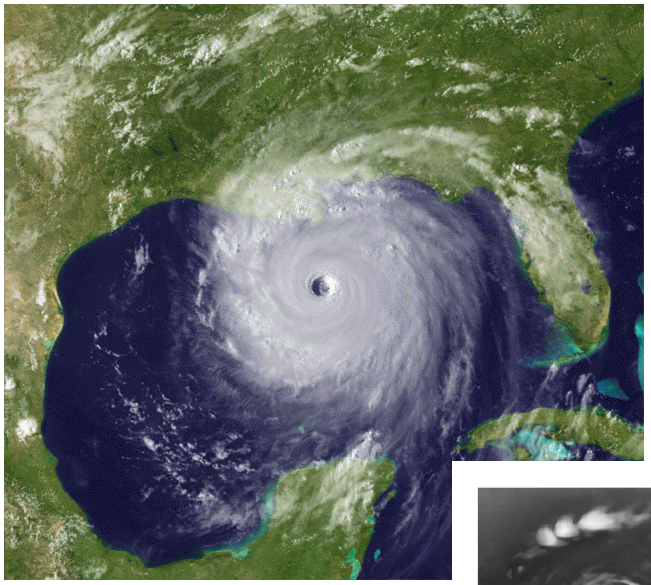
Dynamical downscaling of tropical cyclone activity: an update on the use of the GFDL hurricane model for Atlantic projections and expansion to multiple basins

Hurricane Katrina, Aug. 2005



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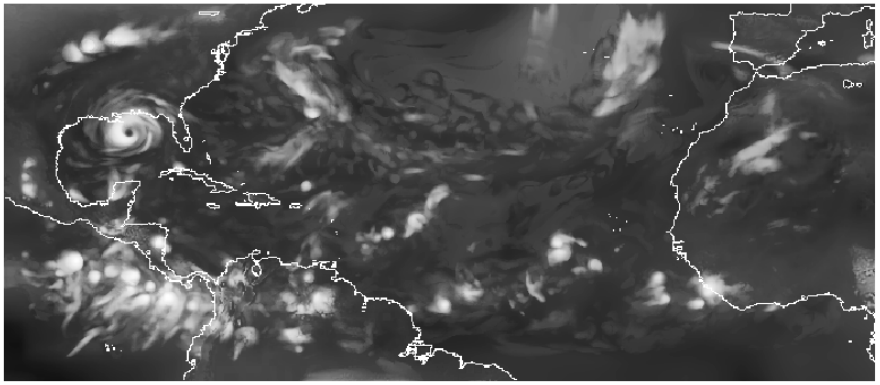
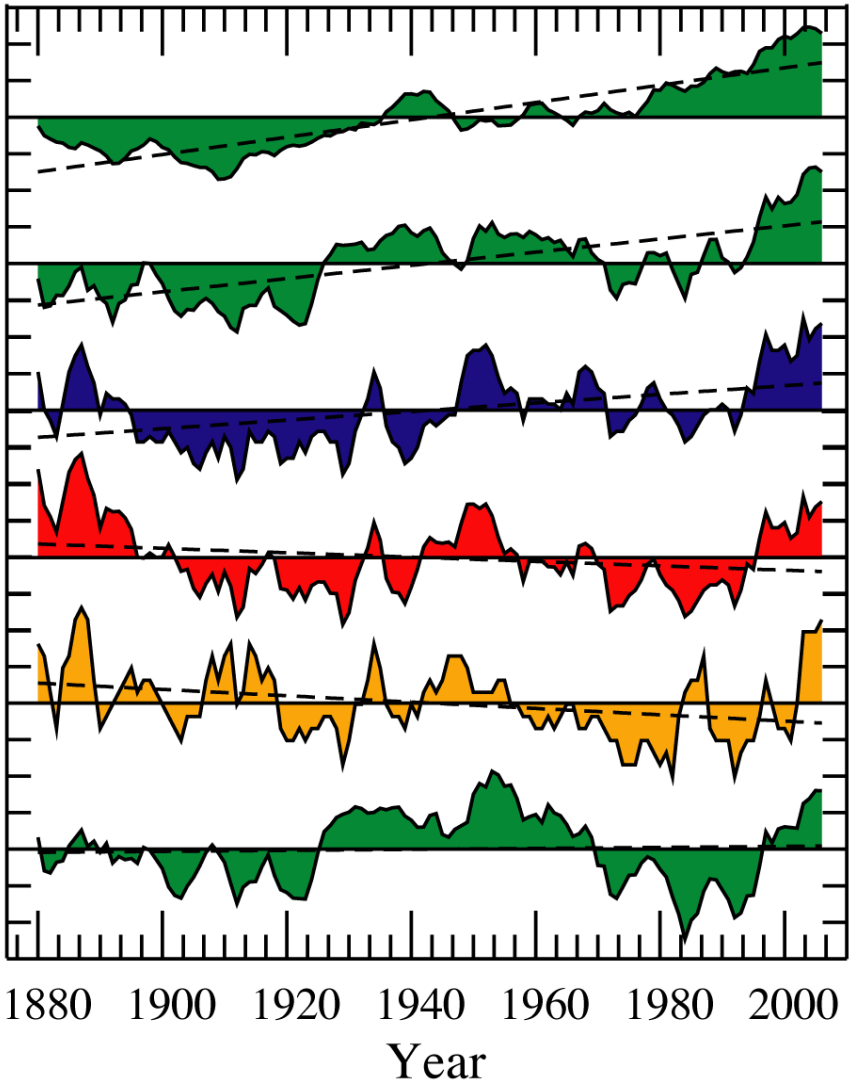


GFDL model simulation of Atlantic hurricane activity

A strategy for obtaining more confident future projections of tropical cyclone activity

- Is there a detectable past human influence on tropical cyclone activity? If so → confidence increases in projections…
- Can our models simulate characteristics of present-day tropical cyclone activity and its variability?
- How robust are downscaling projections to the use of different models? CMIP3 or CMIP5 models? Downscaling model?

Normalized Tropical Atlantic Indices - Hurricane Focus



Global Mean Temperature

Tropical Atlantic Temp.

Raw Hurricane Counts

Adjusted Hurricane Counts

U.S. Landfall. Hurricanes

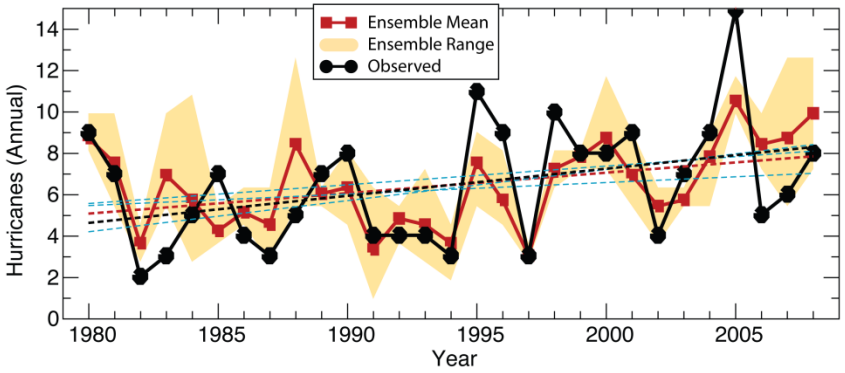
Atlantic Temp. Relative to Tropical Temp.

Source: Vecchi and Knutson (2011).

Two GFDL models reproduce the interannual variability of Atlantic hurricane counts; trend in NCEP reanalysis-forced ZETAC model is too large

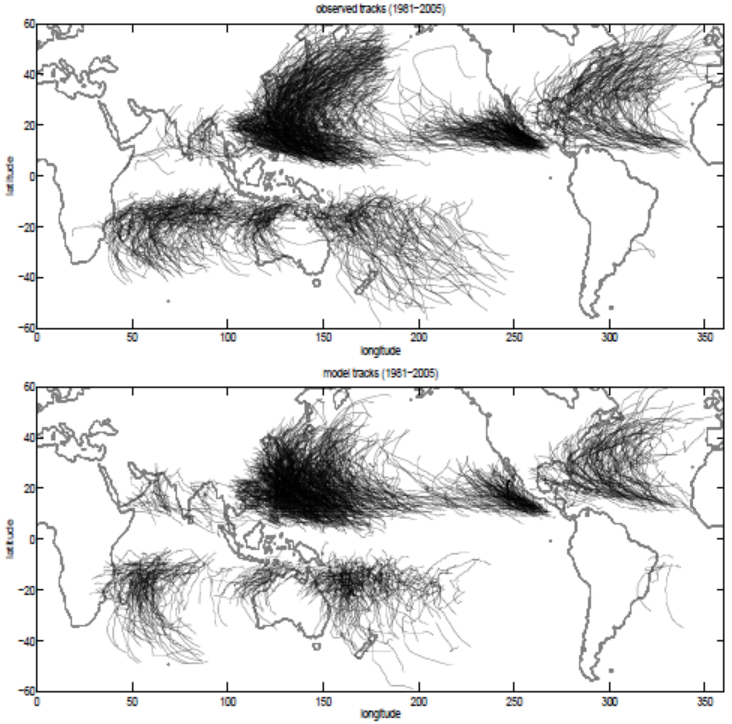
Atlantic Hurricanes (1980-2008): HiRAM-Simulated vs. Observed

Correlation: ens-mean = 0.69; Linear trends: +0.10 storms/yr (model ens mean)
ens-range = [0.47,0.59] [+0.06, 0.15] storms/yr (model ens range) +0.13 storms/yr (observed).



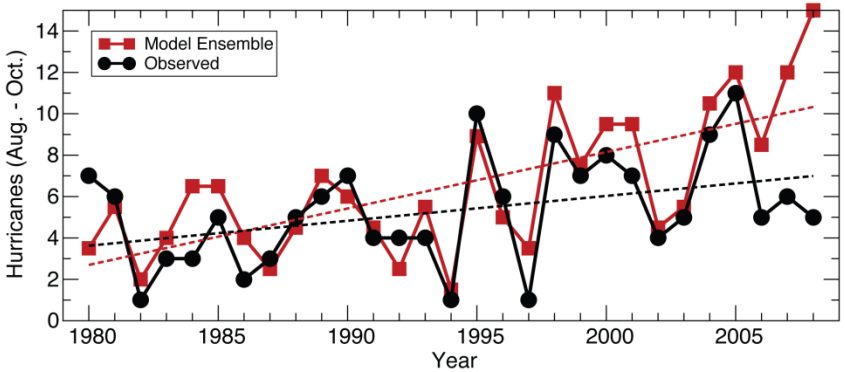
GFDL HIRAM 50km grid global model (SST-forced):

Simulated vs Observed Tropical Storm Tracks (1981-2005)

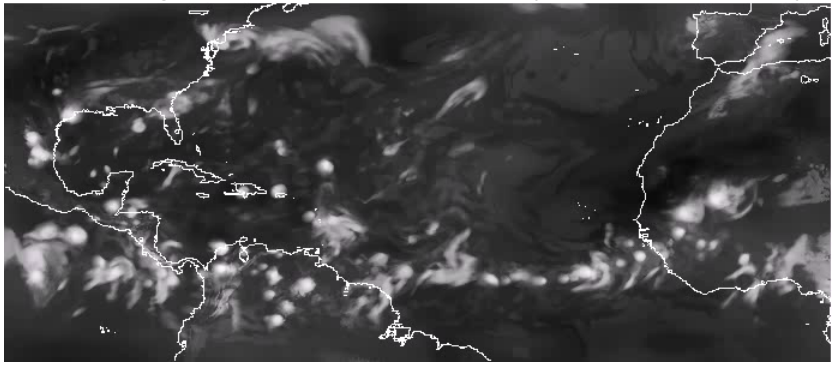


Atlantic Hurricanes (1980-2008): ZETAC-Simulated vs. Observed

Correlation = 0.69; Linear trends: +0.27 storms/yr (model) and +0.12 storms/yr (observed).

