TECHNICAL TRANSACTIONS 10/2019
CIVIL ENGINEERING
DOI: 10.4467/2353737xct.19.109.11033
SUBMISSION OF THE FINAL VERSION: 08/07/2019

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A short historical overview of wind characteristics and wind pressure for design in Romania

Krótki przegląd historyczny charakterystyk i ciśnienia wiatru z projektu badawczego w Rumunii

Abstract
This paper provides an overview of wind observations in Romania with historical data, particularly after the establishment of the national meteorological network in 1884. Data on wind directions and velocities is presented, focusing on a sample of fourteen cities including the capital Bucharest. The historical evolution of national zonation maps for wind pressure is shown. A statistical description of the maximum annual wind velocity data is also presented.

Keywords: wind direction, wind velocity, wind pressure map, wind code, meteorological station

Streszczenie
Atrykuł przedstawia zbiór danych z obserwacji wiatru w Rumunii wraz z zapisami z poprzedniego stulecia, dokładnie zbieranymi od momentu ustanowienia krajowej sieci meteorologicznej w 1884 roku. Przedstawiono dane dotyczące kierunków i prędkości wiatru. Skupiono się na próbie czternastu miast, w tym stolicy – Bukaresztu. Pokazano historyczną ewolucję map krajowych stref obciążenia wiatrem. Przedstawiono również statystyczny opis danych dotyczących maksymalnej rocznej prędkości wiatru.

Słowa kluczowe: kierunek wiatru, prędkość wiatru, mapa ciśnienia wiatru, norma wiatrowa, stacja meteorologiczna

1. Introduction

Located in the East of Europe, Romania is a country with a transition temperate--continental climate [1]. Its territory spreads from 43.55° to 48.28° N and from 20.25° to 29.83° E.

Ovid (Publius Ovidius Naso, 43 BC – AD 17/18), an exiled Roman poet from ancient Tomis (present day Constanța) made, in his *Poems of Exile* [2], some of the oldest written mentions (AD 8-12) on the hard winters and the cold strong winter winds on the Romanian Black Sea coast, winds that were even causing damage to the built environment:

> [...] Snow falls, and, once fallen, no rain or sunlight melts it,
> since the north wind, freezing, makes it permanent.
> [...] The power of Aquilo's* northern gales is such
> it razes high towers, and blows away the roofs.
> [...] The Danube itself, no narrower than lotus-bearing Nile, [...]
> congeals, the winds hardening its dark flow,
> [...] and, like the snow the rainy south wind melts,
> [...] Zephyrus* lessens the cold, now the past year's done,
> [...] Here's the source of the north wind, Boreas, and this coast
> is his home, and he gains power from the location.
> But Notus*, the south wind, blows warm from the opposite
> pole, is far from us, is rarely experienced, and is feeble.
> [...] and though Boreas* roars and thrashes his wings,
> there's no wave on the besieged waters.
> The ships stand locked in frozen marble,
> [...] Whether the savage power of wild Boreas
> freezes the sea-water or the flowing river,
> as soon as the Danube's levelled by dry winds [...]
> *Aquilo – the North wind, as a god he is Boreas; Auster – the south wind; Eurus – the east wind; Zephyrus – the west wind.

More evidence of strong winds and storms is found in documents dating from the Middle Ages especially from foreign travellers. For example, in 1720–1723, captain Friedrich Schwanz von Springfels travelled to the southern part of Romania and noted the following with regard to the mountain crossing: "no road could be done because of the high and big mountains and because of the storms [...] if such a storm catches up someone, it almost blinds men and cows and throws them down the cliffs, and, unfortunately there are many sad examples as every year people and animals are dying in this way" [3]. In 1786, the German merchant Jenne Lebprecht travelled in the Romanian territories and noted: "After 10 p.m. the silence changed into a terrible storm from SE [...] after midnight the storm changed into a heavy rain and in the morning the NE winds got stronger and it was one of the strongest storms I can recall [...] at 3 p.m. the rain changed into snow [...] the NE wind blew during the snow [...] At 8 a.m. in the morning the NE wind got again stronger [...]" [4].

Meteorological observations were sparse, random and unmethodical until the second half of the nineteenth century. The start of these observations was presented by Hepites in 1886 [5]: the first organised reports were available for the city of Iași for the years

1839 and 1840, but no data on the instruments and/or methodology are known; the first meteorological station to be properly organised was in Sulina on the Black Sea coast from the network organised by the Danube European Commission in 1859; measurements were also performed in Bucharest in the period 1857–1869 and occasionally in Brăila and Galaţi. The national network was organised at the initiative of the Minister of Agriculture, Commerce, Industry and Territories. The Meteorological Institute of Romania was created in 1884 and started to provide data on 1st July of the same year. At the beginning of 1885, there were five stations in operation: Bucharest, Sulina, Galaţi, Giurgiu and Strehareţ. In the same year, another six stations were established: Turnu-Severin, Balota, Constanța, Craiova, Păncesci--Dragomiresci and Iași. According to Hepites' detailed report [5], twelve measurements per

