0063:551.52

INTERNATIONAL SYMPOSIUM ON THE INVESTIGATION OF RADIATION PROCESSES

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Usp. Fiz. Nauk 85, 564-577 (March, 1965)

AT the invitation of the Academy of Sciences of the USSR, the regular International Symposium on the Investigation of Radiation Processes was held in Leningrad on 5—12 August, 1964. Convoked once every three years by the Commission on Radiation of the International Association of Meteorology and Atmospheric Physics, these symposia are convened regularly in different countries and provide contacts for specialists working in the field of atmospheric optics and actinometry. The initially relatively modest scale of the symposia has greatly increased during the last decade, principally because of the rapid growth of research connected with the use of satellites and rockets for atmospheric investigations and with the problem of clarifying the role of radiative heat exchange in atmospheric dynamic processes that determine the development of weather.

The scientific problems which arise as these problems become more deeply studied have acquired more and more varied facets and call for the participation of larger circles of specialists of different types. Therefore, in particular, the program of the Leningrad symposium certainly could not cover all aspects of modern atmospheric optics and actinometry, and confined itself to some (not always the most urgent) of these;

1. Theory of radiation transport in planetary atmospheres.
2. Infrared spectroscopy of the atmosphere.
3. Experimental investigations of the radiation field in a free atmosphere.
4. Radiation problems connected with dynamics and general circulation of the atmosphere.
5. Radiation climatology.
6. Land based and network apparatus.

In spite of such a limitation (for example, problems involving the scattering of light were not discussed at all), the program was quite rich and attracted to the symposium the majority of leading specialists. This added special interest to numerous "corridor" sessions, which actually greatly expanded the scope of the program, but at the same time strongly limited, owing to the lack of time, the possibility of public discussion.

Among the delegations, representing 26 countries, the largest were those from the USSR (119 persons) and USA (45 persons). The total number of foreign delegates was 107, of which 12 came from socialist countries.

In addition, in the sessions, which were held in the Tavricheskiĭ Palace, some 200 to 500 guests participated. The program included a total of 145 papers (including 30 of survey character, presented at the invitation of the section chairmen) of which 80 were read and 65 presented in the form of abstracts and preprints. The principal working languages were English and Russian.

The symposium was opened by the president of the International Commission on Radiation **F. Moeller** (West Germany). After briefly outlining the tasks of the symposium, he recalled the role played by Russian scientists during the earlier stages of development of actinometry, and expressed gratitude to the Soviet scientists for the good preparation and organization of the symposium.

Greetings to the participants of the symposium were delivered by the deputy chairman of the executive committee of the Leningrad City Council I. Ya. Popov, the chairman of the Soviet for the Interdepartmental Geophysical Committee of the Academy of Sciences, V. V. Belousov, the chairman of the Soviet Interdepartmental Organizing Committee of the symposium M. I. Budyko, and the president of the International Association for Meteorology and Atmospheric Physics A. M. Obukhov.

The chairman of the section on the theory of radiation transport in planetary atmospheres, **Z. Sekera** (USA), outlined in his introductory paper the latest attainments of foreign science in this field, and noted that they bring us closer to the solution of many real problems. Substantial results were attained in the development of methods of mathematical formulation of problems of various types, particularly for the cases of inhomogeneous media with anisotropic scattering, and for spherical planetary atmospheres. However, the lecture considered more important the tasks of improving methods for solving the matrix transport equation and further development of the theory of Chandrasekhar. Comparing various methods using a single model as an example, the lecturer dwelled in detail on a method developed by him to reduce the matrix equation to scalar form convenient for numerical solution, which is usable in the case of an arbitrary form of the scattering matrix.

Among the most complicated and least investigated problems in transport theory is the problem of radiation propagation in media with large optical thickness such as clouds, snow cover, water basins, etc. Until recently, only the simplest highly idealized problems were amenable to rigorous solution, without account of many circumstances that are essential for real media (elongation of the indicatrix, polarization effects, etc). For applications, therefore, particularly for an account of the experimentally unstudied optical and radiation properties of clouds, it was necessary as a rule to resort to extremely crude and theoretically unjustified approximations (for example, the so-called two-flux approximation). Only most recently has serious progress been made in this field.

A paper "Optical and Radiation Properties of Clouds," delivered by G. V. Rozenberg (USSR) in the name of four authors (**G. V. Rozenberg, L. M. Romanova, E. M. Feĭgel'son,** and **K. S. Shifrin**), contained a review of the principal results obtained in this direction by Soviet workers. **G. V. Rozenberg** has obtained in a series of papers, in simple analytic form, approximate solutions of the matrix transport equation for thick layers of scattering media with arbitrary scattering matrix. The resulting formulas, subjected to extensive experimental and theoretical verification, separate explicitly the influence of absorption and of the thickness of the layer, and contain indicatrix and polarization effects in the form of parameters which can be readily determined empirically. **L. M. Romanova** has developed an effective numerical method for solving the transport equation for strongly elongated scattering indicatrices in the case of thick optical layers, and explained several laws that are peculiar to their optical conditions. **E. M. Feĭgel'son** obtained approximate solutions of the transport equation for models which closely imitate the properties of clouds. With their aid he calculated the flux densities and the angular distributions of reflected and transmitted radiation, the effect of clouds on the thermal regime of the atmosphere, and the influence of radiative heat exchange on the process of cloud formation. **K. S. Shifrin** calculated the absorption and scattering coefficients of cloud droplets in a typical cloudy medium, and also calculated the radiation fluxes which penetrate into a cloud and are reflected by it. The foregoing investigations, on the one hand, have led to effective methods for calculating optical and radiation properties of clouds and fogs (and also snow cover, some soils, for example clays, sands, and water basins), and have made it possible to display the degree of applicability of various types of approximate methods. On the other hand, both quite extensive and varied ideas, qualitative and quantitative, concerning the influence of various parameters of the medium on these properties have been obtained as a result of these investigations, ensuring thereby the possibility of using existing data for the analysis of varied meteorological problems.

The same problem was dealt with by **J. Lenoble** and **M. Hermat** (France), who investigated experimentally the light conditions deep in a scattering medium as a function of the parameters of the medium. The authors observe good agreement between the measurement data and the theoretical expectations resulting from calculations for the corresponding scattering indicatrices. They have disclosed in passing some possibilities for determining the scattering indicatrix from the shape of the brightness solid deep in the scattering medium.

