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Understanding ice nucleation characteristics of selective mineral dusts suspended in solution

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Introduction & Objectives
Freezing of liquid droplets and subsequent ice crystal growth affects optical properties of clouds and precipitation. Field measurements show that ice formation in cumulus and stratiform clouds begins at temperatures much warmer than those associated with homogeneous ice nucleation in pure water, which is ascribed to heterogeneous ice nucleation occurring on the foreign surfaces of ice nuclei (IN). Various insoluble particles such as mineral dust, soot, metallic particles, volcanic ash, or primary biological particles have been suggested as IN. Among these the suitability of mineral dusts is best established. The ice nucleation ability of mineral dust particles may be modified when secondary organic or inorganic substances are accumulating on the dust during atmospheric transport. If the coating is completely wetting the mineral dust particles, heterogeneous ice nucleation occurs in immersion mode also below 100 % RH.
A previous study by Kaufmann (PhD Thesis 2015, ETHZ) with Hoggar Mountain dust suspensions in various solutes (ammonium sulfate, PEG, malonic acid and glucose) showed reduced ice nucleation efficiency (in immersion mode) of the particles. Though it is still quite unclear of how surface modifications and coatings influence the ice nucleation activity of the components present in natural dust samples. In view of these results we run freezing experiments using a differential scanning calorimeter (DSC) with the following mineral dust particles suspended in pure water and ammonium sulfate solutions: Arizona Test Dust (ATD), microcline, and kaolinite (KGa-2, Clay Mineral Society).

Methodology
Suspensions of mineral dust samples (ATD: 2 weight%, microcline: 5% weight, KGa-2: 5% weight) are prepared in pure water with varying solute concentrations (ammonium sulfate: 0 – 10% weight). 20 vol% of this suspension plus 80 vol% of a mixture of 95 wt% mineral oil (Aldrich Chemical) and 5 wt% lanolin (Fluka Chemical) is emulsified with a rotor-stator homogenizer for 40 s at a rotation frequency of 7000 rpm. 4 – 10 mg of this mixture is pipetted in an aluminum pan (closed hermetically), placed in the DSC and subjected to three freezing cycles. The first and the third freezing cycles are executed at a cooling rate of 10 K/min to control the stability of the sample. The second freezing cycle is executed at a 1 K/min cooling rate and is used for evaluation. Freezing temperatures are obtained by evaluating the onset of the freezing signal in the DSC curve and plotted against water activity values corresponding to the solute concentration (obtained via Koop et al., (2000)).

Observations
A decrease in ice nucleation ability of the minerals (for immersion freezing) with increasing solute concentration (hence, decreasing water activity) was observed, similar as for homogeneous ice nucleation. Though the decrease was more pronounced in case of microcline and ATD as compared to kaolinite. Therefore, there seem to be specific interactions which needs to be studied further to explain the freezing behavior of minerals.

The current study could be helpful in investigating the ice nucleation behavior of individual minerals when present in conjunction with a solute, viz. ammonium sulfate, which is of high atmospheric relevance.

References
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Koop et al., (2000), doi:10.1038/35020537.
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