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DEPENDENCE OF WIND DIRECTION AND SPEED ON THE OROGRAPHY IN THE WESTERN PART OF THE BESKIDY MOUNTAINS

Abstract: This study presents the anemological relations in the western part of the Beskidy Mountains. Data from 28 meteorological stations was used, concerning wind direction and speed. The data was collected during the years 1961-1970. Attention was drawn to the significant spatial variability of wind direction frequency during the cold and warm half-year, which indicates a strong modification of the general wind circulation by the mountains, as well as the creation of the orographic winds which depend on both the altitude above sea-level and the form and direction of mountain ranges.

Key words: speed wind rose, direction wind rose, orography, cold half-year, warm half-year, Western Beskidy Mountains.

1. Introduction

Wind direction and speed are influenced by such general circulation factors as the composition of the highs and lows and the related horizontal gradient force of pressure, as well as others. Mountain winds are modified by the shape, width, length, and the height of mountain ranges, as well as by the outline and the depth of main and side valleys. Local conditions also have to be accounted for, such as the measurement point being shielded by the forest, rock formation, buildings, or its location at a slope of certain exposition. The factors to be considered when discussing the prevailing wind directions at a certain location, can be divided into constant and variable factors. All the above conditions may to a large extent modify the air flow in the lower part of the troposphere, resulting from the general circulation.

The basic aim of our study is to show the variance of low-level winds in the cold and warm half-year, at various altitudes above sea-level in the area of the western Beskidy Mountains. The detailled characteristics of the anemological relations in the area described, were recognised by T. Niedźwiedź, on the basis of the materials gathered by J. Orlicz and M. Orlicz (Niedźwiedź et al. 1985). In a year, on average, the Carpathian foreland is dominated by western winds, although a relatively large share belongs to eastern winds. In the Carpathian foreland, winds from the western sector constitute 40% of the total of winds within a year, while 20-30% of them come from the eastern sector. In the summit parts, at mountain passes and in higher parts of the slopes, the southern winds dominate (sometimes exceeding 20%).

The share of winds from latitude directions in contrast to winds from longitude directions in the area studied, is interesting. At the foreland of the Carpathians, one can observe a significant domination of latitudinal air flow, which reaches maximum values in summer. In the valleys located at the heart of mountain ranges, the domination of zonal circulation is observed only in June. It must be stressed that in May, and sometimes in June, the western circulation is lower in comparison with the eastern one; being similar to the circulation in autumn. A quota of winds from the north (also from the whole northern quadrant), totalling up to a dozen or so percent, is observed both in summer and in winter. Yet the decisive domination of the southern sector (in relation to the northern sector) occurs during the whole year, totalling up to 20%.

The frequency of observations with calm depends on local conditions. In the shielded valleys of the Carpathians, it is estimated to be ca. 50%, while in the summit parts it is the lowest – ca. 5%. The frequency of observations with calm in the vertical profile of the Carpathians was presented by J. Trepińska (1985). The dependence of the occurrence of calm on an altitude above sea-level is more complex (non-linear) in concave areas.

2. Methodology of the study

In order to describe in detail the anemological conditions in the western part of the Beskidy Mts. and their foreland, data from 28 meteorological stations was studied (Fig. 1, Tab. 1). The main criteria for the choice of these measurement points was the possibility of gathering numerical data, both from the archives at the Climatology Department at the Institute of Geography of the Jagiellonian University and from the specialist literature (Niedźwiedź et al. 1985). The height of the anemometers (Tab. 1 – H_{Wild}) used for estimation of the wind parameters, unfortunately varied – from 10 to 25 metres, which had an impact especially on the wind speed measured. The study concerned low-level winds, which define air flow in the friction layer of the atmosphere, yet it must be remembered that the main slowing of winds (especially of the weak winds) occurs in the surface layer, up to 2 metres above the ground. The measurement results concerning wind speed, obtained from manual anemometers are therefore unreliable.

On the basis of the anemological measurements from the stations, annual average wind speeds were estimated, concerning winds from the eight main directions, as well as mid-year average – for the cold half-year (from November to April), and the warm half-year (from May to October). The seasonal values were presented in more detail, as the share of winds from particular directions were calculated, together with observations of calm, in frequency percentage terms, as well as the wind speed in $m \cdot s^{-1}$ from these

Tab. 1. List of the meteorological stations with the measuremets of wind (1961-1970).
Tab. 1. Spis stacji meteorologicznych z pomiarami wiatru (1961-1970).

Station-Stacja	H_S (m)	φ	λ	H_{Wild} (m)
1. Jastrzębie Zdrój	227	49°57'N	18°34'E	--
2. Bieruń Stary	236	50 05	19 05	--
3. Wadowice	260	49 53	19 31	--
4. Zaborze	265	49 53	18 50	--
5. Pszczyna	270	50 00	18 55	--
6. Inwałd	300	49 53	19 26	--
7. Cieszyn-Bobrek	300	49 45	18 39	14
8. Porąbka	310	49 49	19 13	14 -17
9. Międzybrodzie Bialskie	321	49 47	19 12	10
10. Żywiec-Sporysz	356	49 41	19 13	21
11. Maków Podhalański	360	49 44	19 41	18
12. Brenna	370	49 45	18 53	--
13. Nowy Dwór	380	49 39	19 10	--
14. Aleksandrowice	398	49 48	19 00	20
15. Żywiec-Burga	420	49 42	19 13	--
16. Wisła-Centrum	430	49 39	18 52	15
17. Istebna-Zaolzie	580	49 34	18 56	15 -19
18. Zwardoń	674	49 30	18 59	19
19. Laliki	680	49 33	19 01	--
20. Zawoja -Widły	697	49 37	19 31	18
21. Istebna Stecówka	750	49 35	18 57	13
22. Istebna Kubalonka	800	49 36	18 54	26
23. Stańcowa	871	49 33	19 32	19
24. Leskowiec	876	49 48	19 27	16
25. Klimczok	1010	49 44	19 00	16
26. Markowe-Szczawiny	1180	49 35	19 31	--
27. Skrzyczne	1230	49 41	19 02	--
28. Pilsko-Hala Miziowa	1270	49 32	19 19	13

directions. Most source data was used from the publication by T. Niedźwiedź, M. Orlicz and J. Orlicz (Niedźwiedź et al. 1985). Additionally, data from the archives was applied, gathered by the authors of the study at the Climatology Department of the Institute of

