Rainfall-Temperature Relationships

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Introduction

At the October workshop I noted some biases in surface (air) temperature *T* and precipitation *P* over Australia in our UM AMIP run, and showed some preliminary work on relationships between *T* and *P*.

There are several motivations for further work on relationships:

1. Understanding uncertainty in projections of future climate based on CMIP3.
2. Understanding interdecadal variability, and incorporating it into PDFs (probability density functions) for climate change.
3. Developing projections which include the *T* and *P* relationships.
4. Evaluating processes associated with *T* and *P* in models, which may help improve ACCESS.

Analysis of data sets *(courtesy of Janice Bathols)* including:

'Scaled' change in *T* and *P* over 21st C of CMIP3 simulations

Variability in control runs of models, Mk3.5 and four others.

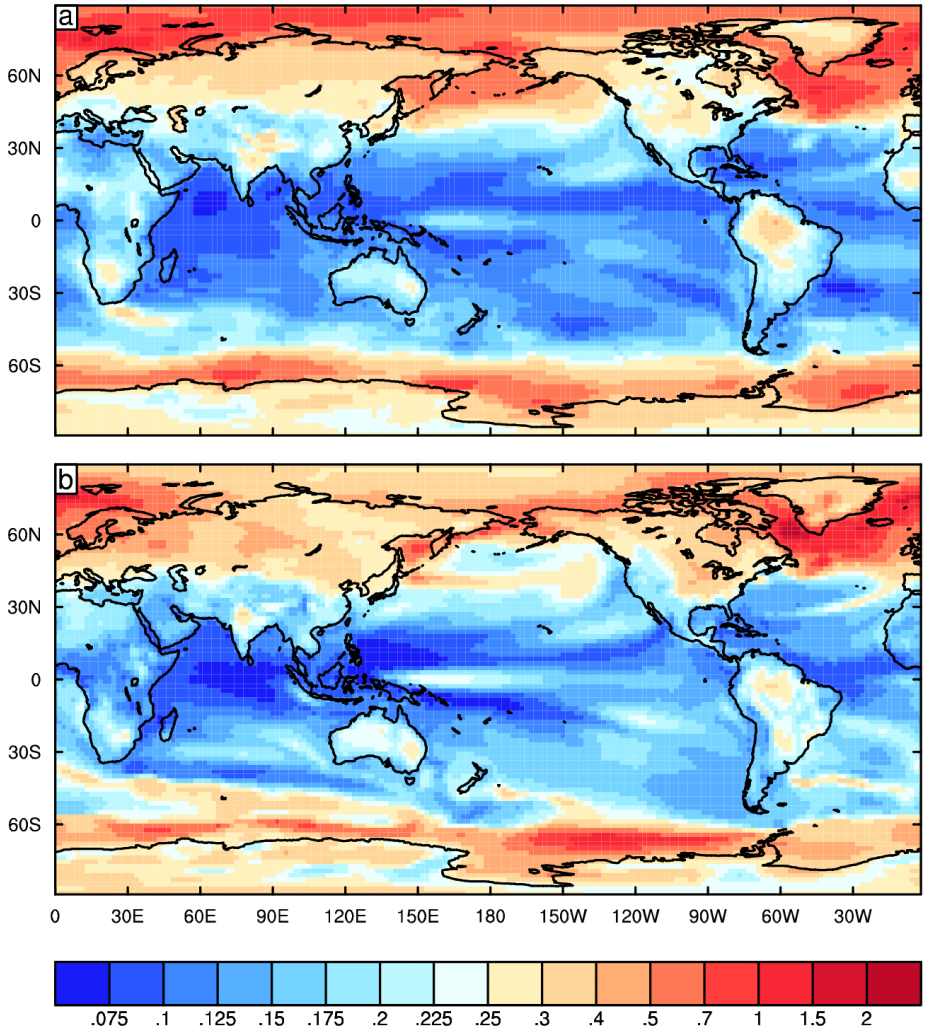
Variation in climate change simulations and decadal variability

Standard deviation of *T* at each grid point

annual case

23 CMIP3 model trends, per 1°C global warming

108 decadal means from Mk3.5 control



Global means:
trends 0.22°C
decadal 0.22°C
***r* = 0.81**

Surprisingly close, meaning that uncertainty in forced change for 1°C global warming is about the same as interdecadal variability

