The review is cited underlined; answers of authors are formatted indented:

We thank Mauri Pelto and Andreas Bauder for their important comments and suggestions, which will help us to improve this manuscript. We fully agree with the comments and we are sure that we can consider them point by point. Regarding the 1919 velocity on HEF: The velocity increased to the maximum within a few years and decreased very quickly until 1922 (m/a 1915-1922: 28, 38, 50, 80, 125max (1919), 70, 43, 24) resulting in an advance of the glacier tongue by about 60 m (Span et al. 1997). We will add this information in more detail.

We consider the direct velocity measurements plausible, because they were performed, despite of WWI, by the same team of observers twice a year. Although measurements in the firn area could not be done during war, the measurements in the ablation area have been continued. The measurements include deep drilling holes as well as stone lines (see Tab. 6 from Hess, 1924) The observers (Hess, 1924) did use the same network of fixed points as before and after the acceleration. They critically reflected the velocity increase and found additional points showing that the velocity increase is plausible:

In 1914, Kesselwandfener lost connection to Hintereisferner, but advanced again afterwards. The terminus position was mapped in 1917, 1918, 1919 and 1920. The velocity increase, which was also found remarkably by Hess, triggered a cartographic survey of the glacier surface with 6 stereo pairs, using the fixed point network. Hess (1924) found indications for increasing glacier mass potentially triggering the velocity increases in 1919. The lowering of the surface elevation at the terminus coincides with the decreasing velocities.

With respect to the state of science at the time of measurements, the time series can be considered amongst the most reliable and best documented world wide. We will add additional data and information from Hess (1924) to the text.

Tab. 6 Geschwindigkeiten in Meter/Jahr.

	m Höhe	1913/14	1914/15	1915/16	1916/17	1917/18	1918/19	1919/20	1920/21	1921/22
40-m-Loch	2408	11,5	23,0	18,3	25,7	45,8	—	—	—	—
Untere ziegelrote Linie, Punkt 7	2438	20,0	29,0	25,7	29,9	51,3	—	—	—	—
Grüne Linie, Punkt 8	2527	28,9	44,2	41,4	55,5	77,8	109,1	68,8	49,4	13,5
Untere rote Linie, Punkt 9	2564	33,9	90,2		64,1	84,3	126,6	72,7	44,1	21,8
153-m-Loch	2557	30,8	85,6		63,4	83,8	124,8	60,1	36,5	23,2
214-m-Loch	2570	29,4	90,4		65,1	82,2	121,5	64,0	44,0	22,3
Mittlere blaue Linie, Punkt 8	2600	33,1	103,8		63,4	—	—	—	48,2	—
Obere ziegelrote Linie, Punkt 10	2635	35,0	← 189,5 →			← 296,2 →			—	—
Blaugrüne Linie, Punkt 9	2689	37,8	109,0		80,8	94,7	123,0	91,1	46,5	14,2
Bohrloch von 1910	2685	—	—	—	75,1	97,5	112,0	70,2	46,1	13,8
Obere blaue Linie, Punkt 9	2720	← 240,3 →				← 302,2 →			—	—
Stange β	2747	37,1	← 187,8 →			81,5	118,6	77,9	—	—
Dreikant II	2811	44,6	← 379,3 →						57,5	—

Hess, H.: Der Hintereisferner 1893 bis 1922. Ein Beitrag zur Lösung des Problems der Gletscherbewegung. Zeitschrift für Gletscherkunde, 13, 145-2013, 1924.

Span, N., Kuhn, M., and Schneider, H.: 100 years of ice dynamics of Hintereisferner, Central Alps, Austria, 1884-1994. Annals of Glaciology, 24, 297-302. doi:10.1017/S0260305500012349, 1997.

Referee #1: Mauri Pelto

Stocker-Waldhuber et al (2019) provide the context for a rare long term glacier velocity record in the Ötztal Alps. Because mass balance records exist on some of the glaciers for significant periods it is evident that velocity change is useful for identifying responses to climate caused mass balance change. This type of record is an impor-tant data set to report. The specific comments below are focused primarily on clarity. I encourage more scrutiny of the stone line velocity error assessment on HEF. Also the 1919 velocity on HEF is that plausible?

2-6: "...and estimates of the state of regional glacier inventories are needed, glacier flow velocities which can be derived from remote sensing data are an important parameter that provides essential information on dynamic response, which is part of the mass balance evolution of a glacier."

2-21: Replace "but" with "that"

2-31: provide a descriptive sentence on KWF similar to that for GPF, the main glacier rests on a wide but hilly plateau and the tongue descends through a narrow valley.

3-10: provide a descriptive sentence on TSF similar to that for GPF.

2.6 – 3.10: We will change to the suggested text and add the descriptive information.

3-30: What is the size range of the stones?

The stones are flat with a diameter ranging from 15 cm to a maximum of 30 cm. We will add this information.

4-11:...calculated to the lower end of the stake, its base point."

Ok

4-24: define better what is "lower cm-level" 5-10 cm?

