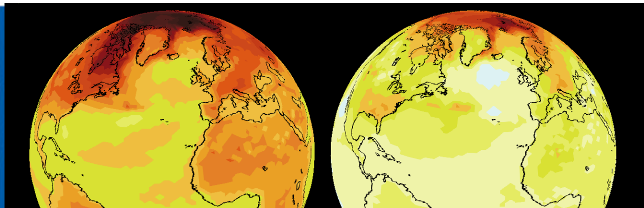
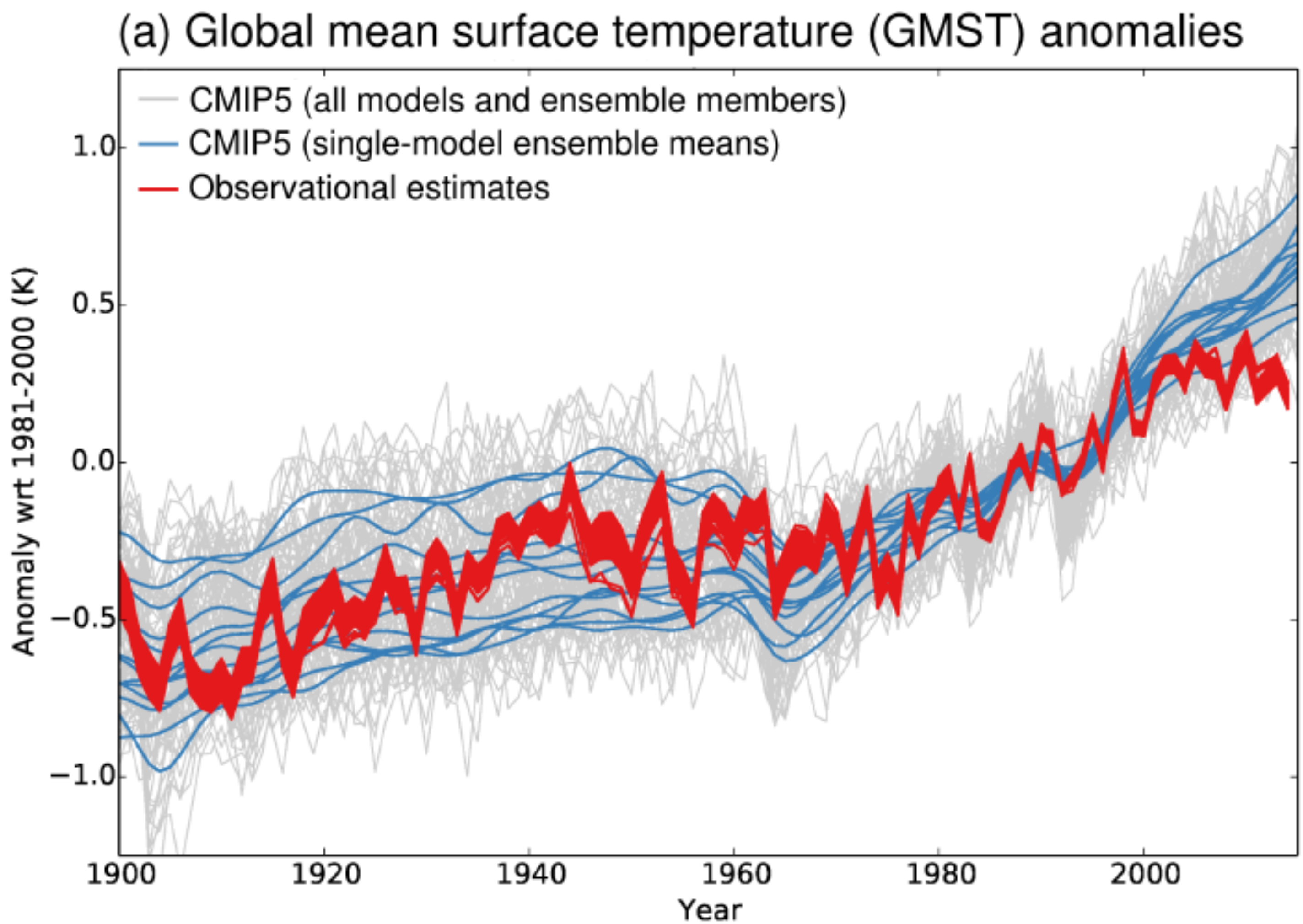
Decadal Climate Variability and Climate Change in the Pacific

Mat Collins *et al.*

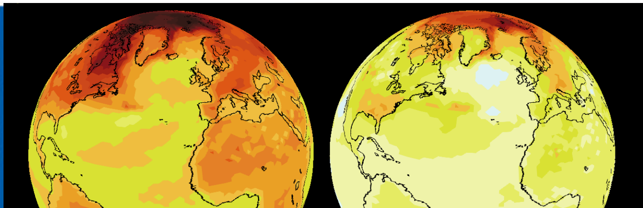
@mat_collins



Warming ‘Pause’ or ‘Hiatus’

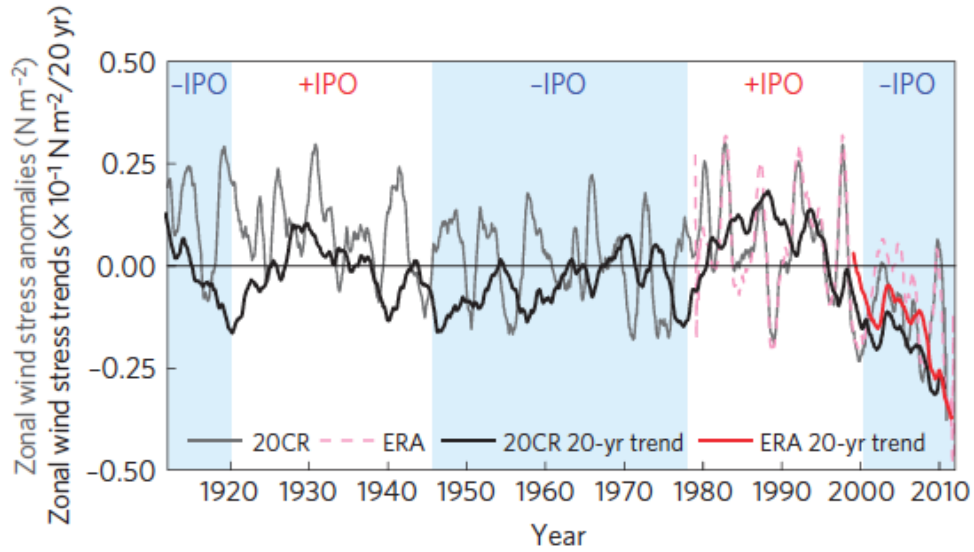


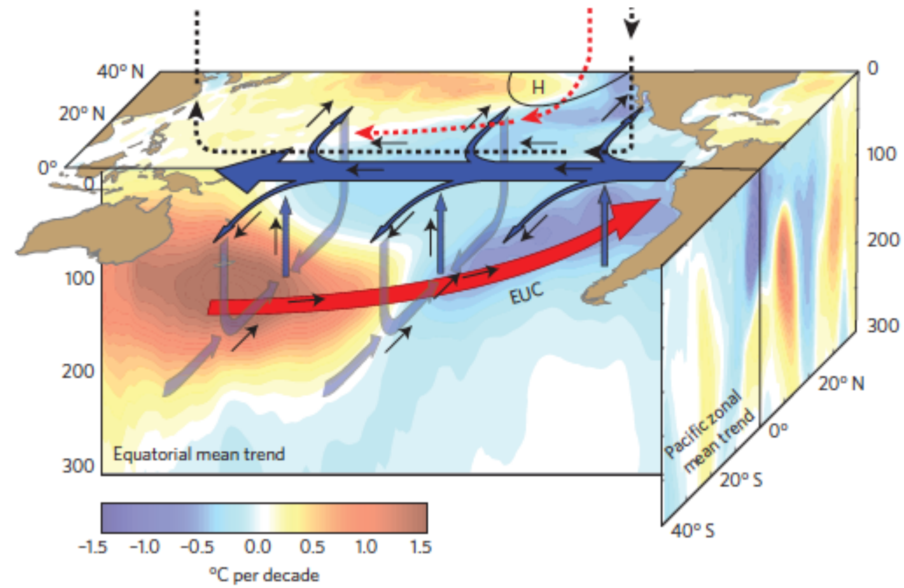
Roberts, Palmer, McNeall,MC, 2015

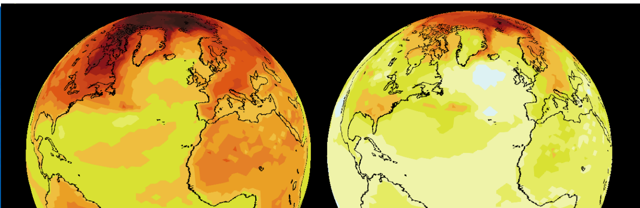


Hiatus –
Kosaka & Xie 2013
England et al. 2014

- Tropical Pacific trade winds intensifying (-ve IPO/PDO)
- Drives additional uptake of heat by the ocean
- Impacts temperatures over land
- [Other ocean basins may also be involved + natural forcing]



