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The Recent Extreme Sea Waves affecting the Black Sea

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Abstract

Extreme wave conditions on the oceans and seas affect both transportation and offshore or coastal structures. Recently, several researches and national sources have shown that some sea storms with destructive effects have been observed in the Black Sea. These storms could have a negative impact on increasing coastal use in recent years and also cause significant damage. For this reason, just like in the Black Sea, good knowledge of sea wave conditions in our seas is extremely critical in order to carry out these activities appropriately. This study aims at investigating several important storms announced by some researchers and/or national publications in the Black Sea in recent years using wave estimates from wave prediction models developed in our previous studies. The following events have been analyzed in this study: February 6th, 2012 storm that caused damage to Karasu beach in Sakarya, September 23, 2014 storm that led to serious problems on Zonguldak coasts and February 5, 2016 storm at İnebolu Harbor. The formation and development of the storms were determined and heights of waves affecting the shore were estimated. As a result, estimation and monitoring of the risks that the coast areas may be exposed to, using the developed model, is considered.

Key words: Extreme waves, storms, waves, Black Sea

1. Introduction

The Black Sea has of recently seen a substantial boost in activities like commercial ports, transportation harbors, pipelines for fuel, as well as many kinds of infrastructure intended for recreation or tourism. These activities are taking place, both on the shoreline and areas surrounding the shoreline. Recently, several researches (for instance [1]) and national sources have shown that some sea storms with destructive effects have been observed in the Black Sea. These storms could have a negative impact on increasing coastal use in recent years and also cause significant damage. It is important to know the maximum wave heights that can be generated by analyzing the extreme wave conditions. Designs and plans can be made according to these conditions to prevent damages in storms. Three different storms have been investigated in this study, which have been observed in recent years and are the subjects of the news about damage to coastal areas. The first of these storms hit the Karasu shores on the 6th of February, 2012 in the province of Sakarya. According to the report given in [2], the storm damaged the shore and coastal structures. The other storm was observed on the shores of Zonguldak on September 23, 2014. At this time, high waves were seen on the shore, and even waves that exceeded harbor's breakwater were declared in [3]. Among the extreme wave conditions examined, the current one is the storm that affected the Port of İnebolu on 5 February 2016. According to the information given in the news [4], the waves reached into the harbor and the coast road.

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The storms were modeled using the 41.20 version of the SWAN, 3rd generation wave model. Information on the model setup and all the settings are available in [5]. In addition, the calibration and verification steps of the used model are presented on the same article. At 10 m level NCEP Climate Forecast System Version 2 (CFSv2) data was used as the wind input in the model. The time resolution of the wind data is 1 hour and the spatial resolution is 0.205 x 0.204 degrees. Bathymetric data at 30 arc-seconds resolution was obtained from GEBCO (General Bathymetric Charts of the Ocean). The model was established with this data and firstly point output data were taken near the mentioned shores. By creating time series with point data, storm times and wave heights at those points (Fig. 1 and Table 1) are determined. Then, the spatial maps generated and the formation and propagation of storms has been examined. With the help of these plots, the spatial and temporal development of the storms can be seen.

