Chemical composition of atmospheric aerosols over background areas of the southern part of Western Siberia observed during the IAO Complex Atmospheric Radiation Experiment carried out in December 2015.

Boris D. Belan, Tatyana M. Rasskazchikova, Denis V. Simonenkov*, Gennadii N. Tolmachev, and Aleksander V. Fofonov

V.E. Zuev Institute of Atmospheric Optics SB RAS
1, Academician Zuev square, Tomsk 634055 Russia

ABSTRACT

The study presents the data on the concentrations of chemical components measured in aerosol samples collected during the IAO complex atmospheric radiation experiment (organized by the V.E. Zuev Institute of Atmospheric Optics) carried out in December 22, 2015. Their vertical distributions derived from the sampling data performed with the use of "Optik" Tupolev-134 aircraft laboratory are reported. Both parts of the experiment were conducted on the same route over background areas of Tomsk and Novosibirsk regions in the daytime. General time duration of the flight was about 3,5 hours. Sampling was carried out on both routes onto Petryanov's filters AFA-HP-20 in the following troposphere layers 7000-5500, 4000-3000, 2000-1500 and 1000-500 m. The differences in concentrations of carbon-free inorganic ions and chemical elements in the aerosols on the Tomsk and Ordynskiy routes are discussed in the paper. An altitudinal distribution of inorganic ions in both areas is very similar only for one ion - SO_4^{2-}. The top layer is characterized by the smallest differences in the concentrations of the other components under consideration, and even almost complete coincidence of the total concentration of ionic macro components for both sensing areas. The trend in the vertical distribution of elements stored for 2/3 of them like ionic component. As many ionic components in the Tomsk region of sensing we observed inverse nature of the distribution of a large part of the element concentrations in the middle layers.

Keywords: atmospheric aerosol, chemical composition, inorganic ions and chemical elements.

1. INTRODUCTION

Since 2011 the complex atmospheric radiation experiments in the area of the rivers Ob and Tom at latitude 56-56.5°N near the city of Tomsk, covering the vertical layer of the atmosphere from the surface up to 7000 m, are carried out approximately one time per year (lasting up to a month) in the spring, summer or autumn period by means of the staff of all departments of the V.E.Zuev Institute of Atmospheric Optics SB RAS. In 2015, a similar experiment was first conducted in the winter period.

Selection of winter is associated not only with the peculiarities of atmospheric circulation and transport of aerosols in this time, but the fact that in winter, when the ground is covered with snow, mainly aerosols are of anthropogenic origin. Researches elemental composition of solid airborne particles deposited in snow within Tomsk city shows the specificity of their composition depending on the source of emissions.[1,2]

In the course of the complex experiment using "Optic" Tu-134 airborne laboratory, which produces in a clear or slightly overcast weather measure in situ the concentrations of a number of greenhouse gases, e.g. ozone, methane, carbon monoxide and water vapor, and microphysical properties and optical parameters of aerosol particles and soot into the atmospheric layer 500 - 7000 m over already the noted area in the Tomsk region, as well as over the territory of monthly airborne sensing over the Karakan boron on the right bank of the southern part of the Novosibirsk reservoir (fig. 1).

*simon@iao.ru; phone +7 3822 492-340; fax +7 3822 492-086; http://lop.iao.ru/eng/

22nd International Symposium Atmospheric and Ocean Optics: Atmospheric Physics, edited by Gennadii G. Matvienko, Oleg A. Romanovskii, Proc. of SPIE Vol. 10035, 1003549 ·
 doi: 10.1117/12.2249244

