The kriging method for combining multi-mission altimetry over the Mekong River

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Abstract

In recent years, water level variations of inland water bodies measured by satellite altimetry got well established. Only a few multi-mission approaches combine different missions and passes over lakes in order to increase the accuracy and temporal resolution of the time series. However, it is not possible so far to combine different altimeter missions and passes over rivers.

We developed a new methodology to combine altimetry data from different missions in a statistical robust way along the river. The methodology is based on kriging which is an interpolation method originating from geostatistics. We expanded the concept to spatio-temporal kriging along the river. The interpolation is a weighted average of available measurements based on empirical correlations not only in the spatial domain but in the temporal domain as well. The empirical correlation are modelled by a spatio-temporal product covariance model.

With this approach we are able to combine data along the Mekong River. We employed the kriging method on altimeter measurements of the Envisat, Envisat EM, Jason-2, and SARAL/AltiKa mission. With this we are able to achieve a higher temporal resolution time series at any given location and close the data gap between the end of the Envisat and the start of the SARAL/AltiKa mission with only three Jason-2 time series. The resulting estimated time series are compared to in-situ data from gauging stations along the river and show a high agreement with these.

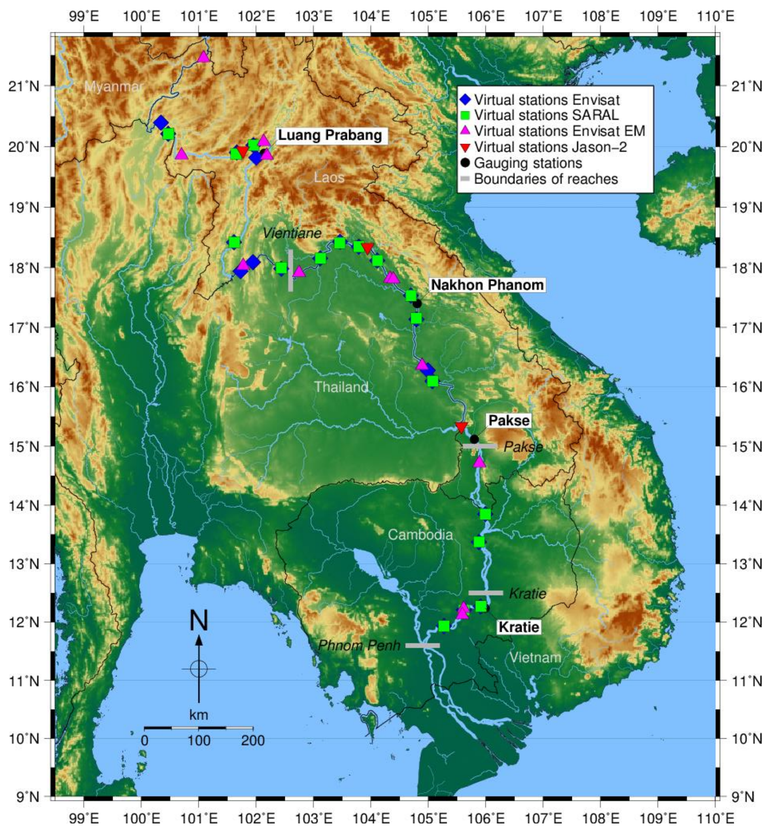
Data

Altimetry data:

- Envisat 2002-2010
- Envisat EM 2010-2011
- Jason 2 2008-today
- SARAL/AltiKa 2013-today
- Time series were processed with DAHITI [4] and a hooking correction [2]

In-Situ data:

Gauge data provided by the Mekong River Commission (MRC) till end of 2012.



Methods

Spatio-temporal Ordinary Kriging along Rivers

- Interpolation method governed by spatial and temporal dependencies [3]
- Yields the best linear unbiased estimator (in terms of mean-squared prediction error)
- *Spatio-temporal ordinary kriging* is an extension to *spatial ordinary kriging.*
- For kriging along rivers the spatial domain is transformed to distance along the river according to flow velocity.

