# Black carbon and other light-absorbing impurities in Arctic snow, and their effect on surface albedo

Stephen Warren[1], Sarah Doherty[1], Thomas Grenfell[1], Richard Brandt[2], and Antony Clarke[3]
[1]*Department of Atmospheric Sciences, University of Washington, Seattle, USA*
[2]*Atmospheric Sciences Research Center, State University of New York at Albany, USA*
[3]*Department of Oceanography, University of Hawaii, Honolulu, USA*

Absorption of radiation by ice is extremely weak at visible and near-ultraviolet wavelengths, so small amounts of light-absorbing impurities in snow can dominate the absorption of sunlight at these wavelengths, reducing the albedo relative to that of pure snow and leading to earlier snowmelt. For this study about 1600 snow samples were collected in Alaska, Canada, Greenland, Svalbard, Norway, Russia, and the Arctic Ocean, on tundra, glaciers, ice caps, sea ice, frozen lakes, and in boreal forests. Snow was collected mostly in spring, when the entire winter snowpack was accessible for sampling.

The snow is melted and filtered; the filters are analyzed in a spectrophotometer to infer the mixing ratio of black carbon (BC) and the fraction of absorption due to non-BC light-absorbing constituents. The non-BC impurities, principally brown (organic) carbon, are typically responsible for ~40% of the visible and ultraviolet absorption. Median BC amounts (in ppb) are: Greenland 3, Arctic Ocean 7, Arctic Canada 8, subarctic Canada 14, Svalbard 13, northern Norway 21, western Arctic Russia 26, northeastern Siberia 17. In a global survey, we find BC mixing ratios in snow ranging over 4 orders of magnitude from 0.2 ng/g in Antarctica to 1000 ng/g in northeast China; the Arctic values are intermediate between these extremes. Chemical analyses, input to a receptor model, indicate that the major source of BC in most of the Arctic is biomass burning, but industrial sources dominate in Svalbard and the central Arctic Ocean.

When the snow surface layer melts, much of the BC is left at the top of the snowpack rather than carried away in meltwater, thus causing a positive feedback on snowmelt. This process was quantified through field studies in Greenland, Alaska, and Norway, where we found that only 10-30% of the BC is removed with meltwater. In the percolation zone of South Greenland at the end of July, the subsurface snow had 2 ppb but the top 5 cm had 10-20 ppb.

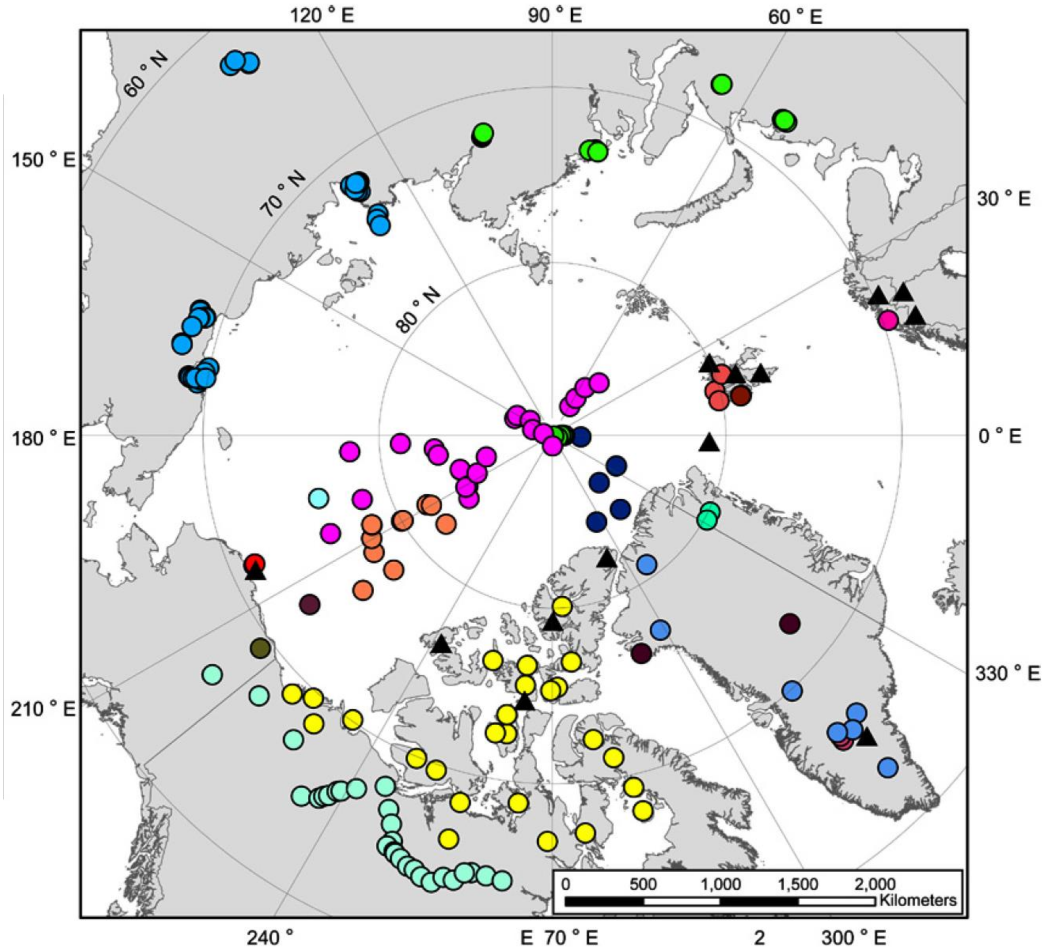
The BC content of the Arctic atmosphere has declined markedly since 1989, according to the continuous measurements of near-surface air at Alert (Canada), Barrow (Alaska), and Ny-Alesund (Svalbard). Correspondingly, our recent BC concentrations for Arctic snow are lower than those reported by Clarke and Noone for 1983-4. It is therefore doubtful that BC in Arctic snow has contributed to the rapid decline of Arctic sea ice in recent years.

In some regions, particularly the Canadian Arctic islands and the Arctic coast of northeast Siberia, the snow cover, even at its maximum depth in April before melting began, was thin and patchy; in these regions the albedo is determined more by snow thickness than by impurities.

The reduction of snow albedo by BC is typically only 1-2%, which is significant for climate but difficult to detect experimentally, because snow albedo depends on several other variables. Albedo reduction can be computed in a radiative transfer model, using the BC amount from the filter measurement together with snow grain size, but the model requires experimental verification. To do this verification we use an artificial snowpack with large soot content so as to produce a large signal on albedo.

Satellite remote sensing will not be useful to detect BC in Arctic snow, for several reasons, particularly because thin snow has the same spectral signature as sooty snow.

Reference. Doherty, S.J., S.G. Warren, T.C. Grenfell, A.D. Clarke, and R.E. Brandt, 2010: Light-absorbing impurities in Arctic snow. *Atmos. Chem. Phys.*, **10**, 11647-11680.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