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 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 may lead to an increase in cloud droplet number concentration and a corresponding decrease in cloud droplet effective radius, when the cloud liquid water content (LWC) remains constant. The resulting cloud droplet spectrum may also lead to reduced precipitation and increased cloud lifetime. The overall result 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 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 22 Global and some 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. The current GAW instrumentation that is continuously run by PSI consists of

• CPC (TSI 3010)	Particle number density (particle diameter D_p>10 nm)
• Nephelometer (TSI 3563)	Scattering coefficient at various wavelengths
• Aetalometer (AE-31)	Absorption coefficient at various wavelengths; black carbon (BC) concentration
• MAAP	Absorption coefficient; black carbon (BC) conc.
• Filter packs	Aerosol major ionic composition (PM1 and TSP)
• Betameter	Aerosol mass (PM1)

For these measurements, ambient air is sampled via a heated inlet (25 deg 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 is called the *total* inlet.

The ambient light scattering and absorption coefficients are important quantities in assessing the direct effect of aerosol on climate. The conducted measurements reflect these quantities under dry conditions, and they may therefore be significantly different from the values under ambient, climate relevant conditions. In order to correct for these shortcomings, Nessler *et al.* (2005a) calculated the relative change in the scattering coefficient to be greater than a factor of 1.5 for ambient relative humidity higher than 60% or 70% in winter or summer, respectively. The effect on absorption coefficient is smaller, but also significant (Nessler *et al.*, 2005b).

In summer, the site is influenced by injection of planetary boundary layer air into the free troposphere during sunny afternoons due to thermal convection, while in winter it is always in the undisturbed free troposphere. This causes all extensive aerosol parameters, to be higher in summer than in winter (see Figure 1).

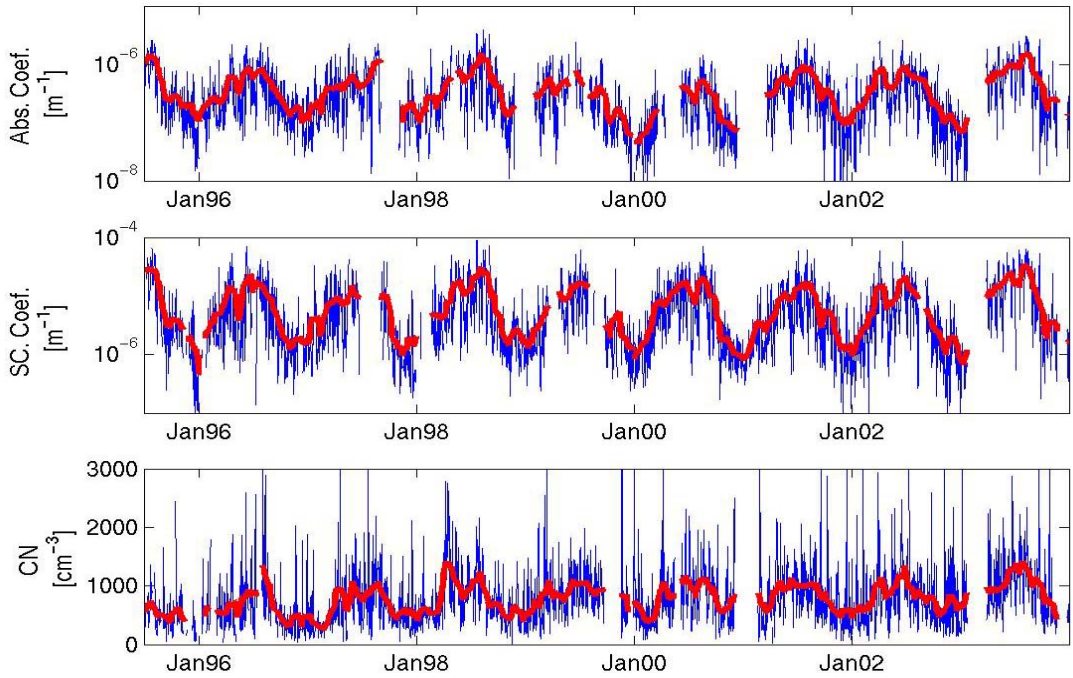

Figure 1. Long-term measurements of the absorption coefficient (at 880 nm), the scattering coefficient (at 450 nm), and the number concentration (above 10 nm diameter). Values are given as daily average (thin blue line) and 30 day running average (thick red line).