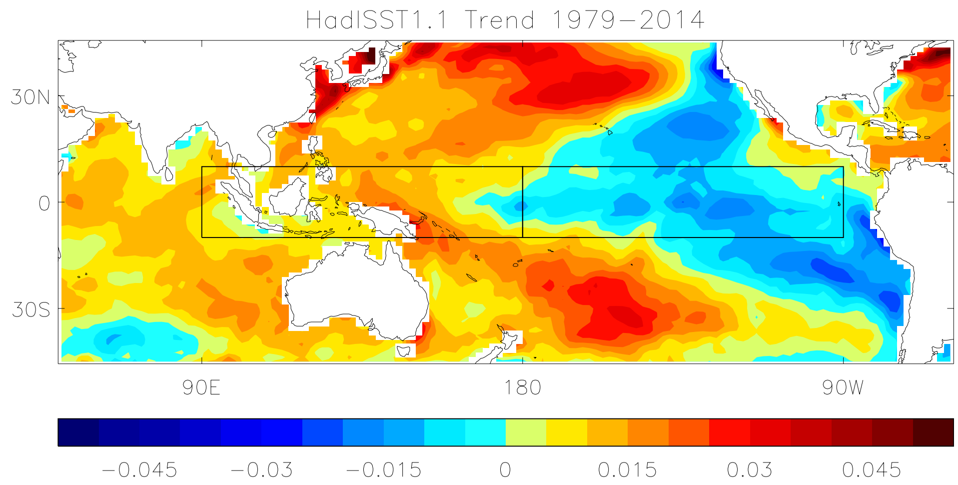


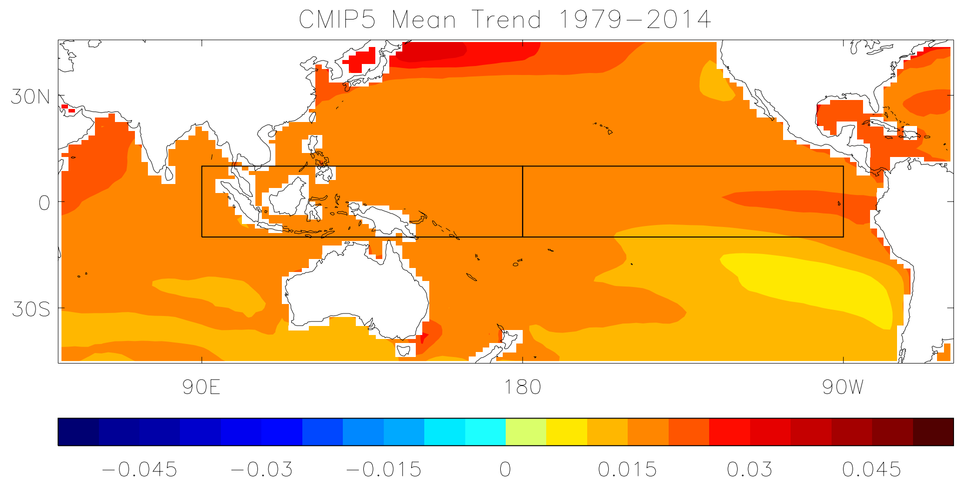


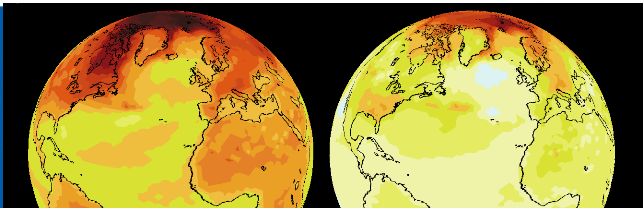
SST Trends 1979-2014

- HadISST trends over the period where satellite data are available show marked east Pacific cooling

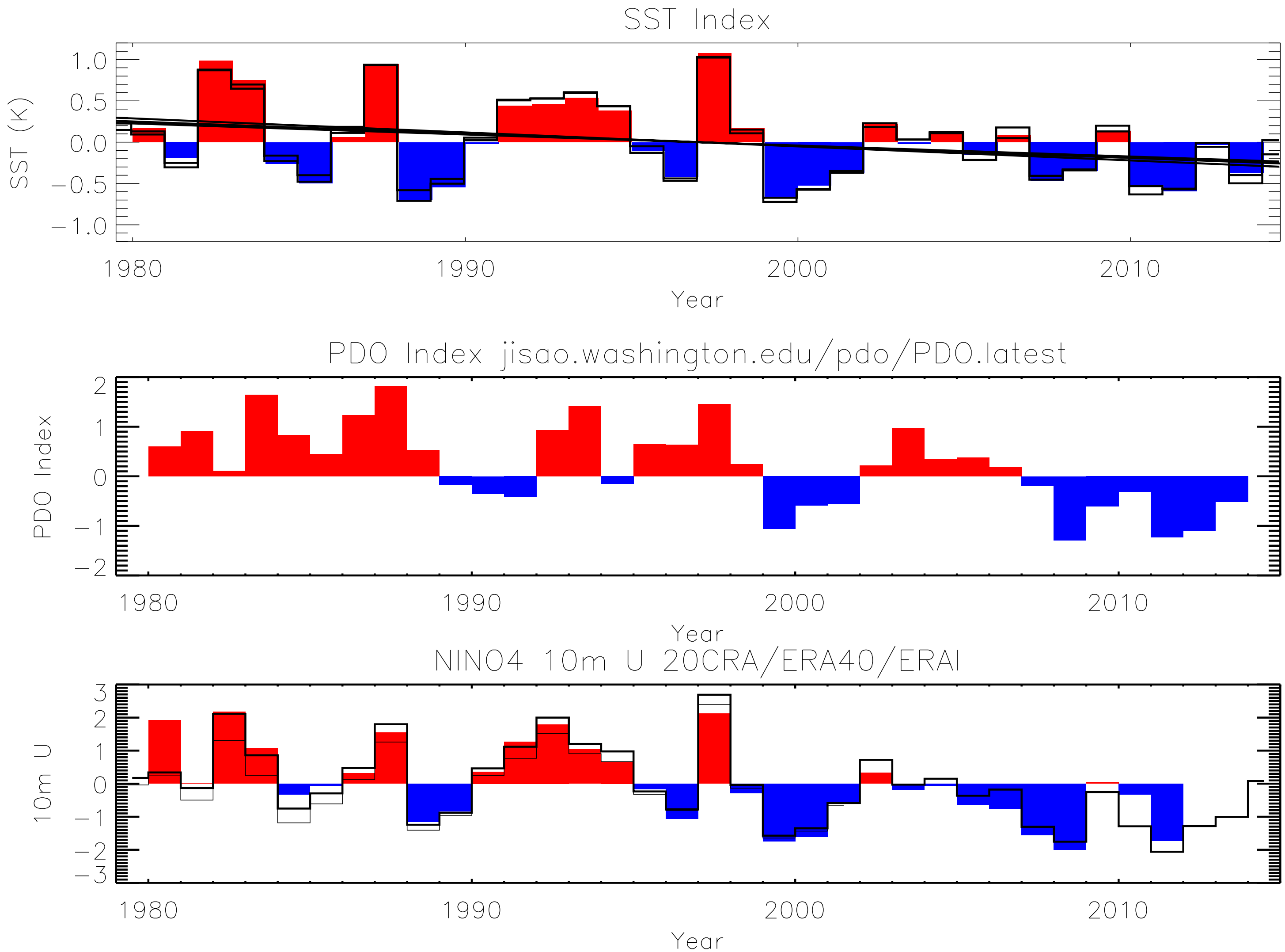
- Not seen in CMIP5 ensemble mean (historical + RCP4.5)







