Correcting the Hooking Effect in satellite altimetry data for time series estimation over smaller rivers

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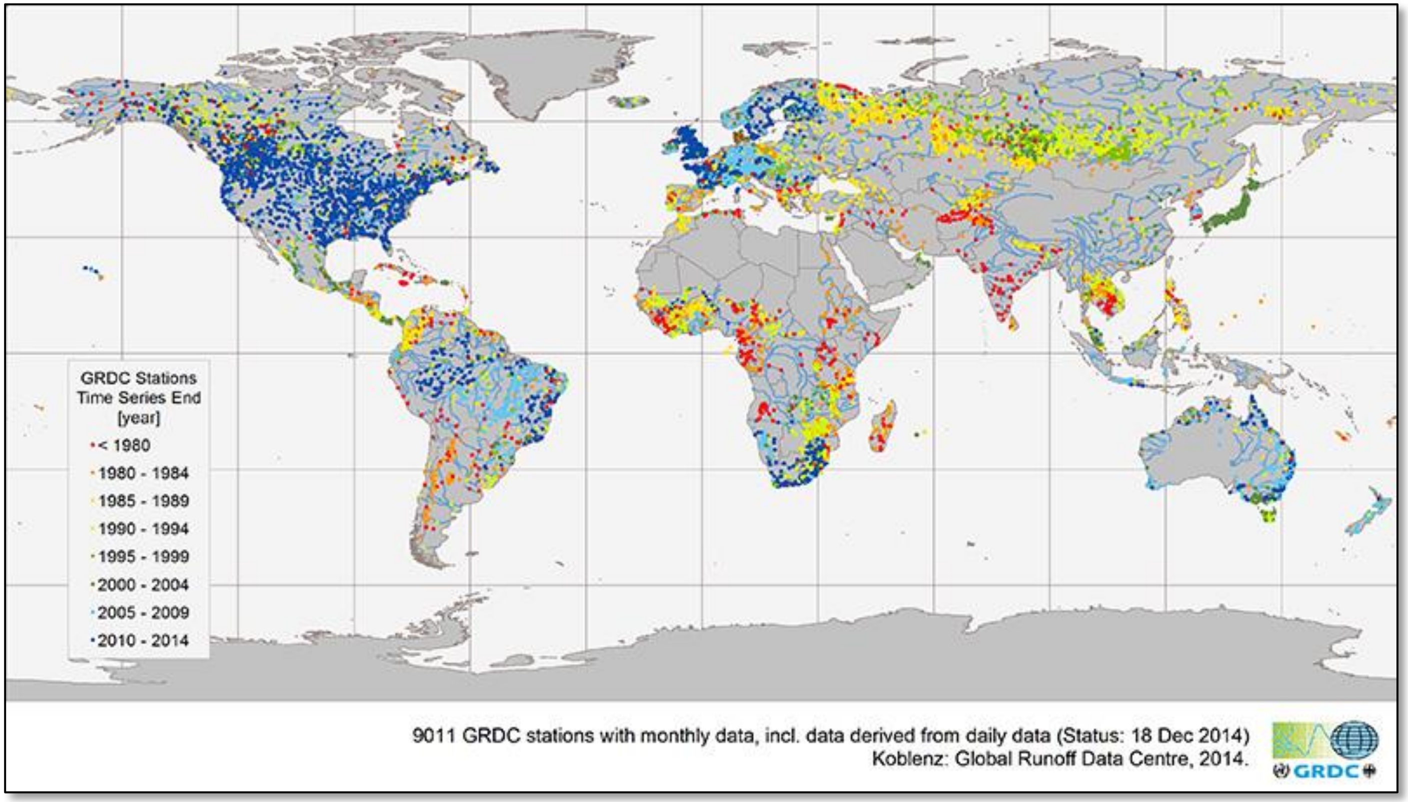
Motivation

- For monitoring and modelling the water cycle it is necessary to have knowledge of water level of inland waters
- However, the number of available in-situ gauge is decreasing

