ON THE APPLICABILITY OF WIND LIDAR MEASUREMENTS TO INVESTIGATIONS OF LOCAL AND REGIONAL CLIMATES

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The paper studies the feasibility of application of three–path correlation wind lidar measurements to investigations of the local climate. An estimate is made by comparing a local model, based on the wind lidar measurements, with a regional climatic model for a given quasihomogeneous region.

Within a wide range of fundamental investigations on the problem of climatic monitoring of local territories (for example, territories of individual mesometeorological polygons of typical scale from several tens to several hundreds of kilometers), of special interest are the developments associated with a solution to problems of adequate estimation of the atmospheric circulation regime in the atmospheric boundary layer (at altitudes up to 1–2 km) since it markedly affects the formation of regional and local climates. This effect manifests itself both directly through the circulation mechanism of the cold and warm air mass exchange determining climatic regime of separate regions[1] and indirectly through the transfer of anthropogenic pollution strongly affecting the radiative and optical characteristics of the atmosphere of separate regions and hence the formation of the above climates.

It should be emphasized that to estimate the atmospheric circulation regimes in the boundary layer, we need the data on the wind velocity field with sufficiently high altitude resolution. However, it is well known that standard radiosonde observations do not meet these requirements and hence cannot provide a reliable solution of the above problem. Taking into account this fact, we should choose a more reliable and efficient method of high–altitude sounding.

Among all methods for determining the wind characteristics in the atmospheric boundary layer, the methods of active remote sounding with the use of laser radiation sources[2] have the best spatiotemporal resolution, and in particular, the methods based on the use of a three–path correlation lidar for measuring the wind speed and direction.[3] In Ref. 4 we have already studied the feasibility of application of this lidar data to the solution of the problems of atmospheric–ecological monitoring of local territories.

This paper deals with the problem of the applicability of measurements performed with a three–path correlation wind lidar to the investigations of the local climate. We have already compared the two statistical models of wind velocity characterizing the vertical structure of the wind field in the atmospheric boundary layer in territories of a certain mesometeorological polygon and of a typical quasihomogeneous region (in this region the mesometeorological polygon was located) determined as a result of the objective classification of regional climates (Ref. 5).

To construct the local statistical wind velocity model, we used the data of routine measurements carried out six times a day with a wind lidar from July 10 to August 12, 1994 in the territory of the mesometeorological polygon located in Tomsk (56°N, 85°E). When developing the regional climatic wind velocity model, we used a statistical sample of radiosonde observations made over a period of many years (1961–1978) at the reference station Novosibirsk (56°N, 83°E). The data of this station characterize one of quasihomogeneous regions of the northern hemisphere.

All the wind velocity observations, taken for construction of both models, were adjusted to a standard grid of geometric altitudes h, being equal to 100, 200, 300, 400, 600, 800, and 1200 m, which makes it possible to describe the vertical structure of the wind field in the atmospheric boundary layer in sufficient detail. Both the models being compared include the vertical profiles of the mean values ($\bar{\xi}$) and standard deviations (σ_ξ) of zonal (U) and meridional (V) components of the wind vector. In what follows we sometimes name them as zonal and meridional winds as is often done in practice.

Now we dwell on an analysis of the results of comparison between local and regional wind velocity models, made by the procedure of qualitative comparison of their statistical parameters, i.e., without using special criteria applied commonly to estimate the significance or randomness of the discrepancy in the

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parameters being compared (for example, average ones or their variances). This is due to the fact that the use of any criteria of such kind (e.g., Student's criteria for comparison of mean values or the Fisher criteria for comparison of their variances obtained for the two samples[5,6]) in our case is impossible since the variances of the local model, used for calculation of the above criteria, inadequately describe the real variability of wind characteristics, being therefore essentially underestimated, because of finite period of lidar observations and their incomplete adequacy (for example, the observations were performed with heavy cloudiness, precipitation, or fogs).

For a qualitative comparison of statistical parameters of the two models (local and regional) we use the data from Table I containing the vertical profiles of mean values ($\bar{\xi}$) and standard deviations (σ_{ξ}) of zonal and meridional wind components obtained for each of these models.

