CLIMATIC–ECOLOGICAL MONITORING OF SIBERIA (CEMS): PROGRAM OF PHYSICAL INVESTIGATIONS ON LOCAL, REGIONAL, AND GLOBAL CHANGES IN THE ATMOSPHERE

M.V. Kabanov

"Optika" Design and Technology Institute,
Siberian Branch of Russian Academy of Sciences, Tomsk
Received November 15, 1993

The paper deals with methodological bases, purposes and problem orientation of the program of physical studies of the Siberian air basin. Much importance is attached to the Siberian region from the viewpoint of global changes of the environment as well as the necessity of complex monitoring of long–term climatic–ecological changes for stable development of Siberia. The program includes the main atmospheric–physical objects of monitoring such as meteorological state and dynamics of the atmosphere, atmospheric gases and aerosol, optical and radiowave radiation fluxes, atmospheric electricity and radioactivity, physical state of the upper atmosphere and underlying surface, astrophysical and geophysical factors, medical–biological consequences of climatic–ecological changes. Realization of the program is based on construction of a regional network of climatic–ecological monitoring, regional geoinformation system, regional center of metrology, and certification of ecological–meteorological technical means.

INTRODUCTION

Physicochemical state of the Earth's surface and the processes occurring in each specific point of space and at every instant of time are determined by a combination of interacting natural and anthropogenic factors.[1] The role and relationships between these factors in different regions of the planet are diversified, but their influence as a whole on global changes in the environment is an extreme environmental hazard that is substantiated and written in the documents of the United Nations International Conference held in Rio–de–Janeiro.[2] Therefore, the primary goal of the CEMS program is not only the solution of local and regional problems of Siberia but also contributing to the solution of problems of global changes of the environment.

Three groups of problems, connected with climatic–ecological changes on global, regional, and/or local scales can be recognized under established conditions as the independent ones from the stand point of their scientific, technological, or organization solutions.

The first group of problems is related to discovery and removal of extraordinary situations and disasters appearing due to partial or decisive influence of industrial pollutions on the environment. Solution of these urgent problems should be responsibility of special services and is commonly based on the use of the currently available scientific–technological advances and available technical means.

The second group of problems is related to the discovery and removal of dangerous effects of industrial activities on the environment. These problems can be solved by the production organizations. In this case the scientific–technological potential is used for developing new technical means and know–how as well as for elaboration of medical–sanitary, social–legal standards, and expert evaluations.

The third group of problems is connected with the long–term changes of state of the environment on global, regional, and local scales under the effect of natural and anthropogenic processes. Solution of these fundamental problems forms a basis for strategic planning of social and economic development and is mainly realized by scientific organizations. Solution of these problems is based on the performance of a series of such international and national programs as "International Geospheric–Biospheric Program," "Global Changes of Environment and Climate," "Atmospheric–Radiation Monitoring," "Ecological Safety of Russia," and so on. The main feasible goal of the CEMS program is to solve the third group of problems. Solution of the above problems is to reveal and adapt the basic regularities of global and regional climatic–ecological changes and, hence, the development of scientifically justified recommendations and expert evaluations concerning stable development of Siberia.

The main technological line of attack on the problem proposed is to organize and realize a complex regional climatic–ecological monitoring of basic states and processes occurring in the atmosphere and governing the climatic–ecological situation and trends. This technological line comprises three basic elements:

1) Network of climatic–ecological monitoring providing the acquisition of data on long–term homogeneous observations[3] of the main objects of monitoring;

2) Information–analytical system (geoinformation system) of data acquisition, storage, and processing of all necessary information for subsequent expert estimates and prediction of climatic–ecological changes due to the influence of regional anthropogenic factors;

3) Regional center for metrology and certification of technical ecological–meteorological means as well as testing of the means for serial production.

0235-6880/94/02 78-08 $02.00

Material and technical support of all the three above–mentioned elements is expensive but obligatory for successful realization of the CEMS program. Besides, the existing material and technical resources of the main agencies executing the program are diverse and powerful for successful start. Among the main organizations are the academic institutes (Joint Institute of Atmospheric Optics (JIAO), Tomsk; Institute of Solar–Earth Physics (ISEPh), Irkutsk; Computer Center, Novosibirsk) and higher school ones (Siberian Physico–Technical Institute and Scientific Research Institute of Biology and Biophysics at the Tomsk State University; Scientific Research Institute of Nuclear Physics at the Tomsk Polytechnical University).

