SPECTRAL REPRESENTATION OF RAIN FEATURES AND DIURNAL VARIATIONS OBSERVED WITH TRMM PR OVER THE EQUATORIAL AREA

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1. INTRODUCTION

Space-borne precipitation radar (PR) launched on TRMM satellite has enabled us to obtain vertical profiles of the precipitation rate over any places of the tropics. The classification between convective and stratiform rain became more straightforward utilizing observed vertical rain profiles. Since diabatic heating profiles associated with these two types of rain differ substantially, this classification is crucial in evaluating the impact of precipitating systems on the dynamical fields.

Here we summarize the precipitation statistics over the equatorial region utilizing TRMM PR2a25 version 5 (Iguchi *et al.* 2000) data. Rain characteristics over ocean and over land and their diurnal variations are discussed with an emphasis on convective/stratiform differences. Primary part of this study will be found in Takayabu (2002).

2. DATA AND ANALYSIS METHOD

All nadir rain rate profiles of the PR2a25_v5 products over the equatorial area (10°N-10°S) for the period of 1998-1999 were analyzed. Convective and stratiform rain classification was obtained from rain flags based on PR2a23 algorithms (Awaka *et al.*, 1998). Ocean and land pixels were determined with method flags. The threshold of 0.3 mm hr^{-1} and rain-certain flags are used for the detection of rain tops. For analyses of diurnal variations, data are binned to 3 hourly local times.

3. SPECTRAL REPRESENTATION

A spectral representation of rain profiles is introduced in Fig. 1, to overview all rain profiles used in this study. All rain-certain profiles with 0.3 mm hr^{-1} rain-top threshold are accumulated and stratified with rain-top heights. Actual numbers of sampled profiles for convective:stratiform rain are 56,920 : 225,809 (20:80) over land and 149,008 : 724,083 (17:83) over ocean. Since Liu and Fu (2001) reported that the warm rain is scarce over 10°N-10°S, we focus on the convective and stratiform rain.

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While properties of convective rain profiles in Fig. 1 show near monotonic change with cumulative frequency, stratiform rain consists of two groups: shallow stratiform rain and anvil rain. The latter is characterized with the intensity maximum around the melting level, much less intensity above and clear downward decrease below. A large part (about 50% over ocean and about 70% over land in area) of the stratiform rain consists of anvil rain. The remaining 50% and 30% are shallow stratiform rain. The strength of the stratiform rain is less than 5 mm hr^{-1}, which is significantly weaker than the convective rain that reaches 30 mm hr^{-1}.

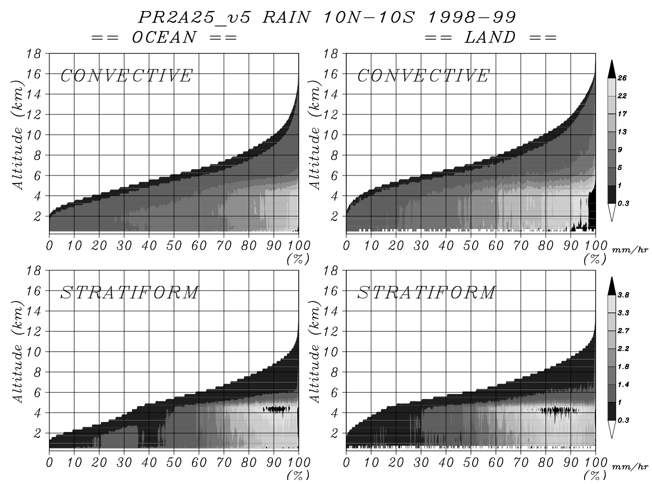

Figure 1: Spectral representation of all nadir rain profiles stratified with precipitation top height for convective rain (top) and for stratiform rain (bottom), over ocean (left) and over land (right). Abscissa is cumulative frequency and ordinate is altitude, and the rain intensity is indicated with shades. Threshold of 0.3 mm hr^{-1} is used for the rain top detection.

Figure 2 shows 25 percentile average profiles of Fig. 1. Convective rain over land is stronger and taller than that over ocean. On the other hand, the stratiform rain profiles look similar between over land and over ocean, especially for the tallest 25 percentile average with a maximum at around 4.25 km. A larger fraction of shallow stratiform rain is observed over ocean, which probably consists of the rain over the trade inversion region, as well as in the episodic trade wind regimes over the warm pool region (Johnson and Lin, 1997).

