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ANALYSIS OF HYDROMETEOROLOGICAL CONDITIONS IN THE SOUTH BALTIC SEA DURING THE STORMY WEATHER ON 27TH NOVEMBER, 2016

ABSTRACT

The paper presents results of research concerning hydrological and meteorological conditions during the stormy weather on 27th November, 2016 in the South Baltic Sea and over the Polish coast. The wind which occurred the South Baltic Sea at that time reached the force of 7 Beaufort degree and in gusts 8 to 9 Beaufort degree. The south part of the Baltic Sea was affected by the low pressure system (981 hPa) which the centre was situated in South Finland and Northwest Russia. Some destroys were observed on the Polish coast line and in ports of the Gdansk Bay. The analysis is concerned on the wind force, the wind direction, the atmospheric pressure and the sea water level in some places of the Polish coast line and especially in the Gdansk Bay.

Key words:
sea water level, weather conditions, the South Baltic Sea.

INTRODUCTION

Occurrence of strong winds in the area of the Baltic Sea and on the Polish coast is related mainly with active cyclones. This means that the strong winds zone is of the synoptic scale, i.e. it extends in an area of over 500 NM across and it lasts for a few days. Storms cause serious difficulties or they are even threats to safety of sea navigation and work in harbors. They often destroy hydrotechnical devices and coast facilities. Although only a part of the storms are classified as extreme ones,

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climatological studies indicate that they are relatively frequent on the Baltic Sea. Hydrometeorological support of sea navigation is therefore an important task aimed also to reduce the risk of victims and losses. Direct hydrometeorological and remote sensing measurements results become more and more common data applied to detecting, monitoring and forecasting processes conductive to storms development [3].

On 23rd November, 2016 over the waters of Newfoundland's Bank has created a low-pressure system with a value of 998 hPa, which quickly moved to the Straits of Denmark, initially filling, and then, after passing north of Iceland it was deepening to the value of 985 hPa. From Iceland route of movement of that low was throw the North Atlantic towards the Norwegian Sea, the Scandinavian Peninsula, the North Botnic, Finland, around Saint Petersburg and Russia. Over Finland and Russia the pressure dropped to 981 hPa, and then began to increase to 995 hPa and filled up and disappeared over the territory of Russia. The route of movement of this low--pressure system from the Newfoundland Bay throw the North Atlantic Ocean and European continent content from 23th November, 2016 to 28th November, 2016 is illustrated in figure 1.

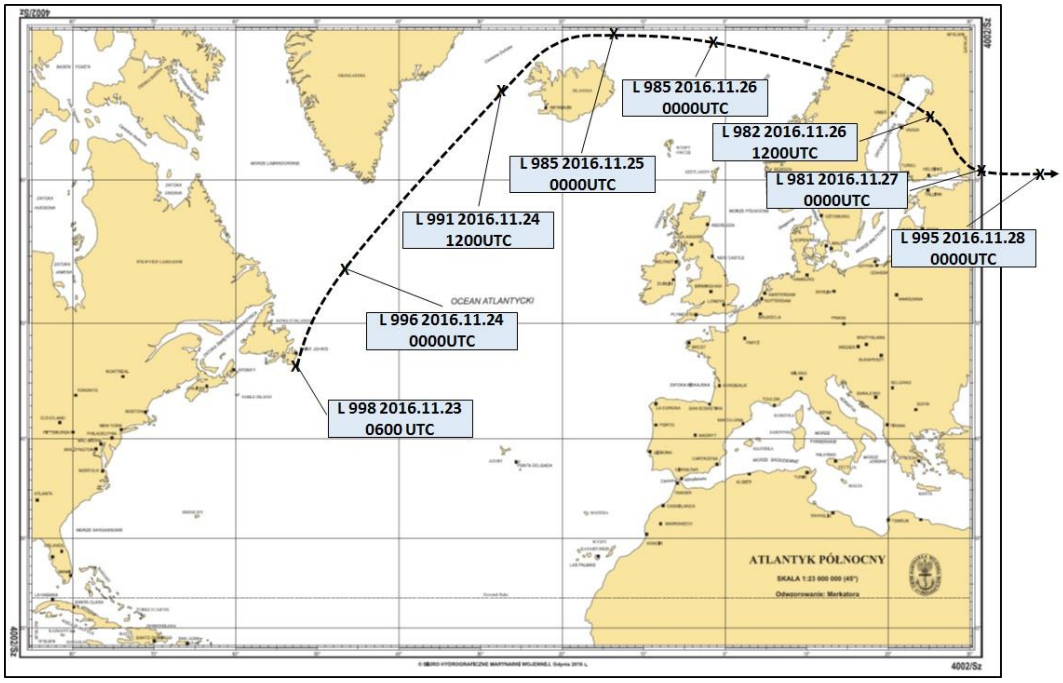

Fig. 1. The route of the low-pressure system on the North Atlantic Ocean and the European continent from 23rd November, 2016 to 28th November, 2016 [own work]

Moving low-pressure system analysed by the Scandinavian Peninsula, the Gulf of Bothnia, Finland and Russia it was accompanied throughout the waters of the Baltic Sea occurrence of strong winds and high waves. Stormy weather occurred over all waters of the Baltic Sea.

On the development of that weather on the waters of the South Baltic and the Polish coast during this type of circulation is affected by the air mass coming from the north-west and then north. This type of weather is most common in autumn and winter. It is caused by the influx of polar-sea air with the Norwegian Sea and North-East Atlantic. Winds north-western reaches of speed 10–15 m/s and more, cloudy is mostly complete.