PROBLEM ORIENTATION AND CEMS NETWORK

Interrelation of the climate–forming and ecological factors in the atmosphere determines the efficiency of monitoring and prediction of climatic–ecological changes only when performing a comprehensive and joint monitoring. Problem on reduction of the number of controlled parameters due to technical and economical reasons cannot be solved by cutting the number of scientifically grounded list of key parameters.

The CEMS program governs the monitoring of the main parameters of the atmosphere on the principle of a closed experiment when the missing number of parameters to be measured is supplemented by the calculated ones based on well grounded atmospheric–physical models. The present methods of atmospheric studies[4] as well as the results of closed atmospheric–radiation experiments[5] and complex aerosol investigations[6] give a methodological basis for the extended use of this principle when developing the network of climatic–ecological monitoring of Siberia.

Interrelation of physical, chemical and biological processes in the biosphere determines the complexity of global, regional, and even local climatic–ecological monitoring. Practical realization of such a complex monitoring is rather difficult without the problem orientation. In the CEMS program the monitoring of those atmospheric processes and phenomena is preferable, where cause and effect relationship is determined by physical processes. The choice made in monitoring specialization is necessary for successful start (in organization) and enables one to concentrate attention of specialists both on the investigation of atmospheric–physical processes and on the effective use of modern technical means. In this case geochemical and geobiophysical observations are planned, whose time schedule and scope at the initial stage depend on the scientific–technical potential in these fields of knowledge.

Global, regional, and local versions of climatic–ecological monitoring represent such a system of observations, estimate and prediction of state of the environment, which makes it possible to distinguish the changes in the state of the biosphere on natural background under the effect of anthropogenic activities at the scale of planet, region, and separate districts.[1] The global monitoring, realized within the framework of international programs, allows for operation of many centers of regional monitoring whose geography is determined by climatic–geographical position taking into account peculiarities of economic activities and administrative division of a region.[7]

Program of climatic–ecological monitoring of Siberia is oriented towards the scales of such a region, which is of independent and special interest from the viewpoint of global monitoring. First, paleoscale and paleoclimate of Siberia have common history both in the geological time[8] and at the present stage of economic activities. Second, the boreal forests of Western Siberia together with the forests of Canada are "the lungs" of the earth's biosphere in the northern hemisphere,[9] and the Siberian marshes, as a high–power methane generator, play a leading role in the greenhouse effect on the earth. Third, an intense industrial development of Siberia in the twentieth century is an essential factor of possible climatic–ecological variations not only in the region but on a global scale as well.

The above–mentioned principle of a closed experiment, problem orientation to physical processes in the atmosphere, and regional peculiarities of Siberia form the scientific basis for arrangement of ground–based climatic–ecological monitoring for the CEMS program. It is worth noting, in this case, that besides the organizing–technical structure of the CEMS network there is an extensive network of ground–based hydrometeorological observation points operating in a routine mode in Siberia. Aerological sounding by means of balloonsondes at altitudes up to 30 km is performed at 36 points of this network. Besides, there are some modern stationary and unique technical means of atmospheric observations in Siberia. The additional atmospheric parameters for climatic–ecological monitoring are observed using these means. Among the unique and expensive means there are

– high–altitude lidar sensing stations (Tomsk);

– solar radiotelescope with a unique antenna system (Irkutsk);

– four stations for radiosensing the ionosphere (Tomsk, Novosibirsk, Irkutsk, Jakutsk);

– basic experimental complex including lidars, sodars (acoustic radars), and stationary trace gas and aerosol analyzers (Tomsk);

– "Optik" airborne laboratory on board an AN–30 aircraft equipped with a unique complex of measuring devices for investigating the atmospheric air under field conditions (Tomsk);

– basic complexes of long–term biophysical observations of natural–territory complexes of the lake Baikal and Ob' river flood plain (Irkutsk, Tomsk);

All the above–mentined network of existing points and stations together with the nearest points for receiving information from spaceborne platforms (Novosibirsk, Khabarovsk, Tashkent) is a starting basis for a complex climatic–ecological monitoring of Siberia. Further development of this network allows for creation of additional observation points. In this case the central basic polygon in Tomsk should solve the problems on the development of combined observation techniques and preparation of central geoinformation system of monitoring as well as creation of center of metrology and certification of technical means for climatic–ecological observations. The total structure of CEMS network is presented in the table, and a part of the network in Tomsk and Kemerovo regions is given in the Fig. 1.

