Department of Meteorology

University of Reading

Changing water cycle

NATURAL ENVIRONMENT RESEARCH COUNCIL

Precipitation change and its response to the interannual climate variability

Chunlei Liu (c.l.liu@reading.ac.uk) | Richard P. Allan (r.p.allan@reading.ac.uk)

Introduction

Precipitation (P) is expected to increase based on the energy and moisture balance constraints [*Held and Soden*, 2006]. Global P has been monitored by satellites over the last two decades, particularly since 1997. Model simulations from coupled and atmospheric only experiments (CMIP5 and AMIP5) provide plenty of data to study the water cycle change in the recent past which has implications for the confidence in the projections of the future climate change.

- **What do observation say about the precipitation change and its response to temperature (T) change?**
- **Are precipitation changes and its response from observations and model simulations consistent?**
- **How will precipitation change in the future?**

Precipitation data sets

The available precipitation datasets from satellite observations and model simulations are listed in Table 1.

Table 1. Datasets and brief descriptions

dataset	period	Description
GPCP v2.2	1979 – 2008	Monthly, global ocean and land,1°
AMSRE v5	2002 – 2012	Daily, global ice free ocean, 0.25°
SSM/I v6 (F08, F11, F13)	1987 – 2009	Daily, global ice free ocean, 0.25°
SSMIS v7 F16 F17	2003 – 2012 2006 – 2012	Daily, global ice free ocean, 0.25°
TMI v4	1997 – 2012	Daily, tropical ocean (40°N-40°S) 0.25°
HOAPS v3	1987 – 2005	Daily, global ice free ocean, 1°
TRMM 3B42 v6	1998 – 2012	Daily, tropical ocean and land (50°N-50°S) , 0.25°
CMIP5	1850 – 2005	Monthly, global ocean and land.
AMIP5	1979 – 2008	Monthly, global ocean and land.
RCP4.5	2006 – 2100	Monthly, global ocean and land.

Current changes in precipitation

Deseasonalised tropical ocean P anomaly time series from recent study by *Liu and Allan* [2012] are plotted in **Fig. 1**.

- Over the tropical ocean, all datasets are consistent except for the TRMM 3B42 dataset for known reasons (Huffman et al 2007).
- Over the tropical land, there is good agreement between GPCP and TRMM 3B42.
- HOAPS dataset shows higher variability than others.

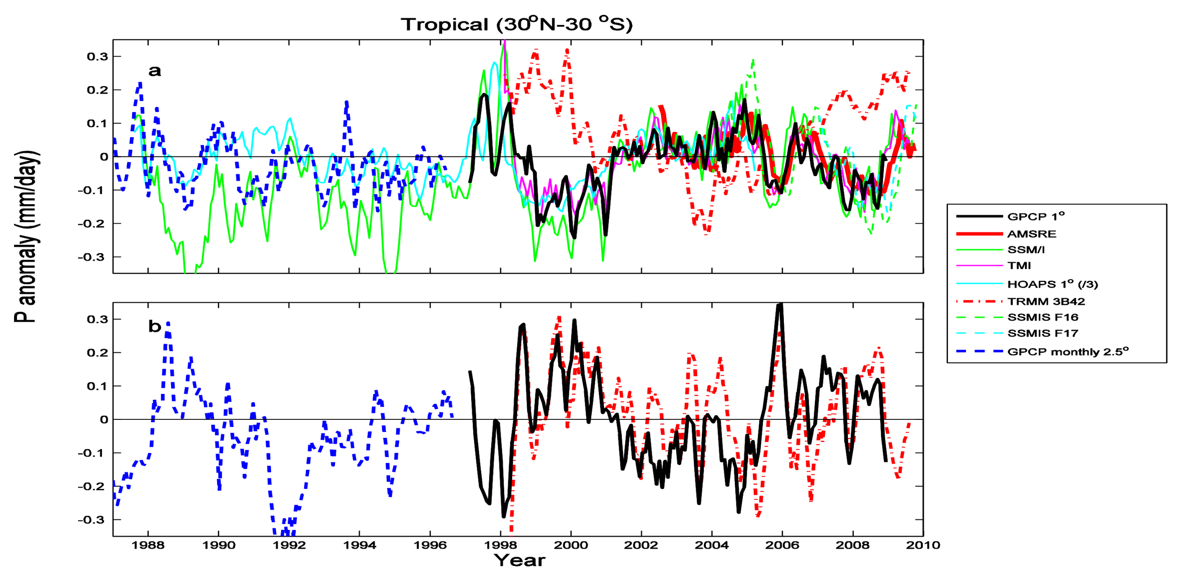

Fig. 1 Deseasonalised anomalies of precipitation over (a) the tropical ocean and (b) the tropical land.

