Influence of temperature and precipitation on decadal Baltic Sea level variations in the 20th century

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http://w3g.gkss.de/staff/huenicke.html/Poster.html

Introduction

The main goal is the estimation of the influence of climate forcing on past, present and future sea-level changes in the Baltic Sea by using statistical methods and global climate models. Thereby, the analysis of the statistical relationships between sea-level and climatic datasets (e.g. sea-level pressure, precipitation and temperature) should yield a clearer picture of the main climatic factors responsible for sea-level variations at decadal and centennial timescales. This is essential to understand the future *regional* sea-level changes under global climate change.

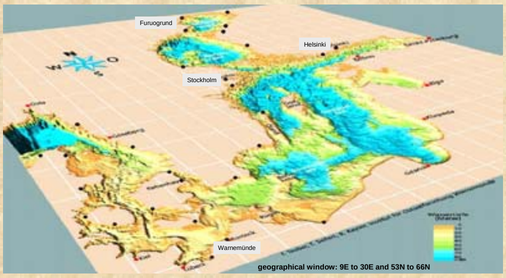

Fig.1 The Baltic Sea Region with locations of sea level gauges (PSMSL) used for this analysis

Sea-level variations at inter-annual to decadal timescales are generally believed to be caused essentially by variations in wind forcing, in particular (although not exclusive) by the North Atlantic Oscillation (NAO). Thereby, the correlation between the NAO-index and the sea-level variations are predominately weaker in summer than in winter and in general weaker in the Southern Baltic Sea (Fig.2). The correlation between atmospheric circulation (SLP) and sea-level shows also remarkable changes over time, e.g. ranging between 0.25 to 0.8 in wintertime for the period 1900-2000.

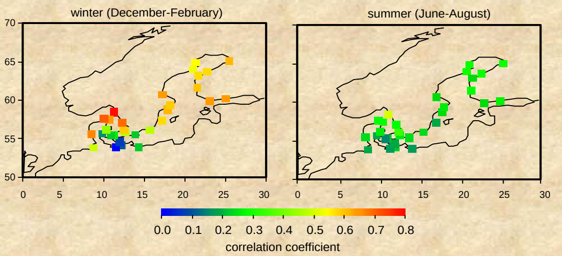

Fig.2 Correlation between the seasonal means of the North Atlantic Oscillation index (NAOI) and seasonal mean (linearly detrended) Baltic Sea level, 1900-1998.

Strategy

Focusing on summer and winter seasons, we apply statistical regression models, in which Baltic Sea level is the predictand, and sea-level-pressure (SLP), regional *air* temperature and precipitation are the predictors.

$$SL(t)=\sum_{k=1}^{N_{eof}^S} a_k^S\, pc_k^S(t)+\sum_{m=1}^{N_{eof}^P} b_m^P\, pc_m^P(t)+\sum_{i=1}^{N_{eof}^T} c_i^T\, pc_i^T(t)+SLR^{SPT}(t)$$

where $pc_k^S(t)$ are the time series of the k^{th} EOF and a_k^S are the regression coefficients of the leading N_{eof}^S, whereby the super index S stands for SLP, P for precipitation and T for temperature. The predictors have been introduced in the model stepwise. The first three terms in the r.h.s. in eq.1 represents the part of sea-level variations that can be linearly described by the evolution of the stepwise included predictor fields. The fourth term in the r.h.s of eq.1 is SLR_i^S i.e. the Baltic Sea level residuals that cannot be linearly described by the stepwise included predictor fields. Fig.3 shows the results for the winter season, for four representative stations.

