CONVECTIVE VARIABILITY ACROSS THE EAST PACIFIC

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1. INTRODUCTION

A number of studies have examined differences in the structure of convection and associated precipitation characteristics between the tropical east and west Pacific (e.g., Berg et al. 2002). However, few studies have attempted to quantify possible differences within the east Pacific domain itself. Satellite data indicates large differences in the spatial distribution and magnitude of seasonal rainfall across the eastern Pacific depending on the algorithm utilized and satellite sensors available, indicating important differences in precipitation vertical structure (and resulting latent heating) across the region (Fig. 1).

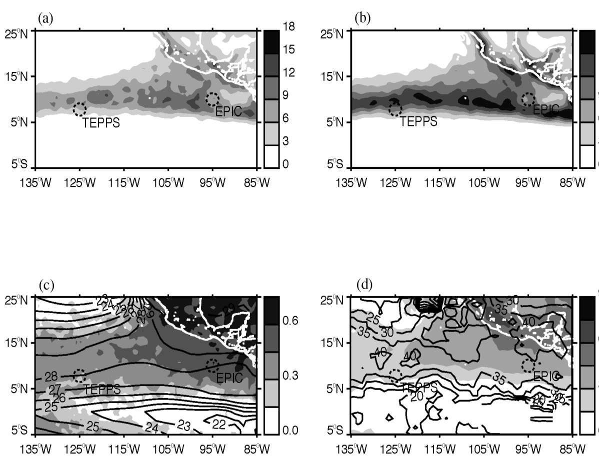

Figure 1. August-October 1998-2003 TRMM PR rainfall (mm/dy) in (a), TMI rainfall in (b), PR convective fraction (shaded) and NCEP SST (contoured °C) in (c), and mean maximum precipitation feature height of 30 dBZ echo (shaded, km) and mean feature maximum horizontal dimension (contoured, km) in (d).

Previous ship-based radar studies (Yuter and Houze. 2000; Serra and Houze 2002; Petersen et al. 2003) have shown that convective activity is strongly modulated by the passage of Easterly waves in both the Pan American Climate Studies Tropical Eastern Pacific Process Study (TEPPS) and the East Pacific Investigation of Climate Processes in the Coupled Ocean-Atmosphere System (EPIC) domains. TEPPS (EPIC) was conducted at 7.8º N, 125º W (10º N, 95º W) in August (September) 1997 (2001).

Broadly speaking, the EPIC and TEPPS regions are both located within the east Pacific ITCZ with similar sea surface temperatures (SST); however, the EPIC region is located only ~ 400 km from the Americas in the region of low SST gradients while the TEPPS domain is located near the fringe of the warm pool region (Fig. 1) and more representative of an open ocean location.

2. METHODOLOGY

In this study, radar reflectivity and upper air sounding data are used to compare precipitation structure and environmental characteristics between the TEPPS and EPIC regions. The data sets collected during the two field programs are similar: both experiments were focused in their respective ITCZ locations for approximately three weeks; radar data was collected continuously throughout each campaign using the 5-cm scanning radar on board the NOAA research vessel Ronald H. Brown; and upper air soundings were launched at a frequency of six times/ day (from the Ronald H. Brown).

The radar data were Quality Controlled (QC'd) using an algorithm from the NASA Tropical Rainfall Measuring Mission (TRMM) Office to remove spurious echos (e.g., sea clutter). The data were interpolated to a cartesian grid extending 120 km from a fixed point (7.8º N, 125º W for TEPPS and 10º N, 95º W for EPIC) in the horizontal direction at 1 km resolution and 18 km in the vertical at 0.5 km resolution. The sounding data were QC'd by the UCAR Joint Office for Scientific Support (JOSS) following the methodology of Loehrer et al. (1996). Convective Available Potential Energy (CAPE) was calculated assuming a 50 mb mixed layer and pseudo adiabatic ascent with no contribution from ice processes.

Over 200,000 (60,000) precipitation features were identified in the EPIC (TEPPS) interpolated radar data using an objective algorithm to isolate contiguous regions of echo. An ellipse fitting technique (similar to Nesbitt et al. 2004) was performed on each feature in order to examine differences in precipitation feature horizontal morphology. Statistics of major/minor axis length were retained, as well as eccentricity and

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orientation of the major axis. In this study, only “full” features (i.e., the feature occurs entirely within 120 km of the radar location) are examined.

