RETRIEVING AEROSOL AMOUNT FROM GEOSTATIONARY SATELLITE

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ABSTRACT: Using 30 days of hourly visible channel data and DIScrete Ordinate Radiative Transfer (DISORT) model (6S), Aerosol optical depth (AOD) at 0.55μm was retrieved over the East Asia. In contrast with the AOD retrieval using low-earth-orbit satellites such as MODIS (Moderate-Res olution Spectroradiometer) or MISR (Multiangle Imaging SpectroRadiometer), this algorithm with geostationary satellite can improve the monitoring of AOD without the limitation of temporal resolution. Due to the limited number of channels in the conventional meteorological imager onboard the geostationary satellite, an AOD retrieval algorithm utilizing a single visible channel has been introduced. This single channel algorithm has larger retrieval error of AOD than other multiple-channel algorithm due to errors in surface reflectance and atmospheric property. In this study, the effects of manifold atmospheric and surface properties on the retrieval of AOD from the geostationary satellite, are investigated and compared with the AODs from AERONET and MODIS. To improve the accuracy of retrieved AOD, efforts were put together to minimize uncertainties through extensive sensitivity tests. This algorithm can be utilized to retrieve aerosol information from previous geostationary satellite for long-term climate studies.

KEY WORDS: Aerosol Optical Depth(AOD), surface reflectance, atmospheric property, Radiative transfer model, Geostationary satellite

1. INTRODUCTION

Despite extensive studies on the role of aerosol in the atmosphere to date, the magnitude to which aerosols impact the climate system of the Earth is still uncertain (e.g. Hansen, 2000; IPCC, 2001). On this score, previously numerous studies have pointed out that aerosols are the source of the large uncertainties in evaluating climate forcing (e.g. IPCC, 2001). So, it is very important to quantify the transportation, source, sink, and amounts of aerosol, by using observation networks of satellite and/or ground-based instruments.

The goal of this study is to develop a retrieval algorithm of AOD using a single visible channel for geostationary satellites. The retrieved results are compared with the AOD observed by the ground-based AERONET and the MODIS to investigate the quality of the retrieval. Many uncertainties exist in this AOD retrieval algorithm, above alluded to the background optical depth, radiative transfer model, atmospheric properties, surface reflectance, and so on. The major uncertainties in this retrieval process are investigated for BRDF (Bi-directional Reflectance Distribution Function), gaseous transmittance and background optical depth. This result can be applied to the aerosol events over the globe but will be focused on the events in the East Asian region, in particular. In this algorithm, the AODs are retrieved from the MTSAT 1R data to obtain better sensitivity to AOD than other satellites. The background optical depths (BODs), one of the dominant effect in AOD retrieval process, are considered by BODs from the MODIS and the AERONET AODs.

2. ALGORITHM

The basic conception of AOD algorithm is comparing two satellite images to obtain an aerosol estimate. The hazy day (a significant amount of aerosols) provides the estimate of aerosol amount (e.g. AOD). Otherwise, the clear day (relatively low aerosol burden) provides the estimate of the surface contribution (e.g. surface reflectance). This conception is shown in Figure 1 which shows the flow chart of AOD algorithm. Retrieval using MTSAT 1R visible channel is organized by three processes. The first step is the creation of semi-surface reflectance, where reflectances observed at satellite is converted to the surface reflectance by using the 6S regardless of sky condition for each observation time. Second, the minimum of semi-surface reflectances for the previous 30days is selected to obtain surface reflectance which is regarded as clear sky values. Last, satellite-measured reflectances are used to retrieve AOD with the known surface reflectance.

