# The lidar sounding of the atmosphere in St. Petersburg

Dmitry Samulenkov (1), Maxim Sapunov (1), Irina Melnikova (1), Vladislav Donchenko (1), Anatoly Kuznetsov (2)

(1) St.Petersburg State University, Reasearch Park, Resource Center "Observatory for Ecological safety", Universitetskaya nab., 7/9, St.Petersburg, 199034, Russia, irina.melnikova@pobox.spbu.ru
(2) Russian State Hydrometeorological University, Malookhtinsky, 98, St. Petersburg, 196195, Russia, kuznetsov1946@inbox.ru

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**Abstract** Measurements of the vertical profile of aerosols parameters, wind velocity and direction in the Observatory of ecological safety, Research Park, St. Petersburg University in the center of St. Petersburg was held from the beginning of 2014, the height of laser sounding of wind characteristics of up to 12 km and of aerosols properties is up to 25 km. The results of vertical profiling aerosol particles and wind parameters above the central part of St. Petersburg in day and night obtained from observations 5 March 2015 time are presented. Results include profiling the extinction and backscattering coefficients, particle size distribution, depolarization rate, particle concentration and real and imagine parts of refractive index. The wind characteristics are presented in the nearest time and the same date. It is shown that the meteorological parameters of the atmosphere and time of day affect the dynamics of changes "pollution cap" over the city.

**1. Introduction**. The Observatory of ecological safety in ranges of the Resource Centre (RC) of the St. Petersburg state University (SPbSU) is located in the center of St. Petersburg on Vasilievsky Island, $10^{th}$ Line, 33/35 at the height 35 m, geographical coordinates Lat 59.943N, Lon 30.273E. The main objectives of the Observatory of environmental safety of RC St. Petersburg state University are [1]:

1. Formation of models of the influence on the environment of potentially hazardous industries and large-scale construction works;
2. Estimation of transboundary pollutant transport in the atmosphere;
3. The creating forecast models of the development of the unfavorable situation in the Environment and methods for the assessment of possible economic damage;
4. Preparation of the situational synthesized maps of suspected areas and sites of occurrence of environmental safety threats with the assessment of the state of environmental safety of the areas and sites of high ecological risk;

The SPbSU lidar RC is included in the frames of the European lidar network station (EARLINET) that enables the use of data of lidar monitoring stations for modelling transboundary pollutant transport over Europe. Stationary multi-wave lidar complexes provides information on the concentration and the physical nature of atmospheric aerosol at a distance of 20 km in the vertical direction and the wind and turbulence at a distance 10 km. Lidar complex includes components and state of the art technology, both Russian and foreign manufacturers and allows remote sensing in a wide spectral wavelength range. Klett and Raman methods are used for retrieving aerosol optical parameters [2].

Values of polluting components concentrations in the atmosphere obtained with the laser complex in the Observatory of environmental safety allow directly, comparing the obtained results with the threshold values of concentrations, determine the occurrence of dangerous situations for ecosystems and population (Melnikova et al., 2010). Lidar sounding is successful only in the clear sky. Heavy clouds are not suitable for the lidar remote sensing because of prevalent multiple scattering and very low values of the backscattering part of cloud phase function.

## 2. Observational and inversion results

Here we demonstrate results of observation accomplished in St. Petersburg center 5 March 2015.

Figures 1 shows an example of a vertical profile of the volume extinction coefficient $\alpha(z)$ in the coordinates height (m) – time (hour) obtained from observation to the zenith direction in the channel 355 nm, accomplished 05 March 2015 during 12 hours. The figures clearly traced a "pollution cap" above the city up to the height of 1.8 km. One can see that extinction coefficient reach maximal values from 15:30 till 17:30, and remains high values till 20 hours. After 22 hours extinction coefficient is 4 times less than in day time and significantly dissipates and elevates.

Another characteristic of aerosol particles is their form. Usually one differs particles of spherical (or close to spherical) and not spherical (crystals, chains and other). The shape of the particles is determined by their origin and may indicate the source of aerosols.

