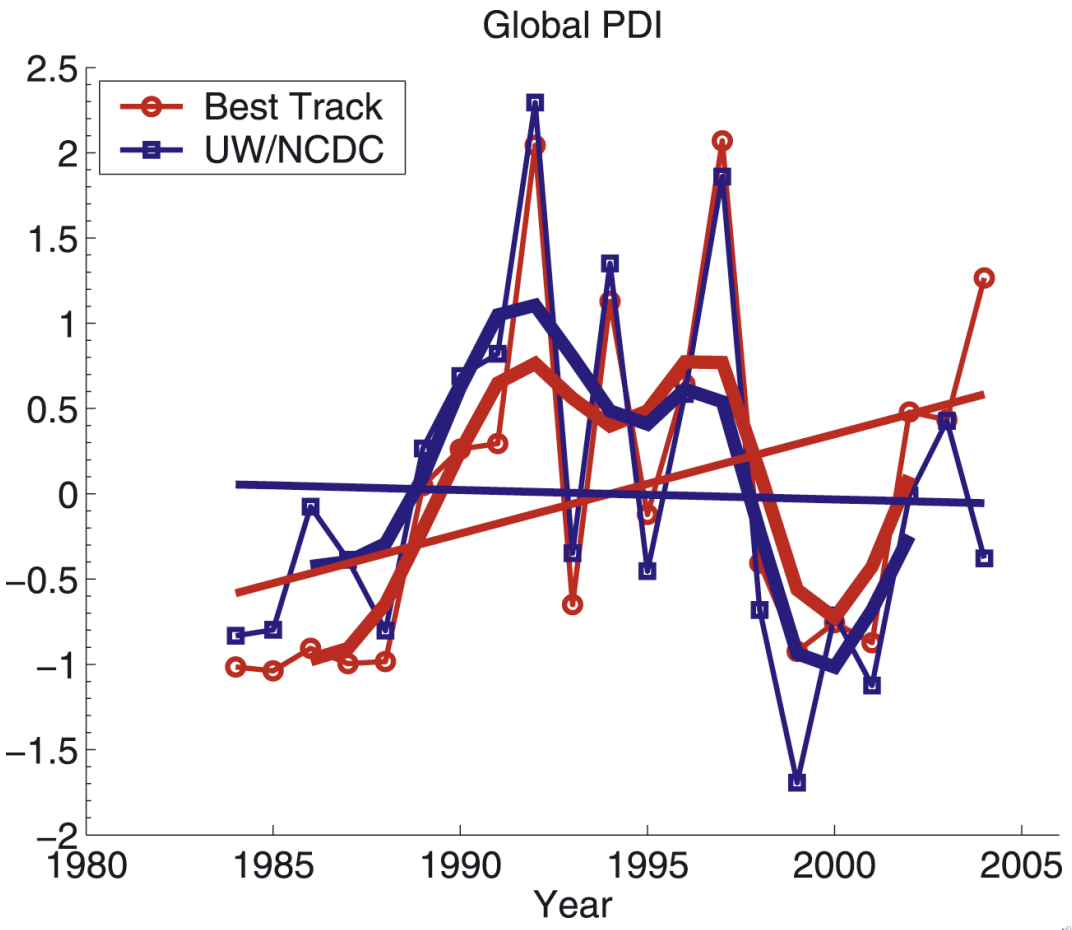
Observations

- Hurricane databases **NOT** built as climate data records.
- Efforts continue to:
  - Identify issues
  - Homogenize
  - Estimate uncertainty

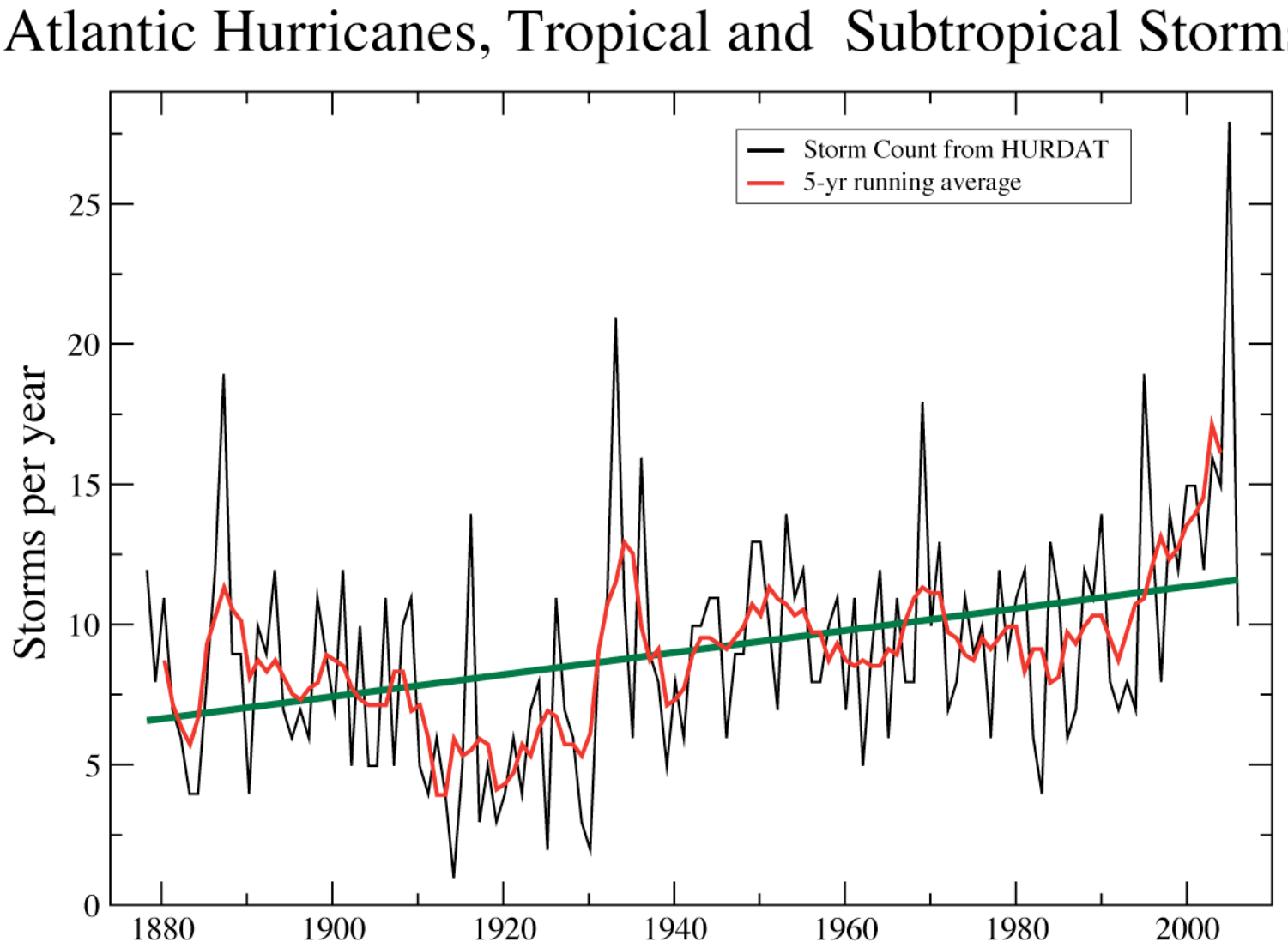
Uncorrected global activity

Activity corrected for changes in satellites

Kossin et al (2007, GRL)

