TRANSNAV International Journal on Marine Navigation and Safety of Sea Transportation
Volume 6 Number 1 March 2012

Polish Seaports – Unfavorable Weather Conditions for Port Operation (Applying Methods of Complex Climatology for Data Formation to be Used by Seafaring)

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ABSTRACT: The use of methods of complex climatology, which treats climate as a many-year weather regime, made it possible to define the annual structure of weather states observed in seven Polish sea ports, i.e. Elbląg, Gdańsk, Hel, Łeba, Ustka, Kołobrzeg and Świnoujście. This work uses data originating from OGIMET and covers the period 2000-2009.
Weather conditions that make port operation either difficult or even impossible are considered to be those when, during a day, we observe negative air temperatures, cloudiness, precipitation and strong winds at the same time. Once the frequency of occurrence of unfavorable weather conditions has been defined for the port operation then for each port a climatogram was drawn illustrating their frequency in the following decades of a given year.
Weather conditions which are unfavorable for the work in Polish sea ports are observed only in autumn and winter, and during early spring; they are most frequent in the ports of Ustka and Gdańsk. Their annual frequency in none of the described ports exceeds 1% so the conditions in Polish sea ports may be regarded as favorable for port operations. The worst weather conditions are observed in the last decade of December, third decade in January and in the second and third decades in February as well as i the first decade of April.

1 THE PROBLEM

Description of climatic conditions which are found in aids to navigation (Pilots, Routing Charts, and Pilot's Charts) make use of average values of meteorological elements. Such an approach follows the methods applied in classical climatology where climate is treated as "a mean state of atmosphere in a many- year period".

Climatic characteristics based on averaged courses of meteorological elements and on their extreme values, in some situations, seem to have restricted use as it does not give any information as to the correlations between them. It says nothing about the real state of the atmosphere, about the weather. Complex climatology provides such a possibility as it treats climate (many–year weather regime) as "an average structure and a sequence of weather". This approach makes it possible to describe, at the same time, a series of meteorological elements observed, i.e. real state of atmosphere (real weather).

The frequency of occurrence of **types of adverse or unfavorable weather conditions** is extremely important for sea ports, for their effective work. No matter what cargo is handled in a given port, strong and very strong winds are to be treated as weather conditions which disturb or even do not allow working properly. In number of cases the routine work of a port is made difficult when the air temperature falls below zero and remains as such during the whole or part of the day (when the air temperature is around or below 0º C during the day). Loading and discharging of some cargoes is impossible or ceased during precipitation. Poor visibility or visibility restricted by fog or any type of precipitation may cause great problems in ports both during vessels maneuvering and while loading certain kinds of goods. Because precipitation is difficult to forecast and because rain or snow or other types of precipitation is connected with clouds, so the occurrence of certain clouds can provide us with information which is important for port operation.

Port efficiency decreases significantly if, even one, of the mentioned meteorological element is observed. Thus, negative air temperatures result in freezing of moist bulk cargoes, precipitation restricts visibility and makes loading or discharging of goods which are susceptible to moisture impossible and strong winds affect safe navigation and have influence on proper operation of cargo handling facilities. Greater problems arise when the meteorological elements are observed together. With the air temperature falling below 0ºC and strong wind which cools the air at the same time cause that port operation is difficult. When minus temperatures are accompanied by strong wind and precipitation then icing of vessels and cargo handling facilities can be observed.

A lot of hydrological and meteorological phenomena both dangerous and favorable for ports and navigation take place as a result of concurrence defined by certain liminal values of meteorological elements. The presentation of hydro-meteorological data proposed by complex climatology can make the assessment of climatologic conditions for this type of work easier and can help to define the periods which are marked by adverse or favorable climatic conditions with reference to port operation.

2 METHOD AND OBSERVATIONAL DATA

Basic theory regarding methods of complex climatology as well as its detailed description can be found in work by Olszewski (1967) and Woś (1970, 1977a and b). This analysis makes use of partially modified weather classification proposed by Marsz (1992). This classification, as well as a detailed description of procedure used in dealing with input data can be found in author's earlier works (among others 1994, 1996, 1997), and the way of interpretation is presented by Ferdynus, Marsz and Styszyńska (1995) and Ferdynus (1996, 2000).

The classified period comprises a given day and the elements by which it is characterized - covered mean minimal and maximal air temperature (T), mean overall cloudiness (N), sum of atmospheric precipitation (R) and mean and maximum wind speed (V). In this way each day is described by means of four figures – TNRV and the number of possible weather conditions in such classification amounts to 486 (9×3×2×9) – see Table 1.

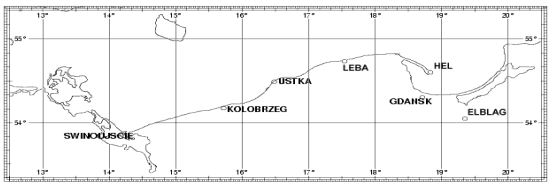

Fig. 1. Location of the meteorological stations used in his study.

The data used above were taken from 7 ports (Fig.1) from the ten-year period 2000 – 2010. Daily values of meteorological elements originate from OGIMET data sets. They are averaged values of daily synoptic observations. These data were thoroughly checked and in doubtful cases were compared to the data originating from ECA&D and where it turned to be necessary, they were corrected accordingly.