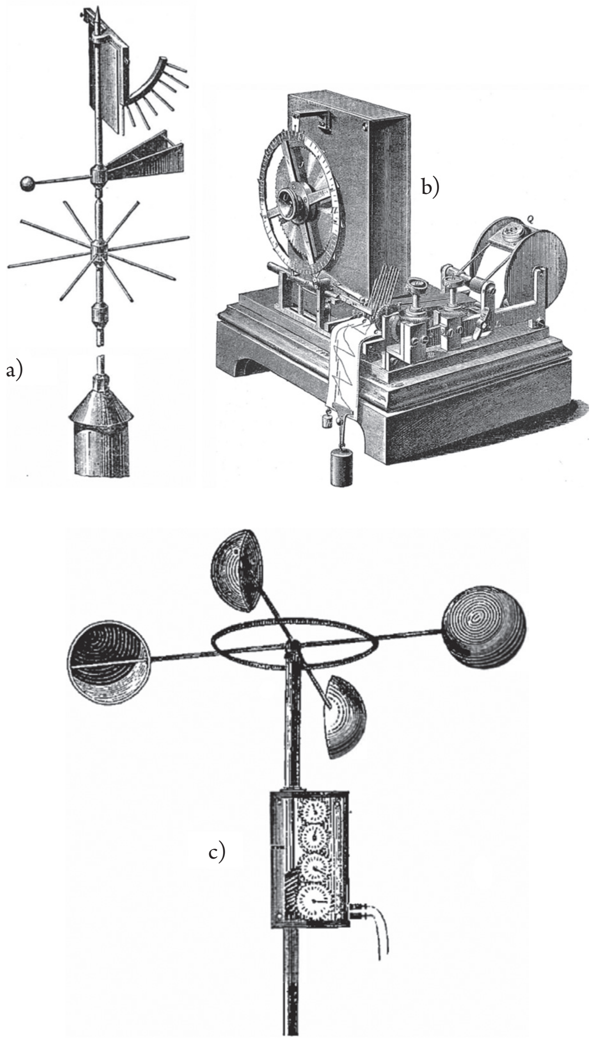


Fig. 1. Wind measurement equipment at the first Romanian meteorological stations (1885):
a) Wild weathervane, b) Sprung anemometer and recorder, and c) Robinson anemometer [5]

day were performed with a Wild weathervane (Fig. 1a), a Sprung anemometer and recorder (Fig. 1b) and a Robinson anemometer (Fig. 1c) with cups located at a height of around 15 m above the ground.

The meteorological network developed rather quickly: 1887 – 30 stations, 1899 – 50 stations, 1906 – 66 stations [7], 2013 – 258 stations [1].

In the present day, the National Meteorological Administration [1], is officially in charge of meteorological observations. It operates 160 automated stations: 71% of the stations are in lowlands, 12% are in hilly areas, 4% are on the coast and 13% are in mountains. Some stations are located at high altitudes, such as Ceahlău Toaca (1897 m) and Călimani (2021 m), the highest station being Vărful Omu, located at 2504 m.

On 3rd July 1948, Romania joined the convention of the World Meteorological Organisation [6] (created in Washington on 11th of October 1947). The Romanian meteorological network is part of the permanent world survey, Region VI – Europe, of the World Meteorological Organisation.

2. Wind characteristics in Romania

2.1. Wind directions

In Romania, wind directions are influenced by regional air movement and by the Carpathian Mountains. On the open mountain heights, the dominant wind direction is from the west, which is characteristic for temperate latitudes [7]. A good example is provided by the highest meteorological station at Vârful Omu (altitude 2504 m) for which the west winds (SW, W, NW) account for a total of 57.9% of the annual frequency. Other stations on mountain tops display similar frequencies, sometimes even higher than 60%. The frequency of calm conditions for these stations is approximately 11%.

Local landforms strongly influence the wind direction at lower altitudes in the mountain area. In the centre and south of the Romanian Plain, the main wind directions are from the west and the east. In western Romania, the predominant wind direction is from the south. A certain directional frequency variability was observed on both a monthly and seasonal basis over the duration of one year, and for different time intervals.

A sample of fourteen stations has been selected (geographically distributed as shown in Fig. 2), and their directional mean wind frequencies are presented in Table 1 with data from two time intervals: 1941–1955 [8] and 1961–2000 [7]. Some graphics based on Table 1 data are given in Fig. 3 (note that this does not include data relating to calm conditions).

The data from Constanța confirms the ancient observations of the poet Ovid who noticed the predominance of strong north winds in the winter. This is also indicated Hepites [9] the predominance of North winds for Constanța region in 1901: N – 35%, S – 24%, W – 22% and E – 13%, calm – 6%. Data from 1961–2000 [7] indicates a similar distribution: N – 36.1%, S – 29.5%, W – 16.4% and E – 6%, calm – 12%, as does the data from 1941–1955 [8]: N – 42%, S – 24%, W – 12.7% and E – 6.1%, calm – 15.2%.

