Capsule: The significance of the work is that in the knowledge of the weather forecast, expected concentrations of pollens, involving serious health risk, can be indicated.

THE GROUPS OF THE PÉCZELY'S LARGE SCALE WEATHER SITUATIONS FOR SZEGED, HUNGARY WITH SPECIAL ATTENTION TO PLANTS' POLLEN LEVELS

*László Makra[1], Miklós Juhász[2], Aristides Bartzokas[3] and Zoltán Sümeghy[1]

[1]Department of Climatology and Landscape Ecology, University of Szeged, H-6701 Szeged, Hungary, E-mail makra@geo.u-szeged.hu, sumeghy@geo.u-szeged.hu;

[2]Department of Botany, University of Szeged, H-6701 Szeged, Hungary,
E-mail juhaszm@bio.u-szeged.hu

[3]Laboratory of Meteorology, Department of Physics, University of Ioannina,
GR-45110 Ioannina, Greece, E-mail abartzok@cc.uoi.gr

*Author for correspondence:
László Makra[1]
Department of Climatology and Landscape Ecology, University of Szeged,
H-6701 Szeged, Hungary
Telephone: +(36 62) 544 856
Fax: +(36 62) 544 624
E-mail: makra@geo.u-szeged.hu

Abstract This paper discusses the six groups of a subjectively defined system of air mass types; namely, the six groups of the thirteen Péczely's large-scale weather situations over the Carpathian Basin in relation to the plants' pollen levels. Based on the ECMWF data set, daily sea-level pressure fields analysed at 00 UTC were prepared for the six groups of the thirteen Péczely-types in order to relate their sea-level pressure patterns with the pollen levels in Szeged. The data basis comprises daily values of twelve meteorological parameters and daily pollen concentrations of twenty four species for their pollination term in the five-year period 1997-2001. It was found that groups III and V are favourable, while groups II, IV and VI are negligible in classification of pollen concentrations. Role of group V in accumulation and group VI in dilution of pollen levels is in agreement of our expectations. However, role of group III in accumulation and groups II and IV in dilution of pollen concentrations is complex. Nevertheless, winds speed seems to be an important factor. On the other hand, the cyclonic and anticyclonic components of groups II and III as well as the ambivalent role of the anticyclonic ridge situations (group IV) make it difficult using groups of Péczely-types in classification of pollen levels. Hence, the groups of Péczely's large-scale weather situations can not be considered as an overall system in categorization of pollen concentrations.

Keywords: Péczely's large-scale weather situations, groups of Péczely-types, plants' pollen levels, ANOVA weather classification

Number of Figures: 7 (Fig. 1a-b; Fig. 2-3-4; Fig. 5a-b)
Number of Tables: 6 (Tables 1-6)

1. INTRODUCTION

Studying plants’ pollen levels in relation to meteorological elements is of high practical importance because of its health concern. During the last decades, the prevalence of allergy has increased worldwide. Allergic rhinitis ("hay fever") and asthma are two of the most common allergic diseases. A possible cause for increased allergy to pollen is the ever increasing air pollution. The increase of industrialization and the increasing levels of exhaust gases and particles in the air coming form traffic are parallel with the increase in allergic airway diseases. About one-third of Hungary’s inhabitants have some type of allergy, two-thirds of them have 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, 2004; 2005a). Nevertheless, pollen sensitivity depends substantially 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, which is influenced by the meteorological elements. In Szeged, Southern Hungary, pollination term of species lasts from the beginning of February till the end of October.

Plants' pollen levels and their relation to meteorological elements have been studied by several authors. Minero (1999) detected from the air of Seville that the mean temperature of the months prior to pollination is in close relation with the start of pollen emission. Pollen concentrations of species examined showed significant positive correlations with temperature parameters [mean air temperature, (Jato et al., 2002; Gioulekas et al., 2004; Stennett and Beggs, 2004), minimum air temperature (Makra et al., 2004; Rodríguez-Rajo et al., 2004a), maximum air temperature (Rodríguez-Rajo et al., 2004a; 2004b), dew point temperature (Stennett and Beggs, 2004)], with sunshine duration (Gioulekas et al., 2004; Rodríguez-Rajo et al., 2004b) and significant negative correlations with air pressure (Stennett and Beggs, 2004a). However, the connection of pollen levels to the other meteorological parameters is not so clear. While in some cases daily pollen counts show significant negative correlations with precipitation (Jato et al., 2002; Green et al., 2004; Rodríguez-Rajo et al., 2004b), in another case no correlation was found between pollen and relative humidity and rainfall (Gioulekas et al., 2004), The daily sums of precipitation are generally taken out of consideration (e.g. Giner et al. 1999). The reason for this is that the role of precipitation is complicated just because of the opposing effect of rain intensity on pollen counts (Galán et al. 2000). On the one hand, the best correlation was obtained by comparing pollen concentrations (Urticaceae) and meteorological parameters on non-rainy days (Fornaciari et al. 1992). On the other hand, correlating rainfall and pollen concentrations is very difficult. Pollen levels of species studied showed significant positive correlations with wind speed (Stennett and Beggs, 2004; Gioulekas et al., 2004) and wind components (Damialis et al., 2005) displaying the importance of wind persistence in pollen transport. However, Makra et al. (2004) found significant correlation between daily pollen number and wind speed with both signs, which seems to explain both high and low pollen concentration as a consequence of high wind speed. This might indicate an ambivalent role of wind speed. Furthermore, Makra et al. (2004) draw the attention to their result, according to which if seasonality is subtracted, then the explained variance of the regression decreases. The reason of this might be that a statistical description of pollen data simplifies the complex process like phenology and dispersion of pollen in the air.

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). Athens seems to be an ideal place for such work (Kambezidis et al., 1998; 2001; Adamopoulos et al., 2002) and Thessaloniki (Gioulekas et al., 2004; Damialis et al., 2005), where the weather and the mountains which surround the cities from the north, favour extreme accumulations of both pollen levels and chemical air pollutants. The position of Hungary, situated in the Carpathian Basin with long-lasting antiyclonic weather both in the summer and winter, also favours the enrichment of air with pollutants (Fig. 1a).

However, pollen levels depend on social factors, too. Singh et al. (2003) report that the reduction in pollen numbers from 1990 to 1997 in Delhi is due to massive clearing of vegetation for developmental activities of the city.

The major aim of the present study is to analyse whether the subjective classification system of air mass types established by Péczely for the Carpathian Basin (six groups of thirteen Péczely-types), which is characteristic over Szeged, Hungary (Péczely, 1957; 1983; Károssy, 1987; 2004) is suitable for classifying pollen levels. The relation of Péczely's weather types with air pollution levels has already been studied as an application of the Makra-test (Makra, 2005b). Namely, the Makra-test was suitable for detecting whether a given individual Péczely-type is favourable for significant accumulation or dilution of a given pollutant. Nevertheless, inter-Péczely-type comparison of their efficiency in enriching or diluting pollen concentrations, as an overall analysis of the above object, has not yet been performed for the six groups of the thirteen Péczely-types. The base of classifying air mass types is the position, extension and development of cyclones and anticyclones relative to the region of the Carpathian Basin considering the daily sea-level pressure maps constructed at 00 UTC (UTC = Universal Time Centre) in the North-Atlantic–European region (Péczely, 1957; 1983). For each of the six groups of the thirteen Péczely's large-scale weather situations (Péczely's macrosynoptic types) the concentration of the main air pollutants in the area of Szeged is calculated in order to reveal the possible relationship between the prevailing atmospheric conditions and the spatial distribution of mean sea-level pressure fields. Furthermore, when characterizing the six groups of the thirteen Péczely's macrotypes, much more meteorological parameters are taken into account and the efficiency of the six groups of Péczely's macrotypes is statistically evaluated in grouping pollutant concentrations.

Studies on the relationship between synoptic weather conditions and pollution levels are carried out 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. (2005c) who classified air mass types concerning the traditional Main Air Pollutants (MAPs) for Birmingham (UK), Athens (Greece) and Szeged (Hungary), respectively. On the other hand, Kassomenos et al. (1998), Péczely (1957, 1983) and Károssy, (1987, 2004) have given interesting results on weather categorization for Athens and Budapest by using subjective methodologies.

On the other hand, stability classes are often used, e.g. in air quality modelling, to classify whether the dispersion of air pollutants is high or low due to the prevailing meteorological conditions (determined empirically from wind speed, temperature gradient, cloud cover or solar radiation). However, these models classify only chemical air pollutants, disregarding biological agents (Pasquill, 1962; Turner, 1964; Golder, 1972). The method used in our paper is a subjective classification, similarly to the subjectively determined categories of Pasquill (1962) and Turner (1964). Furthermore, our method takes into account much more meteorological parameters when classifying subjectively determined air mass types and the efficiency of the classes received in grouping plants' pollen levels is statistically evaluated.

This study represents an application of a subjective weather classification method, which might also serve as a starting point for the creation of a monitoring/forecasting system, with an ultimate goal to debate plants' pollen load in the city of Szeged. The methodology used in the paper is not proposed as a substitute of other chemical transport modelling systems but it comes as a supplement to the existing methodologies, attempting to contribute to our efforts to forecast pollution levels and thus adopt appropriate measures when necessary.

2. TOPOGRAPHY, CLIMATOLOGY, ECOLOGY AND POLLEN RELATED AIR QUALITY OF SZEGED AREA

2.1. Topography

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 characterized 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 characterized by extensive lowlands but they have the lowest elevations in Hungary and the Carpathian Basin as well (Fig. 1a). This results in 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 (e.g. due to cool air flow from the basin slopes) and prevail longer than in a flat terrain, leading to an enrichment of air pollutants within the inversion layer.

2.2. Climatology

According to the climatic classification system of Köppen, the majority of the Hungarian territory, including Csongrád county and the agglomeration of Szeged, belongs to the *Cf* climate zone characterized by temperate-warm climates with an almost even distribution of precipitation or that of Trewartha's *D.1* climate zone characterized by continental climates with long warm seasons.

