Remote Sensing Cloud' s Microphysical Properties by Satellite Data

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Abstract: Cloud' s properties can be showed on different spectral channel. The 0.65μm reflectance is mainly function of cloud optical thickness and reflectance of 1.6μm is sensitive to cloud phase and particle size distribution. So we can use multi-spectral information to analysis cloud' s microphysical properties.

Key words: cloud, microphysical, satellite

1. Introduction

It is well known that clouds are a strong modulator of the shortwave and longwave components of the earth' s radiation budget. It is also now recognized that knowledge of cloud properties and their variation in space and time is critical to studies of global climate change. Cloud properties can be expressed by some parameters such as particle size distribution, effective particle radius, thermodynamic phase and water content. Thus study of cloud optical properties is of paramount importance to the enhance understanding of the global climate system.

It has been shown that 8μm, 11μm and 12μm bands can be used together to distinguish water clouds from ice clouds[1-3]. The physical principles depend on the different bulk and single scattering properties of water droplets and ice crystals at two bands that are from 8μm to 11μm and from 11μm to12μm.

There are many studies on the determination of the cloud particle phase[4-6]. The underlying principle on which these techniques are based is the fact that water and ice have distinct absorption at 1.6μm. Ice has larger absorption at 1.6μm. As a result ice has lower reflectance at 1.6μm. Water has contrary properties. Thus reflectance at 1.6μm is sensitive to the phase of cloud.

In this paper, a physical basis of the thermodynamic phase analysis of cloud particles is provided. The radiative transfer (RT) calculation results for spectral properties are then discussed. Finally, as a case study, the cloud' s properties of middle-scale storm are analyzed with satellite data.

2. Modeling calculation and analysis for satellite spectral channel property

Liu et al[7] used radiative transfer model to explain the relationship between 0.65μm and 1.6μm reflectance when cloud particles are different phase. The calculated result is showed as figure 1. SBDART[8] was selected as a radiative transfer model in this study. Reflectances for water and ice clouds at 1.6μm and 0.65μm are a function of cloud' s

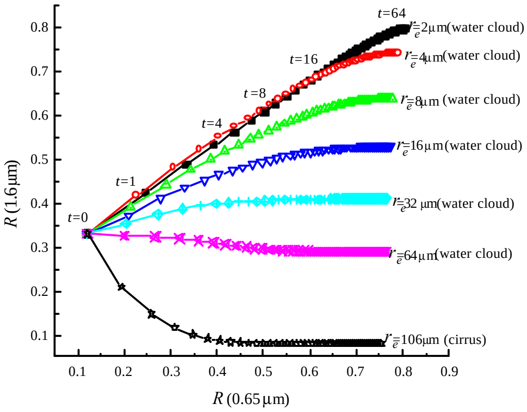

Fig. 1 Radiative transfer calculation results for 1.6mm reflectance versus 0.65mm reflectance for clouds with different effective radius and optical thickness

optical thickness. As the model input parameters, midlatitude summer atmosphere profile is selected as atmosphere profile data. Results are shown in Figures 1. From Figure 1, it can be seen that the reflectance at 0.65μm is insensitive to the effective radius of particles, especially when optical thickness τ is larger (τ>50) or smaller(τ<2). The optical thickness affects the reflectance at 0.65μm greatly. The thicker optical thickness, the larger the reflectance. There is an almost linear relationship between the reflectance at 0.65μm and optical thickness. On the other hand, the reflectance at 1.6μm is affected greatly by effective radius of particles, the larger effective radius the smaller the reflectance. When r_e <32μm and τ <20, the reflectance at 1.6μm increases as optical thickness growth. If r_e>32μm the reflectance decreases with increasing optical thickness. For τ >20, the reflectance changes little with increasing optical thickness.

According to the above analysis, there is a larger difference of the reflectance between 0.65μm and 1.6μm. The reflectance at 1.6μm is smaller than that at 0.65μm when cloud particle effective radius becomes larger. Thus ice cloud can be distinguished from water cloud by using the reflectance difference.

Radiative transfer calculations are also performed for that cirrus cloud overlies low water cloud[9]. In calculation, effective radius of lower water cloud is 8μm, effective radius of upper cirrus is 106μm, and other calculated conditions are the same as the signal layer cloud. Figure 2 shows relationships between 1.64μm reflectance and 11μm brightness temperature. For a fixed low water cloud optical thickness, either reflectance or brightness temperature decreases with increasing cirrus optical thickness. Both reflectance and brightness temperature become less sensitive to the presence of the lower cloud as the cirrus optical thickness increases.

