The Cryosphere Discuss., 7, C3486–C3498, 2014
www.the-cryosphere-discuss.net/7/C3486/2014/

Interactive comment on "A 10 yr record of black carbon and dust from Mera Peak ice core (Nepal): variability and potential impact on Himalayan glacier melting" *by* P. Ginot et al.

P. Ginot et al.

patrick.ginot@ird.fr

Received and published: 7 April 2014

⇒ In this document, I have copied Koji Fujita comments, and answered them in the lines with →

Overview

Manuscript by Ginot and others reveals a ten year record of impurities in an ice core drilled at high elevation accumulation site of Mera Glacier, Nepal Himalaya. The ice core well preserves seasonal signals of stable isotope, chemical compositions and impurities. Although effect of black carbon (BC) on glacier mass balance has been pointed out in some previous studies, this study evaluates both impact of BC and dust

in terms of albedo, absorption of solar radiation and excess melt quantitatively. The record shown in this manuscript seems important and thus worth to be published in TC. In particular, it is meaningful that the authors successfully distinguished the impacts and seasonality of dust and BC because the impact of BC seems to have been overstated in previous studies. However, impacts of the impurities on absorption of solar radiation and excess melting are based on various and vulnerable assumptions.

Considering use of these values by following researches, the manuscript seems to draw somewhat over-conclusion though the authors described limitation of their analysis.

Major comments

A similar paper is now under discussion in an open discussion journal, ACP. The paper by Kaspari and others deals with the same element, BC, taken at the same glacier. I recommend that both authors exchange their information not for competing each other, but for improving both manuscripts.

Kaspari, S., Painter, T. H., Gysel, M., and Schwikowski, M.: Seasonal and elevational variations of black carbon and dust in snow and ice in the Solu-Khumbu, Nepal and estimated radiative forcings, Atmos. Chem. Phys. Discuss., 13, 33491-33521, doi:10.5194/acpd-13-33491-2013, 2013. http://www.atmos-chem-phys-discuss.net/13/33491/2013/acpd-13-33491-2013.html

⇒ We are in contact with Susan Kaspari and I've proposed to combine our results for the quantification of the vertical gradient od BC and dust deposition fluxes

Uncertainty in sample retrieval and analysis

Although the BC analysis is not my expertise, I have heard that BC particles could decrease during transportation and storage. Also heard was that refreezing could alter the analytical result significantly. The manuscript does not touch those technical points.

⇒ I absolutely agree that the technical aspect for the analytical procedure of BC was really weak in our manuscript. Main explanation is that all these points are part of another paper now published in AMTD by Lim et al. 2014.

Lim, S., Faïn, X., Zanatta, M., Cozic, J., Jaffrezo, J. L., Ginot, P., and Laj, P.: Refractory black carbon mass concentrations in snow and ice: Method evaluation and inter-comparison with elemental carbon measurement, Atmos. Meas. Tech. Discuss., 7, 3549-3589, 10.5194/amtd-7-3549-2014, 2014. http://www.atmos-meas-tech-discuss.net/7/3549/2014/amtd-7-3549-2014.html

⇒ As this point was one of the main comment of Reviewer 1, I've prepared a detailed answer to them.

Analyses of the ice-core records

Analysis and discussion of the ice core record are insufficient. Although many space is spent to explain general behavior and source of ammonium (P6010), for instance, the profile is not sufficiently analyzed. Consistency and inconsistency among different species and impurities may provide more information in terms of source, emission and transportation processes.

⇒ As you know, we can learn so many things from an ice core. However, this manuscript focuses on the radiative impact of impurities on Mera glacier. For these purposes, I've extracted and presented only the ice core detailed information necessary for this study: dust and BC profiles, proxies for seasonal dating (δ18O and ammonium).

⇒ For the other tracers illustrated in Figure 2 (F, Ca, SO4, NO3), my analyses and discussion is reduced. I could expand these analyzes to "provide more information in terms of source, emission and transportation processes", but would need to integrate additional information also (backtrajectories, other analyzes…) and my feeling is that these should appear in a future paper with atmospheric measurements comparison.

In particular, comparison with meteorological record has to be performed. I suppose that data at Lukla and Namche Bazar should be available together with the NCOPyra-

mid. Onset of monsoon varied year by year and it will affect the assumptions that every 1st June is end of dry season, and that impurity concentrations linearly increased during every dry season toward the their maxima on 1st June.

