Reviewer 1

I would like to thank Troilo and co-authors for providing a point-by-point detailed answer to the comments of the referees. I believe that the manuscript has undergone important and significant improvements since the first version of the paper. Similarly, the structure of the paper, the methodology, and the figures are much clearer. The authors also proposed a comparison with previous velocity estimations, which is a really positive progress towards improving the manuscript quality. However, some points remain to be further clarified before publication.

We thank the reviewer for the positive evaluation. We worked very hard to fix the manuscript according to the suggestions of both referees.

A large share of the paper deals with seasonal velocity fluctuations, but there is no description of these specific changes in a quantitative way. Therefore, the authors must describe these variations precisely, as this is one of the specific goals of the paper. More specifically, the authors must provide an accurate analysis of the amplitude of the seasonal signals, as well as an estimate of the dates of the peaks and minimum speeds.

Thank you for the comment. We quantitatively described the seasonal behaviour in section 4.4 and in figure S5, where we showed that some glaciers have seasonal variation between 50-100% (sometimes even greater), while others do not have any particular seasonal trend. We added in section 4.4 a statement about the dates of the peaks: "Overall, the maximum velocity occurs in August-September, while the annual minimum is reached in March (Fig. 8)."

The evolution of the amplitude of the seasonal signal over time is also very interesting and important. Why does the seasonal signal vary so significantly for one particular glacier? For example, on Brenva in 2016, winter speeds were around 320 m/yr and summer speeds around 460 m/yr. However, in 2017 and 2018, the summer speeds did not even reach 400 m/yr. The same can be seen at Pra Sec, Nant Blanc, Des Glaciers, Dome, Lex Blanche, or Mer de Glace. Can the authors propose a physical explanation for this?

Thank you for stressing on this important and interesting remark. We cannot give a physical explanation for all of the variability observed in this study, but we can stress on some points on which literature studies have shown some different types of velocity variability in the study area.

To our knowledge, steeper and shallower glaciers seem to exhibit larger variability in the seasonal signal and interannually compared to flatter and thicker glaciers. Let's take 2 examples from which ground data are available:

The main central tongue of Argentière (flat and thick) and the lower part of the Planpincieux Glacier (steep and shallow), time series of daily displacements have been published for both glaciers:

Argentière horizontal velocity time series obtained by GNSS measures (2018-2019-2020 time series - Vincent et Al 2022 https://doi.org/10.1029/2021JF006454) show winter minimums around 35cm/day and summer maximums around 60 cm/day. Little variability is noticed in different years.

Planpincieux velocity time series (2014-2018 time series - Giordan et Al. 2020 https://doi.org/10.1017/jog.2019.99) show velocity variability from 10-15 cm/day in winter up to 50 cm day in summer on average, but some seasons may be very different to each other. For example, in 2017 high summer velocities -considering the B sector, a larger part of the glacier -reached 50 cm/day in august while in 2017 there was no summer acceleration at all, as the glacier showed summer velocities comparable to the winter ones; just in autumn, a speed up reached about 30cm/day in end of September/October.

Explanations are also required for why some years show seasonal variations while others do not. For example, some glaciers in 2019 do not show a peak in summer speeds, unlike other years. The same observation is made for Brenva in 2019, Lex Blanche in 2017 and 2019, and Mer de Glace in 2016, 2017, and 2019.

For the same reasons we highlighted in the previous comment we believe that some years, for some particular glacier, can exhibit different velocity variations.

In fact, we think that the subglacial hydrology strongly influences seasonal variations of some glaciers in relation to the degree of development of the subglacial hydrological network. It should also be noted that the seasonal variation probably linked to the state of the ice-bedrock interface, is onset on a baseline velocity that should be mostly controlled by the glacier geometry and thickness, which can also vary over different years and for different glaciers.

Additionally, explanations and descriptions regarding the timing of seasonal peaks should also be provided (an uncertainty estimate for the speed peak would also be welcome). Why do these summer peaks change over time? For example, on Mer de Glace, maximum speeds are observed at the beginning of the year (thus in winter), whereas for Bionnassay (IT), the peak is located in the last third of the year (thus it seems to be late summer, which is more natural). Another example: the peaks observed on Estelette also seem to occur earlier than, for example, A Neuve C or Grande Jorasse.

In general, as stated in the two previous comments, we can provide some hypotheses on some of the changes and behaviours on the timing and extent of the seasonal peaks but we cannot give a scientific interpretation for all of them.

