SURFACE REFLETANCE PRODUCTS FROM THE GEOSTATIONARY ENVIRONMENTAL MONITORING SENSOR

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ABSTRACT: The Geostationary Environmental Monitoring Sensor (GEMS) onboard the GEO-KOMPSAT 2B (GK2B) is the world first geostationary environmental observation sensor. The GK2B satellite is planned for launch in the 1st quarter of 2020, will stationed at 128° East. The surface reflectance is an operational product to be produced in the routinely generated in the GEMS data algorithm. Using advantage of geostationary observation, derivation of directional reflectance with high frequency of observation during short periods is available. To provide the GEMS science teams and other interested users, surface reflectance data including the geometry dependent Lambertian equivalent reflectivity (GLER) and the daily bidirectional reflectance distribution function (BRDF) have been processed for the second stage of algorithm development period. The algorithm has been used to correct atmospheric transmission and create clearest composited reflectance from the OMI l1b data. The comparing between retrieved products and MODIS level 2 surface reflectance during a year showed relative errors of 0.024 and RMSE of 0.029. Because GEMS viewing area is affecting by the heavy air pollutants and rapid topographic change, large perturbations in the satellite observations are anticipated. Therefore, improvement of the algorithm by minimizing these perturbation effects in the next stage of algorithm will be developed.

1. INTRODUCTION

Geostationary satellite views with different solar locations are affected due to the changes of atmospheric transmissions and inhomogeneous surface reflection. Geostationary satellite provides highly temporal observation data that can be used to derive the directional land surface with high temporal frequency. In general, satellite derived surface reflectance products are using a kernel-driven bidirectional reflectance distribution function (BRDF) which is angular dependent and the atmospherically corrected reflection data during daytime observations. For the separation of surface reflection from the total reflectance, radiative transfer simulations coupling with surface-atmosphere has been basically employed in retrieval process.

The Geostationary Environment Monitoring Spectrometer (GEMS), designed to be focused on the environmental monitoring with better spatial and temporal resolutions (300-500nm, ~7km) then the current polar orbit mission such as the Ozone Monitoring Instrument (OMI) (Kim et al., 2019). The retrieval of aerosol or gaseous properties is ill-posed problem due to the relatively strong contribution of the earth's surface reflectance with atmospheric transmission to the radiation measured by the satellite instrument. The Lambertian surface assumption is still widely used in most surface retrieval algorithms for the simplifying the inhomogeneous surface reflection. However, error caused by the assumption of isotropic surface reflection (or Lambertian reflection) can create systematic biases in the aerosol retrieval, because most land surfaces are bright targets at the visible wavelengths. BRDF can be acquired when accurate surface compositions such as land cover type, shape, aspect, shade, etc. are available. With the known surface condition data, radiances observed by the satellite can be estimated theoretically using the radiative transfer model (RTM). The errors in the radiative transfer process were vary from 1% to 40% by comparing the reflectivity values derived by using an BRDF for specific land cover cases with those derived using the parameterized Lambertian assumption (Hu et al., 1999; Franch et al., 2013). From this point of view, surface BRDF simulation will be applicable for the effects on aerosol retrieval for the satellite measurements using the known targets.

In this study, radiative transfer simulations coupling with surface-atmosphere are employed were tested to estimate how much uncertainties are introduced from the Lambertian surface assumption in the GEMS surface reflectance retrieval algorithm. Also, GEMS surface reflectance algorithm has been tested with the proxy satellite data for the evaluation of the performance.

2. METHODOLOGY

TOA reflection defined by the function of satellite measured radiance (L) at a given sun-satellite geometry can be calculated using following the first order radiative transfer equation (1).

$$\rho_{Sfc}(\theta_0, \theta_V, \varphi, \lambda) = \rho_{Atm}(\theta_0, \theta_V, \varphi, \lambda) + \frac{T_0(\theta_0,\lambda)\cdot T_V(\theta_V,\lambda)\cdot \rho_S(\theta_0,\theta_V,\varphi,\lambda)}{1-S_0\cdot \rho_S(\theta_0,\theta_V,\varphi,\lambda)} \quad (1)$$

Where ρ_{TOA}, ρ_{Atm}, ρ_{sfc} are reflectance at TOA, by atmosphere, and surface. θ_0, θ_V, φ, are sun zenith, viewing, and relative azimuth angles. λ is wavelength. T_0 and Tv are the atmospheric transmission for illumination and satellite observation, respectively. S_0 is the hemispheric reflectance. The assumption of a Lambertian reflection can lead to biases in the retrieved values at sun-satellite observation geometry.