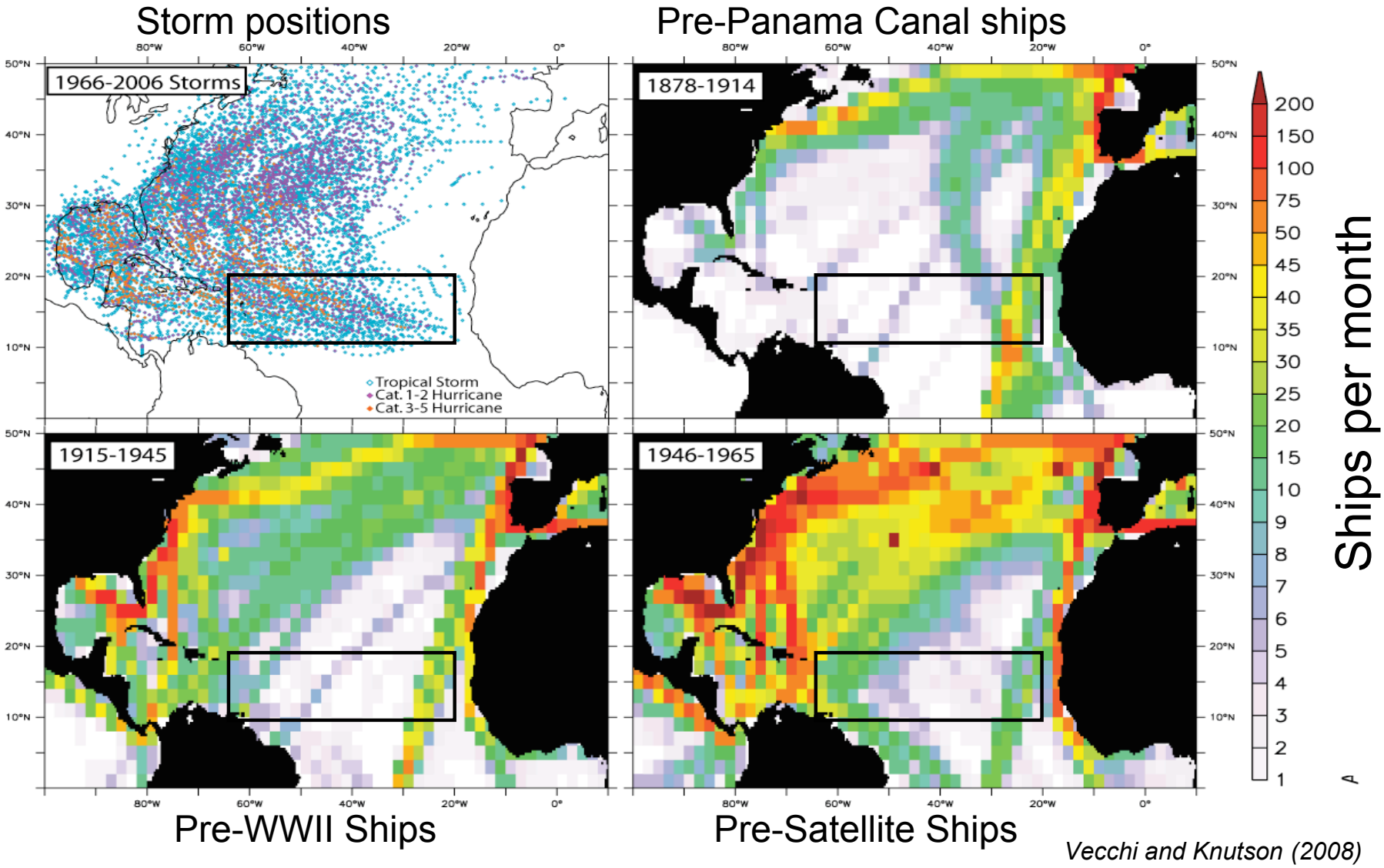


Raw record of Atlantic tropical storms shows strong century-scale increase



Vecchi and Knutson (2008, J. Climate)

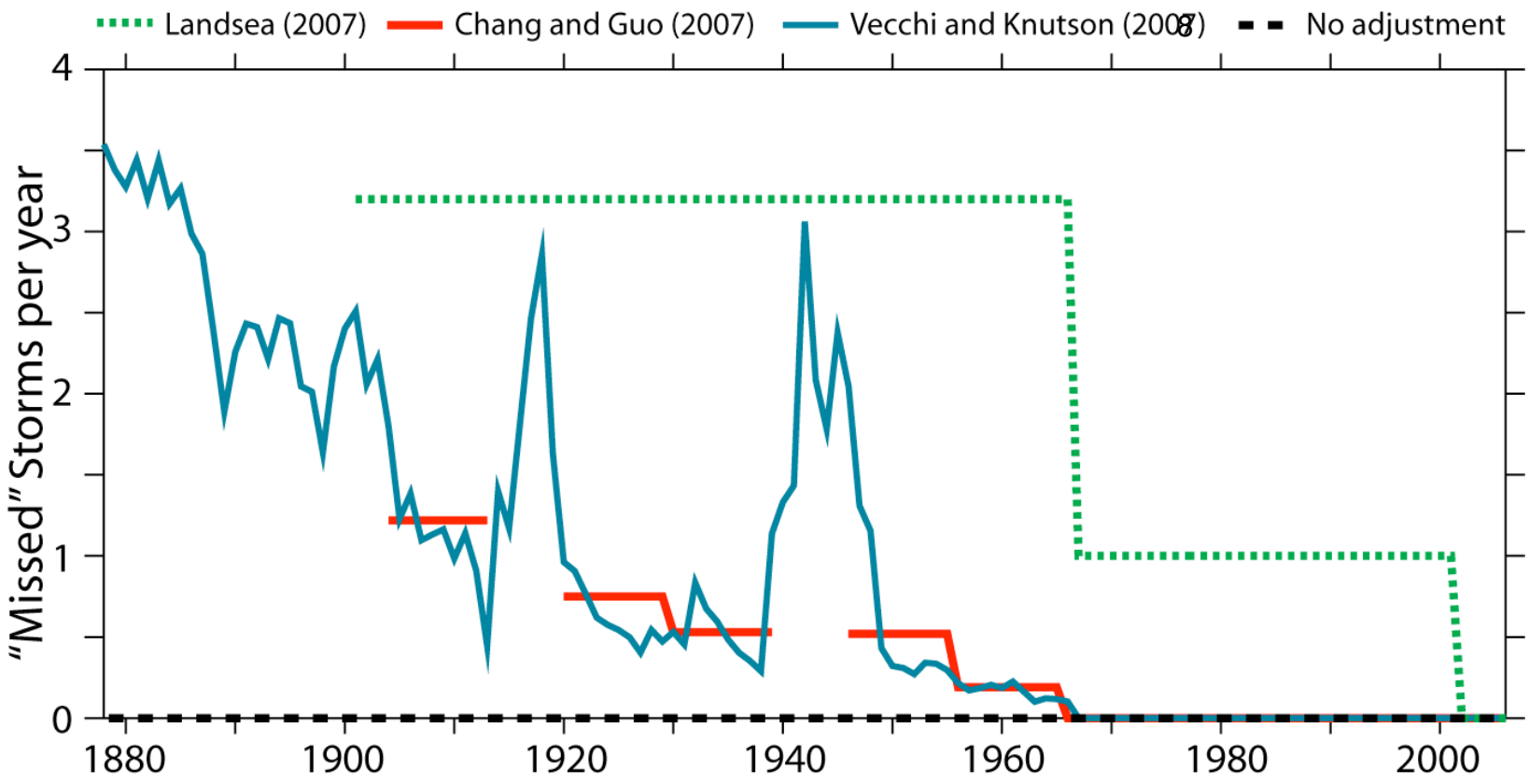
Can we be sure the long-term increase is real? Observational methods have changed with time….



Vecchi and Knutson (2008)

