

Interactive comment on “Combining high-resolution satellite images and altimetry to estimate the volume of small lakes” by F. Baup et al.

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General Comments

This manuscript estimates water levels, water areas, water volume changes and water volumes of Lake la Bure. It is a small lake of maximum 52 hectare in size, and this makes it interesting to pursue the publication of this paper. By gradually moving from larger to smaller lakes, the scientific community becomes closer to the estimation of water volumes in small reservoirs and ultimately water depths in rivers. This will have great potential for manifold applications. Radar altimetry (ENVISAT-RA2) and high res-

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olution images from one optical and two SAR satellites are all combined, being a good example of fusion of multi-source satellite data. This study is valuable for the hydrologic community to understand the potential of satellite observations to monitor water stocks in ungauged basins. It fits the scope of HESS. The manuscript is technically sound and the work can be published by HESS, if more attention to small lakes and the dependency of in situ data is provided. Also more emphasis should be given to the systematic mapping of lake levels (possible but not very regularly), lake area (easy and accurate), volume changes (difficult, unless in situ data is used) or volumes (impossible, unless in situ data is used). If these major critique is addressed in a next version of the manuscript, then I recommend this paper to be published.

1. The study objectives should be more clearly described. Many other research groups have published methodologies related to satellite measurements for estimating volume changes in larger lakes and reservoirs. In that sense, the level of innovation of this paper is limited. The core objective should be described more precisely: detect limitations of the remote sensing technology for small lakes ? To use radar measurements for the detection of the size of water bodies, instead of optical imagery ? Is it new because volumes are estimated, instead of volume changes ?

2. The manuscript refers to volume changes by using altimetry and water body sizes. The manuscript refers to volumes if bathymetry information is used. The difference and integration of these different approaches need to be spelled out more clearly. What kind of information is used when ? Figure 5 is a good start, but needs to be made more complete, with explicit descriptions of levels, areas, volume changes and volumes.

3. The Radar Altimeter onboard Envisat had a footprint of 2 to 10 km, depending on the geographical area. This footprint is approximately 10 times larger than the size of the water body, hence elevation effects of the surround terrain are incorporated into the altimeter signal. How is this potential mismatch of scale solved ? By ascribing all differences in elevation to water, assuming that the elevation differences on land can be ignored ? What is the effect of a growing crop on the RA-2 signal ?

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4. This study only tested one lake (42-52 ha) but the title was generalized to small lakes. A plural term could be justified if more discussion on the challenge of measuring small lakes is included. It is for instance interesting to quantify the limit of small lakes to which the method can be applied.

5. What is the accuracy of the estimated lake area from images? The estimated level and volume have been validated and presented in this manuscript, but a discussion on the accuracy of estimates lake area is absent. The lake area is an important input to the investigated first and third methods, thus it is also relevant to validate the estimated lake area. As a matter of fact, I like to see also the views from the authors on using optical vs. radar imagers for lake area detection. A small discussion on accuracy vs. time intervals, complexity of processing and costs would increase the value of this paper.

6. The captions are all rather short in general. The graphs and tables will be better understood if more technical information is provided. Like "in situ measurements of water level" or "Formosat satellite data" Specific comments

P2 L17: It should be $R^2 = 0.98$? as the same in the text and conclusions

P3 L30: Envisat and Alos are no longer current systems (both died)

P4 L 13: Describe why earlier solutions are not applied to small lakes, and mention more explicitly how you envisage a solution that tackles this problem P5 Figure 1: A messy figure, and difficult to interpret. What does the cloud of points in the lower figure represent ? Are this all individual radar pulses ? Explain in the main text how many original RA-2 data points you have, and how is this processed further into one single final value of the water level

P5 Figure 2: No need to present this time table. The intervals and frequency is clear when you present the results

P6 L4. Better to provide spatial and temporal resolutions for the three sensors in Table

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P7 L13. Provide the links for each data source throughout the text.

P8 L24. Table 2, Better to specify the dates, e.g. for water levels, 2003-2010; please check the date for the rainfall, shouldn't be 2003-2010? As in Figure 4, the rainfall data last from 2003 to 2010.

P8 Figure 4: Explain the plateau for maximum volume. Is that a spillway effect because the water level cannot rise further ? Figure 4 could be improved by showing $P - ET_0$, because lake evaporation will largely affect the volumes. Actual lake evaporation is rather complex to compute, but I suggest to take a simple reference evaporation for this sake. That is at least better than ignoring the effects of evaporation on lake volumes.

P9 Figure 6: This confirms that RA-2 is not having a central overpass over the lake. How did you derive the lake level fluctuations (see comments before) ? More details on the footprint size, the intervals between two footprints and number of valid footprints within lake should be given.

P10 L23. More details are needed here. How to determine a footprint as an outlier? What was the procedure to correct for hooking effects ?

P10 L25. No geoid was used? What datum/reference the water level is with respect to? The error bar for the estimated water levels should be provided.

P10 L28. On average, how many valid footprints were finally captured for each cycle ? Better to provide the minimum and maximum value for a certain cycle. How many water levels were finally obtained during the studied period?

P11 L24. Specify the RRMSE when it was used at the first time.

P12 L7. The satellite images were acquired on certain days, while as described in Table 2 the in-situ levels and volumes were at weekly intervals, specify how you did match them for regression and validation. Similar comment applies to matching altimetry level

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and weekly in-situ data later.

P12 L9-13. Different units have been used such as ha, hm³, m³, km² through the text. It is better to keep consistency and use only one type of unit.

P12 L20. As commented above about the datum of the estimated water level, are in-situ level and estimated water level at the same reference datum? In addition, the in-situ level was at weekly interval, while altimetry measures at a specific date. How did you match altimetry-level and validate them to compute the RMSE? Here it is relevant to give more details.

P12 L27. Is there any possible explanation for such high difference ~ 1.3 m?

P13 section 4.3: this section is very important, but it does not come out easily. You need to describe the analysis and finding more systematically, and probably make this section a bit longer. To compensate for the length of the paper, the general description of the radar signals is not relevant for this type of analysis, and can be left out in the next version of the manuscript. Section 4.3 pertains to various combinations of in situ and satellite data, and finally the dots in Figure 14 tell me what the result of a full remote sensing method is: 5 dots for the season, a fluctuation between -0.75 to + 0.75 hm³ and $R^2=0.98$ with a average slope of 0.76 (or a bias of 24%). Is this accurate enough for the managers of lake La Bure ?

P13. L21. It should be "the RMSE never exceeded..."

P13 figures 9 and 10: Different values for RA-2 are used, probably because of an offset calibration involved. This makes it difficult to compare figures 9 and 10. Please prepare one range of values. Discuss the results of Fig. 10 in relation to the results demonstrated as part of Figure 3

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