TABLE I. Vertical profiles of mean values ($\bar{\xi}$) and standard deviations (σ_{ξ}) of zonal (U, m/s) and meridional (V, m/s) wind velocity components for local (1) and regional (2) models.

Altitude, m	Zonal wind				Meridional wind			
	$\bar{U}$		$\sigma_{\bar{U}}$		$\bar{V}$		$\sigma_{\bar{V}}$	
	1	2	1	2	1	2	1	2
100	–0.4*	–0.9	0.7	3.2	–0.7**	–0.4	0.7	3.5
200	–0.2	–0.9	1.3	4.1	–0.4	–0.2	1.5	4.3
300	–0.2	–0.7	2.1	4.2	–0.7	–0.1	2.7	4.5
400	–0.4	–0.4	3.1	4.3	–0.2	–0.1	2.9	4.7
600	0.3	0	3.6	4.5	–0.3	0	3.5	4.8
800	1.6	0.2	3.4	4.4	–0.9	0	3.3	4.6
1200	2.9	0.6	3.3	4.6	–0.8	0	3.6	4.7

*Positive values correspond to the western direction of zonal wind, and negative values correspond to the eastern direction of zonal wind.

**Positive values correspond to the northern direction of meridional wind, and negative values correspond to the southern direction of meridional wind.

It should be noted that all tabulated statistical parameters of the local models were corrected by us by excluding the systematic errors estimated previously in Ref. 4 from the initial data.

Analysis of Table I allows us to draw the following conclusions:

first, for both the models being compared the directions of zonal and meridional winds of the same sign are typical, and whereas for zonal wind the same directions (eastern direction in the layer 100–400 m and western direction at $h > 400$ m) are observed over the entire thickness of the atmospheric boundary layer, for meridional wind the same direction for both models (southern) is observed only at altitudes up to 400 m (above this altitude, the southern direction is typical of local model and calmness – of regional model);

second, zonal wind in both the models being compared has the same and well–defined change of its direction (from eastern to western) which is observed at the same atmospheric layer located at $h = 400$–600 m;

third, the profiles of mean values of zonal and meridional components of wind velocity, constructed for each model, do not practically differ from each other. Actually, the differences between $\bar{U}$ and $\bar{V}$ values, calculated for local and regional models, do not exceed 0.7 m/s almost at all examined levels (except for the levels of 800 and 1200 m), that is, they are less than the error in measuring the zonal and meridional wind components, being equal to 0.7 m/s (Ref. 8);

fourth, the values of standard deviations $\sigma_{\bar{U}}$ and $\sigma_{\bar{V}}$, obtained for local and regional models, in spite of their essential differences in magnitude (the reasons for this fact are mentioned above), have the common well–defined maximum of variability of zonal and meridional wind velocities at 600 m altitude as well as the same altitude behavior of the parameters $\sigma_{\bar{U}}$ and $\sigma_{\bar{V}}$ over the entire boundary layer, namely, the increase of $\sigma_{\bar{U}}$ and $\sigma_{\bar{V}}$ in the layer 100–600 m followed by their subsequent decrease toward the 800 m level, and their repeated increase toward the top of the atmospheric boundary layer.

Thus, the results of qualitative comparison between the two models of wind velocity (local and regional) have shown that the local statistical model of vertical distribution of zonal and meridional components of the wind vector in the atmospheric boundary layer, constructed on the basis of the wind lidar measurements, adequately describes the main peculiarities of the vertical structure of fields of these meteorological parameters typical of the atmospheric boundary layer not only in the examined mesometeorological polygon but also in the region as a whole. From this we can draw a common conclusion important for practice that the data of wind lidar can be used with profit for construction of the local and regional wind velocity models as well as for investigations of local and regional climates.

In summary it should be noted that this conclusion is preliminary since the local wind model was constructed on the basis of the data of only one season and one year (summer, 1994).

To justify our results, a further study is required, already on the basis of longer–time lidar observations of wind velocity with the use of several meteorological polygons located in different physical–geographic regions. However, all this will be the subject of our further investigations.

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