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INVESTIGATING THE EFFECT OF ENSO UPON OCEANIC RAINFALL ESTIMATES

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1. INTRODUCTION

Large variations in oceanic precipitation occur with the El Niño-Southern Oscillation (ENSO) where anomalies in equatorial Pacific sea surface temperatures (SST) influence variations in the structure of atmospheric wind, temperature, and moisture to bring about regional changes in the cloud distribution and precipitation throughout the tropical oceans (Alexander et al. 2002; Held and Soden, 2006; Su and Jiang, 2012). These ENSO driven perturbations, however, affect rainfall differently between individual precipitation estimates in observations and models. This is particularly noticeable between active and passive microwave oceanic precipitation retrievals derived from the Tropical Rainfall Measuring Mission (TRMM, Kummerow et al, 1998), during different phases of ENSO where passive precipitation retrievals exhibit a systematic shift in precipitation seemingly correlated with ENSO phase. Oceanic rainfall estimates from the TRMM microwave imager (TMI) as well as global climate models show an increase in oceanic precipitation as a response to increased SST associated with El Niño events. This increase in precipitation is not observed in rainfall estimates derived from the TRMM precipitation radar (PR) (Wang et al., 2008). Inconsistencies in the observed interannual variability between the TRMM rainfall estimates create difficulty in understanding the sensitivity of global precipitation to a changing climate. This paper focuses on understanding how differences in precipitating regimes over the tropical oceans may lead to the discrepancies observed in TRMM precipitation products.

2. TRMM PRECIPITION DATA

The primary data products used in this work are derived from the TRMM satellite, which has provided reliable quantification of the evolving rainfall field for the past 16 years using the TRMM microwave imager and the first space-borne precipitation radar. Data used from the TRMM mission includes surface precipitation estimates provided in the TRMM TMI 2A12 product and vertical profiles of reflectivity, precipitation intensity, and the convective and stratiform partitioning included in the TRMM PR 2A25 product.

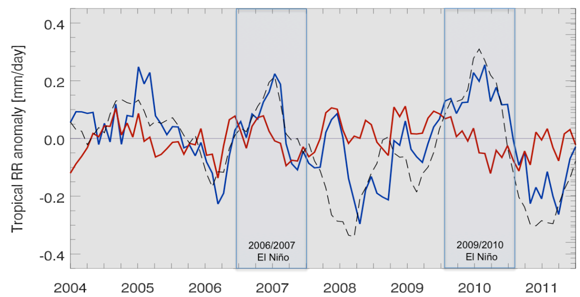

Figure 1 Tropical mean TMI (blue) and PR (red) oceanic rain rate anomalies and the ENSO 3.4 index (dashed)

Time-dependent biases between TMI and PR oceanic rainfall estimates are visible during the 2007 and 2010 El Niño events (Figure 1). During these events TMI precipitation anomalies systematically shift positive along with the ENSO 3.4 index and peak during the winter DJF periods. PR rainfall anomalies generally exhibit an opposite trend over the same period. Berg et al. (2002) found that discrepancies between the satellite rainfall estimates, such as the ones found during El Niño events, are the result of time-dependent regional biases and could be further linked to fluctuations in convective organization. This research focuses the causes for global and regional biases between the TMI and PR rainfall estimates for various precipitating regimes during the 2009-2010 El Niño event. Precipitation data from the El Niño event will be compared to post-boost period from 2002-2010 over a tropical belt covering 30°N to 30°S.

3. PRECIPITATION TYPE CLASSIFICATION

To identify tropical precipitation systems a methodology for classifying the varying degrees of oceanic convection was constructed based upon Elsaesser et al. (2010). The classification is created by inputting the distribution of precipitating cloud echo top heights, average convective rainfall, and the ratio of convective to stratiform rainfall contained within a 1° box centered along nadir PR 2A25 pixels, into a k-means clustering algorithm. The

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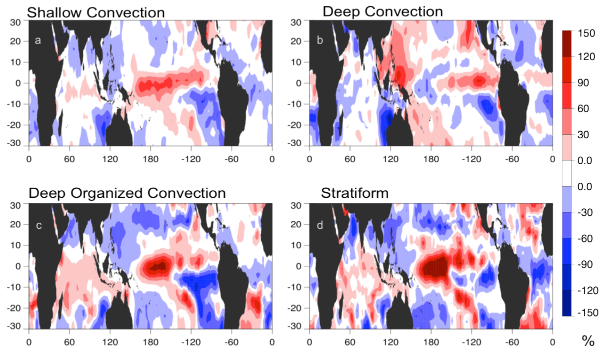

