# ANNOTATED REPORT ON THE PROJECT OF CLIMATIC–ECOLOGICAL MONITORING OF SIBERIA AS PART OF THE REGIONAL SCIENTIFIC–ENGINEERING PROGRAM SIBERIA

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## INFORMATION

The Editorial Board of the Journal *Atmospheric and Oceanic Optics* has decided to publish an annotated report on the Project of Climatic–Ecological Monitoring of Siberia for 1994. It was sent to the Executive Management of the Scientific–Engineering Program Siberia as an integral part of the Project.

Implementation of this Project goes back to 1993. The objective of the Project is to coordinate the work of various scientific–research, project–design, and other institutions concerned with the problems of regional climate changes and effect of anthropogenic factors on these changes. Now, eight research institutions from different Siberian towns take part in this Project.

The Project covers investigations of a while class of atmospheric–physical and a number of medico–biological factors contributing to climatic and ecological problems of Siberia. Key directions of investigation and methods and hardware used for implementation of the Project were described at length in the paper entitled "Climatic–Ecological Monitoring of Siberia (CEMS): Program of Physical Investigations of Local, Regional, and Global Changes in the Atmosphere" by M.V. Kabanov, Coordinator of the Project, Corresponding Member of the Russian Academy of Sciences, Director of the Design and Engineering Institute "Optika" of the Siberian Branch of the Russian Academy of Sciences (Tomsk), published in the seconds issue of our Journal in 1993.

The Editorial Board would like to hope the publication of such annotated reports in thematic issues of our Journal will become a tradition.

## MONITORING OF METEOROLOGICAL (THERMODYNAMIC) STATE OF THE ATMOSPHERE

*Design and Engineering Institute "Optika",*
*Siberian Branch of the Russian Academy of Sciences,*
*Tomsk*
*Tomsk State University*

To solve the problems formulated in this part of the Project, the work has been done on both creation of the material–technical basis for monitoring of the key physical parameters of the atmosphere and analysis of climatic changes in Siberia on scales from a season through a decade.

A Climatic–Ecological Observatory started its operation as the main experimental base in October of 1994. It consists of:

– a standard meteorological station created under technical, economic, and methodological support of Western–Siberian Administration of Roskomgidromet;

– an actinometric station;

– a station for observing the atmospheric electricity and a set of posts for observing aerosol and gas composition of air, atmospheric radioactivity, etc. This Observatory is unique in Russia in both observational means and a set of measurable parameters.

The average monthly and annual temperature variations in different regions were evaluated based on theoretical studies with the use of database comprising temperature measurements at 28 stations of Tomsk region performed since 1952 till 1992. In particular, a positive trend of temperature in the entire region was found. Its magnitude varied from 0.84 to 5.15 deg/century depending on specific region of observations. It was found that throughout the vast territories the trend magnitude distribution was focal in character. Moreover, in the last forty years the estimated rate of temperature rise (3.26 deg/100 years) has increased substantially compared to its estimate for the period between 1975 and 1992 (1 deg/100 years).

## MONITORING OF ATMOSPHERIC DYNAMICS

*Computer Center,*
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Some basic mathematical models have been developed to study climatic changes in industrial regions as well as transport and transformation of atmospheric pollutants caused by the joint effect of natural and anthropogenic factors. System architecture of models is oriented to problems of atmospheric–ecological monitoring and search for prerequisites to arising ecologically unfavourable situations. The base models implement the principle of nested spatiotemporal scales from local to mesoregional. The models and methods of their application are tested for Novosibirsk industrial region, including Novosibirsk, as an example.

The models have been adapted to the conditions of this region. There are three modifications of the model for an individual zone, a town, and a region. The models can operate in the regimes of both current and prognostic–expert scenarios of modeling. To combine the problems of monitoring and forecasting the methods of direct and inverse modeling were realized. In particular, the method of regionalization by severity of anthropogenic effects and evaluation of the regions exposed to these effects for specific protected zones and for observers who measure the pollutant concentration was realized. These computations allow one to schedule the observations using the functions of sensitivity of functionals that simulate the regimes of observations.

To update the hardware for monitoring of the thermodynamic state of the atmosphere, a three–component ultrasonic anemometer–thermometer has been modernized to provide measurements of both mean and turbulent characteristics of the temperature and wind velocity, heat flux, and air momentum.

