RUSSIAN ACADEMY OF SCIENCES

NATIONAL GEOPHYSICAL COMMITTEE

NATIONAL REPORT

to the International Association of Meteorology
and Atmospheric Sciences
of the International Union of Geodesy and Geophysics
1999 – 2002

Presented to the XXIII General Assembly
of the International Union of Geodesy and Geophysics

Moscow 2003

This report of the Meteorology and Atmospheric Sciences Section (MASS) of the Russian National Geophysical Committee presents information on atmospheric research in 1999-2002 in Russia. It is based on reports of 10 National Commissions:

1. Atmospheric Chemistry (Chairman I.K. Larin),
2. Atmospheric Electricity (Chairman V.N. Stasenko),
3. Atmospheric Ozone (Chairman N.F. Elansky),
4. Climate (Chairman I.I. Mokhov),
5. Dynamic Meteorology (Chairman M.V. Kurgansky),
6. Meteorology of Middle Atmosphere (Chairman A.A. Krivolutsky),
7. Physics of Clouds and Precipitation (Chairman A.A. Chernikov),
8. Planetary Atmospheres (Chairman O.I. Korablev),
9. Polar Meteorology (Chairman A.I. Danilov),
10. Radiation (Chairman Yu.M. Timofeyev).

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CONTENTS

ATMOSPHERIC CHEMISTRY

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The works in the field of atmospheric chemistry which is carried out by the Russian scientists in this period, cover a wide circle of problems connected to processes, occurring in troposphere, stratosphere and higher layers of an atmosphere. These researches were done on a number of traditional directions, including laboratory study of atmospheric physico-chemical processes, theoretical analysis of atmospheric mechanisms, field observations and mathematical modeling. During this work a number of new important results of general scientific importance were received that allow better to understand processes and mechanisms working in the atmosphere and determining its properties. Basic the "applied" purpose of these researches consist in the analysis of mechanisms of influence of the antropogenic factors on properties of environment; thus the special attention was given to ozone layer and climate change, to processes of formation of acid rains, and also processes of pollution of air in urban areas.

The materials of the report are presented in sections " Chemistry of the troposphere", "Ozone layer and reasons of its change ", "Chemistry of climate and its change ", "Chemistry of urban areas", "Monitoring of the atmosphere", "Atmospheric modeling".

1. Chemistry of the troposphere

Last years the most important achievement in tropospheric chemistry are connected to study of heterogeneous processes playing a key role in formation of acid rains and, as has appeared, in depletion of the ozone layer.

The heterogeneous chemical reactions of sulfur dioxide oxidation in dropplets of tropospheric clouds were intensively studied last years in the Institute of energy problems of chemical physics RAS. The basic attention was concentrated on the study of dynamics and mechanism of liquid-phase oxidation of sulfur dioxide at the presence of ions of iron and manganese (acid rains). The fact of running of these katalitic reactions is connected with presence in their mechanism of a link of a chain branching. For dynamics of permanently developing reaction it is important what link of the iron ions cycle (F(III) ⟷ F(II)) is limiting. Depending on it or a long - chain oxidation of sulfur dioxide either katalitic one is realized. Within the framework of these representations it was possible to explain the reasons of variety of the majority of "whims" of this reaction, not being stacked in frameworks of habitual representations about radical - chain transformations.

In addition it was were developed a box chemical model of tropospheric clouds, with taking into account of reactions of iron ions that allowed to reveal such features of liquid-phase oxidation of sulfur in real atmospheric conditions as initiation of the reaction by fluxes of radicals OH/HO2 from outside, absorption UV radiation and some others. It has been found, that in day time the iron ions in liqued phase provide fast conversion seized from a gas phase chemically inert radicals HO_2 in the very active ion - radical SO_5^-. The result of this conversion appears sharp (»10^3 times) acceleration of the reaction in the atmosphere in comparison with that in laboratory conditionshis that results in growth of the rate of the atmospheric self-purificationof. The results mentioned above are presented in [1-13].

In connection with observable anomalies of ozone concentration in coastal sea zones for the first time in laboratory experiments (with use of a method of ESR with matrix isolation and mass - spectrometry) studies were carried out for the uptake of NO_2, $ClNO_3$ and NO_3 radicals on crystallites such as NaCl, NaBr, $MgCl_2 \times 6H_2O$ and NaCl doped with

$MgCl_2 \times 6H_2O$ crystalline hydrate under conditions of varying humidity and of reactant concentrations ranging between 10^{10} and 10^{14} cm^{-3}. Based on experimental dependences obtained and an analysis of literature data, a model representation of the uptake initial step is proposed. The main outcome of the model is an analytical representation of the uptake probability in terms of some elementary parameters and the rate coefficients of elementary processes that determine the reversible adsorption and the elementary heterogeneous reactions. Based on a handling of experimental data by the proposed model, some elementary rate coefficients were evaluated, i.e. the desorption rate coefficients and the adsorption heats, the rate coefficients of elementary heterogeneous reactions and their activation energies. The model representation allows us to extrapolate the laboratory data to real tropospheric conditions. Results of these works are presented in [14-18].

The aerosol particles can not only give rise to ozonedepleting substances (as it was shown in [14-18]), but also can promote preservation of ozone layer through destraction of fluorine-, chlorine containing substances. It has been shown in [19] that the substances are destructive photosorbed on MgO, that confirms a hypothesis about the contribution of photoprocesses on the MgO surface into destruction halogenated carbohydrates in the troposphere.

It is known, that the charged particles can serve as nuclei of condensation under formation of aerosol particles. In this connection in [20, 21] the influence of cosmic radiation and highenergy protons on optical properties of the low atmosphere of middle and high latitudes caused by ionization under action of these factors has been investigated.

Connection between processes of aerosol and ozone formation in the low troposphere and solar activity has been analysed in [22].

In work [23] are summarized of systematic researches of a matrix of distribution of light by atmospheric air, which have allowed to establish principles of temporary variability of the optical and microphysical characteristics of aerosol, to develop optical and microphysical models of aerosol, that has allowed to estimate radiation effects of these particles.

In conclusion of this part we shall note interesting results about influence of orographic effects on the ozone content in the troposphere and stratosphere

[24], and on the estimations of the contribution of lightnings in the formation of ozone and odd nitrogen in the troposphere [25].

2. Chemistry of ozone layer and reasons of its change

In this field the study of chemical reactions halogenous cycles of stratospheric ozone depletion has been proceeded. The significant attention was given to less investigated iodine cycle. In this connection it is possible to specify works, in which the rate constants of the reactions of IO radicals with ozone [26], with H_2S, $(CH_3)_2S$ and SO_2 [27] and with radicals ClO [28] were measured, and also work [29], where the results of long-term research of atmospheric reactions of iodine containing components in the Institute of energy problems of chemical physics RAS were presented.

The influence of the antropogeneous factors on both tropospheric and stratospheric ozone and the temperature of these areas was investigated in [30, 31], and influence of the natural factor - variations of solar radiation in 21 and 22 solar cycles - on the ozone content - in the work of the same authors [32]. The influence of other natural factors on озоновый a layer was analyzed in [33, 34].

The analysis of ozonospheric processes is carried out mainly with the help of atmospheric models of various complexity, that we shall discuss later. At the same time there are more simple methods and approaches, which can be used in the same purposes. So, in [35] the simple empirical method of an estimation of relative influence antropogeneous and natural factors on ozone layer was suggested. The method is based on the found before correlation of interannual anomalies of the total ozone contents with changes in the stratospheric moment of impulse and consists in construction of linear regression of these characteristics.

In [36] with the help of the four scenario of antropogeneous gases emissions over 2000-2100 (A1, A2, B1, B2), developed by the Intergovernmental Pannel on Climate Change, and one-dimensional photochemical model of the middle atmosphere an increase in total ozone content for spring-summer months (March - August) has been estimated. It has

been shown that the relative increase of the total ozone in 2000-2100 in comparison with 1990 can make from + 3,8 % (B1) up to + 13,1 % (A2) and appropriate reduction of intensity of biologically important UV-B radiation (wavelength range of 285-315 nm) makes from -5,0 % up to -15,9%. In view of rcovery of ozone layer in XXI century designed in assumption, that regulations of the Montreal protocol and its amendments will be carried out, the total relative change in atmospheric ozone in XXI century can make from + 9,2 % up to + 18,8 %, and appropriate reduction in intensity of UV-B radiation - from -11,6 % up to -21,9 %.

In conclusion of this part we shall underline, that in the Russian scientific literature during last years the rather sharp discussion about the reasons of ozone depletion continued. New "arguments" for the benefit of the natural factors have appeared, and the authors of some works even try to prove indemonstrable - that Antarctic ozone hole has natural origin. The part of such works is critically analyzed in [37], and others - in site http: // iklarin.narod.ru.

3. Chemistry of urban areas

The chemistry of urban areas represents an extremely complicated complex of physico-chemical interactions of the large number of various chemical compounds in gas, liquid and solid phases, which are emitted out in the atmosphere by transport, industrial enterprises and other objects of municipal economy. To understand consequences of such powerful antropogeneous influence on environment it is necessary to use mathematical models, which take into account first of all chemistry of the urban atmosphere. Let's specify in this connection two works, which answer this requirement. In [38] for the first time an inclusion of mathematical model in the geoinformation system has been is realized, that has allowed to solve a problem of the most complete information maintenance of model and its adaptation to simulated object (for conditions of Almaty). In [39] the empirical model of interaction of polluting antropogeneous pollutants of variuos origin is described, constructed on the basis of results of the mutual correlation analysis of long temporary series of concentration of aerosol, carbon oxide, nitrogen oxide and dioxide and other compounds with taking into account of meteoparameters.

For development of the urban environment protection measures against antropogenic influence it is important to estimate a measure of this influence. So, in [40] the antropogeneous constituent of a daily variability of both gas and aerosol concentrations is investigated; in [41] the sources of emissions in the atmosphere benzpyrene and others polycyclic aromatic carbohydrates in industrial regions near lake Baikal are established and the dependence of intensity of the sources on fuel-energy technology, aluminium, building, petrochemical manufactures; in [42] the basic specific substances, emitted in the atmosphere by sources of an aluminium factory are considered.

Aerosol particles are the most typical pollutant of urban area. This question is considered in [43-45], and in the last work the influence of antropogeneous aerosol on health is analysed.

In conclusion of this part we mention a work [46], where on the data long-term (1980-1999 г.г.) measurements of Meteorological observatory of the Moscow State University the temporary variability of atmospheric precipitation acidity pH is investigated; it has been shown, that there is an essential distinction in pH of rains and snow: in the warm period precipitation is more acid (average pH = 4,7) than in cold (pH = 5,7), and essential change in precipitation acidity in Moscow for these years is not observed.

4. Chemistry of climate and its change

The role of chemistry in climate change is determined by that the atmospheric content of greenhouse gases (such, as O_3, CH_4, chlorofluorohydrocarbons and some others), and also content of aerosol particles is appreciably controled by atmospheric chemical and photochemical processes. On calculations of climatic effects with the help of mathematical models which are taking into account atmospheric chemistry, the "chemical" contribution remains unnoticed, because it does not calculated specially. At the same time analysis of this question seems to be very important by many reasons. In this connection we shall mark a work [47], in which the role of atmospheric chemical processes in climate change has

been analyzed. In this work with help of photochemical model of the middle atmosphere, developed in the Institute of energy problems of chemical physics RAS, the direct and indirect effects caused by both a depletion and recovery of the stratospheric ozone, by increase in tropospheric ozone, and also additional increase in concentration of methane, hydrochlorofluorocarbons and hydrofluorocarbons have been estimated. In the work four scenario of emission of greenhouse and other antropogeneous gases in 2000-2100, developed by Intergovernmental Panel on Climate Change, have been used and for each scenario the relative total contribution of chemical processes in global warming in XXI century have been estimated. The forecast of change in global everage surface temperature in 2000-2100 with taking account the mentioned above chemical effects has been done in [48].

Reliability of the climatic forecast and maximum complete account of all climatic factors, including atmospheric chemistry, become today especially important in connection with a problem of expected global warming under action of antropogeneous factors. The role of these factors is considered in [31, 49-51].

The important indication of a possible global warming is the measurements of temperature trend. In this respect works [52-54] are especially interesting, because they information on negative trend of temperature at altitudes of 25-110 kms in the period 1955-1995, which makes 0,1- 0,9 K/yr for different layers in the specified range of heights.

In conclusion of this part we shall mention a work [55], where results of investigation of global climate in a context of the reports IPCC-2001 and National Academy of Sciences of USA are examined and some considerations about priorities of the further investigations of global climate and its changes are stated.

5. Atmospheric monitoring

From numerous and various results of atmospheric monitoring received for last four years, we first of all note results of works under the long-term programs. One of them is the project "Aerosols of Siberia", begun in 1991. During its performance the ground-based system of monitoring of atmospheric aerosols covering territory of Western and East Siberia with a distance between points of observations up to 1500 kms has been created. Besides the system of space monitoring is advanced. The important information on scales of fires in boreal forests of Siberia [56] is assembled, other important results are received, which partly presnted in [57-59].

Other large project is the international one "Troica", started in 1995. During performance of this project the near surface concentrations of O_3, NO, NO_2, CO, CO_2, CH_4, SF_6 and some VOCs were measured in continental areas of Russia from Moscow up to Khabarovsks and from Kislovodsk up to Murmansks. The results of these investigations are submitted in special release of "Izvestiya, Atmospheric and Oceanic Physics", 2001, № 7 Supplement.

Large volume in-situ measurements has been done in Central Aerologic Observatory (CAO, Dolgoprudnyi, Moscow region). The regular measurements of both altitude distribution and total ozone in Siberia (in Salehard and in Yakutsk) both under the national programs and within the framework of the international projects have been carried out [60, 61] . The large complex of measurements have been done in Arctic Region [62 - 68] and Antarctic Region [69, 70].

Besides a regular in-sity measurements of atmospheric components have been proceeded at a number of Russian stations of monitoring - Siberian Lidar Station [71- 73], scientific station in Dolgoprudnyi [74], station in Voeikovo(near St.-Petersburg) [75], station at lake Issyk Kul' [76], station of Atmospheric Physics Institute of RAS in Zvenigorod (near Moscow) [77, 78], station in southeast part of lake Baikal [79] and station in area of Tomsk [80].

In conclusion of this part we mention work [81], in which the anomalies and trends of the ozone content in 1979-1992 have been analysed.

6. Mathematical modeling of atmospheric processes

Last years in Russia a number of new atmospheric models of a world level was created. Not discussing details, we list here most important achievements in this field.

In Central Aerologic Observatory the photochemical trajectory model for the low stratosphere has been created [82], which allow us to use in calculations thousand back (in time) trajectories for initial coordinates with account of chemical transformations for each trajectory. With help of this model, in particular, evolution of the ozone active components along trajectories having a place in Arctic Region and Antarctic Region has been calculated that has allowed us to advance in understanding of stratospheric ozone depletion mechanisms in spring time in these areas.

In Hydromet of Russia a model for the description of processes occurring in system "ground - vegetation - surface layer of the atmosphere" in frameworks of prognostic model of general circulation has been developed [83], and also a global spectral model of the atmosphere with a high vertical resolution for the upper troposphere, low and middle stratosphere is created [84].

Other achievements in the field of modeling are presented in works [85-89].

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APPENDIX I

NONLINEAR PROCESSES IN ATMOSPHERIC CEMICAL SYSTEM

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The nonlinear dynamical properties of the Polar Lower Stratospheric Photo-Chemical System (PLS PCS) and the Mesospheric Photo-Chemical System (MPCS) have been investigated under actual atmospheric conditions [1-5, 8].

The sequence of bifurcations of PLS PCS, as demonstrated in [1,8], occurs during Antarctic late winter and spring and influences on ozone layer evolution. Changes of characteristics of the bifurcations due to increasing inorganic chlorine abundance seem to be a reason, as motivated in [1,8], of abrupt development of Antarctic ozone hole in the mid-1980s. Future changes of these characteristics due to changes of other control parameters of PLS PCS can influence significantly on process of the ozone hole recovering [8]. The mechanisms of nonlinear behavior of mesospheric photochemistry were investigated [5]. The dependence of nonlinear dynamical properties of the MPCS on the vertical eddy diffusion rate may be a reason, as shown in [4,8], of summer amplifying of quasi-two-day wave observed in the mesosphere and lower thermosphere. The novel approach to construction of the mathematical models of atmospheric systems that demonstrate complex dynamic behavior has been developed [6,7]. The approach is based on the nonlinear dynamical analysis of time series generated by the system under investigation. The novel neural network based method for studying nonlinear relationships between observed characteristics of the atmosphere has been developed [9-10].

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APPENDIX II

PHOTOCHEMICAL MODELING

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1. The response of atmospheric chemistry to aircrafts emissions have been investigated using photochemical modeling for different situations and seasons:

I.L. Karol, A.A. Kiselev, Y.E. Ozolin, E.V. Rozanov, Plume Transformation Index (PTI) of the Subsonic Aircraft Exhausts and Their Dependence on the External Conditions. Geophysical Research Letters, 2000, v. 27, № 3, pp. 373-376.

2. The evolution of radioactive active gases and its influence on hydrogen radicals have been studied using photochemical model simulations for the period 1850-2050:

A.A. Kiselev, I.L. Karol Modeling of the tropospheric carbon monoxide distribution in the northern temperate belt. Chemosphere: Global Change Science, 1999, v. 1, № 3, pp. 283-300.

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ATMOSPHERIC ELECTRICITY

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Atmospheric electricity problem in the field of operative practice has been transformed during last few years from global aspects of fair weather electricity, atmospheric potential gradient to thunderstorm electricity including lightning detection networks, modeling of cloud electrization processes, investigation of cloud microphysics, dynamics and electricity interrelations and development of thundercloud modification methods.

1. The number of theoretical works deals with non-stationary electric processes resulted from thunderstorm interaction with atmosphere and boundary layer as well [15,21]. The influence of the varying cloud charge structures on electric fields in atmosphere taking into account cloud boundary – atmosphere conductivity step-wise variations is investigated in [4,11,18]. Calculation of electric fields in the upper atmosphere able to initiate lightning discharges from cloud top to ionosphere is an important application of this investigation, it was published [9,22] and reported to the International Conference on Atmospheric Electricity [23,24].

Influence of height profiles on electric conductivity of the atmosphere on distribution of cloud stationary electric field is considered in [6]. This result is important for the global electric circuit modeling and outlines important role the height profile of electric conductivity plays in estimation of electric current flowing to the upper atmosphere.

2. Thunderstorm investigation by means of diverse methods expands and demonstrates a potential for severe storm moderation when cloud modification technologies will apply. Different experimental techniques are developed [2, 10, 11, 12, 13, 29] and various cloud seeding methods, for example, by means of aircraft, can be realized to alter cloud electric activity [2]. Artificial triggering of lightning flash (LF) generates a growing interest as the method for improving of lightning safety. Lidars as tool for artificial lightning need a preliminary investigation of cloud time and space windows for lightning triggering to be successful. Results of multi wave active-passive sounding of thunderstorms and numerical modeling show promise for such a targeting procedure [17, 20].

Possible mechanisms of convective cloud contact electrization are considered [7, 16, 17, 19]. Numerical model of convection based on a detailed microphysics with cloud particles size and mass distributions is available [16]. The necessity of implementation of aircraft measurements to the cloud models noticed in [19].

3. Thunderstorm modification techniques by means of glaciogenic agents delivered by anti-hail rockets and shells are developed. Physical and statistical analysis of experimental data revealed most informative characteristics of lightning activity can be used to assess the effectiveness of thunder- and hail-cloud seeding [30]. Criteria for glaciogenic agent efficiency evaluation and overall cloud seeding effect as well were developed for operative use. Positive effect of cloud treatment has been observed during pre-thunderstorm cloud stage. Mass glaciogenic seeding alters significantly intensity of lightning activity (number of flashes per minute), spectral properties of cloud EM emission, stroke current wave steepness, electric charge amount neutralized by LF, and pulse-time sequence from non-lightning processes in a cloud. Ns type clouds upon a certain weather conditions when seeded can produce electric discharges too. Some of thunderstorm characteristics detected remotely can be used for hailstorm monitoring and hail suppression effect evaluation.

4. In the field of thunderstorm detection use test of lighting sensors of different design is underway [13]. The sensors' data on lightning flash location and time and space sequence indicate reliably thunderstorm evolution. Distributions of thunderstorm event duration, flash rate and total flash amount generated during convective cell lifetime, and regression equations for these characteristics listed in [32].

Time dependence of LF EM emission of VHF band, radar return signals and fast variations of electric field strength in thunderclouds were measured [30]. The effect of range, type and time-space structure of LF, thunderstorm intensity and stage of cloud development on the above characteristics was investigated.

Technique for electric charge amount evaluation, which is neutralized by LF of different type, has been developed based on the use of radio means. Statistical distributions of stroke peak currents and charge amounts neutralized by LF were obtained too. Total amount of electric charge generated during the life cycle of convective cell, considering an average rate of charge generation, estimated in [33].

5. Rocket electrostatic flux meter able to measure three orthogonal components of field strength inside of thundercloud within the range of $5.10^{-8} – 10^{-6}$ V/m with 10% accuracy and noise-to-signal ration 0,01, density of the noise current within the range of $5.10^{-9} – 10^{-6}$ A/m^2 when cloud droplets affect the sensor's electrodes and rocket sensor total charge within the range of $5.10^{-8} – 5.10^{-6}$ C as well has been reduced to practice [31].

6. Thunderstorm rocket sounding indicates average field strength of $1 – 2.10^5$ V/m in active thunderstorms with upper limits of 10^6 V/m. Hail containing clouds revealed 7.10^5 V/m. Design of electrostatic flux meter with electrodes of special shape minimizes noise current influence caused by the impact of charged droplets [34].

7. Theoretical and experimental linkage among elements of atmospheric electricity and atmospheric aerosols (pollutants) analyzed in [1,3,5]. Results of atmospheric electricity measurements in Cuba presented in [8].

8. Based on field strength measurements near the ground , search of meteorological factors responsible for health worsening of cardiological patients when weather changes revealed that it isn't pressure variation alone but the weather as a whole causes worsening in the general physical and mental state of people. The data on electric field of the atmosphere can be used as one of the predictors of health state weakening upon weather alternation [25, 26, 27, 28].

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APPENDIX

ATMOSPHERIC ELECTRODYNAMICS

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1. Among the classical problems of atmospheric physics a search for *universal spectra of atmospheric field pulsations* like the Kolmogorov spectra of temperature and wind velocity, and analysis of *coherent structures*, are of particular importance. Recent studies of short period electric-field pulsations gave evidence for universal spectra of electric field fluctuations and aero-electric structures in the atmosphere.

