Evolution of storm surge extreme events in Greek Seas under climate change scenario

Krestenitis, Y.[1], Androulidakis, Y.[1], Makris, C.[1], Kobiadou, K.[1], Baltikas, V.[1], Diamanti, P.[1]
[1]*Laboratory of Maritime Engineering and Maritime Works, Aristotle University of Thessaloniki, ynkrest@civil.auth.gr, iandroul@civil.auth.gr, cmakris@civil.auth.gr, kobiadou@civil.auth.gr, vmpaltik@civil.auth.gr*

Abstract

Extreme storm surge events pose a great threat to coastal areas and can cause loss of land and property, damages to structures and even human casualties. We explore the trends of sea level over the Greek Seas for a period of 150 years (1951-2100) under the A1B future climate scenario, using a high-resolution storm surge model. Our results suggest that there is a general decreasing trend in storminess under the considered climate scenario. More extreme events may occur over the Ionian region, while the southern regions reveal stronger decreasing trends.

Keywords: storm surge, Greek Seas, climate change

1. Introduction

Low-elevation areas along the Greek coastline are at high risk in cases of extreme storm surge events; extreme storms may induce significant direct (e.g. flooding, coastal erosion, damage to property) and indirect (e.g. salt intrusion, land subsidence, water supply contamination, vegetation destruction) impacts on the coastal zone. The existence of numerous coastal cities, river deltas, islands, low land elevation coastal areas and topographically complicated regions (e.g. Adriatic Sea, Aegean Archipelagos) over the Mediterranean coastal zone support the need to consider possible climate change impacts in coastal planning. In the present work, we seek to explore the trends of sea level extremes due to atmospheric conditions for a period of 150 years, under a climate scenario with highly increasing concentrations of atmospheric greenhouse gases (A1B scenario; Houghton et al., 2001). The A1B emission scenario has been applied on the 3rd version of the Regional Climate Model (RegCM3; Tegoulias et al., 2014). Within this work, the RegCM3 model, in turn, forces a hydrodynamic storm surge model, namely Greek Climate Surge Model (GrCSM), for a period of 150 years, starting from 1951.

2. Materials and methods

2.1 Model description

GrCSM is a two-dimensional hydrodynamic model (Krestenitis et al., 2011) that solves the depth-averaged shallow water equations and is used to predict the Sea Level Height (SLH) for all Greek Seas on a $1/20^{o} \times 1/20^{o}$ horizontal grid (Fig. 1a). The 6-hourly atmospheric forcing, namely the winds at 10 m elevation from mean sea level and the Sea Level Pressure (SLP) fields, are provided by the RegCM3 simulations. The major sub-regions of the model domain are presented in Fig. 1b. The eastern and western boundary conditions were derived from a respective climatic Mediterranean simulation (Krestenitis et al., 2014).

2.2 Observations

Data from the Hellenic Navy Hydrographic Service (HNHS) were used to evaluate the performance of the model. The SLH data cover an 11-year period, from 2002 to 2012. An attempt was made to remove the low-frequency oscillatory components from the available gauge time-series. A period of 30 days was considered as an adequate filter length for such effects based on Conte & Lionello (2013).

