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Black Carbon and other Short-lived Climate Pollutants: Impacts on Antarctica

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Information Paper Submitted by ASOC[1]

Summary

Black carbon and other short-lived climate pollutants (SLCPs), especially from local and southern hemispheric sources, may be hastening warming and melting in Antarctica. Conversely, emission reductions from these sources could provide the possibility of slowing warming in the near-term, though only when combined with longer-lived greenhouse gas mitigation actions. Analysis of the extent of SLCP emissions and impacts on Antarctica, especially from local sources, should be a priority for ongoing research, and included in the Strategic Workplan.

Background

A number of studies from the UN Environment Programme (UNEP) and elsewhere have increasingly indicated the potential importance to global warming of black carbon and other "short-lived climate pollutants" (SLCPs) such as tropospheric ozone and methane. UNEP estimates that mitigation of these substances carries strong near-term regional climate benefits, with significant co-benefits to human health and crop yields.[2]

Globally, these substances accounted for about one-third of observed global warming in the 20th century. However, the Arctic Council Monitoring and Assessment Programme (AMAP) has estimated that they may account for as much as half or more of observed warming in the Arctic region, due to the enhanced radiative forcing of black carbon in the Arctic atmosphere and especially when black carbon is deposited on the white ice and snow surface.[3 4]

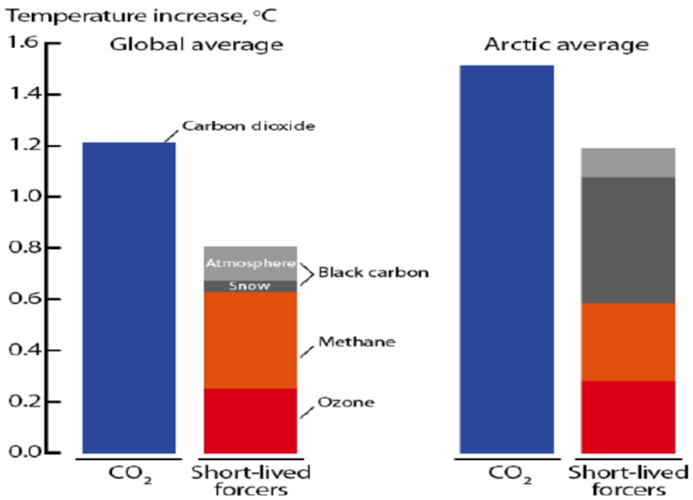

Figure 1: The Impact of Black Carbon on Arctic Climate. Source: AMAP 2011

[1] Lead author Pam Pearson.
[2] United Nations Environment Programme/World Meteorological Organization. 2010. Integrated Assessment of Black Carbon and Trophosperic Ozone.
[3] Quinn et al. 2008. Short-lived pollutants in the Arctic: Their climate impacts and possible mitigation strategies. Atmos Chem Phys 8: 1723-1735.
[4] Arctic Monitoring and Assessment Programme. 2011. The Impact of Black Carbon on Arctic Climate.

The Arctic Council spearheaded much of this work due to the rapid nature of observed warming in the Arctic, and a desire to slow these processes to allow human communities and Arctic ecosystems a greater chance at adaptation. However, what holds for the Arctic likely applies in the rest of the global cryosphere: work has begun to document the impacts of black carbon in high alpine regions such as the Himalayas, the Alps and the Andes. Global concerns motivated the early focus on the Arctic, as the impacts of warming there may be felt most strongly far from the Arctic itself, through enhanced sea level rise or releases of methane and other greenhouse gases (GHGs) from permafrost and the seabed.

The Antarctic is experiencing rapid warming along the Antarctic Peninsula (greater even than that of the Arctic) and the potential instability of the West Antarctic Ice Sheet (WAIS) is worrying. While potential melting of the Greenland ice sheet has attracted much of the attention regarding future sea level rise, a recent study concludes that sea level rise during the last inter-glacial may have come to a far greater degree from Antarctica instead.[5] An examination of SLCP impacts on Antarctica, and their possible mitigation is highly timely as a science-policy input to CEP/ATCM discussions.

Short-lived Climate Pollutants in Brief

Black carbon results from incomplete combustion. Its major sources globally include diesel (transport in terms of on-road, off-road, marine, and stationary generators), open field and forest burning, biomass stoves (cookstoves, woodstoves and boilers, including household coal use), oil and gas flaring, and kerosene lanterns. Black carbon from these sources is emitted as a complex mixture of aerosols that also includes light-reflecting substances that cool the climate at the same time as black carbon warms it. However, over ice and snow these "cooling" substances are still darker than the reflective substrate. A large consortium of researchers in the so-called "Bounding" study recently reached consensus that all the above-named sources result in warming over cryosphere regions such as Antarctica, despite the fact that there is still uncertainty about the impacts of black carbon sources in non-cryosphere regions.[6]

Tropospheric (ground-level) **ozone** is a powerful climate forcer that arises from other substances (ozone precursors), primarily methane, carbon monoxide (CO), nitrogen oxides (NOx) and volatile organic compounds (VOCs). Because CO, NOx and VOCs already are regulated to varying degrees for air quality benefits, mitigation efforts to provide near-term climate benefits tend to focus on **methane**, which is a climate forcer both in itself, and through its contribution to formation of tropospheric ozone. Methane arises from anthropogenic sources such as oil and gas leakage, wastewater and landfills, coal mines, and agriculture (both crops such as rice, and livestock).

