Hurricane Predictions and Projections

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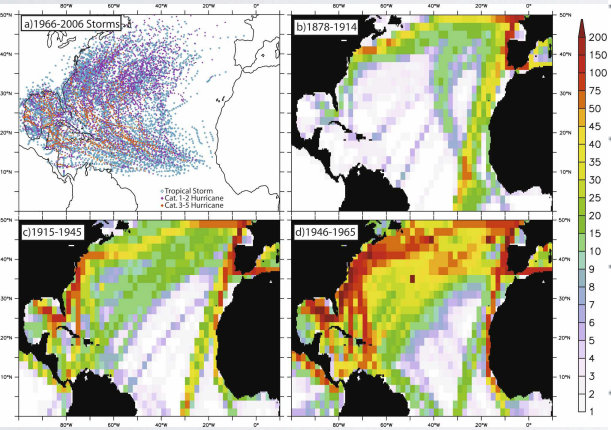
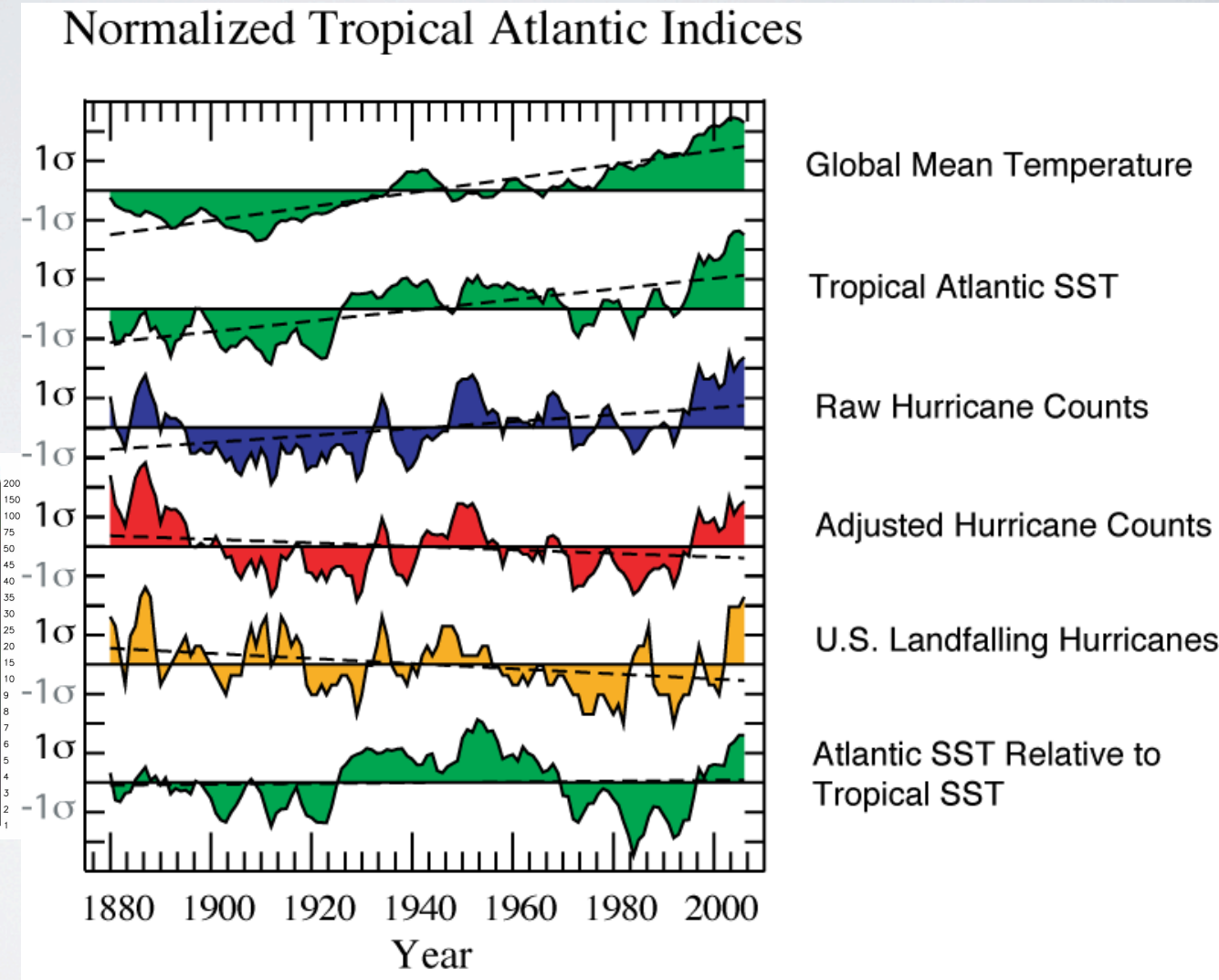
Image: NASA.

