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Reference atmospheres

ADDENDUM 1 : Wind supplement

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ADDENDUM 1 : Wind supplement

0 Introduction

A specification summarizing the characteristics of the wind is required for many practical problems, such as aircraft design, the planning and operation of air routes and airfields, estimates of the global transport of atmospheric contaminants, etc., in which the wind is one of the primary factors.

Air motions in the atmosphere occur as a result of phenomena related to air temperature and atmospheric pressure, the nature of the surface over which the air is moving, the rotation of the earth, etc. Such a complex relationship leads to large wind variations in time and space, including the seasonal variation of the general circulation of the atmosphere and the formation of disturbances on a wide range of scales from that of cyclones and anticyclones to that of small-scale turbulence.

The observed features of the wind distribution in the meridional plane are as follows :

a) a predominantly easterly component in the airflow of the lower and middle troposphere of tropical latitudes, and in the whole of the atmosphere in equatorial latitudes;

b) the existence of systematic meridional components in the zone 0 to 30° N — a northerly component in the lower troposphere and a southerly component in the middle troposphere;

c) a predominantly westerly flow in sub-tropical latitudes (30 to 40°); the wind speed increases sharply with altitude, reaching a maximum at altitudes of 10 to 13 km in the sub-tropical jet stream;

d) in temperate latitudes (40 to 60°), a generally westerly flow having a wave-like form; jet streams with axes at altitudes of about 8 to 9 km are associated with systems of mobile cyclones and are therefore more variable than the sub-tropical jet stream and much of the detail of their structure and location is lost in the averaging process;

e) in the stratosphere, the air flow is characterized by a seasonal of monsoon-type of direction change; to the north of 30° N, westerly winds occur in winter, changing to easterly in summer, with negative wind shears (wind speed decreasing with height) prevailing in the altitude range 9 to 20 km; to the north of 60 to 65° N, abrupt positive wind shears prevail in winter, and there is a strong westerly jet stream in the polar stratosphere.

The World Meteorological Organization (WMO) and several countries have published detailed tables and atlases of the wind characteristics[1, 2, 7], and these can be used to provide information in the form required for a given purpose. However, it would probably be wrong to expect the specialist user, who may not be a meteorologist, to extract the required information from the huge store of climatological material available.

It seems reasonable, therefore, the present wind data, averaged over major regions, in the form of this addendum to ISO 5878.

1 Scope and field of application

The addendum presents data on spatial distribution of wind characteristics, for use in estimating the performance of aircraft in the design stage or of aircraft already in service, for planning air routes and for estimating the global transport of atmospheric contaminants.

2 Methodological aspects and analysis of the data

The tables and graphs given are based on a comprehensive study and statistical analysis of wind data for the earth's surface and eight isobaric surfaces over the northern hemisphere.

The analysis is based on a large and uniform statistical sample, the major part of which has been published[3, 4]. About two million observations from 369 aerological stations for the nine-year period 1957 to 1965 were processed. In addition, statistical data from 50 further stations[5, 6] were included in the analyses. Other works[1, 2] were also used.

The following maps were compiled on the basis of the average monthly wind characteristics at the main isobaric surfaces :

a) mean scalar wind speed, $\overline{V}_s$;

b) mean zonal component (zonal component of the vector mean wind), $\overline{V}_x$;

c) mean meridional component (meridional component of the vector mean wind), $\overline{V}_y$;

d) standard deviation of the zonal component of the wind, σ_x;

e) standard deviation of the meridional component of the wind, σ_y.

The seasonal changes of the wind characteristics at the different isobaric surfaces and the effects of topography and surface roughness were taken into account in the analysis of the maps and in drawing isotachs.

The information read off at the grid points at intervals of 10° of longitude and 10° of latitude for the earth's surface and for the 850, 700, 500, 300, 200, 100, 50 and 30 mbar isobaric surfaces served as a basis for the calculation of the average wind characteristics within each of the latitude zones.

Thus the mean value for a zone, $\overline{V}$, of a characteristic is given by the equation :

$$\overline{V} = \frac{1}{n} \sum_{i=1}^{n} \overline{V}_i \qquad \ldots (1)$$

and the corresponding standard deviation, σ, by

$$\sigma = \sqrt{\frac{1}{n} \sum_{i=1}^{n} \sigma_i^2 + \frac{1}{n} \sum_{i=1}^{n} (\overline{V}_i - \overline{V})^2} \qquad \ldots (2)$$

where

$\overline{V}_i$ is the monthly mean value of the characteristic at the i-th grid point;

σ_i is the standard deviation at the i-th grid point;

n is the number of grid points within the region of averaging; for each latitude circle, $n = 36$.

For each isobaric surface the mean values of the zonal and meridional components of the wind and the values of the scalar mean wind speed were calculated from equation (1), and the standard deviations of the components from equation (2). Then each of the wind characteristics was plotted as a function of the geopotential altitude H, using the mean value of H for each isobaric surface. The values interpolated from these plots for the required values of H were used in constructing the tables.

