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Observed and simulated precipitation responses in wet and dry regimes

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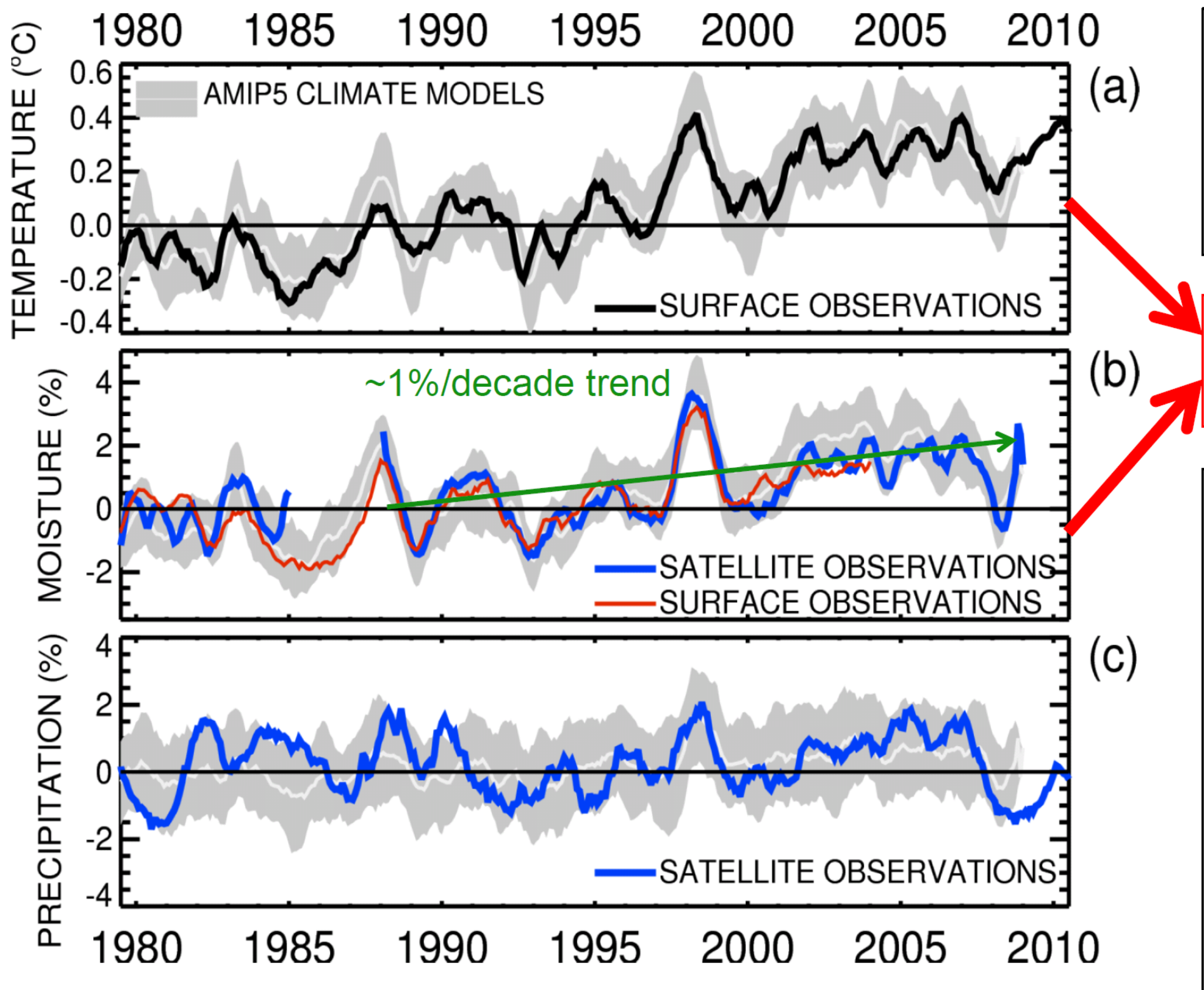
Introduction

