ISSN 2052-0018 (print)
Geographical Locality Studies – June 2013, Volume 1, Number 1. pp. 132–149.

KÁROLY TAR
CSc, College Reader, Senior Lecturer
College of Nyíregyháza, Faculty of Science and IT, Institute of Tourism and Geography
tar.karoly@nyf.hu

University of Debrecen, Faculty of Science and Technology, Institute of Earth Sciences, Department of Meteorology
tar.karoly@science.unideb.hu

Energetic Parameters of the Wind Directions

Abstract

The objective of this study is to assess whether changes in the surface pressure field over Europe are reflected in the statistical structure and the inner definiteness of the wind energy field over Hungary, despite the specific pressure field of the country. The investigated energetic parameters are: relative frequency, relative energy content, mean velocity and mean length of time of wind directions. The investigation was carried out for two time periods (1968–72, 1991–95) at three meteorological stations which are on nearly the same geographical latitude, but their orographic environment differs from each other.

Key words

Relative frequency; Relative energy content; Mean velocity and mean length of time of wind directions; Characteristic, non-characteristic and prevailing wind directions; Linear correlation

Introduction

The rise in global surface air temperature, due to the increase of the atmospheric concentration of greenhouse gases, has probably induced a redistribution of the surface pressure field. According to SCHÖNWIESE, C. D. *et al.* (1994) and MEYHÖFER, S. *et al.* (1996), this process has occurred in *Europe*: in the winter half-year, the average values of surface pressure, converted to sea level, increased in the south and decreased in the north of the continent between 1961 and 1990. In the summer half-year, however, there were no significant changes. On the other hand, METAXAS, D. A. *et al.* (1991) and BARTZOKAS, A. – METAXAS, D. A. (1996) found that the average intensity of influx of cold air masses in summer, coming from the north and northwest to the southeast of *Europe*, had increased. Therefore, according to their investigations, the summer circulation system is also changing, as a consequence of the redistribution of the surface pressure field in summer, as well.

The spatial distribution of annual and monthly average sea level pressure fields in *Hungary* is due to the so called "basin character". Roughly in the middle of the *Great Hungarian Plain*, a pressure minimum can be found. This is caused by strong warming in summer and the frequent passing through of the Mediterranean cyclones in winter (DOBOSI, Z. – FELMÉRY, L. 1971). The aim of the former investigations (TAR, K. 1998a, 1998b, 1999, 2001; MIKA, J. *et al.* 1999; TAR, K. *et al.* 2000, 2001; MAKRA, L. *et al.* 2000a, 2000b) was to decide whether or not the observed changes in the pressure field over *Europe* could be detected in the statistical structure of the wind field over *Hungary*, despite the specific pressure field over the country.

In this paper, the useful properties of some energetic parameters of wind directions and the change in time and space of stochastic relationship between these parameters are analysed.

1. Database and research methods

The database consists of hourly wind direction data and wind velocities of three meteorological stations—*Debrecen, Budapest* and *Szombathely*—between the periods of 1968–72 and 1991–95 measured at

10 meters. These stations are about on the same geographical latitude, but their orographic environment differs from each other *(Figure 1).*

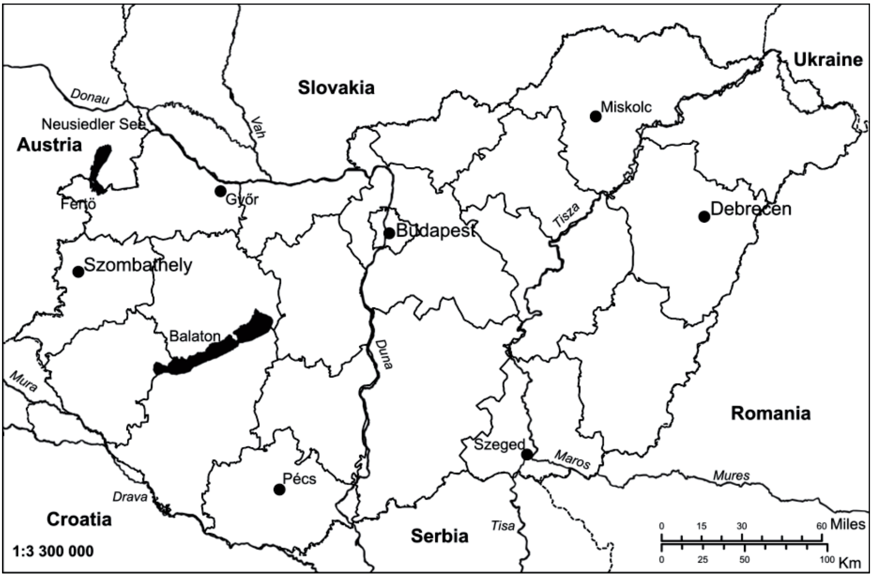

Figure 1 – Locations of the meteorological stations in Szombathely, Budapest and Debrecen
Edited by SZELESI, T. (2013)