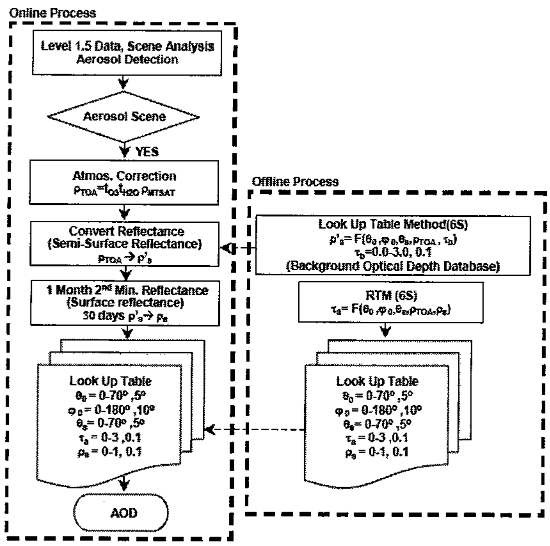

Figure 1. The flow chart of the AOD retrieval algorithm.

3. UNCERTAINTY STUDY

AODs still require further refinement to resolve uncertainties in the algorithm. Various uncertainties exist in the AOD retrieval algorithm, for example aerosol model, surface reflectance, BRDF, background optical depth, atmospheric properties, sensor calibration, and RTM (radiative transfer model), etc. Dominant uncertainties lie in the surface reflectance, as the algorithm depends mainly on the difference between the observed reflectances at TOA and estimated surface reflectances.

3.1 Background optical depth

The time length for finding clear day must be determined between using enough days to observe a clear day and few enough days to minimize the variation of surface properties. In this period, surface reflectance is calculated with minimum reflectance among TOA reflectances at the same time. BOD is assumed zero in other previous studies (Knapp, 2002; Wang, 2003). Because the surface properties are estimated by radiative transfer model, the assumptions of clear day are necessary in the previous studies. However, the assumption of BOD is not true in real conditions, especially in East Asian region where both anthropogenic and natural sources of aerosols are dominated throughout the year. To investigate this assumption, the values of the 30 days minimum AOD at 0.551mm during many years are shown in Figure 2 from the selected AERONET sites. As expected the minimum values never become zero and ranged from 0.1 to 0.5. These differences of BOD between measurement and assumption affect TOA reflectance, therefore result in errors in surface reflectance that does not take into consideration of real BOD.

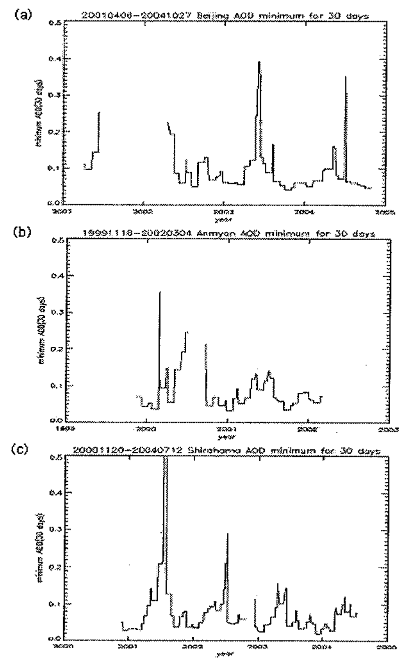

Figure 2. The minimum AOD databases of the AERONET AOD for 30 days at (a) Anmyon, (b) Beijing, and (c) Shirahama.

3.2 BRDF

The lambertian reflectance is assumed to calculate surface reflectance in this algorithm. However lambertian surface does not follow lambertian reflectance in reality. The lambertian reflectance is independent of viewing geometry for each pixel while the real ground reflectance is the function of those in geostationary satellite. Natural surface reflects light anisotropically, having a specific variation with illumination and viewing angle: the bidirectional reflectance distribution function (BRDF) (Knapp, 2002). So to understand the magnitude of this uncertainty, the range of BRDF error is simulated with the BRDF of Rahman in 6S. The BRDF of Rahman is designed to be applicable to arbitrary natural-surface both in visible and near-infrared using 3 parameters (solar zenith angle, satellite zenith angle and relative azimuth angle)(Rahman, 1993a, 1993b). The percent differences between the input and retrieved AOD are presented in Figure 3 for four. The error due to BRDF to AOD generally ranged from -100% to 0%. The hotspot of error corresponds to the location around when satellite zenith angle becomes close to the solar zenith angle and when the relative azimuth angle is close to zero(nearest the backscatter), as shown in Figure 3. In general, the effect of BRDF difference is not within 50% thus to be considered always except in the backscatter region.