3 Wind models

Taking into account the features of the atmospheric circulation over the northern hemisphere, namely the presence of long waves within certain latitude zones and the existence of jet streams in certain locations, the wind fields may be represented by the following models :

a) For latitude zones; in addition, within each latitude zone data derived from actual observations are given for two selected stations, one with very strong winds and the other with very light winds (tables 1, 2, 3; figures 1 to 4).

b) For meridional cross-sections (tables 4, 5; figures 5 to 8) supplement the models and illustrate the global circulation over the northern hemisphere.

Specifically, models are presented for the following latitude zones and meridians :

1) tropical zone, 0 – 20° N (zone of the trade-wind circulation and easterly jet streams in the near-equatorial upper troposphere and stratosphere);

2) sub-tropical zone, 20 – 40° N (region of the strong westerly sub-tropical jet stream (at altitudes of 10 to 13 km);

3) temperate zone, 40 – 60° N (zone of strong cyclonic activity and maximum horizontal turbulent exchange);

4) polar zone, 60 – 80° N (zone of the polar-night stratospheric westerly jet stream of winter);

5) meridional cross-section along 140° E : this illustrates the circulation near the east Asian coastline of the Pacific Ocean, where the sub-tropical jet stream reaches its maximum intensity;

6) meridional cross-section along 80° E : this illustrates the circulation over the Siberian anticyclone in winter, the jet streams over Tibet, the monsoon circulation over India and the easterly jet stream over the northern parts of the Indian Ocean;

7) meridional cross-section along 20° E : the meridian crosses eastern Europe and central Africa, and the cross-section is characteristic of the area of cyclonic activity over Europe and the Mediterranean and of the sub-tropical jet stream over northern Africa;

8) meridional cross-section along 80° W : the meridian crosses the eastern regions of North America and the Caribbean Sea, and the profile illustrates the jet streams over the western Atlantic.

The values of the quantities describing the wind fields, obtained for the altitude range 0 to 25 km from actual observations and by estimation using the circular normal distribution, are presented for the above models for January and July.

The following quantities were obtained from the actual observations :

- mean zonal component of the wind, $\overline{V}_x$, and mean meridional component of the wind, $\overline{V}_y$;
- vector mean wind, $\overline{\vec{V}}_r$, magnitude of the vector mean wind, $\overline{V}_r$, and direction of the vector mean wind, θ; the scalar mean wind speed, $\overline{V}_s$;
- standard deviation of the vector mean wind, σ_r;
- maximum wind speed observed once in ten years, v_{max}.

The speeds equalled or exceeded on 1, 10, 20, 80, 90 and 99 % of occasions were calculated using the circular normal distribution. The scalar mean wind speed, $\overline{V}_s$, for each zone was both obtained from the actual observations, $\overline{V}_{sa}$, and calculated using the law of circular normal distribution, $\overline{V}_{sc}$.

For four meridional sections the mean speed $\overline{V}_s$ is given only based on actual observations — $\overline{V}_{sa}$.

4 Calculation of wind characteristics by use of the circular normal distribution

Wind is a vector. In a sample of a large number of winds observed over a long period of time, each individual vector is a stochastic, or random, value, and for estimating wind distributions, probability theory may be used. For the calculation of the

characteristics, the circular normal distribution may be used, the probability density, $f(v)$, being given by the equation :

$$f(v) = \frac{2\,v}{\sigma_r^2} e^{-(v^2 + \bar{V}_r^2)/\sigma_r^2} \times I_o\left(\frac{2\,v\,\bar{V}_r}{\sigma_r^2}\right) \quad \ldots (3)$$

where :

v is the wind speed;

$\bar{V}_r$ is the magnitude of the vector mean wind;

σ_r is the standard deviation of the vector mean wind;

$I_o(x)$ is the zero-order Bessel function of imaginary argument.

The circular normal distribution law may be regarded as valid for the four latitude zones, since $\sigma_x = \sigma_y = \sigma_r / \sqrt{2}$, taking into account that $\sigma_r = \sqrt{\sigma_x^2 + \sigma_y^2}$, with an accuracy acceptable for most practical purposes. In addition, for calculating the mean characteristics for latitude zones above 20° N, where $\bar{V}_y$ does not exceed 6 % of $\bar{V}_x$, and the absolute value is not more than 1 m/s, it is assumed that $\bar{V}_y = 0$, so that $\bar{V}_r = |\vec{\bar{V}}_r| = |\bar{V}_x|$. This allows the basic parameters of the distribution for zones 20 – 40°, 40 – 60° and 60 – 80° N to be determined by $\bar{V}_x$ and σ_r only.

The values of wind speed which are likely to be equalled or exceeded on 1, 10, 20, 80, 90 and 99 % of occasions may be estimated from equation (3). The expected scalar mean speed, $\bar{V}_{sc}$ is given by equation (4) (mathematical expectation) :

$$\bar{V}_{sc} = \int_0^\infty f(v)\, V\, dv \quad \ldots (4)$$

The analysis of the scalar mean speed derived from observations, and calculated from the circular normal distribution for each zone confirms that the circular normal distribution may be used to calculate the values of wind speed with an accuracy sufficient for most practical purposes.

