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Unexpected increase in elemental carbon concentrations and deposition in a Svalbard ice core since 1970 and its implications for Arctic warming

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Changes in albedo and related feedbacks in the Arctic have been suggested to be one of the driving mechanisms for the observed amplified Arctic warming. Black carbon (BC) is an aerosol produced by incomplete combustion of biomass and fossil fuels. Due to its strong light absorption it warms the atmosphere. Its climate effects are intensified in the Arctic where its deposition on snow and ice decreases surface albedo. BC has been suggested to have caused 20% of the Arctic melting hitherto. Despite the significant role of BC in Arctic warming, there is little information on its concentrations and climate effects in the area in the past. Here we present results on elemental carbon (EC, proxy for BC) concentrations and deposition on a Svalbard glacier (Holtedahlfonna) from 1700 to 2004. The inner part of a 125 m deep ice core was melted, filtered through a quartz fiber filter and analyzed for EC using a thermal optical method. The EC values increased after 1850 and peaked around 1910, similar to previous ice core records from Greenland. Strikingly, EC values increase abruptly since 1970. Such a rise is not seen in Greenland ice cores, and it seems to contradict atmospheric measurements indicating decreasing atmospheric BC concentrations since 1989 in the Arctic. However, the trend gains additional credence from a melt index derived from the same ice core indicating increased summer melt since 1970. The rise in EC values since 1970 is possibly explained by increased washout ratio of BC especially due to increased temperatures. In addition, post-depositional processes, such as increased melt, may enrich EC in most recent ice layers. These processes enable rising EC values in the ice core while atmospheric concentrations have decreased. Possible explanations for the differences in the recorded ice core BC trends from Greenland and Svalbard in the recent decades are partly different sources and the vertical distribution of emissions in the atmosphere. Specifically, the Svalbard ice core may record flaring emissions from northern Russia that do not reach the Greenland ice core sites. The results indicate that BC deposition may not necessarily be straightforwardly connected to atmospheric BC concentrations and that BC trends recorded from different ice cores may be dissimilar due to several factors independent of atmospheric concentrations. Regardless of the cause for the increasing EC values, the present results have significant implications for the past radiative transfer at the coring site. It remains to be determined how broad the signal and its albedo implications are. The results may give rise for further investigations on the significance of BC deposition to the Arctic sea ice retreat.