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The Cryosphere Discussions

Interactive comment on "Getting around Antarctica: new high-resolution mappings of the grounded and freely-floating boundaries of the Antarctic ice sheet created for the International Polar Year" *by* R. Bindschadler et al.

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As with the first anonymous reviewer, on behalf of the author team, I thank this reviewer for the comments submitted and for their acknowledging the magnitude of this mapping effort. Most of the offered comments have led to improvements in the revised manuscript, some directly and others by illustrating confusion on the part of a reader that led to clarifications of the text. Below, detailed responses are given with the first few words taken from the associated paragraph of the review.

"It is inherently difficult, if not impossible, to determine the exact location of the grounding line (grounding zones) from satellite imagery or DEMs alone…" Grounding zones are complex regions yet mapping the position of the grounded to floating transition has such significance to studies of ice sheet behavior, they have been addressed (and mapped) for many years, by many investigators, employing many methods. As Rignot pointed out and Fricker et al. (2008) richly illustrated and discussed, different methods detect different areas of the grounding zone. Scambos' comments to this paper provide a vigorous defense of the use of optical imagery as one useful method for mapping this area. The slope break can be easily recognized along the majority of the coast and is less sensitive to the diurnal movements of the grounding line that, for example, strongly affects the interferometric SAR method. We acknowledge the difficulties of our technique in low-slope, fast flowing outlets and the revision describes more carefully the method we employed there (e.g., drawing the grounding line so the most downstream grounded areas, usually hummocks, lay upstream of our boundary). This methodology is consistent with others who have employed optical imagery and has resulted in many instances of measurable grounding line change (Rignot (2008) among them). Elsewhere, which is the majority of the coast, the method is very robust and is aided by the higher resolution of Landsat panchromatic band (15-m) as compared to the 125-m resolution MODIS (as we discuss and illustrate). These facts leave no doubt that this method has a demonstrable record of providing a valuable metric to the glaciological community.

As for the comment about the utility of the hydrostatic line, I responded to this viewpoint in the first review as follows: calculating mass balance is not the purpose of the paper, in the revised manuscript we defend the value of mapping this diagnostic property in its own right. As ice shelves thin and warm, the position of the H line will change. Thus, for the same reason that the grounding line position has been monitored as a change diagnostic, the H line is similarly of interest. Nor has this boundary ever been measured before. The advent of repeat precise laser altimetry provided a new capability to map these positions and we employ our technique to interpolate these measurements to a more complete data set. It has errors and it will be improved with time, but just as the initial mapping of the grounding line had errors and was improved, one has to start. These reasons are enough to justify mapping the H line, but I also dispute the reviewer's contention and defend the use of the H line as a useful "gate" for mass balance calculations. If the discharge at the grounding line were known, then measuring the discharge at the H line gives additional spatial resolution of where mass gain/loss is occurringâĂŤmultiple discharge gates is a very common goal of mass balance calculations and adds value to the interpretation of mass balance calculations.

"Moreover, the potential use of the mapped grounding line locations and elevations is limited by the positional and elevation errors." Error quantification has been massively revised with the incorporation of over 1000 BEDMAP-compiled points used for a more in-depth analysis.

"(1) The potential of using a single satellite imagery for detecting surface morphological features or for mapping topography is somewhat limited." The limitations are minor and not dependent upon the surface being a Lambertian reflector (see Bindschadler and Vornberger, 1994). The source and sensor positions are nearly constant and clear atmosphere scenes were used. The sinuous nature of the grounded ice boundary also minimized the difficulty in following the slope break over large distances. Finally, the MOA grounding line provided a useful independent estimate and, in combination with the MOA imagery, provided a confident interpretation of the Landsat imagery. In short, none of the listed effects limited the accuracy of the mapped products.

"(2) An additional complication is caused by the fact that grounding line elevations were determined from elevation models that refer to different time periods and have different spatial resolution." The disagreements between DEMs in the coastal area overwhelm possible elevation changes between DEM epochs. Coastal rates of thinning or thickening are generally modest, but even a large rate of change (say 1 m/a) would create a 10 meter change in a decade. DEM disagreement was more typically many tens of meters. Our reliance on ICESat elevations is primarily because they are most

accurate in this region, but they also were collected close to the time of the Landsat imagery used.