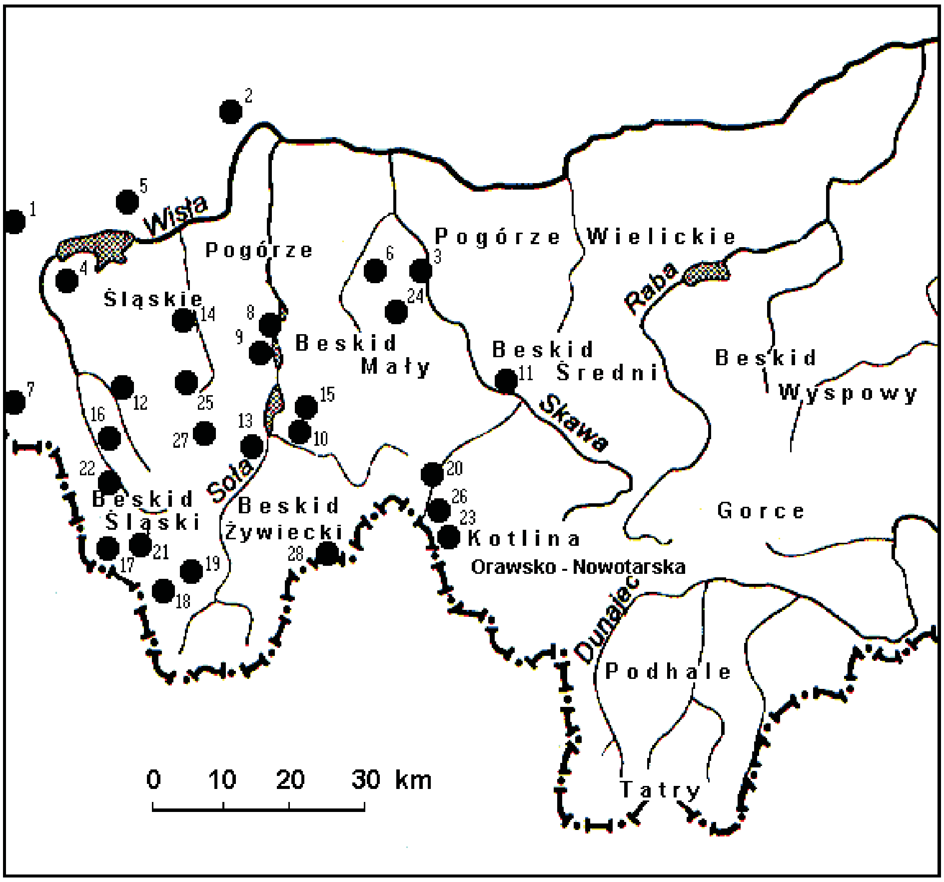

Fig. 1. Location of the meteorological stations in the western part of the Beskidy Mts. Numbers of the stations according to Table 1.

Ryc. 1. Rozmieszczenie stacji meteorologicznych w zachodniej części Beskidów. Numery stacji wg tabeli 1.

Geography at the Jagiellonian University. Most of the data came from the years 1961-1970. For Aleksandrowice, data from the automatic measurement station was used from the years 1951-1995. Data for Hala Miziowa (northern slopes of Pilsko summit) and from the peak station at Klimczok (Beskid Śląski Mts.) came from the period 1954-1963. Unfortunately, the data does not cover the whole of the period.

The graphic illustration of the study includes the wind roses (Fig. 2-13) and the charts (Fig. 14-18).

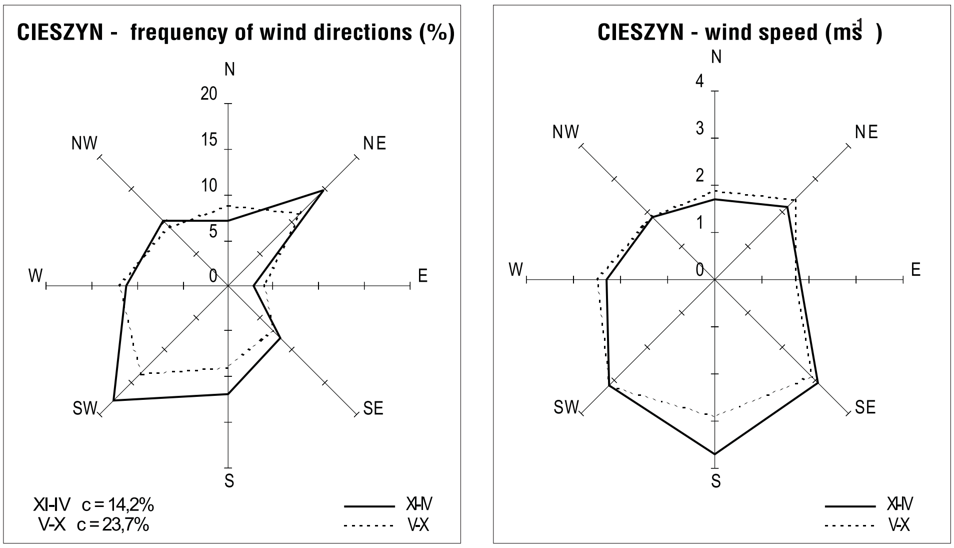

Fig. 2. Wind roses. Frequency of wind directions and calms (c) in %. Wind velocities in $m \cdot s^{-1}$.

Ryc. 2. Róże wiatrów. Częstość kierunków wiatru i cisz (c) w %. Prędkości wiatru w $m \cdot s^{-1}$.

Cieszyn-Bobrek, H_s – 300 m n.p.m. (a.s.l.), φ – 49°45'N, λ – 18°39'E

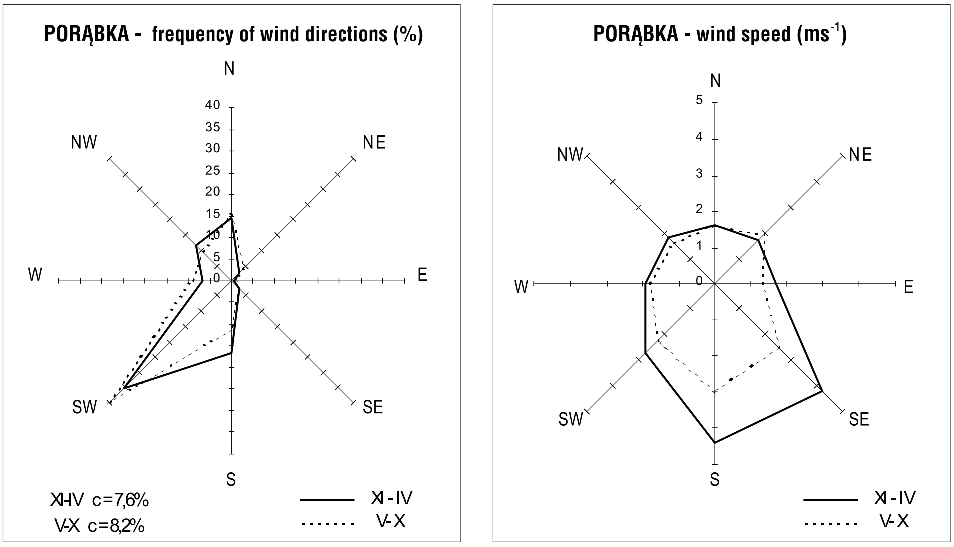

Fig. 3. Wind roses. Frequency of wind directions and calms (c) in %. Wind velocities in $m \cdot s^{-1}$.

Ryc. 3. Róże wiatrów. Częstość kierunków wiatru i cisz (c) w %. Prędkości wiatru w $m \cdot s^{-1}$.

