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Russian Studies of Atmospheric Radiation in 2003–2006

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Abstract—The Russian Radiation Commission, in cooperation with interested departments and institutions, has held two international symposia on atmospheric radiation for the Commonwealth of Independent States in the recent past. The participants of the symposia discussed problems that are currently particularly relevant in atmospheric physics: radiative transfer, atmospheric optics, greenhouse gases, clouds, aerosols, climate changes, remote sensing, and new observational data. Five directions covering the complete spectrum of investigations on atmospheric radiation are presented in this report.[1]

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RADIATIVE TRANSFER THEORY

Numerous studies in this field are concerned with the processes of radiative transfer in different media with different geometries of measurements and are aimed at developing methods and algorithms to solve the radiative transfer equation as applied to the problems of atmospheric optics.

At the Institute of Atmospheric Physics, Russian Academy of Sciences (IFA), a linearized vector model of radiative transfer has been developed for a spherical atmosphere [1–3], the effect of multiple scattering and aerosol on the polarization of radiation has been assessed [4, 5], and a comparison with other radiative transfer models has been made [6]. Different methods of the theory of radiative transfer are being developed very actively at the Moscow Power Institute (MEI). The efficiency of representing the solution to the transfer equation as the sum of a singular component (on the basis of a small-angle modification of the method of spherical harmonics) and a regular, smoother, part for describing the transfer in media with strongly anisotropic scattering has been studied [7–10]. The method of discrete ordinates, which makes it possible to generalize the approach to the case of an arbitrary three-dimensional medium with consideration for polarization, was developed [11–14].

At the Keldysh Institute of Applied Mathematics, Russian Academy of Sciences, numerical methods to simulate radiative transfer in the atmosphere with inhomogeneous clouds and aerosol are being improved, and algorithms are being developed to solve the radiative transfer equation in the problems of atmospheric optics on computers with a parallel architecture via the method of discrete ordinates. Special attention is given to methods to improve accuracy in approximating the aerosol and cloud scattering phase functions. Algorithms for approximating the collision integral with the aid of the scattering matrix have been developed to calculate sunlight fields in both one- and many-dimensional regions and to account for a detailed structure of the medium scattering sunlight (clouds, buildings, trees, etc.) [15]. The algorithms of the method of discrete ordinates have been reviewed in detail [16], and algorithms for calculating the fields of polarized light in three-dimensional regions with the method of discrete ordinates are being developed. The influence of atmospheric horizontal inhomogeneities on the sky reflectance has been studied [17], and simplified models that make it possible to estimate the dimension of the boundary layers have been developed. The results on mathematical models of radiative transfer theory and methods for a numerical solution to the problems of radiative transfer theory are summarized in [18].

At St. Petersburg State University (SPbGU), scientists continue to study the processes of nonequilibrium

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radiation transfer in the middle and upper atmospheres. The earlier-developed generalized model of radiative transfer under non-LTE conditions in a rotation–vibration band has been used to study the influence of temperature disturbances of a Gaussian form in an isothermal atmosphere [19]. Radiation processes in the CO_2 absorption bands have been studied thoroughly: the effect of solar proton events on atmospheric self-radiation [20] were estimated, as well as the contribution of solar-radiation absorption [21] and emissions in these bands [22, 23] (which are caused by tidal temperature variations) to the processes of warming and cooling the mesosphere and lower thermosphere. The parametrization of solar-radiation absorption in the CO_2 bands in the near IR region was included in the Canadian model of the middle atmosphere [24]. An approximate dimensionless approach to estimating the thermal effect of the CO_2 15-μm band in the thermosphere is proposed in [25]. This approach has been used to construct a semiempirical model of the globally averaged temperature structure of the Earth's thermosphere.

