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Method of Determining Characteristic Values of Average and Maximum Wind Pressure from the Carpathians Zoning Trans Carpathian Region

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Abstract. Based on observations of climate parameters in 1955-2005, respectively 9 weather stations using 8 directions between the initial eight weather stations and Playa ultimate meteorological station by the average and maximum characteristic values of wind pressure in July and January to the highest peak of the Carpathians - Hoverla. For 4 directions between the initial weather stations altitude coefficients and formulas using parameters atmospheric pressure, the average outdoor temperature (in January and July) calculated comparative characteristic values of summer and winter average and maximum wind pressure for 9 peaks of the Carpathians.

1. Introduction

Taking account of the wind load is important when designing wind power stations, calculating structures of high-rise buildings and edifices, preparing general layouts of settlements and so on. The wind load is of a complex physical and probabilistic nature; it depends upon physical and geographical features of the area, in particular, on the geographical altitude.

The territory of the former USSR was divided into 7 zones (from 24 m/s to 47 m/s). Ukraine belonged to zone 3 with an average wind speed of 29 m/s [18]. According to the Ukrainian National Building Code DBN V.1.2-2: 2006 [17], the territory of Ukraine is now divided into five wind zones: 1st – 400 Pa, 2nd – 450 Pa, 3rd – 500 Pa, 4th – 550 Pa, 5th – 600 Pa. The map of zoning of the Ukrainian territory according to the average wind pressure is shown in Figure 1. The Transcarpathian Region is classified as wind zones 1 and 2.

2. Analysis of recent research sources and publications

Starting from the 80-ies, probabilistic researches of the wind load [11 - 16] have been conducted in Ukraine, the main result of which is the development of the national norms of loads [17] relying on the modern scientific basis in conjunction with the European norms Eurocode. The concept of the characteristic value of the wind pressure Wo has been introduced into these standards, which is equal to the average (static) component of the wind pressure at an altitude of 10 meters above the ground, which can be exceeded on average once every 50 years and is determined in accordance with the existing rules according to the map of the zoning of Ukraine.

Zone No	Wind pressure	W_0 Pa
1	400	
2	450	
3	500	
4	550	
5	600	

Figure 1. Map of Ukraine with zoning according to the characteristic values of the average wind pressure

The characteristic value of the wind pressure W_o is calculated by the formula:

$$W_o = 0.61\ V^2, \quad (1)$$

where - V is the appropriate wind speed, m/s.

Unlike the previous norms [18], according to which Ukraine was divided into three wind zones, the regulatory document [17] divides now the territory of Ukraine into five zones with the corresponding characteristic values of wind pressure: 1st – 400 Pa; 2nd – 450 Pa; 3rd – 500 Pa; 4th – 550 Pa; 5th – 600 Pa.

Identification of the aspects of the problem, which have not been solved earlier.

According to the norms [17], the Transcarpathian Region belongs to the 1st and 2nd wind zones, which does not have any probabilistic substantiation. Most of the territory of the Region was designated as a mountainous region, for which the estimated dependence of wind pressure applies depending on the geographic altitude that is allowed to be detailed subject to available meteorological data. At the beginning of the twenty-first century, there were no reliable data about the detailed description of the wind conditions for the mountainous part of the Transcarpathian Region.

The aim of the study is to work out the detailed wind zoning of the Transcarpathian Region, taking into account the geographical and climatic characteristics of this mountainous region.

3. Methods and research results

In order to calculate the wind parameters we have used: diagram 23 of directions between 9 weather stations and 18 intermediate stations (Figure 2), the data of observations of climate parameters in 1955-2005 at 9 weather stations in the Transcarpathian Region (Table 1).

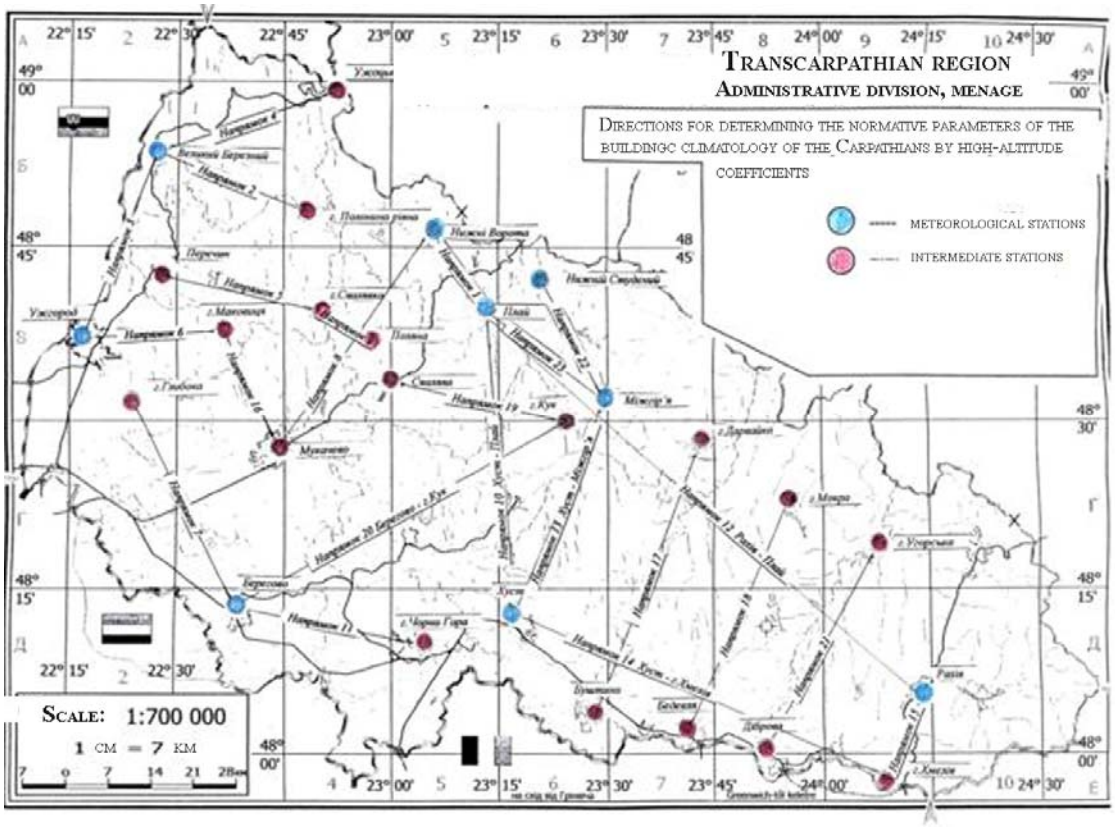

Figure 2. Weather and intermediate (transitional) stations with appropriate directions
Designations: 1- Transcarpathian Region; 2 – directions for determining the normative parameters of building climatology; 3 – weather stations; 4 – intermediate stations; 5 – scale 1:700000, 1cm = 7 km

3.1. Methodology of studying the wind parameters

In order to calculate the wind speed and pressure and compare the calculations [6-8, 12], the formulas of high-altitude factors were used: a) the maximum wind speed difference divided by the difference of the absolute marks of stations 1, 2 of direction 1 - 2; b) wind pressure difference divided by the difference of absolute marks of stations 1, 2 of direction 1-2. In order to calculate the atmospheric pressure: the atmospheric pressure difference divided by the difference of absolute marks at stations 1, 2 of direction 1-2.

a) General formulas of high-altitude factors are as follows:

$$Z_X = Z_1 \pm K_{Z1-2} \cdot \Delta H_{X-Z}, \tag{2}$$

$$\Delta H_{1-2} = H_2 - H_1, \tag{3}$$

$$K_{Z1-2} = \frac{Z_2 - Z_1}{H_2 - H_1}, \tag{4}$$

$$\Delta H_{X-Z} = H_X - H_Z, \tag{5}$$

or for controlling:

$$Z_X = Z_2 - K_{Z1-2} \cdot H_{Z-X}, \tag{6}$$

where: Z_X, Z_1, Z_2 are parameters (summer, winter) at stations X, 1, 2, namely:
Wo is characteristic values of wind pressures HPa;
V is the wind speed, m/s;
P_{atm} is winter and summer atmospheric pressure at stations X, 1, 2 HPa;
$K_{Z,\,1\text{-}2}$ is an altitude factor of wind and atmospheric parameters between weather stations 1, 2;
H_X, H_1, H_2 are the height of stations X, 1, 2 above the Baltic Sea level, m.

