Determination of the optical thickness of aerosol at 1.6*μm* and 2.2*μm* using Skyradiometer

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Abstract

A method is presented for determining of the optical thickness of aerosols from the direct solar radiation at 1.6 um and 2.2 um measured by Skyradiometer POM-02. Because 1.6 um and 2.2 um band are weakly absorbed by water vapor, these bands need to subtract the optical thickness of water vapor from the measured optical thickness. Skyradiometer has a channel at 0.94 um water which can obtain the column water vapor. The optical thickness of water vapor at the 1.6 um and 2.2 um channels is calculated using the column water vapor. The optical thickness of aerosol at 0.94 um has been corrected with the optical thickness of aerosol at 0.87 um and 1.02 um bands.

Keywords : aerosol, optical thickness, skyradiometer

1. Introduction

Skyradiometer POM-02 is a radiometer for deriving aerosol properties from the direct and defuse solar radiation measurements. Skyradiometer POM-02 has channels at 1.6 um and 2.2 um to derive cloud properties such as the effective radius of cloud particle. We developed a method determining the aerosol optical thickness at 1.6 um and 2.2 um using the direct solar radiation measured by Skyradiometer POM-02 for validation of the aerosol properties of GOSAT TANSO-CAI 1)(Nakajima et. al, 2008). It is a problem of deriving aerosol properties using these two channels that there is weak absorption by water vapor at 1.6 um and 2.2 um. Using water vapor amount derived from 0.94 channel of Skyradiometer POM-02, effect of water vapor absorption at 1.6 um and 2.2 um can be reduced.

2. Determination of water vapor amount

Skyradiometer POM-02 has been used to measure the direct solar radiation at discrete wavelength between 0.315 and 2.2um. Skyradiometer POM-02 has a channel for water vapor absorption band at 0.94 um which can derive column water vapor amount. We calculate the relationships between the absorption and the water vapor amont using rstar4b radiation transfer code including LOWTRAN 7 2)(Kneizys et. al, 1988). Rstar4b is modified for satellite data analysis, which calculates the reflected radiance at the top of atmosphere. We calculated the reflectance of ground surface instead of the transmittance of the atmosphere. The surface is assumed to be lambertian and the ground albedo 0.5. The solar zenith angle is 60 degree, and the radiometer nadir angle is 0 degree. Airmass (optical path length) is 3 for water vapor.

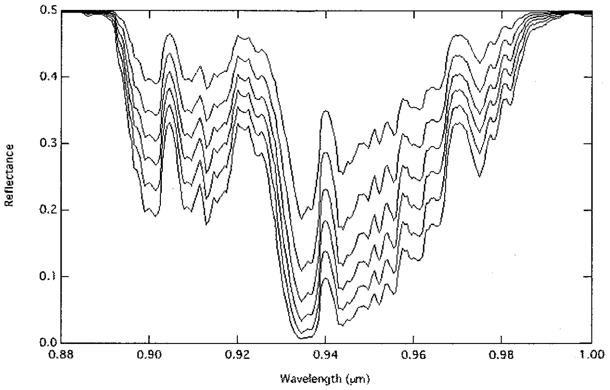

Fig. 1. Calculations of reflectance at ch8 (0.94□m) as a function of wavelength for water vapor.

Figure 1 illustrates the reflectance of solar radiation at 0.94 um as a function of wavelength at 0.5 nm intervals for 7 atmosphere models (tropical, mid latitude summer, mid latitude winter, high latitude summer, high latitude winter, US standard and US standard except for no water vapor).

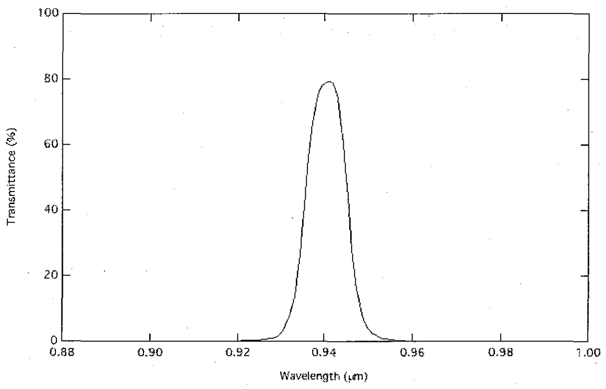

Fig. 2. Filter transmittance of ch8 (0.94□m) as a function of wavelength.

