Rapid adjustments of precipitation to climate forcings – are they real and can we observe them

Piers Forster, Thomas Richardson, Tim Andrews

(University of Leeds)

Thanks to

Bjorn Stevens, Sandrine Bony, Christopher Bretherton, Jonathan Gregory, Steve Sherwood, Olivier Boucher

Rapid adjustments and precipitation

1. What are rapid adjustments?
2. Global precipitation response
3. Regional precipitation response
4. Observing changes in reality

Rapid adjustments of precipitation are probably real but observing them could be hard

2. WHAT ARE RAPID ADJUSTMENTS?

Adjustments – missing component of energy budget

Effective radiative forcing ΔF=

RF +adjustments

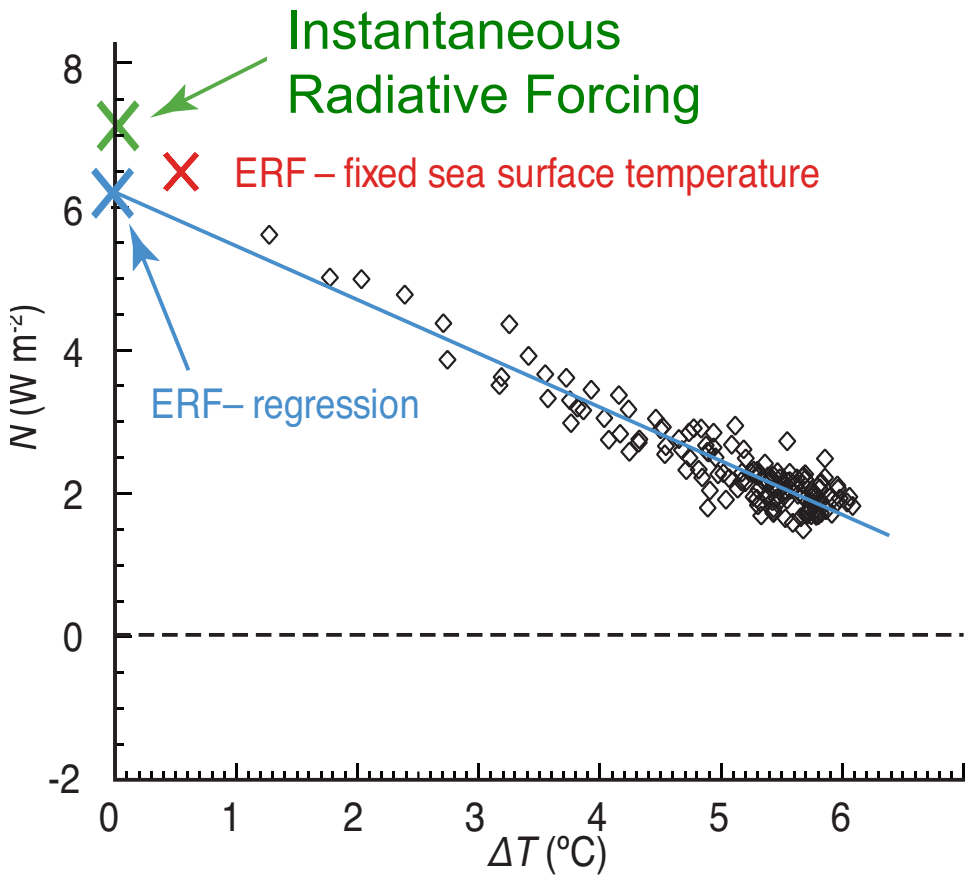
+

=

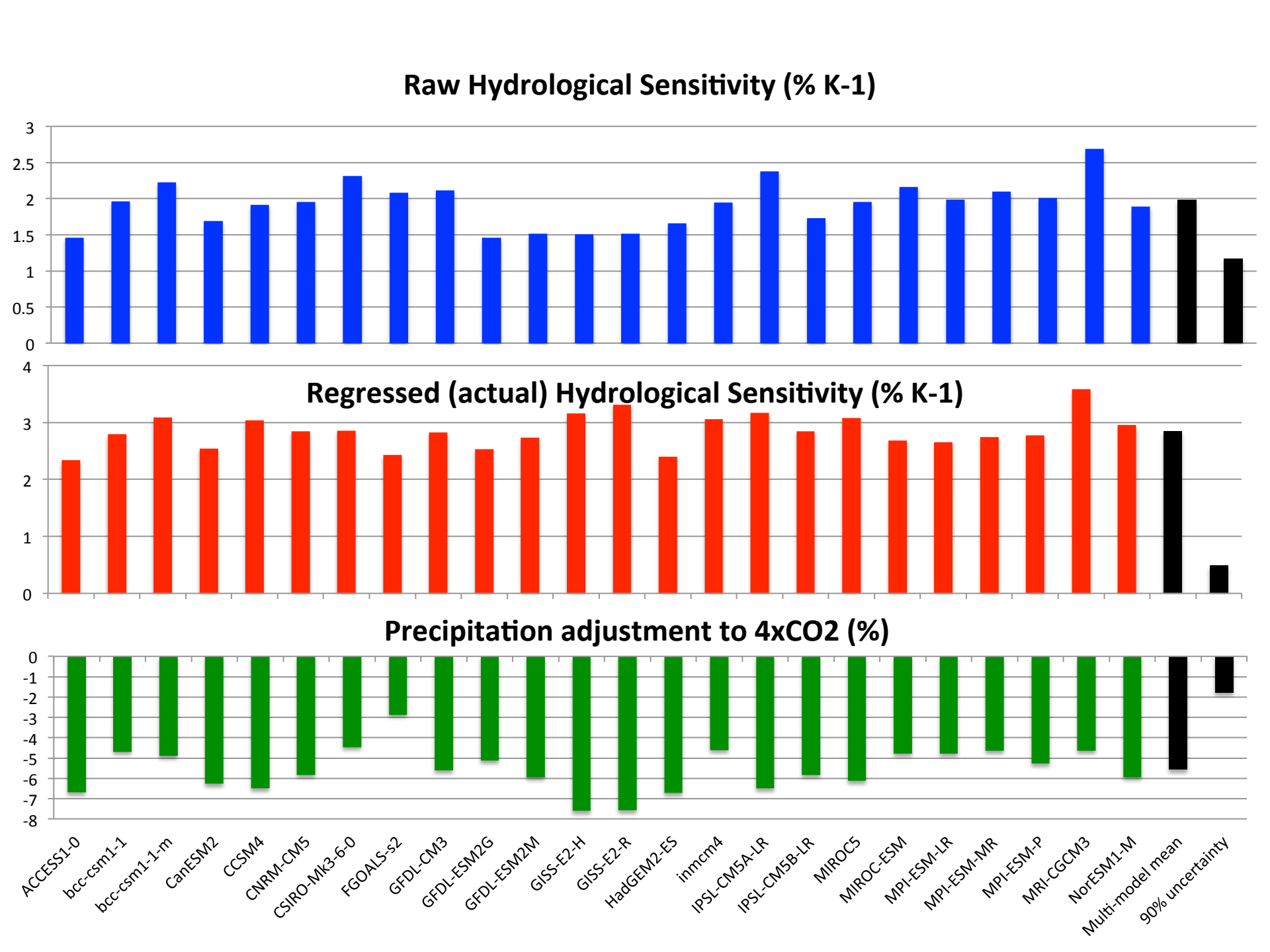
Feedback terms =