⇒ Right, our dating approach was too simple. Now I've used the isotopic record from the core to split between monsoon and inter-monsoon season. As observed in IAEA data, most enriched isotopic value is reported for the month of May. From the core record, I've used each annual most enriched value to calculate annual mean composition. From each annual mean, I've split the year into "monsoon" and "inter-monsoon" and attributed the monsoon dates according to Nepalese Monsoon onset and withdrawal dates (http://www.dhm.gov.np/uploads/climatic/535305507monsoon onset n withdrawal.pdf). Time scale was developed for the record using a linear regression between each attributed date. With this method, each analyzed sample corresponding to each depth was his own date.

I agree with that the winter accumulation is expected to have been eroded by wind though it will be negligibly small amount. But it will be meaningful to compare whether the ice-core derived accumulation is consistent with the observational precipitation records at the neighboring stations.

⇒ The accumulation measured close to the drilling site since 2008 is presented in Wagnon et al., 2013 (Fig. 5). The accumulation ranges between 380 and 1250 mm weq with a mean of around 830 mm weq. The core, with 12.47 m weq and spanning over 11 years correspond to a mean net accumulation of 1130 mm weq.

⇒ Wagnon et al. (2013) presents also in Table 2 the annual mean precipitation measured at NCO-P station at 5035m: 389±44 mm for 2007-2012. This value is "likely underestimated" in case of solid precipitation.

Description and discussion of stratigraphy

In addition to the analysis above mentioned, stratigraphy such as ice layers and grain size have to be described and discussed. The relevant descriptions are fragmentally shown through the manuscript.

⇒ I will add stratigraphy description on the beginning of “2.3) Sample analysis” and markers of the three observed ice layers in fig. 2 profile (1.52 – 1.57 , 1.83-2.13 and 4.0 m weq depth)

Definition of seasons

Although pre-monsoon, post-monsoon, monsoon and winter seasons are surely defined in the manuscript, "inter-monsoon" suddenly appeared at the middle part (P6011L21), and then used through the latter part of the manuscript. Also undefined is "non-monsoon" season. I just imagined from Figure 4 that the inter-monsoon and non-monsoon are the season consisting of post- and pre-monsoon seasons excluding winter.

⇒ That is right. The 4 seasons are based on climatology. However, along the core, we can only distinguish between two situations: “Monsoon” as a wet season, and “Inter-monsoon” as dryer season (identified from stable isotopes cycles, see my answer for the new seasonal cycle identification above). I will define and homogenize the “inter-monsoon”.

Linear assumptions

I do not agree with the authors’ assumptions in which the surface concentrations in dust and BC have increased linearly toward 1st June because this directly affects the succeeding results and I feel that the authors overstated their estimates. At least, it is better to be assumed that the surface concentrations are distributed according to those in the ice core profiles.

⇒ With the new dating method, see above, each sample was dated. With this dating, the concentration with depth from the core is transformed in a time evolution of surface concentration as illustrated in the new figure 4 (enclosed).

⇒ This methods also improved the comparison with atmospheric measurements at NCO-P for BC

⇒ These profiles were now used for the revised albedo modeling.

Potential melting evaluation

The "potential melting evaluation" will mislead readers. Decreased albedo by dust and BC could warm up temperature of the snow pack, but no melt should have occurred in the cold snow condition as the authors mentioned. Under such condition, projection of "additional melt" is meaningless. Although the authors further evaluated the impact of dust and BC as additional melt by comparing the mass balance in the ablation zone, the surface condition should be completely different from that in the accumulation zone, at which the ice core was retrieved and albedo reduction was estimated. In addition to the complicated "mass balance" of impurities as the authors mentioned in the text, it is questionable that the impact of additional dust and BC would be "additive" on a surface condition in the ablation zone, on which mud like material is usually found (e.g. Takeuchi et al., 2001). Fujita et al. (2011) have demonstrated that the lowering of surface albedo could alter the mass balance around the equilibrium line altitude while no significant consequence was found at the accumulation zone and at the ablation zone. At the accumulation zone, additional meltwater caused by albedo reduction could be captured by refreezing, while the dirty surface could be exposed (almost) throughout the melting season at the ablation zone.

Takeuchi, N., Kohshima, S., and Seko, K.: Structure, formation, and darkening process of albedo-reducing material (cryoconite) on a Himalayan glacier: A granular algal mat growing on the glacier, Arct. Antarct. Alp. Res., 33(2), 115–122, 2001.

Fujita, K., Takeuchi, N., Nikitin, S.A., Surazakov, A.B., Okamoto, S., Aizen, V.B., Kubota, J.: Favorable climatic regime for maintaining the present-day geometry of the Gregoriev Glacier, Inner Tien Shan, Cryosphere, 5(3), 539-549. doi:10.5194/tc-5-539-2011, 2011

⇒ This paragraph is a key section in the manuscript, to link the "Additional absorbed energy" produced by the impurities, with their impact on the glacier melting. In Figure 7, we present the "Daily mean forcing due to impurities" in W.m-2. This radiative forcing was calculated with the impurities fluxes measured in the accumulation area (only this glacier area allows such reconstruction).

