The Cryosphere Discuss., 8, C2817–C2823, 2015
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The Cryosphere Discussions
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Interactive comment on "Measurements of light absorbing particulates on the glaciers in the Cordillera Blanca, Peru" *by* C. G. Schmitt et al.

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Received and published: 10 January 2015

The authors would like to thank the anonymous reviewers for their thorough reviews. We feel that the manuscript is significantly improved due to the reviewers' suggestions.

Reviewer 1: (1) The significant defect in this paper is a lack of discussion of the vertical variation of particulate concentration in the top few centimeters. At each site the authors sampled both surface snow (top 2.5 cm) and subsurface snow, as indicated on page 5083 lines 25-30, but the paper does not show results for the difference between the two levels. Melting and sublimation are expected to enhance the surface concentrations, as the authors note, and it is the top 2.5 cm that are most important for albedo. The authors did observe huge differences between summer and winter layers in one crevasse wall, but did not discuss the results of their paired surface-subsurface

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samples from their geographical survey. For example, page 5089 line 19-20 states that for Figure 7 the surface and subsurface samples were averaged; why was this done?

The dry season in the Cordillera Blanca is not without precipitation. Typically, about once per week or so in the dry season, there is precipitation generally amounting to a few to 20 centimeters of new snow. This leads to unexpected results at times when comparing the surface snow to the sub-surface snow. The surface snow sample is expected to contain more light absorbing particles as the reviewer states, due to accumulation at the surface from melting, sublimation, and dry deposition. In numerous cases during our sampling, snow was sampled immediately after a fresh snowfall. If the snow event resulted in only a few centimeters, the surface sample would be composed solely of snow from the recent snow storm while the sub-surface might contain older snow and thus snow from the previous surface. For this reason, often the sub-surface sample contained more light absorbing particles than the surface sample. Upon reviewing the paired measurements, the difference in eBC between the surface and sub-surface varied by up to a factor of 10 with a similar number of pairs having higher concentrations in the surface sample as in the sub-surface sample. A new section and figure have been put into the manuscript to discuss this part of the work. The figure shows the frequency of occurrence of different ratios of surface vs subsurface values.

(2) Undercatch. The quartz fiber filters apparently did not capture small particles efficiently, as the authors indicate (p 5086 lines 5-7 and 24-29.). This observation is consistent with the thorough study by Torres et al. (2013) on the collection efficiency of quartz fiber filters, which should be cited. For typical BC concentrations in rainwater, Torres found a maximum recovery of 38%. (Aerosol Science and Technology, DOI:10.1080/02786826.2013.868596)

The fullerene soot calibration BC that was used in our tests was created with atmospheric sized BC particles which generally ranged from 0.2 to 0.8 microns. BC size distributions showed that the quartz filters were missing a high percentage of the smaller

particles. For that reason, we started using the Millipore 0.22 micron filters as well. In tests the Millipore 0.22 micron filters collected 97% of the mass and nearly all BC particles larger than .2 microns in the standard. The downside to the Millipore 0.22 micron filters is that it takes a lot longer and much more force to filter the samples rendering them nearly impossible to use in the field. In 2014, for approximately 20 measurements in the Cordillera Blanca, near Cusco, and in Bolivia, snowmelt was filtered through the quartz fiber filters, then collected and filtered through the 0.22 micron Millipore filters immediately thereafter. In the most extreme case, the eBC determined by the LAHM technique for the Millipore filter amounted to 20% of the eBC value measured on the quartz filter. The average was closer to 5% with there often being undetectable levels of particles on the 0.22 micron filters. These tests were conducted on samples with quartz filter eBC values ranging from less than 5 ng/g up to 100 ng/g (quartz filters) and no discernable trend was observed in the 0.22 micron eBC percentage with respect to the quartz filter eBC concentrations. As there is some dust in the samples, it is suspected that either the BC can stick to the dust particles and/or dust particles may substantially clog the pores of the quartz filters reducing the effective pore size sufficiently to enable more efficient capture. Also, this the Cordillera Blanca snow often went through at least one and perhaps several snow transformations before being collected which tends to lead to aggregation of the BC particles.

(3) The calibration curve. Page 5086 line 16-18. The reason for the nonlinearity in Figure 3c is that at high loading the incident light is absorbed by the topmost particles, so the lower particles will not be exposed to much light. The curvature in Figure 3c indicates that the method will be unreliable for loadings >30 micrograms. In Figure 5, the outlier at rBC=75 is beyond the end of the calibration curve in Figure 3c. Perhaps this point could be used to extend the calibration curve.

