Geophysical Research Abstracts
Vol. 17, EGU2015-8415, 2015
EGU General Assembly 2015

Cloud shortwave radiative effect and cloud properties estimated from airborne measurements of transmitted and reflected light

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Surface cloud radiative effect, or the perturbation of sunlight by clouds, is often estimated by cloud properties retrieved from reflected sunlight, however transmission-based retrievals may lead to a more representative surface radiative effect than reflection-based counterparts. Transmitted light interacts with cloud particles throughout the vertical extent of the cloud, while reflected light, commonly used for satellite remote sensing of clouds, is more influenced by the top-most cloud particles. We showcase the difference in measurement-based estimates of cloud radiative effect at the surface when using transmitted light instead of reflected light for particular cases during recent field missions. Along with cloud radiative effect, we present the retrieved cloud properties based on light transmitted and reflected by clouds in the Gulf of Mexico, sampled during the Studies of Emissions and Atmospheric Composition, Clouds and Climate Coupling by Regional Surveys (SEAC4RS), and in the Gulf of Maine, sampled during the Two-Column Aerosol Project (TCAP).

To quantify cloud properties from transmitted shortwave radiation, a new retrieval utilizing spectrally resolved measurements is employed. Spectral features in shortwave radiation transmitted through clouds are sensitive to changes in cloud properties including cloud optical thickness, effective radius, and thermodynamic phase. The absorption and scattering of light by liquid water and ice clouds result in shifts in spectral slopes, curvatures, maxima, and minima of cloud-transmitted radiance. A new framework is introduced to quantify these spectral features that are observed in measured and modeled transmittance. This new framework consists of 15 parameters that are independent of spectrally neutral variations in radiometric calibration quantifying spectral slopes, derivatives, spectral curvature calculations, and ratios. These parameters are used to retrieve cloud properties from measurements of zenith radiance from aircraft by using the Spectrometer for Sky-Scanning, Sun-Tracking Atmospheric Research (4STAR) instrument. The 4STAR instrument was deployed on an airborne platform during SEAC4RS and TCAP.

During SEAC4RS, the Solar Spectral Flux Radiometer (SSFR) was also deployed alongside 4STAR. The cloud optical thickness and effective radius from the retrieval based on transmitted shortwave radiation are compared to cloud properties obtained from above the cloud by using reflected shortwave radiation measured with SSFR, with the enhanced MODIS Airborne Simulator (eMAS), with the Research Scanning Polarimeter (RSP), and from in situ cloud probes. For TCAP, we compare cloud properties retrieved using 4STAR and the Moderate Resolution Imaging Spectroradiometer (MODIS).