Global sea level reconstruction 1807-2002

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Abstract

We present unique reconstruction of global sea level from 1023 tide gauge records. Why it is unique? All previous assessments of global sea level rise have been done estimating linear trends from limited number of individual long- term time series. We have developed a new 'virtual station' method to overcome geographical bias and which can quantify the uncertainties due to representativity issues of the used stations. How good is the reconstruction? Our global sea level trend estimate of 2.4 ± 1.0 mm/yr for the period from 1993 to 2000 is comparable with the 2.6 ± 0.7 mm/yr sea level rise calculated from TOPEX/Poseidon altimeter measurements. However, we show that over the last 100 years the rate of 2.5 ± 1.0 mm/yr occurred between 1920 and 1945, is likely to be as large as the 1990s, and resulted in a mean sea level rise of 48 mm. What is new? We demonstrate that advanced statistical methods improve error estimations and reduce uncertainties for calculation of regional and global sea level rise. In contrast with linear trends, where the rate of mean sea level rise is constant, our results reveal the evolution of global and regional sea level rise during the past 200 years. We show as well that changes in sea level are not uniformed; smoothed by the 30 year SSA window, the trends from the different ocean regions show slightly dissimilar patterns and still demonstrate some low-frequency variability.

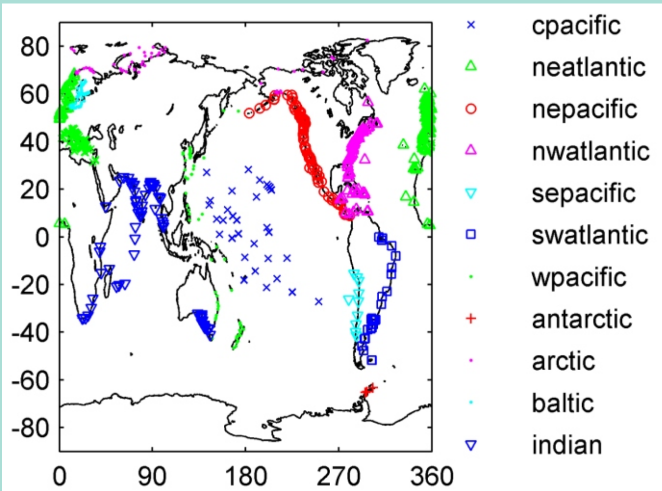

Figure 1. Location of tide gauges included in this study (12 regions)

Data

We use all relative sea level (RSL) monthly mean time series in the Permanent Service for Mean Sea Level (PSMSL) database [*Woodworth and Player*, 2003]. However, data from Japan were excluded from the analysis due to uncertainty in earthquake-related land movement of bench marks and tide gauge stations.
Detailed descriptions of the RSL time series are available from www.pol.ac.uk/psmsl. No inverted barometer correction was applied. RSL data sets were corrected for local datum changes and glacial isostatic adjustment (GIA) of the solid Earth [*Peltier*, 2001]. This procedure results in data from 1023 stations containing 385324 individual monthly records. The maximum number of stations in any year is 585, with only 70 stations in 1900, and 5 in 1850. Due to the time lag between data collection and supply to the PSMSL recent decades have also seen reductions in station numbers with only 390 stations in 2000.
We assign each station to one of 12 regions (Figure 1).

Objectives:

The main questions we answer:

1. Is it achievable to reconstruct global sea level using the tide gauge records?

2. Can we provide additional information using the nonlinear trends compared with linear estimations?

'Virtual Station' method

We have developed a new 'virtual station' method to overcome geographical bias and which can quantify the uncertainties due to representativity issues of the used stations.

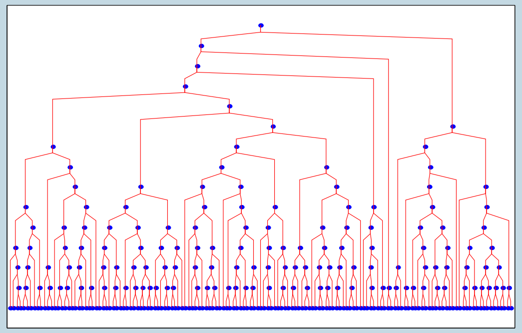

Figure 2. Binomial tree to illustrate the 'virtual station' stacking method. Top-node represents the regional average, bottom nodes the tide gauge records, and rest of nodes are virtual stations

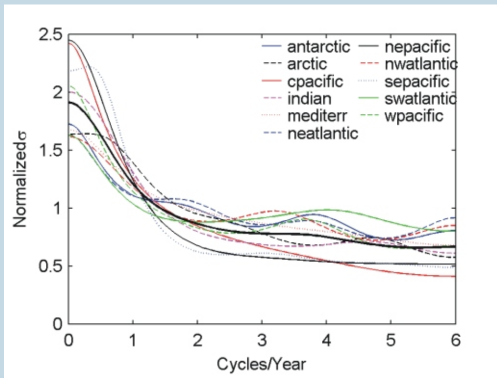

Figure 3. Normalized square rooted power spectrum of the mismatch error between each of the regions (Figure 1), except the Baltic, and the mean global sea level rate, calculated using an order 6 maximum entropy method. The thick black curve is the region mean spectrum. The power spectrum peaks at low frequencies due to long period oscillations, while the high frequency tail represents the "correct" mismatch error.