(λ_{Planck} + $\lambda_{WV/LS}$ + $\lambda_{surface}$ + λ_{cloud}) ΔTs

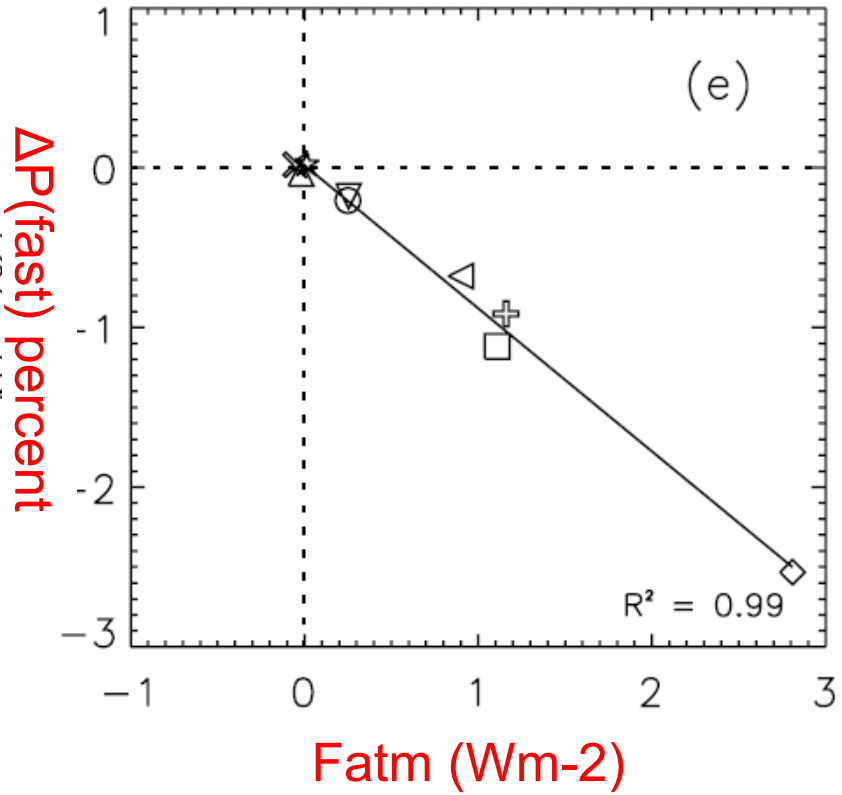
Change in ocean heat content ΔQ


Instantaneous
Radiative Forcing
ERF – fixed sea surface temperature
ERF– regression
N (W m-2)
ΔT (ºC)
8
6
4
2
0
-2
0
1
2
3
4
5
6

2. GLOBAL PRECIP RESPONSE


Raw Hydrological Sensitivity (% K-1)
3
2.5
2
1.5
1
0.5
0
Regressed (actual) Hydrological Sensitivity (% K-1)
4
3
2
1
0
Precipitation adjustment to 4xCO2 (%)
0
-1
-2
-3
-4
-5
-6
-7
-8
ACCESS1-0
bcc-csm1-1
bcc-csm1-1-m
CanESM2
CCSM4
CNRM-CM5
CSIRO-Mk3-6-0
FGOALS-s2
GFDL-CM3
GFDL-ESM2G
GFDL-ESM2M
GISS-E2-H
GISS-E2-R
HadGEM2-ES
inmcm4
IPSL-CM5A-LR
IPSL-CM5B-LR
MIROC5
MIROC-ESM
MPI-ESM-LR
MPI-ESM-MR
MPI-ESM-P
MRI-CGCM3
NorESM1-M
Multi-model mean
90% uncertainty