3. Case studies

As an example of cloud microphysics properties analyses, June 23 2002 is selected. We got three

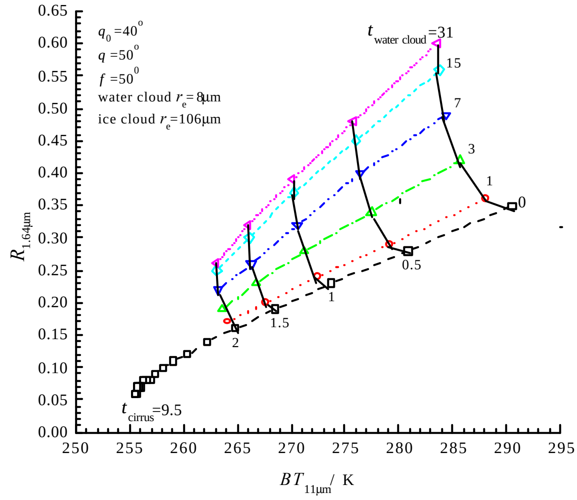

Fig. 2 Relationship between 1.64mm reflectance(*R*) and 11 mm brightness temperature(*BT*) as a function of optical thickness for a case when cirrus overlies low

kinds of satellite data. According to observation time, they are FY-1D, EOS and NOAA. Figure 3 is the images of thermodynamic phase retrieval result. White color is density ice cloud, cyan is cirrus, purple color is multiplayer cloud, and yellow is low water cloud. The hour precipitation data are overlay on the images. From the images, it is showed that the center of rain is match to density ice cloud area. There are 120 auto-precipitation observation stations in selected area. From June 23 to June 27, we got 1200 observations. Among these observed data, the rain appeared 203 times, it is 17 percent of total observation. Among these precipitation data, 76% precipitation was caused by density ice cloud. Detail analyses data is listed follow.

Table 1. Statistic analyses between cloud's microphysical properties and precipitation

precipitation > 0			precipitation = 0		
	Ice cloud	Water cloud		Ice cloud	Water cloud
Pixel number	155	48	Pixel number	389	608
Average 0.65μm reflectance	72%	61.7%	Average 0 .65μm reflectance	48.6%	35.5%
Average 1.64μm reflectance	19.9%	42.7%	Average1. 64μm reflectance	21.5%	35.1%

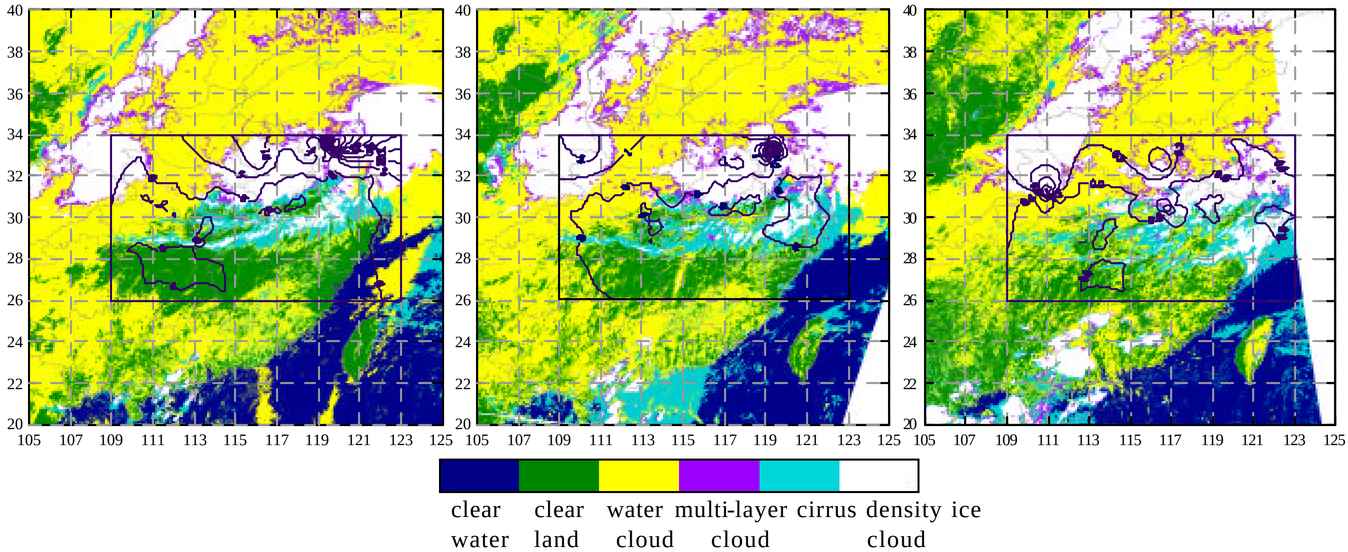

Fig3 cloud phase analysis result FY-1D (left) ,EOS(middle) and NOAA (right)

4. Conclusions

Based on the modeling computation and cases study, the preliminary conclusion is as followings:

1) The 0.65μm reflectance of is larger for both ice cloud and water cloud with similar particle size and distribution. However the reflectance of 1.6μm for ice cloud is smaller compared with 0.65μm.11.0μm is sensitive to clouds for its 11μm window and it is used for cloud detection.
2) Case studies indicate that multi-channel satellite data can be used efficiently for analyses properties of cloud.

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