Standard deviation of *P (% of mean)* at each grid point

annual case

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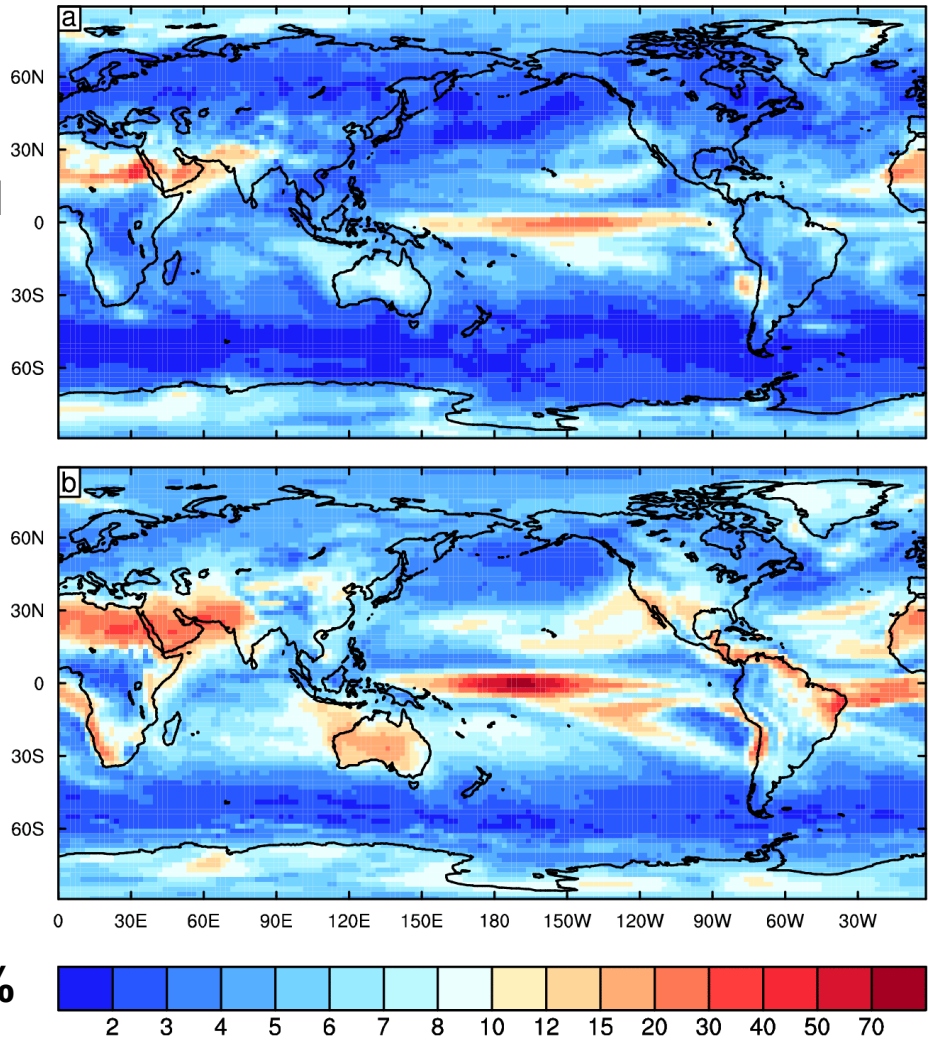
Global means:
trends 4.6%
decadal 7.3%
***r* = 0.72**



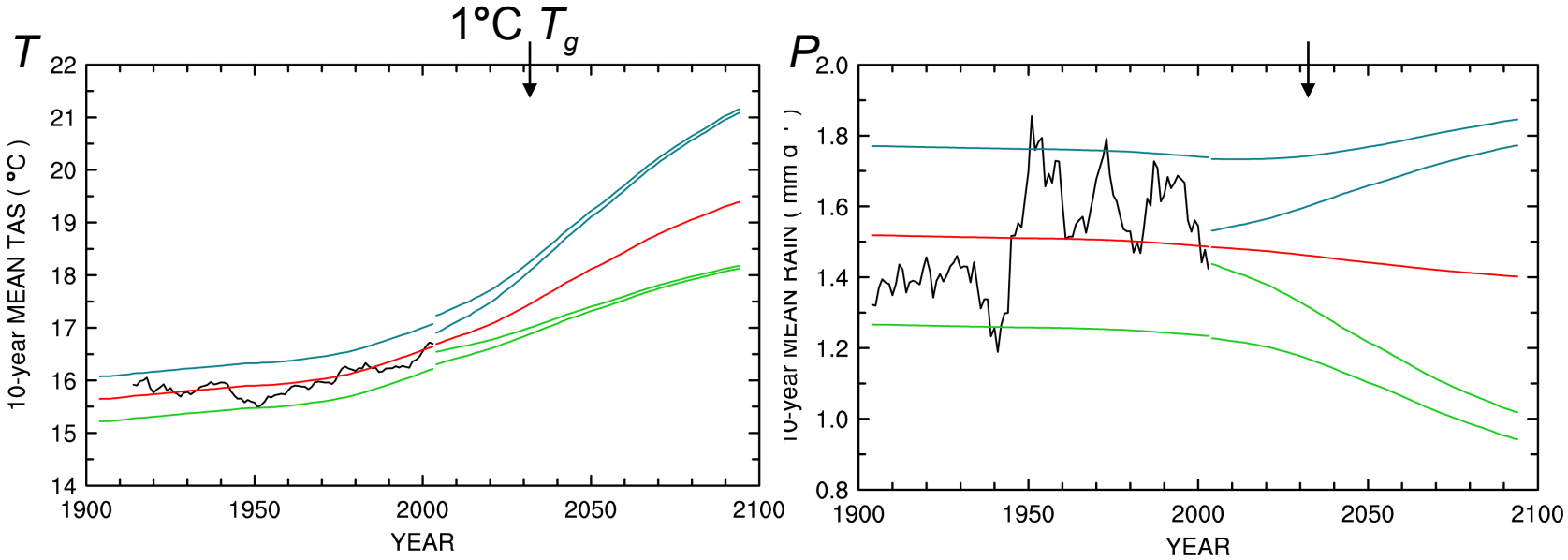
Again similar pattern, with variability often larger. Presumably similar physical processes affect patterns of variability and model GHG response

Climate Projections

Based on CMIP3 simulations, CSIRO/BOM published probabilistic projections of climate change for Australia in 2007. Recent work includes depiction of time series of range of change and of decadal variability.