Generally, we noticed that data from large valley glaciers can highlight early spring speedups (Vincent 2022 https://doi.org/10.1029/2021JF006454), while *higher slope glaciers tend to activate later in the season. Autumn speedups due to pressure buildup for increased water input by precipitation or late season melting in contracting subglacial channels seem on the other hand possible to appear on both type of glaciers.*

One of the main objectives of this manuscript is to propose an approach that can be useful for identifying these trends and variations; we think that, thanks to this dataset and others obtained in other sectors of the Alps, the scientific community could improve its knowledge of glacier behaviour and try to solve the important questions you suggested.

From a purely methodological point of view, can the authors provide details on their data fitting methods? For example, why are very high-speed values not considered in the fit at the end of 2018 on Planpincieux? Similar remarks are made on Dome, Aiguille de Tré la Tête, Bionnassay (FR), Mont Blanc, and Mer de Glace. Another remark on Planpincieux, specifically at the end of 2016 and the beginning of 2017, the fit appears to suggest a minimum in speed. I think this is an obvious artifact induced by two lower-than-normal speed values at that time, rather than a real minimum in the glacier's flow. Why are the outlier speeds considered in this case, while at the end of 2018, speeds greater than 150 m/yr seem to be excluded from the fit?

To smooth the time series, we used "a quadratic locally weighted scatterplot smoothing (LOWESS) (Cappellari et al., 2013) evaluated on a rolling window of twelve months" (L250). This method automatically weights less the data with greater residuals and rejects very anomalous values.

We are unsure of what pertains to the comment about the Planpincieux Glacier. In 2016-2017, the minimum is not anomalous either considering the raw or fitted values. Concerning the end of 2018, the velocity of the last three months has been calculated using a single pair of images between September 2018 to January 2019 (see Supplementary Materials), due to poor visibility of the images in that period. In fact, you can note that the velocity values of all the time series are equal in the last three months of 2018. Plus, in the images of 20180912 and 20180922, there were some clouds scattered over the Mont Blanc massif including the Val Ferret (where the Planpincieux is located) and also other glaciers in this sector show some anomalous values (e.g., Pre de Bard, Dome, and Nant Blanc). In these cases, we excluded these data from the rolling smoothing.

In their review responses, the authors provided details on the repeat cycles used and the weighting method for calculating the monthly time series. After taking note of the changes made, I have two remarks. Using this methodology, the number of repeat cycles >30 days is four times greater than those <30 days (which are more likely to observe monthly speed changes). Including so many periods of repeat cycles >30 days can largely impact the magnitude of the monthly speed mosaics because the largest share of repeat cycles will represent the displacement averaged over more than a month. Next, my concern goes toward the weighting method. How are the repeat cycles between 5 and 30 days weighted? From the description provided in the manuscript and response letter, it seems that more weight will be given to the repeat cycles that have the largest overlap in a given month, therefore to the repeat cycle with small temporal baselines, hence with the greatest uncertainties. How do you account for this in the final error assessment?

Unfortunately, we believe that there was a misunderstanding. Considering a pair of images separated by a given temporal baseline B, the weight assigned to the velocity of a given month is proportional to the fraction of B which overlaps that specific month. Therefore, shorter periods are likely to have higher weights compared to longer ones. We refer to the original publication that proposed this particular method Van Wyk De Vries, M. and Wickert, A. D.: Glacier Image Velocimetry: an open-source toolbox for easy and rapid calculation of high-resolution glacier velocity fields, The Cryosphere, 15, 2115-2132, 2021. Moreover, we respectfully make notice that we did not use baselines of 5 days.

The authors also mention a manual filtering of glaciers that may be subject to significant shading, which could bias the speed estimates. Can you develop on how these shading can impact the speed in a more quantitative way? A time series visualization of the L1C products on https://browser.dataspace.copernicus.eu/ shows that the Charpoua Glacier is subject to strong seasonal shade projections. Aren't the authors worried that this would affect calculations in speed changes, similarly to the other glaciers that were discarded? The same problem exists for all the small glaciers in the region of interest. Consequently, the authors should be careful in providing time series for small glaciers, specifically in one of the steepest terrains in the entire European Alps.

