Towards Attribution of Hurricane Activity Changes

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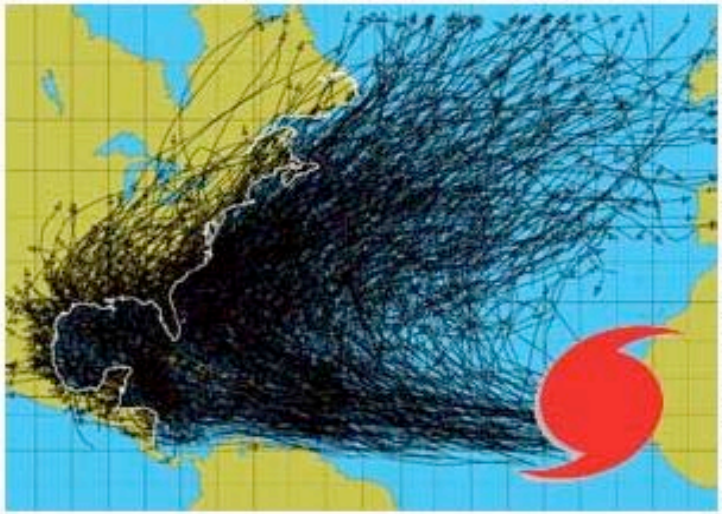
1-GFDL; 2-Princeton/AOS; 3-U. Miami; 4-U. Wisc.-Milw.; 5-Old Dominion U.

- Why hurricanes?
- What do we need? (relatively general)
  - Two part attribution: A -> B ; B -> Hurricanes
- Recent efforts at GFDL.

Why?

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."

ROSS GELBSPAN

The Boston Globe

Katrina's real name

By Ross Gelbspan | August 30, 2005

THE HURRICANE that struck Louisiana yesterday was nicknamed Katrina by the National Weather Service. Its real name is global warming.

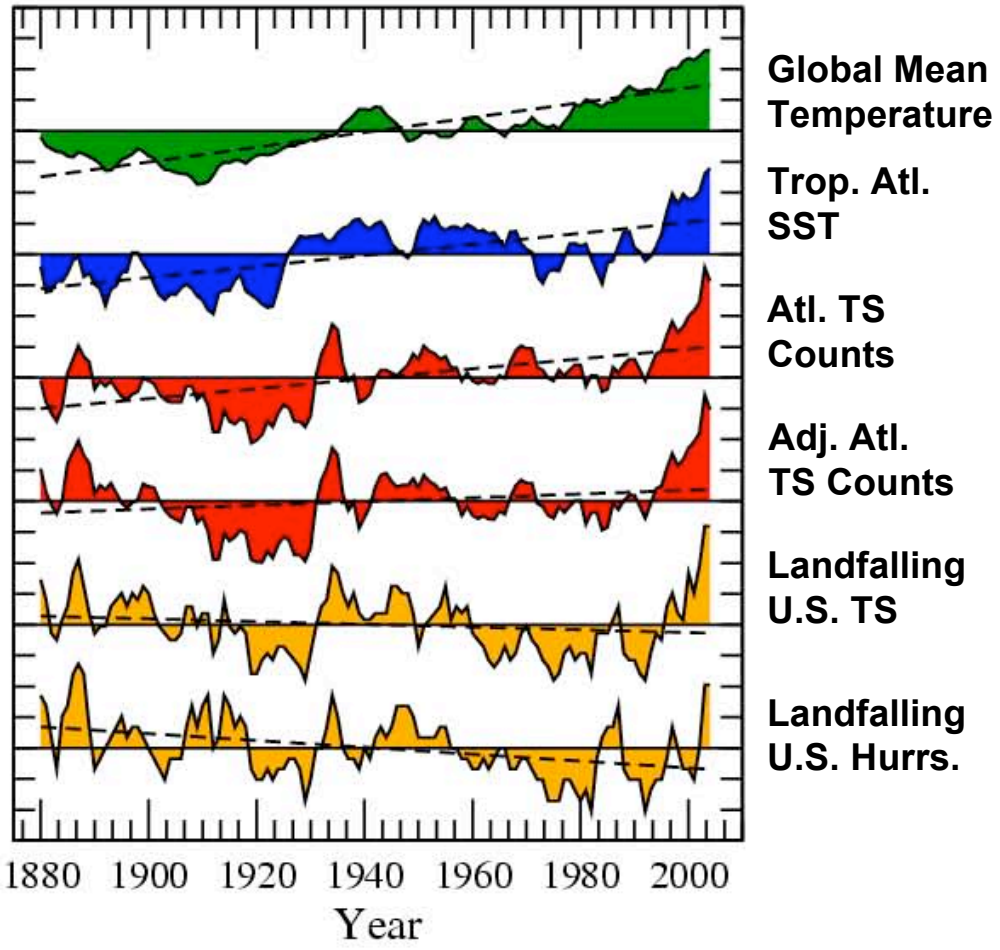
Requirements for attribution

Interconnected, complement/limit each other.

- Well-defined measure.
- Observations:
  - As homogeneous as possible
  - Uncertainty assessment
- Comprehensive dynamical models:
  - Capable of reproducing obs.
  - Play mix-and-match with forcings
- Understanding:
  - Theoretical framework
  - Idealized experiments

Measure of Activity

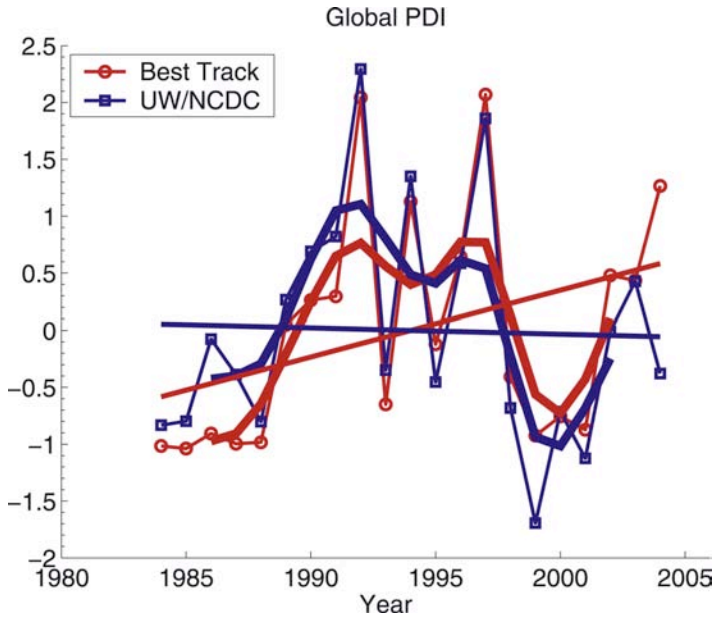
- Which measure?
  - Hurricane count
  - Landfalling storm count
  - Extremes in intensity
  - Shifts in mean intensity
  - Integrated intensity
- Must balance demand with current ability to detect/attribute.
  - Obs, models and theory limit.
- How to communicate differences?



