Response to the Interactive comment on

"Recent dynamic changes on Fleming Glacier after the disintegration of Wordie Ice Shelf, Antarctic Peninsula"

by Peter Friedl et al.

Anonymous Referee #1
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We would like to thank the reviewer again for the constructive and helpful comments on our manuscript.
All comments have been considered and a list of responses and changes in the manuscript is given below. Responses are written in bold face type and changes in the manuscript are written in *blue*.

Friedl et al. present a study on glacier retreat and changes in ice flow for Antarctic Peninsula outlet glaciers after disintegration of Wordie Ice Shelf. The work is based on analysis of remote sensing data from various sources. It extends the period of observations on frontal retreat, flow acceleration and glacier thinning that was reported by Rignot et al. (2005) and Wendt et al. (2010) up to the year 2009. Of particular interest is the production of a close time series of surface velocities, up to the year 2016, including the filling of gaps from previous years. The analysis of surface elevation change, comparing the change 2011 to 2014 to that of previous years, and the time series of frontal retreat are also very relevant for describing glacier behaviour. The review on previous work and the presentation and interpretation of the observations are presented in coherent manner at large. However, there are various individual points that are not well explained or questionable. The presented data sets are very useful for characterizing the glacier behaviour during the last two decades, but the discussion and conclusions focus on the description of the observed phenomena and do not provide any substantial new insights into the processes leading to the observed changes.
We have largely restructured and reformulated the Discussion and the Conclusion sections. In particular we have included a discussion of recently published data on atmospheric driven CDW upwelling events and elevation change in Wordie Bay. By linking these findings to our results on high resolution surface velocity change, ice thinning and grounding line retreat, we are able to provide new insights in the timing of the processes and reasons for the observed changes in Wordie Bay.

Specific Comments:

P1, L16: The conclusion on "pronounced basal melt at the grounding line" is not based on any direct observations for these glaciers.
We understand the reviewer`s concerns. However, Depoorter et al. (2013) and Rignot et al. (2013) observed high basal melt rates for the remaining parts of the ice shelf, similar to those found for ice shelves in the Amundsen Sea sector (see answer P2, L13, L14). Furthermore the coincident timing of exceptional warm water intrusions in 2008/2009 and 2010/2011 into Marguerite Bay found by Walker and Gardner (2017) and the two acceleration phases found by us indicates that ocean warming and the observed changes in glacier dynamics are strongly correlated. Anomalously low sea ice extent in Marguerite Bay observed in 2008 and 2010 suggests that the warming events affected the upper water column, but Walker and Gardner (2017) found that the years 2009-2011 had the highest temperatures also at depths of 400 m. Hence, it is very likely that submarine ice melting was increased during phases of strong CDW upwelling events and that this has triggered unpinning and grounding line retreat. We rewrote the abstract in such a way that it points out that our conclusion on basal melt at the grounding line is not based on direct observations made in this study but on reasonable assumptions upon existing evidence. We also discuss this in more detail in the restructured Discussion and Conclusion parts.

P1, L19: The length of the centreline (for which this values is valid) should be specified

We thank the reviewer for this suggestion. We have changed the sentence into:

The resulting loss in buttressing is able to explain a remarkable median speedup of ~1.3 m d^{-1} (~30 %) between 2007 and 2011 observed along a centreline extending between the grounding line in 1996 and ~16 km upstream.

P1, L21: Fig. 5 shows in the downstream part of the profiles for 2011-2014 thinning rates that are smaller than for 2004 to 2008. 60% to 70% higher rates are only evident for a subsection of the profile shown in Fig. 5.