Using satellite and ground-based observations and CMIP5 simulations we identify (i) increases in atmospheric moisture, (ii) contrasting precipitation responses in wet and dry regimes and (iii) an amplification of precipitation extremes

1. Changes in the global water cycle

- Column integrated water vapour from **SMMR** and **SSM/I** satellite microwave instruments over ice-free oceans, **ERA Interim reanalysis** over remaining regions
- Surface specific humidity from **HadCRUH**
- Precipitation from **GPCP** combined satellite and gauge product
- Comparison with **AMIP5** simulations (prescribed observed sea surface temperature and sea ice & realistic radiative forcings)



Trends in global water vapour (W) consistent with thermodynamics

Co-variation: dW/dTs ~ 7%/°C

Trends in global precipitation are not yet expected due to the large offsetting heating effect on the atmosphere from greenhouse gases relative to modest warming

See Allan et al. (2013) Surv. Geophys for details

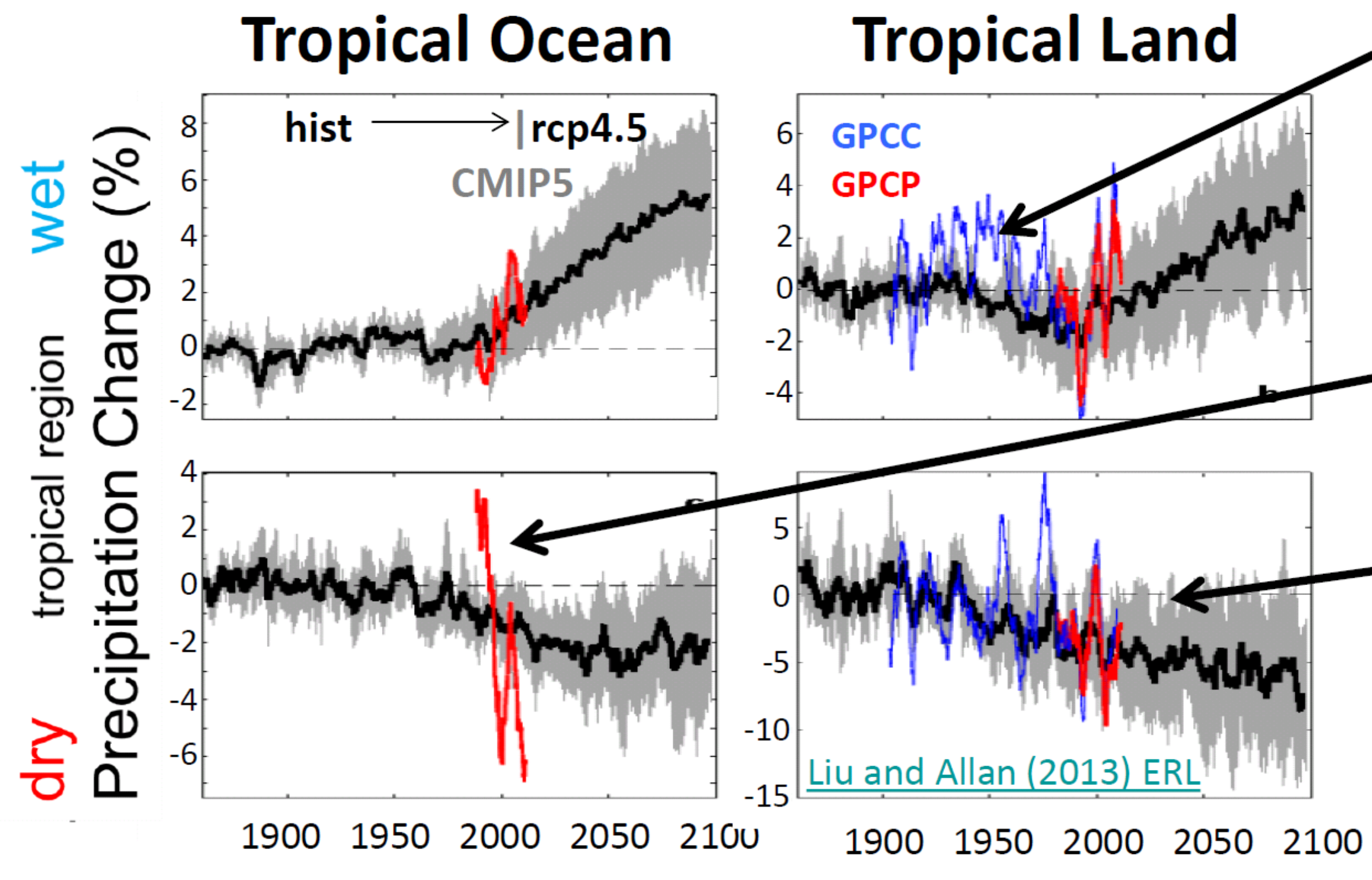
2. Wet events wetter, dry events drier

- Contrasting wet and dry regime responses to current and future tropical warming is anticipated from basic physics
- Does not apply simply over land (Greve et al. 2014; Allan 2014) and variability influenced by El Niño Southern Oscillation

$$\mathit{Thermodyn.}: \frac{1}{q_s}\frac{dq_s}{dT} = \alpha \sim 7\%/K \quad \mathit{Moisture\ bal.}: (\mathrm{P}-\mathrm{E}) \approx -\nabla.(u\,q)$$

$$\frac{\Delta(P-E)}{\Delta T} = -\nabla.\frac{\Delta(u\,q)}{\Delta T} \approx -\nabla.u\frac{\Delta q}{\Delta T} \approx -\alpha\nabla.(u\,q) = \alpha(P-E)$$

$$\Delta P/\Delta T \approx \alpha(P-E)+\Delta E \approx \alpha(P-E)+kE = \alpha(P-\beta E)$$



Liu and Allan (2013) ERL

Discrepancy: wet tropical land

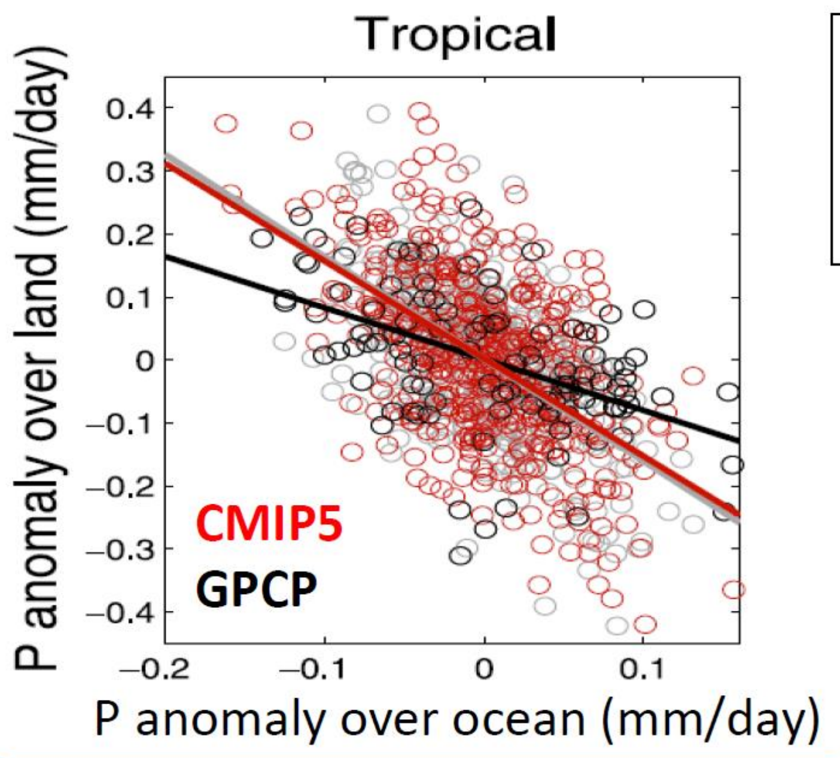
Pre 1988 GPCP observations over ocean don't use microwave data

