# Numerical simulation of the pine (*Pinus sylvestris*) pollen dispersal in the atmospheric boundary layer of the Southern Baikal region

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The paper describes the processes of the pine pollen dispersal in the atmosphere using a three-dimensional nonlinear nonstationary model of transport, diffusion, and transformation of impurities. The sources of pine pollen are the forests and pine groves of the Olkhinskoye Plateau, slopes of the Primorskii Ridge and the Khamar–Daban Ridge. A comparison is made between the calculated results and the data of the instrumental measurements.

Many investigations show that the atmospheric aerosols have a profound effect on the climate and human health. The atmospheric aerosols contain also bioaerosols, i.e., biological objects suspended in the air and following the same regularities, which are characteristic of any aerosols of the appropriate size. The plant pollen and spores make up a substantial part of the largest fraction of biological aerosols.[1] The investigation of transport processes of the plant pollen enables us not only to add to our knowledge of the behavior of aerosols in the atmosphere but also contributes to the fulfillment of palynological and palaeogeographic reconstructions resulting in an understanding of mechanisms of the formation of palaeoclimates that furnishes the insights into the changes of the present-day climate and even the future climate.

This paper describes the investigations of different characteristics of bioaerosol – the pinus sylvestris pollen – and the processes of its dispersal in the atmosphere over southern part of Baikal region.

The coast of the entire hollow of Lake Baikal and adjacent to it hillsides is characterized by dominance of the mountain – taiga forests with small variety of wood types: larch, pine, Siberian pine, spruce, fir, birch.[2] The area of zone of the mountain vegetation takes second place as compared with the mountain taiga.[3] In the lower parts of the mountain slopes of southern regions, on the Ol'khon Island, in the Ol'khon Region the areas of steppe vegetation are observed.

The material for the investigation are samples of aerosol, collected over the southwest coast in 1996–1997, as well as the samples of aerosol over the water area of Lake Baikal. The standard microscope slides with a special adhesive solution were placed in the outskirts of the settlement Listvennichnoye at 2 m height above the soil surface. When taking samples over the Baikal water area, the slides were placed on board a research vessel. Before exposing the slides were coated with a dye solution containing a protein dye-stuff, which, reacting with a carboxyl group of protein, colors the protein containing substances, i.e., biological particles, being blue of different intensity, therefore all the pollen grains as biological particles were bright blue. The identification of the pollen and spores was made up to the level of genus for the group of wood and bush plants, to the level of family – for the pollen of grass and spores. The concentration of the pollen and spores was calculated for the entire glass surface during the exposure time.

Aeropalynological studies conducted in 1996 in the southwest coast of Lake Baikal have shown that during the vegetation period, from the middle of May until the end of September, the concentration of pine pollen in the air varies within wide limits.[4] Single pollen grains of the pine *Pinus sylvestris L.*, which were, evidently, transported from the ground surface after snow melting, and recorded in April. Early in June the pine pollen Pinus dominates (the basic part of it is the pollen of a simple pine). This pollen also dominates in the first decade of July.

At aeropalynological investigations on the southwest coast of Lake Baikal in 1997, an absolute supremacy of the pine pollen was observed from June 10 to July 4. In the middle of August, the concentration of pine pollen is low, about 200 pollen grains as compared with 1400–2500 grains in June and July.

On the whole, maximum quantity of the pollen grains in the samples of 1997 exceeds the same in the samples of 1996 by a factor of three.

The second important result of the research of 1996–1997, i.e., the maximum concentrations of the wood plant pollen in the air are observed at different times. Thus in 1996 the peak of flowering, and, hence, the period of existence of the wood plant pollen in the air is from May 23 to July 5. In 1997 the maximum pollen concentrations were observed from May 12 to June 30.

The maximum pollen concentrations over the lake water area in July 1997 were 270–780 pollen grains. These concentrations were observed from July 11 to 14.

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The pine pollen was observed in all the samples. Analysis of the results of the field measurements in 1996–1997 has shown that the pine pollen concentrations in the air are determined by the weather conditions during the time of plant flowering.

To study the processes of the pine pollen dispersal, we used the three-dimensional nonlinear nonstationary model of the transport and transformation of impurities. The pollen sources are the forests and pine groves of the Olkhinskoye Plateau, hillsides of the Primorskii Ridge, and the Khamar–Daban Ridge. The pine area was determined on a basis of data from Ref. 2. The wind field characteristics were obtained during field measurements.[5,6]

The numerical experiments were carried out in the region of 500×250 km$^2$ area and at 3 km altitude above Lake Baikal surface. The steps in time and in the horizontal were 150 s and 5 km, respectively. The step in the vertical was given as follows: up to 1000 m height above Lake Baikal level the step was equal to 20 m, and further – 250, 750, and 1000 m. The coefficients of the turbulent diffusion were calculated using the relations of the semiempirical theory of turbulence.[7]