A large number of studies are devoted to methods of calculating radiative transfer as applied to the problems of remote sensing of the atmosphere and underlying surface. At the Kurchatov Institute Russian Scientific Centre (RNTs), an algorithm has been developed for ab initio calculations of thermal radiation in a plane-parallel atmosphere containing aerosols and clouds [26]. This algorithm makes it possible to accurately take into account gas absorption and multiple scattering by particles in any spectral ranges. In cooperation with the Brazilian National Institute for Space Research (INPE), a model has been developed on the basis of this algorithm to measure atmospheric radiation with multichannel satellite spectrometers of any resolution [27] and to reproduce the outgoing thermal radiation for sensors with high, medium, and low resolutions. The fundamental limitations on the accuracy of direct-integration models, which are due to an uncertainty of modern spectroscopy, have been studied [28]; such a model has been tested in an international comparison of radiation programs [29] and in an in situ experiment [30]. The results of comparing different codes of three-dimensional radiation models, which were made by scientists from the Institute of Atmospheric Optics of the Siberian Branch of the Russian Academy of Sciences (IOA), the RNTs Kurchatov Institute, and the Institute of Computational Mathematics and Mathematical Geophysics of the Siberian Branch of the Russian Academy of Sciences (IVMMG), have been published [31]. Significant results have been obtained at the IOA in the development and validation of statistical methods for studying radiation fields in atmospheres with stochastic models of broken cloudiness [32]. Methods of numerically simulating the sky brightness in the vicinity of the horizon [33–35] are being developed to determine the optical depth of aerosol scattering [36]. At the Taifun Research and Production Association, the basic optical characteristics of ice-crystal and mixed clouds have been calculated. The cross sections of radiation extinction, scattering, and absorption, as well as the radiation scattering phase function, have been parametrized for individual ice particles and for their systems, which are characteristic of real clouds [37]. At the Russian Hydrometeorological Research Center (GMTs), a method for describing the interaction between solar radiation and clouds while taking into consideration their microphysical properties has been developed to calculate solar radiation fluxes in a cloudy atmosphere [38]. The combined algorithm of calculating microphysical characteristics and radiation fluxes made it possible to study the dependence of the optical properties of clouds, albedo, and transmission on microphysical parameters. At the Shirshov Institute of Oceanology of the Russian Academy of Sciences (IO, St. Petersburg Branch), scientists continue to develop models and methods for calculating radiative transfer as applied to oceanic optics. The theory of sea-bed imaging from the atmosphere through a rough sea surface under natural illumination has evolved through the generalization and development of the earlier theory of underwater imaging with the use of optical models for the sea water, surface, and atmosphere [39]. A new efficient algorithm has been developed and analyzed for a computer simulation of a random image of an inhomogeneous sea bottom observed through a rough sea surface [40].

ATMOSPHERIC MOLECULAR SPECTROSCOPY

Studies on the molecular spectroscopy of atmospheric gases are mainly aimed at improving the methods of calculating the parameters of spectral lines and at providing spectroscopic databanks (IOA, the Institute of Applied Physics, Russian Academy Sciences (IPF), and SPbGU). In determining the frequencies and intensities of the basic atmospheric components (H_2O and CO_2), most attention was given to their isotopic modifications and highly excited vibration–rotation states [41–46]. In these studies, the calculations were performed with the use of the effective-operator method. Based on perturbation theory, this method allows one to significantly decrease the volume of calculations and to simulate spectra with an accuracy close to that of experiments; in this case, the high computational power of supercomputers is not needed. The same approach was used to calculate the spectra of the N_2O and C_2H_2 molecules [47, 48].

The effect of intermolecular interactions on the parameters of lines has been the objective of many studies [49–52]. In these studies, the exact calculations of the trajectory of colliding molecules are performed using classical mechanics, and the calculation results are compared to those obtained by different approximate methods. The calculated half-widths of lines are compared to those measured in experiments [53].

B.A. Fomin (RNTs Kurchatov Institute) [54, 55] has developed a fundamentally new *k*-distribution technique which properly takes into account the overlapping of the bands of different absorbers and allows parametrizations of unrestricted accuracy. Having the same accuracy level as other methods, this technique is two–three times faster and can be used successfully for both the upper atmosphere and the troposphere. With this method, the first parametrization version was developed for weather and climate models which uses 23 and 15 terms for thermal and solar radiation, respectively. This is two–three times less than in its analogues.

Studies on submillimeter absorption should also be noted. The studies of oxygen spectra (with a high spectral resolution and a high measurement accuracy) are of particular interest [56–58]. The parameters of oxygen lines and their temperature variations have been determined, and the effects of line interference have been assessed. The rotational lines of the H_2O molecule and the continuum absorption related to this molecule have been investigated thoroughly [59, 60].

The simulation of line-mixing effects is studied in [61, 62]. Here, different models of constructing the rotational-relaxation matrix, which governs the form of the vibration–rotation bands, are compared; and the spectral ranges where the manifestation of this effect should be expected are determined.