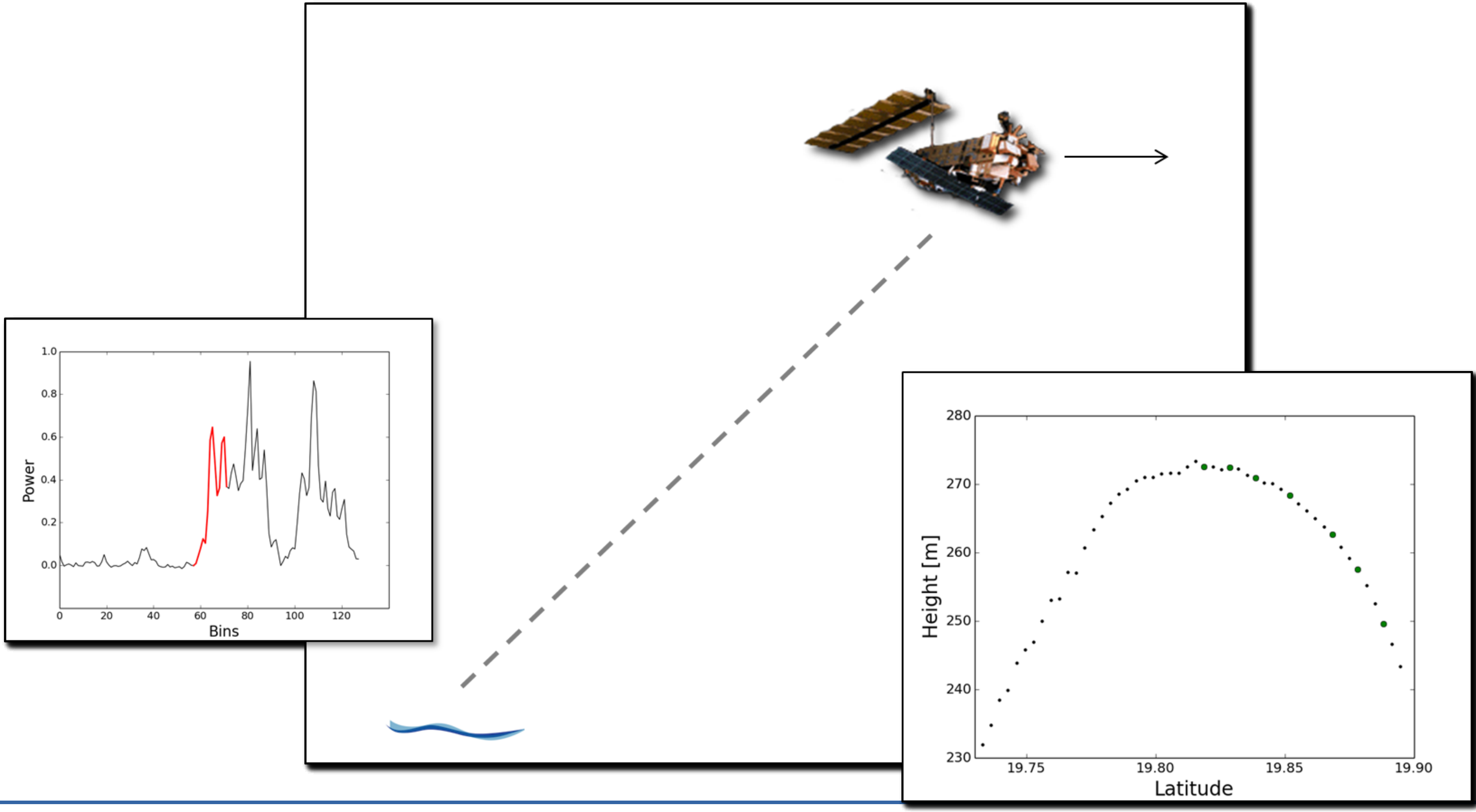


Motivation

- Satellite altimetry can close this gap of data
- So far only for larger inland waters like lakes and wider rivers (> 1km) were gaugeable with satellite altimetry
- We developed a new method to improve the time series of altimetry over smaller rivers
- This methods uses off-nadir measurements (hooking effect) of the river to determine the water heights

Hooking Effect

- The hooking effect occurs at the transition between land and water in the altimetry footprint
- Water has a stronger reflection than land which leads to off nadir measurements


Power
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
120
Bins
Height [m]
280
270
260
250
240
230
19.75
19.80
19.85
19.90
Latitude

Hooking Effect

- The hooking effect occurs at the transition between land and water in the altimetry footprint
- Water has a stronger reflectance than land which leads to off-nadir measurements
- Vertex of parabola is the water level height
- Over very small rivers (width less than 1 km) there are often no measurements at all not influenced by the hooking effect

