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Source, variation, and removal of black carbon in the Arctic during the ARCTAS aircraft campaign

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Black carbon (BC) aerosols contribute to global warming by absorbing solar radiation. Particularly in the Arctic, BC reduces snow reflectance and alters snowmelt timing and snow spatial coverage, which are tightly coupled to climate effects through snow-albedo feedback. Generally, the sources of BC in the Arctic are considered biomass burning and/or fossil fuel combustion from the middle or high latitudes. However, spatial and temporal variations of BC in the Arctic region are not understood well, because there were few BC measurements with high accuracy, large spatial coverage, and long periods in the Arctic. The purposes of this study are to understand 1) concentration and vertical profile, 2) source region and processes, and 3) wet removal process during the long-range transport, for BC in the Arctic using the data of ARCTAS aircraft campaign conducted April and June-July 2008.

The median dBC (dCO) concentrations in the Arctic in spring and summer were 36.5 (10.2) and 4. 86 (16.4) ng/m3 (ppbv), respectively. dBC concentrations in spring were about an order higher than that in summer, while dCO concentrations were higher in summer than in spring. Since there are few emission sources of BC in the Arctic, dBC and dCO concentrations generally increased with altitude in both seasons. When the source regions of individual air masses were classified into each continent and/or country by backward trajectory calculations, dCO concentration was higher for air masses from Russia, Asia, and Europe (median dCO is 20 -- 80 ppbv) than those from Canada and U.S for both in spring and summer. For BC, similar tendency was seen in spring (median dBC is 50 -- 100 ng/m3 for Russian, Asian, European air masses), while dBC is lower than 20 ng/m3 for all source regions in summer. The Canadian and U.S. air masses, relatively close to observed points, were dominant for lower altitude, while the contributions from Russian and Asian air masses, far from observed points, increased with altitude.

To understand the differences of BC concentrations between in spring and summer, we calculated the accumulated precipitation for individual measured air masses using backward trajectory calculations and GPCP global precipitation data. The dBC/dCO ratio decreased with increasing accumulated precipitation for both seasons. It was also found that 2 times greater accumulated precipitation in summer than that in spring was one of the largest causes making distinct differences of dBC/dCO ratio and dBC concentration between spring and summer. Temporal variations of hydrophilic species and BC size distribution also support wet removal processes during the long-range transport.

Finally, we estimated the source processes (fossil fuel combustion or biomass burning) of each measured air mass using organic/sulfate aerosol concentration ratio. The contribution from Asia was relatively large for air masses of fossil fuel combustion (FF). On the other hand, the contribution from Russia was relatively large for air masses of biomass burning (BB). Since the sources of FF air masses were farther than those of BB air masses, the accumulated precipitation

and BC wet removal ratio were larger for FF air masses. The difference of BC/CO emission ratio between FF and BB air masses was also implied from measured dBC/dCO ratio. These factors induced that dBC/dCO ratio of BB air masses was 2 and 4 times larger than that of FF air masses in spring and in summer, respectively. Consequently, it was suggested that the contribution of BC from biomass burning sources could be larger than that of CO in the Arctic.

Keywords: aerosol, black carbon, Arctic, long-range transport