Moving from Global to Regional Projections of Climate Change

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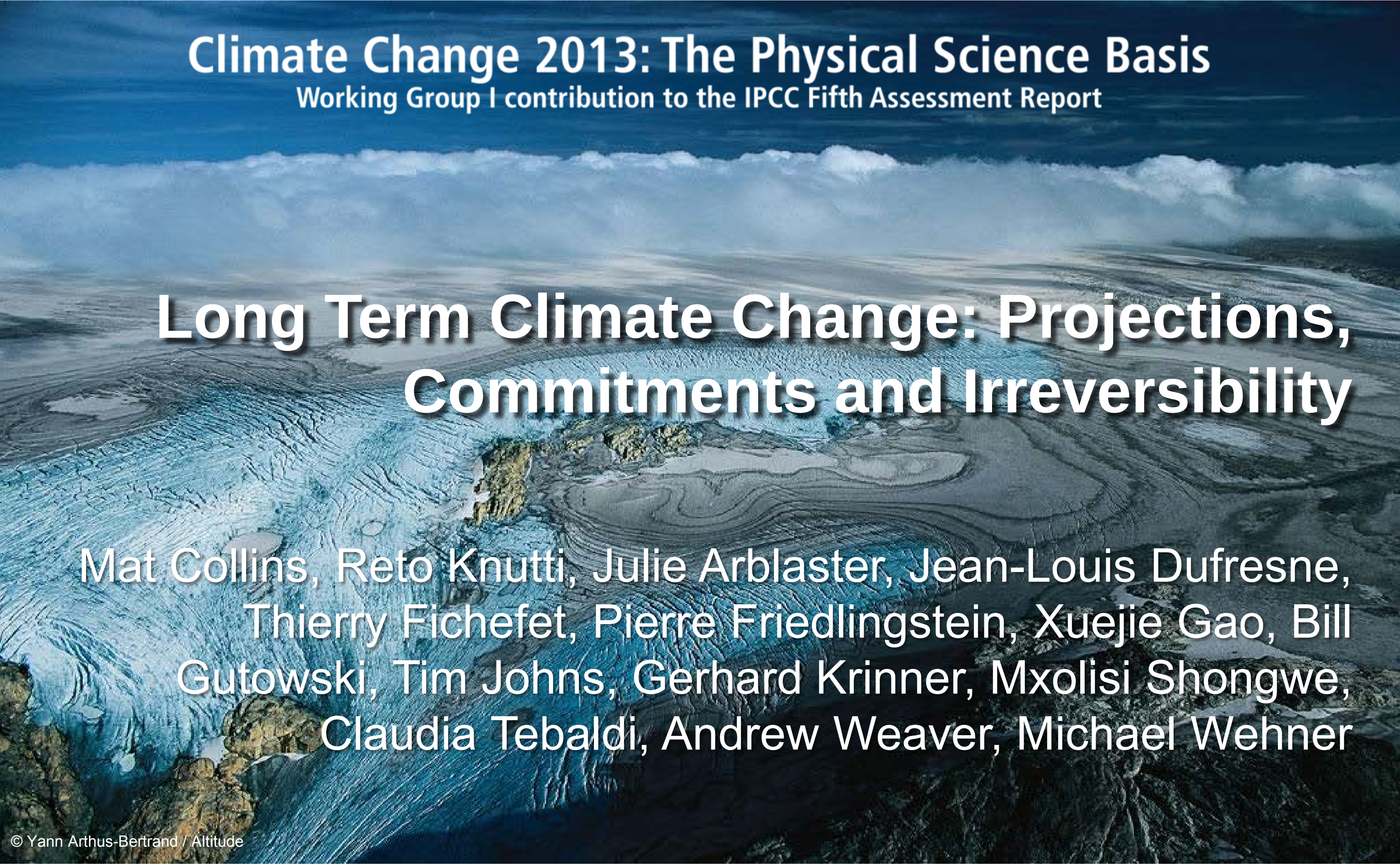


Climate Change 2013: The Physical Science Basis

Working Group I contribution to the IPCC Fifth Assessment Report

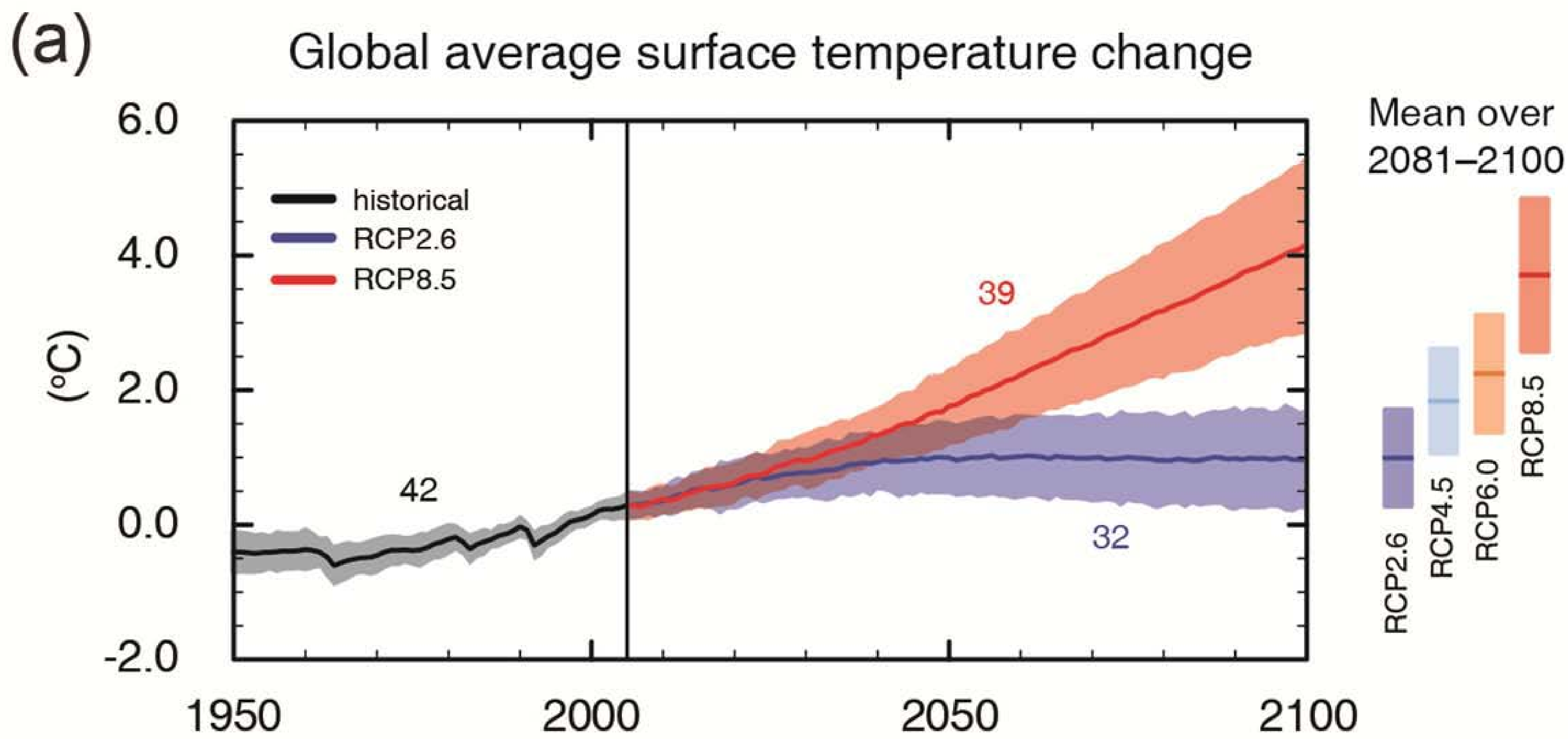
Long Term Climate Change: Projections, Commitments and Irreversibility

Mat Collins, Reto Knutti, Julie Arblaster, Jean-Louis Dufresne, Thierry Fichefet, Pierre Friedlingstein, Xuejie Gao, Bill Gutowski, Tim Johns, Gerhard Krinner, Mxolisi Shongwe, Claudia Tebaldi, Andrew Weaver, Michael Wehner

