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The Atmosphere and Ionosphere

Dynamics, Processes and Monitoring

With 59 Figures and 8 Tables

Springer

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Abstract

The first part of the book is devoted to the modern methods for calculating the energy eigenvalues of Rydberg atoms A^{**} and molecules XY^{**} perturbed by neutral particles of a medium and to the results of studying the interaction processes with them. Interest in this study is caused by numerous applications in plasma chemistry, aeronomy, and astrophysics.

The second part of the book is devoted to the atmospheric aerosol – one of the most important factors affecting the Earth climatic and weather conditions. The study of the mechanisms of formation and evolution of atmospheric aerosols is of primary importance for predictions of the climatic changes on our planet. Special attention is given to the last achievements in theory of particle formation and their subsequent growth.

The third part of the book is devoted to numerous phenomena occurred in the mesosphere, ionosphere and the magnetosphere of the Earth caused by the sources located in the lower atmosphere and on the ground. Effects produced by lightning activity and by ground-based transmitters operated in high frequency and very low frequency ranges are described.

The fourth part of the book is devoted to modern methods of earthquake prediction. First section contains first results of special satellite "COMPASS 2" destined for detection of seism-electromagnetic effects. A whistler group in higher-order guided mode was recorded. Probably it was propagating between two layers, caused by onion-like structure of in homogeneities in the plasmasphere. Extremely low and very low frequency effects observed over seism-active regions by the satellite "INTERCOSMOS-24" are considered.

The achievements of the basic researches of the upper atmosphere and ionosphere processes with the mathematical modeling methods are briefly presented in the fifth part of the book. The mathematical problem of the model atmosphere/ionosphere description and existing global theoretical model of environment and results of the investigations with their using are considered.

The last part of the book is devoted to ball lightning investigations. Researches historical review is presented. They consist of gathering and data processing of observations, experiments on reproduction of long-lived shining formations in electric discharges, and theoretical models. Detailed descriptions of three high-energy ball lightning models are presented.

About Editors

Vladimir L. Bychkov is a leading researcher of the physical department of Lomonosov Moscow state university; he is also head of a laboratory of Moscow Radiotechnical Institute, Russian Academy of Sciences. He received MS degree in theoretical physics from the University of Peoples Friendship, Moscow, Russia, a Ph.D. in plasma physics and chemistry from Kurchatov Institute of Nuclear Energy, and Doctor of Sciences degree from Moscow Regional State University. He has 35 years of experience in plasma physics researches, namely, in the physics of elementary processes, gas discharges, electron-beam plasmas, plasma chemistry, and ball lightning. He is head of the Russian Committee on ball lightning, vice president of the International Committee on Ball Lightning, and a member of Moscow Physical Society.

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Introduction

From July 7 to 12, 2008 in Zelenogradsk, a cosy resort on the bank of the Baltic Sea near Kaliningrad in Russia, the 1st International Conference "Atmosphere, Ionosphere, Safety (AIS-2008)" has been carried out. The State Russian University of I. Kant, Semenov Institute of chemical physics of the Russian Academy of Sciences, Pushkov Institute of terrestrial magnetism and radio-waves propagation of the Russian Academy of Sciences, and Russian Committee on Ball Lightning (BL) have acted as organizers of the conference. Financial support was made by Russian Fund of Fundamental Research Project N. 08-03-06041 and European Office of Aerospace Research and Development Grant award FA8655-08-1-5052.

The International conference "Atmosphere, Ionosphere, Safety" (AIS-2008) was devoted to (i) the analysis of the atmosphere–ionosphere response on natural and man-made processes, the reasons of occurrence of the various accompanying geophysical phenomena, and an estimation of possible consequences of their influence on the person and technological systems; (ii) the study of the monitoring possibility and search of the ways for the risk level decrease. Discussion of the physical and chemical processes accompanying the observable geophysical phenomena was undertaken.

One can see from a list of the Conference sections that questions of safety took only rather modest place, so main topics of the Conference became discussion of processes taking place in the atmosphere, ionosphere and methods of monitoring these processes.

