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Earth Surface Dynamics Discussions

Interactive comment on "A low-cost technique to measure bank erosion proces ses along middle-size river reaches" *by* Gonzalo Duró et al.

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Anonymous Referee #2:

RC: The paper covers mapping a 1.2 km long river bank using a low-cost drone and structure from motion, and a comparison of this method with airborne laser scanning and RTK-GPS data. I do find this to be an interesting topic relevant for those working with morphology, environmental assessment and measurements in rivers, and it shows the potential of using drones and photogrammetry to gain data for river analysis. The comparison between different methods is also useful and relevant for other similar data collection efforts. The paper is introduced in the abstract mostly as an example of developing a lowcost drone and the SfM method to measure the bank processes.

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Discussion paper

The authors have employed a commercially available drone and commercial available software for this process, which in practice means that you already have a low-cost technique readily available. This is then applied here to a new problem, and I think the manuscript should be focused on what is new here from the many other applications of the same combination of drone/software. Issues related to the SfM procedure is covered in detail in another comment, but in line with the previous comment I would also like to ask for some more discussion in the paper on: - The linear placement of the GCPs and the effect this might have on the point cloud. The placement of the control points and the effect this has on accuracy beyond the control points, and this could be combined to a more through discussion. - Issues related to the selection of flight paths only in parallel with the river bank that was measured.

AC: We thank the referee for his comments which helped improving the manuscript. A new section 5.3 has been added to discuss the novel challenges that the case study presents for the UAV-SfM application. A discussion on the linear placement of GCPs and its effect on the point cloud has been done in section 5.3.2. The placement of GCPs and their effect on the accuracy beyond GCPs has been discussed in sections 5.1 and 5.3.1. The main effect is the non-linear distortion beyond GCPs that produces the “dome” shape of the model, visible in Figure 7 at the extremes of the reach. The selection of parallel UAV paths and their role in the model registration has been discussed in the new section 5.3.2.

RC: I also think it would be good to show the targets used to define the GCP (what was the size of the tile?), and maybe also a picture showing how these looked in the images from the drone and how they were identified in Photoscan since this is relevant for the accuracy.

AC: A photo of a target has been added in Figure 3, together with two more panels that show how it is seen from UAV tracks 1 and 2. The plaques were 40x40 cm (this has been added in section 3.2). The targets were manually identified in Photoscan, and with the help of PageUp/PageDown keys we achieved consistency between all photos focusing on every target. This was useful since the target resolution varied with the sensor-GCP distance and some plaques at oblique perspectives reflected too much light to identify the CD (usually from track 1 and far away from the cross-section where the target was). In these cases, the background texture with the plaque boundaries were also used as references to locate the plaque's centre. If the plaque's centre was not clear enough to be identified, the GCP at that photo was discarded. The explanation and discussion of this criterion has been added to the new section 5.3.3.

RC: Further on GCPs, on P12 there is a discussion on the GCP identification between tracks. It would be particularly interesting to see some more info on how well you think the accuracy of the GCP identification from pictures were for Track 1 were you see the GCP tiles at an angle in all pictures. To what extent do the identification of the tile centre influence the results.

AC: Indeed, from the inclined angle of track 1 a smaller target area was captured, proportionally diminished by the cosine of the viewing angle with respect to the normal of the plane in which the GCP laid (say alfa). Following the previous explanation, this created more light reflection especially from the largest distances (oblique in two directions), but logically there also was a lower resolution to identify the target centres. The error introduced by a coarser resolution translated into elevation errors, and these directly affect rotational errors. On the other hand, the lateral view helped to compensate for this, since this elevation errors decreased with the cosine of alfa. Yet, positioning errors in transverse direction are relevant to quantify bank erosion rates, so these should be kept as low as possible, for instance, with inclined targets. A clarification on the influence of GCP identification on accuracy and a recommendation have been added in the new section 5.3.1.

RC: P7 – Was the grid from the ALS automatically generated from the scanner software or did you make it from the 10 points pr. square meter measured by the instrument? If it was automatic, could generating a finer grid improve the ALS results?

AC: We did not process the raw data because we did not have access to it. We only worked with the 0.5x0.5m grid provided to us. The grid resolution is in principle limited by the footprint size of the laser beam on the ground and the number of points per square metre. The footprint size was approximately 0.16m (one third of the grid resolution), from the beam divergence angle and the flight height. So, a finer grid could have been produced, for instance a 0.33x0.33 m grid from the 10 points/m^2 to approximately have one cell per each point. In this sense, the ALS results could have probably improved to capture more irregularities on the ground, which for banks proved essential. Still, even with a finer resolution, ALS can only survey 2.5D without capturing undermined profiles. These clarifications were added to sections 3 and 5.2.

