Near-Real Time Monitoring of Global Lakes and Reservoirs: Water Resources, Irrigation Potential and Agriculture

Charon Birkett  ESSIC, University of Maryland College Park
Brian Beckley  SGT, NASA/GSFC
Curt Reynolds, Brad Doorn USDA/FAS/OGA
Christa Peters-Lidard, Hydrological Sciences Branch, NASA/GSFC
OGA Objectives

To examine the contribution of lake/reservoir water surface elevation information
a) For the determination of irrigation potential in agriculture-sensitive regions
   b) As general indicators of drought/high-water situations

Requirements

Provision of products in near-real time for a designated set of lakes and reservoirs.
  Graphical and text output, relative variations with respect to
    a historical mean datum
Weekly updates, with products incorporated within the CropExplorer web-site database

Data Sets

  Near Real Time IGDR Jason-1 (post 2002)
  Temporal Sampling = 10 days
  Time Period Coverage = September 1992 to present day

Expectations

60-100 lakes (~180 large lakes with expected success rate of ~35%)
  Elevation Accuracy < 5 cm rms for the largest lakes, 10-20 cm rms for smaller (<500 sq km) lakes
  and calm-water surfaces, tens of centimeters rms for ribbon lakes in extreme terrain
  Product Delivery Latency = 7-14 days after satellite overpass

PHASE 1
Focus on Africa, with on-line T/P and J-1 products, and preliminary database construction

PHASE 2
Global outlook, ~100 targets, web site completion, routine product delivery and updates, NASA benchmarking exercises

PHASE 3
Operational updates, enhancement of the products, and overall program review

PHASE 4
Enhancement and expansion, multi-mission approach
EXAMPLE PRODUCT

Altimetric graph+text products

USDA United States Department of Agriculture
Foreign Agricultural Service
Crop Explorer

Toolbox

Lake Aral (0277) Height Variations from TOPEX/POSEIDON and Jason-1 Altimetry

Aral Sea Height Variations
TOPEX 10 Year Geo-referenced 10Hz Along Track Reference

LakeNet Profile
View Satellite Image
View 3D Image
Topex/POSEIDON/Jason Data

3-D Imagery

EXAMPLE PRODUCT

US non-profit organization with database archive, data set collation + www links.
USGS Global Visualization Viewer

USDA/NASA/Raytheon/UMD team acknowledges the AVISO data center at CNES and the NASA Physical Oceanography DAAC for the provision of the TOPEX/POSEIDON and Jason altimetric datasets.
http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir
On-line and operational with ~70 target lakes and weekly updates
NASA Integrated Systems Solutions - USDA Crop Explorer

**INPUTS**
- Altimetric Repeat Track Techniques
  - SGT/UMD
- Adaptations for lake and reservoir monitoring
- Earth Observations
  - Satellite Radar Altimetry
  - T/P, Jason-1
  - GFO, Topex-Tandem
  - (ERS, ENVISAT)

**Outputs**
- Products (SGT)
  - Computation of Stage Measurement
- Validation and Verification
  - ESSIC/UMD
- Accuracy and delivery checks
- Near-Real Time Operations
  - SGT/USDA

**Outcomes**
- USDA/FAS Global Crop Production DSS
  - Integration of multiple Datasets and Modeling Outputs
- Crop Condition and Production

**Impacts**
- Application and Impact
  - USDA + other users
  - Shared Datasets for Policy and Management Decisions

**Research:** NASA, UMD, SGT
**Partners:** USDA/FAS
Benchmarking

Comparison of original system requirements with final output
Number of targets, spatial distribution, latency of product delivery, timeline delay for target results, V+V exercises (product accuracy), Jason-1 and T/P cross-validation, project problems (surface tracking, demise of Jason-1 data).

