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Analysis of hydro-meteorological conditions in the area of the Port of Świnoujście between 2011–2015

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Abstract

Świnoujście is a Polish seaport located on the Pomeranian Bay, on the southern coast of the Baltic Sea island of Usedom and Wolin. The port is situated in the Świna Strait in Świnoujście, Western Pomerania. The harbor consists of a cargo handling quay, passenger terminal and marina. The seaports of Świnoujście and Szczecin are closely linked economically to form a team and are connected by a passage through the Szczecin Lagoon. All big ships directed to Szczecin have to be routed through the port of Świnoujcie. The hydro-meteorological conditions in the Świnoujście Port area and surroundings, affecting safe maneuvering of ships, are analyzed by statistical methods. The conditions studied, with the aid of Port Captain logbook, are: currents, winds, water level, ice conditions and visibility. The statistical distribution of water level was analyzed and proposed as decision-making tool during a ship's approach to Świnoujście Port.

Introduction

Navigational safety analysis requires a large extent of data regarding navigational conditions. A statistical approach to data analysis is used here to process the collected data and draw useful conclusions for navigational safety. The following factors affecting navigational safety were analyzed and statistically elaborated:

1. currents in entrance to Świnoujście affecting maneuvering safety;
2. wind affecting maneuvering safety;
3. water level affecting maneuverability and under keel clearance;
4. ice conditions maneuvering safety;
5. visibility affecting mostly safety of navigation in anti-collision aspects.

The analyses were based on logbooks compiled by VTS Świnoujście. The analysis covers the period going from 2011 to 2015, with regards to water level and visibility and from 2013–2015, for wind measurements. Water level and visibility were analyzed on the basis of handwritten records, in which data had been reported every 3–6 hours. The winds were analyzed based on 15-min interval records by and ultrasonic anemometer located at a 5 m height on central breakwater and located along 0.5 km of Szczecin–Świnoujście waterway.

Surface current

In the coastal zone of the Baltic Sea, a decisive factor is the formation of a ripple currents and the wind energy carried with them. The most important of these currents run along coastlines and return (Boniecka et al., n.d.).

Generally, currents are related to the direction and the force acting over the wind area. It has been found that, for weak winds, the deviation in the direction of the wind current is about 15°, while at wind speeds greater than 5°B the direction is deflected only by about 2°.

In the Pomeranian Bay, both on the surface and at the bottom of the sea, similar characteristic distribution of current directions can be observed. Strong and moderate currents in the directed to the west or southwest are prevalent over 50% of cases. Strong winds flow throughout the water column (0 to approx. 18 m) have virtually the same direction. Due to the seasonal variation of barometric pressure conditions, which determine the flow rates, isolated currents in different directions can arise, depending on the season:

- I quarter – dominated by currents toward the west – more than 50% of cases.
- II quarter – almost exclusively dominated by western currents.
- III quarter – eastern currents.
- IV quarter – dominated almost exclusively by c northwestern and northeastern currents.

Current conditions in the port of Świnoujście area should be considered in the context of existing research on the, topic regarding the Strait of Świna (Jasińska & Robakiewicz, 1999). Based on studies previously carried out it can be concluded that:

- Current conditions in the Strait of Świna depend mainly on the nature and magnitude of changes in water levels and their mutual relations in the Pomeranian Bay and the Szczecin Lagoon. Wind indirectly impacts the currents by influencing the level of water in the bay, and has a negligible impact on surface currents.
- Flows in the Strait Świna may be fixed or transient. Steady inflows and outflows across the riverbed are present. Their velocity distribution varies depending on depth. Transient and quasi–periodic flows can be single- or two-way, and because of their random nature are difficult to describe. A three-dimensional model has been built, based on data measurements and on a hydraulic model and has allowed to reach the following conclusion on velocity: the maximum measured speed that occurred during a storm accumulation was approximately 180 cm/s at a 1.3 km distance from the collective channel. The probability of this occurrence is lower than 1%.

Wind conditions

Verification of the speed and direction of perennial winds was performed based on observations carried out at the VTS station in 2013–2015. The maximum, average, and minimum wind speeds are shown in the Table 1.

The average occurrence of specific wind directions is shown in the graphs on Figures 1, 2, 3 and 4.