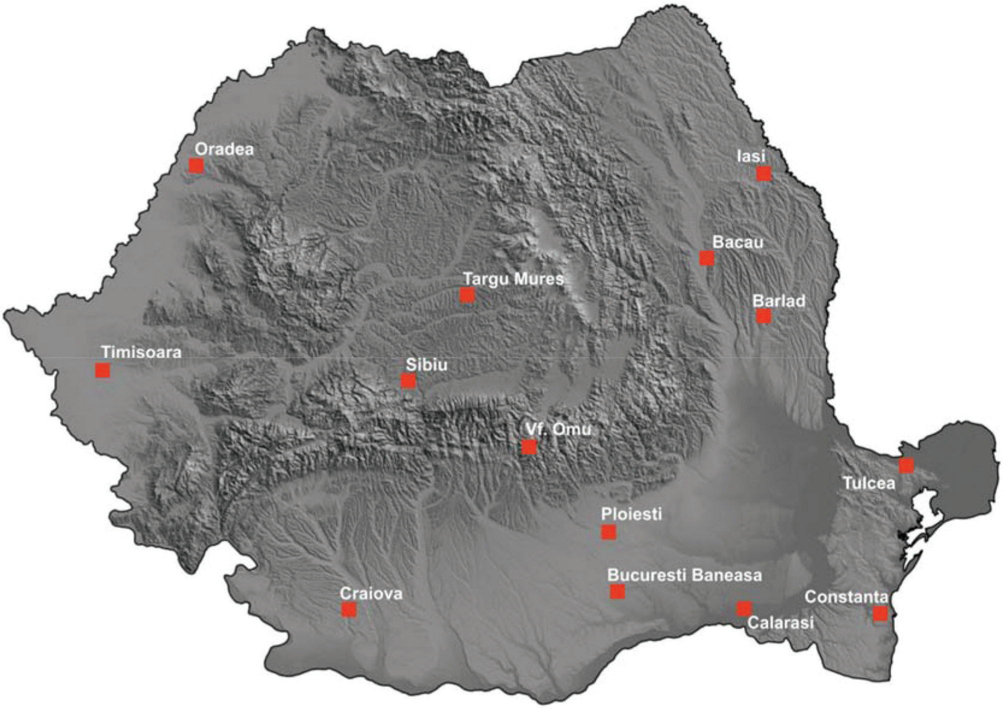


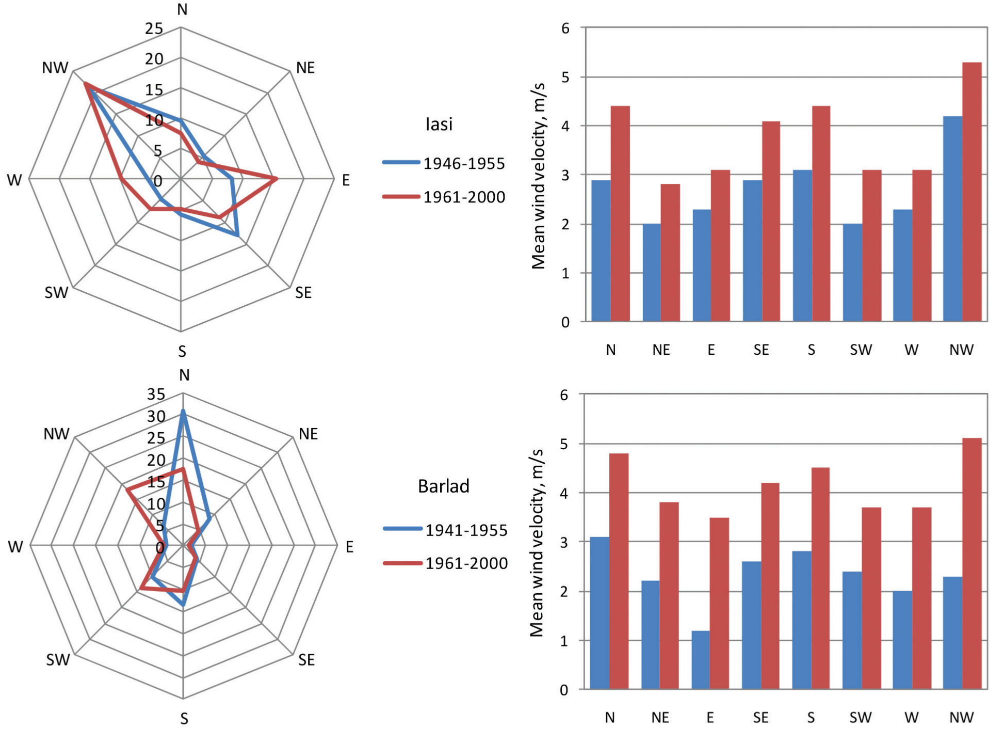
Fig. 2. Geographical distribution of the selected sample of fourteen meteorological stations in Romania

Table 1. Examples of mean frequencies (%) of wind directions (data from [8, 7])

Meteorological station	Time period	Direction								
		N	NE	E	SE	S	SW	W	NW	Calm
1	2	3	4	5	6	7	8	9	10	11
Iași	1946–1955	9.5	5.3	8.3	13.0	5.7	4.6	5.5	21.5	26.6
	1961–2000	7.6	4.0	15.4	8.7	4.8	7.0	9.7	22.1	20.7
Bacău	1941–1943; 1945–1955	19.4	4.0	2.0	13.4	13.6	4.0	3.4	17.5	22.7
	1961–2000	16.4	0.9	0.5	7.6	16.0	2.0	3.1	12.3	41.2
Bârlad	1941–1955	30.9	8.5	1.8	4.4	13.5	10.1	4.0	6.3	20.5
	1961–2000	17.6	4.8	1.2	3.8	10.4	13.7	4.4	17.9	26.2
Tulcea	1946–1955	3.2	5.5	9.7	3.3	1.6	3.5	13.9	17.1	42.2
	1961–2000	12.3	7.5	5.6	8.1	9.7	5.8	9.8	17.4	23.8
Constanța	1941–1955	21.5	11.7	6.1	8.7	9.4	5.9	12.7	8.8	15.2
	1961–2000	13.1	12.0	6.0	10.5	11.9	7.1	16.4	11.0	12.0
Călărași	1941–1955	14.8	13.3	8.0	9.8	4.6	12.4	16.4	7.8	12.9
	1961–2000	9.2	16.6	10.2	8.7	5.7	9.6	17.4	5.7	16.9

Tab. 1 (cont.)

1	2	3	4	5	6	7	8	9	10	11
Ploiești	1946–1955	11.6	14.9	13.3	4.9	6.3	10.4	6.0	6.8	25.8
	1961–2000	14.6	16.0	9.5	2.8	2.5	7.8	9.2	5.6	32.0
Bucharest Băneasa	1941–1955	5.0	21.6	19.7	5.0	3.3	16.8	13.8	4.9	9.9
	1961–2000	3.4	16.4	10.3	1.8	1.5	11.7	9.2	2.3	43.4
Craiova	1941–1955	3.4	9.1	24.6	3.0	1.9	3.4	18.7	9.6	26.3
	1961–2000	2.5	12.0	21.1	4.0	2.9	4.6	20.2	5.6	27.1
Timișoara	1941–1955	16.9	8.7	15.0	7.4	8.4	6.6	7.0	9.1	20.9
	1961–2000	7.2	5.5	5.7	3.9	9.1	6.4	9.4	12.7	40.1
Oradea	1947–1955	11.0	8.9	7.9	5.7	13.3	12.1	3.4	7.0	30.7
	1961–2000	9.3	4.8	7.3	11.3	18.2	14.6	6.1	5.0	23.4
Târgu Mureș	1946–1955	7.8	10.8	6.2	9.2	4.9	7.3	6.9	12.4	34.5
	1961–2000	15.1	9.2	3.0	4.8	4.6	10.4	12.3	14.4	26.2
Sibiu	1941–1955	7.9	3.2	9.5	21.4	5.2	4.0	6.1	18.5	24.2
	1961–2000	2.0	0.9	4.2	8.1	2.6	2.5	8.4	11.2	60.1
Vârful Omu	1941–1955	4.6	7.9	6.0	7.1	8.4	17.2	21.5	25.6	1.7
	1961–2000	6.9	9.3	4.5	2.9	6.6	20.8	20.9	17.8	10.3