Example: central Murray Darling Basin

10-y running means of BOM observations (black)
Best estimate of forced change (red)
Percentile 5 (green) and 95 (blue) of uncertainty.
Before 2003, internal variability (Mk3.5). After, inner- forced change (since 1990), outer- 'total'



From Watterson et al (2009, in prep.) 'Uncertainty of decadal means..under global warming)

Correlation between *T* and *P* at each grid point

annual case

23 CMIP3 model trends

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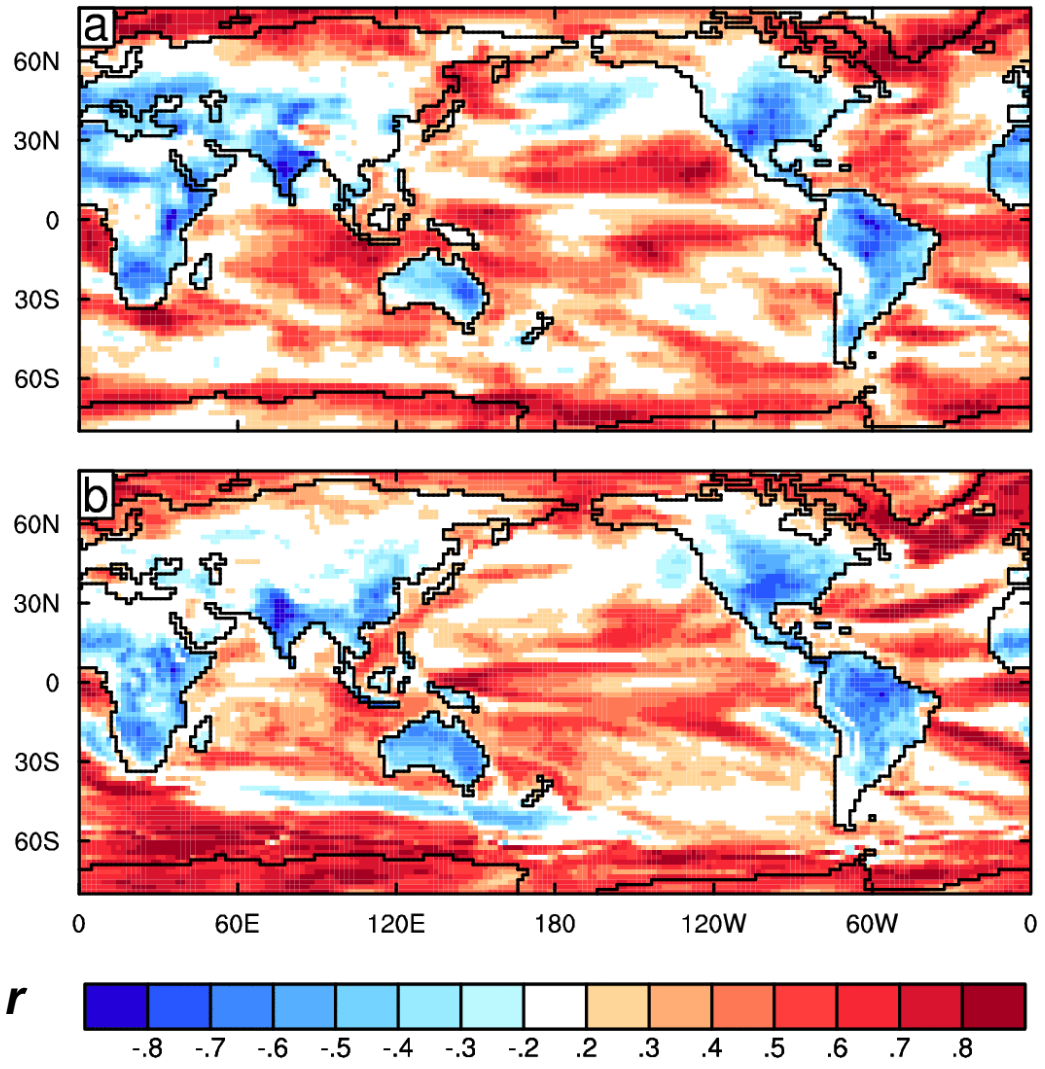


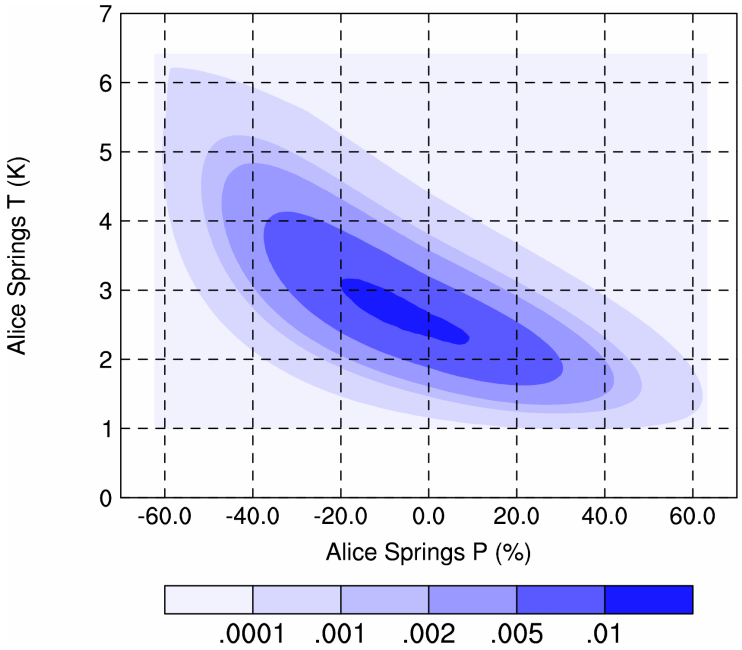
Mostly positive over ocean, negative over land (stronger in summer case)

