Response to Referee #2

We are very grateful for the referee's critical comments and suggestions, which have helped us improve the paper quality substantially. We have addressed all of the comments carefully as detailed below in our point-by-point responses. Our responses start with "R:".

I have read the manuscript titled: Properties of black carbon and other insoluble light absorbing particles in seasonal snow of northwest China. Overall, I feel that the manuscript is well written and is worthy of publication in The Cryosphere. The first referee made multiple comments regarding the chemical analysis. As this is not my area of expertise, I will comment on some additional issues that I noticed.

R: Tanks very much for your comments and suggestions, we have addressed all of the comments carefully as detailed below.

This research (as well as many publications reporting on this topic) suffers from one common uncertainty. Since results are presented from data collected in one moment in time, how useful are the results in reality? How representative is that one point in time for representing conditions at any other time in the snow year? Different weather conditions can significantly affect the snow ILAP concentrations. While this is a common problem with this type of measurements that can only be overcome by more intensive sampling, I feel that the authors should include wording that state that the results are from one time measurements at each location and may not be representative of the long term characteristics of the snow in that location.

R: Generally, the sampling sites were selected 50 km away from cities and at least 1 km upwind of the approach road or railway to minimize the effect of pollution from local sources across northwestern China. But we also agree with the reviewer that understanding spatial and temporal differences of ILAPs in snow is still challenges. Therefore, the comparison of the seasonal and interannual variability of the ILAPs in snow was investigated, and the result shows that the differences of ILAPs in snow are relatively small in the Arctic and northeastern China (Doherty et al., 2010; Wang et al., 2013, 2017). We note that further snow field campaigns were still performed worldwide to limit the uncertainties of ILAPs in snow due to the spatial and temporal differences across northern China, the Himalayas, North America, Greenland and the Arctic since 1980s (Cong et al., 2015; Dang and Hegg, 2014; Doherty et al., 2010, 2014; Hegg et al., 2009, 2010; Huang et al., 2011; Xu et al., 2009, 2012; Zhao et al., 2014; Warren and Wiscombe, 1980, 1985). For instance, a similar paper on the mixing ratios of ILAPs in Arctic snow has been widely used for validating modeled snow BC mixing ratios (Doherty et al., 2010). Therefore, we indicated that the datasets in this study can contribute to advancing remote sensing techniques and reducing the uncertainties of the

model simulations to enhance our further understanding of the climate impacts of ILAPs in snow and ice.

If I recall correctly, the Hegg technique requires that the snow is relatively fresh.

R: We have carefully looked through the papers by Hegg et al. (2009, 2010). The major points in the literatures are the attribution of the chemical species and the mixing ratios of BC in seasonal snow, which were based on the results of light absorption of BC in both fresh and aged snow by Doherty et al. (2010). Recent studies also mentioned that using the chemical and optical data, which are included both fresh and aged snow samples, were input to a Positive Matrix Factorization (PMF) analysis of the sources of particulate light absorption (Doherty et al, 2014; Zhang et al., 2013). Therefore, the PMF technique is mainly based on different species as the input without considering the snow samples as fresh or aged.

There do not appear to be any comments regarding the time since the most recent snow storm for each of the sites (other than the mention of the 13 sites where it was snowing during collection). Could this affect some of the chemical analysis as some chemical constituents may have washed out of the snowpack?

R: We note that the snow field campaign was conducted in winter season and the surface snow kept frozen and hadn't yet melted during our sampling processes in most of the snow sampling sites. Therefore, the melting or washing effects were negligible in this study. But we also agree with the reviewer that the melting and washed out effect of the snowpack should be considered if the snow samples were really melted. Details for the melting and washed out processes of ILAPs in snow could be found by Wang et al., (2013, Equation 1 & Figure 3) and Doherty et al. (2013, Figure 1) .

Page 3 line 11, Using the SNICAR online model (http://snow.engin.umich.edu), using the default snow constants then either 0 or 10 ng/g, the broadband albedo reduction is closer to 0.3% rather than 1%. The Warren and Wiscombe (1980) paper shows possible values with some relatively extreme cases depicted. Could the authors clarify what snow conditions they are using and then clarify the appropriateness of these conditions?

R: We have revised the sentence as "Warren and Wiscombe (1980) indicated that a mixing ratio of 10 ng g^{-1} of BC in snow with snow grain size of 1000 μm may reduce the snow albedo at 400 nm by approximately 1%."

Page 14 line 19: Earlier the authors stated that they sampled in 5 cm steps down through the snow pack. Is this comparable to other studies where you compare the results?

R: Sure, the methods on snow collections and spectrophotometric analysis are definitely comparable with the previous studies (e.g. Doherty et al., 2010, 2014; Wang et al., 2013).

If the surface sample is the top 5 cm of snow, how does the density of the snow affect the measurement (if dry deposition on the surface is the main source, then the 5 cm of snow would dilute the measurement significantly with density as an additional factor).

R: We agree with the reviewer that it is still a challenge to separate the dry and wet deposition of the ILAPs in the top 5 cm snow. The most important reason is that the snow albedo is mainly influenced by the surface snow, especially for the top 5 cm. Therefore, in order to compare and improve the model simulation, we use the top 5 cm as the cumulative values, which include both wet and dry deposition. However, we also indicated the dirty layers and new fallen snow were collected in all sites separately, even for the filtration processes. Doherty et al. (2010) also indicated that if there was obvious layering, for example a thin top layer of newly fallen snow or drift snow, that layer was collected separately, however thin.

If all of the BC is on the surface, then sampling the top 1 cm of snow versus the top 5 cm of snow (assuming uniform density) would give you a factor of five difference in mass mixing ratio since BC is generally reported in a mass per volume unit.

R: The same as above comment. Generally, we collect the vertical profiles of snow sample in every 5 cm when the snow looks uniform. Otherwise, the snow samples will be gathered separately, if it is a significant dirty layer or new fallen snow, whatever 1 cm or thick layers.

Nomenclature: The different variable names are not well defined at their first use in the manuscript. Ie. What specifically do “MAX”, “EQUIV”, and “EST” in superscript mean next to C subscript BC? It might be nice to have these and the many others in a table for easy reference. If they are equivalent to something used in other literature (eBC in Grenfell), please list the equivalents as well.

R: Thanks for your suggestion. We have added the description of variables in Table 1.

Table 1. Variables derived by using the ISSW spectrophotometer.

Symbols	Description of variables
C_{BC}^{max}	Maximum BC is the mass of BC per mass of snow, if all particulate light absorption (650–700nm) is due to BC.
C_{BC}^{est}	Estimated BC is the estimated true mass of BC per mass of snow,

	derived by separating the spectrally resolved total light absorption.
C_{BC}^{equiv}	Equivalent BC is the amount of BC that would need to be present in the snow to account for the wavelength-integrated (300–750nm) total light absorption of down-welling solar radiation by all particulate constituents.
$Å_{tot}$	Absorption Ångström exponent is calculated between 450 and 600nm, for all particulate deposited on the filter.
f_{nonBC}^{est}	Fraction of light absorption by non-BC ILAPs, is the absorption by non-BC particulate constituents, weighted by the down-welling solar flux, then spectrally integrated from 300 to 750nm.

Page 18 line 2: Something is missing: "vertical differences were missing at could sites, . . ."

R: We have revised the sentence as "…although apparent vertical differences could be observed at could sites, such as site 47".

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