W. M. Irvine (USA) has shown in his communication that the use of the Neumann method for solving the transport equation in the case of strongly anisotropic scattering is preferable if the optical thickness is smaller than unity. **J. V. Dave** and **W. H. Walker** (USA) have shown by means of a numerical experiment, in the case of molecular scattering, that when calculating the brightness of light passing through a plane-parallel layer, the role of multiple scattering is much higher than was previously assumed. Thus, for calculations accurate to four significant figures, it is necessary to take into account, at an optical thickness $\tau = 0.1$, scattering up to fourth multiplicity, for $\tau = 1.0$ up to tenth multiplicity, and for $\tau = 10.0$ up to 30th multiplicity. The contribution of high-multiplicity scattering decreases approximately in geometrical progression, wherein for $\tau = 1.0$ the brightness of the n + 1-st fold scattering was approximately 2/3 the brightness of the n-fold scattering. The role of multiple scattering is even larger in the analysis of polarization effects (for a correct calculation of the position of the neutral points at $\tau = 1.0$ it is necessary to take into account no less than 10-fold scattering). **V. V. Ivanov** (USSR) considered the little-investigated case of propagation of radiation in an atmosphere with large optical thickness in the region of an isolated spectral line. When the quantum survival has a great probability, the problem greatly simplifies and admits of an approximate solution that ensures an accuracy sufficient for the majority of interesting problems. The formulation of the transport equation as applied to statistically inhomogeneous anisotropic media such as vegetation cover was proposed by **Yu. K. Ross** (USSR).

G. I. Marchuk (USSR) found a general mathematical formulation of the inverse problem of radiation transport theory, which follows from a simultaneous analysis of the transport equation and the equation conjugate to it for the value of information, connected with a functional describing the readings of measuring instruments. Making use of a perturbation theory developed by him (the deviations of the structural parameters of the medium, such as an atmosphere, from standard conditions are regarded as perturbations), it becomes possible to make, in particular, recommendations concerning the organization of measurements on meteorological satellites.

An extensive group of papers was devoted to problems of radiation transport in planetary (predominantly terrestrial) atmospheres. **V. V. Sobolev** (USSR) reported a theory, developed by him in conjunction with **I. N. Minin,** for the transport of radiation in a spherically symmetrical atmosphere of a planet, with account of refraction, for an arbitrary law of scattering. Two methods were developed for the solution of the problem of a spherically-symmetrical atmosphere, and results were obtained of importance for the investigation of optical conditions in the region of the terminator.

The main results and methods of the theoretical analysis of the field of short-wave radiation in the case of a cloudless sky, carried out in a series of investigations at the main geophysical observatory (**K. S. Shifrin** and co-workers) and the institute for atmospheric physics (**E. M. Feĭgel'son, M. S. Malkevich,** and co-workers) were the subject of a paper delivered by K. S. Shifrin (USSR). Sufficiently simple and effective calculation methods have been developed, making it possible to take into account the elongation of the atmospheric scattering indicatrix and the altitude variation of the turbidity of the atmosphere. Extensive tables were compiled for the brightness of the atmosphere in different directions and at different altitudes (including the characteristics of the radiation field reflected by the planet into outer space) for various models of the atmosphere, different underlying surfaces, and all possible conditions of illumination in a wide spectral range. Many theoretical predictions were verified experimentally. **M. Kano** and **Z. Sekera** (USA) investigated theoretically the influence of the altitude of location of a turbid layer on the polarization of light from the daytime sky. It was shown that the position of maximum polarization, and especially the positions of the neutral points, are sensitive to the altitude distribution of the aerosol.

C. L. Coulson, G. M. Buricius, and **E. L. Gray** (USA) measured under laboratory conditions the reflectivity of clay and sand in different regions of the spectrum, and also the polarization of the light reflected by them, and calculated the brightness of the atmosphere of different optical thickness τ with molecular scattering and different underlying surfaces. They have shown that the properties of the underlying surface are appreciable when $\tau \lesssim 1.0$ and become practically immaterial when $\tau \gtrsim 1.0$

O. A. Avaste and **Yu. R. Mullamaa** (USSR), on the basis of calculations made by Yu. Mullamaa of the reflectivity of the surface of the sea as a function of the wind velocity and the height of the sun, calculated the angular distribution of the brightness of light reflected by the surface of the sea and emerging outside the atmosphere under different states of the atmosphere. Laboratory measurements of the dependence of the albedo of different objects on the conditions of irradiation were made by **V. Volz** (East Germany), **E. de Bari** and **K. Bulrich** (West Germany) who proposed an empirical approximate method for determining the brightness of light multiply scattered by the atmosphere, based on the assumption that the fraction of the multiple scattering in the presence of aerosol remains the same as for the molecular atmosphere.

Of greatest interest among the experimental papers was the communication by **J. Noxon** and **R. Goody** (USA), who observed with the aid of precision polarization measurements, in the vicinity of strong Fraunhofer lines, excess daytime glow of the atmosphere, due either to the fluorescence of the aerosol, or to Raman scattering. A report on the results of measurements of polarization of the light of the daytime sky under different conditions was presented by E. V. **Pyaskovskaya-Fesenkova** (USSR). Using abundant observational material, the author investigated the influence of cloudiness, multiple scattering, and properties of the aerosol on the degree of polarization. **K. Sekihara** (Japan) reported an attempt he made to determine the true absorption of light by the atmospheric aerosol, by comparing the results of many years of land-based actinometric observations in different regions of the spectrum with the theoretical expectations.

The problem of solving the inverse problems of scattering theory was the subject of a report by **K. S. Shifrin** and **A. Ya. Perel'man** (USSR), who developed methods for the calculation of the dimension distribution of small particles in a polydisperse system, starting from measurements of either the scattering of light at small angles, or the spectral dependence of the extinction coefficient, or else (in the case of "soft" particles) of the scattering indicatrix. Requirements were established for the uniqueness of the solution of this problem using the spectral variation of the extinction. The spectral variation of the extinction coefficient of the atmospheric aerosol for different Gaussian particle dimension distributions was calculated by **L. Feutzik** (East Germany).

Several papers were devoted to radiative heat exchange in planetary atmospheres. **J. I. King** (USA) in his paper "Radiation Transport in the Presence of Sources Inside the Medium" developed a formalism for the solution of the radiation transport equation in the case of a semi-infinite medium with spherical scattering indicatrix, if sources of thermal radiation are located inside the medium. The solution is expressed in terms of Ambartsumyan's Φ-functions, generalized for a complex argument. Turning to the atmosphere and considering the solar-light energy absorbed by it as a source distributed in the medium, the author arrives at a model of the "hothouse" effect and calculates the vertical distribution of the temperature for different models of atmospheric structure. The existence of a tropopause is one particular result of the theory.

