Operational and Archive Data Records: Surface Elevation Measurements of Lakes, Wetlands, and Rivers for Resources and Hazards

OST
7-11th November 2023
San Juan, Puerto Rico,

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Supported by NASA grant NNH20ZDA001N-OSTST

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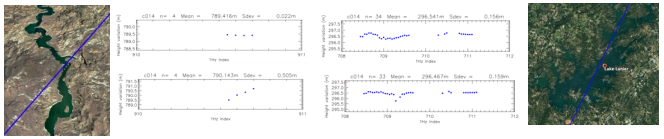
Introduction

A NASA/USDA funded program offers satellite-derived products for lakes, reservoirs, river reaches, and wetland zones. These are currently being derived from the 10-day and monthly-resolution radar altimeter series. However, observational parameters from the laser-based ICESat-2 mission, and the enhanced SWOT KaRIn instrument will also be integrated to meet various end user requirements. The resulting measurements will ultimately be a combination of surface water level and slope, surface water extent, water storage and basin bathymetry, plus a suite of Status Indicators which highlight deviations from long-term and seasonal averages. The main stakeholders are the USDA/Foreign Agricultural Service, the US Geological Survey, USACE/NGA, and various Wetland-related organizations. Applications centre on water and energy resources and fish-catch potential, and on natural hazards (floods and droughts). There is a demand for a global monitoring service, but primary focus is on regions where gauge measurement access is restricted or delayed, or where gauge deployment is hazardous. Ongoing surface acquisition checks and feedback to CNES focusses on the success or failure of the on-board DEM's on a case-by-case basis. Multiple projects are also underway to improve the surface elevations measurements and the along track resolution (minimum water body width) via exploration of the high resolution (Doppler) Range estimates, the FF-SAR technique, and the high- resolution radiometer-based wet tropospheric correction. And while Level3+4 surface water products are being directed by end user requirements, the overriding NASA objectives are the formation of high-quality Earth Data Records with high accuracy and uniformity across multiple decades.

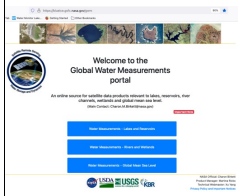
Improving Surface Acquisition

Team projects are becoming focused on i) the acquisition of new reservoirs (≤100km^2) often found in mountainous terrain, and ii) with respect to the State of Alaska and several Canadian provinces, the acquisition of small ponds within the Yukon Flats and on the North slope, and iii) a selection of glacially dammed lakes in the USA and Canada. These are presenting the smallest water extent or width to the conventional radar altimeters. The programs are thus turning to ICESat-2, SWOT-KaRin, and the use of Delay Doppler radar altimetry with application of the FF-SAR technique. Exploration of FF-SAR is ongoing via collaboration with NOAA/STAR and GST. Delay Doppler-processed and FF-SAR case studies have begun on 4 USA test sites using Sentinel-6 for which Gauge data and/or Low Resolution GWM altimetry products are available: the Chena and Minnesota Rivers, and the Owyhee and Sidney Lanier Reservoirs. FF-SAR is still under development but comparisons between Low-Resolution and High-Resolution elevations based on the ice retracker (OCOG) are underway with mixed results with respect to quantity/quality. Similar comparison using the SAMOSA/SAMOSA+ retrackers will be undertaken.



Low Res Versus High Res : For Owyhee (left) and Sidney Lanier (right) with an elevation profile for 1 select 10-day repeat cycle from Low Resolution (top row) and High Resolution (SAR) processing and utilizing the ice (OCOG) retracker for both.

