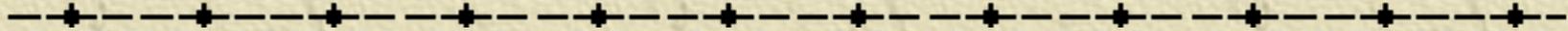




ESA: 2nd Space for Hydrology Workshop  
WMO, Geneva, 12-14th November, 2007



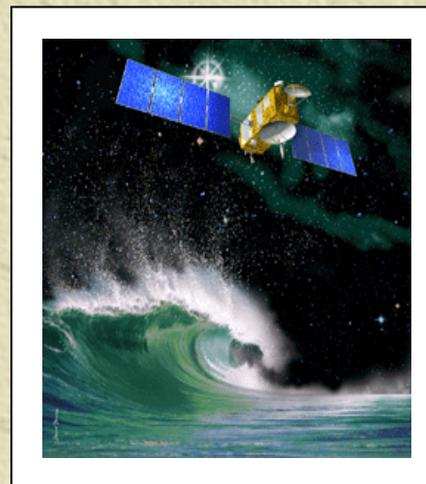
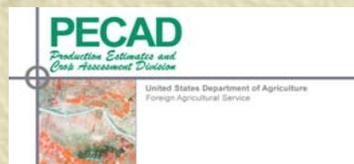
## Near-Real Time Monitoring of Global Lakes and Reservoirs: Water Resources, Irrigation Potential and Agriculture

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

Archive TOPEX/POSEIDON (1992-2002)

Near Real Time IGDR Jason-1(post 2002)

Temporal Sampling = 10days

Time Period Coverage = September 1992 to present day

## Expectations

60-100 lakes (~180 large lakes with expected success rate of ~35%)

Elevation Accuracy < 5cm 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 = 7-14days after satellite overpass

Product Availability = [http://www.pecad.fas.usda.gov/cropexplorer/global\\_reservoir](http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir)



**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 ?????**

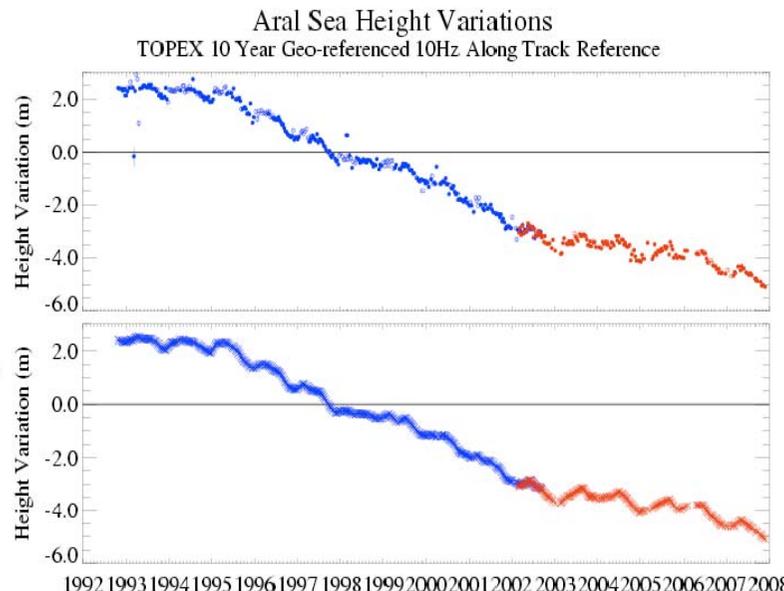
**Enhancement and expansion, multi-mission approach**

# EXAMPLE PRODUCT



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

- Aral Sea
- enlarge image
- LakeNet Profile
- View Satellite Image
- View 3D Image
- Topex/Poseidon/Jason Data



1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008

\*\*\* TOPEX/Poseidon historical archive  
 \*\*\* Jason-1 Interim GDR 20hz altimetry

Version TPJ.2  
 Last valid elevation : 23 Oct., 2007

Click anywhere on the graph to view or download the lake level data file.

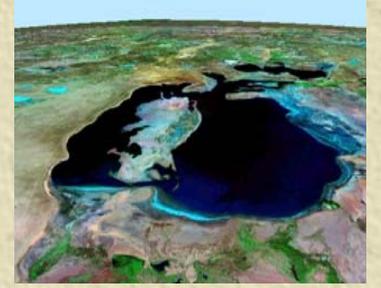
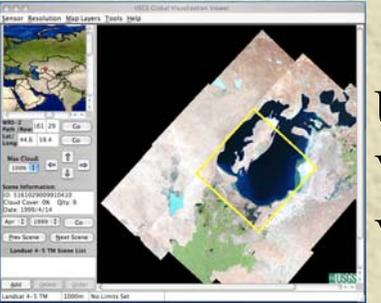
Shown above are relative lake height variations computed from TOPEX/POSEIDON (T/P) and Jason-1 altimetry with respect to a 10 year mean level derived from T/P altimeter observations. The Jason-1 near real time observations are obtained from the currently available Interim GDR (IGDR) from CNES via JPL PODAAC. These data have preliminary medium precision orbits (MOE) and several correction fields that are still being finalized. The top panel displays the raw height variations (open circles denote potential icy or calm-water conditions, large error bars may denote noise or dry lake-bed conditions), while the height variation time series in the lower panel has been smoothed with a median type filter to eliminate outliers and reduce high frequency noise.

