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Structure of the states of weather in Świnoujście in decades 1971–1980 and 2001–2010

Jacek Ferdynus

Gdynia Maritime University

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Abstract

Comprehensive climatology allows to specify not only the structure of the weather conditions, meaning the frequency of particular individuals, but also frequency of "favorable" or "unfavorable" weather, for example, for shipping and port operation. Comparison of "favorable" or "unfavorable" frequency of the weather types in Świnoujście have revealed that in the first decade of the twenty-first century, there was less of the latter than in the years 1971–1980. "Unfavorable" weather are primarily associated with the influx of air masses from northern and eastern sector, although there are among them also the western sector.

Formulation of the problem

One of the chapters of Pilots, namely the climatic tables of ports, describes the climatic conditions based on averaged results of observation of meteorological elements, such as air temperature, barometric pressure, wind speed, etc. This approach treats the climate as the average state of the atmosphere of a many year period. Climatic characteristics based on averaged meteorological elements and the extreme values of these elements (classical climatology) says nothing about the real state of the atmosphere. A complex climatology gives such a possibility to define climate as the average structure and sequence of weather conditions. The use of complex climatology methods allows describing the simultaneous occurrence of several meteorological factors (e.g. temperature, cloudiness, precipitation and wind). It allows describing the actual state of the atmosphere.

The first attempt to apply this method to prepare climate characteristics for the purposes of navigation was taken in the mid-90s of the twentieth century [1]. It included the characteristics of the climate in the port of Świnoujście based on meteorological observations of the decade 1971–1980. This work indicated that this method was very useful for the characterization of the port in terms of climatic constraints for cargo handling operations – estimation of the time when certain temperature, cloudiness, wind and rainfall were observed at the same time. In subsequent years, similar works were developed for other ports on the Polish coast [2, 3, 4], in which the author defined 4 groups of weather, assuming that Group A is made up of weather type particularly "unfavorable" for port operation and even making such operations impossible (all four "unfavorable" meteorological elements occurred at the same time). Group B is the weather combining three "unfavorable" meteorological elements, and Group C, two. Weathers in Group D should be considered as those that do not reduce the efficiency of ports operations, so they are "favorable" ones.

In climatic descriptions of ports in Pilots it can find many-year data from meteorological observations. The question is whether the characteristics of the climate for the purposes of navigation using the complex climatology method also requires a comprehensive long observational series or it is enough, in this case, to include shorter periods, for example a 10-year period. In order to answer this question a frequency of "favorable" and "unfavorable" types of weather in Świnoujście was defined for two decades, 1971–1980 and 2001–2010 and it was stated whether the differences in frequency of occurrence of given weather groups in the examined periods are statistically significant.

Method and observational data

To determine the structure of annual weather states, the methods appropriate for complex climatology were used, weather classification proposed by Marsz [5] and described in previous works by Ferdynus (among others [2]) was followed. The period for which the classification was made, was a specific day, and the features characterizing that day were: the average, minimum and maximum air temperature (T), mean overall cloudiness (N), sum of atmospheric precipitation (R) and average and maximum wind speed (V). In this way, each day is described by four digits – TNRV, and the number of potential weathers classified in this way is 486 (9×3×2×9) – see table 1. After classifying each day to a specific weather state, they were grouped according to periods in which they occurred and the frequency of taxonomic units, which are the groups and subgroups, classes and types of weather were defined.

Then, on the basis the frequency of types of weather in the consecutive decades of the year, each weather type was assigned to one of four weather groups marked by the letters A, B, C and D, where:

Group A – $T \wedge N \wedge R \wedge V$;
Group B – $(T \wedge R \wedge V) \vee (T \wedge N \wedge R)$;
Group C – $(T \wedge R) \vee (T \wedge V) \vee (R \wedge V) \vee (N \wedge R)$

where:

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

The "adverse" weather conditions for the port operation were considered to be such conditions where the average daily air temperature values were lower than 0°C (T = 2÷6, see table 1), there was precipitation (R = 1) and a strong wind (V = 3÷8, see table 1) blew. The Group D includes the weather, which does not interfere with the port operation: Group D = 100% (Group A ∧ Group B ∧ Group C). They were called weathers "favorable" for the port operations.

