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Correcting for 3D Radiative Effects in the Estimation of Cloud Properties from Reflected Solar Radiation

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Polar-orbiting and geostationary satellite imagers provide a unique view on clouds and their role in the climate system. While current active satellite sensors offer more direct measurements, they cannot yet rival passive observations in terms of spatial and temporal coverage, and only span a significantly shorter time period. Hence, it is of importance to further improve the retrieval algorithms used to analyze passive satellite images. In particular, the underlying radiative effects of clouds, and their dependence on small-scale variability in cloud properties, are not yet fully understood, and remain an active area of research.

A novel method has recently been proposed by one of the authors to account for the effects of sub-scale variability in the estimation of cloud properties from reflected solar radiation. In contrast to traditional retrievals, it also utilizes the second statistical moment (the covariance matrix) of reflectances in addition to the first moment (mean) as input, and links them to the mean and covariance of cloud properties. This method shows promising results at typical satellite resolutions in comparison to results obtained at higher spatial resolution by adopting the independent pixel approximation. This method of validation does however neglect uncertainties introduced by the 3D radiative effects.

In the present study, we use simulated reflectances generated with the EarthCARE SIMulator (ECSIM) using Monte Carlo radiative transfer calculations in order to investigate the sensitivity of the proposed retrieval to 3D radiative effects. As input scene, a stratocumulus cloud model field corresponding to conditions encountered during the FIRE campaign is used. This approach provides us with known reference data for our evaluation, and allows us to separately study the different mechanisms responsible for uncertainties. Special attention is paid to the effect of horizontal photon transport, and its dependence on wavelength and on sensor resolution. In particular, we investigate the scaling behavior of the covariance matrix of reflectances for typical conservative and absorbing satellite channels. Implications of our finding for the accuracy of cloud properties in the presence of small-scale cloud variability are discussed.