【2-1703】

Black Carbon and Dust Particles in the Arctic: Behavior in Association with Global Radiative Forcing

KOIKE Makoto
The University of Tokyo
7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, JAPAN
E-mail: koike@eps.s.u-tokyo.ac.jp
Key words: black carbon, iron oxide, Arctic, SLCF

Black carbon (BC) particles, a short-lived climate forcer (SLCF), have been intensively studied in the Arctic because reductions in their emissions can reduce positive radiative forcing on a much shorter timescale than reductions in CO_2 emissions can. One aim of this study is to elucidate the behaviors of Arctic BC by making accurate measurements and advanced numerical model calculations. This study also aims to characterize anthropogenic iron oxide (FeOx) particles, which are an overlooked SLCF in the atmosphere. We then provide estimates of radiative forcing of these light absorbing aerosols as a scientific basis for policy making.

In this project, we used COSMOS, a high-accuracy instrument developed in Japan, to measure BC concentrations in the atmosphere at two Arctic sites (Sinha et al., 2017). We confirmed the accuracy of the Arctic COSMOS measurements by comparing them with measurements made with a single-particle soot photometer (SP2, Ohata et al., 2019). We also developed a method of measuring BC mass concentrations in precipitating snow and snowpack with an SP2 (Sinha et al., 2018) and then measured them in snowpacks in various Arctic regions (Mori et al., 2019). Our results show that previous studies have greatly overestimated BC mass concentrations in the Arctic snowpack. We also developed a new global aerosol model that reproduced BC observations in the Arctic better than before (Matsui, 2017; Matsui & Mahowald, 2017; Moteki et al., 2019). Shortwave effective radiative forcing of BC over the Arctic region (60-90°N) at the top of the atmosphere (TOA) in the year 2014 relative to the year 1850 was estimated to be +0.60 W m^{-2}.

In this project, we introduced a new SP2 measurement technique to study anthropogenic iron oxide (FeOx). Data from five ground-based and three aircraft-based observation campaigns in the Asian and Arctic regions showed that most of the detected FeOx particles were of anthropogenic origin. FeOx to BC mass ratios of 20% to 80% suggest that anthropogenic FeOx is ubiquitous in the troposphere (Yoshida et al., 2020). The data also indicate that automobiles are likely more important than iron mills as emission sources of FeOx (Ohata et al., 2018). Based on the observation of polluted air from China, the global emissions of anthropogenic FeOx were estimated (Yoshida et al., 2018). By using these measurements to constrain numerical model calculations, we estimated global radiative forcing by FeOx for the first time (Matsui et al., 2018). Furthermore, we showed that deposition of anthropogenic FeOx on the ocean's surface may be an important source of iron in the ocean, where it may increase the ocean's ability to absorb CO_2. Consequently, anthropogenic FeOx may affect the climate in two ways: a short-term climate effect by increasing positive radiative forcing, and a long-term climate effect by increasing the supply of iron to the ocean.

Finally, by analyzing an ice core from Greenland, we obtained BC data with high accuracy and high time resolution covering the last 350 years. BC particle size distributions over this time period were also obtained for the first time. Comparisons of numerical model calculations with these ice core BC data showed that the CMIP5 and CMIP6 emissions inventories may not account for long-term BC variation.

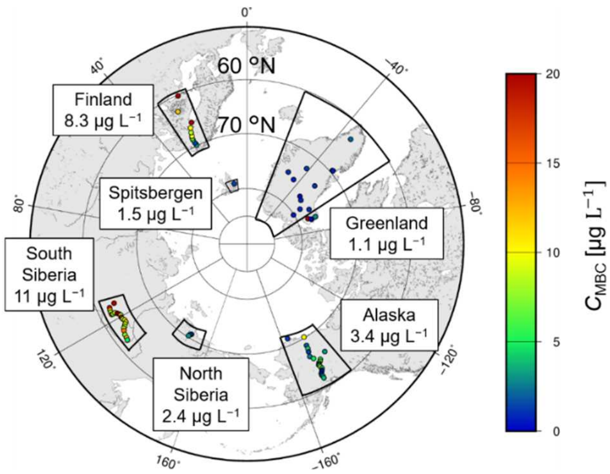

Fig. 1 Map showing locations of snow samples (circles). Circle color represents BC mass concentration in snowpack. Median values are also shown for each outlined region.