DATA AND METHODS

In November 2016 a mobile hydrometeorological stations located at the Polish Naval Academy in Gdynia (laboratory METOC) recorded four minimum values of atmospheric pressure (2nd, 8th, 18th and 26th November, 2016), which shows the barogram located in figure 2. The figure of the atmospheric pressure includes the observation period from 1st November to 1st December, 2016 year. At the end of the month of November it occurred minimum, which reached its lowest value on 2nd December, 2016 and therefore is not subject to assessment.

The article is subjected to analysis last November the pressure drop due to the direction and strength of the wind, which occurred in the southern part of the Baltic Sea, and in particular on the Polish coast. The minimum pressure was recorded at the mobile hydrometeorological station on 27th November, 2016 was 1000.1 hPa, and the minimum monthly value in November reached 993.8 hPa (5th November, 2016). Winds on 27th November, 2016 fluctuated within the range NW-N, and his strength reached force of 6°B to 9°B. Long-term wind from northern direction in the Southern Baltic Sea gives rise to the phenomenon of raising the water level. The water level in the relevant waters is not directly related to the surge, but the effect of wind on the sea surface is the process of wind waving.

The wind speed and directions in the Southern Baltic Sea (over the Polish coast line) are shown in figure 3 on the surface analysis chart of the UK Meteorological Office on 27th November, 2016 1200 UTC. The low pressure system with 985 hPa was situated at that time E of Saint Petersburg (Russia) and its influence on the Southern Baltic Sea and the Polish coast line was extremely strong by the direction and force the wind. The Polish coast line at that time was influenced by NW-N wind force of 6°B to 8°B.

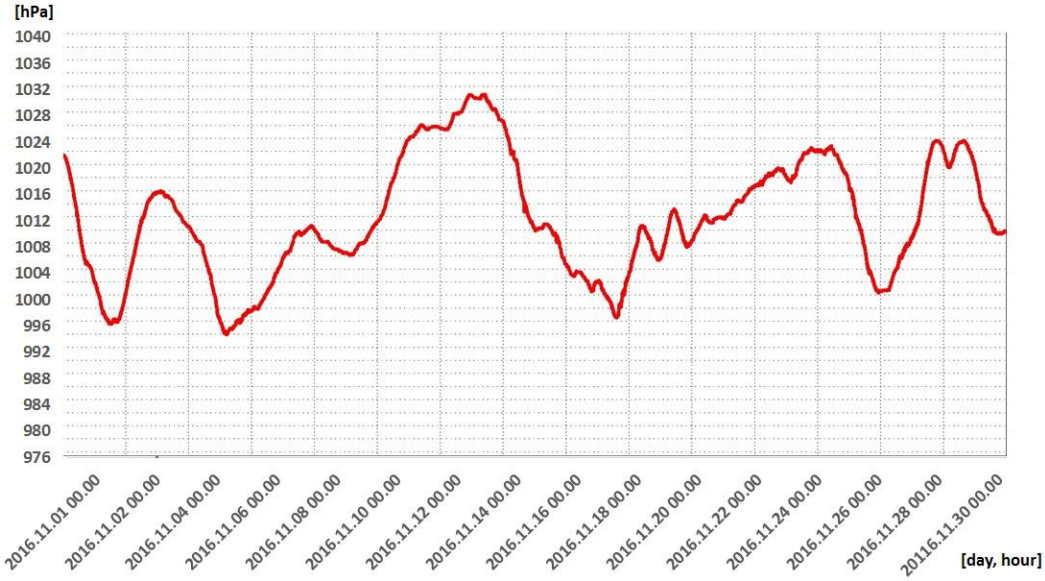

Fig. 2. The pressure situation measured in the Polish Naval Academy (METOC Laboratory) from 1st November, 2016 to 1st December, 2016 [own work]

