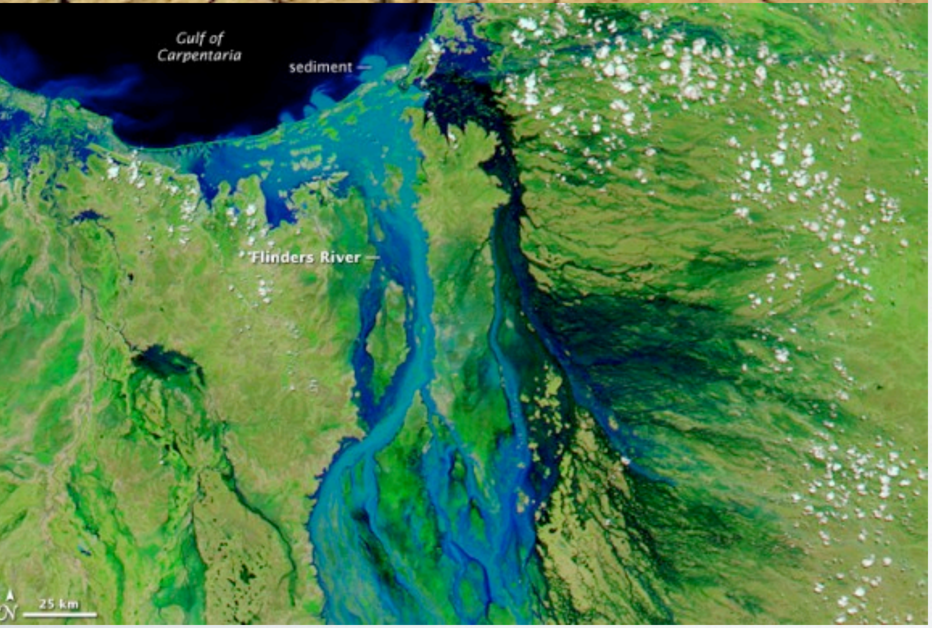


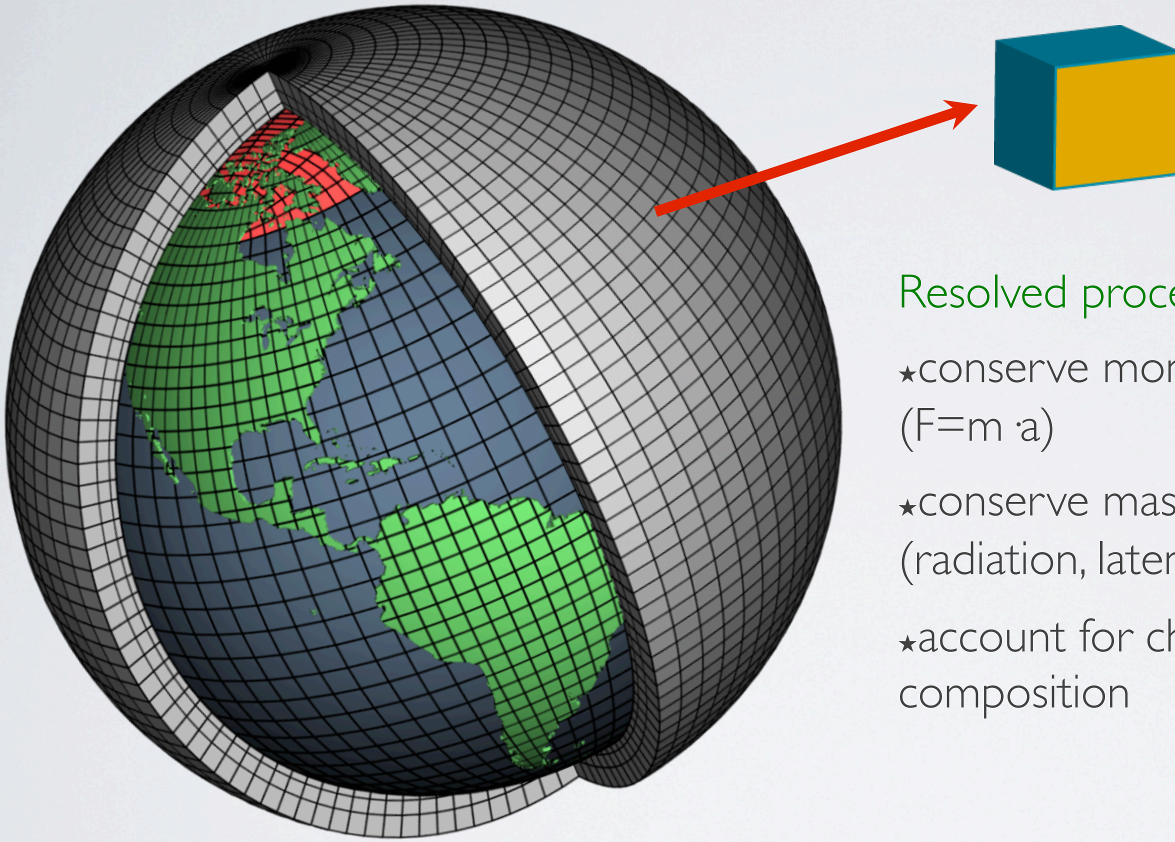
Images: NASA

Precipitation Response in Climate Models: What's new in CMIP5? (thus far)

Gabriel Vecchi
NOAA/GFDL
Princeton, NJ

Gabriel.A.Vecchi@noaa.gov

Global climate model: Mathematical representation of processes controlling ocean, atmosphere, land and ice system (and interactions)



In each grid cell:

Resolved processes:

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

Parameterized processes:

- ⋆spatial/temporal resolution or understanding limit explicit solution.
- ⋆e.g., clouds, convection, etc.
- ⋆key to much of uncertainty

"Force" with solar radiation, structure of continents, land use and atmospheric composition (CO_2, O_3, aerosols, volcanoes, etc.)

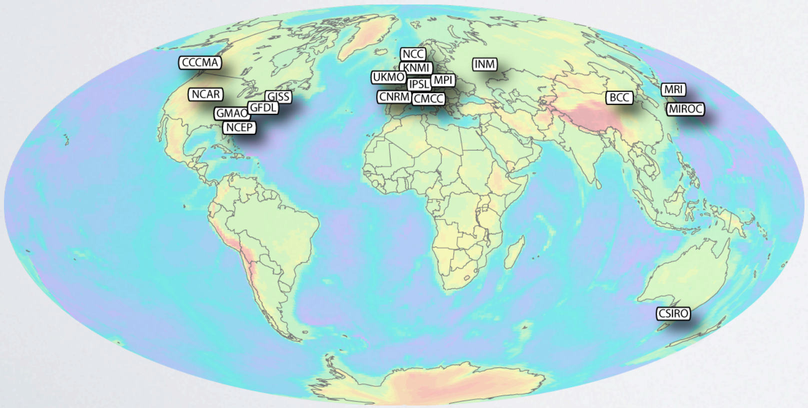
Coupled Model Intercomparison Project #5 (CMIP5)