1a. Short-term (Df @ 10^{-3}–1 Hz) electric field pulsations have been measured in the surface atmospheric layer during 1999 and 2001 under fair-weather conditions. At the frequencies 10^{-2}–1 Hz these pulsations have a power-law spectrum with the spectral index varying in the range from -1.23 to -3.36 while the most probable values of the index fall into the range from -2.25 to -3.0, unlike the temperature fluctuation spectra which obey in the inertial sub-range the Kolmogorov power law with the spectral index close to –5/3.

Anisimov S.V. and Mareev E.A., Pulsation spectra of electrical field of the near-surface atmosphere, *Doklady RAS*, 381, №1, 1-5, 2001.
Anisimov, S.V., E. A. Mareev, N. M. Shikhova and E. M. Dmitriev, Mechanisms for the formation of electric field pulsation spectra in the near-surface atmosphere, *Radiophysics and Quantum Electronics*, vol. 44, pp. 562-579, 2001.
Anisimov, S.V., E. A. Mareev, N. M. Shikhova and E. M. Dmitriev, Universal spectra of electric field pulsations in the atmosphere, *Geophys. Res. Letters*, V.29, №24, 2217, doi:10.1029/2002GL015765, 2002.

1b. The detection of aeroelectrical structures (AESs), accompanying usually time intervals of the most intensive atmospheric turbulence and fog condition, put forward the problem of relationship between the AESs and spectra formation. Remote sensing of aeroelectric pulsations with a changeable inter-sensor distance allowed us to study the relation between the power indexes of structure functions and spectra decay slopes for respective aeroelectric structures. Approximation of the latter by linear function $a_S = a_D + C$ has revealed $a_{S10} = a_{D10} + 1{,}85$ and $a_{S3} = a_{D3} + 1{,}79$ for the 10-m (energy-supply) and 3-m sub-ranges of the inertial interval of aeroelectrical turbulence.

Anisimov, S.V., E. A. Mareev and S. S. Bakastov, On the generation and evolution of aeroelectric structures in the surface layer, *J. Geophys. Res.*, vol. 104, D12, pp. 14359-14367, 1999.
Anisimov S.V. and Mareev E.A., Aeroelectrical structures in the atmosphere, *Doklady RAS*, 371, №1, 101-104, 2000.
Anisimov, S.V., E. A. Mareev, and N. M. Shikhova, Sructures and spectra of turbulent pulsations of electric field in the atmosphere, Proc. 12th Int. Conf. on Atmospheric Electricity, Versailles, France, 279-282, 2003.

2. The electrical properties of the fog have been described in detail on the basis of aero-electrical observations and theoretical modeling. Fog is shown to increase the intensity of electric field pulsations by more than an order of magnitude. Nevertheless, in the majority of observations, the exponent of the spectrum does not differ drastically from the spectrum exponents typical for fair-weather conditions. The results of structure–time analysis offer the possibility of specifying two types of electrical states of fog: one is characterized by aero-electric structure generation, and another one, by chaotic structure–time variations. Possible mechanisms of electric-field profiles and spectra formation were considered with allowance for fog-particle charging, neutral gas turbulence and aero-electric structures in the fog.

Anisimov, S. V., Mareev E.A., Sorokin A.E., Shikhova N.M. and. Dmitriev E. M, Electrodynamical properties of the fog, *Izvestiya, Atmospheric and Oceanic Physics*, vol. 39, N1, p. 58-73, 2003.
Sorokin, A.E., Anisimov S.V., Mareev E.A., Horizontal long-wire antenna as a fog electrical properties analyzer, in *Proc. of Conference on fog and fog collection*. St.John's, Canada, p. 473-476, July 2001.
Anisimov, S. V., Mareev E.A., Shikhova N.M., Sorokin A.E., and Dmitriev E. M, Electrodynamic of the fog, Proc. 12th Int. Conf. on Atmospheric Electricity, Versailles, France, p. 411-414, 2003.

3. A complex of research on *the global electric circuit* has been carried out.

3a. Extensive database obtained after long-term ground-based aero-electrical and magnetic measurements at the Geophysical Observatory “Borok”, enables a unique insight into the main components of the global electric circuit and their interconnection from the middle-latitude observation point. Analysis of atmospheric electric field allows us to represent the global electric circuit as an aggregation of structures with different spatio-temporal scales. These structures are generated by troposphere and space sources of quasi-DC electric field. The energy and evolution of such structures are defined by efficiency of origins and physical property of weakly ionized quasi-neutral atmosphere with inhomogeneous electrical conductivity in the external magnetic field.

Anisimov S.V., The global electric circuit and lower atmospheric electricity, Proc. 12th Int. Conf. on Atmospheric Electricity, Versailles, France, 2003, pp. 693-696.
Anisimov S.V., Dmitriev E.M., Anisimova E.B., Sychev A.N., The database of Geophysical observatory "Borok", *Herald of the DGGGMS RAS,* #4(19), 2001, URL: ***http://www.scgis.ru/russian/cp1251/h_dgggms/4-2001/anisimov.htm#begin***
Anisimov S.V., Mareev E.A., Fine structure of the global electric circuit, Proc. 12th Int. Conf. on Atmospheric Electricity, Versailles, France, 2003, pp. 781-784.

3b. The global electric circuit has been represented as a hierarchy of multi-scale dissipative systems with the atmospheric part of the circuit to be a thermodynamically open system driven by the external sources of energy. Estimates for the energy input into the large-scale field growth, fine structure generation and micro-scale electric field perturbations, as well as for the dissipation rate were carried out. The estimate of the electrostatic energy growth rate for a thunderstorm cell has been performed in the framework of the diffusion equation for the electric field in the thundercloud. Mechanisms of dissipative instabilities leading to structure generation were suggested.

Mareev E.A., Anisimov S.V., Global electric circuit as an open dissipative system, Proc. 12th Int. Conf. on Atmospheric Electricity, Versailles, France, 2003, pp. 797-800.
Mareev E.A., A.E. Sorokin, Autowave regimes of a thunderstorm electrification, *Radiophys. Quantum Electr.*, 39, N1-2. P.797-814, 2001.
Davydenko S.S., Mareev E.A., Marshall T.C., Stolzenburg M., On the calculation of electric fields and currents of mesoscale convective systems and their influence on the global electric circuit, Proc. 12th Int. Conf. on Atmospheric Electricity, Versailles, France, 2003, pp. 697-700.
Davydenko S.S., Mareev E.A., Marshall T.C., Stolzenburg M., Calculation of electric fields and currents of mesoscale convective systems and their influence on the global electric circuit, *J. Geophys. Res.*, submitted.

3c. A new source of atmospheric electricity - planetary electric generator, caused by the non-rigid rotation of the magnetized planet and its plasma envelope, has been suggested and investigated. This mechanism provides a difference of the electric potential between the ground and ionosphere about 90 kV and thus can play a significant role in the global electric circuit. An influence of the altitude and latitude variations of the atmospheric conductivity on the electric field and current density distributions in the lower atmosphere were analyzed. The electric field and current density in the lower atmosphere as calculated in the framework of the planetary electric generator model are of the order of the observed values in the fair weather regions of the terrestrial atmosphere.

P.A. Bespalov, Yu.V. Chugunov, and S.S. Davydenko, Planetary electric generator under fair-weather conditions with altitude-dependent atmospheric conductivity, *J.Atm. Terr.Phys*., 1996, v.58, N5, 605-611.

P.A. Bespalov, and S.S. Davydenko, On the manifestation of the latitudinal variation of atmospheric conductivity in the electric field and current distributions in the global circuit, *Geomagnetizm I aeroniomiya*, 2000, vol.40, No.2, p.71-77.
A.O. Soldatkin, and Yu.V.Chugunov, Stationary axially symmetric structures of weakly ionized plasma in the field of the rotating magnetized sphere, *Plasma Phys. Rep*., 2003, v.29, No.1, p.72-84.

4. *Fine structure of electric field* in thunderstorm clouds and lightning inception.

4a. Several electric field soundings through strat-form clouds and convective regions of a mid-latitude mesoscale convective system, made with balloon-borne electric field meters and radiosondes, have been examined. All these soundings demonstrate the presence of fine structures in the electric field distribution, with characteristic spatial scales of irregularities ranging from hundreds to tens of meters. Fourier analyses of the measured in-cloud electric fields give power-law spectra with the spectral index close to –2. Our theoretical studies to date have shown that a thundercloud has the ability of self-organization manifested as small-scale electrical stratification. As a result, electric cells are generated, which is of particular interest for understanding intra-cloud, cloud-to-ground and high-altitude discharge inception.

Mareev E.A., Sorokin A.E., Iudin D.I., Trakhtengerts V.Yu., Marshall T.C., Stolzenburg M., Fine structure of thunderstorm electric field: spectra from soundings and significance for charge generation mechanisms, Proc. 12th Int. Conf. on Atmospheric Electricity, Versailles, France, 2003, pp. 123-126.
Mareev E.A., A.E. Sorokin, and V.Yu. Trakhtengerts, Effects of collective charging in a multiflow aerosol plasma, Plasma Physics Reports, 25, N3, 289-300, 1999.

4b. A very important feature of the process of electric cell generation is that the electric field in these cells may exceed the mean field value substantially, reaching locally the critical breakdown field. The breakdown inside such a cell initiates breakdown in neighbouring cells, forming a widely branched nonstationary conducting network, occupied the full volume of the cloud. This network can be defined as a "drainage" system of the macroscopic space charge gathering in the cloud. The fractal approach to the quantitative description of this drainage system has been elaborated.

Iudin D.I., Trakhtengerts V.Yu., Grigoriev A.N., Hayakawa M., Electric charge fractal transport and electromagnetic high-frequency radiation on the lightning dicharge preliminary stage, Proc. 12th Int. Conf. on Atmospheric Electricity, Versailles, France, 2003, pp. 605-608.
Iudin D.I., Trakhtengerts V.Yu., Fractal dynamics of electric charge in a thunderstorm cloud, *Izv. RAN, Atmospheric and Oceanic Physics*, V.36, N5, p. 317, 2000.
Iudin D.I., Trakhtengerts V.Yu., Hayakawa M., Fractal dynamics of electric discharges in a thundercloud, *Phys. Rev. E,* 2003, accepted.

5. One of important aspects of atmospheric electrodynamics is nowadays the studies of runaway electron mechanism in the lightning initiation, generation of energetic particles, X-ray and gamma-ray emissions connected to the discharge processes in the atmosphere.
Gurevich A.V. and K.P. Zybin Runaway breakdown and electric discharges in thunderstorms (review). Uspekhi Fizicheskikh Nauk, vol. 171, N11, 2001, pp. 1177-1199.
Gurevich A.V., L.M. Duncan, Yu.V. Medvedev and K.P. Zybin, Radio emission due to simultaneous effect of runaway breakdown and extensive atmospheric showers, Physics letters, A 301, 2002, pp. 320-326.

6. A new quasi-electrostatic model of high altitude electric field generation due to the lightning - induced change of a thundercloud electric structure is presented. The key point of the model is the assumption that a highly conducting channel arises due to a cloud - to - ground discharge, which brings the ground potential to a region near the cloud bottom soon after the discharge initiation. Substantial increase in the electric field strength above the thundercloud at this moment is found. A horizontal extension of the lightning channel is taken into account in the framework of the bi-directional model of the channel propagation. This geometry provides a substantially bigger electric field perturbation than the simplest geometry of the vertical lightning channel does.

Smirnova E.I., Mareev E.A. and Chugunov Yu.V., Modeling of electric field transitional processes, *Geophys. Res. Lett*., V.27, N23, p.3833-3836, 2000.

7. The problem of large-scale quasi-stationary electric field and space charge generation in the moving weakly ionised medium (electric dynamo) is of fundamental significance for atmospheric electricity, as well as for dusty plasmas. Electric dynamo due to random motion of a medium is of particular interest with respect to numerous applications especially to thunderstorm clouds. General criteria for large-scale electric field generation in a continuous conducting medium have been formulated. The present focus of the theory is the turbulent electric dynamo in multi-component multi-flow systems and its application to thunderstorm electrification problem. Theory is based on the calculation of turbulent convective current and its further account in the large-scale evolution equations. Inductive and non-inductive charging mechanisms are taken into account. It is turned out that for inductive mechanism quasi-stationary aerodynamic turbulence might support large-scale charge separation. Estimations have been performed for a thunderstorm cloud conditions when Kolmogorov spectrum for turbulence is valid. These results were drawn for the explanation of large electric field strength in thunderstorm cells with high level of turbulence.

Mareev E.A. and V.Yu.Trakhtengerts, On the problem of electric dynamo, *Radiophysics and Quantum Electronics*, 39, N6, p. 797-814, 1996

Mareev E.A. and G.F.Sarafanov, On spatial structures formation in dusty plasmas, *Physics of Plasmas*, 5, N5, p. 1563-1565, 1998

Mareev, E.A., Turbulent electric dynamo in thunderstorm clouds, Proc. 11th Int. Conf. on Atmospheric Electricity, Gunterswille, USA, 1999, p. 272-275.

ATMOSPHERIC OZONE

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Observations and data analysis

Over 2000-2001, regular monitoring of the total ozone content (TOC) have been continued at 27 ozonometric stations of the Rosgidromet (Russian Hydrometeorological Department). The Scientific Center of Remote Sensing of the Atmosphere (SCRSA) representing a branch of the Central Aerological Observatory (CAO) provided engineering, metrological, and technical means for the measurements. Members of the SCRSA modernized the M-124 ozonometers being now in operation at the stations. A system of routine prompt inspection of the adequacy of the values measured at the stations was developed.

To supply the ozonometric stations with modern instrumentation, members of the Voeikov Main Geophysical Observatory (MGO), the State Institute of Optics, and the Institute of Fine Mechanics and Optics designed and manufactured in 2001 the pilot UV-spectrophotometer intended for measurements of the TOC, UV spectra, aerosol optical density, and so on [Shalamyanskii et al., 2002]. The spectrophotometer is supplied with the polychromator representing the diffraction grating allowing an analysis of radiation in the spectral range from 230 to 420 nm with a resolution of 0.8 nm. The instrument is automated; it is intended for long-term operation under different meteorological conditions. In 2002, principal characteristics of the instrument were studied and field measurements were performed in Voeikovo (the suburb of St. Petersburg). In September 2002, the instrument was calibrated against the standard UV-radiation sources designed in the Finland Meteorological Institute; the calibration was performed in the town of Iokioinen (Finland) [Shalamyanskii et al., 2002].

The CAO performs daily monitoring of the TOC over Russia and neighboring states through accumulation of the observational data obtained by the satellite supplied with the TOMS instrument and by the ground-based ozonometric network.

The scientific stations located at Kislovodsk, Moscow, Dolgoprudnyi, Lovozero, Tomsk, and Mond'ya continued monitoring of surface ozone.

The Kislovodsk high-mountain station (KHMS) located at a height of 2070 m above sea level has performed the ozone concentration measurements for the most long-term period (since March 1989) with a Dasibi-1008 AH gas analyzer. This instrument automatically introduces corrections for the pressure and temperature variations. It is characterized by a sensitivity of 1 ppbv, an absolute measurement error of 1-2 ppbv, and an inspection interval of 10 s. At regular intervals, the instrument is checked against the Dasibi-1008 AH and Dasibi-1008 RS gas analyzers installed at other stations of the Oboukhov Institute of Atmospheric Physics, Russian Academy of Sciences (IAP RAS) and at the mobile laboratory used for the International TROICA experiments [Crutzen, Golitsyn, et al. 1996; Elansky, Markova, 1999]. The gas analyzers have been occasionally calibrated against the ozone generator built into the Dasibi-1008 RS instrument and against the GP-024 ozone generator. In 2002, the instrument installed at the KHMS was calibrated against the mobile standard no. 014. On the whole, the ozone variations over the KHMS are noticeably weaker than those over the other European high-mountain stations are. The character of the daily and seasonal ozone variations changes from year to year almost not at all. The surface ozone measurements performed simultaneously at the KHMS and at the Kislovodsk station located in the Recreation Park (870 m above sea level) showed that the urban and regional pollutants

affect insignificantly the high-mountain ozone concentration.

The KHMS is an important component of the system of global surface ozone monitoring. The region of its location is characterized by a stable climate, by low activity of natural and anthropogenic sources of ozone precursors, and by weak uphill-downhill atmospheric circulation. The upward transport of pollutants in this region is not intensive. As a consequence, the KHMS differs from the ozonometric stations located in this latitudinal belt by smallness of the ozone seasonal variations, by a stable noon minimum in the daily behavior of the ozone concentration, and by inactivity of the chemical processes of daytime ozone formation. As a rule, the boundary atmospheric layer is localized under the KHMS and, therefore, the data obtained at this station characterize the atmospheric state over the entire globe.

The KHMS identified a significant negative trend in the ozone concentration (-1.75±0.40% per year), which was not identified by the Alpine stations over the period of observations. At night (from 01:00 to 05:00), when the station is within the free troposphere and no fog or heavy precipitation occur, the yearly trend is equal to -1.45±0.35% [Senik et al., 2001; Kuznetsova et al., 2001]. The KHMS identified several long-term ozone anomalies, which were opposite to those identified by the Alpine stations. This fact gives grounds to assume that the long-term variation in the ozone concentration and the variability in the large-scale circulation are closely related.

The IAP RAS and the Max Planck Institute of Chemistry (Germany) carried out a series of the TROICA experiments (Trans-Siberian Observations of the Chemistry of the Atmosphere) on the basis of the mobile carriage-laboratory moving along the Trans-Siberian Railroad. The laboratory allows atmospheric monitoring over the regions having no observation stations. From 1995 to 1999, five TROICA experiments were carried out along the railroads Moscow-Vladivostok (9300 km) and Murmansk-Kislovodsk [Krutzen et al., 1996; Crutzen, Elansky et al., 1998; Bergamashi et al., 1998].

To monitor the minor gaseous and aerosol components in the atmospheric surface layer, a set of computerized instrumentation was designed. It includes measuring devices for O_3, NO, NO_2, CH_4, CO, CO_2, and unsaturated organic substances, for aerosol concentration and microphysical and chemical properties, and for temperature profile in the layer 0-600 m, solar radiation, and meteorological and other parameters.

The characteristic peculiarities of the daily ozone variations in the atmospheric surface layer over the continent are the concentration minimum and maximum before sunrise and sunset, respectively. The daily variations of ozone are predominantly influenced by its dry deposition and daytime generation; the former is most intense at night under the condition of temperature inversions. The intense and prolonged inversions over Siberia initiate there a deeper minimum in the ozone concentration in comparison with other regions of the globe.

Over continental Russia, the seasonal ozone variations beyond settlements do not differ from those in remote background regions, namely, the spring maximum occurs. This similarity testifies that photochemical ozone sources over Russia are of lesser importance in comparison with those over Europe and North America.

In cities and industrial regions, the ozone concentration is low. However, in the Far East, intensive ozone generation up to 166 ppb was sometime observed in polluted air under the conditions of high temperature, humidity, and irradiation. In air polluted by products of biomass burning, intensive ozone generation proceeds as well; therewith, the ozone concentration increases by 20-30 ppb.

The nighttime rate of ozone dry deposition under inversions was measured over extensive regions of continental Russia. The maximum rate was observed in summer. Its year-to-year average value was equal to 0.7 cm/s. In winter, over snow-covered regions, the rate is equal to 0.08 cm/s. The summer rate of NOx dry deposition is equal to 0.14 cm/s.

Estimations show that the intense stratospheric intrusions increase the surface ozone concentration by a value ranging within 20 ppb.

On the basis of the mobile laboratory, unique data on the year-round variations in the surface concentrations of volatile organic compounds (VOC) in the atmosphere were obtained for the continental Russian regions lying from Moscow to Khabarovsk and from Murmansk to Kislovodsk.

It was found that the major contribution (67-95%) to the total VOC concentration is made by alkanes. Alkenes and aromatics contribute 2-10% and no more than 15%, respectively. Carbonyl compounds and alcohols contribute less than

15%.

It is shown that the VOC distributions are mainly determined by the local sources and long-rang transport from Central Europe. The atmospheric concentrations of the principal anthropogenic ingredients tend to decrease in the eastward and northward directions. The long-range transport affects predominantly alkanes due to their relative stability.

It is found that remote forest fires affect the composition and concentration of atmospheric organic compounds. Enhanced contents of light C_2-C_3-hydrocarbons, trichloroethane, trichloroethylen, benzene, and toluene and also the occurrence of o-xylene were identified in the plumes of forest fires [Elansky et al. 2001; Shakina et al. 2001].

Methods and instruments intended for stratospheric and mesospheric ozone monitoring based on remote sensing of the millimeter-wave radiation have been developed.

Members of the Lebedev Physical Institute, Russian Academy of Sciences (PI RAS) have performed continuous monitoring of ozone over Moscow since January 1996. They retrieved the ozone concentration profiles in the height range from 15 to 75 km and computed the height-time ozone distribution [Solomonov et al., 2001]. The stratospheric ozone variations associated with the planetary waves were registered and studied; the seasonal behavior of stratospheric ozone was determined; the peculiarities in the daytime and nighttime mesospheric ozone profiles were revealed; and some anomalous phenomena manifesting themselves in long-term significant falls of the ozonospheric ozone content in the height range 25-45 km were identified.

In the framework of this study, pioneering simultaneous nighttime spectral measurements of the mm-wave rotational ozone radiation (PI RAS) and near-IR hydroxyl radiation (IAP RAS) emitted from the same region of the upper atmosphere were performed. A procedure for retrieval of the nighttime ozone profiles up to 100-km height was designed. It uses spectrophotometric data on the hydroxyl temperature at heights of 80-90 km. Significant nighttime variations in the mesospheric and lower-thermospheric ozone concentrations were revealed; the day-to-day variations over the height ranges 55-75 and 85-95 km are characterized by a factor reaching a value of 2-3 and by an increment of 1-8 ppm, respectively. Information on the ozone, atomic oxygen and hydrogen content and on the atmospheric temperature and density at the height of the mesopause were obtained [Perminov et al., 2002].

Simultaneous microwave spectrometric measurements of the stratospheric ozone content were performed in the city of Nizhni Novgorod and at the town of Apatity (the Institute of Applied Physics) located in the polar region. A portion of these measurements were performed in the framework of the International SOLVE program. The results obtained at the sites spaced widely testify that the ozone content measured is always closely associated with the state of the circumpolar vortex [Kulikov et al., 2002, Krasil'nikov et al., 2002].