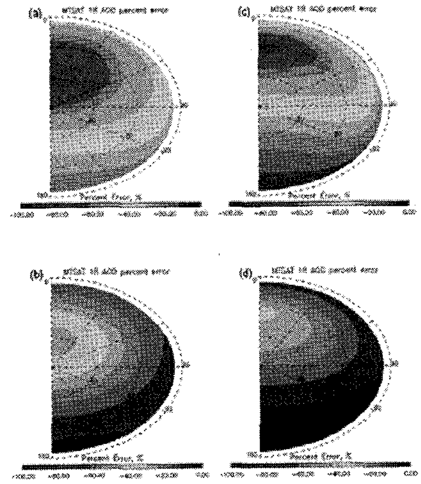

Figure 3. AOD reflectance percent error for neglecting the BRDF of a grass land with the sun at θ_o=30° and φ_o=0 ° for (a) τ=0.2, and (b) τ=1.5. and at θ_o=60 ° and φ_o=0 ° for (c) τ=0.2. and (d) τ=1.5.

3.3 Atmospheric absorption

The primary absorbers in the spectral range of the visible channel of MTSAT 1R are water vapor(H_2O) and ozone(O_3) which both have seasonal and temporal variations. However, the magnitude of these uncertainties due to O_3 and H_2O variations are small for the expected ranges of variation as shown in Figure 4. The error of absorption gases is very small, so this algorithm neglects the O_3 and H_2O variations.

The uncertainty study investigated general algorithm uncertainty and specifically looked at background optical depth. The overall uncertainty of the AOD algorithm in this study is about ±50% of aerosol optical depth. Main uncertainty comes from background optical depth, which is considered by using AOD from the AERONET. Finally, the overall uncertainty is almost effect of BRDF. However, the BRDF errors are solved by calculating the surface reflectance for each time, too.

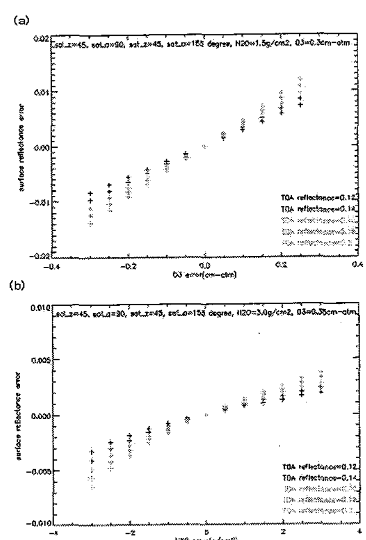

Figure 4. Surface reflectance error as a function of (a) O_3 and (b) H_2O content error.

4. VALIDATION WITH AERONET AND MODIS

The AOD algorithm is validated against two AOD data sets. The first dataset is the AERONET aerosol observations at selected sites. Sun photometers of organizing AERONET provide the best information available for validation of satellite retrievals of AOD as stated above. The photometer observes the light extinguished from the direct solar beam and calculates the optical depth from the Beer-Lambert Law. The AERONET observations have uncertainties of ±0.01 (Holben, 1998).