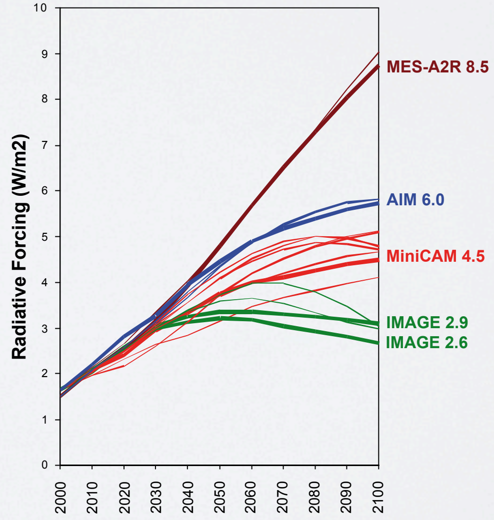
Taylor et al. (2012)

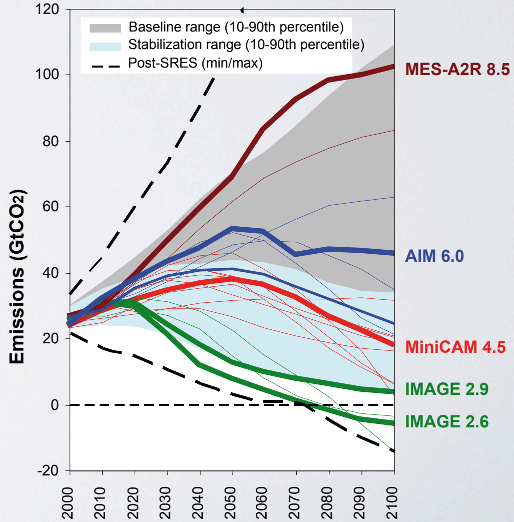
- Coordinated GCM experiments to address key issues in climate science:

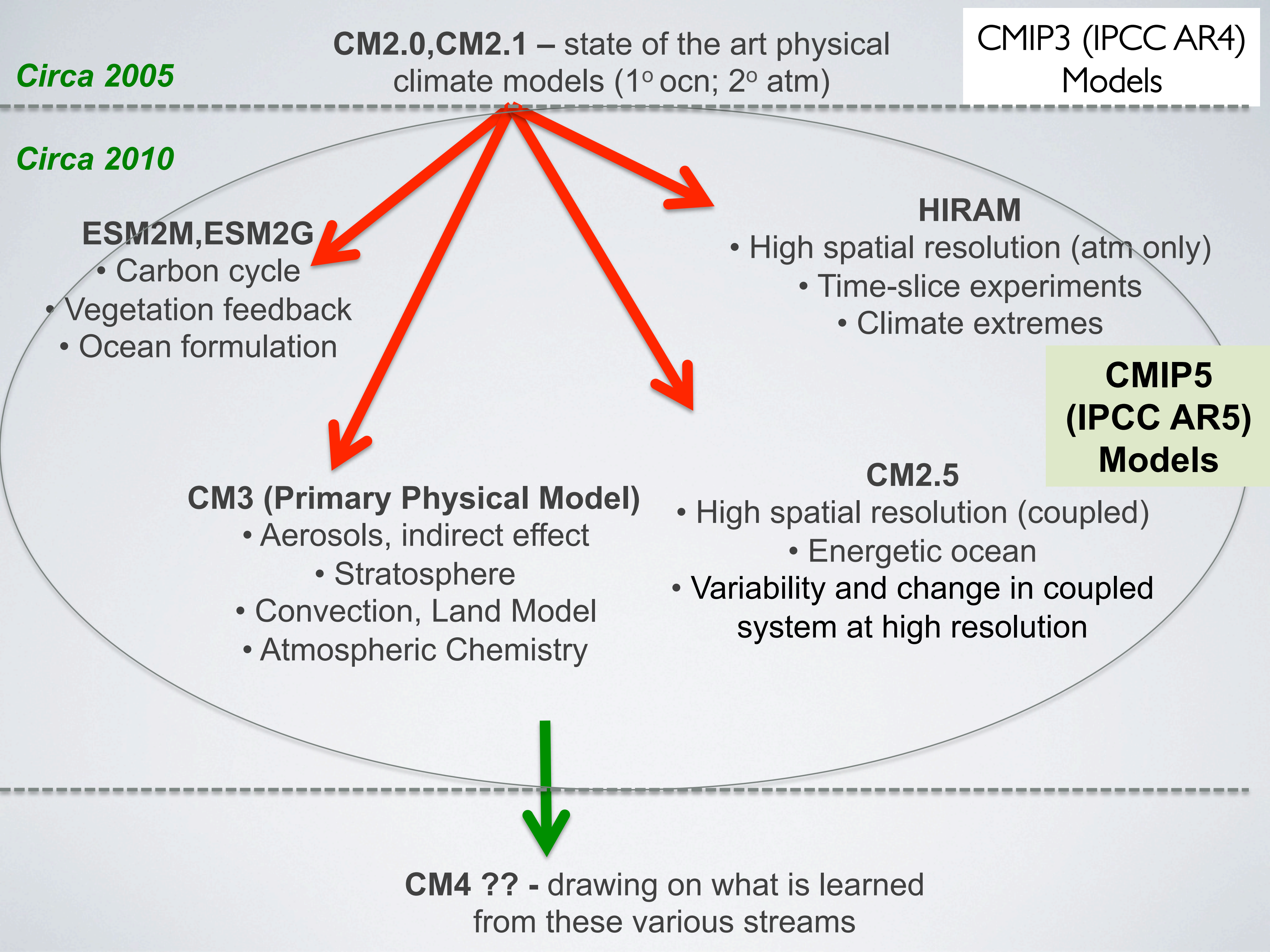
  Paleoclimate, response to CO_2, aerosols, volcanoes, high-resolution, decadal predictability, earth-system modeling, geoengineering…

- Around 20 centers worldwide (including GFDL)
- Entering the "analysis" phase: centers have made data publicly available
- Follows on to CMIP3 (mid-2000s), CMIP2 (late 1990s) and CMIP (early 1990s).
- Some results will be assessed in IPCC-AR5