Table 1. Classification of weather's

Symbols		Partitions	Name of weather
T	0	$20{,}0° < t_{av} < 29{,}9°C$, $t_{min} \geq 0°C$	exceptionally warm
	9	$10{,}0° < t_{av} < 19{,}9°C$, $t_{min} \geq 0°C$	very warm
	8	$5{,}0° < t_{av} < 9{,}9°C$, $t_{min} \geq 0°C$	warm
	7	$0{,}0° < t_{av} < 4{,}9°C$ $t_{min} \geq 0°C$	moderately warm
	6	$t_{min} < 0°$ and $t_{max} > 0°$	transitional
	5	$-0{,}0° < t_{av} < -4{,}9°C$, $t_{min} < 0°C$	moderately frosty
	4	$-5{,}0° < t_{av} < -9{,}9°C$, $t_{min} < 0°C$	frosty
	3	$-10{,}0° < t_{av} < -19{,}9°C$, $t_{min} < 0°C$	very frosty
	2	$-20{,}0° < t_{av} < -29{,}9°C$, $t_{min} < 0°C$	exceptionally frosty
N	1	$0{,}0 < N < 2{,}0$	blue sky
	2	$2{,}1 < N < 5{,}9$	party clouded
	3	$6{,}0 < N < 8{,}0$	cloud
R	0	RR = 00 mm	no precipitation or precipitation < 0,1 mm
	1	RR > 00 mm	precipitation
V	0	$0{,}0 < v_{av} < 1{,}5$ m/s	calm or light air
	1	$1{,}6 < v_{av} < 7{,}9$ m/s, $v_{max} < 11$ m/s	light breeze
	2	$1{,}6 < v_{av} < 7{,}9$ m/s, $v_{max} \geq 11$ m/s	light breeze with periods of strong breeze
	3	$8{,}0 < v_{av} < 16{,}9$ m/s, $v_{max} < 17$ m/s	strong breeze
	4	$8{,}0 < v_{av} < 16{,}9$ m/s, $v_{max} \geq 17$ m/s	strong breeze with periods of gale
	5	$8{,}0 < v_{av} < 16{,}9$ m/s, $v_{max} \geq 30$ m/s	strong breeze with periods of storm
	6	$17{,}0 < v_{av} < 29{,}9$ m/s, $v_{max} < 30$ m/s	storm
	7	$17{,}0 < v_{av} < 29{,}9$ m/s, $v_{max} \geq 30$ m/s	storm with periods of hurricane
	8	$v_{av} \geq 30$ m/s	hurricane

With reference to their location the examined ports can be divided into those located in the region of the Vistula Lagoon (Zalew Wiślany), the Gulf of Gdańsk, those located on open sea and in the region

of Szczecin Lagoon (Zalew Szczeciński) (Fig.1). When taking into account morphological features, we can distinguish the following types of ports: those situated in bays, gulfs, e.g. (Gdańsk – the North Port), those located close to river mouths (Łeba, Ustka, Kołobrzeg), and river and canal ports (Świnoujście, Elbląg, Gdańsk – Inland port), and those located on open sea (Hel). If we take into consideration their size (e.g. cargo handling capacity or the port area) then we can talk about big and small ports.

3 FREQUENCY OF ADVERSE WEATHER CONDITIONS FOR PORT OPERATION

As it was mentioned in the introduction, weather elements which have influence on the efficiency of port operation are the following: low air temperature, strong wind and clouds. It was also denoted that concurrence of these elements is extremely unfavorable. This work, making use of classification mentioned above (Table 1), treats weather conditions, which are regarded as those having negative influence on port operation, as:

$T \cap N \cap R \cap V$ – group A;
$(T \cap R \cap V) \cup (T \cap N \cap R)$ – group B;
$(T \cap R) \cup (T \cap V) \cup (R \cap V) \cup (N \cap R)$ – group C;

where

$T = 2, 3, 4, 5, 6;$
$N = 3;$
$R = 1;$
$V = 3, 4, 5, 6, 7, 8.$

Weather types from Group A should be treated as especially unfavorable for port operation as they combine concurrence of all four adverse weather elements. Group B is made up of three of these elements and in Group C there are two meteorological elements which make port operation difficult and in this way lower the port efficiency. Weather conditions which do not fall into any of the above groups are regarded to be neutral and are classed as Group D.

The examined ports are situated in the same climatic zone (maximum difference in latitude is only about 1°φ), so the observed differences in the frequency of occurrence of certain weather groups can only be attributed to local conditions.

3.1 *Elblag*

The port of Elbląg (φ = 54°10'N; λ = 019°23'E) is the biggest port located on the Vistula Lagoon, situated on the river Elbląg in a distance of 6 km from its mouth to the Vistula Lagoon. It is a regional port rendering services for coastal navigation both for merchant (coal, building materials, sand, broken stone) and passengers vessels and for tourists. In 2008 only 14 vessels of total tonnage 4.6 thousand GRT called at the port of Elbląg (ten times fewer than in 2005). In 2008 cargo handling reached 5700 tons, in this amount 1700 tons of steel constructions and 4000 tons of sand.

The transport of passengers amounted to 39909 people. In 2008 cargo handling and passenger transport in the port of Elbląg reached totally 4000 tons and 32899 people respectively (Rocznik Statystyczny Gospodarki Morskiej 2009).