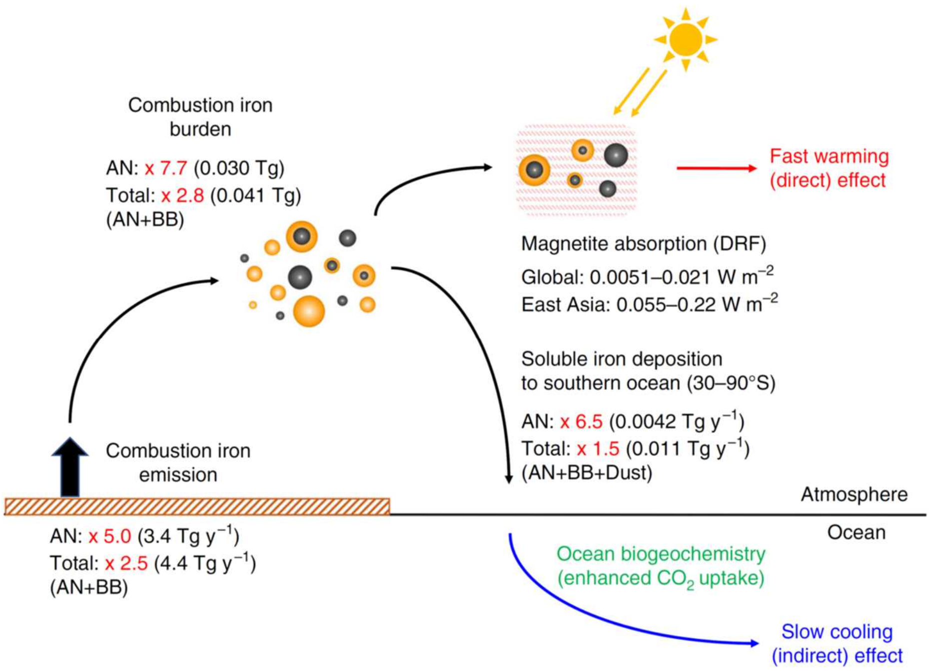

Fig. 2 Schematic figure of the findings on anthropogenic FeOx aerosols. The values shown in black are global or regionally averaged statistics on combustion iron emissions and burden, magnetite direct radiative forcing (DRF), and soluble iron deposition flux to southern oceans from anthropogenic (AN) and all sources (Total). The values shown in red are enhancement ratios in the observation-constraint simulation from the base simulation. BB in the figure stands for biomass burning.

References:

Matsui, H. (2017) Development of a global aerosol model using a two-dimensional sectional method: 1. Model design, *J. Adv. Model. Earth Syst., 9*, 1921-1947. doi:10.1002/2017MS000936.

Matsui, H. and Mahowald, N. (2017) Development of a global aerosol model using a two-dimensional sectional method: 2. Evaluation and sensitivity simulations, *J. Adv. Model. Earth Syst., 9*, 1887-1920. doi:10.1002/2017MS000937.

Matsui, H., Hamilton, D.S. and Mahowald, N.M. (2018) Black carbon radiative effects highly sensitive to emitted particle size when resolving mixing-state diversity, *Nat. Commun., 9*, 3446, doi:10.1038/s41467-018-05635-1.

Mori, T., Goto-Azuma, K., Kondo, Y., Ogawa-Tsukagawa, Y., Miura, K., Hirabayashi, M., Oshima, N., Koike, M., Kupiainen, K., Moteki, N., Ohata, S., Sinha, P. R., Sugiura, K., Aoki, T., Schneebeli, M., Steffen, K., Sato, A., Tsushima, A., Makarov, V., Omiya, S., Sugimoto, A., Takano, S. and Nagatsuka, N. (2019) Black Carbon and Inorganic Aerosols in Arctic Snowpack. *J. Geophys. Res. Atmos.*, 124, 13, 325-13, 356. https://doi.org/10.1029/2019JD030623.

Moteki, N., Mori, T., Matsui, H. and Ohata S. (2019) Observational constraint of in-cloud supersaturation for simulations of aerosol rainout in atmospheric models, *Climate and Atmospheric Science,* 2:6; https://doi.org/10.1038/s41612-019-0063-y

Ohata. S., Yoshida, A., Moteki, N., Adachi, K., Takahashi, Y., Kurisu, M. and Koike, M. (2018) Abundance of light-absorbing anthropogenic iron oxide aerosols in the urban atmosphere and their emission sources. J. Geophys. Res. Atmos., 123, 8115-8134. https://doi.org/10.1029/2018JD028363.

Ohata, S., Kondo, Y., Moteki, N., Mori, T., Yoshida, A., Sinha, P.R. and Koike, M. (2019) Accuracy of black carbon measurements by a filter-based absorption photometer with a heated inlet. *Aerosol Sci. Technol.*, 53, 1079-1091. https://doi.org/10.1080/02786826.2019.1627283.

Sinha, P.R., Kondo, Y., Koike, M., Ogren, J.A., Jefferson, A., Barrett, T.E., Sheesley, R.J., Ohata, S., Moteki, N., Coe, H., Liu, D., Irwin, M., Tunved, P., Quinn, P.K. and Zhao, Y. (2017) Evaluation of ground-based black carbon measurements by filter-based photometers at two Arctic sites. *J. Geophys. Res. Atmos*., 122, 3544-3572, doi:10.1002/2016JD025843.

Sinha, P.R., Kondo, Y., Goto-Azuma, K., Tsukagawa, Y., Fukuda, K., Koike, M. and Pedersen, C.A. (2018) Seasonal progression of the deposition of black carbon by snowfall at Ny-Ålesund. Spitsbergen, *J. Geophys. Res. Atmos.,* 123, 997-1016. https://doi. org/10.1002/2017JD028027.

Yoshida, A., Ohata, S., Moteki, N., Adachi, K., Mori, T., Koike, M. and Takami, A. (2018) Abundance and emission flux of the anthropogenic iron oxide aerosols from the East Asian continental outflow. *J. Geophys. Res. Atmos.*, 123, 11194-11209. https://doi.org/10.1029/2018JD028665.

Yoshida, A., Moteki, N., Ohata, S., Mori, T., Koike, M., Kondo, Y., Matsui, H., Oshima, N., Takami, A. and Kita, K. (2020) Abundances and microphysical properties of light-absorbing iron oxide and black carbon aerosols over East Asia and the Arctic. *J. Geophys. Res. Atmos*.,125, e2019JD032301, https://doi.org/10.1029/2019JD032301.