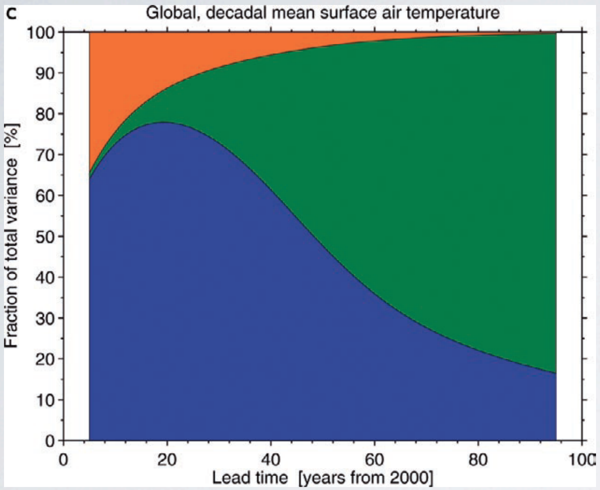




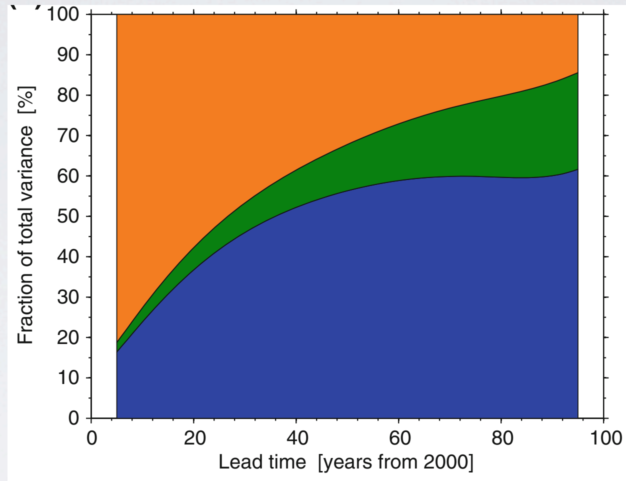

CMIP3 (IPCC AR4) Models
Circa 2005
CM2.0,CM2.1 – state of the art physical climate models (1° ocn; 2° atm)
Circa 2010
ESM2M,ESM2G
• Carbon cycle
• Vegetation feedback
• Ocean formulation
HIRAM
• High spatial resolution (atm only)
• Time-slice experiments
• Climate extremes
CMIP5 (IPCC AR5) Models
CM3 (Primary Physical Model)
• Aerosols, indirect effect
• Stratosphere
• Convection, Land Model
• Atmospheric Chemistry
CM2.5
• High spatial resolution (coupled)
• Energetic ocean
• Variability and change in coupled system at high resolution
CM4 ?? - drawing on what is learned from these various streams

Multiple models, scenarios and ensembles: to address key uncertainty sources in projections

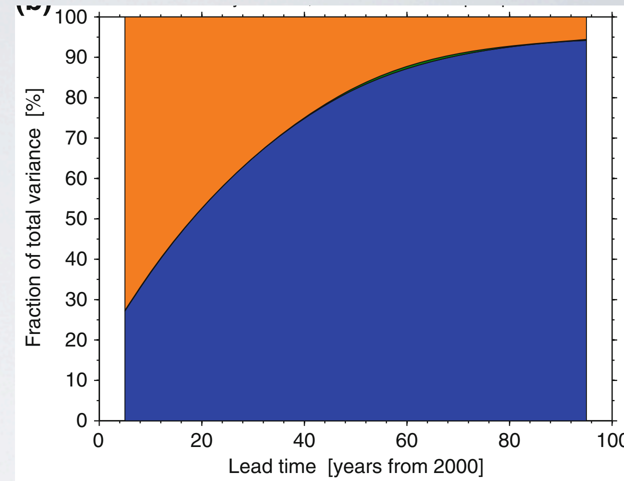
Global Surface Temp



SE Asia JJA Precip



Sahel JJA Precip

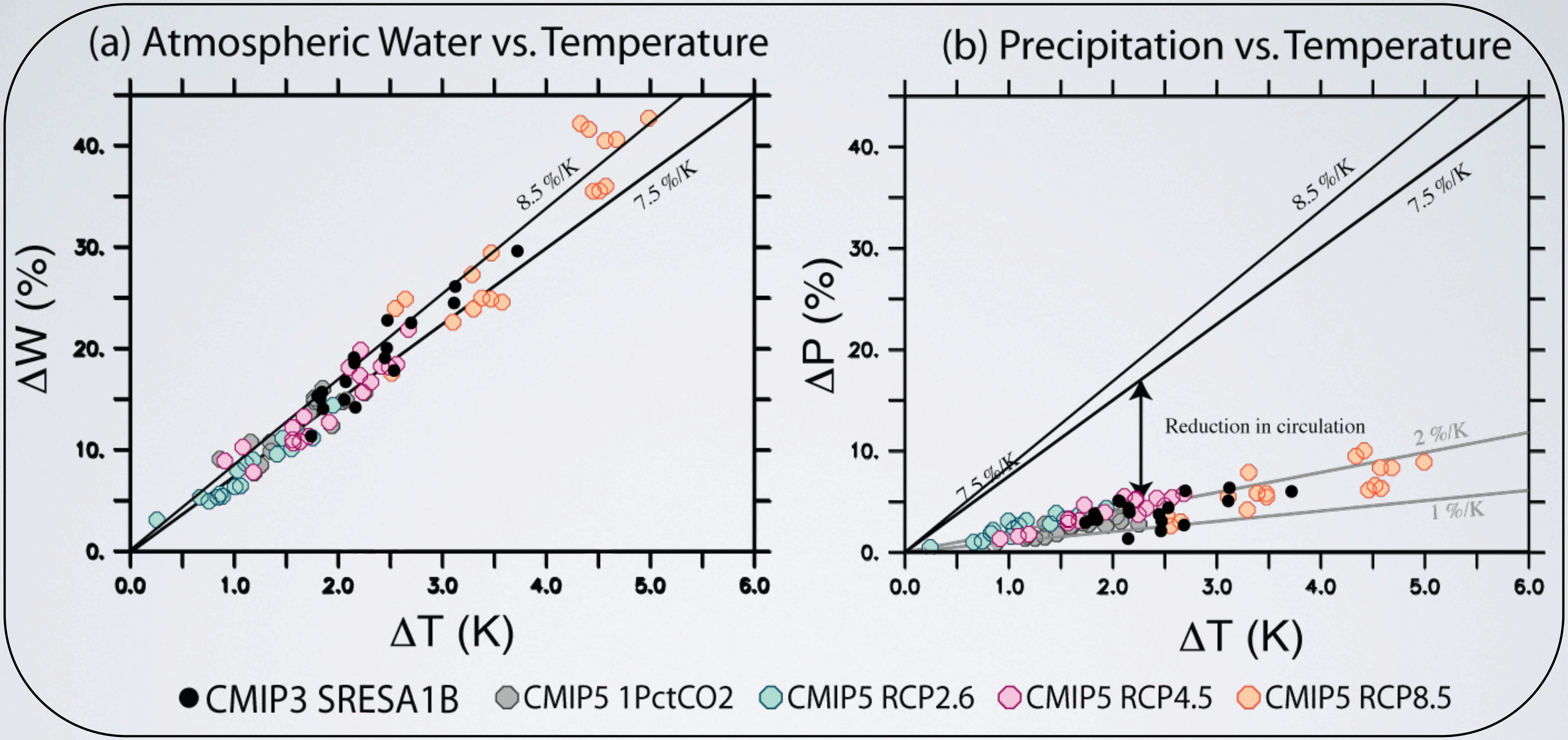


Sources of uncertainty (after Hawkins and Sutton 2009, 2011)

