We appreciate the constructive comments and suggestions from the editor and reviewer. 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.

Editor:

I fully agree with the reviewer. The key now for you is to put your results into context and make sure the readers/users are aware of the validity domain of the correction you propose. This will help our colleagues to fully understand the importance of your contribution.

Response:

Thanks. The manuscript is revised accordingly to explain the validity domain of the correction and importance of the contribution (mainly in the first response and then in detailed responses in the following text).

Referee #2 (Chad A. Greene):

Main Issues

In my first review of this paper, I commended the authors for raising awareness of an issue that could potentially introduce a systematic bias into any study of ice dynamics that compares recent satellite measurements to velocities measured decades ago, when the satellite record was sparse and image pairs were often separated by many years. The paper presented a reasonable approach for dealing with overestimation from a technical standpoint, but I felt the manuscript needed improvement in communicating

1. **why the overestimation effect matters,**
2. **how big of a problem it is, and**
3. **when it should be taken into account in scientific studies.**

On these three points, I don't see that much has changed in this revised manuscript. A few sentences were added in this revision to mention the effects of OE at PIG, but no attempt was made to put the effect into any greater context or generalize

the findings beyond the specific case at PIG… …

Response:

(Line 387 in the marked-up manuscript) After presenting three experiments in Totten, Davis and PIG in Section 3 *Results*, we added a paragraph to address these three points: "*In summary, OEs exist in historical long span velocity maps of Antarctica, from smaller glaciers, such as David Glacier, to the fast-flowing glacier of PIG, where spatial accelerations are produced by, e.g., bed topography and slopes. In general, they are less significant in slow-flowing grounded regions with low spatial accelerations. Instead, they take effects in places of high ice dynamics, for example, near grounding lines and often in ice shelf fronts. Velocities in these areas are important for estimating ice sheet mass balance and contribution to global sea level changes, and for analyzing ice shelf instability. For instance, in the David Glacier the large OE corrections (up to 36 m a^{-1}) occur on the ice shelf (Fig. 6). The OEs of a 7-year span, up to 69 m a^{-1} (Table 1), would be about ~50% of the velocity increase detected during 1989 – 2015 in the Totten Glacier (Li et al., 2016). The PIG experiment showed an extreme case in Antarctica where the OEs of a 7-year span can go as large as 626 m a^{-1} (~20%) near the grounding zone (Table 3); furthermore, the OEs of a 15-year span can reach up to 1,300 m a^{-1} along the grounding line and cause an overestimated GL flux of 11.5 Gt a^{-1} if not corrected (Fig. A4). Therefore, the magnitude of the OEs contained in the long span historical velocity maps is significant. When overestimated historical maps of 1960s – 1980s are used alongside recent maps of 1990s – 2010s for assessment of the long-term global climate change impact on the Antarctic ice sheet and for forecast modeling, overestimated historical states may lead to underestimated long-term changes. Furthermore, compromised forecasting may be resulted. Thus, the OEs in the long span historical maps must be seriously examined and corrected.*"

(Lines 17 and 525) Accordingly we made changes in Abstract and Conclusions.

… … Notably, one of the new sentences states that OE is negligible when computing GL flux at PIG. As a reader I am left wondering, if OE is negligible at

PIG, does it matter anywhere?

Response:

(Line 465) We deleted the sentence "…… ~~*Therefore, the influence of the velocity OEs on the GL flux appears to be not very significant.*~~"

Most of this paper is devoted to specific case studies of PIG, Totten, and David Glaciers, but the results are never generalized beyond the specific image pairs that were analyzed in this study. Readers are tasked with absorbing pages of details about tenth-of-a-meter-per-year level accelerations in some arbitrary pixels from a handful of image pairs, but the findings from these case studies are never synthesized in any way that could be applied beyond the image pairs that are analyzed in this study.

Response:

We synthesized the findings and generalized the results. The text is included in the new paragraph in *Results* (Line 384, see the response above to the first comment).

