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
Mr. Lukas Zimmermann

Project description:

The relevance of biological ice nucleation for cloud processes, such as initiating precipitation, is ambiguous. Very little is known about abundance and nucleation spectra of biological ice nucleators (IN) at tropospheric cloud altitudes. Reasons for this are typically small number concentrations of IN active at relatively warm temperatures and related difficulties in their detection. However, this does not mean that biological IN do not play a potentially important role in clouds. At temperatures between about -3 to -8 °C a few initial ice particles can multiply in number by orders of magnitude through the process of riming and ice splintering (Hallett-Mossop process) and thereby initiate precipitation.

In 2012 we pursued two goals. First, to improve and facilitate the measurement of IN active at warm temperatures (> -12 °C) through technical innovation. Second, to get more data on IN number concentrations in air and in precipitation (snow) at tropospheric cloud altitude, to which Jungfraujoch Station provides excellent access.

Regarding the first goal, we made some progress by developing and building an apparatus for immersion freezing assays. Its principle of operation is based on the reduction of light transmission through water upon freezing because light gets scattered by inclusions in ice, such as air bubbles and brine pockets. In immersion freezing assays the phase change from liquid to ice can therefore be detected visually when the sample changes from translucent to ‘milky’. The apparatus we built around this principle consists of an array of 8 x 7 red LEDs submersed in a cold bath and pointing upwards through 0.5 ml Eppendorf tubes containing between 0.1 and 0.4 ml sample liquid (e.g. snow water). Four tubes have a Pt_{1000} temperature sensor cast in (Figure 1). A camera in a black hood placed above the sample array looks down onto the lids of the tubes, which are illuminated from below. Images are recorded every five seconds. Light intensity in the area of each tube lid is extracted from each image and written into a file together with the temperature at the time the image was taken. This apparatus is an open hardware (and software) project and we have already made some effort to publicise it, including pictures, technical drawings and an example of an application (http://azug.minpet.unibas.ch/~lukas/FNA/index.html).

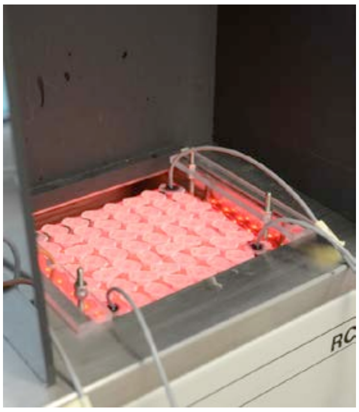

Figure 1: Part of the freezing nucleation apparatus, showing sample tubes and temperature sensors mounted on top of an array of red LEDs and submerged in the cold bath, ready for analysis.

The apparatus was already useful in analysing snow samples for IN at Jungfraujoch. Snow was collected in a Teflon®-coated tray (0.1 m^2) over periods of a few hours on the upper Sphinx terrace, then melted slowly, immediately transferred into Eppendorf tubes and exposed to decreasing temperatures in a cold bath, where freezing temperatures were recorded with above mentioned apparatus. Analysis of one snow sample takes less than ½ an hour. The nucleation spectra show generally larger number concentrations of IN at the beginning of November, when air temperatures were on average around -9 ^oC, compared to the beginning of December, when mean air temperatures were around -18 ^oC (Figure 2). However, in December onset of freezing seemed earlier. One third of the samples had a dectectable number of IN already at -5.0 ^oC, whereas in November this was the case only at temperatures < -6.0 ^oC. These results are the first field data in the SNF-funded PhD project, which Emiliano Stopelli started in September 2012 and which will continue at least until 2015.

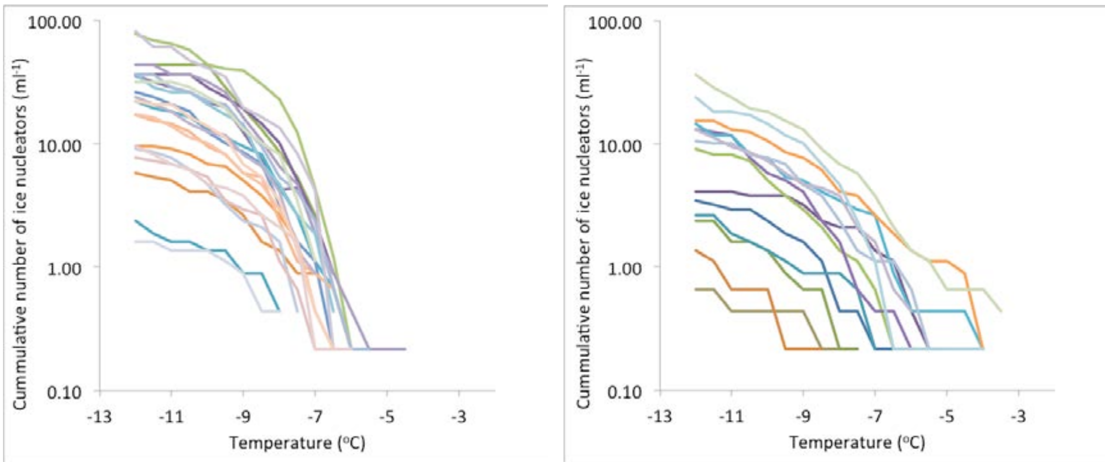

Figure 2: Ice nucleation spectra of snow water collected at Jungfraujoch (left) between 31. October and 05. November 2012 and (right) between 07. and 12. December 2012.

