Monitoring lake levels by retracking Envisat altimeter data: A case study on Lake Constance

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Introduction

For many years satellite altimetry has not only been used over open ocean but also over coastal and inland waters. It is becoming more important in hydrological applications. Since the 1980s the number of level stations all over the world has been decreasing. This can be seen at the Global Runoff Data Center (GRDC) in Koblenz. Therefore timeseries from altimetry can be used to exend timeseries from level stations which stopped measuring. On the otherhand new „station levels" from altimetry can be established over rivers and lakes all over the world. Another application is to improve and validate hydrological models. The results from altimetry can be used for comparing water storage changes in river basins.

In comparison to altimeter data over oceans, the waveforms are often contaminated by land. This is a major problem because on board retrackers are usually optimized for ocean waveforms. Over rivers and lakes these retrackers often fail because the waveforms do not have an ocean-like shape. Therefore, different retracker have to be used to achieve better results.

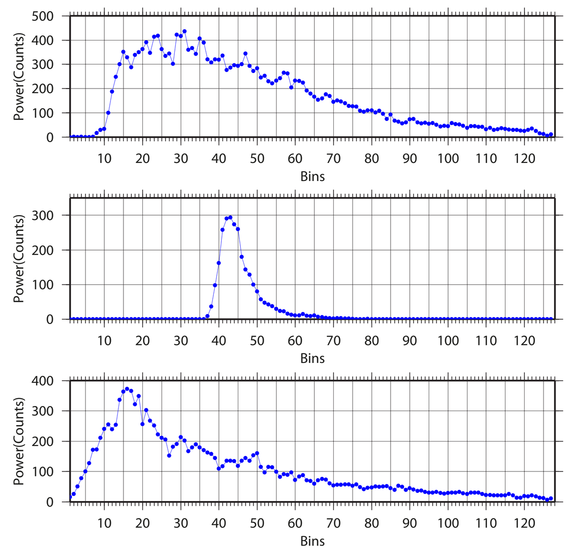

Figure 1: Collection of different waveforms over Lake Constance

In addition to the retracker problem also errors in geophysical corrections such as a wet troposphere have to be considered.

In this poster the possiblity to monitor the lake level of Lake Constance by using satellite altimeter data from Envisat is investigated. Therefore we compare different approaches of retracking algorithms which should be more reliable over lakes and rivers than the onboard retracking algorithms which are optimized for ocean and ice applications, respectively. Lake Constance seems to be a very good study area because there are many level stations around the lake for validation.

Lake Constance

Lake Constance, located at the border of Switzerland, Austria and Germany, has a length of 63km (East-West) and a width of only 14km. The primary inflow and outflow is the river Rhine.

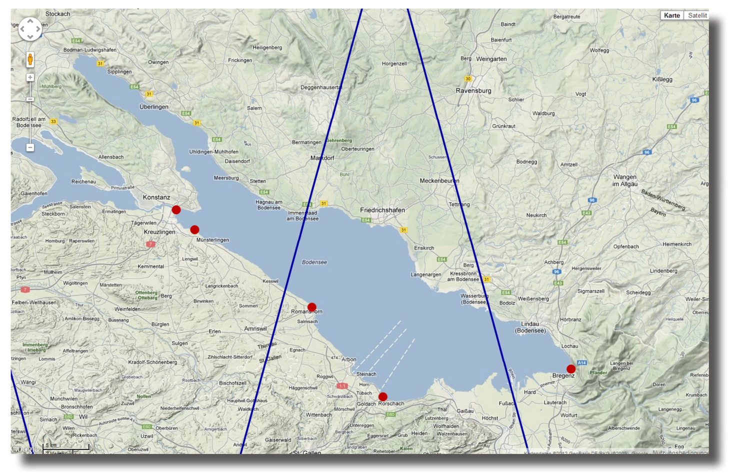

Figure 2: Map of Lake Constance with two a Envisat Tracks and 5 station levels

There are two Envisat tracks (Pass 216 and 171) crossing the lake over a length of about 10km. But five level stations are available around the Lake Constance for the validation in the period 1998 to 2011.