In Świnoujście, in the 1965–2008 period, the annual average wind speed has been 3.9 m/s. The highest average speed was observed for April winds (4.2 m/s), but only a small variation was presents in other months (the smallest average value was measured in August and was equal to 3.5 m/s). The occurrence of strong winds (with speeds greater than 10 m/s) is mainly related to the passage of strong low-pressure systems over the Baltic Sea. These cause an increase in high-speed winds, mainly coming from the fields to the north and northwest, causing an accumulation of water and, as a result, of backwater. Strong winds in Świnoujście were observed for 10 days and very strong winds (with a speed of over 16 m/s) for 0.45 days. The maximum wind speed observed in Świnoujscie was 22 m/s west (1995) (Pluta, 2000).

In the 2013–2015 period, the maximum wind speed observed in Świnoujście was 18.7 m/s. Yearly duration of strong wind in Świnoujście is presented in Table 2.

Table 1. Maximum, average, and minimum wind speed (from 2013 to 2015)

Month	Wind speed [m/s]				Days > 12.5 m/s		
	max	aver	min	med	2013	2014	2015
December	16.972	5.232	0.139	5.083	3.750	0	0
November	14.250	4.227	0.194	4.000	0.417	0	0
October	12.750	4.064	0.83	3.889	0.042	0	0
September	13.722	4.159	0.28	3.806	0	0	0
August	11.194	3.959	0.028	3.694	0	0	0
July	12.500	4.426	0.028	4.056	0	0	0
June	13.722	4.316	0.083	3.944	0.625	0	0
May	16.694	4.509	0.083	4.194	0	5.708	0
April	13.556	4.439	0.028	4.194	0	0.083	0
March	17.472	4.943	0.000	4.611	0.458	1.666	0
February	16.306	4.302	0.083	4.000	0.125	0	2.083
January	18.667	5.000	0.083	4.833	0.041	0.125	0.458

