The Impact of Climate Change on the Storm Surges of the Mediterranean Sea

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Intense storm surge events threaten low-elevation coastal areas with large inundation risk. In the past, storm surges have been responsible for human casualties, loss of land and property, damages to onshore infrastructure, harbor structures and coastal defenses. Global climate change is associated with impacts on the regional regime of sea level variations, i.e. influencing the intensity and frequency of occurrence of extreme storm surges. In the present work, the storm surge patterns in the coastal zone of the Mediterranean Sea are investigated for a period from 1971 to 2100 covering the observed past- and estimated future-climate. The future variation trends of the storm-induced extremes of sea level in the Mediterranean are also explored. The surge-induced sea surface height (SSH) in coastal areas is numerically simulated with MeCSS (Mediterranean Climatic Storm Surge) model. MeCSS is a 2-D barotropic model for hydrodynamic ocean circulation based on the depth-averaged shallow water equations (Androulidakis et al., 2015; Makris et al., 2016). Simulations cover three 35-year time-windows, i.e. the Reference (1971-2005), short-term Future (2021-2055) and long-term Future (2066-2100) periods. The atmospheric forcing of the MeCSS model consists of wind (velocity and direction) and atmospheric pressure fields produced by three Regional Climate Models (RCMs), namely the CMCC-CCLM, CNRM-ALADIN, GUF-CCLM-NEMO, implemented in the framework of the MED-CORDEX initiative (https://www.medcordex.eu/; Ruti et al., 2016). Historical climate data by all the RCMs for the Reference Period are validated against ECMWF reanalyses, based on assimilation system fields produced under CERA-20C (https://www.ecmwf.int/en/research/projects/cera). Estimations of future climate change projections from the RCMs are based on two climatic scenarios of the Representative Concentration Pathways, RCP4.5 and RCP8.5 (IPCC, 2014). In situ SSH observations from tide gauges by national hydrographic services, during the last 50 years, are used to evaluate the performance skill of MeCSS model in several coastal areas of focus. Appropriate statistical measures (Storm Surge Index, high-order percentiles, probabilities of exceedance, etc.) of intra- and inter-annual extremes reveal the agreement between historical sea-level data and simulation outputs. This confirms the ability of MeCSS to estimate the episodic sea surface response to intense climatic conditions. Our results support that there is a general decreasing trend only in the averaged patterns of storminess under the considered climate scenarios. However, the magnitudes of SSH maxima are estimated to increase locally in certain regions of the Mediterranean during the 21st century. Different topographical characteristics of the regional seas (e.g. northern Adriatic and Aegean Seas, Gulf of Gabes, etc.) in the Mediterranean basin have a significant influence on the variability of storm surge maxima.

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Abstract

Intense storm surge events threaten low-elevation coastal areas with large inundation risk. In the past, storm surges have been responsible for human casualties, loss of land and property, damages to onshore infrastructure, harbor structures and coastal defenses. Global climate change is associated with impacts on the regional regime of sea level variations, *i.e.* influencing the intensity and frequency of occurrence of extreme storm surges. In the present work, the storm surge patterns in the coastal zone of the Mediterranean Sea are investigated for a period from 1971 to 2100 covering the observed past- and estimated future-climate. The future variation trends of the storm-induced extremes of sea level in the Mediterranean are also explored. The surge-induced sea surface height (SSH) in coastal areas is numerically simulated with MeCSS (Mediterranean Climatic Storm Surge) model. MeCSS is a 2-DH barotropic model for hydrodynamic ocean circulation based on the depth-averaged shallow water equations (Androulidakis et al., 2015; Makris et al., 2016). Simulations cover three 35-year time-windows, i.e. the Reference (1971-2005), short-term Future (2021-2055) and long-term Future (2066-2100) periods. The atmospheric forcing of the MeCSS model consists of wind (velocity and direction) and atmospheric pressure fields produced by three Regional Climate Models (RCMs), namely the CMCC-CCLM, CNRM-ALADIN, GUF-CCLM-NEMO, implemented in the framework of the MED-CORDEX initiative (https://www.medcordex.eu/; Ruti et al., 2016). Historical climate data by all the RCMs for the Reference Period are validated against ECMWF reanalyses, based on assimilation system fields produced under CERA-20C (https://www.ecmwf.int/en/research/projects/cera). Estimations of future climate change projections from the RCMs are based on two climatic scenarios of the Representative Concentration Pathways, RCP4.5 and RCP8.5 (IPCC, 2014). In situ SSH observations from tide gauges by national hydrographic services, during the last 50 years, are used to evaluate the performance skill of MeCSS model in several coastal areas of focus. Appropriate statistical measures (Storm Surge Index, high-order percentiles, probabilities of exceedance, etc.) of intra- and inter-annual extremes reveal the agreement between historical sea-level data and simulation outputs. This confirms the ability of MeCSS to estimate the episodic sea surface response to intense climatic conditions. Our results support that there is a general decreasing trend only in the averaged patterns of storminess under the considered climate scenarios. However, the magnitudes of SSH maxima are estimated to increase locally in certain regions of the Mediterranean during the 21st century. Different topographical characteristics of the regional seas (e.g. northern Adriatic and Aegean Seas, Gulf of Gabes, etc.) in the Mediterranean basin have a significant influence on the variability of storm surge maxima.

Acknowledgements

This research is part of the MEDAQCLIM project: *Integrated Quantitative Assessment of Climate Change Impacts on Mediterranean Coastal Water Resources and Socio-Economic Vulnerability Mapping*, which is financed by National Action Plan: "European R&D Cooperation - Grant Act of Greek partners successfully participating in Joint Calls for Proposals of the European Networks ERA-NETS" and the "Competitiveness, Entrepreneurship & Innovation" Program.

Keywords

Storm surge; Mediterranean Sea; Climate change; Coastal Zone; Impact; MeCSS model

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