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The hydrometeor partitioning and microphysical processes over the Pacific Warm Pool in numerical modeling

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ABSTRACT

Numerical modeling is conducted to study the hydrometeor partitioning and microphysical source and sink processes during a quasi-steady state of thunderstorms over the Pacific Warm Pool by utilizing the microphysical model WISCDYMM to simulate selected storm cases. The results show that liquid-phase hydrometeors dominate thunderstorm evolution over the Pacific Warm Pool. The ratio of ice-phase mass to liquid-phase mass is about 41%: 59%, indicating that ice-phase water is not as significant over the Pacific Warm Pool as the liquid water compared to the larger than 50% in the subtropics and ~80% in the US High Plains in a previous study. Sensitivity tests support the dominance of liquid-phase hydrometeors over the Pacific Warm Pool.

The major rain sources are the key hail sinks: melting of hail and shedding from hail; whereas the crucial rain sinks are evaporation and accretion by hail. The major snow sources are Bergeron-Findeisen process, transfer of cloud ice to snow and accretion of cloud water; whereas the foremost sink of snow is accretion by hail. The essential hail sources are accretions of rain, cloud water, and snow; whereas the critical hail sinks are melting of hail and shedding from hail. The contribution and ranking of sources and sinks of these precipitates are compared with the previous study.

Hydrometeors have their own special microphysical processes in the development and depletion over the Pacific Warm Pool. Microphysical budgets depend on atmospheric dynamical and thermodynamical conditions which determine the partitioning of hydrometeors. This knowledge would benefit the microphysics parameterization in cloud models and cumulus parameterization in global circulation models.

1. Introduction

Poor precipitation performance in general circulation models (GCMs) has been a serious problem in the atmospheric science community. The parameterizations of cloud species have close links to convection and precipitation modeling, which is closely related to radiation and large-scale circulation in GCMs, and thus has large impacts on climate modeling as well. Successful numerical modeling of precipitation in GCMs depends very much on model resolution and cloud parameterization. It was suggested that if the resolution of GCMs can resolve convective systems realistically, the problems on the numerical modeling of precipitation and tropical cyclones will meliorate (Hourdin et al., 2006; Randall et al., 2007).

If the convective cloud parameterization in GCM can include the effect of the Microphysical budget of convective clouds in different geographic zones, the predictions of convective cloud properties in GCM would be greatly improved. The microphysical budgets such as hydrometeor partitioning, microphysical processes, etc. in the quasi-steady state in mature convective storms in the US High Plains and some subtropical locations have been previously investigated by Lin et al. (2005, hereafter LWS05). Their results show that partitioning of hydrometeors in deep convective clouds is sensitive to geographical location. At the present stage, it is impossible to include detailed cloud microphysical processes in a GCM and hence it is useful to parameterize the cloud partitioning in deep convective clouds that take the geographic location into account.

One of the regions of great importance to climate studies is the Pacific Warm Pool (Wang and Xie, 1998; Barlow et al., 2002). The Pacific Warm Pool plays a significant role in global heat and water vapor transport; hence, the understanding of the cloud properties including how hydrometeors are partitioned is of great importance. There has been some research related to the hydrometeor partitioning over the Pacific Warm Pool. Chen and Yin (2011) showed the hydrometeor partitioning in a case study in Darwin using a three-dimensional nonhydrostatic convective cloud model with a double-moment bulk microphysics scheme and explicit droplet activation from cloud condensation nuclei. Based on cloud budget employing a two-dimensional cloud-resolving model and simulation data during TOGA COARE, Li et al. (2011)

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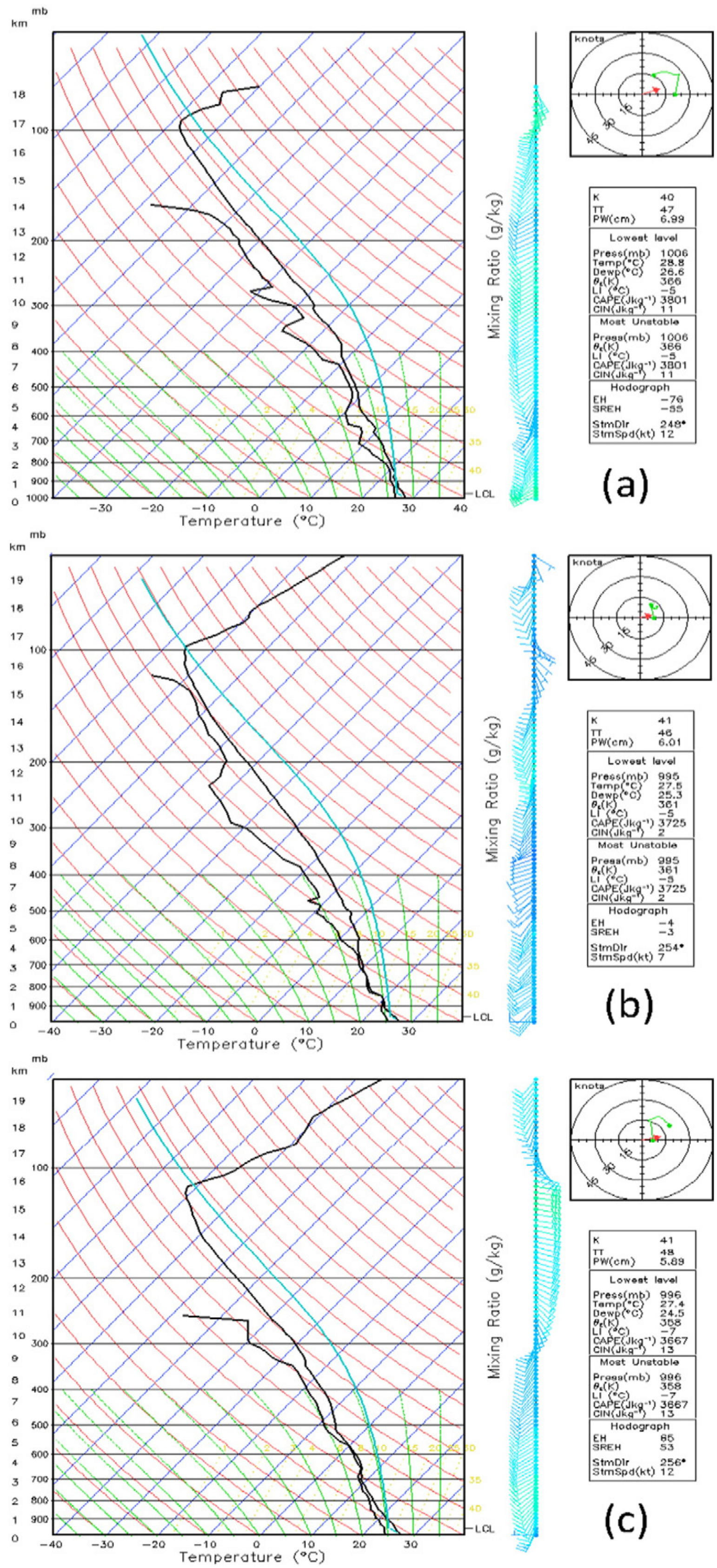

Fig. 1. Skew T – log P diagram at (a) Darwin, Northern Territory, Australia at 1200 UTC on 23 January 2006; (b) Singapore at 0000 UTC on 28 March 2013; (c) Medan, Indonesia at 1200 UTC on 18 July 2013.