Aerosol number size distributions in the lower troposphere over a background region and megalopolis (Novosibirsk) on result of airborne sounding in 2011-2013

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ABSTRACT

In this paper we present a comparison of the data on aerosol number size distribution measured with GRIMM 1.109 aerosol spectrometer in the lower troposphere over Novosibirsk and background area 150 km south-west of it during research flights of Optik TU-134 aircraft laboratory carried out along the route Novosibirsk - Ordynskoye - Novosibirsk in 2011-2013. Aerosol number size distributions averaged over 3 years as together so for warm and cold seasons separately are considered here. It is shown that the accumulation of anthropogenic aerosol within the BL over the city is typical for the cold period, which is most likely caused by inversions those are rapidly destroyed by vertical mixing during warm season and anthropogenic aerosols from the city are transported into the free troposphere.

Keywords: atmospheric aerosol, number size distribution, boundary layer (BL).

1. INTRODUCTION

Aerosols contain contaminants in solid, liquid and multiphase states. Aerosols are generally of a very small fraction of the mass of the atmosphere (10^{-9}), but they play a significant role in the formation of Earth's radiative balance, weather and climate. In addition to natural aerosols exist in the atmosphere, a great part of suspended particles are formed due to human activity (anthropogenic aerosols), which often cause irreparable damage of nature, constitute a very serious threat to human health, both by themselves and participating in various physico-chemical reactions in the atmosphere. The average anthropogenic contribution into atmospheric aerosol is of 12%. Moreover, almost all emissions of anthropogenic aerosols occur at 3-4% of the urbanized land area, where more than half the world's population lives.[1] Therefore, knowledge of the properties and composition of atmospheric aerosols, including anthropogenic fraction is of great importance for the problems of ecology, climatology, atmospheric physics and chemistry.

Since 80[th] years of the last century Institute of Atmospheric Optics SB RAS began its studies of tropospheric aerosols with the use of airborne-laboratory "Optik-E" on the platform of Antonov-30 aircrafts.[2] During more than 20 years (up to 2011) IAO SB RAS performed a number of scientific missions to investigate atmospheric aerosol composition over industrial and background regions. Size distribution of atmospheric aerosols was measured by means of modified photoelectric counter AZ-5.

In 2011 the V.E.Zuev IAO SB RAS together with Siberian Aeronautical Research Institute named after S.A.Chaplygin (SibNIA, Novosibirsk) established aircraft laboratory "Optik" on plane Tu-134, allows us to investigate the composition and atmospheric parameters is achieved throughout the spatial range established on board the means of measurement. Complex equipment includes contact and remote devices and sensors that measure the gas and aerosol composition of the atmosphere at different altitudes, while controlling the meteorological variables and navigation parameters. Specially developed software is collecting, processing, control and visualization of measured values on the aircraft laboratory.[3] For measuring submicron and coarse fractions of aerosol the laser spectrometer firm GRIMM model 1.109 is used presently.

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2. SITES AND METHODS OF AIRBORNE MEASUREMENTS

Airborne sounding of the atmosphere on the aircraft laboratory Tu-134 "Optik" held since March 2011, with an almost monthly basis in the tropospheric layer up to 7 km above Karakansky boron (conditionally background area), located 100-200 km south-west of Novosibirsk on the border with the Altai Region. The sounding above the background area was performed on eight high-altitude levels: 7000, 5500, 4000, 3000, 2000, 1500, 1000 and 500 m. Takeoff and landing aircraft were carried out on the northeastern outskirts of Novosibirsk, i.e. climb immediately after takeoff and reduction of aircraft before landing was carried out over the megalopolis or in the immediate vicinity. The typical flight route map for March 2011 is shown on Fig. 1.

