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A self-consistent high- and low-frequency scattering model for cirrus

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With the advent of the A-train, that samples cirrus nearly simultaneously, across the electromagnetic spectrum, it is important to construct ice crystal scattering models that are physically consistent across the electromagnetic spectrum. To meet this condition, an ensemble model of cirrus ice crystals has been developed, and combined with a parametrized PSD, to predict the scattering properties of cirrus across the electromagnetic spectrum. The ensemble model consists of six elements, the simplest of which, is the hexagonal column of aspect ratio unity, six-branched bullet-rosette, then hexagonal monomers are arbitrarily attached, creating spatial three-branched, five-branched, eight-branched and finally ten-branched hexagonal aggregates. The ensemble model is combined with a moment estimation parametrization of the PSD, where the moments are linked to each other, via the IWC and in-cloud temperature, through power law relationships. The ensemble short-wave and long-wave scattering properties are predicted using geometric optics and exact T-matrix methods. In the short-wave region, the ensemble model is initially pristine, then successively randomized, to produce featureless phase functions. The short-wave and long-wave bulk-scattering properties are predicted as functions of IWC and cloud temperature, rather than as a function of effective diameter.

It will be shown that the ensemble model, when combined with the parametrized PSD, is self-consistent. In that, it predicts the bulk IWC, mass and effective density of ice crystals that is consistent with new state-of-the-art in situ measurements of bulk IWC. The in situ measurements were obtained from a number of mid-latitude cirrus cases, that occurred over the UK, during the winter of 2010. The ensemble model derived mass- and effective density-dimensional relationships are used to forward model ground-based 94 GHz cloud-profiling radar and space-based AMSU-B microwave measurements, respectively, using the same mid-latitude case. Results of the radar and microwave comparisons will be presented.

The pristine and randomized ensemble model predictions of the solar radiative properties of mid-latitude cirrus are compared against PARASOL directional spherical albedo measurements, as a function of scattering angle, on a pixel-by-pixel basis, to estimate the best ensemble model. Moreover, lidar measurements obtained at 0.355 μm are used to test the ensemble model prediction of the total solar optical depth. The ensemble model predicted solar properties are then used to forward model the high-resolution infrared spectrum from 3.3 to 18 μm. The predicted forward modelled infrared spectrum, is compared against measurements, using an aircraft-mounted high-resolution interferometer. Results of the spectral comparisons will be presented.

The paper demonstrates that it is possible to construct physically consistent single scattering models of cirrus that follow universal power-law relationships, without the need for specific models, which may vary, depending on cirrus type.