RC: P8 – Did you use automatic or manual settings for shutter speed, ISO, etc.?

AC: We used automatic camera settings. Some considerations on this respect have been added in section 5.3.3.

RC: P10 – Figure 3: A top-view perspective could be added to improve the understanding of camera positions.

AC: A top view has been added to Figure 3, with two lines representing UAV paths 1 and 2-4.

RC: P10 – Line11: How was the removal of trees etc. done?

AC: The removal of vegetation from the point cloud was manually done in PhotoScan, simply by rotating the DSM and selecting those points above the surrounding ground level. Trees were easy to remove and some bushes required finding a correct perspective not to erase points from the ground.

RC: P11 – Table 2: Can you give a short explanation for the colour scale in the caption? Do the colour change for every 0.01 meters? I also think grouping mean and std.dev. together like it is done for the "all grounds" would be more readable also for Grassland, Bank and Terrace.

AC: For the mean values, the colour scale highlights the deviation from the zero value. For the naked eye it is possible to distinguish colour changes every 0.005 m, for the given range of values between -0.13 and +0.13 m (Table 2). In the case of the standard deviation, the colour scale highlights the deviation from the zero value too, but for a range of values between 0.00 and 0.13 m. Table 2 has been rearranged according to the suggestion and a description of the colour scale has been added in the caption.

RC: P13 – Figure 7 is hard to read. Is it possible to divide it into a panel with different sections of the bank in each panel to improve the readability of the figure?

AC: Figure 7 has been divided into two panels to increase the data visibility.

RC: P13 – Figure 8. I assume this is based on results after the removal of the data outside the GCP limit. How is the GCP limit defined?

AC: That is correct. The limit was defined by cross-sectional straight lines at the centre of the extreme GCPs. These lines have been added to Figure 7.

RC: P16 Figure 10a: Do I understand it correctly that the change of elevation of the flood plain is mainly caused by development of the grass?

AC: That is correct. The floodplain grass is mowed every year in October and usually grows during spring and summer time. The development of grass can be now observed in a new Figure 13 showing UAV photos from track 1.

RC: P16: Figure 10. Would it be possible to illustrate the development here by also showing the images of at least some of the observations? The data presented in figure 10 is useful, but since there is both images and DTMs it would be interesting to see these processes and the basis for the development of figure 10.

AC: A new Figure 13 has been added to show the development through three consecutive surveys at km. 153.9 (cross section 4), with a short description of processes linked to Figure 10 (called Fig. 12 in the new manuscript).

RC: P17-line 29: Can0t you just write “A RMSE of 2.8 cm”?

AC: Of course, thanks.

RC: P18 – Line19: Do you think GCP0s at the bank toe would reduce the error? With reference to the previous comment on GCP placement and the further discussion on page 18, what was the rationale for the selected choice of GCP locations?

AC: We think that non-linear errors could be reduced if GCPs were placed at the bank toe, but at the same time, there was no clear evidence of this type of error at the bank face. Regarding linear errors, the contribution to avoid or reduce rotation errors around the GCP axis would be minor, especially compared to wider horizontal GCP distributions across the floodplain. This is because the bank was roughly 3.5 metres high and its horizontal extent was also relatively short, compared to the floodplain that could allow for much larger cross-sectional distances to stabilize the DSM. What is more, GCPs were not systematically placed at the bank toe throughout the surveys for practical reasons. First, it was faster just to place GCPs on the floodplain than to descend to the bank toe, measure the coordinates, climb up, fly the UAV and sometimes recover the plaques afterwards (not all of them were left on the field to save them from vandalism). Second, we tried placing plaques at the bank toe but ship waves were able to take them away. Therefore, the GCPs were located only over the floodplain, following the bankline. With sufficient cross-sectional GCP footprint and photo overlaps, the model should be stable enough to measure bank erosion, as in the case study presented. The criterion has been indicated in section 3.2, and a discussed in section 5.3.2.

RC: A last question just out of curiosity. Was the flight done in autonomous mode or under control? What regulations govern the use of small drones for research purposes in this area? I understand that this varies between countries and could be an issue in planning similar st

AC: The flight was done in autonomous mode with the software UgCS. There are regulations regarding no-fly zones that are typically close to airports (see https://kadata.kadaster.nl/dronekaart/) and pilot licenses are now necessary to fly UAVs. It is true that it can be an issue to fly UAVs so it is necessary to check beforehand what the local regulations are and sometimes ask for specific permissions before a mission.

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