Atlantic Hurricanes and Climate Change

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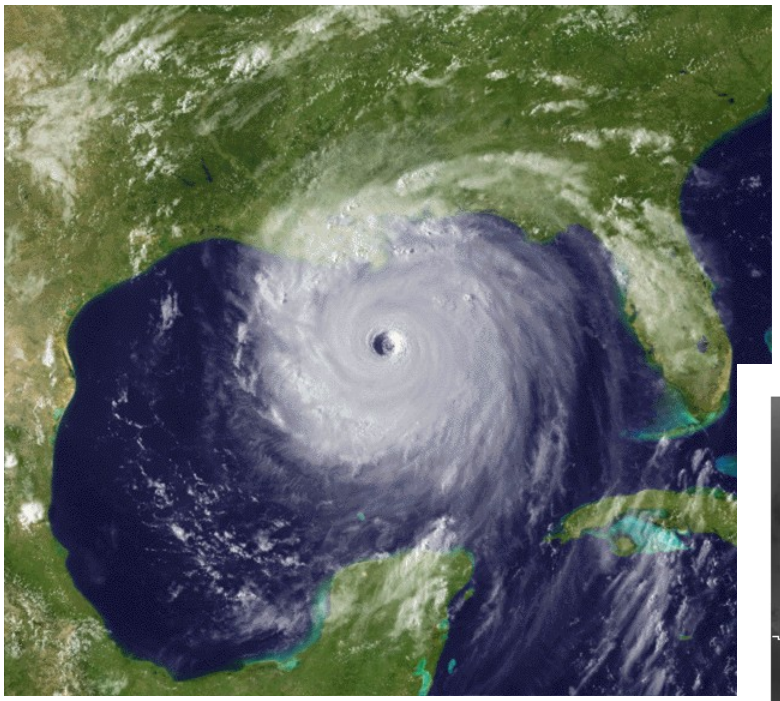
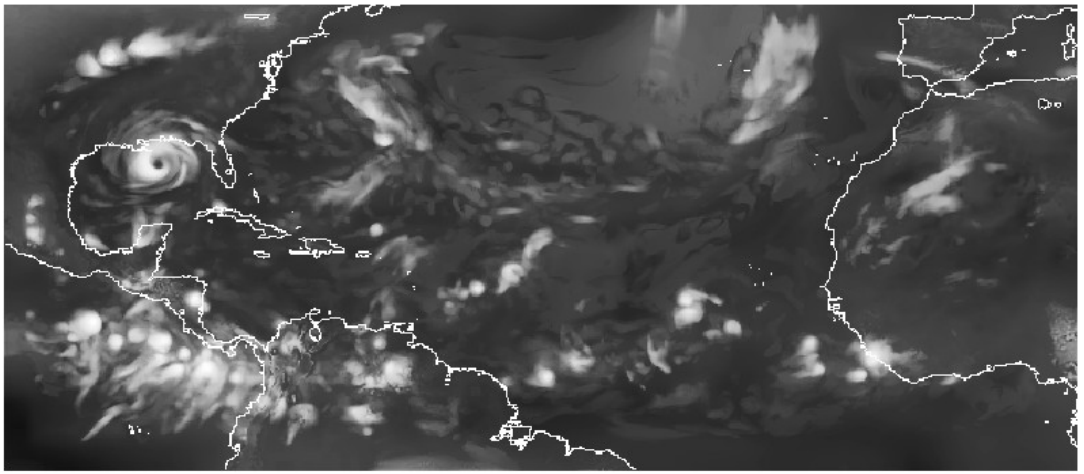


Hurricane Katrina, Aug. 2005

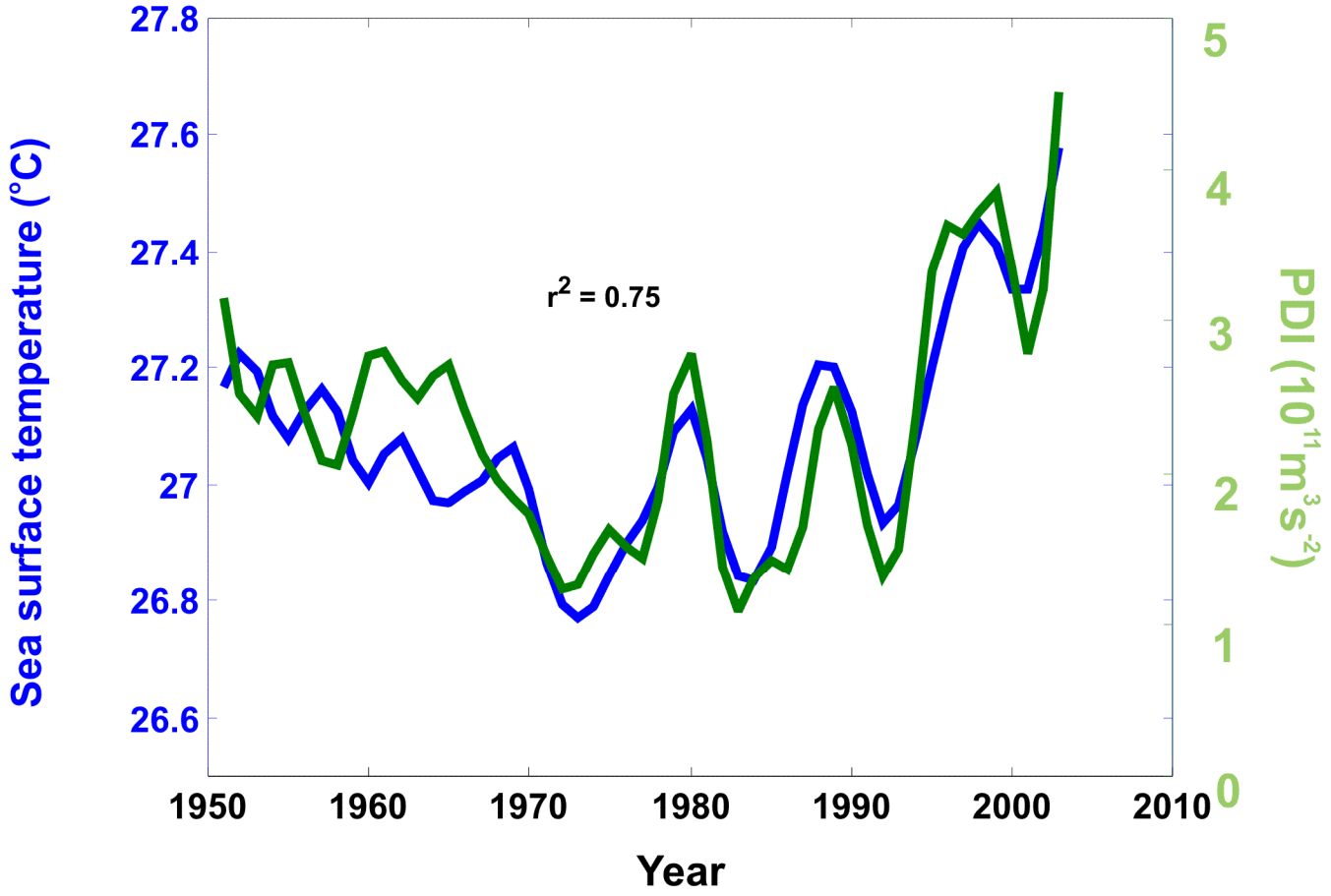


GFDL model simulation of Atlantic hurricane activity

GFDL Collaborators

- Joe Sirutis
- Isaac Held
- Gabe Vecchi
- Bob Tuleya
- Morris Bender
- Steve Garner
- Ming Zhao
- S.-J. Lin

