Acoustic remote sensing of the Atmospheric Boundary Layer wind structure in Moscow city

Ksenia Akhiyarova and Mikhail Lokoshchenko

Department of Meteorology and Climatology

Faculty of Geography

Lomonosov Moscow State University, Moscow, Russian Federation

Introduction

The acoustic remote sensing allows studying the fine wind structure with high spatial and temporal resolution. Sodar (abbreviation of words: sonic detection and ranging) is source of mostly detailed and regular data of vertical structure in the low troposphere. The Doppler sodar "MODOS" of METEK production operates at Moscow University Meteorological Observatory (MO MSU) since 2004 till nowadays (Fig.1) and it is characterized by:

1. vertical range from 40 to 500 m;
2. spatial resolution: 20 meters;
3. period of reliable averaging: 10 minutes;
4. accuracy of wind velocity: 0,2-0,3 m/s,
   accuracy of wind direction: 3-4°;
5. operation frequency : 2000 Hz

Fig.1. The "MODOS" sodar (made by METEK, Germany) at Meteorological Observatory of MSU

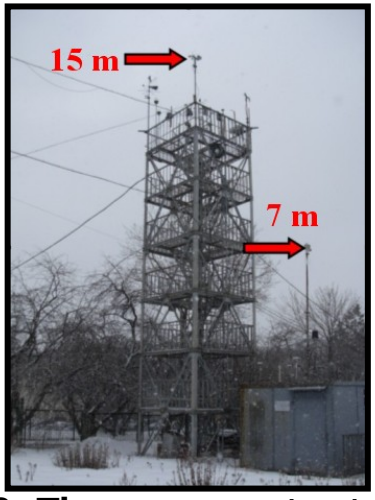


Fig.2. The anemometer tower with anemometers (7,15 m) at MO of MSU

The dynamics of wind velocity in the atmospheric boundary layer (ABL) above Moscow city have been analyzed by long-term data (2004-2012) of sodar measurements. Besides, data of two anemometers (Fig.2) on 7 and 15 m heights inside 'dead zone' of the sodar have been added to analysis. Moreover, use of the sodar data allows studying mostly interesting weather phenomena such as thunderstorms.

Purpose and tasks

Main purpose: to present the results of wind measurements from three instruments (the Doppler SODAR and two anemometers).

Partial tasks:

to analyze general features of both annual and daily courses of wind profiles;

to research the crossover height of wind velocity above Moscow;

to investigate interrelation between wind turnings and synoptic situations

Materials and methods

All sodar data are manually tested and included into the electronic database.

Software packages such as Microsoft Excel, Microsoft Access were used at this investigation. The statistical analysis (mean, standard deviation, confidence interval, correlation) was used for meteorological parameters.

Results

1.Wind dynamics for several years (2004-2012) with using of two anemometers and sodar

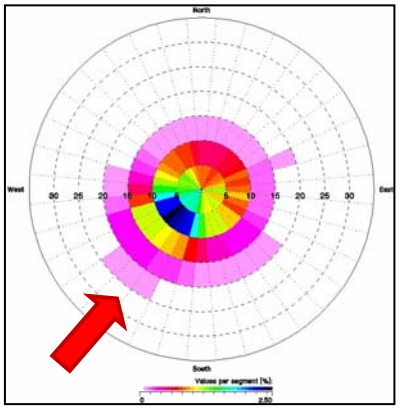


Fig.3. General wind rose for the period 2004-2012

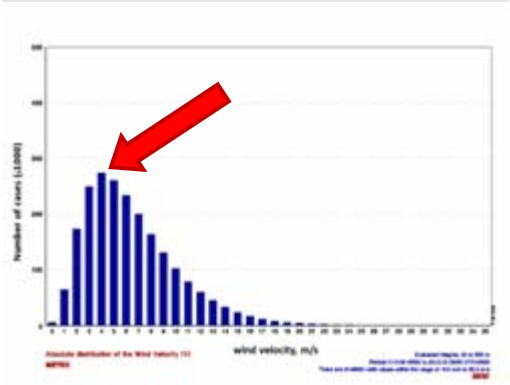


Fig.4. Histogram of wind velocity for the period 2004-2012

The most often wind direction from 2004 to 2012 above Moscow is southern-western (Fig.3). The mode of wind velocity distribution is usually 4-5 m/s (Fig.4).