In 2012, four students from the University of Basel started their BSc project on the topic of IN at tropospheric cloud height at Jungfraujoch. Two have already completed their work, finding, among other things, that number concentrations of IN at Jungfraujoch (IN m^{-3}) are well below those at urban PM_{10} monitoring stations in Switzerland, but close to, or only slightly below, those at rural monitoring stations at low altitudes. The specific IN activity of PM_{10} (number of IN per unit mass of PM_{10}) is largest in urban environments and smallest at Jungfraujoch during Saharan dust events. However, in the absence of a Saharan dust event, PM_{10} at Jungfraujoch has a larger specific activity (at temperatures < -7 ^oC) than PM_{10} at rural sites, possible because of a non-negligible contribution of urban PM_{10}. All filters were generously provided by Martin Steinbacher, Claudia Zellweger and Christoph Hüglin at Empa. In total, we have analysed 42 filters from Jungfraujoch. The method of analysis has been published (Conen et al., 2012). Our data so far show only a weak positive correlation (r^2 = 0.19) between the log of IN number concentration and the log of PM_{10} mass. The lower and upper quartiles of number concentrations of IN m^{-3} active at -10 ^oC are 1.6 and 8.2, respectively (Table 1). Lower and upper quartiles for the same IN numbers per microgram PM_{10} are 0.3 and 1.4, respectively. To date, we have analysed mainly filters from the months of March to July. We plan to expand this work and link it to other measurements, such as IN analyses of snow samples.

Table 1: Number concentrations of ice nucleators found on PM_{10} filters from Jungfraujoch.

Date	PM_{10} ($\mu g\ m^{-3}$)	IN at -10 °C (m^{-3})	IN at -10 °C / $\mu g\ PM_{10}$
10.06.10	5.9	2.0	0.3
11.06.10	7.1	11.6	1.6
29.06.10	7.8	15.5	2.0
30.06.10	5.9	13.8	2.3
01.07.10	6.6	14.6	2.2
09.07.10	18.9	6.3	0.3
10.07.10	28.0	9.5	0.3
11.07.10	14.8	12.0	0.8
03.04.11	18.4	2.2	0.1
04.04.11	6.9	8.4	1.2
05.04.11	3.0	7.5	2.5
06.04.11	1.9	0.4	0.2
07.04.11	5.4	1.6	0.3
10.04.11	27.7	1.0	0.0
11.04.11	27.2	1.3	0.0
12.04.11	9.6	2.8	0.3
13.04.11	3.0	3.5	1.2
14.04.11	3.1	10.1	3.3
15.04.11	4.4	0.6	0.1
19.04.11	6.3	2.7	0.4
20.04.11	6.6	1.8	0.3
21.04.11	8.4	3.2	0.4
11.05.11	8.6	3.9	0.4
12.07.11	12.3	6.3	0.5
21.08.11	32.0	5.2	0.2
16.03.12	1.6	2.8	1.8
17.03.12	5.3	1.6	0.3
18.03.12	1.2	0.9	0.7
19.03.12	0.7	0.2	0.2
20.03.12	1.9	1.4	0.8
13.04.12	1.5	0.4	0.3
14.04.12	0.8	0.7	0.9
15.04.12	1.4	0.6	0.4
26.04.12	1.0	5.2	5.2
27.04.12	14.7	4.4	0.3
28.04.12	13.9	4.6	0.3
19.06.12	8.0	6.3	0.8
20.06.12	20.5	15.9	0.8
21.06.12	12.8	9.9	0.8
22.06.12	2.1	33.2	15.8
23.06.12	2.0	3.6	1.8
24.06.12	2.6	3.9	1.5
MIN	0.7	0.2	0.0
MAX	32.0	33.2	15.8
MEDIAN	**6.5**	**3.7**	**0.5**
AVERAGE	8.9	5.8	1.3
25^{th} percentile	2.2	1.6	0.3
75^{th} percentile	12.7	8.2	1.4

Key words:

Ice nucleation, biological, snow, PM_{10}

Internet data bases:

http://pages.unibas.ch/environment/

Collaborating partners/networks:

Dr. Ernest Weingartner, Aerosol Physics Group, PSI, Villigen
Group for Climate Gases, Empa, Dübendorf
NABEL, Empa, Dübendorf
Dr. Cindy Morris, Plant pathology research unit, INRA, Avignon, France

Scientific publications and public outreach 2012:

Refereed journal articles and their internet access

Conen, F., S. Henne, C.E. Morris, C. Alewell, Atmospheric ice nucleators active ≧ −12 °C can be quantified on PM_{10} filters, Atmospheric Measurement Techniques, **5**, 321-327, doi: 10.5194/amt-5-321-2012, 2012.
http://www.atmos-meas-tech.net/5/321/2012/amt-5-321-2012.html

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