Pacific Trends 1979-2014



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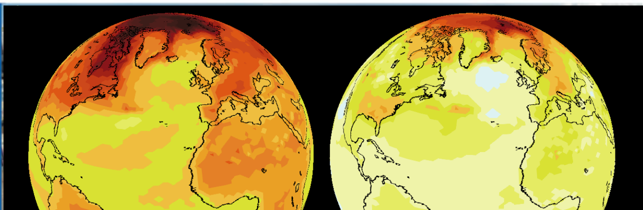
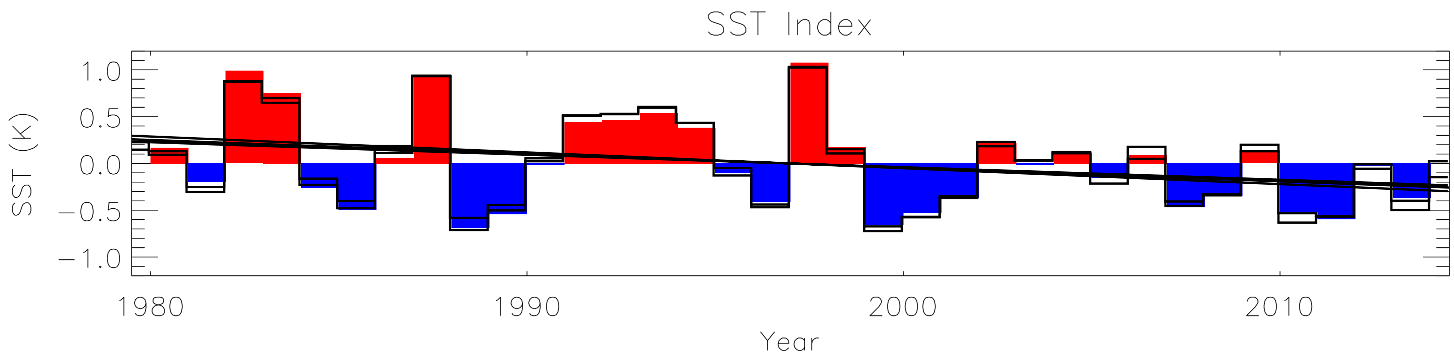
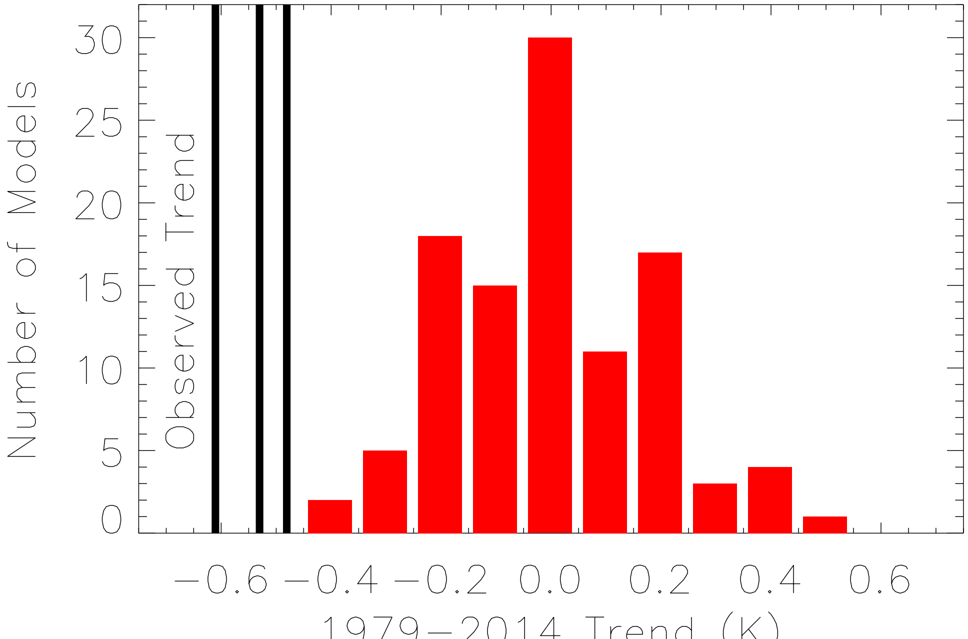
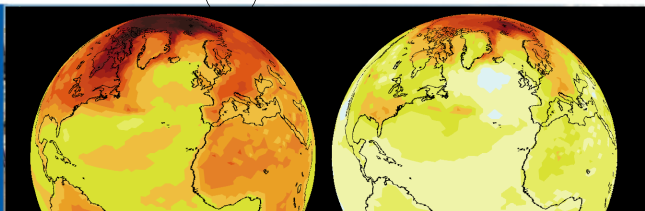


Null Hypothesis: It's a Trend



In fact, observed trends are outside the range of modelled trends (CMIP5 Historical + RCP4.5)



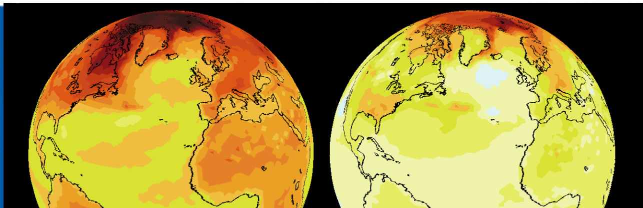


Theories of SST Changes

There are opposing theories of greenhouse-gas induced long-term SST trends

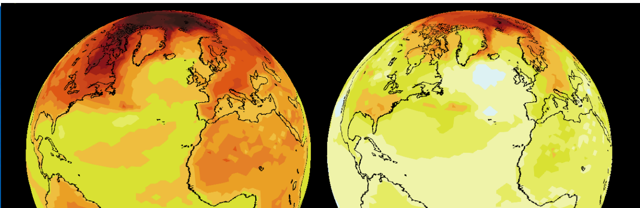
- Local maximum of equatorial warming across the basin due to weakening trades (Liu et al., 2005; Xie et al. 2010)
- Ocean ‘dynamical thermostat’ hypothesis predicting cooling in the east with respect to the west due to the upwelling of cold water from depth (Clement et al. 1996)
- Other hypotheses predicting warming in the east relative to the west (Knutson; Manabe 1995)

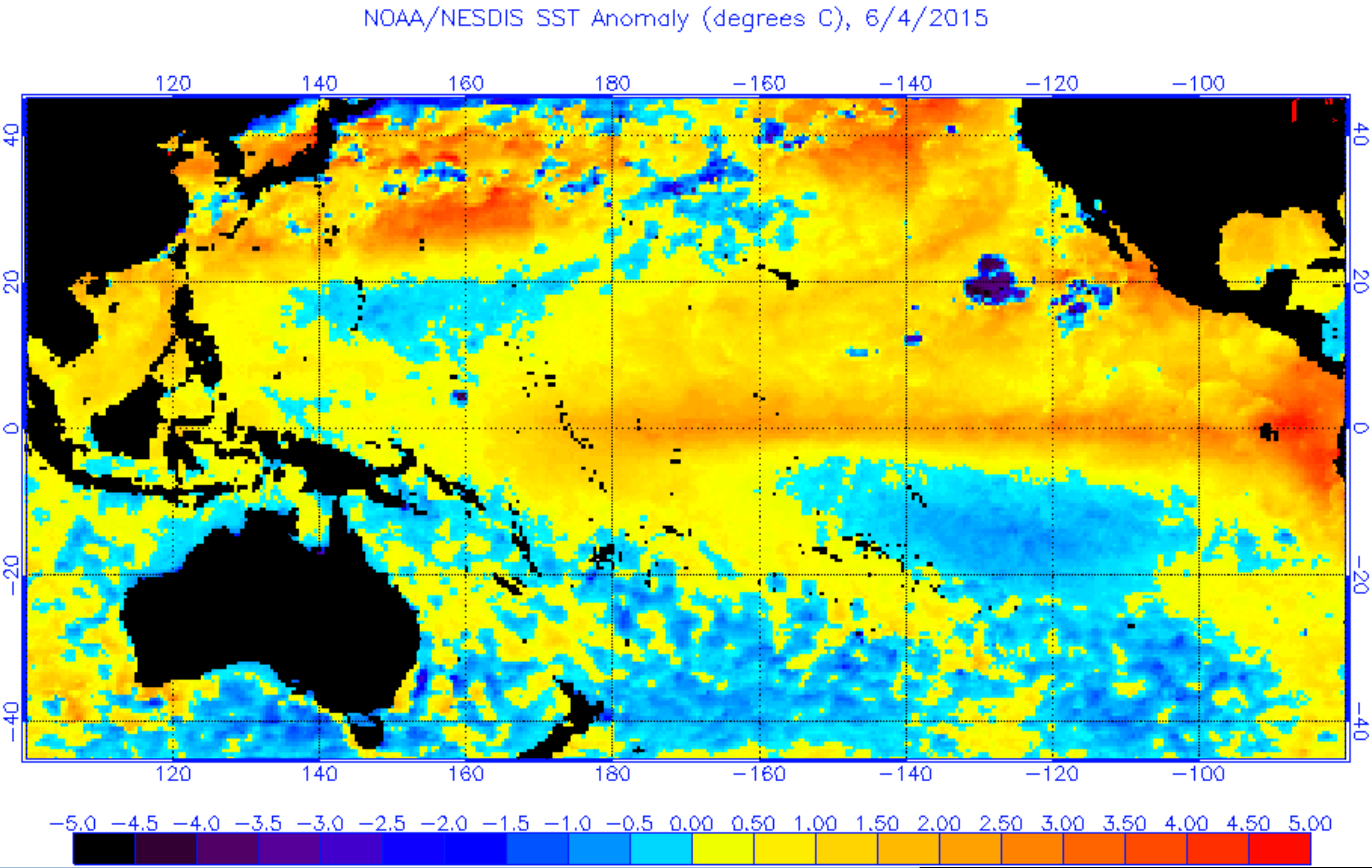
- These are really theories of equatorial SST changes. Observed patterns are meridionally broader

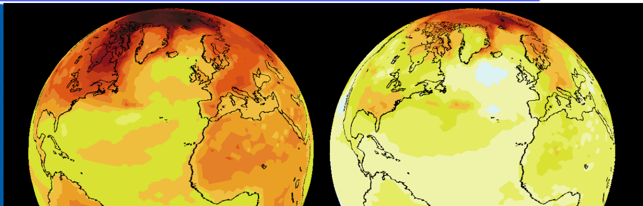


Pacific Multi-Decadal Variability

- Are these really long-term trends in the Pacific, or just a manifestation of a recent large-amplitude decadal variability?
- Do we need to revise our theories of long-term Pacific trends?
- Or is this just a decadal sampling issue?
- Or is real-world decadal variability larger than seen in models?
- Are we now entering a positive PDO phase?