Table 1. Results of the observations of climate parameters in 1955-2005 at 9 weather stations in the Transcarpathian Region

No	Name of the weather station	The height above the Baltic Sea level, H, m	Wind speed - numerator m/s, wind pressure - denominator, Pa				Atmospheric pressure, HPa		The average air temperature, °C	
			average		maximal					
			July	January	July	January	July	January	July	January
1	2	3	4	5	6	7	8	9	10	11
1.	Berehove	113	2.9/5.1	2.5/3.8	24/351	20/244	1000.5	1005.0	+20.2	-2.7
2.	Uzhhorod	114.6	3.3/6.6	3.6/7.9	26/412	24/351	1000.3	1004.8	+19.9	-2.8
3.	Khust	166	2.2/2.95	1.8/1.98	20/244	20/244	995.6	1000.0	+19.2	-4.3
4.	V.Bereznyi	209	2.5/3.8	2.1/2.7	20/244	25/381	990.5	995.1	+18.1	-4.1
5.	Rakhiv	438	1.5/1.4	8.7/46.2	30/549	20/244	968.2	972.5	+17.0	-4.3
6.	Mizhhiria	456	2.1/2.7	2.5/3.8	35/747	24/351	966.4	970.7	+16.4	-5.0
7.	Nyzhni Vorota	500	2.4/3.5	3.9/9.3	21/269	20/244	962.0	966.3	+16.2	-4.6
8.	Nyzhnii Studenyi	615	2.2/2.95	3.3/6.6	18/198	24/351	950.5	954.8	+15.2	-5.8
9.	Plai	1330	7.0/29.8	8.7/46.2	40/976	40/976	867.1	861.2	+11.1	-6.3

3.2 The results of the studies of wind parameters

Table 2 shows the results of calculations of summer and winter maximum characteristic values of wind pressure in four directions using high-altitude factors, calculated on the basis of parameters of atmospheric pressure, average ambient air temperatures in July and January obtained from observations at nine weather stations in the Transcarpathian Region in 1955 - 2005. Table 3 shows the results of calculations according to high-altitude factors and 23 directions between 9 weather stations and 18 intermediate stations of maximum wind speeds and characteristic values of wind pressure (summer and winter) for 46 settlements, peaks and passes in the Transcarpathian Region.

Table 2 - Results of calculations of the characteristic values of maximum summer and winter wind pressures for 9 Carpathian peaks according to high-altitude factors

No	Name of the peaks	The altitude above the Baltic Sea level, m	Numerator – summer, denominator - winter				
			a) according to the high-altitude factors of the difference of maximum wind speeds in July and January divided by the difference of absolute heights of stations 1,2, HPa	b) according to the high-altitude factors of the difference of maximum summer and winter wind pressures divided by the difference of summer and winter atmospheric pressures at stations 1, 2, HPa	c) according to the high-altitude factors of the difference of maximum summer and winter wind pressures divided by the difference of absolute altitudes at stations 1,2, HPa	The proposed regulatory parameters	
						Maximum wind pressures, HPa	Maximum wind speeds, m/s
1.	Hoverla	2061	1.397/1.86	1.397/1.86	1.397/1.86	1.397/1.86	47.85/55.20
2.	Petros	2020	1.36/1.81	1.37/1.82	1.37/1.82	1.37/1.82	47.28/54.46
3.	Pip Ivan	1936	1.30/1.71	1.32/1.75	1.32/1.75	1.32/1.74	46.13/52.96
4. 5.	Syvulia, Tovsta	1818	1.21/1.57	1.25/1.66	1.26/1.66	1.23/1.64	44.50/50.84
6.	Ungariaska	1707	1.13/1.45	1.19/1.57	1.19/1.57	1.15/1.52	42.98/48.85
7.	Tempa	1634	1.07/1.38	1.15/1.51	1.15/1.51	1.12/1.45	41.97/47.54
8.	Velykyi Verkh	1598	1.05/1.34	1.13/1.48	1.13/1.48	1.10/1.45	41.48/46.90
9.	Polonyna Rivna	1470	0.98/1.21	1.05/1.36	1.05/1.36	1.00/1.30	40.00/46.60

Based upon the data of Tables 1, 2 and 3, graphs were drawn, showing changes in the maximum wind speed in July and January (Figure 1) and the characteristic wind pressure in July and January (Figure 2) depending on the location of the weather stations and the Carpathian peaks above the Baltic Sea level. The graphs clearly illustrate almost a linear dependence of the speed and pressure of the wind on the geographic altitude starting from the altitude of 600 m.