Despite of lower ice thinning rates measured towards the ice front in 2011-2014, our data show an overall increase of median ice thinning rates of ~1.1–1.3 m a-1 or ~70 % between the periods from 2004 to 2008 and from 2011 to 2014. Median elevation change rates were calculated for entire profiles, including subsections with lower and increased ice thinning rates. Hence the numbers refer to full profiles not just to the upstream parts. In some upstream parts ice thinning rates increased by even more than 100%. We have changed the corresponding section in chapter 5.2 in such a way that we hope it makes this now clearer to the reader:

Despite of lower ice thinning rates measured towards the ice front in 2011–2014, our data show an overall median increase of ice thinning rates along the profiles of ~1.1–1.3 m a^{-1} or ~70 % between the periods from 2004 to 2008 and from 2011 to 2014. However, in some areas 10–15 km upstream, ice thinning rates even doubled in the latter period.

P1, L26: Hardly possible that the glaciers draining into Wordie Bay have “a huge potential for an increase in sea level rise”.

Our choice of words was probably too dramatic. We have changed the sentence into:

Hence, this endangers upstream ice masses, which can significantly increase the contribution of Fleming Glacier to sea level rise in the future.

P2, L4: 4.21 Gt/a refers to Larsen-A and Prince-Gustav-Channel glaciers, 2011-2013.

We apologize for this inaccuracy. We have changed the sentence into:

Rott et al. (2014) estimated the total dynamic ice mass loss for the glaciers along the Nordenskjöld Coast and the Sjögren-Boydell glaciers after ice shelf disintegration to be 4.21 ± 0.37 Gt a^{-1} between 2011–2013.

P2, L13, L14: Rignot et al. (2014), Suppl. Material, show for Wordie Ice Shelf clear dominance of calving losses compared to ablation, rather than “basal melt exceeding the ablation induced by calving”.

We agree with the reviewer. Indeed Fig. 1 in Rignot et al. (2013) indicates that mass loss from Wordie Ice Shelf is much bigger from calving than from basal melt. However, mass losses of George VI, Wilkins, Bach and Stange ice shelves are shown to be clearly dominated by basal melt. Tab. 1 in Rignot et al. (2013) reveals that mass loss at Wordie Ice Shelf is calculated to be 7.6 ± 3 Gt/a for calving and 6.5 ± 3 Gt/a for basal melt, which means that ~54 % of mass loss can be attributed to calving and ~46 % to basal melt. However, the calculated basal melt rate of 23.6 ± 10 m/a is the second largest value obtained for Antarctica in this study. Interestingly a similar study of Antarctic wide basal melt rates by Depoorter et al. (2013) attributes 82 % of the mass loss of Wordie Ice Shelf to basal melt and only 18 % to calving flux (Fig. 1, Depoorter et al., 2013). The values correspond to a calving flux of 2 ± 3 Gt/a and a mass loss of 10 ± 4 Gt/a (or 14.79 ± 5.26 m/a respectively) due to basal melt (Table 1 in Suppl. Material, Depoorter et al., 2013). The high basal melt rates at Wordie Ice Shelf are similar to those found for ice shelves in the Amundsen Sea sector (Table 1 in Suppl. Material and Fig. 2, Depoorter et al., 2013). The differences between the two studies seem to be mainly caused by the different datasets used for the computations (e.g. Rignot et al., 2013 used ice thickness from Bedmap-2 whereas Depoorter et al., 2013 calculated ice thickness from satellite borne surface elevation data). Despite of the differences, both studies show that Wordie Ice Shelf undergoes pronounced basal melt.

Consequently we have changed the section into:

For the south-western Antarctic Peninsula Rignot et al. (2013) demonstrated that basal melt of George VI, Wilkins, Bach and Stange Ice Shelves exceeded the ablation induced by calving. For Wordie Ice Shelf high basal melt rates of 23.6 ± 10 m a^{-1} and 14.79 ± 5.26 m a^{-1} have been reported by Rignot et al. (2013) and Depoorter et al. (2013) respectively. However, the presented melt ratios (i.e. the ratio between basal melt and the sum of calving flux and basal melt) differ between 46 % (Rignot et al., 2013) and 82 % (Depoorter et al., 2013).

