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REMOTE ACOUSTIC SOUNDING OF WIND FIELD ABOVE CITY: NOISE INFLUENCE ON MEASUREMENT STATISTICS

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Results of two-year acoustic sounding of wind field over Moscow are reviewed. Urban noise and echo clutter influence on statistical data generalization is analyzed.

Acoustic sounding is a useful method of wind field monitoring in urban environment [1]. Good accuracy of wind velocity and direction measurements was demonstrated in many in situ experiments and comparisons with contact instruments in many countries [1, 2]. Real wind field pattern is required in urban pollution monitoring, control of wind shear and thermal balance of tall houses and other applications.

Continual measurements of wind velocity and direction vertical profiles and their variations in atmospheric boundary layer (ABL) are carried out at Physics Faculty of MSU together with Obukhov Institute of Atmospheric Physics (IAPh RAS), under the supervision of prof. M.A.Kallistratova. Simultaneous measurements are carried out in center of Moscow, in IAPh [3]. In both points observations are carried out using a sodars Latan-3, developed in IAPh, under common program and data are processed by one algorithm. Therefore, it is possible to evaluate difference in wind field between the city center and periphery.

Research Doppler 3-component sodar Latan-3 [4] uses a free and open architecture, so it can be used both for scientific investigation, and for educational courses in atmospheric physics [5]. Students also can to measure the impact of city noise on acoustic measurements, to study the efficiency of different sounding frequencies, to prove variant algorithms of signal processing and so on.

The altitude range of Latan-3 sounding is between 30 and 200-500 m. Upper sounding limit depends on vertical distribution of natural acoustic waves' scatterers – turbulent temperature heterogeneities, what is determined by temperature stratification of the ABL [3].

All-year 24-hour measurements have been being carried out at both sites since spring of 2005. In this work the observation results for both the MSU site and the IAPh site are processed and analyzed. Period of one measure of radial velocity vertical profile is 15 seconds. Possible data failure is compensated by averaging of measurements for longer time interval (from 5 to 60 minutes). Then data are averaged monthly and seasonally, as well as for every time interval for obtaining of average diurnal variation. Beside this, data are averaged for particular samplings: day/night, windy/calm and so on.

More then 2 billions measurements for year in every point of sounding let to speak about reliability not only for mean values and dispersions of velocity components on different heights, but also probability distributions, including accurate estimation of strong and weak winds appearance, average diurnal circle and etc.

Traffic noise restricts the altitude range of sounding. For that reason, in big cities the conditions for sodar operation are not favorable. Therefor the sodar measurements were performed mostly in city periphery or in city parks. However, because of heterogeneity of land development and city orography data obtained in such places often is not representative for city center and center of urban heat island. At the same time maximum of air pollution take place in the core of city so wind field monitoring in downtown is important for atmospheric dispersion studies and pollutants accumulation prediction.

Analysis of observation data revealed, that vertical wind profile over Moscow is defined by the of two basic factors: irregular synoptic variability, which connected with cyclone and anticyclone passage and their fronts, and with two main regular circles of thermal conditions in ABL: diurnal and annual. Diurnal variation of ABL stability can be apparently seen in wind velocity profiles (Fig.1). Comparison of day-time and night-time observations demonstrates more profile declination in stable (nocturnal) stratification. Especially this difference is clear in summer and it is less in autumn when conditions of thermal stratification in ABL is close to neutral because of cloud cover. It’s possible to speak, that diurnal variance of vertical wind velocity gradient has an annual circle associated with insolation and radiation balance change.

Fig.1 Vertical profiles of wind velocity above Moscow (measurements at MSU site) for all seasons from September 2005 to September 2006. Day-time (from 2 to 5 pm of local time) and night-time (from 2 to 5 am) are also presented. Measurements at 110 m height and in the range 190 – 210 m are interpolated because of echo clutters from main building of MSU