The investigation was carried out for the two complete periods and for the subsets of those. The subsets were produced by two methods: *(1.)* by the differentiation of natural seasons and *(2.)* by defining the macrosynoptic-type groups from *György Péczely*'s macrosynoptic-types. As opposed to PÉCZELY, GY. (1983), the central type is handled separately on the base of its obviously different air flow characteristics. According to this, the following categories and centres are used: Meridional Northern (MN), Meridional Southern (MS), Zonal Western (ZW), Zonal Eastern (ZE) type groups and anticyclone centre (A) and cyclone centre (C) types. The base of the classification is the place of the cyclone or anticyclone centres relative to *Hungary*. The types that govern the weather of *Hungary* can be grouped in as cyclonal type group (CG). Anticyclonal type group (AG) can be defined similarly. For the classification of the individual days, the macrosynoptic codes of PÉCZELY, GY. (1983) and KÁROSSY, CS. (1998) have been used. The sizes (the length of days) of the macrosynoptic-types/type groups for the two five-year-long periods are shown in *Table 1*.

Table 1 – The number of days of the various type groups (days) and their length relative to the whole length of the period (%) in the two complete 5-year-periods

	1968–72		1991–1995	
	days	%	days	%
MN	301	16.5	401	22.0
MS	529	32.4	434	23.8
ZW	429	23.5	390	21.4
ZE	348	19.1	235	12.9
A	134	7.3	269	14.7
C	22	1.2	97	5.2
Σ	1826	100.0	1826	100.0
AG	1187	65.0	1259	68.9
CG	639	35.0	567	31.1
Σ	1826	100.0	1826	100.0

It is evident that the difference between the number of days of the type A is about two times larger than that of the type C, and the frequency of the days in the AG-type group is higher by 4 per cent in the second period. Based on this, we can conclude that the wind velocity and wind energy in this period decreased. Stagnation or a small increase occurs in a few cases only in *Debrecen* (winter, ZE, A). The largest decrease is in *Szombathely*: in the MN, MS, ZE and CG-type groups and in type C, the decrease is above 1 m/s. The spatial average of the decrease is the largest in the type C, and then the MN, MS and the CG-type groups follow.

2. Energetic statistics of the wind direction

In the following, the relationship among relative frequency (%), relative energy content (%), average velocity (m/s) and the average length of time of the wind directions are going to be investigated. The relative energy content of a D wind direction for a sub-period (season, type, type group) can be determined by the mean specific wind power, namely with the equation,

$$P_{f1}(D) = \frac{\rho}{2}\sum_{j=1}^{k}\frac{f_{Dj}}{N}v_j^3$$

where f_{Dj} is the frequency of the speed of the D wind within the (v_j-0.5Δv, v_j+0.5Δv) interval, k is the number of intervals and N is the number of days of the time period, respectively. If P_{f1}, denoting the mean specific wind power of time period, is independent of the wind directions then the ratio

$$p(D) = \frac{P_{f1}(D)}{P_{f1}}$$

is equal to the relative energy content of the given D wind direction. The average velocity of this direction is:

$$\overline{\mathrm{v}}(\mathrm{D}) = \sum_{\mathrm{j=1}}^{\mathrm{k}}\frac{\mathrm{f}_{\mathrm{Dj}}}{\mathrm{N}}\mathrm{v}_{\mathrm{j}}.$$

The value of the last parameter strongly depends on the height of the anemometer. This height is regularly 10 metres in the meteorological stations, but the measure of the wind speed can happen on lower or higher levels. In these cases, the height correction is achieved by the following equation:

$$v_h=v_{10}[0.233+0.656\lg(h+4.75)]$$

where v_h is the measured wind speed on $h\neq10$ m and v_{10} is the calculated wind speed on 10 m. The average length of time of the wind directions can be determined by the distribution of hours with the same wind direction (MEZŐSI, M. – SIMON, A. 1981).

