V.E. Zuev Institute of Atmospheric Optics, SB RAS on the eve of fiftieth anniversary of Siberian Branch

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History of Siberian Branch establishment

Siberian Branch of the Academy of Sciences of the USSR was founded on May 18 in 1957. It was the day, when the Council of Ministers of the USSR issued a resolution on the establishment of Siberian Branch of the USSR Academy of Sciences. It was written in the resolution: "The main task of SB of the USSR AS is the development in every possible way of theoretical and experimental investigations in physicotechnical, natural, and economical sciences directed toward solving the most important problems and the problems whose solution would foster successful development of productive forces of Siberia and the Far East." The Far East branch of the USSR AS was separated out of Siberian Branch in 1970.

Historically, the universities of Tomsk (founded in 1878) and Irkutsk (1918) were the first educational and research centers in Siberia. Academic research and development institutes have appeared in Siberia yet in 30–40s of the XX century as stationary bases and small branches of the USSR AS in Irkutsk, Novosibirsk, and Yakutsk. On the eve of Siberian Branch inauguration, 300 Candidates of science, 40 Doctors of science and 1 Corresponding member of the USSR AS had been working at the universities. When the Soviet Union started the intense development of natural resources and productive forces in Siberia, there appeared a necessity in cardinal strengthening of the scientific potential of the region. In the end of 50s, when the world-famed soviet scientists Academicians M.A. Lavrent'ev, S.L. Sobolev, and S.A. Khristianovich initiated establishing a series of large scientific centers of the USSR AS in the east of the country, and the government of the USSR supported this proposal. The program of scientific development in Siberia was realized in the shortest time, as well as a series of other important government programs (such as space exploration, development of oil-and-gas resources of the West Siberia). So, the first Novosibirsk scientific center SB of the USSR AS was established in 1964. The leading scientists of prestigious institutes of Moscow, Leningrad, and Kiev left their institutes in European part of the USSR and moved to Siberia with their students. The first chairman of the Presidium of Siberian Branch of the USSR AS was Academician M.A. Lavrent'ev (1957–1975), then G.I. Marchuk (1975–1980), V.A. Koptyug (1980–1997), and N.L. Dobretsov (since 1997). From the beginning of its existence, the main principles of the the Siberian Branch activity were:

– advanced development of complex investigations on basic problems aimed at gaining new knowledge that is useful for solving various practical tasks;

– close cooperation with national economy, active support of innovations;

– integration of science and education: participation of scientists and use of material resources of academic institutes in personnel training.

These principles are still the basic ones in work of the Branch. Enthusiasm of scientists and devotion to science allowed establishing powerful scientific center in Siberia for quite a short period. At present, Siberian Branch of the Russian Academy of Sciences is the advanced territorial distributed system of complex of scientific centers, institutes, permanent establishments and scientific stations, covering almost the whole territory of Siberia. The scientific centers of SB RAS are based in Novosibirsk, Tomsk, Krasnoyarsk, Irkutsk, Ulan-Ude, Yakutsk, Kemerovo, Tyumen, and Omsk. Some institutes work in Barnaul, Kyzyl, Chita, and Biysk. Siberian Branch of RAS includes 76 research and development as well as design-engineering institutes working in the fields of physical and mathematical, technical, chemical and biological sciences, Earth's sciences, humanities, and economical sciences. On January 1, 2007, a total number of personnel working in Siberian Branch made 31100, including 25471 of the total staff of scientific institutions, and 5629 persons working in scientific service organizations and in social services. The number of researchers is 8952, among them 67 full members and 77 Corresponding members of RAS, 1894 Doctors of Science and 4901 Candidates of Science. Ages of researchers are distributed as follows: 30.9% under 39 years, 18.8% from 40 to 49 years, and 25.8% from 50 to 59 years old.

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Establishment of the Institute of Atmospheric Optics

The laboratory of IR-radiations at Siberian Physicotechnical Institute of Tomsk State University was the basis for establishment the Institute of Atmospheric Optics (IAO). The laboratory included more than 100 personnel in 1966. The main merit of this body both in the USSR and abroad was the competent interpretation of research results on propagation of optical radiation in the atmosphere in view of laser radiation absorption by atmospheric gases, attenuation by aerosols, refraction, meteorological conditions, and other factors.

