Global and Regional Sea Level Change

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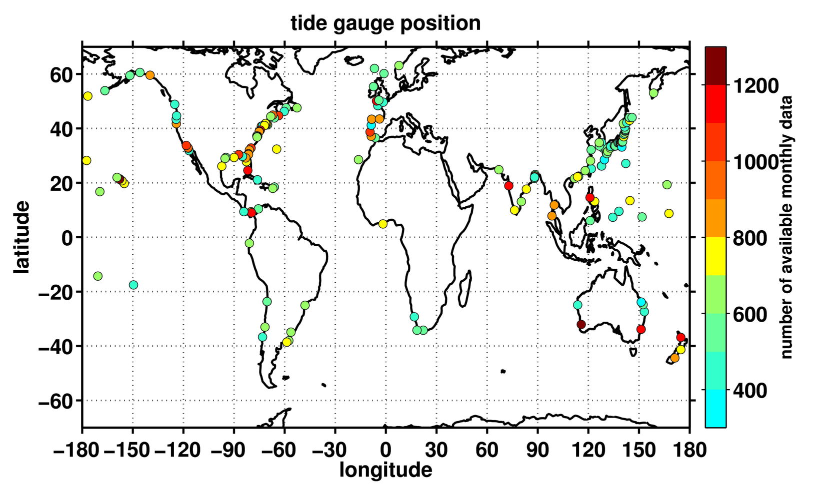
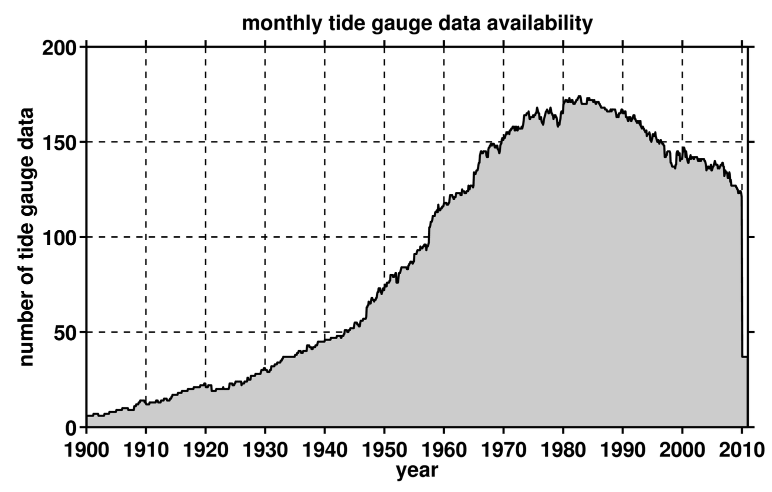
Abstract

Sea level variations prior to the launch of satellite altimeters are estimated by analysing historic tide gauge records. Recently, a number of groups have reconstructed sea level by applying EOF techniques to gappy data. We complement this study with alternative methods. In a first step gaps in 178 records of sea level change are filled using the pattern recognition capabilities of artificial neural networks. Afterwards satellite altimetry is used to extrapolate local sea level change to global fields. Patterns of sea level change are compared to prior studies. Global mean sea level change since 1900 is found to be on average 1.65 +/- 0.26 mm per year.