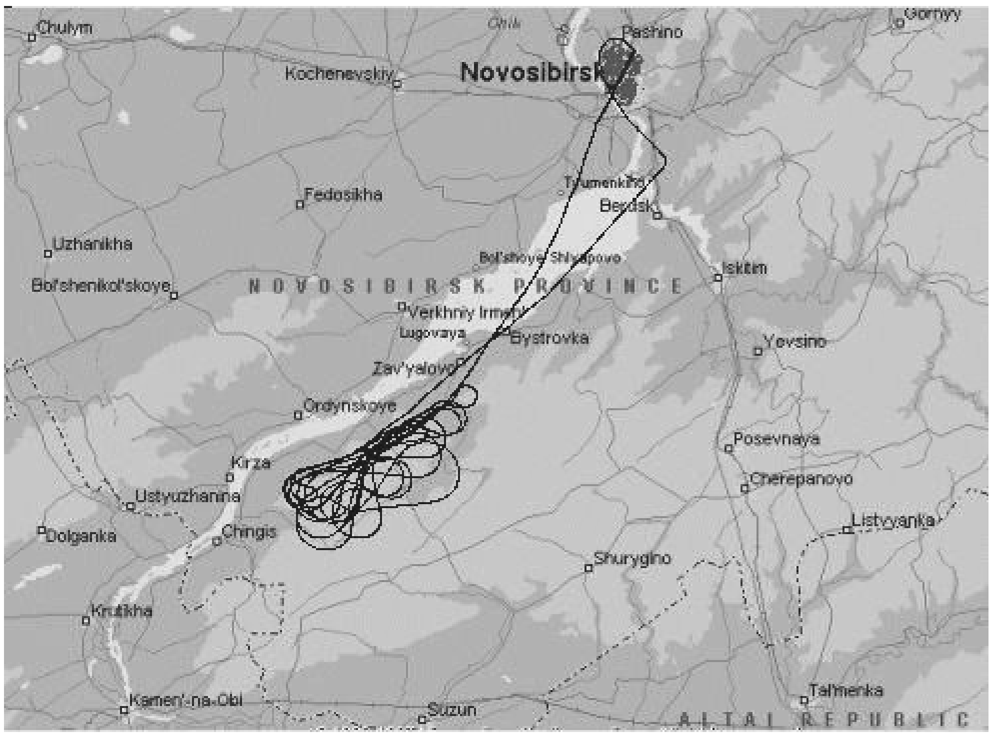

Figure 1. Horizontal track of typical flight of the aircraft laboratory Tu-134 "Optik" for March 2011 on the map of Novosibirsk region.

The altitude-time course of typical flight of the aircraft laboratory in March 2011 consisted of the following steps:

12:15-12:30 - off the north-eastern outskirts of Novosibirsk, climb to 3000 m, the approach to the background area;

12:30-13:40 - climb to 7000 m; step by step down up to 500 m sampling and sounding 8 tall background levels;

13:41-13:45 - climb to 1800 m; leaving the background area, return to Novosibirsk;

13:45-14:00 - flight over the suburban and urban areas of Novosibirsk, including descent and landing.

Described high-altitude flight time profile is shown in Fig. 2.

At the initial stage of the study it was necessary to allocate all of the high-altitude flight time course sensing those time intervals where the airborne laboratory was above the background area and the area of the city of Novosibirsk. Given that in the beginning of the flight instruments yield a steady-state measurements are not always achieved over the city, we used a reverse flight track for urban sample measurements. Usually a return to the city was carried out at high altitude 2100-1800 m levels. Because of this, the data for the background area were taken, the resulting sensing gap heights ranging from 2000-1800 m and height 500 m. The data obtained allow to quantify the content of atmospheric aerosols in the background troposphere layer 500-2000 m and in the same troposphere layer over urban area of Novosibirsk, and evaluate the composition of aerosol particulate characteristic of these areas.

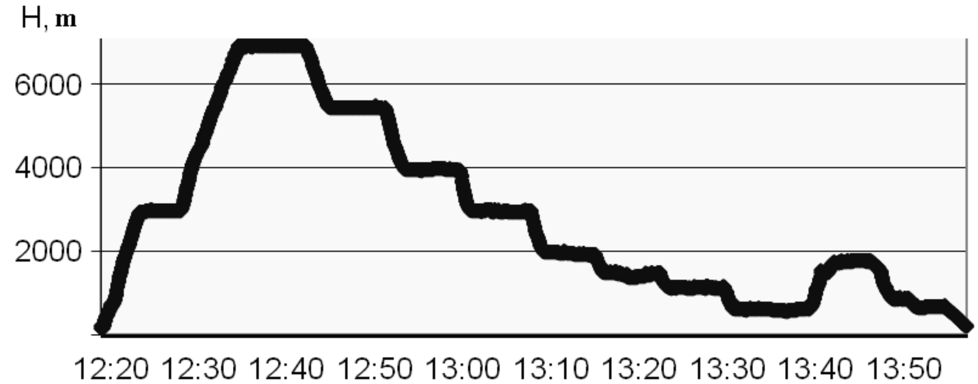

Figure 2. The high-altitude flight time profile of typical flight of the aircraft laboratory Tu-134 "Optik" for March 2011.