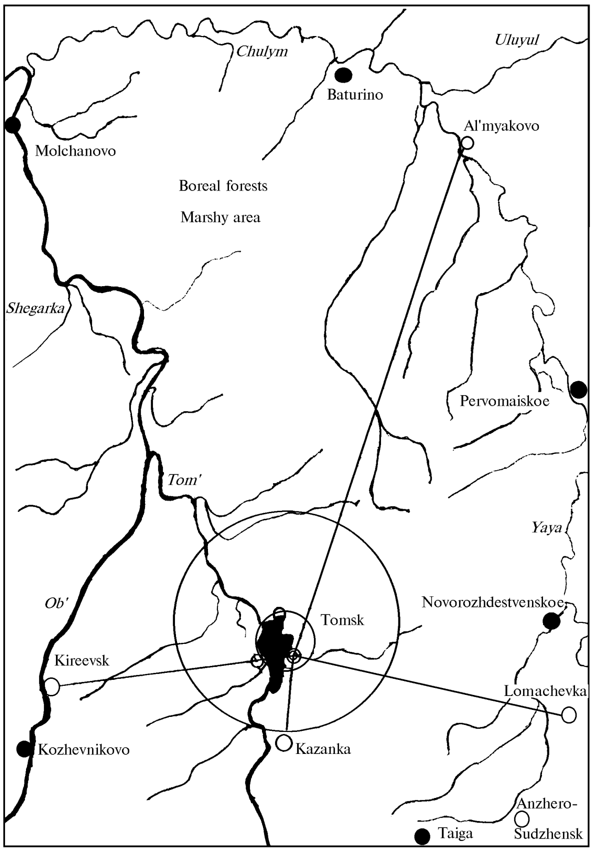

FIG. 1. Network of stations of climatic–ecological monitoring of Tomsk region: Ë Operating stations of State meteorological network, Í stations of network of climatic–ecological monitoring under construction.

THE PRIORITY OBJECTS OF MONITORING

The subject of the present program is organization, development of methodology, and long–term climatic–ecological monitoring. In accordance with the main goal of the program the objects of climatic–ecological monitoring are the fundamental physical fields of different nature, physical processes and phenomena in the atmosphere. The climatic–ecological monitoring is a complex monitoring due to multicomponent composition of the atmosphere and multiparameter nature of atmospheric–physical fields, processes, and phenomena. Below the priority objects of monitoring are described.

1. Monitoring of the meteorological (thermodynamic) state of the atmosphere represents further development of traditional meteorological observations in the ground layer. The first systematic meteorological observations in Siberia were started at Tomsk hydrometeorological station in 1830.[10] Traditional network of meteorological observations when performing this monitoring are supplemented with the measurements of altitude profiles of meteorological parameters. The basic observed parameters are: temperature, pressure, humidity, and wind velocity. Traditional observational means are now out of date and the process of their replacement for less inertial means is conducted, that is, more adaptable automation of the measurement processes and recording of the measurement results. When performing actual monitoring some modern technical means should be tested and certified, including the development of methodical recommendations to be used in an extended network.

2. Monitoring of atmospheric dynamics is separated out into an independent branch of study from the common monitoring of meteorological state of the atmosphere due to the particular importance of the problems on weather formation, general and regional circulation of the atmosphere, problems on the atmospheric turbulence, and atmospheric jet streams as well as the diffusion of the main components and impurities in the atmosphere. The influence of atmospheric dynamic processes on the local, regional, and transborder transfers of the atmospheric contaminants determines their ecological importance.

Much information comes from spaceborne photographs of cloud dynamics, from the network of stations of aerological sounding (up to 30 km altitude), and ground–based hydrometeorological network. Monitoring system discussed here uses sodars, lidars, and balloonborne sensors of turbulence as complementary means of atmospheric observations.

3. Monitoring of atmospheric aerosol, cloudiness, and precipitation is a complex monitoring of the most important climate–forming and ecological components of the atmosphere. The troposphere–background, industrial, and stratospheric aerosols are of primary importance in studies of the atmospheric aerosol. Traditional observations performed on the basis of the network for cloudiness and precipitation observations are supplemented with systematic observations of detailed structure of cloud formations including spatial and time scales of a solid cloud cover and broken clouds, chemical composition, and microstructure of clouds and precipitation.

Traditional technical means of this monitoring are to be replaced for more precise and operative ones. Among the new facilities, lidars, radar stations, survey photometers, nephelometers, and spectrophotometers should be mentioned as those whose usefulness has been already proved.

