



Ice nucleation activity in the widespread soil fungus *Mortierella alpina*

Janine Fröhlich-Nowoisky (1), Thomas C. J. Hill (2,3), Bernhard G. Pummer (1), Petya Yordanova (1), Gary D. Franc (3), and Ulrich Pöschl (1)

(1) Multiphase Chemistry, Max Planck Institute for Chemistry, Mainz, Germany (j.frohlich@mpic.de), (2) Department of Atmospheric Science, Colorado State University, Department of Atmospheric Science, Fort Collins, USA, (3) Plant Sciences Department, University of Wyoming, Laramie, USA

Biological residues in soil dust are a potentially strong source of atmospheric ice nucleators (IN). However, the sources and characteristics of biological – in particular, fungal - IN in soil dust have not been characterized. By analysis of the culturable fungi in topsoils, from a range of different land use and ecosystem types in south-east Wyoming, we found ice nucleation active (INA, i.e., inducing ice formation in the probed range of temperature and concentration) fungi to be both widespread and abundant, particularly in soils with recent inputs of decomposable organic matter. For example, in harvested and ploughed sugar beet and potato fields, and in the organic horizon beneath Lodgepole pine forest, their relative abundances and concentrations among the cultivable fungi were 25% (8×10^3 CFU g^{-1}), 17% (4.8×10^3 CFU g^{-1}) and 17% (4×10^3 CFU g^{-1}), respectively. Across all investigated soils, 8% (2.9×10^3 CFU g^{-1}) of fungal isolates were INA. All INA isolates initiated freezing at $-5^{\circ}C$ to $-6^{\circ}C$ and all belonged to a single zygomycotic species, *Mortierella alpina* (*Mortierellales*, *Mortierellomycotina*). By contrast, the handful of fungal species so far reported as INA all belong within the *Ascomycota* or *Basidiomycota* phyla. *Mortierella alpina* is known to be saprobic (utilizing non-living organic matter), widespread in soil and present in air and rain. Sequencing of the ITS region and the gene for γ -linolenic elongase revealed four distinct clades, affiliated to different soil types. The IN produced by *M. alpina* seem to be extracellular proteins of 100-300 kDa in size which are not anchored in the fungal cell wall. Ice nucleating fungal mycelium will ramify topsoils and probably also release cell-free IN into it. If these IN survive decomposition or are adsorbed onto mineral surfaces, these small cell-free IN might contribute to the as yet uncharacterized pool of atmospheric IN released by soils as dusts.