IRS2012-352
International Radiation Symposium 2012
Dahlem Cube, Berlin, Germany, 06 – 10 August 2012

Sensitivity of multiangle imaging photo-polarimetry to absorbing aerosol properties

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The impact of tropospheric aerosols on climate varies greatly even for relatively small variations in aerosol properties, such as composition, shape and size distributions, and vertical layering. Multi-angle spectropolarimetric measurements have been advocated in recent years as an additional tool to better understand and retrieve the aerosol properties needed for improved predictions of aerosol radiative forcing on climate. The central concern of this work is the assessment of the effects of absorbing aerosol properties in light of measurement uncertainties achievable for the next generation of multi-angle polarimetric imaging instruments. The currently defined requirement (e.g., for the Aerosol-Cloud-Ecosystem (ACE) mission) is ± 0.005 measurement uncertainty in Degree of Linear Polarization (DOLP). In addition, the uncertainty in intensity observations of our simulated instrument was chosen to be 1.5%, which is consistent with the relative camera-to-camera calibration uncertainty for the Multi-angle Imaging SpectroRadiometer (MISR).

We focus on sensitivities to absorbing aerosol layering and refractive indices resulting in various single scattering albedos (SSA) for both spherical and non-spherical absorbing aerosol types. In particular, we consider one flaming smoke type and two smoldering smoke types, whose refractive indices are constrained by direct measurements, and two dust types whose refractive indices are calculated according to observationally-constrained hematite content. The phase matrices for the spherical smoke particles were calculated using a standard Mie code, while those for the non-spherical dust particles were calculated using the numerical approach described by Dubovik et al., 2006.

Modeling experiments were performed to determine how the measured Stokes vector elements in the ultraviolet, visible, and near-infrared (UV/VNIR) range are affected by the vertical distribution, mixing and layering of smoke and dust aerosols, and aerosol SSA. Two vector codes, VLIDORT and a vector successive-orders-of-scattering (SOS) model, which show excellent agreement, were used to calculate the angular distribution of the polarized radiation reflected from layers of aerosol embedded in a Rayleigh scattering atmosphere. The calculations were performed for a range of optical depths from 0.1 to 3.0 for both black and polarizing ocean surfaces. In the blue and UV channels, the scattered light sensitivity to aerosol height and vertical mixing comes from Rayleigh scattering contributions originating above and below the absorbing aerosol layer.

Based on these studies, we demonstrate advantages and disadvantages of wavelength selection in the UV/VNIR range to assess absorbing aerosol properties. In particular, polarized UV channels do not show a significant advantage for absorbing aerosol height or property characterization due to the dominance of the Rayleigh scattering signal. Although the polarimetric sensitivity to SSA is small, it may be non-negligible when attempting to retrieve other aerosol parameters using polarimetric measurements.