Selected Tide Gauges





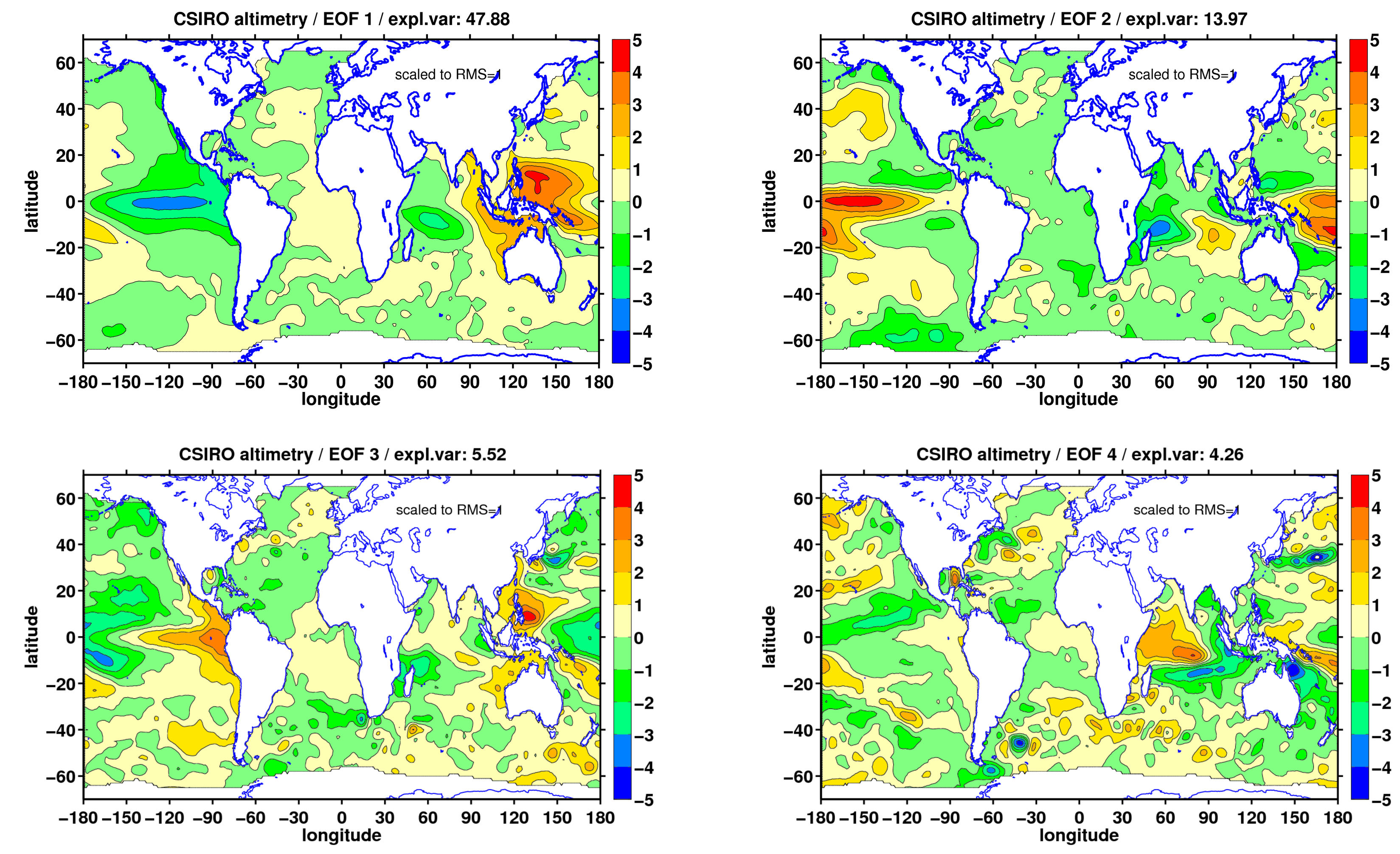
The left graph shows the position of the selected tide gauges. The color coding gives the amount of available monthly data at the corresponding tide gauges, while the right graph shows the monthly availability of tide gauge data.

For the purpose of this work 178 tide gauges are selected from the PSMSL database (RLR, monthly) in the latitudinal band 65°S-65°N that have at least 30 annual mean values given for the years after 1950. It is obvious that many data are missing especially prior to 1950 and that there is no month that has complete data.
Thus the first task will be to fill these data gaps in an appropriate way.
For the task of filling the data gaps a neural network is used as an time stepping operator. The unknown parameters of the neural network as well as missing values in the initial conditions are estimated by minimizing a weighted least square cost function. See our **OSTST poster**: **Reconstruction of global sea level variations from tide gauges and altimetry** for more details on this topic.