Table 1 — Parameters of the observed wind distribution in selected latitude zones, and calculated values of the scalar mean wind speed and of high and low percentile values of wind speed, in metres per second

0 – 20° N, January

Geopotential altitude H, km	Actual observations					Based on circular normal law of distribution						
							1 %		10 %		20 %	
	$\bar{V}_x$	$\bar{V}_y$	$\bar{V}_{sa}$	σ_r	v_{max}	$\bar{V}_{sc}$	low	high	low	high	low	high
0	−2,9	−1,6	5,5	3,0	—	3,1	—	—	—	—	—	—
1	−3,9	−1,2	7,6	5,9	—	6,0	1,0	14,7	3,0	11,0	3,0	9,0
2	−2,7	−0,7	7,2	6,4	—	6,2	1,0	15,2	3,0	10,7	3,0	8,8
3	−1,6	−0,3	7,2	7,0	60	6,3	1,0	16,0	3,0	11,0	3,0	9,0
4	−0,7	−0,2	7,7	7,7	59	7,0	1,0	17,0	2,8	11,6	3,3	9,7
5	0,2	−0,1	8,5	8,5	59	7,6	1,0	18,5	3,0	12,7	3,5	10,8
6	1,2	−0,1	9,6	9,4	61	8,5	1,0	20,7	3,0	14,3	4,3	12,2
7	2,9	0,0	10,9	10,5	67	9,7	1,4	23,5	3,4	16,4	5,0	13,8
8	4,8	0,2	12,3	11,6	76	11,0	1,7	26,5	4,0	18,8	6,2	15,8
9	6,8	0,4	13,7	12,7	80	12,6	2,0	30,3	4,5	21,7	7,4	18,0
10	8,9	1,0	15,4	13,7	78	14,3	2,0	34,5	5,5	25,0	8,5	20,8
11	10,5	2,2	17,2	14,9	73	15,9	2,0	38,2	6,5	27,5	9,4	23,2
12	11,5	2,9	18,8	15,9	70	16,9	2,0	40,5	7,0	29,5	9,8	25,8
13	11,2	2,8	18,6	15,7	73	16,5	1,7	40,2	6,5	28,7	9,4	25,0
14	9,7	2,3	16,9	14,5	85	15,0	1,4	37,7	5,7	26,0	8,3	22,5
15	8,0	1,8	15,1	13,4	94	13,7	1,2	34,0	5,0	23,5	7,3	20,3
16	6,1	0,9	13,6	12,4	100	12,2	1,0	29,8	4,5	21,2	6,5	18,0
17	4,6	0,4	12,1	11,5	96	10,9	1,0	25,6	4,0	19,0	5,9	16,0
18	3,3	0,3	10,8	10,8	82	10,0	1,0	23,2	3,6	17,4	5,5	14,3
19	1,9	0,2	9,7	10,1	65	9,3	1,0	22,0	3,4	16,2	5,2	13,0
20	0,7	0,1	8,7	9,7	54	8,7	1,0	21,3	3,2	15,4	5,0	12,3
21	−0,4	0,0	8,4	9,4	48	8,5	1,0	21,0	3,0	15,0	5,0	12,0
22	−1,3	−0,1	8,6	9,4	44	8,6	1,0	21,0	3,0	15,2	5,0	12,2
23	−2,1	−0,2	9,2	9,7	42	8,7	1,0	21,5	3,0	15,6	5,0	12,6
24	−2,9	−0,2	9,9	10,3	39	9,5	1,0	22,3	3,0	16,3	5,0	13,3
25	−3,5	−0,2	10,9	11,4	38	10,7	1,0	23,3	3,0	17,0	5,0	14,2

Table 1 — Parameters of the observed wind distribution in selected latitude zones, and calculated values of the scalar mean wind speed and of high and low percentile values of wind speed, in metres per second (*continued*)

