Response to reviewer comment 1 (RC1) by Patrice Carbonneau

David Mair[1], Ariel Henrique Do Prado[1], Philippos Garefalakis[1], Alessandro Lechmann[1], Alexander Whittaker[2], Fritz Schlunegger[1]

[1] Institute of Geological Sciences, University of Bern, Baltzerstrasse 1+3, 3012 Bern, Switzerland
[2] Imperial College, Department of Earth Science and Engineering, South Kensington Campus, London SW7 2AZ, United Kingdom

Correspondence to: David Mair (david.mair@geo.unibe.ch)

General response

We thank Patrice Carbonneau for the constructive comments and are glad for the positive reception of our work. We will first address the main comment about the transferability of the UAV study design before respond to the in-line comments below.

We thank the reviewer for providing us the opportunity to address the "*practical implications of* [our] *recommendations*". First, we want to emphasize that we do not intend to give a general advice on optimal UAV survey design, we merely want to point out some implications that our findings might have for specific applications (e.g., using the raw image acquisition format when very high SfM models are imperative). Second, we used a setup with low altitude and high image overlap in an effort to increase the pixel resolution and thus to detect smaller grains for the scale of a single bar if the aim is to study intra- and inter-bar variability. We do not generally recommend this as the setup for UAV-based grain size surveys. In the light of this, we address the specific points:

"1 element that is missing from table 1 and survey description is some indication of survey duration or drone velocity."

Table 1 already contains the "net flight time", which in our case represents the survey time, since we started directly on the bars. We add statements to the text to clarify this in section 3.1.

" […] they are recommending that imagery be acquired in raw format, ie much bigger files"

We acknowledge the need to clarify in the article that we do not recommend raw image acquisition *in general*. We merely want to document that we indeed saw an effect of the image acquisition format, and that for very high quality SfM models such an acquisition could be considered. We use this opportunity to add a statement to section 4.5 to caution the reader against the cost of such a format

(larger files, slower acquisition due to lower flying velocity and longer file writing time, only few apps allow for raw images in “mapping” mode).

“I'd like some explicit detail about the time and battery cost of the recommendations.”

Flight time and battery cost are UAV platform specific and strongly dependent on the wind conditions, thus they might vary significantly. We therefore refrained from giving too much detail on this before. For example, for our K1 survey we retrieved 401 images during c. 50 min net survey time with 3 batteries, while for L2 we retrieved 119 images within a survey time of c. 32 min again with 3 batteries. However, we agree that more information might be useful for readers in this regard. Therefore, we added a short statement in section 3.1 to better reference the net flight time (Table 1) and to give information on battery consumption of our specific platform.

Regarding the underlying concern of scalability of our flight/acquisition design and the general trajectory of UAV based fluvial grain size measurements (i.e. the *“direction of travel for airborne fluvial remote sensing should be upscaling, not downscaling”*), we acknowledge the need for clarification. We used a specific study design for a local, bar scale (which we now specify in section 2.1). It is tailored to alpine streams and gorges, and would fail to produce useful data sets for very large-scale applications (as the reviewer correctly points out). We note here that we do not think that these flight patterns are easily transferable to larger scales, nor that they should be (we now caution readers in the beginning of section 4 against such endeavours). However, the uncertainty framework and the implications of the uncertainties are transferable to other scales (within their limitations, i.e., that individual grains are detected and measured). In detail, accuracy and precision estimation are largely not affected by changes in scale/flight altitude, other than the cut-off for the smallest detectable grain sizes would be shifted and uncertainty would scale with changing pixel resolution.

Therefore, we added the above-mentioned statements, which reflect these notions to sections 2.1, 3.1, 4 and 4.5, respectively. We indeed do not consider a discussion of optimal UAV survey designs as the major scope of this work (see also corresponding comments by referee 2). Instead, we now clarify the intension of our UAV survey design, give more details on the operational and computational costs and caution readers to consider the target scale when designing UAV surveys.

Line by line responses

L10: *It might be time to start changing this acronym to 'uncrewed'*

Gladly changed.

L13: *This key claim is overly generalised. It's not entirely false and I know that some unknowns remain, but see Dugdale et al 2010 in ESPL (Aerial Photosieving) which give a table for error estimates on grains sizes based on yet more literature. Need to clarify that we do have knowledge of uncertainties due to photosieving.*

Statement changed accordingly.

L 20: *do you mean individual, non-mosaicked, images? might be worth clarifying this in the abstract.*

Specified now in line 21.

L24: Suggestions followed.

L50: *Worth adding James et al 2014 in ESPL (the one on doming mitigation)*

Reference added.

L52: *Perhaps just an issue of phrasing, but Mike James would strongly object to this statement. If you are referring to how these choices impact grain size estimation, say so more clearly.*

Statement rephrased and shortened.

L468: *But this was observed exclusively for a DG workflow*

Statement for clarification added. We note here, that we saw similar, relative decrease of model quality independent of the referencing method, i.e., for S9 the second altitude added more noise to model irrespective of the usage of GCPs (of course the overall quality was higher when using GCPs; see Table 2 in the manuscript).

L483: *But at what cost? Does the bus speed on the new P4 match pace with the writing of a large DNG? Do you have to significantly reduce forward speed and thus take longer to finish the survey with the associated cost on batteries?*

We slightly modified the statement to clarify that we merely want to highlight that we indeed found an effect of the format that might be worth considering when designing UAV studies. Furthermore, we now address this issue (among other costs of the raw format) explicitly at the beginning of section 4.5 to caution readers.

L537: *This was first observed by Woodget et al 2018* (cited here) and *ok, noted below*

Our strategy here is to note our observation at the end of section 4.3 and then begin section 4.4 by comparing these findings to previous studies. We interpret the comments by the reviewer in way that this is appropriate.

L599: *think you've glossed over some practicalities. Acquisitions at 7m are slow and costly thus severely limiting the scale of work. This needs to be approached*

We do not want to recommend flight altitudes of < 10m (see also main response above). We clarify our reason for choosing the UAV survey design and explicitly address this and related issues in sections 2.1, 4 and 4.5.