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Interactive comment on "Connected subglacial lake drainage beneath Thwaites Glacier, West Antarctica" *by* Benjamin E. Smith et al.

Anonymous Referee #2

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1 General Comments

The authors demonstrate for the first time the existence of active lakes in the fast flowing Thwaites Glacier catchment akin to those identified through InSAR and repeat laser altimetry in the Siple Coast and East Antarctica. Most persuasive is the signal seen in the repeat WorldView DTM data, which unfortunately has limited coverage. If the authors address concerns related to their integration of two Cryosat products (detailed below) this paper will provide valuable observations on the distribution of these features. In addition, any potential signal seen from IceBridge flights over these targets should be addressed. The comparison with grounding line velocities is informative.

There are problems with the discussion and conclusions. There are gaps in the litera-

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Discussion paper

ture addressed, and some apparent confusion about literature that is cited. The paper is strongest on the observational side; much of the hydraulic routing is not novel, and doesn't matter that much to their conclusions - I would suggest focusing the paper more on the observations and less on the routing and recurrence time arguments. The statement in the conclusion that subglacial hydrology is not important is to focus to much on the transient response using the Byrd Glacier paradigm, and to make assumptions about what is fundamentally organizing the basal shear stress on the bed.

Figures could do with a work over (detailed below) for clarity, and much of the terminology for datasets needs to be rendered consistent. **While the primary observation is clearly worthy of publication in the Cryosphere, I recommend major revisions.**

2 Specific Comments

page 1: line 29 Schroeder et al., 2013 (doi:10.1073/pnas.1302828110) and 2015 (doi:10.1109/LGRS.2014.2337878) were explicit that the observed basal hydrology was highly collimated large aspect ratio canals, a little bit different from "small pockets". Notably, as can be seen in figure 2B of Schroeder et al., 2013, and from Young et al., 2015 (doi:10.1098/rsta.2014.0297) the region of the proposed lakes lies within the region of the anisotropic water system. The geometries inferred from the 2005 radar in Schroeder et al., 2015 are difficult to reconcile with the amount of storage inferred by the 2014 observations. The authors might want to place this lake observation in context of these other papers.

2: 4 It appears that there are two IceBridge ICESat reflight lines (OIB 20111112 and 20141122) that crossed these features with ATM data spanning the interval in question **- the authors should either perform that straightforward dtdz comparison or explain why it is invalid.**

2: 21-38 A big deal is made of the combined use of the POCA and swath products, but

there is little representation of where POCA and swath products are used; in particular for where these products are with respect to the lakes. **I suggest that the authors add a figure for the 2011 DEM showing where POCA returns and swath points are wrt the lake outlines.**

The WorldView product validates to the dzdt result, however it seems the (apparently unbiased) POCA will cluster on the highs, and swath (with significant inter-season biases) should fill the topographic lows - exactly where the majority of the dHDt is observed. Note that the simulated image in Figure S2 will primarily respond to the highs that will be well mapped by POCA, and not have much as signal for the local, flat lows mapped by swath. **On line 34, the source of the DEM that the ambiguous swath measurement is compared with should be explicitly stated.**

Grima et al., 2014 (doi:10.1002/2014GL061635) point out that this exact area of Thwaites Glacier has considerable variability in firn density (notably one detected at radio frequencies due to variations in dialectic contrast) that is related to surface slope. As the steepest surface slopes (and higher density firn) bound the features, its seems plausible that low density firn preferentially fills the lake features. **The authors should present a case that either time varying penetration of low density firn or actual densification of low density firn does not represent part of the lower signature.**

3:22 Provide a citation for the laser altimetry datasets

6:33 The Bedmap2 derived flow routing should be shown in supplementary materials, in addition to the comparison bed and hydraulic maps.

