Ice nucleation ability investigations of atmospheric aerosol samples by environmental scanning electron microscopy

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MOTIVATION

The effects of aerosol particles on heterogeneous ice formation are currently insufficiently understood and is recommended to study the role of IN in clouds (e.g., Levin *et al*., 2007). Modelling studies have shown that the type and quantity of atmospheric aerosol particles acting as ice nuclei can influence ice cloud microphysical and radiative properties as well as their precipitation efficiency. Therefore, a quantitative description of the ice nucleation processes is crucial for a better understanding of formation, life cycles, and the optical properties of clouds as well as for the numerical precipitation forecast.

ENVIRONMENTAL SCANNING ELECTRON MICROSCOPY

Samples are analyzed in an environmental scanning electron microscope (ESEM), which enables in-situ observation of interactions between water vapour and aerosol particles in the sub-micrometer range (Ebert et al., 2002; Zimmermann et al., 2007). The crystallization of ice on the mineral particles in the condensation freezing mode and in the deposition mode is observed by secondary electron imaging, and the supersaturation (for an activated particle fraction of 1 – 3 %) is determined as function of temperature.

Recently the supersaturation-temperature-curves for initial ice formation of the most abundant minerals occurring in desert aerosols (quartz, albite, microcline, kaolinite, montmorillonite, illite, calcite, gypsum, and hematite) in the temperature range typical for mixed-phase clouds were determined by this technique (Zimmermann, 2008).

Kaolinite, illite and hematite are the most efficient IN. The highest temperatures for 1 – 3 % activation vary between -10 °C and -16 °C, and the corrresponding onset relative humidities relative to ice (RH_i) between 107 and 117 %. The temperature dependence of the onset relative humidity is strongly dependent on mineralogy (Figure 1b).

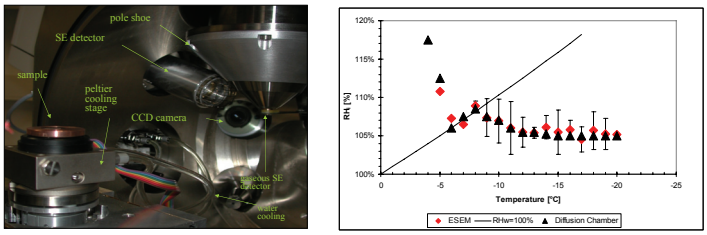

Figure 1: (a) Instrumental setup in the ESEM (b) temperature – supersaturation curve (1 – 3 % activation) for AgI.

IN ABILITY of AMBIENT DESERT DUST

The temperature – supersaturation curve (1 – 3 % activation) were determined for two ambient desert dust samples from Saudi-Arabia, collected in Israel, by in-situ ESEM measurements. The mineralogical composition of the clay-fraction is given in Table 1. The results from the ESEM measurements exhibits, that the IN ability of the total ambient samples is almost identical with the values of the mineral with best IN capability (sample 1: illite; sample 2: palygorskite).

	mineral	sample 1	sample 2
clay minerals	smectite	0.1%	6%
	illite	2.4%	-
	kaolinite	3.5%	17%
	palygorskite	-	17%
non clay minerals	calcite	63%	47%
	quartz	27%	13%
	gypsum	4%	-

Table 1: Mineralogical composition of the clay-fraction (< 2 µm) of two ambient desert dust samples from Saudi-Arabia, collected in Israel.

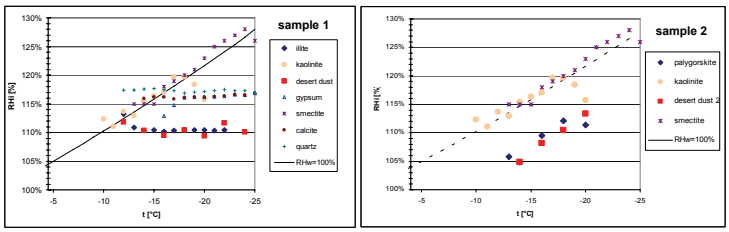

Figure 2: Temperature – supersaturation curves for the two desert dust samples (red) and for the main clay components (sample 1 – left and sample 2 - right).

ANTHROPOGENIC INFLUENCE on IN ABILITY

To study the influence of anthropogenic emissions on the IN-ability of ambient aerosols, aerosol sampling at different metereological situations at Kleiner Feldberg, Germany, was performed. Depending on specific wind direction clean or urban polluted air masses can be found at this location (Ebert et al., 2004). First ESEM-results show that clean air masses always yield more ice crystals than polluted air masses (Figure 3). This can be explained by the enhanced presence of sulphate, nitrate or organic particle coatings in polluted air masses, leading to droplet formation instead of IN.

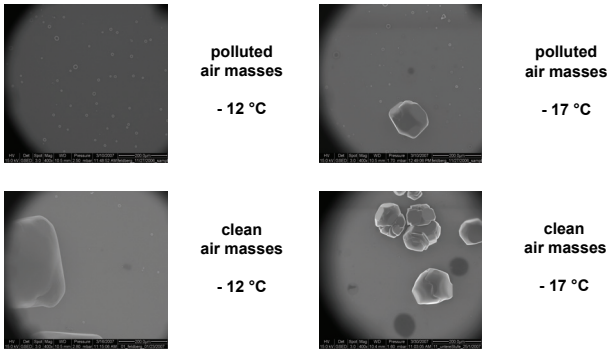

Figure 3: Secondary electron images of growing ice crystals in the ESEM.

CONCLUSIONS

We conclude that initial IN ability of desert dust is entirely determined by the mineral with the best IN capability.

Polluted air masses at Kleiner Feldberg, Germany, show decreased IN-capability, most probably due to enhanced presence of sulphate, nitrate or organic coatings.

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