Geophysical Research Abstracts
Vol. 13, EGU2011-1049, 2011
EGU General Assembly 2011

From ice crystal single-scattering to climate prediction: the way forward?

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The most recent fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) concluded that the radiative coupling between clouds, aerosol and the earth's atmosphere is one of the most significant remaining uncertainties in climate prediction. One cloud type that significantly contributes to this uncertainty in climate change prediction is cirrus. This uncertainty arises because cirrus is composed of non-spherical ice crystals which can vary from simple pristine hexagonal ice columns, plates, bullet-rosettes composed of n-branches, to roughened forms of these particles, which can also combine to form complex ice aggregates. The sizes of these ice crystals can also vary over orders of magnitude as well as their total ice mass or ice water content. With such an array of possible ice crystal shapes/sizes and complexity or randomization(s) the single-scattering properties of cirrus can significantly vary and it is this variability in their light scattering properties that adds to the uncertainty in the radiative coupling between the cloud and atmosphere. The current methods and ice crystal models used for solving the single-scattering properties will be reviewed, as well as the need to physically constrain the single-scattering properties of cirrus using space-based measurements from across the electromagnetic spectrum. The question as to how best to represent the single-scattering properties of cirrus in operational general circulations models (GCMs) is also addressed.

To improve the parametrization of cirrus in GCMs it will be demonstrated that this is best achieved by directly linking the total optical properties to GCM prognostic variable(s) such as ice water content (IWC), and the in-cloud temperature, (state of the atmosphere), where the IWC and in-cloud temperature are linked to a universal particle size distribution function (PSD) generated in the cloud scheme of the GCM. Thus, in this approach the GCM cloud and radiation schemes become physically consistent as opposed to physically inconsistent when the concept of an "effective dimension" is used to construct the cirrus optical property parametrization.

Results from an atmosphere-only 10 year climate run of the Met Office HadGEM3 model will be shown which demonstrates the usefulness of a prognostic variable optical parametrization in highlighting systematic GCM error. Such a diagnosis will ultimately reduce the uncertainty in predicting the radiative coupling between cirrus and the atmosphere.