The more detailed, higher resolution climatic classification of Hungary is based on the mean temperature values of the growth season (t_{VS}) and the aridity index (H) [where $H = E_S/(L \cdot C)$ (E_S is the annual mean radiation balance; L is the latent heat of vaporization and C is the total annual mean precipitation)]. Based on the climatological characteristics of the period between 1901-1950, the climate of Szeged can be considered as *warm-dry* with $t_{VS} > 17.5°C$ and $H > 1.15$ (Péczely, 1979).

The E_S energetic component of the aridity index (H) changes only slightly in Hungary. Its mean annual value, considering the period between 1901-1950, is 1760 MJ m^{-2} yr^{-1} (Péczely, 1979). On the other hand, the total annual precipitation amounts for Szeged in this period may fluctuate quite substantially. Its average value is P_{mean} = 573 mm, while its extreme values were P_{min} = 203 mm and P_{max} = 867 mm, respectively. On the basis of this information, the aridity index calculated for an average year is $H = 1.25$, for the most arid year was $H = 3.47$; while that of the most humid year was $H = 0.81$, respectively. The typical vegetation assigned to the most arid year value is desert, while that of the most humid is woodland. On the other hand, the typical vegetation belonging to an average year is steppe. Though persistence of high H values is not observed all-year or all-summer round, the climate of some summers inclines towards semi-arid or arid conditions in the Szeged area. This is reflected in the composition of the natural vegetation as well. In the southern part of the Great Hungarian Plain we can come across several semi-desert species being native plants such as needle grass (Stipa stenophylla) (Makra et al., 1985).

The climate of Szeged is characterized by hot summers and moderately cold winters. Mean daily summer temperatures are around 22.4 °C, while the mean daily winter temperatures are 2.3 °C. The irradiance values also exhibit large-scale variances with an average of 20.2 and 4.2 MJ m^{-2} in summer and winter days, respectively. The most frequent winds blow along a NNW – SSE trajectory, with prevailing air currents arriving from NNW (42.3 %) and SSW (24 %) in the summer and from SSE (32.6 %) and NNW (30.8 %) during the winter. Due to its unique geographical position, Szeged is characterized by relatively low wind speeds with average daily summer and winter values of 2.8 and 3.5 m s^{-1}, respectively. The highest hourly wind speeds have been recorded during the spring with a rate of 5 m s^{-1} (Péczely, 1979).

2.3. Ecology

The climate of the Great Hungarian Plains has been arid for several thousand years. According to this, xerophilous floras are native here [Illiric = species coming from Western Balkans; Pontian = species of steppes arriving from the Black Sea region; Turanian (Aralo-caspian) = species coming from the region of the Aral and Caspian Seas; Sub-Mediterranean = species arriving from the regions bordering the Mediterranean areas of Southern Europe; Mediterranean = species coming from the region of the Mediterranean Sea (namely, species arriving from warmer and drier regions compared to the sub-Mediterranean conditions]. Most species of the mentioned floras described in the region immigrated to Hungary in the so-called "Hazelnut" era (between 7 000 – 6 000 BC). Besides, some species arrived into the Carpathian Basin even in the recent era, namely during the last two thousand years (mainly during the warm-dry periods), too. Deforestation, drainage of swamps and the comprehensive land drainage performed in the Great Hungarian Plains, which made the climate drier and warmer on a meso-scale, contributed to the settlement of the species mentioned above. According to the so called "two-eras theory", which is accepted among ecologists, long-lasting settlement of xerophilous species in the region can be attributed to two factors. Namely, to the dry and warm climate in the so-called "hazel-nut" era and to the recent environmental changes, such as anthropogenous factors, which resulted in a climate change.

The dry and warm climate of the region is especially favourable for the Turanian (Aralo-caspian) semi-arid species. One of their groups consists of those species, which prefer extremely arid conditions; while species belonging to the other group indicate aridity; namely, they are so-called xero-indicators (indicate long and dry periods in the climate). The Ellenberg's indicator number (Ellenberg et al., 1991) for the one group is **1**, while for the other group is **2**. The lower an Ellenberg's indicator number belonging to a species (min = 1) is, the more it prefers dry and warm climate. Similarly, the higher the number mentioned (max = 12) is, the more it favours a humid environment. Hence, the Ellenberg's indicator number is a 12-degree scale, applied firstly by Borhidi (1995) in Hungary, and was introduced into the Hungarian literature as a WB-value. The WB-value is a relative indicator number for ground water or soil humidity (WB = Water Borhidi). Borhidi also indicated the characteristic species for the Hungarian flora, which Ellenberg dealt with little on the scale.

In the East Hungarian catchment area of the Tisza River the native species of the Turanian (Aralo-caspian) semi-desert floras **(with their Ellenberg's indicator number)** are as follows: Crested Couch (Agropyron pectinatum) **(1)**, Sea Buckhom (Hippophaë rhamnoides ssp. carpatica **(1)**, Lying Broomgrass (Kochia prostrata) **(1)**, Pepperwort (Lepidium crassifolium) **(1)**, Wild Rye (Secale sylvestris) **(1)**, Spring Speedwell (Veronica verna) **(1)**, Sickle Buttercup (Ceratocephalus testiculatus) **(2)**, Brush Orache (Ceratoides latens) **(2)**, Bulbous Meadow-grass (Poa bulbosa) **(2)** and Prickley Saltwort (Salsola kali ssp. Ruthenica) **(2)** (Horváth et al, 1995).

The analysis is applied to the pollination term of species in Szeged; namely, for the period 1 February - 31 October of the year.

2.4. Pollen related air quality

Pollen levels are modified and influenced by the prevailing atmospheric conditions, which are controlled by the prevailing meteorological parameters, mainly temperature profile close to the ground level. The recorded averages of these for the city of Szeged are the following: annual mean temperature: 11.2°C; mean January and July temperatures: –1.2 °C and 22.4 °C, respectively; mean annual relative humidity: 71 %; mean annual precipitation total: 573 mm; mean annual sunshine duration: 2102 hours; mean annual wind speed: 3.2 m s^{-1}.

The city structure is a very simple one characterized by an intertwined network of boulevards, avenues and streets sectioned by the River Tisza. While the industrial area is mainly restricted to the north-western part of the city.

In a detailed analysis, Szeged was ranked to the 32nd position of 88 Hungarian cities, according to the quality of the environment and the level of environmental awareness. [The city ranked to the 1st position was considered to have the best environmental conditions (Makra et al., 2002)].

On the basis of the frequency of pollutant concentrations exceeding the air quality limits, measured at the Regional Immission Examining (RIE) network of stations for Hungary in 2001, the air quality of Szeged, according to a three-category classifying system (satisfactory, moderately polluted, polluted), can be listed into the “polluted” category (Mohl et al, 2002).

The information that Szeged was ranked 32nd of 88 Hungarian cities gives the impression that this is a city with rather moderate air quality. Therefore, the information that Szeged is ranked “polluted” according to the RIE database seems to be surprising. In the above-mentioned analysis, the cities were ranked according to seven different categories (of nineteen environmental indicators), which are as follows: water consumption (1), energy consumption (3), public utilities supply (4), traffic (1), waste management (3), settlement amenities factors (4) and air quality (with average concentration of particulates deposited, sulphur-dioxide and nitrogen-dioxide). As air quality is only one of the seven categories considered and is only represented with three parameters (environmental indicators), its weight is little in the rank of the cities. However, pollen levels were disregarded from the environmental indicators, owing to the lack of an overall pollen monitoring system in the Hungarian cities.

Climatic parameters are favourable to pollen dispersion in the Carpathian Basin, especially in the Great Hungarian Plains. Considering the phenological phases of the 24 species examined, their pollination term lasts from the beginning of February till the end of

October (Fig. 2). Daily mean pollen counts of the species are generally below 100 pollen grains per m^3 of air (Fig. 3). However, those of Acer (maple) (mean pollination term: from the beginning of March till the end of March, Fig. 2) exceeds 100 pollen grains per m^3 of air on some days (Fig. 3). Nevertheless, pollen dispersion of Ambrosia (ragweed) (mean pollination term: from the beginning of July till the end of October, Fig. 2) is the most efficient of all species considered. On peak days its release (exceeding 450 pollen grains per m^3 of air) is about one order of magnitude higher than that of the other species (Fig. 3).

With its highest pollen dispersion, Ambrosia pollen, considering its history, characteristics, impacts (Makra et al., 2005a), as well as its relation to meteorological elements (Makra et al., 2004) has been analysed in detail. All the highest counts on peak days are reported from the Carpathian Basin, the southern part of the Great Hungarian Plains. The highest values observed in Szeged on peak days are about one order of magnitude higher than those in other cities of Europe, considered as highly polluted.

Pollen of the species examined, depending on individual sensitivity, may induce serious environmental-health problems. Nevertheless, Ambrosia pollen is the most aggressive of all pollens of plants in Hungary (Járai-Komlódi, 1998). More and more people suffer from pollinosis caused by it and other allergic symptoms in Hungary. High pollen levels of species are in close connection with the development of respiratory diseases. Environmental pollution may also affect pollen allergenicity through a direct effect on the pollen grain itself. It has been shown that the prevalence of hay fever in the urban environment is twice of that in the rural one, even though the pollen concentrations are higher in the latter (D'Amato, 2000). Therefore, the determination of pollen threshold levels that elicit allergy response is a complex task, since allergy depends on the combined effects of several factors: the patient, the allergens, the timing, the duration of exposure and the qualities of the environment (Geller-Bernstein et al, 1996; 2002).

The “double basin” situation of Szeged favours longer persistence of weather conditions both in summer and winter months, which contributes to an enrichment of not only Major Air Pollutants (including sulphur dioxide, nitrogen dioxide, carbon monoxide, particles, lead and ozone) but pollens as biological agents, as well. The role and efficiency of objectively defined large-scale weather situations in grouping plants’ pollen levels was the main impetus to prepare the present work.

3. DATA COLLECTION

3.1. The pollen data

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 with its top level belonging 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 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 found in Table 1.

3.2. The meteorological data

The 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 (Universal Time Centre) 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. Data for the ECMWF Re-Analysis ERA 40 project are verified, dynamically correct, the pressure field is true even over the Atlantic Ocean and there is no lack of data. When using the method, the measured false input data are omitted. On the other hand, if original station data are used, false data can frequently be accounted.

