ICE NUCLEATION PROPERTIES OF SOIL DUST PARTICLES

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1 INTRODUCTION

Aerosol particles exert a significant influence on clouds [1] with mineral dust particles and sea salt residuals being the most abundant aerosol species in terms of mass [2, 3]. However, the composition of atmospheric aerosol is strongly dependent on regional source patterns. Laboratory studies and in-situ measurements have explored the different pathways through which aerosols influence both warm, liquid clouds and ice clouds. Mineral dust particles emitted from arid and desert areas have been identified as potentially efficient ice nuclei under many atmospheric conditions [4, 5]. These mineral dust particles consist mainly of silicates such as kaolinite and quartz. In contrast to these silicate-rich mineral dust particles, soil dust from agricultural areas also contains major amounts of biological components such as plant debris, fungi and bacteria. Some of these biological agents (such as bacteria) have been found to nucleate ice at even higher temperatures than mineral dusts [6, 7, 8]. Thus, it has been proposed that soil dust from agricultural area can act as a very efficient ice nucleus species [9] and thus may have a regional impact on clouds.

In this study the relevance of biological agents for the ice nucleation effiency of soil dust particles is investigated with laboratory measurements at the AIDA cloud chamber facility (KIT, Karlsruhe, Germany). From these measurements a preliminary parameterization for immersion freezing of soil dust particles is developed. Estimated emission fluxes from the COSMO-ART model will be used to calculate upper limits for the contribution of soil dust particles to the global ice nuclei burden.

2 EXPERIMENTAL RESULTS

At the AIDA cloud chamber facility (KIT, Karlsruhe, Germany) the interaction between aerosol particles and clouds is investigated unter atmospherically relevant conditions because the AIDA chamber simulates the ascent of an air parcel through the quasi-adiabatic expansion of humid air within the vessel. Our measurements cover a temperature range from 263 K to 223 K which corresponds to the regime of tropospheric mixed-phase and cirrus clouds.

For a sample from an agricultural area near Karlsruhe, the ice nucleation efficiency was measured and compared to mineral dusts from desert regions.

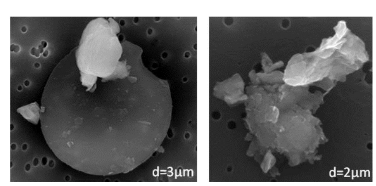

Fig. 1: Electron microscope (ESEM) images of soil dust particles

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Fig.1 shows microscope images of soil dust particles which occur as single particles and complex agglomerates. Biological agents in soil dust particles have been qualitatively investigated by cultivating soil dust on agar plates and by using fluorescence microscopy to visualize dead and living bacteria attached to soil dust particles.

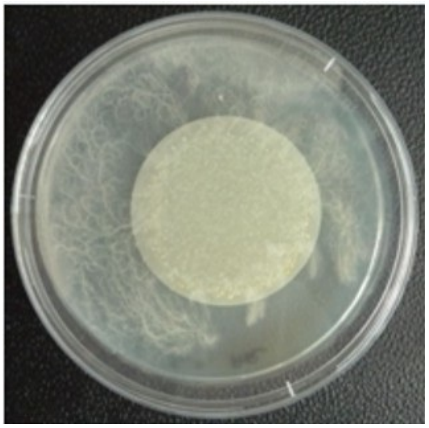

Fig. 2: Agar plate with AIDA filter sample of soil dust particles after cultivation at 20°C (courtesy of A. Rieder)

After dispersion of the soil dust sample within the AIDA chamber, a filter sample was taken and incubated at 20°C on an agar medium. After a day, a close coverage with numerous bacteria colonies is visible (Fig.2) which indicates the presence of viable organisms on the soil dust particles. Fluorescence microscopy images confirm this finding and also show that not only living, but also dead bacteria are attached to the surface of soil dust particles (Fig.3).

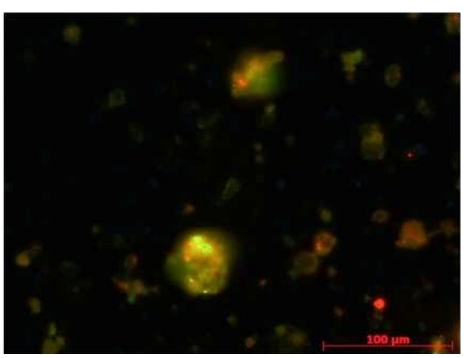

Fig. 3: Fluorescence microscopy image of several soil dust particles with dead (red fluorescence) and living (green fluorescence) bacteria (courtesy of A. Rieder)

The ice nucleation efficiency of the soil dust particles is quantified by the ice-active surface site density n_s which is given by the ratio between the measured ice crystal concentration n and the total aerosol surface A [10]. The ice-active surface site density depends on temperature and saturation over ice. We found indications that for immersion freezing as well as for deposition nucleation the ice nucleation efficiency might be enhanced for organic-rich mineral dust particles in comparison to mineral dusts from desert areas. Exposing the soil dust samples to a higher temperature (T=100°C) leads to a reduction of the ice nucleation efficiency in immersion freezing mode as can be seen from the decrease in ice-active surface site density (Fig.4). This reduction in ice nucleation efficiency might be related to destroying the protein structures of biological agents.

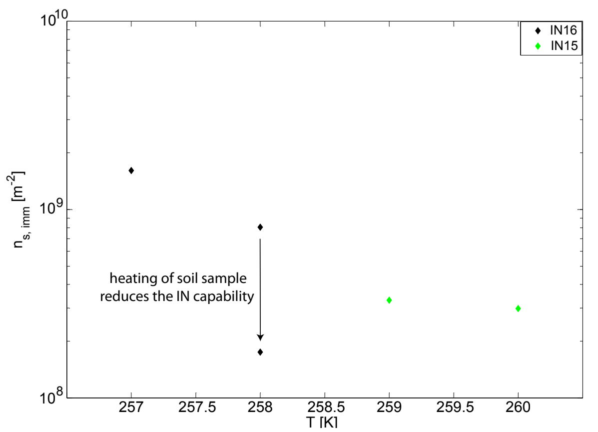

Fig. 4: Reduction of ice nucleation efficiency by heat treatment of soil dust sample

3 OUTLOOK

In future studies, further results from ice nucleation experiments with soil samples from several geographic regions (such as Argentina) will be presented. Also, the elemental composition of the samples and the population of viable organisms will be investigated.

From the measured ice-active surface site densities a parameterization can be derived which expresses the expected ice crystal concentration as a function of aerosol surface area, temperature and saturation over ice. For estimating the contribution of soil dust particles to the global atmospheric ice nuclei burden this parameterization will be applied to the COSMO-ART model where ice nuclei concentrations can be diagnosed from the emission fluxes of aerosol particles. Dust from agricultural areas is emitted by dry exposed soil surfaces and during tillage activities. Currently, the emission fluxes from these sources are not very well quantified. Within this work we will present first estimates for the maximum emissions of soil dust particles and the corresponding ice nuclei concentrations.

Further measurements are needed in order to establish a closer link between biological soil dust components and the average ice nucleation efficiency. Also, in-situ measurements which confirm the presence of soil dust particles in the atmosphere are currently not available. These measurements will also be needed to constrain further refined ice nuclei calculations estimated with COSMO-ART.

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