

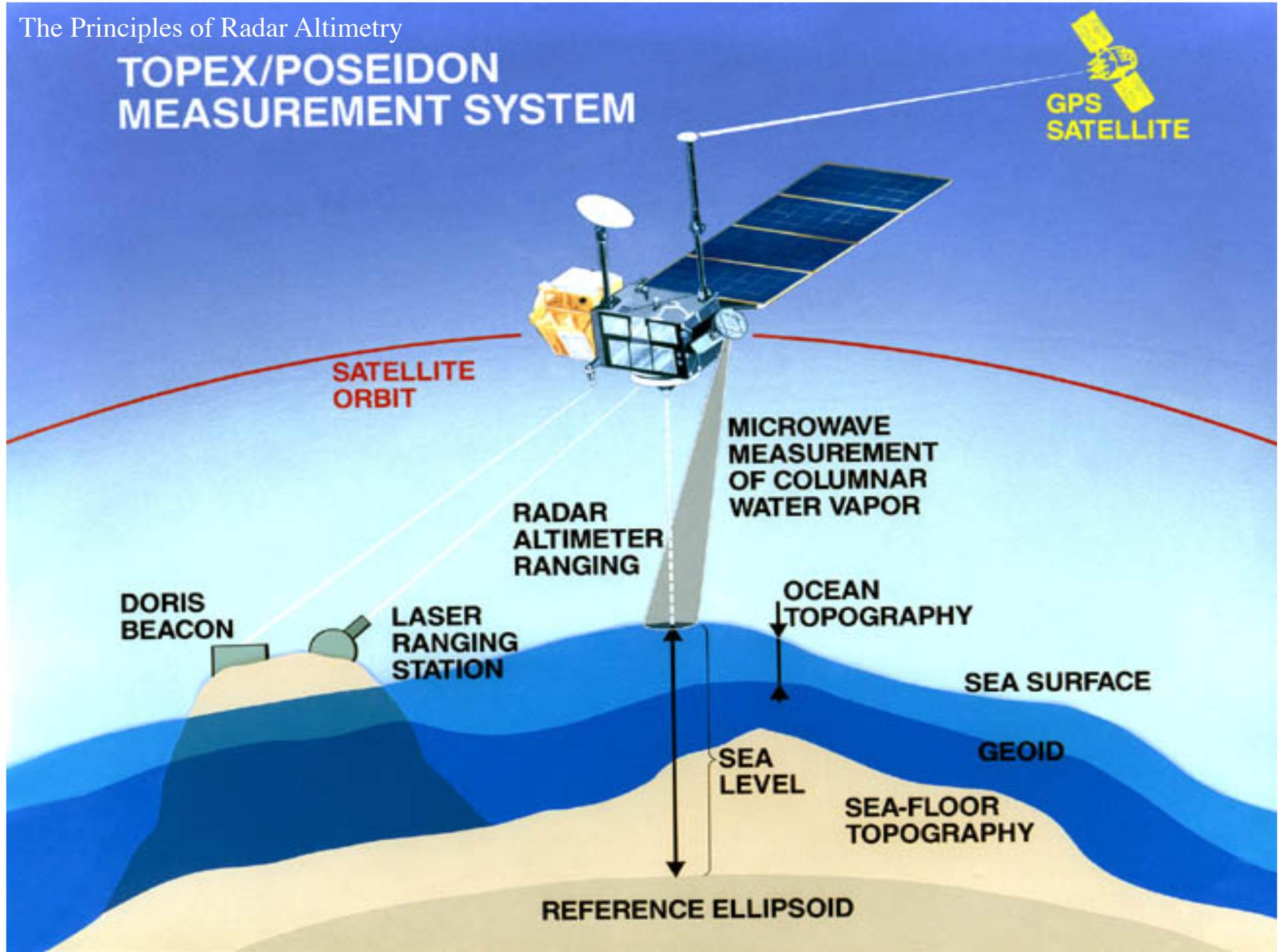


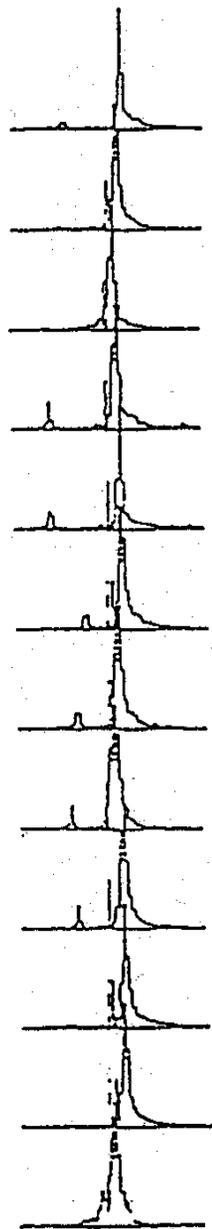
Webinar November 2013

(Part 1) Satellite-based determination of Reservoir and Lake Surface Water Heights

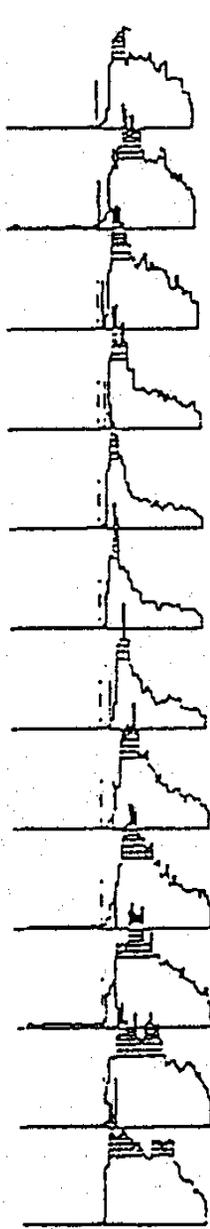
Dr. Charon M. Birkett
Earth System Science Interdisciplinary Center
University of Maryland, College Park
Maryland 20740, USA
Tel: 301-405-9296
cmb@essic.umd.edu

TOPEX/POSEIDON MEASUREMENT SYSTEM

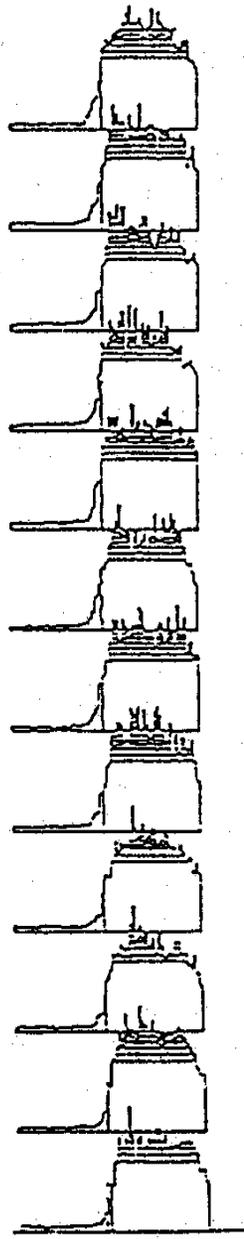




Narrow-peaked



Broad-peaked



Ocean-like

Fig. 1. Three sequences of radar echoes or "waveforms." Each waveform is a representation of power returned as a function of time. Over lakes waveforms are typically ocean-like, but can become broad-peaked or even narrow-peaked under very calm or icy conditions.

Radar Echoes and Surface Elevation

The instruments do not record an image but collect radar echoes along the ground track.

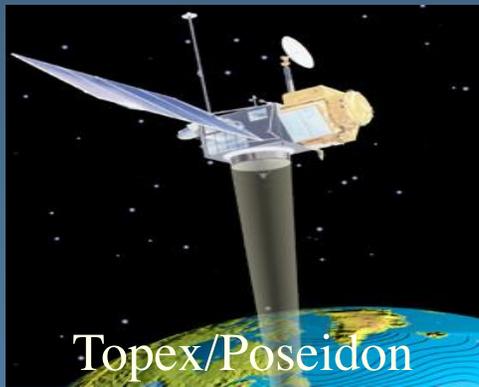
Altimetric "range" is derived from these waveforms.

With knowledge of the satellite orbit location, and certain atmospheric and tidal corrections, the range can be converted to a surface elevation – usually given with respect to a reference ellipsoid datum.

Satellite Radar Altimeter Missions

Ku- and Ka-band frequencies. Lake/reservoir surface water level products are generally derived from the long-term “repeat-track” missions which fall into 2 groups having different temporal sampling.

