A new Database of Water Level Time Series for Lakes, Rivers, and Wetlands from Multi-Mission Satellite Altimetry

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Motivation

Since many years satellite altimetry is becoming increasingly important for hydrology. The fact, that satellite altimetry, originally designed for open ocean application, can also contribute reliable results over inland waters helps to understand the water cycle of the system earth and makes altimetry to a very useful instrument for hydrology. In this poster, we present the new "Database for Hydrological Time Series of Inland Waters" (DAHITI). This database provides water level time series for lakes, rivers, reservoirs, and wetlands from multi-mission satellite altimetry which are computed by a Kalman Filter approach.

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Data

For the estimation of the water level time series we use altimeter data from all available altimeter missions except ERS-1 and ERS-2 (no land coverage). Figure 1 shows all altimeter mission since 1985. All data are manually cross-calibrated to remove the range bias between the missions allowing to use all missions as a single altimeter system.

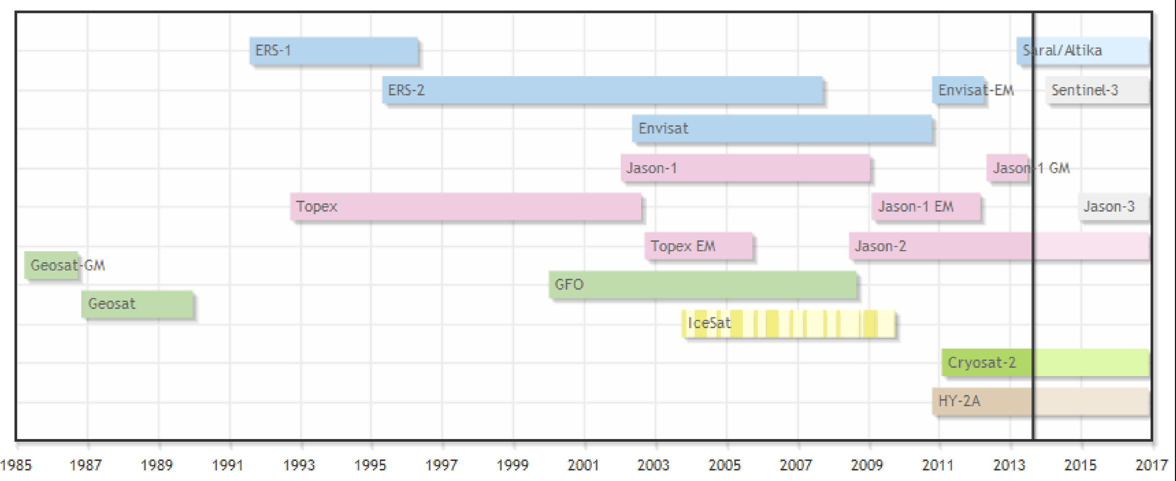

Figure 1: Overview of all satellite altimeter missions since 1985

Data Holding of DAHITI

The DAHITI database contains currently time series of about 180 worldwide distributed time series of lakes, rivers, reservoirs, and wetlands which are shown in Figure 2.

Figure 2: Data holding of DAHITI

Data Access

All time series of DAHITI are provided via OpenADB (Open Altimeter Database) (Schwatke et al., 2010) at DGFI which is available under http://openadb.dgfi.badw.de. After a short registration process all time series are free and public available.