Table 3. Results of calculations of the maximum wind speeds and maximum wind pressure characteristic values in July and January for intermediate stations, individual settlements, peaks and passes based on 23 directions, high-altitude factors and data of observations at 9 weather stations in the Transcarpathian Region in 1955-2005

№	Names of intermediate stations, settlements, peaks and passes	The altitude above the Baltic Sea level, m	Longitude grades, min.	Latitude, grades, min.	The maximum wind speed, m/s – numerator, characteristic value of wind pressure, kPa - denominator	
					summer	winter
1	2	3	4	5	6	7
1.	Chop	100.0	22°18'	48°21'	23.71/340	19.61/230
2.	Batiovo	102.5	22°23'	48°22'	23.71/340	19.61/230
3.	Mukacheve	116.5	22°44'	48°26'	24.08/350	20.11/240
4.	Velyja Palad	120.0	22°53'	47°59'	24.04/350	20.09/240
5.	Vynohradove	127.4	23°02'	48°08'	24.09/350	20.2/250
6.	Dovhe	166.0	23°16'	48°21'	24.69/370	20.87/270
7.	IIrshava	141.5	23°02'	48°18'	24.37/360	20.47/260
8.	Perechyn	142.0	22°28'	48°44'	25.71/400	22.84/310
9.	Bushtyno	195.8	23°19'	48°02'	20.62/240	20.42/250
10.	Svaliava	203.5	23°00'	48°32'	23.88/350	20.09/240
11.	Tiachiv	210.0	23°34'	48°00'	20.92/270	20.62/260
12.	Bedevlia, Teresva	225.2	23°39'	48°02'	21.23/270	20.83/260
13.	Poliana	242.0	22°58'	48°36'	23.07/320	20.07/240
14.	Dibrova	250.0	23°51'	48°00'	21.75/280	21.17/270
15.	Velykyi Bychkiv	290.9	24°00'	47°58'	22.60/310	21.74/290
16.	Mountain Hlyboka	301.1	22°24'	48°32'	28.18/480	25.73/400
17.	Dubove	363.7	23°53'	48°10'	23.74/340	23.23/330
18.	Kobyletska Poliana	387.3	24°05'	48°03'	24.10/350	23.54/330
19.	Vilshany	420.0	23°37'	48°20'	25.41/390	23.60/340
20.	Volovets	472.9	23°12'	48°42'	21.22/270	20.01/240
21.	Ust-Chorna	502.0	23°56'	48°19'	26.10/420	25.79/400
22.	Kvasy	513.0	24°09'	47°55'	30.84/590	21.68/290
23.	Mountain Svaliavka	525.0	22°49'	43°40'	29.56/530	21.01/380
24.	Bohdan	525.0	24°21'	48°02'	30.98/590	21.95/290
25.	Bukovets	550.0	22°57'	48°54'	22.14/300	21.20/270
26.	Mountain Chorna Hora (Vynohradiv)	565.0	23°03'	48°09'	26.86/440	26.86/440
27.	Lopukhiv	615.0	23°58'	48°22'	28.09/480	27.39/460
28.	Yasinia	636.6	24°22'	48°16'	32.23/630	24.45/360
29.	Pass Pshelench-Beskyd	790.0	22°42'	49°05'	33.39/680	29.21/520
30.	Mountain Prapor	819.0	22°29'	48°59'	33.80/700	29.67/540
31.	Pass Serednio-Veretskyi	839.0	23°09'	48°48'	28.76/500	28.16/480
32.	Mountain Darvaika	883.0	23°45'	48°28'	34.99/740	29.98/540
33.	Mountain Khmeliv	887.0	24°67'	47°55'	35.04/750	30.07/550
34.	Vyshkivskyi Pass	930.0	23°37'	48°42'	30.84/580	30.36/560
35.	Yablunetskyi Pass	931.0	24°26'	48°18'	35.53/770	31.05/590
36.	Mountain Makovytsia	978.0	22°36'	48°39'	36.10/790	32.20/630
37.	Pass Beskyd	981.0	23°20'	48°45'	32.01/630	31.59/610
38.	Mountain	1017.0	22°57'	48°29'	35.72/780	34.90/740
39.	Mountain Dakhmaniv	1225.0	23°55'	48°21'	38.82/920	37.65/860
40.	MountainVerkhni Debri	1237.0	24°28'	48°15'	38.80/918	37.50/858

