CLIMATE PROFILE

OF PAKS AND ITS ENVIRONS WITHIN A 30 KM RADIUS

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Short name	Full name
OMSz	Hungarian Meteorological Service
MISH	Meteorological Interpolation based on Surface Homogenized data
REMO	the regional climate model developed by the Max Planck Institute in Hamburg
ALADIN-Climate	regional climate model developed by Météo France in Toulouse in the scope of international cooperation

10 CLIMATE PROFILE OF THE ENVIRONS OF PAKS IN A 30KM RADIUS

10.1 ABOUT THE FEATURES OF THE NATURAL ENVIRONMENT

Under the definition set forth in Act LIII of 1996 on the Protection of the Natural Environment, a landscape is a part of the earth's surface that can be delimited in space, has a distinctive structure and characteristics, and includes the natural assets and natural systems that are typical to it, as well as the characteristic features of human culture, where natural forces and artificial (man-made) environmental elements can be found to interact. When utilising a landscape and using natural assets, the natural and close to natural state of landscapes must be preserved, and the survival of the natural assets, natural systems and unique landscape assets that determine the aesthetic characteristics of a landscape and its character must be provided for.

Originality, diversity and health level are usually evaluated in addition to biological activity when describing the characteristics of a landscape (appearance, structure). These factors are primarily determined by plant populations, other landscape elements and the presence or lack, quantity and type (quality) of hedges:

- The biological activity of the examined territory is currently of a medium degree. The share of forests is somewhat lower than the nationwide average, and grassland surfaces are also relatively small. The proportion of water surfaces (primarily the Danube and fishing lakes) exceeds the average. The agricultural areas that cover almost half of the area are also partially active in terms of biology, since they are covered with vegetation during a part or the whole of the vegetative period.
- The degree of anthropogenic influence is significant (power plant, other industrial areas, transportation surfaces, high voltage power transmission lines, etc.), even at patches that are nature-like. (E.g. the shelter forest is more of a plantation than a true forest. Grazing at the eco-park has significantly deteriorated the original sandy steppe's condition.) The vicinity of the envisaged new units has therefore lost most of its originality on account of man's transformation work, i.e. its originality is low. Patches that are close to nature and almost untouched are located mainly along the Danube, and on the run of hills that lies in the north-westerly direction and is primarily planted with vines and orchards. The protected 'Ürge-mező' field in Paks is also part of that.
- The examined region reflects the characteristics of the Great Plains regarding its geographical features. In terms of diversity, however, its territorial structure was already more diverse, articulated and colourful than an average plains landscape even before the nuclear power plant was established. The water surface and the forest, which is to say the presence of the Danube and its vegetation along the banks are among the main reasons for this, and they act as characteristically distinctive spatial boundary edges even visually.
- The health level of the region in landscape terms is decreasing continuously. Human interference was already typical before the power plant was established, and flora and fauna has responded to that by degradation, as well as the retreat or extinction of valuable species. Surfaces covered with natural vegetation throughout the year were already largely missing at that time. Industrial utilisation often goes hand in hand with a diseased plant population, erosion, as well as weed proliferation and the spread of alien species (e.g. large scale weed proliferation on grassland below transmission lines or in the shelter forest). This unfavourable process has been reinforced by the interventions seen in recent years, as well (e.g. the increase of the industrial area, the commissioning of the M6 motorway, the creation of the eco-park).

In summary, therefore, one may conclude that the close environs of the Paks site of operations are medium rich in terms of landscape structure, are significantly transformed in terms of the landscape, and the traces of human intervention are definitive. The appearance of the Danube and its bankside vegetation is a favourable feature from the landscape perspective, along with significant articulation, diversity, and a part of the edges resembling a natural state. Among the elements that are definitive from the land and landscape perspective, water surfaces and their accompanying vegetation are present, as are relief forms that act as the western edge. There are no unfavourable visual elements (e.g. landfills) or they only appear hidden. The city of Paks and the Paks Nuclear Power Plant are pronounced artificial elements of the landscape. The **landscape appearance of the territory carries no significant value** (either towards the positive or the negative) [10-1].

Natural landscapes

According to the taxonomic division of Hungary's natural landscapes, the 30km radius environment of Paks is situated on the "Alföld" macrolandscape's two mesolandscapes, on 3 of their microlandscapes each.

The characteristics of the microlandscapes concerned are shown in the following table:

Macrolandscape	**1. ALFÖLD**					
Mesolandscape	**1.1 DUNAMENTI-SÍKSÁG**			**1.4 MEZŐFÖLD**		
Microlandscape	**1.1.22 Solti-sík**	**1.1.23 Kalocsai-Sárköz**	**1.1.24 Tolnai-Sárköz**	**1.4.21 Közép-Mezőföld**	**1.4.24 Sárvíz-völgy**	**1.4.25 Dél-Mezőföld**
area	691km^2	992km^2	680km^2	1470km^2	344km^2	503km^2
Land use						
Distribution	Inhabited area: 4.5 % Plough-land: 59.5 % Orchard: 1.4 % Vineyard: 1.1 % Pasture, grazing-land: 17.9 % Forest: 5.2 % Water surface: 10.4 %	Inhabited area: 4.9 % Plough-land: 67.8 % Orchard: 1.1 % Vineyard: 0.7 % Pasture, grazing-land: 9.9 % Forest: 6.0 % Water surface: 9.6 %	Inhabited area: 5.4 % Plough-land: 58.7 % Orchard: 0.5 % Vineyard: 1.5 % Pasture, grazing-land: 3.3 % Forest: 23.6 % Water surface: 7.0 %	Inhabited area: 7.0 % Plough-land: 76.7 % Orchard: 1.7 % Vineyard: 1.0 % Pasture, grazing-land: 5.8 % Forest: 6.7 % Water surface: 1.1 %	Inhabited area: 4.0 % Plough-land: 57.1 % Orchard: 0.4 % Vineyard: 1.1 % Pasture, grazing-land: 19.1 % Forest: 7.5 % Water surface: 10.8 %	Inhabited area: 4.7 % Plough-land: 61.0 % Orchard: 0.6 % Vineyard: 2.0 % Pasture, grazing-land: 6.8 % Forest: 24.4 % Water surface: 0.5 %
Topography						
Height above sea level	93.7-123.7m	89.4-125.6m	88.1-162m	97-204m	89-161m	90-213m
Type	flood plain level flatland	flood plain level flatland	flood plain level flatland	loess covered alluvial cone flatland	river terrace vale	drift sand and loess covered alluvial cone flatland
Average relief	4m/km^2, decreasing to the E	1m/km^2 on the surface that slopes slightly S	1-2m/km^2	10m/km^{2}at the NE part, around 20m/km^2 at the SW part	3-6m/km^2 in floodplains, 10–12 m/km^2 elsewhere	12m/km^2 at the NNW-SSE part, 4-6m/km^2 elsewhere

Table 10.2.1-1: Characteristics of microlandscapes in the examined region [10-2]

The affected microlandscapes' climate profile

The affected microlandscapes' climate profile is set out in Table 10.2.1-2.

	1. ALFÖLD							
	1.1 Duna-menti síkság					**1. 4 Mezőföld**		
	1.1.22 Solti-sík		**1.1.23 Kalocsai-Sárköz**		**1.1.24 Tolnai-Sárköz**	**1.4.21 Közép-Mezőföld**	**1.4.24 Sárvíz-völgy**	**1.4.25 Dél-Mezőföld**
Climate type	moderately warm/dry		moderately warm/dry (close to the warm type)		moderately warm/moderately dry (close to the warm type)	moderately warm/dry	N: moderately warm/dry S: moderately warm/moderately dry	moderately warm/moderately dry (N: dry)
Sunshine	Annual sunshine duration	2000-2020 hours	2040 hours		2050 hours	N: 1960 hours S: >2000 hours	N: 2000 hours S: 2020-2030 hours	2050 hours
	Number of sunshine hours	in the summer quarter	780-790 hours	800 hours	810 hours	N: 780 hours S: 800 hours	N: 800 hours S: 810 hours	800-810 hours
		in the winter quarter	180 hours	200 hours	200 hours	180 hours	190 hours	190-195 hours
Temperature	Annual mean temperature	10.4-10.5°C	10.5°C		10.5°C (S: 10.6-10.7°C)	10.2-10.4°C	N: 10.0-10.2°C S: 10.4-10.6°C	N: 10.2-10.3°C S: 10.5°C
	Average temperature in the vegetation period	17.5°C	17.5°C		17.5°C	17.3-17.4°C	17.0-17.4°C	17.2-17.3°C
	Days with an average temperature exceeding 10°C	198-200 days (Apr. 4 to Oct. 20)	198-200 days (Apr. 2-4 to Oct. 20)		200 days (Apr. 1-3 to Oct. 21)	194-196 days (Apr. 4-6 to Oct. 18-20) S: 198-200 days (Apr. 1-3 to Oct. 20-22)	198-200 days (Apr. 1-4 to Oct. 20)	195-198 days (Apr. 2-5 to Oct. 19-21)
	Frost free period	starts	Apr. 4-5	Apr. 4-5	Apr. 3-5	Apr. 5-13 Along the Danube: Apr. 1	N: Apr. 12-15 S: Apr. 5	N: Apr. 8-10 S: Apr. 3
		ends	Oct. 25-30	N: Oct. 25 S: Oct. 27-28	Oct. 25-30	Oct. 20-25 Along the Danube: Oct. 28-30	N: Oct. 23 S: Oct. 30	N: Oct. 23 S: Oct. 28
		length	200-205 days	N: 203 days S: may even exceed 206 days	200 days	190-200 days Along the Danube: >205 days	N: 188-190 days S: 205 days	N: 195 days S: 206 days
	Multi-annual average of yearly absolute maximum temperatures	34°C	34°C (S: 34.5°C)		34°C	34°C	34°C	34°C
	Multi-annual average of yearly absolute minimum temperatures	(-16) to (-17)°C	(-16) to (-17)°C		(-16) to (-17)°C	-16°C	(-16) to (-16.5)°C	(-16) to (-18)°C
Precipitation	Annual total precipitation	530-550mm	550-580mm		580-610mm (N: 580mm)	540-580mm	560-600mm (N: 550mm)	560-580mm (S: 600mm)
	Average total precipitation in the vegetative period	310-320mm	320-340mm		330-340mm (N: 310-330mm)	320-340mm	320-350mm (N: 310-320mm)	320-350mm S: 360mm)
	Maximum precipitation per 24 hours	168mm (Apostag)	128mm (Hajós)		98mm (Mözs)	130mm (Előszállás)	130mm (Sióagárd)	101mm (Paks)
	Average number of days with snow cover	30-32 days	30 days		30 days	30-34 days	31-33 days	31-34 days
	Average maximum snow depth	20cm	20cm		20cm	20-22cm	20-22cm	23cm
Wind	Most common wind directions (in sequence)	NW	NW, S, SW		NW, S	NW	NNW, S	N, NW, S
	Average wind speed	2.5-3m/s	2.5-2.8m/s		2.5m/s	2.5-3.3m/s	2.5-3 m/s	3 m/s

Table 10.2.1-2: Characteristics of microlandscapes in the examined region

10.2 CLIMATIC ANALYSIS OF PAKS AND ITS ENVIRONS WITHIN A 30KM RADIUS

The Hungarian National Meteorological Service (OMSz) conducted the climatic analysis of Paks and its 30km radius environs by analysing certified data sets measured at OMSz metering stations in the region, and stored in OMSz's electronic database. The selected meteorological parameters are suitable for exhaustive climate profiling.

Data from the Paks meteorological station for the period between 1981 and 2010 were used for the climatic analysis; in the case of precipitation analyses, data from the following conventional precipitation metering stations located in the 30km vicinity of Paks were also used: Előszállás, Sáregres (Cece), Simontornya, Bikács, Paks Gyapa, Dunapataj, Kölesd Borjád, Tengelic, Bátya, Hajós.

The geographical coordinates of the Paks meteorological station are:

- latitude: 46° 34' 25"; longitude: 18° 50' 44"
- height above sea level: 97.2m

The 30-year period used is sufficiently long for providing a good profile of the climate's stability and variability. Data sets from the stations selected for profiling only seldom contain omissions, and their volume has no bearing on results.

A number of extreme weather situations have occurred during the post-1997 period in the territory of Hungary, including the Paks region, as well. Detailed data processing was conducted for the period between 1997-2010 to report these situations, having particular regard to deviations from average and extreme values.

When processing precipitation data, it was not only measurements by the Paks meteorological station that were taken into consideration for the various examinations, but also data from conventional precipitation metering stations located in the 30km vicinity of Paks that have complete data sets (Figure 10.2.1-1).

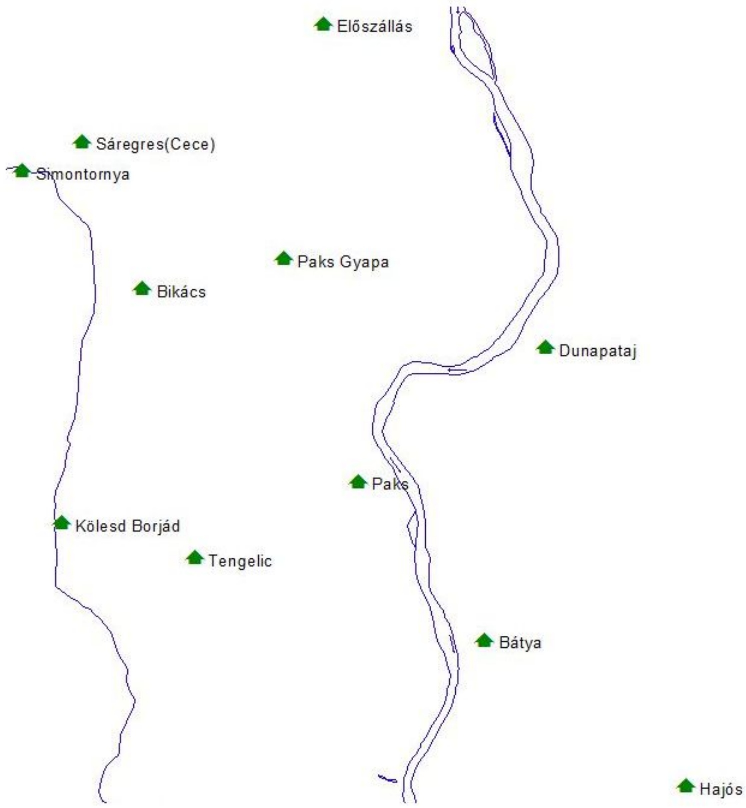


Figure 10.2.1-1: Conventional precipitation metering stations located in the 30km vicinity of Paks that have complete data sets

10.2.1 CLIMATE PROFILE DETAIL LEVEL

The climate profile examines the following meteorological parameters:

- Temperature conditions
  - the development of monthly, annual and summer mean temperatures,
  - temperature extremes, daily and monthly maximum and minimum temperatures, number of hot and sweltering days,
  - maximum and minimum temperature return values up to 20 000 years frequency for the following return periods: 2, 4, 5, 10, 20, 50, 100, 200, 500,….20 000
- Precipitation conditions
  - monthly, annual, winter and summer half yearly total precipitation amounts,
  - extreme monthly total precipitation amounts (maximum, minimum), daily amounts maximum per month,
  - snow condition profiling: number of days with snow, maximum snow depth, number of days with snow cover, characteristics of the length of periods with snow cover,
  - extreme daily total precipitation amounts and snow depth return values up to 20 000 years frequency for the following return periods: 2, 4, 5, 10, 20, 50, 100, 200, 500,….20 000 years,
  - thunderstorm activity: number of days with thunderstorms and their distribution within the year
- Duration of sunshine
  - average annual progression of sunshine duration
- Average annual progression and monthly extreme values of air pressure converted to sea level
- Evaporation, evapotranspiration: monthly average values of actual and potential evaporation
- Soil temperature, average annual progression at depths of 2, 5, 10, 20, 50, 100cm
- Wind conditions profile for the 1997-2010 period at a height of 10 metres
  - wind direction frequency in respect of 16 directions, in annual, as well as summer and winter half year breakdown
  - monthly and annual wind speed values, monthly and annual development of windless conditions frequency
  - average daily and annual progression of wind speed
  - maximum wind gust velocity and frequency per 16 wind directions
  - development of the number of days with moderate gale force winds (daily maximum wind > 15m/s)
  - relative frequency of average wind speeds
  - atmospheric stability conditions profiling: the relative frequency of synoptic wind speed and wind direction according to the Pasquill Index
  - maximum wind gust extrema's return values up to 20 000 years return frequency for the following return periods: 2, 4, 5, 10, 20, 50, 100, 200, 500,….20 000 years,
  - investigation of tornado occurrence probability, determining tornado characteristics (rotation, translation speed, maximum rotation speed radius, pressure difference and change)

10.2.2 METHODS USED

Method applied to estimating the return value of extreme values

In engineering practice, the question as to what value the maximum of a meteorological element will exceed, and what value its minimum will remain below with a given *p* probability over a period that is *n* (years) long is often asked during design. This value is the design value, which is also known as the return level. In the case of the maximum, this *p* probability is usually defined in the p=1-1/T format, where *T* stands for return time, also referred to as the return period, during which the value in excess of the design value occurs once on average. In the course of design processes—for instance when canals, bridges and levees are designed—a return time of 50, 100, 1000 years is usually used depending on the structure; what is more, return levels of 10 000 years has to be used for calculations in nuclear power plant technical designs.

The minimum, maximum and other characteristics for profiling extremes also correlate to the probability distribution function of a probability variable that represents a particular meteorological element relative to a given period. Experience from the study of extreme values in time series has shown that extrema behave similarly regardless of base distribution. As a consequence of that fact, some sort of fringe distribution or fringe distributions exist, and it or they can be used to model the distribution of extreme values well in the case of an appropriately large number of samples. Asymptotic distributions are known by the names Gumbel distribution, Fréchet distribution and Weibull distribution. These three functions can be described in the common

$$G_J(z) = \exp(-(1 - z/a)^a), \quad z/a < 1, \quad z = (x - u)/b$$

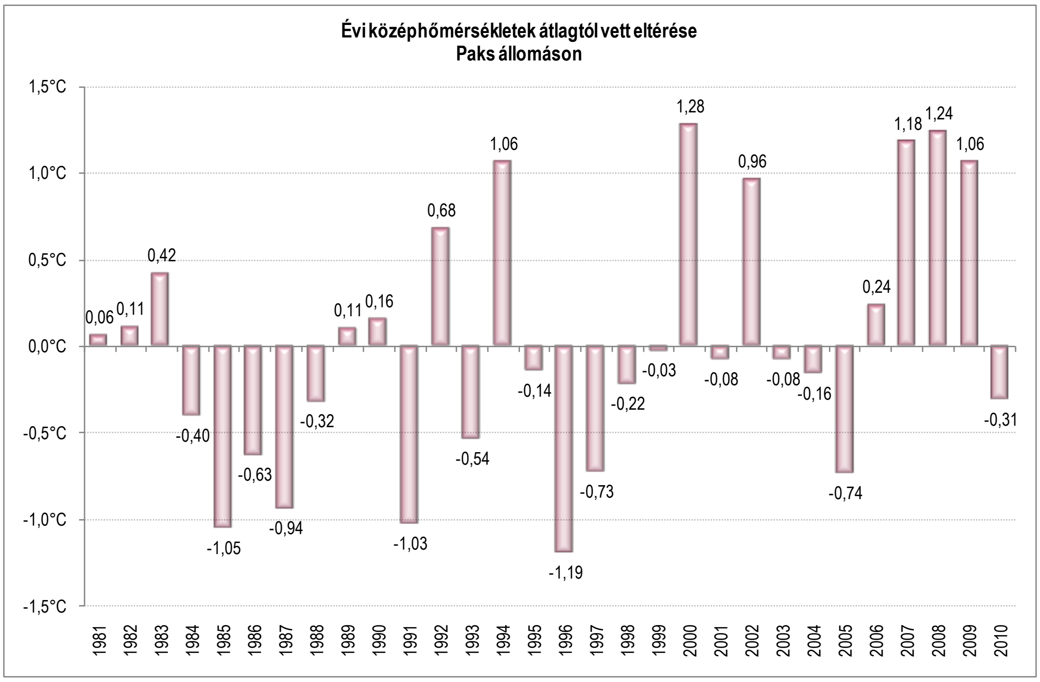
form, which is called a generalised extreme value distribution or a Jenkinson distribution (Coles, S.G., 2001). Taking the initial letters of the more generic Generalised Extreme Value distribution name gives us the GEV designation, frequently found in literature. *u* is the GEV distribution's location, b its distribution a.k.a. scale, and *a* what we refer to as its shape parameter. Base distribution allows us to infer the type to which extreme values' fringe distribution belongs. Where the density function of a base distribution decreases to zero in exponential order to capital *x*s, fringe distribution will be Gumbel type (Gumbel, 1958), if it does so at a lower rate than that, at some power of *x*, then it will be Fréchet type. Weibull type results if the base distribution's density function is identically zero to capital *x*s. For climatology related applications, the Gumbel approach to extrema is most commonly used, since meteorological elements can usually be described with normal, lognormal, exponential or gamma distribution.

The single variable extreme value theory is based on properly elaborated asymptotic formulas, and the different estimation techniques afford the opportunity of modelling extreme distribution, as well as the verification of aligned models (Matyasovszky, 2002). Among parameter estimation techniques, the maximum likelihood estimate is applied extensively (Faragó and Katz, 1990), as it has 'good' properties from the perspective of statistics, with estimates generally being free of distortions, but at least asymptotically undistorted.

10.2.3 TEMPERATURE CONDITIONS

Average annual mean temperature (1981-2010) comes to 10.7°C at the Paks station, which exceeds the nationwide average.

The development of annual mean temperatures for the period between 1981-2010 in relation to the normal for the same period is shown on a chart (Figure 10.2.3-1).



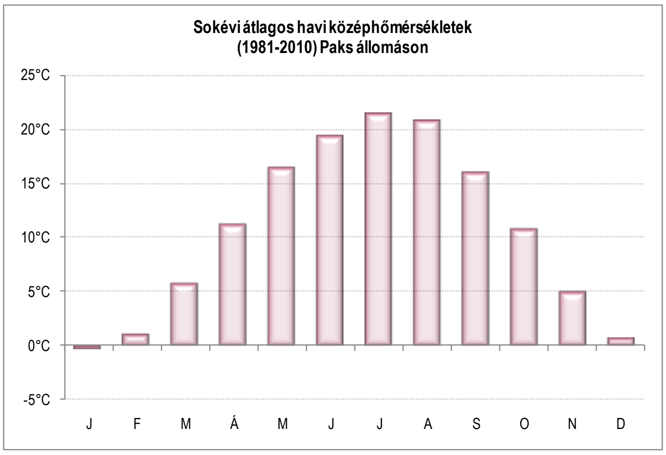
Legend:
Évi középhőmérsékletek átlagtól vett eltérése Paks állomáson – Deviation of annual mean temperatures from the average at the Paks station

Figure 10.2.3-1: Deviation of annual mean temperatures [°C] from the multi-annual average (1981-2010) at the Paks station between 1981-2010

1996 was the coolest year of the period, when the average temperature measured was 1.2°C lower, while year 2000 was the hottest one, when it was 1.3°C warmer than the multi-annual value. Significant positive anomalies were likewise observed in years 2007, 2008 and 2009 (1.1 to 1.2°C).

Looking at deviations from the past eleven years one may say that way higher than average temperatures could be observed in six years, they were somewhat cooler than average in four cases, and the only major negative anomaly was observed in 2005. This period can therefore be considered a hot one relative to the average, while a cooler period could be observed at the middle of the 80s, with anomalies of varying algebraic signs in the other periods. In other words, the tendency comes out to be positive looking at the period overall.

Looking at the average annual progression of temperature (Figure 10.2.3-2) one can see that July is the hottest (21.4°C) month in the region, and January the coldest (-0.3°C). Average annual heat fluctuation, i.e. the difference between the mean temperature of the hottest and the coldest month, is 21.7°C.



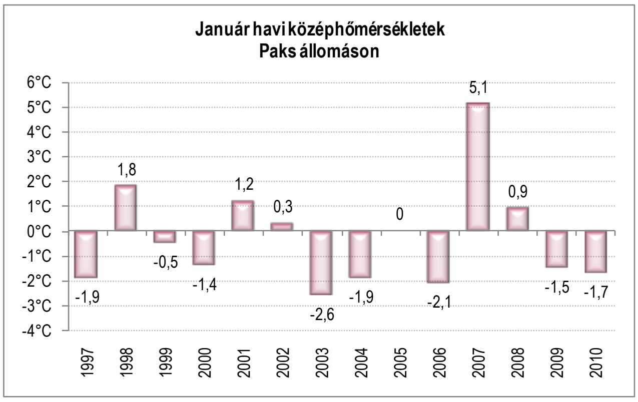
Legend:
Sokévi átlagos havi középhőmérsékletek (1981–2010) Paks állomáson – Multi-annual average of monthly mean temperatures (1981-2010) at the Paks station

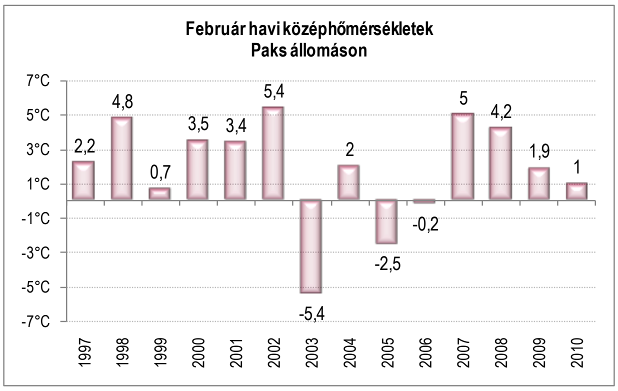
Figure 10.2.3-2: Multi-annual average of monthly mean temperatures [°C] at the Paks station (1981-2010)

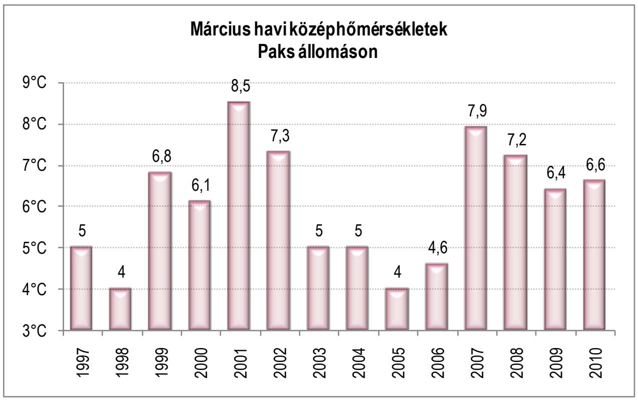
The highest daily maximum was measured in July 2007 (40.6°C), and the lowest in January 1987 (13°C). For minimum temperature, the lowest value (-30.3°C) was observed in January 1987, and the highest (22.7°C) in August 2003. These are, at once, the most extreme values since measurements began at Paks.

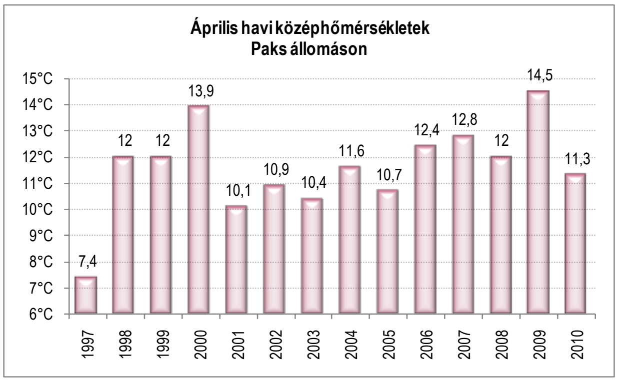
Looking at the annual level, 2009 had the most (129 days) and 1984 the fewest (61 days) summer days since 1981. The least hot days (14 days) were likewise observed in 1984, with the most (66 days) in 2003. The greatest number of sweltering days (13 days) was in 1992, while maximum temperatures in excess of 35°C were not registered in 1982, 1994, 1986, 1997 and 1999.

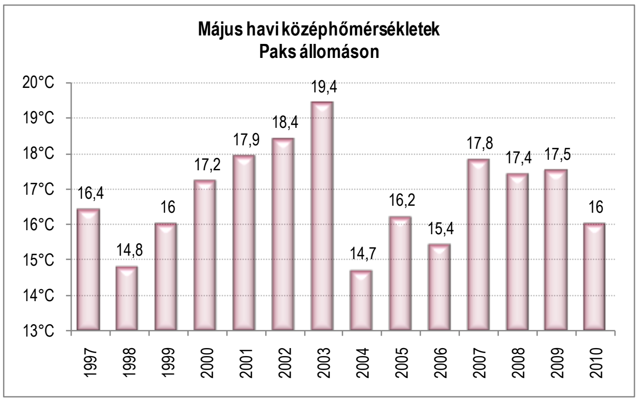
The following section presents the development of monthly mean temperatures (Figure 10.2.3-3) and their deviations from the 1981-2010 average (Table 10.2.3 -1) in respect of the years between 1997-2010 and the Paks station. Based on that one may declare that fluctuation from one year to the next is, on average, greater during the months of the winter half year than it is in the case of the summer months.

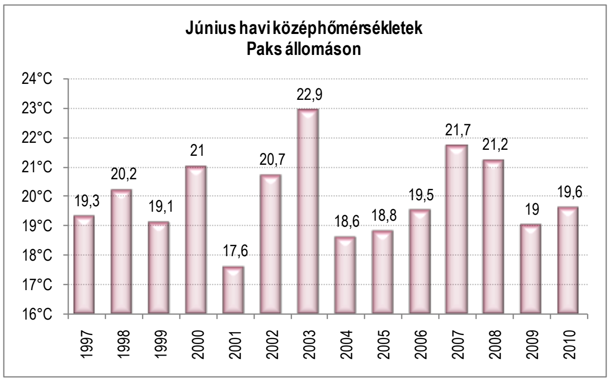


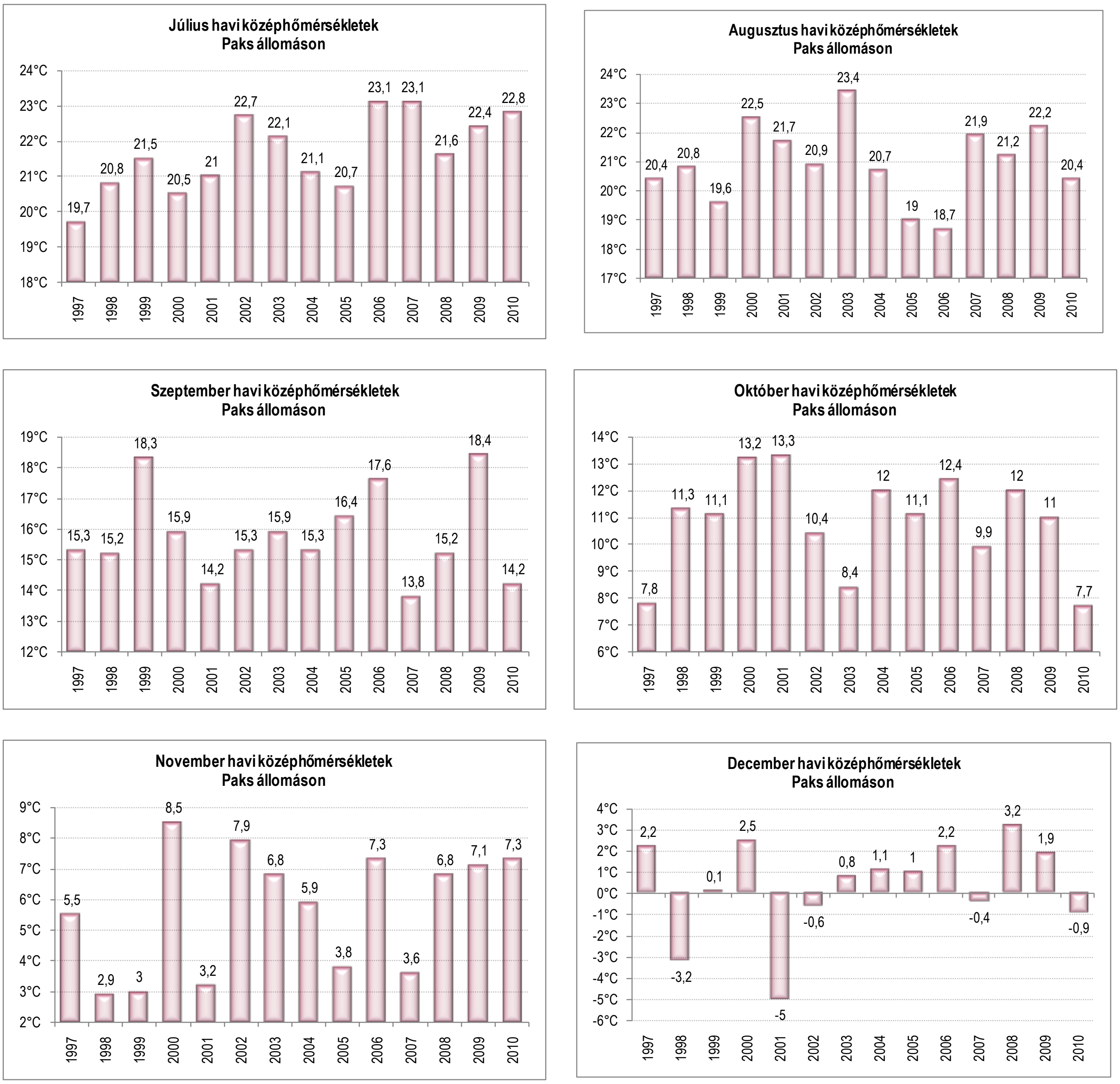












Legend:
havi középhőmérsékletek Paks állomáson – Mean temperatures at the Paks station for the month of
január – January
február – February
március – March
április – April
május – May
június – June
július – July
augusztus – August
szeptember – September
október – October
november – November
december – december

Figure 10.2.3-3: Monthly mean temperatures [°C] between 1997-2010 at the Paks station

Deviation for monthly mean temperatures from the multi-annual average [°C]														
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
January	-1.6	2.1	-0.2	-1.1	1.5	0.6	-2.3	-1.6	0.3	-1.8	5.4	1.2	-1.2	-1.4
February	1.1	3.7	-0.4	2.4	2.3	4.3	-6.5	0.9	-3.6	-1.3	3.9	3.1	0.8	-0.1
March	-0.8	-1.8	1.0	0.3	2.7	1.5	-0.8	-0.8	-1.8	-1.2	2.1	1.4	0.6	0.8
April	-3.8	0.8	0.8	2.7	-1.1	-0.3	-0.8	0.4	-0.5	1.2	1.6	0.8	3.3	0.1
May	0.0	-1.6	-0.4	0.8	1.5	2.0	3.0	-1.7	-0.2	-1.0	1.4	1.0	1.1	-0.4
June	0.0	0.9	-0.2	1.7	-1.7	1.4	3.6	-0.7	-0.5	0.2	2.4	1.9	-0.3	0.3
July	-1.7	-0.6	0.1	-0.9	-0.4	1.3	0.7	-0.3	-0.7	1.7	1.7	0.2	1.0	1.4
August	-0.3	0.1	-1.1	1.8	1.0	0.2	2.7	0.0	-1.7	-2.0	1.2	0.5	1.5	-0.3
September	-0.7	-0.8	2.3	-0.1	-1.8	-0.7	-0.1	-0.7	0.4	1.6	-2.2	-0.8	2.4	-1.8
October	-3.0	0.6	0.4	2.5	2.6	-0.4	-2.4	1.3	0.4	1.7	-0.9	1.3	0.3	-3.1
November	0.5	-2.1	-2.0	3.5	-1.8	2.9	1.8	0.9	-1.2	2.3	-1.4	1.8	2.1	2.3
December	1.5	-3.9	-0.6	1.8	-5.7	-1.3	0.1	0.4	0.3	1.5	-1.1	2.5	1.2	-1.6

Table 10.2.3 -1: Deviation of monthly mean temperatures from the multi-annual average (1981-2010) [°C] at the Paks station between 1997-2010

Regarding temperature extremes, the lowest, highest, as well as the average maximum and minimum temperatures were first collected in a tabular form per month in respect of the Paks station, on the basis of daily data from 1981-2010 (Table 10.2.3-2, Table 10.2.3-3).

Maximum temperature (1981-2010) [°C]					
	Lowest	Year	Highest	Year	Average
January	-13	1987	17.4	2002	3.2
February	-10	1985	20.7	1998	5.9
March	-5.2	1987	26.4	1989	11.5
April	3	1986	29.3	1992	17.6
May	8.2	1987	33.9	2008	23.0
June	11.2	2005	36.8	2000	25.9
July	15.5	1997	40.6	2007	28.4
August	14.6	1989	37.5	1992	28.0
September	11.1	2008	36.1	2008	23.0
October	3.4	1985	28.7	2000	17.3
November	-6.3	1988	23.3	2008	9.4
December	-10.1	1996	19.9	1989	4.0

Table 10.2.3-2: The lowest, highest, as well as average values of maximum temperatures [C°] per month (1981-2010) at the Paks station

Minimum temperature (1981-2010) [°C]					
	Lowest	Year	Highest	Year	Average
January	-30.3	1987	7.5	1983	-3.9
February	-24	1985	12.1	1998	-3.3
March	-22	1987	11.4	1981	0.4
April	-7.3	1997	14.1	1996	4.7
May	-2.9	2007	19.6	1993	9.5
June	1.1	1997	22.2	1994	12.8
July	4.9	1996	21.5	2009	14.4
August	4.8	1984	22.7	2003	13.8
September	-0.9	1986	20.3	2009	9.8
October	-11.5	1997	15.8	1992	5.3
November	-22.8	1988	13.7	2002	1.0
December	-23.3	2001	11	1989	-2.4

Table 10.2.3-3: The lowest, highest, as well as average values of minimum temperatures [C°] per month (1981-2010) at the Paks station

The highest daily maximum was measured in July 2007 (40.6°C), and the lowest in January 1987 (13°C). For minimum temperature, the lowest value (-30.3°C) was observed in January 1987, and the highest (22.7°C) in August 2003. These are, at once, the most extreme values since measurements began at Paks.

The next table (Table 10.2.3-4) includes the return values of maximum and minimum temperatures, which were calculated on the basis of measurements from the period between 1981-2010 by applying Gumbel's statistical method. These return values reveal how many years one may expect to pass on average between the occurrence of the given temperature. It is important to note that these are average values, in other words, identical extreme values may occur even in consecutive years, and there may also be periods without any extremes. A maximum temperature of around 36°C appears every two years on average, that of 40°C approximately every 50 years. One is to expect a minimum temperature of -20°C less than every four years, that of -30°C, however, only appears more than every 50 years around the vicinity of Paks.

Maximum and minimum temperature return values shown as a Gumbel distribution		
Return period (years)	Maximum temperature [°C]	Minimum temperature [°C]
2	35.9	-17.7
4	36.8	-20.7
5	37.1	-21.6
10	37.9	-24.2
20	38.7	-26.6
50	39.7	-29.8
100	40.4	-32.2
200	41.1	-34.6
500	42.1	-37.7
1,000	42.8	-40.1
2,000	43.6	-42.4
5,000	44.5	-45.6
10,000	45.3	-47.9
20,000	46.0	-50.3
100,000	47.7	-55.7

Table 10.2.3-4: The Gumbel distribution of maximum and minimum temperature return values in respect of the Paks station (based on data from 1981-2010)

The number of what is referred to as threshold days—which is the number, expressed in days, of daily highest and lowest temperatures that reach and/or exceed the given temperature values—represents additional information for characterising temperature conditions. One can talk about summer, hot or sweltering days if the daily temperature peak value reaches or exceeds 25°C, 30°C or 35°C respectively. Our following tables (Table 10.2.3-5 to Table 10.2.3-7) and figures (Figure 10.2.3-4 to Figure 10.2.3-6) show the development of the number of such threshold days regarding the Paks station.

Upon considering the monthly breakdown tables one will see that the greatest numbers of days above the threshold were observed in the months of July and August, and something else that stands out is that while more days like this tended to appear in August at the beginning of the period between 1997-2010, by its end, this shifted more to the month of July. Summer days were observed all the way from April through to October, hot days during the May to September period, but sweltering days only from June to September. Since 1997, the greatest number of summer days were observed in June and August 2003 (30 days), that of hot days in August 2003 (24 days), while the most sweltering days in July 2007 (10 days).

Looking at the annual level, 2009 had the most (129 days) and 1984 the fewest (61 days) summer days since 1981. The least hot days (14 days) were likewise observed in 1984, with the most (66 days) in 2003. The greatest number of sweltering days (13 days) was in 1992, while maximum temperatures in excess of 35°C were not registered in 1982, 1994, 1986, 1997 and 1999.

Number of summer days (Tmax≥25°C)								
	IV.	V.	VI.	VII.	VIII.	IX.	X.	Year
1997	0	15	19	21	28	12	5	100
1998	0	10	22	21	22	3	1	79
1999	0	8	20	27	21	20	1	97
2000	11	17	23	23	29	10	6	119
2001	1	17	15	24	25	2	8	92
2002	0	18	22	28	24	12	1	105
2003	2	24	30	29	30	10	2	127
2004	0	4	17	21	27	12	0	81
2005	0	10	20	23	14	12	0	79
2006	3	6	19	27	15	16	3	89
2007	3	13	30	27	28	3	1	105
2008	1	15	20	27	28	12	0	103
2009	9	19	20	29	28	20	4	129
2010	1	8	16	25	25	0	0	75

Table 10.2.3-5: Number of summer days (T_{max}≥25°C) per month between 1997 and 2010 at the Paks station

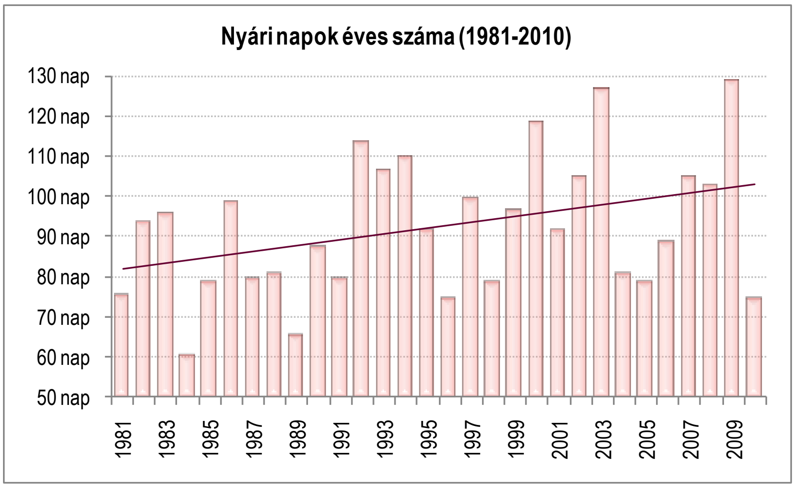
Number of hot days (Tmax≥30°C)						
	V.	VI.	VII.	VIII.	IX.	Year
1997	2	7	1	6	0	16
1998	0	10	11	14	0	35
1999	3	3	5	5	1	17
2000	4	14	12	17	0	47
2001	2	2	10	17	0	31
2002	1	11	19	5	2	38
2003	10	15	14	24	3	66
2004	0	2	13	7	1	23
2005	5	3	8	2	0	18
2006	0	14	22	5	1	42
2007	6	14	18	16	0	54
2008	3	12	14	15	5	49
2009	6	2	17	16	3	44
2010	0	8	16	9	0	33

Table 10.2.3-6: Number of hot days (T_{max}≥30°C) per month between 1997 and 2010 at the Paks station

Number of sweltering days (Tmax≥35°C)					
	VI.	VII.	VIII.	IX.	Year
1997	0	0	0	0	0
1998	0	1	3	0	4
1999	0	0	0	0	0
2000	5	1	5	0	11
2001	0	2	2	0	4
2002	2	2	0	0	4
2003	3	2	4	0	9
2004	0	1	0	0	1
2005	0	1	0	0	1
2006	1	0	0	0	1
2007	1	10	1	0	12
2008	0	1	2	2	5
2009	0	2	2	0	4
2010	0	5	0	0	5

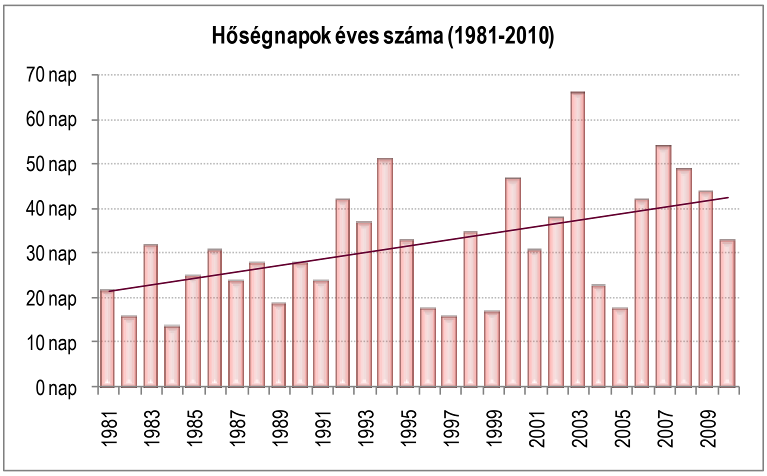
Table 10.2.3-7: Number of sweltering days (T_{max}≥35°C) per month between 1997 and 2010 at the Paks station

The charts also illustrate the linear trends aligned with the data series, which proved positive for each of the three threshold days, meaning that the number of warm and extremely hot days increased over the past period.



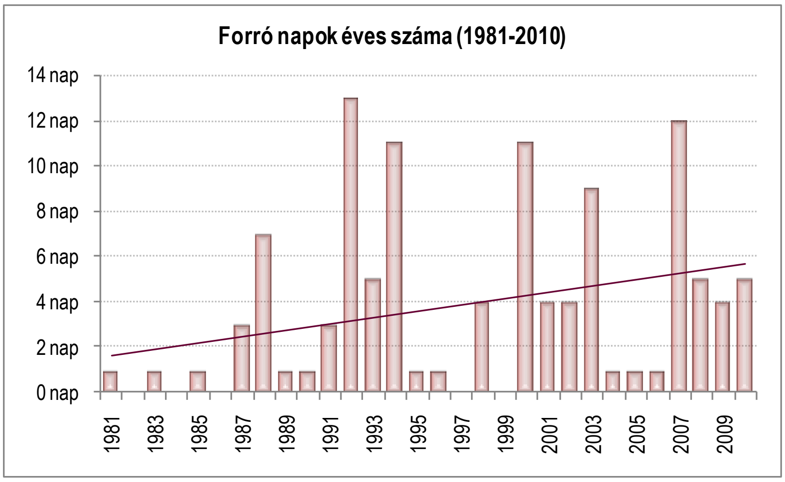
Legend:
Nyári napok éves száma (1981–2010) – Annual number of summer days (1981-2010)
nap - day

Figure 10.2.3-4: The number of summer days (Tmax ≥ 25°C) per year (1981-2010) at the Paks station; linear trend aligned to this data series



Legend:
Hőségnapok éves száma (1981–2010) – Annual number of hot days (1981-2010)
nap - day

Figure 10.2.3-5: The number of hot days (Tmax ≥ 30°C) per year (1981-2010) at the Paks station; linear trend aligned to this data series



Legend:
Forró napok éves száma (1981–2010) – Annual number of hot days (1981-2010)
nap - day

Figure 10.2.3-6: The number of sweltering days (Tmax ≥ 35°C) per year (1981-2010) at the Paks station; linear trend aligned to this data series

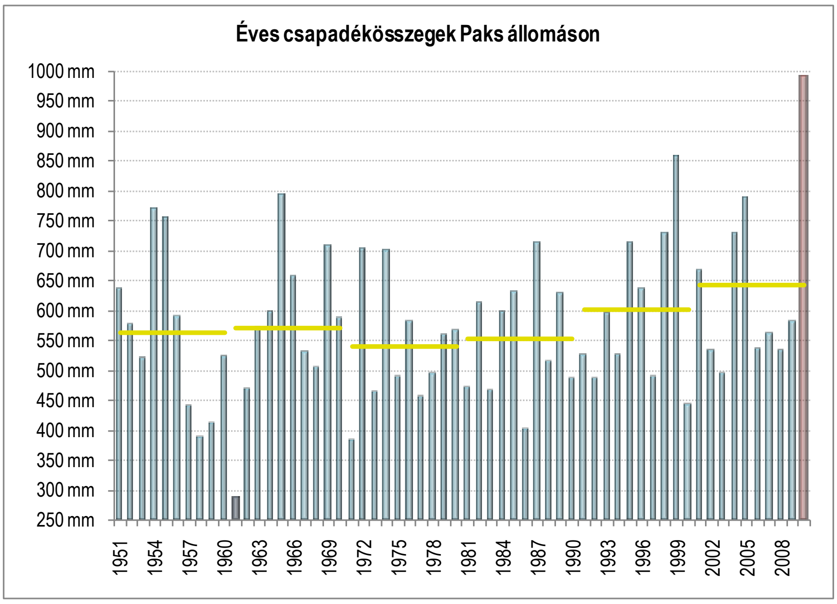
Based on the temperature analysis one can see that average temperature is showing an increasing trend at annual level; and the analysis of the daily occurrence of summer, hot and sweltering days also allows observing ever more frequent extremities within single years.

10.2.4 PRECIPITATION CONDITIONS

Precipitation—unlike temperature—is a meteorological element that is not continuous in either space or time. Short or long dry periods alternate with various quantities, sometimes quite large, or precipitation, frequently subject to erratic territorial and temporal distribution.

Regarding annual total precipitation (Figure 10.2.4-1), 1961 was the driest year (285.9mm) in Paks since 1951, while the wettest one—with an amount that stands out in the data set—was 2010 (990.9mm), which also broke the absolute maximum record to date (887mm in 1937). Upon observing ten-year averages one may declare that the last ten years was the wettest during the period (with an average of 642mm, while the average annual total precipitation for the 60 years under review is 579mm), but this is mainly owing to the extraordinary total from year 2010. Let us note that should we disregard that year, the resulting value would still be close to the same as the average for the 1991-2000 period, which was the second wettest ten years since 1951. Similarly to temperature, therefore, we believe a positive trend can also be discovered here at annual level.

We have to note that the scatter of annual totals was also higher in the last ten years, and this suggests the occurrence of extreme precipitation.

