Black carbon deposition in Northeast Greenland over the past 350 years

Kumiko Goto-Azuma[1, 2], Kaori Fukuda[1], Jun Ogata[1], Yuki Komuro[3], Motohiro Hirabayashi[1], Fumio Nakazawa[1, 2], Ikumi Oyabu[1,2], Kyotaro Kitamura[1], Shuji Fujita[1, 2], Nobuhiro Moteki[4], Tatsuhiro Mori[5], Sho Ohata[6], Yutaka Kondo[1], Makoto Koike[4], Naga Oshima[7], Ayaka Yonekura[8], Yoshimi Ogawa-Tsukagawa[1], Kenji Kawamura[1, 2], Teruo Aoki[1], Naoyuki Kurita[6], Sune O. Rasmussen[9], Giulia Sinnl[9], Trevor J. Popp[9], Dorthe Dahl-Jensen[9, 10]

[1]*National Institute of Polar Research*

[2]*SOKENDAI (The Graduate University for Advanced Studies)*

[3]*Laboratory for Environmental Research at Mount Fuji*

[4] *The University of Tokyo*

[5]*Keio University*

[6]*Nagoya University*

[7] *Meteorological Research Institute*

[8]*Marine Works Japan*

[9]*University of Copenhagen*

[10]*University of Manitoba*

Black carbon (BC) is one of the essential light-absorbing aerosols, which can affect Earth's radiation budget. BC in the atmosphere absorbs sunlight and heats the atmosphere, whereas BC deposited on snow and/or ice reduces the surface albedo and enhances snowmelt. Black carbon can also act as cloud condensation nuclei and ice nucleating particles. The records from the preindustrial period are of particular importance in understanding the role of BC in the pristine environment. However, data are still sparse, especially in the Arctic, a vital region on Earth where climate and environment have been changing drastically. There have been no direct observations of BC in the preindustrial time, unaffected by anthropogenic input. Ice cores can provide proxy records of the BC concentration and size distribution since the preindustrial time.

We analyzed an ice core drilled at the EastGRIP site, Northeast Greenland, down to the depth of 133 m using a Continuous Flow Analysis (CFA) system at the National Institute of Polar Research. The CFA system enabled us to obtain high-resolution data on BC, stable isotopes of water, microparticles and eight elements (Na, Mg, Al, Si, S, K, Ca, Fe). For BC analysis, we used a recently developed Wide-range (WR) SP2 (Single Particle Soot Photometer), which can detect BC particles in a size range between 70 and 4000 nm (Mori et al., 2016). A combination of WR-SP2 and a high-efficiency nebulizer allowed us accurate measurements of BC concentrations and size distributions. We dated the core by annual layer counting using mainly Na concentrations (Nagatsuka et al., 2023). We also used concentrations of microparticles and Ca supplementary. As reference horizons, we used volcanic sulphate peaks and tritium peaks originating from nuclear bomb testing. Local maxima and minima of Na concentrations were assumed to correspond to January 1 and July 1, respectively. The EastGRIP ice-core record covers the past millennia. We divided each half-year evenly into six months and calculated monthly averaged BC concentrations and size distributions. Here, we report the EastGRIP BC record for the past 350 years and compare it with the previously obtained BC record from SIGMA-D in Northwest Greenland.

Both number and mass concentrations at EastGRIP started to increase around 1860 due to the inflow of anthropogenic BC. The concentrations reached their maximum around 1920 and decreased again since then. This temporal trend is similar to that at SIGMA-D, but slightly different from that at southern Greenland sites. The difference in the anthropogenic trends might reflect the difference in emission source contributions between northern and southern Greenland. Anthropogenic BC at EastGRIP had larger sizes than biomass-burning BC, as was reported for SIGMA-D. In the preindustrial period, BC concentrations peaked in summer. However, the inflow of anthropogenic BC has shifted the peak season from summer to winter/early spring. Unlike SIGMA-D, the BC peak season did not return to summer in the 1990s.

Our new accurate and high temporal-resolution data on concentrations and sizes provide essential information to understand sources, transport pathways and deposition processes. Our new data would also constrain and validate aerosol and climate models, leading to better future climate and environment projections.

References

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