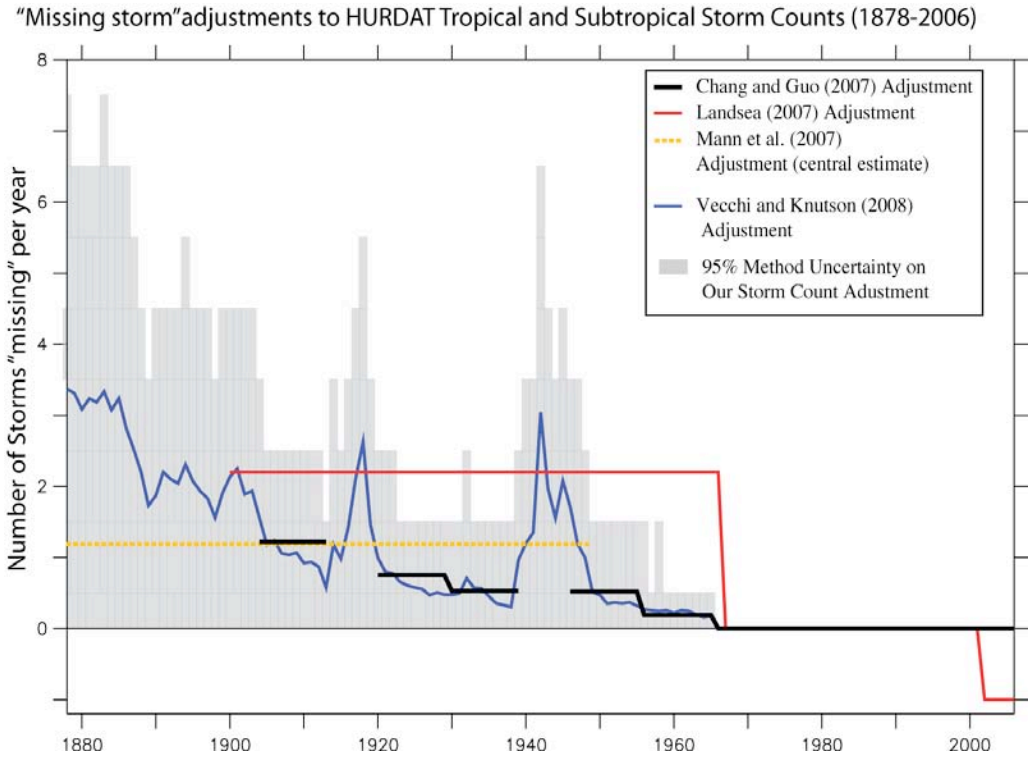
Vecchi and Knutson (2008, J. Clim.)

Observations

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



Kossin et al (2007, GRL)



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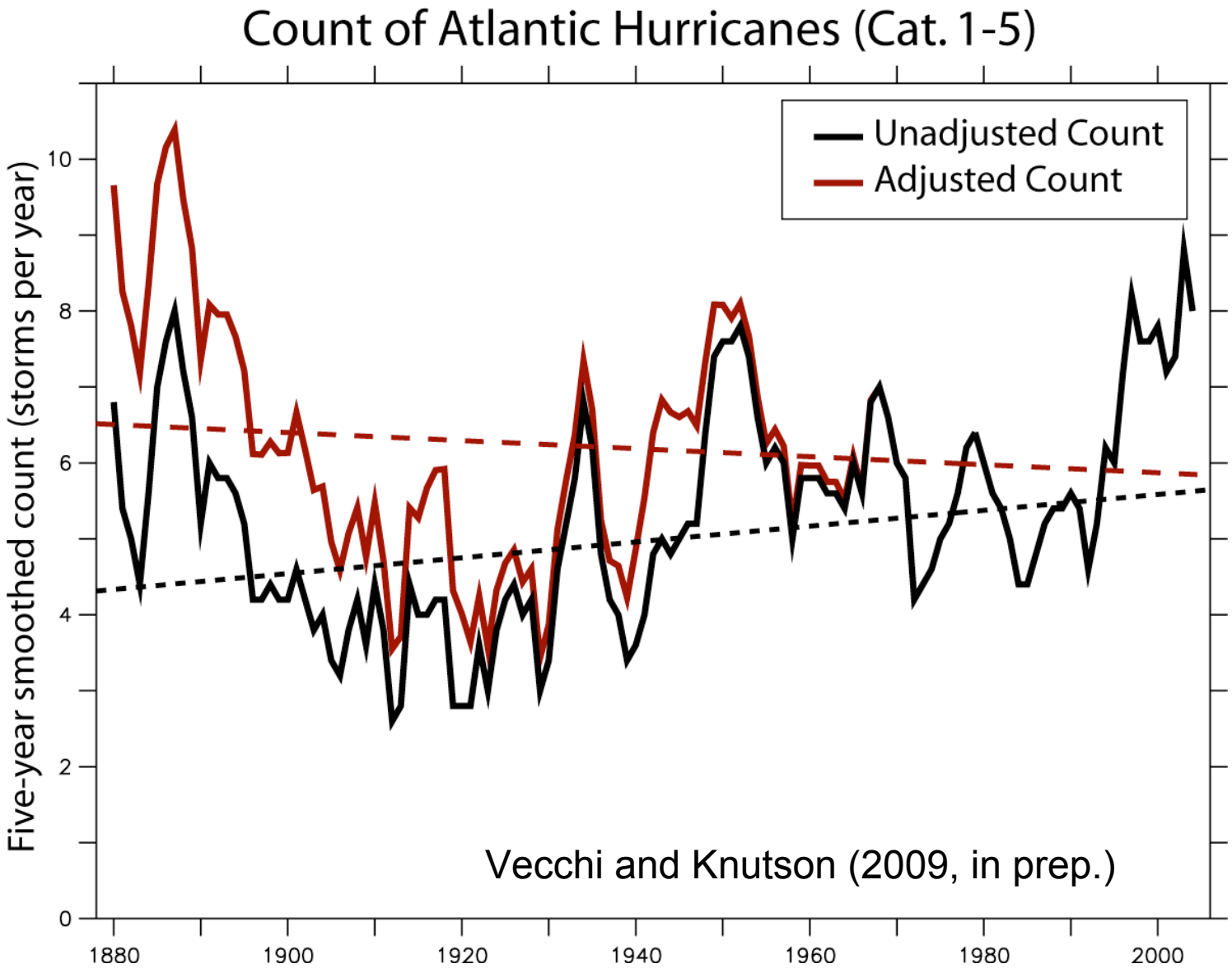
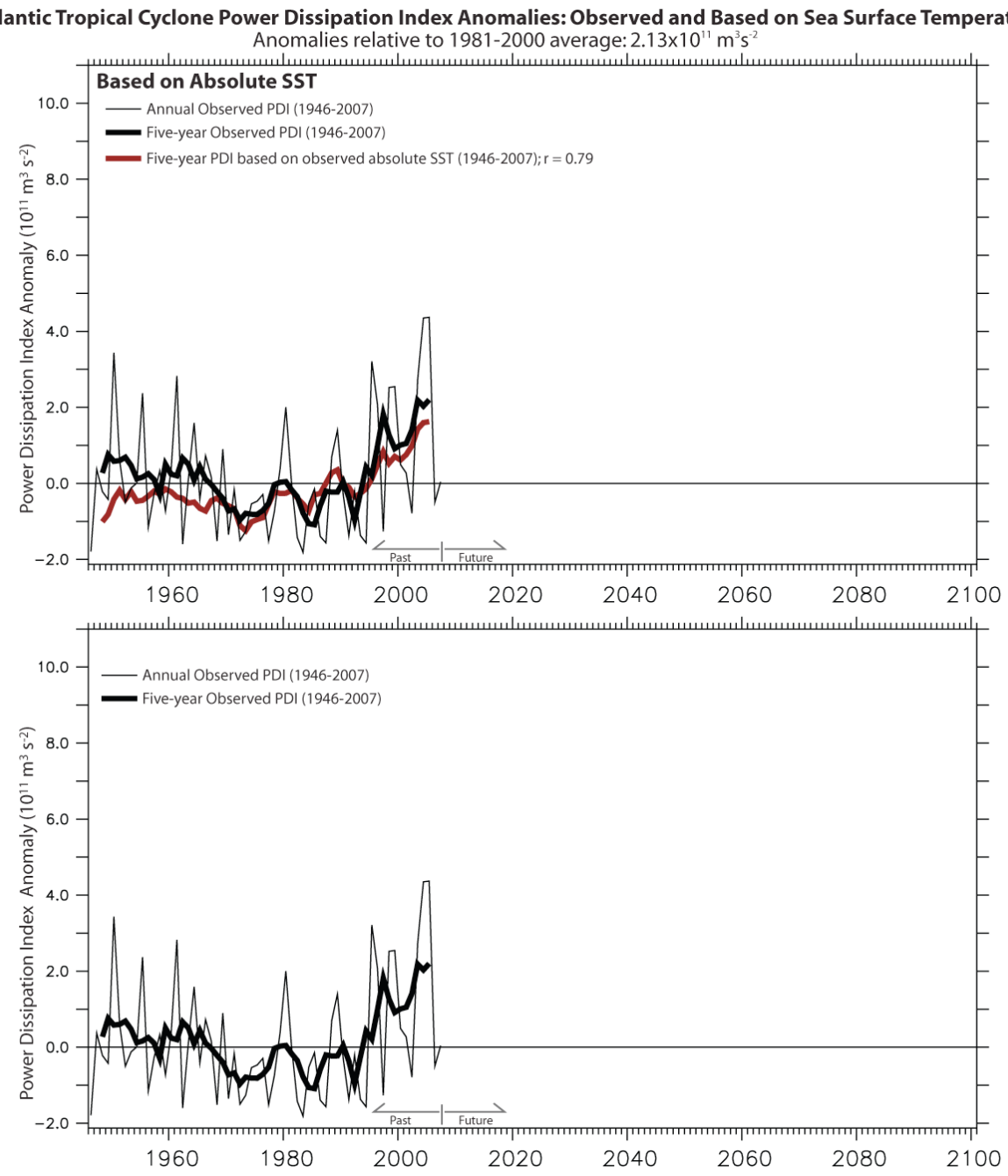


