On the Deep Convection and High Clouds in the Multi-scale Modeling Framework

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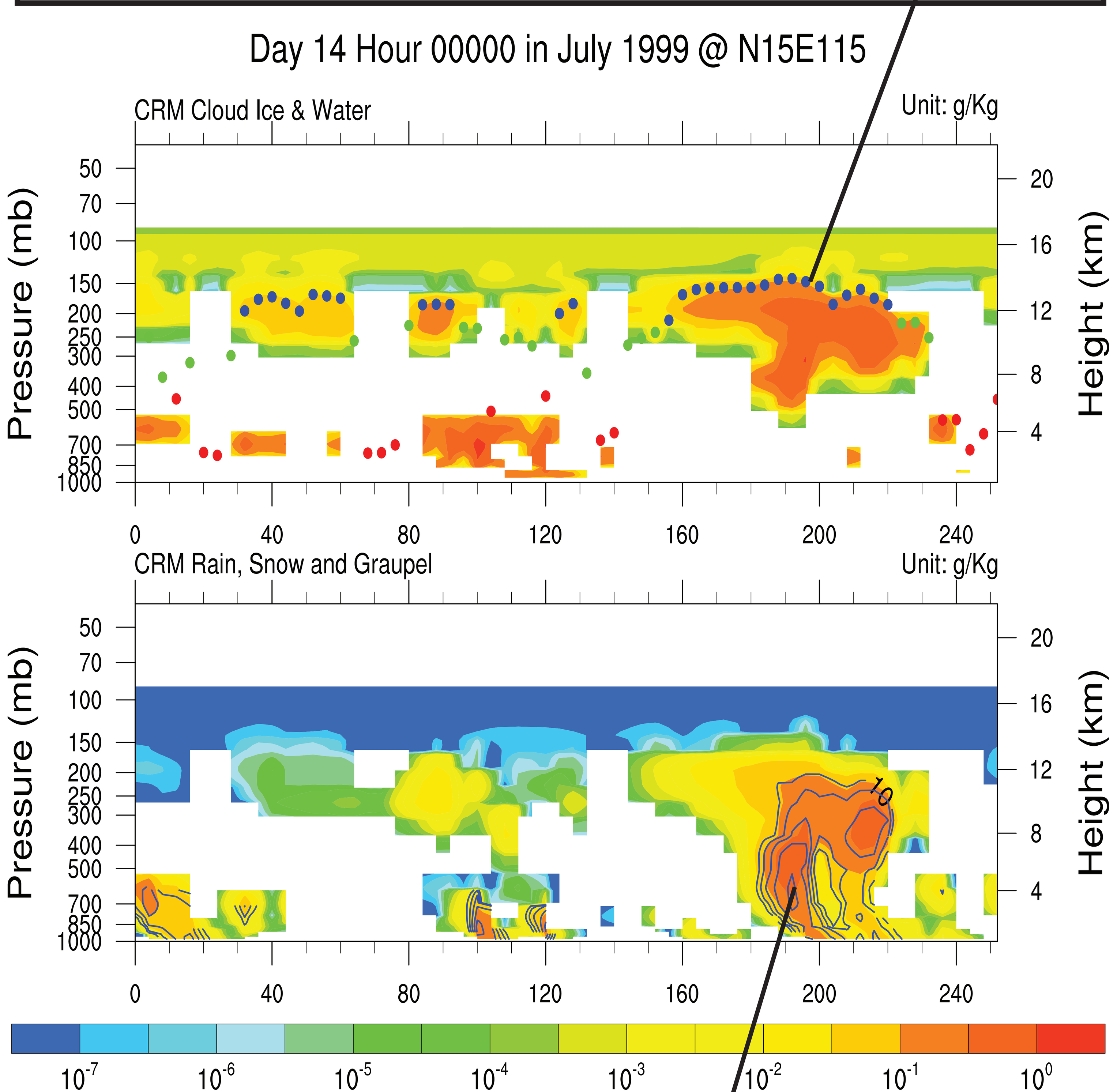
Introduction

