

## ***Interactive comment on “The decreasing albedo of Zhadang glacier on western Nyainqentanglha and the role of light-absorbing impurities” by B. Qu et al.***

**B. Qu et al.**

petermingjing@hotmail.com

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Responses to the comments of Referee #2 General Concern The manuscript entitled “The decreasing albedo of Zhadang glacier on western Nyainqentanglha and the role of light-absorbing impurities” by Qu et al. discussed the influences of LACs (light-absorbing constituents, e.g., BC and dust) on the snow/ice albedo and mass balance of glacier based on in-situ measurements and satellite data. Authors found a good correlation between the decreased glacier mass balance and its surface albedo derived from MODIS. The BC and dust are suggested as two dominant factors driving the glacier albedo reduction. From both the science and societal impact perspectives,

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Tibetan Plateau is a very sensitive and important region in regulating Asian monsoon and hydrological cycle, which would potentially affect the water resources ecosystem, cryosphere change and even national securities in Asian countries. This study provided some very valuable in-situ measurement data over Zhadang glacier in Tibetan Plateau. While this is an interesting and appropriate topic for ACP, especially this SOAR-TP special issue, the analysis procedure of the data and presentation of the article can be greatly improved. Authors failed to present the data in a context that would logically support the major findings. For example, a good correlation between the glacier mass and surface albedo doesn't necessarily mean it must be the snow/ice impurities that caused the surface darkening. Other factors, such as the warming of atmosphere, no matter from whatever reasons, could reduce the snow surface albedo by increasing the snow gran size thought snow aging process, resulting in a glacier mass lose. The lack of long-term measurements of LACs (impurities) in snow/glacier (so no way to support your conclusion in a stronger way) is a serious flaw in this study. Also the presentation needs to be improved. The paper may need more work in improving the writing by a native English speaker. There are quite several grammatical errors or inappropriate use of English. This reviewer suggests that following comments and suggestions should be addressed before the manuscript can be considered for formally publication in ACP. Re: We would like to thank the anonymous referee for approving the importance of the work and commenting that the work “provided some very valuable in-situ measurement data over Zhadang glacier in Tibetan Plateau” and “is an interesting and appropriate topic for ACP, especially this SOAR-TP special issue”. We also think the kind but critical comments from the referee are very helpful to improve the interpretation and presentation further. To improve the English presentation, the manuscript has been submitted to the Elsevier language editing service, which will take us approximately one week. We will resubmit a revised paper to ACP after getting the language-editing version. Considering the main points raised by the referee in the beginning of the report have been included in the major and minor comments, we will address our responses according to the comments item by item in follow. Most

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of the revised places are marked in red in the revised manuscript. Major Comments 1. Surface albedo inferred from satellite measurements have typical errors of a few percent, the bias could be even larger in mountainous area like Tibetan Plateau, so a signal of reduced or increased albedo will be difficult to detect. So how you can detect the albedo trend or change shown in Figure 4 is significant and reliable? The inference of albedo from a nadir radiance measurement can be biased low because of undetected thin clouds, multiple reflectance in the mountains or blowing snow altering the angular reflectance pattern (Warren, 2013). But even if the albedo could be measured perfectly from satellite, its attribution would be ambiguous because of the vertical variation of snow grain size, absorbing aerosol in the atmosphere above the snow, and especially because of sub pixel heterogeneity of the thin and patchy snow cover of the treeless regions. The spectral signature of thin snow resembles that of BC in snow. For these reasons, Warren (2013) suggests that attempts to use satellite remote sensing to estimate the variability of albedo by BC are unlikely to be successful. Authors suggested a downward trend of albedo in Zhadang glacier as shown in Figure 4. However, it would appear an upward trend if last two years of data are removed. This is a critical issue that should be more carefully addressed. Re: There are some literatures already discussing the possible usage of MODIS albedo data in mountainous regions, which are properly cited in this study. Warren (2013) suggested that it is unlikely to detect the impact of black carbon on snow albedo by remote sensing, which has been properly addressed in the method section. Particularly in our study, we did some validation work on MODIS albedo data using the observation data measured by the sensors mounted on automatic weather station on the saddle of Zhadang glacier. We collected more mass-balance and MODIS-albedo data on Zhadang glacier during the period 2010-2012 and added them into Figure 3 and 4. The linear relationship in Figure 3 between MODIS and observational albedo data becomes more statistically significant than that in the previous ACPD paper (Fig. S1). And we also found the decreasing trend of surface albedo becomes more robust varying from -0.001 (ACPD) to -0.003 (now) (Fig. S2) and the albedo variations was strongly related with the mass balances between

