Future Tropical Cyclone Activity

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Image: NASA.

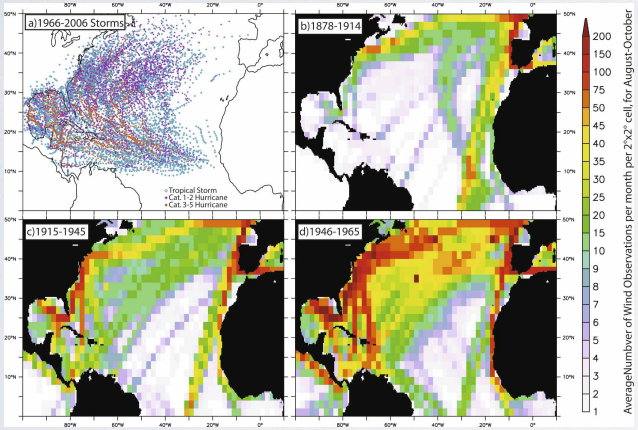
Topics to be addressed

To what extent:

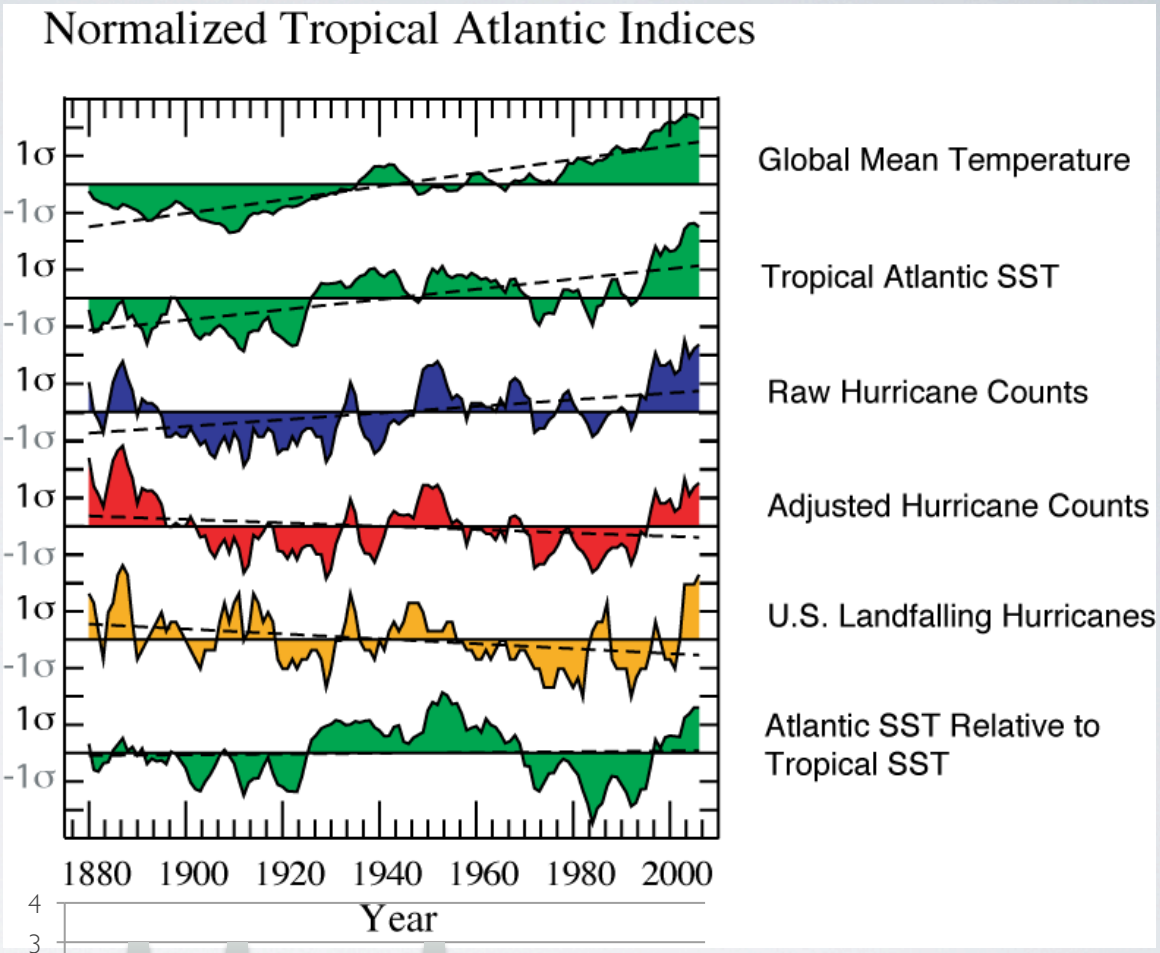
- …are hurricane activity records representative of the past?

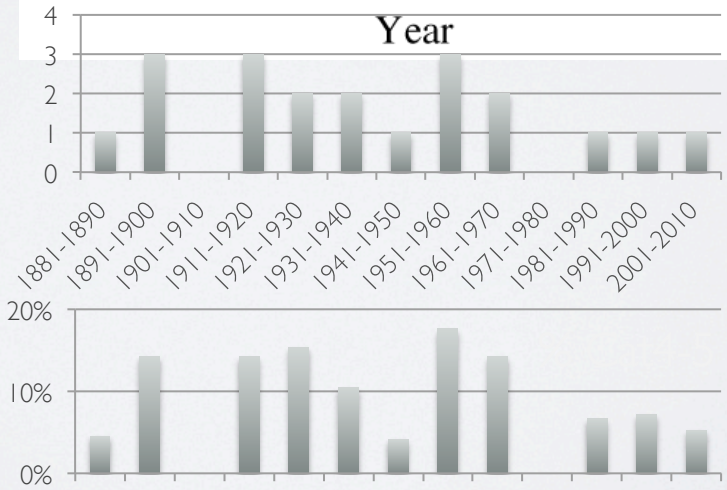
- …is past hurricane activity representative of the future?
  - Internal climate variability (*e.g.,* El Niño, Atlantic Multidecadal Variation)
  - Forced climate change (*e.g.,* CO_2, soot, dust & other aerosols…)
  - Key sources of uncertainty

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.)