ipcc
INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

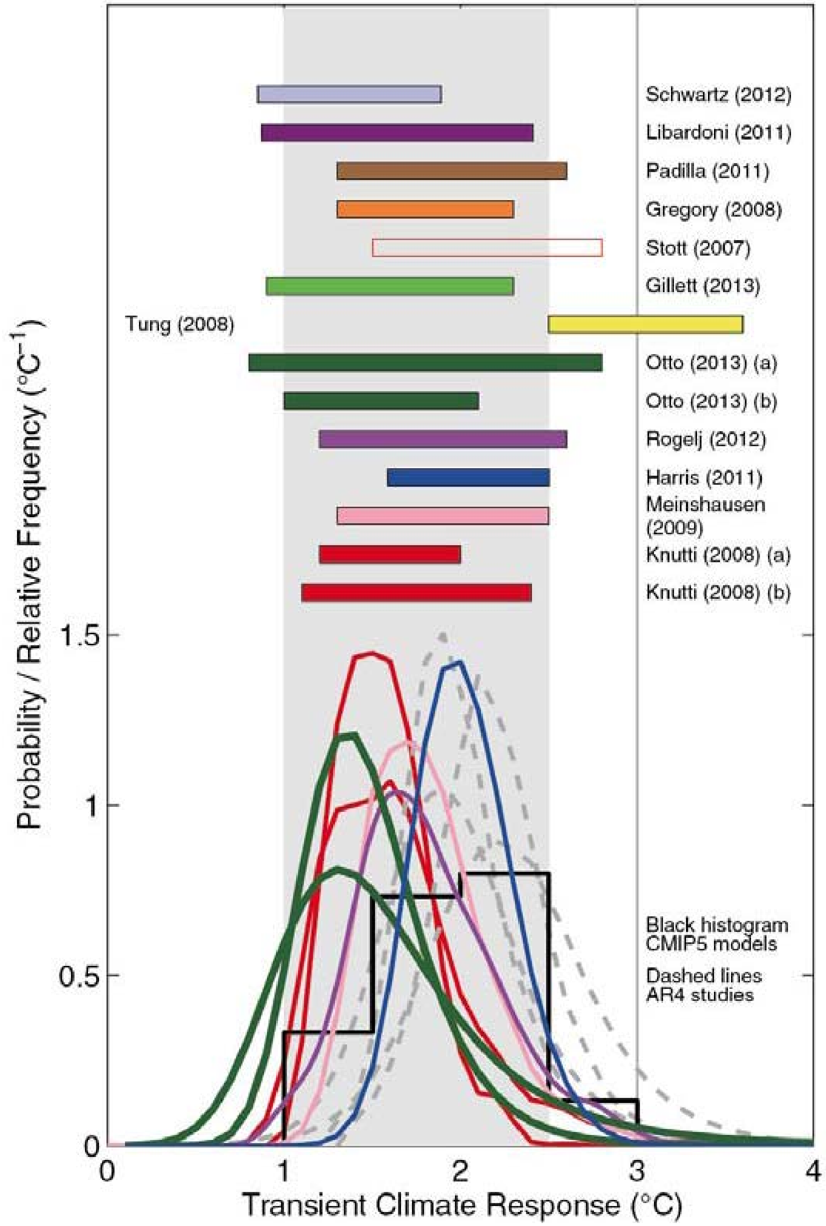
Global Mean Surface Air Temperature Change



Anomalies w.r.t 1986-2005 average

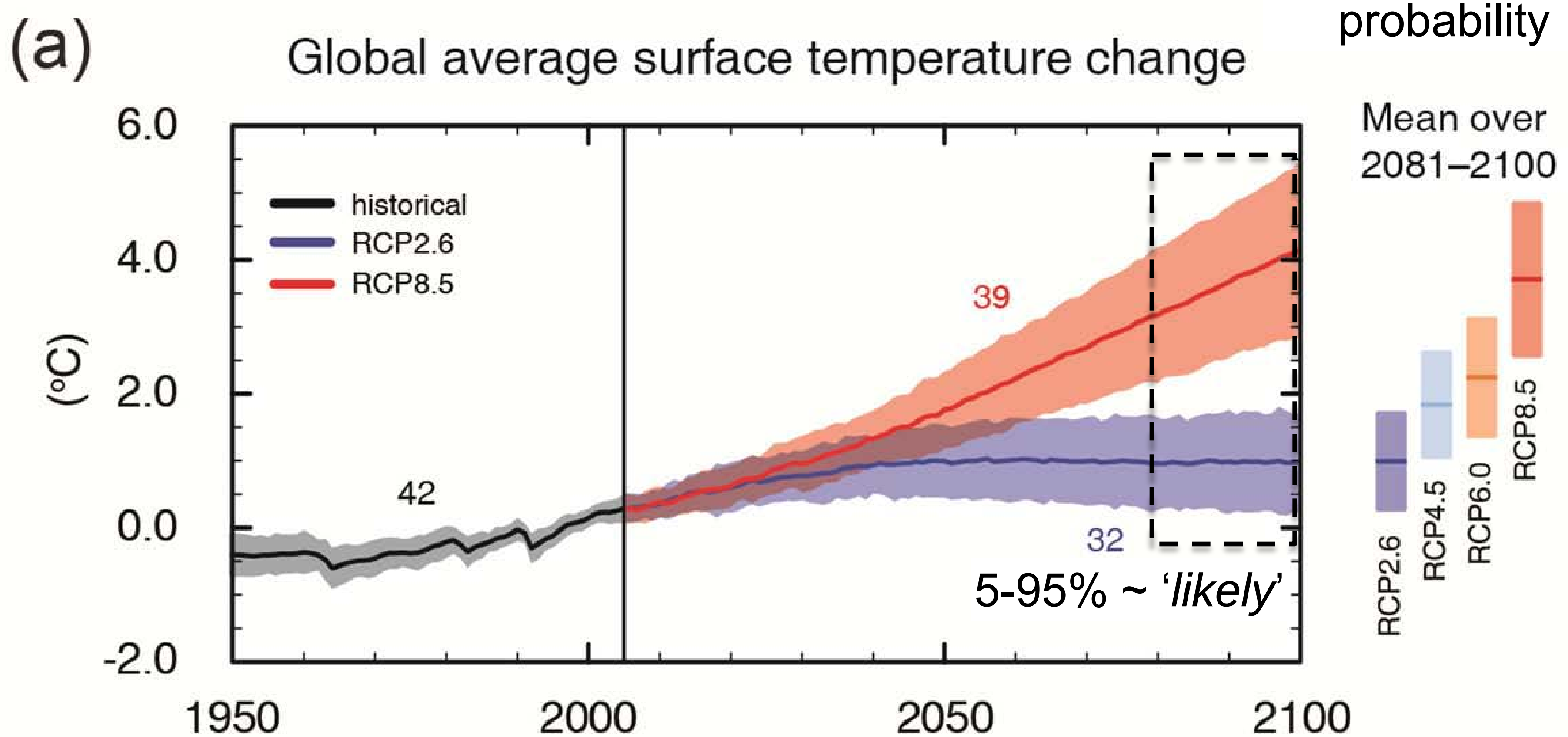
Global Temperature Assessment

•The transient climate response is *likely* in the range of 1.0°C to 2.5°C (*high confidence*) and *extremely unlikely* greater than 3°C
• The CMIP5 models coincide with this range
• The RCPs are dominated by greenhouse gas forcing by the end of the century
• Associate the 5-95% range of model simulations (+/- 1.64 standard deviations) with the *likely* range (66-100%)
• Only valid for *likely* (66-100%)
• Only valid for global mean temperature in long-term



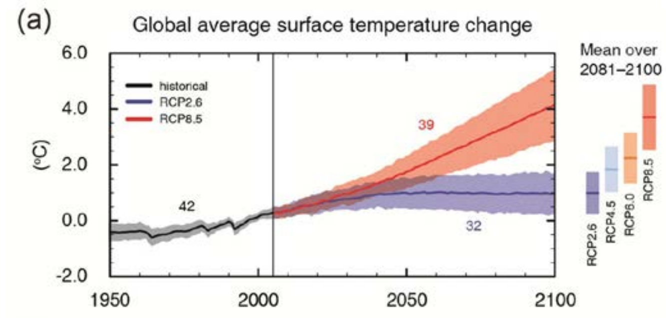
Global Mean Surface Air Temperature Change

likely = 66-100% probability



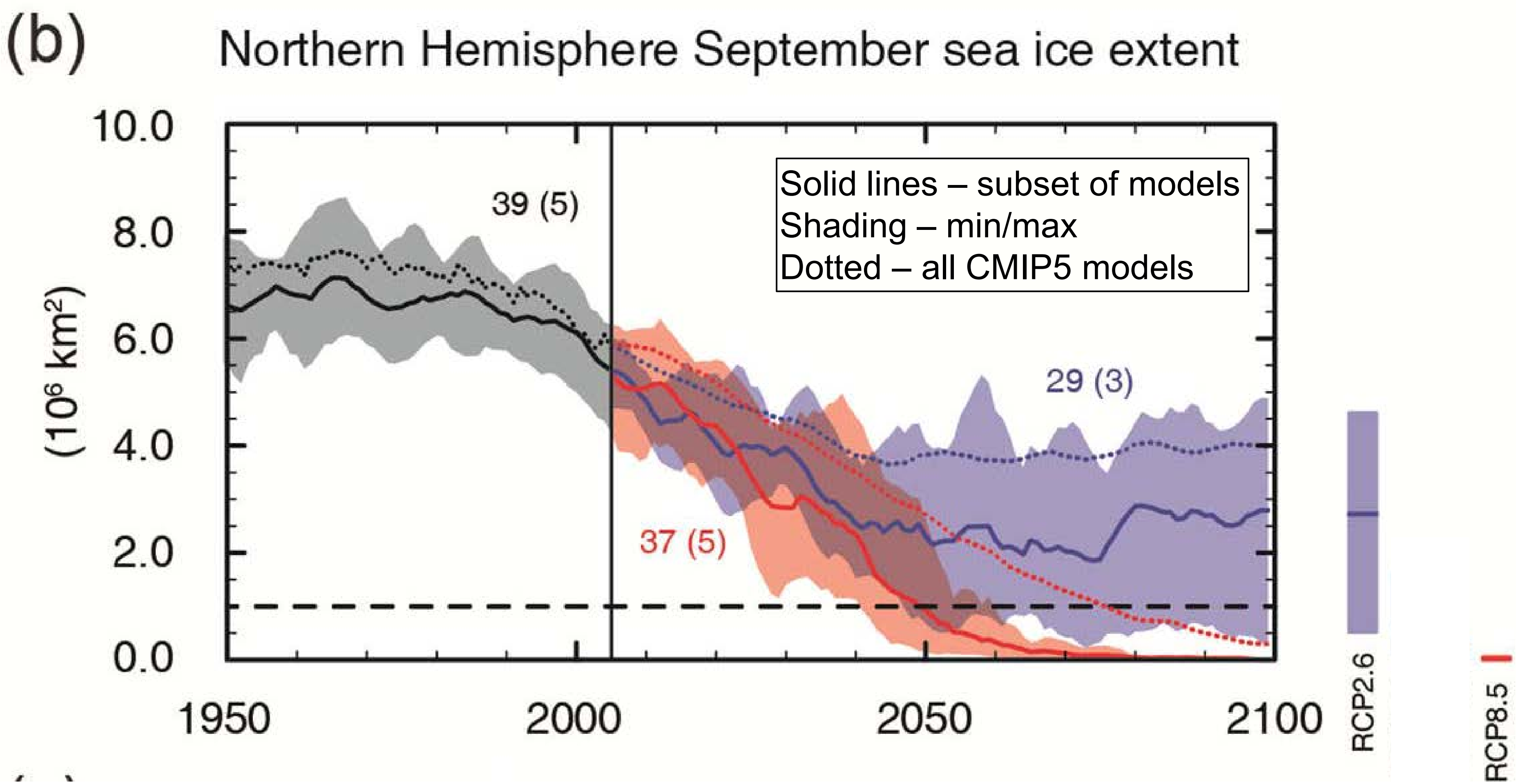
Assessing uncertainty and robustness in projections is much more that just counting CMIP models