Multi-scale Modeling Framework (MMF) is a new approach in which the conventional cloud parameterization in global climate models (GCM) is substituted by the cloud resolving models (CRM), thus cloud related dynamical, physical and chemical processes can be represented on their native scale. In this study, we use an infrared (IR) brightness temperature simulator (Soden et al., 2000, Tian et al, 2004) and a radar simulator (Haynes et al, 2007) to investigate the high clouds and deep convections in the MMF. The MMF simulation was performed at PNNL. The GCM is CAM 3.0 with finite volume dynamic core at 2.5 by 2. degree horizontal resolution and 26 vertical levels. The CRM is SAM aligned the east-west direction at 4 km spacing with vertical levels identical to the lowest 24 ones in the GCM. Surface precipitation index (PI), high clouds amount (CLD), upper tropospheric relative humidity (UTH) are retrieved based on the simulated IR brightness temperature at 11 and 6.7 micrometer, and compared with both the geostationary satellite retrievals and the MMF output. Precipitation radar (PR) reflectivity is retrieved at 13.8 GHz and compared to TRMM satellite data.

Retrieved 11 micro brightness temperature (Tb) height: Blue dots, Tb<230k; green dots, 230k<Tb<260k; red dots, 260k<Tb. Color contour is the sum mixing ratio of cloud ice and water.



Blue line contour: retrieved precipitation radar reflectivity at 5 dBZ spacing starting from 10 dBZ.
Color contour is the sum mixing ratio of rain, snow and graupel

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Application of Infrared Brightness Temperature Simulator

