

CLIMATE SIMULATIONS OF STORM SURGES AND WIND WAVES IN THE MEDITERRANEAN SEA

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1 INTRODUCTION

The severity of future hazards along the coastlines depends on sea level rise, vertical land motion and intensity of marine storminess. This study describes the effect of climate change on this last factor at the coast of the Mediterranean Sea. Specifically, we have computed the distribution of large surges and wave heights along the Mediterranean Sea coastline in the present condition and in a future climate scenario. This analysis is obviously important for evaluation of coastal risks and management of coastal defences (e.g. Nichols & Hoozemans, 1996).

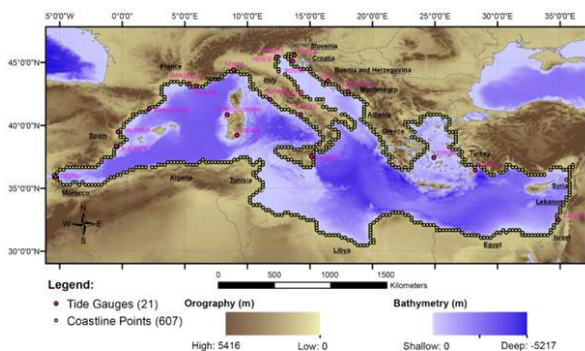


Figure 1: the Mediterranean basin and the coastal points analysed in this study.

2. MODELS AND DATA

This study performs an ensemble of simulations of sea level using a hydrodynamical shallow water model (HYPSE, Hydrostatic Padua Sea Elevation model) and

of wind waves using the WAM model. HYPSE, which is a two-dimensional model based on depth averaged currents (Lionello et al. 2005), has been implemented on regular lon-lat grid, which covers the whole Mediterranean sea with a 0.2 degree resolution. WAM (WAMDI, 1988) covers the whole Mediterranean Sea at a 0.25 resolution. Simulations cover the period 1951-2050 under the A1B emission scenario Nakićenović et al. (2000).

HYPSE and WAM are driven by the meteorological fields produced by a 7-member model ensemble which has been produced within the CIRCE project (Gualdi et al., 2012). These climate models have the peculiarity of including an ocean circulation component describing the marine circulation in the Mediterranean Sea at high resolution. Therefore, air-sea interaction at sub-regional scale is expected to be better reproduced in these than in previous simulations. The ensemble is composed of the following simulations:

- CMCC-LR (Euro Mediterranean Centre for Climate Change Low Resolution), which has used the global climate model CMCC-Med with a horizontal resolution of about 0.75 x 0.75 degrees;
- CMCC-HR (Euro Mediterranean Centre for Climate Change High Resolution), which has used the CMCC-CLM Regional Climate model (a climate version of the regional

COSMO model) with an horizontal resolution of 0.12 x 0.12 degrees

- MPI (Max Plank Institute-Germany), which has used REMO (REgional Model) with a horizontal resolution of 0.22 x 0.22 degrees, coupled to the Max-Planck-Institute for Meteorology ocean model (MPI-OM)
- ENEA (Italian National agency for new technologies, Energy and sustainable economic development) which has used the PROTHEOUS system (consisting of REGCM3 with a lat/lon resolutions of 0.27 x 0.35 degrees coupled to MITGCM implemented in the Mediterranean Sea at 1/8° resolution)
- CNRM (Centre National de Recherches Météorologiques - MeteoFrance), which has used the ARPEGE atmospheric circulation model (Déqué and Piedelievre, 1995), whose stretched grid reaches a minimum 50 km resolution over Europe-Mediterranean-North Africa) and it is coupled to NEMO-MED8 (1/8° resolution) for the Mediterranean Sea circulation;
- IPSL3 (Institute Pierre Simon Laplace) dataset, which has used LMDZ RCM (30km resolution) coupled to MEMO-MED at 1/8° deg resolution in the Mediterranean Sea.
- The IPSL2, which has used the same models as IPSL3, but adopted a two away coupling for the nest, that is four models -- two atmospheric (global and regional) and two oceanic (global and regional) -- have been run together allowing the results at regional scale to feedback on the global models.

