The continuous and long-term aerosol monitoring programme at Jungfraujoch

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1. Project description

Aerosol particles affect the Earth's climate by influencing the atmospheric energy budget through direct and indirect effects. Direct effects (aerosol – radiation interactions, ARI) are the scattering and absorption of radiation by aerosol particles. Indirect effects (aerosol – cloud interactions, ACI) refer to the role of particles as cloud condensation nuclei (CCN) and ice-nucleating particles (INP). The climate relevance of both ARI and ACI results from their effect on the planetary albedo (incoming shortwave radiation). ACI furthermore affect the Earth's outgoing longwave radiation. The IPCC report states ARI and ACI remain one of the major uncertainties in the anthropogenic radiative forcing due to their limited scientific understanding.

The Global Atmosphere Watch (GAW) program is an activity coordinated by the World Meteorological Organization (WMO) to gain a better understanding on aerosol particles worldwide. The goal of GAW is 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 spatial-temporal distribution of aerosol properties related to climate forcing and air quality up to multi-decadal time scales. The GAW monitoring network consists of 31 global (including the Jungfraujoch site) and about 400 regional stations. The aerosol program at Jungfraujoch is further a member of the Pan-European Aerosols, Clouds, and Trace gases Research Infra Structure (ACTRIS).

The aerosol records at Jungfraujoch are among the most extensive within Europe and worldwide (Bukowiecki et al., 2016). By the end of 2021, some specific observations have been performed continuously for 26 years (Figure 1). The current GAW long term monitoring instrumentation at the Jungfraujoch is consisting mainly of instruments to determine the physical and optical properties of aerosol particles. For these measurements, ambient air is sampled via a heated inlet (35°C), designed to prevent ice build-up and to evaporate cloud droplets at an early stage, ensuring that the residual particles of cloud droplets and ice crystals are also sampled. Data are delivered to GAW and ACTRIS data warehouses, including near real time data provision.

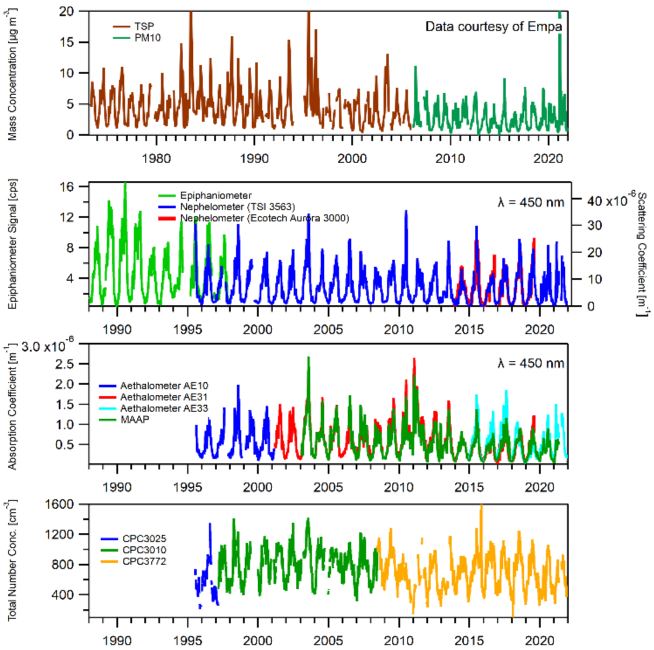

Figure 1. Temporal evolution of the continuously measured aerosol parameters at the Jungfraujoch (30-day running average of the daily average values). Particle mass concentration data values of total suspended particles (TSP) and particles with aerodynamic diameters <10 µm in the top panel are provided in courtesy by Empa/NABEL.

Renovation of the measurement infrastructure

The renovation of the Sphinx laboratory was a key endeavour of 2021. This opportunity was taken to reorganize and refurbish the aerosol measurement instrumentation extensively. The aerosol inlet system has been completely overhauled. This was particularly necessary for its electrical safety and lightning protection. In addition, temperature control was redone and data acquisition was expanded. The electrical supply was completely redesigned. This also improves in particular possibilities for remote control and thus hopefully also data coverage. Furthermore, the measurement devices are now organized in three rack cabinets. This not only creates a better organization, but also easier facilitates troubleshooting and maintenance tasks. The new setup is shown in Figure 2. All instruments have been taken to PSI, where maintenance was carried out. They were then re-installed at JFJ step by step, starting in mid-July. By the end of the year, the majority of the aerosol measurements are operational again. Only the second nephelometer and the cloud condensation nuclei counter require further repairs and will be re-installed in 2022.