⇒ We agree that this forcing has two consequences: 1) increasing the snow temperature for cold snow in the accumulation area, and 2) melt the snow that reaches melting temperature (0°C) close to the equilibrium area. In the ablation area, the impurities load is different and we can't calculate the forcing.

⇒ To link and compare these results with our mass and energy balance information (in mm.yr-1 melting rates), the way was to convert the radiative forcing in "potential melting" with two STRONG conditions: 1) the firn is at melting temperature that is the case close to the equilibrium area where the mass and energy balance measurements are performed, and 2) that the impurities deposition fluxes are in the same order of magnitude between 6400m and 5360m.

⇒ These conditions allow to compare the "potential melting" (real melting in that case) with the balances values at this altitude only.

Deposition timing of impurities

The authors assumed that the surface was dirtiest on 1st June in every year. This assumption is not sufficiently discussed though the timing when the surface was dusted (BC added) is substantially important for the melt acceleration. Fujita (2007) has demonstrated this aspect.

Fujita, K.: Effect of dust event timing on glacier runoff: sensitivity analysis for a Tibetan glacier, Hydrol. Process., 21(21), 2892–2896, doi:10.1002/hyp.6504, 2007.

⇒ This aspect was corrected with the new dating.

Minor comments

Many abbreviations are used without spelling out. Many sentences are grammatically incomplete, probably because of position of parentheses. The manuscript must be checked by any native English speakers.

⇒ I plan to send the revised manuscript to professional English proof

P6007L20 How did the authors know the site temperature? Need reference or description how it was measured or estimated.

⇒ We have measured the temperature in the borehole: -5.7°C at 20m, -5.0°C at 15m and -3.2°C at 10m. To be included in the manuscript

P6011L8-18 The authors interpreted that the upper most part of the ice-core was accumulated during early winter. But in the profile of stable isotope (Fig. 2), I cannot identify any signatures of post-monsoonal precipitation which should show heavier values.

⇒ The assumption of the winter snow is related to 1) the lowest ammonium concentration and 2) most depleted isotopic signal and 3) small snow crystals that can correspond to cold snow from "cleaner" area.

⇒ As the core was extracted in November, the following heavier isotopic snow deposition can occur until next monsoon season.

P6013L15- Nothing is explained why the authors can conclude that the principal component 1 is controlled by deposition processes.

⇒ Because all proxies varies together: low concentrations related to dilution during the wet season, high concentrations related to post deposition processes (dry deposition and sublimation) during the drier season.

P6013L23 Need evidence or reference for the emission source to be salt lake.

⇒ I used previously Lithium as a tracer of salt lake in the Andes. The same Lithium is reported in the North Tibetan salt lake and several reference are available on Lithium resources and extraction from this region.

P6014L12 What are the 4 species?

⇒ Sulfate, nitrate, ammonium and BC

P6014L16 Need any references for the limited transportation.

⇒ From NCO-P publications (Marinoni et al., 2010 ; Bonasoni et al., 2010 ; . . .)

P6014L18- I totally agree with this description. Therefore it is important to analyze variability of the ice core signals.

⇒ To be improved in the revised manuscript. I this point refers to your comments about the insufficient "Analysis and discussion of the ice core record", I fully agree and I can add some analyzes for the evolution of some deposition trends for example

P6015L6-10 Was dust either "in the snow" or "in the atmosphere" measured at the NCO-P?

⇒ At NCO-P station, dust was only measured in the atmosphere. We used PM10 minus PM1 to approximate atmospheric dust concentration.

P6020L6 Are solar radiation incident and solar irradiance different? If they are same meaning, use a single term.

⇒ Both terms indeed have the same meaning. Incident solar radiation was thus replaced by solar irradiance in the revised version of the manuscript.

Figure 1 Replace the Asian map (lower left panel) by close-up regional map, in which NCO-P, Ronbuk Glacier and other stations are shown. I think that the location of Mera Glacier (red star) is incorrect.

⇒ OK

Figures 5 and 6 Labels and legends are too small to be seen.

⇒ This has been changed in new figures 5 and 6.

Figure 6 Same scale of y axes is appreciated for two panels.

⇒ This has been changed in new figures 5 and 6.

Figure 8 Is any different color used for "monsoon"?

