Response to Comments from Reviewer 2

Comment: This is a really interesting paper evaluating accuracy of SfM/MvS models scaled by low resolution GNSS derived camera positions. This is one of several very important resolution issues that have arisen in this new technique and as such this paper will get a lot of interest. That is, there are precious few experiments of this type. I compliment the authors on giving one of the best descriptions of the quantitative side of SfM and MvS in a compact form—I had to read much of a book to get comparable information that can be gleened from their nice figures. So bravo there.

- **Response:** Thank you very much for praising our description of SfM-MVS – it was a product of extensive literature review on a relatively novel technology.

Comment: I felt like a reader of a whodunnit novel getting to the end and find that the answer to the main question remained unclear—like a trial that ends with an undecided jury. What the paper desperately needs is a discussion of the results of the experiments and why the last experiment (with the pseudorock pile) went abruptly from having a pretty lousy solution to an impressive solution by simply doubling the number of photos. The other experiments suggested that linearly increasing the number of cameras would linearly increase resolution, but in that experiment it was clearly nonlinear—any idea why? That is what should be discussed, rather than just making and observation in the conclusions.

- **Response:** We agree on this point and have decided to improve the discussion of the results. Even though the measurement of the wooden box was relatively very accurate, this investigatory data set produced a less accurate reconstruction quality-wise compared to previous models (duplicate and missing features, and the muckpile was harder to distinguish) as was hypothesized earlier. Due to this reason, the result of the reconstruction on the dataset of 200 images is listed separately from the first 2 in the table of results. (Lines 403-431, Section 4, Page 17)

Comment: I think there should be more of a discussion up front about scale of the models being developed vs GNSS error. https://doi.org/10.1016/j.jsg.2018.05.014 ran into this problem head on when they tried to image an outcrop ~100m across with GNSS location. Their main result was that they had large rigid body rotation errors due to their imaging array (a serendipitous experiment because they didn't think of the problem ahead of time, and not that relevant here), but they also realized they had scaling issues and geometric warping related to GNSS errors. That led them to the "oh, they were not thinking this through" realization that GNSS error was a contributing factor because the GNSS error was a significant fraction of the scale of the model. That is almost certainly at play here in the pseudomuck pile experiment—it is irrelevant to the lab experiment where positions were very accurately recorded by the grid. They have found (work in prep) that problems like that disappear at large scale, presumably because the gnss error gets small relative to the model size. I wonder if this gnss error vs model size is what is happening here in the pseudomuck pile model? I think it is likely a factor and needs to be discussed.

- **Response:** We agree on this point as well, and have added a discussion with a citation to the mentioned study that goes into detail the possible effect of the experiment scale on the GNSS error. (Lines 419-431, Section 4, Page 17)

Comment: A small issue is a couple bookkeeping things. One of them is you never state what software you are using. For those of us who are more users than developers, that is an important question. For example, we use both pix4D and metashape, and although they usually yield broadly similar models, there are distinct differences. No need to rerun your experiments with different software, just state what you're using.

- **Response:** Thank you very much for this reminder, mention of the software that was used has been added. (Line 334, Section 3, Page 12)

Comment: A somewhat different issue is there is an alternative solution to the main problem posed in this paper. That in no way negates the importance of this paper, but there are two simple ways to deal with model scaling that we have used. One is within SfM/MvS software like metashape—placing a scale bar in the scene, or use a known pair of features as a scalebar. That allows automatic scaling within the software. A related solution (which also requires a scale bar) is after processing the data, you can use a scale bar to rescale the model in other software, like cloud compare, or maybe more important for mining applications, maptek's point studio. That is a simple procedure, albeit requiring an additional step, but you should at least admit this alternative.

- **Response:** We agree on this point and we have included the discussion of this alternative and its merits as a traditional solution to the problem the study is trying to tackle. (Lines 88-90, Section 1, Page 3)

Comment: Finally, another trivial point, but distracting, is a style issue. The fact I can even say this is a complement to non-native English speaking authors, but use of the future tense in scientific writing can lead to confusion. When you use future tense it isn't clear you are referring something you are going to do in the future (not part of this paper) vs something within this text. So it is better to use past and/or present for the text to avoid this confusion.

- **Response:** We fully agree on the use of past/present tense for scientific writing and have made the requested proceeding corrections.

Comment: In summary, I really like this paper despite the points I make above. I think these fixes are easy and if the authors add a few sentences on some of these points it will really increase the impact of the paper, raising it to the level it deserves.

- **Response:** Thank you very much for this comment, and we have done our best to comply with the requested revisions to the paper.

Comment: 57: Might make a brief statement here about the size of the muckpiles being analyzed. Beyond the specifics reported here, those of us involved in other SfM related experiments would benefit greatly from knowing what the range of scales are that you're analyzing. For example, is the muckpile a km across, or is it 10m (I'd assume probably something in between, but would be nice to state) Also, state clearly here what data type you are analyzing in the analysis—are you using a point cloud, a tin, or both?