Changes Conditional on Global Mean Temperature Rise



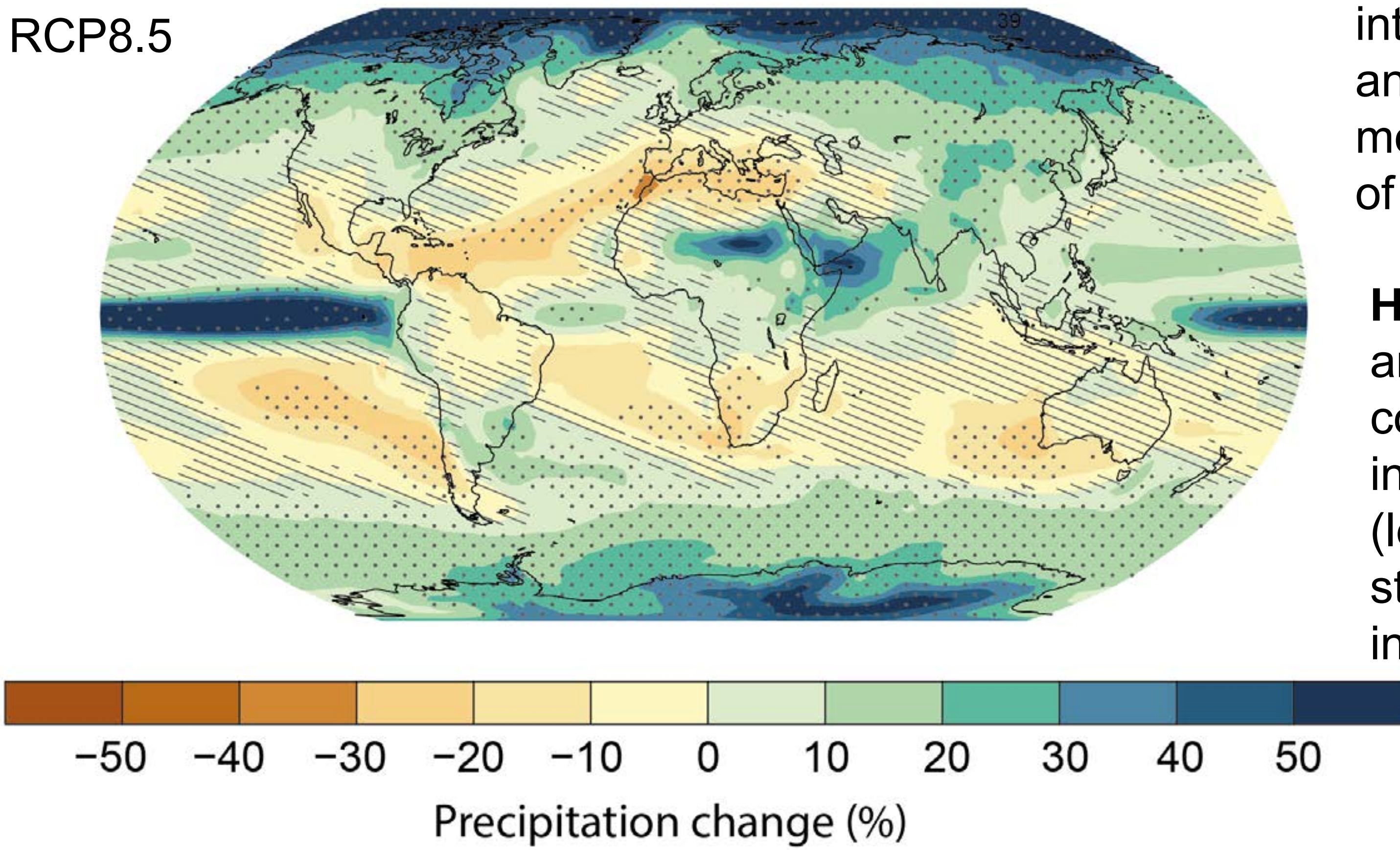
- High northern latitudes expected to warm most
- Land warms more than ocean surface
- More hot and fewer cold extremes
- Global mean precipitation increases but regional patterns of change not uniform
- Contrast between wet and dry regions and seasons to increase (with regional exceptions)
- Tropical atmospheric circulations expected to weaken, subtropics creep polewards
- Arctic summer sea-ice to melt back – ice free conditions *likely* by mid century under RCP8.5
- Permafrost and snow cover to retreat
- Atlantic Meridional Overturning Circulation (AMOC) to weaken but not collapse
- N. Hemisphere storm track changes – *low confidence*

Cryosphere



Requires the use of physical understanding in quantifying changes

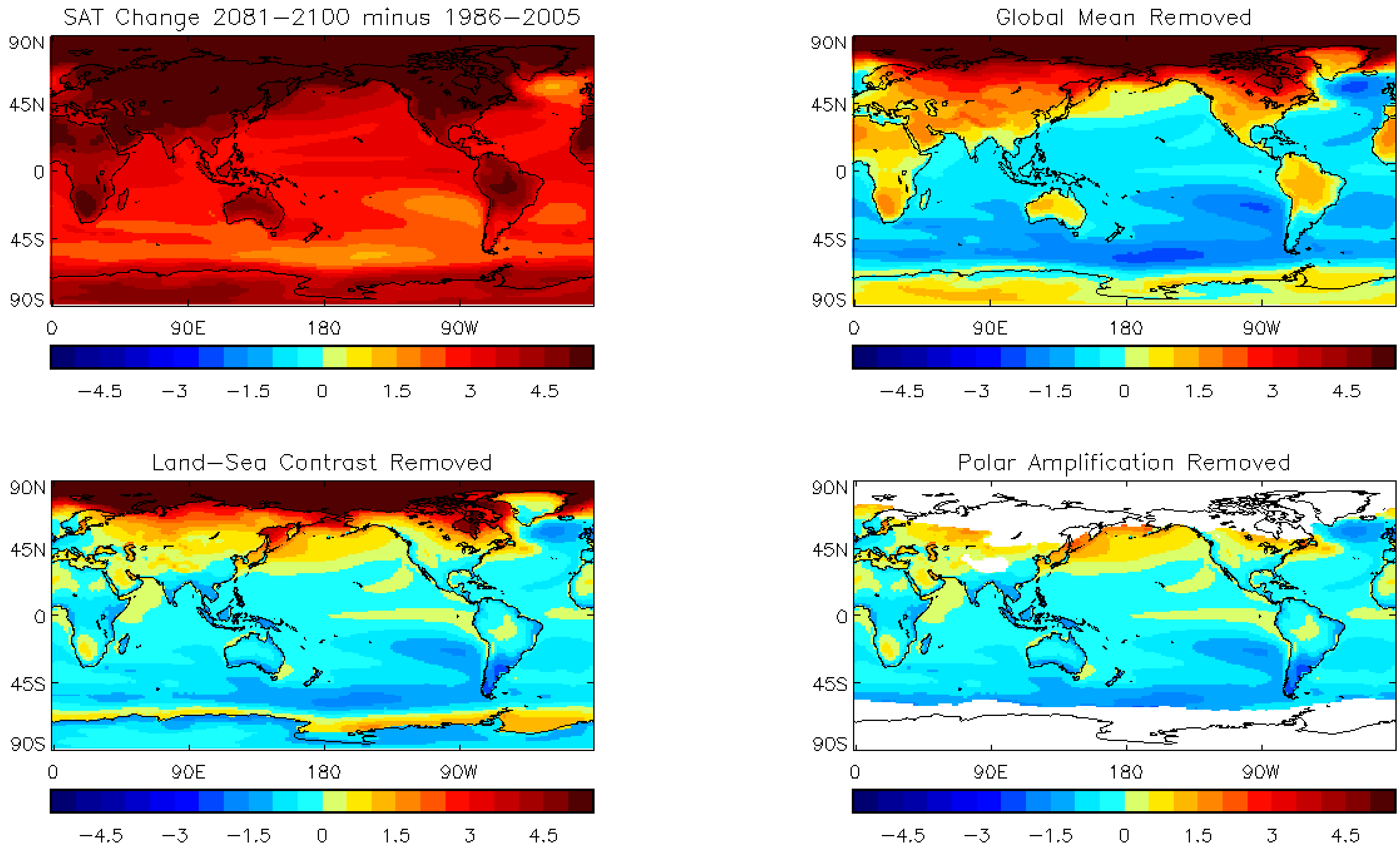
How large is the projected change compared with internal variability?