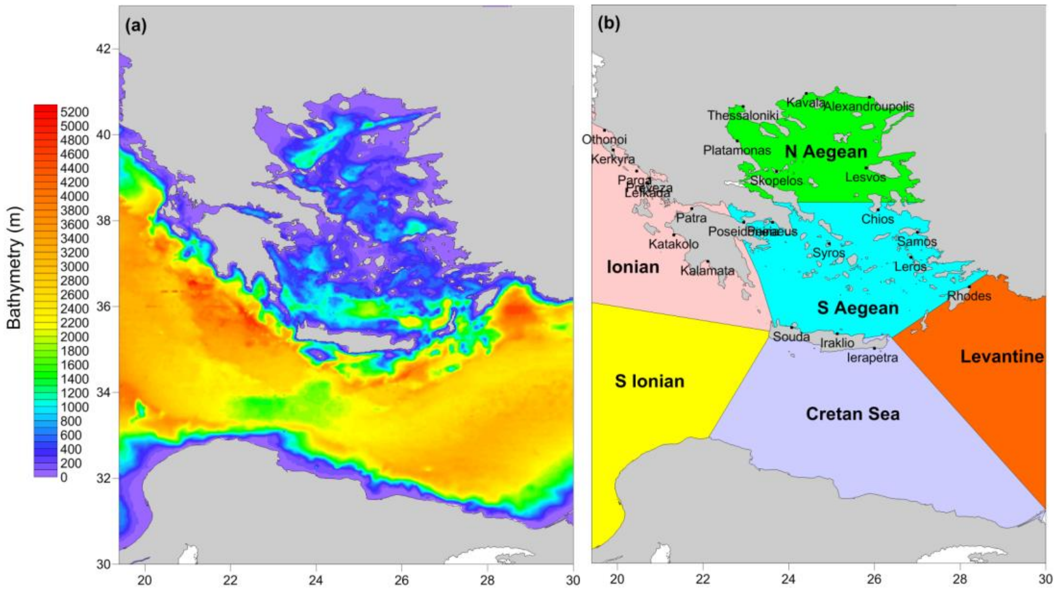

Fig. 1. (a) Bathymetry (m) of model domain and (b) locations of the SLH stations and the sub-regions (SC: South-central, N: North and S: South).

3. Results

3.1 Comparisons between model results and observations

The statistically significant values of the largest annual sea level anomalies can be investigated using the Storm Surge Index (SSI). SSI is defined as the average of the three (3) highest independent storm surge maxima per year, separated at least by 120 hours (Conte & Lionello, 2013). The SSI for both simulated and observed time-series was calculated for four stations (Fig. 2). The highest (~30 cm) and the lowest (~23 cm) values from both time series are observed for Alexandroupoli (N Aegean) and Lefkada (Ionian) station, respectively.

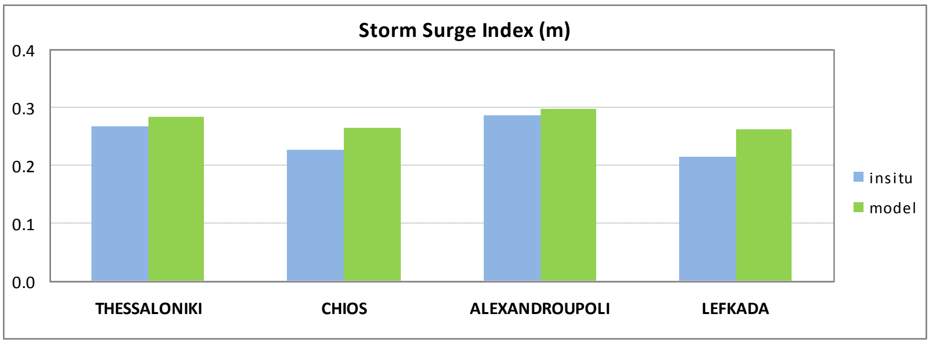

Fig. 2. Comparison of Storm Surge Index (SSI) values between model and in situ time series (2002-2012), for Thessaloniki, Chios, Alexandroupoli and Lefkada stations.

3.2 General trends

Fig. 3 presents the annual peak SLHs for each sub-region. The Ionian Sea presents very high maximum SLHs (>60 cm) due to storm passages, for both Past and Future Periods. It is the only region that does not show strong decreasing trends of annual maximum values during the entire 21st century. Contrastingly, a strong decreasing trend during both periods is identified for the Levantine and South Cretan regions indicating the storminess attenuation especially during the future period. Although the general trends decrease, significantly high events may occur during the 21st century at all regions.