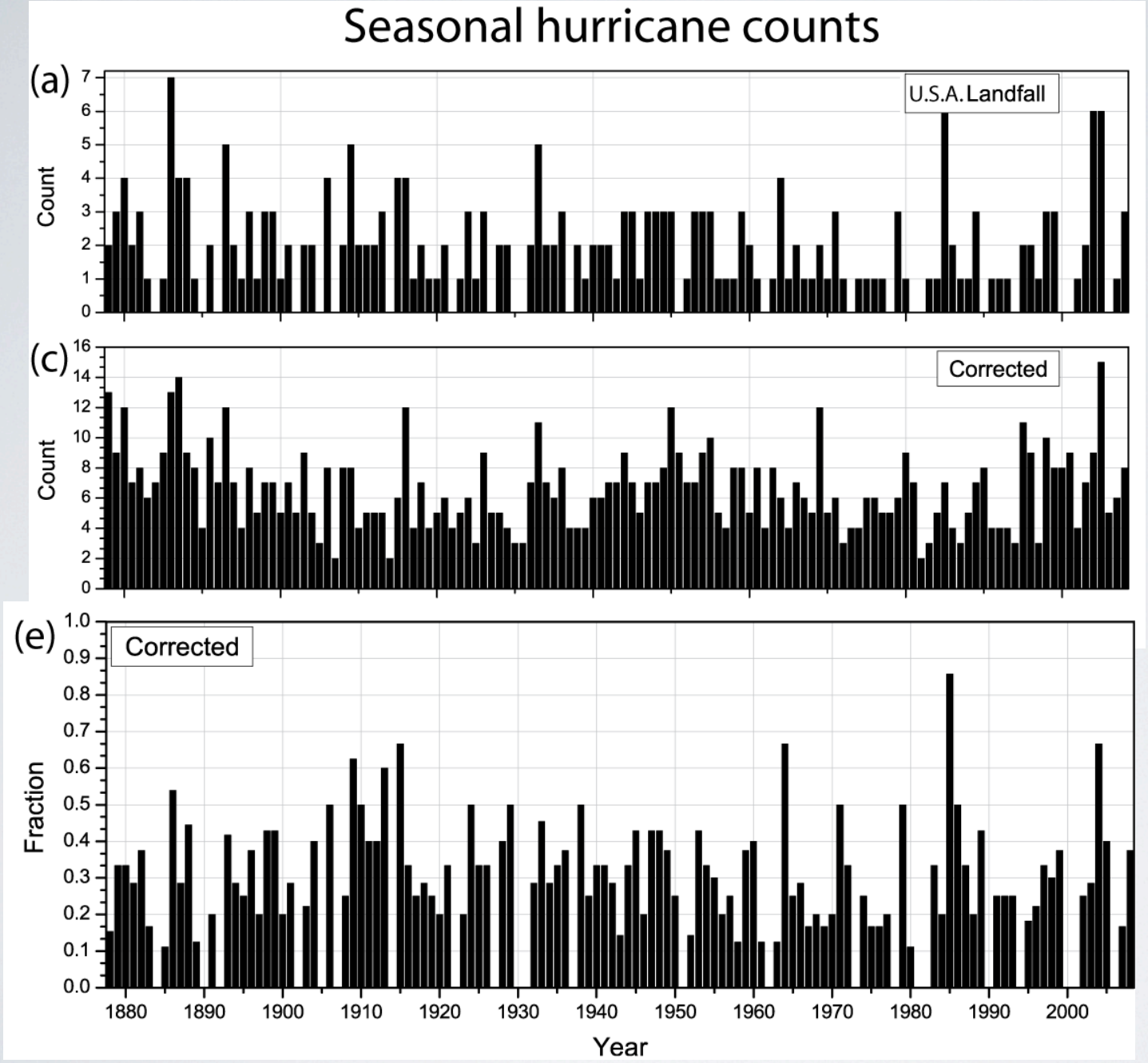
Historical Hurricane Records

Adjustments to storm counts based on ship/storm track locations and density



Vecchi and Knutson (2008, J. Clim.)
Landsea et al. (2009, J. Clim.)
Vecchi and Knutson (2011, J. Clim.)
Villarini et al. (2011, J. Clim.)





U.S. Landfalling Hurricanes

Basinwide Hurricanes

Fraction of Basinwide Hurricanes Making U.S. Landfall

Vecchi and Knutson (2011, J. Clim.); Villarini et al. (2012, J. Clim.)

Sources of & Limitations on climate predictability

hours to a year

Climatology

(what happens typically, including randomness)

need good observations

Evolution of initial conditions

(*e.g.*, weather or El Niño forecast)

need good observations, models, initialization schemes

Many decades to centuries

Climatology

Climate response to forcing

(*e.g.*, CO_2, aerosols, sun, volcanoes)

need good models and estimates of forcing

Merge multiple tools and understanding to build experimental long-lead hurricane forecast system: skill from as early as October of year before

April & onward forecasts fed to NOAA Seasonal Outlook Team

Hi-Res AGCM in many different climates. Count storms.

Build statistical model of the response of hurricanes in HiRAM

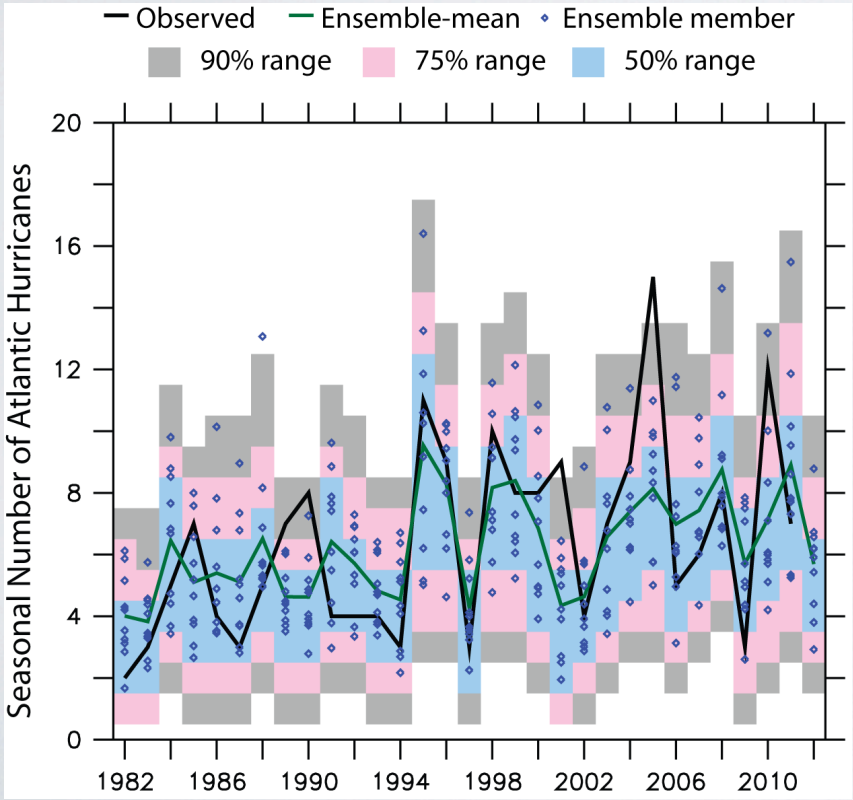
Use initialized coupled model to forecast future values of SST

