AN ANALYSIS OF THE EXPECTED STORM DYNAMICS IN THE BASIN OF THE BLACK SEA

Keywords: Black Sea, storms, 2050, RCP scenarios, historical data, climate change

Eugen Rusu

erusu@ugal.ro

"Dunarea de Jos" University of Galati, Romania

Department of Mechanical Engineering

1. Objectives and highlights

The proposed work has as main target the analysis of the storm dynamics in the Black Sea in the context of the climate changes. The target area is an enclosed sea basin, which might be considered as the most distant extension of the Atlantic Ocean, to which is linked via the Mediterranean Sea and various straits. A numerical wave prediction system based on spectral phase averaged models have been implemented in this sea. The spectral model considered is SWAN (Simulating Waves Nearshore), which is a third generation wave model. Extensive validations of this wave prediction system have been performed both against remotely sensed and in situ measurements. In the present work, the climatic wind fields provided by the Rossby Centre regional atmospheric model were used to force this wave modelling system for the 30-year period 2021-2050. The Representative Concentration Pathway (RCP) scenarios 4.5 and 8.5 have been taken into account. For the first RCP scenario an enhancement of the green house gas greenhouse gas emissions until 2040 is considered and a decline afterwards, while the second scenario assumes that this enhancement will continue along the entire 21st century and afterwards. Furthermore, in order to have a credible base of comparison, an analysis of the historical wind data coming from the same RCM for the past 30-year period 1987-2016 is also carried out. In this way a more comprehensive image of the expected storm dynamics in the Black Sea is provided.

2. Materials and methods

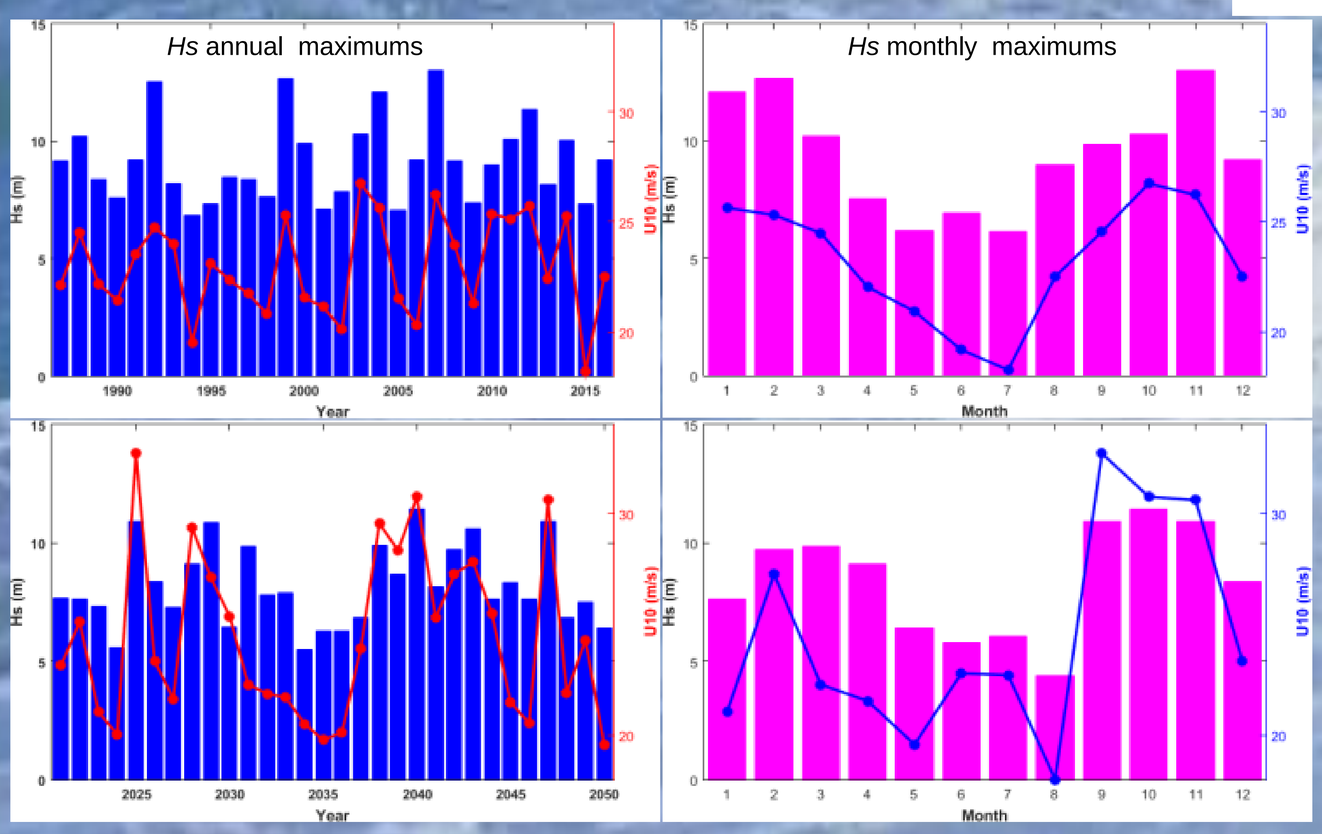
The wind fields provided in the public domain by SMHI (the Swedish Meteorological and Hydrologic Institute) resulted from the Rossby Centre regional climate model – RCA4 model (Samuelsson et al, 2011), forced with initial and lateral boundary conditions given by EC-EARTH Global Climate Model (GCM), are used in this study. The first dataset considered relates the historical wind fields that cover a 30-year period, from 1976 to 2005. The second dataset covers the 30-year interval from 2021 to 2050 and provides projections of the future wind fields simulated by the RCA4 model under RCP4.5 and 8.5 scenarios. The first scenario describes an intermediate concentration with radiative forcing stabilized at around 4.5 W/m^2 at the end of the 21st century. This is the most probable scenario, in relationship with RCP2.6 that assumes a stabilization of the emissions around 2020 or RCP8.5 according to which the emissions are supposed to increase along the entire 21st century. A wave modelling system, based on SWAN, has been implemented in the basin of the Black Sea and validated against both in situ and remotely sensed data.