In the second stage, after a certain sampling intervals flight schedule, counted separately the total content of aerosol particles for each month separately for background district and the city of Novosibirsk. Often when plotted temperature and aerosol concentration with height is determined by the inversion process, especially at descent of plane over the urban area in Novosibirsk (fig. 3). In this case the data for underinversion layer was counted also separately.

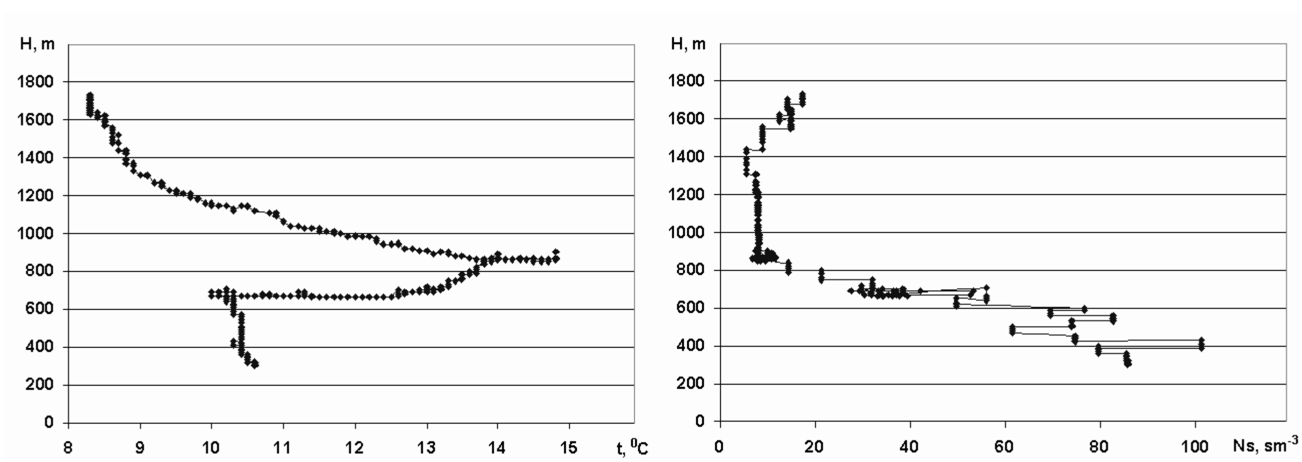

Figure 3. Vertical profiles of temperature and particle number concentration at descent of the aircraft laboratory over the urban area in Novosibirsk in March 2011.

The third stage is data processing, construction of curves counting atmospheric aerosol concentrations and mean curves dispersed composition (countable concentration) aerosol in the atmospheric boundary layer over 3 years as a whole, for each of areas: background, suburban and urban, and urban under inversion layer.

For measuring submicron and coarse aerosol fractions used laser spectrometer firm GRIMM model 1.109, range of measured particle: 0.25 - 32 microns, with close to lognormal breakdown on Channel 31; error of ± 5%; the duration of one measurement (frequency) - 6 sec.

3. RESULTS AND DISCUSSION

According to the obtained data for 3 years particulate aerosol composition from 0.25 microns were calculated mean values of the counting of aerosol concentration for each of the 31 measurement channel laser spectrometer GRIMM 1.109 for the lower troposphere (2000-500m) background area south-west of Novosibirsk region, and those same heights and below - for the urban and nearby zone of Novosibirsk, as well as often observed at lower over the city under-inversion zone separately.

