INTERCONNECTION BETWEEN TEMPERATURE AND WIND SPEED PROFILES FOR THE URBAN AND RURAL ABL

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Abstract

Preliminary results of multi-point measurements of vertical profiles of wind speed and air temperature in the atmospheric boundary layer are presented. The measurements were carried out simultaneously over the Moscow megalopolis and over nearby countryside. Two types of ground-based remote sensing tools were used. Wind speed was measured by three-component monostatic Doppler sodar, while the temperature was measured by UHF scanning radiometer. Examples of some statistical characteristics of the temperature gradient over the urban and rural areas are given. Qualitative comparisons of the sodar echograms and the wind speed profiles with the temperature gradients were made for the conditions of stable stratification.

Key words: Urban boundary layer, Ground based remote sensing, Long-term continuous observations, Profiles of temperature and wind velocity

1. INTRODUCTION

The problem of interconnection between profiles of the wind speed, *V(z)*, and the air temperature, *T(z)*, in the atmospheric boundary layer (ABL) is an object of many theoretical and experimental studies in the last decades. This problem is especially difficult under the conditions of a stably stratified urban boundary layer (UBL). The current proliferation of devices for ground-based remote sensing (including sodars and radiometers), which enables to carry out the long-term continuous automated measurements, allows a large number of experimental data to be acquire for the study of this problem. At the same time, the methods of parametrization of such an interconnection is poorly developed. In the theory, two basic characteristics of the ABL are generally accepted: parameter of stability Richardson number, *Ri* (or Monin-Obukhov length, L_{MO}), and also the mixing layer height, MH (Zilitinkevich and Baklanov, 2002). However, when processing the real experimental data on *V(z)* and *T(z)*, these parameters can be determined only in ideal cases: under condition of a stationary anticyclonic weather. In the vast majority of cases the top of the mixing layer is fuzzy. The value of *Ri* undergoes large variations in height and time: the root square mean value of these variations has the same magnitude as the *Ri* itself. Thus it is difficult to find any quantitative characteristics of the interconnection from measurements of the profiles. Nevertheless, measurements of *V(z)* and *T(z)* in the UBL are important for the problem solving.
This work contains preliminary results of multi-point remote measurements of *V(z)* and *T(z)*, which were held in 2005-2007 at the Moscow megalopolis and nearby countryside simultaneously. Some statistics on the temperature gradients over the urban and rural areas is given. Results of qualitative comparisons of the sodar echograms and profiles of wind speed with the temperature gradients at the stable thermal stratification are presented as well.

2. EXPERIMENTAL SETUP

The continuous simultaneous measurements were made in the Moscow downtown (IAPh and GMC sites), in the south-west district of Moscow (MSU site), and also in a rural area 50 km west from Moscow (ZSS site). All the sites were equipped by identical devices. The time averaging of all measurements was equal to 30 minutes.
The wind measurements were carried out with the help of PC-based Doppler sodar Latan-3 developed at Obukhov Institute of Atmospheric Physics (Kouznetsov, 2007; Yushkov et al., 2008). Carrier frequency is 1700 Hz, vertical resolution is 20 m, height range of sounding is from 50 m to 250-500 m. The maximum accessible height hinges on the current thermal stratification of the ABL and on the level of ambient acoustic noise.
The air temperature measurements were carried out with the help of 60-MHz scanning radiometer MTP-5, developed at the Central Aerological Observatory, ATTEX, Russia (Kadygrov et al., 2003). The vertical resolution is 50 m, height range of sounding is from 20 m to 600 m.

3. RESULTS

Comparison of temperature profiles statistics at the three urban sites shows that the anthropogenic heating is not uniform in the megalopolis. At MSU site (that is located near a forest park) daily course of the air temperature are close to that in the rural site. Absence of uniformity is more pronounced in the lower part of the ABL. Above 150-200 m the local features are smoothed over. In Figure 1 the empirical probability functions for temperature gradients are shown for urban (MSU) and rural (ZSS) sites.