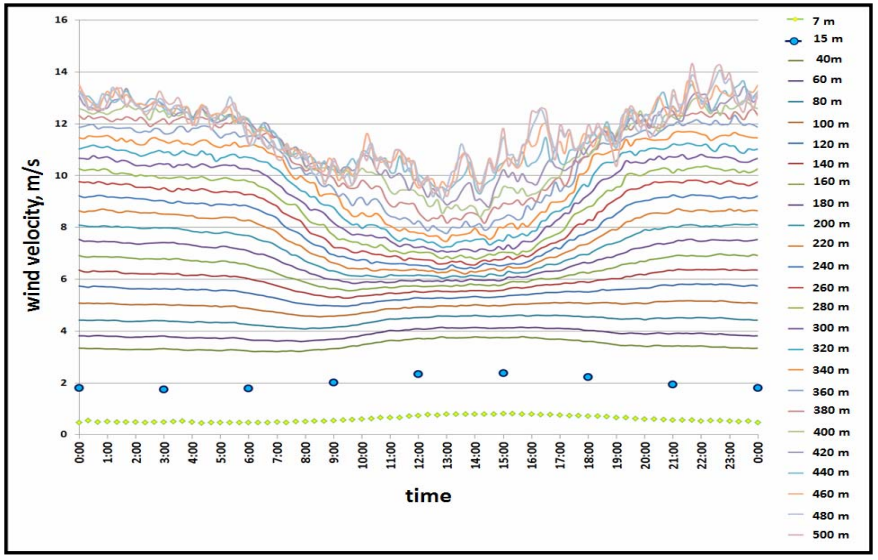
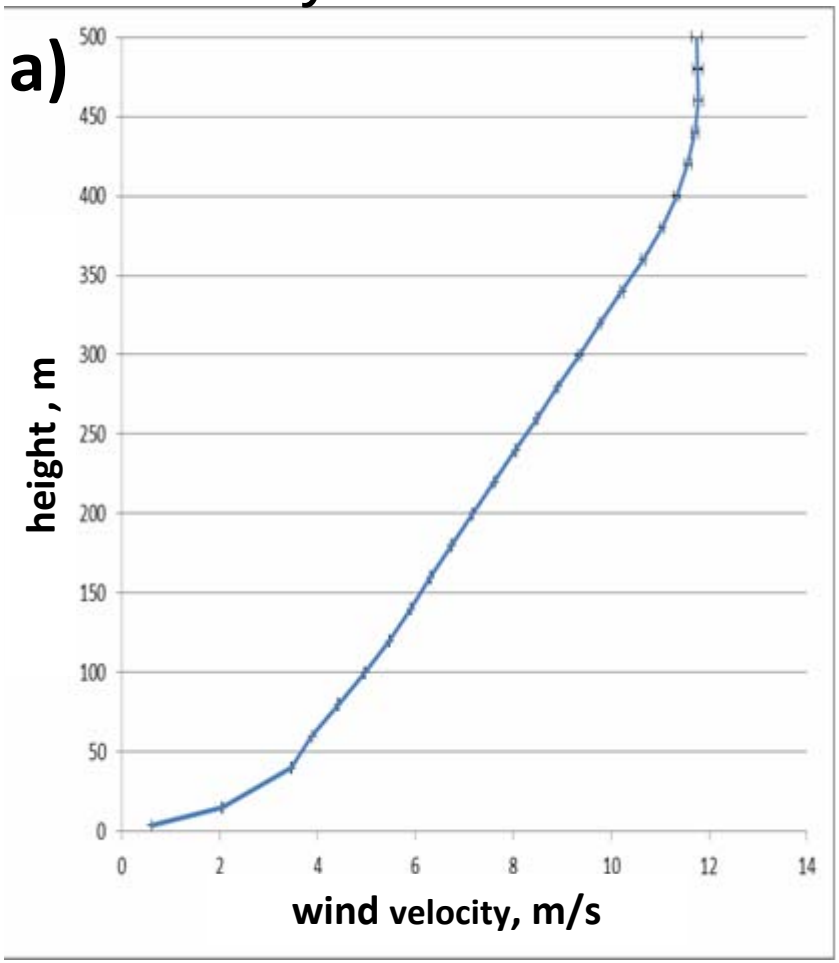


Fig.5. Diurnal course of wind velocity from 2004 to 2012 above Moscow by data of sodar and two anemometers

As one can see on Fig.5 the diurnal course of wind velocity is characterized by daily maximum up to 60 m, whereas the opposite nocturnal maximum is clear above 120 m. The crossover height-CH (a point of intersection between daily and nocturnal wind profiles in the low troposphere) is found between 80 and 100 meters.

