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Remote Investigations of Atmospheric Catastrophes

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Abstract—The generation and evolution of atmospheric catastrophes (tropical cyclones) represents a very serious and still unresolved problem for mankind. The existing physical hypotheses and theoretical approaches which form the basis for a number of space programs on the investigation of physical conditions for the genesis and evolution of tropical cyclones are critically analyzed. The most significant stages of the history of development of the scientific aspects and concepts about tropical cyclones, which are reflected in the pages of the I*nvestigation of the Earth from the Space* journal, are observed. The significance and role of remote (optical, infrared, and microwave) sensing in the evolution of scientific views are analyzed. The fundamental contribution which Russian researchers and, first of all, specialists of the Space Research Institute, Russian Academy of Sciences, as well as Russian developers of space missions and remote instrumentation, have made to the present-day understanding of the problem and to the formation of the present-day image of microwave remote sensing (RS) of the excited atmosphere is emphasized.

Keywords: tropical cyclones, remote sensing, thermal and kinematic hypotheses, local and plural cyclogeneses, ionosphere, solar activity, ocean surface temperature, optical, infrared, and microwave systems.

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INTRODUCTION

It is well known that the tropical zone of the global ocean–atmosphere system plays the key role in the dynamics and evolution of synoptic and climatic meteorological processes on the Earth. The ocean–atmosphere system of the tropical zone of the Earth possesses an extremely unique property of generating fairly well organized and stable mesoscale eddy structures, namely, tropical cyclones (TCs), from the atmospheric turbulent chaos in the global circulation system. Attention to the investigation of such systems is explained by a number of circumstances. In the first place, these atmospheric processes present a direct physical hazard to people; they are accompanied by considerable material damage, as well as administrative and economic problems arising in this case (Riehl, 1979; Pielke and Pielke, 1997), and sometimes even initiate political and governmental reforms. For a rather long time, human society regarded TCs as the most destructive elements of the ocean–atmosphere system, which involved considerable material losses and human victims. Serious efforts were undertaken (first of all, in the United States, and it should be noted, without any result) in order to suppress by some technical means this kind of ocean–atmosphere activity. These attempts on the side of a number of administrative (governmental) structures have not been stopped to date.

For a long time, the process of generation of these eddy systems in the Earth's atmosphere was considered on the basis of standard meteorological approaches as purely a meteorological phenomenon (Shuleikin, 1978; Riehl, 1979; Tarakanov, 1980; Khain and Sutyrin, 1983). Only beginning in 1983, after the series of works under the supervision of Academician R.Z. Sagdeev and Professor S.S. Moiseev (Moiseev et al., 1983a, b), did it become clear that any serious progress in the study of such complex systems can be obtained only with the use of new physical approaches, in both the theoretical and experimental aspects. Thus, from the standpoint of the prognostic analysis of such complex systems, it is necessary, first of all, to clearly understand the spatiotemporal pattern of this global phenomenon as a plural process, which particularly relates to the search for possible determinate components and revealing them on both global and regional scales, which is explained by a number of both scientific and practical circumstances.

Moreover, the latest investigations with the use of space RS data and the newest achievements in the theory of complex systems point to a basically different viewpoint on tropical cyclogenesis; we can state with a large fraction of probability that TCs play a constitutive role in the formation of global mass and energy exchanges in the ocean–atmosphere system and in the establishment of the greenhouse effect favorable for biological life (including human society) on the Earth (Kondrat'ev, 1992). Therefore, global tropical cyclogenesis is, most likely, a necessary and, possibly, a constitutive factor in the ecological equilibrium (under-

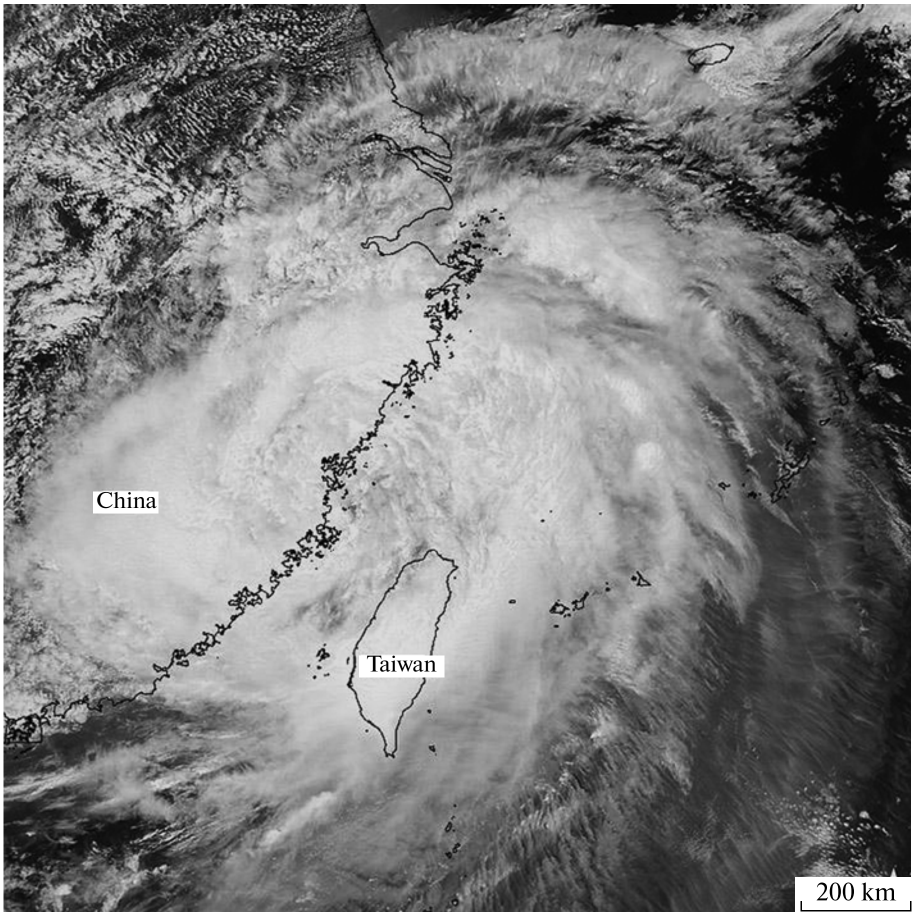

Image of TC Moracot at the stage of its maximal development (typhoon stage) in the South China Sea over Taiwan from data of the MODIS spectroradiometer of the Aqua satellite (August 9, 2009, at 05:15 UTC).

stood in a broad sense), both in the ocean–atmosphere geophysical system and in ecosystems of the Earth. Catastrophic atmospheric eddies represent a peculiar mechanism of the effective drop of excess heat in the atmosphere under conditions where the action of ordinary mechanisms based on turbulent convection and global circulation obviously becomes insufficient. Therefore, catastrophic phenomena play an important (and, paradoxical as it may sound, useful to mankind) role in establishing the temperature regime of the Earth (greenhouse effect), removing excess heat and preventing the planet from overheating in the tropical zone.