The precipitation from observations are compared with AMIP5 (10 models) and CMIP5 (12 models) ensemble mean as displayed in **Fig. 2.**

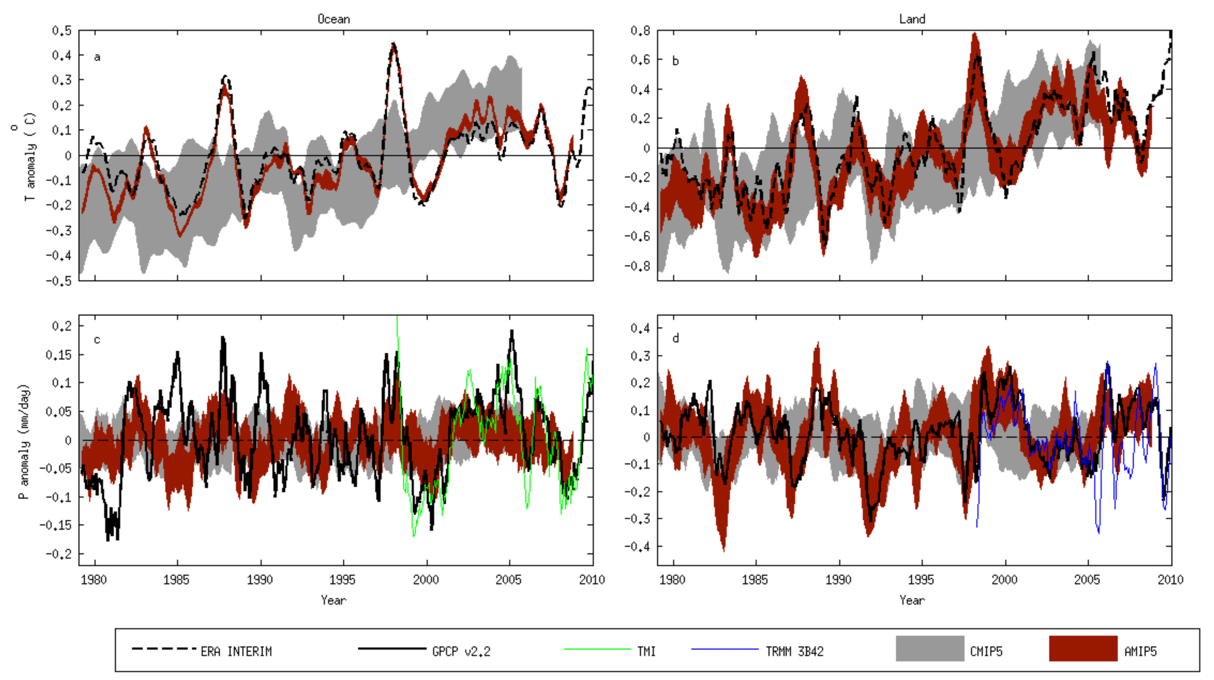

Fig. 2. Temperature and precipitation anomaly time series over the tropical ocean and the tropical land. The black line is from ERA INTERIM for temperature (a-b) and from GPCP for precipitation (c-d). The shaded curves are from CMIP5 and AMIP5 respectively and they are mean value ± one standard deviation.

- Striking agreement between GPCP and AMIP5 P over land.
- Prescribed SST and realistic radiative forcings are sufficient for simulating the interannual variability in continental P.
- Discrepancies between GPCP and TRMM after 2004 over land.
- Discrepancies over oceans between GPCP and AMIP5.

Error sources

Tropical ocean P anomaly difference (ΔP') between AMIP5 ensemble mean and GPCP is plotted in **Fig. 3**.

- ΔP' is slightly reduced after TRMM employment.
- Error is mainly from the Western Pacific.
- Mean P difference over 1988-2008 provides further evidence .