Members of the PI RAS designed the low-noise mm-wave radio-spectrometer supplied with a wideband acoustooptic spectrum-analyzer (AOS) [Esepkina et al., 2002] designed in the St. Petersburg State Polytechnic University. The performance specification of the AOS characterized by an analyzing band at a frequency of 500 MHz and a frequency resolution of 0.9 MHz and also the peculiarities of the AOS application to measurements of the spectral line of the atmospheric ozone radiation at a frequency of 142.2 GHz were studied. The instrument was successfully applied to the ozone concentration measurements; the members of the PI RAS pioneered in applying such a technique in Russia.

In the city of Tomsk, at the Siberian Lidar Station (the Institute of Atmospheric Optics SD RAS), the lidar measurements of the stratospheric profiles of the ozone and aerosol concentrations and temperature and also the spectrophotometric measurements of the TOC and of the NO_2 total content and profiles have been continued. On the basis of the lidar data consideration, the mechanisms of the ozonosphere variability and of the dynamics of optical characteristics of the stratospheric aerosol layer were improved [Zuev, 2000]. The data obtained in 1999-2002, under conditions of the long-term background state of the stratosphere were used to design models of the ozone and aerosol profiles [El'nikov et al., 2000]. The ozone paleobehavior was retrieved from the dendrochronological data [Zuev and Bondarenko, 2002].

Members of the St. Petersburg State University (StPSU) in cooperation with their German colleagues have performed remote sounding of the temperature profile and of the atmospheric gas composition, basing on interpretation of the downward heat IR-radiation spectra measured with the Fourier-interferometer OASIS under cloudless conditions. A

procedure specially adapted to the data interpretation allowing clarification of the atmospheric parameters and improvement of the parameters for the spectral absolute calibration and for the atmospheric radiative model was proposed and analyzed on the basis of numerical experiments. It was shown that the remote method allows rather exact retrieval of the total content for different minor gases, such as N_2O, CH_4, CFC-11, CFC-12, and CO, and also of the tropospheric ozone content [Virolainen et al., 2001].

The routine releases of ozonesondes and TOC measurements at the Salekhard and Yakutsk stations were continued in the framework of a number of international and national programs. Consideration of the measurements performed during the winter of 2000 showed that the intensive Arctic polar cyclone can lead to ozone chemical destruction and to its cumulative losses reaching 60% at a height of the ozone maximum in the winter-spring period. The retrieved ozone profiles were used to validate the data obtained with the following satellite techniques: ADEOS-I/ILAS, POAM-III, and SAGE-III/METEOR-3M [Yushkov et al., 2002; Tsvetkova et al., 2002**]**.

Much attention was given to the methods of interpretation of satellite measurements of atmospheric ozone. The TOC trends and anomalies over different atmospheric zones were analyzed on the basis of the NOMS data [Chernikov et al., 2002; Smirnov et al., 2000]. A series of technical works oriented on the development of methods of data processing and analyzing as applied to the IASI high-resolution IR spectral sounder intended for installation aboard the prospective EPS/METOP European meteorological satellite was performed. A method of ozone profile estimation on the basis of the information expected from the IASI sounder was considered [Uspenskii et al., 2003].

Members of the StPSU have completed interpretation of the space experiment performed on the basis of the Mir Space Station supplied with the Ozon-Mir instrumentation. It is the first experiment aimed at occultation sounding and using the multi-channel instrumentation capable to operate in the UV, visible, and near-IR spectral ranges. The retrieval of such ozonospheric parameters as the O_3 and NO_2 profiles, spectral coefficients of aerosol attenuation, and parameters of the aerosol size distribution was performed by the method of statistical regularization. A comparison between the values of the retrieved parameters and independent measurements showed a high quality of the applied techniques and procedures [Poberovskii et al., 1999; Polyakov et al., 1999, 2001]. A new procedure of parametrization of the spectral coefficient of aerosol attenuation was proposed for solution of the problem of ozonospheric occultation sounding from space objects [Polyakov et al., 1999, 2001a], and numerical studies of the expected accuracy of retrieving the profiles of the O_3 and NO_2 concentration and aerosol attenuation spectral coefficient with the SAGE III instrumentation were performed.

The CAO contributes to the METEOR 3/SAGE-III Project. Members of the CAO determine the gaseous and aerosol composition of the atmosphere through retrieval of the atmospheric spectral transmittance functions obtained by using 80 spectral channels arranged in the interval from 280 to 1500 nm with a maximum spectral resolution of 0.95 nm and with a height resolution of about 500 m. In the framework of this project, methods, algorithms, and software were developed for retrieving the profiles of the O_3 and NO_2 concentrations and also of the aerosol and water-vapor extinction from spectral transmittance functions [Chayanova and Borisov, 1999].

Members of the StPSU, IAP RAS, and MGO validated the data on the TOC obtained in 1996-2001 with the GOME (Global Ozone Monitoring Experiment, the ERS-2 satellite) instrumentation, comparing these data with the coordinated data of measurements with the Russian ground-based instrumentation and of the simultaneous measurements with the TOMS (Total Ozone Mapping Spectrometer, the EarthProbe satellite) instrumentation [Ionov et al., 2002]. The data of the Russian ozonometric network are in good agreement with the TOMS data; the mean systematic discrepancy between the data obtained with the ground-based instrumentation and with the GOME instrumentation are equal to 3%.

Numerical modeling

Members of the MGO designed a three-dimensional transport-photochemical model of the stratosphere. They estimated the effect of implementation of the Montreal Protocol on the ozonosphere. Model computations showed that evolution of the ozone layer over the period 1992-2000 was determined almost entirely by the current meteorological situation and implementation of the Montreal Protocol changed the ozone content by only 1-2%; therewith, the most

pronounced increment was computed for the atmosphere over Antarctica [Egorov et al., 2002; Egorov et al., 2003; Zubov et al., 1999].

The spring depletions of the Antarctic ozone layer ("ozone hole") over 1993-1996 and 2002 were estimated. To simulate the situation, the accumulated meteorological data resulted from the UKMO reanalysis for the periods under consideration were used. Successful description of the gaseous and heterogeneous photochemical processes provided a good agreement of the model results with the data measured at the Seva (Japan), Marambio (Argentina), and Amundsen-Scott (USA) stations and reproduction of the unique behavior of the "ozone hole" in 2002 [Ozolin et al., 2003; Karol' I.L. et al., 2003].

Members of the RSHMU (St. Petersburg) studied the physico-chemical processes determining the space-time distribution of the atmospheric ozone and other atmospheric gases sensitive to the solar radiation. The computational technique allows accumulation of the measured results by the models of the atmospheric gaseous composition [Smyshlyaev et al., 1999; Yudin et al., 2000]. A set of models of the lower and middle atmosphere was designed. It is focussed on accumulation of the data on the atmospheric gaseous composition measured by different measuring systems (satellite, ground-based, airplane, balloon, etc.) in real-time, i.e., at each step of the model computations. This set of the models was used for a comprehensive analysis of the causes of the atmospheric ozone variability observed in 1970-2000, predictions of the ozone-layer variability in the 21st century, studies of the peculiarities in the distributions of ozone and nitrogen-containing gases in the Antarctic atmosphere, and studies of the effect of the large-scale transfer and convective flows of air masses on the distributions of ozone and other gases in the atmosphere. The degree of adequacy of the SAGE I and SAGE II satellite measurements was analyzed, and the results representing crude errors were rejected. The height-latitude diagrams for the non-measurable minor atmospheric gases participating in the chemical reactions with the gases under measurements are obtained [Smyshlyev and Geller, 2001; Geller and Smyshlyev, 2002].

Members of the IAP RAS studied the effect of disturbances of air flowing over orographic irregularities on the distribution of the ozone concentration in the troposphere and stratosphere. The effect of such a kind was estimated on the basis of numerical modeling of the air flowing around the Antarctic Peninsula. A stationary three-layer nonlinear model unlimited in height was used. The form of the irregularities corresponded exactly to the actual topography of the peninsula. According to the data of the numerical modeling, curves characterizing the flows and distributions of ozone over the range of the orographic disturbances were plotted. Within some layers, the ozone concentration variations reach 60-70%. The TOC over the leeward zone of the mountain ridge varies by 2.1%. Similar variations should be taken into account for interpretation of the ozone measurements performed by ground-based stations, airplanes, and satellites [Elansky et al., 2003].

Members of the Novosibirsk State University (NSU) used a numerical two-dimension zonally-averaged interactive dynamic radiative-photochemical model of the atmosphere to study the global atmospheric gaseous and temperature variations caused by anthropogenic emissions of the following greenhouse and ozone-destroying gases: CO_2, CO, CH_4, N_2O, HCFCs, HFCs, CFCs, CH_3CCl_3, CCl_4, H-1211 and H-1301 halons, and sulfate compounds. The influence of sulfate aerosol and polar stratospheric clouds on the effect of the supersonic aircraft on the ozone layer was studied [Dyominov et al., 2000]. Numerical experiments aimed at clarification of the relative contribution of the natural and anthropogenic factors to the observable variations in the atmospheric ozone content were performed [Dyominov and Zadorozhny, 2000; Dyominov and Zadorozhny, 2001]. The ozone layer state over the period up to 2050 was predicted [Dyominov and Zadorozhny, 2000].

The numerical experiments showed that the sulfate aerosol layer of the atmosphere and the polar stratospheric clouds over the Northern Hemisphere represent the buffer attenuating the susceptibility of the atmospheric ozone layer to the supersonic aircraft effect computed on the basis of the predictable emissions of sulfur compounds and nitrogen oxides from the supersonic aircraft engines. Over the Antarctic region, the heterogeneous processes occurring at the surfaces of the sulfate and polar stratospheric clouds intensify the supersonic aircraft effect on the ozone layer [Dyominov et al., 2000].

It was shown that the 11-year variations in the UV solar radiation and the El Chichon and Pinatubo eruptions

contributed significantly to the global ozone content variations observed late in the 20th century [Dyominov and Zadorozhny, 2001]. The effect inherent in the atmosphere influenced by anthropogenic pollutants and manifesting itself in prolongation of the influence of volcanic eruptions on the global ozone content was revealed and explained [Dyominov and Zadorozhny, 2001].

Greenhouse gases influence the ozone layer because they change the atmospheric temperature. The predicted stratospheric cooling [Dyominov, Zadorozhny, 2000] initiated by the continuous increase in the content of greenhouse gases intensifies the polar ozone depletion through intensification of the heterogeneous processes at the surface of the polar stratospheric clouds; however, on the other hand, it decreases the ozone photochemical losses associated with the temperature dependences of the gaseous reactions. The computations show that, at the 45^{o}N latitude, the CO_2 and CH_4 emissions will lead in December 2050 to the increasing in the TOC by about 2.9 and 1.7%, respectively, and the N_2O and haloid emissions will lead to the decreasing in the TOC by about 1.9 and 3.5%, respectively. The model computations predict that the continuing increase in the atmospheric CO_2 content will accelerate significantly the ozone layer rehabilitation after termination of the anthropogenic haloid emissions. This effect will be clearly pronounced after 2010 and, at the 45^{o}N latitude, will lead to the relaxation of the ozone depletion from 3.5 to 0.65% in 2050.

Members of the Institute of Applied Physics RAS studied the nonlinear dynamical properties of the polar lower-stratospheric photochemical system (PLS PCS) and the mesospheric photochemical system (MPCS) revealing themselves under actual atmospheric conditions [Konovalov et.al., 1999; Sonnemann, Feigin, 1999; Sonnemann, Feigin, 1999; Sonnemann et al., 1999; Konovalov, Feigin, 2000; Feigin et al., 2002].

It was shown that, over the Arctic, under the conditions of late winter and spring, a series of the PLS PCS bifurcations occurs. It can influence significantly the evolution of this system [Konovalov et.al., 1999; Feigin et al., 2002]. Increasing in the atmospheric inorganic chlorine content leads to changes in characteristics of these bifurcations. In [Konovalov et.al., 1999; Feigin et al., 2002], it was shown that this phenomenon might initiate the "sudden" appearance of the Antarctic ozone hole in the mid-1980s. Possible future bifurcation variations caused by trends of other PLS PCS control parameters, such as the concentrations of the greenhouse gases and temperature, may influence significantly the process of rehabilitation of the ozone hole [Feigin et.al, 2002].

The mechanisms of the nonlinear behavior of the mesospheric photochemistry were studied [Konovalov, Feigin, 2000]. It was shown [Sonnemann et al., 1999; Feigin et.al, 2002] that the dependence of nonlinear dynamic properties of the MPCS on the vertical turbulent diffusion intensity may initiate multiple intensification of the quasi-two-day waves observable over the mesosphere and lower thermosphere.

A new approach to formulation of mathematical models of atmospheric systems characterized by a complicated dynamic behavior was developed. This approach is based on the nonlinear dynamic analysis of the temporal dependences characteristic for the system under consideration [Feigin et. al., 2001; Feigin et.al, 2002].

A new method for revealing the nonlinear correlations of observable atmospheric characteristics is proposed and developed. This method is based on application of artificial neuron nets [Konovalov, 2002; Konovalov, 2003].

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APPENDIX

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1. Cosmic influence on ozone layer

Special focus was made to investigate the response of ozone and other species to energetic charged particles (solar and galactic cosmic rays). Ionization caused by solar cosmic rays after solar proton events (SPEs) leads to additional production of nitrogen and hydrogen oxides in the mesosphere- stratosphere region, which could destroy ozone in catalytic cycles. Physics and history of these directions of atmospheric chemistry was published in Review (Krivolutsky et al., 1999). Ozone response to several SPEs including occurred in October 1989, and also during last solar maximum were studied on the basis of photochemical modeling (Krivolutsky et al., 1999; Krivolutsky et al., 2001; Krivolutsky, 2001). The results of photochemical calculations shown that ozone may be practically destroyed in the mesosphere after strong SPEs like events in October 1989, July 2000. The results of comparison between model simulations and observations (HALOE instrument on board of UARS) gave rather good correspondence.

Galactic cosmic rays (which has decadal variability) may influence ozone and other species in the troposphere (Krivolutsky et al., 2002), however data analysis shows more eleven-year signal in ozone than calculated effect.

2. Photochemistry of ozone spring anomaly in presence of air depression over Antarctica

A role of specific atmospheric condition (low air pressure) over South Pole for stratospheric gas-phase photochemistry have been investigated on the basis of data analysis and photochemical numerical modeling (Krivolutsky, 1999; Krivolutsky and Vyshkova, 2002). There were no heterogeneous reactions were used in calculations to estimate a pure effect of gas phase chemistry and photolysis rates on ozone in presence of air depression. The results of model runs have shown a strong correlation between air pressure deficit over South polar region and column ozone. The behavior of ozone content after sunrise in Antarctica, in accordance to calculations, has a visible cavity with time and looks like “ozone hole”. The maximum of calculated ozone depletion was placed above 20 km level (in contrast to the observations) in presence of negligible vertical transport caused by eddy diffusion, but when diffusion was took into account the results were more similar to observations. Correspondent rapid ozone depletion after sunrise may equals about 100 DU in presence of vertical eddy diffusion. So, some rather rapid solutions is possible to find inside gas-phase stratospheric photochemical system if real annual cycle and inter-annual variability in pressure is took into account. Strong enhancement of ClO content after sunrise has been found also in calculations around 20 km level. This effect was initiated by increased photolysis rates. A physical explanation of described effects is based on strong dependence of ozone destruction on the air density and its non-linear character which leads to a very short time of ozone relaxation after sunrise over South Pole.

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CLIMATE AND ITS CHANGES: DIAGNOSTICS AND MODELING (1999-2002)

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Problem of the possible climate changes is one of the key problem for the XXI century. In the global climate studies a significant role play those related to the Russian observed data analysis. Russia is the largest country in the world stretched from the polar latitudes to the subtropics and from the Atlantics to the Pacific. A large number of regional climate anomalies has been registered at the Russian territory. Additionally, accordingly to the model estimations, the strongest temperature changes related to the global warming are expected to be in high latitude, in particular in Siberia (Climate Change 2001 (a,b,c), 2001).

Essential results of the last decade Russian studies in the field of climate changes and evaluation of their impacts were published in (Global climate changes and their impacts for Russia, 2002; Climate changes and their impacts, 2002).

Empirical studies, reanalysis and paleoreconstructions

Important role in the Russian climate studies play empirical analyses for wide band of time variability ranging from the hundreds of thousand years (Barkov et al., 2002, Kotlyakov and Lorius, 2000; Velichko, 2002) till the climate of last millenia (Klimanov, 2002; Krenke and Chernavskaya, 2002) and more detailed - for the climate of the last two centuries and especially for the climate of the 20th century (Alexeev et al., 2000; Bardin, 2002; Budyko et al., 1999; Gruza and Rankova, 2002; Kiktev et al., 2002; Kitaev, 2002; Mirvis, 2002; Nazarov et al., 2002; Nesterov, 2001; Perevedentsev et al., 2001; Golubev et al., 2001; Groisman and Rankova, 2001; Gulev et al., 2001; Polyakov et al., 2002; Savelieva et al., 2000; Sun et al., 2001; Wiedenmann et al., 2002).

Strong resonance (see, e.g., (Houghton et al., 2001)) have got the results of the multiannual project to drill and analyze the ice core data from the Russian Antarctic Station Vostok. This activity allowed to reconstruct climate changes, e.g. temperature regime, and atmospheric radiative-active constituents content, e.g. carbon dioxide and methane, as well as marine and continental aerosol for the last 420 thousands of years (Barkov et al., 2002, Kotlyakov and Lorius, 2000). These results are of great importance to assess cause-effect relations in the Earth climate system on different time scales including those on the scales of tens of thousands years due to changes in orbital parameters (the Milankovitch cycles) and on much faster scales due to anthropogenic influence during the last century (Mokhov et al., 2002). According to the climate reconstructions from the Vostok ice core data the Holocene continuing about 11 thousand years is the most long interglacial for the last more than 400 thousand years (Kotlyakov and Lorius, 2000).

Strong climate changes have been noted in the XX century, especially during its last few decades, in the regions of Russia (Budyko et al., 1999; Gruza and Rankova, 2002; Mirvis, 2002). Annual mean surface air temperature has increased on about 0.9K in Russia with the strongest growth in Siberia (Gruza and Rankova, 2002). For the second part of the XX century in Siberia the temperature trend of 3.5K/100yr is found. Largest warming for Russia is obtained in winter (4.7K/100yr) and spring (2.9K/100yr).

About 2/3 of the Russia is covered by permafrost (Global Climate Changes and Their Impacts for Russia, 2002; Izrael et al., 2002c; Anisimov et al., 2002). Regime of cryolithozone serves as an important indicator of climatic changes. According to (Pavlov et al., 2002) since the late 1970s the most northern continental areas exert weak tendency of active layer deepening. Tendency of warming for perennially frozen soils is found in the northern part of Western Siberia since the late 1970s. At the same time, in the central Yakutiya despite of the drastic regional climate warming, the latter tendency is weak and inhomogeneous.

According to model simulations the largest temperature changes, related to the anthropogenically induced global warming, have to be exhibited in high latitudes. At that the large variability in polar latitudes with strong interdecadal variations masks tendencies of long-term climate change (Polyakov et al., 2002; Bengtsson et al., 2003; Johannessen et al., 2003). An analysis of interrelations of wintertime climate changes in the Arctic and in the lower latitudes during the XX century is made in (Alexeev et al., 2000).

Studies of the changes in snow cover in the northern Eurasia, alongside with a general tendency for its retreat, exhibited for the last few decades of the XX century the regional increase of snow cover thickness and snow storage at the surface (Krenke et al., 2000). In particular, it is found eastward of the Lena River (Kitaev et al., 2002; Krenke et al., 2001). In contrast in the northern part of North America snow thickness decreases.

In the XX century, especially during the last few decades, statistically significant climate changes are found in different regions. Most significant changes are exhibited for extremal regimes. For example, in (Kiktev et al., 2002) by empirical data for the second half of the XX century it was found that alongside with the general tendency toward warmer and wetter climate a number of statistically significant shifts in extrema have occured. In particular for the Asian part of Russia (excluding Western Siberia) a significant decrease of the number of frost days is exhibited. A tendency for warm nights during the year is also noted, significant for the north-western and Asian parts of Russia. For the European part of Russia (excluding its northernmost parts) a tendency for the number of days with heavy rains is obtained. At that regional tendencies for precipitation intensity increase are found. For the northern and southern (Kuban, Caucasus) regions of the European part of Russia and in the central Siberia the maximal number of dry days decreased.

There is a series of papers devoted to the analysis of peculiarities and regional impact of quasi-cyclic phenomenon El Nino (which is associated with the strongest variations of global surface air temperature on the interannual time scale), North Atlantic and Arctic Oscillations (with strong influence on the Northern Hemisphere climate), quasi-biennial oscillations (Gruza et al., 1999: Mokhov et al., 2000a,b; Nesterov, 2003; Petrosyants and Gushchina, 2002; Gruzdev and Bezverkhny, 2000). Tendencies of change of annual cycle of climate, in particular for surface air temperature, with an analysis of regional processes were studied in (Eliseev et al., 2000; Mirvis, 2002; Eliseev and Mokhov, 2003).

In (Sklyarov, 2001) an analysis of the variations of solar constant for the last two decades of the XX century was performed with a comparison with variations of global surface air temperature. It was noted that the former quantity does not show any drift during this period while the latter has grown.

Alongside with the data of observations the climate variability in the second part of the XX century were analyzed using the data of reanalyses. In particular based on the NCEP/NCAR reanalysis data the changes of extratropical cyclones and blockings, characteristics of the surface air temperature annual cycle and temperature trends at different heights were analyzed (Gulev at al., 2001; Eliseev and Mokhov, 2003; Khan et al., 2003; Wiedenmann et al., 2002; Zveryaev and Chu, 2003).

Theory of climate and climate modelling

The role of the climate modelling and model-based diagnosis of past and future climate variations is increasing continiously (Alexeev and Ryabchenko, 2000; Arpe et al., 1999; Volodin, 2000; Galin and Volodin, 2002; Demchenko et al., 2002; Diansky and Volodin, 2002; Dymnikov et al., 2002; Kislov, 2001; Meleshko et al., 2000; Mokhov et al., 2002;

Anisimov et al., 2002; Claussen et al., 2002; Eliseev and Mokhov, 2003; Joussaume et al., 1999; Kattsov and Walsh, 2000; Semenov and Bengtsson, 2002). Russian models take part in the international intercomparison projects AMIP, CMIP, PMIP, EMIP (Diansky and Volodin, 2002; Claussen et al., 2002; Joussaume et al., 1999; Walsh et al., 2002).

Climate models can be divided according to their complexity into three classes: conceptual models, models of intermediate complexity and (most detailed) general circulation models (Claussen et al., 2002). Here the model's complexity is characterized by the number of climate variables computed explicitly, by the number of explicitly considered processes and by the complexity of their determination.

