Influence of meteorological conditions on spreading and transformation of aerosol and gas components in the Lake Baikal region

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The influence of weather conditions on the spreading and transformation of sulfur, nitrogen, and other minor gas constituents in the Lake Baikal region is studied through numerical simulation. The sources of the atmospheric pollutants under study are the industrial enterprises and automobile transportation of the Irkutsk–Cheremkhovo industrial region, as well as Slyudyanka, Baikalsk, Ulan-Ude, Selenginsk, and Gusinoozersk towns.

The results of instrumental and theoretical investigations show that weather conditions significantly affect the processes of transport, diffusion, and transformation of pollutants in the atmosphere. Therefore, it is important to assess the quantitative characteristics of such impacts.

The conditions in the Baikal region and over Lake Baikal are favorable for accumulation of pollutants in winter and summer periods in the low-gradient fields of the increased and decreased pressures. The pollution transfer from local sources and automobile transport in the winter period, under the conditions of high occurrence of surface and elevated temperature inversions due to intense fuel burning in heat and power enterprises of the Irkutsk–Cheremkhovo industrial region has been studied most thoroughly. In summer months, unlike the winter period, the intensity of the migratory cyclone formation is much lower, but the role of convection is high. In addition, in summer, the enhanced solar radiation flows result in increasing rates of photochemical reactions in the atmosphere with formation of more toxic chemical compounds. It is of interest that now just in summer the trend component in the surface pressure increase is most pronounced over the territory under study (Fig. 1). This component indicates some intensification of the anticyclone formation; and the observed reduction of wind (Fig. 2) favors less intense spreading of pollutants in the atmosphere. With this tendency, the concentrations of sulfur- and nitrogen-containing pollutants at the territory under study in the warm period may increase.

To estimate possible changes, we have analyzed weather characteristics for the summer period of 1994–1995 from the data of hydrometeorological stations in the Angara and Baikal regions and considered various weather situations.

We used the nonlinear nonstationary Euler spatial model.[1] Industrial enterprises and automobile transport of the Irkutsk–Cheremkhovo industrial center, as well as Slyudyanka, Baikalsk, Ulan-Ude, Selenginsk, and Gusinoozersk served as sources of pollution; data on their total powers were taken from Refs. 2–4.

The processes of spreading pollution were simulated for the area of 500×250 km^2 and the height of 5 km above Lake Baikal surface. The time and horizontal steps were 150 s and 5 km; the vertical step was specified as follows: up to the height of 350 m it was equal to 50 m and then 150, 1000, 1500, and 2000 m. The initial concentrations were taken equal to 0.93 kg/m^3 for molecular nitrogen [N_2], 0.297 kg/m^3 for molecular oxygen [O_2], $2.23\cdot10^{-4}$ kg/m^3 for water vapor [H_2O], and 10^{-7} kg/m^3 for molecular hydrogen [H_2]. It was assumed that hydrogen peroxide H_2O_2 is always present in air, and its concentration of 10^{-9} kg/m^3 is constant both in space and time. The coefficients of the turbulent diffusion were calculated using the equations of semi-empirical theory of turbulence.[1]

Weather characteristics for the first group of numerical experiments corresponded to anticyclone intensification in the southern part of the Baikal region, and the second group corresponded to a deep cyclone passing from the west through the territory under study. At the height of the steering flow (3 km), meridional flows from the north dominated during the anticyclone intensification, and zonal and southern flows prevailed during the cyclone passage. In the calculations of the mass flow density of sulfates, nitrates, and nitrites (dry sedimentation), the rate of gravitational sedimentation was taken equal to 0.5 cm/s.