Fig. 1

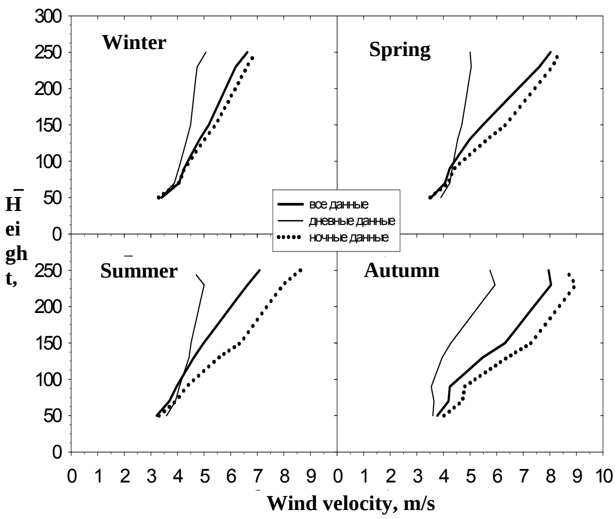

Fig. 2

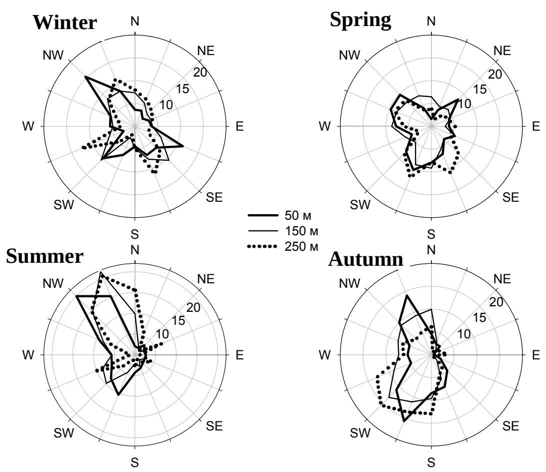

Fig. 2. Distribution of wind direction – wind rose – for all seasons at MSU site. Radial scale is a percentage of measurement number. There are 16 angular intervals. Three levels are shown: 50, 150 and 250 m for all seasons. Ekman’s wind turn may be seen between 50 and 250 meters.

As may be seen from fig.1 minimum diurnal variability of wind velocity is observed at the MSU site at 50 meters height, while in city core (at IAPh site) the level of minimum variability is 150 meters. Possibly, such difference may be explained by MSU site elevating (Vorob'ovy Hills is about 70 m above Moscow center and point of observing on the roof also is elevated on 40 meters above the surface). Wind field differences between Moscow core and Vorob'ovy Hills were described in previous works [2].

Average wind velocity over Moscow at the level of minimum diurnal variability is 4.4 m/s. RMS deviation of annual velocity distribution at this level is about 2 m/s. Probability of strong winds

(>8 m/s at 150 m) and weak winds (<2 m/s at 150 m) is about 6.3% and 13.5% of observing time respectively.

The inversion layer formed in nocturnal conditions above urban territory has greater height with smaller vertical temperature gradient in comparison with the suburban area [3,6], what may be connected both with anthropogenic heating and with roughness increasing and dynamical mixing. Average vertical wind shift in Moscow core at 150 m height is 2.8 m/s on 100 m in nocturnal conditions, as well as 1.5 m/s on 100 m in day-time. At the day-time for convective conditions at the low levels wind shift became large: 4 m/s on 100m in summer at the level 50 m, and in the same time it decreases in upper layers to 1.5 m/s on 100m at 150 m.

Wind turn mainly take place in lower part of ABL, however at these levels the impact of buildings is large. This impact decreases the accuracy of wind turning measuring because of acoustic clutters from buildings. Besides, wind turning at lower altitudes depends on air streams in streets canyons and city orthography. Higher then 100 meters average turning of wind direction is about 5º on 100 m. This estimation close to value in contact measurements on meteorology mast in Obninsk [7]. Distribution of wind direction – wind rose – for all seasons at MSU site shown on fig.2 . Ekman's wind turn is seen weakly, however a distribution dispersion of wind turning at all altitudes exceeds the average value, that suggest the necessity of separation of inner-mass and frontal wind turn.

Using of acoustic method for of wind field measuring has serious restrictions for statistical generalization. Reflected from buildings signal has a zero Doppler shift and even small distortion of wind velocity (0.1-0.2 m/s) became systematical one. Whereas this deformation usually is observed in one of two declined antennas, in wind direction distribution the probability for perpendicular direction became longer. For example, such deformation presented on lower level at IAPh's measuring, possibly mixed with wind field deformation near tall buildings and in street canyons.