Apply Stat model to Predicted SST

HyHuFS

Make Prediction of Full PDF of Hurricane Activity

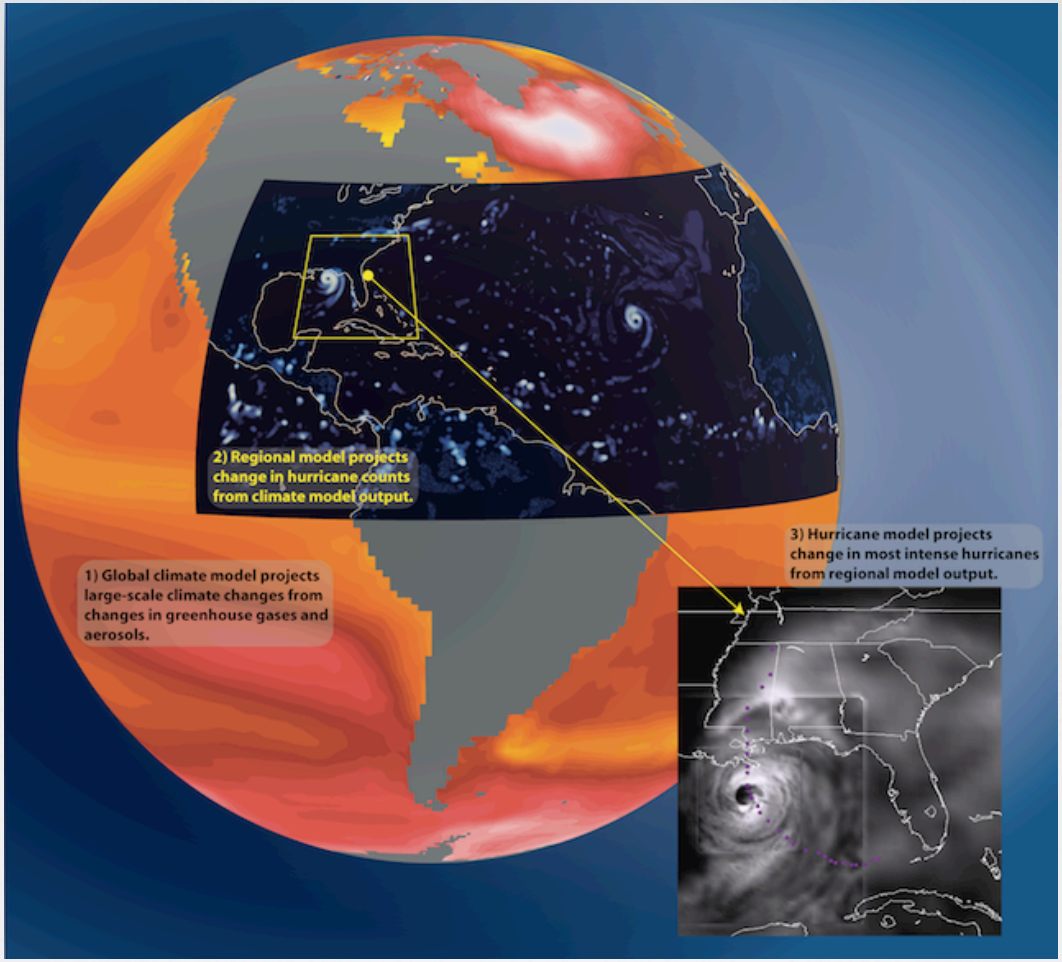
Initialized January: r=0.66



http://gfdl.noaa.gov/HyHuFS

Vecchi et al. (2011); Villarini and Vecchi (2012, submitted)

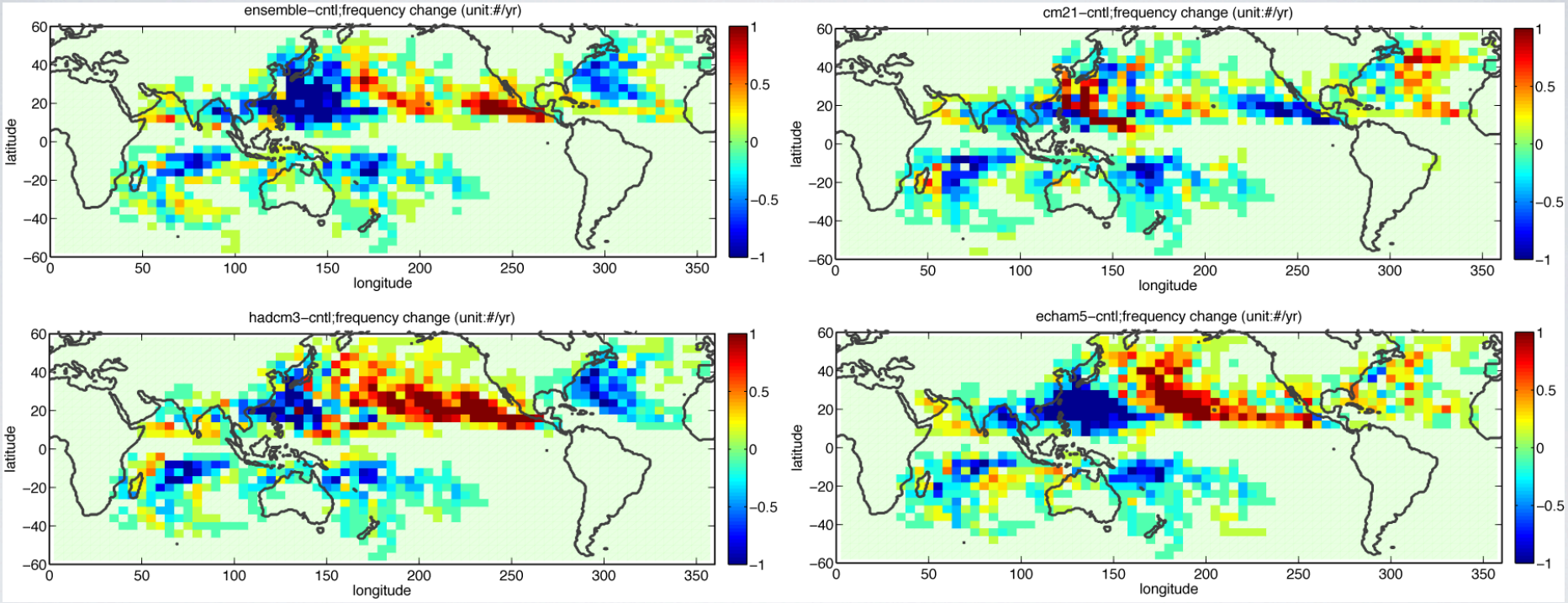
Multi-decadal projections



Global Climate Models -> High-Res Model -> Hurricane model

Large-scale TS Frequency Intensity

Response of TC frequency in single 50km global atmospheric model forced by four climate projections for 21st century