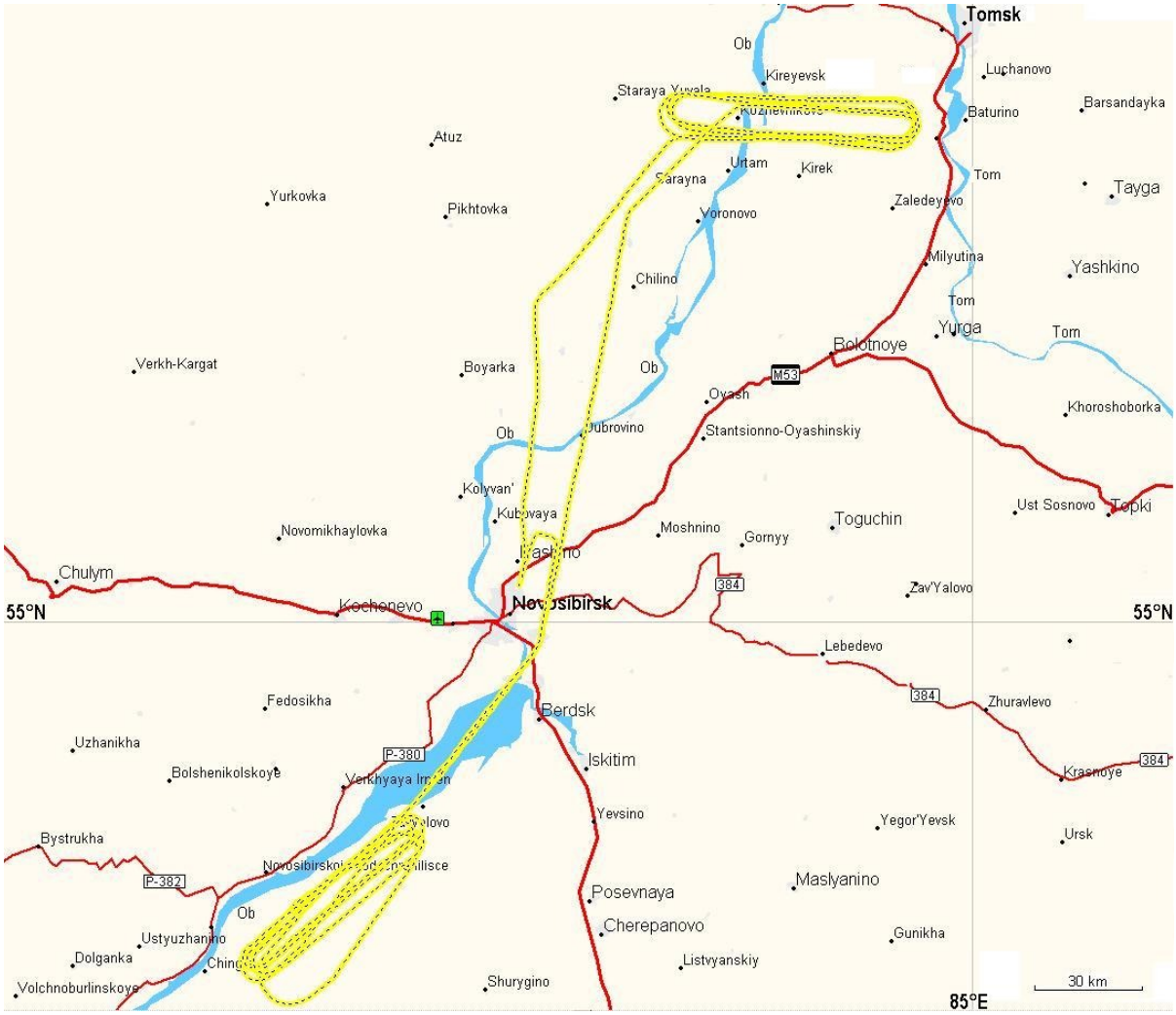

Figure 1. The map of sensing areas and the sensing route (yellow dotted line) of the aircraft-laboratory Tupolev-134 "Optic" December 22, 2015

The total time duration of such an integrated flight is about 3.5 hours. Work directly in the areas of sensing takes approximately 2.5 hours. Besides the mentioned *in situ* measurements at heights in layers 7000 - 5500, 4000 - 3000, 2000 - 1500 and 1000 - 500 meters above both the sensed areas we produced aerosol sampling on to Petryanov filters AFA-CP-20 for subsequent laboratory quantitative analysis of the content of non-carbon inorganic ions and chemical elements in the aerosol composition: Na^+, K^+, NO_3^-, Cl^-, SO_4^{2-}, Al, Ba, Ca, Cu, Fe, Mg, Mn, Mo, Ni, Pb, Sn, Ti, V, Be, Cd, Si, Co, Cr, Sr, Zn, Zr. Quantitative analysis is performed in the Environmental monitoring Laboratory of Tomsk State University by physical and chemical methods.

