Relationships between TRMM precipitation characteristics and large-scale vertical motions in four reanalysis datasets over tropical oceans

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1. Motivations

• Different precipitation characteristics result in different latent heating profiles. Therefore, quantifying relationships between precipitation characteristics and large-scale environment in the tropics is important to better understand roles of tropical precipitation in large-scale circulations. In this study, we ask a question "What determines various precipitation characteristics over tropical oceans?"

• Yokoyama and Takayabu (2011, submitted) found that precipitation is highly correlated with shallow convergence (1000-925 hPa) over the eastern Pacific, consisting of mostly small shallow systems and large systems with moderate heights; but over the western Pacific, precipitation is correlated with deep convergence (1000-400 hPa) consisting of of mostly small tall systems and large very tall systems. In this study, we expand these findings to six subsets of the tropical oceans on a monthly time scale over 13 years.

• Four different reanalysis datasets are used here to examine relationships between retrieved precipitation and vertical motions, on the scale of the reanalysis grid.

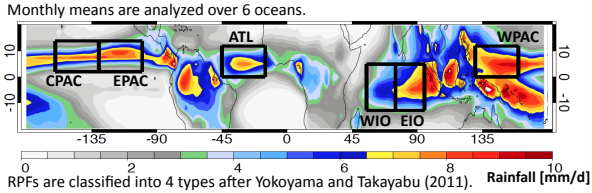
• But these reanalyses are known to have some differences (e.g., Zhang et al. 2008; Chang and Nigam 2009; Ling and Zhang 2011), so we are especially motivated to document and understand the differences in their behavior over the heavy rainfall regions of tropical oceans.

2. Data and methodology

The following data are used from Jan. 1998 to Dec. 2010:

- TRMM **3B43** precipitation data (Huffman et al. 1995, 1997; Huffman 1997)
- Univ. of Utah Radar Precipitation Feature (**RPF**) data (Liu et al. 2008)
- Vertical pressure velocity (ω at 850 and 300 hPa) and precipitation in 4 reanalyses
  (a) **NCEP** (Kalnay et al. 1996) (b) **ERA-Interim** (Dee et al. 2011)
  (c) **JRA25/JCDAS** (Onogi et al. 2007) (d) **MERRA** (Rienecker et al. 2011)

Monthly means are analyzed over 6 oceans.



RPFs are classified into 4 types after Yokoyama and Takayabu (2011).

	Small shallow	Small tall	Large and moderately tall	Large and very tall
Area of RPF	< $10^{3.5}$ km²	< $10^{3.5}$ km²	≥ $10^{3.5}$ km²	≥ $10^{3.5}$ km²
Max height of RPF	< 8 km	≥ 8 km	8-14 km	≥ 14 km

3. Spatial correlations between 3B43 and ω (2.5° grids)

EPAC and CPAC

• Correlations tend to be high at both 850 hPa and 300 hPa in **JRA** and **ERA**.
• Correlations tend to be high at 850 hPa and fairly low at 300 hPa in **NCEP** and **MERRA**.

WPAC

• Correlations tend to be fairly high at 300 hPa and fairly low at 850 hPa.
• Correlations tend to be higher at 300 hPa than at 850 hPa in **NCEP**, **ERA**, and **JRA**.
• Correlations tend to be low at both 850 hPa and 300 hPa in **MERRA**.

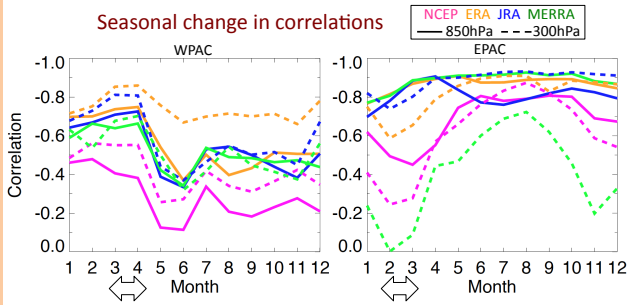
EIO, WIO, and ATL

• Both Indian Ocean regions resemble WPAC more than other regions.
• Atlantic resembles EPAC and CPAC more than other regions.

Mean correlations for 13 years

	WPAC	CPAC	EPAC	ATL	WIO	EIO	
ω300	-0.41	-0.59	-0.61	-0.63	-0.53	-0.50	NCEP
	-0.74	-0.76	-0.82	-0.88	-0.79	-0.72	ERA
	-0.58	-0.86	-0.88	-0.89	-0.77	-0.70	JRA
	-0.51	-0.26	-0.40	-0.58	-0.58	-0.45	MERRA
ω850	-0.28	-0.65	-0.68	-0.64	-0.35	-0.26	
	-0.55	-0.90	-0.87	-0.89	-0.75	-0.57	
	-0.53	-0.87	-0.81	-0.86	-0.67	-0.52	
	-0.52	-0.89	-0.88	-0.88	-0.66	-0.54	

Seasonal change in correlations



Higher in Mar-Apr when ITCZ appears

Lower in light-rain season

4. How are correlations determined?

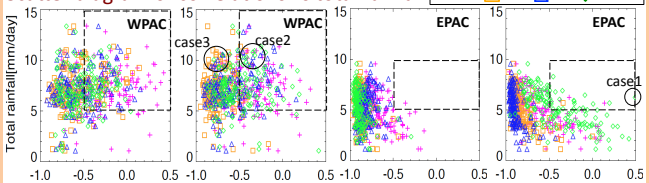
EPAC

• Correlations tend to be stronger with higher rainfall amounts, but trend is not very clear.
• **MERRA** often has subsidence at 300 hPa over the ITCZ, while **the others** have ascent.