According to the decision of the USSR AS Presidium, at the beginning of January 1967, a commission arrived in Tomsk with the famous Academician, Nobel Prize winner, A.M. Prokhorov and I.I. Sobel'man, known expert in spectroscopy. The commission made a positive decision that it is quite expedient establishing the IAO SB of the USSR AS, the first academic institute in Tomsk.

In August 5, 1968, the Presidium of the Council of Ministers of the USSR passed a resolution № 594 on establishment of the Institute of Atmospheric Optics in Tomsk, and in September 5, 1969, the Academician M.A. Lavrent'ev approved the resolution of the Presidium of SB of the USSR AS about inaugurating the IAO and providing it with the first five established positions.

Vladimir Evseyevich Zuev was appointed the director-organizer of this new Institute.

From the very beginning, the staff included 1 professor-doctor, and 10 Candidates of science.

In December 19, 2006, Presidium of the Russian Academy of Sciences had decreed to name the Institute of Atmospheric Optics after V.E. Zuev.

Scientific activity of IAO

At present, the Institute carries out investigations in three main fields of the basic research.

1. Atmospheric optics and spectroscopy, propagation of optical radiation in the atmosphere.
2. Investigation of the processes determining optical state of the atmosphere.
3. Optoelectronics systems and technologies of the environmental researches.

These research fields have been approved in 2001 by the Department of oceanology, atmospheric physics and geography RAS (Resolution of November 15, 2001, Protocol № 12).

The subjects of research conform to the foreground programs of research and development, technologies and engineering in Russian Federation, and the list of critical technologies of RF and main areas of the basic research of RAS.

In conformity with transition to the program-oriented planning, the Institute takes part in the following programs of SB RAS:

– optics, laser physics;
– basic problems of interaction between radiation and substance;
– urgent problems in atmospheric optics;
– instrument making fundamentals for Earth's sciences and solution of special problems;
– radiophysics methods of environmental diagnostics.

The Institute realizes nine projects under the above-mentioned programs.

The Institute takes part in a series of programs of the Presidium of RAS and RAS departments, and the interdisciplinary and complex integration programs of SB RAS.

Programs by the Presidium of RAS

1. Femtosecond optics and new optical materials (project "Femtosecond atmospheric optics", under the leadership of the director of IAO Prof. G.G. Matvienko).

2. Climate and environment changes: natural disasters (project "Complex investigations of aerosol and gas components of Siberian atmosphere in order to improve the radiation models, development of methods and instrumentation for optical monitoring in the climate problems," Principal Investigator of the studies Prof. B.D. Belan).

3. Basic problems in oceanology: physics, geology, biology, ecology (project "Investigation of the properties and regularities of atmospheric aerosol variability above the ocean", Principal Investigator of the studies Prof. S.M. Sakerin).

Programs of RAS departments

1. Laser systems, based on new active materials, and optics of structured materials (project "Experimental and theoretical investigations of the processes of stimulated light scattering and multiphoton luminescence in dielectric spherical microresonators at their unsteady excitation by ultrashort laser radiation," Principal Investigator of the studies Prof. A.A. Zemlyanov; project "A new type of active medium: vibronic crystals with electronic pumping," supervisors of the studies Drs. A.N. Mal'tsev and V.P. Lukin).

2. Optical spectroscopy and frequency standards (project "Spectroscopy of the ultra-high resolution," supervisor of the studies Prof. L.N. Sinitsa).

3. Coherent acoustic fields and signals (project "Investigation of acoustical waves coherence propagating in the randomly inhomogeneous stratified atmosphere," supervisor of the studies Dr. S.L. Odintsov).

4. Problems in radiophysics (project "Development of radiophysical methods in atmospheric turbulence investigation," supervisor of the studies Prof. V.A. Banakh).

5. Atmospheric physics: electric processes and radiophysics methods for tropospheric research (project "Acoustic and optical methods of studying the atmospheric processes," supervisor of the studies Prof. M.V. Panchenko).

6. Nonlinear optics of unique laser systems (project "Adaptive amplitude-phase correction of laser beams," supervisor of the studies Prof. V.P. Lukin).

7. Laser systems based on new active materials and optics of structured materials with electronic pumping, supervisors of the studies Dr. A.N. Mal'tsev and Prof. V.P. Lukin.

8. Nanoparticles in natural and technogenic systems (project "Behavior (generation, transfer, transformation, runoff, spatiotemporal variability) of nanoparticles in the atmosphere," supervisor of the studies Prof. B.D. Belan.).