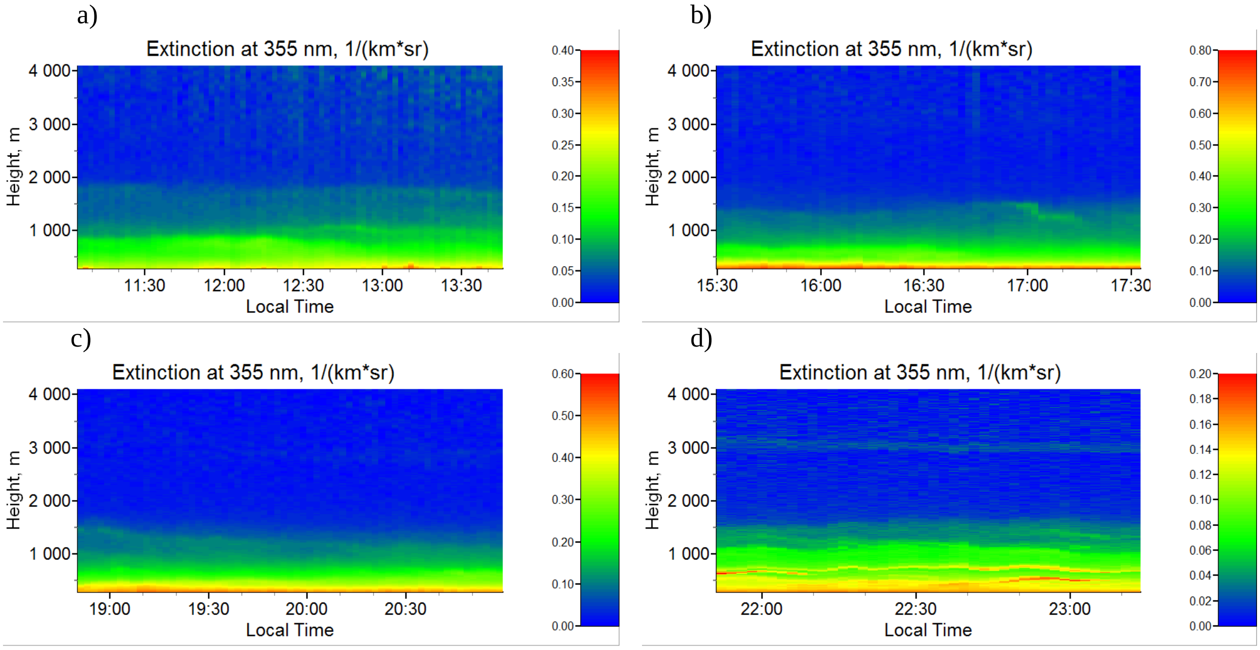


Fig.1. Dynamics of the aerosol extinction vertical profile variations during 12 hours from observations 5 March 2015 in 532 nm channel

