Name of research institute or organization:

Departement Umweltwissenschaften, Universität Basel

Title of project:

Biological ice nucleators at tropospheric cloud height

Project leader and team:

Dr. Franz Conen, project leader
Mr. Emiliano Stopelli
Ms. Corinne Baudinot
Mr. Lukas Zimmermann
Dr. Pierre Amato

Project description:

We have made progress in this project along two lines. First, we have continued sampling and analysis of ice nuclei (IN) in precipitation at Jungfraujoch, including new analytical approaches. Second, we have investigated the seasonal cycle of ice nuclei in air, based on the analysis of PM_{10} collected on quartz-fibre filters.

Ice nuclei in precipitation

A total of 123 samples of snow were collected on the rooftop of the Sphinx building between October 2012 and September 2013 within the frame of the SNF-funded PhD project realised by Emiliano Stopelli. The main goal of these observations was to study at tropospheric cloud height the abundance and variations over time of IN active at temperatures warmer than -12 °C. All samples were melted and immediately analysed in a droplet freezing assay directly on site. Interestingly, concentrations of IN varied by orders of magnitude not only over the course of the year, but also within a few hours, suggesting that time of year is a poor descriptor of IN dynamics (Fig. 1). In contrast, the fraction of water vapour lost (1-f_V) from an air mass prior to its arrival at Jungfraujoch (determined from $\delta^{18}O$ values of snow) very closely matched the observed IN dynamics (Fig. 1).

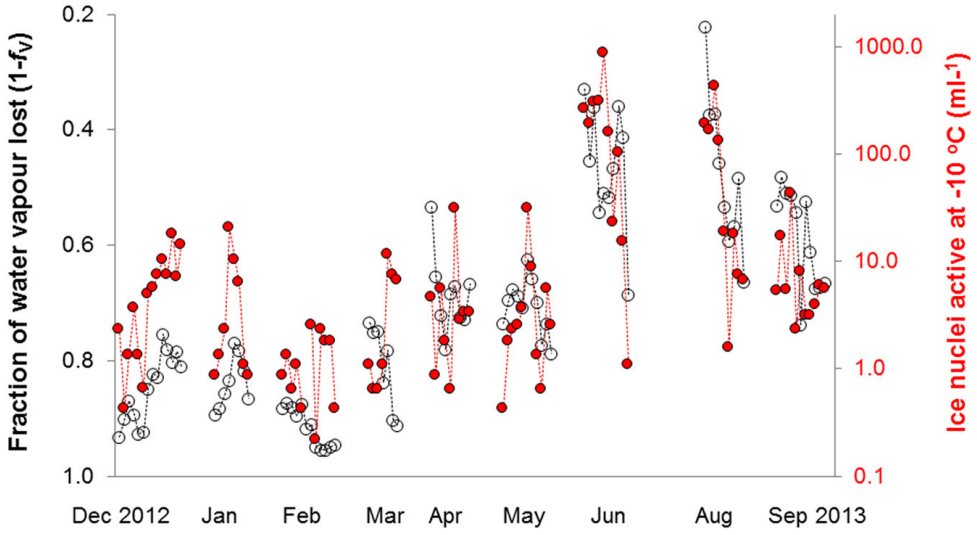

Figure 1. Similar dynamics over time of ice nuclei concentrations in snow (red, log-scale) and the fraction of water vapour lost from an air mass prior to its arrival at Jungfraujoch (open circles). The time axis is not to scale. Each symbol signifies a snow sample collected during about 2 hours (median). Each campaign (all symbols connected by an uninterrupted dotted line) lasted from 3 to 5 consecutive days.

Further analysing this relationship, we found that IN must be rapidly lost during the early stages of precipitation. Their concentration likely halved with every 10 % of vapour lost, while that of other particles of similar size (> 0.5 µm, data kindly provided by the Laboratory of Atmospheric Chemistry, PSI) probably halved with every 20 % of vapour lost through precipitation. A multi-linear regression model built on 1-f_V and wind speed data was capable to explain 75 % of the complex IN dynamics observed over the year.

From May to October 2014 a second series of samples (15 in total) was obtained with the help of our Master student Corinne Baudinot, both to verify the model built on data from the 1st year of observations and to gain some insight into the kinds of IN precipitation. Regarding the latter, progressive filtration and the heating of samples allowed to separate classes of IN by dimension and denaturability and provided clues of their likely origin.