0 – 20° N, July

Geopotential altitude H, km	Actual observations					Based on circular normal law of distribution						
	$\bar{V}_x$	$\bar{V}_y$	$\bar{V}_{sa}$	σ_r	v_{max}	$\bar{V}_{sc}$	1 %		10 %		20 %	
							low	high	low	high	low	high
0	– 0,6	0,2	5,2	3,4	—	3,0	—	—	—	—	—	—
1	– 1,4	0,3	7,8	7,0	—	6,4	1,0	15,8	2,3	12,0	4,0	10,0
2	– 2,2	0,2	7,9	7,4	—	6,8	1,0	16,4	2,5	12,0	4,0	10,0
3	– 2,8	– 0,1	8,0	7,6	60	7,2	1,0	16,8	3,0	12,0	4,0	10,0
4	– 3,2	0,0	7,9	7,6	61	7,4	1,0	17,5	3,0	12,7	4,0	10,2
5	– 3,6	0,1	7,8	7,4	61	7,3	1,0	18,3	3,0	13,3	4,0	10,5
6	– 3,9	0,2	7,8	7,4	60	7,4	1,0	19,0	3,0	14,0	4,0	11,0
7	– 4,1	0,2	8,0	7,6	58	7,5	1,0	19,5	3,0	14,1	4,0	11,2
8	– 4,3	0,2	8,3	7,9	58	8,1	1,0	20,0	3,0	14,4	4,2	11,7
9	– 4,4	0,1	8,8	8,4	59	8,4	1,0	20,5	3,0	14,5	4,5	12,5
10	– 4,5	– 0,1	10,2	9,4	61	9,2	1,0	22,0	3,2	15,8	5,2	14,0
11	– 4,8	– 0,5	12,4	12,4	65	11,8	1,0	26,8	3,4	19,0	6,0	17,0
12	– 5,4	– 0,8	13,6	14,0	69	13,4	1,1	31,2	4,7	22,3	6,7	19,5
13	– 6,5	– 0,7	13,8	14,3	73	14,2	1,2	33,0	5,4	23,5	7,4	20,2
14	– 7,6	– 0,3	13,7	14,0	76	13,7	1,4	33,5	5,7	24,0	7,8	20,1
15	– 8,8	0,0	13,6	13,5	79	15,0	1,6	33,5	6,0	24,0	8,0	20,0
16	– 9,9	0,2	13,4	12,8	80	15,5	1,8	33,2	6,0	24,0	8,2	20,0
17	– 10,8	0,3	13,2	11,9	78	16,3	2,0	32,5	6,2	23,8	8,2	20,0
18	– 11,6	0,3	14,0	10,8	70	15,4	2,3	31,5	6,5	23,4	8,5	20,0
19	– 12,3	0,2	14,8	10,0	61	14,2	2,5	30,7	7,0	23,0	9,0	20,3
20	– 13,1	0,2	15,7	9,6	53	13,7	2,8	30,0	7,5	22,8	9,5	20,6
21	– 14,1	0,2	16,7	9,4	51	13,8	3,1	30,5	8,2	23,5	10,5	21,3
22	– 15,2	0,3	17,9	9,9	51	14,7	3,5	32,4	8,9	25,0	11,3	22,7
23	– 16,5	0,4	19,2	10,5	63	16,0	3,8	34,7	9,5	27,0	12,2	24,3
24	– 17,8	0,7	20,5	11,1	70	17,4	4,0	37,3	10,0	29,0	13,0	27,3
25	– 19,2	1,0	21,9	11,9	77	18,7	4,5	40,2	10,7	31,5	14,0	28,3

Table 1 — Parameters of the observed wind distribution in selected latitude zones, and calculated values of the scalar mean wind speed and of high and low percentile values of wind speed, in metres per second (*continued*)

20 – 40° N, January

Geopotential altitude H, km	Actual observations				Based on circular normal law of distribution						
	$\overline{V}_x$	$\overline{V}_{sa}$	σ_r	v_{max}	$\overline{V}_{sc}$	1 %		10 %		20 %	
						low	high	low	high	low	high
0	1,0	6,4	5,5	—	5,1	—	—	—	—	—	—
1	1,8	8,5	9,4	—	8,5	1,0	20,0	2,5	15,0	4,5	11,7
2	4,7	10,0	10,4	—	10,3	1,0	24,4	3,5	17,5	5,5	14,5
3	8,0	11,8	11,5	70	12,6	1,0	29,2	4,5	20,8	6,7	17,5
4	10,5	14,2	13,1	72	15,8	1,3	34,0	6,0	24,5	8,1	21,0
5	13,2	17,0	15,0	76	17,3	1,6	39,5	7,0	28,8	9,8	25,0
6	16,0	20,6	17,0	84	21,8	2,2	46,0	8,5	33,7	12,0	29,5
7	18,8	24,2	19,2	102	24,7	2,8	53,5	10,2	39,5	14,7	35,0
8	21,5	27,0	21,3	124	28,1	3,7	62,5	12,2	47,0	17,5	41,0
9	24,3	29,5	22,7	140	31,6	4,4	70,0	13,8	53,8	19,7	45,5
10	26,8	31,6	23,4	142	34,6	4,7	72,5	15,0	55,7	21,0	48,0
11	28,7	33,2	23,4	132	35,6	5,0	72,2	15,7	55,5	21,7	48,0
12	29,7	34,0	22,8	124	36,1	5,0	70,0	16,0	54,0	22,0	47,0
13	28,5	33,0	21,5	118	32,9	4,9	64,0	15,5	51,3	21,2	44,7
14	26,5	31,1	19,9	112	29,6	4,7	58,5	14,7	47,7	20,0	41,6
15	24,3	28,4	17,8	107	26,6	4,5	53,0	13,4	43,5	18,2	38,0
16	21,8	25,0	15,7	102	24,7	4,0	48,3	11,5	38,7	15,7	33,5
17	18,1	21,0	14,0	96	21,4	3,5	43,2	9,3	33,5	12,8	29,0
18	14,2	17,2	12,8	88	18,0	2,5	38,5	7,3	28,0	10,2	24,5
19	10,4	13,6	11,6	80	14,7	1,8	33,8	5,6	23,5	8,0	20,6
20	7,0	11,1	10,9	73	11,9	1,3	29,4	4,5	20,3	6,2	17,3
21	5,3	10,0	10,6	68	10,8	1,0	26,2	4,0	18,6	5,4	15,7
22	4,4	9,6	10,8	65	10,6	1,0	25,4	3,8	18,2	5,4	15,2
23	3,5	9,4	11,1	62	10,5	1,0	25,0	3,8	18,0	5,6	15,0
24	2,9	9,6	11,6	60	10,8	1,0	25,0	4,1	18,0	6,1	15,0
25	2,3	9,8	12,4	60	11,3	1,4	25,0	4,5	18,3	6,7	15,0