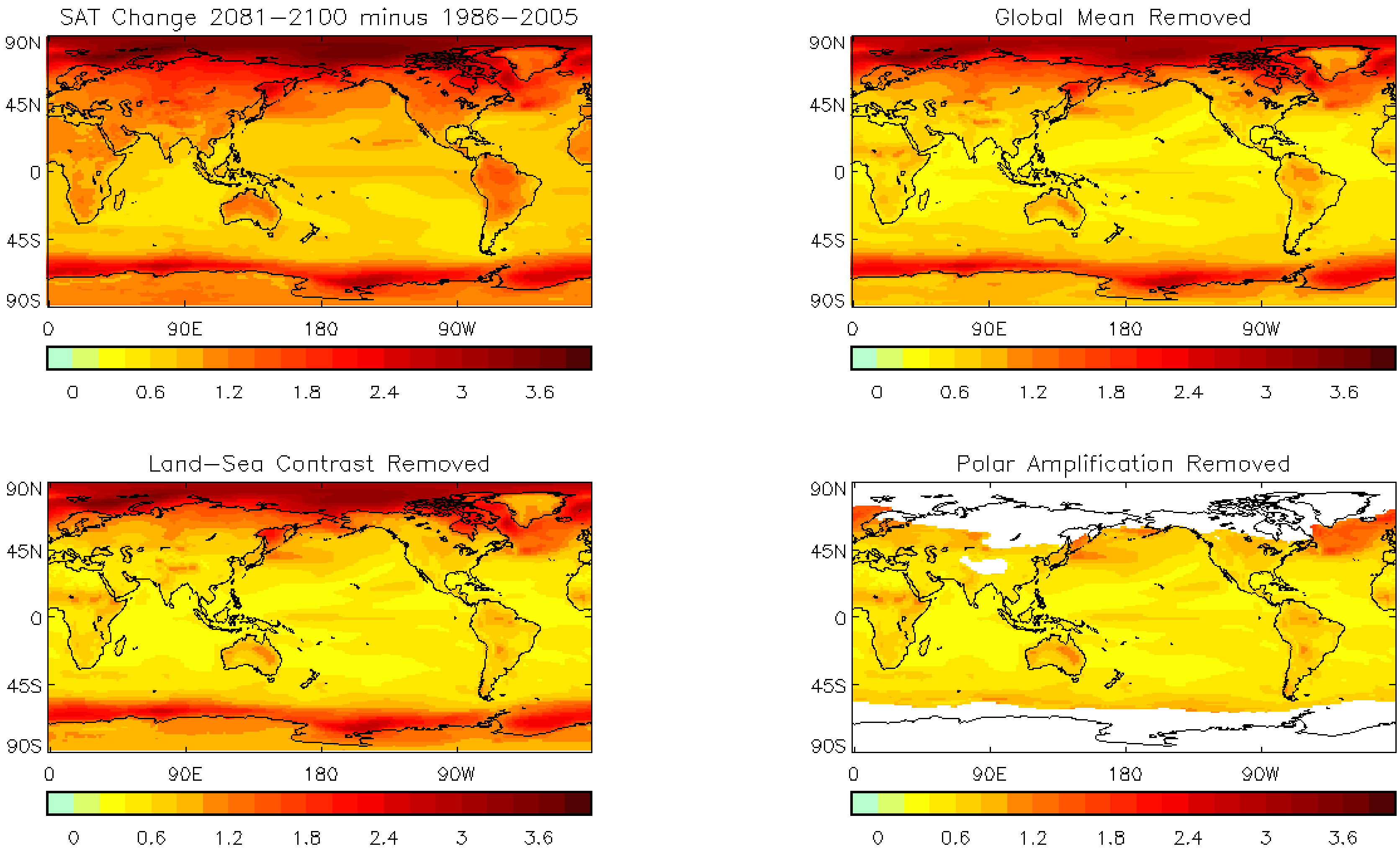
Stippling: changes are “large” compared with internal variability (greater than two standard deviations of internal variability), and at least 90% of models agree on sign of change

Hatching: changes are “small” compared with internal variability (less than one standard deviation of internal variability

Surface Air Temperature Change: CMIP5 Mean



Surface Air Temperature Change: CMIP5 Std. Dev



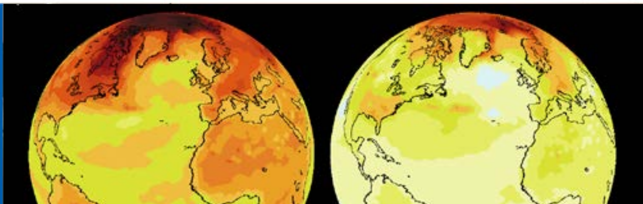
For Regional Surface Air Temperature Changes:

- Mean pattern of change and its uncertainty is largely driven by ‘thermodynamic’ processes; global mean, land-sea contrast, polar amplification
- We could build a quantitative theory of thermodynamic changes

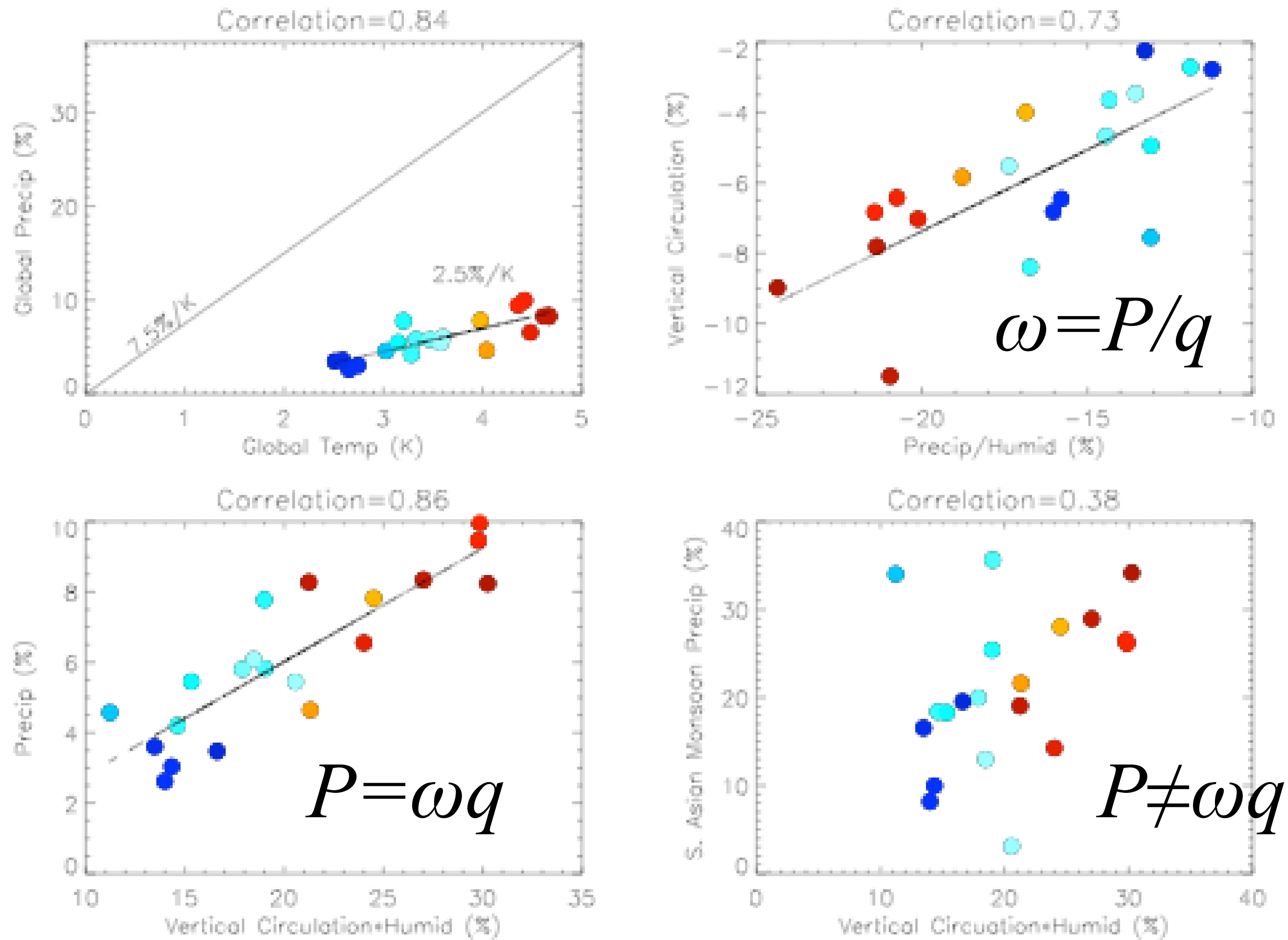
$$\Delta T(x,y,t) = \Delta T_g(t)[P(x,y)L(o,l)] + R(x,y,t)$$

