Author´s response to referee comment # 1

First of all, we would like to thank the reviewer for such a detailed and constructive review. It has shown us which aspects need to be explained in more detail and has certainly helped us to improve the manuscript.

In the following, we quote the reviewer´s comments followed by our replies, which are marked in orange.

General comments

The manuscript reports on the temporal evolution of surface velocity of the glacier Vernagtferner in the Eastern Alps with focus on a period of major slowdown in recent years after the glacier broke up in several parts. The presented velocity data are based on in situ stake measurements and manual feature tracking in optical airborne images. The presented material and related discussion cover two main topics: (i) the presentation and description of the derived velocity field and of factors responsible for slow-down, including a review of the glacier behaviour since 1966; (ii) an overview on specific remote sensing products on glacier velocity, leading to the conclusion that these products are not suitable for application to slowly moving glaciers. Topic (i) is an interesting case study on a glacier in retreat, demonstrating the impact of long-term negative mass balance and related glacier thinning on a previously quite active Alpine glacier. Factors responsible for the decline are discussed, but an in depth assessment of the governing processes is missing. The presented material on topic (ii) does not contain any novel aspects. In summary, the paper presents an interesting case study on slow-down of an Alpine glacier in decay but has substantial shortcomings. Major revisions and shortening (in particular regarding topic ii) are required.

Topic (i): We have included a classification of the relevant processes for slowing down glacier velocity. Please see in the last comment of this response.

Topic (ii): We agree with the reviewer, that this topic does not provide any new aspects. However, the use of global data sets and standard remote sensing would be the most obvious choice, as these data also provide velocity maps for the area. We aimed to demonstrate that neither the existing global datasets nor our remote-sensing attempts specifically focussed on VF provide/are able to generate a reliable velocity field. We do not want to rule out the possibilities of semi-automated feature tracking. Rather, we would like to explain why we chose manual feature tracking and point out the problems caused by ablation in more detail (see comments). Based on this finding, we generate an interpolated velocity map based on in-situ measurements. The focus of the manuscript is more on the historical data sets, whereby we believe that an examination of current ice dynamics is relevant in order to provide a velocity map ready for other studies, e.g. ice flow modelling. We will try to better clarify this in an updated manuscript.

Specific Comments

Satellite remote sensing: Major parts of the manuscript refer to spaceborne remote sensing of glacier velocities (Introduction line 45 to 53, Sections 3.2, 3.3.1, 4.3.1, Section 5.2, Fig.2, Fig. 9). These sections refer to properties and suitability of particular products, but do not provide any novel information on methods, accuracy assessment and constraints regarding remote sensing techniques and products for mapping glacier surface motion. During more than three decades results of detailed performance analyses on glacier surface velocity methods and products have been reported in publications and product specification documents, both for so-called “standard satellite remote sensing products” as well as for products derived from data of different satellite missions. These publications show that the pixel size and errors of the “standard products” (based on offset tracking) do not match the accuracy and spatial detail required for mapping very slow velocities at comparatively small spatial scale as observed on Vernagtferner. Taking this into account, the sections on satellite remote sensing can be largely shortened and replaced by references on documents and publications specifying performance numbers for specific satellite-based velocity products. Furthermore, Figures 2 and 9 can be omitted because there is no need showing examples of deficient velocity maps using input data that are not matching the technical requirements needed for velocity retrievals of the study glacier.

Thank you very much for your feedback. You are absolutely right, further information on the accuracy assessments is missing, especially for the velocity products. We have added some information on this. We also agree that, due to the pixel size and errors, the “standard products” cannot provide any meaningful values for a slow-flowing glacier such as the VF. However, we would like to point out that many “standard products” still provide values for the region, even though, as you have already mentioned, it is clear that these cannot be meaningful. Slow-flowing glaciers (which make up a large proportion of Alpine glaciers) should therefore be excluded from the complete “standard products.”
We have now explicitly included this note.
We do not want to rule out the possibility that, in principle, no velocity data can be derived for the VF via remote sensing. Therefore, in Section 3.1 with Fig. 9, we would like to include an analysis of the significantly higher-resolution TerraSAR-X data with a spatial resolution of 2 m, which makes detection quite realistic, assuming a detection capability of 0.1 of the pixel size. On VF the challenge is not only in the slow flow, but also in the high ablation and therefore the change of features due to ablation. To explain this in more detail we added an Appendix.