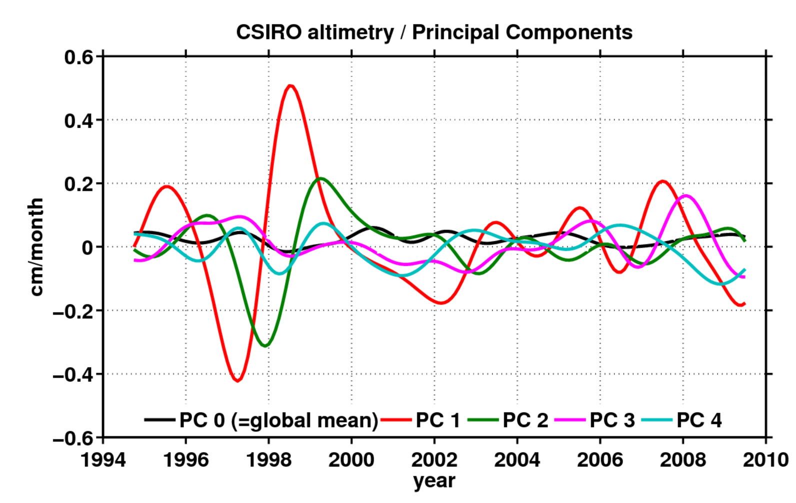
Altimetry Data - EOF Decomposition

For the reconstruction of the global and regional sea level we use altimetry data provided on the CSIRO sea level web site. From the available versions the one with no IB correction applied has been chosen.

The altimetry data are processed further as follows:
i) take the monthly differences,
ii) filter the local time series to exclude the annual cycle and
iii) subtract the global mean value.
The latter will be treated as the given zero'th principal component (PC) of the following empirical orthogonal function (EOF) decomposition, that results in 27 EOF's, whereof 16 are needed to explain 98% of the variance.

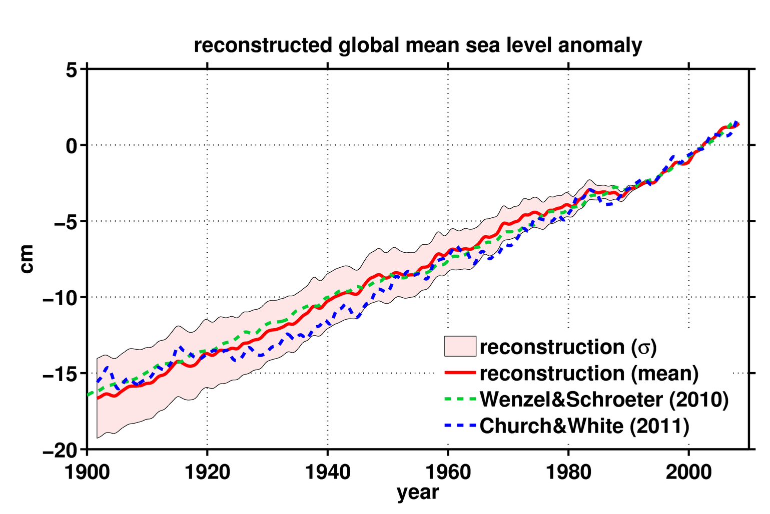


*The figures above show the four leading EOF's from the filtered CSIRO altimetry data (monthly differences). The corresponding PC's are given in the graph on the right (red, green, magenta and blue line) together with the global mean (=**PC 0**; black line) that was subtracted prior to the decomposition.*



Global mean sea level trend 1900-2009 resulting from different training conditions

	training error	trend correct.	ridge regress	GMSL trend [mm/year]
1	*no*	*no*	*no*	1.652
2	*yes*	*no*	*no*	1.997
3	*no*	*yes*	*no*	1.196
4	*yes*	*yes*	*no*	1.613
5	*no*	*no*	*yes*	1.832
6	*yes*	*no*	*yes*	1.909
7	*no*	*yes*	*yes*	1.437
8	*yes*	*yes*	*yes*	1.537
	mean:			**1.65 ± 0.25**



Reconstructed global mean sea level anomaly (=cumulative sum of ***PC 0****). Shown are the mean and standard deviation σ from the estimates listed in the table above.*

Results

PC 0 (=global mean) to **PC16** are reconstructed from the accordingly filtered TG data to give global sea level anomaly fields from 1900 onwards. Each of these principal components, $\mathbf{PC_k(t)}$, is reconstructed from the TG data **TG(t)** by estimating a transfer vector $\mathbf{M_k}$ that provides

$$\mathbf{PC_k(t) = < M_k , TG(t) >}$$

i.e. the PC values are the weighted sum of the TG values wherein the weights might even be negative. The vector $\mathbf{M_k}$ is estimated from the period where PC data exist via a least square fit and assumed to be valid for the whole period starting from 1900. Eight estimates (see table on the left) are performed for each PC that differ in whether or not:
i) errors in the tide gauge data are accounted for.
ii) a correction of the TG trend is applied to compensate the effect of vertical land movement that is not inherent in altimetry.
iii) a ridge regression constraint is applied to the transfer vector $\mathbf{M_k}$, that reduces the influence of TG's with low absolute correlation between tide gauge data and PC.
Finally the global sea level anomaly fields are reconstructed by combining the estimated PC's with the altimetry EOF's.

