We appreciate the constructive comments from two reviewers and the community. Our manuscript will be much improved by their input. We have made changes to our manuscript. In the following responses, we use "**bold**" text for comments, "non-bold" text for our responses, and "*italic*" for changed text in the manuscript.

Referee #2 (Chad A. Greene):

This paper identifies three key shortcomings of a common velocity measurement technique, and provides a solution that addresses all three. At issue are 1. the true location of a feature tracked velocity measurement, 2. the acceleration that a parcel of ice may experience between image acquisition times, and 3. the fact that ice does not always move in a perfectly straight line between image acquisition times. The problem and solution are described well in this paper, and the authors demonstrate that they have a good handle on the data and how velocities are interpreted from a glaciological standpoint.

This work will be of value to the community, both to raise awareness of the overestimation issue, and to provide a solution to it. I recommend publication, with just a few suggestions that may help readers understand the impact of overestimation and how it should affect our interpretation of previous studies.

Main Issues

The paper does a good job of describing the problem and solution from a technical standpoint, and anyone who has written feature-tracking algorithms will benefit from reading the paper. However, there are many readers who don't write their own algorithms, but will nonetheless want to understand how overestimation might affect their scientific results. Some work could be done in this paper to better communicate the overall impact of how overestimation impacts long-term studies.

Here's a type of analysis that I would find much more insightful than the stats for PIG, Totten, and David Gl that are currently presented in the abstract: I would like to see a figure showing Eulerian grounding line flux calculations as a function of dt, where dt might range from a day to 20 years. This would provide readers with some intuition for a threshold value of dt, beyond which Eulerian measurements produce significantly different estimates of ice flux. It's possible that the percentage reduction in GL flux as a function of dt might vary regionally, and that diversity could be interesting to show as well.

Response:

We performed an experiment of "GL flux vs. time span" for PIG. We used a baseline velocity map of PIG 2013 (Fig. R2-1a) from ITS_LIVE (Gardner et al., 2019). The flux gate (red line) is set along the grounding line (GL, black line) and separated into flux nodes every 240 m where the ice flow velocity and ice thickness data are used to calculate ice flux. We calculated L-velocities along GL with time spans of 1-15 years based on the 2013 E-velocity map (Fig. R2-1b). Instead of suggested 20 years, we used 15-year time span mainly because the 20-year tracking distance from GL would run beyond the ice shelf front.