Yes, 5 to 10 cm. We will add this information

5-17: The error assessment on HEF should be better stated. That 5% is used is okay, what is this in terms of cm per year for the most rapid areas of motion? I do wonder if the 5% is realistic for stone slippage, or too large at areas of rapid motion, slippage should not be that different based on velocity alone for example stone slippage in 1980 at 5 m per year is much different than for the 1920's maximum of 120 m, yet the stone slippage mechanism should have changed little.

We will write this in more detail and give some absolute values. The slipping motion mainly depends on the ablation rate and the surface slope.

5-24: Is this maximum velocity for a point or a line?

5-25: The increase in velocity implies a major mass balance change, based on other observed and reported changes in this record, and would suggest more than a minor advance would occur. Here or in the discussion could you identify why the terminus change or mass balance changes was not as significant as the velocity change would imply. What was the velocity in 1918 and 1920? If the change to 1919 is really large is that acceleration plausible or the ensuing deceleration?

> 5.24 – 5.25: For point measurements and the mean value for line 3 (Fig. 3). (cf. comments above and table 6 by Hess (1924)). We will add additional values and information and discuss this in more detail.

6-8: The two following sentences conflate actual velocity and temporal velocity change. Be consistent in reporting the difference in the second sentence. "The surface velocity of the glacier increased, but with decreasing magnitudes from the terminus (L10) to the uppermost stake (L1) within the accumulation area. This means an increased velocity gradient along the glacier, with maximum of about 90 m per year at the terminus declining to a few metres per year at the highest elevations."

> We will write this as suggested

6-14: Worth commenting on the velocity response in Figure 4 where terminus velocity response was large simply to declining positive mass balance after 1978, and a significant change in velocity near the ELA at L6 did not occur until negative mass balances occurred around 1985.

> We will add comments on the different responses.

6-16: Reference for the higher ELA, should provide a quantity for this shift as well.

> We will give values on the rising ELA on KWF (Fischer et al. 2014)

> Fischer, A., Markl, G., Schneider, H., Abermann, J., and Kuhn, M.: Glacier mass balances and elevation zones of Kesselwandferner, Ötztal Alps, Austria, 1952/1953 to 2012/2013. PANGAEA, doi:10.1594/PANGAEA.818757, 2014.

6-21: There is an insignificant velocity decline through time on TSF (54-56) which is contrast to the other glaciers, why?

> This is related to the specific topographic changes of TSF. We will discuss this in more detail at 7-30.

6-26: "...with a larger decline in velocity at the upper profile (71-75) than at the terminus."

> "…with a larger decline in velocity at the terminus than at the upper profile (71-75)."

7-22: To identify state is it not the deviations in velocity that identify changes in state, simply the actual velocity measurements at a moment in time would not be useful in determining the state of an unknown glacier "This means that changes in observed velocity, especially at ablation stakes......."

Yes that's true, we will change to "… changes in observed velocity…"

7-32: The conclusion of peak in velocity in the summer deserves closer definition and referencing. Most alpine glaciers have a velocity peak sometime early-mid summer as the drainage network matures, and a decline late in summer. The extent to which any of these four differ from this is important to note. Given the annual data for HEF and KWF is may only be GPF and TSF where such comment can be made.

We will give details on the summer peak at GPF and TSF and we will add the following references: Iken, 1978 or Gudmundsson, 2002 (c.f. comment below by A. Bauder)

8-5: The rapid response in terms of velocity is documented in studies that look at terminus response time of glaciers which lag both velocity and mass balance. There is useful response time data for the Alps that can be cited here ie. Huss (2012). This would enhance the value of the statement and the methods applied here.

Thank you, we will add this citation.

8-5: The following statement is incomplete and not accurate, please modify. In fact ELA is sometime above the summits, surface mass balance observations still provide an accurate measure. The date that the transient snow line goes above the glacier is also a measure that provides value. "As conventional parameters like ELA tend to be above summit for the investigated glaciers under current conditions and specific mass balance is affected by rapid changes in area."

We will delete the rest of the sentence ("…monitoring of ice flow can be recommended as additional surveyed parameter at mountain glaciers").

Figure 4-6: Each of these figures have numerous time series that simply are hard to distinguish with gray scale lines. A color scheme is recommended which can be based on zone of the glacier as well.

We will change to colour schemes.

Huss, M.: Extrapolating glacier mass balance to the mountain-range scale: the European Alps 1900–2100, The Cryosphere, 6, 713– 727, doi:10.5194/tc-6-713-2012,2012

Referee #2: Andreas Bauder

The paper presents a data-set of surface flow velocities measurements on 4 glaciers in Austria ranging from more than 100 years of observations on Hintereisferner to a decade on Gepatsch- and Taschachferner. Velocity fluctuations are interpreted in terms of glacier wide mass balance and length fluctuations.

General comments:

Indeed, ice flow is an important property of glacier and this parameter has got surprisingly low attention in monitoring programs. Ice flow velocity depends on ice thickness and surface slope. So ice thickness change is most suitable for interpretation of velocity variations. I do understand that surface elevation was measured as long with the position of the flow markers, and thickness change can be determined (as an example see Fig 5.3 of the latest Glaciological Report http://doi.org/10.18752/glrep_137-138). Sure the surface topography is a result of mass balance but with some dynamical response and local ice thickness is more appropriate than glacier wide balance quantities. Moreover, I would recommend - if shown - to plot the cumulative mass change rather than annual values.

