THE STORMINESS AND THE WIND WAVE CLIMATE IN THE BALTIC SEA PRODUCED BY THE SWAN MODEL

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INTRODUCTION

Nowadays the study of natural hazards such as storm waves is one of the most essential problems of oceanology. The analyze of wind wave climate helps to forecast the impact of future climate changes. Wind waves have great importance for shipping, constructing on coasts and shelf, developping oil and gas fields. The Baltic Sea is a challenging area for wave scientists. A combination of its relatively small size (that virtually excludes the presence of long-period remote swells), extremely complex geometry and high variability in the wind fields naturally leads to widespread variability in the wave fields in both time and space. In present study to estimate decadal and interannual changes of the wave fields for the entire Baltic Sea the wave parameters, such as significant wave heights and periods, were simulated for the period 1948–2011 years using model SWAN (Simulating WAves Nearshore). To estimate the accuracy of the model the statistical characteristics, such as correlation coefficient, bias, scatter index and RMSE were calculated. Such extreme characteristics as wave height possible once in 100 years and significant wave heights with 0.1, 1, and 5-% probability were obtained. It was revealed that the storminess of the Baltic Sea tends to increase and the twenty-year periodicity with the increase in the 70-s and 90-s years of XX century.

METHODS

In this study to estimate decadal and interannual changes of the wave fields for the entire Baltic Sea the third generation spectral wind-wave model SWAN and the data fields of wind reanalysis NCEP/NCAR were used (http://www.esrl.noaa.gov/psd/data/reanalysis/reanalysis.shtml). The parameters of the wave fields, such as significant wave heights and periods, were simulated for the period 1948 – 2011 years. Time step of wind forcing is 6 hours and computations of wave generation were done for every hour. Space resolution of reanalysis is ~1.9×1.9° and the final computational grid for the Baltic Sea is 0.05×0.05°.

The simulated data were compared with instrumental data of the Sweden buoys (http://www.smhi.se/ecds), with the results of operational regional models and with the results of other similar numerical experiments (Blomgren *et al*., 2001; Kriezi, Broman, 2008; Saremi, 2010; Soomere *et al*., 2008). To compare obtained NCAR results a few numerical experiments were realized using another reanalysis NCEP/CFSR (http://cfs.ncep.noaa.gov/cfsr/) with time resolution 1 hour and space resolution ~0.3125×0.3125° and using different mechanisms of wave generation from SWAN model (http://swanmodel.sourceforge.net).

CONCLUSIONS

The SWAN model usually underestimates the significant wave heights and peak periods. The statistical characteristics were calculated to estimate the accuracy of the model. The correlation coefficient between simulated and instrumental data was high enough (tab. 1). The calculated values belong to the average range of the statistical characteristics according to previous studies of different authors (Blomgren *et al*., 2001; Kriezi, Broman, 2008; Saremi, 2010; Soomere *et al*., 2008). It allowed us to use SWAN with NCEP/NCAR Reanalysis wind forcing for research of the climatic variability of wind waves of the Baltic Sea. But numerical simulations using CFSR reanalysis shows evidently better results (fig. 1). The question, which generation mechanism is better for the Baltic Sea is debatable. For example in the deep ocean mechanism GEN3 (http://swanmodel.sourceforge.net) is more adequate, but in the shallow water errors are more negligible for the mechanism GEN1.

Regime average and extreme maximum and minimum characteristics of wind waves for the Baltic Sea were calculated and analyzed. Such extreme characteristics as the significant wave height possible once in 100 years exceeded 13 m in the Baltic Proper, in the East Gotland Basin. This region of the Baltic Sea is characterized by the most intensive storm activity due to the trajectories of cyclones crossing this area. The significant wave heights with 0.1, 1, and 5-% probability for the Baltic Proper were identified as 5-5.4 m, 3.2-3.6 m and 2.2-2.4 m respectively.