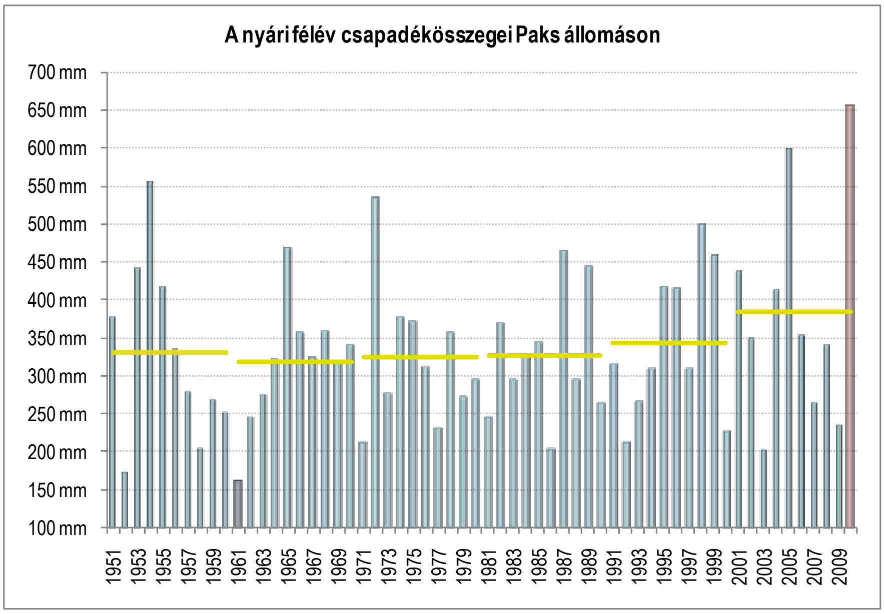


Éves csapadékösszegek Paks állomáson – Annual total precipitation at the Paks station

Figure 10.2.4-1: Development of annual total precipitation [mm] between 1951-2010, and the ten-year averages at the Paks station

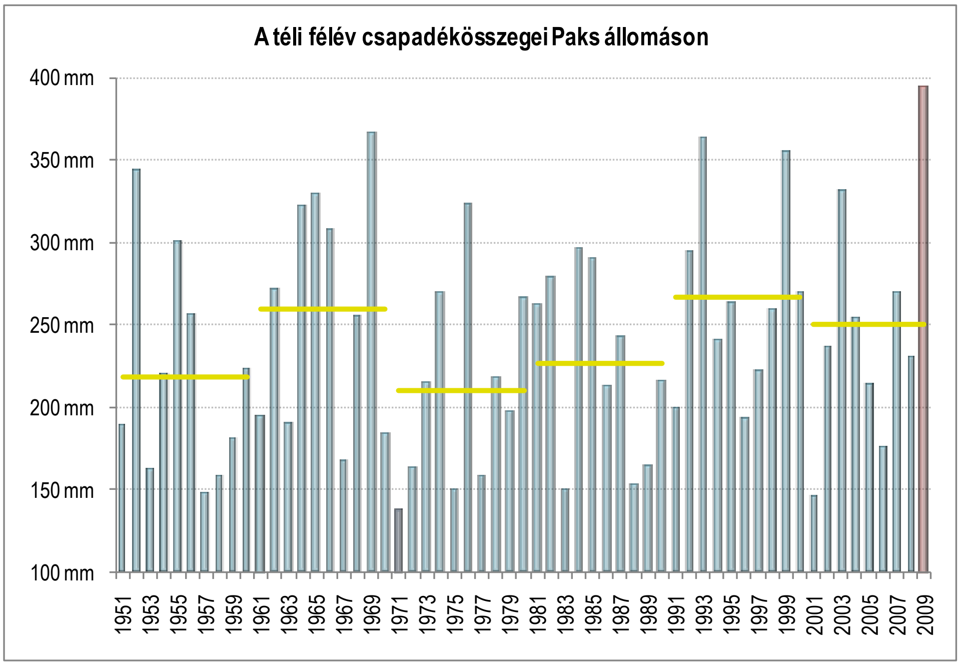
In terms of annual total precipitation, a somewhat increasing trend is likewise typical in the vicinity of Paks, and upon examination of extreme values, century old records were relegated to history in multiple cases during this 30 year period.

Total precipitation was also examined for the summer and winter halves of the years after we split them. It is clear to see that the summer half of the year shapes-up wetter than the winter half in most years (in approximately 78 % of the cases). In the case of the summer half year (Figure 10.2.4-2), the minimum and maximum values appeared in the same year as for the annual totals, and the trend also shows similar development, with the last two decades turning out to have been wetter than the four preceding ones. For the winter half year (Figure 10.2.4-3), the driest weather was seen in 1970. This half of the year also deviates from the annual figures in respect of ten-year averages, the wettest winter halves were those in the decades between 1991-2000 and 1961-1970. Although a slightly increasing trend can also be observed here on the basis of calculations, but it is less steep than in the summer half of the year.



A nyári félév csapadékösszegei Paks állomáson – Total precipitation for the summer half of the year at the Paks station

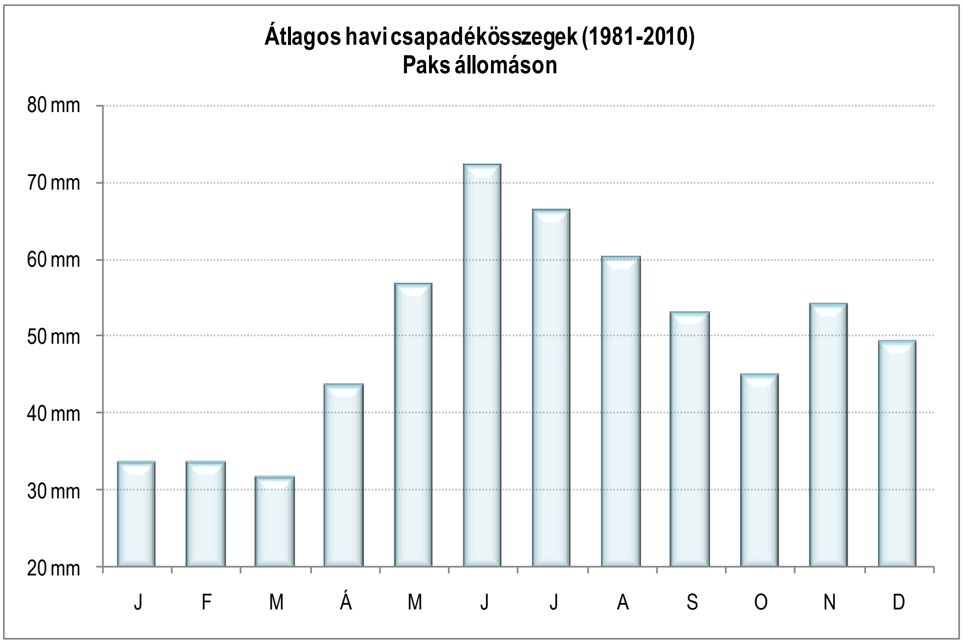
Figure 10.2.4-2: Development of total precipitation [mm] for summer half years between 1951-2010, and the ten-year averages at the Paks station



A téli félév csapadékösszegei Paks állomáson – Total precipitation for the winter half of the year at the Paks station

Figure 10.2.4-3: Development of total precipitation [mm] for winter half years between 1951-2010, and the ten-year averages at the Paks station

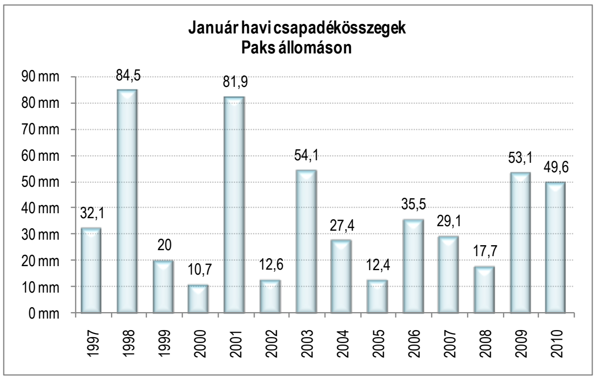
Regarding the yearly progression of precipitation (Figure 10.2.4-4) one may state that June is the wettest month (72.3mm) in the vicinity of Paks, followed by the other two summer months and May, in other words, most precipitation falls during the summer period. After that period, a secondary maximum (54mm) can be observed in November. March is the driest month (31.7mm), but precipitation is usually also small in January-February.

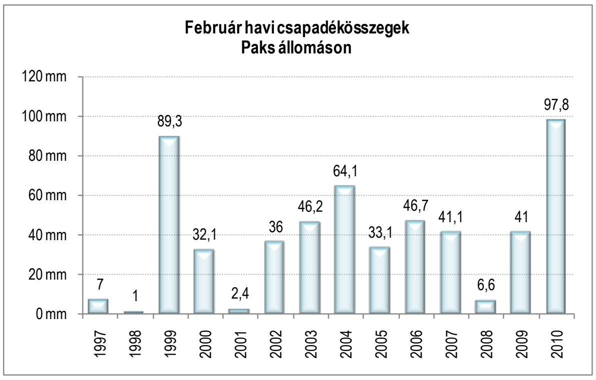


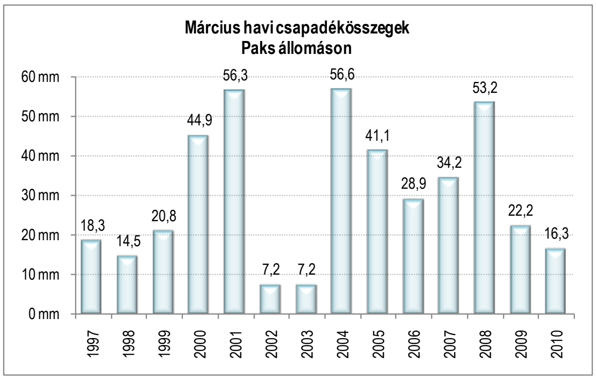
Átlagos havi csapadékösszegek (1981–2010) Paks állomáson – Average monthly total precipitation (1981-2010) at the Paks station

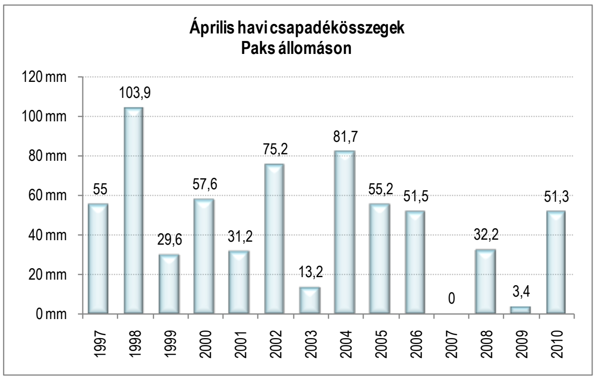
Figure 10.2.4-4: Average monthly total precipitation [mm] at the Paks station (1981-2010)

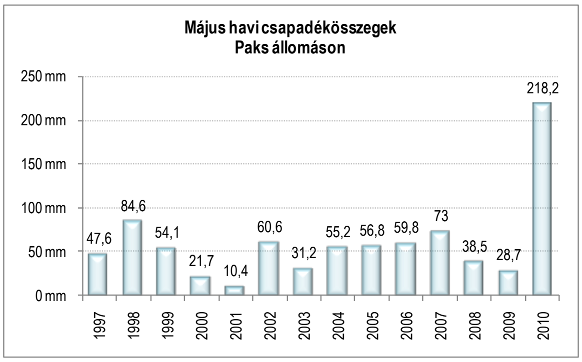
The development of total precipitation is also represented in a monthly breakdown for the Paks station from 1997 (Figure 10.2.4-5), which clearly reflects the large degree of variability within years, and among them, as well.

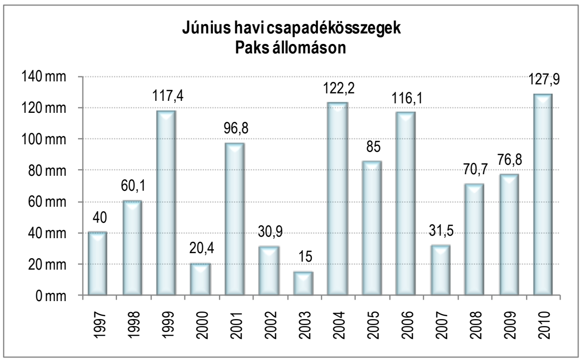

Január havi csapadékösszegek
Paks állomáson
32,1 84,5 20 10,7 81,9 12,6 54,1 27,4 12,4 35,5 29,1 17,7 53,1 49,6

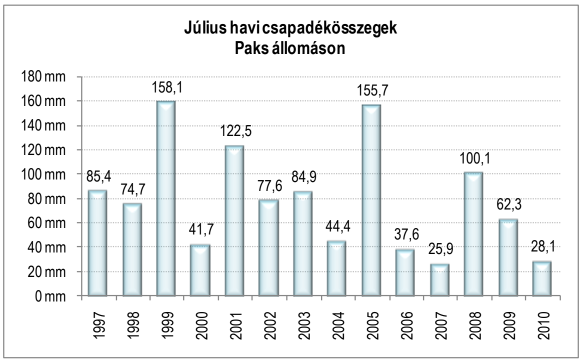

Február havi csapadékösszegek
Paks állomáson
7 1 89,3 32,1 2,4 36 46,2 64,1 33,1 46,7 41,1 6,6 41 97,8

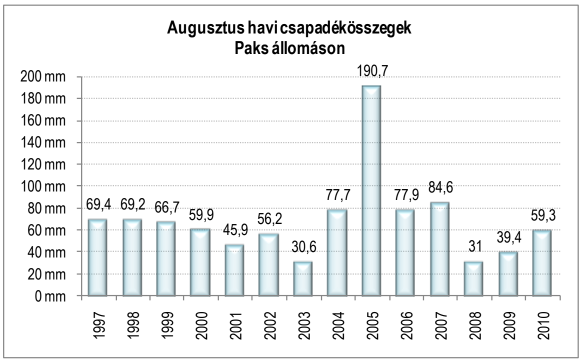

Március havi csapadékösszegek
Paks állomáson
18,3 14,5 20,8 44,9 56,3 7,2 7,2 56,6 41,1 28,9 34,2 53,2 22,2 16,3

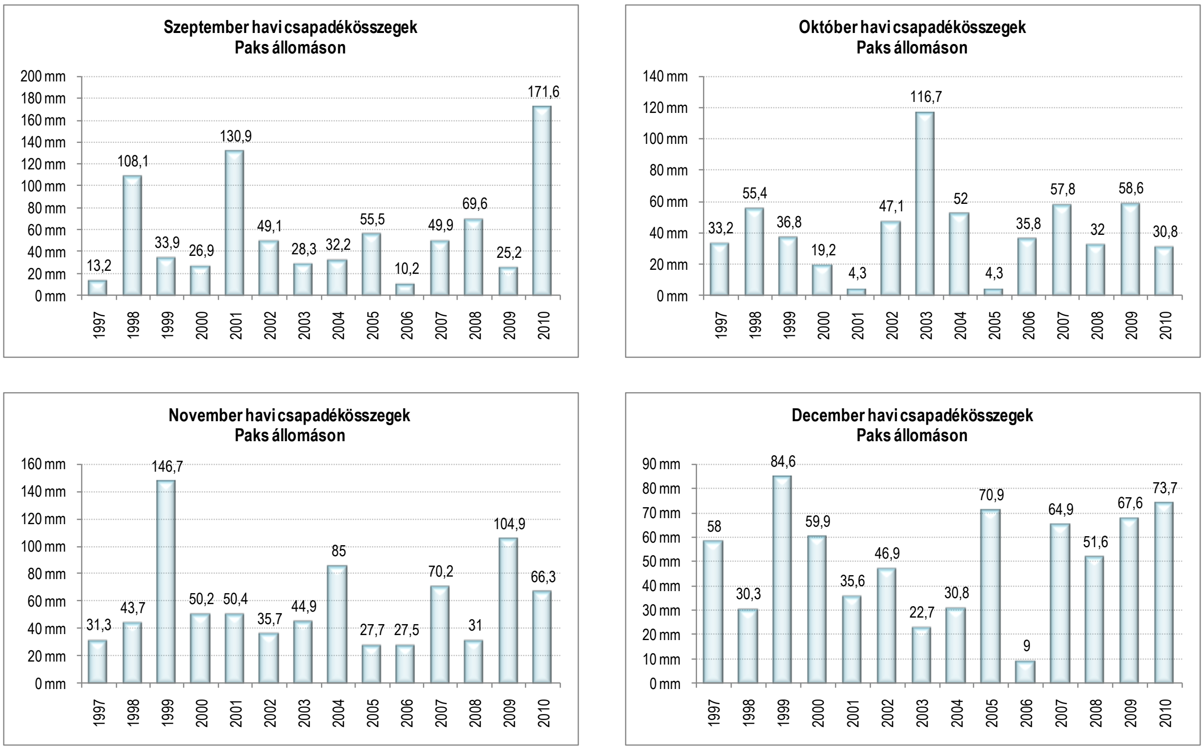

Április havi csapadékösszegek
Paks állomáson
55 103,9 29,6 57,6 31,2 75,2 13,2 81,7 55,2 51,5 0 32,2 3,4 51,3


Május havi csapadékösszegek
Paks állomáson
47,6 84,6 54,1 21,7 10,4 60,6 31,2 55,2 56,8 59,8 73 38,5 28,7 218,2


Június havi csapadékösszegek
Paks állomáson
40 60,1 117,4 20,4 96,8 30,9 15 122,2 85 116,1 31,5 70,7 76,8 127,9


Július havi csapadékösszegek
Paks állomáson
85,4 74,7 158,1 41,7 122,5 77,6 84,9 44,4 155,7 37,6 25,9 100,1 62,3 28,1


Augusztus havi csapadékösszegek
Paks állomáson
69,4 69,2 66,7 59,9 45,9 56,2 30,6 77,7 190,7 77,9 84,6 31 39,4 59,3



… havi csapadékösszegek Paks állomáson – Total precipitation at the Paks station for the month of …
január – January
február – February
március – March
április – April
május – May
június – June
július – July
augusztus – August
szeptember – September
október – October
november – November
december – december

Figure 10.2.4-5: Monthly total precipitation [mm] between 1997-2010 at the Paks station

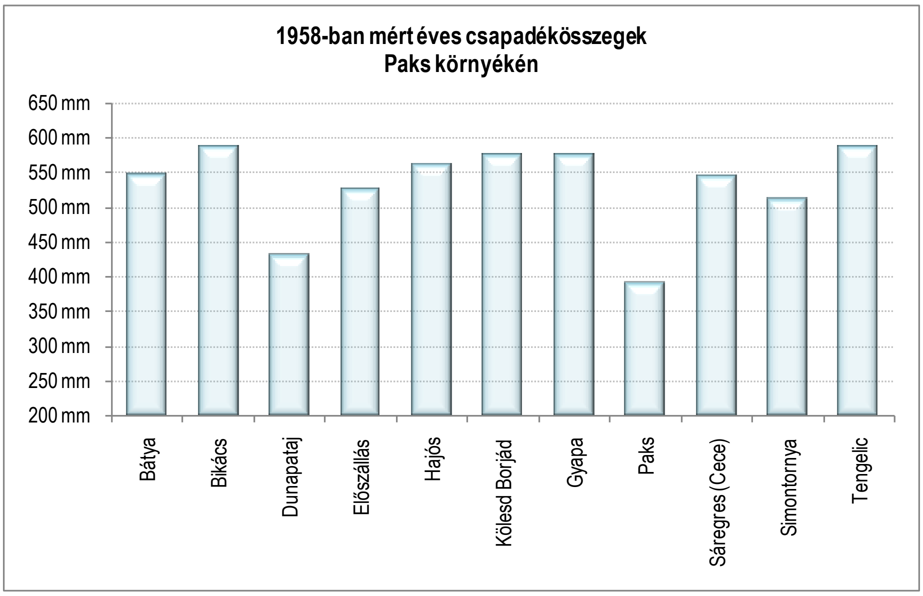
A number of extreme weather situations that can be considered dangerous and are related to precipitation activity have occurred during the post-1997 period in the territory of Hungary, including the Paks region, as well. The following data processing was completed for the period between 1997-2010 to report these situations, having particular regard to deviations from average and the occurrence of extreme values. The deviation of monthly precipitation totals from normal is first shown in Table 10.2.4-1.

Deviation for monthly precipitation totals from the multi-annual average [mm]														
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
January	-1.4	51.0	-13.5	-22.8	48.4	-20.9	20.6	-6.1	-21.1	2.0	-4.4	-15.8	19.6	16.1
February	-26.6	-32.6	55.7	-1.5	-31.2	2.4	12.6	30.5	-0.5	13.1	7.5	-27.0	7.4	64.2
March	-13.4	-17.2	-10.9	13.2	24.6	-24.5	-24.5	24.9	9.4	-2.8	2.5	21.5	-9.5	-15.4
April	11.3	60.2	-14.1	13.9	-12.5	31.5	-30.5	38.0	11.5	7.8	-43.7	-11.5	-40.3	7.6
May	-9.0	28.0	-2.5	-34.9	-46.2	4.0	-25.4	-1.4	0.2	3.2	16.4	-18.1	-27.9	161.6
June	-32.3	-12.2	45.2	-51.9	24.6	-41.4	-57.3	50.0	12.8	43.9	-40.8	-1.6	4.6	55.7
July	19.2	8.5	91.9	-24.5	56.3	11.4	18.7	-21.8	89.5	-28.6	-40.3	33.9	-3.9	-38.1
August	9.2	9.0	6.5	-0.3	-14.3	-4.0	-29.6	17.5	130.5	17.7	24.4	-29.2	-20.8	-0.9
September	-39.7	55.2	-19.0	-26.0	78.0	-3.8	-24.6	-20.7	2.6	-42.7	-3.0	16.7	-27.7	118.7
October	-11.8	10.4	-8.2	-25.8	-40.7	2.1	71.7	7.0	-40.7	-9.2	12.8	-13.0	13.6	-14.2
November	-22.7	-10.3	92.7	-3.8	-3.6	-18.3	-9.1	31.0	-26.3	-26.5	16.2	-23.0	50.9	12.3
December	8.8	-18.9	35.4	10.7	-13.6	-2.3	-26.5	-18.4	21.7	-40.2	15.7	2.4	18.4	24.5

Table 10.2.4-1: Deviation of monthly precipitation totals from the multi-annual average (1981-2010) [mm] at the Paks station between 1997-2010

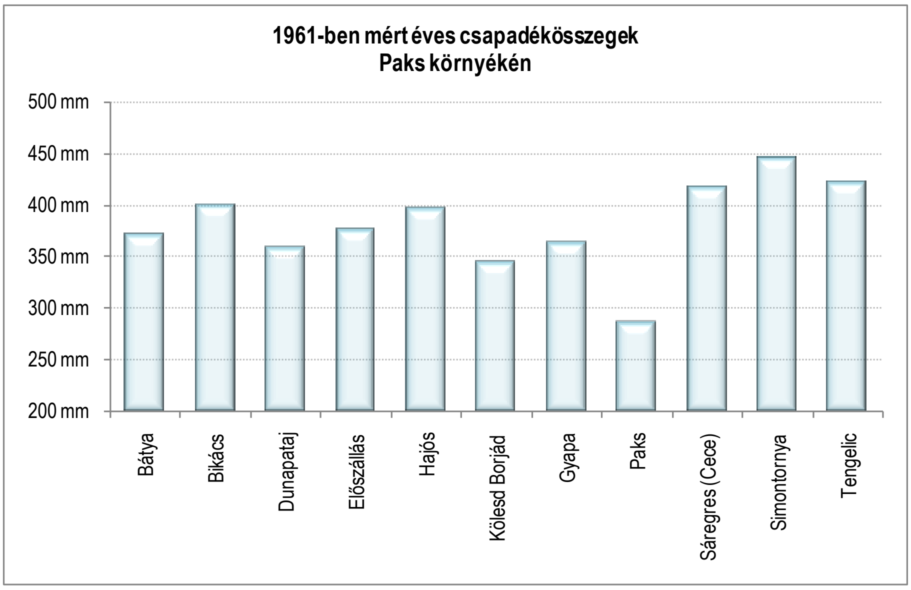
Large amounts of precipitation can be expected anywhere and at any time. Because of this, the following precipitation processing was not done for just a single point, but in the 30km vicinity of Paks, on the basis of conventional measurements from the precipitation metering stations that have complete data sets there.

Precipitation totals for the three years deemed driest (1958, 1961, 1971) were charted concerning the region based on data from Paks (Figure 10.2.4-6, Figure 10.2.4-7,Figure 10.2.4-8).



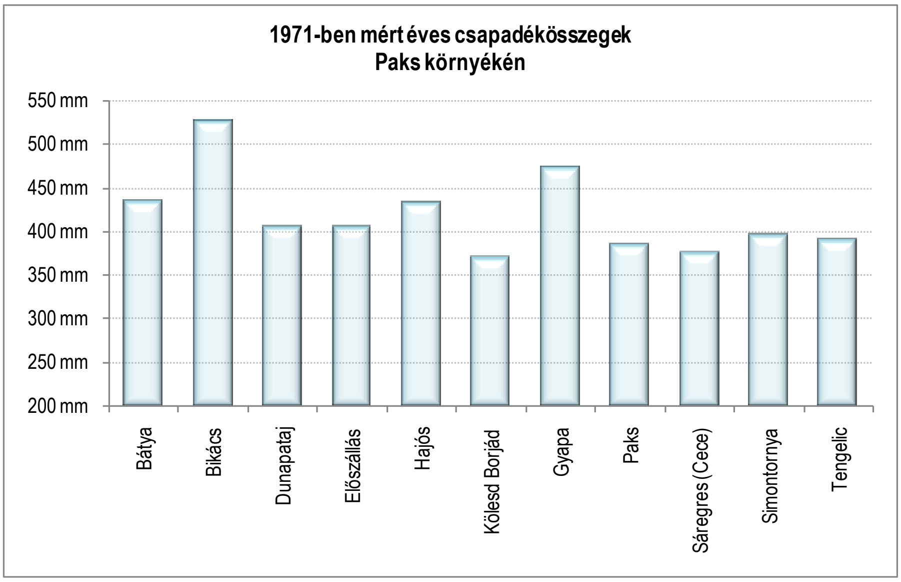
1958-ban mért éves csapadékösszegek Paks környékén – Annual total precipitation measured in the vicinity of Paks in 1958

Figure 10.2.4-6: Annual total precipitation [mm] measured by the precipitation metering stations that operate in the 30km vicinity of Paks in 1958



1961-ben mért éves csapadékösszegek Paks környékén – Annual total precipitation measured in the vicinity of Paks in 1961

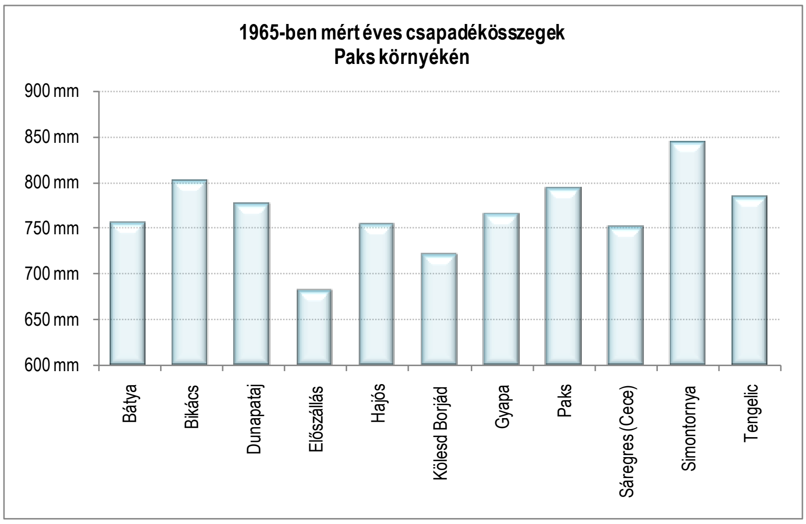
Figure 10.2.4-7: Annual total precipitation [mm] measured by the precipitation metering stations that operate in the 30km surroundings of Paks in 1961



1971-ben mért éves csapadékösszegek Paks környékén – Annual total precipitation measured in the vicinity of Paks in 1971

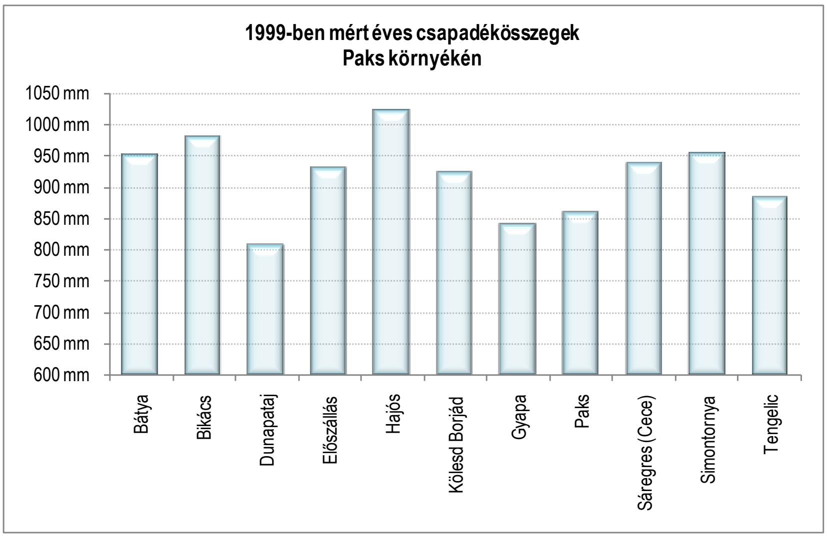
Figure 10.2.4-8: Annual total precipitation [mm] measured by the precipitation metering stations that operate in the 30km surroundings of Paks in 1971

Total precipitation for the three years (1965, 1999, 2010) considered to be the wettest—based on data from Paks—are illustrated on the following charts (Figure 10.2.4-9, Figure 10.2.4-10, Figure 10.2.4-11).



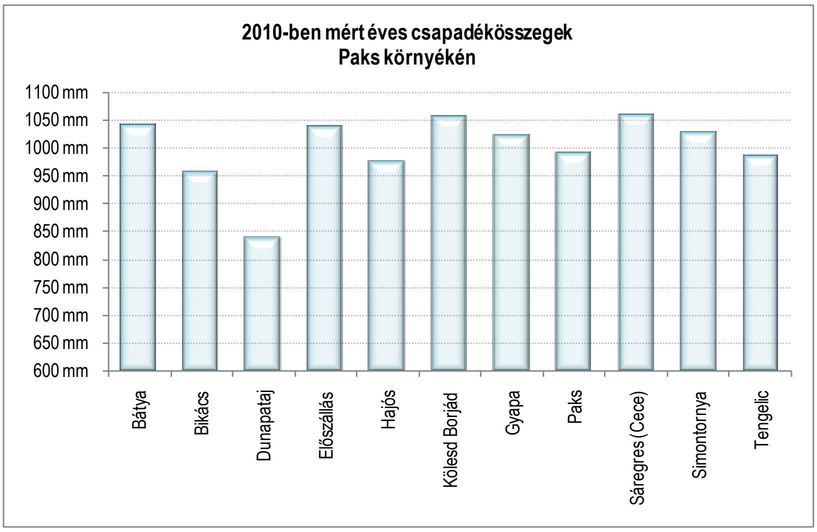
1965-ben mért éves csapadékösszegek Paks környékén – Annual total precipitation measured in the vicinity of Paks in 1965

Figure 10.2.4-9: Annual total precipitation [mm] measured by the precipitation metering stations that operate in the 30km surroundings of Paks in 1965



1999-ben mért éves csapadékösszegek Paks környékén – Annual total precipitation measured in the vicinity of Paks in 1999

Figure 10.2.4-10: Annual total precipitation [mm] measured by the precipitation metering stations that operate in the 30km surroundings of Paks in 1999



2010-ben mért éves csapadékösszegek Paks környékén – Annual total precipitation measured in the vicinity of Paks in 2010

Figure 10.2.4-11: Annual total precipitation [mm] measured by the precipitation metering stations that operate in the 30km surroundings of Paks in 2010

Table 10.2.4-2 shows extreme precipitation totals from between 1981-2010. One may see that during this period there were two instances in the 30km surroundings of Paks when no precipitation fell at all: in April 2007 and September 1986. There were several century records that were set in the case of the highest monthly values during this period (for the stations marked in the table with an asterisk): precipitation in January 1987, May 2010, June and July 1999, as well as September 1996 all exceeded the highest values that had been measured—since 1901—until then.

Monthly total precipitation (1981-2010) [mm]						
	Lowest	Year	Station	Highest	Year	Station
January	2.0	1992	Hajós	113.0	1987	Sióagárd*
February	0.4	1998	Előszállás	119.6	1999	Sióagárd
March	3.0	2003	Solt	75.4	1988	Harta
April	0.0	2007	Tengelic	103.9	1998	Paks
May	1.9	1993	Paks	261.1	2010	Kölesd*
June	0.7	2003	Bikács	224.4	1999	Sióagárd*
July	5.8	1995	Murga	259.2	1999	Hajós*
August	0.4	1992	Simontornya	237.9	2005	Sióagárd
September	0.0	1986	Apostag	234.3	1996	Sióagárd*
October	0.5	1995	Sáregres (Cece)	139.5	1992	Murga
November	8.6	1983	Sióagárd	146.7	1999	Paks
December	5.5	1989	Kalocsa	160.1	1981	Hajós

** total precipitation at the stations marked with an asterisk are absolute maximums for the respective month*

Table 10.2.4-2: The lowest and highest values of monthly total precipitation [mm] by months (1981-2010) in the 30km surroundings of Paks

Daily total precipitation maximum values were also examined regarding this period (1981-2010), in a monthly breakdown (Table 10.2.4-3). Values that exceeded the maximum measured since 1901 were likewise registered, and these are marked in the table with an asterisk. Looking at entire years, furthermore, the total of 130.5mm measured on 17 July 2003 stands as the greatest daily precipitation ever measured in the 30km surroundings of Paks.

Daily maximum total precipitation (1981-2010) [mm]			
	Value	Year	Station
January	49.0	20/01/1998	Bikács*
February	41.3	26/02/1995	Hajós
March	32.0	21/03/1989	Bikács
April	53.0	13/04/2004	Bikács
May	81.7	16/05/2010	Kölesd Borjád*
June	83.0	28/06/1989	Bikács
July	130.5	17/07/2003	Előszállás*
August	100.0	04.08.2005	Sióagárd
September	80.0	10/09/2010	Dunaföldvár
October	52.8	09/10/1982	Dunapataj*
November	77.1	10/11/2009	Dunaföldvár*
December	45.0	21/12/1993	Szekszárd

** total precipitation at the stations marked with an asterisk are absolute maximums for the respective month*

Table 10.2.4-3: Daily maximum total precipitation [mm] by months (1981-2010) in the 30km surroundings of Paks

Extreme precipitation values that can be expected every 2, 4, 5…, 100 000 years were calculated using the Gumbel statistical method on the basis of daily total precipitation measured at Paks between 1981-2010 (Table 10.2.4-4). Based on these, one may expect a daily total exceeding 50mm less than every 5 years on average, 75mm less than every 50 years, and a value of around 100mm approximately every 500 years.

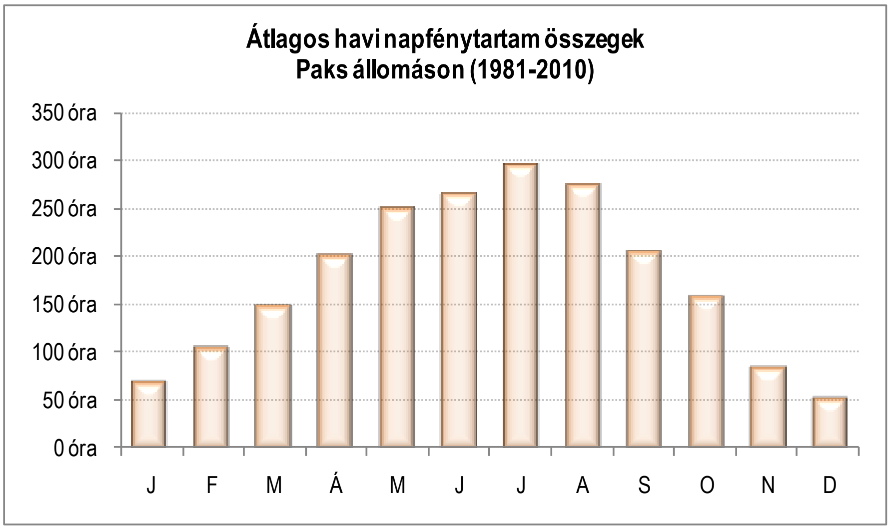
Daily total precipitation return values shown as a Gumbel distribution	
Return period (years)	Daily total precipitation [mm]
2	40.5
4	49.6
5	52.2
10	60.0
20	67.4
50	77.4
100	84.3
200	91.5
500	101.0
1,000	108.1
2,000	115.3
5,000	124.8
10,000	132.0
20,000	139.1
100,000	155.7

Table 10.2.4-4: The Gumbel distribution of daily precipitation total return values in respect of the Paks station (based on data from 1981-2010)

10.2.5 DURATION OF SUNSHINE

The number of hours with sunshine is referred to as duration of sunshine, this being the number of hours when the shining sun casts a shadow, and the ground surface is exposed to direct sunshne. The value of sunshine duration expressed in hours therefore expresses the length of time when the sun shines. The astronomically possible duration of sunshine is the length of time between sunrise and sunset at any particular geographical latitude. Its maximum falls on the date of the summer solstice (June 21), its minimum on that of the winter solstice (December 21). Cloud cover usually causes a reduction in sunshine duration, but does not always unequivocally determine how actual sunshine duration shapes-up. Sunshine duration values measured in completely clear weather do not reach the value of calculated possible sunshine duration even on flat terrain as the incidence of rays during sunrise and sunset is so slanted that their impact on the ground surface energy balance is negligible, and direct sunshine reaching the ground is not or only hardly measurable.

The average annual total of actual sunshine duration is approximately 45% of that astronomically possible, in other words it is even less than half of it. The ratio is worse in December, when sunshine is just 18-20% of that possible, while it reaches approximately 60% thereof in July. Figure 10.2.5-1 shows the multi-annual average of daily sunshine duration values (1981-2010).



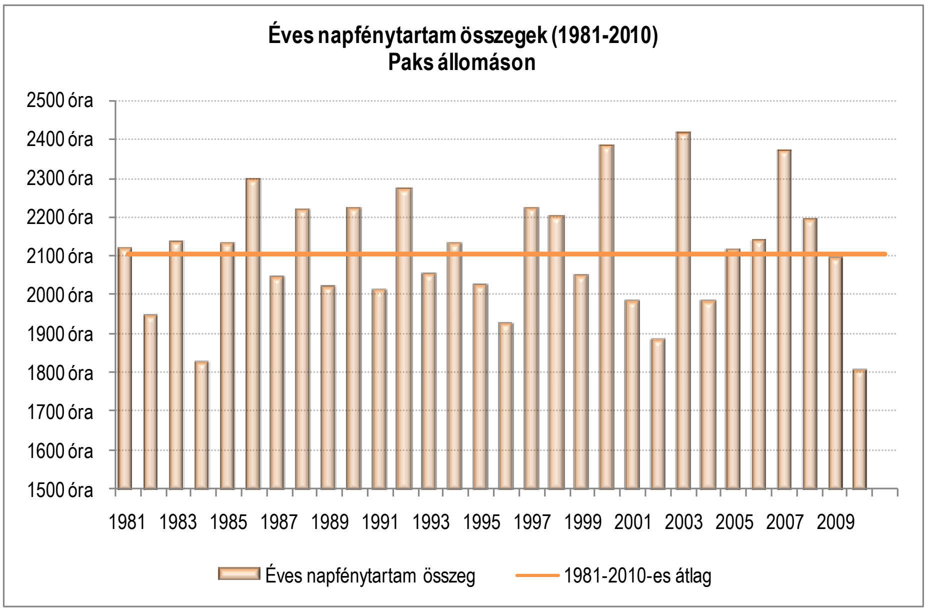
Átlagos havi napfénytartam összegek Paks állomáson (1981–2010) – Average monthly total sunshine duration at the Paks station (1981-2010)
… óra – … hours

Figure 10.2.5-1: Multi-annual (1981-2010) averages of daily sunshine duration [hours] at the Paks station

Based on that one can conclude that December is the month with the least sunshine in the vicinity of Paks due to extended cloud cover and short daylight hours; average daily sunshine duration comes to just 53 hours then. The months of May to September are the richest in sunshine; values above an average of 250 hours occurred in this period, and the month of July was the sunniest among them in terms of the past 30 years' average (with close to 300 hours), followed by August, then June. Sunshine duration for the summer half of the year is close to two and a half times that of the winter half; on the one hand, that is when the astronomically possible value is also higher, and on the other, the sunshine limiting effect of cloud cover is greater during the winter months than it is in summer.

Since regular measurements began at Paks, the lowest sunshine duration value was measured in December 2000, with just 15 hours for the month. Sunshine was also quite little in the extremely wet August 2005 (190 hours) and May 2010 (172 hours); markedly high values, however, were measured in May 2003 (304 hours) and June 2000 (357 hours).

The following diagram (Figure 10.2.5-2) presents annual total sunshine duration measured in the period between 1981-2010, along with the 1981-2010 average. The highest annual value was measured at Paks (2412 hours) in 2003, and the lowest one during the unusually wet year 2010 (1818 hours).



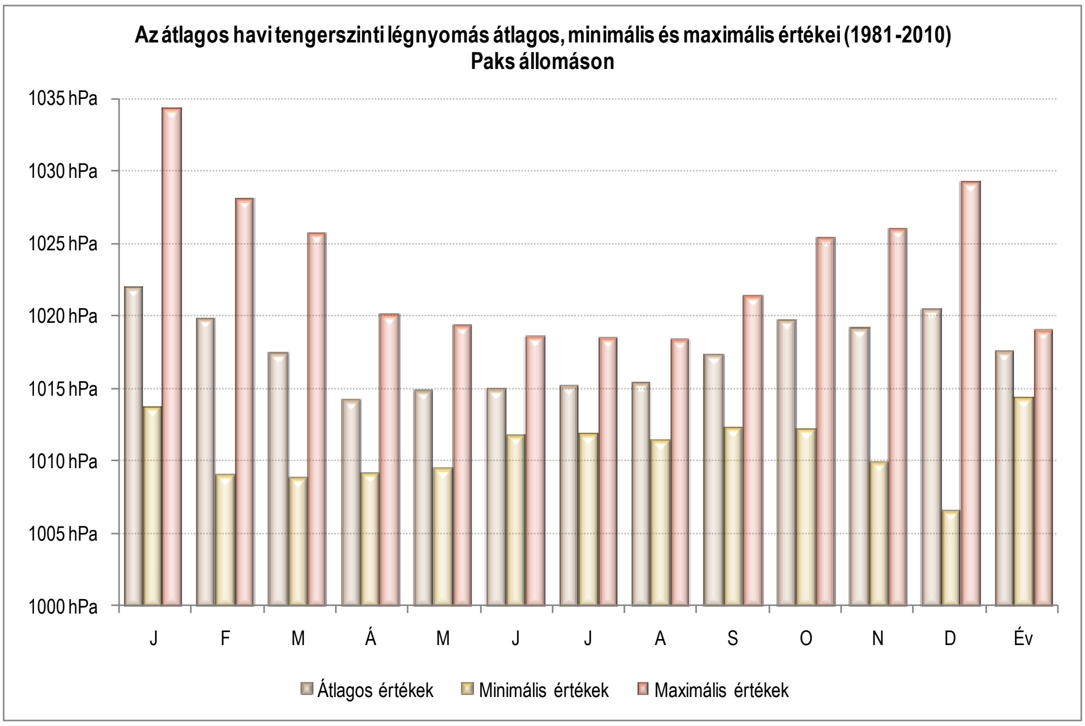
Éves napfénytartam összegek (1981–2010) Paks állomáson – Annual total sunshine duration (1981-2010) at the Paks station
… óra – … hours
Éves napfénytartam összeg – Annual total sunshine duration
1981–2010-es átlag – Average for 1981-2010

Figure 10.2.5-2: Annual total sunshine duration [hours], as well as the multi-annual average value for 1981-2010 at the Paks station

10.2.6 Sea level pressure

The mass of air exerts a compressive force on bodies as the result of gravitational force, and pressure is the value of its effect on surfaces. Air pressure is the pressure of an air column with a unit area at the base, hectopascal (hPa) is its unit of measure used in meteorology—millibars (mb) and millimetre mercury (Hgmm) were the units of measure that were formerly used; its master unit at sea level is 1 atmosphere (atm), which equals 1013.25hPa / 1013.25mb or 760Hgmm. As one climbs above sea level, air pressure decreases exponentially relative to increasing height. This is exactly the reason why air pressure value converted to sea level is used for monitoring changes in the air pressure field, because otherwise it would be the different heights of observation points that would primarily be reflected in actual air pressure data. The value converted to sea level is, for all intents and purposes, a fictitious value that specifies how much the air pressure would be at sea level below the observation point if the intermediate space were filled with air.

Annual mean sea level pressure in the vicinity of Paks is 1017.5hPa, its progression during the year (Figure 10.2.6-1) is similar to the nationwide progression, with the highest values usually occurring in January (1021.9hPa), and the lowest ones in April (1014.1hPa).



Nyári napok éves száma (1981–2010) – The average, minimum and maximum values (1981-2010) of monthly mean sea level pressure at the Paks station
Átlagos értékek – Average values
Maximális értékek – Maximum values
Minimális értékek – Minimum values

Figure 10.2.6-1: The multi-annual average, minimum and maximum of monthly mean sea level pressure [hPa] (1981-2010) at the Paks station

Average air pressure for the summer half of the year is lower than it is in the case of the winter half. The maximum monthly average value since 1981 was measured in January 1989 (1034.4hPa), and the minimum in December 1981 (1006.5hPa). The lowest annual average was observed in year 2010, which was plentiful in cyclones (1014.3hPa), and the highest in 1989 (1019hPa).

The lowest and highest air pressure values are also specified per month regarding the Paks station in a table format (Table 10.2.6-1). The absolute minimum—surprisingly—was not observed in the summer half of the year, but in February 1989 (977.1hPa), while the absolute maximum was seen in January 1999 (1045.9hPa). These data allow us to conclude that winter months are more unsteady from the perspective of air pressure, with those in the summer being more balanced.

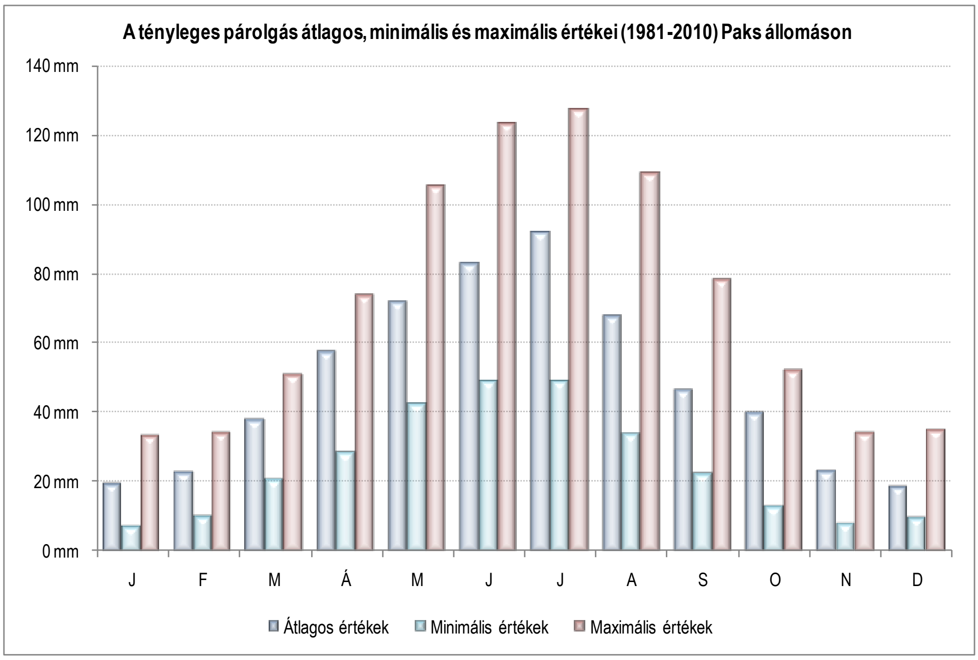
Sea level pressure (1981-2010) [hPa]				
	Lowest	Year	Highest	Year
January	990.8	1988	1045.9	1993
February	977.1	1989	1043.3	2008
March	989.3	2007	1041.8	1990
April	993.2	2000	1033.8	1997
May	993.4	1995	1029.1	1995
June	1001.5	1991	1028.2	2000
July	1001.1	2003	1026.3	1985
August	1002	2002	1025.5	1981
September	994.4	1998	1032.8	1986
October	995.9	1990	1039.4	1997
November	988.7	2010	1038.9	1999
December	987.2	1999	1043.1	2008

Table 10.2.6-1: The lowest and highest values of sea level pressure [hPa] by months (1981-2010) at the Paks station

10.2.7 EVAPORATION

Evaporation is the most significant element on the spending side of the Earth's hydrological budget. Its unit of measure is the millimetre, which expresses the height of the water column that evaporates from a surface of one square metre.

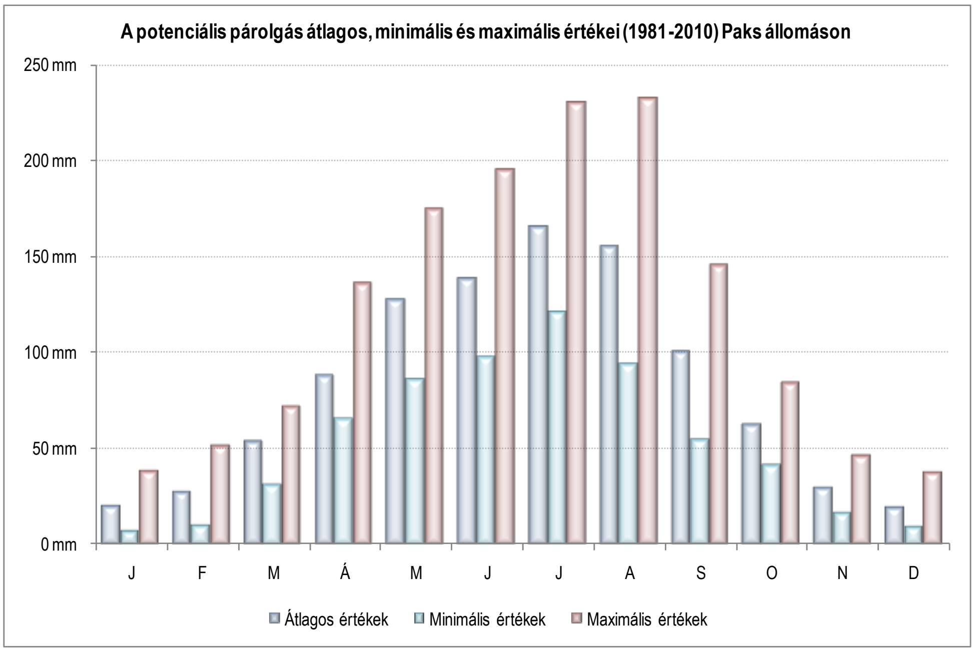
Actual evaporation means the amount of water that actually evaporates from the ground surface. It is difficult to measure and calculate on account of its complexity. Our study presents calculated values. Its quantity depends on the amount of water that is available in the soil, in other words the surface hydrological budget, along with how much energy is available for evaporation, in other words temperature and soil coverage. In the vicinity of Paks, actual evaporation is the lowest in the period from November to February (cold period with less precipitation), and the greatest in the period between May and August (hotter and wetter with) (Figure 10.2.7-1).



A tényleges párolgás átlagos, minimális és maximális értékei (1981-2010) Paks állomáson – The average, minimum and maximum values of actual evaporation (1981-2010) at the Paks station
Átlagos értékek – Average values
Maximális értékek – Maximum values
Minimális értékek – Minimum values

Figure 10.2.7-1: The average, minimum and maximum values [mm] of actual evaporation (1981-2010) per month at the Paks station

Potential (possible) evaporation is one of the characteristic quantities of climate in a particular area, specifying the amount of vapour the atmosphere—i.e. the vapour absorbing system—can absorb as a maximum (in this case, an unlimited quantity of water is the assumption). The rate of actual evaporation is never greater than that of potential evaporation. In the case of evaporation from water surfaces—and completely saturated soil—actual and potential evaporation are identical. In the case of Paks, potential evaporation is lowest during winter, when it is almost the same as actual evaporation; however from spring to autumn—and mainly during summer (when the rate of potential evaporation is the highest)—it far exceeds the latter (Figure 10.2.7-2), since an appropriate quantity of evaporable water is not available.



