Decomposition of Sea Level Rise in the Southern North Sea

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PURPOSE - To provide an adapted design basis for the planning of ports or coastal protection to climate change we determine an individual rise of the sea level (rSLR) for a stretch of the coast. Changes of the water level at the coast must be seen as a function of several processes - e.g. tides or atmospheric effects on time scales of a few days to years can be identified. Selective description of long-term scales provide a basis to describe future states.

METHODS – Together with an advanced quality management (Hein e al., 2010) we identified from geodetic measurements the effects of land subsidence and zero point corrections at ***tide gauges***. Due to a shared adjustment of hydrologic and geodetic observations epistemic uncertainties were reduced. We used a fuzzy logic to fill gaps and extended shorter time series of individual gauges. The next step was to calculate a weighed mode as representative spatial mean (red-white line in the upper right map). Both, an analysis of the main components of the eigenvectors by means of a singular spectrum analysis and an additional wavelet analysis, are used to detect individual long-term processes. The effects of inter-annual and decadal variability are also worked out to separate the climate signal of sea level rise. Moreover, we compared ***numerical long-term simulations*** with the observations. To understand the estuarine hydrodynamics long-term simulations are helpful (Kappenberg, and Grabemann, 2001). However, they depend on sufficiently precise boundary conditions. Therefore, numerical simulations are downscaled with a model-chain from global to regional climate models to provide the simulation of estuarine processes.

REGIONAL RISE OF THE MEAN SEA LEVEL – The blue line in Figure 1a (left) shows the observed rise in the mean sea level (MSL = 18.6 year filter length = Nodal Tide, IHO, 1997). The orange line represents a Fourier function adapted to the observations, which indicate a principle determinability of the long-term changes. The probability density functions of the rSLR in Figure 1b indicates a bimodal rSLR in the southern North Sea, hence an oscillation between periods of in- and decreased rise. Obviously there is a significant long-term variability (> Nodal tide). Figure 1c shows the acceleration of the rSLR in comparison to the global one (here: Church and White, 2006). While on a global scale an acceleration is likely, in the southern North Sea neither a significant deceleration or acceleration occurs, which may support the assumption of mass adjustment (Mitrovica et al., 2001).

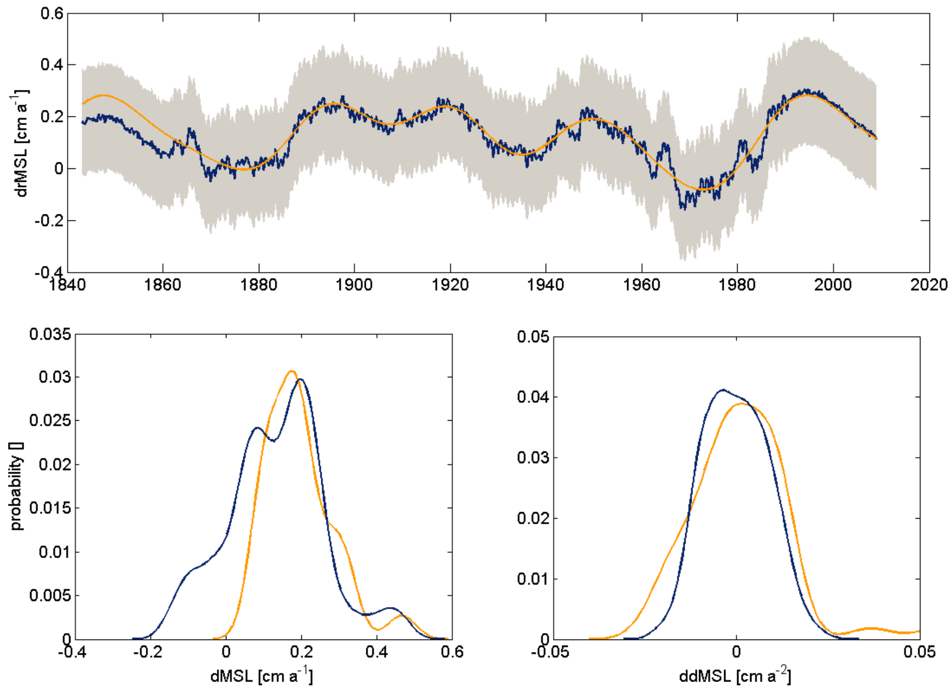

Figure 1: a) blue line rSLR for the Southern North Sea, orange line: functional fit with fourier function; b) blue line: PDF of rSLR in the Southern North Sea, orange: PDF from gSLR (Church & White, 2006); c) sea level acceleration, blue line: Southern North Sea, orange line: global