Porąbka, H_s – 310 m n.p.m. (a.s.l.), φ – 49°49'N, λ – 19°13'E

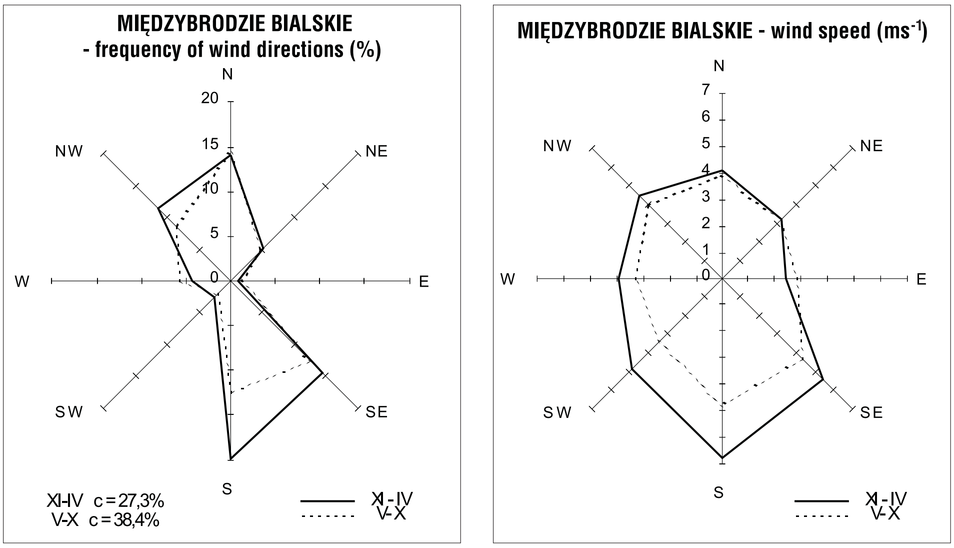

Fig.4. Wind roses. Frequency of wind directions and calms (c) in %. Wind velocities in m·s^{-1}.

Ryc. 4. Róże wiatrów. Częstość kierunków wiatru i cisz (c) w %. Prędkości wiatru w m·s^{-1}.

Międzybrodzie Bialskie, H_s – 321 m n.p.m. (a.s.l.), φ – 49°47'N, λ – 19°12'E

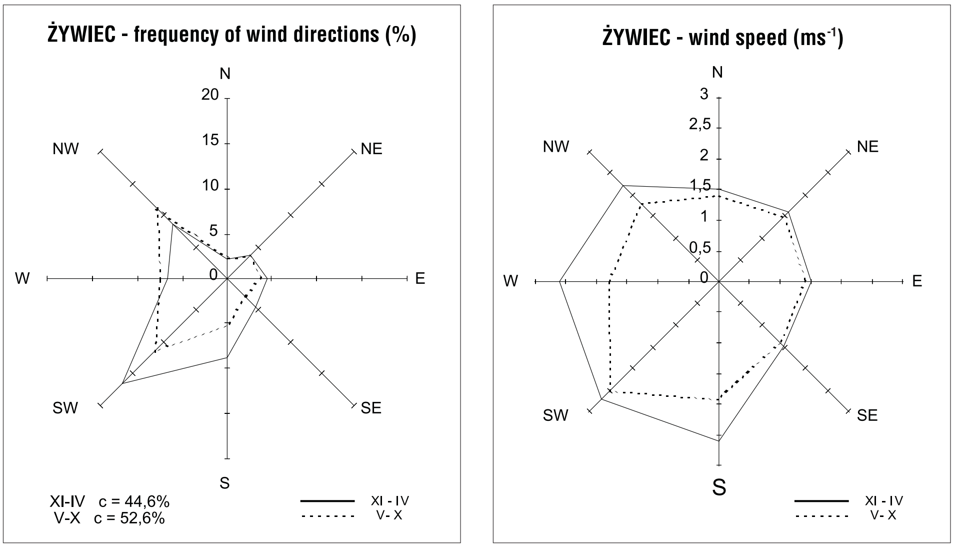

Fig.5. Wind roses. Frequency of wind directions and calms (c) in %. Wind velocities in m·s^{-1}.

Ryc.5. Róże wiatrów. Częstość kierunków wiatru i cisz (c) w %. Prędkości wiatru w m·s^{-1}.

Żywiec-Sporysz, H_s – 356 m n.p.m. (a.s.l.), φ – 49°41'N, λ – 19°13'E

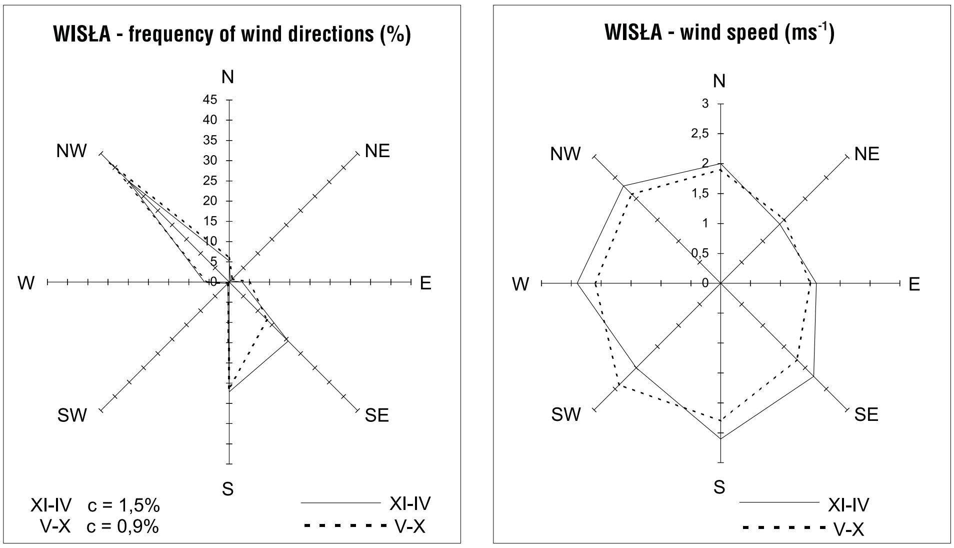

Fig. 6. Wind roses. Frequency of wind directions and calms (c) in %. Wind velocities in $m \cdot s^{-1}$.

Ryc.6. Róże wiatrów. Częstość kierunków wiatru i cisz (c) w %. Prędkości wiatru w $m \cdot s^{-1}$.

Wisła-Centrum, H_s – 430 m n.p.m. (a.s.l.), φ – 49°39'N, λ – 18°52'E

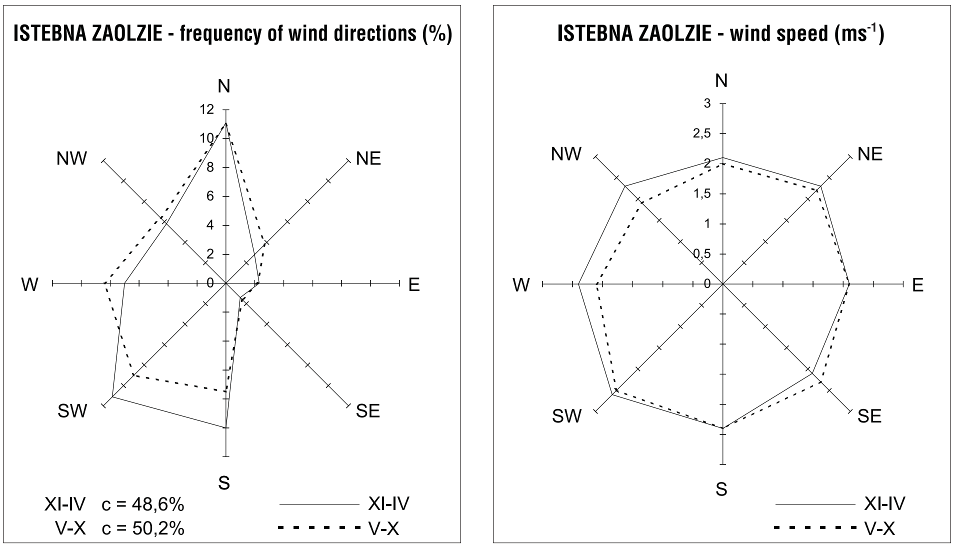

Fig. 7. Wind roses. Frequency of wind directions and calms (c) in %. Wind velocities in $m \cdot s^{-1}$.

