CLIMATE CHANGE IMPACTS ON STORM SURGE LEVELS IN THE MEDITERRANEAN SEA

Filippo Giaroli, University of Genoa, filippo.giaroli@edu.unige.it
Andrea Lira Loarca, University of Genoa, andrea.lira.loarca@unige.it
Giovanni Besio, University of Genoa, giovanni.besio@unige.it

INTRODUCTION

Global warming is expected to drive environmental changes throughout the XXI century. In coastal environments it results in increasing extreme sea levels and flooding risk (Oppenheimer, 2019).
Coastal environments are generally characterized by a high population density, by important socio-economic activities, by the presence of trading nodes both by sea and land and by important infrastructure, therefore they can be considered a crucial place for the development and the life of modern society. So, due to their importance, protective actions must be taken to preserve these regions. Among the different coastal hazards, storm surge has a great impact in determining the extreme sea levels which can lead to flooding phenomena with consequent damage to the anthropic environment in which they occur (Tebaldi, 2021).

Therefore, it is important to investigate future trends, using climatic projections, to help to prioritize adaptation efforts, assessing which region may see an increase in coastal flooding frequency in the future due to the changing climate.
This work presents the outputs of a high spatial and temporal resolution storm surge model for the entire Mediterranean basin capable of reproducing storm surge conditions starting from atmospheric hindcast datasets as well as future climatic projections of wind and pressure.

METHODS

The model is based on an unstructured computational mesh at high resolution in the whole Mediterranean basin, having a maximum size of 50 km in the open sea and a minimum size of 200-300 meters in the proximity of the coast (Fig. 1), with a total of more than 270 thousand computational points.

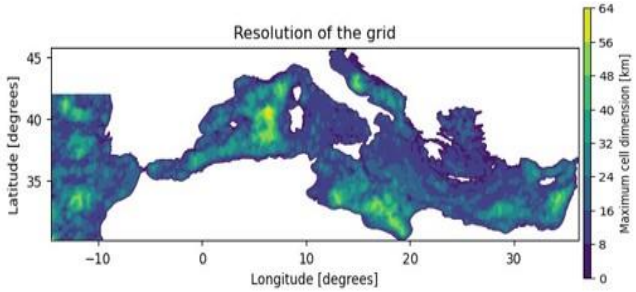

Figure 1 – Resolution of the computational grid used for the storm surge model.

Such features of the mesh are required to satisfactorily reproduce in detail the coastal environment, as storm surge is more evident and impactful in narrow and close locations where the sea water can be channelled by the wind action. So, the shape of the coast and the bathymetry of the sea bottom has been represented with high accuracy to maintain geometrical, territorial, and morphological features.

The computational grid has been obtained using the python-based OceanMesh (Roberts, 2019), which contains specific functions and settings to produce meshes respecting the desired constraints, while the storm surge model has been developed by the Delft 3D Flexible Mesh software (Deltares System, 2023 version), whose aim is to model hydrodynamic, hydrological, morpho-dynamic conditions related to coastal, estuarine, and other applications, and it is used in the present project to model the storm surge both for past and future atmospheric conditions.
The hydrodynamic analysis has been performed for the entire basin of the Mediterranean Sea plus a portion outside the Strait of Gibraltar, in order to provide more accurate boundary conditions in terms of sea water level to the only opening to the Mediterranean Sea with the Atlantic Ocean (Menemenlis, 2006).

The model has been validated with real observations coming from tide gauges and compared to the open-source data coming from models, having different features and resolutions (Vousdoukas, 2016, Toomey, 2022).

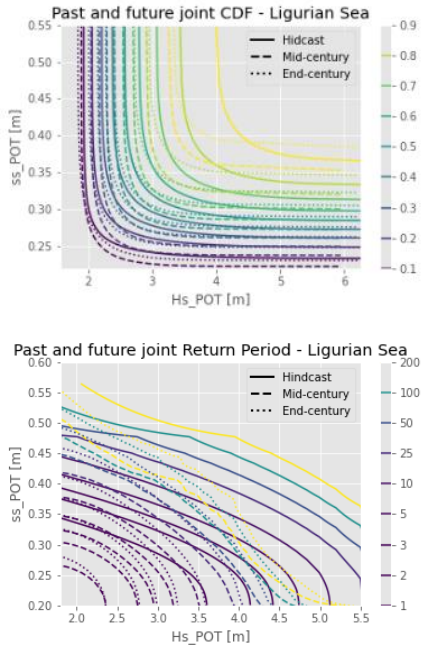

Figure 2 – Joint CDF and joint Return Period of storm surge and wind waves in a point located in the Ligurian Sea.

One of the main aims of this work is to couple the storm surge levels with the wind waves in order to investigate the

extreme sea levels focusing attention on the joint cumulative distribution function CDF and the joint return period as reported in Figure 2, which refers to past and future datasets for a point located in the Ligurian Sea.

DATA

Both for the hindcast analysis and the future projections, high-resolution atmospheric variables, up to 10 km, are required to model the storm surge levels, in order to have significant information.

Regarding historical conditions, the hindcast data developed by the MeteOcean group of the University of Genoa have been employed (Lira-Loarca, 2021).

The atmospheric information at high resolution coming from EURO-CORDEX models from the CMIP6 will be used as input for the future projections.

Several RCPs-SSPs scenarios of the IPCC, differing each other according to the future hypothesized anthropogenic impact on the environment, are considered observing how the marine variables response varies depending on the increase in atmospheric temperature. Furthermore, the differences in future projections caused by the varies used Climatic Models are investigated.

RESULTS

The hindcast dataset and future projections of storm surge up to the end of the XXI century will be presented and the results of the analysis will be shown.

Through a comparison of the output of the model for the reference period, the trend of variation due to the climate changes is identified and quantified.

Additionally, the changes in the occurrence of the most intense events are analyzed as well; the most vulnerable locations are identified.

Particular attention will then be paid to identifying if extreme events are expected to become more or less frequent in the future in the different coastal zones.

REFERENCES

Lira-Loarca, Ferrari, Mazzino, and Besio (2021): Future wind and wave energy resources and exploitability in the mediterranean sea by 2100. Applied Energy.

Menemenlis, Fukumori, and Lee (2006): Atlantic to mediterranean sea level difference driven by winds near gibraltar strait.

Oppenheimer, Glavovic, Hinkel, van de Wal, Magnan, Abd-Elgawad, Cai, Cifuentes-Jara, Deconto, Ghosh, Hay, Isla, Marzeion, Meyssignac, and Sebesvari (2019): Sea Level Rise and Implications for Low Lying Islands, Coasts and Communities.

Roberts, Pringle, and Westerink, (2019): OceanMesh: Python-based software for two-dimensional unstructured mesh generation in coastal ocean modeling, Geoscientific Model Development, 12, 1847-1868.

Tebaldi, Ranasinghe, Vousdoukas, Rasmussen, Vega-Westhoff, Kirezci, Kopp, Sriver, and Mentaschi, (2021): Extreme sea levels at different global warming levels. Nature Climate Change, 11(9):746–751.

Toomey, Amores, Marcos, and Orfila (2022): Coastal sea levels and wind-waves in the mediterranean sea since 1950 from a high-resolution ocean reanalysis. Frontiers in Marine Science.

Vousdoukas, Voukouvalas, Annunziato, Giardino, and Feyen (2016): Projections of extreme storm surge levels along europe. Climate Dynamics, 47(9):3171–3190.