Laboratory studies on secondary ice production

Mixed-phase clouds are essential elements in Earth’s weather and climate system, exist at temperatures between 0°C and -38°C and are characterized by simultaneously occurring supercooled liquid water droplets and ice particles (Fig. 1). Primary ice particles are formed via a nucleation process. Above approx. -38°C ice nucleation takes place if an ice nucleating particle (INP) catalyzes the process. Aircraft measurements of particular mixed-phase clouds demonstrated a strong discrepancy between the observed ice particle and INP number concentration of one to four orders of magnitude [1-5]. Secondary ice production (SIP) mechanisms as for example mechanical fragmentation of ice crystals, droplet shattering on freezing and ice splinter production due to droplet-ice collisions and ice-ice collisions have been hypothesized which can increase the total ice particle number concentration by multiplication of primary ice particles and hence might explain the observed discrepancy.

Fig. 1: Schematic representation of microphysical processes in a mixed-phase cloud with regard to secondary ice particle production, source: Susan Hartmann/TROPOS.

Fig. 2: SEM (Scanning Electron Microscopy) image of a rimed (small frozen droplets) hexagonal ice crystal published in Rango et al. (2003) [9].
Fig. 3: CFD simulation with OpenFOAM® for chamber design: velocity field around the graupel (gray circle) with trajectories of secondary emitted ice particles (white dots), source: Susan Hartmann/TROPOS.
Here at TROPOS, we focus on a SIP mechanism which is a consequence of droplet-ice collisions, i.e. when small supercooled droplets freeze upon contact with a larger ice particle (rime or graupel, Fig. 2) and eject small ice splinters under certain conditions to be determined. Commonly, this SIP mechanism is known as Hallett-Mossop [8] or rime-splintering process.

The DFG funded project is a joined project together with the Institute of Meteorology and Climate Research of the Karlsruhe Institute of Technology (KIT) and started in spring 2018. The KIT focus on the SIP mechanism of shattering of large freezing droplets.

The main objectives of the project are:

- Development of a new experimental set-up for investigating secondary ice particle production via droplet-ice collision and droplet shattering on freezing
- Identification of the SIP underlying physical mechanisms for both processes
- Quantification of the number of secondary produced ice particles for both processes.

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References: