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Supercooled Droplets and Ice Crystals in Mixed-Phase Clouds: Numerical Simulations Considering Isotropic Turbulence of the Ambient Flow Field

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In midlatitudes the formation and evolution of precipitation is the result of a chain of processes taking place in mixed-phase clouds. Due to the coexistence of supercooled water drops and ice particles in such clouds mutual interactions by collisions, i.e. riming and aggregation, take place leading to ice hydrometeors of a large precipitation size. In the past these collision mechanisms have been investigated - besides laboratory measurements – by numerical simulations of the collision process where trajectories of the participating hydrometeors have been calculated as occurring in an environment at rest (Pruppacher and Klett, Kluwer Academic Publishers, Dordrecht, 1997). However, as it is well-known the flow field in clouds is almost always turbulent (Siebert et al., Atmos. Res. 97 (2010) 426–437) except in undiluted updrafts of single strong convective clouds. And it has been argued that turbulence may enhance precipitation formation. As a consequence turbulence effects on the collisional interaction of cloud and other heavy particles came into focus during the last decade and gave rise to the description in terms of radial distribution function, mean radial relative velocity and the collection efficiency all derived from numerical simulations. Up to now mostly the turbulence influence on cloud droplet/cloud droplet collisions has been investigated (Ayala et al., New J. Phys. 10 (2008) 075015), (Bec et al., J. Fluid Mech. 646 (2010) 527–536).

Much less is known about the influence of turbulence on particles in mixed phase clouds. This is mainly due to the various and complex shapes of the ice particles depending on the temperature, the supersaturation, and their life time. Hence, our knowledge about the behavior of ice crystals in turbulence is based on wind tunnel experiments. In the early stage ice crystals often have the shape of hexagonal plates or needles. In theoretical and numerical studies these are commonly approximated by ellipsoids. However, except in (Pinsky and Khain, Atmos. Res. 47-48 (1998) 69-86) only laminar flows have been considered so far. Therefore we have developed a numerical experiment with a novel setup (Kunnen et al., under review in Atmos. Res. (2013)). Therein synthetic turbulence is generated at the inflow and is then advected by a mean flow through the domain. The full Navier-Stokes equations are solved using a DNS method on an Eulerian Cartesian grid. The evolving decaying turbulence shares similarities with the grid-generated turbulence of wind tunnels. In this flow several million particle spheres as well as ellipsoids are advanced in a Lagrangian manner in order to represent the supercooled droplets and ice crystals out of a small region of a mixed-phase cloud. Statistics will be gathered about the orientation, the sedimentation velocities, the clustering, and the relative velocities of these particles. From this basis collision kernels can be calculated. These are input parameters for cloud models estimating the evolution of precipitation.