CLOUD LIQUID WATER RETRIEVAL IN NON-PRECIPITATING CLOUD WITH SATELLITE MIVROWAVE DATA OVER HENAN REGION

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1. Introduction

Cloud Liquid Water (CLW) is one of the most important uncertainty factors on the analysis of global climate change and local precipitation condition. The condition of CLW has the significant effect on the conversion process of hydrometer and the balance of radiation in troposphere. The data of CLW are the key parameter for improving simulating precipitation process. CLW is also one of the most important indices for cloud seeding of precipitation enhancement.

The data of CLW taking by aircraft are basic data for the study of rain process, but they are unwonted and very expensively. Multichannel microwave radiometer on the ground can get abundant information of CLW over a site by retrieval method without influence from the different surface emissivity, but it is very difficult to get the whole information of a cloud system with one immobility observation site. Satellite data, however, are very useful for retrieving different levels of CLW with particular spatial and temporal speciality. The advance of satellite technique will provide plenty of cloud information for the study of precipitation condition in future. The CLW sounding from TRMM Microwave Imager (TMI) can provide potential information to the precipitation condition and it is the key data source to verify the analysis result of CLW by various retrieval method.

2. Retrieval Method for CLW in Non-Precipitating Cloud

The radiis of cloud particle in non-precipitating cloud is less than the microwave length. According to the Rayleigh theory, the absorption section of cloud particle in non-precipitating cloud is bigger than the scatter section when assuming a horizontal and parallel atmosphere in a local thermal steady state.

The particulate scattering is related to the sector of cloud particle and the absorption is related to the bulk of cloud particle, so the atmospheric absorption is directly related to the total CLW in cloud particle and less effected by the distribution of cloud particles according to the Planck assumption.

Most incunabular retrieval tests for CLW in non-precipitating cloud with satellite microwave are limited on the clouds over oceans where the physical status is simple. The surface radiative character of land is much more complexity than that of sea surface. Firstly a strong radiance background exists because the surface emissivity is bigger than that of the sea surface. In addition, the microwave radiation over land is very complicated, and the surface emissivity varies with the substantial configuration, the thermal temperature, the geometry shape, the particle structure inside, the surface roughness, and the physical character of land. The intricacies of surface property make it difficult to retrieve CLW in non-precipitating cloud over land with satellite microwave data.

Grody et al. (1976) set a regression equation for CLW in the various kind of cloud by assuming that surface emissivity is uniformly distributed from 0.9 to 1.0 . But their results showed that the retrieval error is too large to reflect the true state of CLW. Jones et al. (1990) retrieved CLW using iterative method with a radiative transfer model and the data at 85.5GHz SSM/I. Greenwald et al. (1997) and Combs et al. (1998) retrieved CLW using polarization difference of brightness temperature. The method reduces the CLW retrieval error in lower cloud and decreases the influence from the vertical profile of CLW, but it can be only applied to the polar surface and the random error of CLW aggrandizes with the instrumental error.

The precision of retrieved CLW is limited when using surface emissivity from experiential result and calculation methods by Grody (1976), Feddes and Liou (1978), Liou and Duff (1978). Jones et al (1990) are very complex to calculate surface emissivity using the infrared channel data. Zhao and Wang (1997) calculated surface temperature and surface emissivity by a method with the data of 2 channels or 3 channels. Deeter and Vivekanandan (2005) calculated CLW with the data of dual channels without surface emissivity assuming that the polarization difference of surface emissivity is not relate to frequency.

Using TRMM/TMI 85.5GHz vertical polarization brightness temperature data, surface emissivity is calculated by an iterative method with VDISORT from the cloudless data on 6 Mar. 2005. According to the analysis by Jones et al., surface emissivity has less change in 15 days. The amount of CLW over Henan region on 21 Mar. 2005 and its distribution were retrieved using NCEP data, the calculated surface emissivity on 6 Mar. 2005 and brightness temperature data. Compared with the infrared image of FY-2C Satellite, TRMM 2A12 products, and NCEP data, the method used in this paper was feasible in retrieving CLW in non-precipitating cloud.