The vector radiative transfer model was used to compute spectral radiances due to the difference by the Lambertian and kernel-driven BRDF models. For the Lambertian surface, vegetation type from the ASTER spectral library was used. For the bidirectional surface, two different BRDF models for land and ocean were used in these calculations, which are a land cover directional reflection model defined by kernel functions. Detail descriptions of BRDF models are discussed in the past studies (Lucht et al., 2000; Wanner et al., 1995). For example, BRDF is expressed as a sum of theoretically constructed kernel functions $K_i(\theta_0, \theta_V, \varphi)$ and the reciprocal model uses three kernels (Ross, 1981).

$$\rho_S(\theta_0, \theta_V, \varphi, \lambda) = F_{iso} + F_{vol} K_{vol} + F_{geo} K_{geo} \quad (2)$$

where F_{iso}, F_{vol} and F_{geo} are linear kernel coefficients representing the isotropic, volumetric and geometric components, respectively. K_{vol} and K_{geo} represent volumetric scattering and geometric-optical mutual shadowing model of surface objects (Roujean et al., 1992; Li and Strahler, 1992). For the satellite retrieval, the algorithm has been designed to the modified previously developed algorithms such as OMI and MODIS surface reflectance algorithms (Strahler et al., 1999).

3. RESULT

Figure 1 shows an example of the differences in the simulated reflectance with Lambertian and BRDF models at the selected wavelengths (415nm, 500nm, 665nm, and 862nm) at TOA under the clear sky condition (no aerosols and clouds, θ_0=50°). The radial axis represents the satellite view angle, and the tangential axis represents the relative azimuth angle. The results show that Lambertian reflection tends to agree with that of bidirectional reflection for the satellite view angle range of 20° to 30° in the forward scattering direction (-30°<φ < 30°). At reflection differences are largest in the range of large viewing angles from 60° to 80° and their shape is convex whereas the differences are close to concave at longer wavelength. The differences are less for the longer wavelengths because larger surface reflection is resulting. TOA reflectances for different aerosol loads (AOT = 0, 0.5, 1.0, 2.0) in the atmosphere were also estimated. Given the different input parameters referred above, the results for the BRDF cases are assumed to be "truths" and relative differences (RD) is defined as;

$$\mathrm{RD}(\%) = \frac{\mathrm{R}_{Lambert} - \mathrm{R}_{BRDF}}{\mathrm{R}_{BRDF}} \times 100 \quad (3)$$

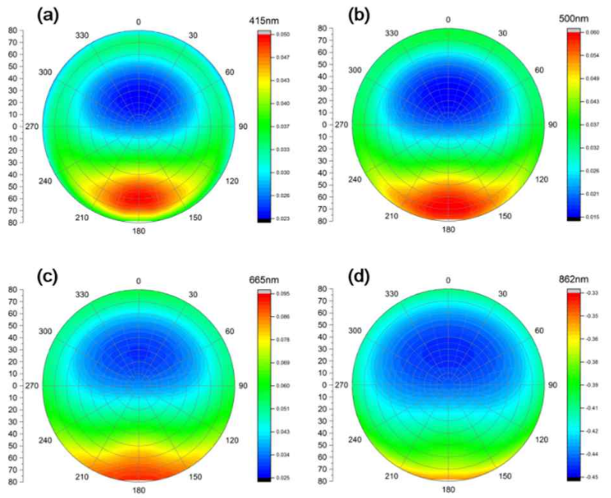

Figure 1. Example of an absolute differences in the simulated radiance between Lambertian and Ross-Li BRDF model at (a) 415nm, (b) 500nm, (c) 665nm, and (d) 862nm (aerosol optical thickness =0.0, sun zenith angle = 50).

The magnitude of the absolute differences (AD) between a Lambertian and bidirectional reflection ($\Delta\rho_{BS\text{-}LS} = \rho_{BRDF} - \rho_{Lamb}$) is significant for aerosol retrieval. East Asian regions are currently undergoing the most rapid industrial development, and indicating that they are particularly generation large air pollutants. Therefore, it is important issue to improve how surface reflection affects the interaction of radiation with the surface at different conditions. Backward scattering region, the RD values are larger than those for forward scattering region. Large differences (RD = 81.15±0.11 %, absolute difference = ~ 0.42) were found in this comparison. In result, the reasonable BRDF model instead of the simple albedo or Lambertian surface models is most appropriate parameter to atmospheric remote sensing. The importance of this interaction between atmospheric transmission and surface reflection is also found which indicates that the TOA reflectances by the larger AOT values are more increasing then BRDF effect.