At carrying out of the Conference besides plenary sessions, five sections worked in parallel: (A) Dynamics of atmospheric aerosols; (D) dynamics of an ionosphere and atmosphere – their communication through an ionosphere; (E) elementary processes in the upper atmosphere and the ionosphere; (P) the electromagnetic and optical phenomena in atmosphere, including long-lived and plasma objects and ball lightning; and (S) information systems of environment monitoring and prevention of incidents. At the Conference, nine plenary reports, 65 reports on sections and 40 poster reports have been presented.

The analysis of reactions in system "atmosphere–ionosphere" and influences of natural and technogenic processes on them was the basic question brought for

discussion of conference participants. In this connection, considerable attention has been given to the study of reasons and cases of the various geophysical and atmospheric phenomena display, an estimation of their influence on people and technological systems, development of systems of monitoring, and decrease in risk of negative influence of natural processes on mankind ability to live.

The physical and chemical phenomena proceeding in the upper atmosphere and ionosphere occur in the conditions and the scales that are not available in usual laboratories. Moreover, it is possible to create such nonequilibrium conditions to study the response of an environment on the external perturbations, the realization of which is difficult on the earth in general. All atmospheric layers interact among themselves by means of various physical and chemical processes, forming the complex system subject to influences of flashes on the Sun, earthquakes on the Earth, man-caused catastrophes, etc. The primary goal of theoretical and experimental researches consists in revealing interrelations of dynamics of various atmospheric layers, parameters of the atmosphere and ionosphere, an establishment of a role of various physical factors, in studying, understanding, and, finally, forecasting of dynamics of the environment in development of external perturbations. Research of these phenomena is impossible without the deep analysis of features of interaction of participating particles and also a detailed study of the elementary chemical processes occurring here. The trustworthy information is necessary for their solution about reactionary ability of the excited particles, about activation efficiency of various freedom degrees of interacting reagents that requires development of absolutely new techniques of measurements. In turn, it leads to the necessity of improving the existing theory that would not only qualitatively but also quantitatively explain observable laws. The last puts forward not trivial problems which at first sight seem in general insoluble for theorists. Overcoming of difficulties arising here is probably possible only within the limits of essentially new theoretical approaches different from traditional methods of quantum chemistry, though substantially using its achievements. Now we have extensive data on an electronic structure of atoms and molecules and about dynamics of their interaction. Sometimes, it is reliable to calculate cross sections and rates of elementary chemical processes because in most cases (and especially with participation of the electronically excited fragments), we do not have any trustworthy information about features of these particles interaction acts.

One of the most reliable and effective enough tools for their studying is fast molecular beams. This area of science has intensively developed since last 20 years, thanks to its numerous practical applications – from space programs to problems of ecology and chemical technology. Advantage of fast beams is connected first of all with the possibility of carrying out the reagents relative speeds variation measurements in a wide range – from thermal to high ($\propto 10^{10}$–10^{11} m/c). Thus, in crossed (or combined) beams, the recording resolution of counter particles relative energy can reach $\propto 10^{-3}$ eV that opens possibility of a detailed study of elementary chemical processes (including determination of endothermic reaction threshold, a role of initial excitation for the reaction rate and course, etc.).

One of the major processes taking place in the Earth upper atmosphere is dissociative recombination (DR) of slow electrons and molecular ions. Researchers who study

ionized states have to solve problems relating to various fields of physics. Many of these problems are associated with the microscopic properties of plasma, that is, with states of atomic and molecular species and with the elementary processes involving them. These properties depend substantially on the presence of positively charged molecular ions, since reactions involving these species even at low concentrations can lead to a noticeable increase in the rate of the volume charge disappearance in decaying plasma. The latter is accompanied, as a rule, by the formation of excited atomic fragments followed by light emission. Thus, the recombination of electrons and ions determining the ionization structure of the plasma and the recombination spectrum, in turn, provides the necessary information on the physical conditions in the medium in which the emitting species are located. However, the measurement of partial cross-sections of recombination using the cross beam technique is complex due to the fact that for beams, there are no reliable methods for detecting the initial and final states of the recombining system. Therefore, the observed cross-sections are averaged over the energy distribution in electron beams and over vibrational and rotational states, which hampers the direct comparison of experimental and theoretical results. Recently, results of new experiments where DR was studied in storage rings were obtained. The measurements undertaken in the presence of external laser radiation can also play an important role and allow control of a reaction course.