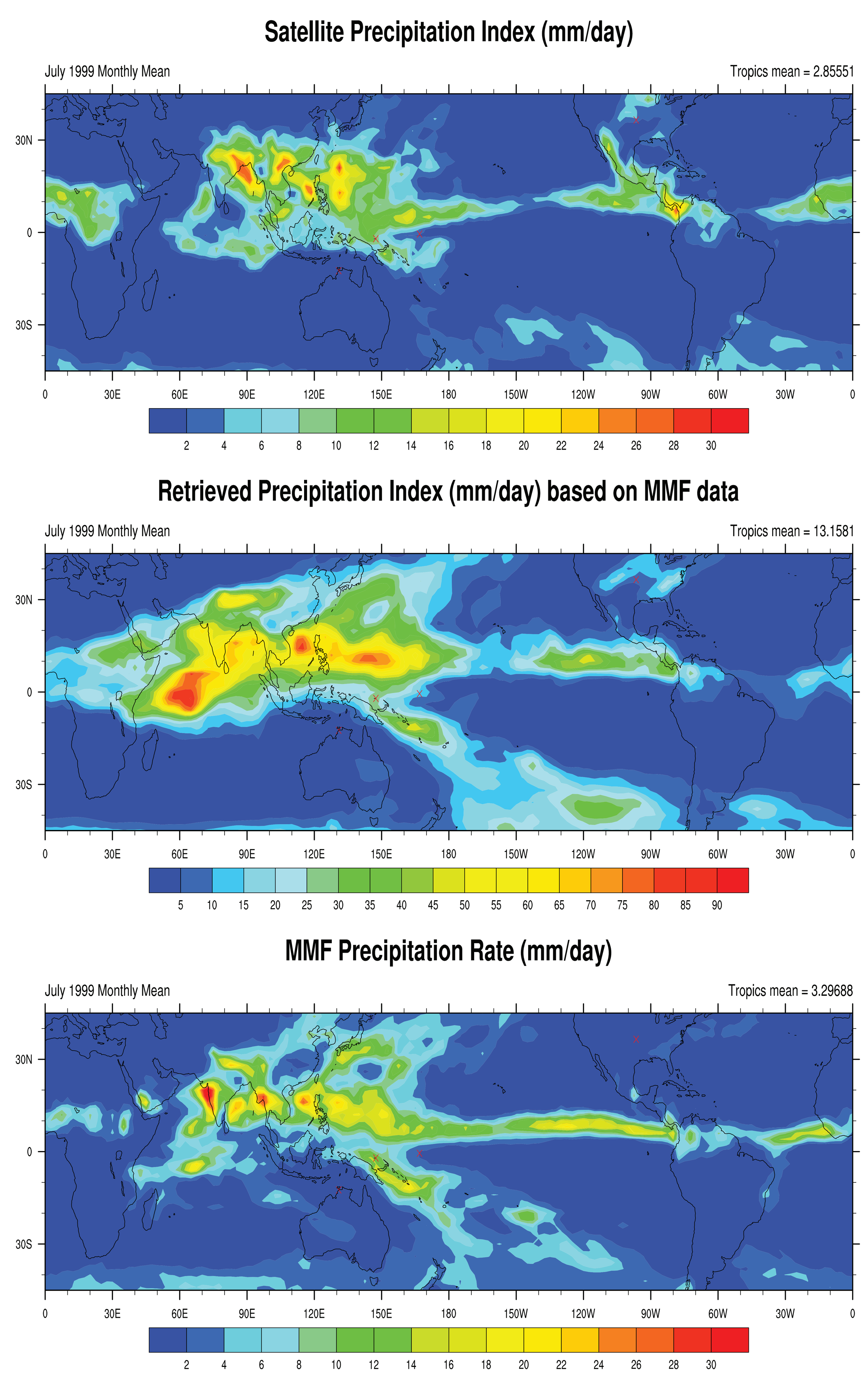

Fig 2: Monthly mean precipitation. Notice that in the middle panel, the retrieved PI is much higher than both the satellite data (upper) and the MMF model output (lower).