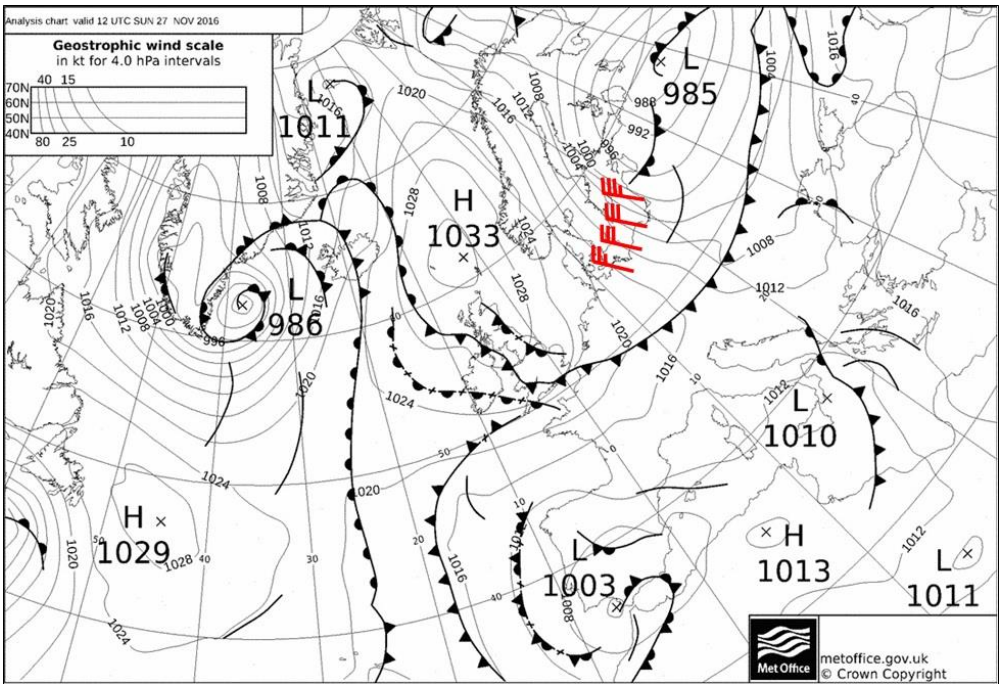

Fig. 3. Surface analysis chart of the UK Meteorological Office on 27th November 2016 1200 UTC with wind speed and directions in the South Baltic Sea [own work based on the Met Office chart]

The hourly sea level data from stations over the Polish coast line were obtained from the Institute of Meteorology and Water Management — Maritime Branch in Gdynia. In figure 4 sea level data from Polish stations (Świnoujście, Kołobrzeg, Darłowo, Ustka, Łeba, Władysławowo, Hel, Puck, Gdynia and Gdańsk Port Północny) from 25th November, 2016 0000 LT to 29th November, 2016 2300 LT were illustrated. In general, we can observe an increase the high of sea level on all Polish stations. That situation started on 26th November, 2016 approximately after 1200 LT. Raising of the sea water level was continued about to 27th November, 2016 at approximately to 2100 LT. Falling down the sea water level was started at about from 28th November, 2016 at 0800 LT.

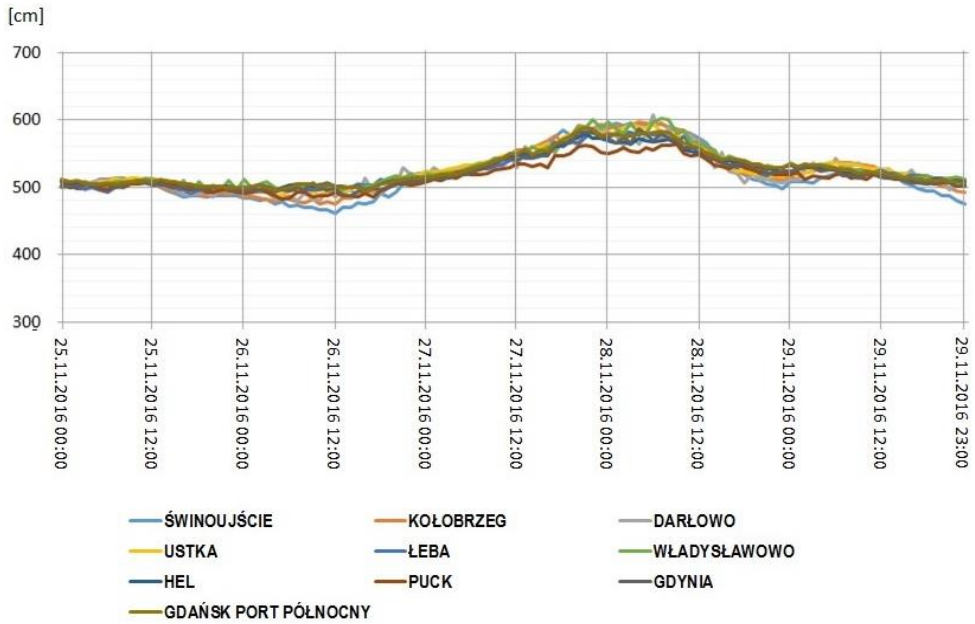

Fig. 4. Sea level data from Polish stations from 25th November, 2016 0000 LT to 29th November, 2016 2300 LT [data obtained from the Institute of Meteorology and Water Management — Maritime Branch in Gdynia, Chart Datum Kronstadt 86]

In table 1 sea level warning states and states of emergency are presented. Sea level data from Polish stations from 27th November, 2016 at 0000 LT to 29th November, 2016 at 0000 LT with stages of emergency from the sea level 570 cm to 610 cm are marked in figure 5. The states of emergency have been reached and exceeded in following Polish stations: Świnoujście, Władysławowa, Hel, Gdynia and Gdańsk Port Północny. States of emergency haven't been reached in Kołobrzeg, Darłowo, Ustka, Łeba and Puck. The lowest sea states compared with other Polish stations have been achieved at the station Puck.

Tab. 1. Sea level warning states and states of emergency at Polish stations
[data from the System MONITOR of the Institute of Meteorology and Water Management]

Name of station	Warning state	State of emergency
GDAŃSK SOBIESZEWO	550	570
GDAŃSK PORT PÓŁNOCNY	550	570
GDYNIA	550	570
PUCK	550	570
HEL	550	570
WŁADYSŁAWOWO	550	570
ŁEBA	570	610
USTKA	570	600
DARŁOWO	570	610
KOŁOBRZEG	570	610
DZIWNÓW	560	580
ŚWINOUJŚCIE	560	580

