Atmos. Chem. Phys. Discuss., 14, C5032–C5037, 2014
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Atmospheric Chemistry and Physics Discussions

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

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Received and published: 17 July 2014

Responses to the comments of Referee #1 General Concern This study investigates changes in the surface albedo of the Zhadang glacier in the southern Tibetan Plateau, a topic of relevance for the special issue that the manuscript was submitted to. Three main issues are explored in this study: (1) trends in the albedo of the glacier during 2001-2010, determined from MODIS satellite observations, (2) the relationship between albedo anomalies and surface mass balance anomalies, and (3) the impacts of black carbon (BC) and dust on the albedo of different parts of the glacier, and under different snow and ice conditions. All of these issues are important and worthy of publi-

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cation. The discussion of BC and dust impacts is somewhat disconnected from issues (1) and (2), because the in-situ measurements only occurred during July and August of 2012. The study could have been more coherent if the decadal-scale changes in albedo had been linked to changes in dust and BC, but this does not appear possible because of the limited time extent of the ground measurements. Nonetheless, readers will likely be left wondering about the relationship between aerosols and the long-term changes in albedo, and consequently it would be helpful for the authors to comment more on this, perhaps leveraging findings from Ming et al (2012) and others. Such a discussion would help tie the different components of this study together. Aside from this, the issues described below relate mostly to need for justification or more detail on methods. Re: We would like to thank the anonymous referee for approving the importance of our work and commenting that the work is “a topic of relevance for the special issue that the manuscript was submitted to” and all three issues addressed by our work “are important and worthy of publication”. Zhadang glacier locates very far away from the human settlements, and has no power and accommodation supports. Harshly logistic conditions there do not allow researchers to conduct a long-term in-situ observation to date. Usually, the researchers will choose late springs and summers as the possible campaign time to do some measurements and samplings there. During the melting seasons in some Tibetan glaciers, the reduction of albedo has been related with the deposition of LACs suggested by previous studies (e.g. Ming et al., 2009 in Atmos. Res.; Ming et al., 2012 in ERL; Takeuchi and Li, 2008 in Arctic, Antarctic, and Alpine Research). In the original ACPD paper, we found a decreasing trend (-0.001 a-1) of the surface albedo in Zhadang glacier during the period 2000-2010, in which the mass balance between 2006 and 2010 is well associated with the variation of albedo. Obviously the albedo decreasing cannot be not primarily attributed to the regional warming which has been sufficiently addressed by many previous studies. However, aside from the warming, the deposition of LACs will also induce surface darkening especially in strong melting seasons, i.e. late spring and summer (See Ming et al., 2009 in Atmospheric Research). It is the very motivation

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that we conduct this study investigating the variation of surface albedo and the impact of LACs on albedo reduction in various surfaces of the glacier. After collecting more data and adding them into Figure 4, 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 2006 and 2012. Most of the revised places are marked in red in the revised manuscript. Issues 1. Why does the MODIS albedo analysis (Figure 4) only extend to 2010? Presumably this could be extended through 2013. (Figure 3 includes 2011 MODIS data). Does the downward trend continue during 2011-2013? Including 2012 MODIS data would also allow a comparison between ASD-measured (in situ) albedo and MODIS albedo, similar to the comparison between AWS and MODIS albedo that is shown in Figure 3. Re: Yes, the referee has supposed a very helpful suggestion. Our work was firstly finished in 2012, when the dataset has not been updated to 2012. In the revised paper, we extended the mass balance and MODIS albedo data to 2012, because the dataset of mass balance in 2013 has not been released by the handling institute. Yes, the decreasing trend of albedo continues to go downward and goes even more negative (-0.003 a-1) than the original one (-0.001 a-1). The revisions have been made in the new Figure 3 and Figure 4. 2. Abstract: Mention that the BC and dust albedo impacts only apply to measurements taken in 2012. Re: Agree, the statement in the abstract has been revised. 3. p.13111, 11: The "darkening" referred to here probably relates to increasing grain size. I suggest being more precise. Re: Agree, we revised the statement. 4. p.13111, 26-29: What are these albedo reductions relative to? Are these absolute albedo reductions relative to winter values, percentages of total impurity-induced albedo reduction, or something different? Please clarify. Re: We meant to suggest the albedo reduction was due to the deposition of black carbon and dust. We have revised the statements in the context. 5. p.13113, 18-20: Wording here is unclear. Are these criteria applied by the authors, or are they "built in" to the product? Also, is the QA value binary or is it one of several possible values? If the latter, which threshold was applied? Re: These criteria

