G-REALM: Sustained Water Level Monitoring for Agriculture, Regional Security, and Inland Fisheries

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USDA/FAS output global monthly crop conditions and crop production estimates. Estimates drive price discovery, trade and foreign policy, farm programs. Statistics are produced via a monthly operational USDA/OGA DSS process.

Availability of stored water for irrigation is unknown in many regional locations. Such information is sensitive, with denied or delayed access.

Satellite remote sensing (radar altimetry) provides long-term and operational surface water levels for the world’s largest lakes and reservoirs.

Instrument technology and data interpretation are rapidly evolving. There is also satellite continuity and three new missions will be operating simultaneously. While the technique is equally applicable to wetlands, there is now a greater ability to acquire the water level of much smaller lakes. In addition, satellite-based determinations of surface extent, reservoir operating rules, and regional DEM, are also making great strides.

There is opportunity to monitor water levels of a) many hundreds of lakes and reservoirs for agriculture and regional security applications, and b) many lakes/wetlands for inland fisheries studies.

The near future could see a transition from delivery of operational water level products to delivery of operational surface extents, and storage change products.
Current partners and user community

Co-PI: Mr. Robert Tetrault (Agriculture)
USDA/FAS, Washington DC
Original sponsors of development and system integration
Continuity of funding contributions for operational (product update) tasks
Total contribution to date $1.23m

Co-PI: Ms. Jeanne Roningen, (Regional Security)
Engineer Research and Development Center
CERDC/USACE, New Hampshire

Collaborators for Inland Fisheries test case studies:
Prof. Jeppe Kolding, University of Bergen, Norway
Mr. Simon Funge-Smith, FAO, Rome
Mr. Lammert Hilarides, Wetlands International, The Netherlands

CropExplorer/G-REALM exists in the public domain, user community is diverse
**G-REALM: Sustained Water Level Monitoring**

**Additional partners**

Additional funding from the 2012 NASA MEaSUREs program (Manager: Martha Maiden).

*Making Earth System Data Records for Use in Research Environments*

“Development of pre-SWOT ESDRs for Global Surface Water Storage Dynamics and River Discharge Predictors”, PI: Prof. Dennis Lettenmaier, UCLA

Project is running to FY19, is non-operational, and looks to G-REALM for the delivery of archival products (1992-2016) relevant to high latitude lakes and reservoirs that are outside the current region of G-REALM agricultural interest (<40deg South, > 25deg North).

G-REALM products are being archived at the JPL DAAC.
Potential Future Partners?

G-REALM could engage with:
- Additional USACE and ERDC stakeholders (Water, Energy, & Food Nexus).
- The wetland conservation&ecology orgs (Water Quality, Surface Extent).

G-REALM could also be further developed to be:
- Part of a one-stop-shop for hydrological parameter access. This would contain both archival and operational data sets, and offer various satellite-based parameters including precipitation, water temperature, soil moisture, groundwater, water levels, surface extent, basin/lake bathymetry, stored volume, lake ice thickness, water quality, etc.

This type of one-stop approach is already underway by non-US groups e.g., Globolakes, Copernicus, Hydrolare.
Key datasets and technical tools

Standard “repeat track” techniques utilizing conventional and enhanced satellite radar altimeters. Enhanced instruments utilize SAR processing methods.

10-day repeat cycle altimeters:
NASA/CNES  Topex/Poseidon, Jason-1,-2,-3, Jason-CS

27/35-day repeat cycle altimeters:
ESA/ISRO  ERS-1,-2, ENVISAT, [Cryosat-2], SARAL, Sentinel-3

Continuity is assured via requirements of sea level/ice sheet/coastal/hydrology communities and the planned Jason/Sentinel missions.

The “game-changer” pathfinder missions, ICESat-2, SWOT, GEDI and innovative research techniques (e.g. FF-SAR) could additionally offer the highest spatial resolutions and thus the acquisition of the smallest water bodies.
Approach

**Continuous operation** along pre-determined satellite reference ground tracks results in many potential virtual gauging stations across the water surface. Surface elevations can be constructed at set spatial resolution intervals along these narrow (nadir) tracks. Elevations are averaged from bank-to-bank, and the means compared to additional repeat cycle overpasses. A time series of water level variations can be constructed and the results merged across **multiple follow-on missions**. The result is a **multi-decadal overview** revealing short- and long-term droughts, recharge periods, and sustained recoveries.
Impacts (achieved and anticipated)

G-REALM enhances the USDA/FAS DSS via the provision of archive and near real time information on water levels in lakes and reservoirs. It provides data in remote arid and semi-arid regions where water resources vulnerability or poor infrastructure affects regional security. Expected number of monitored lakes/reservoirs = 1,000.

