Remote Sensing of Atmospheric Aerosol and Ocean Color for the COMS/GOCI

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ABSTRACT

The Geostationary Ocean Color Imager (GOCI) on board the Communication Ocean Meteorological Satellite (COMS) requires accurate atmospheric correction for the purpose of qualified ocean remote sensing. Since its eight bands are affected by atmospheric constituents such as gases, molecules and atmospheric aerosols, understanding of aerosol-radiation interactions is needed. Aerosol optical properties based on sun-photometer measurements are used to analysis aerosol optical thickness (AOT) under various aerosol type and loadings. It is found that the choice of aerosol type makes little different in AOT retrieval for AOT<0.2. These results will be useful for aerosol retrieval of COMS/GOCI data processing.

Keywords: GOCI, COMS, aerosol, AOT

1. INTRODUCTION

Remote sensing of the atmospheric aerosols from ocean color sensors on satellite has been the convenient technique to obtain spatial and temporal information on aerosol distributions. In contrast, aerosols can interfere with the primary measurements of ocean parameters for the sensors observing spectral range from UV to near IR. In all cases, there is a need to develop and validate the algorithm to infer the aerosol properties from the satellite-based observations. During the past few decades lots of aerosol retrieval algorithms have been developed to characterize the global or regional scale distribution of aerosol properties with various ocean color sensors, such as CZCS, OCTS, Sea-viewing Wide Field-of-view Sensor (SeaWiFS), the Moderate Resolution Imaging Spectroradiometer (MODIS) [1, 2].

The Geostationary Ocean Color Imager (GOCI) instrument on the Communication Ocean and Meteorological Satellite (COMS) platform developed by Korea Aerospace Research Institute (KARI) include 8 narrowband channels covering similar wavelength ranges to SeaWiFS which is reflected solar radiation between 0.412 and 0.865μm but at a much higher spatial resolution (500m at nadir). After the launch, it will provide advanced capabilities to detect, monitor, quantify, and predict short term changes of ocean or atmospheric environment. The GOCI observing area, 110~150E and 21~50N, is quite often affected by heavy aerosol loads [3], to be providing aerosol information for distribution and correction in oceanic science by relevant aerosol retrieval algorithm. Aerosol retrieval from satellite data requires that highly accurate knowledge of surface reflectance and aerosol microphysical properties requires for the accurate estimation.

In this study, we investigated to develop the aerosol retrieval algorithm for COMS/GOCI. The proposed algorithm, GIST Aerosol Retrieval (GSTAR), is scheduled to be used as off-line procedure for the aerosol retrieval over East-Asia with the GOCI. The algorithms are tested with proxy data generated from existing satellite observations and forward simulations. Furthermore, the errors that could be introduced in aerosol optical thickness (AOT) retrievals due to the assumptions about the aerosol optical properties and ocean nature. Comparisons with SeaDAS and ground-based sunphotometer measurements will be presented.

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The main objective of this study is to develop an aerosol retrieval algorithm for the ocean color sensor of upcoming satellite, the COMS/GOCI, which has similar spectral bands to SeaWiFS. The OPAC aerosol microphysical and optical database is used to model the radiative properties of atmospheric aerosols with different sizes and components for aerosol retrieval over the East Asian regional ocean. Based on the LUT approach, proposed algorithm, GSTAR, employs the spectral shape matching (SSM) method is performed to retrieve aerosol optical thickness (AOT).

2. DATA & METHODOLOGY

The datasets used in this study include SeaWiFS Level-1 (L1) data for aerosol retrieval. The 1-km resolution SeaWiFS L1 data covering the study area (20°~ 50°N, 110°~ 150°E) obtained from NASA ocean color data archive (http://oceancolor.gsfc.nasa.gov/) were collected and the SeaWiFS L2 data at eight visible bands (0.412, 0.443, 0.490, 0.510, 0.555, 0.670, 0.765, 0.865 μm) are well-known for aerosol retrievals [4, 5]. Currently, 11 years (1997-2008) observation data were collected. SeaWiFS Level-2 (L2) aerosol products [Gordon and Wang] and ground based AERONET sunphotometer measured aerosol property data (http://aeronet.gsfc.nasa.gov) are also used for the comparison purpose.