The retrieved AODs are compared with limited AERONET data, as scatter plot at Anmyon and Gosan in Figure 5. In Figure 5, after the initial comparison (Figure 5 (a) and (b)), the AOD is removed with the threshold value of standard deviation within 5x5 pixels. This method filters out the retrieved values with larger standard deviation. The standard deviation method is useful for removing cloud-contaminated values in particular. Yet the criterions are absent to separate aerosol from cloud, this method is difficult to adapt in all regions. The retrieved AOD are also compared with MODIS data and the standard method is used to remove cloud, as shown in Figure 6. The results are not good enough yet because of our cloud masking in MTSAT 1R images. The AOD values from MTSAT 1R is much higher than those from MODIS, which indicate a cloud-contamination in MTSAT 1R image as shown in Figure 6. This result can be improved when the cloud masking algorithm is refined.

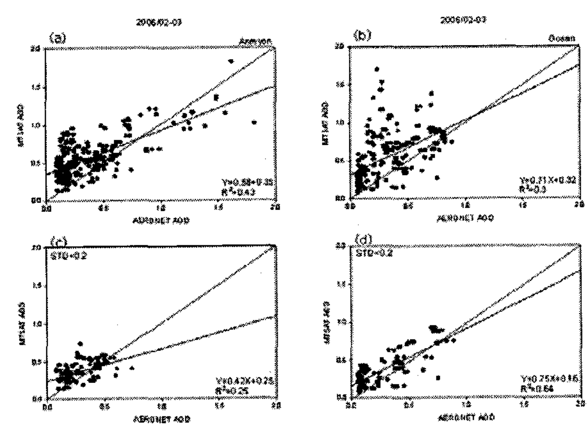

Figure 5. Comparison of initial AODs with those from AERONET (a) without standard method, and (c) with standard method at Anmyon site, and (b) without standard method, and (d) with standard method at Gosan site.

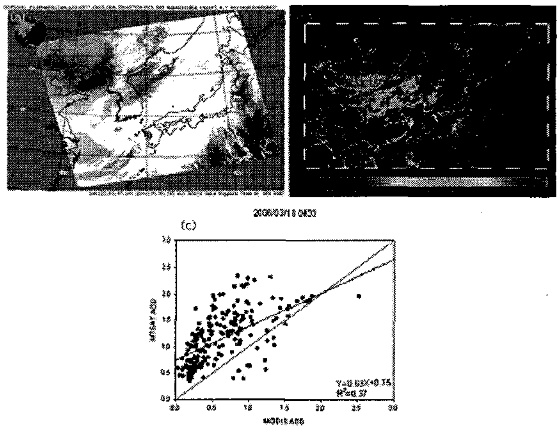

Figure 6. (a) The RGB image from MODIS, (b) the image of AOD, and (c) comparison of initial AODs with those from MODIS on March 18, 2006 at 04:33 UTC.

5. CONCLUSIONS

A method for computing AOD from geostationary satellite is described, retrieved, and compared over the East Asia. The AOD is retrieved from a single visible channel onboard the geostationary satellite by using the LUT which is constructed with the radiative transfer model, 6S.

AODs are retrieved in three step processes. The first step is the conversion of the semi-surface reflectance from the observed reflectance by satellite for each observation time. The atmospheric effect is corrected to convert TOA reflectance to semi-surface reflectance to take the variation of solar angles for 30 days into consideration. Then the darkest pixel is chosen to represent surface reflectance for clear day. Lastly, satellite detected reflectance from all observation times are converted into AOD using the surface reflectance obtained at the same pixel, by the radiative transfer model.

However, the results of comparison with other measurements are not still satisfactory due to cloud noises in particular. There exists many uncertainties, thus the accuracy of retrieved AOD is needed to be improved by calculating exact surface reflectance, selecting proper aerosol models, bidirectional reflectance, and effective cloud masking. Further algorithm development for better accuracy must be carried out though the better cloud removal, more accurate directional information of surface reflectance and so on. If the aerosol types can be classified, the accuracy of retrieved AOD is expected to be improved.

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7. ACKNOWLEDGEMENTS

This work was partially supported by the 2nd phase Korean Brain 21 Research Program 2006, the METRI, and through the COMS (Communicate, Oceanic, and Meteorological Satellite) Program.