- The predicted values are a weighted sum with

$$p(Z(\boldsymbol{x}_0)) = \sum_{i=1}^{n} \lambda_i Z(\boldsymbol{x}_i), \quad \text{where} \quad \sum_{i=1}^{n} \lambda_i = 1$$

$$\boldsymbol{\lambda} = (\boldsymbol{c} + \mathbf{1}\frac{(1 - \mathbf{1}^\top \Sigma^{-1}\boldsymbol{c})}{\mathbf{1}^\top \Sigma^{-1}\mathbf{1}})^\top \Sigma^{-1}$$

with the covariances

$\boldsymbol{c} = (C(\boldsymbol{x}_0, \boldsymbol{x}_1), \ldots, C(\boldsymbol{x}_0, \boldsymbol{x}_n))^\top$ and $\Sigma = (C(\boldsymbol{x}_i, \boldsymbol{x}_j))_{i,j=1\ldots n}$

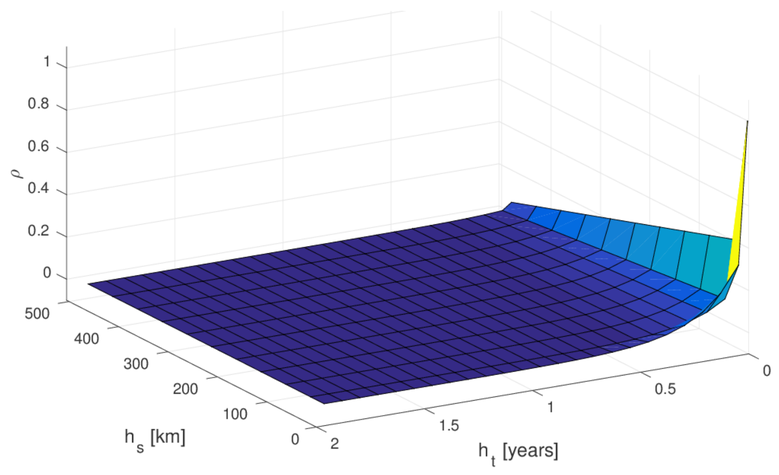
and $Z(\boldsymbol{x}_i)$ the observations at the space time location $\boldsymbol{x}_i$.

Stationary Covariance Model

- The spatio-temporal covariance C needed in kriging is modelled by a product model of a temporal and spatial covariance