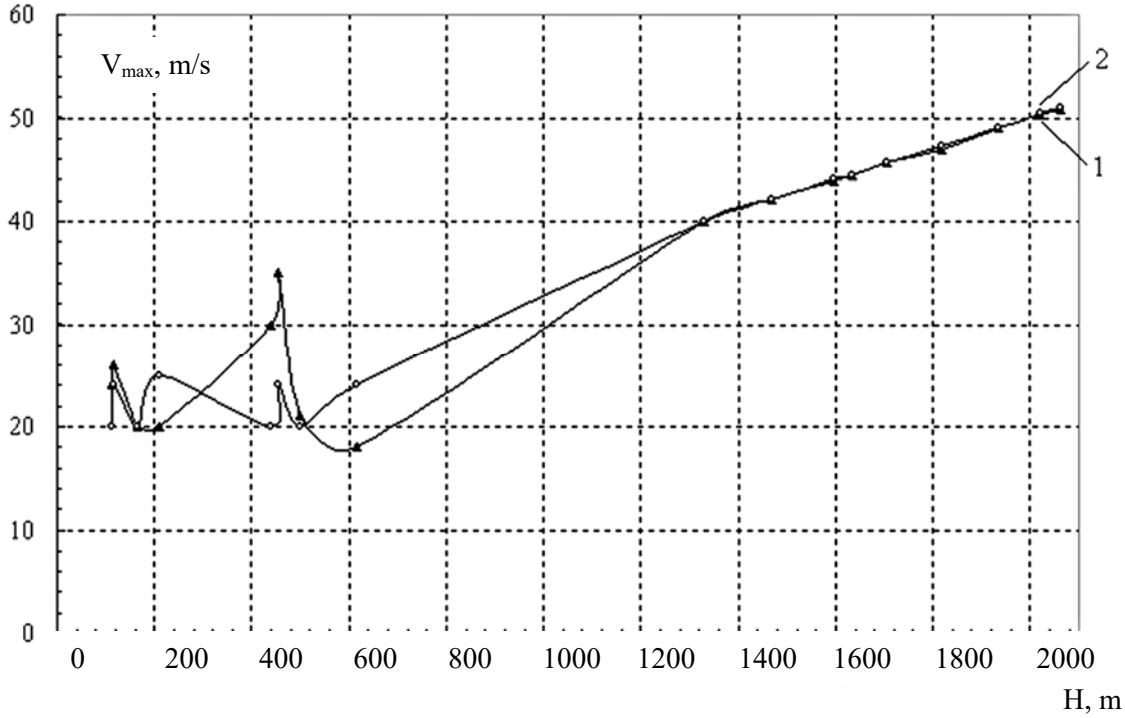

Figure 3. The graph of changes in maximum wind speed, depending on the location of the weather stations and peaks of the Ukrainian Carpathians above the Baltic Sea level: 1 – July; 2 – January

