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Introduction: Studying pollen concentrations in relation to meteorological elements is of practical importance because of its health concern. About one-third of Hungarian inhabitants have some type of allergy, two-third of them has pollen sensitivity. The aim of the study is to compare the efficiency of objectively defined air-mass types with the subjectively defined Péczely's weather types in classifying airborne pollen grain concentrations for Szeged, Hungary.
Methods: Based on the ECMWF data set, daily sea-level pressure fields analysed at 00 UTC were related to the pollen levels for both the objective air-mass types and the Péczely types in Szeged. The data basis includes daily values of twelve meteorological parameters and daily airborne pollen grain concentrations of twenty four species for their pollination term in the period 1997-2001. The objective definition of the characteristic air-mass types prevailing over Szeged, Hungary, was performed by using Factor Analysis and Cluster Analysis. Péczely's classification was based on the position, extension and development of cyclones and anticyclones relative to the Carpathian Basin. Statistical evaluation and quantitative comparison of the differences of the mean plants' pollen levels calculated for both classification systems were performed by ANOVA and Tukey's honestly significant difference test, respectively.
Results: Two-third of the weasther types are anticyclonic situations both for the objective, and the Péczely classification. Objective types 2, 4 and 8 are the most favourable, while types 5 and 6 are the least characteristic in classifying pollen levels. Namely, types with anticyclonic character are mostly favourable, however, some of them are negligible in the classification of pollen concentrations. This result might hint the ambivalent role of anticyclonic types in the accumulation of pollen levels. Concerning the individual Péczely situations, types 6 (CMw) (cyclonic type) and 12 (A) (anticyclone centre over the Carpathian Basin) are the most favourable, while types 3 (CMc) and 7 (zC) (both cyclonic types) are the most negligible in the classification of pollen grain concentrations.
Discussion and Conclusions: Prevalence of anticyclonic situations are characteristic for both classifications, while their persistence is significantly higher for the Péczely types. Types of anticyclone centre are among the most favourable ones in classifying pollen levels for both systems of weather situations. Role of anticyclonic ridge types and cyclonic types are complex: they can either favour or prevent accumulating pollen concentrations for both systems. The pressure patterns compared can only influence the pollen levels, which depend mostly on the phenology of the species considered.

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COMPARISON OF OBJECTIVE AIR-MASS TYPES AND THE PÉCZELY'S WEATHER TYPES AND THEIR ABILITY OF CLASSIFYING AIRBORNE POLLEN GRAIN CONCENTRATIONS IN SZEGED, HUNGARY

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SUMMARY
This paper compares the efficiency of a system of objective air-mass types and the Péczely's weather types in classifying airborne pollen grain concentrations over the Carpathian Basin for the pollination period between 1 February and 31 October. Based on the ECMWF data set, daily sea-level pressure fields analysed at 00 UTC (UTC = Coordinated Universal Time) were related to the pollen levels for both the objective air-mass types and the Péczely types in Szeged. The data basis comprises daily values of twelve meteorological parameters and daily airborne pollen grain concentrations of twenty four species for their pollination term in the period 1997-2001. Mean sea-level pressure fields of the Péczely types show higher independence from each other than those of the objective clusters. Prevalence of the anticyclone centre and anticyclonic ridge situations are observed both for the objective, and the Péczely classification in the period examined. Persistence of the types with anticyclonic character is significantly lower for the objective types, than for the Péczely types. Objective types 2, 4 and 8 are the most favourable, while types 5 and 6 are the least characteristic in the classification of pollen levels. Namely, types with anticyclonic character are mostly favourable, while other types with anticyclonic character are negligible in classification of pollen levels. This result might hint the ambivalent role of types with anticyclonic character in accumulation of pollen levels. Concerning the individual Péczely's situations, types 6 (CMw) and 12 (A) are the most favourable, while types 3 (CMc) and 7 (zC) are the most negligible in classification of pollen grain concentrations. Hence, the Péczely's large-scale weather situations can not be considered as an overall system, but distinguished types have an emphasized role in classifying pollen grain concentrations. Concerning the relation of the Péczely's large-scale weather situations with respect to the meteorological elements in Szeged, Péczely macrotypes 4, 5, 6, 12 and 13 differ mostly from the others, so they are considered to be the most specific ones. In the pollination period, the role of atmospheric pressure (P) is the most definite among the twelve meteorological parameters in representing the differences in the Péczely's weather types. Furthermore, RH and I are also characteristic. On the other hand; T_{mean}, T_{max}, T_{min}, E, VP and T_d have practically no influence on separating the Péczely types. At the same time, Péczely macrotypes 3, 7 and 9 are considered intermediate. Atmospheric circulation is not the only factor controlling pollen grain concentrations in Szeged. The revealed pressure patterns can only influence the pollen levels, which depend mostly on the phenology of the species considered. Thus, for a precise forecast of pollen grain concentrations, apart from a good weather forecast, a good knowledge of phenology is necessary.

