13.B.3 CONVECTION AND EASTERLY WAVES OBSERVED IN THE EASTERN PACIFIC ITCZ DURING EPIC 2001

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1. INTRODUCTION

During September 2001, the East Pacific Investigation of Climate Processes in the Coupled Ocean-Atmosphere System (EPIC2001) intensive field campaign focused on studies of deep convection in the Mexican warm-pool region of the E. Pacific ITCZ near 10°N 95°W. Major observational platforms deployed during the field phase included the NOAA R/V Ronald H. Brown (RHB), NSF R/V Horizon, NOAA P-3 and NCAR C-130 aircraft. This study utilizes C-band Doppler radar and rawinsonde observations collected aboard the RHB to describe the structure of ITCZ convection and rainfall as a function of 3-5 day easterly wave passages.

2. EASTERLY WAVE STRUCTURE

Three distinct easterly wave passages occurred during EPIC2001. Each wave originated in the eastern Atlantic Ocean and after moving westward over Central America were easily identified in time-height profiles of wind and thermodynamic data collected aboard the RHB (Fig. 1). In all three cases, the wave trough axes (defined by U, V direction changes and departures in pressure altitude) exhibited relatively modest northeasterly tropospheric shear (cf. Serra and Houze, 2002), and tended to tilt slightly westward with height (cf. Reed and Recker, 1971). Associated positive perturbations in relative humidity (not shown) either tilted little with height, or even tilted slightly *eastward* with height through the trough axis.

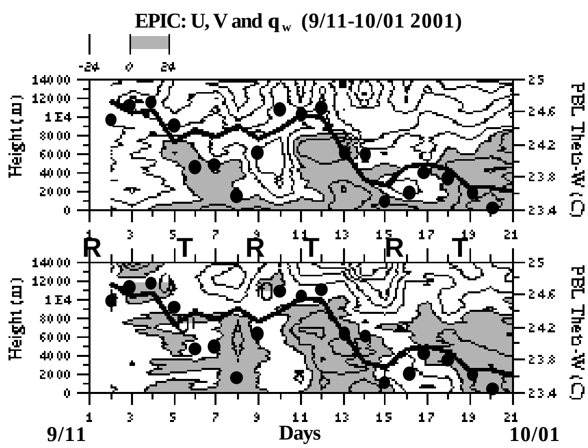

Figure 1. Daily mean U (top) and V(bottom) wind (m/s) as a F(height, time)] for the EPIC ITCZ sampling period. Filtered values of mean daily PBL θw (cloud-to-ground lightning; relative values) on the right (left) ordinate are also indicated by the bold black line (circles). The approximate dates of ridge (**R**) and trough (**T**) passage are indicated.

Peaks in conditional instability, indicated in Fig. 1 by peaks in θ_w (highly correlated to CAPE), occurred 1-2 days prior to the passage of each wave trough. In turn, the trends in PBL θ_w were highly correlated to changes in convective intensity as indicated by nearly coincident peaks in lightning activity (Fig. 1).

3. MODULATION OF CONVECTIVE STRUCTURE AND RAINFALL

As suggested by the trends in instability and lightning flash count, the vertical structure (Figs. 2a-b) and coverage (Fig. 3) of convection were strongly modulated by the passage of each wave. Peaks in convective cloud top height were similar between all the wave passages (e.g., 4 dBZ contour, Fig. 2a), and reached a relative maximum 1-2 days prior to trough passage. The intensity of convection, as measured by the vertical extension of relative frequencies of reflectivity > 30 dBZ at a given height (Fig. 2b), exhibited a trend similar to that of the echo-top height but tended to decrease faster with trough passage. The relatively high echo top heights and decreasing echo intensity during and after the trough passages suggest a transition from heavier raining convection to weaker/decaying convective rainfall and stratiform rain in the middle and east sides of the wave troughs (Fig. 3).

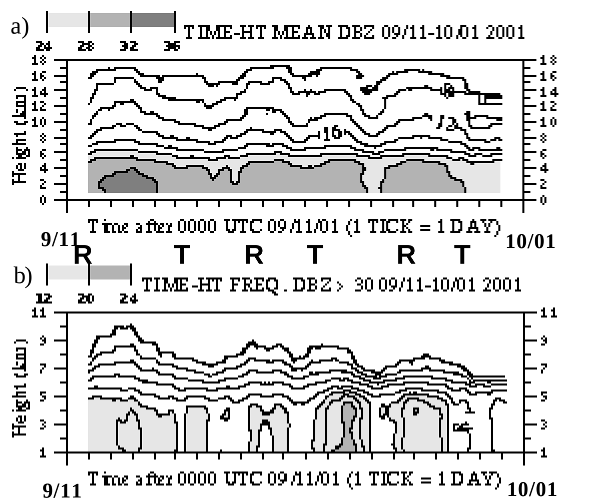

Figure 2 a) RHB Time-height series of mean radar reflectivity. Contours every 4 dBZ starting at 4 dBZ. b) as in (a) but relative frequency of pixels with reflectivity > 30 dBZ. Contours at values of 0.5, 1, 2, 4, 8, 12, 16, and 20 %. Ridges(**R**) and troughs (**T**) indicated.

