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Predicting the abundance of ice nucleating particles of biological origin in precipitation

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Ice nucleation is a key step for the formation of precipitation on Earth. Ice nucleating particles (INPs) of biological origin catalyse the freezing of supercooled cloud droplets at temperatures warmer than -12 ˚C. In order to understand the effective role of these INPs in conditioning precipitation, it is of primary importance to describe and predict their variability in the atmosphere.

Over the course of two years, 14 sampling campaigns in precipitating clouds were conducted at the High Altitude Research Station Jungfraujoch, in the Swiss Alps, at 3580 m a.s.l. A total of 106 freshly fallen snow samples were analysed immediately on site for the concentration of INPs active at -8 ˚C ($INPs_{-8}$) by immersion freezing. Values of $INPs_{-8}$ ranged from 0.21 to 434·ml^{-1}. Environmental parameters (like temperature of the air, wind speed, the stable oxygen ratio $\delta^{18}O$ of snow, the number of particles larger than 0.5 μm) were used as independent variables to build a set of multiple linear regression models to describe and predict the observed variations of $INPs_{-8}$ over time. The model providing the best results was based on f_V (the fraction of remaining vapour in precipitating clouds, derived from $\delta^{18}O$) and on wind speed. It indicates that a coincidence of strong atmospheric turbulence and little prior precipitation from a cloud coincides with large concentrations of $INPs_{-8}$. These conditions can be frequently encountered when air masses are suddenly forced to rise, for instance by the passage of a cold front, where also meteorological conditions are favourable to the onset of precipitation.

To obtain more information on the presence of $INPs_{-8}$ of biological origin and their relative composition, a set of precipitation samples were progressively filtered through different meshes (5 μm, 1.2 μm, 0.22 μm) followed by heating (40 ˚C and 80 ˚C). Almost all ice nucleating activity is lost after heating at 80 ˚C, and a significant part of $INPs_{-8}$ is sensitive to warming at 40 ˚C. This indicates that the $INPs_{-8}$ we measured are of biological origin and can be readily denatured. Still, each sample presents a specific distribution of the sizes of $INPs_{-8}$, suggesting that $INPs_{-8}$in environmental samples are a mix of molecules and cells either freely floating in the atmosphere or clumped or attached to mineral and soil particles. The abundance of bacterial cells and the presence of culturable *Pseudomonas syringae* were studied as well. Just a minor fraction of the $INPs_{-8}$ is potentially due to bacterial cells or living *P. syringae*, indicating that the majority of $INPs_{-8}$ measured in environmental samples may be therefore made of molecules released or detached from organisms.