3. Characteristic and non-characteristic wind directions

In this and the following subdivisions, the relationship between the relative frequency and the relative energy content of wind directions in a special case will be investigated.

To decide which are the wind directions with significant definite frequency—i.e. it is not random that they are present in a given place at a given time— the statistical test for hypothesis of probability evenness has been used (VINCZE, I. 1975). This can be applied to the problem as it follows: in a given ε probability level, we can determine a critical interval with h_1 and $h_2>h_1$ borders. If there is, at least, one D wind direction with f_D frequency, so that $f_D > h_2$, we cannot consider the distribution of the wind direction to be even. In this case, D is called a characteristic wind direction (CWD), otherwise, it is a non-characteristic wind direction (NWD) on 1-ε probability level (TAR, K. 1991a, 1991b). The values of h_1 and h_2 are (VINCZE, I. 1975):

$$h_1 = p_0 n - u_\varepsilon \sqrt{np_0(1-p_0)}$$

$$h_2 = p_0 n + u_\varepsilon \sqrt{np_0(1-p_0)}$$

where p_0 is equal to $\frac{1}{16} = 0.0625$, as we used 16 wind directions, n is the number of cases (24*number of days), u_ε satisfies the equation

$$2\Phi(u_\varepsilon) - 1 = 1 - \varepsilon$$

where Φ(x) is the distribution function of the standard normal distribution. Let be ε=0.0027; i.e. the small value used by PÉCZELY, GY. (1957) for the efficiency of the test. In this case $u_\varepsilon=2.98$.

If f_D is given in %, then the limits of the critical interval are $H_1=100h_1/n$, $H_2=100h_2/n$. The value of H_2 changes between 6.6 (whole period) and 9.4 (type C in period 1968–72), so we can say, it moderately depends on the number of cases.

We can determine the total and the mean relative energy content of the characteristic and non-characteristic wind directions by the way written previously. CWD_e and NWD_e denote the relative energy content of one characteristic and non-characteristic wind direction, respectively; i.e. the mean relative energy contents.

Table 2 – Relative energy contents (in %) of one characteristic wind direction (CWD$_e$) and one non-characteristic wind direction (NWD$_e$)

	Debrecen				Budapest				Szombathely				mean			
	1968–72		1991–95		1968–72		1991–95		1968–72		1991–95		1968–72		1991–95	
	CWD$_e$	NWD$_e$	CWD$_e$	NWD$_e$	CWD$_e$	NWD$_e$	CWD$_e$	NWD$_e$	CWD$_e$	NWD$_e$	CWD$_e$	NWD$_e$	CWD$_e$	NWD$_e$	CWD$_e$	NWD$_e$
year	10.1	4.0	8.5	4.9	11.7	3.0	12.3	3.5	13.2	0.9	11.9	0.6	11.7	2.6	10.9	3.0
winter	12.7	2.5	10.9	3.4	13.2	2.1	12.8	3.3	12.3	1.5	13.5	0.6	12.7	2.0	12.4	2.4
spring	11.6	3.8	7.6	5.4	9.2	4.0	11.8	3.7	14.0	1.6	22.3	0.9	11.6	3.1	13.9	3.3
summer	9.8	4.1	8.3	5.3	15.3	2.1	13.0	3.2	25.9	1.7	21.7	1.1	17.0	2.6	14.3	3.2
autumn	13.1	4.0	8.7	4.8	10.3	3.1	12.2	3.5	13.5	0.6	13.3	0.8	12.3	2.6	11.4	3.0
MN	15.3	3.2	10.1	4.5	27.5	1.3	19.5	1.8	23.4	0.5	18.0	0.9	22.1	1.7	15.9	2.4
MS	7.2	5.5	7.4	5.4	7.7	5.6	8.7	5.2	14.7	1.2	13.6	0.5	9.9	4.1	9.9	3.7
ZW	14.2	3.6	9.3	4.8	16.6	1.5	19.6	1.8	11.7	2.0	14.2	1.5	14.2	2.4	14.4	2.7
ZE	17.8	1.0	17.9	2.4	12.5	2.5	13.7	2.9	42.9	1.0	18.8	0.6	24.4	1.5	16.8	2.0
A	10.0	5.0	9.5	4.8	8.1	5.6	6.1	6.3	11.7	3.8	11.7	3.0	9.9	4.8	9.1	4.7
C	9.3	5.2	12.1	4.3	29.1	1.0	17.7	2.4	42.2	1.1	31.2	0.5	26.9	2.4	20.3	2.4
AG	11.3	3.2	8.9	4.7	11.7	3.0	10.9	3.5	13.1	1.0	11.9	0.6	12.0	2.4	10.6	2.9
CG	12.3	4.2	9.9	4.6	13.6	2.9	12.6	2.5	13.2	0.8	13.3	0.7	13.0	2.6	11.9	2.6