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## MONITORING OF ATMOSPHERIC AEROSOL, CLOUDINESS, AND PRECIPITATION

*Institute of Atmospheric Optics,*
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*Tomsk*

In parallel with routine monitoring of controllable parameters, full–scale processing and analysis of the results obtained in 1993 have been accomplished. We investigated diurnal and monthly variations in aerosol particle number density and aerosol disperse composition under background rural conditions and near large industrial center (Tomsk). The aerosol particle number density in the ground atmospheric layer was found to be maximum in winter due to the lowest seasonal height of the mixing layer. It was noted that variations in coarsely dispersed fraction of aerosol in going from spring to summer can be attributed to a certain extent to photochemical processes of its generation.

In 1994, we focused our attention on intercalibration of contact and noncontact (remote) means of monitoring of the parameters of atmospheric aerosol in the ground layer and troposphere. The following systems were employed: airborne nephelometer, meter of spectral transmission, meter of spectral aerosol thickness of the atmospheric column, aerosol lidar LOZA–3, aerosol wind lidar LISA, airborne lidar MAKREL', and polarization lidar STRATOSFERA. Summer measurements were carried out at the Climatic–Ecological Observatory (Tomsk) and from onboard the OPTIK–E aircraft–laboratory. The comparison results revealed satisfactory agreement of the measured optical parameters of aerosol at altitudes up to 4.5 km. Some systematic deviations of lidar profiles, accounted for by imperfect algorithms for processing lidar returns, have been found. The entire range of variation of the discrepancy of the values measured with different instruments, on average, did not exceed 30–50%.

## MONITORING OF ATMOSPHERIC GASES

*Institute of Atmospheric Optics,*
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At this stage, the methodology and logistics of observations about the current concentration of the basic biospheric ($O_2$, $N_2$, etc.), greenhouse ($CO_2$, $CH_4$, $H_2O$, $O_3$, etc.), and natural and anthropogenic gases hazardous to human health (mercury vapors, heavy hydrocarbons, fluorine– and chlorine–containing compounds, sulfuric and nitric oxides, etc.) has been created in accordance with the previously given priorities.

Techniques for detecting mercury and its compounds in water and soil have been developed and sent for certification to the State Standard Committee. The techniques for detecting mercury in biological objects have been certified by the State Standard Committee. Aureoles of mercury scattering round anthropogenic sources were investigated. Some biological objects were simultaneously analyzed with the RGA–11 analyzer, employed in monitoring of mercury vapors, and the Perkin Elmer instrumentation. A disagreement among the results did not exceed 5%.

For certification of opto–acoustic gas analyzers, the International Program of Developing Means of Opto–Acoustic Gas Analysis was drawn up in collaboration with the Institute of Physical Chemistry of the Czech Academy of Sciences. The threshold sensitivity of an opto–acoustic detector was investigated in 1994 as part of this program with simultaneous detection of $C_2H_4$ and $CO_2$ in air at optimal $CO_2$–laser wavelengths (10.591 and 10.532 μm). These investigations were carried out on a stand of the Institute of Physical Chemistry of the Czech Academy of Sciences in Prague with simultaneous use of standard analytical methods.

An opto–acoustic meter of CO concentration in air was incorporated into the gas–measuring instrumentation at the experimental base of the Climatic–Ecological Observatory. In 1995, we plan modernization of this instrumentation and its international intercalibration at the Institute of Physical Chemistry of the Czech Academy of Sciences.

## MONITORING OF OZONE AND COMPONENTS OF OZONE CYCLE

*Institute of Atmospheric Optics,*
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*Tomsk*

During 1994, regular lidar observations were made about vertical distribution of stratospheric ozone and aerosol. An analysis of lidar data revealed the reduction of volcanic aerosol pollution of the atmosphere. The maximum scattering ratio decreased from 2 in the early 1994 down to 1.2 in late 1994 that only slightly exceeds its background value (1.15). This clearly demonstrates the completion of the effect of volcanic aerosol, emitted after eruption of Pinatubo Volcano, on the ozone layer that was observed even in 1993.

The total ozone content (TOC) and near–ground ozone were regularly observed. In July of 1994, the M–124 ozonometer was calibrated at the Main Geophysical Observatory (St. Petersburg) with subsequent correction of previously measured TOC data. The observations about TOC showed high correlation of variability of the atmospheric ozone with variability of synoptic atmospheric processes. The total ozone content was found to increase by 7–8% as compared to that in 1993.

