

## Chapter 4

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# Anemometric Conditions of North-Eastern Poland in 1981-2005

### Introduction

Wind is one of the key natural threats. Wind speeds above a certain limit can be dangerous, since in extreme situations they cause extensive damage, injuries and even fatalities [LORENC 1996, 1999, 2000]. The occurrence of maximum wind speeds in the north-eastern Poland is related to two genetically different meteorological situations [LORENC 1999].

Hurricane speed winds are related to the circulation over the area of Poland and the southern Baltic. Those situations are accompanied by gusts of wind, exceeding the average 10-minute speed by at least  $5 \text{ m s}^{-1}$ . Strongly-gusting circulation types according to classification provided by Lityński [LORENC 1999] include: the north-western cyclonic circulation with the low pressure centre over Scandinavia, and the north-west circulation, without a clear pressure characteristic. A percentage share of days with circulation types in which wind with gusts occurred in the northern region of Poland is 25% per year (30% in the winter season and 18% in the summer season) [LORENC 1996]. The range of impact includes the area of northern and central Poland. In the opinion of LORENC [1999], the occurrence of the north-western circulation in November, January, February or March, and the western circulation in March or April accounts for 75% likelihood of the occurrence of maximum wind speeds in northern Poland. Generally, the period of an increased frequency of strong winds lasts from October to April.

Another situation posing a threat is related to creation of meteorological conditions leading to formation of small-scale whirl vortices, known as whirlwinds. The risk of the occurrence of this wind is the highest in warm parts of the year. DOTZEK [2003] calculated that every year Europe experienced on average 170 whirlwinds over the land surface and 160 over water. They are created in the zone of the atmospheric front between air masses that are strongly diversified in terms of temperature and humidity (e.g. tropical marine air and polar air) most often

in the afternoons. Storm clouds are then created with strongly-developed vertical and horizontal currents and whirls of air. A whirlwind in Poland has a diameter of a few to about a dozen meters, and a vertical or diagonal spin axis in relation towards the Earth surface. They are usually formed during storms, rain and hail. A zone of destruction caused by a windwhirl corresponds, more or less, to the crosswise diameter of the whirl, it moves at  $30\text{-}40\text{ km}\cdot\text{h}^{-1}$ , and the wind speed in the whirl is between  $50\text{ and }100\text{ m}\cdot\text{s}^{-1}$ , while its duration is between a few seconds and less than twenty minutes. LORENC [1999] determined that the frequency of whirlwinds in Poland ranged between 1 and 7, mostly in the Małopolska region, completely excluding the coast.

## Material and methods

In order to identify the threat which can be posed by wind, maximum daily wind speeds and wind speeds in gusts were subject to analysis. Meteorological data referring to the area of north-eastern Poland originated from five synoptic stations in Elbląg, Kętrzyn, Mikołajki, Olsztyn and Suwałki, and covered the period of 25 years (1981-2005). Absolute maximum values in a year and in individual months were selected from maximum daily winds speeds and their relationships were examined.

Spatial distribution of mean multi-year wind speeds in the region was established, along with the standard deviation, the course of the mean annual maximum speeds and the trend of their changes, ranges of normal maximum speeds and anomalous years in this regard.

The study also presents classification of the wind speed distribution in the examined locations. With this aim in view, a classification proposed by PARCZEWSKI [1960] was applied (Table 1).

Although the gust of wind, which by definition is a sudden increase of its speed exceeding at least by  $5\text{ m}\cdot\text{s}^{-1}$  the average wind speed in the last 10 minutes and does not last longer than 2 minutes, it can cause material damage and even pose a threat to life in extreme circumstances.

Although standard measurements of wind gusts are carried out at synoptic stations, this element does not belong to the set of standard observation data which can be obtained from any station. Therefore, the analysis of this threat was carried out only on the basis of documentary material obtained from stations located in Kętrzyn and Olsztyn.

The study included the analysis of monthly and annual wind speeds in gusts, taking into consideration the trend of their changes. Also, the average course of wind speed was presented for all months of the 25-year period on the basis of classification provided by LORENC [1999] (Table 2). As mentioned above, due to the lack of data concerning wind gusts in Elbląg, Mikołajki and Suwałki, an analysis of linear correlation was carried out. Maximum wind speeds and maximum wind speeds in gust from Olsztyn were correlated with data originating from Elbląg and Mikołajki, and values from Suwałki with the data from Kętrzyn.

## Discussion of results

The distribution of maximum wind speeds was analysed on the basis of mean maximum wind speeds. Those values in individual locations ranged from  $4.3 \text{ m s}^{-1}$  in Mikołajki to  $5.6 \text{ m s}^{-1}$  in Suwałki (Fig. 2).