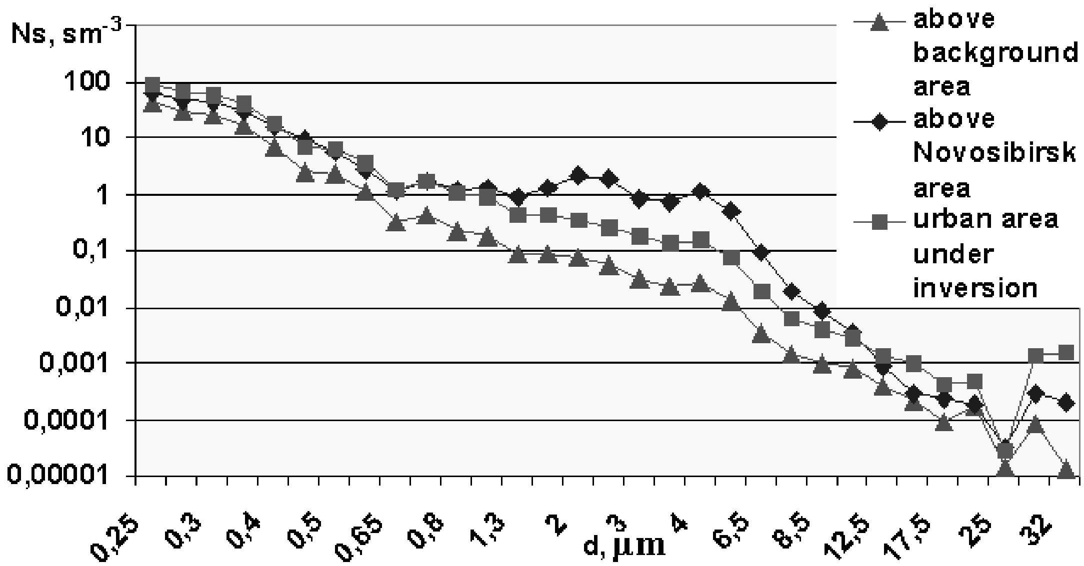

Figure 4. Mean curves of number aerosol concentration with particles size more than 0,25 µm, constructed on all values measured by the aircraft laboratory in atmospheric BL over the background region and Novosibirsk in 2011-2013.

Measurements have shown that in the region of Novosibirsk content of aerosol particles around the measured laser aerosol spectrometer range steadily more than the particle content in the background area. Such a pattern is obviously connected with a large contribution to the atmosphere of the city of artificial sources of aerosol particles (industrial) origin. Exceeding the content of particles with a size in the range 2 to 6.5 microns over a city compared to the background area achieves a half orders of magnitude. This indicates that over the area of the megalopolis active processes of aggregation of submicron particles of the spectrum is likely due to possible processes of interaction due to the high concentration of fine aerosols ejected city, gases and vapors of aerosol precursor compounds.

However, if to consider average aerosol number concentration distributions depending on the time of year, the significant differences are found in their nature. When this was evident as their contribution to the different seasons, and distribution in the boundary layer of the atmosphere the city in different periods of the year.

To find out seasonal features disperse composition of atmospheric aerosol in the background area and near the megalopolis, the aerosol number concentration distributions were considered depending on the time of year. Measurements for all three years were conditionally divided into two periods: warm - from April to October, and cold - from November to March. Average curves of number aerosol concentration for the background aerosol concentration district and the city of Novosibirsk, as well as under-inversion layer in or near presented in form of the graphs in Figures 5 and 6.

Fig. 5 shows that during the cold period in the region of Novosibirsk content of aerosol particles around the measured laser aerosol spectrometer GRIMM 1.109 range is slightly higher than the particle content in the background area. In the cold period has been a clear accumulation of aerosol particles in the under-inversion atmosphere layer the megalopolis and its suburbs from one half orders value for submicron particles and up to 2 orders of magnitude for the coarse fraction, compared to the background area. Moreover, diffusion of impurities through the inversion layer is very small urban caps almost absent for the smallest particles, and gradually grows to a large area of the particles.