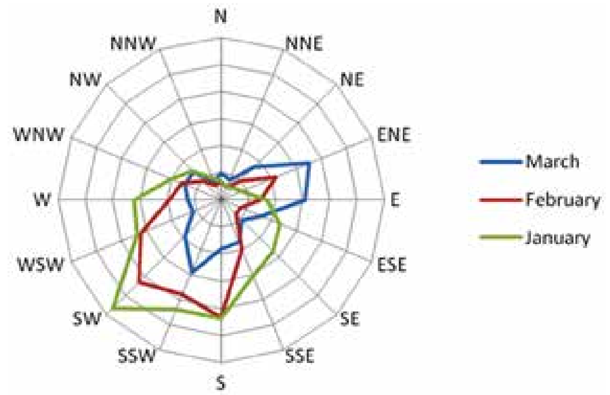


Figure 1. Average wind direction (2013–15) I–III

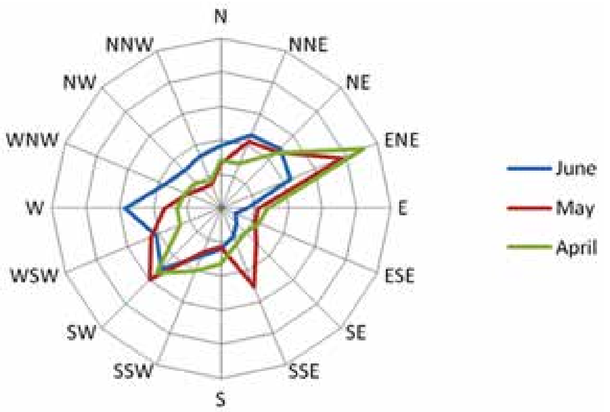


Figure 2. Average wind direction (2013–2015) IV–VI

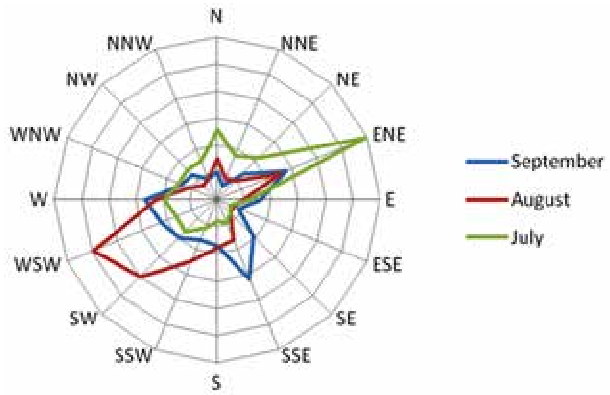


Figure 3. Average wind direction (2013–2015) VII–IX

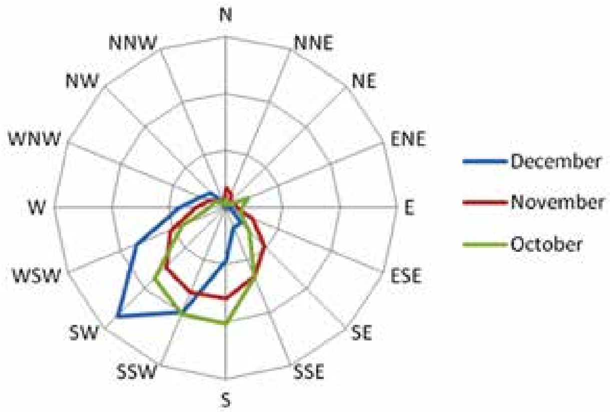


Figure 4. Average wind direction (2013–2015) X–XII

Table 2. Number of days in with strong and very strong winds in Świnoujście (1965–2008) (Pluta, 2000)

Wind speed V_w [m/s]	Number of days
10–12	10.06
13–15	2.43
16–18	0.45
> 18	0.06

Given the above results, it can be concluded that the longest period of occurrence of maximum wind does not exceed T_{max} = 1.4 h.

Water level

Verification of the water level in the port of Świnoujście was based on observations carried out at the VTS station during in Świnoujście from September 2011 to November 2014 (1605 measurements).

The mean and extreme water levels are shown in Table 3, while the CDF function of the incidence of individual water levels is shown in Figure 5.

The probability distribution of water level, measured in cm, was fitted to 5 types of distributions

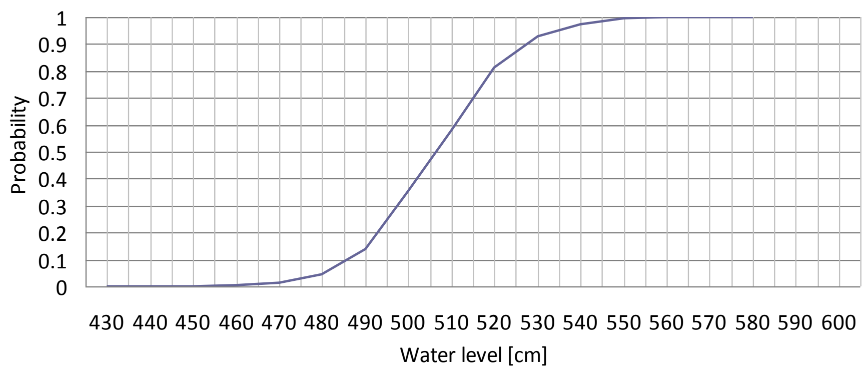


Figure 5. Cumulative distribution function of water level occurrence in port of Świnoujście

Table 3. Statistical parameters of water level in Świnoujście for the period 2011–2015

Measure	Value [cm]
Mean	509
Median	509
Mode	508
St. dev.	16
Min	446
Max	572

(logistic, log logistic, lognormal, normal, and extreme value). The best and almost ideal fit (critical probability of popular fit tests: Chi-sq. 0.00, A-D<0.05, K-S<0.05) gave a logistic distribution with parameters a = 508.95 cm and b = 9.23 cm (Figure 6).

Probability of water level changes (drop) during ships approach

The major problem arising when large ships enter the port is the probability that water level will drop during approach. It is important to understand this issue because, usually, once the decision of approach has been taken there is no possibility to stop the ship. A statistical approach can be used here to evaluate the probability of a water level decrease as a consequence of a large ship's approach. The time of ship approach to the port may be calculated by considering the speed of the ship and then maximum water level drop during that time.

The hourly water level drop was calculated with use of data recorded from September 2011 to November 2014 and is presented in Figure 7. It can be observed that the maximum drops are up to 20 cm in this period.

It could be very useful for navigators and decision-makers to assess the probability of such water drop during approach. Based on data from Figure 7, the cumulative frequency of water drop was calculated and is presented in Figure 8. These values could be used for designing depth of the waterways and UKC correction for given changes of water level (Gucma et al., 2011).