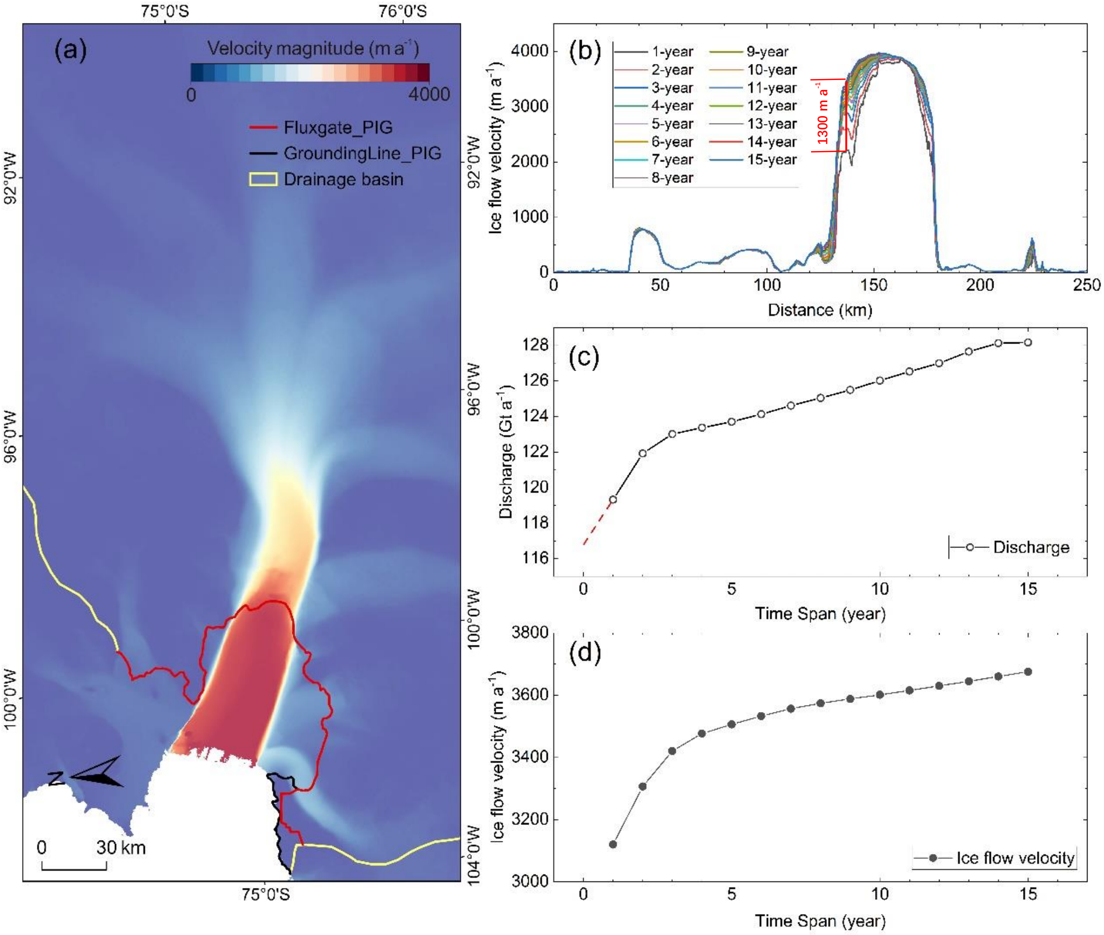

Figure R2-1: (a) Annual ice velocity map of PIG (2013) from ITS_LIVE (Gardner et al., 2019) with the flux gate (red line) set on GL (black line), (b) L-velocities of 1- to 15-year span V_{0-i}^{L} (*i*=*1, 2, … 15*) along GL calculated from the 2003 annual map, (c) GL ice flux (estimated from V_{0-i}^{L}) vs. time span, and (d) L-velocities $\bar{V}_{0-i}^{L}$ (averaged over the GL portion across main trunk, over 1500 m a^{-1}) vs. time span.

The L-velocity along GL increases mainly in the margin areas of the main trunk as the time span increases (Fig. R2-1b). The maximum velocity OE reached ~1300 m a^{-1} for the 15-year span. The annual maximum OE rate started at ~461 m a^{-1} and decreases to ~31 m a^{-1} as the time span increases, because the later part of the trajectory reached the flat part of the ice shelf front (high velocity, but low acceleration).

Consequently, the OE induced GL flux increase (flux overestimation) speeds up quickly at an annual rate of ~2.1 Gt a^{-1} for the first 4 annual spans, by ~6.3 Gt a^{-1} from ~116.7 Gt a^{-1} to ~123.0

Gt a^{-1}. Thereafter the annual rate is maintained at 0.4 Gt a^{-1} until the 15-year span, reaching the maximum flux OE of 11.5 Gt a^{-1}. This flux OE has the same trend pattern as the average L-velocity over the GL portion across main trunk (Fig. R2-1d), indicating that the main flux OE "came" across GL from the main trunk portion.

Due to the limited time and amount of work related to the responses to all three sets of comments we will investigate the same issue in other diverse types of glacier regions in the future.

In addition to a figure showing how dt affects GL flux in Eulerian measurements, I'd like some clear guidance in the abstract for when the Eulerian approximation is sufficient or insufficient.

The above simulation result shows that a GL flux OE of ~11.5 Gt a^{-1} in PIG would be induced by a 15-year span L-velocity map, which is significant in comparison to the flux uncertainty σ_{Flux} of 5.8 Gt a^{-1} in PIG given by Rignot et al. (2019). Therefore, assuming σ_{Flux} = 5.8 Gt a^{-1}, we estimated a "flux-OE-free" time span of ~3 years using the curve in Fig. R2-1c.

At the end of *Experiment 3* we added: "*In addition, based on a 2013 E-velocity map in PIG from ITS_LIVE, L-velocities along GL with time spans of 1-15 years and the associated GL ice flux were computed. The results show that the OE of the 15-year span can reach up to ~1300 m a^{-1} in the GL region. This OE in velocity further caused an overestimation in GL flux, which rapidly increases by ~6.3 Gt a^{-1} within the 4-year span; thereafter it slows down until the 15-year span, resulting in a total flux OE of ~11.5 Gt a^{-1}. Consequently, the results indicate that a velocity map of a time span within 3 years would be "flux OE-free", inducing a flux OE less than a threshold σ_{Flux}. We used σ_{Flux}=5.8 Gt a^{-1} that is the flux uncertainty in PIG reported by Rignot et al. (2019). Overall, the influence of the OEs on the GL flux appears not very significant, with the OE of a 15-year span map less than 2 σ_{Flux}.*"

We added a statement in Abstract: "*……Our experiment results in PIG with a 15-year time span showed that the flux overestimation caused by the OE in velocity increases rapidly within the first 4-year span before it slows down and reaches the maximum of ~11.5 Gt a^{-1}; the flux OE is negligible within a time span of 3-years……*"

In the abstract and/or discussion, I suggest flipping the logic/wording around at least once to make it clear that the overestimation of historical velocities could mean that previous papers have underestimated the magnitude of glacier acceleration over the past few decades. It's only a minor change in wording, but I think it's an important take-home message of this paper that should be stated directly.