(Other missions include GEOS-3, Seasat, Geosat, GFO, CryoSat, and HY-2A)



Topex/Poseidon



10-day
Temporal
sampling
over a 21year
period,
1992 to the
present day



Jason-1



Jason-2/OSTM



ERS-1,-2

35-day temporal
sampling over a
19yr period, 1994
to the present day.



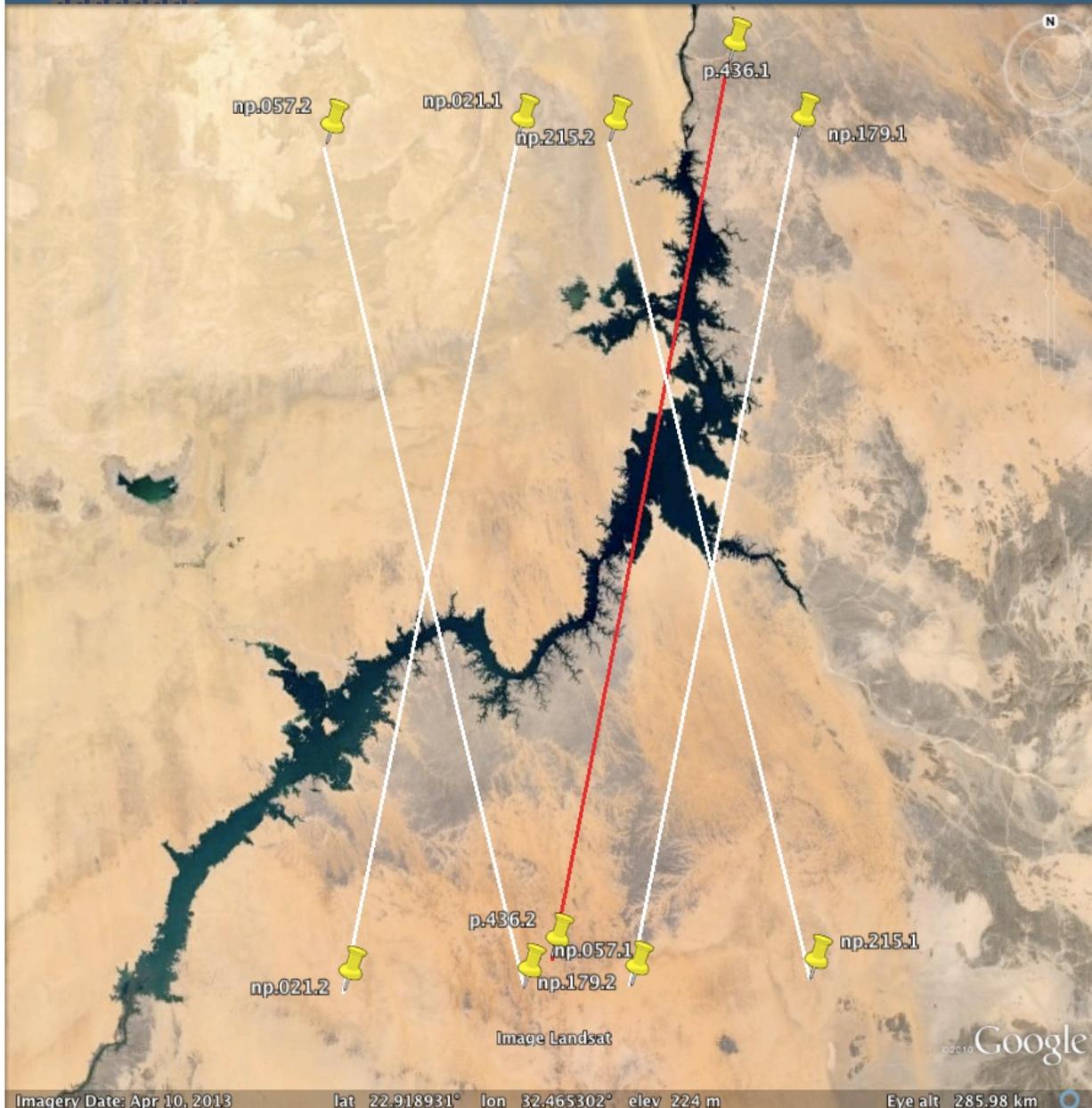
ENVISAT



ISRO



Radar Altimetry - Along and Across Track Spatial Resolution



Along the ground tracks the spatial resolution of the height data is a few hundred meters. The density of ground tracks will depend on the temporal repeatability of the mission.

For example, there are many more 35-day ground tracks (white) over Lake Nasser than offered by the 10-day altimeter suite (red).

How Many Lakes and Reservoirs?

Current satellite radar altimeters only view a certain proportion of the world's largest water bodies, with a trade-off between temporal and spatial resolution.