From March 2009 ACCSP workshop

Given PDFs for forced climate change in *T* and *P*, and knowing that the pair are anticorrelated, can we construct Joint PDF with desired properties?

Currently using a simple iterative method –example:

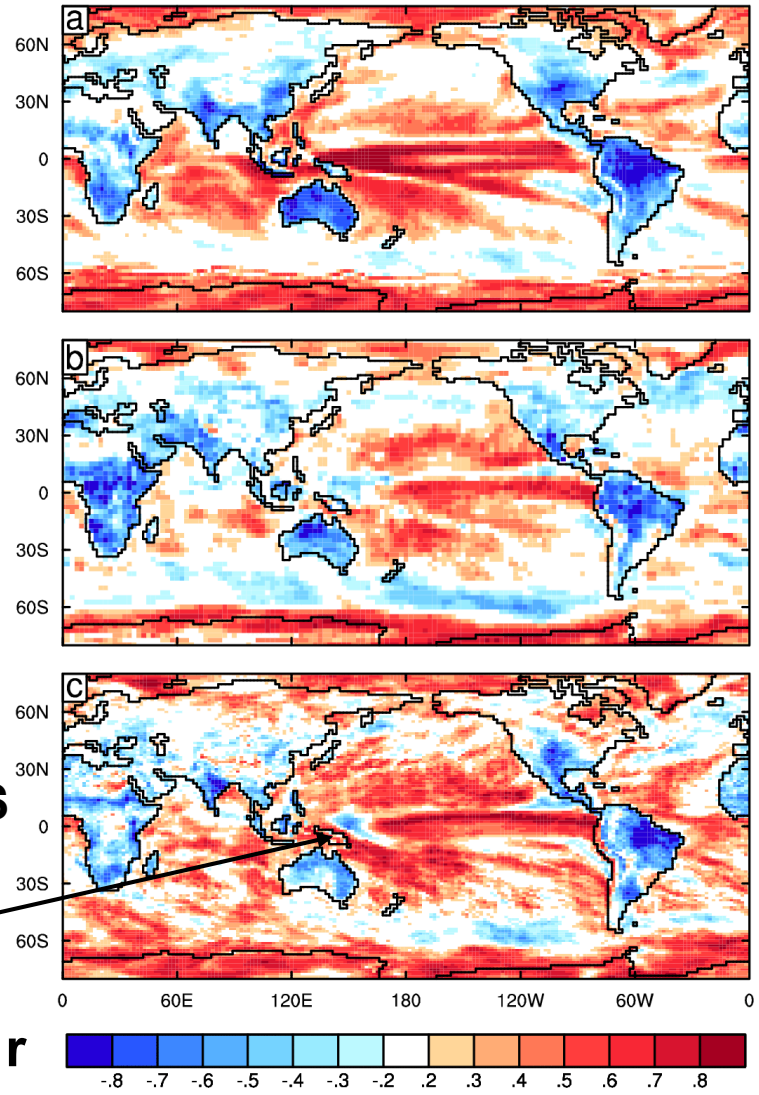
Joint PDF for change in summer *T* and *P* at Alice Springs 2070 under A1B, with the desired marginals and with $r = -0.73$



From 2008 workshop

Relationship between *T* and *P* as an evaluation tool?

With annual means



Fairly similar to the results for CMIP3 trends, and decadal means.