This is of course another important remark, on which we can stress more in detail about the topic. In fact, this is most important on glaciers lying on north facing slopes and underlying high rock faces. Fortunately, not all shading gives rise to anomalous velocity detections: when an area is fully shaded, the tracking algorithms, along with the associated filtering and the choice of using an infrared band, can still successfully track movements in shaded areas. This is the example of Bossons glacier, which stays in almost total shadow from November to February, but it quickly transits from totally shaded to totally illuminated. Problems arise when persistent mountain silhouettes move along the glacier maintaining their shapes, which of course can be recognised by the tracking algorithms and give rise to unwanted feature tracking (see for example the mountain silhouettes of Grandes Jorasses onto Leschaux Glacier – a very interesting glacier indeed, with gps ground data available, or the higher area of the Argentière glacier). Last but not least, we checked maps and time series of *the glaciers that we did not exclude and believed that those did not present significant velocity anomalies, possibly due to shadowing effects (winter accelerations in particular). For these reasons, we believe that the time series that we present are not influenced by this type of bias. An important effort has been made both on the glacier selection and in the image selection, in order to get the most reliable outputs that were possible to obtain.*

Concerning Section S4 of the Supplementary material, the authors should provide a more quantitative comparison with previous estimates. Are the timing of the summer peak velocities similar in both studies? For Bosson, the magnitude and timing of the peak seem to be different. Similarly, for Bionnassay no significant peaks are observed in Rabatel whereas Troilo et al. clearly observed velocities peaking at 140 m/yr. A more detailed discussion should be made in that direction with precise metrics and statistics to assess the difference between the products.

Generally, we can distinguish Brenva and Brouillard Glaciers, on which both timing and magnitude of the summer peaks find good agreement, and Bionassay and Bossons, where actually the matching of timing and amplitude of the summer peaks is not so evident.

It should be stressed that Bossons and Bionassay glaciers are glaciers for which we highlighted very low variability and seasonal fluctuations, making it more difficult to detect those variations in velocity.

We provide comparison metrics in the Supplementary Materials. Relative errors are around 10%.

The correspondence of amplitude and timing of the peaks on Brenva and Brouillard glaciers is very good.

For the Bionassay Glacier, we highlight similar values and general trends, but single velocity peaks seem to differ consistently:

First of all, we should highlight that the amplitude of the variations that we are trying to analyse represent differences of 10 to 40 m/yr between the two datasets on a baseline velocity of around 100m/yr.

We believe that both processing chains can fail to detect a particular velocity variation to its full extent at times, and further investigation should be made on understanding how and why some velocity peaks are correctly detected by one method compared to the other, but a lack of ground truth data limits this kind of research on those type of glaciers as of today.

My final remark concerns Figure S2 of the paper, which is a mosaic of glacier surface velocity from 2016 to 2023. Theoretically, this velocity map accumulates a very large number of observations and should therefore be the map with the best signal-to-noise ratio. However, it is possible to observe in stable regions an important number of pixels with very large displacements on the order of 50 m/yr. Even though such high values are not excluded in stable regions, possibly due to local heterogeneities, they appear quite homogeneous and distributed consistently in Figure S2. This suggests that biases of similar (or superior) magnitude are present also in the individual velocity maps, hence that not all biases have been removed (cf. Mouginot et al., 2023), or that some have been introduced when doing the shift correction. Would it be possible to have an example of velocity before and after the shift correction? These very high velocity values are a concern, especially near glaciers like Nant Blanc or Charpoua, which have not been excluded from the time series analysis and have similar magnitudes of speeds.

On top of the shift correction biases that can still be present, the areas that you highlight in figure S2 are not representative stable areas as those areas are densely vegetated by forests (which can introduce biases) and moreover north sloping and hence potentially influenced by shadow effects. Representative stable areas where forests, lakes, agricultural land or landslides are not taken into account, maintain very low movements (for example the valley bottoms around Chamonix and the Val Ferret in Fig, S2 in the Supplementary), indicating that the coregistration process has worked properly.

Reviewer 2

This is the second review of this manuscript, which creates a new multitemporal velocity map for all glaciers in the Mont Blanc Massif using Sentinel-2 imagery and analyses the seasonal velocity changes in detail. In the previous review, I noted that the paper contained much useful data, but required a number of modifications before being ready for publication in this journal. Overall, I think the authors have done an excellent job addressing our review comments and have produced a manuscript which is both clearer and more robust than the previous iteration. I have included some brief points below, and recommend this paper be published following these minor corrections.

We thank the reviewer for the positive comments.

L1 - I wonder if adding the word 'massif' to the title makes sense? I like the change relative to the previous iteration. Another idea could be to add 'seasonal variation' in there somewhere which is now an important element of the manuscript. Also, if I understand correctly your timeseries now stretches to 2024, so that would be the correct date.