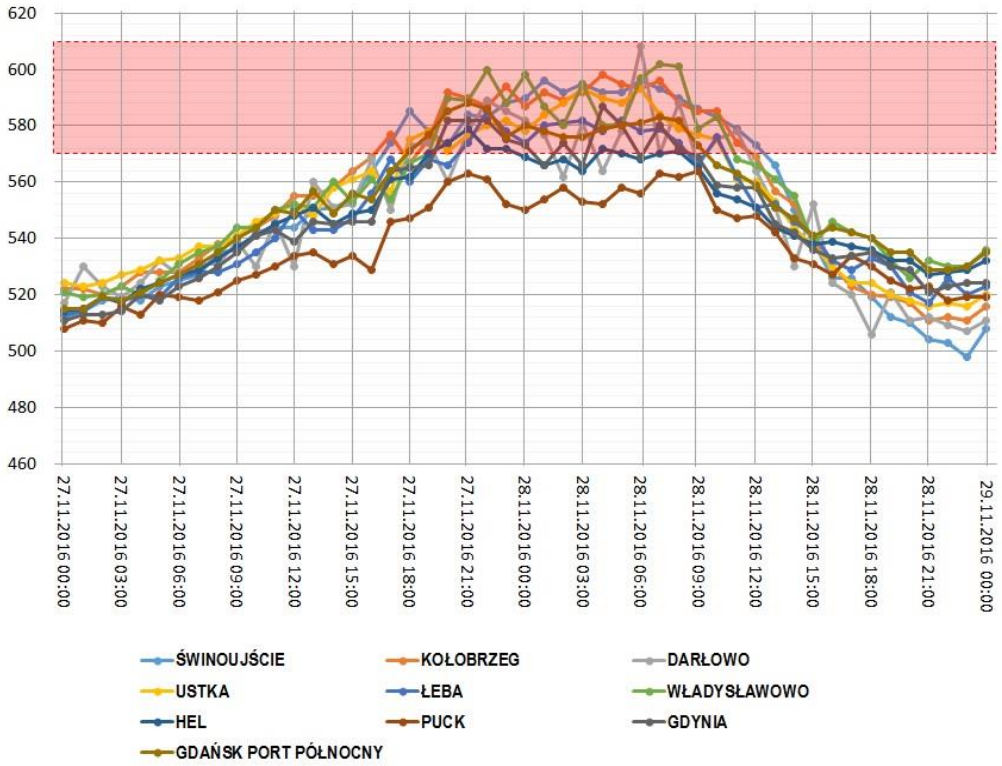

Fig. 5. Sea level data from Polish stations from 27th November, 2016 0000 LT to 29th November, 2016 0000 LT with stages of emergency marked on levels from 570 cm to 610 cm [data obtained from the Institute of Meteorology and Water Management — Maritime Branch in Gdynia]

Data connected with this analysing weather situation which were recorded at the Coastal Research Station of the Institute of Hydroengineering of the Polish Academy of Sciences in Lubiatowo has been adopted as the basis for further deliberations.

In figure 6 are shown wind speed (mean velocity — blue, wind gust — red), wind azimuth and water level in period of time from 25th November, 2016 0000 UTC to 29th November, 2016 0000 UTC. It can be observed that water level in Lubiatowo started to rise when wind direction changed from direction 270° (about at 2000 UTC 26th Nov 2016) and went throw 300° and 330° to 000° (about at 1400 UTC 27th Nov 2016). Wind speed reached the maximum at about 0700 UTC 28th November, 2016 and started to go down. It was the moment of start the going down the water level. Wind direction started to change at about 1400 UTC 28th November, 2016 and went back to direction 270°. The water level were going down although wind speed increased.

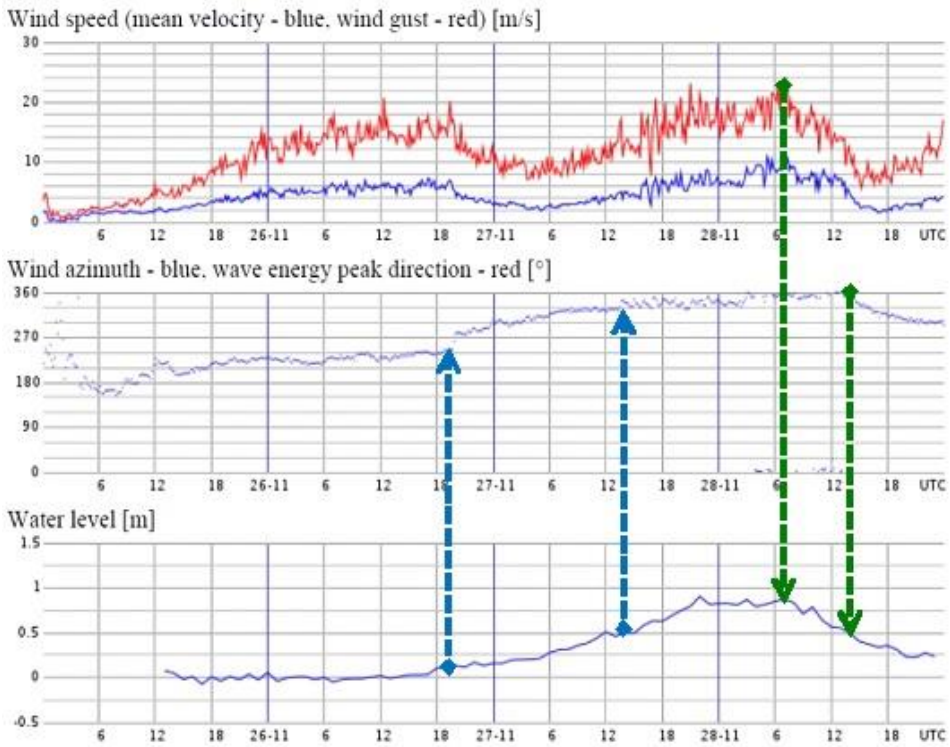

Fig. 6. Wind speed, wind azimuth and water level recorded at the Coastal Research Station in Lubiatowo on 25th November through 29th November, 2016 [own work based on data from the Costal Research Station in Lubiatowo]

ANALYSIS OF METEOROLOGICAL CONDITIONS

The assessment of meteorological conditions over the Southern Baltic Sea and the Polish coast line was made using:

- synoptic analysis charts of the Polish Institute of Meteorology and Water Management;
- the direct measurement conducted at the METOC Laboratory in the Polish Naval Academy;
- Surface analysis chart of the UK Meteorological Office on 27th November, 2016 1200 UTC.