Response:

We added a statement in the discussion section: "*…… The implication is that, when using newer* *velocity maps of short spans along with historical maps of long spans in previous studies for estimation of glacier acceleration over the past few decades, the overestimation of historical velocities could have caused an underestimation in the acceleration magnitude. On the other hand, new efforts in historical velocity mapping at an ice sheet – wide or large regional scale should be made with a full consideration of the OE correction.*"

Minor comments

Abstract: The case studies of PIG, Totten, and David Glacier provide decent testing grounds for the methods presented in this paper, but the details of these studies feel somewhat anecdotal and very specific to the exact images that were used in these particular cases. I recommend generalizing the results in the abstract to give readers a better overview of the problem. Only after discussing the overall impact of the overestimation, then it may be helpful to mention a specific case of PIG, Totten, or David to as a tangible example.

Response:

Accepted. We revised Abstract accordingly: "*…… In comparison to velocity maps derived from recent satellite images of monthly to weekly time spans, historical maps, from before the 1990s, generally cover longer time spans, e.g., over 10 years, due to the scarce spatial and temporal coverage of earlier satellite image data. We found velocity overestimations (OEs) in such long-term maps that can be mainly attributed to ice flow acceleration, time span of the images used, and glaciers with complex geometry. If used for long-term change studies, these OEs in historical velocities may further affect the estimated trends of ice flow dynamics and mass balance. For example, the OEs can reach from ~69 m a^{-1} (7-year span) in Totten Glacier, East Antarctica, up to ~930 m a^{-1} (10-year span) in Pine Island, West Antarctica……*"

L29: This line mentions "the input-output method" and some good references are provided for it, but some readers may be unfamiliar with the term. If the term is necessary for some point that's being made, then I recommend briefly describing what is meant by "the input-output method" here. If the term is not important for this paper, then consider removing it.

Response:

The phrase "using the input–output method" is removed.

L69: Recommend changing "It is proven that…" to "We show that…" to make it clear that the correction is original work that is presented in this paper.

Response:

We changed the sentence accordingly.

L80: I'm not entirely sure what "descending passages" means. Consider rewording.

Response:

The sentence is revised: "*We describe an acceleration-induced overestimation using a typical scenario in AIS (Fig. 1a) where ice flow accelerates over a long slope from several glaciers originated from the inland interior, running through the main trunk, and discharging to the ocean*."

L160: "At each grid…" I think this should be "At each grid cell…" or "At each pixel…"

Response:

We changed it to "*At each grid cell* ……"

Figure 5 is very compelling, and I want to make sure I understand it. Unfortunately, the labels and caption are somewhat cryptic, so I'm not sure if I'm even getting the main message right. The caption contains a list of the data labels that are mostly redundant with labels that are presented directly in the figure. What's missing is physical interpretation or any direct take home message. For example, the variables U, U', and V are labeled in the figure and in the caption, but there's no physical definition of what U, U', or V mean. Help readers by providing a sentence or two in the caption that directly states the main point and any secondary point(s) that may be worth noticing. The main point, I assume, is that the black line is consistently higher than the red and blue curves. State that in the caption, in terms of what it means physically. What causes the red and blue curves to cluster together or spread apart from each other? Mention the underlying mechanism in the caption. Most of these points are described in detail on page 11, but most readers will appreciate having the main points stated directly in the figure caption.

Response:

The caption is revised according to the suggestions: "*Figure 5: Velocities in five areas (rectangles in Fig. 4) of the Totten Glacier are used to validate Premises I and II. (a) Panels 1a–5a show the reconstructed 1-year velocity maps $V_{2013\text{-}2014}$ in the areas; matched points (red triangles) are used to map E-velocity V_{2013-i}^{E} (i=2014, …, 2020) (red lines in Panels 1c-5c); points along the flow line (blue dots) are tracked from the 1-year maps and used to calculate L-velocity V_{2013-i}^{L} (blue lines in Panels 1c-5c). (b) Similarly, Panels 1b–5b illustrate the reconstructed 7-year velocity maps $V_{2013\text{-}2020}$ in the areas with the matched points (red triangles) for E-velocity $V_{2013-i}^{E(7)}$; points along the flow line (black crosses) are tracked from the 7-year span velocity map and used to calculate L-velocity $V_{2013-i}^{L(7)}$ (black lines in Panels 1c-5c). (c) In each area (Panels 1c–5c) the difference between red (straight) and blue (curved) lines increases with time, but is limited within $k\sigma$ at the end (Premise I), except a large k in Area 4 because of effect of a calving event; the black line is above blue line because of the spatial acceleration-induced OE over 7-year span; but they are relatively parallel(Premise II) and thus, a correction can be estimated.*"