In my previous review, I suggested that readers would benefit from clear guidance on when to consider the effects of OE. The authors responded with a beautiful Figure R2-1 that for some reason is not included in the manuscript. I've recreated panel C of R2-1 below (the code is provided at the end of this review) and I find a similar overall curve for PIG. The GL flux curve for PIG takes an interesting shape—why does the OE effect appear to level off after a couple of years? That phenomenon is worth exploring and discussing in the manuscript.

Response:

(Lines 460 and 723) We give a guidance on when to consider the effects of OE based on the GL flux trend in PIG, and added the suggested figure in Appendix as Figure A4. In *Discussion* we added the following text: "*…… Such OEs in velocity can further cause an overestimation in ice discharge cross flux gates upstream the GL, which increases rapidly by ~6.3 Gt a^{-1} within the first 4-year span (Fig. A4c); thereafter the flux overestimation slows down until a maximum of 11.5 Gt a^{-1} is reached at the 15-year* *span. This suggests that in fast-flowing glaciers like PIG, OEs in velocity maps with a time span of greater than 0.5 – 2 years should be corrected. The fact that the OE effect in PIG appears to level off after a couple of years is mainly because the velocity in the majority of the ice shelf is approximately leveled at ~4000 km a-1 and the acceleration is thus very small. This makes the average L-velocities along the GL to increase in a much-reduced pace where an integral of E-velocities is performed in the leveled velocity area a few years after crossing the GL (Fig. A4d). Consequently, the flux OE indicated in Fig. A4c showed a similar trend.*"

Is the same effect seen elsewhere around Antarctica? When I synthetically "measure" GL flux as a function of dt for the entire continent* , it doesn't appear to matter much on the whole. This suggests that while overestimation is in effect at PIG, there is some compensating underestimation elsewhere around Antarctica. Where does this happen? A discussion of the physical phenomena that affect ice velocity measurements would be insightful.

*** My GL flux values for "the entire continent" are low, because I excluded GL datapoints that would calve into the ocean within 15 years.**

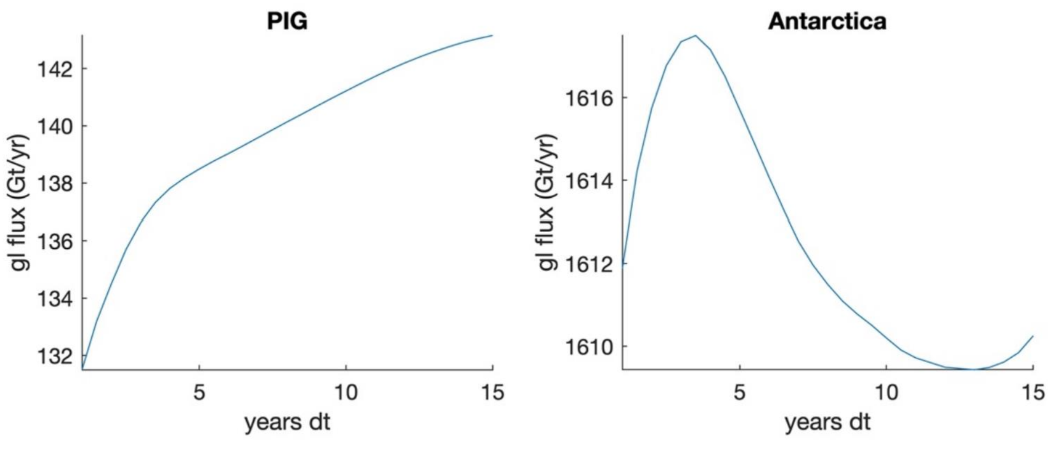

Figure 1. GL flux in PIG and Antarctica (Chad A. Greene)

Response:

Thanks for your code. We used it to calculate GL flux of a set of selected glaciers. The results of four glaciers are illustrated below.