7:7-8 *"Before this acceleration, this area was slowing at about 50 m yr^{-2}, and after the start of 2014 it returned to this slowing rate."* The sentence is difficult to follow because the reader is tasked with keeping track of four demonstratives. **Reword for clarity by explicitly stating what "this", "this", "it", and "this" mean.**

7:14 This section is a completely incorrect representation of the Siegert et al 2014

paper. Seigert et al., 2014 based on radar observational concurred with the uncited Sergienko and Hulbe, 2011, (doi:10.3189/172756411797252176) that fast flowing ice streams subglacial water would cling on the lee side of subglacial topography, rather than forming a classic subglacial lake - a result that is supported by this work (the inferred lakes are all hanging off of bedrock ridges, rather than siting in the middle of bedrock basins). **Section should be rewritten after a more careful rereading of Seigert et al 2014 and Sergienko and Hulbe, 2011.**

7:17 A quantitative value for the volume of subglacial material is mentioned for the first time here, but the authors have not been clear about how the subglacial volume has been calculated. We are left to assume that the authors have equated surface elevation change with subglacial volume change. If that's true, state it explicitly. Sergienko et al. 2007 (doi.org/10.1029/2007GL031775) argue that the surface volume change corresponding to a subglacial lake drainage event should not be conflated with the volume of subglacial water drainage, although it may be admissible if there is not change in velocity. **Explicitly state how surface measurements have been used to estimate subglacial water volumes, and provide appropriate justification.** Also remove the hyphen from "4-km^3 volume".

8:12 *"With this model, and upstream lake could overflow into a downstream lake, which would subsequently cause it to overflow, which would trigger the next event."* The process described here and the methods used to observe the process are quite similar to Flament et al. 2014 (doi.org/10.5194/tc-8-673-2014), yet there is no mention of the Flament et al. paper anywhere in this manuscript. **Cite Flament.**

8:30 The steady state method routing of Schroder et al., 2014 (doi:10.1073/pnas.1405184111), as stated in that paper, only was applied to regions where radar reflectivity as of 2005 indicated that hydrostatic canals with smooth interfaces dominated the bed echo return. In addition, its important to say in this context that transient lakes such as these have not been shown to have a strong enhanced radar reflectivity signature - while the geothermal flux method of Schroder

et al., 2014 is relying on the spatial variability of the “background” reflectivity signature of the hydrostatic canals, as they cover more or less of the bed.

9:23 The Conclusions section begins by mentioning a value of >3.5 km^3 for subglacial water volume, although this value did not appear anywhere in the Results section. It is unclear whether >3.5 km^3 refers to the 4 km^3 mentioned on page 7, line 17. Do these different values represent the same physical quantity? Why don’t they agree? **Clarify.**

9:37 The logic that the subglacial water system does not matter much because of the lack of response to the individual drainage event is flawed. As the authors point out, (and is pointed out in Sergienko et al., 2014), much of the basal drag in this system is restricted to distinct bands, which control the stress state and flow of the glacier. The conclusion of Schroder et al., 2013 was that in these high drag zones, more water would not affect bed coupling (even if it was episodic). However, much of the ice flow between these bands is currently over sliding bed with distributed water systems. The argument of Schroder et al., 2013 is that it is the transformation of these distributed water systems into channelized flow (like the current high drag bands) that would change the stress state of the entire system.

3 Technical Corrections

1:17 TWG is not defined and is not used anywhere else in the manuscript.

1:21 and throughout the manuscript "Thwaites glacier" should be "Thwaites Glacier".

2:21 and throughout the manuscript "Cryosat-2" should be "CryoSat-2".

2:30 comma needed; change "$-2\pi 0$, and 2π" to "$-2\pi, 0,$ and 2π".

3:10 "AMES" should be "Ames".

3:18 Fix "We generated a bed DEM was generated based on..."

3:19 and elsewhere "BEDMAP-2" should be "Bedmap2".

3:21 MCoRDS is miscapitalized and misspelled.

4:29 "LANDSAT" should be "Landsat".

4:29 TSX is defined but not consistently used later.

4:32 "Landsat-8" should be "Landsat 8".

5:31 "Worldview-2" should be "WorldView-2".

5:32 Inconsistent lake naming: "THW$_{124}$ and Thw$_{70}$" should be "Thw$_{124}$ and Thw$_{70}$".

6:3 Two issues here: Previous sub-figures have been identified with capital letters, but here "Figure 3a" is identified with a lowercase "a". Inspection of Figure 3 reveals no panels labeled "a" or "A".