The 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://hqsquill.gov/mass.gov/images/takes/take0277.sp.txt
0277 Aral
43.00 49.00      = Lake database ID number and name
43.00 49.00      = Latitude and Longitude (Degrees East) of
43.00 49.00      = Start Latitude and Longitude (Degrees East)
43.96 49.14      = End Latitude and Longitude (Degrees East)
44.10 49.40      = Latitude range of pass traversing Lake #
142  1         = Satellite pass and revolution number see
Column 1: satellite mission name
Column 2: satellite repeat cycle
Column 3: year/month/day of along track observations traversing Lake
Column 4: hour of day at mid point of along track pass traversing Lake
Column 5: distance of hour at mid point of along track pass traversing Lake
Column 6: lake height variation with respect to TOPEX/POSEIDON 10 yr
Column 7: lake height variation with respect to Jason-1 altimetry 20 hr
Column 8: mean along track 10-day bandwidth coefficient, 0.0000000000
Column 9: wet atmospheric correction applied to range observation
DOPEX  1 19920208 15 57 2.42 0.043 12.42 TMS
DOPEX  2 19920208 13 55 2.39 0.043 11.73 TMS
DOPEX  3 19920208 11 54 2.36 0.043 11.04 TMS
DOPEX  4 19920209  9 52 2.38 0.044 10.37 TMS
DOPEX  5 19921057  7 51 2.31 0.044 10.05 TMS
DOPEX  6 19921137  5 49 2.27 0.043 11.03 TMS
DOPEX  7 19921225  3 48 2.13 0.044 10.29 TMS
DOPEX  8 19921225 23 45 2.43 0.044 10.29 TMS
DOPEX  9 19930128 21 44 2.44 0.044 11.09 TMS
DOPEX 10 19930128 19 43 2.44 0.044 10.43 TMS
DOPEX 11 19930128 17 42 2.40 0.044 10.04 TMS
DOPEX 12 19930128 15 39 2.42 0.049 12.57 TMS
DOPEX 13 19930128 13 37 2.40 0.044 10.04 TMS
DOPEX 14 19930224 11 36 2.30 0.044 11.30 TMS
DOPEX 15 19930224  9 35 2.02 0.048 10.30 TMS
DOPEX 16 19930306  7 33 2.74 0.048 10.53 TMS
DOPEX 17 19930326  5 32 1.09 0.133 10.54 TMS
DOPEX 18 19930326  3 30 2.39 0.044 11.83 TMS
DOPEX 19 19930426  1 29 2.09 0.048 10.09 TMS
    
