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Lidar observations of ice-nucleating particle (INPC) and ice crystal number (ICNC) concentrations: height-resolved INPC-ICNC closure studies in mixed-phase altocumulus layers

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During the six-week Cyprus-2015 field campaign in March and April 2015, conducted in the framework of the BACCHUS project (Impact of Biogenic versus Anthropogenic emissions on Clouds and Climate: towards a Holistic UnderStanding, collaborative project of the seventh EU framework programme, ENV.2013.6.1-2), we observed the evolution of extended liquid-water altocumulus fields with subsequent heterogeneous ice formation. The altocumulus layers developed in aged Saharan dust layers between 3.5 km (-20°C) and 7.5 km height (-35°C cloud top temperature). We observed such altocumulus developments on 12 days.

By applying our recently developed polarization-lidar method we estimated the ice-nucleating particle concentration (INPC, immersion freezing) at cloud level (before the clouds developed and after their dissolution). Simultaneously performed Doppler lidar observations of the terminal velocities of falling ice crystals in virga below the shallow altocumulus layers allowed us to estimate the ice crystal number concentration (ICNC) of the falling ice crystals. In this retrieval, a realistic ice crystal size distribution has to be assumed. In addition, the volume extinction coefficient of the ice crystals has to be known (to obtain the total ice crystal concentration), and is obtained from the polarization lidar observations by using classical backscatter or Raman lidar retrieval methods. We assume that all ice crystals, which nucleated in the 300-500 m thick altocumulus layers, grow fast (according to the literature to about 100 μm size within 1 minute) and immediately fall out of the main shallow cloud layer so that the derived ICNC values provide us with the number of nucleated ice crystals as a function of cloud top temperature and given INP conditions.

Based on this unique observational approach we investigated, to our knowledge for the first time, the consistency between the INPC and ICNC in mixed-phase clouds. We found reasonable agreement between INPC (immersion freezing) and ICNC for cloud layers with cloud top temperatures between about -20 and -30°C. INPC/ICNC ratios were mostly in the range of about 1-10. However, for lower cloud top temperatures, INPC was often found to be up to two orders of magnitude higher than ICNC. The full analysis results will be presented at the conference.