P2, L15: Please explain the "small coastal atmospheric and oceanic processes".
Padman et al. (2012) found that changes in basal melt at Wilkins Ice Shelf are primarily determined by small-scale coastal atmospheric and oceanic processes that can alter the depth of the cold winter water layer, rather than by large-scale atmospheric forcing of benthic inflows of warm CDW along troughs cutting across the continental shelf. Such small-scale processes include complex interactions between coastal wind stress, surface radiation balance, sea ice and freshwater fluxes (including land runoff, sea-ice production and melt, and feedbacks between the ice shelf and regional hydrography and circulation). For example, increased freshwater fluxes from runoff and ice-shelf basal melt consolidated by downwelling forced by enhanced wind stress can lead to a depression of the cold winter water layer and hence to a reduction of basal melt. For the sake of clarity we have changed the corresponding sentence into:
Wilkins Ice Shelf experienced amplified basal thinning controlled by small-scale coastal atmospheric and oceanic processes that assist ventilation of the sub-ice-shelf cavity by upper-ocean water masses (e.g. variations in wind stress or reduced freshwater fluxes from runoff and ice-shelf basal melt) until ~8 years before break-up events took place in 2008 and 2009 (Braun and Humbert, 2009; Padman et al., 2012).

P4, L4: Date and source for the Bedmap2 DEM section over the study area should be mentioned (may have some impact for geocoding and analysis of surface elevation change).
The Bedmap2 DEM is a combination of several DEMs covering all or part of Antarctica (Fig. 5 and Tab. 3, Fretwell et al., 2013). The multiple surface elevation datasets were gridded together into a seamless DEM of Antarctica. On the Antarctic Peninsula north of 70° S the Bedmap2 DEM is entirely based on the improved ASTER GDEM by Cook et al. (2012), providing a vertical accuracy of ±26 m. The ASTER GDEM is compiled from stacked photogrammetric DEMs from ASTER scenes acquired between 2000 and 2009 that are unspecified in the final product. On the Antarctic Peninsula south of 70° S the Bedmap2 DEM consists of data from the SPIRIT DEM, compiled from SPOT images, acquired in 2007-2008 (vertical accuracy is ±6m) and from the NSIDC DEM (DiMarzio et al., 2007), derived from ICESat data acquired in 2003–2005 (vertical accuracy varies from ±0.4 m to ± 20 m).
We used the Bedmap2 DEM as a source of topographic information for orthorectification of the velocity fields and for the derivation of local incidence angles required for the conversion from slant to ground range displacement. Here consistency of the elevation data is more important than the date. Since the extent of our Sentinel-1 scenes exceeded 70° S (i.e. the extent of the improved ASTER GDEM by Cook et al., 2012), the coverage of the Bedmap2 DEM allowed us to use a single consistent topographic reference for all velocity products. This is important when comparing velocities obtained from the different sensors.
We would like to clarify that we did not use the Bedmap2 DEM for the calculation of elevation changes between the Bedmap2 DEM and the TanDEM-X DEMs. Of course in this case the dates of the data would have been important. Instead, we used the differential phase between the simulated phase of the Bedmap2-DEM and the topographic phase of TanDEM-X to support phase unwrapping. However in the revised version of the manuscript we now use a subset of the TanDEM-X Global DEM for this procedure, as described in answer P5, L34.
Notwithstanding the above, we of course agree with the reviewer that providing more information on the Bedmap2-DEM is an asset. We have therefore changed the corresponding section into:
The Bedmap2 digital elevation model (DEM) of Antarctica (Fretwell et al., 2013), resampled to 100 m resolution, was taken as a topographic reference for orthorectification of the surface velocity fields and for the derivation of local incidence angles required for the conversion from slant to ground range displacement. Over the Antarctic Peninsula the Bedmap2 DEM provides a seamless

compilation of data from the improved ASTER GDEM (from ASTER stereo images acquired between 2000 and 2009) (Cook et al., 2012), the SPIRIT DEM (from SPOT stereo images acquired in 2007 and 2008) and the NSIDC DEM (from ICESat data acquired between 2003 and 2005) (DiMarzio et al., 2007).