## MONITORING OF UV, VISIBLE, AND IR RADIATION FLUX

*Institute of Atmospheric Optics,*
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Measurements of net and scattered radiation flux, direct solar radiation, and solar radiance time (SRT) have been automated as part of the Program on Monitoring of the Optical Radiation Flux. An automated radiative system developed at the Institute of Atmospheric Optics consists of a standard pyranometer M80–m, an electromechanical attachment for shading the pyranometer, an SRT detector, a multiwave photometer, and an IBM PC AT 386/387 with an analog–to–digital converter. This system was tested in the regime of continual measurements. A two–month (spring–summer) cycle of radiative observations (in Tomsk and at the Rural Scientific Base of the IOA) was realized.

Moreover, processing of the data on monitoring of variations in visible and IR radiation flux in Tomsk region obtained in 1993 has been completed.

The foundations have been laid for creating an electronic database of the solar UV radiation flux incident at the Earth's surface. According to the algorithm, observation results are recorded in three spectral ranges and 3–8 different modes. A run of measurements carried out in 1 or 3 minutes revealed certain quasiperiodicity superimposed on the bell–shaped dependence of UV irradiance of the Earth as a function of time of a day. The quasiperiodicity (with typical period of 20–30 min) is not always related to cloudiness since it is sometimes observed in clear weather.

## MONITORING OF RADIO WAVE RADIATION FLUX

*Siberian Physical–Technical Institute*
*at the Tomsk State University*

A mathematical model of spatiotemporal density distribution of the strength of electro–magnetic field (EMF) from anthropogenic and natural sources in the circumterrestrial space has been constructed to evaluate the EMF strength in different regions of the Earth surface and in the ionosphere. A series of numerical experiments on estimating the effect of arrangement of radio wave sources, state of ionospheric plasma, characteristics of reflection and absorption of radio waves by the Earth's underlying surface, as well as some other factors on spatiotemporal distribution of electromagnetic radiation density in the ground layer and circumterrestrial space have been made for the developed model.

Following the developed concept of monitoring of the electromagnetic flux, a receiving measurement–computational complex was designed and put in regular experiments. The complex allows one to store information about the measured spectra of signal power in the frequency ranges between 1 and 30 Hz and 90 and 1000 Hz and power spectra in the frequency range between 1 and 40 Hz of envelopes of signals of LF radio range between 1 and 300 kHz and similar spectra of envelopes of SW signals of the radio range between 1 and 30 MHz at the selected frequencies. The spectra of four envelopes of signals of regularly operated radio stations were measured. Electromagnetic monitoring of radio wave flux in the frequency range between 1 and 30 MHz was performed on regular days of International Geophysical Calendar.

Regularities and anomalies in variations of the levels of electromagnetic background of the environment were studied. In the radio wave range 1–30 Hz, instrumentation detected global resonances of the resonator Earth–ionosphere, the so–called Schumann resonances. The detected changes in resonance frequencies and $Q$–factors of resonators can be attributed to anomalies. They are obviously caused by local variations in the parameters of resonator walls under the effect of man's activity. In the frequency range of Schumann resonances, there are spectral lines of signals of anthropogenic origin.

## MONITORING OF ATMOSPHERIC ELECTRICITY

*Siberian Physical–Technical Institute*
*at the Tomsk State University*

To record the strength and to map electric fields in a town and in the vicinity of industrial enterprises, a mobile complex incorporating vibrating wire transducers was developed. Possible ways of construction of computer maps of electric field strength were considered based on an analysis of the available hard– and software as well as on international experience in creating and using regional and cartographic computer databanks (geoinformational systems). Functions, architecture, and principles of designing and determining hard– and software needed for constructing the sought–after maps have been chosen.

The varying electric fields are known to affect biosystems only starting from 1–2 V/m. The electric field strength measurements performed in 1994 under "good weather" conditions showed the fluctuations are always observed that intensify in daytime and with stable wind blowing from an industrial enterprise. Under real conditions and joint natural (wind, Sun, etc.) and anthropogenic effects on the atmosphere, 260 V/m strength variations were observed at a frequency of 5 Hz. In thunderstorm the electric fields attain 2000–3000 V/m in a matter of 0.1 s.

## MONITORING OF PHYSICAL STATE OF THE UNDERLYING SURFACE

*Institute of Atmospheric Optics,*
*Siberian Branch of the Russian Academy of Sciences,*
*Tomsk*
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*at the Tomsk State University*

In 1994, we concentrated on collecting data and developing the algorithms of their usage for compiling the first version of Atlas of Electric Characteristics of Soil in Tomsk region and its neighborhood. The studies were accomplished in two directions. The first one was the collection of data on soil and long–standing observations about seasonal changes of its state: temperature, moisture, composition, etc. The second direction was related to the development of algorithms for electrical mapping of territories based on results of observation of nonelectric parameters of soil. To this end, it was necessary to develop a physico–mathematical model to describe with reasonable accuracy the behavior of electric characteristics of soil of different composition under various conditions.

