Name of research institute or organization:

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Title of project:

The Global Atmosphere Watch Aerosol Program at the Jungfraujoch

Project leader and team:

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Project description:

Airborne aerosols affect our climate primarily by influencing the atmospheric energy budget through direct and indirect effects. Direct effects refer to the scattering and absorption of radiation and their influence on the planetary albedo and the climate system. Indirect effects refer to the increase in available cloud condensation nuclei (CCN) due to an increase in anthropogenic aerosol concentration. This leads to an increase in cloud droplet number concentration and a decrease in cloud droplet effective radius, when the cloud liquid water content (LWC) remains constant. The resulting cloud droplet spectrum leads to reduced precipitation and increased cloud lifetime. The overall result in the global atmosphere would be an increase in cloud albedo which cools the Earth's climate. Despite the uncertainty it is believed that in regions with high anthropogenic aerosol concentrations, aerosol forcing may be of the same magnitude but opposite in sign compared to the combined effect of all greenhouse gases.

The Global Atmosphere Watch (GAW) program is an activity overseen by the World Meteorological Organization (WMO). It is the goal of GAW to ensure long-term measurements in order to detect trends and to develop an understanding of these trends. With respect to aerosols the objective of GAW is to determine the spatio-temporal distribution of aerosol properties related to climate forcing and air quality up to multi-decadal time scales. Since the atmospheric residence time of aerosol particles is relatively short, a large number of measuring stations are needed. The GAW monitoring network consists of 29 global (including the Jungfraujoch) and about 300 regional stations. While global stations are expected to measure as many of the key variables as possible, the regional stations generally carry out a smaller set of observations.

The Jungfraujoch aerosol program is among the most complete ones worldwide. By the end of 2013 it has reached 19 years of continuous measurements for part of the instruments (illustrated in Figure 1 by the time series of the total scattering coefficient and absorption coefficient). Since December 2011 the aerosol program at the Jungfraujoch is also part of the ACTRIS (Aerosols, Clouds, and Trace gases Research Infra Structure) network.

Table 1 shows the current GAW instrumentation that is continuously running at the Jungfraujoch. For these measurements, ambient air is sampled via a heated inlet (25°C), designed to prevent ice build-up and to evaporate cloud particles at an early stage, ensuring that the cloud condensation nuclei and/or ice nuclei are also sampled. This inlet is called the *total* inlet.

Hourly and daily averages are calculated and the data is visualized in real-time for different time periods in the internet, see http://aerosolforschung.web.psi.ch/onlinedata or https://gawrtl.psi.ch.

In 2013 a new public information screen was installed at PSI, streaming online data from the Jungfraujoch (see Figure 2).

Table 1. Current GAW aerosol instrumentation

Instrument	Measured parameter
CPC (TSI 3010 or 3772)	Particle number density (particle diameter D_p>10 nm)
Nephelometer (TSI 3563)	Scattering coefficient at three wavelengths
Aethalometer (AE-31)	Absorption coefficient at seven wavelengths; equivalent black carbon (BC) concentration
MAAP	Absorption coefficient at one wavelength; equivalent black carbon (BC) concentration
Filter packs	Aerosol major ionic composition (PM1 and TSP)
Betameter and HiVol[1)]	Aerosol mass, PM1 and TSP[1)]
SMPS, OPC	Particle number size distribution, D_p = 20 - 22'500 nm
CCNC	Number concentration of cloud condensation nuclei