In order to examine trends in rainfall as they relate to easterly wave forcing and convective intensity, instantaneous rain rates and daily rainfall accumulations were computed

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using a general (e.g., no convective-stratiform partitioning) TOGA COARE Z-R relationship (Tokay and Short, 1996). This relationship was applied to gridded radar reflectivity values (1 x 1 km pixels; uncorrected for attenuation or range aliasing and filtered with 48-hr running mean), at the 1 km height level, within 120 km range of the RHB. The results of these rainfall calculations are presented in Figs. 3-4.

Figure 3 suggests that peaks in heavy convective rainfall area (rain rates $\geq$ 20 mm hr^{-1}) occurred 1-2 days prior to each trough passage, followed by a transition to broader area coverage of light rain within and just behind each wave trough. Note that although the area coverage of rain rates $\leq$5 mm/hr is approximately two orders of magnitude larger than that of the $\geq$20 mm/hr rain rates (Fig 3), cumulative distributions of rain accumulation and rain rate (not shown) indicate that a disproportionate amount of accumulated rainfall (40-50%) occurred in association with the relatively small area of rain rates exceeding 20 mm/hr. Corresponding relative maxima in rainfall accumulation and heavy rainfall area in Fig. 3, do suggest the presence of a weak, but detectable, relationship between rain

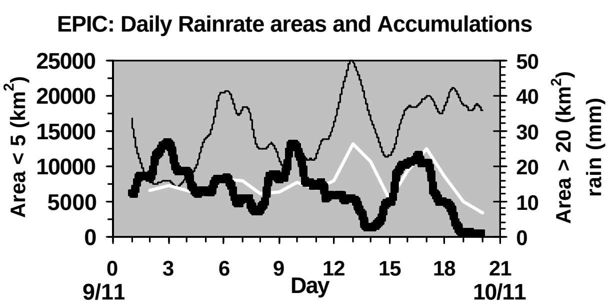

Figure 3. Filtered (48-hr running mean) raining area (km^2) > 20 mm hr^{-1} (bold solid; right ordinate) and < 5 mm hr^{-1} (light solid; left ordinate); daily accumulation (mm) white) right ordinate.

accumulation and the occurrence of heavy convective rain rates. However, it is also clear that large peaks in accumulation can occur in association with large areas of persistent light rainfall (e.g., day 13-14 in Fig. 3).

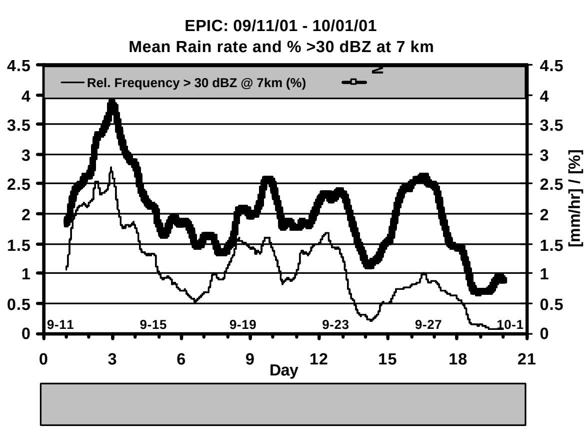

Figure 4. Time series of conditional mean rain rate (mm/hr; bold) and relative frequency of 30 dBZ at a height of 7 km (%; light). Approximate dates of trough (**T**) and ridge (**R**) axis passages are indicated.

A strong correlation between easterly wave forcing and rainfall is also observed in a time series plot of conditional mean rain rate (Fig. 4). The conditional mean rain rate was computed from raining pixels in the sample domain where the rate exceeded 0.2 mm hr^{-1} (~15 dBZ). In addition to the CMR, we also plot on Fig. 4 the relative frequency of 30 dBZ reflectivities at a height of 7 km. Note that both the CMR and the 30 dBZ frequency at 7 km exhibit peaks ~2 days prior to the passage of each trough axis, consistent with peaks in instability and lightning (Fig. 1), the area of rain rates > 20 mm hr^{-1} (Fig. 3) and to a lesser extent, relative maxima in accumulated rainfall (Fig. 3).

To the extent that intense, vertically developed convection influences the CMR in Fig. 4, we might intuitively expect a positive correlation to exist between the CMR and the frequency of 30 dBZ reflectivities aloft. Conversely, the expected dominance of warm rain precipitation processes commonly observed over the tropical oceans would argue against such a strong correlation since the presence of $\geq$30 dBZ reflectivities in the cold region of a cloud is by no means required for warm rain processes to produce heavy rainfall. The observations presented in Fig. 4 do, in fact, suggest that a very strong correlation exists between the relative frequency of high reflectivities at the 7 km level in the ITCZ clouds sampled during EPIC and the near surface CMR. Coupled with the observed, correlated trends in conditional instability and lightning (Fig. 1), the strong correlation between CMR and 30 dBZ reflectivities at 7 km (Fig. 4) may indicate that ice processes contribute significantly to surface rainfall in the pre-trough phase of easterly waves.

4. SUMMARY AND CONCLUSIONS

Three distinct 3-5 day easterly waves were observed in the EPIC 2001 domain over the Mexican warm-pool by the NOAA ship R/V Ronald H. Brown during September, 2001. The momentum structure in each wave exhibited a westward tilt with height while the humidity structure exhibited either little, or a slight eastward, tilt with height. Peaks in conditional instability, lightning, conditional mean rain rate and deep convective vertical structure were generally found in the pre-trough phase of the waves, occurring approximately 2 days prior to the passage of each trough axis.

5. REFERENCES

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