P7.1 Retrieval of aerosol optical depth from geostationary satellite, MTSAT-1R, over East Asia

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1. INTRODUCTION

Aerosols in the atmosphere have effects on climate system and on human life. Aerosols affect the radiation budget of the Earth-atmosphere system by the scattering and absorption of solar and thermal radiation. With increasing interests on aerosol effects, there have been demands to monitor and understand the global distribution of aerosol by extensive ground-based and satellite measurements, and the development of algorithm using satellite is necessary to overcome limitation of ground-based measurements.

To date, most of the aerosol optical depth (AOD) algorithms were developed by using the high resolution multi-channel reflectances from the LEO satellite rather than GEO. In contrast to the AOD algorithm using LEO satellites, the algorithm for GEO satellites enables one to monitor AOD at a higher temporal sampling rate (e.g. Kim et al., 2008).

The basic aim of AOD algorithm is to derive the aerosol reflectance from the total satellite received signal. Thus the estimation of surface reflectance is the key factor in aerosol retrieval. For GEO satellites, the clear sky composite method have been used by assuming that at least one clear day exist and surface reflectance variation is not significant for the periods. The use of MODIS Bidirectional Reflect Distribution Function (BRDF) method is another possible approach.

In this paper, we develop a retrieval algorithm of AOD for the East Asia region using single visible channel onboard the MTSAT-1R satellite, and investigate the feasibility of using MODIS BRDF product to estimate land surface reflectance.

2. THE AOD ALGORITHM

The visible channel (0.54 ~ 0.93 ㎛) data from MTSAT-1R observation was used for aerosol retrieval over East Asia for year of 2006. The satellite-observed top of atmosphere (TOA) reflectance,

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$$\rho(\lambda) = \rho_R(\lambda) + \rho_a(\lambda) + \rho_c(\lambda) + \rho_s(\lambda).$$

It includes contribution from scattering by the atmospheric (ρ_R), aerosol (ρ_a), clouds (ρ_c), and surface (ρ_s). Thus, for clear-sky pixel without aerosol, the surface reflectance can be obtained when contribution of the Rayleigh scattering can be eliminated. Then, aerosol effect can be retrieved by using measured TOA reflectance and estimated surface reflectance at cloud free pixel. Figure 1 shows the work flow of aerosol retrieval in this study.

Lookup table (LUT) is the list of TOA reflectance as a function of sun and satellite angle, surface reflectance and atmospheric condition. The scattering or absorbing processes of the incoming solar radiation to atmosphere are affected by both amount and microphysical properties of aerosol. That is the reason why consideration about aerosol optical properties to calculate LUT is essential part to retrieve AOD. Because single visible channel algorithm has a limitation on estimation of aerosol properties in real time, aerosol characteristics over East Asia are analyzed from the long term AERONET measurements at Anmyon, Beijing, Hok Tsui of ong Kong and Hong Kong Polytechnic University, and applied to calculate LUT. Therefore, 4 type of LUT's are used for each season (AT : Anmyon type, BT : Beijing type, HT : Hong Kong Hok-Tsui type, PT : Hong Kong Polytechnic University type).

BRDF parameters from MODIS product (MCD43) are used to obtain land surface reflectance due to the change of surface condition. The MODIS BRDF/albedo model parameter product (8-day, 0.5 degree grid) provides the weighing parameters associated with the BRDF model that best describes the anisotropy of each pixel [http://www-modis.bu.edu/brdf/userguide/param.html]. From the spectral response functions of MODIS and of MTSAT-1R visible channels (not shown), it is found that channels 1, 2 and 4 of MODIS overlap with the visible channel of MTSAT-1R. In this study, at first, semi-land surface reflectance is calculated by use of BRDF parameters of these three spectral bands and the geometry of MTSAT-1R measurement such as solar zenith angle, viewing zenith angle and relative azimuth angle. The three semi-land reflectance datasets are then combined into the spectral response function of the visible channel of MTSAR-1R through appropriate weighting.

Under the given surface reflectance and atmospheric conditions, TOA reflectance at visible range from satellite measurement increase in proportion to increase of aerosol amount. With the known surface reflectance as above, AOD can be retrieved by using calculated LUT through the comparison between TOA reflectance from satellite measurement and those from model calculation. According to analyzing aerosol characteristics, there are 16 kinds of seasonal and regional LUT, and there are 4 kinds of AOD results in each retrieval.