Rapid adjustment of global precipitation scales with atmospheric forcing

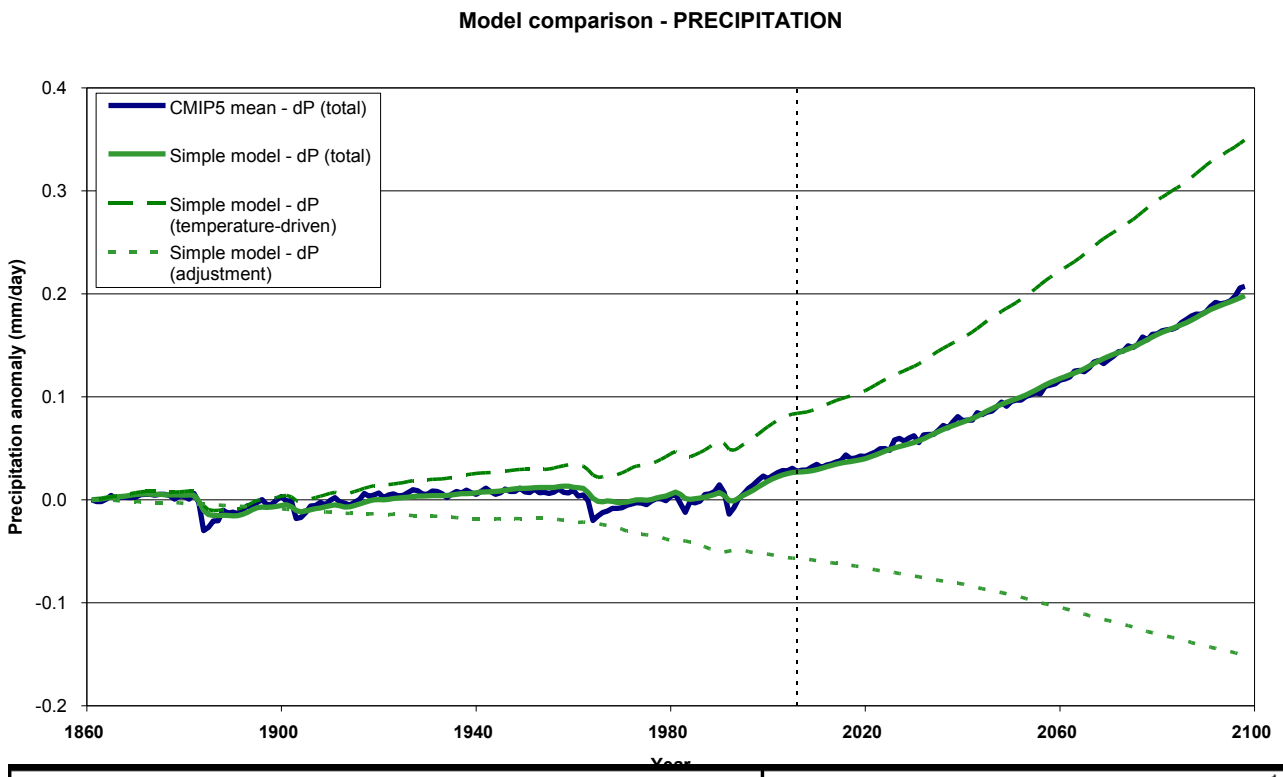


Fatm =
Ftoa - Fsurface

□ CO_2
◇ $2xCO_2$
CH_4 ○
Albedo △
✙ Solar
✕ O_3
SO_4 ☆
BB ▽
BC ◁

Andrews et al., 2010,
Geophys. Res. Lett

Rapid adjustment of global precipitation scales with atmospheric forcing

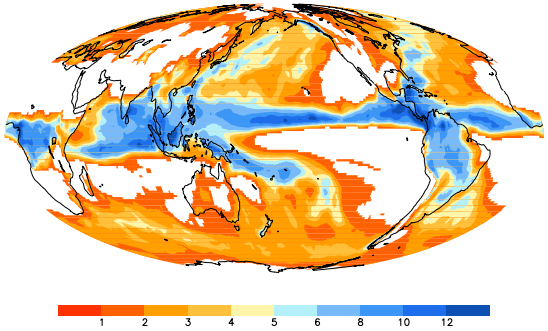


Hydrological sensitivity, k	*0.0633-0.0972 mm day^{-1} K^{-1}*

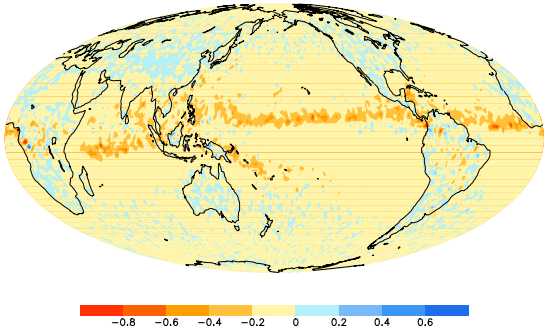
$$\Delta P_{adj} = \sum_i (\Delta Ftoa_i - \Delta Fsurf_i) \Big/ L$$

3. REGIONAL PRECIP RESPONSE

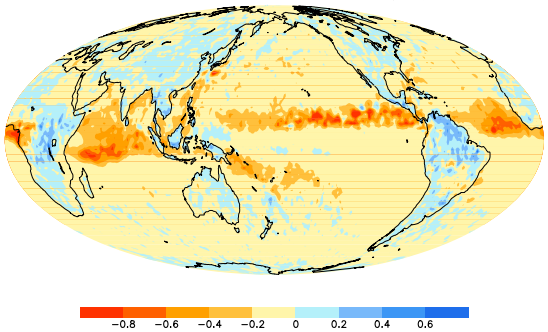
ECMWF precipitation October 2011 : 1xCO2



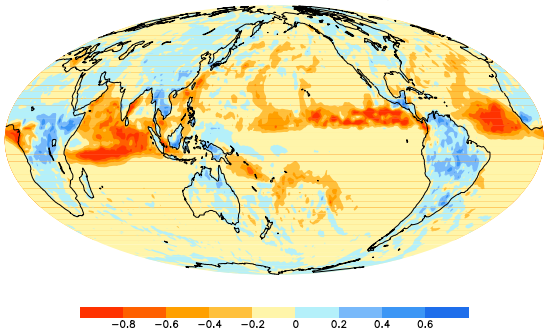
ECMWF dP : 4xCO2−1xCO2 (day 1)



ECMWF dP : 4xCO2−1xCO2 (day 5)

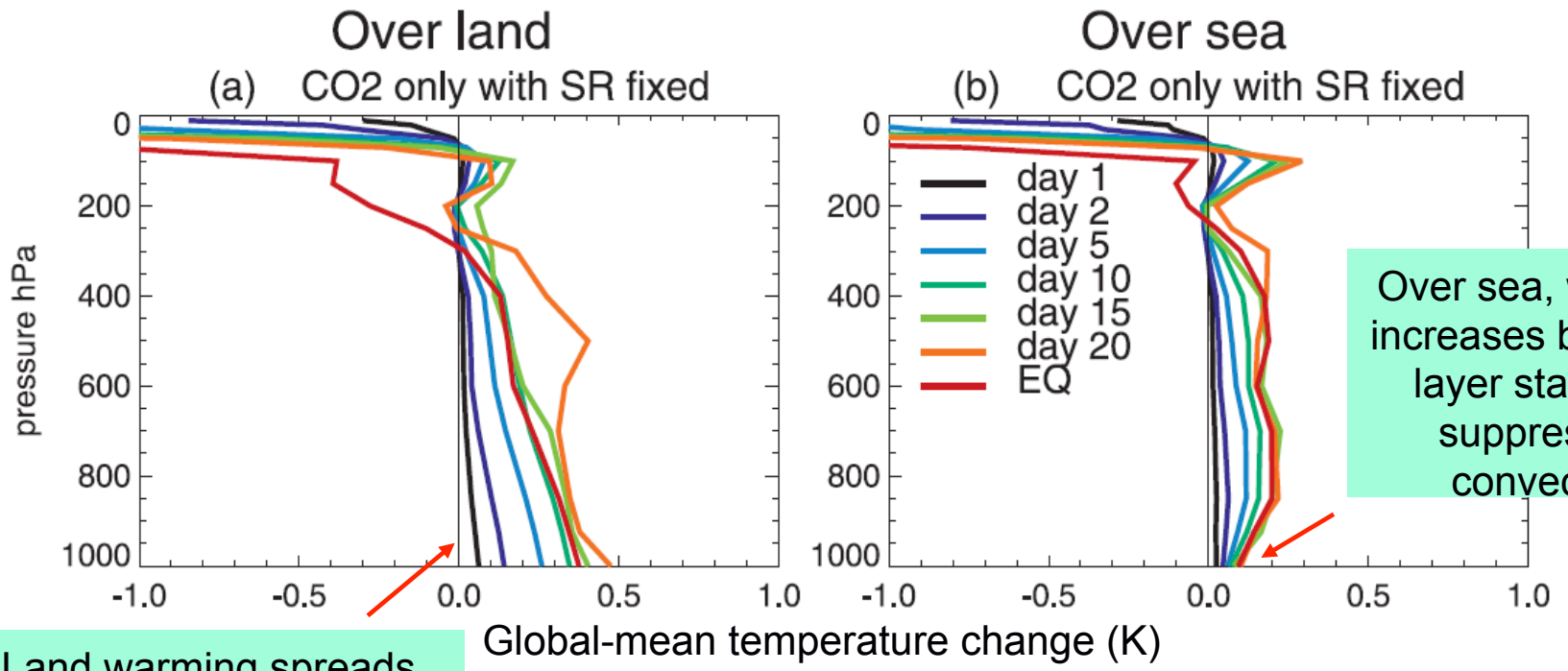


ECMWF dP : 4xCO2−1xCO2 (day 10)



Rapid land warming: How fast is fast?

