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Effects of cirrus spatial heterogeneity and ice particle shape on remote sensing of cirrus optical thickness and effective crystal radius - A case study

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The relative importance of three-dimensional (3D) effects and ice crystal shape of spatially heterogeneous cirrus on the remote-sensing of optical thickness and effective crystal radius is evaluated. In current ice cloud retrievals, the single-scattering properties of ice crystals have to be assumed a-priori. Likewise, the effects of spatial cloud heterogeneity are ignored in current techniques. Both simplifications introduce errors in the retrievals. The study is based on 3D and independent pixel approximation (IPA) radiative transfer calculations. As model input a cloud case that was generated from data collected during the NASA Tropical Composition, Cloud, and Climate Coupling (TC4) experiment is used. First, spectral upwelling radiance fields from the input cloud as they would be sensed by airborne or spaceborne radiometers were determined with 3D radiative transfer simulations. Then the cirrus optical thickness and ice particle effective radius that would be obtained in standard satellite techniques under the IPA assumption were retrieved. The ratios between retrieved and original fields are used as a metric for cloud heterogeneity effects on retrievals. Second, in the retrieval single-scattering properties (crystal shapes) different from those in the radiance calculations were used. In order to isolate ice crystal habit effects, the net horizontal photon transport was disabled here. Thus, the ratios between retrieved and original values of optical thickness and effective radius serve as metric for ice crystal habit effects. When comparing the two metrics, it is found that locally both can be of the same magnitude (up to 50% over- and underestimation), with different dependencies on cirrus optical thickness, effective radius, and optical thickness variability. On domain average, shape effects bias the retrievals more strongly than 3D effects.