The value commonly suggested for under keel clearance, corrected long-term water level drops in Świnoujście, is 0.8 m (Mazurkiewicz, 2006). This value could be replaced by those reported in Figure 8, obtaining great accuracy when dynamic under keel clearance is used. Analyzing the data from Figure 8 it could be stated, for example, that a water drop of 0.2 m (20 cm) occurs with a frequency $6.23 \cdot 10^{-4}$ (estimated for observation time period = 3.17 years = 38 months).

Visibility

The period from September 2011 to February 2015 was strongly dominated by conditions of good and very good visibility. Verification of the visibility in the port of Świnoujście was based on observations carried out at the VTS station from September 2011

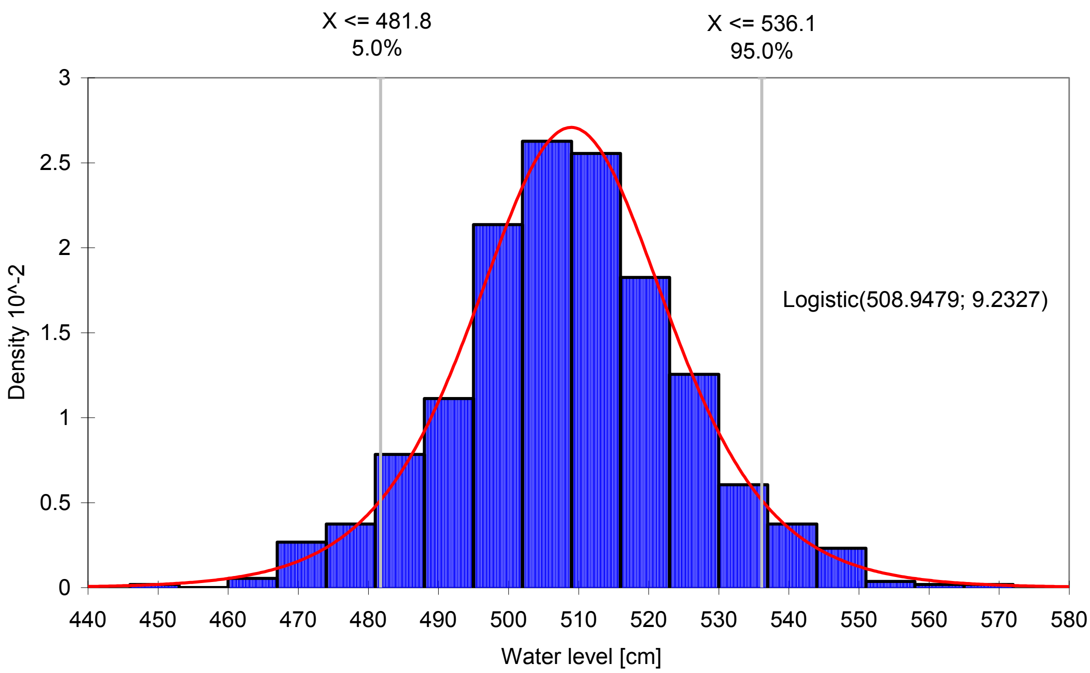


Figure 6. Cumulative distribution function of water level occurrence in port of Świnoujście