"(3) To compute elevations by using photoclinometry the authors used a single image mosaic and they integrated the photofunction only in one direction." This would have been a more severe restriction if photoclinometry were the only method to derive elevations. Our experience was that when photoclinometry was the preferred elevation source, the curtain effect was not noticeable, i.e., there were not curtain-related discontinuities in the elevation profile following either the grounded ice boundary or the hydrostatic line. In practice, a second Landsat image collected with a different sun azimuth is usually not availableâĂŤone of the disadvantages of using the higher-resolution imagery.

"(4) The selection of single ICEsat elevation profiles along each ICESat ground track is based on visual inspection only." This method proved satisfactory because, as the paper describes, the two primary criteria for selecting the preferred transect were continuity (so the derived elevation field had maximum control) and consistency with other profiles (to ensure it was representative of the surface). I support use of the various flags when culling a data set in a blind manner, but I defend the use of visual inspection as an excellent means of determining the most useful and representative profile and a method that I have yet to trust a computer is capable of automatically reproducing.

"(5) Complex mapping projects, such as the grounding line mapping attempted by ASAID, are difficult to accomplish and usually need a strict protocol,. . ." This point repeats some objections and confusion already addressed above. The purpose of the paper is to describe and document the production of the grounded ice boundary and hydrostatic line and to discuss some characteristics of Antarctica that were extracted in this exercise. The purpose is not to discuss the penultimate goals of ASAIDâĂŤthe revision has attempted to make this clearer. I dispute the characterization of using multiple data sets as "ad hoc", but the revision includes an explanation of why any attempt to correct each DEMs to a common epoch is not feasible. The issue of validation is relevant to the paper because it affects the use of the described data products. Additional validation was undertaken in response to these reviews and is discussed in more detail in the revision.

"Summary:. . ." More explanation of the applied criteria is provided in the revision and the figures are improved for readability.

Detailed comments: "The abstract should be overhauled." It has been. I don't agree with putting many references in the abstract as the abstract often appears separate from the paper. The major quantitative results now appear in the Abstract.

"Introduction:" More to the point of addressing other objections, the revised Introduction now makes explicit that this paper is not about the ASAID project and its penultimate goal, but rather a presentation of the boundaries mapped, why they are important, how they were obtained, and how accurate they are. Specific descriptions of other methods appear when those details are contrasted with the details of the ASAID approach. This makes for a more tractable section and presents the material when it has most relevance.

"Page 188, 15-20: it is not clear how the effort deriving ice sheet scale velocity data. . ." Not the point of the paper.

"Page 190: The previous mapping efforts should be mentioned in the introduction. . ." More is said in the revision, but past mappings of the grounding line were not presented with comparable rigor to this product. (maybe I now understand why).

"Page 199-202. The description of the 3D grounding and hydrostatic line generation Method. . ." Switching from one elevation source to another at locations where they intersect is the method we used to avoid frequent discontinuities. This seemed obvious from the description, but it is stated explicitly in the revision.

"(p 200, 15-20), is a daunting task for an operator using interactive tools and a very challenging problem for automation.." Daunting, yes, but it was the best way to accom-

plish the task. Errors are addressed through the confidence parameter. The revision discusses not only the method employed, but why it was chosen over other approaches that would make the errors more obscure.

"Page 204. The paper incorrectly refers to the geoid height as elevations on WGS- 84 geoid." First author error that is corrected in the revision.

"As for the accuracy of the different DEMs,..." The general errors of any of the DEMs seem to be generous underestimates in the Antarctic coastal region. Our error estimate, captured by the confidence rating, better, especially now that the revised accuracy assessment is more quantitative.

"Validation:. . ." Massive revision of the accuracy assessment is included in the revision.

"Figures:. . ." These have been improved. We considered focusing on just one area, but there was no single area that gave an optimal illustration of all aspects of the mapping, so we chose to , and retain, a suite of examples that best illustrate key steps of our methodology.

References Bindschadler, R.A, and P.L. Vornberger, 1994. Detailed elevation map of ice stream C using satellite imagery and airborne radar, Annals of Glaciology, Vol. 20, 327-335 .

Rignot, E, 2008. Changes in West Antarctic ice stream dynamics observed with ALOS PALSAR data, Geophysical Research Letters, Vol. 35, L12505, doi:10.1029/2008GL033365

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