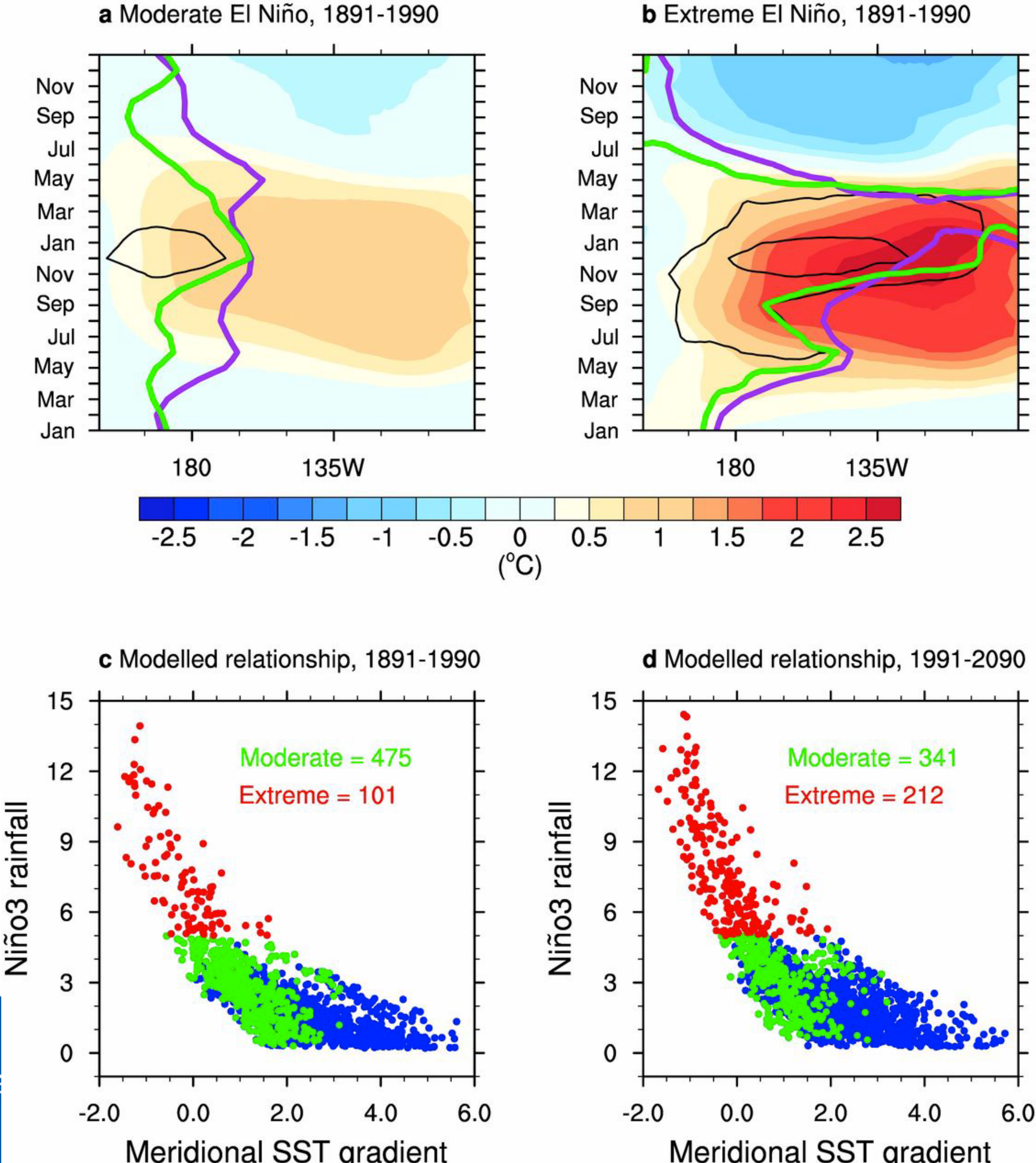



NOAA/NESDIS SST Anomaly (degrees C), 6/4/2015
120 140 160 180 −160 −140 −120 −100
40 20 0 −20 −40
−5.0 −4.5 −4.0 −3.5 −3.0 −2.5 −2.0 −1.5 −1.0 −0.5 0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00

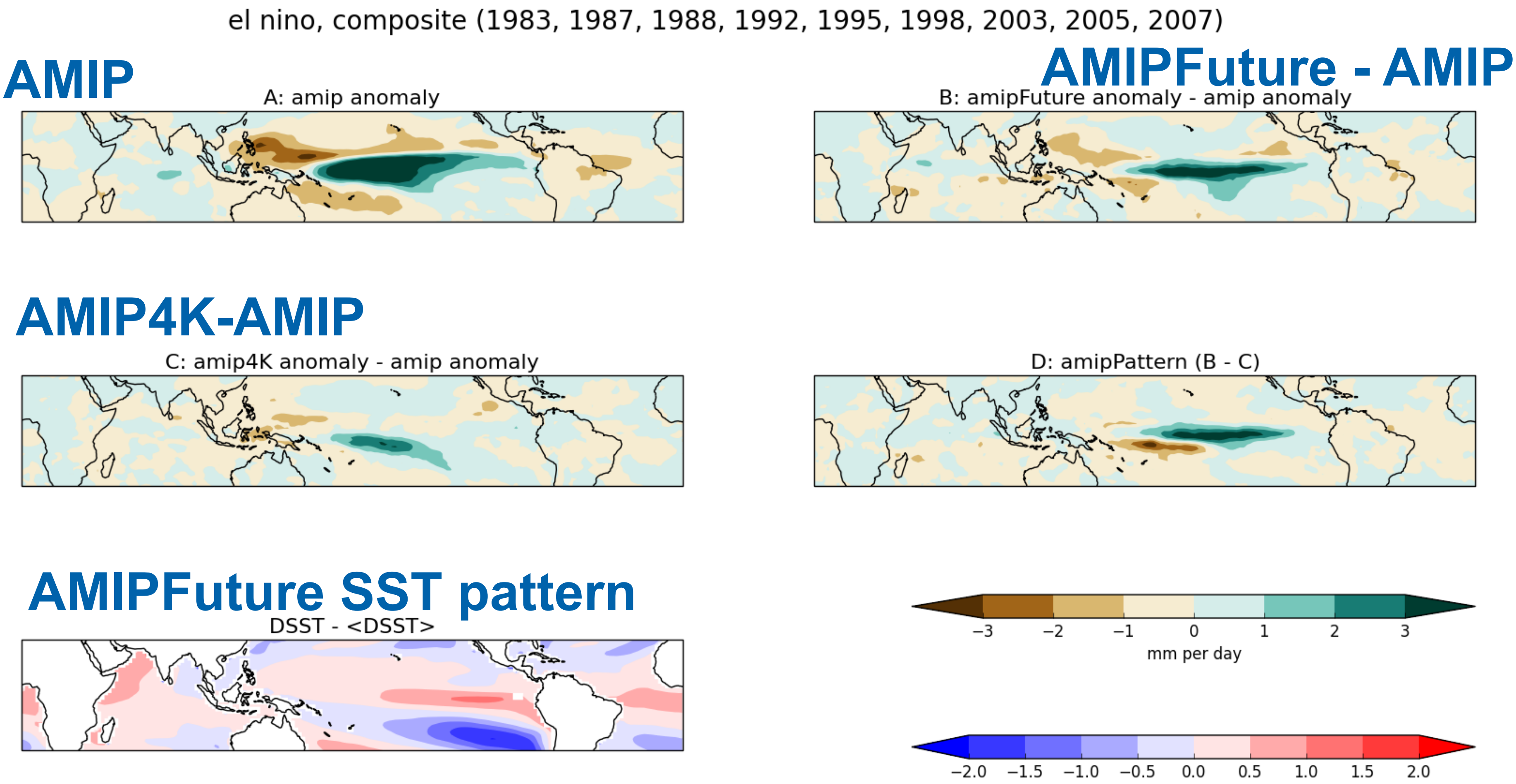


Future Projections: Extreme El Niños

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



Mean SST Changes are Important



- Analysis of CMIP5 AMIP experimens

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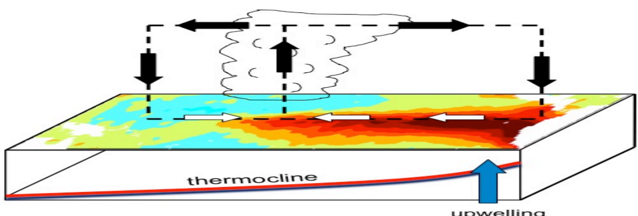
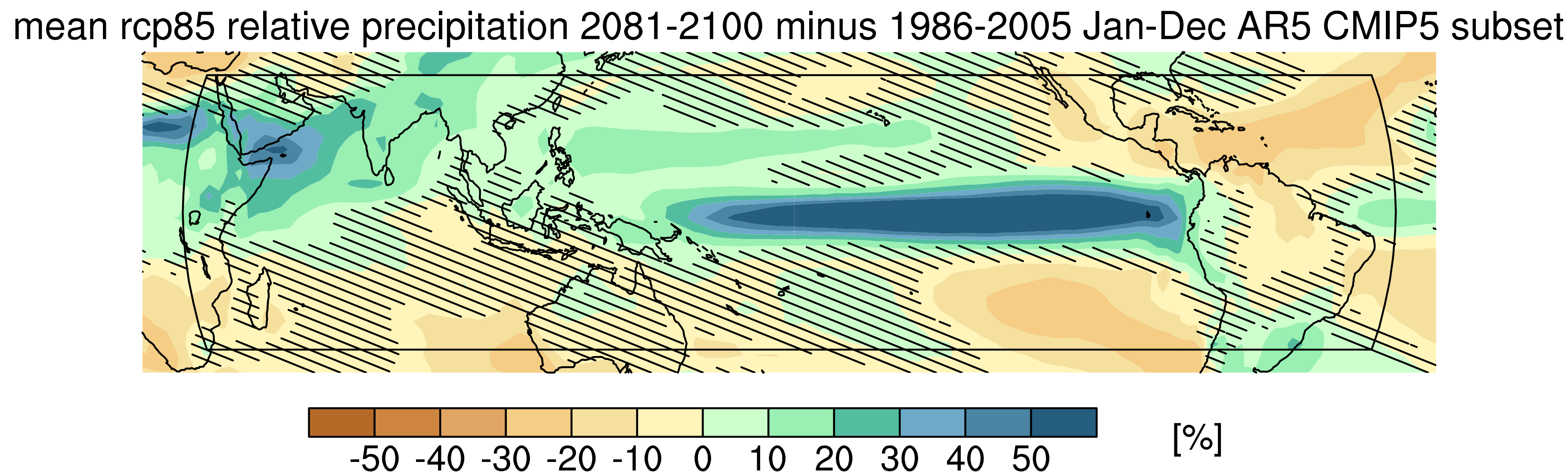
Katy Richardson,
Rob Chadwick, MC