Thank you for the suggestion. We decided to modify the title in: "Monthly velocity and seasonal variations of the Mont Blanc glaciers derived from Sentinel-2 between 2016-2024"

L13 Unless you think you have sub-m precision, I would round these to the nearest m.

Done

L21 "Glacier flow was one of"

Done

L129 This new combined section, with material moved around, works much better.

We are glad that you appreciated it

L151 2023 -> 2024

Done

L180 Give the year for this glacierized area since this will vary.

Done

L191 2023 -> 2024

Done

L235 2023 -> 2024

Done

L240 2023 -> 2024

Done

L251 I still think you need a note here about the challenge of a seasonal cycle when fitting a linear trend. Since the cycle is truncated at the start and end of the timeseries this will can affect trends (and outlier robustness will not help as these are not outliers).

We are unsure about this comment. We evaluated the linear fit over the period February 2016 to February 2024, thus we considered an integer number of seasonal cycles.

L265 Mer de Glace is larger than either glacier here, so this needs rewording. Also I am curious what values you find for the Mer de Glace icefall (Seracs du Geant) as I'd expect them to be on this order.

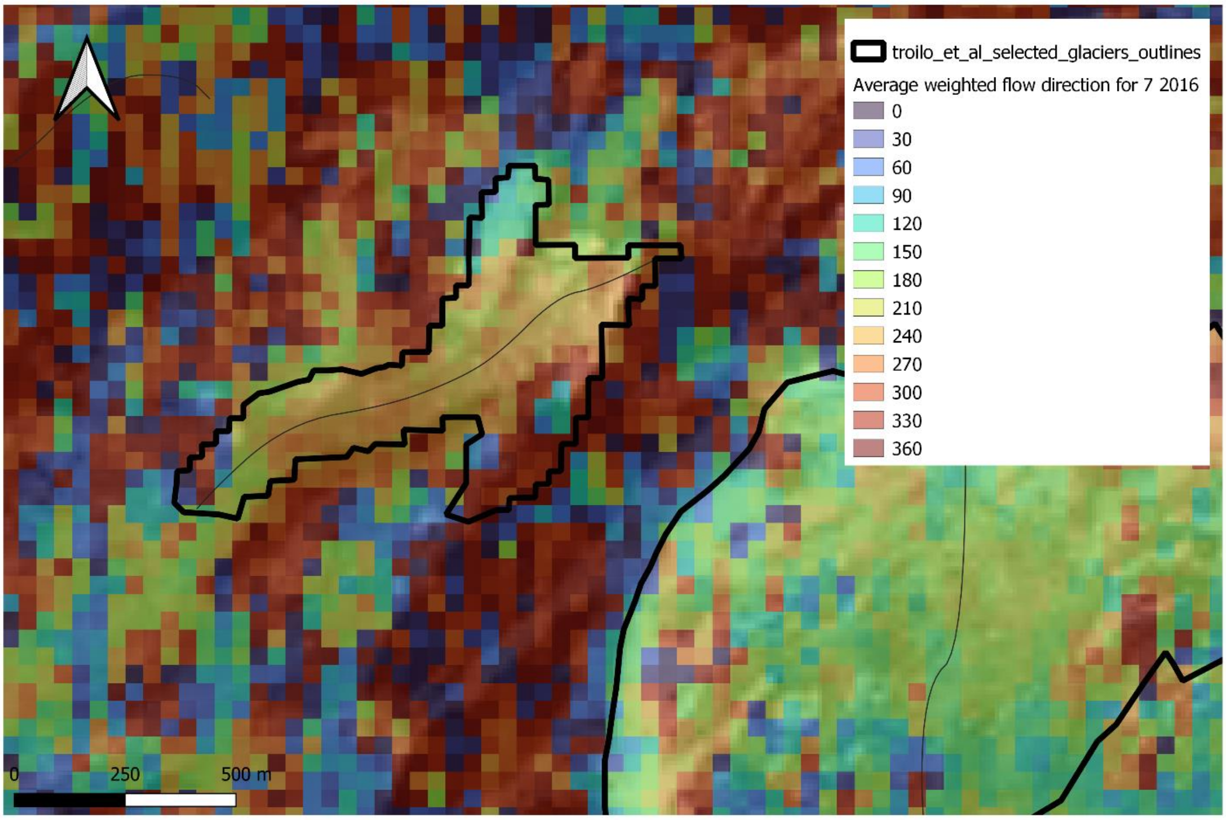
We removed the words "the two large glaciers". The precise values of velocity over the fastest region of the Mer de Glace can be extracted by the velocity maps that we uploaded on Zenodo. Overall, this area moves at >400 m/yr

L275 Again no mention of the situation at the largest glacier. Any particular reason why not?

