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A new high- and low-frequency scattering parametrization for cirrus and its impact on a high-resolution numerical weather prediction model

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The most recent 4th assessment report (2007) of the Intergovernmental Panel on Climate Change (IPCC), concluded that one of the most significant remaining uncertainties in GCMs is the coupling between clouds and the earth's atmosphere. Cirrus is a cloud type where its radiative coupling to the earth's atmosphere is still highly uncertain. The representation of cirrus radiative properties in GCMs is still generally based on a de-coupling between the cloud physics and radiation schemes. In this paper, a new high- and low-frequency parametrization of cirrus scattering properties is presented, that directly couples the radiation scheme to the cloud physics scheme in a GCM.

In this paper, an ensemble model of cirrus ice crystals is used to predict the randomized high- and low-frequency scalar scattering properties of cirrus. The optical properties are parameterized as a function of ice mixing ratio and in-cloud temperature. The ensemble model consists of six ice crystal geometrical models, which vary as a function of ice crystal maximum dimension, the first of which is the hexagonal ice column of aspect ratio unity, representing the smallest ice crystals in the particle size distribution function (PSD). The second element is the six-branched bullet rosette, thereafter, hexagonal elements are arbitrarily attached, forming spatial three, five, eight, and until finally, a ten-branched hexagonal ice aggregate is constructed. The spatial ten-branched hexagonal ice aggregate represents the largest ice crystals in the PSD. In the short-wave, the principle of geometric optics is applied to each element of the ensemble, to predict the scalar optical properties. In the long-wave and in the microwave, the exact method of T-matrix and Mie-Lorenz theory is applied, respectively. In the microwave region, the ensemble model predicted effective density-size relationship is applied to Mie-Lorenz theory to generate the scalar optical properties.

Tropical and mid-latitude PSDs are generated from a parameterization of the PSD; this PSD parametrization relates the shape of the PSD to the ice water content (IWC), and in-cloud temperature (Tc). Therefore, the bulk scalar optical properties are directly related to the GCM prognostic variable IWC and Tc. This new parametrization is more radiatively interactive, with the cloud physics scheme, than previous schemes, due to the removal of the diagnosed quantity, ice crystal effective diameter.

The new ensemble model parameterization has been implemented into an operational configuration of the Met office high-resolution numerical weather prediction (NWP) model. We demonstrate, the impact of the new parameterization on the NWP model, by comparing the forward modelled short-wave and long-wave top-of-atmosphere irradiances with CERES, and forward modelled microwave radiances with AMSU-B. We demonstrate, for the first time, the impact of a new cirrus parametrization on an operational NWP model, which relates directly, GCM prognostic variables to radiation fields.