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Interactive Comment

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.

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

Ginot et al (2013) provide a fascinating and detailed description of the impurities in a 10 year firn core form Mera Glacier in the Nepal Himalaya. They further utilize modeling to identify the likely impact of black carbon and dust on the mass balance of the glacier. Most of the comments below are minor. The two most important are the need for a better qualitative description of where on the glacier surficial impurities can meaningfully impact albedo and ablation. Second is a better examination of the progression

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of ablation seasonally, putting in context the ablation during the pre-monsoon versus monsoon season. This also necessitates identifying the percentage area of the Mera Glacier that could be influenced.

6003-9: that to than

⇒ Corrected

6003-14: Quantify the melt rate from mass and energy balance.

⇒ Done: “Compared to the melting rate measured by mass and energy balance at 5360 m asl on Mera glacier between November 2009 and October 2010, -3000 kg m-2 yr-1 and -3690 kg m-2 yr-1 respectively, the impact of rBC represents less than 8% of annual potential melting while the joint contribution of dust and rBC of the surface melting represents a maximum of 22%.”

6003-17: reword- the rBC variability in the ice core signal is primarily reflecting the variability of the monsoon signal compared to emission intensity variation.

⇒ Done : “Furthermore, over this 10-yr time span, the rBC variability in the ice core signal is primarily reflecting the variability of the monsoon signal compared to emission intensity variation.”

6004-10: current emissions globally? Define emissions of what better.

⇒ Done: “aerosol emission”

6005-13: profits not ideal word choice.

⇒ Changed with “uses this alternance”

6006-5 and/or 6022-9: Additional discussion is needed on where dust and black carbon may play a role and where it will not. The particles in snow and ice reduce the surface albedo increasing ablation. This can only occur if the BC is at or very close to the surface. On Himalayan glaciers BC will not alter albedo in regions that are debris covered or in areas with frequent accumulation events that bury the BC. Since the glaciers in this region are summer accumulation type glaciers, with the highest solar radiation during a period when frequent new snow would bury BC, there is a limited role for BC in the accumulation zone. Since most of the larger glaciers have significant debris cover in there lower reaches, this also limits the role of BC in the lower ablation zone. Hence, the region on Himalayan glaciers where BC can alter albedo by remaining at the surface is in the clean ice zone of the mid-upper ablation zone, and the area around the snowline, where accumulation events are not as frequent. Bolch et al (2011) have previously noted this region as the area of greatest thinning.

⇒ Absolutely right. In the case of Mera Glacier, we focus our study to the accumulation area. The ablation area of Mera glacier is not debris covered but our studies cannot conclude for the ice surface impurities load. In the accumulation area, we consider that during the monsoon, the impurities are wet deposited, concentration are low and continuously buried with fresh precipitation so that the impact is weak (figure 8). During the drier seasons, impurities are mostly dry deposited, the high loaded surface is therefore exposed for longer time to the solar radiation and the impact is higher (figure 8).

⇒ I have changed the surface concentration evolution of the impurities according to 1) a more accurate record dating based on stable isotopes seasonal variation, and 2) the high resolution impurities profile measured along the core (not only the annual maximum and monsoon mean as previously illustrated in figure 4 (=Fig 1 enclosed)). The new seasonal dating increases also the timing comparison between Mera core and NCOP atmospheric measurements.

⇒ New paragraph on the beginning of 4.4: "Like more than 85% of all glacierized areas in Nepal (Bajracharya et al, 2014), Mera Glacier is a debris-free glacier area. Dust and rBC particles concentrated in surface snow increase surface absorption of solar radiation, and in turn enhance melting in some specific areas where surface temperature may reach the melting point, where snowfalls are not large or frequent enough to systematically cover the surface, and where debris are not too dense to mask their influence. Therefore, the mid-upper part of the ablation area is usually the most affected area of the glacier. Considering that the mean ELA for a zero glacier-wide mass balance is at 5550 m a.s.l. on Mera Glacier (Wagnon et al., 2013), the concerned area is around this elevation and represents a large part of the total area (38% of the total area when considering the 5400-5700 m a.s.l. altitudinal range). The temporal evolution of the impurity concentrations (Fig. 4) is representative of the highest part of the accumulation area, where the effect is the least considering that during the monsoon, regular snowfalls bury these impurities. Nevertheless, these impurities trigger additional energy transferred to the surface, and then used to increase the temperature of superficial layers, and extremely occasionally to melt snow, when surface temperature reaches 0°C. As observed by Kaspari et al. (2013), this impurity deposition measured at the drilling site can be considered as the lower limit for impurity deposition of the mid-upper part of the ablation area. Consequently, our study gives a theoretical quantification of the lowest expected induced melting triggered by impurity effect."

6006-22: precipitation is.

⇒ Corrected

6006-24: Hence, Mera Glacier is a summer accumulation type glacier with peak accumulation and ablation occurring simultaneously. Temperatures at NCO-P are highest June-August.

⇒ Changed

6010-19: New paragraph.