A summary list of the mean maximum wind speeds recorded every year demonstrated that the highest values almost always occurred in Suwałki, then in Kętrzyn, and the lowest values in Mikołajki. A threat of higher wind speeds in the north-eastern part of the examined area is confirmed by the studies concerning the period of 1951-1970. Although the range of those studies did not include Elbląg and Suwałki, they demonstrated that the lowest mean monthly wind speeds occurred along the Lidzbarsk Warmiński, Kętrzyn and Szczuczyn line [NOWICKA, GRABOWSKA 1989].

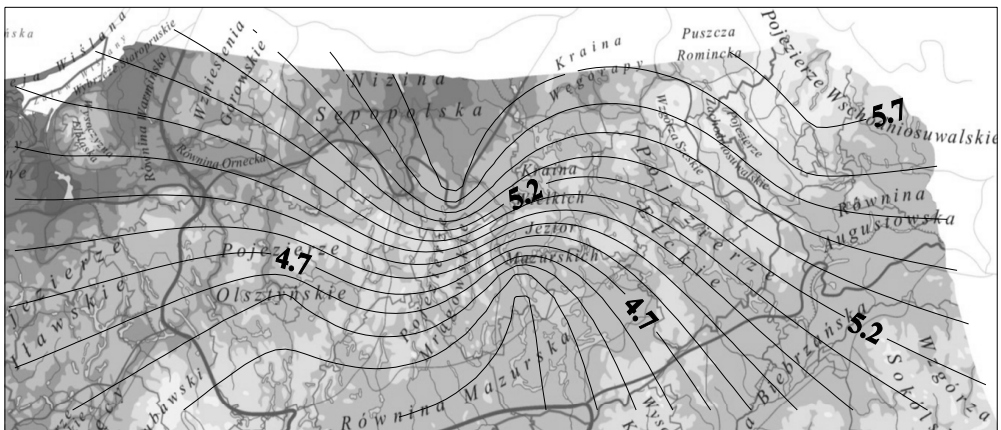
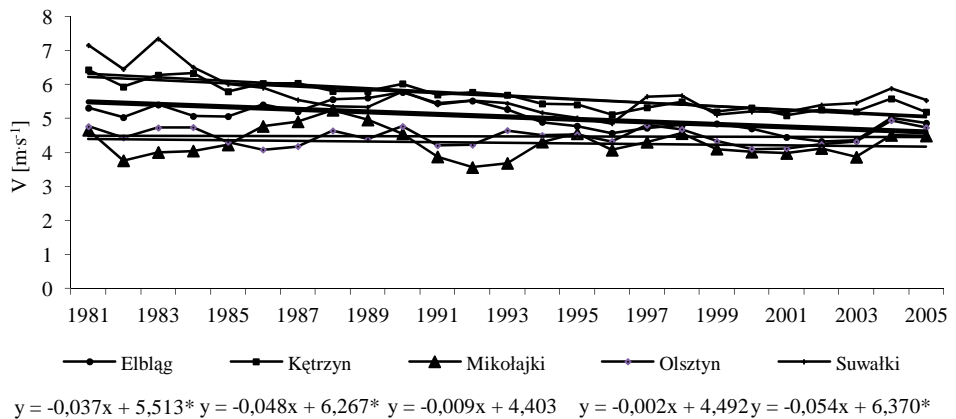


Fig. 2. Mean maximum wind speeds in the period of 1981-2005 in north-eastern Poland



\* – statistically significant with  $\alpha = 0,05$  – applies to all tables and figures

Fig. 3. Annual course of mean maximum wind speeds in the period of 1981-2005 in north-eastern Poland

Trends of time variability of the mean values of maximum wind speeds revealed a declining character in all examined locations of the region. In the north zone of the region, i.e. in Elbląg, Kętrzyn and Suwałki, this tendency was statistically significant (Fig. 3).

Although winds recorded in Kętrzyn were blowing with a higher speed than in Mikołajki, the variability of conditions was the same in both locations. A lower variability was observed only in Olsztyn, while the highest value of standard deviation was found for Suwałki. Normal, mean maximum wind speeds in Mikołajki ranged from 3.9 to 4.7 m·s<sup>-1</sup>, while in Kętrzyn those values varied from 5.2 to 6.0 m·s<sup>-1</sup>. The highest number of years with anomalously low mean wind speeds was recorded in Kętrzyn and Olsztyn, and the lowest number in Suwałki. The highest number of years with anomalously high mean wind speed was recorded in Olsztyn, and the lowest number in Kętrzyn. There were more years with anomalously high mean wind speeds than years of anomalously low speeds. Maximum wind speeds were of a local character, since there was not even one anomalous year in the entire area of research (Table 3).

