Year-round measurement of PM_1 aerosol and its chemical composition in the Swiss high Alps using the Time-of-Flight Aerosol Chemical Speciation Monitor (ToF-ACSM)

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The newly-developed Time-of-Flight Aerosol Chemical Speciation Monitor (ToF-ACSM) is conceptually related to the Q (quadrupole)-ACSM (Ng, 2011), which itself is based on Aerosol Mass Spectrometer (AMS, Jayne, 2000) technology. The ACSM systems are designed for long-term, low-maintenance operation. These features, combined with their lower cost relative to the AMS, makes them suitable for long-term deployment (> years) and integration into monitoring networks. The ToF-ACSM provides online measurements with high sensitivity (e.g. detection limit for sulfate: 3.1 ng/m^3 at 30 min time resolution) of the major non-refractory species of the submicron aerosol (organics, NO_3, SO_4, NH_4 and chloride).

Initial deployment of the ToF-ACSM was performed at the Sphinx research station on the Jungfraujoch (JFJ, 3570 m a.s.l.) in the Bernese Alps. For many years measurements at the JFJ have provided excellent insights into the properties of high alpine aerosols. Most of the winter the station lies within the free troposphere while in summer aerosol generated at lower altitudes can reach the Jungfraujoch due to vertical exchange processes (Henne, 2004). However, despite the vast number of experiments performed there, we here present the first dataset of an online year-round measurement (resolution: 15 - 30 min) of the aerosol chemical composition at the Jungfraujoch.

This one-year exercise proved the measurements and tested the operational stability of the new instrument. The deployment included an intercomparison between the ToF- and Q-ACSM for a period of five months. The instrument time series were strongly correlated (e.g. organics July 27 - August 05: slope = 0.98; R^2 = 0.95) and the ToF-ACSM improved on Q-ACSM detection limits by a factor of 4 to 62, depending on the species measured. Furthermore, we plan to report the correlation to a CToF-AMS instrument from measurements during the CLACE2013 campaign in the first months of 2013.

The aerosol data shows a distinct seasonal cycle with higher concentrations in summer ($C_{av(26Jun-07Sept)}$ = 3.3 μg/m^3, $C_{max(26Jun-07Sept)}$ = 27.8 μg/m^3)† and low concentrations during wintertime ($C_{av(01Nov-07Jan)}$ = 0.5 μg/m^3)†. In summer the aerosol consists mainly of organics (58 %) with some sulfate (25.2 %), ammonium (9.4 %) and nitrate (6.8 %) and exhibits a regular diurnal cycle corresponding to PBL movement; that is, the aerosol concentration increases during the day with a maximum around 16:00 and decreases again after sunset. The concentrations of all measured species follow this cycle more or less the same way. In winter this diurnal pattern disappears and the concentration stays relatively constant on a low level with the exception of a few rare pollution events (see Fig. 1). This suggests that the JFJ research station is situated in the free tropsphere during the cold season. Sulfate becomes the major fraction in winter with a share of 54.6 %. 30.1 % of the aerosol are organics and the fractions of ammonium and nitrate are similar to summer (8.7 % and 6.0 %)

Preliminary analyses with statistical techniques (Multilinear Engine version 2, Paatero, 1999) show that the organic fraction in summer mainly exists of highly oxidized species, i.e. "aged" aerosol (mostly LV-OOA, some SV-OOA). As expected, the influence of fresh aerosol from local sources like HOA or BBOA is low at the Jungfraujoch (< 15 % of total).

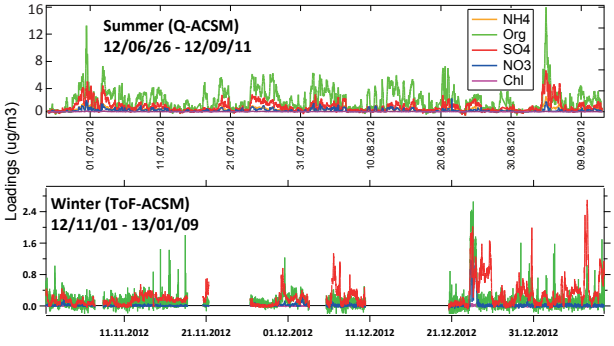

Figure 1: Sample time series recorded at the Jungfraujoch. Top: 2.5 months in summer measured with the Q-ACSM. Bottom: 2 months in winter measured with the ToF-ACSM. Note the different scaling of the y-axis.

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†all values calculated assuming collection efficiency CE = 0.5