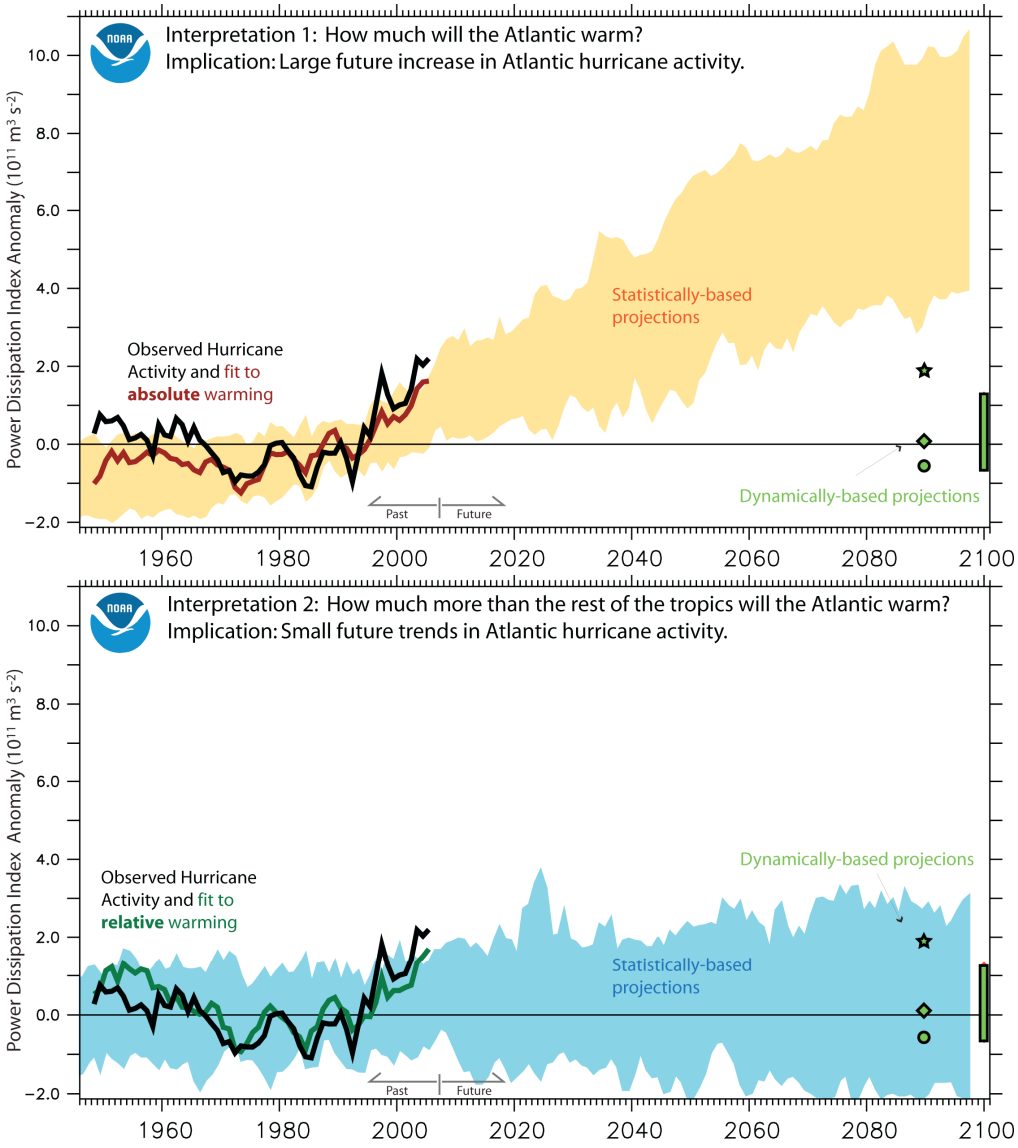
There is some recent evidence that overall Atlantic hurricane activity may have increased since in the 1950s and 60s in association with increasing sea surface temperatures…



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: Kerry Emanuel, J. Climate (2007).

Statistical projections of 21st century Atlantic hurricane activity have a very large dependence on the predictor used.



