5B.1 **VARIABILITY OF CONVECTIVE STRUCTURE AND LIGHTNING ACTIVITY IN TROPICAL EASTERLY WAVES**

Walter A. Petersen[1*] and Dennis J. Boccippio[2]
[1]ESSC/NSSTC, University of Alabama-Huntsville, Huntsville Alabama 35899
[2]NASA Marshall Space Flight Center, Huntsville, Alabama

1. INTRODUCTION

Petersen et al. (2003) used ship borne radar, sounding and long range lightning data collected during the EPIC-2001 field campaign to demonstrate that lightning flash density, convective vertical development, and conditional mean rain rates all varied systematically as a function of 3-5 day Tropical Easterly Wave (TEW) phase in the Mexican warm-pool of the E. Pacific. Specifically, Petersen et al. found that convective vertical development, areas of heavy rain rate, lightning flash rates, and CAPE all reached maximum (minimum) values just prior to (after) the passage of TEW troughs. Conversely, convective echo coverage and light rain area were an order of magnitude larger *after* trough passage.

One limitation of the Petersen et al. study was the rather small sample of TEWs sampled (a total of three). Herein we extend the results of Petersen et al. by taking full advantage of a new Tropical Rainfall Measurement Mission (TRMM) combined dataset that includes space-borne precipitation radar (PR), lightning imaging sensor (LIS), NCEP Reanalysis winds and PR reflectivity-profile cluster analysis (Boccippio et al., 2004), to characterize 4D convective structure in TEWs as a function of wave phase. This analysis is performed for TEWs occurring over remote regions of continental West Africa and the eastern Pacific Mexican warm-pool.

2. DATA AND METHODOLOGY

Following Petersen et al. (2003) and many previous studies in the literature, NCEP meridional winds at 700-hPa were used to partition TEWs into four wave phases; *ridge, northerly, trough, or southerly*. Subsequently TRMM PR, TMI, and LIS data [including 16 archetypical vertical structures identified via multivariate cluster analysis; Boccippio et al., 2004], were combined for each TEW to produce wave phase and diurnal cycle composites of lightning and convective structure occurring over regions of the eastern Pacific Ocean Mexican warm-pool region (100-90°W; 5°-15°N) and tropical West Africa (15W – 5W; 5°N – 20° N). The composites were created from data collected during the months of June-October spanning the years of 1998-2000.

3. RESULTS

Figs. 1a-b present an example of joint conditional and unconditional frequency distributions of vertical convective structure types for TEW wave phases in the E. Pacific ITCZ. “Deep convective” structure types include, for example, TRMM PR grid columns associated with convective systems possessing large reflectivities (e.g., ≥ 30 dBZ) above the 0°C level and LIS-detectable lightning flash rates (e.g.,, ≥ 1/min). “Warm” structure types include PR grid columns identified as either shallow convective or stratiform. Deep stratiform structures are associated with heavier stratiform rainfall, such as that observed in tropical MCSs. The conditional frequency is defined as the number of samples associated with a given category type divided by the sum of all raining pixels. Alternatively, the unconditional frequency is computed using all PR pixels from each orbit in the domain, regardless of the presence of precipitation features. Comparison of these different statistical samples in each phase enables discernment of both vertical development when it is raining, and relative area coverage as it relates to the area fraction of deep convective cores.

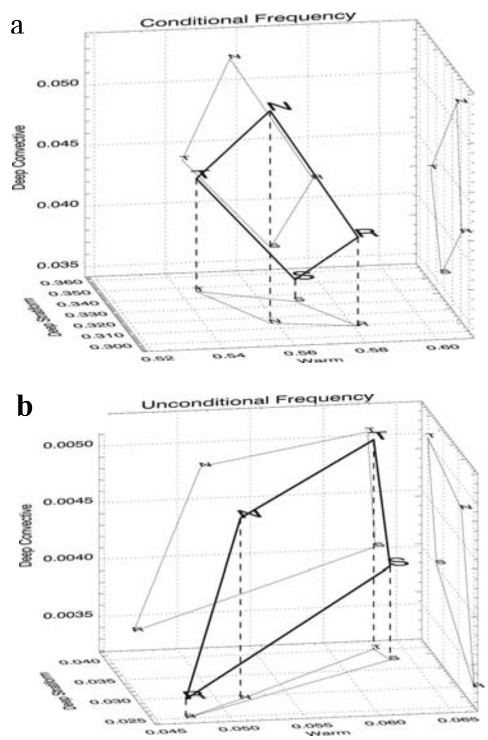

Figure 1. a) Conditional relative frequency of deep convective (z-axis), deep stratiform (y-axis) and warm convective/stratiform PR echo structure types for Ridge (R), Northerly (N), Southerly (S), and Trough (T) regimes. (**b**) As in (a) but unconditional frequency.

The multi-year trends in convective structure type combined with trends in partitioned TRMM LIS and U.S. Long Range National Lightning Detection Network (LR-NLDN) lightning flash counts (Table 1) reveal coherent trends in convective vertical structure as a function of wave-phase. Statistically, when convection is present in Mexican warm-pool TEWs (Fig. 1a) it tends to be slightly more (less) vertically developed and somewhat more likely to produce

[1] *Corresponding Author: W. A. Petersen, ESSC/NSSTC University of Alabama Huntsville, Huntsville, AL. 35899; e-mail: walt.petersen@msfc.nasa.gov

lightning in the northerly (trough) phase (Table 1). Deep stratiform precipitation is occurs more frequently in the trough and post-trough southerly phases and deep vertical development is the weakest during the ridge and southerly TEW phases. For the unconditional sample, Fig. 1b suggests that the northerly and trough phases are associated with nearly the same relative frequency of deep convection, a manifestation of the greater overall area coverage of convection in the trough phase. In summary, for the Mexican warm-pool of the E. Pac., our results suggest that *TEW northerly phases are associated with a smaller number of deeper, more electrically active storms (and attendant robust ice phase), while trough phases are associated with weaker, more widespread thunderstorms and stratiform precipitation..*