Keywords: objective air-mass types, Péczely's weather types, airborne pollen grain concentrations, ANOVA weather classification

1. INTRODUCTION

Studying plants' pollen levels in relation to meteorological elements is of practical importance because of its health concern. About one-third of Hungarian inhabitants have some type of allergy, two-third of them has pollen sensitivity and at least 60 % of this pollen-sensitivity is caused by *Ambrosia* (Járai-Komlódi, 1998) and 50-70 % of allergic patients are sensitive to ragweed pollen (Mezei et al, 1992). The number of patients with registered allergic illnesses has doubled and the number of cases of allergic asthma has become four times higher in Southern Hungary by the late 1990s over the last 40 years. According to annual totals of pollen counts of various plants measured between 1990 and 1996 in Southern Hungary, *Ambrosia* produces about half of the total pollen production (47.3 %). Though this ratio highly depends on meteorological factors year by year (in 1990 this ratio was 35.9 %, while in 1991: 66.9 %), it can be considered the main aero-allergen plant in Hungary (Juhász, 1995; Makra et al, 2004a; 2004b). However, pollen sensitivity depends on the individuals. Pollination term of species in Szeged lasts from the beginning of February till the end of October.

Plants' pollen, as a biological agent of the Hazardous Air Pollutants [HAPs], is a seasonal air pollutant, related to the phenological phase of the given plant, concentrations of which are influenced by the meteorological elements.

Airborne pollen concentrations and their relation to meteorological elements have been studied by several authors. Pollen levels of species examined showed partly significant positive correlations with temperature parameters (mean air temperature, minimum air temperature and maximum air temperature), dew point temperature and sunshine duration, partly significant negative correlations with precipitation, air pressure and wind speed. On the other hand, no correlation was found with relative humidity and rainfall. In another case, pollen levels did not show significant connection with relative humidity and precipitation. Significant connection between, on the one hand, daily pollen number and, on the other, wind speed and precipitation with both signs might hint the ambivalent role of these meteorological parameters in accumulation of pollen levels (Table 1).

Long-lasting clear weather situations, due to long summers with undisturbed irradiation and calm or weak breezes, are favourable for studying relations of pollen levels with meteorological elements. In Europe, the Mediterranean is considered to be such a region (Vázquez et al., 2003; Rodríguez-Rajo et al., 2003; 2004a; Gioulekas et al., 2004; Damialis et al., 2005). Especially for Athens (Kambezidis et al., 1998) and Thessaloniki (Gioulekas et al., 2004; Damialis et al., 2005), this weather and the mountains, which surround the cities from north, favour extreme accumulation of both pollen levels and chemical air pollutants. Position of Hungary, situated in the Carpathian Basin with long-lasting antiyclonic weather, favours enrichment of air pollutants (Fig. 1a.).

Studies on the relationship between synoptic weather conditions and pollution levels are carried out by either using objective multivariate statistical methods or subjective classifications based on the long experience of meteorologists. Examples of objective approaches are the works of McGregor and Bamzelis (1995), Sindosi et al. (2003) and Makra et al. (2006) who classified air-mass types (in fact weather types) and then investigated the corresponding Main Air Pollutants (MAPs) concentrations for Birmingham (UK), Athens (Greece) and Szeged (Hungary), respectively. On the other hand, Kassomenos et al. (1998a; 1998b; 2001), Péczely (1957, 1983) and Károssy, (1987, 2004) have given interesting results on weather categorisation and its applications for Athens and Budapest by using subjective methodologies. Nevertheless, comparisons of efficiency of objectively-defined and subjectively-determined weather classification systems to separate weather types with respect to pollutant levels have only been carried out by Makra et al. (2006) according to literature.

The major aim of the present study is to compare the efficiency of two systems in classifying airborne pollen grain concentrations for Szeged, Hungary; i.e. a methodology which objectively defines air-mass types with the subjectively defined Péczely's weather types. Another objective is to study the relation of the Péczely's large-scale weather situations with respect to the meteorological elements; namely, to detect the most important climatic factors separating the subjectively-defined thirteen Péczely's weather types.