State-of-the-art coupled general circulation models allow ones not only to simulate spatial peculiarities of the Earth climate but also realistically reproduce climate changes, both global and regional (Global Climate Changes and Their Impacts for Russia, 2002; Arpe et al., 2000). New results were obtained using different numerical experiments with general circulation models (Arpe et al., 2000; Demchenko et al., 2002; Diansky and Volodin, 2002; Dymnikov et al., 2002; Galin and Volodin, 2002; Kislov, 2001; Meleshko et al., 2000; Volodin, 2000). In (Diansky and Volodin, 2002) the results of CMIP2 numerical experiments with the first Russian coupled general circulation model (CGCM) - INM GCM were presented with the scenario CMIP2. First results of simulations with this model extended by the RSHMU chemistry module (Yudin et al., 2000) were presented in (Galin et al., 2003). In (Meleshko et al., 2000) using the MGO general circulation model an analysis of important climate feedbacks such as cloud-radiative and water vapour feedbacks is performed. Features of annual cycle were studied in (Kurbatkin, 2000). An implementation of the new module for land surface hydrology into the HMC general circulation model allows for realistic simulation of river runoff annual cycle in a number of Siberian regions (Rubinstein and Shmakin, 1999).

A perspective area of climate studies is due to regional climate models (with substantionally increased spatial resolution) coupled to a global (of a relatively coarse resolution) climate model (Krupchatnikov, Fomenko 1999; Shkolnik et al., 2000).

Special class of global climate models consists of the Earth system models of intermediate complexity (EMICs) (Claussen et al., 2002; Demchenko et al., 2002; Eliseev and Mokhov, 2003; Ganopolski et al., 2001; Handorf et al., 1999; Mokhov et al., 2002; Petoukhov et al., 2000). The only Russian model of this type participating in the international intercomparison is the IAP RAS climate model (Claussen et al., 2002). This is the first Russian global three-dimensional climate model, which was run under different scenarios of continiously evolving anthropogenic forcing (e.g., CO2 atmospheric content) for the XIX-XXI centuries (Mokhov et al., 2002). EMICs have a rather detailed description of climatic processes and allow one to simulate much larger and longer (in comparison to CGCMs) number of scenarios due to a number of parameterizations and/or relatively coarse spatial resolution.

Model estimations of possible global and regional climate changes and their impacts

Using global climate models possible regional climate changes are simulated for different scenarios of anthropogenic forcing, e.g. for greenhouse gases atmospheric loading. In particular, in (Anisimov et al., 2002; Demchenko et al., 2002; Izrael et al., 2002; Malevsky-Malevich and Nadezhina, Nelson et al., 2002) possible changes in the permafrost cover are estimated. According to (Demchenko et al., 2002) sensitivity of the area with climate conditions favourable for permafrost scatter significantly between different models but changes only slightly between studied scenarios of anthropogenic forcing, in particular taking and not taking into account aerosol aerosol loading into the atmosphere. A comparison of simulations with the paleoreconsructed data showed that the southern boundary of continious permafrost for the Holocene Optimum is similar to that potentially approached in the middle XXI century if an aerosol loading is taken into account. If this loading is not taken into account these potentially approached conditions are similar to the Eemian Interglacial.

Nagurny et al. (2002) simulated long-term changes in temperature and precipitation in the Arctics under different

scenarios of anthropogenically-induced forcing including those due to atmospheric greenhouse-gases and sulfate aerosol content.

According to model simulations alongside with significant interannual and interdecadal variability a general growth of precipitation and river discharge in the watersheds of the Volga river and the Caspian Sea, the Neva river and the Ladoga Lake, Ob, Yenisei and Lena rivers and their variability in the XXI century are projected (Mokhov et al., 2002). Changes in wintertime and summertime precipitation differ substantionally between each other (Semenov and Bengtsson, 2002). In particular, for the central European part of Russia a general increase of precipitation in the XX-XXI centuries accompanied by significant interdecadal variations (Mokhov et a., 2002). It is related mostly to the wintertime precipitation, while the summertime precipitation decreases. At that a general decrease of precipitation is possible in the first quarter of the XXI century. Significant growth is found for precipitation intensity and the number of days with heavy precipitation. At that for the number of days with precipitation an increase of variability in the XXI century in comparison to the XX century is found. According to the model simulations in the XXI century contribution of heavy precipitation into total precipitatuion increases.

Similar model estimations are made also for other regions (Mokhov et al., 2002). For Siberia as a whole and for the Lena river watershed in particular, an increase of total precipitation, heavy precipitation frequency and heavy precipitation intensity is found. Changes in the number of days with precipitation in this region (with its general increase) differ substantionally from those for central European Russia (where an amplitude of variations increases in the XXI century).

It is very important to estimate changes in biologic production under climate changes possible in the XXI century (Golubyatnikov and Denisenko, 2001; Global Climate Changes and Their Impacts for Russia, 2002). Biologic production in the European part of Russia can increase on about 2 ton per hectare per year with a maximum (of about 4 ton per hectare per year) in 60-70N under the CO_2 content doubling in the atmosphere (Golubyatnikov and Denisenko, 2001). At that maximum near 50N shifts northward on about 5 degrees in latutude.

Climate changes and the problem of sustainable development

In a number of papers the problem of climate change is discussed in relation to the problem of Kyoto protocol and to the conclusions made by the Intergovernmental Panel on Climate Change - IPCC (Izrael et al., 2001, 2002a,b; Kondratyev and Demirchan, 2001; Kondratyev, 2002). In particular, in (Kondratyev and Demirchan, 2001; Kondratyev, 2002) based on the results of the Third IPCC Assessment (2001), Sixth Conference of the Parties (COP-6), subsequent COP-6.2 in Bonn and World Summit on Sustainable Development (Rio+10) in Johannesburg (2002) the recommendations and mechanisms of the Kyoto Protocol about the limitations of the greenhouse gases emissions into the atmosphere to prohibit global climate changes in the XXI century are discussed. In (Izrael et al., 2002b) the data on greenhouse gases (CO_2, CH_4, N_2O, as well as HFC, PFC and SF6) emission changes in Russia during 1900-1999 are presented for the first time. Annual mean CO_2 sink in the Russian forests is evaluated - about 100 Mt. At that annual mean CO_2 loading is evaluated as 450 Mt and emissions due to fires and forest cutting as 50 and 300 Mt per year, respectively. Egorova et al. (2001) estimated of the effect of the Montreal Protocol related to the decrease of stratospheric ozone content found in the late XX century.

Realistic estimation of positive and negative effects of climate change needs interrelated studies of economical, ecological, social and political processes with a systematic modelling both on the global and regional levels. In particular, in (Sustainable Development of Russia and Its Regions, 2001) the project is considered which deals with the systematic interdisciplinar study of sustainable development of Russia in the first quarter of the XXI century related to the problem of the climate change.

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DYNAMIC METEOROLOGY

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Stability and sensitivity of the atmosphere

The response of a system of equations describing the dynamics of a baroclinic atmosphere to small external forcing of an arbitrary form is studied. The possibility of predicting the response on the basis of simplified models constructed from model data is considered. With the aid of the Monte-Carlo method, the operator of the model response to the small external forcing is directly calculated. It is shown that this operator can be assumed to be linear in a wide range of variation of the perturbation norm. The maximum response of the system is close to the first low-frequency empirical orthogonal function (EOF) of the system. In order to predict the sensitivity of the model system, a linear dynamic–stochastic model is constructed whose low-frequency variability is identical to that of the original system. The linear operator of such a model, in which the right-hand side is a random process, can be calculated from model data. A comparison between the linear operator, which controls the response of the original system to small external forcing, and the operator of the linear model shows that their singular vectors are close. Hence, in order to predict the sensitivity of the model in question, one can use its dynamic–stochastic analogue. Moreover, the autocovariance matrix of the right-hand side of the linear model can be taken to be equal to $c\mathbf{I}$, where c is a number and $\mathbf{I}$ the identity matrix. The consequence of this result is that the maximum response of the linear system, as well as the maximum response of the original system, falls at the first low-frequency EOF of model circulation (Gritsun and Dymnikov, 1999).

The class of adjoint equations for hydrodynamic-type systems is investigated. Such equations are used to construct new integral invariants. A subclass of adjoint equations is singled out whose solutions are Lyapunov stable regardless of theirs stability respective to the original system (Dymnikov, 2001).

A study was conducted showing that the fluctuation–dissipation relation (FDR) can be used to reconstruct the dynamic response of the atmosphere to tropical sea surface temperature (SST) anomalies. The study was based on numerical results produced by the atmospheric general circulation model developed at the Institute of Numerical Mathematics, Russian Academy of Sciences. A Monte Carlo numerical experiment was performed to trace the evolution of the model response to a prescribed SST anomaly. The response was reconstructed by applying an FDR-based relation derived via introducing several assumptions on the spatial-temporal structure of correlations in the atmosphere. A small perturbation of the dynamic forcing associated with the SST anomaly was specified as a rapidly forming response in the tropics (localized response) normalized by the period of its development. A method for selecting an optimal basis for

calculations is discussed. The reconstructed response was shown to agree with the response calculated by averaging over a large ensemble of realizations. The proposed technique gives the correct temporal behavior of the response (Glazunov and Dymnikov, 2002).

Tropical Cyclones: Statistical Regularities of Distribution Functions Depending on Intensity and Lifetime

The analysis of characteristic features of tropical cyclones is carried out on the basis of multiyear data. In particular, the distribution functions of these cyclones depending on intensity and lifetime are analyzed for different ocean basins. It is found that the exponential functions rather than power ones are typical for the distribution of a number of tropical cyclones with respect to their lifetime and intensity. It is shown that corresponding cumulative distributions are also well approximated with exponential functions in sufficiently large range of values for intensity and lifetime of tropical cyclones (Golitsyn et al., 1999).

Atmospheric Centers of Action and Tendencies of Their Change

Tendencies of change in the characteristics of atmospheric centers of action (ACAs) in the Northern Hemisphere are analyzed using empirical data over the period 1891–1995. The results are compared to model estimates. The hydrostatic equation is used to obtain the simplest model estimates. A more detailed model is based on the consideration of quasi-stationary Rossby waves on a sphere at the equivalent-barotropic level. For the mode with meridional wave number 5 and zonal wave number 2, which makes a major contribution to the formation of Northern Hemisphere ACAs, the coupled dynamics of the pressure and temperature fields at the equivalent-barotropic level is analyzed analytically. The interrelation between the corresponding surface fields is estimated with allowance for a functional relationship between the tropospheric temperature lapse rate and the surface air temperature. The resulting model expressions can be used for a qualitative analysis of the relative role of various climatic variables in the formation of the sensitivity of ACA characteristics to global changes, both anthropogenic, caused by changes in the atmospheric contents of greenhouse gases and aerosol, and natural, associated, for example, with phenomena like El Niño. Model estimates are used to explain a possible strengthening of ACA intensity under global warming of the climate, which is detected, in particular, for the wintertime Siberian High by analyzing empirical data. The corresponding tendencies of change in the ACA location (latitude and longitude) are estimated (Mokhov and Petukhov, 2000).

The Climatology of Blocking Anticyclones for the Northern and Southern Hemispheres: Block Intensity as a Diagnostic

A 30-yr climatology of blocking events was compiled by stratifying the data into seasonal and three regional categories for both the Northern and Southern Hemispheres using the NCEP–NCAR reanalysis. Several characteristics of blocking anticyclones were included in the study and these were frequency of occurrence, preferred formation regions, duration, blocking days, and intensity. The block intensity (BI) calculation was modified successfully from a previous study in order to automate the procedure for use with large datasets, and it is applied for the first time to derive a long-term observational record of this quantity. This modification also makes BI suitable for its use as a diagnostic tool. Blocking events in the Northern (Southern) Hemisphere were the most persistent and strongest during the cold season and over the Atlantic (Pacific) region, as found using BI as the blocking action measure.

The characteristics of blocking events derived in this study were compared to previous long-term climatological studies and across each hemisphere. It was found that the temporal and spatial distributions in both hemispheres were similar to those of longer-term studies. The interannual variability of blocking was also examined with respect to ENSO-related

variability for the entire blocking year. It was found that Northern (Southern) Hemisphere blocking events were stronger and more frequent during La Niña (El Niño) years, a result that is consistent with cyclone variability level in each hemisphere. Additionally, these results were compared with previously published studies of interannual variability in blocking occurrence (Wiedenmann et al., 2002).

Study of Extreme Weather Events and Development of the Theory of Adiabatic Invariants

In 1999-2002 research efforts have been concentrated on the study of extreme weather events, with emphasis on tornadic vortices. A modification of turbulent dynamo model has been proposed in (Kurgansky, 1999) to explain the initial tornado-like vortex formation, which takes place in the foot of a rotating storm. General thermodynamically and fluid dynamically based arguments have been given to construct a simple version of similarity theory for the mature, quasi-steady stage of a helical moist-convective vortex. On this basis, a steady reference distribution of tornadic vortices with respect to the Fujita scale wind speed has been introduced and critically compared with some statistical data on tornadoes over the territory of Russia and also USA (Kurgansky, 2000). A general review of physical and fluid dynamical processes, which may explain the tornadoes genesis and maintenance, have been given in (Kurgansky, 2001).

A general theory of adiabatic invariants of the atmospheric fluid motion has been further developed, with the focus on a fundamental notion of the Ertel potential vorticity (PV). It has been proposed (Kurgansky and Pisnichenko, 2000) to use the properly (optimally) modified Ertel PV as a climate variable, and a negative-exponential distribution of the atmospheric mass on modified Ertel PV values has been introduced as the best fit to observational data. This adiabatic invariant theory has been summarized in (Kurgansky, 2002); its implications to an oceanographic problem of the absolute fluid motion determination have been given in (Kurgansky et al., 2002).

Effect of Helicity in the Atmospheric Boundary Layer

Ekman spiral flow in the planetary boundary layer (Ekman flow) is helical and obviously produces helicity of the turbulent flow component. In its turn, the helical properties of turbulence may change the structure of the Reynolds stress tensor, which affects steady-state regimes, including the Ekman flow itself. The self-consistent, semi-empirical model of the Ekman boundary layer with allowance for the helicity of the turbulent velocity field has been constructed (Chkhetiani, 2001). Helicity reduces the mean turbulent energy, modifies the Ekman flow, diminishes the deflection angle of the Ekman spiral and increases the effective height of the boundary layer. These effects directly manifest the reduction of the energy flux toward the small scales in helical turbulence.

In (Ponomarev et al., 2003), the stability of the modified Ekman flow is considered. The account for turbulent helicity raises an inflection-point-instability threshold, compared to the previous results. On the contrary, the threshold for parallel instability is slightly lowered. There are changes in scales and orientation of the unstable modes. The comparison with classical and modern boundary layer models and also with observation data on secondary roll circulation is discussed.

Parameterizations of Boundary Layers

The new parameterization is developed for use in the Global Circulation Models. The closure scheme uses the turbulent kinetic energy balance, Kolmogorov hypothesis and includes generalization of the von Kármán hypothesis onto the stratification case. Numerical solutions are provided through the universal non-dimensional functions (UNFs) using the similarity theory, where UNFs of the real planetary boundary layer (disturbed by baroclinicity, vertical circulation and by

quasi-stationary change of the boundary parameters) are split into combinations that depend only on two non-dimensional parameters. The coupled system of atmospheric and oceanic governing equations is closed via the local balances of surface heat and mass. Broad family of tests demonstrates good agreements with data (Dethloff et al., 2001; Makshtas et al., 2002).

A Turbulence Closure for the Convective Boundary Layer Based on a Two-Scale Mass-Flux Approach

The closure problem for the convective turbulence of the shear-free and low-to-moderate wind atmospheric boundary layer is considered. Non-Gaussian parameterizations are developed for fourth-order moments based on a two-scale mass-flux approach. With this approach the ballistic stirring of a fluid by coherent structures is taken into account and the differences in the horizontal scales and spacing of the velocity and temperature fields are recognized. The fractional coverage of positive temperature variations is introduced, as well as the fractional coverage of positive vertical velocity fluctuations. The parameterizations are compared to those of the traditional mass-flux scheme and of the classical eddy-damped quasi-normal approach, and the principal similarities and dissimilarities are outlined. The results of testing the parameterizations against aircraft measurements at moderate wind and against large eddy simulation data of free convective conditions show good agreement between model predictions and data (Gryanik and Hartmann, 2002).

"Negative Heat Capacity" of Stratified Two-Component Geophysical Media (Moist Air and Salt Water)

The development of turbulent convection in the stratified moist air or salt water heated from below or cooled from above is considered. To describe the turbulent convective exchange, one uses an approach based on semi-empirical theory of turbulence and dimensionality/similarity arguments. The known analytical models of the convection arising from isolated heat-sources (convective plumes and thermals) are extended to the situations when the medium is stratified on both hydrodynamic components. It has been shown that for a two-component medium, the temperature field solutions exist, which are radically different from the known earlier (for one-component medium). It has been shown, that the addition of the stable salinity stratification to the pre-existing stable temperature stratification can result in the essential increase in the amplitude and penetration depth of the thermal disturbances arising due to the inhomogeneities at the surface. The situations are feasible, when the sign of temperature disturbances at the water surface layer is opposite to the sign of stationary disturbance of the given heat inflow at the surface area. Similar effects are possible in the atmosphere surface layer taking into account the moisture stratification (Ingel', 2001).

The Previously Unexplored Mechanism of a Convective Instability

A previously unexplored mechanism of convective instability in the two-component media and near water-air interface has been found. This is a mechanism of convective instability of the atmospheric boundary layer over a water mass. In the air, stratified by moisture, vertical motions produce variations in specific humidity (mixing ratio) near the interface surface. This, in turn, causes variations in evaporation from the water surface and horizontal thermal inhomogeneities that can, under certain conditions, strengthen the initial vertical motions. In (Ingel', 2002), the linear stability problem for the system under consideration is solved. The results show the possibility of the development of disturbances with horizontal scales of several hundred meters for a period of about one hour even for a stable stratified atmospheric layer over a water surface and in the absence of destabilizing velocity shears.

The semi-Lagrangian vorticity-divergence variable resolution model

The global finite-difference semi-Lagrangian variable resolution numerical weather prediction model is developed and tested (Tolstykh, 2001). The distinct features of the presented model are the use of vorticity and divergence as prognostic variables in conjunction with the fourth-order compact finite differences on the unstaggered regular latitude-longitude grid. This model uses the set of parameterizations for subgrid scale processes from French operational ARPEGE/IFS model. The results of the standard test set for shallow water equations on the sphere demonstrate the accuracy and computational efficiency of the 2D version of the model with the time steps several times greater than in Eulerian model (Tolstykh, 2002).

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During 1999-2002 Russian scientists used actively the cooperation with partners from Europe and United States as well as support from Russian Science Foundation. Some interesting results have been obtained in Middle atmosphere studies. Now we will make a focus on long-term variability of middle atmosphere parameters and the effects of solar activity and of cosmic influence in general. The processes in the D-region of ionosphere will be included partly also. We did not include the problem of ozone change here (see Part "Atmospheric Ozone" of this issue).

1. LONG-TERM VARIABILITY

The problem of climate variability of the middle and higher atmosphere (in range 20-300 km) was out of the focus of the investigators up to the beginning of 80th. Long-term effects in this range of altitudes, not connected to 11-cycle of solar activity, has been revealed only in the beginning of 90th. Then different groups announced about the results, which demonstrated such variability in different parameters of the atmosphere based on measurements by different methods and instruments. Several Russian groups had it own observations and initiated the organization International Meeting "Cooling and subsidence of the middle and higher atmosphere" (Moscow, 6-10 July 1998; see Review published by Golitsyn and Givishvili, 1999).
This Workshop shows the future directions and focuses for observations, data analysis, and numerical modeling. Now we will describe briefly obtained results after Meeting in Moscow.

1.1 Temperature (observations)

Long-term temperature trends in the range of altitudes between 25-110 km have been studied on the basis of rocket, radiophysical and optical Russian measurements for middle latitudes (Lysenko et al, 1999), and 1955-1995 period. It was shown that the levels of fixed temperature has negative trends in the middle and higher atmosphere. Negative temperature trend (0.1-09 K/Y) during last decade between 25-100 km and positive trend (0.8 K/Y) at 110 km was found. It was suppose that positive trend in temperature at 110 km was caused by a subsidence of the atmosphere.

Long term data of auroral ray heights according to Stormer's measurements have been analyzed with removing regular seasonal and solar activity variations (Starkov et al., 2000). The result reveals a lon-term linear negative trend of mean auroral heights (-0.8 km/y and -0.5 km/y) at heights 160-180 km during the period from 1918 till 1944 and at 145 km for the period from 1957 till 1988, respectively. There is satisfactory agreement with the atmospheric subsidence for the period 1918-1944 and 1955-1995. Thus, there was a stable process of middle and upper atmospheric cooling and subsidence over the 20th century.

Seasonal dependence of the temperature trends in the mesosphere have been investigated on the basis of OH emission measurements at different locations (Golitsyn et al., 2000). Negative temperature trend for winter seasons (-0.92 K/Y) has been detected, but practically zero trend was found for summer. Amplitudes and phases of seasonal harmonics were calculated for maximum and minimum of solar cycles. Obtained results based on hydrogen radicals emissions jointly with rocket and radiozonde observations would be useful for the construction of new empirical models of the

temperature regime of the middle atmosphere.

The velocity of atmospheric subsidence and the magnitudes of temperature trends was investigated also in the middle atmosphere and lower thermosphere (Semenov et al., 2000; Semenov et al., 2002) on the basis of temperature measurements not only in Russia, but at several points in different countries including lidar observations in Brazil. In accordance to lidar observations close correlation between temperature and Na content exists and developed regression model gives good correspondence for temperature with the temperature obtained by another methods near 92 km level. The important result of this study is the estimation of the atmospheric subsidence. For example, such subsidence at the level of NCL (82-83 km) equals about -50 m/Y. So, respective trend in atmospheric density at these altitudes is -1.5% per year. At the same time the increasing of solar activity (if we use rather short intervals for analysis) leads to compensation of described atmospheric subsidence, and, thus, the level of NLC may be practically constant.

