Atmos. Chem. Phys. Discuss., 10, C4792–C4798, 2010
www.atmos-chem-phys-discuss.net/10/C4792/2010/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Preliminary estimation of black carbon deposition from Nepal Climate Observatory-Pyramid data and its possible impact on snow albedo changes over Himalayan glaciers during the pre-monsoon season" *by* T. J. Yasunari et al.

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Received and published: 2 July 2010

Anonymous Referee #2

This study applies observations of atmospheric black carbon (BC) concentrations from a remote high altitude observatory in Nepal to infer potential pre-monsoon snow albedo changes caused by BC. Starting with the observations, the authors make conservative assumptions of deposition velocity, mixing within surface snow, and BC-albedo reduc-

tion to argue for a lower bound on the effect of BC on Himalaya snow albedo and glacier runoff. Although numerous assumptions are made, this study has the benefit of starting from real observations, the applicable scope of the results is cautiously defined (for the most part, see one exception below), the analysis is acknowledged to be preliminary, and there are several compelling reasons presented why the actual effect is larger than that quantified here. Overall, I think it is a useful study and should be published after (relatively minor) issues listed below are addressed.

I reviewed this study several months ago when it was submitted to a different journal. The authors have since bolstered their argument and elaborated considerably on their methods, addressing several concerns I originally had including: 1) quantification of dilution from any precipitation falling during the pre-monsoon season (they also quantified enrichment resulting from sublimation, which they show to be likely greater than precipitation during the pre-monsoon season), 2) some discussion of why 2cm was chosen as the particle mixing depth (although this assumption still seems somewhat arbitrary), 3) further justification/explanation for deriving deposition velocity from atmospheric concentrations, and 4) quantification of albedo perturbation using different assumptions of environmental conditions (snow grain size, etc).

>Thanks a lot for giving us your useful comments on current and previous versions of our paper. We are happy to hear that you reviewed our previous paper submitted to a different journal because we revised our paper along your previous comments and here we can let you know the revised parts from the previous paper. We will answer the followings again point by point.

Issues: 1) There is one important point which is made only in Conclusions, which I think needs to be raised earlier in the manuscript: (p9311,2): "Our results are applicable to white glaciers only (not for debris cover glacier)". This is a very important point because ablation zones of glaciers typically ARE debris covered, and this could significantly reduce the influence of BC (perhaps even beneath the current lower bound). I suggest stating this qualification earlier in the manuscript, and referring to "white" or "clean"

or "non-debris covered" glaciers throughout the text (i.e., p9305,26: "our numbers are likely to underestimate the actual albedo reduction for Himalayan glaciers").

>As you mentioned, the debris-covered glaciers exist in ablation zone, but also snow surfaces do in the zone. Hence, we added the following sentences in the introduction part and used non-debris covered (NDC) on related sentences throughout the text: “Some parts of the Himalayan glaciers in ablation zone are covered by debris. Our discussion is not applicable to these completely debris-covered glacial surfaces. Our study will be applicable for non-debris covered (hereafter, NDC) snow surface areas in the ablation zone and other glacial zones at higher altitudes.”

2) In the abstract and conclusion (and perhaps elsewhere) "dust deposition" is mentioned in context suggesting that neglecting it leads to a conservative estimate of the BC effect. However, the simultaneous presence of dust (as with debris) may DECREASE the influence of BC by absorbing photons in place of BC. Please describe more clearly the likely (sign of) effect of neglecting dust on your lower bound estimate. However, you also appear to have good justification for neglecting dust in your analysis, based on your statement (p9298,19) that "Marinoni et al (2010) found negligible dust contribution to aerosol absorption coefficient at NCO-P". If this is a robust result, you may wish to mention it in the context of excluding dust from your quantification of albedo reduction by BC. But are low dust concentrations robust? p9308,19: "Highest concentration was detected from a dirty layer": Were other impurities contributing to the "dirtiness" of this layer? If not, wouldn’t (by definition) the highest concentrations be detected in the dirtiest layer?

>Thanks for this point. However, we think your point is opposite from our point of view corresponding to general understanding and we would like to explain it and make it clearer for you. Over non-debris covered (NDC) glacial surface, BC and dust are BOTH very important for discussing snow albedo reductions. In general understanding, the BC has higher absorption of solar radiation in visible wave and dust does absorption but less than BC. On the other hand, deposition amount of dust is in general larger and

