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CHARACTERISTICS OF AMAZONIAN RAIN DURING CONTRASTING WET SEASON REGIMES

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1. INTRODUCTION

The Tropical Rainfall Measuring Mission (TRMM) is a NASA satellite project initiated to address a gap in our ability to accurately observe detailed rainfall patterns over the tropical continents and oceans. To support TRMM, several field campaigns were conducted. The TRMM-LBA (Large-scale Biosphere Atmosphere) experiment was conducted over the southwestern region of the Amazon (state of Rondônia, Brazil) in order to provide detailed information on the precipitation characteristics in the interior of a tropical continent. Information from TRMM-LBA will be used for validation of TRMM satellite products and for the initialization and validation of cloud-resolving models and passive microwave retrieval and ground validation algorithms. TRMM-LBA was conducted in parallel with the WETAMC-LBA campaign aimed at examining the effect of land use change on rainfall in Amazonia.

During the TRMM-LBA field campaign, a variety of instrumentation was deployed during the wet season (January - February 1999) to measure rainfall including a rain gauge network and S-band polarimetric (NCAR S-POL) radar.

2. DATA AND ANALYSIS METHOD

The S-POL radar data were carefully quality controlled and corrected by applying polarimetric methods (Carey et al., 2000). Maps of rain rate (R) and median volume diameter (D_0) were calculated from observations of S-POL horizontal reflectivity (Z_h), differential reflectivity (Z_{dr}), and specific differential phase (K_{dp}) every ten minutes from 10 January to 28 February 1999 (Carey et al., 2000; Cifelli et al., 2002). On the order of 10^6 samples of R and D_0 were available for this study.

Using observations of Z_h, Z_{dr} and the difference reflectivity (Z_{dp}), the rain mass (M_w) and precipitation ice mass (M_i) were estimated (Carey and Rutledge, 2000; Cifelli et al., 2002) at each 2 km x 2 km grid point throughout the entire three-dimensional echo for all S-POL sector volume scans collected during TRMM-LBA, resulting in over 10^7 samples of rain and ice mass.

For more details regarding TRMM-LBA SPOL radar data quality control, processing, analysis method, validation and scientific results, link to the TRMM-LBA web page at http://radarmet.atmos.colostate.edu/trmm_lba/.

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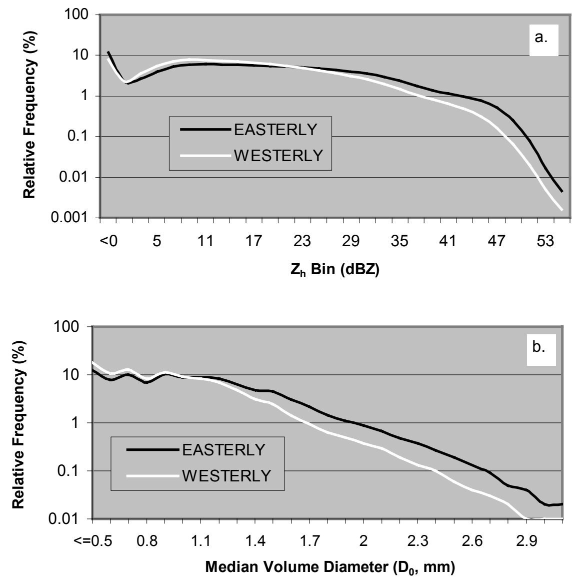

Fig. 1. Relative frequency (%) histograms of observed and derived S-POL radar quantities according to low-level wind regime. (a) Horizontal reflectivity (Z_h, 2 dBZ bins) and (b) median volume diameter (D_0, 0.1 mm bins) where $D_0 = 1.529*(Z_{dr})^{0.467}$.

3. BACKGROUND

Initial results from the TRMM-LBA field campaign suggest that wet season convection over Rondônia, Brazil occurs in distinct intraseasonal meteorological regimes as defined by the direction of the low-level wind direction (Rickenbach et al., 2001). Westerly wind periods feature modest CAPE, significant moisture through a deep layer, and shallow westerly wind shear. Conversely, easterly wind periods were associated with significantly larger CAPE, reduced humidities in the lower and middle troposphere, a stronger and deeper wind shear layer, and a weak low-level capping temperature inversion (Halverson et al., 2002).

These differences in the thermodynamic and wind properties of the regimes resulted in convection with contrasting properties (Cifelli et al., 2002; Rickenbach et al., 2002; Halverson et al., 2002). Compared to the westerly regime, precipitation systems that occurred during low-level easterlies were more vertically developed, exhibited more horizontal organization, and were characterized by stronger updrafts at low-to-mid levels, a more active mixed phase precipitation process and significantly more lightning.