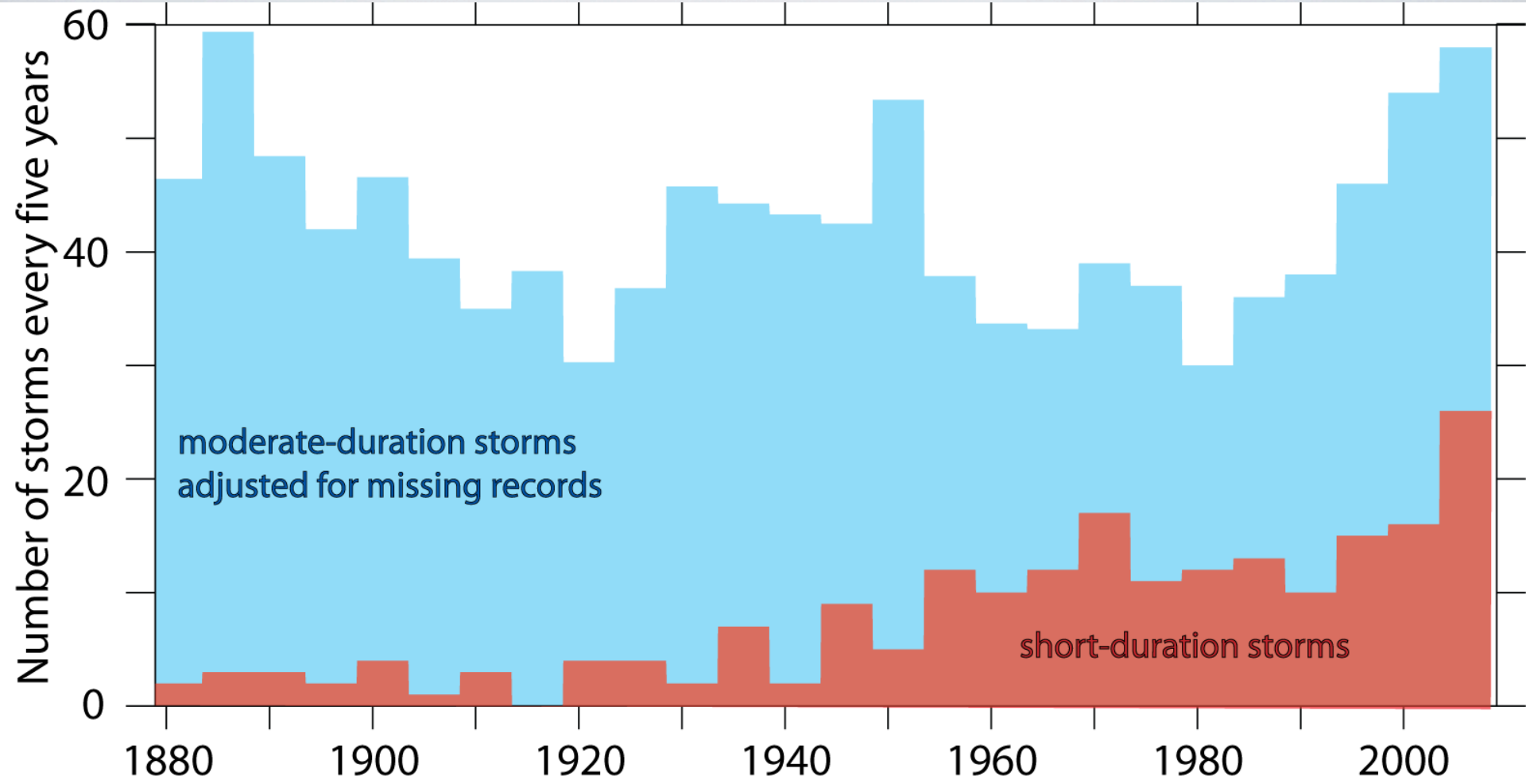




US Landfalling Cat4-5

US Landfalling Cat4-5
As % total

Recorded North Atlantic tropical storm frequency increase due to storms lasting 2 days or less ("shorties")

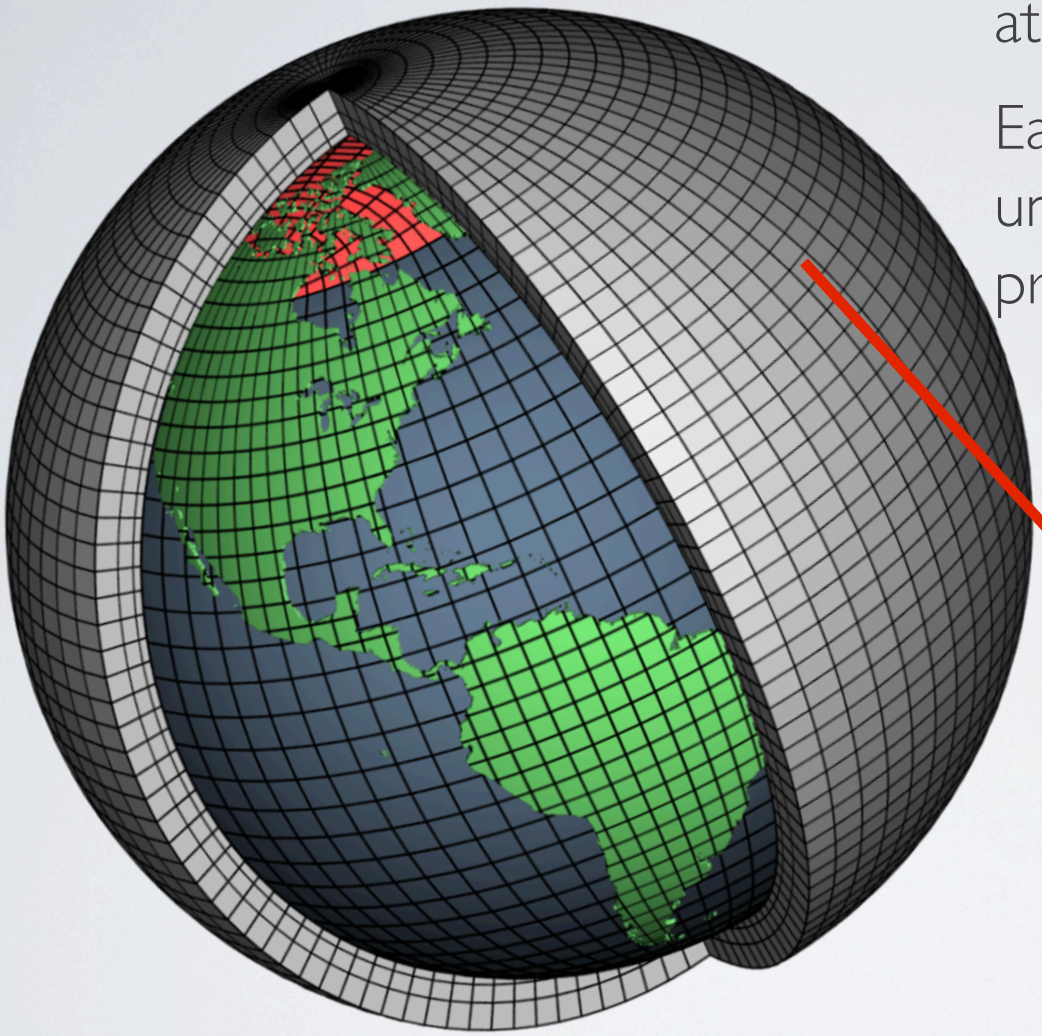


Atlantic tropical storms lasting more than 2 days have not increased in number.
Storms lasting less than two days have increased sharply, but this is likely due to better observations.