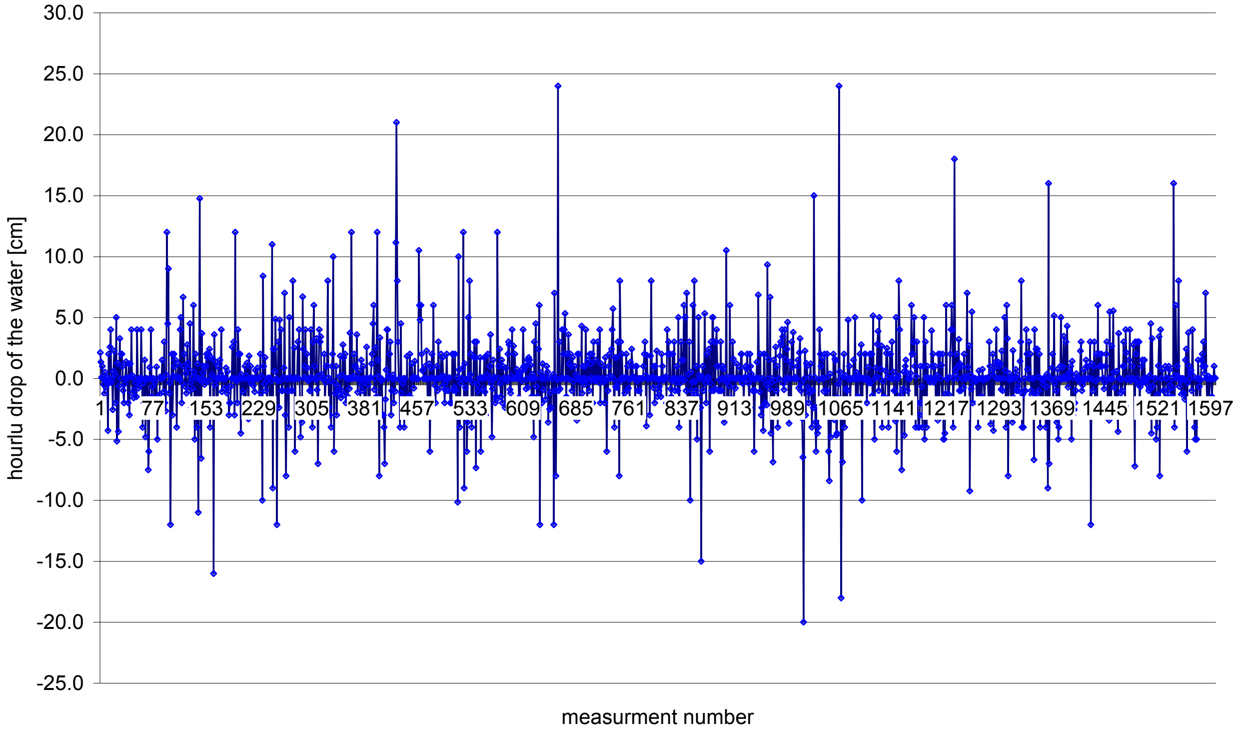
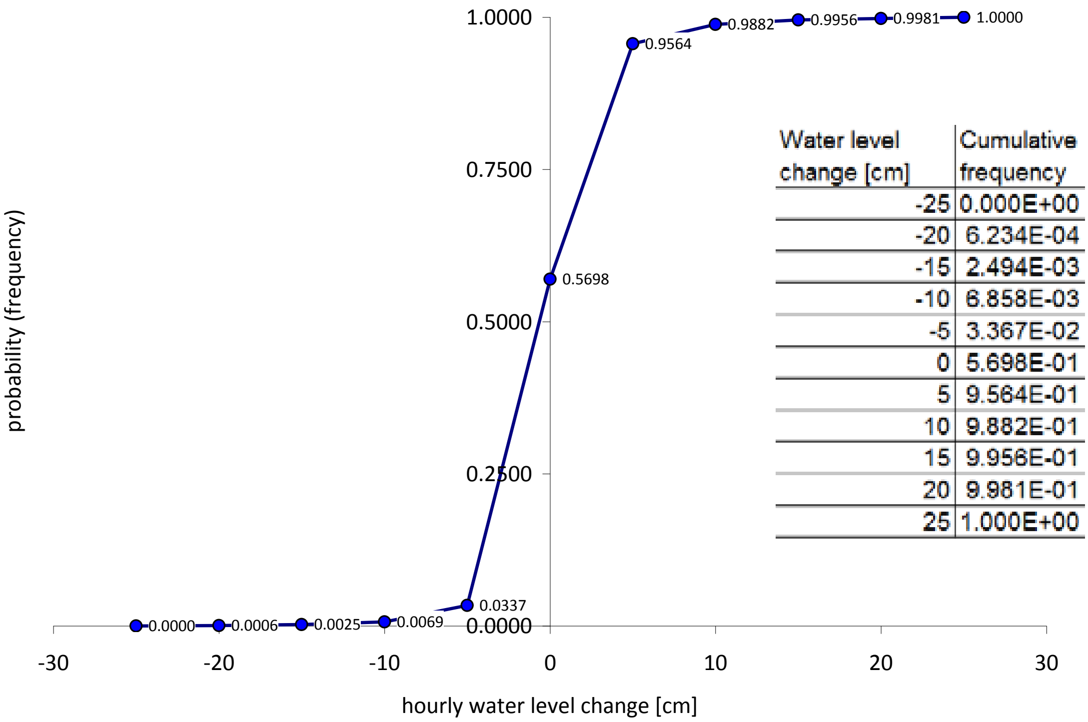


Figure 7. Hourly differences in water level [cm] within observation period



Water level change [cm]	Cumulative frequency
-25	0.000E+00
-20	6.234E-04
-15	2.494E-03
-10	6.858E-03
-5	3.367E-02
0	5.698E-01
5	9.564E-01
10	9.882E-01
15	9.956E-01
20	9.981E-01
25	1.000E+00

Figure 8. CDF of hourly water level change [cm] within time of observation (38 months)

to February 2015 (2441 measurements). A histogram of the relative frequency distribution of visibility is shown in Figure 9. The presence of mist in Świnoujście was mostly recorded in autumn and winter (Figure 10).