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 of the thirteen Péczely’s weather types, average daily sea level pressure patterns were constructed by applying the Surfer 7.00 GIS software. Isobars for an average day, i.e. for an average Péczely-type, were drawn by using 28x51=1428 grid data on the basis of the standard Kriging method without increasing element number of data and with maximum smoothing. As a result of the procedure, the curved surface on the Earth as a spherical trapezoid with 40.5° difference of latitude and 75° difference of longitude was transformed into a plane rectangle with equal spacing both horizontally and vertically. Isobar maps produced in this way can only be fitted to those informative background maps, which are prepared with the same projection. For this reason, the background map of the investigated region was produced in an equidistant cylindrical projection. The major advantage of this map is that it is free from longitudinal distortion along each meridian and, therefore, the determination of the points of the compass is simple at any location of the map. Namely, the north-south and east-west directions are parallel with the vertical and horizontal sides of the rectangle; hence, geographical co-ordinates of various locations and air pressure formations can easily be determined with the help of the spaces indicated on the rectangle both horizontally and vertically (and, if required, by making linear interpolation). The only drawback of its use is that the background map becomes longer at higher latitudes in east-west direction. The grid denotes a horizontal distance of about 107.3 km at the latitude of 50°N.

4.2. The Péczely's large-scale weather situations

The classification is based on the position, extension and development of cyclones and anticyclones relative to the region of the Carpathian Basin considering the daily sea-level pressure maps constructed at 00 UTC in the North-Atlantic–European region. The daily sea-level pressure maps, according to which Péczely defined his macrosynoptic types, were prepared by the Hungarian Meteorological Service. However, based on the ECMWF data and applying the Surfer 7.00 GIS software, the sea-level pressure map of the typical day of each

Péczely weather type is constructed again. Then mean sea-level pressure maps of the typical groups I-IV were prepared using those of the typical days of the Péczely-types. (Mean sea-level pressure maps of the typical groups V-VI correspond to those of their typical days, since these groups, contrary to the former ones, are identical with 1-1 type, namely, with types A and C, respectively.) In this way more precise maps for the typical groups of the Péczely-types are received (Fig. 4). Based on the period examined, mean daily sea-level pressure maps for the six groups of the thirteen Péczely-type were also constructed, which were then the basis of further analysis.

The daily catalogue of Péczely's macrosynoptic types was first determined for the period between 1877-1956 (Péczely, 1957), which was later completed till the end of 1982 (Péczely, 1983). Then, after the death of Péczely, 1984, the daily classification of weather types has been performed by Károssy, with the same subjective methodology (1987; 2004).

Péczely defined altogether thirteen large-scale weather situations relative to the region of the Carpathian Basin (Péczely, 1957). These types with their typical days are found in the Appendix (Péczely, 1957; 1983).

4.3. 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 two random variables (ξ and η) are independent. According to the 0-hypothesis, ξ and η are not independent.

4.4. ANOVA and Tukey's honestly significant difference test

When determining the synoptic types, only meteorological parameters are taken into account, excluding pollen concentration data. Hence, the differences of the mean plants' pollen levels calculated for each synoptic type need a further statistical evaluation. This is performed by the method of one-way Analysis of Variance (ANOVA) for each pollutant. By using the method, significant differences in plants' pollen concentrations of different synoptic types 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 synoptic type (pairwise multiple comparisons) (McGregor and Bamzelis, 1995; Sindosi et al., 2003).

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

5. RESULTS

5.1. χ^2-test, independence analysis

In order to decide whether the mean sea-level pressure fields of the six groups of the thirteen Péczely-types differ significantly from those of the six groups of the typical days of the thirteen Péczely-types, respectively, the χ^2-test was applied. The 0-hypothesis means that there is no significant difference between the sea-level pressure fields compared. On the basis of our computations, probability of the 0-hypothesis for each of the six groups of the sea-level pressure field pairs compared is 0. Namely, this means that mean sea-level pressure fields of all the six groups of the thirteen Péczely-types differ significantly from those of the six groups of the typical days of the thirteen Péczely-types, respectively. 87 % of the pairwise mean sea-level pressure fields of the six groups of the thirteen Péczely-types differ significantly from each other. Nevertheless, probability of the 0-hypothesis between the sea-level pressure fields of the groups of Péczely-types I-VI and III-V is 1. Namely, in these cases the sea-level pressure fields of the groups of Péczely-types mentioned can not be considered independent (Table 2).

5.2. Basic statistical characteristics of the groups of Péczely's macrosynoptic types

Basic statistical parameters of the pollen concentrations of the 24 species are calculated for the days within the groups of Péczely-types, when pollen release was observed. The variance proved to be the highest for Ambrosia of all plants' pollen, in agreement with the higher variability of its pollen concentrations (Fig. 3). The next highest variances, in decreasing order, are indicated by Populus, Alnus and Morus. Variation coefficient (standard deviation expressed in the unit of the average) for pollen concentration of Ambrosia is the highest, which also denotes its higher variability. However, the difference is not significant compared to that of the 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 and Corylus.

5.3. The groups of Péczely-types

Here, we should note the following. The classification of the days into homogeneous groups of Péczely-types, i.e. into groups of days with the same weather, was performed based on the meteorological parameters only and not on pollen parameters. Pollen is examined in the second stage of the work. Therefore, the results are not affected by pollen distribution in time. Since pollen dispersion of the 24 species, owing to the different phenological phases, is not observed each day of the period 1 February – 31 October, the mean daily pollen concentrations of the species within the individual groups of Péczely-types are only calculated for those days, when pollen release of the species examined was detected (Table 3). Therefore, the number of days belonging to a given groups of Péczely-type is generally higher than those with pollen release for the species in that group of Péczely-type. Pollination term of species for the days belonging to the six groups of Péczely-types is reported in Table 4.

Group I (mCc, AB, CMc), types connected with northerly current: It is characterised by, on the one hand, an extended low pressure system over NE Europe and, on the other hand, a large high pressure system in SW Europe. High north-westerly winds are observed over the Carpathian Basin. This group of types is the most frequent with 23.0 % of the total number of days and with fairly uniform monthly distribution. During such weather conditions, pollen levels are low or medium. Only Quercus and Taxus indicate the lowest pollen concentrations (Fig. 5a; Table 3).

Group II (mCw, Ae, CMw) Types connected with southerly current: A weak low pressure system is found over the Bay of Genoa and the Italian Peninsula. Furthermore, a developed high pressure system extends from Asia over SE Europe, while the extended Azores high in the former group contracts substantially. This group of types, with the second highest frequency of all, amounts to 22.8 % of the total number of days. The Carpathian Basin is ruled by clear southerly currents. This group brings warm air into the region. Mean temperature (15.0 ºC) and saturation vapour pressure (25.1 hPa) are the lowest, while sea-level pressure (1011.6 hPa) is the second lowest and wind speed is high. Carpinus and Plantago reach their highest, while Ambrosia, Artemisia and Poaceae their lowest pollen levels (Fig. 5a; Table 3).

Group III (zC, Aw, As) Types connected with westerly current: A narrow belt of the Azores high stretches out up to the western border of the Carpathian Basin. On the other hand, the mid-latitudes (40ºN-60ºN) indicate high pressure gradient with high westerly winds. This group amounts to 20.1 % of the total number of days. Meteorological variables indicate medium values. Besides, pollen levels of Betula, Fraxinus, Morus and Ulmus are the highest, while those of Chenopodium, Juglans, Plantago and Rumex are the lowest (Fig. 5a; Table 3).

Group IV (An, AF) Types connected with easterly current: A highly developed anticyclone rules the continent, with its centre over Middle Europe and the Baltic region. This type comprises 17.3 % of the total number of days. Air pressure and wind speed are high and irradiance is the second highest (24.1 MJ m^{-2}). High winds do not promote accumulation of plants' pollen. However, pollen levels of Pinus and Rumex are the highest and, on the other hand, those of Acer, Betula, Morus, Populus and Salix are the lowest (Fig. 5a; Table 3).

Group V (A) anticyclone over the Carpathian Basin: An anticyclone stays, mostly for several days, with its centre over the Carpathian Basin. Due to orographic effects (Alps, Carpathians, and Dinari Mts.), the Carpathian Basin favours long-lasting anticyclones in the region. During this weather type undisturbed irradiance can be observed with its other typical meteorological characteristics: maximum temperature (22.1 ºC), daily temperature range (13.7 ºC) and irradiance (25.9 MJ m^{-2}), potential evaporation (4.4 mm) and the air pressure (1020.0 hPa) are the highest, while minimum temperature (8.4 ºC), wind speed (0.7 m s^{-1}), relative humidity (64.3 %), water vapour pressure (17.2 hPa) and dew point temperature (9.1 ºC) are the lowest, respectively. This group of type amounts to 12.1 % of the total number of days. Such weather conditions seem to be favourable in accumulating pollen levels. Contrary to this, only one-third of the 24 species (Alnus, Artemisia, Cannabis, Chenopodium, Corylus, Juglans, Taxus and Urtica) reach their highest pollen concentrations in this type, and unexpectedly, four species (Carpinus, Fraxinus, Platanus and Tilia) indicate lowest pollen levels (Fig. 5a; Table 3).

Group VI (C) cyclone over the Carpathian Basin: A depression, originating from the Bay of Genoa, moves over the Carpathian Basin. The cyclone, relating to this type, comes mostly from the Mediterranean. It comprises 4.6 % of the total number of days, with higher frequency in late spring and summer. This type has the most extremes of meteorological variables, which are typical to low pressure centre situations: minimum temperature (12.8 ºC), wind speed (1.2 m s^{-1}), relative humidity (79.89 %), water vapour pressure (21.6 hPa) and dew point temperature (13.7 ºC) are the highest, while irradiance (16.9 MJ m^{-2}) and sea-level pressure (1009.1 hPa) are the lowest, respectively. Contrary to the fact that weather of type 13 favours dilution of pollutant concentrations, it is surprising that mean maximum pollen levels of several species (Acer, Ambrosia, Platanus, Poaceae, Populus, Quercus, Salix and Tilia) are found in this type, while minimum is detected for less species (Alnus, Cannabis, Corylus, Pinus, Ulmus and Urtica) (Fig. 5b; Table 3).

