Is Baltic Sea level rise accelerating?

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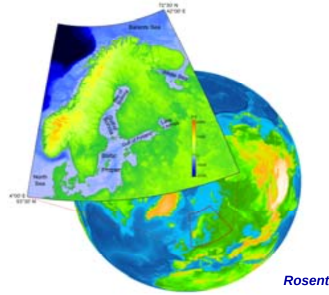
http://coast.gkss.de/staff/huenicke/pdfs/Poster_EGU_0510.pdf

Introduction:

As a consequence of increasing concentrations of greenhouse gases in the atmosphere, the global rate of sea-level rise is expected to accelerate in the future. Some studies indicate that this acceleration has already been detected in the 20th century record of global sea-level rise *(Merrifield &Merrifield, 2009)* while others do not detect a significant change *(Holgate, 2007)*. For regional planning agencies more important than the global number is, however, the change in the rate at regional due to isostasy.



Rosentau et al., 2007

Fig.1 Location of the Baltic Sea Region and the Baltic Sea Area

The Baltic Sea (Fig.1) is a region strongly influenced by isostatic rebound from the last deglaciation, with the Earth crust in the Northern Baltic rising at roughly 10 mm/year and in parts of the Southern Baltic sinking at about 1 mm/year. Time series of sea-level measured by coastal gauges thus display strong linear trends due to isostasy. The values of these trends form the basis for sea-level rise projections related to coastal protection, with a rough estimate of possible sea-level rise caused by climate change added to the isostatic trends.

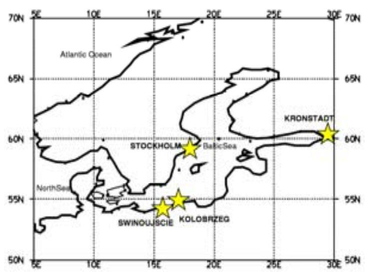


Fig.2 Location of sea-level gauges used in this study: Swinoujscie (Permanent Service for Mean Sea Level [PSMSL], Kolobrzeg (PSMSL; before 1951 provided by TU Dresden), Stockholm (Ekman, 2003) and Kronstadt (Bogdanov et al., 2000).

Deviations from a constant long-term trend, e.g. as an accelerating component, may be indicate the presence of a global warming signal. The identification of a change in the long-term trend is hampered by other regional factors that cause variations in sea-level at multiple timescales, such as the North Atlantic Oscillation and other temperature and precipitation variations (e.g. Hünicke et al., 2008).

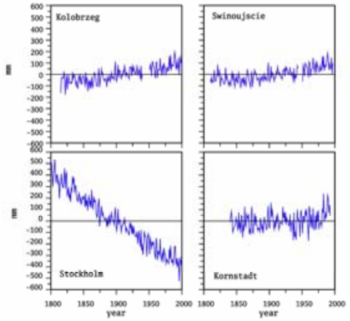


Fig.3 Annual mean sea-level in four gauge station in the Baltic Sea that report particularly long records.

Method:

Four series of annual mean sea-level (Fig.3) are assumed to follow the statistical model:

$$sl(t) = sl_o + bt + at^2 + e(t)$$

sl : annual mean sea-level ***t*** : time (years) ***e*** : residuals

The parameters ***b*** and ***a*** are estimated by fitting the observed annual sea-level records to the statistical model by Ordinary Least Squares (OLS). This method is known to be not optimal when the residuals ***e*** are not distributed as Gaussian white noise. However, even when these conditions are not fulfilled , the OLS estimation is unbiased.

For the **statistical significance** of the present of trends or acceleration, the structure of the residuals has to be taken into account. Here, a method based on *bootstrapping* of the residuals that conserves their serial correlation structure has been applied (*Christiansen et al., J. Clim, 2009*):

- estimate of ***a*** and ***b*** using Ordinary Least Squares
- calculate the residuals from the difference between observations and residual-free reconstruction $sl_0 + bt + at^2$
- perform a Fourier Analysis of the residual series
- randomize the Fourier phases of the residual series
- compute the inverse Fourier transform and obtain a new random residuals series with the same serial correlation as the original
- add the new residual series to the residual-free reconstruction
- estimate new values of ***b*** and ***a***
- repeat 1000 times and, from these 1000 samples, calculate the 5th and 95th percentiles of the parameter ***a*** and ***b***

Results

The estimated accelerations of annual sea-level in the Baltic Sea are all positive, and statistically significantly different from zero (Table 1). Also, the estimated magnitudes are similar and they can be considered equal within the uncertainty ranges.

