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Interactive comment on "Satellite-based remote sensing data set of global surface water storage change from 1992 to 2018" *by* Riccardo Tortini et al.

Riccardo Tortini et al.

riccardotortini@gmail.com

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We are thankful to the anonymous reviewer for the thoughtful comments, which led to significant improvements to our manuscript. All comments were addressed as described below.

Best regards,
Riccardo Tortini

In this study, the authors produced a global lake/reservoir volume change dataset. The water levels are derived from altimetry data between 1992 and 2018. The water areas are mapped from MODIS data between 2000 and 2018. Finally, the water storage gain or loss for 347 lakes/reservoirs are estimated. This study is suitable to published in ESSD, but some improvements (see comments below) are necessary.
We are thankful to the anonymous reviewer for recommending the publication of our manuscript in ESSD.

1. The WSA is estimated using 500-m MODIS data. It looks that 120 MODIS pixels are included, but the lake surface area change is used. This is not suitable for most of lakes with small area changes. It could be fine for reservoirs, as the reservoirs have large inundated area dynamics. Many studies have used lake mapping from 30-m Landsat images, which is better than MODIS data.
We agree with the reviewer on this point. Landsat's finer resolution (i.e. 30 m) compared to MODIS (i.e. 500 m) would ensure the monitoring of smaller lakes, further expanding our list of 347 lakes/reservoirs. However, compared to MODIS, Landsat's 16-day revisit time would not be suitable for dense time series of observations and therefore to establish a robust relationship between WSE and WSA in order to model ΔV. We now emphasize this point in page 16, line 1-10 as reported below.
"Despite GOLA's moderate spatial resolution it can potentially affect the accuracy of ΔV estimates, higher resolution satellite missions have longer satellite revisit time (e.g., 16 days for Landsat, 10 days for Sentinel-2A starting in 2015 and 5 days for Sentinel-2A and -2B in tandem formation starting in 2017). Because we leveraged the relationship between WSE and WSA to estimate ΔV, such satellite revisit times would produce sparser records, especially for water bodies located at high latitudes and/or altitudes as they are more affected by cloud cover. In fact, despite being highly desirable for monitoring of surface water dynamics, imagery from optical sensors is strongly affected by the presence of cloud cover, which can be extensive in late fall and

winter, and in combination with low sun angle experienced at high latitudes may limit its usefulness at the global scale (Duguay et al., 2015). However, the integration of optical imagery (e.g., MODIS, Landsat, Sentinel-2) and radar altimetry data provides long-term continuity in the production of consistent and calibrated records, and we encourage to re-explore the lakes in our study using Landsat and/or Sentinel images with 20-30m spatial resolution."

2. How many lakes in the Tibetan Plateau are included? The existed studies have reported that about 60 lakes with altimetry data and the corresponding estimates of lake volume variations.

We created elevation, area, and storage variation records for 30 lakes in the Tibetan Plateau (cfr. list below). As explained in the previous comment, the spatial resolution of the satellite imagery limited the number of lakes for which a reliable WSE-WSA relationship could be established to estimate storage variation. We now highlight this in page 9, line 5-7 as reported below.

"The majority of the water bodies (223, 64.26% of the total) are located in Asia (110, of which 30 in the Tibetan Plateau) and North America (113), with Australasia represented by just eight targets."

3. The Equation (1) is correct? It is WSEt+1 - WSEt?

We thank the reviewer for spotting the typo. We edited Equation (1) in the manuscript as:

$\Delta V = (WSA_{t+1} + WSA_t)(WSE_{t+1} - WSE_t)/2$

4. The linear regression between elevation (WSE) and surface area (WSA) was used. How about polynomial correlation? The authors test them?

We agree with the reviewer’s comment that the bathymetry of a lake should not follow a linear behavior, and acknowledge that the 0.5 multiplier used in Equation (1) usually underestimates the actual volume change by not taking into account factors such non-linear bathymetries and the shape of the shoreline. However, volume changes are dominated by WSE rather than WSA changes, suggesting that bathymetry errors are less important than WSE errors. Such approach works reasonably well at most lakes/reservoirs (cfr. Gao et al., 2012), ultimately proving more portable to lakes/reservoirs at the global scale. We now account for this in page 15, line 25-35 as reported below.

"The quality of both elevation and surface area contribute to the accuracy of their relationship, but volume changes are mostly dominated by elevation changes. High correlations between elevation and area generally indicate reliable ΔV estimation. However, if either variable is systematically biased, the error associated with the relationship is carried to the estimated ΔV. For example, low correlation may arise when the target shows nearly constant WSA (vertical walls, in which case a variation in elevation reflects in a negligible change in WSA) or nearly constant elevation (i.e., shallow lakes, in which case a variation in surface area reflects in a negligible change in elevation). In these cases we proceeded in the modelling of ΔV with the parameterization of the invariant variable with its mean value. All the factors listed above introduce some degree of error in the WSE-WSA relationship; however, in most cases a linear approximation does not appear to be a major contributor (cfr. Gao et al., 2012)."