Figure 2 shows that the examples of the monthly GEMS surface reflectance based on the proxy satellite data. In these monthly images, the performance of the GEMS L2 surface reflectance algorithm was tested using the OMI L1b data.

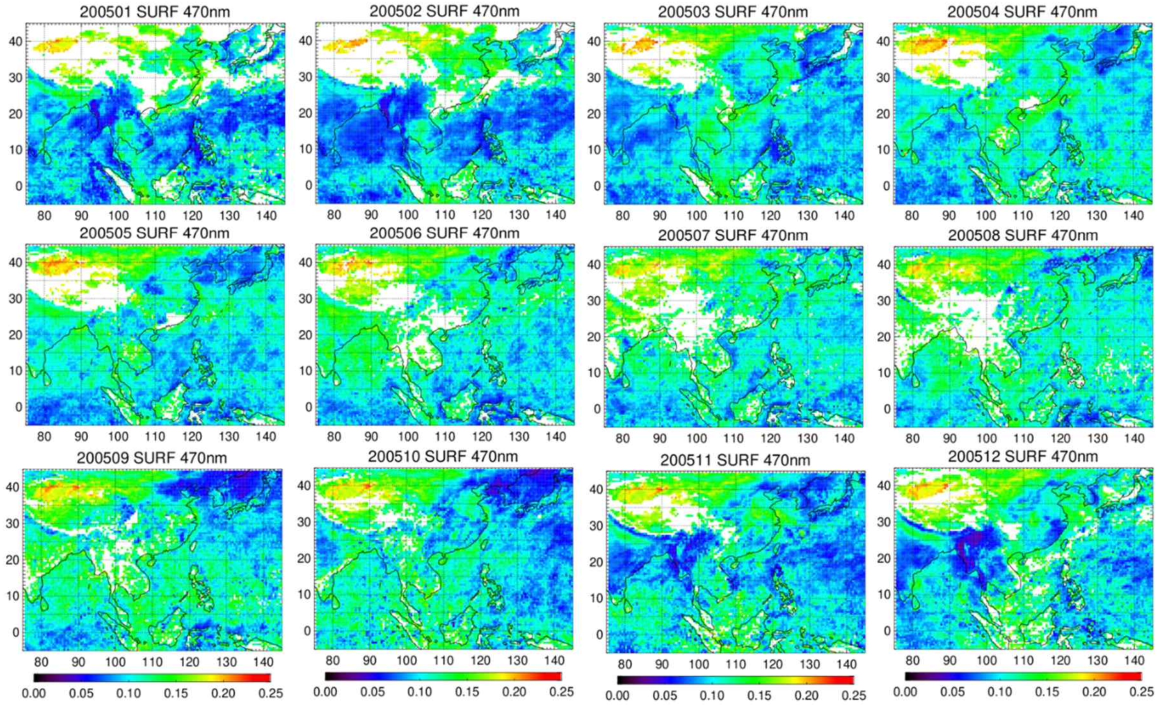

Figure 2. Examples of the monthly GEMS surface reflectance based on the proxy satellite data.

The comparing between retrieved surface reflectance products and MODIS level 2 surface reflectance showed that the retrieved GLER result generally leads to relative errors of 0.024 and RMSE of 0.029. Uncertainty becomes larger for SZA and VZA > 60° and more hazy conditions. The assumption of Lambertian reflection can lead to biases in GLER retrieval using OMI l1b data. The magnitude of the offset is relatively significant compared to the MODIS. GEMS viewing area is currently affecting by the atmospheric pollution and topographic change, indicating that they are systematically sensitive to atmospheric transmission pathways. It is, therefore, important to improve the algorithm by minimizing these perturbation effects in the next stage of algorithm development period.

4. SUMMARY

This study estimated that directional surface reflection has great impacts on aerosol retrieval especially in terms of sun-satellite geometry. Directional surface reflection is recognized as a source of uncertainty in retrieval of atmospheric parameter from the satellite data. Because the uncertainties mainly depend on the anisotropy of the surface target, the more difference exists between the reflectance along satellite observing direction and the measured reflectance. Moreover, the aerosol layer having large optical depth scatter more lights before reaching surface and after reflected by surface, thus surface-atmosphere interaction on satellite measured radiances are not easy to separate each contribution. Thus, reduction of the uncertainty requires a qualitive and quantitive knowledge of the effects of the surface reflection properties on atmospheric remote sensing.

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