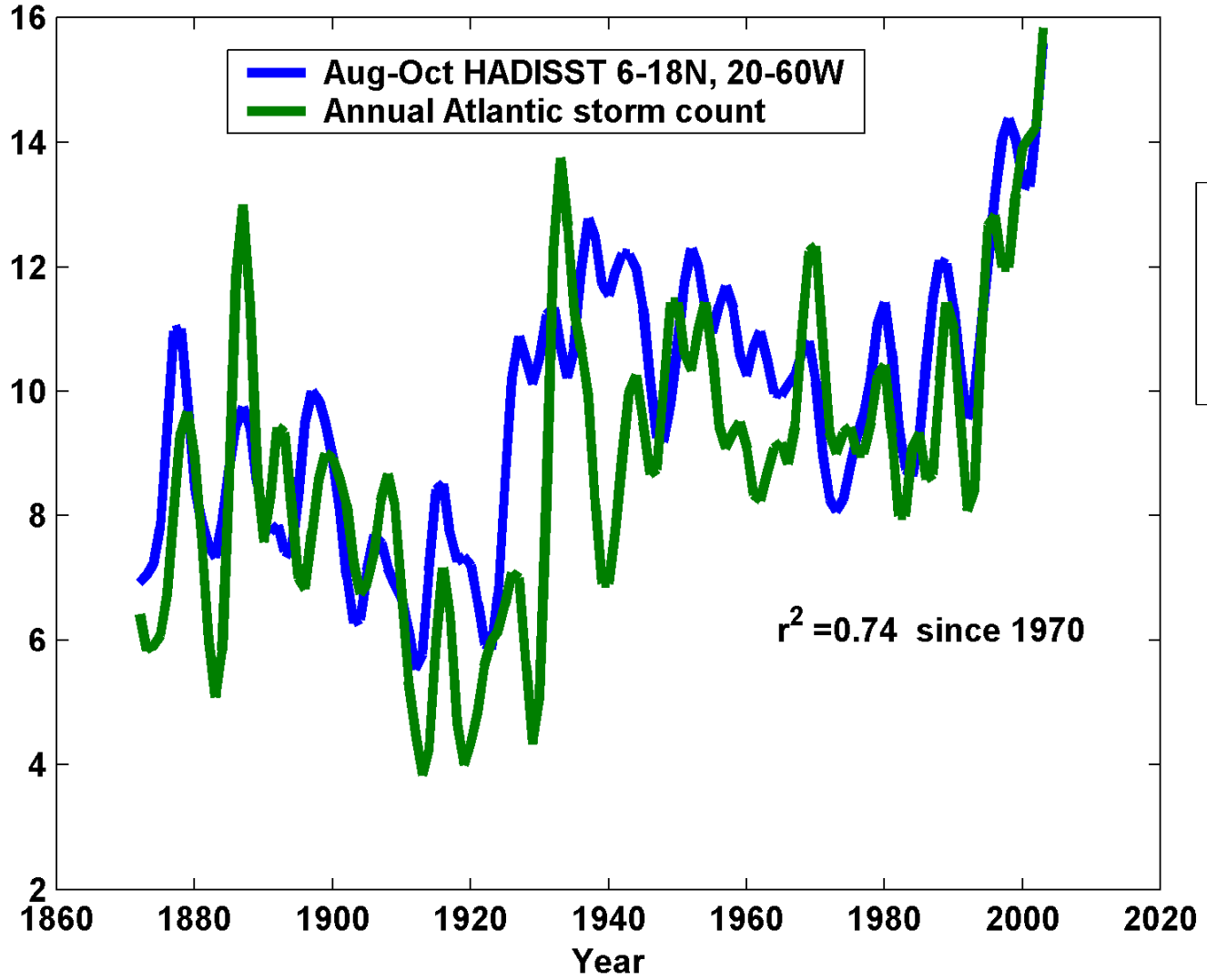
Projection 1: Absolute SST

(~300% increase in Power Diss.)

Projection 2: Relative SST

Source:
Vecchi et al. *Science* (2008)

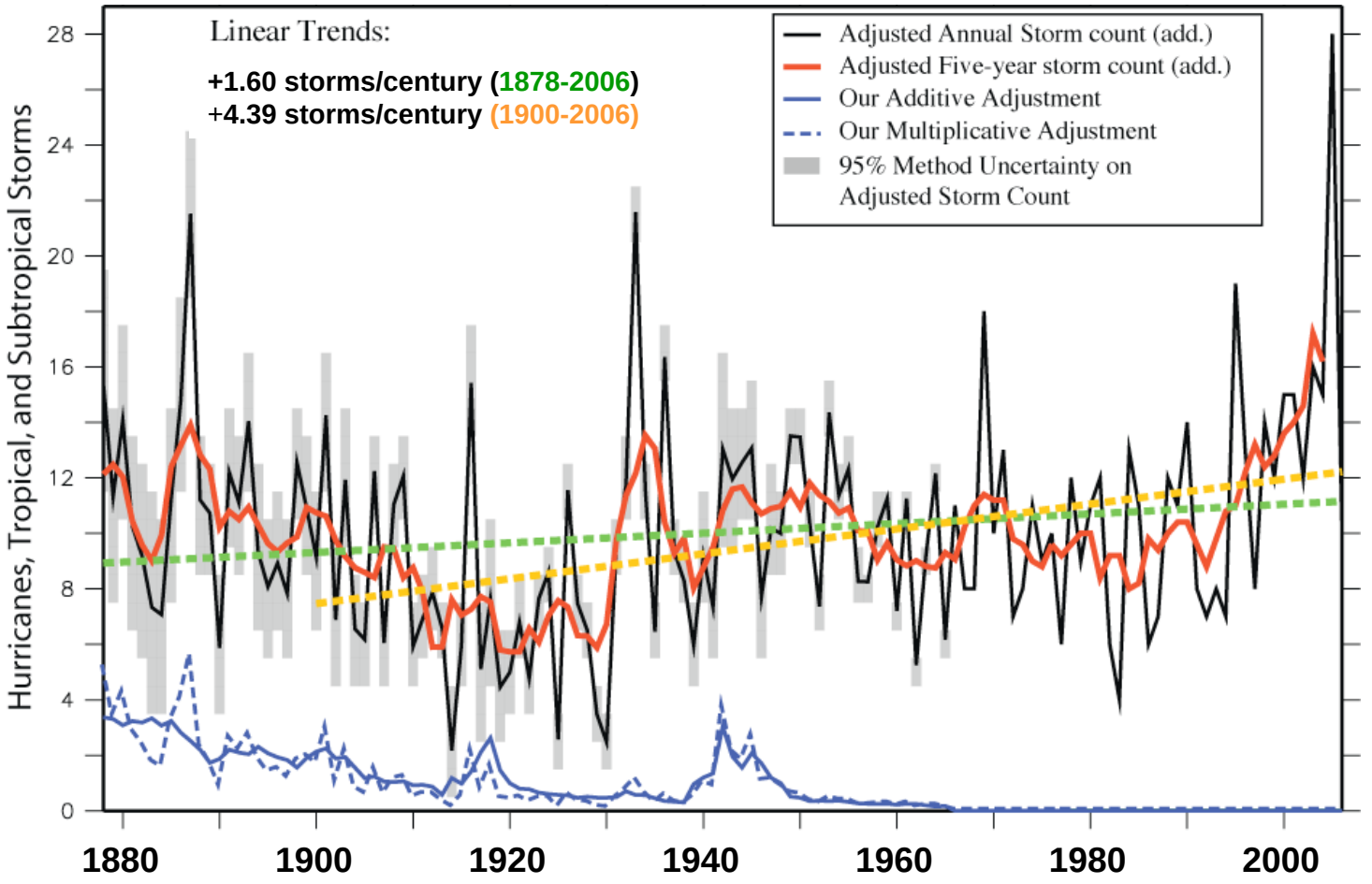
The frequency of tropical storms (low-pass filtered) in the Atlantic basin is well-correlated with tropical Atlantic SSTs



But is the storm record reliable enough for this?