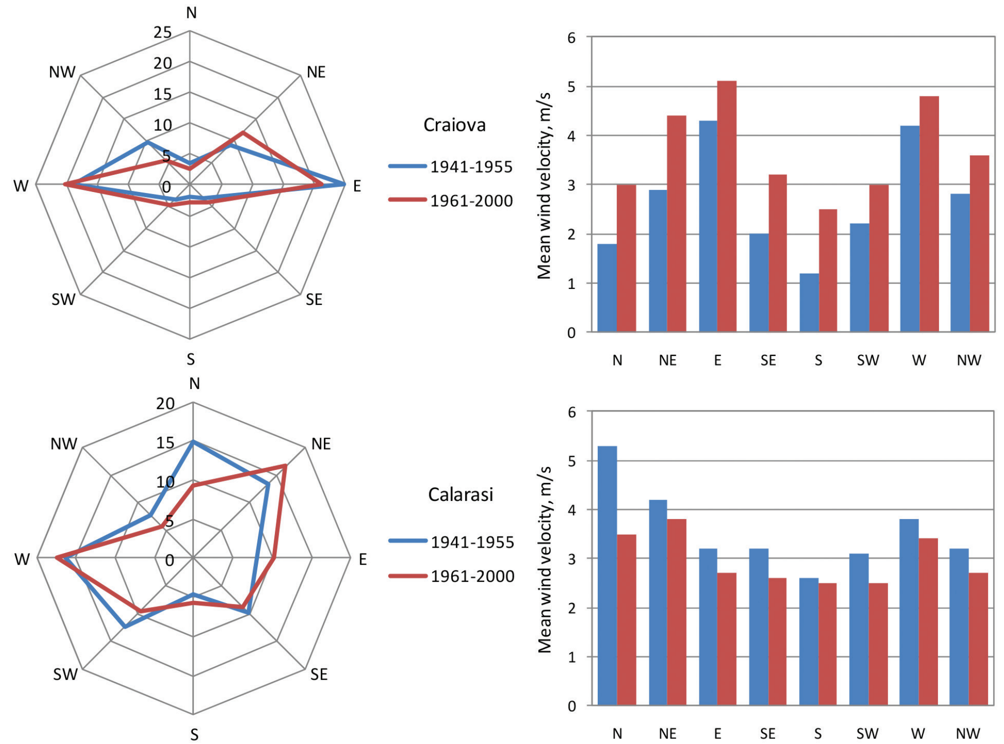


Fig. 3. Examples of mean frequencies of wind directions (%) – left, and of directional mean wind velocity (m/s) – right

2.2. Wind velocity

The highest directional mean wind velocities are generally observed on the directions with higher frequencies. In Table 2 are presented the directional mean wind velocities based on data from two time intervals: 1941–1955 [8] and 1961–2000 [7]. One may observe that except for two stations (Călărași and Târgu Mureș), the mean wind velocities are higher in the 1961–2000 period than in the 1941–1955 period. Some graphs based on Table 2 data are presented in Fig. 3.

Table 2. Examples of directional mean wind velocity (m/s) [8, 7]

Meteorological station	Time period	Direction							
		N	NE	E	SE	S	SW	W	NW
1	2	3	4	5	6	7	8	9	10
Iași	1946–1955	2.9	2.0	2.3	2.9	3.1	2.0	2.3	4.2
	1961–2000	4.4	2.8	3.1	4.1	4.4	3.1	3.1	5.3
Bacău	1941–1943, 1945–1955	3.8	1.8	1.2	3.8	3.8	2.9	2.8	4.1
	1961–2000	4.8	3.2	2.5	4.5	4.1	4.5	5.0	4.8
Bârlad	1941–1955	3.1	2.2	1.2	2.6	2.8	2.4	2.0	2.3
	1961–2000	4.8	3.8	3.5	4.2	4.5	3.7	3.7	5.1

Tab. 2 (cont.)

1	2	3	4	5	6	7	8	9	10
Tulcea	1946–1955	0.8	2.6	3.2	2.3	0.8	1.5	2.3	3.4
	1961–2000	4.2	3.9	3.5	4.7	5.1	4.1	3.3	3.9
Constanța	1941–1955	4.3	3.8	2.4	3.4	3.6	3.6	4.0	3.1
	1961–2000	6.5	6.4	4.6	4.2	4.0	3.5	4.0	4.5
Călărași	1941–1955	5.3	4.2	3.2	3.2	2.6	3.1	3.8	3.2
	1961–2000	3.5	3.8	2.7	2.6	2.5	2.5	3.4	2.7
Ploiești	1946–1955	2.3	3.1	3.1	2.6	2.8	2.9	2.6	2.3
	1961–2000	2.3	3.0	3.4	2.9	2.8	3.3	3.1	2.4
Bucharest Băneasa	1941–1955	2.6	4.5	3.8	2.4	2.2	3.1	3.4	2.3
	1961–2000	2.7	4.0	3.7	2.7	2.7	3.3	3.4	2.5
Craiova	1941–1955	1.8	2.9	4.3	2.0	1.2	2.2	4.2	2.8
	1961–2000	3.0	4.4	5.1	3.2	2.5	3.0	4.8	3.6
Timișoara	1941–1955	3.4	2.2	2.2	2.6	3.8	2.6	2.8	2.9
	1961–2000	3.7	2.4	2.3	2.8	3.6	3.2	3.2	3.4
Oradea	1947–1955	3.2	3.1	2.2	2.6	4.0	3.8	2.6	2.8
	1961–2000	4.1	3.9	3.1	2.8	4.2	4.2	3.4	3.3
Târgu Mureș	1946–1955	2.2	1.8	2.3	2.6	2.2	2.4	2.6	3.1
	1961–2000	1.7	1.8	2.3	2.4	1.9	2.1	2.3	2.6
Sibiu	1941–1955	0.8	2.6	3.4	2.3	0.7	1.5	2.3	3.4
	1961–2000	2.8	2.6	3.4	4.4	4.9	3.1	4.1	3.9
Vârful Omu	1641–1955	5.1	4.7	4.5	5.7	7.2	7.2	6.6	8.1
	1961–2000	9.0	10.0	9.3	10.6	11.1	9.7	9.1	10.6

The study of the Meteorological Institute [8] indicates maximum wind velocities of 29 m/s in the south and east of Romania, and of 23–27 m/s in the west. In Central Romania, wind velocity extremely rarely reached 20–25 m/s. At Vârful Omu, wind velocity exceeds 30 m/s almost every year; on 9th December 1955, a maximum of 43.8 m/s was recorded.