4. Monitoring of atmospheric gases, which are also an important climate–forming and ecological component of the earth's atmosphere, is the most complex and significant. All the main and minor atmospheric gases can be divided into some groups due to their influence on the climatic–ecological situation. This program includes the following priority groups of trace gases:

– fundamental biospheric gases (O_2, CO_2, etc.);

– greenhouse gases (CO_2, H_2O, CO_4, O_3, and nitric oxides);

– cancerogenic gases (sulfur–containing gases, heavy hydrocarbons, fluorine and chlorine containing gases, vapors of heavy metals, etc.).

The methods and technical means of measurements of atmospheric gases concentration have been developed and tested both for remote measurements (laser and other optical remote sensors as well as radiometers and spectrometers) and for contact measurements (sensors and samplers). Selection and certification of the most effective means of measuring the atmospheric gases concentration under natural conditions are most important technological problems of this monitoring.

TABLE I. Organization–Technical Structure of CEMS network.

I. Network of climatic–ecological monitoring of Siberia	
Network of Western Siberia	– Joint Institute of Atmospheric Optics SB RAS (Tomsk)
Network of Eastern Siberia	– Institute of Solar–Earth Physics SB RAS (Irkutsk)
II. Geoinformation system CEMS	– Siberian Information–Computing Center (consisting of JIAO SB RAS, Tomsk) – Institute of Atmospheric Optics SB RAS (consisting of JIAO SB RAS, Tomsk)
III. Regional center of organization of monitoring, metrology and certification of technical means of CEMS	– "Optika" Design and Technology Institute SB RAS (consisting of JIAO SB RAS, Tomsk)
IV. Industrial Circular Location of the CEMS–network in Tomsk	
Basic polygon (Akademgorodok)	– "Optika" Design and Technology Institute SB RAS
Southern station (Juzhnaya square)	– Siberian Physico–Technical Institute (at the Tomsk State University)
Western station (Zarechnyi)	– IAO SB RAS
Northern station (Sputnik)	– Scientific Research Institute of Nuclear Physics at Tomsk Polytechnical University
V. Background Circular Location of the CEMS network in Tomsk and Kemerovo regions	
Eastern station (Lomachevka, Kemerovo region)	– Scientific Research Institute of Biology and Biophysics at Tomsk State University
Southern station (Kazanka, Tomsk region)	– Siberian Physico–Technical Institute (at the Tomsk State University)
Western station (Kireevsk, Tomsk region)	– IAO SB RAS
Northern station (Al'myakovo, Tomsk region)	– "Optika" Design and Technology Institute SB RAS

5. Monitoring of ozone and components of the ozone cycle is of particular importance in complex monitoring of the atmospheric gases owing to ecological significance of the problems on the tropospheric and stratospheric ozone (ozone holes). The components of ozone cycle are the following: spectrum of the ultraviolet solar radiation, a series of atmospheric gases (mainly, nitric oxides), and atmospheric aerosol. The present monitoring can provide synchronous observations of all these components if there are no such observations in other monitoring programs. The main technical means for systematic observations in Siberia is the unique high–altidude lidar sensing station (HAS–2) of the Institute of Atmospheric Optics of the Russian Academy of Sciences (Tomsk), which is operated since 1989. There are some laser sounding channels and a receiving mirror 2 m in diameter at the station. The additional means of the station are the following: the high–altitude station (HAS–1) (receiving mirror 1 m in diameter), ground–based and balloonborne ozonometers, and a number of another hardware and software developed.

6. Monitoring of the atmospheric radiation, including optical radiation in the ultraviolet, visible, and infrared spectral ranges, represents further development of observations performed using the existing network of actinometric stations and points of observations of ultraviolet radiation. The necessity of developing the above–mentioned means is dictated by the modern medical–biological requirements to the data on spectral composition of UV–radiation (UV–radiation quality) and is substantinated in the USA National Project "Atmospheric radiation measurements" (ARM).[9]

Modern ground–based observation methods and technical means (spectrophotometers, radiometers, actinometers, phytoactinometers) facilitate the solution of independent problems and calibration of aerospace observation means. Practical use of existing technical means in regular observations needs for additional arrangement of systematic metrological control. When performing the monitoring under discussion the additional methodical and design–technological developments are required on the systems of optical tomography of the atmosphere, including high resolution of spatial and temporal structure of atmospheric radiation fluxes.