Table 3

Essential characteristics of mean maximum wind speeds in the period of 1981-2005 in north-eastern Poland

Mean maximum wind speeds		Elbląg	Kętrzyn	Mikołajki	Olsztyn	Suwałki
$\sigma$		0,4	0,4	0,4	0,3	0,6
$\bar{x} - \sigma$		4,6	5,2	3,9	4,2	5,1
$\bar{x} + \sigma$		5,4	6,0	4,7	4,7	6,3
Anomalously low mean maximum wind speeds	years	1996 2001 2002 2003	1996 1999 2001 2003 2005	1982 1992 1993	1986 1987 1991 2000 2001	1995 1996
	frequency [%]	16	20	12	20	8
Anomalously high mean maximum wind speeds	years	1988 1989 1990 1991 1992	1981 1983 1984	1986 1987 1988 1989	1981 1984 1990 1997 2004 2005	1981 1982 1983 1984
	frequency [%]	20	12	16	24	16

Anemometric conditions of the Mazurian Lake District in 1951-1970 ranged, on average, from 3 m·s<sup>-1</sup> in the west to 4 m·s<sup>-1</sup> in the east [HUTOROWICZ *et al.* 1996], and at the Gdańsk Seashore – 3.9 m·s<sup>-1</sup> in the period of 1951-1965 [HUTOROWICZ 1982]. Mean annual wind speeds in the Mazurian Lake District in the subsequent multi-year period (1971-1990) amounted to 3.4 m·s<sup>-1</sup> [GRABOWSKI 1996].

The lowest mean values ( $3.6 \text{ m s}^{-1}$ ) and the maximum values ( $9 \text{ m s}^{-1}$ ) were recorded in Mikołajki, while the highest were observed in Suwałki (Fig. 4). The highest maximum wind speed was recorded in Suwałki and in 1983 it amounted to  $23 \text{ m s}^{-1}$ . Absolute maximum wind speeds decreased towards the south-west, while the lowest maximum values were recorded in Mikołajki and Elbląg, where they amounted only to  $16 \text{ m s}^{-1}$  (Fig. 5).

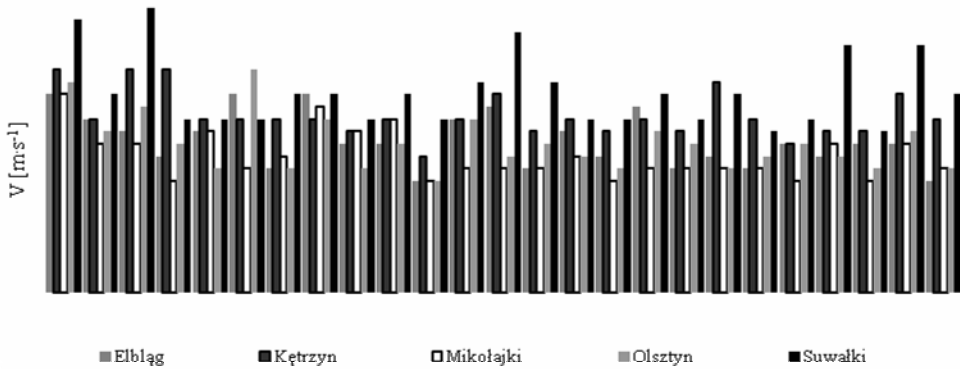


Fig. 4. Course of maximum wind speeds in the period of 1981-2005 in north-eastern Poland

The research [LORENC 1996] on the documentation material for 1966-1990 demonstrate that once per 100 years maximum wind speeds can reach values from  $16 \text{ m s}^{-1}$  in Kętrzyn,  $22 \text{ m s}^{-1}$  in Olsztyn,  $25 \text{ m s}^{-1}$  in Elbląg,  $26 \text{ m s}^{-1}$  in Mikołajki, to  $34 \text{ m s}^{-1}$  in Suwałki. On the other hand, in 1983 and 1984 the observed maximum wind speed in Kętrzyn was  $18 \text{ m s}^{-1}$ .

As follows from the data presented (Fig. 6), the highest diversity of maximum wind speeds was observed rather in individual locations than in months, although generally higher wind speeds were observed in winter than in summer.