Table 1 — Parameters of the observed wind distribution in selected latitude zones, and calculated values of the scalar mean wind speed and of high and low percentile values of wind speed, in metres per second (*continued*)

20 – 40° N, July

Geopotential altitude H, km	Actual observations				Based on circular normal law of distribution						
	$\overline{V}_x$	$\overline{V}_{sa}$	σ_r	v_{max}	$\overline{V}_{sc}$	1 %		10 %		20 %	
						low	high	low	high	low	high
0	– 0,3	4,9	5,0	–	4,5	–	–	–	–	–	–
1	0,5	6,9	7,4	–	6,7	1,0	15,5	2,2	11,7	4,0	9,8
2	0,9	7,2	7,8	–	7,1	1,0	16,5	2,5	12,2	4,0	10,3
3	1,4	7,5	8,1	61	7,4	1,0	17,7	2,9	12,7	4,0	10,8
4	2,1	8,0	8,4	58	7,7	1,0	18,8	3,0	13,5	4,3	11,3
5	2,7	8,5	8,7	58	8,2	1,0	19,8	3,0	14,0	4,5	11,7
6	3,3	9,3	9,2	62	8,7	1,0	21,2	3,1	15,0	5,0	12,3
7	4,5	10,3	9,8	70	9,5	1,0	23,5	3,5	16,8	5,4	13,7
8	5,6	11,6	10,8	79	10,6	1,0	26,5	4,0	19,0	5,9	15,6
9	6,6	13,0	12,1	87	12,2	1,0	29,7	4,5	21,3	6,5	17,6
10	7,3	14,3	13,7	93	13,8	1,2	33,0	5,0	23,6	7,2	19,5
11	7,8	15,2	15,6	96	15,7	1,5	36,2	5,5	25,8	8,5	21,8
12	8,0	15,7	16,5	92	16,7	1,8	38,6	6,0	27,8	9,0	23,6
13	7,3	15,5	16,4	88	16,1	1,6	38,5	5,7	27,3	8,5	23,5
14	5,3	14,3	15,3	87	14,4	1,5	34,5	5,0	24,0	7,3	20,0
15	3,0	12,8	14,0	89	12,8	1,2	30,3	4,5	20,7	6,0	17,0
16	0,8	11,8	12,4	91	11,2	1,0	26,5	4,3	18,0	5,2	14,7
17	– 1,8	11,6	10,7	88	9,8	1,0	23,2	4,2	16,7	5,0	13,8
18	– 4,4	11,9	9,4	79	8,9	1,1	22,4	4,5	16,5	5,5	14,0
19	– 6,7	12,4	8,4	70	8,6	1,3	22,5	4,7	16,7	6,2	14,4
20	– 8,8	13,0	7,8	64	8,8	1,5	23,0	5,2	17,2	7,0	15,0
21	– 10,5	13,7	7,5	60	9,4	2,0	24,0	6,0	18,0	8,5	16,0
22	– 11,9	14,7	7,6	62	10,5	2,3	25,5	6,7	19,3	9,0	17,2
23	– 13,1	15,7	7,8	65	11,1	2,6	27,0	7,7	21,0	10,0	18,9
24	– 14,3	16,9	8,2	69	12,2	3,0	28,7	8,9	22,6	11,0	20,7
25	– 15,4	18,2	8,8	74	13,1	3,2	30,5	10,2	24,5	12,0	22,5

Table 1 — Parameters of the observed wind distribution in selected latitude zones, and calculated values of the scalar mean wind speed and of high and low percentile values of wind speed, in metres per second (*continued*)

40 – 60° N, January

Geopotential altitude H, km	Actual observations				Based on circular normal law of distribution						
	$\overline{V}_x$	$\overline{V}_{sa}$	σ_r	v_{max}	V_{sc}	1 %		10 %		20 %	
						low	high	low	high	low	high
0	1,2	6,2	8,9	—	8,2	—	—	—	—	—	—
1	3,4	10,2	11,8	—	10,8	1,0	26,0	4,0	18,5	6,0	15,2
2	5,3	11,5	12,7	—	12,5	1,0	28,8	4,3	20,5	6,5	17,2
3	7,1	13,2	13,8	77	14,2	1,0	32,3	5,0	23,0	7,2	19,5
4	8,8	15,1	15,4	88	16,0	1,5	36,5	5,7	26,4	8,1	22,3
5	10,2	17,2	17,2	97	18,0	2,0	41,5	6,7	30,4	9,5	25,5
6	11,5	19,5	19,3	101	20,2	2,3	47,4	7,5	34,5	10,8	29,5
7	12,7	21,8	21,2	102	22,2	2,6	53,0	8,3	38,0	12,3	32,5
8	14,0	23,7	23,0	101	24,1	3,0	57,5	8,7	40,8	13,5	35,0
9	15,1	24,8	23,8	99	25,2	3,0	59,0	9,1	42,0	14,0	36,0
10	16,2	24,5	22,2	98	24,0	3,0	57,5	9,4	41,2	14,0	35,3
11	17,0	23,9	20,7	100	23,9	3,0	55,3	9,2	39,7	13,5	34,5
12	17,4	23,1	19,4	99	23,9	3,0	52,7	9,0	38,0	12,7	33,5
13	17,6	22,3	18,1	96	23,8	3,2	50,3	9,2	37,1	12,5	32,5
14	17,6	21,4	17,0	93	23,5	3,2	48,0	9,3	35,2	12,4	31,3
15	17,3	20,6	16,1	91	23,4	3,1	45,7	9,2	34,0	12,3	30,1
16	16,7	19,9	15,3	89	22,1	3,0	44,0	9,0	33,0	12,0	28,7
17	16,0	19,4	14,8	88	20,7	2,5	43,0	8,6	32,3	11,5	27,7
18	15,5	19,0	14,6	89	20,1	2,3	42,5	8,2	31,8	11,2	27,0
19	15,0	18,9	14,9	90	19,7	2,0	42,5	8,0	31,5	11,0	26,8
20	14,6	19,0	15,5	91	17,6	2,0	42,8	8,0	32,0	11,0	27,0
21	14,5	19,5	16,5	93	20,0	2,2	44,4	8,1	32,7	11,0	27,5
22	14,7	20,3	17,5	96	20,7	2,5	46,7	8,4	34,4	11,2	29,0
23	15,1	21,4	18,9	99	22,0	2,8	49,5	8,8	36,2	11,6	31,0
24	15,6	23,0	20,4	103	23,0	3,3	52,5	9,2	38,3	12,2	33,0
25	16,1	24,8	22,2	107	24,0	3,8	55,5	9,7	40,5	12,8	35,5

