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

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The authors provide an interesting long term data set on velocity in concert with mass balance on two glaciers Kesselwandferner (KWF) and Hintereisferner (HEF). They provide a short term data set on two others. The data is limited to the ablation zone on HEF. The paper examines the concept that the velocity changes observed might have a comparable use to the annual mass balance or ELA observations. This concept cannot be demonstrated with the spatially poor and temporally infrequent velocity record. The results indicate several long periods of glacier acceleration during periods of positive mass balance, and glacier deceleration during periods of negative mass balance, which has been documented and is expected. The annual mass balance record and terminus change record provide a more detailed record for both glaciers. The terminus record reflects the cumulative mass balance over a span of years commensurate with a glaciers response time. Velocity is a lagging record to cumulative mass balance over a span of years. This lag varies by glacier and location on the glacier, hence does not provide a good climate record. If the velocity record had a broader spatial distribution on the glacier and had been completed with greater frequency over the period of record, the results would be useful. The level of detail and analysis of HEF and KWF provided by one of the authors Fischer (2011) sets a high bar for mass balance and geodetic analysis of these glaciers that this paper does not add to.

Specific Comments:

1-16: Catastrophic in what sense?

1-23: Remove sentence. No need to discuss ice sheet dynamic changes particularly since these often have retreat associated with acceleration. Ice sheets also have long response times. Marine margins of ice sheets also impacted by ocean temperatures in contact with the ice.

2-3: Not sure the point of this sentence. Feature tracking is quite valuable in velocity determination, particularly to build a rich spatial data set across a glacier and through the seasons. It is true we do not have long term velocity records from feature tracking.

2-12: Not sure how the term mass balance theory is used. The suggestion of velocity replacing mass balance is poorly outlined. Mass balance is a good annual measure of volume change for a glacier. Velocity is a longer term response, not an annual measure it is a lagging indicator (Johannesson et al 1989; Zemp et al. 2015). A mass balance perturbation is distributed over a glacier at a finite rate, which results in a lagged response of both glacier velocity and glacier length to changes in mass balance forcing (Johannesson et al 1989; Bahr et al 1998). Velocity changes can identify changes in state, but these are typically associated with other easily observed changes such as terminus change or snow line rise.

2-14: There have been some years where the ELA has risen above a number of glaciers. A glacier cannot be sustained in such a situation as it has no accumulation zone (Pelto, 2010). The AAR of zero is a good measure in such a year as well and can be identified using satellite imagery as well. Six and Vincent (2014) have illustrated the quantitative relationship between ELA and temperature at a number of glacier indicating the value for understanding climate response. Such a quantitative relationship between climate and velocity has not been established.

5-20: The acceleration is not necessarily the cause of the advance. The increase in mass balance which leads to higher volume flux down glacier would be the formative cause. Schwitter and Raymond (1993) observed some of the complexity noting a difference in longitudinal thickness changes (profile shape factor) for short time-scale changes compared to long time-scale changes illustrating on a short time-scale response where transient responses may cause complex localized thickness-change patterns, as observed here on GPF, and a long time-scale response displaying changes in near steady-state profiles.

5-23: This sentence and figure 3 underscore the insufficiency of the velocity data series as a replacement for annual mass balance. There is a consistent decline in velocity, while this fits the mass balance trend line it does not identify the annual mass balance variability. Berthier and Vincent (2012) in looking at the contribution of mass balance versus surface flux to ice thickness changes on the tongue of Mer de Glace note that “Between 1979–94 and 2000–08, two-thirds of the increase in the thinning rates was caused by reduced ice fluxes and one third by rising surface ablation.” To interpret the velocity record for KWF or HEF in the context of climate requires this level of flux analysis is required.

6-9: The pattern of this glacier of acceleration during a period of mass gain followed by reduction during a period of retreat, does not offer any new insights to the glaciers behavior.

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6-12: The decline of velocity to nil on KWF raises the same issue as an ELA rising above a glacier it does not offer a specific annual value of use for climate measure.

6-17: The velocities reported for TSF are of insufficient temporal and spatial range to be a useful measure for understanding glacier mass change or climate response.

6-21: The GPF velocity record is of both short duration and generally limited to the terminus reach of the glacier and is not capable of addressing glacier wide velocity changes in response to climate change. Nor can it be demonstrated that velocity change is consistently responsive to mass balance or climate change.

7-5: And what was the response time?

7-10: It is not demonstrated that the simultaneous velocity change is indicative of mass change in a single year. This can be a response due to a similar multi-year mass balance pattern. The multi-year response affect is indicated by the sequence of small positive balances in the early 1980's that led to glacier velocity reduction despite this positive balance, simply because the balance was not as positive as it had been.

8-1: The long term velocity data set presented here is from two glacier HEF and KWF, with data in the accumulation zone only from KWF. This data set does not demonstrate that velocity consistently responds rapidly to climate change. The data indicates decadal velocity responses, not annual velocity changes that are correlated with climate data or mass balance. The velocity observations here do not provide the seasonal details that mass balance records do. This allowed Zemp et al (2015) to observe from the WGMS records a seasonal difference in mass balance "The increased mass loss over the past few decades is driven mainly by summer balances which are dominated in most regions by ablation processes. Winter balances seem to be of secondary importance and show no common trend. As a consequence of both the extended period of mass loss and the delayed dynamic reaction, glaciers in many regions are in strong imbalance with current climatic conditions and, hence, destined to further substantial ice loss." The delayed dynamic response to climate change makes identifica-

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tion of seasonally driven trends difficult. The velocity change smooths out response and will lead to continued velocity change despite short term mass balance changes that could or will influence the glacier.

8-2: The ELA is traditional and may not be the right measure, but the transient snow line elevation on specific dates, including the date when it rises above the glacier if it does, can provide a useful comparable measure (Mernild et al 2013).

Berthier, E., and Vincent, C.: Relative contribution of surface mass-balance and ice-flux changes to the accelerated thinning of Mer de Glace, French Alps, over 1979-2008. Journal of Glaciology, 58(209), 501-512. doi:10.3189/2012JoG11J083, 2012.

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Mernild, S., Pelto, M., Malmros, J., ; Yde, J., Knudsen, N., ; Hanna, E.:: Identification of snow ablation rate, ELA, AAR and net mass balance using transient snowline variations on two Arctic glaciers. Journal of Glaciology, 59, 649-659, 2013.

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Six, D., & Vincent, C.: Sensitivity of mass balance and equilibrium-line altitude to climate change in the French Alps. Journal of Glaciology, 60(223), 867-878. doi:10.3189/2014JoG14J014, 2014.

Zemp, M., and 16 others. Historically unprecedented global glacier decline in the early 21st century. J. Glaciol. 2015, 61 (228), 745-762. doi: 10.3189/2015JoG15J017, 2015.

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