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Modeling polarized solar radiation for CLARREO inter-calibration applications: Validation with PARASOL data

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ABSTRACT

The Climate Absolute Radiance and Refractivity Observatory (CLARREO) is a high-priority NASA Decadal Survey mission recommended by the National Research Council in 2007. The CLARREO objectives are to conduct highly accurate decadal climate-change observations and to provide an on-orbit inter-calibration standard for relevant Earth observing sensors. The inter-calibration approach is based on providing highly accurate spectral reflectance measurements from the CLARREO Reflected Solar Spectrometer (RSS) as the reference for existing sensors and to monitor and characterize their response function parameters including gain, offset, non-linearity, optics spectral response, and sensitivity to polarization of light. The inter-calibration of instrument sensitivity to polarization requires on-orbit knowledge of polarization state of light as function of observed scene type and viewing geometry. In this study, we validate polarization parameters calculated with the adding-doubling radiative transfer model (ADRTM) for developing the Polarization Distribution Models (PDMs). These model results are compared with observations from the Polarization and Anisotropy of Reflectances for Atmospheric Science instrument coupled with Observations from a Lidar (PARASOL) data. Good agreement between model results and satellite data is shown for both liquid water clouds and ice clouds. Difference between model results and satellite measurements for clear-sky oceans is explained as due to the presence of undetected clouds, that are super-thin or whose spatial and temporal mean optical depth is small, in the PARASOL clear-sky scenes. These results demonstrate that the ADRTM provides a reliable approach for building spectral PDMs for the inter-calibration applications of the CLARREO mission.

1. Introduction

The Climate Absolute Radiance and Refractivity Observatory (CLARREO) is a high-priority NASA Decadal Survey mission recommended by the National Research Council [1]. The mission represents a calibration laboratory in orbit for the purpose of accurately measuring and attributing climate change. The CLARREO observations will establish new climate-change benchmarks with high absolute radiometric accuracy and high statistical confidence across a wide range of essential climate variables. The CLARREO benchmarks are derived from measurements of the Earth/atmosphere reflectance (320–2300 nm) and the thermal infrared (5000–50,000 nm) spectra, and radio occultation from which accurate temperature profiles are derived. The CLARREO's inherently high absolute accuracy will be verified and traceable on-orbit to Systeme Internationale

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(SI) units. The mission will provide the first orbiting reference calibration standard for other radiometric sensors, essentially serving as a National Institute of Standards and Technology (NIST) in orbit. This will improve the accuracy of measurements a factor from 5 to 10 in reflected solar domain, and the relevance of numerous space-borne instruments for decadal climate change.

The inter-calibration approach in reflected solar wavelength range is based on providing highly accurate spectral reflectance measurements from the CLARREO Reflected Solar Spectrometer (RSS) as the reference for other radiometric sensors and to monitor and characterize their response function parameters including gain, offset, nonlinearity, optics spectral response, and sensitivity to polarization of light. Measurements of many satellite radiometric instruments have some dependence on the polarization state of the reflected light from the Earth–atmosphere system. The radiance errors solely due to light's polarization and the sensors' polarization dependence could decrease the measurement accuracy below the requirement of a reliable climate modeling [1–3]. To correct the polarization-caused errors in the solar radiance measured by various satellite sensors, the polarization state of the reflected light at the top of atmosphere (TOA) must be well known. At the 3 wavelengths of 490, 670, and 865 nm, the Polarization and Anisotropy of Reflectances for Atmospheric Science instrument coupled with Observations from a Lidar (PARASOL) data [4,5] can be used to obtain the polarization distribution models (PDMs) empirically [2]. However, to obtain the PDMs for the solar spectra from 320 to 2300 nm at which the CLARREO will perform the inter-calibrations with various space-borne sensors, spectrally modeling the polarized solar radiation at TOA cannot be avoided [3]. In Sun and Lukashin [3], the adding-doubling radiative transfer model (ADRTM) for modeling the polarized solar radiation from the ocean–atmosphere system is reported. The ADRTM results are also compared with those from the discrete ordinate method [6]. However, it is essential that the validity of a theoretical model should be examined, not