The NASA/CNES series

10-day resolution

Sampling ~380
water bodies

Including ~90
reservoirs

The ESA/ISRO/CNES series

35-day resolution

Sampling ~1065
water bodies

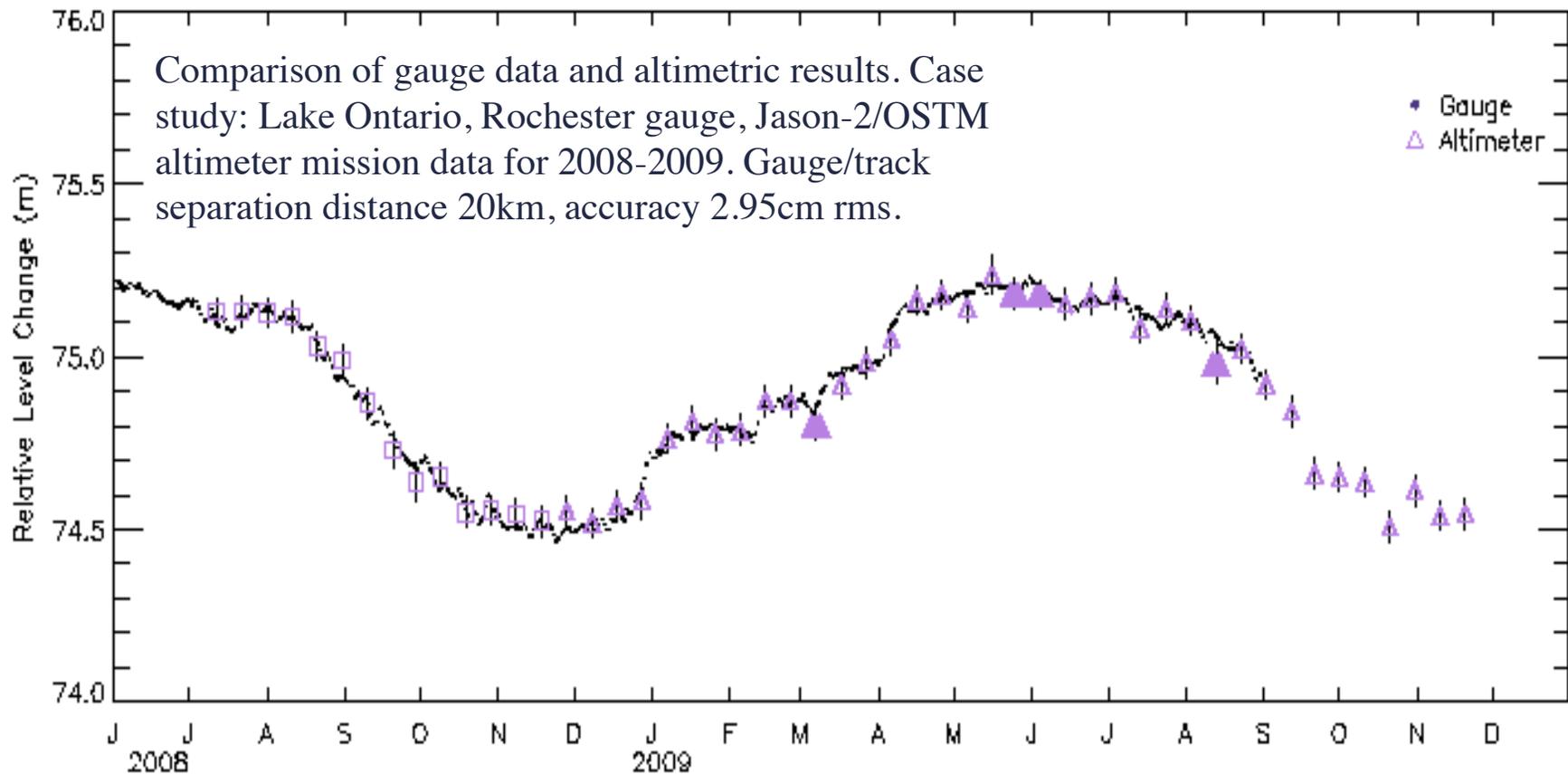
Including ~230
reservoirs

Common
Sampling ~315

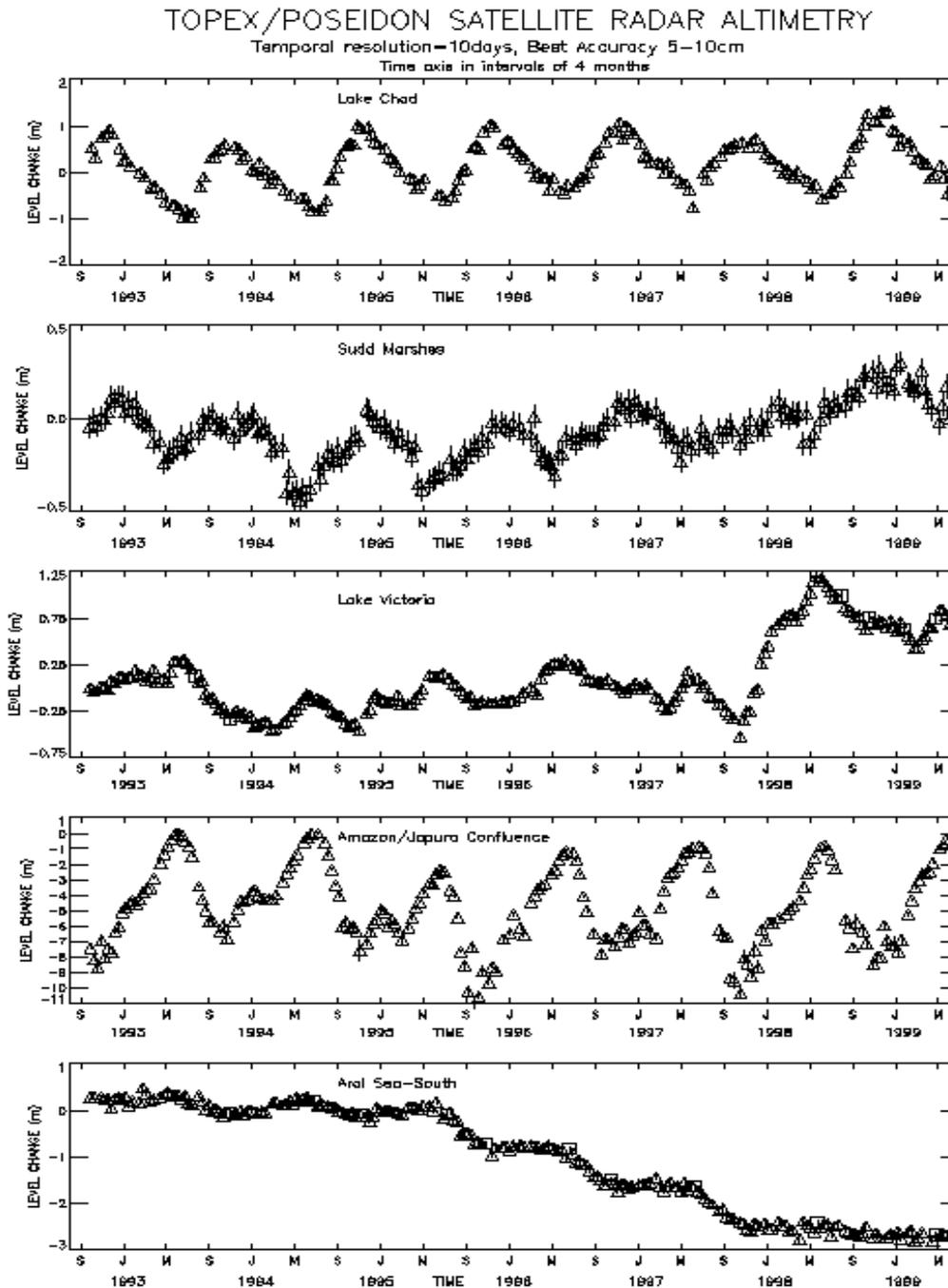
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graph TD; A((The NASA/CNES series)) --> C[Common Sampling ~315]; B((The ESA/ISRO/CNES series)) --> C;
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Validation of Altimetric Height Variations

Comparison with daily or hourly gauge (in situ) data over the same time period.



Early Pioneering Examples of Satellite Radar Altimetry



Demonstrating application of the altimetric technique to the derivation of water level variation for large lakes, wide river channels and large expanses of inundated wetland.

Radar Altimetry - Advantages and Limitations

ADVANTAGES

The contribution of new height information where traditional gauge (stage) data is absent.

Day/night and all weather operation.

Generally unhindered by vegetation or canopy cover.

Determined surface heights are with respect to one common reference frame.

Repeat orbits (to $\pm 1\text{km}$) enable systematic monitoring of rivers, lakes, wetlands, inland seas and floodplains.

Surface water heights are potentially obtainable for any target beneath the satellite overpass.

The ability to monitor seasonal to inter-annual variations during the lifetime of the missions.

Validated techniques.

LIMITATIONS

The satellite orbit scenario determines the spatial and temporal coverage.

Data can only be retrieved along a narrow nadir swath.

Highly undulating or complex topography may cause data loss.

Height accuracy (4-20cm rms large open lakes) is dominated by the size and surface roughness of the target.

Major wind events, heavy precipitation, tidal effects, ice formation, will effect data quality and accuracy.

Minimum target size ($50\text{-}100\text{km}^2$) is also dependant on many factors and the retrieved heights are an "average" not a "spot" height at a specific location.

Continental Water Monitoring – Web based sources

Several web sites, sponsored by various agencies, offer water-level products derived from the satellite radar altimeters,

http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/

<http://www.legos.obs-mip.fr/soa/hydrologie/hydroweb/>

<http://tethys.eaprs.cse.dmu.ac.uk/RiverLake/shared/main>

<http://openadb.dgfi.badw.de/index.php?id=85>

US Dept. of Agriculture/Foreign Agricultural Service Office of Global Analysis

The need to monitor agricultural (seasonal) and hydrological (long-term) drought.

USDA integrates a wide variety of data sets.

Information is input into a monthly 'lockup' process which sets global Crop Condition/
Production numbers and provides an 'Early Warning of Events'.

Output information is shared between USDA and US Gov agencies for various
Decision Support Protocols.

Estimates drive or influence markets, price discovery, trade and foreign policies, agriculture
production, and farm and food programs.

Missing Input - The VOLUME of stored water for irrigation potential considerations.

USDA Requirements: "The monitoring of water levels within all large globally-distributed lakes and reservoirs between 40°S-52°N to an accuracy of 10-20cm rms making both archival (20yrs) and near real time data products (1-2weeks) available to the USDA and the public via a freely-accessible web interface".

USDA/FAS Crop Explorer

A portal for data sets that assist agriculture-based decisions

<http://www.pecad.fas.usda.gov/cropexplorer/>

USDA United States Department of Agriculture
Foreign Agricultural Service

Linking U.S. Agriculture to the World
FAS

Crop Explorer

Global Food Supply Monitoring

Home Help Contact Us

Explore by Region

Switch to CE Google Maps

North America
United States
Canada

Central America
Mexico
Central America and Caribbean

South America
Brazil
Northern South America
Southern South America

Europe
Europe

Middle East
Iran, Iraq, Syria and Turkey

Oceania
Australia

Former Soviet Union
Kazakhstan
Russia, Azerbaijan,
Armenia and Georgia
Ukraine, Moldova,
and Belarus

Africa
North Africa
Southern Africa
East Africa
West Africa

Asia
Eastern China
South Asia
Southeast Asia
Central Asia
Korea

Site Index

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Explore by Crop

Select a Commodity

Commodity Intelligence Articles and Reports

Pakistan: Rice and Cotton Production Regions Damaged by Floods.
(Sep 13, 2010)

From late July through August, Pakistan received abundant to excessive monsoon rainfall across the country including many of the major rice and cotton growing areas. The excessive precipitation triggered severe overland and river flooding. The impact of the floodwater is most severe in Khyber Pakhtunkhwa (N.W.F.P), Baluchistan, Punjab, and the northern districts of Sindh. These provinces have experienced significant loss of cropland and damage to agricultural infrastructure. The major kharif season (June-November) crops are rice and cotton, but a substantial amount of corn, millet, and sorghum is grown during the kharif season as well. The floodwaters are receding in the mid- and upper reaches of the Indus Valley but continue to expand in the southern district of Sindh. The final extent of the floodwaters and the resulting damage to crops is still uncertain. The USDA's preliminary assessment, based primarily on satellite imagery, indicates significant crop damage in major rice and cotton areas along the Indus River in Punjab and Sindh provinces. The USDA forecasts 2010/11 Pakistan rice production at 5.3 million tons, down

