Geophysical Research Abstracts
Vol. 21, EGU2019-479, 2019
EGU General Assembly 2019

Heterogeneity of ice nucleating particles measured in Swiss alpine snow samples

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Ice nucleating particles (INPs) produce ice through heterogeneous freezing in the atmosphere. Since the concentration of ice crystals affects the radiative properties of clouds as well as their precipitation, constraining INP concentrations could help reduce the aerosol-cloud interaction uncertainties in climate modelling. A number of studies have investigated INPs at high-altitude research stations, yet the representation of these stations compared to their surrounding mountainous terrain remains unclear. Although INPs have been collected at the Jungfraujoch research station (at 3500 m a.s.l.) in central Switzerland, spatially diverse data on INP occurrence in the Swiss Alps are scarce. We address this scarcity through our Swiss Alpine snow sample study which took place during the winter of 2018. We collected a total of 88 fallen snow samples across the Alps at different locations, altitudes, terrains, times since last snowfall and depths. The INP concentrations were measured using the homebuilt DRop freezing Ice Nuclei Counter Zurich (DRINCZ) and were then compared to spatial, meteorological and chemical parameters. Large variability in INP occurrence was found during the field campaign, even for samples collected in close proximity. Indeed, undiluted samples had INP concentrations ranging between 1 and 100 INPs per ml over a temperature range of -5 to -19 °C. From this field-collected data set, we parameterize the INP concentrations as a function of temperature, which compares well with previously reported precipitation data. When assuming a typical cloud water content, the majority of the snow precipitated from clouds with mixed-phase cloud activation temperatures between -5 and -20 °C. Major correlations of INP occurrence with distance, altitude, terrain, TOC, pH and conductivity were weak and statistically insignificant. We conclude that studies conducted at the alpine research station Jungfraujoch are representative for INP assessments in the Swiss Alps. The generated parameterization for INP concentrations and temperatures could help reduce uncertainty in climate models caused by aerosol-cloud interactions.
Furthermore, we also introduce a new way of displaying frozen fraction (FF) data. Instead of plotting the FF as a two-dimensional curve as a function of temperature, we propose visualizing freezing temperatures in a boxplot. This new ansatz allows showing the FF in only one dimension, instead of the former two, which allows a more condensed display of measurement results while still allowing the same visual interpretation of the data.