```



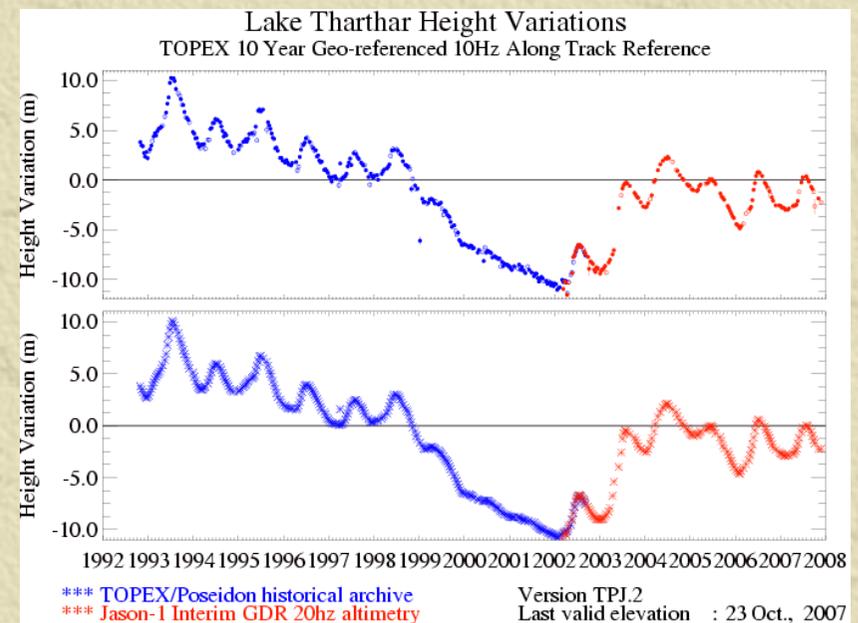
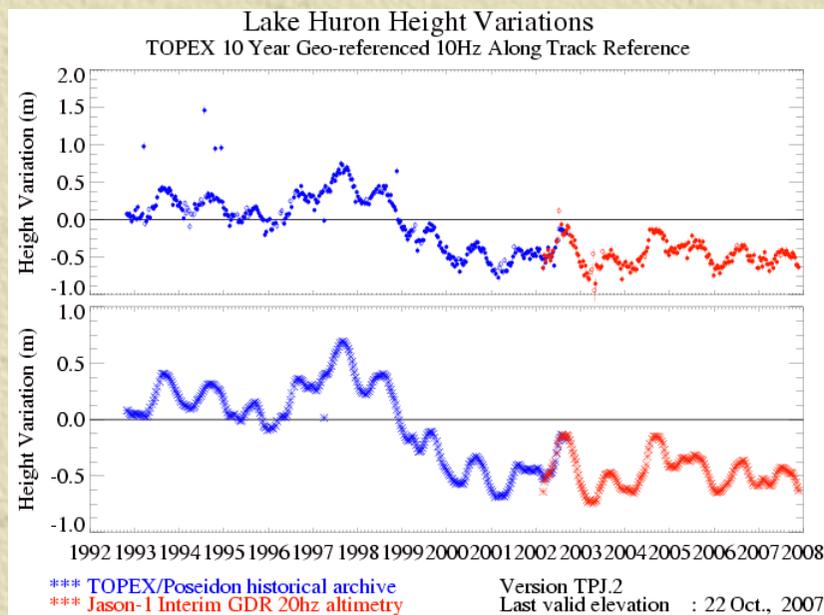
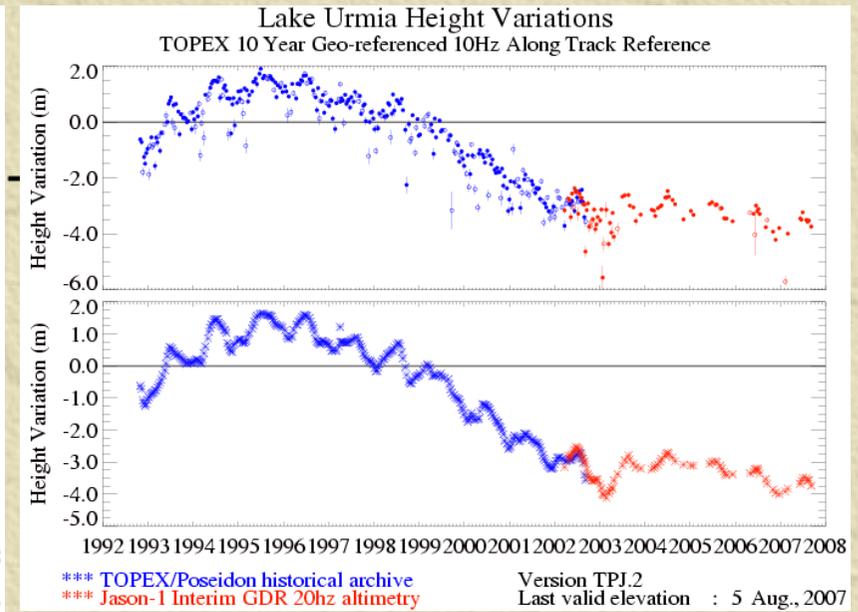
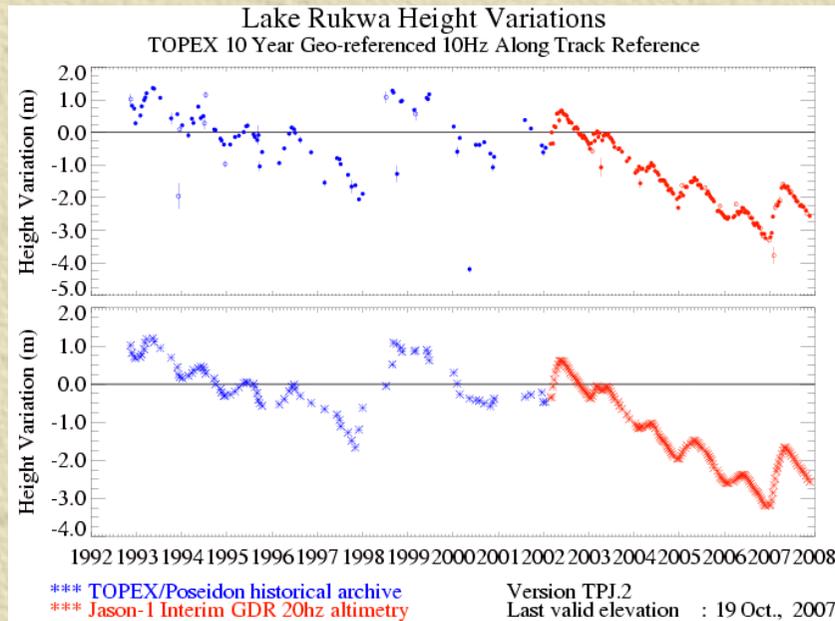
Altimetric graph+text products

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

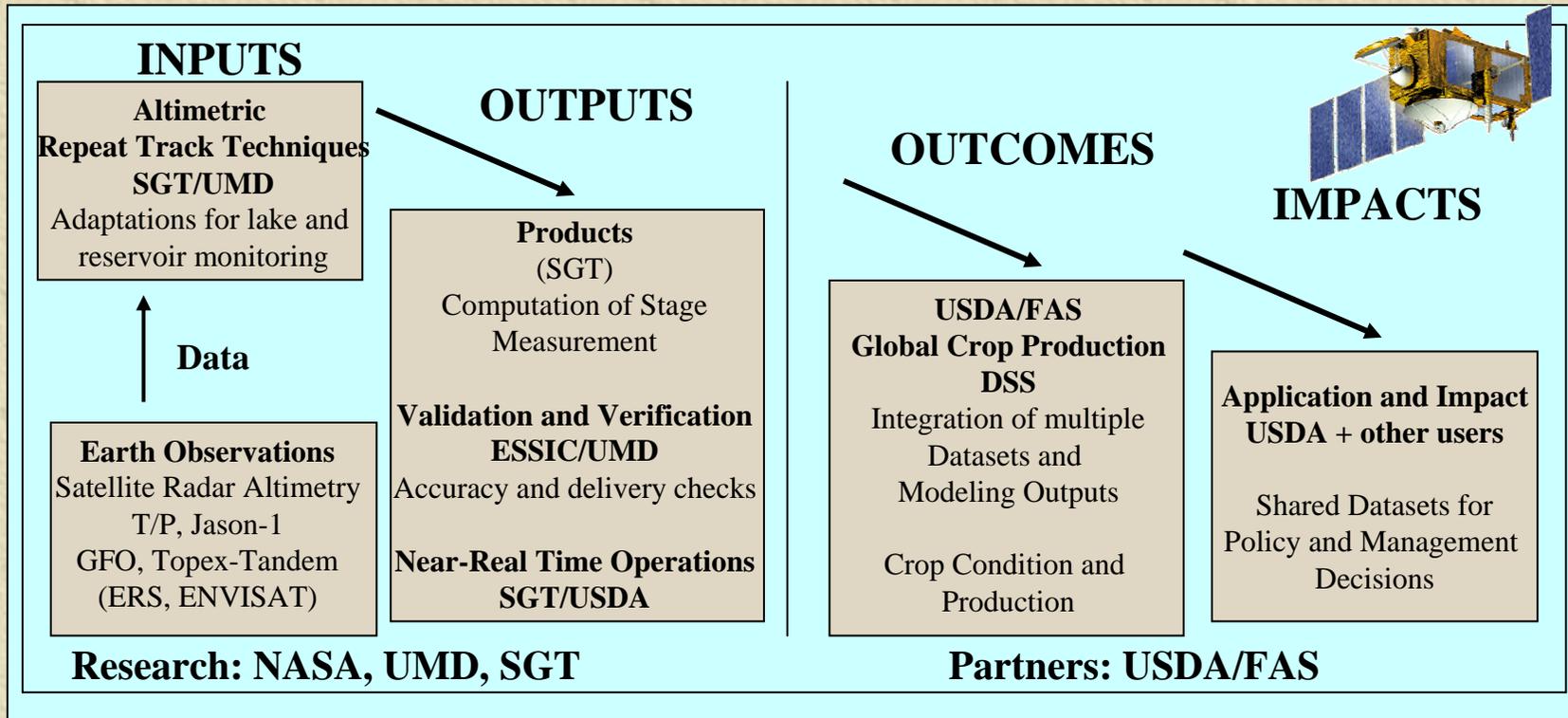
3-D Imagery

[http://www.pecad.fas.usda.gov/cropexplorer/global\\_reservoir](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



USDA United States Department of Agriculture  
Foreign Agricultural Service

**Crop Explorer**

Explore by Region: North America, Central America, South America, Europe, Middle East, Oceania.

Explore by Crop: Select a Commodity [ ] Submit

Commodity Intelligence Reports: Russia Excessive Heat Places Sunflowers and Corn Under Stress. The USDA August 2006/07 estimate for Russia sunflowered production is 6.5 million tons...

Partnerships: NASA, USGS, FEWS, NET.



# Benchmarking

(Integrated Product Team for Agriculture Efficiency, Systems Engineering and V+V Reports, 2004, 2006, NASA/Stennis Space Center Internal Publications).

