Lakes monitoring from satellite Altimetry and satellite imagery

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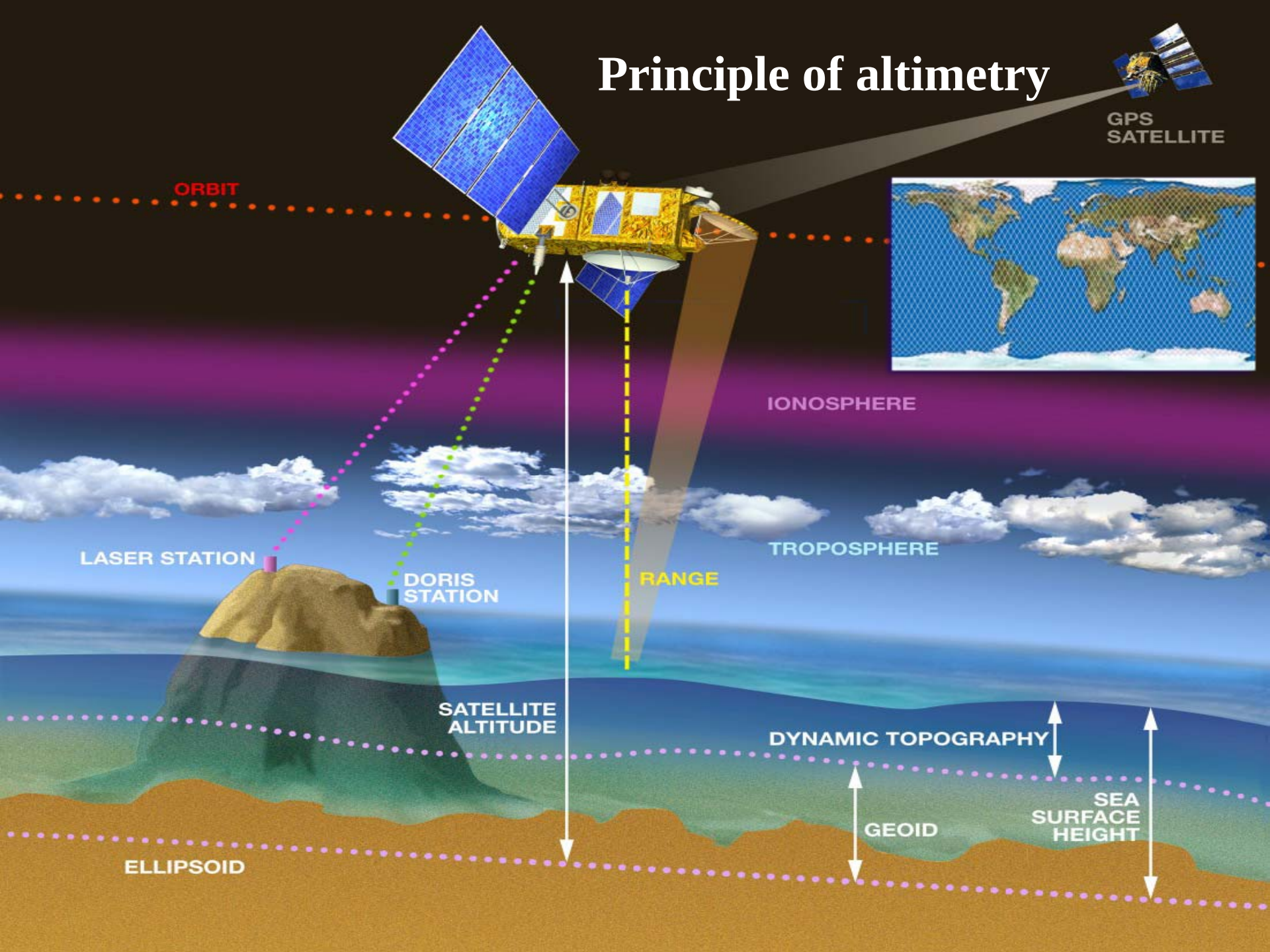
P. Maisongrande & A. Cazenave

Hydrolare Kick off meeting,
St Petersburg, July, 15-17, 2009

Principle of altimetry



Field of applications in Hydrology

Which water bodies?

- Lakes and man made reservoirs
- Big river basins
- Floodplains and temporary lakes

Which objectives ?

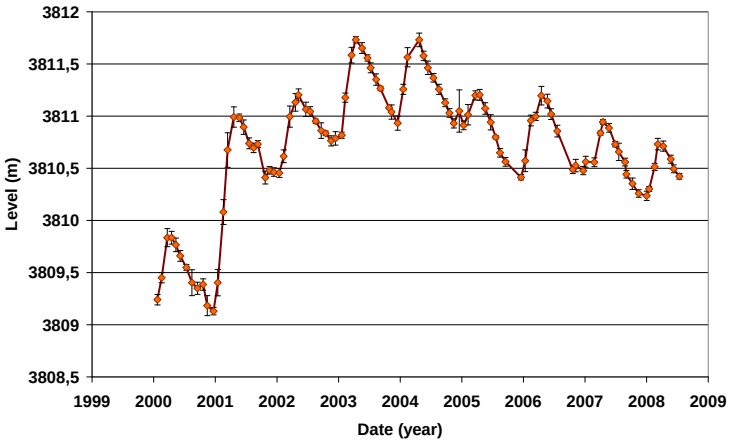
- Survey of inter-annual water level variations
- Global scale and local water budget
- Cartography of floodplain dynamics
- Assimilation in hydrodynamical models
- Cal/Val of space missions
- setting up global terrestrial database

Which remote sensing technics involved?

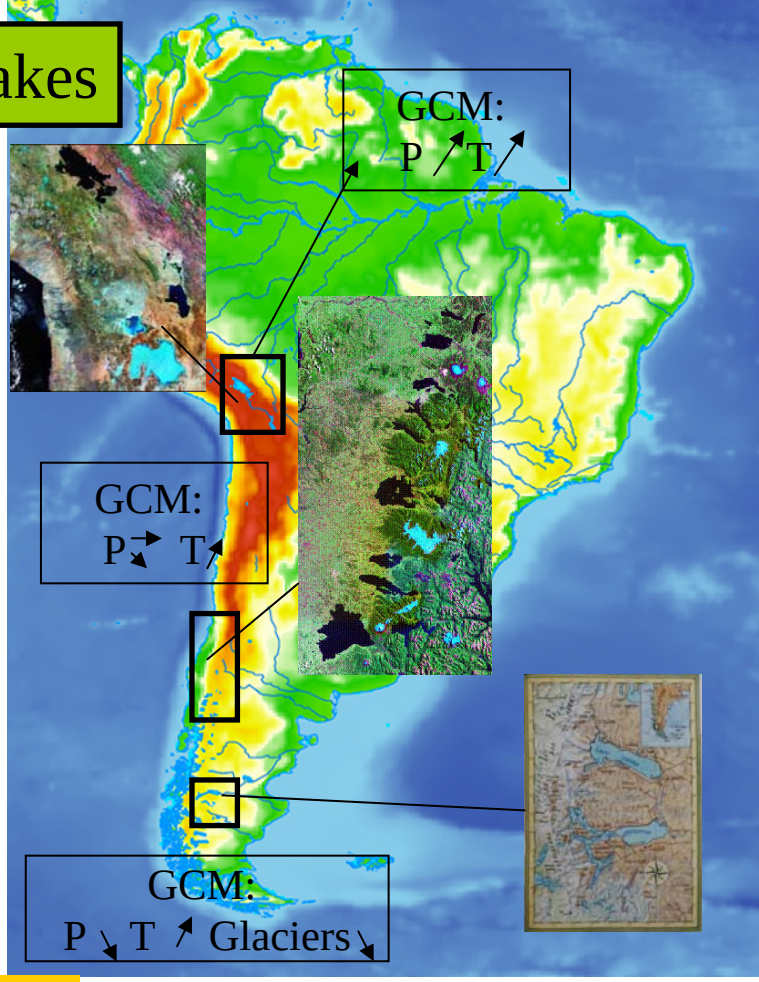
- Laser and Radar altimetry
- Multispectral optical and IR imagery

