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# Multi-satellite observed responses of precipitation and its extremes to interannual climate variability

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## Introduction

**Global precipitation has been monitored by satellites over the last two decades, particularly since 1997.**

- **Are observed precipitation responses from different satellite products consistent with each other?**
- **Is there any robust response signal of precipitation to surface temperature variation?**
- **How do different temporal and spatial resolutions affect the computed responses?**

## Observed precipitations

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

**Table 1**. Datasets and brief descriptions

| dataset | period | Description |
|---|---|---|
| GPCP v1.1 | 1996-2009 | Daily, global ocean and land, $1^{o}$ |
| AMSRE v5 | 2002-present | Daily, global ice free ocean, $0.25^{o}$ |
| SSM/I v6<br>(F08, F11, F13) | 1987-2009 | Daily, global ice free ocean, $0.25^{o}$ |
| SSMIS v7<br>F16<br>F17 | <br>2003 – present<br>2006 – present | Daily, global ice free ocean, $0.25^{o}$ |
| TMI v4 | 1997 – present | Daily, tropical ocean ($40^{o}$N-$40^{o}$S) $0.25^{o}$ |
| HOAPS v3 | 1987-2005 | Daily, global ice free ocean, $1^{o}$ |
| TRMM 3B42 v6 | 1998-present | Daily, tropical ocean and land ($50^{o}$N-$50^{o}$S) , $0.25^{o}$ |
| GPCP v2.1 | 1979-2008 | Monthly, global ocean and land, $2.5^{o}$ |

## Precipitation comparison

Deseasonalised precipitation and temperature anomaly time series are plotted in Fig. 1. Temperature data are from ERA Interim.

- Temperature (Fig. 1a) shows ENSO (1998, 2005) and volcanic (1991) effects
- Globally, GPCP and hybrid datasets are consistent.
- 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.

