Towards Attribution of Hurricane Activity Changes

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1-GFDL; 2-Princeton CEE; 3-U. Miami

Can we say what drove recent Atlantic increase?

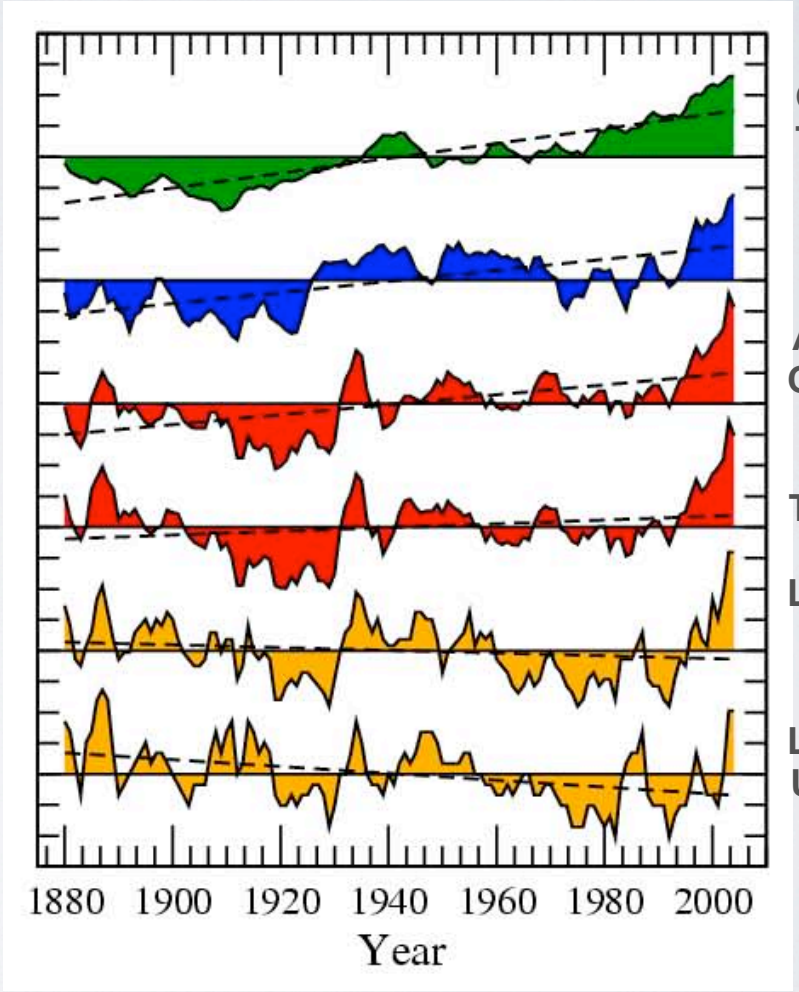
How do we attribute?

Two part attribution: A -> B ; B -> Hurricanes

2011 ASLO Meeting

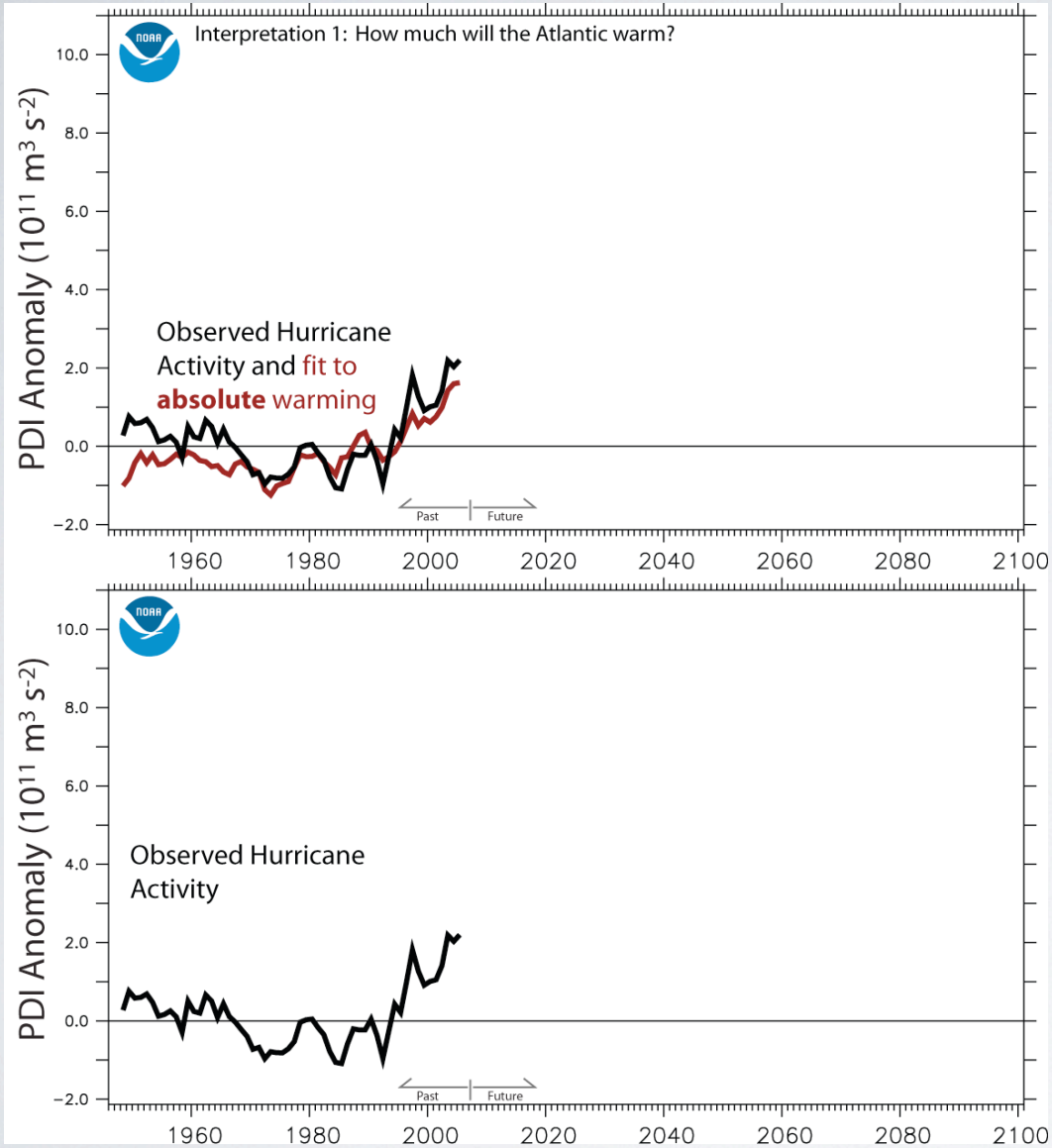
Measure of Activity

- 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.
- Must communicate differences



Vecchi and Knutson (2008, J. Clim.)