Andean Lakes

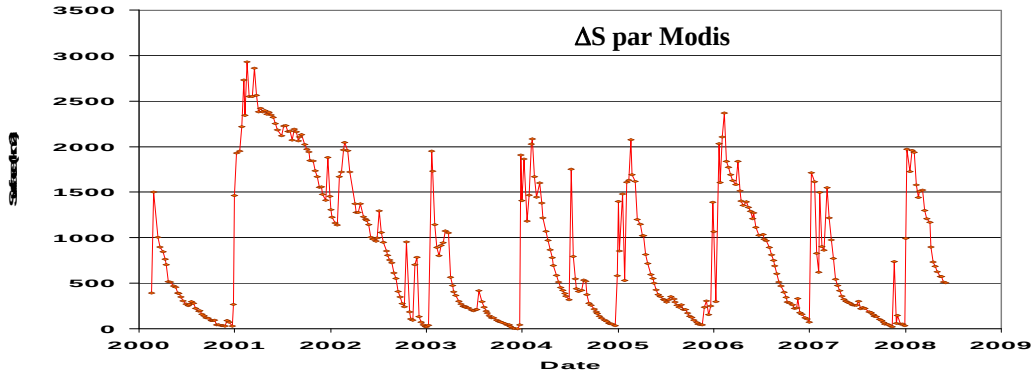
Titicaca



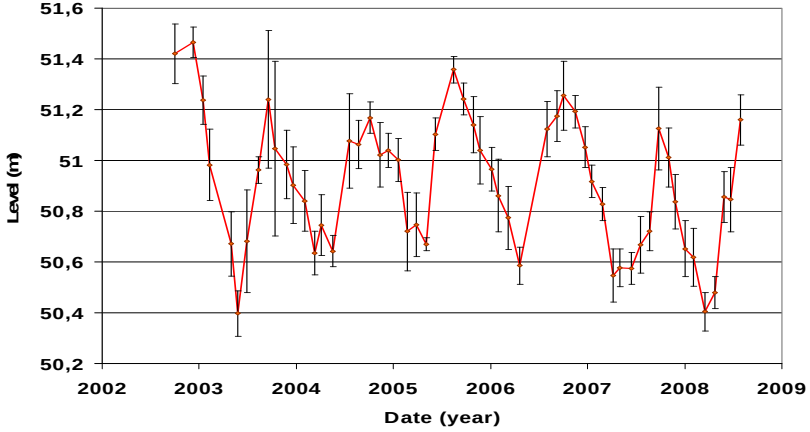
Radar altimetry monitoring of ~20 lacs +imagery: ΔS => Water Storage



Coipasa



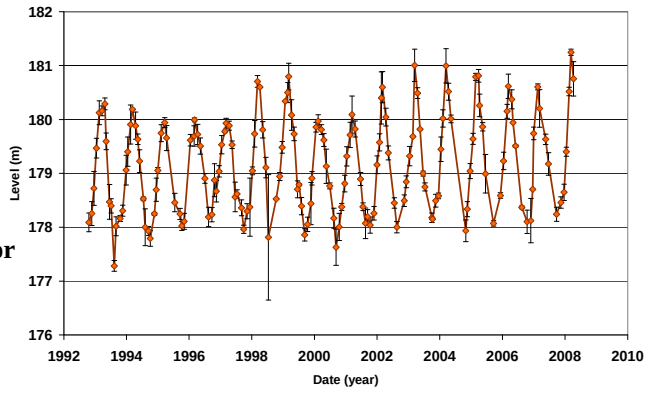
Llanquihe



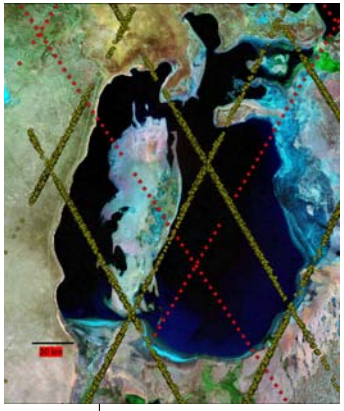
Impact of SO ?
Impact of El Nino ?
Impact of PDO ?
Impact of Glaciar melting?
Impact of Precipitation?
Impact of Temperature change?
Impact of Underground water?

Lake level monitoring is a first step for
Understanging the climate impact on
Terrestrial water storage variability
In situ gauges very sparse
Potential scientific application for RS

Argentino

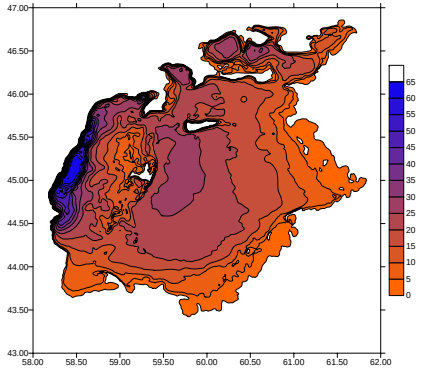


Hydrologycal water balance of lakes

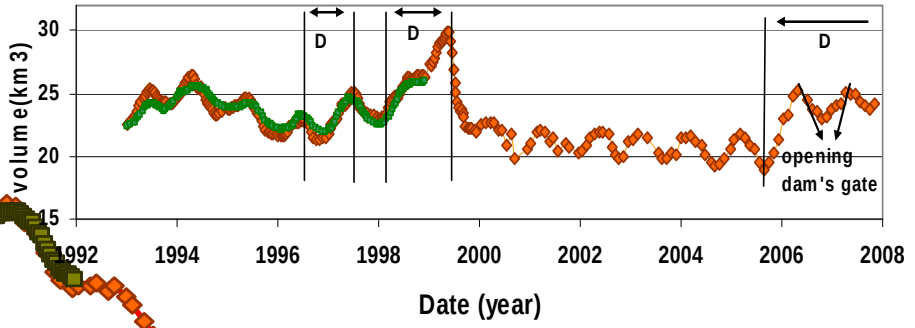


Deficit of water supply: 5km^3/yr

Underground water, residuals errors, inflow from Syr Darya



Small Aral, volume variations



Deduced from in situ data

Deduced from altimetry

Big Aral volume variations

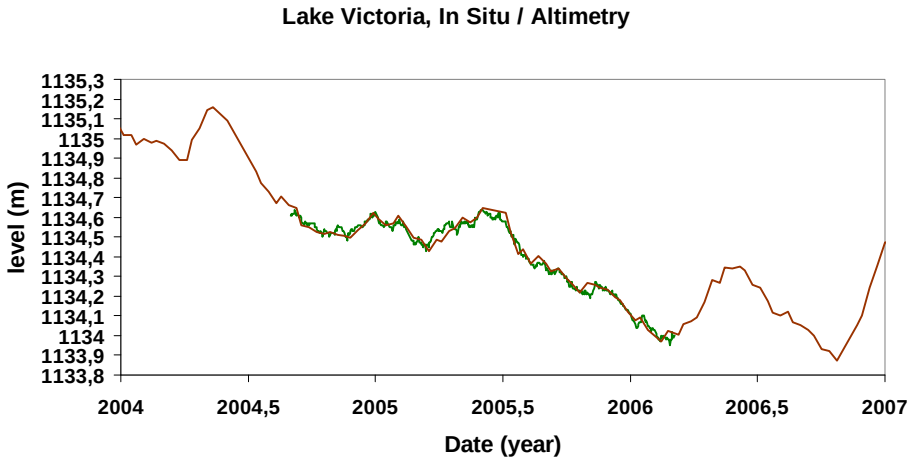
Volume (km3)

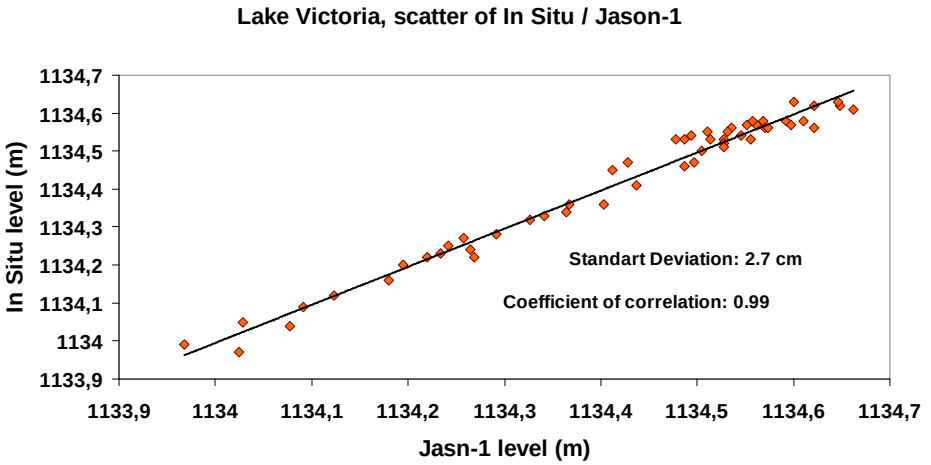
270
220
170
120
70

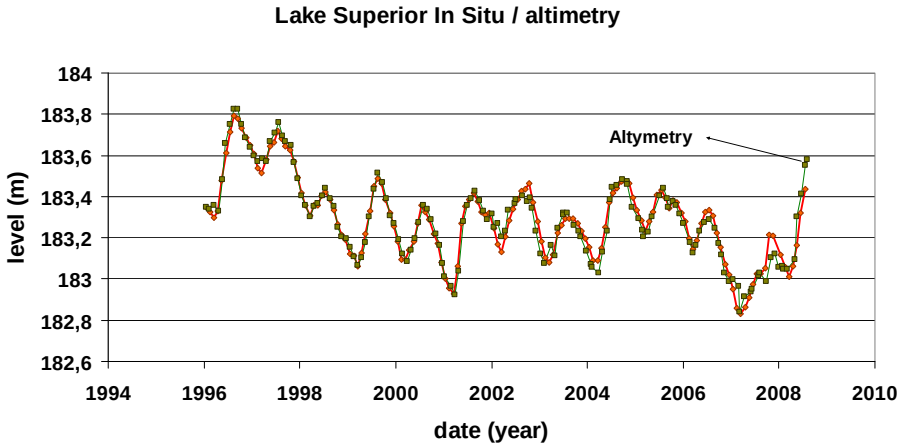
1993
1995
1997
1999
2001
2003
2005
2007

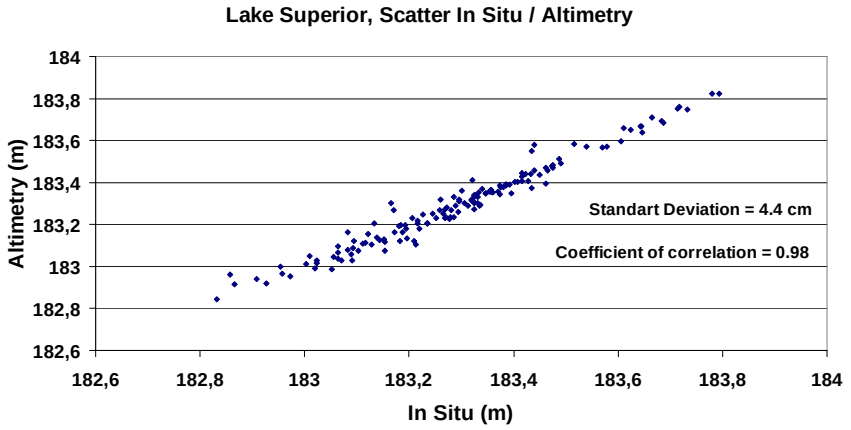
Date (year)