Adjustment changes sign of hurricane count trend



Observed Activity

Absolute MDR SST

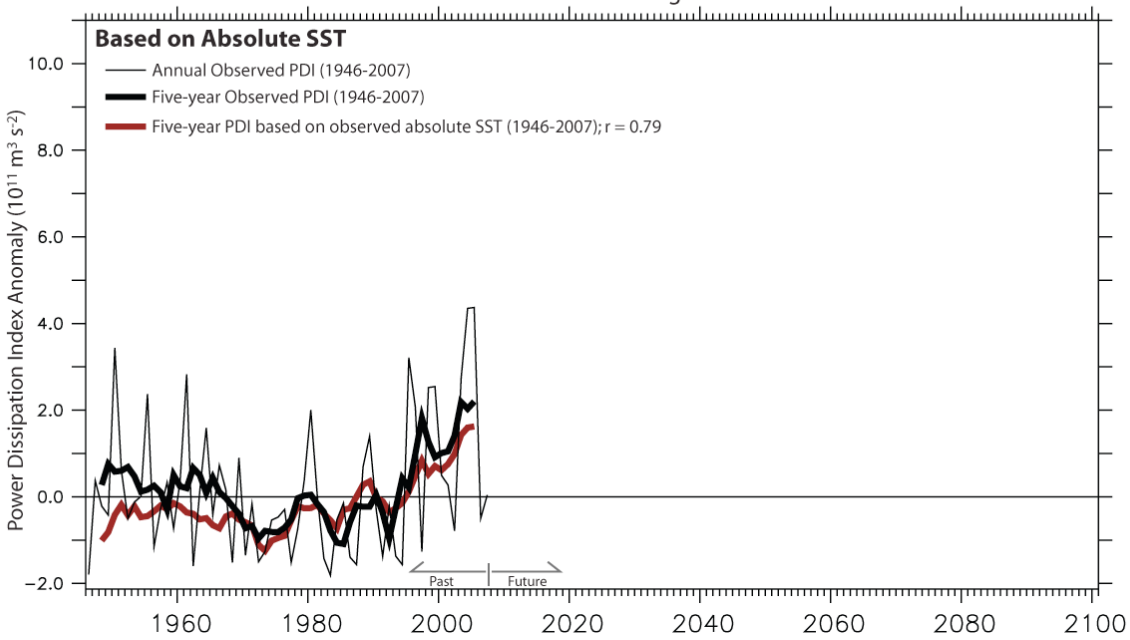
If causal, can attribute.

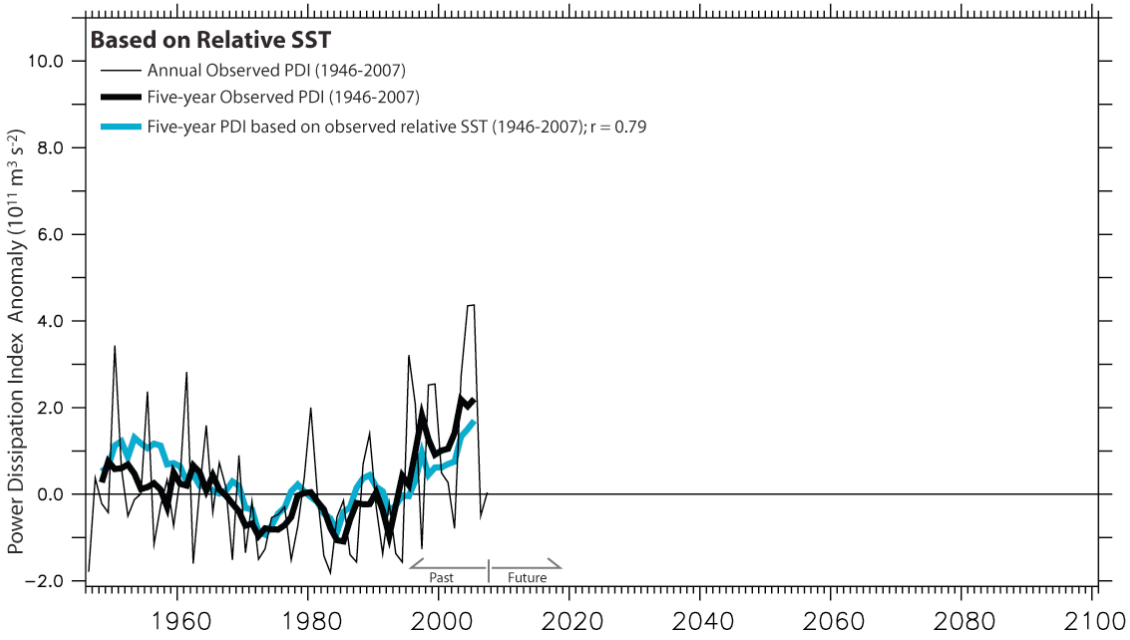
Vecchi, Swanson and Soden (2008, Science)

Gabriel Vecchi, NOAA/GFDL, Princeton, NJ

Atlantic Tropical Cyclone Power Dissipation Index Anomalies: Observed and Based on Sea Surface Temperature

Anomalies relative to 1981-2000 average: 2.13×10^{11} $m^3 s^{-2}$





Observed Activity

Absolute MDR SST

If causal, can attribute.

Relative MDR SST

If causal, cannot attribute.

Vecchi, Swanson and Soden (2008, Science)