3. RESULT AND VALIDATION

Figure 2 is the comparison result of BRDF method and lower 50 percent boundary dataset is used for both comparisons. We classified the data that AOD faring at the lower 50 % boundary and compared with the results from AERONET to remove cloud effect. The result with BRDF method shows the reasonable correlation with AERONET data over Hong Kong (with correlation coefficients in the region of 0.5 to 0.7). With this method, validation result represents variation of R from 0.5 to 0.8, but 'without BRDF method' shows this variation from -0.4 to 0.8 (not shown). Generally, AOD with BT model shows best correlation coefficient and that with PT shows best fitting line. Validation result suggests that applying BRDF is mostly effective over Hong Kong (Polytechnic University) and more challenge remains over Beijing.

One of the dominant error sources in retrieving AOD is assuming aerosol model. In this single visible channel algorithm, we can't estimate the real time aerosol optical properties. In the validation result showed as Figure 2, slopes between AODs from MTSAT-1R and those from AERONET are varying with aerosol type. This fact suggests that the aerosol optical properties applied to calculate LUT are not representing real properties. Ignoring lower AOD case during analysis of aerosol properties by using AERONET products also affects the retrieval accuracy over lower AOD.

The correcting process of BRDF reflectance is another error sources. Correlations between BRDF reflectance and Lambertian reflectance are changing with time (not shown). In point of fact, each pixel has different correlation by varying characteristics of surface reflectance. That is the reason why the validation result over Hong Kong region has shown markedly improvement. So, to apply BRDF more accurately, pixel by pixel correcting process is required. Additionally, cloud masking process is important to understanding distribution of aerosol without noise signal.

4. EXAMPLE

On 21 March 2010, sand and dust spread southward along Taiwan Strait to affect the southern part of China. The time sequence of MTSAT-based AOD maps is shown in Figure 3. It could be seen that an area of higher AOD spread southwards during the day. Such maps would be useful in monitoring the southward movement of the sand and dust weather over Taiwan Strait and along the southeastern coast of China.

The MTSAT-derived AOD values are compared with those obtained by MODIS. The period of study is from 15 to 31 March 2010. Only daytime images of 00:30, 03:30 and 06:30 UTC are considered. All the values are averages over an area of 0.3 degrees by 0.3 degrees. The comparison results are shown in Figure 4. It could be seen that the two datasets correlate well with each other.

5. CONCLUSIONS

AOD at 0.55 μm is retrieved in East Asia from a single visible channel onboard the geostationary satellite. Calculated LUT with aerosol properties over East Asia analyzed from the long term AERONET retrieval data is used also. By utilizing this algorithm, AOD distribution in East Asia can be obtained with high temporal resolution. However, a single visible algorithm has limitation in estimating surface reflectance due to clear-sky assumption over a previous period. To overcome these limitations, MODIS BRDF parameter at channels 1, 2 and 4 are used to correct surface reflectance. The comparing result shows that the application of BRDF in retrieving surface reflectance have the potential in retrieving more accurate AODs from geostationary satellites. However, cloud masking process and more stable aerosol model is necessary to reduce retrieval errors.

References

Kim, J., J.M. Yoon, M.H. Ahn, B.J. Sohn, and H.S. Lim, 2008: Retrieving aerosol optical depth using visible and mid-IR channels from geostationary satellite MTSAT-1R. *International Journal of Remote Sensing*, **29**, 6181 – 6192.

