Ph.D. Defense Announcement
Yasutaka Murakami
July 21, 2021 at 9:00 a.m.

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Ph.D. Defense

Wednesday, July 21, 2021
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Defense
Virtual (full Teams link below)

Post Defense Meeting
Virtual

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EXPLORING PRECIPITATION PROCESSES IN STRATOCUMULUS CLOUDS FROM SATELLITE-DERIVED CLOUD TOP MACROPHYISCAL PROPERTIES

Marine stratocumulus clouds are convective low-level clouds that develop within the marine atmospheric boundary layer and have a large impact on the global radiation budget and hydrological cycle. Drizzle plays an important but complicated role in their longevity and microphysical properties. Many studies have examined the response of cloud base rain rate to varying cloud droplet concentration and cloud thickness as well as LWP and found that cloud base rain rates are enhanced with lower cloud droplet number concentration and greater cloud thickness or LWP.

In warm stratocumulus clouds, cloud base rain rate is a combination of raindrop embryo production through collision coalescence (i.e. auto-conversion) and raindrop embryo growth by collecting cloud droplets (i.e. accretion). Previous studies have shown that cloud base rain rate depends on LWP or cloud thickness and the geographical location of stratocumulus clouds, but the dependence of the auto-conversion process to these variables is not known because cloud base rain rate is a combination of both auto-conversion and accretion. This two-part dissertation explores the dependence of stratocumulus clouds precipitation processes on cloud thickness and geographical location by examining the cloud top macrophysical properties retrieved by A-Train satellites observation from CloudSat's Cloud Profiling Radar (CPR), CALIPSO's Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) and Aqua's Moderate Resolution Imaging Spectroradiometer (MODIS).

In the first part, the relations between near cloud top macrophysical properties (radar reflectivity, LWC and cloud droplet number concentration) and cloud geometrical thickness are investigated for subtropical stratocumulus clouds. Satellite-observations show that cloud top LWC and effective radius increase as clouds become thicker. It was also suggested that auto-conversion is more enhanced in thicker clouds. These findings are consistent with the previous studies that thicker clouds have larger cloud droplets and thus produce more rain embryos. However, it was also found that clouds separate into two sub-groups as they transition from thick (i.e. geometrical thickness of 384-480m) to very thick clouds (i.e. geometrical thickness of 624-720m). Drizzling clouds have higher LWC and their drops have larger effective radii, whereas non-drizzling clouds have lower cloud top LWC and smaller effective radii.

In the second part, the climatology of satellite-derived near cloud top macrophysical properties (radar reflectivity, LWC and cloud droplet number concentration) for 8 stratocumulus cloud regions are presented. While LWP tends to be larger for midlatitude clouds, cloud top LWC tends to be larger at subtropical stratocumulus clouds. Since midlatitude stratocumulus clouds are thicker, these results suggests that effective condensation rates are larger for subtropical stratocumulus clouds. Both cloud top and base radar reflectivity tend to be larger for subtropical stratocumulus clouds. Based on these findings, the sensitivity of cloud top radar reflectivity on LWC and cloud droplet number concentration are examined. Cloud top radar reflectivity is more (less) sensitive to changes in LWC and cloud droplet number concentration for cloud with stronger (weaker) cloud top radar reflectivity. This agrees with the fact that collision-coalescence efficiency between liquid water droplets (i.e. approximately 20 μm in diameter) increases non-linearly with droplet size.

The overall results presented in this dissertation indicate that the auto-conversion process can be represented with a globally uniform function of cloud top LWC and cloud droplet number concentration for all stratocumulus clouds regardless of their geolocation and geometrical thickness. It was also demonstrated that cloud top raindrop embryo generation rate is an important factor for determining the precipitation generation rate for stratocumulus clouds as a whole. In general, accretional growth is controlled by both the total cross-section of rain drops and LWP. By comparing spatial patterns of cloud top radar reflectivity (i.e. total cross-section of rain drops) and radar reflectivity increase from cloud top to bottom (i.e. accretional growth), it was found that accretional growth depends more on total cross-section of rain drops and less on LWP in stratocumulus clouds.

These conclusions can explain the findings of previous studies that cloud base rain rate depends on LWP (or cloud thickness) and geographical location of stratocumulus clouds. Cloud base rain rate is dependent on geometrical thickness because cloud top LWC increases as cloud become thicker. Subtropical stratocumulus clouds tend to have stronger precipitation at a given LWP compared to midlatitude ones because effective condensation rate of subtropical clouds is greater and so is the cloud top LWC. The results presented in this dissertation represent more than one hundred thousand independent pixels and provide a benchmark that numerical models should reproduce.