## Comparison of original system requirements with final output

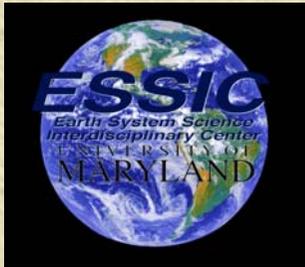
Number of targets, spatial distribution, latency of product delivery, timeline delay for target results, V+V exercises (product accuracy), Jason-1 and T/P cross-validation, project problems (surface tracking, demise of Jason-1 data).

## 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”

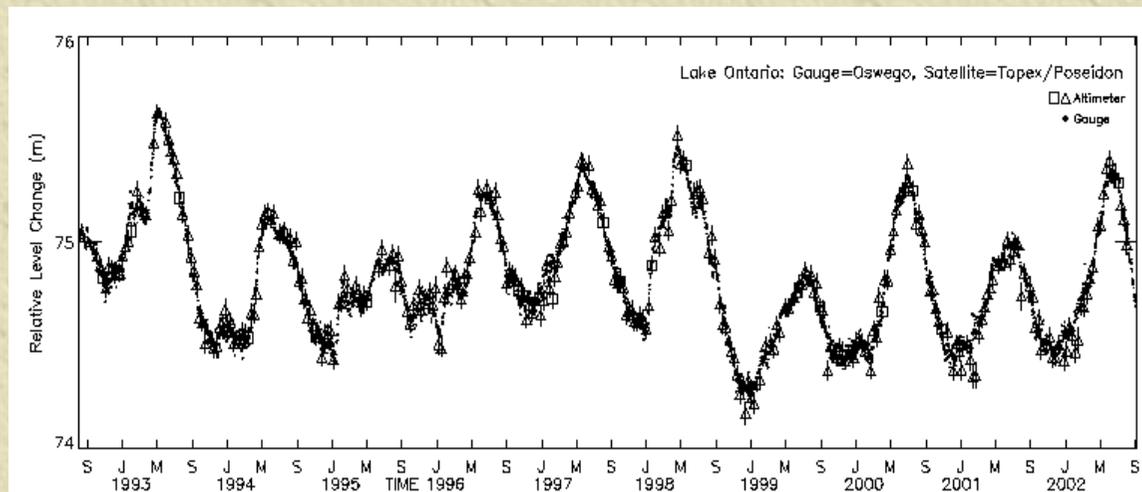
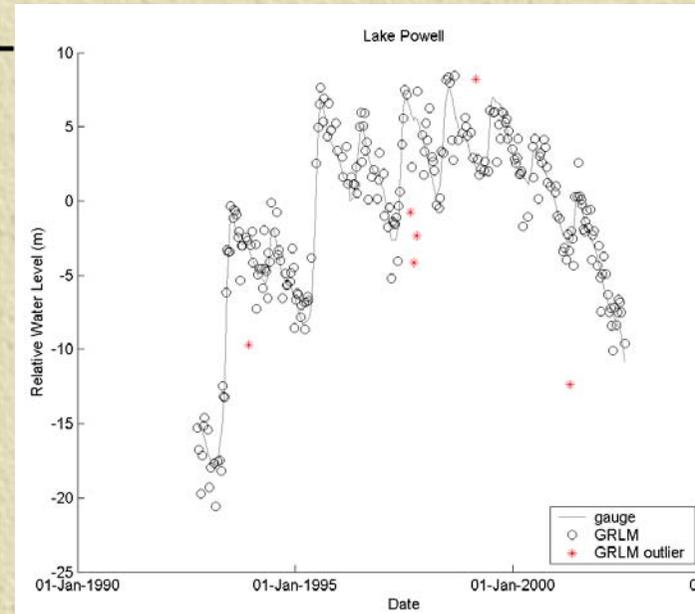
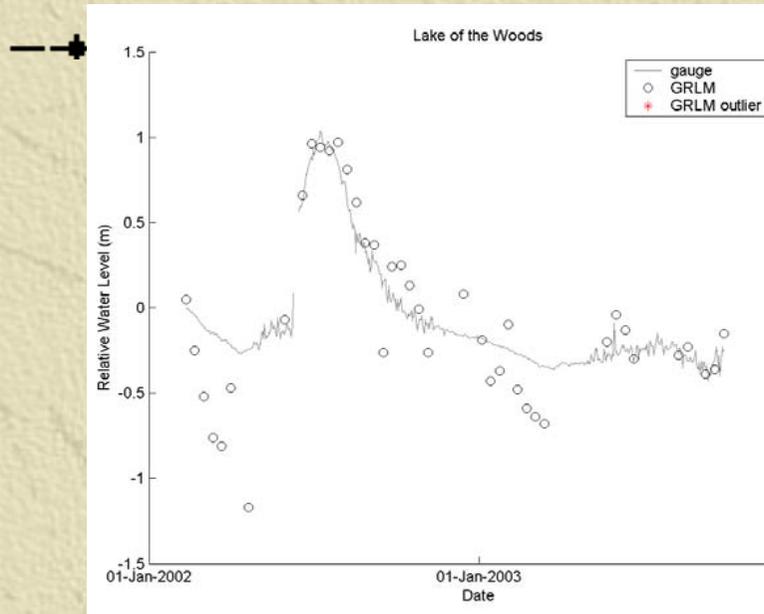
## Recommendations

- \* 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

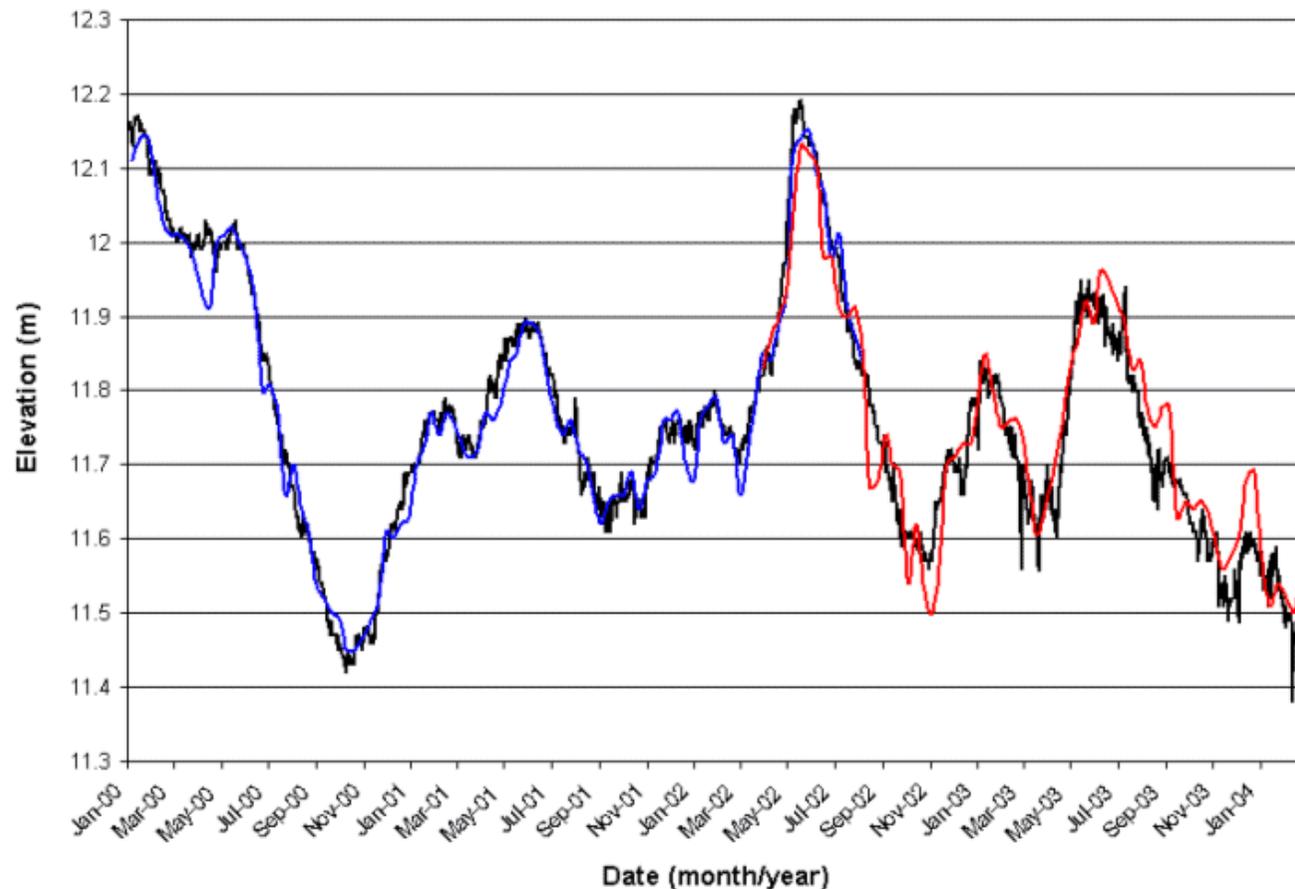
(examples from Birkett, JGR, 1995 and Ross, McKellip, Moore, Fendley, V+V Report, NASA SCC. 2005)



# Validation and Enhancement of existing products

## NASA/CNES Jason-1 GDR versus IGDR

### Water-Level Gauge Measurements Compared to Satellite Radar Altimeter Observations



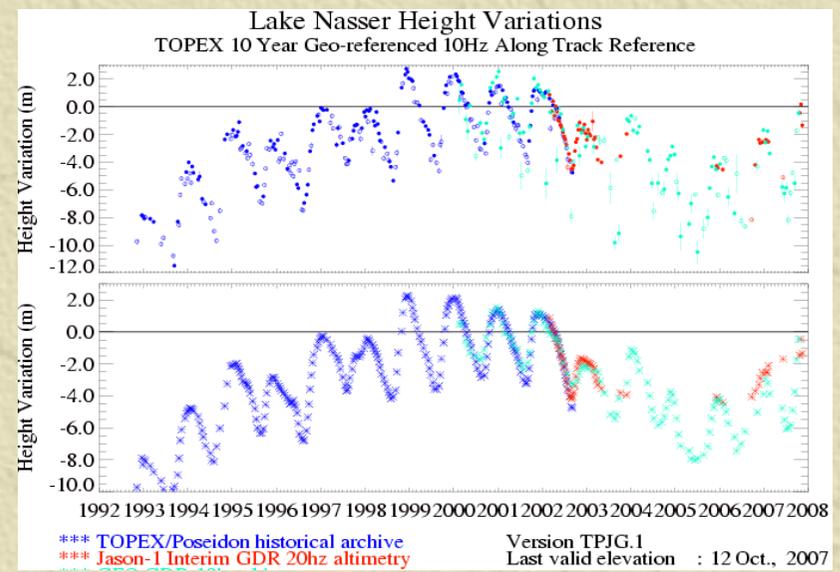
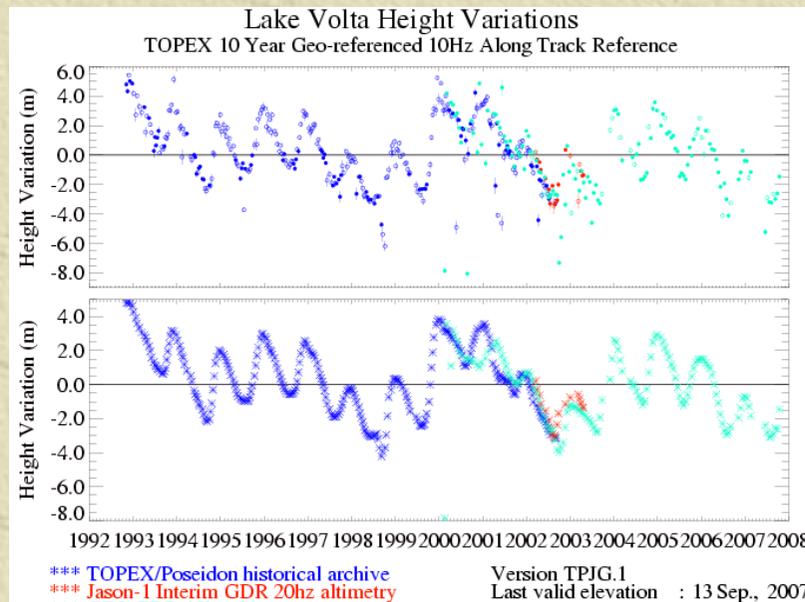
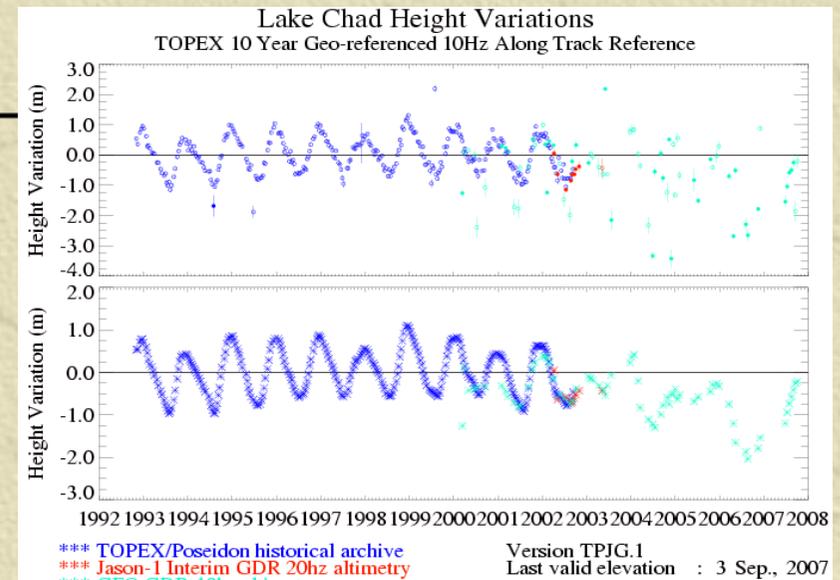
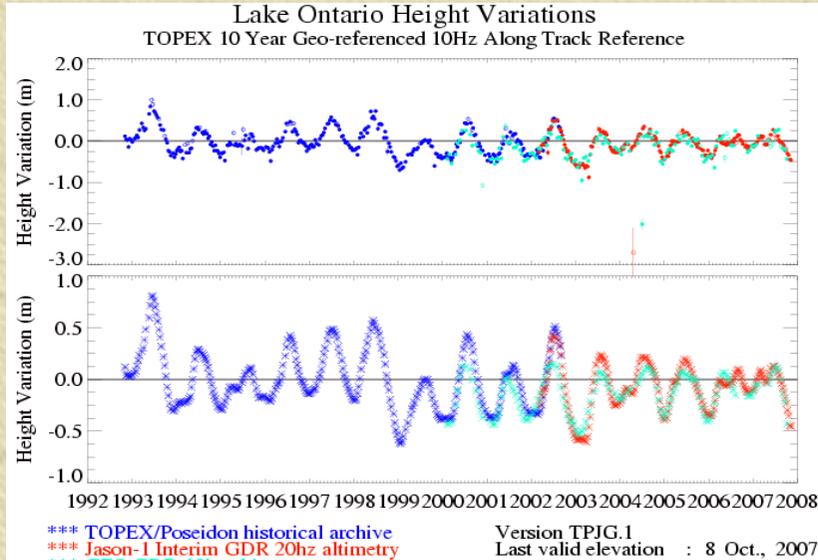
