

Abstract

Of all storm events taking place in the Gulf of Gdańsk, only selected few are characterized by a set of properties that makes them critical for this area in the southern Baltic Sea. Events extreme with regard to the integral wave parameters, particularly wave heights, are of interest for several reasons. These events are highly dynamic processes, influencing many aspects of marine environment as well as marine-atmospheric boundary layer. On the other hand, institutions managing and protecting the coastal zone and safeguarding human safety on the sea, are keenly interested in the description of wave events critical to the most vulnerable areas. With changes observed in the natural environment due to the climate change, study of past storminess gives better understanding of the effects of climate variations on severe wave events. The analysis of storm events is typically focused on the wind extremes or effects observed in the coastal zone. Less emphasis, however, is placed on the sea state away from the shores. Empirical orthogonal function (EOF) analysis is widely used in earth sciences to present spatial patterns of environmental parameters, together with principal components representing their temporal variability.

In the presented doctoral dissertation, results of EOF analysis used on the fields of atmospheric pressure and wind speed are analysed in order to assess whether this technique can be used to identify meteorological characteristics of extreme wind wave events in the Gulf of Gdańsk and to describe these characteristics in comparison with typical conditions. Additionally, statistical analysis of modelled data presents wave climate of the Gulf of Gdańsk in the second half of the 20th century.

Results of numerical modelling of sea level atmospheric pressure, wind speed fields and wind wave fields over the Baltic Sea for years 1958–2001 were used in this work. Statistical analysis was performed, including analysis of spatial and temporal (multi-year and seasonal) changes in wind wave parameters: significant wave height, mean period and mean direction of wave propagation. Typical meteorological conditions were presented based on the results of the EOF procedure used on the fields of meteorological parameters. Observed, seasonally variable, anomaly of air flow was correlated with air flow directions resulting from pressure fields connected with large scale circulation patterns, i.e. NAO, AO, SCAND and others. Then, extreme storm events based on the significant wave heights were selected in the spatially variable areas within the Gulf of Gdańsk. Characteristics of meteorological parameters during these events, present in the EOF modes were presented. Similar properties between selected events were identified based on the number of parameters, for instance spatial distribution of integral wave parameters, evolution of principal components both for fields of pressure anomaly and wind direction anomaly and track of low pressure centres generating high pressure gradient and storm wind speeds.

This study shows that Empirical Orthogonal Function technique can be successfully used to identify characteristics of natural phenomena based on the fields of its drivers. Several areas in the north-eastern Europe are characterized by the largest anomalies of atmospheric pressure during storm events in the Gulf of Gdańsk, for instance the central part of the Scandinavian Peninsula, and region to the east of the southern Baltic Sea. Analysis of principal components of both atmospheric pressure and wind field anomalies, confirms what was present in the spatial distribution of integral

wave parameters, namely the presence of two groups of extreme storm events in the Gulf of Gdańsk, for which the evolution of the subsequent EOF patterns is different. Moreover, while the intensity of the wind speed anomaly is mostly governed by the properties of the Baltic Sea, the anomaly of air flow direction seems to depend, at least in part, on the large-scale circulation occurring on the larger scale than the Baltic Sea itself. In general, extreme storm events with regard to the wind waves in the Gulf of Gdańsk can be characterized by several coherent characteristics which distinguish them from typical conditions. Analysis of storm events was extended by identifying paths of low-pressure systems that result in high wind speeds in the region. Here, two main pathways of low-pressure systems were identified.

Presented statistics of distribution of integral wave parameters in the Gulf of Gdańsk in the second half of the 20th century can be used as a reference point in the wide array of applications, for instance in the modelling of changing conditions with observed climate variability.