5.3.1. ANOVA-statistics for the groups of Péczely-types

The effect of the groups of Péczely-types on pollen levels was also determined by using analyses of variance (ANOVA). The results are shown in Table 5. It can be observed that except eleven species (Alnus, Fraxinus, Juglans, Morus, Pinus, Populus, Quercus, Taxus, Tilia, Ulmus and Urtica) the other ones show significant Péczely's inter – weather type group differences in mean pollen concentration values at the 99 % probability level. However, for Alnus (47 %) Juglans (56 %) and Pinus (23 %) the above differences are only significant below the 60 % probability level. Considering that differences are found among the mean pollen levels of species considered, Tukey's tests were applied in order to receive a pairwise multiple assessment of the differences.

The statistically significant differences are presented in Table 6 at the 95 % and 99 % probability levels, respectively. It can be observed that the pairs of groups III-IV, II-IV and V-VI differ significantly for six (Ambrosia, Artemisia, Chenopodium, Corylus, Plantago and Poaceae), five (Ambrosia, Artemisia, Chenopodium, Plantago and Poaceae) and again five (Acer, Betula, Carpinus, Platanus and Salix) species, respectively. Furthermore, each of the groups I-VI, III-VI and IV-VI differ substantially for four species [(Betula, Carpinus, Platanus and Salix), (Acer, Betula, Carpinus and Platanus) and (Betula, Carpinus, Platanus and Salix)], respectively. In general, groups of Péczely-types III-IV, II-IV and V-VI can be regarded to be the most different, since pollen levels of the most pairs of species show substantial difference for them. This can basically be explained by their different sea-level pressure systems, and, hence, by the related different meteorological variables. It is stressed that group V indicates the lowest, while group VI the highest wind speed and that is different in groups II, III and IV, too. Different sea-level pressures result in different irradiance, which involves different temperature and humidity parameters, and, hence, different pollen levels of the species examined. Group V, which equals type 12 (A), is an anticyclone centre situation over the Carpathian Basin. This is a clear, sunny type with undisturbed weather, which favours accumulation of plants' pollen. (Fig. 5a-b; Table 3; Table 6).

Intermediate groups of types, considering pollen levels, can not be established, since the number of the least pairwise differences for a group of types amounts to eight species. On the other hand, group VI, which equals a cyclone centre situation (type 13) and group IV (types 10 and 11), show the most, namely 19 and 18 pairwise differences, respectively. Hence, these groups can be considered to be the most characteristic in classifying air pollutants (Fig. 5a-b; Table 3; Table 6).

6. DISCUSSION

In order to assess the effect of the six groups of the thirteen different Péczely's weather types on pollen levels in Szeged, multivariate statistical methods were applied to meteorological and pollen data.

The procedure of establishing objective pressure patterns over the North-Atlantic–European region and to assess their effect on air pollutant levels has been applied in the literature [McGregor and Bamzelis (1995), Sindosi et al. (2003) and Makra et al. (2005c)]. The base of the Péczely-classification is the same with the objective categorization: daily sea-level pressure fields measured at 00 UTC. Péczely defined 13 large-scale weather situations for the Carpathian Basin. As regards the period examined (1 February – 31 October), the share of the six groups of the thirteen Péczely's macrotypes is as follows: 1) types connected with northerly current (23.7 %); 2) types connected with southerly current (23.6 %); 3) types connected with westerly current (20.0 %); 4) types connected with easterly current (17.1 %); 5) type of anticyclone centre (12.0%) and 6) type of cyclone centre (4.6 %). Anticyclonic and anticyclonic ridge situations between 1 February and 31 October are predominant in the Péczely types (66.9 %).

The Péczely-types determined for the period between 1 February – 31 October were also related to pollen levels in Szeged. Relation of the Péczely-types and pollen concentrations of the 24 species in Szeged detected that pollen levels can be connected to different pressure patterns ruling the region examined. In a former paper (Makra et al., 2005c) we argued that specific weather types favour high concentrations of pollutants assuming almost equal emissions every day (uniform distribution). However, here it has to be underlined that atmospheric circulation, based on the pressure patterns of the 13 Péczely-types, is not the only factor controlling the pollen concentrations in Szeged. The pressure patterns of these subjectively defined air mass types can only partially influence the pollen levels, which are basically of natural origin. Namely, pollen concentrations depend firstly on the phenological phase of the given species (seasonality) and climate, and secondarily on the values of the meteorological elements. Hence, we must keep in mind that synoptic conditions do not influence concentrations of pollen as much as concentrations of the main air pollutants.

Thus, for a precise forecast of pollen levels, apart from a good weather forecast, a good knowledge of phenology is necessary. It might be that a statistical description of pollen data for the aim of predicting pollen concentrations simplifies the complex process of phenology and dispersion of pollen in the air. Finally, another factor, which cannot be ignored either, is weather persistence. It must be kept in mind that the presence of pressure patterns favouring high pollen levels for a long period of time may cause even worse pollen conditions.

7. CONCLUSIONS

The paper analyzed pollen levels in Szeged during the sea-level pressure based subjectively defined groups of Péczely's weather types over the Carpathian Basin. Specific groups of large-scale weather situations were found to play a significant role in the pollen concentrations in Szeged.

Results revealed that pollen appear with higher concentration when irradiance is moderate or high and light breezes occur (groups III and V; Fig. 5a; Table 3; Table 6). This is the situation, partly when types connected with westerly current rule the weather of the country and partly when the Carpathian Basin lies under the influence of an anticyclone centre type (group V = type 12). The lowest pollen concentrations of the species examined are connected to the group II (types connected with southerly current), group IV (types connected with easterly current) and group VI a cyclone centre type (group VI = type 13). The lowest pollen levels are due to high wind speeds, which are characteristic to all the three groups mentioned. However, their sea-level pressure and, as a consequence, irradiance and the other meteorological parameters are different (Fig. 5a-b; Table 3; Table 6). Besides, with more than ten pairwise differences group VI (19 pairwise differences) and group IV (18) are considered to be the most characteristic in classification of pollen concentrations. Among them, group VI [with the most frequent pairwise differences of Carpinus and Platanus (5-5 cases)] is a cyclone centre type, while group IV [Artemisia (3 cases)] comprises types connected with easterly current. On the other hand, intermediate groups of types, considering pollen levels, can not be established, since the number of the least pairwise differences for a group of types amounts to eight species (Fig. 5a-b; Table 3; Table 6).

It should be established that two measures of classification were considered: a) for how many species the two groups of Péczely-types compared differ significantly; b) how many significant pairwise differences belong to the given group of type. On the basis of this, as a final conclusion, it was found that considering the groups of Péczely's situations, groups III and V are favourable, while groups II, IV and VI are negligible in classification of pollen concentrations. Role of group V in accumulation and group VI in dilution of pollen levels is in agreement of our expectations. However, role of group III in accumulation and groups II and IV in dilution of pollen concentrations is complex. On the one hand, considering the meteorological elements, winds speed seems to be an important factor. On the other hand, the cyclonic and anticyclonic components (groups II and III) as well as the ambivalent role of the anticyclonic ridge situations (group IV) make it difficult using groups of Péczely-types in classification of pollen levels. Hence, the groups of Péczely's large-scale weather situations can not be considered as an overall system in categorization of pollen concentrations.

ACKNOWLEDGEMENTS

The authors thank the Department of Analysis and Methodology, Hungarian Meteorological Service for providing the sea-level pressure data for the investigated period, Csaba Károssy (Department of Physical Geography, Berzsenyi Dániel College, Szombathely, Hungary) for classifying daily Péczely's large-scale weather situations over the Carpathian Basin for the investigated period and Áron Deák József (Department of Climatology and Landscape Ecology, University of Szeged) for advice on plant ecology. This study was supported by the Hungarian National Foundation for Scientific Research (OTKA No. T 034765).

APPENDIX

The thirteen Péczely’s large-scale weather situations with their typical days concerning their sea-level pressure maps constructed at 00 UTC for the North-Atlantic–European region are as follows:

Types connected with northerly current
Type 1 (mCc): Hungary lies in the rear part of an East-European cyclone
(typical day: 28 August, 1981)
Type 2 (AB): anticyclone over the British Isles
(typical day: 6 April, 1981)
Type 3 (CMc): Hungary lies in the rear part of a Mediterranean cyclone
(typical day: 17 December, 1981)

Types connected with southerly current
Type 4 (mCw): Hungary lies in the fore part of a West-European cyclone
(typical day: 20 September, 1981)
Type 5 (Ae): anticyclone east of Hungary
(typical day: 15 February, 1982)
Type 6 (CMw): Hungary lies in the fore part of a Mediterranean cyclone
(typical day: 14 January, 1981)

Types connected with westerly current
Type 7 (zC): zonal, cyclonic
(typical day: 4 February, 1981)
Type 8 (Aw): anticyclone extending from the west
(typical day: 22 August, 1982)
Type 9 (As): anticyclone south of Hungary
(typical day: 22 November, 1981)

Types connected with easterly current
Type 10 (An): anticyclone north of Hungary
(typical day: 26 February, 1981)
Type 11 (AF): anticyclone over the Fennoscandinavian region
(typical day: 28 March, 1981)

Type of anticyclone centre
Type 12 (A): anticyclone over the Carpathian Basin
(typical day: 14 January, 1982)

Type of cyclone centre
Type 13 (C): cyclone over the Carpathian Basin
(typical day: 2 January, 1982)

REFERENCES

Adamopoulos, A.D., Kambezidis, H.D., Zevgolis, D. 2002. Case studies of total NO_2 column in the atmosphere of Athens, Greece: Comparison between summer and winter. Fresenius Environmental Bulletin 11, 484-487. Sp. Iss. SI

Borhidi, A., 1995. Social behaviour types, the naturalness and relative ecological indicator values of the higher plants in the Hungarian Flora. Acta Botanica Hungarica 39, 97-181.

