Name of research institute or organization:

Laboratory of Atmospheric Chemistry – Paul Scherrer Institute

Title of project:

Study of new particle formation in the free troposphere (NUCLACE-2013)

Project leader and team:

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Project description:

The aim of this project is to study the nucleation process in the free troposphere. It is well known that atmospheric aerosols can affect the climate directly by absorbing or scattering light and also indirectly through their ability to act as cloud condensation nuclei (CCN). A recent study calculates that up to half of the CCN are formed by a gas to particle conversion mechanism (nucleation). Unfortunately, only little information is available for the free troposphere. The questions that we would like to answer are:

What is the sulphuric acid concentration while nucleation is taking place?
Are there other species than sulphuric acid and water participating in the nucleation process?
What is the chemical composition of the growing clusters?
What is the role of the ions in the nucleation process?

To address these questions, several state-of-the-art instruments for nucleation measurements were deployed during the year 2013 (see Table 1).

Instruments present at the Jungfraujoch site during the winter 2013 campaign.	
Device	Measured property
2 atmospheric pressure interface time-of-flight mass spectrometers (APi-TOF)	Chemical composition of the positive and negative ions (D < 2nm)
2 Chemical ionization-APi-TOF	Sulphuric acid concentration and neutral clusters chemical composition (D < 2nm)
Neutral and air ion spectrometer (NAIS)	Particle and ion size distribution from D = 0.4 to 40 nm
Nano scanning mobility particle sizer (SMPS)	Particle size distribution from D = 4 to 100 nm
Condensation particle counter (CPC)	Particle number concentration (D >2.5 nm)
Particle size magnifier (PSM)	Particle number concentration (D >1 nm) and growth rate between D = 1 and 2.3 nm

Table 1. Instrumentation that has been used during NUCLACE 2013. D=particle or cluster diameter.

During the first campaigns, several nucleation events were observed at the Jungfraujoch station. Most of the observed events occurred during clear sky conditions. Figure 1 shows an example of the particle number size distribution during a nucleation event. Sulphuric acid concentration increases during the morning reaching a maximum at noon. Then, a nucleation mode appeared in the SMPS instrument, lasting until 6 p.m. In the two-month campaign the H_2SO_4 concentration mostly showed a clear diurnal behavior but there was no correlation with nucleation events.

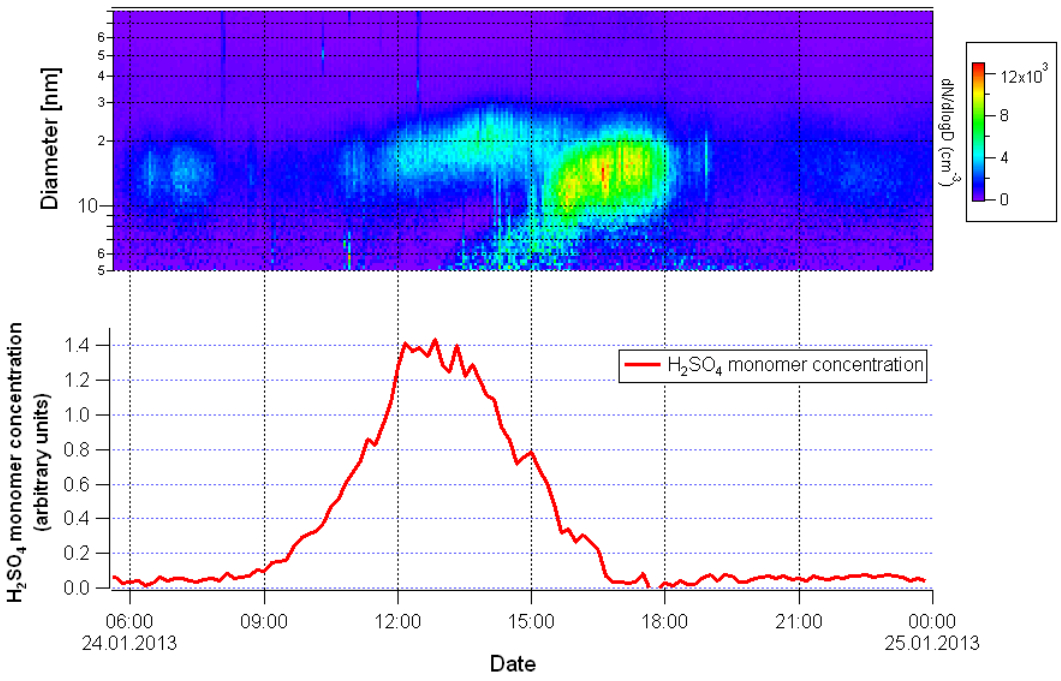

Figure 1. Number size distribution (top panel) and sulphuric acid concentration (bottom panel) during a nucleation event. The sulphuric acid concentration is shown in arbitrary units because the instrument is not yet calibrated at this pressure (619 mbar < p < 675 mbar).

