

The Cryosphere Discuss., referee comment RC1  
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## Comment on tc-2021-90

Anonymous Referee #1

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Referee comment on "Proglacial Lakes Elevate Glacier Surface Velocities in the Himalayan Region" by Jan Bouke Pronk et al., The Cryosphere Discuss.,  
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The paper entitled "Proglacial Lakes Elevate Glacier Surface Velocities in the Himalaya Region" aims at quantifying the impact of proglacial lake on glacier dynamics. The paper is divided into two distinct sections. A first part based on remote sensing observations, that compares velocity pattern of lake versus land terminating glaciers, regarding different set of attributes and a second part that models the impact of different parameters on the dynamics of lake terminating glaciers. The main conclusions of the paper are that (1) land terminating glaciers have on average larger ice velocity than land terminating glaciers, (2) high front velocities are correlated with surface lowering, indicating dynamic thinning, (3) ice velocity from lake terminating glacier is mostly sensitive to changes in terminus conditions.

The authors processed satellite data from ESA's Sentinel-2. While their processing chain is based on previous work (Gardner et al., 2020 ; Dehecq et al., 2015) and seems fairly robust, some points are not clear and needs to be more explicit (postprocessing, selection of stable areas, center line analysis, choices of repeat cycles...) and compared with existing studies that uses Sentinel-2 data to map ice flow velocity of glaciers. Specifically, if the aim of the study was to calculate a composite map, I do not understand why the author only choose to process pairs of images separated by 1 year ? Studies have shown, that using all possible repeat cycles and stacking them would largely improve (1) the signal to noise ratio and (2) the spatial and temporal coverage. This would be of great interest for the authors that are looking at glaciers with frontal velocity that rarely exceeds few tens of meters.

I found the measure of the uncertainty on the ice velocity to be somewhat inconsistent throughout the paper : velocity profiles provide a measure of the median and interquartile range, the table are showing the mean and standard error of the mean, and the numbers in the text are not always clear. Something that is even more confusing, most velocity profiles are showing IQR at +/- 10 m, (hence it is difficult to draw conclusion from this), while uncertainty on the velocity in the text rarely exceeds 2 m. Right now, it is hard to tell if the difference in velocity pattern between lake and land glaciers is really over the uncertainty ? Concerning the standard error of the mean given in the Table 4, how was this calculated ? The authors need to keep in mind that the ice velocities do not follow a Gaussian distribution, hence using the standard error of the mean does not apply.

All of this is a bit confusing, and things need to be more homogeneous throughout the text in order to have more confidence in the results. Additionally, the error estimation is largely based on the analysis of velocity fields on stable ground that are selected by the author. However, the selection of these regions is not clear at all throughout the text. Is it selected randomly (including valleys, mountain peaks etc.) ? More details need to be provided in this regard, with potential additional figures.

Moreover, despite the fact that the authors processed a large number of Sentinel-2 data, the entire study is based on the analysis of a composite map, hence completely losing the temporal variability in glacier dynamics. I was in turn, a bit surprised to see that the observation part is only based on the comparison of velocity patterns between lake and land terminating glaciers, despite assessing the real influence of lake changes on glacier dynamics.

While the dataset from ITS\_LIVE is less resolved than this dataset, it would have been exciting to monitor changes in ice dynamics directly related to changes in lake heights (measured from altimetry for example) or lake area (from optical or SAR imagery), during the last 20 years. As a consequence, this would have been directly related to the second part of the paper that is modeling the influence of several parameters on glacier dynamics.

This brings me to my final point : I found the two main sections of the paper a bit disconnected from each other's. The first one investigates the relation between several parameters (glacier orientation, area, debris cover) and velocity patterns, but there is little in common with the second section that really deal with what processes that are influencing lake-terminating glacier dynamics (where there is also no comparison with land terminating glaciers). This raises a number of interesting questions. Indeed, is it right now possible to observe the influence in proglacial lake changes on changes glacier dynamics (ex: changes in lake level to be consistent with the modeling section) ? Is there data available to see the formation of proglacial lakes, and how a change in the area of those lakes have influenced surface flow velocity ? Can we replicate these observations with the models presented in the last section ? With the large quantity of optical data to map lakes and already available velocity fields (ITS\_LIVE, Golive, Dehecq et al., 2019), I think that it might be possible to assess. Finally, it is not clear to me why the author restricted their study area to the central Himalayas. It excludes an entire section of the Himalayas that is very dynamic, and with a lot more diversity in terms of glacier size, orientation, slope and velocity magnitude.

Figures and Tables are overall clear and well presented.

