Cloud Observation by Visible/Infrared Imager and Microwave Radiometer

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Abstract

The global distribution of microphysical properties of water clouds is investigated on the basis of satellite-retrieved spectral radiances over wide wavelength range from visible to microwave. Following our previous study using ISCCP and SSM/I data, the results from the Tropical Rainfall Measuring Mission (TRMM) data are presented employing Visible and Infrared Scanner(VIRS) and TRMM Microwave Imager(TMI). Use of the TRMM sensors has the advantage that highly simultaneous observation is possible in comparison with analysis of combined data from sensors on different platforms such as ISCCP and SSM/I.

Combination of visible and near-infrared radiances, denote by Vis-NIR method, can retrieve cloud microphysical parameters such as the cloud optical thickness and effective droplet radius. The effective droplet radius can be obtained also from visible and microwave radiances (Vis-Mic method) by combining the optical thickness and the liquid water path. The effective radius retrieved by Vis-NIR method may tend to be biased toward the value near the cloud top due to strong abortion in the near-infrared wavelengths, while Vis-Mic would yield the effective radius averaged throughout the vertical extent of clouds.

The basic idea is to find a characteristic difference between the global distributions of effective cloud droplet radii from Vis-NIR and Vis-Mic methods. The difference would be caused in part by vertical inhomogeneity of droplet size within clouds, and therefore is expected to be a possible indicator of occurrence of drizzle.

1 Introduction

Clouds are known to play significant roles in the earth's radiation budget, and it is inevitable to clarify the global distribution of cloud characteristics for climate system studies. Satellite remote sensing of the microphysical and optical properties of clouds has been an important subject in the last decade. An established scheme to retrieve the effective droplet radius and optical thickness of clouds employs a pair of shortwave channels (Nakajima and King 1990; Han, Rossow, and Lacis 1994; and references therein).

LWP can be retrieved from microwave brightness temperatures as well as from shortwave radiances. A large number of algorithms have been developed to obtain LWP by microwave radiometers over oceanic environment (e.g., Wilheit and Chang 1980; Petty 1990; Greenwald et al. 1993; Lin, Wielicki et al. 1998). Comparison of the microwave-retrieved LWP with the shortwave-retrieved LWP obtained by spaceborne sensors has been done by some authors (Greenwald et al. 1993; Lojou, Frouin, and Bernard 1991; Lin and Rossow 1994; Lin, Minnis et al. 1998). However, it is important to reexamine the difference between the microwave and shortwave LWPs in terms of variation of the effective droplet radius since the effective radius was assumed to be constant in the past studies.

We describe in section 2 the data and retrieval algorithm adopted in this study, and show the results in section 3.

2 Data and Retrieval Algorithm

Following our preceding study using visible and infrared radiances from International Satellite Cloud Climatology Project (ISCCP) data and microwave brightness temperature from Special Sensor Microwave/Imager (SSM/I) data (Kuroda 1999), we employ Visible and Infrared Scanner (VIRS) and TRMM Microwave Imager (TMI) as counterparts of ISCCP and SSM/I respectively, where the both sensors are boarded on Tropical Rainfall Measuring Mission (TRMM) Satellite. There are some advantages to use the TRMM sensors for our purpose: (1) Use of imagers on the same platform enables us highly isochronous observation, and (2) The global distribution of rain rate retrieved by Precipitation Radar (PR) aboard on TRMM is available for direct comparison with our results. On the other hand, TRMM data require us longer term average to obtain a global map of clouds than other satellites' data such as ISCCP and SSM/I data, because VIRS and TMI have narrow swath due to a low altitude (~350km) of the TRMM orbit. Variable solar angles, since TRMM is sun asynchronous, also cause difficulty in retrieval of the cloud properties by VIRS.

VIRS and TMI data are assigned on the common $0.25^\circ \times 0.25^\circ$ grid. Present analysis is concentrated on water clouds ($T_c \geq 273$K) over marine environment. We retrieve the effective droplet radius, cloud optical thickness, and clout top temperature from VIRS radiances of ch.1(0.63μm), ch.3(3.75μm), and ch.4(10.8μm) by a modified version of the algorithm developed by Nakajima and Nakajima(1995). TMI brightness temperatures at 19.35, 21.3, and 37.0GHz yield the column water vapor (CWV) and liquid water path(LWP). In order to construct a look-up table for retrieving CWV and LWP, we have performed microwave radiative transfer calculations.

We present the ratio of effective droplet radii retrieved in two independent methods. One of them (Vis-NIR method) employs shortwave radiances of ch.1 and ch.3 of VIRS to obtain the effective radius by the Nakajima and Nakajima(1995) algorithm. Another scheme (Vis-Mic method) yields the effective radius, R_e, from the cloud optical thickness at an optical wavelength, τ_c, and the microwave LWP according to the well-known formula,

$$R_e = \frac{3}{2}\mathrm{LWP}/\tau_c. \tag{1}$$

The results are shown in the next section.

3 Results and Discussion

We present here the retrieved values averaged over three months from January to March in 2000. Fig. 1 illustrates the ratio of R_e retrieved in Vis-Mic method and Vis-NIR method. One can see that areas where the ratio is less than unity corresponds to the regions with low precipitation rates, and vice versa. A possible interpretation is that the ratio R_e(Vis-Mic)/R_e(Vis-NIR) correlates with occurrence of drizzle. The effective droplet radius given by Vis-NIR method tends to represent the microphysical condition near the cloud top because of large extinction in an absorption channel in the near-infrared, while R_e by Vis-Mic method is considered to be an average value in the whole cloud. The ratio R_e(Vis-Mic)/R_e(Vis-NIR) therefore would depend on inhomogeneity in the vertical distribution of the effective droplet radius. This presumption leads us to an idea that the R_e ratio is an indicator of drizzling clouds, for which R_e(Vis-Mic)/R_e(Vis-NIR) is expected to be larger than unity because of large drizzle droplets accumulated near the cloud base.

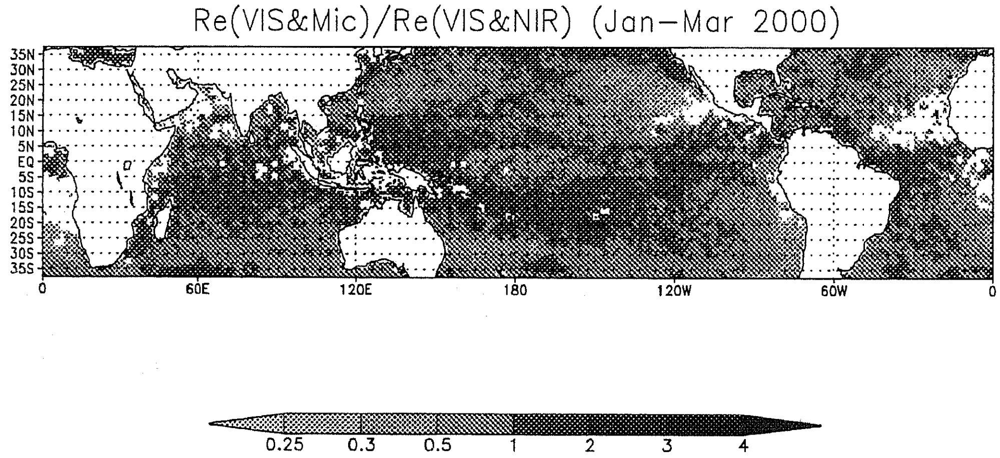

Figure 1: Global map of ratio of the effective droplet radii R_e(Vis-Mic)/R_e(Vis-NIR) during Jan-Mar, 2000.

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