2. SYNOPTIC CONDITIONS

First, we briefly dwell on the description of the synoptic conditions in the region in the days of the winter experiment. On the eve of sensing, 21 December, the weather conditions in the south of Western Siberia were defined by the northern part of the Asian anticyclone with one of the centers in the region of Semipalatinsk. Temperature and humidity

conditions in the region at this time are determined by the Arctic air mass. V-shaped depression was observed at the beginning of the day; the center of the cyclone was in the district of the New Siberian Islands.

By the day of sensing, the 22nd of December, anticyclone moved to the east, and to the region is subject to its north-western periphery. The center of the anticyclone by that time was located in the western part of Mongolia. In the morning hours of the day of sensing there was a change of the pressure field from the crest at an altitude of 1500 m up to the trough at an altitude of 5000 m. In the ground at this time in the district of the Island of Spitsbergen was the center of a powerful cyclone, spreading to the entire European part of Russia and the North West Siberia; This formation, deepening, shifting to the east in the direction of Franz Josef Land. During the sensing region is almost completely fell under the influence of contrasting areas related to these entities. At the height of the main stream of 2-3 km for practically the entire period remained west-east transport.

3. RESULTS AND DISSCUSION

Altitude profiles of the defined chemical components of aerosol matter, both individual and aggregated – ionic and elemental components, and total inorganic amount - for both sensing areas: over the between the rivers Ob and Tom in the Tomsk region - "Tom", and over Karakansky boron in the Novosibirsk region - " Nsk ", presented in Figure 2.

It is obvious that only one non-carbon ion macrocomponent - sulfate anion SO42- - altitudinal distribution is very similar in nature to both areas. Independent of the region a stable stratification of sulfate aerosol shows the ubiquity of the prevalence and multiplicity of sources of its precursor gas - sulfur dioxide, and, apparently, both natural and anthropogenic origin. That is, in the winter the remoteness of marine sources of sulfur and the unevenness of their effect depending on the process of transfer and washing fully compensated by local anthropogenic sources, obviously, primarily associated with widespread activity in the temperate latitudes of the winter fuel and energy enterprises of all sizes, including the use of stove heating in the private residential sector. The uppermost layer of 5500-7000 m the content of sulfate aerosol below the detection threshold, which is generally defined low volcanic activity in the current period. Also, for the top layer is characterized by the smallest differences in the concentrations of the other components under consideration, and even almost complete coincidence of the total concentration of ionic macro components for both sensing areas. This is understandable maximum removal of this layer from any surface water that forms in it the most balanced state not only for the gas components of the atmosphere, but also for the majority of aerosol components, especially in the face already marked by a relatively weak effect of volcanoes on the middle and upper troposphere.

Compared with the ions, the elements because of the greater variety of sources and forms of stay in the aerosol, both soluble and insoluble form, is quite reasonable that the last concentration variation will be much larger and the picture patterns of their vertical distribution is not as universal as ionic component.

Nevertheless, it can be stated that the trend in the vertical distribution of elements stored for 2/3 of them, like the ionic component. As many ionic components in the Tomsk region of sensing observed inverse nature of the distribution of a large part of the element concentrations in the middle layers. In Karakan Boron area for many macroelements (aluminum, calcium, silicon, magnesium, etc.), the vertical profile was observed close to the theory - a decrease in their concentration with height. For the whole group of "black" metals with the similar natural origin - iron, manganese, tin, zinc - peak concentrations observed at an altitude of 1500-2000 meters. Three-day back trajectories in this area, built to these heights (Figure 3), cross the region's largest iron and steel industry - the Southern Urals.