The influence of radiative heat exchange in the spectral region corresponding to the absorption band of carbon dioxide near 15 microns on the thermal conditions of the mesosphere was considered by **G. M. Shved** (USSR). Account was taken of the line shapes and the rotational structure of the band as functions of the pressure and temperature. The most important result was the disclosure of the appreciable role played by weak absorption lines and small changes in the isotopic composition of CO_2. It is noted that in the case of a very cold mesopause, the carbon dioxide acts like a heating agent. A method is also discussed for taking into account the deviations from thermodynamic equilibrium and the influence of the presence of water vapor on the radiative transport in the CO_2 absorption region.

V. A. Baryshev (USSR), starting with certain premises concerning the nature of atmospheric inhomogeneities, considered the connection between the correlation properties of the radiation field and the statistical characteristics of the main meteorological elements. **G. Ohring** (USA), using simple models of the atmospheres of the earth, Mars, and Venus, calculated the "hothouse" effect and the average temperature of the surfaces of these planets. The calculation method has made it possible to determine the influence of the quantity and height of clouds, and also to find the height of the tropopause. In a paper by **F. Bartko** and **R. A. Hanel** (USA) the question is discussed of the influence of a small water-vapor impurity (with allowance for the dependence of its absorption on the wavelength, temperature, and pressure) in the model of the atmosphere of Venus, consisting of carbon dioxide and nitrogen, on the equilibrium altitude profile of the temperature.

The most extensive (37 communications) was the program headed by **J. Howard** (USA) of the section "Infrared Spectroscopy of the Atmosphere." The problems connected with it started to attract especial attention in view of the fact that infrared spectroscopy was the basis of the majority of modern methods of indirect investigation of the atmosphere (for example, from satellites), and at the same time this discipline turned to be the theoretical basis for investigations of radiative heat exchange.

The investigation of the fine structure of absorption and emission spectra of atmospheric gases was the subject of relatively few papers. The session opened with a paper by **W. S. Benedict** (USA) "Modern Theoretical Investigations of the Spectra of Molecules of Atmospheric Gases." In particular, the lecturer dwelled on problems of determining the energy levels and molecular constants of the molecule H_2O, the probabilities of vibrational transitions and line broadening of H_2O, CO_2, and N_2O, and the structure and intensities of Raman bands of methane. The lecturer reported also the publication of a photometric atlas of the solar spectrum, which contains the interpretation of both the solar radiation spectrum, and the telluric spectrum in the region 7498—12,016 Å. The atlas was prepared by him in conjunction with **L. Delbouge and J. Roland** (Belgium) from measurements made on the Jungfrau.

A report by **K. P. Vasilevskii**, **V. A. Kazbanev**, and **T. E. Dervits** (USSR) concerned the results of laboratory measurements of the vibrational-rotational band $4\nu_2 + \nu_3$ ($\nu_0 = 4853.55$ cm^{-1}) of the absorption spectrum of carbon dioxide. The equivalent line width was measured by adding different amounts of nitrogen. The oscillator strengths and the line half-widths of the P and R branches were obtained, and the optical cross sections were calculated for both self-broadening and for broadening due to the presence of the foreign gas. **M. Becart** (France) reported results of an investigation undertaken by him of the third positive system of bands of CO, including the intensity distribution in the band. **A. T. Stair** (USA) observed the sequence of bands $\Delta\nu = 1$ of the rotational-vibrational spectrum of radiation of the hydroxyl, essentially in the electronic state, excited during the course of the reaction between atomic hydrogen and ozone. A glow of the atmosphere, unobservable from the earth's surface, in the region of 2.5 μ, is predicted.

Principal attention was paid at the meetings of the section to the investigation of the characteristics (primarily the transmission functions) of the unresolved absorption bands of atmospheric gases. **D. Williams** (USA) discussed in detail methods and results of "laboratory investigations of infrared absorption of atmospheric gases" performed under his guidance. By demonstrating typical absorption spectra and transmission functions (growth curves) for the principal vibrational-rotational bands of water vapor, carbon dioxide, CO, N_2O, and methane, and also for the rotational band of water vapor, the lecturer considered in detail methods for determining the line broadening due to the presence of different gases, and mentioned briefly the effects connected with nondipole transitions.

Results of an experimental investigation of the "absorption spectrum of oxygen in the near infrared region of the spectrum" were reported by **V. I. Dianov-Klokov** (USSR). Measurements covering the pressure range 2—35 atm have shown that in the region from 3030 to 12,600 A the absorption spectrum of oxygen is the result of a superposition of "atmospheric" bands of O_2 with the line structure and the diffuse bands of the complex $[O_2]_2$, and the latter predominate everywhere at pressures on the order of 1—2 atm, except in the region 6889—7620 A. The oscillator strengths were determined and the lifetime of the complex $[O_2]_2$ estimated. Measurements in the atmosphere have shown the existence of a diffuse band near 10,640 A, the intensity of which is in good agreement with laboratory data.

D. E. Burch (USA) reported on the "Most Recent Measurements of the Infrared Absorption in Very Large Thicknesses of Carbon Dioxide" in the region 1—5.5 μ. The measurements were made in multipassage cuvettes with path lengths up to 930 meters (pressure from 5×10^{-3} to 1.9×10^2 mm Hg), and up to 40 meters (pressure up to 12 atm) with a spectral width of the slit from 0.4 to 2 cm^{-1}. Many weak bands were investigated, including some previously unobserved.

M. S. **Kiseleva** and B. S. **Neporent** (USSR) investigated experimentally the "infrared absorption of gas mixtures in the region of unresolved bands." It was shown that the spectral constants retain their magnitudes in a broad range of values of the transmission function, including the regions of the square-root law and the logarithmic dependence. The spectrum of the transmitted radiation is uniquely determined by a transmission function which does not depend on the ratio of the concentrations of the absorbing and the non-absorbing gases.

The temperature dependence of the integrated intensity of infrared absorption and transmission bands of atmospheric gases was determined by **K. C. Ferrizo** (USA), who obtained data for the 6.3, 2.7, 1.87, 1.34, and 1.1 μ bands of H_2O, 4.3, 2.7, and 1.9 μ bands of CO_2, and 5.3 and 2.2 μ bands of NO in the temperature interval 300–3000°K. A theoretical model constructed on the basis of the harmonic-oscillator approximation has led (in agreement with experiment) to the absence of a temperature dependence of the intensity of the fundamental bands, unlike the overtones and combination bands.