One Temperature Predictor of Atlantic Hurricane Activity



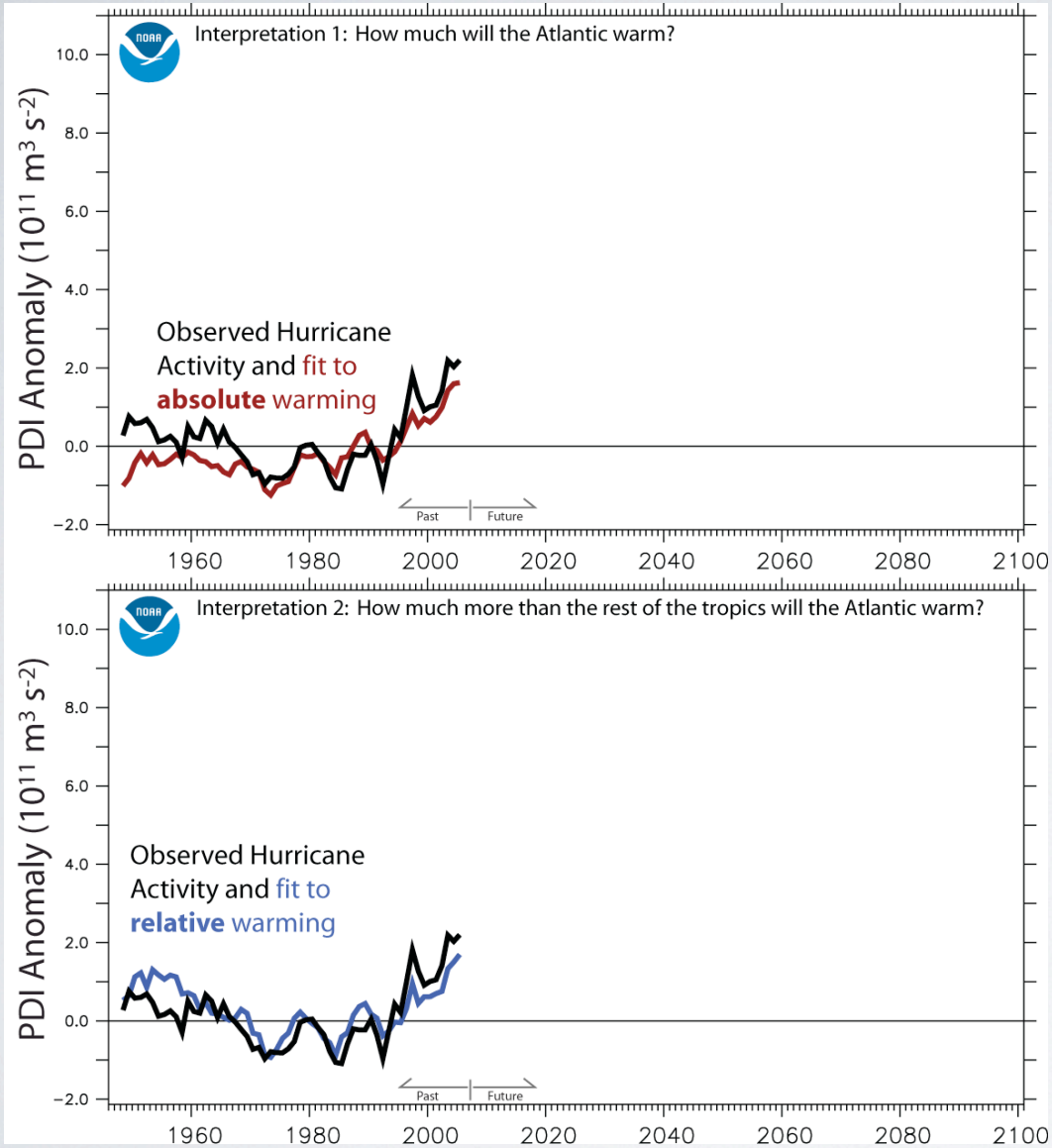
Observed Activity

Absolute Atlantic Temperature

If causal: can attribute

Vecchi, Swanson and Soden (2008, Science)

Two Temperature Predictors of Atlantic Hurricane Activity



Observed Activity

Absolute Atlantic Temperature

If causal: can attribute

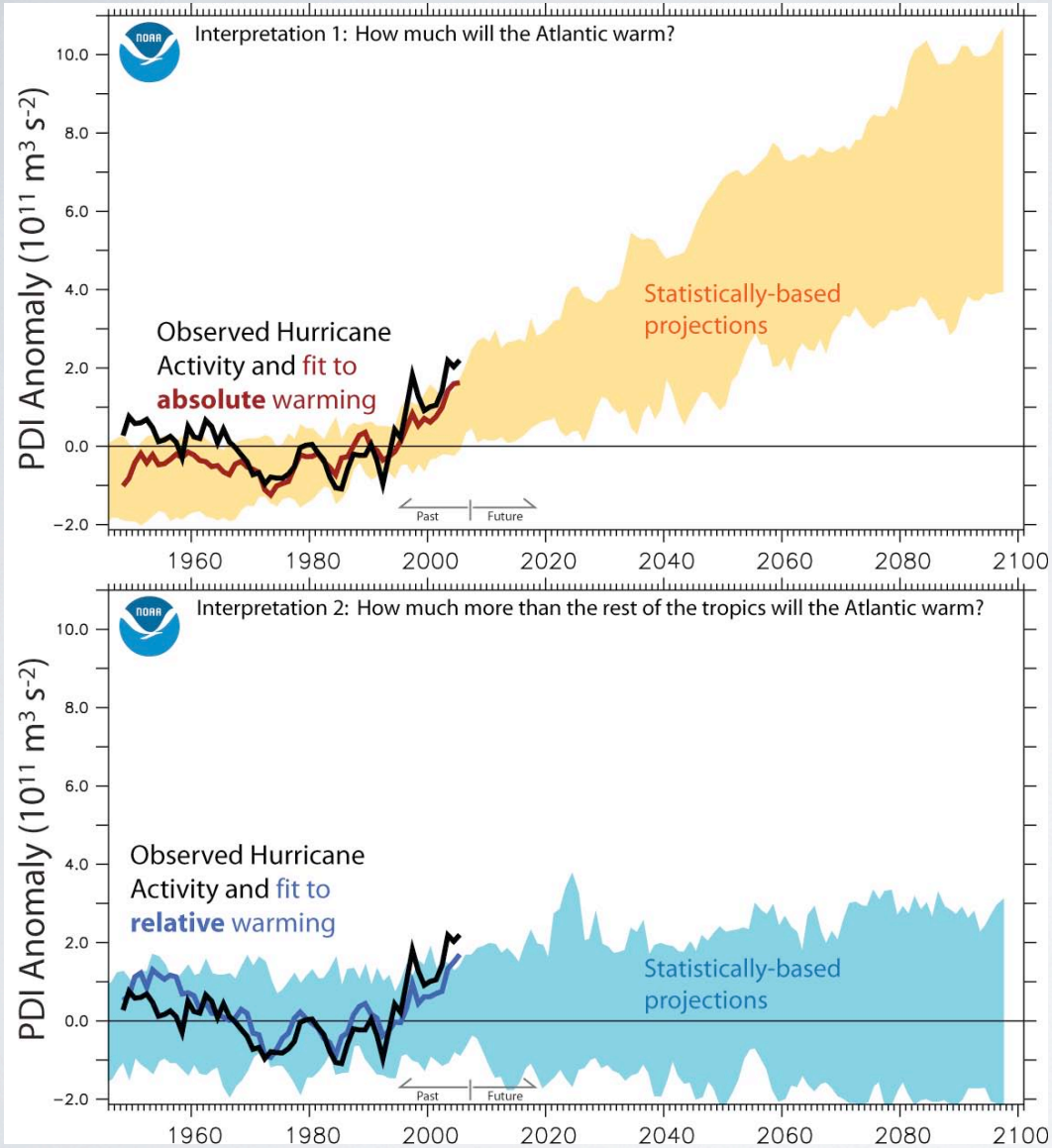
Observed Activity

Relative Atlantic Temperature

If causal: cannot attribute

Vecchi, Swanson and Soden (2008, Science)