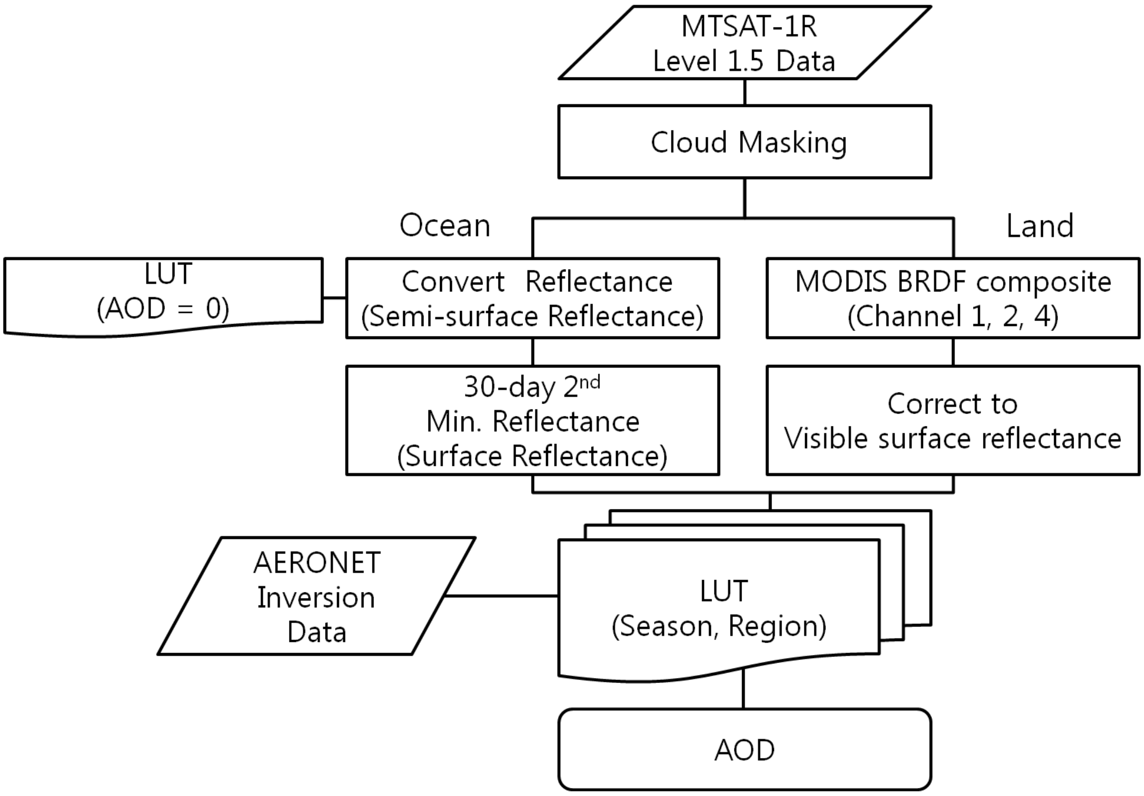

Figure 1 The flow chart of aerosol retrieval algorithm in this study.