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

Precipitation and CO_2 in CMIP5

Global-mean response of precipitation and humidity has not changed in recent models

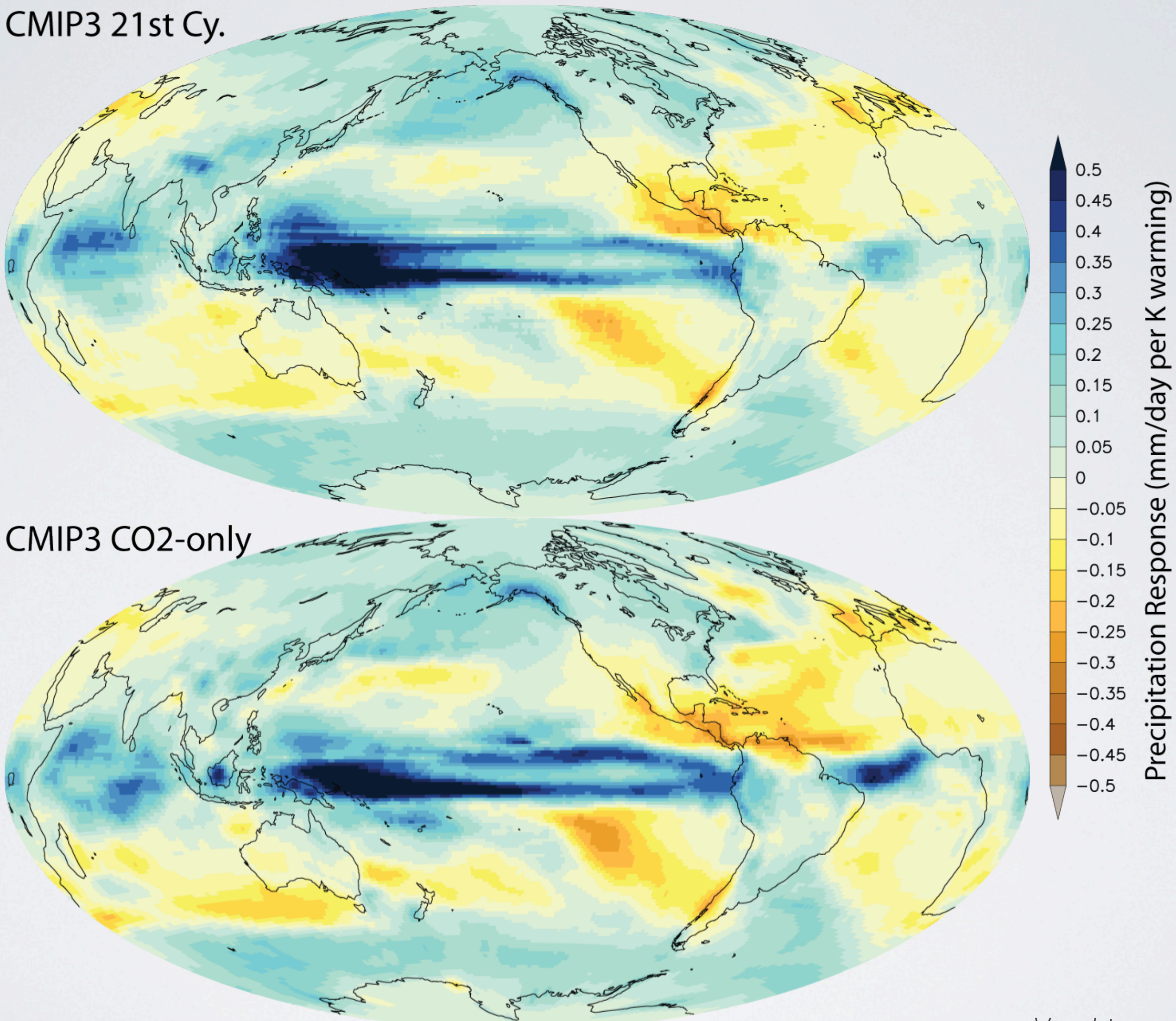


Increase like Claussius-Clapeyron

Increase controlled by radiative cooling

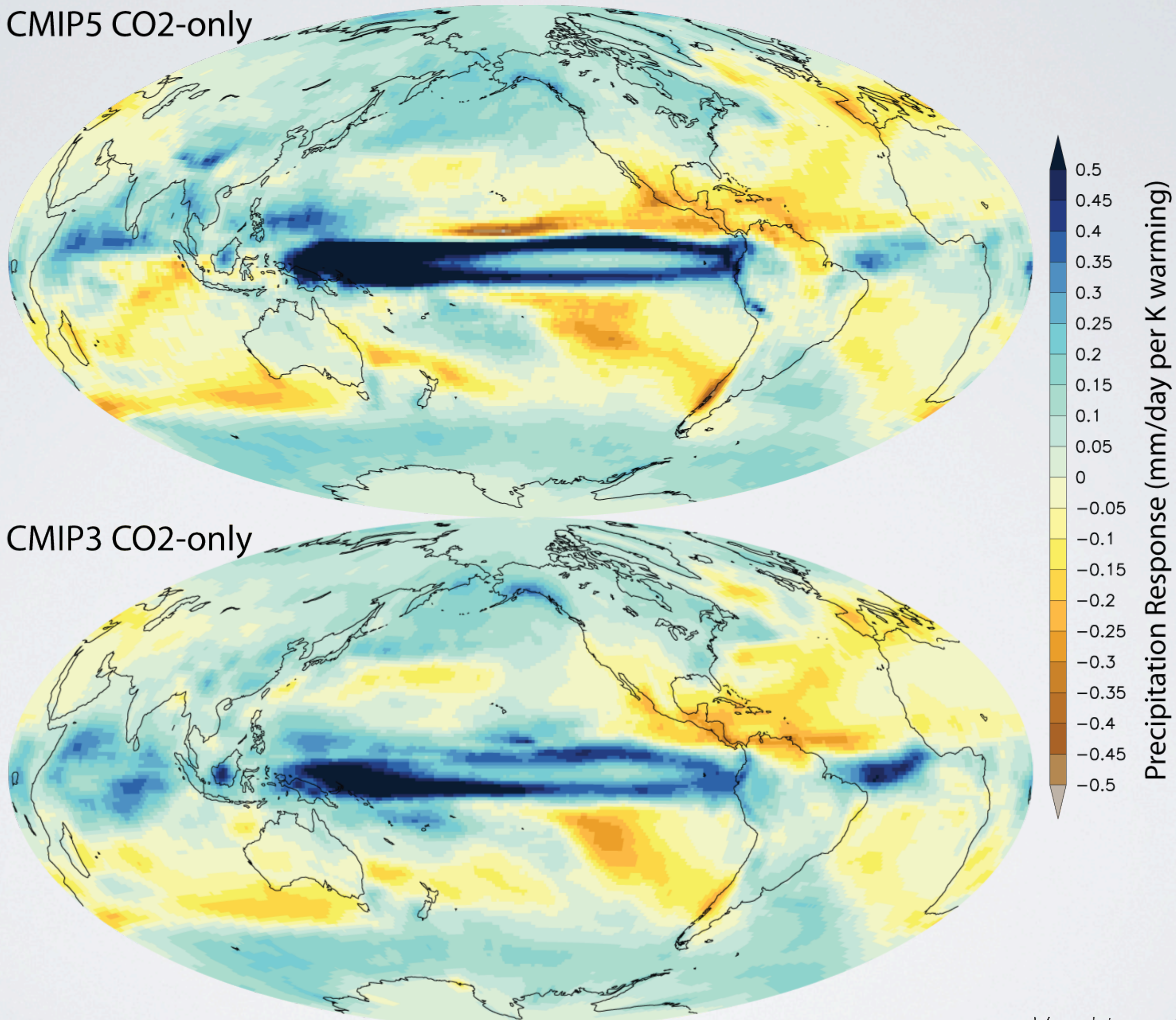
Held and Soden (2006), Vecchi et al. (2012, in prep.)

