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Uncertainties of aerosol retrieval from neglecting non-sphericity of dust aerosols

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The Mie theory is conventionally applied to calculate aerosol optical properties in satellite remote sensing applications, while dust aerosols cannot be well modeled by the Mie calculation for their non-sphericity. It has been cited in Mishchenko et al. (1995; 1997) that neglecting non-sphericity can severely influence aerosol optical depth (AOD, τ) retrieval in case of dust aerosols because of large difference of phase functions under spherical and non-spherical assumptions, whereas this uncertainty has not been thoroughly studied.

This paper aims at a better understanding of uncertainties on AOD retrieval caused by aerosol non-sphericity. A dust aerosol model with known refractive index and size distribution is generated from long-term AERONET observations since 1999 over China. Then aerosol optical properties, such as the extinction, phase function, single scattering albedo (SSA) are calculated respectively in the assumption of spherical and non-spherical aerosols. Mie calculation is carried out for spherical assumption, meanwhile for non-spherical aerosol modeling, we adopt the pre-calculated scattering kernels and software package presented by Dubovik et al. (2002; 2006), which describes dust as a shape mixture of randomly oriented polydisperse spheroids. Consequently we generate two lookup tables ($LUT_{spheric}$ and $LUT_{spheroid}$) from simulated satellite received reflectance at top of atmosphere (TOA) under varieties of observing conditions and aerosol loadings using Second Simulation of a Satellite Signal in the Solar Spectrum – Vector (6SV) code. All the simulations are made at 550 nm, and for simplicity the Lambertian surface is assumed. Using the obtained LUTs we examine the differences of TOA reflectance ($\Delta\rho_{TOA} = \rho_{spheric} - \rho_{spheroid}$) under different surface reflectance and aerosol loadings. Afterwards AOD is retrieved using $LUT_{spheric}$ from the simulated TOA reflectance by $LUT_{spheroid}$ in order to detect the retrieval errors ($\Delta\tau = \tau_{retreived} - \tau_{input}$) induced by straightforwardly utilizing Mie theory in dust aerosol retrieval.

As expected we find that the uncertainties mainly result from the obvious difference of phase functions ($P_{spheric}$ and $P_{spheroid}$). Errors may be positive or negative, depending on the specific geometry. In scattering angle (Θ) regions where $P_{spheric}$is greater (30º∼85º & 145º∼180º), we generally get positive $\Delta\rho_{TOA}$ and negative $\Delta\tau$, and vice versa (85º∼145º). For low aerosol loading (τ ∼0.25) and black surface, $|\Delta\rho_{TOA}|$ could be greater than 0.004 and 0.012 around Θ ∼120º and Θ ∼170º, with $|\Delta\tau|$ of ∼0.04 and ∼0.12 respectively. In most back scattering cases (Θ >100º), the magnitude of $\Delta\tau$ is about ten times that of $\Delta\rho_{TOA}$, while this ratio ($|\Delta\tau|/|\Delta\rho_{TOA}|$) significantly reduces to as low as ∼0.5 for forward scattering, and can reach ∼20 at Θ ∼145º. Moreover, this errors and $|\Delta\tau|/|\Delta\rho_{TOA}|$ can increase more than ten times as aerosol loading gets higher and surface gets brighter. Therefore we conclude that the neglect of non-sphericity introduces substantial errors on radiative transfer simulation and AOD retrieval. As a result of this study, a representative aspheric aerosol model other than Mie calculation is recommended for inversion algorithms related with dust-like non-spherical aerosols.

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