Retrieval of atmospheric water vapor amount over land using ADEOS-II / GLI near infrared data

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Abstract

A retrieval algorithm of vertically integrated water vapor amount (precipitable water) over land was applied to the near infrared data of Global Imager onboard Advanced Earth Observing Satellite-II (GLI / ADEOS-II). Comparing the retrieved precipitable water with radiosonde observation, we had some underestimation with some systematic bias for larger water vapor amounts in a preliminary analysis. Accordingly, we re-evaluated a relationship between radiance to be observed with GLI and water vapor amount, carrying out more detailed radiative transfer simulations. The retrieved water vapor amount with the coefficients was compared to radiosonde observation and ground-based microwave radiometer measurements. As a result of the validation, we have a relative error of about 30% and 10%, respectively. It also turns out that the linearity is quite good between the precipitable water with GLI and that with the radiosonde or microwave radiometer observation. Further, it is necessary to compare the satellite-retrieved results with the skyradiometry on a local basis as well as other satellite products on a global basis.

Keywords **:** Water vapor, ADEOS-II, GLI, AMSR, Radiosonde, Microwave Radiometer

1. Introduction

Water vapor is one of typical gas species governing the greenhouse effect as well as aerosol modulator through the humidity effect. Investigation of water vapor distribution is a clue to understand the radiation budget of earth atmosphere system as well as the global energy and hydrological circulation. Although water vapor is mostly distributed in the lower atmosphere (planetary boundary layer from surface to a few kilometers), the water vapor amount often increases in the middle and upper troposphere accompanying horizontal advection of humid air mass. Thus, precipitable water, (i.e. the vertically integrated water vapor amount) is considered to be the most representative quantity of water vapor amount in the atmosphere.

Historically, TIROS-N Operational Vertical Sounder (TOVS) data have often been used to estimate water vapor amount at lower, middle, and upper regions of the troposphere. [1)] Although TOVS is a splendid vertical sounder with a number of channels sensitive to water vapor absorption, their footprints are about several tens kilometers, rather larger than those of environmental sensors onboard earth-observing satellites. Better spatial resolutions of several hundred meters to several kilometers are available with MODIS / EOS sensors, wavelengths and bandwidths of which are very similar to those of TOVS. Combining the near infrared data of water vapor absorbing and non-absorbing channels with the thermal infrared data, precipitable water is derived from the MODIS mission with a relatively high spatial resolution along with information of clouds and aerosols. [2)]

In contrast to TOVS and MODIS, GLI onboard ADEOS-II is designed to obtain data of both the surface properties (vegetation, ocean color, and snow and ice, etc.) and atmospheric properties (cloud, aerosol, and radiation budget, etc.). In general, atmospheric correction is indispensable when surface geophysical properties are retrieved from satellite remote sensing data. Correction of atmospheric ozone, aerosol, and in particular, water vapor is important for precise retrieval of vegetation conditions and ocean color. In the GLI mission, the water vapor information is incorporated from the quasi-real-time objective analysis data. Nevertheless, it is desirable to use the water vapor information concurrently obtained with the same spatial resolution as other channels. In this context, we developed a retrieval algorithm of precipitable water with near infrared channels of GLI. The outline of the retrieval algorithm is described in Sec. 2 together with an initial result of a global map. In Sec. 3, results of the validation are analyzed and discussed. Section 4 presents the summary and related future works.

2. Analysis of Data

We developed retrieval algorithm for water vapor amount (vertically integrated water vapor amount i.e., precipitable water) using GLI near infrared channel (1135nm) based upon the MODIS algorithm. With a sensitivity study, this algorithm is more sensitive to water vapor amount over land (higher albedo region) than over ocean (lower one). [3]

The relationship between radiance ratio RR and precipitable water W (mm) is as follows:

$$RR = a + b\exp\left(-c\sqrt{W\left(\frac{1}{\cos\theta}+\frac{1}{\cos\theta_0}\right)}\right), \quad (1)$$

where the coefficients a, b, and c are 0.0690, 1.23, and 0.209 ($mm^{-1/2}$), respectively over land. Using Eq. (1), we can retrieve precipitable water from radiance ratio estimated from GLI observation.