Gabriel Vecchi, NOAA/GFDL, Princeton, NJ

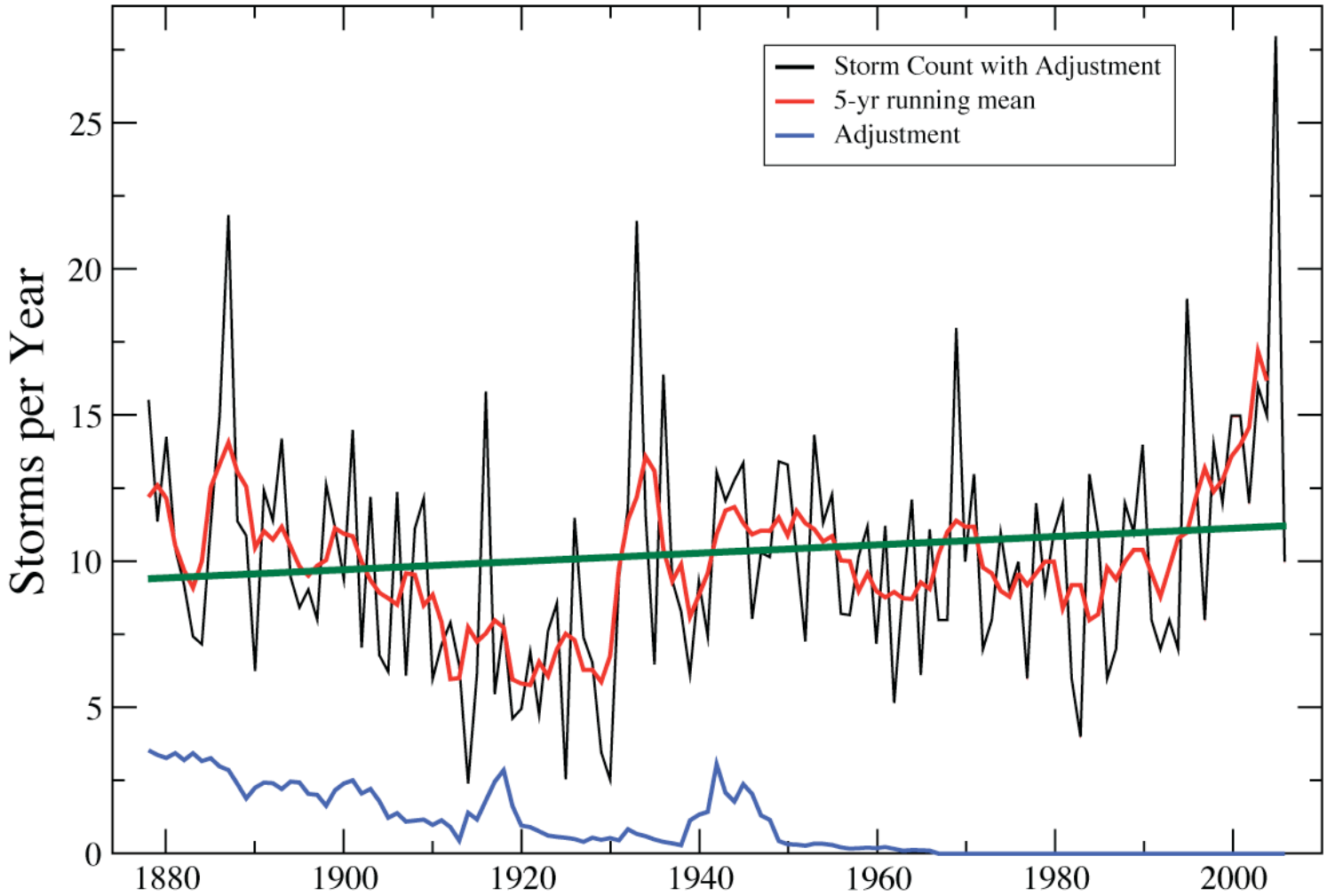
…but we can estimate number of "missed" storms



Landsea (2007): Assumes constant landfall fraction.
Is this justified (see *Holland, 2007*)?

Chang and Guo (2007), *Vecchi and Knutson (2008)*:
How many storms "slip" through ship tracks?

Adjusted Atlantic Hurricanes, Tropical and Subtropical Storms

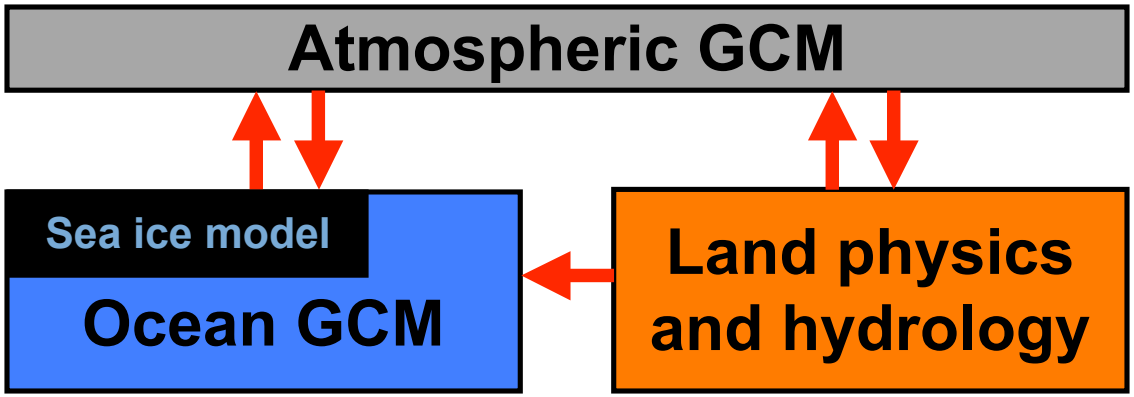


-Adjusted storm count trend since 1878 **not** distinct from “noise”
-Decadal swings ***not*** a simple “cycle”, either.

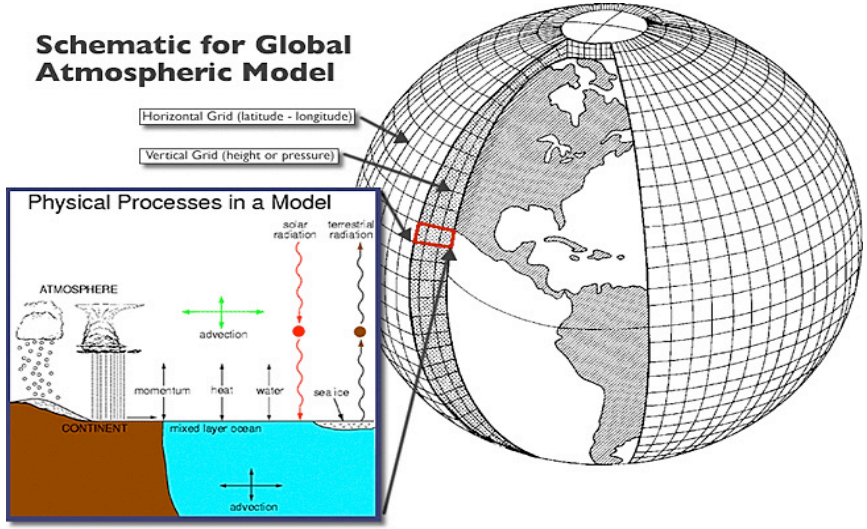
Gabriel Vecchi, NOAA/GFDL, Princeton, NJ

Understanding: what controls hurricanes?

- Potential Intensity theory exists:
  - *e.g.* Emanuel, Holland…
  - What are limitations?
- What is theory for genesis? Duration? …
- Why are there about 100 cyclones a year globally? Why not 200?



Can global climate models give guidance about changes in Atlantic storm activity?



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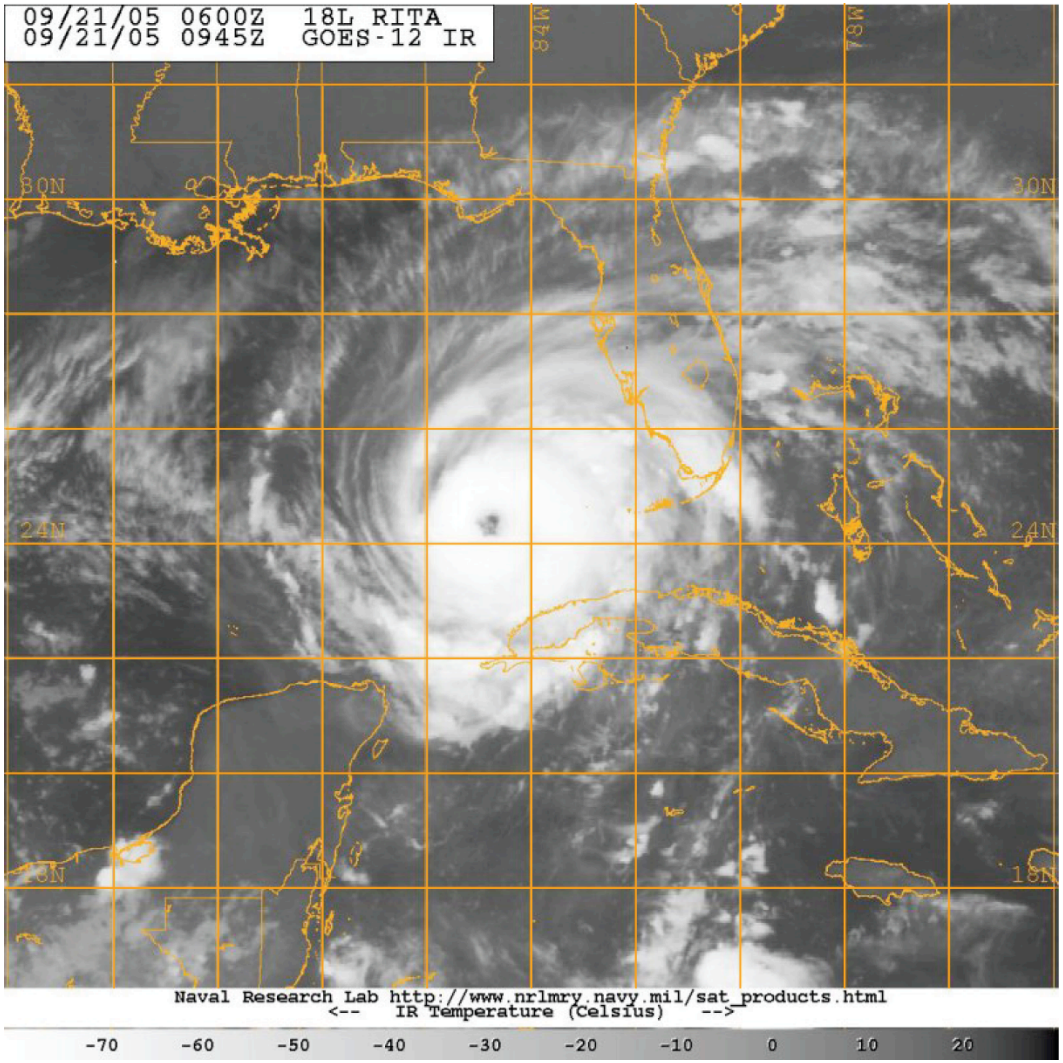
But, current computing power limits ability of global climate models to represent hurricanes