Westward extent of ENSO in coupled model seems to remove negative values

Regression coefficient for *T* relative to *P* at each grid point

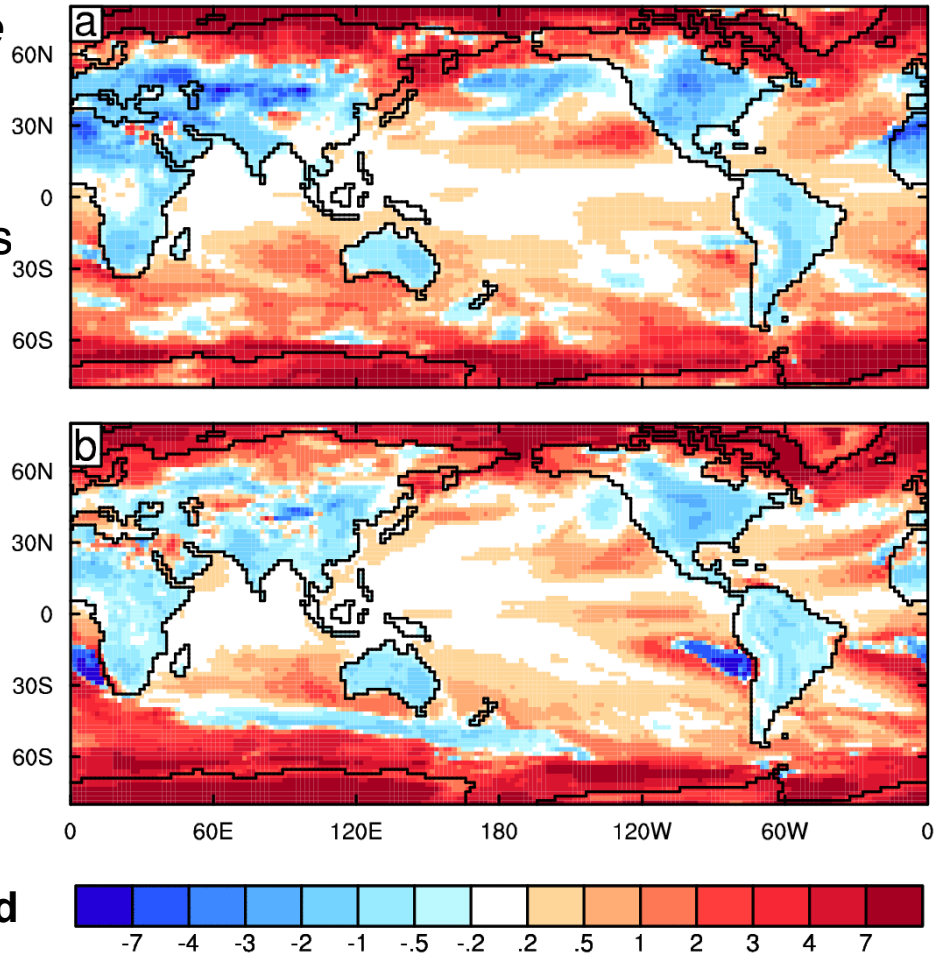
i.e. 'b', in T=a+bP

For land, how much cooling, for each additional mm/d of rain?

annual case

23 CMIP3 model trends

108 decadal means from Mk3.5 control



Rather uniform cooling of mid and low latitude land, with greater rainfall. In polar regions warmth and rain go together.

Presumably relates to surface schemes and character of rainfall, cloud.

CAWCR

Regression coefficient for *P* relative to *T* at each grid point

For oceans, how much additional rainfall (and latent heating) is there for a 1°C SSTA?

annual case

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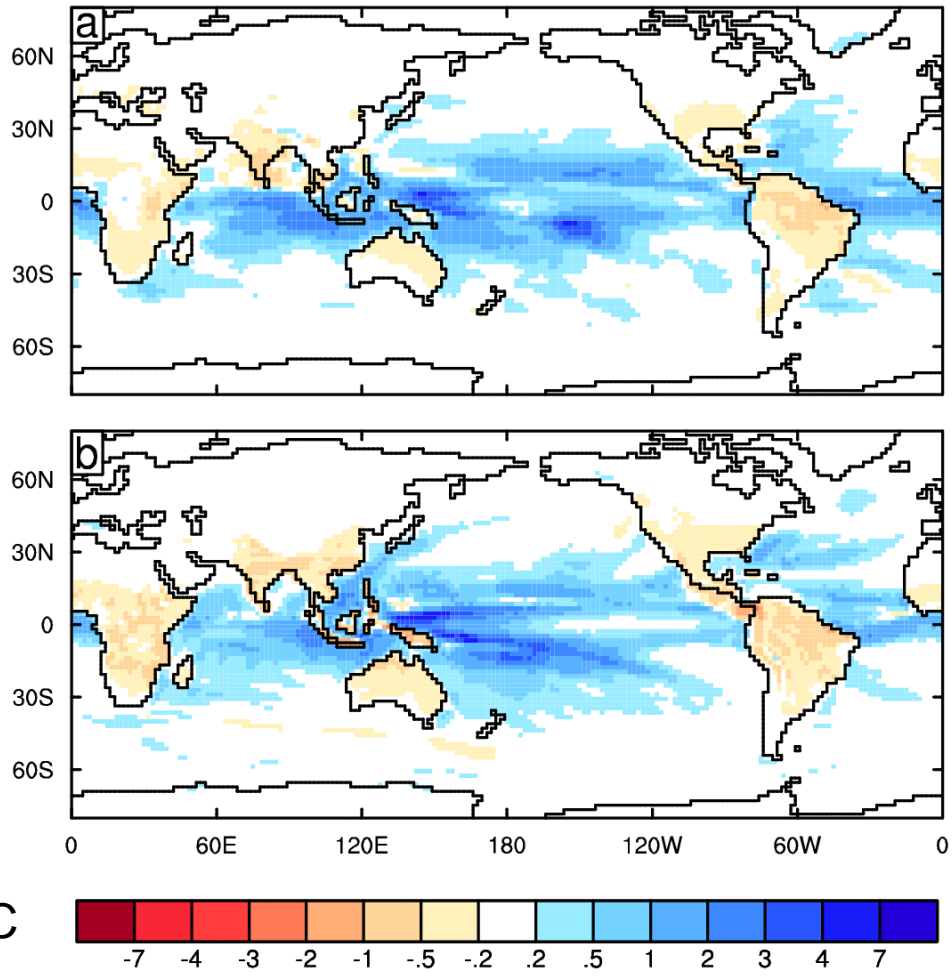


Equatorial regions have larger latent heating above the SST anomalies.

