# Study of characteristics of the Asian High and its effect on atmospheric pollution in the Lake Baikal region

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Quantitative characteristics of sedimentation of suspended matter, as well as nitrogen and sulfur compounds onto the area of south Lake Baikal have been estimated under different conditions of the Asian High development.

The main baric formation determining the climatic conditions in Southern Siberia during a cold season (September–April) is the Asian High, developing under the complex combination of thermal and circulation factors, intensified by the effect of orography.

The spatial structure of this formation is now studied in detail, the statistical characteristics are refined, and the relation between weather factors in different regions of Eurasia and the Asian High dynamics is found.[1,2] Note that the Asian High dynamics is closely connected with the influence of the high-altitude Tibetan High, that is, with southern latitudes.[3]

The aim of this work was to study the synoptic conditions for formation and development of the Asian High, as well as to estimate the effect of its intensity on the state of the air basin in the southern part of Lake Baikal based on the data of Irkutsk Territorial Administration for Hydrometeorological and Environmental Monitoring and on the results of numerical simulation.

The analysis of near-surface synoptic maps for 2000–2003 has shown that movable anticyclones determining the Asian High are observed within 30–79°N and 30–143°E. In the most cases ($\geq$ 54%) the center lied in Mongolia (50°N, 99°E).

Most often the formation of the Asian High was caused by the passage of western (29%) and south-western (19%) anticyclones, as well as by the local anticyclonegenesis (14%) under conditions of convergence of the cold arctic air in the rear of the upper trough, oriented from Yakutiya or Khatanga regions ($\geq$ 55%). The convergence of the subtropical air in the front of the upper ridge, oriented from Mongolia (37%), contributes significantly to the dynamics of the winter anticyclonegenesis.

In the long-term variations of the Asian High intensity since the 1970s till now, the increase of the atmospheric pressure in the fall period and some decrease in winter were found against the background of the increase of geopotential heights and an insignificant increase of temperatures in the 500–1000 hPa layer (Fig. 1).

One of the possible causes for the observed climatic changes in the region of the Asian High may be the increase of the meridional temperature gradient between the low and high latitudes at a more pronounced manifestation of El Niño, which correlate well with the intensification of subtropical jet streams in the model experiments.[4] The development of the subtropical zone of increased pressure leads to an increase in the zonal transport rate and more frequent continental transport of warm air masses, which weaken the winter anticyclonegenesis over Asia.

Along with the trend component, in the interannual variability of the surface pressure in winter we can clearly see the quasi-decennial and quasi-vicennial oscillations, characteristic of the intensity of oceanic centers of action in the atmosphere of the Northern Hemisphere. The superposition of the trend component, caused by southern processes, and the shorter variations, associated with northern latitudes, determines significant spatiotemporal inhomogeneity of the pressure field in the region of the Asian High, especially, in the regions lying at the turn of the influence of upper troughs from the north and upper ridges from the south, in particular, the Pre-Baikal region.

Against the background of the climatic changes observed in the Pre-Baikal region in winter, in the past 15–17 years the decrease occurs in the concentrations of some pollutants, except for nitrogen oxides, whose increase in the recent years is likely connected with the higher traffic (Fig. 2).

To study the influence of the Asian High intensity on the state of the air basin in the south of Lake Baikal, we have considered the synoptic situations at the well-pronounced Asian High (for the anomalously cold winter of 2001 taken as an example) and the weak Asian High (for the anomalously warm winter of 2002).

The typification of synoptic processes over Asia has shown that, in the anomalously cold winter of 2001, the axes of the upper troughs, determining the intensity of cold influxes from the north, in the most cases ($\geq$ 60%) passed near the 110°E meridian. In the anomalously warm winter of 2002, most often they were shifted to the east (120–130°E), and the