On the other hand, it is very important to reveal during the initial cyclogenesis and the intensification of different TC forms a quick-response energy source, which very rapidly (in several hours, on a water area of about 40000–100000 km^2) intensifies and generates mature TC forms. The opinion that only the ocean with a high surface temperature can be such a source has a long history and many supporters (Minina, 1970; Shuleikin, 1978; Anthes, 1982; Khain and Sutyrin, 1983; Khain, 1984). However, clear indicators of the dissatisfaction with such a viewpoint have appeared recently, for example, in connection with the catastrophically rapid intensification of TC Katrin and its subsequent impact on coastal regions of the United States. An analogous situation took place very recently during the catastrophic action of TC Moracot (August 2009) on the territory of the island of Taiwan (figure). In the first case, the special services for emergency situations of the United States were incapable of recording beforehand the process of intensification of TC Katrina, because they were guided by the standard procedures aimed at the search for thermodynamic features of the water areas (the so-called model of warm water) over which the TC travels. In the second case, the special services on Taiwan could not timely take the corresponding measures of emergency character, although all the necessary prognostic data were at their disposal.

The ideas that investigations of the TC interaction with the ocean–atmosphere system cannot be restricted to the troposphere and must be based on consideration of the large-scale crisis state as a global phenomenon affecting various geophysical media, beginning with the ocean surface and troposphere and ending with the ozonosphere and ionosphere, were advanced by scientists at the Space Research Institute, Russian Academy of Sciences (Balebanov et al., 1996a, b). The study of kinematic, thermodynamic, and electrodynamic relations between elements of the ocean–troposphere–upper atmosphere–ionosphere system in crisis states must become, undoubtedly, the most important component of space research, and at present, we are trying to organize complex investigations with the aid of rocket-borne and radiolocation sounding of the ionosphere.

On the other hand, for a long time, from the end of the 19th century to the present day, researchers tried many times to establish relations between the occurrence of TCs and solar activity, which seemed quite obvious at that time. However, these investigations did not led to unambiguously and physically clearly interpretable results. This was caused (as is becoming clear today) by the multiscale and nonlinear character of the process of interaction between solar activity and cyclogenesis, as well as by the use of insufficiently correct mathematical procedures.

The first systematic investigations of tropical cyclogenesis with the use of new physical approaches were carried out by Russian scientists and were published for the first time in a number of scientific publications and in the journal *Issledovanie Zemli iz Kosmosa* (*Investigation of the Earth from Space*), in accordance with the scientific problems formulated previously (Sidorenko, 1980).

The goal of this work is to present a brief critical analysis of the existing physical hypotheses and theoretical approaches which form the basis for the formulation of a number of space programs on the investigation of physical conditions for the genesis and evolution of catastrophic atmospheric phenomena (TCs), to describe the most significant stages of the history of development of scientific views and concepts about TCs, and to consider the significance and role of RS in the evolution of scientific views.

EARLY SCIENTIFIC VIEWS

The history of development and evolution of human knowledge and concepts about atmospheric catastrophes is very dramatic and instructive, beginning with the primitive (and, of course, incorrect) comparison of TCs with the hydrodynamic funnel of water leaving a bathtub to the construction of complex hydrodynamics of a compressive fluid.

According to the present-day concepts, tropical cyclogenesis stably functioned in the World Ocean for a very long time (at least, from the last glacial period). However, Europeans became aware of the existence of such unusual natural phenomena only from the data of Christopher Columbus's second expedition in 1494. It was believed that this phenomenon is nothing more than a usual storm but with a very strong wind force. The first attempts at a purposeful search for and observation of such phenomena, or, in the modern phraseology, first scientific expeditions, were organized in 1508. However, up to the beginning of the 19th century, TC observations were purely fragmentary and occasional, mainly with an emotional description of events.

Only vigorous administrative and economic activity in developing the American continent provided purposeful and (it should be admitted) quite qualified scientific and technical approaches to the study of tropical cyclogenesis in the Atlantic Ocean. In the first place, we must mention the identification of a TC (hurricane) among other meteorological phenomena and the determination of its quantitative characteristics (wind velocity and the sea surface state) by Admiral Sir Francis Beaufort. At the same time, W. Redfield made his first attempts to form the chronology and climatology of Atlantic cyclones (database, in the modern language), and his chronologies were so qualified that even present-day researchers continue to use them. In addition, W. Redfield made one great stride forward: he understood that a hurricane is a unified spiral structure.

A fundamental breakthrough in the physical understanding of the nature of TCs was made in the 1820s–1830s: the thermal and dynamic hypotheses of +TC formation were proposed. The first of these hypotheses is based on a beautiful and seemingly clear physical assumption: the "hot" ocean evaporates water vapor, which passes into cloud systems with the release of vast amounts of heat. These cloud systems unite under the action of the Coriolis force and form a large-scale eddy. This hypothesis proved so attractive and seemingly corresponded to field observations that its various modifications have supporters even at present (170 years later). However, the main feature, namely, a large-scale thermodynamic instability, is absent in this hypothetical mechanism, i.e., the element which would couple and retain small-scale air flows in a unified spiral eddy. The mathematical modeling and laboratory experiments conducted considerably later (in the 1960s) showed the entire insolvency of this model.

After the Second World War, scientists tried to construct a cyclone model on the basis of the Carnot thermodynamic cycle known from a course on general physics. According to this cycle, the external work on a certain volume of gas during its expansion and compression takes place at different temperatures (conditionally, in a refrigerator and in a heater), and thereby such a reversible cycle provides a positive coefficient of efficiency for devices (or processes) based on this principle. This model is also very attractive because we can point to the warm energy source (ocean) and to the cold one (upper atmospheric layers), and in accordance with the Carnot rules, we can obtain the coefficient of efficiency for such a machine and then convert it into the kinematic energy of an eddy. It is remarkable that the obtained quantitative estimates are very reasonable, and the model could be assumed as a base but for a single fundamental detail: a TC has no relation to closed thermal machines because it represents an open system working by means of a continuous exchange of various types of energy with the environment. As soon as this exchange is disturbed, the cyclone will be "filled" and transformed into various posttyphoon forms.