Dynamical component

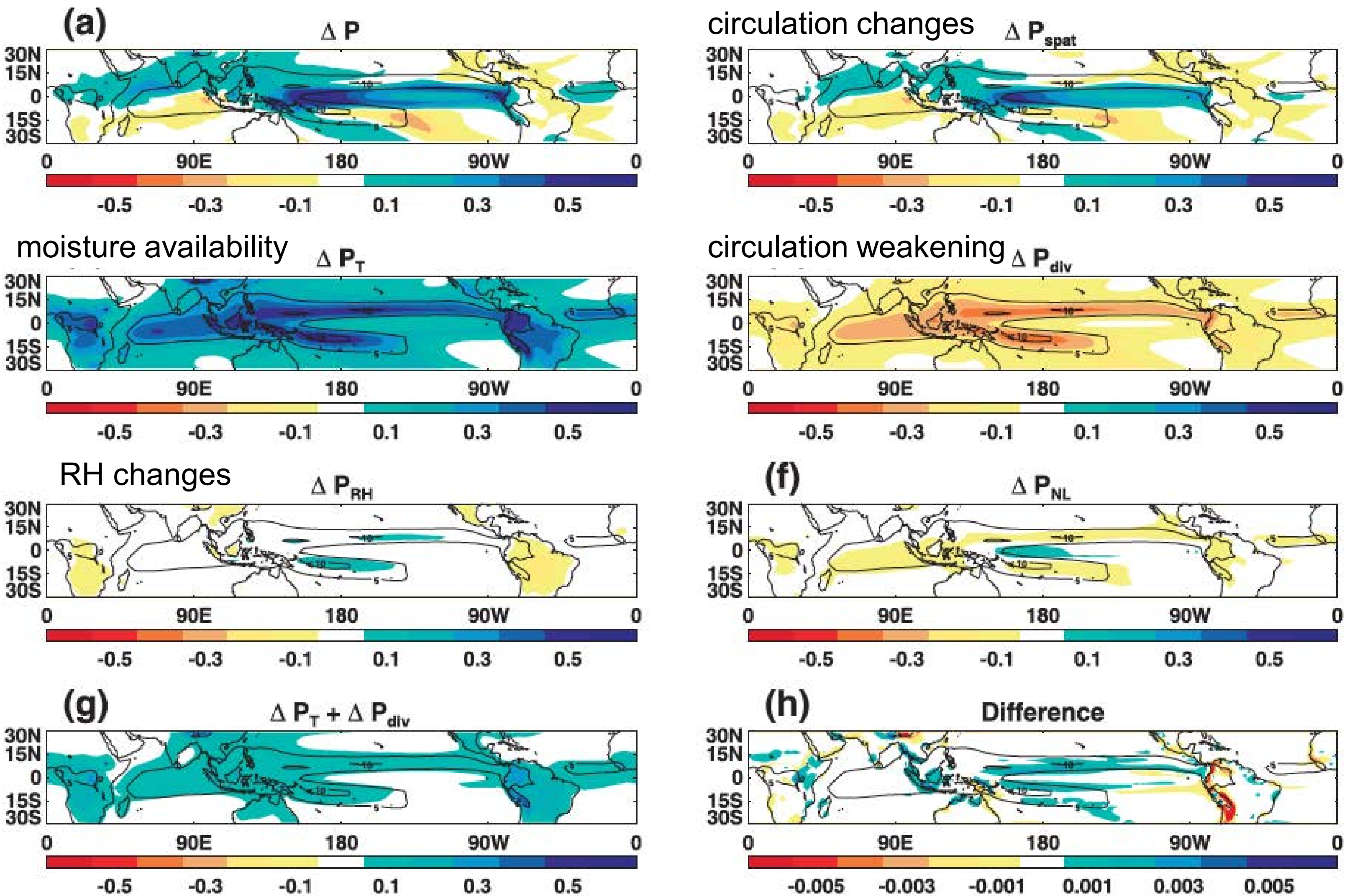
•‘Dynamical’ SAT changes seem much smaller – although of crucial importance in the tropics (e.g. Xie et al., 2010)



Changes Tropical Precip + Atmospheric Circulation



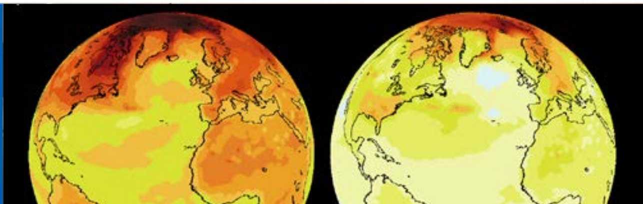
Tropical Precipitation Changes: Chadwick et al., 2013



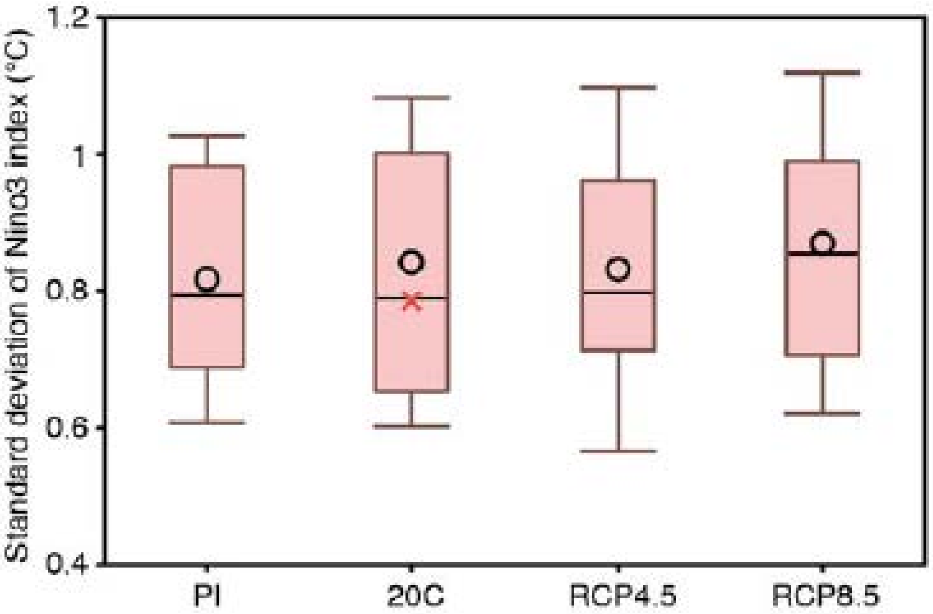
For Regional Precipitation Changes:

- Global mean changes are sub-Clausius-Clapeyron, constrained by tropospheric energy balance and lead to a weaker tropical circulation
- Regionally the reduced circulation is largely balanced by moisture availability leaving other factors as important drivers of regional change; SST changes, land-sea contrast, land-surface feedbacks, …
- Dynamics clearly important here – long time-scale coupling?

- In mid-latitudes, precipitation increase is largely due to increased moisture availability with relatively unchanged storminess. Confidence in storminess projections is low