Dong et al. (2008) used 6 member 4xCO_2 fixed-SST HadSM3 ensemble with daily diagnostics to look at timescale of adjustments:



Over sea, warming increases boundary layer stability – suppressing convection

Land warming spreads upwards from surface

Day 1: Land warms due to increased LW

Days 2-5: Processes adjust (e.g. clouds, precip)

Days 6-20: Troposphere approaches eqm

Ties is nicely with process-based understanding

Circulation changes

Wyant et al. (2011) use a superparameterized climate model, SP-CAM (2D cloud resolving model in each grid column), with 4 x CO_2 and fixed-SSTs over the tropics to investigate tropical cloud adjustment

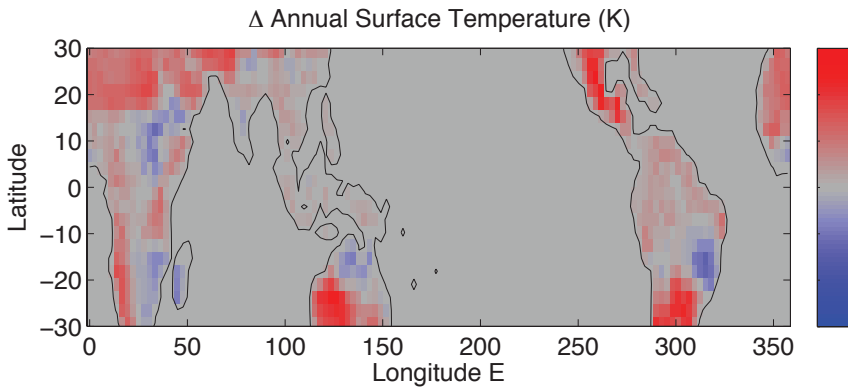
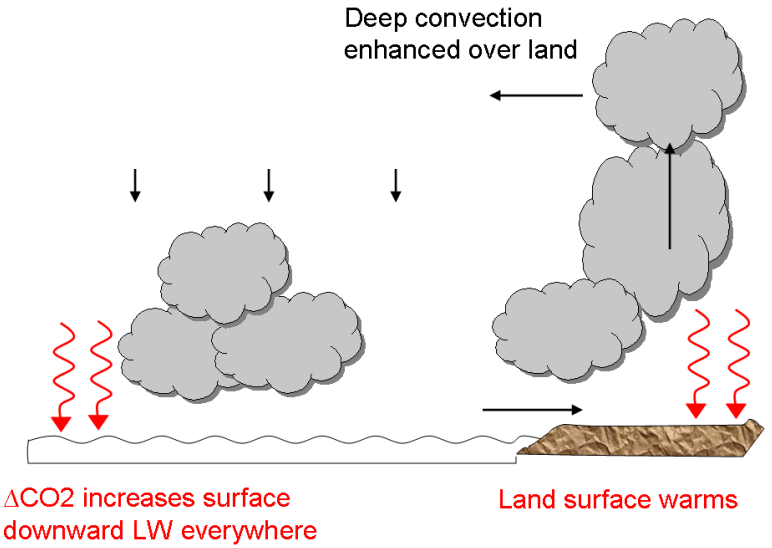


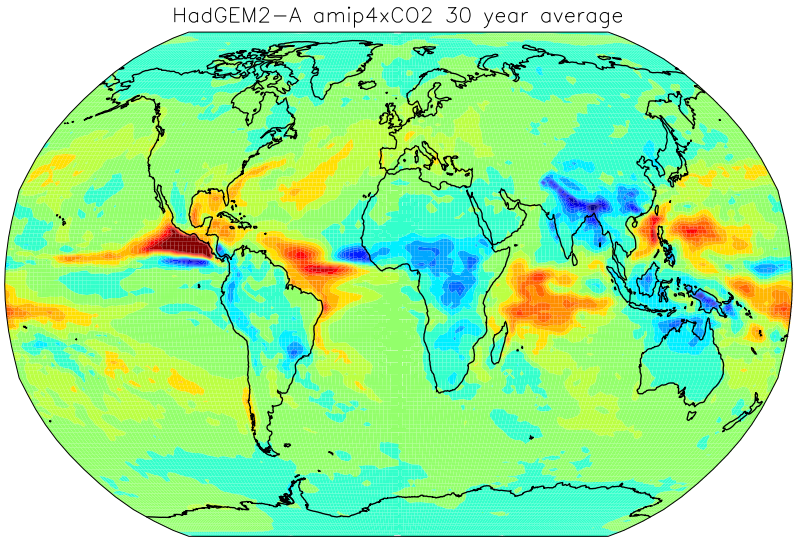
Figure 1: Annual mean change in surface temperature for SP-CAM due to 4xCO_2.