Subsequently, the frequency of groups A, B, C and D in the consecutive decades was calculated and on this basis climatograms are plotted – see figures 1 and 2. In climatograms on the OX-axis the consecutive decades of a year were determined and on the axis OY – the frequency of given weather groups.

The data used to complete this study come from two decades, i.e. 1971–1980 and 2001–2010. The data source for the first decade was the daily values of meteorological elements from the Institute of Meteorology and Water Management, and for the other from OGIMET (http://www.ogimet.com/).

In either case these are the average values of the daily synoptic observation. These data were carefully checked and in doubtful cases compared with the data from the databases of ECA & D (http://eca.knmi.nl/).

Table 1. Classification of weather's

Symbols		Partitions	Name of weather
T	0	$20.0° < t_{av} < 29.9°C$ $t_{min} \geq 0°C$	exceptionaly 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	$–20.0° < t_{av} < –29.9°C$ $t_{min} < 0°C$	exceptionaly frosty
N	1	$0.0 < N < 2.0$	blue sky
	2	$2.1 < N < 5.9$	partly clouded
	3	$6.0 < N < 8.0$	cloudy
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 whit 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 whit periods of gale
	5	$8.0 < v_{av} < 16.9$ m/s $v_{max} \geq 30$ m/s	stron 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

Structure of the weather states in Świnoujście

Frequency of weather conditions "unfavorable" for the port operations in Świnoujście in the decade 1971–1980

Analysis of figure 1 shows that weather from Group A (the least favorable for cargo handling operations – all four adverse meteorological elements occurring at the same time) in Świnoujście, in the decade 1971–1980 was only sporadically observed. It was noted in three groups of decades, the first of which began in the third decade of November and lasted until the first decade of January, the second remained throughout February and the third from the second decade of March to late April. In autumn and early winter it appeared more frequently than in the spring, although it never reached more than 5% frequency (half a day during the whole decade).

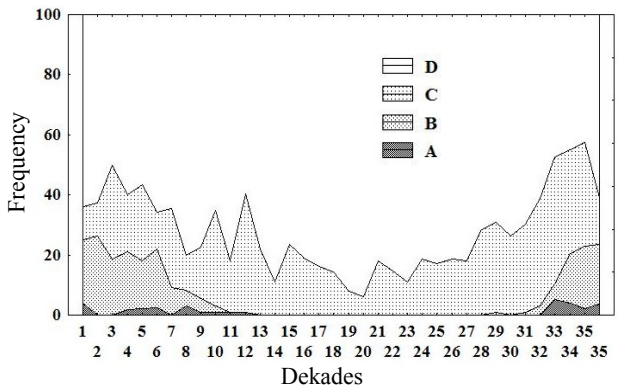

Fig. 1. Climatogram for Świnoujście (1971–1980)

Weathers from group B – three "unfavorable" meteorological elements – occur more frequently than weather from Group A. For the first time they were recorded in the first decade of October and the last time in the first decade of April. Maximum, over 20% frequencies were observed in the second decade of February (in 2.6 days of this decade). Weather of this group often, along with Group A remained for nearly three days during this decade – this applies to a few decades from the late December to late February.

Another group of weathers is made up of weather characterized by two "unfavorable" meteorological elements – Group C – which were observed in all decades, with a maximum frequency of occurrence in the autumn and winter and spring. In a few decades they remained for more than three days – from the second decade of November to the second decade of December, in the third decade of January, and the first and third decade of April.

Frequency of weather conditions "unfavorable" for the port operations in Świnoujście in the decade 2001–2010

The analysis of figure 2 indicates that it is different from the previously discussed figure 1. The weathers of Group A in the decade 2001–2010 in Świnoujście could be, as in the decade 1971–1980, observed only in a few individual decades, with the fact that for the first time they were noted in the first decade of December (about a decade later), then additionally in the second and third decade of February, in March and the first decade of April. In none of these decades they reached the frequency of more than 2% (except for the second decade of February). Thus, in the decade 2001–2010, they were fewer than in the decade 1971–1980 and they were observed in a smaller number of decades.