9. Processes in the hydrosphere and atmosphere and interactions; the Earth climate. Regularities and factors of formation, variation and control of climate, forecast (project "Investigation of natural and anthropogenic factors determining the atmospheric composition, estimation of current variations," supervisor of the studies Prof. Yu.A. Pkhalagov).

10. Formation of land water resources, prediction of their condition and quality with regard for climate variation and economic development (project "Gas exchange processes in the system "surface waters of Baikal – atmosphere"; prediction under conditions of global climate variation and anthropogenic load," supervisor of the studies Prof. M.V. Panchenko).

Interdisciplinary integration project SB RAS "Investigation of laser radiation propagation in ultrasonic gas flows and development of turbulent pulsation diagnostic methods," supervisor of the studies Prof. V.A. Banakh.

Complex integration project SB RAS "Propagation of femtosecond terawatt laser pulses through the atmosphere along extended paths," supervisor of the studies Prof. G.G. Matvienko.

Complex integration project SB RAS "Features of tropospheric aerosol formation over continental Siberia and fields of ozone and aerosol above the water area of Far-East oceans," supervisor of the studies Corresponding Member of RAS V.V. Zuev.

Complex integration project SB RAS "Development of photometric network AEROSIBNET for investigations of climate-ecological action of the atmospheric aerosol in Asian part of Russia," supervisor of the studies Prof. S.M. Sakerin.

Complex integration project SB RAS "Development of adaptive image correction systems for the ground-based telescopes," supervisor of the studies Prof. V.P. Lukin.

The project is conducted jointly by IAO SB RAS and ISTP SB RAS.

Besides, the Institute takes part in the following interdisciplinary and complex integration projects of SB RAS:

– Ice cover of Lake Baikal as a model medium for studying the tectonic processes.

– Establishment of the distributed information-analytical medium for investigation the ecological systems.

– Investigation of the cosmic rays effect on aerosols and cloud formation.

– Production and investigation of supernarrow optical resonances in order to form a laser frequency standard with the stability of $\sim 10^{-16}$ for precision measurements and fiber-optic communication lines.

The Institute takes an active part in large international projects:

– International program "Geospheric and biospheric investigations" in cooperation with the National Institute of Environmental Researches, Japan. The Russian part of the program is being done the team of the airborne laboratory and the ground support group of IAO SB RAS.

– Institute joined the realization of YaK-1 project launched under the Agreement on establishment of the Russian-French European scientific association on studying the carbon and ozone cycle in Eurasia. Agreement was concluded between CNRS (France) and RAS, RFBR.

– Institute was included into the list of collaborators of Siberia-2 project, which is being performed under the 6th EU frame program.

– International program "Global aerosol automated network" (AERONET), is being performed in cooperation with NASA, USA.

– Atmospheric Radiation Measurement (ARM) Program the contract № 5012.

– European Space Agency (ESA) "Development of Novel Techniques for CO_2 Retrievals over Boreal Forests from Satellite Measurements Suitable for Assessing Carbon Fluxes and Stocks."

– Project of ISTC № B-1063 "Monitoring of atmospheric aerosol and ozone in regions of CIS by means of lidar stations network (CIS-LiNet)."

It is necessary to specify new research areas that have been dynamically developed at IAO SB RAS during few recent years:

1. Femtosecond atmospheric optics.

2. Complex (network) investigations of aerosol and gas components of the atmosphere over the Siberia.

3. Investigations of ozone layer and UV-solar radiation in Siberia on the basis of synthesis of optical, bioindication, and analytical methods.

4. Global modeling techniques in molecular spectroscopy.

A series of foreground scientific results has been obtained in these fields, which are presented as achievements of the Institute in the reports of SB RAS and RAS. Let us mention some of them.