The next century, up to the 1960s, passed under the badge of the desperate fight of man with this terrible natural phenomenon, which ended with the implementation of the expensive Stormfury program (USA, 1963–1983) with the participation of a considerable part of the US Air Force quartered in the Antarctic and in the Pacific Ocean (Willoughby et al., 1985). In spite of the obtained immense experimental data, the main goals and tasks of the program (suppression of the cyclogenesis activity) were not accomplished (Gray, 1997), which was responsible for an abrupt change in the direction of investigations in the United States on tropical cyclogenesis from active actions (on TCs) to predictions. The first optical and infrared TC images were obtained from low-orbit spacecrafts (SCs) and polar artificial Earth satellites (AESs) precisely at this time (the mid-1960s) and later, in the mid-1970s, from geostationary AESs, which caused the exultation of meteorologists, who believed that the problem of predicting the trajectory of TC motion had been solved. However, their enthusiasm was premature. Prognostic (including modern) schemes and models based mainly on statistical data yielded (and continue to yield) very rough errors in their predictions (this was especially noticeable during the geophysical attacks on US territory by the series of hurricanes from the Atlantic in August–September 2004 and in September 2005), and it has become clear that, even with the availability of space information, it is physical models of the genesis of initial TC forms and the evolution of mature TC forms that must play an important role.

Nevertheless, the active searches for indicator families (dimensions, special forms, the structure of boundaries of cloud systems reveled at a certain height, the relationship of cloud systems of different scales, etc.) in remote optical and infrared images of evolutionary stages of TC development were continued. The point is that cloud forms recorded on satellite images usually contain indicators of the subsequent intensification or weakening of the storm before the latter achieves a stage of considerable intensity (Dvorak, 1975). These indicators serve as a basis for elaborating certain rules which make it possible to predict the intensity of a developing storm. Further, the information obtained is standardized in order to obtain a certain intensity code which will be subsequently used for prognostic purposes. However, all these indicators are mostly phenomenological, i.e., in essence, guessed on the basis of some physical prerequisites. The active work on revealing such indicators in space infrared and optical images continues to date.

At present, the method of animating a succession of satellite images (multiplication) is one of the most important methods for analyzing the motions of tropical storms. When such a succession is projected onto a screen, an analysis in the real-time mode becomes possible. Forecasters can extrapolate the tropical storm motion to the future (of course, with not a very large term of forecast). The public demonstration (on TV and on the Internet, and, recently, via mobile communication as well) of such animated successions imparts persuasiveness to the prediction, for example, of the place where the storm will reach land, which allows people to take independent measures on saving their own lives. This was demonstrated in the United States during the attack of the geophysical element in August–September 2004.

PRESENT-DAY APPROACHES

At present, investigations of the genesis and evolution of stable eddy systems against the background of specific features of the global circulation and turbulent chaos of the tropical atmosphere are developed in two basically different directions (Sharkov, 2000). The local approach (individual cyclogenesis) is used for investigating the formation of the unit (individual) eddy structure from wave motions in the atmosphere and turbulent chaos in conditions of a rather strong nonequilibrium of the ocean–atmosphere system. The global approach (plural cyclogenesis) considers the formation of eddy systems in the World Ocean as a set of centers of generation of eddy systems in the active medium of the ocean–atmosphere natural system (the latter is considered on the global scale). This approach was proposed by scientists of the Space Research Institute in 1993 (Pokrovskaya and Sharkov, 1993b) and is being successfully developed at present (Sharkov, 2000).

Local Approach

A TC is a large-scale natural phenomenon, and it would be logical to believe that its genesis (formation) is caused by a large-scale hydrodynamic instability, i.e., the state of the physical system in which its physical parameters are liable to undergo sharp changes owing to the appearance of internal energy sources in the system. Attempts to detect such instabilities in the hydrodynamics of the atmosphere (along with the primitive models mentioned above) have led to the construction of the so-called model of conditional instability of the second kind, or in the English abbreviation, the CISK model (Charney and Eliassen, 1964). This, significantly phenomenological, model was regarded during the past four decades as the main model and was responsible for the appearance of the whole pleiad of daughter models. The model was constructed on the basis of the incompressible fluid equations, and its essence resided in the fact that disturbances in the tropical zone and disturbances on the scale of a cumulus cloud interact through the (at first glance, strange) mechanism of surface friction of air fluxes against the sea surface. A special mathematical method, namely, the so-called parametrization of small-scale convection, has become the main element of the CISK model. Such a parametrization ensures the feedback of the large-scale instability through the geostrophic motion intensification when the pressure in an outlined tropical depression increases. In spite of obviously artificially introduced concepts and methods, the CISK model was shown to describe the large-scale instability. However, going beyond the incompressible fluid approximation, the model lost all its advantages. No experimental results which would clearly indicate that this theory is valid were obtained over the past four decades, and at present, it is rapidly losing its supporters.

Finally, it became clear by the beginning of the 1980s that the solution of this extremely complex problem must be based on the main physical laws of thermodynamics without inclusion of phenomenological (i.e., external with respect to the theory under consideration) concepts and parameters. The advantages of such an approach (whose realization, by the way, is very difficult) are obvious, because they make it possible to justify the existing empirical rules of the satellite data processing and to formulate new missing rules on the basis of first physical principles. Note that physicists at the Space Research Institute were the first to realize the necessity for such a conceptual changeover and put it into practice.

At present, the results obtained by the authors of this direction include the theory of generation of large-scale eddies of the TC type on the basis of small-scale spiral turbulence, i.e., turbulence of air flows with special geometric (helical) properties. These works were accomplished at the Space Research Institute under the supervision of Academician R.Z. Sagdeev and Professor S.S. Moiseev (Moiseev et al., 1983a, b). These works initiated investigations on the generation and development of atmospheric catastrophes on the basis of the concept of the spirality of small-scale turbulence of the atmosphere, which is new to hydrodynamics. This direction is successfully being developed in a number of institutes of the Russian Academy of Sciences. The concept of spirality parametrizes the nonlinearity, Coriolis force, and energy of the system, and therefore, it proved to be very effective for the model description of large-scale eddy generation. Special expeditions into active cyclogenesis zones of the Pacific Ocean were carried out in 1989 and 1990. In the course of these expeditions, the theory which existed at that time was verified, and data of meteorological sounding in the western part of the Pacific Ocean were obtained (Zimin et al., 1991; Klepikov et al., 1995). However, after a prolonged stage of realization of the role of the spiral concept, it was understood that small-scale turbulence is not the main factor controlling the eddy system energy (although at some stages of evolution, it, possibly, plays a noticeable role). It was known from the rich observational experience that the latent heat release during phase transitions of atmospheric moisture is the main energy element of tropical storms. There is simply no other such powerful energy source (considered on mesoscales) in the Earth's atmosphere. Therefore, it raised the question concerning the thermodynamic formulation of the hydrodynamics of moist air, because, if for the solution of meteorological problems, such as the formation of clouds in the atmosphere, we could restrict ourselves to phenomenological approaches, such an approach would obviously prove insufficient for detecting the new instability underlying the generation of a large-scale eddy structure in the atmosphere. It was necessary to be guided by the main physical principles of moist air thermodynamics with an explicit inclusion of the release of latent heat participating in phase transitions. Early primitive models were developed for dry and moist air and differ only in their energy characteristics. For such models, the role of phase transformations in the atmosphere is only auxiliary. Therefore, in essence, models of the dry atmosphere with the phenomenological inclusion of water vapor as an energy source are considered. In this case, the possibility that the processes of phase transformations of atmospheric moisture can lead to basic changes in the atmospheric dynamics is excluded from consideration.