Text:
Chapter: Review of existing products
There are user-ready glacier surface velocity products from NASA's |ITS_LIVE| (Gardner.2022), FAU's glacierportal (Friedl.2021) or a dataset published by (Millan.2022) for almost all glacier regions worldwide. The databases provide image pair velocity fields for individual glaciers. The results are based on feature tracking algorithms applied to Sentinel-1 Synthetic Aperture Radar (SAR) acquisitions, as well as optical imagery from Sentinel-2 and Landsat missions.

The products are based on imagery with spatial resolutions of 10-30 m and provide results at 120-200 m spatial resolution. The accuracy of the products can vary strongly locally and depends on the velocity level, coherence, existing features, etc., but can be estimated at 0.08 m per day for a temporal baseline of 12 days, for example (Gardner.2022,Friedl.2021,Millan.2022). The accuracy is insufficient for a slow-moving glacier such as the VF, as the speed is lower than the uncertainty of the measurement. Nevertheless, the products still provide values for this area. We analyzed the mosaics, which show high spatial coverage and some kind of displacement signal on the glacier surface. However, a closer inspection of the displacement rates and in particular the directions showed that the displacements are very noisy and that the displacement directions are not aligned with glacier flow directions. Figure 2 shows exemplarily the ITS_LIVE and Millan data base annual mosaic for 2018, with maximum velocities at the glacier terminus of the Taschach area.

Appendix A:

The figures show the same situation at different points in time:

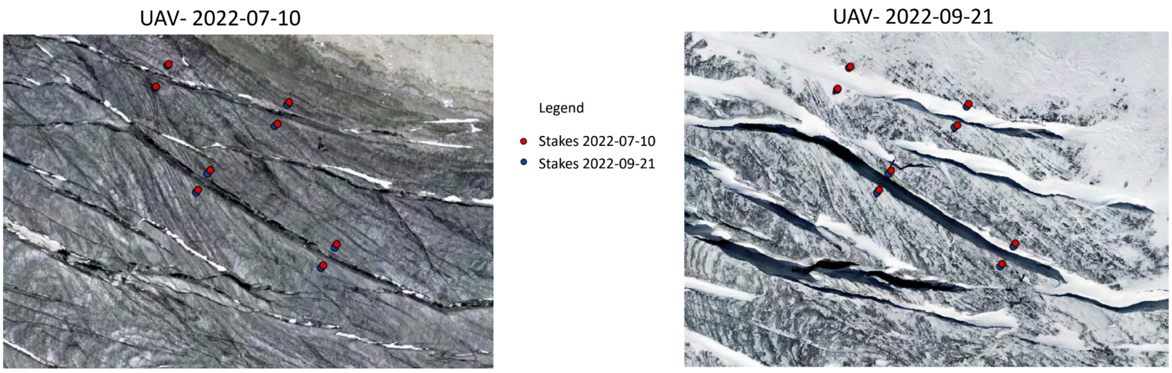

Fig. 2:. Melt-induced changes to crevasses. *The example is taken from the upper part of the Taschach area at an altitude of approx. 3150 m. Maximum velocities occur in this area at the VF.*

Figure 2 clearly shows a change in surface features, in particular a widening of the crevasses. We examined two of the crevasses in more detail using two stakes at the upper and lower edges of each crevasse. The average movement of the eight stakes (shown in Fig. 2) over the two months is approximately 0.73 m (change from the red to the blue points), with a standard deviation across the eight stakes of 0.12 m . The stakes rule out the possibility that a significant actual break-up of the crevasses has taken place. The stakes show an even shift of the upper and lower edges of the crevasses. Thus, the change in the surface is probably largely due to melting. Even if identical features (in this case, crevasse edges) could be identified during the period, the movement would be significantly overlaid by ablation due to the crevasse edges (and their varying melt rates), resulting in erroneous dynamics.