Table 1 — Parameters of the observed wind distribution in selected latitude zones, and calculated values of the scalar mean wind speed and of high and low percentile values of wind speed, in metres per second (*continued*)

40 — 60° N, July

Geopotential altitude H, km	Actual observations				Based on circular normal law of distribution						
	$\overline{V}_x$	$\overline{V}_{sa}$	σ_r	v_{max}	$\overline{V}_{sc}$	1 %		10 %		20 %	
						low	high	low	high	low	high
0	0,8	4,5	6,0	—	5,5	—	—	—	—	—	—
1	1,8	7,5	8,4	—	7,6	1,0	18,5	3,0	13,5	3,6	10,5
2	2,9	8,0	8,9	—	8,4	1,0	19,5	3,0	14,5	4,2	11,4
3	4,1	8,9	9,5	70	9,3	0,9	20,8	3,0	15,9	5,0	12,7
4	5,3	10,0	10,2	69	10,4	0,8	23,2	3,7	17,5	5,7	14,4
5	6,5	11,4	11,1	69	11,5	0,8	26,5	4,5	19,5	6,5	16,4
6	7,8	13,1	12,6	70	13,3	1,0	31,5	5,0	21,8	7,3	18,5
7	9,0	15,4	14,4	73	15,0	1,2	36,7	5,5	25,0	8,2	21,2
8	10,5	17,5	16,2	76	16,8	1,5	41,3	6,0	28,5	9,3	24,0
9	11,5	19,0	17,9	79	18,9	1,9	45,0	6,5	31,5	10,4	26,6
10	12,7	20,0	18,8	82	20,6	2,0	47,0	7,5	33,8	11,5	28,5
11	13,6	20,3	18,8	83	21,3	2,0	47,5	8,0	34,5	12,0	29,4
12	14,3	20,3	18,1	81	20,9	2,0	47,0	8,0	33,8	11,9	29,0
13	14,0	18,0	16,5	80	21,4	1,7	43,5	7,2	31,5	10,5	27,0
14	12,0	15,0	14,2	83	18,9	1,5	37,2	6,3	27,0	8,8	22,8
15	9,0	12,0	12,0	86	14,8	1,2	31,0	5,4	22,0	7,2	18,5
16	6,0	9,8	10,2	89	11,0	1,1	25,5	4,5	18,5	5,8	15,5
17	4,0	8,4	9,0	88	8,9	1,0	21,5	3,7	16,0	4,7	13,2
18	2,2	7,8	8,2	79	7,6	1,0	19,2	3,3	14,4	4,3	11,8
19	0,1	7,2	7,6	70	6,8	1,0	17,6	3,0	13,3	4,0	10,7
20	−1,8	6,8	7,2	63	6,7	1,0	16,8	3,0	12,5	4,0	10,1
21	−3,1	6,8	7,2	60	7,2	1,0	16,8	3,0	12,0	4,0	10,0
22	−4,5	7,2	7,3	62	7,9	1,0	17,5	3,1	12,5	4,3	10,7
23	−5,5	7,8	7,4	66	8,6	1,0	18,5	3,4	13,5	4,5	11,5
24	−6,5	8,9	7,4	68	8,9	1,0	19,6	3,8	14,5	4,9	12,5
25	−7,2	10,4	7,5	72	8,6	1,0	21,0	4,2	15,8	5,5	14,0

Table 1 — Parameters of the observed wind distribution in selected latitude zones, and calculated values of the scalar mean wind speed and of high and low percentile values of wind speed, in metres per second (*continued*)