2. TOPOGRAPHY OF THE SZEGED AREA

The city of Szeged being the largest town in SE Hungary (20°06'E; 46°15'N) is located at the confluence of the Tisza and Maros Rivers characterised by an extensive flat landscape with an elevation of 79 m a.s.l. (Fig. 1b). The built-up area covers a region of about 46 km^2 with about 155,000 inhabitants. Szeged and its surroundings are not only characterised by extensive lowlands, but also they have the lowest elevation in Hungary and the Carpathian Basin, as well. This results to a "double basin" situation. Due to the position of the city in a basin (a smaller one within a larger one), temperature inversions form more easily in the area and prevail longer than in flat terrain, leading to an enrichment of air pollutants within the inversion layer. The climate of Szeged is characterised by hot summers and moderately cold winters. The distribution of rainfall is fairly uniform during the year. The mean daily summer temperature is 22.4 °C, while the mean daily winter temperature is 2.3 °C. More details on the climatology and air quality of the Szeged area have already been presented in a former work (Makra et al., 2006).

3. DATA COLLECTION

In Szeged, the pollen content of the air has been examined with the help of a "Hirst-type" pollen trap (Lanzoni VPPS 2000) since 1989. The air sampler is located on top of the building of the Faculty of Arts, University of Szeged (20 m above the city surface). The building itself is found in the downtown and with its top level belongs to the highest ones of the city. Daily pollen data were obtained by counting all pollen grains on four longitudinal transects (Käpylä & Penttinen, 1981).

The pollen data basis consists of daily mean plant pollen counts (pollen grains per m^3 of air) of altogether 24 species from the five-year period between 1997 – 2001 for the pollination term between 1 February – 31 October. The species considered with their Latin (English) names are as follows: Acer (maple), Alnus (alder), Ambrosia (ragweed), Artemisia (mugwort), Betula (birch), Cannabis (hemp), Carpinus (hornbeam), Chenopodium (goosefoot), Corylus (hazel), Fraxinus (ash), Juglans (walnut), Morus (mulberry), Pinus (pine), Plantago (plantain), Platanus (platan), Poaceae (grasses), Populus (poplar), Quercus (oak), Rumex (dock), Salix (willow), Taxus (yew), Tilia (linden), Ulmus (elm), Urtica (nettle).

The meteorological data basis consists of a 30-minute data set from the five-year period between 1997 – 2001 for the pollination term between 1 February – 31 October. Daily values of the 12 meteorological elements considered are as follows: mean temperature (T_{mean}, °C), maximum temperature (T_{max}, °C), minimum temperature (T_{min}, °C), daily temperature range ($\Delta T = T_{max} - T_{min}$, °C), wind speed (WS, m s^{-1}), relative humidity (RH, %), irradiance (I, MJ m^{-2} day^{-1}), saturation vapour pressure (E, hPa), water vapour pressure (VP, hPa), potential evaporation (PE, mm), dew point temperature (T_d, °C) and atmospheric pressure (P, hPa).

Daily sea-level pressure fields measured at 00 UTC (UTC = Coordinated Universal Time) come from the ECMWF (European Centre for Medium-Range Weather Forecasts) Re-Analysis ERA 40 project, in the frame of which daily data have been re-analyzed since September 1st, 1957. The procedure has been performed with a uniform method from the data being available in the investigated period.

The investigated area is in the North-Atlantic – European region between 30°N–70.5°N latitudes and 30°W–45°E longitudes. The grid network is selected with a density of 1.5°x1.5°, which indicates 28x51 = 1428 grid points for the region.

4. METHODS

4.1. Cartographical background

For the days classified in each objective type and the thirteen Péczely's weather types, average daily sea level pressure patterns were constructed by applying the Surfer 7.00 contouring, gridding and surface mapping software. Isobars for an average day, i.e. for an average objective or Péczely type, were drawn using 28x51=1428 grid data on the basis of the standard Kriging method without increasing data quantity and with a maximum smoothing (Makra et al., 2006).

