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Monitoring of Saharan Dust – Influence on aerosol composition and snow chemistry

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Abstract

Long-range transport of Saharan dust (SD) serves as a significant source of high particulate matter (PM) concentrations far away from the source region. High PM loads are relevant for climatic issues such as the radiation budget or cloud formation processes as well as for environmental issues such as acidity, ionic loads of precipitation and nutrient supply, but also for air quality issues and related topics such as human health. Extensive investigations and long-term studies of Saharan dust form the basis for further impact related studies.
We investigated the influence of SD on the aerosol composition as well as on high alpine snow chemistry and found a strong increase in aerosol mass and big differences in the aerosol size distribution with an increase of particle numbers in the coarse mode during SD-episodes. Besides our measurements of the snow chemistry underline the assumption that SD serves a high cationic input of especially Calcium as well as a high alkaline input, shown as an increase in the pH.

Keywords

Saharan Dust, air quality, snow chemistry, aerosol composition

Introduction

The Sonnblick Observatory, located in the Nationalpark Hohe Tauern, runs an extensive aerosol and snow deposition monitoring, providing an ideal data set to study the impact of SD. The occurrence of Saharan dust events (SDEs) is regularly identified based on optical aerosol properties (COEN et al., 2003). This, together with the observed aerosol mass, allows the computation of a "Saharan dust index" indicating a potential Saharan dust influence (SCHAUER et al., 2016). Besides, since spring 2016, the aerosol monitoring within the project DUSTFALL (funded by the Austrian Research Promotion Agency, FFG) comprises also a filter sampling of different particle sizes.
Complementary to this extensive aerosol monitoring, a 30 years long time-series (1987-2017) of the chemical composition of the annual winter accumulation snow is available from a glacier nearby the Observatory. It is well known, that the chemical composition of the snow is strongly influenced by long range transport of mineral dust (e.g. SD), markedly changing the cation concentration and the alkalinity of the snow cover, especially in such remote areas far off of human influence (e.g. MAUPETIT & DELMAS, 1994).

The aim of this study is to investigate the influence of SD on the aerosol composition, in particular the chemical differences of the coarse (PM10) and fine (PM1) particles via the analysis of weekly aerosol filter samples of these two size fractions. Besides, the ecological issues of SD are investigated by evaluating the influence of SD deposition on high alpine snow chemistry of the last three decades from 1987 until 2016.

Methods

For the investigation of the aerosol composition during SDEs the particles are separated in two size fractions (PM10 and PM1). The PM10 fraction is sampled on quartz fibre filters via a Digitel High-Volume Sampler with a PM10 separator at the aerosol inlet, including the coarse and fine particle fraction. The PM1 fraction is also sampled on quartz fibre filters. Size segregation is performed by a low pressure impactor, installed at the whole air inlet available at the Observatory. Optical analysis of the filters comprises the measurement of transmitted light through the filter in the IR (880 nm) and UV (371 nm) using an OT-21 transmissiometer (Magee Scientific). The chemical analysis covers the measurements of soluble cations (Ca^{2+}, Mg^{2+}, NH_4^+, K^+, Na^+) and anions (SO_4^{2-}, NO_3^-, Cl^-) as well as the determination of sugars (mainly levoglucosan) via ion chromatography using standard protocols and the determination of organic and elemental carbon via a thermo-optical OC-EC Analyser (Sunset Lab) and the ESUAAR2 temperature program.

Snow samples of the whole winter accumulation snow cover were collected every year at the end of April, just before snow melt is likely to occur, in a 10 cm vertical resolution. Samples were kept frozen until the analysis in the lab where the pH, the conductivity as well as the ion composition (Ca^{2+}, Mg^{2+}, NH_4^+, K^+, Na^+, SO_4^{2-}, NO_3^-, Cl^-) via ion chromatography was measured. We identified Saharan Dust Layers (SDLs) in the 30-year long snow pack data set via a two-step approach based on ROGORA et al. (2004). In a first step we identified alkaline layers via a pH higher than 5.6 and in a second step SDLs out of the alkaline layers were identified via a Ca^{2+} concentration of more than 15µeq/l.

Results and Discussion

Influence of SD on aerosol composition

The influence of SD on aerosol composition, in particular the chemical differences of the coarse (PM10) and fine (PM1) particles, is studied via the analysis of weekly aerosol filter samples of these fractions. Focus is put on two different episodes (Fig. 1), one without (02.06.2016-09.06.2016) and one with SD influence (21-07-2016-28.07.2016). Considering the first episode PM1 and PM10 samples feature almost the same colour due to a negligible influence of coarse particles. In contrast, during the second episode with SD influence, the larger PM10-filter has a brownish colour, whereas the small PM1 filter has a dark grey colour. As can be seen in the time series of the particle numbers of the two size fractions, a very high number of coarse particles was observed, whereas the fine particle mode does not really differ from the week before and after. More details become visible when chemical analysis is considered.