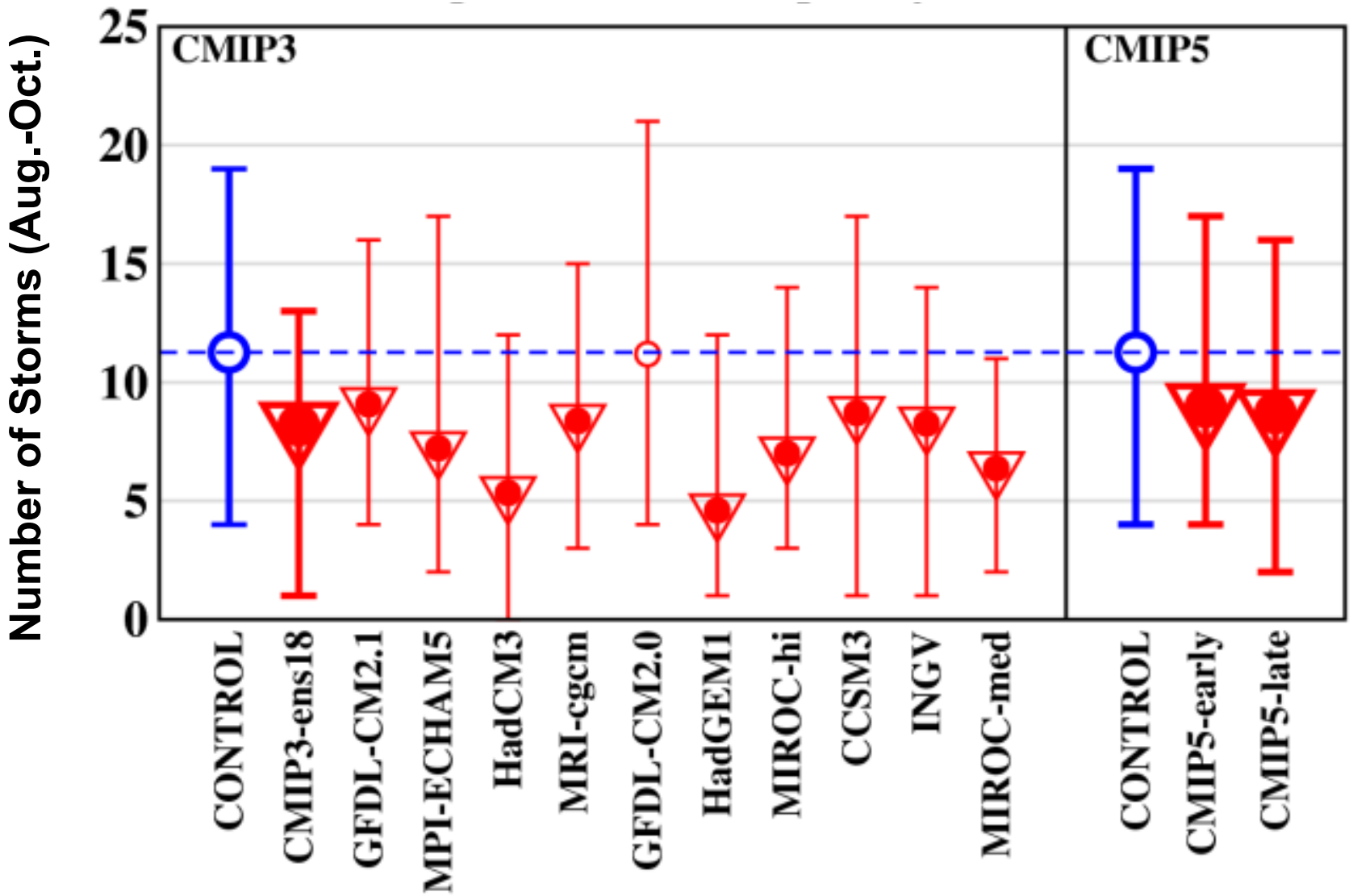


ZETAC regional model: forced by NCEP Reanalysis



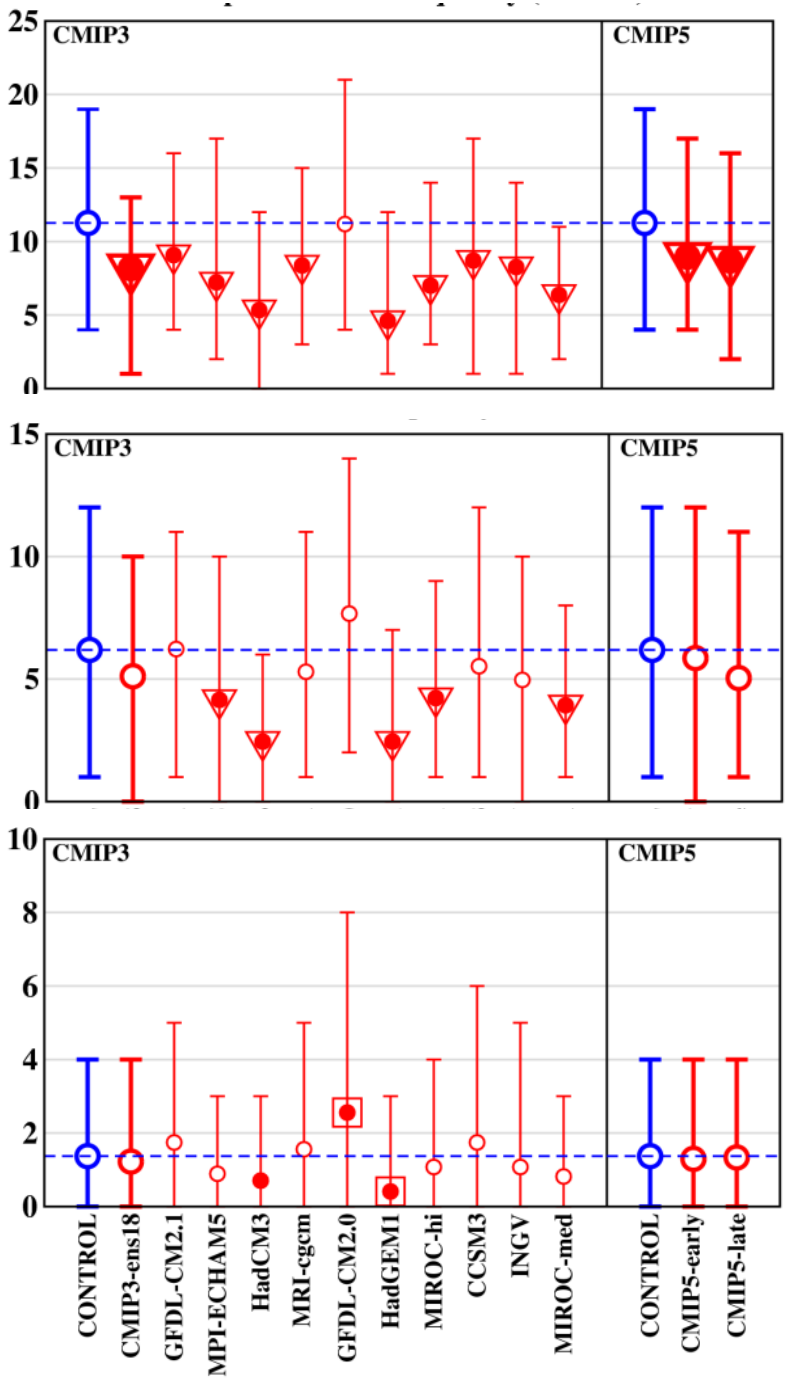
Sources: Knutson et al., *2007*, Bull. Amer. Meteor. Soc.; Zhao et al., 2009, J. Climate

Changes in Tropical Storm Frequency: Zetac Regional Model (18 km grid)



Source: Knutson et al., 2013. J. Climate (in press)

Changes in Storm Frequency: Zetac Regional Model (18 km grid)

