

Nat. Hazards Earth Syst. Sci. Discuss., referee comment RC1  
<https://doi.org/10.5194/nhess-2021-32-RC1>, 2021  
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## Comment on nhess-2021-32 - Review

Anonymous Referee #1

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Referee comment on "GNSS and RPAS integration techniques for studying landslide dynamics: Application to the areas of Victoria and Colinas Lojanas, (Loja, Ecuador)" by Belizario A. Zárate Torres et al., Nat. Hazards Earth Syst. Sci. Discuss., <https://doi.org/10.5194/nhess-2021-32-RC1>, 2021

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## General comments

The manuscript presents a study of landslide movement from a series of campaigns obtained with GNSS and UAS surveys at two test sites. The presentation of the manuscript is good in terms of details on data collection, understanding and interpretation of results. The scientific questions are also relevant to the scope of NHESS. While the methodology adopted in the manuscript generally follows the common practice, it does not provide any novel concept or tool and does not directly attract readers. For example, in order to improve the manuscript the authors should think beyond the fundamental applications of GNSS and UAS processing, they could further explore errors associated with those techniques and the impact those errors can often have on landslide estimation. Alternatively, they could also explore other morphological attributes of DEM to identify cracks and scarps in a more automated fashion. These are some examples to further investigate landslide dynamics with a step away from the conventional geomatics techniques (i.e. GNSS and UAS). I would recommend some major revision of the manuscript to include some more interesting concepts that are currently missing and correct other issues that are included in the specific comments. The positive point in this study is that there are a lot of data collected which is not always feasible. The authors should take this as an opportunity to generate something catchy and interesting providing greater value to the geomorphological research community.

While the authors have nicely given good credit to related work there are few publications worth including in the manuscript that I have commented below in the specific comments. Additionally, there are some recommendations to change the structure of the text and explain the error propagation law earlier within the Methodology section. The UAS camera calibration part is also missing, and SfM self-calibrating bundle adjustment should be mentioned in the Methodology. It would be clearer if there are some figures showing the unstable/stable regions and which targets have been used for GCPs and which for CPs. Some more figures of detailed maps over particular scarps would be also good to add. The

abstract is currently under presented. The authors should show in a better way the bigger picture in the abstract (why this study is important) and the novel part of the methodology, with some tangible comparable results to attract the general audience.

## Specific comments

Line 43: RPAS also known as UAS too.

Line 50: Strictly Speaking, these processes (i.e. SfM and MVS image matching) constitute a pipeline that does not result only in an orthophoto. The actual output is a dense point cloud, then this is converted into an orthophoto, and a DEM via interpolation methods. The DTM is a by-product after ground classification. The DSM is also a by-product after some additional processing to create the surface model without noisy points. As a generic term I would recommend to use DEM throughout the manuscript.

Figure 2. Caption: What do you mean by photograph February 2016? Is this a UAV-based orthophoto of the entire study site or a single image taken by a UAV? Please make sure to specify this in the caption.

Line 82: Figure 2 shows an orthophoto reconstructed with UAV imagery, and detailed views over particular scarps and cracks taken with a compact camera? Please specify accordingly, see also the previous comment.

Figure 3: Same correction as for the caption of Figure 2. This is not a photograph, it seems like a UAV-based orthophoto.

Figure 4: What do you mean by ventral camera? Is this a typo? Could you please state here the GoPro camera that was carried by the quadrotor?

Line 109-110: A reference base station is used from SIRGAS which means that the accuracies mentioned earlier are relative to this station. How far is this station from the study areas (i.e. how long the baselines are)? Please make it clear that relative accuracies have been calculated with Trimble and also mention the length of the baselines.

Table 2: Could you please elaborate more in the text on what is the number of flyovers? Also, it is more interesting to include in the table the number of tie points reconstructed.

Line 136: It should be mentioned that the 2.77 mm focal length is the nominal one and not the calibrated one, since no calibration was performed. It is quite important to be specific with those terms to help the readers.

Line 140-141: This sentence is a bit vague. What do you mean that textured digital 3D models where appropriate? I assume you created a texture of the reconstructed 3D model for the entire study site. Also, I believe that DEM is more correct rather than using DSM as a terminology here see previous comment.

Just for clarity: SfM pipeline constitutes the first step for image alignment which leads to tie points (or sparse point cloud reconstruction based on Agisoft terminology), the densification of point cloud results in a dense point cloud and is performed with the aid of dense image matching multi view stereo algorithms, texturing helps the orthophoto creation. I would suggest to rephrase those sentences and make the description clearer. A good reference to use when it comes to terminology in photogrammetry is: <https://doi.org/10.1111/phor.12146>. Please correct some terminology throughout the manuscript using this reference: for example "point cloud is reconstructed"

Line 148-149: It is very good that ASPR standards are mentioned here, but we should be quite careful when it comes to accuracies. As only 3 and 4 check points were used, it should be mentioned that the achieved accuracies were based on a low redundancy. Such a small number of check points is not adequate to claim high accuracies in general. I recommend to read this publication (<https://doi.org/10.1016/j.geomorph.2016.11.021>) and apply some of the concepts presented there to understand how errors are propagated through the SfM process. The error values Agisoft gives are not directly adequate indicators of accuracy.

