HELMHOLTZ GEMEINSCHAFT

AWI

Regional and global sea level change since 1900 estimated from tide gauges and altimetry

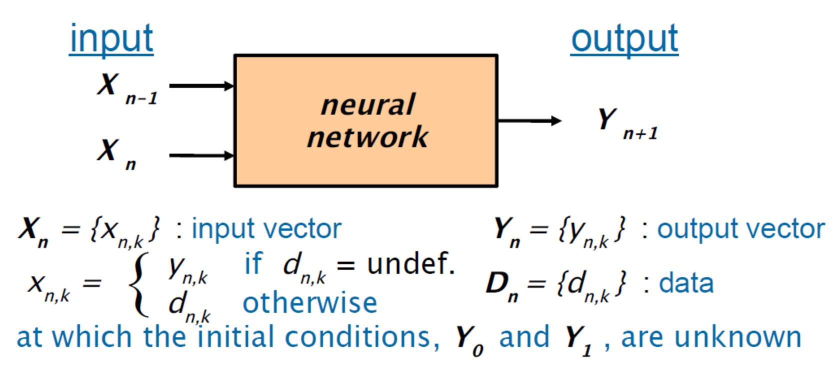
Manfed Wenzel and Jens Schröter

Introduction

Global sea level anomaly fields are reconstructed from tide gauges for the period 1900-2009 in a two step procedure. First we present an improved way to train a neural network to fill data gaps in time-series, e.g. from tide gauges. In the paper of Wenzel and Schröter (2010) the network used for this purpose was trained using only time steps that have complete data. Here we describe a method that can deal with arbitrarily distributed missing values even during the training phase.
Sea level anomaly are then calculated from these completed tide gauge records. This is done by estimating their projection onto the principal components from the EOF decomposition of the altimetry data.

Tide Gauge Reconstruction

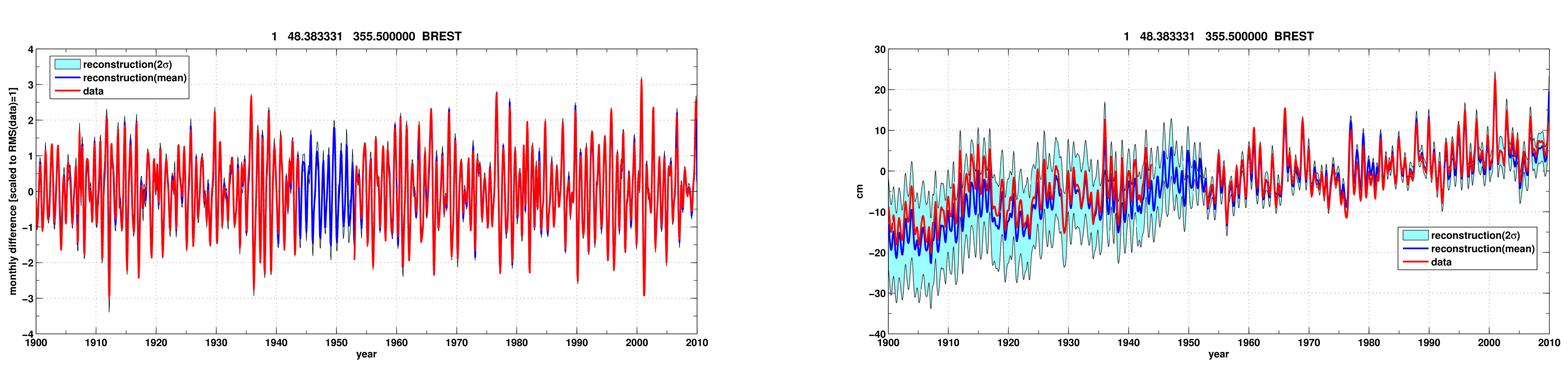
For the task of filling the data gaps the neural network is used as an time stepping operator as outlined below:



The unknown matrices ***H, O*** and the bias terms b_H and b_O of the neural network as well as missing values in the initial conditions are estimated by minimizing a weighted least square cost function:

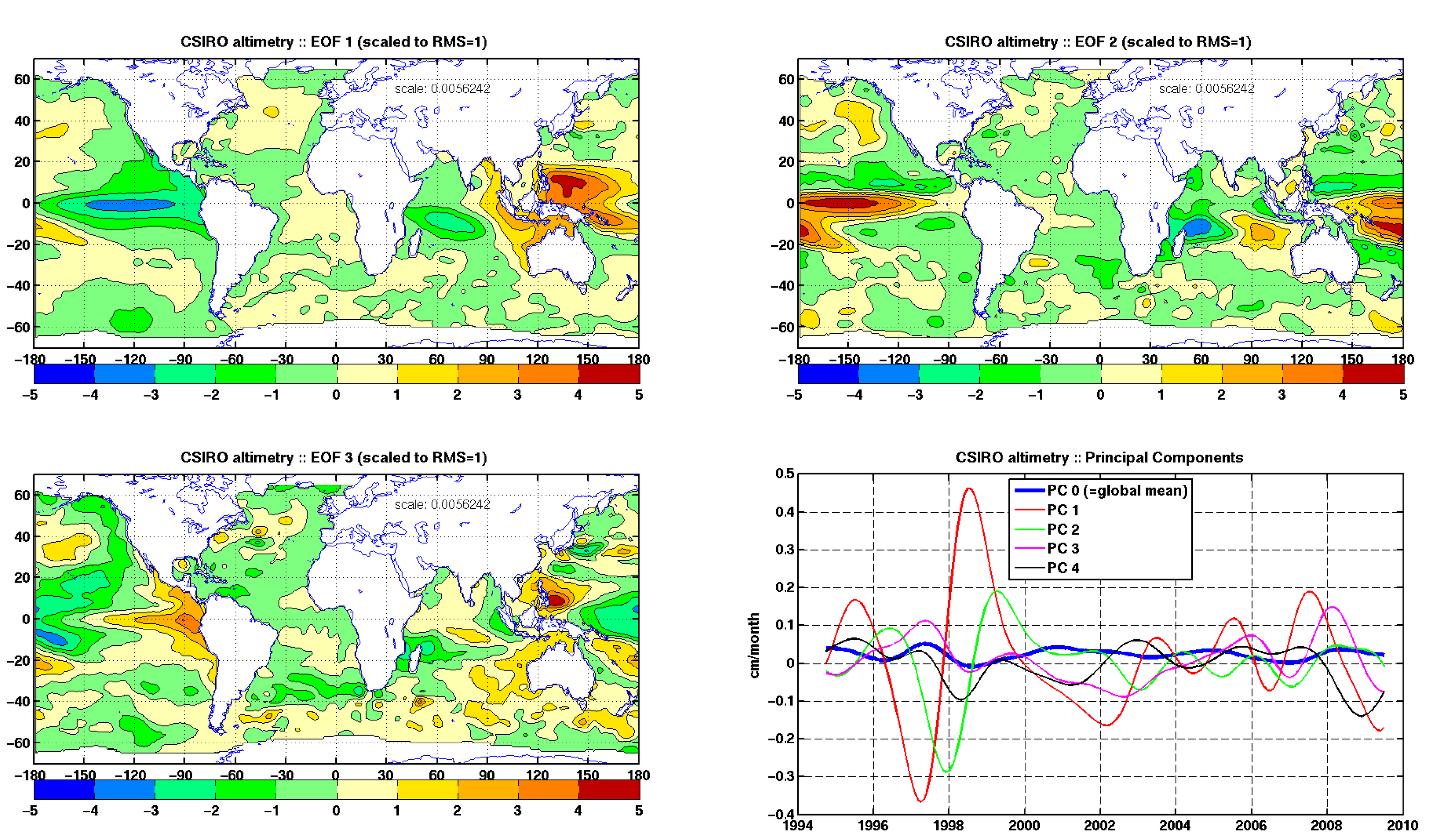
$$K = \sum\sum w_{n,k}\,(y_{n,k} - d_{n,k})^2 + C_r \cdot n_{dat} \cdot [\,1/n_O \sum\sum (o_{ij})^2 + 1/n_H \sum\sum (h_{ij})^2\,]$$

that includes a *ridge regression constraint* c_r to minimize / suppress less importent entrees in the matrices. Eight realizations of the network are trained using different prior estimated/optimized weights c_r .