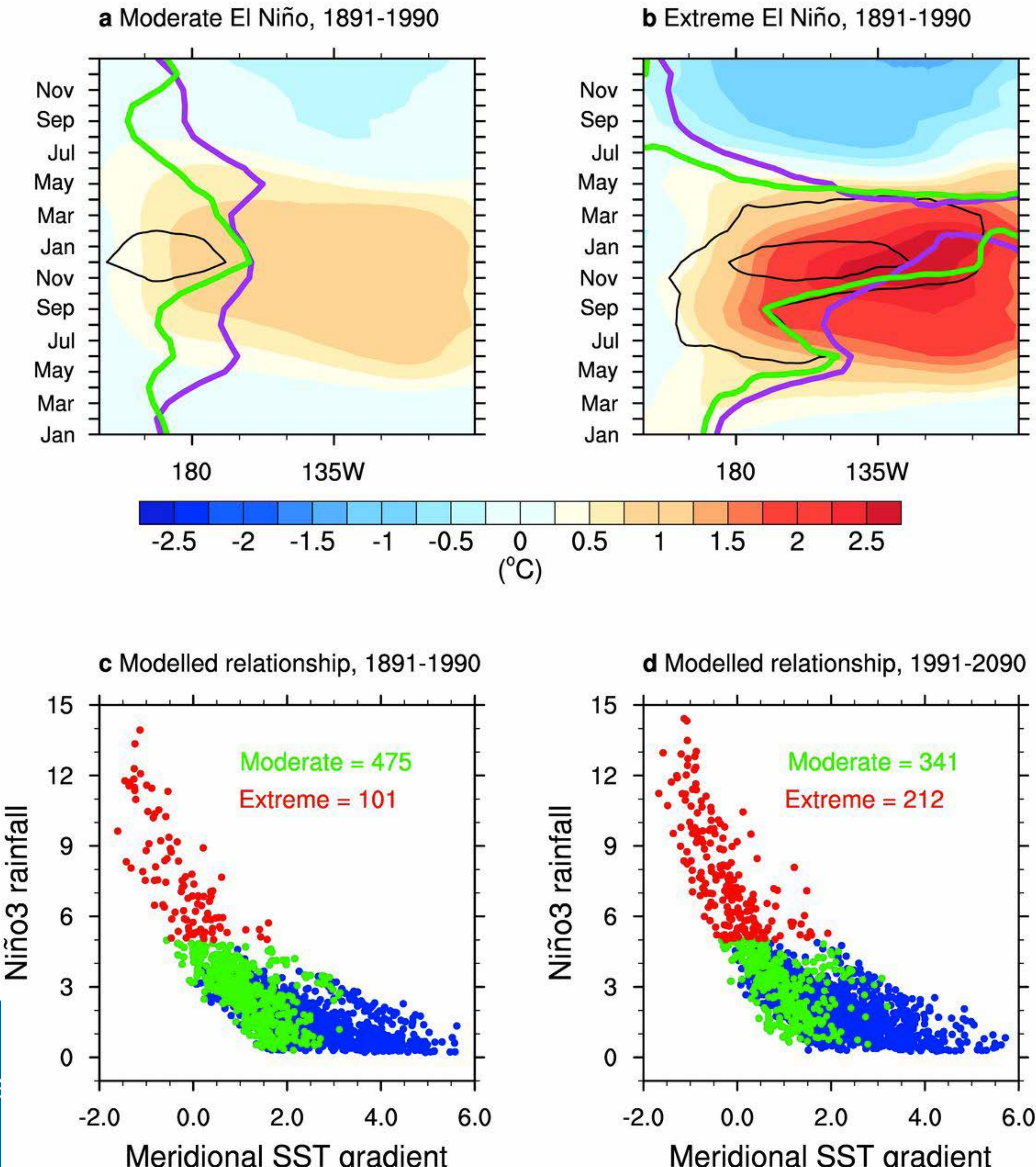
Chapter 14: Climate Phenomena and their Relevance for Future Regional Climate Change



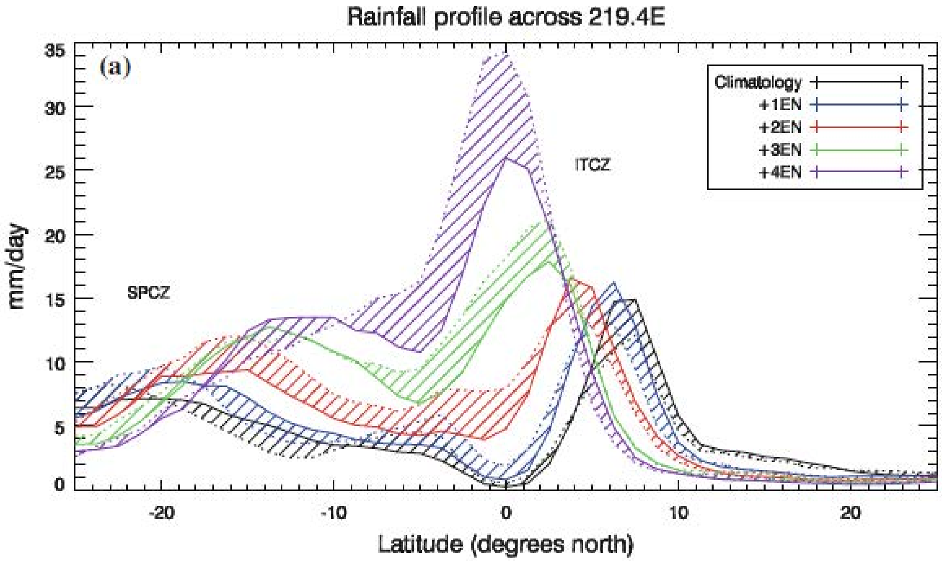
• El Niño-Southern Oscillation *very likely* remains as the dominant mode of interannual variability in the future and due to increased moisture availability, the associated precipitation variability on regional scales *likely* intensifies….. natural modulations of the variance and spatial pattern of El Niño-Southern Oscillation are so large in models that confidence in any specific projected change in its variability in the 21st century remains *low*.

Extreme El Niños

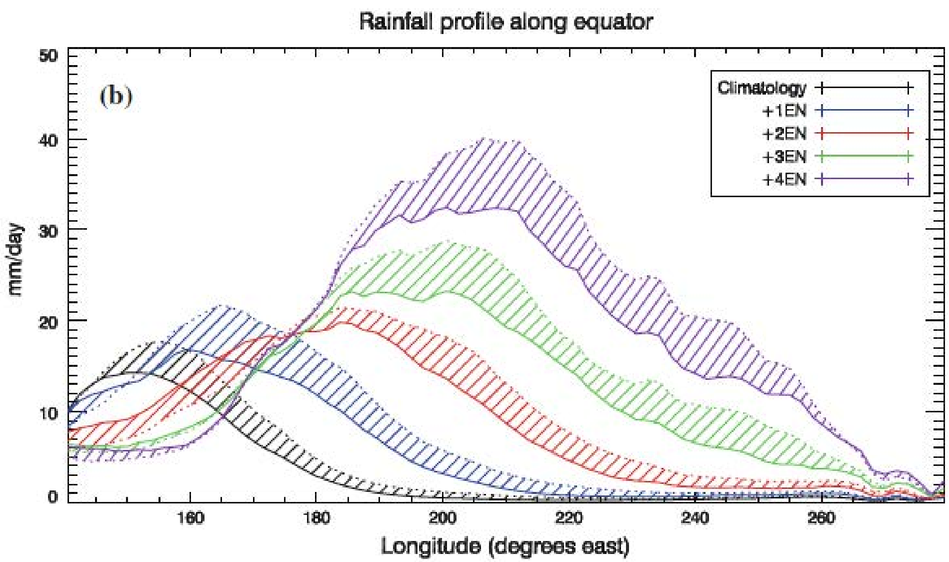
Cai, Borlce, Lengaigne, van Rensch, Collins, Vecchi, Timmermann, Santoso, McPhaden, Wu, England, Guilyardi, Jin. Increasing frequency of extreme El Niño events due to greenhouse warming. Nature Climate Change, 2014