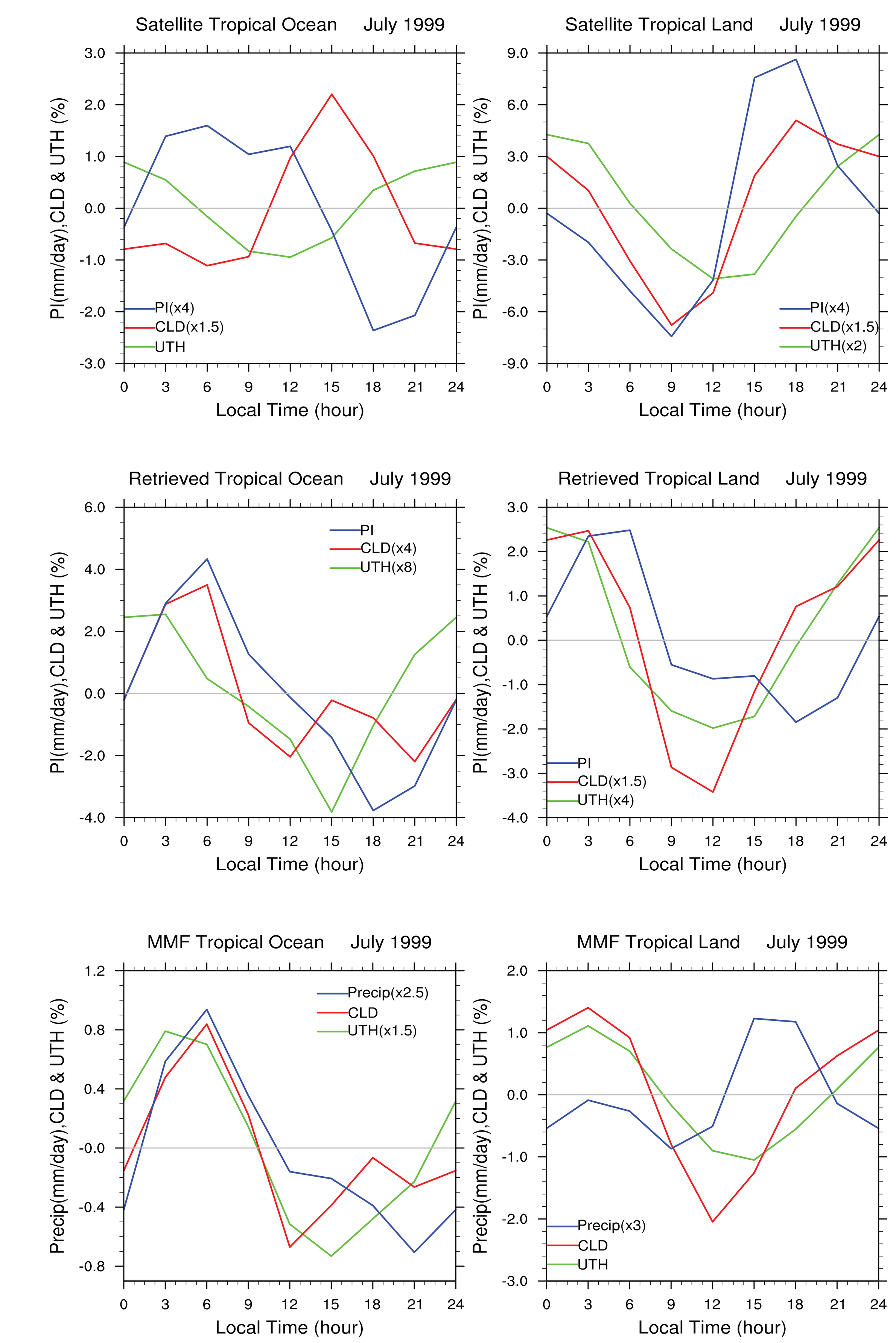

Fig.3: Diurnal anomalies in deep convection precipitation (PI), high cloud amount (CLD), and upper tropospheric relative humidity (UTH) for spacial weighted average over tropical ocean (left three) and tropical land (right three) regions.