E. K. **Gora** (USA), in a communication "Role of the Structure of the Wings of the Spectral Line in Infrared Absorption of the Atmosphere" proposed a phenomenological theory that combines two types of "statistical" line broadening beyond the limits of validity of the Lorentz contour. **A. P. Gol'tsev** (USSR) formulated a new approximation for the Elsasser model, taking into account the fact that for large amounts of absorbing gas the Ladenburg-Reiche formula for the absorption function of an isolated spectral line loses its validity. "The Laws of Absorption of Selective Infrared Radiation by Carbon Dioxide in the 4.1–4.7 μ Region" were investigated by **E. S. Kuznetsova** and **M. V. Podkladenko** (USSR).

In the communication by **L. D. Kaplan** (USA), "Determination of the Intensity and Line Width of CO_2 Bands by the Method of Growth Curves," the possibility was discussed of using data on the integral absorption in the band for the calculation of the transparency of the atmosphere. It is shown that for the heat balance (especially of the stratosphere), an important part is played by the absorption of carbon dioxide in the near infrared bands, and that Doppler broadening can be neglected. Measurements of the transmission function of long-wave radiation as a function of the temperature of a black-body radiator (10–80°C) at distances 60–250 meters were made by **A. M. Brounshteĭn** (USSR).

The possibilities of investigating the vertical distribution of water vapor in the atmosphere by measuring the infrared radiation spectrum of the sun at various altitudes were investigated by **B. S. Neporent** and **M. S. Kiseleva**. The authors introduced the concept of optical depth, which replaces the optical thickness for the transmission function, and which is additive for the effective amount of water vapor. On the basis of this concept, the authors have reviewed critically both the experimental methods and the observational data obtained by them and by others.

K. Cumming (Canada), observed on the basis of an analysis of the infrared spectrum of the sun near 3855 cm^{-1}, measured over Florida at altitudes of 10.7, 12.2, and 13.7 km with the aid of airplanes, a strong variability of the content of water vapor between these levels and over the uppermost level. Measurements of the spectra of the sun, performed with the aid of balloons at an altitude of 29 km, have made it possible for him to determine the altitude variation of the concentration of H_2O, O_3, and CO_2.

The measurements of the spectrum of the sun from balloons at different altitudes up to 31.4 km were made on 28 May 1963 by **D. J. Meurcry, F. H. Meurcry,** and **W. J. Williams** (USA) in the 1400–2600 cm^{-1} region. The data for the 2350 cm^{-1} band of CO_2 were in good agreement with the calculations of Plass; for the 1595 cm^{-1} band of water vapor, no agreement was obtained. **J. H. Shaw** (USA) analyzed approximately 700 spectra of the sun, obtained in 1954–1955 at the Mt. Wilson observatory and containing the 1–0 bands of CO_2, and found that the amount of CO_2 is on the average 0.06 atm-cm, but sometimes increases noticeably.

Spectral measurements of the transparency of the atmosphere from the earth, in the regions 3–13 and 0.4–0.9 μ were made by **I. Ya. Badinov, S. D. Andreev,** and **L. V. Daeva** (USSR). The absorption by the water vapor was determined and it was shown that in the 8–9 μ region the aerosol attenuation is comparable with the absorption by water vapor. The distribution of the energy in the spectrum of the sun outside the atmosphere was determined. Measurements of the transparency of the entire thickness of the atmosphere in the far infrared region of the spectrum (from 8 to 1000 μ), with resolution 0.5–1.0 cm^{-1}, were made at an altitude of 5300 meters by **S. V. Farmer** (England).

N. M. Gopshteĭn and **V. I. Kushpil'** (USSR) measured with the aid of balloons the brightness of the daytime sky in the region of 1.0, 1.25, and 1.59 μ. Whereas the brightness in the regions 1.0 and 1.59 μ decreases monotonically with altitude, the brightness decrease in the region of 1.25 μ stops with an altitude of 18–20 km, which, in the author's opinion, is the consequence of the existence of a selectively radiating layer over this level.

The brightness of the daytime sky and of the sun in the region of 0.98 μ, separated by means of an interference light filter, was measured by **V. Volz** (West Germany). In the case of cloudiness, the magnitude of the absorption depends on the height of the clouds and is distorted by the presence of an absorption band of liquid water.

The spectra of the atmosphere's own radiation (the clear night sky) in the region 4—25 μ were investigated at sea level, with a resolution of 0.1—0.4 μ, by **S. V. Ashcheulov** and **D. S. Styro** (USSR). Comparison with calculations made on the basis of radiosonde data has shown that the correspondence for the CO_2 band (15 μ) is good, for ozone (9.6 μ) worse, and for water vapor (6.3 μ) poor.

A series of papers was devoted to the recently acute problem of determining the transmission function on inhomogeneous paths. **R. M. Goody** (USA) analyzed a three-parameter model based on taking into account the superposition of two lines, using for this purpose the Fourier transformation method proposed by Van de Hulst. Comparison with rigorous numerical calculations has shown that the proposed method is effective and of satisfactory accuracy.

Calculations of infrared spectra of the transparency of the atmosphere were undertaken by **D. M. Gates** (USA). The program included the calculation of the position, intensity, and half-width of all the lines in the absorption bands, and an account of the effect of pressure and temperature, and also the influence of the wings up to a distance of 150 cm^{-1}. The calculation was carried out for the 2.7 μ band of H_2O, 2.7 μ of CO_2, and 6.3 μ of H_2O at constant pressure and temperature and at infinite resolution or triangular apparatus function. The calculated transparencies on inclined paths were in good agreement with the observational data.

S. D. Willshaw (England) calculated the errors of the Curtis-Godson approximation for several models of the atmosphere and proposed an empirical method for checking the correctness of this approximation. The method was tested to calculate the cooling of the atmosphere due to radiation transport in the 9.6 absorption band of ozone.

G. N. Plass (USA) advanced certain considerations pertaining to the physical causes that limit the region of applicability of the Curtis-Godson approximation.

Problems involving the influence of aerosol on the spectral transparency of the atmosphere were touched upon in only two communications. **K. S. Shifrin** and **G. M. Aĭvazyan** (USSR) calculated the spectral brightness of light singly scattered by aerosol striking a receiver in measurements of extinction. An estimate of the error brought about by this, for several models of the atmosphere, has shown that the error can reach several percent and can imitate a spectral dependence. **V. E. Zuev, M. V. Kabanov, B. P. Koshelev, S. D. Tvorogov,** and **S. S. Khmelevtsev** (USSR) made extensive experimental and theoretical investigations of the influence of the microstructure of clouds on their spectral transparency in the 0.5—14 μ region. The method developed by the authors was used to calculate the dependence of the coefficient of extinction on the parameters of the γ distribution of particles by dimensions. Measurements of the transparency were made in chambers with artificial fog and were accompanied by measurements of the microstructure with the aid of specially developed flow-through traps and optical devices. On the basis of more than 2000 measurements, in 120 fogs, satisfactory agreement with theory was obtained.