Nyári napok éves száma (1981–2010) – The average, minimum and maximum values of potential evaporation (1981-2010) at the Paks station
Átlagos értékek – Average values
Maximális értékek – Maximum values
Minimális értékek – Minimum values

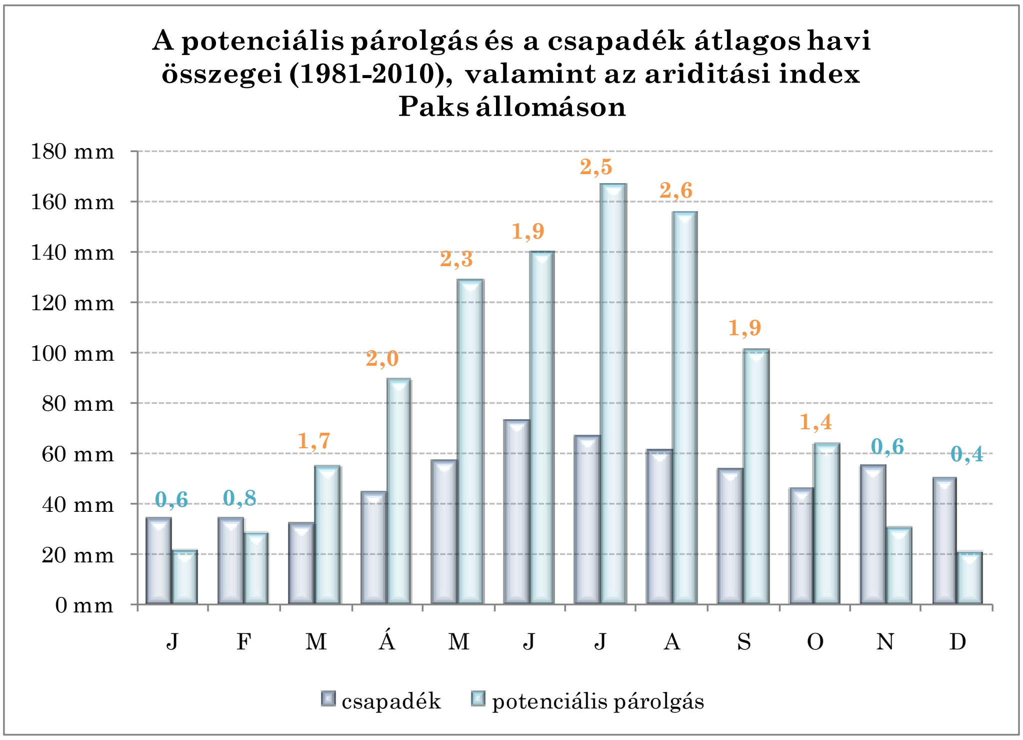
Figure 10.2.7-2: The average, minimum and maximum values [mm] of potential evaporation (1981-2010) per month at the Paks station

The relationship of evaporation and precipitation

It is also worth the trouble to examine the relationship of evaporation and fallen precipitation, which essentially describes the relationship of the heat balance of the atmosphere and the hydrological budget. The ratio of these two meteorological elements shows the value of water supply level, which is called the aridity index (H): H = potential evaporation / precipitation.

The aridity index calculated on the basis of average annual totals from 1981-2010 concerning the Paks station is 1.7. What this means is that the vicinity of Paks qualifies as an arid area from the perspective of precipitation supply.

Upon examination of multi-annual monthly values (Figure 10.2.7-3) one can see that the sum of precipitation within the year in the period between November and February exceeds the value of potential evaporation, in other words, in this period the aridity index describes lower than 1, i.e. wet conditions. In contrast, greater solar energy in the period between March and October guarantees the evaporation of more water (potential evaporation > precipitation), the aridity index is greater than 1 and may even exceed 2, which is to say that in terms of water supply, arid conditions are typical during these months based on the multi-annual average.

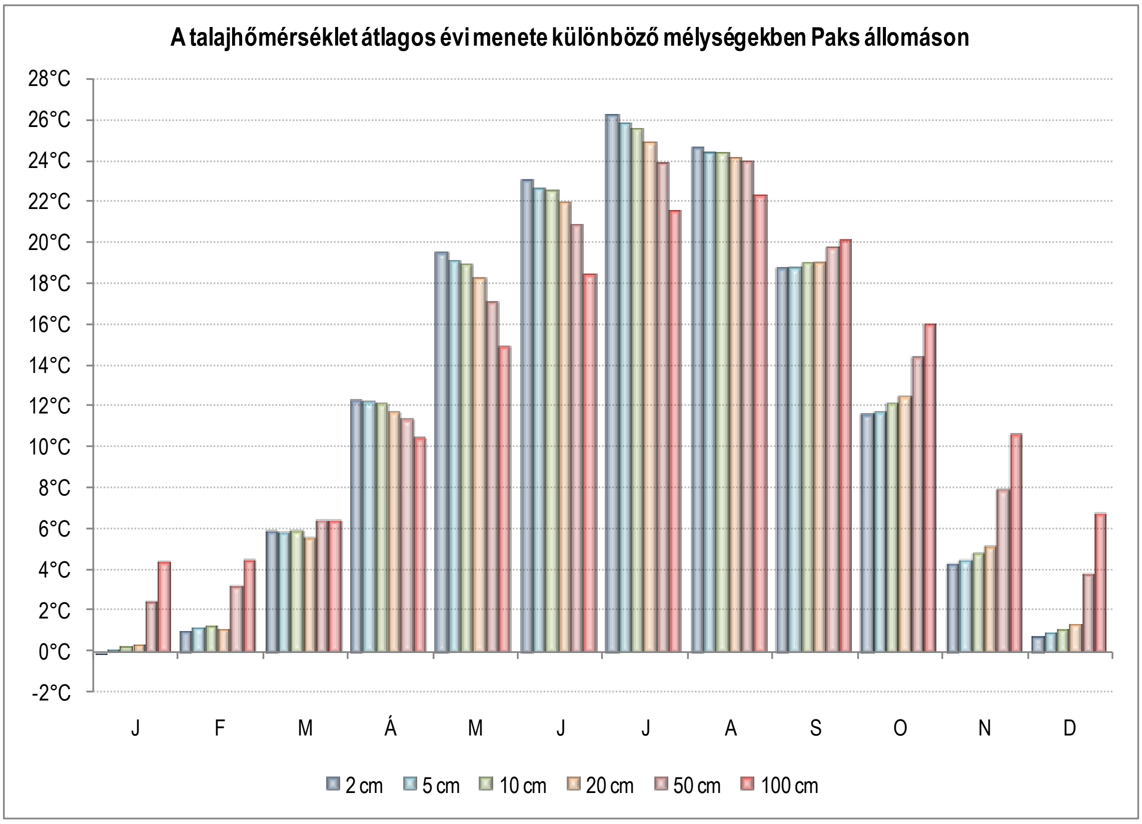


A potenciális párolgás és a csapadék átlagos összegei (1981-2010), valamint az ariditási index Paks állomáson – Average totals for potential evaporation and precipitation (1981-2010), along with the aridity index at the Paks station
csapadék – precipitation
potenciális párolgás – potential evaporation

Figure 10.2.7-3: Average totals for potential evaporation and precipitation [mm] per month (1981-2010), along with the aridity index calculated from those at the Paks station

10.2.8 SOIL TEMPERATURE

The temperature of the soil surface follows the sun's progress directly, and thus the warming up and cooling down of the soil's top layer changes in parallel with air temperature day by day and year by year. As depth increases, however, the effect of the sun weakens more and more, both daily and seasonal fluctuations decrease, and temperature becomes constant at a certain depth. At a depth of one metre, average temperature is close to equal to the temperature of the air, it is just that relative to this latter, there is a delay of approximately one month in terms of annual progression, in other words this is the length of time required for warming to permeate a one metre thick soil layer. The next diagram presents the multi-annual average of temperatures at 2, 5, 10, 20, 50, and 100cm depths concerning the Paks station (Figure 10.2.8-1).



A talajhőmérséklet átlagos évi menete különböző mélységekben Paks állomáson – Average annual progression of soil temperature at different depths at the Pask station

Figure 10.2.8-1: Average annual progression (1986-1995) of soil temperature [°C] at different depths at the Pask station

10.2.9 WIND CONDITIONS

The distribution of air pressure is essentially uneven on a horizontal plane. Because the atmosphere seeks to attain a state of equilibrium, it tries to reach conditions in which equal pressures prevail. This is the reason why forces striving to equalise air pressure differences come about in the atmosphere. These forces result in the horizontal realignment of air masses, which we sense as the wind. In meteorology, the unit of measure used to express the magnitude of wind is m/s.

Since 1997, wind has been measured at the Paks station using an automated VAISALA WAA type anemometer positioned at a height of 9.8m above the ground. The period that has elapsed since then has been found sufficiently long for conducting climate studies, therefore wind data measured using other (mechanical) methods were not taken into consideration during our examination, only these measurements (1997-2010).

The direction in which pollutants will spread is primarily influenced by the prevailing wind direction, and the distance that emitted substances will reach depends on the magnitude of wind speed.

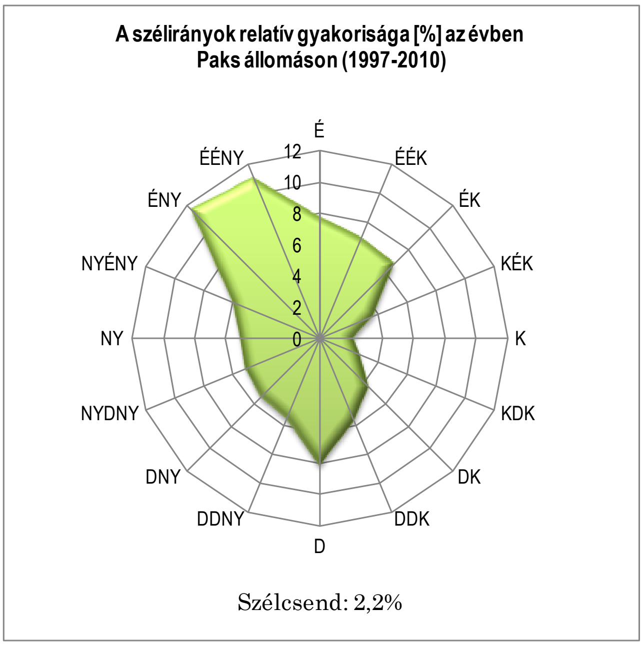
10.2.9.1 Wind direction

Wind direction is the direction from which the wind blows. The wind direction with the greatest frequency is called the prevailing wind direction.

In the processing at hand, our examinations were focused on 16 wind directions.

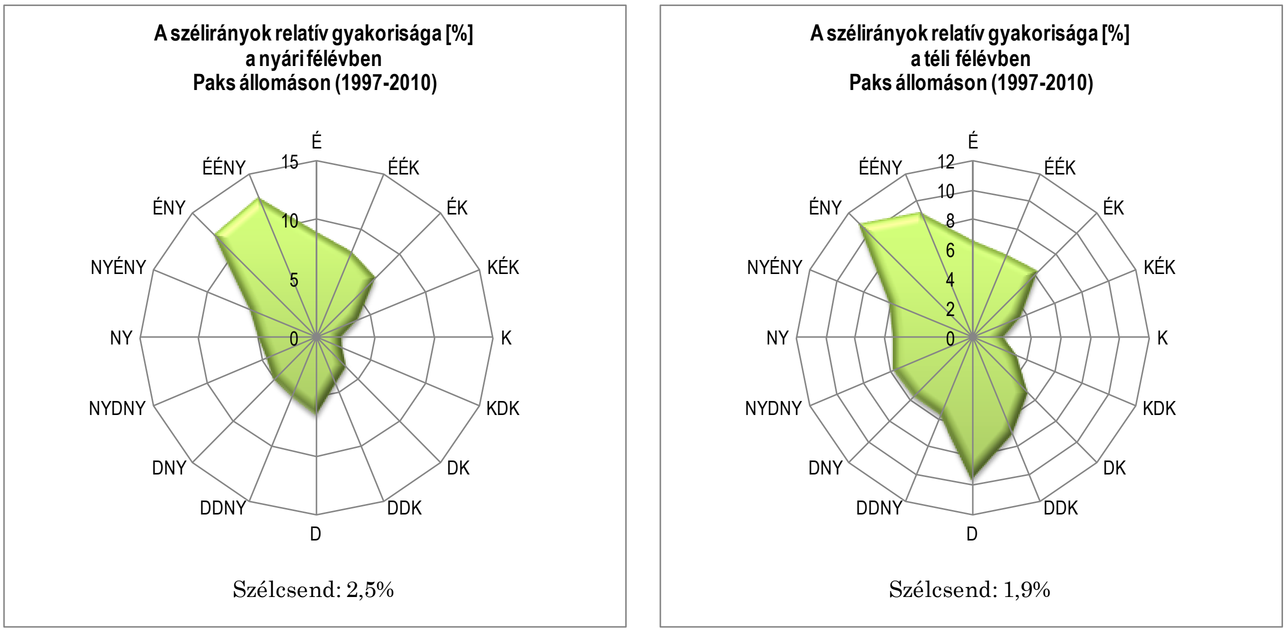
The relative frequency of wind directions was first analysed at annual level (Figure 10.2.9-1), as well as regarding the summer and winter halves of the year (Figure 10.2.9-2).

One can see that northwesterly (11.6%) and north-northwesterly (11%) are the most common convections by annual comparison, with the southern direction appearing as the secondary maximum (8.1%).



A szélirányok relatív gyakorisága [%] az évben Paks állomáson (1997-2010) – The relative frequency of wind directions [%] during the year at the Paks station (1997-2010)
Szélcsend – Calm wind
É / K / D / NY – N / E / S / W

Figure 10.2.9-1: The relative frequency of wind directions at annual level [%] based on measurements at the Paks station between 1997-2010

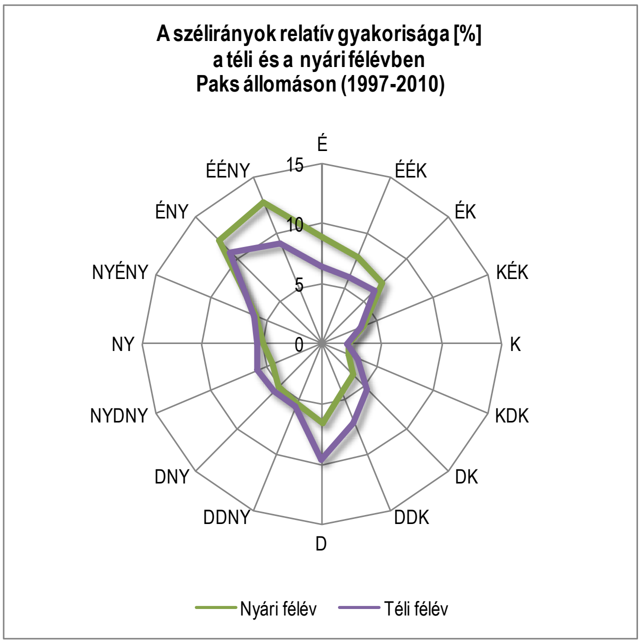


A szélirányok relatív gyakorisága [%] a téli félévben Paks állomáson (1997-2010) – The relative frequency of wind directions [%] during the winter half of the year at the Paks station (1997-2010)
A szélirányok relatív gyakorisága [%] a nyári félévben Paks állomáson (1997-2010) – The relative frequency of wind directions [%] during the summer half of the year at the Paks station (1997-2010)

Szélcsend – Calm wind

Figure 10.2.9-2: The relative frequency of wind directions during the summer and winter halves of the year [%] based on measurements at the Paks station between 1997-2010

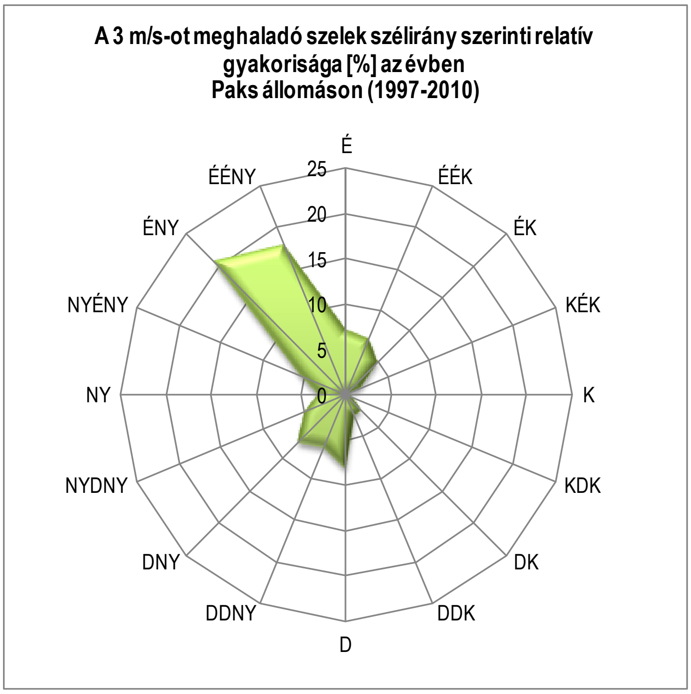
In the summer half of the year, north-northwest dominates (12.7%), followed by the northwest direction (12.2%), then north (8.9%), with the southern direction relegated to fourth place (6.7%). In the winter half of the year, the prevailing wind direction is northwest (10.8%), but the southerly direction takes second place here (9.6%), with north-northwest being third (9.1%). (Figure 10.2.9-3)



A szélirányok relatív gyakorisága [%] a téli és a nyári félévben Paks állomáson (1997-2010) – The relative frequency of wind directions [%] during the winter and summer halves of the year at the Paks station (1997-2010)
Nyári félév – Summer half
Téli félév – Winter half

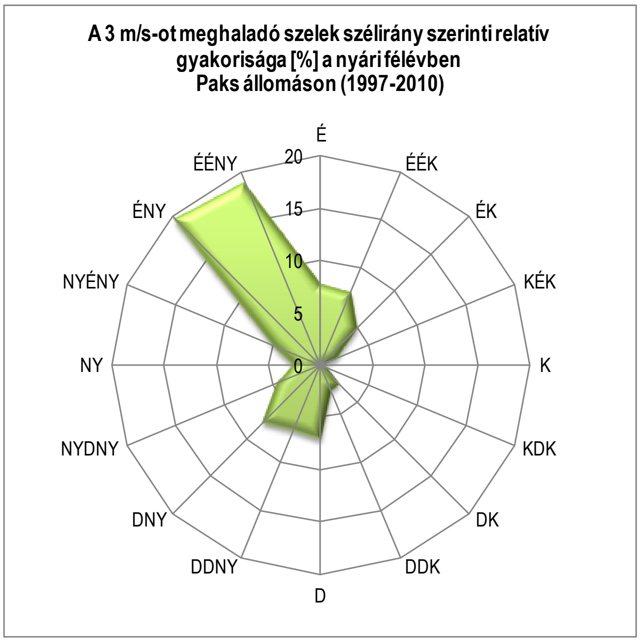
Figure 10.2.9-3: The relative frequency of wind directions during the winter and summer halves of the year [%] based on measurements at the Paks station between 1997-2010

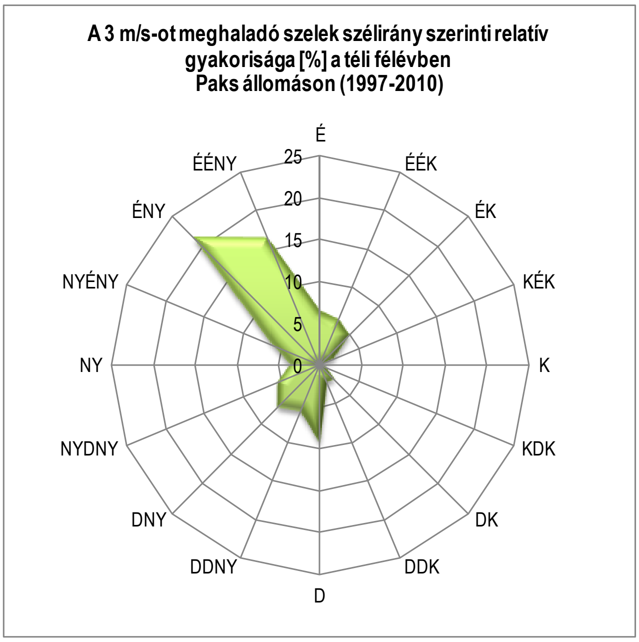
The relative frequency of wind directions was also examined for cases of stronger air motion (i.e. when average wind speed exceeds 3m/s). In such cases, winds mainly blow from the northwest and north-northwest (Figure 10.2.9-4 to Figure 10.2.9-6).



A 3 m/s-ot meghaladó szelek szélirány szerinti relatív gyakorisága [%] az évben Paks állomáson (1997-2010) – The relative frequency [%] of winds exceeding 3m/s by wind directions during the year at the Paks station (1997-2010)

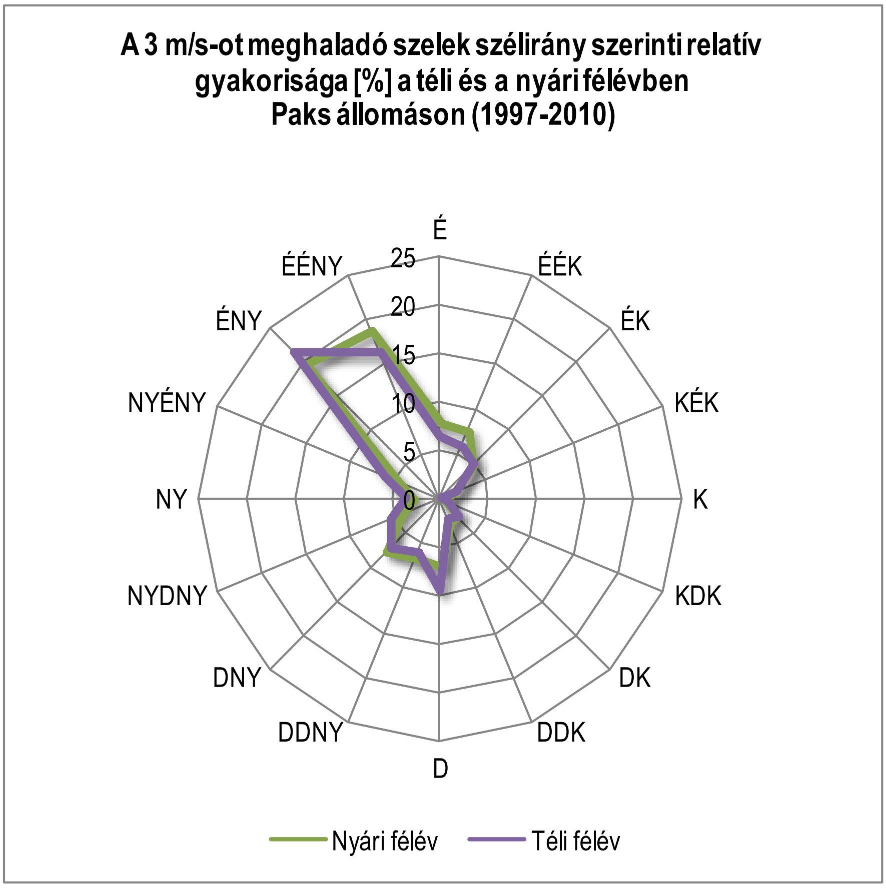
Figure 10.2.9-4: The relative frequency [%] of winds exceeding 3m/s by wind directions at annual level at the Paks station (1997-2010)





A 3 m/s-ot meghaladó szelek szélirány szerinti relatív gyakorisága [%] a nyári félévben Paks állomáson (1997-2010) – The relative frequency [%] of winds exceeding 3m/s by wind directions during the summer half of the year at the Paks station (1997-2010)
A 3 m/s-ot meghaladó szelek szélirány szerinti relatív gyakorisága [%] a téli félévben Paks állomáson (1997-2010) – The relative frequency [%] of winds exceeding 3m/s by wind directions during the winter half of the year at the Paks station (1997-2010

Figure 10.2.9-5: The relative frequency [%] of winds exceeding 3m/s by wind directions during the summer and winter halves of the year at the Paks station (1997-2010)



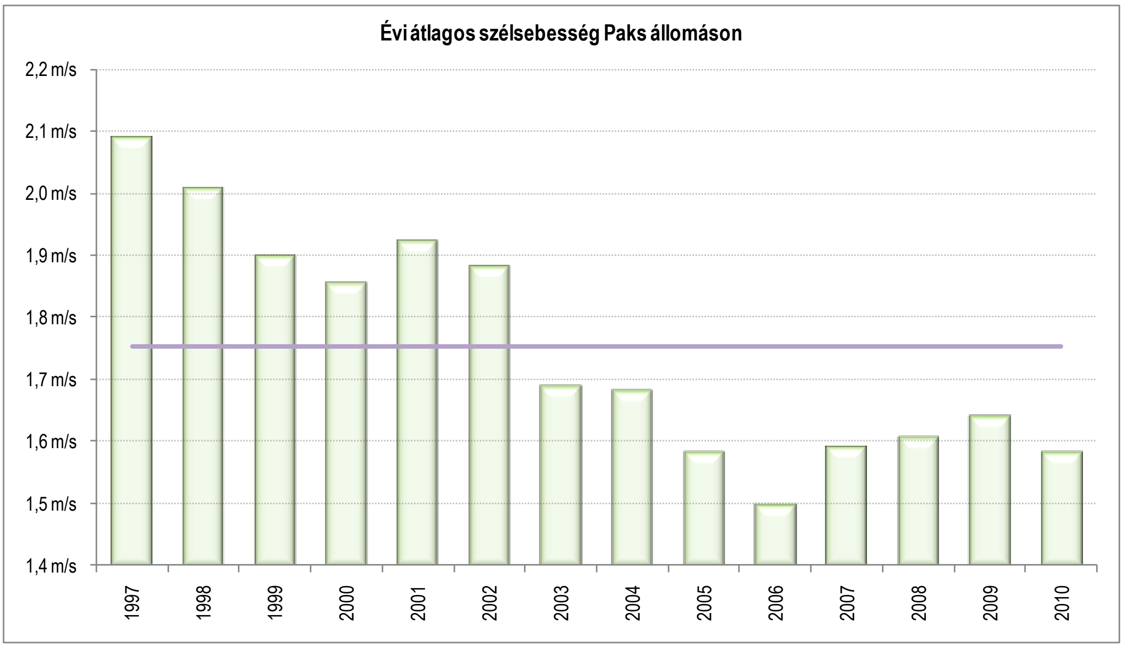
A 3 m/s-ot meghaladó szelek szélirány szerinti relatív gyakorisága [%] a téli és a nyári félévben Paks állomáson (1997-2010) – The relative frequency [%] of winds exceeding 3m/s by wind directions during the winter and summer halves of the year at the Paks station (1997-2010)
Nyári félév – summer half
Téli félév – winter half

Figure 10.2.9-6: The relative frequency [%] of winds exceeding 3m/s by wind directions during the summer/winter half of the year at the Paks station (1997-2010)

10.2.9.2 Wind speed

10.2.9.2.1 Average wind speeds

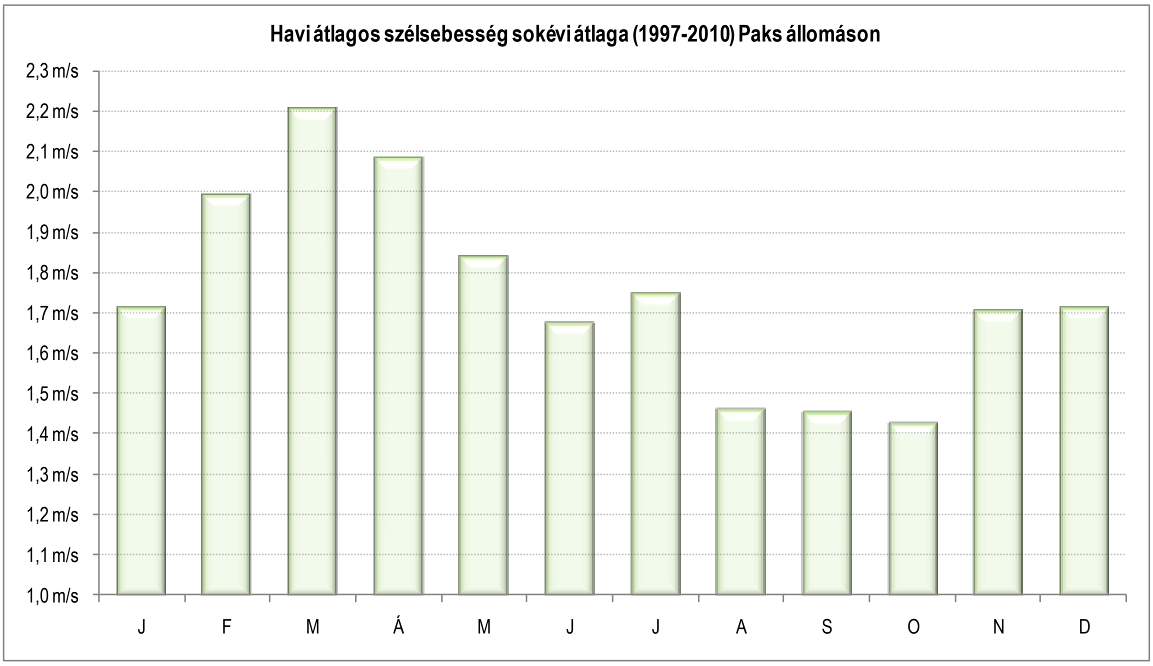
The chart in Figure 10.2.9-7 presents the annual average wind speeds at the Paks station, starting from 1997. While values around 1.92m/s could be observed at the start of the period, observations from recent years were between 1.6-1.7m/s on average, in other words, a decreasing trend is characteristic of annual average wind speed in the 1997-2010 period. The natural instability of the climate is the probable reason for this decrease in wind speed. It can also be observed in timelines from Baja, and in part from Tevel and Soltvadkert.



Évi átlagos szélsebesség Paks állomáson – Annual average wind speed at the Paks station

Figure 10.2.9-7: Annual average wind speeds [m/s] between 1997-2010, and the multi-annual average (1997-2010) at the Paks station

Regarding average annual progression, the highest wind speed values can be observed during March-April, while the lowest ones in the period between August-October (Figure 10.2.9-8).



Havi átlagos szélsebességek sokévi átlaga (1997-2010) Paks állomáson – Multi-annual (1997-2010) average of monthly average wind speeds at the Paks station

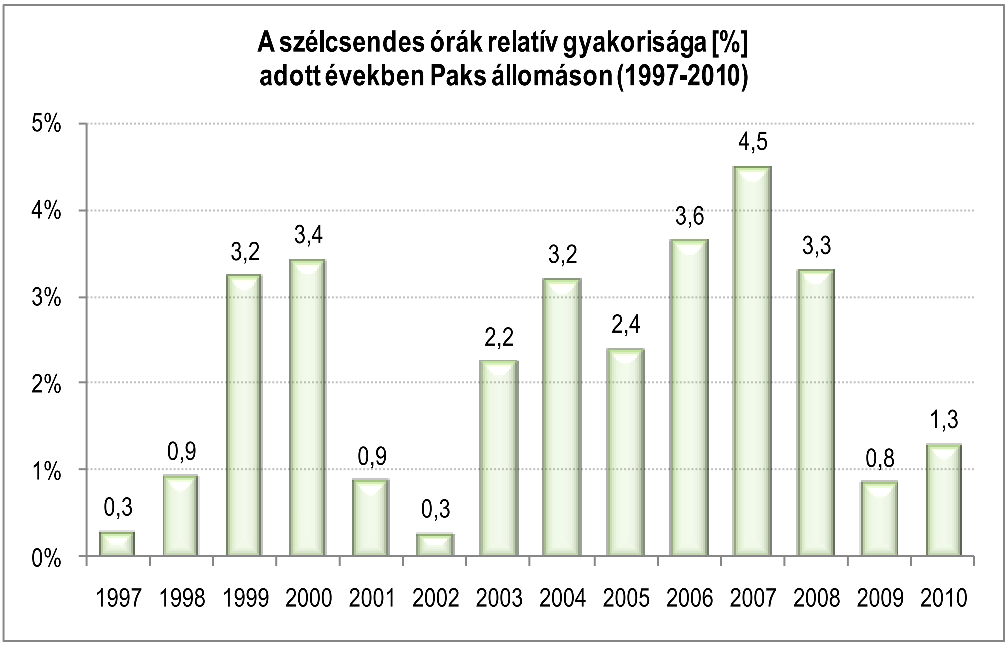
Figure 10.2.9-8: Multi-annual average (1997-2010) of monthly average wind speeds [m/s] at the Paks station

The next table (Table 10.2.9-1) contains monthly average wind speeds for years 1997-2010. The lowest monthly value was 1.1m/s in this period, that was the average wind measured in September 2006, as well as in October 2004, 2005, and 2006. April 1997 was the windiest month, when the monthly average wind speed turned out to be 3.1m/s.

Monthly average wind speeds [m/s]														
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
January	1.6	1.9	1.7	2.1	1.9	1.8	1.6	1.9	2.0	1.4	2.0	1.4	1.3	1.4
February	2.2	2.2	2.4	2.1	2.4	2.1	1.5	2.3	1.7	1.6	1.8	1.7	2.2	1.7
March	2.3	2.7	2.2	2.5	2.3	2.2	1.8	2.0	1.9	2.2	1.9	2.2	2.5	2.2
April	3.1	2.5	2.1	2.2	2.3	2.2	2.5	1.8	2.0	1.9	1.5	2.0	1.5	1.6
May	2.6	1.9	1.9	1.6	2.1	1.9	1.8	1.9	1.7	1.6	1.6	1.6	1.6	2.0
June	1.8	1.9	1.8	1.8	2.2	1.8	1.5	1.4	1.7	1.4	1.4	1.4	1.7	1.7
July	2.2	2.0	1.9	2.3	1.8	1.9	1.8	1.6	1.4	1.2	1.7	1.7	1.6	1.4
August	1.8	1.7	1.2	1.5	1.4	1.7	1.4	1.5	1.3	1.5	1.5	1.4	1.4	1.2
September	1.6	1.9	1.3	1.5	1.8	1.7	1.5	1.2	1.2	1.1	1.5	1.5	1.3	1.3
October	1.8	1.7	1.8	1.5	1.2	1.9	1.7	1.1	1.1	1.2	1.2	1.1	1.5	1.2
November	1.9	1.9	2.2	1.7	2.1	1.7	1.4	2.1	1.2	1.7	1.7	1.4	1.5	1.4
December	2.2	1.8	2.3	1.5	1.6	1.7	1.8	1.4	1.8	1.2	1.3	1.9	1.6	1.9

Table 10.2.9-1: Monthly average wind speeds [m/s] in the period between 1997-2010 at the Paks station

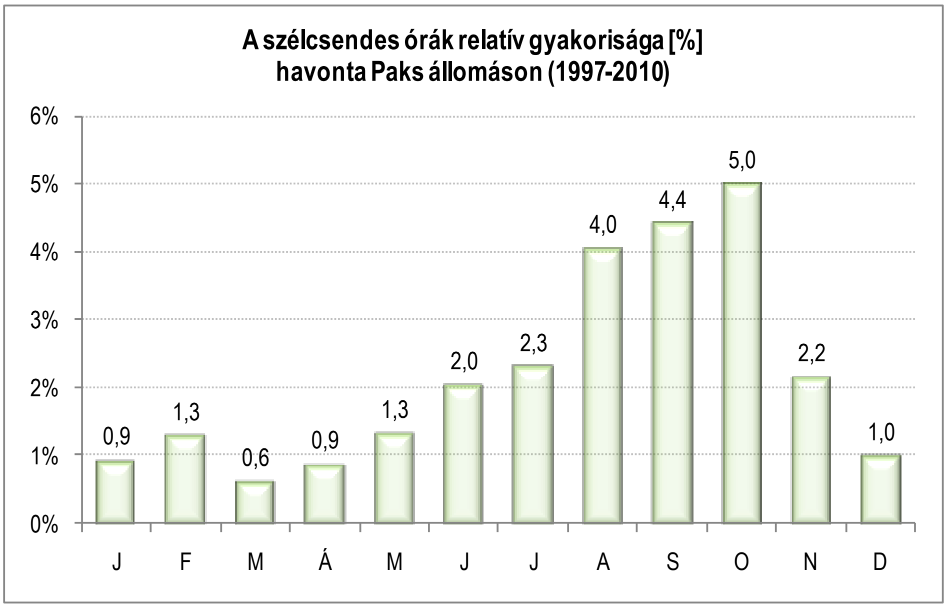
Winds are calm for 2.2% of the year, but fluctuation among years is quite large; for instance, this was only true for 0.3% in 2002, but stood at 4.5% in 2007 (Figure 10.2.9-9).



A szélcsendes órák relatív gyakorisága [%] adott években Paks állomáson (1997-2010) – The relative frequency of hours with calm winds [%] during the given years at the Paks station (1997-2010)

Figure 10.2.9-9: The relative frequency of hours with calm winds [%] by year at the Paks station (1997-2010)

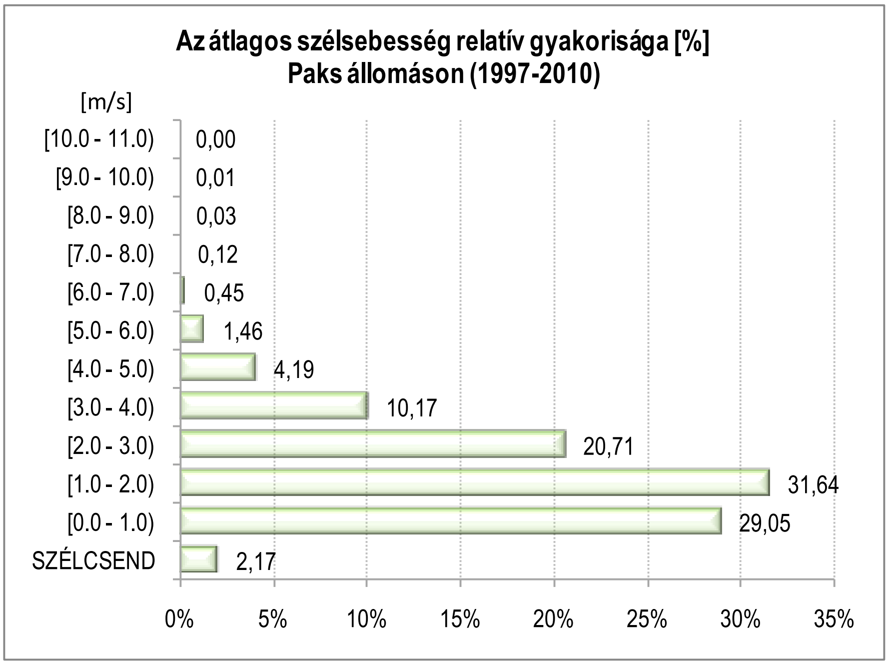
In terms of the monthly distribution of hours with calm winds we can state (Figure 10.2.9-10) that weather with no wind can be expected at the end of the summer and the beginning of autumn (August-October) with the greatest likelihood, and least frequently during early spring (March-April).



A szélcsendes órák relatív gyakorisága [%] havonta Paks állomáson (1997-2010) – The relative frequency of hours with calm wind [%] per month at the Paks station

Figure 10.2.9-10: Multi-annual average of the relative frequency of hours with calm winds [%] per month at the Paks station

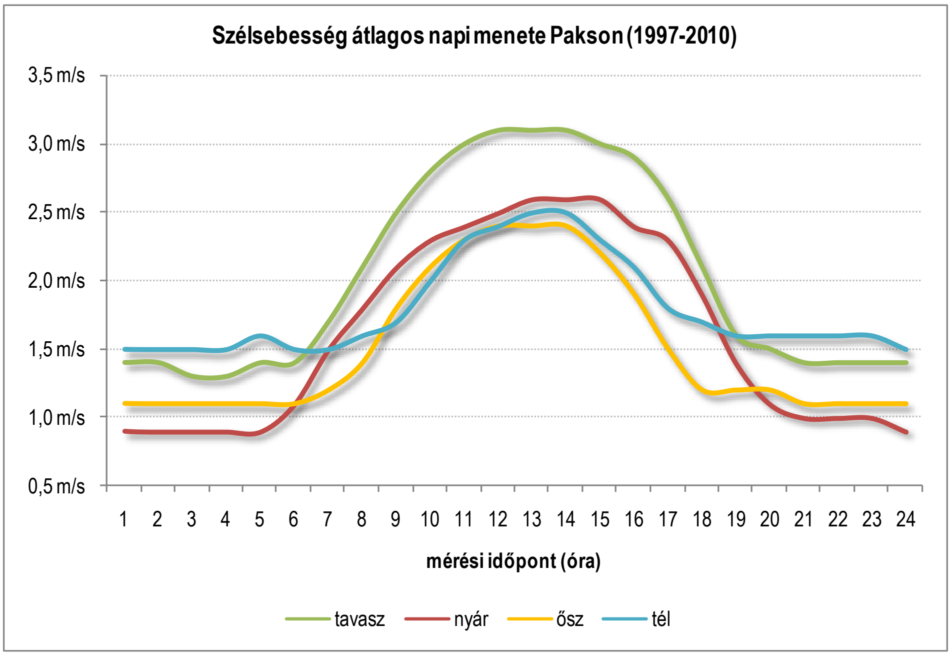
The relative frequency of average winds by speed were also examined (Figure 10.2.9-11), based on which one may state that winds between 1.1-2m/s blow most frequently, followed by the 0.1-1m/s, then the 2.1-3m/s range. Wind speeds between 5.1-6m/s occur at a lower percentage, and those above 6m/s quite seldom.



Az átlagos szélsebesség relatív gyakorisága [%] Paks állomáson (1997-2010) – The relative frequency of average wind speed [%] at the Paks station (1997-2010)
SZÉLCSEND – CALM WIND

Figure 10.2.9-11: The relative frequency of average wind speed [%] at the Paks station (1997-2010)

Figure 10.2.9-12 presents the average daily progression of wind speed broken down by seasons. One may see that wind speed is greater during daytime hours than at night, as well as evening and morning hours. The highest speeds usually occur between 1 and 2 PM, while the lowest values can be expected between midnight and 5 AM. The daily fluctuation of wind speeds is generally greatest at springtime (1.8 m/s), and lowest in winter (1 m/s).



Szélsebesség átlagos napi menete Pakson (1997-2010) – Daily progression of wind speed at Paks (1997-2010)
mérési időpont (óra) – time of measurement (o'clock)
tavasz – spring
nyár – summer
ősz – autumn
tél – winter

Figure 10.2.9-12: Daily average progression (1997-2010) of wind speed [m/s] at the Paks station

10.2.9.3 Maximum wind gusts

Aside from average wind speed, wind observations also extend to cover determining the strength of wind gusts. The table below presents the development of maximum wind gusts during the years between 1997-2010, broken down by months (Table 10.2.9-2). The strongest gust of 24.8m/s in the period was registered on 19 November 2004. This, however, did not exceed the absolute maximum measured to date: 31.6 m/s (3 February 1985). Maximum wind gusts in October 2009 (21.2m/s) and November 2004 (24.8m/s), however, did exceed the highes values for October and November during the period before 1997.

Monthly maximum wind gusts [m/s]														
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
January	13.6	13.5	16.5	20.1	15.3	16.8	13.3	14.9	15.1	17.6	21.6	19.7	10.1	17.2
February	19.5	23.7	14.9	17.4	18.2	15.4	15.3	17.7	12.1	13.9	19.5	14.8	16.3	18.1
March	18.5	21.6	13.5	20.1	16.0	19.8	17.7	15.6	15.4	17.7	16.2	18.8	20.1	15.4
April	22.5	19.2	14.4	18.4	19.2	14.0	20.5	15.8	14.0	16.5	15.5	18.0	17.0	14.5
May	17.6	16.0	15.3	17.6	18.8	15.5	14.9	15.1	17.6	15.0	19.5	13.0	14.4	21.9
June	18.3	17.7	19.1	14.5	18.0	17.1	14.2	18.5	14.4	19.3	17.3	17.2	17.3	16.4
July	19.4	16.3	13.4	18.6	13.1	14.6	17.9	13.8	12.1	18.0	17.0	14.4	15.6	13.5
August	24.0	13.3	15.9	14.9	14.2	15.1	21.0	13.4	14.7	15.7	16.9	18.7	13.6	18.6
September	19.2	13.1	12.0	15.5	16.1	11.5	14.1	15.2	12.7	11.4	14.0	20.1	15.4	16.5
October	16.7	15.7	12.2	11.6	9.8	20.4	19.8	12.0	11.2	19.4	14.9	13.0	21.2	14.4
November	14.7	13.8	11.8	12.2	16.5	14.9	11.3	24.8	13.1	16.1	15.7	14.9	11.9	13.0
December	15.9	14.5	13.3	10.8	13.0	12.8	19.3	14.2	14.6	10.7	13.6	18.3	12.4	18.7

Table 10.2.9-2: Maximum wind gusts by month (1997-2010) at the Paks station

10.2.9.3.1 Relative frequency of maximum wind speeds

Table 10.2.9-3 shows the relative frequency of maximum wind gusts by wind speed and wind direction, in the annual timeframe. Regarding frequency by direction, the direction of maximum wind gusts is northwest in most cases, followed by the southerly, then the north-northwest directions. Looking at speed, wind gusts between 2-4m/s occur most of the time, but those between 1-2m/s and 4-6m/s are also common. Wind speeds exceeding 12m/s only occur at in lower proportion during the year, and those exceeding 17m/s only seldom.

Relative frequency of maximum wind speed by wind direction (%)																		
v (m/s)	**Calm wind**	**N**	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**	**S**	**SSW**	**SW**	**WSW**	**W**	**WNW**	**NW**	**NNW**	**Total**
[0.0 to 0.1)																		0.769
[0.1 to 1.0)		0.179	0.303	0.211	0.033	0.044	0.042	0.252	0.192	0.273	0.158	0.461	0.195	0.267	0.338	0.612	0.185	3.745
[1.0 to 2.0)		0.675	1.279	0.784	0.111	0.236	0.303	1.367	1.029	1.312	0.637	1.242	0.644	0.964	0.821	1.787	1.196	14.385
[2.0 to 3.0)		0.626	1.101	1.328	0.383	0.684	0.684	1.743	1.251	2.123	0.855	1.166	0.756	1.163	0.748	1.576	1.242	17.428
[3.0 to 4.0)		0.478	1.152	1.560	0.529	0.879	0.649	1.291	1.010	2.241	0.869	1.196	0.624	0.971	0.751	1.280	0.937	16.419
[4.0 to 5.0)		0.385	0.860	1.344	0.524	0.811	0.494	0.927	0.748	1.518	0.647	0.969	0.489	0.739	0.594	1.214	0.783	13.045
[5.0 to 6.0)		0.401	0.674	1.048	0.436	0.491	0.218	0.654	0.447	1.092	0.535	0.689	0.394	0.667	0.543	1.201	0.823	10.314
[6.0 to 7.0)		0.290	0.477	0.638	0.225	0.204	0.135	0.366	0.259	0.723	0.369	0.482	0.259	0.433	0.392	1.150	0.704	7.106
[7.0 to 8.0)		0.253	0.301	0.371	0.128	0.106	0.072	0.220	0.172	0.405	0.241	0.362	0.171	0.327	0.320	0.922	0.784	5.155
[8.0 to 9.0)		0.192	0.195	0.193	0.074	0.060	0.032	0.160	0.051	0.229	0.132	0.250	0.118	0.222	0.237	0.818	0.631	3.593
[9.0 to 10.0)		0.100	0.125	0.109	0.033	0.012	0.011	0.072	0.040	0.109	0.077	0.178	0.083	0.134	0.190	0.688	0.551	2.512
[10.0 to 11.0)		0.079	0.074	0.095	0.014	0.007	0.007	0.044	0.018	0.028	0.035	0.130	0.058	0.088	0.148	0.538	0.440	1.803
[11.0 to 12.0)		0.051	0.030	0.040	0.007	0.007	0.011	0.019	0.009	0.004	0.011	0.086	0.047	0.060	0.086	0.470	0.376	1.314
[12.0 to 13.0)		0.042	0.021	0.018	0.002	0.002		0.004	0.005	0.002	0.011	0.049	0.021	0.051	0.063	0.315	0.255	0.860
[13.0 to 14.0)		0.025	0.009	0.009				0.002	0.002	0.005	0.004	0.026	0.019	0.012	0.056	0.227	0.185	0.580
[14.0 to 15.0)		0.021	0.005	0.009			0.002		0.002			0.019	0.021	0.011	0.016	0.150	0.120	0.375
[15.0 to 16.0)		0.009	0.002									0.009	0.005	0.011	0.016	0.090	0.090	0.230
[16.0 to 17.0)		0.005	0.004	0.002								0.004	0.002	0.002	0.011	0.090	0.040	0.158
[17.0 to 18.0)			0.004	0.002								0.002	0.002	0.004	0.002	0.049	0.023	0.086
[18.0 to 19.0)												0.004	0.004	0.002	0.004	0.018	0.025	0.055
[19.0 to 20.0)														0.002		0.019	0.016	0.037
[20.0 to 21.0)		0.002										0.002		0.002		0.007	0.007	0.019
[21.0 to 22.0)														0.004		0.002	0.002	0.007
[22.0 to 23.0)															0.002			0.002
[23.0 to 24.0)																0.002		0.002
[24.0 to 25.0)																	0.002	0.002
Total	**0.769**	**3.815**	**6.613**	**7.762**	**2.501**	**3.542**	**2.659**	**7.120**	**5.233**	**10.062**	**4.580**	**7.326**	**3.912**	**6.131**	**5.338**	**13.223**	**9.415**	**100.000**

Table 10.2.9-3: The relative frequency [%] maximum wind gust by speed and direction at the Paks station (1997-2010)

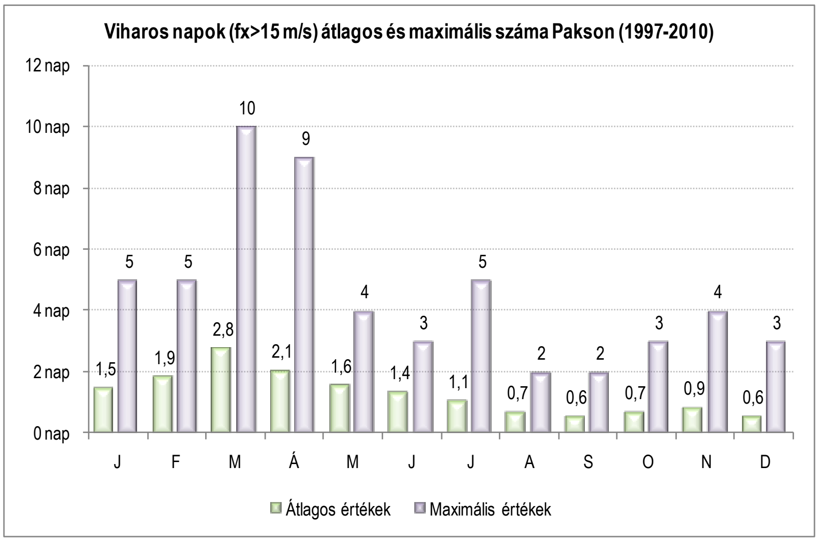
10.2.9.3.2 Return values of maximum wind gusts

In addition to frequency values, the 2, 4, 5…, 100 000 yearly return periods of maximum wind gusts were also determined (with Gumbel's statistical method). Based on that one may see that a gale force wind speed of 20m/s can be expected every two years on average in the vicinity of Paks, that of 24m/s magnitude—which counts as strong gale—can occur approximately once every 10 years, winds of 30m/s once every 500 years on average, while 34-35m/s hurricane strength winds just once every 5 000 years (Table 10.2.9-4).