Figure 1 shows the study area for aerosol retrieval in this study and it also shows the locations of available AERONET sites selected for the consistency checks. At these AERONET sites, spectral AOTs and angstrom exponent (α) values are derived from Cimel sunphotometer measured direct sun beam and aureole radiances [6]. Quality-assured Level 2.0 AERONET data (version 2.0) are used to estimate the optical and microphysical properties of atmospheric aerosols in this study.

There exists an inherent problem in determining ocean surface reflectance for aerosol retrieval, since photons reflected by the surface (or near surface) reach the satellite after they transmit through the atmosphere. In order to solve this problem, the following radiative transfer equation has been introduced to determine aerosol reflectance by separating surface reflectance and Rayleigh path radiance from TOA reflectance. In the current study, forward radiative transfer calculations of spectral radiances with aerosol models from OPAC [7] were made using the Santa Barbara DISTORT Atmospheric Radiative Transfer (SBDART) code [8] which computes plane-parallel radiative transfer in the Earth’s atmosphere. The collection of radiance spectra was then used in the spectral shape matching (SSM) technique [3], in order to determine AOT of best fitted aerosol model in a SeaWiFS image. As shown in Figure 2, the process therefore has two main parts: 1) forward calculations using SBDART, and 2) application to SeaWiFS data for inversion process.
To calculate the spectral radiances, 7 aerosol models with 8 RH provided by the OPAC served as input parameters for SBDART. Aerosol extinction, SSA, and asymmetry parameters are examples of such parameters. Figure 3 shows the six aerosol models used in this study. Bidirectional reflectance distribution function (BRDF) for ocean surface, which includes the Fresnel reflection off the surface waves, reflection by whitecaps, foam, underwater scattering (sediments, chlorophyll, etc), is also used. The surface level wind speed for the Fresnel reflection and foam calculations is assumed fixed at 6.0 m/s. Due to variable/unknown ocean color properties from chlorophyll and sediments, we used default values provided in the SBDART.

Using the SBDART, spectral radiances \( L(\lambda) \) were computed for each of 7 aerosol models associated with 8 RH for all possible combinations of preset values which are 12 AOT at 550nm (0–4.0), 17 sun zenith angles (0–80°), 17 satellite viewing angles (0–80°), and 13 relative azimuth angles (0–180°), respectively. Total number of combinations of calculated hypothetical radiances and AOTs at the eight bands is 20,197,632. Radiances then can be converted to spectral reflectance \( \rho_{\text{TOA}} \) as:

\[
\rho(\lambda) = \frac{\pi \cdot L(\lambda)}{F_0(\lambda) \cdot \cos \theta_0}
\]

Where, \( \theta_0, \theta_s, \theta_r \) are sun zenith, satellite viewing, and relative azimuth angle, respectively. \( F_0(\lambda) \) is extraterrestrial solar irradiance.
Given the observation geometry for the satellite measurement, the modeled satellite reflectance is interpolated in the step-sized LUT. Then the SSFA was executed through the iteration with minimum RMSE. If best fitted model is found, AOT can be converted from the measured reflectance using selected LUT. The maximum allowable root mean square error, RMSE, was set to 1%.

3. SENSITIVITY STUDY

Satellite aerosol retrieval algorithm relies on simplified assumptions concerning the aerosol optical properties and earth’s surface. LUTs currently used in aerosol retrievals from SeaWiFS have been made by RTM calculations by using microphysical and optical properties of aerosols (e.g. size distributions and complex refractive indices) from the OPAC model. These are not necessarily representative of the actual aerosol present in the atmosphere being observed. Validation and inter-comparison studies indicated that the current models may not be optimal. To explore this issue, this paper examines the sensitivity of retrieved AOT to changes in the sensor’s calibration, aerosol size distribution, absorption. The uncertainty $\Delta \tau$ on the AOT retrieval is calculated as;