Station Name	Country	Start Date	End Date
Bregenz	A	1999-01-01	active
Konstanz	D	2003-01-01	active
Kreuzlingen	CH	1998-01-01	2004-12-31
Romanshorn	CH	1998-01-01	active
Rorschach	CH	1998-01-01	2004-12-31

Table 1: List of station levels around Lake Constance

After converting all stations from their country height to the German reference height, we receive a timeseries over 12 years which only shows differences of a few centimeters between the level station over the Lake.

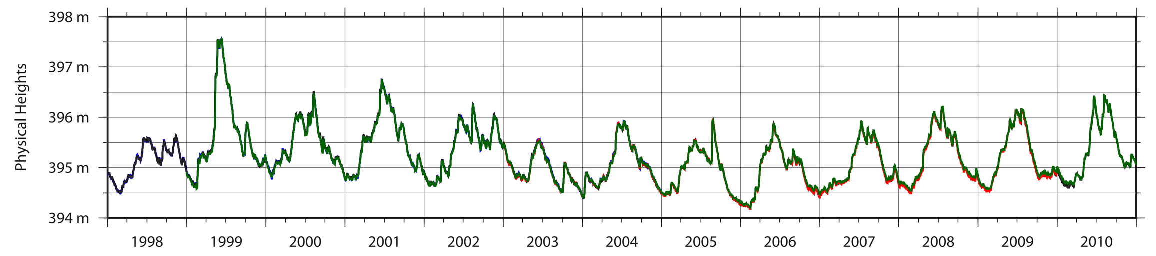

Figure 3: Timeseries of station levels over Lake Constance

In the following, we compare the results of the retracking with the physical heights of the level stations. We have to bear in mind that there can be a constant offset due to different reference heights.

Retracking Algorithms

In this paper, we investigate ranges which are produced by five different retrackers. The SGDR data from Envisat contain four different already retracked ranges. These retrackers are the „Ocean", „Ice1", „Ice2" and „Sea-Ice". We use the „Ocean" and „Ice1" ranges for our investigations. The „Ice1" retracker should be the best of these four for coastal applictions. Additionally, we carry out an own retracking by using the „OCOG", „Beta5" and „Beta4" retracker (Gommenginger et al. 2011).

Offset Center of Gravity Retracker (OCOG)

The „Offset Center of Gravity" (OCOG) (Wingham et al. 1986) retracker is a very robust retracker. The objective of this retracker is to calculate the center of gravity (COG) of each waveform. The leading edge can be estimated by substracting the half width of the waveform from the COG point. Due to the statistical approach no fitting of any functional form is neccessary. The advantage is that this method can compute the leading edge for every waveform if the leading and trailing edge is in the window.

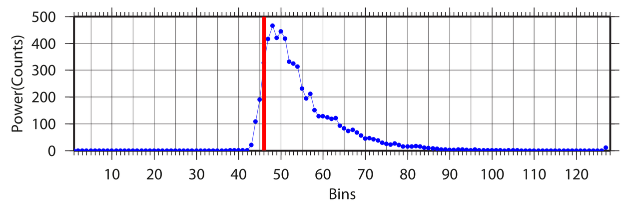

Figure 4: Example of a retracked waveform with OCOG-Retracker

Beta-Retracker with 5 Parameters

The Beta-Retracker (Martin et al. 1983) with 5 paramaters is a retracker which is optimized for ocean-like waveforms. This retracker tries to adapt the functional form (see below) which is defined by five parameters (thermal noise, signal amplitude, mid-point of leading edge, width of the leading edge and slope of the trailing edge) to the waveform as best as possible.

$$y(t) = \beta_1 + \beta_2(1 + \beta_5 Q)P\left(\frac{t - \beta_4}{\beta_4}\right)$$

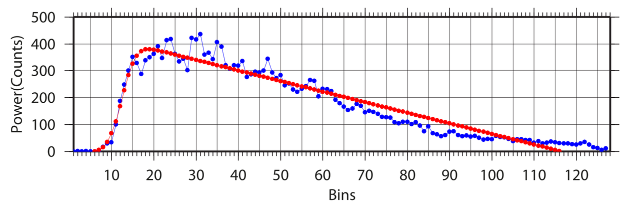

Figure 5: Example of a retracked waveform with Beta5-Retracker

By using this retracker over lakes the success is not as good as over ocean because there are less waveforms which can be retracked with this method. The main problem is the fitting of the trailing edge slope to the functional form which should be more or the less linear.