In *Table 2,* the values of the three stations in both 5-year-periods in the cases of the whole database (year) and the different sub-periods are presented. The most remarkable feature of the table is that there is only one case (type C, first period) when the minimum value of NWD$_e$ is not in *Szombathely*. Regarding the CWD$_{e,}$ we find that yearly maximum value of this is in *Szombathely* in the first and in *Budapest* in the second period, but its minimum value is in *Debrecen* in both periods. The seasonal values are orderly small: the maximum value occurs in *Szombathely* except in the winter in the first period. In the second period, the minimum values occur in *Debrecen* in every season, but their time changes in the first period. The orographic environment probably has a stronger influence on the investigated phenomena due to the general decrease of the wind velocity. In the type-groups of macrosynoptic-types and the two central types, we can say that the maximum values of CWD_e can never be spotted in *Debrecen*, but the minimum values are not evident in every case. The picture is more orderly only with the differentiation of anticyclonal (AG) and cyclonal (CG) type-groups: the maximum is in *Szombathely* in the second period, whereas the minimum is in *Debrecen* in both periods. The reason for this is that the circulation system of macrosynoptic-types and type groups is influenced in a stronger way by the barometric formations as by the orography (but their effects decrease from west to east as in the cases of any weather events in *Hungary*).

For a more exact investigation about the temporal and sub-periodical changes, different averages for the three stations are determined *(Table 2)*. It is evident from these that in the seasonal case of CWD_e, the summer maximum and spring or autumn minimums are highlighted in both periods. Its values decreased in the second period except in spring. In the case of four type-groups and the two central types, the maximum of CWD_e is in the type C, its minimum is in the type A and the order of type-groups is ZE, MN, ZW, MS in both periods. In the type-groups AG and CG, values of CWD_e change like in the central types, but with significantly smaller differences. Only the values in the MS and ZW groups do not decrease in the second period. The values of NWD_e also have a little annual course (maximum in the spring, minimum in the winter in both periods) and we can see differences in the sub-periods (maximum in the type A, minimum in the type-group ZE in both periods) and certain increase in the second period.

Definite orographical differences are shown when it comes to the significance of the relationship between the average wind velocity of sub-periods and the energy content of one characteristic wind direction (CWD_e). The value of linear correlation coefficient is not significant in *Debrecen* in both periods, but it is positively significant at the other two stations. The reason for this is the stability of wind directions (TAR, K. – SZEGEDI, S. 2002): the weak winds are unstable, they are disordered, i.e. the number of characteristic wind directions and so they have less energy in these places. The average wind velocity of sub-periods decreases by the geographical altitude in the first period with the exception of zonal type-groups. On the other hand, the minimum wind velocity is, in all cases, in *Budapest* in the second period.

Table 3 – The ratios of energy content of one characteristic and one non-characteristic wind direction (CWD_e/NWD_e)

	Debrecen		Budapest		Szombathely		mean	
	1968–72	1991–95	1968–72	1991–95	1968–72	1991–95	1968–72	1991–95
year	2.5	1.7	3.9	3.5	14.7	19.8	4.4	3.6
winter	5.1	3.2	6.3	3.9	8.2	22.5	6.3	5.1
spring	3.1	1.4	2.3	3.2	8.8	24.8	3.7	4.2
summer	2.4	1.6	7.3	4.1	15.2	19.7	6.5	4.5
autumn	3.3	1.8	3.3	3.5	22.5	16.6	4.8	3.8
MN	4.8	2.2	21.2	10.8	46.8	20.0	13.2	6.6
MS	1.3	1.4	1.4	1.7	12.3	27.2	2.4	2.7
ZW	3.9	1.9	11.1	10.9	5.9	9.5	6.0	5.3
ZE	17.8	7.5	5.0	4.7	42.9	31.3	16.3	8.5
A	2.0	2.0	1.4	1.0	3.1	3.9	2.1	1.9
C	1.8	2.8	29.1	7.4	38.4	62.4	11.0	8.5
AG	3.5	1.9	3.9	3.1	13.1	19.8	5.0	3.6
CG	2.9	2.2	4.7	5.0	16.5	19.0	4.9	4.6