Ryc.7. Róże wiatrów. Częstość kierunków wiatru i cisz (c) w %. Prędkości wiatru w $m \cdot s^{-1}$.

Istebna-Zaolzie, H_s – 580 m n.p.m. (a.s.l.), φ – 49°34'N, λ – 18°56'E

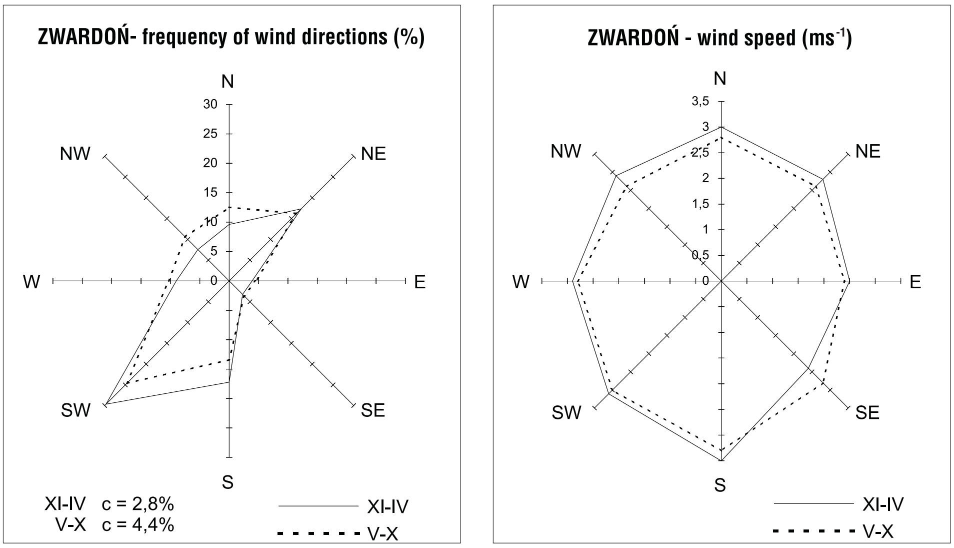

Fig. 8. Wind roses. Frequency of wind directions and calms (c) in %. Wind velocities in m·s[-1].

Ryc. 8. Róże wiatrów. Częstość kierunków wiatru i cisz (c) w %. Prędkości wiatru w m·s[-1].

Zwardoń, H_s – 674 m n.p.m. (a.s.l.), φ – 49°30'N, λ – 18°59'E

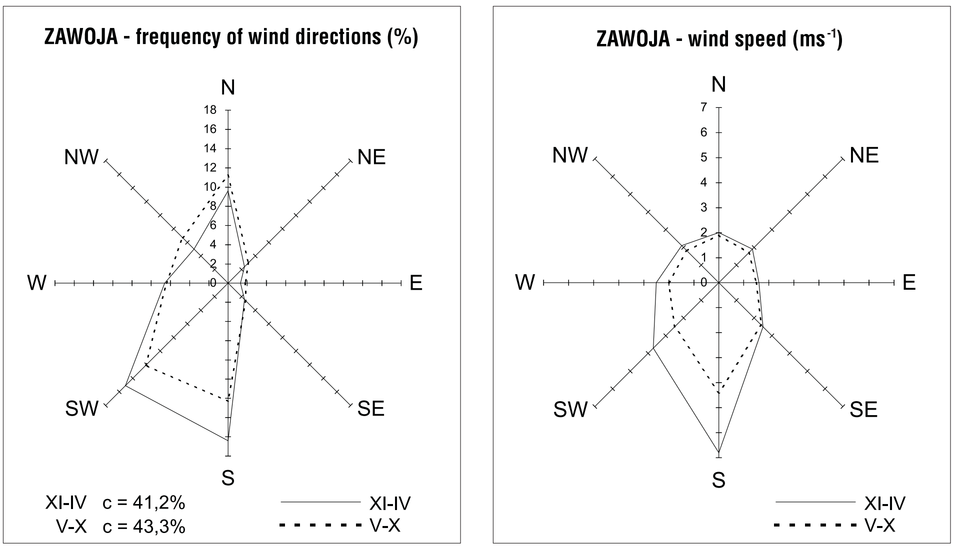

Fig. 9. Wind roses. Frequency of wind directions and calms (c) in %. Wind velocities in m·s[-1].

Ryc. 9. Róże wiatrów. Częstość kierunków wiatru i cisz (c) w %. Prędkości wiatru w m·s[-1].

Zawoja-Widły, H_s – 697 m n.p.m. (a.s.l.), φ – 49°37'N, λ – 19°31'E

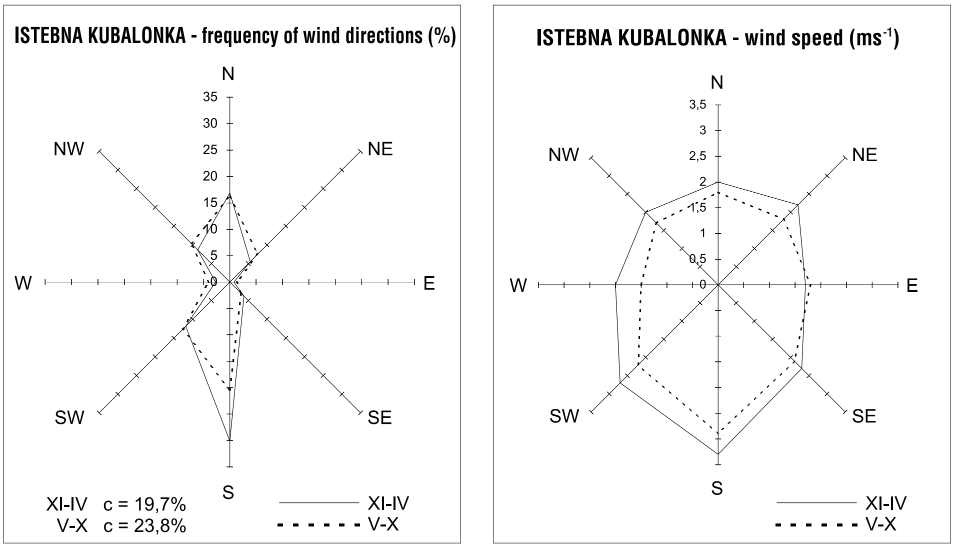

Fig. 10. Wind roses. Frequency of wind directions and calms (c) in %. Wind velocities in $m \cdot s^{-1}$.