The wave climate of the Baltic Sea is characterized by specific features, such as: very instable character, localization of the period of strong storms in autumn and winter months, significant spatial and temporal variability of the wave properties, predominance of relatively short and steep waves, existence of waves with such heights as in much larger Mediterranean Sea (Soomere, 2008). The storm situations, when the significant wave height exceeded 2 meters, were identified for the 64-year period. In total the quantity of the storm situations was more, then 2900 cases, of about 50 storms per year happened in the Baltic Sea in this time period (fig. 2). The storminess of the Baltic Sea tends to increase (according to the linear trend). The typical time interval periods of the wave activity increase is 10–12 years. In the 1970s and 1990s, the activity was quite intensive, and in the end of 1980s and in the middle of 2000s it was low. In this work twenty-year-periodicity was revealed, which includes a ten-year increase and a ten-year decrease of the storminess. The average yearly significant wave height rises in the second part of the century too and varies from 2.4 to 3.3 m, but there is no such clear periodicity as for the quantity of the storm situations.

Storm cyclones are connected with the global atmosphere circulation patterns. According to similar research of the other west seas .of Russia, which were done in the Natural Risk Assessment Laboratory (Arkhipkin *et al*., 2014; http://www.nral.org/ru/) by the same methods, such kind of twenty-year periodicity was revealed for the Caspian Sea and the Sea of Azov. For the Black Sea there is no such clear correlation, but the connection with the NAO index (November–March) shows that periods with the lowest NAO index are accompanied by higher storminess. Such task for the Baltic Sea will be solved in future study. In contrast to the Baltic Sea the storminess of the Caspian Sea and the Sea of Azov tends to decrease, and for the Black Sea – there is no evident trend. To understand mechanisms connections between the storm features and the global atmospheric circulation is planned in future researches.