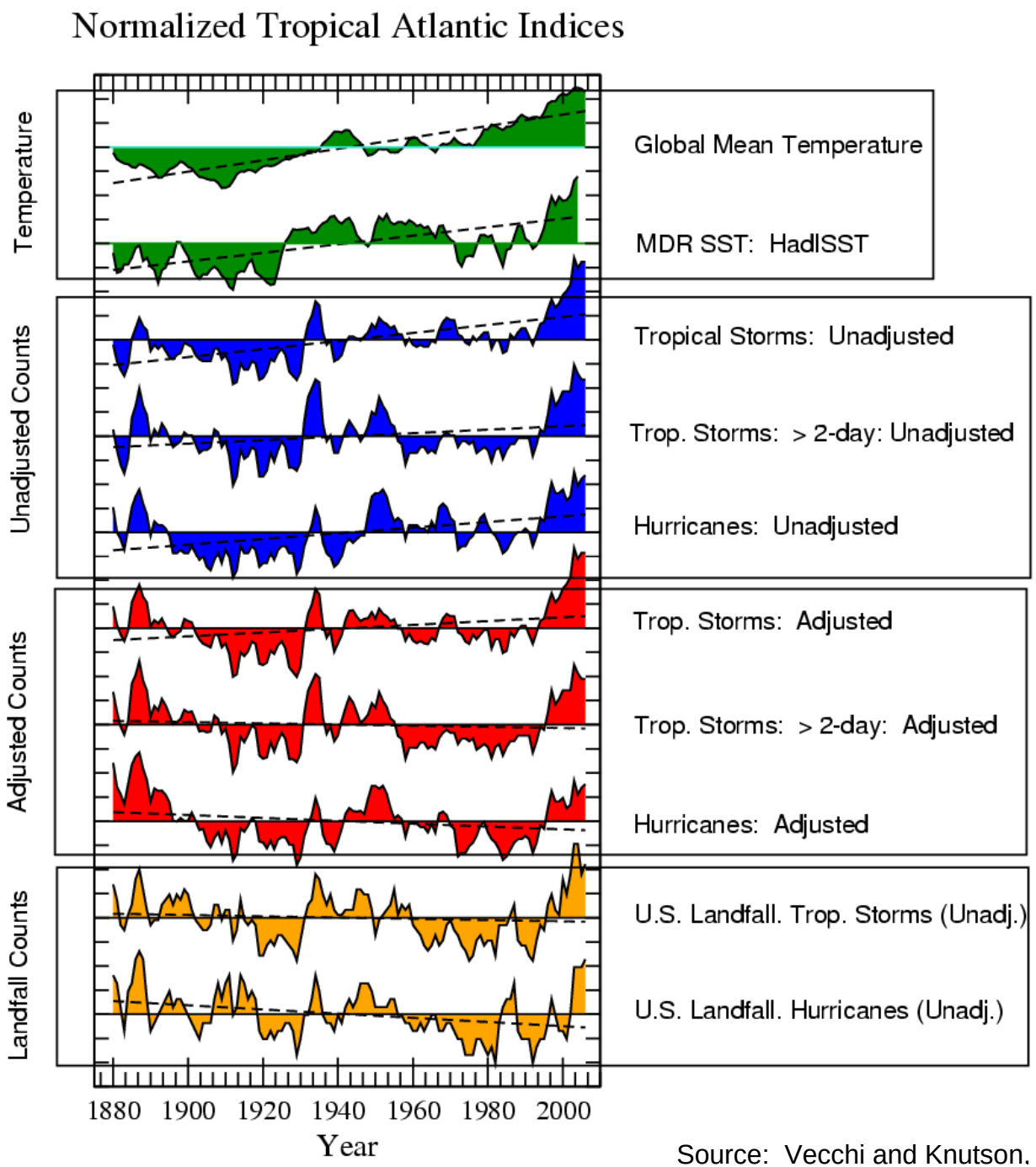
Source: Emanuel (2006); Mann and Emanuel (2006) EOS. See also Holland and Webster (2007) *Phil. Trans. R. Soc. A*

Atlantic Tropical Storm counts show no significant trend from 1878 after adjusting for 'missing storms' based on ship track densities.



Trend from 1878-2006: Not significant (p=0.05, 2-sided tests, computed p-val ~0.2)
Trend from 1900-2006: Is significant at p=0.05 level

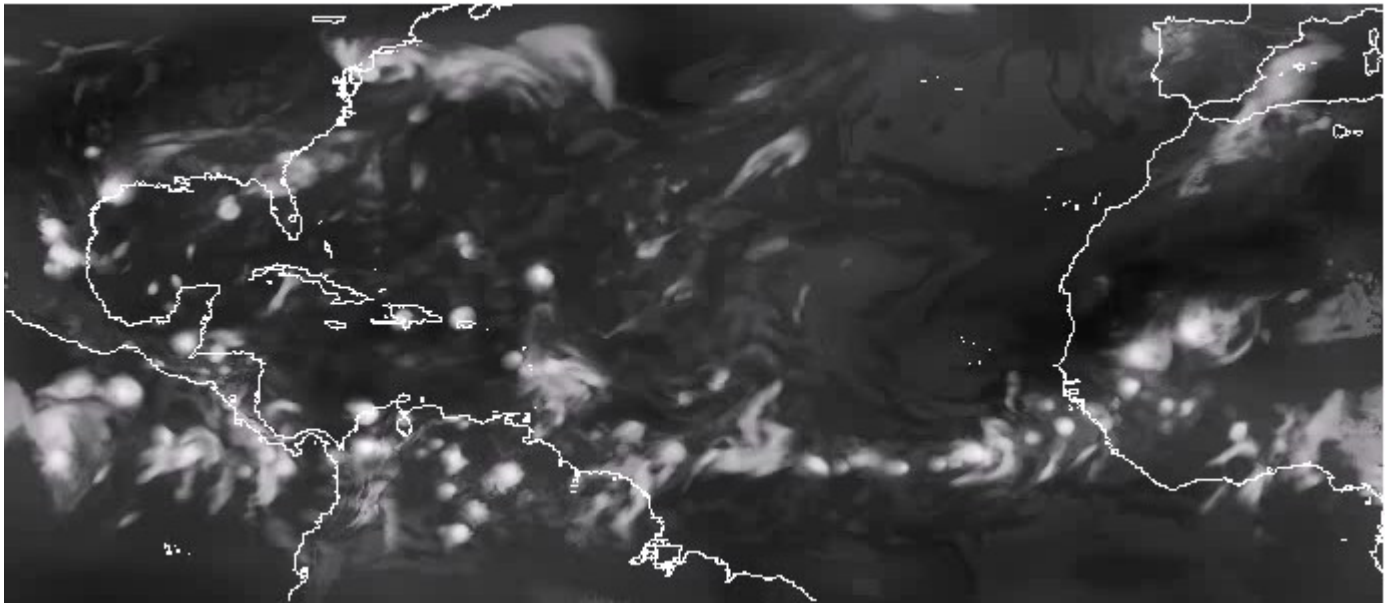
Source: Vecchi and Knutson, J. Climate, 2008.

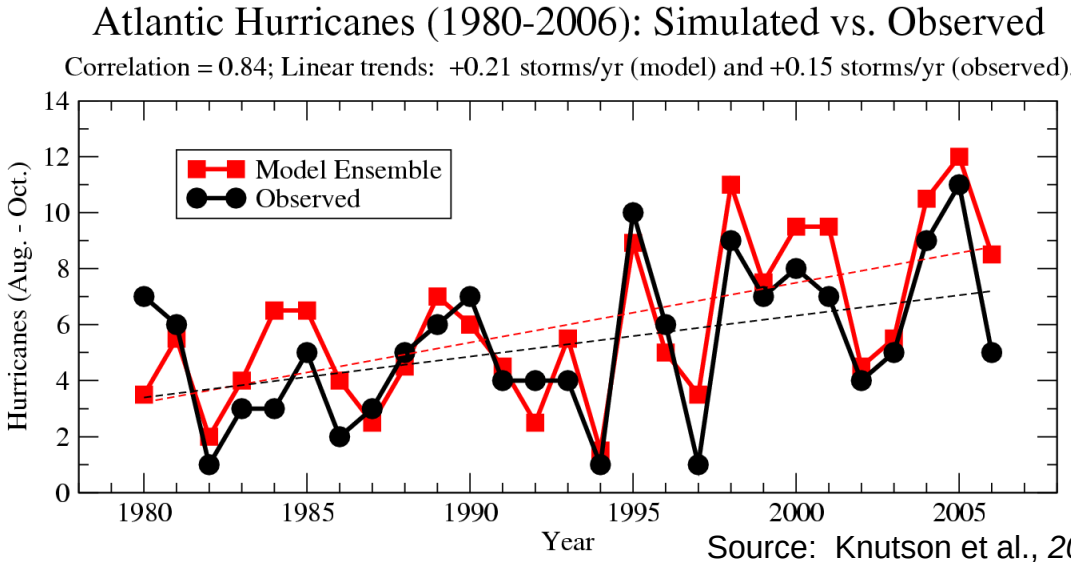


Source: Vecchi and Knutson, in preparation.

