Retrieval of Aerosol Single Scattering Albedo Based on Time-Space Sequence Data of Himawari8 Geostationary Satellite

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Abstract. The influence of aerosols on the energy balance of earth atmosphere radiation mainly depends on its aerosol characteristics, such as particle size distribution, chemical composition, and optical characteristics. The optical properties of aerosols have two basic parameters, aerosol optical depth (AOD) and single scattering albedo (SSA). SSA is the ratio of aerosol scattering coefficient to extinction coefficient, indicating the absorption of aerosol, and largely determines the positive and negative aerosol radiative forcing. However, there is still a lack of research on the hourly variation of aerosol absorption. Based on characteristics of high-frequency observations of geostationary satellites Himawari8, a new SSA inversion algorithm using the radiative transfer model parameterized by two-stream approximation is proposed in this paper. We preliminarily obtained the SSA inversion results of China in April to October 2020 and verified with 7 AERONET sites data, showing that the N (total matchups) =156, R (correlation coefficient) = 0.38, and Q_0.05 (the percent of N that fall within the absolute difference of 0.05) = 55.6%. The obtained results will further help to understand the changes of aerosol absorption characteristics on an hourly scale.

1.Introduction

Aerosol not only affects the environment and human health, it directly affects the Earth's radiation budget through the absorption and scattering of sunlight, and indirectly affects the radiation balance through the process of cloud microphysical properties (Hartmann et al. 2013). The influence of aerosols on the energy balance of earth-atmosphere radiation mainly depends on its aerosol characteristics, such as particle size distribution, chemical composition and optical properties. However, there is still a lack of detailed and accurate understanding of the optical properties of aerosols, making aerosol radiative forcing an uncertain factor in the current research on the energy balance of Earth's atmospheric radiation (Hansen et al. 1997). In the past few decades, satellite remote sensing has played an important role in understanding the global distribution of atmospheric aerosols and limiting the climate effects of aerosols. However, according to the assessment of the Intergovernmental Panel on Climate Change (IPCC), the aerosol effect is still the biggest factor causing the uncertainty of radiative forcing (Boucher et al. 2013). The radiative forcing of aerosols recently evaluated is as follows: The 90% probability is between -2.0 W/m2 and -0.4W/m2 (Bellouin et al. 2020).

The optical properties of aerosols have two basic parameters, Aerosol Optical Depth (AOD) and Single Scattering Albedo (SSA), which reflect the influence of aerosols on atmospheric radiation. AOD is the vertical integral of the extinction coefficient of the entire atmosphere. It is used to describe the total extinction ability of aerosols on solar radiation, including scattering and absorption, and the asymmetry of the phase function affects the atmosphere. The magnitude of sol radiative forcing (Dubovik et al. 2002). The SSA is the ratio of the aerosol scattering coefficient σ_s to the extinction coefficient σ_e, reflecting the relative magnitude of the aerosol's absorption and scattering of solar radiation, and to a large extent determines the positive or negative of aerosol radiative forcing, that is, heating or cooling (Russell et al. 2002). The size of SSA mainly depends on the complex part of the complex refractive index and the particle size, and the current aerosol radiation transmission model has great uncertainty for the calculated value of SSA.

Based on Himawari8 data and the characteristics of high-frequency observations of geostationary satellites, an SSA inversion algorithm based on the radiative transfer model is proposed in this paper.

2.Data

2.1 Himawari-8/AHI Data

AHI onboard Himawari-8 has 16 channels, including three visible (VIS) channels (0.47, 0.51, and 0.67μm), three near Infrared channels, 10 mid and thermal infrared channels. With a spatial resolution of 0.5 – 2 km for different channels at the subsatellite point. AHI provides a full-disk observation every 10 min, which provides data to obtain the aerosol information with high temporal resolution.

