The Cryosphere Discuss., 6, C1015–C1021, 2012
www.the-cryosphere-discuss.net/6/C1015/2012/

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.

kelsterle@gmail.com

Received and published: 16 July 2012

Thank you for your comments regarding this manuscript. We note that throughout the comments refer to a review of an earlier manuscript that we submitted to GRL. Taking advantage of that earlier review, we substantially revised and slightly lengthened the paper. The reference to the previous review is confusing, because it is not always clear whether the referee is describing the previous GRL manuscript or this manuscript.

Specific responses to your concerns are given below.

1. This paper is nearly identical to a paper by the same authors, with the same title, which I rejected last year for Geophysical Research Letters. Therefore, my review of the revised manuscript is correspondingly similar to my earlier review.

Response 1. We substantially revised the paper since the GRL submission, taking into account all of this referee's concerns and adding more references. The revision notes that the manuscript describes an initial study and that the findings are highly relevant to the design of future experiments and thus worthy of publication.

2. The authors start with a reasonable hypothesis, namely that insoluble particles (dust and soot) are left behind at the surface as a snowpack melts. They then set out to collect data in the Sierra Nevada of California to test the hypothesis and quantify it. Their measurements were apparently done carefully, and the techniques are well documented. It turns out that their data do not support the hypothesis, but it is premature to draw any conclusion, because the data analysis was botched, as described below.

Response 2. We restate that the manuscript has been substantially revised and therefore requires a new review. We explain that the investigation is exploratory, that the experiments were to determine: (1) characterization of rBC concentrations in Sierra Nevada snow, (2) changes in concentration and movement of rBC during snow accumulation and melt, and (3) modeling of surface radiative forcing from measured rBC and continental dust. Therefore, we were able to fulfill the objectives of the study and draw conclusions based on the data collected.

3. . . . it is premature to draw any conclusion, because the data analysis was botched, as described below. The snowpack reached its maximum depth of 2 meters on 29 April, and after this date the snowpack was melting. Vertical proïňĄles were obtained occasionally during March and April, and then weekly during May as the snow depth diminished by 35%. The measurements were terminated on 30 May, when 65% of the maximum snow depth still remained (1.3 m).

Response 3. The data analysis was not botched; all data on which we base our conclusions are shown in the Figures. Discrepancies in data consistency (i.e. number of surface samples, existence of dust samples) is a direct function of obtaining more samples as the season progressed. Furthermore, the sampling campaigns were done in collaboration with other research on snow, we could not disturb the entire fenced-off experimental site. 65% of the maximum snow depth did remain when sampling was suspended due to inaccessibility of the site and the need to avoid trampling the sample area. The observed elution of solutes in the May snowpits shows that the snowpack is melting. In addition the remaining rBC in the snow profile suggests that the rBC is staying behind, until we observed the final flush 30-May. While it may appear we are using the data in our favor, we are rather taking the values assertively and only speculating on the trends that we had to work with.

The sample volumes taken in the field also directly influenced the chemistry analysis we could do in the lab. For example, the April 18 and May 10 samples were not large enough to measure rBC and soluble ions, so we interpolate for those dates. Dust measurements from the ICP-MS also required enough sample and funding, so we chose to only test the top 30 cm from all pits except April 18.

4. Reading values for the top 2 cm from the vertical proïňĄles in Figure 1, I ïňĄnd the surface black carbon (BC) values for April 29, May 10, 17, 23, and 30 are approximately 18, 10, 73, 58, and 6 ng/g respectively. The surface concentrations do increase from 29 April to 17 May, but the last value on 30 May is the lowest.

Response 4. The differences in rBC ng/g values in Figure 1 and Figure 2a are described in the captions. As mentioned earlier, our sampling became more intensive as the seasonal progressed – especially for “surface snow” samplings. As the season progressed, the snow surface became visibly darker, and thus, in addition to the snow profile taken in 10 cm intervals from the surface to the bottom, we scraped $\sim$200 gram of snow from the top 2 cm of the snow surface at 3-5 areas around the site. Although there are only values for the 5 of 8 sampling days, the data still suggests that rBC concentrations in surface snow are both spatially and temporally variable.

5. Furthermore, the highest BC content found during the entire experiment was 94 ng/g, during the accumulation season on 28 March. On that date there was extreme

variability in the upper layers (again reading from Figure 1): 0-1 cm, 9 ng/g; 2-4 cm, 1.5 ng/g; 4-8 cm, 94 ng/g. Variability in the near surface snow concentrations may be due to other possible causes besides incomplete scavenging of the BC with melt, such as temporal or spatial variability of deposition (e.g. from nearby vehicle trafïňĄc). While previous studies have indicated that BC is indeed preferentially left at the snow surface during melt, (a) the data shown here do not deïňĄnitively show this (and instead appear to show the opposite in late May); and (b) the high variability in concentrations before 29 April indicate that deposition is driving some of the variations.