Zetac Regional Model reproduces the interannual variability and trend of Atlantic hurricane counts (1980-2006)

18-km grid model nudged toward large-scale (wave 0-2) NCEP Reanalyses

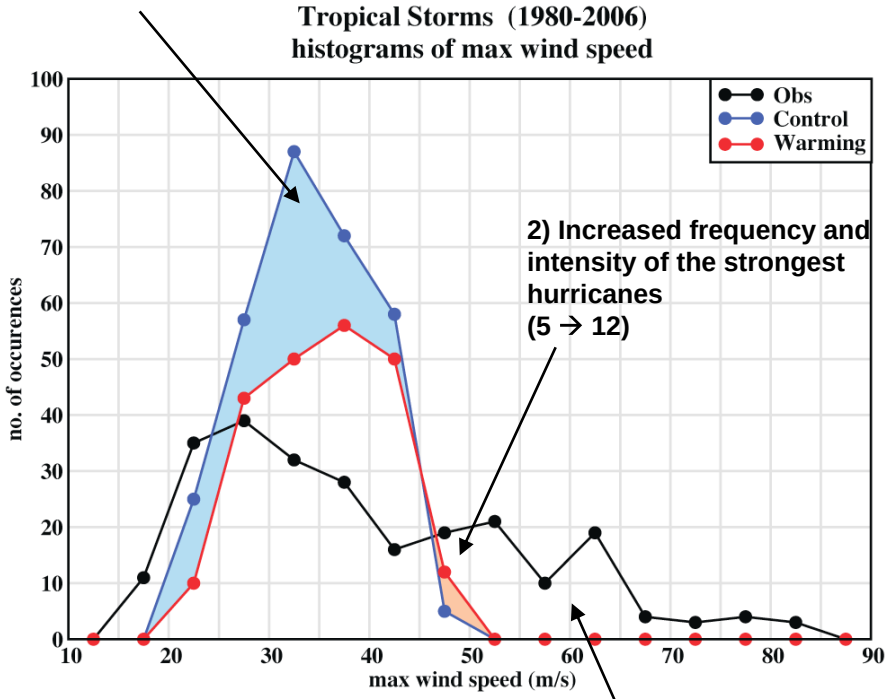




Source: Knutson et al., *2007*, Bull. Amer. Meteor. Soc.

The regional model projects a ***decrease*** in Atlantic hurricane and tropical storm ***frequency*** for late 21st century, downscaling from an IPCC A1B climate change scenario (18-model ensemble):

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

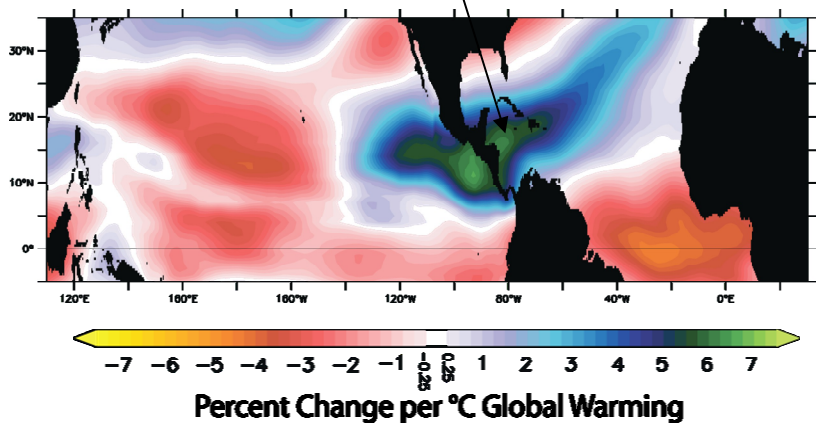


2) Increased frequency and intensity of the strongest hurricanes (5 → 12)

3) Caveat: the regional model does not simulate hurricanes as strong as those observed.

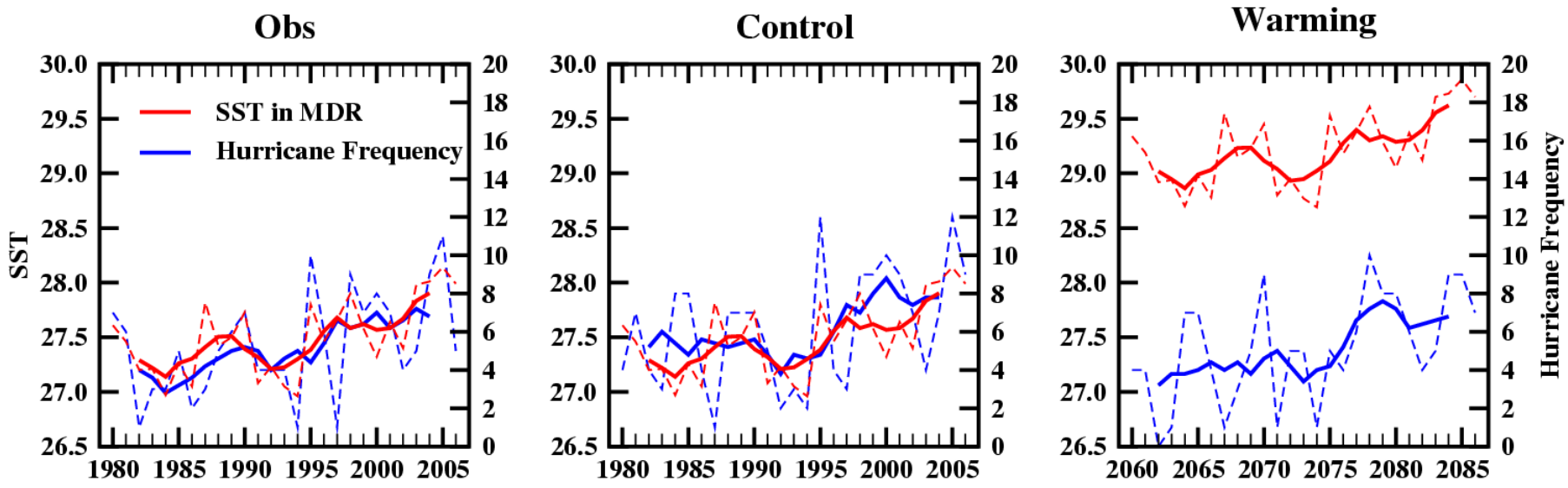
Source: Knutson et al., *2008*, Nature Geoscience.

Global models project increased vertical wind shear over the (warmer) Caribbean



Source: Vecchi and Soden, *Geophys. Res. Lett.,* (2007)

The control model reproduces the observed close relationship between SST and hurricane frequency (1980-2006), but this statistical relationship does not hold for future human-caused warming in the model.