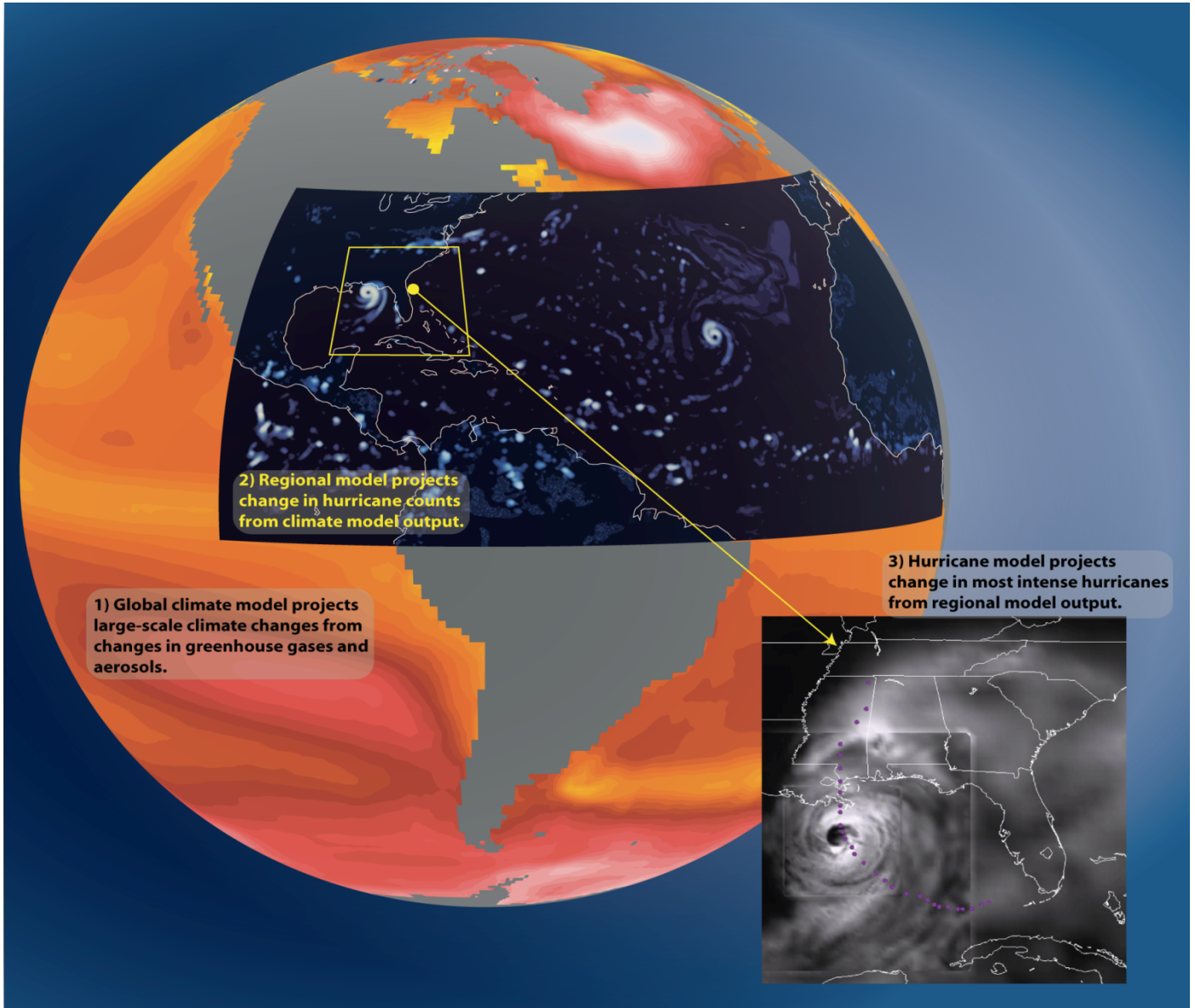


Tropical Storms

Hurricanes (1-5)

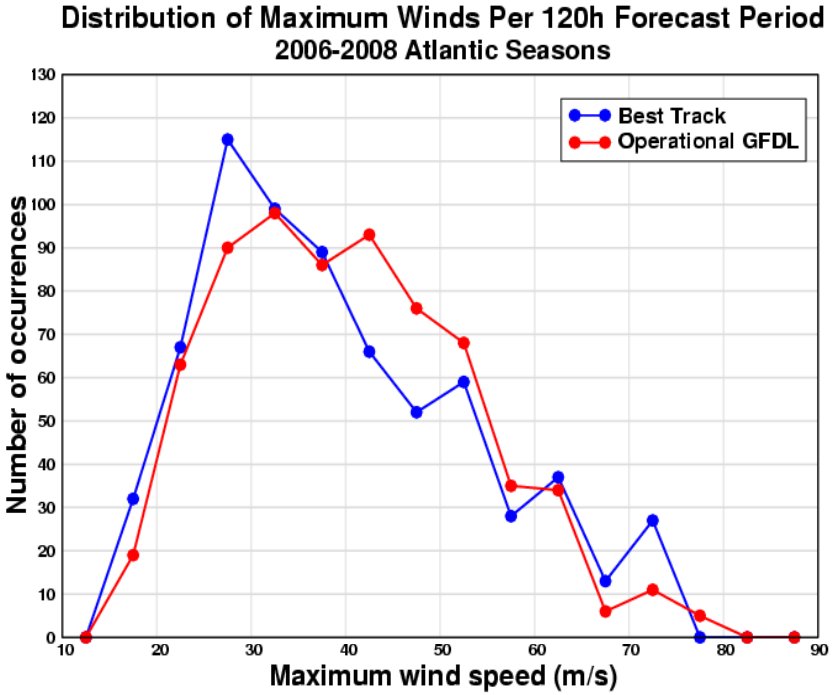
Major Hurr. (3-5)

A “double-downscaling” approach for modeling the frequency of intense Atlantic hurricanes. Bender et al., *Science,* 2010.



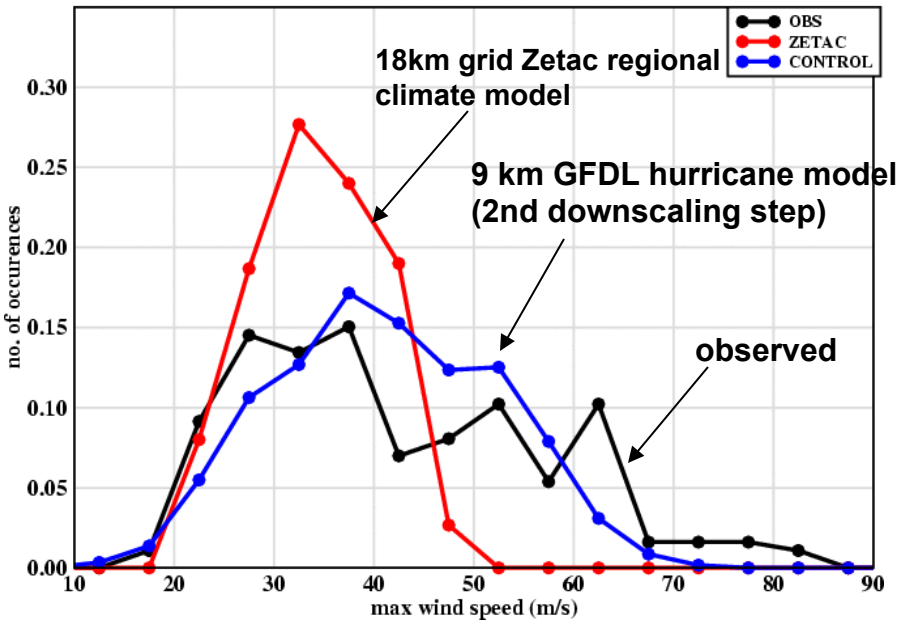
The GFDL Operational Hurricane Prediction System simulates a realistic distribution of Atlantic TC intensities in both operational and climate mode…

Operational Performance:



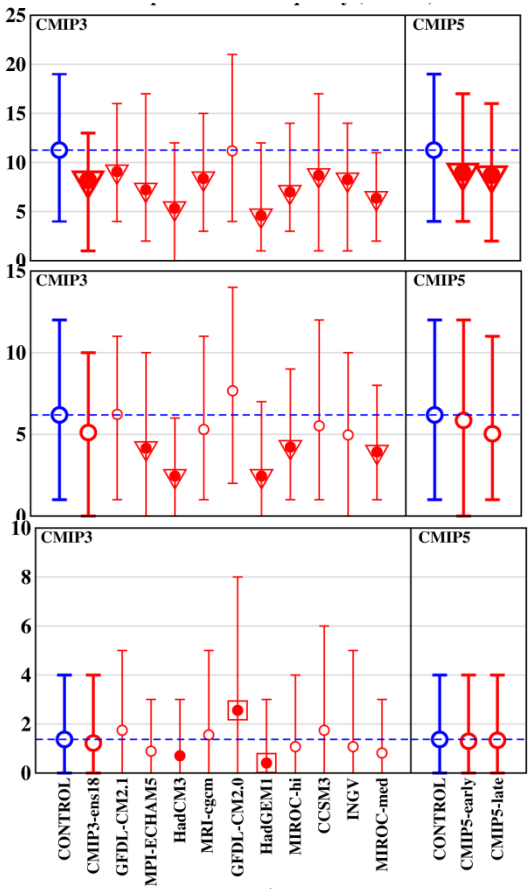
Control climatology of Intensities:

Simulated distributions of maximum wind speeds, downscaling from NCEP Reanalysis



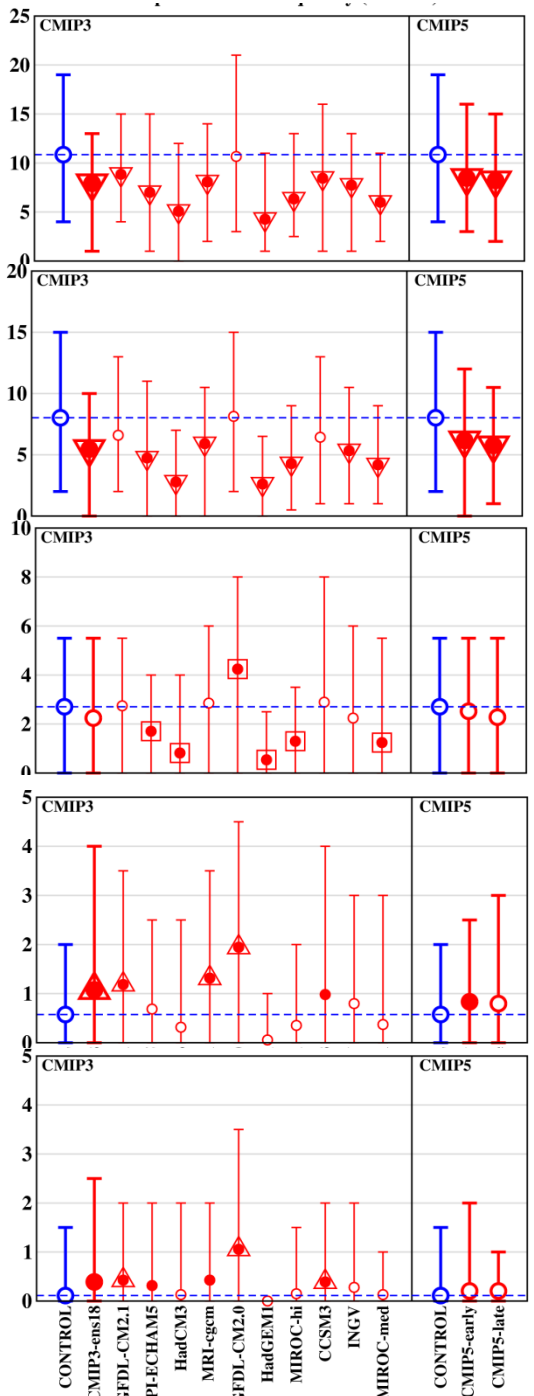
Source: Bender et al., *Science* 2010.

