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The Cryosphere Discussions

Interactive comment on "Assessment of altimetry using ground-based GPS data from the 88S Traverse, Antarctica, in support of ICESat-2" *by* Kelly M. Brunt et al.

Anonymous Referee #2

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The paper reports the acquisition and processing of ground GPS data along the 88S Traverse and compares the surface elevations to those derived from airborne laser altimetry. The ultimate goal of the 88 Traverse is to validate ICESat-2 surface elevation data. Ground GPS data were processed by using Precise Point Positioning (PPP) post-processing method. The paper provides a detailed analysis of surface elevation mapping results from ground-based GPS and airborne laser altimetry.

The manuscript would benefit from including a summary on how the ground and airborne elevation datasets will be used for ICESat-2 validation. While the authors make a strong argument for using the 88S traverse because of the abundance of ICESat-2

measurements, they don't elaborate on how the data sets collected at different times and characterized by different errors will help to validate the ICESat-2.

In my opinion, the analysis presented in the paper does not provide sufficient support for the assumption that the ground GPS data depicts the real surface and thus provides ground truth for the airborne laser altimetry. While the PPP processing used for processing kinematic ground GPS data can provide vertical accuracy up to 3 cm, errors can be up to 10 cm (e.g., https://www.novatel.com/an-introduction-to-gnss/chapter-5-resolving-errors/gnss-data-post-processing/), or somewhat lower because of the filtering the authors applied. The vertical accuracy of the ATM laser altimetry points is similar to the accuracy of PPP processing. For example, Martin et. al., 2012 (Table 7) quoted a vertical accuracy of 6.6 cm with a vertical precision of 3 cm for an operating altitude of 500-750 meter above the surface.

To demonstrate the accuracy of the ground GPS surveys, the authors compared the measurements made with vehicles A and B and obtained a small elevation difference of 1.1$\pm$4.1 cm. However, this comparison does not fully characterize the absolute accuracy of surveys. Some of the errors, in particular, the ionosphere and troposphere errors, could be quite large and correlated within a short time that elapsed between data acquired with the GPS systems on the two vehicles.

Thus, the results presented in the paper do not adequately support the attribution of the elevation difference between ground GPS and airborne lidar surveys to a single source, i.e., to the random error (precision) of the airborne laser altimetry data sets. Instead, the elevation differences between the different airborne surveys (not included) as well as relative to the ground GPS survey (Figures 4 and 5) should be analyzed with the inclusion of any available calibration and/or validation information. For example, the correlated patterns in the residual elevation differences between the airborne and ground survey have characteristic spatial wavelengths of 15-50 km that corresponds to 2-7 hours with the ground speed of 2 m s$ˆ{-2}$. This pattern might indicate modeling errors of the ionospheric and tropospheric corrections which typically decorrelate within a few hours. Only a comprehensive analysis could shed light on the source of the errors and attribute them to the different surveys.

Detailed comments:

General comments:

- The description of the horizontal and vertical reference frames is somewhat confusing in the paper. The reference of the geographic coordinates is not mentioned and the elevations are described to be referenced to the ITRF reference frame of the WGS-84 ellipsoid. The correct information for ATM laser altimetry is that elevations are given in the ITRF08 reference frame, and geographic coordinates are referenced to the WGS84 ellipsoid (e.g, https://nsidc.org/data/ILATM1B). Similar information should be included for the other data sets.

Page 1, lines 19-25: of course, these sentences should be in past tense after the successful launch of ICESat-2

Line 24: include the spatial scale of the ICESat-2 mission requirement of 0.4 cm/yr

Page 2, lines 13-18: according to the authors the ground tracks will be spaced randomly in time (line 15) and evenly (line 16). It is a confusing description and needs clarification. Also, how are the ground tracks distributed relative to the ICESat-2 subcycles?

Lines 24-30: these statements are too concise to understand without consulting the referenced studies. For example, what are the surveys to which the surface measurement precisions refer?

Lines 32-33: use the words spaceborne and airborne consistently, preferably without a hyphen

Line 33: does the surface elevation change minimally or not? In my opinion, enough is known about the elevation changes of the East Antarctic Plateau to make a definitive

statement and even quantify the changes

Page 3, section 2.1: more details about the kinematic GPS surveys should be included. What was the typical distance (space and/or time) between the two vehicles during data acquisition? Did they always travel in the same order or did they switch place? Was there any static GPS collected?

Line 10-12: How many times was the antenna height measured? If only twice (line 10), the standard deviation mentioned in line 12 is not meaningful.

UAF lidar: the configuration of the UAF lidar – line scanner – should be mentioned.

ATM: please refer to the information included in Martin et al., (2012) about the accuracy and precision of the ATM system, instead of the somewhat outdated Krabill et al., 2002

Page 4, lines 11-14: What is the difference between the ATM T4 and T6 systems? What was the flying height of those ATM flights that are not included? Is there a study/personal communication that can be referenced about the presence and cause of the across-track tilt, i.e., uncorrected attitude error?

Page 5, lines 4-15: it would be useful to repeat the data acquisition times in this section.

Line 11: use “geographic coordinates” instead of latitudes and longitudes.

Line 26: what is the spatial scale to compute the standard deviation? Why using 1-sigma instead of the more widely used 2-sigma or 3-sigma?

Page 6, line 24: which flight provided higher elevations?

Page 7, lines 5-22: Were the biases removed from the differences before computing the variograms? Was there any additional preprocessing applied? Using the standard terminology for the description of the variograms (sill, range, etc.) would improve the section. The difference between elevations from GPS unit A and ATM (Figure 6, top panel) has a non-zero nugget effect, while the other differences do not exhibit any. What could cause this difference?

Lines 30-32: contrary to the statement about “no discernable signal is evident,” in my opinion, all differences show a clear and correlated spatial variation, which requires an explanation.

Figures:

Figure 1: adding the easting/northing would allow cross-referencing this figure with figures 4-5.

Figure 3: explain the significance and meaning of the different shades of red

Figure 4-5: X and Y axis titles should use larger fonts. The vertical axis should refer to the computed quantity, eg., “Residual elevation difference (m)” rather than the interpretation “Precision.” Adding the data sources, e.g., GPS A minus UAF Lidar Dec 3, 2017, as a title to each panel would make it possible to view the figure without reference to the figure caption

Figure 6-7: axis titles and labels are tiny, should be larger. The figure caption is too descriptive, use the standard terminology of variograms (sill, range, nugget) instead. Figure 8: describe the artifact in the title, e.g., narrow ridge of elevations parallel with flight direction

References:

Martin, C. F., Krabill, W. B., Manizade, S. S. & Russell, R. L. Airborne Topographic Mapper Calibration Procedures and Accuracy Assessment. NASA Technical Memorandum 2012-215891, (2012).

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