Adapted from Landsea et al. (2010), see also Villarini et al. (2011)

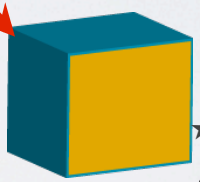
Change in baseline risk due to climate (refs. at end)

- Forced climate change due to:
  - greenhouse gases: forcing changes slowly, global impact more well constrained than regional impact, incremental impact over next decade may be smaller than variability. Sea level rise
  - aerosols: could be influential, forcing can change rapidly (*i.e.,* uncertain), impact not yet fully understood, spatially heterogeneous.
- Internal climate variability
  - Interannual and decadal modes of variation
  - Ongoing efforts to assess predictability of climate and its impacts – variability, predictability and impacts likely regionally dependent.
  - Random, fully unpredictable "weather" can be a factor in year-to-year variations



Models have land, ocean, atmosphere and ice components.

Each encapsulates our best understanding of underlying processes controlling its evolution.



In each grid cell:

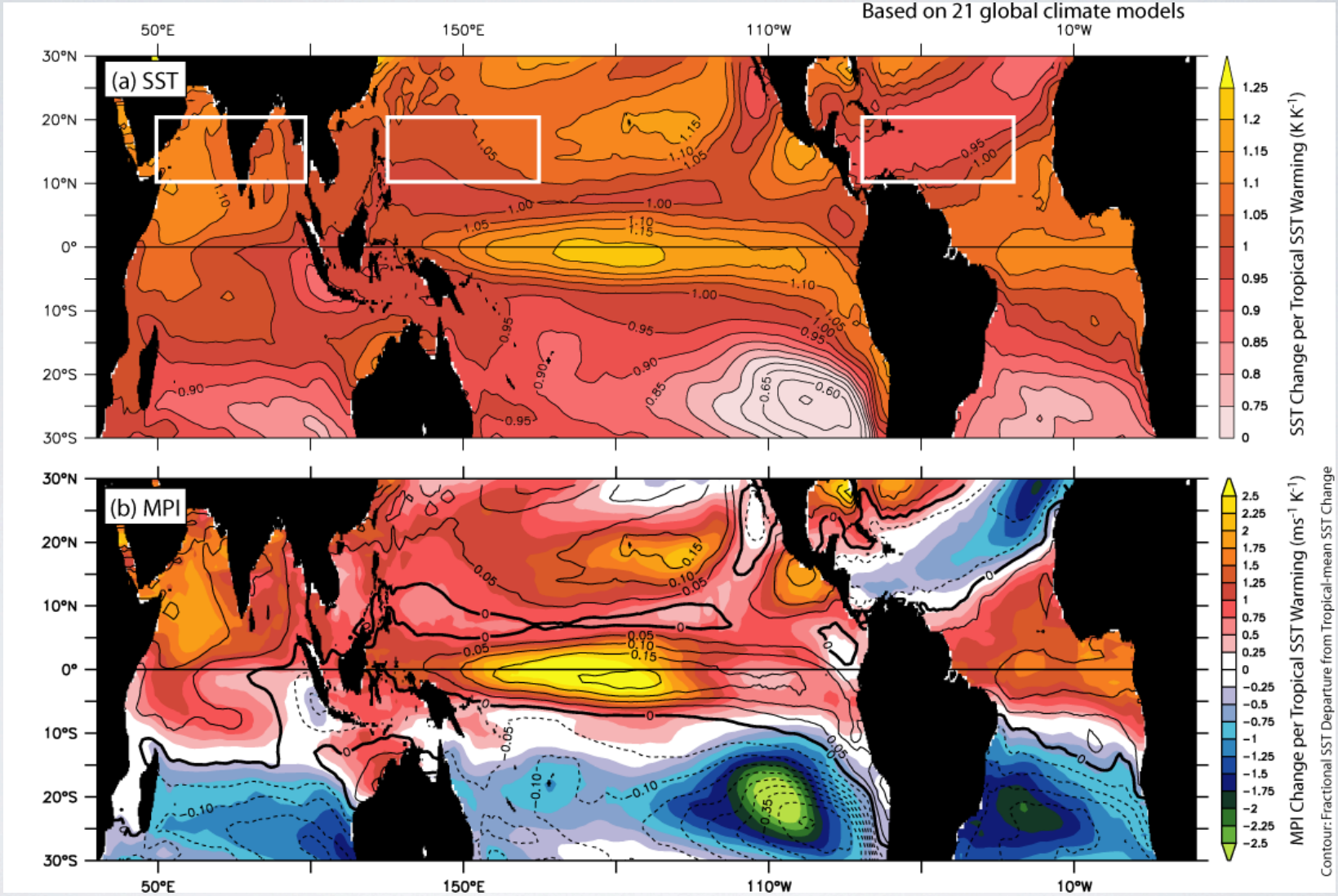
- ⋆conserve momentum ($F=m \cdot a$)
- ⋆account for changes in mass and composition
- ⋆conserve energy (radiation, latent, etc...)

"Force" with solar radiation, structure of continents and atmospheric composition (e.g., CO_2)

GCM Projections of 21st Century Changes

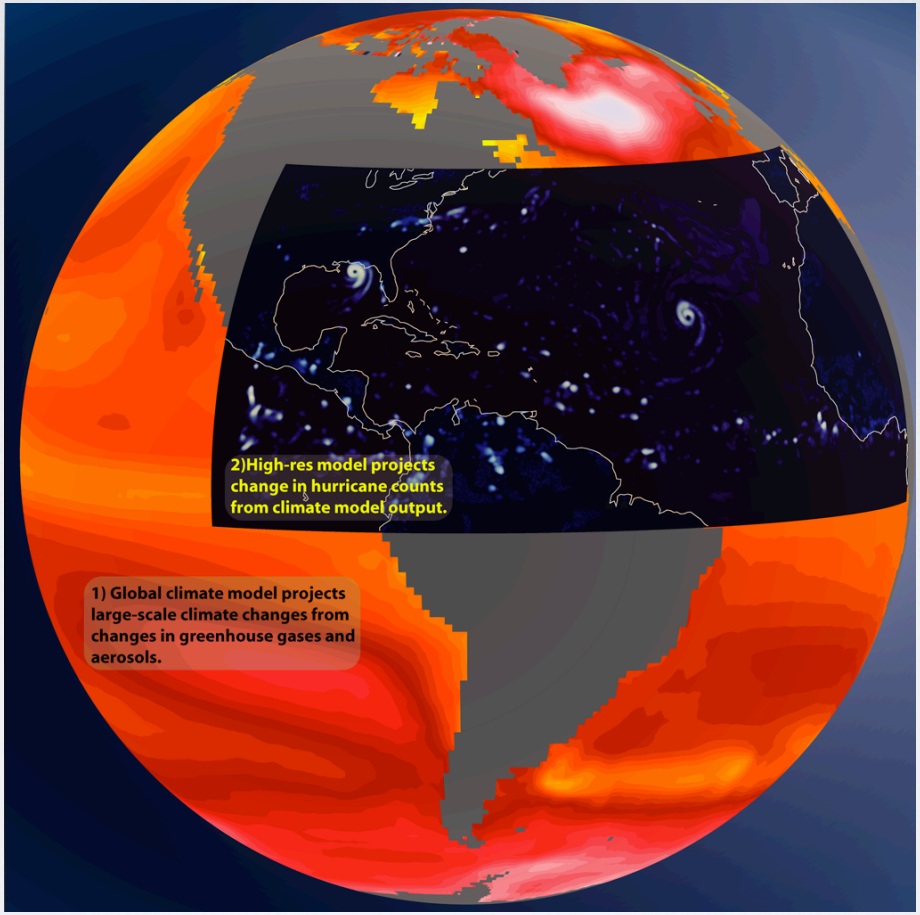
Surface Temp.