CO_2 Dominated CMIP3 Multi-model Precipitation Projections



Vecchi et al. (2012, in prep.)

CMIP5 precipitation response to CO_2 similar to that of CMIP3



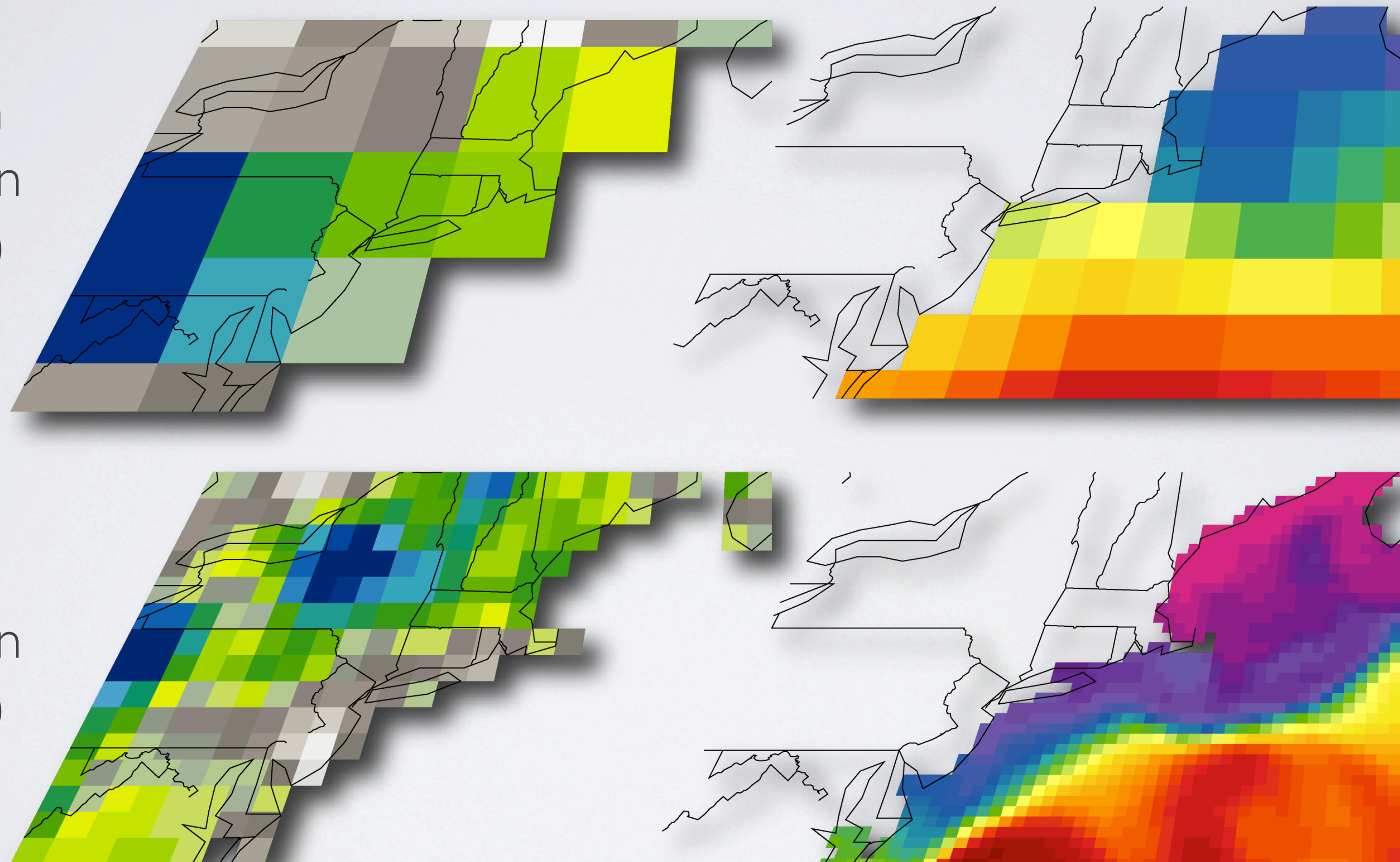
Vecchi et al. (2012, in prep.)

Resolution (computer power) can help represent processes and phenomena

c.f. Sarah Kapnick's talk

Medium resolution (CM2.1)

High resolution (CM2.5)