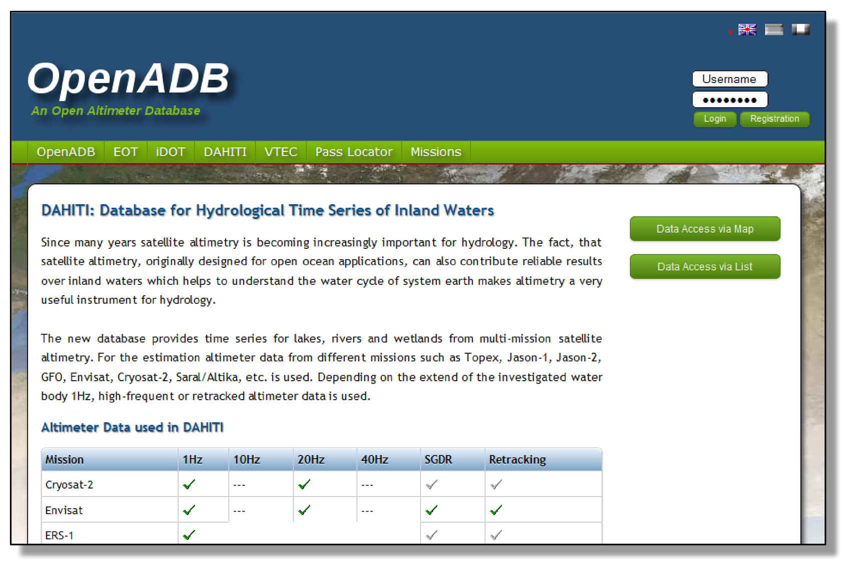

Figure 3: Website of DAHITI on OpenADB

Methodology

The methodology used for DAHITI includes new approaches for outlier detection (Support Vector Regression (SVR)) (Burges, 1998) and estimation of the resulting (Kalman Filter) water level time series. The work flow is divided in a „Preprocessing" and an „Estimation" step.

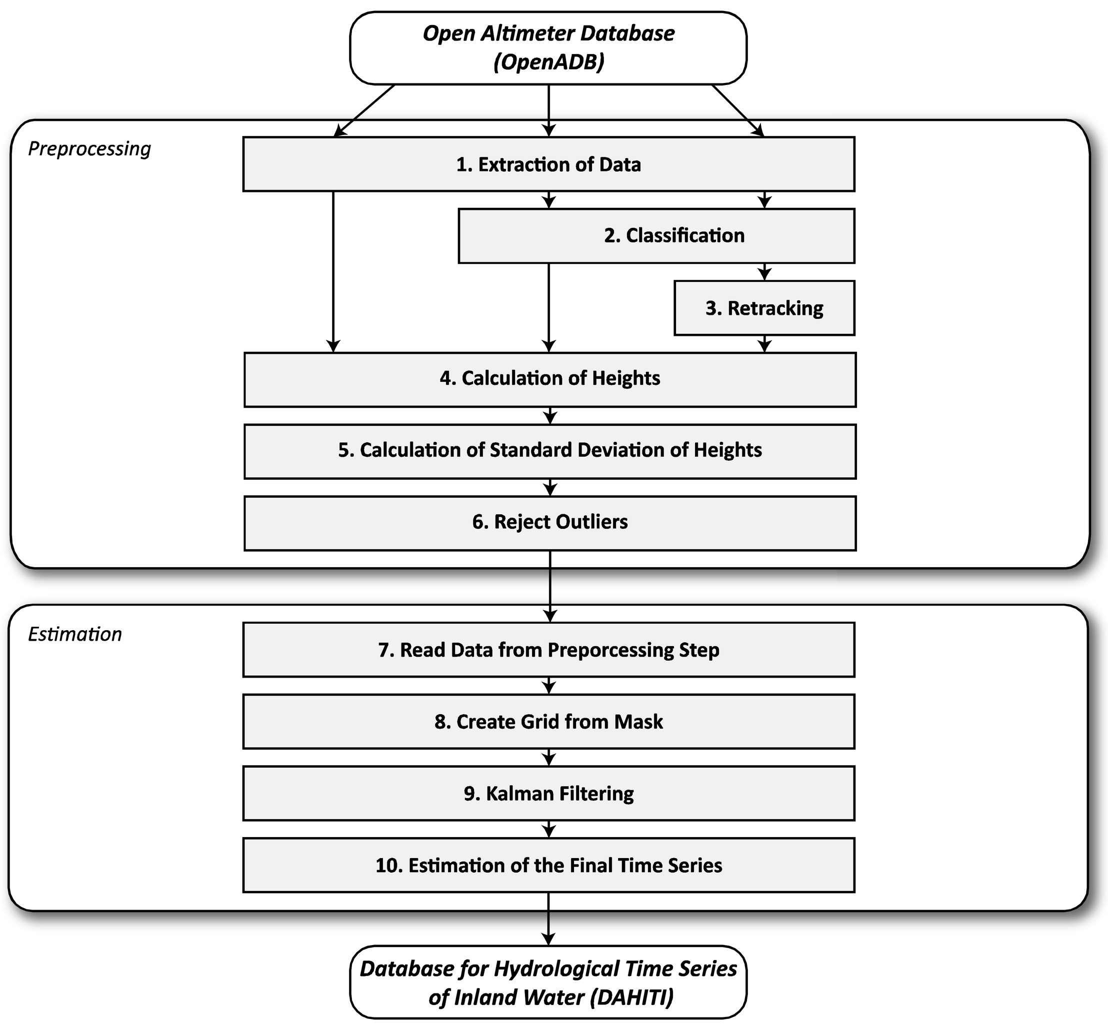

Figure 4: Methodology for the estimation of water level time series from satellite altimetry

1. Extraction of Data

For each water body, all necessary altimeter data such as position, satellite height, range, geophysical corrections, time, geoid and waveforms are extracted from OpenADB.

