Impact of biological and mineral dust aerosols on mixed-phase clouds

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Freezing of supercooled water droplets, at temperatures between 0 and -37°C, is facilitated by insoluble aerosols acting as ice nuclei. Numerous laboratory experiments have investigated the efficiency of aerosol particles to induce freezing. Different particle types (e.g., mineral dusts or ice nucleation active bacteria) are usually studied in isolation. Here we summarize experimental results by using the metrics of "surface site densities" [1], which allows a more quantitative comparison than if only the nucleation onset temperatures are studied. This approach accounts for the size dependency of the nucleation process, but does not consider any time dependency.

In the atmosphere, in addition to the ice nucleation efficiencies, the available surface and number concentrations at cloud altitudes of the various ice-nucleating particle types are main determinants of their contribution to cloud ice formation. The concentrations of bacteria, fungal spores, pollen and mineral dust are simulated in the global climate model CAM-Oslo [2,3], and (so far for pollen and mineral dust only) the mesoscale model COSMO-ART [4]. In the global model, ice nucleation is dominated by mineral dust due to its higher average concentrations. The mesoscale model is capable of capturing small-scale fluctuations. The implications of this variability will be investigated.

[1] Connolly *et al* (2009), *Atmos. Chem. Phys.* **9**, 2805–2824. [2] Hoose *et al* (2010), *Environ. Res. Lett.* **5**, 024009. [3] Hoose *et al* (2010), *J. Atmos. Sci.* **67**(8) 2483–2503. [4] Vogel *et al* (2009), *Atmos. Chem. Phys.* **9**, 8661–8680.

Bacterial oxidation of pyrrhotite and troilite under acidic conditions

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To study the influence of microorganisms on sulfide oxidation, experiments on pyrrhotite in the presence of the two acidophilic species *Acidithiobacillus ferrooxidans* (*A.f.*) and *Acidithiobacillus thiooxidans* (*A.t.*) were performed. Pyrrhotite cubes with approximate dimensions of ca. 3×3×3 mm were polished on four faces to a smooth mirror finish. The host pyrrhotite was of the NC-type and contained 1-3 μm wide, fine exsolution lamellae of troilite [1].

First, oxidation experiments with *A.f.* cells were carried out in a simple acidic medium supplemented with pyrrhotite cubes for different time intervals (1 to 40 days). A consistent abiotic experiment was performed, serving as a control. *A.f.* developed a whitish biofilm on the cubes within 40 days. The surface underneath had deep trenches, inferring a preferential dissolution of the embedded troilite lamellae. Surfaces between these trenches displayed a layered and frayed structure, indicating enhanced pyrrhotite surface dissolution. XPS results indicated that *A.f.* drastically enhanced the oxidation of Fe(II) to Fe(III) on the pyrrhotite surface, whereas the pure abiotic experiment did not show any alteration, under the given conditions.

Further oxidation experiments with both acidophilic species (*A.f.* and *A.t*) were performed similarly. *A.f.* and *A.t.* distinctly augmented the pyrrhotite oxidation and particularly enhanced troilite lamellae dissolution. Experiments with bacteria in a dialysis capsule revealed a slower increase in surface roughness compared to free cells, indicating an active involvement of bacteria in the dissolution. Troilite lamellae dissolved similarly in both biotic experiments, but not in the control. The total rate constant for pyrrhotite dissolution was lowest for the control (1.9×10^{-9} mol/(m²×s)) and highest for the *A.f.* experiment with free cells (1.4×10^{-8} mol/(m²×s)). Both bacterial strains oxidized pyrrhotite and especially the troilite phase. The bacterial cell contact to the mineral surface seemed to be irrelevant for the process, therefore a contact-independent mechanism is most likely for biotic pyrrhotite/troilite oxidation.

[1] Harries *et al.* (2011) *Am. Min.* **96**, in press (DOI: 10.2138/am.2011.3644).