If response of atmosphere is driven by latent heating then tropical SSTAs will have much greater effect. Appears to provide a similar mechanism for uncertainty in midlatitudes via teleconnections. Important for our droughts –c.f. SST anomaly experiments.

Further evaluation of data sets

Observations

CRU gridded, land only *(not shown)*

ERA-40: 4 whole decades,
but satellite data changes P

Plcntrl simulations* *(detrended)

Mk3.5: 108 decades

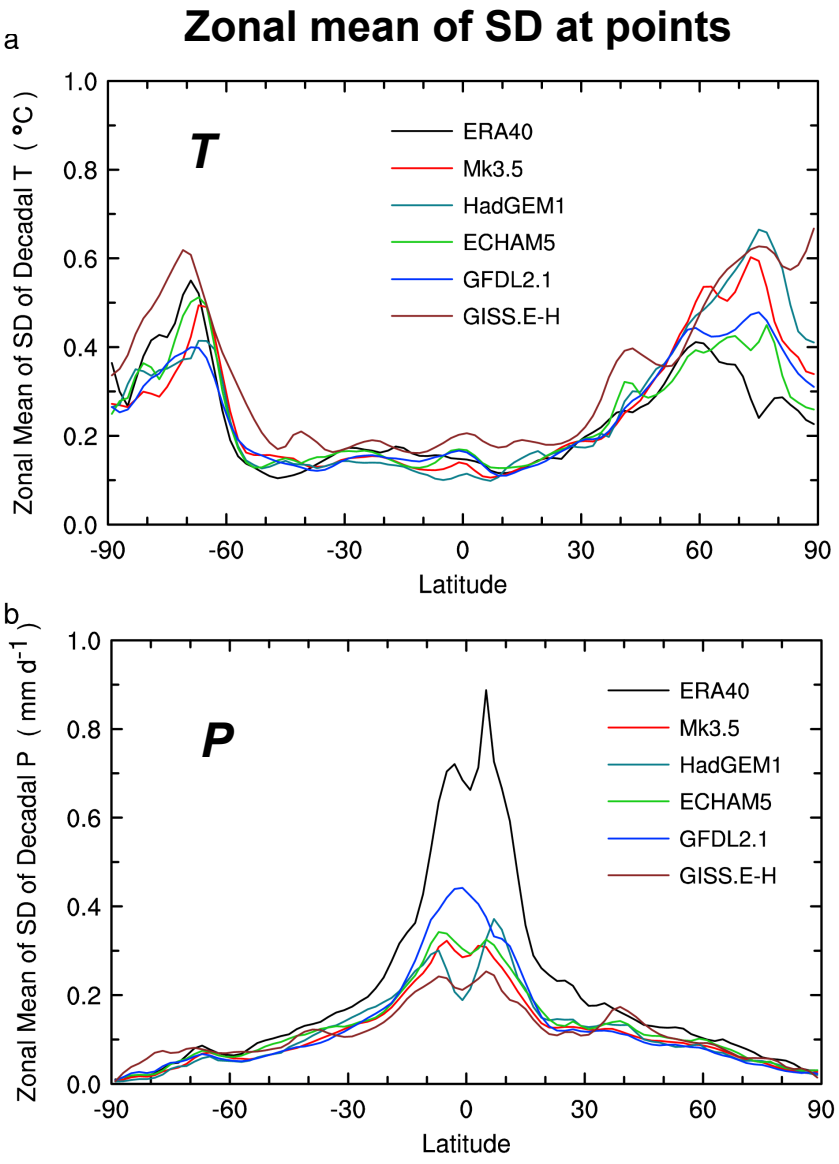
HadGEM1: 14

ECHAM5: 50

GFDL2.1: 50

GISS EH: 40

Gleckler et al. 2008 find first 4 to have good interannual variability, but GISS poor (with large drift).