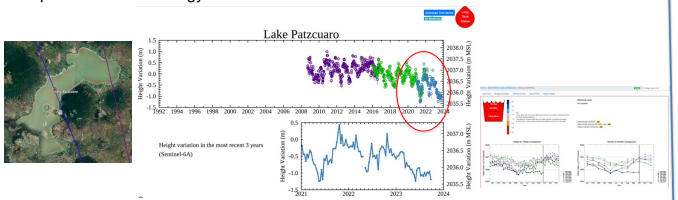
Application

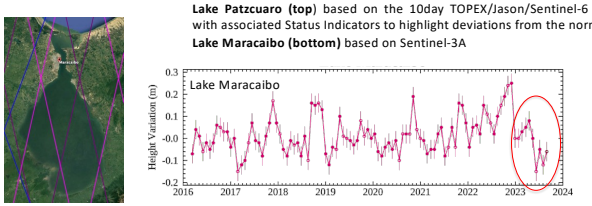


The Global Water Measurements Portal
https://blueice.gsfc.nasa.gov/gwm

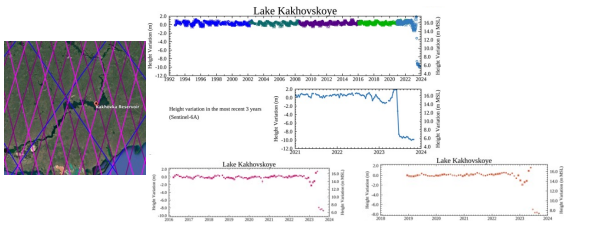
- Availability of near real time and archive data.
- Surface water level products available 3 days after overpass.
- Advantageous for supplementing existing gauge data, or for providing new elevation data where gauge deployment is hampered.
- Currently offering surface elevation and associated Status Indicators, and prototype surface extents
- Applications focusing on dynamics, hazards (flood/drought), and resources (water, energy fisheries, ecology/conservation

Drought: A reduction in rainfall and increasing industry/municipal demands for water are leading to a long-term decline in lake water levels in many regions around the world. Examples here are for Lake Patzcuaro (Mexico) and Lake Maracaibo (Venezuela). Patzcuaro, originally a 100km^2 semi-closed water body with ground seepage, is now connected to a system of canals and irrigation channels and is important for agriculture and local fisheries. Maracaibo, a large brackish bay connected to the Gulf of Venezuela by the Tablazo Strait is fed by numerous rivers. A dredged channel allows shipping in/out of the lake. Drought, pollution, and lack of water governance is leading to a complete collapse of the lake ecology.

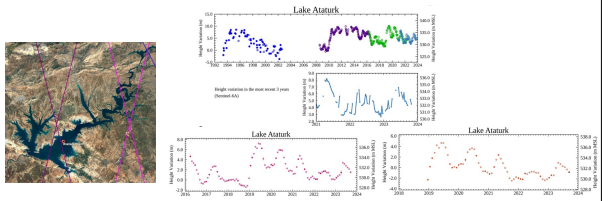




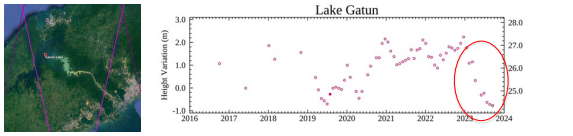
Lake Patzcuaro (top) based on the 10day TOPEX/Jason/Sentinel-6 series with associated Status Indicators to highlight deviations from the norm.
Lake Maracaibo (bottom) based on Sentinel-3A



Floods: Russian/Ukraine conflict caused a breach in the Kakhovskoye Dam leading to downstream flooding of the Kherson communities and an emptying of the reservoir. Multiple end user requests led to multi-platform measurement development and additional Ukrainian reservoirs being observed.



Earthquake: The spring 2023 earthquake along the Turkey/Syria border led to a National inspection of regional reservoirs along the earthquake zone to check for physical damage and it reported negative impacts. Rumors on social media though suggested that the Ataturk Dam had been compromised. Requests from US agencies requested independent satellite-based measurements to confirm the situation. Despite multiple available platforms, the swath-based SWOT-KaRIn would have provided a much better country-wide coverage.



Drought and Transport: Lake Gatun is part of the Panama Canal system. Its waters are used to supply the various locks and so is an essential element that aids international shipping. Drought during early 2023 caused lake water levels to decline causing restrictions on the passage of the heaviest ships and tankers.

