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The Cryosphere
Discussions

Interactive comment on "Cascading water underneath Wilkes Land, East Antarctic Ice Sheet, observed using altimetry and digital elevation models" *by* T. Flament et al.

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1 General Comments

In this paper the authors assimilate a suite of elevation data derived from satellite remote sensing, primarily ICESat, Envisat, and SPOT5, to better characterize a highly unusual subglacial drainage event (the so-called "CookE2 Flood" first described by Smith et al., (2009)) and infer the fate of the water released from this lake. This follows

upon work by Carter et al., (2011) and Fricker et al., (2010) showing that a greatly improved understanding of the large scale subglacial hydrologic system can be revealed through the careful analysis of complimentary lines of remote sensing data analysis and the application of water budget modeling to account for water released from upstream. Overall the analysis part of the study appears to be based on solid analyses and logic, and is potentially quite interesting

While this manuscript holds promise, in its current form it suffers from confusing organization, and poor and sloppy use of the English language. The result is that some important concepts are not explained very clearly and other pieces of logic cannot be located without a certain amount of hunting. Furthermore, there are some surprisingly naïve statements made about subglacial hydrology to introduce the study, that really have no place in a paper on subglacial hydrology, for example "It might seem surprising that liquid water can exist under the ice of the coldest continent on Earth." Given the 3rd author's publication record on sub ice sheet hydrology (e.g. Remy et al., 2003), it is surprising that the paper does not convey a fuller sense of immersion in the extensive literature that has preceded it. The paper requires major revision to bring it up to standard. Although I have compiled an extensive list of fixes and edits, the list should be thought of as a representative subset of larger structural problems. I recommend that the authors engage a (preferably native English) proof-reader to assist them with the significant editing task that lies ahead. It is above and beyond the task of any Editor or Reviewer to improve the English and grammar in the manuscript to the level that would be acceptable for TCD. Overall the combination of poor organization, awkward wording, lack of perspective with regards to related literature, and the sloppy figures is consistent with authors who have rushed their submission of the manuscript. While there can be many motivations for doing so, none of them justify such an abuse of the TCD open access system.

Overall, the illustrations are interesting and show a great deal of logical progression, but unfortunately they fail to communicate some concepts that I believe are essential for a study of this nature. The most importantly omission is a map of the regional hydropotential. To assist here, I have included a hydropotential map based on Bedmap2 (Fretwell et al., 2013) and a velocity map (based on Rignot et al., 2011) with my review. A figure of this nature would be a critical addition to the manuscript. Secondly the layout and inconsistent labeling between figures makes them appear as if they were imported directly from the analytical software into the manuscript without any attention given to making them presentable to a non-specialist. This is particularly frustrating because the authors have plenty of experience making presentable figures (e.g. Flament and Remy, 2012) and many of the fixes necessary would not have been particularly time consuming (I was able to create improved versions of Figures 4 and 5 in less than an hour (see figures R1 and R2 (supplemental file))).

2 Specific Comments:

Introduction

P842 L21: This sentence is kind of awkward.

L23: The presence of liquid water at the base of the ice sheet is not surprising at all, we have known about this for decades (e.g. Oswald and Robin, 1973). You are trying to say that over 300 lakes have now been identified beneath the Antarctic Ice Sheet, the coldest place on earth at the surface. Liquid water persists at the base due a combination of geothermal/deformational heat and the insulation provided by the overlying ice. This is well established! In fact you can probably shorten this whole paragraph and make it sound a lot better (here is where the proof-reader comes in!).

P843 L4: This is an awkward sentence that requires rewriting and proofreading. You're

saying that the ability of various methods of satellite monitoring of surface elevation change have allowed us to infer the filling and drainage of subglacial lakes, but that their influence on the flow of the overlying ice is uncertain.

L14: Here you want to cite Smith et al., 2009 as the first *continent-wide* inventory of lakes.

L15. This is not the correct use of the phrase "In particular". It's an important fact for your paper, but was a small part of Smith and others, 2007.

L23: I recommend the term "leverage" instead of "take advantage of."

It should be stated more clearly that the CookE2 flood was a pretty exceptional event when compared to any of the other lake drainage events in Antarctica. While the volume lost was only 1.5 - 2 times that for any other lake, the vertical change was nearly an order of magnitude greater than what is observed anywhere else on the continent. Indeed it is closer in magnitude to the floods from subglacial lakes under the Vatnajokull Icecap (e.g. Björnsson et al., 1998).