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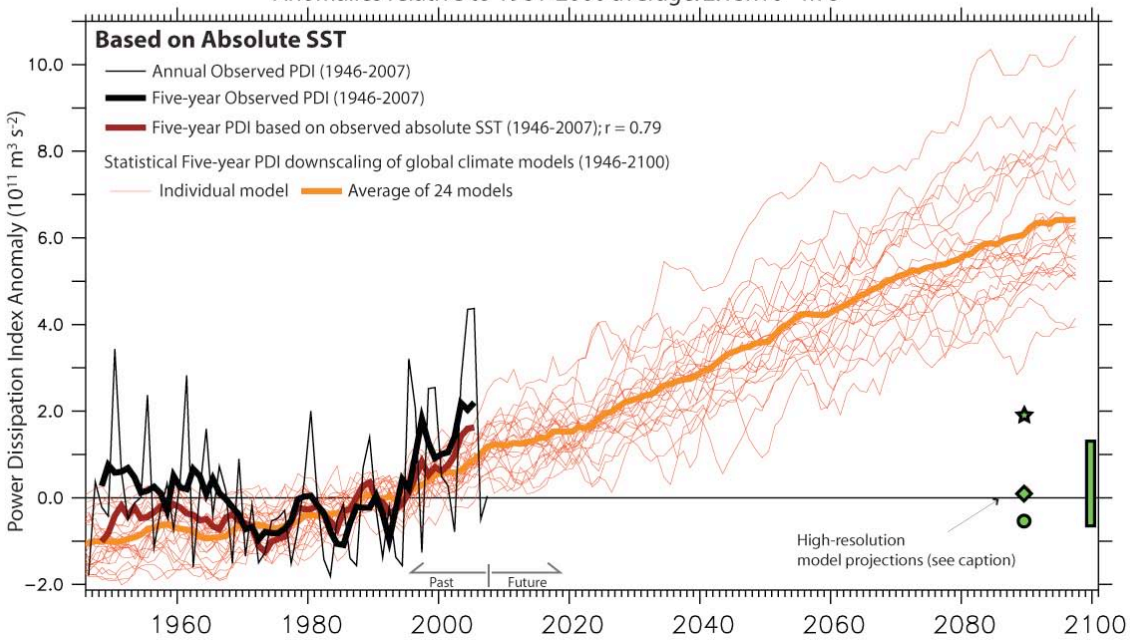
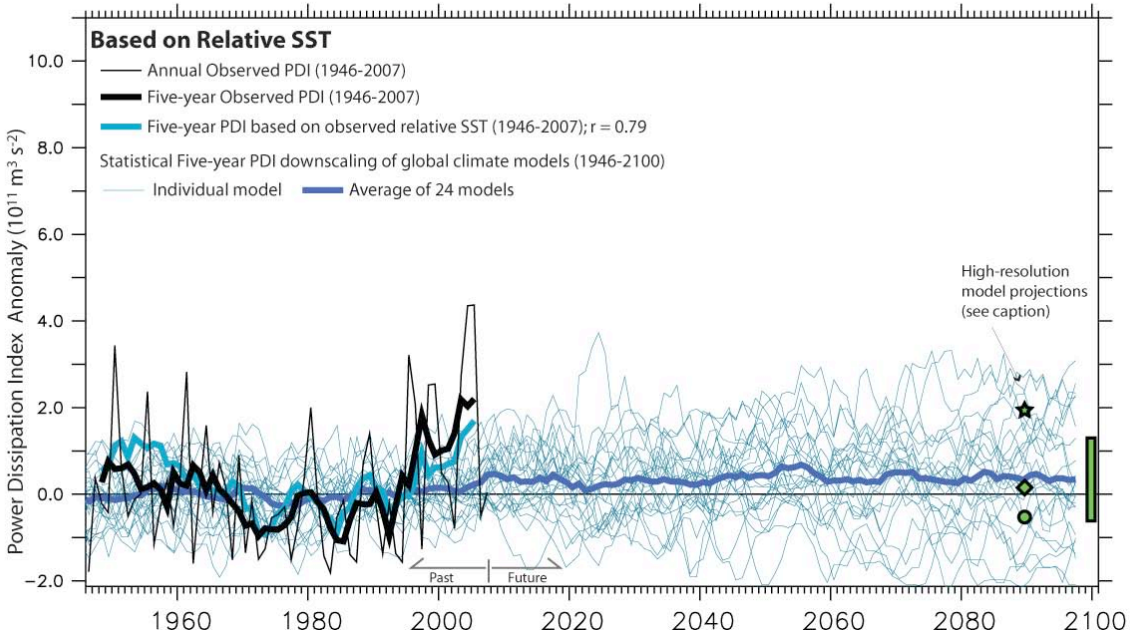




Observed Activity

Absolute SST

Model Abs. SST

High-resolution model activity change

Emanuel et al (08),Knutson et al (08)
Oouchi et al (06),Bengtsson et al (07)

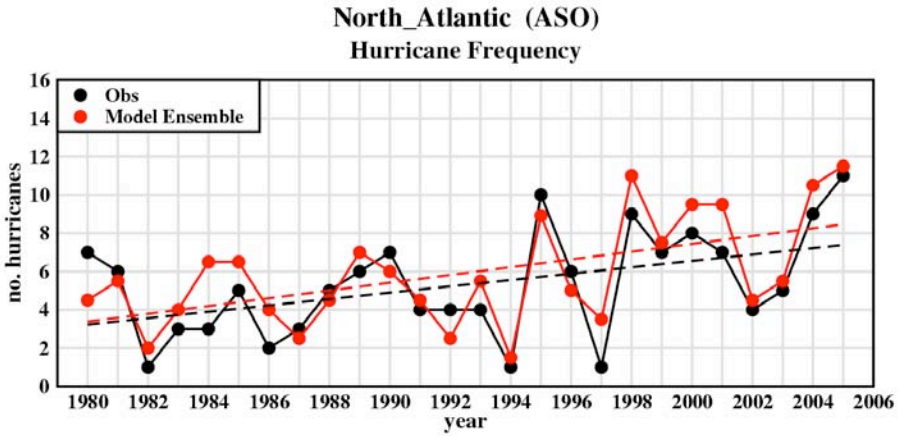
Relative SST

Model Rel. SST

Vecchi, Swanson and Soden (2008, Science)

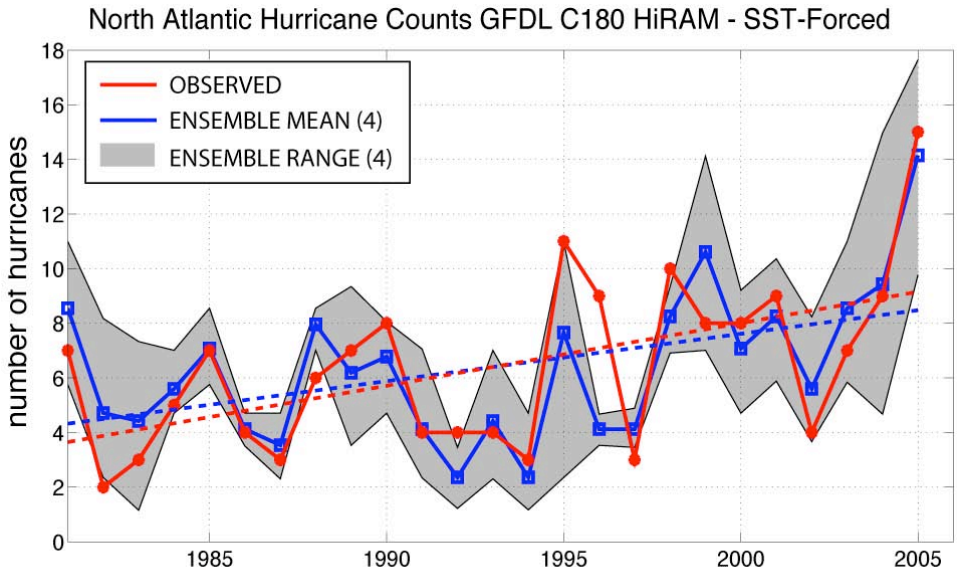
Comprehensive models

- Downscaling models using 3D forcing.
  (Emanuel et al 2008, Knutson et al 2007,2008,…)
- SST-forced AGCMs able to reproduce counts:
  - *e.g.* GFDL HiRAM (50km, 100km; Zhao et al 2009)
- Intensity requires refined tools.