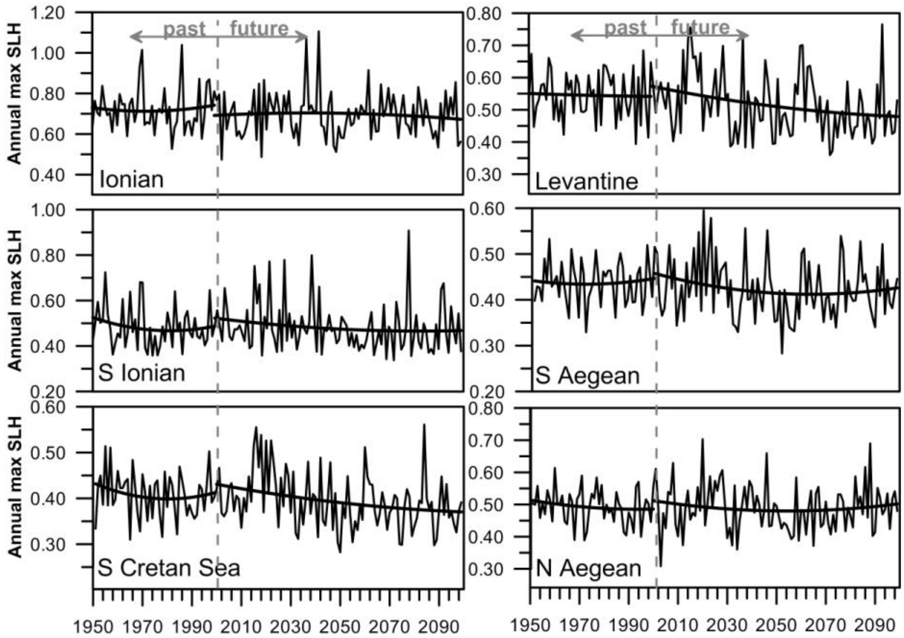

Fig. 3. Temporal evolution of annual maximum SLH (m) for the 6 regional seas of the Mediterranean (Fig. 1b); the 2nd degree polynomial trends of Past and Future Periods are indicated with a thick solid black line.

The SSI values along all coastal grid cells are calculated for the entire study period and presented in Fig. 4, showing the distribution of the potential annual maximum SLH with a 150-year return period along the entire Greek coastline. The SSI levels along the Ionian and central Aegean Sea may fluctuate around 35 cm. Extreme SSI values (>40 cm) could occur at the N. Aegean coastal zone, with the maximum values located over the northeastern area, which is in agreement with measured values during the 2002-2012 period. The SSI values for the southern Greek coasts are lower than 30 cm. Generally, it is noted that in all the Greek coasts, the SSIs range above the values of the African coastline (<25 cm).

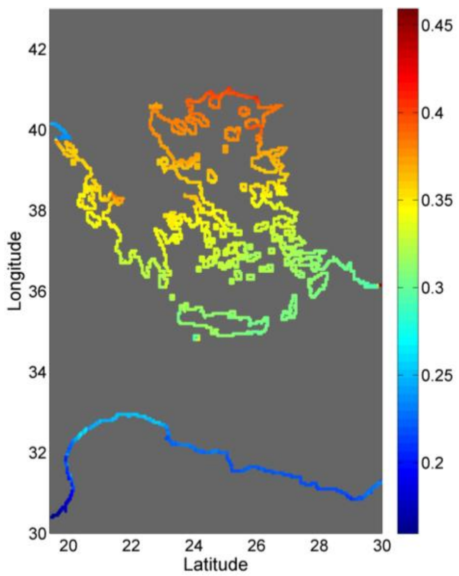

Fig. 4. Storm Surge Index (SSI, in m) along the entire coastline as derived from the 150-year GrCSM simulation.