Two Statistical Projections of Atlantic Hurricane Activity

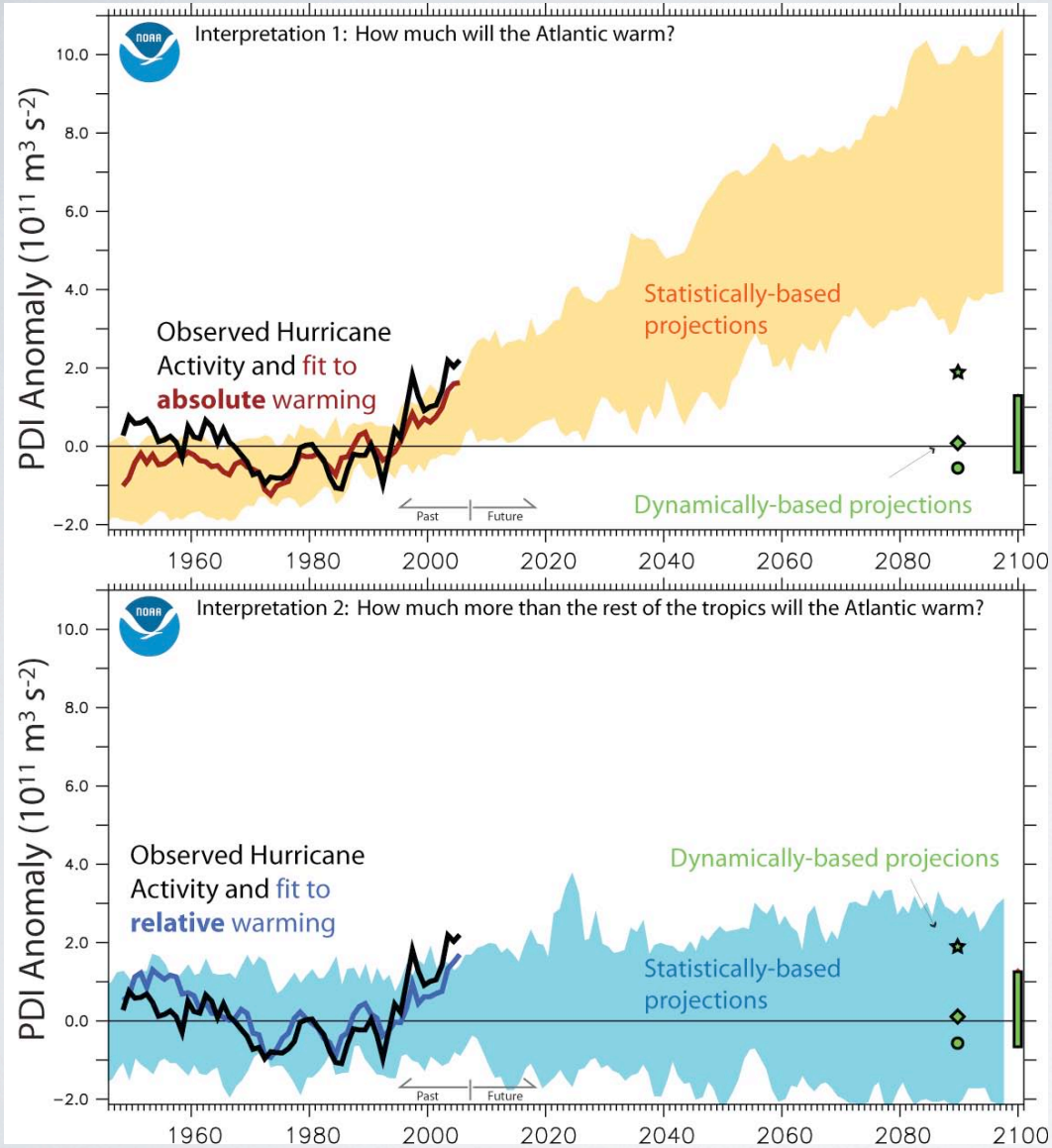


Observed Activity
Absolute Atlantic Temperature

Observed Activity
Relative Atlantic Temperature

Vecchi, Swanson and Soden (2008, Science)

…Add Dynamical Projections of Atlantic Hurricane Activity



Observed Activity
Absolute Atlantic Temperature

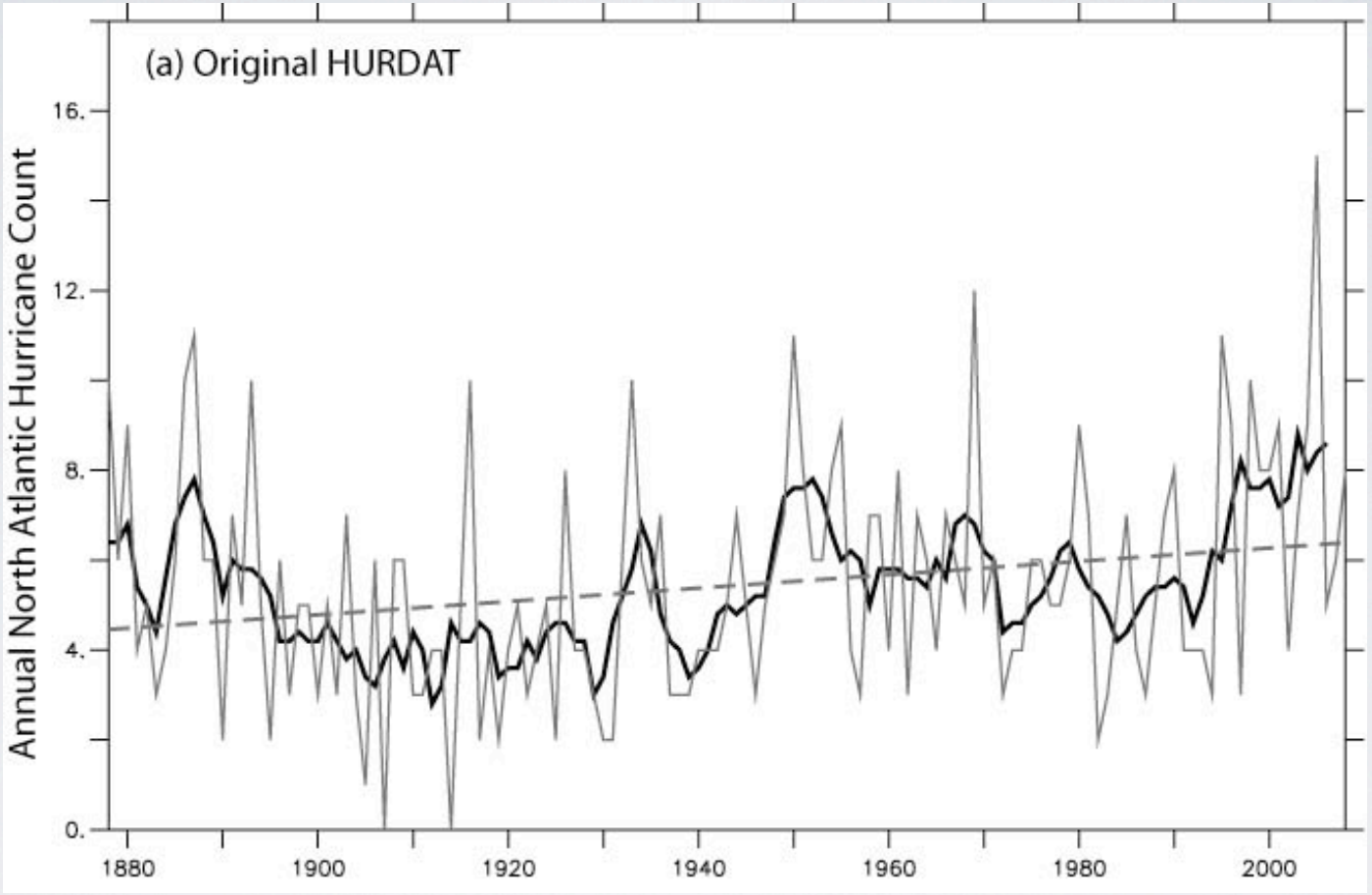
Dynamical Model Projections

Observed Activity
Relative Atlantic Temperature

Vecchi, Swanson and Soden (2008, Science)

Recorded NA Hurricanes Show Clear Increase

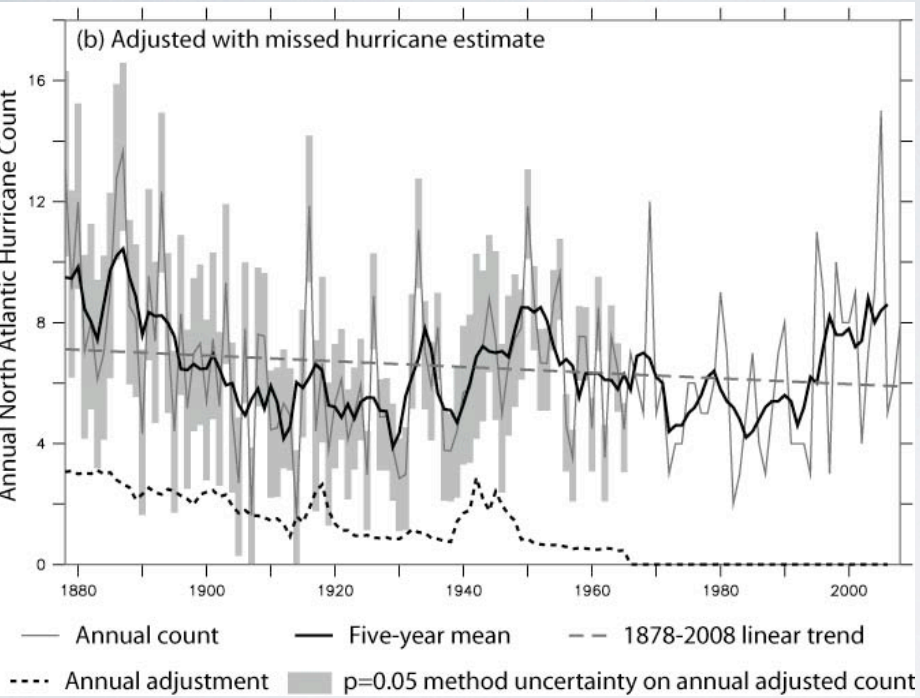
But was there really an increase?