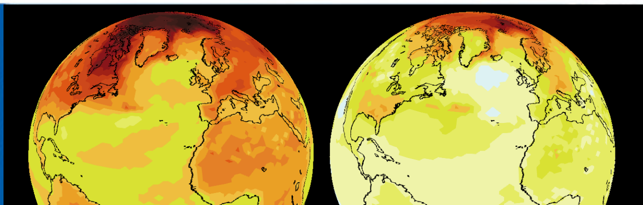


Changes in Mean Rainfall

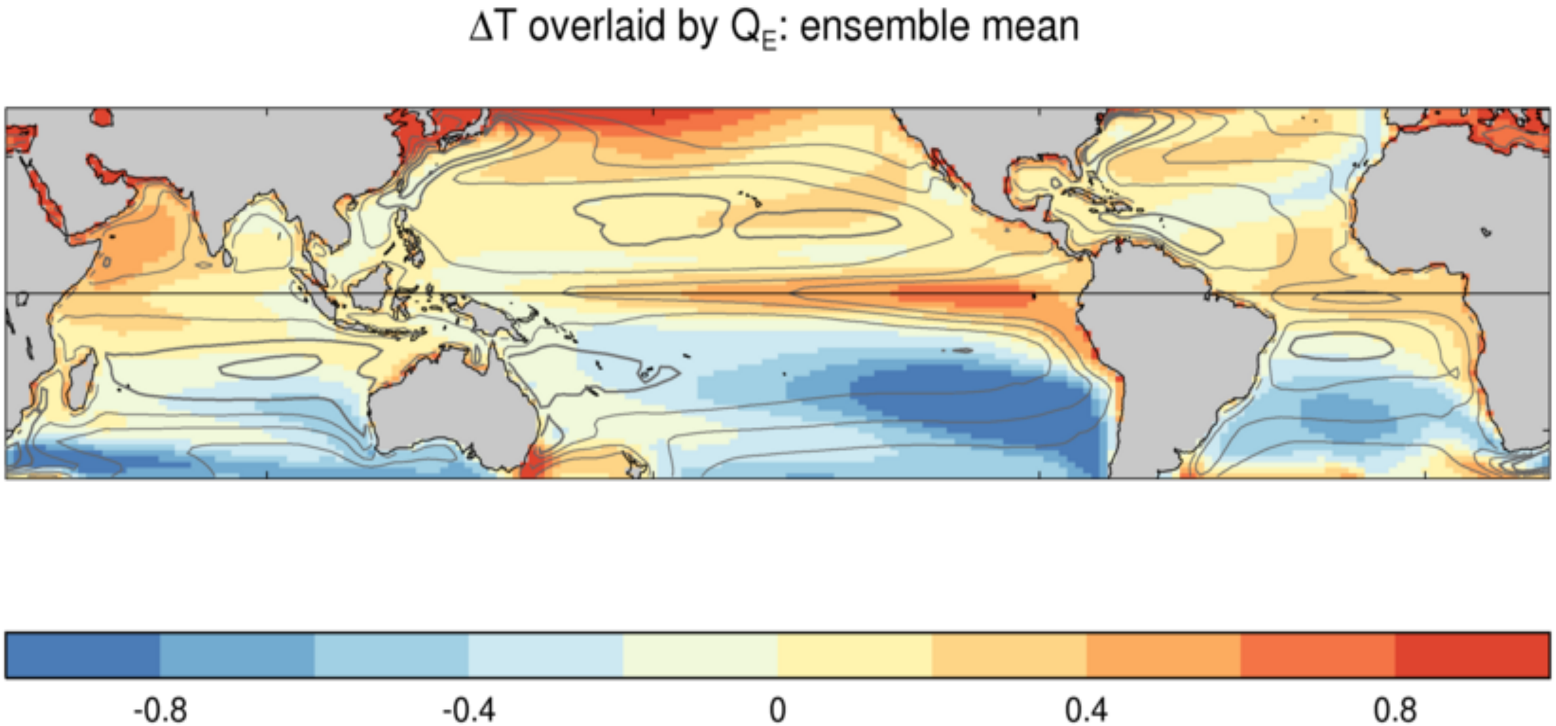


- Rainfall change anchored to an equatorial peak in SST warming across the Pacific
- Although the models agree, there are common SST biases in this region. Model agreement ≠ robustness

http://climexp.knmi.nl/plot_atlas_form.py

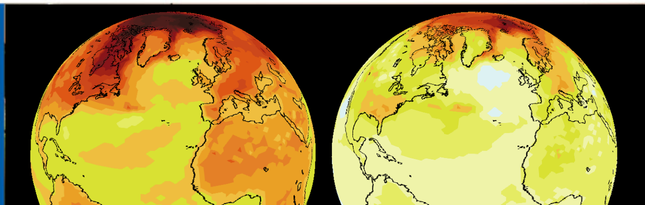


Long-term forced SST Change

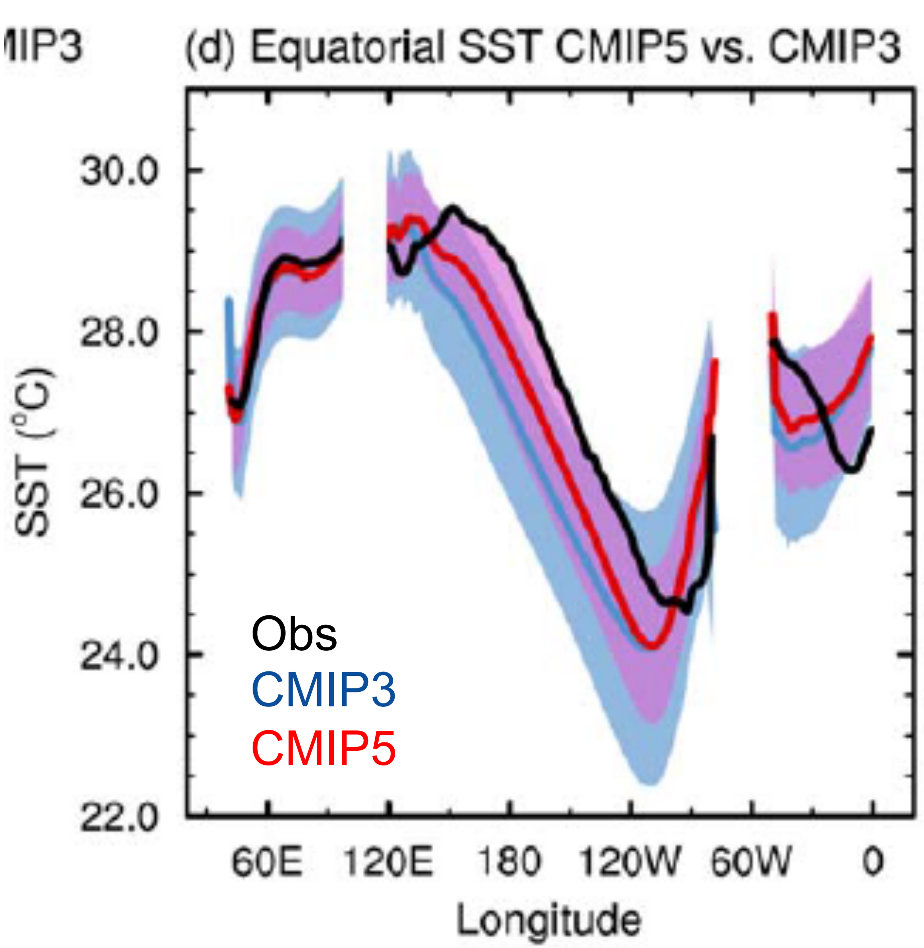


- Colours: SST change under RCP8.5
- Contours: Q_E from historical simulation
- Based on Xie et al., 2010