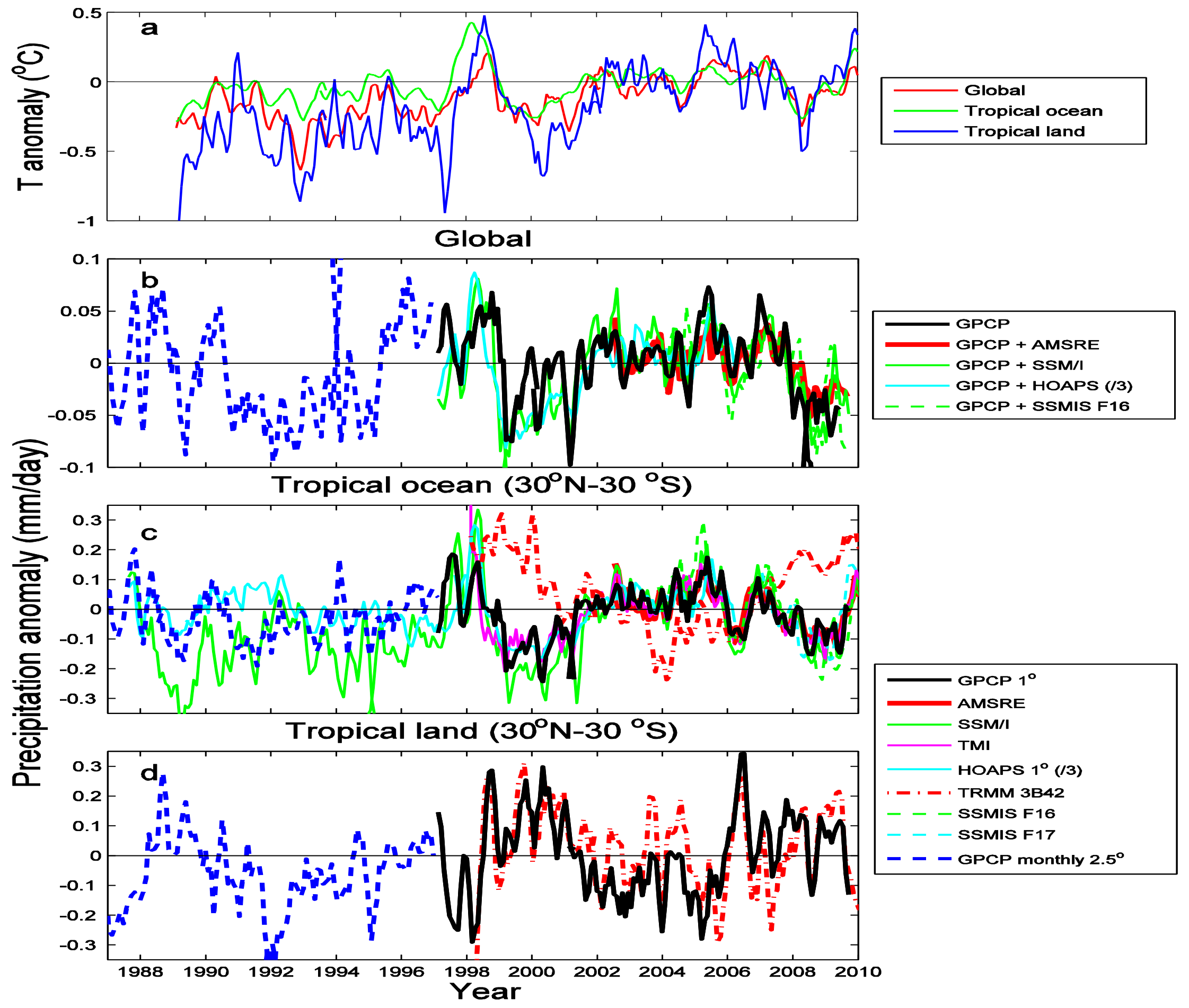

**Fig. 1** Deseasonalised anomalies of temperature and precipitation over the globe, the tropical ocean and the tropical land based on the climatology period of 2003-2008. All curves are plotted with three month running means. The amplitude of HOAPS precipitation anomalies are scaled down by a factor of 3 to improve the clarity of the plot.

## Precipitation response to surface temperature variation

The scatter plot of precipitation and temperature anomalies from **Fig. 1** is shown in **Fig. 2**, and the correlation (r) and $dP_{\%}/dT$ are also listed in Table 2.

- Over the global, the $dP_{\%}/dT$ is between 3.3 and 8.8%/K. The upper range is consistent with Wentz et al. (2007).
- 3.6 %/K from monthly GPCP data is similar to the value found by Adler et al. (2008).
- Over the tropical ocean, $dP_{\%}/dT$ is above 10%/K and as much as 30%/K, similar to but a little higher than the sensitivities calculated by Allan et al. (2010).
- Over the tropical land, it shows negative response, but shows little coupling using the monthly GPCP data.