Even with larger temporal baselines, manual feature tracking can be used to exclude features that are likely to have changed due to ablation, as is often the case in 2022. Crevasse trace intersections are particularly well suited for this purpose, as can be seen in Fig. 3 Identifying identical features that have not been subject to high ablation is challenging even for the human eye, especially over longer baselines, such as the example in Figure 4 over a period of two years.

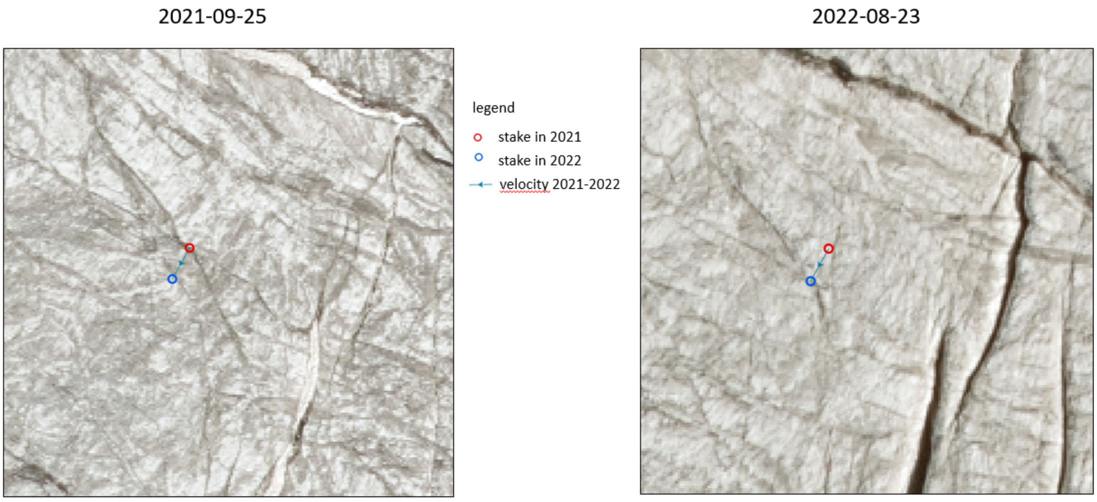

Fig. 3: Melt-induced changes to crevasses. *Example from the upper part of the Brochkogel area at an altitude of about 3200m.*

Fig. 4: Crevasse pattern in a period without significant melt. Crevasse pattern in a period without significant melt. *Example from the highest part of the Brochkogel area at an altitude of about 3250 m.*

Analysis and interpretation of surface velocities: The new velocity data, presented in the manuscript, refer to the period 2018 to 2023 when maximum velocities of Vernagtferner were below 5 m yr^{-1}. The presented velocities are horizontal displacements referring to individual points on a main branch of the glacier, based on manual feature tracking in optical airborne images and on stake measurements. Considering the average velocity of 1 m yr^{-1}, it is obvious that the magnitude of vertical surface lowering exceeds that of the horizontal displacements. Consequently, the vertical displacement of the surface (mass depletion due to surface/atmosphere exchange processes) is the dominating component for the glacier mass balance in the current state and ice dynamics plays a minor role. In this context, quantitative information on the annual mass balance (respectively the related topographic change) and its spatial pattern during the study period would be of interest.

We agree. We provided further analysis. Please see the last comment of this response.

Line 45 to 53: This is a one-sided introduction on space-borne remote sensing applications for ice velocity monitoring. The statement on the use of space-borne remote sensing "particularly in Antarctica" does not reflect the actual situation in which ice velocity products are generated routinely on behalf of various organizations, covering at large all global land ice areas. Several of these products exploit also radar repeat-pass interferometry in regions and seasons where coherence is preserved.

That´s true! The specialization in Antarctica should refer specifically to the cited literature. To avoid misunderstandings, we will rephrase this:

Space-borne remote sensing data can be utilized to estimate ice velocity of mountain glaciers and in particular of the large polar ice sheets (Dirscherl et al., 2020).

Line 56-57: Temporal decorrelation is not a particular problem for slowly flowing glaciers, but rather for fast movement, particularly in shear margins where interferometric fringes are often tightly spaced or aliased.