7. Monitoring of the radio wave radiation fluxes in the microwave, short–wave, mean–wave, long–wave, and superlong–wave ranges is of primary importance due to an intense development of radioelectronics and the problems that have arisen on the electromagnetic compatibility of different radioelectronic means of industrial and general purposes, including their effects on the environment.[12] At the same time, an essential increase of the total intensity of anthropogenic electromagnetic fields, as compared with natural background, represents, on a time scale of bioevolution process, a sudden jump with unclear yet medical–biological consequences.[13] Recently the influence of radiowave radiation in some ranges on the weather forming processes has been revealed.[14] Technical means for systematic observations of the radiowave radiation fluxes are nowadays in a wide practical use. Their direct use in monitoring is connected with the need for further improvement, certification, and arrangement of a systematic metrological control.

8. Monitoring of atmospheric electricity, affecting the rates and the consequences of the most of the geophysical and biophysical processes in the earth's atmosphere,[15] is one of the key factors in complex climatic–ecological monitoring. The main parameters of monitoring are the following; electrostatic potential and atmospheric conductivity at different altitudes as well as a number of other parameters of "calm" and thunderstorm electricity. The existence of global atmospheric–electrical current circuit and unitary variations of the electric field strength, connected with the change of electric charge of the earth as a whole,[14] determines the fundamental importance of regional centers for monitoring atmospheric electricity.

The existing technical means for ground–based and balloonborne observations can make a reliable basis for the monitoring discussed. Further development of new methods and means is required for remote sensing of the atmospheric electricity. For these purposes of considerable promise are the laser methods based on the use of effects of electroorientation of aerosols on scattering of optical radiation.

9. Monitoring of physical state of the underlying surface determining the lower boundary of the earth's atmosphere is an important and necessary component of a complex monitoring of climatic–ecological changes. Close correlation between a number of meteorological parameters of the ground layer and the potential of the so–called telluric currents in the earth's crust is well–known.[12] Geological structure of the earth's crust is clearly seen during such a bright atmospheric phenomenon as aurora polaris. The transfer of optical and microwave radiation in vegetation[17] and the reflectivity (albedo) of underlying surface are among the direct climat forming factors. As a whole, from the standpoint of climatic–ecological changes, the underlying surface is an the effectively interacting and modifying boundary of the atmosphere. The priority parameters for the present monitoring are the electrophysical parameters of soil and ground, albedo of different types of underlying surfaces for the visible, infrared, and microwave radiation.

Pulsed and cw georadars for microwave sensing at a depth of several dozens of meters are most valuable tools for remote measurement of electrophysical parameters. In this case standard agrobiophysical methods of analysis of soils and grounds are necessary for metrological provision. Ground–based measurements of reflecting characteristics of the earth's surface in the optical range are usually carried out by means of standard spectrophotometers though based on the independent technological methods. The operation problems of monitoring also comprise the conjugation of measured characteristics of the underlying surface in different ranges of electromagnetic radiation as well as the development of methods of measurements of polarization characteristics of vegetation.

10. Monitoring of the physical state of the upper atmosphere interacting with the near space,[18] is another one necessary boundary region for complex climatic–ecological monitoring. In this case the ionosphere is a priority object, whose monitoring in Siberia is performed since 1936 (at the Tomsk Ionospheric Station). Regular monitoring of the ionosphere performed by several ionospheric stations in Siberia provides the control of processes in the lower and middle layers of the atmosphere as well as fluctuations of the earth's surface and ocean due to earthquakes, explosions, shore effects, etc.[19] Monitoring of the ionosphere is nowadays a very important and reliable technique for predicting the state of channels of short–wave radio communication.[20]

Basic methods and means of radio sensing of the upper atmosphere at altitudes from 50 to 400 km have recently been developed and certified for regular observations. A method of vertical radio sensing is among the above methods. It is used at the world wide network including 25 stationary points on the Russian territory. Application of the technical means used in this case to slant radio sensing together with adaptive mathematical models increases the content of information about such parameters of the upper atmosphere as temperature of electrons, ions, and neutral particles, wind velocity vector, distribution and composition of neutral and charged particles.[18] In recent years other methods of radio sensing of the upper atmosphere have been developed based on the use of high–power radioengineering means or unique solar radiotelescope of ISEPh SB RAN (Irkutsk).