Hurricane Rita (2005): orange grid is representative of current ***global*** climate model resolution.

Size of grid limited by power of computers.

Nonetheless, tropical storms are affected by ***large-scale*** conditions that today's climate models ***can*** represent.

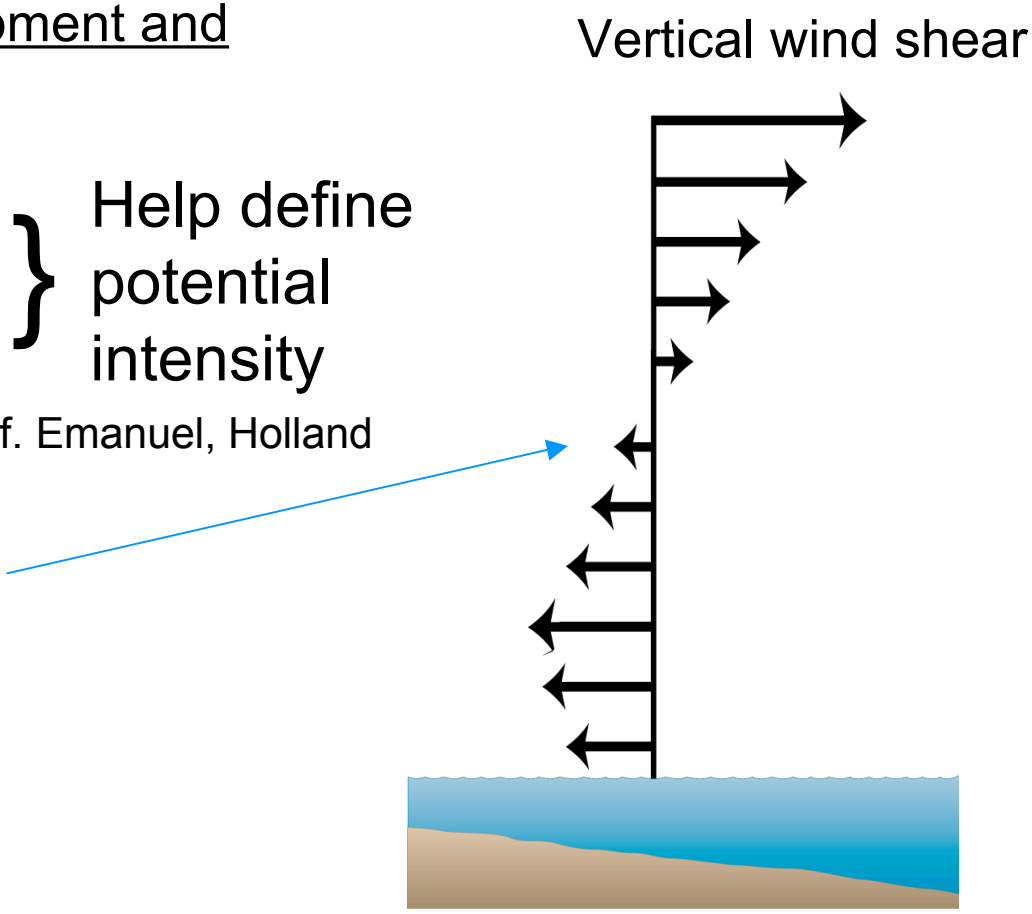
<u>Factors that favor storm development and intensification</u>:

- Warm ocean surface
- Cool upper atmosphere

} Help define potential intensity

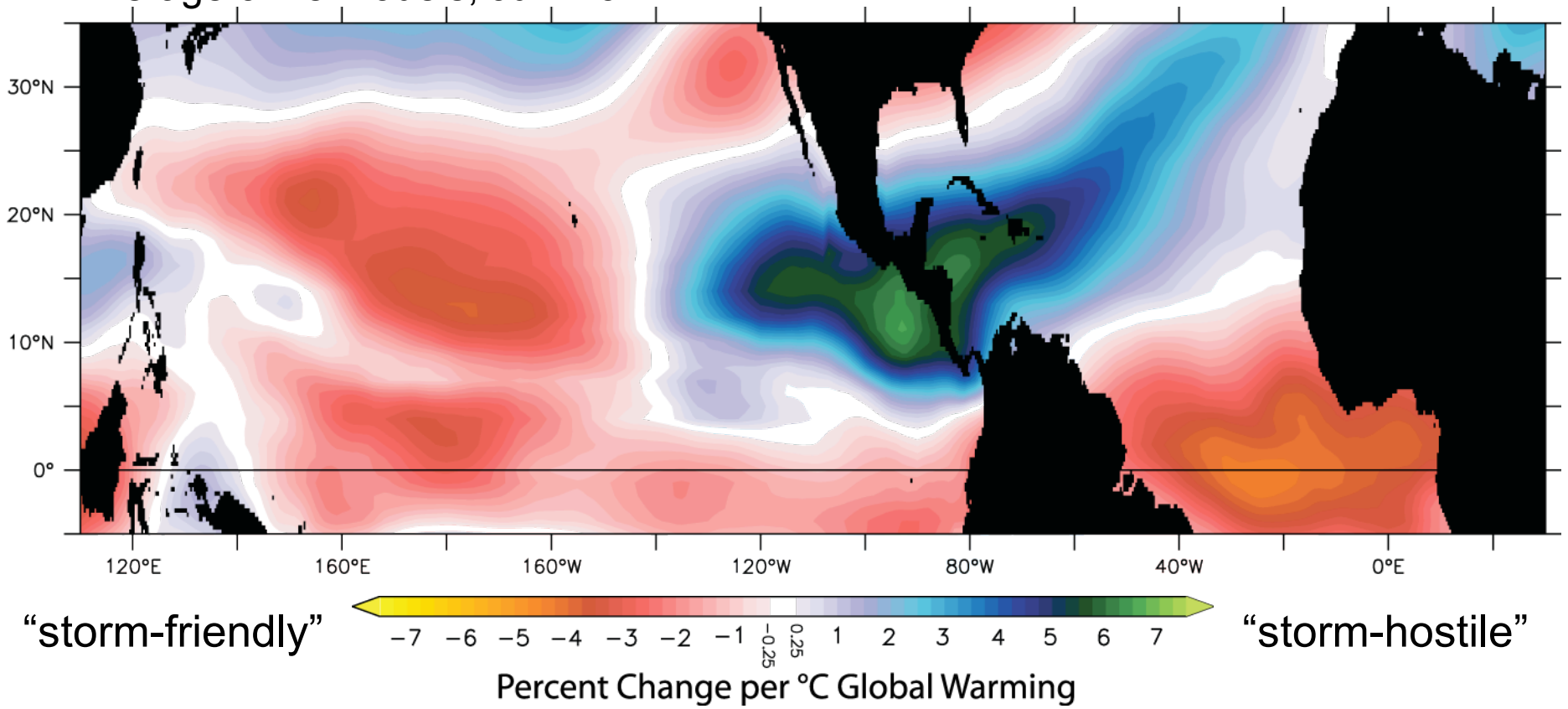
cf. Emanuel, Holland

- Low vertical wind shear
- Moist middle atmosphere
- etc.