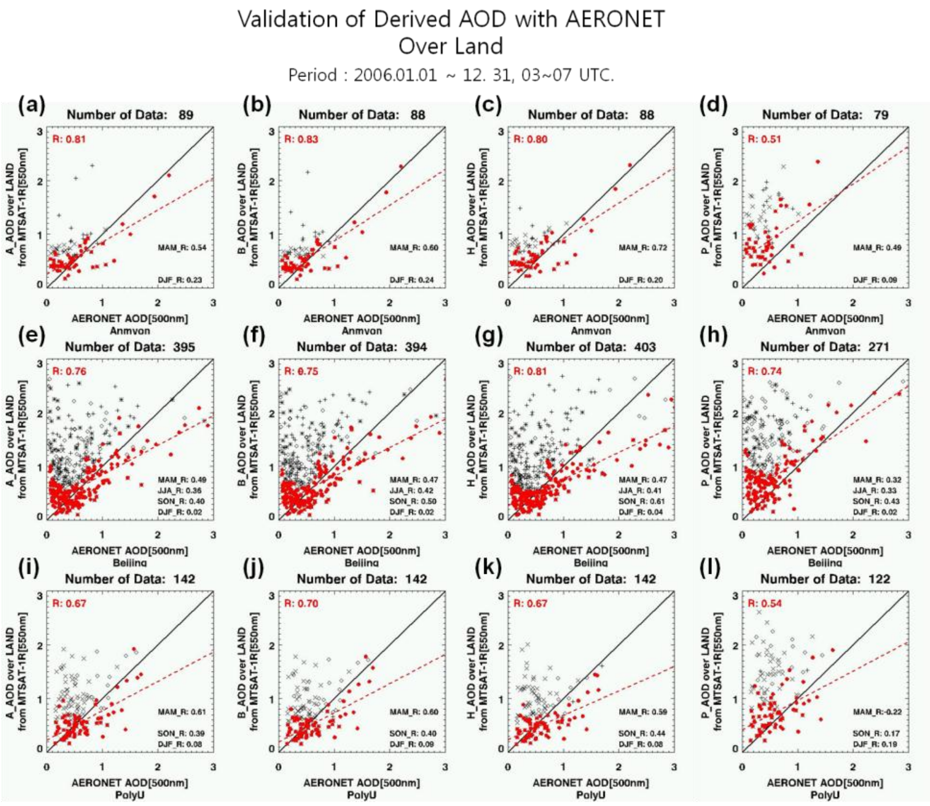

Figure 2 The comparison between AODs over land derived from MTSAT-1R (550 nm) with aerosol model against measurements from AERONET (500 nm). Aerosol model: (a), (e) and (i) - Anmyon type; (b), (f) and (j) - Beijing type; (c), (g) and (k) - Hong Kong Hok Tsui type; (d), (h) and (l) - Hong Kong Polytechnic University type. Each point symbol indicates season (MAM : plus sign (+), JJA : asterisk sign (*), SON : diamond (◇), DJF : x) and red circle shows the dataset in lower 50% boundary. The black solid line is 1 to 1 line and red dashed line is regression line for the red data points.

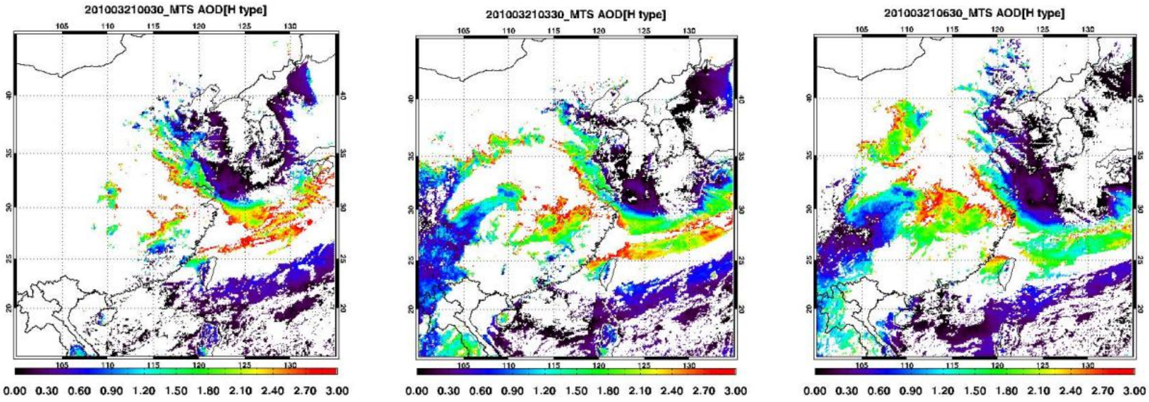

Figure 3 MTSAT AOD maps at 00:30 UTC (left), 03:30 UTC (middle) and 06:30 UTC (right), 21 March 2010.

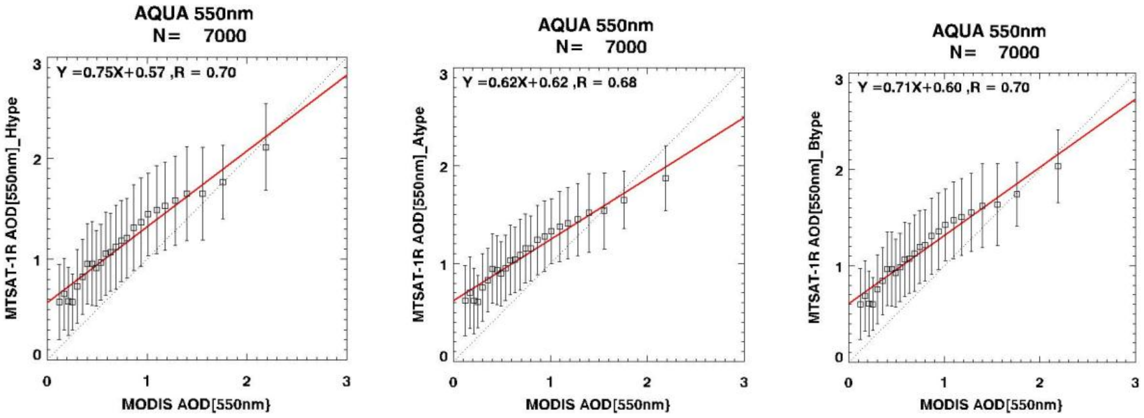

Figure 4 Comparison between MTSAT AOD and MODIS AOD in the period 15 – 31 March 2010: 00:30 UTC of all days (left), 03:30 UTC of all days (middle) and 06:30 UTC of all days (right).