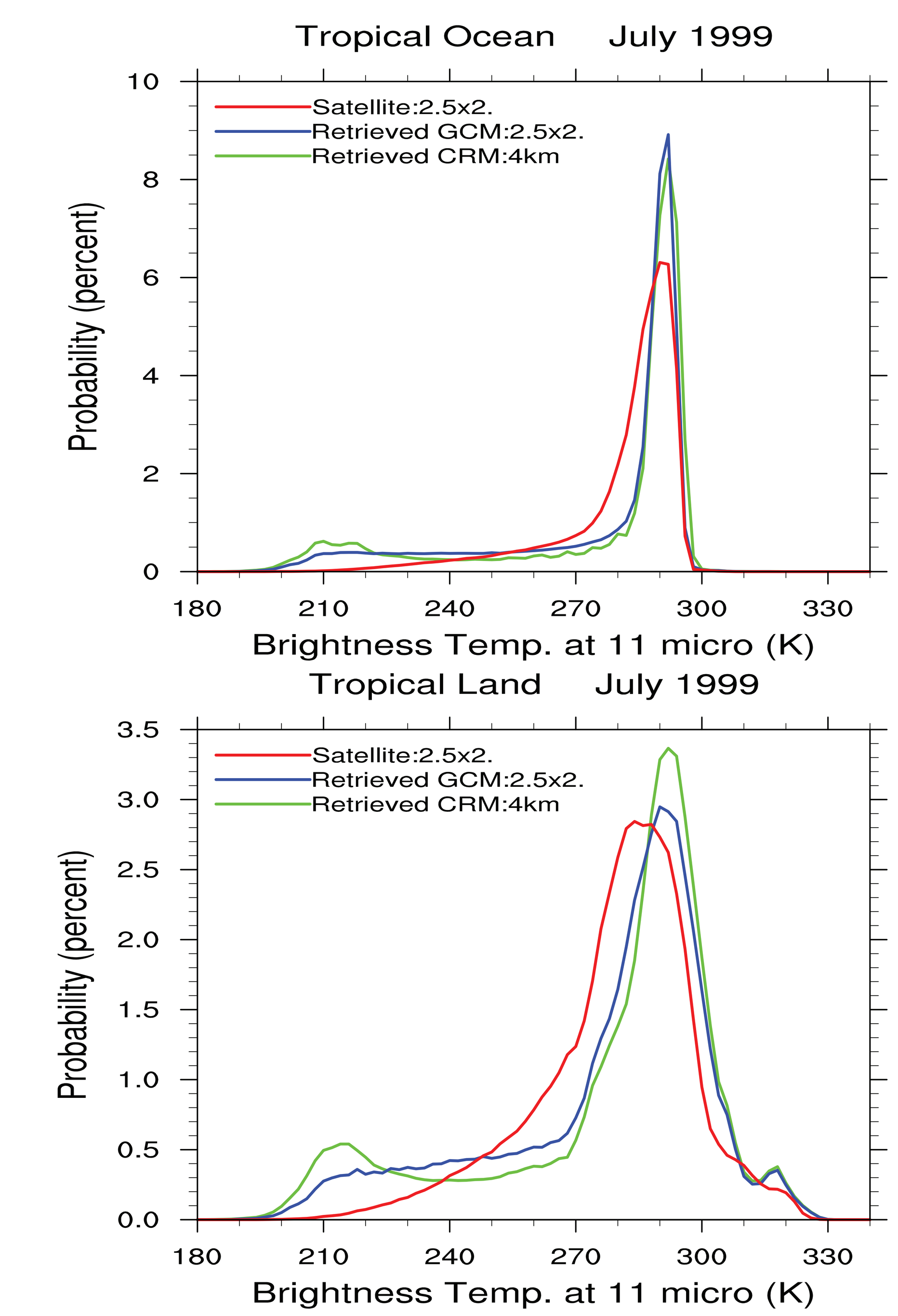

Fig 4: The probability density function for retrieved TB11 on land (lower) and ocean (upper) compared to observations.

The overestimation of both monthly mean value (Fig 2.) and biased phase on land (Fig 3.) in the retrieved PI fields are related to the cold bias in the retrieved TB11 fields (Fig.4) based on MMF data. This is because of the layer of high clouds in the MMF, thick and persistent with a high cloud top, which is not consistent with the precipitation fields in the MMF direct output.

Application of Precipitation Radar Simulator

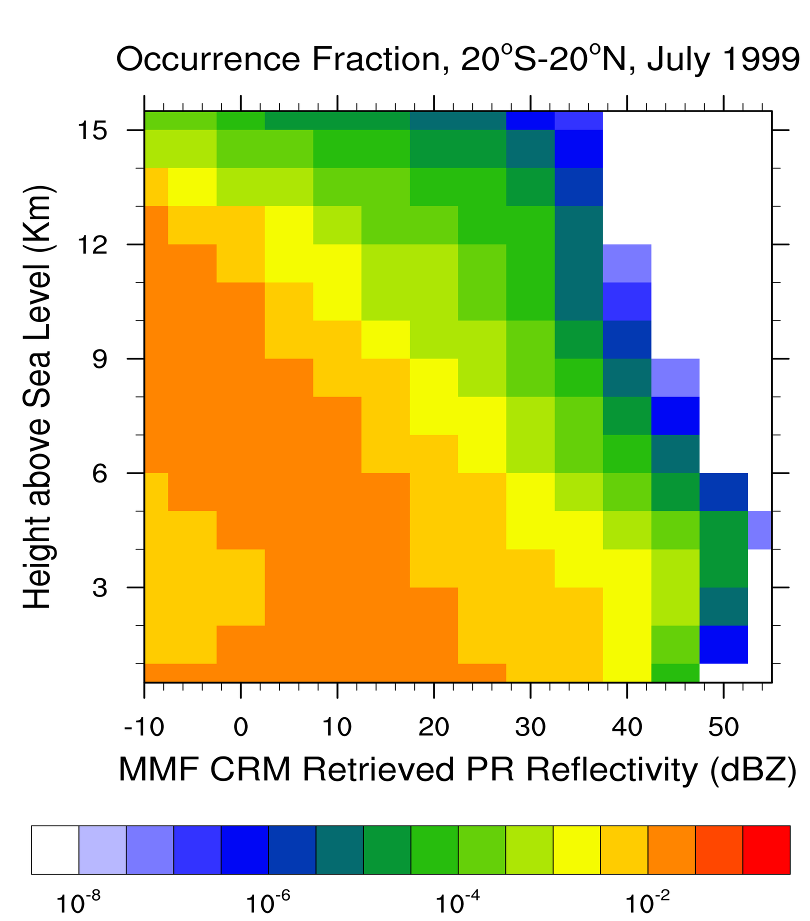

Fig.5: color contour presents the occurrence fraction of different PR reflectivity among all the MMF CRM columns