3. THERMODYNAMIC CHARACTERISTICS

Scatter plots of CAPE vs. equilibrium level for all available soundings launched from the Ronald H. Brown during EPIC and TEPPS are shown in Fig. 2. The relative differences in the environments of the two regions are dramatic: the CAPE sampled during EPIC was substantially larger, on average, compared to TEPPS (mean values are 1674 vs. 669 J kg^{-1}, respectively), with a much narrower equilibrium level distribution in the EPIC soundings. CAPE values never exceeded about 1900 J kg^{-1} in the TEPPS soundings, whereas a number of EPIC soundings had CAPES well in excess of 2000 J kg^{-1}. These results suggest that the EPIC environment was more conducive to deep and intense convection compared to TEPPS, despite the fact that the sea surface temperatures (SST’s) were similar during the field campaigns (~29° C - not shown).

4. VERTICAL STRUCTURE

Figure 3 shows cumulative frequency distributions (CFD) of radar reflectivity for EPIC and TEPPS. The mode of the EPIC CFD is shifted several dB higher relative to TEPPS at all levels. The differences in radar reflectivity distributions becomes especially pronounced above the melting level (~ 5 km). For example, the height of the 99.0% occurrence of 30 dBZ is about 8 (5.5) km in EPIC (TEPPS). These results are consistent with lightning flash rate climatologies from the TRMM Lightning Imaging Sensor (LIS – not shown) and suggest more vigorous updrafts and resulting mixed phase processes in EPIC convection compared to the TEPPS region.

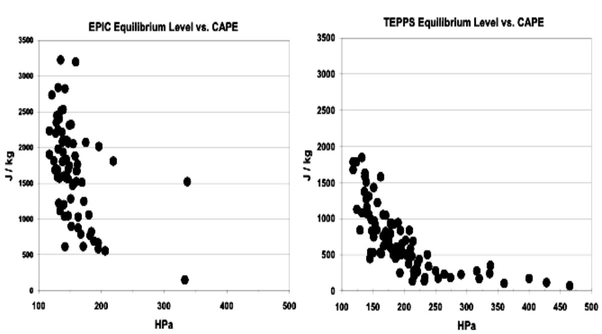


Figure 2. Scatter plot of equilibrium level (mb) vs. CAPE (j kg^{-1}) for (left) EPIC and (right) TEPPS.

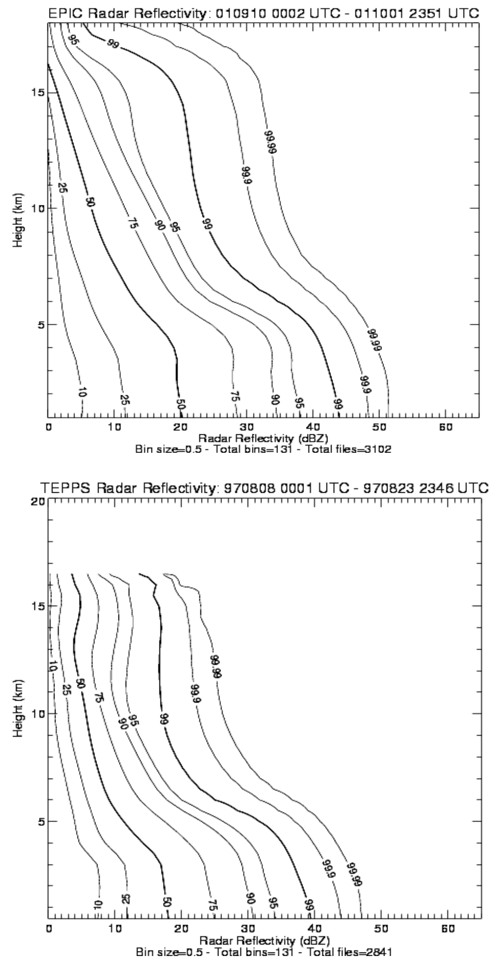


Figure 3. Cumulative frequency distributions of radar reflectivity (dBZ) for (a) EPIC and (b) TEPPS. The 50% and 99% contours are highlighted.

5. PRECIPITATION CHARACTERISTICS

Time series of total and conditional rain rate for each campaign are shown in Fig. 4. Consistent with the larger buoyancy and more developed vertical structure, the EPIC time series shows higher rain rates. Conditional rain rates are especially higher, which is consistent with the higher convective rain fraction observed in the EPIC domain (not shown). The difference in rain intensity characteristics is illustrated in histogram form in Figure 5. In EPIC, there is much higher frequency of occurrence of rain rates above about 3 mm hr^{-1}. Moreover, 90% of the rain rate distribution occurs below ~ 5.5 mm hr^{-1} (2.5 mm hr^{-1}) in EPIC (TEPPS).