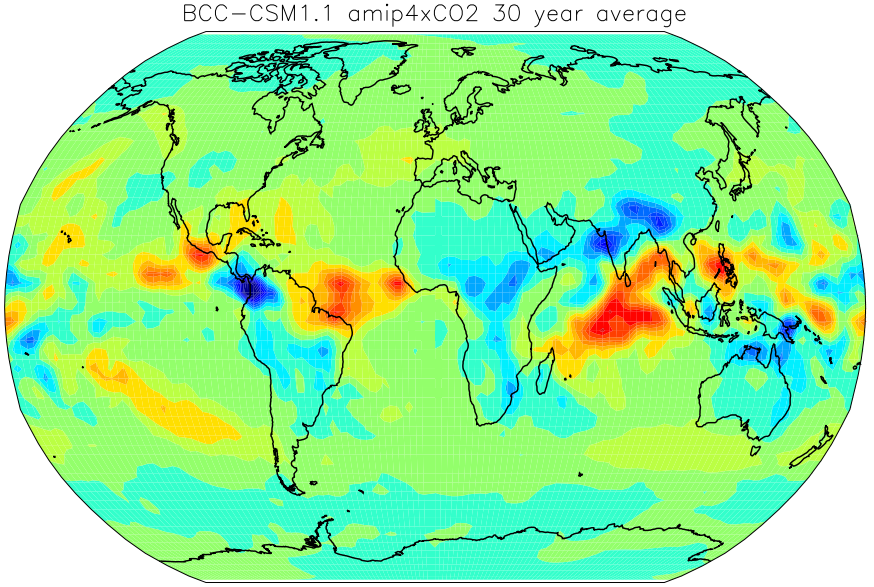


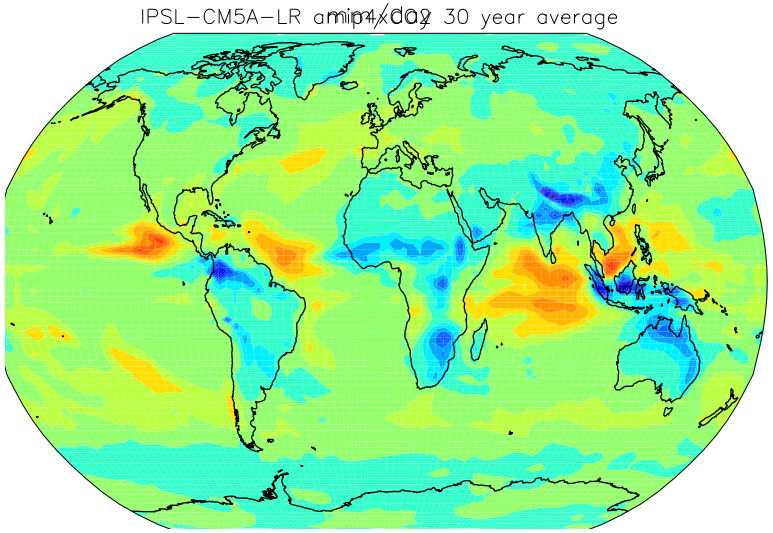
Courtesy of C. Bretherton

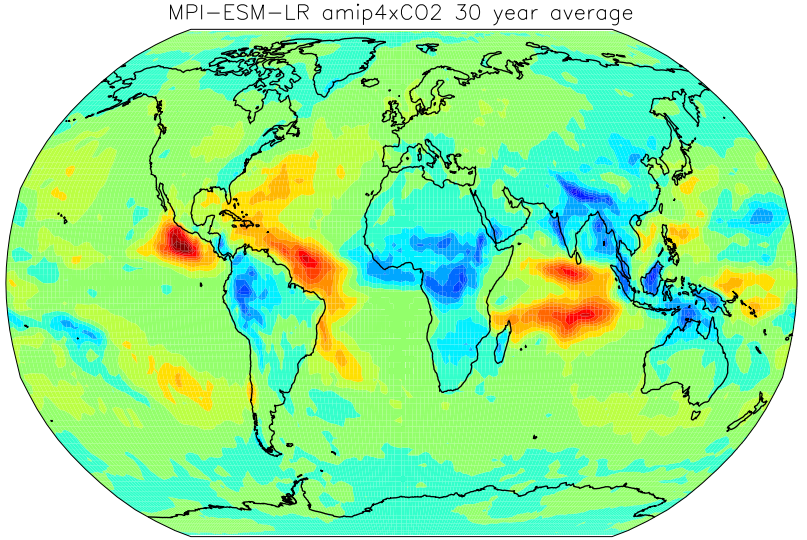
Find that land surface warming leads to more convection, with the opposite happening over the oceans (which dominates global-mean change)

