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Impacts of Short-Lived Climate Pollutants from Asia on the Arctic Climate and Environment

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Black carbon (BC) is a key air pollutant with a great impact on the climate and environment in the Arctic, where temperatures have increased more rapidly than the global average during recent decades. East Asia is considered to be a major source region of anthropogenic pollutants, with its BC emissions having a dominant contribution of 36% in the northern hemisphere. We examined pathways and efficiency of transport of BC from various anthropogenic and biomass burning emission sources to the Arctic. We also quantified the source contributions, using Asia-specific tagged tracer simulations implemented in a global chemistry-transport model, GEOS-Chem. We found that BC emitted from East Asia was transported mainly in the middle troposphere (~5 km) into the Arctic due to uplifting during poleward transport. The East Asian contribution was dominant for BC in the middle troposphere (41%) and the BC burden over the Arctic (27%) because of its large emissions (Fig. 1). This suggests that East Asian BC is important in radiative forcing at the top of the atmosphere. In contrast, BC emitted from Europe and Russia was transported to the Arctic mainly in the lower troposphere during winter and spring, i.e., the Arctic haze season. In particular, Russian BC had a dominant contribution of 62% to Arctic BC near the surface and 35% to deposition as annual mean. This suggests that BC from Russia and Europe is more important in surface air pollution and warming in the Arctic.

In addition to the Eulerian model, we used the Lagrangian transport model “Flexpart” (version 10), to quantify the sources of BC in the Arctic region from different geographic regions and emission sectors. This exercise helped us compare different types of modeling techniques and evaluate uncertainties in the estimates of BC contributions derived from current state-of-science modeling efforts. With the Flexpart model, we found that anthropogenic emissions in Russia are the dominant source (56%) of BC at the Arctic surface (500 m) annually. On the other hand, biomass burning in the boreal regions contributes 56-86% to Arctic surface BC in summer. A large fraction (40%) of BC at high altitudes in the Arctic region comes from anthropogenic emissions in East Asia. Excellent agreement was found between the GEOS-Chem and Flexpart model results. These results suggest regulatory needs for controlling BC emissions from gas flaring in Russia and from anthropogenic sources in Asia, where the economy has been rapidly growing.

We also performed a statistical analysis of the observations of BC and carbon monoxide (CO) at Fukue Island to estimate BC emissions from source regions in East Asia. The BC/CO ratios estimated for the emissions sources in central Eastern China and Korea were significantly smaller than those used in the bottom-up emission inventory “Regional Emission inventory in Asia (REAS)” version 2, by factors of 1.3 and 2.8, respectively. This strongly points to the necessity of revising the emission database. The BC emission rates from individual regions were estimated by multiplying the observed ΔBC/ΔCO ratios by reliable estimates of the CO emission rate. The estimated rates from China, Korea and Japan were 0.90–1.1, 0.0046, and 0.027 Tg y^{-1}, respectively. The amount for Japan was comparable to the bottom-up estimate from REAS version 2, 0.026 Tg y^{-1}.

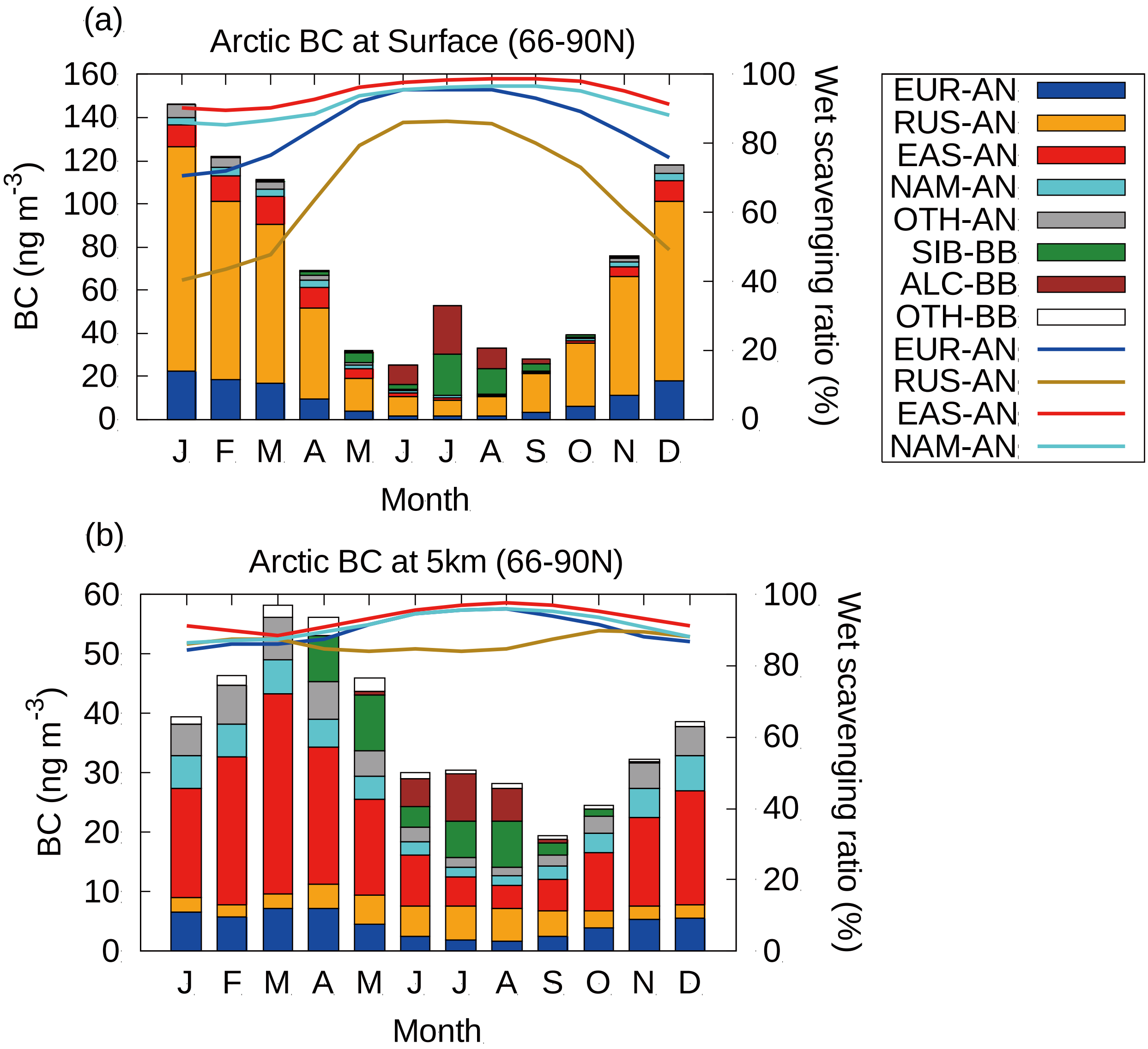

Fig. 1 Seasonal variations in mean BC concentrations (left axis) from individual sources (a) near the surface and (b) at 5 km altitude in the Arctic (66-90 deg. N). EUR-AN, RUS-AN, EAS-AN, NAM-AN, and OTH-AN denote European, Russian, East Asian, North American and other anthropogenic sources, respectively. SIB-BB, ALC-BB, and OTH-BB denote Siberian, Alaskan and other biomass burning sources, respectively. Mean wet scavenging ratios (right axis) for major anthropogenic source regions are also shown by solid lines: EUR-AN, RUS-AN, and NAM-AN.

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