In *Table 3,* the ratios CWD_e/NWD_e from *Table 2* are presented, it can unambiguously be stated that the maximums of these are in *Szombathely* in both periods except for the type-group ZW. The occurrence of extreme values does not show regularity in the seasons and types/type-groups. Therefore, we counted the orographical averages ('mean' column in *Table 3*). In the seasonal case, the maximum of these is in the summer in the first period and in the winter in the second period. The minimum is in the spring in the first and in the autumn in the second period. Now, the four type-groups show uniformed pictures: the maximum of ratio CWD_e/NWD_e is in type-group ZE, its minimum is in type-group MS in both periods. The value of this ratio is greater in type C from the central types, but this difference is not reflected in the corresponding (AG and CG) type-groups.

4. Wind directions with extreme energy content

In the meteorological literature, the most frequent wind direction is called the prevailing wind direction. This direction is entitled to this because BACSÓ, N. (1959) proved that the largest mean wind velocity belongs to this or a very close wind direction. For the objective determination of the prevailing wind directions of macrosynoptic-types, a statistical test was worked out by PÉCZELY, GY. (1957). His test produced one direction in the majority of cases, two directions in a few cases from one data by days (06 GMT) with the distinction of eight wind directions only.

The test described in the previous section is available to select the prevailing wind directions with another condition. We use a parameter which includes the two features of the prevailing wind direction: large frequency and large average velocity. As we also know from the previous sections, this parameter constitutes the energy content of wind directions. In our previous papers (TAR, K. 1991a, 2001; TAR, K. – VERDES, E. 2003), we defined the prevailing wind direction as the characteristic wind direction with the largest energy content. In these papers, we investigate some features of this direction. The most general result of our investigations supports the energetic definition of prevailing wind direction and does not conflict with the traditional one, mainly in the macrosynoptic-types. In *Table 4,* the wind directions and their energy content are shown which meet the condition mentioned above. With the further analysis of the table, our aim is to show the space and time change of the (energetic) prevailing wind direction.

The distributions of the two periods differ from each other markedly. The frequency of N and S directions strongly decreased in the second period because of the benefit of NE direction. The frequency of direction with W component increased with the exception of NW, so their distribution became more even.

The second conclusion from *Table 4* reflects the effect of orographical differences, too. The prevailing wind direction changed in all cases in *Debrecen*, but it did not change in the seasons and the type-group AG in *Budapest*, and it changed only in three cases (ZE, AG, A) in *Szombathely* in the second period.

Table 4 – The energetic prevailing wind directions and their relative energy contents (in %).

	Debrecen				Budapest				Szombathely			
	1968–72		1991–95		1968–72		1991–95		1968–72		1991–95	
	prev. dir.	ener.cont.	prev. dir.	ener.cont.	prev. dir.	ener.cont.	prev. dir.	ener.cont.	prev. dir.	ener.cont.	prev. dir.	ener.cont.
year	N	21	NE	15	NNW	19	NNW	24	N	57	N	43
winter	N	24	NE	15	NW	31	NW	29	N	65	N	45
spring	N	16	NE	15	NW	23	NW	22	N	53	N	41
summer	N	31	NE	18	NNW	34	NNW	34	N	50	N	46
autumn	S	18	SW	12	NW	27	NW	25	N	57	N	40
MN	N	40	NE	16	NW	40	NNW	31	N	60	N	47
MS	S	27	NE	12	ESE	10	NNW	16	N	56	N	38
ZW	N	20	SW	16	NW	32	NNW	28	N	46	N	49
ZE	NNE	30	NE	36	E	25	ENE	24	N	70	NNE	53
A	S	20	NE	14	ESE	10	S	11	S	23	NNE	35
C	SW	17	SSW	13	NW	45	NNW	31	N	49	N	65
AG	N	25	NE	20	NNW	24	NNW	26	N	55	NNE	38
CG	S	19	SW	14	NNW	25	NW	26	N	59	N	52

We made the change of the prevailing wind directions numerical in the sub-periods by the subtraction of their values in degrees. The difference was positive when the direction of the change was N–E–S–W (i.e. anticyclonal, clockwise). The absolute value of the difference was less than 180° or equal to this. It can be found by the average values that the negative changes are dominant in all three stations. If we do not take into account the 0 values for the averages, then we get unambiguous orographical differences: the absolute value of the change is the largest in *Szombathely* (37° from 3 cases), followed by *Budapest* (11° from 7 cases) and finally there is *Debrecen* (5° from 13 cases).