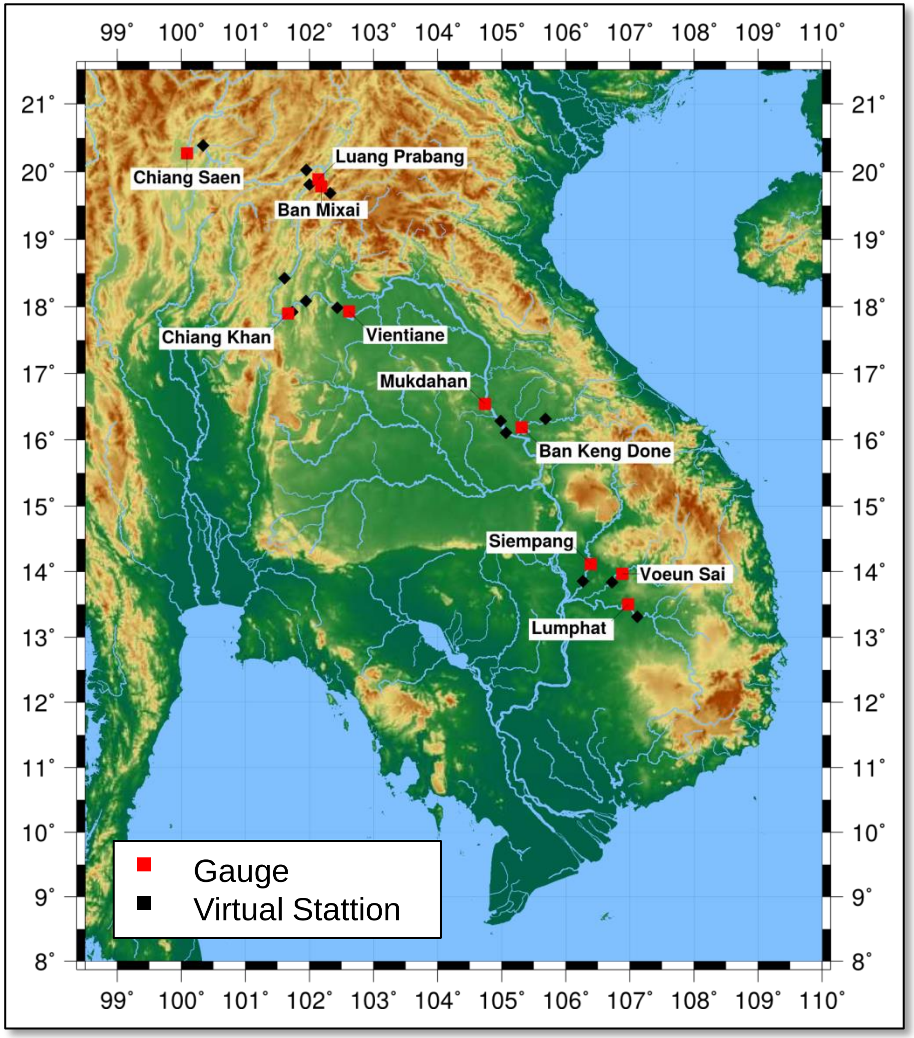
Data

Altimetry Data:

- Envisat high frequency data between 2002-2010

In-Situ Data:

- selection of 10 gauging stations along Mekong River and tributaries, maintained by the *Mekong River Commission*
- time frame: starting 2002, ending from 2006 to 2012, some with gaps



Methodology

In order to use the off-nadir measurements, we implemented the following procedure:

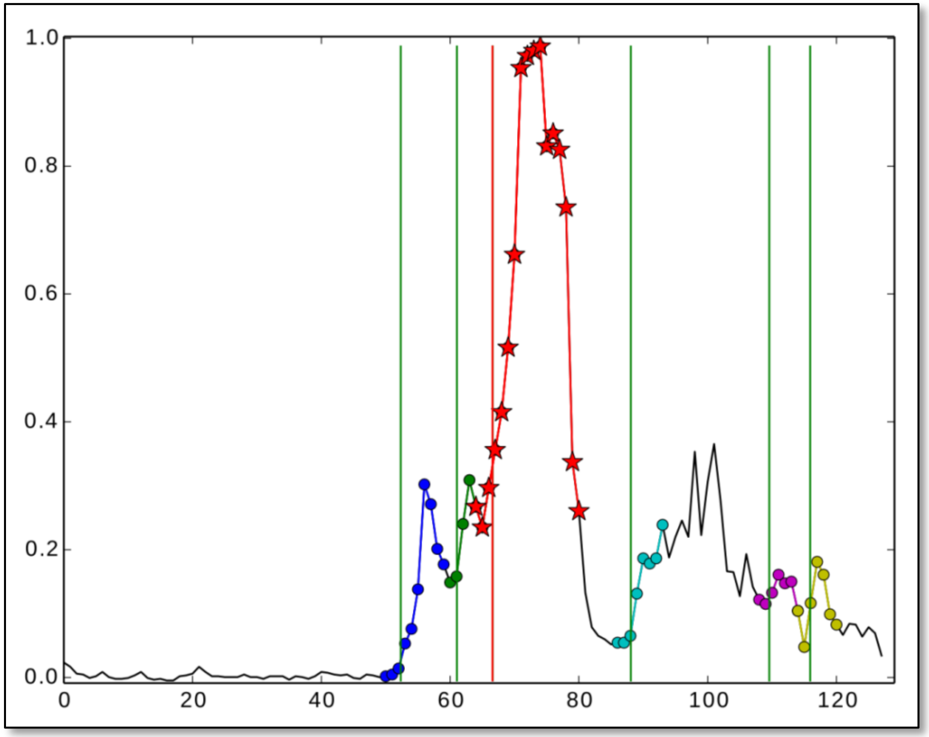
1) **Retracking:** Multi-Subwaveform Retracker

2) **RANSAC** for fitting the hooking parabola

3) **Water height estimation**

4) **Outlier rejection**

- We are using the newly developed *Multi-Subwaveform Retracker*
- Based on the Improved Threshold retracker (ITR) we are extracting all subwaveforms
- ITR uses the first subwaveform but we are using the ‘best‘ subwaveform, i.e. the subwaveform with the highest amplitude and the steepest
- On this subwaveform a threshold retracker of 10% is applied



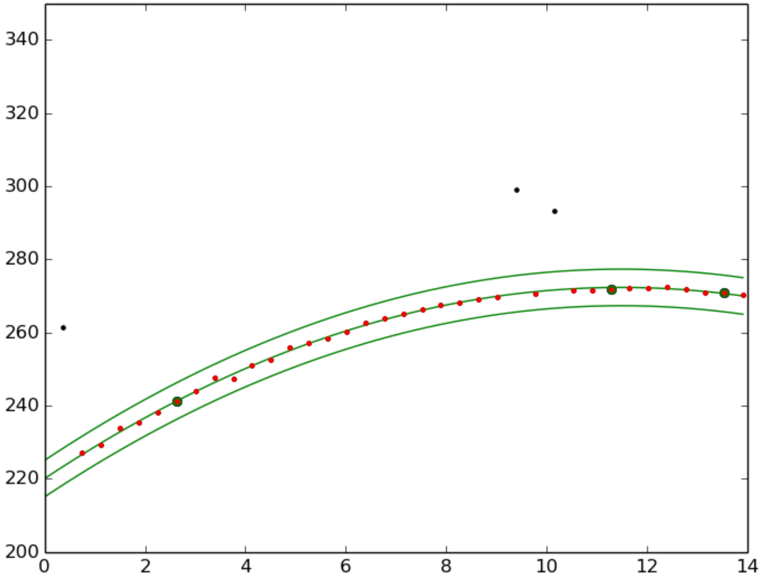
RANSAC

- The RANSAC (Random Sample Consensus) algorithm is used to identify the measurements affected by the hooking effect
- non deterministic algorithm
- robost with a large quantity of outliers
- identifying two parabolas and optional one horizontal line

Algorithm:

1. Chose 3 (resp. 2) random points
2. Calculate model (i.e. parabola or line) from these points
3. Test all other points on agreement to this model, within a given limit → consensus set