P4, L24: May mention here that the OIB and Huss bedrock data are compared in Fig. S5.
We have added a reference to Fig. S5 at the end of the corresponding sentence.

P5, L15: point clouds of differential elevation measurements are shown in Fig. 5. (not Fig. 4).
In Fig. 4 the locations of the measuring points are depicted which form the point clouds shown in Fig. 5. For more clarity we have changed the corresponding sentence into:
The locations of the resulting points of differential elevation measurements are shown in Fig. 4.

P5, L34: It is not meaningful using a low resolution DEM from a different epoch for performing DEM differencing with high resolution TanDEM-X data, if an up-to-date high resolution DEM from TanDEM-X is available.
As already mentioned in answer P4, L4 we originally subtracted a simulated topographic phase from the Bedmap2 DEM from the TanDEM-X phase prior to the unwrapping of the TanDEM-X phase and re-added the subtracted height-information afterwards. The fact that then only a differential phase has to be unwrapped, facilitates the phase unwrapping and makes it more robust. So the only purpose of subtracting the phase was facilitating the phase unwrapping rather than calculating elevation changes between Bedmap2 and TanDEM-X. Nevertheless, in the revised manuscript we now use a subset of the TanDEM-X global DEM with a spatial resolution of 12 m (Rizzoli et al., 2017) for the procedure. This is because we have also changed the vertical referencing in such a way that we now use the TanDEM-X global DEM to vertically adjust the TanDEM-X DEMs (see answer P6, L19 to L28).
We consequently have changed the corresponding sentence into:
A subset of the TanDEM-X global DEM, covering the two TSX/TDX-DEMs, was chosen to be the reference DEM.
We also have added a sentence to chapter 3 (Data):
A simulated phase from a subset of the TanDEM-X global DEM with a spatial resolution of 12 m (Rizzoli et al., 2017) was used to facilitate phase unwrapping during the generation of the two TSX/TDX DEMs. The TanDEM-X global DEM was also used as a reference for the absolute height adjustment of the TSX/TDX DEMs.

P6, L19 to L28: The differences between ATM and (uncorrected) TanDEM-X rates of elevation change (up to 2m/a) need further explanations and checks. 2m/a corresponds to 6 m difference for the 3 year time span. The area for the profile is located in the percolation zone. Typical values for TanDEM-X penetration bias in the percolation zone are about 4 m (see e.g. Wessel et al., ISPRS Annals. VL-III-7, doi:10.5194/isprsannals-III-7-9-2016). If the morphology of the snow and firn medium is the same on both dates, the penetration bias cancels out for DEM differencing. A difference in dh/dt of 6 m versus optical data can only be explained if the snow morphology is completely different on both dates (e.g. melting surface snow without penetration vs. completely frozen snow volume). This should show up clearly in the backscatter signatures.
We thank the reviewer for raising this important issue. We completely agree with the reviewer that a penetration bias of 6 m is pretty large for the percolation zone. We found that our approach of vertically referencing the TSX/TDX DEMs by calculating mean offsets over sea ice was not optimal. We therefore changed the vertical registration procedure in such a way that we now use a subset of the TanDEM-X global DEM at 12 m resolution as an absolute height reference. Before differencing, both TSX/TDX digital elevation models were vertically adjusted to the TanDEM-X global DEM according to their median offsets measured over stable ground. This improved the vertical registration and resulted in a more realistic penetration depth bias.
The maximum difference between ATM and uncorrected TDX/TSX elevation change rates was 1.25 m/a, corresponding to a 3.75 m difference for the 3 year time span. However, differences in elevation change were only measured in the lower areas of the glacier tongue, where surface melt occurs. In the upper areas (above 600 m altitude) the difference between ATM and