The ground air layer accordingly to logarithmic law exists up to 60 m (quasi-linear range from 7 to 60 m-Fig.6.b) above Moscow city



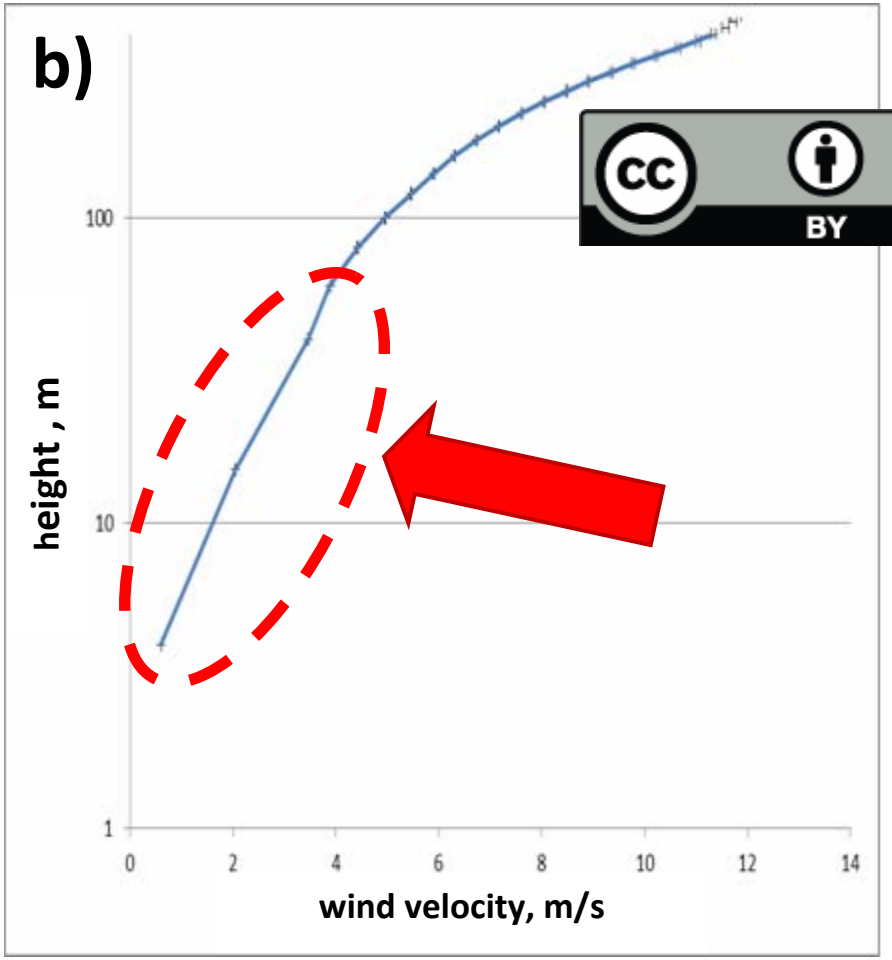
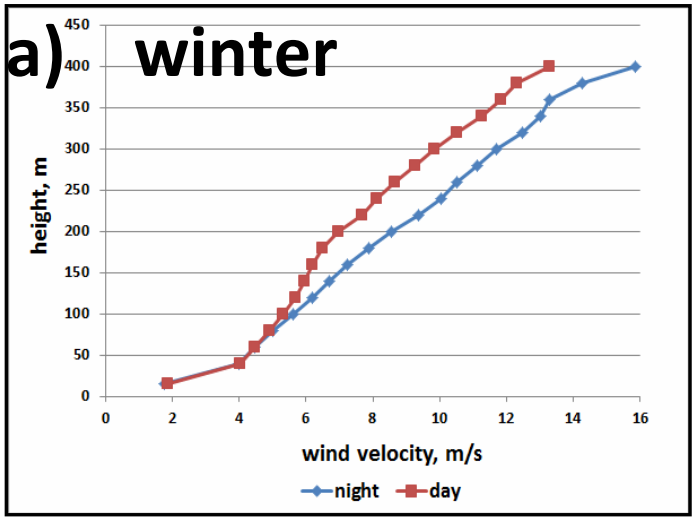
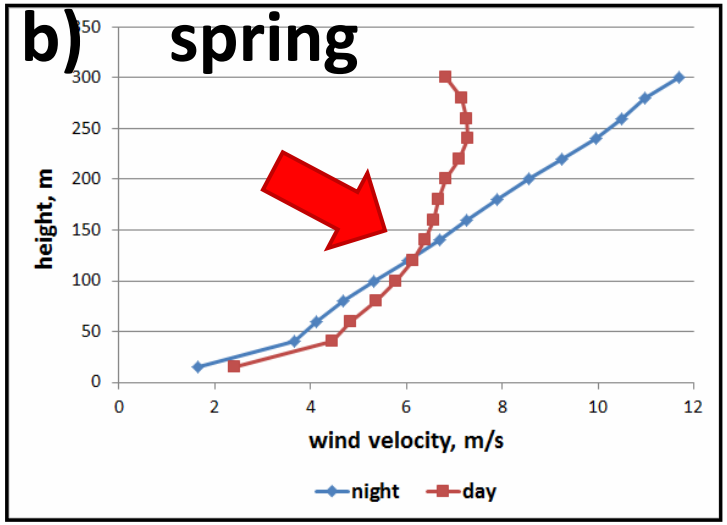
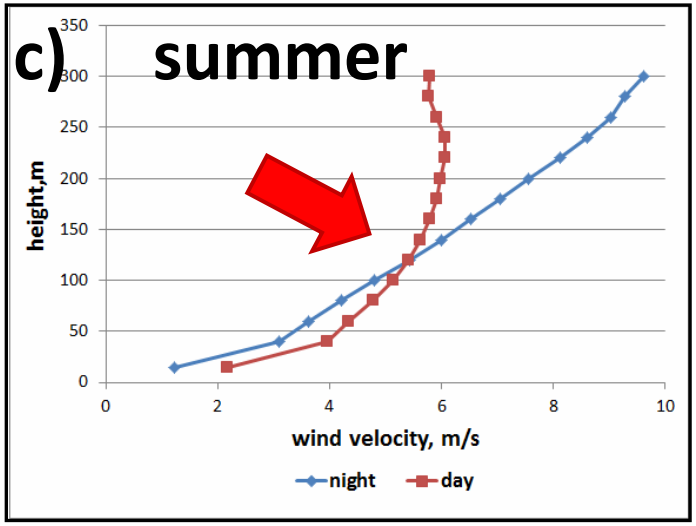