D'Amato, G., 2000. Urban air pollution and plant-derived respiratory allergy. Clinical and Experimental Allergy 30, 628-636.

Damialis, A., Gioulekas, D., Lazopoulou, C., Balafoutis, C., Vokou, D., 2005. Transport of airborne pollen into the city of Thessaloniki: the effects of wind direction, speed and persistence. International Journal of Biometeorology 49, 139-145.

Ellenberg, H., Weber, H.E., Düll, R., Wirth, V., Werner, W., Paulissen, D., 1991. Zeigerwerte von Pflanzen in Mitteleuropas. Scripta Geobotanica 18, Göttingen. Goltze Verlag (in German)

Fornaciari, M,, Bricchi, E., Greco, F., Fascini, D., Giannoni, C., Frenguelli, G., Romano, B., 1992. Daily variations of Urticaceae pollen count and influence of meteoclimatic parameters in East Perugia during 1989. Aerobiologia 8, 407-413.

Galán, C., Alcázar, P., Cariňanos, P., Garcia, H., Domínguez-Vilches, E., 2000. Meteorological factors affecting daily Urticaceae pollen counts in southwest Spain. International Journal of Biometeorology 43, 191-195.

Geller-Bernstein, C., Kenett, R., Waisel, Y., 1996. Aerobiology in the prevention of allergy, in: Tariq, S.M., Emberlin, J. (Eds.), Clinical Applications of Aerobiology. Braine-L'Alleud, The UCB Institute for Allergy, pp. 69-75.

Geller-Bernstein, C., Lahoz, C., Cárdaba, B., Hassoun, G., Iancovici-Kidon, M., Kenett, R., Waisel, Y., 2002. Is it "bad hygiene" to inhale pollen in early life? Allergy 57, 37.

Giner, M.M, Carrión Garcia, J.S., Garcia Sellés, J., 1999. Aerobiology of Artemisia airborne pollen in Murcia (SE Spain) and its relationship with weather variables: annual and intradiurnal variations for three different species. Wind vectors as a tool in determining pollen origin. International Journal of Biometeorology 43, 51-63.

Gioulekas, D., Balafoutis, C., Damialis, A., Papakosta, D., Gioulekas, G., Patakas, D., 2004. Fifteen years' record of airborne allergenic pollen and meteorological parameters in Thessaloniki, Greece. International Journal of Biometeorology 48, 128-136.

Golder, D., 1972. Relations among stability parameters in the surface layer. Boundary Layer Meteorology 3, 47-58.

Green, B.J., Dettmann, M., Yli-Panula, E., Rutherford, S., Simpson, R., 2004. Atmospheric Poaceae pollen frequencies and associations with meteorological parameters in Brisbane, Australia: a 5-year record, 1994–1999. International Journal of Biometeorology 48, 172-178.

Horváth, F., Dobolyi, Z.K., Morschhauser, T., Lőkös, L., Karas, L., Szerdahelyi, T., 1995. Flora database 1.2. Ecological and Botanical Institute of the Hungarian Academy of Sciences, Vácrátót, Hungary (in Hungarian)

Járai-Komlódi, M., 1998. Ragweed in Hungary. in: Spieksma, F.Th.M. (Ed.), Ragweed in Europe. Satellite Symposium Proceedings of 6th International Congress on Aerobiology, Perugia, Italy. Alk Abelló A/S, Horsholm, Denmark, pp. 33-38.

Jato, V., Dopazo, A., Aira, M.J., 2002. Influence of precipitation and temperature on airborne pollen concentration in Santiago de Compostela (Spain). Grana 41, 232-241.

Juhász, M., 1995. New results of aeropalynological research in Southern Hungary. Publications of the Regional Committee of the Hungarian Academy of Sciences, Szeged, 5, 17-30.

Kambezidis, H.D., Weidauer, D., Melas, D., Ulbricht, M., 1998. Air quality in the Athens basin during sea breeze and non-sea breeze days using laser-remote-sensing technique. Atmospheric Environment 32, 2173-2182.

Kambezidis, H.D., Adamopoulos, A.D., Gueymard, C., 2001. Total NO_2 column amount over Athens, Greece in 1996–97. Atmospheric Research 57, 1-8.

Käpylä, M., Penttinen, A., 1981. An evaluation of the microscopial counting methods of the tape in Hirst-Burkard pollen and spore trap. Grana 20, 131-141.

Károssy, Cs., 1987. Catalogue of the Péczely's macrosynoptic types (1983-1987). Légkör 32, 28-30. (in Hungarian)

Károssy, Cs., 2004. Péczely's macrosynoptic types, 1988-2003. Manuscript (in Hungarian)

Kassomenos, P., Flocas, H.A., Skouloudis, A.N., Lykoudis, S., Asimakopoulos, V. Petrakis, M., 1998. Relationship of air quality indicators and synoptic scale circulation ant 850 hPa over Athens during 1983-1995. Environmental Technology 19, 13-24.

Makra, L., Kiss, Á., Palotás, J., 1985. The Spatial and Temporal Variability of Drought in the Southern Part of the Great Hungarian Plain. Acta Climatologica Universitatis Szegediensis 18-20, 65-85.

Makra, L., Horváth, Sz., Sümeghy, Z., 2002. An objective analysis and ranking of cities on environmental and social factors. in: Nkemdirim, L.C. (Ed.), Climates in Transition. IGU 2002. Geographical Renaissance at the Dawn of the Millennium. Durban, South-Africa, 2002. Minuteman Press, pp. 161-172.

Makra, L., Juhász, M., Borsos, E., Béczi, R., 2004. Meteorological variables connected with airborne ragweed pollen in Southern Hungary. International Journal of Biometeorology 49, 37-47.

Makra, L., Juhász, M., Béczi, R., Borsos, E., 2005a. The history and impacts of airborne Ambrosia (Asteraceae) pollen in Hungary. Grana 44, 57-64.

Makra, L., 2005b. Relation of pollutant concentrations to the Peczely's large scale weather situations in Szeged, Southern Hungary. Epidemiology 16/5, S63-S63.

Makra, L., Mika, J., Bartzokas, A., Béczi, R., Borsos, E., Sümeghy, Z., 2005c. An objective classification system of air mass types for Szeged, Hungary with special interest to air pollution levels. Meteorology and Atmospheric Physics (in press)

McGregor, G.R., Bamzelis, D., 1995. Synoptic typing and its application to the investigation of weather – air pollution relationships, Birmingham, United Kingdom. Theoretical and Applied Climatology 51, 223-236.

Mezei, G., Járai-Komlódi, M., Papp, E., Cserháti, E., 1992. Late summer pollen and allergen spectrum in children with allergic rhinitis and asthma in Budapest. Pädiatrie Pädologie 27, 75.

Minero, F.J.G., 1999. Relationship between air temperature and the start of pollen emission in some arboreal taxa in Southwestern Spain. Grana 38, 306-310.

Mohl, M., Gaskó, B., Horváth, Sz., Makra, L., Szabó, F., 2002. 2nd Environmental Programme of Szeged, 2003-2007. Manuscript (in Hungarian) (Mayor's Office, H-6720 Szeged, Széchenyi tér 10, Hungary)

Pasquill, F., 1962. Atmospheric diffusion, Van Nostrand, London

Péczely, G., 1957. Grosswetterlagen in Ungarn. Kleinere Veröffentlichungen der Zentralanstalt für Meteorologie Budapest 30, Budapest (in German)

Péczely, G., 1979. Climatology. Tankönyvkiadó, Budapest (in Hungarian)

Péczely, G., 1983. Catalogue of the macrosynoptic types for Hungary (1881-1983). Hungarian Meteorological Service 53, Budapest (in Hungarian)

Rodríguez-Rajo, F.J., Frenguelli, G., Jato, M.V., 2003. Effect of air temperature on forecasting the start of the Betula pollen season at two contrasting sites in the south of Europe (1995-2001). International Journal of Biometeorology 47, 117-125.

Rodríguez-Rajo, F.J., Dacosta, N., Jato, V., 2004a. Airborne olive pollen in Vigo (Northwest Spain): a survey to forecast the onset and daily concentrations of the pollen season. Grana 43, 101-110.

Rodríguez-Rajo, F.J., Iglesias, I., Jato, V., 2004b. Allergenic airborne pollen monitoring of Vigo (NW Spain) in 1995-2001. Grana 43, 164-173.

Sindosi, O.A., Katsoulis, B.D., Bartzokas, A., 2003. An objective definition of air mass types affecting Athens, Greece; the corresponding atmospheric pressure patterns and air pollution levels. Environmental Technology 24, 947-962.

Singh, A.B., Pandit, T., Dahiya, P., 2003. Changes in airborne pollen concentrations in Delhi, India. Grana 42, 168-177.

Stennett, P.J., Beggs, P.J., 2004. Pollen in the atmosphere of Sydney, Australia, and relationships with meteorological parameters. Grana 43, 209-216.

Turner, D.B., 1964. A Diffusion Model for an Urban Area. Journal of Applied Meteorology 3, 83-91.

Vázquez, L.M., Galán, C., Domínguez-Vilches, E., 2003. Influence of meteorological parameters on olea pollen concentrations in Córdoba (South-western Spain). International Journal of Biometeorology 48, 83-90.