Conclusions

The data presented could be helpful to assess the meteorological conditions affecting navigational safety. Such data could be also helpful in establishing

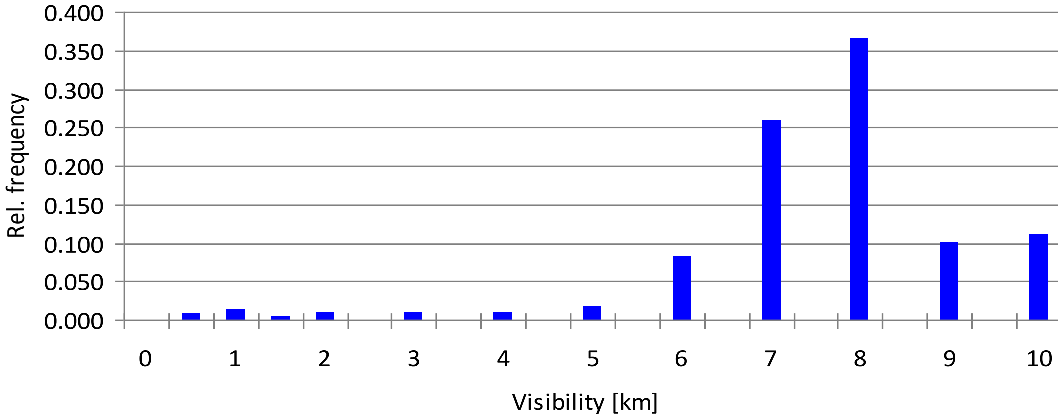


Figure 9. Histogram of visibility in the port of Świnoujście in the period 09.2011 – 02.2015

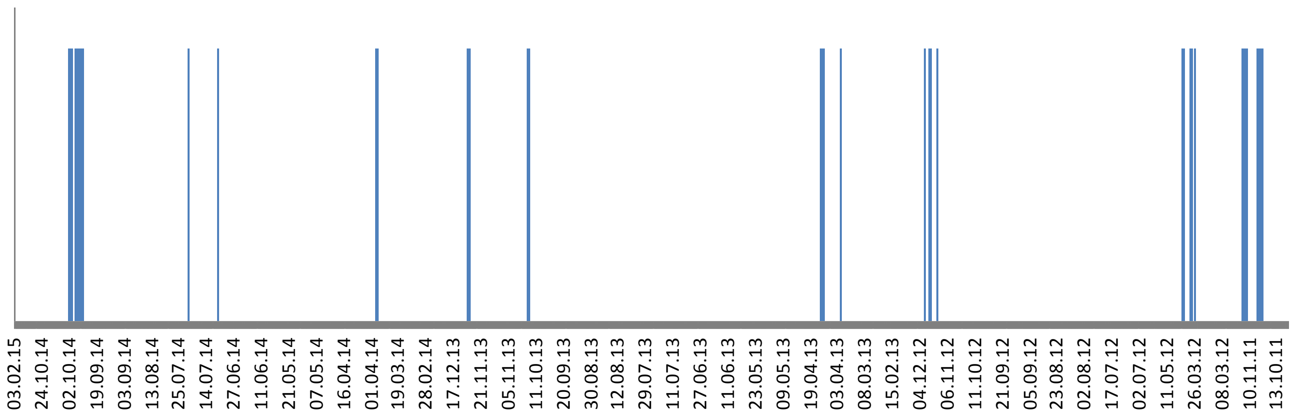


Figure 10. Occurrence of fog in the area of the port of Świnoujście

the conditions of safety operation of infrastructure elements and setting up models for the description of ship maneuvering, needed for work regarding port infrastructure design.

A statistical model for changes in water level was presented. Such a model could be helpful in the port captain decision-making process regarding the entrance of large ships to the ports.

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