In this paper, the VIS channel data are used for the AOD retrieval. The AHI Level 2 calibrated data and navigation data (including latitude, longitude, solar and sensor zenith angle, and azimuth angle) were collected from the Japan Aerospace Exploration Agency Earth Observation Research Center (http://www.eorc.jaxa.jp/ptree/terms.html)

2.2 AERONET Data

Sun photometer measured AODs from AERONET stations were used for the evaluation of the retrieved AOD from AHI. There are three levels of AERONET data (http://aeronet.gsfc.nasa.gov). In order to further guarantee the quality of AERONET AOD datasets, we adopt the Level 1.5 and L2.0 datasets.

3.Model and Method

3.1 Atmospheric Radiative Transfer Model

$$\rho^{TOA}(\theta_s,\theta_v,\varphi) = \rho(\theta_s,\theta_v,\varphi)\exp(-G\tau_a) + \frac{\omega P(\Omega_v,\Omega_s)}{4(|\mu_s|+|\mu_v|)}[1-\exp(-G\tau_a)] + \frac{1}{2\pi[1-g^2(1-|\mu_s|)]}\{(1-g^2)(1+1.5\mu_v)[I_{ms}^{+}(0)-I_{ss}^{+}(0)] + g^2\delta(\mu_v - |\mu_s|)[I_{ms}^{+}(0)-I_{ss}^{+}(0)]\}$$

3.2 BRDF Model

$$\rho_s(\theta_s,\theta_v,\varphi) = f_{iso}(\lambda)K_{iso}(\theta_s,\theta_v,\varphi) + f_{vol}K_{vol}(\theta_s,\theta_v,\varphi) + f_{geo}K_{geo}(\theta_s,\theta_v,\varphi)$$

3.3 Method

The model is based on two-stream approximation, and the atmospheric radiative transfer equation parameterized by this method is used to estimate the value of SSA. In this method, we make the following assumptions: (i)In the N*N pixel window at the same time, the three parameters (f_{iso}, f_{vol}, f_{geo}) of surface Li-Spare BRDF model will change in different pixels, but the aerosol model is stable, that is, SSA and asymmetry factor will not change; (ii)The same pixel at different times, the BRDF parameters and SSA and asymmetry factor will not change. For a single band, K observations, N * N pixel window, only $KN^2 \geq 3N^2 + 2$, and there is a minimum integer solution when K = 4 and N = 2. Since it is a nonlinear equation, we use Genetic Algorithm (GA) to find a numerical solution.

