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The Cryosphere Discussions

Interactive comment on "Ground-penetrating radar reveals ice thickness and undisturbed englacial layers at Kilimanjaro's Northern Ice Field" *by* Pascal Bohleber et al.

Anonymous Referee #2

Received and published: 19 September 2016

This manuscript presents the GPR data collected on Kilimanjaro's Northern Ice Field for the first time and estimate the total ice volume as of September 2015. Also, the integrity of internal reflecting horizons for the majority of the NIF is clearly established here, opening possibilities for future studies such as extending the depth-age relationship obtained from ice cores to reconstruct the historical change of the NIF. The manuscript is well structured and concise. I have only a few minor comments on uncertainty analysis, discussion of results in light of previous studies, editorial comments to clarify the writing, and the size of figures and some text embedded in them. I recommend this manuscript for publication in The Cryosphere after a minor revision.

Specific comments

Section 2.3: There is no discussion about the horizontal uncertainty that could arise from the determination of from where the pulse is returned, for example. Please add some discussion of the horizontal uncertainty.

P4, L27-28: I'm not totally clear on how you calculated the combined uncertainties here. These uncertainty components are independent of each other so I think the proper way to combine the uncertainties in this case is by the root sum of squares. So for the IRH and the bedrock reflection at 200 MHz, they would be sqrt(2.5ˆ2+4ˆ2)=4.7 ns and sqrt(2.5ˆ2+8ˆ2)=8.4 ns, respectively.

P5, L4-5: The total uncertainties for the IRH and bedrock depths would change depending on how you combine different uncertainty components as per the comment above. Please check the final number and change as needed.

P5, L12-13: It is difficult to assess if 0.3 m is appropriate for the uncertainty of the rope length because there is no explanation as to how knots would lead to this number. In addition, I would expect some stretching of the rope unless you specifically chose a static rope with minimal stretching.

P5, L13-14: Why could you neglect potential effects from the image stitching and deskewing routines? Are there any references to justify this?

P7, L1: What is the significance of the "large bedrock inclination"? Is this related to one of the components of the uncertainty, namely losing track of coherent phase? Otherwise, this whole sentence seems to imply that there was in fact a component of uncertainty other than the two you discussed in section 2.3 but you got away with considering only the two by chance. Please clarify.

P7, L14-16: I don't agree that the observed mismatch could be attributed to the combined uncertainty. My interpretation of this statement is that your analysis of the combined uncertainty is wrong, which would require you to revise section 2.3. I don't think that is the case. It seems as though the mismatch could be largely due to the spatial

and possibly the temporal variability (?) of the bottom melting caused by fumarole activities, which are not well documented so you are not able to quantify it, and a potential uncertainty in the core length.

P8, L29-30: The discrepancy between your finding and the interpretation of Thompson et al. is significant. This warrants further discussions, at least further explain what Thompson et al.'s interpretation is and more details on how your result questions their interpretation.

Technical corrections

P2, L28: The use of the word "employed" is awkward. Change to "GPR has also been used..."

P2, L32: Add "e.g.," to the references because these might not be the only studies that used GPR on tropical glaciers.

P2, L32-33: "to our knowledge the study presented here..." should be '"to our knowledge this is the first time a GPR was used at Kilimanjaro's NIF."

P3, L3-5: The sentence "Although not further discussed..." seems unnecessary if not discussed at all in this manuscript.

P3, L5-6: The sentence should be changed to "We estimate the total ice volume presently remaining at NIF by spatially extrapolating the GPR-derived ice thickness."

P3, L8: Change "while" to "and".

P3, L9-10: You've defined the abbreviation already so use "IRH".

P3, L14: Change "as well as" to "and".

P3, L18: Change "employed" to "used".

P3, L18: Change "Technical settings of the setups" to "Details of the technical settings".

P3, L23: Change "The spatial coverage that could be achieved was constrained by" to

"The spatial extent of the GPR survey was constrained by ".

P3, L24: Change "employ" to "use".

P3, L27: Change "800 MHz profiles were not found to provide" to "800 MHz profiles did not provide".

P4, L5: I think "Post-processing of GPR data" reads better as a subsection heading.

P4, L6: "We used the standard routines to process the GPR data including ..."

P4, L9-11: The use of "while" in the sentence "We employed ..." is not appropriate so the sentence should be divided, with the first sentence ending after "5 traces" and the second sentence starting with "For the electromagnetic ...".

P4, L20: "Major contributions to the uncertainty in depth..."

P4, L21: Change "connected to" to "related to".

P4, L25: Change "loosing" to "losing".

P4, L26-27: You don't need the parenthesis.

P4, L29: Delete "relative difference".

P5, L8-9: Change "A 200 MHz CO-profile running towards the vertical wall extends to about one meter distance from the cliff" to "The 200 MHz CO-profile running towards the ice cliff ends within one meter from the cliff".

P5, L9: Change "The cliff height of the wall" to "The height of the ice cliff".

P5, L16: "In order to derive distributed ice thickness" to "To derive the ice-thickness distribution over the NIF", and remove the later "over the NIF".

P5, L16-17: Change "the previously developed approach by Fischer (2009), in interpolating" to "the approached previously developed by Fischer (2009), first interpolating".

P5, L21: "very high resolution" is subjective so remove "very".

P5, L22: No hyphen is needed for surface altitude.

P5, L33: Change “We derived an estimate” to “We estimated”.

P6, L3: Change “In order to estimate the expected loss on surface area” to “To estimate the surface area lost”.

P6, L14: Change “comprises” to “includes”.

P6, L18: Change “reflectors from internal layers” to “internal reflectors”.

P6, L19: Remove “very”.

P6, L28: You don’t need parentheses around the description of locations.

P6, L30: Delete “, however”.

P7, L4: Remove “value”.

P7, L13: “more or less” is ambiguous so remove.

P7, L17: Change “The interpolation of ice thickness” to “The interpolated ice thickness distribution”.

P7, L28: Change “Considering additionally” to “In addition, considering”.

P7, L28-29: Change “regard the values derived from this method with caution only” to “interpret the ice thickness derived from this method with caution.”

P8, L27: Change “large layer” to “thick layer”.

P8, L29: Change “interpret” to “interpreted”.

P8, L29: Remove “in depth”.

P8, L30-32: It isn’t totally clear whether “these findings” refer to your findings or those of Thompson et al. (I assume the former). Rewrite to clarify this.

P8, L30: Change “it seems worth” to “it is”.

P9, L7: Change “near-bedrock ice parts” to “ice just above the bedrock”.

P9, L28-29: Briefly explain why this finding is relevant for new ice core drilling and energy and mass balance modeling.

P9, L31: Change “estimation” to “estimate”.

P10, L2: Change “can be” to “were”.

This is something you could sort out with TC’s but I think figures are a little too small in general. Please pay particular attention to the size of texts embedded in each figures and make sure they are legible without blowing up on a computer screen. Labels of site and profile names in Figure 1, and legends in Figures 5 and 7 are particularly difficult to read.

Figures 1, 2 and 9: Label the top and bottom rows as (a) and (b), respectively, and refer to them accordingly in captions.

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