[1)] measured by EMPA

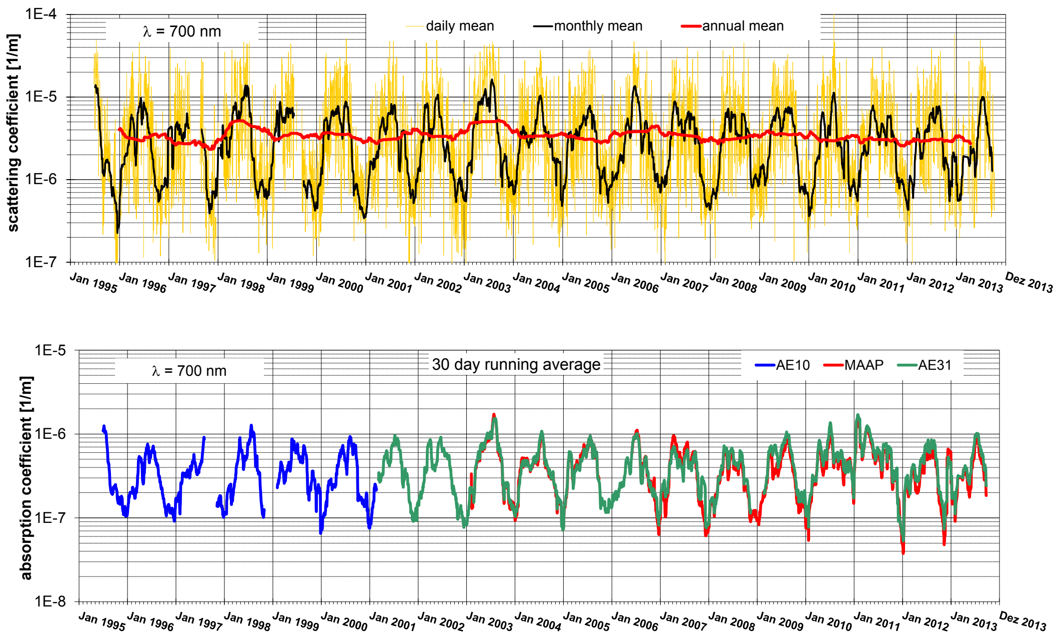

Figure 1. 19-year time series of the total aerosol scattering coefficient (top panel) and the aerosol absorption coefficient (bottom panel) at 700 nm wavelength.

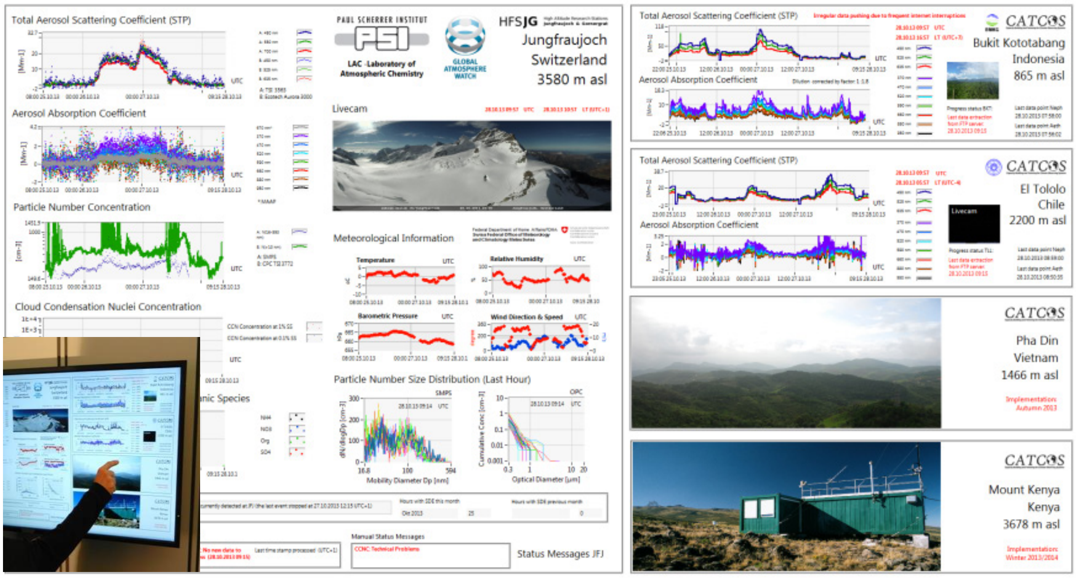

Figure 2. Screenshot of the new public Jungfraujoch online data screen installed at PSI.

The CLACE 2013 campaign: first tests with the new ice selective inlet (ISI)

Previous research has found that cloud radiative properties strongly depend on the cloud ice mass fraction, which is influenced by the abundance of ice nuclei (IN). Increased IN concentrations are also thought to enhance precipitation, thus causing a decrease in cloud lifetime and cloud cover, resulting in a warming of the atmosphere. Burning questions in this context are:

- Which aerosol particles act as IN in our atmosphere?
- By which detailed mechanisms do atmospheric aerosols contribute to the formation of ice?

To answer these questions, a new ice selective inlet (ISI) for the measurement of cloud droplets and ice crystals is currently being developed at PSI and tested at the Jungfraujoch. The inlet will represent a novel tool for the in-situ investigation of clouds and will deliver information that is not available by means of any other existing inlet. The first field deployment of the inlet took place as part of the Cloud and Aerosol Characterization Experiment (CLACE) during January and February of 2013 at the High Alpine Research Station Jungfraujoch. The campaign was conducted together with a number of international collaborators and focused on investigating the properties of ice nucleating particles in mixed-phase clouds and cloud microphysical characteristics.