Altimetry over lakes: comparison with In Situ data (1/2)









Altimetry over lakes: comparison with In Situ data (2/2)

Lake name	*Country*	*Size of the lake (km2)*	*RMS of the differences In Situ / altimetry level (cm)*
Erie	USA, Canada	25821	5
Issykkul	Kyrgyzstan	6236	4
Kariba	Zambia, Zimbabwe	5400	24
Mar de Chiquita	Argentina	6000	13
Powell	USA	380	80
Superior	USA, Canada	82367	4
Titicaca	Peru, Bolivia	8372	17
Victoria	Tanzania, Uganda, Kenya	68800	3

For the biggest lakes (Victoria, Superior and Erie) the accuracy is better than 10 cm, the intermediate (Kariba, Mar de Chiquita, and Titicaca) the accuracy is at the decimetre level, while for some small water bodies, as Lake Powel it is closer to 1 meter, particularly due to the fact that this lake is long but very thin. The Lake Issykkul which is an intermediated lake in size, presents surprisingly very accurate results.

Dissemination of altimetry and RS products
Hydroweb/Hydrolare database

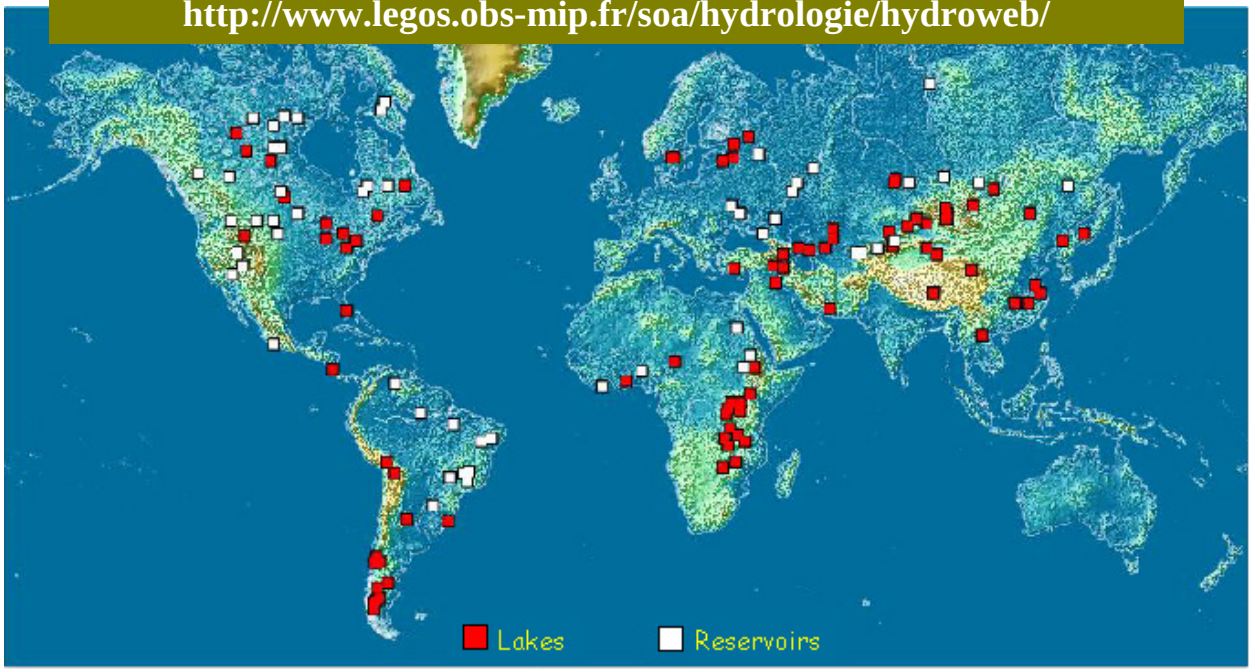
Currently:

Free access and download of water level variations for 150 lakes & reservoirs
More than 300 virtual stations on rivers
Updating every year

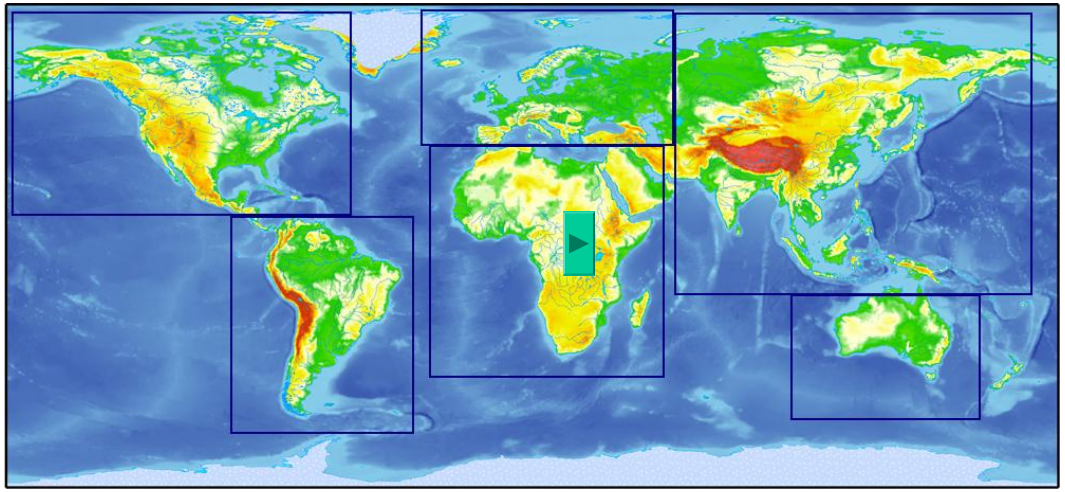
Objectives:

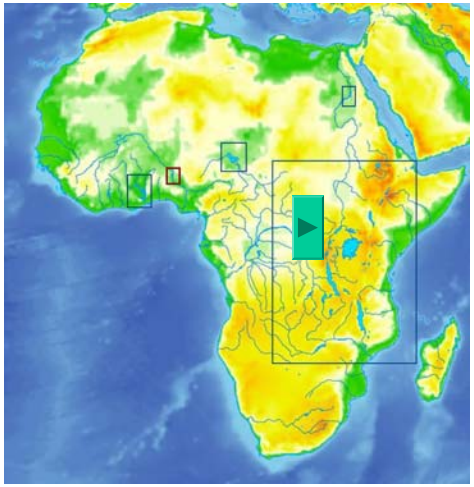
Doubling the number of water bodies for level and surface variations
Operational data center (automatic monthly update) in the frame of Hydrolare

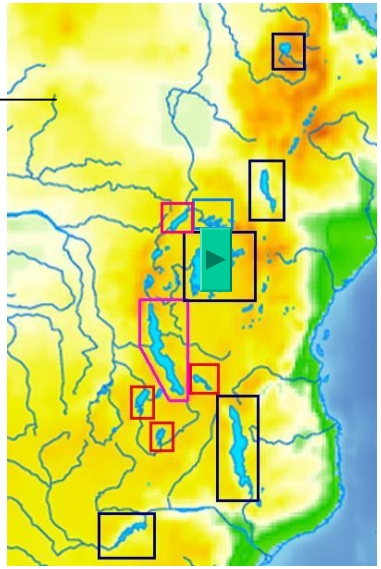
http://www.legos.obs-mip.fr/soa/hydrologie/hydroweb/