The section on "Radiation Problems Connected with Dynamics and General Circulation of the Atmosphere" was headed by **R. M. Goody** (USA). In spite of the fact that its program contained only 14 communications, the work of the section (unlike that of the others) lasted for two days, thus permitting a well-developed discussion, which was particularly fruitful inasmuch as outstanding specialists on the dynamics of the atmosphere participated in it. It must be noted that during the last few years this group of questions has become particularly timely, in connection with requirements for improving methods of weather forecasting and for including in the forecasting scheme non-adiabatic factors, the most important of which is the radiative heat exchange.

L. R. Rakipova and **B. Yu. Shneerov** (USSR) reviewed Soviet work on the account of radiative heat exchange in the theory of climate and numerical weather forecasting, starting with the early work of **I. A. Kibel', E. N. Blinova,** and **S. A. Mashkovich,** in which use was made of a simple model of a "gray" atmosphere, up to the latest work of several authors, which already takes into account many details of the transport process and permits a more reliable determination of radiative heat exchange, and also its response to cloudiness.

The results of a numerical integration of the equations of the general circulation of the atmosphere, with detailed calculation of radiative transport, performed by **J. Smagorinsky, S. Manaba,** and **J. L. Halloway,** were reported by **S. Manaba** (USA). The authors used the so-called primitive equations of motion, supplementing them with a detailed account of radiative heat exchange and the influence of water vapor, CO_2, ozone, and cloudiness on the heat exchange, and also the stabilizing influence of convective transport of the humidity, it being assumed that the distribution of the optically active gases is independent of the time. It was shown that during 200 days in an isothermal atmosphere, a thermal structure is produced corresponding to the troposphere and the stratosphere. The characteristic wavelength in the stratosphere turns out to be approximately twice as large as in the troposphere. The meridional circulation acquires a cellular character and breaks up into three cells in the troposphere and into two cells in the stratosphere. The height of the jet flow coincides with that observed, and its power is larger than actual.

"Some considerations concerning the role of thermal sources in the dynamics of the atmosphere" were advanced by **A. Elliassen** (Norway). Calculating the equilibrium vertical circulation in the troposphere, produced by a simple altitude distribution of the thermal sources, he obtained an indication of the character of the dependence of the influence of a source on its altitude and on the parameters of the atmosphere. **A. R. Robinson** (USA) calculated, for a strongly idealized model of the atmosphere, the character of the development and establishment of dynamic and thermodynamic processes, due to the temperature perturbation of the surface, in the form of a daily wave travelling in a latitudinal direction, under the assumption that the radiative transport corresponds to the gray stratified atmosphere in the sense of Goody. **J. Gill** and **R. M. Goody** (USA) developed a theory which makes it possible to calculate the influence of radiation on the temperature structure, the heat flow, and the condition for the occurrence of cellular convection in a radiating gas placed between plane-parallel walls. The theory was partially confirmed by laboratory measurements. In a paper by **E. A. Spiegel** (USA), presented in conjunction with **D. W. Moore** (England), the convective superstability due to the radiative transport, that is, the occurrence of oscillations with increasing amplitude, was considered using a particular example, and the physical nature of this phenomenon was elucidated.

Different methods for calculating radiative heat exchange in the boundary layer of the atmosphere, where it should play a noticeable role owing to the considerable temperature and humidity gradients, were discussed by **D. L. Laĭkhtman, É. L. Podol'skaya,** and **F. N. Shekhter** (USSR). A closed system of equations was obtained, including the radiative transport and describing the vertical profiles of meteorological elements and the turbulent characteristics of the atmosphere. The influence of radiation on the evolution of clouds is particularly strong.

M. I. Yudin (USSR) considered the problem of parametric representation of radiative heating of the atmosphere, which reduces to a minimization of the number of parameters for the description of the state of the atmosphere at different levels. The method proposed by the author makes it possible to separate the basic information, necessary for the analysis and forecasting of large-scale processes, and filter out redundant information. A method was developed for determining the main radiative parameters of the state of the weather and the characteristic vectors of the temperature field. Examples illustrating the general scheme were calculated.

Calculations of the distribution of the temperatures corresponding to radiative equilibrium in the stratosphere and in the mesosphere were made by **C. Leovy** (USA). It was shown that processes of radiative heat exchange, as also photochemical processes, turn out to exert a hindering influence on the large-scale meridional circulation. **R. Lindsen** and **R. Goody** (USA) constructed a closed system of equations, describing motions in the stratosphere with account of the mutual interdependence of the ozone concentration and the solar radiation. It is shown on the basis of an investigation of three models of the atmosphere, that a mutual relationship exists between the changes in the temperature and the amount of ozone. Possible experimental verification of the main conclusions is indicated.

The role of radiative heat exchange in the dissipation of temperature inhomogeneities and the attenuation of wave processes in the atmosphere was investigated by **G. S. Golitsyn** (USSR). After the linearization of the transport equations relative to the small deviations of the temperature from standard, a Green's function is obtained for a "gray" atmosphere. A logarithmic attenuation of the wave was obtained for a typical atmosphere with a relaxation time of approximately 40 hours, that is, much smaller than for molecular thermal conduction. The radiative thermal conduction becomes more effective than the molecular conduction starting with a scale on the order of 10 meters, and exceeds the latter by 5–6 orders of magnitude at scales of approximately 10 km. In the troposphere, radiative heat exchange plays the fundamental role in the attenuation of acoustic waves with frequencies lower than 15 cps. An analogous problem was considered, using somewhat different methods, by **T. Sasamori** and **J. London** (USA). Following Spiegel, the authors determined the time dependence of the radiative heat exchange and the radiative dissipation of a weak thermal pulse in a plane-parallel atmosphere. The relaxation time for such a pulse was found to be close to two hours.

G. V. Kirillova and **S. P. Malevskiĭ-Malevich** (USSR) have determined experimentally the influence of the inhomogeneity of the underlying surface on heat transport in the lower layer of the atmosphere under night-time conditions. It was found that radiative heating of a water basin at a rate of 0.5° per hour corresponded to a simultaneous cooling of the neighboring soil by 0.3° per hour. **E. L. Podol'skaya** analyzed approximate methods for describing the transport of the integral radiation flux in the earth's atmosphere. It was shown, in particular, that the presence of CO_2 can be taken into account by an equivalent change in the humidity.