Maximum wind gust return values shown as a Gumbel distribution	
Return period (years)	Maximum wind gust [m/s]
2	20.7
4	22.2
5	22.6
10	23.9
20	25.1
50	26.7
100	27.9
200	29.1
500	30.7
1,000	31.8
2,000	33.0
5,000	34.6
10,000	35.8
20,000	36.9
100,000	39.6

Table 10.2.9-4: The Gumbel distribution of maximum wind gust return values in respect of the Paks station (based on data from 1981-2010)

Days when the maximum wind gust exceeds 15m/s are called moderate gale days. Figure 10.2.9-13 shows the average and maximum number of such days per month for the period between 1997-2010 at the Paks station. Moderate gale force winds can usually be observed most often in March (3 days), and they also appear in the months of January-February and April-May on an average of 2 days each. The greatest number of days with moderate gale force winds was measured in March 2000.



Viharos napok (fx>15 m/s) átlagos és maximális havi száma Pakson (1997-2010) – Average and maximum monthly number of days with moderate gale force winds (fx>15m/s) in Paks (1997-2010)
Átlagos értékek – Average values
Maximális értékek – Maximum values
… nap – … days

Figure 10.2.9-13: Average and maximum monthly number of days with moderate gale force winds (1997-2010) at the Paks station

10.2.9.4 Atmospheric stability conditions

The relative frequency of synoptic wind speed and wind direction according to the Pasquill Index concerning the Paks station at annual level (1997-2010)

The relative frequency of synoptic wind speed and wind direction according to the Pasquill Index																			
	P.I.	Calm wind / variable	N	NNE	NE	**ENE**	**E**	**ESE**	**SE**	**SSE**	**S**	**SSW**	**SW**	**WSW**	**W**	**WNW**	**NW**	**NNW**	**Total**
[0.0 to 0.1)	A	0.0																	0.0
	B	0.1																	0.1
	C	0.1																	0.1
	S	0.6																	0.6
	E	0.6																	0.6
	F	3.7																	3.7
[0.1 to 1.1)	A		0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9
	B		0.1	0.0	0.1	0.1	0.2	0.1	0.2	0.0	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	1.5
	C		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	1.3
	S		0.7	0.3	0.3	0.2	0.2	0.3	0.3	0.4	0.3	0.3	0.3	0.4	0.6	0.7	0.7	0.6	6.8
	E		0.5	0.5	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.4	3.6
	F		1.3	1.1	0.5	0.2	0.2	0.1	0.5	0.7	0.7	0.6	0.8	0.8	0.6	1.0	1.1	1.4	11.5
[1.1 to 2.1)	A		0.2	0.3	0.5	0.5	0.3	0.3	0.4	0.3	0.2	0.2	0.2	0.1	0.2	0.1	0.1	0.1	4.0
	B		0.3	0.3	0.6	0.5	0.3	0.4	0.5	0.4	0.3	0.3	0.2	0.2	0.3	0.3	0.3	0.3	5.6
	C		0.2	0.3	0.2	0.3	0.2	0.3	0.4	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.4	0.3	4.1
	S	0.0	0.7	0.5	0.5	0.4	0.3	0.3	0.5	0.6	0.6	0.3	0.2	0.6	0.7	0.9	1.1	1.1	9.3
	E		0.2	0.2	0.2	0.0	0.0	0.1	0.2	0.3	0.4	0.1	0.1	0.1	0.1	0.1	0.2	0.3	2.8
	F		0.3	0.4	0.2	0.1	0.0	0.0	0.1	0.3	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.3	3.3
[2.1 to 3.1)	A		0.2	0.3	0.3	0.2	0.0	0.0	0.1	0.2	0.4	0.2	0.1	0.1	0.2	0.1	0.1	0.1	2.7
	B		0.4	0.3	0.6	0.2	0.1	0.1	0.3	0.4	0.5	0.4	0.4	0.2	0.4	0.2	0.5	0.4	5.4
	C		0.3	0.3	0.3	0.1	0.1	0.1	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.5	0.5	4.1
	S		0.6	0.4	0.7	0.2	0.1	0.1	0.2	0.2	0.5	0.3	0.3	0.4	0.3	0.5	1.1	0.9	6.7
	E		0.0	0.1	0.1	0.0			0.0	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.7
	F		0.0	0.0	0.1	0.0	0.0		0.0	0.0	0.2	0.1	0.1	0.0	0.0		0.0	0.0	0.7
[3.1 to 5.1)	A		0.0	0.2	0.0				0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.9
	B		0.3	0.4	0.3	0.1		0.0	0.1	0.2	0.8	0.6	0.5	0.3	0.1	0.1	0.3	0.4	4.6
	C		0.5	0.3	0.2	0.1		0.1	0.3	0.1	0.4	0.2	0.2	0.2	0.1	0.3	0.7	0.6	4.0
	S		0.5	0.4	0.2	0.1	0.0	0.0	0.2	0.2	0.4	0.5	0.2	0.3	0.2	0.5	1.7	1.4	6.9
	E			0.0	0.0					0.0	0.0	0.0	0.0	0.0	0.0		0.0		0.2
	F		0.0	0.0	0.0						0.0	0.0	0.0	0.0	0.0				0.1

The relative frequency of synoptic wind speed and wind direction according to the Pasquill Index																			
	P.I.	Calm wind / variable	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total
[5.1 to 7.1)	A			0.0								0.0							0.0
	B		0.0	0.0	0.0						0.0	0.1	0.1	0.0				0.0	0.3
	C		0.0	0.0	0.0	0.0	0.0		0.0		0.0	0.1	0.2	0.1		0.0	0.1	0.1	0.7
	S		0.0	0.1	0.0				0.0	0.0	0.0	0.1	0.1	0.2	0.1	0.1	0.7	0.4	1.8
	E												0.0						0.0
	F												0.0						0.0
[7.1 to 10.1)	A												0.0						0.0
	B												0.0	0.0					0.0
	C											0.0	0.0	0.0					0.0
	S		0.0	0.0		0.0						0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.3
	E																		
	F																		
[10.1 to 13.1)	A																		
	B																		
	C																		
	S												0.0				0.0	0.0	0.0
	E																		
	F																		
Total		**5.1**	**7.5**	**6.8**	**6.3**	**3.6**	**2.2**	**2.6**	**4.9**	**5.0**	**7.5**	**5.5**	**4.9**	**5.1**	**4.8**	**5.9**	**10.3**	**9.9**	**100.0**

Note:

P.I. – Pasquill Stability Indices
A – Extremely unstable
B – Unstable
C – Slightly unstable
D – Neutral stability
E – Slightly stable
F – Extremely stable

Table 10.2.9-5: The relative frequency [%] of synoptic wind speed and wind direction according to the Pasquill Index at the Paks station at annual level (1997-2010)

10.3 MICRO AND MESOCLIMATE IN THE ENVIRONMENT OF THE ENVISAGED SITE OF OPERATIONS

10.3.1 ANALYSIS OF DATA FROM THE FOUR WEATHER STATIONS IN THE ENVIRONMENT OF THE ENVISAGED SITE OF OPERATIONS

The Hungarian Meteorological Service (OMSZ) conducted the profiling of the envisaged site of operations by analysing data measured between 1 April 2012 and 30 November 2013 at four weather stations, OMSZ's Paks station, which has been in operation since 1979, as well as three additional t temporary weather stations that were deployed in the scope of the Lévai Project.

The customary measurement and data acquisition procedures were also applied at the 3 temporarily deployed stations, thereby ensuring the comparability of data.

Locations of the weather station under consideration

- Paks station, approx. 300m to the W of the Nuclear Power Plant's south entrance
- Paks, Boathouse ("Csónakház"), approx. 1km to the NE of the Nuclear Power Plant's grounds, on the right bank of the Danube
- Paks, Gesztenyés utca ("Gesztenyés Street"), approx. 4km to the N-NW of the Nuclear Power Plant's grounds, on the western limits of Paks
- Uszód, Baráka Water Works, approx. 5km to the SE of the Nuclear Power Plant's grounds, on the left bank of the Danube

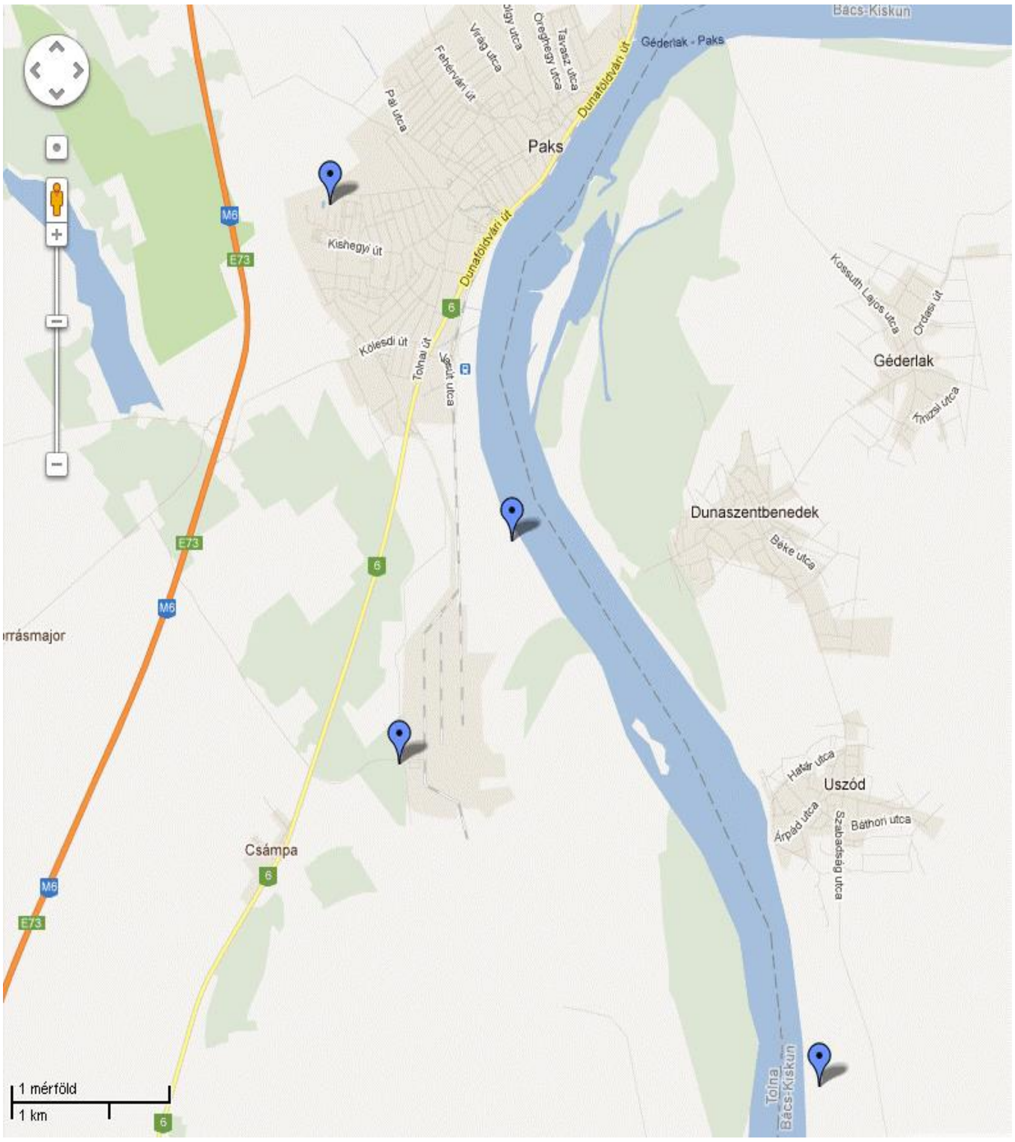


Figure 10.3.1-1: Automatic Weather Station mast locations

The following meteorological parameters were measured during measurements.

Measured element	Sampling frequency	Calculated data (projected to 10 minutes)	Stored value
Air pressure	1 minute	Average, minimum and maximum	Average
Wind speed	2 seconds	Maximum and its duration, average	Maximum and its duration, average
Wind direction	2 seconds	Maximum wind gust direction, average	Maximum wind gust direction, average
Air temperature	1 minute	Average, minimum and maximum	Average, minimum and maximum, momentary
Atmospheric humidity	1 minute	Average, minimum and maximum	Average

Table 10.3.1-1: Measured meteorological parameters

Data measured at the Paks station in the April 2012 to March 2013 period was first correlated with the 1981-2010 average values that were described earlier, then the 4 weather stations' one year (April 2012 to March 2013), as well as 8 month (April 2013 to November 2013) data series were compared with one another.

In part, these examinations permit determining the extent to which the period under consideration deviates from the average conditions, moreover whether or not any material weather difference can be detected in the surroundings of the Paks Nuclear Power Plant.

10.3.1.1 Comparison of data from the Paks weather station for the period between 1 April 2012 and 30 November 2013 with the multi-annual average

As introduction, we are goint to provide a brief overview of how the weather shaped-up around Hungary in the period between April 2012 and March 2013. Regarding nationwide conditions, the period designated for examination counts as extraordinary from multiple aspects. These 12 months were rich in both temperature and precipitation extremes.

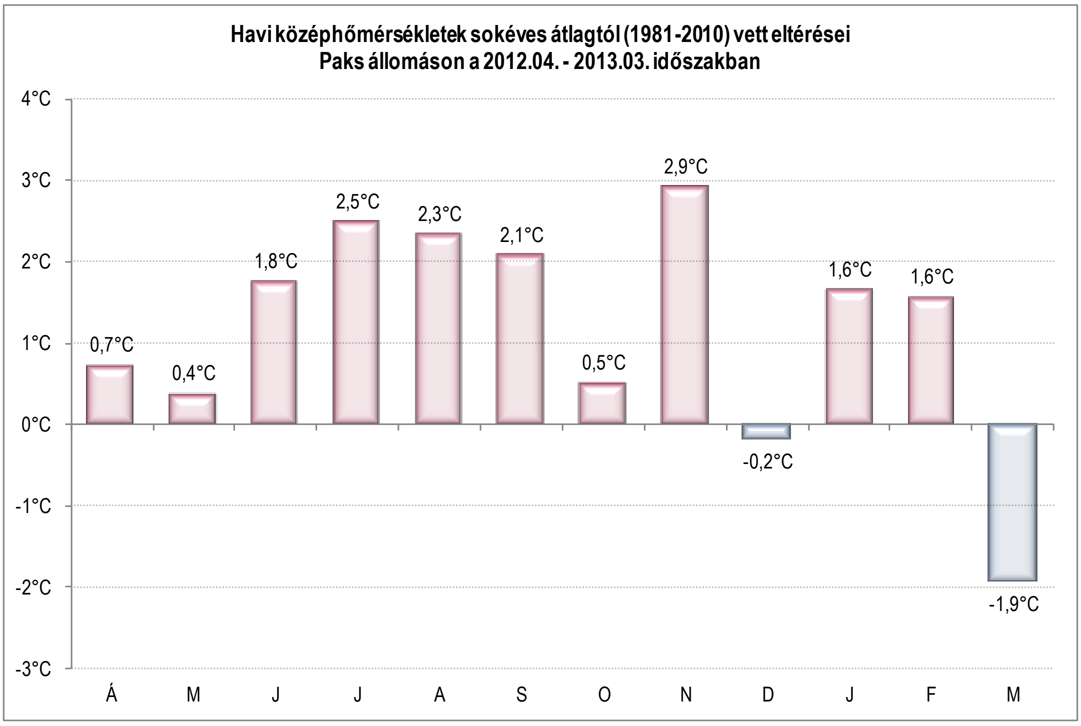
The nationwide average temperature developed way above the multi-annual average in every month, with the exception of two months—December 2012 and March 2013. The greatest anomaly (+3.1 °C) was recorded in November, but differences worthy of mentioning also occurred during the summer months. After the 9th warmest spring, June and August turned out to be the 4th warmest June and August since the timeline began in 1901, while July was the hottest July on record to date. All in all, the summer period in 2012 is considered to be the 2nd hottest summer over the past 112 years. This trend was also left unbroken by autumn average temperatures; the 4th warmest autumn was recorded since 1901, and the winter of 2012/13 occupies a place in the top tertile (33rd). At the same time, the mean temperature of March 2013 is notable, as it was 2.2 °C colder than usual in terms of the nationwide average.

In terms of precipitation conditions, one can find examples of both extremes. A large part of 2012 can be characterised by extraordinary aridity, with two months topping the list that has been recorded since 1901: just 6% of the multi-annual average fell in March 2012 (2mm), while August saw 14% (7.6mm) of the usual amount, making these two months the driest March and August from the last 112 years. Through to October, there were but two months that reached the customary values. A change, however, set in beginning with October, and the country had to struggle with an immense amount of extra precipitation from December. The winter of 2012/13 was the 4th wettest winter in Hungary since 1901, more than two and a half times the usual amount fell in February. The greatest incremental, however, can be linked to March 2013: nationwide average total precipitation was 345% of normal, which is extraordinary even reflecting upon last year, and in terms of how flooding developed.

10.3.1.1.1 Temperature

During the period under consideration, every month but two can be characterised with a positive temperature anomaly relative to the thirty year average (Figure 10.3.1-2*)*. The values from between 1981-2010 were exceeded most by the mean temperature for November: All in all, November 2012 was 2.9 °C warmer than usual at the Paks station. One can also see a positive deviation above a degree and a half between June and September 2012, moreover in the first two months of year 2013. The weather was cooler than average in December 2012, yet a significant negative anomaly can be seen in March 2013: the first month of spring proved 1.9 °C colder than usual.

The development of mean temperature anomalies was consistent with the average nationwide trends in every month of the period under consideration. In most months, conditions that were a few tenths of a degree warmer relative to the nationwide average were typical for the area.



Havi középhőmérsékletek sokéves átlagtól (1981-2010) vett eltérései Paks állomáson a 2012.04–2013.03. időszakban – Deviations of monthly mean temperatures from the multi-annual average (1981-2010) at the Paks station in the 04/2012–03/2013 period

Figure 10.3.1-2: Deviations of monthly mean temperatures from the multi-annual average (1981-2010) at the Paks station in the 04/2012–03/2013 period

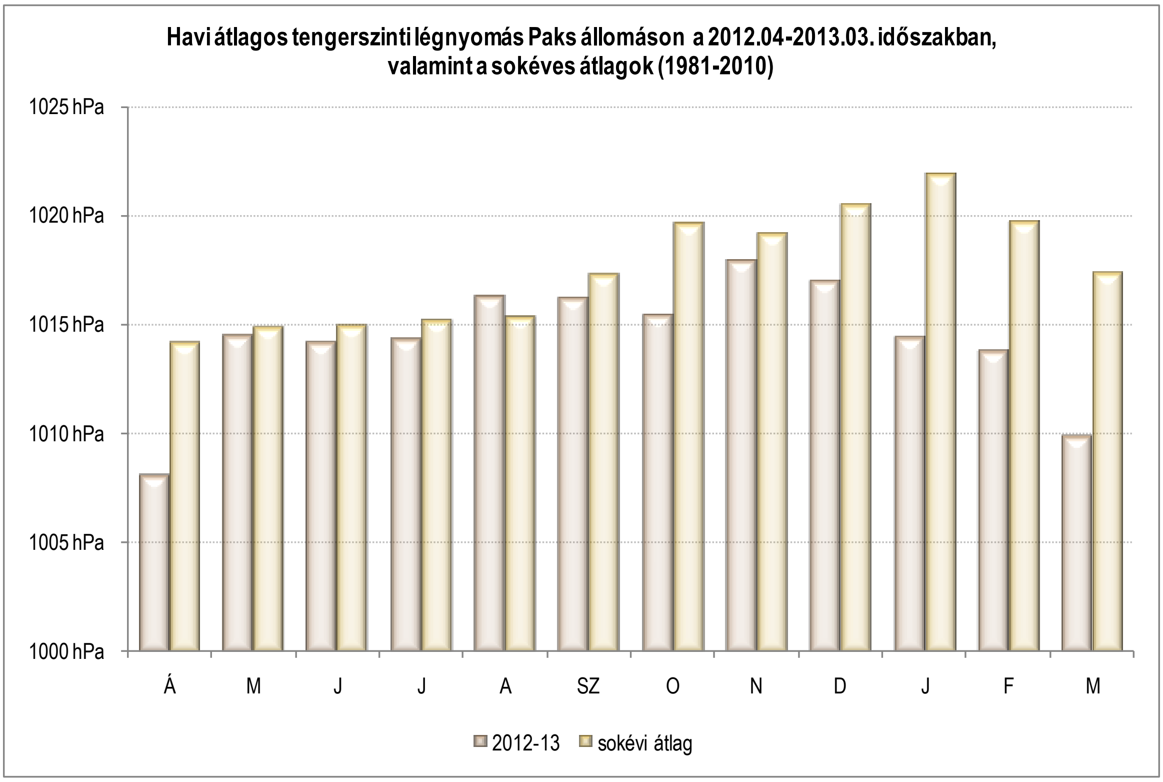
One can talk about summer, hot or sweltering days if the daily temperature peak value reaches or exceeds 25°C, 30°C or 35°C respectively. The development of the number of these threshold days can be seen in Table 10.3.1-2 concerning the Paks station. The impression during the selected period is clearly one of warmer conditions in each category. The biggest deviation in the number of summer days can be seen in September, 18 days of the usual 11 met this criterion. Regarding hot days, the greatest difference can be observed in August, 10 days more than normal were registered. Significantly more than the average sweltering days were noted in two summer months, July and August; there were seven more than usual for both months. All in all, July and August brought the most hot threshold days.

	Number of summer days (Tmax≥25°C		Number of hot days (Tmax≥30°C		Number of sweltering days (Tmax≥35°C	
	2012	Average for 1981-2010	2012	Average for 1981-2010	2012	Average for 1981-2010
April	5	2	3	0	0	0
May	13	11	4	2	0	0
June	21	18	11	6	1	1
July	30	25	18	12	8	1
August	29	24	21	11	9	2
Septembe	18	11	8	1	0	0
October	0	2	0	0	0	0

Table 10.3.1-2: The number of summer days, hot days and sweltering days at the Paks station during the 04/2012–03/2013 period, along with multi-annual averages (1981-2010)

10.3.1.1.2 Air pressure

Based on the multi-annual average (Figure 10.3.1-3*),* sea level pressure is lowest during April in the vicinity of Paks, and this was also fulfilled in the period under consideration (1008.0hPa). At the same time, the highest average was not registered in January, rather in November 2012 (1017.9hPa), which was unlike the usual progression. The January value (1014.4hPa) is even exceeded by six months: May, August, September, October, as well as the aforesaid November and December. The greatest deviation relative to the multi-annual average can be seen in January and March: mean sea level pressure was 7.5hPa lower than usual in both of these months. August 2012 was the only month when sea level pressure exceeding the thirty year average was registered.

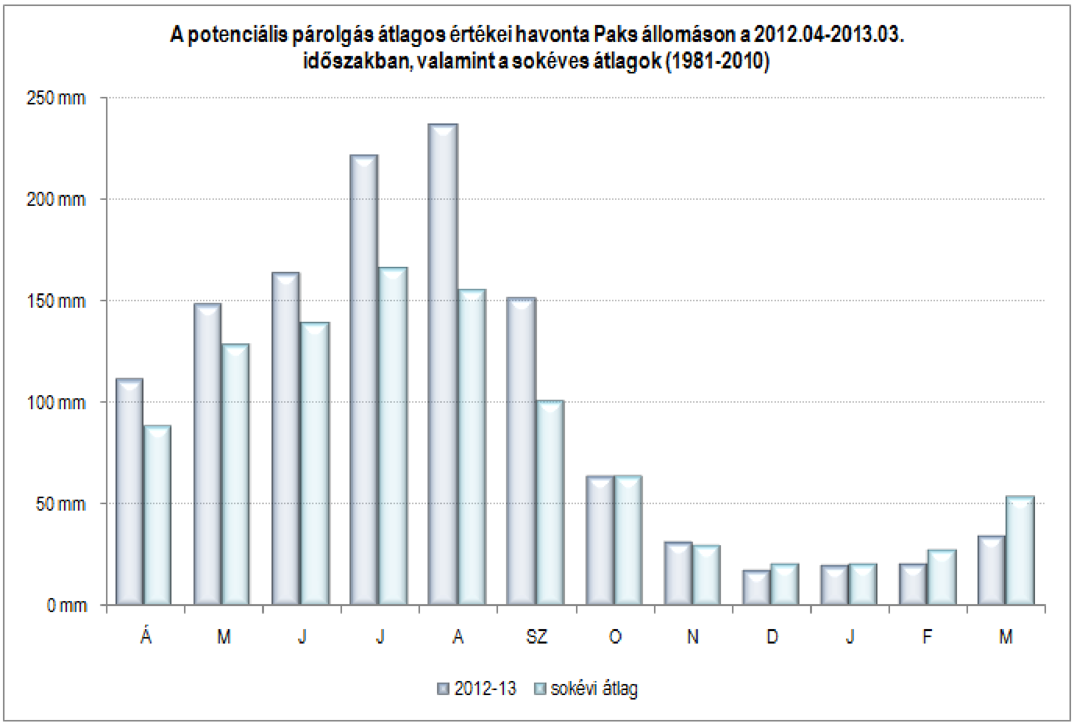


Havi átlagos tengerszinti légnyomás Paks állomáson a 2012.04–2013.03. időszakban, valamint a sokéves átlagok (1981-2010) – Monthly mean sea level pressure at the Paks station during the 04/2012–03/2013 period, along with multi-annual averages (1981-2010)
sokévi átlag – multi-annual average

Figure 10.3.1-3: Monthly mean sea level pressure at the Paks station during the 04/2012–03/2013 period, along with multi-annual averages (1981-2010)

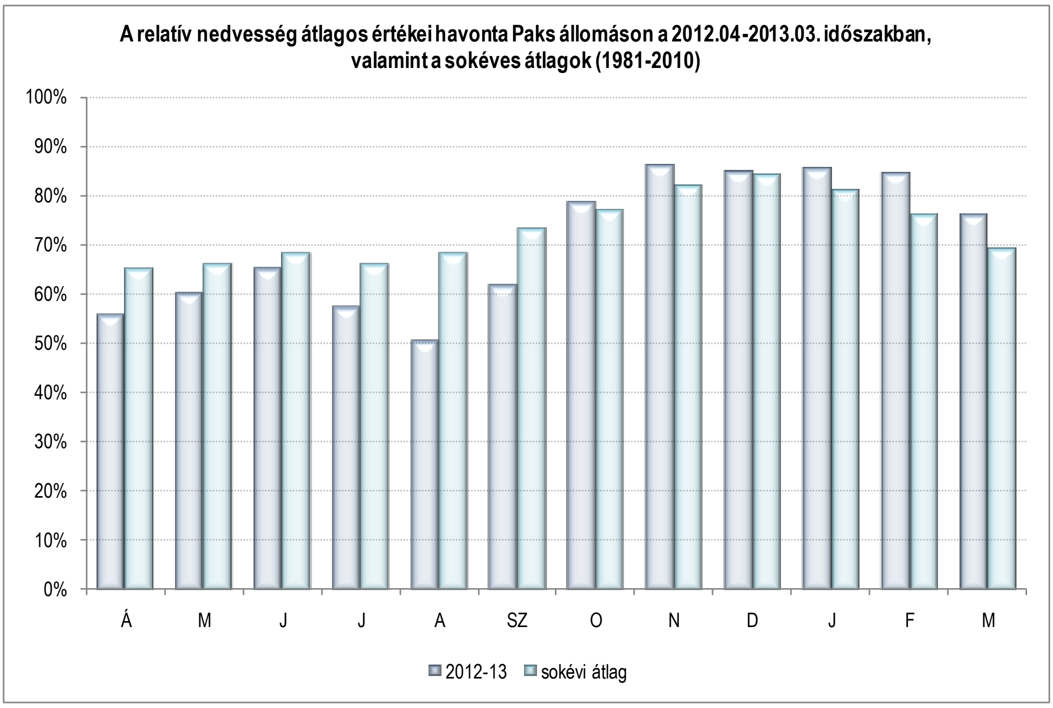
10.3.1.1.3 Atmospheric humidity

The chart about the monthly average potential evaporation values *(*Figure 10.3.1-4*)* shows that in spring and summer 2012, significantly higher values than the multi-annual average were given as the result. In nationwide terms, this period was dryer and considerably hotter than normal, and that was also the case in the vicinity of Paks. Atmospheric humidity was lower in every month in this period at Paks, and this combines with some months that were close to 2.5 °C warmer; all of this together resulted in the atmosphere becoming drier, in other words, the absorption of a lot more evaporation than the average became possible. The period between October-January shaped-up close to the average in terms of potential evaporation, then lower values than the normal from 1981-2010 were registered during the much wetter and partly cooler period in February and March. Lowest potential evaporation was noted in December during the period under consideration, and highest in August.



A potenciális párolgás átlagos értékei havonta Paks állomáson a 2012.04–2013.03. időszakban, valamint a sokéves átlagok (1981-2010) – Average potential evaporation values by month at the Paks station during the 04/2012–03/2013 period, along with multi-annual averages (1981-2010)
sokévi átlag – multi-annual average

Figure 10.3.1-4: Average potential evaporation values by month at the Paks station during the 04/2012–03/2013 period, along with multi-annual averages (1981-2010)



A relatív nedvesség átlagos értékei havonta Paks állomáson a 2012.04–2013.03. időszakban, valamint a sokéves átlagok (1981-2010) – Average relative humidity values by month at the Paks station during the 04/2012–03/2013 period, along with multi-annual averages (1981-2010)
sokévi átlag – multi-annual average

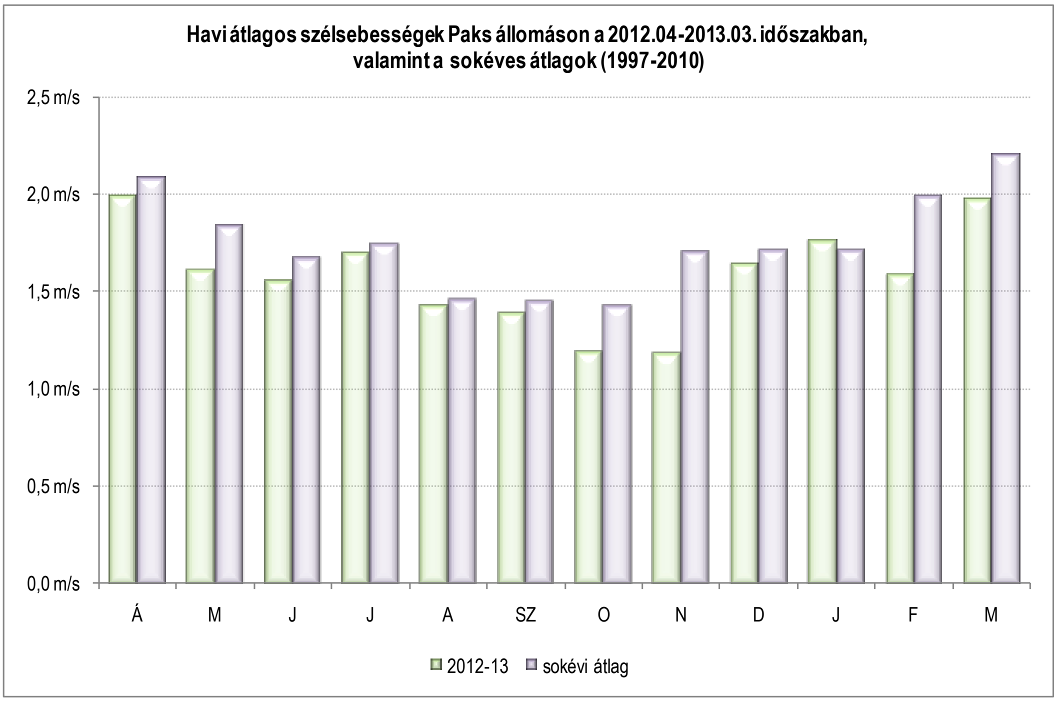
Figure 10.3.1-5: Average relative humidity values by month at the Paks station during the 04/2012–03/2013 period, along with multi-annual averages (1981-2010)

The ratio between relative humidity and the air's actual vapour pressure and saturation vapour pressure. Where water vapour content in the air is increased, vapour pressure no longer grows after a specified value is reached, condensation or precipitation forms instead; this is the saturation vapour pressure.

In the first half of the period under consideration, the relative humidity values that were seen at the Paks station were below average, and above it during the second half of the period. Based on the multi-annual average, relative humidity reaches the highest average value in December (84%), and the lowest on in April (65%). Both the minimum and the maximum were positioned differently during the designated period (Figure 10.3.1-5): The lowest value may be observed in August 2012, which is well below even the lowest multi-annual value (50.4%), while the highest average relative humidity appeared in November (85.9%). The greatest difference came about in the case of the August result: the parameter under review turned out 17.6% lower than normal.

10.3.1.1.4 Wind

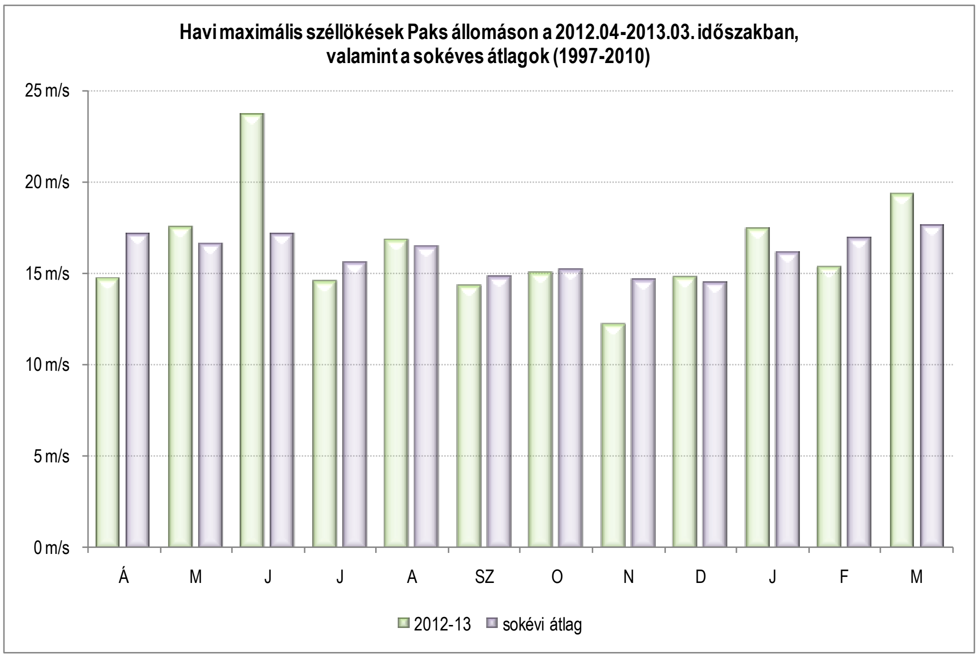
The progression of monthly average wind speeds was well aligned to the multi-annual average during period under consideration (Figure 10.3.1-6). Differences of 0-0.5m/s can be observed relative to the customary values (values below the average appeared in every month except January). Lowest average wind speed was noted in October and November (1.2m/s), and the highest in April 2012 and March 2013 (2.0m/s). The greatest deviation from normal can be observed in November, this month is characterised by average wind speed that is 0.5m/s lower than usual.



Havi átlagos szélsebességek Paks állomáson a 2012.04–2013.03. időszakban, valamint a sokéves átlagok (1997–2010) – Monthly average wind speeds at the Paks station during the 04/2012–03/2013 period, along with multi-annual averages (1997-2010)
sokévi átlag – multi-annual average

Figure 10.3.1-6: Monthly average wind speeds at the Paks station during the 04/2012–03/2013 period, along with multi-annual averages (1997-2010)

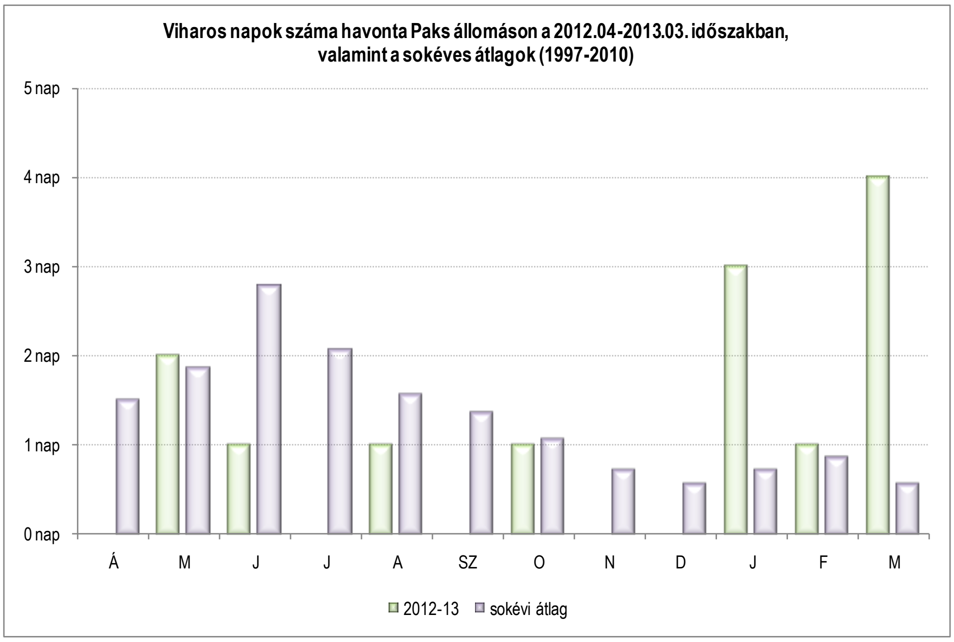
All in all one can say that similarly to average wind speed, monthly maximum wind gusts also developed around to the multi-annual averages with good approximation. There is one bigger deviation that can be observed (Figure 10.3.1-7) in June 2012, when a wind gust more than 6m/s greater than normal was also registered. The greatest maximum wind gust in the period is likewise linked to June: 23.7m/s. The lowest value was noted in November (12.2m/s), and this is also the month in which the greatest negative anomaly relative to the multi-annual average can be observed. Linking the minimum and maximum values to the customary months is not possible: based on the reference period, the highest value can usually be observed in March and the lowest in December, in contrast with this year.



Havi maximális széllökések Paks állomáson a 2012.04–2013.03. időszakban, valamint a sokéves átlagok (1997–2010) – Monthly maximum wind gusts at the Paks sokévi átlag – multi-annual average station during the 04/2012–03/2013 period, along with multi-annual averages (1997-2010)
sokévi átlag – multi-annual average

Figure 10.3.1-7: Monthly maximum wind gusts (the biggest gust of the respective month) at the Paks station during the 04/2012–03/2013 period, along with multi-annual averages (multi-annual average of monthly maximum wind gusts) (1997-2010)

The biggest deviation relative to the customary values for days with moderate gale force winds (Figure 10.3.1-8*)* can be seen in March 2013: exactly seven times the days met this criterion. The value for January also stands out, more than four times the normal one was noted. Unlike the multi-annual average, there were five months in which not a single day with moderate gale force wind was registered (April, July, September, November, December).



Viharos napok száma Paks állomáson a 2012.04–2013.03. időszakban, valamint a sokéves átlagok (1997–2010) – The number of days with moderate gale force winds at the Paks station during the 04/2012–03/2013 period, along with multi-annual averages (1997-2010)
sokévi átlag – multi-annual average

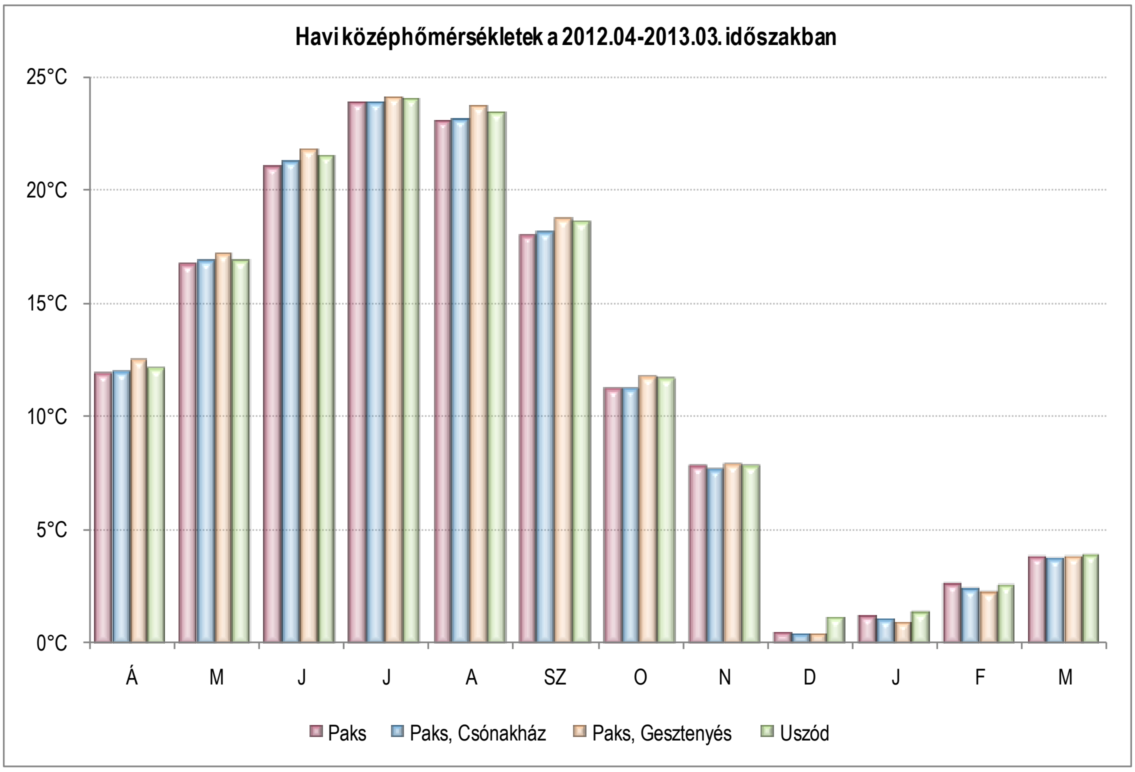
Figure 10.3.1-8: The number of days with moderate gale force winds per month at the Paks station during the 04/2012–03/2013 period, along with multi-annual averages (1997-2010)

10.3.1.2 Comparison of data from the four weather stations in Paks for the period between 1 April 2012 and 31 March 2013

10.3.1.2.1 Temperature

Monthly mean temperature trends from the four stations deployed at Paks and its vicinity are well aligned with one another, but the lesser climatological differences of the various measurement locations are also represented (Figure 10.3.1-9).

Regarding the overall period, average temperature (11.9 °C) at the Paks and Paks Boathouse stations were 0.2 °C less than average temperature measured at the Paks Gesztenyés and Uszód stations (12.1 °C). The higher values from these last two stations could suggest urban thermal effect (for Gesztenyés), and a more southerly location (Uszód). The greatest difference between monthly mean temperature data from the two stations during the designated period appeared in the case of Gesztenyés and Uszód in December 2012 (it was 0.75 °C warmer on monthly average in Uszód). In terms of monthly mean temperature, similarity is greatest regarding the Paks and Paks Boathouse stations (the distance between them is the smallest); average deviation between the various measured data is just 0.1 °C. The two stations that differ from each other most on average are Paks Boathouse and Paks Gesztenyés; average monthly deviation between them comes to 0.3 °C in respect of the entire period.



Havi középhőmérsékletek a 2012.04–2013.03. időszakban – Monthly mean temperatures in the 04/2012–03/2013 period

Figure 10.3.1-9: Development of monthly mean temperatures at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

The highest maximum temperature at all four stations can be pinpointed in August (Table 10.3.1-3), and a value above 38 °C can be seen at each of them on at least one occasion. There are no truly prominent values; if one were to compare the individual stations' highest maximum temperature values, you would only observe differences of no more than 1–2 °C. That notwithstanding, one can still select the warmest measurement location among the series of stations: barring two months, the highest maximum temperature value was noted at the Paks station in every case. The greatest maximum in the period, however, was noted at the Paks Boathouse station on August 6 (39.7 °C). The highest maximum for August at the Paks station to date was 37.5 °C, measured in 1992, a record that the maximum temperatures measured in August 2012 at all four stations now broke. Apart from that, a new record was set in the month of April; the previous record of 29.3 °C, likewise from 1992, was eclipsed by the maximum temperatures measured at the Paks, Paks Boathouse and Paks Gesztenyés stations.

The typical location of maximum temperatures can be chosen regarding the period under consideration the same way: these values are associated with Paks Gesztenyés station with the exception of three months. Taking the entire data table into account, the lowest maximum temperature data also appeared in Gesztenyés Street: the lowest maximum temperature was -2.1 °C there in December.

	Maximum temperature extremes [°C]							
	Paks		Paks Boathouse		Paks Gesztenyés		Uszód	
	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest
April	8.5	31.8	8.6	30.2	7.5	30.2	7.9	29.1
May	11.8	32.8	12.4	31.8	11.6	31.7	12.2	30.6
June	20.6	36.4	20.0	35.9	19.9	35.9	20.0	36.0
July	24.3	38.7	24.9	37.4	24.3	37.3	24.2	38.1
August	23.9	39.0	24.2	**39.7**	24.3	38.8	23.6	38.4
September	16.0	33.3	16.4	32.4	16.1	32.6	16.4	32.7
October	4.4	24.7	4.3	24.2	3.9	24.1	4.3	24.8
November	7.3	20.1	6.8	19.6	6.8	19.3	7.0	19.2
December	-1.7	13.3	-1.6	13.3	**-2.1**	12.6	3.9	12.4
January	0.0	13.1	-0.1	12.4	-0.4	12.2	0.0	11.8
February	0.1	12.7	-0.8	12.4	-1.0	12.1	-0.9	11.8
March	-0.4	20.4	-0.4	19.8	-0.7	19.7	-0.7	18.4

Table 10.3.1-3: Maximum temperature extremes by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

	Minimum temperature extremes [°C]							
	Paks		Paks Boathouse		Paks Gesztenyés		Uszód	
	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest
April	-7.1	10.9	-6.3	5.0	-5.7	6.7	-5.2	10.9
May	3.0	15.8	4.0	17.5	3.8	11.2	4.7	17
June	8.8	20.6	8.8	20.5	8.8	21.4	9.4	20.1
July	8.5	22.4	10.0	21.2	10.9	22.3	12.6	20.3
August	6.3	20.3	7.4	21.0	9.9	**23.5**	8.8	21.5
September	2.4	17.9	3.7	18.3	4.9	17.9	5.5	12.5
October	-1.1	14.8	-1.0	15.3	-1.0	14.8	0.0	15
November	-2.8	8.8	-1.8	8.6	-0.3	8.8	-1.0	9.5
December	-11.8	6.6	-10.7	5.7	-8.7	6.0	-10	6.4
January	-7.7	6.0	-7.4	5.8	-6.8	5.7	-5.5	5.8
February	-11.3	7.3	-11.3	6.3	-8.1	6.7	**-12.7**	6.7
March	-11.2	9.2	-9.5	8.8	-6.6	9.2	-7.7	8.8

Table 10.3.1-4: Minimum temperature extremes by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

Minimum temperature extremes were also collected (Table 10.3.1-4). With the exception of February, the lowest minimum temperature was measured at the Paks station every month. Comparing that to maximum temperature data one can say that of the four stations, Paks station is the one with the greatest monthly temperature fluctuation. The lowest minimum temperature during the period was registered at the Uszód station on 11 February 2013.

Dominance was not as great in the case of the highest minimum temperature, but these also occurred at the Paks station in half the months. The highest minimum temperature of the period, 23.5 °C was measured at the Paks Gesztenyés station on August 6, which broke the previous standing record from 2003 (22.7 °C). The minimum temperatures measured in July also exceeded the highest values to date at the Paks and Paks Gesztenyés stations (record to date: 21.5 °C, 2009).

Comparing warm threshold days at the four stations reveals no major differences (Tables 10.3.1-5, 10.3.1-6, 10.3.1-7). The most summer days were registered at the Paks Boathouse station (118), and the least at Uszód (112), but the difference between them is just 6 days. The Paks station had the most hot days (65 days), and Uszód had the fewest (51 days), so the difference between these two stations for this threshold day is somewhat greater at 14 days. The number of sweltering days developed close to identically at the four locations; a temperature in excess of 35 °C on 18 days was only noted at Paks, with 17 such days each occurring at the rest of the stations.

	Number of summer days (Tmax≥25°C)			
	Paks	Paks Boathouse	Paks Gesztenyés	Uszód
April	5	4	4	3
May	13	14	14	12
June	21	21	21	21
July	30	30	30	30
August	29	30	30	28
September	18	19	16	18
October	0	0	0	0

Table 10.3.1-5: Number of summer days by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

	Number of hot days (Tmax≥30°C)			
	Paks	Paks Boathouse	Paks Gesztenyés	Uszód
April	3	1	1	0
May	4	2	2	1
June	11	12	11	10
July	18	16	16	16
August	21	18	19	18
October	0	0	0	0

Table 10.3.1-6: Number of hot days by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

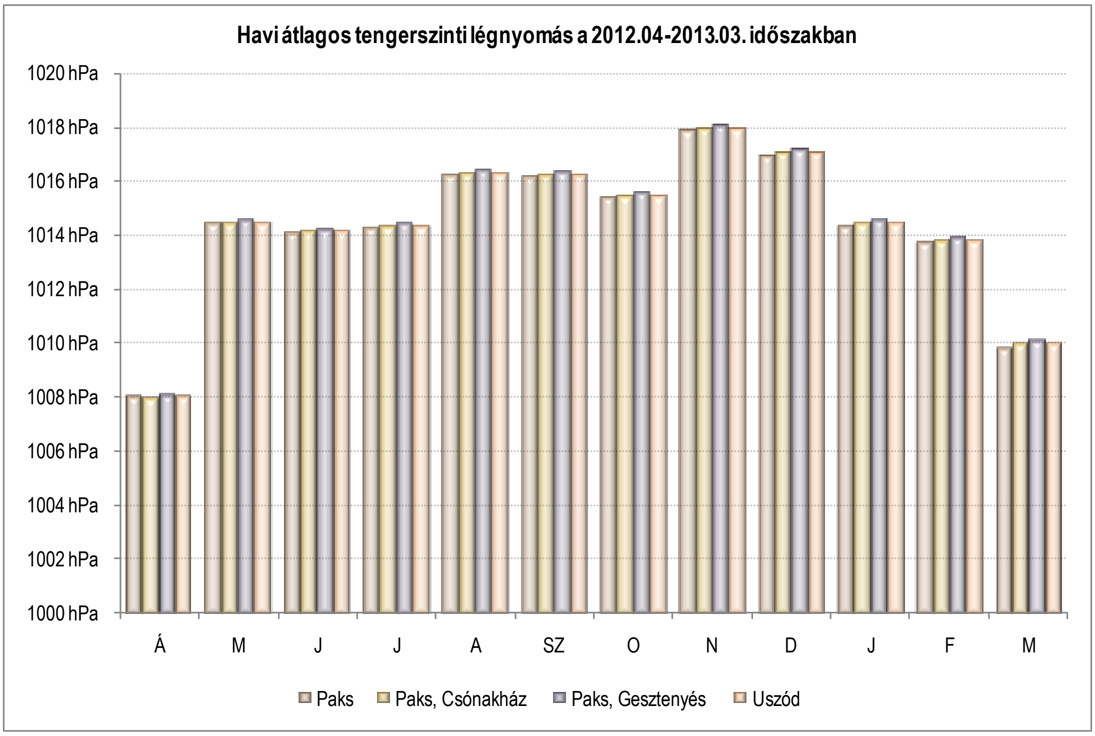
	Number of sweltering days (Tmax≥35°C)			
	Paks	Paks Boathouse	Paks Gesztenyés	Uszód
April	0	0	0	0
May	0	0	0	0
June	1	2	1	1
July	8	8	8	8
August	9	7	8	8
September	0	0	0	0
October	0	0	0	0

Table 10.3.1-7: Number of sweltering days by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

10.3.1.2.2 Air pressure

Since the four stations—at least in terms of extended area processes—are located quite near to one another, the monthly values (Figure 10.3.1-10) of sea level air pressures essentially do not reflect any substantial difference (with 1-2 tenths of a hPa deviations resulting).