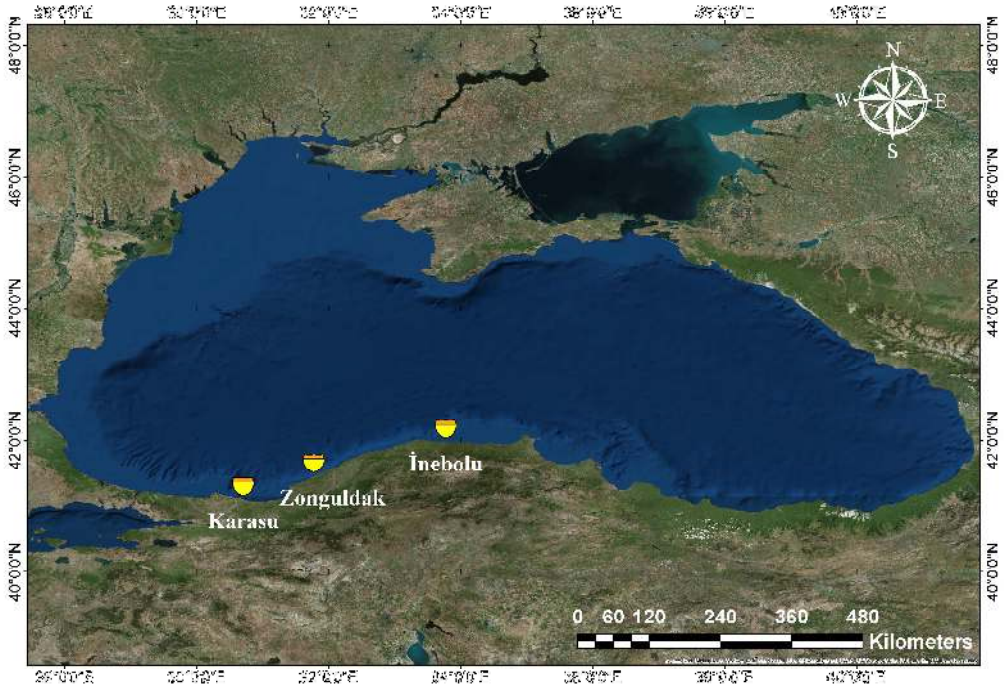

Figure 1. The locations selected in the south western coasts of the Black Sea for the analysis

Table 1. The coordinates of the points taken at a slight open to the coastal zones affected by the storms

Locations	Longitude (º E)	Latitude (º N)
P1 (Karasu)	30.709	41.135
P2 (Zonguldak)	31.776	41.491
P3 (İnebolu)	33.777	42.005

2. Results and Discussion

Firstly 2-month simulations including the storm period were examined in order to see how the storms reached the mentioned coastal regions. Time series were evaluated by taking point data at a location open from the coast with a depth of 20 meters. Fig. 2 shows the time series of H_{m0} data taken at the point determined near the Karasu coastal area. Waves approaching 3.5 m have been observed at the end of January, but it seems that the high storm started on February 6th. In this storm, the wave height has reached 5 m. The spatial maps showing just before and after the storm reaches its peak value is presented in Fig. 3. The spatial maps are plotted at intervals of 6 hours in order to better observe the change of H_{m0} values and the propagation of the waves. When the storm examined from the beginning, waves from the north-east direction appear to have forced the Black Sea's south-western region. Because the fetch distance is too much in that direction, the winds cause high waves to occur. It is seen from these plots that waves are around 4.5 - 5 m near Karasu shores at the peak time of the storm (20120208 at 00:00). Later, the wave heights are reduced, probably due to the loss of the effect of the winds.

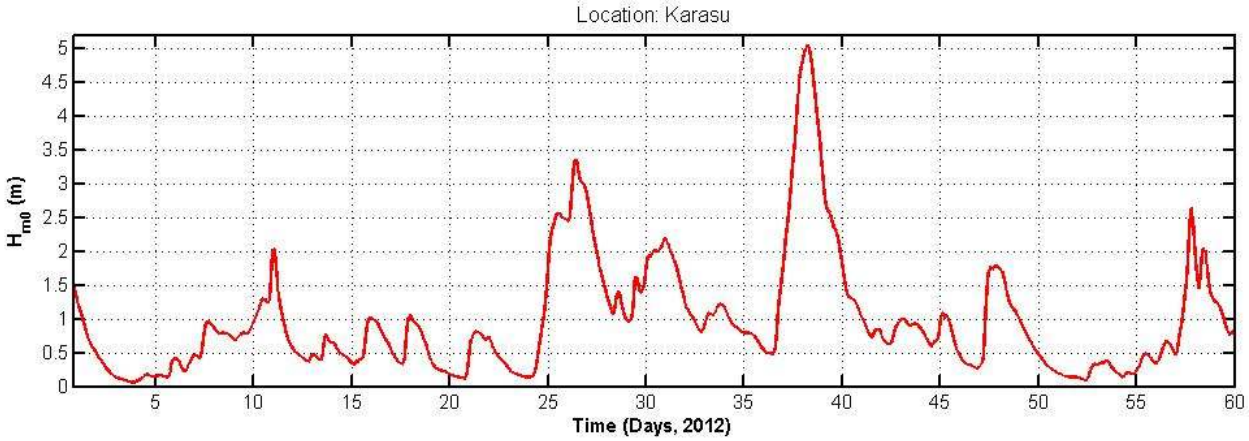

Figure 2. Time series of the simulated H_{m0} values from 01/01/2012 at 00:00 to 02/28/2012 at 23:59 including the storm period at the offshore point near the Karasu coast

Fig. 4 presents the time series of wave heights observed in the Zonguldak coasts in August and September 2014. Although the Zonguldak coasts did not have very high waves, it was determined that a wave of 1.5 to 2.5 m occurred in there. It has been determined that the sea level, which can be described as the storm starting on 23 September, has reached a wave height of 2.5 m. Spatial plots showing the progress of the storm are given in Fig. 5. The waves that developed in the northeast of the Black Sea and advanced in the east direction affected the shores of Zonguldak. Waves between 2 and 2.5 m high were observed near the shore. In the spatial plots, waves which exceed 3 meters are found in the locations slightly far from the shore than the point determined.