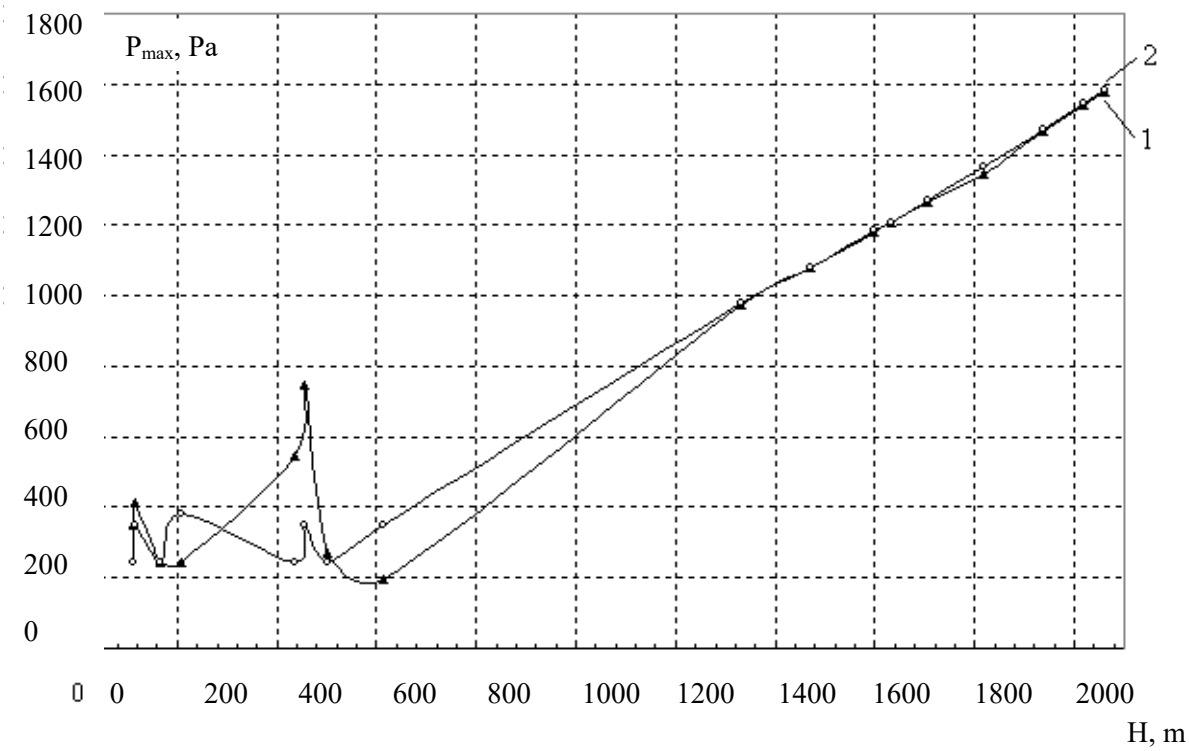

Figure 4. The graph of the change of the maximum wind pressure depending on the location of the weather stations and peaks of the Ukrainian Carpathians above the Baltic Sea level: 1 - July 2 – January

4. Conclusions

1. In the climatic environment, the parameters are interchangeable and interrelated. This has been proved by applying in the formulas the characteristic values of wind loads (summer and winter) and parameters: wind speed, atmospheric pressure, and ambient air temperatures in July and January, obtained according to the observations in 1955-2005 at 9 weather stations in the Transcarpathian Region.
2. The calculated characteristic values of maximum wind pressures depending on the height of location of the stations above the Baltic Sea level [8] range within the following limits:
   - Summer: 340 Pa (Chop – 100 m) - 1370 Pa (Hoverla)
   - Winter: 230 Pa (Chop – 100 m) - 1832 Pa (Hoverla).
3. Existing norms are ensured at the intermediate stations:
   - for the 1st wind zone (400 Pa):
     summer: Town of Perechyn – 142 m (400 Pa);
     winter Mountain Hlyboka – 301.1 m (400 Pa);
   - for the 2nd wind zone (450 Pa):
     summer: Mountain Hlyboka - 301.1 m (480 Pa);
     winter: Pass Lopukhiv - 615 m (460 Pa).
4. Thus, it is not expedient to apply the existing norms from 615 to 2061 m (Hoverla) above the Baltic Sea level.
5. In order to fill the “white spots”, it is recommended to divide the area of the Transcarpathian Region into 9 wind zones according to the maximum winter wind pressure:

Zone 1: 250 - 400 Pa;	Zone 6: 600 - 800 Pa;
Zone 2: 400 - 450 Pa;	Zone 7: 800 - 1000 Pa;
Zone 3: 450 - 500 Pa;	Zone 8: 1000 - 1300 Pa;
Zone 4: 500 - 550 Pa;	Zone 9: 1300 - 1900 Pa;
Zone 5: 550 - 600 Pa;	

and into 8 zones according to the maximum summer wind pressure:

Zone 1: 250 - 400 Pa;	Zone 5: 550 - 600 Pa;
Zone 2: 400 - 450 Pa;	Zone 6: 600 - 800 Pa;
Zone 3: 450 - 500 Pa;	Zone 7: 800 - 1000 Pa;
Zone 4: 500 - 550 Pa;	Zone 8: 1000 - 1300 Pa.

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