Gillian Kay, Rob Chadwick, MC

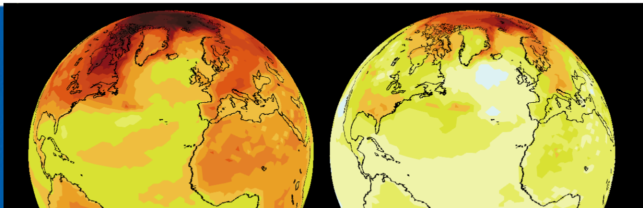


Errors/Biases in Mean Climate



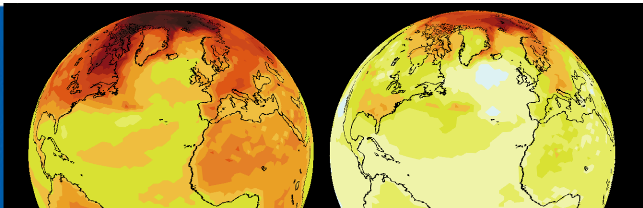
IPCC Ch9, Fig 9.14

- Equatorial Pacific SSTs generally too cold
- Trade winds are too strong
- Equatorial dry bias, off equatorial wet bias and 'double ITZC'
- …

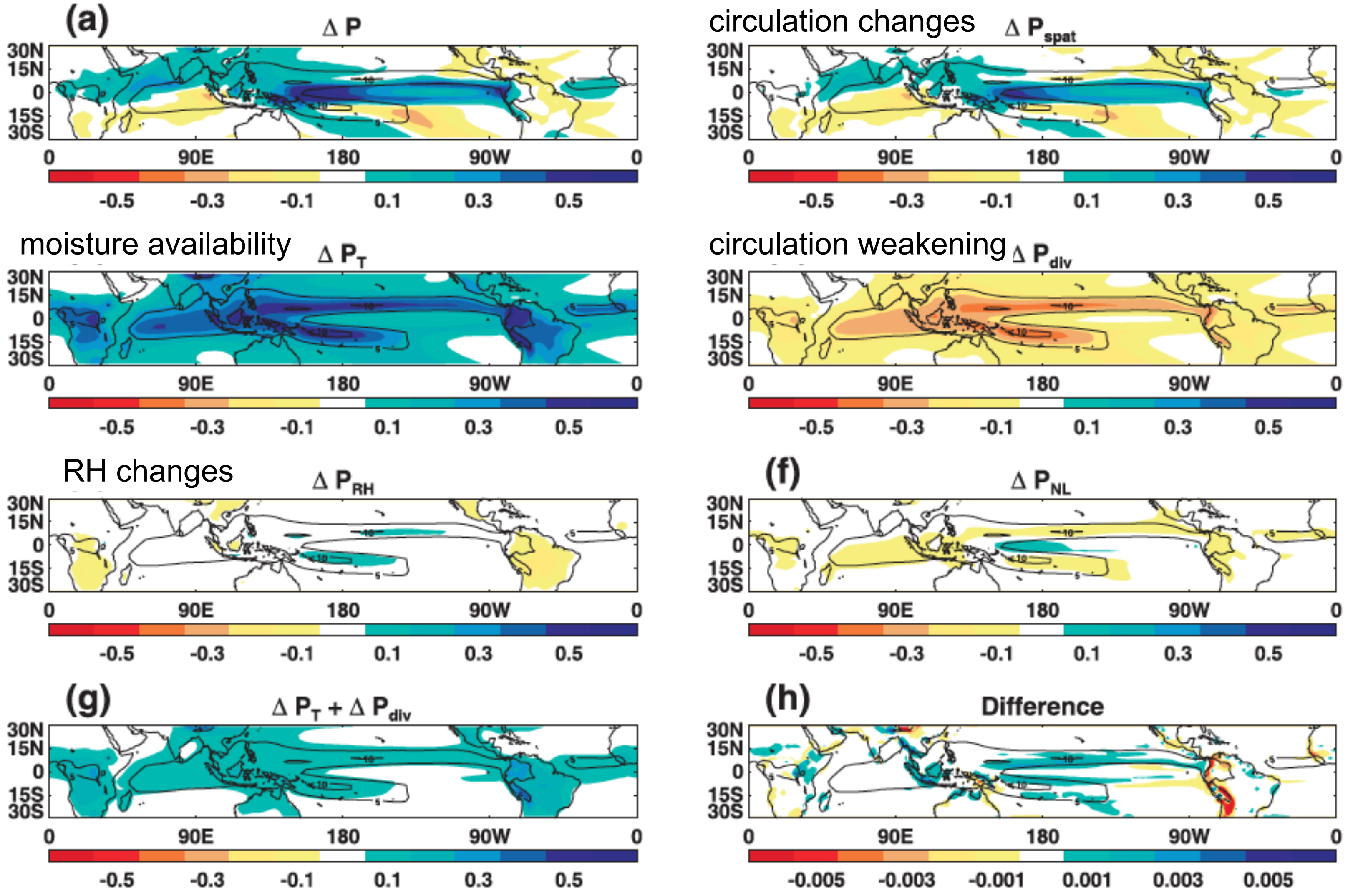


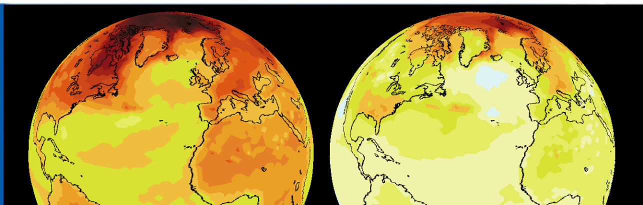
Pacific Climate Change

- Discrepancies between modelled and observed decadal-multi decadal Pacific trends, or just extreme decadal variability?
- Forced SST patterns have a leading-order impact on
    - Mean rainfall changes
    - Extreme ENSO changes
    - ENSO teleconnections
    - …
- The ‘usual’ way of addressing these issues would be to use detection + attribution. This would fail.
- How to make progress with imperfect models?



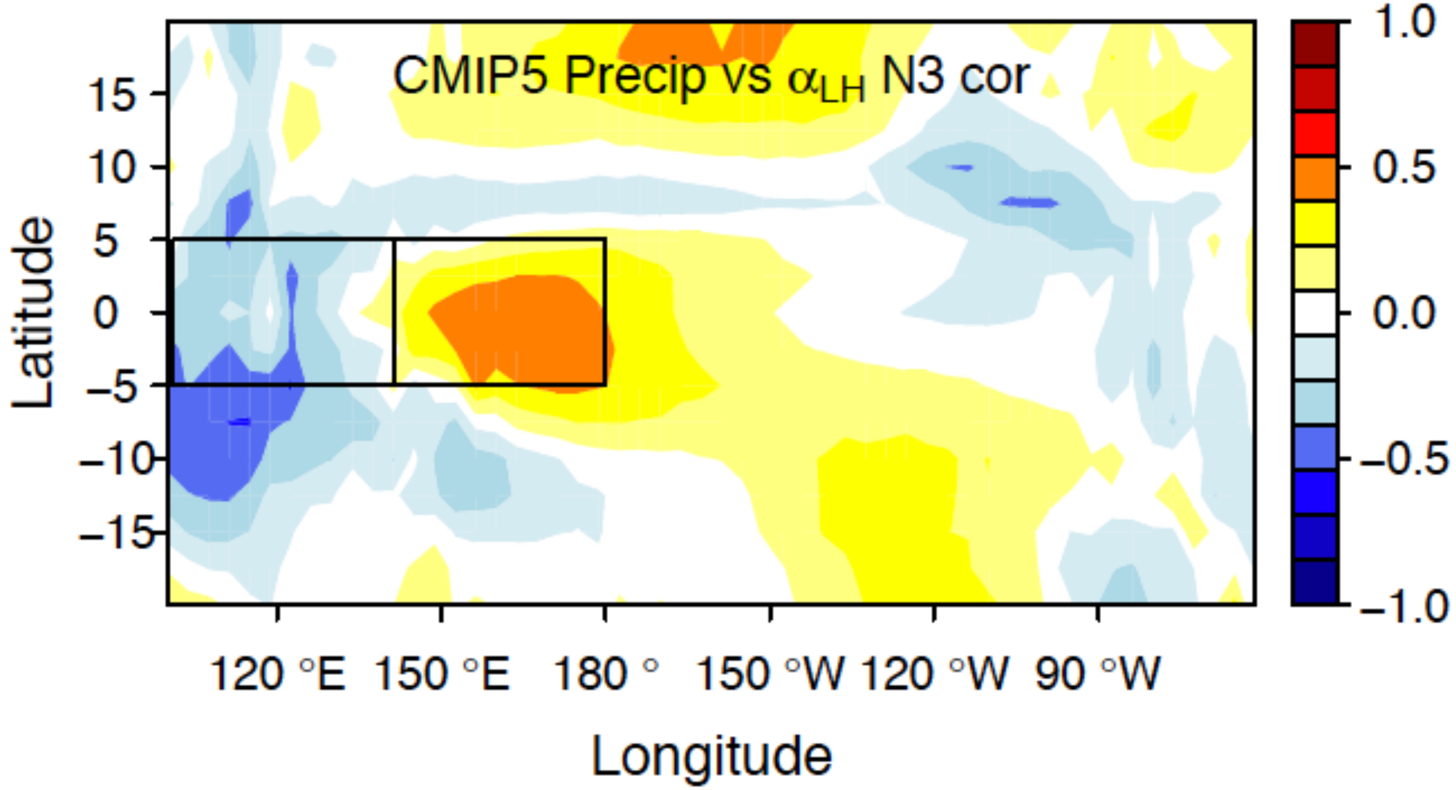
Tropical Precipitation Changes: Chadwick et al., 2013