According to the method we used to extract the time series, only a portion of the highest velocities of the Mer de Glace are included, thus the resulting velocity is low. Since we adopted an automatic extraction method, which is related to the glacier physics (i.e., ideally, the highest velocities occur at the ELA), the velocity that we extracted in the time series should be more representative of the whole glacier. We added this statement "In the time series, the biggest glacier (Mer de Glace) appears slower because we extracted the monthly velocity over an area which does not entirely include the most active sector of the Mer de Glace glacier, where the velocity reached values >400 m yr-1."

L 303 It would be interesting to see the same plot for flow direction/orientation, at least to ensure that none of the high velocities are erroneous.

We attached the maps of velocity orientation.


troilo_et_al_selected_glaciers_outlines
Average weighted flow direction for 7 2016
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330
360
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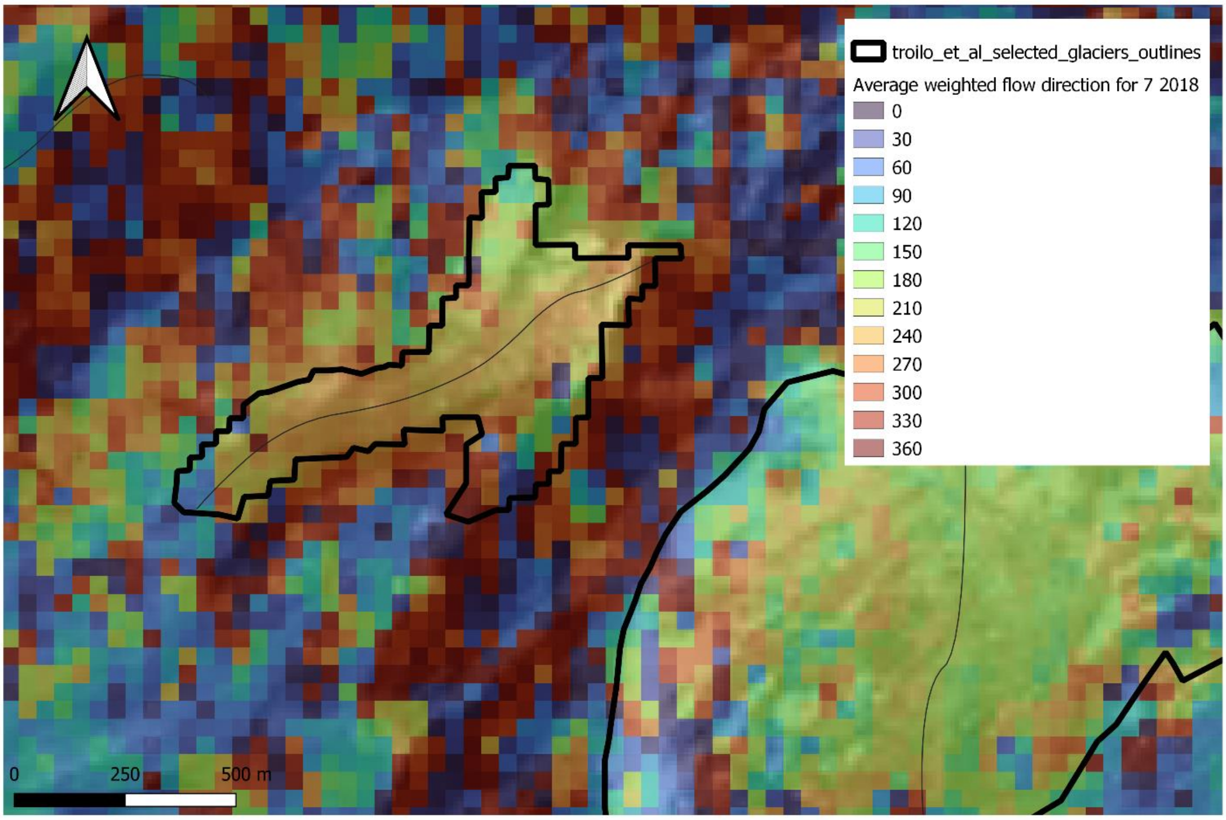
250
500 m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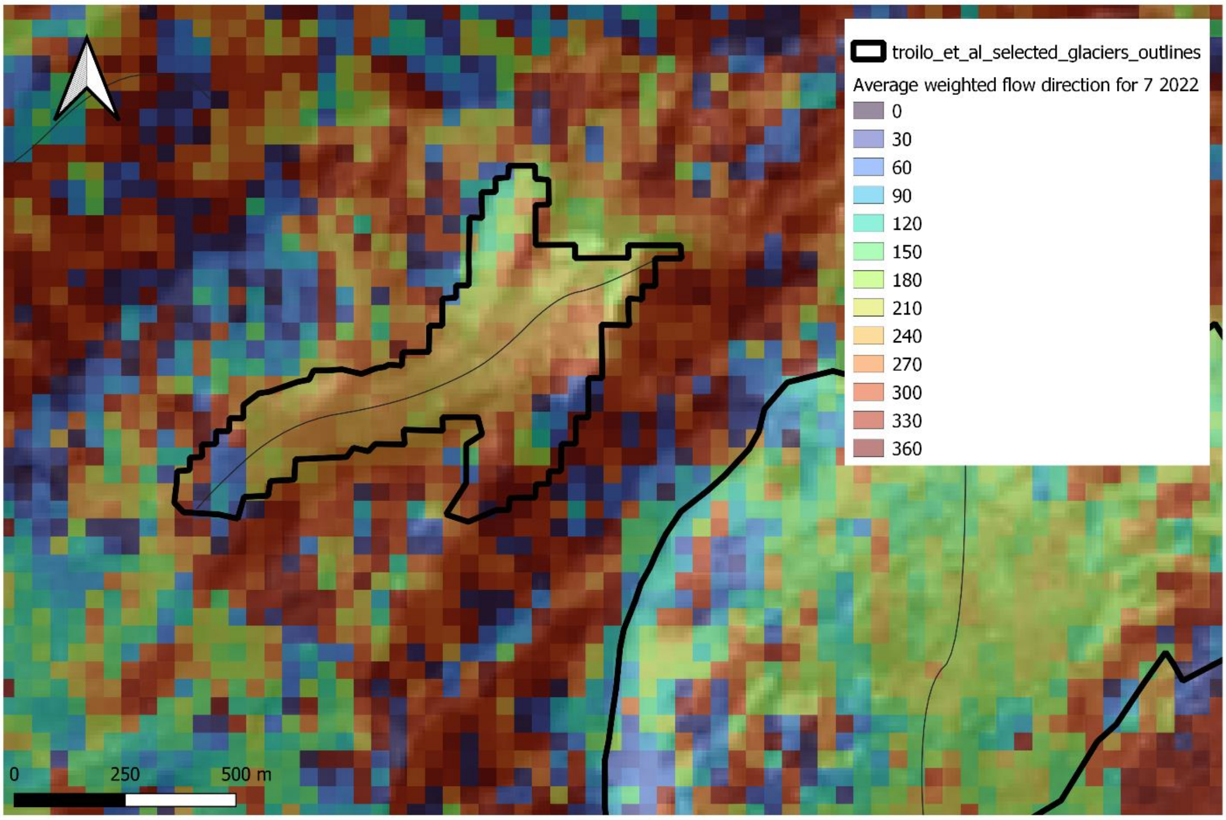