TSX/TDX elevation change rates was close to 0 m. Here the medium was likely completely frozen on both dates of acquisition, so that the penetration bias cancelled out. A comparison of backscatter values showed that in areas below 600 m altitude the backscatter of the 2014 acquisition was lower than the backscatter of the 2011 acquisition. In the upper areas above 600 m, however, the backscatter values were similar.
We have updated the TSX/TDX elevation change rates in the text and all figures that contain TSX/TDX elevation change data (i.e. Fig. 4, Fig. 5 b, Fig. S4 a-c and Fig. S6.1-4).
We have also added a Figure S4 d showing the differences in backscatter between both acquisition dates.
Furthermore we have updated Fig. S1 for the new areas over stable ground used for vertical adjustment and error estimation.
Finally we have largely changed the corresponding section in the text:
Before differencing, the TSX/TDX-DEMs must be vertically referenced. For this purpose the median vertical offset between the DEMs and the TanDEM-X global DEM was measured over stable areas (i.e. tops of nunataks and rock outcrops, which were not affected by image distortions) at altitudes between 150 m and 1000 m (Fig. S1), before both DEMs were adjusted accordingly.
After subtracting the vertically registered DEMs, the elevation differences were converted into yearly elevation change rates. We assessed the accuracy of the vertical registration over another set of stable areas at altitudes between 150 m and 1300 m (Fig. S1). The absolute median value of the extracted change rates was 0.37 m a^{-1} which primarily accounts for errors related to the vertical registration.
…
The comparison between elevation change rates obtained from the 2011–2014 OIB ATM flights and the 2011–2014 TSX/TDX data after the vertical registration of the DEMs showed a maximum overestimation of ice thinning of 1.25 m a^{-1} for the TSX/TDX measurements (Fig. S4 a, b). However, the general trend of the elevation change rates fits well to those calculated from the LiDAR data and significant differences in elevation change were only measured in the lower areas of the glacier tongue. In the upper areas (above 600 m altitude) the difference between ATM and TSX/TDX elevation change rates was close to 0 m. Here the snow volume was likely completely frozen on both dates of acquisition, so that the penetration bias cancelled out. A backscatter comparison showed lower values in 2014 than in 2011 in areas below 600 m altitude, whereas the backscatter in the upper areas above 600 m altitude was similar for both dates (Fig. S4 d).

P7, L23: “determent” is probably the wrong word here.
The word has been deleted during reformulation of the section according to the suggestions of reviewer #2.

P8, L9: It seems there was some slowdown after 1994, and gradual acceleration started in 2003. The selected graphic representation is not favourable for capturing such features.
We thank the reviewer for this helpful comment. We have added a curve showing the (smoothed) median velocities measured along the centreline profile to Fig. 2. The median absolution deviation (NMAD) of the median velocities between 1994 and 2007 is just 0.06 m d^{-1}. Hence, velocities were pretty stable during this time. A comparison of velocities acquired in October 2007 and October 1995 shows almost no difference in median surface velocities. A clear sudden strong acceleration is first visible in 2008 and a strong gradual acceleration is apparent between 2010 and 2011. However, we have changed the corresponding section into:
Figure 2 shows that glacier velocities were rather stable between 1994 and 2007. The normalised median absolution deviation (NMAD) of the median velocities during this time was 0.06 m d^{-1}. A comparison of the velocities on 1995-10-27 and 2007-10-23 (Fig. 3a) along the centreline profile reveals that the median velocity difference between 1995 and 2007 was just 0.04 m d^{-1}.

P9, L7: “Figure 5 shows that prior to the speedup (2004–2008) Fleming Glacier was already affected by pronounced surface lowering.” No elevation change data prior to 2004-2008 are shown in Fig. 5.
We apologize for the misleading phrasing. In Fig. 5 elevation change rates are shown that were calculated from data acquired in 2004 and 2008. The time period 2004–2008 does not refer to the speedup but to elevation change. We have changed the section into:

Figure 5 shows that prior to the speedup in 2008, Fleming Glacier has already been affected by pronounced surface lowering. A clear trend of increasing ice thinning rates towards the glacier front is visible for 2004–2008.

P9, L28: "a vast part of the formerly grounded glacier tongue". "vast part" is a subjective impression; be specific.