How good is our reconstruction?

Our global sea level trend estimate of 2.4 ± 1.0 mm/yr for the period from 1993 to 2000 is comparable with the 2.6 ± 0.7 mm/yr sea level rise calculated from TOPEX/Poseidon altimeter measurements.

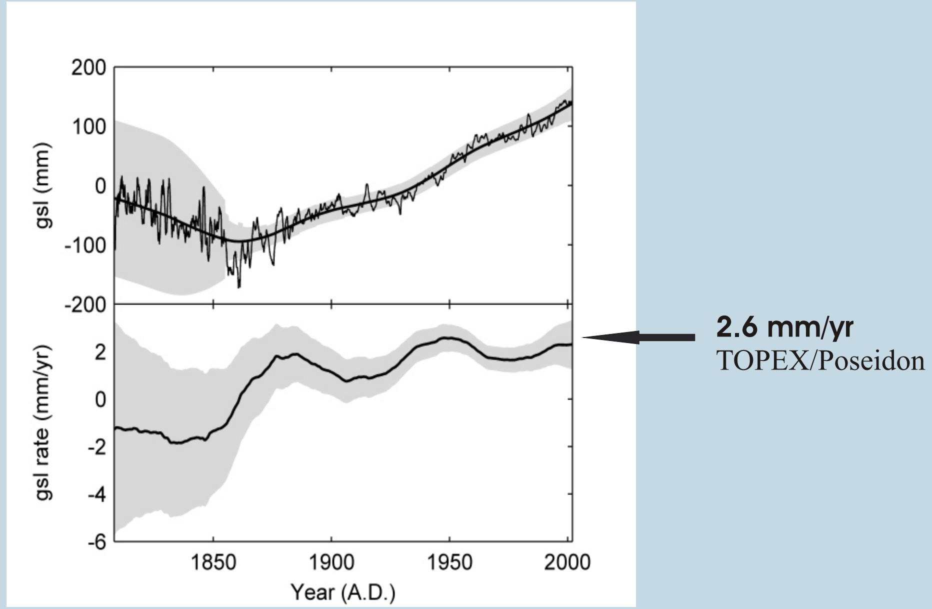

Figure 4. Top: Nonlinear trend (thick black line) in global sea level using an SSA embedding dimension equivalent to 30 years. Paralleling the trend is the 95% confidence interval in the trend found by considering the mismatch between the regional sea level curves, thin curve is the yearly global sea level. Bottom: the rate of the global sea level trend

What is new?

- We demonstrate that advanced statistical methods improve error estimations and reduce uncertainties for calculation of regional and global sea level rise.
- In contrast with linear trends, where the rate of mean sea level rise is constant, our results reveal the evolution of global and regional sea level rise during the past 200 years.
- We show as well that changes in sea level are not uniformed; smoothed by the 30 year SSA window, the trends from the different ocean regions show slightly dissimilar patterns and still demonstrate some low-frequency variability.

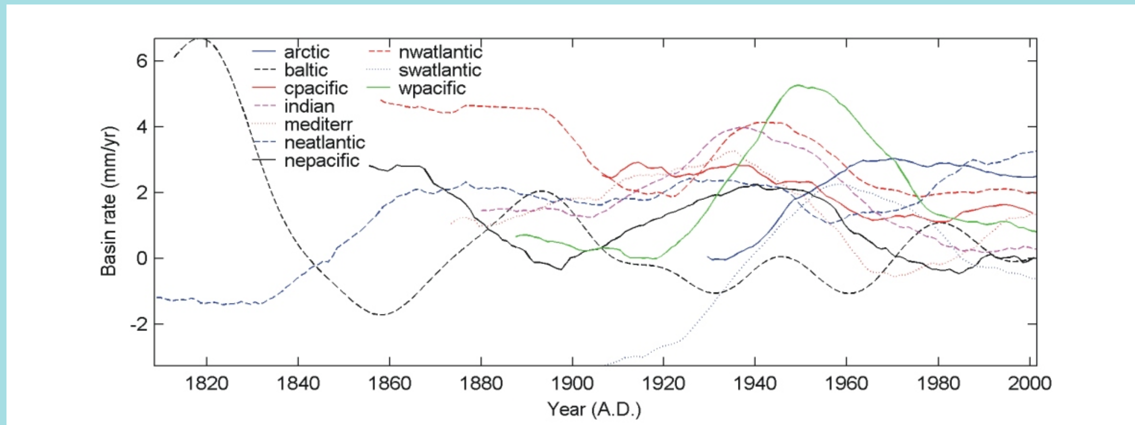

Figure 5. Rates of nonlinear sea level trends in the regions defined in Figure 1, found using an SSA embedding dimension equivalent to 30 years. Errors are not shown in the plot, but using the example of Figure 2 for Northeastern Atlantic, the maximum error at the start of the time series would be about 150*P*/√(12x30x2) = 2-3 mm yr^{-1} and the minimum error about 1 mm yr^{-1}, other regions will have similar errors.

Jevrejeva et al., 2006. Nonlinear trends and multi-year cycles in sea level records, JGR, 2005JC003229