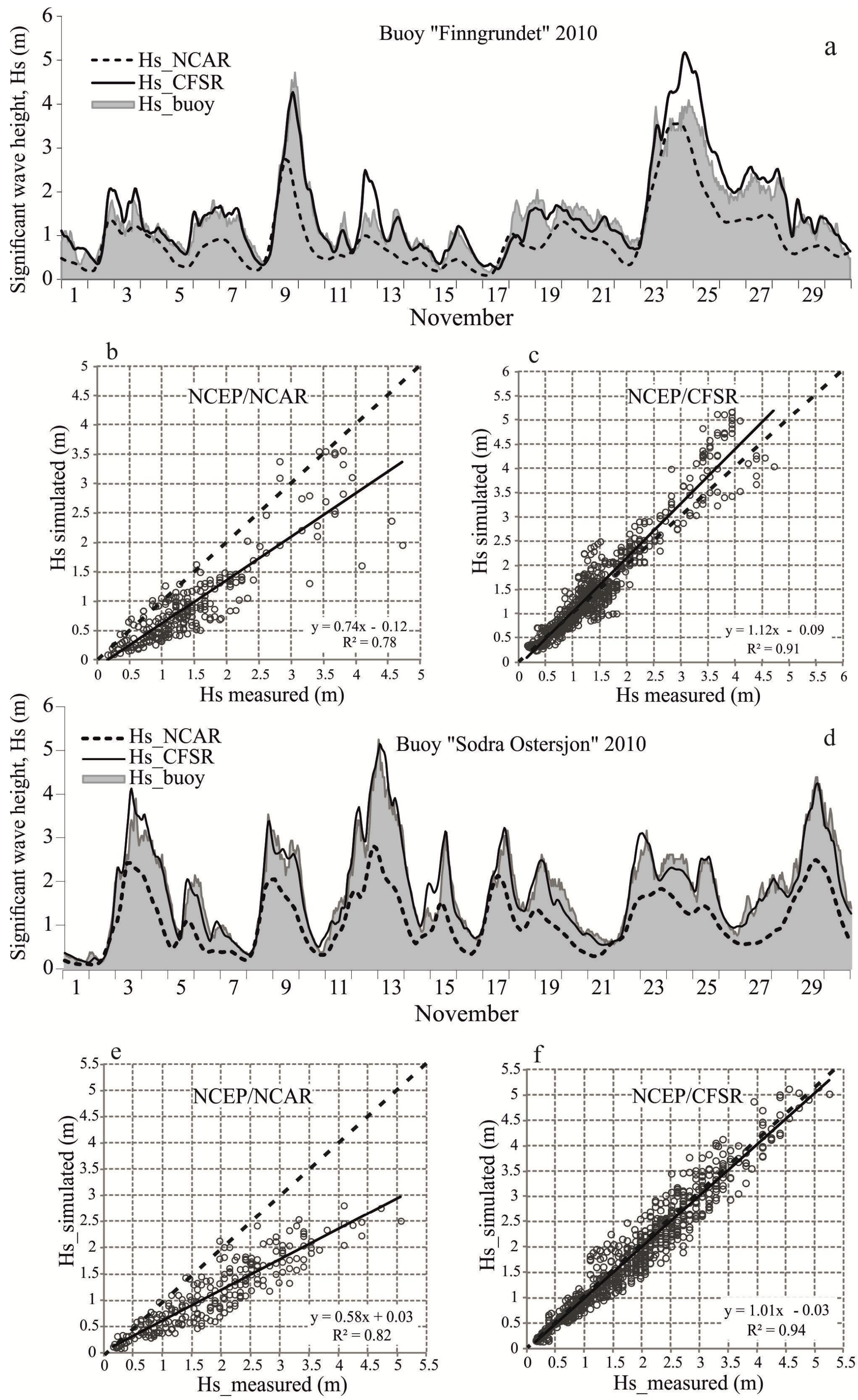

Figure 1. Comparison of measured and simulated data for November 2010 for Finngrundet buoy (a), scatter diagrams (b, c), where *y* is linear equation, R^2 is the coefficient of determination; and for Sodra Ostersjon buoy (d, e, f)

Reanalysis	Mechanism of wave generation	R	Bias	RMSE	SI
Finngrundet buoy (30.6 m) 18.67° N, 61.00° E - November 2010					
NCAR	GEN3/ 1 hour	0.884	-0.498	0.645	0.447
	GEN3/ 15 min	**0.953**	0.083	0.335	0.232
	GEN3/ 30 min	0.944	0.047	0.344	0.239
	GEN3/1 hour	0.878	-0.047	0.459	0.318
	GEN2/ 1 hour	0.950	0.069	0.291	0.202
CFSR	GEN1/1 hour	0.949	**-0.025**	**0.274**	**0.189**
Sodra Ostersjon buoy (111.7 m) 18.78° N, 55.92° E - November 2010					
NCAR	GEN3/ 1 hour	0.908	-0.730	0.889	0.487
	GEN3/ 15 min	**0.967**	**-0.003**	**0.272**	**0.149**
	GEN3/ 30 min	0.959	-0.060	0.303	0.166
	GEN3/1 hour	0.920	-0.180	0.443	0.243
	GEN2/ 1 hour	0.943	-0.041	0.354	0.194
CFSR	GEN1/1 hour	0.946	-0.157	0.367	0.201