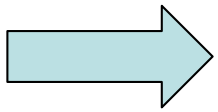
Hurricane frequency actually *decreases* by 18% in the warm climate case… although the model does not simulate hurricanes as intense as observed.

Lesson: Caution using correlations from the present climate to make future climate projections…

Source: Knutson et al., Nature Geoscience (2008).

Intensities of the strongest storms?

- Since the 18-km grid zetac model fails to simulate wind speeds greater than ~47 m/s, a *second downscaling step* is necessary.



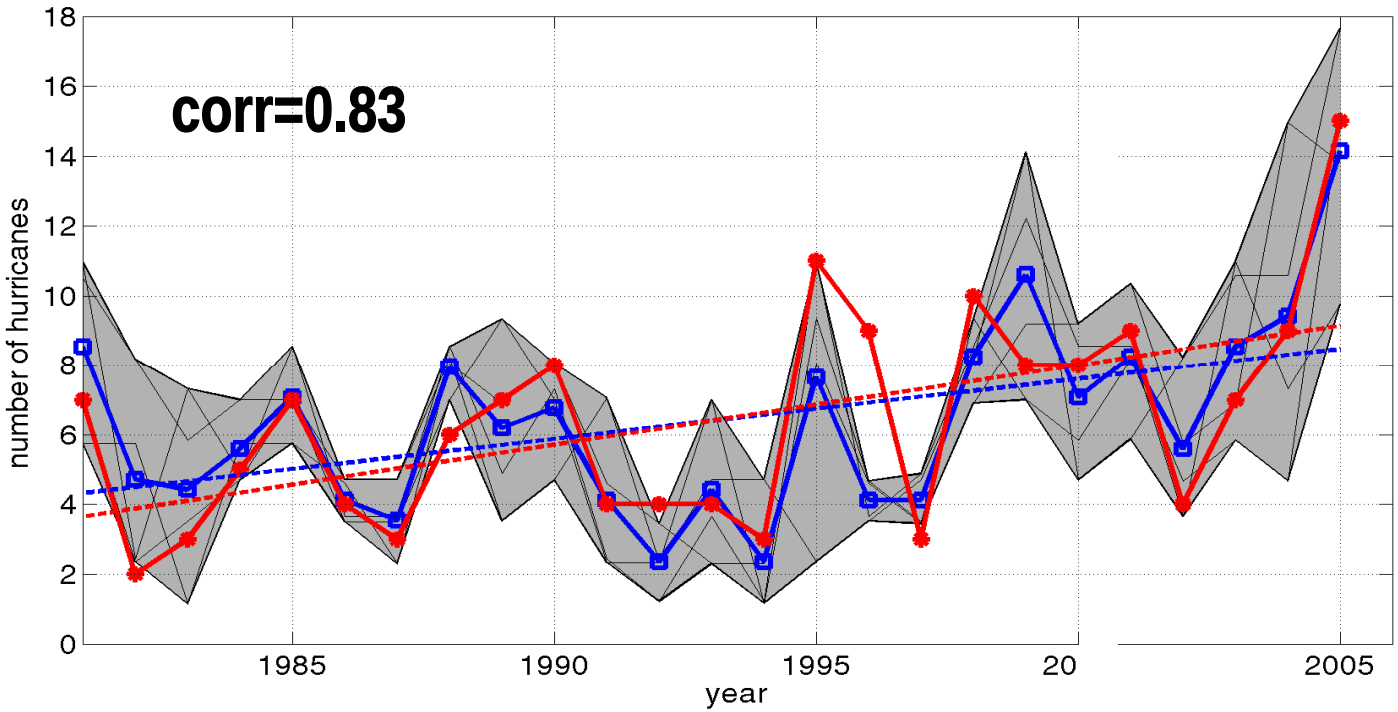
Use GFDL hurricane prediction model to re-simulate all individual storms from the zetac regional climate model runs (control and warm climates).

EXPERIMENTAL DESIGN DETAILS

- Latest version of the GFDL Hurricane Prediction system used for this study (Operational at NCEP and FLEET since 1995).
- Every Zetac Regional Climate model tropical storm was downscaled to the GFDL hurricane prediction model for the 27 years from 1980 to 2006(***control and warm climate***).
- All forecasts were begun 3 days before maximum intensity obtained by the Zetac model or when Zetac model first designated system as tropical storm (if less then 3 days before maximum intensity).
- GFDL Hurricane Model then run for 5 days.
- In the Zetac Warmed climate simulations, the initial conditions and boundary forcing conditions (from NCEP Reanalysis) were perturbed by a late 21st century climate change anomaly from an 18-member ensemble of CMIP3 climate models (A1B) or 4 individual CMIP3 models (GFDL CM2.1, HadCM3, MPI, MRI).
- Maximum surface wind obtained during 5 day simulations emphasized in study.

NOTE: Series of slides from presentation not available 7/14/09 due to journal restrictions on pre-publication. See www.gfdl.noaa.gov/~tk for updates. --TK

GFDL HIRAM (50-km grid global model) reproduces Atlantic hurricane interannual variability and trend (1981-2005) using observed SSTs alone



red: observations
blue: HiRAM ensemble mean
shading: model uncertainty

Hurricane counts are normalized by a time-independent multiplicative factor

Source: Zhao, Held, Lin, and Vecchi (manuscript in review)