This is a very interesting idea that is quite likely to be part of the non-linearity. For further measurements, we have adopted the tactic of reducing the amount of water filtered. Also, 30 micrograms on the filter does not equate to 30 ng/g as filter amounts

are often reduced when the filter gets particularly dirty quickly. As we have gained experience, filters are now loaded until they are approximately 50% gray or until 600 ml (10 syringes) has been filtered. The volume of water filtered is always noted so that the collected particles can be normalized by volume of water. The rBC=75 measurement was at a location where only 300 ml of water was filtered, so the actual loading wasn't substantially higher than the calibration filters. This possibility the top layer of particles absorbing more than hidden layers below is now noted in the text.

Abstract Line 17. How were the samples kept frozen during transport?

The 2013 samples were kept frozen in an ice chest within another ice chest. The entire package was placed into a freezer when available (after 8 hours on a bus and again after 12 hours of aircraft flights). The majority of the samples were pristine upon arrival in Colorado and a few appeared to have been moderately transformed. The samples that appeared to have been severely transformed or completely melted were not included in the results of this publication. Since 2013, it has been found that high quality thermoses will keep snow frozen for several days without the need for re-cooling during transport. The trick appears to be to pack the sample vials in snow, then freeze the entire thermos in a freezer that is turned quite low. Place the thermos in a sleeping bag when packed for travel.

Page 5083 lines 8-9. Warren and Wiscombe 1980 is the wrong reference here. Cite instead Doherty et al. 2010 ACP.

The reference has been changed.

Page 5084 lines 4-5. How long did the melting take? BC may adhere to the wall of the Ziploc bag if meltwater is in contact with the plastic for a long time.

Melting generally takes 5-10 minutes, and filtering is done immediately after melting. From snow to filtering being completed is generally less than 20 minutes and volunteers are instructed that the filtering needs to be done as soon as the snow is melted. The

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stated time in the text is 20 minutes. The text has been clarified that this is from the start of melting to the finishing of filtering.

Page 5086 line 13. “32.5 micrograms”. The points in Figure 3 are plotted at 30 not 32.5.

It was determined after the original writing of the manuscript that the 32.5 microgram filter may have been damaged and have let some BC by the edge of the filter. We eliminated it from the calculation. We have adjusted the text to refer only to the filters used.

Page 5087 line 15. A better reference is Grenfell et al. 2011 Applied Optics, which carefully defines “effective black carbon”.

The reference has been changed.

Page 5090 line 2. How far is Huaraz from Regions 3,4,5?

Distances from Huaraz now shown in this paragraph.

Figure 3c. Exchange the x and y axes, because temperature-increase is the dependent variable.

This change to the figure has been made.

Figure 5 should be a square not a rectangle, since the same units are on both axes.

Changed

Figure 5 horizontal axis. Define “rBC”.

A reference is now given for rBC in the text and it is spelled out on the axis and in the caption.

Figure 6. Exchange the x and y axes, because altitude is the independent variable.

It is common convention in atmospheric and cryospheric sciences to plot altitude on

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the y-axis. We prefer this convention when dependent variables are plotted versus altitude.

Figure 7a. Add a latitude-longitude grid.

Latitude longitude grid added.

Figure 7b. An alternative way to plot these data would be to use the distance from Huaraz (km) as the x-axis.

Each of the valleys are unique and in some valleys, numerous mountains are climbed and sampled. It is thought that the valleys are the main drivers for the local meteorology and pollution transport, so it seems more reasonable to plot the data by valley. The distances between Huaraz and a central location in each valley (or the summit in the case of Vallunaraju) are now indicated in the text.

Figure 7 caption line 5. Change “5 ng/g” to “8 ng/g”.

Caption changed as suggested.

Figure 8. Exchange the x and y axes.

As with figure 6, we prefer altitude as the y-axis.

Figure 9 vertical axis. The depth could be given in meters instead of centimeters; this would simplify the numbers.

Changed

Grammar and spelling The title and abstract indicate that the topic is “particulates”; but page 5082 line 23 instead says “particles”. Are you making a distinction? If not, change all occurrences of “particulates” to “particles”, for simplicity and consistency. But “particulate” does still have a use; it is the adjective corresponding to the noun “particle”.

I agree and have changed all occurrences to “particle” or “particles”.

Page 5084 line 23. Change understand to understanding. done Page 5085 line 4. Change affect to effect. done Page 5087 line 3. Change suggest to suggests. done Page 5089 line 13. Delete “to”. done

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Interactive comment on The Cryosphere Discuss., 8, 5077, 2014.