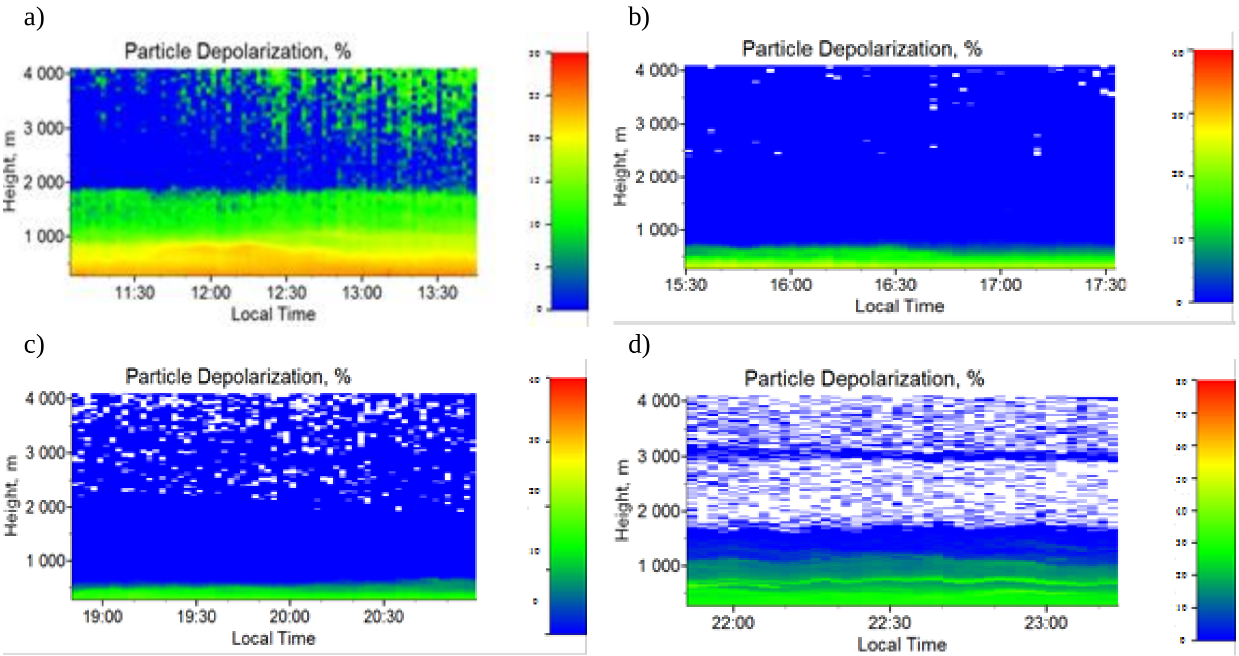


Fig.2. Dynamics of the linear depolarization vertical profile variations during 12 hours from observations 5 March 2015 in 532 nm channel

Figures 2a and 2b show the linear depolarization factor of atmospheric aerosols. One can see that in the near surface layer < 1 km the "pollution cap" where dust particles with a shape close to spherical (but not absolutely spherical) are dominated in the night time (after 19:00 h). It might be soot. Linear depolarization of the backscatter light points to dust (kind of crystal particle) in the first half of day time till 13 hours. It is seen noisy errors in heights upper 2 km.

In the Figure 3 the particle size distributions is presented at two heights: 315 and 1140 m. It is demonstrated for four mentioned time periods: 1 – 11:00–14:00, 2 – 15:30–17:30, 3 – 18:45–21:00 and 4 – 21:45–23:30 hours of the local time that pointed in the figure.

It is seen that larger particle (more 0.75 μm) are only in lower heights and in the period from 11:00 till 17:30 h. In the night time (purple line) the part of larger particle is increased at higher level (a) that differs from the lower level (b).

The transformation of particle size distribution with altitude in the time period 2 (15:30–17:30 h) is shown in the Figure 4a. It is clear a coarse mode of particles at 315 and 700 m levels with radius larger 1-2 μm. One can see the stable during pointed four time period distribution of particles with the mean radius less than 0.5 mm at upper levels higher 900 m. The Figure 4b demonstrates the particle mean radius in the atmosphere from 300 till 1600 m – in the pollution cap. It is seen the increasing of larger particles in the night time (purple line). It might be a growth of small soot particles in the atmosphere with increased moisture [4].

a)