We thank the reviewer for this helpful advice. We have changed the corresponding section into:

However, the same calculations for data acquired in 2011 and 2014 (Fig. 6, Track 3–5) as well as patterns of low and positive elevation change rates in the TSX/TDX 2011–2014 dh/dt map (Fig. 4, S7) show that after the final stage of glacier acceleration in 2011 an area of about 56 km^2 *(referring to the front in 2014) of the formerly grounded glacier tongue of the Airy Rotz Seller Fleming system had been floating*

P10, L14: "A possible location of the grounding line after the initial ungrounding in 2008. . ..". Confusing statement. Was the area floating before 2008 and then became grounded again?

We apologize for the misleading phrasing. Until 2008 the frontal part of the glacier tongue was likely pinned to a subglacial ridge (probably a sill) located at the 1996 GL position. However, an ice cavity between the pinning point and a smaller hump ~ 2.5–3 km upstream of the pinning point has probably already existed. In 2008 the glacier tongue likely detached from its pinning point at the 1996 GL position and from then on the glacier was suddenly only grounded at the hump ~2.5–3 km upstream. The grounding line was stabilized there until between 2010 and 2011 it further gradually retreated to its present position ~ 7–9 km upstream. We have changed this section accordingly during restructuring of the Discussion part. We have further added a view graph to the supplement (Fig. S 8) showing our interpretation of the ungrounding process, in order to make it better understandable to the reader.

P10, L25: The Rothera station data (near Wordie I.S.) do not show a cooling trend for recent years. Oliva et al. (Science of the Total Environment 580, 210–223, 2017) report higher mean annual air temperature for 2006 to 2015 than in the previous decades.

We thank the reviewer for pointing us to the publication of Oliva et al. (2017). In contrast to other studies (e.g. Turner et al., 2016) which found an overall cooling trend for the entire Antarctic Peninsula since the late 1990s based on stacked temperature records, this study provides a regional analysis of temperature trends at different stations across the Antarctic Peninsula and the South Shetland Islands (SSI). Indeed Oliva et al. (2017) report higher mean annual air temperatures (MAAT) for the period 2006-2015 at Rothera and San Martin (which is closer to Wordie Ice Shelf than Rothera) than in previous decades. While the decadal mean temperatures at all stations on the SSI and the N-NE Antarctic Peninsula were 0.2-0.9 °C lower in the period 2006-2015 than in the period 1996-2005, at Rothera and San Martin decadal mean temperatures were 0.1 and 0.2 °C higher, respectively (Fig. 1 and Tab. 5, Oliva et al., 2017). However, when looking at decadal temperature trends, Oliva et al. (2017) reveal that although temperatures at Rothera and San Martin do not show a continuous cooling trend as recorded at other stations since the late 1990s, warming rates at both stations have decreased markedly since the decade 1996-2005 and a cooling trend was present between 2006 and 2015 (Tab. 5 and Figs. 2 and 4, Oliva et al., 2017). We consequently reworded the corresponding section into:

Furthermore, a trend of cooling air temperatures is reported for the Antarctic Peninsula since the end of the 1990s (e.g. Turner et al., 2016). Although decadal mean surface temperatures in the period 2006–2015 were 0.2 °C higher than in 1996–2005 at San Martin station (~120 km north of Wordie Ice Shelf), warming rates have decreased markedly since the decade 1996–2005 and show a cooling trend in 2006–2015 (Oliva et al., 2017). This may have reduced surface melt during recent years.

P10, L31, L32: Here it is stated that "flow acceleration usually affects both the floating and the grounded part of the glacier, but is largest near the grounding zone", and also "This is consistent with our observation of a highest relative speedup by _32–35 % between 7 and 11 km upstream". If the highest speedup is 7 to 11 km upstream, the second statement is not consistent with the first one.

The sentence has been removed during rewriting of the section.

P11, L4: Any direct observations supporting the statement that basal melt is particularly effective in the grounding zone?
Same answer as for P1, L16

P11, L6: In which respect is the bedrock topography "unfavourable"?
The trough underneath Fleming Glacier has a retrograde slope. Such a bed topography is known to be an unstable configuration which fosters rapid grounding line retreat (e.g. Rignot et al., 2014). We have added a note on this during rewriting of the Discussion section.