Finally, some papers sharing common characters discuss the problem of creating databanks. First, this databank can be used to calculate the spectra of gases at high temperatures [63] and, second, this databank can contain not only line parameters but also programs for calculating spectra under specific conditions [64–66].

RADIATIVE CLIMATOLOGY

Studies in this field were conducted in the following directions: (1) monitoring the radiation balance (RB) components and the atmospheric constituents that affect the radiation regime; (2) studying the climatic trends of the RB components at the land surface; (3) developing methods to reconstruct solar radiation; and (4) analyzing the radiation effects of atmospheric gases, aerosol, and clouds.

The multiyear tendencies of variations in the RB components, cloudiness, and atmospheric optical characteristics have been analyzed for the conditions of Moscow [67–69]. On the basis of simple empirical relationships obtained from multiyear observations at Moscow State University (MSU), the maps of photosynthetic active radiation have been constructed for the vegetation period in European Russia [70]. The parameters of variations in the radiation regime of the Antarctic have been obtained using data from the archive of actinometric measurements taken at the Russian Antarctic stations [71]. The multiyear trends of the RB components at the land surface and their relations to the trends of the standard meteorological variables—the temperature and humidity of air and soil, atmospheric pressure, precipitation, and the heat balance components—have been studied at the Voeikov Main Geophysical Observatory (GGO) [72–75].

A method of reconstructing UV radiation has been developed. On its basis, the variability of erythema radiation in Moscow since 1968 has been retrieved [76]. It is shown that the increase in UV radiation in eastern Europe at the end of the 20th century is determined by the combined effect of three factors: a decrease in cloudiness, ozone, and aerosol optical thickness since 1994. The results of ground-based measurements of UV radiation in Moscow have been compared to the TOMS satellite data and the data retrieved via the JRC METEOSAT satellite algorithm [76]. Significant deviations in the UVR retrieved from the TOMS data in the absence of correcting for absorbing aerosol are noted, as well as the need for another way of specifying aerosol in the JRC METEOSTAT algorithm. At the Taifun Research and Production Association, investigators have compared the daytime expositions of surface erythema radiation that were obtained from ground-based measurements with a Brewer spectrophotometer and from satellite measurements with a TOMS spectrophotometer. On the whole, the results of satellite measurements are shown to correlate well with those of ground-based measurements (the correlation coefficient is 0.98–0.99). In this case the results of satellite measurements are, on the whole, overestimated with respect to those of ground-based measurements. It is revealed that the difference between the results of satellite and ground-based measurements of UV radiation contains a periodic component with a period of several years and an annual cycle with regional distinctions. The periodicity and the annual cycle appear to be caused by variations in the aerosol component of atmospheric transparency [77, 78]. The fields of the monthly means of the total ozone (TO) and UV erythema irradiance in the tropics over 25 years, according to the TOMS-8 data, have been analyzed with the method of empirical orthogonal functions (EOFs) [79]. The first two EOF modes (12 and 19%, respectively) of UV irradiance, which are related to the quasi-biennial cycle (QBC) and 11-year solar cycle (as for the TO), have been singled out. In this case, variations in the TO and UV erythema irradiance are in the antiphase.

Atmospheric aerosol is one of the basic factors determining the radiation regime of the atmosphere and the processes of cloud formation. The transport of aerosol from desertificated regions (the Aral region, Kalmykia, and the Astrakhan region) has been studied extensively at the IFA [80, 81]. An empirical model of mineral-aerosol removal from a desertificated region has been developed to estimate the microstructure of the aerosol generated on the underlying surface [82]. Aerosol monitoring over Russia is being developing. One important stage in its development is the successful operation of a number of stations of the international AERONET network and the inclusion of new stations in this network under the AEROSIBNET program [83]. Aerosol measurements have been taken in Moscow (MSU) [84, 85] and in Siberia [86] under the AERONET. A decrease has been revealed in the aerosol turbidity of the atmosphere over Russia in recent years and in different geographical regions [87–89]. Investigators of the Arctic and Antarctic Research Institute (AANII) continue to perform regular measurements of the spectral-aerosol-optical depth in the range 0.395–1.04 μm at the Antarctic station Mirnyi. The results of observations of the spectral-aerosol attenuation of solar radiation in the polar regions have been summarized over the past 25 years [90, 91]. At the IOA, investigators study space and time variations in the optical and microphysical characteristics of atmospheric aerosol and its chemical composition in different regions of the ocean and analyze the factors that determine these variations [92–96].