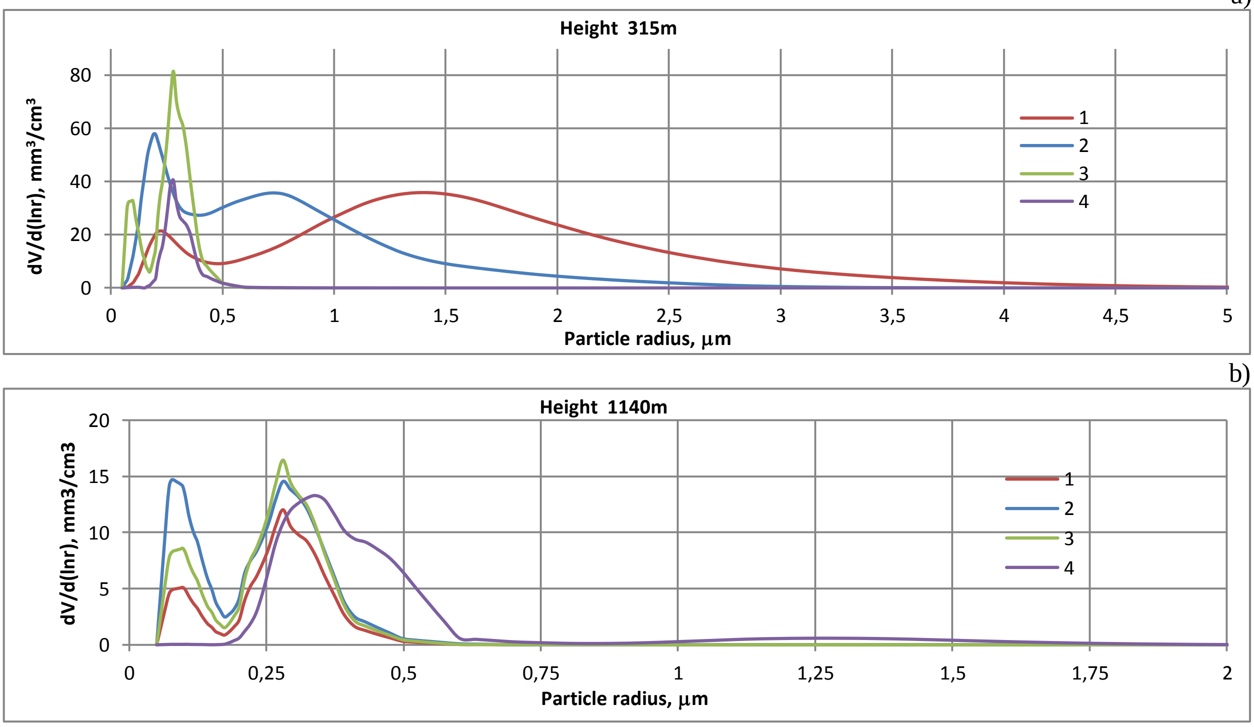


Fig.3. Particle size distribution at two heights 315 (a) and 1140 m (b) in four time intervals: 1 – 11:00–14:00, 2 – 15:30–17:30, 3 – 18:45–21:00 and 4 – 21:45–23:30 of local times

a) b)

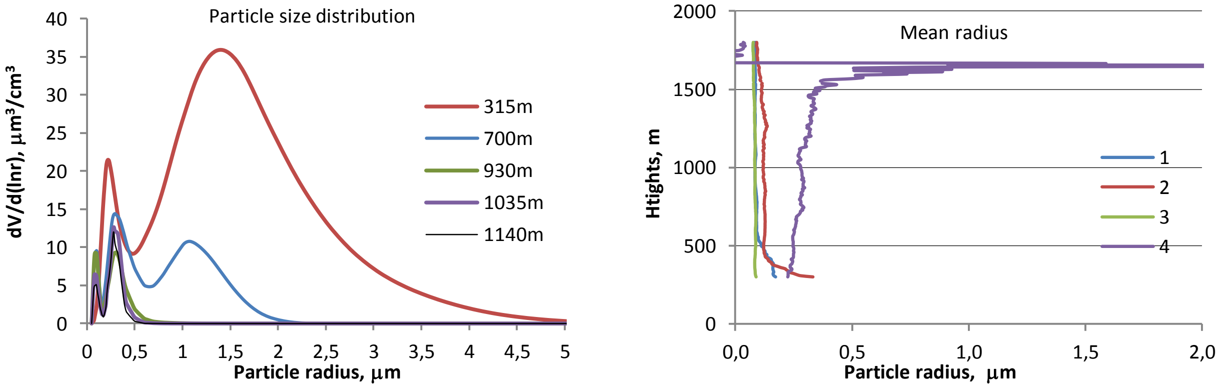


Fig. 4. a) Particle size distribution at 5 altitudes pointed in legend averaged over the time period 2; b) altitudinal dependence of the mean radius in four time periods pointed in legend

The Fig. 5a shows vertical profiles of the volume particle concentrations in considered time periods. One can see how decreasing particle numbers in the pollution cap (layer till 1000 m) during the day. Real part of the refraction index varies in the lowers and highest of the considered levels and remain constant in the middle heights (800-1400 m). In the morning time it points to the aerosols stratification. The layer 600-800 m is expressed in these three parameters.