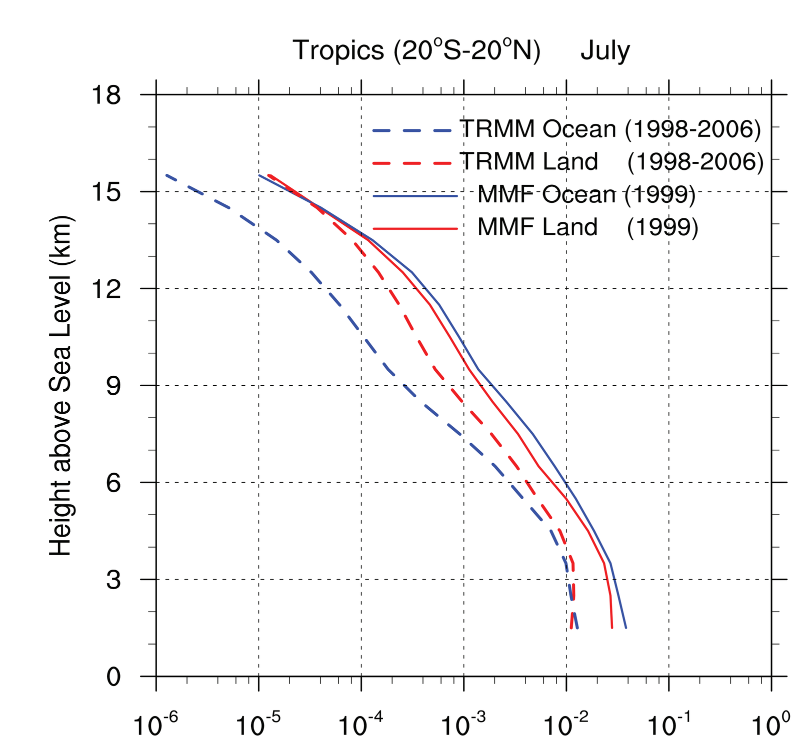

Fig.6: each data point is the occurrence fraction for PR echo above 20 dBZ among all the MMF CRM columns (TRMM samples)

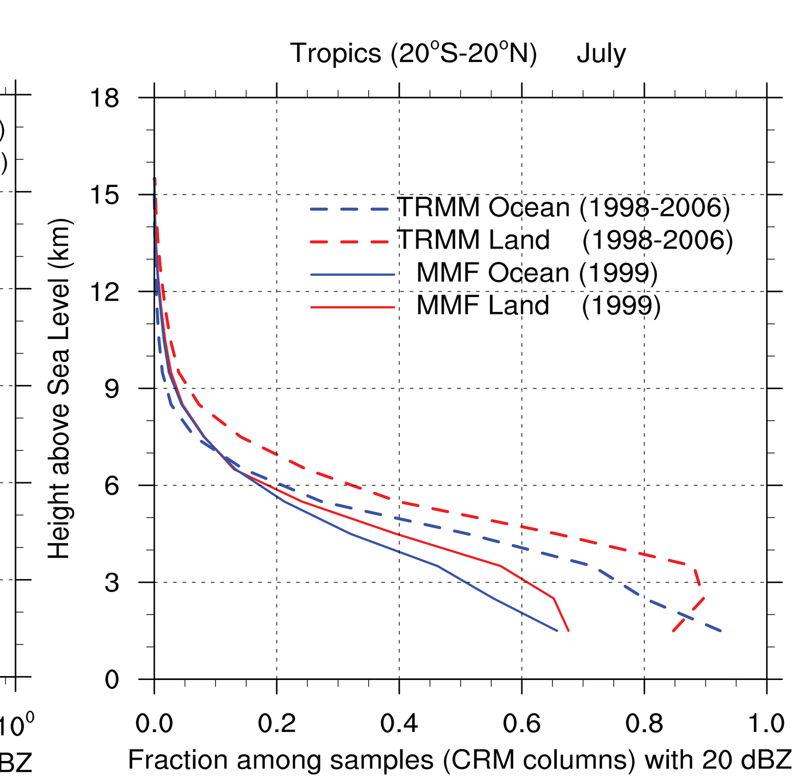

Fig.7: each data point is the occurrence fraction for PR echo above 20 dBZ among all the MMF CRM columns (TRMM samples) with 20 dBZ echo at any level.