The use of the humid hydrodynamics based on the thermodynamics of saturated moist air and admitting phase transformations of atmospheric moisture form the physical grounds for such an approach (Rutkevich, 2002; Rutkevich and Sharkov, 2004). The physical essence of the proposed approach consists in the fact that phase transitions of atmospheric moisture not only play the role of an energy factor (or the thermodynamic phase of the process), as is assumed in primitive models of cyclogenesis, but also produce fundamental changes in the tropical atmosphere dynamics (the dynamic phase of the process) caused by an anomalous behavior of the vertical profile of the velocity of sound in saturated moist air. The point is that under normal atmospheric conditions, the velocity of sound (which is a peculiar critical scale of the velocity of dynamic processes in the atmosphere similar to the velocity of light in electrodynamics, which is the same scale) is proportional to temperature and drops with height in the same manner as temperature (up to the stratosphere). However, the reverse process can take place in atmospheric layers completely saturated with water vapor, i.e., the velocity of sound will increase with decreasing temperature, and thereby, the relationship of dynamic processes in the gaseous medium can be quite different compared with the usual conditions. The theory of generation of large-scale eddies in saturated moist air was developed at the Space Research Institute (Rutkevich, 2002; Rutkevich and

Sharkov, 2004). This theory describes the generation of real TCs based on first thermodynamic principles, because all phenomenological factors are excluded from it, and the characteristics of the solution are described by real thermodynamic parameters. Note that the experimental (and primarily, remote) proof of the existence of the considered instability under natural conditions can substantially change our concepts about the genesis of atmospheric catastrophes and involve basically new tactical and technical requirements on remote-sensing spacecraft and aircraft complexes.

Global Approach

In the global aspect, tropical cyclogenesis still remains a poorly studied physical process. However, nevertheless, scientists at the Space Research Institute already obtained serious and nontrivial results based on the proposed concept of plural cyclogenesis (Sharkov, 2000). Evidently, investigations of plural cyclogenesis must be based on the method of constructing a time series of global tropical cyclogenesis, i.e., the physical process considered simultaneously in the entire water area of the World Ocean (or in the water areas of hemispheres). And here it transpires that the seemingly simple question—in what way the temporal succession of TCs must be formed—is not so simple, and moreover, this question is of fundamental importance because the physical significance of the final result depends on its solution.

Experimental geophysical data on the occurrence and spatiotemporal evolution of TCs in water areas of the World Ocean were collected in the systematized Global-TC database (Pokrovskaya and Sharkov, 2001, 2006), where chronological, hydrometeorological, and kinematic characteristics of large-scale tropical disturbances in the entire water area of the World Ocean are presented as successions of events with allowance for the lifetime of each event over the period from 1983 through 2005. It was shown for the first time that a random process formed in such a manner represents a so-called telegraph process (on diurnal scales) (Pokrovskaya and Sharkov, 1993b, 1994a–d, 1996b–d). Further investigations showed that the stochastic structure of fluctuations of the amplitudes of the studied flux is actually close to the structure of a so-called Poisson-type flux. In other words, the occurring cyclone "knows" nothing about the preceding one (which, as a matter of fact, would be expected). However, quite symptomatic deviations from the Poisson model were also expected if the time scale of observations was increased. It turned out that it is these deviations from the Poisson model that carry the most important information about the nonequilibrium and nonlinearity of the system (Sharkov, 1996, 2000).

The possibility of describing the global cyclogenesis processes in the ocean–atmosphere system as a relaxation regeneration of the kinematic–diffusion (Langevin) type in a weakly nonequilibrium medium was shown on the basis of the results of correlation analysis of the temporal intensity flux of tropical cyclogenesis (formed from data of space observations) (Sharkov, 1996, 2000). The stages of kinematic and diffusion relaxation with the changeover to the regime of flicker noise were revealed. On the other hand, it is known that the kinematic–diffusion approach was successfully applied for the description of nonequilibrium systems in hydrodynamics and chemical kinetics. In this case, kinematic features of the system are defined as the processes of generation and destruction of system elements (reaction mechanism), and diffusion is defined as random wanderings between elements of the volume and elements neighboring to it. Using this analogy, the author of this work proposed and substantiated (with the use of satellite experimental data) in (Sharkov, 1996) a kinematic–diffusion approach to the description of global tropical cyclogenesis, considering it as a discrete Markov process. Evidently, the mechanisms of reaction and diffusion can be interpreted in this case as follows: the processes of generation and destruction of system elements correspond to the occurrence (generation) of a TC and its disappearance (dissipation, destruction), and diffusion can be interpreted as random wanderings of the lifetimes of unit TCs and as a random temporal flux of moments of TC occurrence.

In this case, the revelation of the degree of nonequilibrium of the ocean–atmosphere active system with respect to the generation of coherent structures has an important ecological significance, because this is associated with a possible reorganization of the regime of generation of a succession of individual TCs into a global synchronous catastrophic regime of generation of a supertyphoon, similar to such a process in the atmosphere of the planet Venus. Such a scenario of events would bring colossal damage to mankind, let alone the very possibility of the existence of life on the Earth. Nevertheless, there is quite definite experimental evidence for the possibility of this seemingly hypothetical scenario. For example, multiple TCs are generated rather frequently (two to three at a time). In 1995, the regime of TC generation was so intense that it was called the TC conveyor in the Atlantic: each succession contained four TCs. In August 2004, nine simultaneously acting TCs were fixed in the World Ocean over a period of three days. Nevertheless, it is shown in (Sharkov, 1999, 2000) that the alarm is premature, because the ocean–atmosphere global system (including the tropical zone) is in conditions of a very weak nonequilibrium, and therefore, the possibility of a fundamental reorganization of the regime of the Poisson TC generation into a global synchronous catastrophic regime of supertyphoon generation is negligibly small (Sharkov, 1999).