Red/yellow = increase
Blue/green = decrease

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

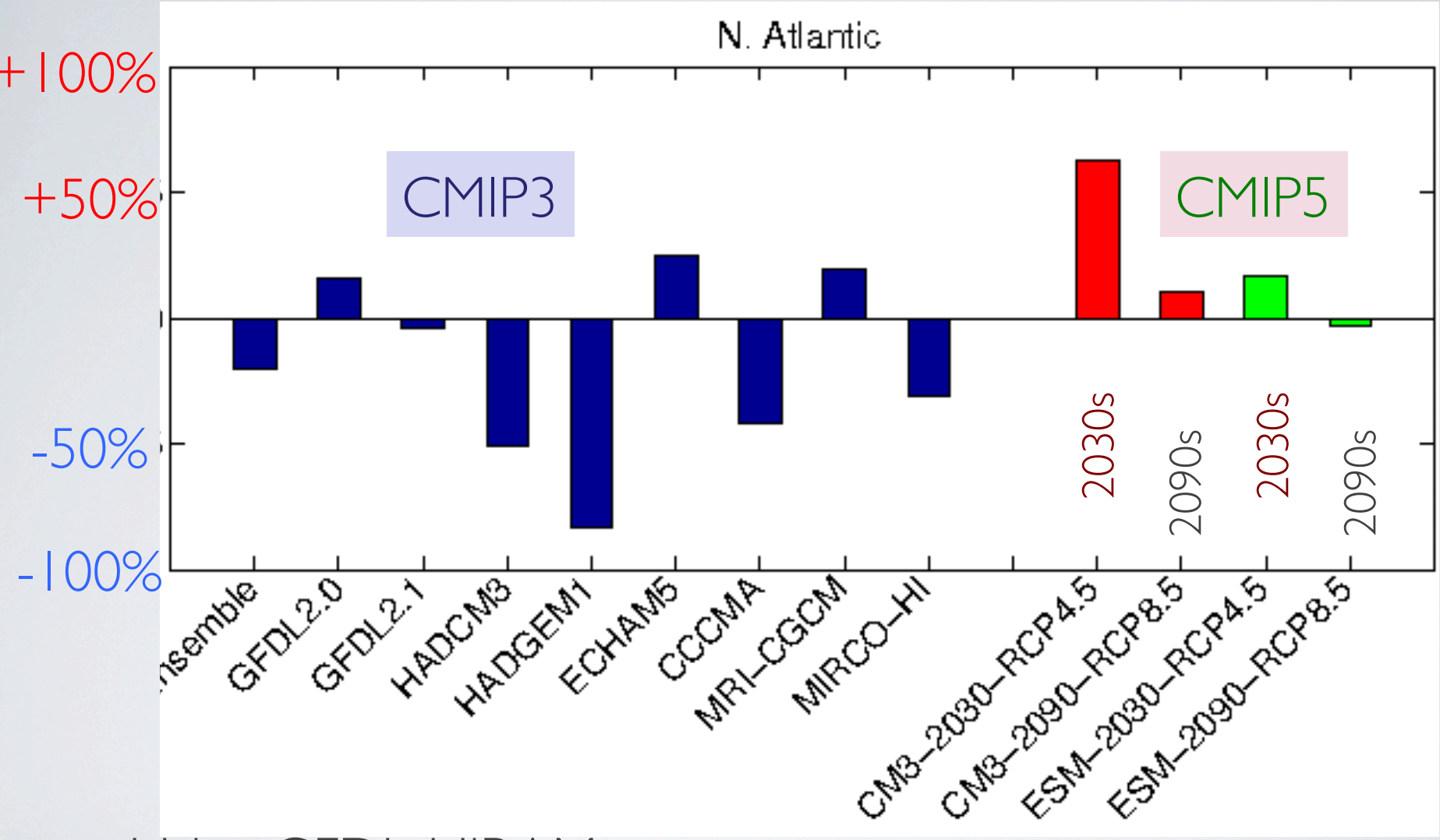
Regional increase/decrease much larger than global-mean.

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, Sugi et al. 2010, Villarini et al. 2011, etc.

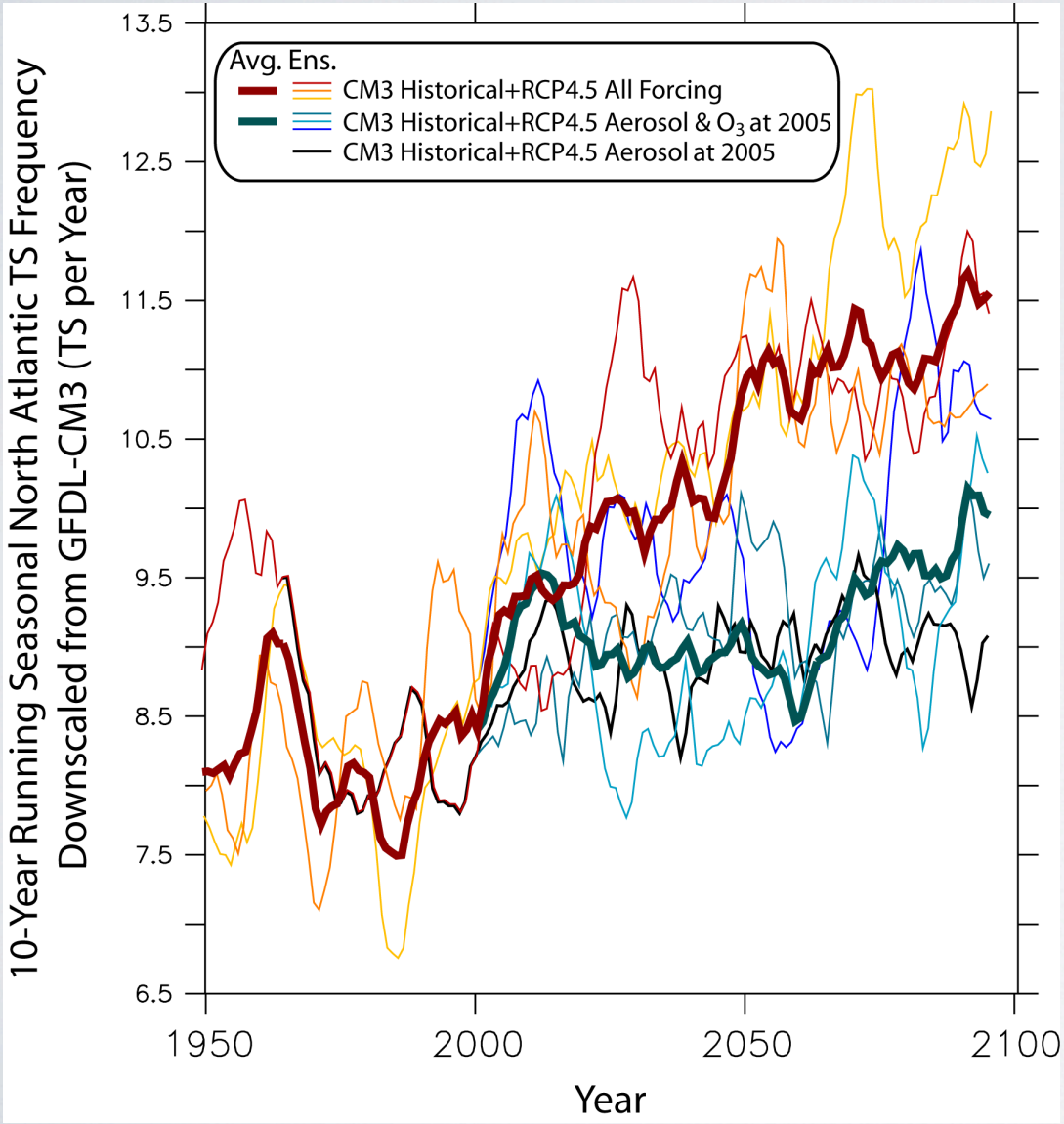
Dynamical Projections of Atl. Hurricanes for end of 21st Century