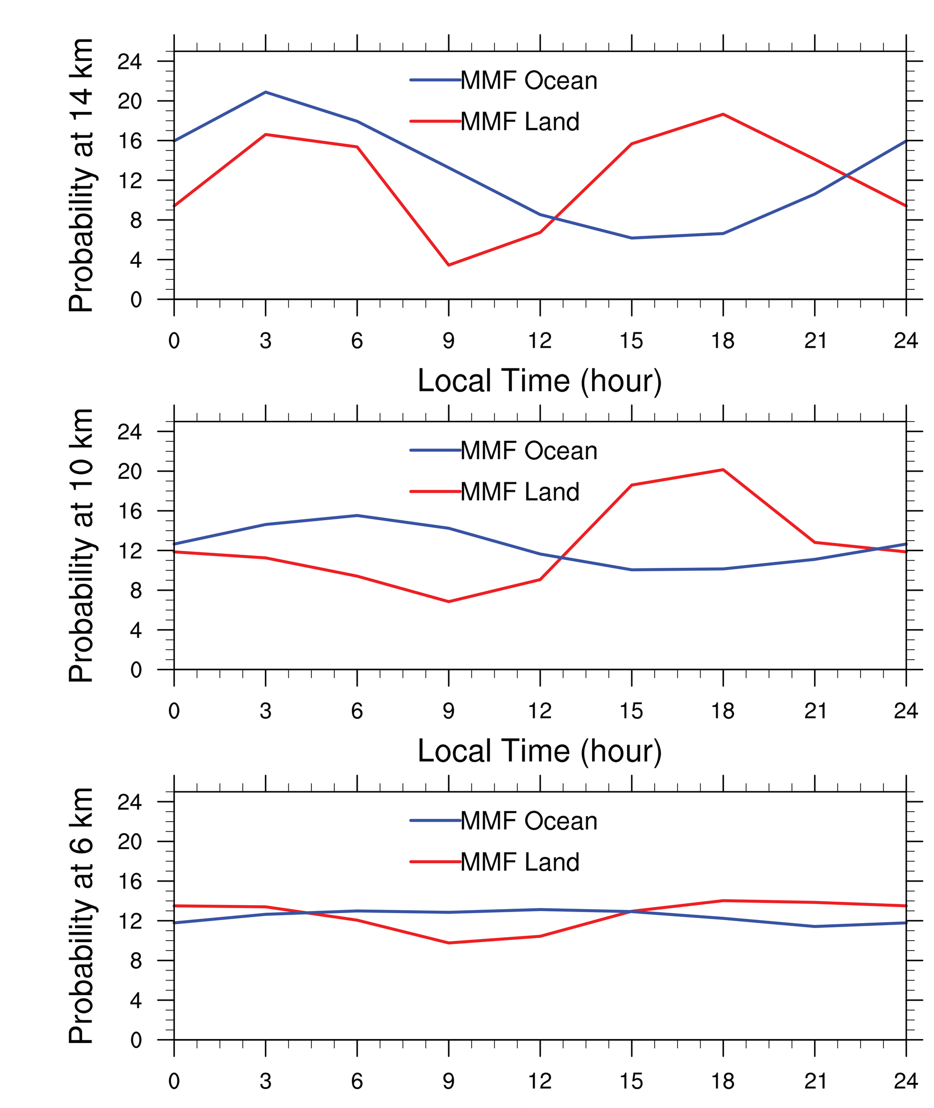

Fig.8: Diurnal cycle of occurrence probability of 20 dBZ PR echo at 6 km (lower), 10 km (middle) and 14 km (upper).