In "Tomsk" sensing area the back trajectory of air parcel to an altitude of 1500 m comes from the Southern Urals (which is almost the same as the path to 1000 meters), so the spike concentration of "black" metal beads or less observed in the layer below. The secondary peak concentrations of some metals in the area at an altitude of 3-4 km, and sometimes higher (for example, lead), due to the fact that the air particles at an altitude of 3000 m and above come here from the Arctic, where the atmosphere is strongly accumulates emissions in winter temperate latitudes and polar regions.

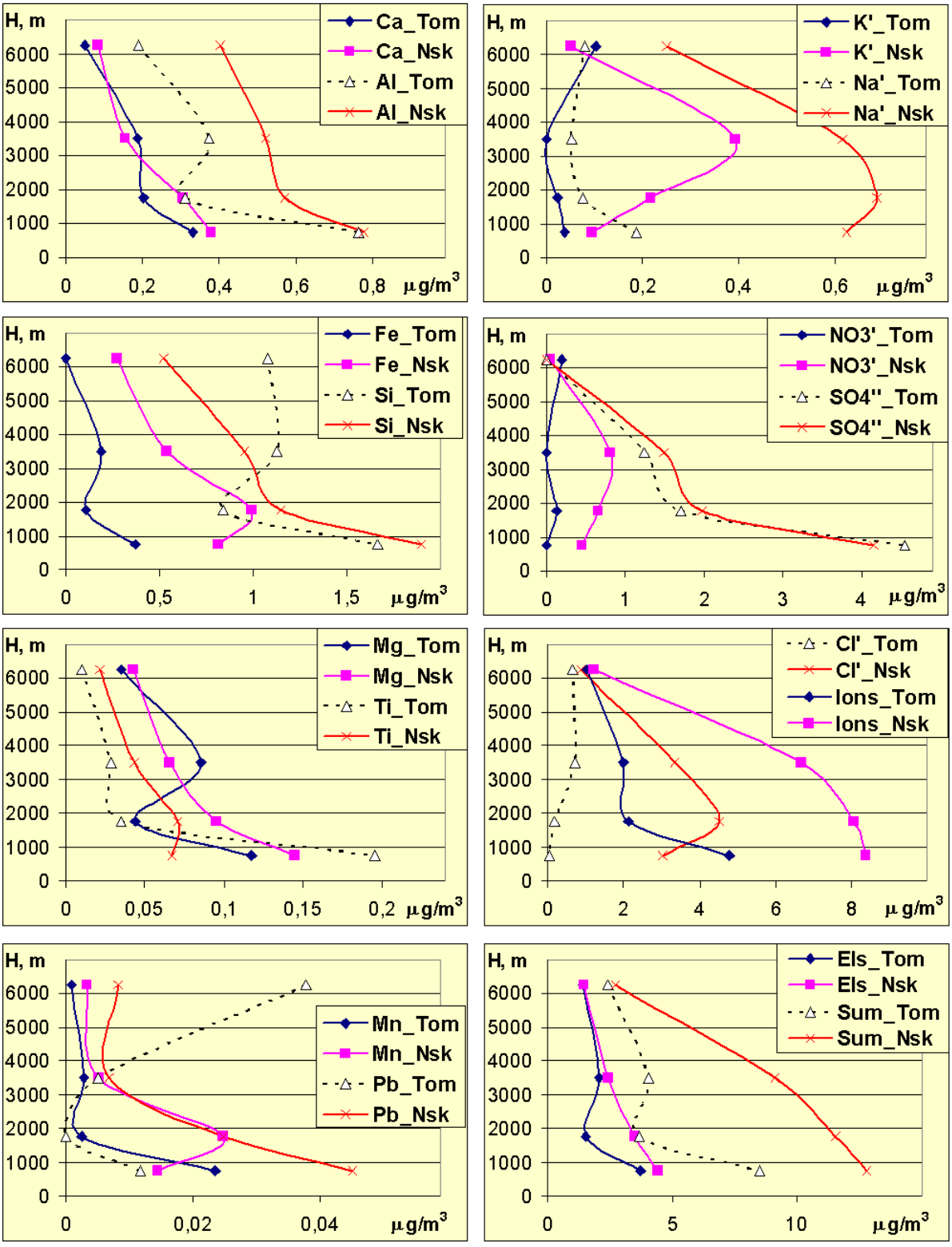

Figure 2. High-altitude profiles of the mass concentration of individual chemical components in the aerosol and their total amounts: Ion (Ion), elemental (Els) and the entire rate defined inorganics (Sum) in two areas of sensing December 22, 2015