Beta-Retracker with 4 Parameters

The Beta-Retracker with 4 parameters is very simillar to the previous retracke. The difference is that the trailing edge slope is ignored. The advantage is that every waveform which has a leading edge without additional peaks can be retracked.

In our application we are only interested in receiving the leading edge and no other parameters. Therefore we modify the values following the maximum amplitude to this value.

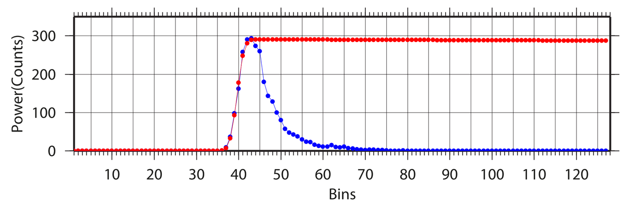

Figure 6: Example of a retracked waveform with Beta4-Retracker

The modified waveform which would fail when using the Beta5-Retracker good results delivers with the modified waveform.

Retracker - Calibration

Due to the land-water transition of the altimeter satellite, different types of waveforms over lakes occur instead of an ocean-like waveform over the ocean. Therefore it is necessary to switch between the retrackers. A comparison of the four retracked ranges of Envisat shows retracker-dependent offsets between the retrackers.

Therefore a calibration between the different retrackers and the level station was performed and the offsets were calculated. This enables us to compare different retrackers with the level station.

	Envisat „Ocean"	Envisat „Ice1"	OCOG	Beta5	Beta4
Station Level	0.452 m	0.705 m	0.250 m	0.220 m	-0.218 m

Table 2: Calculated offsets between different retrackers

The resulting offsets are applied to the retracked ranges.

Results

The resulting heights from altimetry are physical heights above the geoid. Geophysical corrections such as wet troposphere, dry troposphere, ionosphere, etc. are applied. Additionally, the calculated retracker offsets which are related to the level station are applied.

In the following, all heights resulting from each retracker are compared with the station level of Lake Constance.

For every altimeter pass a mean value was created and outliers were rejected.

Envisat „Ocean" - Retracker

The comparison between Envisat's „Ocean" retracker and the lake level shows that the seasonal variations can be recognized but many outliers remain in the resulting heights. **78** points were found which have an RMS of **0.22** m.

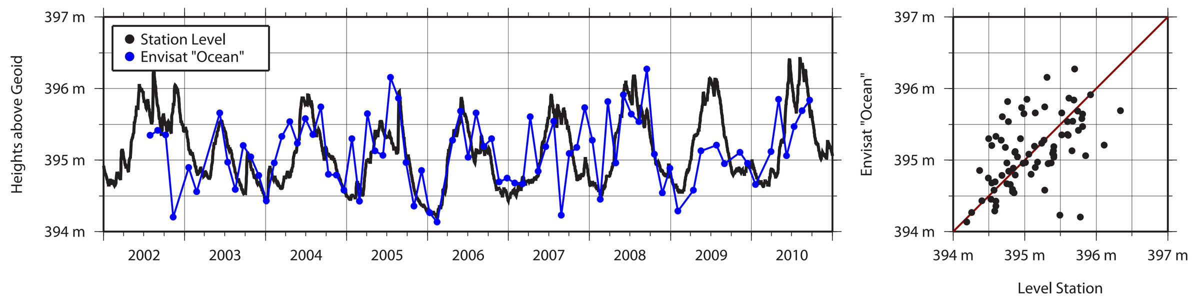

Figure 7: Timeseries of station level and heights from Envisat „Ocean" retracker (left). Correlation between heights from the station level and Envisat „Ocean" retracker (right).

