

What causes uncertainty in regional precipitation projections?

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Regional precipitation uncertainty and Climate Sensitivity

Inter-model precipitation change standard deviation (mm/day/K)

Dependence on global mean temperature change removed

Percentage difference between standard deviations



RCP8.5 2071-2100 minus 1971-2000 20 member CMIP5 ensemble



Kent & Chadwick 2014, Submitted Chadwick et al. 2013, J. Clim.



Convective shifts and SST Pattern Change

Colours = CMIP5 multi-model mean RCP8.5 2071-2100 – 1971-2000



Xie et al. 2010, J. Clim. Chadwick et al. 2014, GRL



Causes of inter-model uncertainty in precipitation change

JJA



Inter-model standard deviation RCP8.5 2071-2100 minus 1971-2000 20 member CMIP5 ensemble

Kent & Chadwick 2014, Submitted

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Using idealised experiments to understand convective shifts

JJA Ensemble mean precip change



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Contribution to uncertainty from different forcing mechanisms

MAM Inter-model Precipitation variance





MAM Inter-model Precipitation variance





Hypotheses for tropical land convective shifts

- 1) Direct heating: Land warming from direct CO₂ forcing leads to an increased surface pressure gradient and increased moisture convergence over land, increasing rainfall. e.g. Bayr & Dommenget 2013
- 2) Remote suppression: SST warming leads to tropospheric warming aloft over land, suppressing rainfall. e.g. Giannini 2010
- 3) RH change: Land RH decrease in response to enhanced land-sea temperature contrast leads to an increase in the height of the LCL, and suppresses convection. e.g. Fasullo 2012



RCP8.5 MAM Inter-model Correlation between RH change and Convective shift change



The need for new experiments

CCSM3 Precipitation Change

CCSM3 Temperature Change



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Courtesy of Chris Skinner.

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- Uncertainty in regional rainfall projections is not strongly related to uncertainty in climate sensitivity.
- In the tropics, uncertainty is dominated by the inter-model spread in spatial shifts of convective regions.
- Over the oceans, much of this is associated with uncertainty in the patterns of SST change, and uncertainty in the atmospheric response to these changes.
- Over land, the response is more complex. Likely to be several competing mechanisms. The dominant driver of uncertainty appears to be the range of responses to a uniform SST increase.
- CFMIP2 amip experiments are useful for understanding these regional changes, but to fully understand uncertainty in regional climate projections new types of experiment are needed.



Circulation change under warming

Scatterplots compare all tropical gridpoints for periods 1971-2000 and 2071-2100 under the RCP8.5 scenario

Least squares fit

Chadwick et al. 2013 J. Climate Ma et al 2012 J. Climate





Mechanisms behind tropical circulation change



Colours = Deviation of total column temperature warming from the tropical mean warming

Line contours = Climatological Omega

Arrows = Vertical wind shear anomalies

SUSI = +2K uniform SST experiment



Ma et al 2012 J. Climate Knutson & Manabe 1995 J. Climate Page 15



Convergence change under warming



$$\Delta \chi \propto -\chi$$

$$\Delta \chi = -\alpha \chi$$

where $\boldsymbol{\alpha}$ is constant

$$\Rightarrow \Delta \delta = -\alpha \delta$$

Line contours = climatological 200hPa velocity potential (χ), (black lines –ve, brown +ve) Colours = change in 200hPa velocity potential (χ) under MASC forcing (red +ve, blue -ve)

Ma et al 2012 J. Climate



Mint

Physical meaning of M*





Line contours = mean convective cloud base and top

1971-2000

2071-2100