Using GFDL-HiRAM

Adapted from Zhao et al. (2009, J. Clim.) and Held et al. (2012, in prep)

GFDL-CM3 indicates aerosols key for NA TS projections (projected aerosol clearing -> more storms)



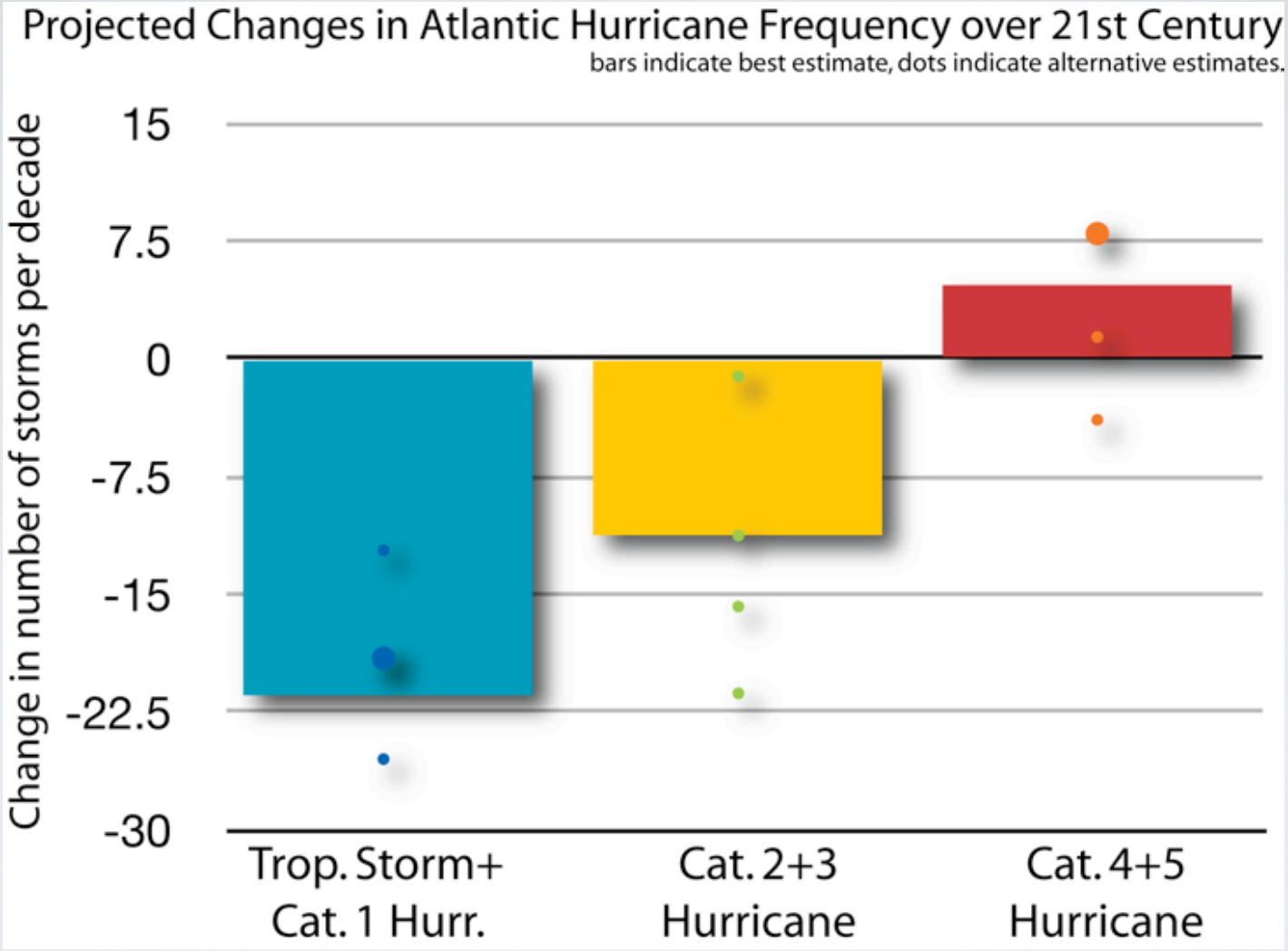
All Forcing

No future aerosol or O_3

No future aerosol

Villarini and Vecchi (2012, Nature C.C.)

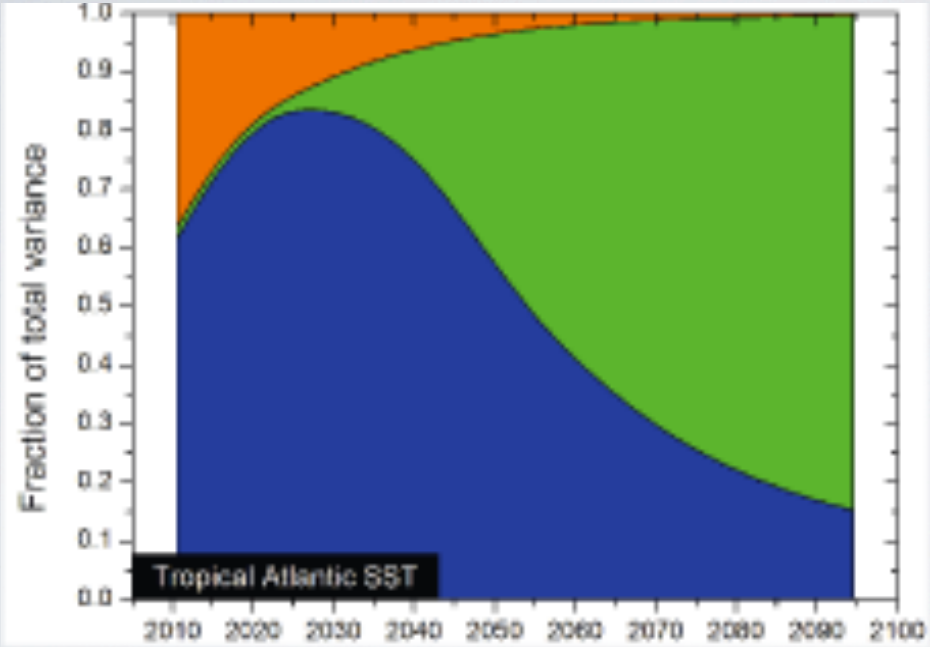
For Atlantic: Overall frequency decrease projected, but more of the strongest storms