Envisat „Ice1" - Retracker

The comparison between Envisat's „Ice1" retracker and the lake level provides a simlar result as the Envisat's „Ocean". The interesting point is that this retracker should lead to better results in coastal areas. **76** points were found which have an RMS of **0.28** m.

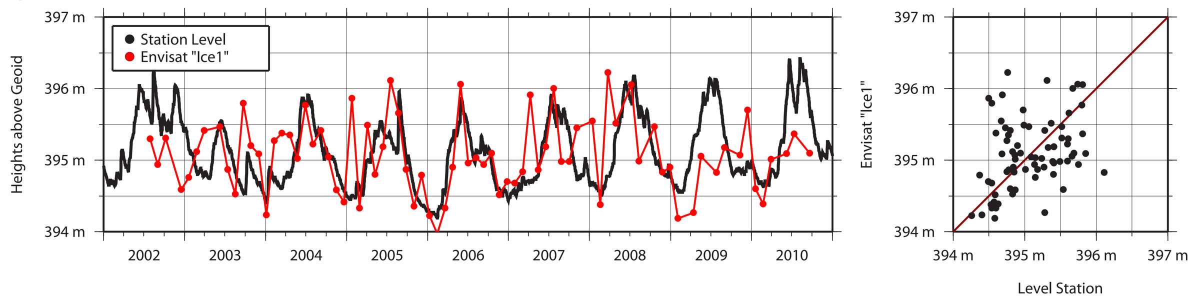

Figure 8: Timeseries of station level and heights from Envisat „Ice1" retracker (left). Correlation between heights from the station level and Envisat „Ice1" retracker (right).

OCOG - Retracker

The comparison between OCOG-retracker and the lake level shows a very good agreement between both timeseries. There are only few outliers left. **73** points were found which have an RMS of **0.12** m.

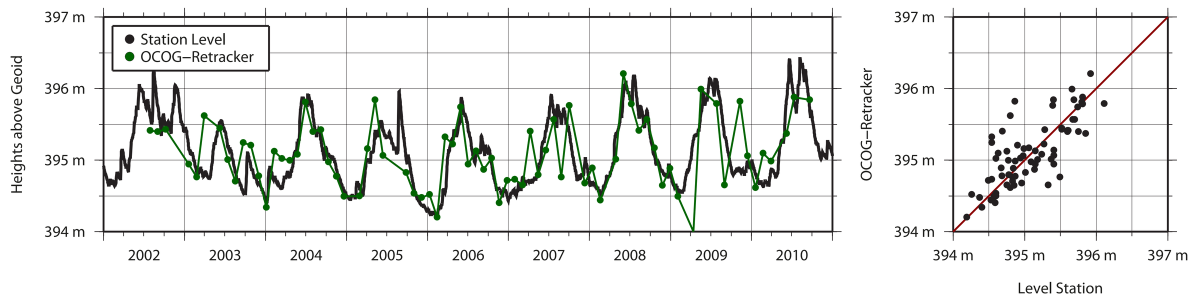

Figure 9: Timeseries of station level and heights from OCOG-retracker (left). Correlation between heights from the station level and Envisat OCOG-retracker (right).

Beta5 - Retracker

The comparison between Beta5-retracker and the lake level shows the best agreement between both timeseries. There are almost no outliers left. **80** were points found which have an RMS of **0.05** m.

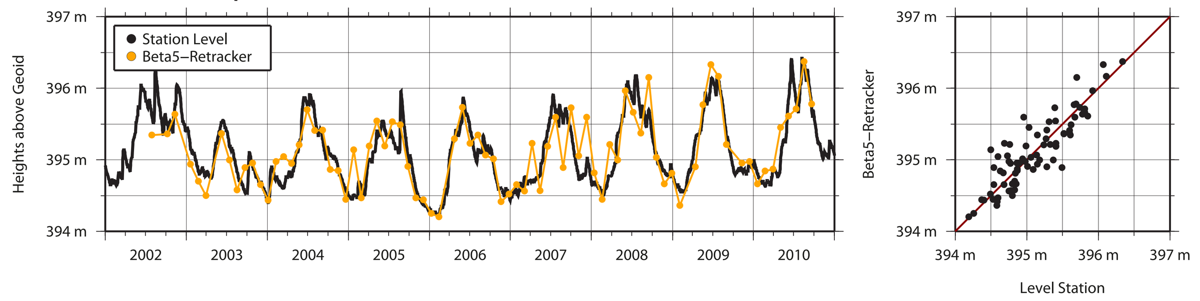

Figure 10: Timeseries of station level and heights from Beta5-retracker (left). Correlation between heights from the station level and Beta5-retracker (right).