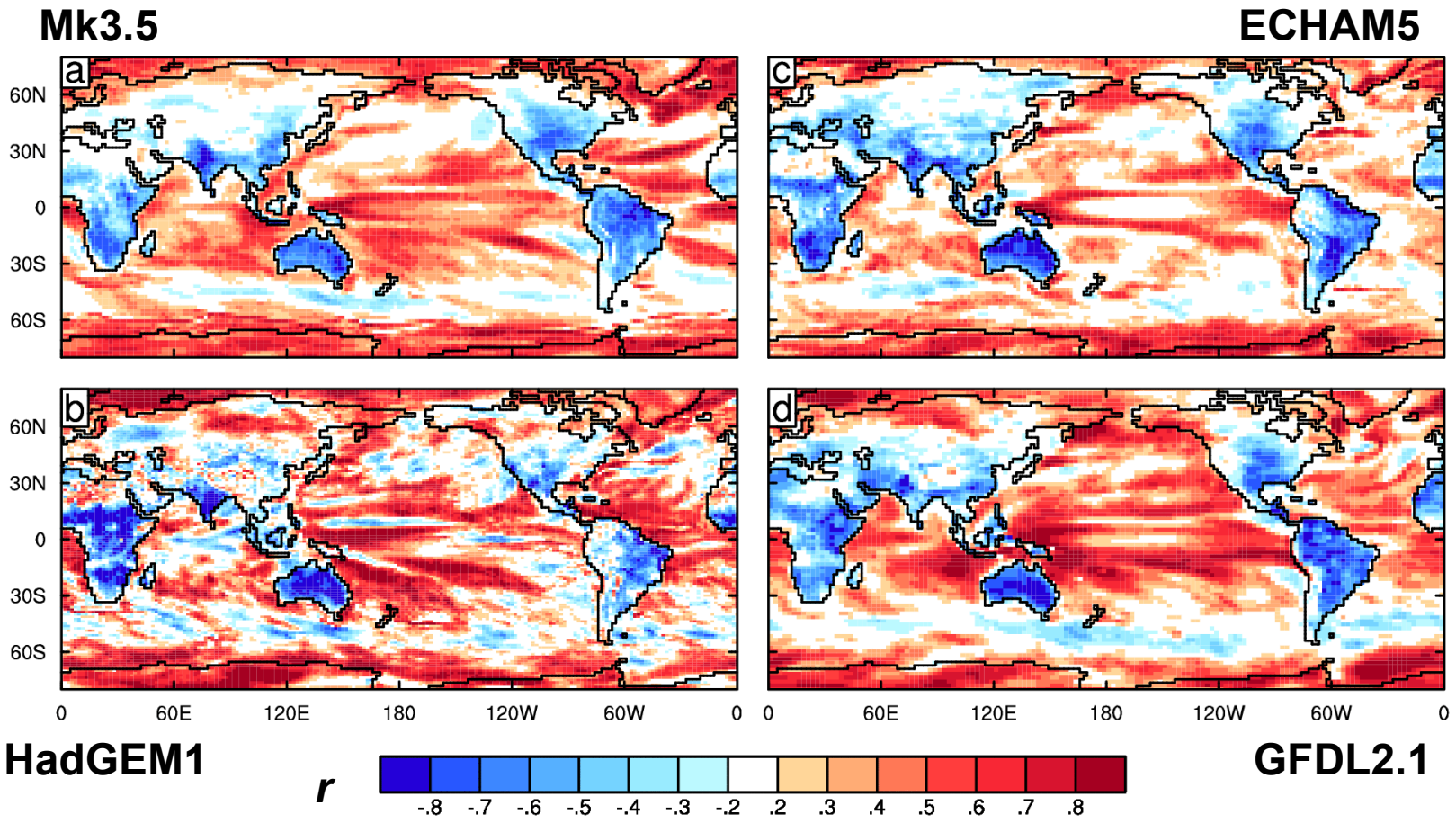


Rather similar amounts of variability overall, but GISS has less variation in P despite more in T.