In climate terms, a key aspect of the short-lived climate pollutants is their relatively short lifespan in the atmosphere: ranging from a few days or weeks for black carbon, weeks to a few months for tropospheric ozone (longer in the dark winter months at the poles), and eight years for methane. This means that reductions in these substances can have a relatively rapid near-term climate benefit, making them a powerful complement to CO2 reductions, especially in regions such as the Antarctic Peninsula where warming is occurring rapidly.

Black Carbon in Antarctica

These substances have not been studied in connection with the Antarctic region until recently, although some sampling of black carbon has occurred on an occasional basis at several Antarctic stations dating back at least to the 1990s [7]. The 2009 SCAR Report on Antarctic Climate Change and the Environment reported on an interesting pathway to the Syowa Station (Japan) in summer, with a high peak of black carbon following

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[5] Quiquet et al. 2013. Greenland ice sheet contribution to sea level rise during the last interglacial period: a modelling study driven and constrained by ice core data. Clim.Past.9, 353-366.
[6] Bond et al. 2013. Bounding the role of black carbon in the climate system: A scientific assessment. Journal of Geophysical Research: Atmospheres. Accepted, in press (doi: 10.1002/jgrd.50171).
[7] Wolff and Cachier. 1998. Concentrations and seasonal cycle of black carbon in aerosol at a coastal Antarctic station. *J.Geophys.Res*.103(D9):11033-11042.

local katabatic wind maximum from the continental side; it was speculated to have arisen from biomass burning in Patagonia or southern Africa. These pathways were reported confirmed by the 2006-7 ANTSYO-II airborne campaign, conducted by AWI, Germany and NIPR, Japan around Neumayer (Germany) and Syowa stations in the 2006/7 season as part of the IPY scientific research.[8]

Ice core studies of black carbon published within the past year have revealed some interesting overall concentrations and historical trends, although caution is necessary since they are based on only a few sampling sites. Overall concentrations from Antarctic ice cores, while tending to be only one-tenth of that found in the Arctic, Alps and Himalayas, nevertheless are surprising given the extreme distance from the largest assumed sources; and surprisingly high even in East Antarctica, where a more pristine environment might have been anticipated.[9][10] These concentrations remain potentially significant in climate terms, especially because black carbon deposited on the Antarctic continent remains there. Unlike in the Arctic, which has shown a general downwards trend in black carbon since the 1950s, black carbon deposition in Antarctica seems to be stable or even increasing over time, including in the past few decades.[11] Speculation on why may include changes in the atmospheric circulation around Antarctica, and/or increases in biomass burning or forest and field fires in the southern hemisphere.

Modelling of SLCP Impacts on the Antarctic Climate

New SLCP modelling studies that focus on cryosphere regions and for the first time explicitly include Antarctica are underway, conducted by the same teams that provided the work for the UNEP/WMO Assessment of 2010: the Joint Research Center (JRC) in Arona, Italy, using the ECHAM model; and NASA/Goddard in New York, U.S. with the GISS model. This new effort involves improved black carbon emissions inventories, including sources that could not be estimated in 2010; and the models themselves take into account an improved understanding of black carbon behavior both while in the atmosphere, and once deposited on ice and snow. Preliminary results indicate black carbon impacts on and near the Antarctic continent from some black carbon sources, as well as anticipated climate benefits from methane-ozone that are approximately 50 percent higher than the global mean.

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[8] SCAR Report, *Antarctic Climate Change and the Environmen*t, p. 217.
[9] Bisaux et al. 2012. Variability of black carbon deposition to the East Antarctic Plateau 1800-2000 AD. *Atmos Chem Phys* 12:3799-3808.
[10] Lee et al. 2013. Evaluation of preindustrial to present-day black carbon and its albedo forcing from Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP). *Atmos Chem Phys* 13:2607-2634.
[11] Bisaux et al. 2012. Changes in black carbon deposition to Antarctica from two high resolution ice core records, 1850-2000 AD. *Atmos Chem Phys* 12:4107-4115.