Excellent Review devoted to temperature trends was published due to the efforts and help from different groups and personals (Ramaswamy et al., 2001) including results obtained by scientists from Russia. In Review the long-term trends from approximately the mid-1960s to the mid-1990s period was presented. The stratosphere has, in general, undergone considerable cooling over the past 3 decades. At northern midlatitudes the lower stratosphere cooling over the 1979-1994 period is strikingly coherent among the various data sets with regard to magnitude and statistical significance. A substantial cooling occurs in polar lower stratosphere during winter-spring; however, there is a large dynamical variability in the northern polar region. The vertical profile of the annual mean stratospheric temperature change in the northern midlatitude over the 1979-1994 period is robast among the different data sets, with 0.75 K/decade cooling in the 20 to 35-km region and increasing cooling above (e.g., 2.5 K/decade at 50 km). Model investigations into the cause or causes of the observed temperature trends are also reviewed. Simulations based on on the known changes in species concentrations indicate that the depletion of lower stratospheric ozone is the major radiative factor in according for the 1979-1990 cooling trend in the global, annual-mean lower stratosphere (to 0.6 K/decade), with a substantially lesser contribution by the well-mixed greenhouse gases. Ozone loss is also an important causal factor in the latitude-month pattern of the lower stratospheric cooling trend. Uncertainties arise due to incomplete knowledge of the vertical profile of ozone loss near the tropopause. In the middle and upper stratosphere, both well-mixed greenhouse gases and ozone changes contribute in an important manner to the cooling, but model simulations underestimate the observed decadal-scale trend. While there is a lack of reliable information on water vapor changes over the 1980s decade, satellite measurements in the early to middle 1990s indicate increases in water vapor that could be a significant contributor to the cooling of the global lower stratosphere.

Long-term variations of atmospheric temperature at different isobaric surfaces above central Antarctica were studied also (Makarova and Shirochkov, 2002). Data of balloon sounding at two Antarctic stations Vostok and Amundsen-Scott (South Pole) taken for the last 40 years were used in this study. It was found that stratospheric temperature at both stations averaged seasonally or annually does not demonstrate any meaningful correlation with correspondent sunspot number variations, but the correlation with solar wind was found. At both geographic poles, stratospheric temperature had the tendency to warming in 1972-1995. On the other hand, temperature data for Vostok demonstrates clear tendency to cooling for the same period. Authors give possible explanation for the difference in temperature tendency for south pole and Vostok station by the existence of different electrical parameters at these points.

1.2 Other parameters (observations)

It should be mentioned that the essential part of the results of long-term measurements of the temperature are based on systematic analysis of the long-term observations of the emissions of hydroxyl and atomic oxygen 557.7 nm which give the possibility to create empirical models for intensities, temperatures and heights of the emissive layers. It was established that regular occurrence of the temperature maximum for heights of 85-95 km with the period of solar activity exists (Shefov et al., 2000). Distribution with height of the atomic oxygen concentration for low and high solar activity conditions have been calculated on the basis of an empirical model of 557.7 nm emission variations and its photochemical theory. It was shown that there is the distinct correlation between an increment of the temperature and the

density of the atomic oxygen. Apparently, a reaction of CO_2 with O_2 causes this phenomenon. Additionally, on the basis on rocket and lidar data about regular variations of the Na maximum and vertical distribution of its emission in range 589-589.6 nm, a linear approximations (variations of Na during night, seasonal variations, variations in solar cycle, long-term trend) have been obtained, as well as empirical model of oxygen emission variations (Shefov et al. 2000; Fishkova et al., 2000, 2001a, 2001b).

Russian rocket data for the period 1969-1993 was used to estimates linear trends in pressure and density in addition to temperature trends. Four points of rocket sounding locations at high (both hemispheres), middle and low (northern hemisphere) latitudes were used for analysis. Linear regression model which included seasonal harmonic, 11-solar cycle and equatorial wind QBO were included in the model as well as linear trend. The results (Glazkov et al., 1999) show that negative trend in both parameters above exists with increasing magnitude above 30 km (zero trends) to its maximum in the mesosphere (-0.5 %/Y in density and about -1.0%/Y for pressure at mid-latitudes). So, these results support the idea of the atmospheric subsidence mentioned above. The results obtained in this paper (Glazkov et al., 1999) leads also to the idea that pressure or density long-term deficit may causes disturbances in photochemistry of the mesosphere and corresponding trends in ozone and other species content (Krivolutsky 1999; Krivolutsky et al., 2002). Calculated changes in ozone content in the mesosphere are similar to observed ozone trends. Negative trend of ozone was also found in the mesosphere on the basis of empirical model of hydroxyl emission, atomic sodium, oxygen emission and analytical photochemical model (Shefov and Semenov, 2002).

The only direct and long-term measurements of electron density in the lower ionosphere were made aboard rockets. However, such measurements are “snapshots” and, therefore, it is practically impossible to find a long series of observations under the same or comparable conditions. To eliminate this difficulty, a method developed by Danilov (1997) for E-region was useful. Positive trends in electron density was found (Danilov and Smirnova, 1999). Only non-winter data were used for analysis. The winter time trend at 80 km is stronger, but with much larger scatter of data. At 85 km the trend is weaker than at 80 km, and at 90 km the trend becomes insignificant. The observed by the authors positive trends in electron densities are consistent with the reported by another authors trend of decrease of the phase reflection heights. They are qualitatively consistent with the idea of thermal shrinking of the mesosphere and thermosphere as a consequence of cooling by greenhouse gases.

2. Dynamics

Dynamical processes in the middle atmosphere were in the focus of different groups in Russia. Russian scientists participated and were active also in different International scientific meetings presenting their results.

One of the important part of this activity was investigation of gravity waves in the middle atmosphere. Several report have been presented at 33rd Assembly of COSPAR in Poland (Gavrilov et al., 2000; Belyev and Moiseenko, 2000; Savina and Molodzov, 2000; Bakhmet’eva et al., 2000; Benediktov, 2000).

Preliminary results, which demonstrate gravity wave structure in infra-red emission of night sky have been presented (Gavrilyeva and Ammosov, 2001), and from radar observations (Gavrilov et al., 1999). Short period waves with periods in range 1-2 h in the atmosphere have been detected (Petrova and Shved, 1999; Shved et al, 1999). Gravity wave parameterization for PSMOS studies was reported by Gavrilov et al. (1999).

Rocket data have been used to study the dynamical response of the lower ionosphere (D-region). It was shown that lower atmosphere influence on the mesosphere and lower thermosphere via wave propagation mostly by gravity waves (Vanina and Danilov, 2001).

Middle atmosphere spatial structure including its seasonal variations and planetary waves were discussed in several publications (Krivolutsky et al., 1999; Fakhrutdinov et al., 2000; Khoutorova et al., 2000; Fakhrutdinova et al., 2000;Portnyagin et al., 2000; Kazimirovsky and Vergasova, 2000). Longitudinal structure of tidal; components in the lower thermosphere was studied on the basis of radars network (Merzlyakov et al., 1999). An empirical model of global

migrating tide winds have been developed on the basis of wind observations by meteor radar in Russia (Portnyagin and Solovyova, 1999).

3. Effects of solar activity

The interaction of solar activity processes and equatorial QBO phenomena have been studied by different authors with a focus to the presence this oscillation in solar activity indexes and UV solar flux (Gabis and Troshichev, 2003; Troshichev et al., 2000; Soukharev, 1999; Ivanov-Kholodny et al., 2001).

Influence of variations of cosmic rays on atmospheric pressure and temperature in the Southern pole region was found using aerological data at Russian polar network (Egorova et al., 2000). Also Influence of the cosmic rays and solar wind variations on atmospheric temperature in the southern polar region (Troshichev et al., 2002).

Quasi-biennial oscillation effects were found in the polar mesosphere and lower thermosphere (Fadel, et al., 2000). So, it looks that we need to make a focus on a solar activity processes as a possible factor, which determines QBO phenomena.

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PHYSICS OF CLOUDS AND PRECIPITATIONS

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1. Cloud Physics

1.1 Condensation nuclei, ice nuclei, and atmospheric aerosol

A monograph on the physics of atmospheric aerosols has been published [1]. At the experimental base of the Main Geophysical Observatory, atmospheric aerosol concentrations within the particle size range of 0.3-1 mm have been measured at the fall out of liquid and solid-state precipitation. The intensity of both dry and wet deposition has been evaluated using a numerical model of a convective cloud [4]. The evolution of a volcano plum has been investigated through numerical modeling [5,6]. The feasibility has been studied of the radar detection of clouds that form following accidents at nuclear power plants [3] and of radar estimation of the resulting radionuclid contamination of the environment [9]. A unit to detect and monitor accident emission [10] has been offered.

The results have been summarized of the systematic measurements of total atmospheric aerosol and ice nuclei concentration conducted at Dolgoprudny (20 km north of Moscow) in 1987-2000. The measured mean semiannual concentrations of submicron particles (0,0075 – 1 mm), large nuclei (0,3 – 10 mm), and ice nuclei have revealed no marked trends during that period [11]. Atmospheric aerosol concentrations were measured in Moscow Region during the summer 2002 smoking event. Scavenging coefficients for different particle sizes have been estimated [12].

Informative potentials have been assessed of up-to-date instrumentation complexes on board weather satellites designed to study the gaseous and aerosol composition of the atmosphere [13].

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1.2 Cloud physics studies

Data on convective cloud features in the northwestern region of Russia are summarized [14]. In [15], a review is presented of the investigations in cloud physics and artificial cloud modification conducted at the Main Geophysical Observatory since its foundation.

The effect of the ionization of medium on phase and microstructural water transformations and on electrization processes leading to the formation of thunderstorm clouds has been investigated in the laboratory [16,15,17]. Ground measurements of freezing precipitation for a decade are summarized and the corresponding charts for the territory of Russia are constructed [18].

The Russian high-altitude airplane M-55 "Geophysika" was employed in pioneering collaborative European-Russian studies of the Antarctic and tropical upper troposphere and lower stratosphere where the dramatic changes observed (ozone hole, chemical and dynamic processes) affect the Earth's climate. In the framework of the European projects such as APE-GAIA, APE-THESEO, and APE-INERA, in which Russian scientists take part, the high-altitude airplane has been equipped with high-precision instruments to measure atmospheric composition; the data of the unique aircraft expeditions have been analyzed [19].

A hygrometer has been created that can operate at very low temperatures [20]. The hygrometer installed on board M-55 “Geophysika” has furnished data relevant to the nature of cloud formation in the zone of the equatorial tropical tropopause. In particular, zones with supersaturation over ice were found at the upper boundary of clouds (sub-visible cirrus) [21]. It is shown that at stratospheric levels, within the ozone hole, chemical ozone destruction exceeded 85 %. The clouds detected in the vicinity of the tropical tropopause are an important element in the balance of water vapor penetrating to the stratosphere and affecting the radiation characteristics and chemical composition of the atmosphere [22].

A technique has been developed to estimate the skill score of the Earth surface observation from space under cloudy conditions, using climatic data on mean cloud amount. The technique makes it unnecessary to use archives of daily satellite-borne data on total cloud amount [23].

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1.3 In situ and remote techniques for sounding clouds and fogs

Investigations of the structure of mesoscale convective systems over the Sea of Japan were conducted using the instrumentation mounted on board IL-18 aircraft. The range of scales in studying the vertical moisture transport has been considerably extended. The weight of different scales from 10 m to 50 km in the integral moisture transport and the spatial variability of the latter have been investigated. The fraction of turbulence has been determined that accounts for 1/3 to 1/6 of the integral moisture transport [24, 25]. Turbulent heat and moisture fluxes in the convective atmospheric boundary layer leading to the formation on its upper bound of a cloud layer have been studied (11-20). Paper [26] is devoted to the investigation of heat, moisture and impulse fluxes in the convective boundary layer from board specially equipped flight vehicles (the aircraft DO-128, FALCON 20-E5, and helicopter-towed measurement complex "Helipod") in the environs of the Lindenberg Observatory (Germany).

Papers [27, 28] describe the instruments and techniques to study the atmosphere (including clouds) from board the Russian aircraft weather lab IL-18; they also present a description of the experiment to study the convective atmospheric

boundary layer in Yakutsk area during April-June 2000. Papers and reports [29-35] discuss the results of the aircraft studies of the convective atmospheric boundary layer in Yakutsk area in April-June 2000.

Radar and radar-radiometric methods of cloud and fog investigation have been further developed in order to improve the accuracy of radar measurements of precipitation, a method of Z-R ratio on-line specification has been worked out on the basis of two-wave measurements of radar signal attenuation in clouds [36]. An automated meteorological system to control fog parameters during fog-clearing operations has been created [37]. Radar-radiometer studies of winter precipitation-generating cloud systems were carried out using the microwave radiometer developed at CAO [38, 39, 40].

Summarized are experimental data on turbulent and convective motions in the lower troposphere which favor the formation in it of convective clouds [41].

Previously unavailable experimental data are first presented on temperature, wind, and, in particular detail, humidity in the vicinity of the equatorial tropopause over the Indian Ocean. Cases of the formation inside the tropopause and above the troposphere of clouds that form due to the presence in this area of local saturation zones in the ridges of internal gravitation waves near the tropopause [42,43].

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2. Artificial weather modification

2.1 Agents and Technical Aids

The historical role of pyrotechnics in the development of the Russian cloud modification means is evaluated [44]. Based on the extensive laboratory studies of the efficiency of currently employed and newly developed ice-forming agents, a new 8% silver iodide pyrotechnic substance with increased efficiency and weather modification aids using it (a cartridge and an anti-hail rocket) have been created [45, 46]. New data have been obtained on the dependence of cloud dissipation on the concentration of the ice-forming aerosol vented into the cloud and on differences in the behavior of coolants and ice-forming aerosol [47]. Research is under way to develop hygroscopic agents to act upon clouds in order to enhance precipitation. Based on a one-dimensional numerical model of a convective cloud, optimal characteristics of hygroscopic agent particles to produce a precipitation enhancement effect have been estimated [48]. A manual on the technique of laboratory checking of pyrotechnic agent efficiency has been compiled [49].

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p. 57-59 (in Russian).
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the efficiency of ice-forming agents and pyrotechnics in laboratory conditions. Gidrometeoizdat, St. Petersburg, 2002, 26 p. (in Russian).

2.2 Artificial precipitation enhancement

The activity of Russia in the field of artificial modification of hydrometeorological processes is described [50]. An analytical review is presented of the problem of precipitation regime changes on the territory from the lee side of the area of precipitation enhancement operations First analyzed and summarized are experimental data on the effects causing cloud modification in zones adjacent to the lee side of the area where clouds of different classes are acted upon [51].

A readily removable aircraft complex of technical aids for cloud seeding by various types of ice-forming agents and coolants (silver iodide aerosol, granulated solid carbonic acid, liquefied nitrogen) [52, 53] and a readily removable air-borne measurement-computation complex to conduct weather modification operations have been developed [54].

50. Chernikov, A.A. Activities in artificial modification of hydrometeorological processes in Russia. Trudy Nauchnoy Conferentsii po Rezultatam Issledovaniy v Oblasti Gidrometeorologii I Monitoringa Zagriazneniya Prirodnoy Sredy v Gosudarstvakh –Uchastnikach SNG, posviashchonnoy 10-letiyu Obrazovaniya Mezhgosudarstvennogo Soveta po Gidrometeorologii, St. Petersburg, 23-26 April 2002, Plenarnaya chast, p. 27-31 (in Russian).
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53 Beriulev, G.P., Korneyev, V.P., Petrov, V.V., Fedorov, O.K. An aircraft technical weather modification complex for operational activities. Trudy Nauchnoy Conferentsii po Rezultatam Issledovaniy v Oblasti Gidrometeorologii I Monitoringa Zagriazneniya Prirodnoy Sredy v Gosudarstvakh –Uchastnikach SNG, posviashchonnoy 10-letiyu Obrazovaniya Mezhgosudarstvennogo Soveta po Gidrometeorologii, St. Petersburg, 23-26 April 2002, Sectsiya 4, p. 19-21 (in Russian).
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2.3 Artificial modification of hail processes for hail protection

The ecological safety of the Russian hail-protection technology has been estimated and ecological conditioning by the Russian Federation Hail-Protection Paramilitary Services has been performed [55,56]. It is established that the maximum concentration of detrimental rocket hail- protection wastes in the atmosphere, soil, and open water reservoirs is 10^4-10^7 time less than the maximum permissible concentration.

A statistical estimate has been obtained of the economic efficiency of the Russian hail-protection technology employed in the Russian Federation, CIS states, Argentina, and Brazil, which shows that nearly everywhere the technology provides a statistically significant 76-90% reduction of loss from hail [57, 58].

An automated technology of artificial hail processes modification has been developed on the basis of the soft-hardware complex ASU “Antigrad” [59-61], which enables increasing the efficiency of hail protection to 85-90%. The improved efficiency together with the reduced hail-protection costs were made possible by upgrading the methods of identifying the categories of hail-hazardous clouds based on the measurement and calculation of a set of radar cloud characteristics [62-64].

Developed, tested and introduced to practice are some new crystallizing agents in the form of propellants, the

anti-hail rockets “Alazan-CM15”, “Alazan-5” and “Alazan-6”, an new-generation small-size automated rocket complex “Alan”, and universal automated facility “Darg-PU” to launch different types of rockets using replaceable unified packs of launching guides [65].

Summarized are the data on thunderstorm features in the Caucasus [66]. Thunderstorm development in a convective cloud is analyzed [67].

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56. Abshaev M.T. Estimation of Ecological Purity of the Russian Rocket-Borne Hail Suppression Technology. Trudy Mezhdunarodnoy Conferentsii po Aktivnym Vozdeistviyam na Gidrometeorologicheskiye Protsessy. Cheboksary, 2000, p. 32-40 (in Russian).
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64. Abshaev, M.T., Malkarova, A.M., Tebuev, A.D. Radar control of the efficiency of artificial modification of hail processes. Trudy Nauchnoy Conferentsii po Rezultatam Issledovaniy v Oblasti Gidrometeorologii I Monitoringa Zagriazneniya Prirodnoy Sredy v Gosudarstvakh –Uchastnikach SNG, posviashchonnoy 10-letiyu Obrazovaniya Mezhgosudarstvennogo Soveta po Gidrometeorologii, St. Petersburg, 23-26 April 2002, Sektsiya 4, p. 12-14 (in Russian).
65. Abshaev, M.T., Varenykh, N.M. et al. Technical means using pyrotechnic aerosol generators for artificial cloud modification. The II Vserossiyskoy Conferentsii “Sovremennye Problemy Pirotechniki, Sergiyev Posad, 21-22 November 2002, p. 63-76 (in Russian).
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67. Adjiev, A.Kh., Kapov, P.Kh., Sizhazhev, S.M. Thunderstorm development in convective clouds. Trudy VGI, Issue 91, 2001, p.90-99 (in Russian).

2.4 Artificial dissipation of fogs

The supercooled fog dissipation technique using liquid nitrogen continues to be upgraded. As a results of laboratory and field studies, ground nitrogen generators of ice particles have been created enabling effective fog dissipation at temperatures close to zero [68]. Nitrogen generators are employed in experimental fog-clearing operations at motorways and airports. An up-to-date three-dimensional numerical model of fog has been constructed which is used to control these operations [69]. A guide regulating the organization and performance of such activities has been published [70,71].

Work to create methods and technical means for artificial warm fog dissipation was being done. Developed and tested was an electrostatic technique of fog droplet precipitation to be used at motorways and airports [72,73] and a technique of warm fog dissipation at airports using thermal systems was investigated [74].

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73. Chernikov A.A., Khaikine M.N. Artificial fog dissipation at motorways by electrostatic techniques. Meteorologia I Gidrologia, 2002, No.3, p.51-60 (in Russian).
74. Bankova, N.Yu., Koloskov, B.P., Krasnovskaya, L.I., Sergeyev, B.N., Chernikov, A.A. Khaikine M.N. Development of a warm fog dissipation method using thermokinetic generators. Abstracts. Vserossiyskaya Conferentsiya po Physike Oblakov I Aktivnym Vozdeistviyam na Gidrometeorologicheskiye Protsessy. Nalchik, 23-25 October 2001, p. 51-53 (in Russian).

2.5 Improving weather in megapolises

Based on the aircraft techniques developed at the Central Aerological Observatory for cloud dissipation and temporary slowing down precipitation formation processes by overseeding supercooled liquid water zones of precipitation-generating clouds, a technique of artificial modification of cloud systems over large cities has been created. It is intended for improving weather on days of mass political, sporting or cultural activities and for reducing precipitation on the territory of megapolises [75,76].

75. Beriulev, G.P., Koloskov, B.P., Melnichuk, Yu.V., Chernikov, A.A., Korneyev, V.P., Diadiuchenko, V.N., Stasenko, V.N. Some results of aircraft activities in weather protection of large cities. Abstracts. Vserossiyskaya Conferentsiya po Physike Oblakov I Aktivnym Vozdeistviyam na Gidrometeorologicheskiye Protsessy. Nalchik, 23-25 October 2001, p. 53-54 (in Russian).
76. Beriulev, G.P., Koloskov, B.P., Melnichuk, Yu.V., Chernikov, A.A., Korneyev, V.P., Fedorov, O.K., Diadiuchenko, V.N., Stasenko, V.N. Weather protection of megapolises: Concept and results. Trudy Nauchnoy Conferentsii po Rezultatam Issledovaniy v Oblasti Gidrometeorologii I Monitoringa Zagriazneniya Prirodnoy Sredy v Gosudarstvakh –Uchastnikach SNG, posviashchonnoy 10-letiyu Obrazovaniya Mezhgosudarstvennogo Soveta po Gidrometeorologii, St. Petersburg, 23-26 April 2002, Sektsiya 4, p.25-27 (in Russian).

3. Instruments for cloud investigation

The instruments ACH&UVH (CAO) for air humidity measurements and IVO (CAO) for measurements of liquid

water content have been recommended by experts of the European Fleet for Airborne Research to be employed on European research airplanes.

77. Mezrin, M. Yu. "The contribution of different scales to integral moisture transport". EUFAR (European Fleet For Airborne Research) Conference, Small-Scale Turbulence Working Group. Capua, Italy, 16-20 of September 2002.

4. **Electrical cloud state**

A two-dimensional numerical non-stationary model of thunderstorm cloud electrization was being constructed, which considered detailed microphysics comprising different elecrization mechanisms that include the interaction on collision between liquid-phase and solid-state particles as well as between solid particles (graupel –ice crystals). Numerical experiments were fulfilled using the model. A laser technique to act upon thunderstorm clouds and control the effect has been developed. Optimal conditions for triggering a lightning discharge (discrimination of zones with the highest electric intensity) were determined based on the model concerned.

Fundamental studies have been carried out of the influence of non-stationary turbulent exchange and varying electric field on atmospheric electrical characteristics.

In the context of constructing an experimental physico-statistical model of a thunderstorm cloud, parameters characterizing the electrical state of convective clouds during the three phases of their evolution have been analyzed. The lightning frequency in zones of precipitation of different intensities was determined. The position of zones with increased reflectivity and turbulence values inside thunderstorm clouds relative to zones of lightning activity was established. Suggested is the structure of a thunderstorm location network, a version of its hardware and software. A feasibility study has been fulfilled for a variety of local thunderstorm location networks.