A more recent study of the National Meteorological Administration [7] indicates that the annual maximum wind velocity was ≥40 m/s at all the mountain stations in open terrain in most of the Moldavia region, north of Dobrogea and on the Black Sea coast. In a few areas in the Transylvania plateau and in the protected mountain areas, the annual maximum wind velocity was lower than 20 m/s, while in the rest of the territory it was 20÷30 m/s.

2.3. Wind direction and velocity in Bucharest

Bucharest, the capital city of Romania, is located in the southern part of the Romanian Plain; its altitude varies between ~60 m and ~100 m.

Perhaps the oldest methodical observations on wind directivity in Bucharest are those made by Lessmann in 1870 (data presented by Hepites in 1904 [11], based on manuscripts).

Lessmann documented the storms and strong winds over the whole year, for each month. In total, he noticed 43 storms (from which 24 were from the north-east direction, 10 were from the east and 6 were from the west) and 24 strong winds (from which 8 were from the north--east and 13 were from the east and south-east).

Wind directivity has a rather constant pattern. In Fig. 4 different mean frequencies of wind direction (in %) are graphically presented for two time-intervals, 1941–1955 (data from [8]) and 1961–2000 (data from [7]), and for individual years, 1885 (data from [5]), 1902 and 1903 (data from [10]). The calm conditions are not included.

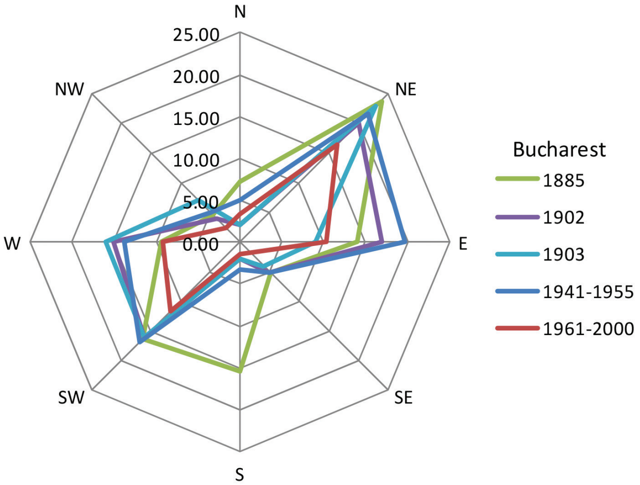


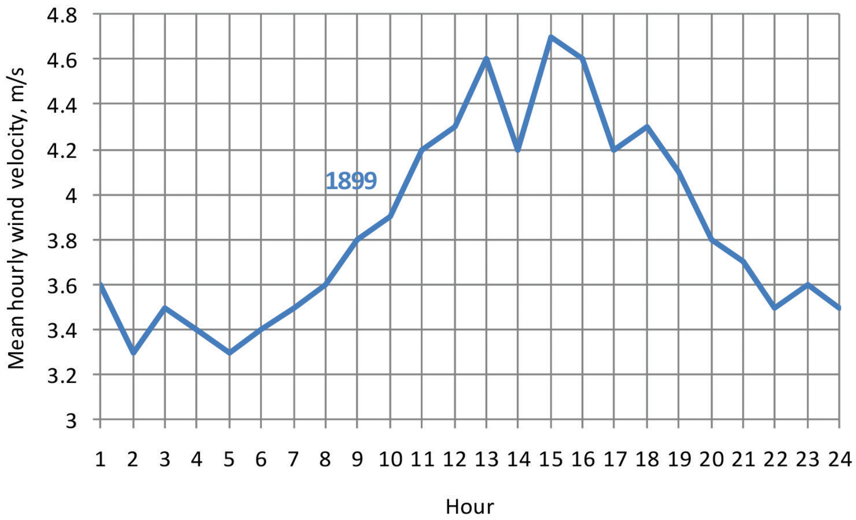
Fig. 4. Mean frequencies of wind directions in Bucharest (in %)

Probably the oldest data on wind speed in Bucharest was presented by Hepites in 1886 [5]: the 1885 annual mean wind speed was 3.9 m/s and the maximum wind speed was 24 m/s (on 19th January 1885). The same annual mean wind speed was reported by Hepites [11] for the year 1899. In the same study, Hepites presented data on the 24 h variation of mean hourly wind speed in 1899, a graphical representation is presented in Fig. 5 (top image). The data from 1902 and from the time period 1885–1900 display the same pattern, Fig. 5 (bottom image, [10]).

For the year 1903, Hepites [9] indicated that strong winds had velocities between 13 and 18 m/s, and he reported a storm on 25th July when the maximum wind velocity reached 22 m/s.

Murat [12] studied the winter of 1906/1907. For comparison, after analysing 23 winters, he evaluated the mean winter wind velocity in Bucharest as 4.3 m/s with a range of between 3.0 m/s in 1906 and 5.6 m/s in 1893. Murat indicated the range of hourly mean wind velocity in the winter months: December – min. 9.7 m/s in 1887, max. 26 m/s in 1897; January – min. 10.7 m/s in 1904, max 24.8 m/s in 1895 and February – min. 9.6 m/s in 1905 and max. 22.5 m/s in 1890. For the winter 1906/1907, he indicated the monthly maximum daily mean wind velocity: 6.8 m/s in December, 6.1 m/s in January and 9.8 m/s in February; and the maximum hourly mean wind velocity: 11 m/s in December and 12 m/s in January and February.