Vecchi and Knutson (2011, J. Climate, in press)

Observed NA Hurricane Frequency Changes

NA Basinwide Hurricane Record



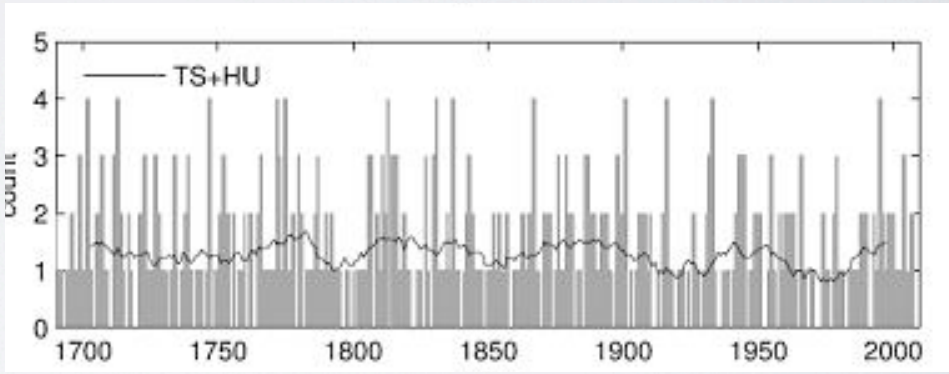
Vecchi and Knutson (2011, J. Climate, in press)

Record Uncertain

Many timescales

Centennial Trend Unclear

Document-based reconstruction of Antilles TS and HU

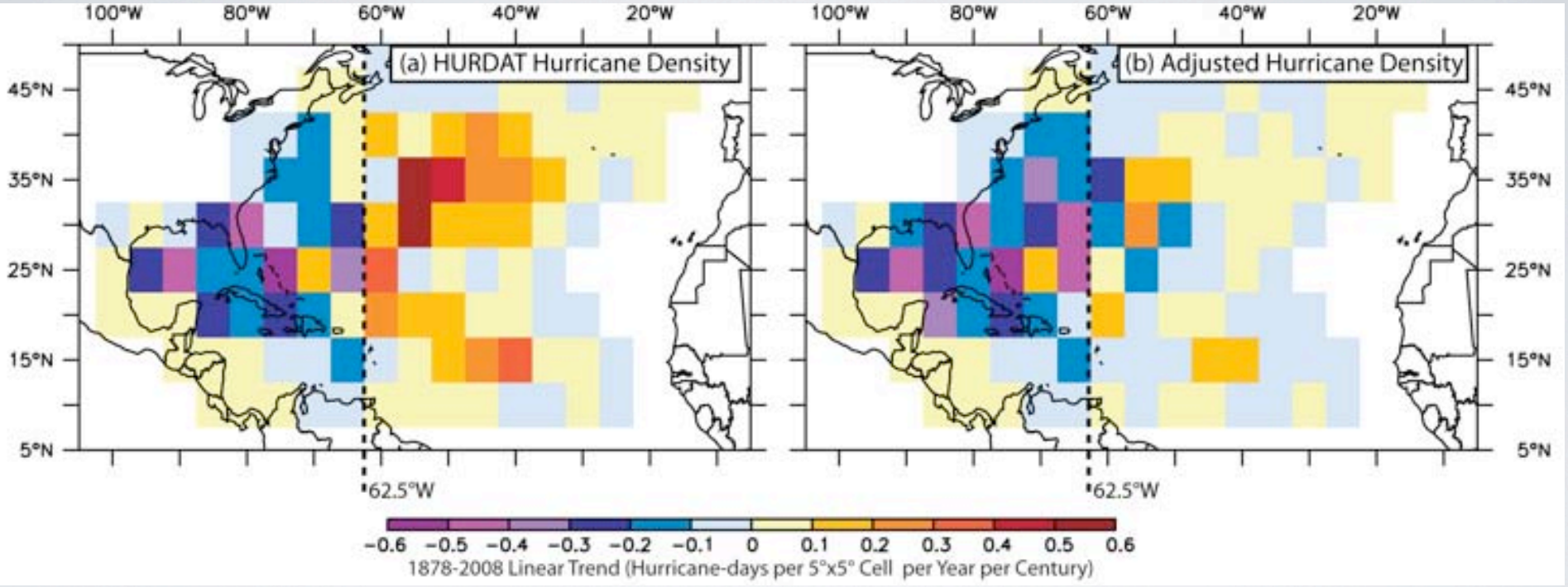


Chennoweth and Divine (2008)

Various efforts to homogenize instrumental TC record (e.g., Kossin et al. 2007, Landsea 2007, Chang and Guo 2007, Mann et al 2007, Vecchi and Knutson 2008, Landsea et al 2010, Vecchi and Knutson 2010).

Data Archeology and Paleo-proxy Indicators Complement Instrumental Records (e.g., Nyberg et al. 2007, Chennoweth and Divine 2008, Mann et al 2009)

West Atlantic has seen century-scale decrease in hurricanes

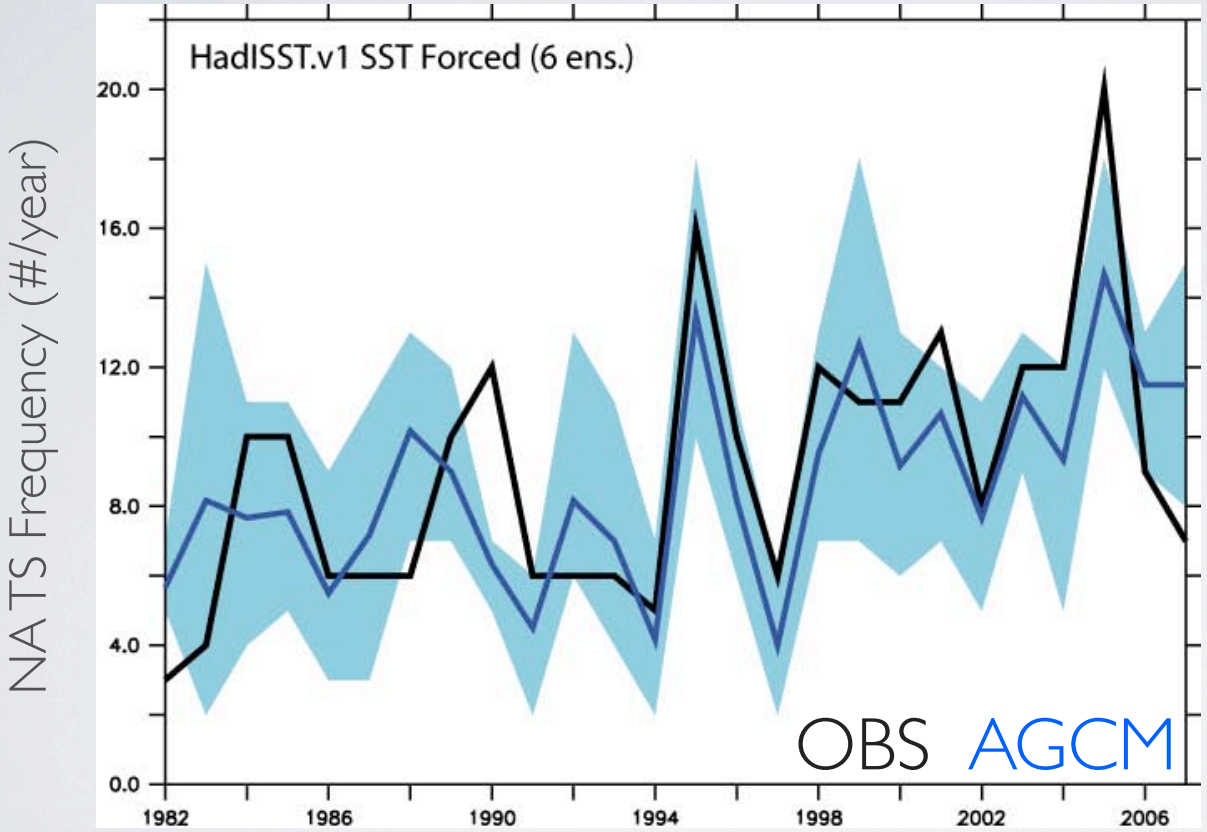


1878-2008 Trend in Hurricane Occurrence

Vecchi and Knutson (2011, in press J. Clim.)