Section 2

A. This section requires significant editing and would benefit from some restructuring. I recommend adopting the first person, active voice for methods, i.e. "We processed the data", rather than "the data were processed". Let me suggest the following sub-section headings:

2.1 Data

2.2 Data processing (where you talk about observing drawdown / uplift)

2.2.1. Error sources

2.3 Water Modeling

B. I recommend a chart or table of each of the remote sensing data products used that includes certain technical information, like footprint, approximate track spacing, along-track sample density, duration of mission and possibly corrections applied. Not every TCD reader is familiar with these instruments and their products.

C. ICESat. There is standard nomenclature when working with ICESat data. The laser campaigns are called “Laser 2a”, “Laser 2b, etc”. The timings of the campaigns are generally given by months rather than seasons, due to confusion with NH and SH seasons. The release of the data you use is not the latest release - Release 531 (not 31) is about 1.5 or 2 years old. You should be using Release R633 for your work. Also, there has now been a Gaussian-Centroid offset identified (see NSIDC website), and this might have some impact on your results. What inter-campaign bias do you apply, if any? It probably doesn’t matter for the drainage of CookE2 (since the signal is so large), but I suspect it might be more of an issue with observing uplift downstream.

D. While it is nice (and useful) to see a comparison between ICESat laser and Envisat radar altimetry, there are some important points that appear to be overlooked. There are substantial differences between radar and laser altimeters, in particular with regards to sub-surface penetration depth, yet this important fact is not even discussed. What about the differences in footprint sizes? This information may appear at other places in the manuscript, but this Data section is the place to discuss the characteristics of the data you are using for the study.

E. Can you provide a hypothesis as to why there was a “tilt” between the Aster and SPOT5 DEM’s? Also could you describe precisely the domain over over-which you are comparing the SPOT5 DEM against ICESat data and the ASTER DEM?

P844 L3: Passive voice. The verb should not be the last word in the sentence. Indeed you could probably shorten this paragraph significantly.

P844 L4: These sentences really do not tell us very much, except that the logic of the techniques applied is apparently well established in the literature.

P844 L24: Please provide some examples of rugged terrain.

P844 L24: In this sentence “In the following, time series . . .” there should be another word between “following” and the comma

P846 L23: I assume you mean ICESat? Other readers might not assume this. Also what do you mean by standard deviation?

P846 L29: I am not sure what you are trying to say here. I understand that you are using ICESat, ASTER and SPOT-5, but it’s not clear how you are accounting for the differences between the various data products.

Section 3

Is this now Results? The Methods sentences at the start of this section should go to Methods.

A. At first it seems as though you assume a 1:1 relationship between surface displacement and volume change, when there are many reasons this might not be the case. While you do mention possibilities of water flow into the depression, ice flow into the depression and snow blowing into the depression, there are several other issues that may be considered (see point B of this section). Moreover, you discuss these sources of uncertainty present many paragraphs after describing the initial assumption, and then go on to perform your calculations for volume change without any further consideration of the errors. This discussion of possible sources of error really needs to be moved up to methods and given more consideration in subsequent calculations.

B. The assumption from Smith et al., (2009) is probably less valid for lake CookE2 than it would be for any other known subglacial lake in Antarctica. The assumption works fine for a lake in a relatively shallow basin surrounded by slippery sediments undergoing a few m of elevation change. The assumption becomes more problematic when you're dealing with a lake undergoing 10's of meters of elevation change, surrounded by steep bedrock topography. Sergienko et al., (2008) has a decent discussion about surface change versus lake volume change. For this situation however, I wonder if ice flowing into the depression following the lake drainage, as described in Pattyn (2008) might explain the apparent refilling? In the end there are a number of hypotheses for the apparent filling during the later part of the observation cycle, all of which seem testable with the current datasets.

C. They authors should include some material on the initiation of lake drainage and subsequent evolution. I suggest starting with reading Fowler (1999) and Evatt et al, (2007), which deal with flood initiation and surface deformation associated with a subglacial flood.

P847 L8: should probably be written like: "we use a combination of . . . . "

P847 L10: Should read something like "the intersection of ICESat tracks XXXX and XXXX appears to coincide with the location of maximum surface drawdown"

P847 L12: Is it a second lake or just another part of the lake missed by the smith et al., 2009 inventory? I suspect the latter.

P847 L21: For perspective: 3m is about the order of magnitude of total elevation change for some lakes.

P848 L1: You seem to have a number of sources of error here. That is fine, but an introduction sentence or list might help the reader follow your logic. Also I am surprised how low the number is relative to the total volume change.

P848 L14: I am not following here. Are you saying that water was flowing out of the lake while it was increasing in volume, or are you trying to account for water flowing into the lake while it was draining? I suspect the bit about ice flow into the lake basin versus water flow might apply here.