⇒ Yes, monsoon color is transparent/light for a better season comparison. It has been applied both to BC only and BC+dust results in the new figure 8. In addition, we present MrBC (BC in fig, to homogenize) and rBC (BC max in fig, to homogenize) results.

⇒ New Figure enclosed

Two important papers by Xu et al. (2009, 2012) are missed.

Xu, B., Cao, J., Hansen, J., Yao, T., Joswiak, D., Wang, N., Wu, G., Wang, M., Zhao, H., Yang, W., Liu, X., and He, J.: Black soot and the survival of Tibetan glaciers, P. Natl. Acad. Sci. USA, 106, 22114–22118, 2009.

Xu, B., Cao, J., Joswiak, D., Liu, X., Zhao, H., and He, J.: Post-depositional enrichment of black soot in snow-pack and accelerated melting of Tibetan glaciers, Environ. Res. Lett., 7, 014022, 2012.

⇒ Thank you

MiscP6006L19-20 Why is February omitted? November is counted twice.

⇒ Monsoon: defined with "monsoon onset and withdrawal date"

http://www.dhm.gov.np/uploads/climatic/535305507monsoon%20onset%20n%20withdrawal

⇒ Post monsoon: from withdrawal to November

⇒ Winter: December- February

⇒ Premonsoon: March to monsoon onset

⇒ Inter monsoon = post monsoon + winter + pre monsoon

P6015L29-P0616L3 Definition of the ratio is unclear because of "between". Is this ratio dust against rBC?

⇒ Yes, ration dust against rBC for the core, and (PM10-PM1) against equivalent BC in the atmosphere

P6019L15 I do not understand what "enhances" means.

⇒ “explains”

P6020L5-6 I do not understand what "solar incident radiation incident". Is this just typo?

⇒ “men solar incident radiation”

P6022L21 Delete "and topographical – image of 2012" because the satellite image does not matter in terms of mass balance in the ablation zone.

⇒ We have used the Pleiade satellite image to obtain the glacier hypsometry used for the mass balance calculation.

Interactive comment on The Cryosphere Discuss., 7, 6001, 2013.

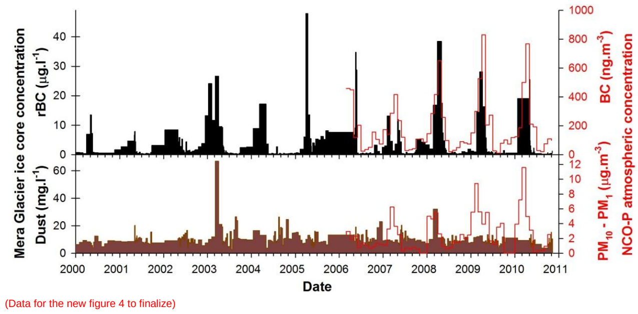

Fig. 1. New Figure 4

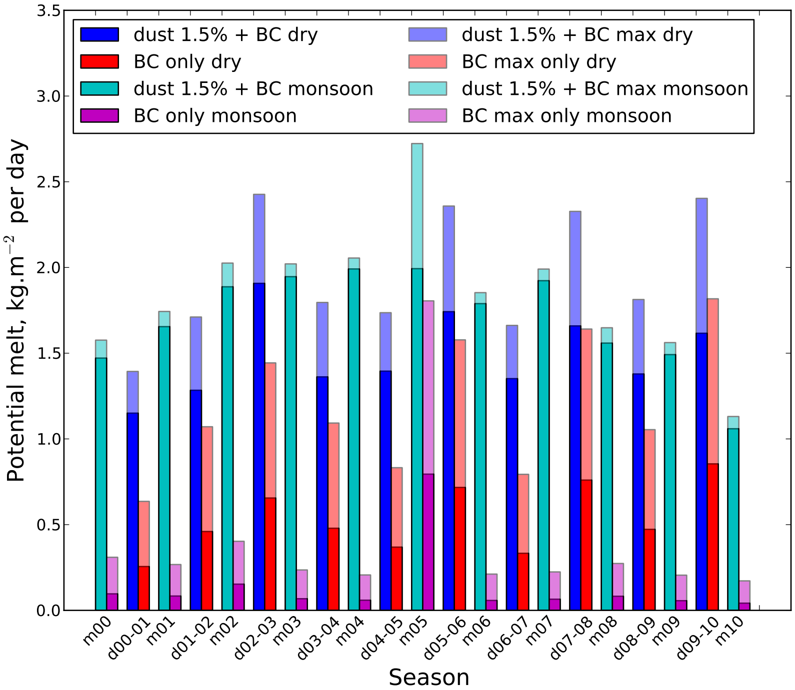

Fig. 2. New Figure 8