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Particle Collisions in Turbulent Mixed-Phase Clouds

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To numerically investigate collisions of small and heavy particles settling in a turbulent environment we introduced a new setup which mimics grid generated turbulence in wind tunnel experiments.
First, the motions of 43 million spherical particles in 20 size classes are tracked using a point particle model. Collisions statistics are gathered at different turbulence intensities in the spatially decaying turbulence (Kunnen et al., 127 (2013), 8-21). We find that turbulence can largely increase the gravitation induced collision probabilities. The collision statistics are validated against the results of other direct numerical simulations (e.g. Ayala et al., New J. Phys. 10 (2008) 075015) and an experimental study with the same setup (Bordás et al., New J. Phys. 15 (2013) 045010). For the latter comparison the large database of numerically determined collision kernels is cast into a fit function (Siewert et al., Meteorol. Z. (2013) under review).
With respect to cloud micro-physics the setup is interpreted as water drops in turbulent clouds and the fit function for the collision kernel can be used to study the impact of turbulence on the droplet growth in warm clouds. However, 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 much less is known about the influence of turbulence on particles. This is mainly due to the various and complex shapes of the ice particles depending on the temperature, the supersaturation, and their life time. 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.
Hence, we extended our particle model to deal with ellipsoids. Depending on the turbulence intensity the ellipsoids preferentially align with the direction of gravity. This is due to the complex coupling of the air turbulence and the particle sedimentation which also causes preferential sweeping, i.e. the increase of the settling velocities due to turbulence (Siewert et al., Atmos. Res. (2013) http://dx.doi.org/10.1016/j.atmosres.2013.08.011). The coupling of the rotational with the translational degree of freedom via the orientation dependent particle drag also leads to different collision probabilities. Comparing spherical and ellipsoidal particles at the same mass and volume we found that collisions of ellipsoids are orders of magnitude more likely (Siewert et al., Phys. Rev. Lett. (2013) submitted for publication). Differently orientated ellipsoids have different gravitation induced settling velocities and due to their inertia they can come into contact with each other featuring these large relative velocities. Due to the same reason the likelihood of particle clustering is reduced. We expect that these effects apply for all kinds of non-spherical particles since the prerequisite of orientation dependent settling velocities is generally fulfilled.
We hope that we can contribute with these findings to the understanding of the aerosol growth and the micro-physical as well as macro-physical properties of mixed-phase clouds such as the radiation budget.