Projected 21st Century Changes in Vertical Wind Shear

Average of 18 models, Jun-Nov

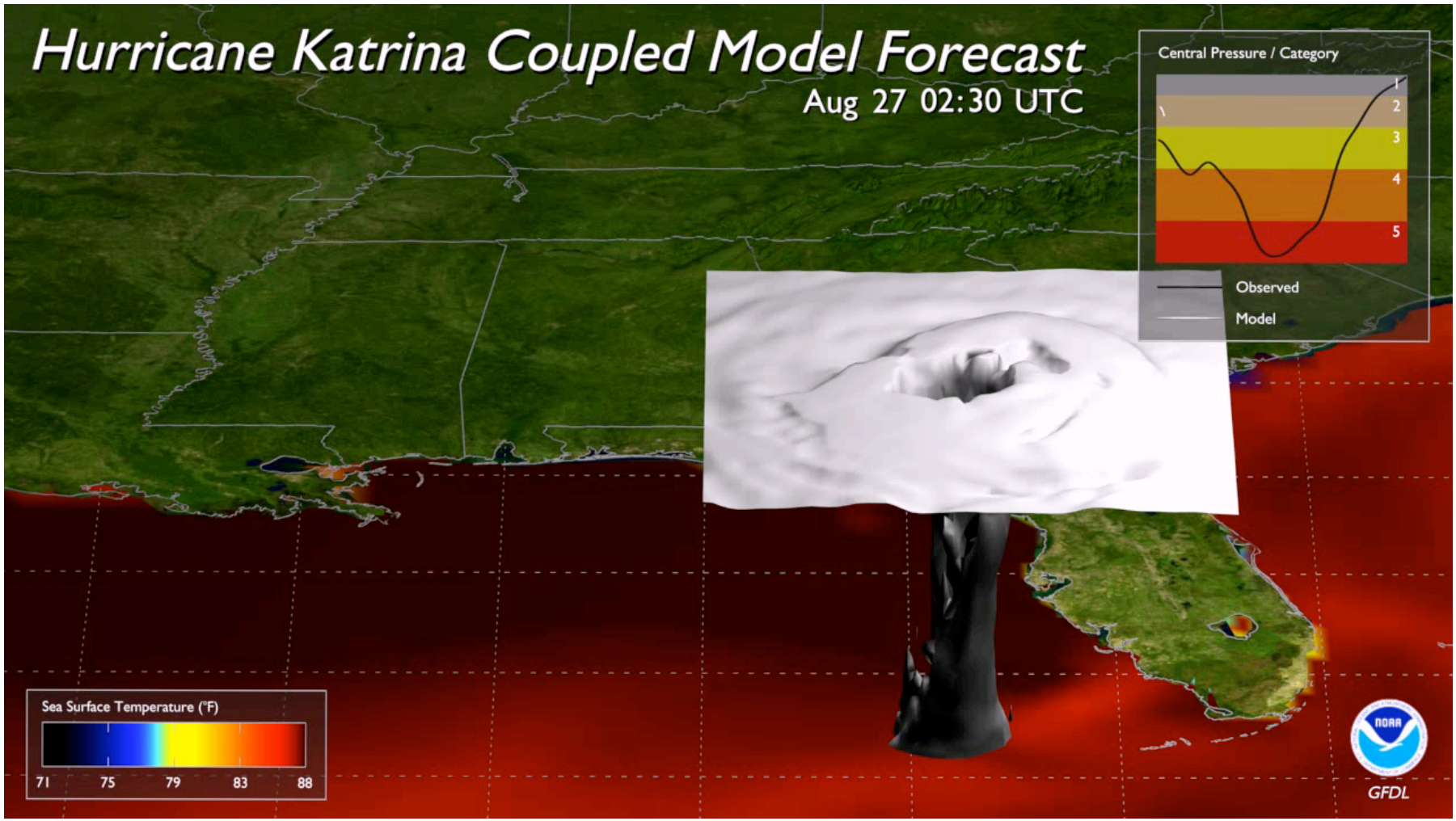


"storm-friendly" "storm-hostile"

Over swath of tropical Atlantic and East Pacific, increased wind-shear.

What is net effect of increased potential intensity and wind shear?

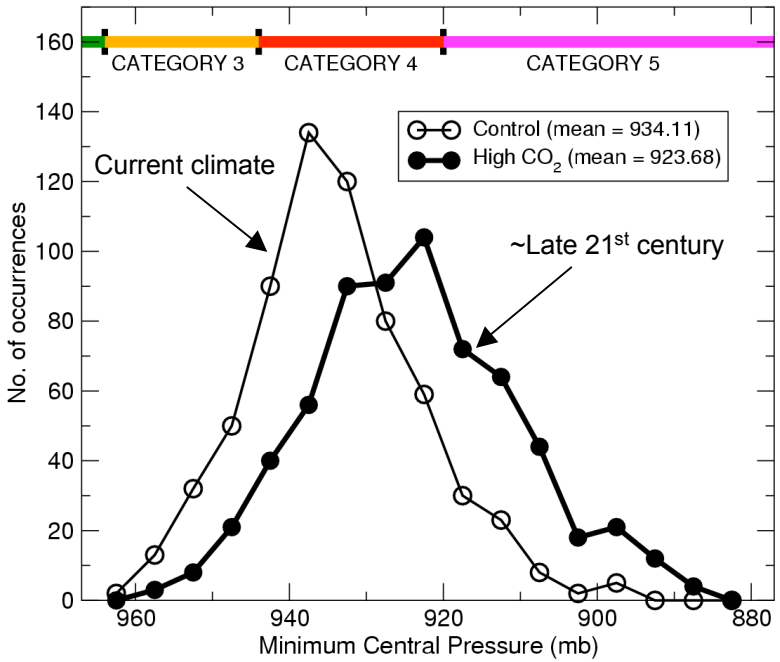
Vecchi and Soden (2007, GRL)



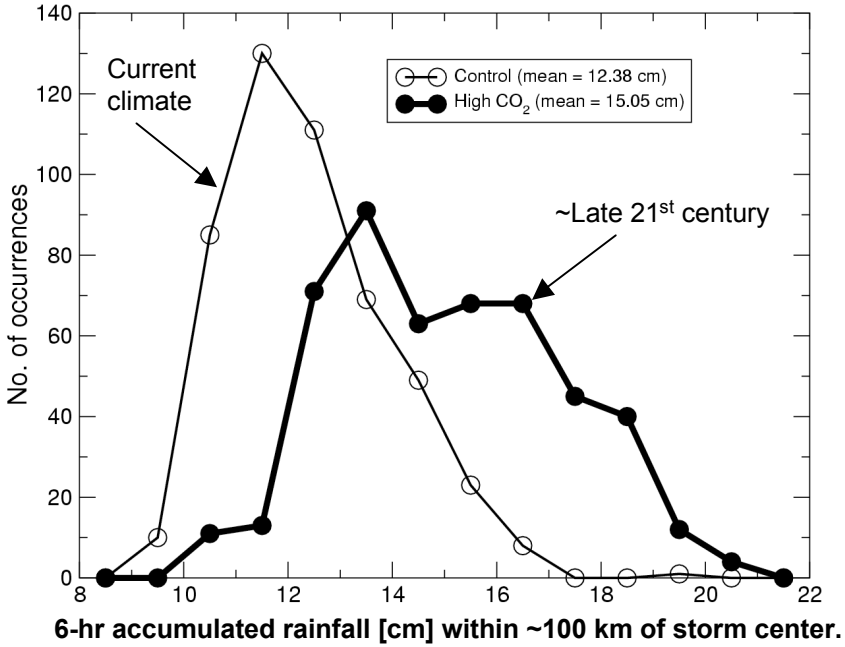
Courtesy Morris Bender and Tim Marchok, NOAA/GFDL

Hurricane models project increasing hurricane intensities and rainfall rates with greenhouse climate warming ...

Hurricane Intensity



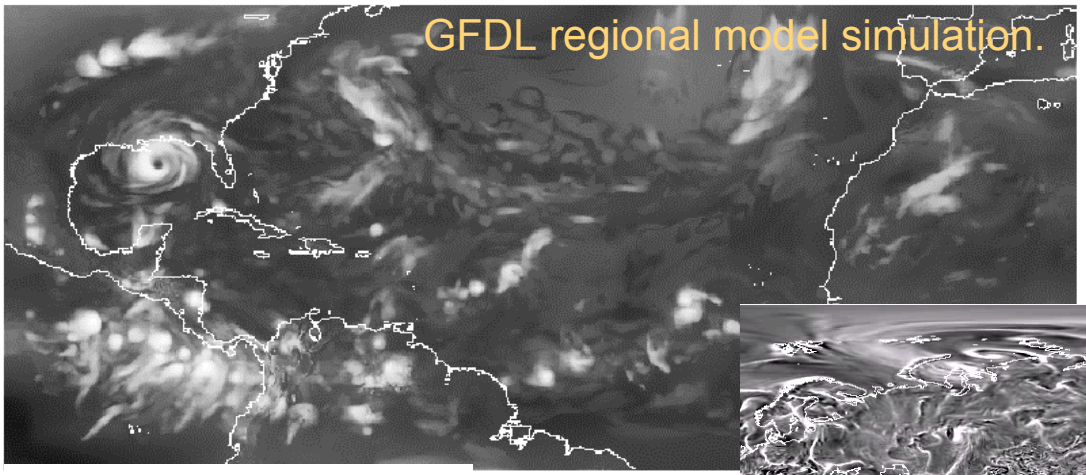
Hurricane Rainfall Rates



Sources: Knutson and Tuleya, *J. Climate*, 2004 (left);
Knutson and Tuleya, 2008; Cambridge Univ Press (right).

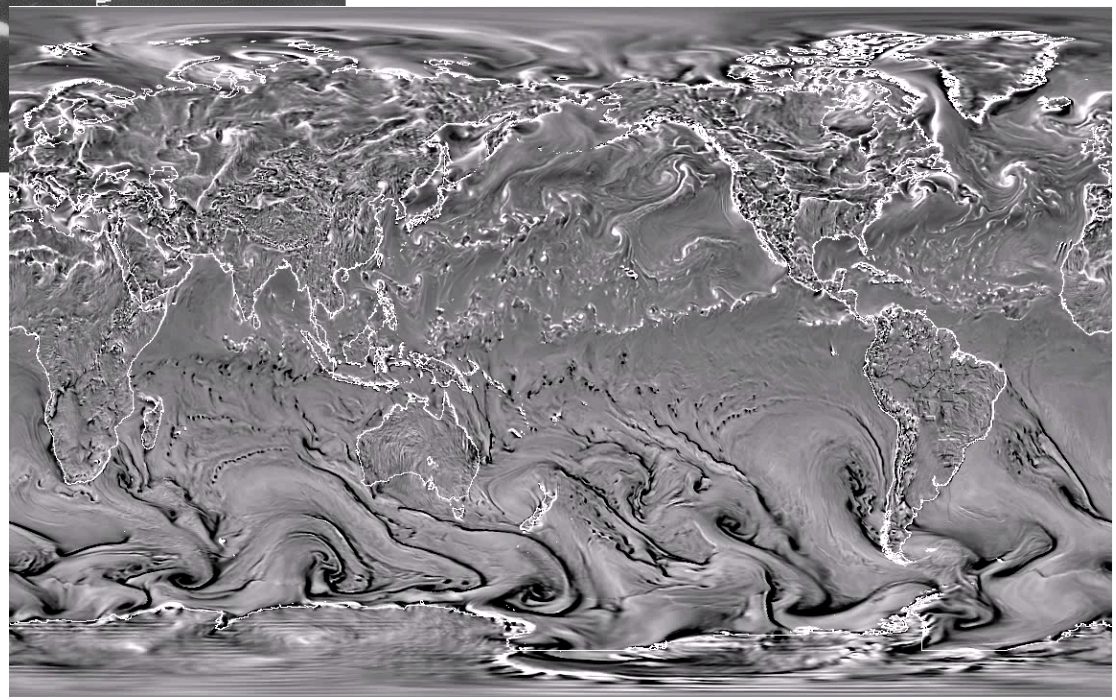
High-Resolution Comprehensive models

Assess TC sensitivity to climate change in a physically-consistent manner



Knutson et al (2007, BAMS)

Models ranging in 100km to 18km resolution.



Zhao, Held, Lin and Vecchi (2009, J. Climate)

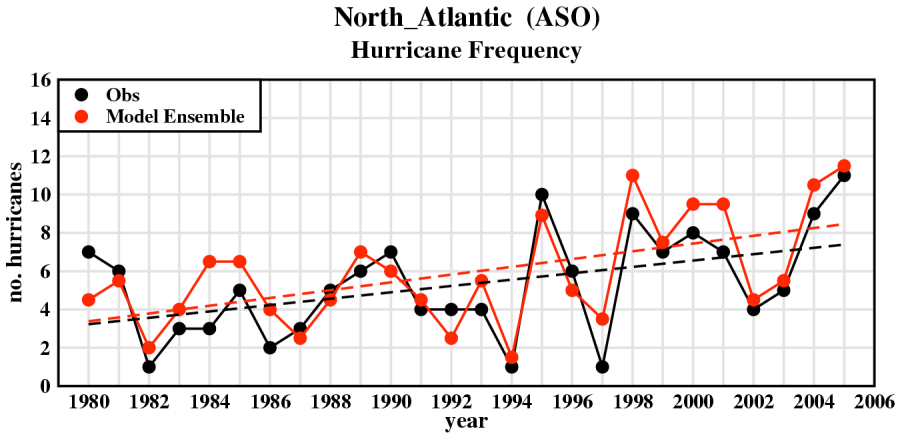
GFDL global model simulation.

Comprehensive models

Given “large-scale” conditions, high-resolution models can reproduce observed changes in hurricane frequency.

Use these models to assess impact of model-projected large-scale response to doubled CO2.

(e.g. Oouchi et al 2005, Bengtsson et al 2007, Emanuel et al 2008, Knutson et al 2008, Zhao et al 2009 ….)



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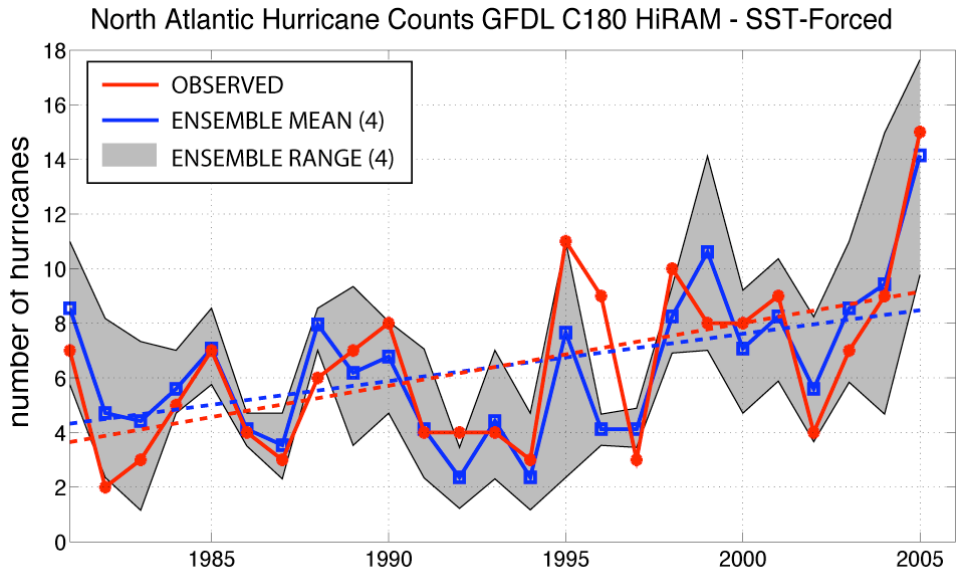


Zhao et al (2009, J. Clim.)

Frequency of weakest storm projected to decrease. Frequency of strongest storms may increase.