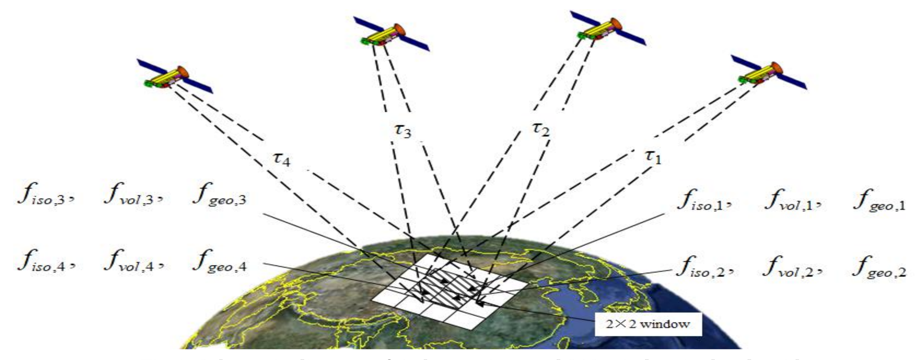

Fig.1. Schematic diagram of 4 observations and 2*2 window in the algorithm

4.Result

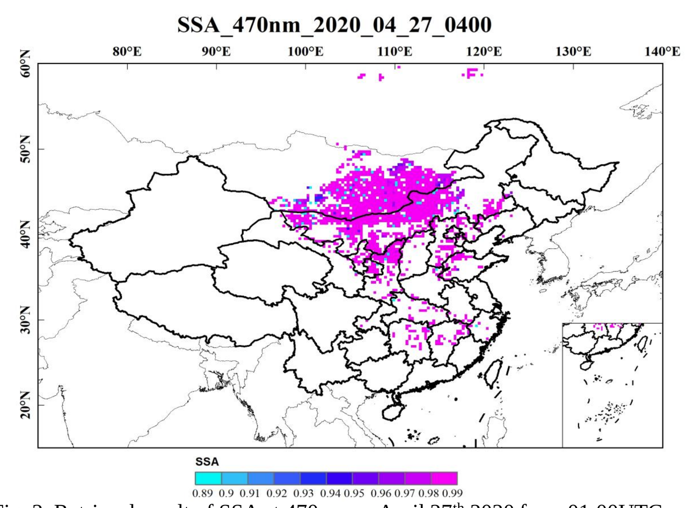

Fig. 2. Retrieval result of SSA at 470nm on April 27th,2020 from 01:00UTC-04:00UTC

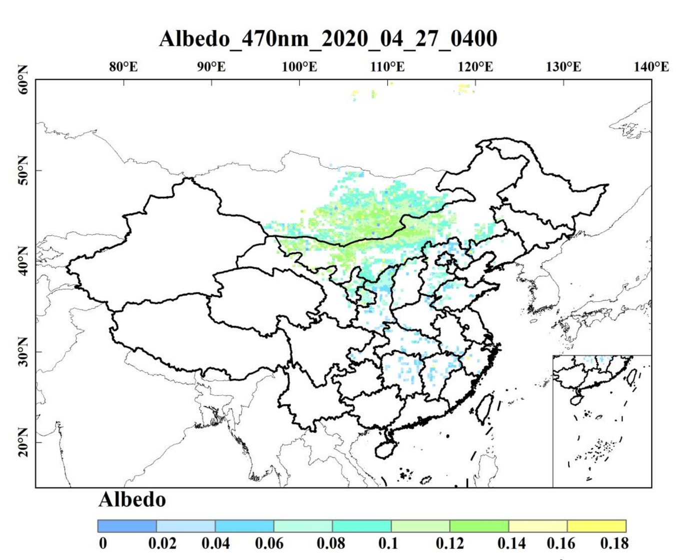

Fig. 3. Retrieval result of Surface Albedo at 470nm on April 27th,2020 from 01:00UTC-04:00UTC

Examples of the SSA and surface albedo results obtained by our inversion are shown in Fig. 2 and Fig. 3. We use the SSA obtained from AERONET ground-based observations to verify the quality of the inverted product. The evaluation parameters used are described in Table 1, and the verification results are shown in Table 2.

It can be seen from Table 2 that the correlation coefficient between the inverted SSA and the currently released SSA product (such as OMI, etc.) is relatively close, and the temporal resolution of the inverted SSA is the best, but Q_0.05 is much smaller than the latter.

Table.1. Error estimate variable description

N	total matchups
R	correlation coefficient
Q_0.05	the percent of N that fall within the absolute difference of 0.05

Table.2. SSA inversion error verification result

N	R	Q_0.05
156	0.38	55.6%

5.Conclusion

5.1 Summarization

In this study, the second-rate approximation model is used, taking advantage of the high-frequency observation characteristics of the Himawari8 geostationary satellite, and using the time-space sequence algorithm to simultaneously retrieve the single scattering albedo of atmospheric aerosols and the surface albedo. From the results obtained, we have obtained the current SSA inversion results with the best temporal resolution and spatial resolution. The inversion result can be used to estimate the change of SSA in a short period of time, and it has great potential for capturing the change of aerosol type in a short period of time.

5.2 Prospect

However, the algorithm still has many areas to be improved.

(i) Only a single band is used, which fails to make full use of the characteristics of geostationary satellite multi-band observations;
(ii) The model itself requires 4 cloud-free observations, and the use of 4 hourly data limits the scope of inversion. Consider choosing the image at the time when the cloud cover is the least in 4 hours to increase the inversion coverage;
(iii) A long-term sequence analysis is required to ensure the stability of the verification results.

Therefore, our future work will work hard to solve these problems, to invert more credible SSA results.

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