60 – 80° N, January

Geopotential altitude H, km	Actual observations				Based on circular normal law of distribution						
	$\overline{V}_x$	$\overline{V}_{sa}$	σ_r	v_{max}	$\overline{V}_{sc}$	1 %		10 %		20 %	
						low	high	low	high	low	high
0	0,0	5,3	7,3	—	6,8	—	—	—	—	—	—
1	1,6	8,8	10,3	—	9,4	1,0	22,5	3,0	15,5	5,0	13,8
2	2,5	10,6	11,4	—	10,4	1,0	24,5	3,5	17,2	5,3	14,6
3	3,5	12,2	12,6	84	11,6	1,0	27,5	4,2	19,5	6,0	16,5
4	4,8	13,8	14,3	93	13,5	1,4	31,4	5,0	23,0	7,0	19,0
5	5,7	15,2	16,4	100	15,5	1,8	36,0	5,8	26,5	7,8	21,6
6	6,3	16,6	18,1	102	17,0	2,0	39,8	6,5	29,0	8,2	24,0
7	6,9	17,8	19,6	101	18,5	2,0	43,0	6,8	31,0	9,4	26,0
8	7,5	19,0	20,5	100	19,4	2,0	45,3	7,0	32,6	9,8	27,5
9	8,0	19,0	20,0	99	19,3	2,0	45,4	7,0	32,3	10,0	27,3
10	8,7	17,8	18,7	98	18,5	2,0	43,5	7,0	31,0	9,7	26,0
11	9,4	17,0	17,6	100	18,1	2,0	42,4	7,0	30,2	9,0	25,1
12	10,1	17,0	16,9	102	17,7	2,0	41,8	6,9	30,0	9,2	25,0
13	10,9	17,2	16,5	102	18,0	2,0	41,7	6,8	30,3	9,7	25,1
14	11,9	17,8	16,3	102	18,4	2,0	41,8	6,9	30,8	10,2	25,5
15	12,9	18,6	16,4	101	18,7	2,0	42,5	7,0	31,5	10,6	26,5
16	14,0	19,6	16,7	98	19,4	2,1	44,0	7,3	32,7	11,3	27,5
17	15,5	21,0	17,3	94	20,9	2,3	46,0	8,0	34,3	12,0	28,8
18	17,0	22,6	18,0	91	22,2	2,5	48,8	8,6	36,5	13,0	30,5
19	18,7	24,4	19,0	90	23,8	2,7	52,4	9,5	39,0	14,0	33,0
20	20,5	26,4	20,3	94	25,8	3,0	56,5	10,4	42,0	15,4	36,0
21	22,5	28,6	22,2	99	28,8	3,4	61,3	11,3	46,0	16,5	39,2
22	24,4	31,0	24,0	106	31,1	3,7	67,0	12,2	50,0	18,0	43,0
23	26,0	34,0	26,0	112	32,6	4,1	72,8	13,3	54,5	19,5	47,5
24	27,5	37,0	28,0	119	34,0	4,5	79,4	14,3	59,5	21,0	52,0
25	28,8	40,4	30,0	126	35,0	5,0	86,0	15,5	65,0	22,5	57,0

Table 1 — Parameters of the observed wind distribution in selected latitude zones, and calculated values of the scalar mean wind speed and of high and low percentile values of wind speed, in metres per second (*concluded*)

60 – 80° N, July

Geopotential altitude H, km	Actual observations				Based on circular normal law of distribution						
	$\overline{V}_x$	$\overline{V}_{sa}$	σ_r	v_{max}	$\overline{V}_{sc}$	1 %		10 %		20 %	
						low	high	low	high	low	high
0	0,2	4,4	5,0	—	4,6	—	—	—	—	—	—
1	0,6	6,8	7,6	—	7,1	1,0	16,0	3,0	11,3	3,7	9,5
2	1,6	7,5	8,4	—	7,6	1,0	18,5	3,0	13,1	4,5	10,6
3	2,4	8,4	9,3	61	8,6	1,0	21,0	3,1	15,0	5,0	12,1
4	3,0	9,5	10,5	64	9,8	1,0	23,5	3,4	17,0	5,3	14,0
5	3,6	10,8	11,6	67	11,1	1,0	26,0	3,7	19,0	5,7	16,0
6	4,5	12,3	13,7	74	12,9	1,0	28,5	4,1	21,5	6,3	18,5
7	5,3	14,0	15,9	85	15,0	1,2	32,5	4,7	24,4	7,0	21,5
8	6,1	15,9	17,7	99	16,7	1,6	37,5	5,3	27,9	8,0	24,0
9	6,5	17,1	18,6	109	17,6	2,0	41,0	5,9	30,0	8,8	25,0
10	6,7	16,7	17,9	107	17,0	1,6	39,6	5,7	27,5	8,4	23,2
11	6,5	14,9	15,6	96	15,2	1,2	35,5	5,5	23,6	7,5	20,2
12	6,0	12,3	12,5	83	12,4	1,0	29,2	4,7	20,6	6,7	17,5
13	5,2	10,3	10,5	76	10,5	1,0	25,0	4,0	18,0	5,7	15,2
14	4,3	8,7	8,9	71	8,9	1,0	21,5	3,5	15,5	4,7	13,0
15	3,4	7,3	7,8	65	7,7	1,0	18,5	2,7	13,5	4,0	11,3
16	2,5	6,3	7,0	61	6,8	1,0	15,8	2,2	11,7	3,2	9,6
17	1,5	5,6	6,4	59	5,9	1,0	14,1	2,0	10,4	2,7	8,5
18	0,6	5,2	5,9	58	5,3	1,0	13,0	2,0	9,5	2,6	7,6
19	−0,3	4,9	5,6	60	5,1	1,0	12,4	1,9	9,1	2,6	7,1
20	−1,3	4,8	5,3	60	4,9	1,0	12,0	1,9	9,0	2,7	6,9
21	−2,2	4,8	5,2	60	5,2	1,0	12,0	2,0	9,0	3,0	7,0
22	−3,0	5,1	5,0	57	5,3	1,0	12,3	2,0	9,1	3,0	7,4
23	−3,6	5,5	5,0	54	5,6	1,0	12,9	2,0	9,4	3,0	7,9
24	−4,3	6,1	5,0	50	5,9	1,0	13,6	2,0	9,6	3,0	8,5
25	−4,8	6,9	5,1	47	6,0	1,0	14,5	2,0	10,0	3,0	9,3