Potential Intensity



Vecchi and Soden (2007, Nature)

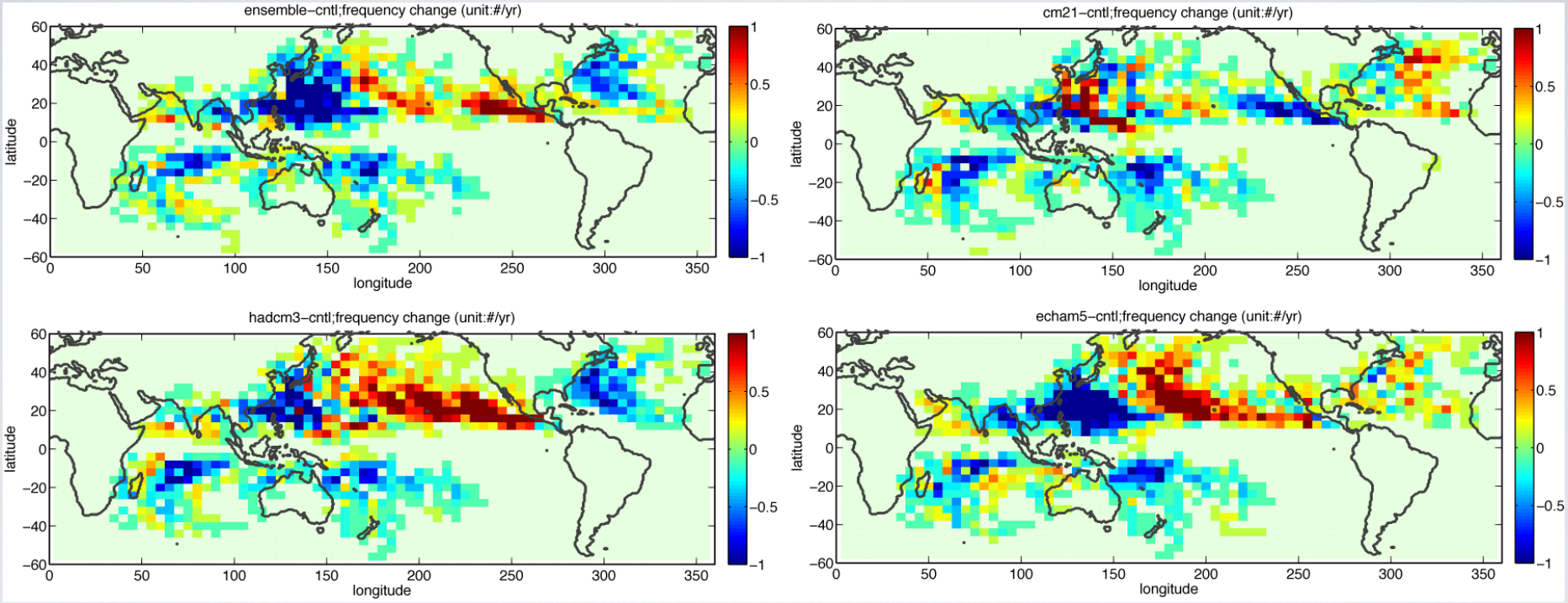
"Downscale" Climate Model Projections With High-Resolution or Statistical Models



Global Climate Models -> High-resolution Model

Large-scale TS Frequency

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)

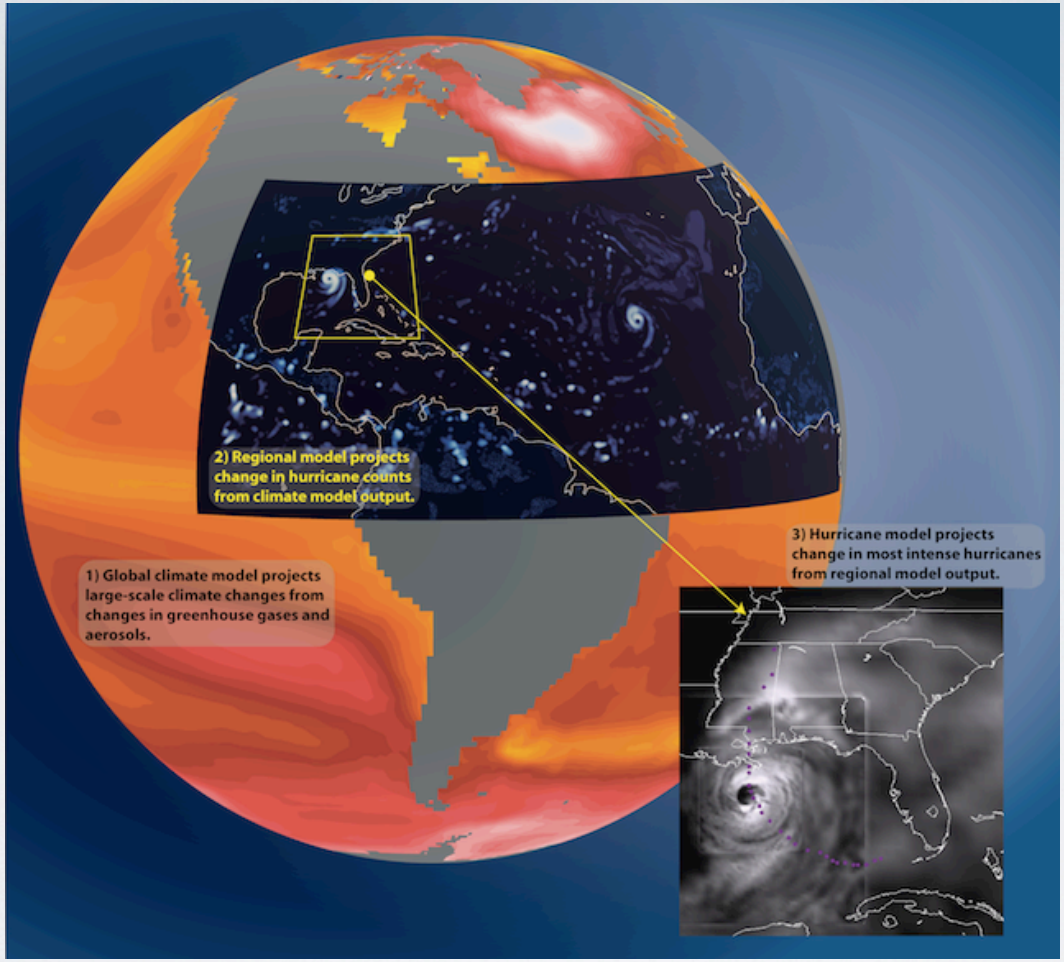
Regional increase/decrease much larger than global-mean.