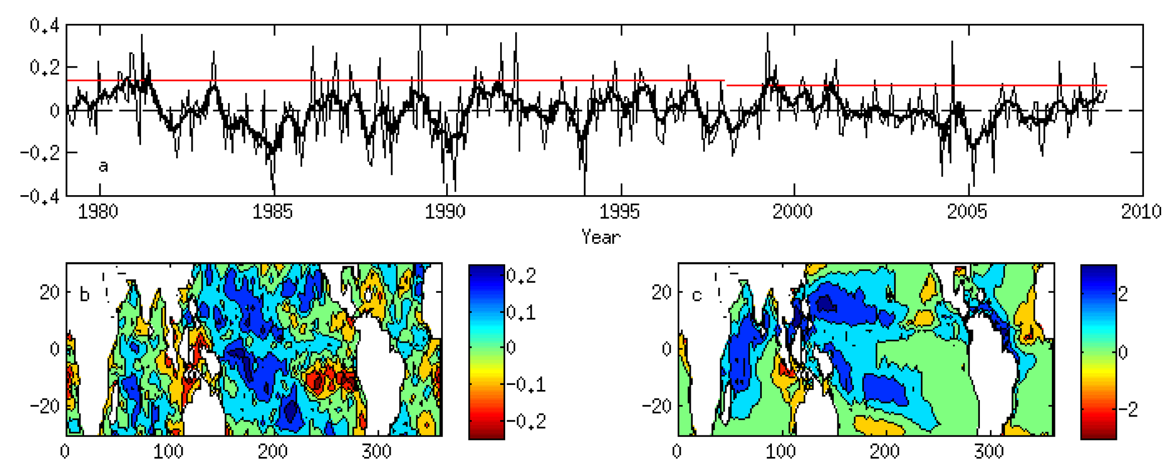

Fig. 3. (a) time series of the area mean P anomaly difference (AMIP5 ensemble mean minus GPCP) over the tropical ocean, together with the five month running mean (thick black line) and the standard deviation of the anomaly difference over 1979-1997 and 1998-2008 periods (red), (b) the correlation between the local anomaly difference time series and that from (a) over the period of 1988-2008, (c) the P climatology difference between AMIP5 ensemble mean and GPCP over 1988-2008.

Response to warming

The scatter plot of precipitation and temperature anomalies from **Fig. 2** is shown in **Fig. 4**, and the correlation (r) and $dP_{\%}/dT$ are also listed in Table 2.

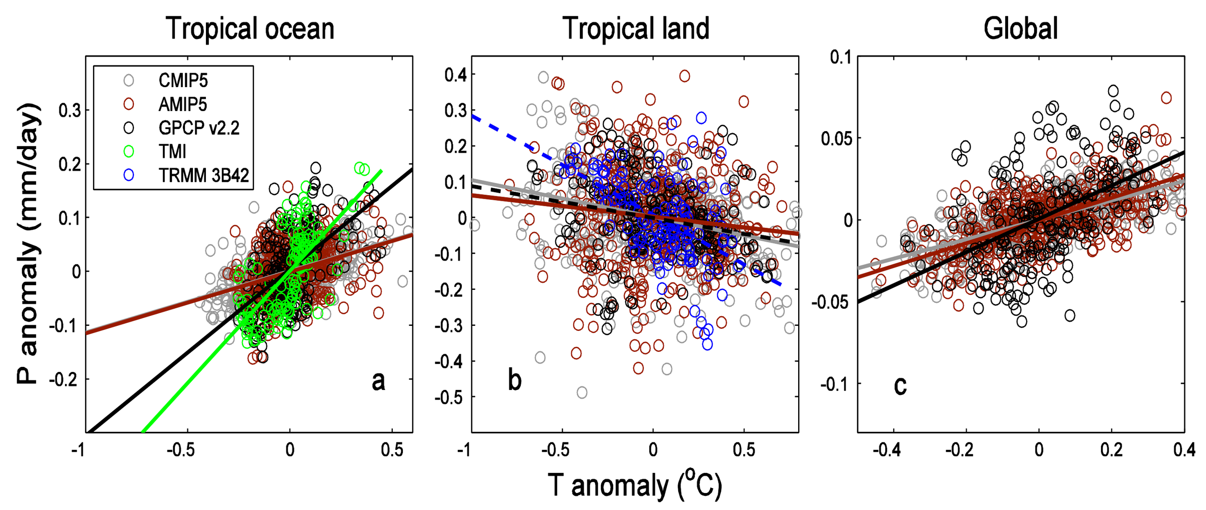

Fig. 4. Scatter plot of P and T anomalies from CMIP5/ AMIP5 models and satellite-based observations. Dashed fitting lines imply the relations are statistically insignificant at the 95% confidence level.

- Over the global, the $dP_{\%}/dT$ is 2.0%/K for CMIP5 and 2.3%/K for AMIP5 over 1988-2005.
- 3.8%/K from monthly GPCP data is similar to the value found by *Adler et al*. [2008].
- Over the tropical ocean, $dP_{\%}/dT$ is ~10%/K for GPCP and ~3.0%/K for models, similar to the sensitivities calculated by *Allan et al.* [2010].
- Over the tropical land, it shows negative response, -3.1%/K from GPCP, -3.4%/K from CMIP5 and -1.9 %/K from AMIP5.