News & Events

- [Tropical Cyclone Monitor](#)
- [Google Gadgets](#)
- [Iraq Operational Agricultural Monitoring Project](#)
- [RSS News Feeds](#)
- [Speaker Presentations on Global Food Security Challenges](#)

Related Sites

- [Agricultural Production](#)
- [Articles and Reports](#)
- [Explore by Crop](#)
- [Future of Land Imaging](#)
- [Geographic Search](#)
- [Global Climate Change](#)
- [Global Crop Production](#)
- [Global Reservoirs/Lakes](#)
- [Landsat GloVis](#)
- [MODIS Image Gallery](#)
- [MODIS Image Archive](#)
- [MODIS NDVI Gallery](#)
- [MODIS NDVI Time Series](#)
- [MPA Rainfall Maps](#)
- [Photo Gallery](#)
- [USDA Satellite Imagery Archive](#)

Metadata

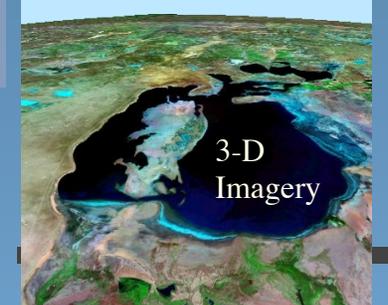
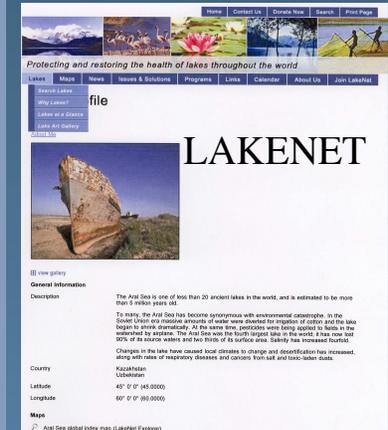
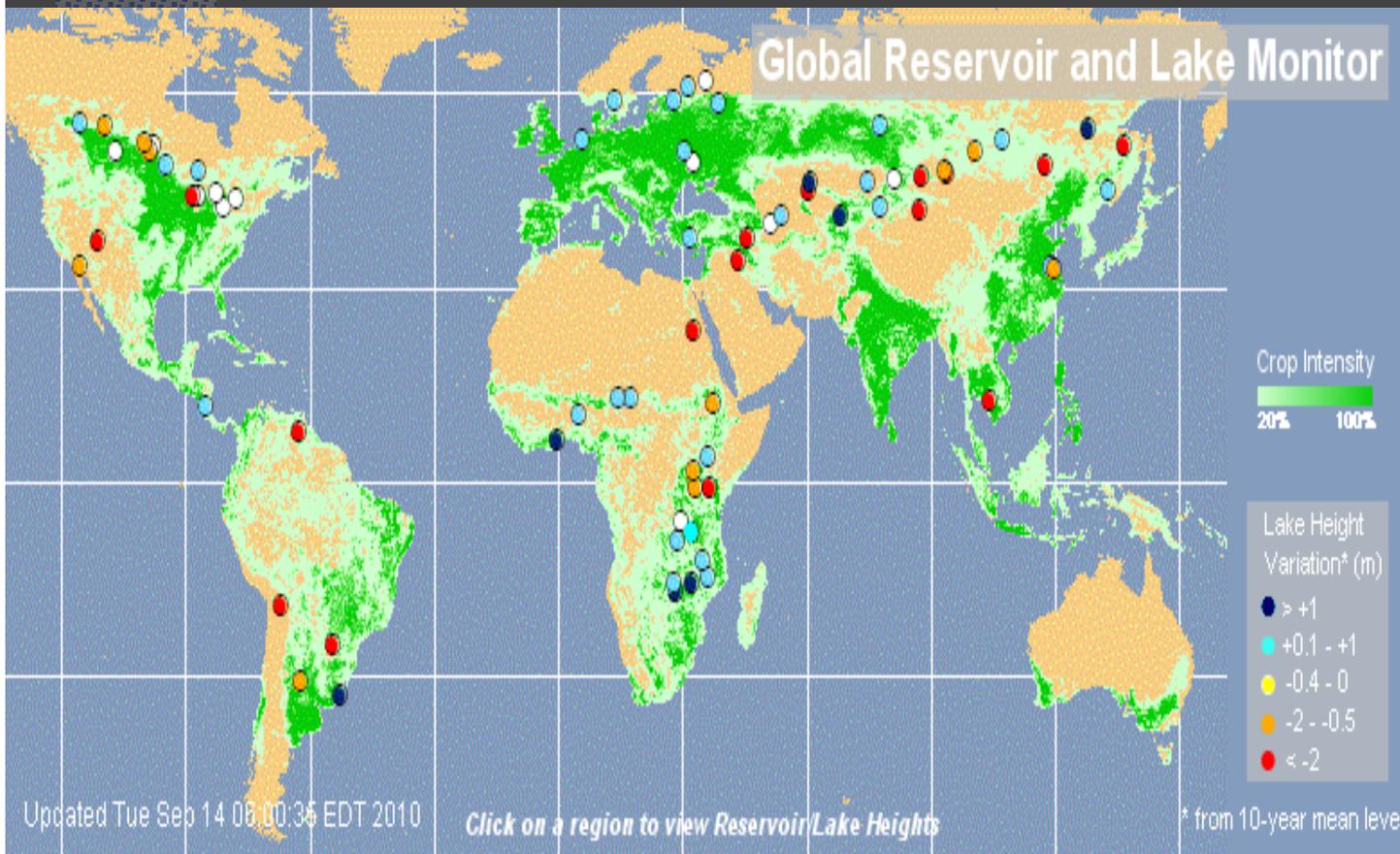
- [Live Data and Maps](#)
- [GeoSpatial One-Stop](#)

Multiple satellite, ground-based and modeled data sets, including water surface heights for lakes and reservoirs

The Global Reservoir and Lake Monitor (GRLM)

http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/

Funded by the USDA/FAS/OGA and NASA and operational since 2003



A "Lake Status" map, based on a ~10year mean, provides a guide to the current storage situation and so helps to assess long-term drought or high-water level conditions.

The Global Reservoir and Lake Monitor – Product Access

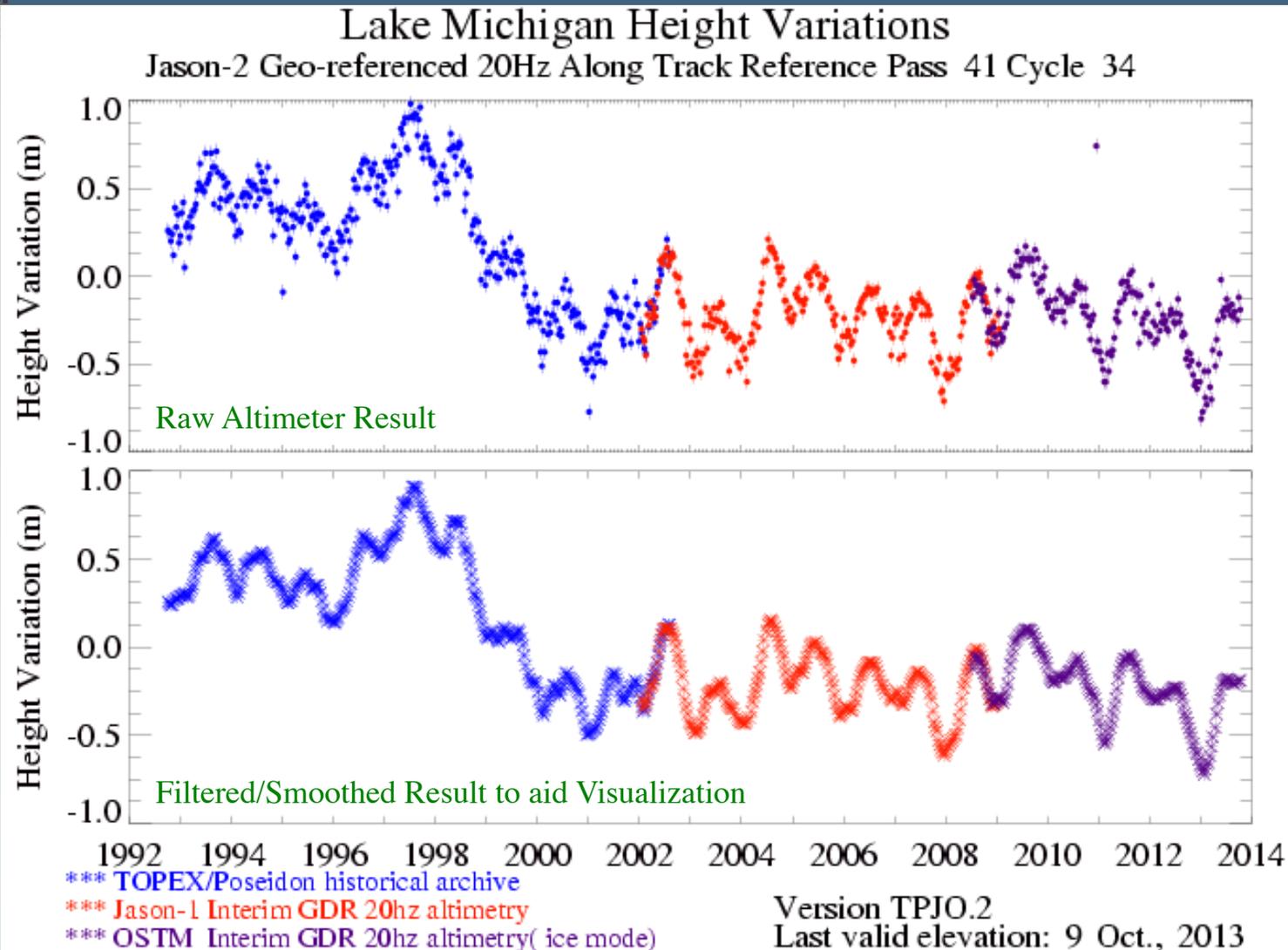
http://www.pecad.fas.usda.gov/cropexplorer/global_reservoir/