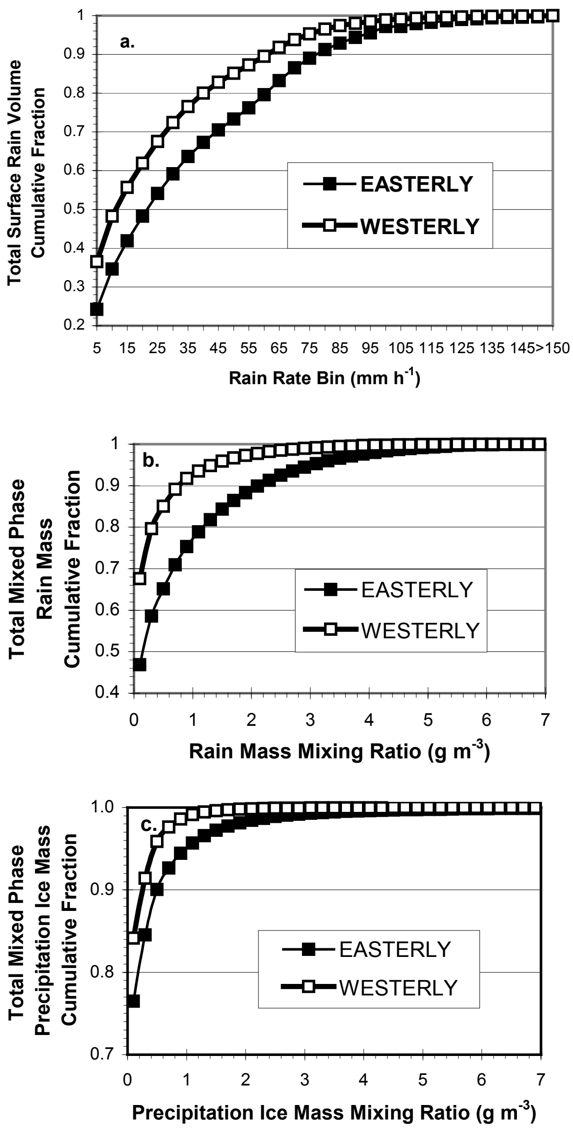

Fig. 2. Cumulative fraction histograms of S-POL radar inferred precipitation quantities, according to low-level wind regime during the Amazon wet season. (a) Total surface rain volume versus surface rain rate (R, mm h^{-1}), (b) total mixed phase zone (4 – 8 km) rain mass versus rain mass mixing ratio (M_w, g m^{-3}), (c) total mixed phase zone (4 – 8 km) precipitation ice mass versus precipitation ice mass mixing ratio (M_i, g m^{-3}).

4. RESULTS AND DISCUSSION

The easterly (westerly) regime has a higher frequency of occurrence of moderate-to-high, $Z_h \geq 25$ dBZ, (low-to-moderate, $2 \leq Z_h < 25$) reflectivity (Fig. 1a). This is consistent with a higher stratiform fraction of rainfall during the westerly regime (Rickenbach et al., 2001). The easterly (westerly) regime has a higher percentage of large, $D_0 > 1$ mm, (small, $D_0 < 1$ mm) raindrops (Fig. 1b).

As shown in Fig. 2a, the westerly (easterly) regime produced nearly 38% (only 25%) of the total rain depth at rain rates less than 5 mm h^{-1}. At moderate rain rates ($5 < R < 50$ mm h^{-1}), the two regimes had similar contributions to the total rain depth (Fig. 2a). At high rain rates ($R > 50$ mm h^{-1}), the easterly (westerly) regime produced nearly 28% (only 15%) of its rain depth (Fig. 2a).

Large values of rain mixing ratio ($M_w > 0.1$ g m^{-3}) accounted for 20% more of the total supercooled, mm-sized rain mass in the mixed phase zone during the easterly regime compared to the westerly regime (Fig. 2b). The availability of larger quantities of supercooled rain mass and stronger updrafts (Cifelli et al., 2002) in the mixed-phase zone of the easterly regime resulted in 7% more of the precipitation ice mass occurring at large values of M_i (> 0.1 g m^{-3}, Fig. 2c)

Given the results in this study and Cifelli et al. (2002), we propose the following hypothesis. The stronger low-level updrafts in the easterly regime convection systematically lofted more and larger mm-sized supercooled rain drops above the height of the 0°C isotherm, where the drops froze to produce hail. These frozen drops grew efficiently by accretion in the water rich updrafts of the mixed phase zone. Within the easterly regime convection, the fallout of these hydrometeors contributed to a higher frequency of rain characterized by very large Z_h, D_0, and R (i.e., enhanced tail of the distribution). As the frozen drops fell toward the surface and melted, the coalescence process likely played an important role in generating the large drops and high rain rates at the surface.

These intraseasonal regime differences in vertical precipitation structure and rainfall properties have important implications for the vertical distribution of latent heating, parameterizations in cloud models, and for the remote sensing of Amazonian rainfall.

5. ACKNOWLEDGEMENTS

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