This contribution considers the climate change along the coast, which is represented by the subset coastal grid points of the model grid (figure 1 shows them for the HYPSE model grid). In the following figures 2 and 3, the Mediterranean Sea coastal points have been ordered clockwise around the whole basin, i.e. eastwards along its European northern coast and westwards along its African southern coast.

The indicators used for describing the intensity of severe marine storms are the yearly mean of the 3-largest values of the

storm surge and the significant wave height in independent events. They are denoted as high SSI (storm surge index) and WSI (wave storm index) in this paper. Only events separated by at least 120 hours, which represent an estimate of the maximum duration of a storm in this area, have been considered, in order to ensure that only independent events are included in the statistics. These two indicators are meant to describe intense meteorological events that occur regularly every year (and not extreme values which would be characterized with longer return times).

3. RESULTS

Figure 2, top panel shows the SSI distribution along the Mediterranean coast for the individual climate simulations. The SSI is largest along two stretches of the coast, which are located in the Northern Adriatic Sea and in the Gulf of Gabes, where high SSI values are explained by the presence of a relatively long wind fetch over shallow water (the effect of the wind is proportional to the inverse of the water depth). Other four local maxima are present in figure 2. Two of them in the Gulf of Lion (France) and at the Tuscany coast (Italy), while the other two correspond to the Aegean sea (at the Greece-Turkey boundary) and the Gulf of Alexandretta (near the Turkey-Syria boundary). These areas are characterized by shallow water too, even though fetch is much shorter than in the North Adriatic Sea and in the Gulf of Gabes. Figure 2 bottom panel shows the percent change of the SSI between the 2021-2050 and 1971-2000 periods. The thick colored parts of the lines denotes the stretches of the coastline where the climate change percent index is larger than its standard deviation. The thick gray line denotes the climate change according to the ensemble mean of all simulation and the black parts where it is significantly different from zero. In general changes are small (maxima changes are lower than 5%), but the ensemble model mean shows a spatially coherent and significant attenuation of large storm surges.

Figure 3 shows the same information, except is consider the SWI and it does not report the analysis of the ARPEGE, IPSL2 and IPSL3 simulations, which has not been completed, yet. The spatial distribution of the WSI is obviously different with respect to that of the SSI and it presents the largest value at the north African coast, where the combination of long fetch and intense winds favors the occurrence of large significant wave height conditions. However, also for wind waves, the ensemble mean (to be extended in future to include the three missing simulations) shows a widespread decrease of high values with climate change.

4. CONCLUSIONS

In general results suggest a future attenuation of marine storminess along the coastline of the Mediterranean Sea. In spite of large differences among the results of the 7 model simulations (the inter-model spread is a large source of uncertainty), their ensemble mean shows a significant decrease of intensity of large surge and high waves. Such decrease of the intensity of marine storms is consistent with the reduction of cyclones, which some simulations suggest for future climate scenarios in the Mediterranean region (e.g. Lionello et al., 2008). The readers are addressed to Conte and Lionello (2013) for more details on the storm surge analysis.

