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High-resolution bathymetry mapping of shallow and ephemeral desert lakes using satellite imagery and altimetry

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Many of the world's drylands are characterized by interior drainage systems that terminate at shallow desert lakes or playas. Except for episodic flooding these largely ephemeral water bodies, remain mostly dry. Surveying and mapping their respective floor topography in a suitable resolution for calculating water balance is a difficult and laborious task. As this is crucial for water resources management and reconstructing paleoenvironmental conditions, diverse methods and efforts were applied. However, detailed, high-quality bathymetric surveys in such environments are rare and have only been conducted in a few such lakes. This is primarily due to their shallow, low-relief, large areas, and often remote characteristics, which complicate application of conventional topographic surveying techniques. Therefore, satellite-based remote sensing is an essential complementary approach for deriving bathymetry of such lakes.

Global digital elevation models, such as NASA's Shuttle Radar Topography Mission (SRTM) or ASTER's GDEM, are unsuitable for accurate measurements of these ephemeral lakes, mainly because of their impenetrability to water and their high signal-to-noise ratio in the low-relief environments. Recent studies addressed these complications by combining remote sensing data with local calibrations of in-situ measurements, or alternatively, by relating shoreline altitudes with precise altimetry. This approach requires a spatial interpolation of individual measurements. Therefore, it is prone to errors that demand intensive efforts to be reduced; even then the errors may remain larger than the actual depth of a flooded lake. Moreover, such methods are hard to apply in complex lakes with multiple sub-basins.

To tackle these problems, we developed a simple methodology to derive a high-resolution (30 m per pixel) bathymetry of shallow desert lakes. In this new method we combine two sources of data: a >30-yr record of Landsat-derived surface water occurrence data; and accurate high-resolution elevation data, acquired by the NASA's recently launched ICESat-2 satellite (Ice, Cloud, and Land Elevation Satellite-2). We test the proposed new method over three ephemeral lakes around the world: Lake Eyre, Australia, with its complex shallow lake system, consisting of a few sub-basins; Sabkhat Al-Mellah, Algeria; Lago Coipasa, Bolivia. The accuracy of the resulted bathymetric maps was evaluated using cross-validation of ICESat-2 scans, yielding low RMSD values of ~0.3 m, versus ~2.5 m of the SRTM data (validated through other ICESat-2 scans). At Lago Coipasa, we show that bathymetry was effectively determined even when the lake was full of water (up to a few meters depth). This high-resolution, low-error bathymetry mapping complement other globally available topographic data.