Data Source:  
Water-level gauge data from Jinja, Uganda (near Lake Victoria's outlet)  
Satellite radar altimeter data from USDS/NASA/UMD at:  
[http://www.pecad.fas.usda.gov/cropexplorer/global\\_reservoir/](http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/)



U.S. Department of Agriculture (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





Production Estimates and Crop Assessment Division  
Foreign Agricultural Service

December 17, 2003

## 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 Azarbayejan, 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 the largest **wheat producers in this region**—Turkey, Iran, Syria, Saudi Arabia, and Iraq—produced an estimated 38.3 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.

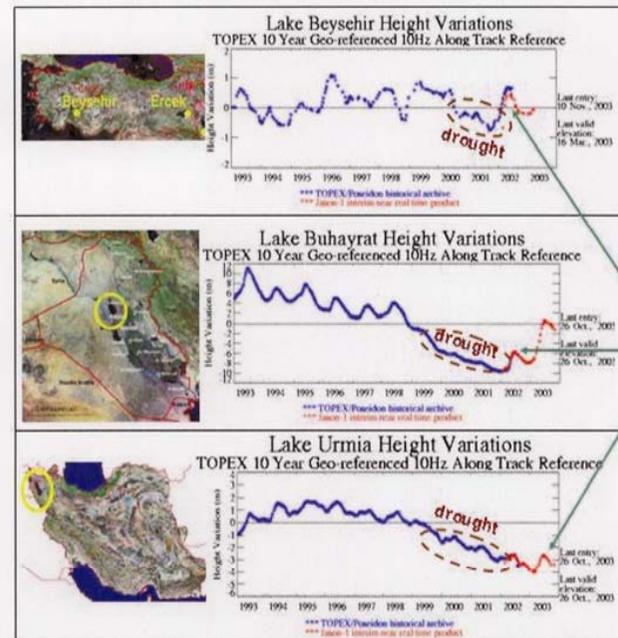
For more information, contact Maria Anulacion  
of the Production Estimates and Crop Assessment Division at 202-690-0139 or maria.anulacion@usda.gov

Return to  
PECAD

Updated: September 05, 2003 Write us: [Pecadinfo@fas.usda.gov](mailto:Pecadinfo@fas.usda.gov) | [Index](#) | [FAS Home](#) | [USDA](#) |



