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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.

Anonymous Referee #2

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General remarks: The authors present the result of the ASAID international IPY project that aimed at generating a comprehensive, high resolution (15 meter) 3D mapping of ice sheet grounding lines and hydrostatic lines from optical satellite imagery and satellite laser altimetry. In particular, changes in surface slopes, indicated by changes in image brightness were used to estimate the location of the grounding lines, while elevations along the grounding lines were extracted from different DEMs. The hydrostatic line, defined as a line formed by "the most landward point that experiences full tidal flexure" was determined from the same data sets and ice thickness was estimated along the hydrostatic line assuming a hydrostatic equilibrium.

Attempting to map the grounding line around the whole Antarctic continent is a tremendous effort and the huge amount of work performed by a large group of researchers has resulted in an important data set that is being distributed through NSIDC. However, there are number of issues affecting the location and elevation accuracy of the mapped ice sheet features and thus limit their uses. It is inherently difficult, if not impossible, to determine the exact location of the grounding line (grounding zones) from satellite imagery or DEMs alone, especially on fast flowing ice streams, as it has been mentioned in the manuscript and pointed out by Review #1 and E. Rignot. Also, due to the lack of direct ice thickness measurements at the grounding line, ice thickness was estimated from the height of the ice surface above sea level at the hydrostatic line. The hydrostatic line is usually located several km seaward from the grounding line. Since significant sub-iceshelf melting could occur between the hydrostatic line and the grounding line, the ice thickness at the hydrostatic line is not a suitable input for mass budget computations (outgoing flux at grounding line), which was one of the main goals of the study.

Moreover, the potential use of the mapped grounding line locations and elevations is limited by the positional and elevation errors. Although the accuracy of the input data sets (e.g., Landsat ETM+, ICESat elevations) is quite well characterized, the use of visual editing and the inclusion of additional data sources don't allow the authors to derive the errors by rigorous error propagation. This is a main limitation of the study, since as the authors pointed out, relatively small elevation errors can cause large errors in thickness, for example. The errors assigned to the different segments of the grounding and hydrostatic lines are only qualitative and probably vary significantly depending on the image acquisition geometry, surface characteristics, temporal variations of ice sheet surface and other factors.

Below is a list of some potential sources of errors:

(1) The potential of using a single satellite imagery for detecting surface morphological features or for mapping topography is somewhat limited. As it is well known, image brightness is a function of surface reflectance, source and sensor positions, and atmospheric effects. Changes in surface slopes can be detected in a robust way if the surface is a Lambertian reflector with uniform reflectivity and the illumination is perpendicular to the changes in slope, in this case to the grounding line. Since only one set of satellite images, namely Landsat ETM+ imagery forming the LIMA mosaic was used to derive the location of the change in slope indicating the grounding line, it is likely that the mapped grounding lines segments have large positional uncertainty if solar illumination direction was similar to the grounding line direction. Moreover, changes in surface slopes can't be detected at all, if the solar illumination direction was parallel with the grounding line. This problem is well known and usually avoided by using multiple satellite imagery with different solar illuminations (e.g., Scambos and Haran, 2002).

(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. Grounding line locations change in time and therefore attention should be paid to reconstruct their geometry from data obtained at the same time period.

(3) To compute elevations by using photoclinometry the authors used a single image mosaic and they integrated the photofunction only in one direction. This treatment could cause relatively large errors in elevation due to the sensitivity of elevation values to errors in slopes derived from the brightness and due to the different expression of surface structure in case of different solar illumination. The "curtain effect", large elevation errors between image columns (sun-up and sun-down), mentioned in the text and very obvious in Fig. 6.a, could be avoided by introducing 2D computation schemes, and topographic features oriented in different directions could be preserved by using multiple imagery (e.g. Scambos and Haran, 2002).

(4) The selection of single ICEsat elevation profiles along each ICESat ground track is based on visual inspection only. While visual inspection can be an effective method, selecting the best profiles from repeat transects, taken at the different times and in slightly different locations, might be a difficult task. While ICESat data are processed to remove all the systematic errors, errors due to unfavorable atmospheric conditions (e.g. forward scattering, scattering from low atmospheric layers, e.g., ground fog) and other sources, for example ranging errors due to signal saturation could still cause elevation errors (Brenner et al., 2007). The GLAS data files include several quality control flag that indicate poor data quality and these flags could have been used to support the selection of the profiles that provide the most accurate elevations (e.g., Slobbe et al., 2008; Smith et al., 2009).