List of Figures

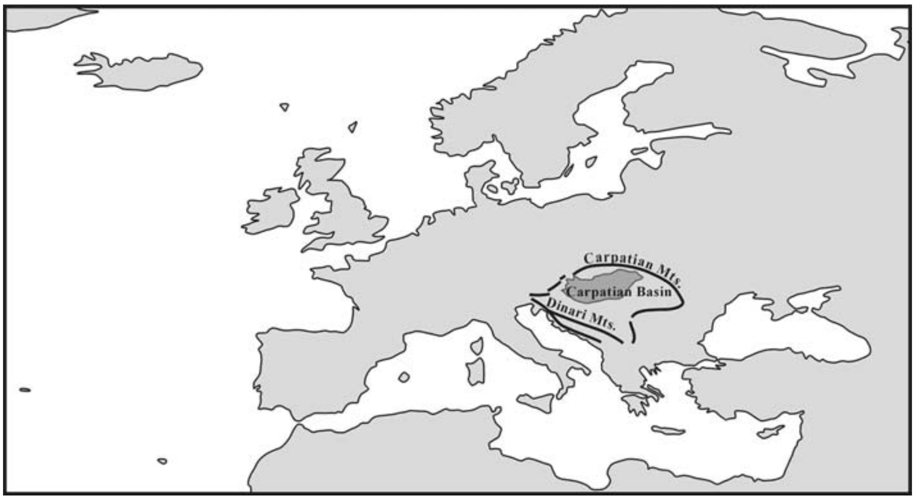


Fig. 1a
Location of the Carpathian Basin

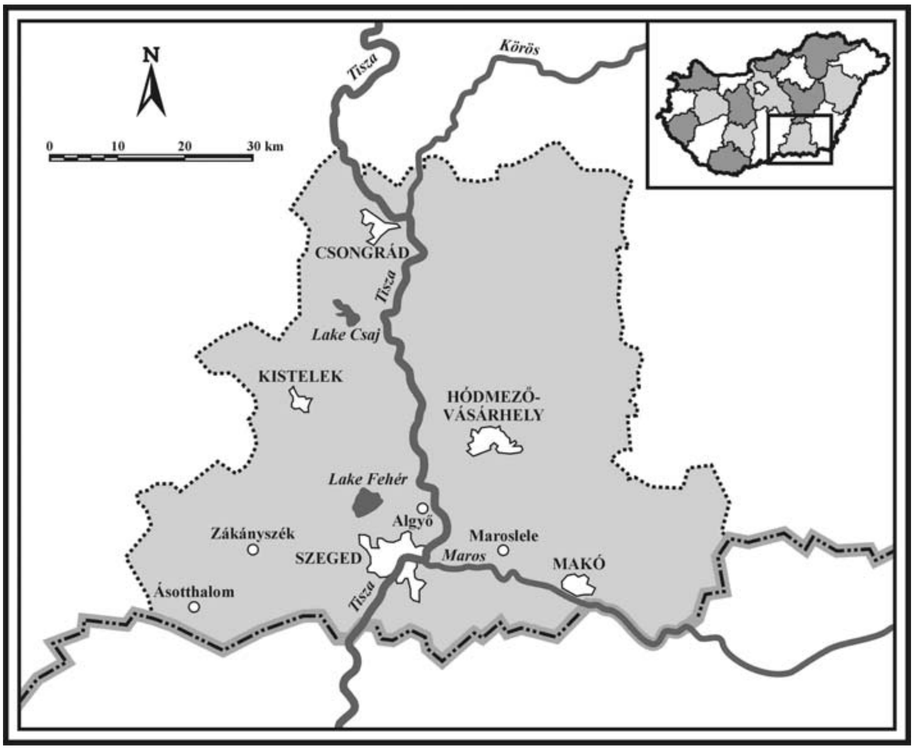


Fig. 1b
Location of Szeged in Csongrád county (centre);
Csongrád county in Hungary (top right)

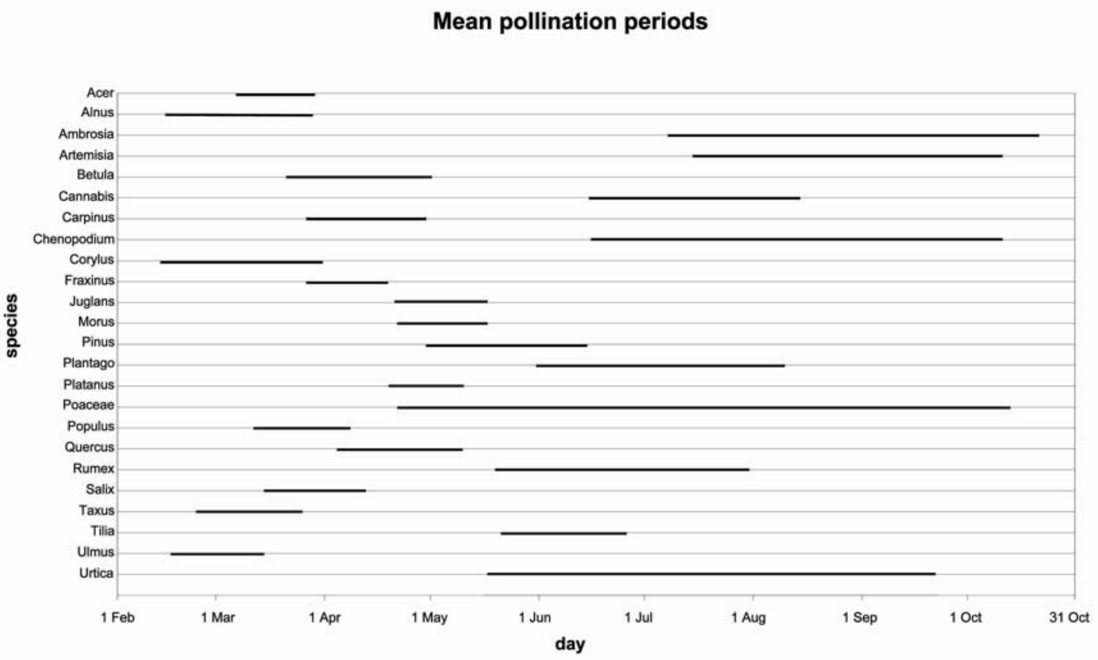


Fig. 2
Mean pollination periods of the species considered, days

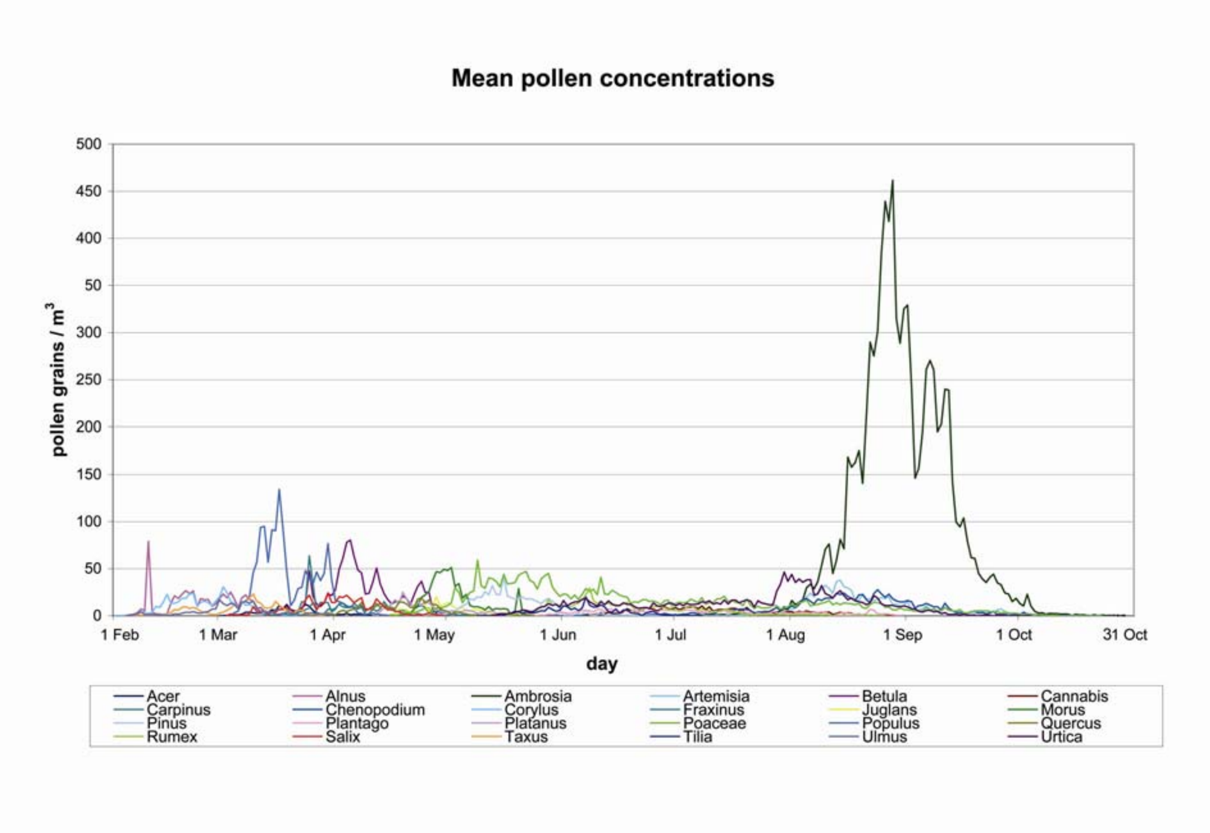
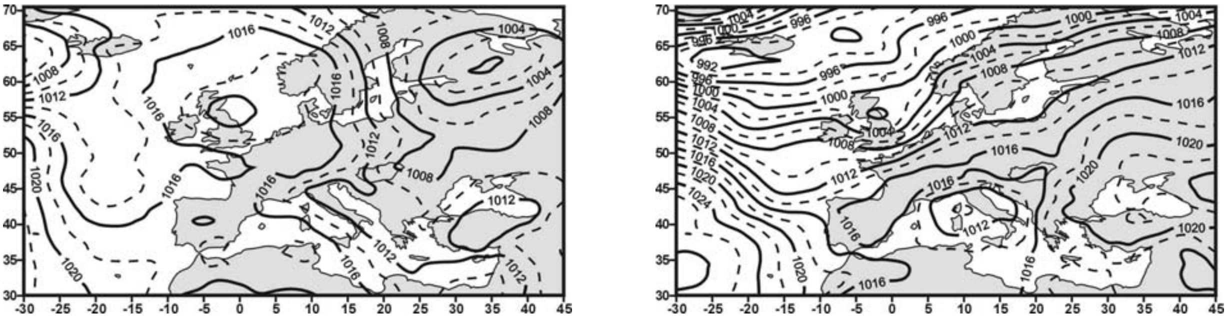
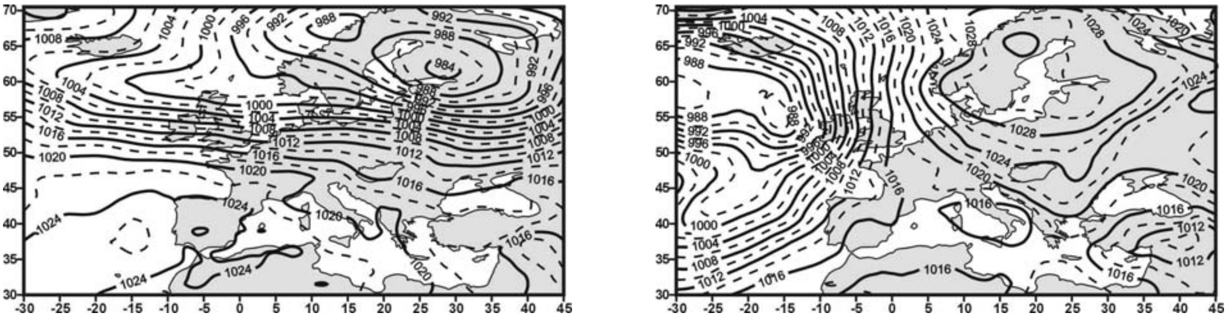