4.2. The objective weather types

The objective definition of the characteristic air-mass types (in fact weather types) prevailing over Szeged, Hungary, was performed by Makra, et al. (2006) by using Factor Analysis (FA) and Cluster Analysis (CA). At first the FA (varimax rotation) was applied on the data matrix in order to reduce the dimensionality of the interrelated meteorological parameters and then CA (hierarchical technique, average linkage method) on the factor scores time series in order to group objectively days characterised by similar weather conditions. Application of the hierarchical technique in this work aims to get objectively defined weather types which can be compared to the Péczely's large-scale weather situations. Here the average linkage method is used since it produces more realistic groupings. These methods were applied in other similar works (e.g. Sindosi et al., 2003). According to the results, nine air-mass types (clusters) were detected. For each of the derived clusters of days, the mean value for every meteorological parameter and means of pollen grain concentrations were computed. In this way, the relations between weather conditions and the corresponding concentrations of pollen grains were revealed. Finally, for each weather type, the composite maps of the mean sea-level pressure distribution over the North-Atlantic – European region (00 UTC) were constructed revealing also the synoptic conditions associated with weather types and pollen levels in Szeged.

4.3. The Péczely's large-scale weather classifications

Péczely (1957) defined thirteen large-scale weather patterns altogether and for each of them he selected the most typical day. The classification was based on the position, extension and development of cyclones and anticyclones relative to the Carpathian Basin considering the daily sea-level pressure maps constructed at 00 UTC in the North-Atlantic–European region by the Hungarian Meteorological Service. Péczely determined the daily catalogue of the 13 macrosynoptic types, at first, for the period 1877-1956 (Péczely, 1957) and later he completed it till the end of 1982 (Péczely, 1983). After his death in 1984, the daily classification of weather types was performed by Károssy (1987; 2004) with the same subjective methodology.

4.4. χ^2-test, independence analysis

In order to decide whether or not the sea-level pressure fields examined differ significantly from each other, the χ^2-test independence analysis was applied. This method determines whether or not two random variables (ξ and η) are independent. According to the 0-hypothesis, ξ and η are not independent.

4.5. ANOVA and Tukey's honestly significant difference test

When determining both the objective air-mass types and the Péczely's macrosynoptic types, only meteorological parameters are taken into account, excluding pollen grain concentration data. Hence, the differences of the mean plants' pollen levels calculated for both the objective air-mass types and each Péczely's macrotype need a further statistical evaluation. This is performed by the method of one-way Analysis of Variance (ANOVA) for pollen levels of each species. By using the method, significant differences in plants' pollen concentrations of different synoptic types (clusters) can be determined. Finally, the Tukey's honestly significant difference test is applied in order to quantitatively compare the mean plants' pollen levels between each pair of both the objective types and the Péczely's macrotypes (pairwise multiple comparisons) (McGregor and Bamzelis, 1995; Sindosi et al., 2003; Makra et al., 2006).

All statistical computations were performed with SPSS (version 9.0) software.

5. RESULTS

5.1. Characteristics of the objective air-mass types and the Péczely's macrosynoptic types

5.1.1. Independence analysis

Mean sea-level pressure fields for the objectively-defined cluster of days and the thirteen Péczely's weather types were compared on the basis of the used grid values (see Chapter 4.1.) in both seasons of the period examined.

In order to decide whether the mean sea-level pressure fields of the nine clusters, on the one hand, and the thirteen Péczely's weather types on the other, differ significantly from each other, the χ^2-test was applied. The 0-hypothesis means that there is no significant difference between the mean sea-level pressure fields of the objects compared.

On the basis of our computations, 66.7 % of all possible objective pairs [24 out of $\binom{9}{2}$ = 36 cases] differ significantly from each other. While considering the subjective classification, 89.7 % of all the pairs of the thirteen Péczely types [70 pairs out of $\binom{13}{2}$ = 78 cases] differ significantly from each other. We note that it must be kept in mind that Péczely (1957; 1983) and then Károssy (1987; 2004) classified pressure patterns directly, while Makra et al. (2006) classified weather conditions in Szeged and then they presented the corresponding pressure patterns. Thus, under the same classification of Péczely, distinct areas in Hungary may have different prevailing weather conditions.

5.1.2. Basic statistical parameters

Basic statistical parameters of the pollen concentrations of the 24 species are calculated on those days both within the clusters and the individual Péczely-types, when pollen release was observed.

Variance for each cluster proved to be the highest for Ambrosia, in agreement with the higher variability of its pollen concentrations. Variation coefficients (standard deviation expressed in the unit of the average) for pollen levels of Alnus and Ambrosia are the highest, which denotes their higher variability. However, the difference is not significant compared to that of other species. The difference of $|median - average|$ remains within the so called interquartile half extent (the interval given by the lower quartile and the upper quartile) for each plants' pollen. The highest differences are detected for Ambrosia.