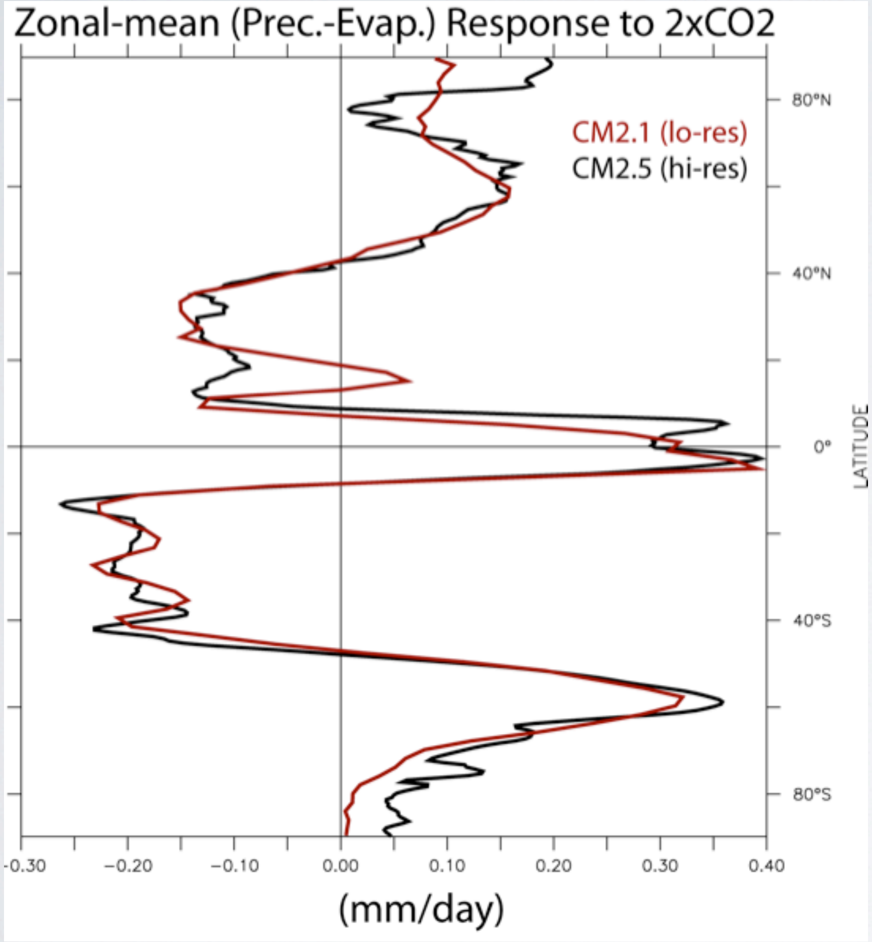


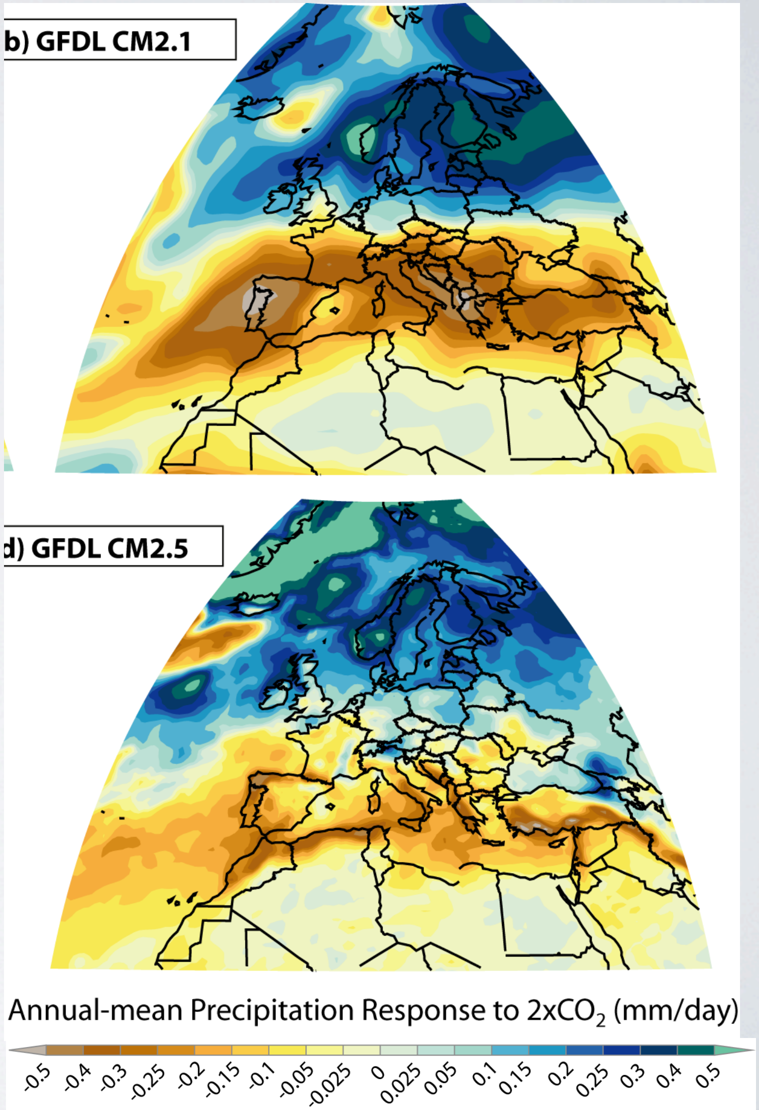
Precipitation

Ocean temp.

Resolution: response of precipitation to CO_2 can show big differences in regional scale, but not global

Delworth et al. (2012, J. Clim.)





"Wet get wetter, dry drier"

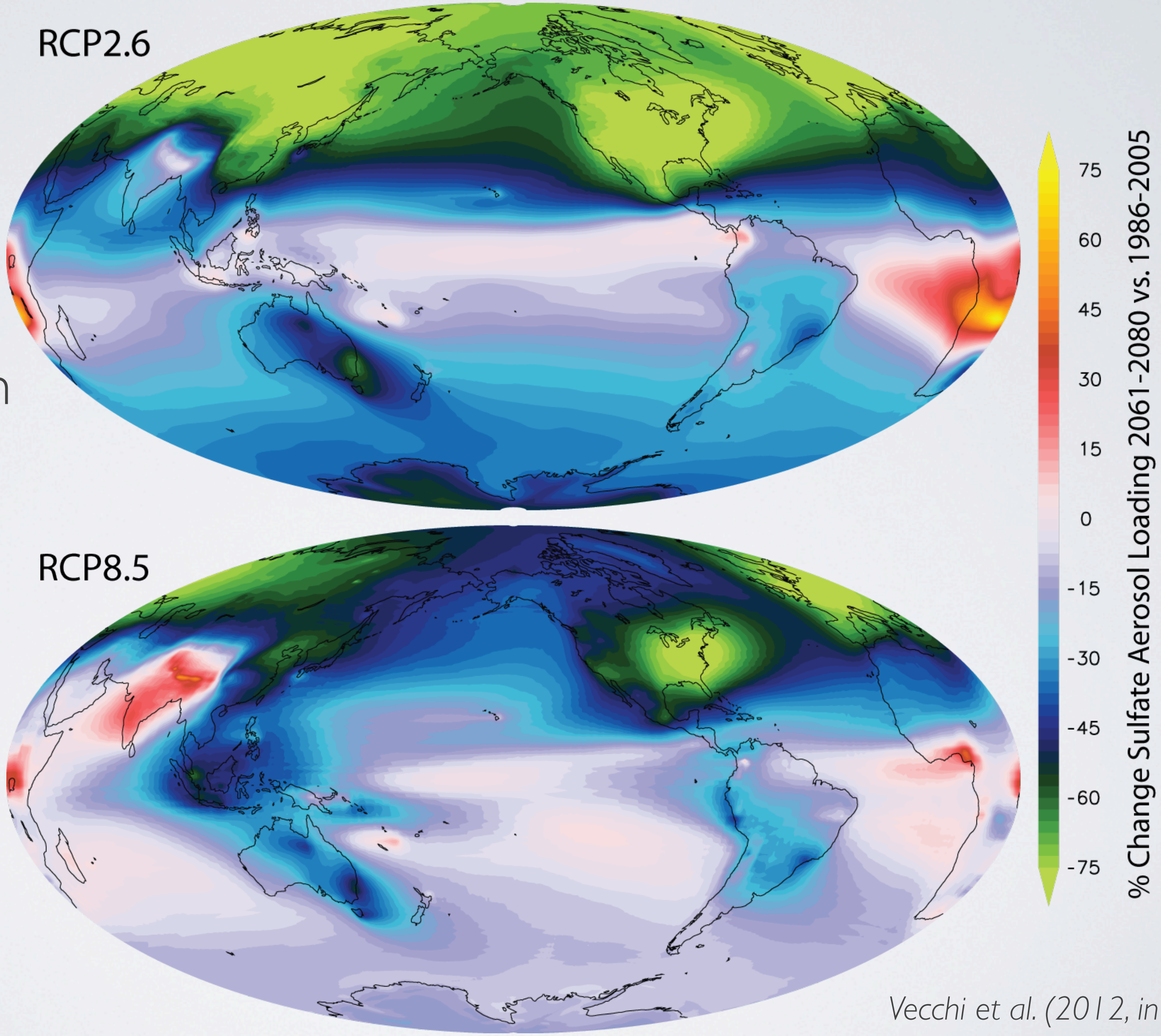
Non-greenhouse forcing

New 21st Century Scenarios include big aerosol forcing, many new models have more ways to respond to aerosols