The effects of gas, aerosol, and cloudiness on solar radiation near the land surface and their radiation forcing and possible effects on the climate system, including the conditions of smoke aerosol, are discussed on the basis of measured and simulated data [97–101]. It is found that a fine-dispersed aerosol with a low absorbing capacity in the visible region and with a higher absorbing capacity in the UV spectral region dominates under smoky-haze conditions [102, 103]. The studies of smog effects in Beijing have revealed that an increase in the volume concentration of aerosol during smog formation is caused mainly by an increase in the size of aerosol particles rather than in their concentration [104]. Variations in the dispersed composition of haze aerosol with an increase in atmospheric turbidity have been analyzed on the basis of multiyear measurements in Tomsk [105]. Certain progress has been made in understanding the effectiveness of absorption by atmospheric gases and aerosol in the UV spectral region. The important role of nitrogen dioxide (as compared to other trace gases) in the absorption of UV radiation under urban and smoky-haze conditions is shown in [106–108].

REMOTE SENSING OF THE ATMOSPHERE AND UNDERLYING SURFACE

Investigators from many institutions (IFA, SPbGU, Physical Institute of the Russian Academy of Sciences (FI), Institute of Experimental Meteorology (IEM) of the Taifun Research and Production Association, Institute of Radio Engineering and Electronics (IRE), GGO, AANII, Central Aerological Observatory (TsAO), and GMTs) perform passive remote sounding of the ozonosphere and atmospheric trace gases in the visible, infrared, and microwave spectral regions; analyze their variations; and improve methods to measure and interpret them.

In 2003–2006, investigators from TsAO and GMTs continued studies under the Global Urban Research Meteorology and Environmental Project (WMO GURME). The vertical structure of the heat island over Moscow was studied by continuously measuring the temperature profiles in the atmospheric boundary layer with MTP-5 Russian microwave temperature profilers in the following three regions: downtown Moscow, a Moscow suburb (the town of Dolgoprudnyi) and an undisturbed zone (the town of Zvenigorod) [109–111]. A spatial inhomogeneity of the thermal regime of the atmospheric boundary layer over the cities of Nizhni Novgorod [112] and Orenburg has been studied. The data obtained during the fires of 2002 in a Moscow suburb on variations in the aerosol concentration and their effect on the thermal regime of the atmospheric boundary layer have been analyzed [113]. The parameters of turbulence [114] and wind velocity in the atmospheric boundary layer [115] are being studied. A review on modern ground-based remote profilers has been prepared for the WMO and published [116].

The concentrations of H_2O, CO_2, CH_4, N_2O, and CO in an atmospheric column are regularly measured using the method of absorption spectroscopy by specialists from the Taifun Research and Production Association in Obninsk and in the Issyk Kul region. In addition, air samples are taken at heights of 25, 100, 200, and 300 m in Obninsk to analyze the content of trace gases in the atmospheric surface layer. In addition to these observations, the vertical distribution and total NO_2 content in the atmosphere are regularly measured in the Issyk Kul region. Atmospheric trace gases were measured regularly at the Novolazarevskaya station during the polar summer and episodically by the research vessel *Akademik Fedorov* (CO_2 and CH_4 by air sampling). Some results of these measurements are analyzed in [117–119]. At the Institute of Physics (IF) of SPbGU, investigators continued ground-based measurements of the total contents of CO and CH_4 with the IR spectroscopic method. On the basis of these and local measurements, variations in the concentrations of these gases over St. Petersburg were estimated, as well as the anthropogenic contribution to the total balance of the methane content [120–122]. Investigators from the AANII continued regular TO measurements at the Antarctic stations Mirnyi, Novolazarevskaya, and Vostok. In 2003–2005, a run of TO measurements over the central arctic basin was performed from the drifting stations Severnyi Polyus (SP)-32 and 33 and from onboard the research vessel

Akademik Fedorov. The results of these observations are analyzed in [123]. The first results from analyzing the data obtained by these drifting stations and this research vessel have been aquired. They characterize the TO variability over the central arctic basin in 2003–2005. In 2000, at the Antarctic station Novolazarevskaya, the measurements of the total contents of carbon dioxide, methane, carbon oxide, and water vapor were resumed with the solar spectroscopic method. These measurements have been performed regularly since 2003. At the IFA, the concentrations of trace gases and aerosol are measured under the TROICA program [124]. In cooperation with specialists from the RNTs Kurchatov Institute and MSU, the problem of simultaneously retrieving the total content of nitrogen dioxide and the microstructure of aerosol in the atmospheric thickness from the AERONET data has been analyzed [125, 126].