Processes of transport and deposition of the pine pollen on the underlying surface over a period from the end of May to July 1997 were simulated. The mass rate of flow was calculated in the following way:

from 05.26 to 06.20.97; $M = M_0 \sin(\tau) \qquad \leq \tau \leq 3\pi/4,$

from 06.21 to 06.30.97; $M = M_0(1.7 - 1.33\tau)$

$$0.75 < \tau \leq 0.9,$$

from 07.01 to 07.04.97; $M = M_0(5 - 5\tau) \qquad 0.9 < \tau \leq 1.$

Here $\tau = t/T$, where $t$ is time, $T$ is the period of flowering. When calculating $M_0$ it was assumed that the pine pollen mass was 2 kg from a tree and 125 kg per one hectare.[8]

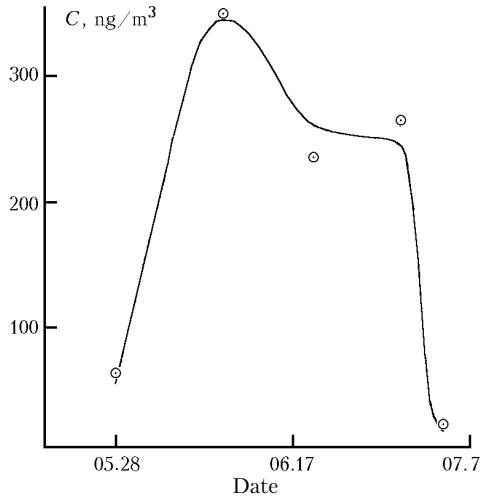


**Fig. 1.** The values of calculated (——) and measured ( ) pine pollen concentrations during a period from the end of May to July 1997 in the region of Listvennichnoye settlement.

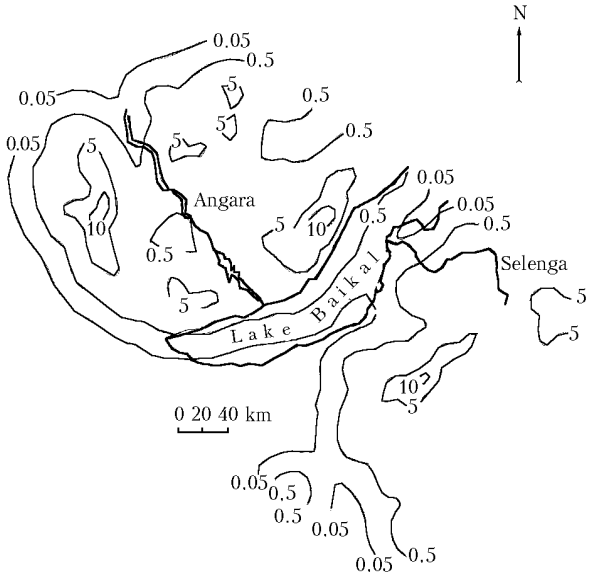


**Fig. 2.** Isolines of the mass rate of the pine pollen flow, mg/(m$^2$·24 h), calculated during the period from June 14 to 18, 2000. (Lake Baikal, Angara, Selenga).

Figure 1 shows the values of calculated and measured pine pollen concentration during the above period in the region of Listvennichnoye settlement. The relative error did not exceed 10%.

Figure 2 shows the isolines of the calculated mass rate of the pine pollen flow during the period from June 14 to 18, 2000. Using mathematical simulations we calculated the value of the pine pollen mass density in the region of Listvennichnoye settlement, 555 μg/(m$^2$ per day), which is close to the measured value during the same period in the same region, 654.5 μg/(m$^2$ per day), the relative error was less than 20%.

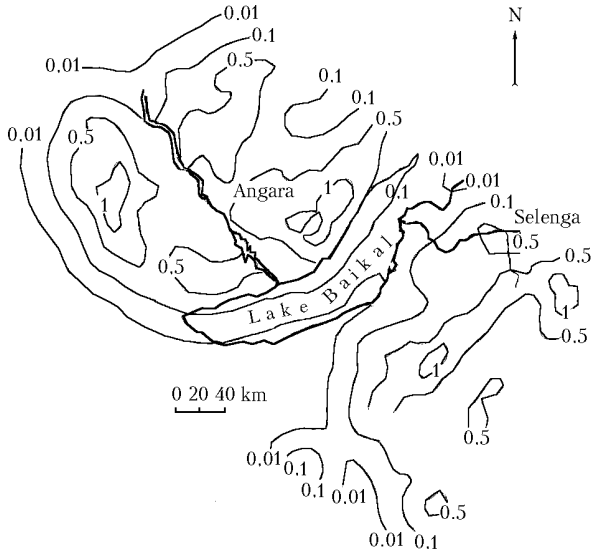


**Fig. 3.** Isolines of the mass rate of the pine pollen flow, g/(m$^2$·season) calculated from June to July 2000 (Lake Baikal, Angara, Selenga).

Figure 3 shows the distribution calculated by the model of the pine pollen mass flow rate during the period from June to July 2000. We determined the mass of deposited pine pollen on the surface of the southern part of the lake of 9000 $km^2$ area in summer of 2000: 1000 kg.

Thus, a comparison of the calculated results and the data of measurements has shown their satisfactory qualitative and quantitative agreement.

## Acknowledgments

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