Attribution of Recent TS Frequency Increase in North Atlantic

100km GFDL-HiRAM AGCM recovers recent NA TS Trend when forced with HadISST.v1 SST



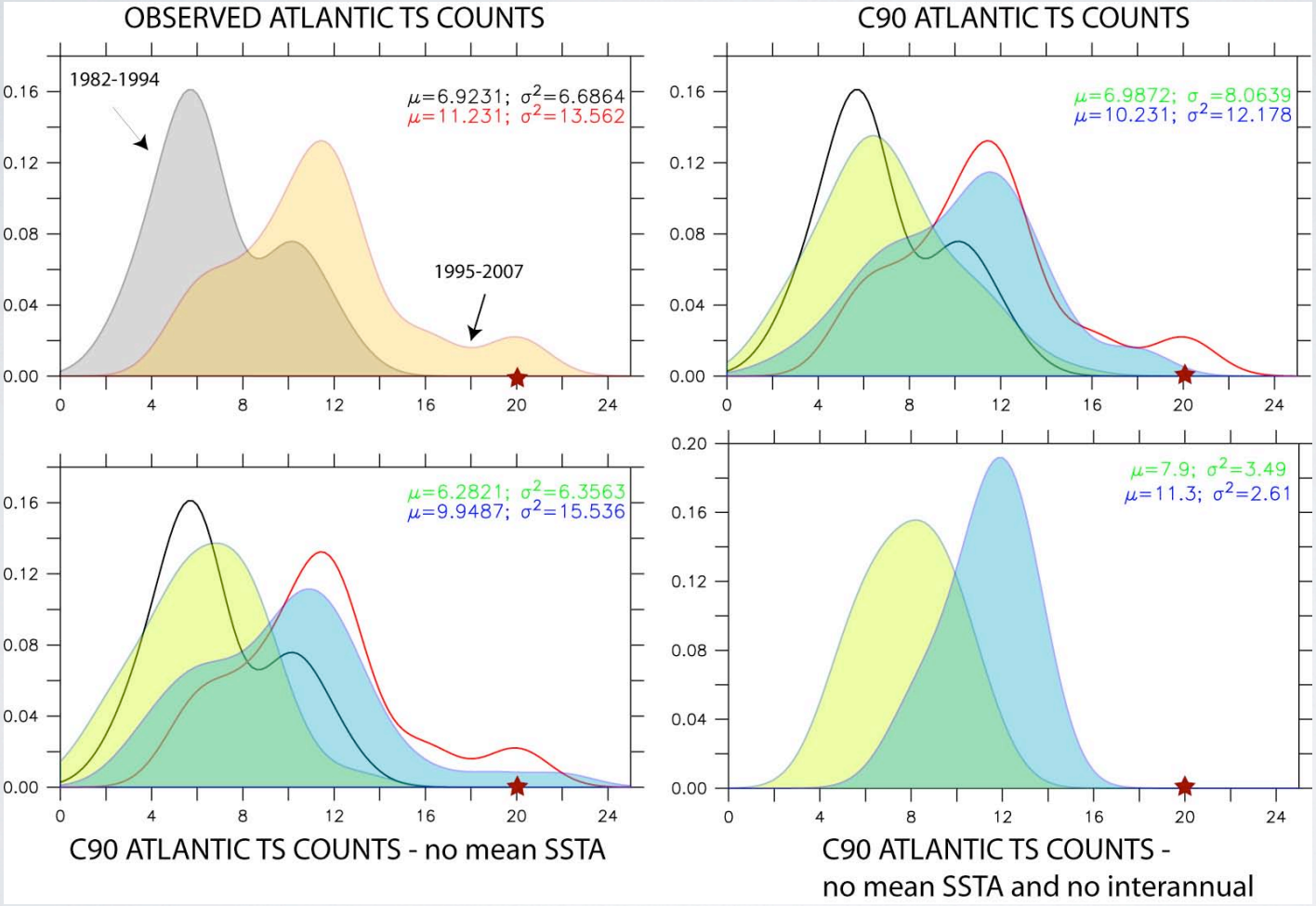
What aspect of SST drove increase?

Vecchi, Zhao and Held (2011, in prep.)

1982-94 AND 1995-2007 PDFs OF NA TS COUNT*

* lasting two days or more

★ 2005 Observed



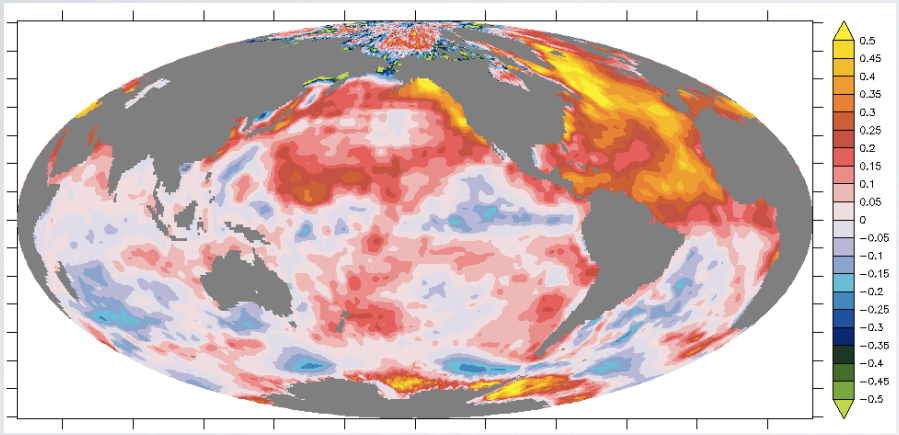
Vecchi, Delworth, Zhao and Held (2011, in prep.)

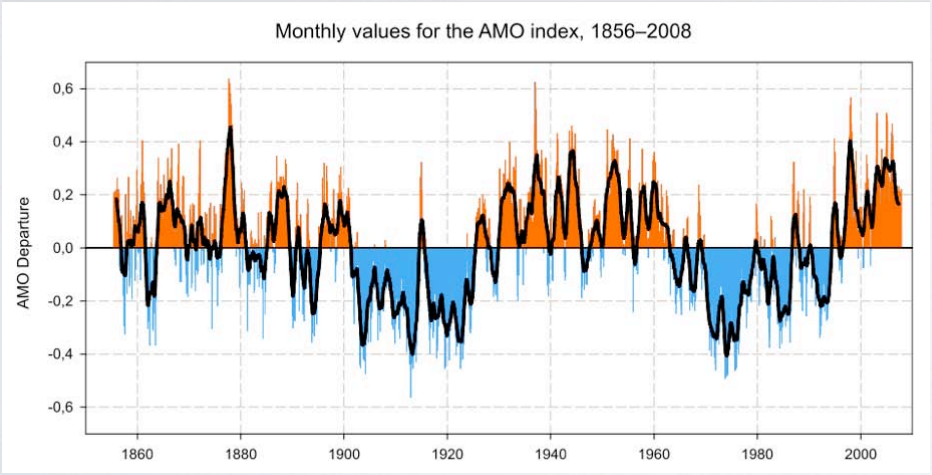
2005: decadal pattern of SSTA and interannual variability.