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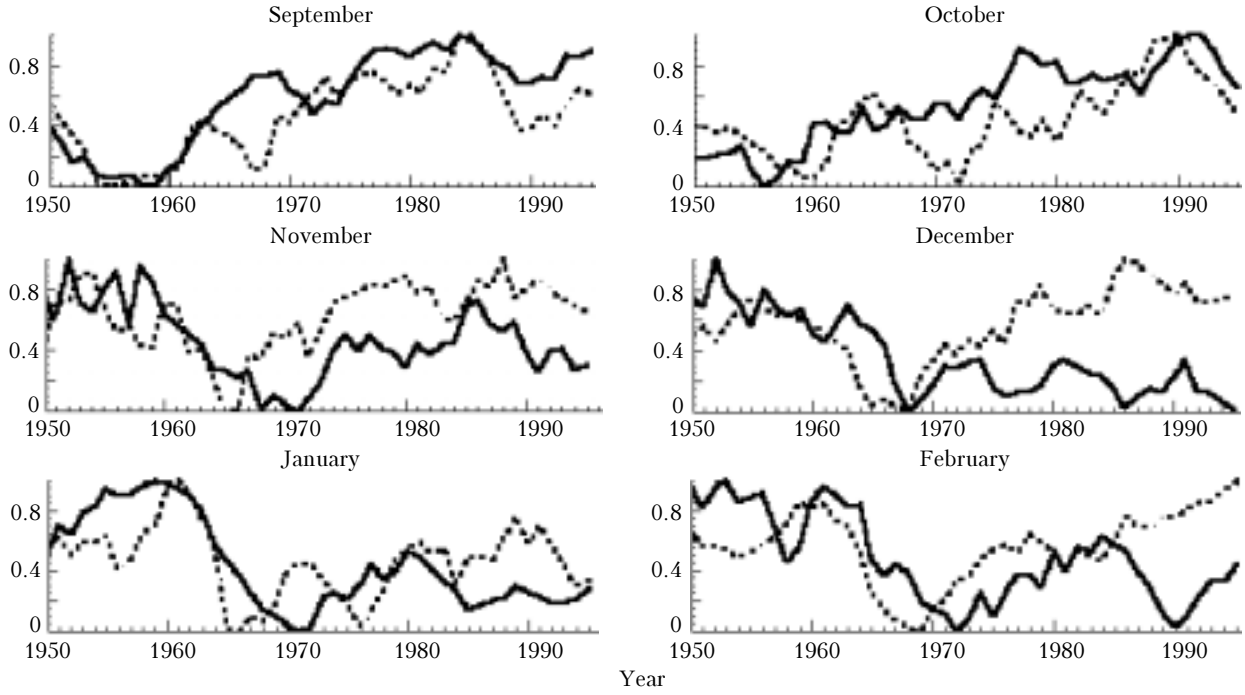


**Fig. 1.** Five-year smoothed curves of the monthly averaged surface pressure (solid curve) and the height $H_{500}$ (dashed curve), normalized to the maximum values, in the region of Ulan-Bator.