In a number of institutions, the characteristics of the underlying surface are studied. The algorithm of retrieving the concentrations of optically active substances in the ocean from spectral measurements of the outgoing radiation with a hyperspectral receiver while taking into consideration its noise has been developed at the IOA [127]. The developed algorithm allows one to optimally design experiments in order to obtain information on optically active substances in the water from vessel, aircraft, and satellite measurements of oceanic brightness. This algorithm has been applied to the problem of retrieving concentrations of phytoplankton, dissolved organic substances, and mineral suspensions with the use of a real multispectral receiver located at an arbitrary height above the sea surface. It is shown that the photodetector noise significantly decreases the retrieval accuracy; however, this accuracy can be increased using a priori information on the conditions of observations [128]. Starting in the early 1980s at the Radiophysical Research Institute (RI), a large number of studies have been conducted on the self-radiation of a rough sea surface in the microwave region under natural rough-sea conditions; methods of determining the fine temperature stratification of the sea-surface layer are being developed [129].

At many institutes, instruments are being developed for radiation investigations and remote sensing. At the IOA, an SP-6 photometer has been developed for a regional network of aerosol monitoring [130]. Compared to its analogues, its distinctive feature is a wider spectral range of measuring the aerosol optical thickness (0.34–4 μm) and meteorological parameters in the region of observations. Specialists from the Keldysh Research Center, SPbGU, Moscow State Technical University (MGTU), State Optical Institute (GOI), and the Institute for Space Research of the Russian Academy of Sciences (IKI) are developing an infrared Fourier spectrometer IKFS-2 for ecological and meteorological monitoring of the Earth's atmosphere from Meteor satellites [131]. This instrument will make it possible to obtain profiles of the temperature (for the troposphere and stratosphere) and humidity (for the troposphere), the total content of ozone and its profile for the stratosphere, the temperature of the underlying surface, and the contents of a number of trace gases from the spectra of the outgoing radiation of the atmosphere–surface system. At the FI and IF, a small gas-correlation IR radiometer is being developed for the aerial cartography of the CO and CH_4 contents in the atmospheric layer up to 20 km; in the future, such instruments can be used for satellite measurements [132, 133]. An experimental instrument to measure methane content with an instrumental error (in determining the methane content) of less than 1% has been made.

INTERPRETING SATELLITE MEASUREMENTS

In this direction, the main part of the studies is concerned with methods of interpreting the results of satellite measurements. Several groups of scientists took part in projects and programs (mostly international) on the methods of analyzing data obtained from experiments and with the aid of future satellite instruments. General information on the program of developing routine domestic satellites for remote sensing is given in [134].

Studies on the development of methods for analyzing the data obtained with IR sounders with a high spectral resolution (IASI/MetOp) have been conducted under the projects supported by the EUMETSAT and the IASI Science Sounding Working Group (ISSWG) in order to reduce information, develop methods of cloudiness detection and identification, obtain data on atmospheric temperature–humidity sounding (ATHS), and estimate the total content of atmospheric ozone and other trace gases. The possibilities of using algorithms for the method of major components and statistical linear regression have been considered to compress information, filter instrumental noise, and numerically solve the ATHS problem [135, 136]. In addition, studies have been conducted on the use of data obtained with a microwave ATHS sounder (a space vehicle of the Meteor series) [137] and on improving ATOVS NOAA satellite data processing [138]. The methods of retrieving the integral parameters of the atmosphere from satellite microwave measurements have been considered [139–141].

