SOME CHARACTERISTICS OF VERTICAL VARIABILITY OF THE WIND
VELOCITIES IN THE ATMOSPHERIC BOUNDARY LAYER

COUNTRY: USSR

TECHNICAL TRANSLATION

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SOME CHARACTERISTICS OF VERTICAL VARIABILITY OF THE WIND VELOCITIES IN THE ATMOSPHERIC BOUNDARY LAYER

by

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In order to solve a great number of practical problems it is highly important to study the characteristics of the regime of meteorological elements in the boundary layer of the atmosphere. In particular, this applies to climatic information on the profiles of meteorological elements, their variability, data on a number of turbulence characteristics, etc.

However, the climatology of the boundary layer is still very poorly developed because research in this field has really only begun. For this reason it is not without interest to give an analysis of some characteristics of the vertical variability of wind velocity based on an analysis of empirical data.

The analysis was based on data from rawin sounding at aerological stations in the USSR (Kiev, Leningrad, Lvov, Minsk, Moscow and Riga) during the period from 1959 through 1963. These data were used in computing the mean and mean square deviations of wind velocity from the vane both for altitudes 0.1, 0.2 and 0.5 km above the ground surface and for 1.0, 1.5, 2.0 and 3.0 km above sea level. In the computations it was taken into account that for a number of known reasons \(1-3\) the maximum loss of wind information will be at the level \(h = 0.1 \text{ km}\). Accordingly, in order to ensure uniformity of a series of observations in the case of lack of data for the mentioned level
The distribution of probabilities of wind velocity pertains to the type of distribution of essentially positive values. The limitation to a zero limit of the probability function if there is only a single peak gives basis for postulating that the values of the computed parameters (mean \( \bar{v} \) and mean square deviations or standard deviation \( \sigma^2 \)) to some degree must be interrelated. However, if there is a calm or weak velocities are close to zero at the height of the vane (10-15 m), a rather common phenomenon, already at a height \( h = 0.1 \) km they are observed much more infrequently and therefore the influence of the zero limit on the distribution curve is considerably attenuated. Accordingly, the possibility of retention of an interrelationship of these distribution parameters in this case requires a checking and evaluation on the basis of empirical data. This relationship for different altitudes is show in Fig. 1. Here the dependence of the standard deviation \( \sigma \) on the mean square wind velocity \( \bar{v} \) with an error of \( \pm 0.7 \) (with a 95% reliability average for all altitudes) can also be represented by the following regression equations

\[
\begin{align*}
\sigma_v &= 0.21; \quad \bar{v}_v + 1.4; \\
\sigma_{0.1} &= 0.33; \quad \bar{v}_{0.1} + 0.7; \\
\sigma_{0.2} &= 0.37; \quad \bar{v}_{0.2} + 0.7; \\
\sigma_{0.5} &= 0.41; \quad \bar{v}_{0.5} + 0.7; \\
\sigma_H &= 0.45; \quad \bar{v}_H + 0.7.
\end{align*}
\]

(1)

where \( H \) is an altitude corresponding to 1.0, 2.0 and 3.0 km; \( \bar{v}_v, \bar{v}_{0.1}, \bar{v}_{0.2}, \bar{v}_{0.5} \) and \( \bar{v}_H \) is the mean monthly velocity for vane altitude, 0.1, 0.2, 0.5 and \( H \) km; \( \sigma_v, \sigma_{0.1}, \sigma_{0.2}, \sigma_{0.5} \) and \( \sigma_H \) are the monthly mean square (standard deviations for vane altitude, 0.1, 0.2, 0.5 and \( H \) km. [See Note]

The regression equations were identical for altitudes 0.1, 2.0 and 3.0 km. Therefore, Fig. 1 for these altitudes gives a common correlation curve and one equation with the subscript \( H \).

[Note: Equations (1) were derived for a range of mean monthly velocities \( \bar{v} \geq 1 \) m/sec.]

Equations (1) can be represented in general form in the following way:

\[
\text{Data for the remaining levels are excluded during analysis.}
\]
It is interesting to note that these relationships are somewhat different according to vane and radiosonde data. Equations (2) show that the free term for radiosonde information has an approximate value 0.7. However, for vane data the free term was twice as great. Here an effect was exerted which is evidently related to the difference in methods for measuring wind velocities (vane and radiosonde) and the characteristics of the wind structure itself in the immediate neighborhood of the earth's surface. However, due to the lack of necessary empirical data a separate evaluation of the measure of the effect of these factors on wind variability is not made in this case and will be investigated later.

Fig. 1. Dependence of \( \sigma \) on \( v \), \( v = \text{vane} \)
On the other hand, it was found that the coefficient $A$ in equations (1) changes logarithmically from vane level approximately to $h = 1$ km. This dependence is represented in Fig. 2 and is described by the equation:

$$A = 0.12 \log h + 0.09,$$

where $h$ is altitude in meters.