Response 5. Although all snow pits were within a 20 m radius, each pit represents a different profile. Although the area is flat and open, there is some spatial variability, and we can dig each pit just once! While pits generally show similar concentrations in certain layers, the very high layer in the March 28 pit is an outlier. We investigated the weather around this time, but we cannot explain this specific high concentration. Moreover, the laboratory analyses were done after the season was over, so we could not go back in time and explore the spatial variability across the site. This identification of seasonally spatial variability is useful information for other scientists planning to sample carbon or dust in snow. This variability was the motivation for “normalizing” the snow pit profile as seen in Figure 2b and 2c.

6. Faced with this puzzling dataset, the authors somehow decide that their hypothesis is validated. To show this, in Figure 2a they plot the surface BC values, but for only 5 selected dates instead of all 8, and these ïňĄve do seem to show a rise in the BC values with time. But even these ïňĄve values are in gross disagreement with values in Figure1: The values for 28 February, 18 April, 10 May, 17 May, and 23 May, respectively, are 11, 6, 10, 73, and 62 ng/g, as best I can read them from Figure 1; but 21, 54, 90, 223, and 173 ng/g in Figure 2a.

Response 6. See response 4.

7. The authors also present results in Table 1,which seem to support their hypothesis,

but Table 1 disagrees with Figure 1. The section of the original table that was in error by a factor 3000 has been deleted in this manuscript, but the table is still full of errors.

Response 7. Table 1 values agree with Figure 1. This comment refers to the older manuscript, not the one we submitted to The Cryosphere.

8. The table gives a range of 20-429 ng/g for the upper 2 cm in May; Figure 1 gives a range of 6 (on 30 May) to 73 (on 17 May). The statement in the abstract "concentrations of rBC were enhanced seven fold in surface snow (25 ng/g) compared to bulk values in the snow pack (3 ng/g)" apparently comes from the table's values of geometric means for January-April of 25 and 3. But this stated geometric mean of 25 (and the corresponding range of 3-81) for the top 2 cm is inconsistent with the data plotted in Figure 1, which show values 11, 10, 6, 18 for the top 2 cm; i.e., a range of 6-18, not 3-81.

Response 8. The values in Table 1 for the top 2 cm of snow are not shown in Figure 1.

9. Since we do not know which set of BC values is correct, and whether the erroneous values were used to compute Figure 3, the radiative forcing values in Figure 3 are not to be believed.

Response 9. The radiative forcing values in Figure 3 were calculated from the rBC measured in the snow pit profiles, as noted in the caption.

10. Another example of where the authors' writing contradicts their own data is in the statement in Section 3.3: "Concentrations of continental dust and rBC measured in the upper 30 cm of the snow pack showed similar patterns (Fig. 2c)". But except for the ïňĄrst and last points, the patterns of dust and BC in Figure 2c are nearly mirror images of each other: when BC goes down, dust goes up (before 29 April); when BC goes up, dust goes down (after 29 April).

Response 10. A similar pattern is observed in the beginning and end of the measured snow periods. The radiative forcing shows a combined “rBC + dust,” showing that a

combined forcing is significant.

11. In the text the authors explain the astonishingly low surface value of BC on May 30 as the result of "rapid ïňĆushing during the fourth week of May", described in the abstract as a "ïňĄnal ïňĆush". But on May 30, the last day of measurement, 65% of the snowpack still remained.

Response 11. Even though 65% of the snowpack still remained, this doesn't change the rBC measured. See response 3.

12. Furthermore, the decrease in the snowpack depth between 23 and 30 May was only 12 cm, smaller than for the preceding weekly intervals 10-17 May and 17-23 May (38 cm and 19 cm, respectively), so of all the "ïňĆushes", it was the smallest. No explanation is given for why BC's behavior would transition on 23 May from being preferentially left at the surface to being preferentially washed out.

Response 12. Figure 2b displays snow pit concentrations normalized to those at maximum accumulation. In our context, flushing does not refer to the depletion of snowpack depth (and SWE), but the release of rBC from the snowpack profile. Because the rBC is released after the solutes, the term “preferentially” is not appropriate.

13. When one simply looks at the data and ïňĄnds the lowest surface BC at the end of May, one has to conclude that the authors' hypothesis is invalidated, or must at least be qualiïňĄed. In any case, the "ïňĆush" demands explanation; for example, was there a heavy rainstorm between May 23 and 30?

Response 13. The flush is defined in the context of preferential elution (page 2254, line 9-17). There was no precipitation between May 23 and 30.

14. In fact, the term "ïňĆush" is invoked to describe just one point in a noisy dataset. Such a description is unjustiïňĄed without evidence or a plausible mechanism. Otherwise there is the risk that climate modelers will seize on this data point to ïňĆush BC out of their model snow packs globally whenever 35% of the snowpack has melted.

Ideally another melt season will be monitored at the Mammoth Mountain site to see how frequent these "ïňĆushes" are, and what causes them.

Response 14. The flush is used to describe the final release of previous retained rBC in the snowpack. In the future this study could implement more meteorological observation in order to learn what causes the flushing. From this study, we feel that the findings of our study contribute to scientific community and gaps in BC literature. This study supported the first author's master's thesis.

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