Table 1 Estimations of the acceleration in annual mean sea-level in four gauges in the Baltic Sea in the period 1800-2000. The last two columns indicate the uncertainty range.

unit: 10^{-2} mm/year²	best estimate	5th	95th
Kolobrzeg	0.55	0.31	0.87
Swinoujscie	0.55	0.35	0.78
Stockholm	0.32	0.15	0.50
Kronstadt	0.46	0.24	0.69

This is consistent with a climate influence in the last 200 years. An alternative interpretation, namely that the isostatic trend is slowing down, would not be consistent with the same sign of the acceleration for all four gauges, some located in sinking others in rising areas.

To illustrate the magnitude of the acceleration, the linear and quadratic trend can be extrapolated into the future unchanged. The additional contribution of the quadratic term to the simple linear extrapolation is, however, small. A value of 0.50 x 10 ² mm/year² implies a contribution of the accelerating term for the year 2100 of 2.5 cm, as illustrated in Figure 4 for one Baltic gauge station.

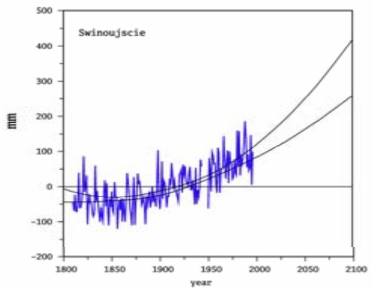


Fig.4 Extrapolation of the linear trend and acceleration for Swinoujscie. The confidence interval stem from the bootstrap distribution of the corresponding parameters.

The question arises how these findings compare with satellite data for the last few decades. For that purpose, all available tide gauge data which report between 1993 to 2008 were selected for the Baltic Sea Region (53N to 67N,12E to 30E) from the PSMSL RLR datasets. In addition, a combined satellite data set on a 1°*1° grid was down-loaded from the CSIRO website:*http://www.cmar.csiro.au/sealevel/sl_data_cmar.html* for the same time period. For both datasets, each of the time-series (annual means) was fit to a linear and quadratic trend over the observed period.

For the tide gauges as well for the satellite data, a positive acceleration of the annual mean sea level averages could be detected (Fig.5).

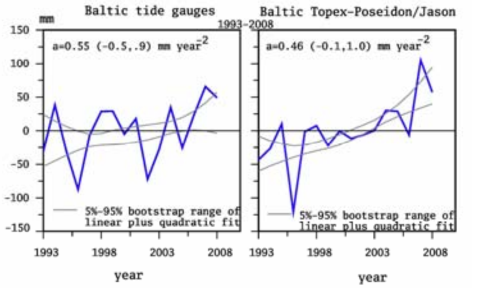


Fig.5 Time-series of annual mean Baltic sea-level averages derived from 24 tide gauges (left panel) and 77 grid points of combined satellite data (corrected for inverse barometer and GIA) of TOPEX/Poseidon, Jason-1 and Jason-2/OSTM sea level fields (right panel).

Spatially resolved, the acceleration values ranges between 0.39 to 0.54 mm/year² for the satellite data. For the tide gauge data, the range lies between -0.38 and 1.12 within the different stations, with a tendency to more positive values in the north and less positive values in the south. The same spatial gradient tendency is depicted in the satellite data (not shown). It has to keep in mind, that the satellite data do not provide measurements near the coast and thus are not directly comparable with the tide gauge data.

Outlook:

Future sea-level rise in the Baltic will be determined by several factors, some of them still poorly known, such as the dynamics of polar ice sheets. Many planning agencies broadly assume a continuation of the present linear trends, allowing for an additional 'climate contribution'. The estimation of an acceleration rate can contribute to improve these pragmatic estimations. A closer analysis of this first findings will be the focus of future research. The analysis is also planned to be expanded to the global scale.

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