L308 I am not sure you have made a case here why PCA represents the overall glacier velocity well here for Fig 8. Why is this better than e.g. a smoothed velocity timeseries.

By definition, the first PC represents the variable that maximises the variance of the dataset. Since the input data are all of the same kind (monthly velocity), the first PC equivales to overall behavior of the dataset. We are unsure about the comment about the smoothed time series.

L339 2023 -> 2024

Done

L430 Table 2: The % difference might be a useful metric to include as well here.

Done

L455-456 'expert based check or further post-processing'? I am not sure if we want to conclude that manual intervention is unavoidable.

Thank you for the comment. We stress that this statement is related to the application of image correlation of satellite data to detect sharp accelerations that can be precursors of ice avalanches. Therefore, if an anomalous acceleration is observed, an expert check is required to evaluate the correctness of the measurement. This is the usual procedure of every monitoring system.

L458 Here and everywhere – change to 2016-2024.

Done

L464 ‘Significative’ – not the word you want. Change to ‘significant’ if you mean in the statistical sense, or ‘large’/etc if not.

Correct

L466 ‘a methodological point…’

Correct

L472 I am not sure this is ‘more complete and widespread’ exactly, perhaps ‘higher spatial and temporal resolution’ or something similar?

Correct

The velocity maps and other supplementary material are available on Zenodo, with assigned doi 10.5281/zenodo.11349445.