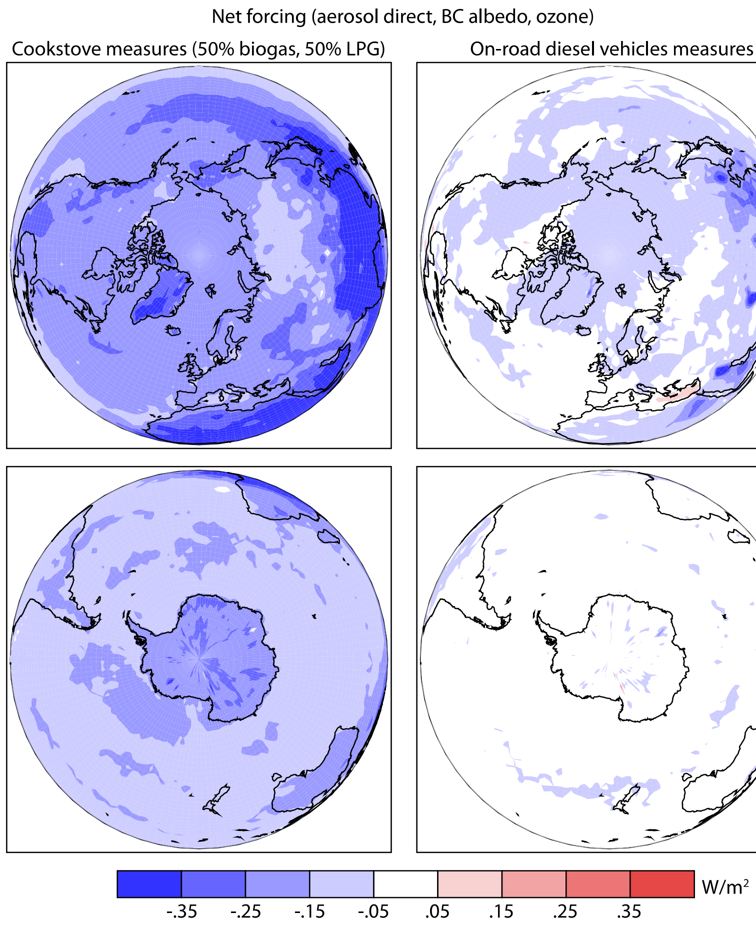

Figure 2: Shindell, 2013, Unpublished preliminary modelling results (NASA-GISS model)

Initial modelling results (Figure 2) indicate black carbon impacts on the Antarctic continent similar to those over much of the Arctic, though less than on Greenland; especially for larger sources prevalent in the southern hemisphere, such as biomass stoves used for cooking, which result in a modelled radiative forcing of .25-.35 W/m^2 over much of the continent. Sources more prevalent in the northern hemisphere, such as diesel, appear much less important. As anticipated, once they become more globally distributed, black carbon emissions show greater impact on the Antarctic continent than elsewhere in the southern hemisphere, likely due to the large reflective surface over the Antarctic continent. It should be noted that this modelling does not include local continental sources of black carbon, as no emissions inventories for Antarctica currently exist. Because work done for the Arctic strongly indicates the importance of within-Arctic black carbon sources (because more local sources deposit more readily on snow or ice), creation of similar inventories for Antarctica comprise an important next step.

The results shown above are preliminary and only from the NASA-GISS model: more complete results from both models will be presented at the ASOC side event lecture on May 20.

In the Arctic, local sources such as shipping (including from tourism), diesel generators and transport, as well as near-Arctic sources such as field and forest burning comprise some of the more important black carbon sources that may have parallels for Antarctica. Significantly, a Norwegian government study of black carbon deposition on Svalbard found that the most rapidly increasing source of black carbon in that archipelago came from marine tourism, which as in Antarctica is primarily ship-based, and growing. [12]

[12] Vestreng et al. 2009. Climate influencing emissions, scenarios and mitigation options at Svalbard. Norwegian Climate and Pollution Directorate TA2552/2009.

Global and Regional Policy Responses

Because of its regional nature, black carbon has garnered early attention from the eight Arctic Council governments and other nations close to the Arctic. Since the majority of black carbon emissions impacting the Arctic come from sources in and near the region, domestic and joint actions by these countries can have a regional climate impact. The Arctic Council, UNEP and the Convention on Long-Range Transboundary Air Pollution (CLRTAP) have to varying degrees recommended early "no regrets" mitigation actions, in particular for black carbon but also for ozone/methane. Black carbon was included in the recent Gothenburg Protocol revision under the LRTAP Convention, and is also being studied by the International Maritime Organization (IMO). On the global policy level, UNEP together with a number of governments in 2012 formed the Climate and Clean Air Coalition (CCAC) to aid in addressing these pollutants, especially in developing countries.

To summarize, black carbon and other short-lived climate pollutants (SLCPs), especially from local and southern hemispheric sources, may be hastening warming and melting in Antarctica. Emission reductions from these sources could provide the possibility of slowing warming in the near-term, though only when combined with longer-lived greenhouse gas mitigation actions.

Further exploration of the extent of SLCP emissions and impacts on Antarctica, especially from local sources such as shipping (including fishing vessels), tourism and research station activities, should be a matter of priority, including as an element in the Strategic Work Plan under climate change activities. This would include more comprehensive research on black carbon deposits on Antarctic ice and snow, especially from southern hemisphere sources but also from more local activities, including station generators and transport, as well as ship-based tourism and fishing. Where feasible, Parties should consider taking into account black carbon emissions when examining ways to limit their environmental footprints in the Antarctic.