4xCO2 AMIP regional precip changes

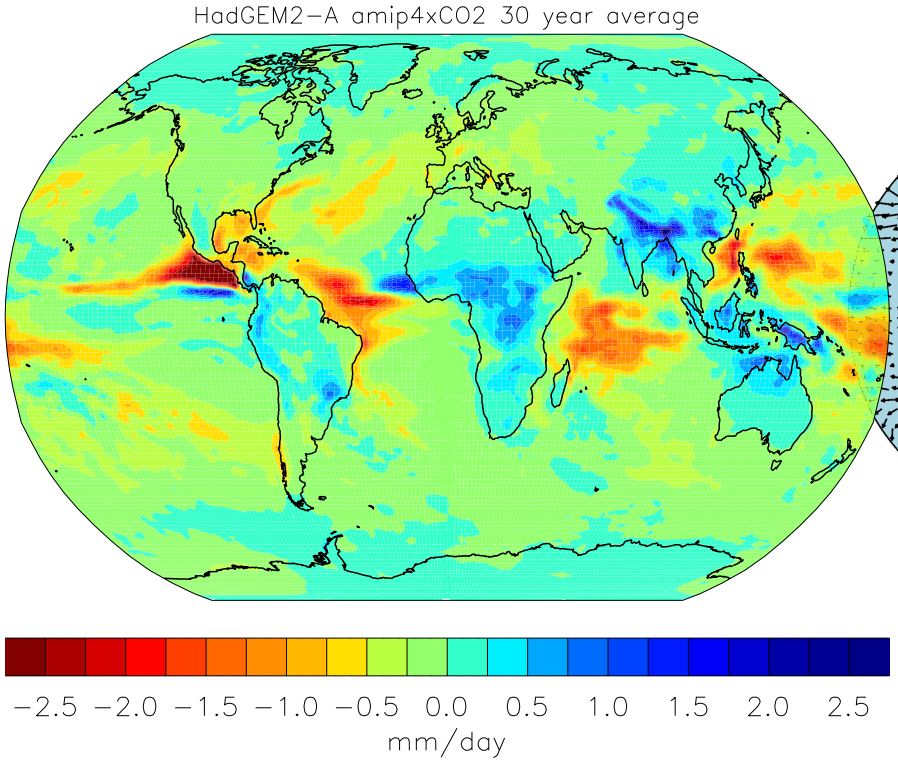


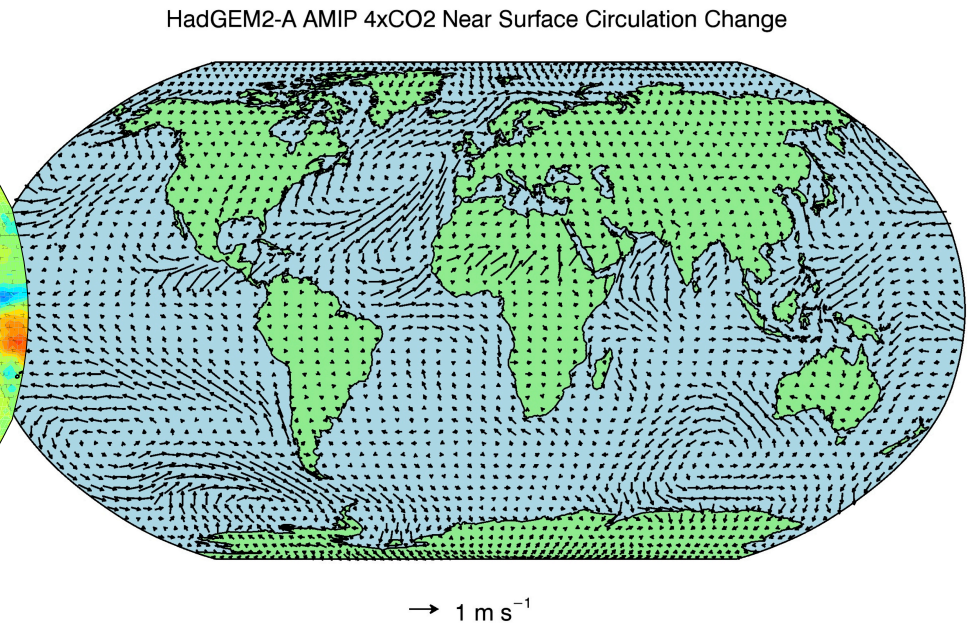




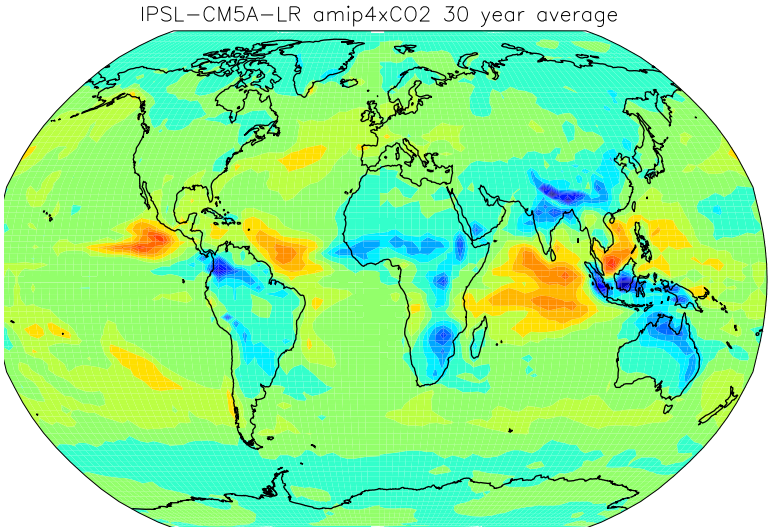


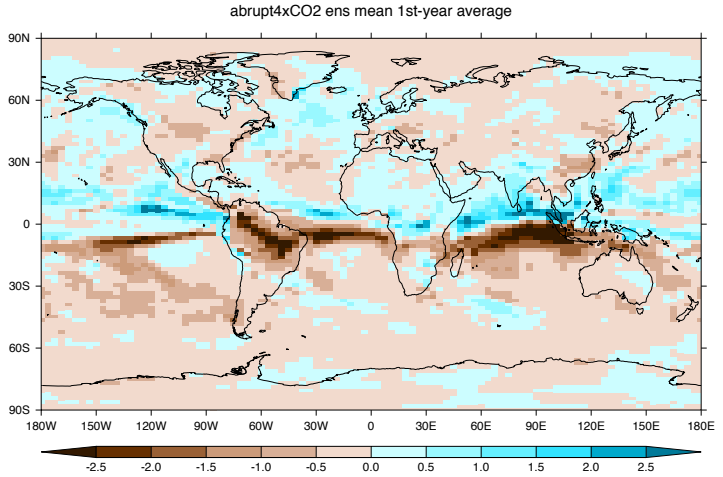
Circulation changes



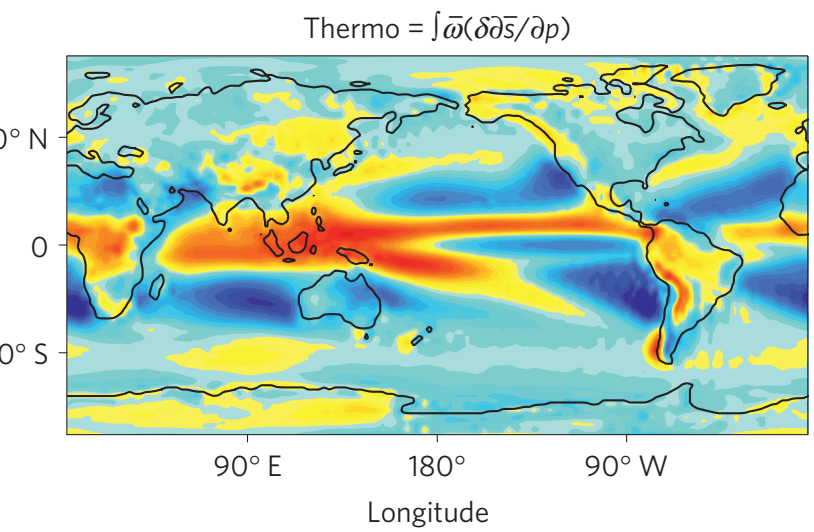


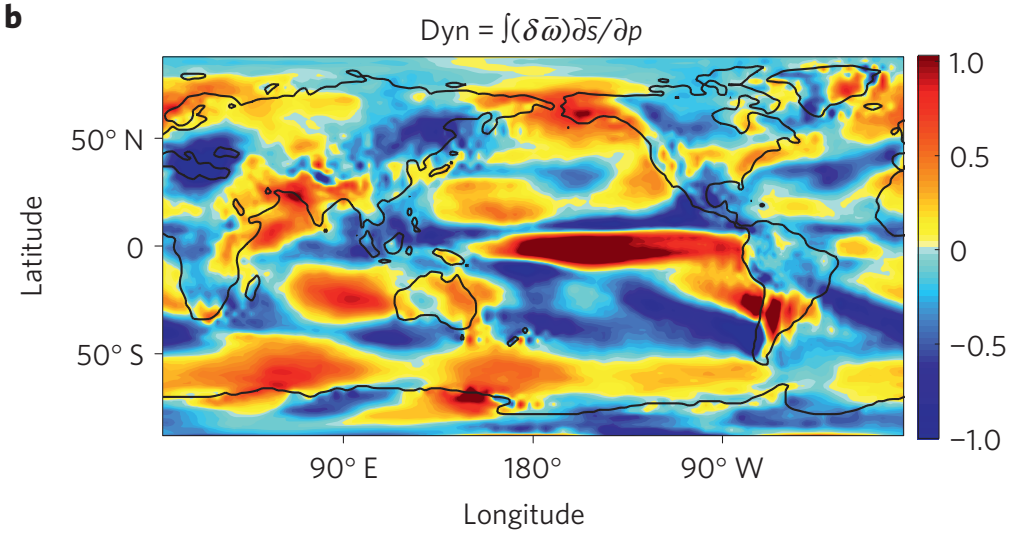
Ocean coupling?