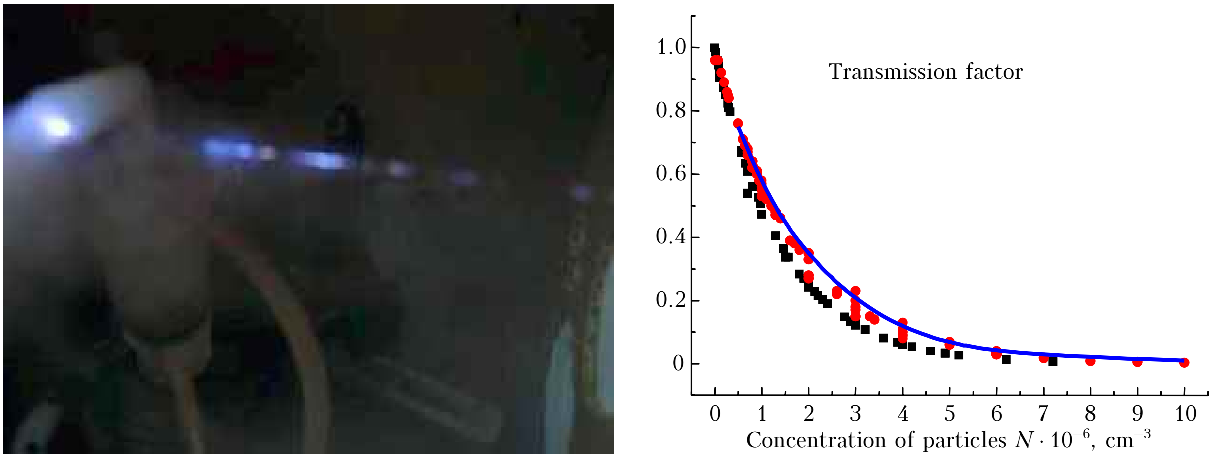
1. It is experimentally and theoretically found that in contrast to the continuous laser radiation transmission, strongly dependent on its power, transmission of a high-power femtosecond pulse by the aerosol atmosphere weakly depends on radiation power (up to 1 TW/cm^2) and it is described by the laws of linear optics (Fig. 1). The effective parameters of femtosecond radiation at its filamentation in the air is determined by the light energy absorbed in plasma channel and by its spatial extension. The effect of nonlinear pulse absorption of femtosecond radiation in molecular gases is

discovered and investigated. A physical model is proposed accounting for this effect by interaction between the induced electric molecular moment and linearly polarized field of laser radiation.[1,2]

2. Development of the "active spectronephelometry" method is completed. This method is based on application of optical aerosol characteristics of the controlled artificial interaction and on the inverse problem solution. It has allowed essentially extending the possibilities of experimental studies of physical and chemical properties of atmospheric submicron particles, including the condensation growth factor and the volatility factor.

Based on long-term all-the-year-round measurements, the annual course of condensation activity of the ground submicron aerosol is established for the first time. It is characterized by the spring maximum and summer minimum stably occurring from year to year.

The results of complex investigation of the CO_2 gas exchange diurnal cycle in the system "atmosphere – water surface" of Lake Baikal have proved[3] that metabolic reaction rates of water biota exceed the rates of physical processes. Therefore, the gas exchange process, in its turn, limits the activity of photosynthesis processes of plankton organisms. Figure 2 presents time behavior of the CO_2 concentration, the coefficient of photosynthesis activity (CPA), and plankton biomass depending on time of the day.



a *b*

Fig. 1. The plasma glow of water drops breakdown under the effect of laser pulse (*a*). Transmission dependence of water aerosol layer on concentration of particles (*b*): under the effect of the high-power femtosecond pulse on the medium (dots); experimental dependence of aerosol transmission for weak He–Ne laser with $\lambda = 0.63$ μm (squares); calculation curve of linear transmission (full line).