Changes In Storm Frequency



Zetac Regional Model

GFDL Hurricane Model



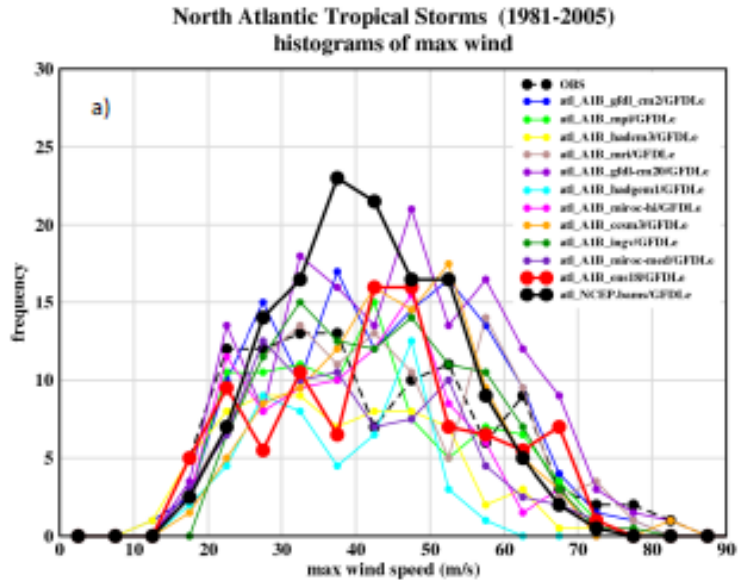
Tropical Storms

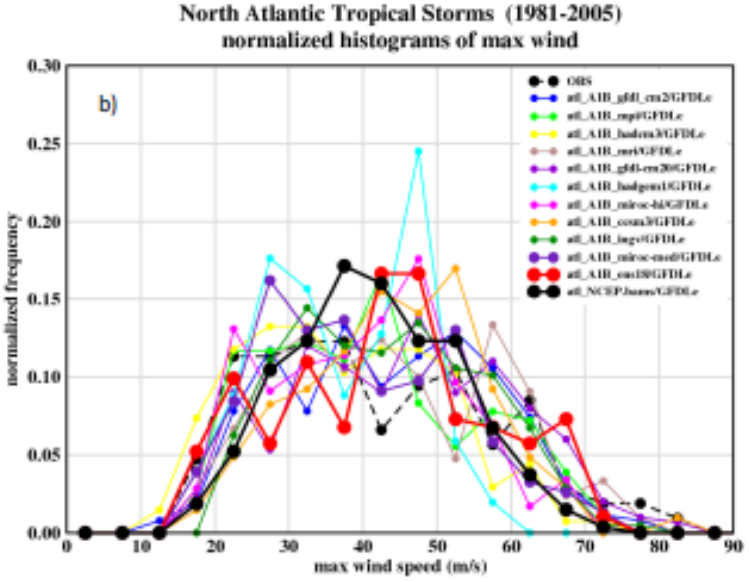
Hurricanes (1-5)

Major Hurr. (3-5)

Very Intense Hurr. (Cat 4-5)

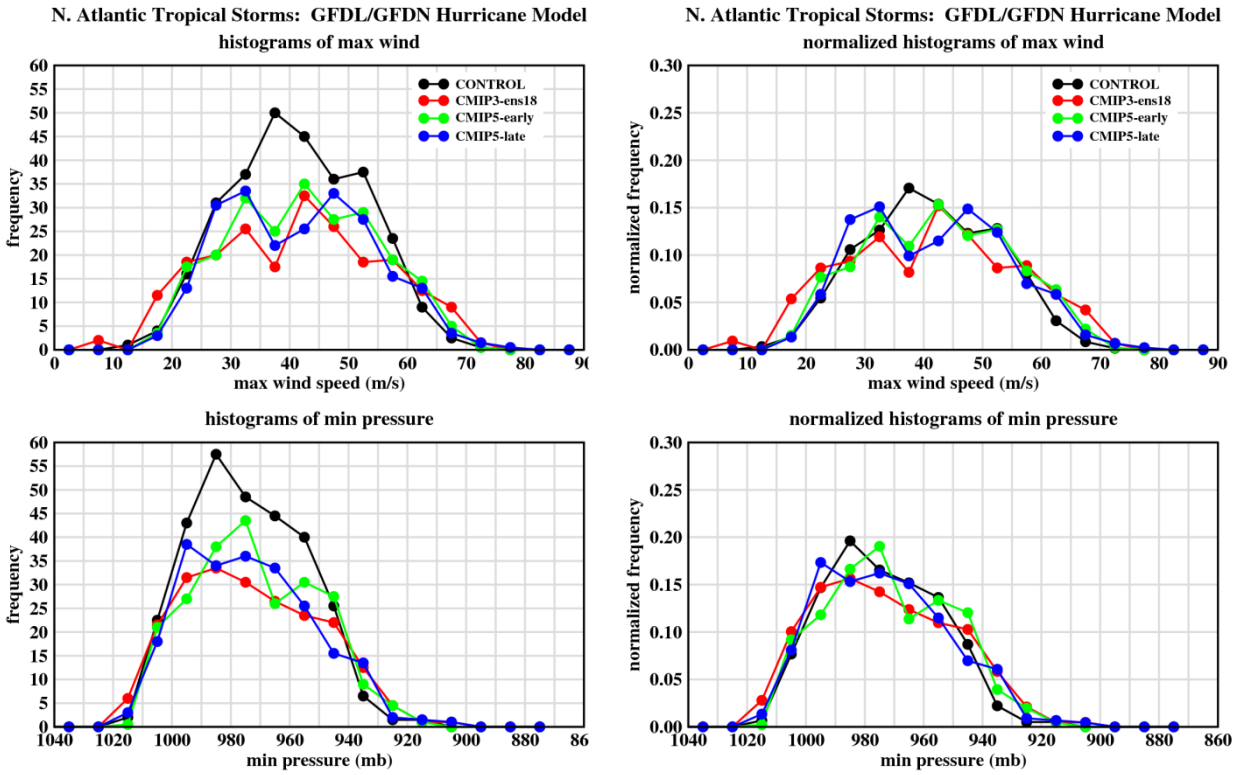
Very Intense Hurr. (>65 m/s)



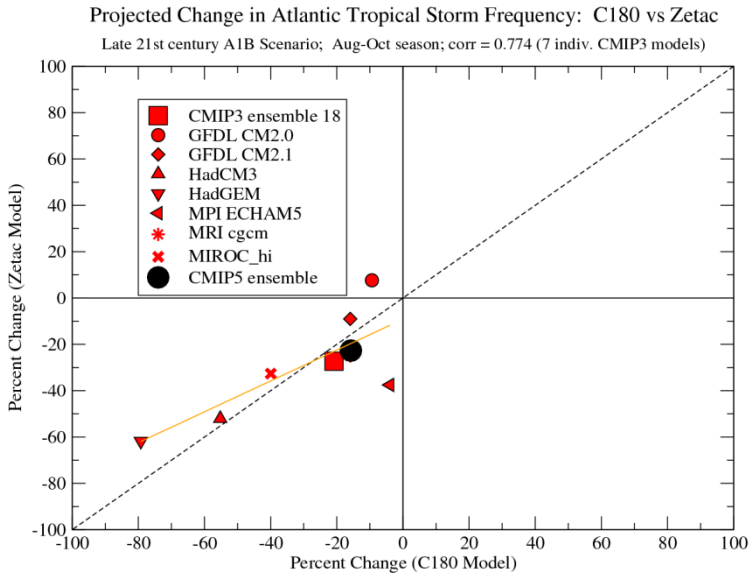


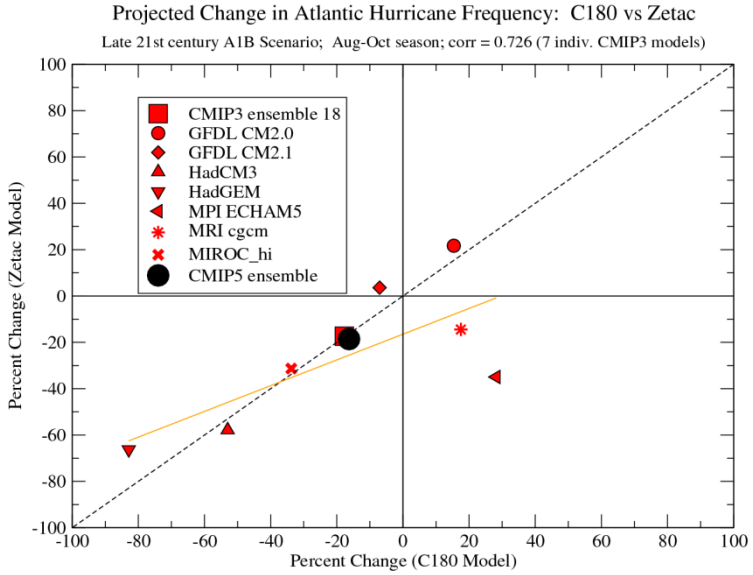
Black solid: Control Runs
Red solid: CMIP3 ensemble