The highest sea level pressure in the period, 1035.5hPa was measured at the Paks Gesztenyés station on 3 January 2013, while the lowest one at the Paks station on 27 October 2012 (Table 10.3.1-8).



Havi átlagos tengerszinti légnyomás a 2012.04–2013.03. időszakban - Monthly mean sea level pressure in the 04/2012-03/2013 period

Figure 10.3.1-10: Monthly mean sea level pressure at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

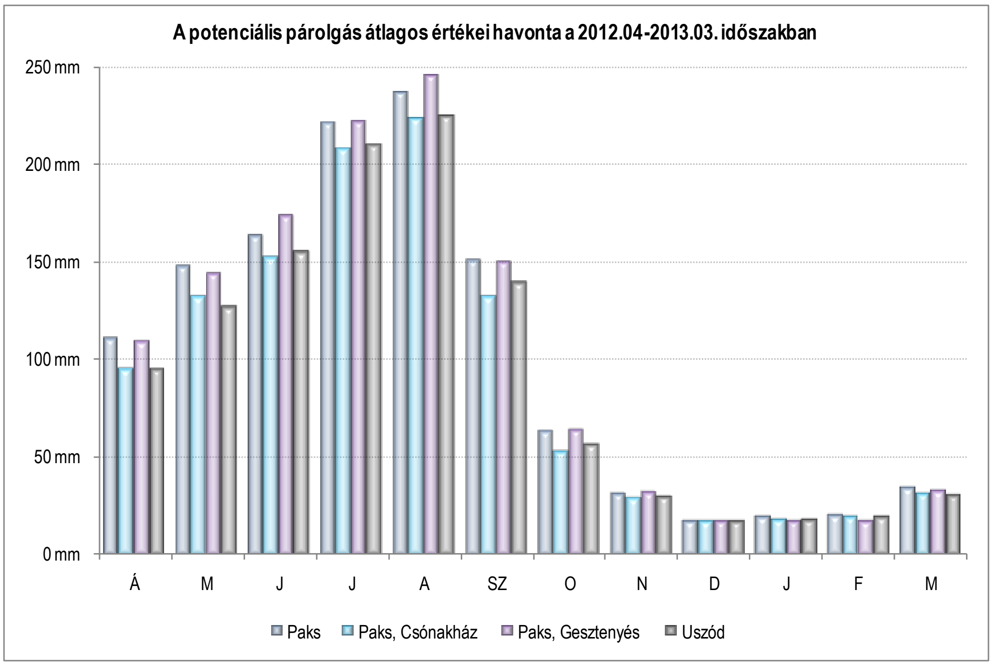
	Sea level pressure extremes [hPa]							
	Paks		Paks Boathouse		Paks Gesztenyés		Uszód	
	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest
April	994.6	1022.8	994.7	1023	994.8	1023	994.7	1023
May	1004.2	1026.7	1004.3	1026.7	1004.5	1026.8	1004.2	1026.9
June	1003.1	1022.8	1003.1	1022.9	1003.1	1022.9	1003.1	1022.7
July	1007.3	1024.5	1007.3	1024.5	1007.5	1024.8	1007.5	1024.4
August	1008.1	1024.7	1008.1	1024.8	1008.2	1024.9	1008.3	1024.7
September	1003.6	1025.7	1003.7	1025.8	1003.7	1025.8	1003.6	1025.9
October	988.8	1024	989	1024.2	989.2	1024.2	989	1024.2
November	992.6	1033.7	992.7	1033.7	992.8	1033.8	992.7	1033.5
December	999.4	1033.7	999.6	1033.8	999.8	1034	999.6	1033.6
January	995.4	1035.3	995.5	1035.4	995.7	1035.5	995.5	1035.4
February	990.9	1027.9	991	1028	991.1	1028.1	991.1	1028.1
March	991.7	1028.8	991.6	1028.9	992.3	1028.9	991.8	1028.9

Table 10.3.1-8: Sea level pressure extremes by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

10.3.1.2.3 Atmospheric humidity

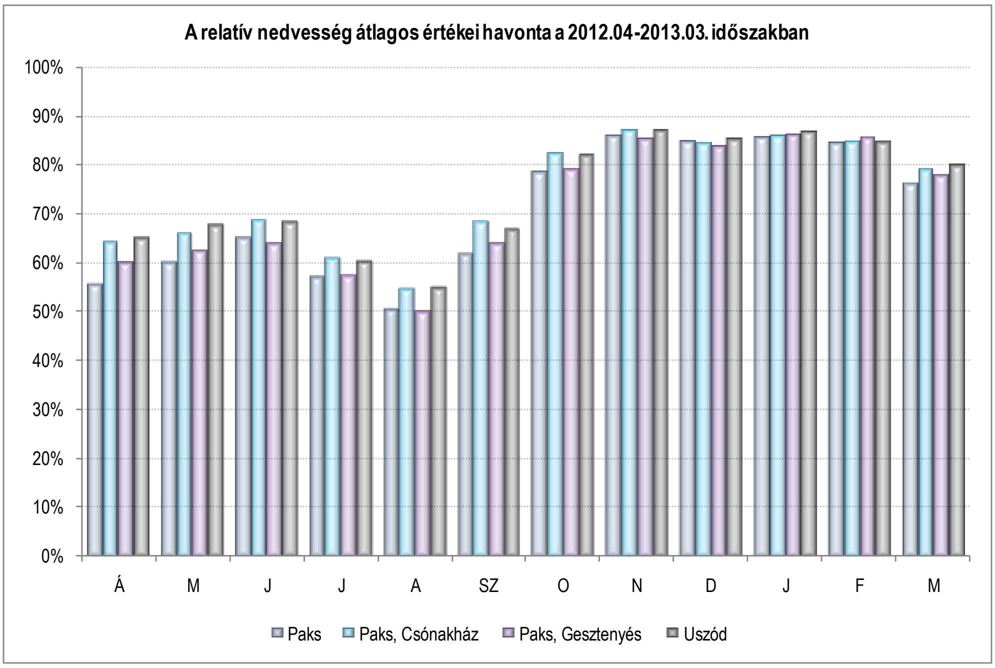
Potential evaporation values also showed very similar annual progression at the four stations (Figure 10.3.1-11). Greater deviations appeared during the summer half of the year, when potential evaporation values were higher. Values from the Paks and Gesztenyés stations exceeded totals from the other two stations, so the former two stations occupy the top two positions even in respect of the overall period (Gesztenyés is first with 1233mm, and Paks is second with 1222mm). All in all, the lowest potential evaporation result is from the Paks Boathouse station: 1117mm.

Relative humidity values likewise reflected greater differences during the summer half, while being close to identical in the winter months (Figure 10.3.1-12).



A potenciális párolgás átlagos értékei havonta a 2012.04-2013.03. időszakban – Average potential evaporation values by month in the 04/2012-03/2013 period

Figure 10.3.1-11: Average potential evaporation values by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

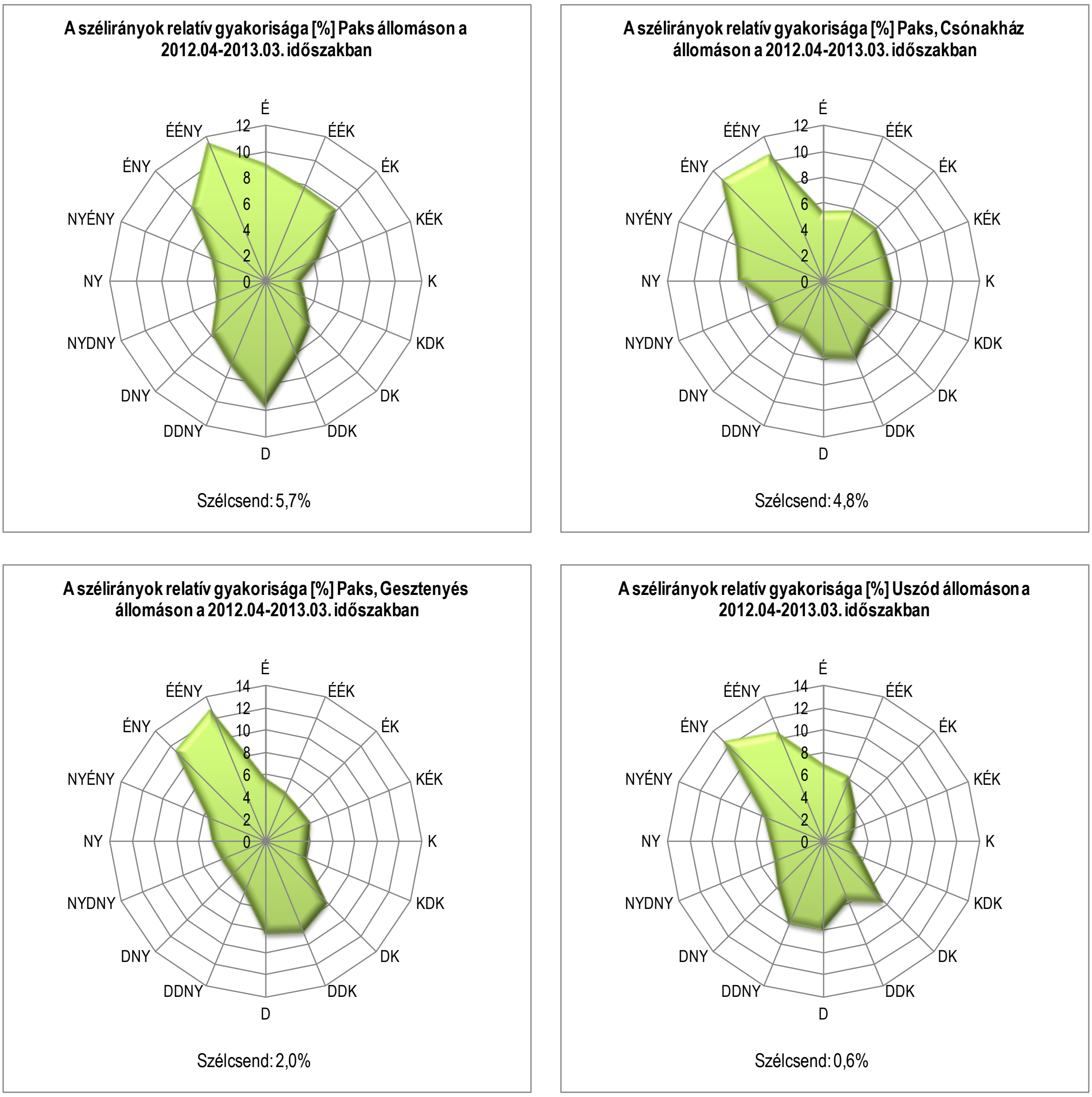


A relatív nedvesség átlagos értékei havonta a 2012.04-2013.03. időszakban - Average relative humidity values by month in the 04/2012-03/2013 period

Figure 10.3.1-12: Average relative humidity values by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

10.3.1.2.4 Wind

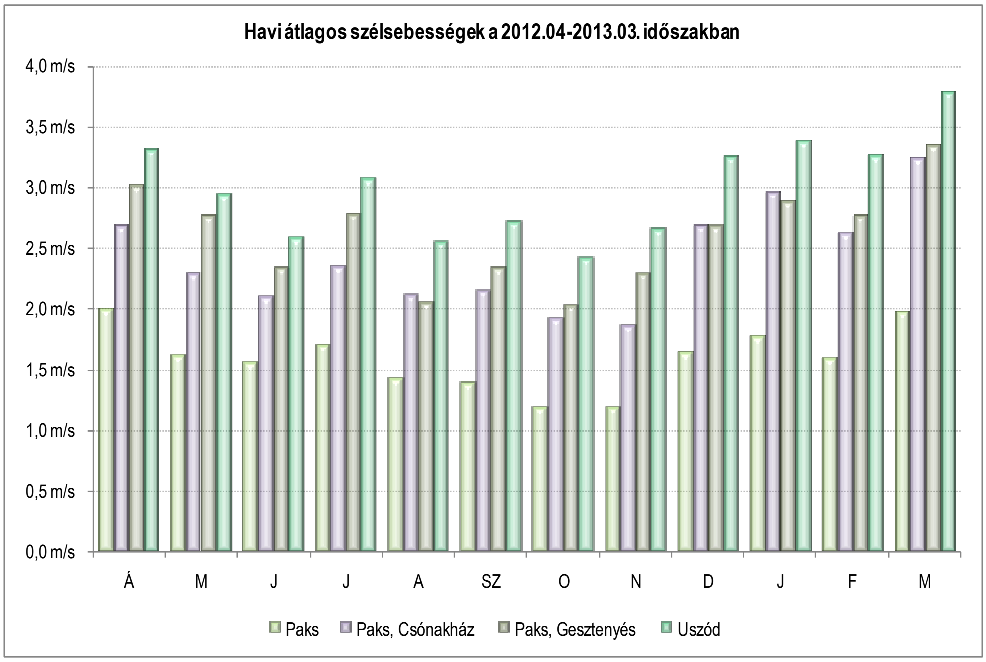
Based on the wind compasses that illustrate the relative frequency of wind directions one can see that wind as an element of meteorology is something that can show much greater differences even within small distances than the parameters examined so far can. In addition to the definitive effect of large scale weather systems, topographical, surface cover and built-up coverage characteristics influence prevailing wind directions to a great degree. The most common wind directions of the four stations showed difference in the period under consideration (Figure 10.3.1-13): The prevailing wind direction at the Paks station was NNW, with S developing as a strong secondary maximum next to that. Wind blew least from the east. In the case of the Paks Boathouse station, the most prevalent winds were NW and NNW, while the rest of the directions occurred with nearly identical frequency. NNW and NW wind also dominated at the Paks Gesztenyés station during the period under consideration, while the SSE, S and SE directions appeared as a secondary maximum. At the Uszód station, NW wind was unequivocally most common, but NNW also occurred many times, and SSW, S and SE winds also blew multiple times.



A szélirányok relatív gyakorisága [%] … állomáson a 2012.04–2013.03. időszakban - Relative frequency [%] of wind directions at the … station in the 04/2012-03/2013 period
Szélcsend – calm wind

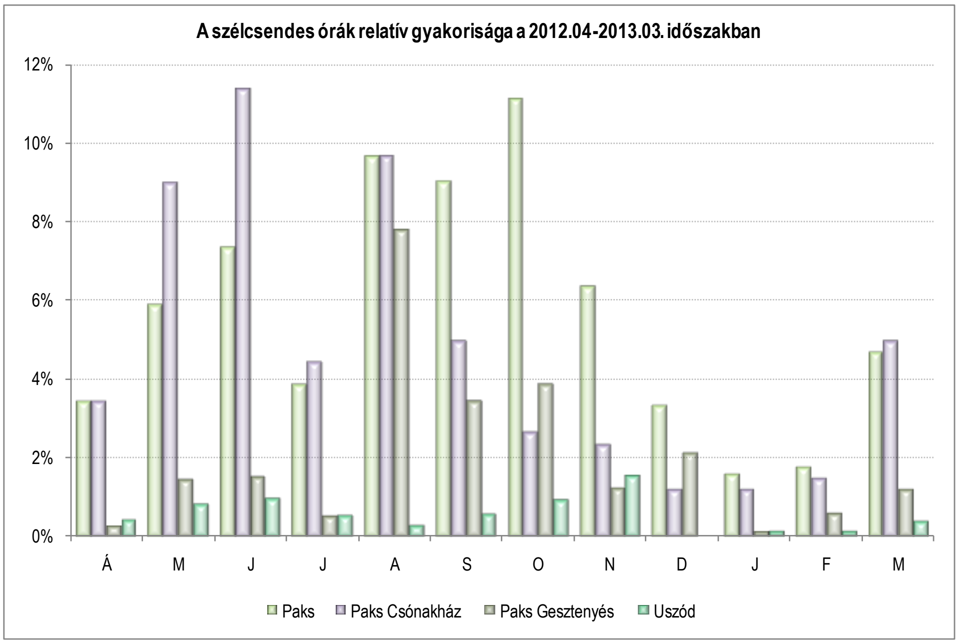
Figure 10.3.1-13: The relative frequency of wind directions at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

Our next chart presents monthly average wind speeds for the period (Figure 10.3.1-14). The difference among the four stations is clear to see; the lowest average winds were measured at Paks, while the highest ones at the Uszód station. The average difference between the monthly average wind values of these two stations is 1.4m/s. The wind speeds of Paks Boathouse and Paks Gesztenyés are positioned between the two stations with the extreme values; average winds at the Gesztenyés station were greater for the most part, but there were two months (August and January) when greater values were noted at the Boathouse station.



Havi átlagos szélsebességek a 2012.04-2013.03. időszakban - Monthly average wind speeds in the 04/2012-03/2013 period

Figure 10.3.1-14: Monthly average wind speeds at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

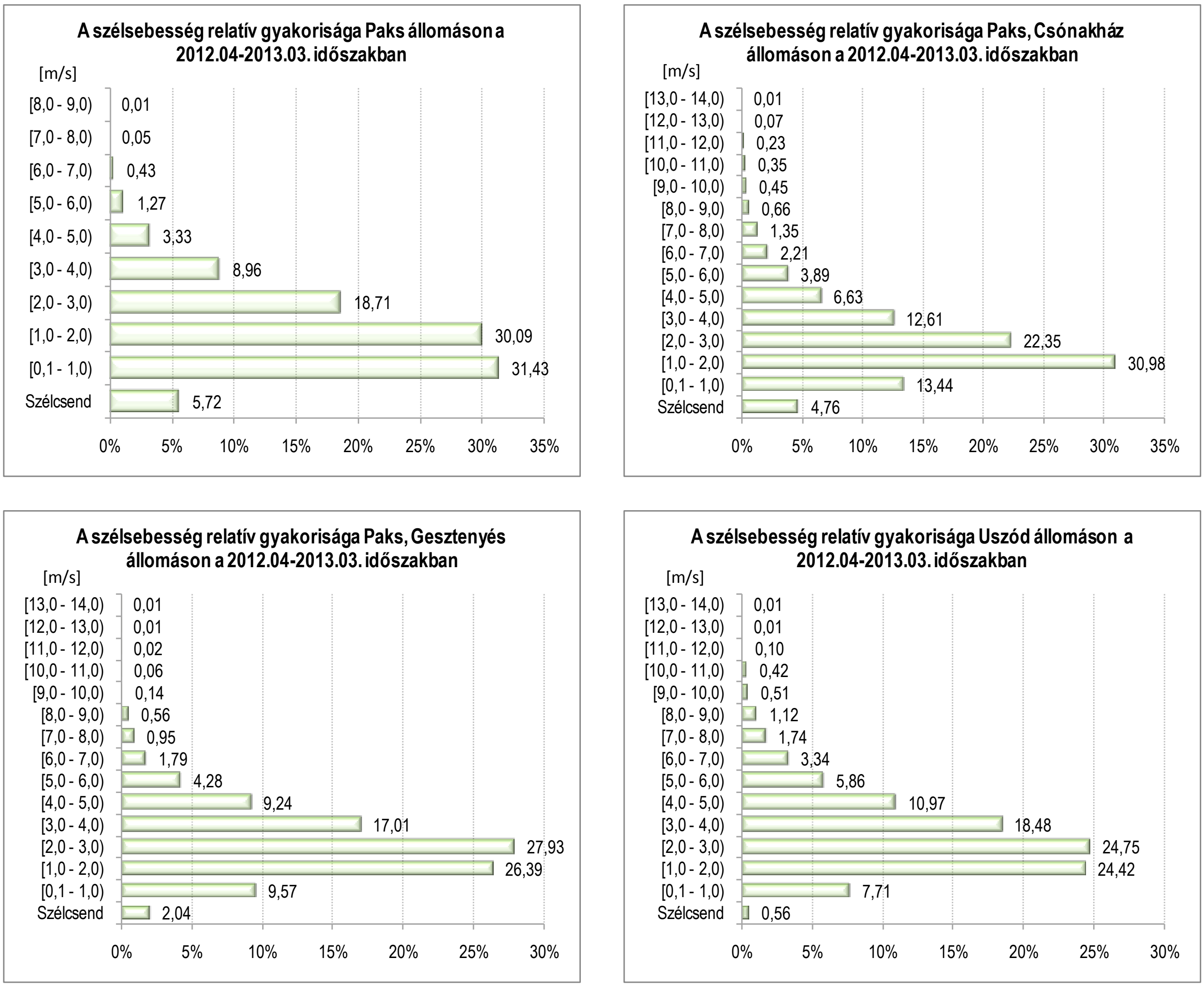


A szélcsendes órák relatív gyakorisága a 2012.04-2013.03. időszakban - The relative frequency of hours with calm wind in the 04/2012-03/2013 period

Figure 10.3.1-15: The relative frequency of hours with calm wind at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

Looking at the incidence of hours with calm winds, the stations also show differences (Figure 10.3.1-15). Calm winds were observed more frequently at the Paks and Paks Boathouse stations during the period under consideration than in the case of the Paks Gesztenyés and Uszód stations. Having regard to the entire period, calm wind was most common at the Paks station (5.7%), followed by the Paks Boathouse (4.8%) and Paks Gesztenyés station (2%), and it was rarest at the Uszód station (0.6%).

The charts in Figure 10.3.1-16 show the relative frequency values for wind speed. While in the case of Paks wind speeds between 0.1-2m/s occurred most frequently, the histogram shifted towards higher wind speeds in that of the other three stations with values between 1-3m/s being the most common there. Progressing toward higher wind speeds shows increasingly lower frequency values, and Paks differs from the other stations in this regard, as well: The greatest hourly average wind speed that occurred at Paks falls in the 8-9m/s range, while far greater frequency appeared in this interval at the rest of the stations, with the highest hourly average wind between 13-14m/s.



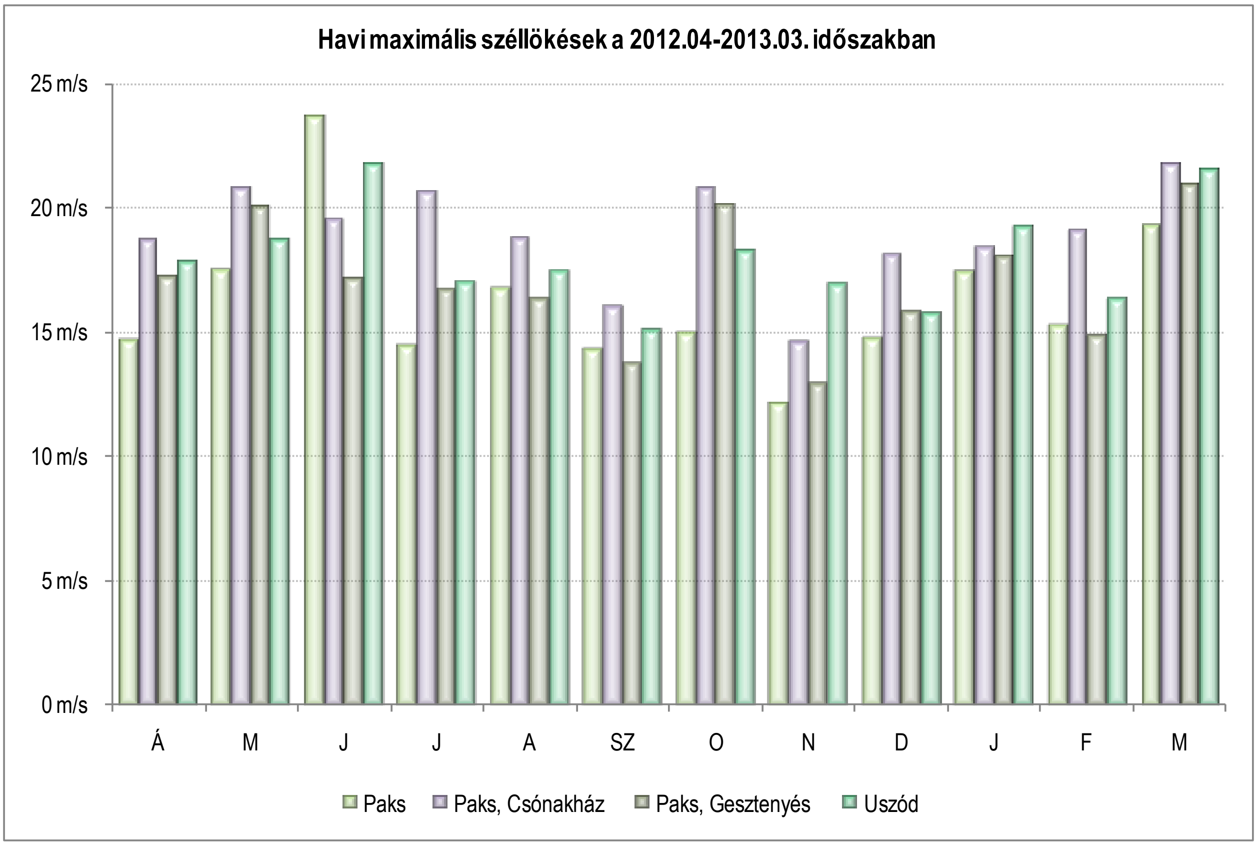
A szélsebesség relatív gyakorisága … állomáson a 2012.04–2013.03. időszakban - Relative frequency of wind speed at the … station in the 04/2012-03/2013 period
Szélcsend - Calm wind

Figure 10.3.1-16: The relative frequency of wind speed at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period (based on hourly average wind speed data)

Our following chart shows greatest wind gust values that occur every month (Figure 10.3.1-17). Out of the 12 months, the greatest maximum wind gust appeared at the Paks Boathouse station in 9 months, while maximum wind gust was lowest at the Paks station in 8 months out of the four months. The highest value of the 12 months (23.7m/s), however, was registered at the Paks station in the month of June.

Table 10.3.1-9 shows the frequency of maximum wind gust by wind directions. One can see based on the data that NW direction maximum wind gust was most common in the case of the Paks and Paks Boathouse stations, while it was NNW at the other two stations.

The frequency of maximum wind gust by speed was also calculated, and these histograms can be seen on the charts of Figure 10.3.1-18. Maximum wind gusts between 2-6 m/s appeared with the greatest frequency at all four stations.

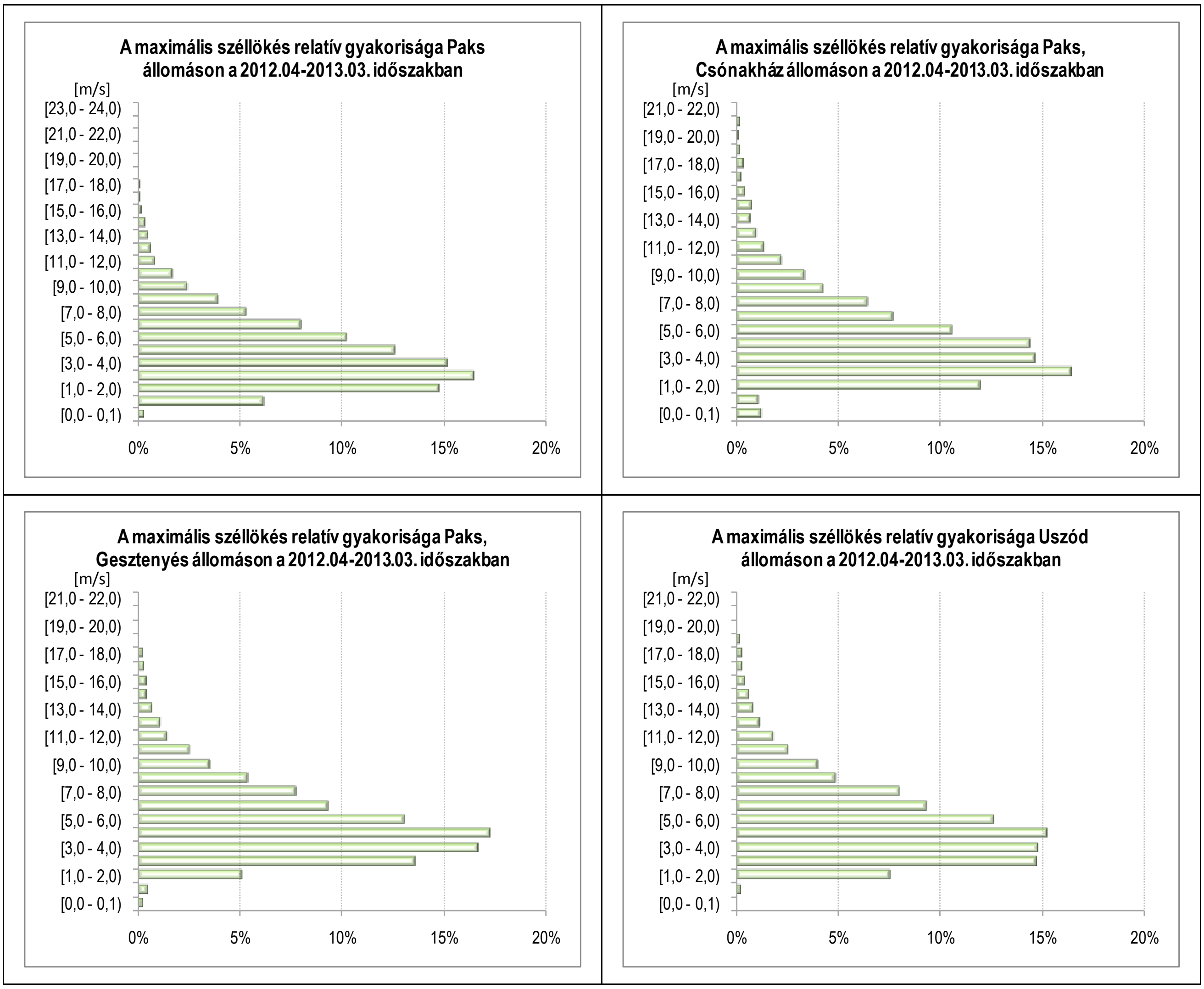


Havi maximális széllökések a 2012.04–2013.03. időszakban - Monthly maximum wind gusts in the 04/2012-03/2013 period

Figure 10.3.1-17: Monthly maximum wind gusts at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

The relative frequency of maximum wind gusts by wind direction in the 04/2012-03/2013 period								
	N	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**
Paks	6.801	8.473	12.469	1.775	2.645	2.278	6.103	4.122
Paks Boathouse	3.608	3.191	7.586	6.545	4.833	4.880	3.677	7.227
Paks Gesztenyés	2.209	5.231	5.002	4.658	3.525	4.040	7.669	10.850
Uszód	2.386	6.782	4.635	3.242	2.946	4.510	7.307	6.485
	S	**SSW**	**SW**	**WSW**	**W**	**WNW**	**NW**	**NNW**
Paks	10.785	5.335	7.763	2.736	4.408	4.534	13.591	6.183
Paks Boathouse	5.863	7.516	1.214	5.527	7.724	6.869	15.206	8.534
Paks Gesztenyés	7.268	4.006	4.292	3.067	6.307	5.952	6.822	19.103
Uszód	7.364	8.346	4.453	4.829	3.220	6.371	10.458	16.669

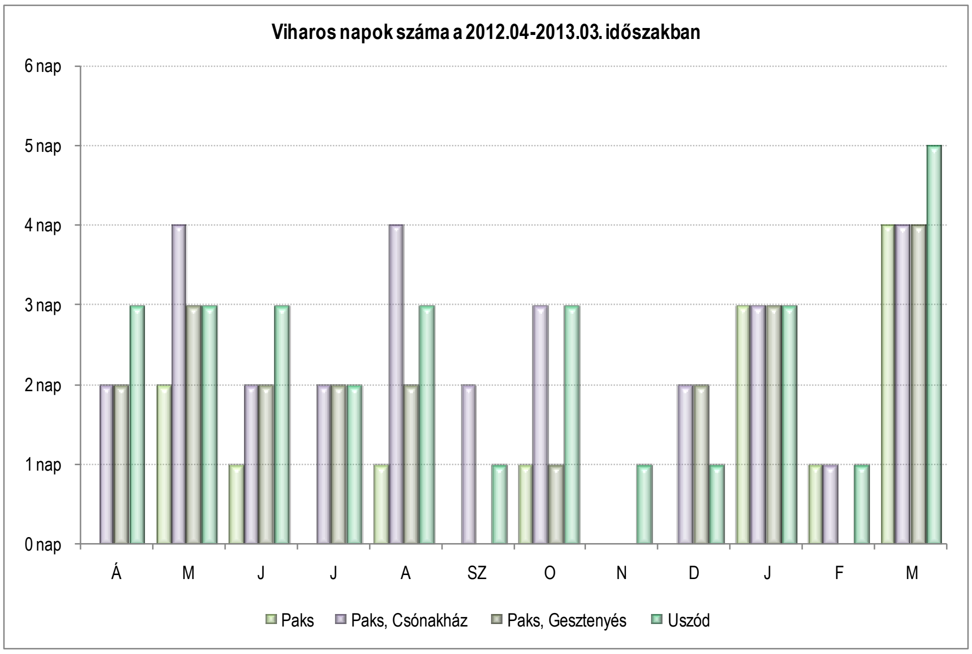
Table 10.3.1-9: The relative frequency of maximum wind gusts by wind direction at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period (based on hourly data)



A maximális széllökés sebesség szerinti relatív gyakorisága … állomáson a 2012.04–2013.03. időszakban - The relative frequency of maximum wind gusts by speed at the … station in the 04/2012-03/2013 period
Paks, Paks Csónakház, Paks Gesztenyés, Uszód állomás - Paks, Paks Boathouse, Paks Gesztenyés, Uszód station

Figure 10.3.1-18: The relative frequency of maximum wind gusts by speed at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period (based on hourly data)

Finally, the monthly number of days with a moderate gale force wind are presented in the chart in Figure 10.3.1-19. The most days with moderate gale force winds were observed at the Uszód station in March 2013 (maximum wind gust exceeded 15m/s on five days). Regarding the entire period, the greatest number of days with a moderate gale force wind was registered at the Paks Boathouse and Uszód stations, 29 days each to be exact; this criterion was met on 21 days at the Paks Gesztenyés station, while there were only 13 days at the Paks station when a wind gust exceeding 15m/s was measured.



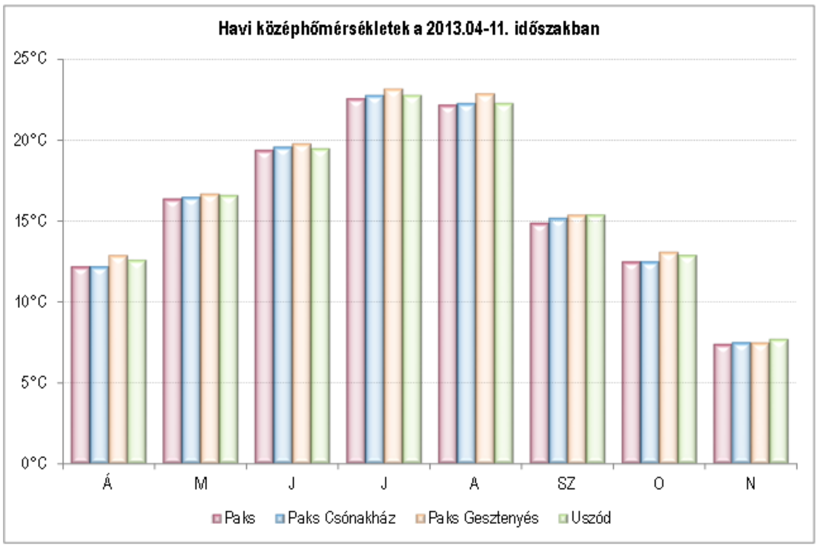
Viharos napok száma a 2012.04–2013.03. időszakban - Number of days with moderate gale force winds in the 04/2012-03/2013 period
… nap - … days

Figure 10.3.1-19: Number of days with a moderate gale force wind by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2012–03/2013 period

10.3.1.3 Comparison of data from the four weather stations in Paks for the period between 1 April 2013 and 30 November 2013

10.3.1.3.1 Temperature

In the second measurement period, one can again observe minor differences among the four stations' monthly mean temperatures (Figure 10.3.1-20). Concerning the nine months, the highest periodic mean temperature was at the Paks Gesztenyés station (16.4°C), followed by the Uszód (16.2°C) and Paks Boathouse (16.1°C) station, trailed finally by Paks (16.0°C). Similarly to the previous period, the higher values from the Paks Gesztenyés and Uszód stations could suggest urban thermal effect (for Gesztenyés), and a more southerly location (Uszód). In terms of monthly mean temperature, the Paks and Paks Boathouse stations are most similar in this period, as well.



Havi középhőmérsékletek a 2013.04–11. időszakban - Monthly mean temperatures in the 04-11/2013 period
Paks, Paks Csónakház, Paks Gesztenyés, Uszód állomás - Paks, Paks Boathouse, Paks Gesztenyés, Uszód station

Figure 10.3.1-20: Development of monthly mean temperatures at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

The highest maximum temperature of the period fell to July at the Paks Gesztenyés station, and to August at the rest of the stations (Table 10.3.1-10). The hottest weather was measured at the Paks station, where the August maximum was 39.1°C, which is a new record for August in this station's line (after 39.0°C from last year). But it was not just this, since the highest monthly maximum temperature among the four stations was measured at the Paks station every month except for April.

The lowest maximum temperatures—similarly to the previous period—appeared at the Paks Gesztenyés station with the exception of three months, and this is also where the lowest maximum temperature (1.8°C) was,

	Maximum temperature extremes [°C]							
	Paks		Paks Boathouse		Paks Gesztenyés		Uszód	
	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest
April	5.6	30.3	5.7	30.5	5.4	29.8	5.7	29.4
May	14.6	32.3	14.8	31.6	14.6	31.2	14.2	30.8
June	16.0	36.4	16.1	35.8	15.9	35.6	15.5	34.9
July	25.0	38.6	24.8	38.5	24.7	38.1	24.2	37.4
August	23.2	**39.1**	22.3	38.6	22.2	37.8	22.9	37.7
September	12.7	29.2	12.7	28.1	12.5	27.7	12.9	28.3
October	11.9	26.7	11.4	26.1	11.2	26.0	12.1	25.2
November	2.2	21.6	2.4	21.3	1.8	20.9	2.4	20.7

Table 10.3.1-10: Maximum temperature extremes by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

	Minimum temperature extremes [°C]							
	Paks		Paks Boathouse		Paks Gesztenyés		Uszód	
	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest
April	-0.7	11.6	-0.3	12.9	-0.5	14.9	0.4	15.7
May	4.4	15.1	5.2	15.4	6.7	16.5	6.7	15.9
June	8.2	20.2	9.3	21.9	9.4	22.7	9.0	21.6
July	7.1	19.0	8.3	19.5	9.8	23.0	8.4	19.3
August	8.3	20.7	9.7	20.8	11.4	20.3	9.6	20.6
September	4.6	15.6	6.0	15.8	6.4	15.5	5.5	16.0
October	**-5.0**	12.7	-3.5	12.6	-1.9	13.6	-3.4	13.4
November	-3.8	9.8	-3.5	10.3	-3.5	10.2	-1.6	10.6

Table 10.3.1-11: Minimum temperature extremes by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

Minimum temperature extremes were also collected (Table 10.3.1-11). The lowest monthly minimum temperature was measured at the Paks stations time and time again, so, similarly to the previous period, this was the station with the largest monthly temperature fluctuation in this period, as well. The lowest minimum temperature was also measured here, a monthly minimum of -5°C appeared in October.

The highest monthly minimum temperatures appeared at the Paks Boathouse, Paks Gesztenyés and Uszód stations (most times at Gesztenyés Street). The highest minimum temperature during the period, 23.0°C was measured at Paks Gesztenyés station in July.

Regarding hot threshold days, the Paks station stood out slightly among the other stations, that was where the greatest number of summer (104 days), hot (46 days) and sweltering days (14 days) were recorded out of all four stations (Table 10.3.1-12 to Table 10.3.1-14). Most hot threshold days appeared during August at the stations, this was when every day of the month was a summer day (i.e. a day with a maximum temperature above 25°C) at Paks, but even the other stations only had a maximum temperature below 25°C on just 1 or 2 days. The definition of hot day was met at around the half mark of the month, and a significant number of sweltering days were also registered. It is worth mentioning that there was 1 day in April each at the Paks and Paks Boathouse stations when maximum temperature went above 30°C, and maximums above 25°C were still measured on a few days even in October.

	Number of summer days (Tmax≥25°C)			
	Paks	Paks Boathouse	Paks Gesztenyés	Uszód
April	8	7	6	6
May	11	8	6	6
June	15	14	15	14
July	31	30	29	29
August	28	26	25	25
September	8	8	6	8
October	3	2	2	2

Table 10.3.1-12: Number of summer days by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

	Number of hot days (Tmax≥30°C)			
	Paks	Paks Boathouse	Paks Gesztenyés	Uszód
April	1	1	0	0
May	2	2	2	1
June	7	7	7	7
July	21	16	15	15
August	15	14	15	14
September	0	0	0	0
October	0	0	0	0

Table 10.3.113: Number of hot days by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

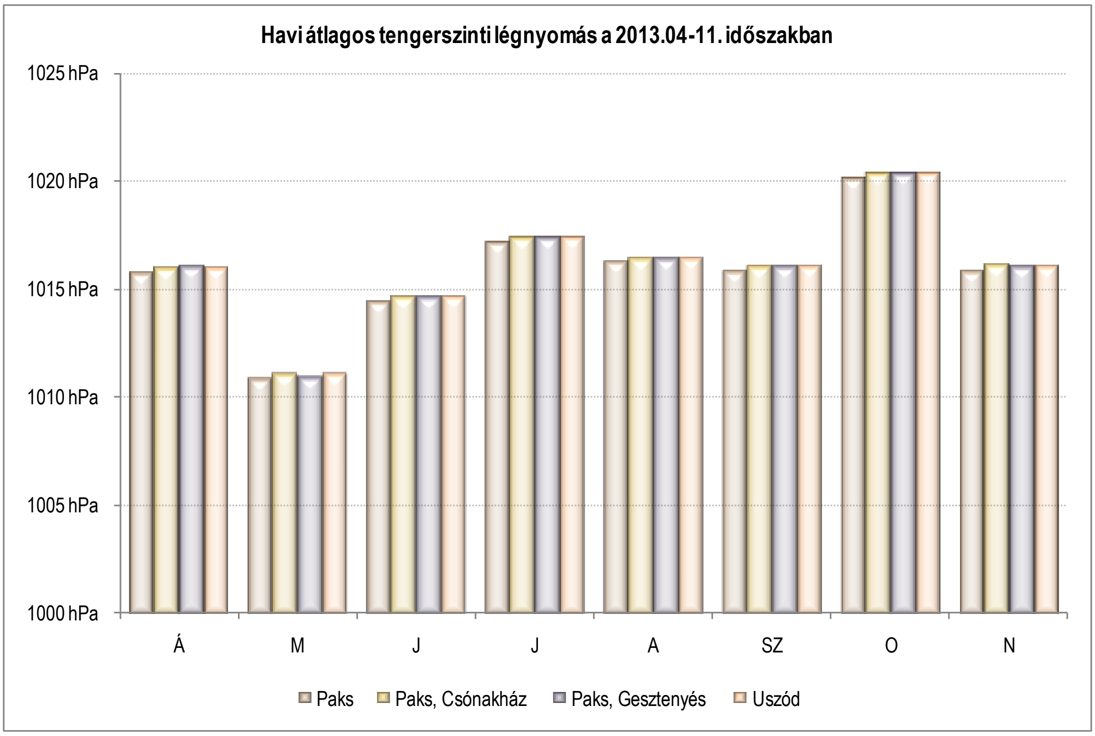
	Number of sweltering days (Tmax≥35°C)			
	Paks	Paks Boathouse	Paks Gesztenyés	Uszód
April	0	0	0	0
May	0	0	0	0
June	3	4	3	0
July	3	2	2	2
August	8	5	6	5
September	0	0	0	0
October	0	0	0	0

Table 10.3.1-14: Number of sweltering days by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

10.3.1.3.2 Air pressure

As we also saw in the preceding period, the monthly averages of sea level air pressure at an area of this size only reflect differences of but a few tenths (Figure 10.3.1-21). The highest values were measured in October, and the lowest ones in May.

The highest sea level pressure of 1034.5hPa was measured at the Paks Boathouse and Uszód stations on 4 October 2013, while the lowest one, 996.5hPa at the Paks station on November 5. (Table 10.3.1-15).



Havi átlagos tengerszinti légnyomás a 2013.04–11. időszakban - Monthly mean sea level pressure in the 04/2013-11/2013 period

Figure 10.3.1-21: Monthly mean sea level pressure at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

	Sea level pressure extremes [hPa]							
	Paks		Paks Boathouse		Paks Gesztenyés		Uszód	
	Lowest	Highest	Lowest	Highest	Lowest	Highest	Lowest	Highest
April	1001.8	1028.5	1002.2	1028.9	1002.3	1029.0	1002.0	1028.8
May	999.9	1021.1	1000.2	1021.4	1000.2	1021.2	1000.0	1021.3
June	1003.9	1024.0	1004.1	1024.2	1004.1	1024.1	1004.0	1024.1
July	1009.3	1024.5	1009.5	1024.7	1009.4	1024.6	1009.6	1024.6
August	1008.9	1022.8	1009.2	1023.2	1009.0	1023.1	1009.0	1023.2
September	997.5	1026.8	997.9	1027.0	997.9	1027.0	997.9	1027.1
October	1005.1	1034.1	1004.9	1034.5	1005.3	1034.3	1005.0	1034.5
November	996.5	1032.0	996.7	1032.3	996.8	1032.2	996.6	1032.2

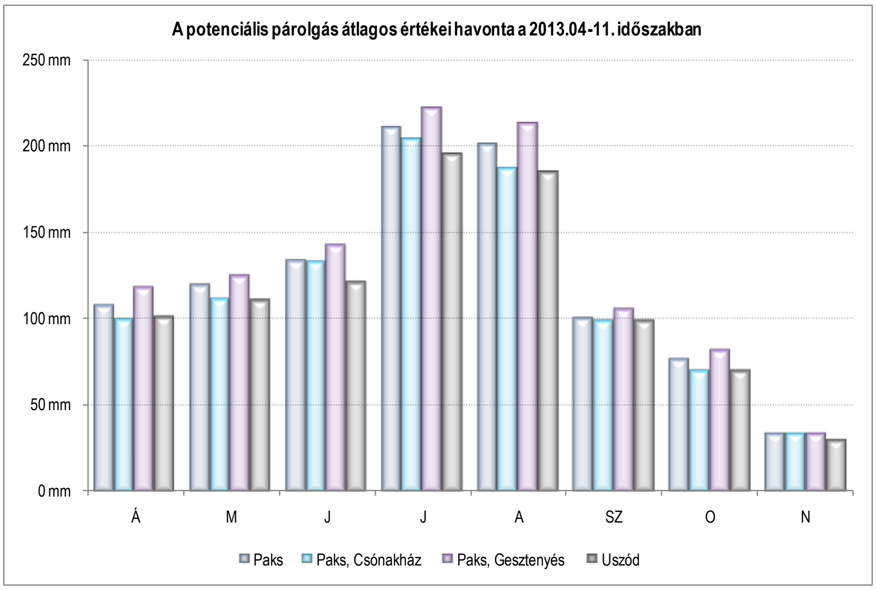
Table 10.3.1-15: Sea level pressure extremes by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

10.3.1.3.3 Atmospheric humidity

The monthly values of potential evaporation (Figure 10.3.1-22) and relative humidity (Figure 10.3.1-23) also roughly moved together at the four stations during the period.

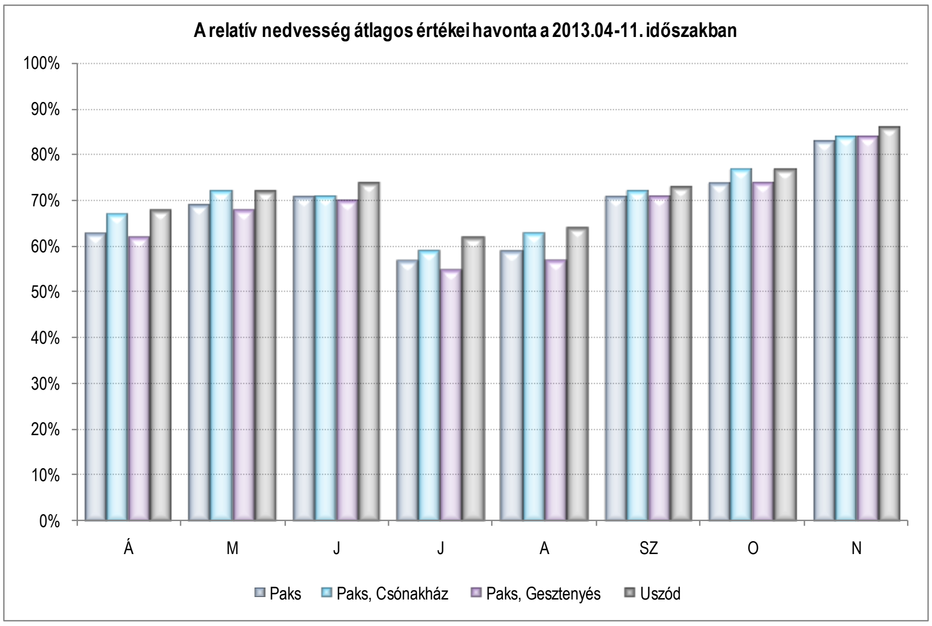
Greater differences appeared for potential evaporation during the summer period. The highest values were measured at the Paks Gesztenyés station over the course of months, and the lowest ones usually at the Uszód station.

In the region, relative humidity was highest in November and lowest in July and August.