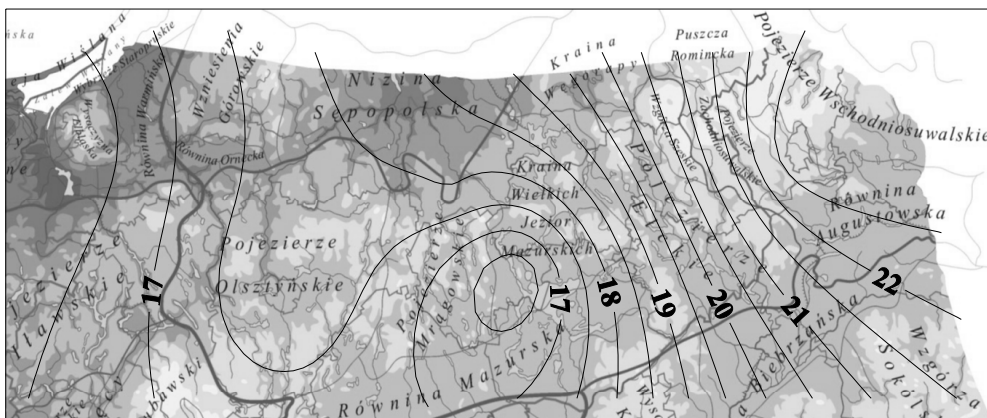


Fig. 5. Maximum wind speeds in the period of 1981-2005 in north-eastern Poland

On the basis of the analysis of the distribution of maximum wind speeds, it was established that the highest wind speeds in all months were recorded in Suwałki, in February and March those speeds reached the value of  $23 \text{ m s}^{-1}$ , and in other winter months it was at least  $20 \text{ m s}^{-1}$ . Values recorded in other locations were lower. Lower wind speeds were observed in a warm part of the year, which was particularly visible in Suwałki, where differences between the highest and the lowest maximum wind speed in individual months were the highest. Such high wind speeds were influenced, most probably, by the elevation of this area in the form of the Suwałki Upland at an altitude of more than 180 m above sea level. The maximum wind speed in July was  $13 \text{ m s}^{-1}$ , i.e. lower by  $10 \text{ m s}^{-1}$  than in March or December. The lowest difference was recorded in Kętrzyn, where it amounted to  $6 \text{ m s}^{-1}$ . There, the maximum speeds in all months were quite high. The lowest wind speeds were recorded in July, June and August, while the highest were observed in December and January (with the exception of Suwałki, where very high maximum speeds were recorded also in February and March). Also, research on mean wind speeds in north-eastern Poland demonstrated that the highest speeds were recorded in January and the lowest in July or August [OLBA-ZIĘTY *et al.* 2007]. A similar variability of the wind speed during a year for the period of 1971-1999 was obtained by GRABOWSKI [1996].

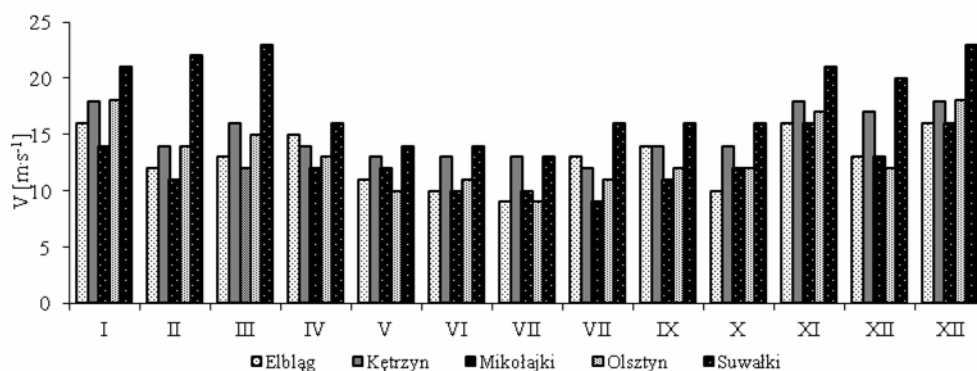


Fig. 6. Distribution of monthly maximum wind speeds in the period of 1981-2005 in north-eastern Poland

Distribution of mean frequencies of maximum wind speeds in individual classes for the locations under analysis made it possible to claim that the majority of days in the region were characterized by moderate and weak wind. Days with quite strong wind occurred most frequently in Kętrzyn (Fig. 8), on average between 3 and 9, and in Suwałki (Fig. 11), on average between 3 to almost 6. The lowest number of days with quite strong wind occurred in Mikołajki (Fig. 9) and in Olsztyn (Fig. 10): 1.7, on average. Strong wind occurred with the frequency of more than one day in Suwałki from October to April, and in Kętrzyn from November to March. In Elbląg, Mikołajki and Olsztyn, the mean frequency of strong wind did not reach the value of even one day, and in June (in Mikołajki and Elbląg) and July, it did not occur at all

(Fig. 7). Very strong wind occurred most frequently in Suwałki, in all months excluding the period from May to July. In other months, this phenomenon occurred only in winter months, i.e. in Kętrzyn in November, December, January and March, in Olsztyn and Elbląg in January and November, and the least frequently in Mikołajki, only in November. Gales were recorded only in Suwałki, from January to March and in November. On the basis of meteorological data originating from the Institute of Meteorology and Water Management, no strong gales or violent gales were observed in the entire region. However, this does not exclude the occurrence of local whirlwinds of the hurricane speeds, the evidence of which was a whirlwind which passed on 4 July 2002 through the Piska Primeval Forest, destroying about 35% of the forest.

