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Interactive comment on "Quantifying the resolution level where the GRACE satellites can separate Greenland's glacial mass balance from surface mass balance" *by* J. A. Bonin and D. P. Chambers

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Thank you for your helpful review. As I understand it, you had several general concerns, regarding the overall clarity of the paper. We hope we have improved this via the following methods:

1.) Including the basic math surrounding the inversion technique, as you suggest.

2.) A major rewrite of sections 3 (simulation definition) and 4 (analysis of results), focusing on a clearer overview of the "SMB" versus "GMB" simulations, the differences

between the two, and the rationale behind them. We have explicitly divided section 4 into separate SMB-misfit and GMB-misfit sections, which should also eliminate potential confusion. This should clarify the differences between figures 7 and 8 as well. We have endeavored to make things more clear in the text and apologize for the confusion. (The typo you mentioned at the beginning of section 4.1 only made the confusion worse, and has since been corrected.)

As to your specific comments:

1.) Page 1317, Line 22: I am sure you are aware, but perhaps it is worth mentioning that some GRACE solutions extend beyond degree 60, but these degrees are mostly contaminated by noise.

Agreed. I have added the line “However, this benefit must be balanaced with the cost of greater satellite errors at higher degrees.”

2.) Page 1318, Line 25: You state that you use the RMS from the RACMO2 ice model. I C406 believe referring to this as a regional climate model is more appropriate.

Thank you. I have made this correction.

3.) Also, please include additional description of what you mean by the RMS. Is this the RMS of SMB anomalies about some mean time period, or are they absolute SMB values? What time period are you computing the RMS for?

I have altered this section to read: “We sum the RACMO2 regional climate model’s [Ettema et al., 2009b] surface mass balance over time, from 2002-2012. This gives grids of cumulative SMB. We remove the mean to create grids relative to the mean mass of 2002-2012 at each location, similar to GRACE monthly mass anomalies.” I hope the above phrasing, including the more accurate term “cumulative SMB” rather than just “SMB” makes things more clear.

4.) I can imagine that in locations for which the mass balance is dominated by dynamics, rather than SMB (such as Northwest Greenland and Southeast Greenland - see

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Velicogna, 2014), that this regional-dependent weighting scheme is insufficient and introduces errors which are unaccounted for in your process. Could you comment on this?

Yes, I am aware that when using SMB only to define the basins, we will not create the "space" to hold mass change via glacier dynamics. That is a large part of the goal of this paper: to see how large errors will be, if we only use the typical technique of estimating basins via SMB. We added this section to make that clear: "While these additional three basins obviously do not include many other areas of active glacier dynamics, the very large signal size of these three glaciers made them a good test case for determining if the effect of glacier dynamics could be backed out using GRACE and an inversion technique. Additional glacial basins could be added as desired in the future."

5.) Page 1322: Why did you choose to make only 6 simulated data sets? This does not seem like enough to achieve statistical significance in your results. Are you confident that you have done so, and can you explain this choice?

We chose a small number of simulations because of the time commitment required. The time needed to run these cases is not too long for the 60x60 cases, but gets very lengthy for 120x120 and 180x180. (For the record, the creation of 250 SMB and 250 GMB simulations at 5 maximum spherical harmonic degrees is still continuing as I type this seven days later. It's not hard to do, just time-consuming.) However, since all of the reviewers felt this was a major concern, we are currently recreating the cases to have 50 simulated runs.

6.) Page 1323, Line 5: The use of GMB and SMB is perhaps a bit careless throughout the manuscript, and it shows very clearly here. In Figure 5c, you have the GMB of a glacier going positive. In fact, the GMB is always negative; glaciers are always discharging. I believe what you are showing in Figure 5 are anomalies with respect to a background discharge rate? Same comment with respect to SMB, for instance on Line 8, you state that the this discharge signal is much larger than the SMB signal. However,

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the full magnitude of the SMB is generally very large and very positive - I believe you mean "SMB anomaly" rather than "SMB signal", where the SMB is an anomaly with respect to some mean timeframe?