2100 CO_2
~1.2x1990

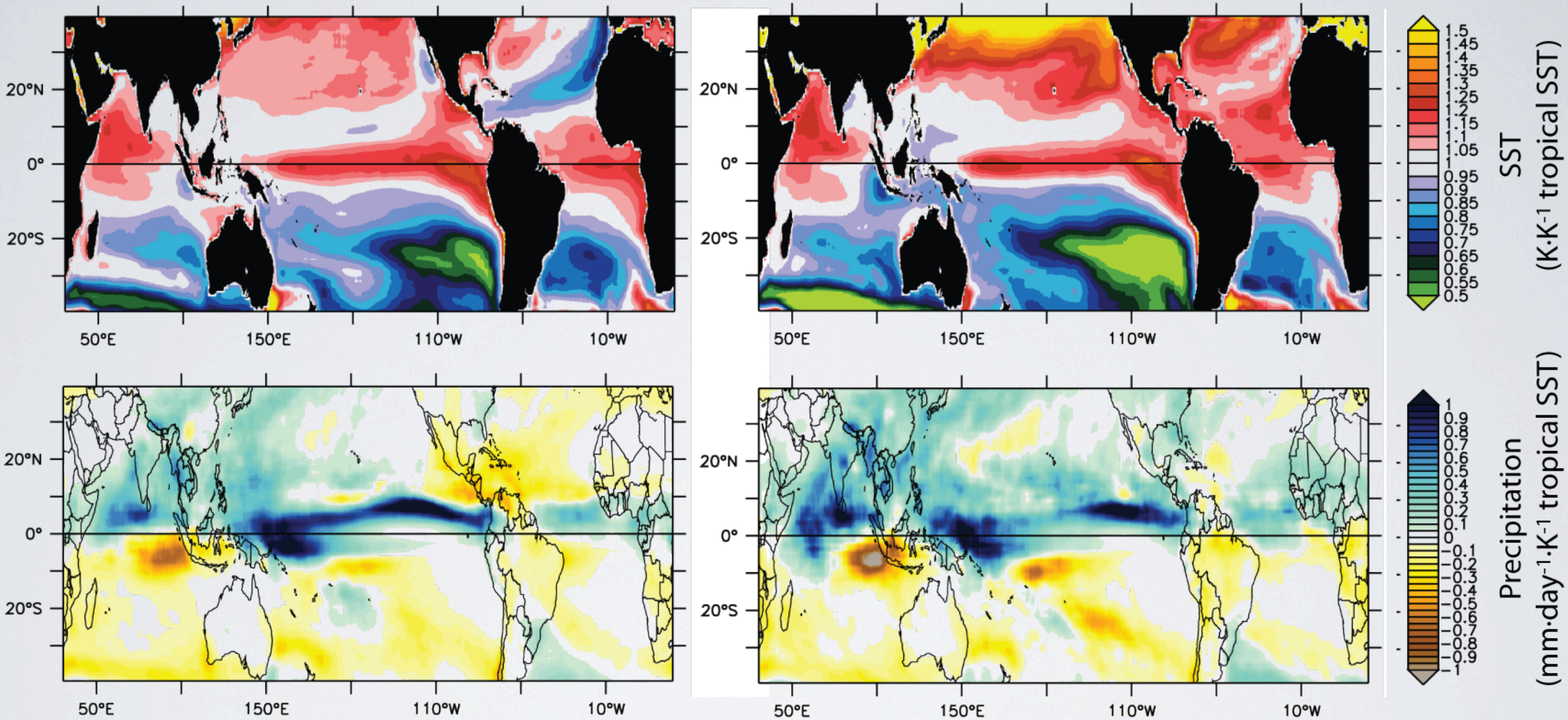
Projected pollution controls: reduced aerosols

2100 CO_2
~4x1990



Vecchi et al. (2012, in prep.)

Response to aerosol changes seen in precipitation projections for 21st century in CMIP5 models



Response to CO_2 increase

RCP2.6: Small CO_2 increase & large aerosol decrease

Jun-Nov averages
left at CO2 doubling
right 2051-2070

Vecchi et al. (2012, in prep.)

Projected precipitation change can differ substantially from CO_2 alone, "pattern scaling" does not hold