⇒ OK

6010-22: Quantify the range of NH

⇒ The atmospheric concentration of ammonium is ranging from minimum of (<0.023–0.14 μg/m3) during monsoon afternoon to maximum of 0.40 μg/m3 for premonsoon afternoon (Decesari, 2010).

6012-25: lack of seasonality in both in overall quantity and size distribution.

⇒ Corrected

6014 4-21: This paragraph could be eliminated if paper is deemed too long.

⇒ The paper is not too long and we prefer to keep this paragraph which brings substantial information regarding the relation between the high altitude ice core record and the regional emission inventories.

6016 4-10: This paragraph is a confusing topic change, is it needed or should it be relocated?

⇒ Moved with more detailed discussion of chemical parameters

6017 9-22: An interesting note on dust composition, but does it dilute the main focus?

⇒ Moved with more detailed discussion of chemical parameters

6020-12: all days

⇒ Corrected

6022-21: How substantial is ablation on Mera and other glaciers in area during the pre-monsoon season? The temperature at NCO-P has a relatively low mean for the March-May period, below 0 C, Figure 2 Wagnon et al (2013). Also worth observing the potential impact of rain during the monsoon for surficial BC deposition since the aforementioned note that on Mera up to 28% of the monsoon season precipitation may fall as rain at 5500 m. This rain potential is also noted for Yala Glacier by Yasunari et al (2010). Thayyen and Gergan (2010) and Singh et al (2010) for example illustrate how minor glacier discharge is in Himalayan catchments until June. This is important to note as a measure of pre-monsoon ablation,even though you do not have specific data to quantify the potential ablation role for BC during pre-monsoon season from Mera

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Peak.

⇒ As explained in (Wagnon et al., 2013), the mass balance measurements were performed only once a year, in November, with some extra stake readings in April 2009 and April 2013.

⇒ On Mera Glacier, at 5360 m a.s.l., an automatic weather station (AWS) has been operating between the November 2009 and October 2010 (see Wagnon et al., 2013, Fig. 2 for the exact location of the station). Over this one-year period, we calculated the surface energy balance at point-scale, and the computed annual ablation at the AWS location was 3.69 m w.e. (3.55 m w.e. of melting and 0.14 m w.e. of sublimation), with only 11% of it (0.39 m w.e.) occurring during the 3 months of the pre-monsoon season (March, April and May). This annual ablation value of 3.69 m w.e. slightly differs from the original value (4.3 m w.e.) of the submitted manuscript, because in the first version, we had considered all events where the surface energy balance was positive. In fact, to compute the melting at hourly scale, we had to consider also only hours where surface temperature was at the melting point. It has been corrected in the revised manuscript

⇒ It is true that up to 28% of total precipitation may fall as rain at 5500 m a.s.l. (Wagnon et al., 2013) but precipitation is only snow at this elevation during the pre-monsoon period

6021-24: How much of Mera Glacier is in this zone of limited melting? Wagnon et al (2013) indicate the ELA near 5500 m with a modest change in net balance above 5700 m, which suggest limited ablation.

⇒ As developed before, highest melting related to atmospheric impurities will take place around the ELA area (If we consider that the ELA for a zero glacier-wide mass balance is 5550 m a.s.l. (Wagnon et al., 2013), the area considered here (between 5400 and 5700 m a.s.l.) corresponds to 38% of the total area). In this manuscript, our modeling resulted in “potential melting” that can only take place in the accumulation area in case of surface snow at 0°C.

⇒ The next step of our study on Mera is to extrapolate the impact overall the glacier, using aerosol deposition fluxes measured at different altitude, and taking care on this snow temperature parameters.

6025-6-20: The conclusion is too long, and contains review of assumptions etc, that do not belong here.

⇒ Has to be corrected for the revised version

6025-26: Sounds like a sales pitch not concluding lines in a paper.

⇒ Scientist funding is difficult. . .ïĄŁ. I'll remove it.

Figure 2 is excellent, would like to see it stretched vertically for better resolution.

⇒ Done

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

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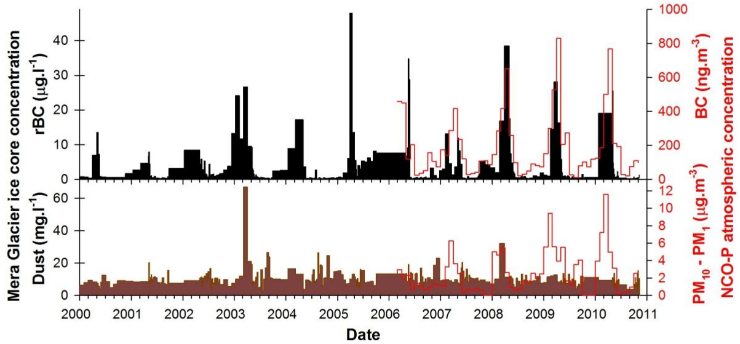

(Data for the new figure 4 to finalize)

Fig. 1. New Figure 4

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