Section 4

A. It would be good to include a few sentences on data quality, and interpolation issues. In this case much of the region around CookE1 and CookE2 is pretty well surveyed

B. There's a little bit of a logic issue here: You may want to refer to Carter and Fricker (2012) Ann. Glaciol. paper discussion on tuning. I appreciate that you have a different method with the probabilistic route finding and that the method is highly reproducible, but it appears resolution limited. LeBrocq et al., 2006 has some other routing methods that may get more water into CookE1, and a close look at the hydropotential from Bedmap2 (Figures R1 and R2 (supplemental file)) suggests that it is possible.

C. I appreciate the work on automatic lake detection, however a review of Carter et al., (2007) and / or Fricker et al., (2010) would indicate that you need a hydropotential low as well. The fact that you can account for the water volume lost from CookE2 from your integration of surface uplift downstream holds substantial promise. I am just not sure how much effort was made to tie surface change to actual lake boundaries. As it stands now each point representing 12 km^2 without considerations to shape is a bit suspect.

P849 L20: Although Carter et al., 2011 discusses water routing and water conservation in a manner that is relevant to this paper, Shreve (1972), is actually the better reference for calculating hydropotential.

P849 L22: you may want to introduce hydropotential a little earlier. We need a figure of this, as I stated earlier.

P850 L20: I'd be curious to see a sentence or two on the distribution of lakes versus bed topography data quality (See Fretwell et al., 2013). Also you should ask yourselves: are the lakes you find located in hydropotential lows? They should be (See Figures R1 and R2 (supplemental file)).

P851 L16: There are many databases for surface mass balance (e.g. Lenearts et al., 2012). I suspect using data from one of these will make your argument stronger.

P851 L22: Could some of this inter-annual variation be essentially "noise? (e.g. Lenearts et al., 2012).

Section 5

Section 5.1. The limitation of relying solely on ICESat for lake shape is not a new concept (Smith et al., 2009; Fricker et al., 2010).

P852 L17: You may want to mention this a bit earlier. Also you have mistated Smith et al., (2009); it was not a "natural assumption" it just making the best out of a limited number of data points.

Section 5.2. I would remove the word "classic". Should this sub-section be renamed "Inability of satellite radar altimetry to..." Also please note that Fricker et al., 2010 described the limitations of satellite radar altimetry for monitoring active lakes under ice streams, noted that it is not possible to retrieve an elevation measurement from inside the surface trough of a lake whose diameter is similar to the PLF of the radar altimeter, and showed that the ICESat time series and Envisat time series for the same period for the same lake were not correlated. In light of that work, I think it's more significant that radar altimetry works so well in other parts of the ice sheet.

Section 6

The new material mentioned in the Conclusions really does belong earlier in the manuscript and should be inserted elsewhere first if you are to use it here.

P856 LL23: It's nice that you make the Iceland comparison, however the Conclusions is not the place to bring up new material (nothing new should appear in the Conclusions).

P857 L9: Try rewriting this as "The dense temporal sampling of Envisat allows a more precise constraint for the onset of lake drainage."

P857 L9: What kind of surface features?

P857 L16: "That outlet glaciers that flow into Cook Ice Shelf drain part of the deep Wilkes Subglacial Basin, where much of the bedrock lies below sea level."

Tables

Table 1 caption

If you are instructing readers to "(see text)" you may want to be more specific as to which part of the text is relevant to the table.

Figures

Figure 1. A color bar would be helpful. I can barely make out the little boxes. I suggest combining this with figure 8 and comparing the estimated areas.

Figure 2. Why do you put the values on each data point? We can all read a graph.

Figure 3a-c. The white arrows don't show up against a white background. Also label the red and blue lines.

Figure 3d. This needs axis labels and longitude latitude lines. Also the time interval is not clear here.

Figure 4. make the map units in km

Add lines of longitude / latitude

This is probably the best place to add hydropotential (Figure R1 (supplemental file)).

Figure 5. I like the concept behind this, however I have several suggestions for improvements:

Use a larger font on the color bar, and perhaps make it months and year (i.e. Jan 2007, Mar 2007 etc . . .)

For the background contour map use hydropotential rather than surface elevation.

Outline your "lakes"?

Make the map units in km.

Add lines of longitude / latitude.

For your caption you may want to specify where in the text.

This might also be a good place to include surface velocity as well as hydropotential.

Figure 6. I appreciate that by changing the sign on the volume change for CookE2 to from volume gained to volume drained you get the curves to match. The danger

in the line you use for CookE2 drainage is that you are implying that it subsequently inflated after drainage. I recommend making the volume change for CookE2 and all downstream lakes all the same sign, otherwise it is confusing to the reader.

Figure 7. It would look much better if you could make the x axis the actual year, rather than years from 01 / 01 / 2000.

Also the "a" and "b" should be in the upper right of each subplot

Figure 8. Why not compare the area of the lake from MOA with the other area estimates you have?

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