The variance, calculated for the days within the individual Péczely-types, proved also to be the highest for Ambrosia of all plants' pollen. The next highest variances, in decreasing order, are indicated by Populus, Morus and Alnus. Variation coefficient for pollen concentration of Ambrosia is the highest, which also denotes its higher variability. However, the difference is not significant, as for the objective clusters. The difference of $|median - average|$ remains within the so called interquartile half extent for each plants' pollen. The highest differences are detected for Ambrosia and Alnus.

5.1.3. ANOVA statistics

In order to determine the influence of the 9 objective air-mass types and the 13 Péczely's synoptic types on pollen grain concentrations, analyses of variance (ANOVA) were performed on the plants' pollen levels. It was found that the objective weather types show significant inter – weather type differences in mean plant pollen counts of all the 24 species at the 99 % probability level. However, this is not the case for the Péczely types. Namely, for some species the above differences are significant only at the following probability levels: Alnus, 81 %; Juglans, 89 %; Morus, 85 %; Pinus, 95 %; Populus, 93 %; Quercus, 89 %; Taxus, 96 % and Tilia, 95 %, respectively. Considering that differences are found among the mean pollutant levels, Tukey's tests were applied in order to receive a pairwise multiple assessment of the differences.

It is calculated that 8 out of the 36 pairs of the objective types (22.2 %) differ significantly for ten or more species (mostly for Artemisia, Cannabis, Chenopodium, Plantago, Poaceae and Urtica), while 7 out of the 78 pairs of the Péczely types (9.0 %) differ substantially for 5 or more species (mostly for Acer, Betula, Carpinus and Salix). Generally, objective types 4-8 and Péczely types 2-4 can be considered to be mostly different, since the levels of most pollutant pairs (20 and 9 pollutant pairs, respectively) show substantial differences. This can mainly be explained by the fact that objective types 4-8 and Péczely types 2-4 show almost the highest difference in wind speed and air pressure, respectively.

Furthermore, *clusters 5* and *6* in the objective types and Péczely types 3, 5 and 13 (with the least pairwise differences) seem to be intermediate patterns considering pollen grain concentrations of the species considered. Objective types 2 (an anticyclone over the Carpathian Basin), 4 (an intermediate type) and 8 (an anticyclone ridge type) (with the most pairwise differences) are found to be the most definite ones in classifying pollen levels. On the other hand, Péczely types 4 (mCw), 7 (zC) and 11 (AF) indicate the most pairwise differences. Hence, considering the 13 subjective types, they are the most characteristic ones in classifying pollen concentrations. Among them, types 4 and 7 are cyclonic patterns, while type 11 is an anticyclonic ridge weather situation.

5.2. ANOVA statistics for the Péczely's weather types

When objective weather types were defined for Szeged, Hungary (Makra et al., 2006), 12 meteorological parameters were used in order to determine groups of days with similar weather in Szeged; and then the corresponding pressure patterns were constructed. On the other hand, the base of the subjective classification of Péczely's large-scale weather situations (1957; 1983) was the sea-level pressure maps constructed at 00 UTC for the North-Atlantic–European region.

So, the ANOVA tests, which have been performed on the pollen levels of the species considered, are now applied to the above mentioned 12 meteorological parameters. If differences are found among the mean levels of the climatic elements, the Tukey's honestly significant difference tests are applied in order to receive a pairwise multiple assessment of the differences, which aims to detect the most important climatic factors to separate the subjectively defined thirteen Péczely's weather types for the pollination period examined.

According to ANOVA, except for T_d with a mere 8 %, all the meteorological parameters present significant inter – Péczely type differences in the mean values at least at the 95 % confidence level (Table 2). Therefore, Tukey's tests were applied to get pairwise multiple assessments of the differences (Table 3). According to this, none of the 78 pairs of the Péczely types showed significant differences in mean values of all the twelve meteorological parameters considered. The highest inter – Péczely type difference is expressed by eight meteorological parameters between Péczely types 4-5, 5-6 and 12-13 and by seven parameters between Péczely types 4-11, 4-12, 6-11 and 6-12 (Table 3).

At least seven meteorological parameters presented significant differences in their mean values for altogether 7 pairs of Péczely types. In general, Péczely types 4, 5, 6, 12 and 13 differ mostly from the others, since the pairwise multiple comparisons detected significant differences for them in mean values of the most meteorological elements. Namely, these types can be considered the most specific ones (Table 3). On the other hand, types 3, 7 and 9 are intermediate ones. The most important meteorological elements in classifying Péczely types (with the highest significant pairwise differences) are RH, I and P, while the negligible meteorological elements (with the lowest significant pairwise differences) are T_{mean}, T_{max}, T_{min}, E, VP and T_d (Table 3).

