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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Observing river stages using unmanned aerial vehicles" *by* T. Niedzielski et al.

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[REVIEWER #1] This paper is about mapping water surface areas reflecting different river stages using a simple UAV. The authors use the standard "Structure from Motion" method, however, without ground control points, and declare that the accuracy of mapping is sufficient to catch differences in the spatial extent of the river water levels due to a sufficiently high internal accuracy of the resulting orthophotomaps. The results indeed seem to be reasonable and supported by a statistical analysis, however, the paper needs to be more clearly written, some parts and methodological aspects are rather poorly explained.

[AUTHORS' RESPONSE] We thank the Reviewer #1 for assessing that the manuscript presents reasonable results. Having read the reviews offered by two Referees we en-

tirely agree that the manuscript should be substantially modified so that some parts on methods are better explained. We hereby declare that, in our opinion, the improvement in question is doable, and the revised version of the text would reveal better quality and completeness.

[REVIEWER #1] Please specify if all flight missions have been carried out using the same parameters, especially flight heights having the impact on the orthophotomap resolution and thus the accuracy of mapping.

[AUTHORS' RESPONSE] Yes, indeed, the five flight missions have been performed with the comparable parameters. We double checked the UAV log files and confirmed that heights (both planned and measured during the mission), which determine the ground resolution, were kept approximately at a similar level. The values below present detailed vertical flight characteristics.

A	B	C	D	E	F	G	H	I
27/11/2012 (1)	109.0	296.4	113.6	109.2	410.0	405.6	451.0	447.5
27/11/2012 (2)	109.0	296.5	112.4	109.1	408.9	405.7	453.5	447.9
13/05/2013 (1)	109.0	297.7	116.0	108.9	413.7	406.6	456.2	449.9
13/05/2013 (2)	109.0	299.8	118.1	109.0	417.9	408.8	458.6	450.4
21/08/2013 (1)	109.0	301.1	117.0	108.2	418.2	409.3	458.8	450.6
21/08/2013 (2)	109.0	295.2	115.0	108.9	410.2	404.1	450.0	444.8
27/09/2013 (1)	109.0	294.5	114.8	108.8	409.3	403.4	452.7	455.5
27/09/2013 (2)	109.0	295.5	114.5	109.1	410.0	404.6	454.3	446.4
02/06/2014 (1)	109.0	305.3	115.3	108.3	420.7	413.6	452.7	461.0
02/06/2014 (2)	109.0	294.3	114.3	108.9	408.6	403.1	451.1	445.4

A – Date and number of flight

B – Planned height above takeoff location [m]

C – Takeoff altitude [m a.s.l.]

D – Maximum height [m]

E – Mean height [m]

F – Maximum altitude [m a.s.l.]

G – Mean altitude [m a.s.l.]

H – Maximum altitude WGS84 [m]

I – Mean altitude WGS84 [m]

Since the information on stability of height parameters is very important for a complete understanding of comparability between the consecutive UAV missions, we produced a new table (expended version of the above-mentioned table) that might be included into the revised version of the manuscript.

[REVIEWER #1] Please explain in detail how you used the LIDAR data to do "a spatial fix and correct for errors". I think the statement that you have used the "spline function in ArcMap" is not sufficient. This part needs to be written more clearly what you have done here.

[AUTHORS' RESPONSE] In order to response to this comment we firstly put an emphasis on our key assumption which may be formulated as follows: "presence of a potential shift between two spatial data sets does not cause meaningful changes in area of the considered objects" (this is expressed in line 5 on page 11 of our HESS Discussion Paper). For instance, if one replicates an orthophotomap and applies a translation vector to such a newly produced spatial data set, the same objects will reveal the same areas (no change in scale and rotation). To support this finding we

refer to a recent paper by Mesas-Carrascosa et al. (2014) [Mesas-Carrascosa F.J., Notario-García M.D., Meroño de Larriva J.E., Sánchez de la Orden M., García-Ferrer A., 2014. Validation of measurements of land plot area using UAV imagery. International Journal of Applied Earth Observation and Geoinformation 33, 270–279]. These authors argue that "[. . .] Other shortcomings include the lack of vertical adjustment of the aerial camera and the unknown or variable interior orientation of the camera. These factors affect point position accuracy but do not necessarily decrease the accuracy of area measurements.[. . .]". Having justified a stability of area measurements in case of smaller point position accuracy, i.e. also in case of shift of orthophotomaps produced without ground control points (GCPs), we hereby describe the spline-based procedure that fixes all orthophotomaps to a single LIDAR data.

We identified characteristic features in the LIDAR digital terrain model (DTM) which were evenly distributed and possible to identify in the orthophotomap. These features comprise: crossings of bounds, crossings of drainage ditches, and centres of bridges or passages (crossings of streams and roads). More than 10 points were used to perform georeferencing, as the spline method requires. A spline function allowed us to precisely georeference the control points (i.e. the aforementioned mutual features) and transform raster data set with continuity and smoothness, such as the rubber sheeting method.

[REVIEWER #1] P. 2, l. 26, "high-resolution visual" is probably "high-resolution visible".

[AUTHORS' RESPONSE] We agree that the sentence does not read well in the initial version of the manuscript. We propose the following formulation of the sentence: "[. . .] For observing water surface area, the use is made of the following satellite-acquired measurements: HIGH-RESOLUTION VISIBLE LIGHT IMAGES OR INFRARED IMAGES, passive microwave data and radar images.[. . .]". We went through several research papers and double checked that the notion of "visible light images" is properly used in the above revised proposition.

[REVIEWER #1] On p. 6, l. 27-31 you have presented the criteria that should be met by the polygon generation procedure. As far as I have understood correctly, you have used a manual digitalization/vectorization of the water extent. Has this procedure met these criteria? Is the accuracy acceptable to catch relatively small variations in the extent of water surface?