Figure 2 illustrates the transmittance of the interference filter at 0.94 um as a function of wavelength.

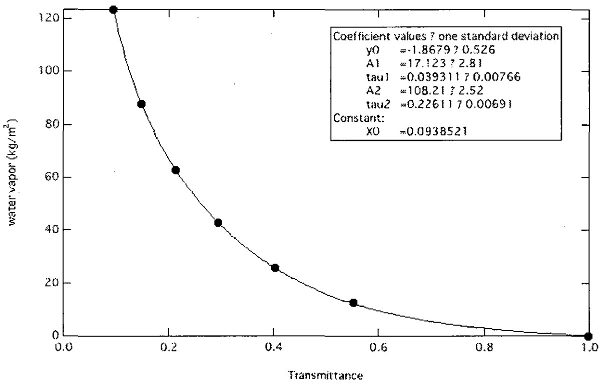

Fig. 3. Calculations of water vapor as a function of transmittance for the direct solar radiation.

Figure 3 illustrate the transmittance of direct solar radiation as a function of water vapor amount (dot) which is calculated with the results of Fig.1 and Fig. 2. Curve fitted line can be written as:

$wv(Tr_{wv0.94}) = y_0 + A_1 exp(-(Tr_{wv0.94} - x_0) / tau_1)) + A_2 exp(-(x-x_0) / tau_2)$, ... (1)

where y_0=-1.8679, A_1=17.123, tau_1=0.039311, A_2=108.21, tau_2=0.22611, x_0=0.0938521. Using the optical thickness determined with 0.87 um and 1.02 um channels, we can calculate the transmittance of aerosols at 0.94 um given by,

$Tr_{a0.94} = exp(-(0.53 * tau_{a0.87} + 0.47 * tau_{a1.02}) / cos(theta_0))$. ... (2)

The transmittance of water vapor can be calculated as follows,

$Tr_{wv0.94} = Tr / Tr_{a0.94}$, ... (3)

where Tr is the transmittance measured by Skyradiometer POM-02 at 0.94um. Column water vapor is given by

$wv_c = wv(Tr_{wv0.94}) * cos(theta_0)$. ... (4)

3. Determination of aerosol optical thickness at 1.6um and 2.2um

Skyradiometer POM-02 has channels at 1.6 um and 2.2 um which are weakly attenuated by water vapor absorption. We calculate the relationships between water vapor amount and transmittance of direct solar radiation at 1.6 um and 2.2 um using rstar4b. Figure 4 and 5 illustrates the reflectance of solar radiation as a function of wavelength at 1.6 um and 2.2 um respectively for lanbertion surface with 0.5 albedo.

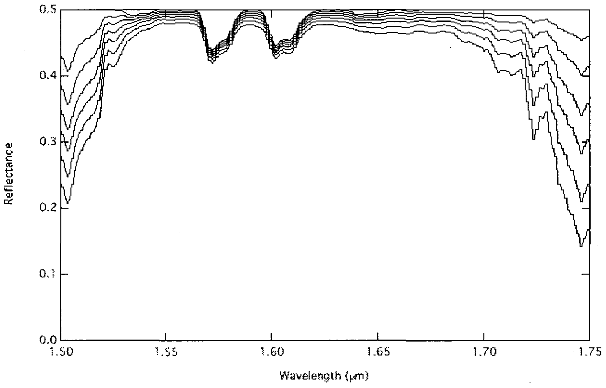

Fig. 4. Calculations of reflectance at ch10 (1.6 um) as a function of wavelength.

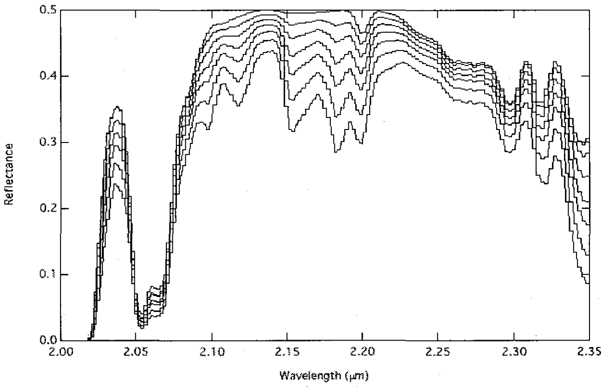

Fig. 5. Calculations of reflectance at ch11 (2.2 um) as a function of wavelength.

