The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2020-330-RC3, 2021
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The Cryosphere Discussions
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Interactive comment on "Assessment of ICESat-2 ice surface elevations over the CHINARE route, East Antarctica, based on coordinated multi-sensor observations" *by* Rongxing Li et al.

Anonymous Referee #3

Received and published: 3 March 2021

1 Overview

Li et al. (2020) deliver results from an Antarctic campaign designed to assess elevation measurements from NASA's Ice Cloud and land Elevation Satellite-2 (ICESat-2). For the most part, this was a well-designed and well-thought-out experiment for evaluating the ICESat-2 data. The work presented by the authors falls within the scope of *The Cryosphere* and could make a good contribution for ICESat-2 calibration and validation (cal/val). Overall, while this is a well-written manuscript, there are a few issues that should be resolved before its publication.

2 Broad comments

- The cal/val data from the CHINARE campaign needs to be publicly accessible to be of use in the ICESat-2 project science office and the scientific community
- There are other supporting and cal/val efforts that should be mentioned in the text (e.g. NASA Operation IceBridge, Greenland Summit Station (Brunt et al., 2017), salar de Uyuni (Borsa et al., 2019), and the updated Antarctic pole hole campaign (Brunt et al., 2021))
- The L/R designations of the ICESat-2 beams do not correspond with weak/strong full time as it depends on the orientation of the spacecraft. Might also help to include statistics on laser spots (1–6) to help determine any drift or biases in a given beam.
- While ICESat-2 will presumably help improve mass balance and sea level determination efforts with satellite altimetry, these are not in the mission requirements as they require modeling efforts
- Links included in the text should have labels for when the website was last date accessed. Some of these links can also be simplified by removing optional URL parameters.

3 Line-by-line comments

Page 1, Lines 9–10: should probably be something like "We present the results of an assessment of ice surface elevation measurements from NASA's Ice Cloud and land Elevation Satellite-2 (ICESat-2) along the CHINARE (CHINese Antarctic Research Expedition) route near the Amery Ice Shelf in East Antarctica."

Page 1, Line 13: "...the ICESat-2 geolocated photon product (ATL03) and land ice elevation product (ATL06)..."

Page 1, Line 17 replace "in a previous study" with " (Brunt et al., 2021)"

Page 1, Lines 21–22 While this is an important study, it is limited to a small region of East Antarctica covering a small percentage of ICESat-2 reference ground tracks (RGTs). Need to be careful not to overstate the results here. Not sure how these results help overcome the uncertainties in East Antarctic mass balance.

Page 1, Line 23 What do you mean by "especially during the later operation period"? Do you mean that such field capabilities cannot be implemented for a couple of years, or that it is important to calibrate against potential degradation of the satellite measurements?

Page 1, Lines 25–27 This sentence is awkwardly phrased.

Page 2, Line 30 ATLAS is the primary instrument along with the GPS transceivers and the star cameras.

Page 2, Lines 33-34 ICESat-2 will likely help improve mass balance and sea level contribution estimates from satellite altimetry, but those are not part of the mission requirements.

Page 2, Line 34 The 0.4 cm/yr target is a mission requirement, not the current state of knowledge or uncertainty in elevation change.

Page 2, Lines 34–37 This sentence is awkwardly phrased. Could be something like "We use Release-3 of the ICESat-2 geolocated photon elevation (ATL03) and land ice surface elevation (ATL06) products provided by the US National Snow and Ice Data Center (NSIDC)."

Page 2, Lines 38–39 "The calibration and validation of measurements is important for all satellite missions, particularly for missions with new instruments or technology, such the photon-counting laser altimeter on-board ICESat-2."

Page 2, Lines 42–43 "Before launch, the ICESat-2 Project Science Office (PSO) funded calibration and validation experiments to be conducted on both the Greenland and Antarctic ice sheets. The annual Antarctic campaigns traverse a 300km stretch of the interior of Antarctica near 88°S covering 20% of the ICESat-2 reference ground tracks (RGTs) (Brunt et al., 2019)."

Page 2, Line 45 "the Antarctic Ice Sheet (AIS)"

Page 2, Lines 47–48 "The NASA-led team also placed and used corner cube retroreflectors (CCRs) to collect ICESat-2 signatures at known points to help determine the horizontal geolocation accuracy of the laser pointing determination."

Page 2, Line 51 Again, while this is an important study, this is not a complete study of the "whole" of Antarctica.

Page 2, Line 56 Replace "mass" with "volume"

Page 2, Line 70 horizontal or vertical accuracy?