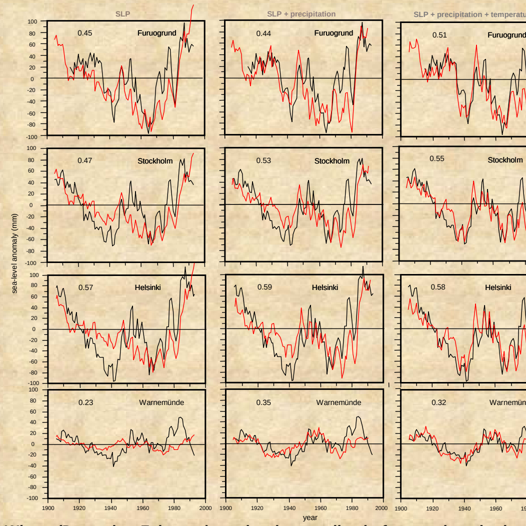

Fig.3 Winter (December-February) sea-level anomalies in four stations in the Baltic Sea (11-year gaussian mean), observed (black) and reconstructed (red) from the SLP field (left column), SLP and precipitation (middle column) and SLP and temperature (right column). The regression model was calibrated in the period 1960-1990. The number in the left upper corner indicates the explained variance (Brier skill score) at interannual timescales in the validation period.

Results

As shown by the model explained variances, SLP is the major contributor in wintertime, but both -precipitation and temperature- contribute to sea-level variations, but their relative contribution is not the same for all stations. Temperature seems a more important factor in the north, with a nodal line close to Stockholm and Hanko in the central part of the Baltic, whereas South of this line precipitation is a more relevant factor (see Fig.4 top panel).

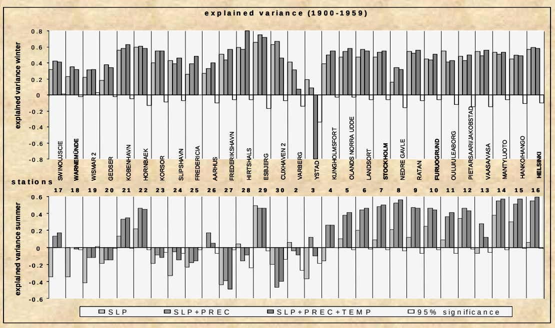

Fig.4 Fraction of inter-annual variance (Brier Skill Score) in the validation period (1900-1959) in winter (top panel) and summer (bottom panel) that can be explained by SLP, by SLP and the additional predictor precipitation (SLP+PREC) and by SLP, precipitation and air-temperature (SLP+PREC+TEMP) for 29 observed stations. The significance level indicates the amount of variance explained by synthetic random temperature and precipitation predictors. The order of stations is clockwise. starting in the South West.

In summer the influence of precipitation and temperature seems much more considerable for most stations (except In the Kattegat region). Sea-level tends to be positively correlated with precipitation and negatively correlated with temperature (not shown), suggesting that the driving role is played by rainfall: temperature and rainfall are in summer negatively correlated, Fig 5.

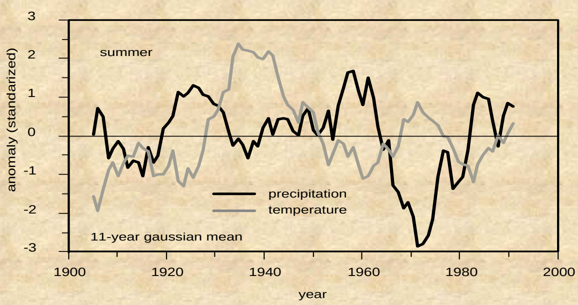

Fig.5 Summer (June-August) mean temperature and precipitation anomalies

Conclusions:

Inter-annual Baltic Sea level variations can be partially, but not totally, explained by the wind forcing linked to the NAO and other atmospheric circulation patterns. It is shown that, in wintertime, precipitation and temperature variations also contribute to explain sea-level variability in the 20th century, in addition to sea-level pressure. In summer, precipitation in general explains a major part of the sea-level variability.

Outlook:

Once the statistical model was validated and physically interpreted, the past sea-level variations related to climatic variations could be reconstructed by feeding these statistical models with past (last millennia) and future climate changes simulated by the global model ECHO-G (and with, ideally, much longer time series of paleoclimatic proxy data in a second approach). The output of the global climate models could indicate that e.g. changes in air-temperature or rainfall in the Baltic-Sea area may be as large as to overcome the expected changes in the NAO in a future climate, and thus become a dominant factor in determining regional future sea-level trends in the Baltic Sea, that will be superimposed on global eustatic changes.

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