In order to verify the operation of the ISI, the first step is to ensure that the droplet evaporation unit of the ISI was operating correctly, removing water droplets and transmitting ice crystals. A comparison of number size distributions from the “Total” OPC (above the droplet evaporation tube) and the “Ice” OPC (below the droplet evaporation tube) can be used to assess the transmission efficiency of particles at different sizes and should therefore provide a first approximation of the extent to which droplets are removed and ice crystals transmitted. For illustration, Figure 3 shows the number size distributions measured by the two OPCs during a cloud on the 12th-13th February and the processes at work within the inlet explaining the observed modes.

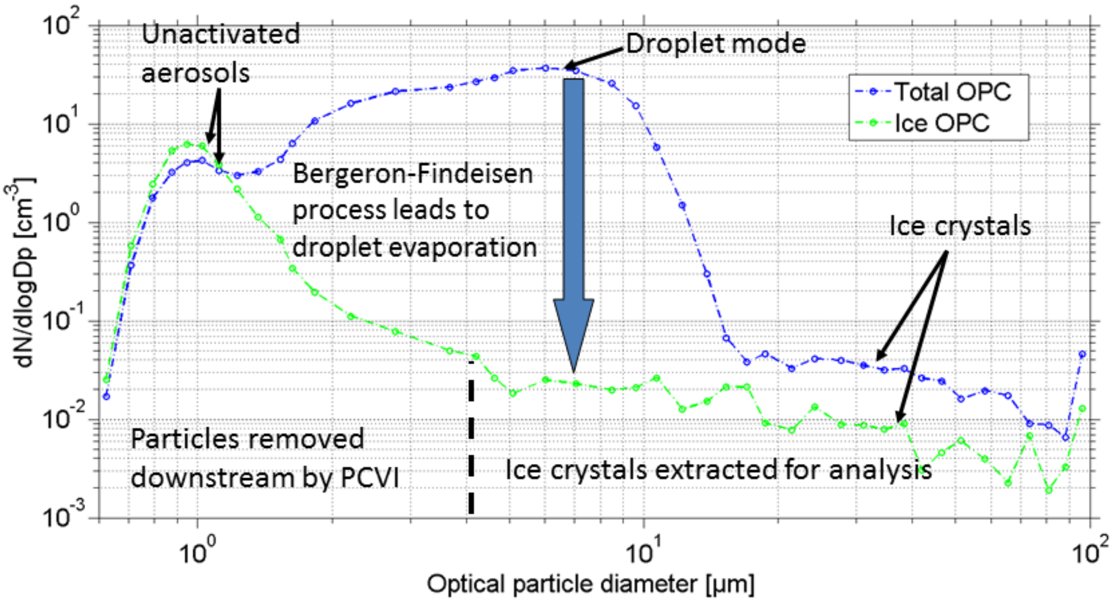

Figure 3. Number size distributions measured by OPCs upstream (blue) and downstream (green) of the droplet evaporation unit in a mixed-phase cloud. The dashed line marks the D50 cutoff of the PCVI (i.e. the diameter at which 50% of particles are transmitted through the instrument).

As becomes immediately obvious, the droplet mode is greatly decreased in number in the Ice OPC, while ice crystals are transmitted to a much greater extent. Analysis of images from the Particle Phase Discriminator, which unambiguously differentiates between ice crystals and liquid droplets, confirms that the droplet evaporation unit consistently removed all droplets in the sample flow. The question arises however, why there are still particles visible in the droplet mode size range as measured by the Ice OPC. The most likely answer to this is that ice crystals are gradually sublimating within the droplet evaporation unit, with transfer of water vapor from the crystals to the ice-covered walls. In view of these results, the current design of the ISI allows for the characterization of the ice crystal residual particles, but does not allow for in-depth characterization of ice crystal microphysical properties, such as habit and surface roughness. The ISI will be modified for the upcoming CLACE 2014 to address these shortcomings.

Key words:

Atmospheric aerosol particles, aerosol climatic effects, radiative forcing, light scattering, cloud condensation nuclei, hygroscopic growth, CCN concentration, aerosol size distribution, remote sensing of aerosol optical properties

Internet data bases:

http://www.psi.ch/lac
http://aerosolforschung.web.psi.ch
https://gawrtl.psi.ch
http://www.meteoschweiz.admin.ch/web/en/meteoswiss/international_affairs/GAW.html

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