that of BC is relatively smaller than dust. Hence, total absorptive effects for dust and BC are considered to be comparable. FOR THE FULL DISCUSSION of impurity effects on snow albedos, we need to consider both dust and BC on snow albedo reductions over NDC parts of glaciers. In calculation of snow albedos including BC and dust, total absorption effects are considered as sum of those dust and BC absorptions in snow albedo theory such as Aoki and Tanaka (2008, Tenki, Meteorological Society of Japan). However, the focus of this study is only BC so as to separate dust and BC effects and here we discussed how much BC itself at least impacts on snow albedo reductions as lower bound. Mixed discussion including both dust and BC are necessary in near future. In addition, what Marinoni et al. (ACPD, 2010) mentioned is not the amount of dust but the effect on the absorption coefficient in the MAAP measurement as follows: “The very good correlation between EC and equivalent BC (R2=0.94), obtained by totally independent methods confirms the fact that, despite the presence of high levels of dust (Duchi et al., 2010), MAAP absorption measurements are primarily influenced by BC. This justifies the use, in the remaining part of the paper, of the term “equivalent BC” for MAAP measurements”. Actually, dust amount in the atmosphere is large and would impact on FULL snow albedo discussion including both dust and BC finally. Please keep in mind again that our focus in this study is only BC here and in near future dust effects should be discussed together with BC on snow albedo discussions.

3) It is assumed that all BC depositing during March-May mixes within the top 2cm of snow, and that dilution occurs only through precipitation (and enrichment through sublimation). But what about snowmelt, especially during May when temperatures rise above freezing? Melt would certainly remove (from the top 2cm) some of the particles that deposited during the last several months (although it could also expose particles that deposited earlier in winter). Please include some discussion of the potential effects of melt on your estimates of BC concentration.

>As you mentioned, we also had already mentioned this effect in Sect. 3.6 as follows: “In addition, BC flushing effect due to snow melting as discussed in Conway et al.

(1996) and Flanner et al. (2007) may also be important for determining albedo reduction at the snow surface". However, currently still much uncertainty lie on this flushing effect because of very limited studies. Hence, currently it is hard to determine whether this effect is large or not. But we think some effects may exist. Taking this into account, we add some on the sentence above as follows: "but quantitative discussions are currently very difficult because of very limited studies. Future studies on this flushing effect on impurities may, perhaps, modify snow albedo estimation to some extent"

4) The discussion could be more concise in some places, which would improve readability.

>Similar points were also suggested by reviewer#1 and we revised the paper based on the specific points as reviewer #1 mentioned. In addition, English corrections with proofreading were carried out by a native speaker at NASA Goddard Space Flight Center leading to increase readability.

Minor issues: p9301,14: "direct depositions": I assume it is specifically DRY deposition which enhances the top-2cm concentration.

>YES. We revised it as "dry".

p9301,19: "deposited in 2-10cm snow": Maybe change to "concentrations in 2-10cm snow", as aerosols are not "deposited" directly in subsurface snow.

>YES. We revised it as you suggested.

p9302,2-6: This passage is unclear to me.

>We made this part clearer as follows: An assumption of pure snow layer of deeper than 2 cm can significantly increase the pure water amount, thus reducing BCC within the same amount of BCD. However, an assumption of a deeper pure snow layer is not realistic, based on the studies as mentioned above (Aoki et al., 2000; Aoki et al., 2007; Tanikawa et al., 2009). Moreover, snow layers below 2 cm usually include impurities to some extent in the real world.

p9306,7: Clarify/correct: "Ice surface is sometimes come up over glacier surface"

>We revised the part together with the following sentence to make it clear: Ice layer is sometimes seen at NDC glacial surface, but the results obtained by using the equation (3) can be applied to the NDC snow surface composed of fresh, compacted, and granular snow grains (not complete ice) because most of the original data for snow albedo estimations were based on some assumptions of snow grain size.

p9309,18-21: This passage needs to be clarified.

>We made this clear as follows: In our numerical tests, we considered that the effects of forced albedo reductions in the transient period from pre-monsoon to monsoon corresponds to the snow darkening effect due to the integrated BC depositions on snow surface during pre-monsoon season (March–May).

p9311,22: Please clarify the meaning of "equilibrium albedo reductions in the mixture of the impurities."

>What we would like to say here is "maximal snow albedo reduction". We added this point in the text. We moved this paragraph to new section 3.7. along the comment by reviewer #1.

Fig 7: What do the symbols represent? Include this in the caption.

>The symbols denote the locations of glaciers and NCO-P site: Fig. 1. Location map of research sites focused in this study. The large circle in yellow denote NCO-P site. The triangle and square in white colour denote the locations of Yala Glacier, and Dongkemadi Glacier, respectively. The cross, triangle, and square in sky blue denote the locations of Kangwure Glacier, East Rongbuk Glacier, and Qiangyong Glacier, respectively, where BC concentrations in snow were measured by Xu et al. (2006) and Ming et al. (2008; 2009). The Merged IBCAO/ETOPO5 Global Topographic Data Product by Holland (2000) was used for topography map.

Fig 8: Should the runoff have units of timeËĘ-1 (perhaps mm dayËĘ-1)? The curve

does not appear to be accumulated (time-integrated) runoff, so I assume the units should have time.

>YES. As you mentioned, the output is daily and we revised the unit as “mm w.e. day-1”.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 9291, 2010.