The results presented in (Sharkov, 2000) make it possible to approach in a new way the solution of the problem about the rate of generation and evolution of atmospheric catastrophes (TCs) on climatic scales. A stable integral regime of plural cyclogenesis generation, both in cyclone-generating water areas of the World Ocean and in water areas of the Northern and Southern hemispheres, was revealed on the basis of the proposed approach associated with the formation of the temporal flux of TC events as a pulse with unit amplitude and a random duration and a random moment of appearance, which was considered over a 25-year period (1983–2007) (Sharkov, 2000, 2009). The cyclogenesis process intensities, considered both on the global scale and on the scales of hemispheres, are universal constants of generation, which do not depend on telecommunication relations in the climatic system of the Earth. A clear dependence on the ENSO (El Niño–Southern Oscillation) episodes has been revealed only for regional cyclogeneses (North America) in a peculiar regime of annual accumulation. However, this telecommunication relation is completely absent for the global cyclogenesis,if the integral regime of generation is considered over the 25-year period. Thus, during the 25-year cycle, the global cyclogenesis was (Sharkov, 2000) a virtually uniform process with a universal constant of its intensity, both on the global scale ($dF/dt = 1.64$ day^{-1}) and on the scale of cyclogeneses developing in the water areas of hemispheres. Thus, for the cyclogeneses in the Northern and Southern hemispheres, the intensities are 1.14 and 0.5 day^{-1}, respectively. Note that specific features of the telecommunication relations in the climatic system of the Earth have no influence on the global cyclogenesis trend, and the universal constant of cyclogenesis remains constant. An analogous construction for a 10-year period described in (Sharkov, 2000) showed that the integral intensity of the global cyclogenesis remains strictly constant for this time interval as well, amounting to 1.64 day^{-1}.

For regional cyclogeneses, the influence of specific features of the telecommunication relations in the climatic system of the Earth on the tropical cyclogenesis can be not simply noticeable but decisive. The problem resides in a correct choice of parameters and their adequate presentation. Since it is known (McPhaden et al., 2006) that the telecommunication relations of the ENSO phenomenon and circulation features of the North Atlantic are expressed rather clearly, an analogous situation should be expected for the North Atlantic regional cyclogenesis. It is shown in work (Sharkov, 2009) that the active ENSO phases rather strongly suppress the accumulation function, and moreover, we can even indicate the critical value of the accumulation function ($F = 66$), which is not exceeded in the active ENSO phase.

TROPICAL CYCLOGENESIS AND THE SURFACE TEMPERATURE FIELD

The study of the geophysical medium during the development of primary TC forms always occupied a special place in programs of remote (and previously, contact) monitoring of tropical disturbances. First, we must note the problems of predicting the occurrence of primary disturbances and the subsequent changeover of a primary tropical disturbance to a developed TC form, as well as detailed investigations of structural, dynamic, and thermodynamic features of a tropical disturbance directly at the moment of appearance of a mature TC form.

However, attempts at remote investigations of primary forms of tropical disturbances encounter a number of difficulties, and first of all is the absence of a generally accepted physical model of this complex geophysical phenomenon and, accordingly, the necessary geophysical parameters to be measured. In spite of considerable efforts of researchers in the observation and recording of individual (and fragmentary) optical and infrared images of tropical eddy disturbances, there are as yet no definite remote criteria of the geophysical medium "nearness" to the generation of an individual tropical disturbance and to the crucial moment of the transition into a well-developed form.

On the other hand, the concept about a set of so-called "necessary" (and to a considerable extent, phenomenological) geophysical parameters ensuring the generation of mesoscale stable eddy systems in the tropical atmosphere (in the climatological aspect) was formed rather long ago. This set is regarded to a degree as classical and is an unfailing attribute of the majority of publications discussing the problems of TC generation. High values of the surface temperature are one of the main items of this set (it is often called "the first necessary condition for the occurrence of typhoons"). These temperature values must exceed 26°C (26.3–26.8°C) (the so-called critical temperature or the cutoff temperature) at a deep upper quasi-homogeneous ocean layer (deep thermocline).

Of course, this problem (search for the critical temperature) is rather topical (especially in the light of the Atlantic cyclogenesis activation in 2004–2005), because, if the presence of a sharp "cutoff" in the surface temperature field is proven, it will be possible to develop certain automatic remote detectors which could substantially simplify the solution of the problems of predictability of crisis situations.

The experimental results pointing to the presence of a rather wide range of surface temperatures at which the processes of generation of primary forms and their transformation into mature forms take place and to the absence of a critical (threshold) temperature and, accordingly, the absence of a rigid boundary during their generation in the field of the surface ocean temperature, both monthly mean long-term and resulting from three-month averaging of each observed year, are obtained in (Sharkov and Pokrovskaya, 2006) from comparing the spatiotemporal fields of the generation of primary forms and the cyclogenesis of mature forms in the surface temperature field determined: (a) with the use of standard oceanological measurements (in situ—at a depth of 1 m); and (b) from remote infrared thermal data (temperature field in the surface skin layer) for oceanic water areas of the two hemispheres. We demonstrated a stable character of statistical histograms showing the distributions of the ocean surface temperatures (OSTs) at the moment of the transition to mature forms of tropical disturbances (OSTs are the monthly mean long-term values), both for a 21-year sample (1983–2003) and for a 5-year sample (1999–2003), in water areas of the World Ocean. It is important to note that the temperature fields of cyclogeneses in water areas of the Northern and Southern hemispheres are rather close to each other, both in qualitative forms and in quantitative characteristics, although this is not true of the intensity of the stochastic process (the differential intensity of the cyclogenesis in water areas of the Southern Hemisphere is three times weaker than the differential intensity of the cyclogenesis in water areas of the Northern Hemisphere).

As would be expected (Sharkov and Pokrovskaya, 2009), regional cyclogeneses have very peculiar ranges of surface temperatures in which primary TC forms are generated ("diffuse" ranges, "extremes with tails," "delta-shaped forms"). It is shown that mature TC forms are generated in a fairly wide range of surface temperatures and that a critical (threshold) temperature is absent. Accordingly, there is no rigid boundary during their generation in the field of the ocean surface temperature, either monthly mean long-term or remote long-term averaged over three months. Statistical histograms of the OST (monthly mean values) distributions are shown to be stable at the moment of the transition of tropical disturbances into mature forms, both for the 21-year sample (1983–2003) and for the 5-year sample (2002–2006) during regional cyclogeneses in water areas of the World Ocean.

CYCLOGENESIS AND THE GLOBAL RADIOTHERMAL FIELD

The multiscale (in space and time) interaction of the ocean and atmosphere including various processes of exchange of energy, momentum, and matter is believed to be one of the most important climate-forming factors on the Earth. The satellite microwave radiometry is the main means for obtaining instantaneous characteristics of this interaction (temperatures of the atmosphere and ocean surface, near-surface wind velocity, total moisture content in the atmosphere, precipitation intensity, etc.). Among the satellite microwave radiothermal systems, we should particularly mention the SSM/I instruments, which are popular in the scientific community owing to the unprecedented reliability of measurements and long-term stable operation in orbit within the framework of the American DMSP (Defense Meteorological Satellite Program) project (http://dmsp.ngdc.noaa.gov/dmsp.html).