The fact that the "adverse" weather types of Group A are associated with specific wind directions, i.e. 4314 (E), 5313 (NNW, NNE and NE), 5314 (N and ENE), 5315 (NW); 6313 (NNE and ENE) and 6314 (N) seems to be interesting. It is not hard to see that the weather is formed when the air masses inflow from northern and eastern sector, although there are also influxes of air masses with the western component.

Weathers from Group B were noted as early as in the second decade of October and first decade of November, but in a continuous manner only from the third decade of November to the first decade of April. They reached 20% frequency in only four decades: the third decade of December, the first and second of January and the second decade of February.

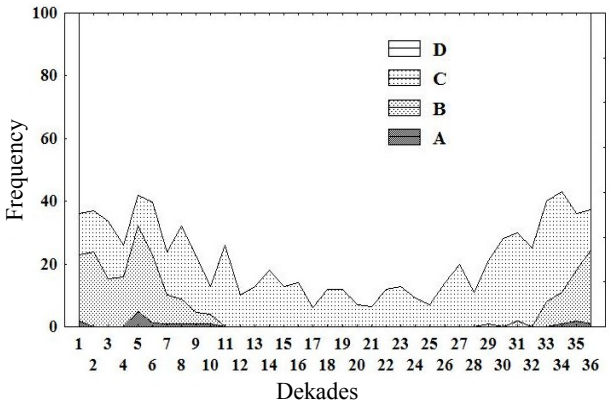

Fig. 2. Climatogram for Świnoujście (2001–2010)

The weathers from next group, Group C, were observed in all decades, but as in the previous decade, these never reached the frequency equal to 50%. Such weathers are typical of the transition seasons of the year.

Changes in weather frequency "favorable" for the work of the port of Swinoujscie in the decades 1971–1980 and 2001–2010

The analysis of climatograms (Figs 1 and 2) shows that in each of the examined decades, in consecutive decades of a year, the weather types belonging to Group D are most frequent. The exception is the period at the turn of November and December in the decade 1981–1980, when the total frequency of weather from groups A, B and C exceeds weather frequency from Group D. In the 2001–2010 decade, never such a situation took place. Weathers in Group D are such that do not hinder cargo handling operations, so it can call them "favorable" weather conditions for port operation. In each of the examined decades, the average annual frequency of such weather conditions is different; different is also their distribution in time.

Therefore, a question arises whether the observed changes in the frequency of weather type "favorable" for the work of the port of Świnoujście between the analyzed decades are statistically significant? In order to answer this question, on the basis of frequency of "favourable" types of weather in the following decades of the year, some simple statistical indicators were calculated and on their basis the corresponding graphs were drawn.

The graph in figure 3 shows that the average values of frequency of weathers "favorable" for the work of the port are clearly different (the decade from 1971 to 1980 – 72.0% and the decade of 2001–2010 – 78.1%) and the limits of the standard errors of estimates of average do not „overlap" with each other. The observed changes are distributed in such a way that an increase in the average of the decade 2001–2010 compared to 1971–1980 decade results from a clearly marked increase in frequency of "favorable" weathers in the individual decades of the year. The frequency range of "favorable" weathers between the first and third quartile shifted towards higher values in the years 2001–2010 and also the range between the minimum and the limit of the first quartile (see figure 4) was significantly reduced compared to the previous decade. The range of variability between the extreme values was also reduced from 51.6% in the decade 1971–1980 to 37% in the decade 2001–2010.

The course of average values for the two periods being compared is shown in figure 5. It can be seen that the course of the average values of "favorable" weather types in 2001–2010 in most decades, in as many as in twenty five decades, runs above the value of the previously analyzed decade. The opposite situation occurs in several, single, isolated decades, but there is no regularity observed in their distribution in time.