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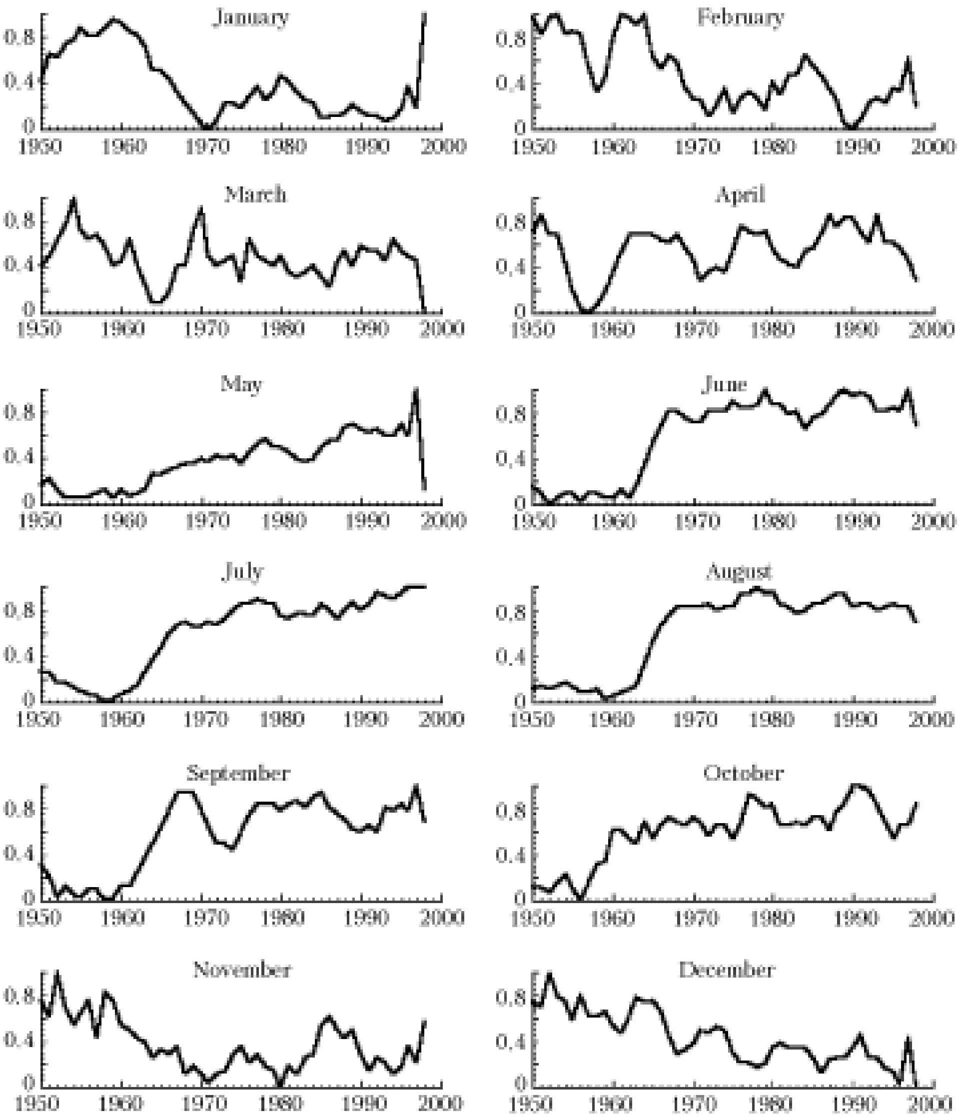

Fig. 1. Many-year behavior of the surface pressure in the Baikal region (in rel. units).

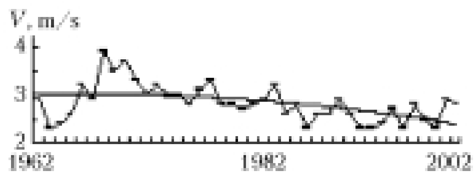

Fig. 2. Many-year behavior of the mean wind velocity in July in the Baikal region.

To estimate the contribution of emissions from each group of enterprises (Irkutsk–Cheremkhovo industrial region, Slyudyanka and Baikalsk, Ulan-Ude, Selenginsk, Kamensk, Gusinoozersk) to pollution of the southern part of Lake Baikal at cyclonic and anticyclonic circulations, model calculations with the real emissions of the above groups separately have been carried out. The results are given in the Table. The first column lists the sources (ICh denotes the Irkutsk–Cheremkhovo industrial region, SU is for the enterprises of Selenginsk and Ulan-Ude, and SB stands for the enterprises and autotransport of Slyudyanka and Baikalsk); it is assumed that other groups emitted no pollutants at that time. All other columns present the calculated contributions of the sources to pollution of the Southern Baikal region with inorganic acids at the cyclonic and anticyclonic circulations.

Contributions of individual sources of emission of sulfur and nitrogen compounds to pollution of the Lake Baikal region

Sources	Contribution to pollution of the southern part of the Lake Baikal region, %, at the circulation					
	cyclonic			anticyclonic		
	H_2SO_4	HNO_3	HNO_2	H_2SO_4	HNO_3	HNO_2
ICh	34	23	23	81	66	38
SU	27	24	4	0	2	0
SB	39	53	73	19	32	72

Thus, at the anticyclonic circulation, the contribution of the Irkutsk–Cheremkhovo industrial center to pollution of the Southern Baikal hollow with inorganic acids is the highest, the influence of the pollution sources of Slyudyanka and Baikalsk is lower, and the effect of Selenginsk, Kamensk, and Ulan-Ude is insignificant. At the cyclonic circulation, the largest contribution is due to the enterprises of Slyudyanka and Baikalsk, the contribution of the Irkutsk–Cheremkhovo industrial center is somewhat smaller, and the effect of the sources located in the River Selenga valley is the weakest.

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