The system could expand to incorporate the routine monitoring of surface water levels in wetlands and small lakes to aid research into the links between basin parameters and fish catch potential. The team anticipate the ultimate introduction of wetland monitoring to serve end users with interests in food security. Expected number of test case wetlands = 20.

USDA Product Application: Lake Dahuk (Mosul Dam, Iraq).
The largest dam in Iraq, the waters are a source for hydroelectric power and spring and summer crop irrigation. Recharge depends on snow melt in North-East Turkey. The most dangerous reservoir in the world due to poor construction and downstream flood potential, the water level has been recently lowered to reduce pressure on the dam. USDA/FAS regional analysts look to G-REALM products to help assess summer crop statistics.

**Transition Strategy**

G-REALM already exists within the USDA CropExplorer web tool. The G-REALM web site pages will transition from USDA to SGT management in 2017, but a site mirroring function will ensure continuity for stakeholders.

G-REALM will continue to be maintained by SGT. There is no planned 100% transition to USDA or to USACE due to the system being semi-automatic requiring some manual input. In addition, each new satellite mission data set has to be investigated and validated prior to integration.

However, the system could be incorporated into a much larger multi-product operational monitoring program. Inquiries are being made into the NASA DAAC databases (e.g., WorldView) though real time/near real time operations are not a primary function and some have user password entry.

Spring 2017 ARL=1 (Sentinel-3a)
Spring 2017 ARL=6 (Jason-3)
Lessons Learned

• Be prepared to be flexible and evolve with changing requirements.

• System in the public domain? Have point of contact with Q&A section, and include FTE for maintaining this public poc service.

• Backup hardware and manpower support essential for maintaining operations.

• Merger of data from multi-platforms non-trivial.

• R&D support must keep pace with Operations support.

• Significant modifications i.e. the incorporation of surface extents for operational storage or storage change estimate, will require FTE and system development funding. Outreach to the various research groups is planned in the new phase. RFI and workshops may follow.
Highlights

1st Quarter 2017: Extending the Jason-2/Jason-3 surface water level product series for 202 lakes and reservoirs with historical Topex/Poseidon and Jason-1 data. The resulting extended products, which now span the 1992-2017 period, are currently undergoing revision prior to delivery.

Fig.1 Extending the OJ.2.3 products to the full TPJOJ.2.3 time line. Examples are for Lake of the Gods (Canada) and the Mosul Reservoir (Iraq). The Jason-1 products (red) are first merged to Jason-2 (purple), and then Topex/Poseidon (blue) merged with Jason-1. Loss of Jason-1 data is problematic, leading to the application of a global mean inter-mission height bias.
G-REALM: Sustained Water Level Monitoring

Fig. 2 Currently available 10-day resolution water level products from the NASA/CNES TOPEX/Jason series of instruments. The map displays the originally monitored 80 lakes and reservoirs (in red), and the additional 202 water bodies added during 2016/2017 (in blue).
Publications and Presentations

April 2017: “Monitoring of Lakes, Reservoirs and Wetlands for Water Resources, Agriculture, and Fisheries”, by Birkett and Tetrault, oral presentation at the 2\textsuperscript{nd} SWOT Applications Workshop, April 5-6\textsuperscript{th}, USGS Reston/Virginia.

April 2017: “Using Google Earth Engine to Monitor the Elevation of Water Bodies” by Nguy-Robertson et al., contributing G-REALM ppt to the oral presentation, at the EGU General Assembly, April 23-28\textsuperscript{th}, Vienna, Austria.

June 2017: “Global lake databases for water level from satellite altimeters”, Lakes and Climate Workshop, June 1-2\textsuperscript{nd}, Toulouse, France

June 2017: “Overview of the future Lidar and Radar nadir altimeters: Icesat-2, GEDI and Jason-CS”, Lakes and Climate Workshop, June 1-2\textsuperscript{nd}, Toulouse, France