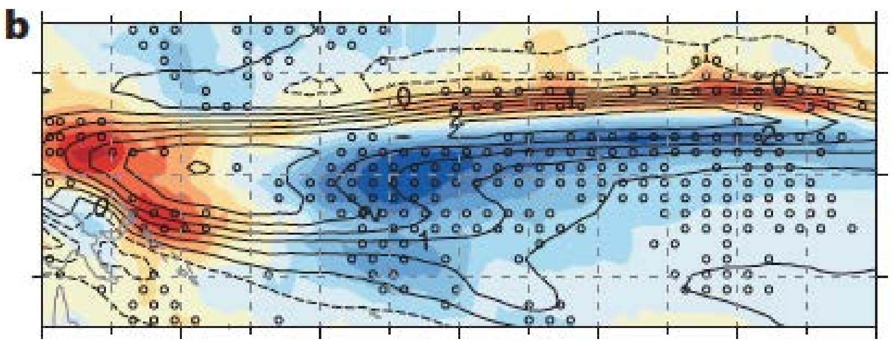
Changing El Niño Teleconnections



Chung, Power, Arblaster, Rashid, Roff, Climate Dynamics, 2014



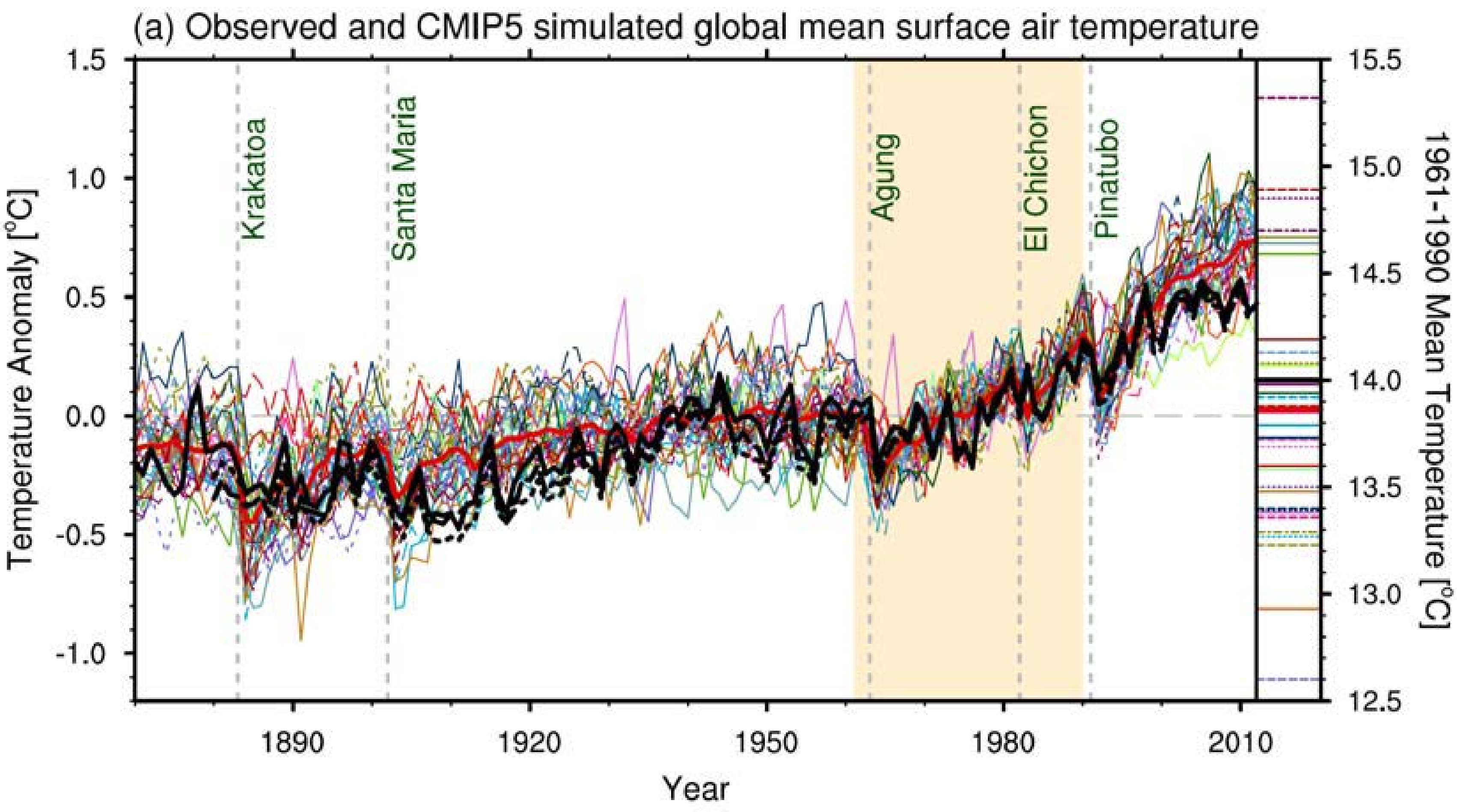
Atmosphere model simulations



CMIP5

Power, Delange, Chung, Kociuba, Keay, Nature 2013

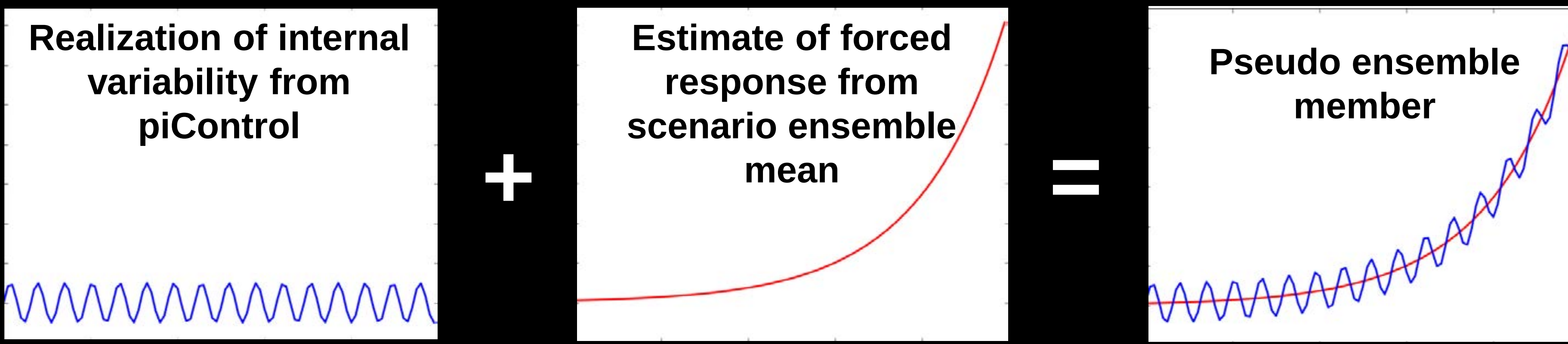
Global Warming 'Pause' or 'Hiatus'



Chapter 9, Box 9.2

Warming hiatus periods in CMIP5 control experiments

Hiatus periods in piControl experiments identified by generation of ***pseudo ensembles***



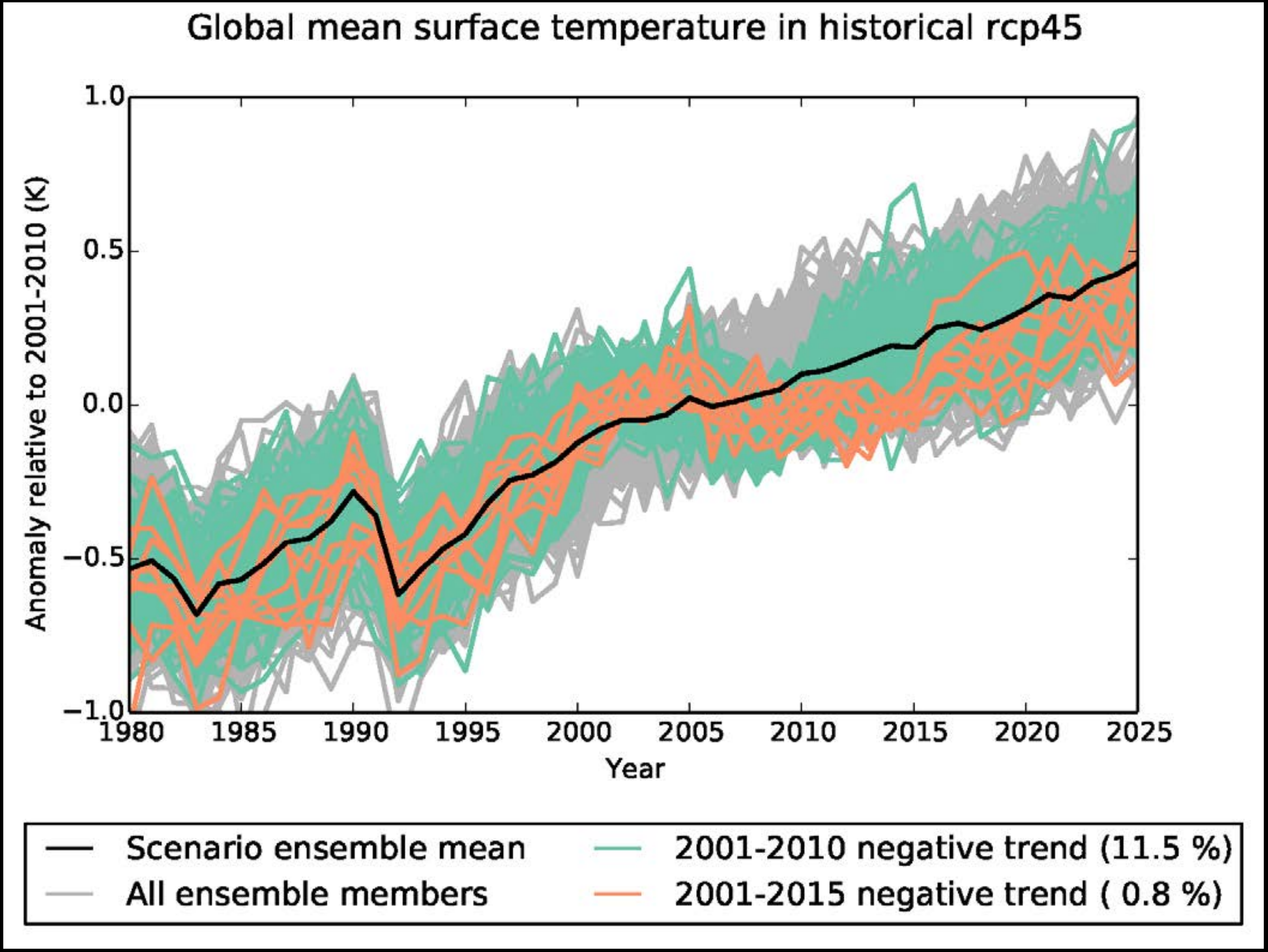
***Pseudo ensemble* hiatus selection criteria:**
Period since 2001 with trend in global surface temperature ≤ 0.00 ° C/yr

Equivalent piControl hiatus selection criteria:
10 year period with trend in global surface temperature ≤ -0.16 ° C/yr