Summary
“The program has made great strides towards meeting the immediate needs of the OGA, intra-governmental and public users. Product latency typically falls within the desired range, products span the globe touching on many crop production and crop security regions, and product accuracy is sufficient for many lakes and reservoirs within the GRLM system”

Recommendations
* Lake coverage be increased
* Jason-1 data drop out further investigated
* The accuracy requirement be revisited
* Possibility of using MODIS-based lake area measurement to enhance existing products.
Product Validation
(examples from Birkett, JGR, 1995 and Ross, McKellip, Moore, Fendley, V+V Report, NASA SCC. 2005)
Validation and Enhancement of existing products
NASA/CNES Jason-1 GDR versus IGDR

Water-Level Gauge Measurements Compared to Satellite Radar Altimeter Observations

Data Source:
Water-level gauge data from Jinja, Uganda (near Lake Victoria’s outlet)
Satellite radar altimeter data from USDS/NASA/UMD at:
http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/
U.S. Department of Agricultural (USDA)
Foreign Agricultural Service (FAS)
Production Estimates & Crop Assessment Division (PECAD)
Project Expansion
Utilization of the Naval Research Lab
Geosat Follow-On (GFO) mission data set
Middle East and Turkey: Warmer Than Normal and Plenty of Moisture

Winter grain (wheat and barley) planting began in September and continues till the end of December in some parts of the region. Early season cumulative precipitation has been near- to above-normal for almost all major wheat growing areas of the Middle East and Turkey. Adequate rainfall created good soil moisture conditions for establishment of winter grains, except in Azerbaijan, in northwest Iran, and parts of northwestern Iraq, where rainfall has been below normal thus far this season. In western Turkey, precipitation in recent weeks provided beneficial moisture after a dry November and has brought seasonal totals closer to normal. Warmer-than-normal weather is aiding early crop growth in the lower elevations and more southerly growing areas of the region. Above-normal temperatures have also reduced snow cover for this time of year compared to last.

This season follows two years of bumper crops that were preceded by the drought years 1999-2001. Drought reduced water supplies for irrigated crops and caused moisture shortfalls for rainfed crops, drastically cutting output for Iran, Iraq, and Syria for two to three years. Favorable weather the past two seasons has permitted production to recover to pre-drought levels, however, and is also recharging water reservoirs and groundwater reserves for irrigated crops.

Last year was the largest wheat producers in this region—Turkey, Iran, Syria, Saudi Arabia, and Iraq—produced an estimated 38.5 million tons of wheat, up 2 percent from the previous year, and 21 percent higher than the five-year average of 31.7 million tons. Only Turkey and Syria do not import wheat. The region also produced an estimated 11.4 million tons of barley last year.

For more information, contact Maria Anulacion of the Production Estimates and Crop Assessment Division at 202-690-0139 or maria.anulacion@usda.gov.
Regional Drought in East Africa

Decrease in lake water levels since 1997/98 El Nino

Lake Turkana

Lake Victoria

Lake Tanganyika

http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/
Lake Victoria’s water level on February 25, 2006 is approximately 10.53 meters, the lowest water level since 1946. The water level recovers slightly during recent rain season, but drops again and is at 10.65 meters on August 12, 2006.

Regional drought, excessive water releases for power generation after 2001 and non-compliance of the 1954 Nile Treaty

Owens Falls Dam was commissioned in 1954 at Jinja Uganda, Lake Victoria’s only outlet.
**Database Users and Applications**

“CropExplorer receives ~ 40,000 hits and 2000 visits per day with 85% of the visits from USA, 15% from international. The Global Reservoir and Lake Monitor is the 9th most popular page with a relatively long viewing time of 2mins.”

**Users:** USDA/FAS/OGA, FAS foreign resource analysts, international governments, humanitarian organizations, conservation groups, commercial sectors, military, research/educational departments, network groups (GLIN, LakeNet), lake development groups and hydraulic institutes, e.g., World Bank, United Nations, USGS, FEWS/USAID, NGA.