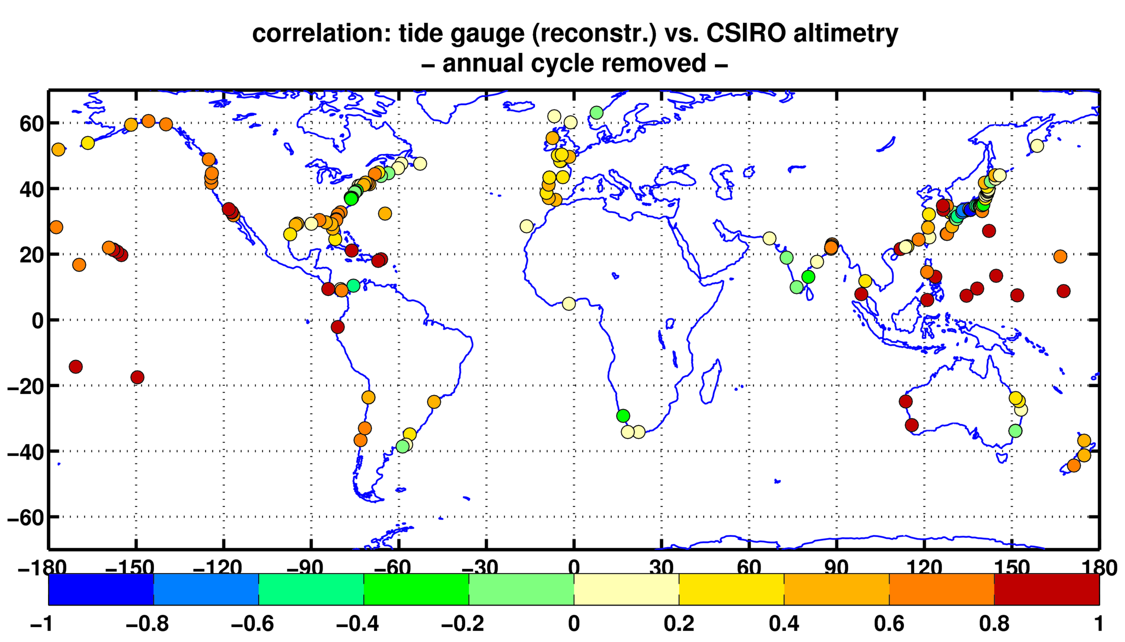
Retrieved monthly sea level differences (left, scaled) and the resulting sea level variations (right) at tide gauge ***BREST****. For the monthly differences the ensemble mean and standard deviation from eight differently trained networks are shown. For the sea level variations the mean and the error are estimated from an ensemble (25 members) created by adding Gaussian noise to the monthly differences.*

