Project**: 900**
Project title: **PEARL: Preparing for Extreme And Rare events in coastaL regions**
Project Leader: **Uwe Mikolajewicz and Alberto Elizalde**
Allocation period: **01.01.2014 - 31.12.2017**

The general project objective is to achieve a better understanding of the coevolution of disasters due to extreme hydro-meteorological events. Methodologies will be developed to assess joint probability of extreme rainfall, storm surges, sea level rise and other hazard events for today's climate and future climate scenarios. In particular, the contribution of Max Planck Institute to the project consists of the realization of transient future climate projections and an analysis of potential sea level rise with a characterization of the sea level extreme events.

Work done during 2014-2015

Finished simulations - During the last two years the following simulations using low (REMO ~50 km, MPIOM 10 km to 600 km) and high resolution (REMO ~25 km, MPIOM 4 km to 180 km) versions of the regional coupled model REMO/MPIOM were performed:

– Validation period (1960-2001) driven by reanalysis data ERA40 (coupled and MPIOM standalone)
– Historical period (1960-2005) driven by CMIP5 model MPI-ESM-LR
– Scenario RCP 4.5 (2006-2100) driven by CMIP5 model MPI-ESM-LR
– Scenario RCP 8.5 (2006-2100) driven by CMIP5 model MPI-ESM-LR
– Control (1960-2100) driven by CMIP5 model MPI-ESM-LR

The high resolution simulations have recently finished on the new machine mistral and the analysis of these runs is still ongoing. The following study is based on the low resolution simulations.

Sea level changes - As part of the project objectives an analysis of the sea level changes as a response to anthropogenic climate warming was carried out. The increase in simulated sea surface height due to changes in the ocean circulation, regional ocean thermal expansion and atmospheric pressure is more than 0.1 m for almost all northern European coasts at the end of the 21st century with respect to present climate for both scenarios (RCP4.5 and RCP8.5). In particular, a stronger increase up to 0.28 m around Scandinavia and the Baltic Sea is simulated in the scenario RCP8.5. The increase in the Baltic is a consequence of the reduction in salinity due to enhanced river inflow and precipitation. (NB. The global model was not able to simulate this adequately as the simulated salinity in the global model was far too low). The outflow of freshwater from the Baltic is enhanced, leading to a strengthening of the lower salinity of the Norwegian Coastal Current and thus to a stronger rise in total sea level along the Norwegian coast. Within the Mediterranean Sea the sea level increases less than the global mean due to enhanced net evaporation and thus an increase in salinity. This effect is strongest in the eastern Mediterranean, where the total sea level rise reaches a regional minimum.

For the present climate period 1993-2010 the rise rate due to global thermal expansion is 2.02 mm yr-1 and 1.88 mm yr-1 for the RCP4.5 and RCP8.5 scenarios, respectively. They are in the range from 0.97 to 2.02 mm yr-1 simulated by the CMIP5 models for the same period (IPCC AR5). All these values overestimate the observed rates from 0.8 to 1.4 mm yr-1. However, in 1993 in our model there is a local minimum of the interannual variability of thermal expansion, thus the trend estimated from our model for this period is biased towards high values. The projected global mean sea level rise rate increases in 2081-2100 relative to the 1986-2005 by 0.21 mm yr-1 (RCP4.5) and 0.30 mm yr-1 (RCP8.5) in a good agreement with rate changes given in the IPCC AR5 (0.14 to 0.23 mm yr-1 and 0.21 to 0.33 mm yr-1 for RCP4.5 and RCP8.5, respectively).

The cryospheric contribution to sea level rise is not included in our regional model system. The mass loss of the Greenland ice sheet due to anthropogenic climate change was taken from Vizcaino et al. (2015). The contribution of the smaller glacier was added from Marzeion et al. (2012). For Antarctica as well as for the future evolution of water storage on land estimates were taken from Church et al. (2013, IPCC report chapter 13). For the long term effect of glacial isostatic the ICE-5G estimate was used.

As mentioned earlier, total relative sea level change is calculated as the sum of all mentioned contributions. In general the total change of relative sea level for the entire European coast including the Mediterranean and Atlantic coasts shows a positive rate in the range of 4 to 6 mm yr-1 and 4 to 8 mm yr-1 at the last decades of the 21th century (2070-2100) for the climate scenarios RCP4.5 an RCP8.5, respectively, with respect to the average of the historical period 1960-1990. The maximum positive rate of sea level in both scenarios is found at the North Sea in the German Bight. Most of the pattern of relative sea level rise distribution at the North of the European continent is dominated by the cryosphere effects. A negative trend in the range of -4 to -2 mm yr-1 and -2 to -1 mm yr-1 is projected for the Scandinavian coast as a consequence of the glacial isostatic rebound for the RCP4.5 and RCP8.5 scenarios, respectively.

Extreme events - Figure 1 shows the return values for sea level height for coupled and uncoupled model data driven with reanalysis forcings as well as for gauges stations from GLOSS dataset [IOC, 2012]. The 100 year return level value is calculated by selecting 5 maximum values per year in the available common period between model and observations within the years from 1960 to 2000. Results depicted in figure 1 show that the spatial distribution of the sea level maxima is well reproduced in both model simulations. The difference between such model results relies on the finer spatial resolution of the surface forcings and the simulation of the air-sea interaction within the coupled model. This influences the mechanisms of storm surges formation at the coastal area (derived by the traveling low pressure systems and direction and speed of the wind). At the Atlantic coast the uncoupled model systematically shows higher values than in the coupled model. It is the opposite case at the North Adriatic but in general the coupled model is closer to the values calculated with observed data.

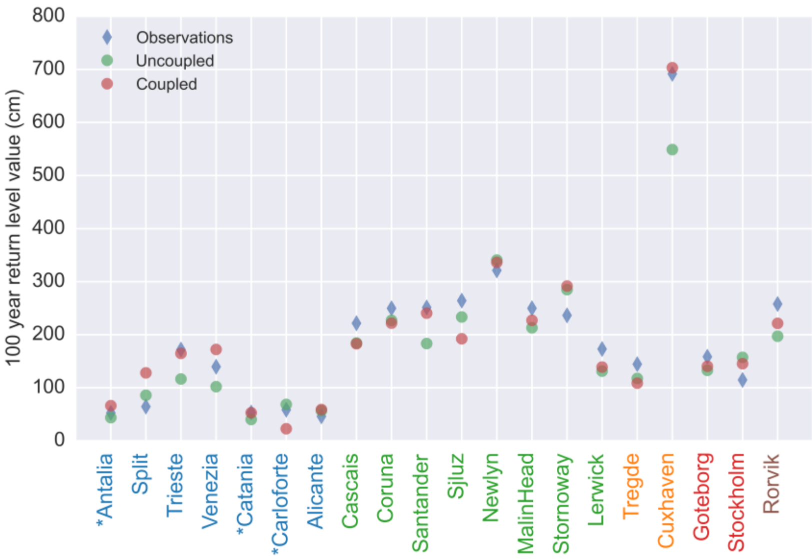

Figure 1. 100 year return level value from model and observations data for different locations at the European coast. Mediterranean (blue), Atlantic (green), North Sea (orange), Kattegat and Baltic Sea (red) and Norwegian Coast (brown). The asterisk indicates locations with time series shorter than 15 years.

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