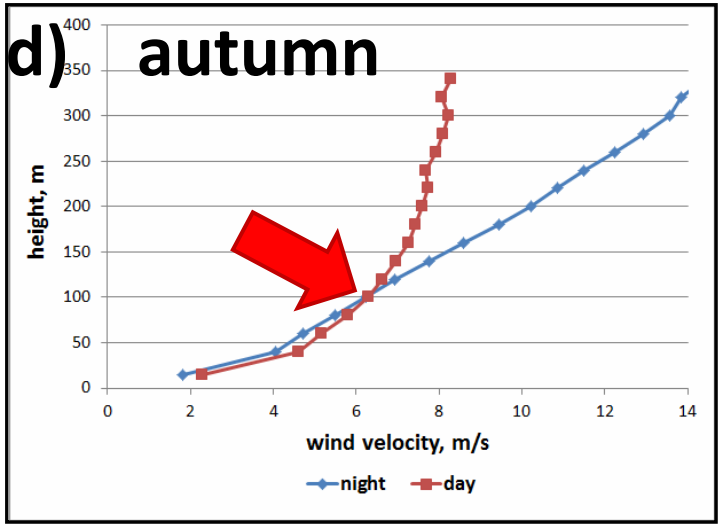
Fig.6. The profile of wind velocity from 2004 to 2012 above Moscow by data of sodar and two anemometers (with confidence intervals with 5% significance level) in Cartesian coordinates (a) and in semi logarithmic coordinates (b)

2. The investigation of wind velocity crossover height above Moscow in 2012 year









The crossover height is equal to since 80 m in winter till 120-130 m in spring and in summer (Fig.7); in autumn it is intermediate: 100 m

Different vertical exchange in different seasons!

Fig.7. The crossover height by data of sodar and anemometer (15 m) above Moscow in 2012 (winter-a, spring-b, summer-c, autumn-d)