5. Artificial weather modification in fighting forest fires

A technique of extinguishing forest fires with artificially induced precipitation in the taiga and forest zone of the Russian Federation has been improved, which enabled a 20% reduction of aircraft fuel consumed during weather modification activities and increased the effectiveness of using agents by 20-30%. The technology permits assigning a lower class of fire risk to forests for fire prevention purposes and putting out fires with artificially induced precipitation. The most intensive precipitation to put out forest fires were induced using the technology concerned by the aircraft forest protection bases of Transbaikalia, Chita, and Syktyvkar areas in 1999-2002.

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PLANETARY ATMOSPHERES

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1.Venus.

1.1. Comprehensive treatment of data measured by the IR Fourier-spectrometry onboard Venera-15 has resulted in 3D zonal mean velocity field in the thermal wind approximation versus latitude, height, and solar longitude. Three jets are revealed in the thermal wind field.

In most of observational sessions, the midlatitude jet was observed at the altitude of 65-70 km, with thermal gradients being provided by the "cold collar". High-altitude tropical jet at the altitude of 81 km is associated with the thermal inversion at 90-95 km. Another tropical jet is observed at the altitude of 68 km, near the upper boundary of the cloud deck.

Based on 3D fields of the zonal thermal wind retrieved during the revision of the IR spectrometric data onboard Venera-15, latitudinal profiles have been built for the wind speed in location corresponding to the maximum of the midlatitude jet on both day and night side of Venus (about 70 km). Those profiles were employed in simulations of the barotropic instability that revealed period of 3-4 terrestrial days and exponential growth time scale less than 20 days. Daytime profiles are dominated by harmonics with n=3, whereas nighttime ones – with n=2. This fact may argue in favor of the presence of the barotropic instability in the middle Venus atmosphere in altitude range about 70 km.

A search for tidal waves in zonal average temperature field and cloud opacities has been carried out. A tidal origin of the zonal superrotation drive is one of the modern hypotheses explaining the nature of Venus atmospheric dynamics. Tide is generated as a result of solar energy absorption, about 50% of which is taking place in the middle atmosphere within a narrow layer at 58-70 km. Thermal and aerosol 3D fields in the coordinates latitude-height-solar longitude (for Venus, the latter is also a measure of the local time), retrieved from the Fourier spectrometry onboard Venera-15, have been investigated for the presence of sun-synchronous waves. In low latitudes the amplitude of the diurnal thermal tide maximizes above 0.2 mbar (92 km) where diurnal tide is dominating. In high latitudes, the diurnal tide dominates below 50 mbar (68 km): its amplitude is twice as high as the amplitude of the semidiurnal tide, reaching the maximal value of 18 K at 57 km altitude in the cold collar. In low latitudes, semidiurnal tide dominates below 90 km, reaching maximum at 83 km, and also in the upper cloud layer above 58 km. At 70-76 km the third diurnal harmonics is dominating. In the upper cloud layer where most of the solar energy is absorbed, all four harmonics, including diurnal and 1/3-diurnal ones, have amplitudes exceeding 3K in their maxima. Zonally averaged altitude of the upper boundary of the cloud deck varies from 69 km in low latitudes to 59 km in the cold collar, with the diurnal component reaching maximum equal to 1.5 km in the cold collar. In the low latitudes, both diurnal and semidiurnal components amplitudes are 0.8-1 km. The areas characterized by strongest tidal activity correlate with jet streams located independently in thermal wind fields.

1.2.A technique has been developed for radiative transfer calculation in the lower Venus atmosphere based the model of

spectral line profile in the far wing approximation in the case when the contribution from line wings is not a small value. Calculations show that in the lower Venus atmosphere incoming solar and outgoing infrared fluxes are not balanced, implying a substantial contribution of the atmospheric dynamics to vertical heat transfer.

A hypothesis was investigated if the turbulence is capable of transferring energy absorbed in the cloud deck to lower atmospheric layers. Such a mechanism may explain some disagreement between solar and infrared fluxes. On the other hand, this mechanism may in principle provide a backward energy transport of heat from the lower cloud layers warmed by upward infrared radiation into the undercloud atmosphere.

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2. Mars

2.1.Based on daytime sky brightness distribution in different wavelengths from camera measurements of Pathfinder spacecraft, aerosol parameters in the atmosphere of Mars have been retrieved. Observations of scattered light brightness distribution resulted in microstructural parameters of the atmospheric aerosol: the effective particle size reff=1.71 (+0.29/-0.26) um and typical dispersion of size distribution nэфф=0.25 (+0.05/-0.1) микрона. Imaginary part of the refractive index varies from 0.015 in the UV to 0.003 in the visible and near-infrared range. Observations have confirmed that aerosol particles in the Martian atmosphere are not spherical. Sky brightness distribution was measured by Pathfinder camera in five filters at 443.6, 481.0, 670.8, 896.1 и 965.3 um during six observational sessions. To the moment, one session has been completely processed Aerosol properties above Pathfinder landing site are close to those retrieved from similar observations of Viking landers. Pathfinder measurements argue that particles shape is oblate, which is typical for highly weathered rocks (clays). Despite the one-mode model used in the analysis, data imply possibility of the presence of a fine submicron mode of aerosol particles.

2.2 A revision of data retrieved from the experiment MAWD onboard Viking spacecraft has been carried out in order to eliminate disagreement between earlier published results of this experiment with recent observations, e.g. from Mars

Global Surveyor spacecraft, and numerical simulations. It is shown that in the perihelion season, when dust amounts in the martian atmosphere maximizes, MAWD spectra may have been significantly affected by aerosol scattering. The technique eveloped for the retrievals of water vapor accounting for aerosol scattering has resulted in quantities that agree with other experiments.

2.3 Thermal structure of the Martian atmosphere was studied based on Fourier-spectrometry data measured by IRIS instrument onboard Mariner-9 spacecraft. Studies showed thermal inversion in the near-surface layer between 13h and 18h local time during the summer season. The inversion reaches 27 K after 17h at the North slope of Arsia Mons. Temperature and aerosol profiles have been retrieved from each spectrum in a self-consistent way. Aerosol opacity varies in time from mean value of 0.45 to 0.15 at 1000 cm-1 within time interval between Ls = 314 and 348. Thermal inertia of the Tharsis surface is 10-15 times lower than in lowland areas, resulting in quick surface cooling as compared to more inertial atmosphere.

Quantitative data on cooling rates in the aphelion season versus perihelion season have been obtained. Data are consistent with the presence of condensational clouds below 20 km altitude.

Temperature profiles have been retrieved for the winter North polar atmosphere (f >65N). Fogs composed of particles of about 1 mm size with opacity t=0.1-1 are present near the surface with the scale height of 1-2 km. CO2 condensational clouds may exist at latitudes > 80N at 10-25 km height or in the near-surface layer. The continuum spectrum in all polar observations is well approximated by a model of the near-surface fog composed of water ice with t=0.1-1, particle sizes about 1 mm, and water column abundance 1-10 pr. mm.

Water vapor abundance retrieved from IR spectra in 20-50 mm covering mostly the Southern hemisphere has been studied, including its seasonal, diurnal, and latitudinal variability. The results mainly confirm generally accepted views on the behavior of water vapor in that season (Ls = 290–350°): net abundance is about 10 pr. mm with the maximum in midlatitudes.

The confidence studies on the interpretation of Mars polarimetry data received during high atmosphric transparency show high sensitivity of this method to properties of the surface as well as to the presence of clouds, along with optical properties of dust. Using the scattering model taking into account nonsphericity of dust particles, the impact of various factors on polarimetry data interpretation results has been studied. Simulations confirm that water ice clouds may introduce a substantial uncertainty to this interpretation. In addition, the presence of fine particles, both icy and dusty, in the upper atmospheric layers, may mask larger particles suspended in lower layers. The impact of particles shape on the polarization curve implies that interesting information on aerosol properties may be retrieved from observatons taken at small phase angle.

2.4 Self-consistent model of water ice clouds that involves microphysics, transport and radiation transfer, was developed and adapted to the general circulation model of the Martian atmosphere SKYHI. The Martian version of SKYHI GCM has been developed at Geophysical Fluid Dynamics Laboratory (Princeton) by R.J.Wilson. For the first time in the GCM practice a realistic microphysics rather than empirical parameterization has been implemented for cloud modeling that was made possible due to moment representation of ice particles size distribution. Numerical experiments gave basic climate characteristics of Mars in the aphelion season (North hemisphere summer), consistent with available ground-based and spacecraft observations. Simulations show that in this season in the latitude interval 0-30Nthe tropical cloud system is developed that constrains the meridional transport of dust – main absorbing agent in the lower atmosphere – and alters its optical parameters, resulting in stabilization of climate at relatively low temperatures. This picture is distinctly different from th perihelion season, when dust loading in the atmosphere increases (t~1) and dust

storms of various scales sporadically appear. The tropical cloud system is developed due to both 40% decrease of the solar flux and intense sublimation of the North polar cap exposed by polar day conditions. At L_S » 143°the tropical cloud system decays and polar cloud hoods are formed, with simultaneous quick (3-10 days) expansion of dust to high latitudes of both hemispheres and global midlatitude warming by 5-10 K. This period is also characterized by excitation of a broad spectrum of planetary-scale waves and chaotic behavior of local pressure and temperature fields. Other seasonally determined circulation reconfigurations connected with change of planetary waves zonal structure are also identified, accompanied with generation of short-living transient waves. Periodicity and wave structure of these transients is consistent with observations. They are coinciding with large scale seasonal climate change, such as appearance and decay of the tropical cloud belt and generation of global dust storms on Mars.

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3. Cometary atmospheres

By means of numerical simulations, it has been shown that observed intensity and polarization phase curves of comets may be explained by the aggregate structure of cometary dust particles. Interpretation of photometric and polarimetric observations of various Solar System objects is often challenged by necessity to account for shape and structure of particles that compose atmospheric aerosol, regolith and cometary dust. Since in many cases particles of natural origin have aggregate structure, scattering properties of aggregate particles (clusters) comparable in size with visible wavelength have been studied by theoretical and numerical techniques. Calculations suggest that sizes of monomers composing clusters significantly affect phase functions of intensity and linear polarization.

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4. Microphysics of clouds in planetary atmospheres

An effective numerical method of simulation of microphysical processes in aerosols and clouds has been developed and implemented in several models. The method deals with few lower moments of particles size distribution. A considerable performance achieved by this technique allows do avoid unphysical parameterization and makes it suitable for self-consistent microphysical calculations in general circulation models of planetary atmosphere with the lack of empirical data.

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5. Development of instruments and methods for space research

5.1. A lightweight near-IR spectrometer based on the acousto-optical tuneable filter (AOTF), has been designed and installed onboard Mars Express spacecraft as a part of SPICAM package. The spectrometer that has no moving parts is aimed at measurements of water vapor abundance in the atmosphere of Mars in nadir observations and solar occultations. In addition, the instrument allows to study properties of the surface and atmospheric aerosol by means of spectropolarimetry in spectral range 1.0-1.7 mm. Net mass of the instrument is 800 g. The spectrometer has been calibrated, observation techniques have been elaborated. Similar spectrometer with extended spectral range and enhanced sensitivity is under development of Venus Express mission.

5.2 A prototype of compact high-resolution spectrometer for spacecraft observations of planetary atmospheres by solar occultation technique has been developed and designed. The instrument that includes echelle spectrometer and the AOTF for preliminary diffraction order selection is capable of resolving power as high as l/Dl=25000-30000 in solar occultation, with its size and mass being rather small. High performance of the instrument has been confirmed by laboratory tests. An implementation of this spectrometer is developed for Venus atmosphere studies in the framework of Venus Express mission.

5.3. A new method has been proposed for the remote sounding of Martian aerosol based on reflected radiaton measurement in the saturated 2.7 mm CO2 band from an orbiter. First opportunity to implement this technique was granted due to data received by shortwave spectrometer SWS onboard ISO satellite (Infrared Space Observatory). This technique resulted in the retrieval of aerosol net opacity t = 0.35±0.13, evaluation of aerosol scale height H = 10±2 км, and also in spectral behavior of aerosol optical parameters, that suggested the presence of dust absorption band near 2.8 mm. Good agreement with observations provide such minerals as montmorillonite and smectite, although palagonite also

gives proper approximation. Opacity data are consistent with simultaneous observations from pathfinder spacecraft and Hubble Space Telescope.

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POLAR METEOROLOGY

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1. Arctic climate

Evidence of warming process in Arctic during last two decades provides prominent interest to quantitative description of regional climate signal on the base of available current, historical and reconstructed data /1-5/, and numerical modeling results also /14,15,17/. There are two prominent periods of warming in Northern Polar area during 20th century (1918-1938 and 1969-2000) and two periods of cooling (1901-1918 and 1939-1968). Generally, there are three significant climatic stages which can be distinguished in observed trends of thermal regime in Arctic during 20th century: before 1920s, 1920-1960s, and 1980-90s.

Joint analysis of hydrological regime parameters of Arctic Ocean and of global atmosphere circulation characteristics demonstrated that the first warming can be connected with intensification of thermohaline circulation in Atlantic sector of Arctic Ocean, and the second one can be caused by intensification of large - scale meridional energy exchange in troposphere. The creation of high quality data sets, which can be used for revealing of climate variability physical reasons and for forecasting of climate change /6, 10/ is an actual scientific problem.

The empirical and modeling estimations of Arctic atmosphere structure reaction for increasing of radiative active gases and aerosol concentrations are executed. The estimates of climate change obtained on the base of completed data sets demonstrate the stable tendency of Arctic warming started in 1960s, but decreasing of warming intensity in both polar areas is observed. The history of warming in Arctic for periods of 1930s and 1990s is considered. Mean annual

surface air temperature over all Arctic region is increased about 0.5^0C during last period of warming, this value is less than temperature increase observed during Arctic warming in 1930s and it is close to increase of Northern Hemisphere averaged temperature. Since 1993 the positive anomalies of mean annual surface air temperature trend take place with more prominent anomalies registered in 1995 and in 2002. In 2002 the largest anomaly (2.9 σ) was observed in summer, the temperature of Arctic troposphere was increased up to 400 hPa level, and above it and in stratosphere the temperature was decreased with increasing of vertical temperature gradient through all the atmosphere. The results of investigations are the input into the realization of climatic projects of (World Climate Research Program (WCRP), including the polar regions into the sphere of interests (ACSYS, CliC).

In Main Geophysical Observatory (MGO) the investigations of polar climate were executed on the base of modeling of High latitudes climate and its changes with help of Global Coupled Atmosphere-Ocean General Circulation Models – AOGCMs /14-26/. The main results are the analysis of systematic errors of atmosphere models and AOGCM in calculations of modern climate, the comparative analysis of estimations of possible polar climate changes in 21th century on the base of calculations with ensemble of AOGCM using external forcing as the latest scenarios of IPCC greenhouse gases and aerosol– SRES (Special Report on Emission Scenarios). Moreover, the Arctic data archive was completed by the data rows from meteorological stations in Alaska with daily resolution and by fully corrected precipitation data /27/. The new version of AOGCM MGO (MGOCM2 T30L14/L33) is used for investigations of natural and anthropogenic polar climate variability in frames of international projects AMIP (Atmospheric Model Intercomparison Project), CMIP (Coupled Model Intercomparison Project) and ACIA (Arctic Climate Impact Assessment) /18,19/.

The field measurements of greenhouse gases concentrations (CO_2 and methane) were executed in Northern part of West Siberia, in the area of largest in the world natural gas fields and vast wetlands /28-35/. The estimations of integral input from local natural (natural complexes of marshes) and anthropogenic (gas extraction and transportation objects) into global atmospheric methane budget are obtained which are equal to 10 Mt/year and 2.5 Mt/year respectively /28-30/.

The regional transport model describing the distribution of methane in troposphere was developed /28-29/. The air sampling on Arctic coastal area /34/ and in Northern Pole were organized.

Synoptic processes dynamics over all Arctic Sea was developed /7-9, 11, 13/.

2. Antarctic climate

A quantitative study of the mechanisms of formation of the climatic variability in the Antarctic requires the reliable information about the statistical structure of the fields of meteorological parameters. Such study has became possible in relation to creating a database of climate of Antarctica /38/ in the framework of the geo-information system (GIS) “The Antarctic” developed at the AARI /44/. This database is intended for numerical analysis of Southern Polar area environment based on available data for all period of observations / 38,56,59,64 /.

Manifestation of the so-called “global warming” in the Southern Hemisphere is most clearly recorded in the vicinity of the Antarctic Peninsula both in the surface layer /37, 39, 41/ and in the free atmosphere /40, 41, 42/. The results of the probabilistic analysis of time series of surface air temperature and air pressure at sea level in this region were used for determining of the interannual variability characteristics obtained by the modulation of annual cycle over the range of interannual and seasonal changes of synoptic scale variability.

The variability from day-to-day and within a year makes the main contribution to the total dispersion, while for temperature, the variability within a year accounts for more than 50% of dispersion, it is less than 20% for pressure /46/. The contribution of the variability of annual averages to the total dispersion comprises less than 5%. However, the interannual variability is described not only by the changes of annual averages. The contribution of daily variations and variability within a day to the total dispersion is also small, for temperature as well as for pressure it is less than 10% of dispersion. However, it is also advisable to consider the variability features over the low-frequency ranges relative to daily variations taking into account the time of the day. This can be useful, for example, for formulation of hypotheses

about the nature of the interannual variability trends /39, 46, 58/.

The interannual variability contains additive and modulation components /46/. The additive component is presented by a sequence of annual averages while the modulation component is manifested through the interannual variability of parameters of the annual variations and in the interannual variations of the synoptic variability characteristics.

In the troposphere of East Antarctica, no statistically significant climatic changes in the temperature field were detected, but in Central Antarctic part a small cooling was found /53/.

The tendency for the tropospheric warming above the Antarctic Peninsula is in agreement with the change of the Antarctic Oscillation index (Southern Hemisphere annular mode) /40, 42/.

The coincidence of the tendencies of the interannual variability of the dynamic Antarctic Oscillation and the thermal regime parameters of the atmosphere above the Antarctic Peninsula indicate that the pronounced regional warming can be related to the prevailing changes in the circulation conditions in the Southern Hemisphere /42/.

Increasing of macro-scale circulation meridional form frequency during last two decades is due to systematic inflow of warm tropospheric air masses coming from the North to Antarctic Peninsula area. The possible influence of oceanic forcing on surface warming formation over Antarctic Peninsula is the Antarctic circumpolar current consumption change due to systematic inflow warm intermediate water masses into Bellingshausen Sea shelf /37/.

The climatic regime of the free atmosphere of the Southern Polar Area is characterized by some specific features as compared with the state of the troposphere and the stratosphere of other climatic zones. These features include powerful spring stratospheric warming events, a unique dynamic regime of a strong circumpolar vortex, maximum resources of available potential energy of Earth, special conditions of the radiation energy exchange and physical-chemical transformations in the atmosphere. Significant experience of upper-air sounding at the Russian (Soviet) Antarctic stations has been presently summarized in the meteorological block of the geo-information system (GIS) “The Antarctic”, which is intended for a numerical analysis of the environmental state of the Southern Polar Area based on available observation data over the period of instrumental measurements.

For quantitative explanation of the seasonal air temperature variations in the stratosphere, especially the formation of strong summer inversion, it is necessary to assess a relative contribution of radiation heating, dynamic factors and the ozone genesis processes. This has become possible in recent years due to construction of three-dimensional models of the general atmospheric circulation with interactive description of photochemical processes /31,51/.

Comprehensive data set for methane content in Antarctic atmosphere is developed /52/, natural methane sources (ornitogenic soil) on sub-Antarctic islands near Antarctic Peninsula were found.

Handbooks for meteorological forecasting in Antarctica was prepared /50/.

Cyclonic and meso-cyclonic eddies parameters for both polar areas atmosphere are calculated /47,48,49,57/ based on reanalysis and satellite data.

3. Geophysical and meteorological processes

Database of geophysical, aerological and meteorological observations in the Antarctica for 1980-1991 and measurements of the atmospheric electric field at Vostok station for 1998-2002 have been used to study structure and dynamics of geophysics processes in the Southern polar cap and their influence on atmospheric processes. The following main results have been obtained in 1999-2002.

1) Relationship between index of magnetic activity in the southern polar cap (PCS index)and interplanetary and ionospheric electric field has been examined. The quadratic dependence of the polar cap electric field on the PC-index has been derived. It has been sown that abrupt increase of the PC index undoubtedly indicates development of the magnetospheric substorm. These circumstances make it possible to regard the PC index as one of the most reliable and accessible indicators of state of the magnetosphere. At present the PCS index is calculated on the basis of magnetic data

from Vostok station and published online at the AARI web-site (http://www.aari.nw.ru).

2) Measurements of the atmospheric, near-surface vertical electric field E^z were started at the Russian Antarctic station Vostok (j = 78°27S, l = 106°52E) in 1998. The unique archives of data has been obtained since the "fair weather" conditions (that is absence of high winds, falling or drifting snow, clouds, and electric field "pollution" from the station's power plant) are fulfilled at Vostok in 78% of days in year. It was shown that the average diurnal variation of E^z for these days follows the global geoelectric field "fair-weather" diurnal variation: the "Carnegie" curve, which describes the global electric circuit formed by the thunderstorm activity occurring mostly over equatorial regions. The E_z diurnal variation shows strong seasonal dependence: it is maximum (~40 % of the average daily magnitude) in summer, but gradually reduces through the equinoctial months and is minimum during the austral winter. Variations of the electric field have been analyzed in conjunction with changes of the interplanetary magnetic field (IMF). E^z field at Vostok is strongly affected by variations in both the IMF B^y and B^z components. The influence of B^y is dominant during geomagnetic daytime hours (1100-1400 UT at Vostok): E^z increases with B^y in the range –10 nT to +10 nT. The IMF B^z effect is mainly seen at dawn (E^z increases with negative B^z) and dusk (E^z increases with positive B^z).

To reveal effects of the thunderstorm lightning flashes on the global electric circuit the behavior of the E_z field at Vostok station is compared with thunderstorm occurrence determined with an accuracy of microseconds from spacecraft measurements in April 1998 and with simultaneous VLF emission measurements at Halley staton (Antarctica) (http://dabs.nerc-bas.ac.uk/~dabs/). There are no correlation between the 5-min averages of E_z and the lightning flashes intensity or between E_z and VLF emissions, although significant correlation between E_z and VLF emissions is observed in particular cases. The same statistical results have been obtained from a comparison of hourly averaged values. Moreover, even the mean diurnal variation of electric field derived for 12 fine weather days in April 1998 turned out to be inconsistent with the mean diurnal variation of the lightning flashes for the same days. Reasons of these inconsistencies are discussed.