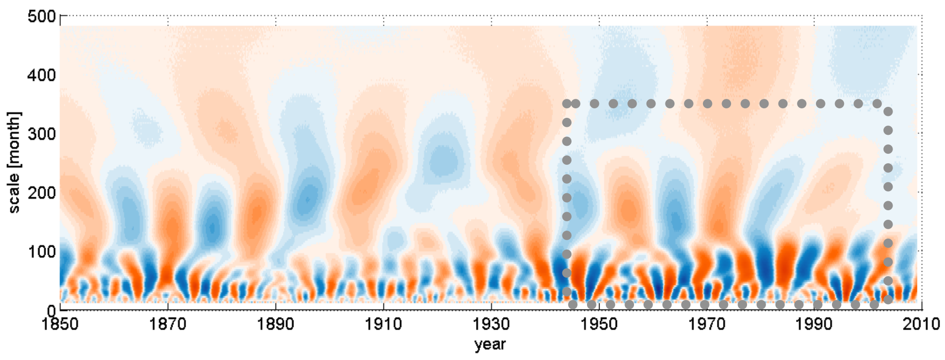

Figure 2: Components of a continuous wavelet decomposition of the sea level rise. Blue indicates rise and red indicates fall of the sea level, short term variability (< 3 month) is removed. The grey dotted box image the area of figure 4a.

NON-LINEAR RISE – The sea level rises non uniformly, hence the long-term mean rise is a sum of several processes on several scales of years or decades. Based on monthly mean values a wavelet decomposition of the rSLR allows to show the components of the rise on different scales. Figure 2 images the influence of the North Atlantic Oscillation on the sea level rise on typical scales between 2 to 7 years (for sea level see also: Yan, 2004). The Nodal tide (223 months) is indicated, but interference with other scales (11 – 28 years) overlays a clear signal. Additionally, fluctuations on a scale of more than 30 years are visible, e.g. Jungclaus et al. (2005) reported from the relevance of the multi-decanal scales in the North Atlantic region. The acceleration of recent years can be distinguished well: Not the long-term trend accelerated, but an interference of the different fluctuations at different scales results in an increase rSLR. Moreover, it seems that the overall variability increases with time, including also a possibly shift to longer scales.

