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Formation of ice particles in cumulus clouds over the uk

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The ICEPIC (ICE and Precipitation In Cumulus) campaign is a consortium measurement and modelling experiment between Leeds University, University of Manchester, University of Hertfordshire, University of Reading and the Met Office to look at ice initiation in cumulus clouds. The *in-situ* microphysical measurements aboard the FAAM BAe-146 included the 'standard' particle size distributions from the 2D-C and the Fast Forward Scattering Spectrometer Probe (FFSSP) and also measurements with the Cloud Particle Imager (CPI) and Small Ice Detector (SID) probes. The SID is unique in that it is able to detect the onset of ice particles – *nucleation* - though analysis of a spatial scattering/diffraction pattern of individual particles. The CPI works on the principle of imaging; it takes high resolution images of cloud particles and is able to accurately determine the size distribution of cloud particles and their shape or 'habit' as they grow into precipitation embryos. Sublimating, melting and supersaturated regions can be identified through analysis of the CPI images.

These detailed microphysical observations are an important part of inferring the dominant ice forming mechanism within growing cumulus clouds. Previous literature on this subject has shown that on some occasion's ice particle number concentrations are in accordance with the number of primary IN within the vicinity of the cloud while on other occasion's ice number concentrations greatly exceed the number of primary IN. The detailed microphysical observations made during ICEPIC enable the discrimination between primary ice nucleation on IN and several proposed mechanisms of *secondary* ice particle production (multiplication). For instance, the importance of multiplication during sublimation of ice particles can be looked at through inspection of CPI images; the Hallett-Mossop (HM) riming-splinter process can be inferred

by inspecting the Habits of ice crystals and their temperature regime: vapour grown columns in the vicinity of graupel pellets within the temperature bounds of -3 and -8C are strong evidence for this process.

Cloud penetrations were made in the tops of cumuli as they developed and any ice formation was noted through analysing the microphysical measurements. Generally ice particles were found to form initially with low concentrations in the tops of developing cumuli, perhaps most notably at around -10C. Results from the flying campaign show that in clouds with no strong 'warm' rain process, ice particle concentrations are low, and are in the order of magnitude of that predicted by the Meyers et al (1992) parameterisation for deposition/condensation nuclei; however, with the presence of 'warm' rain we see strong evidence for ice multiplication by the Hallett-Mossop process. The evidence for this process are numerous ice crystals and the co-existence of pristine ice columnar habits and graupel pellets within the Hallett-Mossop temperature regime (-3 to -8C).

Another aspect of the ICEPIC field campaign is the modelling studies that are applied to the specific case studies. This programme uses previous work developed at the University of Manchester in using the Met Office cloud resolving model (CRM) and the Manchester Explicit Microphysics Model (EMM). The eventual goal of ICEPIC is to provide, through parameterisation of very detailed processes, an improved treatment of mixed phase cloud glaciation for larger scale models and numerical weather prediction (NWP).

In this contribution, the main results from ICEPIC observations, i.e. dominant features of cumulus glaciation for several different clouds and also modelling studies directed at these UK cases will be presented for discussion. This will be put into context of the previous literature of similar measurements at other geographical locations.