11. Monitoring of atmospheric radioactivity within the framework of a complex climatic–ecological monitoring is aimed, first of all, at regular observations of atmospheric radioactive gases and aerosol of natural and anthropogenic origin. Regular background observations of alpha, beta, and gamma–ray emissions at stationary points are of primary importance for this monitoring. Detection of some products of radioactive decay is also very important. The basic problem of this monitoring is to study the processes of interaction of atmospheric radioactivity with the other atmospheric components and the role of these processes in regional climatic–ecological variations.

As technical means for monitoring of atmospheric radioactivity standard devices and spectrometers can be used along with the new types of devices developed, after due tests, calibrations, and certification.

12. Monitoring of cosmic, astrophysical, and geophysical factors is intended for a systematic recording of incidental and regular cosmic, astrophysical and geophysical events affecting the climatic–ecological situation.

Among the basic cosmic and astrophysical factors are such regular events as hard component of solar radiation fluxes and cosmic rays, relative position of planets in the solar system determining fluctuations of the earth's gravitational field as well as occasional approaches to and collisions with meteorites. The main geophysical factors comprise volcanic eruptions and variations of the earth's geomagnetic field, seismic oscillations of the earth's surface due to the earthquakes and cavings, underground and ground explosions, and so on. The influence of all these and other astrophysical and geophysical factors is currently widely used for popular but, in the absence of monitoring, poorly grounded forecasting of weather and enviromental conditions.

Technical means and calculational methods for the present monitoring have been developed nowadays but used in the information–disconnected points of observations. The problem of the present monitoring is to concentrate the data of the observation points within the framework of a unified monitoring.

13. Monitoring of medical–biological results of the climatic–ecological changes is especially important in the CEMS program both for the problem orientation and for defining the monitoring objects. Performance of monitoring in close spatial and temporal connection with physical studies of the atmosphere increases the efficiency of search and safety of testing bioindicators of climatic–ecological changes, on the one hand, and stimulates the choice of priorities of social significance when planning the physical studies, on the other hand. Besides, inclusion of monitoring of medical–biological consequences in the CEMS program provides an increase of the number of methods not only for investigating climatic–ecological changes at present but for reconstructing such changes in the past. Finally, it is necessary to encourage interdisciplinary investigations and prospects for interaction of the present program with the other national and international programs.

The present monitoring is to be performed on the basis of use and further development of bioindicator and psychophysiological methods of investigations under clinical and field conditions.

PRIORITY PROBLEMS OF FUNDAMENTAL RESEARCH

Multicomponent composition of the earth's atmosphere determines the complexity and multiparameter character of atmospheric states, processes, and phenomena. A complex, synchronous, and long–term monitoring of all the main parameters of the atmosphere, provided by regional climatic–ecological monitoring, is the basis for solving the fundamental problems of scientific, methodological, and practical importance. Each of the above–mentioned objects of monitoring is simultaneously an object of fundamental investigation of many scientific groups. To solve a number of fundamental problems of atmospheric physics it is necessary to have such an array of continuous homogeneous series of observations which can be obtained only in the course of a complex monitoring. Below, the list of such priority problems of fundamental investigations is given, whose solution is possible based on the results of monitoring of all or some objects simultaneously.

1. Greenhouse effect in the earth's atmosphere is referred to the decisive factors of climate forming processes.[21] Regional peculiarities of this effect are connected with the specific features of natural and anthropogenic sources and sinks of greenhouse gases (carbon dioxide, methane, carbon monoxide, water vapor, etc.) on the one hand, and with the specific properties of aerosol formation and cloud cover in the region, on the other hand. If an increase of the total content of greenhouse gases in the atmosphere changes the radiation balance in the direction of temperature rise, then an increase in the cloud cover changes it in the direction of temperature drop. The complexity of both processes and their dependence on radiation balance with simultaneous influence of other factors causes the difficulty of studying the greenhouse effect both on the global and regional scales.

2. Stratification of the earth's atmosphere according to altitude profiles of many physical parameters is a result and, simultaneously, a factor affecting many atmospheric processes and phenomena.[22] There are comparatively stable types of stratification including the altitude profile of temperature, ionized layers of the atmosphere (ionosphere), ozone layer, the Junge aerosol layer, the electrostatic layer, and so on. There are some other regional peculiarities in the stratification, which make an important object for fundamental investigations. However, the unstable atmospheric layers of the type of temperature inversions, jet streams, etc. constantly appear and disappear in the earth's atmosphere. These types of stratification of the atmosphere are of particular practical significance. The temperature inversion layers prevent breaks through aerosol contaminants into the upper layers of the atmosphere, that often results in their accumulation to hazardous concentrations in the lower layers. Unstable atmospheric layers usually have the scales of regions. The complex regional monitoring alone may serve as an experimental basis for revealing regularities in frequency of occurrence and power of such layers.