The threshold method has been proposed to automatically classify AVHRR radiometer data. This method allows one to determine the types of cloud cover and to detect precipitation zones [142]. Methods for detecting and identifying clouds from data obtained with IR sounders with a high spectral resolution [143] and methods for monitoring precipitation from the NOAA data [144] have been developed. The disturbances of geophysical fields by intense atmospheric vortices are considered in [145]. A method has been developed that makes it possible to determine a smoothed spatial distribution of the near-water wind speed in the entire cyclone region—from center to periphery—from microwave sounding data [146]. This method has been used for data obtained from the sounding of the ocean–atmosphere system with the SSMI/I radiometers in the tropical-cyclone zones of the Atlantic and Pacific oceans. A method to reveal the regions of intense turbulence in complex atmospheric phenomena, such as jet streams, cyclones in the tropical and middle latitudes, frontal zones, and others, is discussed in [147]. Methods for diagnosing hazardous atmospheric phenomena (heavy showers, thunderstorms, and hail in clouds) from data on the Earth's outgoing thermal radiation obtained by polar-orbiting (NOAA) and geostationary (Meteosat) satellites have been developed [148–150].

Studies on the methods and algorithms for remotely determining the total content of ozone and trace gases (CH_4, CO, and N_2O) from data obtained with the IR sounders of the IASI/MetOp type are in progress [136, 151–153]. In 2004–2006, in cooperation with specialists from the Canada Center for Remote Sensing (CCRS) and Bremen University and with IAF/ESA support, studies on new methods for remotely determining variations in atmospheric CO_2 over boreal forests were conducted at the Planeta Scientific Research Center, Institute of Molecular Physics (RNTs Kurchatov Institute), and IOA. Methods for estimating the total CO_2 content in the upper troposphere from the AIRS/Aqua data, which properly reproduce seasonal variations in CO_2, have been proposed and verified [153, 154]. The improved method of monitoring the total CO_2 content from the Sciamachy/Envisat data has also been considered and verified [155, 156].

Methods for obtaining satellite data on the components of the Earth's radiation balance (ERB) are being developed. The data obtained by the SRRB instruments that are mounted aboard the Meteor-3 No. 7 and Resurs-01 No. 1 satellites and allow remote measurements of the ERB components have been analyzed [157].

At SPbGU, an original method for interpreting the SAGE III data (the Russian–American experiment aboard the Meteor-3M satellite) has been developed. This method allows one to retrieve the vertical profiles of the contents of ozone and nitrogen dioxide and the optical and microphysical characteristics of stratospheric aerosol. The SAGE III observational data have been processed, and the retrieval results have been validated [158–163]. In the method for interpreting the SAGE III data, aerosol extinction is taken into account by constructing statistical models of atmospheric aerosol and an optimal approximation of the spectral dependence of the extinction coefficients. The statistical models were constructed for tropospheric and stratospheric aerosols and polar stratospheric clouds [164–167]. The upper-atmosphere parameters were studied by interpreting the CRISTA data. New data on spatial variations in the kinetic and vibrational temperatures, on the occurrence of mesospheric inversions, and on the contents of carbon dioxide and ozone in the mesosphere have been obtained [168–171]. The effect of a horizontal inhomogeneity of the atmosphere on the accuracy of the limb sounding of the atmosphere has been analyzed [172, 173]. Much attention was given to the validation of different satellite data on the gaseous-composition characteristics of the atmosphere and to their comparison with the results of numerical simulation [174, 175]. A new self-consistent model of the daylight emissions of $O_2(a^1\Delta_g, v \geq 0)$ and $O_2(b^1\Sigma_g^+, v \geq 0)$ in the middle atmosphere was proposed to determine the vertical profiles of the ozone content from satellite observations [176–179].

Scientists from Ural State University have demonstrated the possibility of determining the vertical profile of the HDO/H_2O ratio for the atmosphere from the spectra obtained from satellite nadir measurements with Fourier spectrometers of the IMG, TES, IASI, and other types in the range 600–2000 cm^{-1} with a resolution of ~0.1 cm^{-1}. The method of sequentially determining the vertical profiles of temperature, H_2O, HDO, and HDO/H_2O has been developed and verified by using the IMG spectra for the satellite monitoring of such hydrologic-cycle characteristics as the latitude–altitude distribution of the ratio between HDO and H_2O in the atmosphere [180–183]. The data (obtained from the IMG spectra) on the latitudinal distribution of the HDO/H_2O profiles over the Pacific [184–186] are in agreement (to within procedural errors) with the values of the HDO/H_2O profiles calculated with the NASA, GISS ModelE, and ECAM4 models of the atmospheric general circulation over the region under study and with the later similar results obtained by a TES interferometer. A method has been developed to determine the total content of methane in an atmospheric column from the spectra of the Earth's outgoing thermal radiation obtained with satellite sensors of the AIRS type in the range 600–1500 cm^{-1} with a resolution of ~0.5 cm^{-1}. Data on seasonally averaged variations in the CH_4 content in the atmosphere over western Siberia have been obtained from the spectra recorded over this region by an AIRS sensor mounted aboard the AQUA satellite from March 2004 to December 2006 [187]. A model is being developed for a quantitative estimation of the accompanying gas flow in plumes from satellite-sounding data obtained with sensors of the MODIS type in the atmospheric-transparency microwindow 3.660–3.840 μm.