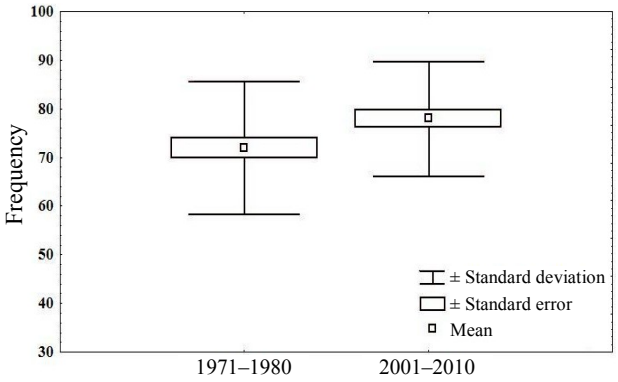

Fig. 3. Mean values of weather types "favorable" for port operation in the port of Świnoujście and ranges of standard error estimation in the decade of 1971–1980 and in the decade 2001–2010

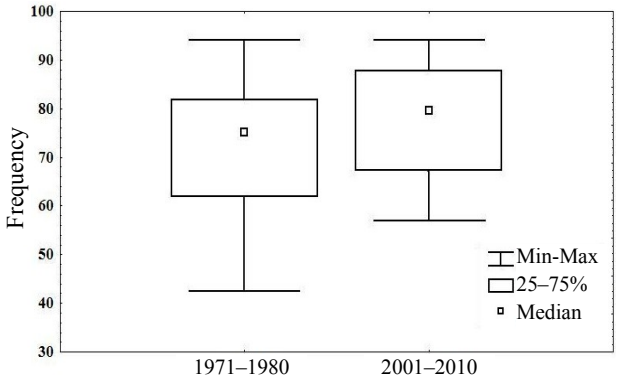

Fig. 4. Range of variability of frequency of weather types „favorable" for port operation in the port of Świnoujście in the decades 1971–1980 and 2001–2010

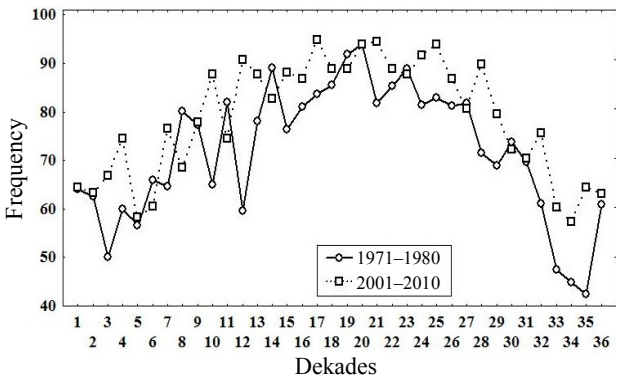

Fig. 5. Frequency of weather types "favorable" for port operation in the port of Świnoujście in the decades 1971–1980 and 2001–2010

On the basis of figure 5 it can be concluded that the differences in average frequencies of "favorable" weather types are distributed unevenly in the decades of both periods. To determine in which periods of the year there was a change in the frequency of "favorable" weather for port operation

of the port of Świnoujście, a number of differences between the decades were subject to filtration using a 3-point moving average.

The results of this analysis have indicated that the main changes (increases) in frequency of "favorable" weather conditions occurred during early spring (11^{th} – 13^{th} decade), in autumn (25^{th} – 29^{th} decade), and the greatest changes in the initial phase of winter (32–35 decade). Minimal changes occurred in the middle of summer (18^{th} – 21^{st} decade) and at the turn of winter and spring (70^{th} – 100^{th} day of a year).

Conclusions

It is well known that some meteorological and hydrological elements cause that navigation or port operation is difficult and that the impact of both of them makes these activities even impossible. Knowledge of the frequency and time of occurrence of "adverse" weather types is essential for proper functioning of the port. Complex climatology provides the necessary information as it treats weather as the co-occurrence of certain meteorological elements.

Using methods of complex climatology made it possible not only to determine the structure of the weather states in the decade 1971–1980 and 2001–2010, but also revealed that in the latter decade there was a decline in frequency of "adverse" weathers for port operation in the port of Świnoujście. It seems that the "regional temperature rise" observed in the first decade of the twenty-first century, especially in the southern Baltic [6] is responsible for the increase in frequency of „favorable" weathers.

The comparison of the two analyzed decades revealed that ten-year periods used to determine the characteristics of climatic conditions with the help of complex climatology, which in a given port can be used for shipping, are too short and, like the classical analysis of climate used in Pilots the periods should be longer so as to cover the periods when the values of the analyzed elements increased and decreased. As air temperature is the differentiating element in climate, the best for such analysis would be a 30-year period.

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