That is correct. It is the combination of high ablation (and the associated significant surface change) and low velocities that makes coherence formation difficult, as the very low velocity is barely measurable when coherence exists or the feature change is overlaid by ablation instead of actual ice dynamics. Therefore we changed the sentence to:

As previously mentioned, the combination of high ablation (and the associated significant surface changes) and low velocities leads to challenging remote sensing detection of velocities. When coherence exists, the very low velocity is hardly measurable and most likely overlaid by feature changes due to melting. This combination of high ablation and slow flow is becoming increasingly typical in the Alps due to thinning in response to global warming.

Line 86: Horizontal displacement and surface velocity are not the same.

Thanks for mentioning that. We change it to:
This allows the calculation of the annual surface velocity.

Line 113-118: Whereas time spans of TerraSAR-X repeat-pass data are 11 days, there are other high resolution SAR constellations offering shorter repeat-pass sequences, well suitable for glacier velocity mapping based on the motion-related interferometric phase. For example, successful glacier monitoring applications have been reported for 1-day, 3-day and 4-day interferometric repeat pass pairs of the COSMO Sky-Med constellation, providing high accuracy velocity products. Coherence tracking applies cross-correlation matching of templates and thus has a spatial resolution and sensitivity similar to feature tracking.

You are absolutely right; in this paragraph, we describe the TerraSAR-X data in a very one-sided manner. We have added information about possible further (including shorter baseline) satellite missions, which have already been used to generate very good velocity information for faster-flowing glaciers. Since the average velocity on the VF is only about 1 m/year, which corresponds to an average movement of about 0.27 cm per day without taking possible seasonal fluctuations into account, baselines of 1-4 days for interferometric displacement mapping, might lead to some results. However, there are no acquisitions available for VF. Moreover, the considerable surface melt in summer will limit this application to winter months, where snowfall also leads to the loss of coherence.

We change the manuscript to:
In addition to user-ready products (which do not provide usable results), there are high-resolution SAR constellations offering repeat-pass sequences beginning at 1-day. To name a few, ICEYE InSAR (Lukosz 2021), Capella Space SAR (Izzard 2025), COSMO Sky Med (Wang 2018), and TerraSAR-X (Schubert 2013) constellations have already been successfully used to generate velocity maps. As an example, we tested the suitability of TerraSAR-X stripmap imagery (2 m spatial resolution) for obtaining glacier surface velocity fields, on VF. Therefore, we applied feature tracking using various tracking window sizes and temporal baselines ranging between 11 days and up to about 2 years to pairwise co-registered images. Coherence tracking or InSAR-based displacement measurements were not feasible to carry out at VF, because the InSAR coherence was not maintained between subsequent acquisitions, which we attribute mainly to the pronounced surface-lowering rates in summer and snow accumulation in winter.

Figure 3: Please provide information on the time periods (years) to which the time sequences of the individual stakes refer.

Due to limited display and space constraints, it is difficult to provide precise information on the exact period of time in this figure. The periods of the longer (more relevant) time series can be read from Figures 4 and 5, as the same color coding has been used here. We have added a note to the caption of Figure 3 to indicate the color correlation with the following figures:
The colors correlate with Figures 4 and 5, which show the temporal resolution of most stakes.

Figure 5 caption: Please provide reference for the source of the ice thickness data 1970.

Thank you for the hint. We have added it, the new caption for Figure 5 is now:

Figure 5. a) Measured and modeled stake velocity according to a shallow-ice approximation for selected stakes. b) Position of the selected measuring stakes with the glacier extent from 1969 and the ice thickness from 1970 (calculated from the bed topography from 2006 (

Mayer et al 13b) and the glacier surface at known points in time (Finsterwalder 1972, Rentsch 1982), scaled using the mass balance), interpolated using the mass balance. Background image: Orthoimage 2016 © Bavarian Academy of Sciences and Humanities (BAdW), 2016.

Furthermore, this information was also added to the Figure 7 caption:
The respective ice thickness is calculated from the bed topography of 2007 (Mayer et al., 2013b) and the glacier surface at known times (Finsterwalder, 1972; Rentsch, 1982 and more recent maps published by the Commission for
Geodesy and Glaciology), temporally interpolated by the mass balance.

