Project: **1019**
Project title: **SeaStorm**
U. Mikolajewicz, A. Lang

Working report (period 2019-01-01 – 2019-10-30)

Main goal of the climate modeling part of the project (WP3) was to investigate the long-term variability of sea level extremes from storm floods in the German Bight and their relation with large-scale climate variability. To this end, we employed the regionally coupled atmosphere-ocean model REMO-MPIOM (Mikolajewicz et al., 2005, Sein et al., 2015) to dynamically downscale the climate variations from a Last Millennium simulation by MPI-ESM. The downscaling approach is needed since the global climate model does not include tides and does not have a high enough resolution to realistically simulate shallow shelf sea processes and extreme events. The downscaling model's combination of the global ocean domain with the full luni-solar tidal potential and a high resolution in the North Sea allows a consistent simulation of signals propagating from the open Atlantic onto the Northwest European Shelf and a more realistic simulation of shelf sea processes. Within the first phase of the project, a full 1000 year long simulation of the last millennium (the PMIP3 simulation *past1000r2* and the subsequent *historical* simulation from CMIP5) has been downscaled, providing a consistent data set of hourly statistics of ocean and atmospheric fields from 1000-2000AD.

Comparison of the simulated extreme sea levels (ESL) with observations from the tide gauge record in the German Bight (data from AMSeL project, see Jensen et al., 2011) shows that the model reproduces observed storm surge statistics, both in terms of magnitude above mean high waters as well as seasonality. However, large centennial variations in the high-impact return water levels (up to 1 m for 100yr return values, see Fig. 1) suggest that the standard procedure of estimating extreme sea levels from typically short (30-50 year) data records may be problematic as the estimations strongly depend on the state of long-term variability during the underlying baseline period.

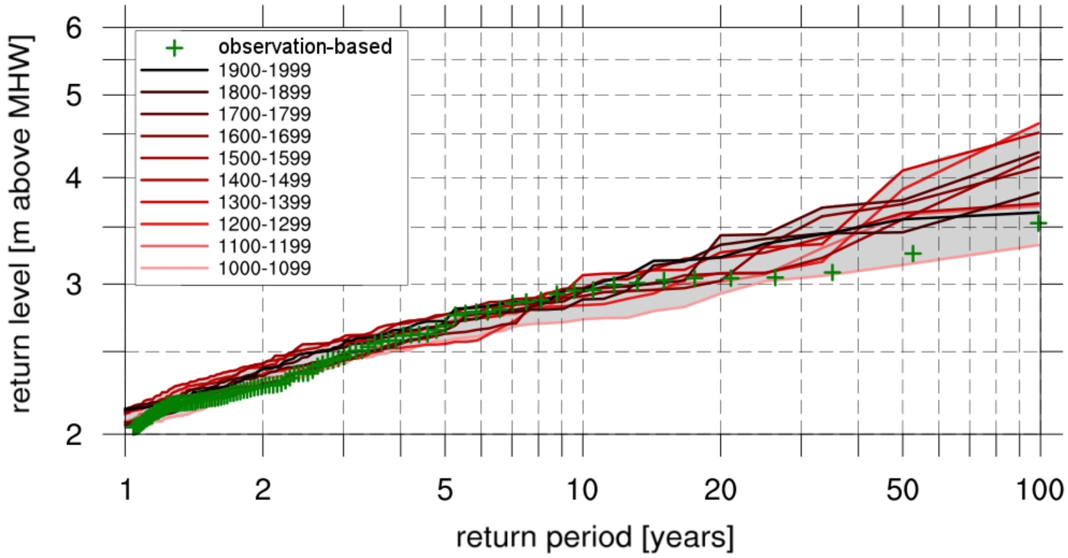

Figure 1: Return value plot of simulated extreme sea level at Cuxhaven (lines representing 100 year long chunks of thefull 1000 years) against observations from tide gauges (green crosses).

Time series analysis of ESL in terms of annual maxima indicates that extreme storm floods (i) have been occurring throughout the entire last Millennium with high inter-annual to multi-decadal variations but no preferred systematic periodicities and (ii) are to a large extent independent from variations of the background sea level. Anomalous long-term temperature regimes or variations in insolation due to changes in solar or volcanic variability have not induced changes in magnitude or frequency of extreme storm floods; however, periods of enhanced storm surge activity are associated with a large-scale circulation pattern comprising a pressure dipole with centers located over Northern Scandinavia and the Gulf of Biscay, respectively. These results have been published in Lang & Mikolajewicz (2019).

Further, two additional downscalings using (i) the same global GCM simulation, and (ii) a different realization of the global *past1000* simulation, have been performed to investigate the sources of variability in the downscaled ESL variations. The similar (different) temporal variability between the original downscaling and the additionally downscaled *past1000* run of the same member (of a different member) of the parent GCM scenario runs has shown that the bulk of the regionalized ESL variability is induced by the internal variability of the parent GCM simulation.

The large ESL variability has implications for the estimation of high return values, which are typically required as flood protection standards. Given the large variations found in the *past1000* simulation, it is clear that estimates based on short data records do not account for the full variability and hence the wide range of potential states. To illustrate this, we compare in Fig. 2 the 100-year return values as best estimate (black), as well as the associated 95% confidence range (grey bars) of one arbitrary 60-year subset with 16 different 60-year subsets taken from the full 1000-year-long simulation (16x60 = 960 years). This stresses the undersampling of potential states of variability if only one short data set is used.
Likewise, this high ESL variability has implications for the assessment of future changes in ESL statistics. Given the large variations in high return periods, such changes cannot be inferred from single simulations or small ensembles. Existing estimates of future ESL changes from small samples are thus likely to be dominated by internal variability rather than climate change signals. Thus, large ensemble simulations are required to assess future flood risks. Such a large ensemble approach to estimate potential changes in future ESL statistics is planned for next year (see proposal).

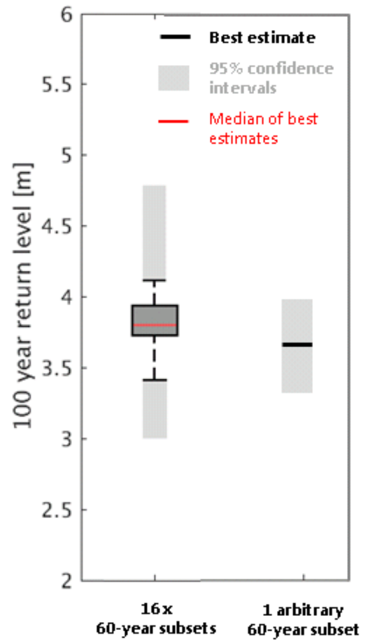

Fig. 2: Range of 100-year return values, expressed as best estimates (black line/whiskers) and associated 95% confidence range for a single 60-year subset vs 16 different 60-year subsets of the same realization. 100-year return values have been calculated based on a Gumbel fit using method of moments.