Control: 11.1 /yr

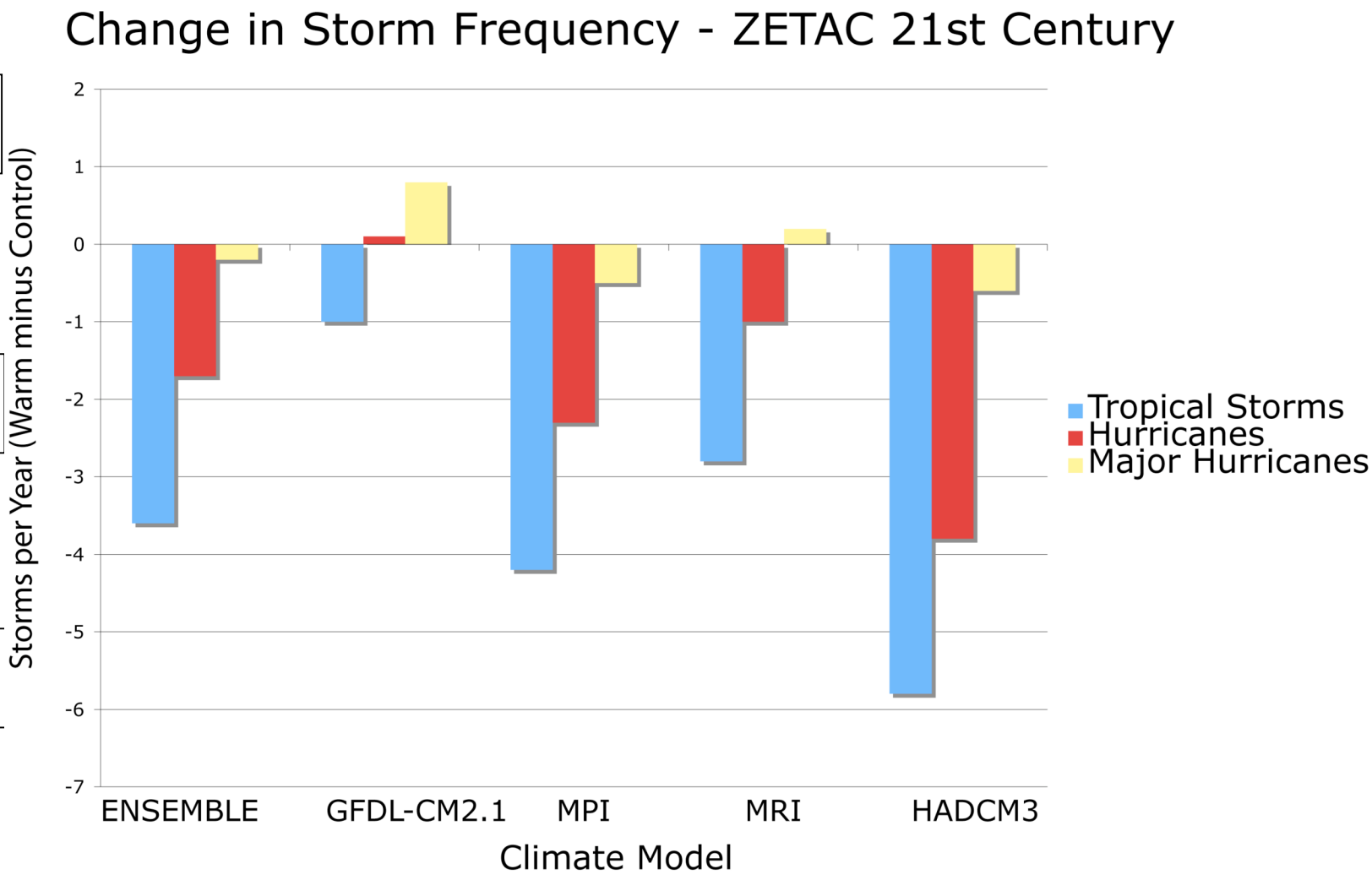
Tropical Storms:
Range: -9% to -52%
Ensemble: -20%

Control: 6.5 /yr

Hurricanes:
Range: +2% to -58%
Ensemble: -26%

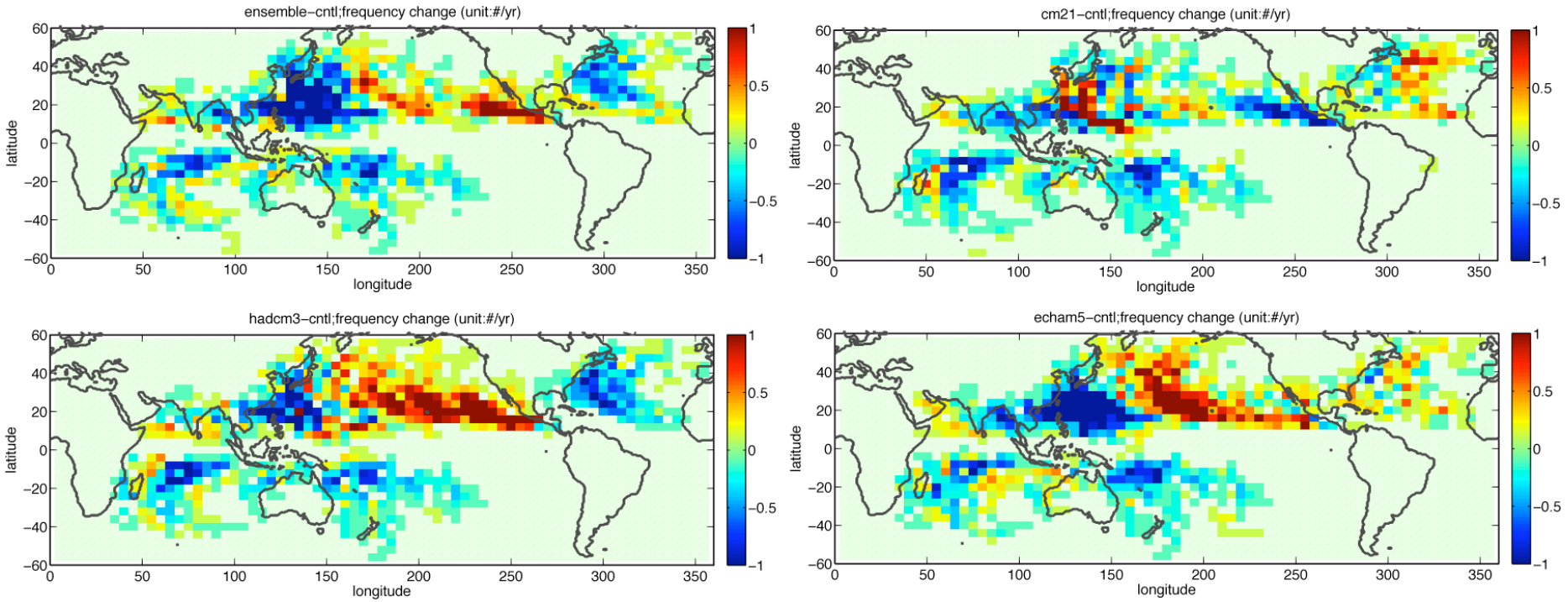
Control:1.4 /yr

Major Hurricanes:
Range: +57% to -43%
Ensemble: -14%



Adapted from Knutson et al (2008, Nature Geosci.)

