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ATMO-ACCESS 4th call for Trans-National Remote Access

Summary

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Scientific activity report

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ATMO-ACCESS Scientific Activity report

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SBO_INP_23

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Executive summary

This field campaign allowed us to measure the ambient INP (Ice Nucleating Particle) concentration at the Sonnblick Obervatory (3106m a.s.l.), a location directly relevant to the formation of ice crystals in clouds. Our aim was to test our newly developed prototype PINEair (Portable Ice Nucleation Experiment airborne) and to compare the new results to our offline freezing technique INSEKT (Ice Nucleation Spectrometer of the Karlsruhe Institute of Technology). The campaign was a great success, we were able to demonstrate that PINEair is capable to perform fully automated INP measurements in both the mixed-phase and cirrus temperature regime.

Scientific objectives

Ice Nucleating Particles (INPs) are a rare but very important subset of aerosols in the atmosphere where they play an important role in the primary ice formation [1]. In mixed-phase clouds, ice crystals often initiate the formation of precipitation [2], and in cirrus clouds they have an influence on the Earth´s radiative budget [3].
Although INPs have been researched for several years, there are still large gaps in our knowledge [4]. One reason for this is that they are very difficult to measure due to their very low and strongly temperature dependent abundance in the atmosphere. A range of measurement instruments have been developed in the past years, but very few can be operated continuously and autonomously. PINEair (Portable Ice Nucleation Experiment airborne) can measure INPs in a fully automated way with a high sensitivity, and it can measure the INP number concentrations at mixed-phase cloud and at the colder cirrus cloud temperatures.
Existing measurements of INP concentrations have been done mainly in the mixed-phase cloud temperature range [5]. Especially at the cirrus cloud relevant temperatures, direct (in-situ) measurements of INP concentrations are rare.
In 2019, we have already installed a filter aerosol sampling system to post-analyze the INP concentration at the SBO and analyze the filters with INSEKT (Ice Nucleation Spectrometer of the Karlsruhe Institute of Technology, [6]) at our institue later on. However, this measurement method can only be used to study the INPs in the temperature range of the mixed-phase clouds from about -10°C to -25°C. In 2021, we additionally investigated the INP concentration in the temperature range from -15° to -30°C with our online instrument PINE (Portable Ice Nucleation Experiment, [7]).
In this project we want to extend the already existing data with the following objectives:

1. Quantifying INP measurements in the cirrus cloud regime with the new prototype PINEair, at temperatures at about -47°C.

2. Comparing the results from the online instrument PINEair to results from simultaneously collected aerosol filter measurements in the mixed-phase cloud temperature range using the offline freezing method INSEKT.

3. Calculating backward trajectories to determine the origin of the air mass present at SBO, thus allowing to analyze the sources and transport processes of INPs in the free troposphere.

Reason for choosing station/ infrastructure

In the near future the aircraft-based version of PINEair will be available and it will measure the INP concentration in the temperature range of mixed-phase and cirrus clouds during aircraft measurement campaigns. Since the SBO is often in the free troposphere, and the ambient pressure at this altitude is already reduced to about 700mbar, it is a well-suited location for not only testing the first version of this innovative new instrument, but also to obtain a first data set of INP concentrations in the free troposphere. Therefore the INPs measured at SBO are representative for the free troposphere and may therefore also be relevant for cirrus cloud formation.

Activities during the TNA (research, training, events, ...)

Pia Bogert was on site to install the newly developed instrument PINEair and get it started. The operation of the instrument was controlled and monitored from Karlsruhe (remote access) by the device developers Ottmar Möhler and Larissa Lacher in order to test the automated operation for the first time. Since it is a new instrument, it should be compared to another measurement method, which is the offline analysis of aerosol filter samples performed by Pia Bogert on site (physical access). She was supported by our project partner Jann Schrod from the University of Frankfurt.

There was no training during the campaign.

Method and experimental set-up

PINEair consists of 3 expansion chambers, which can be operated in an alternating mode, thus providing a very high time resolution.
For the measurements, PINEair is first cooled down to a certain temperature below 0°C. After reaching the desired temperature, all chambers are flushed with the ambient air and aerosols from the environment. Subsequently, the air in the first chamber is expanded, by which the air temperature decreases, its relative humidity increases and any present INPs are activated. An optical particle counter at the outlet of the first chamber is used to determine the number of formed ice crystals, which is equated to the number of INPs. After that, chamber 1 is filled to normal pressure again and the second chamber starts to expand. Afterwards, the third chamber performs an expansion and then a completely new cycle starting at chamber 1 can begin. After some days, background tests are made to check that the chamber walls are not frozen.
PINEair was controlled by Ottmar Möhler and Larissa Lacher with remote access, in case of problems Pia Bogert was able to interfere directly on site. Steffen Vogt helped for the transport and installation of the instrument on site.

Preliminary results and conclusions

The transport and installation of PINEair on site worked very well (see picture 1), we started with our INP measurements already on the evening of our first day of arrival.
During the day we measured with PINEair always in the cirrus temperature range at about -47°C, with a so-called humidity scan we determined at which settings of the instrument the homogeneous freezing of the aerosols starts. Afterwards, we measured the concentration of the heterogeneously formed INP at constant saturation conditions. During our intensive campaign the INP concentration fluctuated strongly, e.g. at a saturation ratio with respect to ice between 1.46 and 1.49 the INP conenctration varied between 0 std/liter and 28.55 std/liter. A good agreement exists between the course of the INP concentration and the number concentration of the aerosol particles with d>0.3µm. Moreover, the INP concentration increases, as expected, when we also increase the humidity conditions in the expansion chamber.

At night, we measured with constant settings in the mixed-phase temperature range (-22.7°C and -27.5C) to compare the data set with our offline filter measurement method. At present, we are not yet able to provide any information about the filter measurements, as they still have to be analyzed with INSEKT. However, as a preliminary result, we observed there is also a good agreement between the INP concentration and the number concentration of the aerosol particles with d>0.3µm in the mixed phase temperature range (see Figure 2).

Outcome and future studies

Our measurement campaign at SBO was very successful, we are able to measure the INP concentration in the cirrus and mixed-phase temperature range with our newly developed instrument PINEair. The results will be published in the PhD thesis of Pia Bogert and in a future paper.
In the future, we plan to use our PINEair prototype to measure the INP concentration in a wide temperature range at other locations as well, to get more information about the abundance of INPs in the atmosphere. Furthermore, we want to gain more experience about the right operation with our prototype, that we can apply it directly to the aircraft-based version later on.

References

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