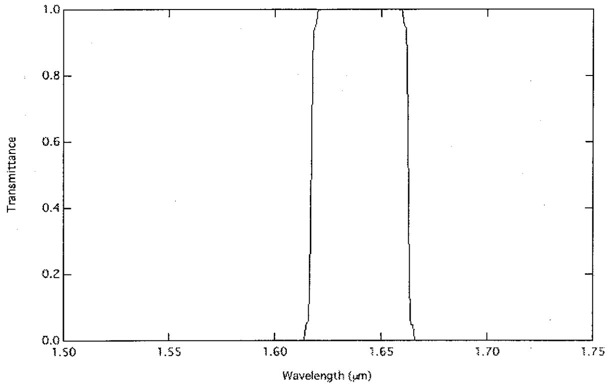

Fig. 6. Filter transmittance of ch10 (1.6 um) as a function of wavelength.

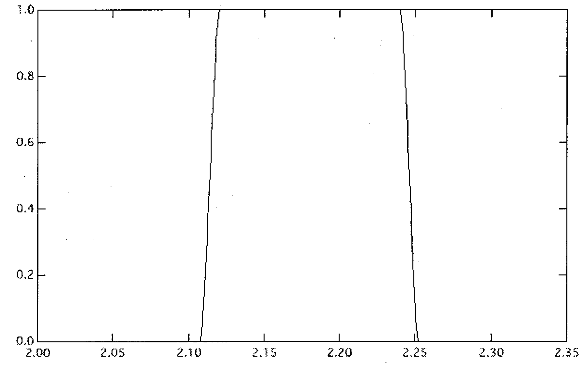

Fig. 7. Filter transmittance of ch11 (2.2 um) as a function of wavelength.

Figure 6 and 7 shows the transmittance as a function of wavelength for the interference filter at 1.6 um and 2.2 um.

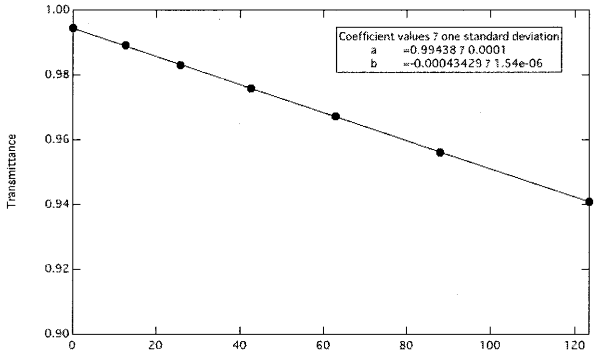

Fig. 8 Calculations of transmittance at ch10 (1.6 um) as a function of water vapor.

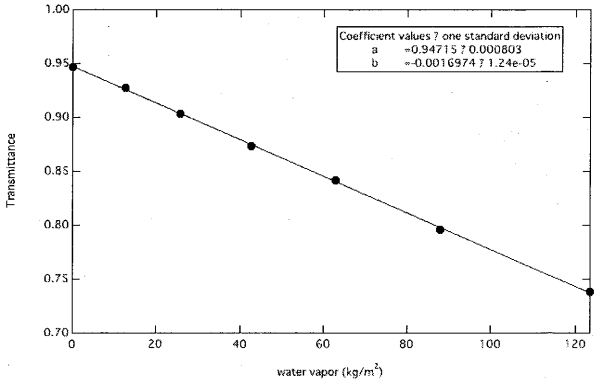

Fig. 9 Calculations of transmittance at ch11 (2.2 um) as a function of water vapor.

Figure 8 shows the transmittance of direct solar radiation as a function of the water vapor amount at 1.6 um calculated with results of Fig. 4 and Fig. 6. Curve fitted line can be written as:

$$Tr_{wv} = a + b*wv, \ldots \qquad (5)$$

where a = 0.99438, b = -0.00043429. When water vapor amount is 0.0, transmittance is not 1.0 due to the absorption with other gaseous compositions of the atmosphere. The optical thickness of gaseous composition except for water vapor is $tau_{o1.6}$ = 0.00018 and coefficients for a $_{1.6}$ = 1.0, b $_{1.6}$ = -0.00043674.