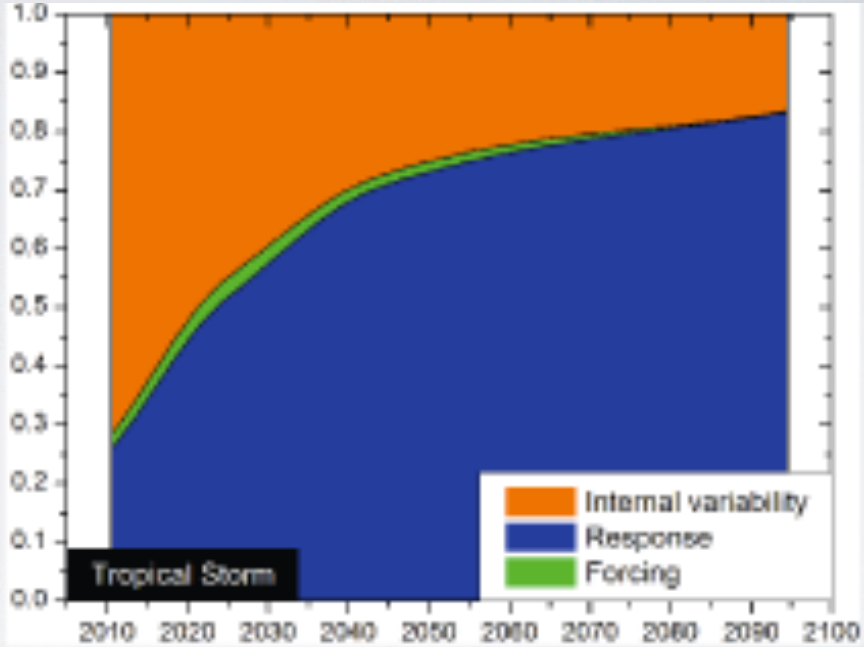
Adapted from Bender et al (2010, Science)
see also Knutson et al. (2008, Nature Geosci.)

Key uncertainty sources to projections of decadal TS activity

Tropical Atlantic SSTA



NA TS Frequency



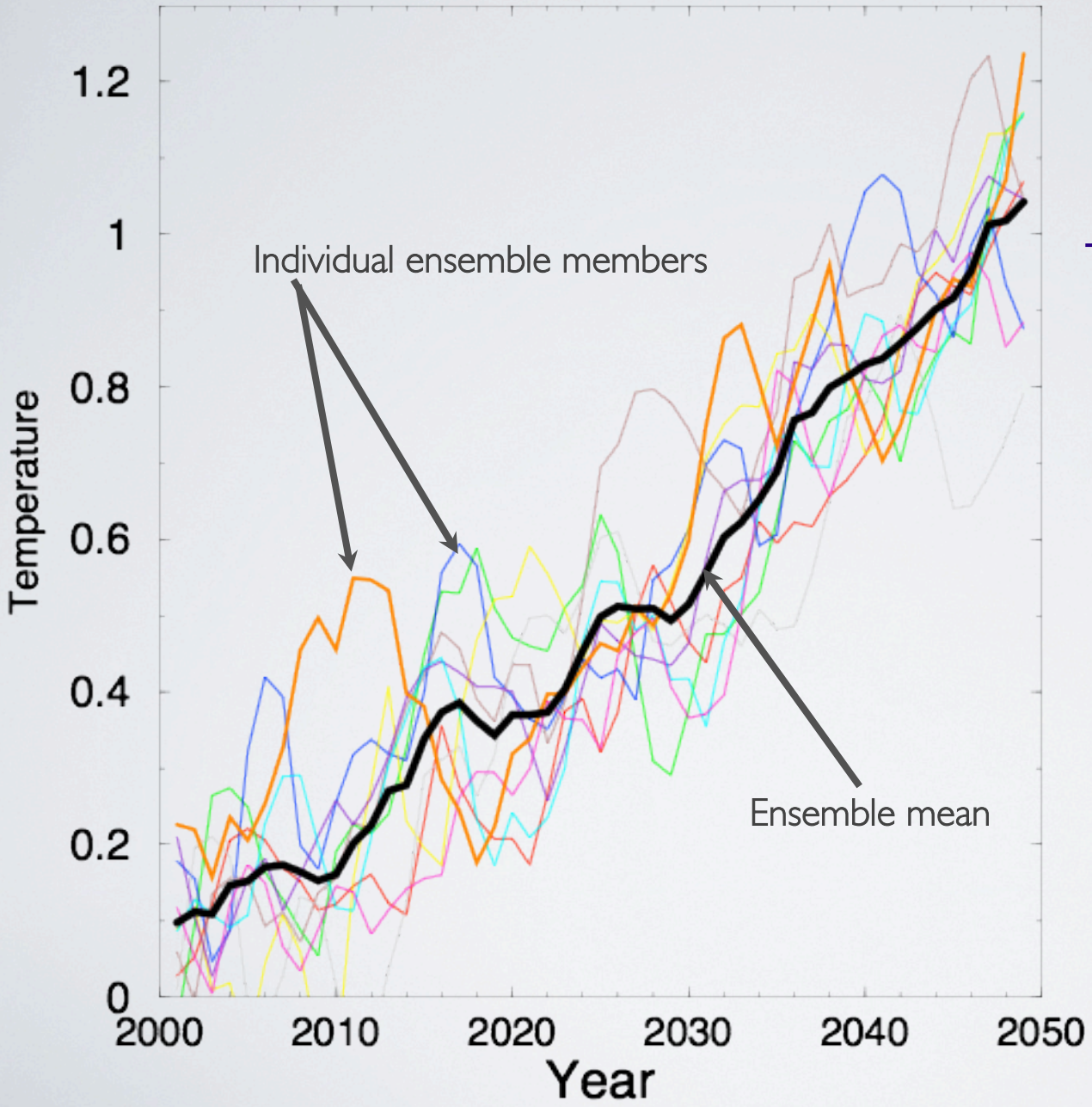
Villarini et al. (2011), Villarini and Vecchi (2012)

Sources of uncertainty (after Hawkins and Sutton, 2009)

- Variability: independent of radiative forcing changes
- Response: "how will climate respond to changing GHGs & Aerosols?"
- Forcing: "how will GHGs & Aerosols change in the future?"

Simulated Atlantic Sea Surface Temperature

(based on GFDL CM2.1)



Can we predict the trajectory of Atlantic temperatures over the next several decades?

How about hurricane activity?