Table 2 — Parameters of the observed wind distributions at four stations with strong winds, m/s

January

Station	H, km	$\overline{V}_s$	$\overline{V}_x$	$\overline{V}_y$	v_{max}	σ_x	σ_y
Dakar φ = 14°44′ N λ = 17°30′ W h = 23 m	Surface	3,2	−1,0	−1,5	—	—	—
	2	5,7	−1,5	−0,2	48	5,8	4,0
	4	7,0	2,3	1,3	50	6,3	5,2
	6	10,5	7,4	2,3	30	6,3	6,3
	8	17,9	15,2	3,1	52	7,6	8,0
	10	25,3	22,8	3,2	72	9,8	10,1
	12	33,0	30,4	1,6	72	12,4	11,4
	14	28,3	26,0	2,4	67	11,7	10,9
	16	20,7	18,5	3,4	58	10,0	9,0
	18	14,2	10,9	2,4	45	9,5	6,8
	20	9,9	3,2	1,0	31	9,4	5,2
	22	9,2	−1,0	0,5	22	9,6	4,8
	24	10,7	−2,0	0,5	20	10,3	5,8
	25	11,6	−2,2	0,5	19	10,8	6,6
Kagoshima φ = 31°38′ N λ = 130°36′ E h = 280 m	Surface	6,5	0,5	−3,1	—	—	—
	2	13,4	11,2	−3,4	31	6,4	6,7
	4	23,6	22,4	−1,1	52	8,3	7,4
	6	35,5	33,6	0,9	72	10,9	9,1
	8	57,4	53,6	4,8	113	13,5	12,8
	10	70,0	68,2	9,0	124	15,5	15,2
	12	67,4	65,2	10,6	99	16,6	14,3
	14	59,6	57,2	9,3	104	15,3	11,6
	16	47,2	45,6	6,2	102	13,3	8,2
	18	29,0	26,0	3,2	84	11,0	6,9
	20	13,6	11,0	1,8	62	9,4	6,4
	22	10,5	3,6	0,9	52	10,0	5,8
	24	9,3	−0,8	0,4	48	11,4	5,1
	25	9,0	−2,4	0,4	46	12,4	4,8

Table 2 — Parameters of the observed wind distributions at four stations with strong winds, m/s (*concluded*)

January

Station	H, km	$\bar{V}_s$	$\bar{V}_x$	$\bar{V}_y$	v_{max}	σ_x	σ_y
New York φ = 40° 39′ N λ = 73° 47′ W h = 7 m	Surface	3,7	3,3	− 1,6	—	—	—
	2	15,8	12,0	− 2,1	44	8,4	9,5
	4	23,3	19,5	− 0,5	55	11,4	12,0
	6	31,0	26,5	0,0	74	15,2	15,6
	8	38,1	32,8	− 0,1	89	18,8	18,5
	10	42,8	38,3	− 0,1	92	19,2	18,8
	12	39,8	36,2	0,2	82	16,4	16,3
	14	33,5	32,1	0,2	69	12,9	12,5
	16	27,4	26,0	0,1	55	9,5	8,6
	18	21,2	20,4	0,8	42	7,5	5,3
	20	14,8	14,4	1,5	37	6,7	3,7
	22	13,1	12,3	2,2	37	7,1	3,6
	24	13,3	12,5	2,8	40	8,1	4,8
	25	13,7	12,8	3,1	41	8,8	5,6
Jan Mayen φ = 70° 57′ N λ = 8° 40′ W h = 9 m	Surface	8,5	1,2	− 2,0	—	—	—
	2	12,1	4,2	− 0,1	48	9,1	10,3
	4	14,6	7,1	− 1,0	76	11,3	11,7
	6	19,2	9,9	− 2,8	94	14,0	14,7
	8	24,0	13,2	− 4,7	94	17,2	17,9
	10	23,5	14,3	− 4,6	95	18,3	17,9
	12	22,8	15,6	− 4,2	95	16,4	16,5
	14	24,2	18,5	− 4,7	94	15,6	15,6
	16	25,8	19,8	− 5,2	87	16,1	14,4
	18	26,8	19,5	− 4,0	74	18,4	12,3
	20	27,2	18,3	− 2,0	69	21,3	9,5
	22	—	—	—	—	—	—
	24	—	—	—	—	—	—
	25	—	—	—	—	—	—