Beta4 - Retracker

The comparison between Beta4-retracker and the lake level does not show the expected agreement between both timeseries. There are still outliers left. **65** points were found which have an RMS of **0.21** m.

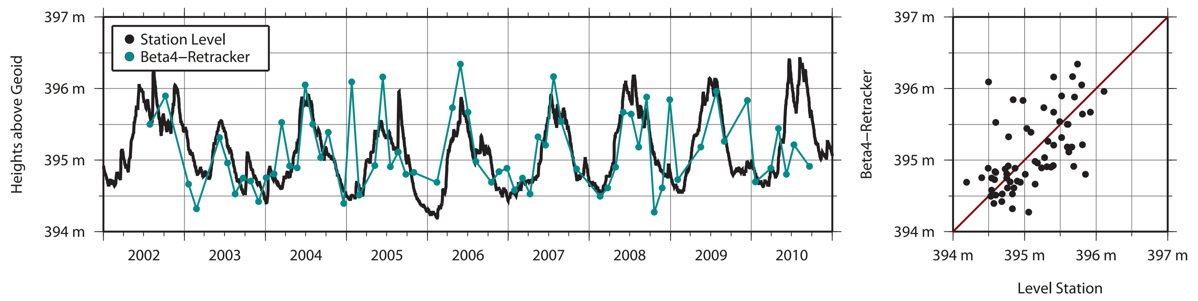

Figure 11: Timeseries of station level and heights from Beta4-retracker (left). Correlation between heights from the station level and Beta4-retracker (right).

„Best fit" solution

In this timeseries the heights with minimal distance to the lake level were used. The comparison between the „best fit" solution and the lake level shows the best result. The problem is that we normally do not know the expected height. **83** points were found which have an RMS of **0.03** m.

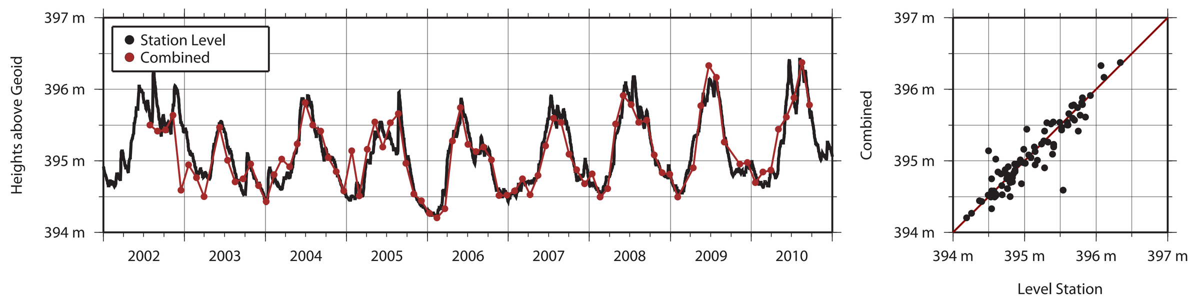

Figure 12: Timeseries of station level and heights from the best fitting retracker (left). Correlation between heights from the station level and best fittingretracker (right).

Conclusion

In this poster, we achieve the best retracking results with the **Beta5** and the **OCOG** retracker. The RMS is **0.05** m, respectively **0.12** m. The „best fit" solution shows us that there is the potential to achieve very promising timeseries. For this solution with preliminary information we get an RMS of **0.03** m.The main problem is to find the best of the retracked heights and to reject bad retracked values.

Additionally a calibration between the different retrackers is indispensable to have the possibility to combine results from different retrackers.

Acknowledgement

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