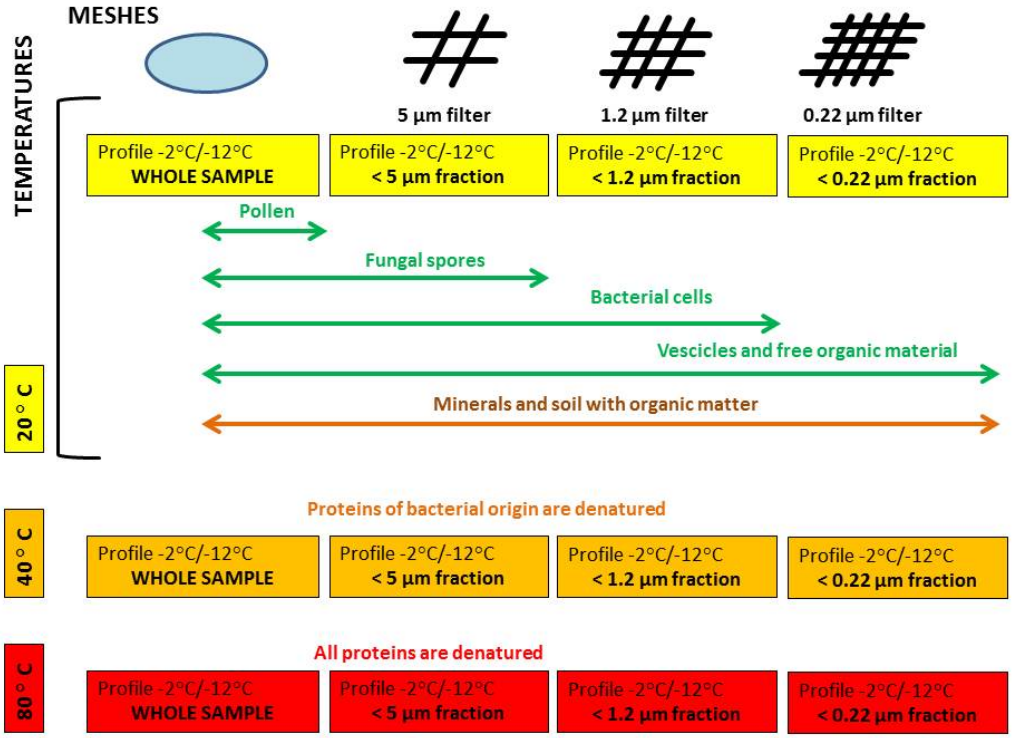

Figure 2. Stepwise procedure to characterise biological IN active at moderate supercooling.

Microbiological assays were also done (total counting, cultivable mesophilic fraction, isolation of *Pseudomonas syringae* as IN active bacterium) to study the bacterial presence in the samples and relate it to the observed IN activity. The major dissolved cations and anions were measured in snow as well, in order to see whether the chemical fingerprint of a sample may be used as descriptor of the IN source strength of a particular source type. These data are currently analysed.

On the 20th of March 2014, Dr Pierre Amato from the University of Clermont Ferrand and four representatives of the US-NSF-funded project "Research on Airborne Ice Nucleating Species" (RAINS; Dr Cindy Morris, Prof David Sands, Prof Brent Christner, Prof David Schmale III) visited the Research Station Jungfraujoch along with Emiliano Stopelli. This fruitful exchange not only generated suggestions on how to improve the quality of our measurements at Jungfraujoch, but it also put our work into the frame of an international cooperation of institutes pursuing research on biological IN.

Seasonal cycle of ice nuclei in air (PM_{10})

To assess the seasonal cycle of ice nuclei in air around Jungfraujoch, we analysed 83 PM_{10} filters covering the period between June 2012 and May 2013. The filters were generously provided by colleagues from the National Air Pollution Monitoring Network (NABEL). A seasonal cycle in ice nuclei active at -8 °C (IN_{-8}) was perceivable despite a fair amount of scatter on a monthly time scale (Fig. 3). Values in the order from 1 to 10 m^{-3} were observed during summer (June, July, August), decreasing throughout autumn to values predominantly smaller than 0.1 m^{-3} during winter and early spring (January, February, March), before increasing again in April. In May 2013 values were smaller than in the preceding month, which may have been due to the fact that May 2013 was around 2 °C colder in Switzerland than usual, while April 2013 had been slightly warmer.