6. DISCUSSION

This paper compared the efficiency of classification of pollen levels in Szeged for days characterised by specific weather, defined objectively and the days characterised by a common pressure pattern over Europe according to the subjective classification of Péczely's weather types over the Carpathian Basin. Specific types for the pollination period were found to play a significant role in the pollen grain concentrations in Szeged.

Overall, objective types 2, 4 and 8 are the most favourable, while types 5 and 6 are the least characteristic in the classification of pollen levels. Namely, types with anticyclonic character are partly favourable, partly negligible in classification of pollen levels. This result might hint the ambivalent role of types with anticyclonic character in accumulation of pollen levels. On the other hand, Péczely types 4, 7 and 11 are indicated as the most favourable, whereas types 3, 5 and 13 being intermediate ones are the most negligible in classifying pollen levels of the species considered.

In the pollination period 97.4 % of the pairs of the 9 objective types and 67.9 % of the pairs of the thirteen Péczely types indicated significant differences in the pollen levels of one or more species. Namely, efficiency of the pollen related objective classification of air-mass types seems to be much more effective, while a substantial decrease of that can be observed for the Péczely's classification.

7. CONCLUSIONS

Mean sea-level pressure fields of the Péczely types show higher independence from each other than those of the objective clusters in the pollination period.

Prevalence of the anticyclone centre and anticyclonic ridge situations are observed both for the objective (68.3 %, Table 4), and the Péczely classification (66.1 %, Table 5) in the period examined. Persistence of the types with anticyclonic character is significantly lower for the objective types (1.19, Table 4), than for the Péczely types (1.70, Table 5).

It should be stressed that Péczely first and Károssy afterwards classified pressure patterns directly, while Makra et al. (2006) classified weather conditions in Szeged and they presented the corresponding pressure patterns. Thus, different areas in Hungary may have different weather conditions under the same pattern of Péczely.

Concerning the relation of the Péczely's large-scale weather situations with respect to the meteorological elements in Szeged, Péczely macrotypes 4, 5, 6, 12 and 13 differ mostly from the others, so they are considered to be the most specific ones. In the pollination period, the role of atmospheric pressure (P) is the most definite among the twelve meteorological parameters in representing the differences in the Péczely's weather types. Furthermore, RH and I are also characteristic. On the other hand; T_{mean}, T_{max}, T_{min}, E, VP and T_d have practically no influence on separating the Péczely types. At the same time, Péczely macrotypes 3, 7 and 9 are considered intermediate.

Relation of both the objectively determined air-mass types and the subjectively-defined Péczely's weather types on the one hand, and pollen grain concentrations in Szeged, on the other, detected that pollen levels can be connected to different pressure patterns ruling the region examined. Hence, in view of the weather forecast, expected pollen levels can be indicated and abatement of episodes of severe pollen levels can be considered. However, it has to be underlined that atmospheric circulation is not the only factor controlling pollen grain concentrations in Szeged. The revealed pressure patterns can only influence the pollen levels, which depend mostly on the phenology of the species considered. Thus, for a precise forecast of pollen grain concentrations, apart from a good weather forecast, a good knowledge of phenology is necessary.

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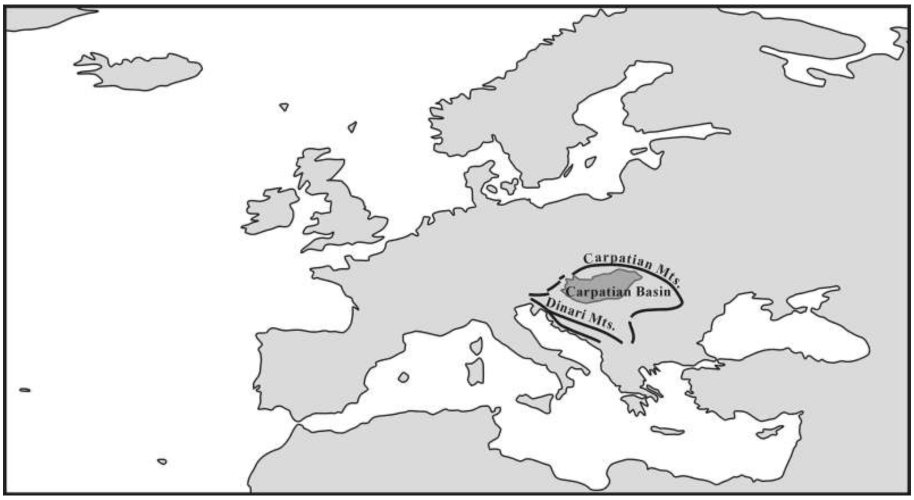