3. Estimation of surface microwave emissivity

There are only 2 radiosonde sites in Henan region. We use temperature, air pressure, and humidity from NCEP 1°×1° data which have the coverage of Henan region. The surface emissivity in Henan region on 6 Mar. 2005 was calculated by the numerical step-by-step method with VDISORT based on the vertical polarization brightness temperature data from TRMM/TMI 85.5GHz channel. TRMM passed over Henan region three times on 6 Mar. 2005, which are 10:31:57 to 10:33:35, 12:09:22 to 12:11:16, and 13:46:41 to 13:48:58. Fig. 1 shows surface emissivity calculated by brightness temperature from TRMM data during 12:09:22-12:11:16 UTC on 6 Mar. 2005 over Henan region. The result from the calculation in Fig.1 is similar to the surface conditions image in cloudless from Google Earth on 8 April 2007 in Henan region.

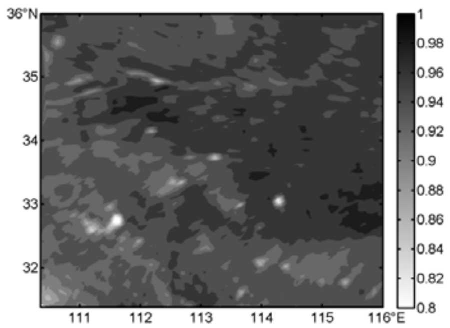

Fig. 1: The distribution of surface emissivity calculated by brightness temperature from the TRMM data during 12:09:22-12:11:16 UTC on 6 Mar. 2005 in Henan region.

4. Retrieval test of CLW in non-precipitating cloud over Henan region

Retrieval test of CLW in non-precipitating cloud over land in Henan region uses the vertical polarization brightness temperature data from TRMM 85.5GHz channel during 03:06:33 to 03:08:11 on 21 Mar. 2005. The surface emissivity calculated from TRMM/TMI data on 6 Mar. 2005 are interpolated to pixels on 21 Mar. 2005. The total CLW in non-precipitating cloud is then calculated using the retrieval method with VDISORT model, combined with the interpolated surface emissivity, vertical polarization brightness temperature data from TRMM 85.5GHz channel during 03:06:33 to 03:08:11, and the NCEP data at 02:00 UTC on 21 Mar. 2005. Fig.2 shows the result of CLW during 03:06:33 to 03:08:11 on 21 Mar. 2005 in non-precipitating cloud calculated by the retrieval method.

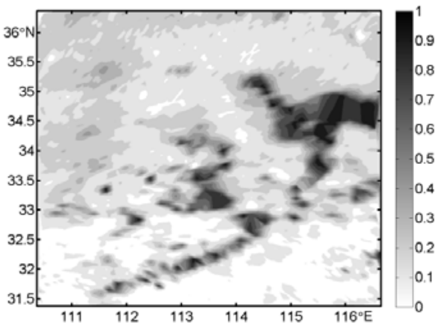

Fig.2: The total CLW during 03:06:33 to 03:08:11 on 21 Mar. 2005 in non-precipitating cloud calculated by the retrieval method

5. Contrast Analysis

5.1 Contrast of the retrieval result with FY-2C cloud image

Fig.3 is an infrared cloud image from FY-2C at 03:00 UTC on 21 Mar. 2005. The cloud distribution in the black box in Fig.2. is similar to the distribution of the total CLW in non-precipitating cloud calculated by using the retrieval method in Fig.1.

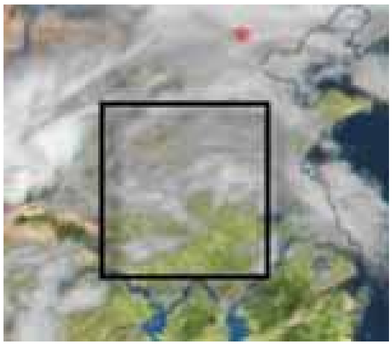

Fig. 3: The infrared cloud image from FY-2C at 03:00 UTC on 21 Mar. 2005.

5.2 Contrast of the retrieval result with TRMM 2A12 product

Fig.4 shows the total CLW from the TRMM 2A12 product during 03:06:33-03:08:11 on 21 Mar. 2005. It is similar to the total CLW in non-precipitating cloud calculated by the retrieval method. The coverage of the CLW observed from TRMM 2A12 is smaller than that from the retrieval method and the CLW value in Fig.4 is about half of the CLW value in Fig.2.