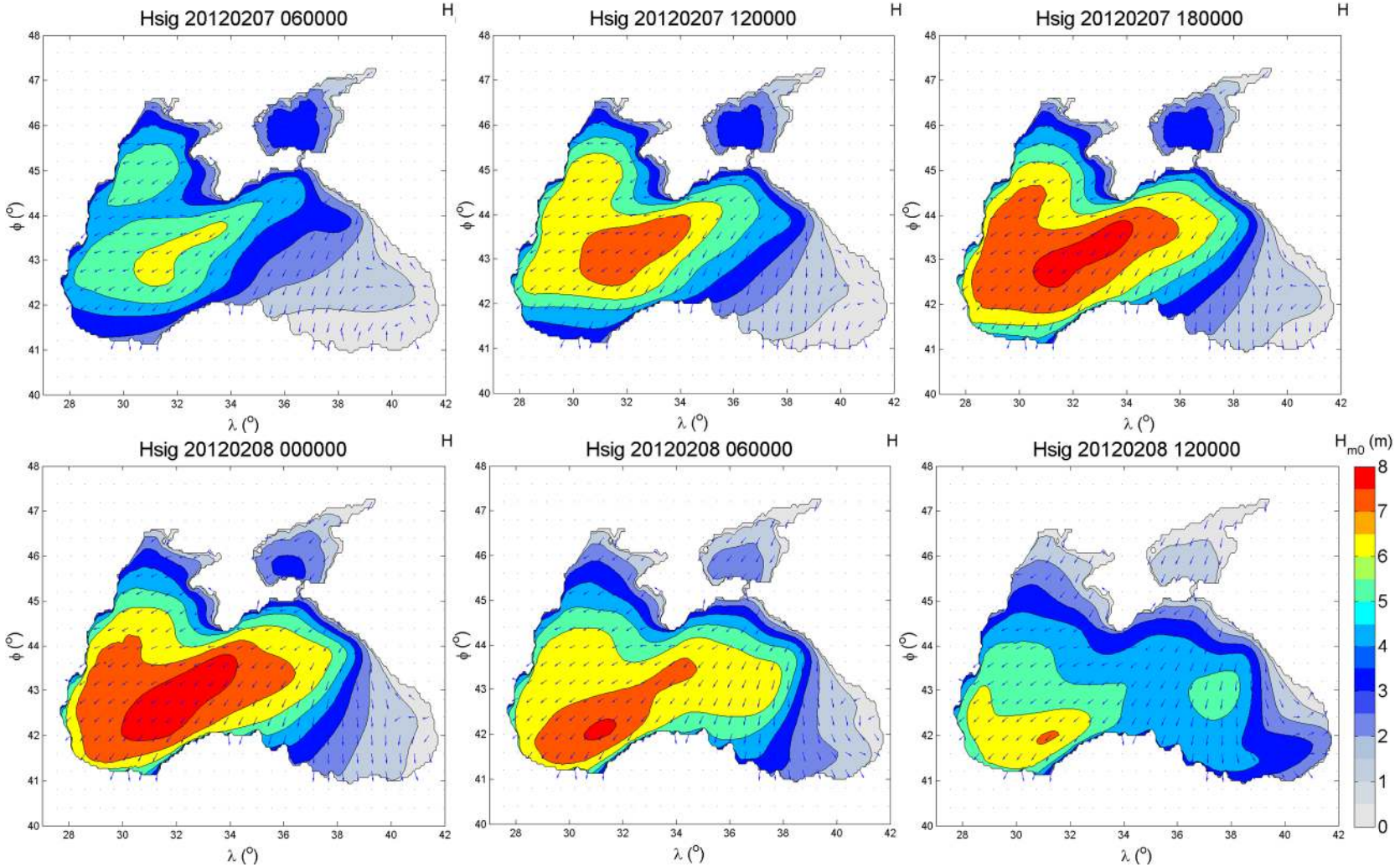

Figure 3. Spatial and temporal development of simulated H_{m0} of the storm on the offshore affected on Karasu coast in February 2012