The area of the Mazurian Lake District was described already by HOHENDORF [1956] as a region threatened by high wind speeds, in which the occurrence of gales and strong winds favours their erosive effects. Strong winds in 1881-1930 of the speed of  $14 \text{ m s}^{-1}$  occurred in Olsztyn on average three times a year, and wind of speed  $17 \text{ m s}^{-1}$  at least once a year [HOHENDORF 1956]. The number of days with strong and very strong wind in Elbląg in 1981-2005 was most similar to the results obtained by WISZNIEWSKI [1973] for the period of 1951-1960. The 25-year period under examination revealed a much lower number of days with strong wind than the period of 1951-1965, since pursuant to the classification adopted, only the days with the speed exceeding  $10 \text{ m s}^{-1}$  were taken into account [HUTOROWICZ 1982].

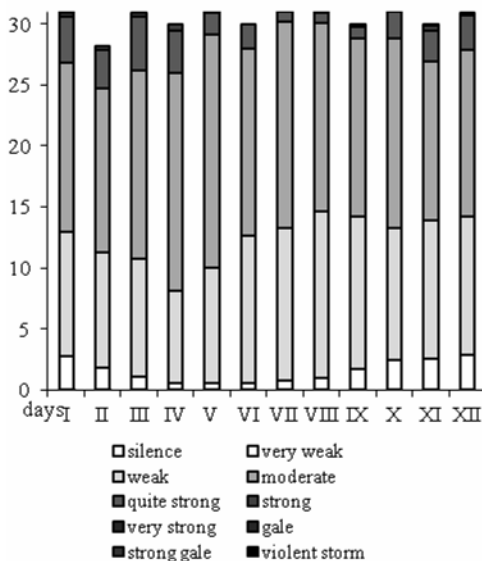


Fig. 7. Distribution of mean maximum wind speeds in the period of 1981-2005 in Elbląg according to PARCZEWSKI [1960] classification

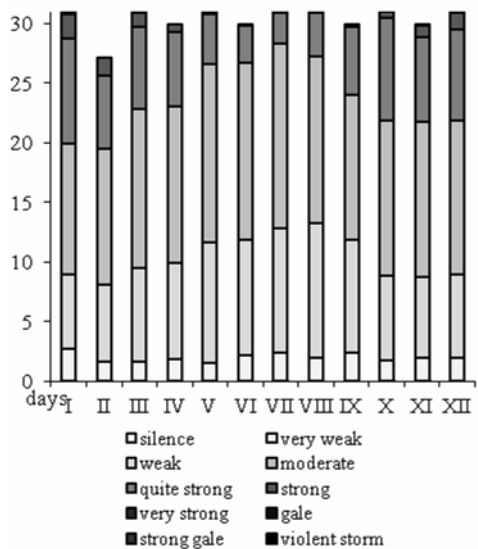


Fig. 8. Distribution of mean maximum wind speeds in the period of 1981-2005 in Kętrzyn according to PARCZEWSKI [1960] classification

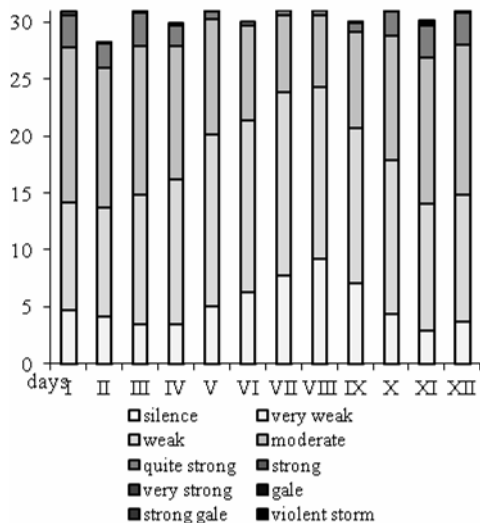


Fig. 9. Distribution of mean maximum wind speeds in the period of 1981-2005 in Mikołajki according to PARCZEWSKI [1960] classification