The energy content of prevailing wind direction also changed: it decreased in the majority of cases. The maximum value of decrease is in

Debrecen in the type-group MN (–24%), in Szombathely in the winter (–20%) and in the type-group MS (–18%). By the spatial averages, the largest decreases are in type-group MN (–15%) and in the winter (–10%).

Table 5 – The minimum energy wind directions and their relative energy contents (%).

	Debrecen				Budapest				Szombathely			
	1968–72		1991–95		1968–72		1991–95		1968–72		1991–95	
	min.en.dir.	ener.cont.	min.en.dir.	ener.cont.	min.en.dir.	ener.cont.	min.en.dir.	ener.cont.	min.en.dir.	ener.cont.	min.en.dir.	ener.cont.
year	SE	1.0	SSE	0.8	SSW	2.2	SE	1.2	E	0.1	SE	0.1
winter	NW	0.9	SE	0.7	SW	0.8	SE	0.7	E	0.0	SE	0.0
spring	SE	1.0	SSE	1.0	NE	1.1	SE	1.0	E	0.1	SE	0.2
summer	SSE	1.7	SSE	1.0	NE	1.3	SSE	1.3	E	0.2	ESE	0.1
autumn	ESE	0.4	SSE	0.4	ENE	0.8	NE	1.4	E	0.1	ESE	0.2
MN	SE	0.3	SSE	0.7	SSE	0.2	SE	0.7	ESE	0.0	SE	0.1
MS	NW	1.0	SSE	1.0	NE	0.8	NNE	1.7	E	0.1	SE	0.2
ZW	E	0.2	ESE	0.3	ENE	0.2	NNE	0.3	E	0.1	ESE	0.1
ZE	WNW	0.3	WSW	0.3	SSW	0.7	SSW	0.5	E	0.1	SE	0.2
A	ESE	0.8	NNW	0.8	ENE	1.7	NNE	1.6	E	0.3	ESE	0.2
C	E	0.6	NNW	0.9	NE	0.2	SE	0.9	ENE	0.0	SE	0.0
AG	SE	1.0	SSE	0.6	SW	1.4	SE	1.5	E	0.1	ESE	0.2
CG	ESE	0.8	SE	0.9	NE	0.6	SE	1.1	E	0.1	SE	0.1

From the point of view of the wind energy utilisation, the wind direction with minimum energy content is remarkable, too. They are called energetic weak winds and they can be seen in *Table 5.* The distributions differ from each other markedly in the two periods which appear mainly in a positive turn of 45°. It is also seen from *Table 5* that the direction of weak winds changes in the second period with the exception of two cases. Considering the direction of changes, orographical differences offer: the dominant changes are negative in De*brecen*, positive in *Budapest*, but positive changes are visible only in *Szombathely*.

5. Correlation analysis of energetic parameters

We determined the measure of stochastic connection among the energetic parameters given in the previous section for characterisation of inner definiteness of the wind energy field. This connection is presumably linear. We counted the linear correlation coefficient by sub-periods and investigated the significance of these; the number of significant connections depending on time and space. We only compared the unfamiliar subsets. We can investigate exactly six connections at a given station and in a given sub-period. We find six significant correlation coefficients in the majority of cases in *Szombathely*, mainly in the first period, since the number of these decreased in the second period. For example: there are altogether 86 and 76 significant correlation coefficients in the first and second period which constitute about 80 and 70 per cent of all possible cases in type-groups MN, NS, ZW, ZE and type A and C, respectively. We can see the details by stations in *Table 6*.