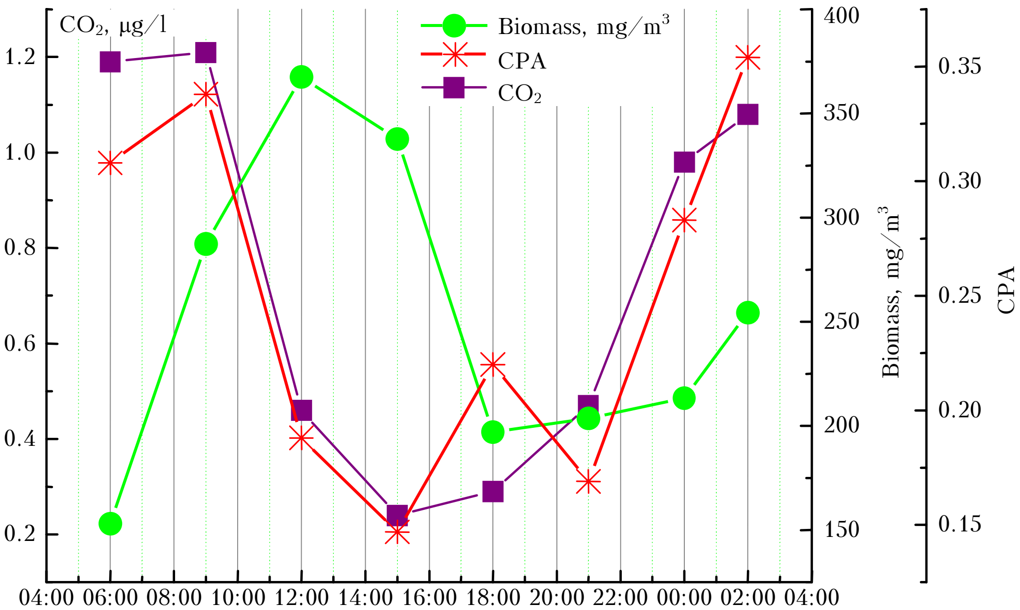


Fig. 2. Diurnal behavior of the CO_2 concentration, CPA, and plankton biomass.

3. Data on the ozonosphere obtained at Siberian lidar station have shown for the first time that seasonal behavior of the stratospheric ozone (Fig. 3) in the extended layer from the tropopause to 16 km is washed away due to the migration of subarctic jet flows. For the first time, on the basis of the dendrochronological data analysis, the behavior of total ozone concentration (TOC) has been reconstructed in the past (500 years ago), the quasicyclicity of the long-period ozonosphere oscillations has been revealed and it is found that instrumentally observed TOC variability at present does not exceed the amplitude of natural oscillations in the past.