Current use of Hydroweb

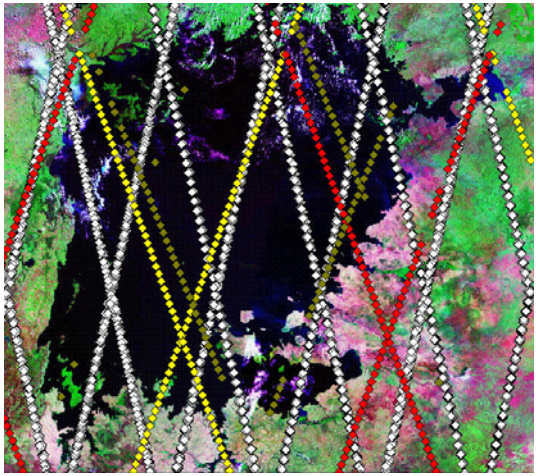


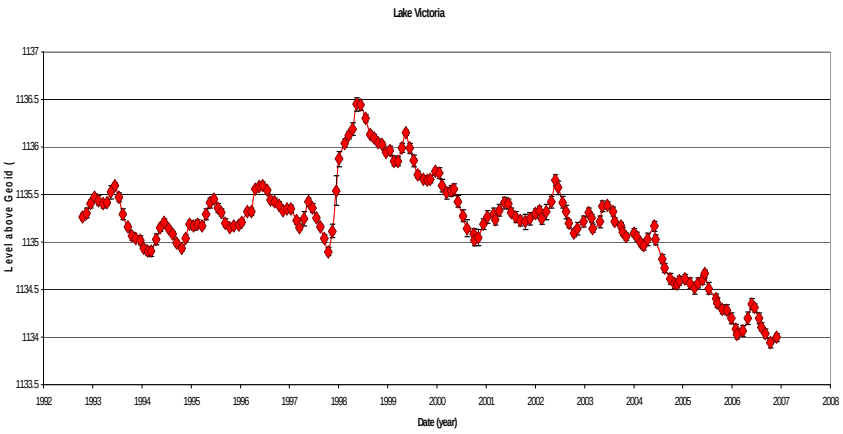




Lake Victoria

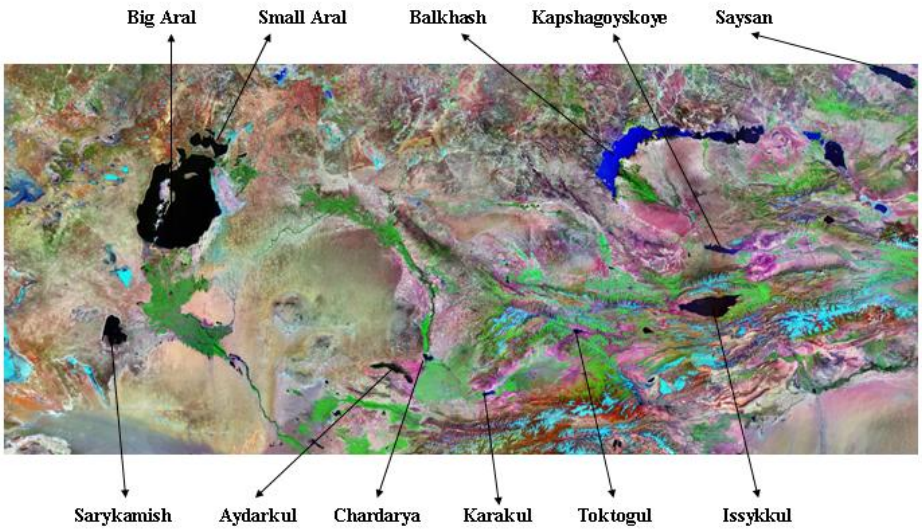
Download

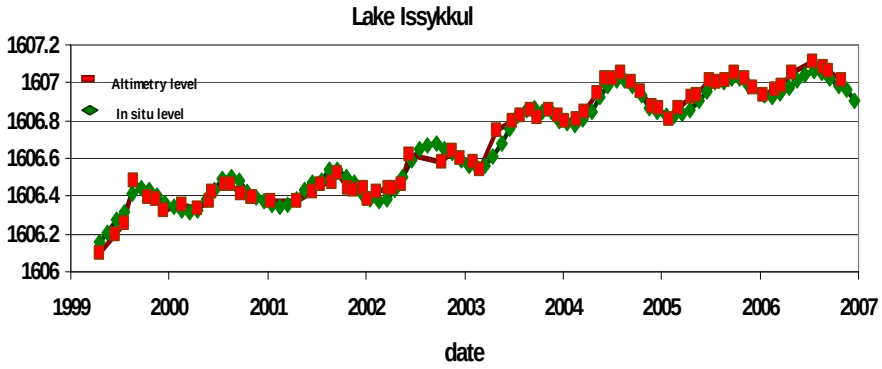


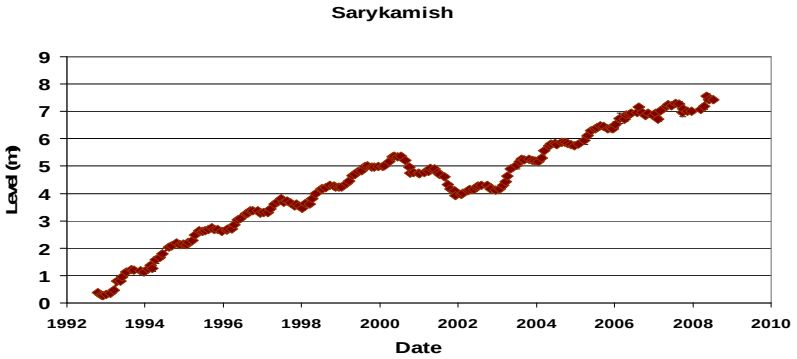


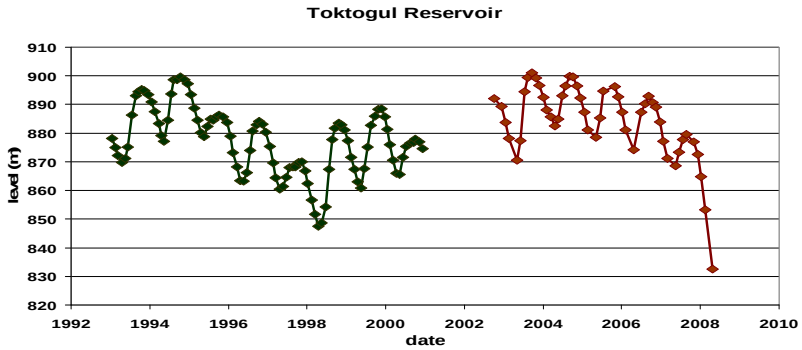
Interest for scientific community and others

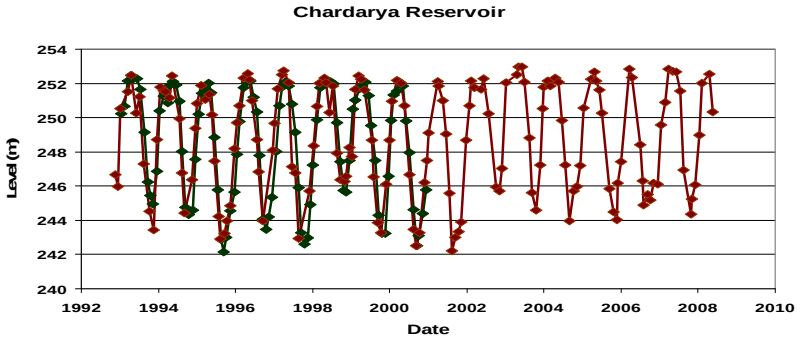
Central Asian river's flow is changed by acceleration of glaciers melting, variability in rain regime, irrigation and artificial reservoirs regulation under interstate agreements. Complex system, hard political framework, and lack of ground network for free water information delivery and sharing. 5 countries with around 50 million of people leaving.











Continuous monitoring of large number of lakes and reservoirs Where no in situ gauges are available

NEW HYDROWEB FOR LAKES SURVEY

Essential Climate Variable (ECV) defined by GCOS: list of products

Products T1.1: maps of lakes in the Global Terrestrial Network for Lakes (GTN-L)

Gridded georef maps of 250 m spatial resolution on monthly basis for 150 lakes
With accuracy of 5%

20 lakes surface water extent has been collected from:
ASAR, MODIS, LANDSAT, CBERS, Bathymetry maps, and SRTM
Only 4-5 images per lakes from min value to max value over historical evolution of each lake
Calibration & comparison has been performed

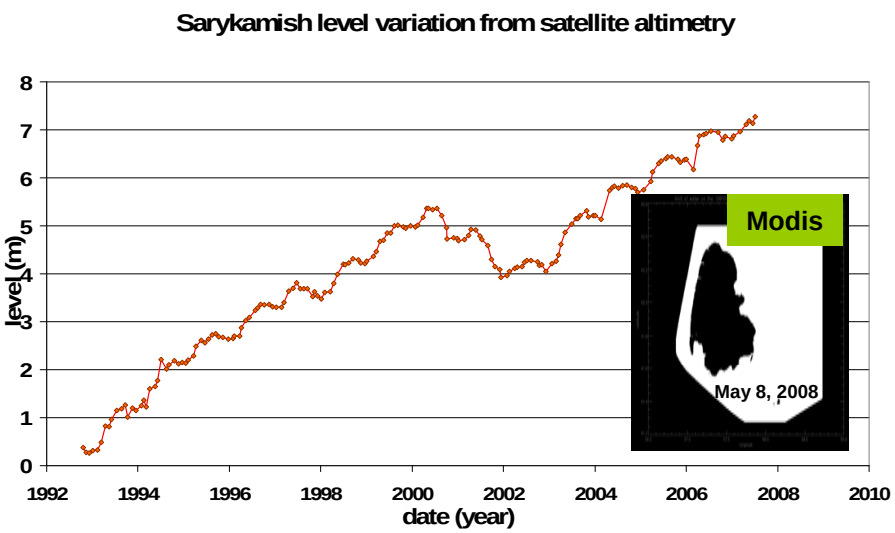
Products T1.2: Lake levels of all lakes in the GTN-L list