To determine the exact mass of the ions that are present in the free troposphere we used two atmospheric pressure interface time-of-flight mass spectrometers (APi-TOF). These instruments consist of two parts, the atmospheric pressure interface and the time-of-flight spectrometer. The first part is needed to efficiently guide the ions into the mass spectrometer and it consists of two quadrupoles and an ion lens. The spectrometer allows us to retrieve the exact mass-to-charge ratio (m/Q) of every single ion smaller than ~2 nm. It was observed that the ion composition depends on the weather conditions. During cloudy days the ion concentration is low due to the fact that the ions are scavenged by the cloud droplets. Almost all the ions present under these conditions are formed by nitric acid.

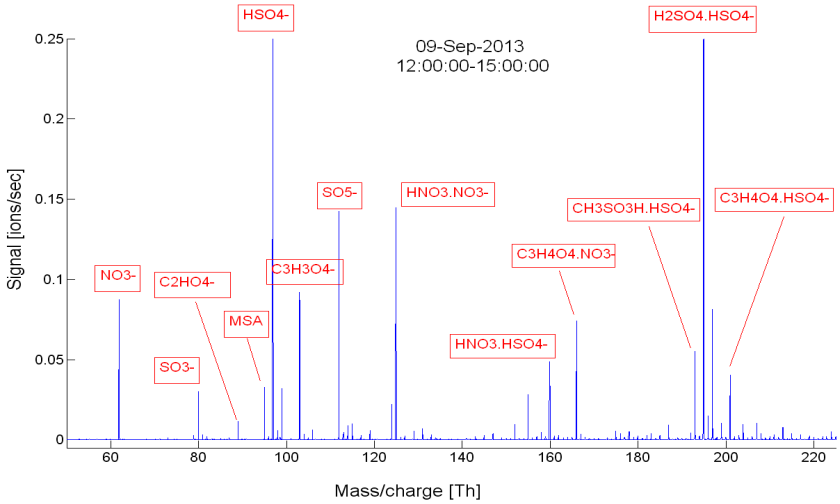

Figure 2. Composition of negatively charged clusters during a sunny day. The main ions are formed by sulphuric acid clusters.

During sunny days there are much more ions and also the chemical composition is quite different. Figure 2 shows the mass spectrum of negative ions during one of these days at the Jungfraujoch. The two main peaks are composed of sulphuric acid monomer and dimer. Other peaks are clusters that are composed of different combinations of acids that are typically present at Jungfraujoch, i.e. nitric acid, oxalic acid, malonic acid, methylsulphonic acid (MSA). Despite the fact that ions can contribute to the nucleation process we did not observe any correlation between ions and nucleation events. However, these first results are encouraging and long-term studies are needed to understand the nucleation mechanism in the free troposphere and the contribution of ions in this process.

Key words:

Nucleation, mass spectrometer, particle size distribution, sulphuric acid

Collaborating partners/networks:

University of Helsinki
University of Frankfurt

Scientific publications and public outreach 2013:

Conference papers

Bianchi F., H. Junninen, J. Troestl, J. Duplissy, L. Rondo, M. Simon, A. Kuerten, A. Adamov, J. Curtius, J. Dommen, E. Weingartner, D. Worsnop, M. Kulmala, and U. Baltensperger, Particle nucleation events at the high alpine station Jungfraujoch, 19th International Conference on Nucleation and Atmospheric Aerosols, Fort Collins, Colorado, USA, June 23-28, 2013.

Tröstl J., J. Duplissy, F. Bianchi, L. Rondo, H. Junninen, A. Adamov, A.P. Praplan, C. Fuchs, J. Dommen, E. Weingartner and U. Baltensperger, Formation and chemical properties of nano-sized particles in the lower free troposphere, European aerosol conference, Prague, Czech Republic, September 1-6, 2013.

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