After 25 years of continuous monitoring of aerosol properties, the reconstruction work has created a substantial gap in the data series for the first time. While light scattering, absorption (AE33) and condensation particle counter (CPC) measurements had a data gap of less than two months, the particle size distribution and multi-angel absorption measurements had a longer gap of more than four months. However, the new setup shall pave the way for another 25 years of continuous aerosol observations compliant with current standards of international observation networks.

Figure 2. New measurement setup for aerosol monitoring. The instruments are organized in three rack cabinets.

Real time chemical composition of atmospheric aerosols

Not only physical properties of atmospheric aerosols, but also their chemical composition is relevant to understand their origin and their chemical evolution in the atmosphere. Besides in targeted efforts (e.g. Fröhlich et al., 2015), particle chemical composition on the Jungfraujoch was routinely measured with filterpacks every sixth day until May 2021. In December 2021, an aerosol mass spectrometer (TOF-ACSM, time-of-flight aerosol chemical speciation monitor) has been installed at JFJ providing chemical information about the measured particles in real time and in situ. First raw data is shown in Figure 3. The data shown in Figure 3 clearly shows the clean tropospheric background conditions indicative for that time of the year. Also clearly identifiable are spikes in the organic mass signal due to local contamination from tourist activities (e.g. cigarette smoke)

Figure 3. Chemical aerosol composition of measured particles with the TOF-ACSM at Jungfraujoch in December 2021. Raw time series of chloride (Chl), ammonium (NH_4), nitrate (NO_3), organics (Org) and sulfate (SO_4) are measured with 40 s time resolution.

References

Bukowiecki, N., E. Weingartner, M. Gysel, M. Collaud Coen, P. Zieger, E. Herrmann, M. Steinbacher, H.W. Gäggeler, U. Baltensperger, A review of more than 20 years of aerosol observation at the high altitude research station Jungfraujoch, Switzerland (3580 m asl), Aerosol Air Qual. Res., **16**, 764–788, doi: 10.4209/aaqr.2015.05.0305, 2016.

Fröhlich, R., M. Cubison, J. Slowik, N. Bukowiecki, F. Canonaco, P.L. Croteau, M. Gysel, S. Henne, E. Herrmann, J.T. Jayne, M. Steinbacher, D.R. Worsnop, U. Baltensperger, A.S.H. Prévôt, Fourteen months of on-line measurements of the non-refractory submicron aerosol at the Jungfraujoch (3580 m a.s.l.) – chemical composition, origins and organic aerosol sources, Atmos. Chem. Phys., **15**, 11373-11398, doi: 10.5194/acp-15-11373-2015, 2015.

Internet data bases

https://www.psi.ch/en/lac/projects/gaw-aerosol-monitoring
https://www.psi.ch/en/lac/projects/actris
https://www.psi.ch/en/lac/projects/last-72h-of-aerosol-data-from-jungfraujoch
https://www.meteoswiss.admin.ch/home/research-and-cooperation/international-cooperation/gaw.html
https://ebas.nilu.no/
https://www.actris.eu/
https://www.meteoswiss.admin.ch/home/climate/climate-change-in-switzerland/aerosol-and-climate.html
https://www.meteoswiss.admin.ch/home/climate/the-climate-of-switzerland/specialties-of-the-swiss-climate/saharan-dust-events.html

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Scientific publications and public outreach 2021

Refereed journal articles and their internet access

Affolter, S., M. Schibig, T. Berhanu, N. Bukowiecki, M. Steinbacher, P. Nyfeler, M. Hervo, J. Lauper, M. Leuenberger, Assessing local CO2 contamination revealed by two near-by high altitude records at Jungfraujoch, Switzerland, Environmental Research Letters, **16**, 4, doi: 10.1088/1748-9326/abe74a, 2021.
https://doi.org/10.1088/1748-9326/abe74a