The 95 and 99 percentiles of SLHs are presented in Fig. 5. These results show that, for the majority of the Greek stations, 5% of the SLHs may noticeably exceed the level of 16 cm, while 1% of the values may exceed 24 cm. There is a clear difference between the N. Aegean and the rest of the areas, with significantly higher values, while the percentiles also increase along the Ionian Sea, towards the North. Low values for both 95 and 99 percentiles occur at south Crete and Rhodes (Fig. 5).

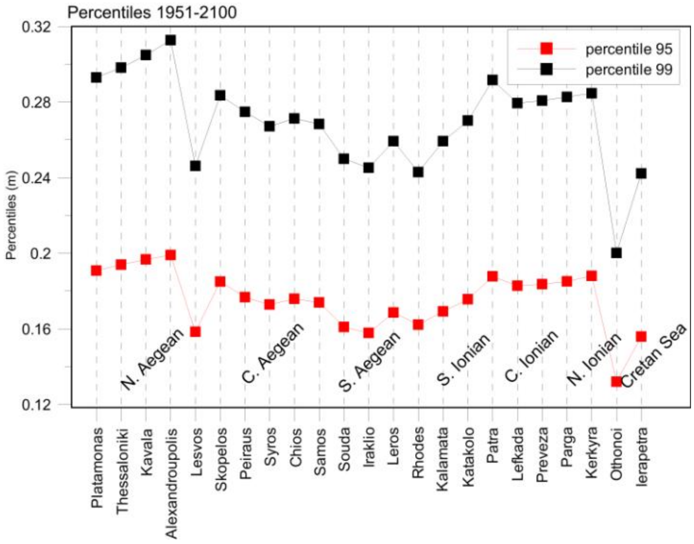

Fig. 5. Storm Surge Index (SSI, in m) along the entire coastline as derived from the 150-year GrCSM simulation.

4. Conclusions

The 150-year climate simulation under the A1B atmospheric scenario showed clear storminess attenuation for the majority of the Greek Seas. It is noted that, although the general trends for extreme events decrease, strong surge events are identified throughout the 21st century in all regional seas. Differences in the evolution of extreme values are observed between the North and South Aegean, with the northern part of the archipelago to present much stronger surges, while the lowest SLH values are observed over the South Cretan and Levantine basins.

5. Acknowledgments

This research has been co-funded by the European Union (European Social Fund - ESF) and Greek national funds through the Operational Program “Education and Lifelong Learning” of the National Strategic Reference Framework (NSRF) - Research Funding Program: “THALES. Investing in knowledge society through the European Social Fund” under the Project “CCSEAWAVS”.

6. References

Conte, D. and Lionello, P. 2013. Characteristics of large positive and negative surges in the Mediterranean Sea and their attenuation in future climate scenarios. *Global and Planetary Change*, 111, 159-173.

Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J. *et al.* (eds) 2001. *IPCC, 2001: Climate change 2001: The scientific basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge and New York, 881 pp.

Krestenitis, Y.N., Androulidakis, Y.S., Kontos, Y.N. and Georgakopoulos, G. 2011. Coastal inundation in the north-eastern Mediterranean coastal zone due to storm surge events. *Journal of Coastal Conservation*, 15 (3), 353-368.

Krestenitis, Y., Androulidakis, Y., Kombiadou, K., Makris, C. and Baltikas, V. 2014. Modeling storm surges in the Mediterranean Sea under the A1B climate scenario. p. 91-95. In: *12th International Conference on Meteorology, Climatology and Atmospheric Physics (COMECAP), 28-31 May, 2014, Heraklion, Greece. Proceedings, Vol. 2.*

Tegoulias, I., Anagnostopoulou, Ch., Tolika, K., Velikou, K. and Vagenas, Ch. 2013. Effects of regional climate model spatial resolution on 10m wind field over the Aegean Sea. p. 642. In: In: *13th EMS Annual Meeting & 11th European Conference on Applications of Meteorology (ECAM), 9-13 September, 2013, Reading, UK. Proceedings, Vol. 10.*