Figure 5 and 6 a and b do not offer anything interesting as they are similar to Figure 2 and 3. It would be more interesting to differentiate which points were GCPs and which were check points in all maps. Also it would be interesting to show the scarps and cracks over the generated DEMs. I think it is better to show the DEMs only rather than orthophotos. If you really want to have all generated orthophotos you can have them as a separate figure in Appendix (or supplementary material).

In terms of dense matching: it would be interesting to mention in the manuscript what method was set up in Agisoft in terms of depth mode reconstruction (e.g aggressive, mild or moderate?) Each method has different results. Also, have you used high (or ultra) accuracy for point cloud generation? What did you do to check any errors in the point cloud (biases e.g. high uncertainties in the tie points)? Have you performed any clean-up process before generating the DEM and orthophoto? Perhaps some points were erroneously located (e.g. flying points etc.).

Line 173-174: Could you map unstable/stable areas on the previous figures, perhaps categorise the GNSS points that are in the unstable and those in stable with different

colours for example. That would help the reader.

Line 176: Why did you use 3 m as a threshold how did this come from, could you please elaborate more on this?

Line 189: The GPS positioning precision equal to  $0.03 \pm 1\text{ppm}$  refers to a measurement of a single point. This value does not apply for the displacements which are the differences between two measurements.

Table 4 and 5 do not really add anything in the narrative, can be just included as complementary materials. Instead, the displacement uncertainty per point is more valuable to be added in a table. For some reason it is not really clear that you have calculated the uncertainties based on the error propagation law from the beginning of the methodology description. I had to reach the Discussion to actually realise that you have adopted the error propagation law but this is placed wrongly too late in the manuscript. I would suggest to move the accuracies and errors section back in section 3 as a main part of the methodology before presenting the results.

Line 234: Before calculating the displacements at monitoring points from the subsequent DEMs, have you checked how well the DEMs are co-registered with each other? The fact that they have been georeferenced with very few GCPs (5 and 6 are not really many points) does not mean that there might be unresolved co-registration errors. This is a step that should be included in the methodology.

Table 6 and 7: SDs and RMSEs in Tables 6 and 7 are relatively high (e.g. 0.08 in xy). Have you considered to remove features above ground first, before calculating DODs? It would be perhaps better to remove/mask/filter out areas with buildings and trees and perform a point cloud cleaning process and then a ground classification to remove unwanted flying points over the grass that might be picked when extracting their location in DEM. Other questions that arise here is how easily you could identify those concrete targets on the DJI images in Agisoft (there are no black and white markers in the middle for a better recognition aren't they) and what are the settings you used for the image alignment?

Lines 315-316: All this section should be part of Methodology before Results. I also think that the way the error propagation law is adopted is not fully correct, as a threshold of 90 or 95 % level of confidence is missing. Please see and also cite these two relevant highly-cited publications <https://doi.org/10.1002/esp.4125> and <https://doi.org/10.1016/j.geomorph.2016.11.021>. I think they should be mentioned as they are very relevant to the presented study and because they provide some very good tips for example among others on how to use Agisoft in geomorphological studies.

Lines 326-327: Displacements of points over stable areas should be null. Table 6 and 7 show high SD and RMSEs with a cm-level mean displacement. So small mean value but high errors, how do you explain this? Do you think that if you had applied point cloud cleaning and ground classification before calculating the displacements would have reduced those errors? Also, what about co-registration errors (see previous comment).

Lines 332-333: I would suggest to clean the point clouds and check any unresolved co-registration errors (Cloud Compare is a good free tool for that) and re calculate the uncertainty threshold, because I think some noise can be reduced at earlier stages of the methodology.

Line 446: Even though it is well acknowledged here in the Conclusions that the methodology need to be improved with vegetation filtering, I still believe that point cloud noise filtering and error checking should be undertaken at this stage and not in the future to further enhance the quality of the results.

## **Technical corrections**

Lines 28-29: instead of "including in the" it is better to write "such as".

Line 40: Better written: DTMs or DSMs are constructed using automatic image correlation techniques.

Line 46: The computer vision algorithms included in SfM are not really new, they have just become popular and have been improved to handle unordered imagery from UAV and big volume of data.

Line 49: It is better to use e.g. for the software in the parenthesis, as those are not the only ones, there are other software such as Context Capture, MicMac that provide very reliable outputs. It should be nice to mention.

Line 65: English correction: It is better to say "The present research was conducted at two study sites: a) ....; and b)..." And you should name those sites in the first sentence as well after a) and b).

Line 78: Typo: The predominant vegetation cover in the study area is grass"

Figure 1 caption: Please correct the citation style. You should cite as follows: "Adapted from Soto et al., (2017)"

Line 110: This is not an antenna, it is a GNSS station named LJEC. Better to rephrase the sentence as: The LJEC station from the Ecuadorian network of the Geocentric Reference System for the Americas (SIRGAS) was used as a reference base station.

Line 112: Better and clearer to say: Six GNSS surveys were conducted in each study site, as outlined..... Please use either study area or study site and not sector for your study areas throughout the manuscript for consistency.

Line 123: Instead of "GNSS measurements were taken", you can write, "GNSS were surveyed"