3. Circulation of the atmosphere and transborder transfer of air masses are currently the main though poorly studied elements in the models of general atmospheric circulation determining the global and regional changes of the environment and climate.[23] Besides, transregional and transborder transfer of air masses are strategically important when planning social–economic development on a regional and state levels from the standpoint of the environmental protection. In all cases, to solve scientific, social–economic, and even social–political problems well–grounded calculational models are needed. These models should be confirmed by the material on actually measured atmospheric parameters. Regional climatic–ecological monitoring could provide material and, hence, produce the basis for successful fundamental investigations of the atmospheric processes accompanying the circulation in the atmosphere and transregional transfer of air masses.

4. Interaction of the atmosphere with underlying surface
is an important atmospheric processes determining both the radiation regime (at the expense of albedo and outgoing thermal radiation) and atmospheric stratification (due to turbulent motion) as well as physico–chemical composition of tropospheric aerosol (due to erosion of soil) and atmospheric gaseous composition according to climatically and ecologically significant components. All these factors have regional peculiarities but their studies are of interest for investigating peculiarities of climatic–ecological changes not only on a regional but also on the global scale. When investigating within the framework of CEMS the following problems should be considered: methane generation by Siberian marshes, seasonal variations of albedo of the underlying surface in Siberia at snow melting and large–scale forest cutting, and so on.

5. Balance and transborder transfer of atmospheric pollutants including aerosol, gaseous, radioactive, and electromagnetic pollutions of the atmospheric air are independent and urgent subjects for fundamental ecological investigations. If the aim of the fundamental investigations within the framework of the CEMS program is to consider the above investigations in the time aspect, then the estimate of the balance of investigation of transborder transfer of atmospheric pollutions should be considered in the spatial aspect. The methods and means for solving this problem are out of the the CEMS program. However, the solution of the above problem cannot be obtained without the use of the CEMS network. Taking into account the significance of this problem for solving interregional and international ecological claims, the program CEMS also puts this problem in the forefront.

6. Methodological grounds for the climatic–ecological monitoring as a complex monitoring of the atmosphere on a regional scale may be considered as an independent area of the fundamental investigations. The above grounds comprise optimization of technology and the set of technical means of monitoring, scientifically grounded territorial location of basic and background polygons, proper choice and optimization of priority objects of monitoring for solving the scientific–practical problems, development of criteria and permissible errors in expert conclusions and estimates of the monitoring efficiency. Vital importance of this area of fundamental investigations is conditioned by the fact that the world network of centers of complex climatic–ecological monitoring is still under development, and timely creation of methodological grounds for the above investigations will make it possible to exclude unproductive expenditure of both material and intellectual resources as well as of social and economic ones.

CONCLUSION

In May 1993 the program of climatic–ecological monitoring of Siberia has taken the status of an officially working program, being a part of regional scientific–technical programs of Siberian regions and the State scientific–technical program "Sibir'". In accordance with the above idea the realization of the CEMS program allows not only data acquisition from a series of observations concerning the basic parameters of the atmosphere, but also analysis of the monitoring results for evaluation and prediction of climatic–ecological changes, being of the utmost importance for social and economic development of Siberia. Consolidation of the efforts of the leading academic and higher school institutes of Siberia within the framework of the CEMS program is not only an important but also a promising scientific event. The nearest task of the institutes activities when realizing the above program is to join the efforts of scientific and engineering collectives of Siberia for development, certification, and manufacturing of technical means for climatic–ecological monitoring. In spite of severity of the transition period in economics and conversion, the solution of this problem is facilitated by the presence of high potential, and in some directions –– by the presence of unique scientific–technical potential.

Vast and rapidly developing area of Siberia is one of the most important regions of the Earth. Siberia affects the climate and ecology and, based on some parameters of the air, determines the global climatic–ecological changes. Therefore, the realization and further development of the CEMS program cannot be limited by solution of regional problems only. Close connection, coordination, and funding of works on the CEMS problem within the framework of international programs are natural and necessary. The first steps on this road have been made.