Figure 2 Percent change in the regional distribution of the shallow convective (a), deep convective (b), deep organized (c), and stratiform (d) precipitation regimes for the 2009-2010 El Niño event.

methodology defines four precipitation regimes: 1) Shallow convection; 2) Deep unorganized convection; 3) Deep organized convection containing deep stratiform rainfall; and 4) Deep stratiform anvils, which occur adjacent to deep organized convection. The algorithm provides instantaneous classification of precipitation systems along the TRMM orbit allowing direct comparisons of TMI and PR rain rates for each classified system over time. To compare rain rates the TMI surface rainfall is collocated to each 1° domain along the TRMM orbit for the 2002-2010 period.

4. IMPACT OF THE 2009-2010 EL NIÑO

4.1 Regional Variability

Maximum SST anomalies usually occur during the boreal winter period of an El Niño. Therefore, the regional impacts of the El Niño event are demonstrated by comparing the occurrence of each precipitation type and TRMM rainfall bias from 2002-2010 to the DJF period of the 2009-2010 El Niño over the tropical oceans. Regional anomalies in each precipitation type are displayed in Figure 2. Increases in precipitation occurrence are generally focused toward the equatorial pacific. The largest increase is associated with organized convection and stratiform rainfall in the Central Pacific Ocean basin where the predominant precipitation type shifts from deep convection to organized convection. These organizational anomalies are coincident with the positive SST and surface convergence anomalies associated with a Central Pacific El Niño event (Kim and Yu, 2012; Ratnam et al., 2011) and are the locations where largest variation in bias occurs between the TMI and PR precipitation estimates.

Distinct variations in regional bias exist for each precipitation classification with the strongest bias occurring in deep convection, deep organized convection and stratiform precipitation types. Deep

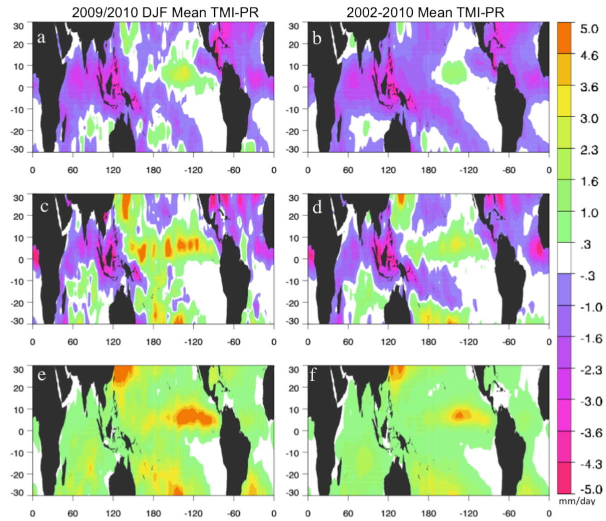

Figure 3. Bias between TMI and PR rainfall [mm/day] for Deep Convection (a,b), Organized Convection (c,d), and Stratiform Rainfall (e,f). Compared are the climatological difference from 2002-2010 (right) and the DJF 2009-2010 El Niño (left).

convective systems contain predominately negative biases and exhibit less spatial variation in the magnitude of bias compared to the 2002-2010 mean rainfall. The most interesting features during the El Niño event appear in deep organized convection and deep stratiform precipitation, where stratiform rainfall is highly biased towards TMI rain intensity – with TMI rain rates on average 75% higher than PR in stratiform raining cases (Figure 3). The increase in organized and stratiform occurrence during the El Niño results in a strong positive bias extending from the equatorial eastern pacific to the central Pacific ocean basins, which then branches north and south toward the East China Sea and Southern Pacific. The positive biases between TMI and TRMM seemed to be linked to increases in stratiform precipitation amount associated with the deep organized convective systems. Stratiform extent in organized systems, as identified by 2A25 classification flags, increases by 7% over the tropical oceans and by 20% over the Central Pacific. The mean bias for all organized systems from 2002-2010 is -0.17 mm/day. When observing only the top 50% of organized systems with the most stratiform precipitation this increases to +0.47 mm/day.

