Leveraging ICESat-2 and Landsat for global-scale, multi-decadal reconstruction of lake levels

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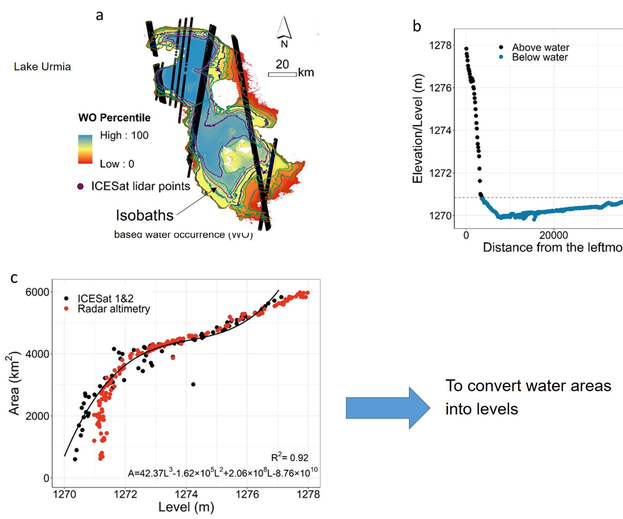
Introduction

Lakes store 87% of Earth's surface freshwater, providing important water supplies and many essential ecosystem services. Climate change and anthropogenic activities are increasingly threatening lakes, as evidenced by record-low levels in some of Earth's largest water bodies. Yet, continuous monitoring of lake levels is rare at a global scale due to the sparse in-situ gauging network and the limited monitoring capacity of existing satellite radar altimeters on inland water levels. Here, we propose a novel proxy approach to derive water levels over recent decades (1992 to the present) based on satellite observations of water areas and lake bathymetry using 30-m Landsat images and a recently launched laser altimeter ICESat-2. We leverage a recently developed algorithm to construct high-frequency water area time series using both cloud-free and partially cloudy images. To convert water areas to levels, we derive lake bathymetry by mapping the extents and elevations of isobaths using ICESat-2 and a 30-m water occurrence map. We evaluate this method on dozens of lakes worldwide with documented long-term water levels that were directly observed from satellite radar altimeters. Given better spatial coverages of Landsat and ICESat-2 missions compared with radar altimeters, the proposed method here can be potentially used to conduct an improved global inventory of time-varying lake levels and thus inform water resources management to a greater extent.

Data & Method

This method automates three steps to reconstruct water levels using Landsat and ICESat-2:

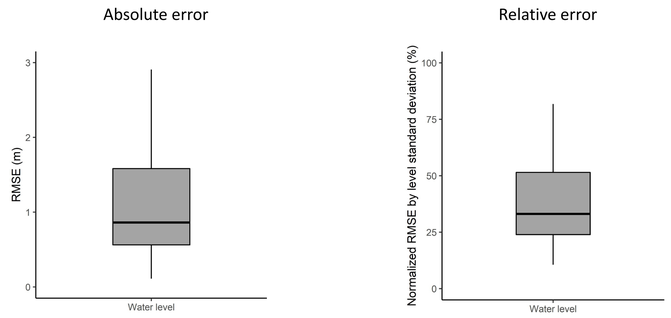
- Step 1: Constructing water area time series using the entire Landsat archive, including partially cloudy images (Yao et al. 2019).
- Step 2: Constructing lake hypsometry using ICESat-2 and a water occurrence map as in JRC-GSW dataset (Pekel et al. 2016).
- Step 3: Converting water areas to levels using the hypsometric curve.



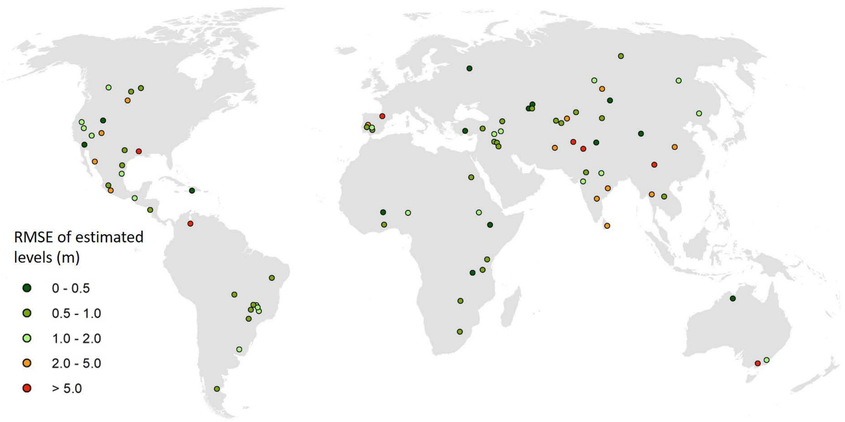
Validation: reconstructed water levels are validated against observed water levels from radar altimeters. We compare a total of 92 lakes worldwide with a size ranging from 2 to 6,000 km²