The first half of the meeting of the section on "Radiation Climatology," under the chairmanship of **M. I. Budyko** (USSR), and also almost all the communications, presented in the form of abstracts, included two groups of problems—radiation climatology proper, and the investigation of the connection between the radiative weather and the state of the atmosphere.

A general review of research on radiation climatology carried out at the Main Geophysical Observatory, including a description of the "Atlas of the Earth's Heat Balance," published in 1963 by the observatory, was contained in the paper of **M. I. Budyko, G. G. Berlyand,** and **I. A. Efimova** (USSR).

The lecturer discussed also investigations of the diurnal variation of the radiation conditions in different zones, and the use of radiative-climatology data to solve many other meteorological problems.

I. Bennet (USA) reported on the results of an investigation on radiation climatology in the USA, based on 12 years' measurements carried out in 50 stations.

An outline of the radiation climate of the territory of the Soviet Union was presented by Z. I. Pivovarova (USSR). N. P. Rusin and M. S. Marshunova (USSR) reported on the results of an investigation of the radiation balance of the Arctic and Antarctic. Investigations of atmospheric radiation and heat balance of the earth's surface were made in India by O. Chakko, N. Ayer, and A. Mani (India). F. P. Parapiperis (Greece) reported results of a determination of the diurnal variation and intra-daily variability of the duration of the solar glow in Athens. Microclimatic temperature differences in Moscow, in connection with radiative factors, were reported by A. A. Dmitriev and G. A. Remizov. Inasmuch as all these communications dealt with extensive factual material, we do not find it advisable to dwell in detail on their content and we refer the reader to the original papers.

From among the papers devoted to the study of the connection between the radiation weather and the state of the atmosphere, mention should be made first of all of the paper by A. Angstrom (Sweden), which discussed the possibility of extracting from the measurements of atmospheric turbidity data on the atmospheric aerosol, and where the problem is raised of investigating the climatology of the aerosol, which determines essentially the radiation climatology. The climatology of the aerosol, on the basis of measurements of the direct radiation of the sun, was reported by G. Yamamoto and M. Tanaka (Japan).

O. D. Barteneva and E. A. Polyakova (USSR) reported the results of numerous investigations of extinction and scattering of light by haze, fog, and rain. The authors have established several correlations and disclosed regularities connecting the optical characteristics with the microstructure and the macroparameters. The same authors investigated the ratios of the illumination to the brightness of the direct radiation in dry atmosphere under high-mountain conditions. The connection between the direct solar radiation and the meteorological element was discussed, on the basis of observations in Central Asia, by M. O. Sitnikova.

O. Chakko and V. Dezikan (India) reduced the results of five years' measurements of atmospheric turbidity in Delhi and in Puna. Some results of network observations of the turbidity of the atmosphere in Europe were reported by V. Volz (West Germany), who discussed also the problem of the nature of unusual twilight phenomena observed over the entire globe in 1963, and ascribed their appearance to the eruption of a volcano on the Bali Island.

I. Yu. Undla (USSR), disclosed from an analysis of data of actinometric measurements a connection between the statistical characteristics of the total radiation and the statistical characteristics of the cloud cover. The temporal and spatial statistical characteristics of the transparency of the atmospheric layer near the earth were investigated by E. N. Dovgyallo (USSR). B. Barg (East Germany) reported in the name of F. Bernhardt and G. Philipps on calculations of the spatial and temporal distributions of radiation and the radiation balance at sea level.

Work performed in the USSR on the development of indirect methods of determining radiation characteristics were reported by S. I. Sivkov (USSR). Procedures for the measurement and determination of corrections in the measurement of scattered light from the sky were the subject of a communication by N. Robinson (Israel).

The second half of the meeting of the section "Radiation Climatology" under the chairmanship of K. Ya. Kondrat'ev (USSR) was devoted to radiation-climatological investigations from artificial earth satellites.

W. G. Stroud (USA) described radiometric systems used on the satellites "Tiros" I, II, III, and VII and on the satellites of the "Nimbus" series. The radiation data obtained with the aid of the satellite Tiros over more than 5000 orbits make it possible to set up maps of the distribution of the cloudiness both during the day and during the night, including the height of the clouds, and also maps showing the distribution of the temperature in the stratosphere and the water-vapor content in the troposphere. However, the apparatus needs further improvement, which was partially carried out in outfitting the Nimbus series satellites.

W. R. Bandin, M. Halev, and I. Strange (USA) reported on some climatological results in radiation measurements with the Tiros satellites. In general outline, the results agree with the data on the heat balance of the planet obtained by indirect methods. However, notice is taken of an unexpectedly strong radiation of subtropical anticylcones, and also an exaggerated value of the meridional gradient of the average zonal albedo.

The angular distribution of the scattered solar radiation emitted from the planet, as measured with the Tiros satellites, was investigated by A. Arking (USA), who used for this purpose the readings of a "short wave" channel of a radiometer. In the mean, the angular distribution differs essentially from a Lambert distribution, and the anisotropy depends strongly on the height of the sun. The indicatrix exhibits a strong peak in the forward part and a weak peak in the region of backward scattering, agreeing in general outline with the calculations of E. M. Feĭgel'son and M. S. Malkevich. The seasonal, latitudinal, geographical, and other dependences of the albedo were investigated, and also the latitudinal dependence of the average magnitude of the cloudiness. The latter turned out to be close to the results of land-based observations, with minima of about 40—45% at 15° southern latitude and 30° northern latitude, with a maximum of approximately 50% at 10° northern latitude, and with values of approximately 70% at 60° northern and southern latitude.

In the paper by **S. I. Rasul** and **K. Prabhakar** (USA) "Thermal Balance of the Atmosphere and General Circulation" an analysis was reported, carried out by the authors, of observational data obtained from the Tiros satellites, for the extraction of geographical and temporal variations of the short-wave albedo of the earth and its long-wave radiation into outer space. Mean monthly distributions were obtained for the heat balance over the planet's surface between 60° northern and 60° southern latitude. Following the calculation of the energy stored by the ocean, by the ground, and by the atmosphere, and also the latent heat of evaporation, the authors obtained the monthly longitudinal energy transport in this belt. The data obtained were compared with the land-based data on the atmospheric circulation. The seasonal distributions and variations of the components of radiative heating of the earth planet from data of measurements with "Tiros IV" were investigated by **J. S. Winston** (USA) and also by **F. House** (USA).