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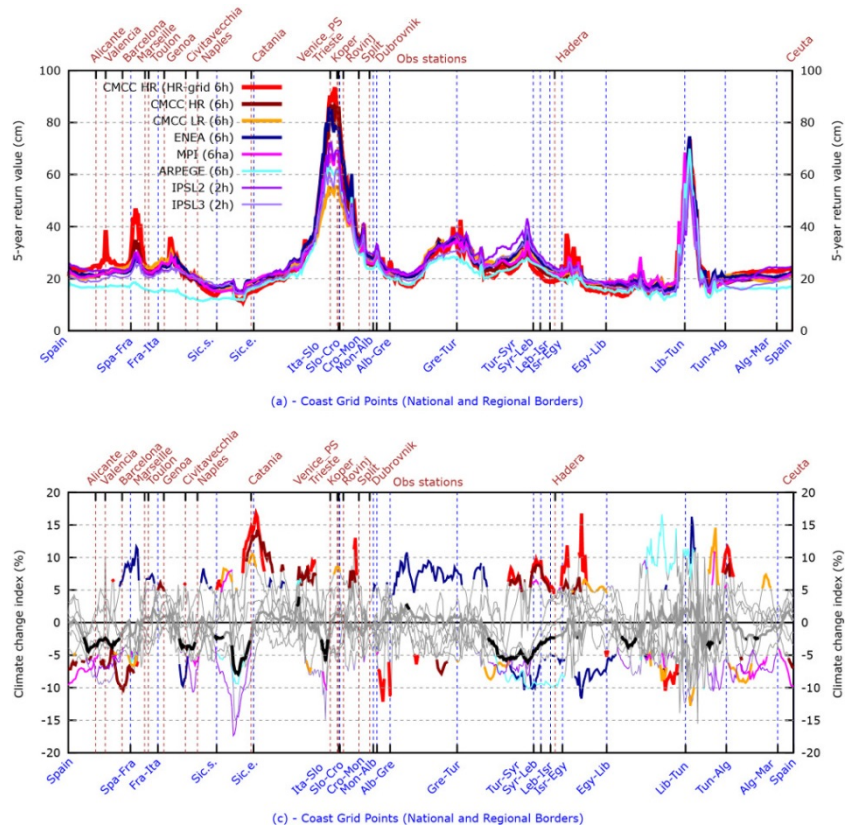


Figure 2: SSI in the present climate in the model simulations (cm, top) and its fractional variation (% , bottom) in the period 2021-2050 with respect to 1971-2000. Coastal points are ordered clockwise starting from Gibraltar. Country national borders and stations used for model validations are marked to help locating the different sections of the Mediterranean coastline. The thick parts of the lines denote where the climate change is significant.

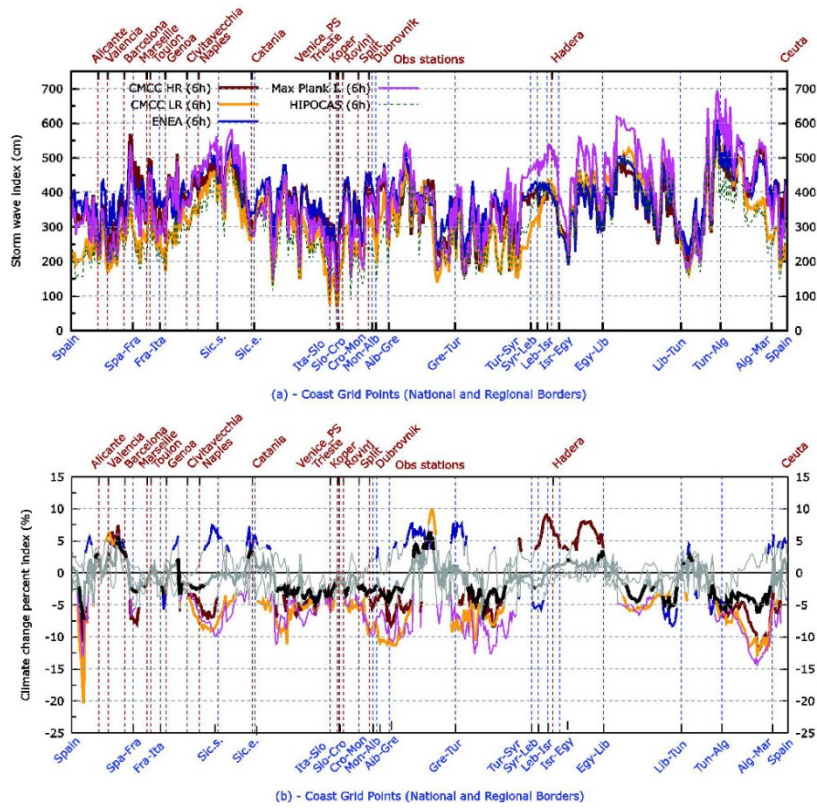


Figure 3: same as figure 3, but considering the SWI and its variation. The analysis of the ARPEGE, IPSL2-IPSL3 simulations is still in progress and corresponding results are no reported in this figure