This model was based on equations of heat and moisture transfer in soil and regularities in the relation between their electric and soil characteristics. The test of the model efficiency based on the experiments carried out at the reference station (village Kazanka of Tomsk region) as well as on the data available in the literature revealed its adequacy to real conditions. Of particular practical importance was the development of the initial database for the first version of the Atlas of Electric Characteristics of Soil of Tomsk region.

A scheme for cataloging spectral albedo of the underlying surface in the examined Siberian territory has been prepared for its loading with specific data. The joint use of ground–based, airborne, and spaceborne observational means is projected. The range of albedo seasonal variations of the main landscapes in Siberia has been estimated. For example, in winter albedo of marshes can reach 65–80%, while in summer it is 11–23%. The albedo contrasts can attain several tens of per cent depending on scales of its spatial averaging.

## MONITORING OF PHYSICAL STATE OF THE UPPER ATMOSPHERE

*Institute of Solar–Terrestrial Physics,*
*Siberian Branch of the Russian Academy of Sciences,*
*Irkutsk*
*Siberian Physical–Technical Institute*
*at the Tomsk State University*

This monitoring was realized by the Institute of Solar–Terrestrial Physics (ISTP) of the Siberian Branch of the

Russian Academy of Sciences (Irkutsk) and by the Siberian Physical–Technical Institute at the Tomsk State University. The ISTP station of vertical sounding of ionosphere incorporates not only a standard channel for observing high–frequency characteristics, but also a modified antenna system which allows one to observe the motion of ionospheric inhomogeneities, their structure and scale using specific mathematical processing of delayed quadrature component.

Observations in a long–wave range of radio frequencies make it possible to measure a wind structure in the upper part of the middle atmosphere or in the lower thermosphere. A lot of observations have been accumulated in this direction which allow one to draw conclusions on interrelation between atmospheric motions and different helio– and geophysical parameters. The relation of these motions with the parameters of the upper layer of the atmosphere is under study now. In particular, the relation with the height of sporadic formations in the ionosphere has been found. The developed database of critical frequencies of ionosphere and indices of solar and geomagnetic activity allows a search for required information, data sorting by user's request, and output of the selected data to a text file for their subsequent processing and analysis. Now the database contains the results of survey from 25 ionospheric stations of the former USSR since late 1950's to late 1980's and the results obtained at some foreign stations.

The processing of information obtained from meteorological satellites has been refined. We plan to realize the observations about the temperature, cloudiness, ozone content, and some other atmospheric parameters.

The Siberian Physical–Technical Institute carried out measurements of ionospheric properties during the regular days of International Geophysical Calendar using systems of vertical and slant Doppler sounding. The average annual values of median critical frequencies of the F2 layer at 12 o'clock of local time and average annual values of Wulf numbers characterizing solar activity during the period between 1936 and 1993 have been analyzed. The high degree of their cross correlation has been found that supports the decisive role of solar radiation in the formation of the Earth's ionosphere. The parameters of wave perturbations in the upper atmosphere appearing over Western Siberia due to environmental anthropogenic effect connected with an orbital injection or manoeuvres of space vehicles were determined from sounding data. The lifetime of these wave perturbations was shown to be several hours. It was found that orbital injection of space vehicles results in the upper atmospheric wave guide excitation.

## MONITORING OF ATMOSPHERIC RADIOACTIVITY

*Scientific–Research Institute of Nuclear Physics*
*at the Tomsk Polytechnical University*
*Design and Engineering Institute "Optika",*
*Siberian Branch of the Russian Academy of Sciences*

Theoretical and experimental studies were made of the radar method of remote detection and measurement of radioactivity of local regions of the atmosphere that differ from the background levels and are caused by discharges of atomic stations and nuclear–chemical production in standard and accidental regimes. Based on the reference data, isotopic composition of discharges and spatiotemporal parameters of radioactive cloud have been calculated, and the processes of thermolization of spatial distributed flux of radiation of different types as well as of interaction of beta–particles and gamma–quanta of radioactive decay with air as a multicomponent medium have been numerically investigated. This provided a basis for estimating an efficient scattering cross section in radar sounding of radioactive regions of the atmosphere. At three sounding stations spaced apart, experiments were carried out on diagnostics of industrial areas of the Siberian Chemical Complex and the Tomsk Oil Chemical Complex as well as of regular discharges of nuclear reactor of the Scientific Research Institute of Nuclear Physics at the Tomsk Polytechnical University that supported the theoretical assumptions and allowed one to construct a schematic map of areas with enhanced radiative pollution relative to the background level.