Robust drying of dry tropical land

30% wettest gridpoints vs 70% driest each month

3. Natural decadal variability important for changes in land precipitation

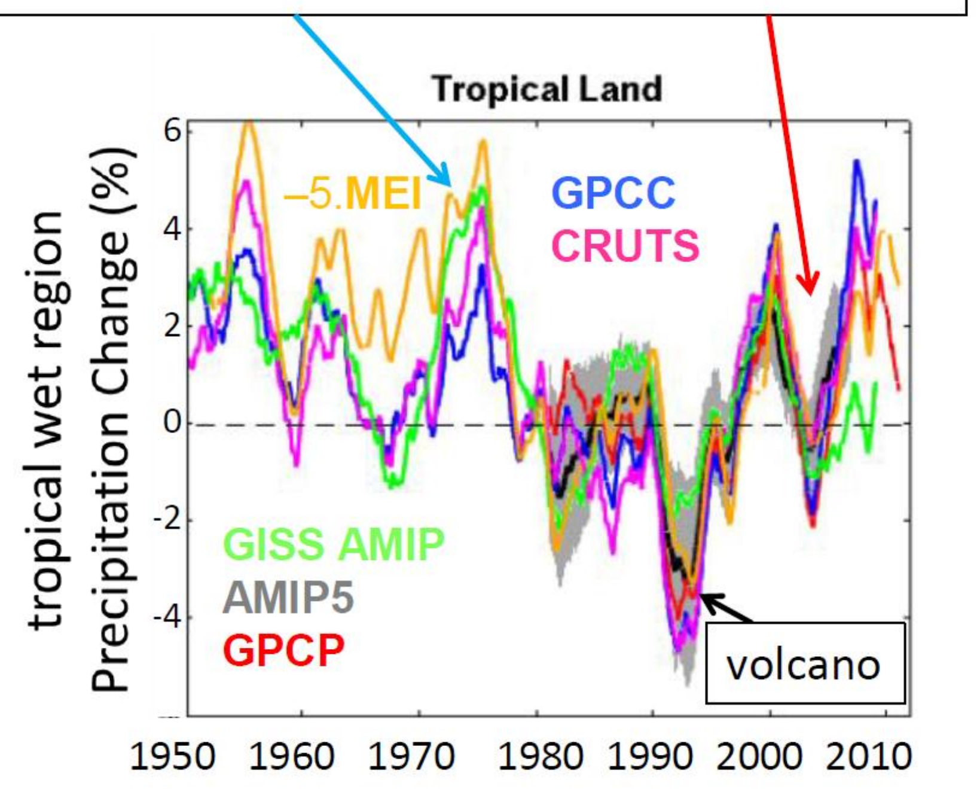
- During warm El Niño years changes in atmospheric circulation cause reduction in land precipitation (anti-correlated with ocean precipitation)
- Decadal changes in El Niño may explain discrepancy between coupled model precipitation anomalies and GPCC observations 1950-70
- Simulations able to capture interannual variability in land precipitation when observed ocean temperature/radiative forcing applied



Land and ocean rainfall anti-correlated on interannual time-scale (above)