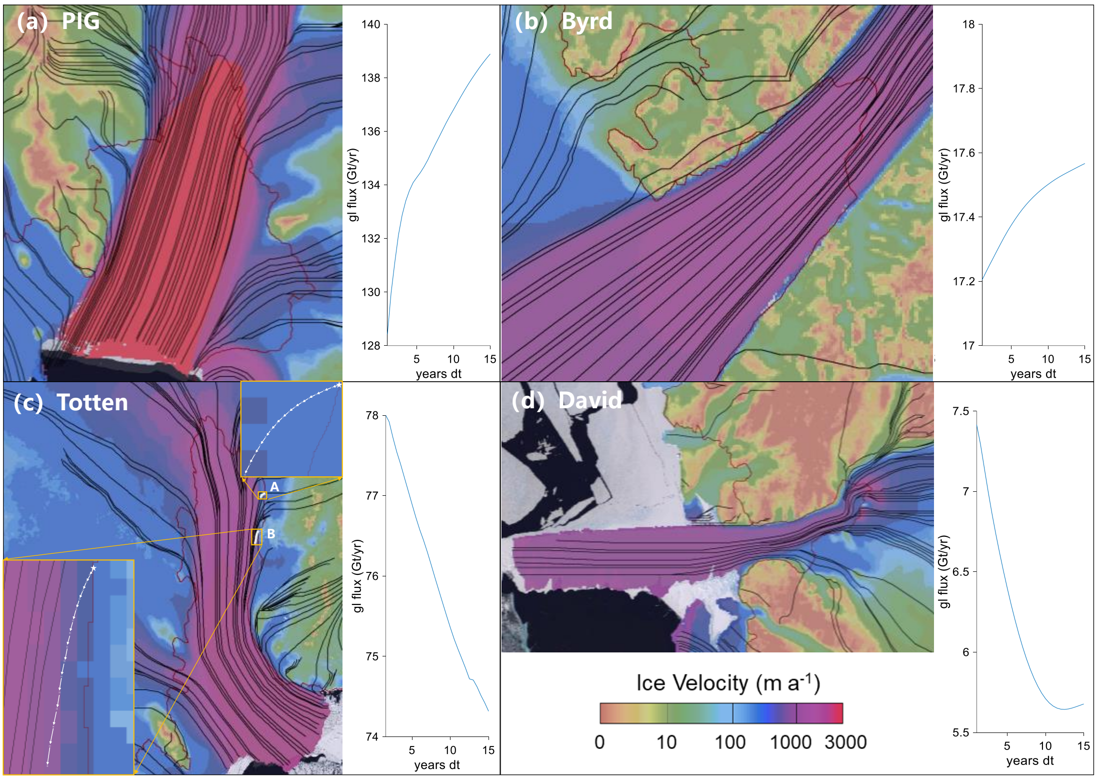

Figure 2. Velocity map from ITS_LIVE (Gardner et al., 2019), flow lines (black), grounding line (red), and GL flux based on 1- to 15-year span L-velocities (blue curve on the right side of each map) in the PIG (a), Byrd (b), Totten (c), and David (d) glaciers.