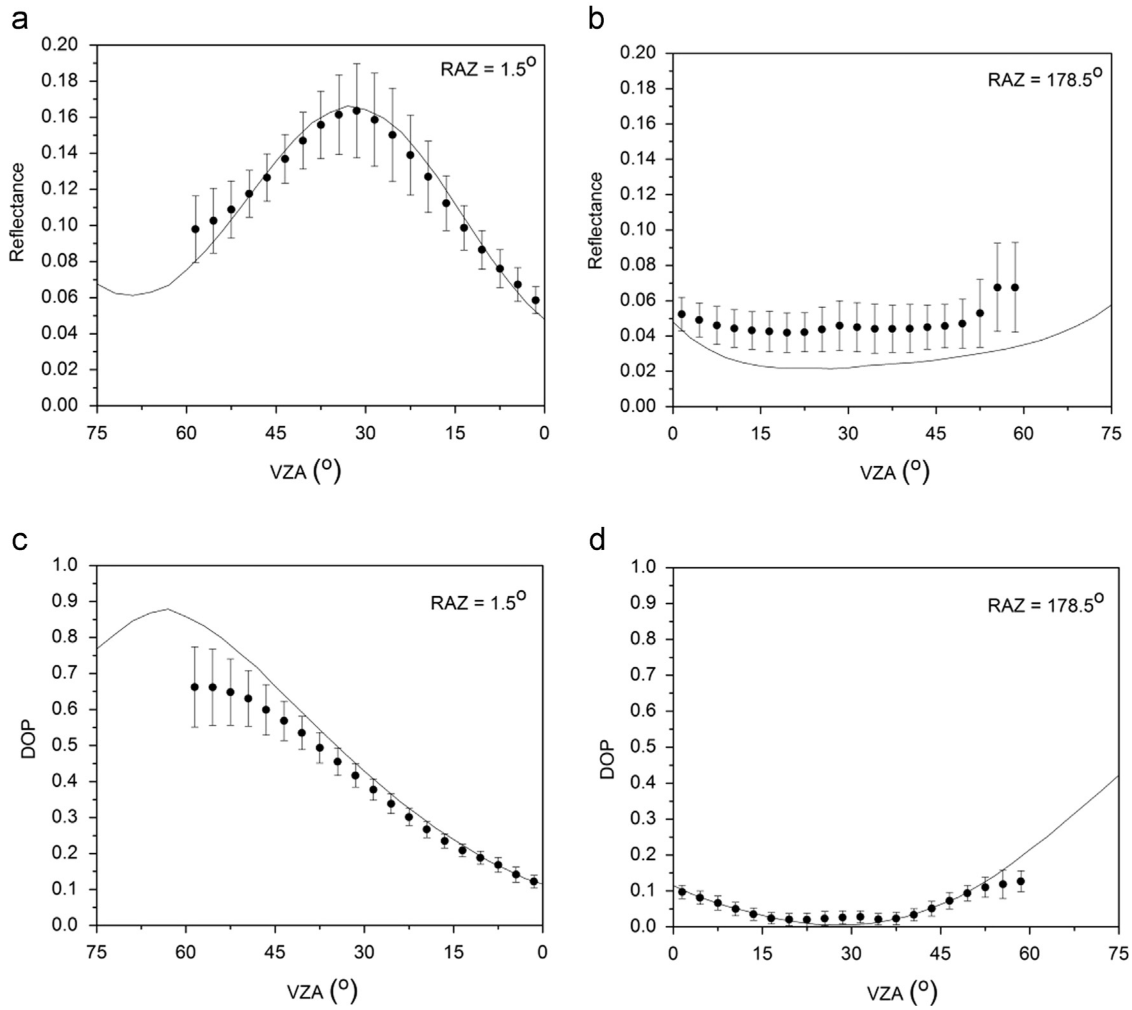

Fig. 1. Total reflectance and DOP at 670 nm from PARASOL data for clear-sky oceans averaged in a SZA bin of 27–30° (black dots) and ADRTM results at a SZA of 28.5° (solid curve). Also shown are the standard deviations of the PARASOL data. The PARASOL data are from the 24-day measurements for a wind speed range of 6 to 9 m/s. In the modeling, the wind speed is 7 m/s, the sea-salt aerosol optical depth (AOD) is 0.06 at the wavelength of 670 nm, and the US standard atmosphere is used.