3. The studying of thunderstorms by sodar

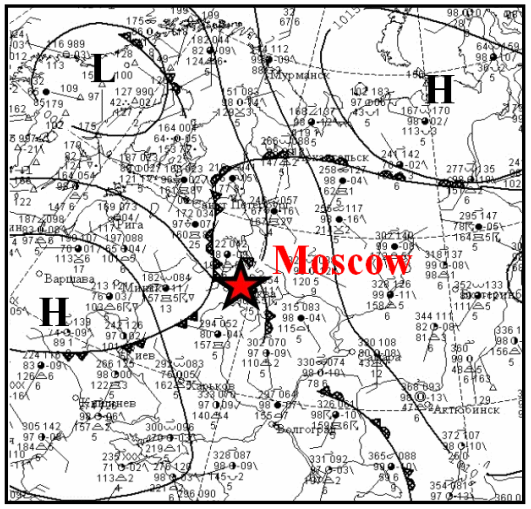


Fig.8. Surface synoptic map 13/07/2012 12:00 UTC

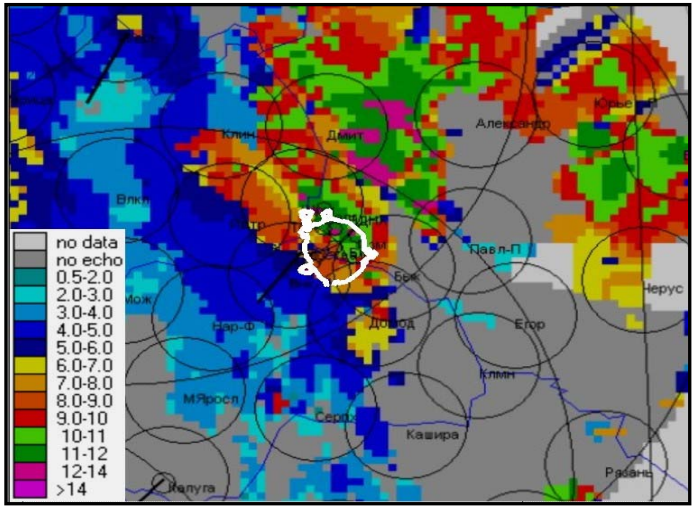


Fig.9. Map of top cloud by radar in 13/07/12 15:30 UTC (white contour-the border of Moscow)

We analyzed 137 cases of thunderstorms in Moscow from 2004 to 2012 (including 7 cases of severe thunderstorms). The severe thunderstorm on July 13th, 2012 was reason of human deaths!

Fig.8. demonstrates the influence of unstable stratification after passing of intense cold front across Moscow

Fig.9. shows strong development of Cb clouds (up to 14 km height!)

developing of severe thunderstorm

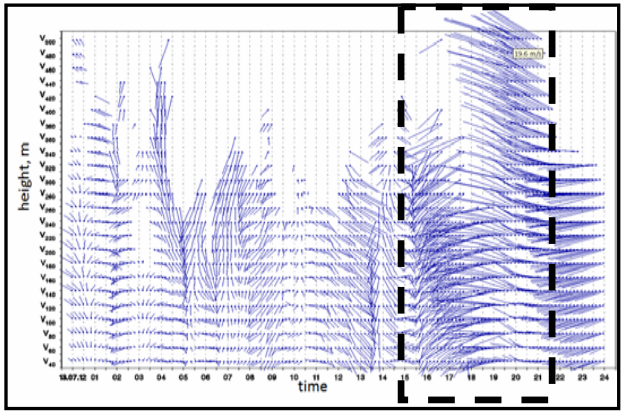


Fig.10.Sodar data of V in 13/07/2012

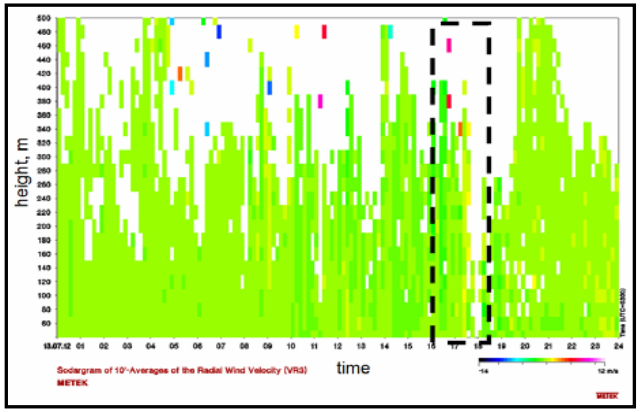


Fig.11.Sodar data of W in 13/07/2012

Total wind acceleration V (Fig.10) and positive (upward) wind vertical component W (Fig.11) were observed in time of this event.

Conclusions

- the daily course of wind velocity has clear daily maximum in the ground air layer up to 60 m and it is opposed (with nocturnal maximum) since 120 m;
- the crossover height represents an intermediate zone from 80 to 100 m where the daily course is smoothed;
- the thunderstorm events are supplied as a rule by wind acceleration in the ABL.