We will add the cumulative mass change to the figures.

The method sections suffers from two shortcomings. (1) A systematic bias results when calculating a mean of a variable number of measurements. I see two potential alternatives - central or maximum value as well as average of a constant, fixed subset of measurements. (2) Although the difference of emergence/submergence and the vertical component of the velocity vector are introduced in detail, throughout the paper (e.g. Fig.5) a misleading terminology of vertical velocity for the emergence/submergence motion. Vertical velocity is only valid with regard to a fixed coordinate system. Emergence/submergence is the motion relative to the surface resulting as a an apparent vertical displacement.

ad 1: We will discuss this problem in more detail and give the current number of stones in the profiles.

ad 2: We will check the paper for the misleading terminology and rephrase these parts.

The effect of melting in and tipping over of flow markers is not addressed. Important with regard for the accuracy/uncertainty is the fact that vertical movement is one order of magnitude lower than the horizontal component and moreover of the same order as the counteracting processes of mass balance and thickness change. So any uncertainty of any of these may affect all. Your interpretation and discussion makes extensive use of length variation. It would be more convincing for the reader if you would plot this information - at least for some glaciers (e.g. HEF) General quality of the Figures is relatively poor and therefore hard to read. Probably this is just a minor problem of Figures generated in vectorized format that have been transformed with a poorly resolved raster format when inserted to the manuscript? Labels are all fuzzy, rather small and gradients between different lines difficult to separate.

We will give some comments on the effect of melting in and tipping over and discuss this in more detail. We will also add information on the length variations of the four glaciers.

The quality of the figures will be improved.

Checking of the online data-set prepared for download on pangea.de was not possible, because access was denied. I made several unsuccessful attempts.

That is true, we are working on this problem, the datasets will be open access.

Detailed/minor points (indicated by page.line):

1.12: Ice age theory was earlier established by Agassiz (Alps) or Lyell (UK) already back in the first half of 19th century. Penck & Brueckner may have confirmed the theory later on.

1.18: I miss proper references of first systematic ice flow measurements in the Alps in the 1840s on Unteraargletscher and Mer de Glace (Agassiz, 1847; Forbes, 1846).

1.12 – 1.18: Thank you, we will add these references.

1.21: I recommend to use the official spelling of 'Rhonegletscher' to be consistent with all the other mentioned glaciers

We will write Rhonegletscher

1.21: Berthiere -> Berthier

Berthier is correct

2.10: I do not agree this paper presents 2 long-term series and 2 series of only about a decade.

Yes, we will change to "two long-term series and two series of about a decade"

2.11: Acronym ALS was not yet introduced

3.14: Acronym DGPS not introduced

2.11 – 3.14: We will add the missing information

5.2: rod level -> level rod

Yes, level rod

7.3: Unclear what is the 'expected inverse process'? Surface elevation change may result from both processes melting or a dynamic adjustment.

We will delete the sentence "A comparison with the geodetic elevation change…" and write in the next sentence: "During winter months the elevation change of the surface form geodetic measurements is close to zero…"

7.11-12: This statement is not correct - velocity variation is a direct response to thickness change as a result of the climatic forcing where as the terminus fluctuations is delayed and damped by the dynamic adjustment. Both are sensitive!

Thank you, that's true, both are sensitive. We will delete this sentence.

7.31-32: The reason for summer speed-up has been well investigated e.g. Iken, 1978 or Gudmundsson, 2002

Thank you, we will add the two references.

Fig.1: Replacing the GI 1, GI 2 and GI 3 labels with the respective years would be more reader friendly.

We will add the respective years to the labels.

15.5: pint mass balance is the right terminology for delta_a and more appropriate.

We will write "point mass balance"

Fig.3: are you sure that the individual, extremely high value of 1919 is correct? Are there any arguments against an outlier?

We give more information on this velocity peak (cf. comments above and Hess 1924).

Fig.7: awkward ticks / tick interval -> using quarters would be easy to read

We will change the tick interval

References:

Agassiz (1847), Système glaciaire ou recherches sur les glaciers, leur mécanisme, leur ancienne extension et le rôle qu'ils ont joué dans l'histoire de la terre. Première partie: Nouvelles études et expériences sur les glaciers actuels, leur structure, leur progression et leur action physique sur le sol, V. Masson, Paris.

Forbes (1846), Illustrations of the viscous theory of glacier motion, Philosophical Transactions of the Royal Society, 136(1), 143-210.

Gudmundsson, G. (2002), Observations of a reversal in vertical and horizontal strain-rate regime during a motion event on Unteraargletscher, Bernese Alps, Switzerland. Journal of Glaciology, 48(163), 566-574. doi:10.3189/172756502781831043

Iken (1978), Variations of surface velocities of some Alpine glaciers measured at intervals of a few hours. Comparison with Arctic Glaciers, Zeitschrift Gletscherkunde,13(1/2): 23-35.