The Cryosphere Discussions

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Review Comment on tc-2022-179

Anonymous Referee #1

Referee comment on "Comprehensive evaluation of black carbon effect on glacier melting on the Laohugou Glacier No. 12, Western Qilian Mountains" by Jizu Chen et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2022-179-RC1, 2022

The authors developed a glacier mass and energy balance model to estimate the impact of atmospheric deposited BC on glacier melting at the the Laohugou Glacier No. 12, Western Qilian Mountains. They found that the BC deposition particularly from industrial emissions significantly accelerates the glacier melting on top of the global warming. The findings are interesting. However, I have a few concerns and suggestions for the authors to address before the manuscript can be considered for potential publication.

Major comments:

- My major concern is that the measurements used to constrain and drive model simulations are collected in different years. This temporal inconsistency can lead to substantial uncertainties in the model simulations and parameter optimization, unless there is very small interannual variability for those measured quantities. The authors need to either justify the negligible impact from interannual variability or quantify the associated uncertainty due to this temporal inconsistency and report it along with the results.
- Lines 107-110: This part is not quite clear to me. How did the authors measure the BC lost in melted snow and then add it to compute the total BC content in snow pit? Particularly, it seems that the authors need to quantify/estimate the amount of BC scavenged by snow meltwater out of the snow pit to compute the total deposited BC in snow. Also, the authors mentioned a little bit about computing the BC lost amount based on removal efficiency in Line 127. However, the removal efficiency has quite large uncertainty (Qian et al., 2014: https://doi.org/10.1088/1748-9326/9/6/064001). This estimation method seems to have large uncertainty for the lost amount of BC. Did the authors conduct any uncertainty analysis to quantify this?
- Section 5.1: The relative importance/contribution of different types of BC (e.g., from

meltout ice, wet deposition, dry deposition) is essentially dominated by the vertical distribution of these BC particle concentrations. The glacier melting caused by BC is mostly driven by the albedo reduction, which is most sensitive to the BC concentration in the top few centimeter snowpack. Thus, physically speaking, the small contributions of BC from meltout ice and wet deposition are probably because the BC locating in the deeper snow layers and BC concentration is relatively low (compared to dry deposition), respectively. Some discussions related to these physical insights need to be added or clarified. Also, the timing of these different BC particles occurring could also have an impact since spring and summer typically lead to the strongest impacts from BC-driven melting.

- This glacier modeling adopted many assumptions, simplifications, and approximations. Thus, a section specifically discussing and/or quantify the uncertainties involved in the model simulations will be very helpful. Some of my comments have touched a little bit on several uncertainty sources.

Minor comments:

- Lines 44-45: "have generally been retreating slowly." Is this relative to the mean retreating rate over the global cryosphere?
- Lines 57-60: This statement is not accurate because there are several previous studies using the simultaneous direct deposition of atmospheric BC from model simulations (including BC emitted from human activities) to estimate the associated BC effects on snow and ice over the Tibetan Plateau (e.g., He et al., 2014: https://doi.org/10.1002/2014GL062191; Ji et al., 2015: https://doi.org/10.1007/s00382-015-2509-1; Gul et al., 2021: https://doi.org/10.5194/acp-22-8725-2022).
- Line 148: This is a little confusing. The first/top snow layer was never depleted by ablation?
- Section 3.4: The authors assumed BC externally mixed with (likely spherical) snow grains in the calculations. However, several previous studies have pointed out that BC-snow internal mixing and non-spherical snow grain shape can have large impacts on the BC-induced snow albedo changes (e.g., Dang et al., 2016: https://doi.org/10.1175/JAS-D-15-0276.1; He et al., 2018: https://doi.org/10.1002/2017JD027752). At least some discussions should be provided regarding the uncertainty related to this aspect.
- Section 3.4: It seems that the glacier melting is only for snowpack, right? How about the glacier ice component? Is there an ice layer in the model? Note that ice layer treatment (in terms of albedo calculation) will be different from that of snowpack.
- Figure 3a: It seems that the model results are consistently higher than observations during winter and spring. What could be the reason(s)?
- Figure 4: Although the simulated mass balance agrees with observations, the simulated snow height is consistently lower than measurements. What are the implications? Is this only the issue with snow density simulation? Would this snow height bias affect the optimization of other model parameters?
- Figure 5: I am a little confused here. Are the BC and MD concentrations shown here both from measurements or model simulations? If they are from model results, how do they compare with measurements?

- Figure 6: The albedo by removing all MD and BC is much higher than that by removing either of them particularly in the low-elevation areas. This nonlinearity seems to suggest the strong impacts from the snow grain growth induced albedo reduction during melting along with the MD/BC induced albedo reduction.
- Section 5.2: Is there any observation to validate the glacier mass change in model results? For example, the GRACE satellite data?