In figure 7 are presented two synoptic analysis charts of the Polish Institute of Meteorology and Water Management on 27th November, 2016 at 0000 UTC and on 28th November, 2016 at 0000 UTC.

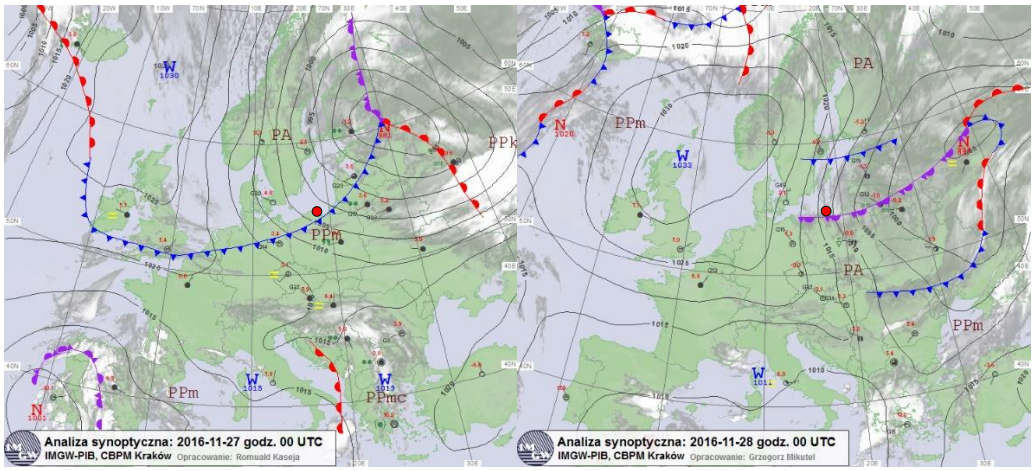

Fig. 7. Synoptic analysis charts of the Polish Institute of Meteorology and Water Management on 27th November, 2016 0000 UTC (26th November, 2016 2300 LT) and on 28th November, 2016 000 UTC (27th November, 2016 2300 LT)

Based on the surface analysis chart of the UK Meteorological Office on 27th November, 2016 1200 UTC (fig. 3) and two synoptic analysis charts of the Polish Institute of Meteorology and Water Management (fig. 7) was prepared a chart (fig. 8) with wind force and direction in the Southern Baltic on 27th November, 2016 at 1200 UTC. Wind direction in the Polish coast was determined from NW to nearly N and wind speed 25 knots in the West coast to 35 knots in the East coast. The change of wind direction for this area was observed from NW to NE with wind speed decreasing to 20 knots.

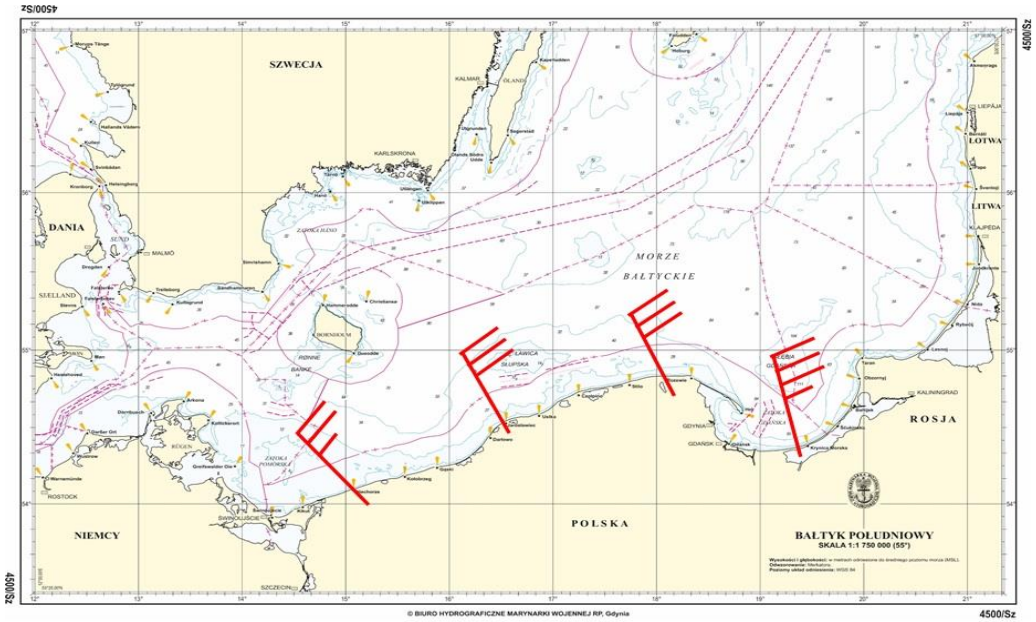

Fig. 8. Wind force and direction in the Southern Baltic Sea on 27th November, 2016 at 1200UTC [own work]