Section 4.2, Seasonal variation: The summer velocities are based on measurements in summer 2022, the ablation period of the mass balance year 2021/22 with the largest mass deficit of the 2018 to 2023 period in the Eastern Alps. Consequently, it is unclear if the number for the seasonal velocity increase 2022 is representative for the whole period.

Thank you for pointing this out. We have added the reference to the extremely negative year.

Text:
However, we consider the derived seasonality to be representative for the entire VF and assume its applicability to other years, although 2021/22 was a year with an extremely negative mass balance.
The calculated seasonal variation is used to standardize displacement observations recorded at different times, converting them into annual velocity values. A seasonal increase of 30\% relative to the annual velocity is assumed for the summer months (July through September). Thus, the seasonality measured in 2022/23 is also assumed for the years 2018--2023.

Figure 8: The presentation of a few numbers (velocities, exact dates) in the form of a table would be more appropriate than the display within a diagram.

Precise data (not averaged) is certainly interesting at this point, which is why we have included a table now. However, to enable quick and easy reading of the 30% seasonal variation, the table has been added in addition to the figure.
The coordinates of the individual measurements are stored in the PANGAEA Database. The table only shows the resulting velocities, separated into the Taschach and Brochkogel areas, whereby the Brochkogel area is only represented by 3 respectively 4 stakes within a few square meters, meaning that they all describe the same situation (one point could no longer be found in August 2023).

Table 2. Exact values of the seasonal variation of glacier surface velocity for Taschach (8 stakes) and Brochkogel area (4 stakes).

Area	Number	$v_{Jul-Aug}$ Juli 22–Aug 22 [m yr^{-1}]	$v_{Aug-Sep}$ Aug 22–Sep 22 [m yr^{-1}]	v_{annual} Aug 22–Aug23 [m yr^{-1}]	$\frac{v_{Jul-Aug}}{v_{annual}}$ seas. var.	$\frac{v_{Aug-Sep}}{v_{annual}}$ seas. var.
Brochkogel	1	3.37	5.05	3.14	1.07	1.61
Brochkogel	2	3.44	4.74	3.03	1.14	1.56
Brochkogel	3	4.52	4.16	3.22	1.40	1.29
Brochkogel	4	4.62	3.00	no measurement		
Brochkogel	**mean**	**3.99**	**4.24**	**3.13**	**1.20**	**1.49**
Taschach	1	4.54	2.21	2.38	1.91	0.93
Taschach	2	3.78	2.39	2.27	1.67	1.05
Taschach	3	3.57	3.85	3.09	1.16	1.25
Taschach	4	4.12	3.97	2.17	1.90	1.83
Taschach	5	1.27	1.52	1.74	0.73	0.87
Taschach	6	1.82	3.84	2.11	0.86	1.82
Taschach	7	2.24	3.49	2.17	1.03	1.61
Taschach	8	2.08	1.95	1.77	1.18	1.10
Taschach	**mean**	**2.93**	**2.90**	**2.21**	**1.30**	**1.31**

Furthermore we determine the standard deviation. Therefore, we add to the manuscript:

in current line 221:
On average, seasonal variation is 1.30 (130%), with a standard deviation across all observations of 0.37 (37%).
and in current line 311:
At Vernagtferner, summer velocities are approximately 30% higher than the annual mean, with a standard deviation across all observations of 37%. The relatively high uncertainty results most likely from the fact that the absolute measured values over a month (July-Aug or Aug-Sep) have maximum values of about 50 cm. However, these values have a relatively high measurement uncertainty of +/-14cm (see chapter Measurement Uncertainty).

Line 200: The statement that it is "not possible to (semi-) automatically produce a reliable surface velocity map from aerial or satellite imagery for slow-flowing Vernagtferner …." is rather speculative, not taking into account capabilities of advanced airborne and spaceborne observation systems and analysis techniques. For example, several large satellite constellations with very high resolution SAR sensors are in space since several years. Some of these constellations provide repeat interferometric observations of excellent quality with repeat-pass intervals from one day onwards, as for example ICEYE InSAR products show.