Table 2. Relations between temperature and precipitation anomalies. Significant correlation coefficients (r) are marked in bold.

	dataset	period	dP%/dT (%/K)	r
Global	GPCP	1988-2005	3.8	**0.48**
	CMIP5	1988-2005	2.0	**0.72**
	AMIP5	1988-2005	2.3	**0.63**
Tropical ocean	GPCP	1988-2005	10.3	**0.57**
	CMIP5	1988-2005	3.1	**0.51**
	AMIP5	1988-2005	3.0	**0.35**
	TMI	1998-2008	15.5	**0.68**
Tropical land	GPCP	1988-2005	-3.1	-0.22
	CMIP5	1988-2005	-3.4	**-0.31**
	AMIP5	1988-2005	-1.9	-0.12
	TRMM 3B42	1998-2008	-10.0	-0.51

Projections

- Over both the tropical ocean and the tropical land, the wet region will become wetter and the dry region will become drier.
- Good agreement between GPCP and simulations over the land.
- Earlier GPCP data over the tropical ocean are not reliable.

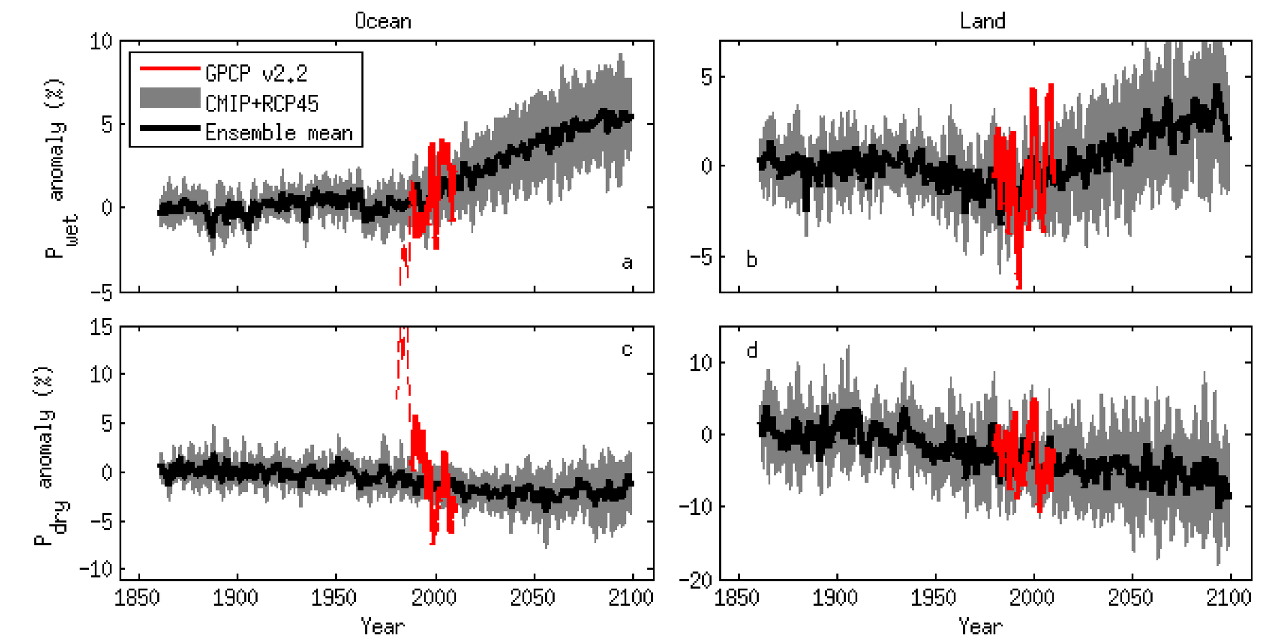

Fig. 5. Projected precipitation anomaly time series over the wet (>70% P percentile) and dry (<70% P percentile) areas of the tropical ocean and the tropical land, together with the GPCP (red line) anomalies.

Conclusions

- Striking agreement of observed and simulated P variability over land.
- Robust increases of total precipitation with warming.
- Tendency for wet region becoming wetter and dry region becoming drier in precipitation projections.

References

Adler, R.F., G. Gu, G.J. Huffman, J.J. Wang, S. Curtis, and D.T. Bolvin (2008), Relationships between global precipitation and surface temperature on interannual and longer timescales (1979-2006), *J. Geophys. Res.*, *113* (D22104), doi: 10.1029/2008JD010536.

Allan, R. P., B. J. Soden, V. O. John, W. Ingram and P. Good (2010) Current changes in tropical precipitation, Environ. Res. Lett., 5, doi:10.1088/1748-9326/5/2/025205.

Held, I., and B. J. Soden (2006), Robust responses of the hydrological cycle to global warming. *J. of Climate, 19(21)*, 5686-99, doi:10.1175/JCLI3990.1.

Huffman, G.J., et al. (2007), The TRMM Multisatellite Precipitation Analysis (TMPA): Quasi-Global, Multiyear, Combined-Sensor Precipitation Estimates at Fine Scales, *J. Hydrometeor.*.

Liu, C., and R. P. Allan (2012), Multi-satellite observed responses of precipitation and its extremes to interannual climate variability, *J. Geophys. Res.*, *117*, D03101, doi:10.1029/2011JD016568.