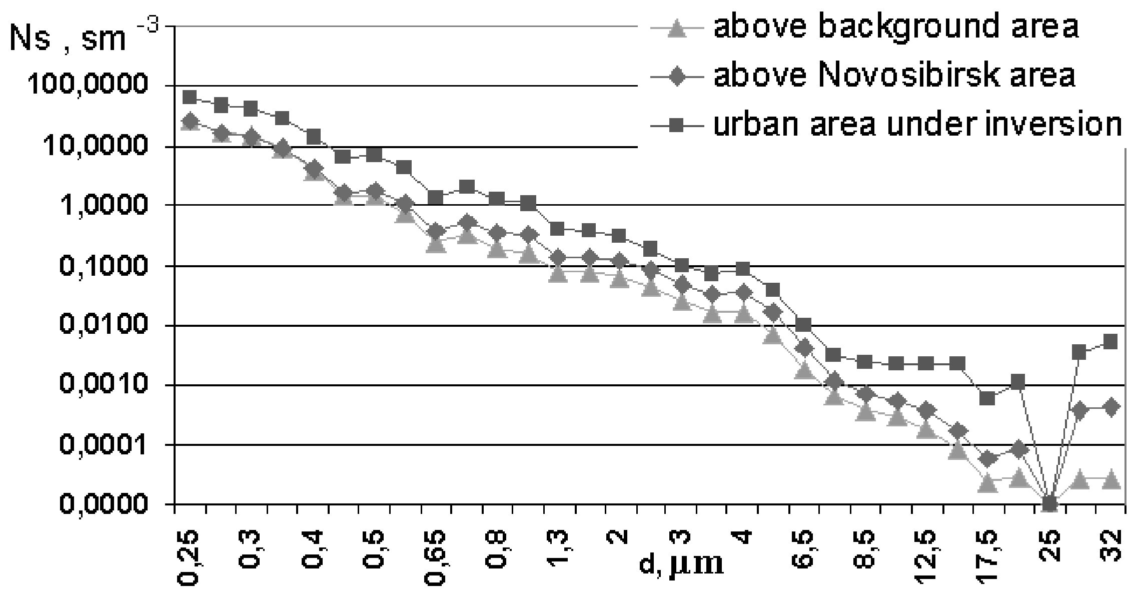

Figure 5. Mean curves of number aerosol concentration with particles size more than 0,25 μm, constructed on values for cold periods of 2011-2013 measured by the aircraft laboratory in atmospheric BL over the background region and Novosibirsk.

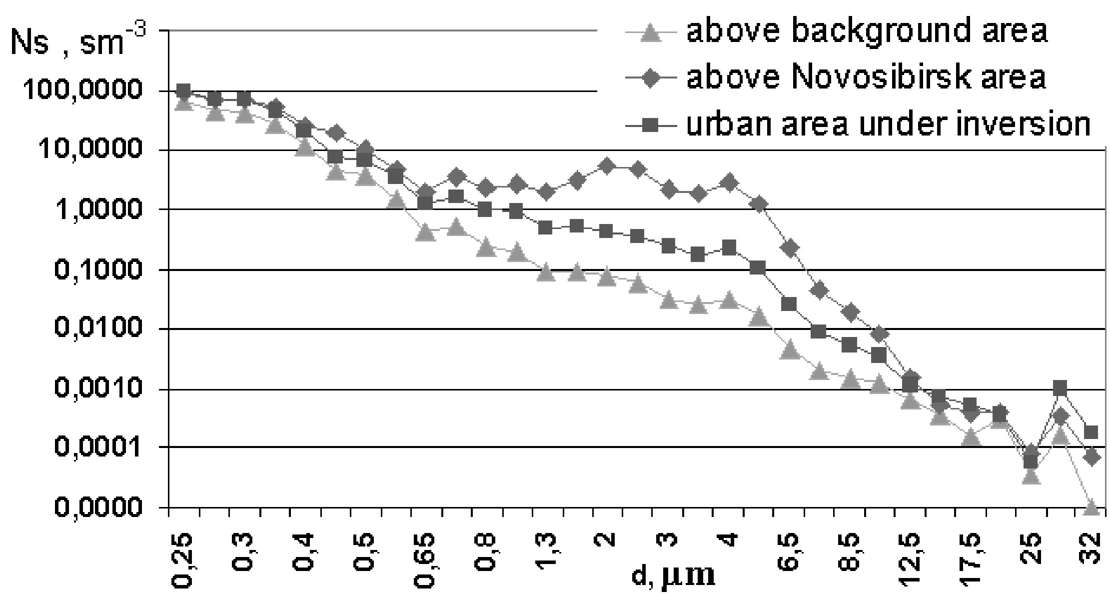

Figure 6. Mean curves of number aerosol concentration with particles size more than 0,25 μm, constructed on values for warm periods of 2011-2013 measured by the aircraft laboratory in atmospheric BL over the background region and Novosibirsk.

The plots in Fig. 6 show that during the warm period in the region of Novosibirsk content of aerosol particles around the measured laser aerosol spectrometer GRIMM 1.109 range exceeds the particle content in the background area. At the same time, compared with the cold period, the position of the curves for the summer disperse composition district has negated character in almost the entire range, except for the largest particle size of tens of microns. This is especially great for counting backward difference in the concentration range of coarse particles, reaching an order of magnitude in the 2 - 7.5 microns. It is likely that during the warm period developed turbulent flows are more conducive to aerosol removal from the city, which contributes to the development of smaller and inversion layers.

4. CONCLUSION

Thus, the separate but joint consideration of the seasonal distributions of number aerosol concentrations in area of the large megalopolis, which is the Novosibirsk, detects differ significantly in the aerosol distribution pattern of atmospheric BL in the immediate vicinity of the town and under-inversion layer in or near to the warm and cold season. Greater development of inversions in the cold period promotes the accumulation of anthropogenic aerosol in the city. Warm period is characterized by the best turbulence in the atmosphere, less extensive inversions, and as a result, the active removal of urban aerosols in to the free atmosphere.

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