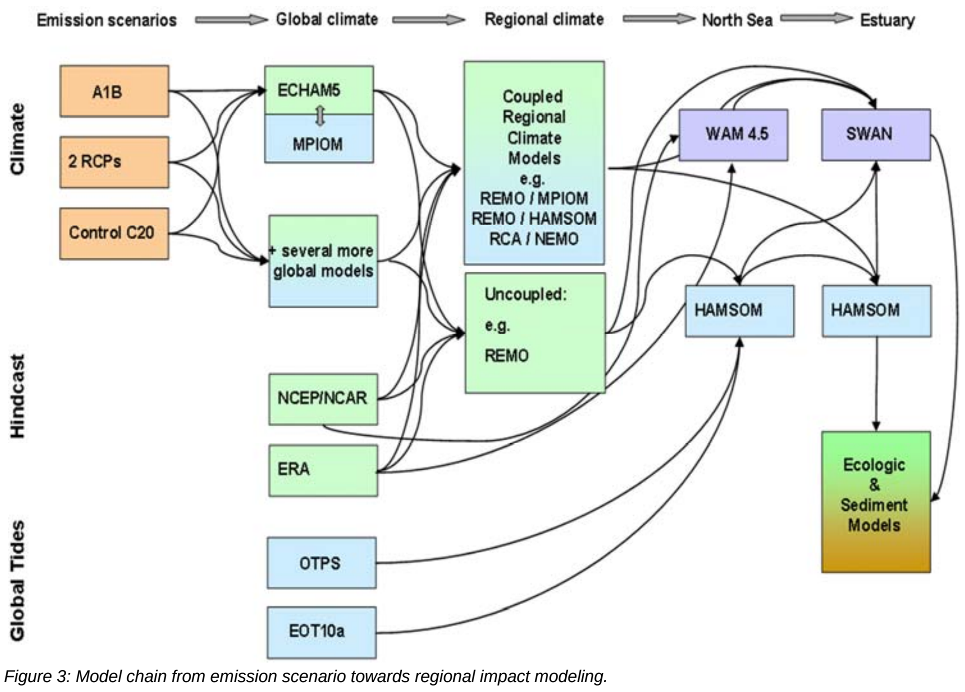

Figure 3: Model chain from emission scenario towards regional impact modeling.

MODEL CHAIN – To look forward to the processes of the non-linear rSLR a so called model chain breaks down the global changes of the sea level towards the regional fluctuations. Therefore, regional coupled and uncoupled models provide boundary conditions for different emissions scenarios. For the modelling of climate impact on the local estuaries, we need fast and simple 3D hydrodynamic models (Hein et al., 2010) to investigate regional processes. These models are forced by the model chain, and provide necessary information for local ecologic and sediment studies. Intensive analysis of hindcasts may allow a more likely projection of future variability. Figure 4a shows the wavelet decomposition of the sea level rise at the mouths of the estuaries from *one* realisation of a regional (North Sea) hindcast model (Pohlmann, 2006) of the presented model chain. A scale resolved mutual information (Brillinger and Guha, 2006) is used to identify solved and unsolved scales in the hindcast (figure 4b). While on typical NAO-scales the model reproduces well the variability of the sea level, the longer-term physical variability is absent. This must be considered in further studies in the estuarine models.

CONCLUSIONS – Predictability of future rSLR depends on the ***functional understanding of the historic variability***. So, if we want to interpret the results of a model chain, there is the need to know which information and on which scales passes through the chain. Therefore ***scale resolved mutual information*** approach is a possible way to indicate missing variability in the simulations. The ***possible increase in variability***, presents potentially greater issues for planning of coastal structures than the mean long-term trend. These ***natural physical variations over a period of years and decades*** will impact other processes: E.g. tidal range, residence times, transport processes and not least erosion processes.

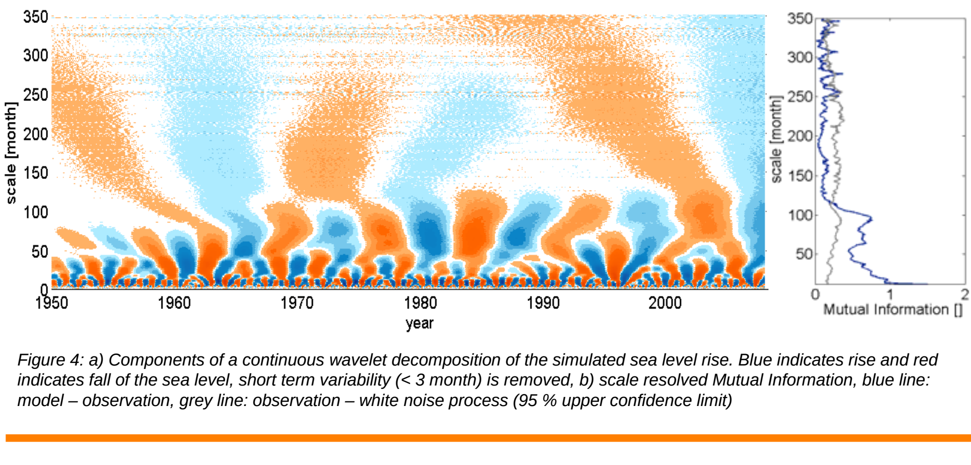

Figure 4: a) Components of a continuous wavelet decomposition of the simulated sea level rise. Blue indicates rise and red indicates fall of the sea level, short term variability (< 3 month) is removed, b) scale resolved Mutual Information, blue line: model – observation, grey line: observation – white noise process (95 % upper confidence limit)

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