Then equation (2) for $h \geq 0.1$ km can be represented in the form

$$\sigma_h = 0.12 \bar{v}_h \log h + 0.09 \bar{v}_h + 0.7. \quad (2)$$

Thus, in the first approximation the standard deviations of wind velocity in the boundary layer vary with altitude logarithmically.

For the territory of the USSR the mean square wind velocities in the boundary layer at standard levels are widely represented in climatological handbooks and atlases but unfortunately they lack the values of the standard deviations.

Using the derived relations it is also easy to determine the measure of wind velocity variability in this layer.

The practical importance of the derived expressions (1) and (2) increases considerably when direct observational data are lacking for a particular station. In particular, experience shows that in many cases when the mean wind velocities
at the ground exceed 3-4 m/sec the increase in mean wind velocities with altitude in the boundary layer in a lowland area occur (as in the boundary layer) logarithmically. The greater the wind velocity in the free atmosphere, the greater is the slope to the x-axis (Fig. 3). This makes it possible to use wind velocities at two points \(h_1\) and \(h_2\) for computing the mean velocity at any other point in the boundary layer \(h\) using the following equation:

\[
\bar{v}_h \approx \frac{\bar{v}_{h_1} (\lg h - \lg h_1) - \bar{v}_{h_2} (\lg h - \lg h_2)}{\lg h_1 - \lg h},
\]

where \(\bar{v}_{h_1}\), \(\bar{v}_{h_2}\) and \(\bar{v}_h\) are the wind velocities at the levels \(h_1\), \(h_2\) and \(h\).

(Note: In such cases for the upper boundary of the boundary layer it is desirable that the mean monthly wind velocity not be determined for a single altitude but as the mean of several closely spaced levels.)

If wind velocities are known at the level of the vane \(h_1 \approx 10\) m and at the upper boundary of the boundary layer, such as \(h_2 \approx 1,000\) m, equation (5) is simplified

\[
\bar{v}_h = \frac{\bar{v}_{h_1} (\lg h - 1) - \bar{v}_0 (\lg h - 3)}{\lg h}.
\]

(\(\phi = \psi = \text{vane}\)).

In those cases when the mean monthly wind velocities at the vane level are unknown, and when the characteristics of the particular station are such that the surface wind profile is considerably influenced by "mesoroughness", the measure of influence of the latter can also be taken into account by using the Sapozhnikova classification [4].

After substituting (5) into (4), we have

\[
\bar{v}_h \approx 0.12 \lg h \frac{\bar{v}_{h_1} (\lg h - \lg h_1) - \bar{v}_{h_2} (\lg h - \lg h_2)}{\lg h_1 - \lg h} +
\]

\[
+ 0.09 \frac{\bar{v}_{h_1} (\lg h - \lg h_1) - \bar{v}_{h_2} (\lg h - \lg h_2)}{\lg h_1 - \lg h} + 0.7,
\]

in particular,
\[ e_h \approx 0.12 \log H \frac{\overline{v_{\text{meas}}} (\log H - 1) - \overline{v} (\log H - 3)}{2} + \]

\[ + 0.09 \frac{\overline{v_{\text{meas}}} (\log H - 1) - \overline{v} (\log H - 3)}{2} + 0.7, \]

\( \phi = \nu = \text{vane}^2 \).

Fig. 3. Vertical profiles \( \overline{v} \) and \( \overline{v_{\text{meas}}} \), \( \overline{v}_{\text{Jan}} \), \( \overline{v}_{\text{July}} \), \( \overline{v}_{\text{Apr}} \) and \( \overline{v}_{\text{Nov}} \) are the wind velocity profiles for January, July, April and November respectively. \( \sigma_{\text{Jan}}, \sigma_{\text{July}}, \sigma_{\text{Apr}}, \) and \( \sigma_{\text{Nov}} \) are the standard deviation profiles for winds in January, July, April and November respectively. a) Kiev, b) Minsk. \( \phi = \text{Jan}; \mu = \text{July}; \alpha = \text{April}; H = \text{November}. A) \text{m/sec}. \)
In Figure 3 we show several examples for the two aerological stations when $v_v < 2$ m/sec. For Kiev we used data for January and July for 1400 hours and for Minsk for April at 1330 hours and for November at 1930 hours.

Here it can be seen graphically that the agreement of empirical and computed data for the reduced relations is satisfactory.

It should be noted that for foreign areas we do not receive observational data for the boundary layer wind regime. However, even under these conditions by using the mean monthly wind velocity given in aeroclimatological atlases for the isobaric surface closest to the ground and also knowing the mean monthly wind velocity at the vane level it is possible to use the expressions derived above for a rough determination of the mean monthly velocity for the corresponding levels and its variability in the entire boundary layer.

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