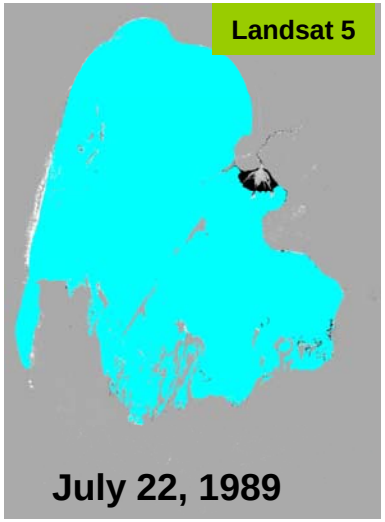
10 cm of accuracy and stability on weekly/monthly basis
Time series based on radar altimetry and in-situ gauges

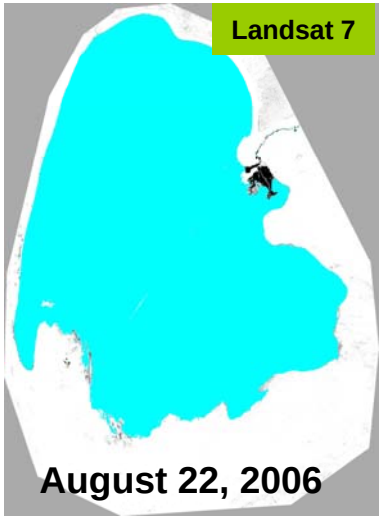
Radar altimetry over 150 lakes with 5 to 50 cm of accuracy depending Of size of the lake including ~40 lakes of the GTN-L

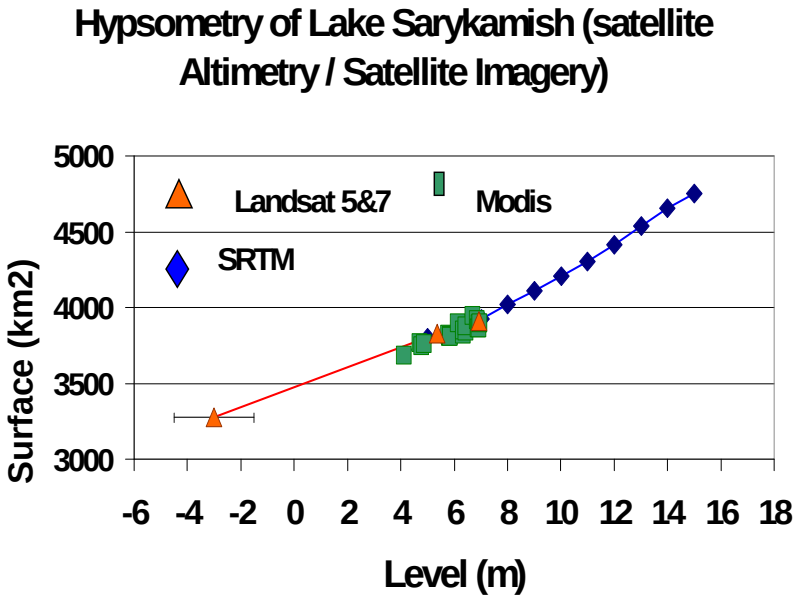
Selection of maps + level from altimetry => hypsometry curve (dh/dS)
=> Reconstruction of past surface variations on weekly/monthly basis through altimetry

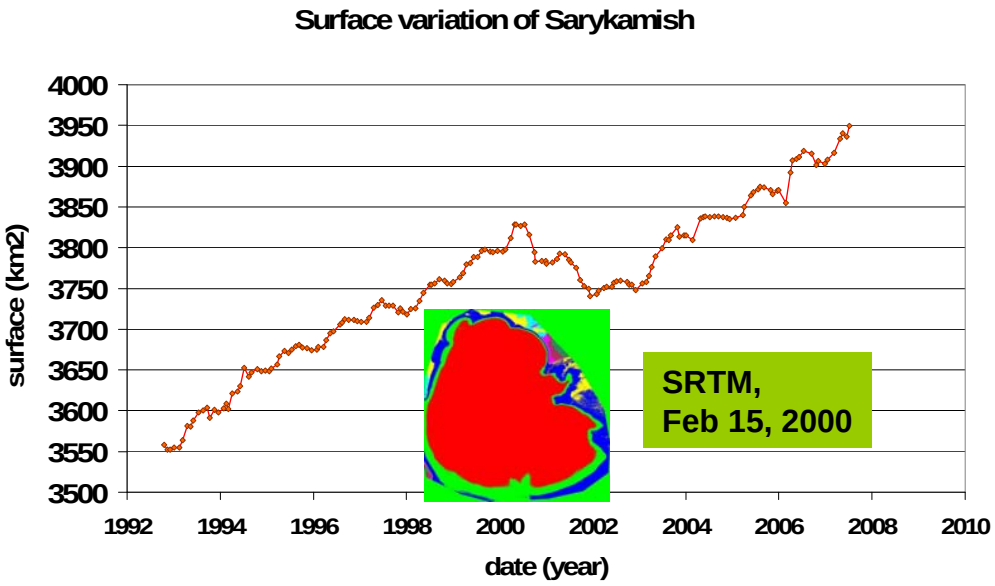
Prototype of new Hydroweb page for a given lake