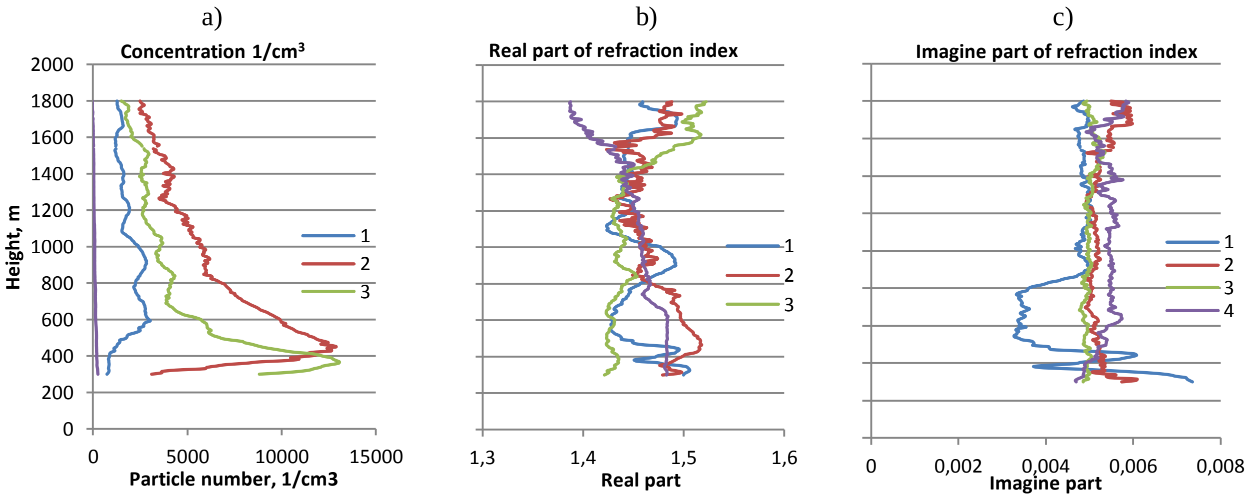


Fig. 5. Vertical profiles of: a) aerosol particles concentration; b) real and c) imagine parts of the refractive index for four time periods

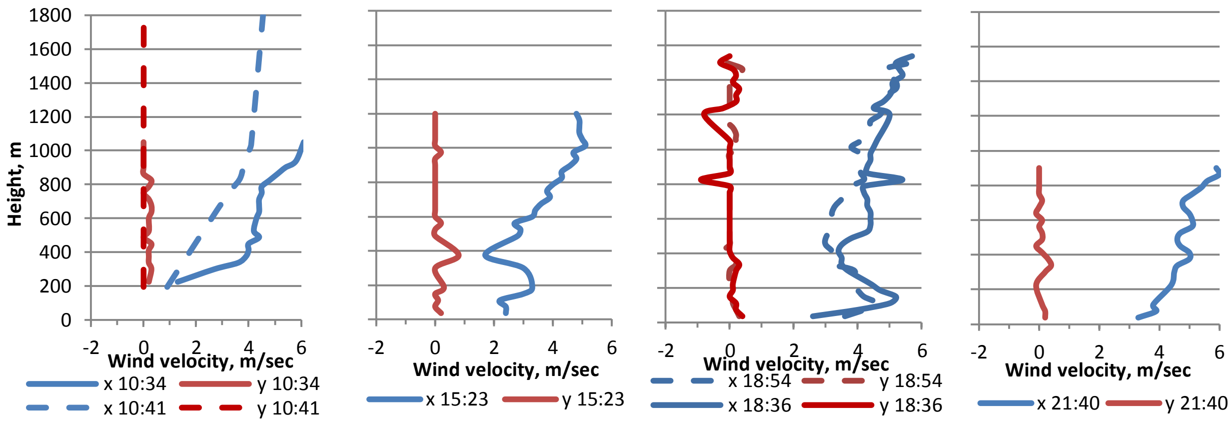


Fig. 6. Vertical profiles of wind horizontal (blue lines) and vertical (red lines) in different time moments pointed in legend.

The horizontal and vertical wind components are in the Figures 6. Wind observations were made between aerosols observations. Time is pointed in the figure. The wind profiles characterize a ground atmospheric layer and show increasing in at 200 m in the day time from 15 till 19 hours. The vertical wind component characterizes upward motion at the 400 m that has a maximum 1m/sec in 15 h. In the evening after 18:00 h the detectable downward motions appears at heights 800, 1200 and 1500 m.