Slide: Tom Delworth (GFDL)

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Decadal/multi-year prediction: New efforts focused mixed initial/boundary value problem

Experimental decadal predictions

Hybrid system: statistical hurricanes, dynamical decadal climate forecasts

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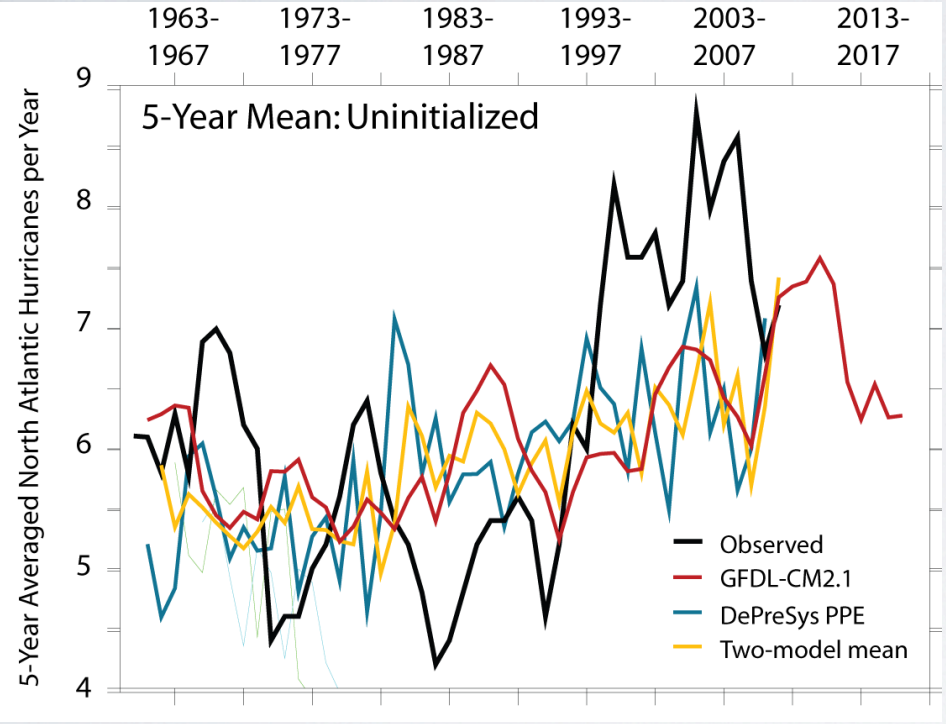

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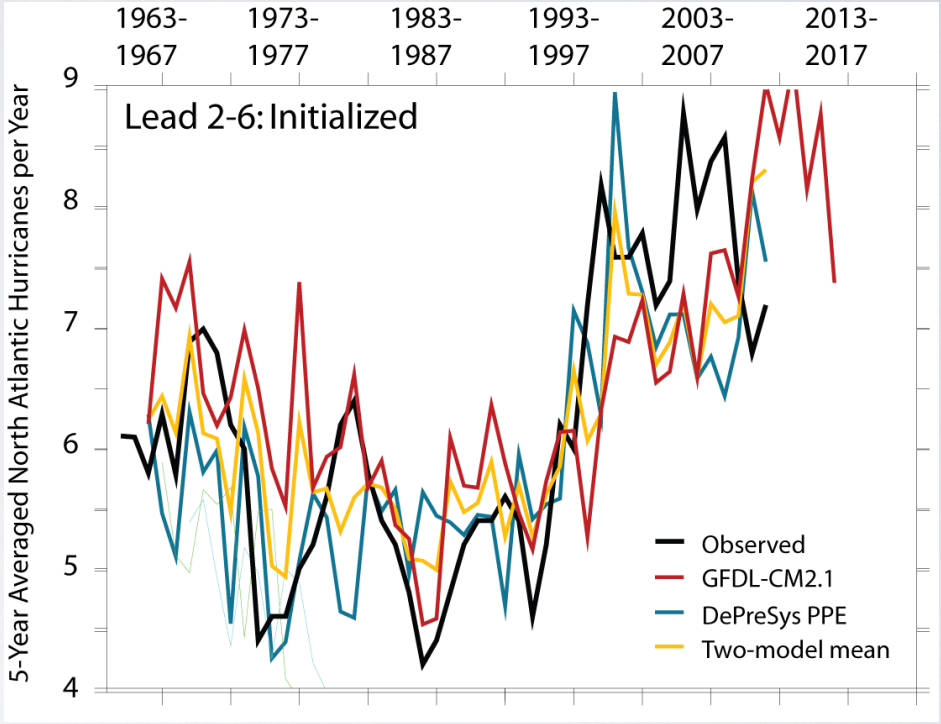

- Retrospective predictions encouraging.
- However, small sample size limits confidence
- Skill arises more from recognizing 1994-1995 shift than actually predicting it.
- This is for basinwide North Atlantic Hurricane frequency only.

EXPERIMENTAL: NOT OFFICIAL FORECAST

Vecchi et al. (2012 submitted), see also Smith et al. (2010, Science)

Experimental decadal predictions

Hybrid system: statistical hurricanes, dynamical decadal climate forecasts

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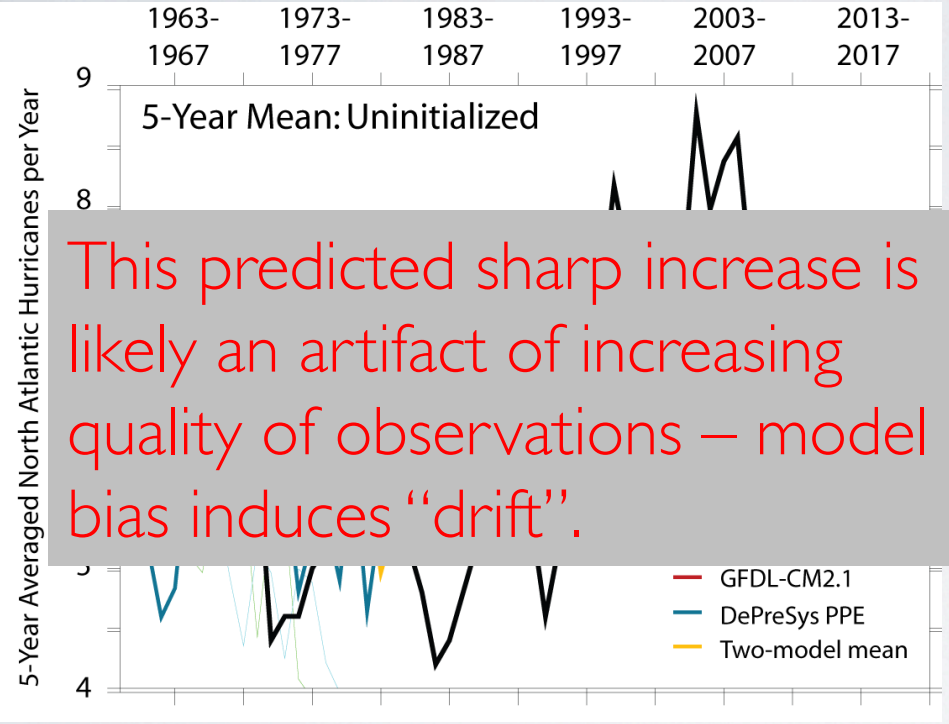

This predicted sharp increase is likely an artifact of increasing quality of observations – model bias induces "drift".