The maximum wind velocities recorded in Bucharest are also presented [10]: the overall maxima at that time were – 28.0 m/s (27th November 1890), 1902 maxima 22.7 m/s (5th December) and 1903 maxima 15.5 m/s (13th December). Significant values were recorded in 1954 – 35 m/s (3rd of February) and in 1962 – 38 m/s (30th and 31st January) [8]. The study of the Meteorological Institute [8] indicated the mean annual wind velocity at Bucharest for the period 1896–1955: 2.0 m/s, varying between 1.2 m/s in 1942 and 1950 and 2.8 m/s in 1904.



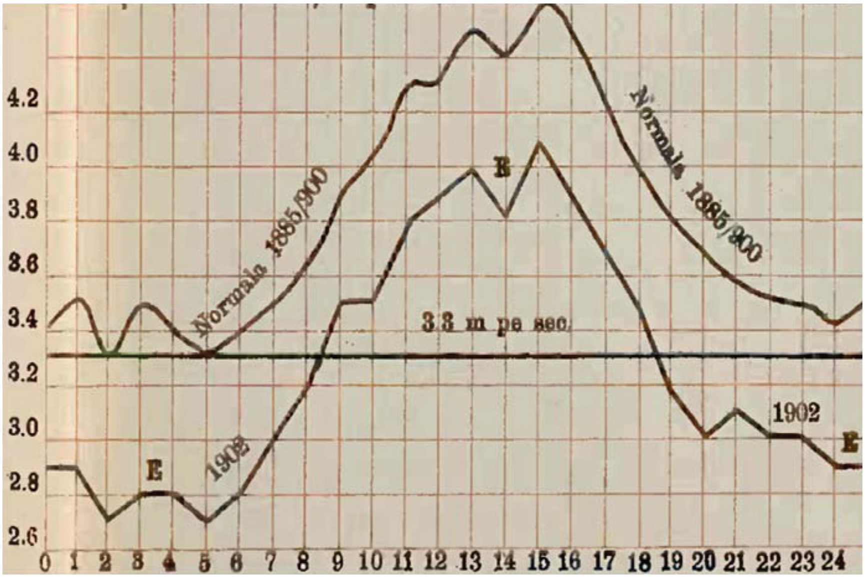


Fig. 5. 24 h variation of mean hourly wind speed in 1899 (top image, data from [11]) and in 1902 and in the period 1885–1900 (bottom image, [10])

Seasonal mean wind velocities are presented in the Bucharest Year Book of 1906 [10], Table 3.

Table. 3. Seasonal mean wind velocity in Bucharest

Season/year	1885–1900	1902	1903
winter	4.4	4.6	3.7
spring	4.5	3.7	3.7
summer	3	2.5	2.4
autumn	3.3	2.8	3.3
average	3.8	3.4	3.3

3. Evolution of wind pressure maps for design

The first provisions for design for wind action were included in the Romanian Standard STAS 946 from 1956 [13] together with those for snow and temperature. It included the 2-zone wind pressure map shown in Fig. 6.

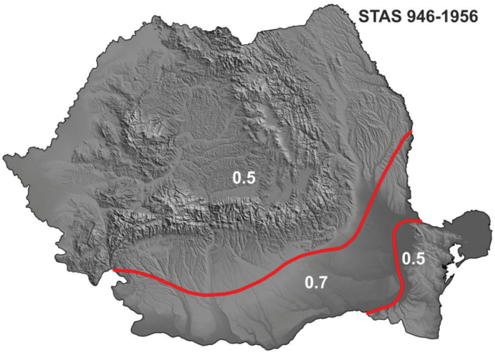


Fig. 6. Wind pressure zonation map in STAS 946-1956 (kN/m^2)

STAS 10101/20 from 1975 [14] and 1978 [15] were entirely devoted to wind actions. The two standards contained the same new five-zone wind pressure map, Fig. 7.

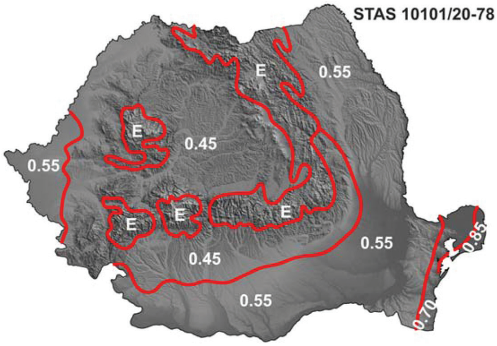


Fig. 7. Wind pressure zonation map in STAS 10101 from1975 and 1978 (kN/m^2)

The STAS 10101/20-1990 [16] included a revised zonation map (Fig. 8), based on reference wind velocities with a 10-year mean return period (the probability distribution model is unknown).

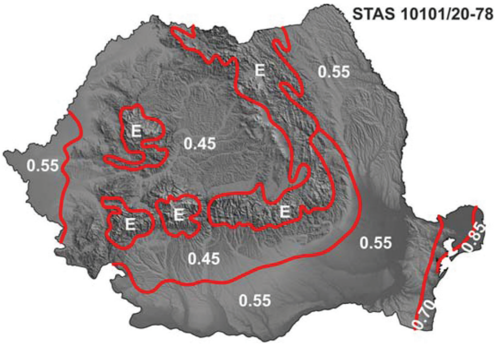


Fig. 8. Wind pressure zonation map in STAS 10101-1990 (kN/m²)

Before joining the EU in 2007, a mandatory code for wind action was issued: NP-082-2004 [17], as a transition towards Eurocodes. The wind pressure map, Fig. 9, had 5 zones and a special mountain area region where wind pressure is ≥ 0.7 kN/². The 50-year mean return period reference wind velocities were computed with a lognormal probability distribution model [18, 19].