Figure 9 is same as Fig. 8 except for 2.2 um channel and curve fitted which can be written same as Eq. (5) where a = 0.94715, b = -0.0016975. The same as 1.6 um channel, the optical thickness of gaseous composition except for water vapor is $tau_{o2.2}$= 0.0181 and coefficients of Eq. (5) will be $a_{2.2}$ = 1.0 and $b_{2.2}$ = -0.00017922. After subtracting affect water vapor absorption from transmittance measured by Skyraiometer using water vapor amount derived from 0.94 um, we can determine the aerosol optical thickness at 1.6 um and 2.2 um as follows,

$$tau_{a1.6} = -log(Tr / Tr_{wv1.6}(wv)) \cos(theta_0) - tau_{o1.6}, \ldots \qquad (6)$$

$$tau_{a2.2} = -log(Tr / Tr_{wv2.2}(wv)) \cos(theta_0) - tau_{o2.2}. \ldots \qquad (7)$$

4. Results from the observation

We have applied the method described

heretofore to the measurements obtained from Skyradiometer at Fukuejima one of the SKYNET observatory site. Figure 10 illustrates the aerosol optical thickness at 0.34 um, 0.4 um, 0.5 um, 0.675 um, 0.87 um, 1.02 um, 1.6 um, 2.2 um and the column water vapor amount as a function of time on 3 Apr. 2008. Calibration constants of Skyradiometer channels were determined using these measurements because Fig. 10 shows that atmosphere condition was stable and low water vapor.

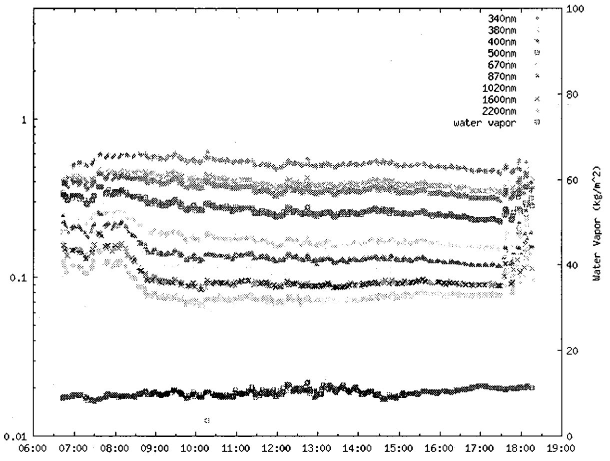

Fig. 10 Aerosol optical thickness at 0.34, 0.38, 0.40, 0.50, 0.67, 0.87, 1.02, 1.6, 2.2 um and water vapor amount on 3 Apr. 2008.

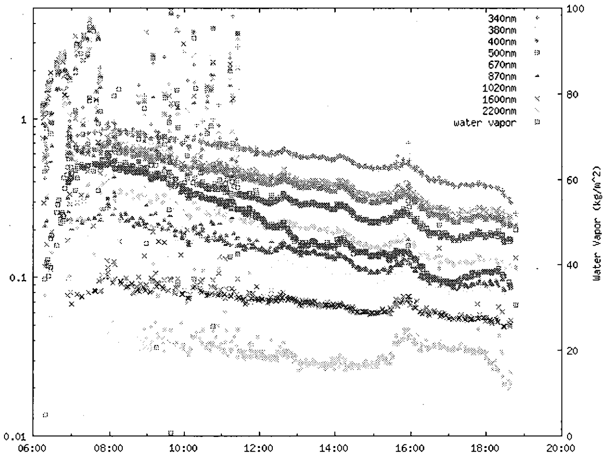

Fig. 11 Same as Fig.10 execpt on 6 Aug. 2008.

Figure 11 is same as Fig. 10 except for date on 6 Aug. 2008. Figure 11 shows that the aerosol optical thickness at 1.6 um and 2.2 um indicate the same variation as the optical thickness of the other channels. This means that the effects of water vapor absorption is successfully removed.

5. Summary

A method has been presented for determining the aerosol optical thickness from direct solar radiation measurements using Skyradiometer POM-02 at 1.6 um and 2.2 um that are weakly absorbed by water vapor. It is shown that we can remove the effect of absorption by water vapor using 0.94 um channel of Skyradiomter,.

References

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