Altimetry Data - EOF Decomposition



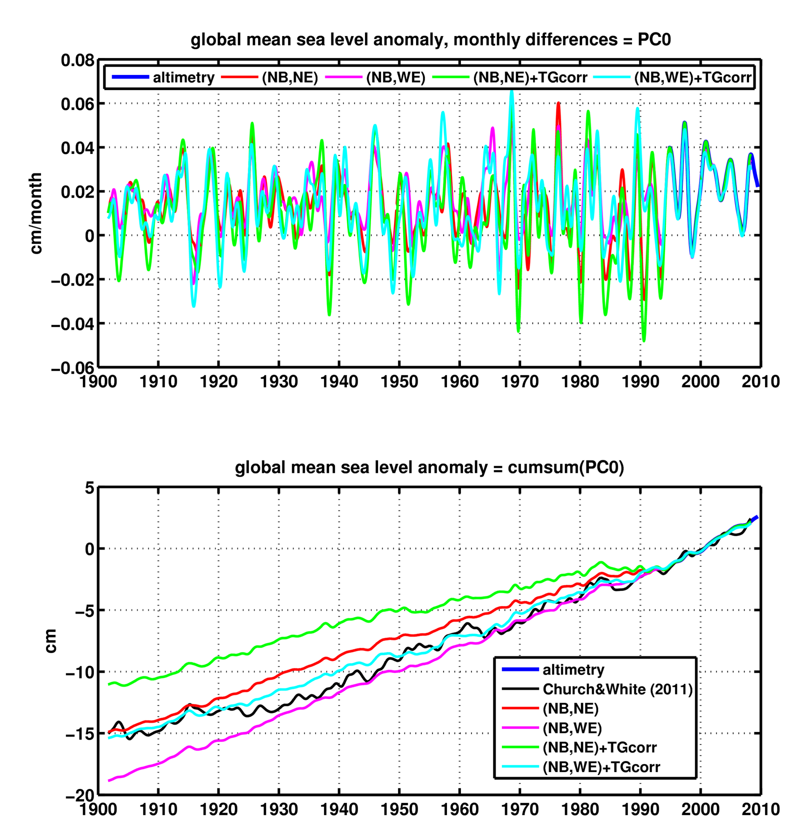
The first three ***EOF****'s from the filtered altimetry data (monthly differences, seasonal cycle excluded) with the global mean SLA subtracted prior to the decomposition. The lower right graph shows the corresponding principal components (****PC****'s), where* ***PC 0*** *stands for the global mean SLA.*
The altimetry data are taken from the CSIRO sea level web site.

Selected Tide Gauges



For the purpose of this work 178 tide gauges are selected in the latitudinal band 65°S-65°N from the PSMSL database (RLR, monthly) that have at least 30 annual mean values given for the years after 1950. The color coding shows the correlation of the tide gauge data (monthly differences) with the corresponding altimetry data at the nearest grid point after eliminating the annual cycle.

Results

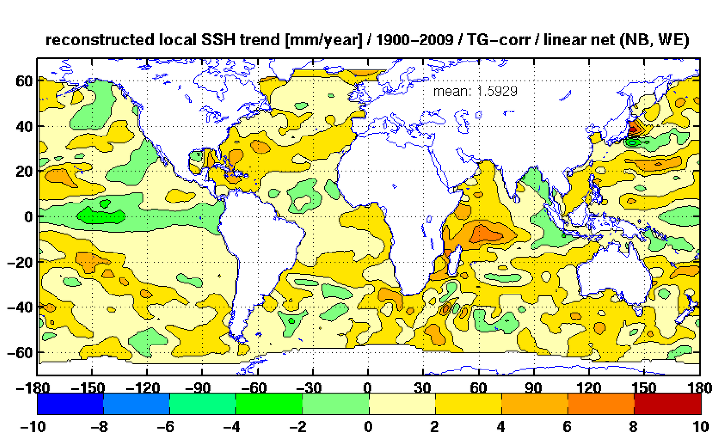


Each single principal component, **PC(t)**, is reconstructed from the tide gauge data, **TG(t)**, by estimating a transfer vector **M** that provides

