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Title of project:

The Global Atmosphere Watch Aerosol Program at Jungfraujoch

Part of this programme:

GAW, ACTRIS

Project leader and team:

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Dr. Martin Gysel, co-leader

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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.

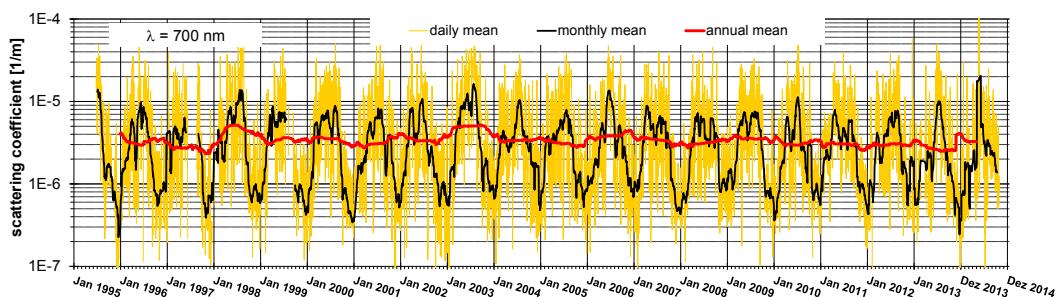


Figure 1. Time series of the total aerosol scattering coefficient as an example of the long-term measurements at Jungfraujoch.

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 site) 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 2014 it has reached 20 years of continuous measurements for part of the instruments (see Figure 1). Since December 2011, the aerosol program at 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 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.

Since 2013, online data from Jungfraujoch are presented on a public information screen at PSI. On the internet, monitoring data can be viewed at these addresses:
<http://aerosolforschung.web.psi.ch/onlinedata> or
<https://gawrtl.psi.ch>

In October 2014, an aethalometer (AE-33) and a condensation particle counter (TSI 3775) were installed at the Jungfrau East Ridge station (3705 m a.s.l., former Swisscom station), to measure aerosol microphysical properties. These measurements will be compared to those performed at the Sphinx Laboratory with a similar setup, to determine the impact of local pollution at Jungfraujoch and to investigate the small-scale spatial variability of aerosol parameters (Picture 1 & Figure 2).



Picture 1. Setup of the instruments at the former Swisscom station at the Jungfrau East Ridge.

Table 1. Current GAW aerosol instrumentation at Jungfraujoch.

Instrument	Measured parameter
CPC (TSI 3010 or 3772)	Particle number density (particle diameter $D_p \geq 10$ nm)
Nephelometers (TSI 3563 & Ecotech Aurora 3000)	Scattering coefficient at three wavelengths
Aethalometers (AE-31 & AE-33)	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

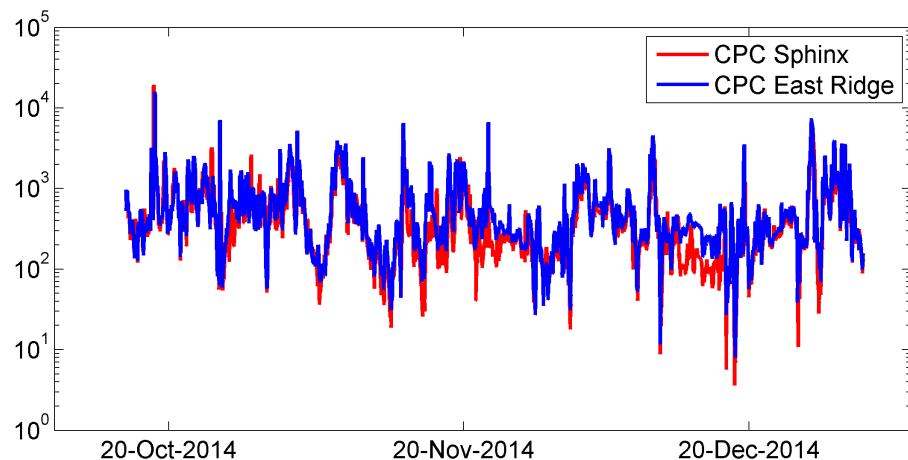


Figure 2. First data on total particle number concentration at the Jungfraujoch East Ridge and comparison to the respective observations at the Sphinx.

The CLACE 2013 and 2014 campaigns: 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 has been developed at PSI and tested at Jungfraujoch. The inlet represents a novel tool for the in-situ investigation of clouds and delivers 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, with a second campaign (CLACE 2014) during the winter of 2014. Both campaigns were 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.