Knutson et al (2007, BAMS)

SST-forced AGCM
Ensemble correlation = 0.83

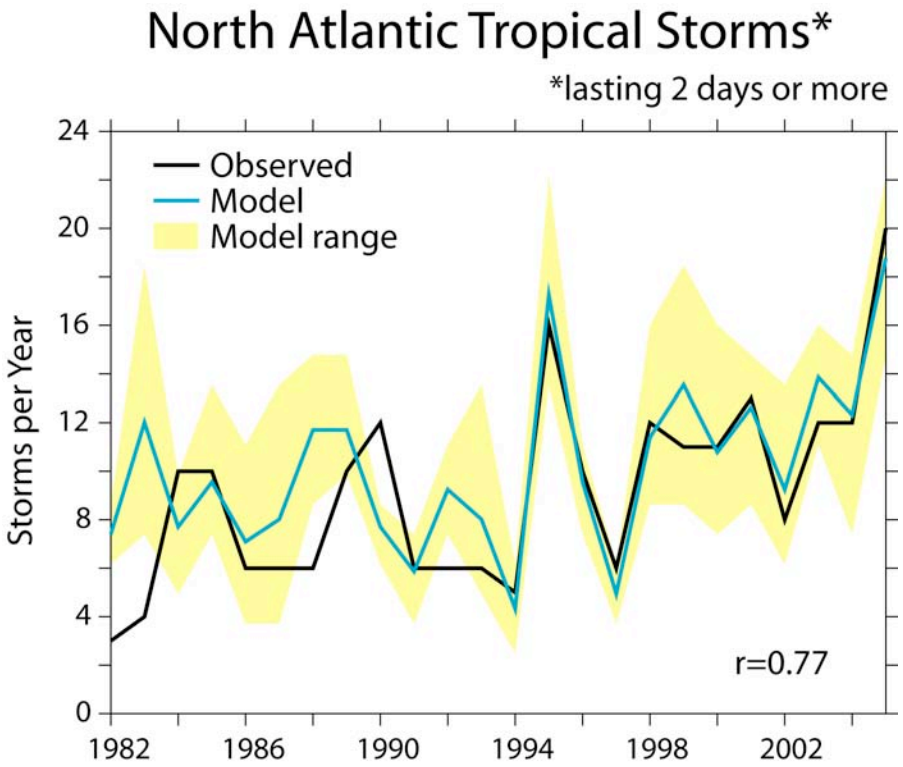


Zhao et al (2009, J. Clim.)

GFDL C-X HiRAM GCMs

Family of global atmospheric models designed for better-representing tropical cyclone frequency. **C90 - 1°,** C180=1/2°, C360=1/4°, C720=1/8°

Ref. Ming Zhao, S-J Lin and Isaac Held.



Adapted from AM2 with:

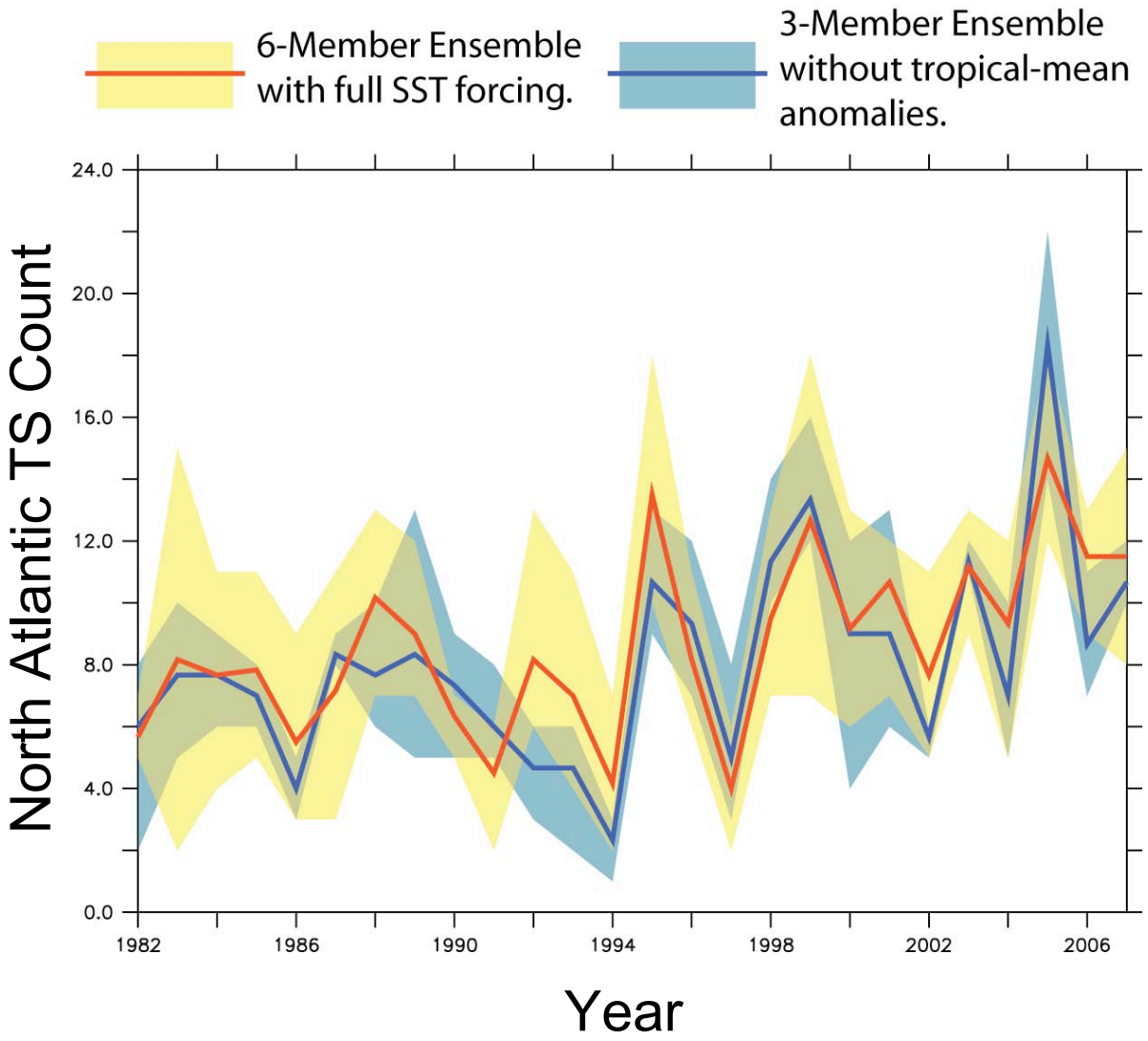
- Deep convection scheme adapted from Bretherton, McCaa and Grenier (MWR, 2004)
- Cubed sphere dynamical core
- Changes to parameterizations of cloud microphysics
- C90 Atm. resolution of 1°x1°