SHIFT IN MEAN TS COUNTS ATTRIBUTABLE TO "AMO" SST CHANGE ACROSS 1994-1995

What drove this SST change? Internal variability? Aerosols? Combination?

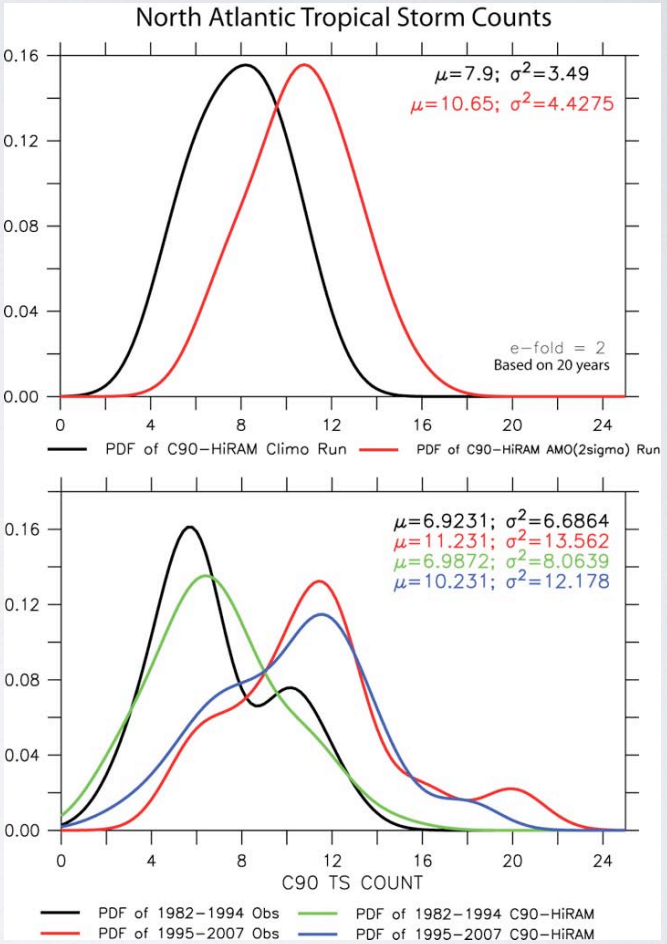
1995-2007 minus 1982-1994 "AMO" SSTA Forcing





AMO Index: Regression of SST onto NA SST

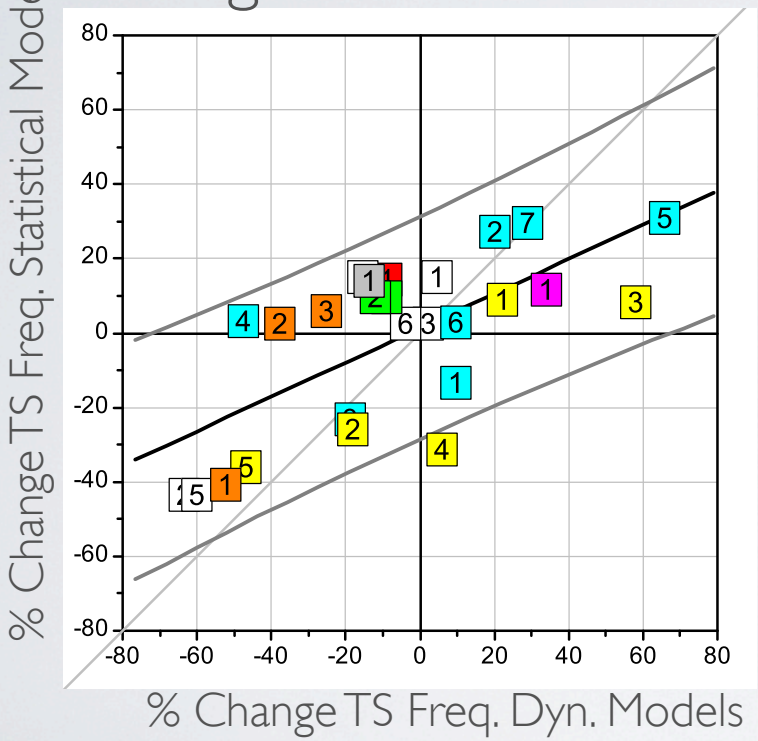
Response to "AMO" forcing



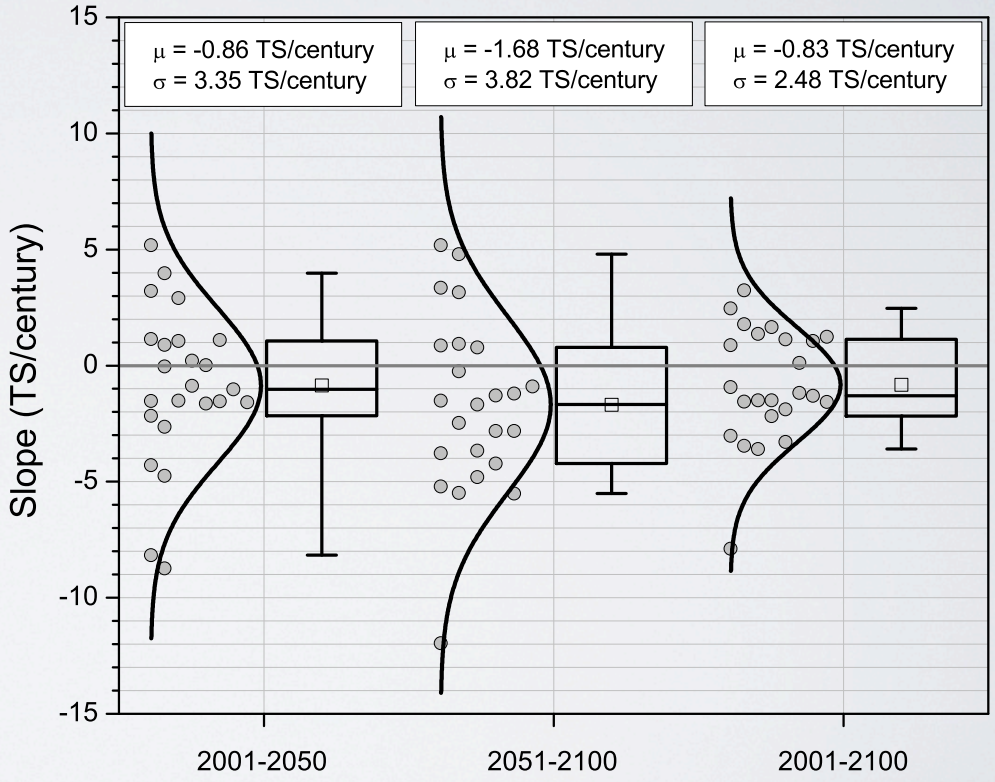
Vecchi, Delworth, Zhao and Held (2009, in prep.)

Statistical Projections of 21st Century NA TS Trends (model based on difference Atlantic to Tropical SST)

Stat. model recovers high-res models



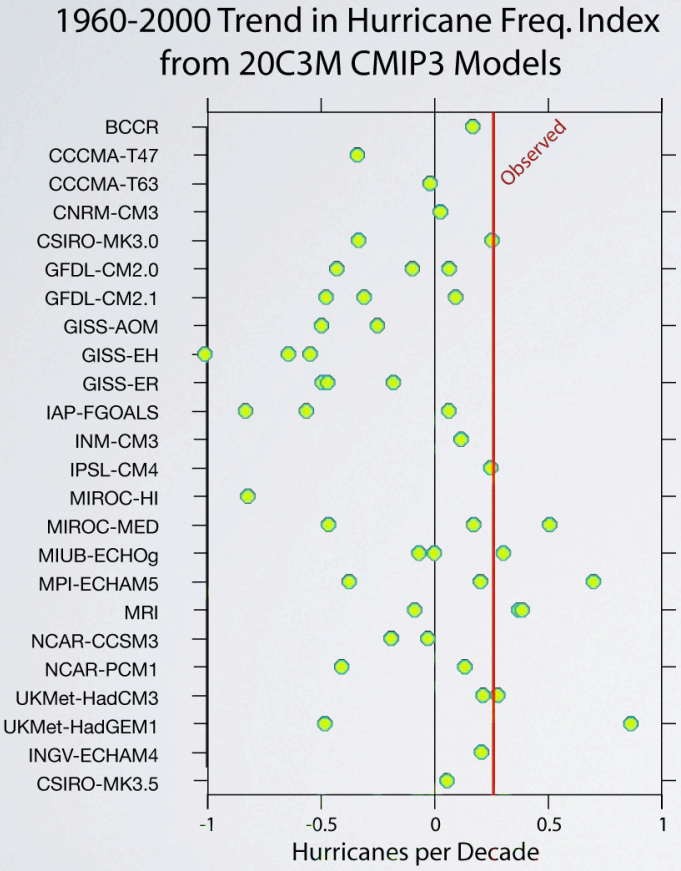
Stat. model projects small changes of differing sign