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, etc

Strongest cyclones projected with double downscaling

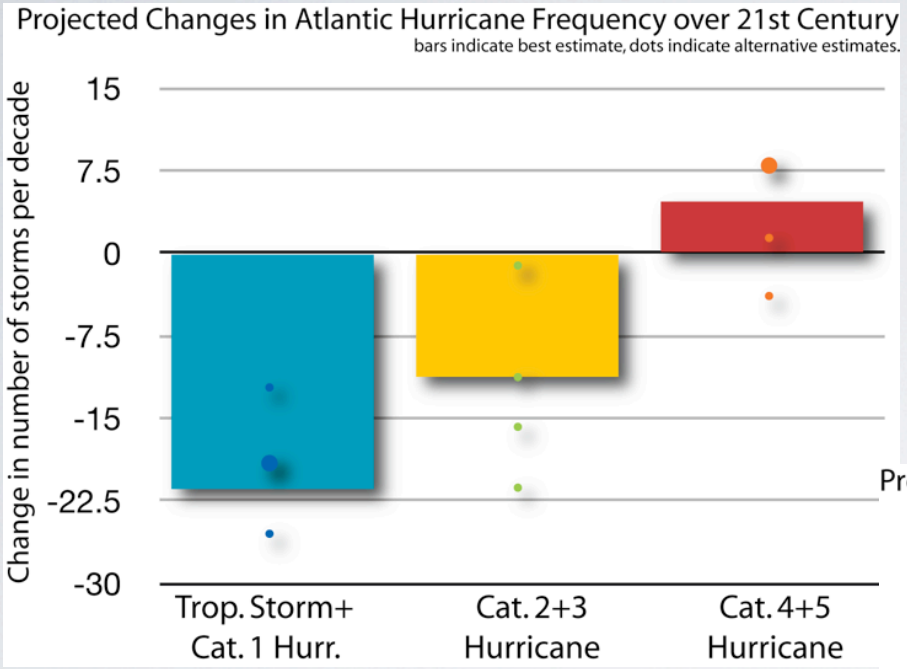


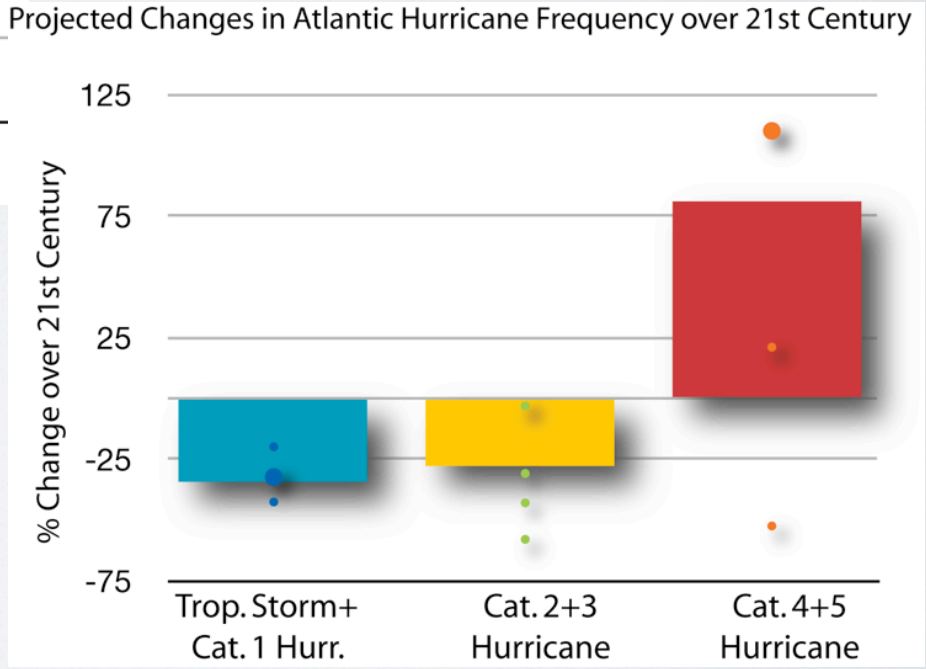
Adapted from
Bender et al (2010, Science)