Thus, the joint investigations are performed on the section "Monitoring of atmospheric radiation" of the CEMS program and the U.S.A. National Program "ARM". Some parts of the CEMS program are supported by the Russian program "Global Changes of Environment and Climate" representing a part of the International Program "Global Changes". Participation in International Programs "Global Wind" and "Global Ozone" also facilitates development of useful scientific orientation for researchers when making investigations on the basis of the CEMS program. Further expansion of joint investigations as well as future international integration of knowledge, experience, and material resources for this program are considered as an important and necessary condition for improvement of scientific–practical significance of the monitoring results on a regional and global climatic–ecological changes.

REFERENCES

1. A.M. Vladimirov, Yu.I. Lyakhin, L.T. Matveev, and V.T. Orlov, *Environmental Protection* (Gidrometeoizdat, Leningrad, 1991), 423 pp.
2. V.A. Koptyug, *Information review: Conference of the United Nations on the Environment and Development (Rio–de–Janeiro, June 1992)*, (SO RAN, Novosibirsk, 1992), 62 pp.
3. S.N. Vernov, Vestnik AN SSSR, No. 12, 41–48 (1990).
4. V.E. Zuev and V.V. Zuev, *Modern Problems of Atmospheric Optics*. V. 8. *Optical Remote Sensing of the Atmosphere* (Gidrometeoizdat, Leningrad, 1991), 232 pp.
5. K.Ya. Kondrati'ev, *Radiation Factors of Modern Changes of Global Climate* (Gidrometeoizdat, Leningrad, 1980), 279 pp.
6. G.V. Rozenberg, G.I. Gorchakov, Yu.S. Georgievskii, and Yu.S. Lyubovtseva, *Optical Parameters of Atmospheric Aerosol* in: *Atmospheric Physics and Problems of Climate*, (Nauka, Moscow, 1980), p. 216–257.
7. *Global Change and Terrestrial Ecosystems. The Operational Plan. Global Change*, Report No. 21 (Stockholm, 1992), 95 pp.
8. S.A. Ushakov and I.A. Yasamanov, *Drift of Continents and Climates of the Earth* (Mysl', Moscow, 1984), 206 pp.
9. *Atmospheric Radiation Measurement. Program Plan.* (Washington, February 1990), 116 pp.
10 S.D. Koshinskii, L.I. Trifonova, and S.A. Shver ed., *Climate of Tomsk* (Gidrometeoizdat, Leningrad, 1991), 176 pp.
11. B.V. Kaul', Opt. Atmos. Okeana **5**, No. 4, 277–281 (1992).
12. V.A. Donchenko, M.V. Kabanov, and A.G. Kolesnik, Soviet Physics Journal, No. 12, 69–79 (1991).
13. G.F. Plekhanov, *Main Peculiarities of Low–Frequency Electromagnetobiology* (State University, Tomsk, 1990), 188 pp.
14. V.L. Krauklis, G.A. Nikol'skii, M.M. Safronova, and E.Yu. Shul'ts, Atm. Opt. **3**, No. 3, 227–241 (1990).
15. J. Chalmers, *Atmospheric Electricity* [Russian Translation] (Gidrometeoizdat, Leningrad, 1974), 316 pp.
16. S.Yu. Balasenyan, *Dynamic Geoelectricity* (Nauka, Novosibirsk, 1980), 231 pp.
17. Yu. Ross, Yu. Knyazikh, A. Kuusk, et al., *Mathematical Simulation of Radiation Transfer in Vegetation* (Gidrometeoizdat, Leningrad, 1992), 198 pp.
18. B.E. Brynemi and A.I. Namgaladze, *Physics of Ionosphere* (Nauka, Moscow, 1988), 528 pp.
19. L.S. Al'perovich, B.A. Vuchmeister, M.B. Gokhberg, et al., Dokl. Akad. Nauk SSSR **269**, No. 3, 573–578 (1983).
20 A.V. Gurevich and E.E. Tsedilina, *Extralong–Range Propagation of Short Radiowaves* (Nauka, Moscow, 1979), 248 pp.
21. B. Bolin, B.P. Dess, J. Yager, and P. Warrick ed. *Greenhouse Effect, Change of Climate and Ecosystem* [Russian translation] (Gidrometeoizdat, Leningrad, 1989), 558 p.
22. L.T. Matveev, *Course of General Meteorology. Atmospheric Physics* (Gidrometeoizdat, Leningrad, 1976), 640 pp.
23. V.Ya. Galin, *"International Project of Comparison and Analysis of Climatic Feedbacks in General Circulation Models of the Atmosphere."* Department of Computer Mathematics RAS, Preprint No. 280, Moscow, 1991,