Thank you for the helpful comment. We agree that the original wording "not possible" was too absolute and did not sufficiently take into account recent developments in high-resolution satellite and aerial remote sensing. We have therefore amended the passage and now refer to it as "challenging" to emphasize the difficulties, but not the fundamental impossibility.

In fact, there are now several satellite constellations with very high spatial resolution and short repeat intervals (e.g., ICEYE-InSAR products with daily repeats) that provide excellent data quality. Such systems open up new possibilities for detecting glacier movements. However, the specific problem of the Vernagt glacier remains: at maximum speeds of < 5 m a^{-1}, even with a repeat interval of one to several days, the displacement is only in the range of a few centimeters to millimeters, which is often within the signal noise in the currently available data. When using longer time periods, on the other hand, the melting process simply dominates the movement too much. We have added examples of other high-resolution satellite constellations to the text (see comment above).

Text:
It is highly challenging to (semi-)automatically produce a reliable surface velocity map from aerial or satellite imagery for the slow-flowing Vernagtferner with maximum velocities of less than 5 m\,yr^{-1}. Therefore, we selected a sub-region …

Line 223ff: Taking into account that the annual melt losses, amounting up to several meters, may cause significant changes of surface features, the estimates of feature position accuracy seem to be rather optimistic. For example, in line 53 it is stated that "surface features (e.g. crevasses) change considerably during this period", a possible source for increased uncertainties in feature tracking. Furthermore, oblique views sideways of the central flowline may introduce errors, in particular if the surface elevation at the time of the survey is not exactly known. Please provide information on the procedures in which way these issues are taken into account.

Thank you for pointing this out. We have amended the description accordingly. In the new version, we now also take into account possible lateral oblique measurements, which we estimate to add approximately 5 cm of further uncertainty. We now state the positional uncertainty at ± 35 cm. As noted by the reviewer, this estimate is optimistic, but we ensure that only suitable features are included in the analysis through manual case-by-case decisions and the targeted selection of stable features (e.g., unchanged column intersections). We have added this note to the text.

The uncertainty of localizing these features depends on the image resolution (<= 20 cm pixel size), the feature size (>= 40 cm), possible sideways oblique views of the features (depending on the respective angle, in the order of around 5 cm) and the co-registration accuracy of the images. Considering these parameters, the feature position uncertainty can be estimated at 35 cm. Manual case-by-case verification and explicit searching for crevasse intersection points ensure that only features that do not change too much are selected, thus guaranteeing this very high quality.

Section 5.1, Ice dynamics: Basic mechanisms related to slow-down of glacier flow are addressed, as well as possible causes for seasonal variations. However, (1.) quantitative estimates on the impact and magnitude of the different processes at the study glacier and their (2) interactions during the observation period are missing. For contributing to the advancement of understanding of processes governing the slow-down of retreating glaciers, quantitative estimates would be essential. (3) Furthermore, hints on the significance of the study results in respect to the general glacier behaviour in this region would be of interest.

(1) Thank you for pointing this out. We have added a further analysis for the quantitative estimation of ice dynamics to the mass balance. This means that it is now possible to quantitatively estimate which process is the main driver at the Vernagtferner (ice dynamics or SMB). An assessment of the extent of the various processes is carried out.