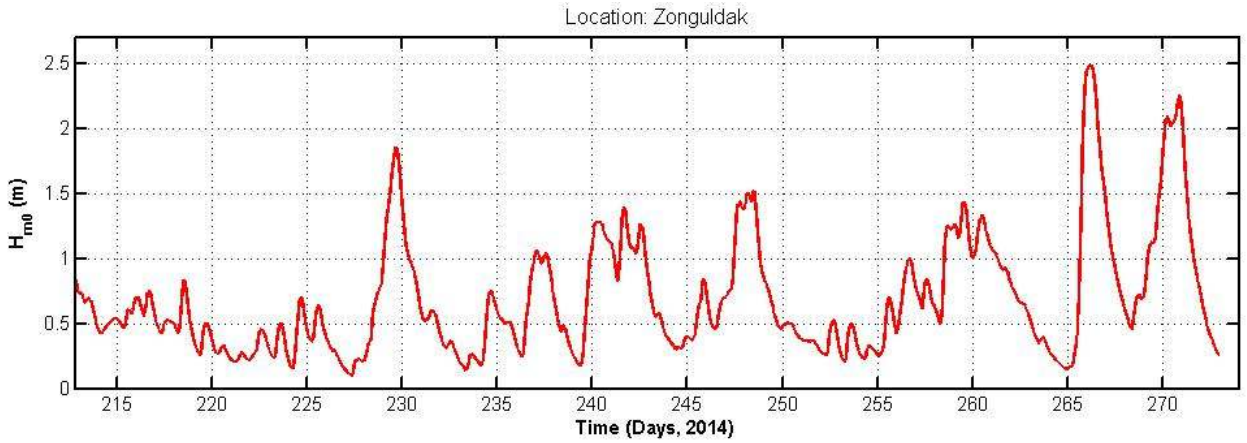

Figure 4. Time series of the simulated H_{m0} values from 08/01/2014 at 00:00 to 09/30/2014 at 23:59 including the storm period at the offshore point near the Zonguldak coast

Fig. 6 shows the time series of waves occurred in January and February 2016. The storm, with the highest waves during the current period, began on 5 February. The wave height at the peak time of the storm is over 2.5 meters. The plots showing the spatial and temporal development of the storm are given in Fig. 7. The development of the storm can be seen with plots at intervals of 6 hours. Similar to the Karasu storm in 2012, waves from the north-east direction reached the shores of the Inebolu coast. When the storm peaked (20160205 at 21:00), waves of around 5.5 m in different locations were formed, and waves at about 3 m height near İnebolu were observed. Later, the storm lost its influence in the south-western part of the Black Sea and began to force the southeastern regions.

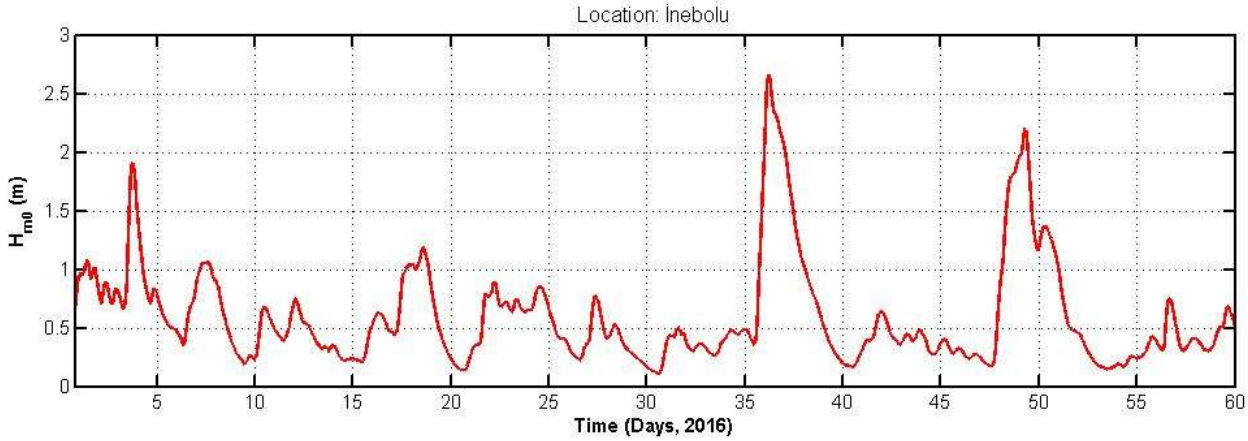

Figure 6. Time series of the simulated H_{m0} values from 01/01/2016 at 00:00 to 02/28/2016 at 23:59 including the storm period at the offshore point near the İnebolu coast