Table 1. Comparison between measurements and modeled data

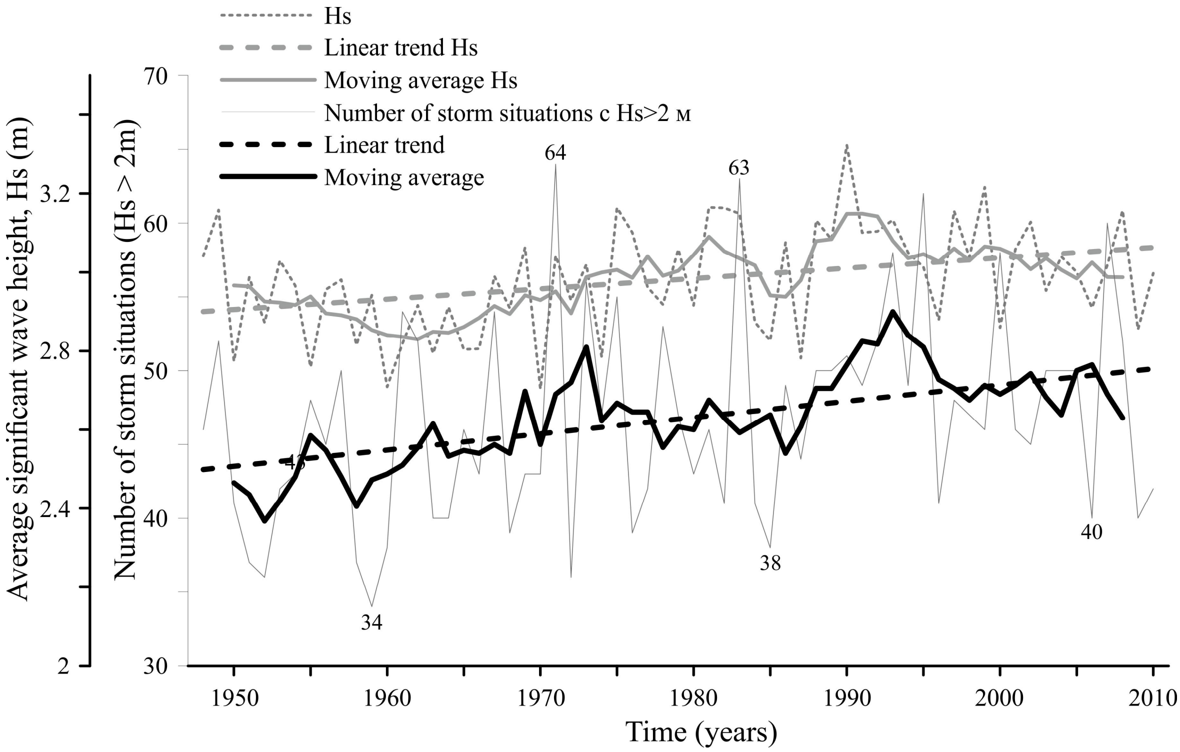

Figure 2. Number of storm situations and the average Hs from 1948 to 2010

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REFERENCES

Arkhipkin V.S., Gippius F.N., Koltermann K.P. and Surkova G.V. (2014). Wind waves in the Black Sea: results of a hindcast study. *Natural Hazards and Earth System Sciences Discussions* 14. P. 2883–2897

Blomgren S., Larson M., Hanson H. (2001). Numerical Modeling of the Wave Climate in the Southern Baltic Sea. *Journal of Coastal Research*. V. 17. № 2. P. 342-352.

Kriezi E.E., Broman B. (2008). Past and future wave climate in the Baltic Sea produced by the SWAN model with forcing from the regional climate model RCA of the Rossby Centre. US/EU-Baltic International Symposium, 2008 IEEE/OES. IEEE (Tallin, Estonia). P. 1-7.

Saremi S. (2010). *Development of a wave database in coastal areas around Sweden using the SWAN wave model: evaluation of the influence of grid resolutions and bathymetric data*, (Chalmers University of Technology, Gothenburg, Sweden).

Soomere T., Behrens A., Tuomi L., Nielsen J. W. (2008).Wave conditions in the Baltic Proper and in the Gulf of Finland during windstorm Gudrun. *J. Natural Hazards & Earth System Sciences*. V. 8. № . P. 37–46.

http://cfs.ncep.noaa.gov/cfsr/

http://swanmodel.sourceforge.net

http://www.esrl.noaa.gov/psd/data/reanalysis/reanalysis.shtml

http://www.smhi.se/ecds