21st Century Hurricane Activity Change: Four possibilities



Red/yellow = increase
Blue/green = decrease

Adapted from Zhao et al. (2009, J. Climate)

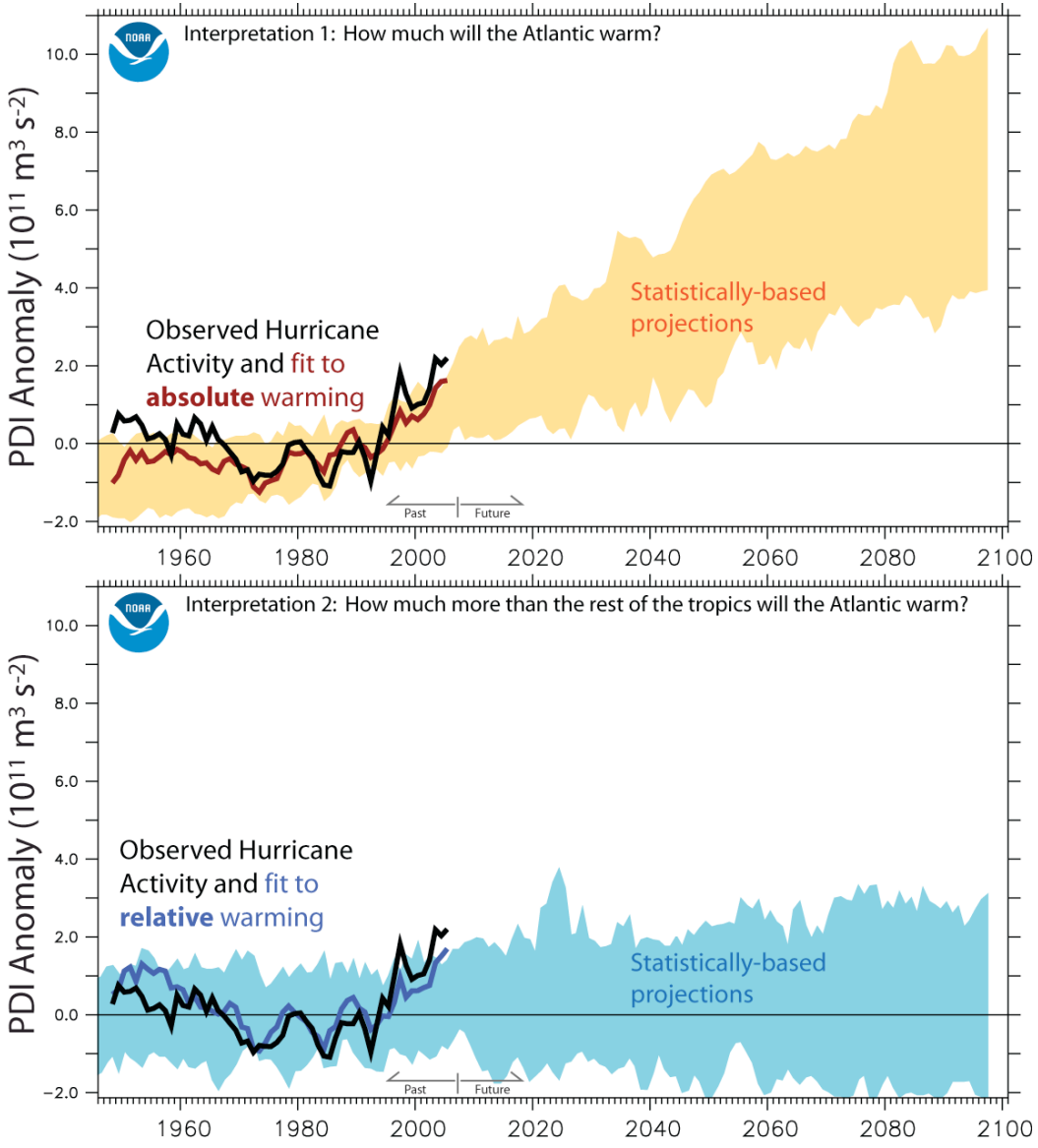
Regional increase/decrease much larger than global-mean.

Pattern depends on details of ocean temperature change.

Sensitivity of response seen in many studies

e.g., Emanuel et al 2008, Knutson et al 2008, etc

Two Statistical Projections of Atlantic Hurricane Activity

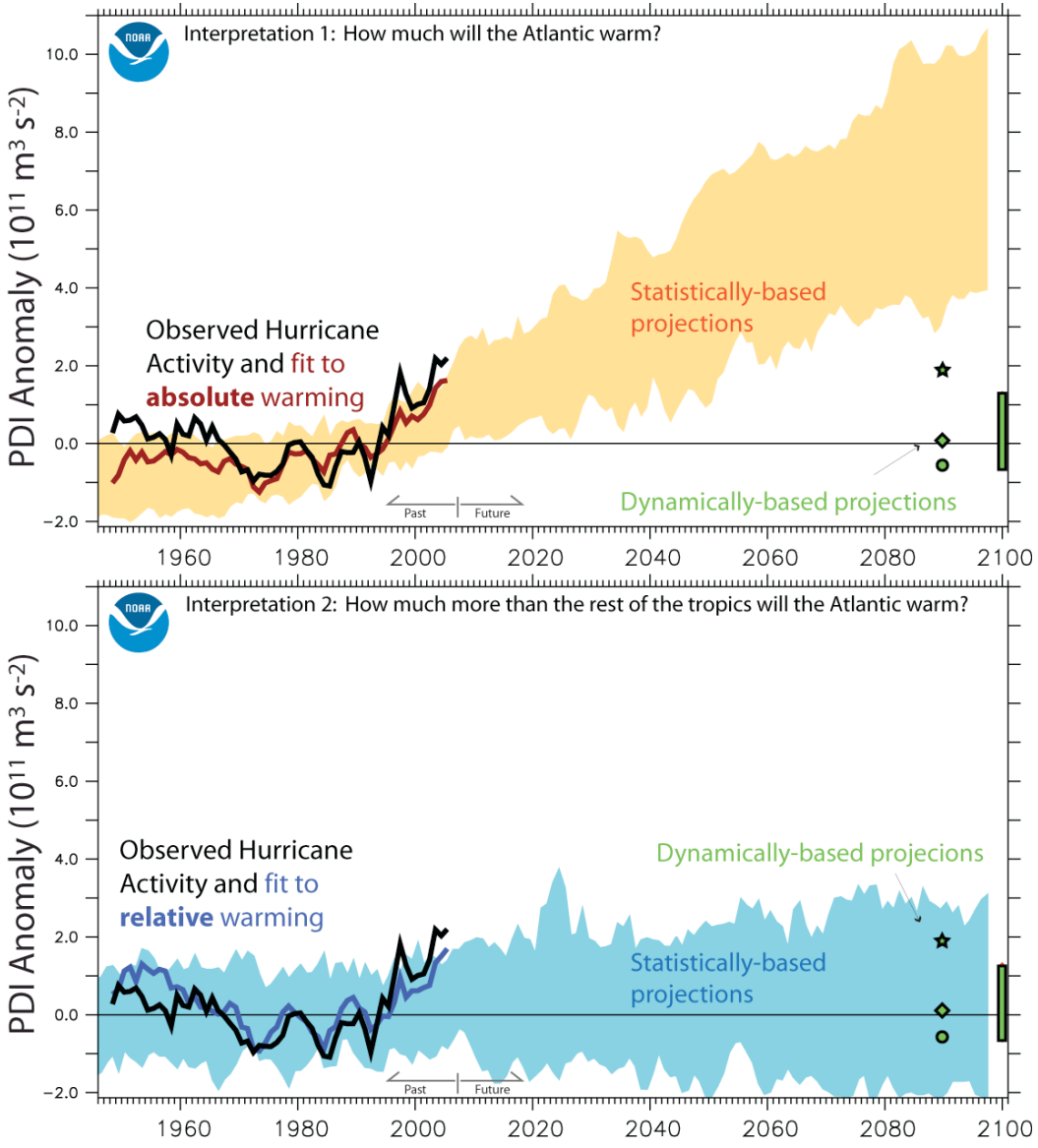


Observed Activity
Absolute Atlantic Temperature

Observed Activity
Relative Atlantic Temperature

Vecchi, Swanson and Soden (2008, Science)

…Add Dynamical Projections of Atlantic Hurricane Activity



Observed Activity
Absolute Atlantic Temperature

Dynamical Model Projections

Observed Activity
Relative Atlantic Temperature

Vecchi, Swanson and Soden (2008, Science)

Gabriel Vecchi, NOAA/GFDL, Princeton, NJ

My current interpretation of evidence

- Observations:
  - Data issues and short records
  - We will never know how many storms we didn't see, or what they were like. We can only estimate it.
- Multiple factors affect change in hurricane activity:
  - Pattern of temperature changes is key.
- Projected changes depend on measure chosen, *e.g.:*
  - Atlantic TC Frequency: small change, possible **decrease**
  - Atlantic TC Intensity: projected **increase**
- Year-to-year and decade-to-decade variations will still exist.
- Increased coastal population and wealth: increased vulnerability
- Sea level rise: same storm greater potential impact.
- This is a topic of vigorous scientific inquiry.

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  - Multiple factors impact hurricanes
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  - Pushing the limits of our theory and computers
- False choice: global warming **OR** climate variability
- Not about one storm or one season ("Katrina effect").
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