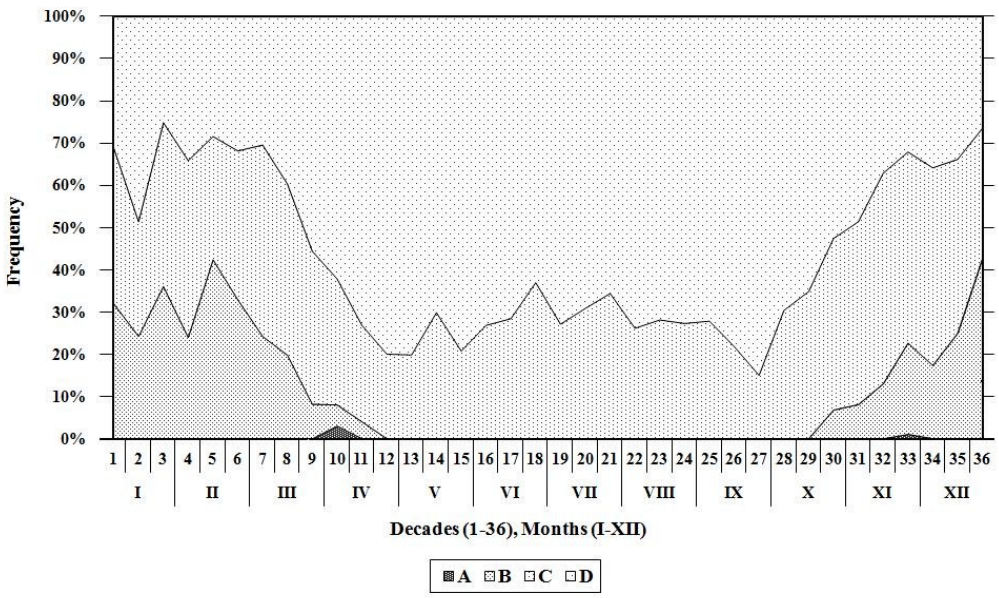

Fig. 2 Climatogram for Elbląg (2000-2009).

The analysis of climatogram drawn for Elbląg (Fig. 2) indicates that in the years 2000 – 2009 the type of weather from Group A is observed very seldom, accounting to only 1.0% in the first decade of December and 3.0% in the first decade of April – and they are the only two decades during the whole year. During the first decade of April there were two weather types 5314 and 6314 and in the first decade of December weather 6314 type.

If we take into consideration the occurrence of weather types from Groups B and C it is obvious that they are much more frequent. Weather types from Group B can be observed for the first time in the third decade of October and the last time in the first decade of April. They are noted in the third decade of December most frequently (around 50%). In the second decade of February a secondary maximum of frequency 42% is observed and from this decade on we can observe the decrease in their frequency. Weather types from Group C are noted in Elbląg during the entire year and they occur most frequently during winter and on the turn of seasons (second decade of November – 50%; first decade of December – 46%; first decade of March).

When we analyze the climatogram it is easy to notice that the weather type from group D comprise the rest of the dominant weather and it means that climatic conditions in the port of Elbląg seem to be favorable. From the third decade of March on, the frequency of that group exceeds 50% and such situation is observed till the third decade of October. The most favorable conditions for the port operation in the port of Elbląg are noted from the second decade of April to the third decade of September – during that period the frequency exceeds 70% and in the third decade of May reaches 87% and in the first decade of May 80%.

3.2 *Gdańsk*

In the port of Gdańsk (φ = 54°24‘N; λ = 018°42‘E) located in the central part of the southern coast of the Baltic Sea we can distinguish two regions of different operational parameters: Inner Port located along the Martwa Wisła and the North Port directly accessible from the Gulf of Gdańsk.

In the Inner Port there are container terminal, ferry terminal and terminal for ro-ro vessels, car terminal, and terminal for handling citrus, liquid and granulated sulphur and for phosphates. The remaining quays have universal character and make it possible to handle general cargo and bulk cargo. Terminals for handling fuel oil, liquid fuel and coal are located in the North Port.

In 2008 the port of Gdańsk served 3999 vessels of total capacity 32793,3 thousand GRT. About 19 mln ton were handled including ore – 16 thousand tons, grain 960 thousand tons, general cargo 3,5 mln tons, coal 2,7 mln ton and fuel 9 mln ton and almost 165 thousand passengers were served (Rocznik Statystyczny Gospodarki Morskiej 2009).

It can be easily noticed when comparing climatogram from Gdansk with the one for Elbląg that weather types from Group A are more frequently noted in the port of Gdańsk. The first record is observed in the second decade of December and it is observed till the first decade of April and their maximum frequency is noted in the second decade of February (at an average six days in a decade). They are weather types 4313, 5313, 5314, 6313, 6314 and 6315. When compared with Elbląg they are characterized by lower air temperature and greater wind speed.

Weather from Group B in Gdańsk is observed from the second decade of October to the first decade of April. Maximum, exceeding 20% frequency is noted in the third decade of December (24%), in the first decade of January (21%) and second decade of February (24%). Weather types from group C are noted during the whole year-in two decades they reach 50% frequency – the third decade of January and November.

When we analyze the frequency of weather which is favorable for the port operation i.e. group D, it should be noted that only in 10 decades their frequency does not exceed 50% (the lowest frequency 25% - in the second decade of February). In 14 decades their frequency exceeds 75% – such situation can be observed from the second decade of April till the third decade of September. The best weather conditions for port operation in Gdańsk occur in the third decade of May (91%). Generally speaking similar to Elbląg weather conditions in Gdańsk are favorable for port operation but they are a bit more difficult than in Elbląg.

3.3 *Hel*

The port of Hel (φ = 54°36'N, λ = 18°48'E) is located in the southern part of the Hel Sandbank, at the western part of the extreme part of the sandbank, on the eastern coast of the Puck Bay. The civil port is situated in the south west part of the town, south of Hel military port. The port of Hel is mainly fishing harbor and is also a port for pleasure crafts (White Fleet) coming from “3city”. Hel has never been a cargo handling port (Krośnicka 2007). In 2008 Hel was visited by 1066 vessels of total capacity 479,8 thousand GRT (Rocznik Statystyczny Gospodarki Morskiej 2009).