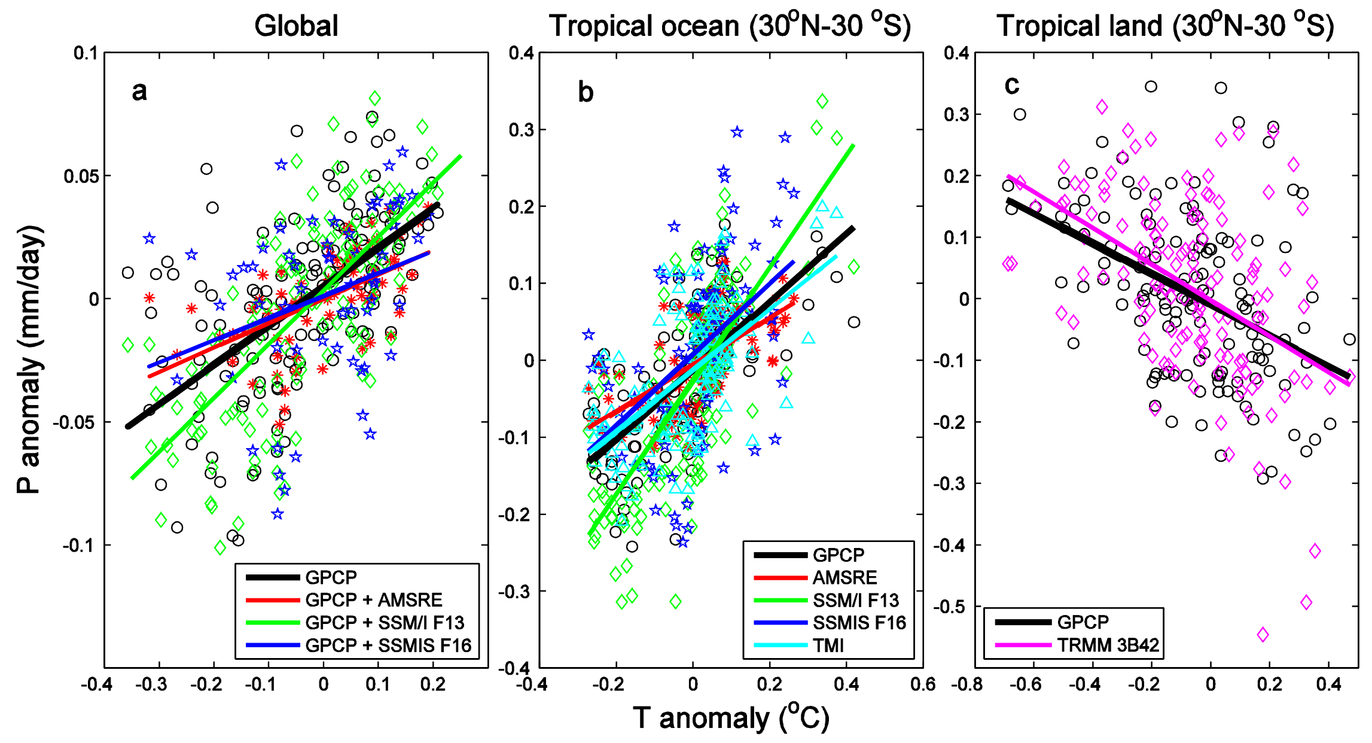

**Fig. 2** Scatter plot showing correlations between precipitation and temperature anomalies (a) over the global, (b) the tropical ocean and (c) the tropical land.

**Table 2**. Relations between temperature and precipitation anomalies

| | dataset | period | dP%/dT (%/K) | r |
|---|---|---|---|---|
| Global | GPCP | 1998-2008 | 6.0 | 0.56 |
| | GPCP+AMSRE | 2003-2008 | 4.3 | 0.56 |
| | GPCP+SSM/I F13 | 1998-2008 | 8.8 | 0.71 |
| | GPCP+SSMIS F16 | 2004-2008 | 3.3 | 0.30 |
| | GPCP monthly | 1989-2008 | 3.6 | 0.30 |
| Tropical ocean | GPCP | 1998-2008 | 14.9 | 0.68 |
| | AMSRE | 2003-2010 | 12.1 | 0.62 |
| | SSM/I F13 | 1998-2008 | 25.6 | 0.75 |
| | SSMIS F16 | 2004-2010 | 30.9 | 0.47 |
| | TMI | 1998-2008 | 14.9 | 0.61 |
| | GPCP monthly | 1989-2008 | 10.2 | 0.48 |
| Tropical land | GPCP | 1998-2008 | -8.2 | -0.43 |
| | TRMM 3B42 | 1998-2008 | -10.6 | -0.46 |
| | GPCP monthly | 1989-2008 | -1.1 | -0.07 |

## Influence of temporal averaging

The tropical ocean is covered by all datasets listed in **Table 1**, so it is ideal to identify discrepancies between different datasets.

Daily precipitation was sorted into bins by intensity and monthly anomalies in each bin are computed. Linear regression with surface T was used to estimate $dP_{\%}/dT$ (**Fig. 3**).

- For daily data, three out of four datasets show negative response at lower intensity and all show positive response over high intensities.
- Averaging over 5 days increases the consistencyof the response between datasets.
- For monthly aveage, the response is noisy over the lower intensity due to averaging over contrasting dynamical situations.