Table 1

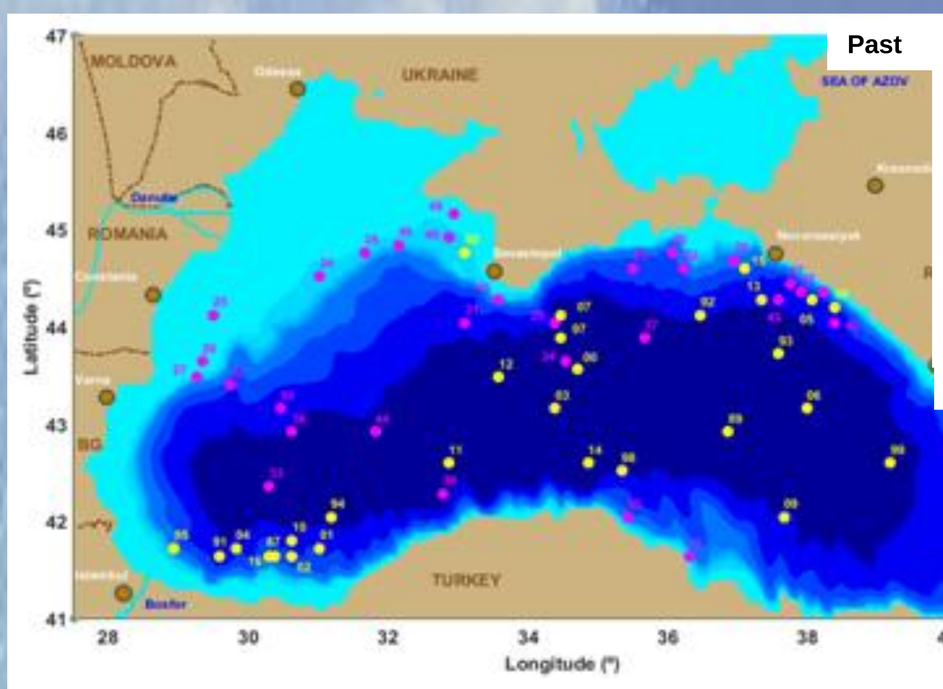
Hs statistics, SWAN against the satellite data corresponding to the time interval 1997-2016

Parameter (m)	*Bias (m)*	*RMS (m)*	*SI*	*r*	*S*	*N*
Hs – total data	0.05	0.38	0.36	0.87	0.99	1174657
Hs >3m	-0.07	0.67	0.21	0.78	1.05	23841