Fig. 1a
Location of the Carpathian Basin

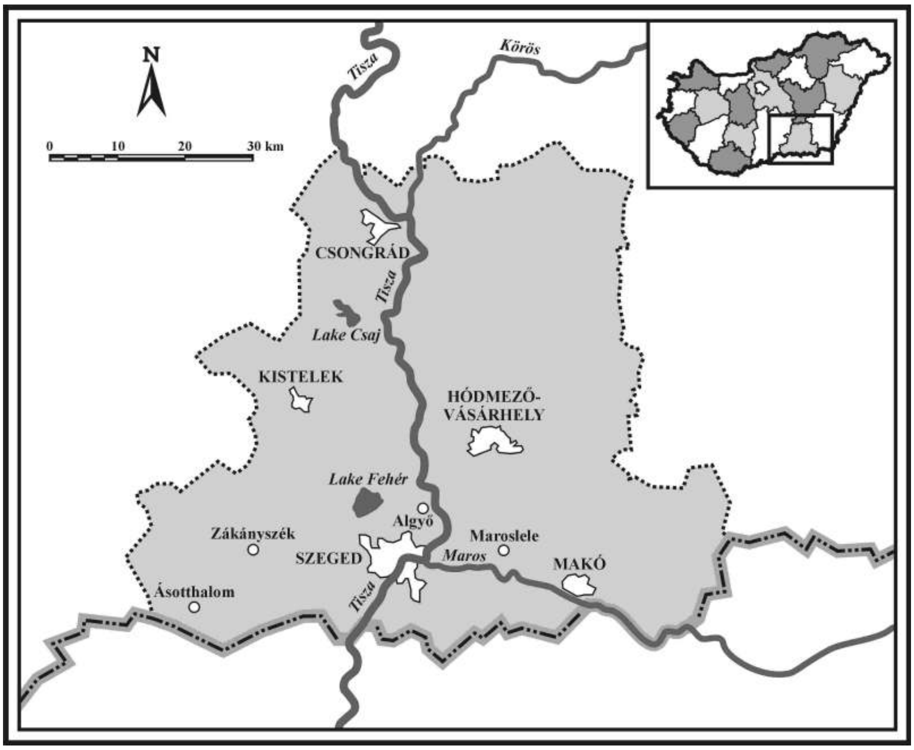

Fig. 1b
Location of Szeged in Csongrád county (centre);
Csongrád county in Hungary (top right)

List of Tables

Table 1
Relations of airborne pollen concentrations and meteorological elements

Author	Significant connection		Not significant connection
	Positive	Negative	
Gioulekas et al., 2004; Stennett and Beggs, 2004	Tmean,		
Makra et al., 2004b; Rodríguez-Rajo et al., 2004a	Tmin		
Rodríguez-Rajo et al., 2004a	Tmax		
Stennett and Beggs, 2004	Td		
Green et al., 2004		Prec	
Gioulekas et al., 2004			RH, Prec
Stennett and Beggs, 2004; Gioulekas et al., 2004	WS		
Stennett and Beggs, 2004		P	
Gioulekas et al., 2004; Rodríguez-Rajo et al., 2004b	SD		
Makra et al., 2004b	WS	WS	

Tmean = mean air temperature; Tmin = minimum air temperature;
Tmax = maximum air temperature; Td = dew point temperature;
Prec = precipitation; RH = relative humidity; P = atmospheric pressure;
SD = sunshine duration; WS = wind speed

Table 2

ANOVA statistics for the Péczely's inter – weather type comparison of meteorological parameters' values, 1 February – 31 October

	Tmean	Tmax	Tmin	DT	E	VP	PE	Td	RH	I	P	WS
Mean square between groups	155.27	234.03	106.87	209.50	253.51	75.59	33.14	626802.32	1916.69	95165.31	1878.53	2.18
Mean square within groups	52.80	62.68	54.26	31.15	76.50	29.80	4.09	1274216.63	102.40	6465.16	45.19	0.23
F-Ratio	2.94	3.73	1.97	6.72	3.31	2.54	8.11	0.49	18.72	14.72	41.57	9.41
Level of significance, %	95	99	98	99	99	97	99	8	99	99	99	99

