An Analysis of the Expected Climate Change Effects in the Vicinity of the Main Harbors from the Black Sea

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Abstract
The objective of this work is to analyze the dynamics of the environmental matrix in the context of climate change in the vicinity of the main harbors from the Black Sea. The main environmental parameters considered for analysis are wind and waves. The climatic wind fields provided by the Rossby Centre regional atmospheric model are analyzed until the end of the 21st century, considering the results corresponding to the Representative Concentration Pathway scenario 4.5. These wind fields are used to force a wave modelling system based on the SWAN (Simulating Waves Nearshore) model. In this way, the wind and wave data expected along the entire 21st century in the vicinity of the most important harbors of the Black Sea are provided. From the analysis of these wind and wave data, an enhancement of the extreme wind conditions can be noticed. On the other hand, due to the high variability in the wind direction, the amplitudes of the extreme waves are expected to slightly decrease.
Keywords: Black Sea, harbors, wind and waves, 21st century, extreme conditions

1. Introduction

Due to the economic development, both navigation and harbor operations in the Black Sea have been constantly increasing in the last decades (see for example Rata & Rusu, 2018). On the other hand, the climate changes have an important influence on the dynamics of the most relevant environmental parameters of the sea environment, represented by the wind speed and the significant wave height (Ganea et al, 2019). Furthermore, many previous analyses (as for example Onea et al, 2015) indicate the fact that in the enclosed sea basins, as the Black Sea is, the effects of the climate chances appear to be stronger than onshore ore in open ocean. Thus, strong storms can be more often noticed in the basin of the Black Sea and also their intensity is increasing (Rusu, 2018). These aspects are affecting the safety navigation in the Black Sea as well as the harbor operations (Rusu et al, 2018). From this perspective, the objective of the present work is to provide a projection of the evolution of the environmental matrix until the end of the 21st century. The study is focused on the most important harbors operating in the Black Sea.

2. Materials and Methods

The wind data considered in this work are those produced by an RCM (Regional Climate Model) from the Swedish Meteorological and Hydrologic Institute, respectively the Rossby Centre regional climate model – RCA4 model (Samuelsson et al, 2011) and provided by EURO-CORDEX. The most probable RCP (Representative Concentration Pathway) scenario RCP4.5 has been considered. This assumes that the CO2 emissions will increase peak around the year 2040 and then decline. Under such circumstances it is assumed that the radiative forcing will be stabilized at around 4.5 W/m^2 at the end of the 21st century. Besides the analysis of the wind data, an analysis of the wave data has been also carried out in six points located near to the harbors Constanta (P1), Istanbul (P2), Samsun (P3), Batumi (P4), Novorossiysk (P5) and Odessa (P6). Thus, a wave modelling system based on the SWAN spectral phase-averaged wave model has been forced with the RCM wind fields. The bathymetry presented in Figure 1 corresponds with the computational grid (resolution of 0.06º in both longitude and latitude) used of SWAN.

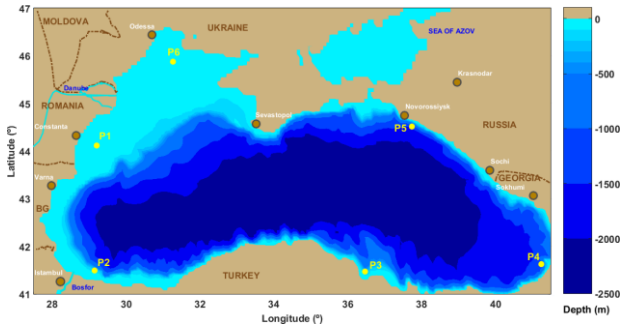

Figure 1. The bathymetric map of the Black Sea basin and the locations near to the harbors considered.

This wave modelling system has been previously implemented and validate in the Black Sea (Rusu et al, 2006). Furthermore, the experience concerning the implementation of the spectral wave models in other coastal environments, where such systems based on numerical models have been extensively tested and validated (Rusu et al, 2005) have been also considered in the setting of the most relevant physical parameterization.

3. Results

The wind speeds at 10 m above the sea level (U10) and the significant wave heights (Hs) resulted from SWAN model are analyzed in six points selected for three periods: historical (1976-2005), near future (2021-2050) and distant future (2071-2100). The mean values of U10 and Hs are presented in Figures 2 and 3. A slightly increase of the near future mean values, followed by a small decrease in the distant future can be observed for both U10 and Hs. In the Black Sea basin a seasonal variability of the wind fields exists, as seen in Figure 4.