Atmospheric aerosols – particles suspended in air – play an extremely important role in the "metabolism" of the atmosphere. Despite their very low mass concentrations and extremely small sizes they remain active agents in the atmospheric chemical cycles and in the energy transfer in the atmosphere. The small sizes of the aerosol particles (comparable to the molecular mean free path) make their physics and chemistry quite unusual. To answer the questions, where are these particle from? What are the mechanisms of their interaction with the atmospheric air and the Sun radiation? How do they affect the weather condition and what is their role in the climate changes?, etc., this is a far from complete list of the aerosol problems. Part of this book devoted to aerosols intoduces the readers to the area of these problems.

As an essentially new method of elementary physical and chemical processes, research can be done by carrying out laboratory measurements to circumterraneous space with the use of techniques of active (radiating) influence and space complexes. In these conditions (when the measuring device is placed in the reacting environment), there are no difficulties with vacuum of the high resolution, no foreign impurity, and so on.

The indicated problems are of interest for a wide range of the investigators working in various areas of science and techniques. At the same time, it is necessary to carry out the additional researches that are connected with the high human activity in the atmosphere–ionosphere system, leading to occurrence of new risks. They concern an active development of the manned and uninhabited orbital systems, aircrafts (using height of an average atmosphere), new kinds of communication, long-distance transmission circuits, etc. Non-stationary atmosphere–ionosphere system is the subject of powerful natural affects. Its bottom level is disturbed by earthquakes, volcanic eruptions, typhoons, thunderstorms, etc. From above, it is influenced by the geomagnetic storms. As a result of these processes such disturbing

factors, as powerful atmospheric perturbations, electric currents, electromagnetic radiations in the various spectrum ranges, the plasma and optical disturbances, an accelerated particles, the increased level of radioactivity, and changing of ionic and molecular components are realized. Besides, the microwave radiation of highly excited particles of the ionosphere accompanying the processes of solar activity increase and the appearance of magnetic storms impacts mankind negatively. Its spectrum, apparently, is completely defined by the neutral ionosphere components. The knowledge of the influencing factor origination allows to use them for disaster monitoring and to create the corresponding techniques on this base.

For low atmosphere, investigation of thunderstorm activity represents substantial scientific and practical interest, in particular, such an uninvestigated phenomenon is ball lightning. One can say that the nature of usual linear lightning is understood to some extent and there are means of surface objects protection; however, the same cannot be said about ball lightning. This state cannot be considered as acceptable since in a number of cases destructions caused by the ball lightning are as serious as those caused by the linear lightning and sometimes results of its impact are unpredictable (ruination of aircraft, explosions in industrial objects). Besides, investigation of ball lightning is interesting from the point of view of physics and power, nature at its example demonstrates a possibility of high-energy density concentration and storing.

During AIS-2008 conference the tenth jubilee Symposium on Ball Lightning was carried out at the electromagnetic and optical phenomena in the atmosphere section. It was an occasion to make the review of Ball Lightning (BL) researches history and, in particular, the work analysis for last 20 years. It can be seen that these years were the time of active researches of a BL problem. Data banks of BL observations collected and replenished; experiments on obtaining and research of long-lived shining formations were carried out, works on creation and check of BL models were conducted. Unfortunately, this activity has yet not brought notable results. The reason for failure, apparently, is implied in the fact that we could not choose "the main link" in properties BL and as a result have incorrectly chosen ways of its experimental modeling. In the field of BL observation data collection there was some saturation: new data practically add nothing to a "portrait" of an average BL which for some reason yet has not helped to create adequate model of this phenomenon. But there is a shortage of information on rare BL properties: its high energy manifestation, capability to penetrate through subjects (glass, composite materials) connection with other geophysical events. Likely time has come to pass to the publication of full descriptions of BL observations. Quite probably, among them, there can be data that can become the "key" opening its secrets. Time has come to seriously consider data file of UFO observations as among them more than half of objects possess properties of BL. It is necessary to realize, that BL science is the interdisciplinary science requiring participation of experts, working in various areas of physics, chemistry, power, synergetic, biology and psychology.

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