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are applied by us. QA value is binary, “good” or “bad”. We clarified the statement in the context. 6. p.13114, 7: "mounted in a pistol-shaped unit" - Was this a tripod unit? How was leveling with respect to the normal conducted? Please include more detail here. Re: The unit is a pistol-shape device that the optical fiber can be fixed inside. The pistol was mounted on the rocker arm of the tripod with a gradienter for levelling. We added these statements in the context. 7. p.13115, 7: "snow size" -> "snow grain size". Re: Has been revised. 8. p.13115, 12: "Snow grain effective radius is taken as the half of observed snow grain size shown in Table 1" - What is the justification for this factor? More generally, it should be pointed out, either here or in section 2.3, that the measure of grain size determined from a hand lens can be quite different from the optical (effective) measure that is relevant for radiative transfer modeling, and consequently uncertainty in snow grain size translates into substantial uncertainty in modeled albedo impacts of impurities. Re: We used the method introduced by Aoki et al., (2007) to measure the grain size of snow crystal. The grain sizes are measured using a 25X lens, which is not easy for operating and thus generated quite large uncertainties. So we can only take the median from the diameter range of the grain sizes from a few measurements in an individual sampling. 9. p.13115, 13: "The albedo of the underlying ground is taken as ..., based on observations" - For the radiative transfer modeling, these values should represent the albedo of whatever surface underlies the snow, which for a glacier is usually some sort of ice substrate. Do the "observed" values applied here represent bare glacier albedo or something different? Please clarify. Re: Yes, the observed values represent the albedo of bare ice after scraping the aged snow off. We have clarified it in the revised context. 10. p.13116, 13: "relative to" -> "related to". Re: We have revised the mistake. 11. Table 2 includes a useful comparison between modeled and observed albedo, but this is not discussed in the text. It would be helpful to include a brief statistical evaluation of the modeled vs. observed albedo (e.g., RMSE, correlation). Re: We have added some evaluations of the modeled and observed albedo into the context. 12. Discussion in section 3.2: Tables 2 and A1 indicate that the modeling work assumes thin snowpack

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(2-5 cm). Although these values are consistent with the measured snow thicknesses (Table 1), this configuration with the SNICAR model implies that impurities contained within the ice beneath the snow do not contribute to the radiative forcing calculations. It is unclear how important this assumption is, but it does contribute to a low bias in the RF estimates. This needs to be acknowledged in the manuscript. Re: Thanks for the comments. We have addressed this concern in the revised manuscript. 13. Figure 3: Do the AWS measurements extend to 2012? If so, it would be very useful to also include a comparison between AWS and in-situ (ASD) measured albedos. Re: Yes, the referee #2 also raise this question. We have extended the data of AWS and mass balance to 2012. 14. Figure 5: The caption should mention that these RF estimates represent mid-day RF (when the insolation measurements were conducted) rather than daily-mean RF. Re: Yes, we have revised it.

Please also note the supplement to this comment:
http://www.atmos-chem-phys-discuss.net/14/C5032/2014/acpd-14-C5032-2014-supplement.pdf

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

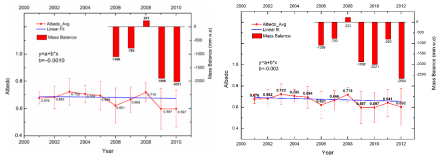

Fig. S2 The decreasing trend of surface albedo in Zhadang glacier derived from MODIS in ACPD Figure 4 (left) and revised Figure 4 after adding new data (right).

Fig. 1. Fig. S2

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