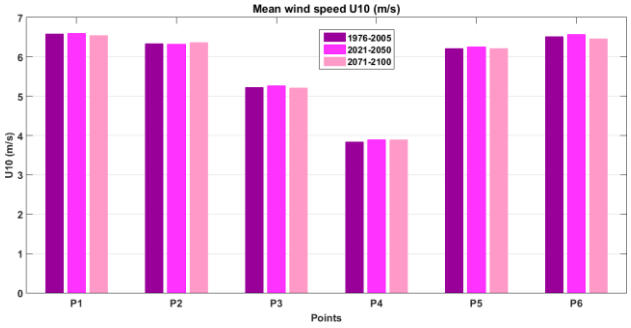

Figure 2. The U10 means in the points located near to the ports for all three periods considered.

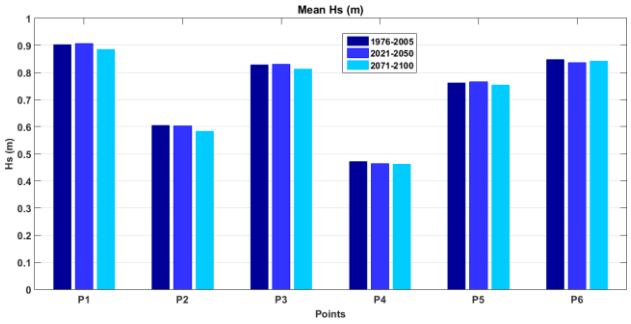

Figure 3. The Hs means in the six points considered for the periods: historical, near future and distant future.

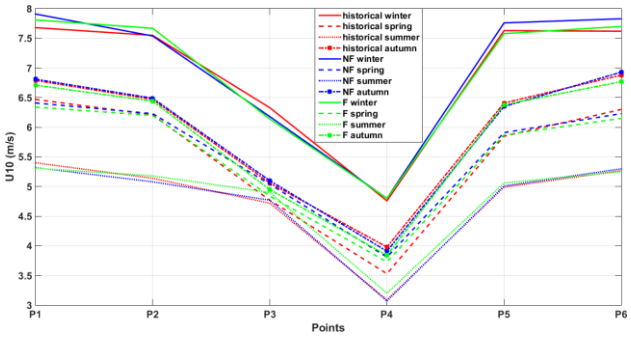

Figure 4. The U10 means in the points located near to the ports for the periods.

The higher mean values are found in the winter time, while the lower in summer. The seasonal variability of U10 induced the same behavior for the sea state conditions. Besides the mean values, the maximum values, the standard deviation, the 50th and 95th percentiles and the skewness were computed using their standard definitions (results are not presented here).

4. Concluding Remarks

An analysis of the parameters U10 and Hs under RCP4.5 scenario was made in the vicinity of six important harbors of the Black Sea. In order to observe the influence of climate changes on these two parameters along the 21st century, three series of data were considered, each covering 30-year. Finally it has to be highlighted that not important differences between the mean values of the parameters U10 and Hs for historical period and future projections were encountered in the locations analyzed.

Acknowledgments

This work was supported by a grant of Romanian Ministry of Research and Innovation, CNCS-UEFISCDI, project number PN-III-P4-ID-PCE-2016-0028 (Assessment of the Climate Change effects on the WAve conditions in the Black Sea – ACCWA), within PNCDI III. The wind data used in this study have been obtained from the EURO-CORDEX data servers.

References

Ganea D., Mereuta E. and Rusu E. (2019), An Evaluation of the Wind and Wave Dynamics along the European Coasts, *J. Mar. Sci. Eng.* **7**(2), 43.

Onea F., Raileanu, A. and Rusu E. (2015), Evaluation of the Wind Energy Potential in the Coastal Environment of two Enclosed Seas, *Advances in Meteorology*, 14p.

Rata, V. and Rusu, L. (2018), Assessing the traffic risk along the main Black Sea maritime routes, Proceeding of the Fourth International Conference on Traffic and Transport Engineering (ICTTE2018), 27-28 September, Belgrade, Serbia, 290-297.

Rusu, E. (2018), An analysis of the storm dynamics in the Black Sea, *Romanian Journal of Technical Sciences - Applied Mechanics*, 63(2), 127-142.

Rusu, E., Ventura Soares, C. and Rusu, L. (2005), Computational strategies and visualization techniques for the waves modeling in the Portuguese nearshore, Maritime Transportation and Exploitation of Ocean and Coastal Resources, **2**, 1129-1136.

Rusu, E., Rusu, L. and Guedes Soares, C. (2006), Prediction of extreme wave conditions in the Black Sea with numerical models, Proceedings of the 9th International workshop on wave hindcasting and forecasting. Victoria, BC, Canada

Rusu, L., Raileanu, A.B. and Onea, F. (2018), A comparative analysis of the wind and wave climate in the Black Sea along the shipping routes, *Water*, **10**(7), 924.

Samuelsson P., Jones C.G., Willen U. and Ulerstig A. (2011) The Rossby Centre Regional Climate model RCA3: model description and performance, Special issue on Regional climate studies using the SMHI-Rossby Centre models, *Tellus*, **63A**(1), 4-23.