In late July and early August of 1994, the expeditionary works have been undertaken to measure expose doses of gamma and beta radiation at individual sites near the motor road Tomsk–Semipalatinsk. The dosimeter GABETA designed and fabricated at the Design and Engineering Institute "Optika" of the Siberian Branch of the Russian Academy of Sciences was used. Along the motor road under study the expose dose rate was found no more than 20 μR/hr. It should be noted that the distribution of dozes with contrast of about 1.5 was of focal character.

## MONITORING OF ASTROPHYSICAL AND GEOPHYSICAL FACTORS

*Siberian Physical–Technical Institute*
*at the Tomsk State University*

To monitor the heliogeophysical factors, a station was constructed for daily observations (at 12 o'clock, local time) about the index of solar activity, equipped with a radio telescope at 10.7 cm wavelength with a 25 $m^2$ effective aperture and an angular width of directional pattern at half power in perpendicular planes of 0.7 and 3°, respectively. Moreover, in the monitoring regime (according to International Geophysical Calendar) the measurements were carried out of variations of $H$ and $Z$ components of the Earth's geomagnetic field in the spectral range up to 10 Hz.

According to the Project, Seismometric Station consisting of three seismographs VEGIK has been put into the regime of preliminary measurements. Preliminary measurements and spectral processing were made which demonstrated the efficiency of sensors and digital channel of data transfer. The Station is being mounted in stationary regime. Thereafter calibration and start of the Seismometric Station will be accomplished in monitoring regime.

The first stage of constructing the Center for Space Monitoring of Parameters and Processes has been completed. To date, the Center has started the information reception from radiometers placed onboard the NOAA satellites in two spectral windows: 0.58–0.68 μm and 11.5–12.5 μm. Viewing swath was 2800 km with 4 km spatial resolution. An algorithmic base is now being developed to use completely the potential of the information received from satellites.

## MEDICO–BIOLOGICAL CONSEQUENCES OF CLIMATIC–ECOLOGICAL CHANGE OF THE ENVIRONMENT

*Scientific–Research Institute of Biology and Biophysics*
*Siberian Physical–Technical Institute*
*at the Tomsk State University*

The ecological monitoring of the effect of climatic and anthropogenic factors on functioning of biological systems was continued in 1994 at Lomachev Hospital (Kemerovo region) of the Scientific–Research Institute of Biology and Biophysics. To solve the problems stated, biological methods were used. In particular, the method of

dendrochronoindication was used to collect an experimental material for retrospective evaluation of climatic conditions in the given region for 100±10 years. This material also can be used for constructing a chronological map of radio nucleotides and some other harmful substances within the span of about fifty years.

The studies have been continued on a structure of trapping nets of *spiders–circular–spinners* and their seasonal and regionals anomalies for different anthropogenic loading. It was found that 1) percentage of anomalous nets increased in the zone with increased anthropogenic loading (areal of Tomsk) as compared to the reference one (Lomachev polygon) and 2) the ratio of different anomalies changed and some new anomalies appeared.

When investigating the effect of seasonal and weather conditions on soil insects and spiders, the observations were made about the variations of *herpetic bionts* (*Arthropoda* living in a near–ground layer) and the dynamics of their population. A stock material has been collected and its analysis has begun.

The observations about the ecology of reproduction were carried out using the model species of birds (*hollow–nest* ones). Based on the available long–standing observations about *starlings*, a factor analysis has been made on investigating the effect of annual, biotopic, and anthropogenic factors (variable electric fields created by electric transmission line–500) on their reproduction indices. Using growth of *starling nestlings* as an example, a technique for investigating the effect of some factors of the environment on growing organisms of birds has been tested.

The works on investigating ecological aspects of dynamics of psychophysiological states of man in a structure of monitoring of physical factors of the environment were continued. Based on an analysis of the complete structure of operators' electrocardiograms taken in 1993–1994 (based on International Geophysical Calendar), we obtained diurnal and annual dependence of mean values of sample statistics of cardiointervals. A number of maxima were found both in diurnal and annual cycles. To test reactions of operators in background electromagnetic field (as one of heliogeophysical factors), a soft– and hardware system was put into operation, which provided polysensory stimulation controlled either by one of the leading biorhythms of organism or by signals in the frequency range 1–40 Hz. The processing of the obtained results made it possible to separate out the optimal psychological tests which can adequately reflect the current psychophysiological conditions of tested objects.