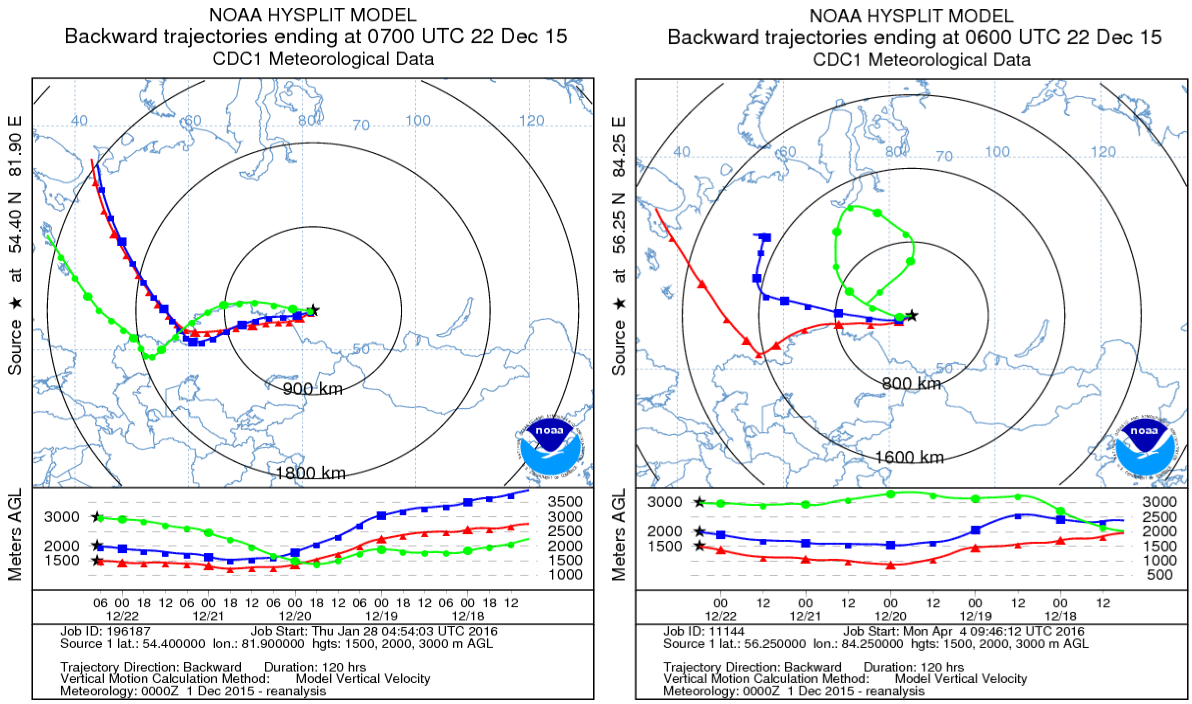

Figure 3. The back trajectories of air parcels at the altitudes of 1500-3000 m to the midpoint probing routes in both areas: Ob-Tom interfluve (right picture) and Karakan boron (left picture).

4. CONCLUSION

Summarizing the above, and considering the last graph of Figure 2, it can be concluded that in the period of the experiment troposphere Ob-Tomsk interfluve near IAO observatory "Background", located on the right bank of the Ob river and 5 km from the Kireevsk village, characterized by a complex vertical stratification of contaminant due to the synoptic conditions in the experiment period and a very large variation of source regions of aerosol origin in different layers of the troposphere. High-altitude distribution of inorganic amount of atmospheric aerosol in the Novosibirsk reservoir area smoothed over.

5. ACKNOWLEDGMENTS

The work was supported by the Ministry of Education of the state contract №14.613.21.0013 (identification number RFMEFI61314X0013).

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