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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Concentrations and source regions of light absorbing impurities in snow/ice in northern Pakistan and their impact on snow albedo" *by* Chaman Gul et al.

Anonymous Referee #1

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This manuscript reported the data of light absorbing particles (LAP, such BC, OC and dust) measured in snow/ice in northern Pakistan and estimated the induced snow albedo reduction and corresponded radiative forcing during 2015-2016. Authors found the concentration of BC, OC and dust in aged snow is higher than in fresh snow and ice and the concentration over northern Pakistan is higher than over the Himalayas and Tibetan Plateau. Estimated LAP-induced daily mean snow albedo reduction is approximately 0.07-12.0% and corresponded radiative forcing is approximately 0.16-43.5 W m-2, depending on snow type, solar zenith angle, and locations. Also different methods are used in this study to identify the source regions of pollutants measured in this region.

Overall the results are interesting and measurement data are valuable for the community. The figures and tables in the manuscript are relevant, but not very good in quality, and need to be improved. In general the paper is well written but in many places the English could and should be improved. There are some major weaknesses in the manuscript, especially in the source region identification part (3.5) and aerosol type frequency distribution part (3.2). After the below comments are appropriately addressed, I would suggest to accept the manuscript for publication in the Atmospheric Chemistry and Physics.

Technical comments:

Introduction, I would suggest use Light-absorbing particles (LAP) instead of Light-absorbing impurities, see Qian et al., 2015, which by the way is a review article for both measurement methods and modeling activities. This article is so relevant so probably should be cited in Introduction part.

Lines 62-65, Besides warming efficiency, another important characteristic of LAPs is its higher snowmelt efficiency, see Qian et al., 2011.

Lines 110, precipitation 0.412 +/- 2 mm for per day or per year?

Lines 123-128, again sample method is summarized in Qian et al., 2015.

Section 2.3.1, without 2.3.2, really needs 2.3.1? More details are needed regarding how the L-2 data are processed.

Lines 155-159, This paragraph should be removed or moved to Introduction section.

Section 2.5 is very poorly organized and kind of just present whatever tools you have or used before, without a clear goal or coherence in science structure. Must be rewritten.

2.5.1 Wind maps, why not use 2005-2006 wind maps instead of 50-year average? 700mb is very high level for low-elevation region and aerosol concentration is very low at that high level. I would suggest use the terrain-oriented level like sigma level near the

surface. I would also strongly suggest (a must do) use MERRA-2 reanalysis data, in which not only the data quality is better than NCEP/NCAR but also it includes aerosol data that can be used to compare with the measurement and is more appropriate for looking at the long-distance transport.

2.5.3, WRF-STEM can only tag CO, because of many differences between CO and LAP in such as emission sources, chemistry and removal, how to quantify their differences in long-range transport and source identifications? How to infer the transport and source for LAPs based on CO and what's the uncertainty? Please see Zhang et al. 2015 and Wang et al., 2015 for source detection methods used over Tibetan Plateau region.

Line 257, 24 hours. Considering–>considered.

Line 318, Jun–>June.

Section 3.2, very weak! How to connect the conclusion from this section with other parts?

Section 4 Summary and conclusion, one more section should be added for discussion in uncertainty and possible future direction for both modeling and measurement campaign. For example, how snow aging (snow grain size) and melting water scavenging efficiency (see Qian et al, 2014) affect the conclusions?

Figure 2, this is a poor figure and should be re-designed. For example, reduce the y-axis range from 300 to 150. Btw why the numbers for y-axis are 50, 100, 150, 200, 150 (should be 250?)?

Figure 3, give full name for MAC in figure caption. Also consider use identical range for y-axis e.g. 0.4-1.0 and for x-axis 0.3-1.2 for Panel c and d.

Figure 4, suggest use identical y-axis range so can highlight the bigger effect over aged snow. The unit for radiative forcing is %? More discussion should be provided regarding how snow aging affect the albedo reduction and radiative forcing (e.g. Qian

et al., 2014)?

Figure 5, what blue contours represent? Again 700 mb is too high and MERRA-2 is a much better dataset.

Figure 6, not clear what color shades represent?

Figure 7, I am not sure how the quantitative number of contributions are meaningful because the numbers for LAP could be very different with that for CO. Anyway again, Section 2.5 is very poorly organized and kind of just present whatever tools you have or used before, without a clear goal or coherence in science structure. Need to be rewritten with a clear conclusion.

Table 2, give full name for MAC (in other tables/ figures as well).

Figure S7, give full names for BC1 and BC2.

References: Qian Y, TJ Yasunari, SJ Doherty, MG Flanner, WK Lau, J Ming, H Wang, M Wang, SG Warren, and R Zhang. 2015. "Light-absorbing Particles in Snow and Ice: Measurement and Modeling of Climatic and Hydrological Impact." Advances in Atmospheric Sciences 32(1):64-91. doi:10.1007/s00376-014-0010-0. Zhang R, H Wang, Y Qian, PJ Rasch, RC Easter, Jr, PL Ma, B Singh, J Huang, and Q Fu. 2015. "Quantifying sources, transport, deposition, and radiative forcing of black carbon over the Himalayas and Tibetan Plateau." Atmospheric Chemistry and Physics 15(11):6205-6223. doi:10.5194/acp-15-6205-2015. Qian Y, H Wang, R Zhang, MG Flanner, and PJ Rasch. 2014. "A Sensitivity Study on Modeling Black Carbon in Snow and its Radiative Forcing over the Arctic and Northern China." Environmental Research Letters 9(6):Article No. 064001. doi:10.1088/1748-9326/9/6/064001. Wang M, B Xu, J Cao, X Tie, H Wang, R Zhang, Y Qian, PJ Rasch, S Zhao, G Wu, H Zhao, DR Joswiak, J Li, and Y Xie. 2015. "Carbonaceous Aerosols Recorded in a Southeastern Tibetan Glacier: Analysis of Temporal Variations and Model Estimates of Sources and Radiative Forcing." Atmospheric Chemistry and Physics 15:1191-1204. doi:10.5194/acp-15-

1191-2015. Qian Y, MG Flanner, LYR Leung, and W Wang. 2011. "Sensitivity studies on the impacts of Tibetan Plateau snowpack pollution on the Asian hydrological cycle and monsoon climate." Atmospheric Chemistry and Physics 11(5):1929-1948. doi:10.

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