Information about the global radiothermal field of the ocean–atmosphere system for various works in the field of climatology and investigations of the atmosphere and ocean carried out at the Space Research Institute necessitated the organization of a special base of remote data (SSM/I). This database is underlined by the principle of considering remote data as long series of observations: spatial (global coverage of the Earth with the possibility of sounding) and temporal (long-term daily observations of individual zones and the whole globe) (Ermakov et al., 2007). In this case, a long succession of radiothermal measurements is considered not as mechanical combination of data from several files corresponding to consecutive moments of photographing or neighboring points on the Earth's surface, but is, from the user's standpoint, the main structural unit of the database generated on the user's request, which can be processed with the use of subsequent operations. Concrete characteristics of these data series (data sources, spatial and temporal extents, discretization, averaging, etc.) are controlled by the parameters of the user's request. The output data can be written into one file or several files. The formation of a series of images or a video clip (animation method) is, evidently, the most natural method visualization of the data obtained.

In our opinion, the formulated approach to the database construction is the most effective for the analysis of global changes in the ocean–atmosphere system on seasonal, annual, and long-term time scales. At the same time, this approach has no complete analogs among open electronic archives of remote observational data (Sharkov, 2000), which, as a rule, simply select and compile data files according to the selection criteria entered by the user without a substantial reprocessing of data structures and methods of data presentation in files. The successive realization of our approach made it possible to determine the most adequate structure of the database and the format of internal data presentation in it, as well as to classify the main data types generated on the user's request, and led to the development of an original software program which combines the necessary versatility and effectiveness in the user's work with the stored data (Ermakov et al., 2007).

The Global-Field electron collection (http://www.iki.rssi.ru) of global radiothermal fields (Astaf'eva et al., 2008) was formed on the basis of data of satellite monitoring of the Earth within the framework of the DMSP program with consideration for the described database. The SSM/I microwave radiothermal complexes installed on satellites of the DMSP series receive radiation at the frequencies of 19, 35, 22.24, 37.0, and 85.5 GHz, which characterize the integral moisture and water reserve of the troposphere. The fields of radio-brightness temperature constructed from daily band data of the SSM/I complexes do not completely cover the planet, leaving large lacunas at low and middle latitudes (which occupy ~25%

of the entire Earth's surface and about 45% of the tropical zone). The developed special methods based on the intercircular and cross-apparatus leveling and additions made it possible to construct the global fields of radio-brightness temperature (two complete fields daily with the resolution $0.5° \times 0.5°$ over the surface), using the information of all satellites of the SSM/I series for filling lacunas. The obtained global radiothermal fields are suitable for the study of thermodynamic processes in the ocean–atmosphere system with scales from hundreds of kilometers to planetary and vary on short-period (synoptic, mesometeorological), annual, and interannual time scales. The latitudinal and regional variabilities of the global radiothermal field over the World Ocean are studied on different time scales over the period 1995–2005. The regions with increased moisture and water contents serve as tracers of atmospheric motions, and the radiothermal fields averaged over different time intervals are sufficiently reliable for the recognition of structures of the atmospheric general circulation. The fields of deviations (from annual mean, seasonal, and long-term radiothermal fields) depend noticeably on the region and vary in time.

Note that it is water vapor (and the field of radio-brightness temperature in the corresponding frequency range) that can be regarded as a very representative tracer of atmospheric motions, because water vapor is frozen in atmospheric motions, and its distribution in the troposphere is controlled by large-scale and small-scale motions. It should be noted that, in spite of a comparatively prolonged lifetime of a cyclone in the Earth's atmosphere, physical measurements in the TC body under natural oceanic conditions are nearly completely absent. The results of detailed study of TC travel from the tropical zone into middle and medium-high latitudes from data of the microwave satellite radiometry with the use of TC Alberto (August 3–23, 2000) as an example are presented in (Astaf'eva and Sharkov, 2008). The official prediction for TC Alberto was, on the whole, satisfactory with the exception of two periods, when the errors in the 72-h prediction were more than 925 km and from 1110 to 1740 km, respectively. In these periods, TC Alberto was under the controlling influence of its large-scale atmospheric surroundings, i.e., the meteorological situation in atmospheric centers of action rather remote from it (the Azores maximum and the Iceland depression). The large-scale atmospheric surroundings had a noticeable, virtually decisive influence on both the trajectory of TC Alberto and changes in its intensity.

Therefore, for an adequate description of the TC dynamics and energy, theoretical models must take into account the dynamic and meteorological conditions in rather remote large-scale surroundings of a cyclone.

In (Sharkov et al., 2008), the trajectory and intensity evolution of TC Gonu (Arabian Sea, northern part of the Indian Ocean, May 31, 2007–June 8, 2007) in the field of integral water vapor (SSM/I data) are comprehensively analyzed on the basis of the method of merging, which develops the method of data formation and accumulation in the infrared and microwave ranges of satellite remote sensing. One of the main energy sources of TC functioning is revealed experimentally from the results of investigations on the basis of remote data with the use of our modified method of merging. It is established that such a source can be a region with increased integral concentration of water vapor which is captured by a cyclone from the tropical zone with the monsoon atmospheric circulation and is retained by it throughout its entire evolution. The TC dissipated over the Strait of Ormuz, because its inner structure was destroyed through the contact with extended high pressure ridges located on the west, over the Arabian Peninsula, and on the east, over Pakistan.

The comprehensive analysis of energy features of TC Hondo (southern part of the Indian Ocean) during its unusual evolution based on the method of merging of different-scale data of satellite remote sensing shows (Kim et al., 2008) that TC Hondo of the fifth category was formed and developed in the southern part of the Indian Ocean under complex conditions of the interaction with circulation systems of the powerful TC Ivan. The source of latent-heat energy for its functioning and intensification can be the water-vapor region captured by the TC from the tropical zone with the monsoon circulation, which noticeably exceeded the dimensions of this cyclone determined in the standard manner from optical and infrared observations. Only from this zone can the TC sufficiently rapidly take the energy in the form of latent heat, whereas the mechanism of evaporation from the ocean surface is rather slow. Such a mechanism of capturing the water-vapor region by the TC, the authors of the cited work proposed to call "the camel method," bearing in mind the well-known property of the vital activity of these native inhabitants of deserts.

However, the detection of the jet structure of the water-vapor field, which unites the water-vapor region confined to the cloud body of the cyclone and the central equatorial water-vapor zone in the intratropical convergence zone is a fundamentally new result obtained in (Kim et al., 2008). The destruction of this jet structure rapidly leads to the TC dissipation. The formation of such a jet structure leads to repeated intensifications of the TC and its posttyphoon forms. It is interesting to note that such an effect of repeated intensifications, true, without the restoration of the integral water-vapor field and, accordingly, the energy of the process, was also fixed during the TC evolution in the North Atlantic, when the dynamics of the microwave field of self-radiation in the region of 22.2 GHz (the line of water-vapor self-radiation) was analyzed (Astaf'eva and Sharkov, 2008). Evidently, all TCs possess this property and owing to this effect (the effect of capturing) eject a vast amount of latent heat into middle and high latitudes, which is responsible for their cardinal role in the formation of climatic processes in the Earth's atmosphere.