I have clarified by using the more exact term “cumulative SMB”. Additionally, due to the suggestion of another reviewer, the glacial dynamic mass balance effects are now named as “cumulative DMB” . Sorry for the confusion due to the short-hand version of the correct term.

7.) Page 1327, Line 7: Please explain what you mean by "relative strength of the SMBmisfit errors over the GMB-misfit errors". Even though there are clumps of 6 in Figure 9, it is difficult to see this, and the reader does not know which clump of 6 belongs to which run?

Because I am now running 50 cases for each simulation set, figure 9 is likely to change entirely. However, when I do finally have the simulations complete and the inversions done, I will keep this in mind and revise the line appropriately.

8.) Figure 9: Here, you show the simulated mass balance for the glacier basins. I assume you could also show this for the other basins (where only SMB was modeled)? Is it possible to do this, or perhaps show just a couple of these, so to elucidate the reader C407 on both your processes as well as your results?

Unfortunately, because the cumulative SMB signal varies with each simulation (unlike the summed GMB signal), such plots are almost impossible to read. I can create plots like this showing the SMB-only inversion results minus their “truth” simulations, but that would really only show each run’s RMS error on top of each other, which is already measured in Figures 7a and 8a. When I did so, the plots were very messy confusing, since the cumulative SMB signal is so much more complex than the simplified GMB signal. I would not recommend it, for that reason.

9.) Page 1330, Line 22: It is stated that a stripe reduction could allow for separation be-

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tween SMB and GMB. However, this separation is only possible for annual timescales, since you must apply a yearly smoothing to the data, is this correct?

That is correct. I added the clarification as: “Significant stripe reduction could potentially allow for cumulative SMB and GMB to be separated using the least squares inversion method, particularly if errors are reduced via temporal smoothing.” In my experience, it would take a much larger error reduction to sufficiently remove the month-to-month stripes, and that’s tough to do without also removing the month-to-month signal. Hypothetically it’s possible, but it’s a far tougher problem.

10.) Also, can you please address the issue of having other smaller outlet glaciers within your "SMB" basin? That is you are trying to separate SMB from the three largest outlet glaciers. However, inherently, there are other glacier dynamics that you are capturing in your SMB because of smaller outlet glaciers that you are not modeling. Is this correct? Could you comment on this in the manuscript?

I have added the following paragraph to the introduction, to clarify our motives and methods, and also explain why we picked only the three “big” glaciers that we did: “We expand this technique to include regions designed to contain the mass signal of the largest of Greenland’s glaciers: Kangerdlugssuaq, Helheim, and Jakobshavn. These glacial regions experience two different physical processes atop each other: the localized DMB signal and the broader-scale SMB signal. Unlike most places in Greenland, the DMB signals in Kangerdlugssuaq, Helheim, and Jakobshavn glaciers are expected to be larger than the local SMB signal. That fact allows us to potentially separate the dynamical effects from the SMB effects in these regions, by making a pair of assumptions. First, since SMB is correlated over fairly large regions, we assume that the SMB signal across each of the large glaciers is similar to the SMB just outside the glacier. Second, we assume that any local signal which is not defined by the broader SMB signal is caused by glacial dynamics. The latter is a reasonable assumption in the case of these three glaciers, due to the relatively large size of the expected DMB signal compared to discrepancies in local SMB relative to nearby SMB. This allows

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us to use two overlapping basins to separate the two independent signals: first, a large SMB basin, similar to those used in previous studies, and second, a small basin covering only the area just around the glacier. The smaller basin is designed to trap the localized signal, which we know to be largely caused by the DMB, while the larger basin will trap the underlying larger-scale signal, which we know to be largely caused by the SMB."

Thank you again for your help,

Jennifer Bonin

Interactive comment on The Cryosphere Discuss., 9, 1315, 2015.