Global Climate Models -> Regional Model -> Hurricane model

Large-scale TS Frequency Intensity

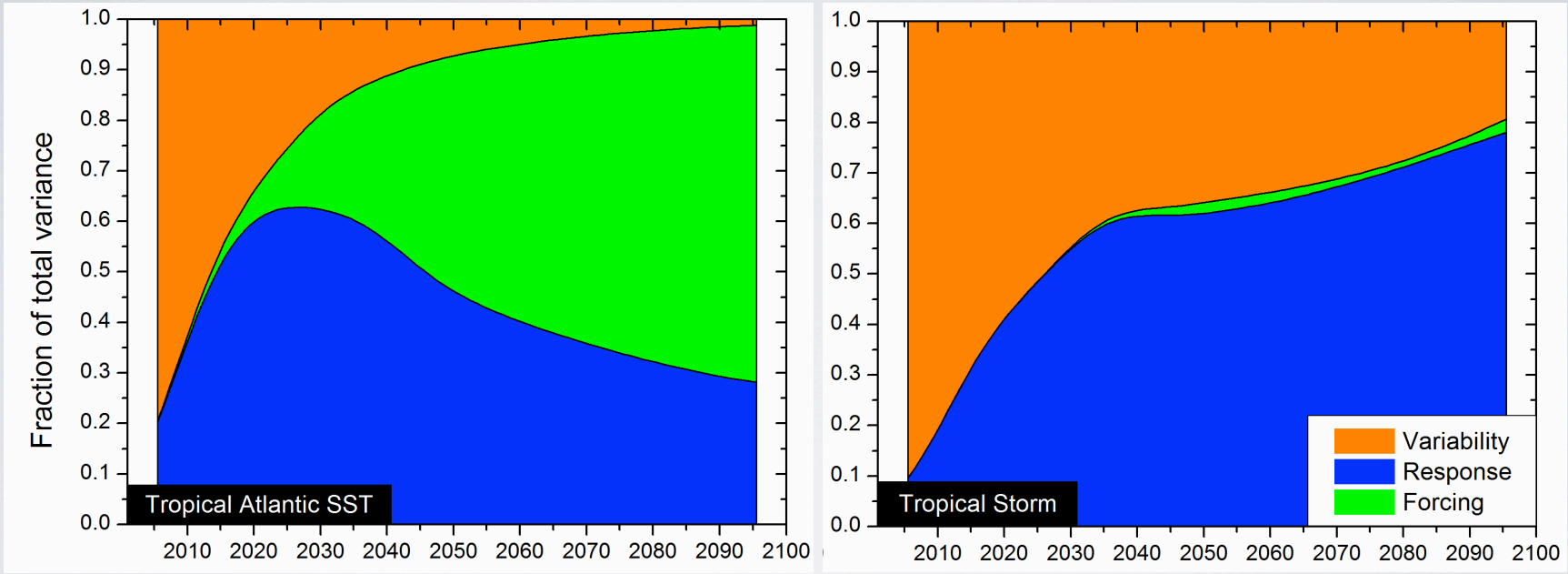
Overall frequency decrease projected for North Atlantic, but strongest storms may become more frequent





Adapted from Bender et al (2010, Science)

Key sources of uncertainty for decadal hurricane activity projections

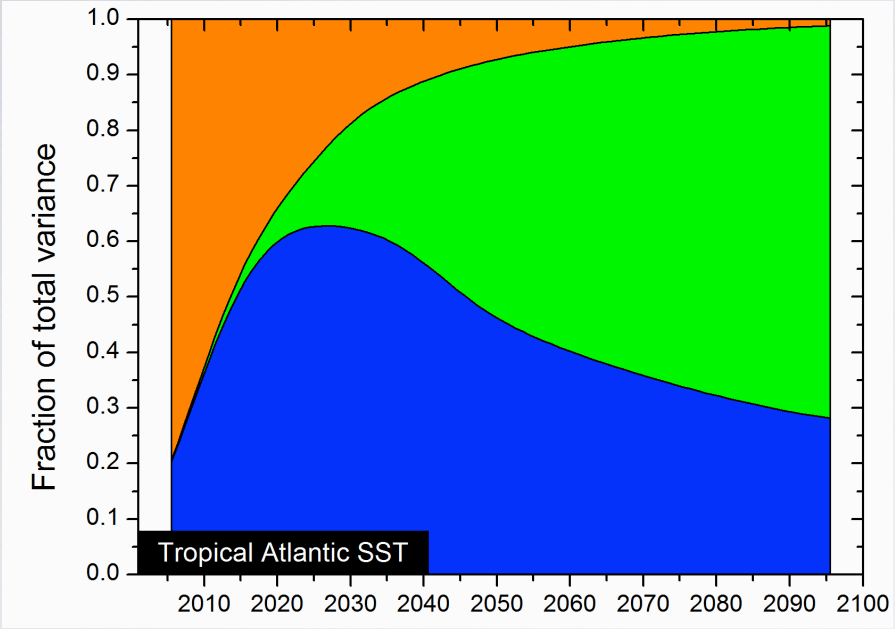


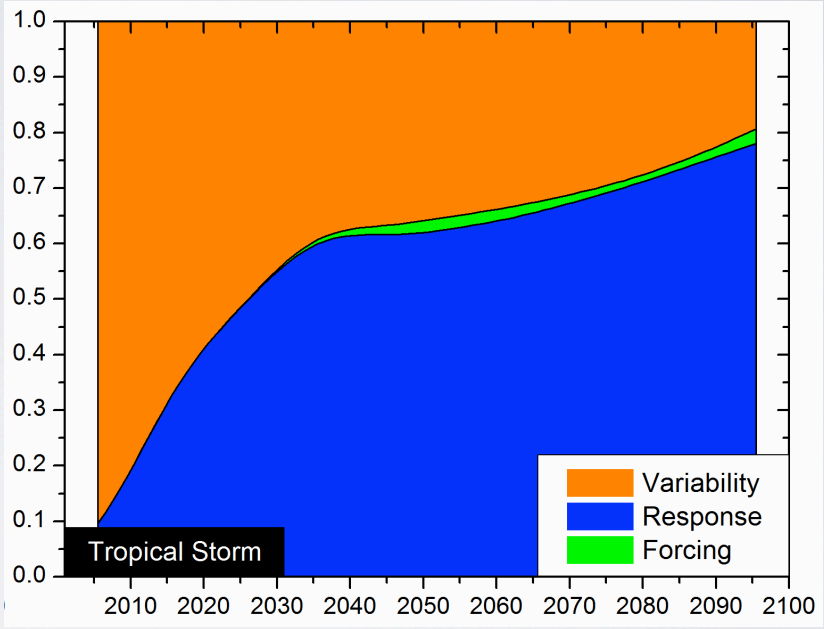
Villarini et al. (2011), Villarini and Vecchi (2012, in prep.)

Sources of uncertainty (after Hawkins and Sutton, 2009)

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

Key sources of uncertainty for decadal hurricane activity projections





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

Partitioning for North Atlantic SST resemble that for other regional temperatures:

- Short term: Variability
- Medium term: Response
- Long term: Forcing & *Response*

Even though Atlantic SST a predictor, partitioning for NA Tropical Storms distinct:

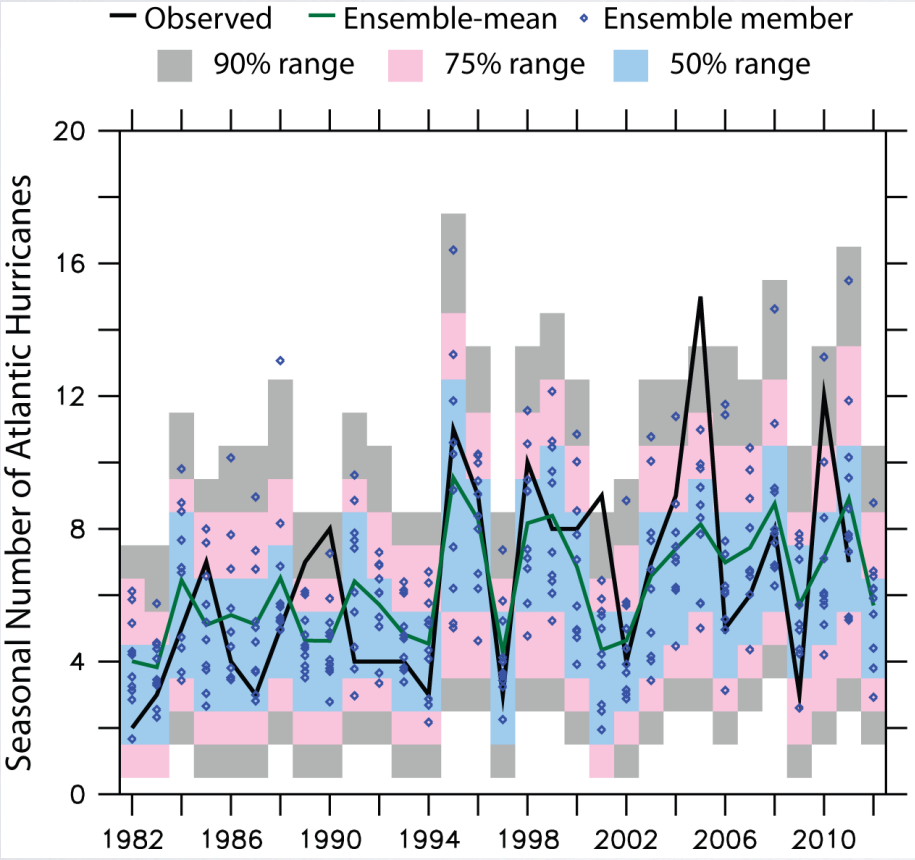
- Short term: Variability
- Medium term: Response & Variability
- Long term: Response & *Variability*

Experimental Extended (one year lead) Atlantic Hurricane Forecasts

http://www.gfdl.noaa.gov/hyhufs

GFDL "HyHuFS ": Experimental forecast for next season

- Hybrid (statistical-dynamical) Hurricane Forecast System: January initialization
- Retrospective performance (1982-2009, with 2010-2011 based on actual forecasts)



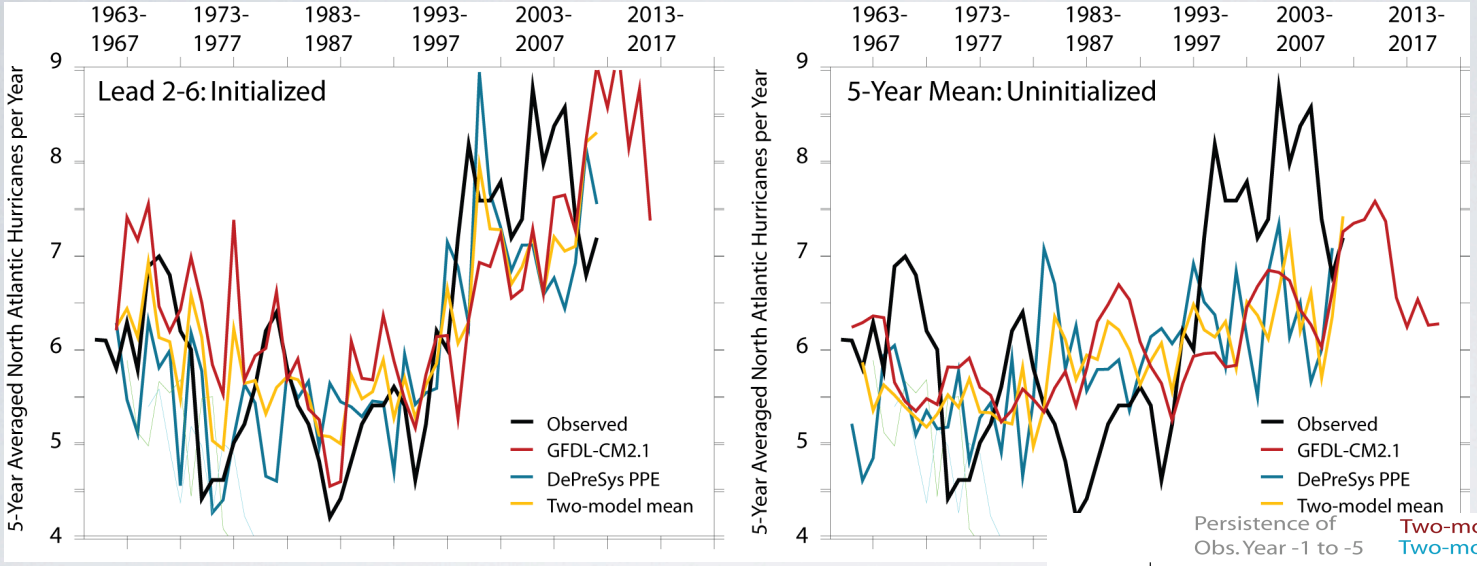
Correlation:
r = 0.66

EXPERIMENTAL:
NOT OFFICIAL
FORECAST

Source: Vecchi et al. 2011 Monthly Weather Review.

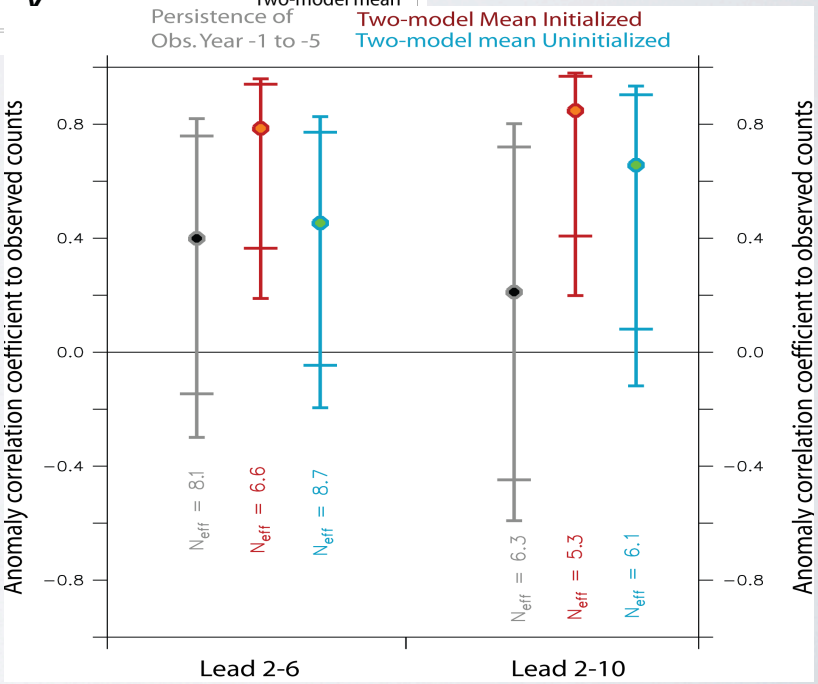
Experimental decadal predictions

Hybrid system: statistical hurricanes, dynamical decadal climate forecasts



EXPERIMENTAL: NOT OFFICIAL FORECAST

- 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.