5. More validations including lakes in different types and continents can be provided?

We thank the reviewer for the recommendation and we agree that validation using further lakes would be beneficial to the global nature of our study. However, we state how "[the] records presented in this paper represent the most complete satellite-derived global surface water storage time series to date, spanning from 1992 (TOPEX-Poseidon launch) to present, with the potential to be extended up to the launch of the SWOT mission planned for 2021" (page 16, line 31-34). In addition, we acknowledge that "[the] data set presented is dynamic and will continue to be extended both in terms of the number of water bodies (with ultimate potential total around 400), and historical time period" (page 16, line 34-35), but this is beyond of the scope of the manuscript.

6. How water storage change in 1992-2000 without MODIS water mapping was estimated?

As explained in section 2 Data and methods (page 7, line 27-28), we used linear regression to approximate the relationship between WSE and MODIS-derived WSA when concurrent measurements are available (2000-2016), and then applied this relationship to estimate WSA from WSE for periods when WSA is unavailable (1992-1999).

Specific comments:

1. "and to characterize how these conditions change through time over long periods (Lettenmaier et al., 2015; Crétaux et al., 2016)" A suggested study here for monitoring lake area, level and volume changes since 1970s: http://dx.doi.org/10.1002/2017GL073773

We thank the reviewer for the recommendation and added the reference to the text as suggested. Zhang G., Yao T., Shum C. K., Yi S., Yang K., Xie H., Feng W., Bolch T., Wang L., Behrangi A., Zhang H., Wang W., Xiang Y., and Yu J.: Lake volume and groundwater storage variations in Tibetan Plateau's endorheic basin. Geophys. Res. Lett., 44(11), 5550-5560, https://doi.org/10.1002/2017GL073773, 2017.

2. "and the Tibetan Plateau (Lee et al., 2011; Kleinherenbrink et al., 2015; Cai et al., 2016)." It looks some key studies of lake changes in the Tibetan Plateau from altimetry data are missed here. https://doi.org/10.1029/2019GL085032, https://doi.org/10.1016/j.rse.2011.03.005, https://doi.org/10.1007/s10712-016-9362-6.

We thank the reviewer for the recommendation and added the references to the text as suggested.

Zhang G., Xie H., Kang S., Yi D., and Ackley S. F.: Monitoring lake level changes on the Tibetan Plateau using ICESat altimetry data (2003-2009). Remote Sens. Environ.,

115(7), 1733-1742, https://doi.org/10.1016/j.rse.2011.03.005, 2011.
Crétaux J. F., Abarca-del-Río R., Bergé-Nguyen M., Arsen A., Drolon V., Clos G., and Maisongrande P.: Lake Volume Monitoring from Space. Surv. Geophys., 37(2), 269-305, https://doi.org/10.1007/s10712-016-9362-6, 2016.
Zhang G., Chen W., and Xie H.: Tibetan Plateau's Lake Level and Volume Changes From NASA's ICESat/ICESatâĂŘ2 and Landsat Missions. Geophys. Res. Lett., 46(22), 13107-13118, https://doi.org/10.1029/2019GL085032, 2019.

3. "a polygon was drawn by hand using high resolution imagery from various sources (e.g., Global Surface Water Explorer, Google Earth, ESRI World Map)" How to make sure the dates between them are matched.

The reviewer brings up a valid point here. However, as explained in section "2.2 Surface water area", these polygons are exclusively used as initial reference for the classification and water surface area extraction. Given the nature of the classification algorithm described in Khandelwal et al (2017), mismatches between actual water surface area extent and reference polygons are taken into account by introducing the concept of "dynamic region width" (page 15, line 17-26). Ultimately, the water surface area records in the GOLA data set are exclusively a function of the MODIS imagery utilized, but volume changes are mostly dominated by elevation changes. We clarify this aspect in the manuscript as follows (page 15, line 21-26).

"Due to the moderate spatial resolution of the GOLA records, the effect of mixed pixels is even more prominent in water bodies with low dynamic region width, which can lead to low correlation values between elevation and surface area. Conversely, the classification of targets with high dynamic region width consistently performs better in the GOLA records. The quality of both elevation and surface area contribute to the accuracy of their relationship, but volume changes are mostly dominated by elevation changes."

4. The links below are not accessed. https://doi.org/10.5067/UCLRS-GREV2,

https://doi.org/10.5067/UCLRS-AREV2, https://doi.org/10.5067/UCLRS-STOV2, https://podaac.jpl.nasa.gov/

The links listed provide the location of the data repositories, and they are all active and publicly accessible. We now state this explicitly in page 16, line 17-18.

"The links listed provide the location of the data repositories, and they are all active and publicly accessible."

5. The correlation (r2) could be presented in Figures 6, 7, 8.

We agree with the reviewer that adding the R2 would enhance the figures' readability. We have done so where applicable (Figure 6 and 8) as suggested. Figure 7 is instead limited to the 2000-2016 period where both WSE and WSA were used to calculate the hypsometric function used to extrapolate records pre-2000 and post-2016.

6. How about the mismatching in Figure 8a-b?

As explained in the text (page 12, line 1-7), we evaluated the statistical accuracy of WSE and storage estimates at Lake Sakakawea based on monthly in situ water measurements at Garrison Dam (black). These measurements were plotted against (a) monthly average WSE records and (b) storage change estimates (red), resulting in 233 and 270 coincident observations, respectively. Panel (c) and (d) directly compare the correspondent measurements, and as described in the text (page 12, line 8-11) the linear fits resulted in R2 0.95 and 0.94, respectively, indicating very good consistency with the in situ measurements.

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Discussion paper