Table 1

Phase	E. Pac. Fl/Hr (*LR-NLDN*) [Night/dayl]	E. Pac. Fl/Hr(*LIS*)	West Africa Fl/hr (*LIS*)
R	24.5 / 6.7	303	**1265**
N	**47.5 / 12.2**	**320**	**1338**
T	**40.2 / 9.4**	**331**	761
S	20.3 /7.4	308	856

Similar trends between convective structure, lightning and TEW wave-phase were observed over W. Africa (Table 1, Figs. 2-4). Lightning flash rate tendencies suggest a clear preference for deep, electrified convective towers over W. Africa during the ridge and northerly (pre-trough) phases. The diurnal cycles in lightning also differ markedly between the TEW phases (Fig. 2), pointing to a robust amplification of vertically developed convection in the afternoon/early evening during the pre-trough and/or ridge phase, and a weaker less amplified peak in afternoon deep convection during the trough phase. The diurnal cycles of 30 dBZ frequency (Fig. 3) are consistent with the lightning data, revealing a much sharper peak in the frequency of 30 dBZ aloft (proxy for deep convection; indicator of large precipitation particles) in the ridge phase. Composited conditional convective structure frequency distributions over W. Africa (Fig. 4a) suggest a greater (lesser) tendency for convective systems to be more vertically developed and less (more) widespread and/or stratiform during African TEW ridge (trough) phases. As in the case of the Mexican warm-pool, unconditional frequency distributions for W. African TEWs (Fig. 4b) reveal similar frequencies of deep convective structure type in the trough and pre-trough phases, but a preference for deep stratiform and warm convective/stratiform precipitation in the trough phase. Collectively, these trends reflect an overall increase in the area coverage and frequency of convection in the trough-phase of W. African TEWs.

4. CONCLUSIONS

Herein we described systematic large-scale changes in 4-D convective structure diagnosed from TRMM lightning and precipitation radar data as a function of 3-5 day TEW wave phase over the Mexican warm-pool of the E. Pacific and W. Africa. These observations are important because convective structure (an observable) is related to convective heating, which likely feedbacks to TEW wave structure and intensification. Importantly, we note that the trends observed for the W. African TEWs seem consistent with recent cloud-ensemble simulations of TEW mass flux, latent heating and water budget profiles (e.g., Xu and Randall, 2000).

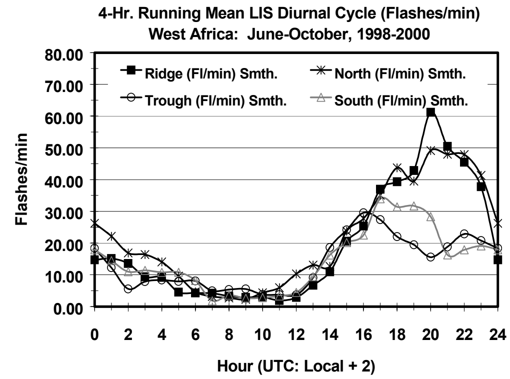

Figure 2. Diurnal cycles of 4-hr running mean TRMM-LIS lightning flash counts (flashes/minute) for West African TEW phases.

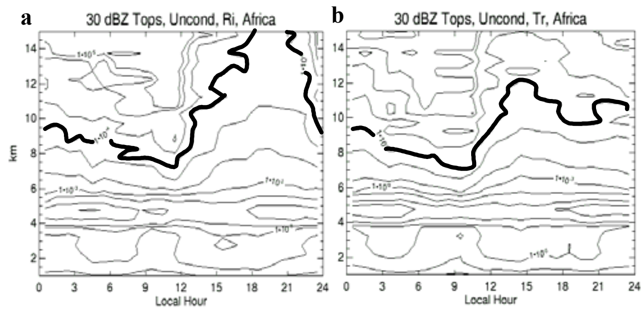

Figure 3. W. Africa diurnal cycle of TRMM-PR 30 dBZ echo top frequency distributions as a function of height (ordinate; km). Contours values at 1, 2, 5 x 10^{-x}(10^{-4} bold). **a)** Ridge and **b)** Trough phases.

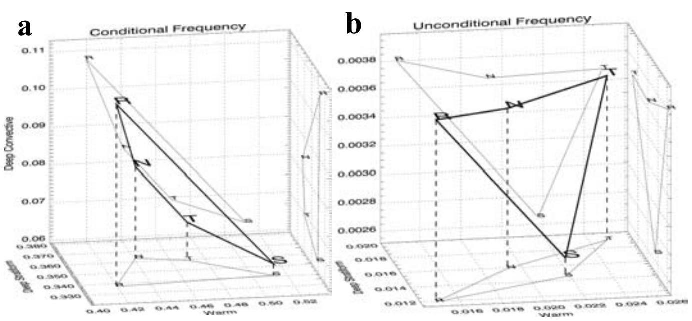

Figure 4. (a) as in Fig. 1(a) but for W. Africa. (b) as in Fig. 1(b) but W. Africa.

Acknowledgements: We acknowledge NASA MTPE and ESE Grants for supporting this research.

5. REFERENCES

Boccippio, D. J., W. A. Petersen, and D. J. Cecil, 2004: The tropical convective spectrum: 1. Archetypical vertical structures. J. Climate, submitted.

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

Xu, K-M., and D. Randall, 2001: Explicit simulation of cumulus ensembles with the GATE phase III data: Budgets of a composite easterly wave. *Q.J.R. Meteorol. Soc*., **127**, 1571-1592.