2. Classification of Waveforms

This option allows us to classify altimeter waveforms into three classes ("linear brown", "linear exponential", "single peak") using the method of "Support Vector Machine (SVM)". (Schwatke et al., 2012)

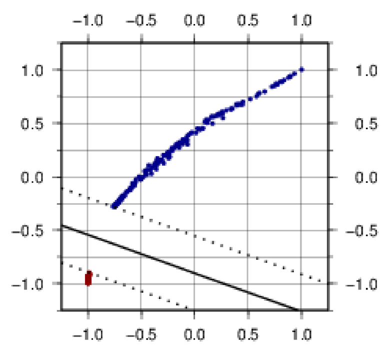

Figure 5: Example of a SVM model dividing two classes

3. Retracking of Waveforms

This option allows us to retrack waveforms after the classification step in order to estimate improved ranges. Every class is assigned to one retracking algorithm .

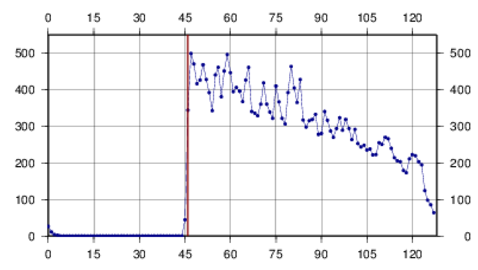

Figure 6: Example of a retracked waveform

4. Calculation of Final Heights

The final heights are estimated considering original or retracked ranges, geophysical corrections, geoid, and manually estimated range biases between different missions.

5. Calculation of Standard Deviations

After estimating the final heights, along track standard deviation are computed.

6. Reject Outliers

In the last preprocessing step outliers are rejected. Hereby we use criteria such as location, max. standard deviation, height limits, along track Support Vector Regression (SVR), SVR for whole missions, waveform classes from classification.

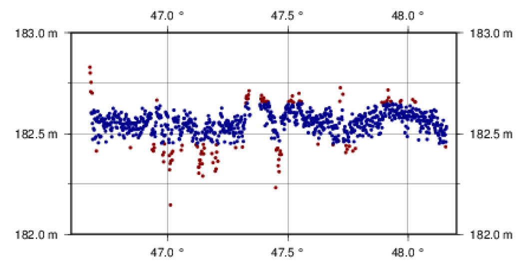

Figure 7: Outlier detection along track with Support Vector Regression

7. Read Data from Preprocessing Step

For the estimation of the water level time series we extract parameters such as longitude, latitude, time, height, and standard deviation.

8. Create Grid from Mask

A spatial grid is derived from a land/water mask which is necessary for the the Kalman filtering step.

9. Kalman Filtering

For the estimation of the water level time series we are using the method of Kalman filtering with time-dependent altimeter measurements as input data. In addition, errors in the altimeter data are considered by using the standard deviations of the heights. The Kalman filter enables us to compute values of water level heights for every epoch and every grid node over the water body. In our case we make a forward and backward Kalman filtering to consider the water level height evolution before and after the current epoch. For more details see Schwatke and Bosch (2012).

10. Estimation of the Final Time Series

For every time step a mean height of all grid nodes is estimated considering an error limit.

