Geophysical Research Abstracts
Vol. 17, EGU2015-5489, 2015
EGU General Assembly 2015

A Microphysics Guide to Cirrus Clouds

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Cirrus clouds still represent one of the largest uncertainties in the prediction of the Earth's climate (IPCC, 2013) since their microphysical and radiative properties remain poorly or only partially characterized. One major reason is that it is difficult to measure these properties on fast-flying, high altitude aircraft. Another problem is that aircraft measurements cannot capture the evolution of the cirrus clouds properties with time. The most common parameters that are measured in cirrus clouds -besides the meteorological variables- are ice water content (IWC), number of ice crystals (N_{ice}) and relative humidity (with respect to ice, RH_{ice}), and sometimes vertical velocity. However, it is difficult to deduce on the history of ice nucleation and development of microphysical properties from these observations.

Our study aims to provide a guide to cirrus microphysics, which is compiled from an extensive set of model simulations covering the broad range of atmospheric conditions for cirrus formation and evolution. The model results are portrayed in the same parameter space as the field measurements, i.e. in the temperature - IWC parameter space. From this representation of simulated cirrus, we can relate the formation mechanism and history to specific combinations of IWC, N_{ice} and RH_{ice} inside of cirrus as a function of temperature. We validate this analysis approach by evaluating measurements of about 60h in cirrus during fifteen aircraft campaigns conducted in the last fifteen years over Europe, Australia and Southern and Northern America. It can be shown that the field observations indeed show the characteristics expected from the cirrus guide. For example, high/low IWCs are found together with high/low N_{ice}.

As a result it is now possible to track, to a certain degree, the formation mechanism and history of the observed cirrus clouds only from the measurement of IWC and RH_{ice}. Important findings from our study are that (i) a substantial part of thick cirrus with high IWC originates from mixed phase clouds, i.e. via freezing of liquid droplets, while thin cirrus are mainly formed directly as ice crystals, and (ii) the major fraction of the observed cirrus are formed by heterogeneous ice nucleation.