HIRAM Results for other basins

red: observations

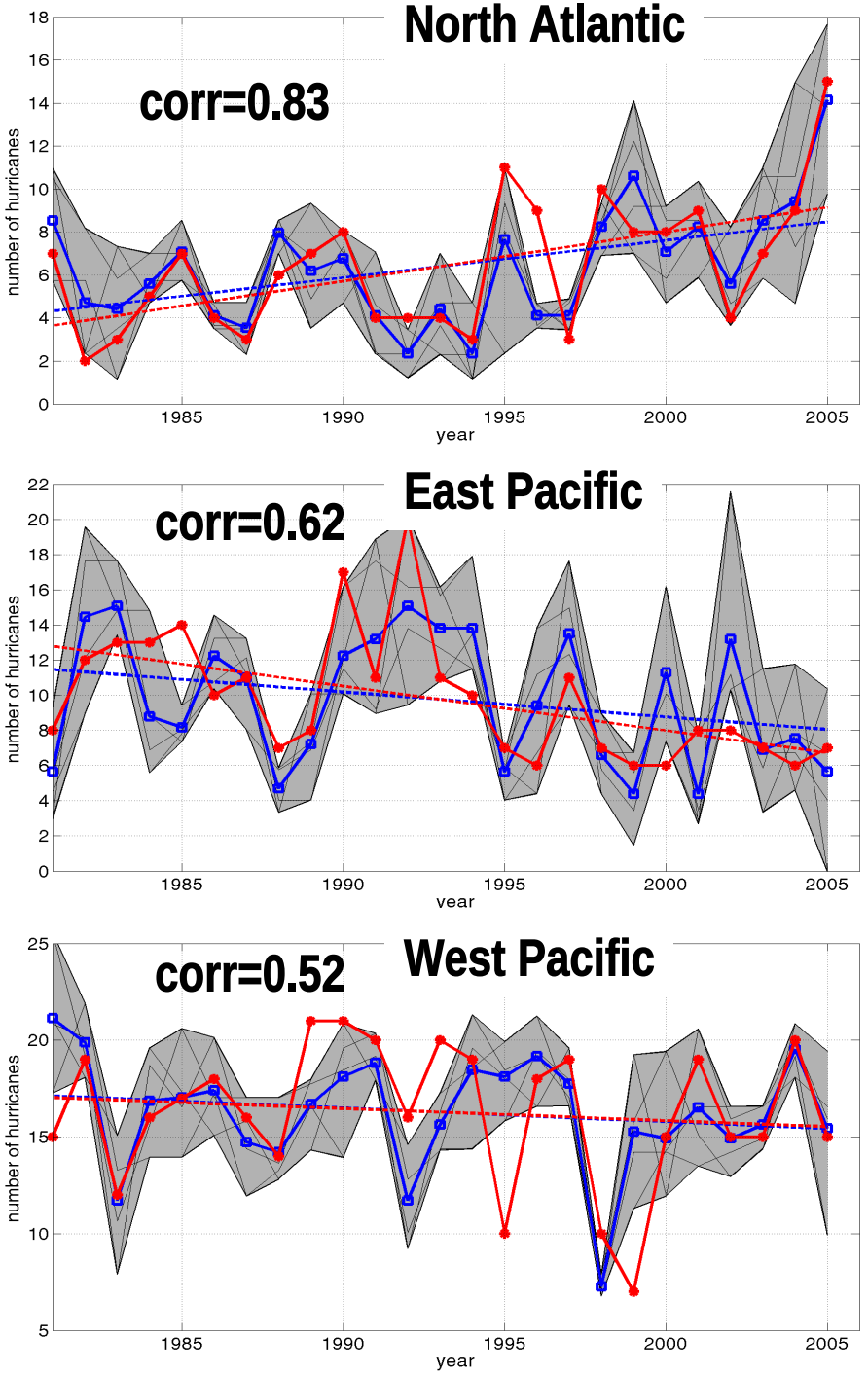
blue: HiRAM ensemble mean

shading: model uncertainty

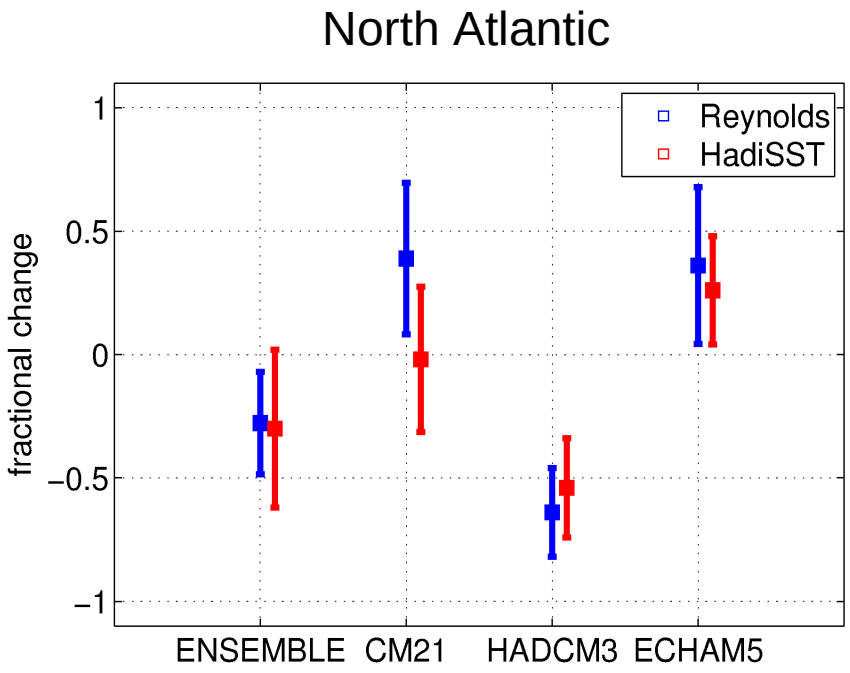
Hurricane counts for each basin are normalized by a time-independent multiplicative factor

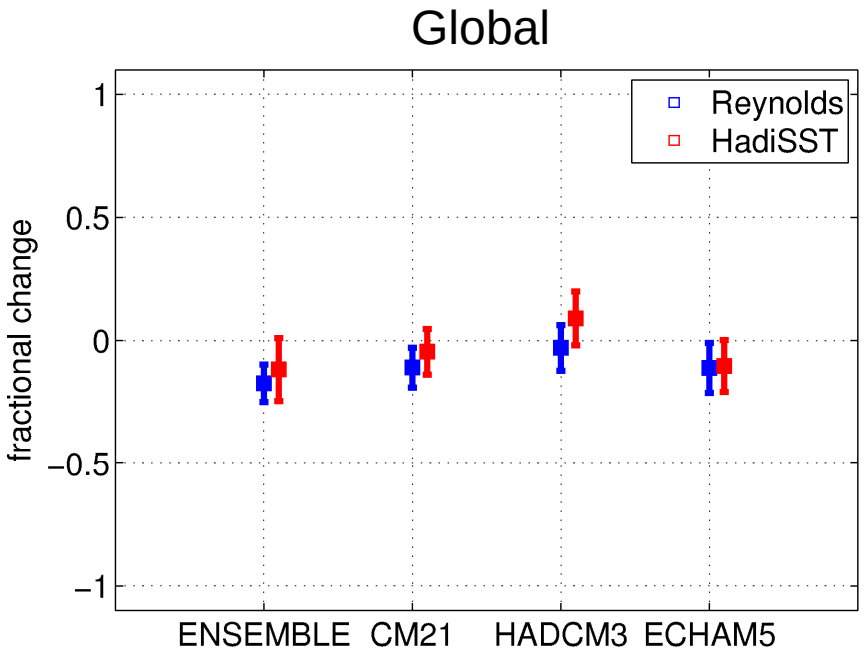
Correlation for the South Pacific is ~0.3 and insignificant for the Indian Ocean

Source: Zhao, Held, Lin, and Vecchi (manuscript in review)



Change of hurricane frequency:
GFDL HIRAM (100 km grid); Late 21st Century Projection

