Response to Anonymous Review #2

We wish to thank Anonymous Reviewer #2 for their detailed critique of our paper and for their considered comments. In the following we provide point by point responses to each of the reviewer's comments.

Response to specific comments:

Comment 1. *First of all, an overview of the method is required, maybe between paragraph 2.1 and 2.2. The different steps of the calculations have to be presented, a small chart could be useful. Furthermore, more details on the algorithms should be given. For example, it is said that "a distorted camera model was generated", could you explain how? I also wonder if the user has to locate the GCPs manually on the pictures. Could you clarify what you call "prominent features"? The calculation of the flow velocities owing to the first steps of the method should be explained. I was also wondering if the water surface elevation is needed or not.*

Reply 1. We agree that a flow chart will be beneficial, in helping to clarify the processing steps and will provide a clear overview of the method. We intend to include one in any revised submission. For brevity, we have not provided details of sub-steps of the approach where other authors have published details of the method. In the example that Reviewer 2 specifies, we adopt the method of Messerli and Grinsted (2015) for the development of the camera model (Page 4 Line 1). Details of this approach and examples of its use are provided within the cited publication. At the start of the processing procedure we ran the KLT algorithm to detect all 'prominent features' (which we define as all features that are extracted using the KLT algorithm). We subsequently manually select the prominent features that we can assign as GCPs. These must be level with the water surface, non-mobile, and clearly visible within the laser scan generated point cloud. These features are then automatically tracked from frame-to-frame using the KLT algorithm. In the final manuscript we will explicitly state how the flow velocities are calculated within Section 2. The method that we adopt here utilises a two-dimensional transformation which assumes that the GCPs are at constant elevation (Page 4 Line 23). By selecting GCPs that intersect with the water surface elevation, we are assuming that the water surface slope is negligible across the image frame. Whilst this assumption is appropriate for relatively small areas such as this application, this may not be appropriate in other applications. We discuss the errors associated with transformation in Section 4.2 and specifically comment on the issue of water surface elevations on Page 8 Lines 19 – 25. This is an issue that warrants further attention and is a current limitation of this method due to the lack of GCPs being established prior to the flood.

Comment 2. *The method lacks a clear validation step. The obtained flow velocities should be compared with measurements performed with other devices. It could be very interesting to apply the technic on a low flow event to control the results. The proposed validation is only based on optically tracked features; more details are required about this major operation. A small map with the measurement area and the trajectory of the UAV could be helpful in the beginning of the paper.*

Reply 2. Due to the localisation of this flash flood within an ungauged catchment we do not have any data that could be used as validation. Indeed, this was the motivation behind our approach. However, the data presented in Figure 4 clearly replicates observations of how the flow interacts with features and structures which modify the flow path e.g. blocked bridge resulting in flow being diverted along the road, while the reported standard deviations show how stable the velocity field is over the 5.6 seconds of recording. However, we do agree that a

quantitative validation of this approach is required. This is something that we intend to assess in forthcoming research activities. We are happy to provide a map of the UAV trajectory within the revised manuscript.

Comment 3. *Could you also specify how you code the different steps (matlab, fortran?). Are the codes open-source?*

Reply 3. The entire work-flow is coded in MATLAB R2016a. Although the code is not currently open-source this is something that we seek to achieve in time.

Comment 4. *In the introduction, you should cite the works dealing with measurements of surface flow velocities from helicopters images. You should also cite the different technics of image analysis such as LSPIV, LSPTV*

Reply 4. We will explicitly mention the different approaches that are available for surface flow measurement, from aerial platforms highlighting different work utilising PIV and PTV methodologies.

Comment 5. *At the end of paragraph 2.1, the error is for all the directions x, y and z?*

Reply 5. Yes the error that we cite at the end of Section 2.1 relating to the stitching of point clouds and the transformation to real world co-ordinates is the totoal error across the x, y, and z planes. We will make this explicitly clear in the revised text.

Comment 6. *Some of the Figures (1 and 4 for example) and table 1 are not cited in the text*

Reply 6. This is an oversight on our part and we will rectify this.

Comment7. *The UAV acronym should be make explicit in the abstract (especially for non-English speaking people).*

Reply 7. We will ensure that the term ‘UAV’ is properly defined in the abstract