View angle dependence of visible/near-infrared cloud liquid water path retrievals

Á. Horváth

Leibniz Institute for Tropospheric Research, Leipzig, Germany
Tel.: +49-341-235-3530, Fax: +49-341-235-2361, E-mail: horvath@tropos.de

The satellite retrieval of cloud microphysical properties is based on interpreting the measured cloud radiation (brightness temperatures or reflectances) with the help of a radiative transfer model (RTM). Operational retrieval algorithms usually employ a 1D plane-parallel RTM, which is a reasonable choice in the microwave spectral range but which is sensitive to 3D effects at visible/near-infrared wavelengths. The statistical consistency, or lack thereof, of cloud retrievals at different view angles can provide important insights about the validity of the 1D RTM. For example, the flagship visible/near-infrared sensor, the MODIS (Moderate Resolution Imaging Spectroradiometer) instrument, is of a scanner design that views clouds from the overhead direction at the swath center and from highly oblique (>60°) directions at the swath edges. In contrast, the state-of-the-art AMSR-E (Advanced Microwave Scanning Radiometer) microwave instrument is a conical scanner with a fixed 55° incidence angle. Comparing simultaneous cloud observations in these two different imaging regimes and spectral bands allowed us to investigate the importance of 3D effects in MODIS retrievals.

Specifically, we investigated the cross-swath dependence of cloud liquid water path (CLWP) retrievals in one year of collocated AMSR-E and MODIS observations averaged down to the 25-km scale of the microwave sensor. The cross-swath variation of AMSR-E CLWP and that of MODIS cloud optical thickness, droplet effective radius, liquid cloud fraction, and CLWP were determined as a function of cloud heterogeneity and solar zenith angle. We found that microwave CLWPs were generally consistent across the swath, the view angle dependence of visible/near-infrared parameters, however, strongly depended on scene heterogeneity and sun angle. Liquid cloud fraction always exhibited a U-shape, that is, a consistent increase with view zenith angle, but with a slight forward/back scatter asymmetry depending on heterogeneity and solar zenith angle. Cloud optical thickness usually showed a slight/moderate decrease with view angle, especially in the forward scattering direction. In the most heterogeneous scenes and at very low sun, however, optical thickness also had a distinct U-shape, that is, a considerable increase towards swath edges. Droplet effective radius, on the other hand, always increased with view angle, particularly strongly in heterogeneous scenes and at low sun. The increase in droplet effective radius towards swath edges also tended to be asymmetric, with significantly larger values in the forward than in the back scatter direction. The overall view angle dependence of MODIS CLWP was, in turn, the result of the complex interplay among the, sometimes opposite, cross-swath variations of optical thickness, effective radius, and cloud fraction. MODIS CLWP could also show strong and usually U-shaped cross-swath variations in the most heterogeneous clouds at oblique sun; however, such cases represented only a small fraction of all retrievals. The most striking difference between microwave and optical CLWPs was not their view angle dependence, but the very strong increase of optical CLWPs with solar zenith angle, which was lacking in microwave retrievals. Besides the data analysis, we also performed retrieval simulations that managed to reproduce and explain the main features of these observed view dependencies.