Appendix A: Ice dynamic

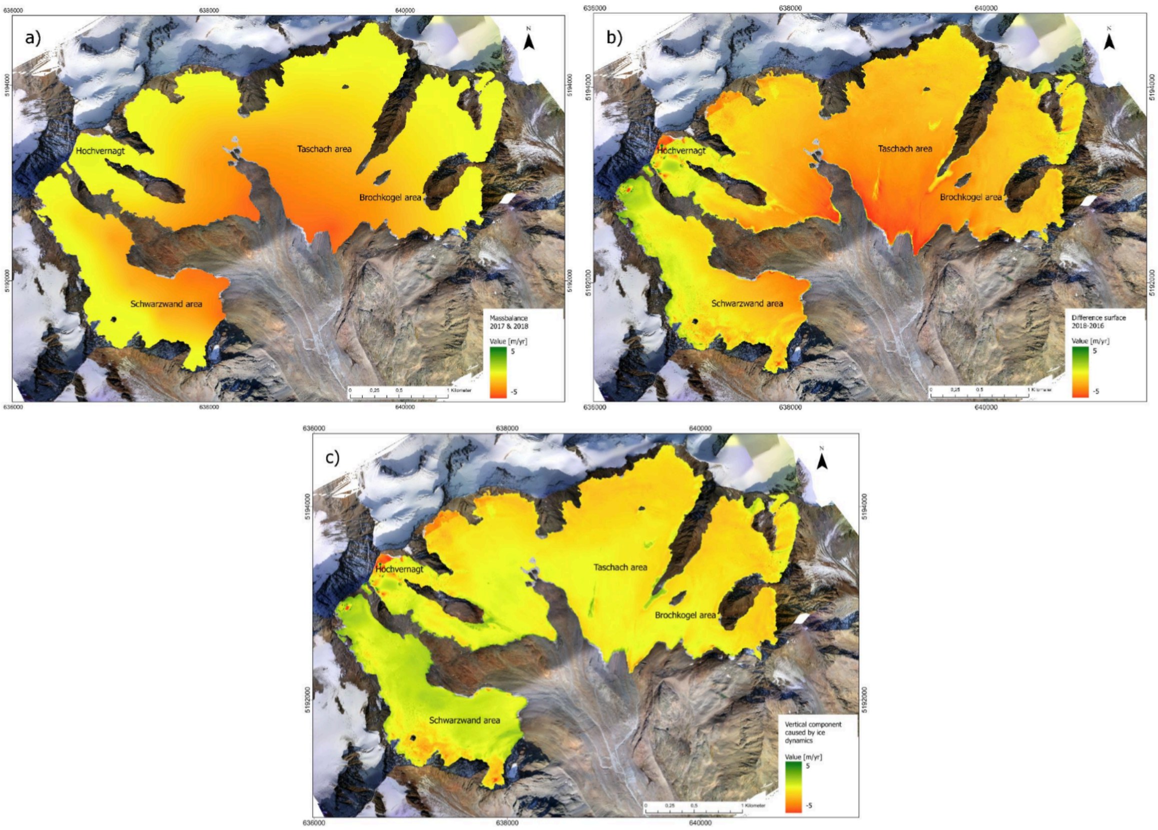

Figure A1. a) areal surface massbalance summed for the years 2017 and 2018, b) surface Difference 218-2016, c) Difference between a ar b, which is the vertical ice transport caused by ice dynamic. Background image: Orthoimage 2016 © Bavarian Academy of Sciences ar Humanities (BAdW), 2016.

We add to the manuscript results:
To quantitatively estimate the magnitude of ice dynamics in relation to other processes, further analysis was carried out. This examines which parameter predominantly drives the VF, the SMB (surface mass balance) or the ice dynamics. The assumption is made that the surface difference between some years mainly reflects changes in the mass balance and the vertical ice transport resulting from ice dynamics. Provided that the surface difference and the areal mass balance are known, it is possible to estimate the influence of vertical ice transport in relation to the SMB. Both a surface difference and an areal SMB are only available for the period 2016-2018, which is a very short period from a glaciological point of

view. A more current surface model is not available and areal SMB has not been generated in earlier years. However, it can be assumed that this period basically reflects the current ice dynamics, as the glacier already has very low velocities during this period, similar to those observed in 2018--2023. The SMB, summed for the years 2017 and 2018, is shown in Fig. A1 a and is derived from observations for the direct, glaciological method of mass balance determination. The surface difference between the years 2018 and 2016 can be seen in Fig. A1 b. The difference between the two parameters gives the vertical ice transport caused by ice dynamics (Fig. A1c). The ice dynamics can be identified as follows: In the accumulation area (or former accumulation areas), negative values (red areas) indicate that ice masses are being transported downward from this location. The more negative the values, the greater the ice dynamics. In the ablation areas, on the other hand, positive values (green areas) indicate ice dynamics. Ice masses are transported to this area, so large positive values indicate high dynamics. Values around zero represent very low ice dynamics. An analysis of Figure A1 c shows that the Taschach and Brochkogel areas exhibit hardly any dynamics (values very close to 0). In contrast, dynamics are still present in the former accumulation areas of these two sub-areas. The two green areas in the Taschach area provide good control. These are rock islands that were not excluded from the areal mass balance. However, the rock islands have remained stable during the period and have not moved, which is why they appear in the vertical component of the ice dynamics.