Ryc. 10. Róże wiatrów. Częstość kierunków wiatru i cisz (c) w %. Prędkości wiatru w $m \cdot s^{-1}$.

Istebna Kubalonka, H_s – 800 m n.p.m. (a.s.l.), φ – 49°36’N, λ – 18°54’E

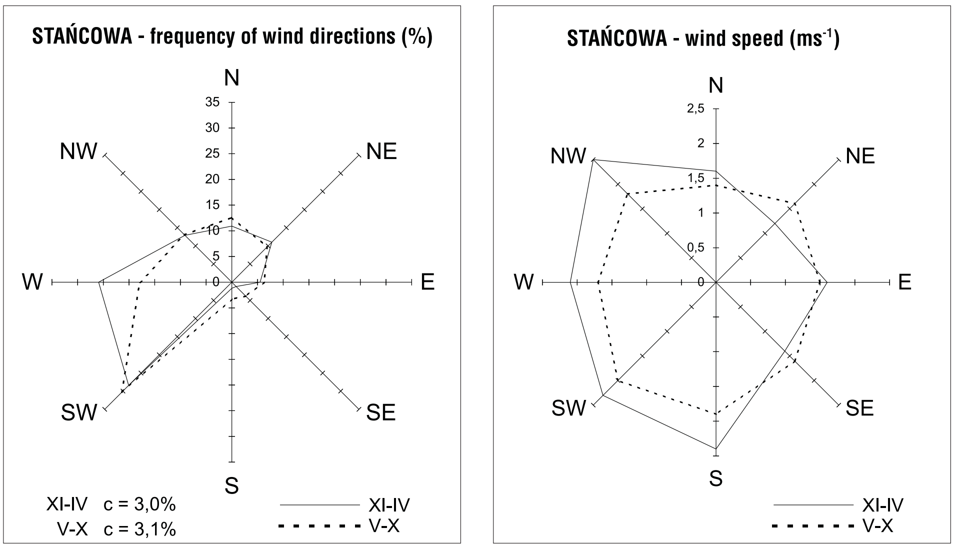

Fig. 11. Wind roses. Frequency of wind directions and calms (c) in %. Wind velocities in $m \cdot s^{-1}$.

Ryc. 11. Róże wiatrów. Częstość kierunków wiatru i cisz (c) w %. Prędkości wiatru w $m \cdot s^{-1}$.

Stańcowa, H_s – 871 m n.p.m. (a.s.l.), φ – 49°33’N, λ– 19°32’E

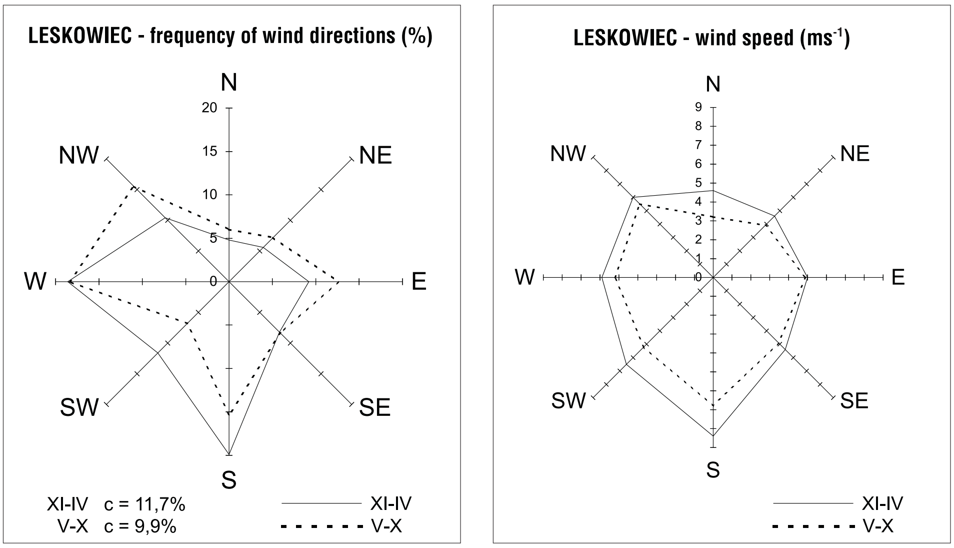

Fig. 12. Wind roses. Frequency of wind directions and calms (c) in %. Wind velocities in $m \cdot s^{-1}$.

Ryc. 12. Róże wiatrów. Częstość kierunków wiatru i cisz (c) w %. Prędkości wiatru w $m \cdot s^{-1}$.

Leskowiec, H_s – 876 m n.p.m. (a.s.l.), φ – 49°48'N, λ – 19°27'E

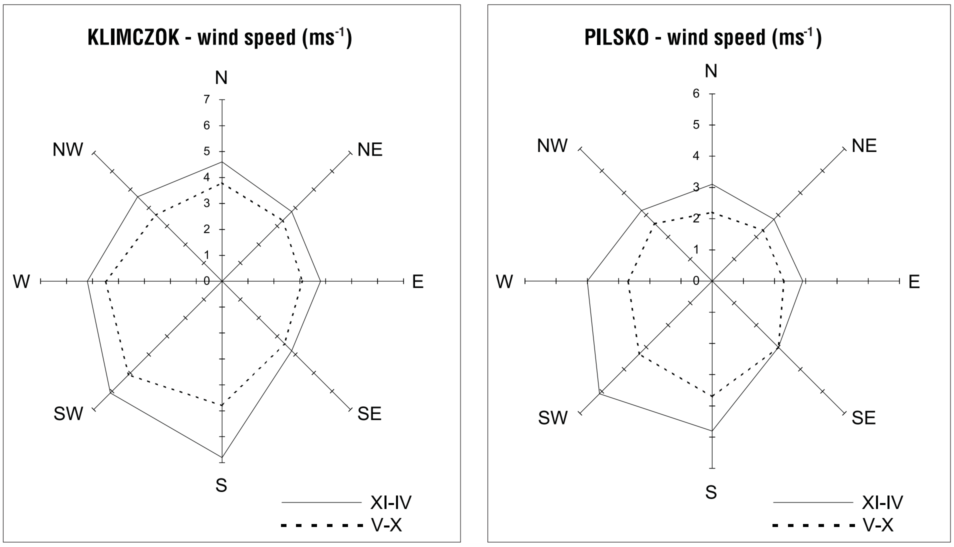

Fig. 13. Wind rose. Wind velocities in $m \cdot s^{-1}$.

Ryc. 13. Róża wiatrów. Prędkości wiatru w $m \cdot s^{-1}$.

Klimczok, H_s – 1010 m n.p.m. (a.s.l.), φ – 49°44'N, λ – 19°00'E
Pilsko-Hala Miziowa, H_s – 1270 m n.p.m. (a.s.l.), φ – 49°32'N, λ – 19°19'E

3. General characteristics of the anemological conditions

At the foreland of the Beskidy Mts. and on the range area, a large quota of the western winds prevails, which is related to the dominating advection of air masses from this direction. A characteristic domination of longitudinal valleys in the western part of the Carpathians forces the change of low-level air flow from the southern direction to the northern direction, or from the south-western direction to the north-western direction (which is most visible in the Tatra Mts.). Yet most often, in the western Carpathians one can observe the air flow from the western quadrant (north-west, west, south-west) – during 46% of the days, while 27% days from the eastern direction (Obrębska-Starklowa et al. 1995). The domination of wind directions from the south to west (S, SW, W) at the northern slopes of the Pilsko summit at Beskid Żywiecki Mts., was also described by A. Łajczak (1996).