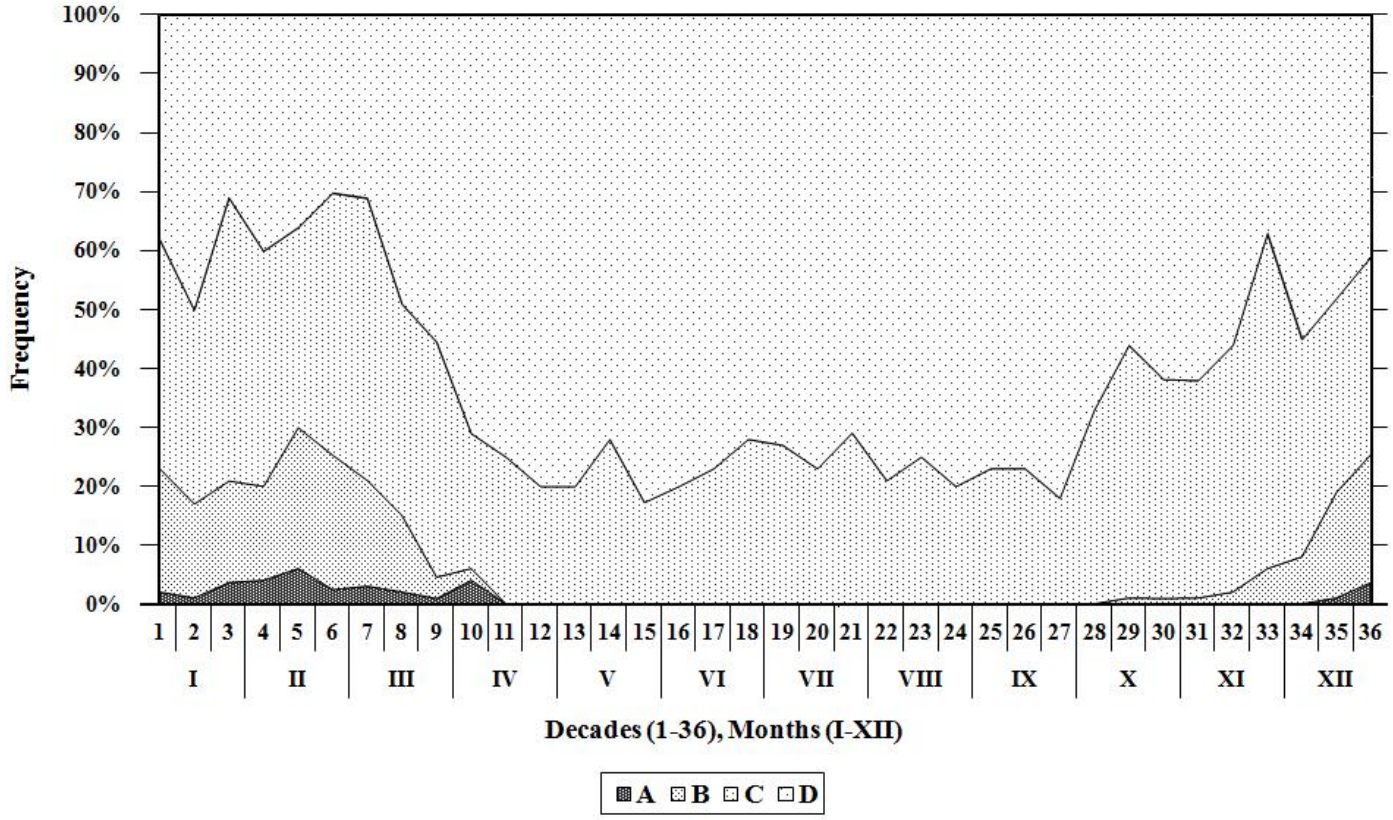

Fig. 3. Climatogram for Gdańsk (2000 – 2009).