A potenciális párolgás átlagos értékei havonta a 2013.04–11. időszakban - Average potential evaporation values by month in the 04/2013-11/2013 period

Figure 10.3.1-22: Average potential evaporation values by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

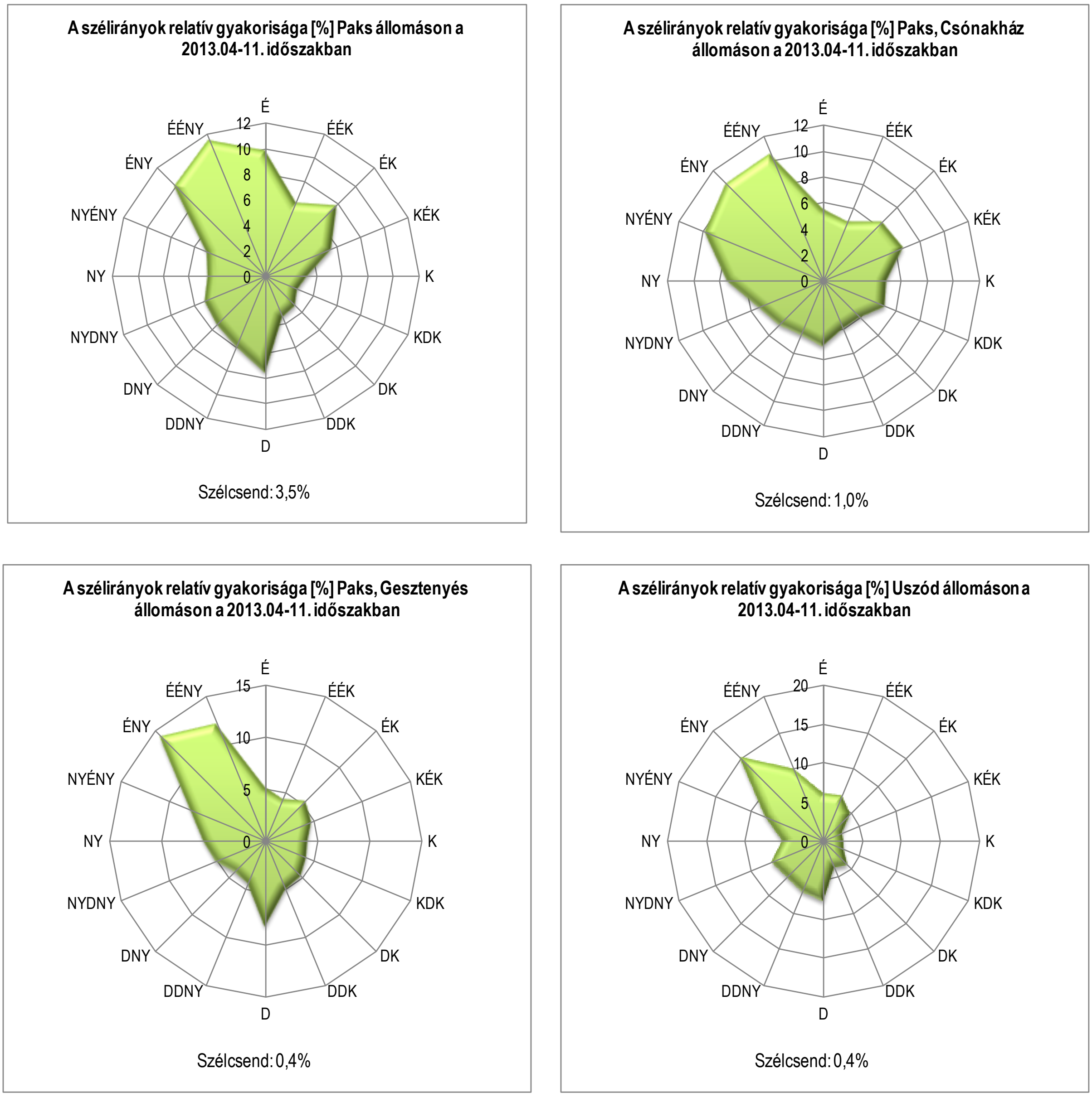


A relatív nedvesség átlagos értékei havonta a 2013.04–11. időszakban - Average relative humidity values by month in the 04-11/2013 period

Figure 10.3.1-23: Average relative humidity values by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

10.3.1.3.4 Wind

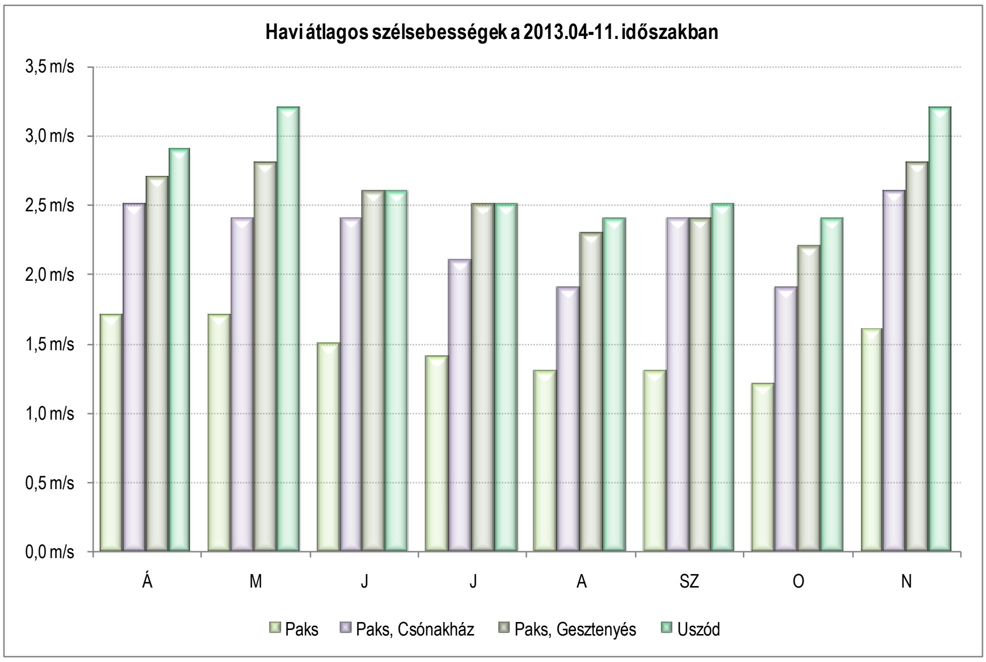
In addition to large scale weather systems, wind speed and wind direction—as we have already mentioned—is also greatly influenced by topographical, surface cover, and built-up coverage characteristics, so this element shows much greater differences across the 4 stations. The following diagrams show compasses depicting the relative frequency of wind directions (Figure 10.3.1-24). The prevailing wind at the Paks stations was NNW, with the NE and N direction trailing just slightly behind that, and the S direction developed as a strong secondary maximum aside those. For Paks Boathouse, the most common wind was NNW, NW and WNW, and it was not possible to highlight a secondary maximum. At the Paks Gesztenyés station, NW wind was most common, but NNW also occurred many times, and S wind turned out to be the secondary maximum. NW wind clearly dominated at the Uszód station.



A szélirányok relatív gyakorisága [%] … állomáson a 2013.04–11. időszakban - Relative frequency [%] of wind directions at the … station in the 04-11/2013 period
Szélcsend - Calm wind
Paks, Paks Csónakház, Paks, Gesztenyés, Uszod állomások – Paks, Paks Boathouse, Paks, Gesztenyés, Uszod stations

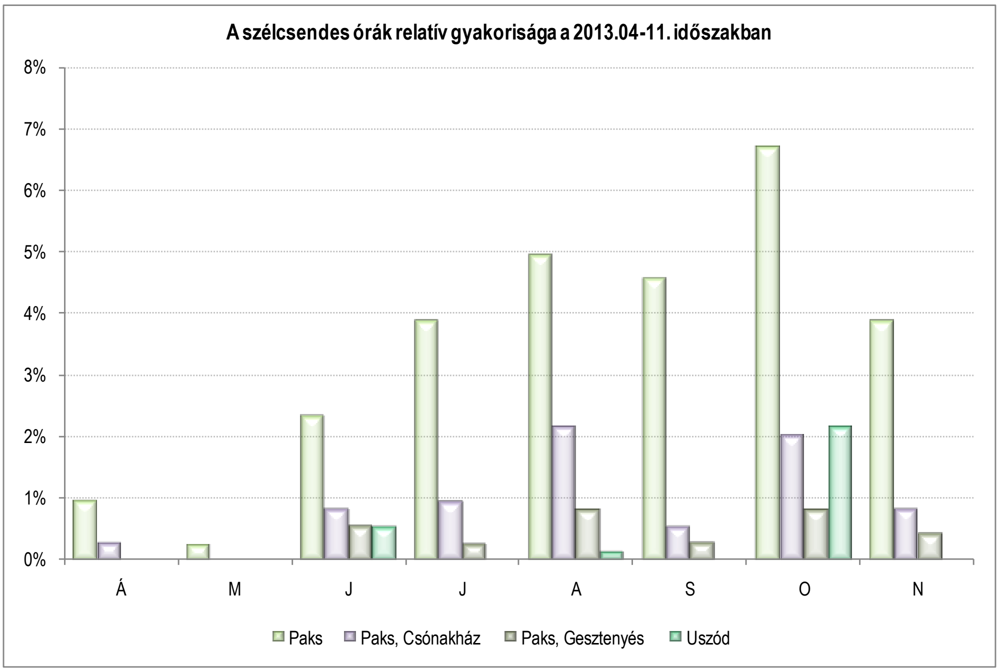
Figure 10.3.1-24: The relative frequency of wind directions at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

Our next chart presents monthly average wind speeds (Figure 10.3.1-25). Similarly to the preceding period, one can clearly see the difference among the four in this respect, as well; the lowest average winds were again measured at Paks, while the highest ones at the Uszód station. The average difference between the monthly average wind values of these two stations was 1.25 m/s during the period. Paks Gesztenyés and Paks Boathouse were the second and third windiest stations respectively. The April, May and November were the windiest months, while the lowest monthly averages were measured in the August-October period.



Monthly average wind speeds in the 04-11/2013 period - Monthly average wind speeds in the 04-11/2013 period

Figure 10.3.1-25: Monthly average wind speeds at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

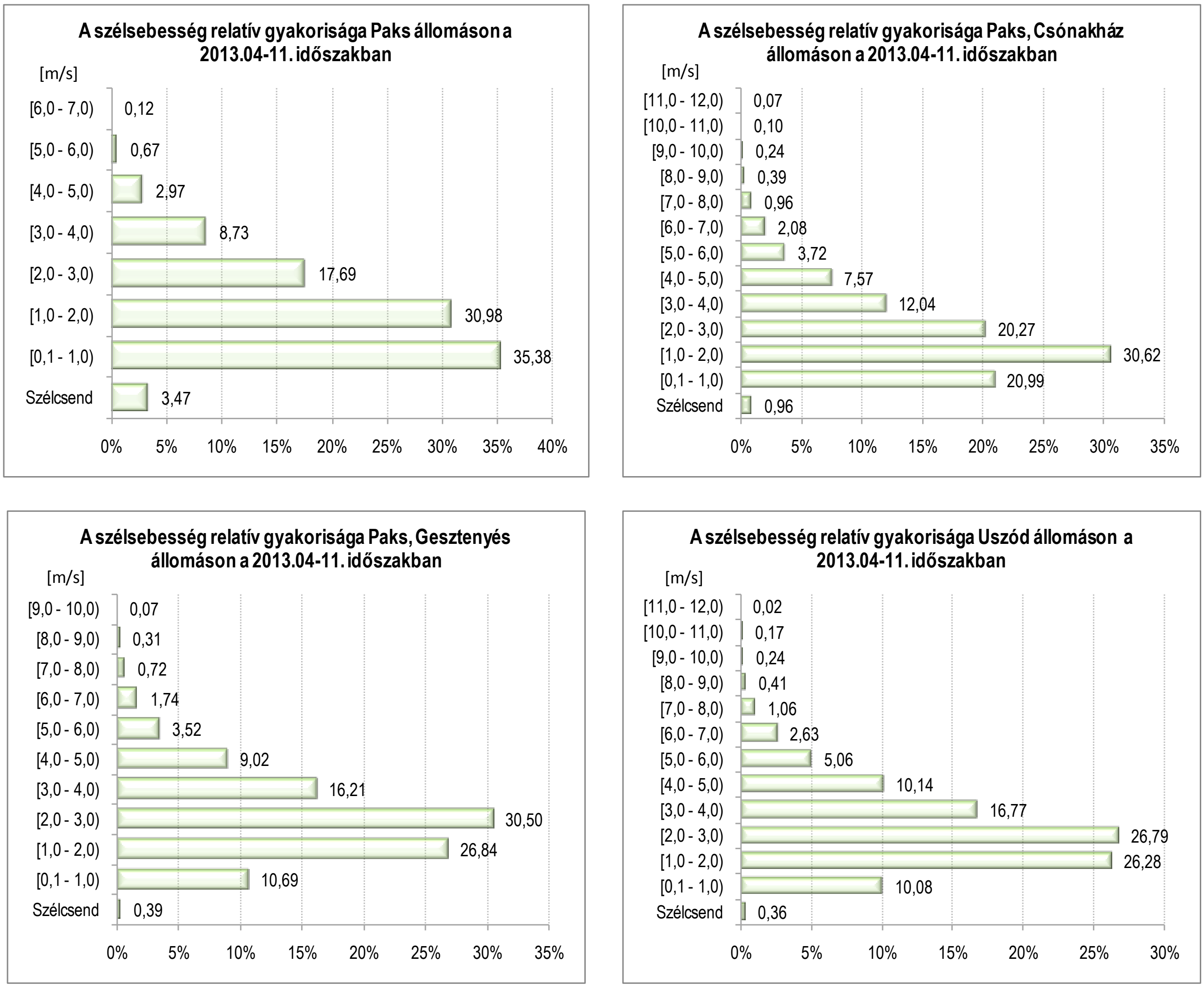


A szélcsendes órák relatív gyakorisága a 2013.04–11. időszakban - The relative frequency of hours with calm wind in the 04-11/2013 period

Figure 10.3.1-26: The relative frequency of hours with calm wind at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

Looking at the incidence of hours with calm winds, the stations also show differences (Figure 10.3.1-26). Having regard to the entire period, calm wind was most common at the Paks station (3.5%), followed by the Paks Boathouse (1.0%) and Paks Gesztenyés station (0.4%), and it was rarest at the Uszód station (0.4%). Regarding the months, the most periods with calm wind were observed in October, while no hours without wind were registered at all at some stations in April-May.

The charts in Figure 10.3.1-27 show the relative frequency values for wind speed. While in the case of Paks and Paks Boathouse wind speeds between 0.1-1m/s and 1-2m/s occurred most often respectively, values between 2-3m/s were most common in the case of the other two stations. Increasingly less frequency can be seen as we head towards greater wind speeds. The highest hourly average wind speeds differed across the four stations; maximum values fell in the 6-7m/s range at Paks, and in the 9-10m/s range at Paks Gesztenyés, while at the Paks Boathouse and Uszód stations their interval was 11-12m/s.



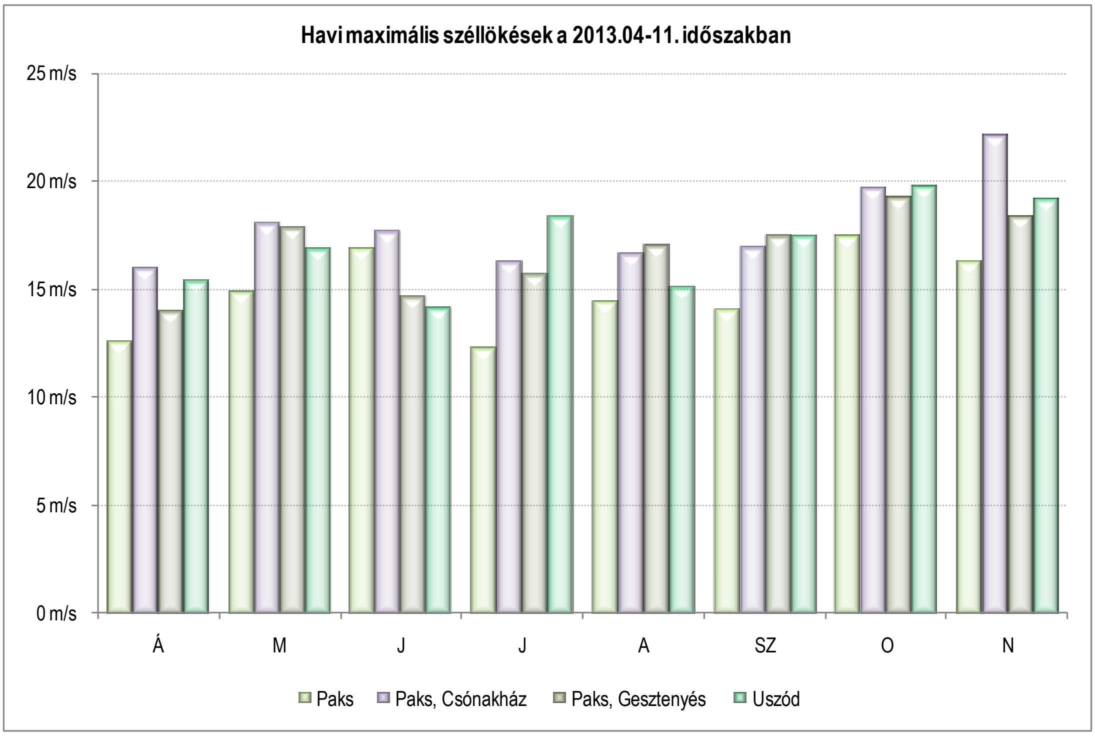
A szélsebesség relatív gyakorisága … állomáson a 2013.04–11. időszakban - Relative frequency of wind speed at the … station in the 04-11/2013 period
Szélcsend - Calm wind
Paks, Paks Csónakház, Paks, Gesztenyés, Uszod állomás – Paks, Paks Boathouse, Paks, Gesztenyés, Uszod station

Figure 10.3.1-27: The relative frequency of wind speed at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period (based on hourly average wind speed data)

Our following chart shows greatest wind gust values that occur every month (Figure 10.3.1-28). Out of the 8 months, the greatest maximum wind gust appeared at the Paks Boathouse station in 4 months, while maximum wind gust was lowest at the Paks station in 7 months out of the four months. The highest maximum wind (22.2 m/s), was registered at the Paks Boathouse station in the month of November.

Table 10.3.1-16 shows the frequency of maximum wind gust by wind directions. One can see based on the data that NW direction maximum wind gust was most common in the case of the Paks, while it was NNW at the other three stations.

The frequency of maximum wind gust by speed was also calculated, and these histograms can be seen on the charts of Figure 10.3.1-29. Maximum wind gusts between 2-5 m/s appeared with the greatest frequency at all four stations.

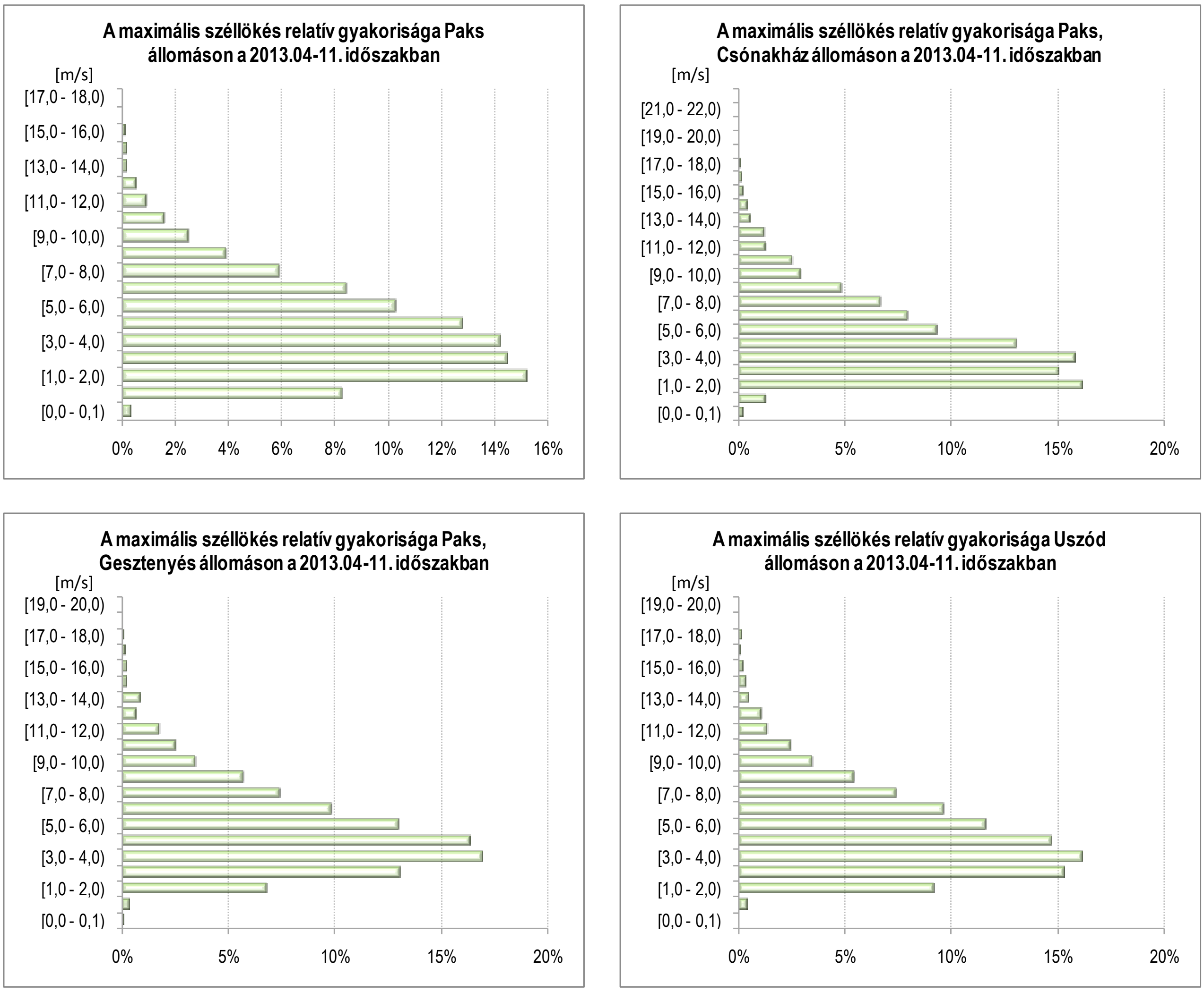


Havi maximális széllökések a 2013.04–11. időszakban - Monthly maximum wind gusts in the 04/2013-11/2013 period
Paks Csónakház – Paks Boathouse

Figure 10.3.1-28: Monthly maximum wind gusts at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

The relative frequency of maximum wind gusts by wind direction in the 04-11/2013 period								
	N	**NNE**	**NE**	**ENE**	**E**	**ESE**	**SE**	**SSE**
Paks	7.816	8.913	13.233	1.903	2.125	1.680	4.457	2.725
Paks Boathouse	2.312	3.082	6.318	10.068	4.675	4.658	2.192	4.452
Paks Gesztenyés	5.079	5.079	6.840	4.976	3.779	3.505	4.856	6.601
Uszód	2.000	7.588	5.127	3.247	3.076	3.179	4.392	4.375
	S	**SSW**	**SW**	**WSW**	**W**	**WNW**	**NW**	**NNW**
Paks	8.296	5.091	8.588	3.445	4.542	5.022	15.787	6.376
Paks Boathouse	4.418	6.712	2.003	5.890	8.202	10.651	8.784	15.582
Paks Gesztenyés	6.857	4.343	3.882	3.779	6.874	8.345	10.226	14.979
Uszód	6.751	8.392	4.820	6.153	4.239	8.939	11.451	16.271

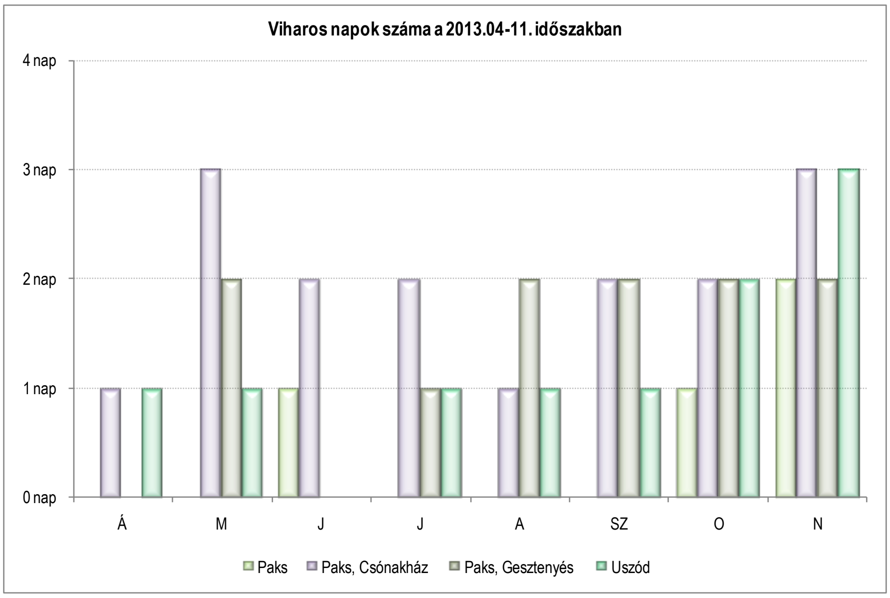
Table 10.3.1-16: The relative frequency of maximum wind gusts by wind direction at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period (based on hourly data)



A maximális széllökés relatív gyakorisága … állomáson a 2013.04–11. időszakban - Relative frequency of maximum wind gusts at the … station in the 04-11/2013 period

Figure 10.3.1-29: The relative frequency of maximum wind gusts by speed at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period (based on hourly data)

Finally, the monthly number of days with a moderate gale force wind are presented in the chart in Figure 10.3.1-30. The most days with moderate gale force winds were observed in May at the Paks Boathouse, and at the Paks Boathouse and Uszód stations in November (maximum wind gust exceeded 15m/s on 3 days each). Regarding the entire period, the greatest number of days with a moderate gale force wind was registered at the Paks Boathouse station, 16 days each to be exact; this criterion was met on 11 and 10 days at the Paks Gesztenyés and Uszód stations respectively, while there were only 4 days at the Paks station when a wind gust exceeding 15m/s was measured.



Viharos napok száma a 2013.04–11. időszakban - Number of days with moderate gale force winds in the 04-11/2013 period
… nap - … days

Figure 10.3.1-30: Number of days with a moderate gale force wind by month at the Paks, Paks Boathouse, Paks Gesztenyés and Uszód stations in the 04/2013–11/2013 period

10.3.2 Summary

Data measured between April 2012 and November 2013 at the four weather stations deployed at Paks and in its vicinity were analysed and compared.

The first part included a comparison of measurements from the Paks station with multi-annual averages. Similarly to nationwide conditions, the result received showed that the period under consideration turned out warmer than 1981-2010 averages (with the exception of two months). Humidity parameters showed the dryness of the atmosphere in the first half of the period, and its becoming wetter from mid-autumn. The examination of wind speeds revealed that with the exception of January, averages remained below normal across every month, in January and March, however, a lot more days with moderate gale force winds than average were registered.

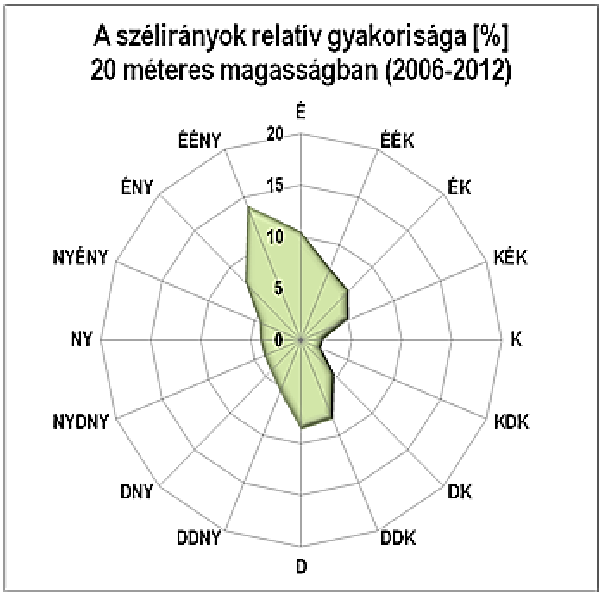
Data from the four stations were compared in the second and third parts, broken down to two periods. Due to the proximity of the stations to one another, most meteorological parameters showed quite similar values, with greater differences resulting only for wind conditions. Regarding minimum and maximum temperature extremes we found that the highest monthly maximum temperatures and lowest monthly minimum temperatures both occurred at the Paks station most times, in other words, this was the station that showed the greatest monthly temperature fluctuations during the period under consideration. Sea level pressure and humidity parameters developed very similarly at the four stations. Upon examining wind conditions, however, differences could be seen both in terms of wind speeds and wind directions. The most important thing to highlight is that the Paks station proved the least windy station, as it was characterised by lower average wind speeds, more hours with calm wind, and lower maximum wind gusts relative to the other three stations. Looking at average wind speeds and hours with calm wind, the Uszód station proved windiest, greatest maximum wind gusts, however, were measured at the Paks Boathouse station most times.

10.3.3 Processing of measurements from the Paks instrument tower

10-minute breakdown data recorded by the instrument tower at Paks are available starting from November 2006. The results of measurements taken at three levels (at 20, 50 and 120 metres) comprise PA Zrt’s property, i.e. they do not constitute a part of OMSZ’s meteorological database, therefore—and in contrast with the wind data discussed above—they did not undergo our customary multi-level data verification and completion procedures. Data received as the first level of data processing were brought to a format that allows processing and then we attempted to filter out any incorrect data. The brevity and format of the data sets, as well as the errors and insufficiencies present in the various data sets only made it possible to process wind data; let us, however, emphasise that the presented results are indicative in nature due to the quality of the available data.

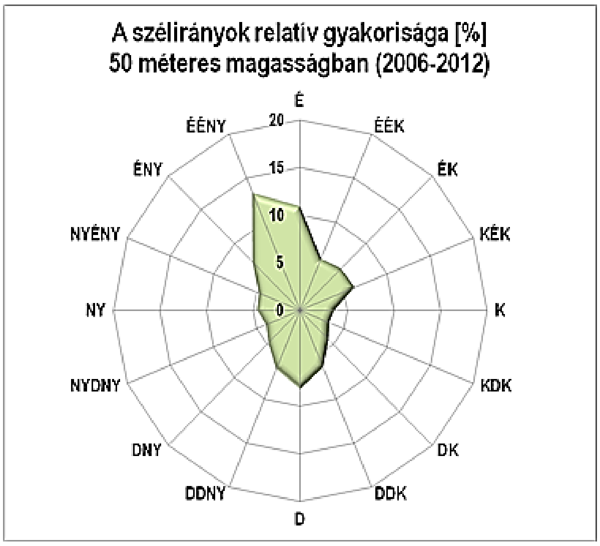
10.3.3.1 Wind direction

Based on data from the 7 years under consideration, the north-northwest wind direction prevailed (14%) at the instrument tower's 20 metre height level (Figure 10.3.3-1), and north occurred most times beside that. The south (8.7%) and south-southwest (8.3%) directions were also relatively common. The north-northwest direction was also most common (13.3%) at 50 metres height (Figure 10.3.3-2), with the order being similar to that at the 20 metre level Figure 10.3.3-3), the signs of the north-western wind direction increasing, however, are already starting to show. Although the north-northwest wind also prevailed here (12.4%), it was followed by the south-western (10.9%) and north (10.7%) wind, so southerly winds were less pronounced than at the lower levels.



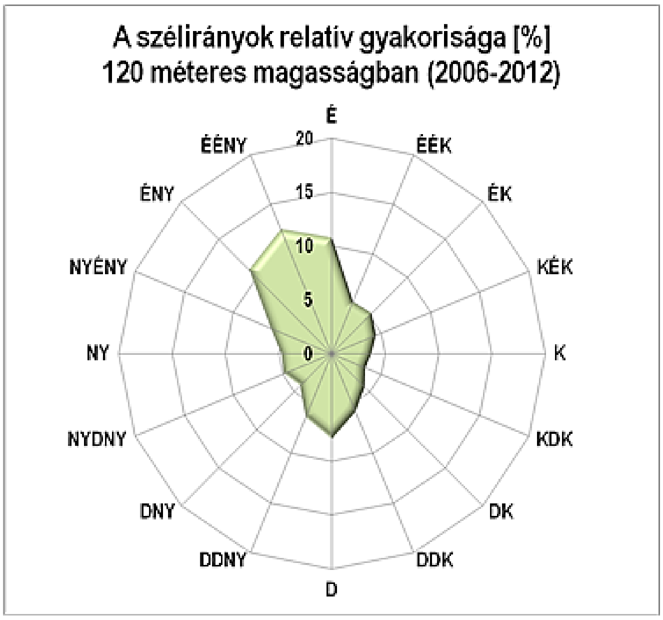
A szélirányok relatív gyakorisága [%] 20 méteres magasságban (2006–2012) - The relative frequency of wind directions [%] at a height of 20 metres (2006-2012)
É / K / D / NY - N / E / S / W

Figure 10.3.3-1: Relative frequency of wind directions [%] at the 20m level of the Paks instrument tower



A szélirányok relatív gyakorisága [%] 50 méteres magasságban (2006–2012) - The relative frequency of wind directions [%] at a height of 50 metres (2006-2012)
É / K / D / NY - N / E / S / W

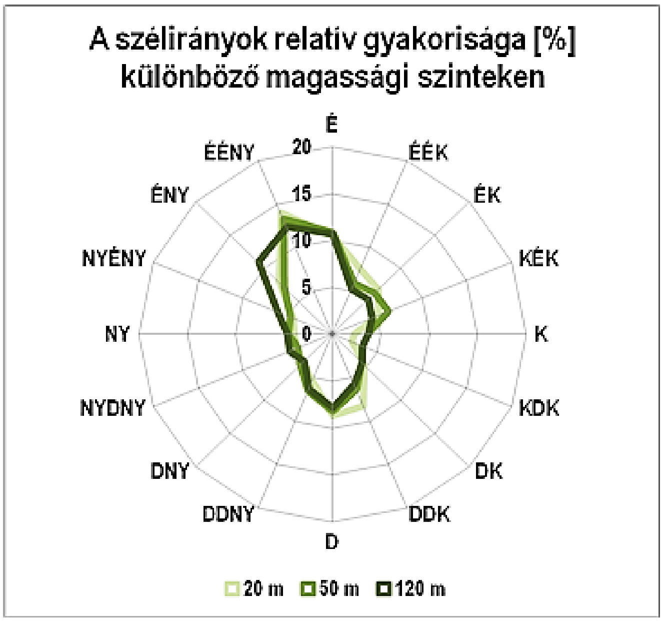
Figure 10.3.3-2: Relative frequency of wind directions [%] at the 50 m level of the Paks instrument tower



A szélirányok relatív gyakorisága [%] 120 méteres magasságban (2006–2012) - The relative frequency of wind directions [%] at a height of 120 metres (2006-2012)
É / K / D / NY - N / E / S / W

Figure 10.3.3-3: Relative frequency of wind directions [%] at the 120 m level of the Paks instrument tower

A comparative diagram was used to illustrate the differences in the frequency of wind directions registered at the different levels (Figure 10.3.3-4). The increase of the north-western direction with growing height is clear to see.

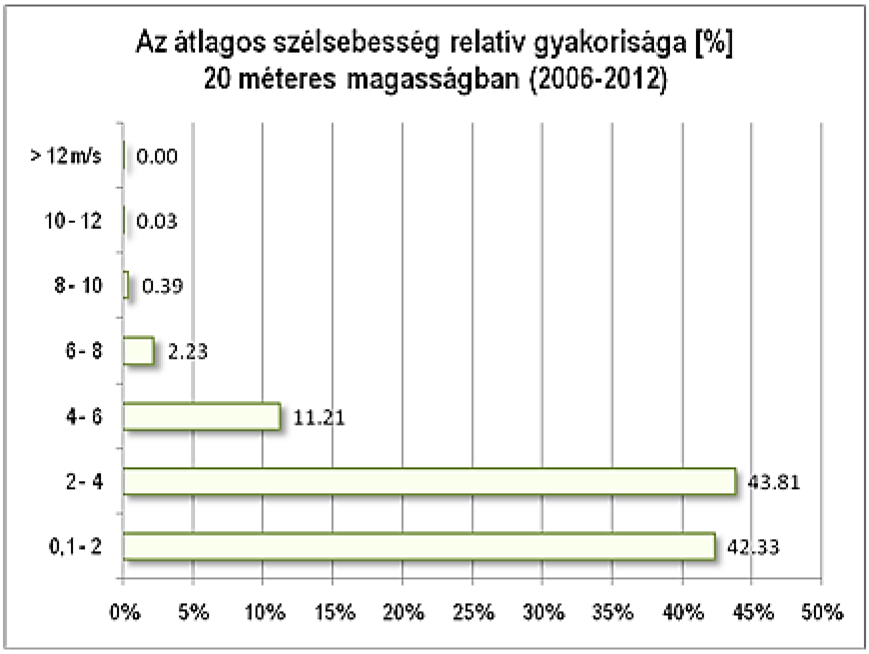


A szélirányok relatív gyakorisága [%] különböző magassági szinteken - The relative frequency of wind directions [%] at different height levels
É / K / D / NY - N / E / S / W

Figure 10.3.3-4: Relative frequency of wind directions [%] at the different height levels of the Paks instrument tower

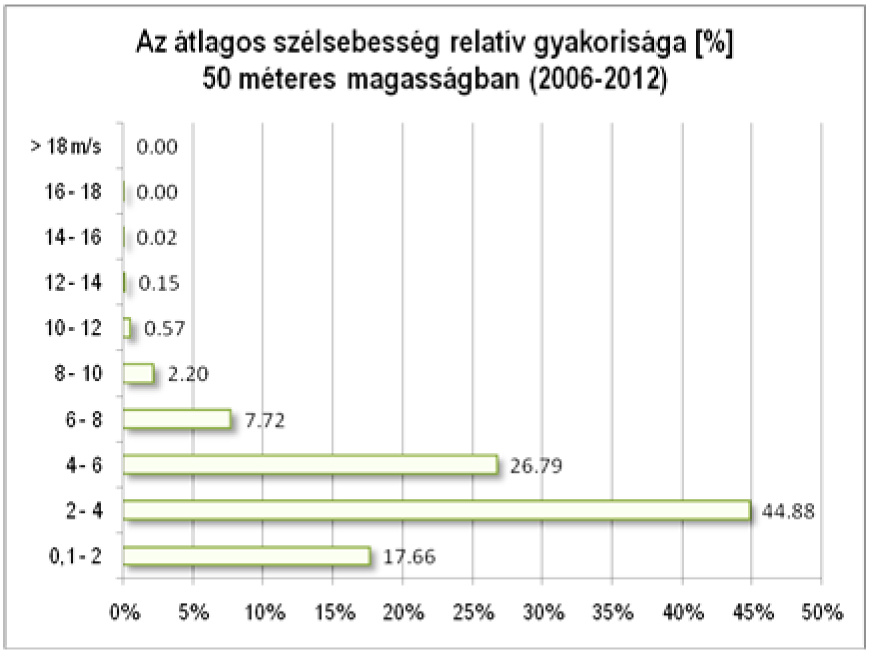
10.3.3.2 Average wind speeds

Wind speed typically increases together with altitude in the troposphere, which is also reflected in the diagrams that process 10 minute average wind speeds measured at different heights. While the frequency of the 2-4m/s range is hardly greater at 20 metres (Figure 10.3.3-5) than that of the range below it, its dominance is already unequivocal at 50 metres (Figure 10.3.3-6), and at 120 metres (Figure 10.3.3-7) the speed that occurred in the greatest proportion was already between 4 and 6m/s. During the length of time under consideration, maximum average speed was 12m/s at 20 metres, almost 18m/s at 50 metres, and values above 20m/s also occurred at 120 metres.



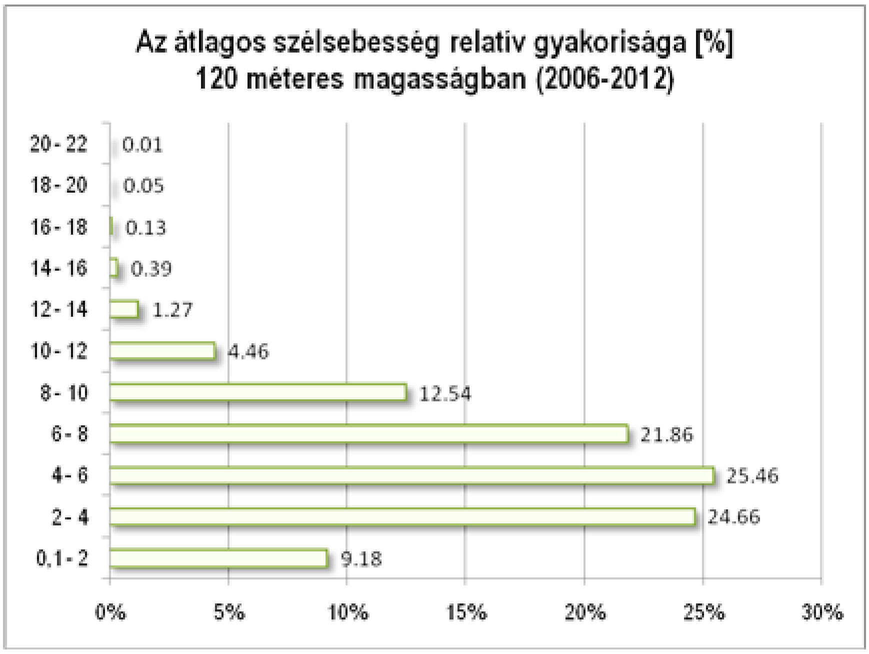
Az átlagos szélsebesség relatív gyakorisága [%] 20 méteres magasságban (2006–2012) - The relative frequency of average wind speed [%] at a height of 20 metres (2006-2012)

Figure 10.3.3-5: The relative frequency of average wind speed [%] at the 20m level of the Paks instrument tower



Az átlagos szélsebesség relatív gyakorisága [%] 50 méteres magasságban (2006–2012) - The relative frequency of average wind speed [%] at a height of 50 metres (2006-2012)

Figure 10.3.3-6: The relative frequency of average wind speed [%] at the 50 m level of the Paks instrument tower

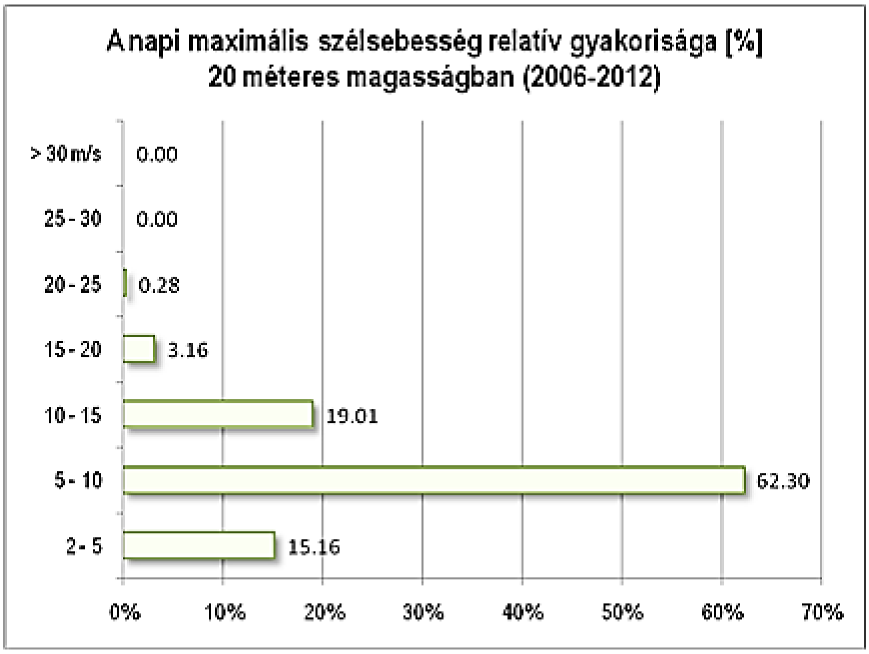


Az átlagos szélsebesség relatív gyakorisága [%] 120 méteres magasságban (2006–2012) - The relative frequency of average wind speed [%] at a height of 120 metres (2006-2012)

Figure 10.3.3-7: The relative frequency of average wind speed [%] at the 120 m level of the Paks instrument tower

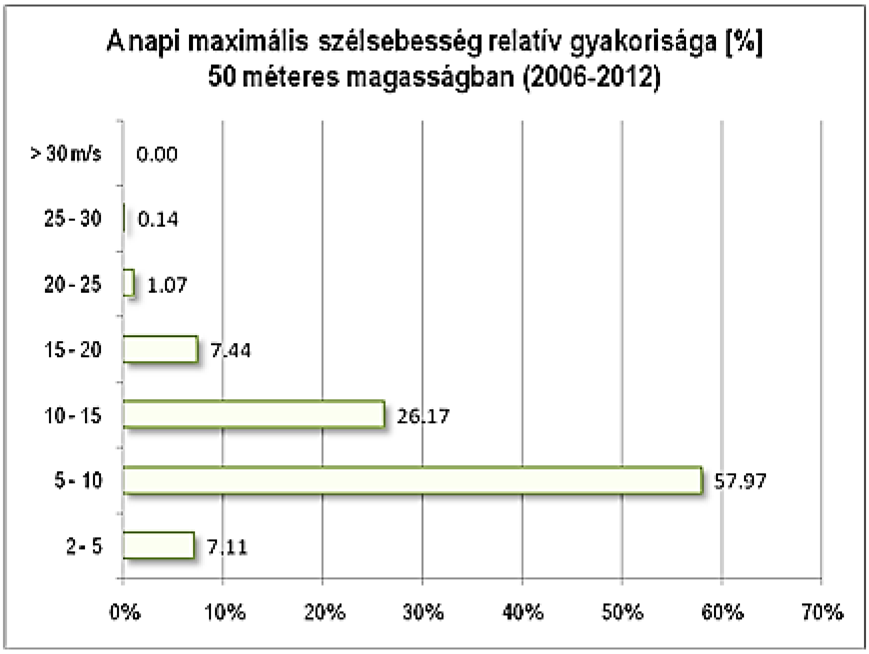
10.3.3.3 Maximum wind gusts

The magnitude of maximum wind gusts also shows an increase with height. The following diagrams present the relative frequency of daily maximum wind speed at the examined levels. One can see that no wind gusts exceeding 25m/s occurred at 20 metres (Figure 10.3.3-8), there were, however, gusts greater than 30m/s at 120 metres (Figure 10.3.3-9).



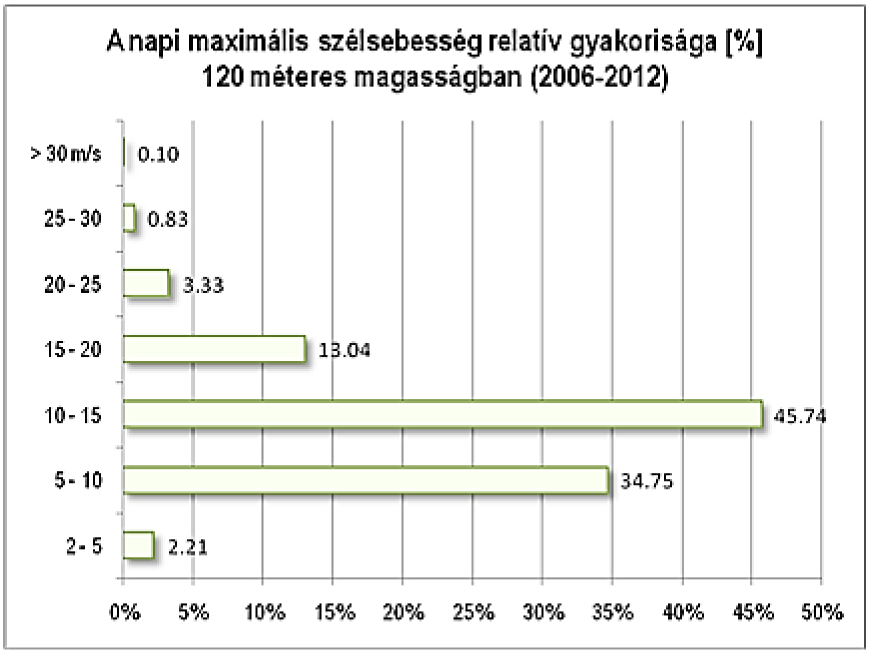
A napi maximális szélsebesség relatív gyakorisága [%] 20 méteres magasságban (2006–2012) - The relative frequency of daily maximum wind speed [%] at a height of 20 metres (2006-2012)

Figure 10.3.3-8: The relative frequency of daily maximum wind speed [%] at the 20m level of the Paks instrument tower



A napi maximális szélsebesség relatív gyakorisága [%] 50 méteres magasságban (2006–2012) - The relative frequency of daily maximum wind speed [%] at a height of 50 metres (2006-2012)

Figure 10.3.3-9: The relative frequency of daily maximum wind speed [%] at the 50 m level of the Paks instrument tower



A napi maximális szélsebesség relatív gyakorisága [%] 120 méteres magasságban (2006–2012) - The relative frequency of daily maximum wind speed [%] at a height of 120 metres (2006-2012)

Figure 10.3.3-10: The relative frequency of daily maximum wind speed [%] at the 120 m level of the Paks instrument tower

10.4 CLIMATE MODELLING

10.4.1 PREPARING OF MODEL SIMULATIONS FOR THE PURPOSE OF UPDATING AVAILABLE MODEL RESULTS WITH MORE DETAILED RESULTS

Two regional climate models have been adopted at the Hungarian Meteorological Service (OMSZ) during recent years for studying climate change:

- ***ALADIN-Climate*** *(Figure 10.4.1-1), a regional climate model developed by Météo France in Toulouse in the scope of international cooperation, moreover*
- ***REMO*** *(Figure 10.4.1-2), the regional climate model developed by the Max Planck Institute in Hamburg.*

Simulations were first run concerning the past with these models in order to test them across a more extended past period known by virtue of measurements, and to help their improvement with conclusions thus discerned.

The regional model experiments were first conducted applying limit criteria that were generated by also using observation information. The targeted quantification of errors in the regional model is possible with the help of such model experiments, since fringe criteria based on measurements (known as *reanalyses*) do not, in theory, introduce any errors in the simulation. These were followed by simulations in which large scale constraints were provided by general global circulation models. Results thus generated concerning the past were also compared with observation data in this case, and since global models, like regional ones, are laden with errors, an impression was therefore obtained about their combined error via this evaluation.

	ALADIN-Climate 4.5		**REMO 5.0**	
Period	1961-2000	1961–2100	1961-2000	1951–2100
Resolution	25 and 10km	10 km	25 km	25 km
Fringe criterion	Reanalyses	GCM	Reanalyses	GCM

GCM: Global Climate Model

Table 10.4.1-1: The characteristics of experiments conducted using the ALADIN-Climate and REMO regional climate models

Having regard to the fact whereby solely the results of global models may be used as a boundary condition concerning the future, reducing the uncertainty of future projections and improvement is a complex exercise, because it demands the parallel development of the regional and global models.