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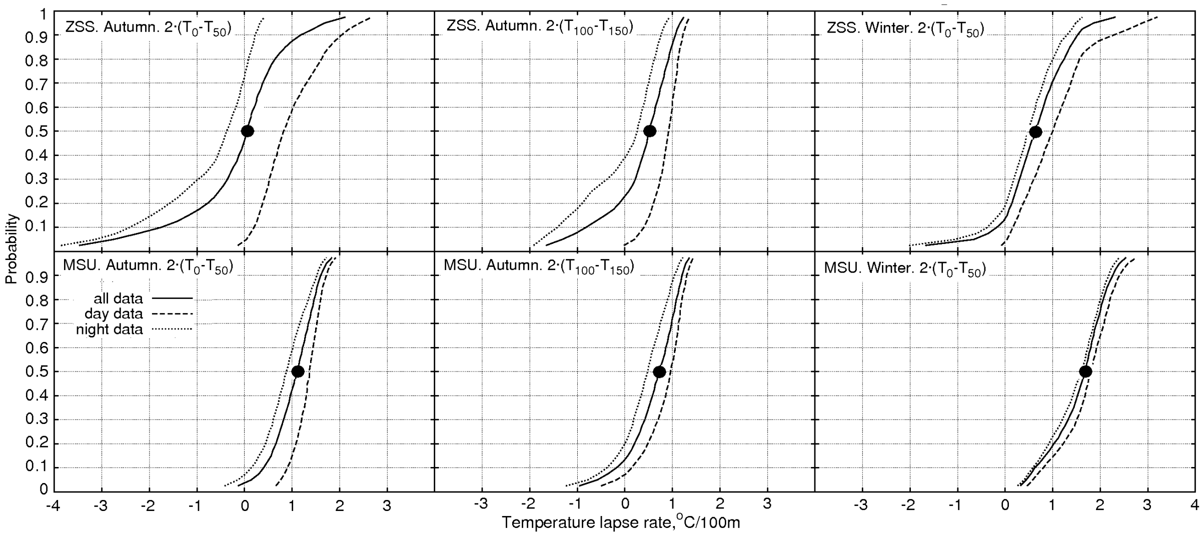

Figure 1: Empirical probability function and medians of temperature difference for two seasons at two heights in rural (top) and urban (bottom) areas.

Figure 2 shows a comparison of PDF of temperature gradient at the «accordant» heights (heights of maximum correlations) over the urban and rural areas. Such a comparison takes into account the orographic differences between the altitude of the sites above see level.

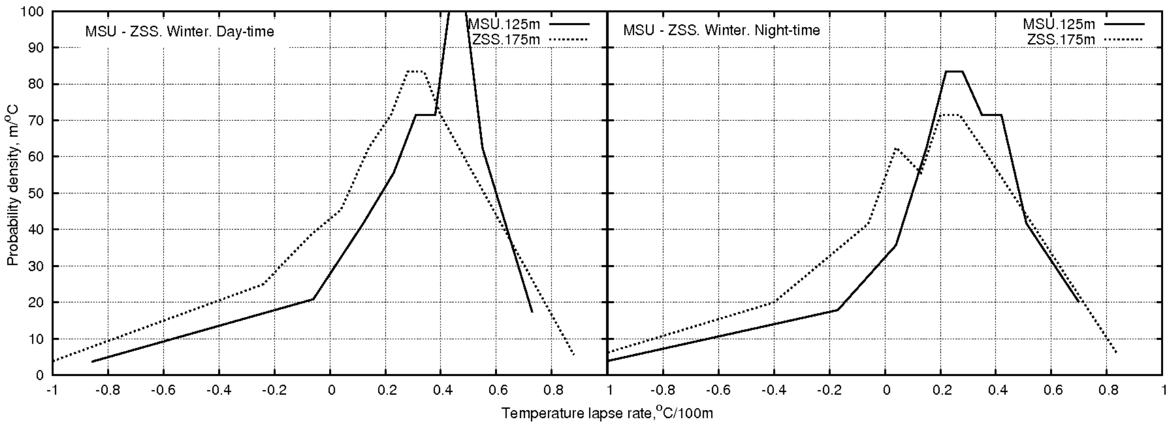

Figure 2: PDF of temperature gradient over anthropogenic heat layer at the urban site (MSU), and at the “accordant” altitude above ground level at the rural site (ZSS).