Explore C90 Model

Unpublished: do not quote or cite

Gabriel Vecchi, NOAA/GFDL, Princeton, NJ

AGCM with and without tropical-mean SST change



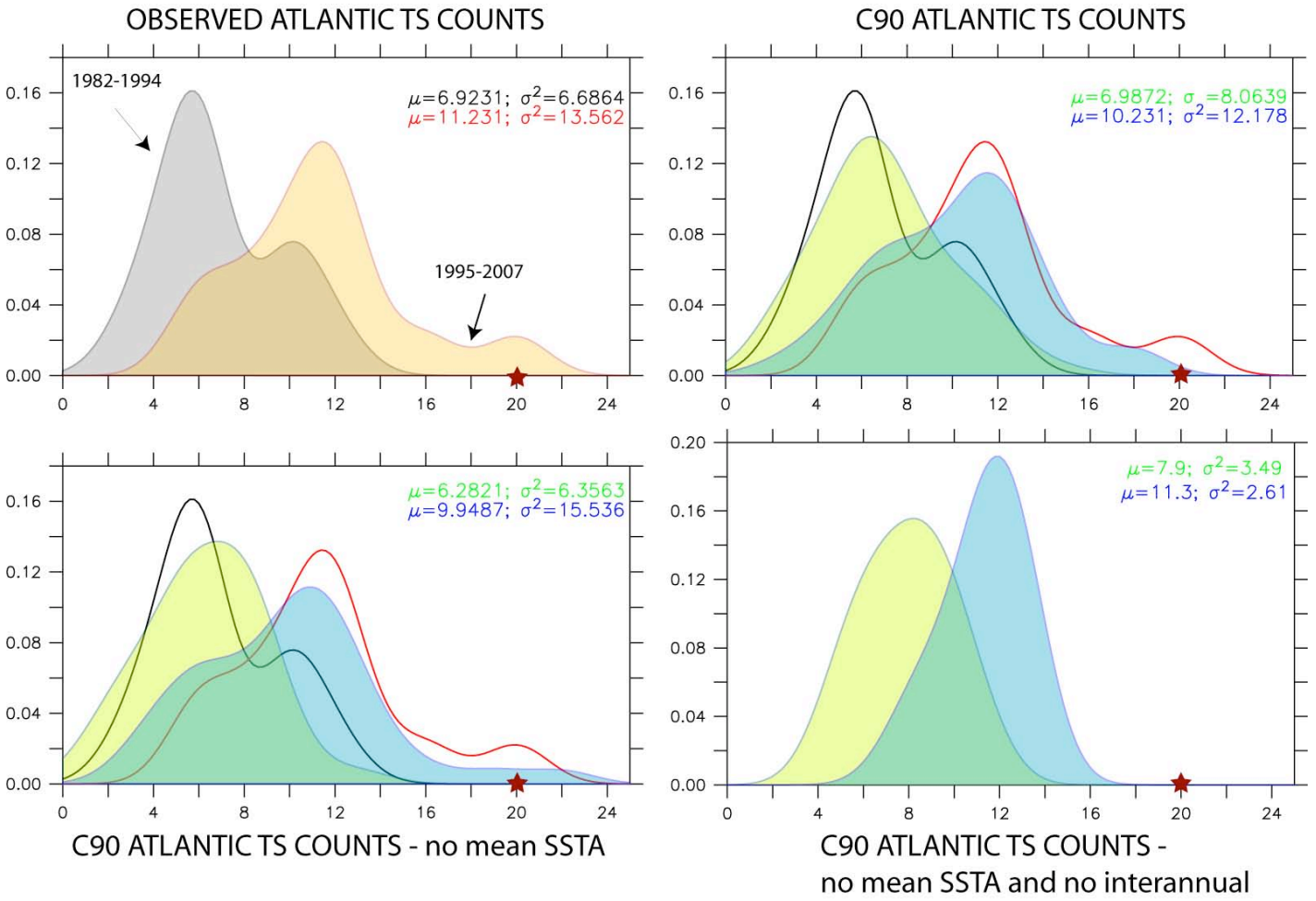
AGCM 1982-2007 North Atlantic tropical storm count solution not sensitive to removing tropical-mean SSTA forcing.

Gabriel Vecchi, NOAA/GFDL, Princeton, NJ

1982-94 and 1995-2007 PDFs of NA TS Count*

* lasting two days or more

★ 2005 Observed



Vecchi et al (2009, in prep.)

2005: decadal pattern of SSTA and interannual variability.

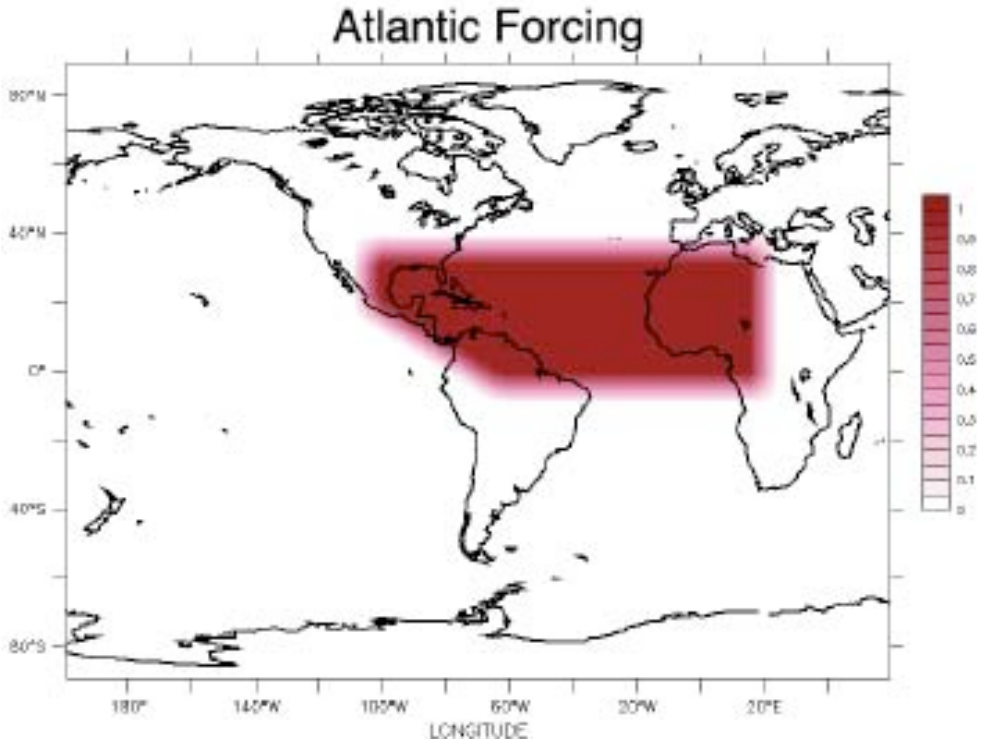
Understanding:
what controls hurricanes?

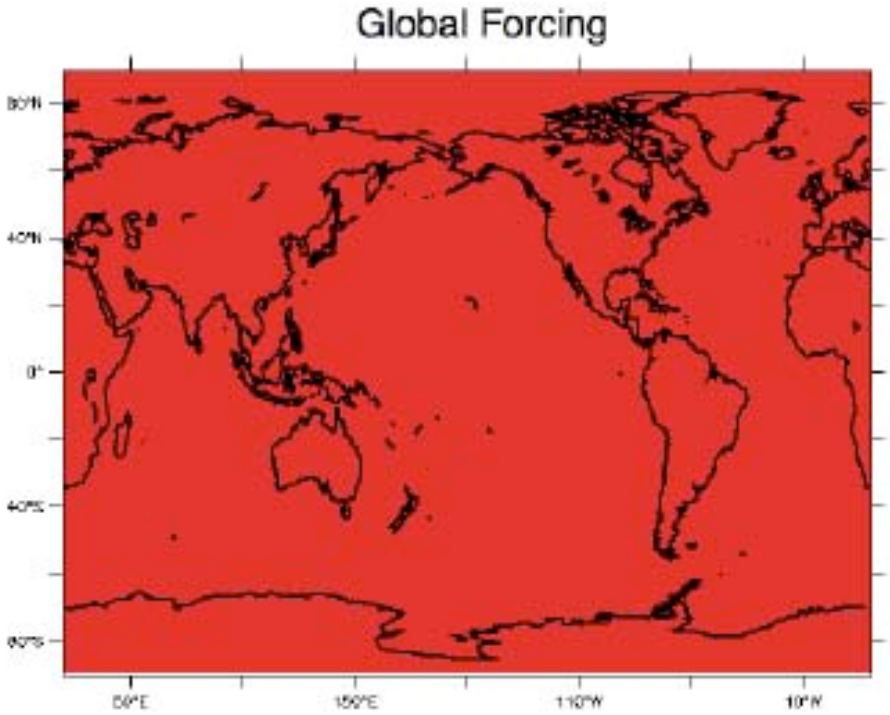
- Potential Intensity theory exists:
  - *e.g.* Emanuel, Holland…
  - What are limitations?
- What is theory for genesis? Duration? … why ~100 cyclones globally?
- Idealized forcing experiments with AGCMs:
  - Patterns of SSTA important
  - How model dependent?