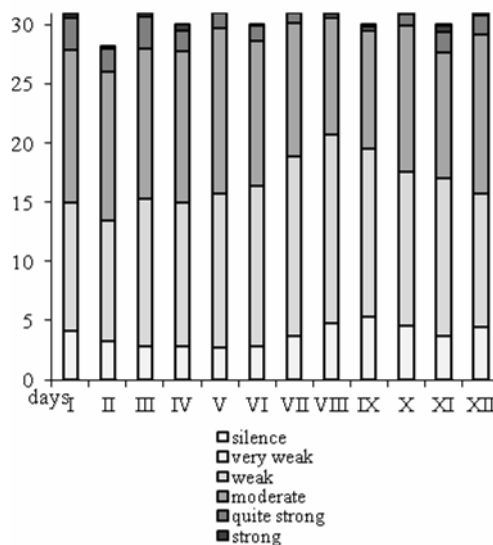


Fig. 10. Distribution of mean maximum wind speeds in the period of 1981-2005 in Olsztyn according to PARCZEWSKI [1960] classification

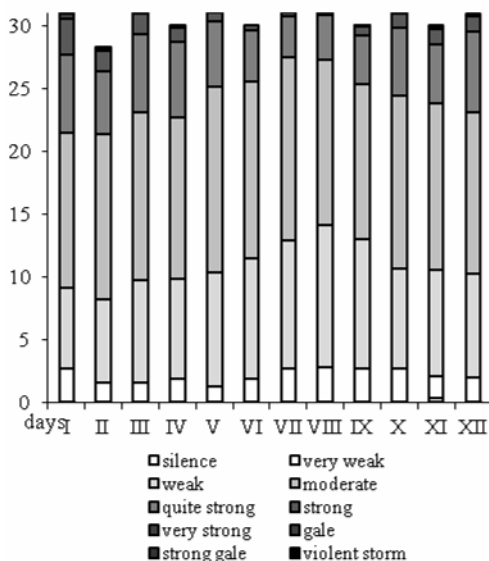


Fig. 11. Distribution of mean maximum wind speeds in the period of 1981-2005 in Suwałki according to PARCZEWSKI [1960] classification



Because of limited availability of data concerning wind gusts, this element was analysed only on the basis of measurements originating from Kętrzyn and Olsztyn. The course of gusts varied year after year. Lower values were recorded in Olsztyn, from  $19 \text{ m s}^{-1}$  to  $31 \text{ m s}^{-1}$ , and higher ones in Kętrzyn, from 20 to  $32 \text{ m s}^{-1}$  (Fig. 12).

The threshold value of the gust is the speed of  $11 \text{ m s}^{-1}$  [LORENC 1996], but speeds can be dangerous only from  $17.2 \text{ m s}^{-1}$  [LORENC 1999]. The wind in the lowest class gust ( $17.2\text{-}20.7$ ) is a violent wind, breaking tree branches and making it difficult to walk upwind. The wind of this class occurred in the examined period as a maximum gust once in Kętrzyn and three times in Olsztyn. A gale with gusts from  $20.8$  to  $24.4 \text{ m s}^{-1}$ , which causes vast destruction and poses a threat to life, appeared on average every other year in Olsztyn (12 times in the examined period) and every 4 years in Kętrzyn (6 times in the examined period). A strong gale ( $24.5\text{-}28.4 \text{ m s}^{-1}$ ) occurred on average once per 4 years in both locations. A violent gale ( $28.5\text{-}32.6 \text{ m s}^{-1}$ ), which causes vast destruction and threatens life – appeared in Kętrzyn on average almost every other year, and in Olsztyn every 6 years. A hurricane wind, strong, destructive and devastating, did not occur at all (Fig. 12).

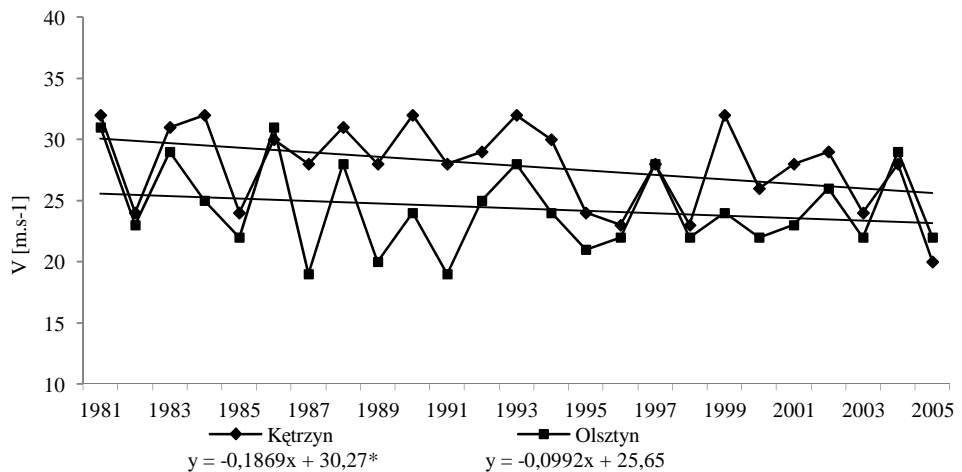
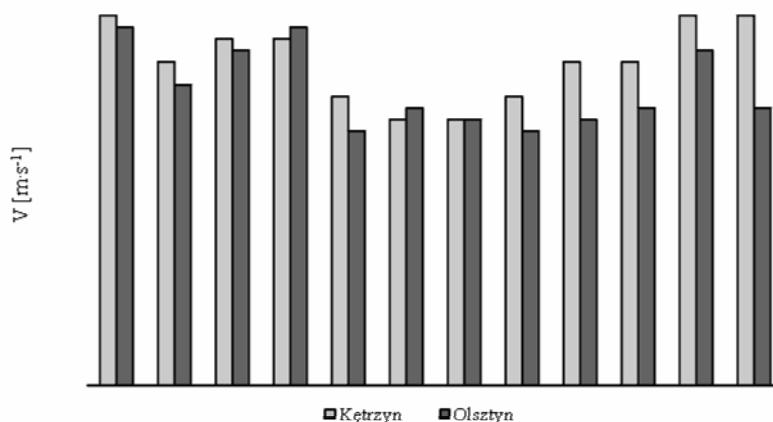