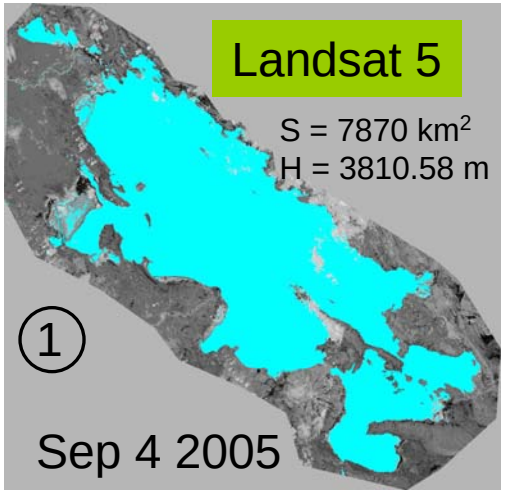


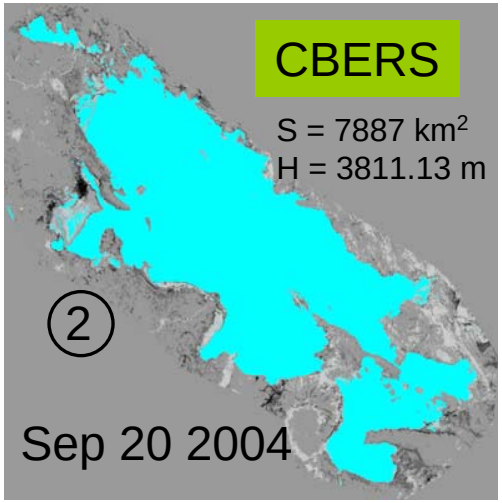


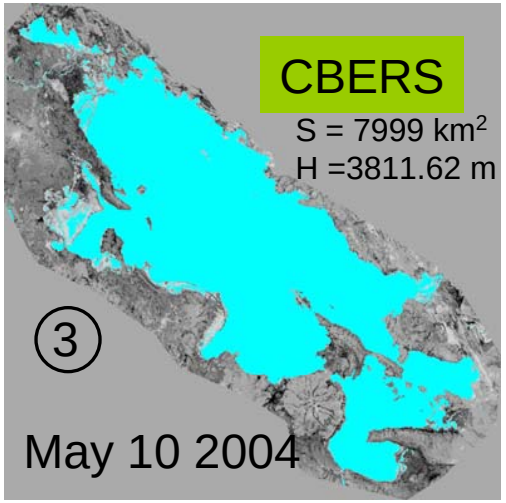


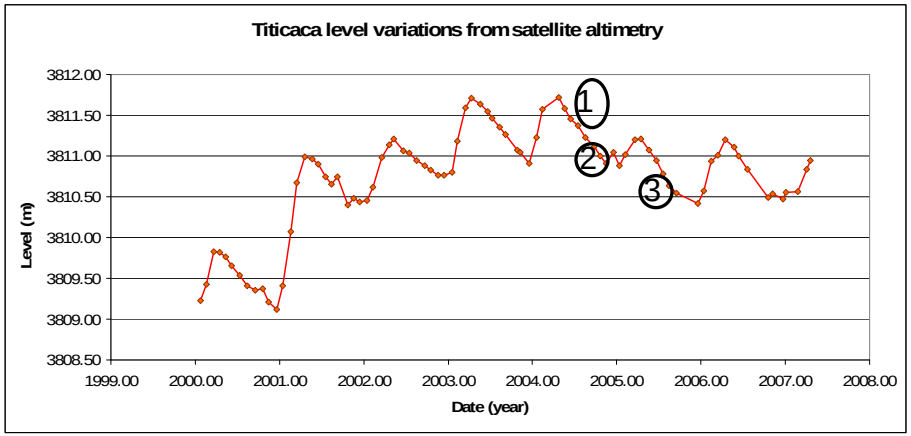






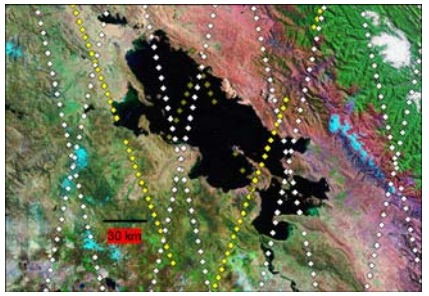


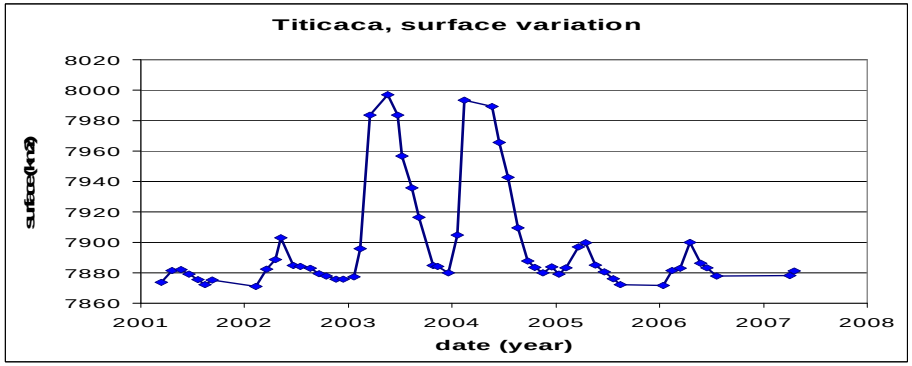


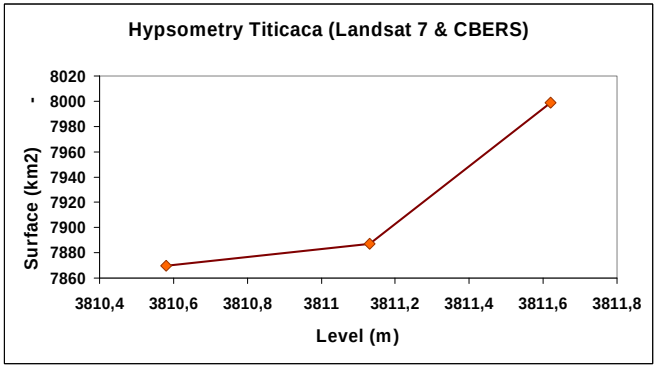


Lake Titicaca

Data download

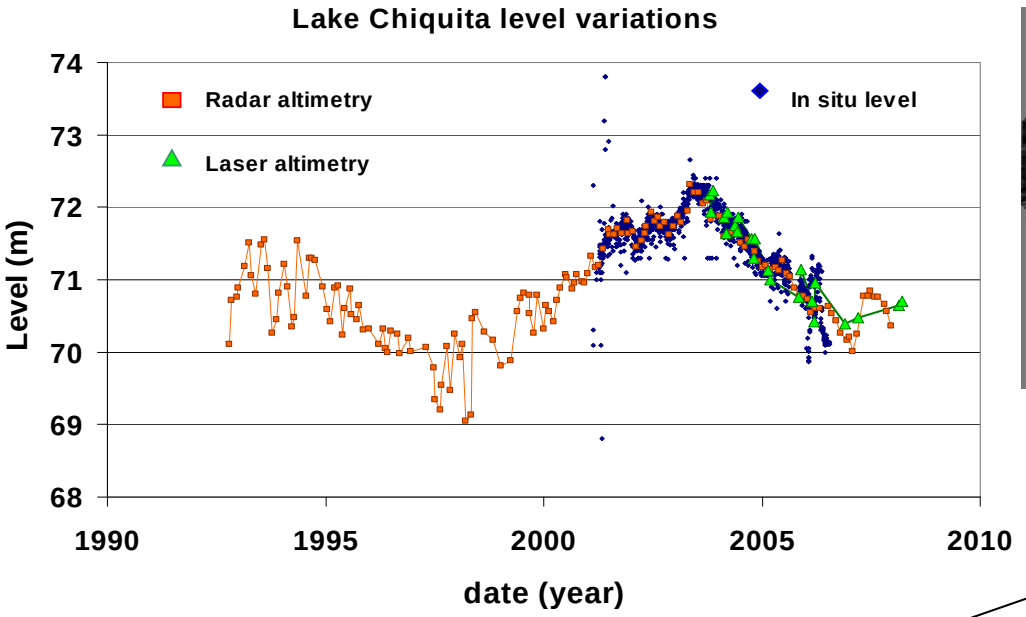


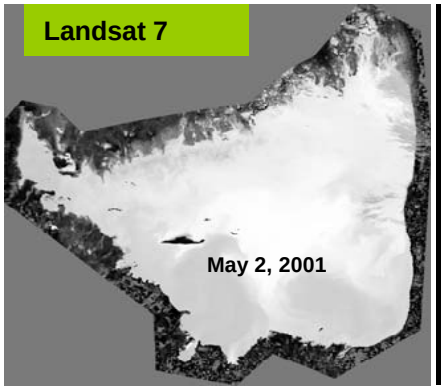


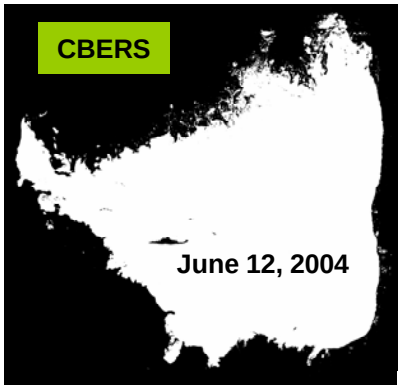


Lake Mar de Chiquita

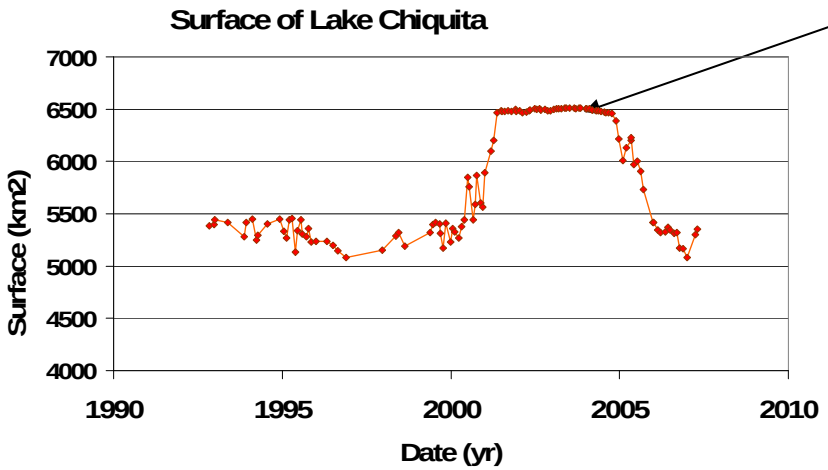
Landsat, CBERS, and modis images, In situ level,
radar altimetry over 15 years and laser altimetry over 5 years (Icesat)