A closer look at the Schwarzwand area reveals more ice dynamics. In the northern accumulation area of the Schwarzwand area (as well as on the Hochvernagt plateau), there are clearly positive values that cannot be explained by ice dynamics. However, in the surface models, these areas are partially covered by snow and have hardly any features. It can therefore be assumed that the surface models in this area are highly uncertain and that these values are attributable to this. Overall, the higher dynamics of the Schwarzwand area may also be partly attributable to a possible slight tilt of a surface model in this direction. Furthermore, error values can be seen in the strongly negative northern areas of the Hochvernagt. These originate from the surface models, where an error has likely occurred in the neighboring aerial image sheet.

In order to enable a numerical estimation of the processes, which excludes outliers as far as possible, the median of the absolute mass balance (1.08 m/yr) and the absolute vertical ice dynamics (0.67 m/yr) were calculated.
Overall, further uncertainties must be taken into account, such as the compression and thus the change in altitude of possible firn areas due to a change in density.

We add to the manuscript discussion:
A quantitative estimation of the magnitude of the ice dynamics in relation to other processes for the period 2016-2018 has shown that the VF is currently mainly driven by SMB, with ice dynamics playing a minor role. Looking at the entire VF, the median absolute values for SMB (median = 1.08 m/yr) and vertical ice transport (median = 0.67 m/yr) suggest that the SMB process predominates.
Overall, there is hardly any ice dynamics left at the tongues, but there are significant changes caused by SMB. In the accumulation areas, on the other hand, there is still some ice dynamics, with a smaller SMB component. There are indications that there may be slightly more ice dynamics in the Schwarzwand area and that this area behaves

fundamentally differently from the rest of VF. This was already suggested by Reinwarth (1999) and can be confirmed here.
Due to a lack of data, it is not possible to estimate earlier dates. However, it can be assumed that in the early years, ice dynamics was the main driver of VF. The measured velocities were significantly higher, particularly around 1980, with an absolute SMB being significantly smaller than it is today.

(2) Thanks for the hint, we add an analysis of the temporal relationship between mass balance and velocity and compare it to other studies.

Stocker-Waldhuber et al 2019 have found evidence that ablation stakes can be well suited to reflecting the current status of a glacier. They show that the Kesselwandferner (also in the Ötztal valley) shows relatively direct response of ablation-area ice dynamics to changes in mass balance, regardless of the geometry of the glacier.

We have found evidence that the ablation stakes at VF also react quickly to a change in the mass balance. Only with a slight decay, the strongly negative mass balance in 1983 appears to lead to a decrease in velocity in the ablation area. This could be attributed to the fact that ice thicknesses at the tongue (in the ablation area) are usually already very low. Even small changes in ice thickness can have a noticeable effect on velocity here, as the driving stress is highly sensitive to ice thickness. In a year with a strongly negative mass balance, the strong melt in the ablation area directly decreases the ice thickness, which represents the current status of the glacier. On VF, there is insufficient data to substantiate this adequately. Further studies (including in other areas) are necessary to investigate this effect in more detail.

(3) Unfortunately, apart from Vernagtferner, Hintereisferner and Kesselwandferner (we added information on that, see above) there are no other long-term measurements available for this region. Since they are two significant glaciers in the region with similar changes in ice dynamics, it can be assumed that the other glaciers in the region behave similarly, but we do not have any data on this. Instead, a comparison was made to a wider regional trend.

text:
Neighboring glaciers, such as Hintereisferner show a similar velocity peak around 1980, followed by a decrease (Stocker-Waldhuber et al., 2019). The velocity peak aligns with a wider regional trend, as a significant proportion of glaciers in the European Alps experienced advances during this temporarily relatively cool phase (Patzelt, 1985; Wood, 1988).