End-users select by lake to retrieve a water surface height product.

The Global Reservoir and Lake Monitor – Product Format

Products are in graphical (gif) and ascii text format and show the relative variations in surface water level over the lifetime of the missions. Example shown for the 10-day resolution NASA/CNES instrument suite over Lake Michigan, USA.



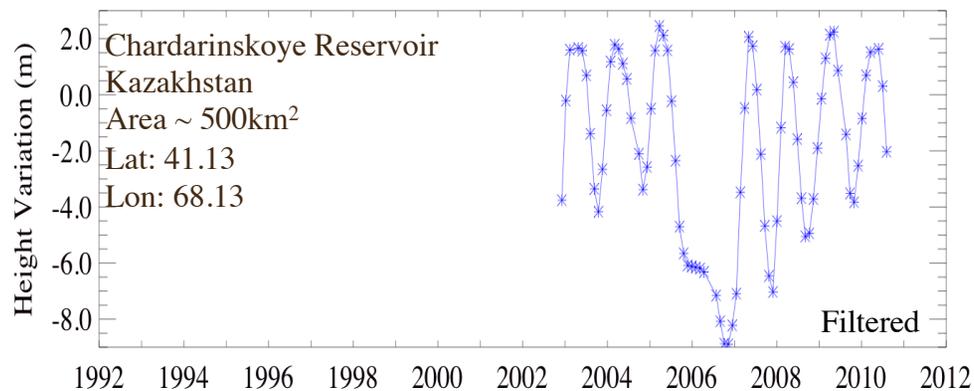
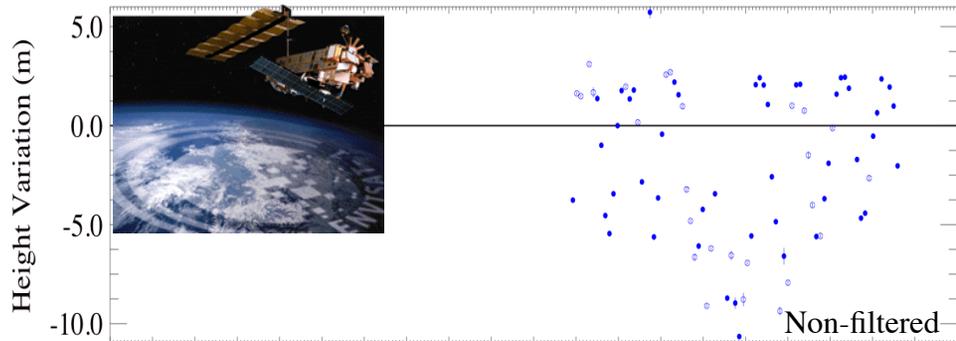
The USDA/NASA Global Reservoir and Lake Monitor

<http://www.pecad.fas.usda.gov/cropexplorer/>

Preliminary archival products from the ESA/ENVISAT (2002-2010) mission.

Lake Chardarinskoye Height Variations

Envisat Pass 825 Cycle 22 Geo-referenced 20Hz Along Track Reference

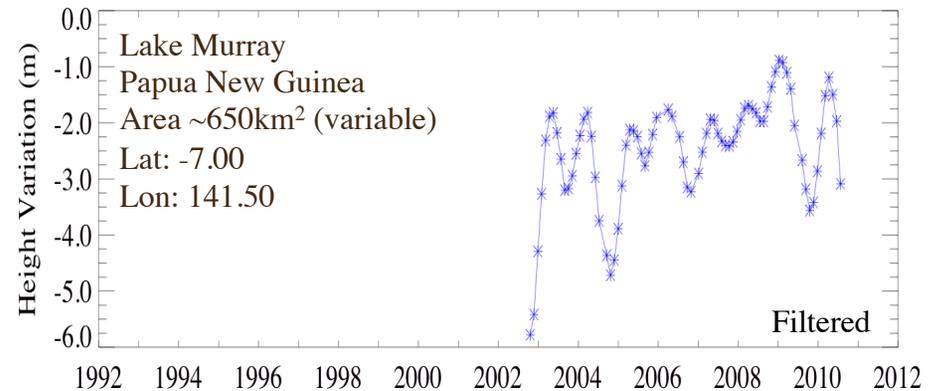
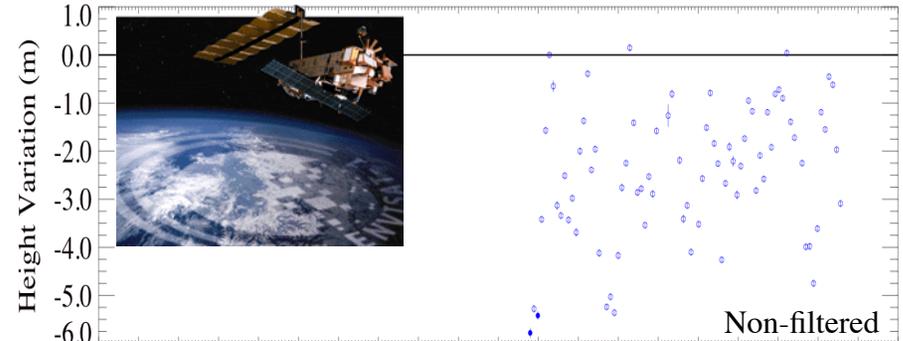