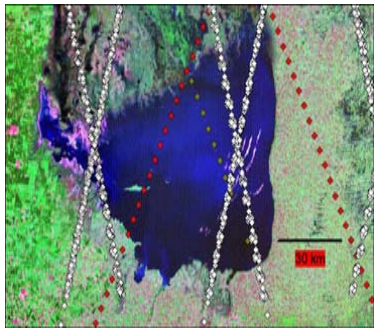


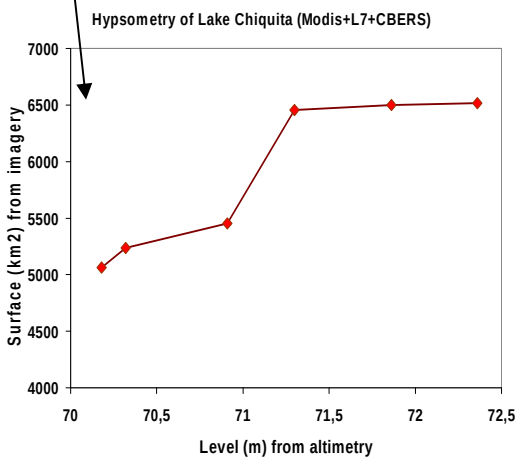




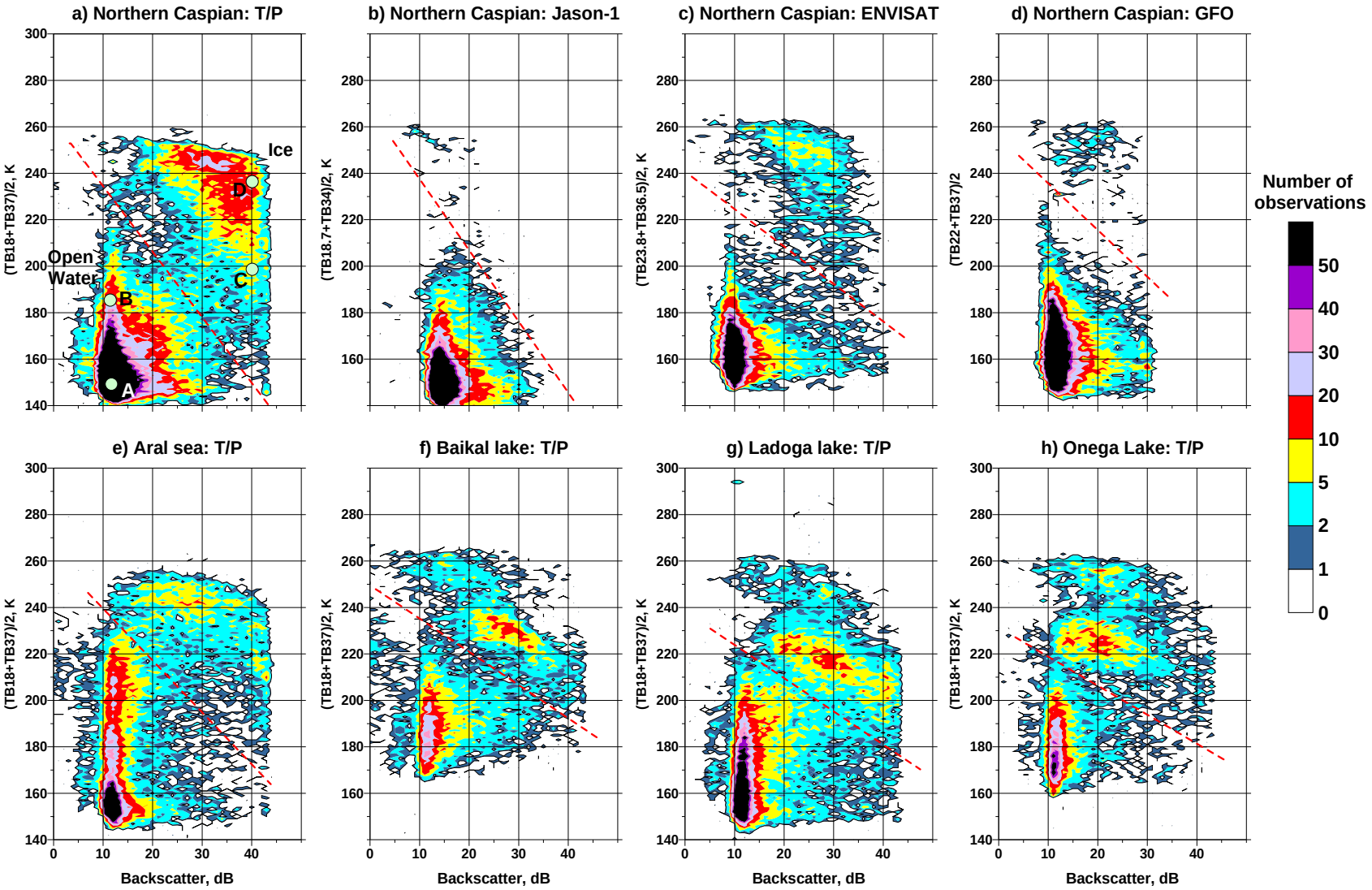
For some lakes the relation dh/dS (hypsometry) is not linear which Explains for Mar de Chiquita the different shape of level and surface variation's plots







ALTIMETRY METHOD: 2

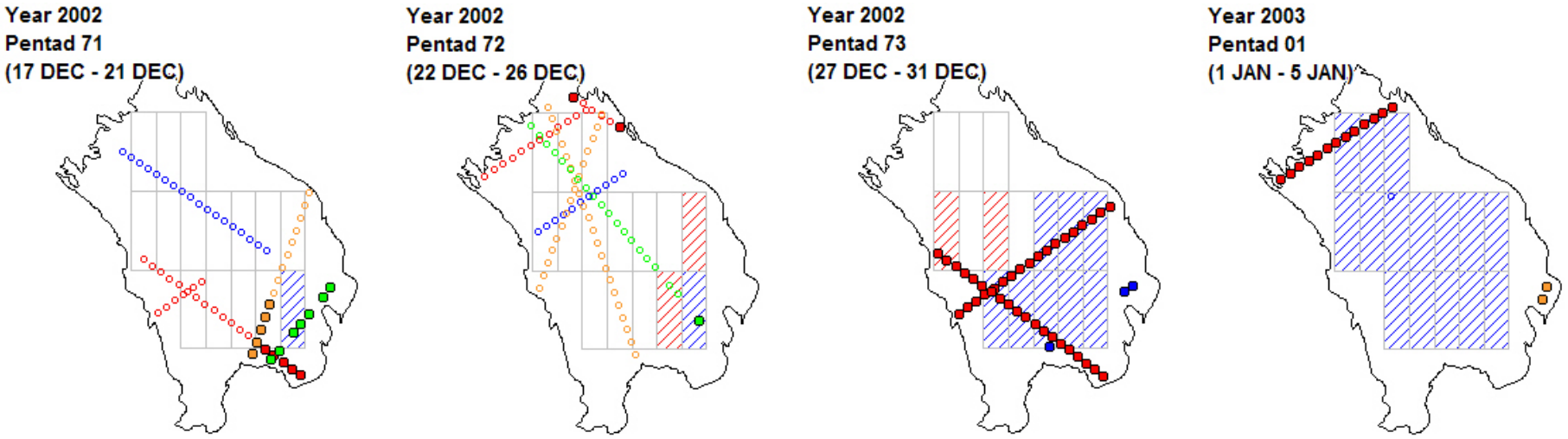


Observations from T/P (a), Jason-1 (b), ENVISAT (c) and GFO (d) for the Northern Caspian, and observations from T/P for the Aral sea (e), Baikal (f), Ladoga (g) and Onega (h) Lakes

Combining benefits of the two platforms

MAPPING APPROACH

Working at 5 days resolution (pentads)



Freezing of the Ladoga Lake - a sequence of four pentads during winter 2002/03

SSM/I - wide spatial coverage, high temporal resolution
Altimetry - high radiometric and along-track spatial resolution

Resulting time series of ice events

BAIKAL LAKE: EXTENDING HISTORICAL DATA

Good relation with historical data

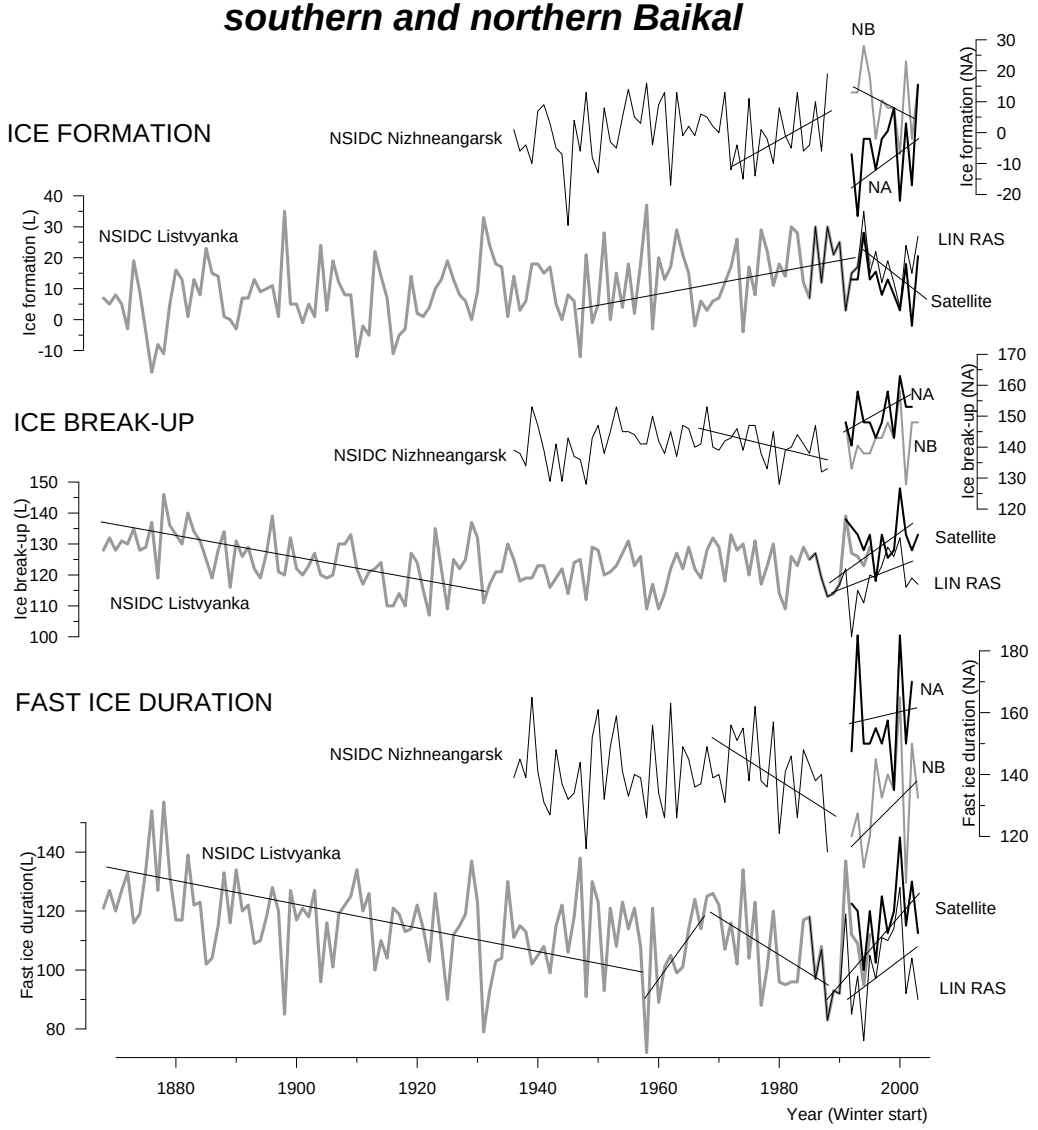
Extension of existing time series, creation of new ones

