



Enhanced soot particle ice nucleation ability induced by aggregate compaction

Kunfeng Gao^{1,2,3}, Chong-Wen Zhou¹, and Zamin Kanji³

¹School of Energy and Power Engineering, Beihang University, Beijing, China

²Shenyuan Honours College of Beihang University, Beihang University, Beijing, China

³Department of Environmental Systems Science, Institute for Atmospheric and Climate Science, ETH Zurich, 8092 Zurich, Switzerland (kunfeng.gao@env.ethz.ch)

Cirrus clouds have an important influence on the climate since the ice crystal size, concentration and distribution of the clouds determine their radiation properties and effects in the atmosphere. Aviation activities in the high troposphere impact cirrus cloud formation indirectly and significantly, due to aviation contrail evolution and aviation soot particles acting as potential ice nucleating particles (INPs). Soot particles have varying ice nucleation (IN) abilities. In cirrus cloud formation conditions, pore condensation and freezing (PCF) is an important ice formation pathway for soot particles, which requires the particle to have appropriate morphology properties and mesoporous structures. In this study, the morphology and pore size of two kinds of soot were changed by a physical agitation method without any chemical modification. The IN activities of both fresh and agitated soot particles with aggregate sizes, 60, 100, 200 and 400 nm, were tested by the Horizontal Ice Nucleation Chamber (HINC) under mixed phase and cirrus cloud conditions.

In general, the IN results show clear size dependence for particles with the same agitation degree both tested soot samples at all tested temperatures (T) from 218 K to 243 K with a step of 5 K. In addition, all soot particles do not form ice at $T > 235$ K (homogeneous nucleation temperature, HNT) but ice nucleation was observed well below homogeneous freezing relative humidity (RH) for $T < \text{HNT}$, suggesting PCF as the dominating mechanism rather than deposition nucleation. Furthermore, there are significant differences between agitated and fresh soot particles for both soot samples studied. We observed that all agitated soot particles reach a higher particle activation fraction (AF) value at the same T and RH condition, compared to the same size fresh soot particles. Moreover, 200 and 400 nm agitated soot particles require much lower ice saturation values to reach $AF = 0.001$ than their fresh counterparts. The enhanced IN abilities of agitated soot particles are attributed to soot aggregate structure compaction thus increasing mesopore occurrence probability induced by physical agitation. Preliminary evidence obtained from the mass measurements of the single aggregates show that agitated soot particles are more dense than fresh soot particles of the same size. Furthermore, soot aggregate morphology comparisons from HR-TEM (high resolution transmission electron microscopy) images, soot-water interaction ability results from DVS (dynamic vapor sorption) tests and micro-pore size distribution results from argon desorption tests will be used to explain the soot particle IN ability promotion

induced by compaction.