- **Response:** Thank you for this insight, we've made note of the general range of sizes of muckpiles found in mining operations in the introduction as well as put a rough size of the pseudo-muckpiles analyzed in the 2nd experiment. Unfortunately, there is no precise specification of how large a

muckpile can be, hence the further explanation that in cases where it is too large, it is suggested that a representative section of the muckpile be selected for measurement. (Lines 67-71, Section 1, Page 3)

Comment: 66: I don't see a red box in figure 1—aah, I see; it is Figure 2!!! Relabel please!

- **Response:** Thank you for the reminder, the error in here was actually in Figure 1 itself, while re-sizing the diagram for better clarity in the PDF, we forgot to place the red box in front of the layers. we have fixed this and replaced Figure 1. (Line 63, Section 1, Page 3)

Comment: 79: "However" at the beginning of this sentence is unnecessary, or even confusing.

- **Response:** We agree with this, and the sentence has then been changed to omit "however". (Line 101, Section 1, Page 4)

Comment: 81: this is a style thing done differently by people, but I am not a fan of using the future tense within a paper. To the reader this is "now", so the present tense is more compact and easily understood, particularly by nonnative English speakers.

- **Response:** As was mentioned before, we completely agree with not using future tense in scientific writing. Sentence has been modified to reflect this. (Line 103, Section 1, Page 4)

Comment: 107: Maybe I'm being math challenged here but I don't understand the equation. I understand the principal where the world coordinate is transformed into the camera coordinates (and the inverse) through a rotation and translation, and scaling. However, the equation is written like a matrix operation, but it isn't a proper matrix operation. I think the reason is there are higher order quantities buried in here (e.g. R and t are stated as vectors, so that 2x2 matrix containing R and t seems like it is probably a third order tensor?). I think you (authors) are trying to make this compact because most readers eyes will just pass over the equation going to the bottom line. I wonder if maybe the equation were presented in Einsteinian tensor notation, would that clarify? I just don't follow it this way.

- **Response:** Thank you for bringing this to our attention, and after discussion, the equation was modified. (Line 130, Section 2.1, Page 5)

Comment: 205: positions is a preferable term to "pose" in this context (and an earlier one). Pose could be misconstrued by readers to mean something different.

- **Response:** Thank you for this insight. We have discussed in detail the difference between the terms and agree with the change and try to ensure the use of the correct term from here on out. (Line 199, Section 2.1.4, Page 7)

Comment: 224: The "although" is awkward here. Although is used to differentiate a dependent clause, not to begin an independent clause in English. You could just remove the period and replace it with a comma (and remove capital A), but then the sentence is a bit of a run on sentence. Consider rewriting the two sentences; or merge and don't worry about the run on sentence.

- **Response:** I've decided to remove "although" and rewrite the two sentences. I've also realized that there is some inherent error in the sentences themselves as they were left after a part of the paper was omitted upon request of my professors. I've modified the sentences to be able to stand on their own. (Lines 252-259, Section 2.2, Page 9)

Comment: 251-252: Awkward sentence; not sure what you mean. Might be mixing tenses—future here, next sentence is past. I'd try to rewrite but might write it wrong

- **Response:** The sentence has been rewritten to be more consistent in tense. (Line 292, Section 2.2.1, Page 10)

Comment: 261: this result is really interesting, but the error is actually bigger than I would have thought given the carefully controlled experiment. For most studies and error of 2% is no problem (anything I do, that would be fine with me), but some people use these systems for geodetic work; e.g. surface change studies. It might be worth adding a sentence here to help direct readers attention to this issue?? (authors call here, this is a mere suggestion to help a broader audience)

- **Response:** Thank you for this insight. Additional sentences have been added to better discuss the error in detail, including a possible source of the error. (Lines 302-308, Section 2.2.1, Page 11)

Comment: 280-285: paragraph suffers from mix of tenses; stick to the present or past tense. Also, 284—not sure what you mean by 50% weight will be used

- **Response:** The sentence has been rewritten to be more consistent in tense, and explanation as to what 50% weight entails is added. (Lines 333-335, Section 3, Page 12)

Comment: 307: It might be worth mentioning that you gnss data were collected beneath partial tree cover (you can see this in the figures), which could be affecting positional accuracy. Kind of a wild card in the experiment, but worth noting

- **Response:** Thank you for this recommendation. Discussion regarding this has been added with a citation to a study discussing this particular phenomenon. (Lines 415-423, Section 4, Page 17)

Comment: 319-324: run on sentence hard to follow. Make it into two sentences?

- **Response:** The sentence has been split in two as per the edits recommended in the word file. (Lines 369-375, Section 4, Page 15)

Comment: 350: Wow, the preceding sentences really leave the reader hanging and beg for a discussion of the meaning of your results here!!!

370-end: but WHY? Why were did the pseudomuck pile experiment show the nonlinear convergence on the right answer? You really need to discuss what some of the causes are for you observation!!!

- **Response:** A more detailed discussion has been included preceding the conclusion. As for the issue of non-linear convergence, we explain in the added discussion that a possible reason for the result of the combined data set test is the combined effect of not just increasing the number of images, but also the size of the scene that is being reconstructed. This also ties into what is discussed in the section further regarding the effect of model size on GNSS error. However, due to the contextual difference in the scenes being reconstructed, we cannot reliably consider it as a datapoint for either dataset 1 or 2 as show by the separation in the table. (Lines 400-431, Section 4, Page 17)