Source: Knutson et al. 2013, J. Climate, in press



Source: Knutson et al. 2013, J. Climate, in press

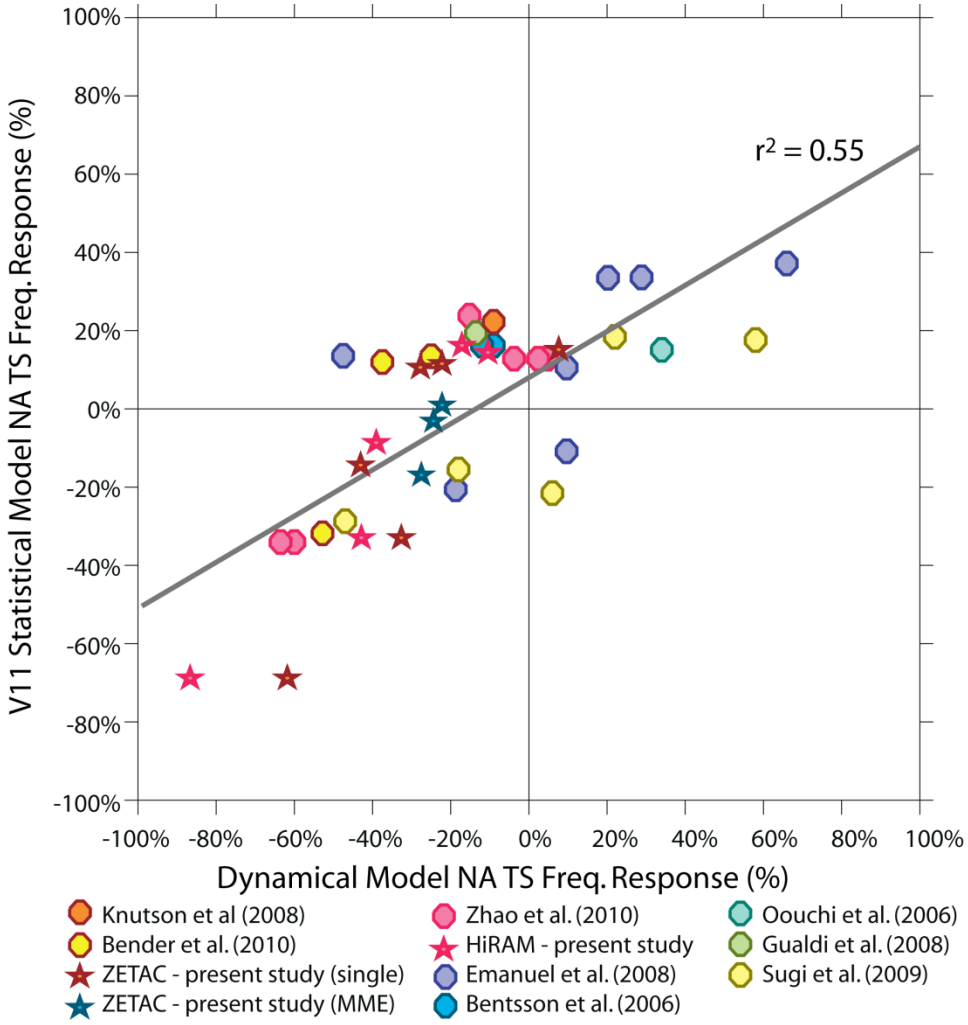




Mon Jul 9 13:36:10 2012

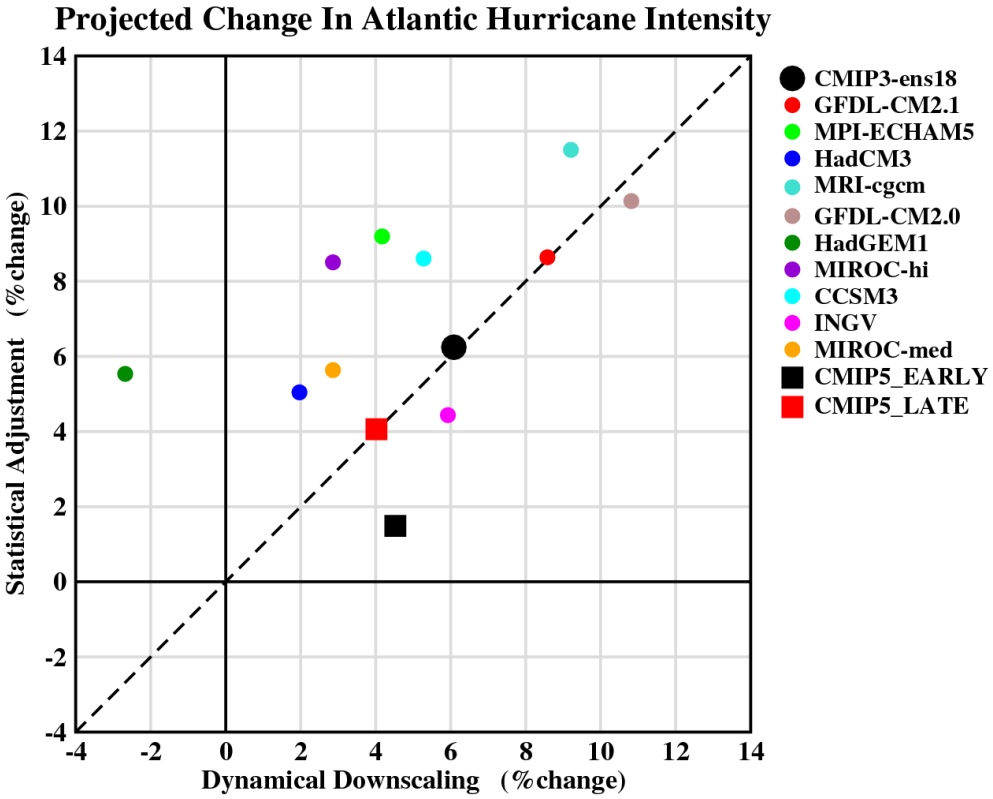
Source: Knutson et al. (J. Climate, in press, 2013).

Relative SST-based statistical model describes Atlantic basin projected tropical storm changes fairly well:



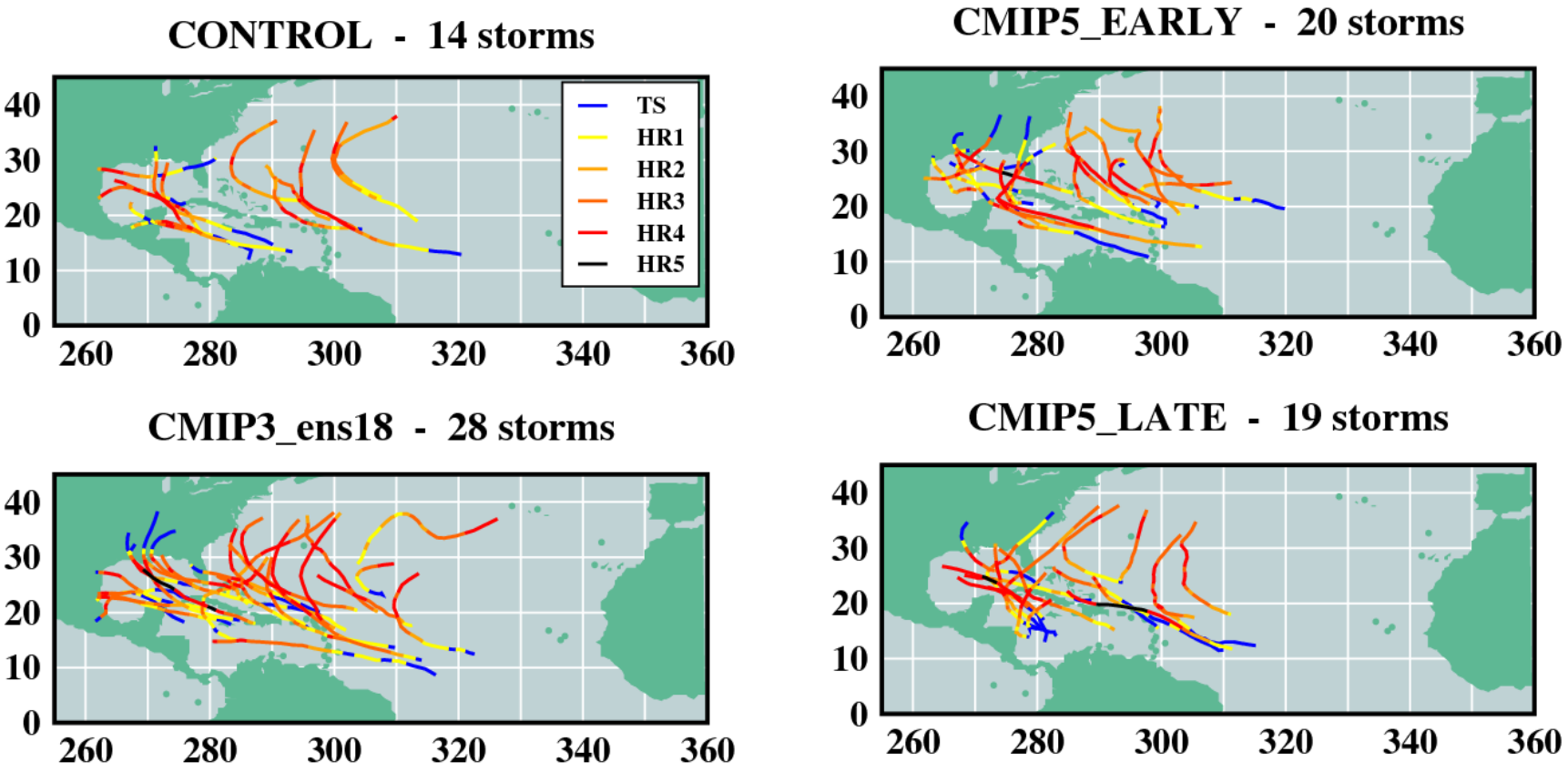
Source: Knutson et al. (J. Climate, in press, 2013).

Statistical downscale vs. dynamical downscale of intensity



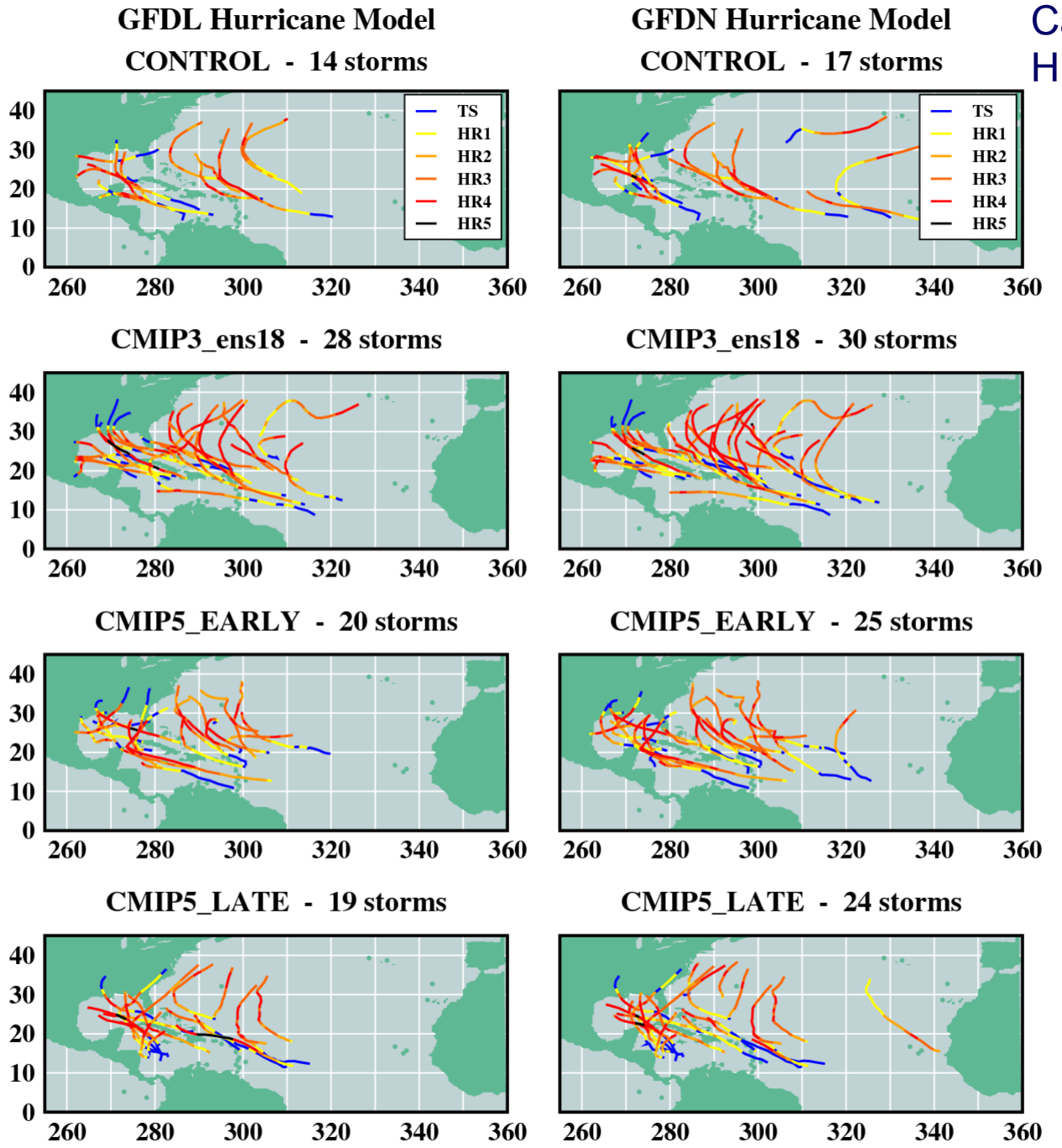
Source: Knutson et al. (J. Climate, in press, 2013).