WPAC

• Correlations are independent of rainfall amounts for **all reanalysis datasets**.
• Correlations tend to be higher, when rainfall is concentrated on a rain band.

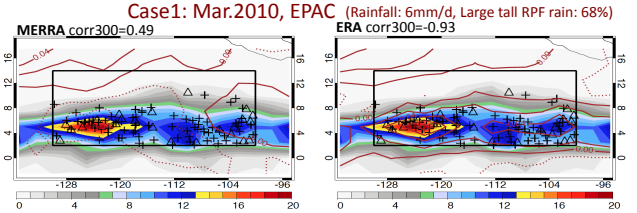
Scatter diagram of correlations vs total rainfall + NCEP □ ERA △ JRA ◇ MERRA



Many points with high rainfall and low correlation from **all reanalysis datasets**

Few points with high rainfall and low correlation (reasonable)

Case1: Mar.2010, EPAC (Rainfall: 6mm/d, Large tall RPF rain: 68%)

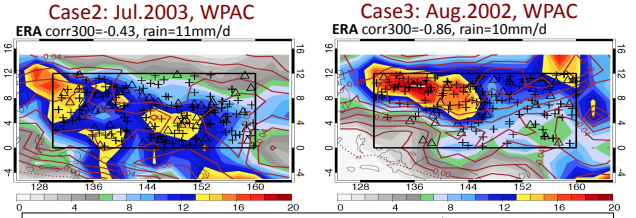


Case2: Jul.2003, WPAC

ERA corr300=-0.43, rain=11mm/d

Case3: Aug.2002, WPAC

ERA corr300=-0.86, rain=10mm/d

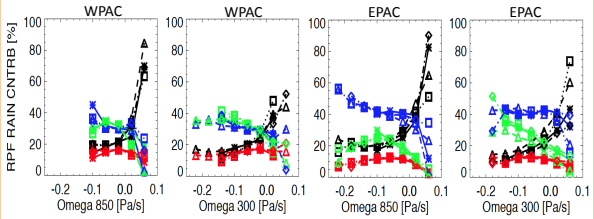


Contour: ω300, Shade: rainfall, +: Large and moderately tall RPF, △: Large and very tall RPF

5. Relationships between RPF types and ω

• In general, the rain contribution of large and moderately tall RPFs is larger in grid boxes with stronger updrafts at 850 hPa, while the rain contribution of large and very tall RPFs is larger in grid boxes with stronger updrafts at 300 hPa.
• These relationships are more obvious over EPAC than over WPAC.

RPF-type contribution against ω in 2.5°-grid boxes

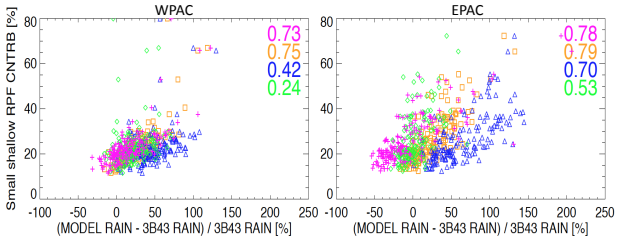


* NCEP □ ERA △ JRA ◇ MERRA
Line colors: Small shallow Small tall Large and moderately tall Large and very tall

6. Estimated rain rates in four datasets

• All models tend to overestimate rain rates, especially when small shallow RPFs contribute more of the total rainfall. Similar relationships are found for the other oceans.
• Differences in total rainfall among models are larger over EPAC than over WPAC.

Difference between monthly rain in each model and 3B43, and its relation to % of rain from small shallow RPFs



+ NCEP □ ERA △ JRA ◇ MERRA

7. Discussion and conclusions

• **Over EPAC**, correlations are high at 850 hPa. Correlations at 300 hPa are smaller and more different among reanalysis datasets than those at 850 hPa.
• Lower correlations over EPAC tend to be found when the total amount of rainfall is smaller. That is reasonable, because ascent of dry air can exist even in months with little rainfall.
• **MERRA** has weak ascent or subsidence at 300 hPa over EPAC, while **all others** have strong ascent. To know if MERRA produces reasonable ω300, we need to examine relationships between rainfall and ω on rainy days.

• **Over WPAC**, correlations are lower than EPAC, and higher at 300 hPa than at 850 hPa.
• Shallow convergence, well correlated with rainfall in EPAC, is known to be forced by the strong SST gradient, while the warm pool of WPAC has no similar forcing tied to any specific latitude belt, and therefore heavy rainfall may occur over a wider area, and monthly mean at any given location may include more no-rain days, which may result in low correlations.

• Contribution of large and moderately tall RPFs relates to stronger ascent at 850 hPa, while that of large and very tall RPFs relates to stronger ascent at 300 hPa.

Future work

• To examine daily relationships between precipitation characteristics and ω
• To compare ATL with EPAC and CPAC, and compare Indian Ocean with WPAC