

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

**Anonymous Referee #2**

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The paper titled “Retention and radiative forcing of black carbon in Sierra Nevada snow” is devoted to the measurement and evolution in time of the concentration of black carbon in snow. The paper is based on 3 months data set and split in 2 periods. One of 2 months during the accumulation period with 4 snowpits and one of 1 month of melting period with another 4 snowpits data. The basic hypothesis that authors wanted to verify is that the impurity content (i.e. black carbon and dust) embedded in the snowpack tends to stay on the snowpack surface when snow is melting, which increases the radiative forcing due to their relative high absorption compared to ice. The impurity content increases in snow surface until a flush at the end of May where surface concentrations are back (and even lower) to the values measured during the accumulation period. The main conclusions are that black carbon and dust particles tend to stay on surface which enhances the radiative forcing with a more important

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effect for dust particles. Authors mentioned also that complementary data should be measured in order to better delineate the retention of black carbon on snow surface and the potential dry deposition of black carbon over the season.

The topic of that paper is of great interest for the community working on black carbon and its effect on snow albedo. The questions raised by the authors is one of the biggest uncertainty namely does the black carbon is moving in time and does the black carbon tends to stay on the snow surface and enhance radiative forcing? This is strongly relevant for the scope of The Cryosphere.

Nevertheless, several uncertainties in the presented paper remain and some important topics such as snow metamorphism and snow density profiles (claimed to be measured) have not been discussed at all (and presented). The data set, presented to be botched by another referee, seems to be valuable but not easily understandable as it is presented. Figure 2 is particularly questionable as the number of points is not the same on each subplot. Below are specific comments.

In section 3, authors stipulated that concentrations showed little temporal variations according to figure 1 and that there are much more variations in surface according to figure 2a. Figure 2b shows averaged profiles of rBC normalized to values of maximum accumulation on 29th April and figure 2c shows the same type of data but for rBc and dust and only in the top 30 cm of the snowpack. Caption and legend of figure 1 and 2 are not very clear. In figure 1, while caption stipulates values in cm water equivalent, the legend stipulates values in cm above soil. What is the good one? I do believe this is in cm water equivalent, according to the number of points and the fact that sampling was done every 10 cm increments in the snowpack. Regarding figure 2, authors always speak about thickness of layers (2 cm for the surface), titled section 3.3 as “dust in the top 30 cm snow depth” but they described in section 4.3 that they calculated the effect of rBC and dust radiative forcing in the top 30 cm of snow water equivalent....?? I am confused...but I do believe that data of figure 2a and 2c represent values respectively for 2 and 30 cm of water equivalent isn't it? If it is not in cm of water equivalent, where

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are the snow density data? 30 cm of snow will include deeper snow layers over time so that it is normal than rBC increases... If it is in cm of equivalent water, where is the correspondence between data of fig 1 and fig 2a? Figure 1 should be modified; we can barely estimate any values.

As I am not sure of what is presented in figure 2 (cm of snow or cm of water equivalent), analyse of that work is hypothetic and needs precision before going further. In both cases, why is there missing data on 18th of April? After reading author's answer to referee 1, it seems that authors were missing snow for analyses. Is it because the snow was too less loaded in particles to obtain enough sensitivity in your measurement technique? That would explain why you concentrated efforts and measurements on main profile (fig 2c), then on 30 cm profile (fig 2b) and afterwards on surface profile (fig 2a). Please present a clear statement on this point.

Nevertheless, some others aspects of that work are questionable. In both cases (cm of snow or cm of water equivalent), the snow density is missing as well as the snow stratigraphy and authors claimed that they have been both recorded (section 2.1). Even if snow start to melt after 29th of April, melt water will not go through the snowpack before snow is really wet. When snow starts melting, liquid water tends to stay in the snowpack and be located at the grain joint and form grain clusters. This would increase the snow density. When snow is really in an advanced melting stage, liquid water will be located around the grain and tends to form rounded particles with a core of ice and a shell of water [Fierz et al., 2009]. If too much liquid water is present then water goes through the snowpack. Liquid water content of the snowpack would have been a very valuable data set to add to this study in order to determine where is located the liquid water and if some of the melt water is retained in the deeper snow layers or released from the snowpack.

Snow metamorphism, i.e. increase of snow density and vapour fluxes through the snowpack, is not taken into account. Could it affect your results?

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As most of non permanent snowpack, the studied snowpack should experience melt refreeze events. The presence of melt refreeze crust could considerably affect the amount of liquid water able to go through the snowpack and ice lenses could create preferable pathways in the snowpack. Where is the stratigraphy claimed to be retrieved?

In section 3.1, authors said that rBC fluxes from the base of the snowpack were estimated on 23th May using lysimeters and measured melt water fluxes in between 23 and 30th of May. Amount of percolated water should also be presented. Such method imply the assumption that there is no relation between the amount of percolated water and the amount of insoluble material release, i.e. liquid water fluxes and size of particles susceptible to be entertained. [Conway et al., 1996] clearly mention the effect of particle size during the melting period in their study.

In fig 2c, rBC and Dust profiles does not show the same pattern. The most important difference is on 10th of May: why the dust concentration on fig 2c on 10th of May is decreasing of 50% while rBC is increasing? Don't you think there is an effect of particles sizes here? This can also be seen in the geometric mean values for dust that are the same ( $12 \mu\text{g.g}^{-1}$ ) for both periods but the range is higher during the accumulation. If Dust is not released and accumulated on surface, higher value than  $53 \mu\text{g.g}^{-1}$  should have been detected during the melt season, as it is the case for rBC.

It seems also in fig 1 that the bottom layers are a bit more concentrated in BC during the melting period. A simple integration of the surface area below the curves for each 30 or 50 cm depth increment would not be clearer? For me, it seems that BC is moving down over time but it does not mean that a part of it does not stay on the surface. Why BC should stay on surface at the beginning of the melt period and suddenly, in end of May, should be released while 65% of the snow is still present. If BC stays on surface during the melting period, rBC should be even greater in end of May. What is causing a flush in end of May?

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Finally, on the modelling study, authors made calculations over the 30 first cm of the snowpack equivalent water using a range of grain size in between 0.1 to 1 mm. In section 2.1, authors claimed that main of the snowpack is constituted of coarse-grain snow cluster (typical of melt refreeze snowpack by the way) with mean grain diameter of 2 mm. Why did you present calculations between 0.1 and 1 mm? This will not change results but will be logical. How is related the forcing calculated with the profiles as the bigger are the grain sizes and the deepest the light will penetrate in the snowpack. A depth study could show different results if rBC is more able to stay on surface compared to dust for instance...Dust profiles should be compared to rBc profiles in the 30 first cm with radiative forcing. If dust contributes 1.5 more than rBc in the forcing, it should be included in the title or black carbon replaced by impurities or insoluble particles.

References Cited in the Document:

Conway, H., A. Gades, and C. F. Raymond (1996), Albedo of dirty snow during conditions of melt, *Water Resources Research*, 32(6), 1713-1718.

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