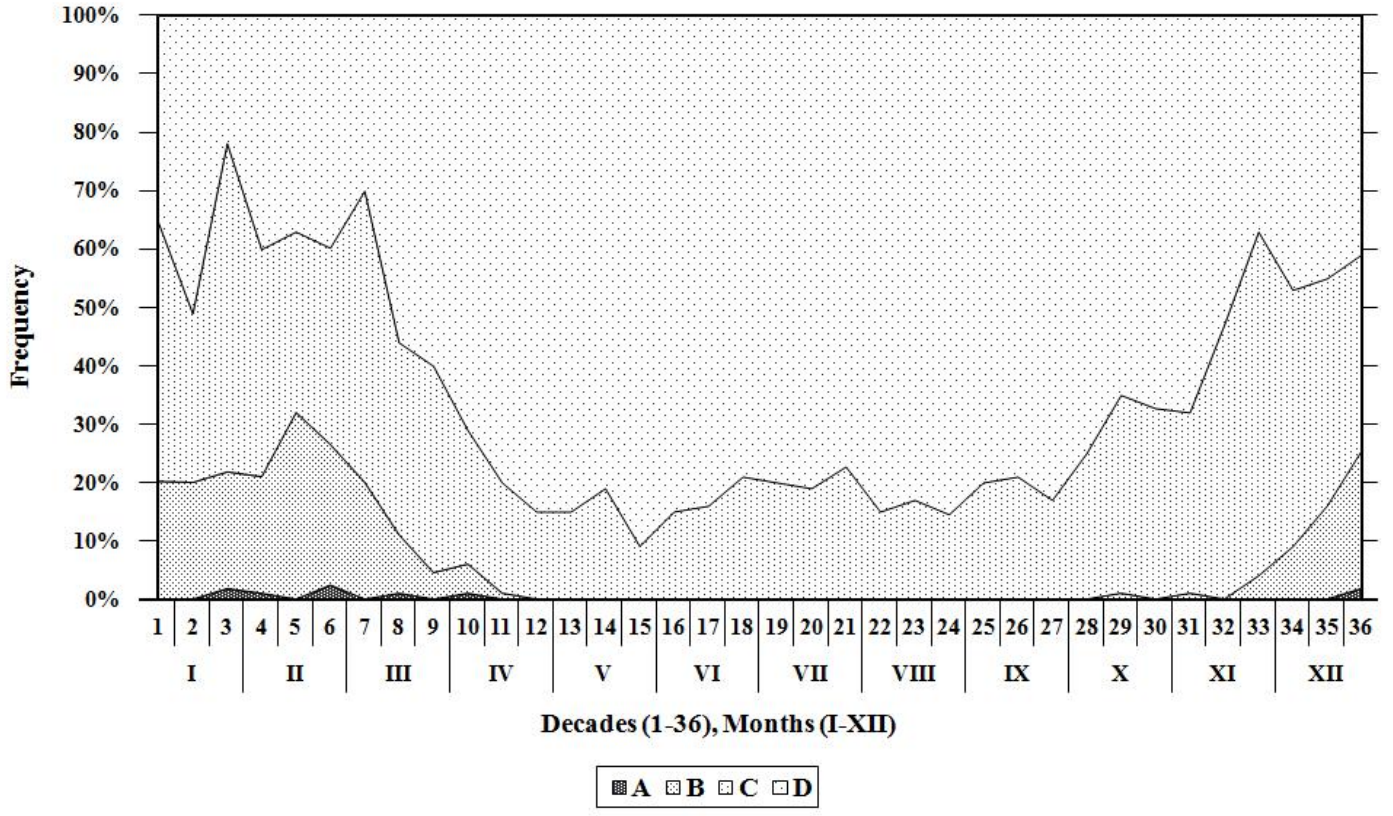

Fig. 4. Climatogram for Hel (2000 – 2009).

Weather types from Group A were observed in Hel only in 6 decades (in Gdańsk in 12 decades). Reaching maximum 2% frequency in the third decade of December, January and February - these weather types are marked with symbols 4314, 5314, and 6314 (Fig. 4). Contrary to Gdańsk the weather types from Group A occur in Hel in single, separated decades.

In the analyzed period 2000 – 2009 weather types form Group B appeared for the first time in the second decade of October, then in the first decade of November and only from the third decade of November they are constantly observed. Such situation is present until the second decade of April. Starting from the last decade of December till the first decade of March weather types form this group reach 20% frequency (maximum 32% in the second decade of February). Weather types form Group C are observed during the entire year and their maximum frequency in noted in the third decade of January (63%) and November (59%) and the first decade of March (50%).

Weather types from Group D are noted during the whole year and from the second decade of April till the first decade of October they reach 75% frequency- at the turn of May and June such weather conditions are noted 9 days in a decade on average.

3.4 *Łeba*

The port of Łeba (φ = 54°46'N, λ = 17°33'E) is situated on the mouth of the Łeba river (the place where the river flows into the sea) and similar to Hel is only fishing and tourist port. It is not fitted with cargo handling facilities (Krośnicka 2007).

Weather types form Group A (5313, 5314, 6313 and 6314) are observed for the first time in the second decade of November and for the last time in the first decade of April (Fig. 5). Similar to the port of Hel weather types from this group do not form one group; the decades during which they can be observed are separated and their frequency drops to 0%. All in all they are noted in 9 decades. When compared with the port of Hel and Gdańsk the frequency of weather types from Group A in Łeba is higher – they can be observed not only more frequently but also sooner, as early as in the second decade of November.

Weather types from Group B are noted from the third decade of October till second decade of April and the frequency exceeds 10% from the third decade of November till the second decade of March. They reach their maximum value during the third decade of December (37%) and January (35%) and in the second decade of February (31%). Weather types from Groups C are observed during the whole year and they reach maximum frequency (above 50%) from the second decade of October till the first decade of March; except the third decade in December, the second in January and the third decade in February.

The most favorable weather conditions for the port operation in the port of Łeba occur from the second decade of April till the second decade of June and from the third decade of July to the first decade of September, when the weather types from Group D reach maximum 75% frequency. When compared with the port of Hel weather types from this group appear more rarely.

3.5 *Ustka*

The port of Ustka (φ = 54°35‘N; λ = 016°52’E) is located on the mouth of the Słupia river and is one of the largest fishing harbors in Poland-about 60 fishing boats permanently berth here. From a few to a dozen of thousands of tons of cargo is handled in the port of Ustka every year (in 2008 – 3.2 thousand tons). Most frequently it is bulk and general cargo. In 2008 twenty one vessels entered the port of Ustka (2 general cargo vessels, 11 barges carrying dry bulk cargo and 7 passenger vessels) of overall capacity 13, 6 thousand GRT (Rocznik Statystyczny Gospodarki Morskiej 2009).

The analysis of climatogram (Fig. 6) indicates that weather types from Group A (5313, 5314, 5316, 6313, 6314) occur in Ustka more frequently than in the previously described ports, reaching maximum 6% frequency in the second decade of February. For the first time they are observed in the third decade of November and for the last time in the first decade of April.