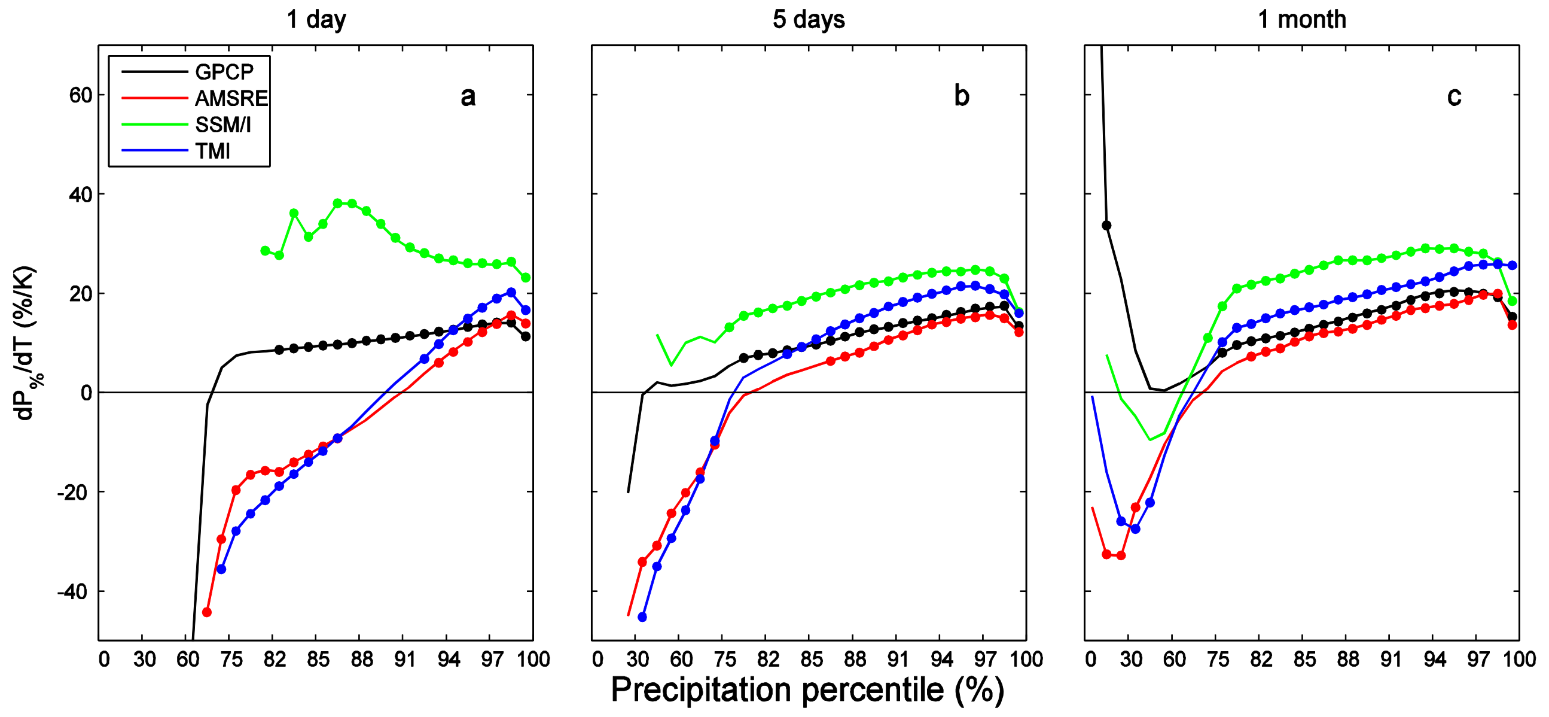

**Fig. 3** Relative precipitation changes over the tropical ocean at different percentile bins. Temporal integrations are one day, five days and one month respectively and all datasets are at $1^{o}$ resolution. The dots show the points where the correlations between precipitation and temperature anomalies are significant after applying a two-tailed test using Pearson critical values at the level of 5%.

## Influence of spatial averaging

- Has similar effect to the temporal averaging.
- There is big difference between resolutions at $0.25^{o}$ and $1^{o}$.