Figure 1 Where is the inset map of Great Wall Station located? Does the inset need to be included if the station was not used as part of the campaign?

Table 1 This is less ICESat-2 data than I would have thought. Are these numbers reduced using quality flags?

Table 1 What do you mean by "not applicable" for ATL06 geolocation accuracy? That these are simply parameterized in the product?

Page 5, Line 97 Why were 6 cm CCRs chosen for this campaign?

Page 5, Line 102 Possible to use a different positioning technique for these to reduce the impact of the station problems? 1 meter vertical is not going to be beneficial from a cal/val standpoint.

Page 5, Line 109 "that are separated by 90 meters"

Page 5, Line 115 "We selected a silver-gray coating with R = 0.235 as it was the closest to the reportedly highest estimated probability (EP) of photon detection coating with R = 0.28"

Page 5, Line 109 Remove "Thus"

Page 8, Line 167 "which are 3 km apart"

Page 8, Line 168 Weak/Strong beams can be either left or right depending on the spacecraft orientation.

Page 8, Line 171 "We reduce the impact of non-signal and noisy measurements by reducing the ATL06 land ice elevation measurements using the *atl06_quality_summary* flag and the ATL03 geolocated photon measurements to medium to high confidence photons using the *signal_conf_ph* flag. We also consider . . . "

Page 8, Lines 174–175 What determination did you use to decide if buffer to low classified photons should be included? In some cases, the buffer to low classified photons often can improve comparisons with ground measurements due to the shape of the ATLAS transmit pulse (which can be truncated in the ATL03 classifier if only including high-quality PEs).

Page 8, Line 177 Remove "On the other hand"

Page 9, Lines 187-189 As this campaign includes multiple different terrains, was slope considered when comparing with the ATL06 measurements? i.e. along-track

slope is estimated when calculating the average surface height in ATL06. Would your ground measurements also provide a metric for the along-track and across-track slopes estimated by ATL06?

Page 9, Lines 194–196 The early mission pointing issue is a known problem (was due to a reference frame mismatch in the onboard software for the star cameras) (Luthcke et al., 2021).

Page 10, Lines 206–212 These sentences are awkwardly phrased.

Page 10, Line 207 11m laser footprint?

Page 10, Line 209 "confidence flag "*signal_conf_ph*" equal to middle to high confidence in order to calculate an average elevation in each pulse with reduced noise". You're calculating averages over individual pulses? Are there enough return PEs to calculate at this along-track length with significance? This is fitting at approximately 0.7 meters along track correct?

Page 10, Line 210 replace "further fitted" with simply "fit".

Page 10, Line 210 Are you using "e.g." here because you use different curves besides a Gaussian? What other functionals do you consider? Did you mean to use "i.e." here?

Figure 6 Is there a way of combining the plots for the same region to not repeat information? Maybe at some middle level of zoom?

Page 11, Line 223 1.0 cm horizontal?

Page 12, Line 250 Can you clarify what is 816 meters apart? As phrased it could be interpreted as the GNSS measurements are over 800 meters from your ICESat-2 measurements.

Table 2 Would be beneficial to have these statistics for laser spots in addition to the oriented beams (to directly map to individual laser beams).

Page 12, Line 263 Again need to be careful to clarify that L/R do not necessarily map to weak/strong as it depends on the spacecraft orientation.

Page 13, Line 273 Replace "orbit" with RGT

Page 13, Line 276 137 medium to high-quality classified photon returns?

Page 13, Line 284 1–2 meters vertical is not going to be accurate enough for cal/val purposes

Page 13, Lines 286–289 This seems possibly circular to use ICESat-2 to evaluate ICESat-2. What are the uncertainties in ATL06 here? What about horizontal geolocation errors of ATL06 and the CCR impacting the heights? What are the slopes?

Page 14, Lines 309–310 The weak beam also returns to 1/4th the number of detectors (4 instead of 16) and has different thresholds for saturation in the ATL03 algorithm.

Page 14, Line 310 This is unfortunate that it was so close to the CCRs.

Table 3 Should these return photon counts be in count/meter?

Page 14, Line 321 Replace "orbit" with "RGT"

Page 15, Lines 341–343 Improving the h_2 measurements seems like a good advance for future campaigns.

Page 17, Line 399 The cal/val data needs to be included here in the *Data availability* section

Page 21, Line 491–492 I believe that within a 20 meter ATL03 segment, only one photon event is directly geolocated in an absolute sense. The other PEs are then geolocated with respect to that reference PE.

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Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2020-330, 2020.