It has been determined how the waves reach the shores by examining wave formation and propagation in 3 different storms. This study only gives information on the progress of the storm. The development of winds should also be examined to understand what phenomenon is affecting the development of the storm. Spectral analysis is also important. These analyzes will be carried out by including different storms in future studies.

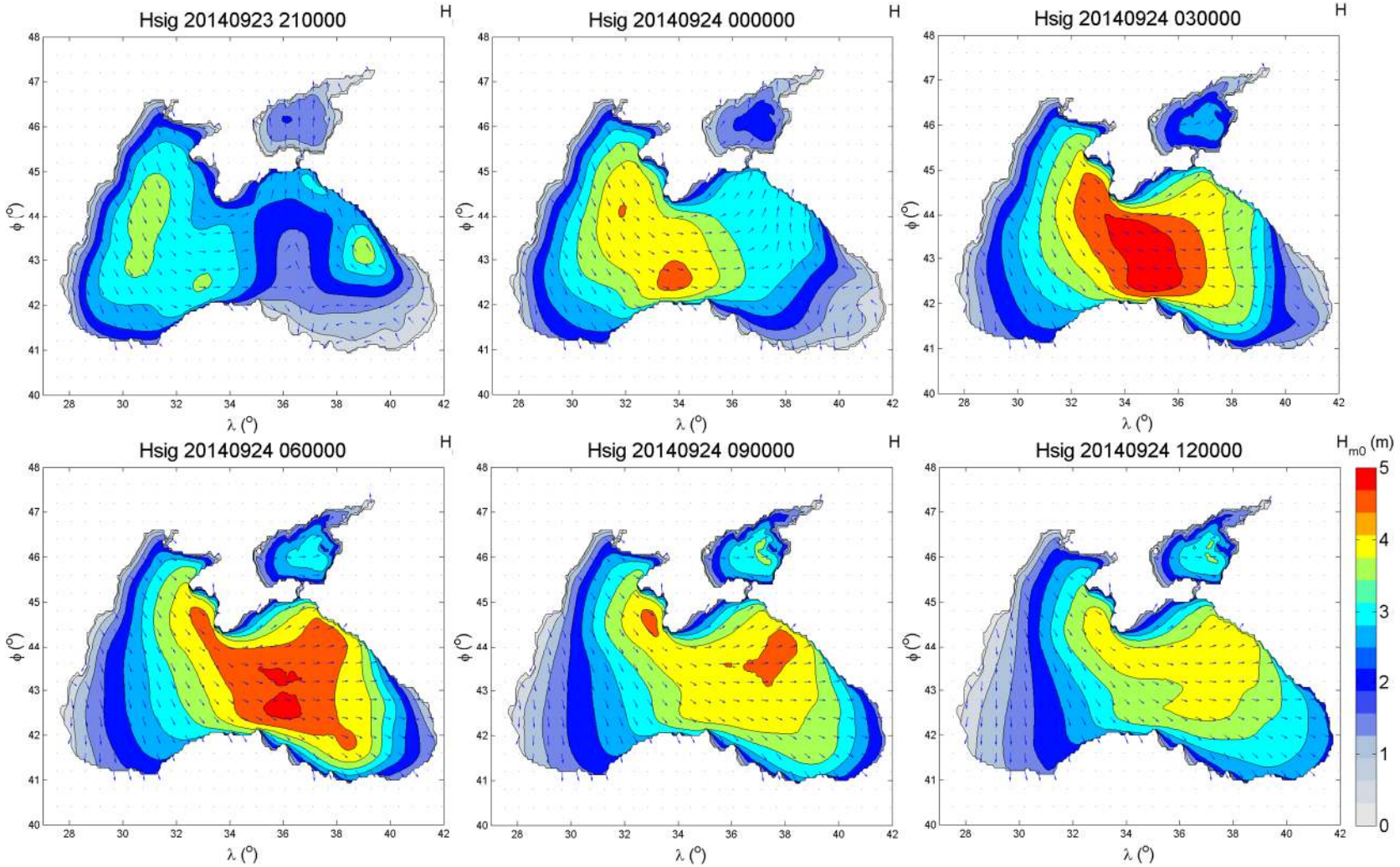

Figure 5. Spatial and temporal development of simulated H_{m0} of the storm on the offshore affected on Zonguldak coasts in September 2014