Weather types from Group B are observed from the first decade of October to the first decade of April and the frequency is more than 10% from the first decade of December to the second decade of March. The frequency exceeding 20% is noted in the third decade of December, in the first and third decade of January and first and second decade of February. Weather types from Group C are noted during the whole year - they exceed 50% frequency from the second decade of October to the first decade of January, in the third decade of January from the third of January to the second decade of February and first decade of March.

Weather types from Group D have 70% frequency from the third decade of April to the third decade of July, in third decade of August and September. The period of continuous occurrence of weather types from Group D is reduced when compared to the above described ports. The optimum conditions for port operations in Ustka are observed in the third decade of July (84%).

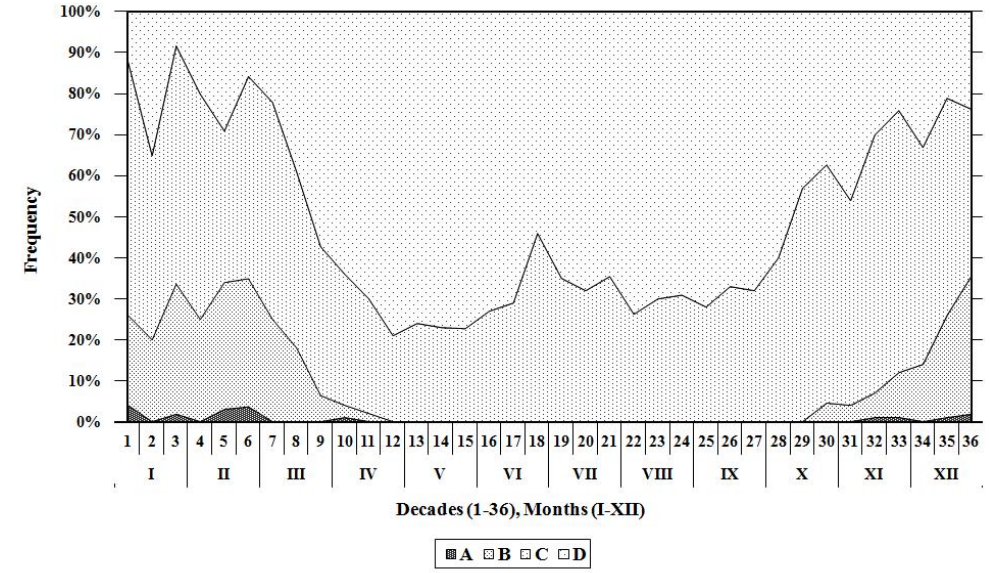

Fig. 5. Climatogram for Łeba (2000 – 2009).

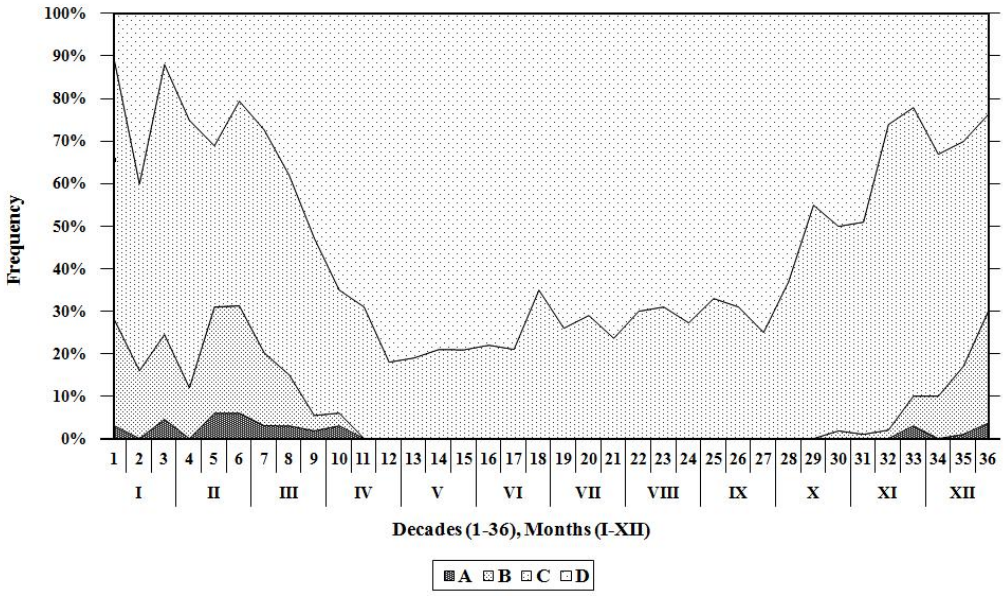

Fig. 6. Climatogram for Ustka (2000 – 2009).