[AUTHORS' RESPONSE] The Reviewer #1 pointed out an important problem of the accuracy of a manual vectorization carried out under several conditions (lines 27-31 on page 6 and the subsequent part of Subsection 2.2 in our HESS Discussion Paper). One of the most important factors that may potentially constrain a vectorization accuracy is related to vegetation. Mapping vegetation with UAVs becomes popular as a recent paper by Husson et al. (2014) shows [Husson E., Hagner O., Ecke F., 2014. Unmanned aircraft systems help to map aquatic vegetation. Applied Vegetation Science 17, 567–577]. These authors focus on delineating edges between water and non-submerged aquatic as well as riparian species. They write that "[. . .] In practise delineation was done by hand on paper printouts [. . .]" and "[. . .] Vegetation mapping, i.e. digitizing the UAS orthoimages, was performed manually by a human interpreter in a GIS using ArcGIS software [. . .]". Although we concentrate on a fluvial environment, the idea behind our manual expert-based vectorization remains similar to what Husson et al. (2014) propose. It is worth noting that our vectorization was practically carried out by two experts (GIS specialist + fluvial geomorphologist). Given this introduction, we unequivocally reply that the procedure met the assumed criteria (this is attained by the expert-based vectorization). We also believe that the accuracy of the produced water surface area is acceptable. However, it was our intention to include Fig. 4 and Fig. 5 which help the reader to identify potential sources of errors.

[REVIEWER #1] P. 6, l 15, explain "GSPs" abbreviation, probably a typo.

[AUTHORS' RESPONSE] Yes, indeed, the "GSPs" is a typo and in the revised manuscript should be replaced by "GCPs".

[REVIEWER #1] P. 9, l 3-7, please describe why you expect that water surface area at the time k will be greater than at the time j. Figure 6 clearly shows that water levels (A)-(E) are not increasing in time. This needs to be better explained because it is centred in the core of your paper with implications for your conclusions.

[AUTHORS' RESPONSE] Being grateful for notifying that the formulation of the hypotheses H0 and H1 is unclear, we hereby clarify the issue and propose how to make the part more comprehensive in the revised manuscript. The two sample Student's t-test is used to test a null hypothesis (H0) that means of two samples are equal, but three alternative hypotheses (H1) are allowed. These three alternatives include: means of two samples are different, mean of the FIRST sample is bigger than mean of the SECOND sample, mean of the SECOND sample is bigger than mean of the FIRST sample. In the latter two alternatives, the order of samples is important and has impact on where rejection region is located. Knowing the aforementioned basics, we stated the research hypothesis H0 with its alternative H1 on purpose, in the way that rejection of the null hypothesis implies acceptance of the alternative one (and this unequivocally indicates which area is meaningfully bigger). To clarify the entire problem, we suggest to consider two combinations of L(j) and L(k) (notations are explained in our HESS Discussion Paper). Recall that we test if mean[L(j)] = mean[L(k)] with the alternative that mean[L(j)] < mean[L(k)].

CASE 1

j = '27/11/2012'

k = '13/05/2013'

mean[L('27/11/2012')] = –1.71727

mean[L('13/05/2013')] = –1.501393

Arithmetically, mean[L('27/11/2012')] IS SMALLER THAN mean[L('13/05/2013')]. This inequality has also been confirmed statistically (the Student's t-test) at the significant

level of 0.01 (see Tab. 5, grey box indicates that the difference in means is statistically significant). Hence, in this case a subsequent episode (time step k) revealed meaningfully bigger water surface area than the preceding one (time step j).

CASE 2

j = '13/05/2013'

k = '27/11/2012'

mean[L('27/11/2012')] = –1.71727

mean[L('13/05/2013')] = –1.501393

Arithmetically, mean[L('13/05/2013')] IS NOT SMALLER THAN mean[L('27/11/2012')]. If we test (mean[L(j)] = mean[L(k)] with alternative mean[L(j)] < mean[L(k)]) we cannot reject the null hypothesis with the Student's t-test at the significance level of 0.01. Hence in this case a subsequent episode (time step k) does not reveal a meaningfully bigger water surface area than the preceding one (time step j).

Since Tab. 5 juxtaposes all cases of the above type (j does not equal to k), we suggest to remove the following phrase "[. . .] (but in practice j < k) [. . .]" from lines 3–4 on page 9 of our manuscript. The deletion of the sentence will make the conclusions straightforward.

[REVIEWER #1] On p. 10, l. 10-20 you have presented several transitions between stages. However, this part is very poorly explained. For example, how it is possible to have a subsequent stage (13/05/2013) after a later stage (02/06/2014).

[AUTHORS' RESPONSE] As we explained above, the order of L(j) and L(k) matters and influences the final results, however it is not necessary that j < k. The stages and transitions listed on page 10 are examples of low, mean, intermediate and high water levels. They have been recorded by real UAV flights on different dates. We used the UAV-observed water surface areas as true data that represent the aforementioned

stages. We believe that, for the analysis that aims to check the procedure proposed in this paper, the chronological order of transitions between stages is not important. Of course, we agree with the Reviewer #1 that it would be ideal to have the chronological set of transitions, however such a data set is not available. Thus, we mixed the order to check various POTENTIAL combinations of transitions. We think that the revised version of the manuscript should explain in a new paragraph which we are ready to prepare.

[REVIEWER #1] I recommend to present a Table with areas of the identified polygons representing identified water extents (equivalent to Figure 8). Some polygons seem to be almost identical and it is difficult to visually identify if it is larger or smaller.

[AUTHORS' RESPONSE] The areas, fractions and logarithms (hence all input data used for the analysis) have already been juxtaposed in Tab. 5 of the initial version of the manuscript.

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