Idealized Forcing Experiments

If local SST the dominant control, as opposed to relative SST:

- Similar Atlantic Response to Atlantic and Uniform F'cing
- Little Pacific Response to Atlantic compared to Uniform





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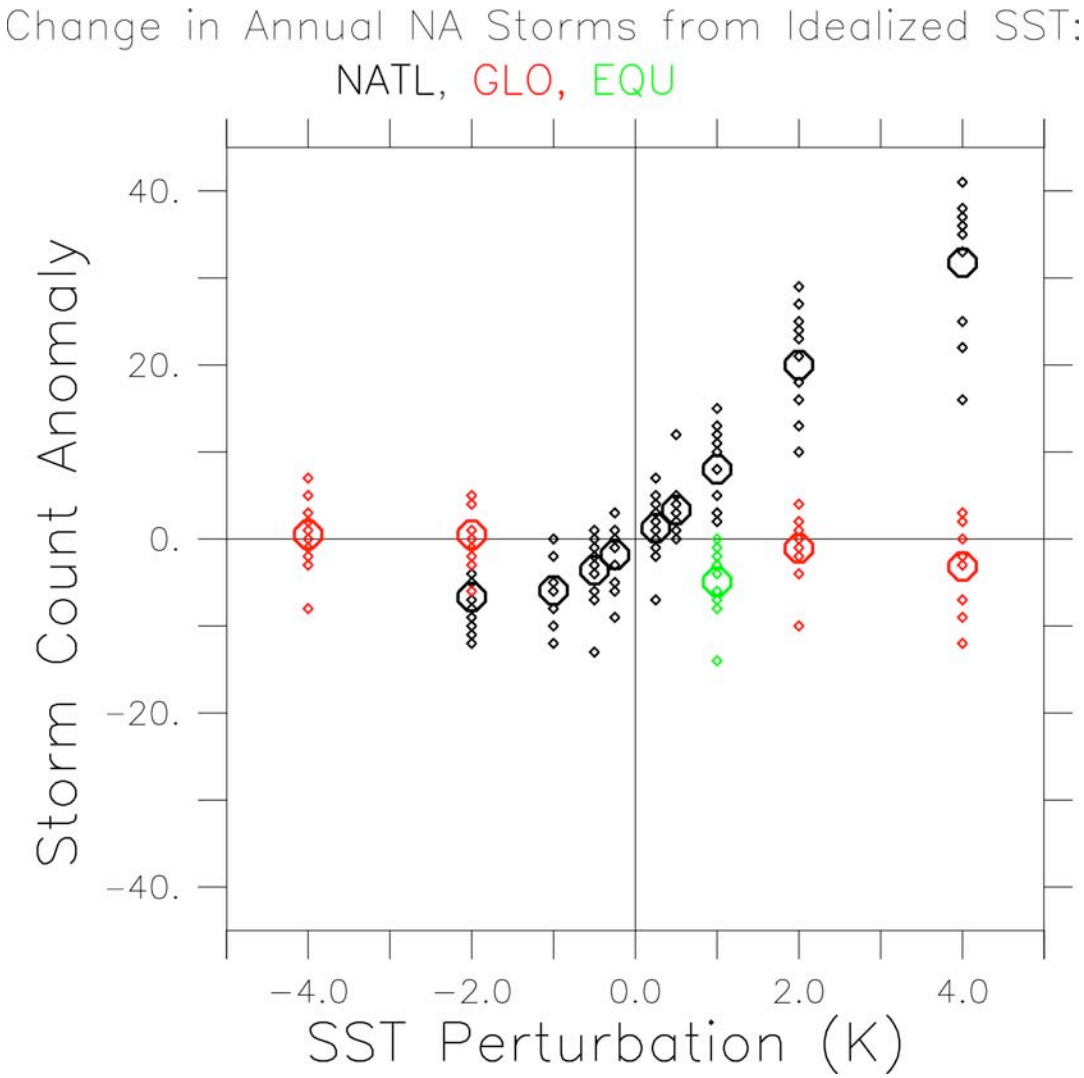
North Atlantic Response to Idealized SST



Atlantic Forcing

Uniform Forcing

Near-equatorial Forcing

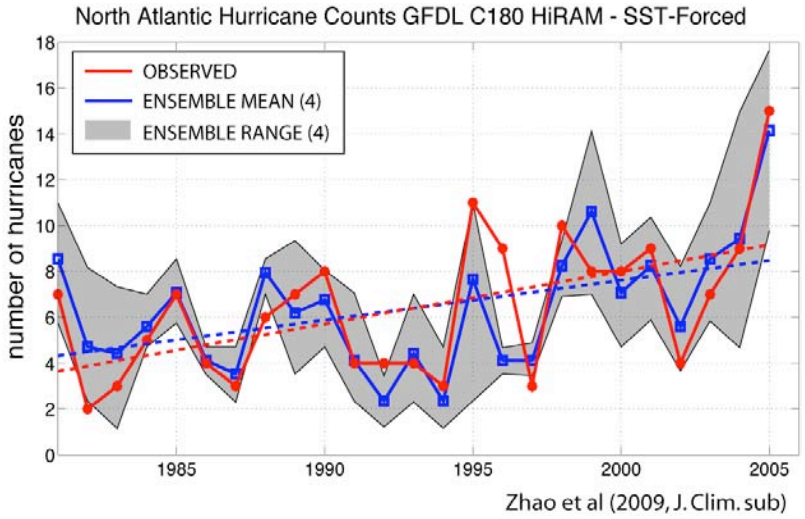
Similar TS frequency response to:
0.25° local warming
4° global cooling

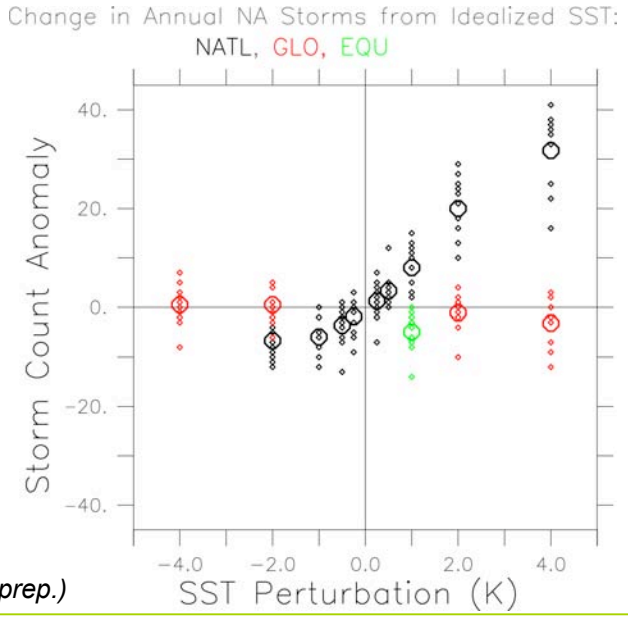
Vecchi et al (2009, in prep.)

Gabriel Vecchi, NOAA/GFDL, Princeton, NJ

Towards Atlantic TS Attribution

- Measure:
  - *Annual TS Counts*
- Observations:
  - *~25yr increase, but accounting for 'missed' storms increase not significant since late-19th Cy.*
- Comprehensive dynamical models:
  - *Recent increase can be forced by SSTs*
  - *Recent increase captured without global SSTA increase*
- Understanding:
  - *Need to attribute patterns of SSTA*
  - ***Theory for genesis lacking***