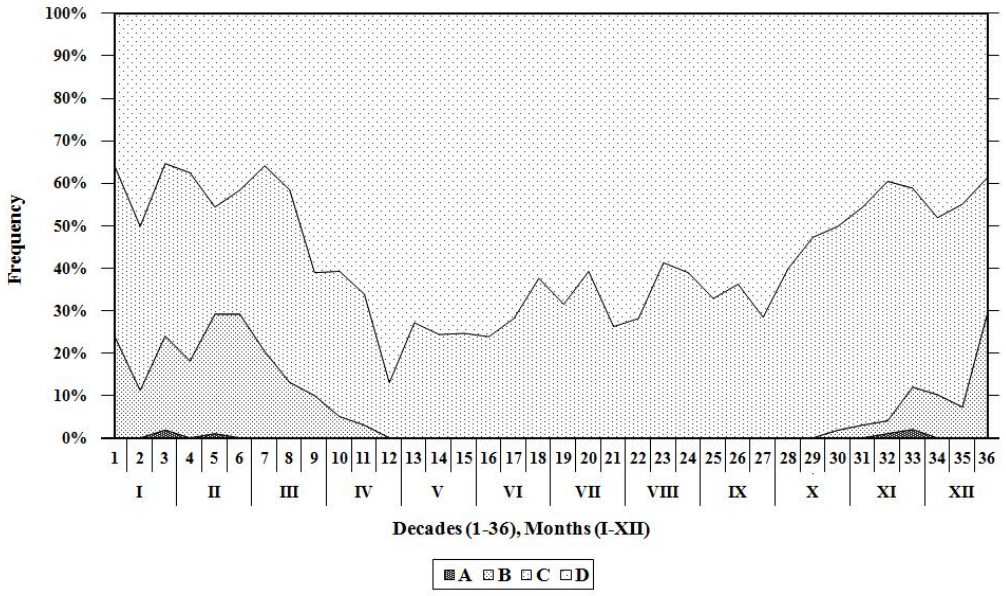

Fig. 7. Climatogram for Kołobrzeg (2000 – 2009).

3.6 *Kołobrzeg*

The port of Kołobrzeg (φ = 54°11‘N; λ = 015°35’E) is situated on the mouth of the river Parsęta and is the sixth biggest merchant sea port in Poland. It handles about 150 thousand tons of cargo every year (84 vessels of total capacity 108,5 thousand tons in 2008). Bulk and general cargo prevail in the cargo handled there. About 60 fishing boats berth in Kołobrzeg and rendering services for them is one of the basic tasks of this port. Kołobrzeg is also tourist port which was visited by 93 passenger vessels in 2008 (Rocznik Statystyczny Gospodarki Morskiej 2009).

Weather types from Group A (6313,6314) appear in single decades, i.e. in the first and second decade of November, the third decade of January, and second decade of February; reaching maximum frequency of 2% (Fig. 7). The noted weather types are: 6313 and 6314. When compared with the previously described ports they are only weather types of periodical weather.

Weather types from Group B appear as early as in the third decade of October and remain until the second decade of April. The highest frequency is observed in the third decade of December (32%). In January and February, at the beginning of March their frequency is similar – reaching 23% and 24%. Weather types from Group C reach their highest frequency at the turn of October and November (more than 50%).

In the last decade of April and May weather types form Group B occur with the frequency of 80%. In a few decades they reach 70% frequency: it is in the first and the second decade of May, second decade of June and the first decade in July and third in September. The frequency of these weather types is not lower than 34% in any of the decades.

3.7 *Świnoujście*

The port of Świnoujście (φ = 53°54‘N; λ = 014°15’E) is located on Wolin and Uznam islands, on the mouth of the Świna river. In 2008 the port of Świnoujście was visited by 5238 vessels of gross tonnage 63104,4 thousand tons. More than half of the cargo handled in the port of Świnoujście is made up of dry bulk cargo, with the majority of coal and coke. About 30% of all cargo handled are ro-ro cargo and lorries (Rocznik Statystyczny Gospodarki Morskiej 2009).

Weather types from Group A (6313) may be observed in the port of Świnoujście only in few separate decades and for the first time they are observed in the second decade of December (Fig.8). Apart from this case they are also noted in the second and third decade of February and March. They do not reach frequency higher than 2% in any of the above mentioned decades.

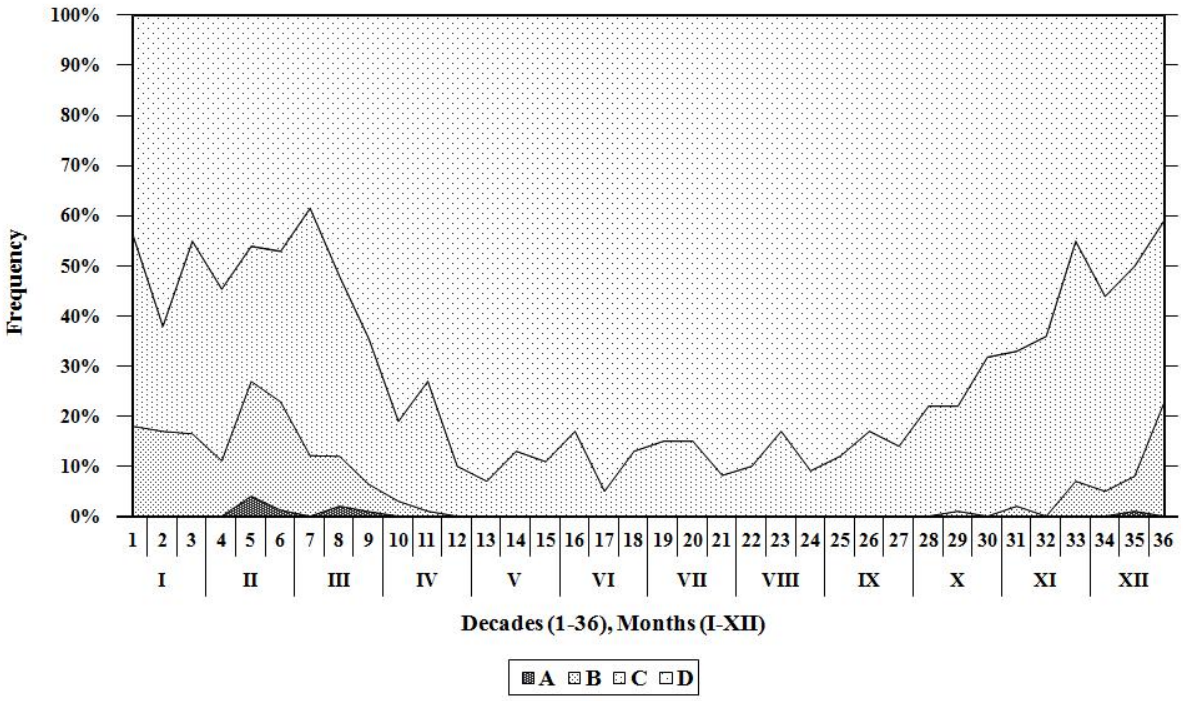

Fig.8. Climatogram for Świnoujście (2000 – 2009).