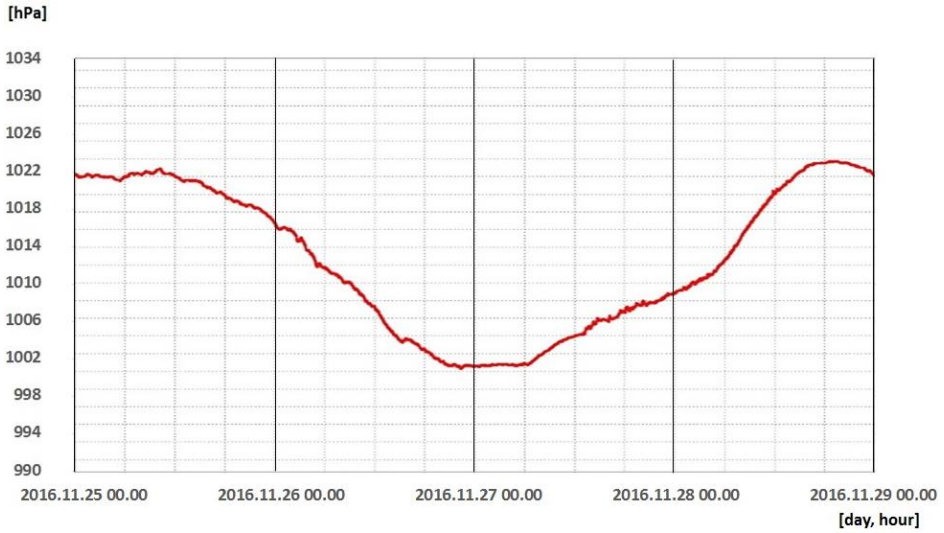

Fig. 9. The pressure situation measured in the Polish Naval Academy (METOC Laboratory) from 25th November, 2016 0000 LT to 29th November, 2016 0000 LT [own work]

In figure 9 is presented the pressure situation in the Polish Naval Academy (METOC Laboratory) from 25th November, 2016 0000 LT to 29th November, 2016 0000 LT. When the pressure reached its lowest value at the point of measuring

the height of the sea level water gradually began to increase with increasing atmospheric pressure. Further systematic increase of atmospheric pressure was accompanied by a drop at the height of sea level on the Polish coast. Analyzing the distribution of atmospheric pressure at the point of its measurement in the Polish coast should take into account the distance to the center of the low located at a distance of over 500 nautical miles.

ANALYSIS OF THE SEA WATER LEVEL

The assessment of sea water level over the Polish coast line was made using the direct measurement conducted at:

- water level stations of the Polish Institute of Meteorology and Water Management;
- the Coastal Research Station of the Institute of Hydroengineering of the Polish Academy of Sciences in Lubiatowo.

In table 2 are presented the highest sea level on the Polish coast from 27th to 28th November, 2016.

Tab. 2. The highest sea level noted on the Polish coast from 27th to 28th November, 2016 [data obtained from the Institute of Meteorology and Water Management — Maritime Branch in Gdynia]

Time of measure	**Świnoujście**	**Kołobrzeg**	**Darłowo**	**Ustka**	**Łeba**	**Władysławowo**	**Hel**	**Puck**	**Gdynia**	**Gdańsk Port Północny**
2016-11-27 21:00:00	584	590	578	577	574	589	**579**	**563**	582	**588**
2016-11-27 22:00:00	583	587	589	580	**585**	600	572	561	582	586
2016-11-28 04:00:00	592	598	564	**590**	578	580	572	552	**587**	579
2016-11-28 05:00:00	592	595	578	588	582	580	570	558	580	580
2016-11-28 06:00:00	**596**	593	**608**	593	578	597	568	556	569	581
2016-11-28 07:00:00	593	**596**	570	584	579	**602**	570	**563**	580	583

In photo 1 is shown nearly the highest sea level (586 cm) observed at station Gdynia on 28th November, 2016.

The hourly sea water level data from Polish stations in Gdansk Bay (Władysławowo, Puck, Hel, Gdynia and Gdańsk Port Północny) were obtained from the Institute of Meteorology and Water Management — Maritime Branch in Gdynia.

Phot. 1. Nearly the highest sea level (586 cm) observed at station Gdynia on 28th November, 2016 [photo C. Dyrcz]

In the Southern Baltic, the main cause of the changes of sea water level are anemobaric factors (wind and atmospheric pressure). Changes caused by the effects of these factors are often very sudden, short and intense. With the same wind direction in one place may experience increases in states of water (sea), and the other lower. Significant increases and decreases water states are sometimes at the same time, with the change of the wind or a little earlier. By total and consistent exposure to the wind and pressure, amplitude changes water States may be significant. Range of fluctuations in sea level decreases from West to East. Rapid and large changes in water states are associated with waves of anemobaric caused by moving deep lows and their associated squalls on the fronts of the cold and wind gusts [2].

In photos 2 and 3 are presented views of waves of the South Baltic Sea in Jastrzębia Góra on 27th November, 2016 at 1334 Lt and in Ostrów on 27th November, 2016 at 1500 LT.