Repeat 1.-3. N times, than chose model with largest consensus set

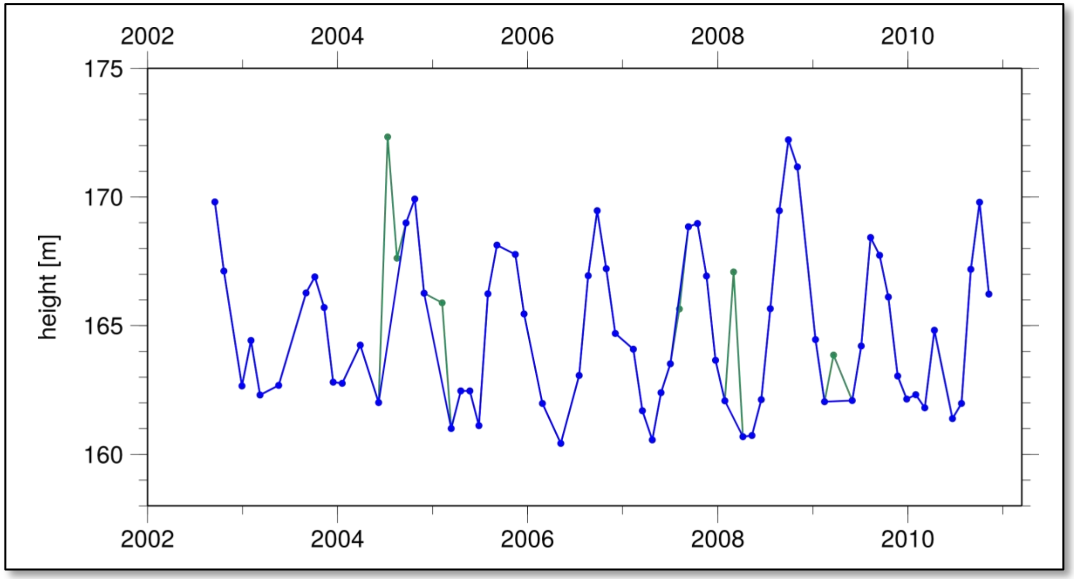


Height estimation:

- Output of the RANSAC algorithm are up to three sets of points/models belonging to 2 parabolas and 1 line
- Hypothesis testing if these models describe the same height
- Combining those models fitting together to one, describing the final water height with standard deviation
- This results in one height per epoch

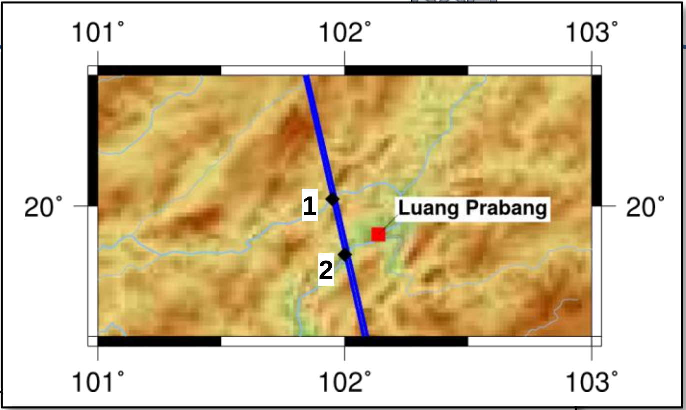
Outliers Rejection:

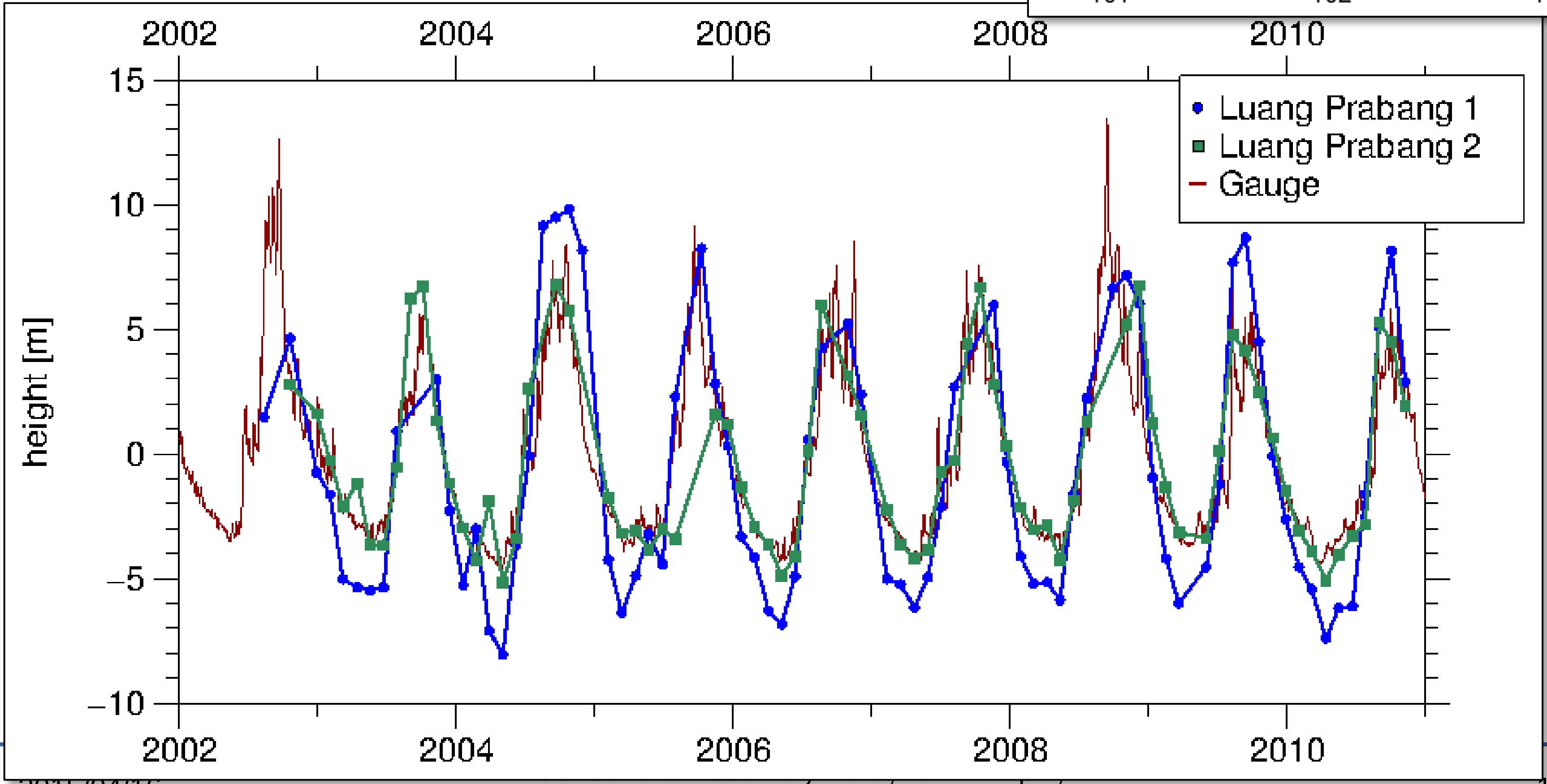
- Points which standard deviation outside a 95% quantile are rejected