One can observe the seasonal dependence of the advection direction. From May to September, air flows from the north-west, while from October to December advection increases from the south and south west. In March and April, as well as in late spring, winds from the south-east and east are observed. In May the advection from the north-east increases, while in July winds from the north prevail (Hess 1965, Niedźwiedź 1968).

In some valleys, a visible prevalence of other wind directions is noticed, untypical of winter circulation (Niedźwiedź et al. 1985). In certain locations, also on peaks and passes, the prevalence of southern winds is quite visible (Zawoja – Fig. 9, Istebna-Stecówka and Kubalonka – Fig. 10, Leskowiec – Fig. 12).

In summer, as mentioned above, western and north-western winds prevail. A weakening of the southern winds is also noted at this time.

The orographic conditions described, however, largely modify the air flow from its original direction. Air flows of the same mass are modified by a different angle from the main axis of the flow, depending on the altitude above sea-level, and on the slope exposition. The size of the turn may exceed 45 degrees. Therefore the average distribution of wind directions in any particular location within the same mountain range, within a close distance (ca. 1 kilometer), may be completely different.

During the high-pressure weather, especially when the centre of the high is above the Carpathians, the local mountain and valley circulation develops, which may fundamentally modify the general image of the air flow direction in the measurement stations within the area. At the weak air movement, one may notice local flows from various directions, irrelevant to the general direction of the advection. These flows are limited to the valley and are characterised with low speeds. Yet with a particular synoptic situation – namely high pressure south to the Carpathians and the low pressure to the north, occasional foehn winds are created from the south, characterised by high speed and gusts. This factor explains the high percentage of southern winds observed at the peaks (Ustrnul 1992).

Wind speeds in the area studied, are characterised by a large variability. Generally, the speed increases with the altitude above sea-level and it is three times greater at the highest peaks than at their base. It is not a rule, however, as the wind speed increases logarithmically with the altitude, while the topographic profile, slope steepness, and the level of flora density, greatly affect air flow speed (Kowanetz 1998). It is highly visible during strong winds (speeds over 10 $m{\cdot}s^{-1}$) above the tree line. In the Beskidy Mts., it especially concerns the range of the Babia Góra summit and Pilsko summit. The mountain and valley circulation, the Liptów winds and foehn winds, develop especially in the Tatra Mts., due to their altitude and the Alpine topography (Bąkowski 1997). At the Podhale and Orawa regions, local winds are originated, due to the characteristic location of the valleys between the mountain ranges. The highest wind speeds are noted during the foehn winds.

4. Wind directions and speeds within a year

In the foreland of the Beskidy Mts. (the western part), western and south-western winds prevail, according to the frequency distribution of winds from various directions. Such dominance is observed at the stations in Cieszyn (Fig. 2), Aleksandrowice, Jastrzębie, Pszczyna, and Zaborze. The stations located in valleys show the dominance of southern winds. The greatest average wind speeds (up to 6 $m{\cdot}s^{-1}$) occur along the north-south axis at the stations in Porąbka (Fig. 3), Międzybrodzie Bialskie (Fig. 4), Brenna, Nowy Dwór, Zwardoń (Fig. 8) and Zawoja (Fig. 9). At higher altitudes: Kubalonka (Fig. 10), Leskowiec (Fig. 12), Klimczok (Fig. 13) and Pilsko (Fig. 13) the air flow from the south and south-west is also the fastest. However, on the northern slopes of Babia Góra (Markowe Szczawiny) and at Skrzyczne, the greatest wind speeds belong to southern, western and south-western winds (4-5 $m{\cdot}s^{-1}$). The winds from the northern and eastern sector are much weaker (2.0-2.9 $m{\cdot}s^{-1}$).

One can observe a large difference in the distribution of wind speeds at two stations in Żywiec: at the Żywiec-Sporysz station (Fig. 5) south-western winds prevail, while at the Żywiec-Burga station (Góra Burgałowska), winds from the western quadrant dominate. At the former, average wind speeds from the south, south-west and west are similar, while at the Burga station, the highest speeds are observed from the north-west and west. At both stations winds from the north and from the eastern quadrant are weaker. At these two measurement points over such a short distance (Fig. 1, Tab. 1), the impact of the direct environment is visible. At the higher station (Burga), the average difference of the wind speed from the western sector (NW-W-SW) is greater by 1.0 to 1.8 $m{\cdot}s^{-1}$ from the wind speeds measured at the Żywiec-Sporysz station, while the difference of average wind speed from the east does not exceed 0.8 $m{\cdot}s^{-1}$. This is caused by: the difference in relative altitude (64 m), the location of the Żywiec-Sporysz station on the eastern slope of the Grojec Mountain – at 612 m above sea-level (cover from the west), and the open space around the station on the peak of Góra Burgałowska.

5. Wind direction and speed in the cold and warm half-year

At the foreland of the Beskidy Mts., the highest wind speeds arise from the south and south-west in the cold half-year (Cieszyn), while in the warm half-year they occur from the western sector (NW-W-SW). The period of calm in winter is estimated at about 14%, in summer ca. 24%. In the valleys, the frequency distribution shows certain similarities (prevailing air flows from the west or south-west), although a fundamentally different percentage of calm is observed as well as the dominance of particular wind directions in particular seasons. For example in Porąbka (Fig. 3) there are few observations with calm – ca. 8% in the cold and warm half-year, while in Żywiec (Żywiec Sporysz – Fig. 5), the calm percentage is very high. In the cold half-year it is ca. 45%, while in the warm half-year, over 50%, thus indicating considerable protection for the station. At Międzybrodzie Bialskie (Fig. 4) the minimum share of western and eastern winds is noticed, with a dominance of winds along the N-S axis. The stations at Porąbka (Fig. 3) and in Zwardoń (Fig. 8) shows similar distribution of wind directions, yet at Porąbka higher wind speeds from the south and south-east are observed. At Zawoja (Fig. 9) the small frequency of eastern winds and a large percentage of observations with calm are noted, over 40% in summer and in the cold half-year.

At village Wisła (Fig. 6) the biggest share belongs to winds from the north-west, south and south-east in winter, and from the north-west and the south in summer. The highest speeds are noted for the southern winds (on average 2.0-2.6 $m \cdot s^{-1}$), and also for winds from the west and north-west in winter. Stations located to the south of village Wisła – Istebna Stecówka and Kubalonka pass (Fig. 10) have similar frequency distribution of winds from particular directions (south and south-west), while the station at Istebna-Zaolzie (Fig. 7) shows flows along the N-S axis, in winter and summer, and a much higher percentage of observations with calm – ca. 50%, which indicates a visible covering of the measurement point.