Table 6 – The relative number of significant correlations (%) in different periods and sub-periods

		Debrecen	Budapest	Szombathely	mean
seasons	1968–72	66.7	66.7	100.0	77.8
	1991–95	50.0	54.2	91.7	65.3
	diff.	–16.7	–12.5	–8.3	–12.5
anticycl.+cycl.	1968–72	66.7	83.3	100.0	83.3
	1991–95	58.3	75.0	100.0	77.8
	diff.	–8.4	–8.3	0.0	–5.5
zon.+	1968–72	69.4	77.8	91.7	79.6
merid.+	1991–95	58.3	69.4	83.3	70.4
centr.	diff.	–11.1	–8.4	–8.4	–9.2

The unfamiliar subsets, which are investigated together, are the seasons, type-groups AG and CG (anticycl.+cycl.), the above mentioned four type-groups and the two central types (zon.+merid.+centr.). According to the table, the greatest number of significant correlations is in type-groups AG–CG, whereas the least number is in the seasons in both periods. The measurement of decrease is reversed. The decrease has an orographical course which appears mostly in the seasons: it is the greatest in *Debrecen* and the least in *Szombathely*. The reason for the decreases is obvious, since the significant correlations in the first period became non-significant. There are altogether 21 cases; the connection of the mean length of time with the other three characteristics appears in more than half of these cases.

Table 7 – The number and relative number (%) of non-significant cases of different energetic characteristics of wind directions

(r.fr.: relative frequency, r.en.: relative energy content, a.vel.: average velocity, a.l.t.: average length of time)

	year	seasons	anticycl.+ cycl.	zon.+ merid.+ centr.	Σ	%
r.fr.-r.en.	0	4	1	8	13	2.8
r.fr-a.vel..	3	14	6	14	37	7.9
r.fr.-a.l.t.	0	1	0	2	3	0.6
r.en.-a.vel.	0	0	0	0	0	0.0
r.en.-a.l.t.	1	6	1	6	14	3.0
a.vel.-a.l.t.	4	15	6	20	45	9.6
Σ	8	40	14	50	112	23.9
possible	36	144	72	216	468	
%	22.2	27.8	19.4	23.1	23.9	

The study of non-significant cases provides useful information, too. In *Table 7,* we give this data by the reduction of the periods and stations in different sub-periods. It can be seen that the least, fewer than 20%, non-significant correlation is in type-groups AG–CG. However, the greatest number is about 28% that occurs in the seasons. It follows from the definitions and their obvious but complicated relationships that there is the least non-significant connection between the relative frequency and the average length of time, and between the relative energy content and the average velocity.

6. Conclusion

The most general result of our investigations is that the value of wind direction's energetic parameters and the ratio of their significant connections are dependent on the orography, too. In addition, it has a decreasing tendency in time, respectively. The most non-significant connections are between the average velocity and average length of time, or between the relative frequency and the average velocity of the wind directions. Based on our results, the inner definiteness of the wind field became weaker in *Hungary* which requires more prudent selection of the place in the procedure of the utilisation of wind energy.

Acknowledgement

The author wishes to express thanks to *OTKA (Hungarian Scientific Research Fund)* and the *Ministry for Environmental Protection* for the sponsorship of researches connected to the subject of this study as well as to the *Hungarian Meteorological Service* for putting the data basis at their disposal.

References

BACSÓ, N. (1959). *Magyarország éghajlata.* – Akadémiai Kiadó, Budapest, 312 p.

BARTZOKAS, A.–METAXAS, D. A. (1996). *Northern Hemisphere Gross Circulation Types. Climatic Change and Temperature Distribution.* – Meteorologische Zeitschrift, N.F. 5. pp. 99–109.

DOBOSI, Z. – FELMÉRY, L. (1971). *Klimatológia*. Egyetemi jegyzet. – Tankönyvkiadó, Budapest, 500 p.

KÁROSSY, CS. (1998). *Péczely's classification of macrosynoptic types and catlogue of weather situations (1992–1997).* In: NOWINSZKY, L. (ed.) *Light trapping of insects influenced by abiotic factors. Part II.* – Savaria University Press, Szombathely, pp. 117–130.

MAKRA, L. – TAR, K. – HORVÁTH, SZ. (2000a). *Some statistical characteristics of the wind energy over the Great Hungarian Plain.* – The International Journal of Ambient Energy, 21/2, pp. 85–96.

MAKRA, L. - TAR, K. - LUKÁCSOVICSNÉ HORVÁTH, SZ. (2000b). *Analysis of wind speed data series in Hungary by using a new statistical test and conclusions in connection with climate change.* – International Scientific Meeting on Detection and Modeling of Recent Climate Change and its Effects on a Regional Scale. Tarragona, Spain, 29–31st May 2000. Abstracts. Climate Change Research Group, 2000, Unity of Geography, URV, 56 p.