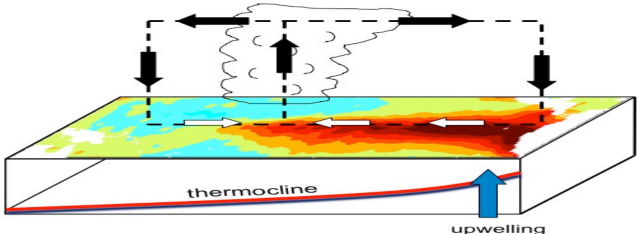




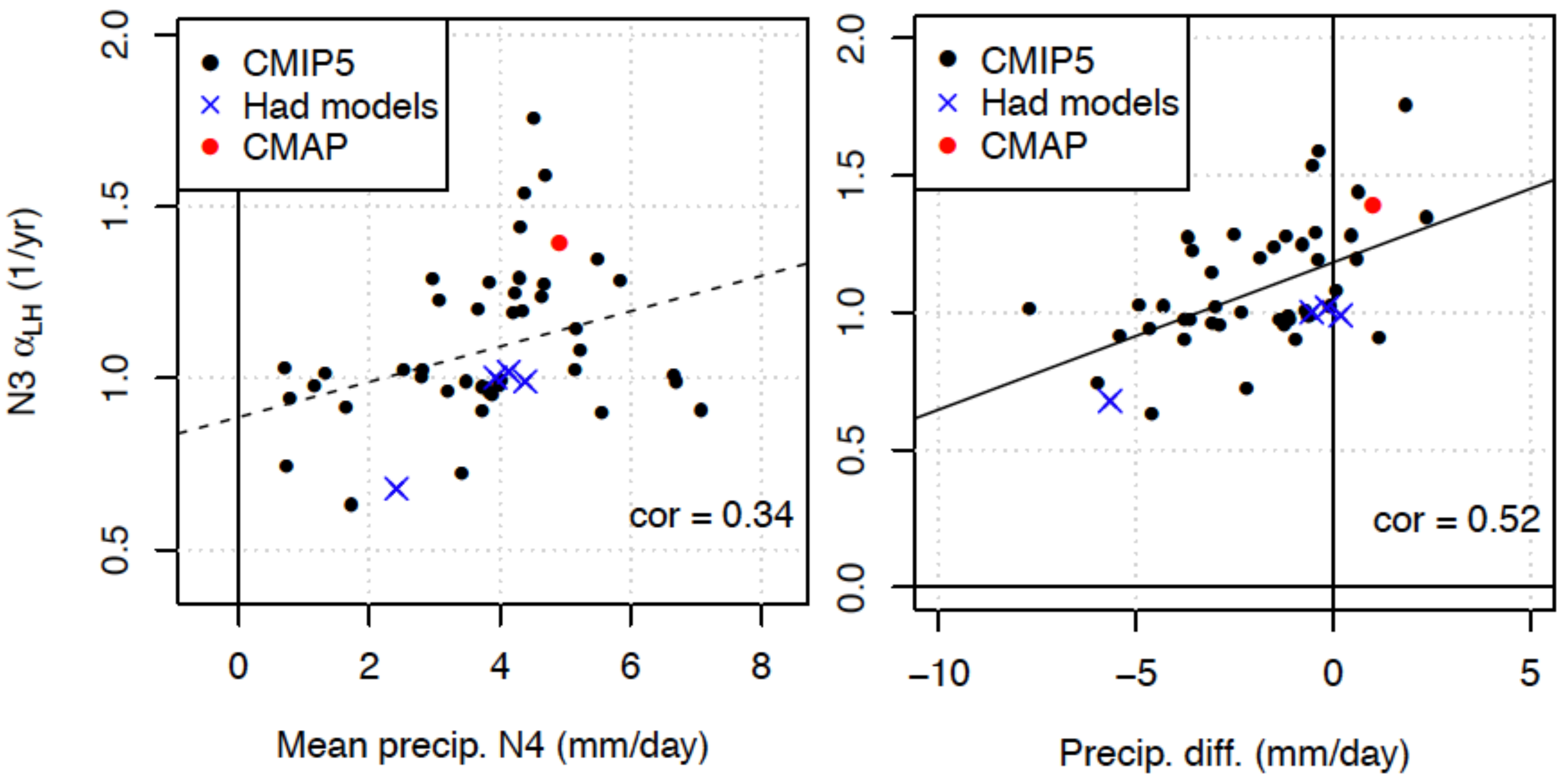
Latent Heat Feedbacks and Mean Precip

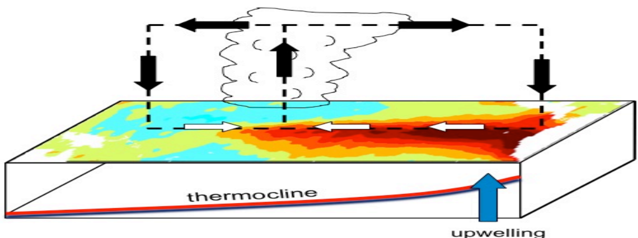
- Relatively strong correlation between mean rainfall and latent heat flux feedback in CMIP5