Open Loop Tracking Command for Hydrology – Testing the Onboard DEM

Introduction

The OLTC is an on-board feature used to set the altimeter wave-forms reception window. It contains a priori elevation information derived from a dedicated database of hydrological targets.

The OLTC tables are computed using on-ground input data (for a list of hydrological targets) and are uploaded to the satellite and held in instrument memory. The tables are updated by telecommand operations once per year.

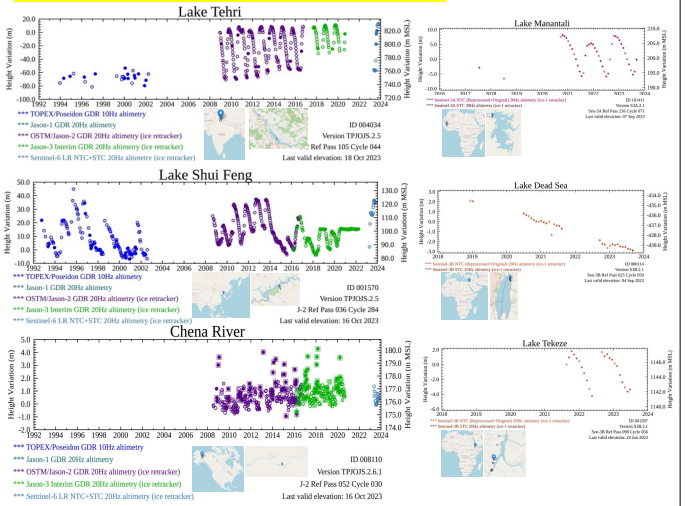
The latest Tables (or pseudo "DEM") upgrades have been : S3A v6.2 active onboard since Sep 08, 2022; S3B v4 active onboard since Aug 24, 2023; S6A v1.3 active onboard since May 10, 2023).

Testing the Onboard DEM: The team have been checking on how accurate the onboard DEM elevations are, by validating them with use of the ICESat-2 altimetry and Google Earth surface orthometric height evaluations. Considering the reception window width (60 meters) and allowances for potential variations (e.g., shift of the on-ground satellite track, propagation delays, natural seasonality), the target elevation must have a +/-10 meters accuracy to ensure a correct echo acquisition. This level of accuracy is sometimes difficult to obtain in certain regions where input data are not accurate enough. In such cases, when no elevation can be supplied, the onboard DEM continues to the target with the latest elevation in the Table (e.g., elevation of previous target). On a global scale, the success of OLTC has been found to better for large lakes, reservoirs, and river reaches, than for small ponds and narrow streams.

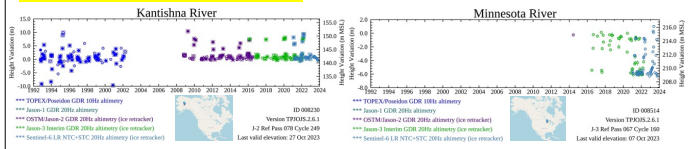
Global Water Measurement (GWM) portal: Of the 914 current global target elevation products, 170 have been DEM compromised at some time during the observation period. Some water bodies were originally incorrectly set in the DEM, or suffered from a later DEM modification, or needed a revised DEM value due to natural or anthropogenic variations. The majority of the 170 have been have addressed are currently GWM only has 19 remaining DEM failures in the Sentinel-6A (10 sites), Sentinel-3A (6 sites) and Sentinel-3B (3 sites) products. To summarize, the content of the GWM portal has transitioned **from 81% acquisition success rate to a 98% success rate**. Regular reporting of DEM failures to CNES and corrections to maintain the successful GWM operations for end users and stakeholders.