6:33 "Bedmap-2" should be "Bedmap2".

6:34 and throughout the manuscript Capitalization of the word "figure" is not consistent. On this page we have "figure 4C" and "figure 5", but elsewhere in the manuscript (e.g., page 2 line 7) we see the more common convention of capitalizing "Figure". Whichever capitalization is chosen, it should be consistent and capitalization of the word "Table" (e.g., page 6, line 37) should match.

7:37 Change "there is uncertainty our" to "there is uncertainty in our".

8:4 A sentence begins "Despite these limitations..." What limitations?

8:5 Change "the lakes drainages" to "the lake drainages".

8:5 Change "where some of deepest closed basins" to "where some of the deepest closed basins".

8:6 and elsewhere The word that previously appeared in the manuscript as "figure" or "Figure" now appears as "Fig" without a period and occurs later on line 10 as "Fig."

with a period. Be consistent.

8:10 Figure 3d is referenced, although no such figure exists.

8:14 Change "its inconsistent" to "it's inconsistent" or "it is inconsistent".

8:14 The word "draining" should be "drained", but for readability consider changing "...which suggest, although not definitively, Thw_{124} drained first." to "which suggests Thw_{124} likely drained first."

8:15 It is not clear what process the word "this" refers to in the phrase "this should not trigger the other lakes" .

8:27 Change "by substantially short paths than shown" to "by substantially shorter paths than shown".

8:41 Remove the period after (Joughin et al., 2009).

9:26 The primary quantitative results of this paper have changed yet again, as subglacial water volume is now listed as 3 $\mathrm{km}^3 - -25\%$ less than its original value.

10:7 The acronym stands for "Ice, Cloud, and land Elevation Satellite".

13:7 This is the second equation numbered 19. Be sure to fix the caption of Table 2 accordingly.

13:37 "terrasar-X" should be "TerraSAR-X".

Table 1 Headings T_{local} and T_{total} should be explicitly defined in the caption.

Table 2 The letter E should be explicitly defined in the caption.

Figures In general, the figure captions don't contain enough information to describe the figures on their own. This is a problem for people who like to skim the figures before reading the paper.

Figure 2 Mention region is the box in fig 1? Is elevation shown as the shading? If so,

which elevation was used? Mention that A and B are cryosat, then give dates Maybe add labels to the 4 lakes, since they're used in Fig 3. Fig 2c There is a green streak that appears to be a correlated error

Figure 2 caption "Worldview" should be "WorldView-2" or use the acronym that was introduced in the main text.

Figure 3 Mention that outlines are from Fig 2. "mean elevation change" with respect to what?

Figure 4 This isn't quite the same outline as shown in Figure 1 for Figure 2. Please provide a context map. What GL are you plotting here? Mention how the melt-rate was derived. "melt rate from basal shear"

Figure 4 caption Rather than simply, "C. Melt-rate estimate." remind readers how melt rates were estimated, or what dataset is plotted. An added suggestion to improve this figure and others: it seems the subplot titles have been left out of the figure itself and have been moved to the caption, where they displace meaningful information and task the reader with keeping track of which subplot is which. Figure captions provide an opportunity to describe processes, to give the reader clues about what we should be seeing, to give insight and understanding. Instead, in this figure caption and in others all we are given is a list of sentence fragments that would be more appreciated as subplot titles.

Figure 5 This suggestion may end up in a too-cluttered figure, but it would be helpful to know which platforms were used to obtain the different velocity measurements. I'd like to have seen dotted lines (or grey bars) for the lake locations Mention that grey bar in inset is the drainage event.

Figure 6 Include AB labels on the right image As mentioned before, I'm worried about region C's location relative to the drainage pathways and where you'd expect velocities to be changing.

Figure 6 caption "Terrasar-X" should be "TerraSAR-X". Include AB labels on the right image As mentioned before, I'm worried about region C's location relative to the drainage pathways and where you'd expect velocities to be changing.

In the supplemental data `bed_DEM.tif` was identical to `surface_DEM.tif`

`Thw_lakes_outline.gmt` had severe parsing problems in gdal with leading spaces and the additional commented lines - a simple ASCII table would be preferable.

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