Fig. 3
Mean values of plant pollen counts of the species considered, pollen grains per m^3 of air, days



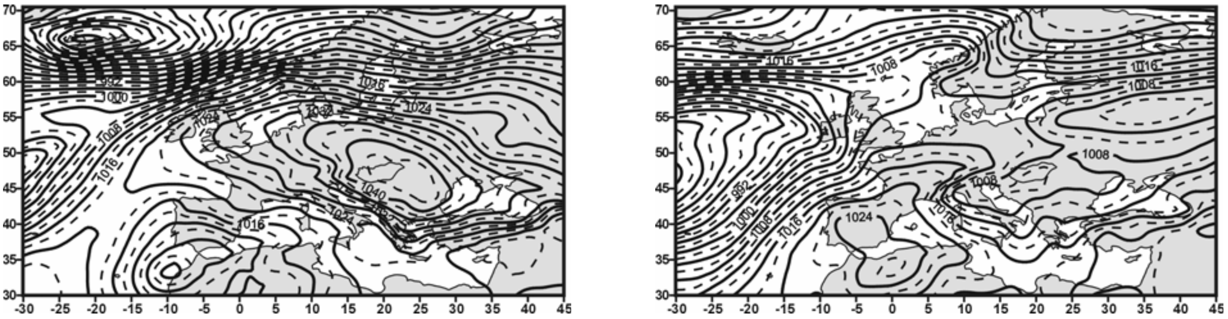
Group I (mCc, AB, CMc)

Group II (mCw, Ae, CMw)



Group III (zC, Aw, As)

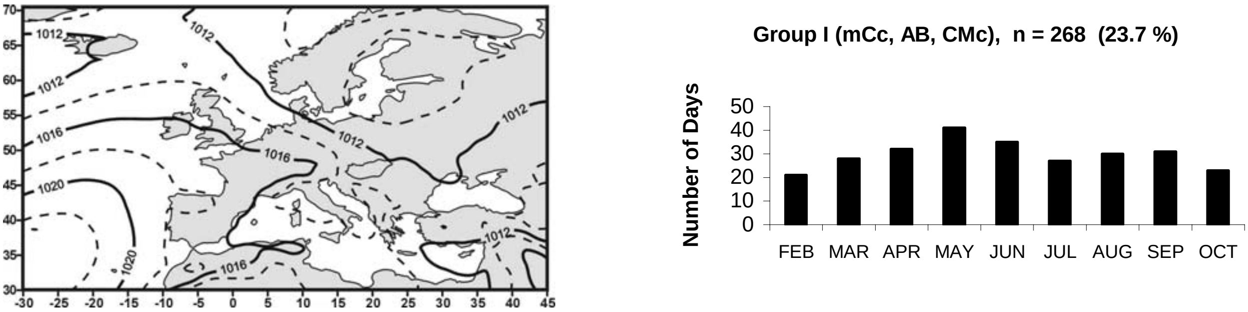
Group IV (An, AF)



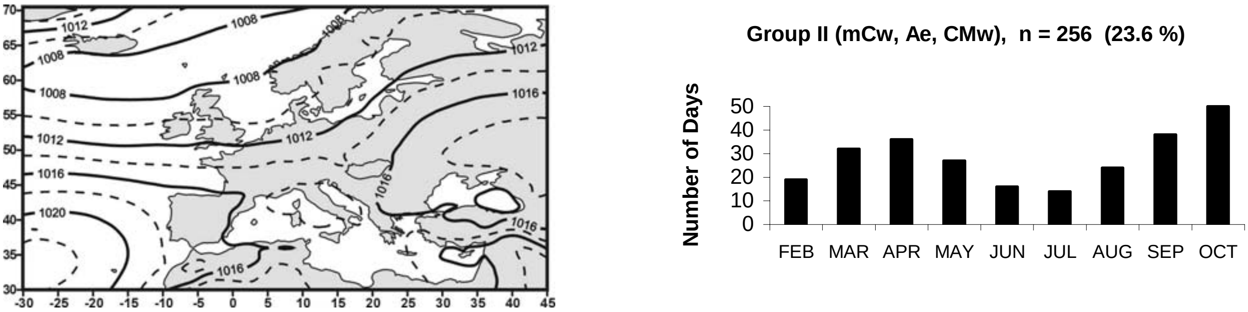
Group V (A)

Group VI (C)

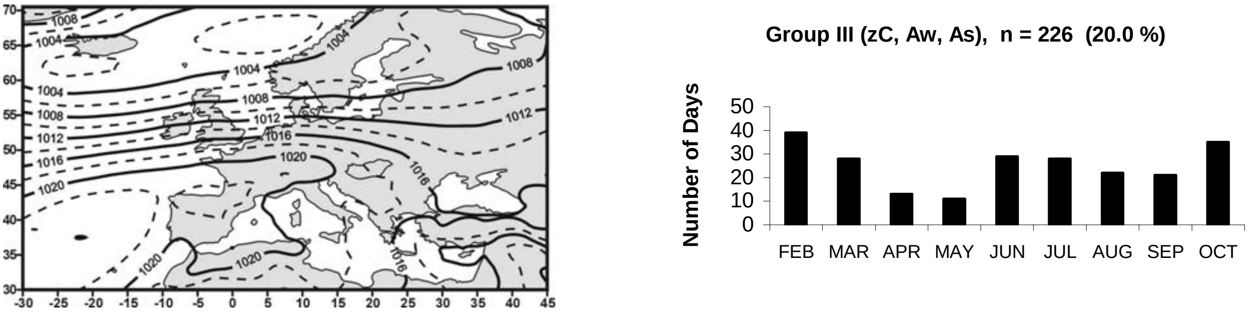
Fig. 4
Mean sea level pressure fields of the typical groups I-IV using those of the typical days of the Péczely-types as well as mean sea level pressure fields of the typical groups V-VI, which correspond to their typical days



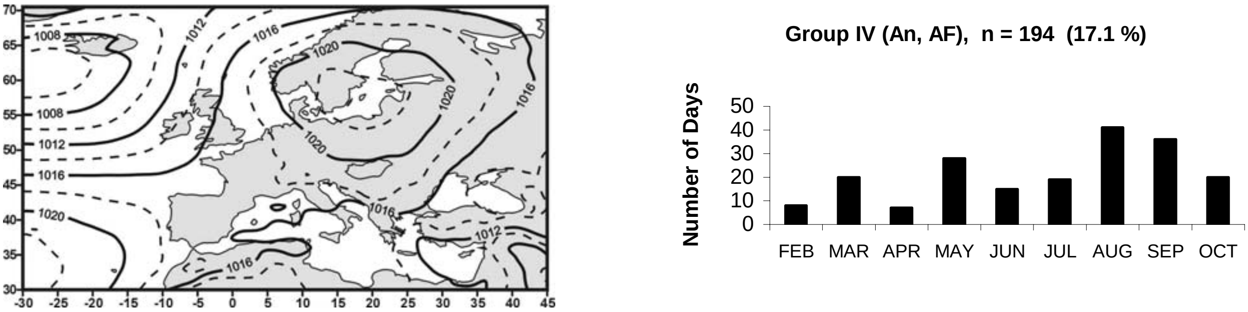
Group I (mCc, AB, CMc)



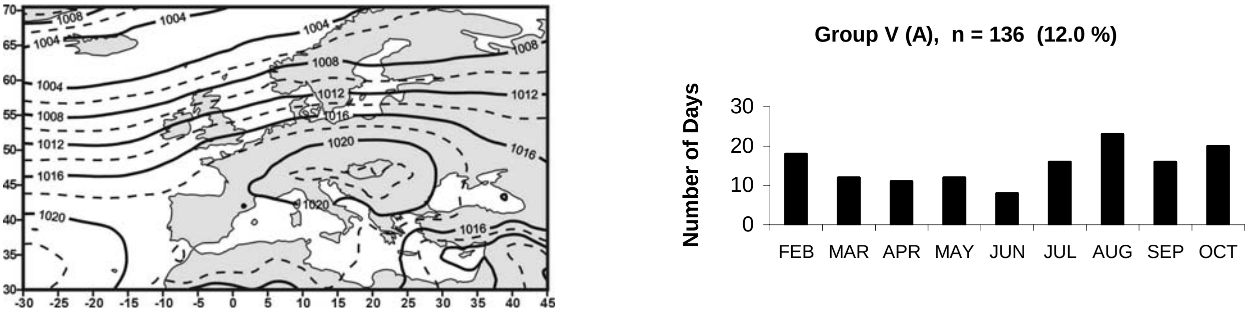
Group II (mCw, Ae, CMw)



Group III (zC, Aw, As)