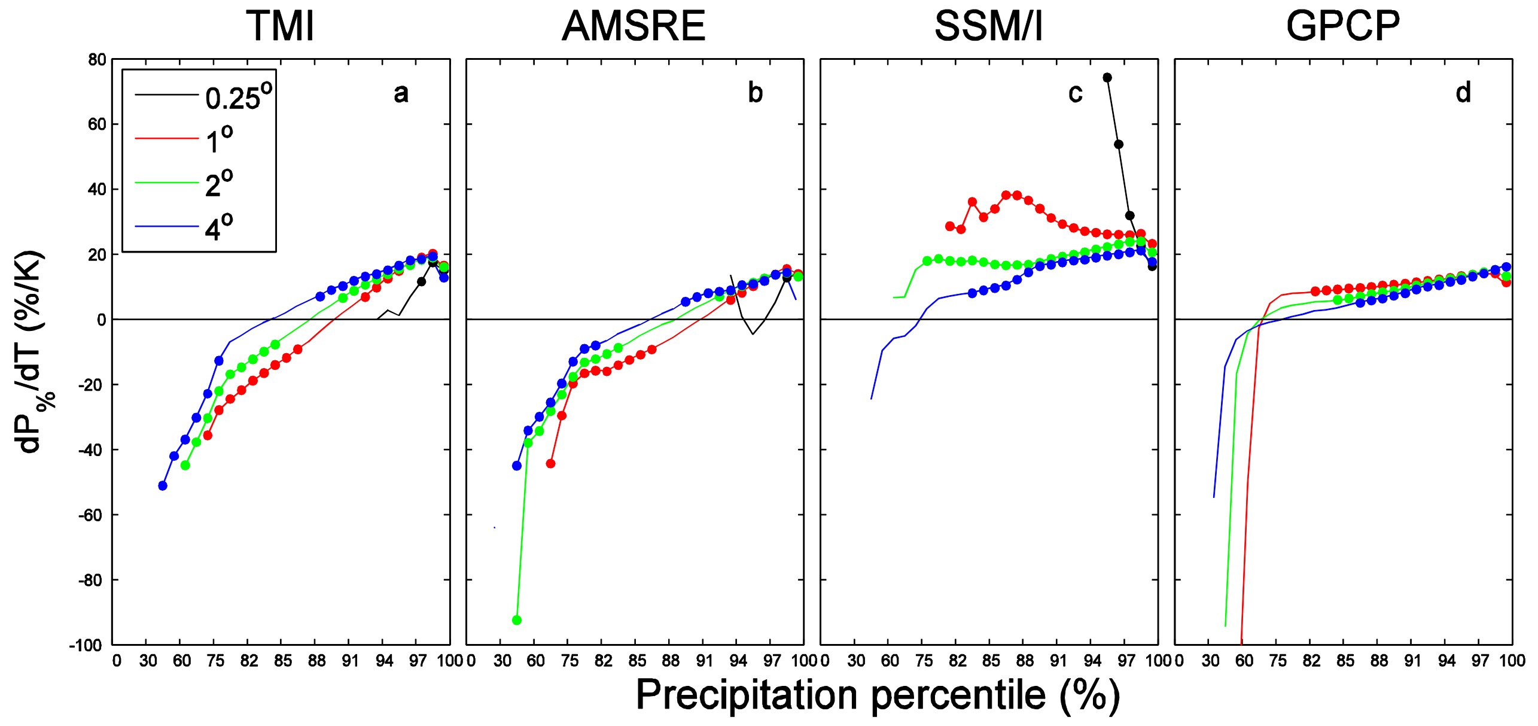

**Fig. 4** Spatial integration effect on precipitation and temperature relations over the tropical ocean from daily datasets of TMI, AMSRE, SSM/I and GPCP.

### Conclusions

- Range of responses of global precipitation to warming: 3.3–8.8%/K
- Robust increases in heavy rainfall with warming; tendency for dry regions and tropical land to become drier with warming
- Averaging to $1^{o}$ and 5-day resolutions improves data consistency

### References

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