Sea level studies at GKSS, Germany

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At the Institute of Coastal Research, GKSS Research Center, Germany, different aspects of sea level variations are studied, namely:

1) methodical issues of deriving *global* sea level changes from limited empirical evidence, and
2) present and possible future changes of *regional* sea level change in the North Sea and Baltic Sea

The estimation of **past and future global sea-level rise (GMSL)** is burdened a number of obstacles, among them the limited evidence of sea level change in the past and incomplete inclusion of processes in scenarios generated with process based models. Thus, statistical methods contribute significantly to our quantification of GMSL.

Estimations of GMSL variations are based on a limited number of long gauge records. One way to evaluate the uncertainty in these estimations is to compare the estimated GMSL with observations with global coverage, either from a dense network or from satellite data, in a recent period. We test such methods by employing the 'perfect model approach' by sub-sampling the output of a coupled model simulations mimicking the availability of observational records. Using the laboratory world of a millennial climate simulation, we find one such method to underestimate GMSL change in historical times, but to overestimate the increase in the 20th century.

Statistical models, such as (VR) $dH/dt = r_0 + a\ T + b\ dT/dt$, have been used to estimate possible **future changes of GMSL**. Here, H= global represents GMSL, T global mean temperature and t time. The physical mechanisms that justify the form of VR are not fully understood. The parameters r_0, a and b of VR are estimated from time series of reconstructions of GMSL from 1880-2000. These reconstructions are strongly smoothed, so that at most 8 independent samples are available.

Open problems related to VR are:

- The estimated value of b is negative, meaning that the third term would assign rising temperatures to declining sea-level rise
- The estimated value of b is very sensitive to the prior smoothing of the time series, turning from negative to positive roughly at the time scale of 30 years, the one used by VR.
- Would another form of the VR-model (e.g., replacing the temperature derivative by a weakly non-linear term) fit the observations as good as VR and yet project significantly different results for the long-term future?

While major efforts have been made in the last IPCC report to quantify past and potential future global mean changes, **regional changes of mean sea level (RSL)** has received only little attention. Since this is also the case, surprisingly, for both, the North Sea and Baltic Sea, efforts have been initiated to determine and to quantify RMSL changes for both regions.

For the **North Sea** an Empirical Orthogonal Function (EOF) analyses from 15 major tide gauges in German Bight, in the south western part of the North Sea, has been performed. The analysis reveals that the leading mode represents a coherent signal among all tide gauges that accounts for more than 90% of the observed variance. While the residuals account for only a small fraction of the observed variance and are not coherent between the different tide gauges we propose that the leading EOF may provide an estimate of observed relative RMSL changes in the German Bight while the residuals provide local changes at the tide gauges due to other reasons such as local water

works, relocation of tide gauges etc. From the time coefficient series of the leading EOF mode a relatively constant rate of about 1.74 mm/year over the period 1924-2008 is inferred. Trends computed over consecutive 20-year periods indicate that rates of RMSL increase were relatively high during the past few decades but not higher than at earlier times.

The **Baltic Sea** is a semi-enclosed nearly tideless sea, which is connected to the Atlantic through the North Sea to narrow and shallow sounds.

Its RMSL is affected by a number of processes, which are insignificant in the North Sea, namely a mean surface salinity gradient from about 20 to 5 psu from NE to SW and a isostatic rebound from the last deglacation, with the Earth crust in the Northern Baltic rising at ~10mm/year and sinking in the South by ~1mm/year. Decadal sea-level variations in the northern and eastern Baltic Sea are strongly influenced by the atmospheric circulation, whereas RMSL variations in the Southern Baltic are better described by area-averaged precipitation through salinity changes and thus to changes in water density. The long term linear trend in sea level is thought to reflect isostatic changes. Scenarios of possible future air pressure changes point to future trends in sea-rise of the central and eastern Baltic Sea of the order of 1 to 2mm/year – additional to the isostatic change and the regional manifestation of GMSL. Using precipitation as predictor for the Southern Baltic Coast, the same scenarios cause significant future trends of about 0.4 mm/year.

Figure

a) Dependency of the estimated values of the parameter in the VR-model as a function of prior smoothing of the global temperature and global mean sea-level data;

b) Estimated regional mean sea level (time series of the leading EOF mode of annual mean RMSL) in the German Bight, North Sea – in red: the 19-year moving average. Units: m