Therefore, one of the main energy sources of TC functioning was experimentally revealed on the basis of the investigation of TC evolution from remote data with the use of the modified method of merging (Kim et al., 2008; Sharkov et al., 2008). According to the results of analysis, such a source is a region of water vapor with increased integral concentration captured by a cyclone from the tropical zone with the monsoon atmospheric circulation and retained by it during its entire evolution, owing to the additional feeding from the main equatorial water-vapor region through flow structures (jets). The break of the feeding jet leads to a rapid (2–3 days) cyclone dissipation. However, the formation of new jets from the central equatorial zone provided the possibility for the secondary genesis of a virtually broken body of TC Hondo and the formation of a new tropical depression with the subsequent dissipation of the jet feeding it.

CYCLOGENESIS AND IONOSPHERE

Astronomical aspects of wave disturbances and variations in the ionosphere state have been investigated for a long time. Physical characteristics are usually sought as long-period (20–50 days and longer) wave disturbances and synoptic variations with discussion of the influence of physical cosmic sources of ionospheric disturbances. Aeronomical works did not exclude the influence of tropospheric sources; however, they did not consider them in detail either (Shefov, 2006). Strange as it may seem, the most powerful atmospheric catastrophes (TCs) were not considered as possible sources of excitement of the ionosphere, although they can produce quite different (rapid) mechanisms associated with powerful ejections of charged particles and neutrals and the radiation of acoustic-gravity waves from the zone of stratospheric TC "ejection" to considerable heights.

The ideas that investigations of the TC interaction with the ocean–atmosphere system cannot be restricted to the troposphere and must involve the consideration of a large-scale crisis state as a global phenomenon affecting different geophysical media, beginning with the ocean surface and troposphere and ending with the ozonosphere and ionosphere, were expressed for the first time in 1996 by scientists at the Space Research Institute (Balebanov et al., 1996a, b). The study of kinematic, thermodynamic, and electrodynamic relations between elements of the ocean–troposphere–upper atmosphere–ionosphere system in crisis states must undoubtedly become the most important component of space research. At present, attempts at the organization of complex investigations with the use of rocket and radiolocation sounding of the ionosphere and optical photographing of self-radiation (nighttime) of the upper atmosphere are being undertaken.

Vanina-Dart et al. (2007a, b, 2008) present the results of complex processing of the data of rocket sounding of the equatorial ionospheric *D* region from the special Tumba research area (India) in the region of intense tropospheric eddy disturbances (TCs), which were observed, according to satellite sensing data, in the northern part of the Indian Ocean. It was shown that the large-scale response of the state of the *D* ionospheric region could be caused by an abrupt decrease (by a factor of 2–4) in the electron concentration in the altitude range of 50–80 km during the active TC phase, which was a fact of the direct fast influence of powerful eddy systems in the troposphere on the overlying lower ionosphere experimentally revealed for the first time. Variants of the physical mechanisms ensuring a fast interaction of tropospheric disturbances with the state of the ionosphere are proposed.

A basically different approach is considered in (Chernigovskaya et al., 2008), where short-period (on the order of tens of minutes or hours) variations in the maximum observed frequencies (MOFs) of signals of the inclined radio sounding along the Magadan–Irkutsk midlatitudinal route (the mean point of the route is located south of Yakutsk) for September months of 2005–2007 are analyzed with the use of a special method for searching for the periodicity of time series. This analysis revealed time intervals with increased energy of short-period variations of a characteristic form (wave packet), which can be interpreted as large-scale traveling ionospheric disturbances (TIDs) caused by internal gravity waves (IGWs) with periods of 1–5 h. The possibility of relating the detected TIDs to an increase in the helio- and geomagnetic disturbances and to meteorological sources in the troposphere was investigated. It has been established that the TID passage is not always associated with an increase in the helio- and geomagnetic disturbances or with the passage of local meteorological fronts. These disturbances are also unrelated to the solar terminator passage, because these disturbances manifest themselves during prolonged periods (about twenty-four hours and longer). Some revealed TIDs, whose possible source (of the traditionally discussed IGW sources) was not identified, can be related to ionospheric responses to TCs which were active in the northwestern part of the Pacific Ocean in the periods under consideration. Since TCs have a powerful pulsed impact on the atmosphere, they can generate IGWs. Under favorable conditions, these disturbances in the form of wave packets of different frequencies can propagate along inclined trajectories for considerable horizontal distances from the place of their generation.

The analysis of events with increased energy of short-period MOF variations for the months of September 2005–2007 showed that the spectral power amplitudes of MOF variations vary by a factor of 1.5–2 in different years. Such distinctions in the energy of the investigated short-period variations for different years can be associated, in our opinion, with possible distinctions in the conditions of propagation of wave disturbances in the atmosphere, as well as with specific features of the formation, development, and travel of concrete TCs in the periods under consideration and, as a consequence of these features, different effects of TCs on the overlying atmosphere.

CYCLOGENESIS AND SOLAR ACTIVITY

From the end of the 19th century to the present day, researchers repeatedly tried to establish correlations (in different ways, from direct comparison to cross-correlation processing) between TC occurrence (in individual regions of the world ocean) and solar (the number of sunspots and even individual sunspots) and magnetospheric activities. However, these attempts did not lead to any unambiguously and physically clearly interpretable results, which was caused (as is apparent now) by a multiscale and nonlinear character of the process of interaction between solar activity and cyclogenesis. For this reason, the standard cross-correlation approaches, extensively used in the processing of time series of observed events as delta functions, cannot, in principle, yield positive results (Sharkov, 2009).

The global approach developed by scientists at the Space Research Institute made it possible to solve experimentally such important problems for the thermodynamics of the Earth's atmosphere as the interactions with solar radiation variations. The solar energy is supplied to the atmosphere both directly as electromagnetic radiation and from solar energy particles through multiple solar–magnetospheric–ionospheric–tropospheric interactions. Since the Earth's atmosphere is a complex thermal–aerodynamic system with complicated and nonlinear transfer characteristics, it should be assumed that the global tropical cyclogenesis can reflect the relations both to direct indicators of solar activity and to indicators of geomagnetic activity. Only the latest complex investigations of solar–terrestrial relations with the use of the modern wavelet analysis yielded surprising results (Afonin and Sharkov, 2003). The response (nearly with the 100% correlation) of 27-day solar-activity variations was detected in time series of the global cyclogenesis. Therefore, it can be assumed that solar activity is a peculiar trigger mechanism (of course, along with other mechanisms) during TC generation (i.e., the dream of researchers at the beginning of the 20th century has come true); however, only the regime of plural TC generation should be considered. It has become clear that tropical cyclogenesis is a manifestation of a complex nonlinear behavior of the Earth's surface–atmosphere unified thermohydrodynamic system with its own dynamic properties, characteristic time scales, and (possibly) resonance frequencies.