GFDL Hurricane Model: Category 4 & 5 Hurricane Tracks (27 years)

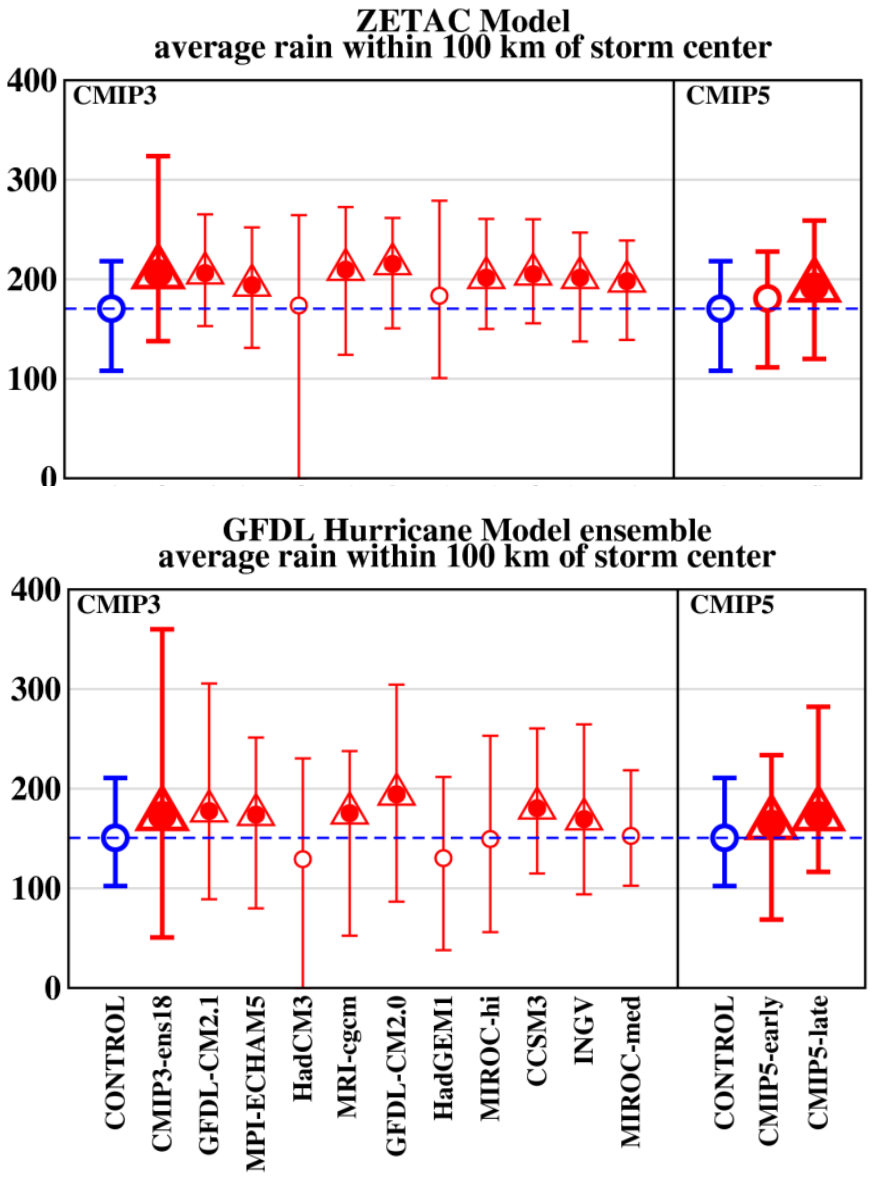


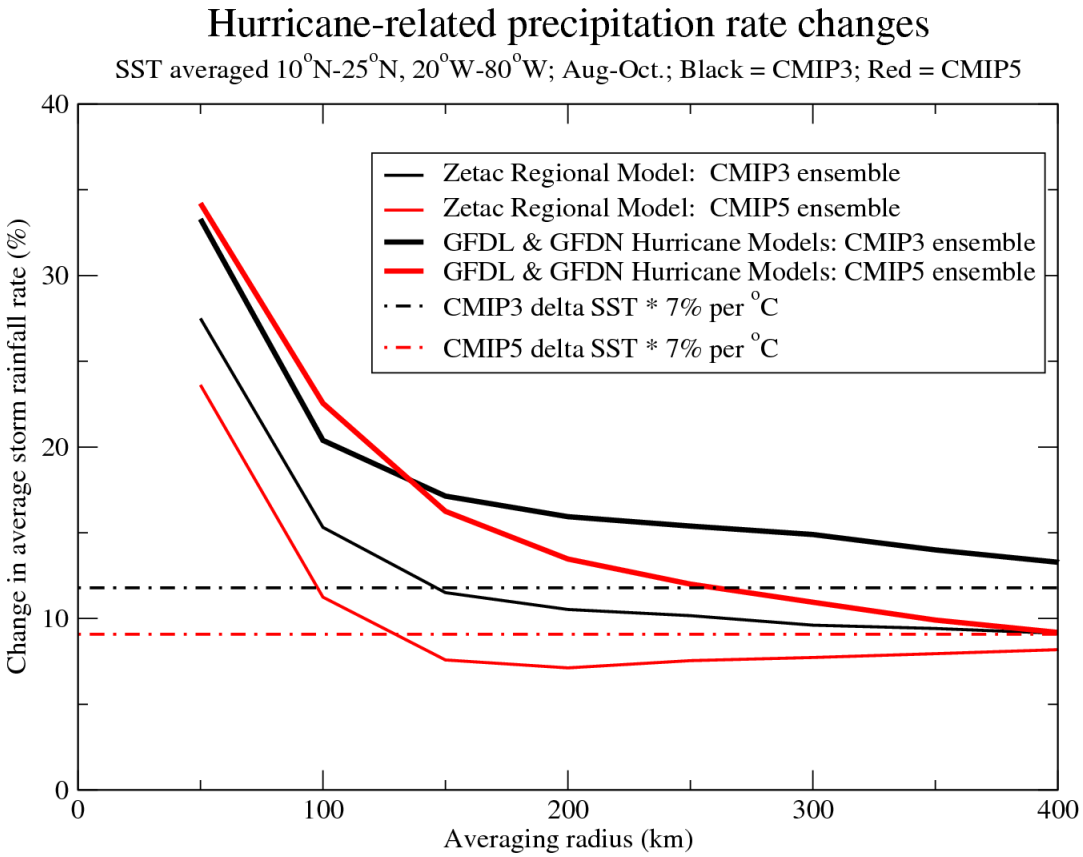
Source: Knutson et al. (J. Climate, in press, 2013).

