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A combined use of the TRMM PR and VIRS for measurements of cloud and precipitation

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1 Introduction

Global climate model simulations for a wide range of scenarios of global warming, suggest that precipitation is projected to increase during 21st century (IPCC, 2001). Recent increases in heavy rain events in urban areas may relate to the global warming due to increase in CO_2. On the other hand, polluted air tends to suppresses precipitation – the second indirect aerosol effect. Precipitation has a role to remove clouds and to control the fractional cloudiness and consequently affects the radiative properties of clouds. Thus the studies of the relation between precipitation and the micro-physical properties of clouds are critical to improve our understanding the role of precipitation in the process of climate change (Rosenfeld and Lensky, 1998).

In this paper, we have examined both cloud and precipitation properties in precipitation clouds in which precipitation and cloud coexist by using data from the Tropical Rainfall Measuring Mission (TRMM).

2 TRMM instruments

The TRMM intends to measure vertical and horizontal variations of precipitation and equips with a precipitation radar (PR), a Visible Infrared Scanner (VIRS), a microwave Imager (TMI), a Lightning Imaging Sensor (LIS) and a Clouds and the Earth's Radiant Energy System (CERES). In this paper, we used two of which, the precipitation radar operated at a frequency of 13.8 GHz for measurements of precipitation and the visible infrared scanner for clouds.

The PR is a scanning radar and can observe the three-dimensional structure of precipitation. The swath is about 245 km at the ground surface. The foot print diameter is 5 km at nadir and the range resolution is 250m. The minimum detectable rain rate is 0.7 mm/h. The VIRS instrument observes radiation at wavelengths of 0.63, 1.61, 3.78, 10.8, and 12 μm. The swath is about 720 km at the ground and the foot print is 2.1 km at nadir. We have collected collocated data of the VIRS and the PR measurements after the uncovered VIRS data with narrower PR swath are omitted.

3 Cloud Retrieval Algorithm

We will derive the cloud optical thickness (τ) and the effective radius from the VIRS measurements. The effective radius (Re) is defined as

$$\mathrm{Re} = \frac{\int r^3 n(r) dr}{\int r^2 N(r) dr}, \tag{1}$$

where r is the radius of cloud drops, N(r) is the size distribution of cloud drops. Both values of τ and Re can be determined simultaneously from radiances measured at a no water absorbing and absorbing wavelengths from space. The radiances at visible wavelength, i.e., no water absorption channel, is sensitive to the optical thickness of cloud. The radiances at near infrared wavelengths is, on the other hand, sensitive to the effective radius because of more water absorption at these bands than that at visible wavelength bands. We have made radiative transfer calculations for water clouds assuming a log-normal drop size distribution and calculate the reflection function defined as,

$$R(\tau, \mu_0, \mu, \varphi) = \frac{\pi I(0, \mu_0, \mu, \varphi)}{\mu_0 F_0}, \tag{3}$$

where μ_0 and μ are the cosine of solar zenith angle and the cosine of emergent angle, respectively. ϕ is the azimuth angle between incident and emergent radiation.

Fig.1 shows reflection functions at 0.63 and 1.61 μm for various values of τ and Re. The cloud optical thickness is mostly determined from the reflection function at 0.63 μm.

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On the other hand, the effective radius mostly depends on the reflection function ad 1.61 μm. Thus, the cloud optical thickness and the effective radius can be determined simultaneously from this diagram. In this paper, we use 3.78 μm instead of 1.61 μm because this wavelength is more sensitive to Re and robust than the pair of 0.63 and 1.61 μm (Kaufman and Nakajima, 1993). The contribution of thermal radiation at 3.78 μm was removed. For gaseous absorption in upper atmosphere above the cloud top, absorption coefficients from LOWTRAN-7 (Kneizys et al., 1988) were adopted. The vertical profile of temperature and humidity are taken from the tropical model.

4 Observations

We have collected collocated TRMM PR 2A25 data and the VIRS 1B01 data that the local time of the observations was in day time in June 2003. These match-up data were mapped 0.5 degree latitude-longitude grids. In mapping, firstly we selected precipitation data. In case of no precipitation data in each grid, we selected data of optically thicker clouds. Finally, we have derived the optical thickness and the effective radius of clouds and studied a relation between microphysical properties of clouds and rain rate measured with the PR.

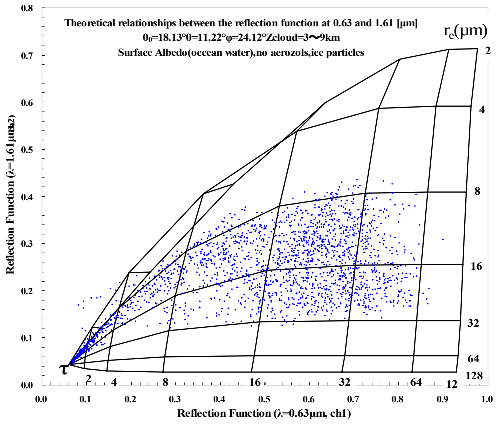

Fig. 1. Theoretical calculations of the reflection function at 0.63 and 1.61 μm for various values of τ and Re.

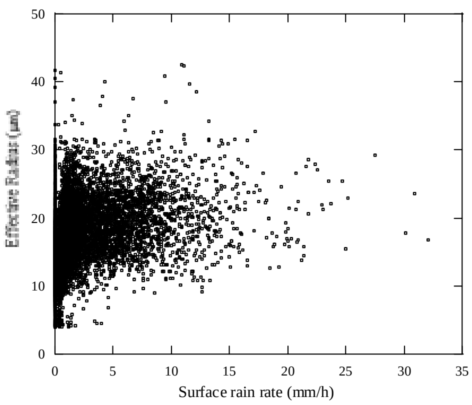

Fig. 2. The derived cloud effective radius vs the rain rate near the ground surface.

Figure 2 shows the cloud effective radius derived by the method mentioned above as a function of the rain rate near the surface measured with the TRMM PR. There are large variations of the effective radius. We focus on the minimum value of the effective radius. For non-precipitating clouds, that is the rain rate=0, the minimum values of the effective radius is 5 μm which is the limit of the retrieval algorithm. On the other hand, the minimum Re is larger than 10 μm for precipitating clouds. For the rain rate larger than a few mm/h, the minimum values of Re increases up to 15 μm which is consistent with the value observed by the Advanced High Resolution Radiometer and a ground-based radar (Rosenfeld and Gutman, 1994). The rain rates are also well correlate with the cloud optical thickness. Optically thicker clouds are observed for precipitation clouds accompanied with higher rain rate.

5 Summary

We have examined both cloud and precipitation properties in precipitation clouds in which precipitation and cloud coexist by using data from the Tropical Rainfall Measuring Mission (TRMM). The microphysical properties of clouds are significantly different between precipitating and non-precipitating clouds. There seem to be a threshold value of cloud effective size for precipitating clouds. A combined use of the TRMM PR and VIRS significantly improves our understanding of cloud-precipitation interaction.

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