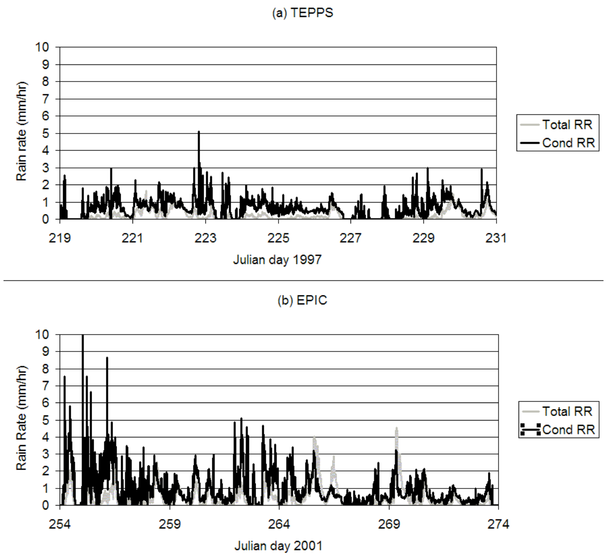


Figure 4. Rain rate time series for (a) TEPPS and (b) EPIC based on radar data within 48 km of the Ronald H. Brown.

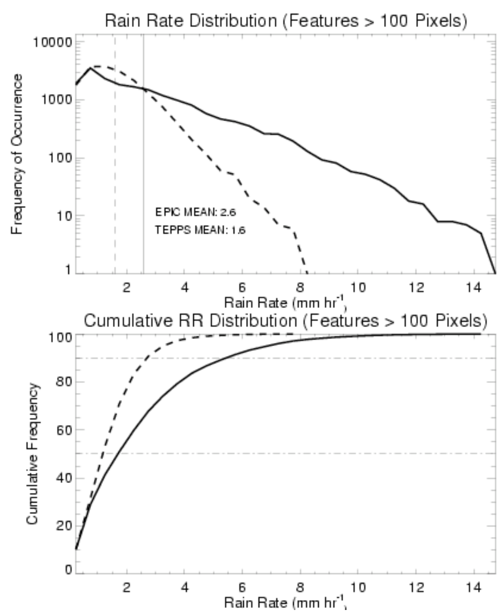


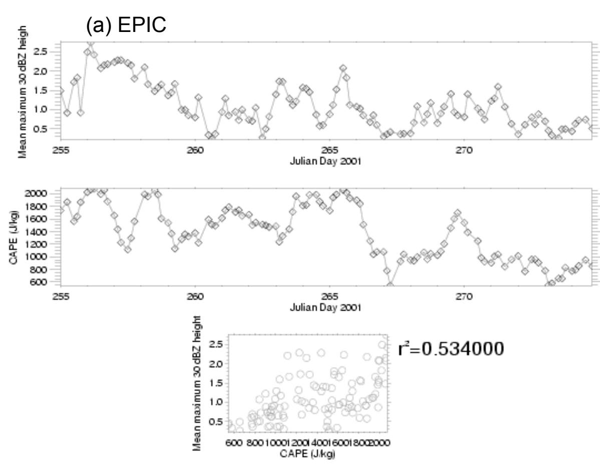
Figure 5. (top) Histogram of rain rate for EPIC precipitation features containing at least 100 pixels (solid line) and TEPPS (dashed line). The vertical lines show the location of the mean value. (bottom) Cumulative frequency of rain rate. The horizontal lines indicate the locations of the 50% and 90% cumulative frequencies.

6. CORRELATION OF RADAR CHARACTERISTICS WITH THE ENVIRONMENT

To explore possible correlations of precipitation feature echo structure with changes in the large-scale environment, the radar data were interpolated to the nearest upper air sounding launch time. Figure 6 shows time series of mean maximum height of the radar 30 dBZ height, CAPE, and the resulting correlation coefficient (R^2). As expected, both the EPIC and TEPPS data sets show positive correlations between CAPE and 30 dBZ height (i.e., *larger CAPE is associated with higher 30 dBZ height*); however, there is significant scatter in the correlation, suggesting that other factors are responsible for modulating the vertical intensity of convection. For EPIC, it was found that deep shear exhibited a negative correlation with 30 dBZ height (R^2 ~ 0.5 – not shown); however, no such correlation was found for TEPPS, probably due to the weaker shear in TEPPS compared to EPIC.

In EPIC, Petersen et al (2003) showed that the largest CAPE and most vertically intense convection occurred ahead of the Easterly wave trough. In contrast, preliminary results for TEPPS (not shown) suggests that the most intense convection occurs behind the wave trough. Analyses are continuing in order to explain the differences in convective intensity and wave phase.