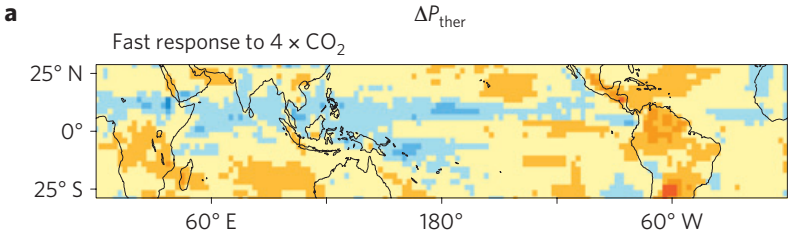


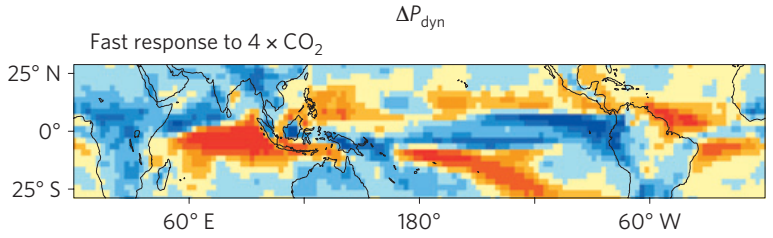


Muller & O'Gorman, Nat CC, 2011
Bony et al. (2013), Nature Geo Sci

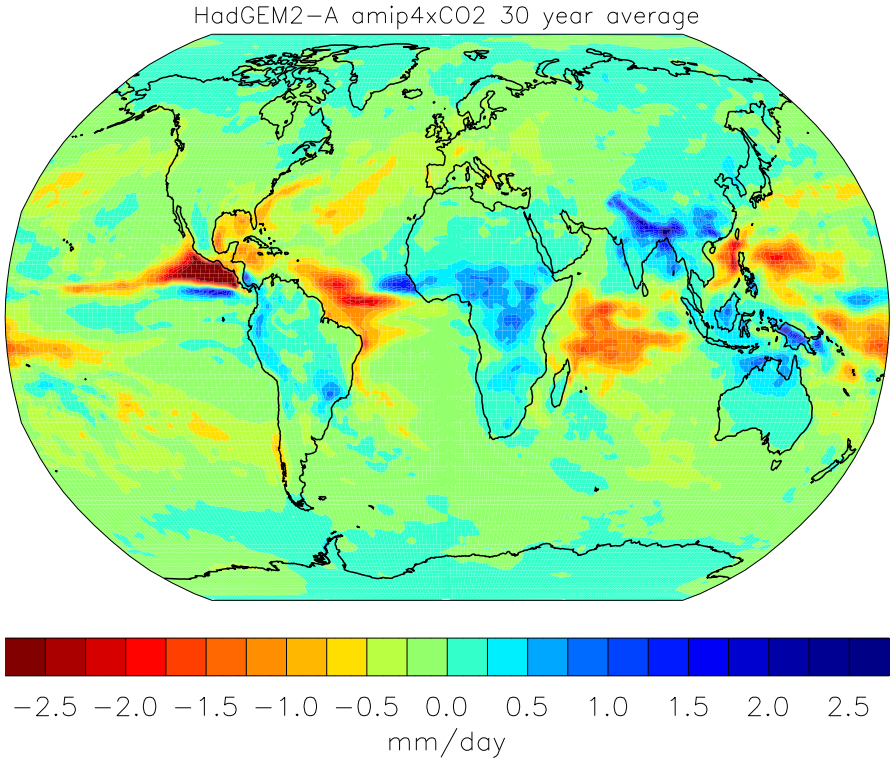


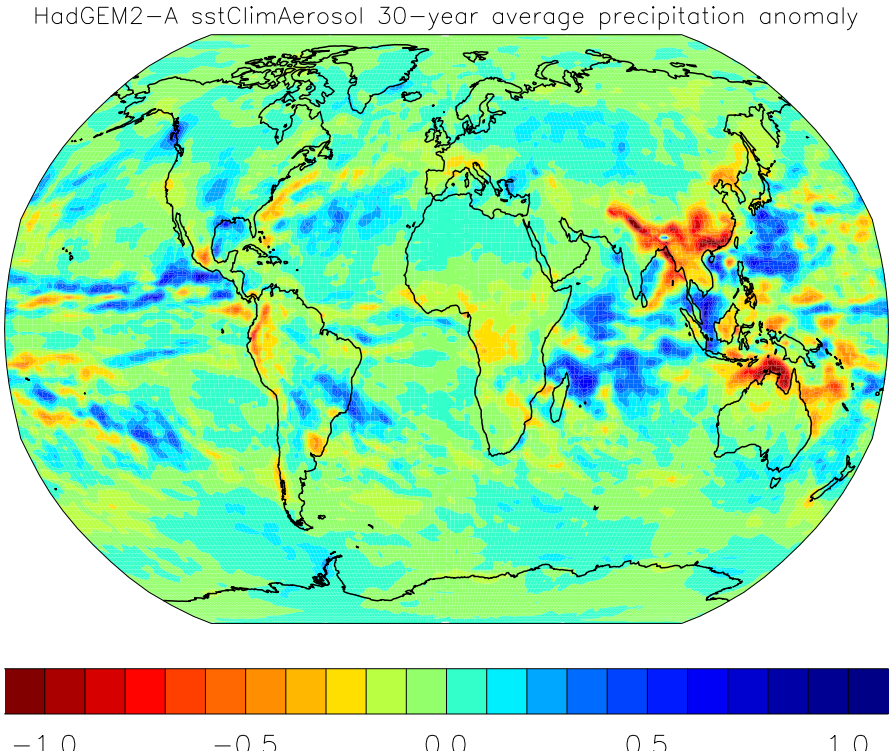






CO2 compared to aerosol





4. OBSERVING CHANGES IN REALITY

Role of forcing?