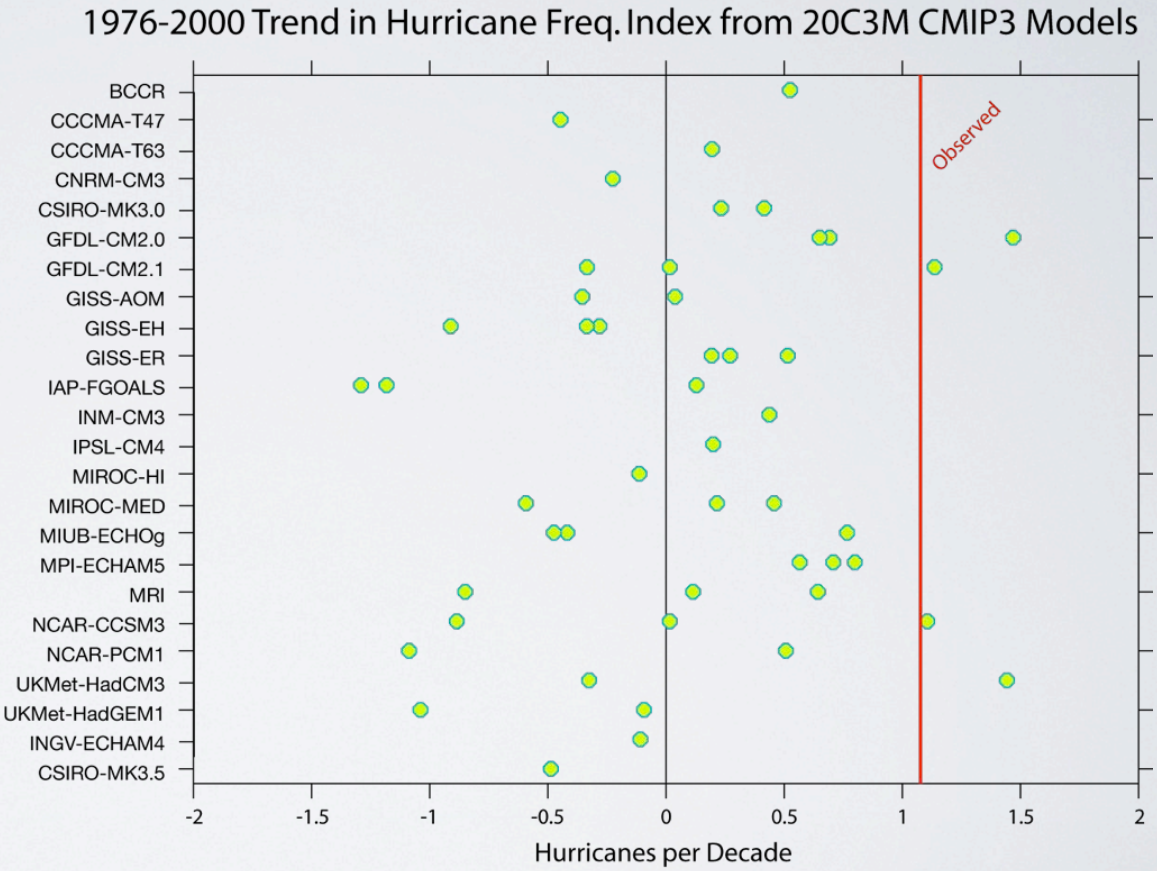


Villarini et al (2011, in press)

Recent Increase Not Robustly "Forced" in CMIP3 Models

Recent trends in **statistical hurricane model** applied to CMIP3 20c3m runs





Vecchi et al. (2011, in prep.)

Conclusions

- It is premature to conclude that human activity (particularly greenhouse warming) has already had a detectable impact on Atlantic tropical storm and hurricane frequency or PDI.

- Atlantic TS frequency appears controlled by SST changes in the Atlantic relative those rest of tropics:

  To attribute Atlantic TS changes need to attribute pattern of SST change (has not been done).

  Same for prediction/projections: what controls regional SST patterns? (see LeLoup and Clement 2009, Xie et al 2009).

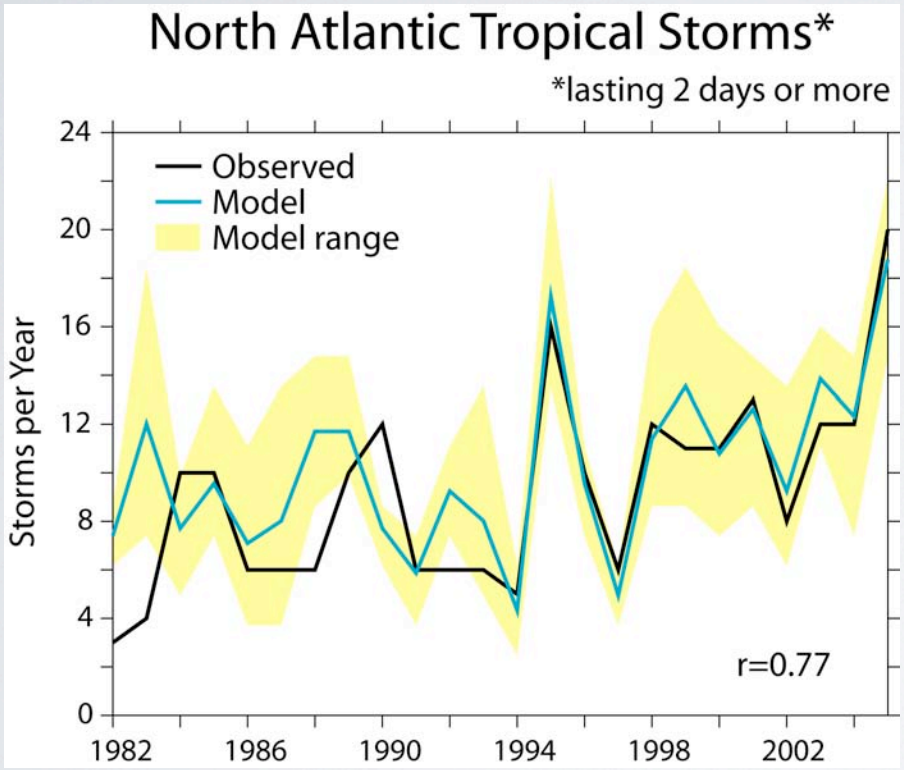
- Change in mean TS frequency across 1994-95 attributable to "AMO-ish" SST change

  What drove SST pattern? What about shift in variance? Interannual variability important.