Production Estimates and Crop Assessment Division  
Foreign Agricultural Service



Shown are relative lake height variations for Lake Beysehir in Turkey, Lake Buhayrat in Central Iraq and Lake Urmia in northwest Iran. A period of drought occurred from 1999 to 2001. Rainfall in Turkey, northern Iraq and adjacent regions increased in both 2002 and 2003 and has gradually recharged reservoirs.

Initial recovery in water levels observed in 2002-2003. Drought began in 1999.



Production Estimates & Crop Assessment Division (PECAD)  
Foreign Agricultural Service (FAS)  
U.S. Department of Agriculture (USDA)  
<http://fas.usda.gov/pecad/pecad.html>



ESSIC (Earth System Science Interdisciplinary Center), University of Maryland, College Park  
NASA Goddard Space Flight Center, Greenbelt, Maryland

For more information on FAS/PECAD's New Global Reservoir Monitor visit  
<http://www.pecad.fas.usda.gov/cropeplorer/> and click on [Global Reservoir Monitor](#) on the bottom right.

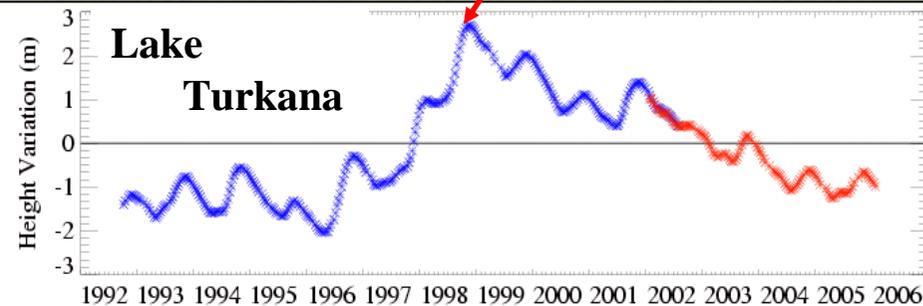
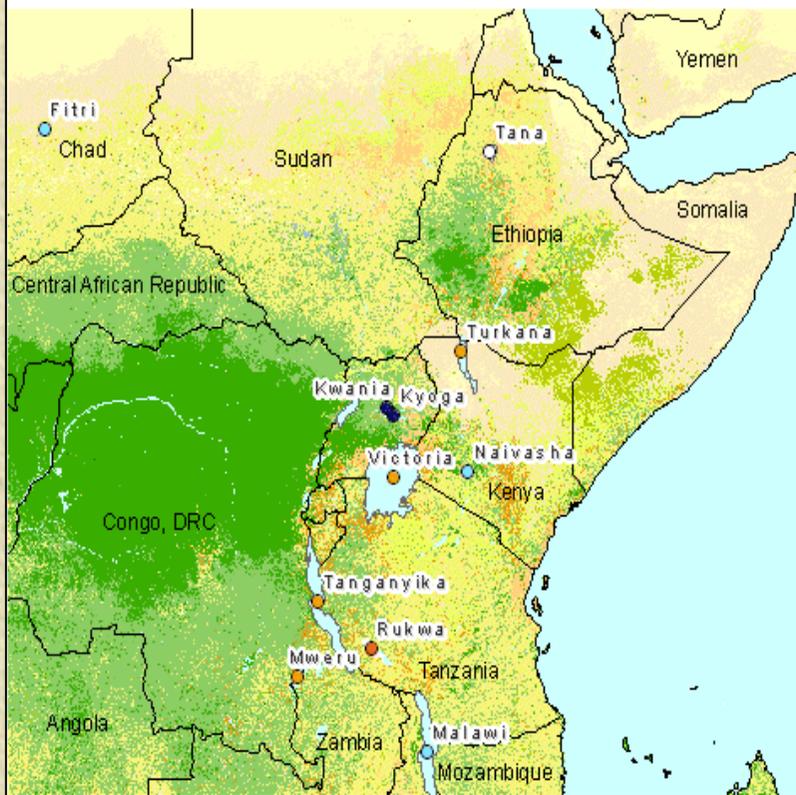
# Regional Drought in East Africa



Toolbox

Global Reservoir and Lake Elevation Database - Eastern Africa

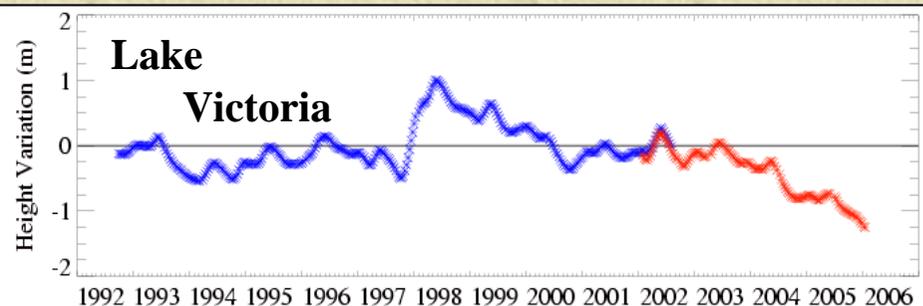
Click on a blue circle to see Lake Level Variations



\*\*\* TOPEX/Poseidon historical archive  
 \*\*\* Jason-1 interim near real time product

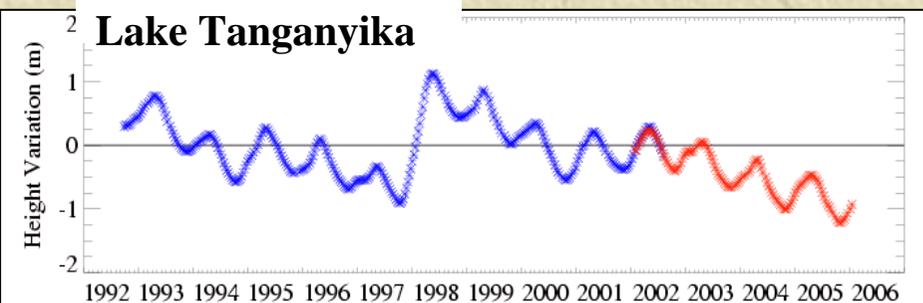
Last observation entry: 22 Jan., 2006  
 Last valid elevation : 22 Jan., 2006

Decrease in lake water levels since 1997/98 El Nino



\*\*\* TOPEX/Poseidon historical archive  
 \*\*\* Jason-1 interim near real time product

Last observation entry: 16 Jan., 2006  
 Last valid elevation : 16 Jan., 2006

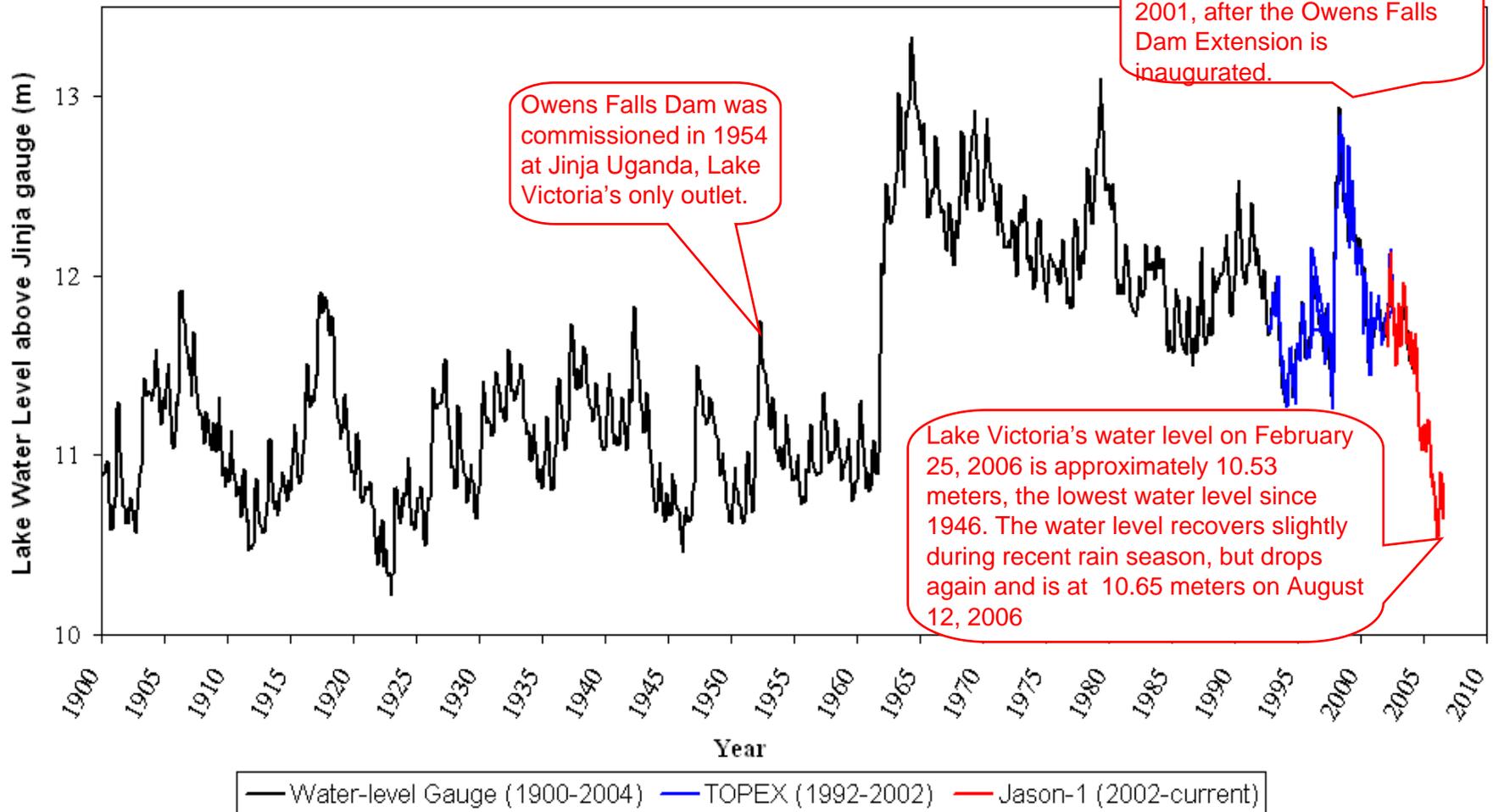


\*\*\* TOPEX/Poseidon historical archive  
 \*\*\* Jason-1 interim near real time product

Last observation entry: 20 Jan., 2006  
 Last valid elevation : 20 Jan., 2006

[http://www.pecad.fas.usda.gov/cropexplorer/global\\_reservoir/](http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/)