No Δaerosol

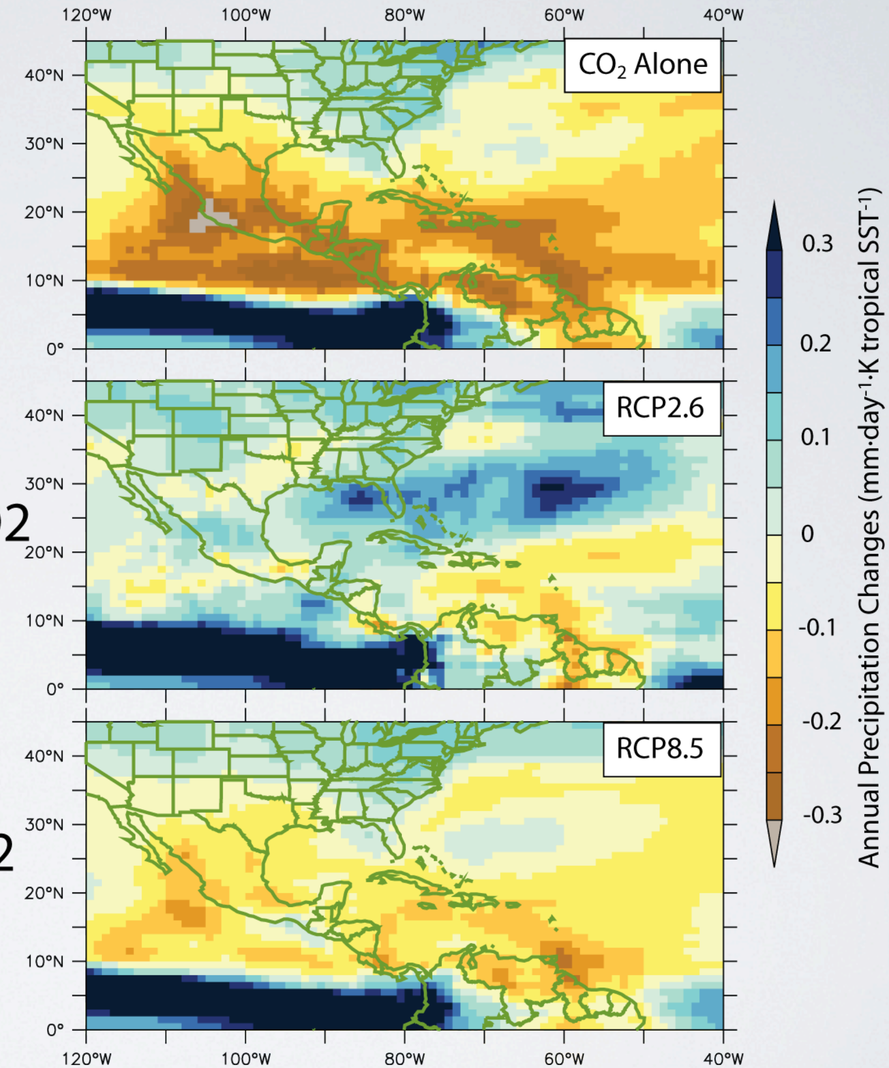
2xCO2

Big Δaerosol

~1.25xCO2

Med. Δaerosol

~4xCO2



CO_2 shows transient response at doubling
Projections show 2081-2100 minus 1986-2005

Vecchi et al. (2012, in prep.)

CO_2 and aerosols influential on hydrological changes – and their uncertainties

These are my interpretations of current "state of science", qualitative

	Knowledge of past forcing	Knowledge of near-term future forcing	Knowledge of century-scale future forcing	Understanding & Ability to Model Impact
CO_2	Good	Decent (large inertia)	Medium-Low (human choices matter, biology, etc.)	Medium on large-scale Medium-Low on local scale
Aerosols	Low (not well mixed in space, many timescales, many types)	Low (human choices matter; don't understand all processes)	Low (human choices matter; don't understand all processes)	Low (don't understand all processes, processes occur across many scales)

References:

- Delworth, T.L. and coauthors. Simulated climate and climate change in the GFDL CM2.5 high-resolution coupled climate model. *J. Climate* doi:10.1175/JCLI-D-11-00316.1 (2012; in press).
- Hawkins, E., & R. Sutton. The potential to narrow uncertainty in regional climate predictions. *Bulletin of the American Meteorological Society* **90**, 1095–1107 (2009).
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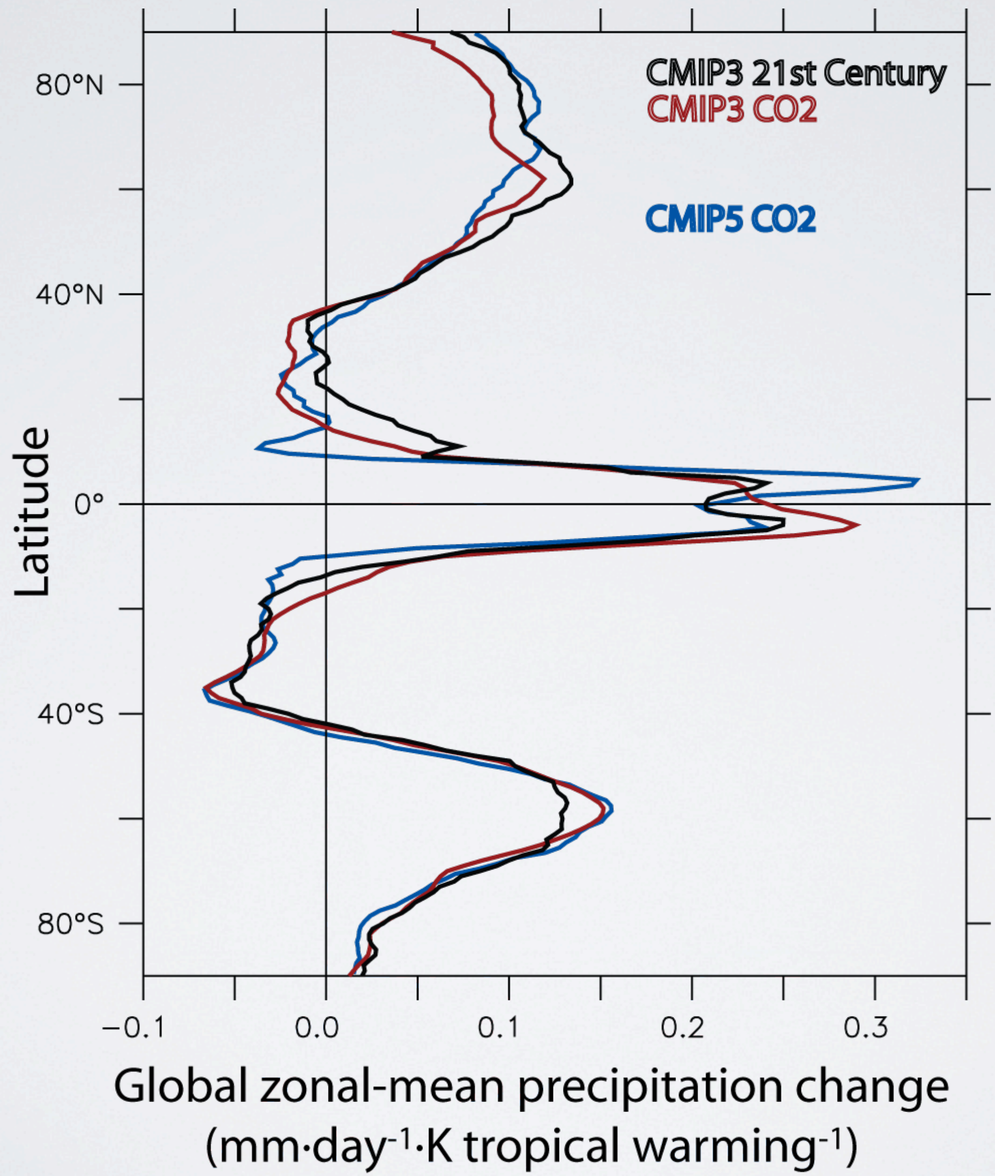
- Held, I. M. & Soden, B. J.. Robust responses of the hydrological cycle to global warming. *J. Clim*. **19**, 5686-5699 (2006).
- Taylor, K.E., R.J. Stouffer, & G.A. Meehl. An overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society*, doi: 10.1175/BAMS-D-11-00094.1, (2012; in press).
- Vecchi, G.A., B.J. Soden, I.M. Held, and coauthors. The response of the hydrological cycle, atmospheric circulation and conditions impacting tropical cyclones in the CMIP5 suite. (2012, in preparation)

Multi-model zonal-mean precipitation response to CO_2 increase is similar to previous generation



Vecchi et al. (2012, in prep.)