$$
\Delta \tau = \sqrt{(\tau_{\text{satellite}} - \tau_{\text{modelled}})^2}.
$$

Satellite observed radiance may contain a systematic error due to an instrumental calibration error. Per the uncertainty from the reported SeaWiFS calibration study [9], a range of uncertainty, 1–5%, is considered. The resulting AOT retrieval error is very small: $\Delta \tau = 0.021 \pm 0.018$. The lognormal size distributions for different aerosol models from OPAC were used for the sensitivity analysis of the AOT retrieval. 10% of uncertainty in $r_i$ and $\sigma_i$ are assumed for each aerosol model gives $\Delta \tau = 0.0012 \pm 0.001$. Significantly, SSA errors ranging from 0 to 0.1 increase with aerosol loading and show largest. The errors are expressed as a function of AOT ($\Delta \omega / \Delta \tau \times 100$) 5–38%. The other parameters affecting aerosol retrieval such as particle shape, RH, and surface reflectance are currently on investigating.

4. RESULTS

The AOT was derived for the whole SeaWiFS measurements during 11 years over the study region, excluding cloud-contaminated pixels. Comparison results between GSTAR AOT and AERONET sunphotometer AOT at each site location are shown as Figure 3. SeaWiFS data were selected nearest location to the AERONET site (i.e. within 3 by 3 pixels), and sunphotometer data nearest in satellite scanning time (i.e. ±30minute) were taken for the comparison. SeaDAS AOT retrieval results were also compared with those from AERONET sunphotometer data in order to verify our GSTAR AOT data (Figure 3). The correlation coefficients obtained from these comparisons are 0.87 and 0.42, respectively, which indicate that GSTAR has better retrieval.

Spatial distributions of the 11year mean AOT at 555nm obtained by the GSTAR-AOT and SeaDAS-AOT are shown in Figure 4. In this figure, AOT distribution over study region is visually shown well in the given color scale as different colors. It is interesting to note that, although two products show a similar distribution each other, GSTAR-AOT values obtained by this study provide much larger and more detail than those from the SeaDAS-AOT. SeaDAS-AOT shows a similar distribution and gradient of AOT, it shows relatively lower than AERONET results (see Figure 4), probably due to use of the low threshold of aerosol reflection. Underestimated surface reflectance separated from satellite signal seems to be the reason for that.

The SeaWiFS data consist of an enormous amount of data which are valuable for understanding ocean-atmosphere interaction. The analysis here shows that the aerosol microphysics introduces a complicating factor in satellite retrieval, so that the better understanding of aerosol intensity and spatial distribution needs to be made by combining reasonable assumptions and parameters. Further, careful cloud masking must be accomplished since ocean color sensors have limited spectral information in longer wavelength.
The Geostationary Ocean Color Imager (GOCI) on board the Communication Ocean Meteorological Satellite (COMS), the first geostationary ocean color sensor, requires accurate atmospheric correction for the purpose of qualified ocean remote sensing. Since its eight bands are affected by atmospheric constituents such as gases, molecules and atmospheric aerosols, understanding of aerosol-radiation interactions is needed.

In this study, we investigated to develop the aerosol retrieval algorithm for COMS/GOCI. The proposed algorithm, GIST Aerosol Retrieval (GSTAR), is scheduled to be used as off-line procedure for the aerosol retrieval over East-Asia with the GOCI. The algorithms are tested with proxy data generated from existing satellite observations and forward simulations. Furthermore, the errors that could be introduced in aerosol optical thickness (AOT) retrievals due to the assumptions about the aerosol optical properties and ocean nature. Aerosol optical properties based on sun-photometer measurements are used to analysis aerosol optical thickness (AOT) under various aerosol type and loadings. It is found

5. SUMMARY

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that the choice of aerosol type makes little different in AOT retrieval for AOT<0.2. Furthermore, the differences between the AOT and angstrom exponent from standard algorithms and this study, and the comparison with ground based sunphotometer observations are investigated. Over the northeast Asian region, these comparisons suggest that spatially averaged mean AOT retrieved from this study is much better than from standard ocean color algorithm. Finally, these results will be useful for aerosol retrieval or atmospheric correction of COMS/GOCI data processing.

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