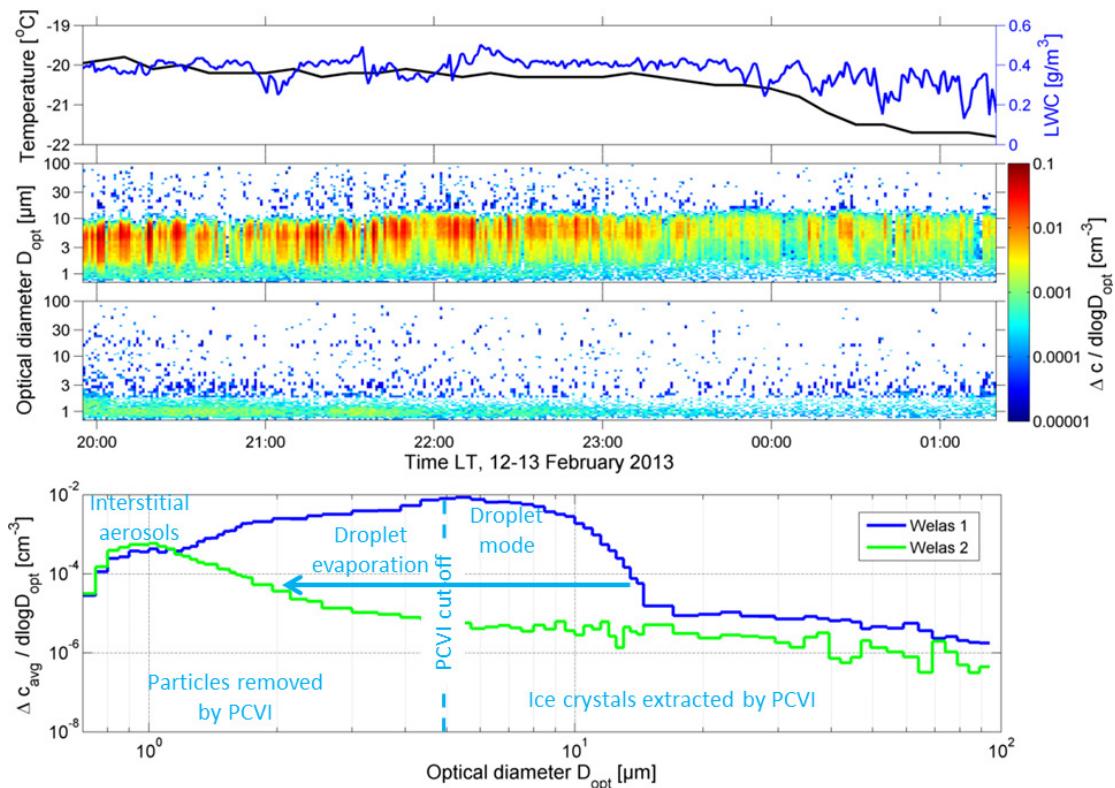


Figure 3. Air temperature, liquid water content (LWC) and particle number size distributions measured by OPSSs upstream (blue) and downstream (green) of the droplet evaporation unit in a mixed-phase cloud during CLACE 2013. The lowermost panel shows the averaged size distributions over the case study period, together with a description of the processes shaping the distributions (Source: Kupiszewski et al., AMTD, 2014).

The two campaigns allowed for verification of the working principle of the ISI. Measurements of hydrometeor size distributions (a case study from CLACE 2013 is shown in Figure 3) using optical particle size spectrometers above and below the droplet evaporation tube (which is designed to evaporate droplets in the sample flow while leaving the ice crystals intact) show that droplets are removed very efficiently. However, it was found that ice crystals are partially sublimated during transport through the inlet. While this is a hindrance for analysis of ice crystal properties, it does not pose an issue for characterising the properties of ice residuals contained within the crystals.

Following the testing of the ISI and successful data collection, analysis of the physical and chemical properties of ice residuals (IR) measured during the CLACE campaigns is ongoing.

Thus far, the ice residuals have been found to predominantly contain minerals, carbonaceous material and metals. However, the composition shows high variability between the measured cloud events. Furthermore, based on measurements using a state-of-the-art waveband integrated bioaerosol sensor (WIBS-4), enrichment of fluorescent particles, potentially of biological origin, has been found during a Saharan Dust Event measured during CLACE 2014. Further analysis will focus on establishing the physical properties of IR, as well as on clarifying the potential contribution of Black Carbon to ice nucleation in the free-tropospheric mixed phase clouds.

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:

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<http://ebas.nilu.no/>
<http://www.actris.net/>

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