Stations at higher altitudes show greater variance. At the peak of Klimczok, one can observe the prevalence of southern and south-western winds in winter, and an equal share of all sectors in summer (with a slight dominance of the directions mentioned). On the northern slopes of Pilsko, the dominance of winds from S to W is visible, especially in winter. At Stańcowa (Fig. 11), the station located near a foresters' house on the southern slope of Babia Góra summit, the highest speeds are noted for north-western winds (2.5 $m \cdot s^{-1}$) and southern winds in winter, as well as very rare southern winds in summer. The most often are, however, winds from the west and south-west in winter, while from the south-west in summer. At Leskowiec summit (Fig.12) the highest average speed (up to 8.4 $m \cdot s^{-1}$) belongs to the southern and south-western winds, both in summer and in winter. The participation of observations with calm is limited – only 12% in winter and ca. 10% in summer.

6. Final remarks

Frequency of wind directions and speeds in the area studied, are characterised by a large variability. The obvious impact of the general direction of advection masses is modified by topography and the altitude above sea-level. At certain stations, the wind parameters measured may indicate the prevalence of local conditions. Generally, particular valleys and isolated peaks or long mountain ranges must be discussed separately, depending on the level of detail of an anemological conditions study. Moreover, in particular years, the wind parameters measured may largely differ from the average values calculated on the basis of measurements from many years. The illustration of

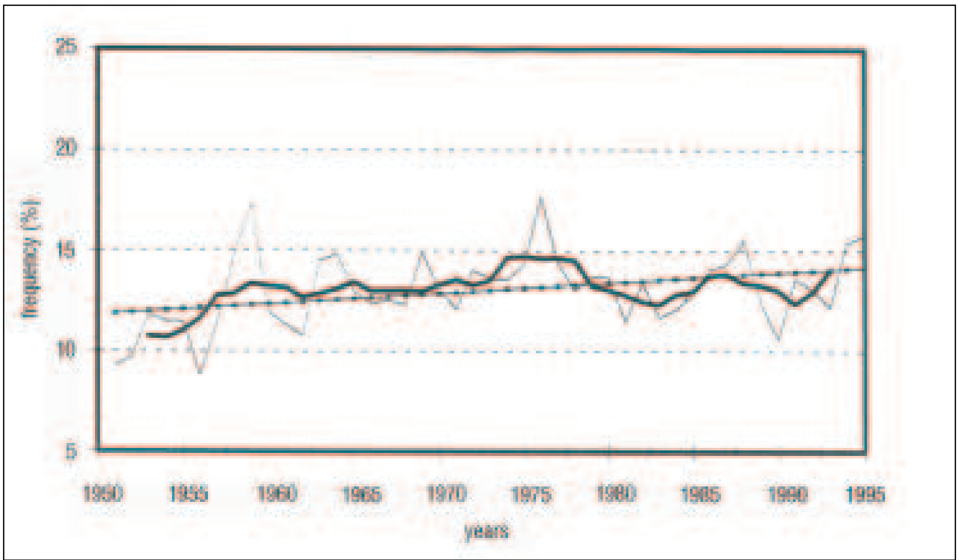

Fig. 14. Frequency of the northern winds in % (1951-1995).

Ryc. 14. Częstość wiatrów północnych w % (1951-1995).

Aleksandrowice, H_s – 398 m n.p.m. (a.s.l.), φ – 49°48'N, λ – 19°00'E

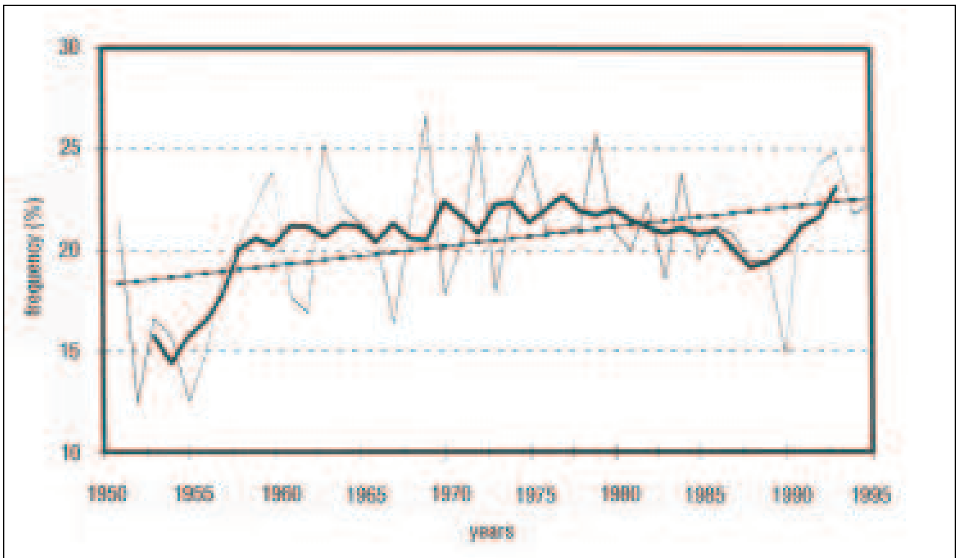

Fig. 15. Frequency of the eastern winds in % (1951-1995).

Ryc. 15. Częstość wiatrów wschodnich w % (1951-1995).

Aleksandrowice, H_s – 398 m n.p.m. (a.s.l.), φ – 49°48'N, λ – 19°00'E

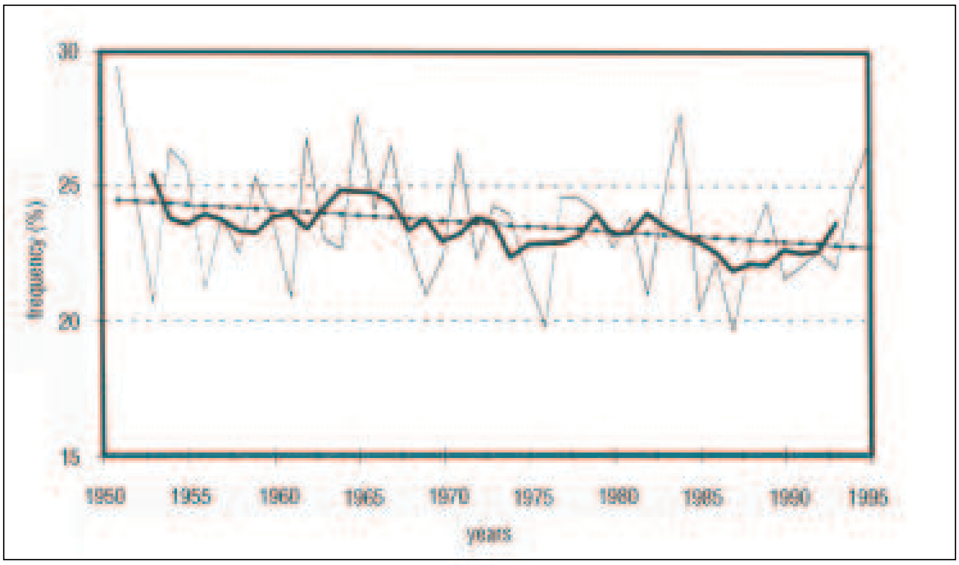

Fig. 16. Frequency of the southern winds in % (1951-1995).

Ryc. 16. Częstość wiatrów południowych w % (1951-1995).