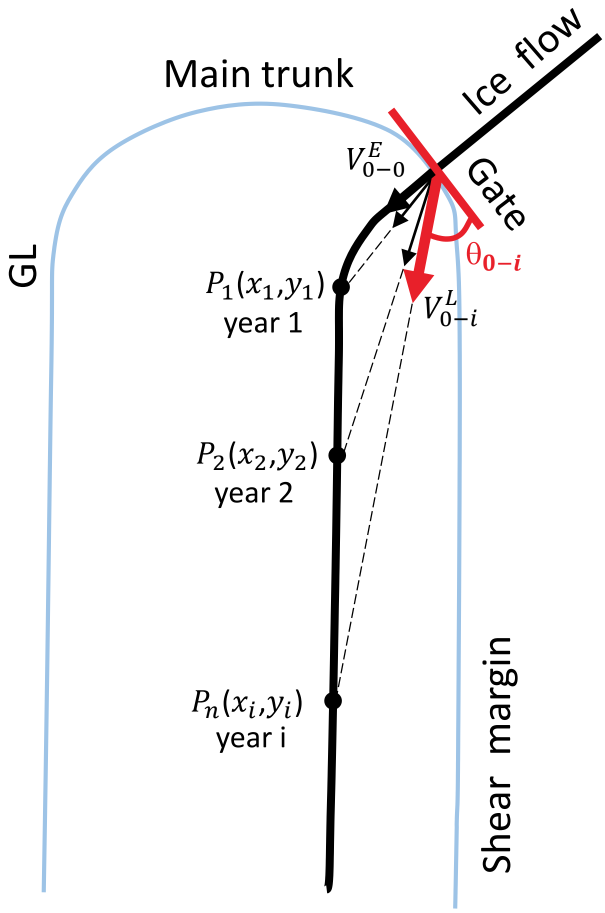

Figure 3. Trend of long span L-velocity directions – approaching the ice shelf margin orientation, and its impact on flux computation.

For a GL point in a given glacier (Fig. 3) the actual GL flux estimated from a non-biased V_{0-0}^{E} map is assumed to be $Flux_0$. $Flux_i$ is calculated from the overestimated i-year span L-velocity V_{0-i}^{L}:

$$Flux_i = \overrightarrow{Gate} \times \overrightarrow{V_{0-i}^{L}} \cdot Thickness \cdot \rho_{Ice} \cdot dt = \left|\overrightarrow{Gate}\right| \left|\overrightarrow{V_{0-i}^{L}}\right| sin\theta_{0-i} \cdot Thickness \cdot \rho_{Ice} \cdot dt \quad (1)$$

"$\times$" is cross product. As time span i increases from 1 to 15 years, $Flux_i$ varies according to both $\left|\overrightarrow{V_{0-i}^{L}}\right|$ and θ_{0-i} (angle between $\overrightarrow{Gate}$ and $\overrightarrow{V_{0-i}^{L}}$, see Fig. 3). The GL flux gate has a fixed direction for all years, while the *i*-year span L-velocity $(\overrightarrow{V_{0-i}^{L}})$ (*i=1, ...n*) direction ***changes*** each year. Given a velocity range in a glacier, θ_{0-i} controls the flux magnitude. A large θ_{0-i} angle allows more ice mass to cross GL (e.g.

at a perpendicular angle), otherwise the flux decreases. The extreme case is flux = 0 when $\overrightarrow{V_{0-i}^{L}}$ is parallel to GL ($\theta_{0-i} = 0$). Changing of θ_{0-i} over a long span (e.g., from 1 to 15 years) and its impact on flux computation is the focus here.

In PIG (Fig. 2a) majority of flow lines cut GL at large angles (approximately perpendicular to GL or large θ_{0-i}) that are mostly not changed significantly over 15 years. Thus, $Flux_i$ increases for all 15 years (a total flux OE of 11.5 Gt a^{-1}) due to continued large θ_{0-i} and velocity OE in $\left|\overrightarrow{V_{0-i}^{L}}\right|$. The Byrd glacier (Fig. 2b) shows a similar case with a small total positive value of flux OE (< 1 Gt a^{-1}). In contrast, in the Totten glacier (Fig. 2c) there are some flow lines that have large θ_{0-i} angles and make direct contributions to ice flux cross GL of the main trunk and a tributary glacier. However, flow lines cut most of the GL (e.g., along shear margins) at smaller θ_{0-i} angles (e.g., enlarged areas "A' and "B"), which continuously decrease over the 15 years (see Table 1), making a decreased trend in flux (a total flux underestimation of ~3.7 Gt a^{-1}). The David glacier (Fig. 2d) has a similar situation with a total flux underestimation of ~1.8 Gt a^{-1} for the 15-year span.

Table 1. Values of θ_{0-i} angle in areas A and B over 15 years.