Phot. 2. View of the South Baltic Sea in Jastrzębia Góra on 27th November, 2016 at 1334 LT [photo C. Dyrcz]

Phot. 3. View of the South Baltic Sea in Ostrów on 27th November, 2016 at 1500 LT [photo C. Dyrcz]

DISCUSSION AND CONCLUSIONS

The main goal of this comparative analysis in this study was to identify factors of rising the sea level on the Polish coast during stormy conditions on 27th November, 2016.

In figure 10 are presented changes of the sea level illustrated comparatively with the change in atmospheric pressure in period from 25th November, 2016 to 29th November, 2016. Generally in this example sea levels measured in Polish stations over our coast started to rise together with the atmospheric pressure and then started to go down with still rising pressure.

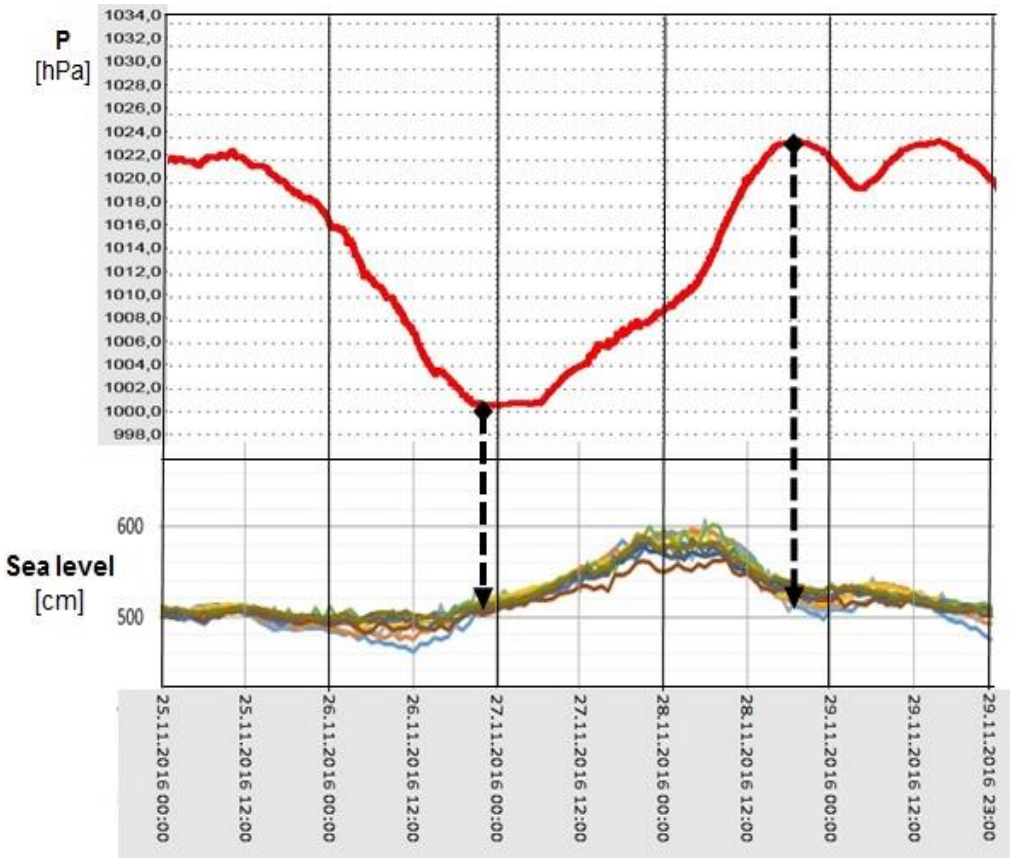

Fig. 10. Changes of the sea level illustrated with a change in atmospheric pressure in period from 25th November, 2016 to 29th November, 2016 [own work based on obtained from the Institute of Meteorology and Water Management — Maritime Branch in Gdynia]