Methods 1/2

Chris Roberts, Matt Palmer, MO

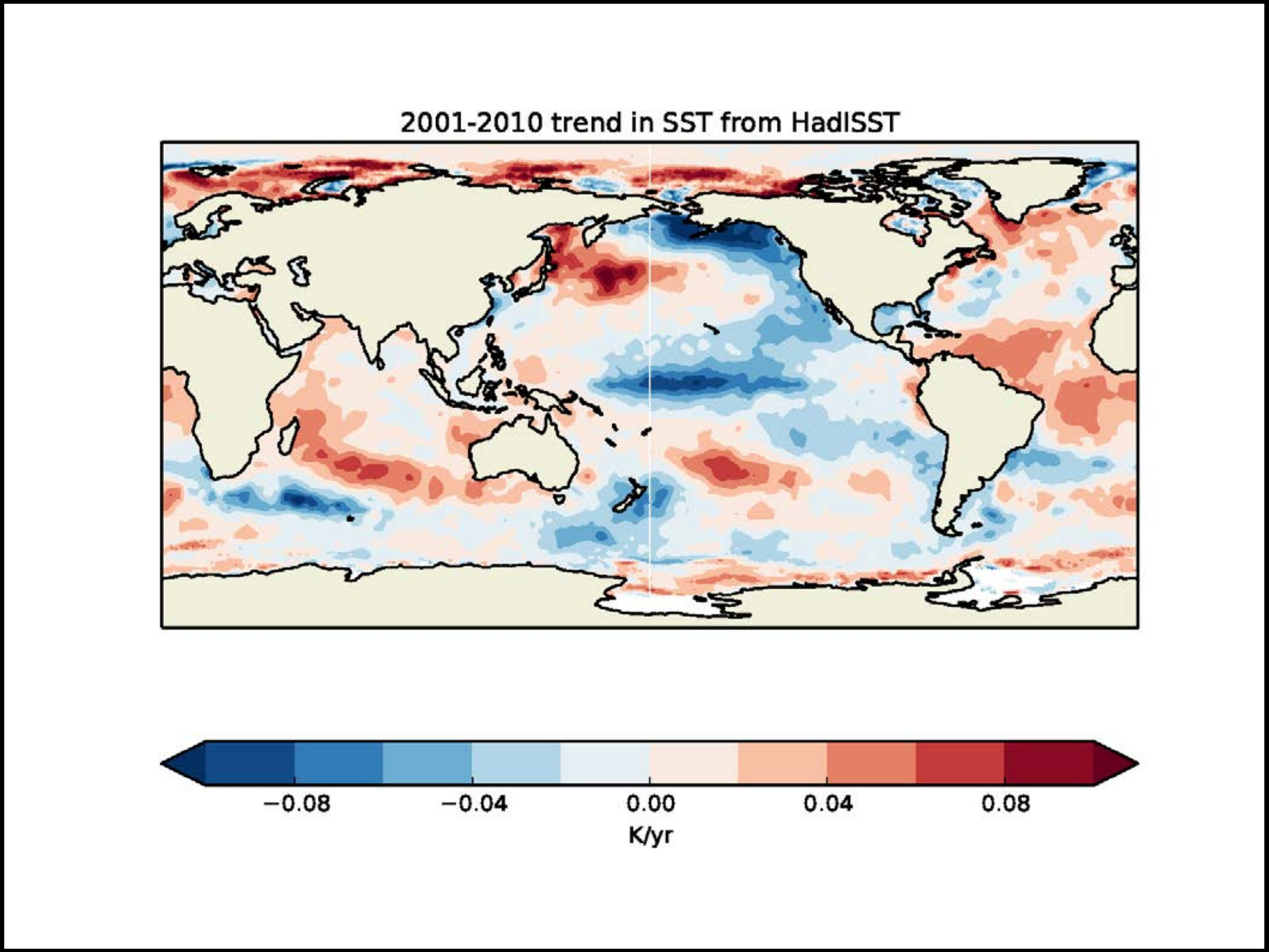
CMIP5 historical + RCP4.5 pseudo ensembles



Results 2/12

Chris Roberts, Matt Palmer, MO

Spatial trends in surface temperature during hiatus decades

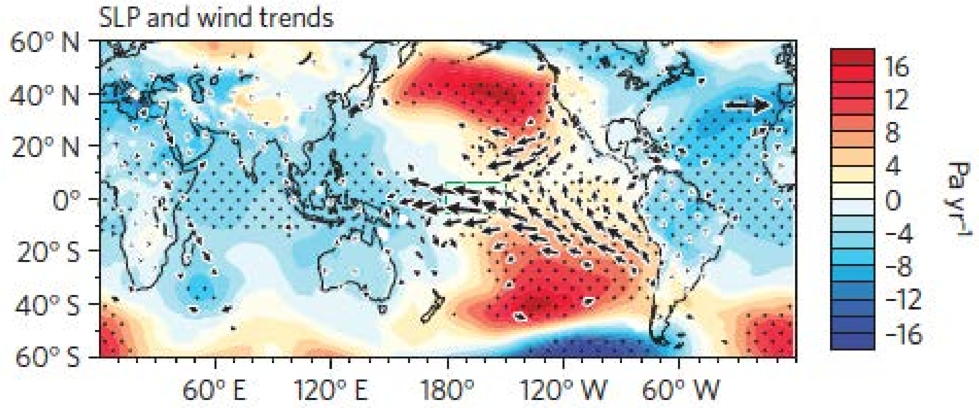


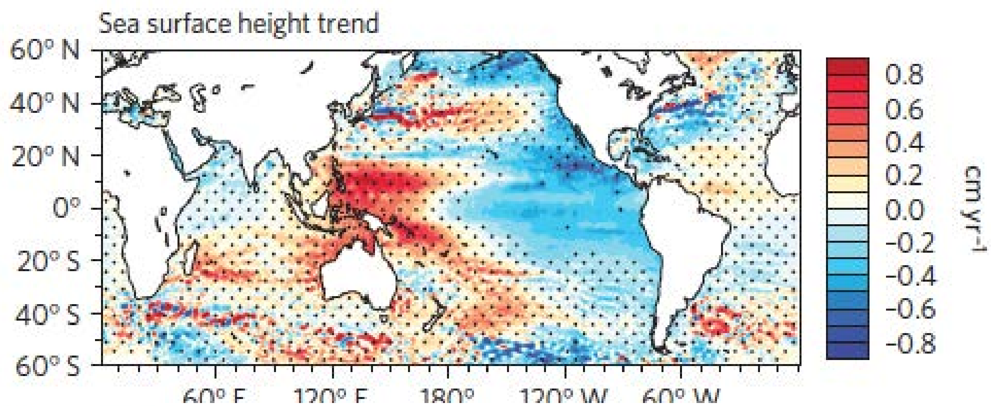
Results 5/12

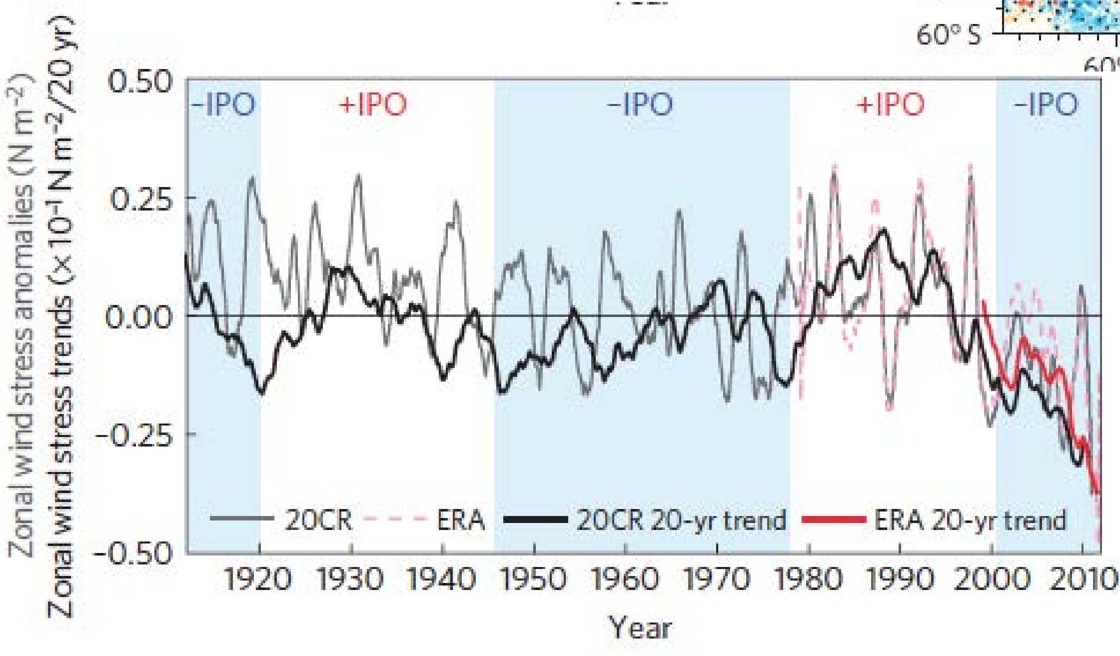
Model hiatus decades shifted by + 0.16 ° C/yr for comparison with observations

Trade Winds Strengthening

England, McGregor, Spence, Meehl, Timmermann, Cai, Sen Gupta, McPhaden, Purich, Santoso, Nature Climate Change, 2014.







See also Kosaka and Xie, 2013

Summary

- Large-scale ‘thermodynamic’ response of temperature relatively well understood in terms of global + land/sea + polar amplification. Could build a quantitative theory
- Global precipitation change understood in terms of energy balance and offset between weakening circulation and increase humidity
- Regional precipitation in the tropics more determined by circulation changes and coupled(?) to ‘dynamical’ SST changes in tropics (RH contribution over tropical land)
- Robust mid-latitude thermodynamic precipitation response but low confidence in dynamical features
- Challenge is to combine information from imperfect models with our (sometimes quite good) understanding of physical processes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Further Information
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