Areas of integration for the model experiments:

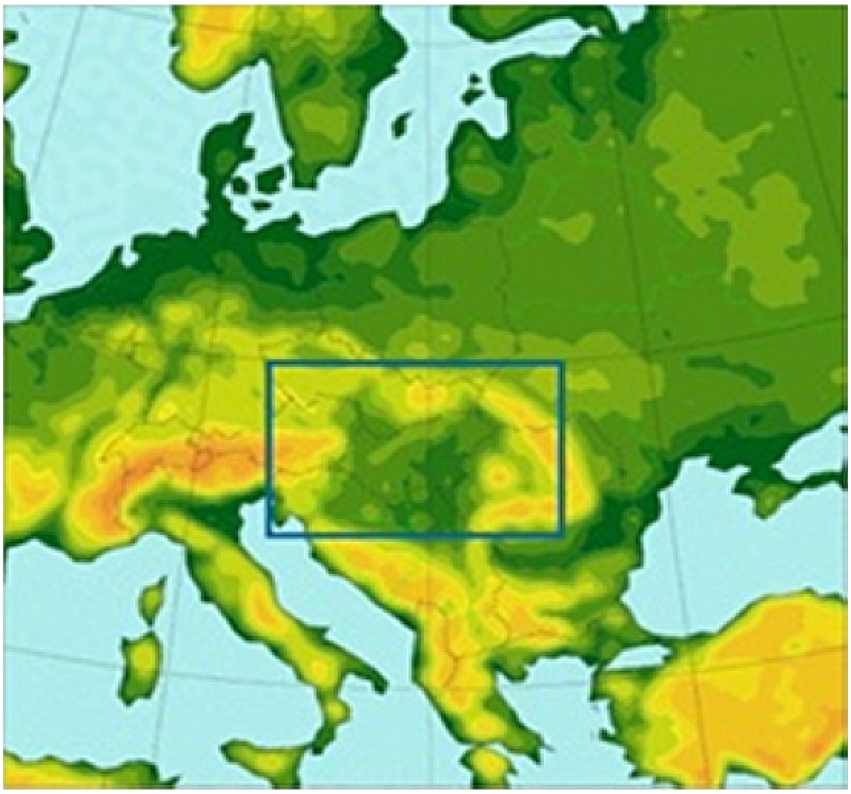


Figure 10.4.1-1: The 25 (entire panel) and 10km (blue rectangle) resolution domains of the ALADIN-Climate model

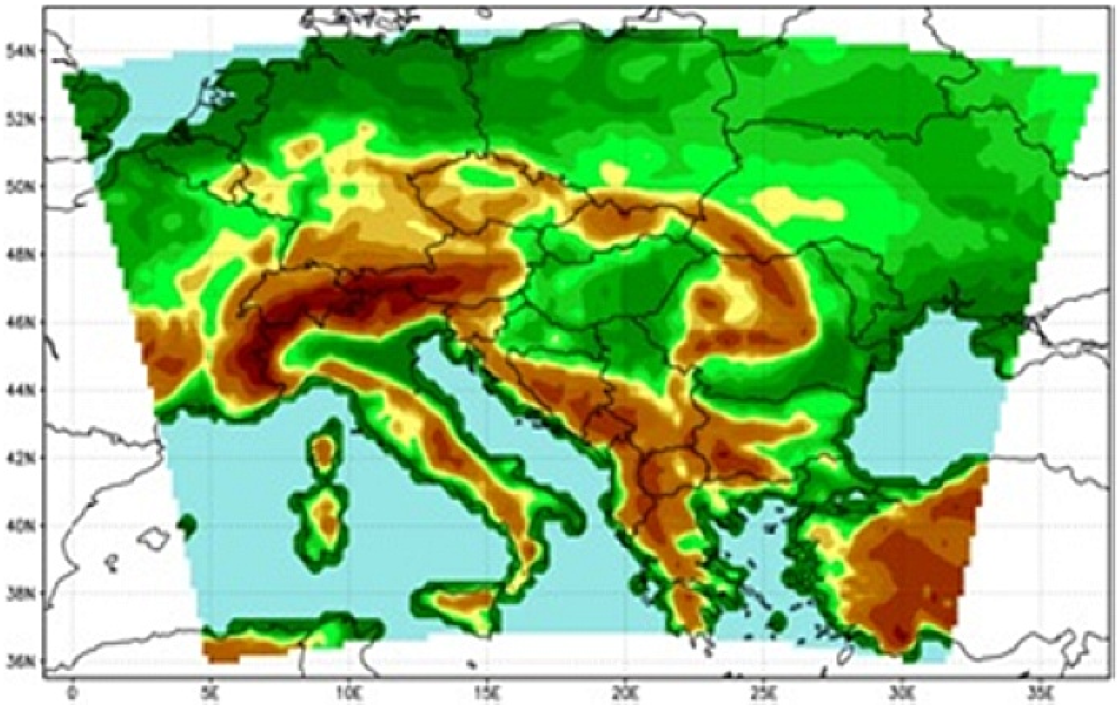


Figure 10.4.1-2: The REMO model's domain covered with 25km resolution

Model results were compared with an observation database interpolated to the grid regarding the 1961-1990 period. We concluded that depending on the boundary condition applied, the regional models can yield a completely different result. We also found that better results can be had when conducting the simulation with rougher resolution for a greater area than by using finer resolution. This leads us to infer that the size of the area selected in the case of the 10km resolution was not sufficiently large; in addition, the edge of the domain being in mountainous country caused a problem for the precipitation results.

Since we are planning to update our current results with 10km resolution results in the future, specifying the optimal integration domain is a key matter for the new model experiments. There are two fundamental criteria that must be taken into consideration when selecting the domain:

(i) the area has to be large enough to describe regional conditions, at the same time

(ii) the maximum size of the area is determined by the calculation capacity that is available.

A sensitivity study is necessary to designate a suitable domain. Aside from the modified integration area, however, the new experiments also involve other changes. Emission scenarios that have been used to date are gradually being replaced in current global model experiments with new and more advanced scenarios which were developed on the basis of principles different than their predecessors. The scaling down of global model experiments prepared with the new scenarios to the European scale is taking place over several steps in the scope of a coordinated cooperation effort, the EUROCORDEX initiative: the new global model experiments are first scaled down to the area of Europe with a 50km resolution, then results from that are taken as the baseline to complete 10km resolution model simulations.

The goals of the international CORDEX cooperation include, among others:

(1) Producing regional climate simulations regarding different areas on Earth,

(2) The joint assessment of results, to which end the experiments are conducted over identical areas using identical resolutions,

(3) To promote closer cooperation between meteorologists and users.

Due to limited calculation resources, the institutions share the workload of conducting the simulations based on different scenarios and regional models, so the harmonisation of the model versions and domains applied carries particularly great significance. That is the reason why a consultation process has also been started at OMSZ, in the interest of our results being possible to use in the international project, and so that we can secure access to international results.

As the first step thereof, the newest version of the ALADIN-Climate model used in the EURO-CORDEX Project was adapted on OMSZ' supercomputer. The model's IT testing was completed first during adaptation: whether or not the model's program code is functioning properly in the Hungarian computer environment was examined. Multiple experiments had to be conducted with the model, in which—among other things—we tested whether or not the model would yield identical results using different compiler switches that leverage the advantages of the multi-processor environment; in other words, whether or not we would obtain the same outcome using for instance 8, 16, 32 CPUs as we obtained on 1 CPU, and whether or not we would get the same result when applying a compilation that accelerates how the model runs and rearranges the code than we would without these. This appears trivial, nevertheless the general experience was that the various models behave in different ways on different platforms, and problems which did not occur in the previous environment can frequently appear for the adaptation. This is also what happened when the ALADIN-Climate model's new version was adapted, and it took several months for us to find the reason for the deviation. Once the model passes IT testing, the physical correctness of the results have to be examined: for one, whether or not the model yields physically meaningful results, and on the other hand, the degree by which results received in the current environment deviate from results obtained in the legacy environment. In the case of ALADIN-Climate, this was no longer a problem after the IT bugs were eliminated, and we were able to conclude the model's adaptation successfully. Therefore the latest version of the ALADIN-Climate model, also used in international experiments, is available to us as a result of that, and we can soon begin the 50km resolution experiments we need to complete before the 10km simulations that were set as the ultimate goal.

10.4.2 UPDATING OF AVAILABLE RESULTS WITH RESULTS FROM MORE DETAILED MODEL SIMULATIONS RUN USING NEWER MODEL VERSIONS

Projections until the end of the 21st century were completed with the two regional climate models (ALADIN-Climate and REMO), taking the A1B emission scenario into consideration. Data are available to us regarding the Carpathian Basin region at 10 and 25km resolution (Table 10.4.2-1).

Model	Resolution	Fringe criterion	Scenario	Period
ALADIN-Climate 4.5	10km	ARPEGE	A1B	1961–2100
REMO 5.0	25 km	ECHAM	A1B	1951–2100

Table 10.4.2-1: Characteristics of the model experiments that were used

These are the results we are planning to update with model simulations completed in accordance with the latest 10km resolution scenarios, known as RCP scenarios. This process includes several steps:

(1) Adapting the latest model version

(2) Conducting the experiments applicable to the past with the model, and validation of results; then

(3) Preparing simulations applicable to the future, and assessing their result.

For the ALADIN-Climate model, fine resolution experiments will be conducted in two stages:

- *results from the ARPEGE-Climat global model will be scaled down to a range covering Europe with 50km resolution first, then*
- *the 50km resolution ALADIN results will be used as the baseline for completing 10km resolution simulations for a smaller area.*

This chapter provides an account of the second step in the above process, namely about the validation of the latest version, v5.2, of the ALADIN-Climate regional model having been completed in the framework of the EURO-CORDEX programme.

The latest RCP scenarios—which are also used in the IPCC's next situation assessment report—are used to produce the climate projections concerning the future. Our envisaged 50km resolution experiments, the results of which are to be scaled further down to reach the fine resolution projections, will be conducted with EURO-CORDEX (i.e. the European branch of CORDEX).

The integration domain is a uniform area that covers the whole of Europe (Figure 10.4.2-1), where modelling groups run with 10 and 50km resolutions. OMSZ' calculation capacities do not make it possible to cover Europe with a simulation of 10km resolution, which is why we committed to conducting a 50km resolution model experiment.

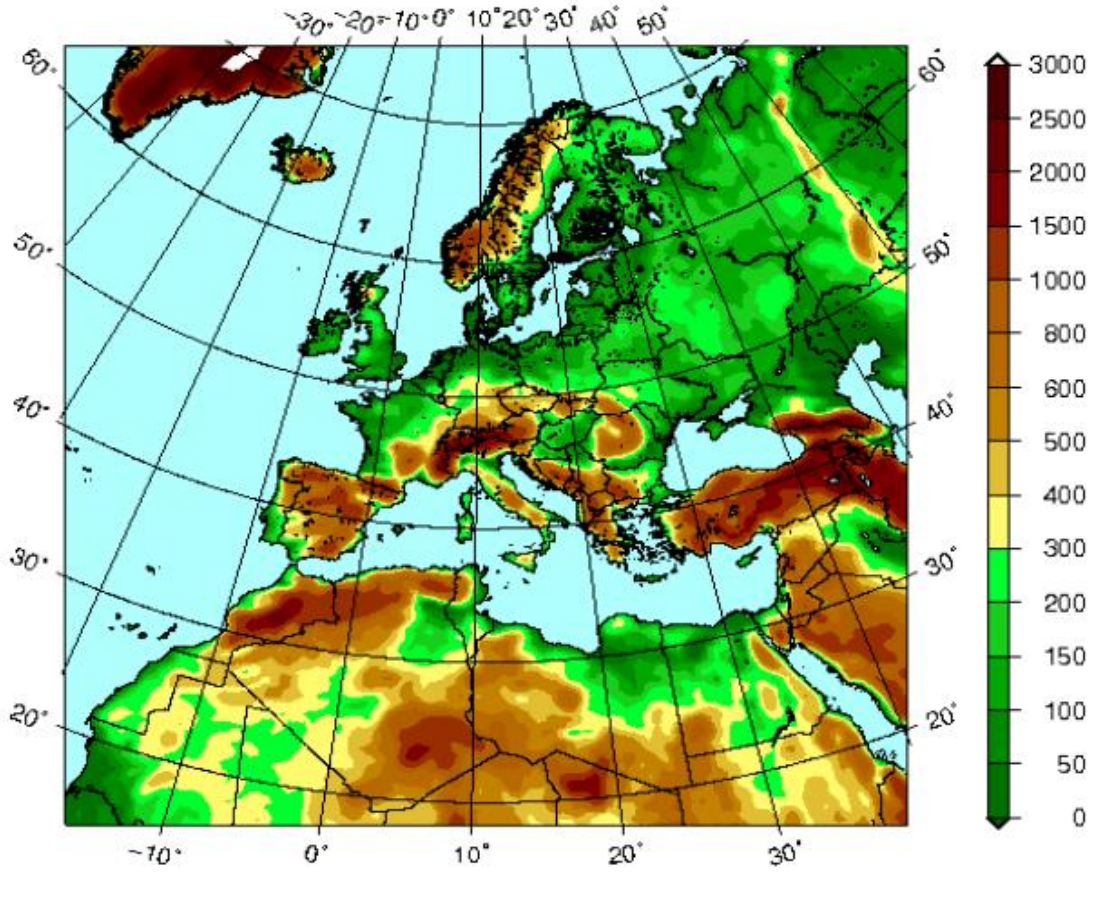
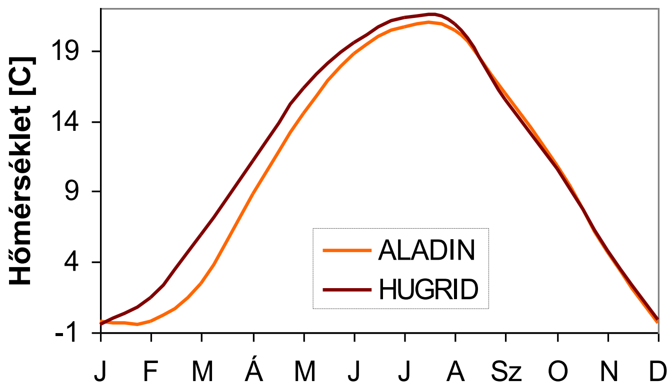


Figure 10.4.2-1: The EURO-CORDEX domain and its 50km resolution topography

Before climate simulations applicable to the future are started, one needs to complete **the validation of the models,** i.e. their testing for the past, in order to have the chance to learn the models' strengths and weaknesses, and to be able to improve them based on these. We expect the model to be able to describe climate conditions from the past, since how else would it be possible to have confidence in its being able to appropriately simulate changes that are anticipated in the future? At the same time, one also needs to realise that a model which profiles the past appropriately will not necessarily yield correct projections for the future exactly because of climate change, just like a model deemed poorer during validation may not necessarily provide bad results regarding the future.

After adapting the latest version of ***ALADIN-Climate,*** the model's validation integration for the 1989–2008 period was completed at the end of the previous year at 50km resolution, for the EURO-CORDEX domain, and using ERA-Interim reanalysis data as fringe criteria. Reanalyses are produced using observations and model simulations from the past, which allows the most accurate possible spatial and temporal description of the three-dimensional atmosphere's momentary state at a uniform resolution. The weaknesses of simulation results that are produced using these as the starting point are derived from the regional model for the most part, because the limit criteria only have a small intrinsic error.

Grid point observation databases were used as a reference when evaluating the results. ALADIN-Climate was relatively successful in representing annual temperature progression in Hungary, but a few degrees of underestimation can be observed in the first half of the year (Figure 10.4.2-2).



Hőmérséklet [C] - Temperature [C]

Figure 10.4.2-2: Measured (HUGRID) and modelled (ALADIN) average temperature values for Hungary

As concerns territorial distribution, bigger errors were received in the eastern half of Hungary, with some minor overestimates in the western parts for the autumn-winter months. The climate model proved excessively rainy throughout the year for a large part of the country, yet it reflected the summer maximum and the secondary maximum in November appropriately.

After validation, the downscaling of the ARPEGE-Climat global climatic model's results to 50km can begin regarding the 1951-2100 period. During the global runs, radiation constraints were taken into consideration according to the most pessimistic emission scenario, RCP8.5. These 50km results will serve as fringe criteria for the 10km simulation, for which we are to determine the optimal size model range through sensitivity testing.

Similar experiments are planned with the latest version of ***REMO.*** Validation integration run with ERA-Interim as the projection basis will be executed on a Europe size area at 10km resolution. The ECHAM global climate model's results will serve as the fringe criteria for the projection experiments. Its approximately 200km resolution results will also be scaled down in two steps, to 10km resolution for the 1951–2100 period, but only the second downscaling step will be performed at OMSZ, and the interim 50km resolution results will be taken from the model simulations of the Max Planck Institute in Hamburg. The reason for this is that the calculation capacity currently installed at OMSZ is insufficient for us to complete two of our own experiments using the REMO model within an acceptable timeframe. Fine resolution experiments will also be preceded by a sensitivity study concerning the optimum integration range. Planned simulations are summed up in Table 10.4.2-2.

Having regard to the fact whereby the updating of our fine resolution simulations is still in its initial stages, data provision in this project will be realised from the experiments appearing in Table 10.4.2-1.

Model	Resolution	Fringe criterion	Scenario	Period
ALADIN-Climate 5.2	50 km	ERA-Interim	-	1989-2008
	10 and 50km	ARPEGE	RCP8.5	1951–2100
REMO 2009	10km	ERA-Interim	-	1989-2008
	10km	ECHAM	RCP8.5	1951–2100

Table 10.4.2-2: The experiment planned with the ALADIN-Climate and REMO models

10.4.3 Processing of Available Results in Respect of Average Conditions

This subchapter will provide a summary of the analyses that are going to be conducted in the scope of the project on the basis of available model results. The means of producing data will be presented, along with the methodology of our examinations associated with climatic conditions. Since climate simulations are laden with uncertainties, one must also declare the uncertainties of simulation in addition to model results as part of interpreting projections, which may be done most simply by applying two models.

10.4.3.1 Examined area

Examinations were completed for the 30km vicinity of Paks. The selected area with the grid points from the model that are associated with it—which entails 7 × 7 points from the 10km, and 4 × 3 points from the 25km resolution model—is shown in Figure 10.4.3-1.

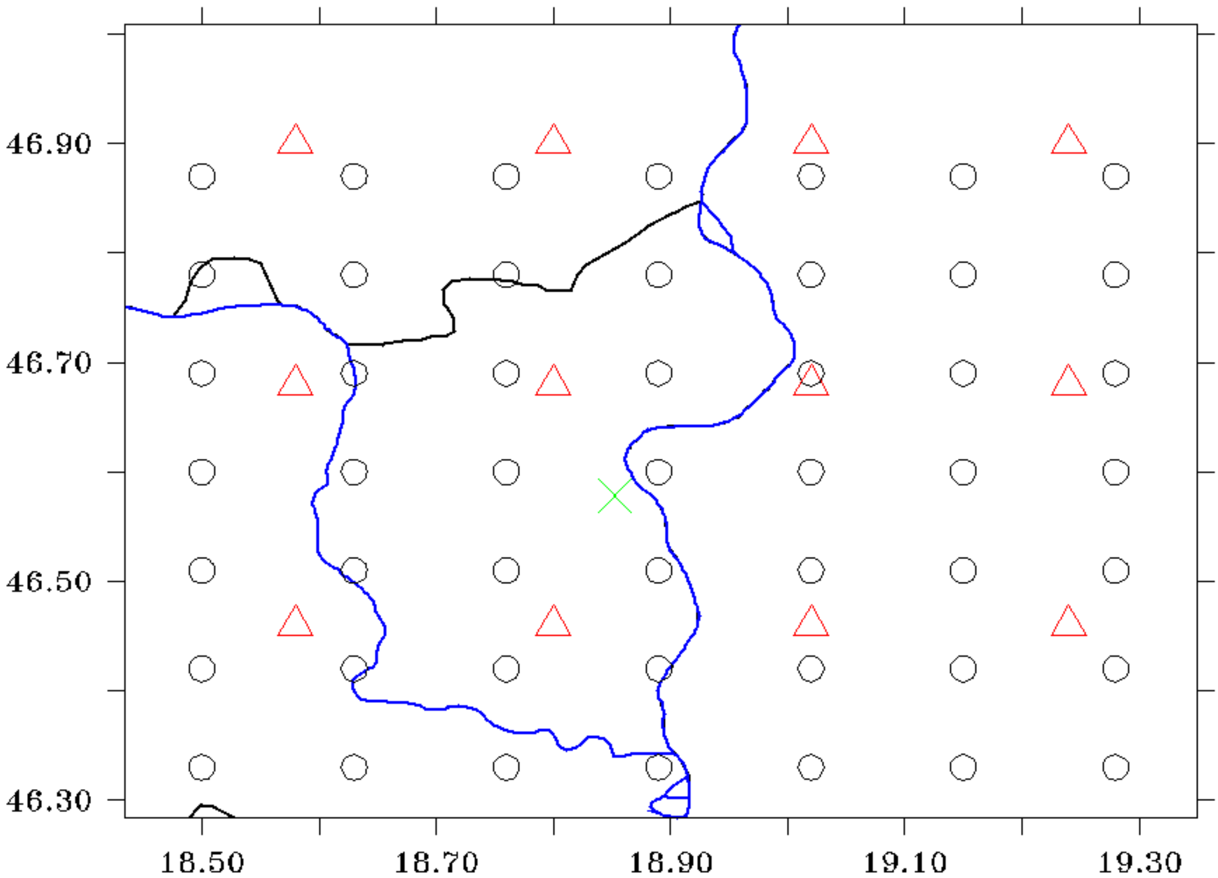


Figure 10.4.3-1: The ALADIN-Climate (black) and REMO (red) models' grid points situated in the surroundings of the Paks Nuclear Power Plant (green)

10.4.3.2 Examined periods

The selected future periods were 2011-2040, 2041-2070 and 2071-2100, since climate can only be interpreted on a longer timescale of at least 30 years according to the World Meteorological Organization's recommendation. The models describe actual processes in an approximated way, therefore results are laden with lesser and greater errors by necessity. In the interest of eliminating systematic errors, future results are not interpreted on their own, rather in relation to the models' own reference period of 1961-1990—meaning that changes are specified (even though the models' defects will not necessarily be constant over time).

In addition to processes that form the natural climate, model simulations also take the effects of human activity into consideration. As we are not in a position to be aware of how that will develop over the entire 21st century, different hypotheses—referred to as scenarios—are determined, which present the different development opportunities of anthropogenic activity in the future. The human impact is quantified in the form of carbon dioxide concentration for the models, i.e. the various scenarios describe different progressions of atmospheric carbon dioxide concentration (all showing strictly monotonous growth). There are optimistic, pessimistic and more subtly differentiated versions among the scenarios; the model experiments conducted at OMSZ relied on the ***A1B*** (***average***) ***scenario***. During implementation, measured carbon dioxide concentration levels are incorporated in the model simulations' section lasting until 2000, and the said hypothetical scenario is taken as the basis beyond that. Thus, when evaluating the results of model simulations prepared with the SRES scenarios, it is reasonable to choose a reference period that lasts until 2000 (e.g. 1961-1990, 1971-2000), because the simulation can only be interpreted as a projection after that. Most specialists who deal with climate modelling usually take the period between 1961-1990 as the basis, because this is how the model can show significant, major change signals concerning the 21st century.

10.4.3.3 Examined variables

Model results are available in a six hour breakdown, out of which a statistical quantity applicable to thirty years is derived: monthly , seasonal and annual climatic averages are taken in the case of average conditions, and average frequency values pertaining to thirty years are regarded when examining extremes. The selected variables included the following in respect of average conditions (*A – annual, S – seasonal, M – monthly values*):

- Average temperature (*A, S, M*)—the extent of change is expressed in degrees Celsius;
- Total precipitation (*A, S, M*): the models distinguish between large scale (frontal) precipitation and that resulting from convection (rain showers, thunderstorms), as well as between snow and rain; all of these are included in total precipitation—the extent of change is expressed in mm or as a %;
- Average relative humidity at a height of two metres (*A, S*)—the extent of change is expressed as a %;
- Average wind speed at a height of ten metres (*A, S*): momentary wind speed is calculated from the two horizontal components (u and v, with directions x and y) of wind on the basis of the $\sqrt{u^2 + v^2}$ formula—the extent of change is expressed in m/s or as a %;
- Most prevalent wind direction (*A, S*): in meteorology, the north wind (N) means that the wind is blowing from the northern direction. Wind direction is calculated from the gradients of the u and v components (tg(u/v)) every six hours, then we check the frequency with which the wind directions fell into the various cardinal points of the compass (N, NNW, NW, WNW, W, WSW, SW, SSW, S, SSE, SE, ESE, E, ENE, NE, NNE; 16 in total) over the entire period (at annual or seasonal level). The greatest one among these will be the most prevalent wind direction. The frequency of the various wind directions is expressed as a %, and their change is plotted.

10.4.4 PROCESSING OF AVAILABLE RESULTS IN RESPECT OF METEOROLOGICAL EXTREME PARAMETERS

This subchapter will present the methodology of our examinations associated with extreme climate conditions. Since climate simulations are laden with uncertainties, one must also declare the uncertainties of simulation in addition to model results as part of interpreting projections, which may be done most simply by applying two models. This is something we also follow for the climate examinations we completed in the scope of the project, and for those that are to be completed still, based on the results of model simulations. The examination area and period correspond to the area and periods presented in subchapter 10.4.2.

10.4.4.1 Examined variables

Different indices were selected to profile extreme conditions. The extreme indices applicable to temperature and precipitation are presented in Table 10.4.4-1. Taking a seasonal breakdown is pointless in the case of temperature indices, since there may be summer days at any time roughly from May to September, so it is best to take their annual number; while for precipitation indices, annual and seasonal results are presented in every case, as they can reflect large variability within the year. For these indices, change is expressed using the particular index's unit of measure (days, mm/day, mm) in addition to relative change expressed as a percentage. It is expedient to treat these two kinds of information together, because that will provide an overall impression about the extent of changes. (E.g. one is inclined to imagine a drastic change where a particular index shows a large relative change because it seldom appeared during the reference period in the past. In such cases, changes expressed in days provide a more subtle differentiation, since they reflect the fact whereby a great relative change actually means a low number of days. At the same time, this is also true the other way around: greater changes expressed in days can also be slight in relative terms in the case of an index that occurs frequently.)

Symbol	Name	Definition	Unit
TX30	Number of hot days	T_{max}>30 °C	days
TX35	Number of sweltering days	T_{max}>35 °C	days
HEAT1	Days with a level 1 heat alert	$T_{average}$>25 °C for 1 day	days
HEAT2	Days with a level 2 heat alert	$T_{average}$>25 °C for 3 days or $T_{average}$>27 °C	days
HEAT3	Days with a level 3 heat alert	$T_{average}$>27 °C for 3 days	days
TN20	Number of hot nights	T_{min}>20 °C	days
FD	Number of freezing days	T_{min}<0 °C	days
RR10	Number of days with precipitation above 10mm	R_i> 10mm	days
RR20	Number of days with precipitation above 20mm	R_i> 20mm	days
RR50	Number of days with precipitation above 50mm	R_i> 50mm	days
SDII	Daily precipitation intensity	R_{total}/day, when R_i> 1mm	mm/day
RX1	Value of max. daily precipitation	max(R_i)	mm
RX5	Value of max. five-day precipitation	max(R_i+R_{i+1}+R_{i+2}+R_{i+3}+R_{i+4})	mm
CWD	Max. number of consecutive wet days	days when R_i> 1mm	bap
CDD	Max. number of consecutive dry days	days when R_i< 1mm	days

Table 10.4.4-1: Definitions of the calculated extreme indices

10.4.5 Deriving uncertainties based on the results of two regional climatic models

This subchapter will describe the three key uncertainties that arise during climate modelling. It presents how uncertainties can be quantified in different ways, as well as the way results from the two climate models that were also applied in the project can be used for all of that.

After year 2010, "last year was extremely wet" is something that was often said, and our experiences from the next statement are perhaps even fresher: "The summer of 2012 was extremely hot." The **variability** of individual years is a natural part of climate, and it exists even without any external constraint whatsoever, therefore such instances cannot be attributed to climate change. When examining the climate, it is values, trends and changes taken as averages of long years that are considered.

The most important uncertainty of climatic modelling is **uncertainty derived from the models**. Models resolve the equations that govern the processes of the climate system with the help of numerical methods. In the course of this numeric solution, state parameters (i.e. temperature, wind speed, etc.) are regarded in the points of a three-dimensional spatial grid, and certain interactions are described in simplified form with the help of what are referred to as parameterizations. The models developed at the various institutes differ in many respects: they may apply different approaches and parameterizations to describe the same physical process, furthermore they might use grids of differing resolutions. All of these differences also have their effect on model results.

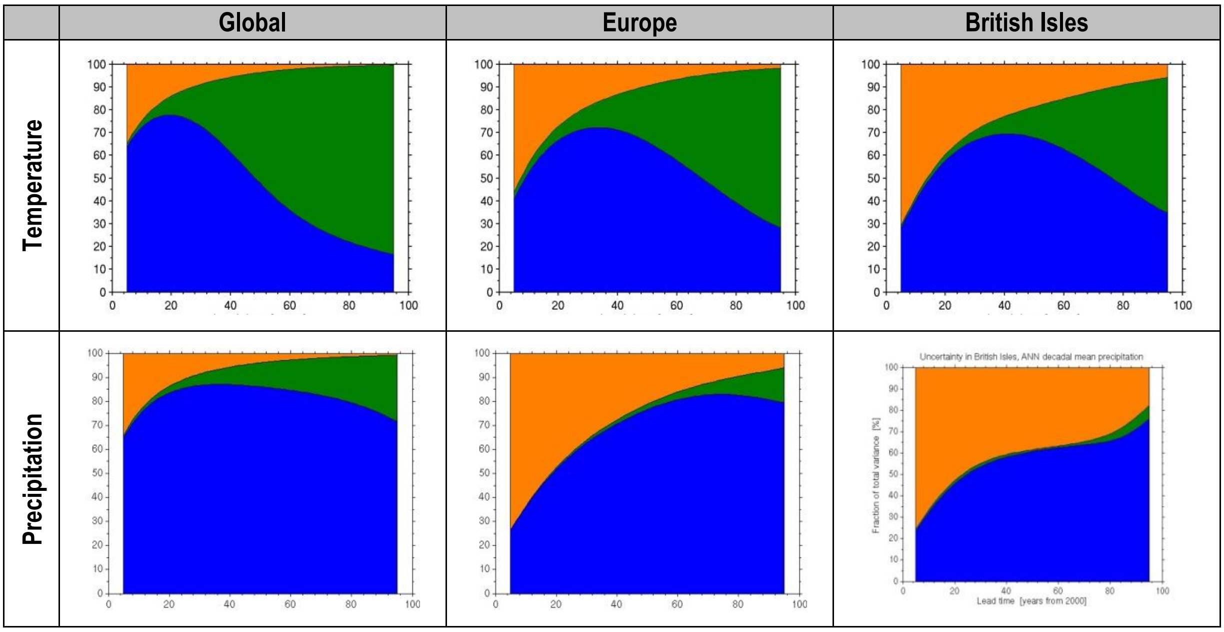
Anthropogenic activity has been proven to have an effect on climate processes, therefore it also needs to be taken into consideration in climate models. It is not possible to define how man's activity will develop in the future in an exact manner: we do not know the degree by which humankind's headcount will increase, what energy and economic policies various countries are going to adopt, what the level of technological development will be, i.e. we cannot tell the amount of pollutant emission in the future either. Multiple kinds of emission scenarios were created to this end (Nakicenovic and Swart, 2000), which quantify the impact of human activity in the form of carbon dioxide emission. There are scenarios that describe a pessimistic future (in other words ones that assume additional significant emissions), but optimistic and average scenarios also exist, and all of them have vastly differing degrees of atmospheric greenhouse gas incidence by 2100. Uncertainties resulting from this are called **scenario uncertainties.**

Models are first tested in respect of the climate of the past, and developed on the basis of the results. After that, simulations regarding the future are conducted with them, using extra greenhouse gases caused by human activity as an input parameter. Since the different models characterise the climate in different ways, results from multiple models are always considered when examining climate change (which is known as the ensemble method), because this way the uncertainties of climate simulation outcomes can be quantified. In their article [10-3], Hawkins and Sutton provide a methodology regarding the ratio of the various uncertainties: they examined the results of temperature and precipitation simulations conducted with 15 global climatic models and taking three scenarios into consideration, and took distributions from these as the basis in determining the ratio of the three factors of uncertainty for the different regions. They concluded that at global level, internal variability has a little role (Figure 10.4.5-1), while narrowing down an area (e.g. the British Isles) renders this significant even in case of averaging for ten years, particularly in respect of precipitation. The uncertainty of the scenarios is manifested rather from the second half of the 21st century, and its significance decreases as the area is narrowed down. In the case of precipitation, it all but loses its role (meaning that the difference between precipitation results from a simulation run with two identical scenarios, but with different models is greater than results from experiments conducted with different scenarios, but an identical model).

The uncertainty resulting from model differences is of critical significance almost throughout the 21st century in the case of both precipitation and temperature, therefore the majority of researchers agree that improving the models will be necessary to decrease uncertainty (to reduce the blue area on the charts in Figure 10.4.5-1).

When examining climate change, it is important to use multiple (at least two) models in order to quantify uncertainty, since all of the models describe the climate of the future as being equally possible.

The Carpathian Basin is probably a more sensitive area than the British Isles; results from the global models are less applicable here also as a consequence, among other things, of their poor resolution. That is why global information needs to be refined with the help of regional climatic models in order to determine the ratio of uncertainties. A number of regional climate models were run with 25 and 50km horizontal grid resolution in the framework of the European Union's ENSEMBLES Project (van der Linden and Mitchell, 2009), applying the A1B average scenario from among the scenarios. The A1B scenarios were likewise used at OMSZ for the experiments conducted with the two climate models—the ALADIN-Climate and REMO models—at 10 and 25km resolution.



Note:
blue: uncertainty resulting from differences among the models
green: inherent uncertainty of scenarios
orange: internal variability

Figure 10.4.5-1: The percentage ratio of uncertainties that are characteristic of global climate models' simulations (using ten year averaging) applicable to the whole Earth, Europe and the British Isles, between 2000 (Year 0) and 2100 (Year 100) [10-1]

The magnitude of simulation results' uncertainty can be illustrated with multiple kinds of techniques that provide good visualisation. One of them, for example, is when one considers different thresholds to see what percentage of the examined models yields a change that exceeds them, and illustrates this result on a probability map (this will answer the question "what is the probability of the given change?"). For instance, if one examines that precipitation change will be greater than 0 % using results from four regional model experiments, then probabilities of 0, 25, 50, 75 and 100 % will exist in the case of the four models, depending on whether 0, 1, 2, 3 or 4 of them show increasing precipitation.

Although the models used at OMSZ do concur in respect of the small change in annual nationwide total precipitation, they fail to agree on even the direction in which winter precipitation will change: one of the models indicates an increase, the other a decline for both the near future and the end of the century. This pinpoints the fact whereby it is worth the trouble to include several models in any examination, and the two models may be complemented with a set containing a greater multitude—e.g. with the ENSEMBLES results (Figure 10.4.5-2)—for the purpose of confirming change direction magnitude.

According to one of the OMSZ models, an increase of 7 % is likely for the near future, while according to the other one, a 10 % drop is probable regarding the nationwide average; if, however, the 17 simulations in ENSEMBLES are also taken into account, then the increase is already 60-80 % probable (i.e. the 17 models show an increase of 60-80 % for Hungary regarding 2021-2050). And looking at the distant future, one may declare with a probability of 80-100 % upon examining the ENSEMBLES results comprising 13 members that the increase of precipitation is likely in the country. In other words, therefore, probability information must be treated appropriately, then incorporated to join the forecast results.

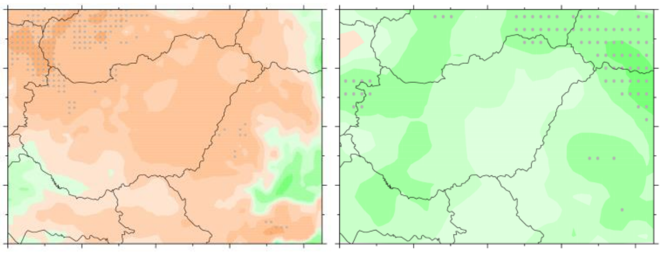
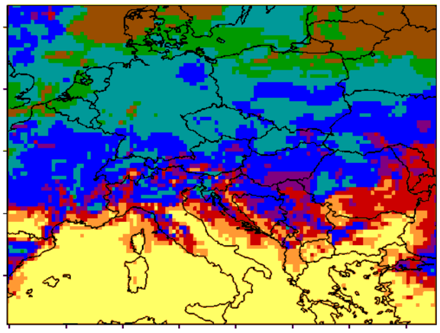
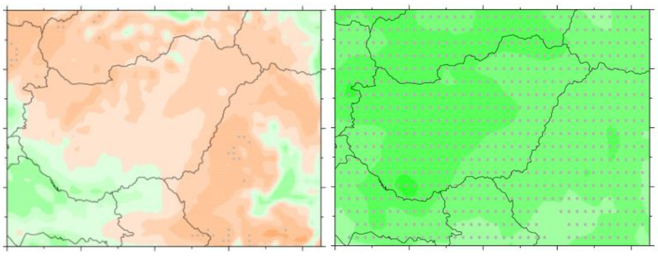
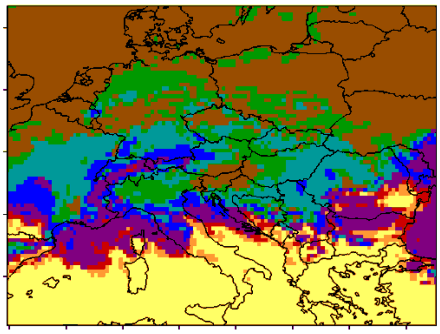
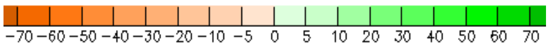
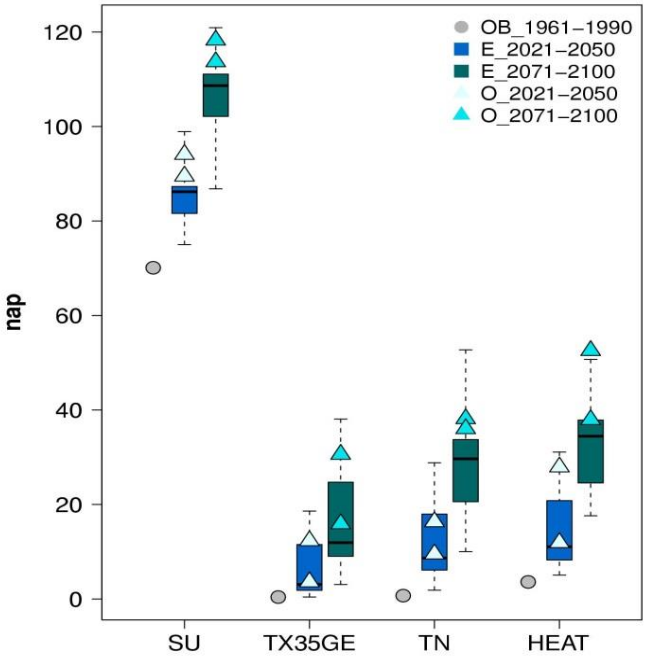
	Change in precipitation (ALADIN-Climate and REMO)	**Probability of an increase in precipitation (ENSEMBLES)**
2021-2050, winter	 nationwide average: -10 % +7 %	
2071-2100, winter	 nationwide average: -3 % +30 %	
		

Figure 10.4.5-2: Winter precipitation change (%) based on the results of the two regional climate models used at OMSZ (left panel), and the probability of winter precipitation increasing (%) based on ENSEMBLES simulations (right panel) for 2021-2050 and 2071-2100. Reference period: 1961-1990.

The other popular way of illustrating uncertainties, known as box-plot charts, can already be interpreted for fewer, but ideally at least five simulations, and this answers the question “how large a change is associated with the given probability?”. In this case information can be gathered about the lowest and highest extreme values, and figures linked to the 25, 50 and 75 % probabilities if sufficient simulations are available.

An unequivocal increase is probable for the 21st century regarding hot extreme values (Figure 10.4.5-3), and this growth is more intensive for the more distant future, but the extent of the change and distribution among the models’ results is not beside the point.

Something that is characteristic of the models used at OMSZ is that the change they indicate always exceeds the median (the middle value, i.e. the one that occurs with a profitability of 50 %) calculated from the results of the ENSEMBLES models; in other words, ALADIN-Climate and REMO belong to models that render greater heating probable, but they only cover a smaller interval out of the overall uncertainty. In the case of extreme hot weather which seldom occurs, the models also indicate a great increase, and large distribution at the same time: e.g. the median will increase from one day with a maximum temperature above 35 °C (known as a sweltering day) on average per year observed nationwide between 1961-1990 to 3 such in the near, and 12 in the distant future, but something that is not beside the point is where this value is located between the 1-18 day extreme values regarding the near, and the 3-38 day range for the distant future.



nap - days

Remark:
When calculating future values, the change indicated by the models was added to the observations.
grey circle: value observed in Hungary
blue and grey box-plot: future value
lighter and darker triangle: ENSEMBLES results
SU: summer day, T_{max}>25;
TX35E: sweltering day, T_{max}>35;
TN: excessively hot nights, T_{min}>20
HEAT: heat waves, $T_{average}$>25°C

Figure 10.4.5-3: The observed and future value of some hot temperature index for Hungary as per the ENSEMBLES results, and OMSZ's two models for the periods between 2021-2050 and 2071-2100

In the case of European model results in the public domain, it is often only the results received for the base variables (daily average temperature and total precipitation) that are published, and this does not allow conducting a widespread study in may cases. In the case of the models used at OMSZ, we have the option to examine significantly more variables and their relationship. In case results from two models are available, changes indicated by both models are disclosed in order to also present the uncertainty of the change. Regarding freezing days, the models used at OMSZ (Figure 10.4.6-5) uniformly indicate a drop of 10-15 % for the 2011-2040 period, in other words, we could even take the average of the two for the sake of simpler handling. The gap starts to widen for 2041-2070, which is to say that the difference between results increases, but they still indicate changes that are close to each other, between 23 and 32 %. By the end of the century, even these two models include significant uncertainty by showing a value between 35 and 58 %, and considering the average of the two models (47 %) would no longer be appreciate.

Therefore based on the above one can see that the results of the simulations are laden with uncertainty, also due to the different physical parameterization, resolution, and other numeric characteristics of the models, which can be reduced further through developing the models. These uncertainties must be taken into consideration when using the results, therefore we need to strive to transfer (and receive) probability information instead of a simple yes/no. The simplest way to do that in the case of two models is to treat results from the two models using an identical approach.

10.4.6 Climate change in the vicinity of Paks based on results from the two climate models

The two regional climate models applied at OMSZ are used to scale down the results of their global counterparts to a bounded range with a finer resolution. Input data for this, known as fringe criteria, were provided by the ARPEGE-Climat general global circulation model in the case of ALADIN-Climate, and the global ECHAM5/MPI-OM Atmosphere and Ocean Global Circulation Model in that of REMO (Table 10.4.1-1). The effect of human activity regarding the future was taken into account based on the global carbon dioxide concentration values of the SRES A1B scenario (which can be considered as an average version among the pessimistic and optimistic scenarios) when the global models were run. Projections run with the two regional models are available for the entire 21st century at 10 and 25km resolution for a domain covering the Carpathian Basin, and one for Central Europe (Figure 10.4.6-1).

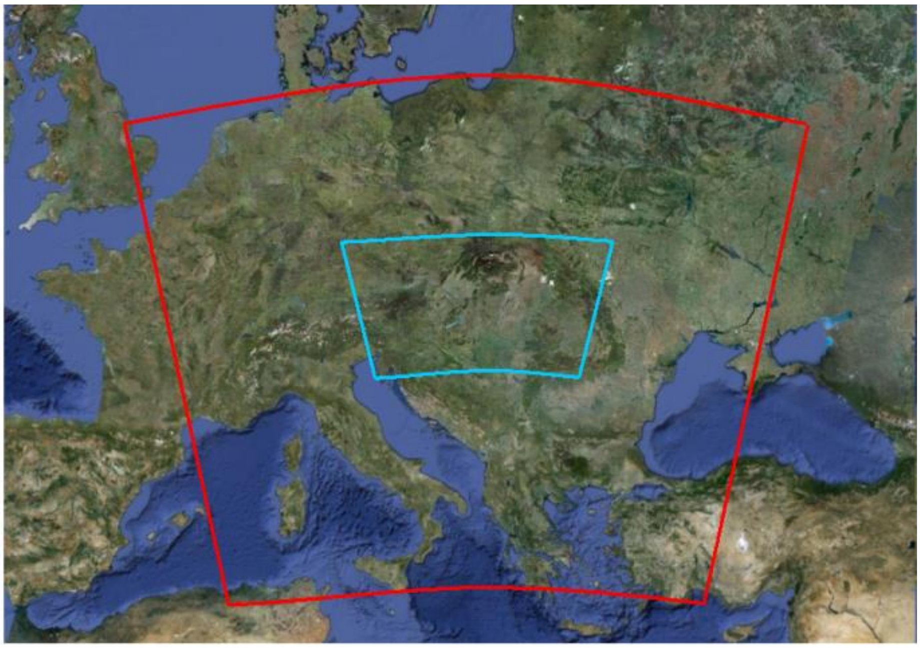


Figure 10.4.6-1: The execution domains for the ALADIN-Climate (blue) and REMO (red) models

This study presents results from these. The combined examination of the two regional models affords the opportunity—even if a limited way—to quantify the uncertainties that originate from the models' differences. The results of both models provide a possible description of future climate conditions, therefore they will be considered jointly, without differentiation going forward.

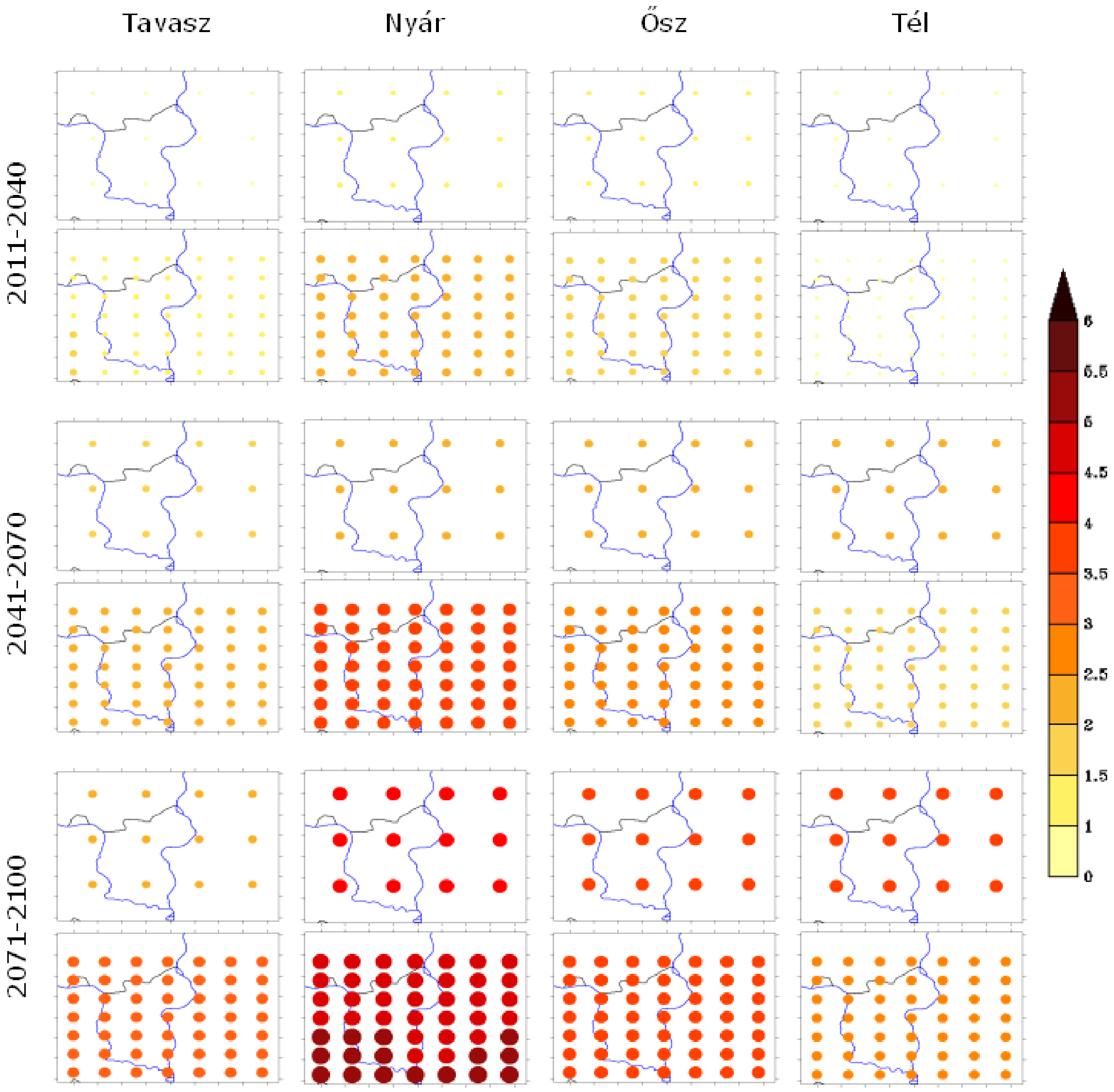
Results were evaluated for the 30km environs of Paks, which entails 7 × 7 points from the 10km, and 4 × 3 points from the 25km resolution model (Figure 10.4.3-1). Focus is going to be on three 30-year future periods when presenting the results: the 2011-2040, 2041-2070, and the 2071-2100 periods. Given the approximative nature of the models, model results are laden with smaller and greater errors, therefore values (temperature, precipitation, etc.) applicable to the future are not provided by themselves, rather as a change relative to the models' own 1961-1990 reference periods. In the case of the tables, average values for the grid point observational database (between lon. N 18.5-19.3 and lat. E 46.3-46.9) generated on the basis of OMSZ measurements are also disclosed, so as to provide a basis for comparing these changes.

10.4.6.1 Temperature

Gradual warming can be expected for the surroundings of Paks during the 21st century according to both models, at annual, seasonal and monthly level alike. What this means is that the farther the 30-year period considered, the stronger the monthly, seasonal and annual average temperature increase will be. There will still be natural variability among the years, so months and seasons colder than the average may also occur in the future. The two models forecast unequivocal increase for the future, yet the extent of the change is not as clear-cut: one model essentially provides warmer value than the other. Annual and seasonal changes in the vicinity of Paks can be read in Table 10.4.6-1. One can see that the strongest warming can be expected in summer for every period, and may already exceed 2 °C even in the near future, and may reach 5 °C at the end of the century. The models show the second greatest temperature increase for autumn, so much so that from the middle of the century, autumns can be expected to become warmer on average than spring. Winter and spring warming is the most moderate at the beginning of the century, and both models project that average winter temperature is more likely to be positive than negative between 2071-2100. As concerns territorial distribution, temperature change is quite homogeneous within the domains under consideration according to both models (Figure 10.4.6-2), we can see a bigger change for summer in the last decades of the century in just one of the models.