Category 4 & 5 Hurricanes

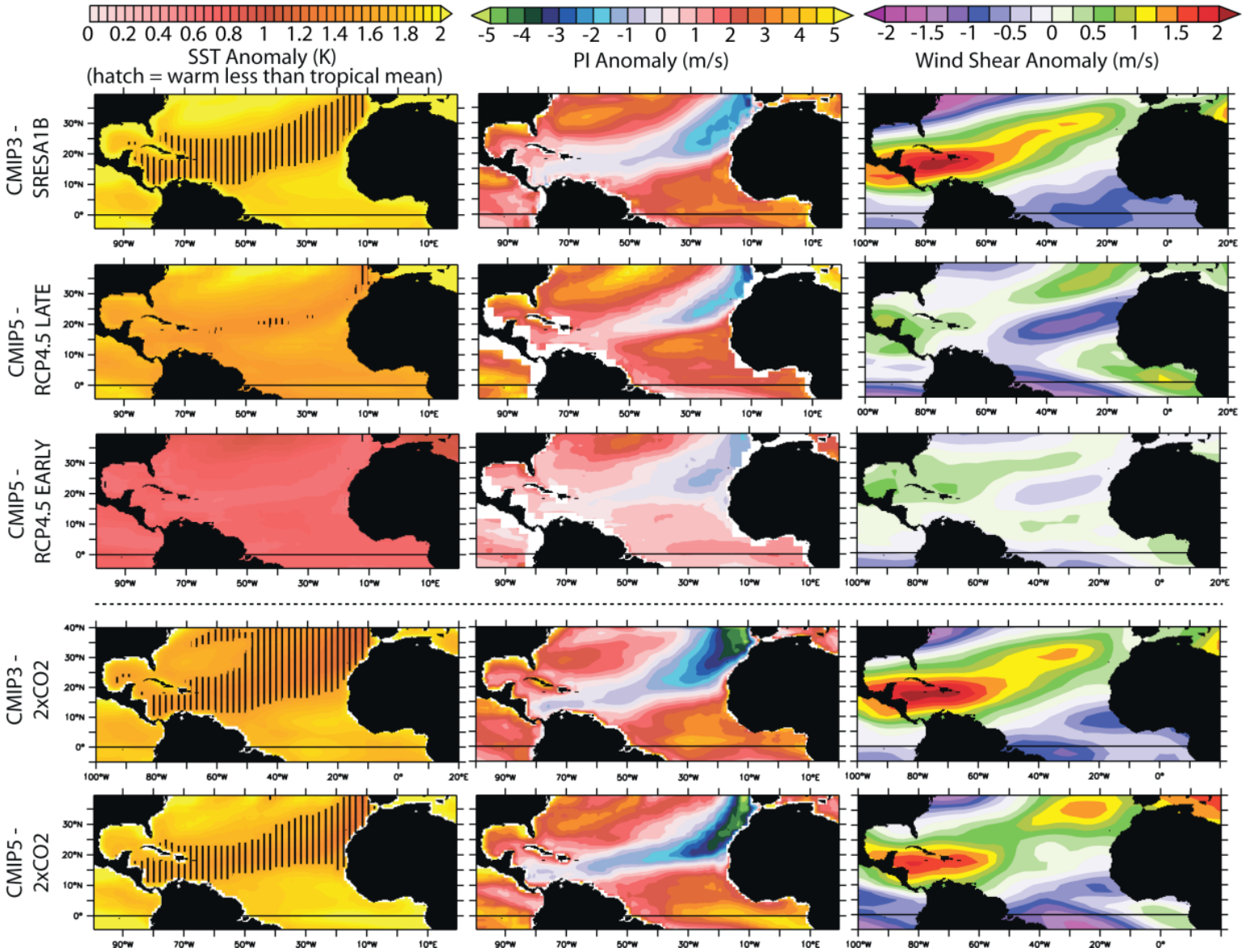


TC Precipitation Rate Projections: Assessment of robustness



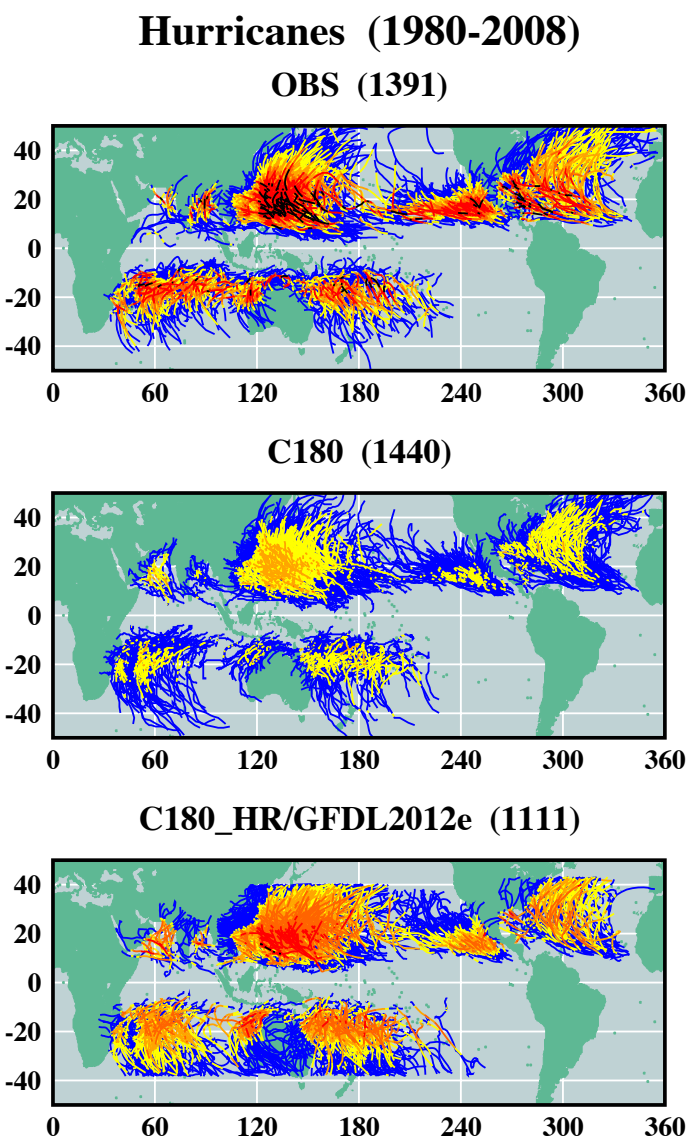


Source: Knutson et al. J. Climate, in press, 2013.

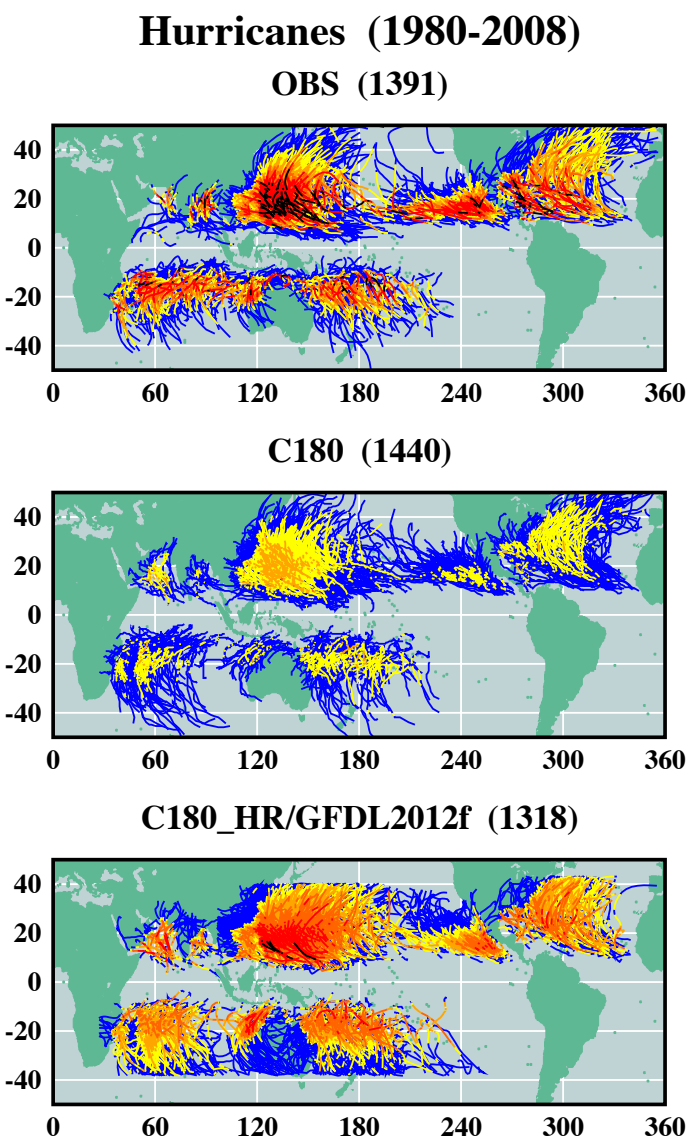


Source: Knutson et al. (J. Climate, in press, 2013).

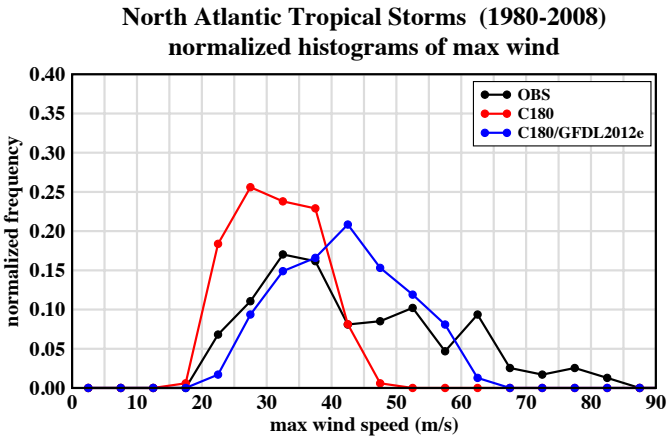
GFDL2012e

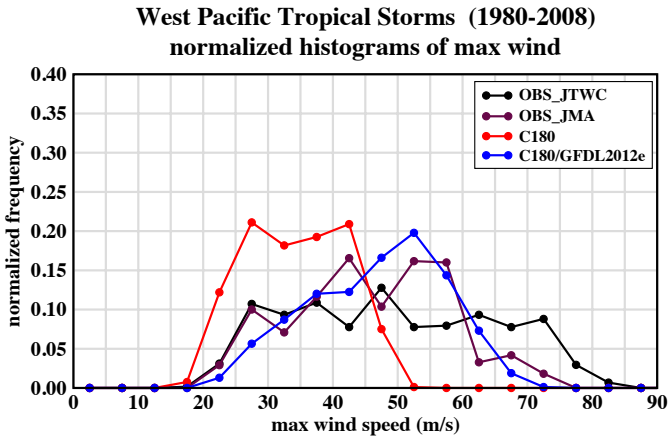


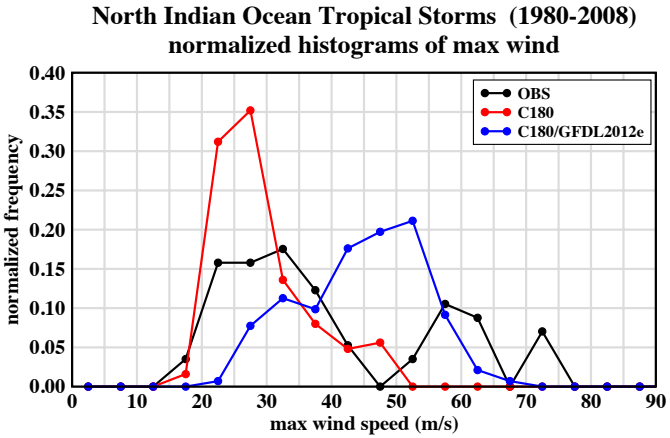
GFDL2012f

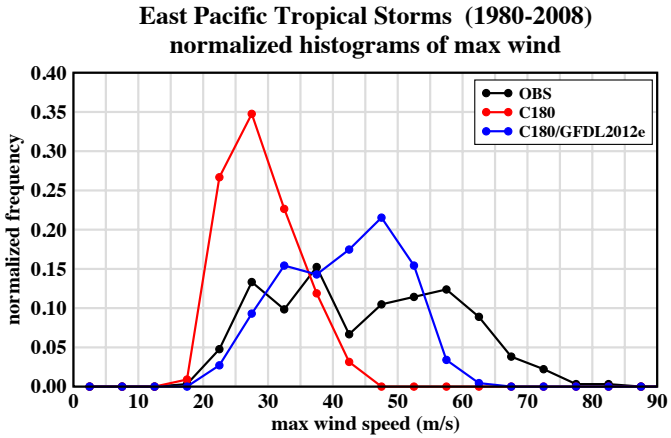


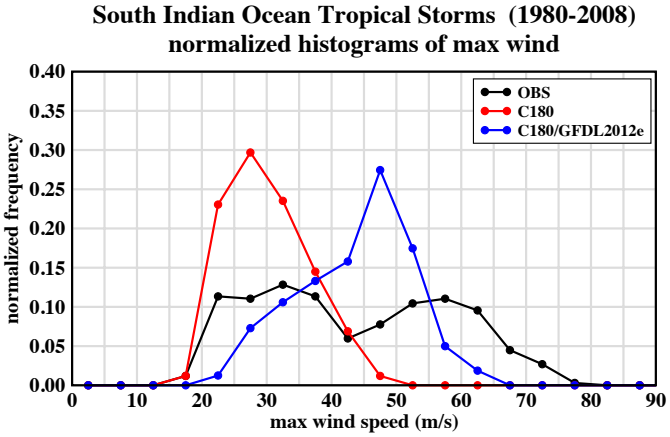
GFDL2012e (with synthetic vortex replacement)
GFDL2012f (no replacement; uses C180 vortex)