Liu, Allan, Huffman (2012) GRL

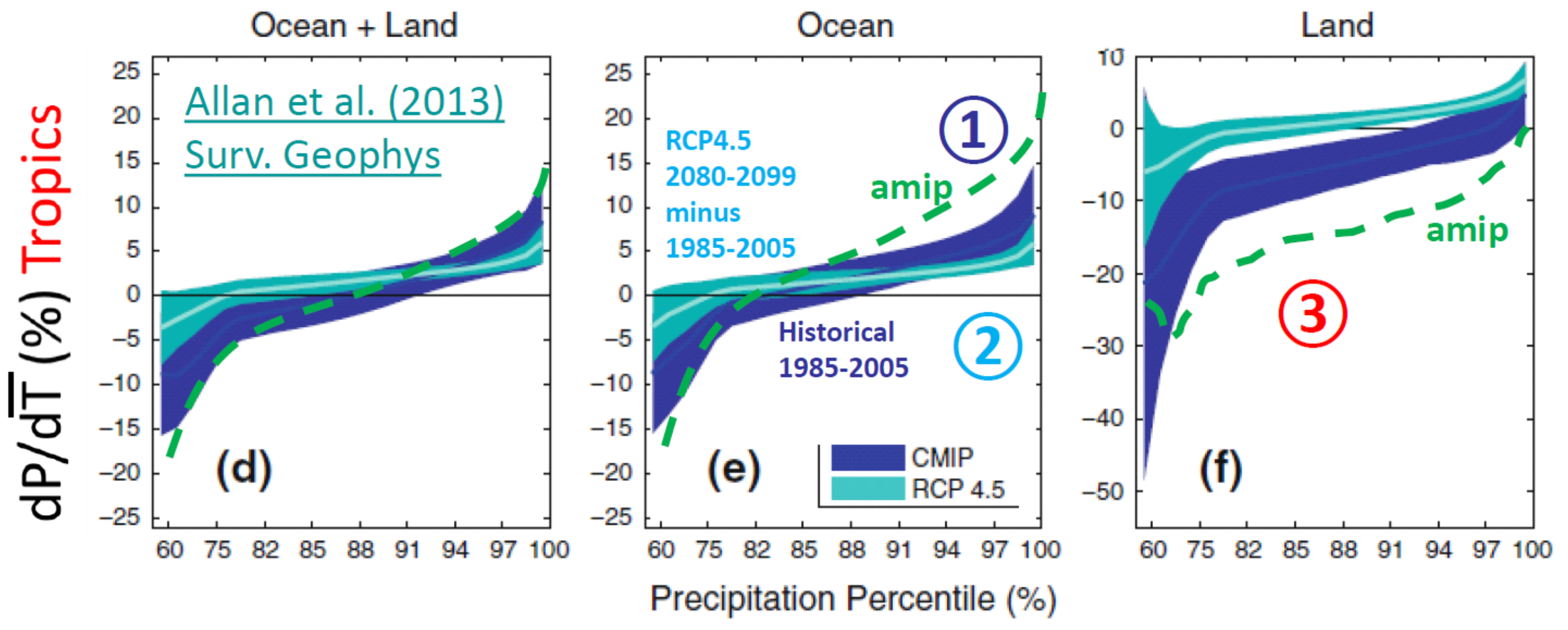
Interannual-decadal changes in continental rainfall dominated by: La Niña (more rain) & El Niño (less rain)



Liu & Allan (2013) ERL

4. Future changes in precipitation extremes

- 5-day average precipitation is split into intensity bins
- Sensitivity to tropical mean temperature changes for interannual variability and climate change are calculated in each bin



① Smaller dP/dT sensitivity for coupled simulations (**historical** vs **amip**)

② Smaller dP/dT sensitivity under climate change (**historical** vs **rcp4.5**) as dP/dT supressed by direct atmospheric heating from rising greenhouse gases

③ More positive dP/dT over land under climate change (**rcp4.5** vs **historical**) as Temperature rises un-related to ENSO for climate change response

- Amplification of precipitation extremes with climate warming
- Interannual variability is not a good proxy for climate change over land

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This work was funded by the UK Natural Environment Research Council PAGODA and PREPARE projects

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