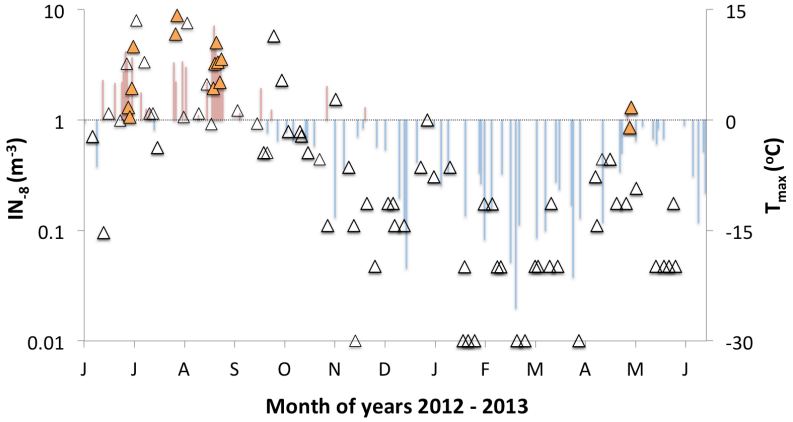

Figure 3. Time course of IN_{-8} at Jungfraujoch (ochre symbols indicate Sahara dust events) and maximum daily temperature (columns). When no freezing event was detected in 108 filter cut-outs (IN_{-8} below detection limit), values were set to 0.01 m^{-3} to keep them in the plot.

Concentrations of IN_{-8} during Sahara dust events were in the upper range of observed values, but not larger than other summer values without Saharan influence. Two processes may contribute to a winter minimum. One is the reduced transport of boundary layer air, which is richer in IN than free tropospheric air, to Jungfraujoch in winter. The other is a greater loss of IN_{-8} through microphysical processing, that is through activation of ice nuclei on their way to Jungfraujoch, where they are subject to increasingly colder temperatures and greater relative humidity, the growth of activated IN by vapour deposition and their deposition in ice particles to the ground before they have reached Jungfraujoch. The median number concentration of ice nuclei active at moderate supercooling is about seven times lower at Jungfraujoch than at Chaumont (1136 m) in the Jura (Fig. 4).

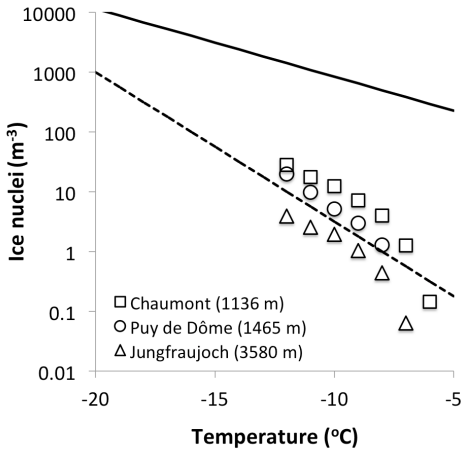

Figure 4. Median concentrations of IN active at -12 °C or warmer at different heights above sea level. Data for Puy de Dôme are from Joly et al. (2014; Atmos. Chem. Phys. Discuss. 14, 3703-3731). Lines indicate temperature dependent parameterisations by (dashed line) Fletcher (1962; The Physics of Rain Clouds. Cambridge University Press) and (continuous line) by Meyers et al. (1992; J. Appl. Meteorol. 31, 708-721).

Key words:

Ice nucleation, biological, snow, PM_{10}

Internet data bases:

https://umweltgeo.unibas.ch/forschung/aktuelle-projekte/biological-nucleators/
http://azug.minpet.unibas.ch/~lukas/FNA/index.html

Collaborating partners/networks:

Laboratory for Air Pollution/Environmental Technology, Swiss Laboratories for Material Science and Technology (Empa), Dübendorf, Switzerland
Laboratory of Atmospheric Chemistry, Paul Scherrer Institute, Villigen, Switzerland
Dr. Cindy Morris, Plant pathology research unit, INRA, Avignon, France

Scientific publications and public outreach 2014:

Conference papers

Stopelli, E., F. Conen, C. Alewell, C.E. Morris, Biological ice nuclei at tropospheric cloud heights: potential conditioning of precipitation, Geophysical Research Abstracts, EGU General Assembly 2014, Vienna, Austria, April 27 – May 2, 2014.

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