

## ***Interactive comment on “Ice flow velocity as a sensitive indicator of glacier state” by Martin Stocker-Waldhuber et al.***

### **Anonymous Referee #1**

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Summary: Stocker-Waldhuber et al. presents a vast number of in situ velocity measurements on four Austrian glaciers spanning over one century. They examine the velocity variations in view of changes in mass balances and explore the possibility to use velocity data as an alternative climate indicators.

In principle, such a study would be very welcome. There is a growing number of publications dealing with velocity measurements from satellite data but the interpretation of the velocity variations, often over a period of  $\sim 20$  years, is far from straightforward. Accurate field measurements of annual velocity at the same location and during a long period as provided in this study could help to understand the drivers/processes of velocity changes (change in sliding vs. internal deformation) and in turn, facilitate the interpretation of regional velocity variations observed from space. This is what I was

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expecting when I read the attractive title “Ice flow velocity as a sensitive indicator of glacier state”.

However and although the data are important to present and publish, the paper fails to address (or even explore) this question of the link between velocity change / mass balance / and climate forcing. Many relevant references are missing and the discussion of the results is nearly absent. I am afraid this is currently hardly more than a data paper and I am sorry that I cannot recommend publication in TC.

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### General comments

1/ Seasonal velocity variations are out of the scope of the paper. Poorly presented and not discussed despite an abundant recent literature on the topic.

2/ As said above, the main weakness is the lack of discussion of the results. There is no comparison to other glaciers for which velocity variations have been reported and analyzed. The authors will find at the end of my review a list of publications that, I think, are relevant to their study and hopefully could inspire them to go deeper into their data analysis and discussion. We also miss a clear comparison to mass balance measurements (and a discussion of how/why they are related). Currently this is only shown in Figure 3 and 4.

3/ The title is misleading and results in too much expectation. The reader expects at some point an answer, even partial, to the question "Can large-scale ice flow velocity monitoring be a potential alternative to mass balance measurement for regional glacier monitoring on an annual basis"? This discussion/answer never comes.

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### Specific comments

Abstract. lack of results. Too general.

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Introduction. I really enjoyed the historical perspective on glacier monitoring.

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2.1 I do not really see the point of discussing velocity measurements for the large ice sheets. It is out of the scope of your paper. It seems much more relevant to discuss recent progress (and limitation) of measuring velocity on glaciers. Two references come to my mind (Heid and Kääb, 2012; Dehecq and others, 2015).

2.10 The Jacob et al. paper is from 2012, not 2013. Note that there results, obtained solely from GRACE data are somewhat controversial, especially for regions with a low concentration of glaciers and a high influence of hydrology. (Gardner and others, 2013) is a more accepted global compilation. [see for example the unreliable result for the European Alps]

2.12. I do not understand why the authors take the example of the ELA to illustrate the need to document glacier velocity change. No link. [I do not challenge the value of ELA observations, just that the link with your study is unclear right now]

2.16. Is "parameters" really the right term? "measurements" maybe?

2.17 I find it strange to look for an "alternative". Velocity measurements are valuable by themselves and are eagerly need for improved dynamical modelling of glaciers. No need to replace other variables! They rather complement themselves in understanding the glacier response to climate change.

2.23 why "empirical"? Are not they just "measurements"?

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3.26. Is not "glaciological" (rather than "direct") the terminology recommended in the UNESCO glossary by Cogley et al.?

3.29 rather "Difference of DEMs" I think —

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4.6 Unclear to me. How do one find in the field the initial (last year) position to make the tape measurements ?

4.9 does it mean that lateral variations (due to lateral drag) are not taken into account? Or are all the stones close to the centerline so that these lateral variations can be neglected?

4.12. this is not a relation but a percentage (or ratio). How variable is this value from year to year? (will depend on the amount of sliding probably). What additional uncertainties arise from this assumption?

4.17 what does "calculated to its base point" means?

4.31 why does "distance" matter for uncertainties in a tape measurement?

4.31 can the authors give us some good reasons to trust their 5% error estimate? Right now we can only believe them.

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5.5 "for the period" is vague.

5.19. Can the acceleration in the 1920s (and the 40s) be related to a period of positive mass balance? Is a positive mass balance measured in model such as those of (Marzeion and others, 2012) and (Huss, 2012)? Typically the sort of analysis/discussion that one expect based on these results.

5.22 why is it more obvious in the geodetic results? Do you mean geodetic mass balance? Why not obvious in the glaciological mass balance?

5.24 surface mass balance? Glacier-wide mass balance? Make sure the vocabulary is clear and follow Cogley et al. (2011) glossary. Authors could also provide here and elsewhere % of velocity change to clarify the magnitude of the signal.

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6.10 I am not sure the authors defined their convention for vertical motion. Worth reminding in the text anyway. (positive upward I assume)

6.12. Can the authors details/quantify what was this "response". They are generally too vague in the description of their results.

6.16 Can we interpret the lack of velocity change for TSF in term of response time? Has this glacier already reached an equilibrium so that no further velocity change occurs? Would such an interpretation make sense according to your knowledge of this glacier?

6.23. I did not understand the causal link between the depression and a limited increase in velocity

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7.8 Can the authors discuss why the response time of the velocity are so different between KWF and HEF?

7.20 Should be named glacier-wide mass balance (even glacier-wide mass balance rate in principle, but I agree that "rate" could be skipped for the sake of simplicity)

7.27 Is this statement that TSF is closer to equilibrium than GPF confirmed in geodetic mass balance using Lidar surveys?

7.28 Do the authors mean seasonal here?

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8.3. do the authors mean glacier-wide mass balance? I would say that surface mass balance at selected sites are not influenced by the changes in area (but influenced by changes in elevation through the mass balance-elevation feedback).

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Figure 4. check title of the Y-axis. The Y-title use specific, the legend "direct". Make sure terminology is used correctly and follow the UNESCO glossary.

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Figure 5 (and4) Do authors need to show all stakes? Why not selecting the ones which are the most informative and used in the text (or show all stakes and highlight some in bold?). Also the velocity seems to be stable for most stakes since 2000. A fact not really discussed in the article.

Good luck for your future work on this important but under-exploited dataset,

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References about velocity changes on glaciers at annual and decadal timescale (certainly not exhaustive but a good start)

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Mernild, S. H., Knudsen, N. T., Hoffman, M. J., Yde, J. C., Hanna, E., Lipscomb, W. H., Malmros, J. K. and Fausto, R. S.: Volume and velocity changes at Mittivakkat Gletscher, southeast Greenland, *Journal of Glaciology*, 59(216), 660–670, doi:10.3189/2013JoG13J01, 2013.

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Gardner AS, Moholdt G, Cogley JG, Wouters B, Arendt AA, Wahr J, Berthier E, Hock R, Pfeffer WT, Kaser G, Ligtenberg SRM, Bolch T, Sharp MJ, Hagen JO, van den Broeke MR and Paul F (2013) A Reconciled Estimate of Glacier Contributions to Sea Level Rise: 2003 to 2009. *Science* 340(6134), 852–857 (doi:10.1126/science.1234532)

Huss M (2012) Extrapolating glacier mass balance to the mountain-range scale: the European Alps 1900-2100. *The Cryosphere* 6(4), 713–727 (doi:10.5194/tc-6-713-2012)

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