$$\mathrm{C}_{st}(h_s, h_t) = \mathrm{C}_s(h_s)\mathrm{C}_t(h_t)$$

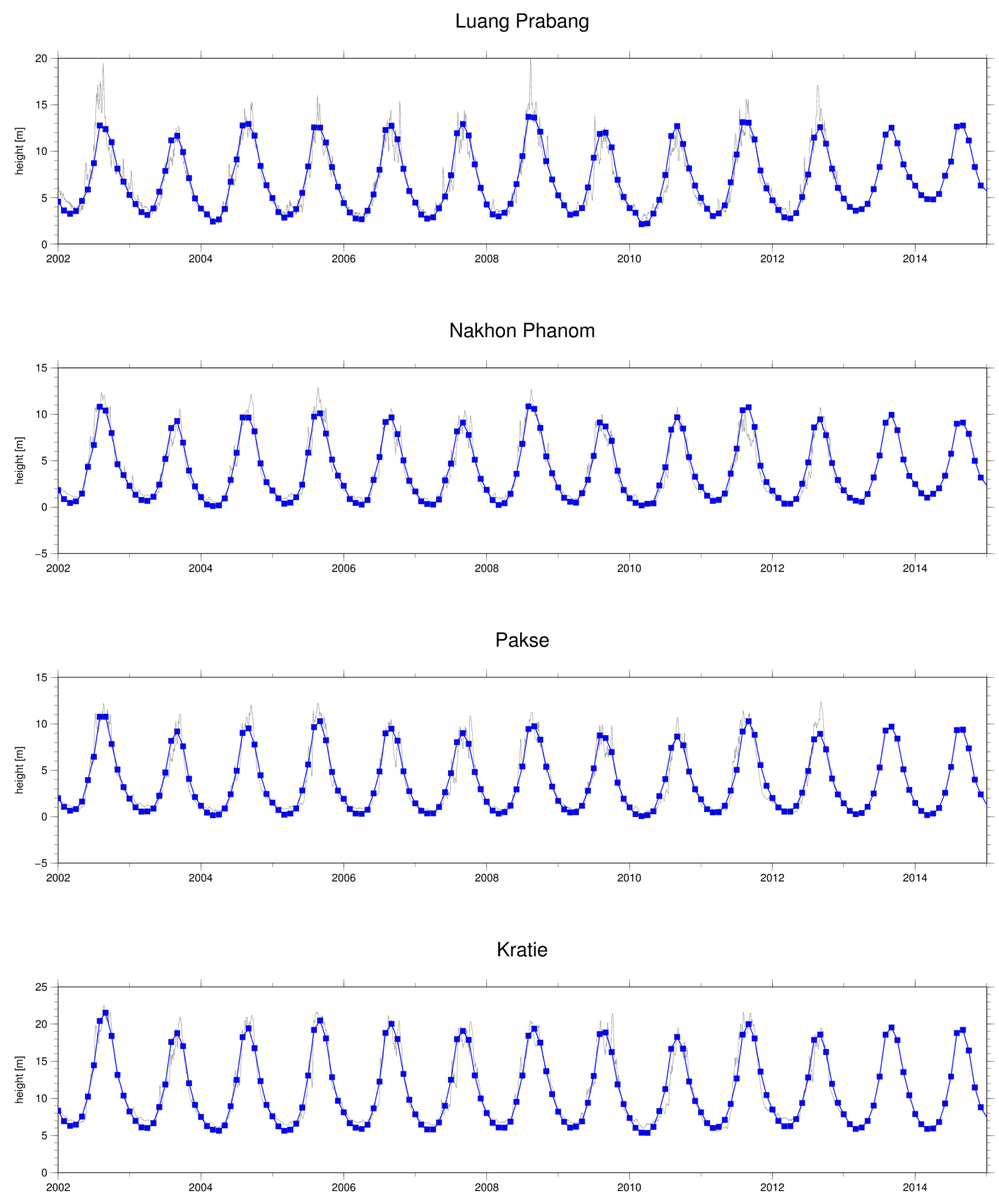
- The temporal covariance is modelled with an exponential covariance model with nugget (discontinuity around zero) and the spatial covariance is modelled with a linear tent covariance model with nugget.



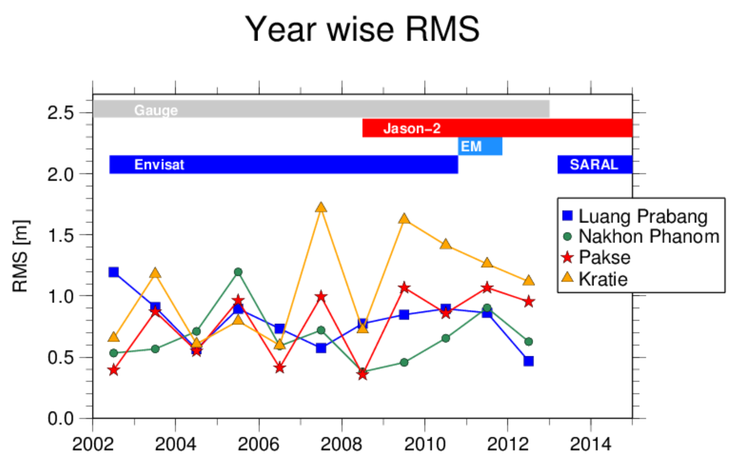
- Other covariance models (non-stationary and localised) were tested as well in [1].

Results

- We predict a monthly time series from 2002 till 2016 at the location of four gauging stations, Luang Prabang, Nakhon Phanom, Pakse, and Kratie.
- These gauging stations are used for validation.



	All missions 2002.4 – 2013.0	
	RMS [m]	**R^2**
Luang Prabang	0.90	0.92
Nakhon Phanom	0.75	0.94
Pakse	0.86	0.92
Kratie	1.17	0.93



- Prediction quality changes interannualy
- The variation of the year wise annual RMS of one station is larger than the differences between the stations.
- No deterioration is visible in the results after the end of the Envisat mission in 2011.

Conclusion

- The kriging method, together with a product covariance model, is able to link water level time series of different altimeter missions along the Mekong River.
- The years of data gap between Envisat and SARAL are well predicted with only three time series of Jason-2.
- Outlook: Combination of Cryosat-2 data with the repeat mission data using the kriging method

References:

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