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The Cryosphere Discussions

Interactive comment on "Retention and radiative forcing of black carbon in Eastern Sierra Nevada snow" *by* K. M. Sterle et al.

K. M. Sterle et al.

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Dear Dr. Nolin,

Thank you for your comments regarding the responses to reviewer 1&2, and our manuscript submitted to The Cryosphere. I will address the specific comments that are not already addressed in the two other referee comments. Substantial revisions and clarifications will be implemented into a new manuscript and supplementary materials that you will find uploaded using the File Manager no later than The Cryosphere deadline (now October 29).

First and foremost, you raise your concern about the number of samples used in various parts of the study, and I will be sure to implement more clear explanations of why

sample size, dates and variables measured differed.

1.In your Response 4 [Reviewer 1] you describe the collection of grab samples of surface snow. You scraped about 200 g of surface snow from the top 2 cm from 3-5 areas. Is that 200g at each of the areas or total? How did you ensure that the snow samples were from exactly 2 cm (shouldn't that be an approximate depth?). How were these 3-5 areas selected? Why are their only values for five of eight sampling days? What happened to the other three? These samples are the only ones that show a clear trend but they are the most nebulous in terms of sampling rigor.

Response 1. Further clarification is required, and will be implemented into the revised manuscript. The response 4 to reviewer 1 should be clarified in further detail, and you raise these concerns. Approximately 200 grams of snow was scraped from each of the 3-6 areas each day. The approximate sample depth was 2 cm. The sampling vigor is average in this study because we did not initially aim to study surface variation. However, field support noticed visible impurities on the snow surface near snowmobile and snowcat tracks (ie: Mammoth Ski Area vehicles used for support on the mountain) and thus surface samplings near tracks became apart of the field methods. Thus, the surface areas sampled were selected at randomly based on the proximity of that days snowpit to the visible surface impurities and snowmobile and snowcat tracks. Samples were not taken on Mar-28 due to time constraints. Samples from 29-Apr and 30-May melted before returning to DRI in Reno, and therefore were not analyzed because we could not guarantee preservation of sampling.

2. I find Table 1 confusing since the sample depths used in the analyses for rBC, ions and dust are different. Why didn't you sample soluble ions and dust for the bulk snowpack? How might these differences influence your interpretation of the data? It's really hard to convincingly compare these since they are different sample regions in the snowpack.

Response 2. Table 1 is meant to display range and geomean values of rBC, ions and dust in the accumulation and melt seasons of the snowpit profiles. “Bulk snow pack” under rBC should read [10 cm depth integration], since these values are a geometric mean and range of the profile values. See response 3 for bulk snowpack reasoning. I will further clarify the units in the table. With the exception of a few dates, soluble ions were measured for all snow pits. The continental dust was not measured for all pits because of funding to run the ICP-MS.

3. Figure 1 shows a great deal of variability in rBC over space and time. Do some of the regions of higher rBC in the snowpit profiles show correlations over time? That is, are there periods of time between snow events where rBC accumulates at the snowpack surface (or increases due to sublimation) and then is buried? I tried going forward in time through the accumulation period and tracking layers but am not able to find anything consistent. During the ablation season there is some consistency for a bottom layer but I'm not sure if it's real. For instance, looking at 30 May, I see a peak in rBC at an approximate height above the soil of 25 cm. I see something similar on 23 May and 17 May. There is a hint of a peak in 10 May and also 29 April but not on 18 April. In fact on 18 April there is essentially zero rBC at 25 cm. As per comment by reviewer #2, you should see if total rBC has changed (integration).

Response 3. Correlations were looked at during initial analysis but are not presented because they did not show significant values. However, I will investigate correlations between regions of snowpit profiles, and present the findings. When we performed integration on the entire snowpit, rBC increased and then decreased. These values will be displayed in a new table to confirm total rBC trends over space and time despite high variability of rBC within intervals of the snowpack profile.

4. As per the comment from reviewer #2, it is unclear what is happening with the snowpack during the season. If you showed snowpack stratigraphy (density, grain size, layer descriptions) then you might be able to keep track of the buried layers and their corresponding rBC. That would be really interesting since you could show how buried rBC can affect radiative heating.

Response 4. Yes, it would be very interesting to show how buried rBC can affect radiative heating. However, the field notes were not convincing or consistent enough to draw any conclusions. Correlations between regions of succession snowpits will improve the contention of soot position in the snowpack (referring to response 3 and response 5), while also supporting findings of high spatial variability. As seen in the ice layer field notes, not all of the ice layers were observed in each snowpit. The supplementary field data provided in the response to reviewer 2 will be present in the final revision of the manuscript.

5. Your contention that the soot is flushed out of the snowpack in late May need to be better supported by the data. Please pay special attention to the relevant comment from reviewer #2. In your conclusions you state that “total snow pack rBC and dust masses increased during the snow accumulation” but you only sampled the top 30 cm of the snowpack for dust so you really don't know that this is the case for dust. Also, your following statements about dust and ions at the surface are not well founded again, because you didn't sample the surface (top 2 cm) for those components.

Response 5. This is very true, and the conclusions will be revised. We will use the data to better support the contention that the soot is flushed out of the snowpack, as this was our findings. However, “dust” should be removed from the concluding statement regarding rBC. The dust and soluble ion findings should rather be concluded separately to impurities comparable in the specific region of the snowpack they were measured.

6. You need to describe the atmospheric and SNICAR models in the Methods section. The first paragraph of Section 4.3 belongs in the Methods section. You then need to describe the modeling results in the Results section. You should include an error assessment in the Discussion section. For instance, what are the uncertainties in dust properties? Same question for rBC. Please include error bars on radiative forcing estimates.

Response 6. These areas will be rearranged and an error assessment will be added to the Discussion section discussing uncertainties in dust properties and rBC with error bars.

7. How could vehicle traffic influence your measurements? Do you mean snowcats? Cars?

Response 7. Yes, we mean Mammoth Mountain Ski Area traffic (snowcats, snowmobiles and BBQ smoke from the Mid-Mountain grill). It is likely localized car traffic is also a factor, but cannot be assumed. In writing the conclusions, we only wanted to suggest sources as this was not a study of source transport.

8. The Discussion section should provide quantitative context for concentrations of rBC and dust at the Mammoth Mountain site. How does this site compare with measurements at other locations described in the literature? Why should we care about this site?

Response 8. Values will be compared to Hadley et al., 2007 & 2010, as this is the other published work to date that investigates rBC in snow in the Sierra Nevada (Donner Pass area). Additional sites throughout the Sierra Nevada were measured as part of my thesis work, and will be noted – specifically Tahoe Meadows, North Lake Tahoe, Mt. Rose Ski Area and Sagehen Creek Experimental Forest.

9. You might also have a look at the 1993 PhD dissertation of Nolin "Radiative Heating in Alpine Snow" who measured and modeled light absorbing impurities and their radiative effects in snow at Mammoth Mountain. It's in the UCSB library and Dozier has a copy.

Response 9. Will do.

Please consider the new manuscript with substantial revisions to be uploaded no later than October 29.

Kind regards,

Kelley Sterle

Interactive comment on The Cryosphere Discuss., 6, 2247, 2012.