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. Zhao et al (2009, J. Climate)



Explore C90 Model

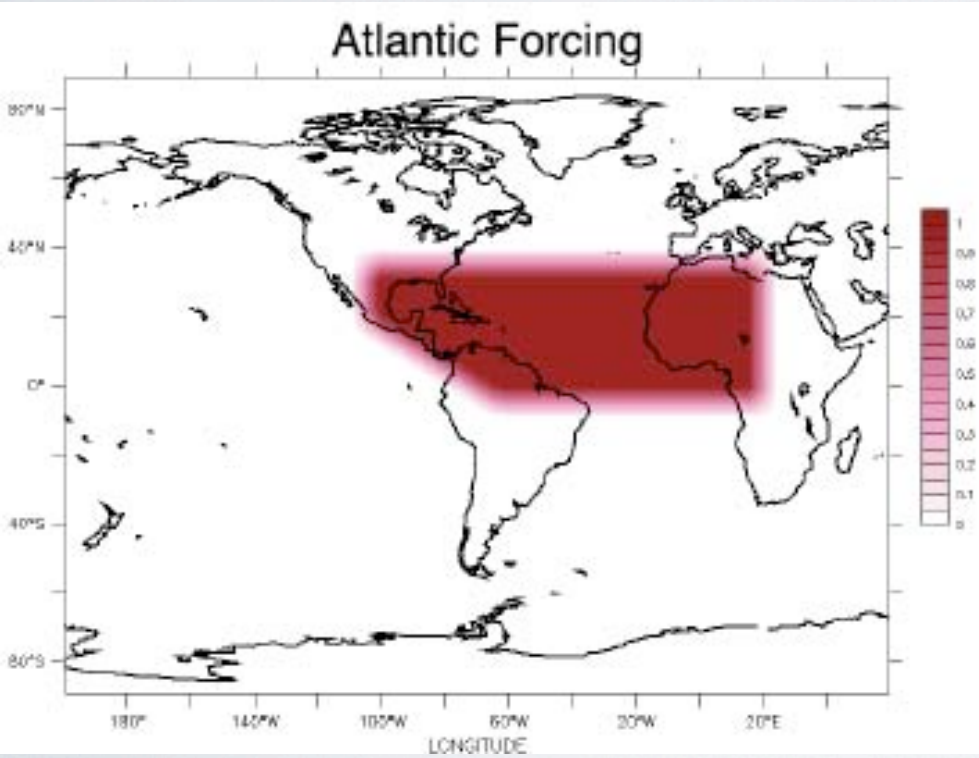
Adapted from AM2 with:

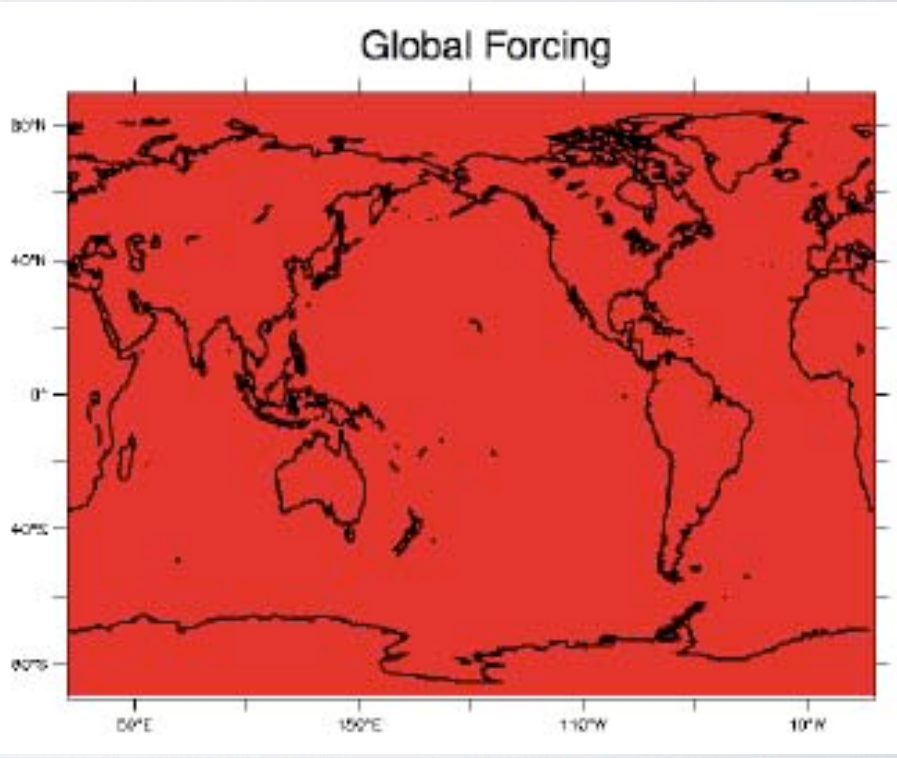
- Deep convection scheme adapted from Bretherton, McCaa and Grenier (MWR, 2004)
- Cubed sphere dynamical core
- Changes to parameterizations of cloud microphysics
- C90 Atm. resolution of 1°x1°

IDEALIZED FORCING

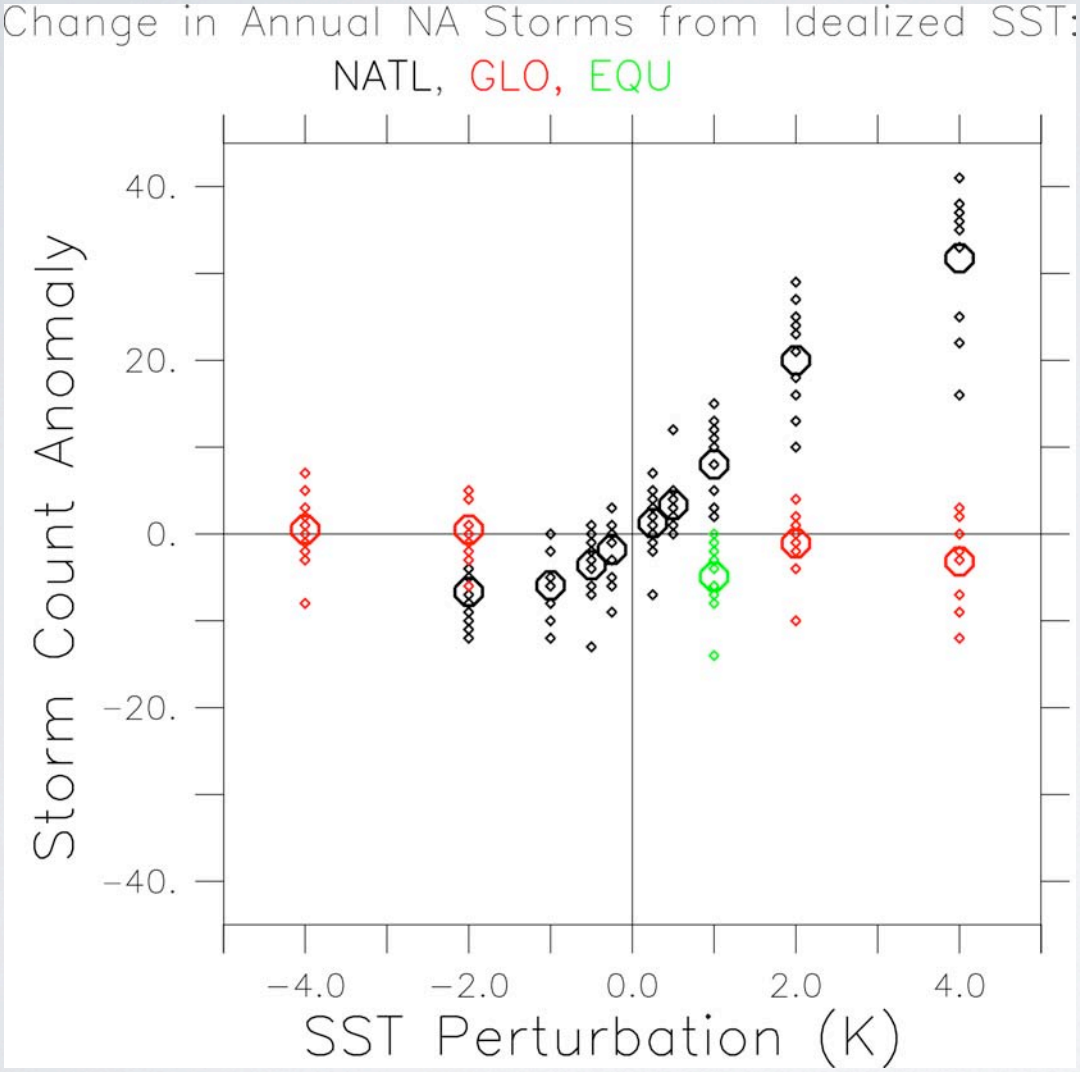
If local SST the dominant control, as opposed to relative SST:

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





NORTH ATLANTIC RESPONSE



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.)