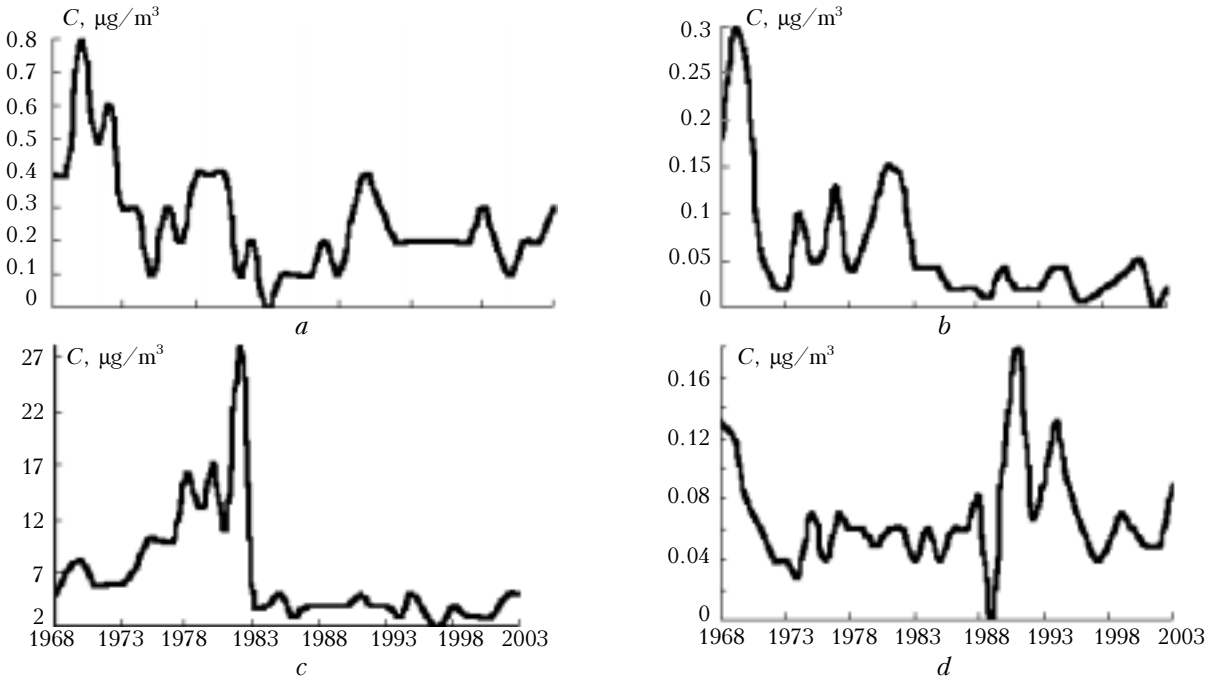


**Fig. 2.** Many-year behavior of the monthly averaged concentrations of suspended matter (*a*), sulfur dioxide (*b*), carbon oxide (*c*), and nitrogen dioxide (*d*) in Irkutsk in January.

territory of Eastern Siberia and Mongolia appeared to be under the weaker influence of the arctic air.

In the selected periods of the first group of processes (January 12–14 of 2001 and December 15–17 of 2001), calm weather conditions prevailed, and the air temperature decreased to –37.5°C. In the second group of the processes (February 9–11 and 24–26 of 2002), the south-eastern winds with the speed of 2–6 m/s prevailed, and the air temperature in some days achieved positive values.

The study of the level of air pollution in industrial centers of Irkutsk Region under the processes mentioned above has shown that the mean concentrations of the suspended matter and sulfur oxides appeared to be higher at the developed anticyclone (respectively, 1.5 and 4 times), while the mean concentrations of carbon

monoxide and nitrogen oxides were higher (roughly 1.5 times) at the weak anticyclone (Fig. 3). The increase of the content of suspended matter and sulfur compounds at low temperatures is caused by the increased fuel combustion at heat and power plants, while the increase in the content of carbon monoxide and nitrogen compounds under conditions of warm winter are caused by the increased contribution of traffic.

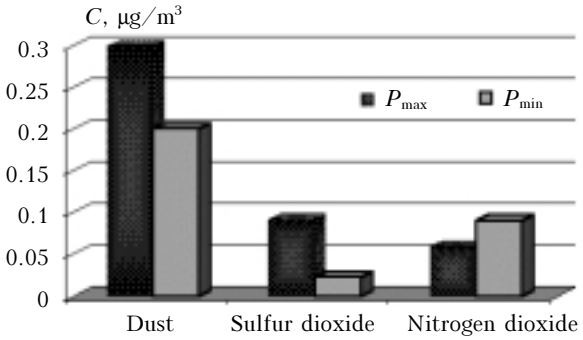


**Fig. 3.** Mean concentrations of pollutants in Irkutsk for the periods of maximum development and weakening of the Asian High in 2001–2002.

Taking into account that the synoptic conditions significantly affect the processes of advective and convective transport, diffusion and transformation of pollutants in the atmosphere,[5–7] to estimate the quantitative characteristics of this effect, the processes of spreading of the solid suspended matter, sulfur and nitrogen compounds in the region of Lake Baikal were simulated numerically with a nonlinear nonstationary spatial Euler model.[8] The pollutants are emitted by plants and traffic of the Irkutsk–Cheremkhovo Industrial Center, Slyudyanka and Baikalsk, Ulan-Ude, Selenginsk, and Gusinoozersk, whose total emission rates are borrowed from Refs. 9 and 10.