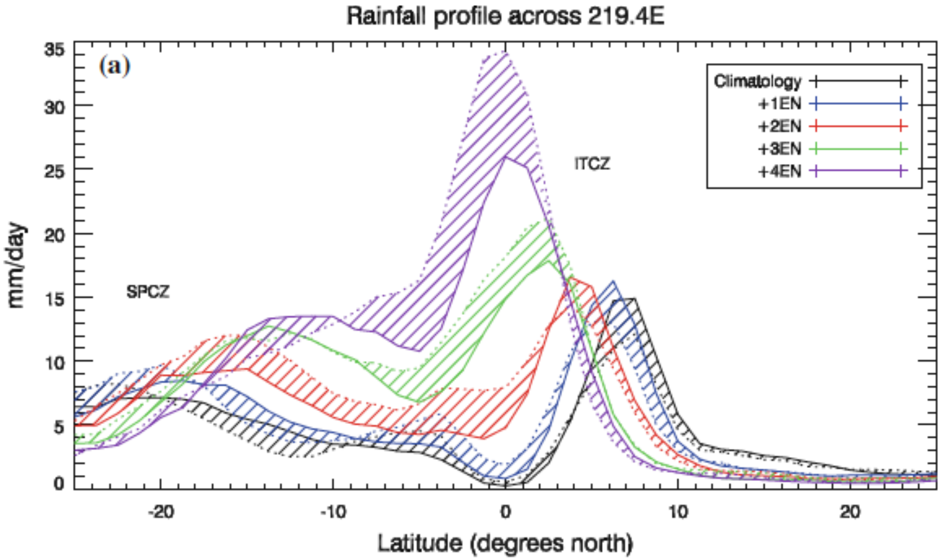


Latent Heat Feedbacks and Mean Precip

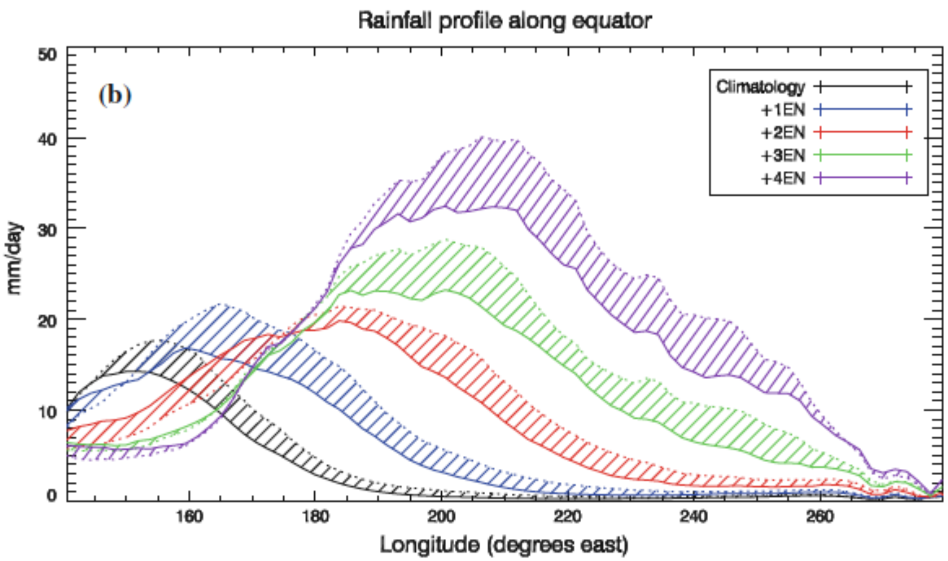




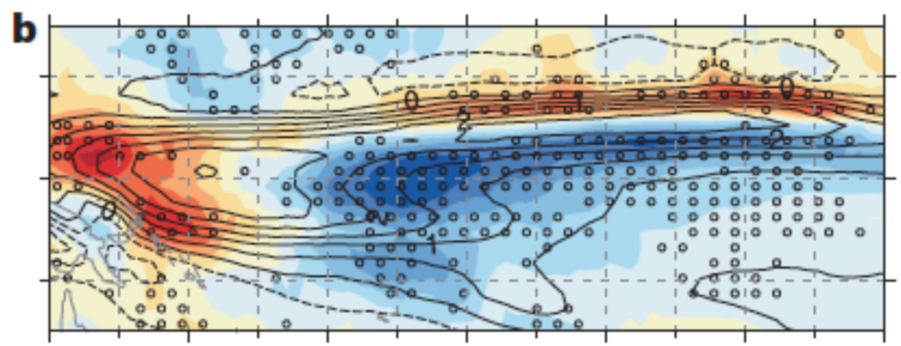
Changing El Niño Teleconnections



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



Atmosphere model simulations



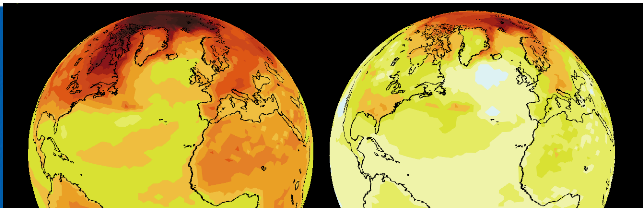
CMIP5

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

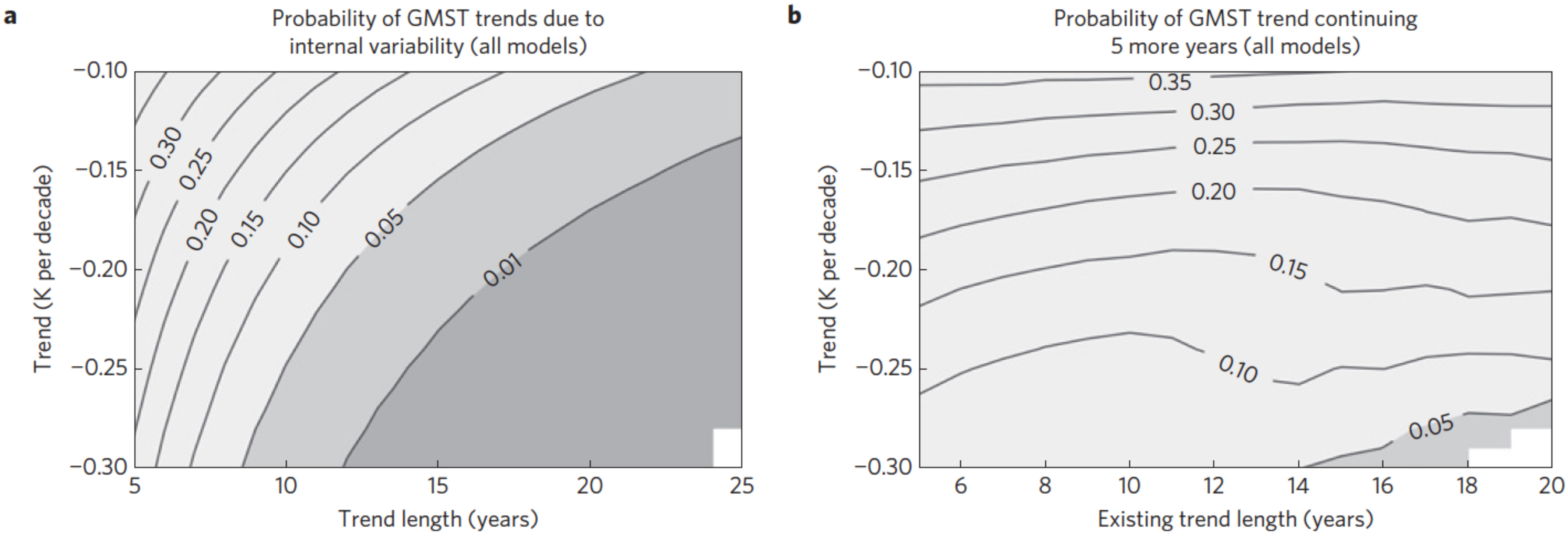
Hiatus

- Estimate forced response by averaging CMIP5 historical simulations (+ test sensitivity to this assumption)
- Generate large synthetic ensemble by adding control run variability to the forced response
- [Sub-select models based on some metrics of ability to simulate interannual variability – makes little difference]
- Estimate probability of occurrence of hiatus events and ‘surge’ or accelerated warming events
- Look at TOA and ocean heat budget during events

Roberts, Palmer, McNeall, MC 2015



Probability of Hiatus Events



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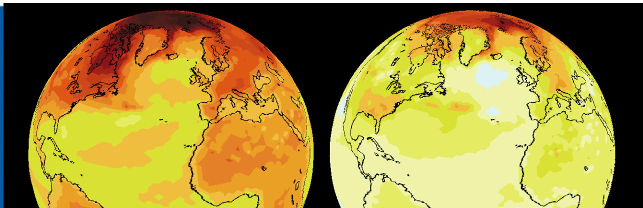
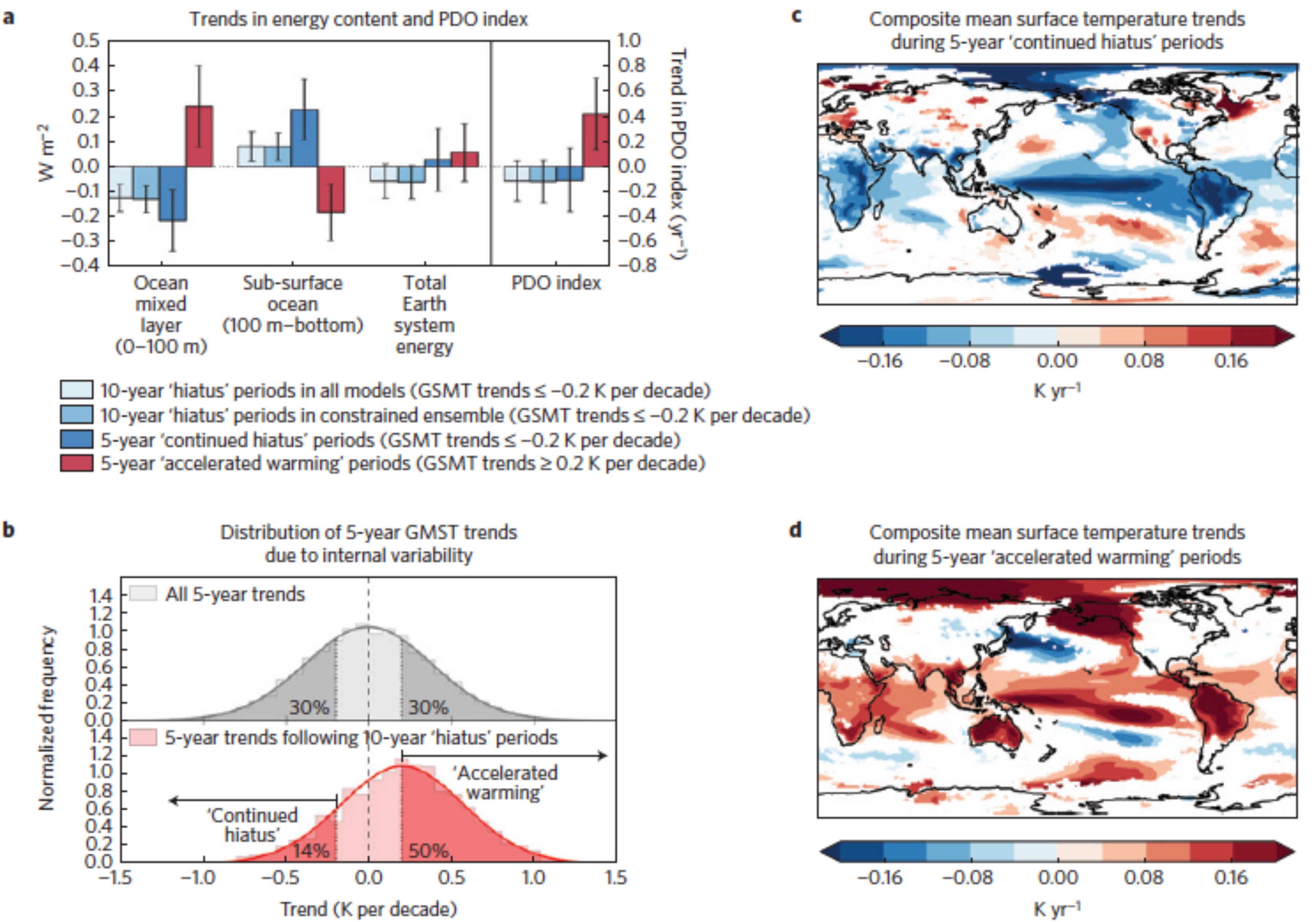


Hiatus



a
Trends in energy content and PDO index
W m^{-2}
Trend in PDO index (yr^{-1})
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
Ocean mixed layer (0–100 m)
Sub-surface ocean (100 m–bottom)
Total Earth system energy
PDO index
10-year 'hiatus' periods in all models (GSMT trends ≤ −0.2 K per decade)
10-year 'hiatus' periods in constrained ensemble (GSMT trends ≤ −0.2 K per decade)
5-year 'continued hiatus' periods (GSMT trends ≤ −0.2 K per decade)
5-year 'accelerated warming' periods (GSMT trends ≥ 0.2 K per decade)
b
Distribution of 5-year GMST trends due to internal variability
Normalized frequency
All 5-year trends
30%
30%
5-year trends following 10-year 'hiatus' periods
'Accelerated warming'
'Continued hiatus'
14%
50%
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
Trend (K per decade)
c
Composite mean surface temperature trends during 5-year 'continued hiatus' periods
−0.16
−0.08
0.00
0.08
0.16
K yr^{-1}
d
Composite mean surface temperature trends during 5-year 'accelerated warming' periods
−0.16
−0.08
0.00
0.08
0.16
K yr^{-1}