P11, L7, L8: Fig. 5 shows thinning rates only for grounded ice. This does not provide any clear link to basal melt rates of the floating part in the grounding Zone
We agree. However, it has been shown by several other studies that Wordie Bay is subject to intruding warm CDW which causes substantial subglacial melt. Hence, it is very likely that basal melt also occurred prior to 2008 at the pinning point (at the 1996 grounding line). The sentence has been deleted during rewriting of the Discussion section and the central statement has been changed accordingly.

P12, L12, L13: "Our data suggest that enhanced basal melt at the grounding line due to increased shoaling of warm CDW most likely played a major role for the recent changes at Fleming Glacier." This conclusion is not based on the measurements presented in this study, but rather on measurements in other locations and reported in other publications.
We agree with the reviewer. We have changed this during restructuring of the Discussion section. Apart from that, same answer as for P1, L16

P12, L21: Please explain the expected "fatal effects on the stability and sea level contribution".
Modelled bed topography shows another deep subglacial trough with a retrograde sloped bed geometry 3-4 km upstream of the current grounding line. If the grounding line retreats to this trough, this may trigger a positive feedback loop of rapid grounding line retreat, flow acceleration, dynamic thinning, increased calving, and mass loss (marine ice sheet instability). However, we have reformulated and weakened the statement during restructuring of the Conclusion part

P19, L5: Fig. 1 caption. Please check the dates for Sentinel-1 data. One year time span for velocity retrieval?
We apologize for the mistake. The data used for calculating the velocity were acquired on 28-08-2015 and 09-09-2015. We have changed this.

P24, L5: Fig. 6 caption. "Fulfillment of floating condition". Does this refer to grounded or floating ice?
We apologize for the misleading phrasing. Orange dots show grounded ice along PIB flight lines as derived from hydrostatic equilibrium for the time before acceleration. We have changed the caption into:
Orange dots: Grounded ice before acceleration as derived from PIB LiDAR and ice thickness data. Dates of PIB flights: a) 2002-11-26, b) 2004-11-18.

P24, L7: "Fulfillment of the hydrostatic equilibrium condition". Same question as for P24, L5.
We apologize for the misleading phrasing. Blue dots show freely floating ice and red dots show grounded ice along OIB flight lines as derived from hydrostatic equilibrium for the time after acceleration. We have changed the caption into:
Blue and red dots: Freely floating and grounded ice after acceleration as derived from OIB laser altimeter and ice thickness data. Dates of OIB flights: c) 2011-11-17, d) 2014-11-16, e) 2014-11-10.

L25, Table 1: SAR, column 6 shows single dates (not "Time Interval") Supplement

We thank the reviewer for pointing us to the misleading labelling of the column. Indeed the dates in the column refer to time intervals of SAR data used in the study. We have changed the labelling of the column to make this clearer to the reader.

Table S2: Pixel size should be accurately specified in along track (or LOS) and across track direction. These can be quite different even for a single sensor (e.g.Sentinel-1).

We agree with the reviewer that pixel sizes can largely differ between the across track and the along track direction. Hence, to make a conservative estimate of velocity errors, we always chose the coarser resolution value to be the image resolution Δx used in Formula 1 (S 2). In order to make this clearer to the reader we follow the recommendation of the reviewer by adding two columns to the table which show the resolution in ground range and azimuth. We also have changed the caption of Table S2 accordingly:

Ground range resolution Δx_{GR}, azimuth resolution Δx_{AZ} and image resolution Δx used in Formula 1 (S2) for calculating velocity errors. For most of the sensors Δx_{GR} is coarser than Δx_{AZ}, except for Sentinel-1a that has a coarser resolution in azimuth direction and TSX/TDX which have fairly equal resolutions in both directions. In order to make a conservative estimate of velocity errors, always the coarser resolution value was chosen to be Δx

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