4.2 Impacts on Total Oceanic Tropical Rainfall

Discrepancies in global rainfall are directly related to regional differences in bias between TMI and PR (Berg et al., 2002). Therefore, the impacts of regional variability observed in TRMM bias associated with each precipitation type can be related to the total TMI and PR tropical rainfall

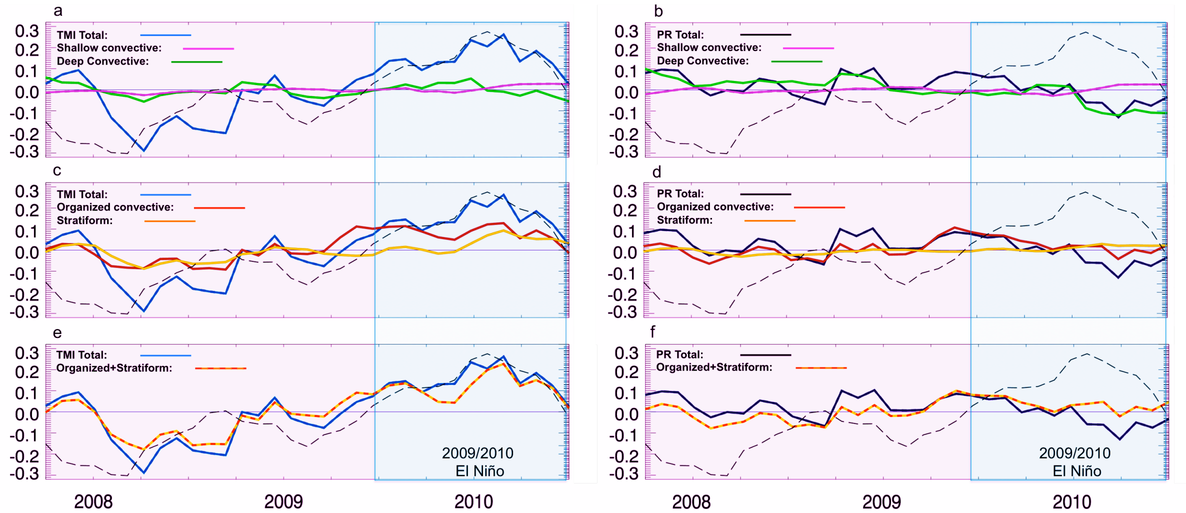

Figure 4 Contributions to the TMI and PR rainfall anomalies by each precipitation type over the tropical oceans. Displayed are the contributions from shallow convection and deep convection (a,b), organized convection and stratiform rainfall (c,d), and combined organized convection + stratiform rainfall (e,f) for TMI (left) and PR (right). Units for rainfall anomalies are mm/day. The 2009-2010 El Niño period is highlighted.

anomalies. Oceanic rainfall anomalies for TMI and PR are deconstructed into their individual contributions from shallow convection, deep convection, organized convections, and stratiform rainfall. Contributions to the rainfall anomaly are shown in Figure 4. Different precipitation types are displayed separately with isolated shallow and deep convection (top), organized convection and stratiform rainfall (middle), and the combined sum of organized convection and stratiform (bottom). Rainfall anomalies shown are from 2008 through 2010, which includes the transition from a La Niña event through the 2009-2010 El Niño event.

Interannual variability in shallow convection rainfall is similar between TMI and PR, however, due to the light rain rates associated with shallow convection the overall impact on total rainfall anomalies is minimal. There is a decrease in PR anomalies during the peak of the 2010 El Niño consistent with the drop in deep convective rainfall during this time period that is less evident in the TMI observations. The major contributors to positive anomalies in TMI rain estimates during the El Niño event are organized convection and stratiform rainfall. This is consistent with the increased stratiform extent and positive bias found regionally in organized convection and stratiform rainfall during the DJF period of the El Niño event. The organized convective systems and their stratiform anvils describe the majority of the precipitation anomaly in TMI rainfall estimates - a relationship not found in PR rainfall anomalies.

5. SUMMARY

A precipitation classification methodology from Elsaesser et al. (2010) is used to identify how specific precipitating systems affect regional and global rain estimates from the TRMM TMI and PR retrievals. During the DJF period of the 2009-2010 El Niño event conditions become more favorable for organized convection. Organized convection becomes the largest source of precipitation over the tropical oceans with larger amounts of the rainfall classified as stratiform rain. Areas of stratiform precipitation are consistently positively biased toward TMI rainfall estimates. The variability occurring with deep organized precipitating systems and their associated stratiform regions appear to be a likely cause for most of the discrepancies found in total oceanic rainfall between the rainfall retrievals.

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