In order to examine controls on horizontal morphology of precipitation features, correlations between feature eccentricity and 3 different shear layers (0-3 km, 0-6 km, and 0-12 km [deep shear]) were performed. For EPIC, the most robust correlation between shear and feature eccentricity was found for low-level shear (Fig. 7). That is, increasing low-level shear is associated with more linear features. However, the correlation is weak, suggesting a more complicated relationship between the large-scale environment and feature morphology. For TEPPS, the best correlation between shear and eccentricity occurred for 0-6 km shear; however, the relationship was very weak (R^2 ~ 0.1), again probably due to the weak shear present during TEPPS.



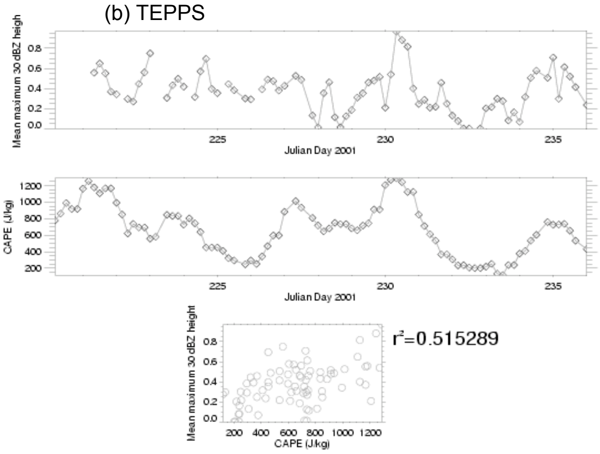


Figure 6. Time series of feature mean maximum 30 dBZ height, CAPE, and correlation coefficient for (a) EPIC and (b) TEPPS.

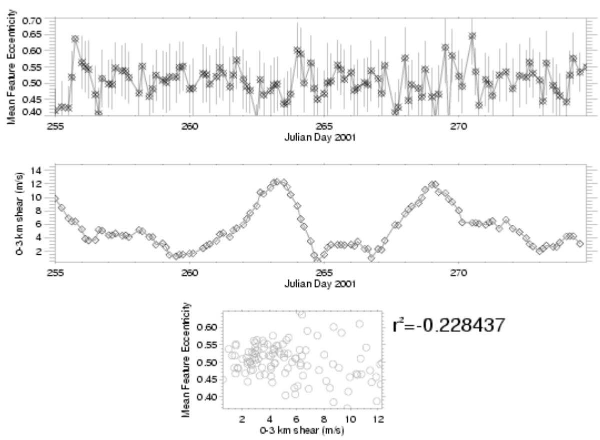


Figure 7. Time series of “large” feature eccentricity (≥ 100 pixels), 0-3 km shear, and correlation coefficient. The vertical bars in the eccentricity time series represent standard deviation values.

7. SUMMARY

Results indicate that the EPIC and TEPPS domains display large differences in environmental properties and precipitation feature characteristics, despite the fact that both field campaigns were conducted during in regions of the east Pacific warm pool with similar SST’s. Previous studies have shown that convective activity in both EPIC and TEPPS was heavily modulated by the passage of Easterly Waves. However, the radar and upper air sounding data indicate that the environment was more conducive to intense, deep convection and that this deep convection occurred much more frequently in EPIC compared to TEPPS. The proximity of the EPIC domain to land and the location of TEPPS relative to the descending branch of the Walker circulation are likely causes for the observed differences. Additional analyses are needed to sort out the large-scale influences on convective horizontal and vertical structure.

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8. REFERENCES

Berg, W., C. Kummerow, and C.A. Morales, 2002: Differences between east and west Pacific rainfall systems. *J. Climate*, **15**, 3659-3672.

Loehrer, S. M., T. A. Edmands and J. A. Moore, 1996: TOGA COARE upper-air sounding data archive: development and quality control procedures. *Bull. Amer. Meteor. Soc*., **77**, 2651-2671.

Nesbitt, S.W., R. Cifelli, S.A. Rutledge, D.J. Boccippio, D.J. Cecil, and E.J. Zipser, 2004: The horizontal structure of precipitating systems in the Tropics according to TRMM. *Preprint volume*, 2nd TRMM International Science Conference, Nara, Japan.

Petersen, W.A., R. Cifelli, D.J. Boccippio, S.A. Rutledge, and C. Fairall,2003: Convection and easterly wave structure in the eastern Pacific warm pool during EPIC-2001. *J. Atmos. Sci*., **60**, 1754-1773.

Serra, Y.L., and R.A. Houze Jr., 2002: Observations of variability on synoptic timescales in the east Pacific ITCZ. *J. Atmos. Sci*., **59**, 1723-1743.

Yuter, S.E., and R.A. Houze Jr., 1997: The 1997 Pan American Climate Studies Tropical Eastern Pacific Process Study. Part I: ITCZ region. *Bull. Amer. Meteor. Soc*., **81**, 451-481.