3) Fluxes of galactic cosmic rays altered by solar wind and spikes of solar cosmic rays are usually examined as one possible mechanism of solar activity influencing the Earth's atmosphere. The detail analysis of the aerological data from Vostok station (Antarctica) for 1978-1992 made it possible to find the dramatic changes of the troposphere temperature influenced by strong fluctuations of the interplanetary electric field E_{SW}. The warming is observed at ground level and cooling at h >10 km if the electric field of dawn-dusk direction is enhanced (when IMF DB_Z <0). The opposite deviation of the atmospheric temperatures (cooling at the ground level and warming at h >10km) is observed if the dawn-dusk electric field decreases (when DB_Z >0). There is a linear relationship between the value of D E_{SW} and ground temperature at Vostok station: the larger is leap in the E_{SW} the stronger is temperature deviation. The effect reaches maximum within one day and is damped equally quickly. The temperature deviations occur not only while passing the front of the interplanetary shocks but while crossing the layers of interaction between the quasi-stationary slow and fast solar wind fluxes those are not accompanied by the cosmic ray variations at all. Analysis of the hourly data from meteorological station MILOS -500 at Vostok along with data from other automatic weather meteorological stations (AWS) located at the Antarctic ice dome made it possible to estimate the typical time delay t_D between changes in the interplanetary electric field and appropriate response in the ground temperature is estimated. t_D turned out to be changed from 12 to 36 hours depending on efficiency of the interplanetary electric field, the value of t_D being estimated as product of magnitude of E_{SW} and duration of it's influence. The appropriate response to the E_{SW} changes is observed in tropospheric pressure and wind as well. Thus a new, effective channel of the solar activity influence on the atmospheric processes, and, thereby, on the weather and climate is found. It is suggested that the interplanetary electric field affects the catabatic system of atmospheric circulation, typical of the ice dome in winter Antarctic.

4) Influence of short-term changes in solar activity on baric (pressure) field perturbations is studied with using of such characteristics as the Sazonov index (IS), describing the intensity of meridional circulation, the Blinova index (IB), describing the intensity of zonal circulation, and "vorticity area index" (VAI) describing the tropospheric cyclonic perturbations. The epoch superposition method is used to reveal effects of the solar central meridian (CM) passage of

active regions, the Forbush decreases (FD) in galactic cosmic rays, and the solar proton (SP) events. The results of the analysis show that influence of short-term changes in the solar activity on baric field perturbations is the most evident in the stratosphere (30 mbar-level). The meridional circulation in case of the Forbush decreases and SP events starts to increase about 5-7 days before the key date, reaches maximum close by the key date and decays after the key date. The meridional circulation in case of the solar CM passage of active regions starts to increase after the key date and reaches maximum by 5-6 day. Fluctuations of baric field with periods of 5-7 days are typical of meridional and zonal circulations in troposphere (500 mbar-level), intensities of meridional and zonal circulations being fluctuated oppositely in phase. VAI index characterizing cyclonic activity in troposphere, shows the striking correspondence to changes of the meridional circulation in stratosphere. Comparison of changes in the stratospheric perturbations with behavior of the UV irradiance in course of the FD and SP events shows the striking resemblance in the initial run of these processes. The conclusion is made that growth of baric perturbations observed in the stratosphere in associations with the FD and SP events before the key date is caused by the solar UV irradiance increase, whereas decay of the baric perturbations after the key date is related to direct influence of the solar energetic corpuscular fluxes on the lower stratosphere.

It has been shown relationship between the short-term disturbances (<27 days) in stratospheric circulation on the level 30hPa with the corresponding variations of the solar UV irradiation: increase of the MgII index leads to growth of the meridional circulation, decrease of the MgII index leads to decay of the meridional circulation. This relationship is modulated by the quasi-biennial periodicity and by the 11 year variation of the solar activity.

A study of relationships between variations in the solar ultraviolet (UV) irradiance and quasi-biennial oscillations (QBO) in the Earth's atmosphere has been carried out by using the composite Mg II index as a signature of the solar UV irradiance. The middle-term changes in the UV-irradiation have been separated after removing the long-term (»11 years) and short-term (»27 days) variations. It has been shown that the solar UV irradiance tends to be higher in years of the east QBO phase and less in years of the west QBO phase. The detail analysis of changes in the stratospheric wind direction at layers from 10 mb to 70 mb for 1978-2001 showed that the wind changes start at higher altitudes and go down to lower ones, the wind intensity being the greatest in layer of the maximum ozone content (about 20 mb). There is obvious rotation in the stratospheric wind profiles, the quiet periods being alternated with active periods, characterizing by strong disturbing winds. Some of these stages occur only in certain seasons, which implies that they are guided by the internal atmospheric mechanisms. Duration of active stages can be affected by level of the UV irradiance. Conclusion is made that variability of the QBO-phase duration in the equatorial stratosphere can be interpreted if influence of the solar UV medium-term variation on basic stratospheric processes is taken into account.

The main result for 1999-2002: It is found that variations of the interplanetary electric field essentially affect the atmospheric processes in the southern polar region.

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ATMOSPHERIC RADIATION

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Topics of investigations performed in Russia in the field of atmospheric radiation are very extensive therefore five lines of studies involving the complete specter of scientific treatments are represented in the review.

Radiative-transfer theory

1. Studies of radiation transfer mechanism by different methods and development of new models

A number of new models have been developed with using the analytical and semi-analytical methods; among those – models of polarized radiation:

- small-angle modification of method of spherical harmonics for solving the vector equation of radiation transfer for infinite homogeneous media with point mono-ward source of non-polarized light (Budak and Veklenko, MEI);
- a method for calculating the polarization characteristics of radiation (with single-scattered assumption) in real atmosphere with point isotropic source (Puzanov, SPS "Radon", Moscow);
- a scheme for precise calculating the brightness of light aureole around lazer beam in atmosphere (IAG);
- analytical approaches for calculating the radiation reflection and transmission by dense cloud layer with taking the polarization into account (Konovalov, IAM RAS).

Methods of statistical modeling are used for determining the radiation fields for more complicated cases. Multi-layer model of broken clouds was developed and used for analyzing the influence of the correlation of cloud layers on radiation fluxes (Zuravleva, IAO SB RAS and Prigarin, ICMMP SB RAS). In IAP RAS (Postylyakov), the statistical simulation was used for determining the connection between data of satellite measurements and distributions of atmospheric trace gases. This connection was further used in the inverse problem of retrieving the atmospheric constituents.

New stage in numerical methods of solving the radiation transfer equation is connected with the making of super-computers with parallel architecture with 10^{12}-10^{13} operations per s. In IAP RAS grid algorithms for solving the transfer equation have been developed and realized in the code RADUGA–5.1 (for single-processor computer) and RADUGA5.1(P) (for multi-processor one). These programs are designed for a wide range of tasks including problems of atmospheric optics (for the time being – without polarization) and make possible calculations for inhomogeneous mediums with two- and three-dimensional geometries with inner and external sources (distributed and δ–shaped), with possible reflection by external boundaries under common assumption on the scattering, reflection and source anisotropy. It was shown that the above codes allow the modeling of radiation transfer for wide class of inhomogeneous mediums for different types of sources and reflecting surfaces (Germogenova and Nikolaeva, 2001; Bass at al., 2001; Germogenova et al., 2001).

2. ***Development of methods and models for calculating the radiation transfer in problems of ocean optics***

Scientists of IO RAS (SPb branch) developed new theories and models (Zolotukhin and Levin, 1999; Kokorin and Shifrin, 2000; Levin, 2000):

- the model for calculating the sea surface irradiance under broken clouds. It takes into consideration the cloud amount and size, the sun evaluation and radiation spectral range. The model may be used in the algorithms of water parameter

retrieval for remote sensing problems;

- the optical model of maritime atmosphere for the problem of optimal experimental design in ocean remote sensing;
- the theory of the oil film imaging on the sea surface from space and recommendations for using the spectral channels of color scanners SeaWiFS, MISR, and MODIS for detection of the surface contamination;
- the optical model of sea bottom imaging through the rough sea surface. The model based on the theoretical and experimental study takes into account the image distortion by surface waves and backscattering in water and atmosphere. It can be used for determination of optimal observation conditions and strategy;

Besides, theoretical studies of scattering parameters of sediment particles and maritime aerosol on the basis of the model of radial-inhomogeneous particles have been completed.

3. ***Studies of radiation transfer in crystal and mixed clouds*** has been performed in IEM SPA "Typhoon" (Petrushin, 2001, 2002).

Principal optical characteristics of scattered radiation (indicatrix of scattering the non-polarized radiation, sections and effectiveness factors for radiation attenuation, scattering and absorption) which are required for calculating the radiative cloud characteristics have been obtained. Parametrization of optical characteristics for crystal and mixed clouds as a function of different parameters of microstructure has been completed.

4. ***Development of the theory of non-LTE radiation transfer***

Following scientific results have been obtained by scientists of SPbSU:

- the standard problem of non-LTE radiative transfer in a rovibrational band for an optically semi-infinite plane-parallel planetary atmosphere using a model of a linear molecule with two vibrational states has been formulated and solved (Shved and Ogibalov, 2000);
- Khvorostovskaya et al. (2002) have presented the first laboratory measurement of the rate constant for quenching the CO_2 (01^10) state during collisions of CO_2 molecules with O atoms at temperatures realized near the Earth's mesopause. The measured values are significantly smaller than those commonly used in solving the non-LTE CO_2 problem for the vibrational states of the mode n_2 in the atmospheres of the Earth, Venus, and Mars;
- three simplified non-LTE CO_2 models for the Earth is presented by Ogibalov and Shved (2002). The models are distinguished by the number of states included in solving for the steady-state populations of the CO_2 vibrational levels;
- estimates of the population of excited vibrational states of the CO_2 molecule and of the rate of radiative cooling of the atmosphere in the 15-mm CO_2 band are produced by Ogibalov and Shved (2003) for the nighttime mesosphere and thermosphere of Mars on the basis of new laboratory data on the rate constant for quenching of the $CO_2(01^10)$ by O, which has been measured for low temperatures by Khvorostovskaya et al. (2002);
- an estimation of population inversion for the (00^00) and (10^00) states of the CO_2 molecule in the Earth's atmosphere has been performed by Shved and Ogibalov (2000);
- a refinement in radiative heat influx and its parameterization have been performed using the new rate constant measured by Khvorostovskaya et al. [2002] by Ogibalov at al. (2000).
- a new self-consistent model of the O_2 daylight emissions in middle atmosphere is developed. It is shown that the O_3 height profiles retrieved with using this model from measured emissivities at 762 nm and 2.27 mm agree within the experimental error (Yankovsky and Manuilova, 2003).

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Atmospheric Molecular Spectroscopy

Scientific studies have been carried out in directions:

1. Development of new informative-computational systems and databases on spectroscopic and photo-chemical parameters of atmospheric gases;
2. Theoretical and experimental investigations of spectroscopic parameters of atmospheric gases and concrete systems,

the modeling of atmospheric radiation and the verification of models by experimental data;

In the last years, ***a number of informative-computational systems and databases*** was developed:

- "Spectroscopy of Atmospheric Gases" (IAO SB RAS), giving the Internet-access to the information on parameters of spectral lines (PSL), absorption cross-sections of atmospheric gases and destined for solving the problems of molecular spectroscopy. The PSL base is databases of spectroscopic information HITRAS-2000 (including the H_2O, CH_4, O_2, NO, NO_2 и C_2H_2 data of 2001) and GEISA-97. In addition CO_2 molecule is presented by original calculation data (Tashkun et al., 2001).
- Internet-accessible information system "Spectroscopy and the Molecular Properties of Ozone" (S&MPO) (IAO SB RAS in collaboration with Reims University), which contains computational and experimental ozone spectra up to 5800 cm^{-1}. S&MPO involves the information on the ozone absorption spectra, enables the modeling of the ozone absorption spectra in inter-active regime and the comparison of calculation spectra with experimental ones. Built-in high-precise database of parameters of CO_2 spectral lines contains the best all-around information on spectral line parameters for four frequent isotopic modifications of the molecule [(http://ozone.iao.ru and http://ozone.univ-reims.fr].
- Database of physical-chemical and spectroscopic parameters for modeling the processes in high-temperature gaseous mediums (SOI), which provides a means for physics–mathematical simulation and calculations of optical gas characteristics in the ranges: temperatures – 200-10000 K; pressures – 10^{-5}-10,0 atm, wavelengths – 0,1-25,0 mm and for arbitrary averaging spectral intervals.
- Database for calculating the spectral characteristics of the CO_2 high-temperature spectra (ITOES).
- Database of atmospheric photo-chemical reactions (TSU and IAO SB RAS) which is the basic component of informative-computational system on atmospheric chemistry. It involves photochemical, biomolecular and thermo-molecular reactions.

In the frames of the second direction, theoretical and experimental studies have been carried out by a number of institutes.

Scientists of IAO SB RAS have put out considerable effort for determining the parameters of vibration-rotation lines. This work was primarily directed to provide databases. Calculation models which present vibration-rotation spectra of the CO_2 (Tashkun et al., 2000), the ozone (Sulakshina et al., 2000), the carbon bisulphide (Naumenko and Compargue, 2001) which describe the vibration-rotation lines with the accuracy close to recent experiment were developed. In addition, the influence of intermolecular interaction on spectral characteristics (the line narrowing due to collisions) (Kochanov, 2000) and the influence of rotational excitation on thermodynamic characteristics of atmospheric gases (Starikov and Kopytin, 2000) have been studied.

The study of line mixing effects on the shapes of vibration-rotation bands in the infrared (IR) absorption spectra of simple molecules was carried out in two directions by specialists of SPbSU. First, experimental and theoretical investigations of the CH_4 spectra in the range of the main bands were investigated. The frequencies and intensities of rotation-vibration lines were estimated from the experimental spectra at Doppler shape conditions and the HITRAS data were refined. The line broadening coefficients were found from lower pressure (below 1 atm) data for mixture spectra. The same values were calculated theoretically and then those were used for the attribution of overlapped lines in clusters (Grigoryev et al., 2001; 2002). The second direction of studies was connected with developing the empirical forms of rotational relaxation matrix which allow to easily calculate the shapes of the vibration-rotation bands for the molecules of practical importance, firstly CO_2 and H_2O. Atmospheric transmittance in the 8-12 mm atmospheric window has been estimated and the mechanism of radiation transfer in the condition of overlapped lines and bands has been considered an example of pure CO_2 gas (Filippov et al., 2002).

Scientists of IAP performed the precision investigation of atmospheric radiation absorption in wide frequency range (from 45 to 203 GHz) by resonator spectroscopic methods. The measurement sensitivity and accuracy exceed the world level by about an order. These studies involve the O_2 absorption band near 60 GHz, a sequence of O_2 lines at 118 GHz and H_2O at 183 GHz and the windows of relative atmospheric transmittance. The experimental results are compared with

theoretical calculations (Tretyakov et al., 2001).

In IAO SB RAS, simulation of continuous absorption by CO_2 and water vapor is carried on (Golovko 2001, 2001a). On the basis of complex laboratory and atmospheric measurements it was determined that, in the macro-windows of the 0.4 мкм - 1.1 mm spectral range, the radiation absorption by small-disperse aerosol particles in the ground atmospheric layer can exceed the input from molecular constituents of atmospheric air by more than an order (Kozlov et al., 2002).

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Radiative Climatology

The research work on this topic was carried out in several directions:

1. Ground and satellite monitoring of radiation balance components as well as solar radiation in different spectral range including biologically active UV radiation. The development of modern algorithms for assessment of different scale variations of solar radiation balance.
2. Numerical estimations of different atmospheric parameters influence on solar radiation on the basis of measurements and modelling and their climatic effects.
3. The development of algorithms for solar radiation computation in weather and climate numerical models.

The research activity within the framework of the first direction is presented by the results of radiation balance components monitoring at the network of actinometric (radiation) stations in Russian Federation and Antarctica (MGO, AASI), long-term measurements of solar radiation balance components as well as solar radiation on different spectral ranges including UV radiation (MSU, IEM, IAP RAS, SSU, etc) and the interpretation of the results.

During the last four years the solar radiation data archive has been created for Antarctica region for the period 1957-2001. Using these data the absence of constant trends in solar radiation has been shown for the period of observations (Radionov et al., 2002, 2002a, The catalogue for Antarctic climate, 2002).

In MSU, since 1999 regular measurements of biologically active UV-B radiation by UVB-1 YES instruments have been

in operation in addition to the large complex of solar radiation measurements. Since 2001 the long-term program has been started for evaluation of aerosol optical properties in the frame of international program AERONET (Uliumdzhieva et al., 2002). Within the framework of the AERONET program the same aerosol measurements are being in operation in Tomsk and Krasnoyarsk at the territory of Russian Federation. The tendencies in long term changes of atmospheric transparency, cloudiness, solar radiation and surface albedo have been shown on the base of measurements in Moscow for the period 1955-1998 (Abakumova, 2000).

The analysis of UV radiation variability for 1968-1997 according to the measurements in Moscow did not reveal the UV trend, however since the middle of 1980s there is a tendency of UV radiation increase, that corresponds to the results of TOMS satellite measurements (Chubarova et al., 2002; Chubarova and Nezval', 2000). On the base of satellite and ground data the variability of biologically active UV iradiance has been reconstructed since the middle of 20 century over Eurasia (Chubarova et al., 2001). The analysis of biologically active irradiance variability for Moscow and Moscow suburbs has been fulfilled (Chubarova, 2002). The monitoring of spectral UV irradiance in Obninsk and Kislovodsk is being in operation, the results of measurements are analyzed (Nerushev et al., 2001).
IAP RAS conducts systematic measurements of optical characteristics of aerosol, develops the microphysical models of ground aerosol and models of radiation characteristics for the whole atmospheric depth (Gorchakov et al, 2001). A numerical procedure of calculation of spectral distributions of scattered radiation of the Earth atmosphere allowing, in particular, to calculate the spectral fluxes (downward irradiances) of biologically active ultra-violet radiation, is developed. The procedure is intended for calibration of results of ground-based measurements of UV radiation downward irradiances from all top hemisphere of the sky, spent with the help of Brewer spectrophotometer (Elansky et al., 1999) and based on the numerical model of scattered radiation of the spherically symmetric atmosphere irradiated from above with a plane uniform stationary flux of monochromatic photons (Belikov et al., 2000). It is supposed, that the atmosphere contains aerosol components of several types, generally, with strong anisotropy of scattering.

The scientists from SSU work on the investigation of radiation balance of the Earth including the measurements of solar constant, outgoing shortwave radiation and albedo from sun synchronous satellite "Resource-01"(Sklyarov, 2001, Sklyarov et al., 2000).

In the MGO, the model description of the energy exchange at the Earth surface based on the method of neural networks (NN). (Pokrovsky et al., 2001, 2002). The combined database of radiative, heat budget and meteorological measurements has been developed, the work on classification of diurnal cycle of main meteorological parameters, radiation balance components and heat budget has been fulfilled, the experiments on tuning and modeling of diurnal cycle with the help of NN as well as the comparison between modeled and measured data have been performed.

The research activity within the framework of the second direction covers large amount of studies which were fulfilled in different institutes (IAP RAS, MSU, Kurchatov Center, IAO SO RAS, SPbSU, etc).

On the base of measurements and modelling the effects of gaseous, aerosol and cloud impact on solar radiation at the Earth surface in different geographical regions as well as their possible impact on climate system are discussed (Tarasova et al., 1999, 2000; Tarasova and Fomin, 2000; Gorchakova et al., 2001, Vasiliev and Melnikova, 2002; Abakumova et al., 1999, 2002; Shilovtseva and Feigelson, 2001). The analysis of "abnormal atmospheric absorption" has been carried out for cloudless conditions based on measurements and modelling results (Chubarova et al., 1999, Rublev et al., 2001; Trembach et al., 2001). The radiative effects of non accounting for vertical correlation between different layers of cloudiness have been assessed on the base of poisson multilayer cloud model (Titov and Zhuravleva 1999; Prigarin et al., 2002). Aerosol radiative forcing in the shortwave region of spectrum is being studied by scientists in IAP RAS (Golitsyn et al., 2002).

The research activity within the framework of the third direction concerns the development and comparison of modern radiative codes, which are incorporated in the weather forecast and climate models.

In the MGO the analysis of modern radiative algorithms incorporated in the hydrodynamic climate models which took

part in AMIP-2 intercomparisons has been performed (Sporyshev et al., 2002). Several scientists from MGO and ICM took part in the ICRCCM3 intercomparison of radiation algorithms (Barker et al., 2002). The accuracy of frequently used cloud overlapping schemes was evaluated as a result of intercomparison with reference algorithms as well as the new better schemes were proposed.

The algorithm for solar flux estimation in cloudy atmosphere with account for microphysical cloud properties has been developed as well as non-spherical particles influence on solar fluxes at the atmosphere boundary and on the albedo of the Earth-Atmosphere system was estimated in RHMC (Dmitrieva-Arrago et al., 2001).

Scientists of CAO, RSC "Curchatov Institute" IMP and IAO SB RAS carry on developing the methods for calculating the radiation transfer in the atmosphere and perfecting the radiation blocks of climate models (Mitsel et al., 2001; Tarasova and Fomin, 2000; Tvorogov et al., 2000). A new reduced radiative model for the one-dimensional atmospheric model with the explicit dependence on temperature has been formulated. Based on the model calculations as well as on the comparison with available estimations it was shown that the observed temperature trends in stratosphere and mesosphere observed in last decades mainly had the radiation nature (Rodimova, 2001, Nesmelova et al., 2002). A new K-distribution technique has been developed, which gives a possibility to increase essentially the accuracy and speed (up to ~ 3 times) of radiation codes for climate models (Fomin, 2003).

On the base of model calculations (Frol'kis, 2002) the possible climatic changes due to changes in gaseous composition is analyzed.

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Remote Sensing of Atmosphere and Underlying Surface

Principal areas of studies:

1. Passive sounding of the ozonosphere and atmospheric trace gases in visible, IR and microwave spectral ranges;
2. Lidar sounding of the environment;
3. Development and the making of the techniques for radiation studying and remote sensing.

Studies in the frames of the first point are long-term measurements of atmospheric constituents, the analysis of their variability and the elaboration of measurement and interpretation methods. Such studies have been performed by a number of institutes (IAP RAS, SPbSU, LPI RAS, IEM, IRE RAS, MGO, etc.)