Wind observations have been accomplished in different cone angle that provides different maximal heights of sounding and different resolution. The figure 7 demonstrates the wind direction obtained in the same times. The significant wind shift is appears in 15 h.

The results of radio sounding in the nearest station Voeikovo that is in 25 km from lidar sounding is available only in night time (03:00 a.m.) hence the direct comparison is impossible. However the tendency of meteo parameters variation is seen. In Fig. 8 the vertical profiles of temperature, relative moisture and wind parameters are presented.

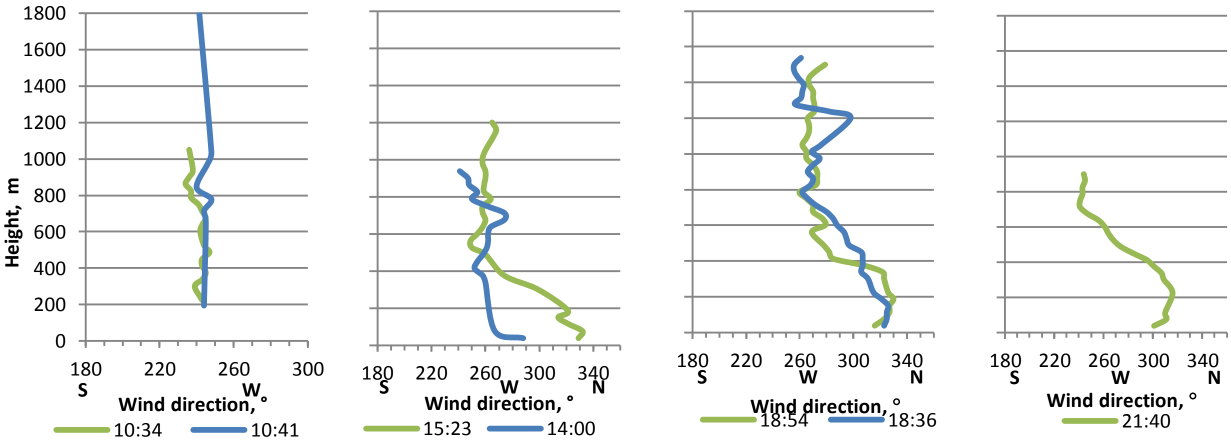


Fig. 7. Vertical profile of the wind direction. Local time of observations pointed in the legend

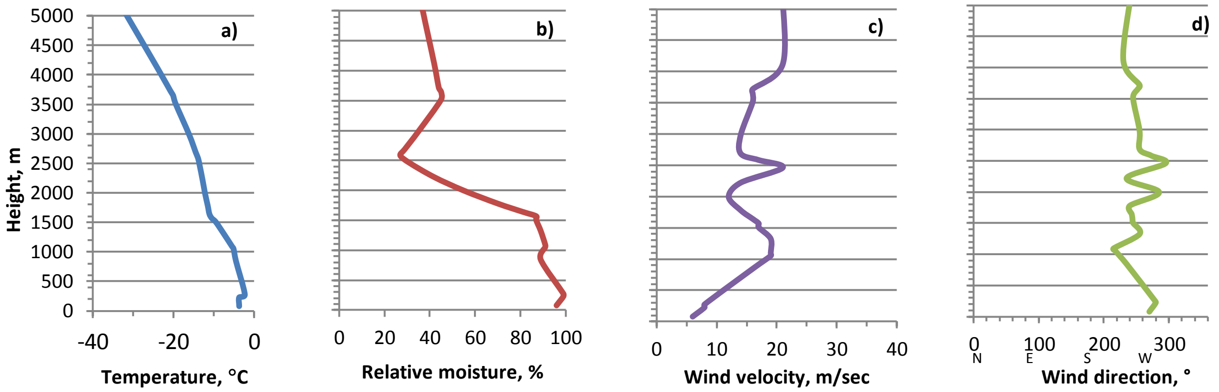


Fig. 8. Vertical profiles of the temperature (a), moisture (b), wind velocity (c) and wind direction (d) from radio-sounding at 03:00 a.m. in Voeikovo station

The analysis of the complicated links between wind characteristics and formation of the pollution cap above the city need in more statistics and it is out this consideration. We are only presenting here the information obtained from one experiment accomplished 5 March 2015 in the city center.

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