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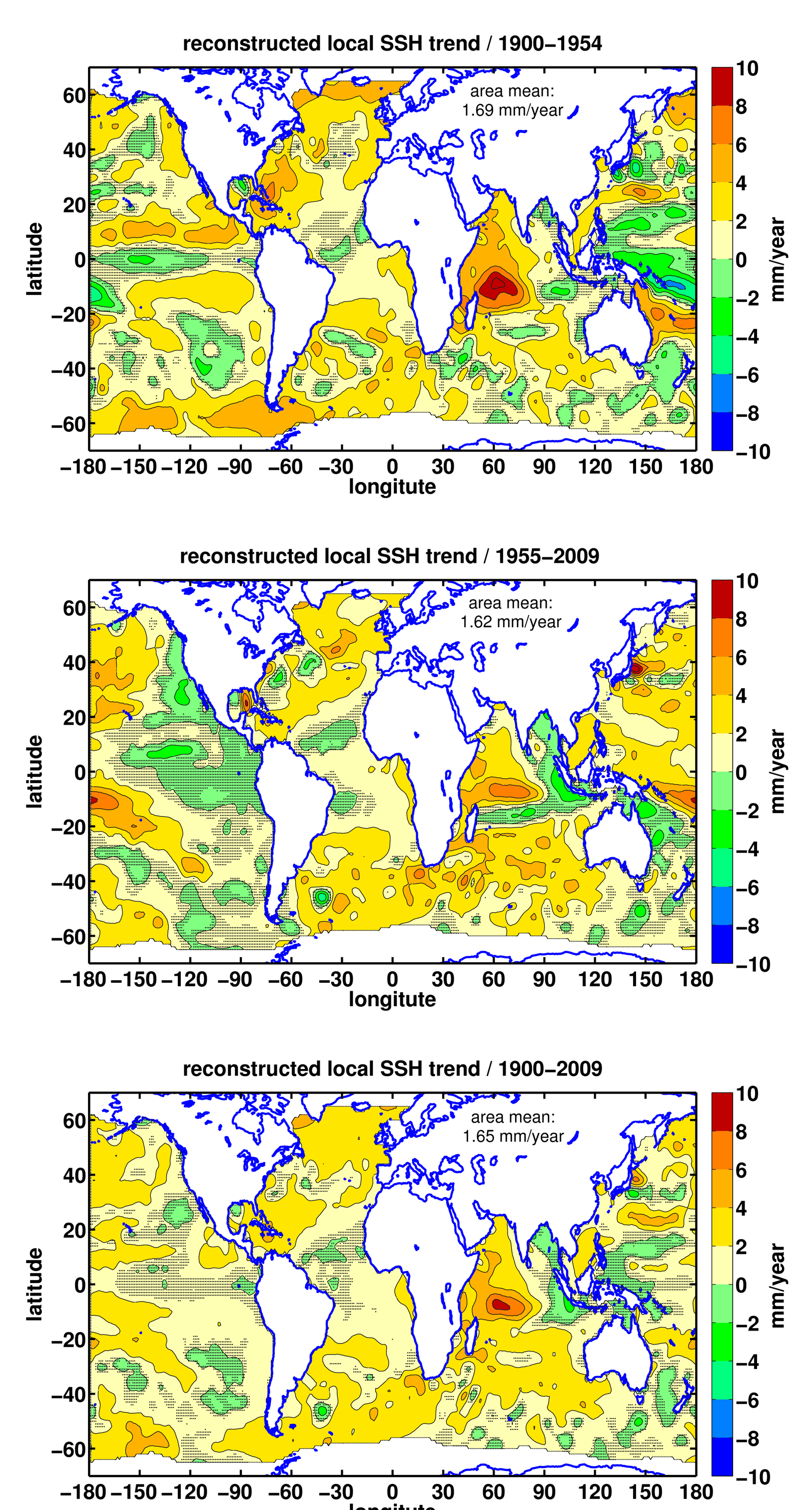

Reconstructed local sea level trend for the periods 1900-1954 (top), 1955-2009 (middle) and 1900-2009 (bottom). Shown are the mean from the training cases given in the table. In the dotted areas these mean trends are below the corresponding standard deviation σ.

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