*** Envisat MWR GDR 20hz altimetry

Version Env.1
Last valid elevation: 3 Aug., 2010

Lake Murray Height Variations

Envisat Pass 462 Cycle 15 Geo-referenced 20Hz Along Track Reference

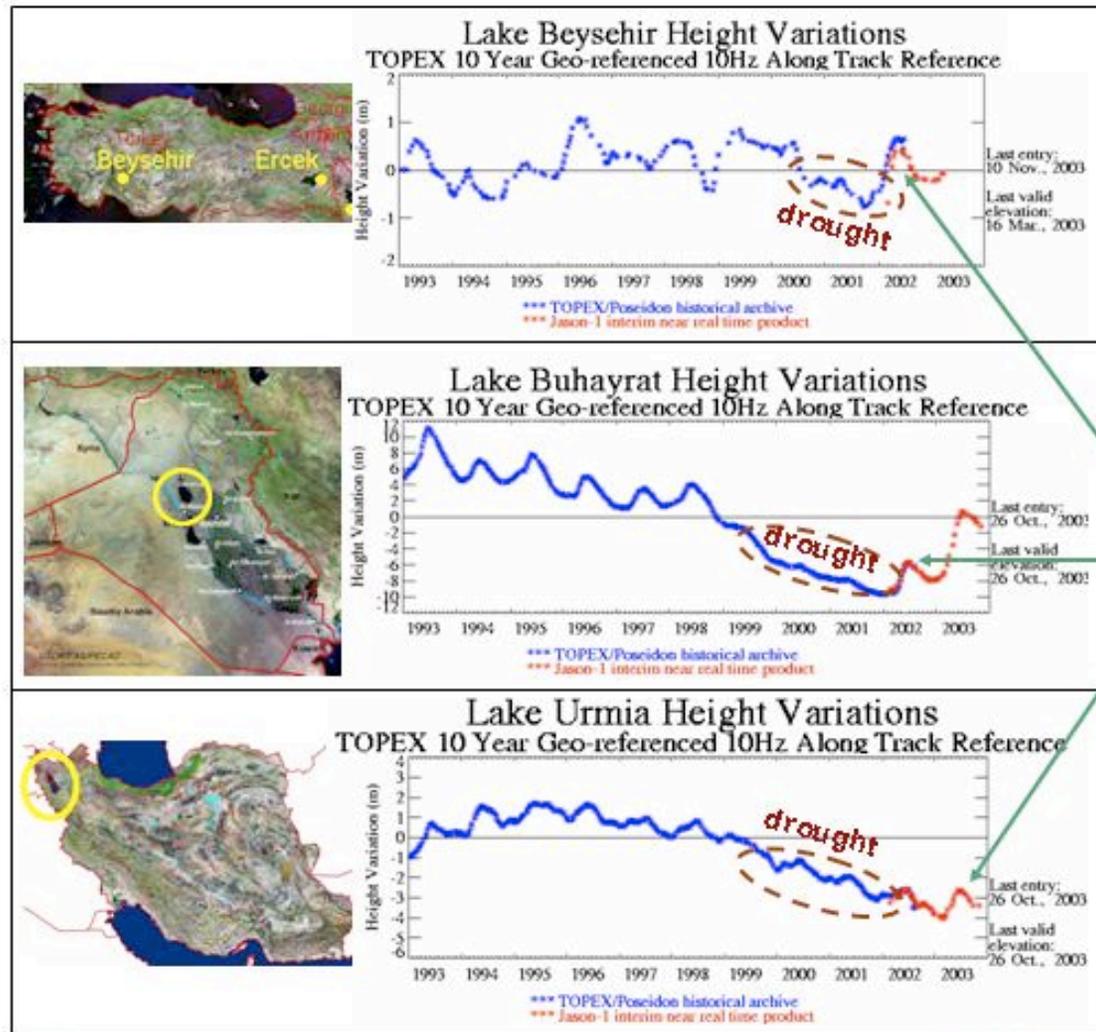


*** Envisat MWR GDR 20hz altimetry

Version Env.1
Last valid elevation: 22 July, 2010



**Middle East and Turkey:
Warmer Than Normal and Plenty of Moisture**



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.



Venezuela to Ration Water Because of Low El Nino Rainfall

October 22, 2009



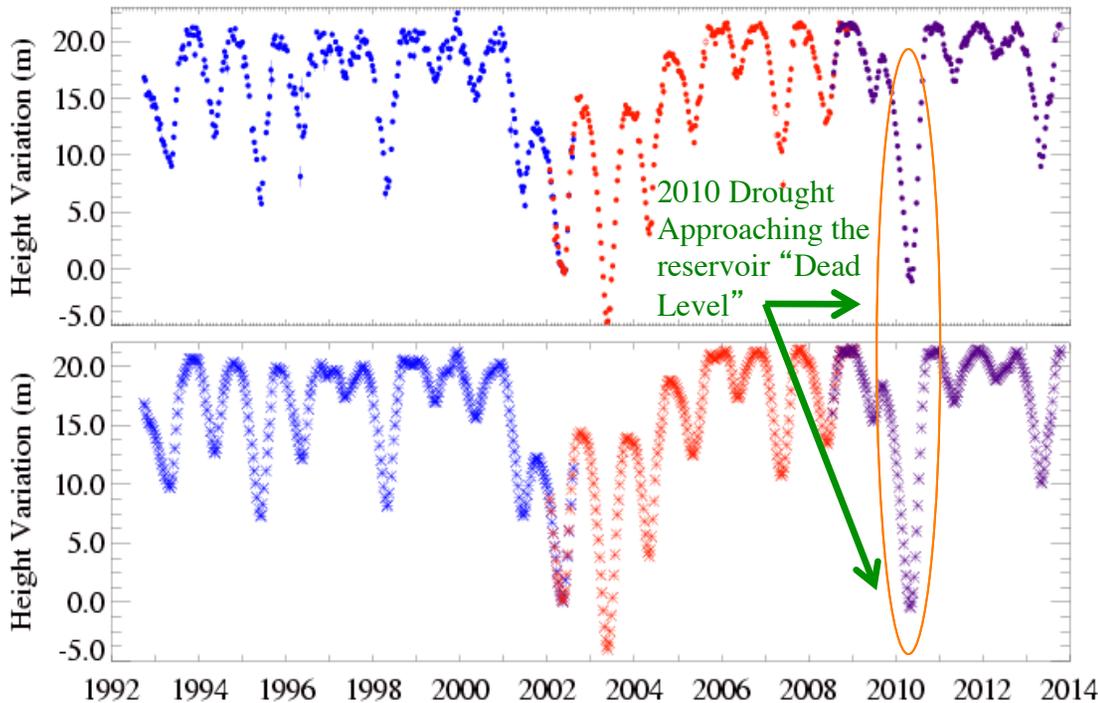
Venezuelan President Hugo Chavez urged citizens to cutback on showering time as the country's electric and water supply problems mount.

Venezuela will enact new water conservation methods, including reducing supply by 25 percent until May, because of low El Nino rainfall, President Hugo Chavez announced on TV late last night.

The drier cycle has caused "critically low" levels for the country's hydroelectric stations and drinking water reserves, including the El Guri reservoir, one of the world's largest dams, Chavez said. The El Guri is located on the Caroni River, which provides 70 percent of Venezuela's electricity. Usually the Caroni River, located in the Orinoco Basin, has a high discharge rate, but it has had difficulty replenishing itself lately.

Lake Guri Height Variations

Jason-2 Geo-referenced 20Hz Along Track Reference Pass 152 Cycle 69



*** TOPEX/Poseidon historical archive
 *** Jason-1 Interim GDR 20hz altimetry
 *** OSTM Interim GDR 20hz altimetry(ice mode)

Version TPJO.2
 Last valid elevation: 13 Oct., 2013

Higher water level in Guri Dam fails to solve power crisis

The water level of the reservoir is growing but thermoelectric generation has not expanded

ENERGY

The rainy season is arriving in Venezuela and the water level of the Guri reservoir is starting to increase, but concerns about the serious power crisis facing the country remain.

In fact, the National Electricity Corporation (Corpoelec) informed the authorities of state-run



Power cut of 2,000 MW required if Guri dam level reaches 240 meters

The largest power reduction must be made in central states and Venezuelan Guayana's Corporation (CVG)

ENERGY

Government authorities believe that the water level of the Guri reservoir will reach the critical level of 240 meters above sea level by June, and at point additional power rationing will be required.

The Executive branch of government has already outlined two scenarios for operating the Guri hydroelectric plant if the reservoir drops to such



The level of the Guri reservoir is declining over 10 centimeters per day due to the lower flow of the Caroni River (Photo: Gudrun Rainfrank)

The peak oil crisis: countdown at the Guri

by Tom Whipple

☆☆☆☆☆

Please [Log in](#) or [register](#) to rate this article.

Most Americans have never heard of Venezuela's great Guri dam. Completed in 1978 with 20 generators and 10,200 MW of generating capacity, at one time it had the most generating capacity of any hydro dam in the world.

By way of comparison, the Three Gorges dam in China is to produce 22,500 MW when completed next year and the U.S.'s Grande Coulee which dates back to 1942 can produce 6,800 MW. If you disregard the ecological damage caused by great dams, they can be wonderful things for they produce prodigious amounts of emissions-free energy at very low cost --- provided, of course, it keeps raining in the dam's watershed. Until recently nobody gave this much thought until last summer when El Niño, and perhaps a touch of global warming, started doing funny things to Venezuela's weather.

The rainy season in Venezuela which refills the reservoirs runs from June to October. The summer of 2009 it was a catastrophe. Rainfall was only about one third of normal so that by last fall alarm bells began sounding as it looked as if the water could fall to the level where the dam would have to shut down most of its generating capacity. The Guri dam has a lower and older generating hall with much less capacity than the main hall and there are two smaller dams located downstream from the Guri. The problem is that if they have to stop letting water through to the turbines in the main Guri dam, the water is no longer available to the downstream plants so their output drops markedly too.