SPECIFIC FEATURES OF REMOTE METHODS AND REQUIREMENTS ON SPACE SYSTEMS

It is important to note that, from the very beginning of the space era, the instrumentation of any particular mission for solving scientific and scientific–technical problems was based on the achievements existing in a concrete historical time interval. The history of remote sensing of the Earth (as in general, of cosmic investigations of planets and remote space) is very instructive and contradictory, because it reflects the conflict of scientific views and concepts about geophysical phenomena caused by imperfection of the instrumentation technique.

Owing to the absence of a completed (and recognized by the scientific community) theoretical model of TC genesis and evolution, investigations of tropical cyclogenesis were regarded for a long time as an accompanying element to space missions intended for the study of other geophysical phenomena (Sharkov, 1997, 1998, 2000, 2003, 2005). Note in the first place that the widely known optical and infrared TC images (see, for example, figure) do not provide any practically significant information about the TC internal structure, because they represent images of a snow–ice blanket occupying a considerable height interval (about 5 km). In addition, another important TC zone, namely, the ejection zone, hardly manifests itself in these ranges of electromagnetic waves. Active microwave methods, first of all, radio locators with a synthesized aperture (RSA), provide some information on the ocean surface state, reflecting in no way thermodynamic and dispersive properties of the atmosphere. In turn, passive microwave methods are rigidly attached to the thermal profile of the atmosphere (in lines of absorption of atmospheric gases) and actively respond to the phase composition of the disperse phase in the atmosphere. The problem (still unresolved) associated with these methods, i.e., a small spatial resolution, is well known (Sharkov, 2003). Low-orbit space AESs and spacecrafts operating in solar-synchronous orbits, providing an acceptable spatial resolution, yield a very low value of the frequency of meetings (Pokrovskaya and Sharkov, 1994a; Sharkov, 2000), which virtually eliminates the possibility of their use for the systematic investigation of a given TC, apart from occasional meetings (random infrared images from the mission DMSP AES and the Aqua AES (figure) are typical examples). On the other hand, if astronauts chose a suitable angle of observations during the photographing from low-orbit manned stations, they can detect the whole spectrum of specific TC cloud structures, information about which cannot be obtained from purely nadir observations (Bondur et al., 1997).

Of course, spacecrafts of the GOES, METEOSAT, and GMS types operating in geostationary orbits made a serious contribution to investigations of large-scale TC dynamics. Their further use is largely hampered by a low spatial resolution (5 km in the optical and infrared regions), not to mention the planned microwave measurements from geostationary AESs (Sharkov, 2003).

Investigations of cloud system boundaries in critical zone from the standpoint of their ordering (fractal dimension) (Baryshnikova et al., 1989) from satellite IR data pointed to a certain methodological possibilities in the recognition of different stages of an atmospheric catastrophe.

The Ekos-A, Zodiak, and Geliks missions proposed at the Space Research Institute pursued basically different goals. The first project (Avanesov et al., 1992) was aimed at the development of a global ecological–climatic model based on the data of remote methods and instruments which were available at that time. A somewhat different concept of the development of systems for environmental monitoring was proposed in (Bondur and Savin, 1992). The concept of the second project (Anfimov et al., 1995, 1996) consists in the use of the conversion rocket and space technique for the simultaneous transportation of a significant number of measurement sondes directly into the zone of TC action. With the use of this technique, measurement sondes can be distributed along the upper boundary of the atmospheric region under investigation, in order to measure simultaneously during their descent several tens of vertical profiles of such atmospheric parameters as wind velocity, temperature, humidity, and pressure with the necessary height resolution.

The proposed method for the transportation of diagnostic instrumentation can be realized with the use of a rocket–space complex delivering several tens of miniature (with a mass of 10–15 kg) automatic radiosondes and tetrons (balloons of neutral buoyancy) into the required region and distributing them over the specified area. The experiment is based on two interrelated procedures: investigations of the kinematic and thermodynamic structures of the free atmosphere and the TC body by using the methods of cross sections and drift. The first method determines instantaneous thermodynamic characteristics and the small-scale part of the kinematics of turbulent flows in the ejection zone and the tropospheric TC body. The second method can provide information about kinematic features of turbulent flows of mesoscales and synoptic scales in the zone of TC action. In essence, this mission is based on the method of operational contact sounding of the TC with the use of long-term balloon stations delivered into the TC body from AES orbit, which was proposed previously by Russian scientists (Aleksashkin et al., 1988). It should be noted that the method proposed makes it possible to use ready constructions of the main elements of the rocket–space technique and instrumental elements installed on interplanetary spacecrafts, which flew to planets of the Earth group and successfully investigated the atmospheres of Venus and Mars.

The concept of the Geliks project (Balebanov et al., 1996) is based on the necessity of considering the large-scale crisis state as a global phenomenon affecting different geophysical media, beginning with the ocean surface and troposphere and ending with the ozonosphere and ionosphere. Therefore, complex experiments with the use of instruments of remote diagnostics intended for the measurement of characteristics of different geophysical media (ocean surface–near-water layer, troposphere, stratosphere–ozone layer, ionosphere) must be included in advanced projects on the study of large-scale catastrophes. According to the Geliks project, investigations of kinematic, thermodynamic, and electrodynamic relations between elements of the ocean–troposphere–upper atmosphere system in its crisis states must be performed with the use of an experimental spacecraft (or a system of small spacecrafts) equipped with radiolocation, Doppler, radiothermal, infrared, and special optical instrumentation.

Experimental observations of the atmosphere under conditions of rotational instability (inversion of the sound height profile) necessitate fundamentally new methods of distance sensing of precrisis and crisis states in the Earth's atmosphere (Rutkevich and Sharkov, 2004). In the first place, this relates to the remote determination of characteristics of the detailed height profiles of the water-vapor content and temperature, both outside and inside cloud systems (of convective and nonconvective character), as well as the field of pressure (and its profile) for vast oceanic water areas. Such investigations can be carried out only with the use of passive geophysical remote space systems of a new generation (Sharkov, 1997, 2003, 2005).

CONCLUSIONS

At present, investigations of atmospheric catastrophes are at a serious transitional stage related to the fact that a fundamentally new thermohydromechanics of a compressible (finite value of the velocity of sound) air medium with saturated water vapor has been proposed and developed. Most likely, this circumstance will substantially change our concepts about the genesis and evolution of atmospheric catastrophes, as well as affect the design and structure of remote systems. The following potential directions are possible: the search for a method of constructing the real pressure field at different heights on the basis of available remote data; the elaboration of methods for a substantially improved reconstruction of the water-vapor concentration profile in both the lower and upper troposphere; and the search for nonstandard solutions in designing remote systems for the diagnostics of different geophysical blocks of atmospheric catastrophes. It is also necessary to continue investigations on the elucidation of the role of atmospheric catastrophes and their contribution to the dynamics and evolution of both the global climate of the planet and its regional components.

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