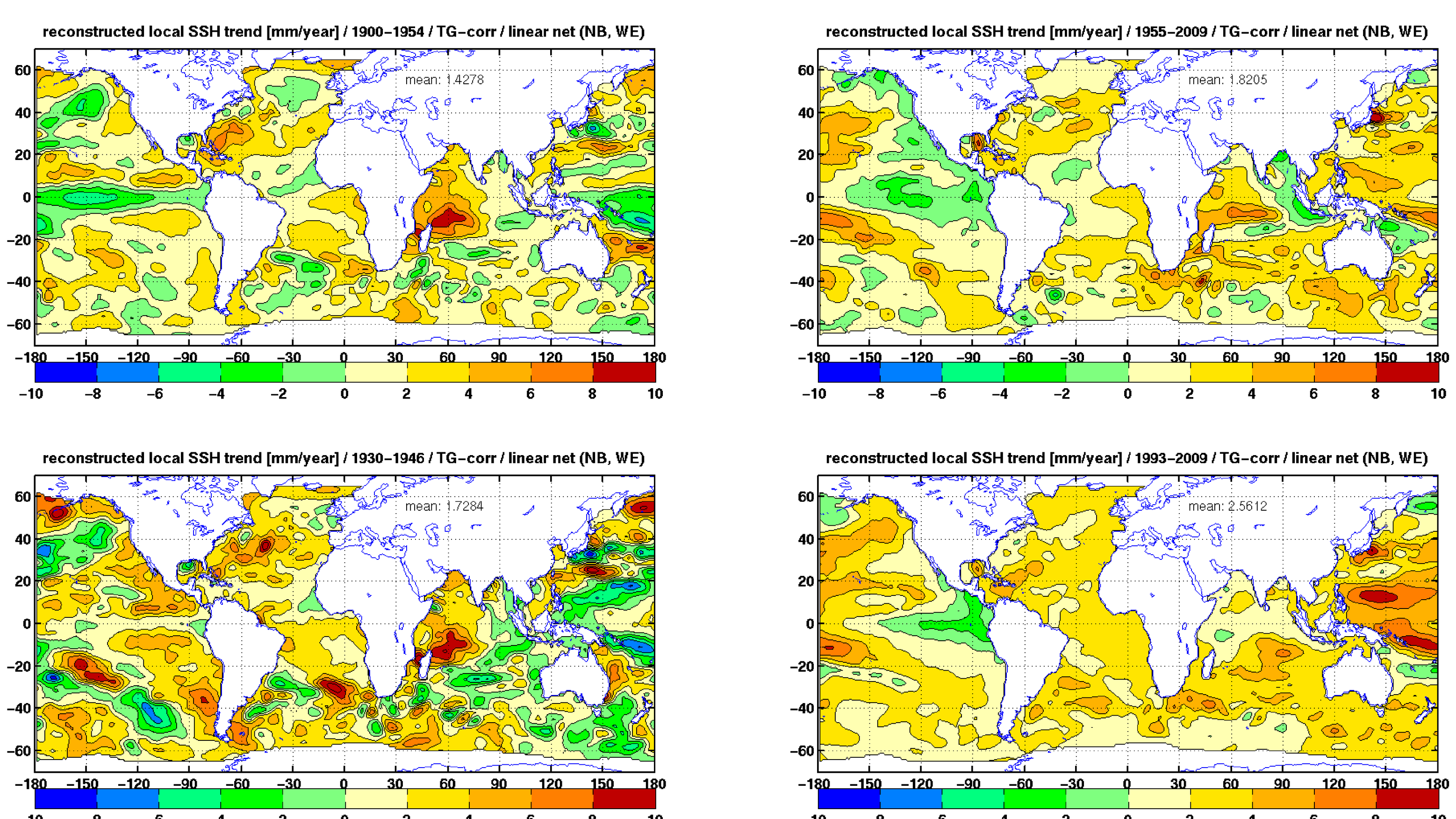
PC(t) = < M , TG(t) >

via a least square fit. In the four cases reported here we did not use any bias element, denoted by **NB** (no bias) in the graphs on the left. The four cases differ in whether or not a correction of the tide gauge trend towards the corresponding altimeter trend is applied (**TGcorr**) and whether or not errors in the tide gauge data are accounted for (**WE**: with error or **NE**: no error).

Reconstructed ***PC 0*** *(upper graph) and it's cumulative sum (=global mean sea level anomaly, lower graph)*



To reconstruct the global SLA fields the leading 16 **EOF**'s plus the global mean (**PC 0**) are used.



Reconstructed local sea level trend for the periods ***[1900-2009]*** *(upper left) ,* ***[1900-1954]*** *(middle left),* ***[1955-2009]*** *(upper right),* ***[1930-1946]*** *(lower left) and* ***[1993-2009]*** *(lower right). Shown are the trends from case* ***(NB,WE)+TGcorr*** *(no bias, with error, with TG trend correction).*

Climate Dynamics Section, Alfred-Wegener-Institute for Polar & Marine Research

Jens.Schroeter@awi.de