(5) Complex mapping projects, such as the grounding line mapping attempted by ASAID, are difficult to accomplish and usually need a strict protocol, as well as comprehensive and well characterized input data sets, which are processed by a well established methodology. Moreover, the results should be thoroughly validated. This project has been successful in several aspects, for example by obtaining comprehensive, standardized data sets and using them following a strict protocol. However, the projects goal is not clearly articulated and the different steps and goals are not explained properly. The use of too many different data sets in an ad hoc manner (for example various DEMs with different acquisition time, spatial resolution and error characteristics) limits the accuracy and applicability of the results. Finally the validation of the results is very limited.

Summary: this paper, describing the generation of this new, Antarctic-wide grounding line data set, is certainly be of interest of the Cryosphere readers. However, instead of a clear explanation of the methodology, assumptions, limitations, errors, etc., the major part of the manuscript is a simple report listing the major steps of processing. Some of the figures are adopted from other, sometimes somewhat outdated papers (e.g., Figure 1 from Rignot and Thomas, 2002), while others are screen captures showing the information displayed at the main processing steps. Also the fonts in the figures are often too small to read and the thin lines and small symbols are hardly visible. Figures, designed for illustrating the important aspects of the study, would help to explain how different DEMs are combined (Fig 6) or illustrate the differences between the grounding lines mapped by different sensors (Figure 4). For example Figure 6 shows a series of colored surface elevation profiles along the same transect derived from different data sets. Well, the surface topography depicted by the different sensors is clearly very different, but this figure doesn't convince the reader that a good strategy was applied for merging these different elevations.

Detailed comments:

The abstract should be overhauled. It clearly reflects the lack of focus and includes details on different sensors and data instead summarizing the objectives and results.

Introduction: In addition to defining the grounding line and providing some motivation for Antarctic grounding line mapping, the introduction should also summarize the currently used approaches, previous ice sheet scale grounding line mapping efforts and results, define and justify the accuracy/resolution/etc. needed for obtaining a useful data set. In general this paper doesn't provide sufficient background information and references, and the lack of references in the abstract clearly illustrates this point.

Page 188, 15-20: it is not clear how the effort deriving ice sheet scale velocity data (I. Joughin) and the grounding line mapping is coordinated and performed. Were the InSAR data, imagery and ICESat data acquired at the same time, for example? What are the plans for computing flux estimates?

Page 190: The previous mapping efforts should be mentioned in the introduction and further explained here. What methodology was applied? What is the estimated error, coverage, etc.?

See comments on the Method section at the beginning of this review.

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Page 199-202. The description of the 3D grounding and hydrostatic line generation method seems to miss very important steps, namely the removal of the biases between the different DEMs as they are combined into a single grounding line and the smoothing of the edges at the boundaries of different segments (“feathering”). A simple manual selection and combination of the segments into a single 3D curve would create a curve with discontinuities at the boundaries of segments selected from different DEMs. Combining countless segments, especially if elevations of segments and points are weighted differently depending on the source, as it is suggested in the manuscript (p 200, 15-20), is a daunting task for an operator using interactive tools and a very challenging problem for automation. The method applied for “fusing” the different elevations/DEMs will also have a major impact on the error of the grounding line elevations and therefore should be explained in detail.

Page 204. The paper incorrectly refers to the geoid height as elevations on WGS-84 geoid. WGS-84 is an ellipsoidal reference frame and not an estimation of the sea level surface. Correct description of the elevations data should include not only the vertical datum (EGM-96 geoid?), but corrections that were applied to the ICESat data used in the study, for example tidal correction and various other corrections related to atmospheric conditions, etc.

As for the accuracy of the different DEMs, a recent study of Nuth and Kaab (2011) reported much larger elevation errors for ASTER DEMs (including the ASTER G-DEM) than for SPIRIT SPOT DEMs. Therefore it might be advisable to apply different error estimates.

Validation: a careful validation of the accuracy of the derived products is essential for the future users. Unfortunately this study falls short of what is expected for validating such a data set. While several data sets are mentioned, only a single example is presented. For this example the disagreement between the grounding lines derived from InSAR and imagery was explained and confirmed. A somewhat smaller disagreement was also detected between the imagery and ICEsat grounding lines, which hasn't been explained. As for thickness, ice thickness derived at the hydrostatic line from the ASAID data set was compared with ice thickness measured along the grounding line. Since the distance between the two lines reached 6.5 – 8 km, the analysis of the thickness differences can't provide meaningful conclusions.

Figures:

As I previously mentioned the figures would require substantial revisions. In addition to editorial changes (larger fonts and symbols for readability), the figure should be more connected to each other and to the story told in the paper. A possibility to select a small area to illustrate the data coverage, fusion, previous results, etc. , while keep the overview map to show the final results.

References:

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