CAWCR

Correlation between *T* and *P* at each grid point

Decadal means, from four CMIP3 models

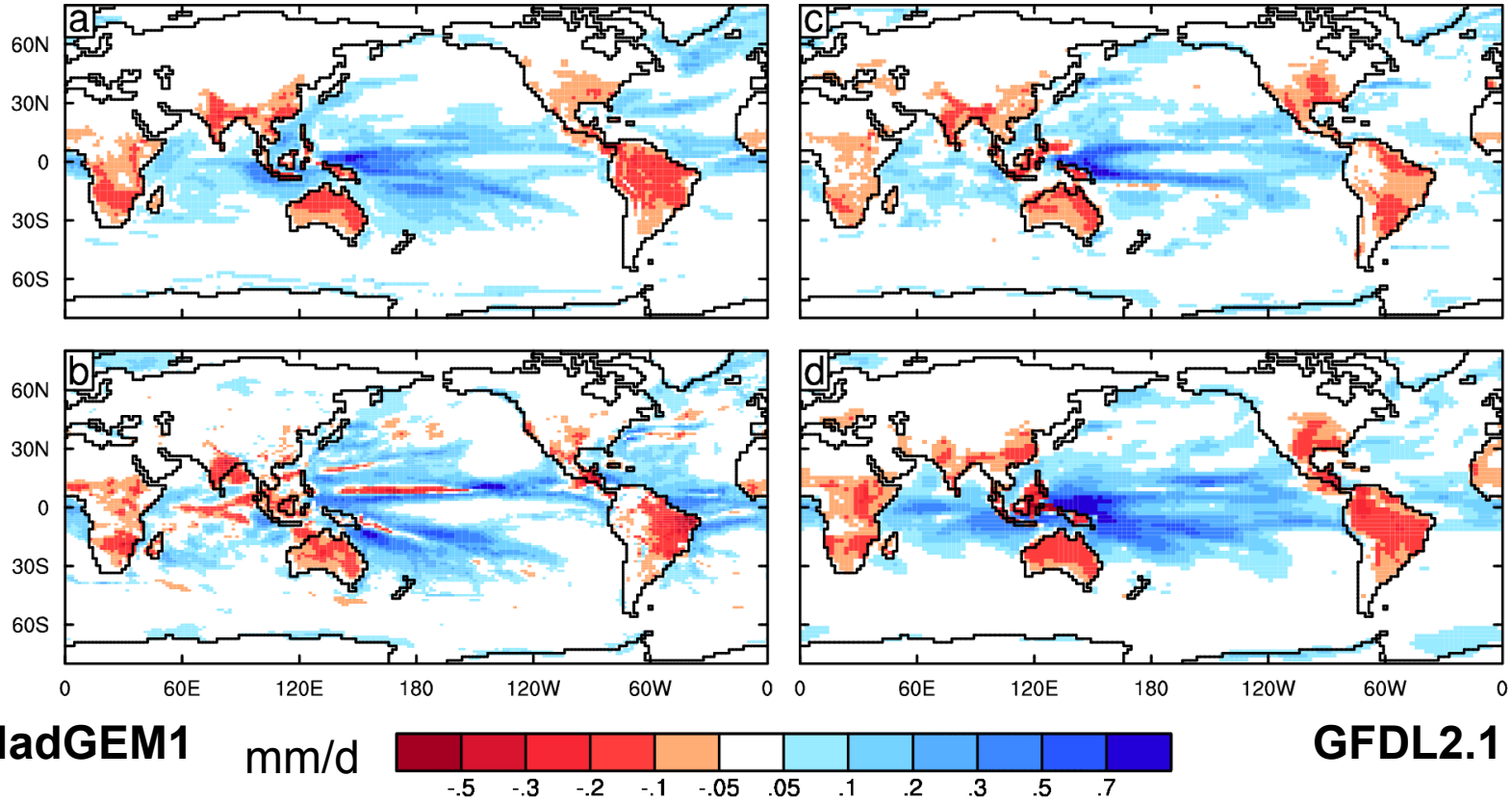


Mostly similar patterns. ECHAM5 has smaller correlations over ocean – especially central Pacific.

P anomaly, for a 1 SD of *T* anomaly from the regression

Decadal means, from four CMIP3 models

Mk3.5 **ECHAM5**

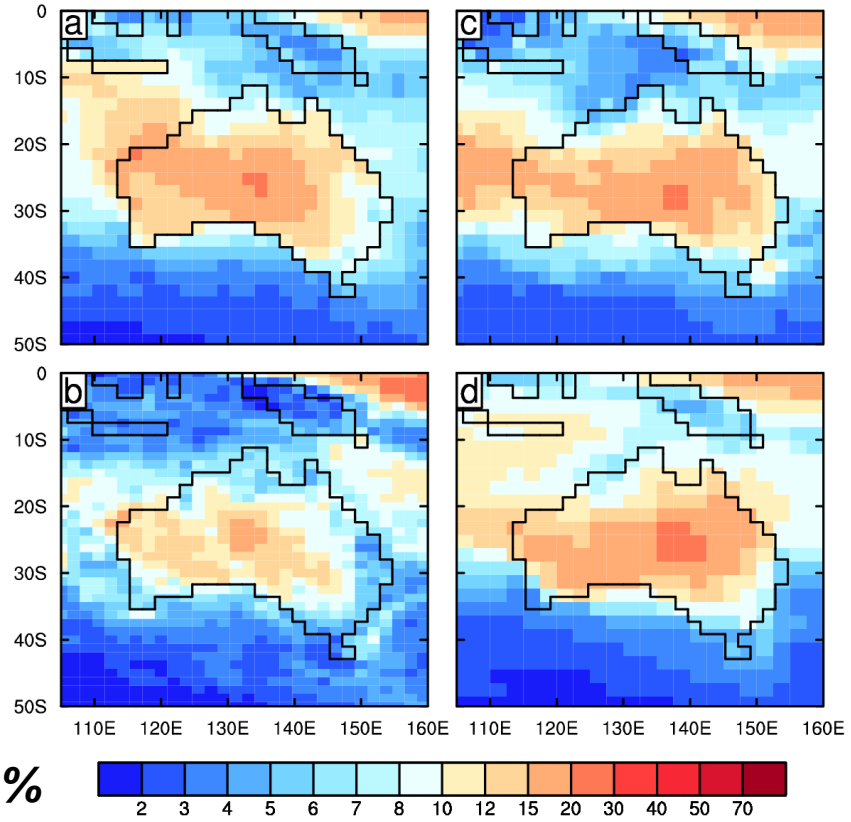


Over oceans, decadal variability of rainfall associated with SSTAs seems strongest in GFDL, weakest in HadGEM1. Likely to relate to rainfall variability.

SD of decadal mean *P* (as % of average)

Mk3.5

ECHAM5



HadGEM1

GFDL2.1

Indeed, Australian rainfall variability is strongest in GFDL, weakest in GEM.

Summary

Uncertainty in GHG-forced changes (per degree warming) in *T* and *P* among CMIP3 models has much in common with variability of decadal means (in Mk3.5) – even in magnitude.

Time series depiction of both types of uncertainty in future decadal means looks useful.

Correlation between forced change and decadal anomalies of *T* and *P* are also similar, with positive values over most ocean, negative over land.

Regression coefficients quantify the size of relationship. Over land, most points are cooler, by about 0.5 K per mm/d. West Equ'l Pacific is wetter by 2 mm/d per K.

These statistics may be useful for evaluation: e.g. if a model doesn't get magnitude of tropical rainfall response to SST anomalies correct, it will impact on teleconnections.

Compare Mk3.5, HadGEM1, ECHAM5, GFDL2-1 (GISS E-H):

- Zonal mean of SD of decadal means fairly similar across four better models.
- Patterns of correlation and *P* response to SSTA rather similar.
- However, smaller response in equatorial Pacific in HadGEM1 may relate to smaller variability of Australian rainfall.