Bressi, M., F. Cavalli, J.P. Putaud, R. Fröhlich, J.E. Petit, J. W. Aas, … A.S.H. Prevot, A European aerosol phenomenology - 7: high-time resolution chemical characteristics of submicron particulate matter across Europe, *Atmospheric Environment: X*, **10**, 100108 (16 pp.), 2021. https://doi.org/10.1016/j.aeaoa.2021.100108

Brunner, C., B.T. Brem, M. Collaud Coen, F. Conen, M. Hervo, S. Henne, M. Steinbacher, M. Gysel-Beer and Z.A. Kanji, The contribution of Saharan dust to the ice-nucleating particle concentrations at the High Altitude Station Jungfraujoch (3580 m a.s.l.), Switzerland, Atmos. Chem. Phys., **21**, 18029–18053, doi: 10.5194/acp-21-18029-2021, 2021.
https://doi.org/10.5194/acp-21-18029-2021

Bukowiecki, N., B.T. Brem, G. Wehrle, G. Mocnik, S. Affolter, M. Leuenberger, M.C. Coen, M. Hervo, U. Baltensperger, M. Gysel-Beer, Elucidating local pollution and site representativeness at the Jungfraujoch, Switzerland through parallel aerosol measurements at an adjacent mountain ridge, Environmental Research Communications, **3**, 2, doi: 10.1088/2515-7620/abe987, 2021.
https://doi.org/10.1088/2515-7620/abe987

Evangeliou, N., S.M. Platt, S. Eckhardt, C. Lund Myhre, P. Laj, L. Alados-Arboledas, … A. Stohl, Changes in black carbon emissions over Europe due to COVID-19 lockdowns, Atmospheric Chemistry and Physics, **21**, 4, 2675-2692, 2021. https://doi.org/10.5194/acp-21-2675-2021

Lacher, L., H.C. Clemen, X. Shen, S. Mertes, M. Gysel-Beer, A. Moallemi, … Z.A. Kanji, Sources and nature of ice-nucleating particles in the free troposphere at Jungfraujoch in winter 2017, Atmospheric Chemistry and Physics, **21**, 22, 16925-16953, 2021.
https://doi.org/10.5194/acp-21-16925-2021

Rose, C., M. Collaud Coen, E. Andrews, Y. Lin, I. Bossert, C. Lund Myhre, … P. Laj, Seasonality of the particle number concentration and size distribution: a global analysis retrieved from the network of Global Atmosphere Watch (GAW) near-surface observatories, Atmospheric Chemistry and Physics, **21**, 22, 17185-17223, 2021. https://doi.org/10.5194/acp-21-17185-2021

Sun, J., M. Hermann, Y. Yuan, W. Birmili, M.C. Coen, K. Weinhold, L. Madueno, L. Poulain, T. Tuch, L. Ries, R. Sohmer, C. Couret, G. Frank, B.T. Brem, M. Gysel-Beer, N. Ma, A. Wiedesohler, Long-term trends of black carbon and particle number concentration in the lower free troposphere in Central Europe, Environmental Sciences Europe, **33**, 1, doi: 10.1186/s12302-021-00488-w, 2021.
https://doi.org/10.1186/s12302-021-00488-w

Conference Papers

Brem, B.T., N. Bukowiecki, G. Wehrle, M. Collaud Coen, M. Steinbacher, S. Henne, S. Reimann, U. Baltensperger and M. Gysel-Beer, Occurrence and Radiative Properties of Long-range Transported Wildfire Aerosol Measured at the Jungfraujoch, 24th ETH-Conference on Combustion Generated Nanoparticles (virtual), Zurich, Switzerland, June 22, 2021.

Gysel-Beer, M., B. T. Brem, S. Kazadzis, J. Gröbner, and M. Collaud Coen, The GAW-CH contributions to constraining aerosol radiative impacts with in-situ and remote sensing measurements, Swiss National GAW/GCOS Symposium, Berne, Switzerland, September 14, 2021.

Magazine and Newspaper articles

«Kleine Partikel, Grosse Auswirkung», Gysel- Beer, M. und Brem, B., ProClim-Flash, 75, s. 20-21, December 13, 2021. https://scnat.ch/en/uuid/i/3469a1b9-10c7-5ca8-afd5-edf7a3f28660-ProClim_Flash_75

Radio and television

«Saharastaub über der Schweiz» – Brem, B. Interview with Radio 1, March 3, 2021.

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