Results

Lake Michigan

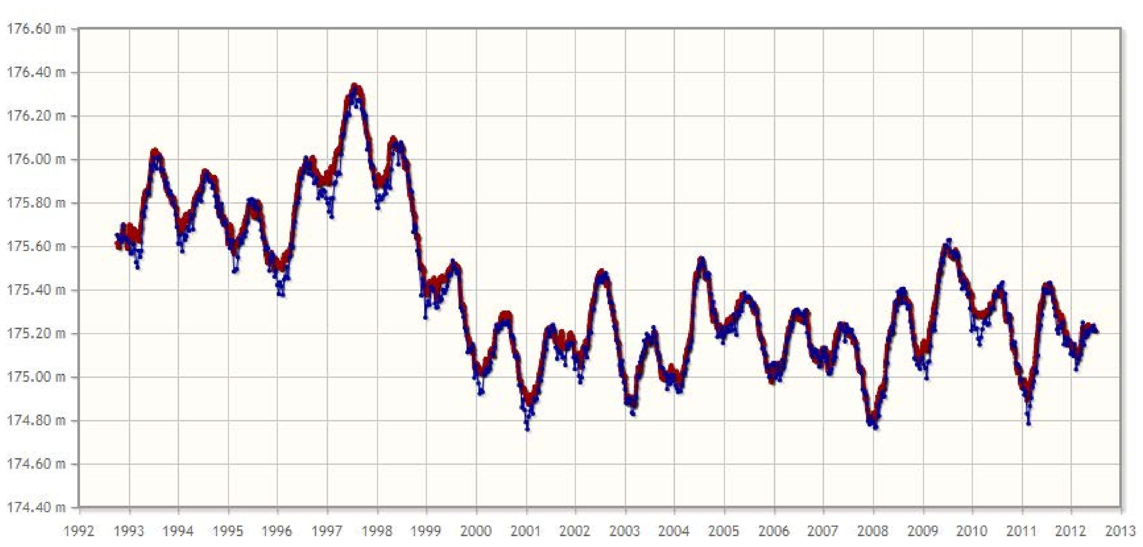

Figure 8: Time series for Lake Michigan from satellite altimetry (blue) and gauge (red)

The Lake Michigan (58.016 km²) is one of the largest lakes worldwide. Due to the lake extent, 1Hz altimeter data (Table 1) are sufficient for the estimation of the water level time series.
The estimated time series of Lake Michigan clearly shows the seasonal variations and also trends of the water level between 174.75 m and 176.35 m. The comparison between altimetry and gauge shows a very high correlation of 0.959.

Mission	Passes
Jason-1 (1Hz)	041, 076, 219, 254
Jason-2 (1Hz)	041, 076, 219, 254
Topex (1Hz)	041, 076, 219, 254
Envisat (1Hz)	7, 338, 465, 551, 882, 923
Topex-EM (1Hz)	041, 076, 054
Jason1-EM (1Hz)	041, 076, 054

Table. 1: Used altimeter data over Lake Michigan

Lake Mweru

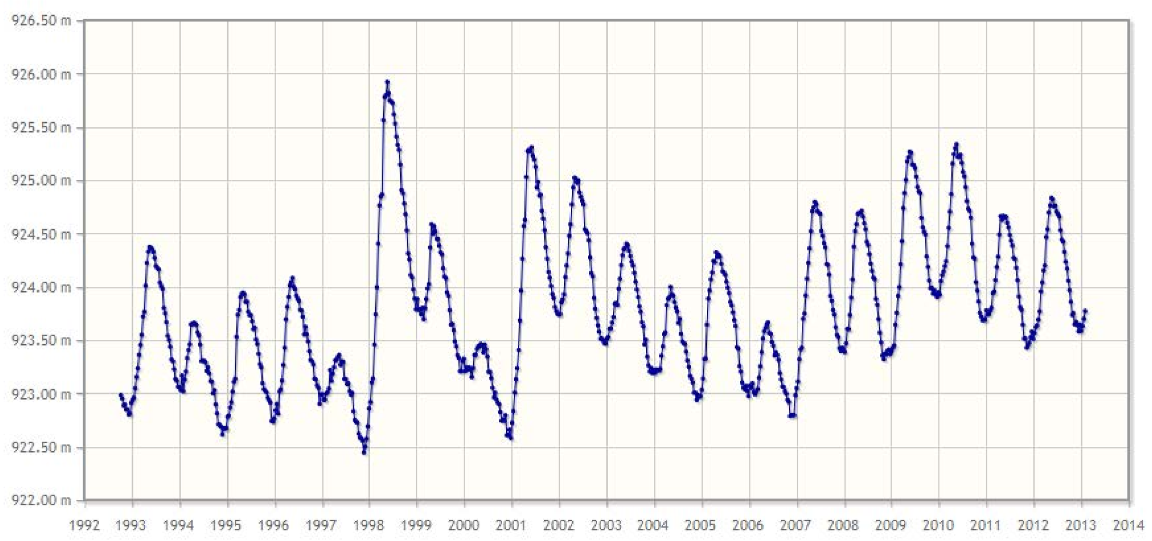

Figure 9: Time series for lake Mweru from satellite altimetry (blue)

In the time series of Lake Mweru (5.120 km²) seasonal variation and trends are also visible. However, the lake area is about 11 times smaller than for Lake Michigan.
For this water body, high-frequent altimeter data are necessary to achieve a reliable time series.