Time (Year)	θ_{0-i} in Box A (°)	θ_{0-i} in Box B (°)
1	45.8	25.8
2	45.2	25.4
3	44.3	24.1
4	43.1	23.1
5	41.8	21.9
6	40.4	20.5
7	38.9	19.0
8	37.3	17.8
9	35.6	16.6
10	33.9	15.9
11	32.0	14.9
12	29.9	14.0
13	27.8	13.8
14	25.7	13.1

15	23.6	12.5

Extension of this exercise to the entire continent involves a complex situation, including deceleration caused by ice rises, mapping errors near shear margins, GL data points that would calve into the ocean within 15 years, and other potential factors. Given the effects of the θ_{0-i} angle on the ice flux that is amplified by the long span of 15 years (as indicated in the code provided, Equation (1) and results in Fig. 2), the "Antarctica" GL flux curve in Fig. 1 mainly reflect the fact that at the continent scale, the GL flux OEs accumulated in glaciers like PIG are compensated by underestimations in glaciers such as Totten and David. These underestimations may be small in localized regions, but they accumulate along the large percentage of the entire Antarctic GL and takes a significant effect at the continent scale (Fig. 1).

(Line 470) We believe that a systematic and in-depth investigation is needed to reach a conclusive result. We added the following text in *Discussion*: "*…… Extension of this exercise to the entire continent involves a complex situation, including deceleration caused by ice rises, mapping errors near ice shelf shear margins, GL data points that would calve into the ocean within n-year span, and other potential factors. It should be noted that given a velocity range in flux computation, the ice flow angle between a flux gate and ice flow controls the flux magnitude. In principle, at the same gate this angle changes with velocities of different time spans and flow line patters, resulting in an overestimation or underestimation in flux for individual glaciers. A systematic and in-depth investigation should be carried out to handle the overestimation issue in GL flux of the entire Antarctica.*"

Summary: I don't believe there's any particular harm in publishing the manuscript in its current form, but I do believe an opportunity has been missed for the authors to share the insights and intuition they have surely developed over the course of this work.

Response:

Thanks for the suggestions. We added those we felt comfortable into this paper and left few for our future work.

Specific comments

Line 394 alludes to experiments that were performed on Jakobshavn Isbrae and introduces the acronym JI for the glacier, but the experiments at Jakobshavn are not described anywhere in the paper, and the acronym is never used. Am I missing something?

Response:

(Line 412) It was suggested by Reviewer 1 to compare Jakobshavn Isbrae (JI) as well. Now we removed everything related JI in the revised manuscript.

Line 399 starts a new section with the word "Furthermore,..." as if a thought is being continued from a previous section. Section breaks are often where readers pause to grab a cup of coffee, so as a general rule I recommend starting each section in such a way that readers can pick up where they left off, without having to re-read the previous section.

Response:

(Line 417) We deleted "Furthermore" and start the section directly with "*Within a long time span ……*"

Line 339 says GL flux was computed. How? What grounding line and ice thickness products were used?

Response:

(Line 456) We added the details: "*In addition, based on an annual E-velocity map of 2013 in PIG from ITS_LIVE (Fig. A4a), L-velocities along grounding line (GL; Gardner et al., 2018) with time spans of 1 to 15 years (Fig. A4b) and the associated ice discharge was computed. The actual flux gates were set with nodes separated every 240 m, which were located up to 13 km upstream the GL to reduce the uncertainty of ice thickness data (Gardner et al., 2019) from BedMachine (Morlighem et al., 2020)……*"

Line 440 says "OEs in velocity can further cause an overestimation in GL flux, which is negligible within a 3-year span" but no evidence or rationale for this statement is presented in the manuscript.

Response:

(Line 461) We deleted that part of the sentence: "…… ~~which is negligible within a 3-year span (≤ σ_{Flux}).~~"

Line 443 says "Therefore, the influence of the velocity OEs on the GL flux appears to be not very significant." Does this mean the main thesis of the paper is more theoretical than practical?

Response:

(Line 465) We deleted the sentence "~~*Therefore, the influence of the velocity OEs on the GL flux appears to be not very significant (11.5 Gt a*~~$^{-1}$ ~~*≤ 2* σ_{Flux}*).*~~"

Lines 445-449 offer concluding remarks on the Jakobshavn experiments that are not described in this paper. This paragraph can be removed.

Response:

(Line 477) Now we removed this paragraph and everything related JI in the paper.