Reacquired targets

Examples: DEM incorrect then rectified



Examples: Forcing a DEM (otherwise instrument toggling between different surfaces)

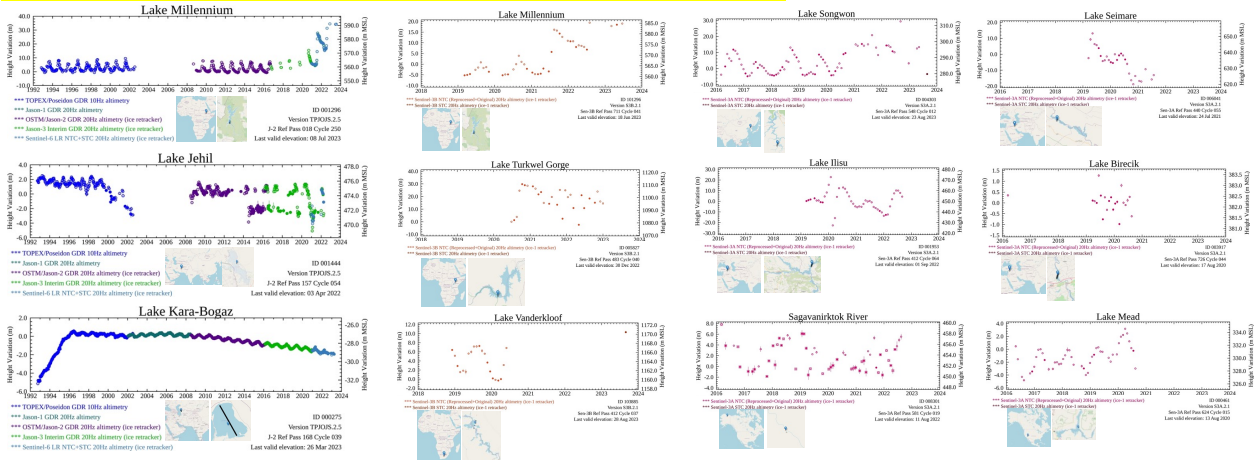


By mission or tandem period: Number of Total/DEM compromised targets.

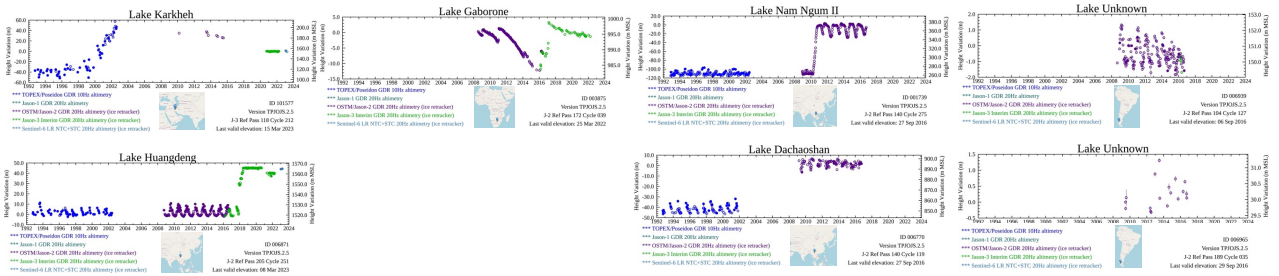
Mission	Lakes & Reservoirs	Rivers	Wetlands
Jason-3	436/44	185/48	32/0
Jason-3/Sen-6A	436/8	185/4	32/0
Sen-6A	436/1	185/0	32/0
Sen-3A	133/43	35/4	8/0
Sen-3B	75/16	7/2	3/0

Remaining DEM Failures

Examples: Successful S6A/S3A/S3B acquisitions transitioning to failures



Long term J3/S6A acquisition failures



Summary: The OLTC for acquisition of hydrological targets is extremely good, but there is the need for continuing checks, validation, and modifications. The next steps aim at using ICESat-2/GEDI blended DEMs to cross-check regional groups of water bodies, rather than record issues on a single target-by-target basis, and to include SWOT KaRIn swath data. Refined OLTC tables are particularly important as the GWM portal starts to address very small ponds, glacial lakes, and high-latitude streams as part of new ICESat-2 and SWOT projects.