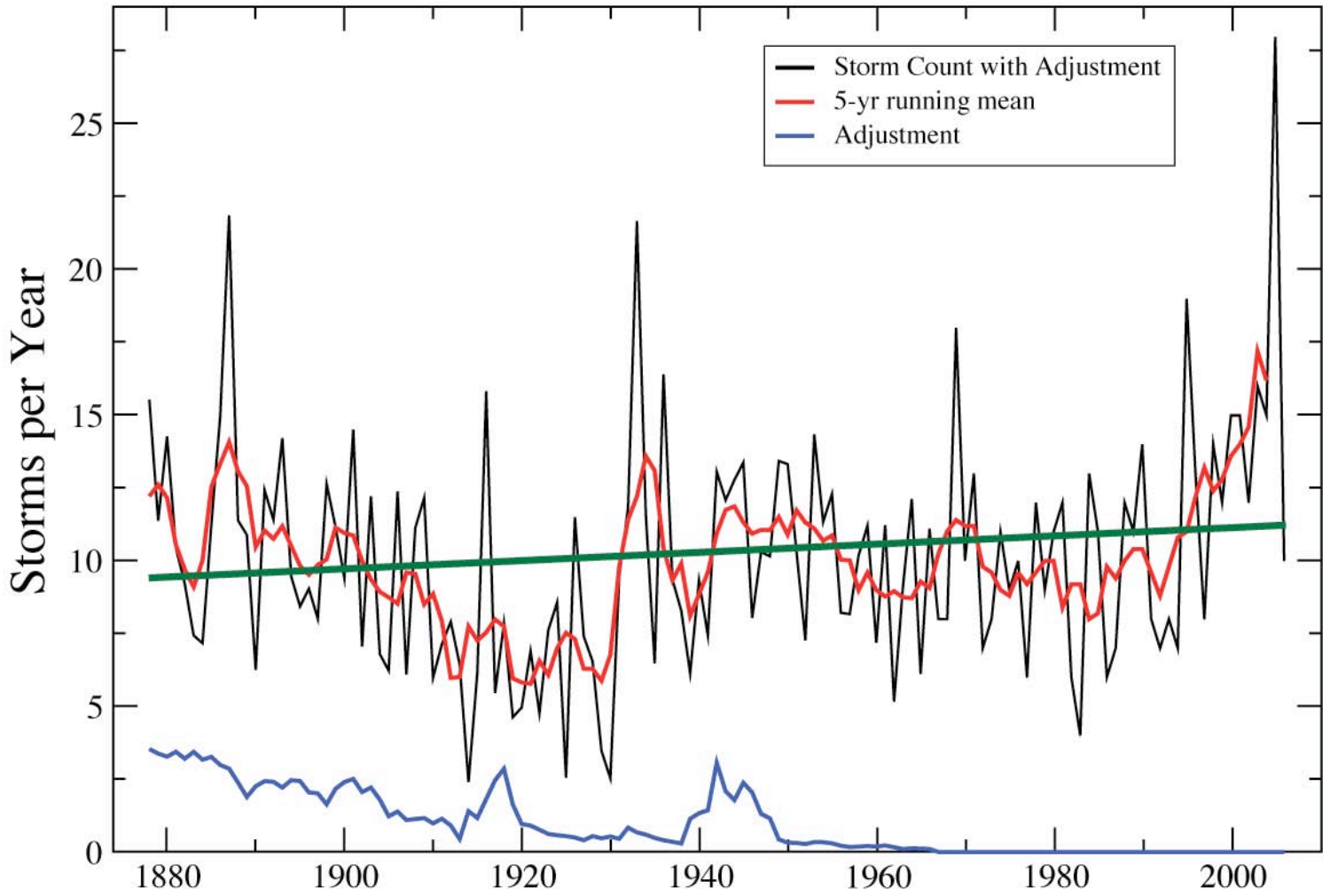


Vecchi et al (2009, in prep.)

Conclusions

- It is premature to conclude that human activity--and particularly greenhouse warming--has already had a detectable impact on Atlantic tropical storm frequency.
- Atlantic TS frequency appears controlled by SST changes in the Atlantic relative those in other basins:
  - To attribute Atlantic TS changes need to attribute pattern of SST change.
  - Same for prediction.

Adjusted Atlantic Hurricanes, Tropical and Subtropical Storms

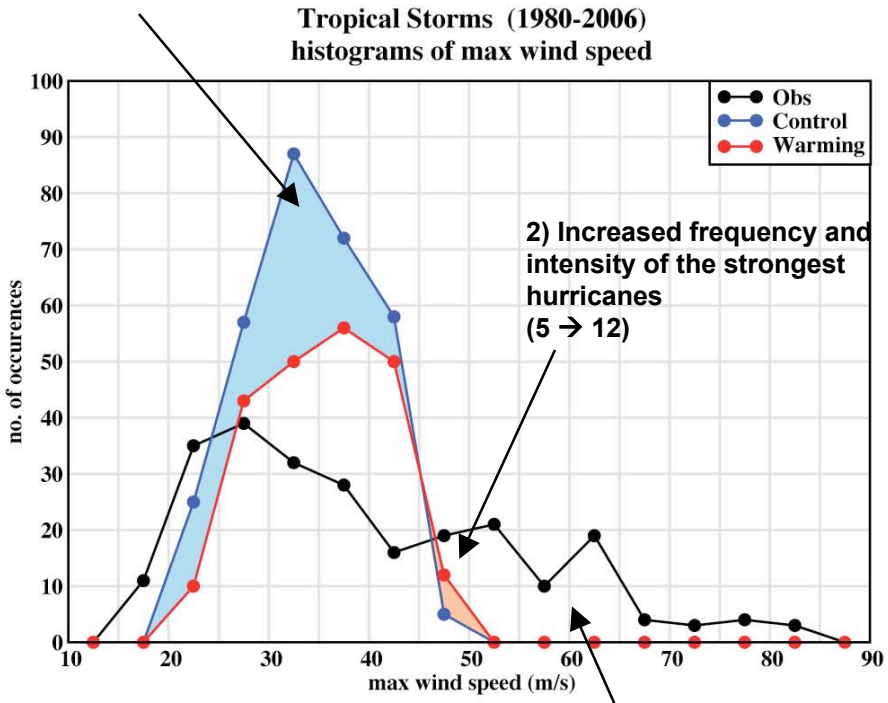


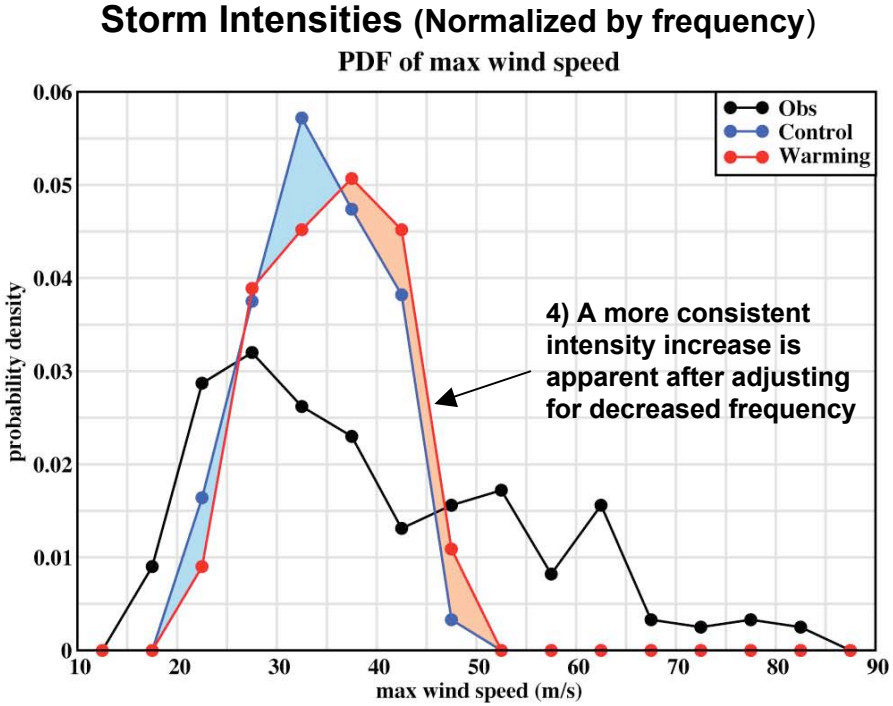
Vecchi and Knutson (2008, J. Clim.)

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

The model provides projections of Atlantic hurricane and tropical storm *frequency* changes for late 21st century, downscaled from a multi-model ensemble climate change (IPCC A1B scenario):

1) Decreased frequency of tropical storms (-27%) and hurricanes (-18%).





Source: Knutson et al., *2008*, Nature Geoscience.