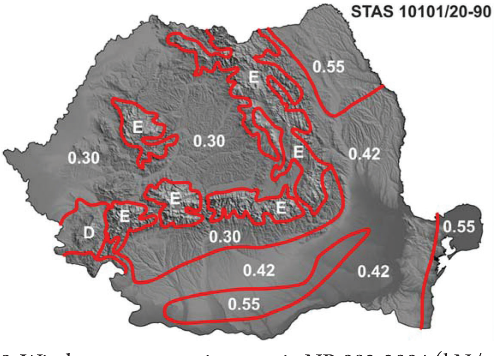


Fig. 9. Wind pressure zonation map in NP-082-2004 (kN/m²)

4. CR-1-1-4/2012 design code

The 2012 edition of the wind code [20] follows the EN 1991-1-4 [21] provisions, it is mandatory and was enforced by the Ministry of Regional Development and Tourism. As the European Standard, the Code applies to buildings and civil engineering works with heights of up to 200 m and to bridges with no span greater than 200 m, provided that they satisfy certain criteria with regard to their dynamic response. The basic (reference) wind velocity and pressure have the same definitions as in the EN. The Code provides a national zonation map (Fig. 10) for the reference wind pressure; this is computed from the fundamental value of the basic wind velocity, which is the characteristic wind speed averaged over 10 minutes, at a height of 10 m above flat open country terrain, having a 2% annual probability of exceedance. The map is to be used for altitudes lower than 1000 m. Based on the zonation map, the Code provides a table with reference wind pressure values for 337 localities.

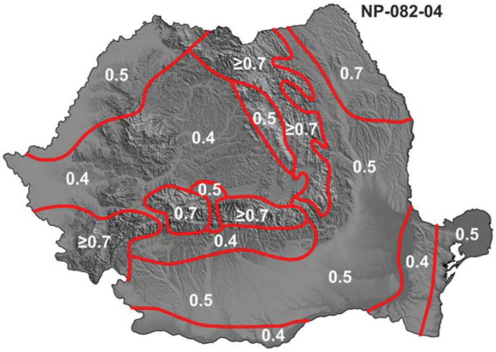


Fig. 10. Wind pressure zonation map in CR-1-1-4/2012 (kN/m[2])

For the region in the south-west of Romania (where the reference wind pressure is ≥ 0.7 N/m[2]) and for the mountain areas at an altitude ≥ 1000 m, the use of data from the National Meteorological Administration is recommended in order to establish the wind pressure.

Annex A (normative) indicates that the reference wind velocity pressure for sites at altitudes higher than 1000m may be determined with the following equation:

$$q_{b,z>1000\,\mathrm{m}} = c_{z>1000\,\mathrm{m}} \cdot q_b \quad (1)$$

where :

- $q_{b,z>1000\,\mathrm{m}}$ – the reference wind velocity pressure for a site at an altitude of z > 1000 m;
- q_b – the reference wind velocity pressure for the site in the zonation map;
- $c_{z>1000\,\mathrm{m}}$ – the altitude coefficient estimated by the formula

$$c_{z>1000\,\mathrm{m}} = 1 + 1.6 \cdot \left(\frac{z}{1000} - 1 \right) \quad (2)$$

Statistical analysis and probabilistic modelling of the maximum annual wind velocities were performed for developing the zonation map. Data from the National Meteorological Administration was available at 145 stations, with records from a period of between 35 and 75 years, up to 2005.

The Gumbel for maxima probability distribution was used for computing the characteristic values of wind velocity with a 2% annual probability of exceedance (mean return period of 50 years).

Gumbel distribution [22] is the probability distribution recommended by EN 1991-1-4 [21] and is used within the EU (for example [23] and [24]), and was also used for modelling wind velocity in other countries around the world, for example, in India [25], Korea [26], Japan [27], Canada [28], Philippines, and Sri Lanka.

The same extreme value distribution for the maxima model is recommended by the Joint Committee on Structural Safety (Lungu and Rackwitz [29]) and ISO 4354, Wind Actions on Structures [30].

For the selected sample of meteorological stations in Romania, the statistical characteristics of maximum annual wind velocities are presented in Table 4 [31].

Table 4. Statistical characteristics of maximum annual wind velocities [31]

Location	**Years of records**	**Observed maxima, m/s**	**Mean, m/s**	**Coef. of var.**	**Characteristic velocity $T = 50$ yr., m/s**
Iaşi	44	33.6	16.6	0.31	29.9
Bacău	44	33.6	14.1	0.32	26.0
Tulcea	44	28.6	16.6	0.31	30.1
Constanța	44	23.5	15.8	0.18	23.3
Călăraşi	44	27.7	14.6	0.29	25.8
Ploieşti	44	23.5	14.9	0.22	23.5
Bucharest Băneasa	42	23.5	14.0	0.26	23.4
Craiova	43	28.6	18.0	0.23	28.9
Timişoara	45	24.4	14.8	0.32	27.1
Oradea	44	21.0	13.4	0.19	20.0
Târgu Mureş	44	18.5	12.4	0.18	18.1
Sibiu	44	28.6	17.5	0.23	27.9

A graphic representation of the maximum annual wind velocity database is presented in Figs. 11–14. Figure 14 indicates that Gumbel distribution is reasonably good; however, the presented data cloud induces the need for a detailed study on the most appropriate probabilistic model.

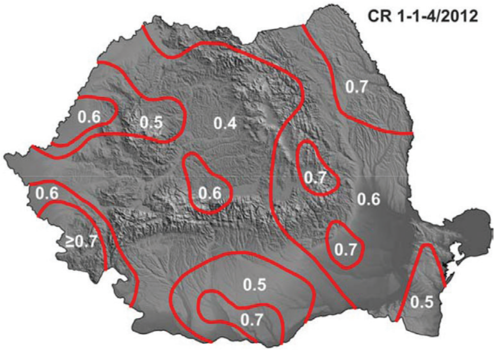


Fig. 11. Standard deviation vs mean annual maximum wind velocity – Romanian data

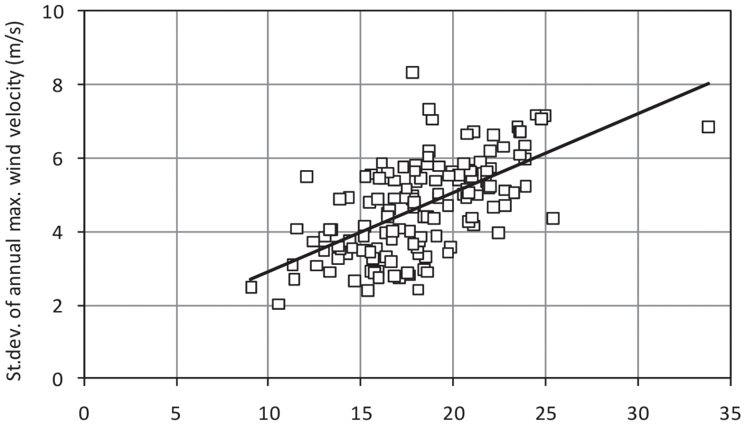


Fig. 12. Coefficient of variation vs mean annual maximum wind velocity – Romanian data