E. Raschke (West Germany) determined from measurements made on the Tiros-III satellite the average relative humidity in the upper atmosphere and the temperature of the underlying surface, and constructed appropriate synoptic maps. **J. King** (USA) analyzed the possibility of using the Gaussian inversion method to determine the temperature structure of the atmosphere from satellite measurement data.

A considerable part of the meeting of the section "Experimental Investigations of the Radiation Field in the Free Atmosphere," under the chairmanship of **D. K. Work** (USA), was as it were a direct continuation of a discussion of the problem of using artificial satellites for meteorological purposes, but from a different, methodological point of view. **D. Q. Wark, H. E. Fleming, J. H. Lienesch,** and **F. VanKleef** (USA) investigated the possibility of determining the structure of the temperature field of the atmosphere on the basis of radiation measurements from satellites. In principle, on the basis of the information concerning the radiation of the atmosphere in different sections of the CO_2 absorption band near 15 μ, it is possible to find the vertical temperature profile of the atmosphere, and to plot from the results of satellite measurements maps of the temperatures at a given isobaric level, and also maps of distances between two isobaric levels. Actually, however, the accuracy of the results is limited by the spectral and angular resolution of the instrument and by the measurement errors. In order to ascertain the accessibility of the corresponding information, radiosonde data were used. For each ascent of the radiosonde the outgoing radiation was calculated, in suitable spectral intervals, with account taken of the cloudiness data. Random errors were then introduced and the temperature profile determination operations performed. The maps obtained were compared with the initial maps. A procedure was proposed for the reduction of radiation data minimizing the influence of the errors.

The possibility of determining the height of the upper edge of the cloud cover for measurements of infrared radiation of the planet from satellites was discussed in a paper by **P. Zirkind** (USA). The measurements, performed with rockets and high altitude balloons, were extrapolated to the satellite flight altitudes and compared with the data of theoretical calculations for a cloudless and cloudy atmosphere, making it possible to advance certain opinions concerning the degree of reliability of the method.

F. Saiedy, D. G. Hillary, and **W. A. Morgan** (USA) reported a method developed by them for determining the height of clouds from the intensity of the oxygen absorption band near 7600 A, in the solar light reflected by the atmosphere. A small-size spectrograph was constructed, intended for the use by an astronaut and ensuring a resolution of approximately 5 A. The transmission functions with the corresponding spectral resolution were calculated by **D. Q. Wark** and verified experimentally in airplane measurements. The spectroscopic measurements of the height of the clouds, made on airplanes, have shown that a systematic discrepancy is obtained of approximately 140 mbar (1.4 km) in the mean, due to the presence of an oxygen absorption band in the spectrum of the albedo of the cloud (the corresponding calculations were made for three models of the cloud in the two-stream approximation). Consequently a special investigation of the influence of the thickness of the cloud, its microstructure, and the albedo of the underlying surface is necessary.

The effect of the darkening towards the edge for the earth's atmosphere in the infrared region of the spectrum was investigated by **J. H. Lienesch** and **D. Q. Wark** (USA) using measurements with the Tiros satellite. It was found that on the average the effect is larger than would follow from theoretical calculations. In the author's opinion, this is due to certain optical peculiarities of the cloud cover. The latitudinal dependence of the effect is small.

L. K. Block and **J. J. Lovett** (USA) reported on the observation of the spectrum of infrared radiation of the earth and its atmosphere into outer space in the region of 5—15 μ, with the aid of a Fourier spectrometer placed on a satellite. The authors have reported also on plans for using Fourier spectrometers on satellites to measure the radiation from the earth in the region of 0.5—20 μ. In particular it is proposed to place Fourier spectrometers on a space ship with a two-person cabin. It is planned to install in it Fourier spectrometers for the 0.5—3 μ region (with PbS receiver) and for the 3—13 μ region (with thermistor bolometer) and also for the 8—13 μ region with a germanium detector and cryogenic system.

J. R. Lambert and **S. K. Koroniti** (USA) produced a compact and light spectrometer with diffraction grating, intended for rockets and satellites. The instrument was designed for the range from 0.2 to 2.2 μ, with resolution 100 A and with a scanning of the entire spectrum in 3 seconds.

Land-based measurements of the brightness of the "Echo-I" satellite, aimed at determining atmospheric extinction, were made by **H. Werner** (East Germany) by photographic photometry methods.

The use of another indirect method for investigating the optical structure of the atmosphere at high altitudes was the subject of a paper by **L. Alterman** (USA) on some results of projector sounding of the atmosphere. Sounding in the Colorado Mountains by means of a beam modulated at a frequency of 33 cps and inclined 75° to the horizon was used. The distance to the receiver was 30 km. It was possible to observe the beam up to an altitude of about 70 km. In agreement with the measurements of Junge and co-workers and Rozenberg and co-workers, a clearly pronounced aerosol layer was regularly observed at altitudes near 20 km. Unlike the data of Rozenberg et al, no clearly pronounced aerosol layers were observed at higher altitudes, but the measurements at these altitudes, in the lecturer's opinion, are not sufficiently reliable.

The second part of the meeting of the section on "Experimental Investigations of the Radiation Field in the Free Atmosphere" was headed by **K. Ya. Kondrat'ev** (USSR) and was devoted to radiation and spectroscopic measurements from balloons and airplanes, which are essential both from the point of view of direct demands of meteorology, and for the development of methods of interpretation of measurements made with the aid of meteorological satellites.

K. Ya. Kondrat'ev (USSR), in an extensive paper delivered in conjunction with **I. Ya. Bodinov, G. N. Gaevskaya, G. A. Nikol'skaya,** and **M. P. Fedorova,** described the program and the results of an exhaustive investigation of the altitude variation of the components of the radiation balance, performed by them with the aid of apparatus lifted on automatic stratospheric balloons. Among the most essential results should be mentioned the experimental confirmation of the fact that the upper limit of the layer of the atmosphere, in which transformation of radiation fluxes takes place, is located between 15 and 20 km, and also the deduction that the radiation balance varies with altitude much less than its components.

J. G. Houghton (England) compared the results of measurements of radiation fluxes in the free atmosphere with the calculated data. In particular, the descending fluxes in the region of 6.3 μ were measured.

G. N. Kostyanoĭ (USSR) reported on the results of reduction of data on the altitude variation of ascending fluxes and total fluxes of long-wave radiation, obtained during night-time launching of radiation radiosondes. In the troposphere, the ascending fluxes decrease rapidly, and the total fluxes increase rapidly with altitude, whereas in the stratosphere the ascending fluxes remain practically unchanged, and the total fluxes remain unchanged from the tropopause to the 15—17 km level, and decrease above this level. Considerable changes are connected predominantly with cloudiness. It is shown that the stratification of the stratosphere is not uniform.