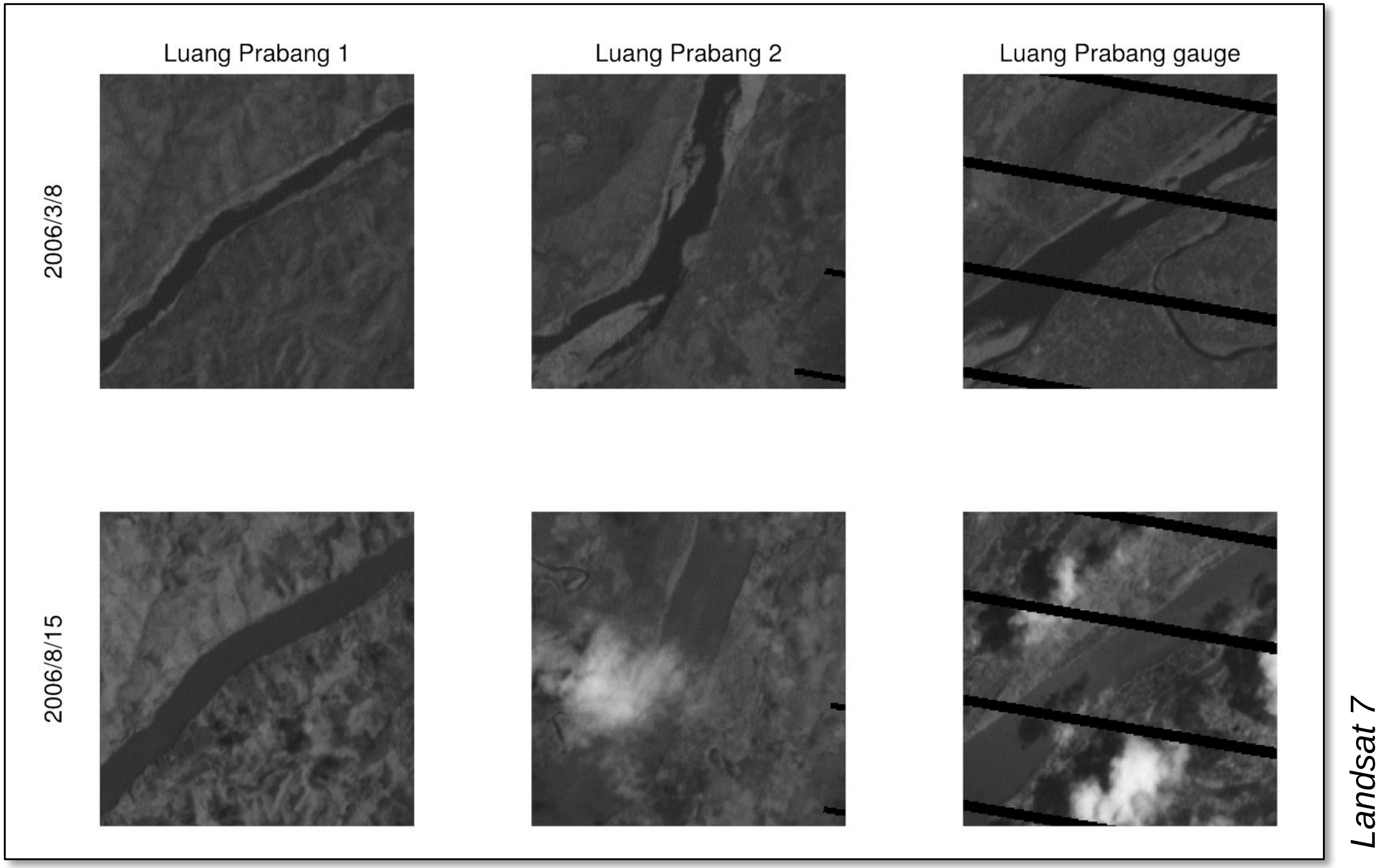
Results Luang Prabang

	Width [m]	RMS [m]	R^2
Luang Prabang 1	380	2.48	0.93
Luang Prabang 2	500	0.95	0.90





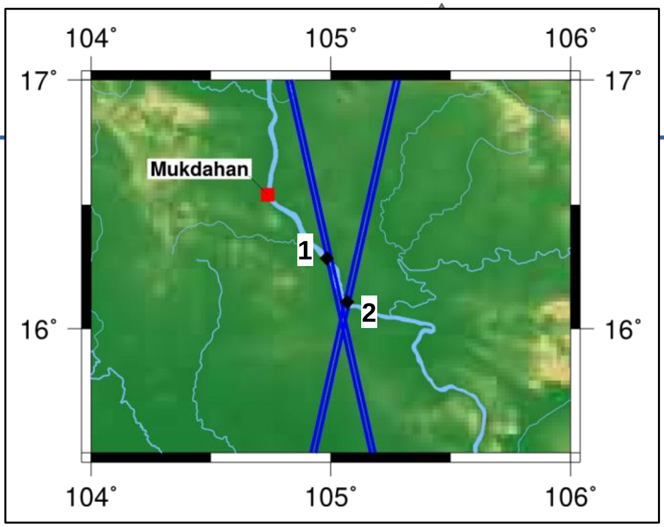
Results Luang Prabang – Amplitude Differences