Aleksandrowice, H_s – 398 m n.p.m. (a.s.l.), φ – 49°48'N, λ – 19°00'E

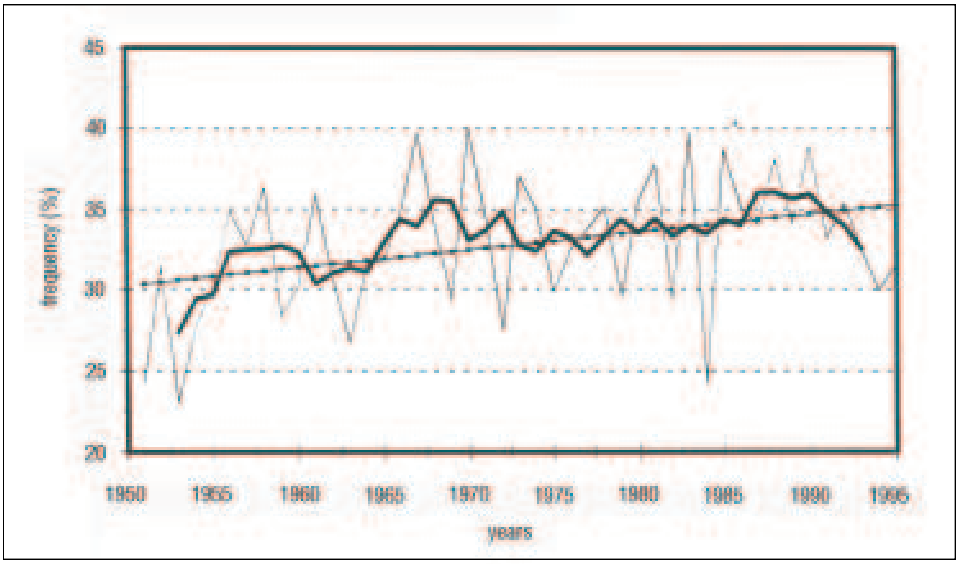

Fig. 17. Frequency of the western winds in % (1951-1995).

Ryc. 17. Częstość wiatrów zachodnich w % (1951-1995).

Aleksandrowice, H_s – 398 m n.p.m. (a.s.l.), φ – 49°48'N, λ – 19°00'E

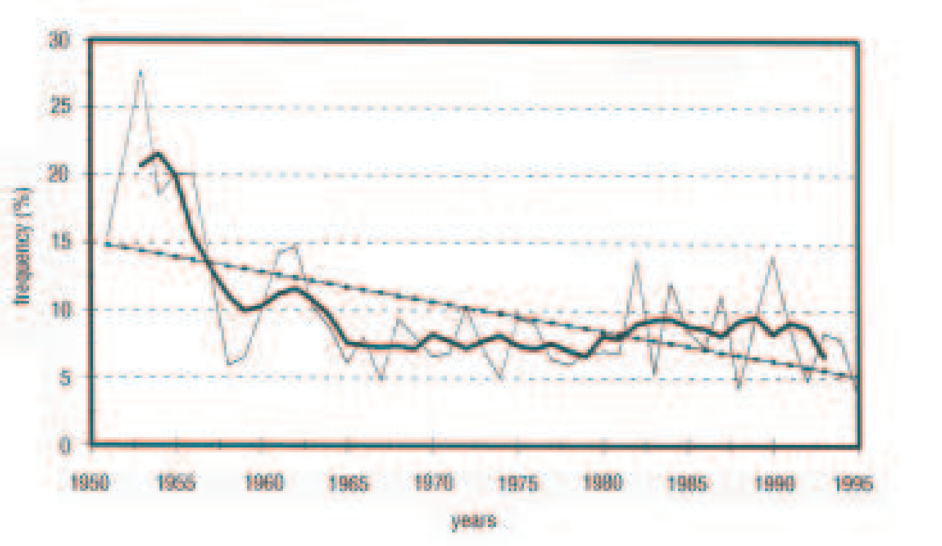

Fig. 18. Frequency of the calms in % (1951-1995).

Ryc. 18. Częstość cisz w % (1951-1995).

Aleksandrowice, H_s – 398 m n.p.m. (a.s.l.), φ – 49°48'N, λ – 19°00'E

such a statement is presented in the set of charts detailing the frequency of the four fundamental wind directions and the frequency of observations with calm, from the years 1951-1995, from the station at Aleksandrowice[1] (Fig. 14-18). One can observe here an increase inthe share of western and eastern winds, with a decrease in the frequency of winds from the south and the frequency of calms.

The value of the climatological study of anemological conditions depends largely on the possibility of obtaining observation data. It must be noticed, however, that this will include numerical data, while wind direction and speed is largely conditioned by the detailed location of the station. Due to this highly visible non-linearity of changes in wind parameters in the mountains, a simple interpolation is not recommended, and the anemological conditions may only be presented generally. It seems therefore necessary to study the meso-climate of the particular mountain ranges and their impact on the air flow modification.

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Zależność kierunku i prędkości wiatrów od orografii w zachodniej części Beskidów

Streszczenie

Zasadniczy wpływ na prędkości i kierunki wiatrów powierzchniowych wywiera sytuacja synoptyczna. Jednakże te parametry wiatru zmieniają się przy przepływie masy powietrza przez pasma górskie. Modyfikacja kierunku i prędkości strumieni powietrza jest różna na szczytach, stokach, w dolinach oraz na przedpolu gór. Zmiana kierunku wiatru może przekraczać 45°. Ze wzrostem wysokości nad poziomem morza w górach obserwuje się nieliniowe przyspieszenie przepływu masy powietrza.

W opracowaniu korzystano z danych z 28 stacji meteorologicznych zlokalizowanych w następujących pasmach górskich: Beskid Śląski, Beskid Żywiecki, Beskid Mały i na ich przedpolu (ryc. 1, tab. 1). Dane te pochodzą głównie z dziesięciolecia 1961-1970. Obserwacje były wykonywane wówczas za pomocą wiatromierza Wilda, umieszczonego na wysokości 10-25 m nad poziomem gruntu. Duże zróżnicowanie prędkości i kierunku

wiatru w zachodniej części Beskidów jest przedstawione na różach wiatru (ryc. 2-13). Opracowanie ma charakter syntetyczny, bowiem posługiwano się rocznymi średnimi wartościami oraz średnimi z półrocza chłodnego (listopad-kwiecień) i z półrocza ciepłego (maj-październik).

Główne wyniki opracowania:

– na przedpolu Beskidów w ciągu roku przeważają wiatry zachodnie i południowo-zachodnie,
– na stacjach w dolinach i kotlinach śródgórskich występuje przewaga wiatrów z kierunków południowych. Niektóre miejsca pomiarowe wykazują wybitną przewagę wiatrów na osi N-S. Południowe wiatry są jednak silniejsze.

W pracy opierano się na wartościach średnich z wielolecia. W poszczególnych latach wartości mogą dość znacznie odbiegać od wyliczonych średnich w zależności od warunków cyrkulacyjnych w danym roku. Zmienność kierunków przepływu mas powietrza prezentują ryciny 14-18.

Opracowanie to zwraca uwagę na trudności w syntetycznym ujęciu stosunków anemologicznych w niewysokim nawet obszarze górskim, ze względu na różną częstość adwekcji mas powietrza z określonych kierunków i rzeźbę terenu.

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