## Historical Water Level Elevations for Lake Victoria



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

Data Source:

Historical water level gauge data from Jinja, Uganda (outlet).

Satellite radar altimeter data from USDS/NASA/UMD at:

[http://www.pecad.fas.usda.gov/cropexplorer/global\\_reservoir/](http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/)



U.S. Department of Agriculture (USDA)  
Foreign Agricultural Service (FAS)  
Production Estimates & Crop  
Assessment Division (PECAD)

## 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

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

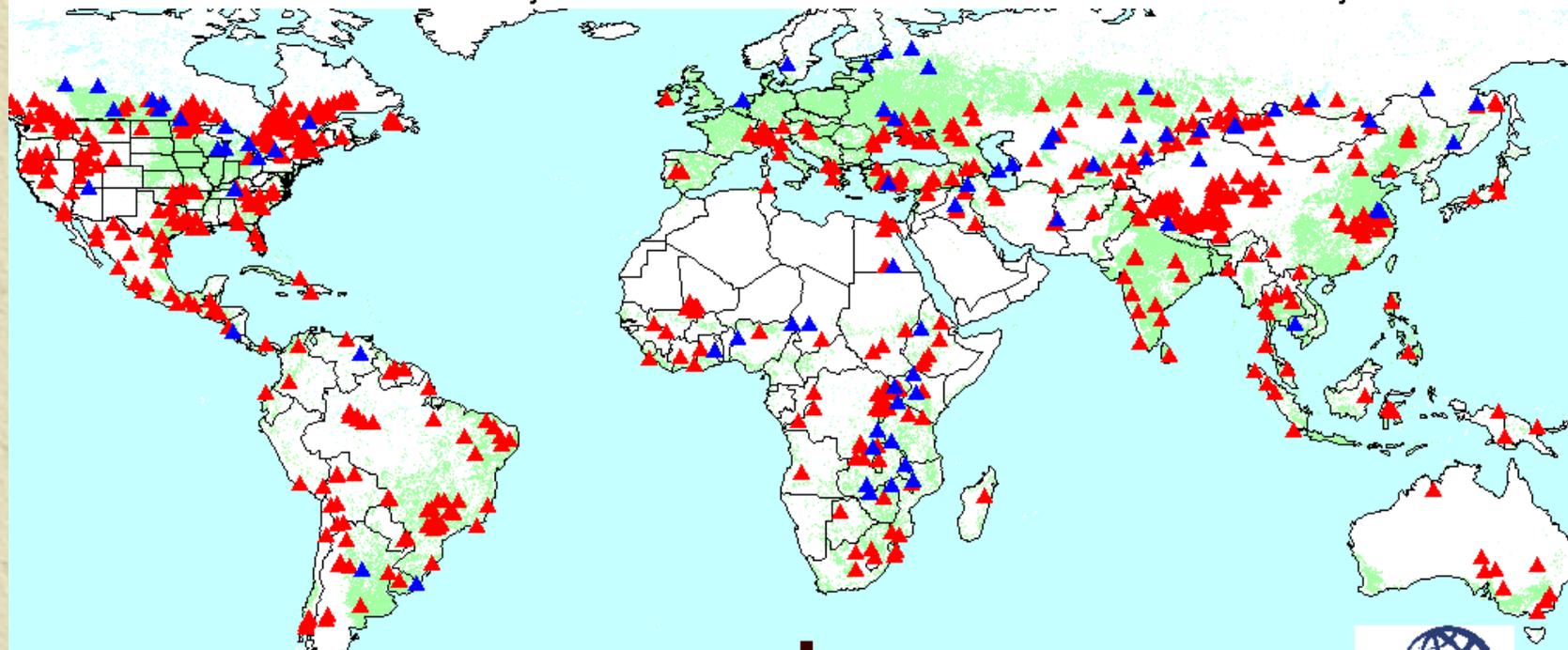
Notes:

1. Lakes (> 100km<sup>2</sup>) and in the latitude range -40South to 52North 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 ~10year 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.

Current Lakes Monitored by Jason-1 and Potential Lakes Monitored by ENVISAT



- ▲ Current Jason Lakes (73)
- ▲ Potential ENVISAT Lakes (611)
- Croplands





## Summary

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.