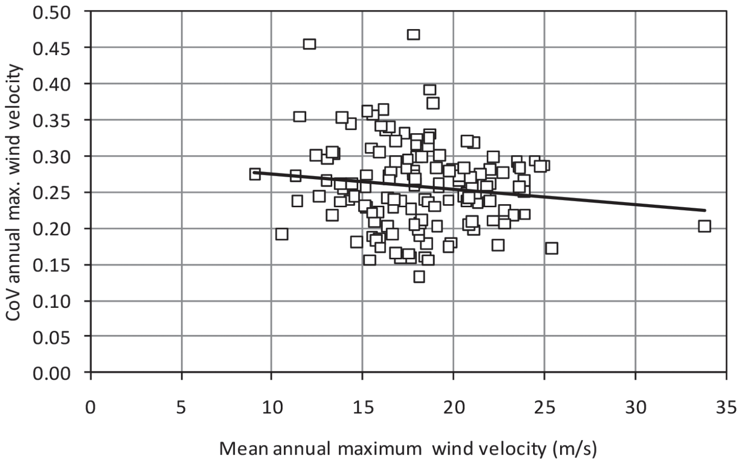


Fig. 13. Skewness vs mean annual maximum wind velocity – Romanian data

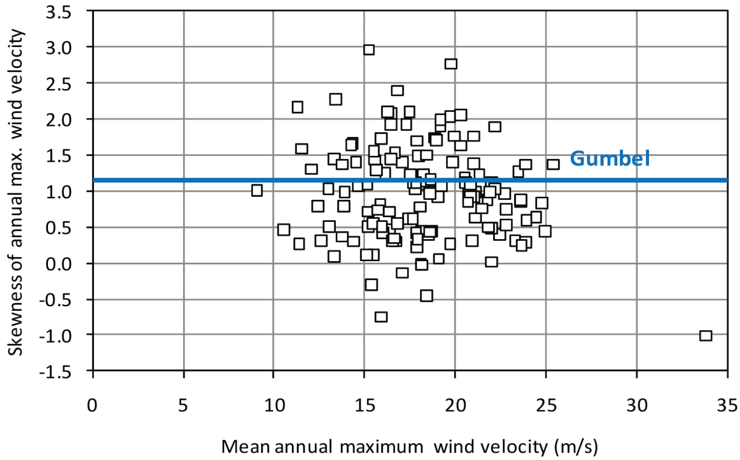


Fig. 14. Skewness vs coefficient of variation of annual maximum wind velocity – Romanian data

The wind pressure for design is established in the Romanian code CR 1-1-4/2012 in the same way as in the Eurocode, with the same approach, coefficients and provisions. However, a supplementary factor is considered: the wind importance-exposure factor γ_{Iw}.

The importance-exposure building categories are defined in the Romanian code CR-0/2012 'Basis of constructions design' [32]. The classification considers the human and economic consequences that may be induced by major natural and/or anthropic hazards and their role and importance in post-disaster activities.

The importance-exposure building categories considered in Romanian practice are as follows:

- Category I – essential for society and for post-disaster intervention;
- Category II – constituting high danger for humans in the event of damage;
- Category III – current buildings and constructions (all except those from categories I, II and IV);
- Category IV – of less importance, constituting low danger for humans in the event of damage.

The wind importance-exposure factor is $\gamma_{Iw} = 1$ for Categories III and IV, and $\gamma_{Iw} = 1.15$ for Categories I and II.

The 1.15 value corresponds to an increase of the mean return period of wind pressure from 50 years to 100 years (computed within the Gumbel distribution for maxima).

Several international codes also have a similar factor, and values within a close range.

The 2005 Canadian National Building Code [33] and the Ontario Building Code (2006) [34] define the following four importance categories and associated importance factors for wind load: importance category Low – importance factor $I = 0.8$, Normal – $I = 1$, High – $I = 1.15$ and Post disaster – $I = 1.25$.

The 2014 New York City Building code [35], defines four structural occupancy/risk categories with associated wind importance factors: $I = 0.87$, $I = 1$ and $I = 1.15$.

An Indian proposal by Krishna et al. [23] considers an importance factor for cyclonic regions (k_4) related to the importance of the structure: structures of post-cyclone importance $k_4 = 1.30$, industrial structures $k_4 = 1.15$ and all other structures $k_4 = 1.00$.

In the AIK 2000 Wind Loads of Standard Design Loads for Buildings and in the Korean National Building Code [24], an *Iw* importance factor for buildings is used in relation to four categories of building importance based on occupancy, function and scale: (Extra) – $Iw = 1.10$, (1) – $Iw = 1.00$, (2) – $Iw = 0.95$ and (3) – $Iw = 0.81$.

5. Final considerations

The recent wind load code of Romania (CR 1-1-4/2012) is harmonised with the Eurocode EN 1991-1-4. The characteristic value of the maximum annual wind velocity is obtained using Gumbel for maxima distribution, and a 2% annual probability of exceedance is considered.

CR 1-1-4/2012 is accompanied by comments and examples that were published as an informative annex. A wind load application/guidebook was published by the Technical University of Civil Engineering Bucharest [36].

An update of the zonation map is necessary for considering the observed wind data from the last thirteen years. Performing a detailed analysis on the most appropriate probability model is also of interest.

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If you want to quote this article, its proper bibliographic entry is as follow: Aldea A., Demetriu S., Văcăreanu R., Lungu D., Arion C., Neagu C., *A short historical overview of wind characteristics and wind pressure for design* in Romania, Technical Transactions, Vol. 10/2019, pp. 97–116.