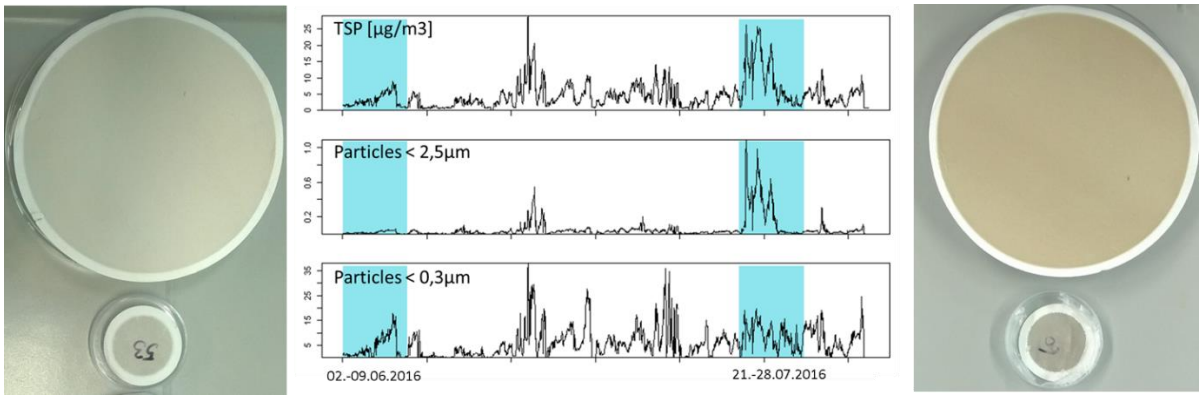

Figure 1: Time series of Total Suspended Particles (TSP) in µg/m3 and number of particles smaller than 2.5µm and 0,3µm in diameter. Filters of the PM10 (big filter) and PM1 (small filter) of the period from 02.-09.06.2016 (left) and of the period from 21.-28.07.2016 (right). Please check the digital conference volume for the true colour version of this figure!

Influence of SD on high alpine snow chemistry

Based on the two-step approach described above, we performed a retrospective identification of SDLs in high alpine snow packs of the last three decades from 1987 until 2016 (compare GREILINGER et al., 2016) to investigate the influence of SD on high alpine snow chemistry.

Fig. 2 shows mean deposition loads of every single ion for all years, separated in the contribution of SDLs and the remaining non-SDLs. Mean contribution of SDLs range between 5-6% for Cl-, NO3-, SO42-, Na+, NH4+ and K+ whereas for Mg2+ and Ca2+ a mean contribution of 16% and 28%, respectively, was found, although only 6% of all layers are identified as SDLs and contribute only 10% to the deposition load of all years.

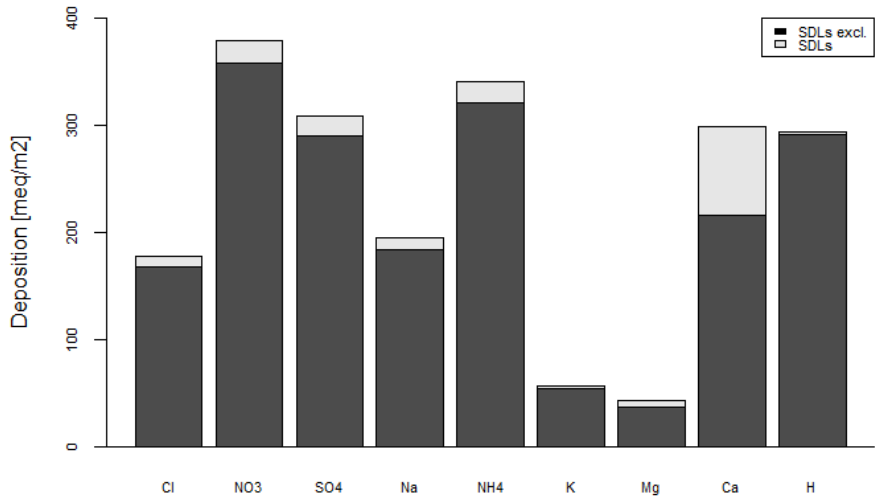

Figure 2: Mean deposition loads of all years in meq/m2 separated in the contribution without SDLs (black) and of SDLs only (grey).

The mean pH over all annual snow packs featuring SD input is 5.46. If layers, identified via the criteria described above, are excluded from the calculations, the mean pH remains in the same range with 5.39. In contrast the mean pH of SDLs only increases up to a mean pH of 6.11 (Fig. 3). Thus the pH in SDLs is 0.7 pH units higher than in other layers. SDLs alone show pH values corresponding to an 80% lower H+ concentration.

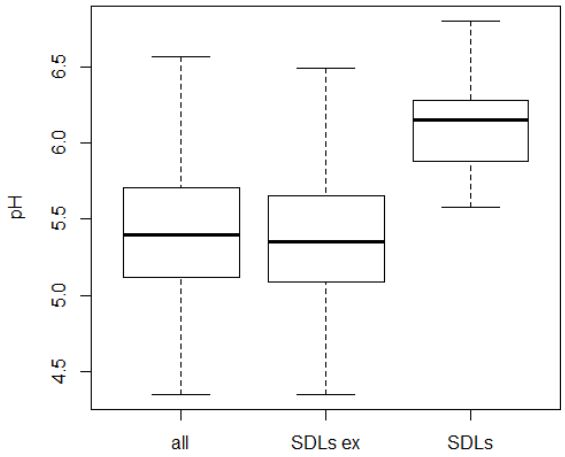

Figure 3: Mean pH values of all layers, layers with SDLs excluded and SDLs alone.

Conclusion

The aerosol filter sampling allows a differentiation between comparable small background aerosol particles, which is usually omnipresent, and the coarse air particles, which can be attributed to long-range transport of desert dust, e.g. from the Sahara, and reach the observatory episodically. These differentiation is of great interest to investigate the occurrence and intensity of SD transported to Austria and to improve the understanding how these episodes influence air quality issues such as exceedances of limit values of PM concentrations at lower elevations.
The investigation of the long-term snow chemistry data set and the retrospective identification of SDLs within the snowpack is very unique and allows conclusions on the impact of SD, not only on high alpine snow ecology, but also on additional ecological issues such as fertilization of surrounding ecosystems due to melt water run-off.

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