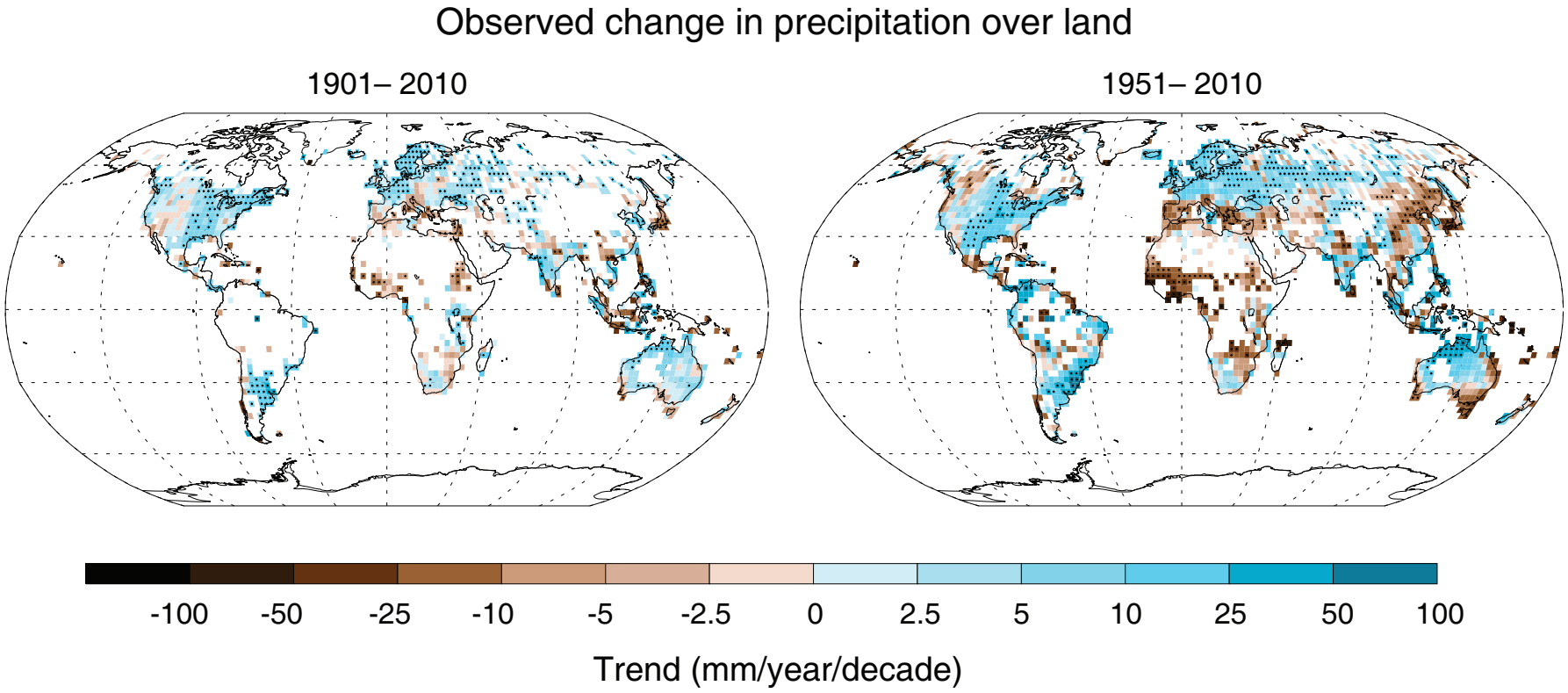
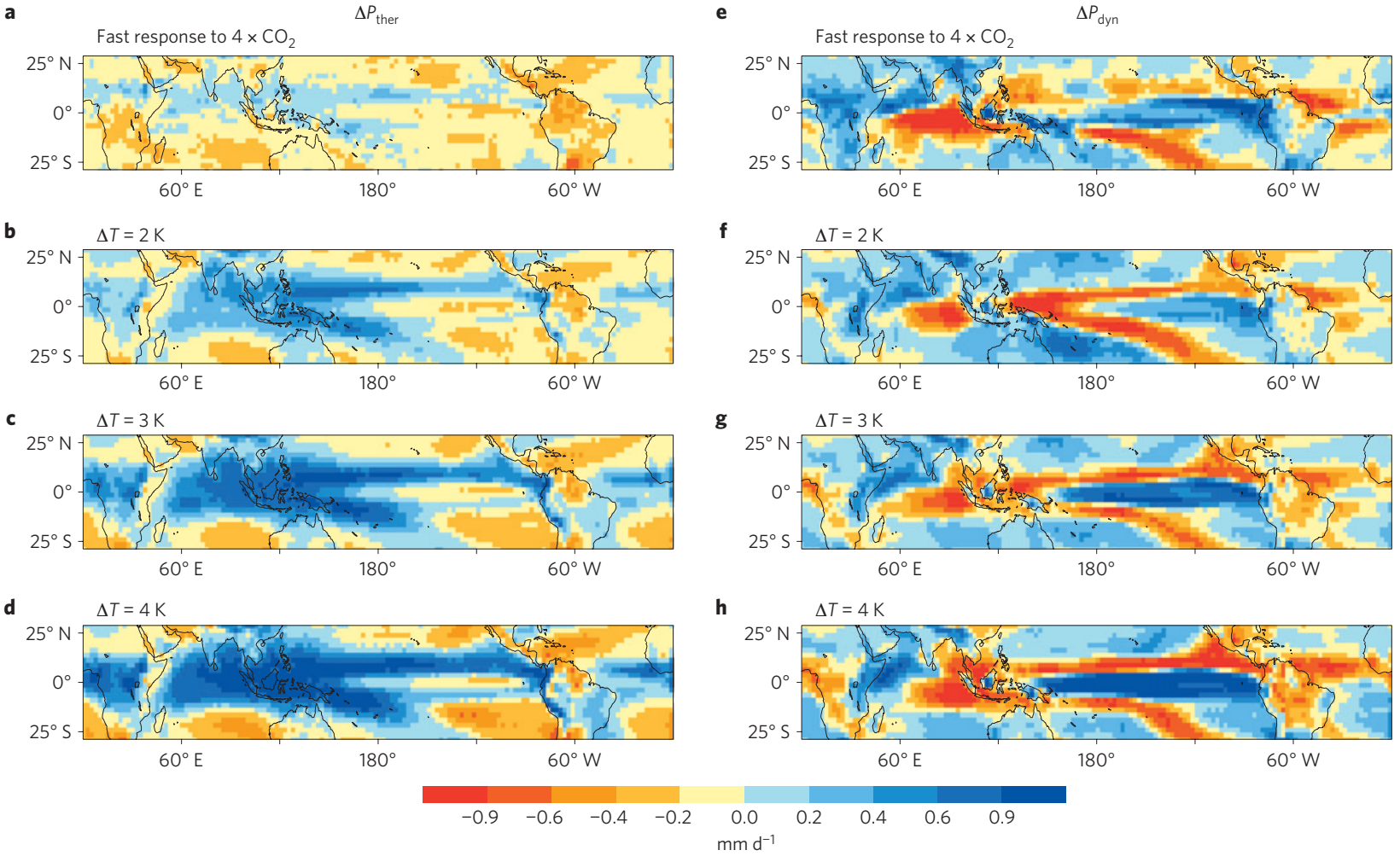


Figure SPM2. IPCC AR5

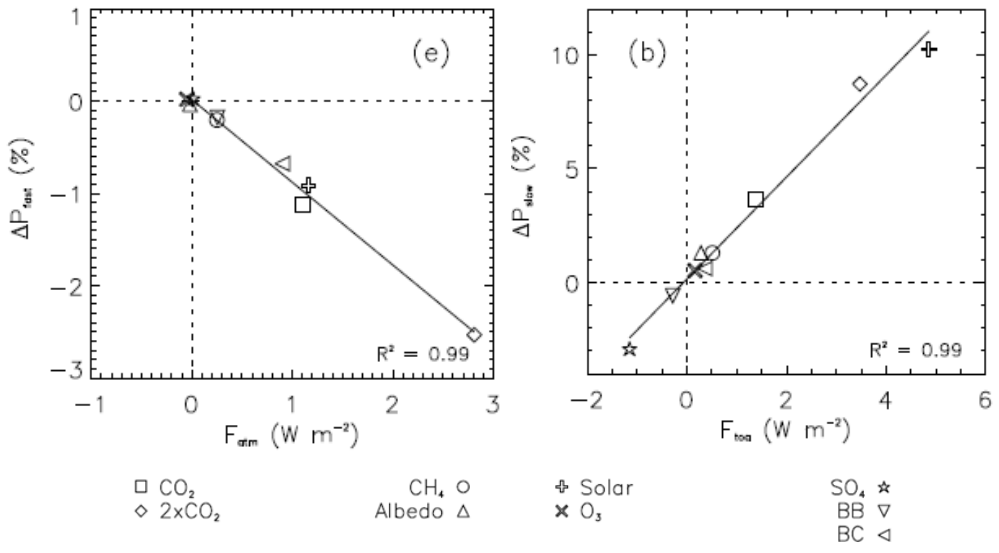
Conclusions

- Rapid adjustments useful diagnostic in models
- Global adjustment in precip scales with atmospheric forcing
- Regional adjustment: increase over land, with dynamical response
- Adjustment may prove difficult to finger in observations?


a
ΔP_{ther}
Fast response to 4 × CO_2
b
ΔT = 2 K
c
ΔT = 3 K
d
ΔT = 4 K
e
ΔP_{dyn}
Fast response to 4 × CO_2
f
ΔT = 2 K
g
ΔT = 3 K
h
ΔT = 4 K
25° N
0°
25° S
60° E
180°
60° W
−0.9 −0.6 −0.4 −0.2 0.0 0.2 0.4 0.6 0.9
mm d^{-1}

Rapid adjustment of global precipitation scales with atmospheric forcing

Andrews et al. (2010)



Kvalevåg et al. (2013)