Results: Validation on dozens of lakes

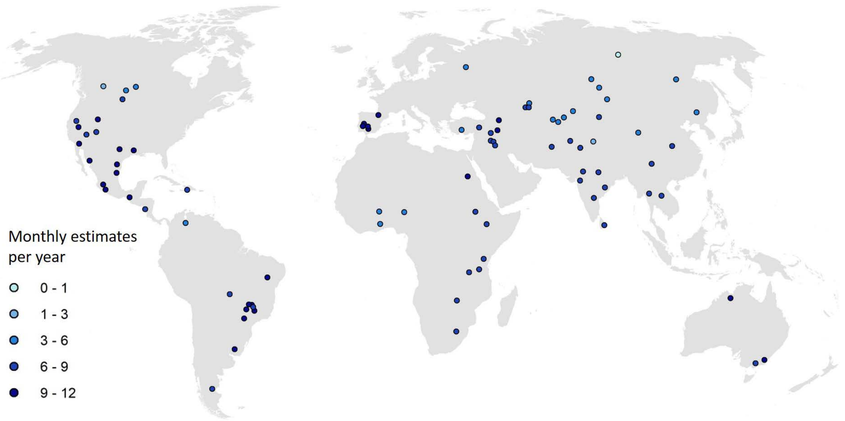
Accuracy of reconstructed lake water levels



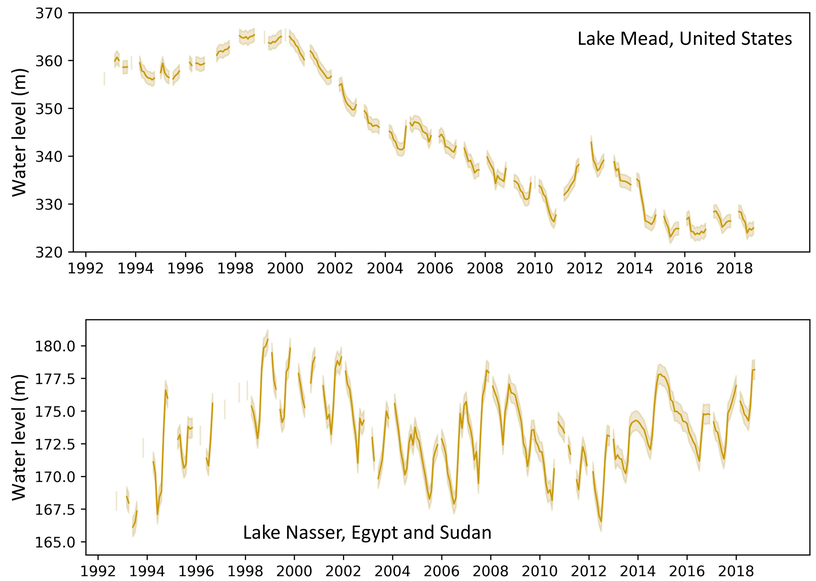
Reconstructed levels in most lakes have a sub-meter accuracy

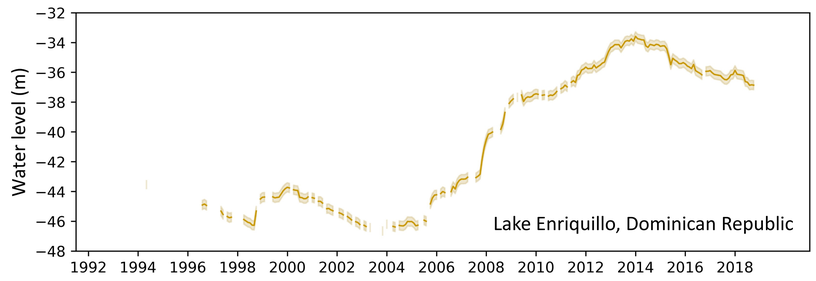


Temporal frequency of reconstructed levels over past 3 decades



Results: Examples of reconstructed level time series





Note: The shading denotes the level uncertainties calculated as RMSE

Conclusions

- We develop a novel method to reconstruct multi-decadal lake levels using ICESat-2 and Landsat. Reconstructed levels have a sub-meter accuracy in more than half of the studied lakes .
- The monthly coverage of reconstructed levels is pretty high, covering 7.5 months per year on average.
- The proposed method can be applied to hundreds of thousands lakes on Earth.

References

Yao, Fangfang, Jida Wang, Chao Wang, and Jean François Crétaux. 2019. "Constructing Long-Term High-Frequency Time Series of Global Lake and Reservoir Areas Using Landsat Imagery." *Remote Sensing of Environment*. doi: 10.1016/j.rse.2019.111210.

Pekel, J.-F., Cottam, A., Gorelick, N., Belward, A.S., 2016. High-resolution mapping of global surface water and its long-term changes. *Nature* 540, 418–422. doi: 10.1038/nature20584