Fig. 12. Maximum wind speeds in gusts in the period of 1981 – 2005 in north-eastern Poland

Higher maximum wind speeds in gusts were always (except April and June) recorded in Kętrzyn, while mean differences between maximum wind speeds in gusts in both location were above  $2 \text{ m s}^{-1}$ . Just like maximum wind speeds, maximum major gusts were also observed more frequently in the colder parts of the year. The lowest absolute maximum wind speeds in gusts in Olsztyn ( $22 \text{ m s}^{-1}$ ) were observed in May and in August, and in Kętrzyn ( $23 \text{ m s}^{-1}$ ) in June and July. The highest wind speed in gusts in Kętrzyn ( $32 \text{ m s}^{-1}$ ) were recorded in January, November and in December, and in Olsztyn ( $31 \text{ m s}^{-1}$ ) – in January and April (Fig. 13).



Rys. 13. Distribution of monthly maximum wind speeds in gusts in the period of 1981-2005 in north-eastern Poland

In Olsztyn, days with wind gusts up to  $17.2 \text{ m s}^{-1}$  occurred more frequently, on average from over 3 days in August to over 7 days in January, while in Kętrzyn there were observed between 2 to 6 such days, although the speed structure was different. Winds posing a threat in Kętrzyn (Fig. 14) occurred on average from 2 days in January to 0.3 day in May and in August. Violent wind occurred most frequently in January and in March, and its mean frequency exceeded one day, i.e. it was observed on average every year. On the other hand, a gale occurred every other year in months from January to March. A strong gale occurred in November with the frequency of 28%, although it also occurred in the period between January to April. In Kętrzyn, maximum wind speeds in gales posing a threat, occurred on average almost four days in January and 0.5 in July. A violent wind was observed most often, with the frequency between 0.3 to 2.3 days a month. A gale occurred every month, most often in January, February and March, on average twice a month. A strong gale did not occur only in June and July, and in January, February and March it occurred even every other year. A violent gale in the examined period occurred seven times in January, once in March, once in April, five times in November and twice in December. In Olsztyn (Fig. 15.) A violent wind and a gale occurred every month. A violent wind most often occurred in January – on average once a year, the least frequently in August – once per five years, while gales occurred with the frequency of from once per two years in January, to once per ten years in June and July. A strong gale most frequently occurred in November – on average every three years. A violent gale was observed in November as well as in the period between January and April.

Statistically significant correlation coefficients between the maximum wind speed and the maximum speed of wind in a gust in most months and the analogous course allows Elbląg, Mikołajki and Olsztyn to be classified as less-threatened

locations, while Kętrzyn and Suwałki can be considered as more threatened (Table 4). The location of Kętrzyn at the end of the Old Prussian Valley, stretching from the Baltic Sea, creates a convergence zone there and results in the occurrence of higher wind speeds and gustiness than in Mikołajki or in Olsztyn. Maximum wind speeds and their frequency in Suwałki were even higher than in Kętrzyn. It can therefore be expected that maximum speeds of wind gusts in Suwałki were even higher, and thus more dangerous.

LORENC [1996] presented a spatial distribution of the maximum, real wind speeds in gusts, and pursuant to her studies, in 1961-1995, in the area of north-eastern Poland, the maximum recorded gusts ranged from  $38 \text{ m s}^{-1}$  in Elbląg,  $34 \text{ m s}^{-1}$  in Olsztyn,  $32 \text{ m s}^{-1}$  in Suwałki to  $28 \text{ m s}^{-1}$  in Mikołajki.