A third intensive measurement campaign, the Cloud and Aerosol Characterization Experiment (CLACE 3) took place from March 1 to 31, 2004, with participation from eight different research groups. During this campaign, additional instrumentation was employed to characterize the aerosol size distribution (Scanning Mobility Particle Sizer, SMPS; Optical Particle Counter, OPC). The University of Manchester (UMIST) and the Max Plank Institute in Mainz (MPI) operated two Aerodyne Aerosol Mass Spectrometer (AMS) for the size segregated chemical composition. Other measured parameters were the particles hygroscopic properties (Hygroscopicity Tandem Differential Mobility Analyzer, H-TDMA), cloud condensation nuclei

concentration (Cloud Condensation Nuclei Counter, CCNC), cloud microphysics (Particulate Volume Monitor, PVM; Forward Scattering Spectrometer Probe, FSSP; Cloud Particle Imager, CPI; Phase Doppler Anemometer, ADA), as well as particle and ice crystal morphology (Environmental Scanning Electron Microscope, ESEM; formvar replicas).

Two additional inlets were used for these instruments: An *interstitial* inlet operated with a PM2 cyclone impactor removed all cloud particles from the ambient air. Within a cloud the sampled air thus represents the interstitial (or unactivated) aerosol fraction. In addition, the Institute for Tropospheric Research (IfT) operated a Counterflow Virtual Impactor (CVI). The CVI was part of a new prototype sampling system (Ice-CVI) which allowed for the separation of small *ice particles* from large ice crystals, cloud droplets and interstitial aerosol particles. The extracted ice particles were dried airborne in the system and the remaining residual particles which correspond to the former ice nuclei were analyzed with a variety of different instruments.

Differencing the response downstream of the different inlets provides insight in the fractionation of aerosol particles between the cloud phase and the interstitial phase. The activated fraction is defined as the fraction of the total particle number (D_p >100 nm) that is activated into cloud droplets (obtained from total minus interstitial). The positive correlation between temperature and activated fraction (see Figure 2) is due to the relative scarcity of ice nuclei as compared to cloud condensation nuclei, and to the Bergeron-Findeisen process, which describes the effect of a water vapour flux from liquid droplets to ice crystals, thus transforming cloud droplets back into interstitial aerosol particles.

