

Quantifying the Effects of Phase State on the Ice Nucleation Abilities of Organic Aerosols

Xiaohan Li, Martin Wolf, Xiaoli Shen, Isabelle Steinke, Zhenli Lai, Sining Niu, Swarup China, ManishKumar Shrivastava, Zhenfa Zhang, Avram Gold, Jason Surratt, Daniel Cziczo, Susannah Burrows, YUE ZHANG, *Texas A&M University*

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Abstract

Organic aerosols (SOA) may serve as deposition ice-nucleating particles (INPs) and impact the formation and properties of cirrus clouds when their phase state and viscosity are in the semi-solid to glassy range. However, there is a lack of direct parameterization between aerosol viscosity and their ice nucleation capabilities.

In this study, we experimentally measured the ice nucleation abilities of 2-methyltetrol aerosol particles, a key component of the isoprene-derived secondary organic aerosols (SOA), as a function of aerosol viscosity to examine the effects of phase state on ice nucleation. A kinetic parameterization based on classical nucleation theory is mathematically developed based on experimental data, connecting the physicochemical properties of organic aerosols with their ice nucleation abilities.

Our parameterization not only quantify the effects of viscosity on the heterogeneous nucleation rate, but also revealing that viscosity has a significant impact on the ice nucleation abilities of SOA at typical cirrus cloud conditions, leading to 2 to 3 orders of magnitude differences in the ice nucleation rate from the liquid state to the semi-solid state. Additionally, based on data collected from a previous field study and this parameterization, we have shown that the INP concentration from SOA can reach up to 10 L^{-1} in the cirrus cloud region in the upper troposphere above the Amazon rainforest. Our study highlight the potential importance of organic aerosols in the heterogeneous ice nucleation process, with parameterizations that can be applied in regional and global climate models to further improve understandings of cirrus cloud formation and climate prediction.