The processes of spreading were simulated for a 500×250 km area at the height of 5 km above Lake Baikal surface. The time and horizontal steps were, respectively, 150 s and 5 km; the vertical step was defined as follows: 50 m up to a height of 350 m, 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 ($O_2$), $2.23 \cdot 10^{-4}$ kg/m$^3$ for water vapor ($H_2O$), and $10^{-7}$ kg/m$^3$ for the molecular hydrogen ($H_2$). It was assumed that hydrogen peroxide $H_2O_2$ is always present in the air and its concentration, equal to $10^{-9}$ kg/m$^3$, remains constant both in space and time. The turbulent diffusion coefficients were calculated using the equations of the semiempirical theory of turbulence.[8] In calculating the density of mass flows of sulfates, nitrates, and nitrites (dry deposition), the gravitational sedimentation rate was taken 0.5 cm/s.

The results of numerical experiments have shown that during 3 days under conditions of a developed Asian High 19 tons of suspended matter are deposited on the Southern Baikal surface, having an area of 9 000 km$^2$, while under weak Asian high this amount reaches up to 9 tons only.

The considered region includes the Baikal State Reserve with the area of 1657 km$^2$. The numerical experiments have yielded that 3.3 tons of suspended matter are deposited onto the Reserve territory at the synoptic situation of the first type, while at the situation of the second type this amount is 1 ton.

Further, to estimate the contribution of emissions from each group of the plants (Irkutsk–Cheremkhovo Industrial Center; Slyudyanka and Baikalsk; Ulan-Ude, Selenginsk, Kamensk, Gusinoozersk) to the pollution of the southern part of the Lake Baikal at different intensity of the Asian High, the model calculations were performed for the active sources of emission of these industrial centers separately. The results are presented in Table 1, where the left column lists the operating emission sources provided that other groups do not emit at the same time. The columns give the calculated contributions of the listed sources to the pollution of Southern Baikal and the Baikal Reserve with the solid suspended matter at the anticyclonic circulation of two types. At the well developed Asian High, the Irkutsk–Cheremkhovo Industrial Center is the main contributor to the pollution of the Southern Baikal hollow with the solid suspended matter (99%), while at the weak Asian High the contribution from plants and traffic of Slyudyanka and Baikalsk dominate (96%).

**Table 1. Contribution of different sources emitting the solid suspended matter to the pollution of Southern Baikal and the Baikal Reserve**

| Group of sources | Contribution, % | | | |
|---|---|---|---|---|
| | Southern Baikal | | Baikal Reserve | |
| | Type of synoptic situation | | | |
| | $P_{max}$ | $P_{min}$ | $P_{max}$ | $P_{min}$ |
| Cheremkhovo – Usol'e-Sibirskoe – Angarsk – Irkutsk – Shelekhov | 99 | 4 | 50 | 86 |
| Slyudyanka – Baikalsk | 1 | 96 | 0 | 12 |
| Kamensk – Selenginsk – Ulan-Ude | 0 | 0 | 50 | 2 |

When the territory of the Baikal State Reserve is polluted by the suspended matter under an intense Asian High, the contributions from the Irkutsk–Cheremkhovo Industrial Center and the plants and traffic of Selenginsk, Kamensk, and Ulan-Ude are roughly equal. Under a weak Asian High, the Irkutsk–Cheremkhovo Industrial Center is the main contributor (86%).

Taking into account the transformation of emitted sulfur and nitrogen oxides, the contributions from the groups of plants to the pollution of Southern Baikal with sulfates, nitrates, and nitrites was estimated as well. The results are summarized in Table 2. At the circulation of the first type ($P_{max}$), the Irkutsk–Cheremkhovo Industrial Center is the main contributor to the pollution of the Southern Baikal hollow with sulfur and nitrogen compounds. At the synoptic situation of the second type ($P_{min}$), the contribution from the plants and traffic of Slyudyanka and Baikalsk prevails.