3. Past (1987-2016) and future (2021-2050) storm dynamics



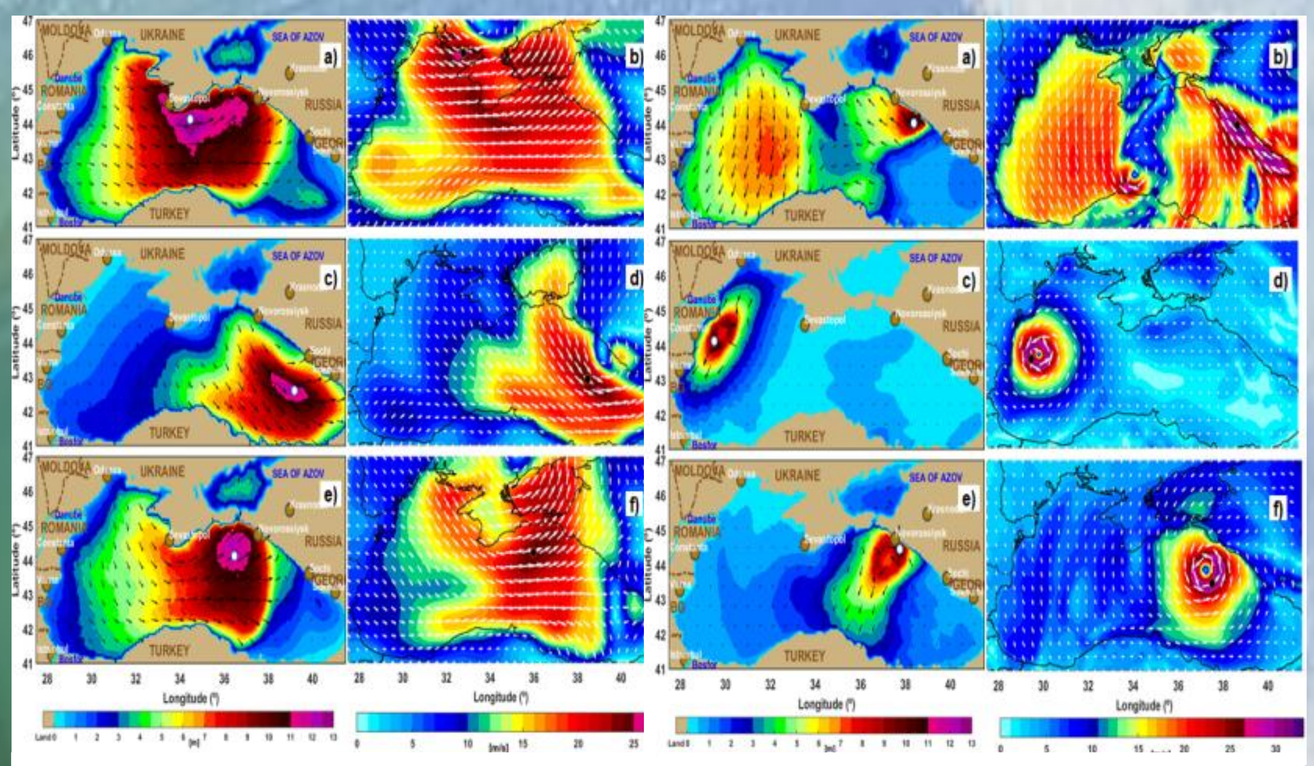
4. Results and discussions



Month	*Hs (m)*	*U10 (m/s)*
January	12.10	25.62
February	12.67	25.30
March	10.20	24.48
April	7.55	22.02
May	6.18	20.92
June	6.91	19.17
July	6.15	18.26
August	8.98	22.50
September	9.84	24.54
October	10.29	26.73
November	13.03	26.21
December	9.20	22.51

Hs (m)	*U10 (m/s)*
7.62	21.05
9.74	27.26
9.84	22.28
9.12	21.54
6.40	19.58
5.80	22.79
6.04	22.71
4.38	18.00
10.93	32.70
11.45	30.75
10.89	30.60
8.36	23.33

Geographical location of *Hs* annual maximums registered in the 30-year time interval 1987-2016, represented by yellow circles against the *Hs* annual maximums expected in the 30-year time interval 2021-2050, represented by magenta circles



Significant wave height fields (*Hs*) wave vectors and corresponding scalar wind fields and wind velocity vectors (*U10*) for the top three storms of the 30-year time interval 1987-2016. The time frames are:

a), b) 2007/11/11-h9, (*Hs*=13.03m,, U*10*=26.21m/s);
c), d) 1999/02/20-h06 (*Hs*=12.67m, *U10*=25.29m/s);
e), f) 1992/11/15-h09, (*Hs*=12.54m, *U10*=24.74m/s)

Significant wave height fields (*Hs*) wave vectors and corresponding scalar wind fields and wind velocity vectors (*U10*) for the top three storms of the 30-year time interval 2021-2050 (RCP8.,5). The time frames are:

a), b) 2040/10/28-h06; (*Hs*=11.45m, *U10*=30.75m/s),
c), d) 2025/09/27-h18; (*Hs*=10.93m, *U10*=32.70m/s)
e), f) 2047/11/11-h12., (*Hs*=10.89m, *U10*=30.6m/s).

5. Conclusions

The results show that the extreme storm waves are higher in the recent past than those expected in the near future. Thus, the annual maximum series indicates that in the period 1987-2016, there were four years with maximum significant wave heights greater than 12 meters (1992, 1999, 2004 and 2007) while in the 30-year period 2021-2050, no such situation is expected, the maximum value of the significant wave height predicted for the entire 30-year period being 11.45m. On the other hand, a substantial increase in terms of the maximum wind speed is expected in the near future, when comparing with the recent past. Thus, an increase in terms of the maximum wind speed of about 5m/s is expected while in three years the maximum wind speed would be even greater than 30 m/s, becoming close to a category 1 hurricane. An explanation is that the cyclonic forms that are often noticed in the climatic wind fields for the extreme storms expected in the near future do not favor the enhancement of the waves, because of the sudden changes in the wind direction. Such wind behavior limits the fetch over which the extreme waves are generated and that is why the substantial enhancements in terms of the wind speed are not followed by an increase in terms of significant wave height. Furthermore, from the analysis of the results another tendency that is noticed for the near future period is a migration of the peak storms from the southwest and the center of the sea in the west and north, coming closer to the coastal environment in the northern part of the Black Sea.

Acknowledgement: This work was carried out in the framework of the research project Assessment of the Climate Change effects on the WAve conditions in the Black Sea - ACCWA (PN-III-P4-ID-PCE-2016-0028), granted by the Romanian Ministry of Research and Innovation, CNCS – UEFISCDI.