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2006 and 2012. 2. To justify the validity of using MODIS data to look at the trend or variability of glacier albedo, authors tried to use in-situ AWS albedo data to evaluate the MODIS albedo data, see Figure 3. This figure shows an overall positive correlation between these two datasets, but also a remarkable scattering and discrepancy can be seen. Especially, if the 5 points at lower albedo end are removed, the correlation would be much smaller. The in-situ AWS observation is point measurement but the MODIS albedo represents an average of 500x500 m<sup>2</sup> pixel, which could contribute to the discrepancy, especially over mountainous area with complex terrain like Zhadang. This part of discussion should be more carefully revised. Re: Yes, as pointed out by the referee, the linear relationship in Figure 3 is not very convincing in the ACPD paper, because the data points are more concentrated in the up-right corner. However, after adding MODIS and observed albedo data in 2010-2012, the linear relationship is much more robust (Fig S1). 3. Authors failed to present the data in a context that would logically support the major findings. For example, a good correlation between the glacier mass and surface albedo doesn't necessarily mean that it must be snow/ice impurities that caused the surface darkening. Other factors, such as the warming of atmosphere, no matter from whatever reasons, could increase the snow grain size (through snow aging process) thus reduce surface albedo, resulting in a glacier mass loss. The lack of long-term measurements of LACs in snow/glacier is a serious flaw in this study. This reviewer would suggest more measurement data that can link the snow albedo and impurities should be added in this study to support your conclusions. Re: The linear relationship between MODIS albedo in Zhadang glacier and mass balance records is good between 2006 and 2010, and even better after extending the data to 2012. And the relationship is associated with the more and more negative mass balances and lowering surface albedo of the glacier. Besides the warming of the atmosphere, we would like to investigate the impact of LACs on the melting of the glacier in different surface conditions. Summer is the best season that can provide strong melting and frequent snow falls. That's why we did the sampling and in-situ observations. We will input this explanation into the context in order to avoid the further confuse.

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Minor Comments 1. Page 13131, Figure 5. How did you calculate the RF driven by BC and dust in the S-I condition? I think the SNICAR model only applies to the impurities in snow rather than glacier. Re: In S-I condition, bare ice denotes the strongly melting surface with wet snow. Actually, it is still a snow surface, which has been showed in the photo (Fig. 2). 2. Page 13112, line 14. "Dust" -> "dust". Re: This has been revised. 3. Page 13113, line 4-5. "The surface conditions are typical in alpine glaciers all around the year" means those conditions are typical all the time in Tibetan too? Re: These conditions are typical in Tibetan glaciers in summers, which has been addressed in the context with proper citations. 4. Page 13116, line 3-4. The albedo increases with elevation, could it also due to lower BC and dust contained in the snow/ice? Re: The concentrations of BC and dust in higher snow are indeed lower with higher albedo. Thanks to the referee, we did not mention the point in the context. Now we have properly addressed it. 5. Page 13116, line 17-18. N=6? Or 5? Re: Originally in the ACPD paper, it should be "5". Now, it should be "7" after adding into two-year data. 6. Page 13116, line 23-26. The BC is accumulates greatly in aged snow/ice, so the concentration in the S-I condition is much higher than the ice core records or fresh snow. The BC concentration in aged snow should not be directly compared with the BC concentrations in ice core or fresh snow. Re: We have deleted the comparison. 7. In calculation of albedo using SNICAR, please make sure the "MAC scaling factor (experimental)" is not MAC. In SNICAR model, the factor of BC in broadband is 1. If the authors just input "11" in the "factor (experimental)", that'll make the results of albedo reduction higher. Re: This is a mistake. We re-calculated the results setting the MAC scaling factor (experimental) as 1, which did not alter the results much. The new results were showed in the revised Table 2. 8. Page 13114, line 10, at sites A and B, it was bare ice. So when sampling, the ice just been picked up? Or chop one piece off from the bare ice? I suggest making the sampling procedure clear. Re: In site A and B, the glacier was covered by aged snow showed in the photo of Fig. 2. We have made it clear in the revised manuscript. 9. Page 13114, line 18, "clean hands-dirty hands", what that means? Re: In short, "clean hands-dirty hands" means the one whose

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hands are collecting sampling won't touch any other material that may contaminate snow samples. We have addressed the issue in the revised manuscript. 10. Page 13126, Table A1. "10. Dust concentration (ppm, 5.0–10.0m diameter)" How get the dust grain size (5.0-10.0 um in diameter)? The concentration is based on the different weights of filters before and after filtration? How get the dust diameter? Re: Yes, the dust concentrations are based on the different weights of filters before and after filtration. Dust grain sizes in Zhadang glacier can be visually measured by simple ways such as a ruler. Thus we chose the largest scale provided by the on-line SNICAR as its diameter. 11. Reference format and arrangement should be corrected. Re: This has been revised. 12. The paper may need more work in improving the writing by a native English speaker. There are quite several grammatical errors or inappropriate use of English. Re: We will submit our manuscript to the Elsevier language editing service for improving the presentation, after the replies to the referees. 13. Introduction: the first paragraph seems too long. Re: The original paragraph has be divided into several parts properly.

Please also note the supplement to this comment:

<http://www.atmos-chem-phys-discuss.net/14/C5024/2014/acpd-14-C5024-2014-supplement.pdf>

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Interactive comment on Atmos. Chem. Phys. Discuss., 14, 13109, 2014.

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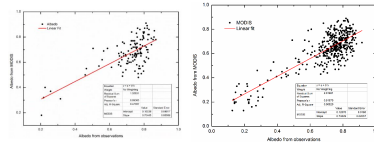


Fig. S1 The linear relationship between MODIS and observed albedo in ACPD Figure 3 (left) and revised Figure 3 after adding new data (right).

Fig. 1. Fig. S1

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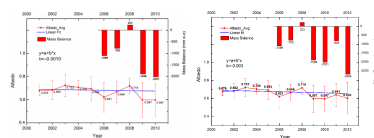


Fig. S2 The decreasing trend of surface albedo in Zhadang glacier derived from MODIS in ACPD Figure 4 (left) and revised Figure 4 after adding new data (right).

Fig. 2. Fig. S2

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