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The adsorption of fungal ice-nucleating proteins on mineral dusts: a terrestrial reservoir of atmospheric ice-nucleating particles

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The occurrence of ice-nucleating particles (INPs) in our atmosphere has a profound impact on the properties and lifetime of supercooled clouds. However, the identities, sources and abundances of airborne particles capable of efficiently nucleating ice at relatively low supercoolings (T > -15 °C) remain enigmatic. Recently, several studies have suggested that unidentified biogenic residues in soil dusts are likely to be an important source of these efficient atmospheric INPs. While it has been shown that cell-free proteins produced by common soil-borne fungi are exceptional INPs, whether these fungi are a source of ice-nucleating biogenic residues in soils has yet to be shown. In particular, it is unclear whether upon adsorption to soil mineral particles, the activity of fungal ice-nucleating proteins is retained or is reduced, as observed for other soil enzymes. Here we show that proteins from a common soil fungus (Fusarium avenaceum) do in fact preferentially bind to and impart their ice-nucleating properties to the common clay mineral kaolinite. The ice-nucleating activity of the proteinaceous INPs is found to be unaffected by adsorption to the clay, and once bound the proteins do not readily desorb, retaining much of their activity even after multiple washings with pure water. The atmospheric implications of the finding that nanoscale fungal INPs can effectively determine the nucleating abilities of lofted soil dusts are discussed.