Traffic noise considerably decreases maximum height of acoustic sounding especially in day-time. Comparing of data availability on different altitudes at MSU site, where influence of noise from Lomonosov and Vernadskiy Avenue is large, and in Moscow center, where nearest buildings screen measurement from traffic noise is shown in Fig. 3. Averaged weekly series of data availability are also presented in this figure and they show the significant role of urban acoustic noise.

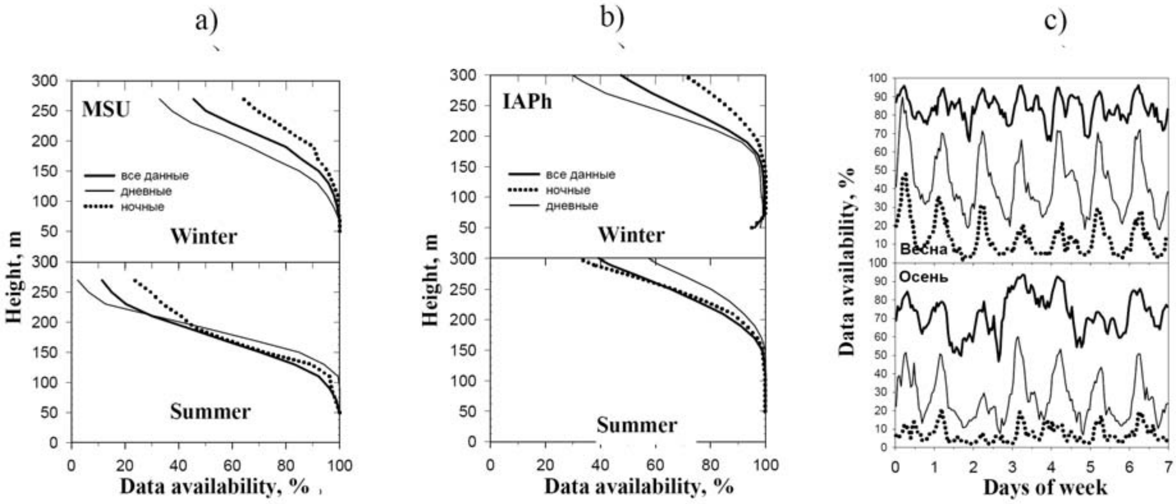

Fig. 3. Vertical profiles of data availability (percentage of successful measurements) at MSU and IAPh sites in winter and summer and average weekly series at MSU site on 3 levels (50,150,250 m) in spring and autumn. Zero is Sunday.

Another trouble is unevenness of urban noise spectrum, when casual high spectral peak is accepted as a signal: multitude of such false signals results deformation of velocity dispersion and accordingly decreasing of altitude of reliable measurement of wind velocity dispersion.

Consequence of noise level relative increasing with altitude and its influence on measurement accuracy is that good agreement of statistics between remote and contact measurements on lower altitudes (60 – 100 meters) is not guaranteed for high altitudes where data availability decreased. Natural velocity variability on high altitudes, characterized by RMS deviation more then 1 m/s in convective conditions, also restrict agreement of contact balloon instantaneous wind measurement and average (for time interval 5-60 minutes) remote sodar measurement.Results of continual wind field measurement at high altitudes of acoustic sounding may include a systematical mistakes connected with data gap in conditions of weak wind shift and weak scattering signal under neutral stratification, so only events of strong scattering, which connected with strong wind shift or strong thermal convection are remained. Appropriate examples will be presented.

Despite of specified restrictions, continual all-year sodar measurements, carried out in IAPh and MSU, present a unique source of wind field data in Moscow city. This data is essential for atmospheric pollution prediction and warning of emergency situation. Routine wind measurements at standard 10-15 meters height above surface are insufficient, especially in city, so sodar, as a remote sensing device, is a practical instrument for metrological monitoring [1].

Nowadays Latan-3 monitoring data is available in real time through Internet, what allows measurement control and using of this information for short range forecast (1-3 hours) of wind field over the city and wind shear and for front passage control.

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