**Applications:** Irrigation potential and agricultural impacts, applications relating to water quantity and quality, fish productivity, water security, vegetation ecology and surveillance, validation (GRACE), basin and continental-scale hydrological modeling, potential set of proxy climate data records (Intergovernmental Panel on Climate Change).
Continuity of Satellite Radar Altimetry Missions

Table 1. Selection and continuity of satellite radar altimetry missions

<table>
<thead>
<tr>
<th>Satellite Mission</th>
<th>Operation Period</th>
<th>Temporal Resolution</th>
<th>No. of Lakes, Reservoirs*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>10-day repeat orbit (A)</strong></td>
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<td></td>
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<tr>
<td>NASA/CNES T/P</td>
<td>1992-2002</td>
<td>10days</td>
<td>122, 55</td>
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<tr>
<td>NASA/CNES Jason-1</td>
<td>2002-current</td>
<td>“”</td>
<td>“”</td>
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<tr>
<td>NASA/CNES/NOAA/EUM OSTM</td>
<td>Launch 2008</td>
<td>“”</td>
<td>“”</td>
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<tr>
<td>NOAA/CNES/EUM Jason-3/GFO2</td>
<td>Launch 2012</td>
<td>10,17days</td>
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<tr>
<td><strong>35-day repeat orbit</strong></td>
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<td></td>
<td></td>
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<tr>
<td>ESA ERS-1</td>
<td>1992-93, 94-95</td>
<td>35days</td>
<td>446, 165</td>
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<tr>
<td>ESA ERS-2</td>
<td>1995-current*</td>
<td>“”</td>
<td>“”</td>
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<tr>
<td>ESA ENVISAT</td>
<td>2002-current</td>
<td>“”</td>
<td>“”</td>
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<tr>
<td>CNES/ISRO SARAL/AltiKa</td>
<td>Launch 2010</td>
<td>“”</td>
<td>“”</td>
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<tr>
<td>ESA Sentinel 3</td>
<td>Launch 2012</td>
<td>“”</td>
<td>“”</td>
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<tr>
<td><strong>17-day repeat orbit</strong></td>
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<tr>
<td>US NRL Geosat</td>
<td>1987-1989</td>
<td>17days</td>
<td>~220, ~95</td>
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<tr>
<td>US NRL GFO</td>
<td>2002-current*</td>
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<td>“”</td>
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<tr>
<td>NOAA/CNES/EUM Jason-3/GFO2</td>
<td>Launch 2012</td>
<td>10,17days</td>
<td></td>
</tr>
<tr>
<td><strong>10-day repeat orbit (B)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NASA/CNES TOPEX-Tandem</td>
<td>2002-2005</td>
<td>10days</td>
<td>145, 65</td>
</tr>
</tbody>
</table>

Notes:
1. Lakes (~100km²) and in the latitude range -40°South to 52°North are potential targets. Numbers shown are approximate and reflect those targets of most interest to the USDA/FAS. Instrument tracking and current data interpretation methods have limited the 10-day repeat orbit (A) targets to ~75 at the present time. Lake number statistics are taken from Birkett and Mason, 1995.
2. Except for the TOPEX-Tandem mission, satellites with the same temporal repeat cross over the same set of lakes. A lake may be crossed over by more than one satellite. Larger lakes will have multiple same-satellite crossings increasing temporal resolution.

* ERS-2 (from 2002) continues to operate with reduced continental coverage. GFO (from 2006) continues to operate with reduced temporal coverage over inland basins.
PHASE IV:
* ENVISAT for near real time monitoring with ERS (WAP) for ~10 year archive and reference datum.
* OSTM for continued near real time monitoring.
* Jason-1 (GDR, SDR) and GFO for 2002-2008 archive upgrade.
* TOPEX/POSEIDON (SDR) for 1992-2002 archive upgrade.
There is a demand for near time operations, but no USGS, NOAA, NASA production system in place. USDA program is successful but mindful of the following for Phase IV:

Strong requirement for multi-instrument program. Technical issues- mergers of datasets, reference datum. Standards and Formats to consider. Benchmarking - cal/val, system maintenance and deliverables. Demand for near-real time to be met. Must have accountability for loss of products - all users. Multi-source funding and uniform transition of “operational” funding to be addressed.