	1961-1990	2011-2040	2041-2070	2071–2100
	observation (°C)	change (°C)		
Annual	10.5	1.1-1.5	2.1-2.6	3.5-3.6
Spring	11	1-1.5	1.7-2.3	2.3-3.1
Summer	20.1	1.2-2.2	2.3-3.9	4.2-5
Autumn	10.8	1.4-1.7	2.1-2.8	3.6-3.8
Winter	0.2	0.8	1.6-2.4	2.6-3.9

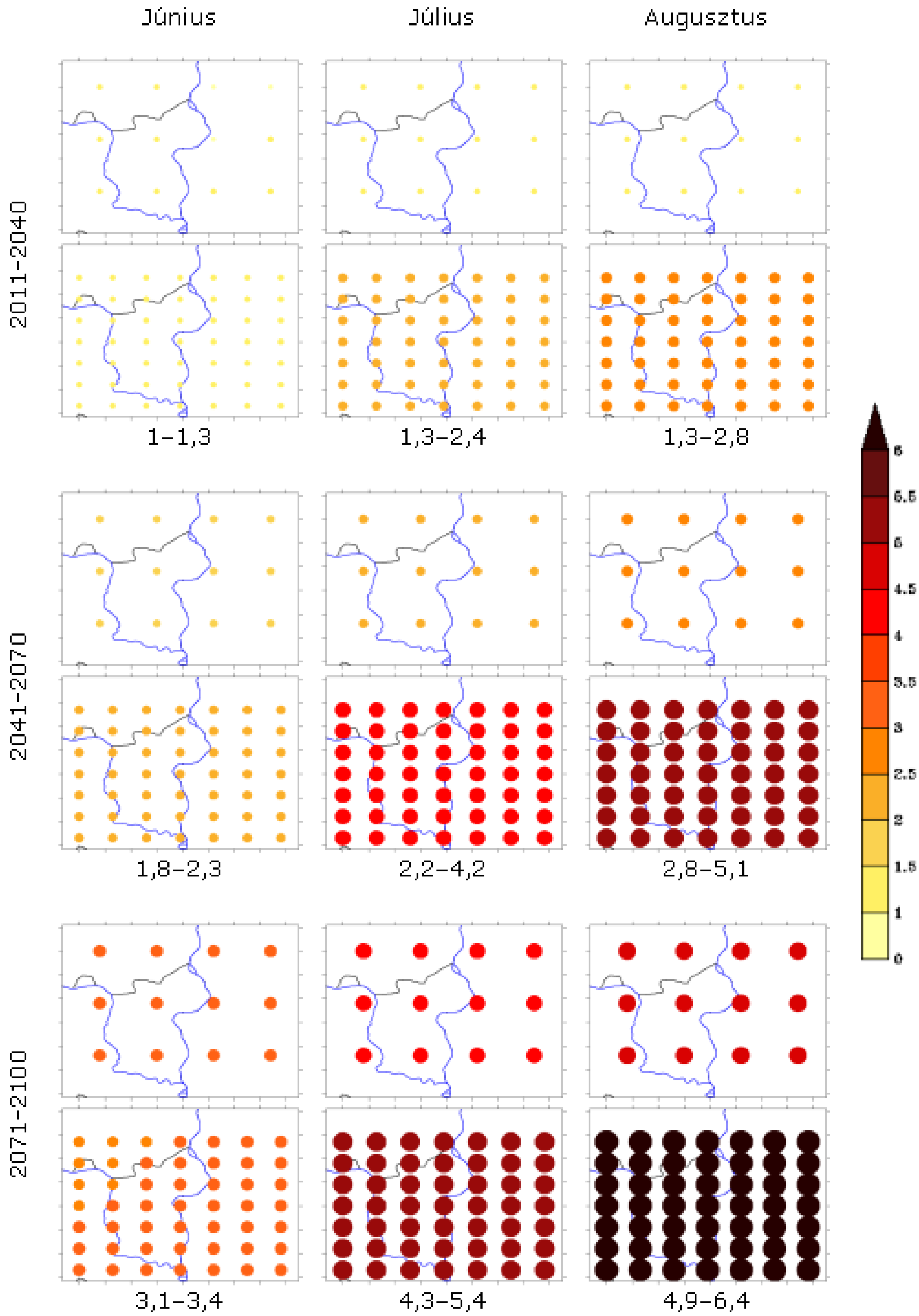
Table 10.4.6-1: Observed annual and seasonal average temperature values (°C) between 1961-1990, and change (°C) anticipated according to the two models in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period



Tavasz / Nyár / Ősz / Tél - Spring / Summer / Autumn / Winter

Figure 10.4.6-2: Seasonal average temperature change (°C) in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period, based on two models

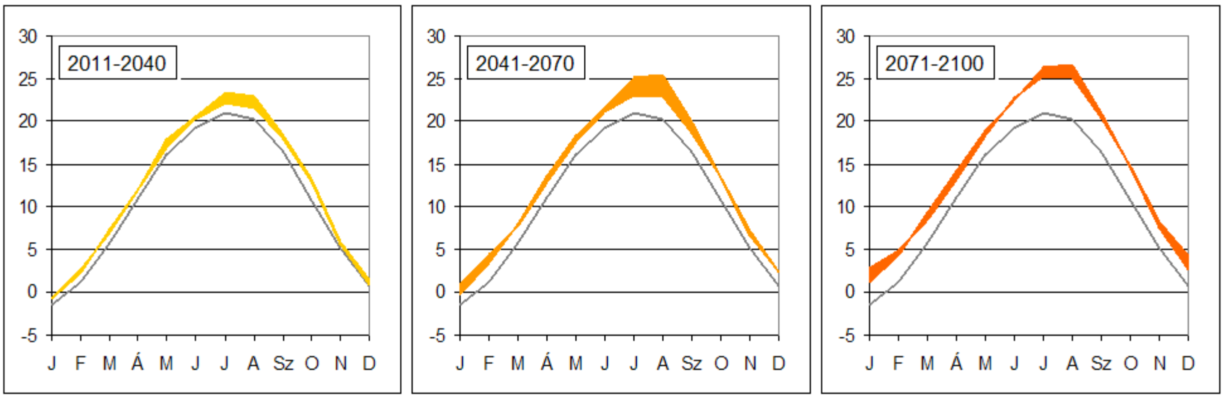
It is a good idea to examine summer months even by themselves, and this is shown in Figure 10.4.6-3. Ever intensifying temperature increase can also be observed here, along with the fact that the extent of change will likely be greatest in August across all three periods according to both models, and it is important to mention that the month of September can be expected to warm-up more than June. The difference in values between the two models will also remain at monthly level, with the greatest discrepancy of more than 2 °C observed in July.



Június, Július, Augusztus – June, July, August

Figure 10.4.6-3: Anticipated average temperature change (°C) for summer months in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period, based on two models

The annual progression of temperature is also expected to undergo some modification from the middle of the century, since instead of the July maximum typical so far, August will be hotter on average on account of the more pronounced change of average temperature for that month (Figure 10.4.6-4). January is the coldest month on average in the vicinity of Paks, and this will not change in the future either. Average temperature, however, for this month will clearly shift towards the positive values from the middle of the century. Monthly maps likewise fail to show any material spatial difference at the grid points under consideration.



Remark:
When illustrating information applicable to the future, change the models indicated for the respective period were added to measurements concerning 1961-1990, then the area between the two annual progressions received on the basis of the two models' results were shaded.

Figure 10.4.6-4: The annual progression of monthly average temperatures (°C) according to observations in 1961-1990 (gray line), and annual progression anticipated on the basis of the two models (°C; the uncertainty interval they limit are in coloured bands) in the vicinity of Paks in 2011-2040, 2041-2070, and 2071-2100.

Different indices are used to profile extreme conditions, and it is the frequency with which the variable under consideration assumes a value lower or greater than a particular threshold that we look at. The development of temperature indices in the future is consistent with average conditions, which is to say that the incidence of warm extremes (e.g. hot days, extreme heat alerts, etc.) can be expected to increase, while that of cold indices (e.g. of freezing days) to drop. (Table 10.4.6-2) The number of hot days (daily maximum temperature > 30 °C) may double as early as the near future, but this is what both of the models indicate for the middle of the century. Let us now consider indices that occurred less frequently in the past: sweltering days, i.e. when daily maximum temperature exceeds 35 °C, as well as hot nights, when daily minimum temperature does not dip below 20 °C. These indices occurred on only 2 days on average during the reference period, their number may nevertheless be expected to increase significantly in terms of proportions: by the end of the century, the models show at least eight times as many sweltering days, and twenty times as many hot nights than between 1961-1990.

Days with different extreme heat alerts (extreme heat alert day: daily average temperature > 25 °C; level 2 extreme heat alert: daily average temperature > 25 °C for 3 days or daily average temperature > 27 °C; level 3 extreme heat alert: daily average temperature > 27 °C for 3 days). The more stringent the incidence criterion, the more marked relative change is, in other words, a shift towards more intensive extremes can be expected. All of this means that there are going to be increasingly more level two and three extreme heat alert days as we progress over time.

	1961-1990	**2011-2040**	**2041-2070**	**2071–2100**
	observation (days)	**change (days)**		
Hot day	19	9.1-23	19-39	38-50
Sweltering day	2	2-13	6-27	17-36
Hot night	2	8.2-15	19-29	39-42
Extreme heat alert	9.1	7.1-23	16-40	37-52
Level 2 extreme heat alert	4.1	4.5-20	12-37	31-49
Level 3 extreme heat alert	0.1	1.3-8.7	3.9-22	14-32
Number of freezing days	89	(-17)–(-9.3)	(-29)–(-24)	(-43)–(-41)

Table 10.4.6-2: Average annual observed values (days) of temperature indices between 1961-1990, and change (days) anticipated according to the two models in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period

In contrast to all of that, the number of freezing days (daily minimum temperature < 0 °C) will decline by half during the century. The extent of changes in the indices is rather uncertain, and the interval of a change may be up to double that of another one in the case of a given model. The least uncertainty can be experienced regarding freezing days (notwithstanding the nearer future). In the case of extrema, territorial variability is also greater than in the case of average conditions. An uncertain SW-NE direction strengthening can be observed for freezing days (Figure 10.4.6-5), while the change of hot extremes in the NW-SE direction becomes unequivocally more intensive (Figure 10.4.6-6).

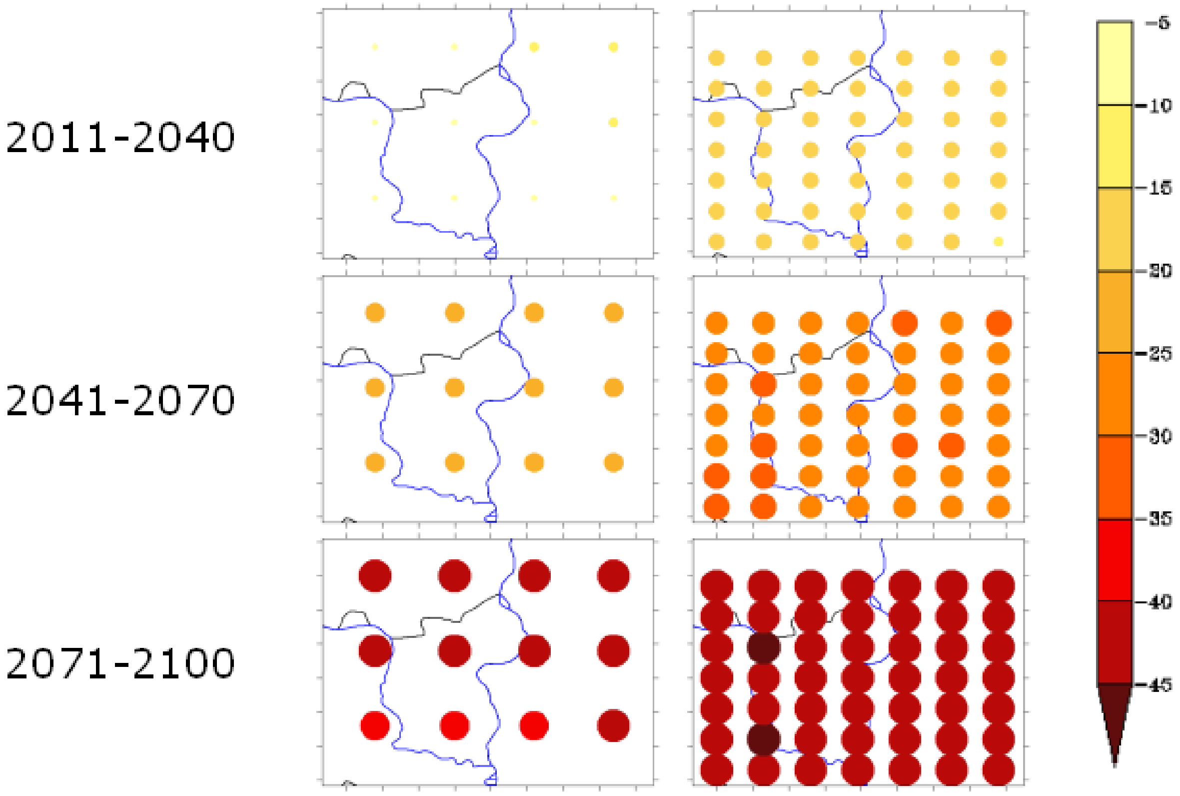
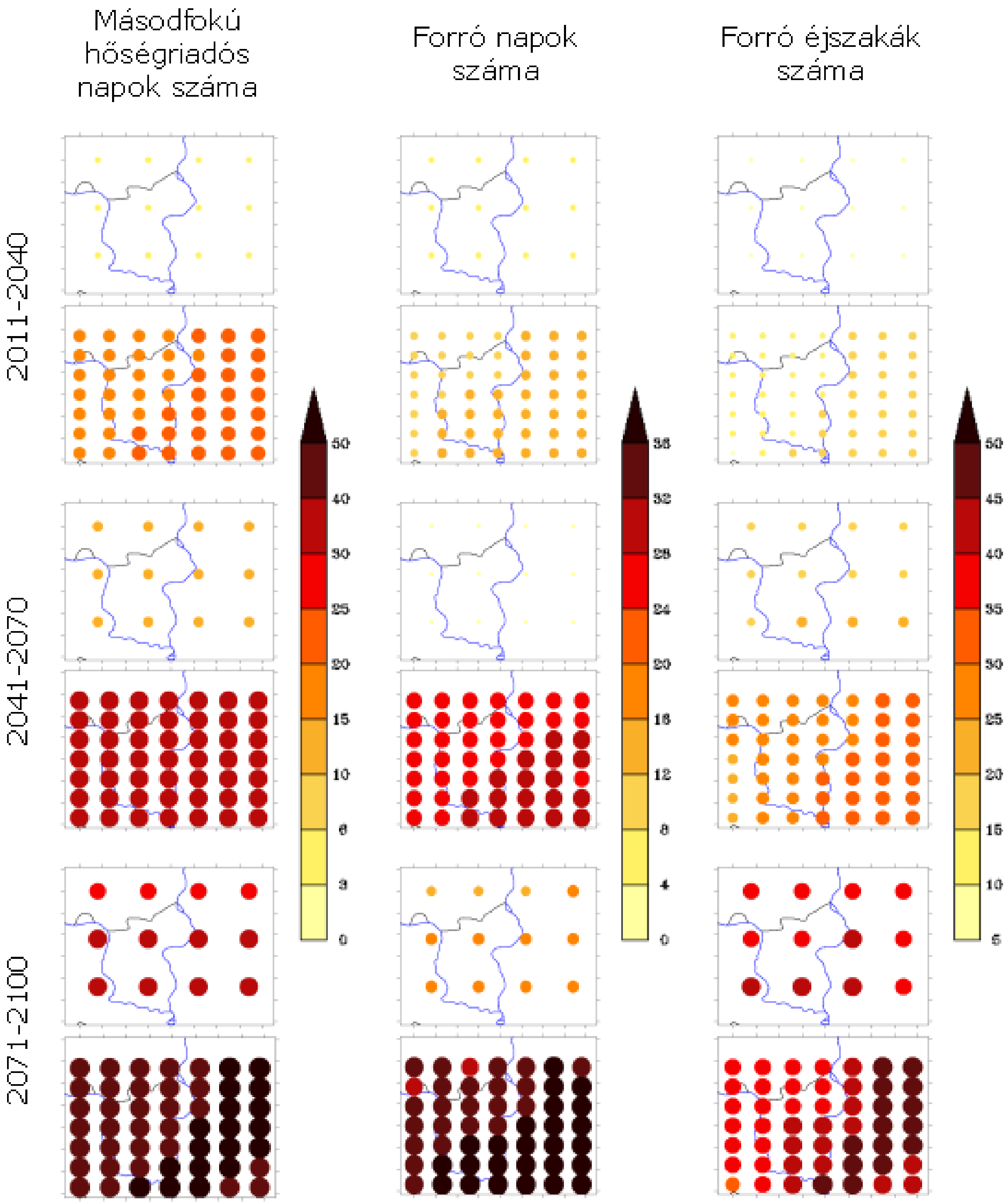


Figure 10.4.6-5: Anticipated change in the annual number of freezing days (days) in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period, based on two models



Másodfokú hőségriadós napok száma - Days with a level 2 heat alert
Forró napok száma - Number of sweltering days
Forró éjszakák száma - Number of hot nights

Figure 10.4.6-6: Anticipated change in the annual number of days with a level 2 heat alert, sweltering days and sweltering nights (days) in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period, based on two models

10.4.6.2 Precipitation

In the case of precipitation, and unlike temperatures, one cannot talk about unequivocal and linear changes over the 21st century, either concerning the three future periods, the seasons or the two models. The models agree about the slight change of annual precipitation, but considering seasonal distributions is also important, and great differences can be seen in this regard.

Annual and seasonal values can be seen for the vicinity of Paks in Table 10.4.6-3.

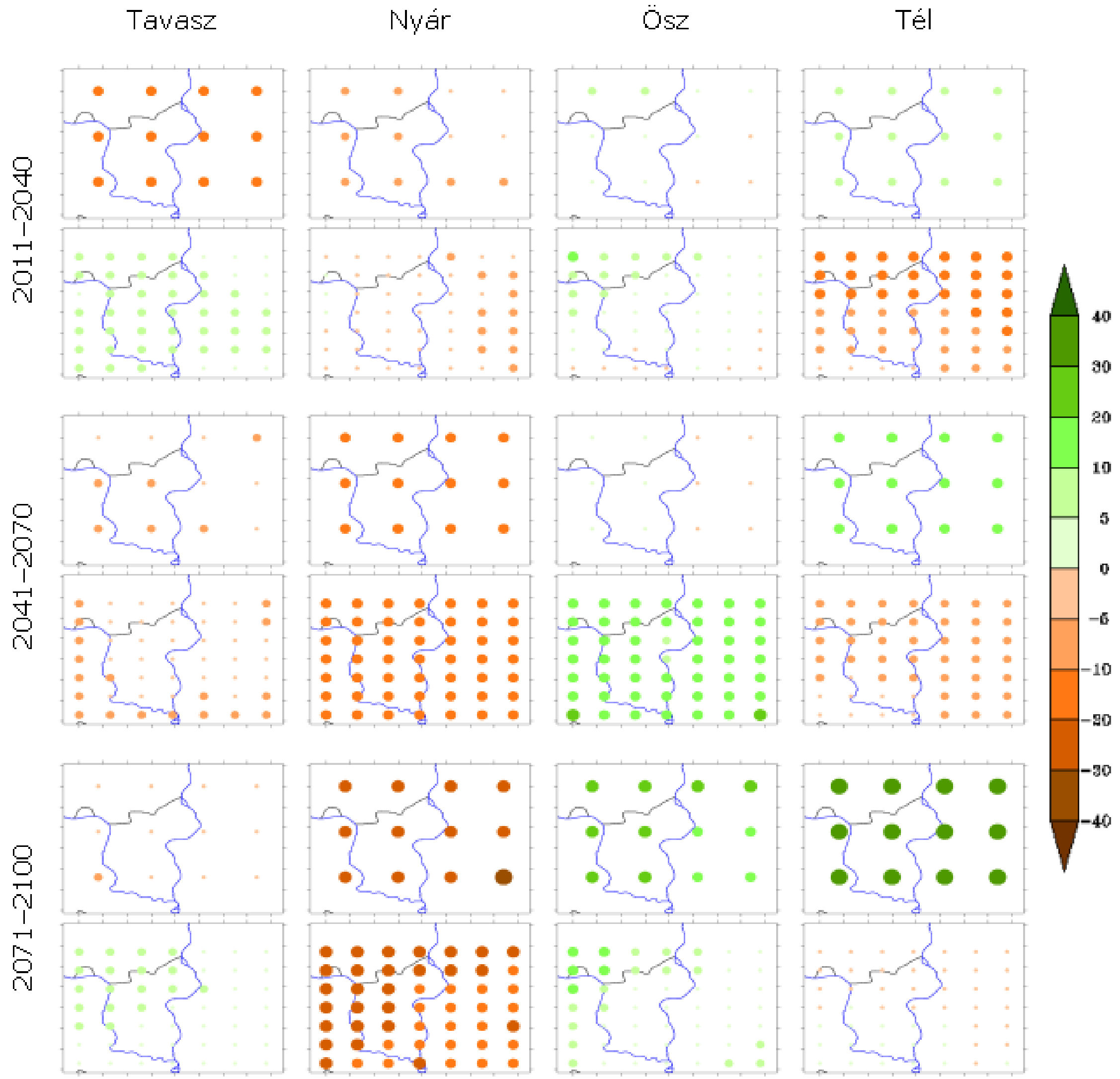
	1961-1990	2011-2040	2041-2070	2071–2100
	observation (mm/month)	change (%)		
Annual	47	(-4)–0	(-5)–(-3)	(-4)–4
Spring	46	(-14)-6	(-5)–(-4)	(-3)–4
Summer	62	(-6)–(-3)	(-16)–(-14)	(-27)–(-20)
Autumn	43	2-3	0-14	5-21
Winter	39	(-6)–7	(-7)–16	2-32

Note:
Yellow/green indicates precipitation decrease/precipitation increase that is clear-cut on the basis of the two models.

Table 10.4.6-3: Observed annual and seasonal precipitation values (mm/month) between 1961-1990, and change (%) anticipated according to the two models in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period

The decrease during summer is clear-cut according to the models, and this is set to intensify to such an extent over time that—unlike what we have become accustomed to—summer precipitation may well end up being lesser in amount than autumns total precipitation (at least based on one of the models). Our statements are in relation to 30 year averages, which is to say that this does not mean that every summer will be arid and every autumn wetter than the summer, since summers that are wetter than average can still continue to occur. The unequivocal increase of autumn precipitation is also conspicuous looking at the values, and this will likewise be more pronounced at the middle/end of the century, in other words, the change will likely be greater than variability by that time. The two models show different results for the winter, and this is also true in the case of spring, notwithstanding the intermediate future period (when a clear-cut decrease is anticipated), in other words, the models are uncertain regarding the direction of the change in spring and winter. If one is also to take territorial distribution into consideration (Figure 10.4.6-7), a decrease is likely at the NE part of the area in winter, while an increase can be expected at the NW and the W in autumn and spring respectively. One can state for each of the seasons that minor changes close to zero are probable for the initial period, a more pronounced realignment of seasonal precipitation is likely by the end of the century, while the weaker increase in autumn and decrease in summer/spring project a decrease in annual precipitation for the middle of the century.

It is also worth the trouble to drill down to the monthly total precipitation level from seasonal totals (Figure 10.4.6-8). This allows us to see that similarly to summer, the decrease of precipitation can be expected for September (although a small degree of increase is also possible), while June does not show any unequivocal decrease the distant future notwithstanding—and the same can be seen concerning temperature increases (September will warm-up more than June will). The figure allows us to observe that the algebraic sign for the change is quite uncertain during the spring months across all three periods. Annual progression may change by 2071-2100, the secondary maximum in November is expected to strongly approach the June value or might even exceed it.



Tavasz / Nyár / Ősz / Tél - Spring / Summer / Autumn / Winter

Figure 10.4.6-7: Seasonal precipitation change (%) in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period, based on two models

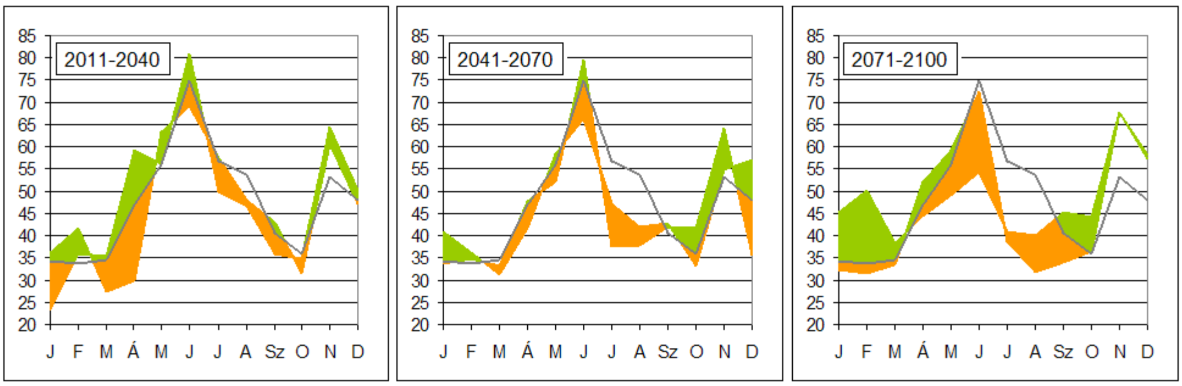


Figure 10.4.6-8: The annual progression of monthly total precipitation (mm) according to observations in 1961-1990 (gray line), and annual progression anticipated on the basis of the two models (mm; the uncertainty interval they limit are in coloured bands) in the vicinity of Paks in 2011-2040, 2041-2070, and 2071-2100

When illustrating information applicable to the future, measurements concerning 1961-1990 were increased by the extent of (strong) relative change the models indicated for the respective period, then the area between the two annual progressions received on the basis of the two models' results were shaded (green for increase and yellow in the case of decrease).

Precipitation indices reflect an extraordinarily varied impression, which does not necessarily correlate to the change of average total precipitation, and it is possible that not even the two models show an identical algebraic sign for changes. The number of days with copious precipitation above 10mm (Table 10.4.6-4) will occur most frequently in summer according to observations, while this will occur least during the winter (approx. half as many times), yet this ratio might well change by the end of the century: the number of events with lots of precipitation may near summer incidence (at least according to one of the models). We need to add to this that decrease during the summer is far from certain at the beginning and the middle of the century, but both models point to this direction by the end of the century, what is more, the extent of the change might be even greater still. In contrast, the models start out from an initially uncertain tendency in spring, and project figures that are more increasing by the end of the century. Increases in autumn and winter (and therefore the increase of annual figures overall) is unequivocal during all three periods according to the models.

	1961-1990	**2011-2040**	**2041-2070**	**2071-2100**
	observation (days)	**change (%)**		
Annual	16.1	4-11	3-10	8-21
Spring	3.4	(-16)-7	(-2)-3	5-6
Summer	5.9	(-2)-17	(-18)-5	(-28)–(-4)
Autumn	4.2	14-16	2-24	17-47
Winter	3.2	2-32	12-60	9-108

Note:
Yellow/green indicates decrease/increase that is clear-cut on the basis of the two models

Table 10.4.6-4: Observed annual and seasonal number of days with precipitation exceeding 10mm (days) between 1961-1990, and change (%) anticipated according to the two models in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period.

Upon examining days with extremely high precipitation (above 20mm) (Table 10.4.6-5) one can state that these appear to be increasing unequivocally, with the exception of spring 2041-2070 and summer 2071-2100 (the incidence of summer events is showing a slight decrease at the end of the century). Relatively small changes can be seen next to the essentially small numbers of past incidence, with the exception of the doubling of autumn and summer values at the end of the century (accompanied by significant scatter between the models), and the 50% increase of spring values.

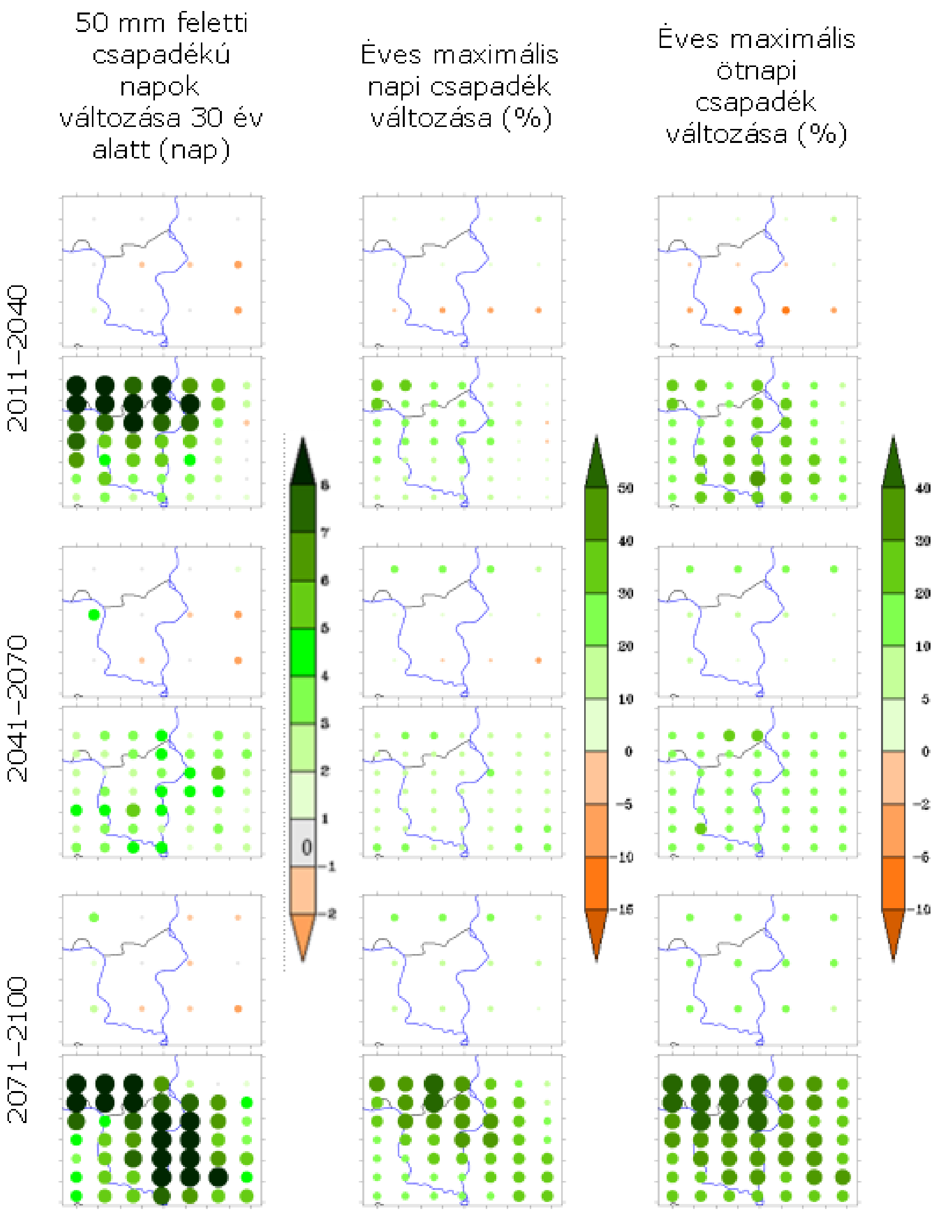
	1961-1990	**2011-2040**	**2041-2070**	**2071-2100**
	observation (days)	**change (days)**		
Annual	3.1	0.1-0.7	0-0.6	0.7-1.3
Spring	0.6	0-0.1	(-0.1)-0.1	0.3
Summer	1.4	0-0.2	0-0.1	(-0.1)-0
Autumn	0.7	0.1-0.2	0-0.3	0.2-0.8
Winter	0.4	0-0.1	0.1	0.1-0.4

Note:
Yellow/green indicates decrease/increase that is clear-cut on the basis of the two models

Table 10.4.6-5: Observed annual and seasonal number of days with precipitation exceeding 20 mm (days) between 1961-1990, and change (days) anticipated according to the two models in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period.

Looking at daily precipitation in excess of 50mm (Figure 10.4.6-9, left panel), something that rarely occurs even during the 30 years (on 1.5 days in terms of territorial average) one can say that a significant increase can be expected at annual level according to one of the models, while the other one shows a negligible change, and a more likely (summer) decrease. Increase can be expected mainly during summer for the first period, more in the autumn in the case of the second one, and clearly during the spring, but even in summer by the end of the century. According to observations, such events will almost not occur at all in winter and spring, and the models show that they will not occur in winter. (Seasonal results will not be discussed here.)

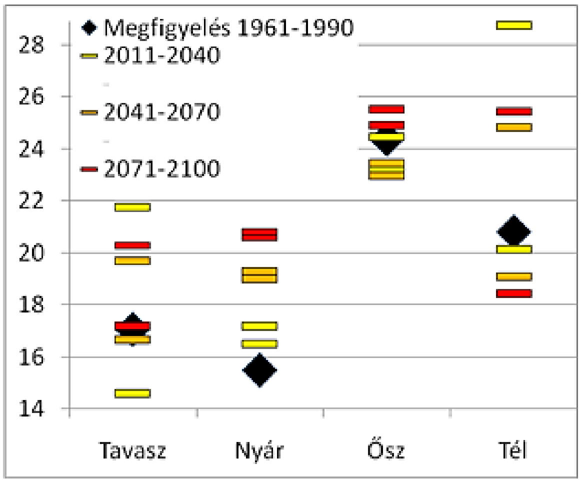
The two models essentially render an increase likely regarding annual maximum daily precipitation and the number of consecutive five-day precipitation (Figure 10.4.6-9, middle and right panel), but according to one of the models, a decrease is also possible in the southern part of the area during the nearer period, which is mainly attributable to decreasing precipitation in summer (the summer half of the year). A stronger increase can be expected in autumn (and, if to a lesser degree, also in winter), with summer and spring showing an uncertain and more variable impression regarding the two indices. By the end of the century, the clear-cut decrease in the summer five-day index is likely on account of the decreasing durability of precipitation events. (Seasonal results will not be discussed here.)



50 mm feletti csapadékú napok változása 30 év alatt (nap) - Change in the number of days with precipitation exceeding 50mm over 30 years (days)
Éves maximális csapadék változása (%) - Change in annual maximum precipitation (%)
Éves maximális ötnapi csapadék változása (%) - Change in maximum five-day precipitation (%)

Figure 10.4.6-9: Change in daily precipitation in excess of 50mm occurring over the 30 years, as well as in annual maximum daily and five-day precipitation (%, and days in the first case) in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period, based on two models

The unequivocal increase, which will be stronger nearing the end of the century, of the length of consecutive dry days (with precipitation below 1mm) in the summer is closely linked to that (Figure 10.4.6-10). Aside from being consistent for the summer, the models' uncertainty is still relatively small in autumn: both models are showing a decrease for mid-century, and an increase for the last decades. A large degree of uncertainty is typical to the two models for winter and spring in 2011-2040 and 2041-2070, in other words, one of the models makes an increase likelier, while the other one renders a decrease more probable in the seasons. The increase of the maximum length of dry days in the spring, on the other hand, appears to be clear-cut by the end of the century, the significant uncertainty, however, remains for winter, along with opposite directions of change in the two models.

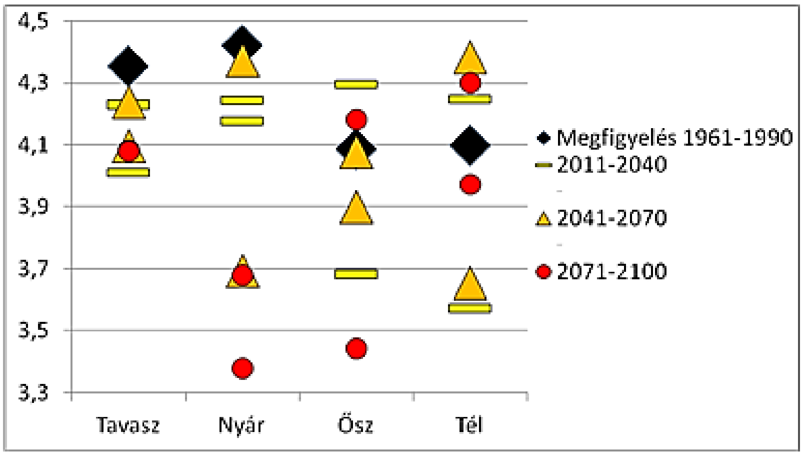


Megfigyelés - Observation
Tavasz / Nyár / Ősz / Tél - Spring / Summer / Autumn / Winter

Remark:
When calculating values pertaining to the future, observations applicable to 1961-1990 were increased with the extent of relative change (with algebraic signs) that the models indicated for the given period.

Figure 10.4.6-10: The maximum seasonal length (days) of consecutive dry days (with precipitation less than 1mm) for 1961-1990 according to observations, and the values (days) indicated by the two models in the vicinity of Paks for 2011-2040, 2041-2070, 2071-2100

The number of consecutive wet days (with precipitation above 1mm) (Figure 10.4.6-11) follows a tendency that is identical to dry days, and decreases unequivocally in summer (scatter between the models is lower at the beginning and end of the century). Unlike the previous index, both models project the durability of spring precipitation events, furthermore scatter between the models is the smallest at that time. For the winter, the difference between the models as already repeatedly mentioned is also typical regarding wet days: a decrease is probable according to one model, and an increase according to the other. Notwithstanding the middle of the century (when a decrease is likely), the models likewise indicate changes with different algebraic signs in the autumn. The greatest uncertainty between the two models is seen in autumn and winter at the beginning of the century, in summer and winter during 2041-2070, and in autumn for the end of the century.

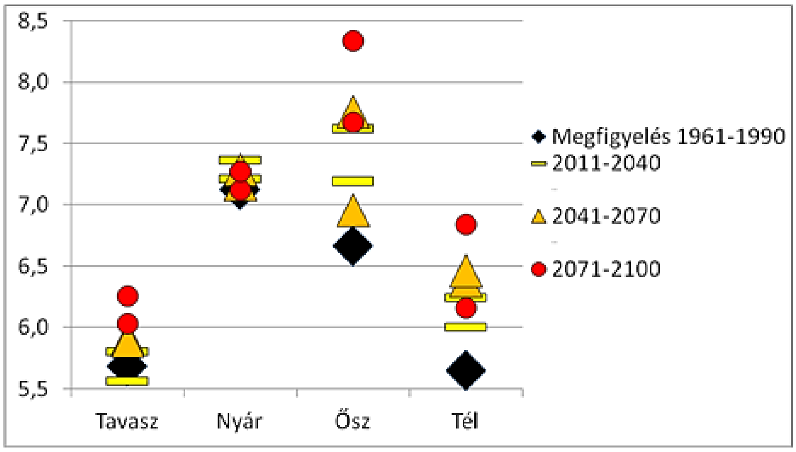


Megfigyelés - Observation
Tavasz / Nyár / Ősz / Tél - Spring / Summer / Autumn / Winter

Remark:
When calculating values pertaining to the future, observations applicable to 1961-1990 were increased with the extent of relative change (with algebraic signs) that the models indicated for the given period.

Figure 10.4.6-11: The maximum seasonal length (days) of consecutive wet days (with precipitation above 1mm) for 1961-1990 according to observations, and the values (days) indicated by the two models in the vicinity of Paks for 2011-2040, 2041-2070, and 2071-2100.

In addition to average total precipitation values, the index that can be expected to garner the most interest could be precipitation intensity, which specifies how wet the wet days are (i.e. precipitation total above 1mm divided by the number of wet days). According to both observations and our experience, days with more intensive precipitation occur in summer, yet this will shift to the autumn in the distant future according to both models (Figure 10.4.6-12) in the vicinity of Paks; at the same time, the uncertainty of the models is greatest during this season next to unequivocal growth. Change of uncertain algebraic sign at the start of the century will transform into increase by the middle and the end of the century, while near constancy will be typical in summer throughout after the very weak initial increase, and this is exactly why scatter between the models is lowest in summer. The models also agree on precipitation becoming more intensive regarding the winter as well (corresponding most at mid-century): the value still remains below summer intensity, yet it will be above the spring values for the most part (although the value of the index is lowest in winter according to observations).



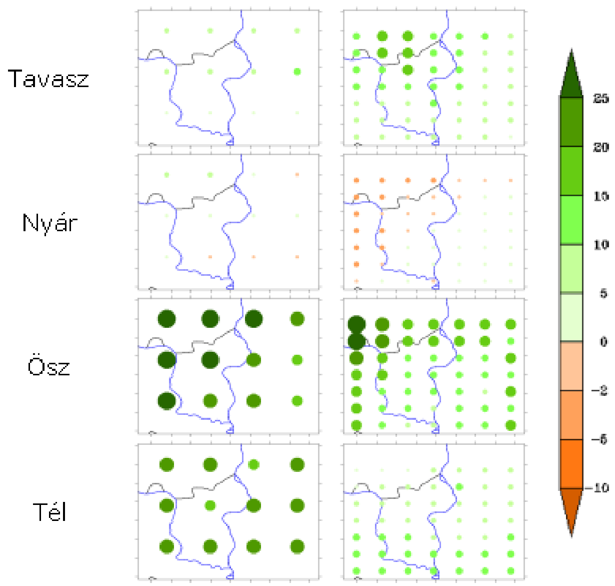
Megfigyelés - Observation
Tavasz / Nyár / Ősz / Tél - Spring / Summer / Autumn / Winter

Remark:
When calculating values pertaining to the future, observations applicable to 1961-1990 were increased with the extent of relative change (with algebraic signs) that the models indicated for the given period.

Figure 10.4.6-12: The seasonal values (mm/day) of precipitation intensity (days with total precipitation above 1mm/number of days) for 1961-1990 according to observations, and the values (mm/day) indicated by the two models in the vicinity of Paks for 2011-2040, 2041-2070, and 2071-2100.

When calculating values pertaining to the future, observations applicable to 1961-1990 were increased with the extent of relative change (with algebraic signs) that the models indicated for the given period.

Although intensification is typical for the overall area at the end of the century, but the differences within the area are also worth examining (Figure 10.4.6-13). Prominent relative change values can be seen in autumn, primarily at the NW part of the area, while the greatest change is more probable in the south during winter. The models are expecting greater change at the northern areas in spring, while changes with different algebraic signs can be expected in summer at the NW and SE part of the area, and to increase the uncertainty, the spatial structure the two models' results yield is incongruous.



Tavasz / Nyár / Ősz / Tél - Spring / Summer / Autumn / Winter

Figure 10.4.6-13: Change in precipitation intensity (%) in the vicinity of Paks for 2071-2100 relative to the 1961-1990 reference period, based on two models

10.4.6.3 Relative humidity

The change of relative humidity as presented in Table 10.4.6-6 is clear-cut according to the models: we can expect a decrease for every season, therefore also at annual level, in respect of all three future periods in the vicinity of Paks. The greatest changes will appear as we near the end of the century, furthermore they always mostly occur in summer and autumn, when atmospheric humidity is lowest anyway. This coincides with more intensive warming-up between July and September, as well as the greater decrease of precipitation, which humidity derived from increasing precipitation in autumn cannot compensate either.

	1961-1990	2011-2040	2041-2070	2071-2100
	observation (%)	change (%)		
Annual	75	(-3)–(-2)	(-5)–(-3)	(-6)–(-4)
Spring	70	(-3)–(-1)	(-3)–(-2)	(-4)–(-1)
Summer	69	(-6)–(-2)	(-13)–(-4)	(-15)–(-8)
Autumn	78	(-4)–(-3)	(-4)–(-2)	(-7)–(-5)
Winter	83	(-2)–(-1)	(-4)–(-1)	(-3)–(-1)

Note:
Yellow is used to highlight a decrease of at least 2% according to both models

Table 10.4.6-6: Observed annual and seasonal relative humidity (%) between 1961-1990, and relative change (%) anticipated according to the two models in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period.

10.4.6.4 Wind speed and wind direction

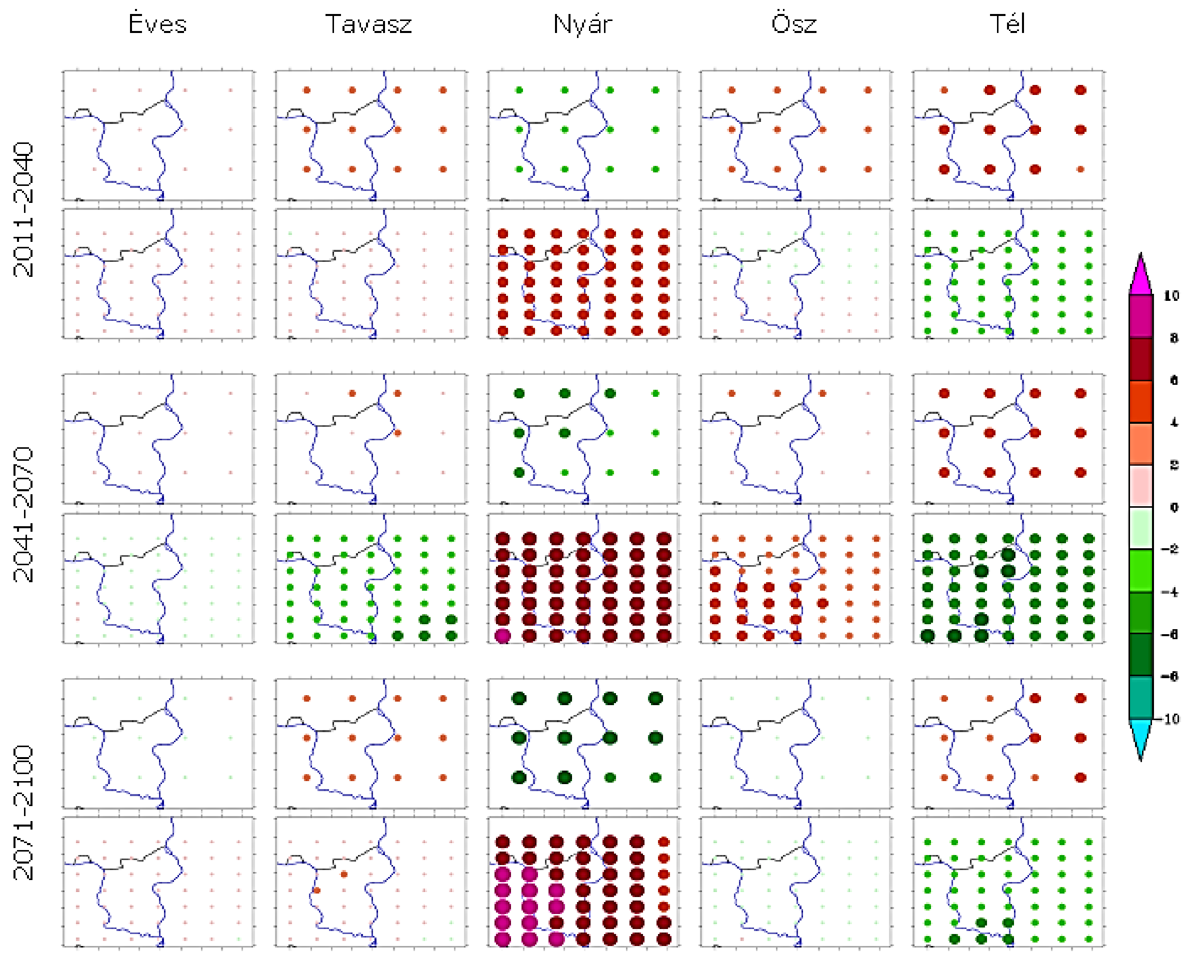
The models do not forecast major or even unequivocal changes regarding wind speed magnitude, particularly not at annual level. The extent of average change in the vicinity of Paks at this point shows a decreasing tendency over time (in other words, smaller changes can be expected for the end of the century than previously), and it is less than 2% for the most part, with uncertainty in its algebraic sign (Table 10.4.6-7).

	1961-1990	2011-2040	2041-2070	2071-2100
	observation (m/s)	**change (%)**		
Annual	2.1	0.4-1.7	(-0.3)-1.1	(-0.2)-0.5
Spring	2.4	0.9-2.5	(-3.5)-1.9	1.3-2.4
Summer	1.9	(-2.9)-5	(-4)-7.3	(-6.3)-7.1
Autumn	1.9	(-0.1)-3.3	1.6-3.6	(-0.7)–(-0.6)
Winter	2.2	(-2.7)-4.2	(-5.5)-5.1	(-3.7)-3.9

Table 10.4.6-7: Observed annual and seasonal average wind speed values (m/s) between 1961-1990, and change (%) anticipated according to the two models in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period

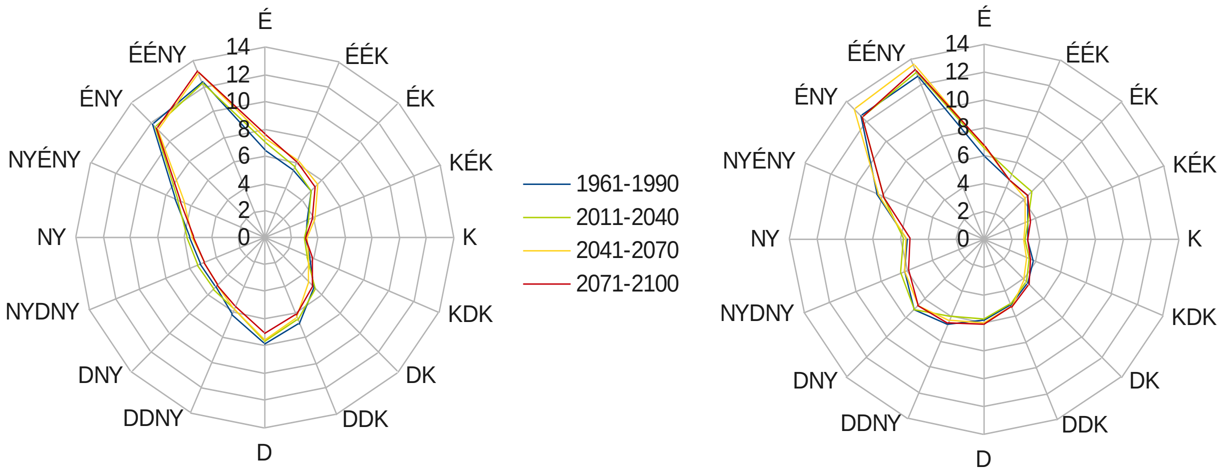
The extent of the change will only exceed 5% in summer, as well as in winter at mid-century, but in these cases the two models always give a change with different algebraic signs, therefore uncertainty is great. Stronger wind speed increases or decreases can also be expected in winter, but the models fail to agree on the direction of these modifications in this case again. The greatest changes in seasonal averages can be expected at the middle of the century, but one of the two models may even change the algebraic sign during in autumn and spring during this middle period—meaning that they indicate a change of a direction different than in the earlier or later period. Therefore uncertainty is quite high all in all, and this is also reflected in territorial distribution: the summer notwithstanding, no unequivocal tendencies can be observed (Figure 10.4.6-14). Strengthening in the hottest season is most pronounced in the SW, while weakening is usually most obvious in the western areas.

Wind direction was examined split into 16 sectors, and its change—just like that of wind speed—is very small, with the distribution of wind directions, as indicated by the two models, not changing considerably. The prevailing wind direction will continue remain NNW at the grid points that lie closest to the power plant (Figure 10.4.6-15) even in the 21st century, and the frequency values linked to the different directions will not change by more than 12%. Small fluctuations among the seasons can be observed for every wind direction, but uncertainty is great in this respect as well, and the two models seldom agree on the algebraic sign. The only agreement is that NNW and N wind will become 1% more frequent, while the SSW wind is to become rarer. When examining the vicinity of Paks, one of the models makes a shift of the borderline between areas where the NW and NNW winds prevail possible towards the NW, but no change can be expected according to the other one.



Éves / Tavasz / Nyár / Ősz / Tél - Annual / Spring / Summer / Autumn / Winter

Figure 10.4.6-14: Annual and seasonal wind speed change (m/s) in the vicinity of Paks between 2011-2040, 2041-2070 and 2071-2100 relative to the 1961-1990 reference period, based on two models



É / K / D / NY - N / E / S / W

Figure 10.4.6-15: Annual wind direction frequency (%) in 1961-1990 (blue), 2011-2040 (green), 2041-2070 (yellow), and 2071-2100 (red) at the two models' grid point nearest Paks (towards the left: lat. 46.509° N, lon. 18.89° E, towards the right: lat. 46.68° N, lon. 18.8° E)

10.5 REFERENCE

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[10-3] Hawkins and Sutton, Percentage of uncertainties typical to precipitation and temperature simulations (with ten yearly averaging) applicable to the entire Earth, Europe and the British Isles between 2000 (Year 0) and 2100 (Year 100), 2009, 2011