Mission	Passes
Envisat (20Hz)	0915
Jason-1 (20Hz)	209
Jason-2 (20Hz)	209
Topex (10Hz)	209

Table. 2: Used altimeter data over Lake Mweru

Lake Chad

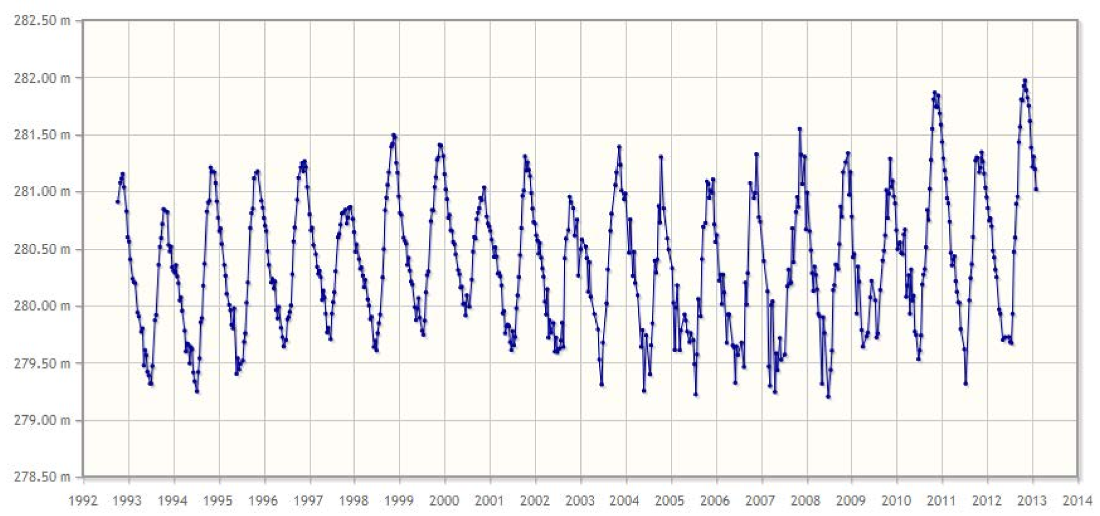

Figure 10: Time series for Lake Chad from satellite altimetry (blue)

The Lake Chad (1.500 km²) is a wetland where retracking of altimeter data is absolutely necessary to achieve an adequate time series. The traditional ocean product of Jason-1 is unsuitable for this area.
Finally, time series where seasonal variations can be clearly identified clearly are achieved.

Mission	Passes
Envisat (20Hz)	0816, 0973
Jason-1 (20Hz)*	248
Jason-2 (20Hz)*	248
Topex (10Hz)	248

*retracked

Table. 3: Used altimeter data over Lake Chad

Validation

For validation we compare in-situ data with time series from satellite altimetry. We obtain high correlations about 0.9 for large lakes and correlations about 0.7-0.8 for smaller lakes and large rivers.

Name	Surface Area	Corr.Coeff
Lake Michigan	58.016 km²	0.959
Lake Ontario	19.011 km²	0.979
Lake Erie	25.667 km²	0.929
Lake Superior	82.103 km²	0.993
Lake of the Woods	4.390 km²	0.798
Mekong River	---	0.776

Table. 4: Corr. between time series from satellite altimetry and in-situ data.

Discussion / Outlook

- DAHITI provides time series of inland waters for hydrological applications.
- A new strategy using Support Vector Regression for outlier detection and using a Kalman filter approach for the estimation of water level time series leads to smooth and reliable time series which show high correlation with gauges.
- In future, DAHITI will be extended to smaller water bodies where an improved classification and retracking strategy is necessary to archive reliable time series.

References:

- *Schwatke C., Bosch W.: **Kalman filter Approach for geophysical lake level Time Series using multi-mission Altimetry.** 20 Years of Progress in Radar Altimetry, Venice, Italy, 2012-09-24/29*
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- *Schwatke C., Bosch W., Savcenko R., Dettmering D.: **OpenADB - An Open Database for Multi-Mission Altimetry**. EGU, Vienna, Austria, 2010-05-05*
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Acknowledgement:

The used data based on altimetry missions operated by CNES/NASA (TOPEX, Jason-1), ESA (Envisat, Cryosat-2), USNavy/NOAA (GFO), CNES/NASA/Eumetsat/NOAA (Jason-2), and ISRO/CNES (Saral). The original data sets are disseminated by AVISO, ESA, NOAA, and PODAAC. The time series of gauges are provided by NOAA Tides and Currents.