Weather types from Group B can be observed as early as in the second decade of October and in the first of November but continuously only from the third decade of November till the second decade of April, reaching 20% frequency only in two decades, i.e. in the third decade of December and second decade of February. The weather types from Group C never reach frequency of 50%.

Weather types from the last group reach maximum exceeding 90% frequency in a few decades- the third decade of April, May, July and August and the first decade of May and second decade in June. None of these decades are marked by frequency lower than 40%.

4 CONCLUSIONS

The analysis of climatograms drawn for Polish sea ports indicates that each of them has its own clearly defined structure of weather. In all of them both frequency as well as distribution in time of weather which is unfavorable for their operation is unique.

The weather types from Group A are most frequently noted in the port of Ustka and Gdańsk and least frequently in Elblag and Hel. In a case of Gdansk the weather of this group was observed in 12 and in Ustka in 11 decades, in Elbląg in two decades in Kołobrzeg in four decades, and in Świnoujście in five. Weather types from this group in none of these ports and in none of the decades reached frequency exceeding 10% which means that they are not observed every year – so they are weather types occurring from time to time only. The weather types from Group A for the first time in an annual cycle appear as early as second decade of November (Łeba, Kołobrzeg) and the latest in the third decade of December (Hel). For the last time these types of weather are noted in the first decade of April (such a situation takes place in five out of seven analyzed ports). Thus, it may be stated that the most unfavorable weather types are observed, not surprisingly, only during autumn, winter and spring seasons. In the analyzed ports it is only Gdansk were the weather is noted in a continuous way from the second decade of December until the first decade of April. In the other ports decades with weather types from Group A are separated by decades during which such weather type is not observed.

Weather types which do not have direct influence on the efficiency of port operation, i.e. weather types characterized by positive air temperatures during the whole day, without clouds, without precipitation and calm are most frequently observed from April till September. The 80% frequency is observed in the decades starting from the first decade of April in Świnoujście, second decade in April in Hel, the third decade in April in Gdansk, Ustka and in Kołobrzeg, and in Łeba in the third decade in May. For the last time such high frequency is noted in the third decade of September (Elblag, Gdańsk, Hel, Świnoujście), in the third decade of August (Ustka) and in the third decade of July (Kołobrzeg). Thus, the periods covering summer, late spring and early autumn turn to be most favorable for carrying out port operations in Polish ports.

REFERENCES

Ferdynus J. 1994, Sezonowość klimatyczna Björnöyi w świetle rocznej struktury pogody. [w:] Problemy Klimatologii Polarnej 4, Gdynia, s. 119–138.

Ferdynus J. 1996, Struktura pogód w Tromsö [w:] Prace Wydziału Nawigacyjnego WSM z. 2. Gdynia, s. 84–93.

Ferdynus J. 1997, Główne cechy klimatu morskiego strefy subpolarnej Północnego Atlantyku w świetle struktury stanów pogód. WSM Gdynia, ss.138.

Ferdynus J., Marsz A. A., Styszyńska A. 1995, Możliwości wykorzystywania metod klimatologii kompleksowej do tworzenia informacji dla potrzeb żeglugi. VI Międzynarodowa Konferencja Naukowo – Techniczna Inżynierii Ruchu Morskiego. WSM. Szczecin, s. 93–103.

Marsz A. A. 1992, Struktura pogód i roczna sezonowość klimatu Stacji Arctowskiego.[w:] Problemy Klimatologii Polarnej 2. Gdynia, s. 30–49.

Rocznik Statystyczny Gospodarki Morskiej 2009, Główny Urząd Statystyczny.

Krośnicka K. 2007, Zagospodarowanie małych portów polskiego wybrzeża, ich stan techniczny, organizacja funkcjonalna oraz powiązania z otoczeniem. [w:] Praca zbiorowa pod red. A. Grzelakowskiego i K. Krośnickiej, Małe porty polskiego wybrzeża uwarunkowania i perspektywy rozwoju. Wydawnictwo Akademii Morskiej w Gdyni, Gdynia, s. 25–90.

Olszewski J.L. 1967, O kompleksowej charakterystyce klimatu. [w:] Przegląd Geograficzny t. XXXIX. z. 3, s. 601–613.

Woś A. 1970, Zarys klimatu Polski Północno-Zachodniej w pogodach. PTPN. Prace Komisji Geograficzno – Geologicznej. T. X. z 3. Poznań, ss. 156.

Woś A. 1977a, Klimatyczne sezony roku w Kaliszu. [w:] Badania Fizjograficzne nad Polską Zach. t. XXX. ser. A Geografia Fizyczna, s. 93–115.

Woś A. 1977b, Zarys struktury sezonowej klimatu Niziny Wielkopolskiej i Pojezierza Pomorskiego. UAM. Seria Geograficzna. nr 15. Poznań, ss. 90