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

Experimental decadal predictions

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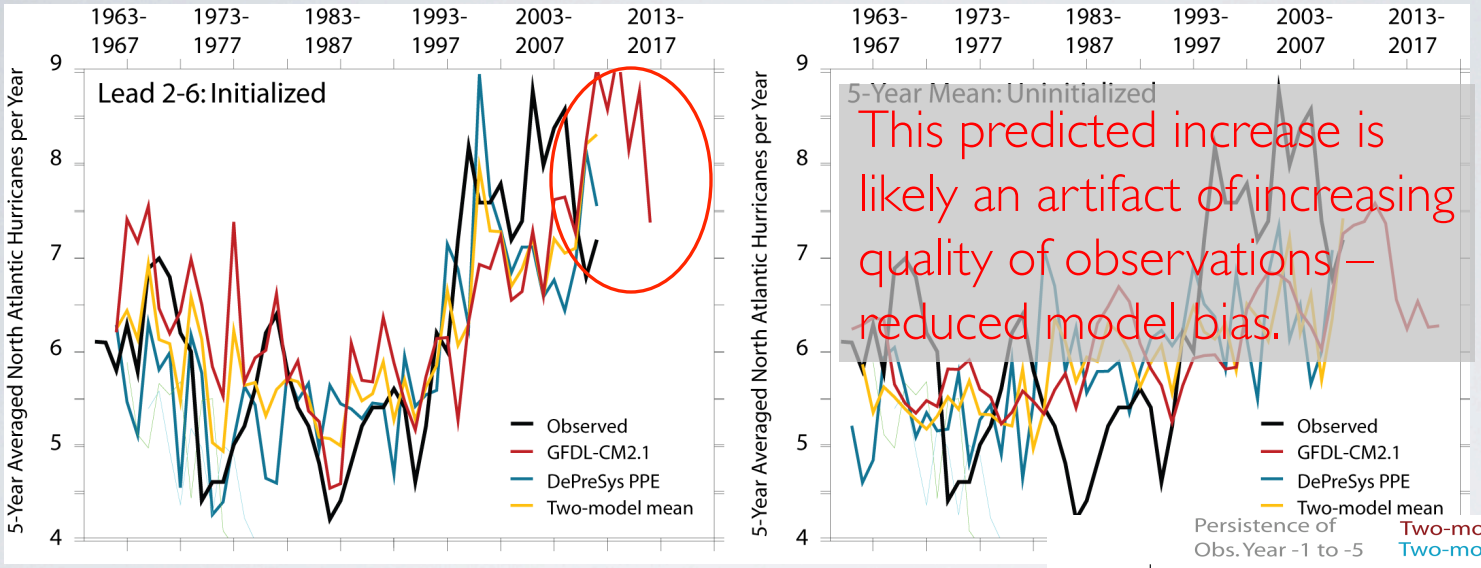

This predicted increase is likely an artifact of increasing quality of observations – reduced model bias.

EXPERIMENTAL: NOT OFFICIAL FORECAST

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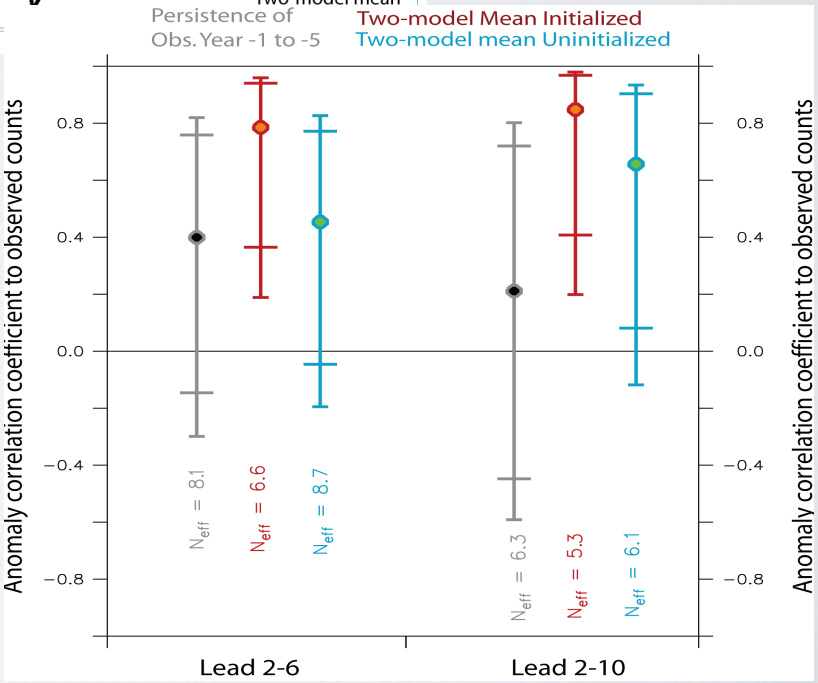

Vecchi et al. (2012 in prep.), see also Smith et al. (2010, Science)

Topics addressed

- Recorded century-scale increase in Atlantic hurricane frequency consistent with observing system changes.

  Issues with intensity records remain.

  It is premature to conclude we have seen hurricane change due to CO_2

- Statistical and dynamical models allow estimates of future activity:
  - Next couple of decades: internal variability dominant player (some may be predictable, some not)
  - NA Hurr. Response to GHG: likely fewer, probably stronger.
  - Aerosol forcing and response a key uncertainty.

- 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 better than alternative…

Change in baseline risk due to climate

- Forced climate change (refs. at end)
  - Due to greenhouse gases *(e.g., Emanuel et al. 2008 Bull. Amer. Meteorol. Soc., Knutson et al. 2008 Nature Geosci., Zhao et al. 2009 J. Clim., Bender et al. 2010, Science, Villarini et al. 2011 J. Clim.…)* forcing changes slowly (i.e., less uncertain), global impact more well constrained than regional impact, incremental impact over next decade may be smaller than variability. Sea level rise
  - Due to aerosols *(e.g., Mann and Emanuel 2006 EOS, Evan et al. 2011, Nature, Villarini and Vecchi 2012 in prep)* Could be influential, forcing can change rapidly (i.e. uncertain), impact not yet fully understood, spatially heterogeneous.
- Internal climate variability
  - Decadal modes of variation *(e.g., Zhang and Delworth 2006, Smith et al. 2010…)* Ongoing efforts to assess predictability of climate and its impacts – variability, predictability and impacts likely regionally dependent.
  - Rectified extreme interannual events (e.g., 1997-8 El Niño): Current estimates of predictability don't extend beyond a few seasons. *(e.g., Camargo et al. 2009 WMO; Vecchi et al. 2011 Mon. Wea. Rev).*

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