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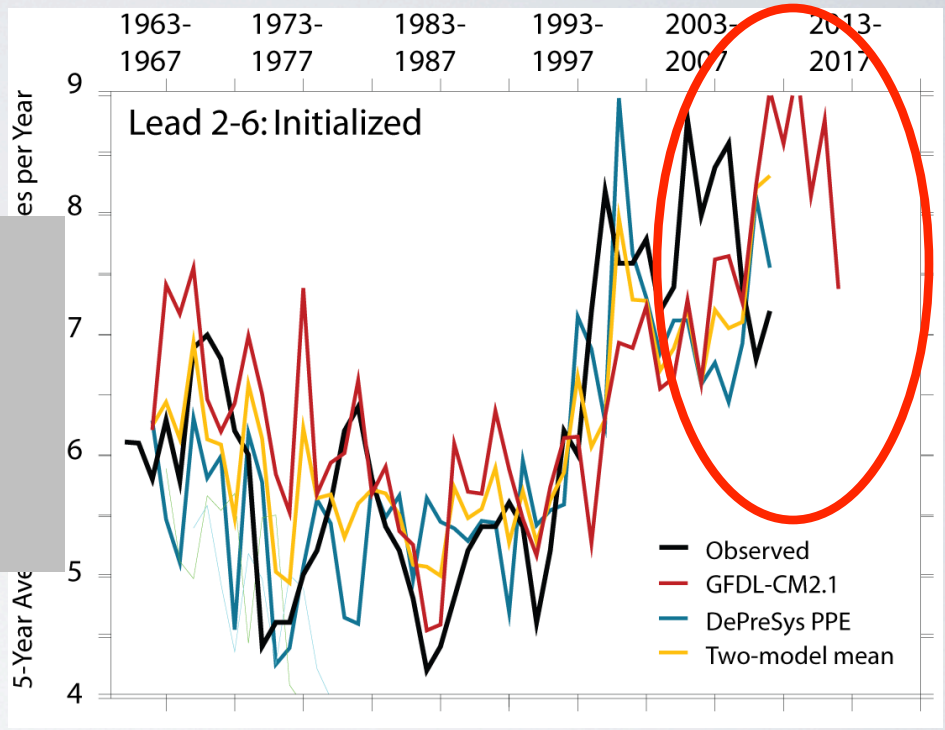

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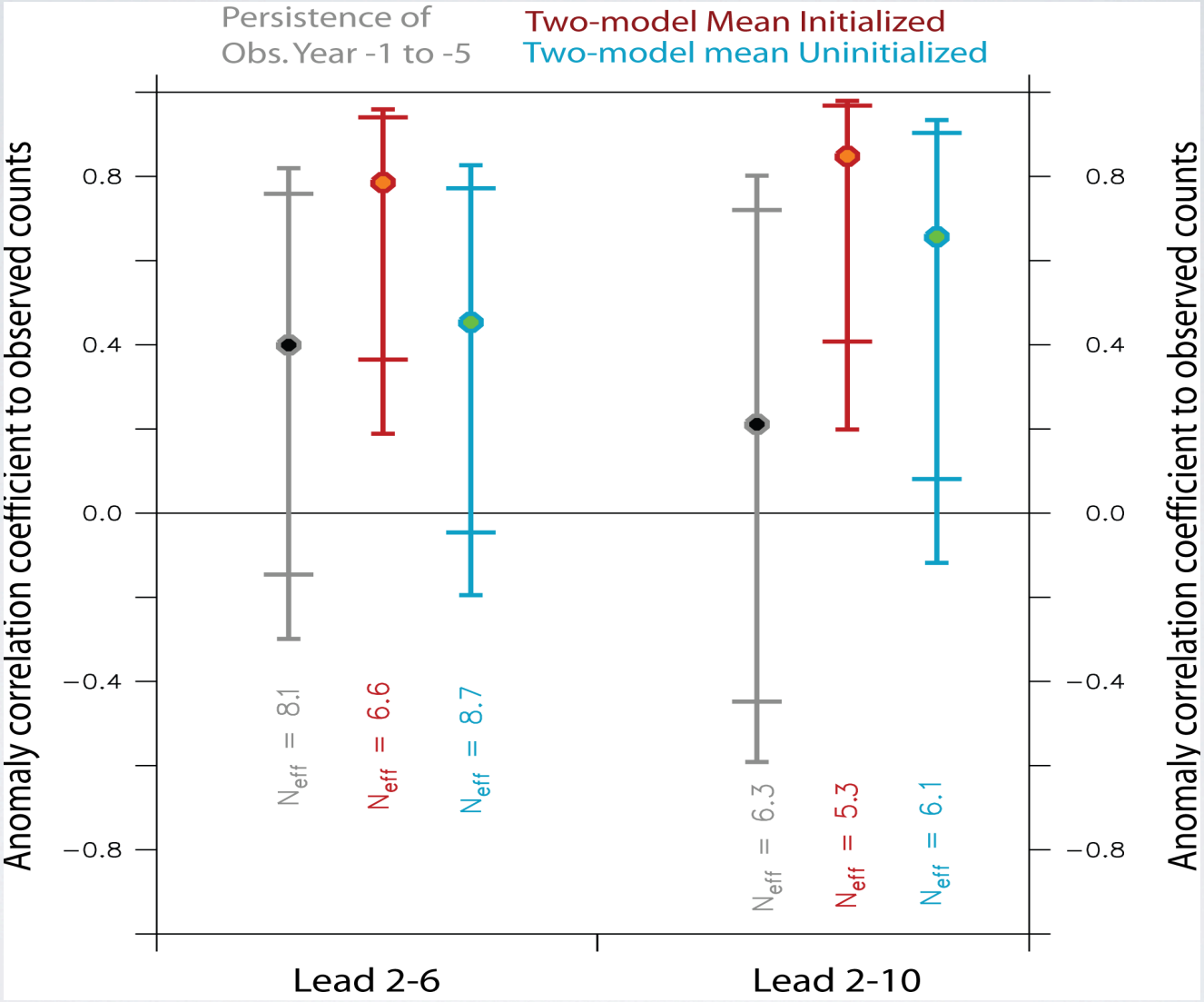

Vecchi et al. (2012 submitted)

Summary

- Premature to conclude we have seen hurricane change due to CO_2
- Models allow estimates of future activity:
  - Next couple of decades: internal variability dominant player
    (some may be predictable, some not)
  - NA Hurr. Response to CO_2: maybe fewer, probably stronger.
  - Aerosol forcing and response key to next few decades.
- Encouraging results from long-lead (multi-season and multi-year) experimental forecasts using hybrid system:

  "past performance no guarantee of future returns"
  but good past performance nice start…

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