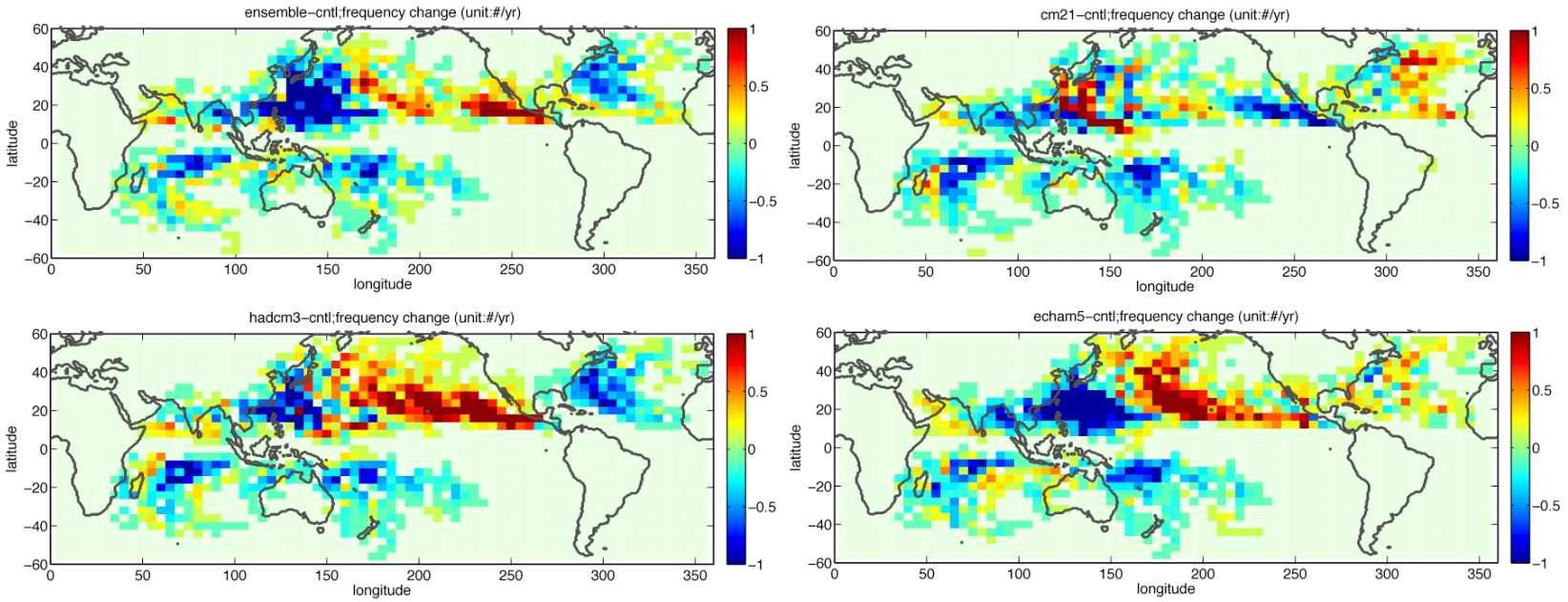




Source: Zhao, Held, Lin, and Vecchi (manuscript in review)

21st Century Hurricane Activity Changes

GFDL 50-km HIRAM, using four projections of late 21st Century SSTs.

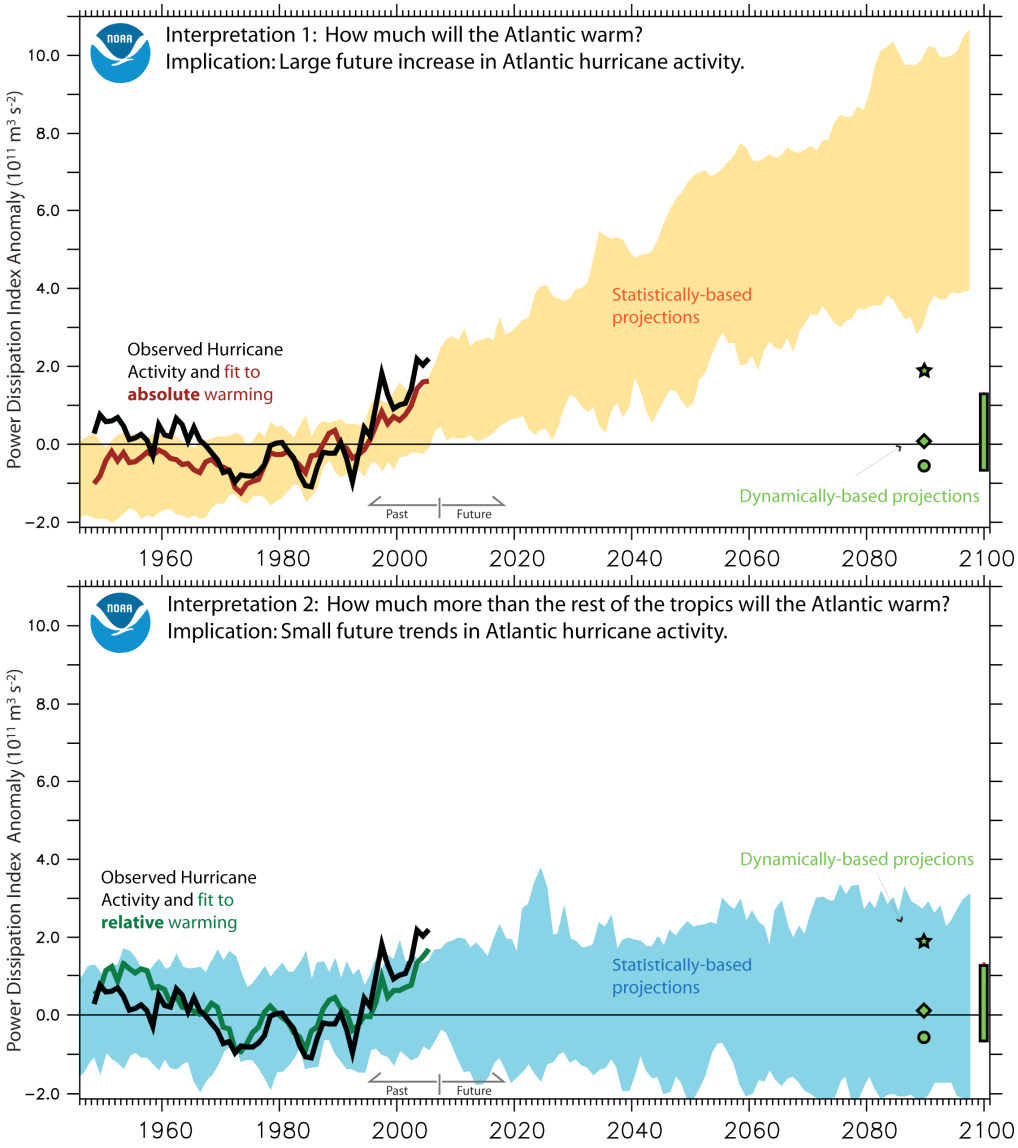


Red/yellow = increase
Blue/green = decrease

- Regional increases/decreases much larger than global-mean.
- Pattern depends on details of SST change.

Source: Zhao, Held, Lin and Vecchi (in review)

Statistical projections of 21st century Atlantic hurricane activity have a very large dependence on the predictor used.



Projection 1: Absolute SST

(~300% increase in Power Diss.)

Projection 2: Relative SST

Source:
Vecchi et al. *Science* (2008)

Main Conclusions:

i) It is premature to conclude that human activity--and particularly greenhouse warming--has already had a detectable impact on Atlantic hurricane activity.

ii) Latest modeling projections suggest that future greenhouse warming may gradually decrease the overall number of hurricanes in the Atlantic, but that the occurrence of rarer, most intense hurricanes may increase by a substantial fraction.

iii) There are substantial differences in future hurricane activity projections depending on the particular global climate model chosen to provide climate conditions for downscaling--an important remaining source of uncertainty.