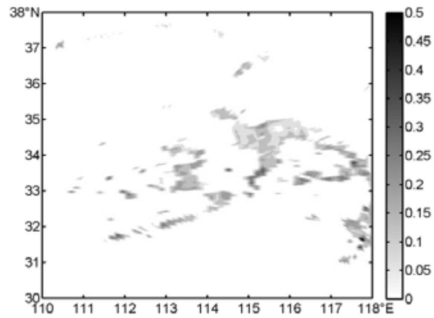

Fig.4 The total CLW from TRMM 2A12 product during 03:06:33-03:08:11 on 21 Mar. 2005.

5.3 Contrast of the retrieval result with the result from NCEP data

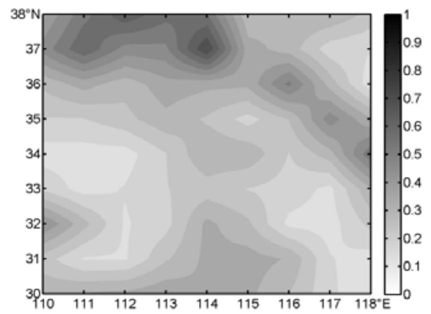

Fig.5 : The total CLW from NCEP at 02:00 UTC on 21 Mar. 2005.

Fig.5 is the total CLW from NCEP at 02:00 UTC on 21 Mar. 2005. Larger difference exists compared with the total CLW in non-precipitating cloud that calculated by the retrieval method (Fig 2).

6. Error Analysis

6.1 Error from the vertical profile of CLW in non-precipitating cloud

Fig.6 is the error effect that the simulation change of CLW at a 2 km depth cloud body with brightness temperature at 85.5GHz SSM/I by VDISORT model from the different cloud base height. The error of the brightness temperature accuracy by VDISORT model is increase with cloud base height uplifting.

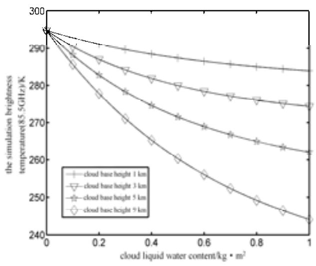

Fig.6: The effect that the simulation change of CLW at a 2 km depth cloud body with brightness temperature at 85.5GHz SSM/I by VDISORT model from the different cloud base height.

6.2 Error from the substitute of the NCEP data in VDISORT

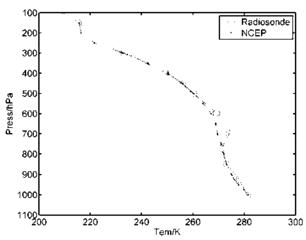

Fig.7: The contrast that the temperature profile from radiosonde data at 5:00 UTC to the corresponding temperature profile from NCEP data at 02:00 UTC on 21 Mar. 2005.

Fig.7 is contrast of the temperature profile from radiosonde data at 5:00 UTC with the corresponding temperature profile from NCEP data at 02:00 UTC on 21 Mar. 2005. The difference of the calculated brightness temperature is only 5K by VDISORT model and the error analysis result is 0.1 g/m^2 with substitute of the radiosonde data by the NCEP data.

7. Conclusions

7.1 It is feasible to estimate surface emissivity using step by step method and calculate total CLW in non-precipitating cloud with VDISORT model and the radiosonde data.

7.2 Compared with NCEP data and TRMM product of the total CLW, the total CLW in non-precipitating cloud calculated by our retrieval method provides the best result. The NCEP data fail to show the total CLW in non-precipitating cloud and the CLW coverage from TRMM 2A12 is smaller than our retrieval result.

7.3 The effect of the simulation brightness temperature by VDISORT model is decrease with cloud base height uplifting.

7.4 The error is 0.1 g/m2 with the substitute of the radiosonde data by the NCEP data. The error elimination should base on the acquisition of radiosonde data with the increase of the temporal resolution in field experiment.

7.5 The retrieval method is only the qualitative analysis for cloud liquid water in non-precipitating cloud with satellite microwave data. The quantitative analysis exist many difficulties to overcome with the help of plenty of observation data in future.

Acknowledgements

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