A recent tendency for colder winters

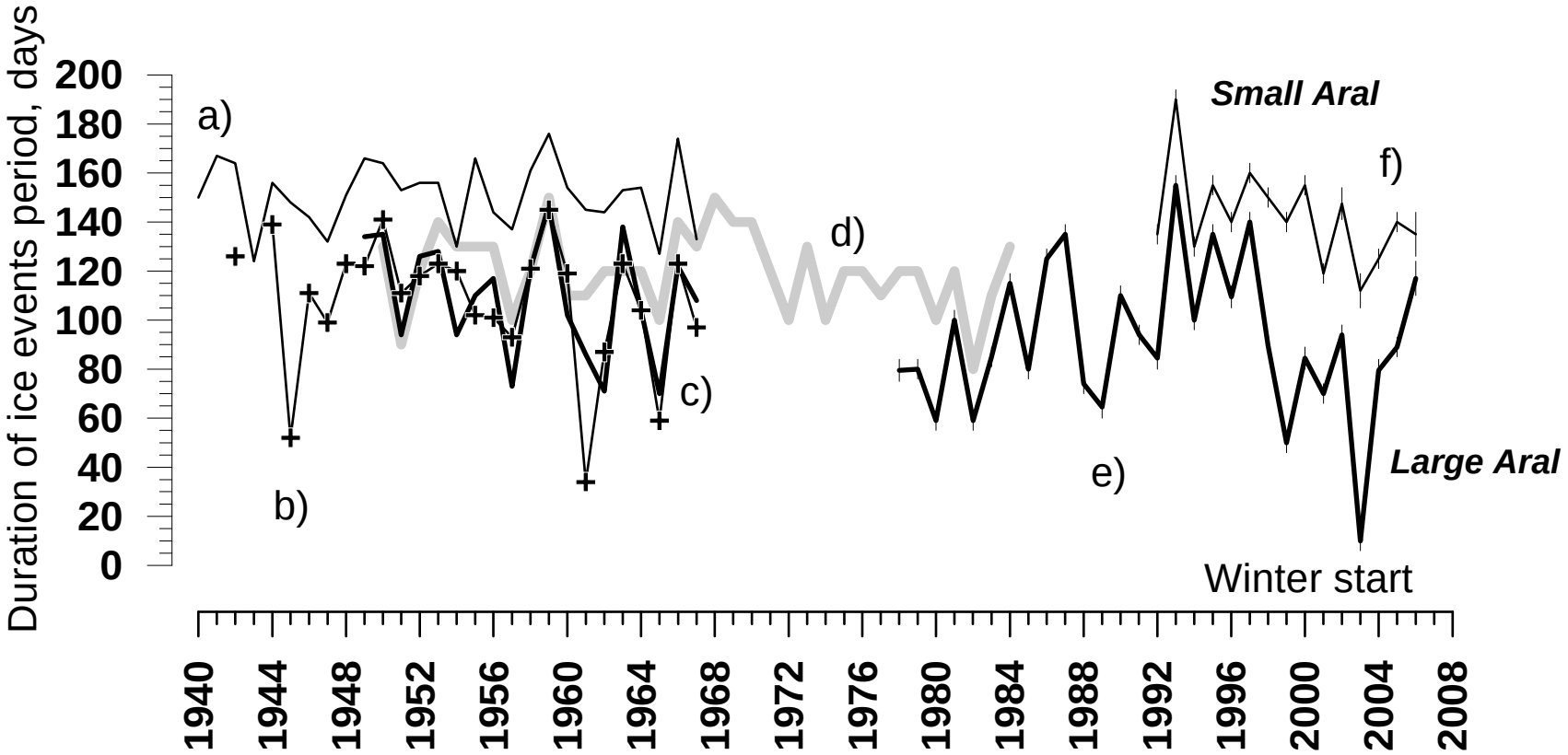
Earlier ice formation, later break-up, longer fast ice duration

New long-term tendency or short-term fluctuation?

Ice formation and break-up, and fast ice duration for southern and northern Baikal



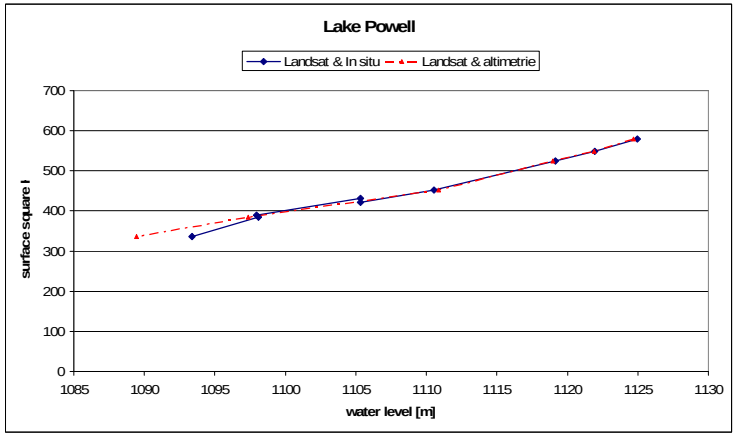
ARAL SEA: Difference between Large and Small Aral

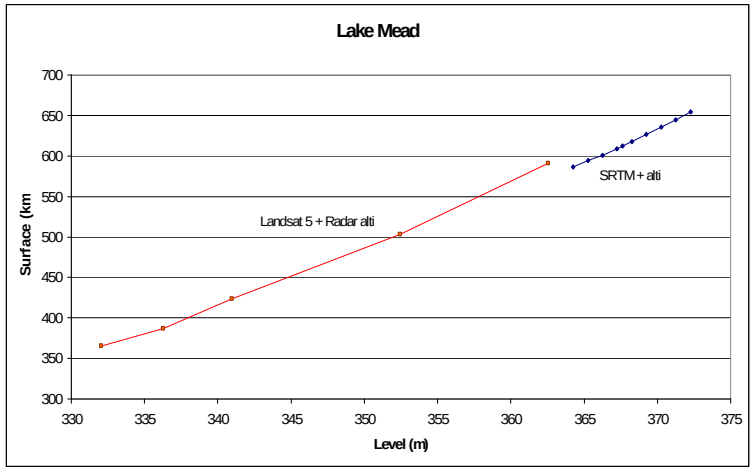


Duration of ice events period, days.

Hydrometeorological stations data (after Atlas of Aral sea ice, 1970): a) Sarychaganak, thin black line, b) Uyaly (sea), thin black line with crosses, c) Barsakel'mes, thick black line. Average dates for the whole Aral sea (after Bortnik and Chistyaeva, 1990),(d, thick grey line). Satellite derived data for Eastern part of the Big Aral (e, thick black line) and Small Aral (f, thin black line) and associated error bars

Next phases of implementation

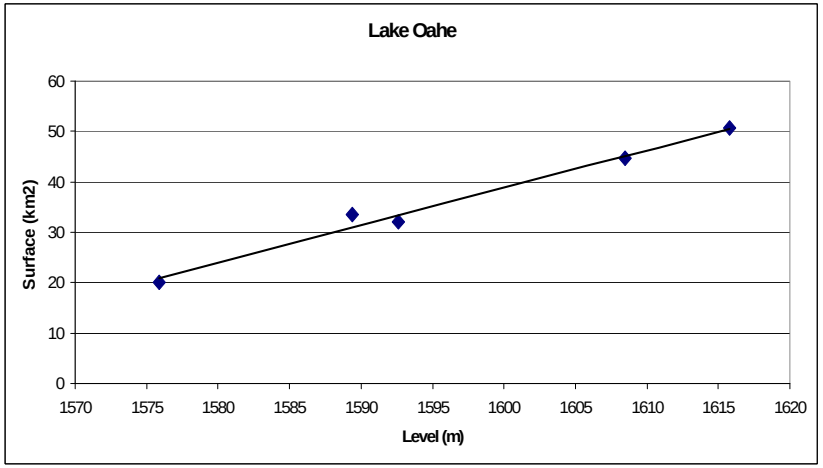




➢**Hypsometry curve has been estimated for 20 lakes & reservoirs**
➢**150 lake levels are currently updated in Hydroweb**
➢**An in situ data base is under development at SHI in St Petersburg for the Hydrloare Project (level, surface temperature, phenology of lake ice, etc.)**

⇒ **Extraction of RS images for all lakes in the GTN-L list**
⇒ **Comparison of in situ level in the frame of cooperation with Official Hydrolare data centre (under the support of GEO & WMO)**
⇒ **Estimation of hypsometry of each lake**
⇒ **Participation in the Hydrolare steering comitee**
⇒ **New pages on the web site and NRT product delivery for lakes level, surface, and volume variations**

⇒ **Regular Updating of data centre web pages in the frame of Hydrolare project:**
Delivery of various products & information from RS and In situ Data, for each lakes of the GTN-L (and also others)



CONCLUSIONS

Altimetry is a usefull and promising technique for lake's monitoring

- **Precision of few centimeters**
- **multi-year time series availability**
- **observation of large number of lakes**
- **Provide reliable data for water mass balance in remote areas**
- **Possibility to combine with other RS data**
- **global database for lakes, rivers & floodplains in NRT mode of operation in development**