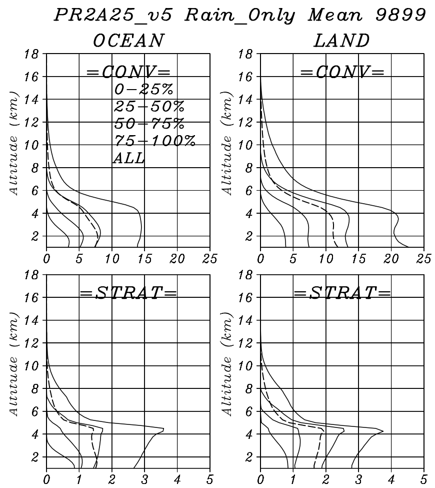

Figure 2: Average vertical rain profiles for each 25 percentiles of Fig. 1 (solid lines). Broken lines indicate the total averages. Left panels are those for over ocean and right panels are those for over land. Those for convective rains are plotted in the top panels and for stratiform rains are in the bottom panels.

4. DIURNAL VARIATIONS

Upper panels in Fig. 3 show mean diurnal variations of the rain rate at 2-4 km. Over ocean, although diurnal variations are small, they are statistically significant. The early morning maximum (03-06LT) is the same as many previous works. What newly added here are, (1) that contributions from convective rain and stratiform rain are about the same and actually 50:50 in total amount, and (2) that stratiform rain varies almost in phase with convective rain, but with a slight delay. It has been known that a significant part of oceanic rain consists of organized systems associated with large-scale disturbances. This in-phase relationship indicates that direct radiative effects modify such organized systems diurnally as a whole.

Over land, on the other hand, diurnal variations of convective rain and stratiform rain look quite independent. Convective rain is apparently dominant and convective:stratiform ratio is 61:39 in amount. Convective rain shows minimum value in 09-12 LT, then drastically increases to the maximum value in 15-18 LT. This diurnal cycle coincides well with a typical boundary layer development. The stratiform rain also reaches minimum in 09-12 LT, however, the maximum is not found in 15-18 LT but found in midnight.

Conditional mean diurnal variations (bottom panels) for only rainy pixels represents 'rain strength'. Curiously, over land, the rain strength is relatively smaller in the hours of afternoon showers (15-18 LT). Stronger convective rain is observed from evening to early morning with a slight peak in 21-24 LT. It means that afternoon showers have large contribution to the total rain due to their frequency but not due to their strength.

By comparing rain spectra for 03-06 LT and for 15-18 LT (not shown),taller convective rain is more frequently found in 15-18 LT. On the contrary, in 03-06 LT, the lower tropospheric convective rain and anvil rain are stronger. It is probably because rain over land consist of two separate phenomena; afternoon showers associated with the boundary layer development, and heavy rain associated with large-scale disturbances. And the latter rain is modified diurnally with the direct radiative effect. Over ocean, on the other hand, without significant development of the boundary mixed layer, the radiative effect becomes the dominant diurnal control for both stratiform and convective rain.

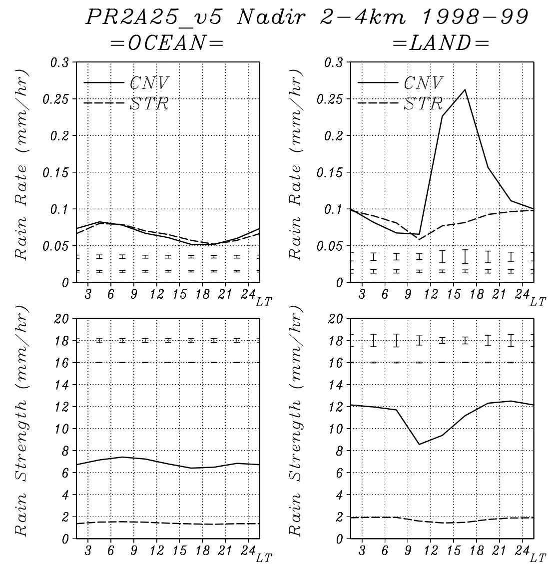

Figure 3: Mean diurnal variations of convective rain (solid) and stratiform rain (broken lines) over ocean (left) and land (right). Bottom panels are rainy-conditional mean variations. Error bars (upper:convective, lower:stratiform) indicate 99% confidence intervals with the Student-t test. Error bars are intentionally plotted away from mean values.

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