Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2020-574-RC2, 2020

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Black Carbon Seasonal and Diurnal Variation in surface snow in Svalbard and its Connections to Atmospheric Variables" *by* Michele Bertò et al.

Anonymous Referee #2

Received and published: 11 August 2020

The goal of the presented analysis is to determine what factors drive changes in the concentration of BC in snow at a site in Svalbard. Snow samples were analyzed for rBC, conductivity (ions), and dust (coarse particle number count); atmospheric eBC was measured with a PSAP and/or aethalometer; and a range of meteorological variables (wind speed, wind direction, solar radiation, temperature, precip) were monitored. Concentrations of rBC in snow were correlated with these other variables, nominally to elucidate the cause of changes in snow concentrations. This was done for two periods: an "80 days" period, where snow was sampled daily and a "3 days" period, where snow was sampled hourly. For the "80 days" campaign, snow was sampled from the top 10cm of the snowpack. For the 3 days of hourly sampling, snow was collected from

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the surface to 3cm depth.

The study suffers from a lack of analytical focus and robust conclusions, in large part stemming from the fact that it appears to take a bunch of variables and see what emerges, rather than starting with a hypothesis, then designing an experiment based on the hypothesis.

Fundamentally, the amount of BC in snow is determined by: atmospheric concentrations immediately above the snow surface and the dry deposition rate (dry deposition); atmospheric concentrations at and below cloud level, the wet scavenging rate of these aerosols, and precipitation amount; and post-depositional processes such as the addition of snow water without BC (e.g. hoar frost), loss of snowpack water through sublimation and melting, and the redistribution of BC in the snowpack with melting. If the goal was to determine what factors control the concentrations of BC in snow, the experiment should have been designed to quantify how these processes specifically affect BC in snow.

The approach of doing systematic sampling of the top 10cm or 3cm depth rather than over, e.g., distinct layers in the snowpack affected by different processes, confounds the ability to separate the role of different drivers. Changes due to dry deposition and hoar frost deposition would be best determined by sampling a very thin surface layer; changes due to deposition with new snowfall would be best determined by sampling the newly fallen snow and the previously snow layer separately; and changes due to the impacts of snow melt would be best determined by sampling multiple layers, with distinct samples for the layer affected by melt and then in layers below this. No reason is given for the selection of the 10cm and 3cm depth snow samples.

It's also difficult to understand why the suite of variables measured was selected. Why would changes in solar radiative flux alter the snowpack BC? Why measure the conductivity of the snowpack (ions)?

There is also a lack of clarity in the presentation regarding what variables could actually

drive change in snow BC, versus simply covary with them. Section 3.1.2 is titled "Variables explaining the snow rBC mass concentration variability, and therein it's stated that (lines 451-452) after snowmelt starts "the number of coarse mode particles is ... the predictor with the highest significance level." But this is not because the changes in dust concentration are actually driving changes in BC. One can only assume, as the authors do, that the two must be co-deposited, possibly from both being lofted from the nearby ground surface.

It's also not at all clear why the authors chose specifically to look at the diurnal cycle in the concentration of BC. (The authors assert that BC concentrations show a "quasi-daily cycle" but I really don't see this. The blue line pointed to in Figure 3 looks to me like it could just be smoothed random variations.) Other than the effects of hoar frost, which might deposit during one part of the day and perhaps sublimate during another part of the day, there isn't any reason to *expect* there to be a diurnal cycle in snow BC concentrations. The authors therefore attribute the diurnal cycle they claim to see in rBC concentrations to this process, but it's again rather hand-waving.

In the end, the factors that are most clearly seen to affect snow BC concentrations are things that we already knew a priori to be important: deposition with new snowfall and snow water loss in sublimation and melting. To this is added the resuspension of local sources of rBC during snow melt, though this is more of a theory than a robust finding. The study doesn't seem to provide any new quantitative information that would, e.g., be useful to improving modeling of processes driving snow BC concentrations. Further, it's not at all clear how generalizable the results of the study at this location are, especially in terms of the role of resuspension and hoar frost.

The finding that there isn't a correlation between the measured atmospheric BC and snow BC concentrations is not at all surprising; in fact, these two would only be correlated if dry deposition was the primary driver of BC deposition, and if the snow samples collected were of a sufficiently thin surface layer. The authors themselves note that ~60% of the BC deposition at Svalbard is through wet deposition – and of course,

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every time it snows, the previous surface layer is buried, confounding detection of the role of dry deposition through sampling of surface snow down to a fixed depth.

Beyond these issues the paper could be considerably shortened. It starts with a fairly broad overview of climate changes in the Arctic and previous measurements of BC in the Arctic. (Notably, the latter doesn't include one of the larger surveys of BC in Arctic snow that appeared in this same journal and that also included sampling from Svalbard: Doherty et al., 2010, "Light-absorbing impurities in Arctic snow"). The goal of the analysis was to reveal the causes behind *variations* of BC in snow; the absolute amounts and the radiative forcing are not the focus so this review of concentrations across the Arctic doesn't seem very relevant. What would have been more useful is a review of what other analyses to date have show about the processes that dominate variations in the concentrations of snow BC.

There is also extensive discussion of meteorological variables (e.g. winds) and back-trajectories really don't add anything to the analysis. These could be cut.

Overall, the paper would need to be significantly revised to be suitable for publication.

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