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Observations of ice production via heterogeneous nucleation in lenticular and layer clouds for temperatures from -7 to -34C

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During the Ice in Clouds Layer Experiment (ICE-L) during November and December 2007, nine flights were conducted in mixed-phase orographic wave clouds (lenticular) and three flights in mixed-phase upslope (stratiform) clouds. The NSF/NCAR C 130 research aircraft carried a suite of instruments and flew sampling patterns that were designed to capture the ice production processes for temperatures warmer than -34C. Eight in-situ instruments were used to collect information on the very first ice particles and the subsequent development: a forward scattering spectrometer probe (FSSP), a fast FSSP, a cloud droplet probe (CDP), a small ice detector (SID-2), a 2D-S (stereo) probe, and a cloud particle imager. A nadir-pointing lidar and an upward and downward-pointing 94 GHz (cloud) radar augmented the in-situ measurements by providing information on the shape of the particles and the evolution as they advected along the wind direction through the initiation, growth and sublimation regions. Properties of the cloud condensation nuclei and the cloud-active ice forming nuclei were also measured. Profiles were flown along and against the wind direction for lenticular clouds and profiles from the top to bottom of the layer clouds for temperatures of -7 to -34C.

As in earlier studies, a wide range of ice concentrations was found within this temperature range. Ice concentrations were highly correlated with the number of ice nuclei available, that is, ice nuclei concentrations are found to be a reliable indicator of the number of ice crystals nucleated. Ice nucleation is found to occur throughout the vertical depth of the wave clouds, not just near cloud top. Ice nucleation also occurs in the rising (upwind) portions of the wave clouds, not just in the descending (downwind) portions. These observations are used to evaluate several hypothesized heterogeneous ice nucleation mechanisms.

The remote sensing observations are evaluated relative to the in-situ ones. A major conclusion is that the particle probes measuring in sub-50 micron sizes may not have adequate sample volumes to discern initial ice production in regions with low ice-crystal concentrations. Polarization lidar has a very large sensing volume and detects the locations of first ice formation, although it is not adequate for making quantitative estimates of number concentrations.