Application: Flood Monitoring Lake Victoria - case study region

Nile River floods in Sudan leaving 200,000 homeless

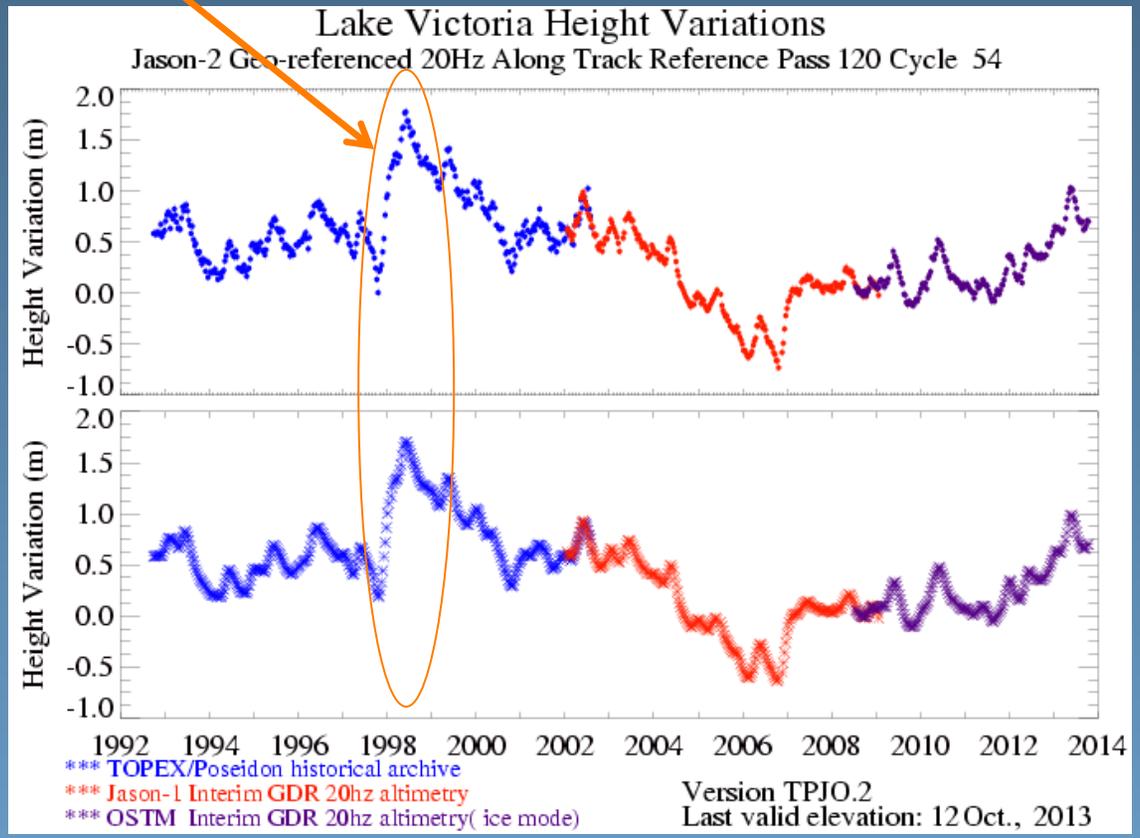
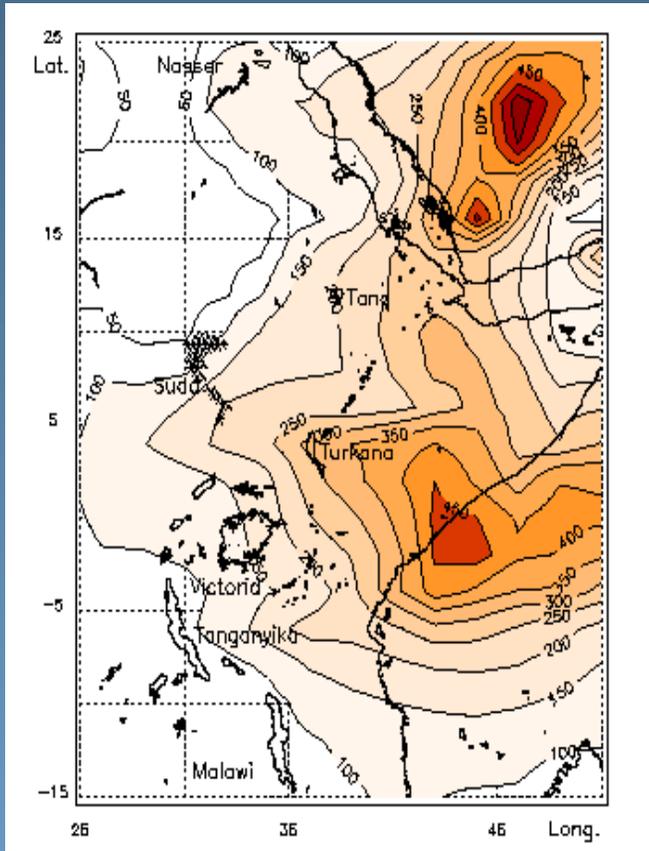
KHARTOUM, Sudan (AP) - Floods and heavy rains have destroyed 119,000 houses and left more than 200,000 people homeless in nine Sudanese states, the government said.

The government's Humanitarian Aid Commission said 65 schools and 60 health institutions have also been destroyed and vast tracts of farmland have been inundated.

The government has mobilized troops to fight the worst flooding along the Nile River in a half century and is considering evacuating thousands of people in districts near Khartoum.

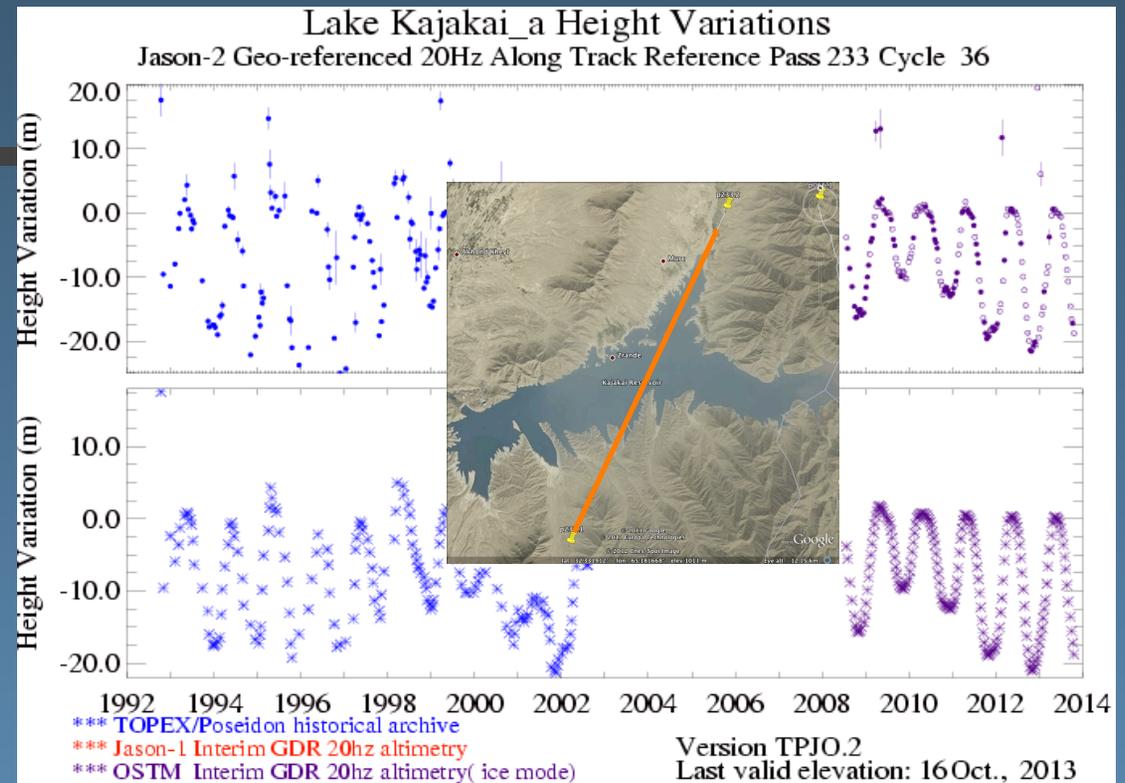
The worst hit regions in Sudan, Africa's large-

1997/1998 Flooding in East Africa



Rainfall rate over the Nile Basin for the period October 1997 to January 1998. 100%=mean rate