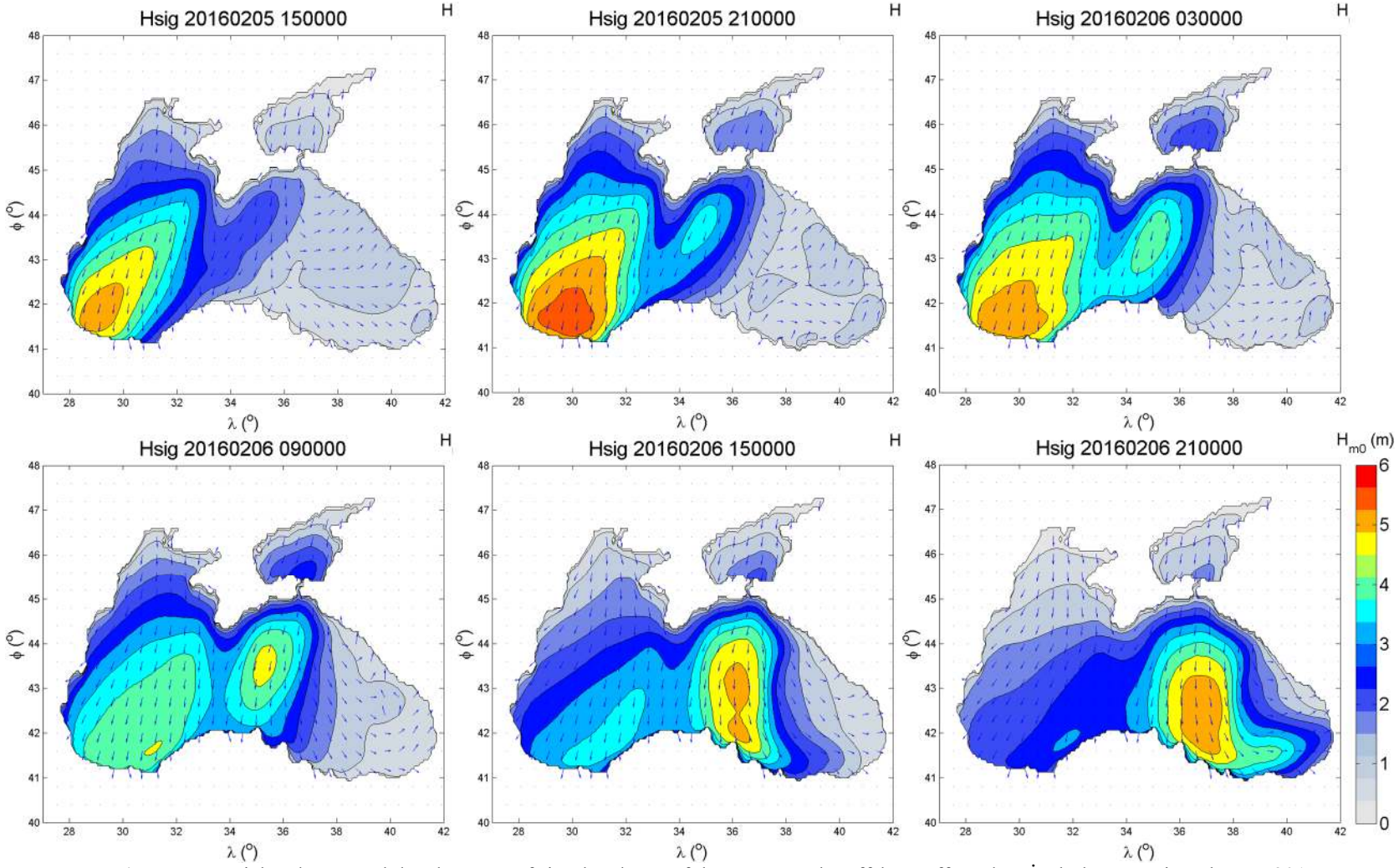

Figure 7. Spatial and temporal development of simulated H_{m0} of the storm on the offshore affected on İnebolu coasts in February 201

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