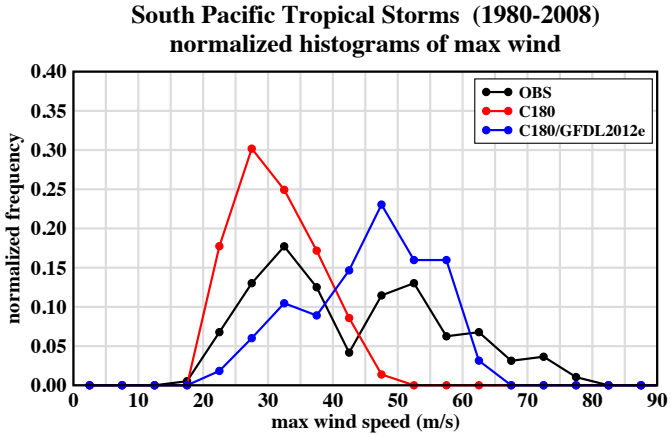








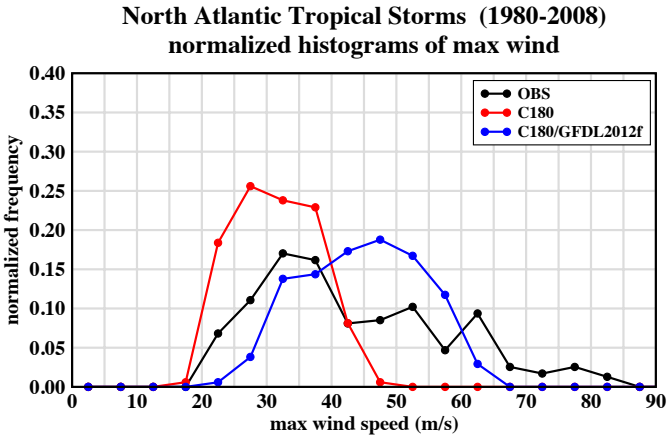


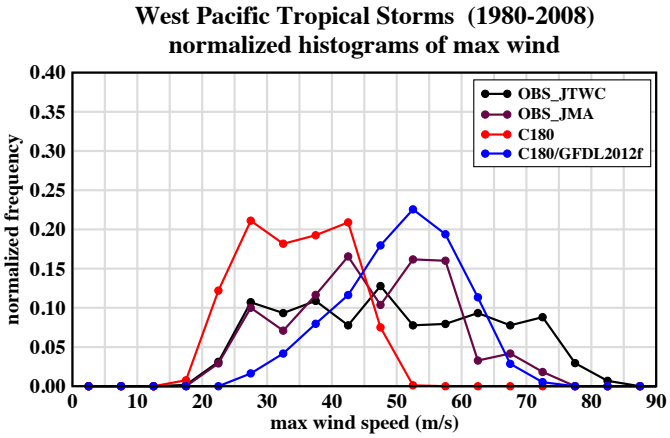


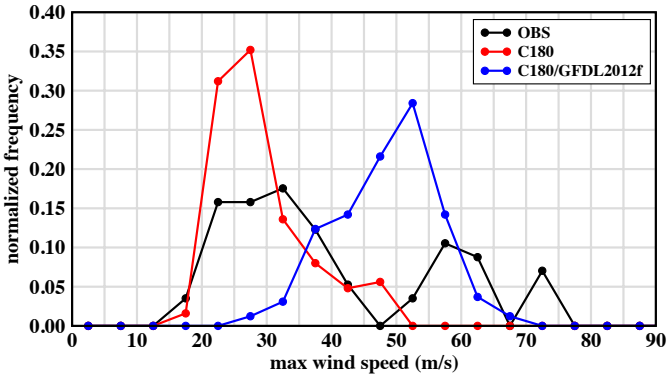
Model:
GFDL2012e

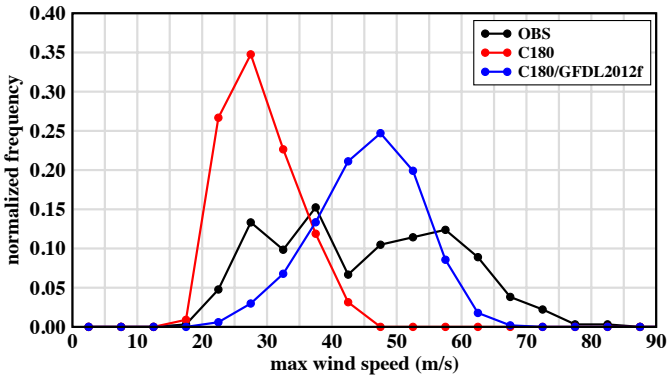
with synthetic initial vortex, but no T or RH adjustment;

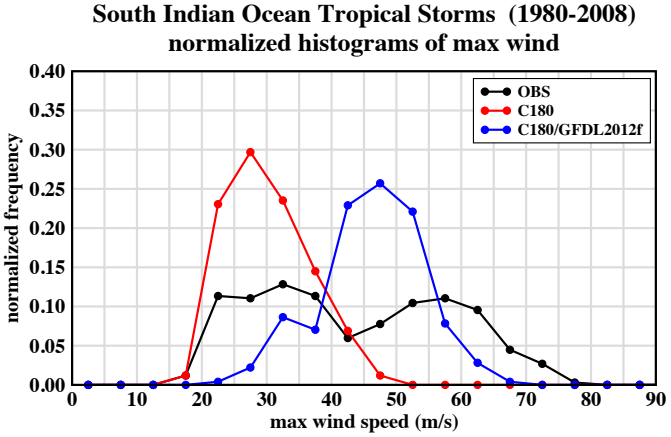
Downscale of **Tropical Storms** in GFDL C180 (50 km GCM)

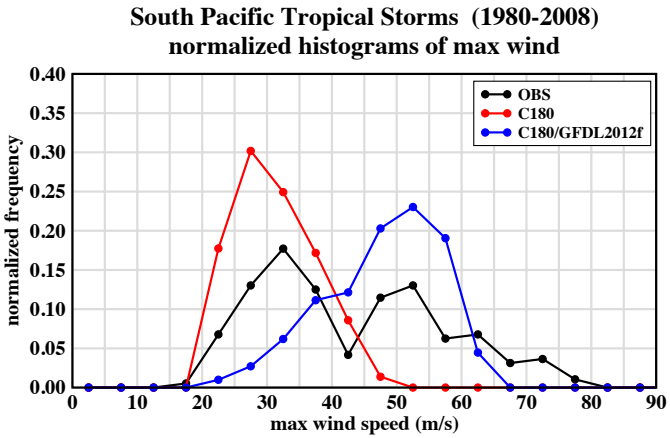








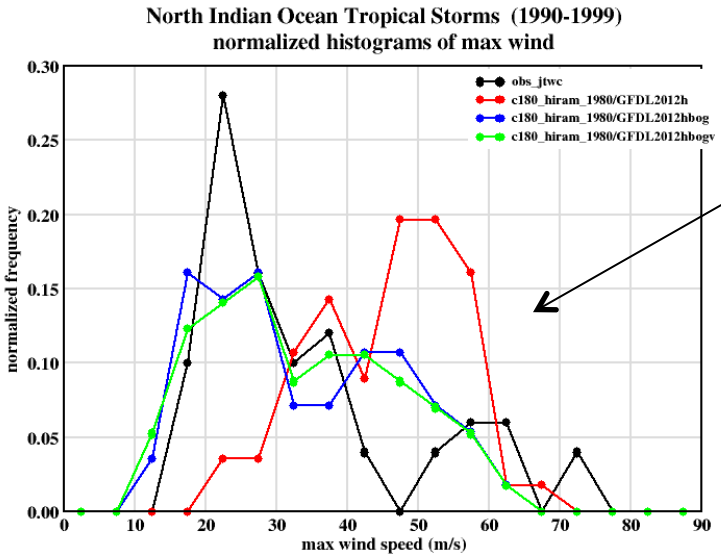




Model:
GFDL2012f

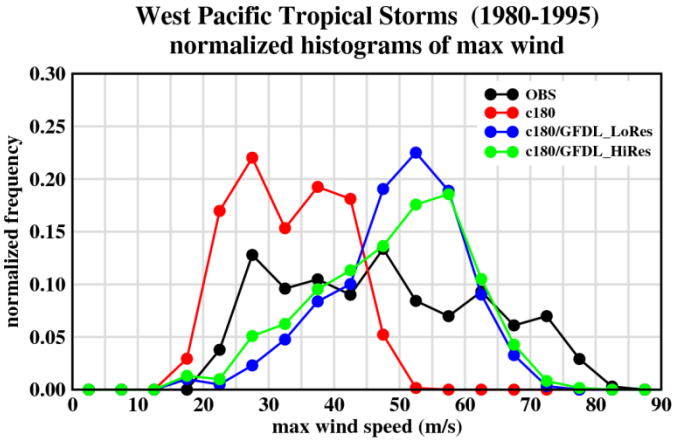
no synthetic initial vortex, and no T or RH adjustment;

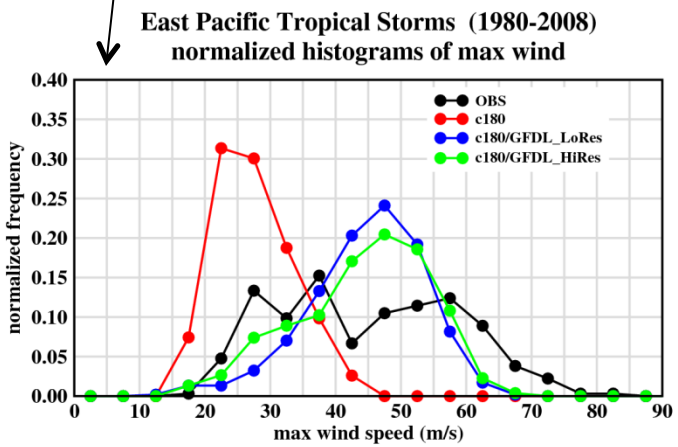
Downscale of **Tropical Storms** in GFDL C180 (50 km GCM)



Impact of bogusing can be substantial: example for NIO basin, 6 km grid model, with (blue, green) vs. without (red) bogusing.

Impact of resolution increase is generally favorable but modest: inner grid spacing of 9 km (blue) vs. 6 km (green)





Black = Observed distribution (JTWC for W. Pac and NIO)

Atlantic TC projections for late 21st century:

Tropical storm frequency: In the Atlantic, GFDL downscaling approaches support a reduced frequency (~-25%, range 0 to -50%)), but the projected range is even wider across a range of studies (-70% to +40%). Relative SST statistically describes this variation across dynamical model projections fairly well (r^2=0.55).

Hurricane intensity: Our models simulate about 5% increase in lifetime maximum intensity (range -4 to +11%).

Frequency of intense hurricanes: does not behave like overall TC frequency. Our model projects +87% for CMIP3 (range -90 to +240%); for CMIP5 it projects +45% (Early 21st) and +39% (Late 21st) though only marginally significant.

Tropical cyclone precipitation: robust increase in rate in model projections. Simulated increase is at a rate expected from Clausius-Clapeyron (total water vapor) or about +11% at 200-400 km radius, but with higher percentage increase (~+30%) closer to the storm center (50-150km). For 100 km radius the range of changes across the models was: -3 to +38%.