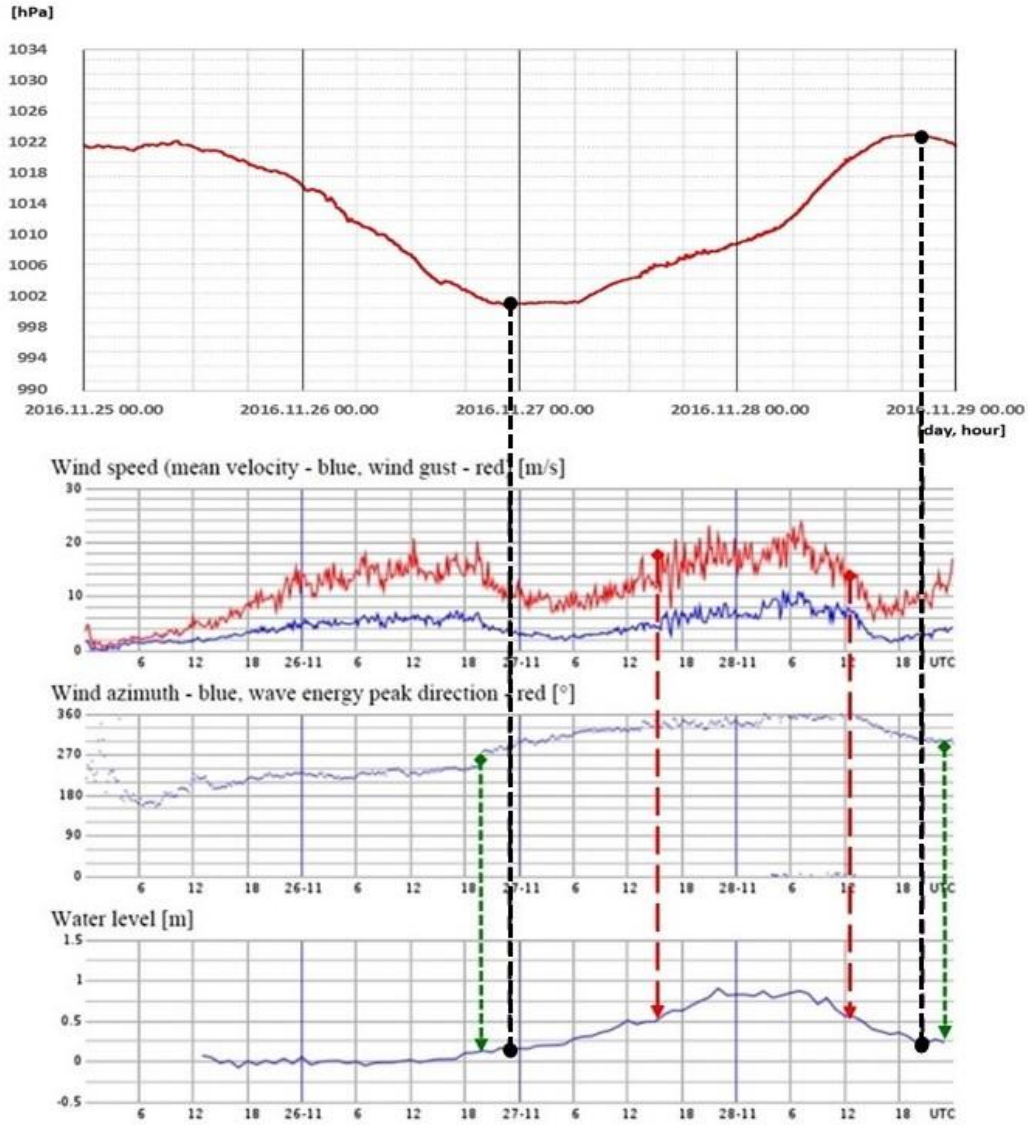

Fig. 11. Changes of wind speed, wind azimuth and water level recorded at the Coastal Research Station in Lubiatowo on 25th November, 2016 through 29th November, 2016 with the barometric pressure measured in The Polish Naval Academy (METOC Laboratory) [own work based on data from the Costal Research Station in Lubiatowo]

Changes of wind speed, wind azimuth (direction) and water level recorded at the Coastal Research Station in Lubiatowo on 25th November, 2016 through 29th November, 2016 with the barometric pressure measured in the Polish Naval Academy (METOC Laboratory) are shown in figure 11. In the station in Lubiatowo is the same

situation with raising and going down the sea level like in all Polish station over the coast. But these data gives us the influence of the wind direction and wind speed on the changes the sea level in the station in Lubiatowo.

As a rule, the occurrence of extreme sea levels — storm surges on the Polish Coast, is dependent on three following components [5]:

- the volume of water in the Southern Baltic (the initial sea level prior to the occurrence of an extreme event);
- the action of tangential wind stresses in an area (wind directions, whether shore- or seaward; wind velocities; and wind action duration);
- deformation of the sea surface by the mesoscale baric lows passing rapidly over the Southern and Central Baltic, which produces the so-called baric waves and generates seiche-like variations of the sea level in the Baltic Sea.

This storm situation occurred on 27th November, 2016 analyzed in this work had an influence on a rising the sea level over the Polish coast. The storm surge was mainly depended on the action of tangential wind stressed in the South Baltic Sea. In this example the most important were the following factors: wind direction, wind speed and wind action duration. Deformation of the sea surface made by the baric low was not possible exactly to identify by the distance to the centre of a baric low more than 500 Nm. It can be assumed that the impact occurred, however, too small values.

Acknowledgements

I wish to thank the Institute of Meteorology and Water Managements (IMGW) and the Coastal Research Station of the Institute of Hydroengineering of the Polish Academy of Sciences in Lubiatowo — for allowing the use of the sea level and observation data.

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ANALIZA WARUNKÓW HYDROMETEOROLOGICZNYCH NA BAŁTYKU POŁUDNIOWYM PODCZAS WARUNKÓW SZTORMOWYCH 27 LISTOPADA 2016 ROKU

STRESZCZENIE

W artykule została przedstawiona analiza warunków hydrometeorologicznych na akwenie Południowego Bałtyku podczas sztormowych warunków 27 listopada 2016 roku. Wiatr, który wystąpił na Południowym Bałtyku, miejscami osiągał siłę 7 stopni Beauforta, a w porywach 8 do 9 stopni Beauforta. Południowa część Morza Bałtyckiego była pod wpływem układu niżowego o wartości ciśnienia w centrum 981 hPa, które znajdowało się nad południową Finlandią i północno-zachodnią Rosją. Odnotowano wiele zniszczeń powstałych na polskim wybrzeżu i w portach Zatoki Gdańskiej. Analiza warunków hydrometeorologicznych skoncentrowana została na sile wiatru i jego kierunku, ciśnieniu atmosferycznym oraz poziomie wody mierzonej na stacjach pomiarowych polskiego wybrzeża, szczególnie w Zatoce Gdańskiej. Głównym celem przeprowadzonych analiz było wskazanie czynników meteorologicznych mających wpływ na podniesienie poziomu wody na polskim wybrzeżu w tych określonych warunkach pogodowych.

Słowa kluczowe:
poziom wody morskiej, warunki pogodowe, Bałtyk Południowy.