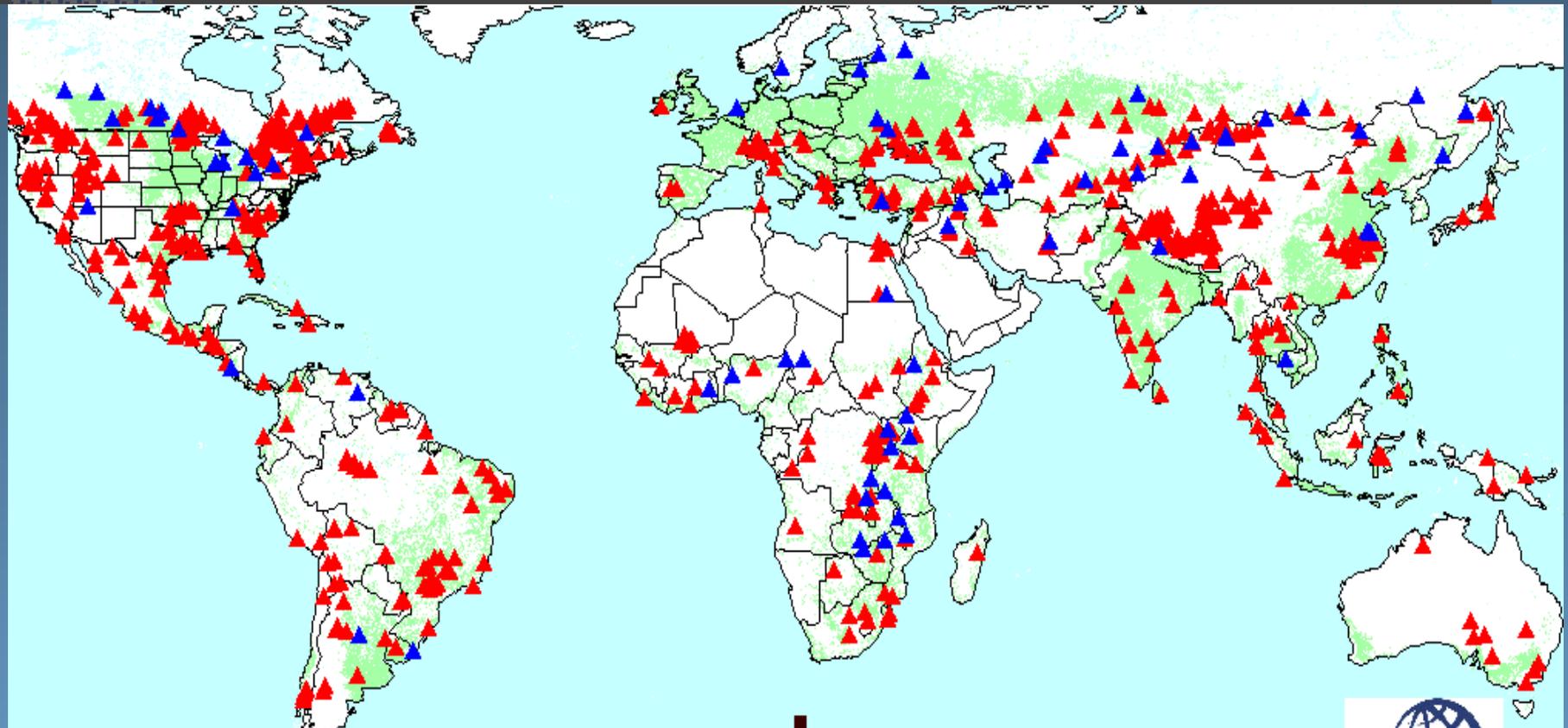
Product Application Post Flood Monitoring



Excessive 2007 snowmelt led to water release out of the Kajakai Reservoir spillway which resulted in large scale inundation of the floodplain. From 2008, the NASA 10-day products are aiding water managers via supplementing the often-sporadic fall/winter in situ data (no 35day ground tracks exist across Kajakai).

The Future – The Global Reservoir and Lake Monitor

Many hundreds of lakes and reservoirs will be added, the GRLM continuing to supply both archival and near-real time water level measurements.



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



The Future – The Global Reservoir and Lake Monitor

Lake level product users span a variety of different organizations including FAS foreign resource analysts, international governments, lake development agencies, conservation groups....

Interests include impoundment effects, water resources, energy supply, fish productivity, regional security, climate change....

The GRLM will continue to enhance and expand existing lake level products. In addition, the scope may be broadened to consider the operational delivery of new products that include lake areal extents, reservoir water storage, and perhaps river channel discharge. The production of such new products are under research development.

The Future – Research and Instrument Development

Striving to improve.....

- the current limitations on target size

- the acquisition of data in mountainous terrain

- the accuracy of the surface water levels

- the delivery time of the lake level products to end users

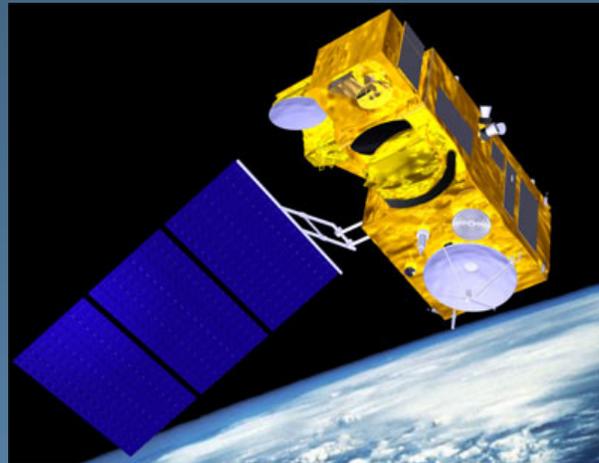
Many research teams are working to maximize the potential of the current altimetric data sets.

Others look to improvements via instrument design modifications.

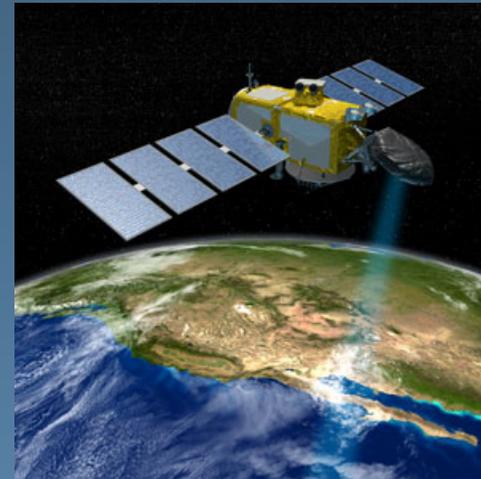
The Future: The Launch of Additional Enhanced Instruments

Providing continuity and new swath-based data sets

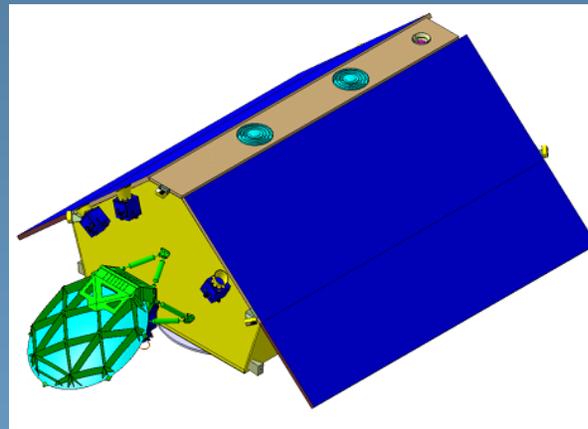
ESA
Sentinel-3
2014



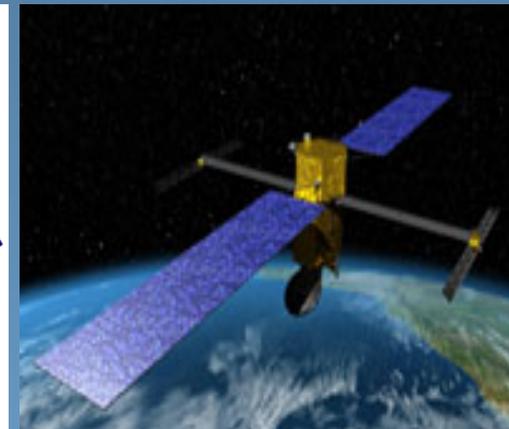
NASA/CNES
Jason-3
2015



ESA/EUMETSAT/
CNES/NASA/
NOAA
Jason-CS
2017



NASA
SWOT
2020



To Conclude

The University of Maryland, NASA, and USDA/FAS welcome all comments and discussions on the altimetric lake level products within the Global Reservoir and Lake Monitor.

Contacts: cbirkett@umd.edu and Curt.Reynolds@fas.usda.gov

Thank You !

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