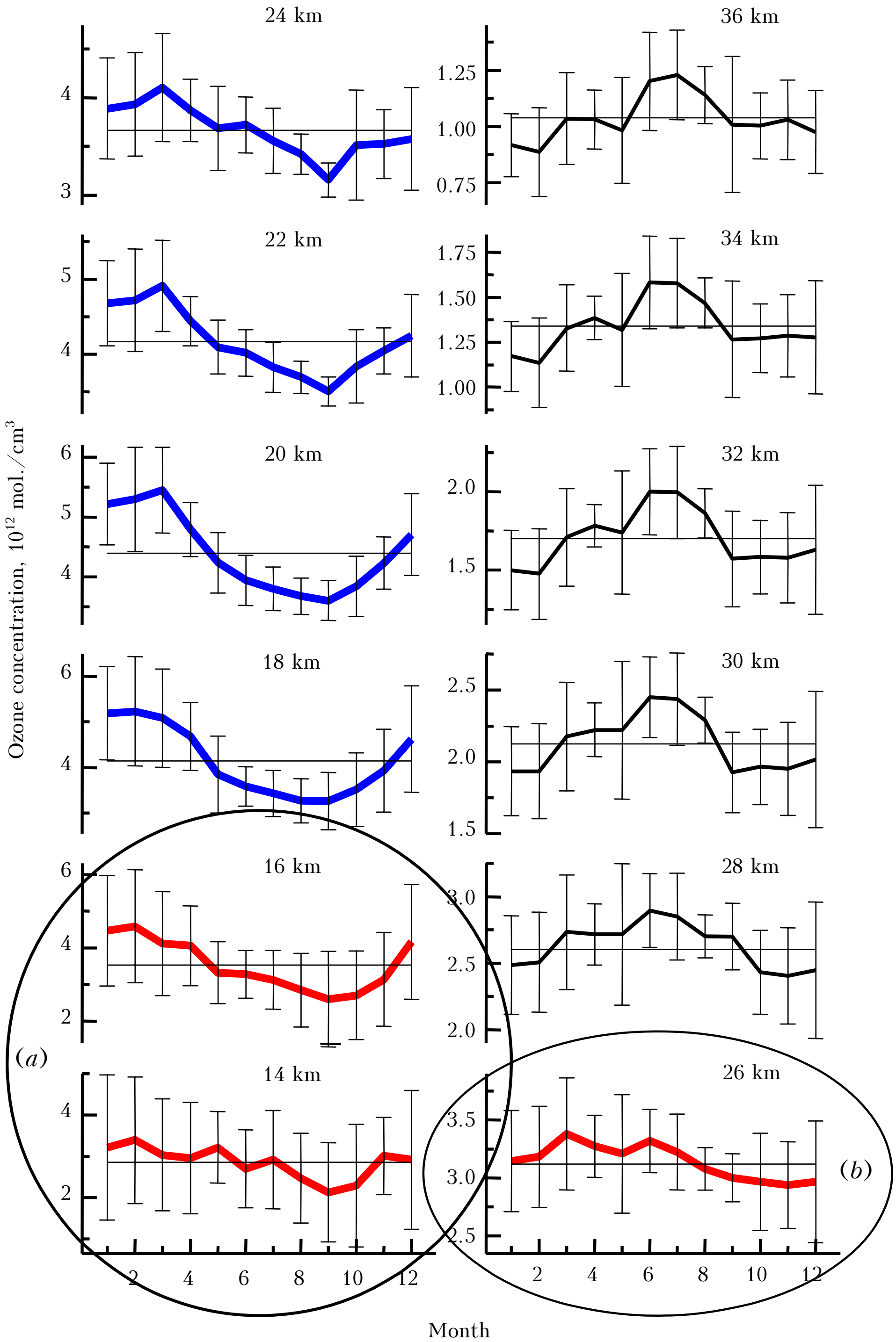


Fig. 3. Results of climatological investigations of the stratospheric ozone based on the data of laser sounding at Siberian lidar station, IAO SB RAS in Tomsk from 1996 to 2003. The regions of stratospheric heights are marked without statistically defined seasonal behavior: region of migrating subarctic jet flows action (*a*), region of velopause (*b*).

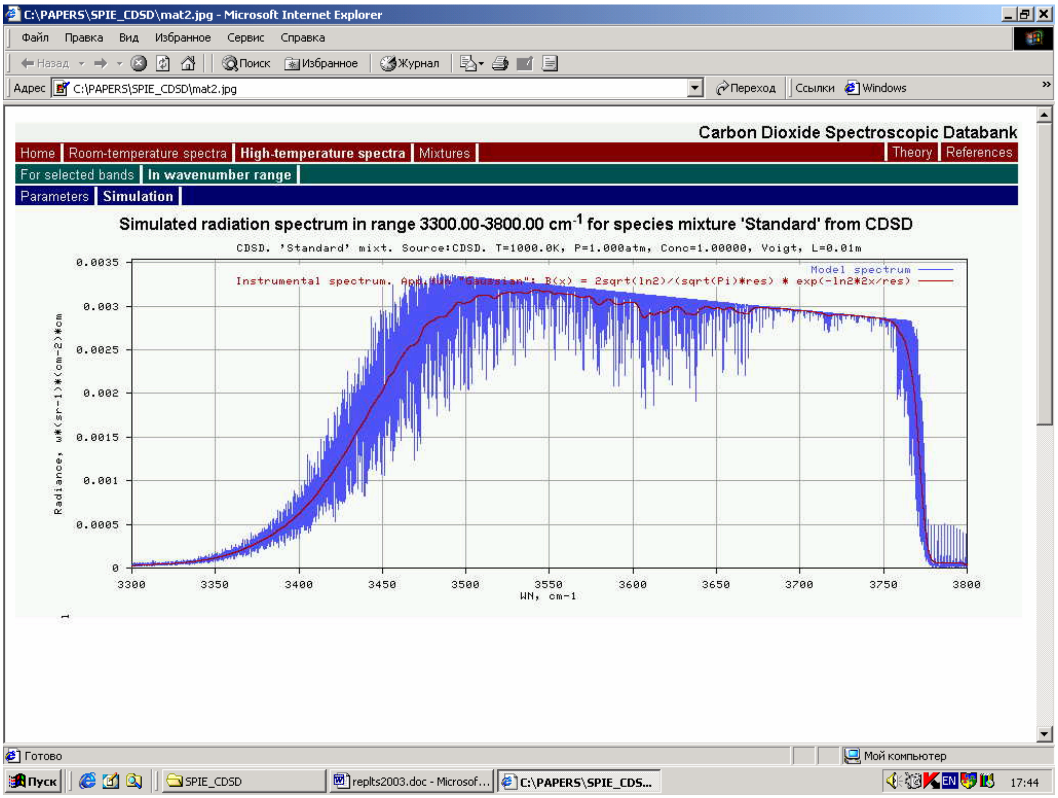


Fig. 4. Internet-available information system CDSD (http://cdsd.iao.ru). An example of calculated emission molecular spectrum of CO_2 of low (—) and high (—) resolution.