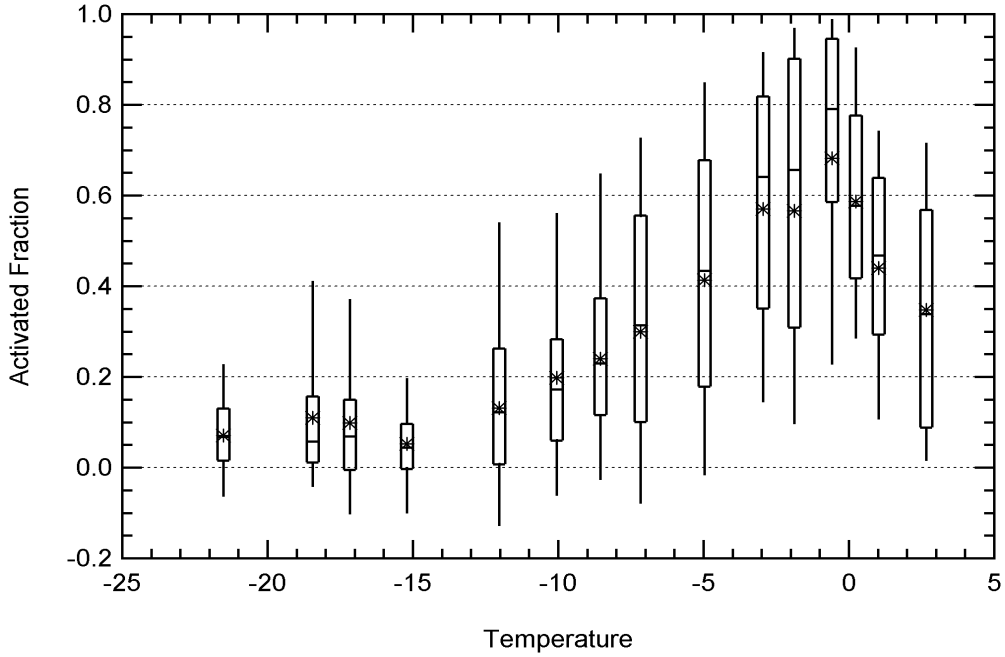

Figure 2. Activated number fraction of aerosol particles as a function of temperature.

The black carbon content of the atmospheric aerosol is activated into cloud droplets to the same extent as the bulk aerosol (see Figure 3). Such behaviour is not expected for freshly emitted soot particles because they have a hydrophobic nature. The soot particles on the Jungfraujoch experienced aging processes which transformed them into an internally mixed hygroscopic aerosol.

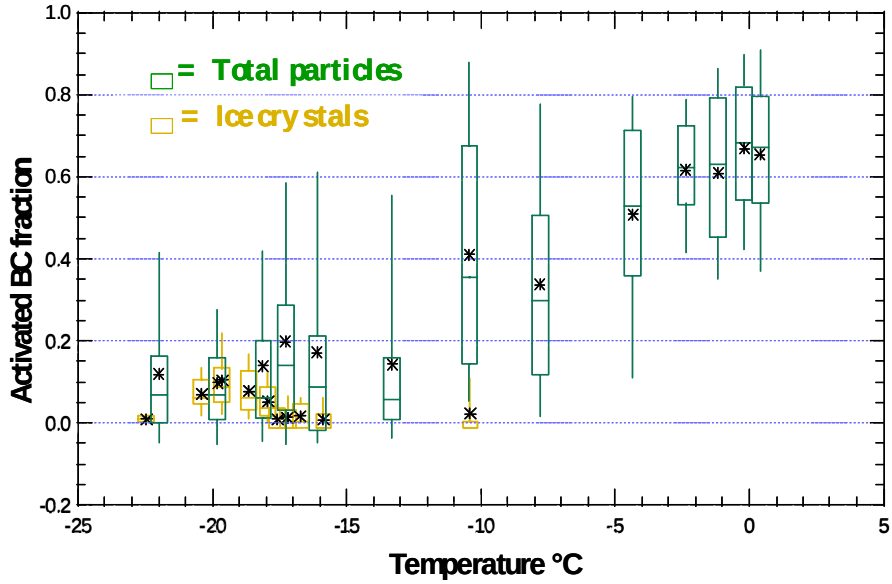

Figure 3. Activated black carbon mass fraction as a function of temperature.

A smaller measurement campaign undertaken by PSI, dubbed CLACE 3½, took place from July 15 to September 30, 2004. This provided data on the aerosol activation behaviour at higher temperatures to complement the winter measurements. For this purpose, size distribution and black carbon measurements were made downstream of both the total and interstitial inlet. Figures 2 and 3 include both the winter (CLACE 3) and summer (CLACE 3½) data.

The activated fraction also correlates positively with the liquid water content, since more available water vapour causes more particles to be activated. The activated fraction correlates negatively with the total number of particles, but only for very low concentrations, in which case the availability of cloud condensation nuclei is the limiting factor for activation.

The newly developed expansion type cloud condensation nuclei counter (CCNC) was also successfully deployed during CLACE 3, providing similar data as the simultaneously run conventional parallel plate type CCNC. The hygroscopicity tandem differential mobility analyzer (H-TDMA) provided measurements that agree well with those from previous campaigns, broadening the basis for a hygroscopicity closure study by comparing its results with chemical mass size distributions as measured with the Aerosol Mass Spectrometer (AMS).

Key words:

Atmospheric aerosol particles, aerosol-cloud interactions, aerosol climatic effects, radiative forcing, cloud condensation nuclei, hygroscopic growth

Internet data bases:

http://www.psi.ch/gaw

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