Please find specific comments below:

L77. What do you mean by lake-driven changes in the velocity field ? is it related to the modeling part. Please present the objectives of this paper in the same order as it appears within the text.

L102. Does that really make a difference ? Mean area of lake terminating glacier is 7 km<sup>2</sup>. How much glaciers are you adding up with these? Be more quantitative.

L105. What do you mean by "very low surface velocity" compare to what and where on the glacier ?

L108. Why do you restrict your study to the Central Himalayas ? By doing so, you are excluding all the glaciers in the Pamir-Karakoram, that are really diverse in terms of size,

velocity magnitude, slope, debris coverage... Here you restrict yourself to glacier to mostly small size and slow-moving glaciers, which limits general conclusions that can be made.

L 129. How does it compare to the geolocation error calculated by Millan et al., 2019 ?

L132. Do you mean removing the average offset calculated off glaciers? Which is mentioned in the post-processing?

L 138. Why do you restrict yourself to image pairs at 1-year interval ? Using all pairs of at least >1 month, would greatly improve your signal to noise ratio, which is really important when looking at small velocity numbers (<30 m/yr.) (cf Millan et al., 2019)

Table 2 and L. 141. I don't understand this effective date. Do you mean the central date between image pairs ? Why is it always 2018 ? I thought you processed all data between 2016 and 2019.

L 147-148. How is the stable ground area selected ? Is it random ? Hence including both mountain peaks (potential higher orthorectification errors) and valleys ? 300 km<sup>2</sup> is a bit limited to see potential deviation across images and to study noise, specifically with a low number of image pairs. Furthermore, you discuss this also in section 3.1.5 right ? Please remove this part and discuss it later in the appropriate postprocessing section.

L 151. Do you calculate gradient in the x and y direction ? Please specify.

Section 3.1.4. This section is too technical and do not bring anything substantially new. The cross-correlation technique has already been widely documented in the literature. Hence, I would suggest to reduce this section and remove equations.

Section 3.1.5. See previous comment.

Section 3.2. See previous comment on the error estimation. Please be consistent throughout the text between IQR, SEM, MAD....

L 216. Is the use of such a large filter size limited compared to the width of the glaciers ?

L 218. By how much does it increase the overall confidence ? Be more specific.

L 256-261. How did you calculate the A value ? Does it vary spatially ? or do you take one value for the entire glacier/region ?

L 275-277. Where are these thickness values coming from ? What do you mean by in line with Farinotti et al., 2019 ? You didn't use the value of the thickness for these specific glaciers provided by Farinotti et al ?

L 278. How was the piezometric surface assessed ? Provide method and reference.

L 280. What do you mean by up-glacier velocity ? Is it the ablation or accumulation zone ? Be more quantitative. Where is the speed value of 50 m/yr coming from ? Has it been taken from the measured velocity data ? Specify.

L 285. Ice thickness from the consensus estimate?

L 288-289. Be more specific. What is the realistic range ?

L 300. How do you change the ice thickness estimate ? Uniformly ? By how much ? How come you keep the maximum velocity at 50 m/yr. ? Do you still conserve mass ?

L 305. Do you mean accuracy or precision ? I think you mean precision here.

Section 4.2. Please provide a figure illustrating the differences between each velocity dataset.

Section 4.4. Considering the very large IQR, I do not find any significant differences between lake and land terminating glaciers that is above the noise. Please include Fig A3 in the main text. I think it provide more concluding evidence than Figure 6.

Figure 4. can you provide error bars for the velocity profiles ? In order to be consistent with the other figures.

Section 4.6. Now this is a bit confusing, some much time have been dedicated to the comparison between lake and land terminating glaciers, but here we left off the land terminating ones. Why is that ? Another aspect that would add even more value to the study would be to check out the influence of debris thickness on glacier velocity pattern and magnitude (check out Rounce et al., 2021 for the dataset).

L 504-509. The relation between the large-scale evolution of the Tibetan plateau and the formation of over deepening is not clear to me at this point. Please be more specific.

L 510-514. Please provide a reference to a figure and section of your paper.

Figure 11. Please provide a colorbar. Displaying the velocity on a log scale would enable to better observe the acceleration at the ice front which is not always clear (a, c, d). Would also be good to show for each glacier maps of surface lowering (Brun et al., 2017 for example).

L 517-520. It is not clear to me where this is going. Split this sentence into one or two difference sentences to make your argument clearer.

L 530. What about the lake temperature ? Could we potentially imagine that rising up the lake temperature would increase the melt at the front of the glacier and triggers an acceleration, as it is observed in Greenland and Antarctica ?

L 609. Change 2017 to 2016 ?