Fig. 3 shows dependence of the MH on thermal stability and on gradient of potential temperature in the rural area. Lesser stability in night-time results to higher mixing layer. In rural area the gradient of potential temperature change monotonously with the altitude. However the height of temperature inversion is not acceptable characteristics in a case of weak inversion.
Fig. 4 shows that higher wind results in a higher magnitude of the return signal intensity.

4. CONCLUSIONS

Temperature gradient in the nocturnal UBL generally connected with MH and wind speed. However, determination of the mixing height by the height dependence of temperature gradient (as it is measured with the help of radiometer) has a very low accuracy. At strong thermal inversions the sodar echograms give a more reliable estimates of the MH value. Under condition of weak thermal stability the value of MH is not well defined.
The observed gradients of wind speed in the ABL have strong stochastic variations. Thus, it is difficult to derive from the experimental profiles the convenient theoretical parameters for UBL simulation.
In general, mixing layer in urban area is higher then in rural one at 100-200 m. Apparently, this phenomenon is caused by a difference in the heat storage, anthropogenic heating in cold period and large roughness of urban area. The largest variability of ABL parameters is observed at the lowest levels. Temperature gradients in lower part of the UBL depend on local features of the observational sites.

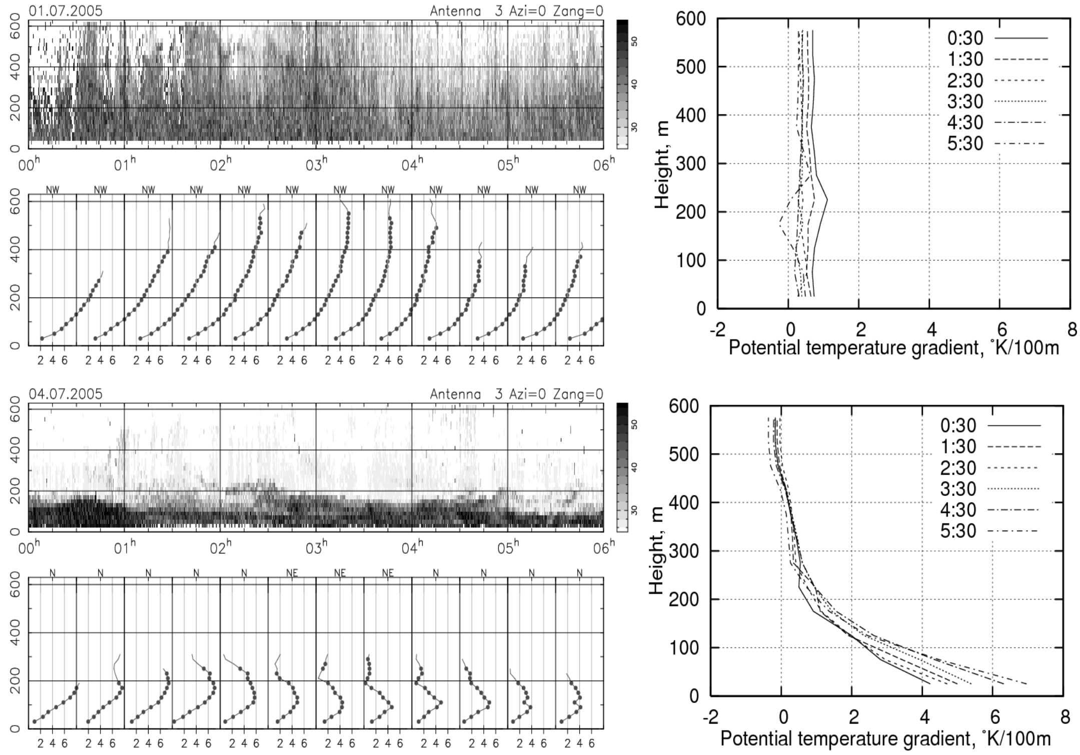

Figure 3: Two examples of echograms of the sodar return signal and wind speed profiles (left panels), and the respective profiles of gradient of potential temperature (right panels) in night-time at ZSS site (rural area) for two cases: 1) (top) weak thermal stability, 01 July 2005; 2) (bottom) strong thermal stability, 04 July 2007. Gray scale on echograms is proportional to intensity of thermal turbulence (C_T^2) in dB. On the left side of the plots of echograms and wind speed profiles the altitudes (in meter) are shown; below the echograms the time (LST hour) is pointed; below the wind profiles the scale of wind speed (m/s) is displayed, and the direction is shown above it as well.

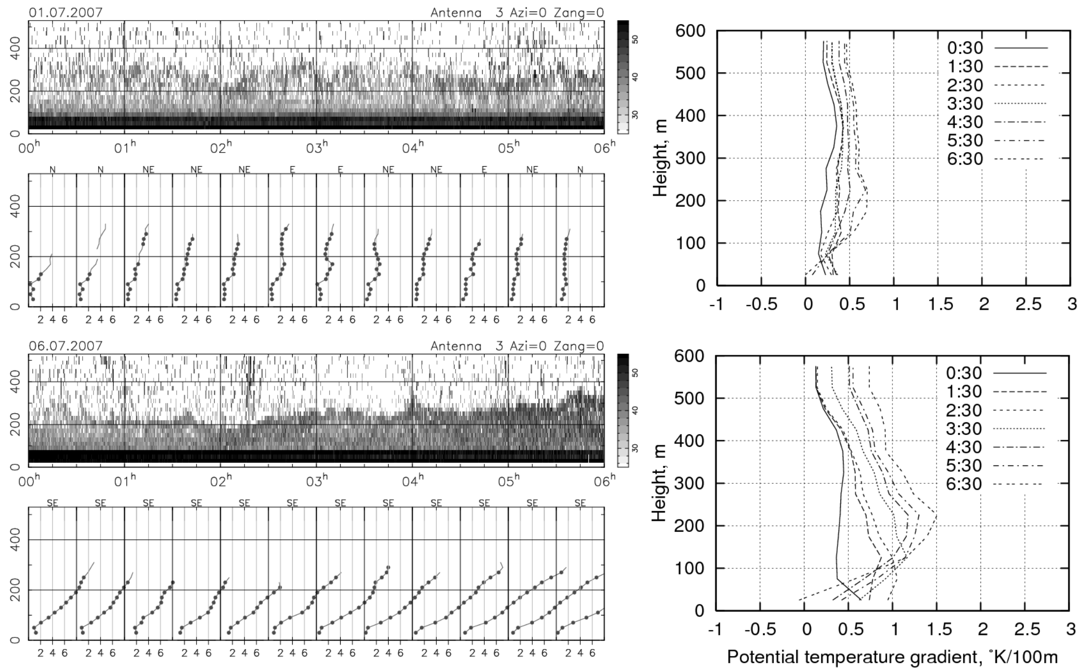

Figure 4: Comparison of the echograms and wind profiles in night time center of Moscow (IAPh site) for a weak wind speed, 01 July 2007 (top), and for a strong wind speed, 06 July 2007 (bottom). At the right panels the respective profiles of gradient of potential temperature are displayed. All notations are the same as in Fig. 3.

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