**Table 2. Contribution of individual sources emitting sulfur and nitrogen compounds to the pollution of Southern Baikal**

| Type of synoptic situation | Contribution, % | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cheremkhovo–Usol'e-Sibirskoe–Angarsk–Irkutsk–Shelekhov | | | Slyudyanka–Baikalsk | | | Kamensk–Selenginsk–Ulan-Ude | | |
| | Sulfates | Nitrates | Nitrites | Sulfates | Nitrates | Nitrites | Sulfates | Nitrates | Nitrites |
| $P_{max}$ | 86 | 85 | 57 | 14 | 15 | 43 | 0 | 0 | 0 |
| $P_{min}$ | 10 | 5 | 2 | 89 | 94 | 98 | 1 | 1 | 0 |

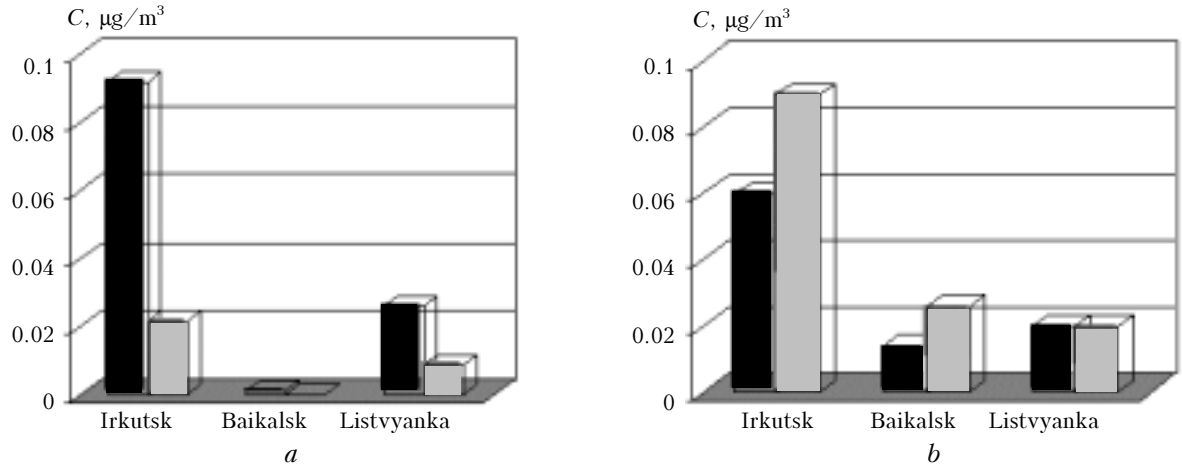


**Fig. 4.** Mean concentrations of sulfur (*a*) and nitrogen (*b*) oxides at the pronounced (black) and weak (grey) Asian High.

The model calculations are in a good agreement with the observations. In the period of the pronounced Asian High, the sulfate content in Southern Baikal (Listvyanka) increases against the background of the increased concentrations of sulfur oxides in Irkutsk (Fig. 4*a*).

The increase of the nitrate content in the period of the weak Asian High is connected with the effect of both the Irkutsk–Cheremkhovo Industrial Center and the plants and traffic of Baikalsk and Slyudyanka (Fig. 4*b*).

Thus, this study has extended the number of ideas on the conditions of formation of the Asian High and its influence on the pollution of the Southern Baikal region.

The quantitative characteristics of the deposition of suspended matter, sulfur and nitrogen compounds on the Southern Baikal surface under different conditions of the Asian High development have been estimated.

At the intense Asian High, the contribution of the Irkutsk–Cheremkhovo Industrial Center to the pollution prevails, but as the Asian High becomes weaker, the contributions from the local sources situated on the southern shore of Lake Baikal increase.

Under conditions of the observed increase of winter temperatures and some weakening of the Asian High, the increase of the contribution of nitrogen oxides from both the local sources and the Pre-Baikal industrial centers may favor the currently observed increase in the acid properties of snow and river waters flowing into Southern Baikal.[11]

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