At the IFA, studies were conducted under the guidance of A.S. Gurvich in the following two directions: (1) observations of atmospheric stellar scintillations from spacecraft and (2) using the radio-occultation method on the basis of the GPS and GLONASS sources. From the results of stellar-scintillation measurements from aboard the *Mir* space station, the height dependences of the inner scale and structure characteristics of turbulence were obtained for heights of 30 to 70 km; and the dissipation rate of turbulent kinetic energy, the outer and collapse scales, and structure characteristics of internal waves in the stratosphere were estimated [188–191]. The possibility of obtaining data on the density structure at heights below 30 km from observations of strong scintillations was theoretically studied [192]. The developed method of processing scintillation data obtained with the GOMOS instrument aboard the ENVISAT satellite made it possible to obtain the global altitude distributions of the parameters of stratospheric density irregularities [193]. A method of processing the GPS and GLONASS satellite data has been developed for the problem of radio transmission in the case of radiation multipath propagation in the troposphere [194–197]; this method is used in solving meteorological problems.

At the Nansen International Environmental and Remote Sensing Centre, intensive studies on the development of methods for using satellite data to monitor the underlying surface are in progress. The mass balance of the Greenland ice sheet was studied using satellite data obtained with the ERS-1 (1992–1996) and ERS-2 (1995–2003) radar altimeters. The spatially averaged (over the whole territory of Greenland) time series of height variations were analyzed; this analysis revealed seasonal and interannual variations of more than 10 cm. For the whole Greenland ice sheet, a positive rate of height variations 5.4 ± 0.2 cm/year or ~60 cm during the period of observations was revealed. On the basis of the data obtained with passive microwave radiometers aboard the SSMR–SSM/I satellites, variations in the concentration of the Arctic ice cover over the period 1979–2006 were analyzed [199, 200]. A biooptical algorithm was developed to study the biotic and abiotic processes in sea and internal waters from the data of satellite radio sounding in the visible spectral region (SeaWiFS and MODIS) [201–203]. The water quality and surface temperature of the Kara and White seas [204–206] were studied, as well as the surface manifestations of dynamic, chemical, and biological processes in Lake Ladoga [207]. A synergetic satellite sounding of lakes Michigan and Erie was performed using visible, infrared, and microwave data (SeaWiFS, Quicksat, AVHRR and other instruments) [208, 209]. A marine information system based on radar measurements with a synthetic aperture (SARMIS) is being developed [210–214], and the influence of sea drops on the atmospheric boundary layer and the possibility of monitoring oil patches are being studied with the aid of developed models [215, 216]. Arctic climate change is studied in [217].

At the GGO, developing a method for retrieving the albedo of land objects from remote multiangle measurements of reflected solar radiation [218, 219] and achieving this on the basis of the BRDF measurements with the POLDER instrumentation [220, 221] are in progress.

Methods for assimilating and using satellite data in the schemes of numerical weather forecasting (NWF) and in climate investigations are being developed. Methods for assimilating data (including those obtained by atmospheric sounding from space) into the schemes of a routine analysis of meteorological fields are considered in [222]. In the available routine scheme (based on an optimal interpolation), the following satellite sounding data are assimilated: wind data determined from cloud motions, retrieved temperature and humidity profiles, and estimates of sea-surface temperature. Studies are being conducted on the inclusion of the satellite data obtained from microwave measurements of the outgoing radiation (AMSU-A/NOAA) and radio-occultation observations of temperature and humidity (GPS) into the 3D-Var analysis system under development. A series of studies have been conducted on assimilating data on the remote sensing of the atmosphere (cloudiness parameters) and underlying surface (temperature, albedo, vegetation and leaf indices, and others) into the models of the hydrologic cycle to calculate the heat and moisture fluxes at the surface level [223].

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