It is shown that global warming of climate in 30s years and the last quarter of XX century occurred in periods of long-term depletion of the ozonosphere above the extended territory of boreal Eurasian forests, when under the effect of UV-B solar radiation amplifying during these periods, the balance of global CO_2 was disturbed owing to the omnipresent photosynthesis depression in plant biota.[4]

4. The global modeling methods have been developed for the high-resolution spectra of ozone molecules, carbon dioxide, and a series of other molecules over a wide wavelength range providing the accuracy of calculations comparable with that of experiment, and the Internet-available systems were established "Spectroscopy and molecular properties of ozone" (S & MPO) and CDSD-1000 (high-temperature CO_2 spectra) (Fig. 4).

It is proved that absorption of the short-wave radiation is induced by the finely divided aerosol and exceeds the contribution of molecular components by more than an order of magnitude.[5]

5. An adaptive correction theory of distortions is developed for atmospheric systems of viewing and optical beams forming. It is found on the basis of numerical modeling, laboratory and full-scale tests that active systems of viewing in scattering media with spatial selection provide 8 to 10-fold increase of the limiting range and 5 to 7-fold contrast improvement. Figure 5 presents the comparison of image contrast obtained in active and general systems of viewing. It is also found that information loss about vortex phase component reduces the quality of adaptive phase correction under conditions of "strong" intensity fluctuations.

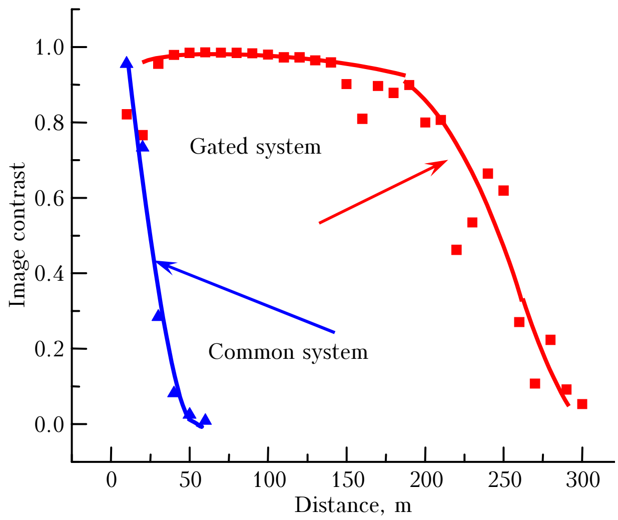


Fig. 5. Comparison of potentialities of two generations of active viewing systems.

Scientific experimental base

A series of unique experimental setups of the world level has been operated at the Institute. One of them, Siberian lidar station, is registered by the Ministry of Science and Technology as a unique setup. A series of large-scale model setups makes a basis for the "Atmosphere", being a part of registry of the collective use centers of Russian Federation.

Regular investigations of gas-aerosol composition and atmospheric meteorological parameters have been carried out at the Institute by use of the airborne laboratory (Fig. 6), which is equipped with unique complex of contact and remote meters for the thorough investigation of atmosphere and ecological monitoring.

A network of solar radiometers is being developed within the frameworks of international aerosol network AERONET, located in background regions, and regional network of photometers near big industrial centers.

Siberian lidar station, located in Tomsk, is the single station on the Asian territory of Russia, providing for regular sounding of aerosol, ozone, gas components of ozone cycle, cloud cover, and temperature.

Fig. 6. AN-30 Instrumented Aircraft laboratory.