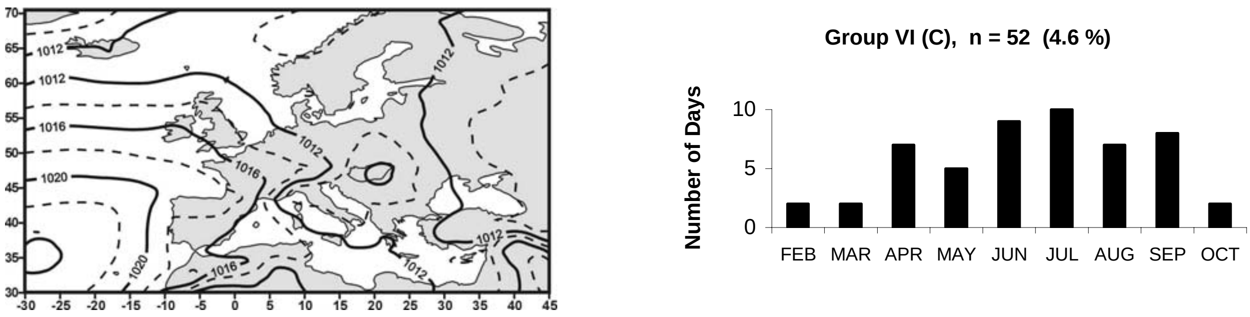


Group IV (An, AF)



Group V (A)

Fig. 5a
Mean sea level pressure fields belonging to the six groups of the thirteen Péczely's weather types and monthly frequency values of the number of days for each group, North-Atlantic – European region



Group VI (C)

Fig. 5b
Mean sea level pressure fields belonging to the six groups of the thirteen Péczely's weather types and monthly frequency values of the number of days for each group, North-Atlantic – European region

List of Tables

Table 1
The species considered with their Latin and English names

Table 2
χ^2-test, independence analysis of the mean sea level pressure fields of the six groups of the thirteen Péczely-types, probability of the 0-hypothesis

Table 3
Mean values of the meteorological parameters and plant pollen counts (pollen grains per m^3 of air) of the species considered for the days belonging to the six groups of the thirteen Péczely's weather types

Table 4
Pollination term of the species considered for the days belonging to the six groups of the thirteen Péczely's weather types

Table 5
ANOVA statistics for the Péczely's inter – weather type group comparison of plant pollen counts (pollen grains per m^3 of air) of the species considered

Table 6
Péczely's weather type group – plant pollen counts difference matrix. Each matrix cell represents the comparison between two Péczely's weather types. Plant species appearing in the matrix cells indicate significant inter – Péczely's weather type group difference in pollen counts (pollen grains per m^3 of air) of the species considered according to Tukey's honestly significant difference test (light-faced characters: 95 % of significance; **bold** characters: 99 % of significance)

Table 1

The species considered with their Latin and English names

Latin name	English name
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

Table 2

χ^2-test, independence analysis of the mean sea level pressure fields of the six groups of the thirteen Péczely-types, probability of the 0-hypothesis

Groups of Péczely-types	I	II	III	IV	V	VI
I	–	0.1650	0.0000	0.0000	0.0000	1.0000
II		–	0.0000	0.0000	0.0001	0.2105
III			–	0.0000	1.0000	0.0000
IV				–	0.0000	0.0000
V					–	0.0000
VI						–

Table 3

Mean values of the meteorological parameters and plant pollen counts (pollen grains per m^3 of air) of the species considered for the days belonging to the six groups of the thirteen Péczely's weather types

Groups of Péczely-types	I	II	III	IV	V	VI
Case number (days)	269	257	227	194	138	52
Freqency (%)	23.7	22.7	20.0	17.1	12.1	4.6
T_{mean} (°C)	15.0	15.0	15.6	16.7	16.1	17.4
T_{max} (°C)	19.8	19.9	21.1	21.8	22.1	21.6
T_{min} (°C)	9.0	9.2	9.4	10.0	8.4	12.8
$\Delta T = T_{max} - T_{min}$, (°C)	10.8	10.7	11.7	11.8	13.7	8.8
WS (m s^{-1})	1.1	1.1	0.9	1.0	0.7	1.2
RH (%)	73.2	73.2	70.4	67.1	64.3	79.9
I (MJ m^{-2})	21.7	18.1	20.6	24.1	25.9	16.9
E (hPa)	25.3	25.1	26.2	28.5	28.3	28.3
VP (hPa)	18.0	17.6	17.7	18.5	17.2	21.6
PE (mm)	3.2	3.3	3.5	4.1	4.4	3.0
T_d (°C)	10.1	10.0	10.1	10.4	9.1	13.7
P (hPa)	1012.6	1011.6	1014.1	1018.1	1020.0	1009.1
Acer	5.8	8.8	4.4	4.1	5.5	16.0
Alnus	14.1	17.7	23.7	13.5	26.9	1.5
Ambrosia	94.7	57.0	62.9	106.9	62.3	111.2
Artemisia	6.9	7.4	9.4	10.6	14.6	10.2
Betula	19.2	25.5	42.7	9.6	11.5	26.9
Cannabis	4.5	5.4	5.3	5.0	5.8	4.2
Carpinus	11.2	19.9	8.1	8.1	7.6	11.9
Chenopodium	6.6	6.5	6.4	10.2	11.0	7.8
Corylus	7.0	10.8	18.6	8.8	24.6	2.0
Fraxinus	9.2	10.1	13.8	9.4	5.8	9.3
Juglans	6.6	9.7	5.8	6.4	17.5	8.1
Morus	12.6	19.8	27.0	8.7	45.3	9.7
Pinus	12.4	11.9	12.7	14.5	10.5	8.7
Plantago	4.2	5.8	3.4	4.7	4.4	3.5
Platanus	14.2	13.8	10.1	6.0	8.1	30.6
Poaceae	14.1	10.3	11.4	14.4	13.0	14.8
Populus	53.2	38.8	60.9	10.4	85.6	187.5
Quercus	6.8	9.0	9.4	8.0	8.9	11.0
Rumex	7.4	6.9	3.4	8.7	3.7	6.2
Salix	9.4	11.9	13.9	6.1	12.4	27.8
Taxus	6.6	8.2	9.1	7.0	14.6	13.0
Tilia	3.9	4.1	6.3	5.2	3.3	7.6
Ulmus	7.7	8.0	9.9	8.6	7.8	0.0
Urtica	11.4	10.4	12.9	12.3	14.5	7.6

Table 4

Pollination term of the species considered for the days belonging to the six groups of the thirteen Péczely's weather types

Groups of Péczely-types	I	II	III	IV	V	VI
Case number (days)	269	257	227	194	138	52
Freqency (%)	23.7	22.7	20.0	17.1	12.1	4.6
Acer	26	32	18	17	2	4
Alnus	34	28	42	13	20	2
Ambrosia	100	116	83	106	59	26
Artemisia	90	94	70	94	50	21
Betula	44	58	17	22	13	9
Cannabis	57	29	57	42	38	18
Carpinus	32	45	14	16	11	9
Chenopodium	119	114	98	113	60	34
Corylus	30	30	44	13	19	2
Fraxinus	21	35	11	10	5	4
Juglans	36	29	12	18	11	8
Morus	33	27	10	18	12	7
Pinus	57	37	26	28	18	15
Plantago	73	34	56	56	33	21
Platanus	28	28	9	12	9	5
Poaceae	189	166	131	147	84	46
Populus	23	40	20	17	10	2
Quercus	44	43	18	18	14	8
Rumex	80	42	59	37	33	25
Salix	38	48	26	18	7	4
Taxus	34	36	39	14	20	2
Tilia	49	25	29	21	12	9
Ulmus	36	27	39	14	18	1
Urtica	137	110	102	109	66	37

Table 5

ANOVA statistics for the Péczely's inter – weather type group comparison of plant pollen counts (pollen grains per m^3 of air) of the species considered

Species	Mean square between groups of Péczely-types	Mean square within groups of Péczely-types	F-Ratio	Level of significance, %
Acer	37.07	12.51	2.96	99.00
Alnus	188.53	227.70	0.83	47.00
Ambrosia	49486.90	12937.35	3.83	99.00
Artemisia	389.93	81.41	4.79	99.00
Betula	793.11	199.57	3.97	99.00
Cannabis	29.71	9.75	3.05	99.00
Carpinus	608.80	139.74	4.36	99.00
Chenopodium	316.87	57.93	5.47	99.00
Corylus	322.27	85.32	3.78	99.00
Fraxinus	28.29	18.86	1.50	81.00
Juglans	15.85	16.49	0.96	56.00
Morus	231.93	179.47	1.29	74.00
Pinus	35.51	59.96	0.59	23.00
Plantago	24.55	7.22	3.40	99.00
Platanus	124.00	29.20	4.25	99.00
Poaceae	830.42	179.61	4.62	99.00
Populus	942.50	851.72	1.11	64.00
Quercus	25.77	19.59	1.32	75.00
Rumex	62.86	21.69	2.90	99.00
Salix	139.12	40.35	3.45	99.00
Taxus	40.39	24.58	1.64	85.00
Tilia	9.64	6.71	1.44	79.00
Ulmus	44.58	17.70	2.52	97.00
Urtica	190.06	155.44	1.22	70.00

Table 6

Péczely’s weather type group – plant pollen counts difference matrix. Each matrix cell represents the comparison between two Péczely’s weather types. Plant species appearing in the matrix cells indicate significant inter – Péczely’s weather type group difference in pollen counts (pollen grains per m^3 of air) of the species considered according to Tukey’s honestly significant difference test (light-faced characters: 95 % of significance; **bold** characters: 99 % of significance)

	I	II	III	IV	V
II					
III	Co				
IV	**Ar** **Ch**	**Am** **Ar** **Ch** Plan **Poa**	**Am** Ar **Ch** Co Plan Poa		
V	Ar	**Can**		Co	
VI	Be **Car** Plat S	**Car** Plat	Ac Be **Car** **Plat**	**Be** **Car** **Plat** **S**	**Ac** **Be** **Car** Plat **S**

Ac = Acer; Am = Ambrosia; Ar = Artemisia; Be = Betula; Can = Cannabis;
Car = Carpinus; Ch = Chenopodium; Co = Corylus; Plan = Plantago;
Plat = Platanus; Poa = Poaceae; S = Salix;