Radiative forcing by elemental carbon and mineral dust on Central Asian Glaciers

J. Schmale[1], M. G. Flanner[2], S. Kang[3,4], M. Sprenger[5], Q. Zhang[4,3], Y. Li[4,3], J. Guo[3,4]

[1] Laboratory for Atmospheric Chemistry, Paul Scherrer Institute, Villigen, 5232, Switzerland
[2]Department of Atmospheric, Oceanic and Space Sciences, University of Michigan, Ann Arbor, Michigan, USA
[3]State Key Laboratory of Cryospheric Sciences, Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI), Chinese Academy of Sciences (CAS), Lanzhou, 730000, China
[4] CAS Center for Excellence in Tibetan Plateau Earth Sciences, Beijing, 100101, China
[5]Swiss Federal Institute of Technology Zurich, 8092, Switzerland

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Presenting author email: julia.schmale@psi.ch

In Central Asia, 90 % of the population depends on water stored in glaciers and mountain snow cover. While temperature, precipitation and glacial dynamic processes are the key drivers of glacial change, the deposition of light absorbing substances such as mineral dust and black carbon can lead to accelerated melting through surface albedo reduction. In this study, we address the implications of deposited mineral dust and black carbon on albedo changes and radiative forcing. In addition, we use co-deposited species such as heavy metals and organic carbon, as well as back trajectory analyses to gain information about aerosol sources.

Snow samples were taken from a total of 13 snow pits on four different glaciers - Abramov (Pamir), Suek, Glacier No. 354 and Golubin (Tien Shan) – generally covering deposited impurities between summer 2012 and summer 2014. A total of 218 snow samples were taken following the "clean hands, dirty hands protocol" and were kept frozen until analysis, however melting could not be prevented completely in some cases. The samples were analyzed for major ions, rare earth elements, heavy metals, mercury, elemental and organic carbon (EC, OC) and total mineral dust among others. Principal component analysis (PCA) was performed to characterize the varying composition of the deposited aerosol. Albedo reduction due to black carbon and mineral dust was calculated with the Snow-Ice-Aerosol-Radiative model (SNICAR, Flanner and Zender, 2005), and surface spectral irradiances were derived from atmospheric radiative transfer calculations to determine the radiative forcing (RF) under clear-sky conditions.

Preliminary results of EC, OC and mineral dust average concentrations per snow pit are shown in Figure 1a). The EC concentrations are about a factor 4 higher than previous measurements from this region (Ming et al., 2012). This might be due to mining activities near Suek and Glacier No. 354, and the 35 km distance from Golubin to the Kyrgyz capital. Triangles indicate the annual deposition flux which shows very high variability among the study sites. The amount of deposited dust is roughly 200 times higher than the EC amount in the Pamirs, and > 300 times higher in the Tien Shan.

PCA analyses indicate that 90 % of the variability in deposited aerosol composition can be explained by 3 components in the Pamir and by 4 in the Tien Shan. The solutions suggest that there is a general mineral dust background component similar for both regions. EC is deposited either together with mineral dust or sulfate and major ions and some heavy metals in the Pamir. In the Tien Shan, EC is less associated with mineral dust but rather with heavy metal enrichment, OC and sulfate. This points to different dominant sources of EC in the two mountain ranges as well as to possible anthropogenic influence. On Golubin, especially Pb is enriched, and the correlation with EC ($R^2 = 0.6$) suggests that traffic from the nearby capital can be one source.

Preliminary mid-day clear-sky RF results for the days of sampling are shown in Figure 1b) with older surface snow on the left and fresh snow on the right. In all but 3 cases RF by BC is larger than by mineral dust, a result which might be sensitive the assumption that dust is only weakly absorbing based on elemental analysis. On average the combined and only BC forcing are twice as high on old compared to fresh surface snow. Old snow layers have undergone melting and freezing cycles leading to accumulation of BC and dust at the surface and hence represent rather high RF values. Our average BC RF results are a factor 4 higher than those by Ming et al. (2012) which is consistent with the higher BC concentrations. Our findings suggest that there is more variability in BC and dust RF than previously thought.

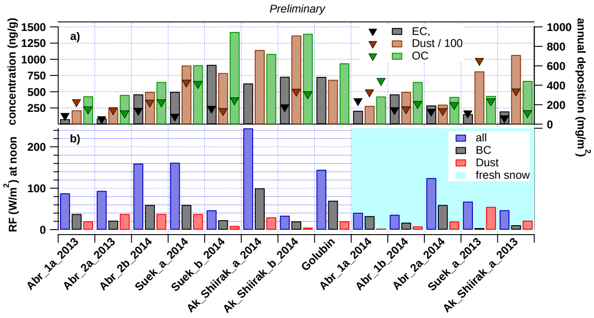

Figure 1: a) Bars indicate average concentrations of EC, OC and mineral dust per snowpit, triangles show the annual deposition flux. Note, the mineral dust concentrations are divided by 100. b) Mid-day radiative forcing by black carbon, dust and their combination based on surface snow concentrations.

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