This method was applied to GLI data over land on a monthly basis. Figure 1 shows a monthly precipitable water maps retrieved with ADEOS-II / GLI over land, in addition to those over ocean retrieved with Advanced Microwave Scanning Radiometer (AMSR) onboard ADEOS-II, and discuss a seasonal contrast of precipitable water on a global basis. From Fig. 1, you could see a good seasonal variation of columnar water vapor amount between spring and summer over both land and ocean.

We made a validation using radiosonde observation. We confirmed the retrieved results are comparable to the radiosonde observation at some observation sites over a northern America continent. But there existed some underestimation of satellite-derived precipitable water.

After this initial validation study, we re-evaluated the coefficients in Eq. (1) with more detailed radiative transfer calculations. The new coefficients are 0.0930, 1.183, and 0.192 ($mm^{-1/2}$) for a, b, and c, respectively.

We have two combinations to estimate the radiance ratio between water vapor absorbing and non-absorbing channels: one is two channel method using 1135nm and 1240nm for water vapor absorbing and non-absorbing channels, respectively; The other is three channel method using 1050nm as well as 1240nm for non-absorbing channel. As a result of the validation study over northern American continent, we found some irregular feature in the retrieved water vapor amount on a histogram basis. The reason of the irregular feature is still open question, but we discuss the results based on the two channel method in this article.

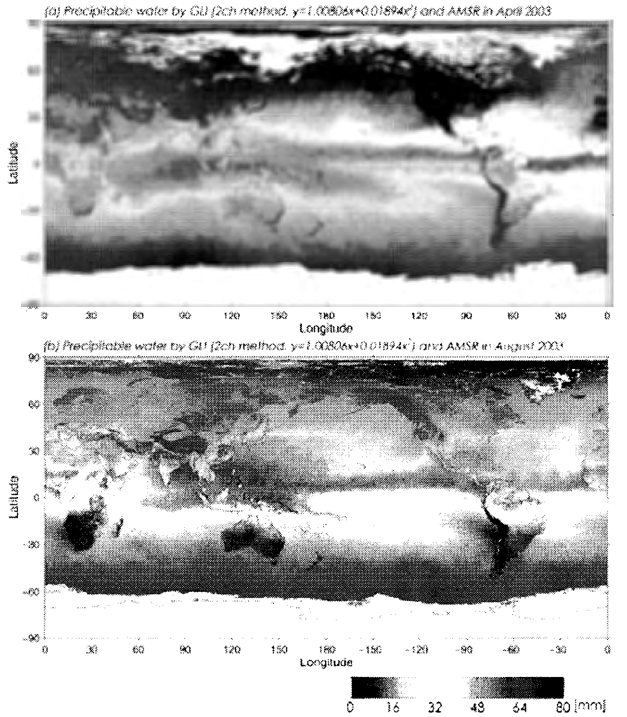

Fig. 1. A global map of monthly average columnar water vapor amount (precipitable water) retrieved with GLI and AMSR onboard ADEOS-II. Upper panel: April, lower panel: August (by courtesy of JAXA / EORC).

3. Validations and discussion

In this section, we describe validation results with radiosonde and microwave radiometry based on the new coefficients described in previous section.

In this validation study, we prepared GLI match-up data set that is small segment of 11 x 11 pixels around the radiosonde or microwave observation sites. Cloud screening is a critical issue in this validation. We adopted the following conditions as cloudy: average reflectance and standard deviation of the match-up segment is more than and equal to 25% and 0.03, respectively. We did not use the cloudy match-up segment in this validation study. We also constrain scan geometries. The condition is adopted that solar and satellite zenith angles is less than and equal to 60 and 30 degrees, respectively. As a result, we prepared the clear (non-cloudy) segments.

Next we prepared radiosonde match-up data out of the world sites over 750 sites of DCDF. The date of the collected data expands from April 2 to October 24, 2003 and we used the data when the observation was carried out within ADEOS-II overpass. We also adopted the following cloud screening condition: if the relative humidity in some atmospheric layer is over 80%, the layer is possibly cloudy, and then the data were not used in this validation.

Figure 2 illustrates the comparison of integrated water vapor amount derived from GLI and radiosonde observation. As a result, GLI retrieved precipitable water has relative error of as much as 30 %.

