Soot particle ice nucleation ability dependence on their volatile content

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Aviation traffic in the upper troposphere can significantly influence the climate via CO_2 and non-CO_2 emissions. Soot particles, as important non-CO_2 particulate emission, interacting with water vapor in the atmosphere can act as ice nucleating particles (INPs), and are able to impact the aviation contrail evolution and further cirrus clouds formation. The latter has a larger coverage than contrails globally and plays an important role in modulating the Earth's radiative forcing and climate. Therefore, the ice nucleation ability of aviation soot particles is of particular interest.

In this study, the dependence of soot particle ice nucleation ability on volatile content (organics) is investigated at mixed-phase and cirrus cloud conditions. Four types of soot sample can be classified into two classes, first, two types of nonporous propane flame soot used as aviation soot surrogates (Ess and Vasilatou, 2018; Marhaba et al., 2019) and second, two types of porous commercial carbon black with different levels of volatile composition. The results show that thermal denuding at 573 K in a pure N_2 and a compressed air (N_2 + O_2) atmosphere modifies the soot particle ice nucleation abilities in a non-systematic manner between 218 and 233 K. However, the same treatments have pronounced effects on the nonporous propane flame soot particle ice nucleation activities. In particular, our results show that organic carbon removal by thermal denuding in compressed air supresses the ice nucleation ability of organic lean propane flame soot particles at $T < 233$ K. On the other hand, organic rich propane flame soot particles treated at the same conditions have a tendency for an enhanced ice nucleation activity. This is contrary to the previous study that reports organic carbon can considerably supress propane soot particle ice nucleation (Mohler et al., 2005).

In brief, this laboratory study demonstrates that soot particle ice nucleation activities show dependence on particle treatment which potentially affects their properties, inclusion of chemical composition and surface oxidization condition changes, as well as aggregate structure compaction. Thus, transport and ageing in the atmosphere that perturb the chemical properties of soot particle should be considered to accurately reflect ice nucleation activities. The findings about propane flame soot are of significance to evaluate the impacts of aviation emissions and contrail evolution on the climate. In particular, the role of volatile substances like organic carbon coating and its effects on soot particle ice nucleation ability deserve further investigation.

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