During last 33 years systematic spectroscopic measurements of CO, CH_4 and H_2O have been carried out at Zvenigorod Scientific Station (ZSS) of IAP RAS, at Highland Scientific Station (HSS) (North Caucasia) and in different expeditions, including Arctic and Antarctic (Yurganov et al.; Grechko et al., 2002). The analysis of total CO and CH_4 multiyear (~ 30 years) observations revealed positive linear trend equal to ~ 0.9 and 0.5 %/yr for CO and CH_4 respectively. In 2000-2002, intercalibration procedures for CO, CH_4 and H_2O measurements were performed by IAP RAS, IEM and SpbSU (Kashin et al., 2001). In 2002, there were made attempts to use a trajectory analysis to assess the influence of natural and anthropogenic sources to the air contamination at Zvenigorod. After a long period measurements of CO, CH_4 and H_2O in Antarctica (station Novolazarevskaya) were restarted. Since 1990 at ZSS regular the NO_2 spectrophotometric measurements of total column content and vertical distribution in the 0-50 km altitude range have been carried out (Elokhov and Gruzdev, 2000). Results of the analysis revealed the NO_2 decrease with the rate of 2-3 % per year.

Regular studies of the CO, CH_4 variability in the atmosphere near SPb have been conducted by SPbSU using ground-based measurements by the grating spectrometer with spectral resolution > 0.3 cm^{-1}. Results demonstrate the decrease of CO, CH_4 atmospheric content after 1985 (Makarova et al., 2001). Besides SPbSU in collaboration with German colleagues performed remote measurements of temperature profile and gaseous content of the atmosphere on the basis of interpreting the spectra of downwelling IR radiation measured under cloudless conditions by the Fourier-interferometer OASIS with spectral resolution equal to 0.3-1.0 cm^{-1} and spectral region 4-18 mm. The special interpretation method involving the retrieval of atmospheric parameters and the correction of parameters of spectra absolute calibration and atmospheric radiation model has been developed and studied. It was shown that the method made possible to retrieve the total content of a number of trace gases (N_2O, CH_4, CFC-11, CFC-12, CO) and tropospheric ozone content with good accuracy (Virolainen et al., 1999; 2001).

Since January 1996 to December 2002 regular observations of the atmospheric ozone over Moscow were done by means of millimeter-wave (MM) radiometer of LPI RAS at frequencies of the ozone spectral line centered at 142.175 GHz. Profiles of the vertical ozone distribution were retrieved for altitudes from 15 to 75 km, and altitude-temporal ozone distribution was drawn (Solomonov et al., 2001). LPI investigations of the ozonesphere in frameworks of the international campaigns CRISTA/MAHRSI (1997), SOLVE 2000 (1999-2000) were successfully performed as well. Studies of observed regularities – seasonal changes in stratospheric ozone and its variations with periods from several days to several weeks, diurnal changes in mesospheric ozone and its night-time variations, anomalous effects in the ozonosphere – were performed. The analysis of data made it possible to study the correlation between ozone content and large-scale dynamical processes in stratosphere, typical conditions of appearance the anomalous effects in the ozonosphere and to estimate the long-term negative ozone trend (decrease in ozone) over Moscow.

For the first time in the world practice, the collocated measurements of ozone emission rotational spectra at MM waves (LPI RAS) and hydroxyl emission spectra in near IR bands (IAP RAS) were measured for the same region of the upper atmosphere. A method of retrieving the vertical ozone distribution at altitudes up to 100 km from its radio emission spectra was developed. Knowledge the atmosphere temperature at altitudes of 80-90 km obtained from spectrophotometry of hydroxyl emission resulted in considerable increase in accuracy of ozone content determination in mesosphere and lower thermosphere. Noticeable variations of night-time ozone concentration in mesosphere (night to

night ozone variations are 2-3 times at 55-75 km altitudes) and in lower thermosphere (the ozone content is varied from 1 to 8 ppm at 90 km altitude) were discovered. A special method allowed to getting the data on concentration of ozone, atomic hydrogen and oxygen as well as on temperature and density of atmosphere at mesopause altitudes (Perminov et al., 2002).

Long-term measurements of total H_2O and height-averaged relative CO_2 concentration have been performed and analyzed by IEM SPA "Typhoon" at Station Issyk Kul. In Obninsk, Moscow region, specialists of this institute leads also systematic measurements of CH_4 concentration near the ground and atmospheric column content and studies of characteristics of landscape for finding the stable identifiers (radiation, spectral, spatial-temporal, actinometric, etc.) to parameterize those at different meteorological conditions. The investigations have been performed by special spectra-radiometric instrument with meteorological tower.

Regular observations of stratospheric ozone (including the measurements in the frames of the SOLVE program) in N. Novgorod and Apatites have been performed by IAP with heterodyne null-balance microwave spectrometer. Results of simultaneous ozone measurements testifies that despite of large distance between observed points, the ozone is the ensemble connecting with behavior of circumpolar vortex (Krasil'nikov et al., 2002; Kulikov et al., 2002).

In August-September 2000 and April-May 2001 IRE RAS and MGO took part in studying the field of atmospheric microwave radiation over Baltic during International Project CLIWA-NET and carried out measurements at 13,7; 22,2; 37,5 и 90 ГГц. Algorithms and codes for automatic processing the data of radiometric and radar measurements, for retrieving the atmospheric total water vapor and cloud water content, participation intensity were developed. In August 2001, the complex experiment for calibration of all radiometers involved in CLIWA-NET was performed at Kabay, Netherlands.

Lidar sounding of environment (and passive sounding as well) has been carried out by specialists of IAO SB RAS at Siberian Lidar Station (Tomsk, 56.5^0 N, 85.1^0 E) . These observations cover lidar measurements of O_3 vertical distribution, stratospheric temperature and aerosol, spectro-photometric measurements of total ozone content, total and vertical distribution of NO_2. The data of lidar measurements are used to study the mechanisms of ozonosphere transformation and dynamics of optical characteristics of stratospheric aerosol layer [Zuev, 2000]. The data of measurements in 1999-2002 obtained under conditions of long-term background stratospheric state have been used for developing the models of vertical ozone and aerosol distribution (El'nikov et al., 2000). A reconstruction of ozone paleobehavior from dendrochronologic data (Zuev and Bondarenko, 2002).

In IAO SB RAS lidar sounding methods are also used for determining the characteristics of water medium (Veretennikov et al., 2001; Kokhanenko et al., 2001). A theory of laser sounding was developed. This theory made it possible to use the multiple-scattering component of lidar signal as the informative one in solving the inverse problems. Effective algorithms of retrieving the vertical profile of light attenuation index in seawater were developed and verified during experiments for sounding the North Sea and Baikal Lake.

A serious effort has been made for studying the possibilities of lidar sounding of crystal clouds and determination of different characteristics of their microstructure (Kaul, 2000; Romashov, 2001; Borovoi et al., 2000, 2002, 2002a; Shefer, 2002). Results of choosing the effective methods of lidar sounding of crystal cloud medium are given by Kaul et all. (2001). A major part of calculated components of the scattering matrix has been included in special databank for interpreting the polarization sounding of crystal clouds (Romashov et al., 2000).

Third line of studies **– Development and the making of the techniques for radiation studying and remote sensing –** *is presented by some institutes.*

Specialists of MGO, SOI and IFMO developed and made the experimental model automatically operated Filter Ozone-UV-meter (AFO-UV) destined for providing the ozone and UV monitoring in Russian ozone measurement network. This instrument bases on UV-polychromator with photo-diode array registering the spectral content of UV radiation in 250-430 нм range and complies with WMO standards.

The compact multi-spectral airborne complex forming simultaneously some digital images in the 0.4-12.5 mm spectral range has been made in ITOES (Sosnovy Bor).

The Infrared Fourier-transform Spectrometer for atmospheric temperature and humidity sounding (IRTFS-2) on board the "Meteor-M" spacecraft has been designed in the Keldych Centre in collaboration with BMSU and IEME (Golovin et al., 2002). Planned time of the launch is 2006. The instrument is designed for measuring the spectra of outgoing radiation of the system "atmosphere-underlying surface". Measurement data will be used for retrieving the temperature and humidity profiles, total ozone content, temperature of the underlying surface and cloudiness characteristics. In addition, measurement data can be used to determine the total content of minor atmospheric gas components: CH_4, N_2O, etc. The retrieval errors for meteorological parameters are given for cloudless atmospheric conditions.

The project of gas correlation radiometer for spectral region of 2,2-2,3 μm which is designed for monitoring the distributions of methane and carbon monoxide total column amounts in low troposphere by nadir measurements of solar radiation reflected by Earth surface has been worked out by LPI in collaboration with the SPbSU and the "NTO Sfera" Ltd. A model of the single-channel (for methane) instrument was built at LPI. It is shown that the instrument energetic sensitivity with such photo-detector make possible measurements of CH_4 total column amount in the atmospheric layer of 0-4 km with accuracy not worse then 10% from background value (Virolainen et al, 2002).

A low-noise millimeter-wave spectrometer with broadband acousto-optical spectrum analyzer (AOS) was built at the LPI (Esepkina et al., 2002). The AOS has been designed at SPbSPU. Performance of the AOS covering total band of 500 MHz with spectral resolution of 0.9 MHz as well as main features of its usage for ground-based measurements of the atmospheric ozone emission in the 142.2 GHz spectral line were investigated. First in Russia ozone measurements with AOS were successfully performed by LPI.

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Satellite Measurements

Principal areas of studies:

1. Development and perfection of methods of analyzing and interpreting the measurement data from recent operative satellites (of hydro-meteorological destination).
2. Development of interpretation methods for data of scientific satellite, preparation to future experiments.
3. Development and refinement of methods for assimilation of satellite data in NWP, climate modeling.

Investigations in the framework of item 1 can be subdivided on the following issues: a) atmospheric temperature and humidity retrievals (ATHR); b) derivation of atmospheric composition (ozone, trace gases); c) identification of clouds and precipitation; d) measurements of the Earth Radiation Budget (ERB); e) atmospheric winds derivation; f) detection and monitoring of severe weather phenomena (SWP).

Atmospheric temperature/humidity soundings. A processing package has been developed to retrieve the temperature and

humidity profiles from the ATOVS/NOAA-16,-17 measurements of local area coverage (Solovjev et al., 2002, 2003). This package is shown to provide the temperature profile retrievals with spatial sampling of 30-40 km and mean RMSE about 1.5^0C within the 1000-70 hPa layer; it is better than the accuracy of 12h NWP forecasts (about 1.8°C). The retrieval of surface skin temperature (in particular, sea surface temperature – SST) is closely related to the above problem of atmospheric sounding. In (Solovjev et al., 2001) the improved technique is developed for the SST field derivation from 5 geostationary weather satellite data. The comparison of satellite SST estimates with collocated in-situ data over the Atlantics and Indian Ocean gives small systematic biases and RMS errors in the range 1.5-2.0°C.

Derivation of atmospheric composition. One of key issues being considered during reporting period is the analysis and interpetation of satellite estimates for Total Ozone Amount (TOA), based on TOMS measurements. The trends and anomalies in the TOA as well as TOA variations in different geographical zones have been studied in (Chernikov et al., 2002; Smirnov et al., 2000).

Scientists of SPbSU, IAP RAS and MGO have performed the comparison of GOME (ERS-2 satellite) measurement data on total ozone content in 1996-2000 with coordinated Russian ground-based measurements and collocated TOMS data (satellite EarthProbe) (Ionov et al., 2002). The data of Russian ozonometric network was found to be in a good agreement with TOMS, with systematic bias in comparison with GOME - by 3% on the average. Besides, GOME total NO_2 measurements (GDP 2.7) were compared with correlative twilight ground-based observations at 2 locations: Zvenigorod (55.4°N, 36.5°E) in 1996-1998 and Lovozero (68.6°N, 35.0°E) in 2000-2002 (Timofeyev et al., 2000). The data of GOME considerably differ from ground-based observations.

In the frames of the Project METEOR3-SAGE-III, scientists of CAO lead the studies dedicated to the investigation and the monitoring of atmospheric gaseous and aerosol composition. Atmospheric content is determined by inverting the spectral transmittance functions measured by SAGE-III in 80 spectral channels in the 280-1500 nm range with the maximal resolution of 0.95 nm and the altitude resolution of about 50 m. Methods, algorithms and an software have been developed for calculating the vertical profiles of O_3, NO_2, aerosol extinction, water vapor from spectral transmittance functions of the atmosphere (Chayanova, 2001; Chayanova and Borisov, 1999).

Identification of clouds and precipitation. The threshold technique for NOAA/AVHRR data automatic classification has been developed (Volkova and Uspensky, 2002) that provides the detection of clouds and the estimation of cloud amount (with accuracy about 75%) as well as delineation of precipitation zones (with accuracy better than 60%) at day time and warm period of year. The new methods to retrieve cloud liquid water over oceans from satellite microwave imager data (SSM/I, DMSP; MTVZA, Meteor 3M N1) has been developed and tested (Zabolotskich et al., 2002). A new method to detect and to identify clouds from merged NOAA AVHRR and TOVS data has been proposed in (Plokhenko, 1999).

Measurements of the ERB. The measurements of outgoing shortwave radiation and albedo by IKOR radiometer as well as the measurements of solar constant values by ISP instrument (solar constant monitor) from "Meteor-3"N7, Resurs-01 N4 satellites have been analyzed in (Sklyarov et al., 1999, 2000; Sklyarov, 2001). In MGO new methods of estimating the ERB components from satellite data and are proposed by Pokrovsky and Korolevskaya (2001), and the problem of land surface albedo retrieval from multi-angular remote sensing data has been set and solved on the basis of the POLDER/ADEOS archives (Pokrovsky and Roujean, 2003).

Derivation of atmospheric winds. The methods for sea surface wind speed (SSWS) retrieval from passive and active microwave measurements have been developed and tested. In (Bukharov, 1999; Bukharov and Geokhlanyan, 2000) estimates of sea surface wind are derived from Ocean-01 RLSBO (Side Looking Radar) measurements. The detecting of zones with dangerous SSWS over Black Sea is discussed in (Bukharov and Geokhlanyan, 2002). The neural network-based algorithms for retrieving the parameters of atmosphere and sea surface (including SSWS) from SSM/I data (DMSP satellites) have been developed by (Zabolotskich et al., 2002). The regression algorithms of SSWS retrieval from SSM/I data are considered in (Nerushev, 2002; Grankov and Mil'shin, 2001).

Detection and monitoring of tropical cyclones and severe weather phenomena. The statistical model of the hemispheres' tropical cyclogenesis based on remote sensing data has been developed in (Pokrovskaya and Sharkov, 1999). The analysis of the ozone layer disturbances by tropical cyclones has been performed by Nerushev and Tereb (2001). The using of

satellite ERB measurements for the description of anomalous regimes of atmospheric circulation is discussed (Golovko and Kozoderov, 2000). Method of satellite observation of hazardous winds is discussed by Bukharov and Geokhlanyan (2002).

Investigations in the framework of item 2 were aimed to the development of methods for analysis of data from research and/or operational (future) satellites. The general overview of development perspectives for future Russian weather satellites are given in (Bedritsky et al., 1999; Uspensky et al., 2001; Dyaduchenko et al., 2002). Several studies are dedicated to the MTVZA/Meteor 3M N2 measurements analysis and processing, see (Uspensky et al., 2001a; Zabolotskikh et al., 2002). The MTVZA sensor presents the MW scanning radiometer with combined functions of imager (similar to SSM/I, DMSP satellites) and sounder (similar to AMSU, NOAA satellites). The high-resolution outgoing radiance spectra to be measured by advanced IR atmospheric sounder IASI (core payload of METOP satellite) can reveal valuable information about meteorological parameters. The capabilities to provide IASI-based retrievals of trace gases (CH_4, N_2O, CO) column amounts are investigated in (Uspensky et al., 1999; Romanov et al., 2002). The method of IASI-based remote sensing of ozone is proposed in (Uspensky et al., 2003). The capabilities to retrieve surface skin temperature with improved accuracy from IASI data are discussed in (Uspensky et al., 2001c). The IASI-based cloud detection scheme is considered by Uspensky et al. (2001b).

In SPbSU, the interpretation of satellite experiment with spectrometer “Ozone-Mir” onboard Space Station “Mir” has been completed. It was the first experiment on Sun occultation sounding using multi-spectral instrument in UV-visible-near IR spectral ranges. Simultaneous complex retrieval of ozonosphere parameters (O_3, NO_2 and spectral coefficient of aerosol extinction profiles, parameters of aerosol size distribution) by optimal estimation method, the use of measurement data in O_2 band (at 0.76 mm) for the height control were principal features of the interpretation procedure (Polyakov, 1999). Comparison of retrieved data with independent measurements demonstrated a high quality of the measurements (Poberovskii et al., 1999; Polyakov et al., 1999, 2001). Polyakov et all. (2001a) have proposed a new method for parameterizing the spectral dependence of aerosol extinction which be used to solve the inverse problem of atmospheric occultation sounding from space. Numerical studies of potential accuracy of retrieving the profiles of O_3, NO_2 and spectral aerosol extinction were conducted using the SAGE III measurement data (Timofeyev et al., 2003).

The original method of simultaneous retrieval of kinetic temperature, pressure, concentration of atmospheric gases and nonequilibrium populations of the vibrational states of molecules of atmospheric gases from limb infrared radiance measurements under the nonlocal thermodynamic equilibrium conditions has been developed. The method has been applied to the interpretation of measurements by CRISTA-1 instrument in the 15mm CO_2 and 9.6mm O_3 absorption bands. The influence of the assumption of the validity of LTE on the kinetic temperature retrieval is estimated. Global fields of kinetic temperature, vibrational temperatures of the excited states of CO_2 and O_3 molecules, pressure, CO_2 and O_3 abundances in the middle atmosphere have been obtained. The retrieved vibrational temperature profiles have been compared to the results of numerical modeling (Kostsov and Timofeyev, 2001; Kostsov et al., 2001).

Scientists of Nansen International Environmental and Remote Sensing Centre in St. Petersburg have been conducted complex investigations of the environment on the basis of data of satellite microwave active and passive sounding. Neuron Network-based retrieval techniques for retrieving the atmospheric parameters (Zabolotskikh et al., 2000), methods for determining characteristics of underlying surface (water quality parameters in natural waters, ice type, forestry composition) have been developed and approved (Pozdnyakov and Lyaskovsky, 1999; Pozdnyakov et al., 2001, 2002). A number of studies is dedicated to the analysis of global changes in ice cover in the Arctic Basin and the Greenland Ice Sheet (Johannessen et all., 1999; Melentyev et al., 2002). Interpretation of SMMR and SSM/I data over 20 years (1978-1998) on the Arctic Ocean ice dynamics has yielded a ~7% per decade-reduction in the multi-year ice area.

Scientists of IAP RAS have studied possibilities of retrieving the turbulence, inner waves and the dissipation rate of a turbulent kinetic energy in stratosphere from satellite star occultation measurements (Gurvich and Brekhovskikh, 2001; Gurvich, 2002; Gurvich et al., 2001; Kan et al., 2001; Dalaudier et al., 2001). In collaboration with SPbSU, methods of interpreting the star occultation measurements from space have been developed. Possibilities of determining the

characteristics of gaseous content have been analyzed (Polyakov et al., 2001b, 2002).

The investigations on item 3 included the development of procedures for satellite data assimilation in the NWP schemes. The algorithms of atmospheric sounding data assimilation similar to well-known 3D-Var, 4D-Var approach, have been developed in (Tsyrulnikov et al., 2003). The problem of satellite data information content with respect to their assimilation in the NWP schemes is discussed in (Pokrovsky, 2001). The derivation and using of satellite data in various problems of climate modeling are described in (Repinskaya and Babich, 1999; Timofeev and Yurovsky, 2000).

The team at the RSHMU (SPb) is actively conducting the study of the physical and chemical processes that define space and temporal distribution of the atmospheric ozone and other radiative gases based on the data assimilation by chemistry-transport models (Smyshlyaev et al., 1999; Yudin et al., 2000). A set of chemistry-transport atmospheric models has been developed to assimilate observational data from the ground-base, satellite and sonde measurements in real-time mode, i.e. at the each model time step. The variational and sequational methods of data assimilation have been tested on the way of the models development The set of the models have been used to carefully study causes of the observed ozone trends during 1970-2000, its future predictions, the examination of the nitrogen gases distribution in the Antarctic atmosphere, and the role of the large-scale dynamics and convective transport in ozone re-distributiion. Developed methods were used for gridding and mapping of the solar occultation satellite measurements of ozone, water vapor, NO_2 and aerosol that were derived from SAGE I and SAGE II raw data. Some data were qualified to be gross errors and were recommended to exclude from the consideration. The distributions of some trace gases which are not observed but chemically dependent on observed gases were calculated (Smyshlyaev and Geller, 2001; Geller and Smyshlyaev, 2002).

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Abbreviations

AASI – Arctic and Antarctic Science Institute, St. Petersburg;
BMSU – Bauman Moscow State University;
CAO – Central Aerological Observatory, Moscow.
IAG – Institute of Applied Geophysics, Moscow;
IAM RAS – Keldysh Institute of Applied Mathematics RAS, Moscow;
IAO SB RAS – Institute of Atmospheric Optics of Siberian Branch of RAS, Tomsk;
IAP – Institute of Applied Physics, N. Novgorod;
IAP RAS – Obukhov Institute of Atmospheric Physics of Russian Academy of Science, Moscow;
ICM RAS – Institute of Computational Mathematics of RAS, Moscow;
ICMMP SB RAS – Institute of Computational Mathematics and Mathematical Physics of Siberian Branch of RAS, Novosibirsk;
IEM SPA "Typhoon"– Institute of Experimental Meteorology, SPA"Typhoon", Obninsk, Moscow Region;
IEME – Institute of Electronic Machine Engineering, Moscow;
IFMO – St. Petersburg Institute of Fine Mechanics and Optics;
IO RAS – Shirshov Institute of Optics RAS (SPb branch);
IRE RAS – Institute of Radio-Electronics of Russian Academy of Science, Fryazino, Moscow Region;
ITOES – Institute of Complex Testing of Optics-Electronic Instruments and Systems, Sosnovy Bor
LPI RAS – Lebedev Physical Institute of Russian Academy of Science, Moscow;
MEI – Moscow Energetic Institute;
MGO – Voeikov Main Geophysical Observatory, St. Petersburg;
MSU – Lomonosov Moscow State University;
RHMC – Russian Hydro Meteorological Center, Moscow
RSC “Curchatov Institute” IMP – RSC “Curchatov Institute” Institute of Molecular Physics, Moscow;
RSHMU – Russian State Hydrometeorological University, Moscow;
SOI – Vavilov State Optical Institute, St. Petersburg;
SPbSPU – Petersburg State Polytechnic University;
SPbSU – Saint-Petersburg State University;
SPS “Radon” – Scientific Production Structure “Radon”, Moscow;
SRC SM “Planeta” – Scientific Research Center for Space Hydrometeorology “PLANETA”, Moscow;
SSU – Saratov State University;
TSU – Tomsk State University.