SPACE-BORNE MEASUREMENTS OF CHANGES IN CLOUD OPTICAL THICKNESS AND CLOUD DROP SIZE ASSOCIATED WITH PRECIPITATION

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The cloud feedback problem is one of the largest uncertainties in climate studies because cloud formation and dissipation are complicated processes. Clouds have mutual relations to aerosols and precipitation. Increases in aerosol concentrations result in a decreased drop size and modify the cloud radiative forcing. Decreased drop size may also suppress precipitation. Precipitation is generated from cloud drops by condensation and coalescence, which in turn generates cloud drops by breakup, and removes cloud drops and controls cloud amount. A study on clouds-precipitation interaction is, therefore, critical to improve our understanding of the cloud feedback problem. Despite extensive studies on cloud-precipitation interactions, our understanding is very limited because of their complex nature.

We examined how cloud optical thickness changes in rain formation process by a combined use of the Precipitation Radar and the Visible and Infrared Scanner (VIRS) onboard the Tropical Rainfall Measuring Mission. The Tropical Rainfall Measuring Mission satellite primarily intends to measure temporal and spatial variations of precipitation with Precipitating Radar (PR) but also measures cloud properties with Visible and Infrared Scanner. Consequently, combined use of the PR and VIRS is well suited for studies of cloud-precipitation interactions. In the analysis, pixels for which the brightness temperature at Ch4 (10.8μm) of VIRS ranged from 273 to 290 K were selected. Thus we examine water cloud properties. Cloud optical thickness and the effective radius were derived from the reflected radiances at Ch1 (0.63μm) and Ch3 (3.75μm) measured with the VIRS. The derived data were used to study how cloud optical thickness relates to precipitation. In particular, we focused on the changes in the size distributions of cloud droplets associated with precipitation.

There were considerable scatter between cloud optical thickness and rain rate on a global scale. However, cloud optical thickness was found to increases with rain rate on average. The tendency to increase was mostly due to increases in liquid water path and depended on rain rate. For heavier rain, relatively small increases in the optical thickness with rain rate were observed. Whereas, for weak rain, larger increases with rain rate were found, which is related to considerable changes in liquid water path and in the effective radius of cloud droplets. Cloud optical thickness is determined primarily by liquid water path but is also influenced by size distributions of cloud droplets. To remove the effects of the changes in liquid water path to cloud optical thickness and to study the effects of drop size on cloud optical thickness, we examined the relationships between cloud optical thickness and rain rate for fixed values of liquid water path.

Results show that there were no significant dependences of cloud optical thickness on rain rate for strong rain. Whereas, cloud optical thickness was found to decrease with rain rate for weak rain. In particular, significant differences of optical thickness were found between non-precipitating clouds and precipitating clouds: smaller cloud optical thickness was observed for precipitating clouds. Previous studies suggest that there exist significant difference in the effective radius of cloud droplets between non-precipitating and precipitating clouds. The differences are associated with the fact that cloud drops grow to raindrops quickly when they exceed the critical radius. This suggests that the size distribution of cloud droplets changes significantly in the formation process of precipitation. We analyzed how the effective radius of cloud droplets changes in the formation process in detail. Results shows that dispersion of cloud drop size was found in the rain formation process, which may relate to broadening in the shape of drop size spectra. The broadened size distribution leads to the decreases in the cloud optical thickness for precipitating clouds This study related to the changes in cloud optical thickness associated with rain formation process can improve our understanding of cloud feedback problem in climate.