Tmean = mean temperature; Tmax = maximum temperature; Tmin = minimum temperature, DT (= Tmax – Tmin) = daily temperature range; WS = wind speed; RH = relative humidity; I = irradiance; E = saturation vapour pressure; VP = water vapour pressure; PE = potential evaporation; Td = dew point temperature; P = atmospheric pressure

Table 3

Péczely's weather type – meteorological element difference matrix. Each matrix cell represents the comparison between two Péczely types. Parameters appearing in the matrix cells indicate significant difference in their values between two given Péczely's weather types according to Tukey's Honestly Significant Difference Test, (1 February – 31 October) (light-faced characters: 95 % of significance; **bold** characters: 99 % of significance)

	1	2	3	4	5	6	7	8	9	10	11	12
2	**I** **P**											
3		**P**										
4		RH **I** **P**										
5	**WS** **RH** **PE** I **P**	PE	**RH** PE P	**Tmean** WS **Tmax** **RH** **PE** **I** **E** **P**								
6	**RH** **I** **DT**	**RH** **I** **P**			Tmean **Tmax** **RH** **PE** **I** **DT** E **P**							
7		**I** **P**			**RH** **P**							
8	**P**		**P**	**RH** PE **I** **P**	Tmax PE **DT**	**RH** PE **I** **P**	**P**					
9	**WS** **P**	WS		**WS** **P**		WS **RH** **I** **DT** **P**	**P**	WS				
10	RH I **P**		RH **P**	**RH** PE **I** **P**		**RH** PE **I** **P**	I **P**					
11	**WS** **RH** **I** **P**		RH P	Tmean Tmax **RH** **PE** **I** **E** **P**		Tmax **RH** **PE** **I** **DT** E **P**	I **P**					
12	**WS** **RH** PE **I** **P**	**WS** RH DT	**RH** **P**	**WS** **RH** **PE** **I** DT E **P**	**WS** P	**WS** Tmax **RH** **PE** **I** **DT** **P**	**RH** **I** **P**	**WS** RH I **DT**	I **P**	**WS** DT		
13	**RH**	**RH** **I** **P**		**VP** Tmin	**WS** **RH** **PE** **I** **DT** **P**			VP **RH** **I** **P**	**WS** **RH** **DT** **P**	**RH** **I** **P**	**WS** **RH** PE **I** DT **P**	**WS** VP **RH** **PE** Tmin **I** **DT** **P**

Tmean = mean temperature; Tmax = maximum temperature; Tmin = minimum temperature, DT (= Tmax – Tmin) = daily temperature range; WS = wind speed; RH = relative humidity; I = irradiance; E = saturation vapour pressure; VP = water vapour pressure; PE = potential evaporation; Td = dew point temperature; P = atmospheric pressure

Table 4
Frequency and persistence (average length) of the objective types,
1 February – 31 October, 1997-2001

Objective type	Frequency, %	Persistence, day
1 (anticyclonic character)	9.28	0.79
2 (anticyclone centre)	6.92	1.13
3 (cyclonic character)	16.73	1.92
4 ((intermediate type)	14.95	1.58
5 (anticyclonic character)	4.68	1.12
6 (anticyclonic character)	12.10	1.46
7 (anticyclonic character)	9.36	1.26
8 (anticyclonic character)	22.04	1.83
9 (anticyclonic character)	3.82	0.72
Anticyclonic types, total	68.32	1.19

Table 5
Frequency and persistence (average length) of the Péczely types,
1 February – 31 October, 1997-2001

Péczely type	Frequency, %	Persistence, day
1 (mCc) cyclonic type	15.43	1.50
2 (AB) anticyclonic ridge type	8.33	2.08
3 (CMc) cyclonic type	0.96	0.81
4 mCw (cyclonic type)	6.03	1.20
5 (Ae) anticyclonic ridge type	11.10	1.69
6 (CMw) cyclonic type	4.63	1.20
7 (zC) cyclonic type	2.00	1.51
8 (Aw) anticyclonic ridge type	13.50	1.50
9 (As) anticyclonic ridge type	4.74	1.20
10 (An) anticyclonic ridge type	8.16	1.52
11 (AF) anticyclonic ridge type	7.63	2.25
12 (A) anticyclone centre type	12.68	1.65
13 (C) cyclone centre type	4.76	1.21
Anticyclonic types, total	66.14	1.70
Cyclonic types, total	33.81	1.24