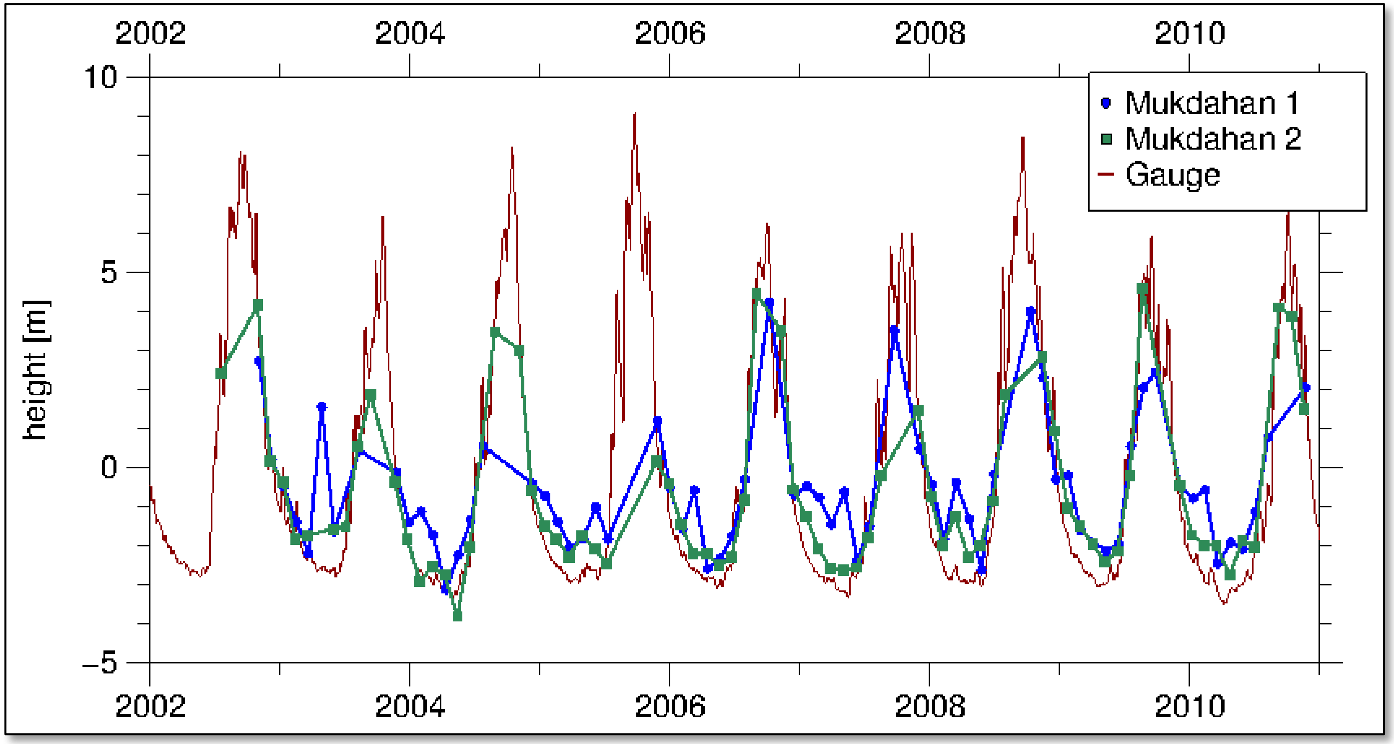


At Luang Prabang 2 and the gauging stations the river can expand more than at Luang Prabang 1. This leads to the differences of amplitude.

Results Mukdahan

	Width [m]	RMS [m]	R^2
Mukdahan 1	1250	1.05	0.81
Mukdahan 2	1500	0.52	0.96





- Different inter-section angles
- The acute-angled intersection (1) results in lower quality of time series

Validation

MRC Code	Station name	lon	lat	width [m]	RMS	R^2	# points / cycles availible
010501	Chiang Saen	100.339	20.390	200	2.45	0.63	66 / 80
011201	Luang Prabang 1	101.949	20.027	380	2.48	0.93	73 / 83
	Luang Prabang 2	102.000	19.814	500	0.95	0.90	68 / 83
011903	Chiang Khan 1	101.612	18.424	420	0.88	0.93	70 / 80
	Chiang Khan 2	101.730	17.919	500	1.08	0.89	64 / 80
	Chiang Khan 3	101.943	18.084	850	1.08	0.90	70 / 80
011901	Vientiane 1	102.436	17.980	800	1.36	0.82	69 / 82
013402	Mukdahan 1	104.984	16.283	1250	1.05	0.81	66 / 83
	Mukdahan 2	105.068	16.109	1500	0.52	0.96	69 / 86
120101	Ban Mixai	102.324	19.686	150	1.79	0.58	46 / 81
350101	Ban Keng Done	105.699	16.318	300	1.42	0.50	69 / 85
440102	Voeun Sai 1	106.713	13.842	470	0.34	0.88	69 / 84
	Voeun Sai 2	106.944	14.043	330	0.93	0.63	63 / 85
430102	Siempang	106.265	13.847	340	1.53	0.72	62 / 85

Conclusion and Outlook

- With the correction of the hooking effect we are able to derive reliable time series over small water bodies
- No knowledge of the exact position of the water body is needed
- Not only improving the quality but also the number of points in the time series compared to other inland water altimetry products
- Topography at the site of crossing can not be neglected at the validation
  - intersection angle
  - widening and narrowing of the river valley

Outlook:

- Including the hooking correction into our DAHITI database

See Poster “Height Estimation and error Assessment of Inland Water Level Time Series calculated by a Kalman Filter Approach using Multi-Mission Satellite Altimetry“ tonight at the **Blue Posters B396**