According to the data from “Climatic atlas...” [1990], maximum wind speeds in gusts occurred with the frequency of once per 50 years. In the area around Elbląg, the occurrence of wind with a maximum speed in gusts of over  $40 \text{ m s}^{-1}$  is possible, in Suwałki and Kętrzyn – over  $35 \text{ m s}^{-1}$ , and of over  $30 \text{ m s}^{-1}$  in other locations.

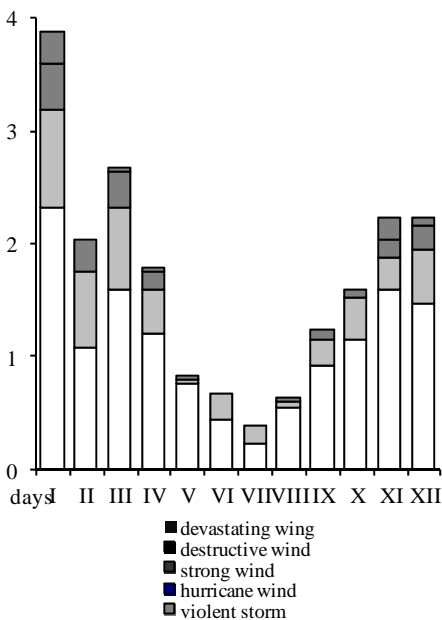


Fig. 14. Distribution of maximum wind speeds in gusts in the period of 1981-2005 in Kętrzyn according to LORENC [1999] classification

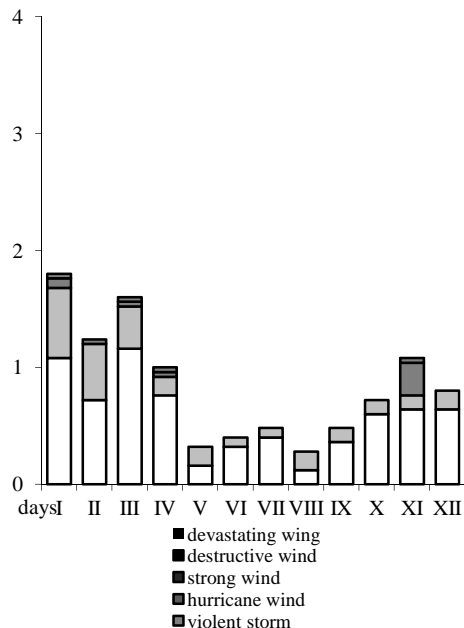


Fig. 15. Distribution of maximum wind speeds in gusts in the period of 1981-2005 in Olsztyn according to LORENC [1999] classification

Table 4

Correlation coefficients of maximum wind speed and maximum wind speed in gusts in the period of 1981-2005 in north-eastern Poland

Miesiąc	Kętrzyn	Olsztyn
I	0.694*	0.695*
II	0.632*	0.493*
III	0.768*	0.740*
IV	0.645*	0.716
V	0.417*	0.376
VI	0.622*	0.752*
VII	0.396*	0.390
VIII	0.144	0.597*
IX	0.634*	0.551*
X	0.485*	0.637*
XI	0.819*	0.734*
XII	0.757*	0.444*

## Conclusions

1. Mean maximum wind speeds ranged from  $4.3 \text{ m}\cdot\text{s}^{-1}$  in Mikołajki to  $5.6 \text{ m}\cdot\text{s}^{-1}$  in Suwałki. A significant declining tendency of mean maximum wind speeds was observed in the northern zone of the research area. The highest maximum wind speed occurred in Suwałki – the highest value was recorded in 1983, amounting to  $23 \text{ m}\cdot\text{s}^{-1}$ . The lowest wind speeds were recorded in July and in June and August, and the highest in December and January.
2. A strong wind occurred on average once a month, from October to April in Suwałki and from November to March in Kętrzyn, while in other locations it was observed less frequently – it did not occur at all in July in Mikołajki or Elbląg. A very strong wind most often occurred in Suwałki from August to April, and in other months it was recorded only in winter months. Gales were recorded only in Suwałki between January and March and in November, while a violent gale was not observed.
3. A violent wind occurred in the examined period once in Kętrzyn and three times in Olsztyn. A gale occurred on average every other year in Olsztyn and every four years in Kętrzyn. A strong gale occurred on average once per four years in both locations. A violent gale in Kętrzyn occurred on average every other year, and in Olsztyn – every six years. A hurricane-force wind (strong, destructive or devastating) did not occur at all.
4. The maximum wind speeds in gusts usually observed in Kętrzyn (except April and June), were higher on average by  $2 \text{ m}\cdot\text{s}^{-1}$ . Statistically significant coefficients of linear correlation between the maximum wind speed and the maximum wind

speed in gusts for most months allows the assumption that the maximum speeds of wind gusts in Suwałki were even higher, and therefore even more dangerous.

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