METAXAS, D. A. – BARTZOKAS, A. – VITSAS, A. (1991). *Temperature fluctuations in the Mediterranean area during the last 120 years.* – International Journal of Climatology, 11/8. pp. 897–909.

MEYHÖFER, S. – RAPP, J. – SCHÖNWIESE, C. D. (1996). *Observed Three-dimensional Climate Trends in Europe 1961–1990.* – Meteorologische Zeitschrift, N.F. 5., pp. 90–94.

MEZŐSI, M. – SIMON, A. (1981). *A meteorológiai szélmérés elmélete és gyakorlata.* – Meteorológiai Tanulmányok, No. 36. Országos Meteorológiai Szolgálat. Budapest, 58 p.

MIKA, J. – KIRCSI, A. – TAR, K. (1999). *A napi maximális széllökés néhány statisztikai tulajdonsága az Alföldön.* – Meteorológiai Tudományos Napok 1999, Országos Meteorológiai Szolgálat, Budapest, pp. 207–213.

PÉCZELY, GY. (1957). *Áramlási viszonyok Magyarországon különböző makroszinoptikus helyzetekben.* – Időjárás, 61., pp. 408–419.

PÉCZELY, GY. (1983). *Magyarország makroszinoptikus helyzeteinek katalógusa (1881–1983).* – Országos Meteorológiai Szolgálat Kisebb Kiadványai, No. 53, 116 p.

SCHÖNWIESE, C.D. – RAPP, J. – FUCHS, T. – DENHARD, M. (1994). *Observed Climate Trends in Europe 1891–1990.* – Meteorologische Zeitschrift, N.F. 3**.** pp. 22–28.

TAR, K. (1991). *Magyarország szélklímájának komplex statisztikai elemzése.* – Az Országos Meteorológiai Szolgálat kisebb kiadványai, 67, 124 p.

TAR, K. (1991b). *The Concept and the Velocity and Energy Distribution of Characteristic and Non-Characteristic Wind Directions.* – The International Journal of Ambient Energy. Vol. 12. no. 2. pp. 95–100.

TAR, K. (1998a). *A magyarországi szélmező statisztikai jellemzői a globális felmelegedéssel összefüggésben.* – Az éghajlatváltozás és következményei. Meteorológiai Tudományos Napok, 1997, pp. 249–258.

TAR, K. (1998b). *Alteration of the Statistical Structure of the Wind Field in Hungary in Connection with the Climatic Change.* – 2nd European Conference on Applied Climatology. Central Institute for Meteorology and Geodynamics. Nr. 19. (CD-ROM. ISSN 1016-6254) Vienna. Austria.

TAR, K. (1999). *Az alföldi szélmező statisztikai jellemzőinek időbeli változása.* In: FÜLEKY, GY. (ed.) A táj változása a Kárpát-medencében c. tudományos konferencia kiadványa. – Gödöllő, pp. 225–230.

TAR, K. – MAKRA. L. – HORVÁTH. SZ. (2000). *Some Statistical Characteristics of the Wind Energy in Hungary in Connection with Climatic Change.* – 3rd European Conference on Applied Climatology (CD-ROM. ISBN 88-900502-0-9). Pisa. Italy

TAR, K. (2001). *A magyarországi szélmező statisztikai szerkezetének időbeli változása a feltételezett éghajlatváltozással összefüggésben.* – OTKA zárójelentés (T 023765), Debreceni Egyetem.

TAR, K. – MAKRA, L. – HORVÁTH, SZ. – KIRCSI, A. (2001). *Temporal Change of Some Statistical Characteristics of Wind Speed in the Great Hungarian Plain.* Theoretical and Applied Climatology. Vol. 69. No.1–2. pp. 69–79.

TAR, K. – SZEGEDI, S. (2002). *A szélirány stabilitása a tenyészidőszakban különböző időjárási helyzetekben. Levegő–növény–talaj rendszer.* – Debreceni Egyetem, Agrártudományi Centrum, pp. 103–113.

TAR, K. – VERDES, E. (2003). *Temporal Change of Some Statistical Characteristics of Wind Direction Field Over Hungary.* – Időjárás. 107. 2., pp. 153–170.

VINCZE, I. (1975). *Matematikai statisztika ipari alkalmazásokkal.* – Műszaki Könyvkiadó. Budapest, 352 p.