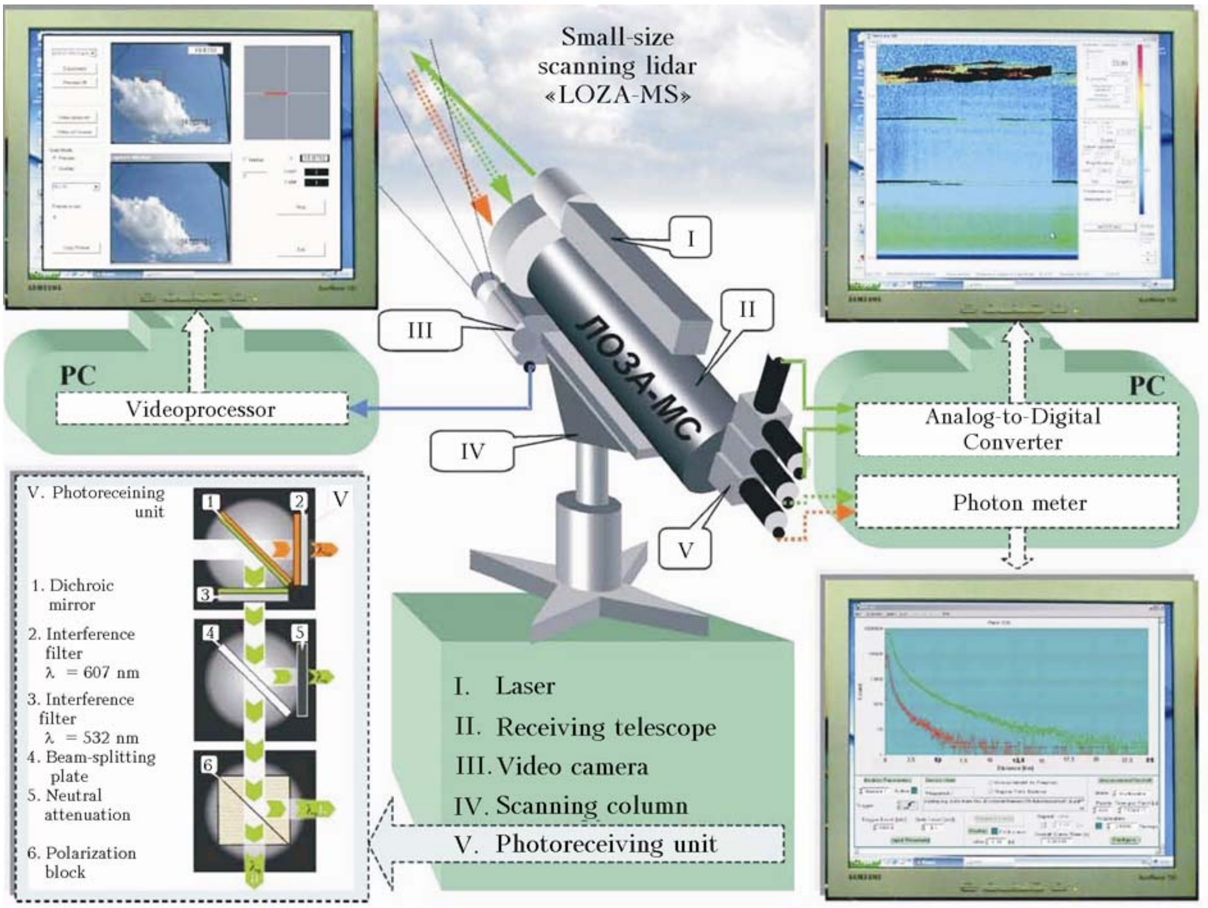


Fig. 7. Functional block-diagram of LOZA-MS lidar and examples of certain realizations of the atmospheric sounding sessions.

A park of mobile lidars of ground-based, shipborne, and airborne ones is permanently modified. Figure 7 presents functional block-diagram of one of the working lidars, LOZA-MS, and examples of certain realizations of the atmospheric sounding sessions.

A stand of the diode laser spectrometers of ultra-high resolution is put into operation.

A center of reception and thematic processing of satellite information for the automated processing and interpretation of data on aerospace sounding of the atmosphere and ground surface is being operated in a routine mode.

In 2006, the Institute was awarded Federal Agency Grant on Science and innovations to make a unique "Laser-biostand" for investigating the optical characteristics and processes of gas-aerosol exchange of plant biota with atmosphere and for the development of physical grounds for remote sensing methods of natural biosystems. The list of laser and Fourier spectrometers, modern transmitters for lidars was increased owing to the support of SB RAS. A lidar station for sounding the atmosphere at high altitudes was put into operation at Yu.G. Shafer Institute of Cosmophysical research and Aeronomy (Yakutsk) within the limits of the "Importosubstitution" program SB RAS.

The Institute laboratories are equipped with necessary facilities for operating within the limits of main research fields. Computer facilities enumerate more than 400 PCs, united into the local network. Besides, the Center of integrated information systems (CIIS) disposes of calculation cluster (10nodes 2^* Pentium III 1 Ghz/1 Gb, server 2^* Pentium III 1 Ghz/1 Gb, 3^* SCSI HDD 18 Gb, network Gigabit Ethernet), put into operation in 2001.

Regular personnel of the Institute

The total number of people working at the Institute in January 1, 2007 was 507 people, among them 224 researchers, including 2 Corresponding members of RAS, 36 Doctors of Science, 91 Candidates of Science, 55 junior researchers under 33 years inclusive, 45 post-graduate students

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