Comparison of the Lidar, Radiosounding and Radar Measurements of Wind Vertical Profiles

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Abstract Measurements of vertical profile of speed and direction of wind in the Resources Center "Observatory of Environmental safety", Research Park of the St. Petersburg University (Lidar) in the center of the big city. A pulsed Doppler wind lidar is used for measuring the vertical profile of wind characteristics. The results are compared with radiosounding data (Radiosonde) at meteorological service in Voeikovo and data of radar in centimeter range, set at Pulkovo airport and in Russian Hydrometeorological University (RSHU). Lidar observations are taken synchronously with the schedule of Voeikovo meteorological station. The distances from lidar to other points of observation are: 25 km to Voeikovo station, 8 km to RSHU, and 15 km to airport Pulkovo. The successful sounding with centimeter range radar needs the presence of clouds. But thick clouds is the disruption factor for lidar sounding, thus cases with a not thick broken clouds are chosen for consideration. The comparison might test an assumption of wind field homogeneity in the indicated scales and elucidate special features of considered instruments. Several dates of 2015 are presented in the article for comparison.

Keywords: Doppler lidar, Wind speed, Wind direction, Radiosonde, Vertical profile, Meteorological radar

1. Introduction
Currently the wind observations obtaining profile of wind characteristics are radiosounding, lidar and meteorological radar. Radiosounding is done typically 2 times a day: 3 p.m. and 3 a.m. in meteorological station Voeikovo in St. Petersburg suburb. Lidar sounding is accomplished in the center of St. Petersburg on Vasilievsky Island synchronously with the schedule of radiosonde. For more regular measurements, one should use other means of measurement, for example, the Doppler lidar. The lidar needs validating and calibrating, for reliable measurements of wind profiles, which one of the stages is a comparison with a certified measurement of wind, for example, with radiosonde and radar. The objectives of this study are to compare results of three observational approaches, and to test the assumption of homogeneity of wind characteristics and to elucidate the wind field in the considered scale. Several dates of 2015 are chosen for comparison, where the coincidence and difference between obtained data are observed.
2. Measurement methods

2.1. Lidar sounding The wind lidar is put in the Resource Center Environmental Safety Observatory of St. Petersburg State University (SPbSU) located, at the roof of the university building: height of 35 m, geographical coordinates: Lat 59.943N, Lon 30.273E [1]. The wind Doppler lidar provides registration of the vertical profile of horizontal and vertical components of the wind speed and direction. Doppler heterodyne lidar is manufactured on the base of a stabilized semiconductor laser emitter at wavelength 1557 nm with laser pulse power 11 mJ, pulse duration 400 ns, and pulse repetition rate 10 kHz. The wind speed measuring range is 0.5–40 m/sec, and ±0.5 m/sec accuracy; the wind direction measuring range is 0–360º, ±5º accuracy. A transmitting-receiving telescope provides the laser radiation beam formation, transmission of the radiation through the scanning system to the studied objects, and receiving useful signals containing information on the speed of aerosol particles motions (Fig.1). The light diameter of the telescope is 350 mm; the reflecting surfaces of the telescope mirror are protected by a special coating. A scanning system for high-precision angular positioning of the viewing line provides azimuth scanning range 0º to 360º; viewing angle scanning range 0º to 110º; angular step 1°; maximum rotational velocity 20º/sec and allows the cone scanning with chosen angle φ with rotational velocity, chosen depending on weather conditions.

The system sends a laser beam in the atmosphere, the received light scattered back by atmospheric aerosols moving with the wind. Signals from moving aerosol particles have a Doppler shift proportional to their velocity, which allows calculating the speed of aerosols. The laser beam circumscribes a cone and signals from moving aerosols inside the cone are averaged over horizontal cross-section of the cone at every fixed height and then processed for wind speed estimation. As a result, it is possible to measure the speed and direction of the wind.

Fig. 1. The lidar measurements of wind speed (a), signal processing (b) and the mapping result

2.2. Radiosonde Radiosondes (Fig. 2a) are launched regularly twice a day in Voeikovo, St. Petersburg suburb and provide vertical profiles of wind direction and speed till 35–40 km height with step 50-350 m. Data obtained are sent to WMO database and free for using. Wind characteristics are detected by fixing the shift of radiosonde coordinates in moments of data sending and calculation its speed and direction (attributed to the wind) [2].
2.3. **Meteoradar** Doppler meteorological radar emitting signal at 9485 MHz (wavelength 3 cm) provides the space field of wind characteristics over the circle with radius 200 km around the sounding site. The phase shift of emitted and received signal is detected that gives the information about speed of moving particles – water droplet in a cloud and other particles reflected the radar radiation at wavelengths 3 and 5 cm. Parameters of the radar reflectivity together with the wind parameters are obtained at geographical net with resolutions: horizontal 2x2 km and vertical 500 m (Fig 2b) [3].

![Fig. 2. The radiosonde (a) and radar (b) wind characteristics observations](image)

The map with pointed all observational sites is presented in the Fig. 3. The distance between Voeikovo and lidar station is 25 km. Radar observations are accomplished in the Russian State Hydrometeorological University (RSHU) in 8 km from lidar point and in Pulkovo airport in 15 km from lidar. Distances between the Finland Gulf and sites of observations are: 5 km for lidar, 10 km for Pulkovo and RSHU radars and 27 km for radiosonde in Voeikovo.

![Fig. 3. The map with marked observational sites by red circles](image)

3. **Results of observations**

The Fig. 3 demonstrates results of observations with three methods, when meteorological radar is situated in RSHU. The best coincidence of all three methods data is observed 27 May 2015 (Fig 3a). Other cases demonstrate a significant difference between all methods (Fig 3b) and between lidar and radar observations (Figs 3c). Wind direction is in good coincidence in all considered cases.

The radar observations in Pulkovo show better agreement (Fig 3d), but the wind direction profiles accord worth (Fig. 3i).
Fig. 3. Vertical profiles of the wind speed from lidar (red), radiosonde (blue) and radar (green) observations

4. **Conclusion**

The comparison between three observational methods demonstrates as coincidence as difference between obtained results. The coincidence is trivial and does not need in discussion. The difference might be explained with differ local wind characteristics or different indicated moving objects: radiosonde (size ~ 1 meter), cloud droplets (size ~10 μm) or aerosol particles (size ~ 0.1 μm). The more rich statistics is necessary for final decision.

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5. **References**