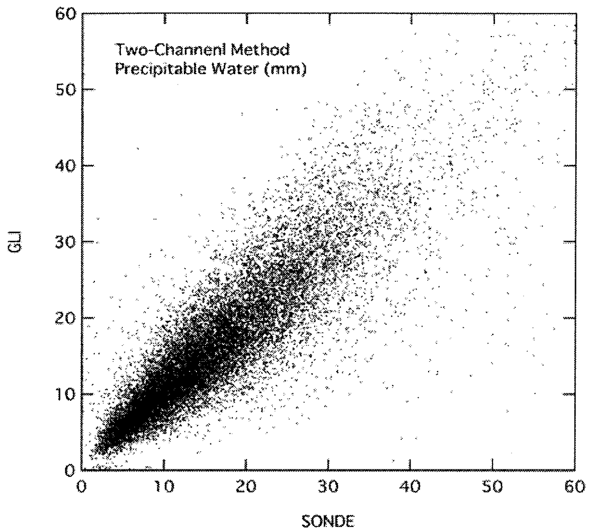

Fig. 2. Comparison of precipitable water between GLI and radiosonde observation.

However, water vapor is one of the most variable gaseous components in the atmosphere spatiotemporally. It is necessary therefore to make a more coincident comparison since radiosonde observation has time lag around several hours from satellite overpasses and it possibly has some departure from the site location due to strong wind in the free troposphere.

We further tried to compare the GLI retrieved water vapor amount to the ground-based microwave radiometer observation coincident within 10 minutes to GLI overpass since the microwave radiometer makes observation continuously.

Figure 3 illustrates the comparison of integrated water vapor amount derived from GLI and ground-based microwave radiometer for Hefei in China where is one of the SKYNET observatory. The microwave radiometer is a model WV-1100 manufactured by Radiometrics Corporation. It has two channels at 23.8 GHz near the water vapor absorption band and 31.4 GHz in the window region. The error bars illustrated in Fig. 3 are sufficiently small, which indicates the standard deviation of GLI water vapor amount for 11x11 pixels. The error of the difference between GLI and microwave radiometer measurements is almost 10 % that is smaller than result of comparison between GLI and radiosonde measurements.

This decrease of the error results from no time lag between microwave radiometer continuous observations and GLI observation as opposed to a time lag between GLI and radiosonde observation for maximum 6 hours. The results show that the water vapor amounts derived from GLI are close to ones derived from microwave radiometer. The other reason of the better estimation with the microwave radiometer than with the radiosonde are ascribed to that microwave radiometry is little sensitive to aerosol loading which is a potential error source in principle.

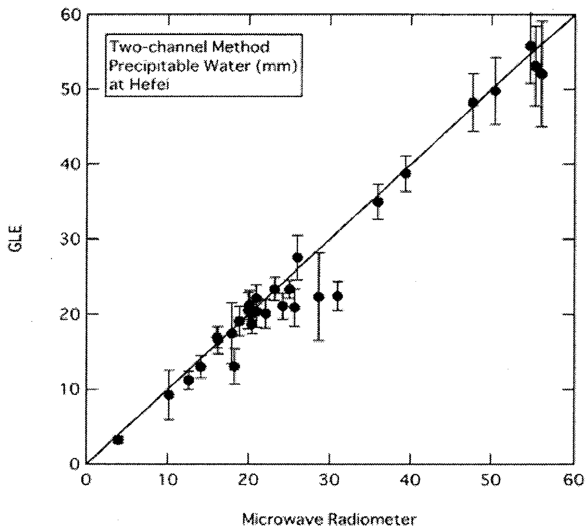

Fig. 3. Comparison of precipitable water between GLI and microwave radiometer at Hefei, China.

4. Concluding remarks

In this study, we applied a retrieval algorithm to ADEOS-II / GLI near infrared data over land. The validation study with radiosonde and ground-based microwave radiometer observation resulted in the relative error of 30 and 10 %, respectively. It is found that such a simple retrieval algorithm is useful to estimate water vapor over land. Water vapor has large spatial variation, so it is further feasible to compare the GLI retrieved precipitable water to the ground-based skyradiometry as well as the other satellite-derived water vapor amounts.

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