Airplane radiometric measurements of the influence of the aerosol on the earth's radiation were reported by **P. M. Kuhn** (USA). During the time of the flights (in California), thin clouds or aerosol layers, not observable in the vertical direction, were observed visually in the vicinity of the tropopause, and their influence on the ascending flux of long-wave radiation was determined and found to be quite appreciable.

Airplane investigations of the radiative properties of the atmosphere and of the earth's surface in the short-wave and long-wave regions of the spectrum, and also in the 5—7 and 8—12 μ intervals, were made by **V. L. Gaevskiĭ** and **V. I. Shlyakhov** (USSR). The authors consider several methodological problems, the altitude profiles of radiative fluxes for different typical stratifications of the atmosphere, the radiative properties of the clouds in the lower and medium strata, the spatial and temporal variability of the radiation field, and the properties of the underlying surfaces (albedo and the radiation temperature as characteristics of the landscape).

F. R. Valovchin (USA) carried out a series of flights over intense thunderstorms, obtaining simultaneously their photographs and data on the radiation in the region of the 8—13 μ transparency window. He has shown that the radiation of the clouds is in good correlation with the topography and the state of the cloud cover, and also with the stage of storm development.

Weekly measurements of the long-wave ascending and descending fluxes with the aid of radiation radiosondes were carried out in Puna by **A. Mani, S. R. Sredharan,** and **V. Shrinivazan** (India). The seasonal variations of the radiation balance are discussed in connection with variations of the water-vapor and aerosol content.

The late **I. P. Funk** (Australia) made a thorough "comparison of the measured and calculated profiles of the divergence of radiation fluxes near the earth." On the basis of measurements pertaining to the 1—2, 3—4, and 10—11 meter layers, he reached the conclusion that at low wind velocities an important role in the radiation heat exchange is played by the aerosol haze.

An ever increasing interest is noted in spectral investigations in the free atmosphere. **F. L. Bartman,**

L. W. Chaney, P. A. Titus, and **M. G. Wibra** (USA) reported measurements made with balloons raised to 33–35 km of the radiation reflected (short-wave) and emitted (long-wave) by the earth and by the atmosphere. The measurements were made with a five-channel radiometer installed on "Tiros" satellites, a radiometer with an average resolution, an infrared radiometer, and a spectrometer with diffraction grating, intended for the "Nimbus" satellites.

A series of airplane measurements of the radiation spectra of the cloudless atmosphere and of the earth's surface in the region 2–6 μ, at altitudes up to 4 km, was carried out by **O. I. Popov** and **E. O. Fedorova** (USSR).

The measurements were made with a spectral slit width of 0.07 μ. The investigations covered the dependence on the altitude, direction, and the illumination conditions. It is shown that in the center of the 4.3 μ absorption band (CO_2) and in the long-wave wing of the 6.3 μ band (H_2O) the radiation is formed in a layer of thickness of several times 10 meters near the place of observation. In the region of the "transparency windows" the radiation depends strongly on the atmospheric and observation conditions. The influence of the scattered light is appreciable up to 4.6–4.7 microns.

E. J. Williamson (England) measured the descending radiation of the atmosphere in the 5.5–7 μ region, by raising a cooled radiometer on balloons to a height of approximately 30 km. From the observation data he determined the content of the water vapor. In particular, the specific concentration of water vapor up to an altitude of 25 km was approximately 3×10^{-3} g/kg.

Spectral measurements of the transparency of the atmosphere in the infrared region up to 35 μ, at altitudes up to 30 km, were made by **D. M. Gates** (USA) with the aid of a balloon-raised vacuum spectrometer with diffraction grating, providing high resolution. The amount of water vapor at different altitudes was determined. The observations have shown that the stratosphere over Texas is very dry and that the total amount of water vapor above 30 km is less than 2.0 μ of precipitation.

A. W. Brewer and **A. W. Wilson** (Canada), raising a radiometer on balloons, measured in the altitude interval 12–35 km the brightness of the solar ultraviolet radiation near 2100 A. This radiation, which penetrates in the narrow "window" between the absorption bands of Schuman (oxygen) and Hartley (ozone), is responsible for the formation of ozone at these altitudes. Both the direct and scattered light were measured, when the sun was near the zenith. Data were obtained on the brightness of the sun outside the atmosphere and on the coefficient of absorption of radiation by the oxygen.

J. Hampson (Canada) investigated theoretically the chemical instability of the atmosphere. It was shown that the pre-calculated variations of the ozone content in a humid atmosphere, as a function of the altitude, the zenith distance of the sun, and of the humidity correspond to the picture of the observed variations.

Experimental investigations of the spectral attenuation of the short-wave radiation (0.4–1.0 μ) in the free atmosphere were carried out with the aid of airplanes by **Yu. I. Rabinovich** (USSR). Using specially developed apparatus, the author measured the vertical variation of the extinction coefficient and of the brightness contrast for the natural landscape at different states of the cloudless atmosphere. The results were compared with the theoretical calculations of the oblique visibility in accordance with the scheme of K. S. Shifrin and his co-workers, and in the mean displayed satisfactory agreement.

V. F. Belov, A. I. German, G. N. Kostyanoĭ, and **L. A. Paramonova** (USSR) investigated with the aid of automatic stratospheric balloons the angular distribution of the brightness of scattered light at different altitudes up to 22 km. For zenith distances smaller than 65°, the measurements are in good agreement with the calculations of K. S. Shifrin, M. S. Malkevich, and E. M. Feĭgel'son; for zenith distances larger than 65°, appreciable discrepancies are noted. Airplane measurements were also made in different regions of the Soviet Union.

The section "Land-based and Network Apparatus" was headed by **A. J. Drummond** (USA) and **Yu. D. Yanishevskiĭ** (USSR).

Yu. D. Yanishevskiĭ, in the paper "Operating Principles of Actinometric Instruments in the Station Network of the USSR" reported in detail the requirements imposed on the construction, installation and operating conditions of instruments of various types, used to carry out regular measurements characterizing the radiation in almost 200 actinometric stations of the Soviet Union.

A. J. Drummond (USA) reviewed the new methods and instruments developed under his guidance for the measurements of the components of the balance of solar and terrestrial radiation. Appreciable improvements were made in the spectral, angular, and temperature characteristics of radiometers with thermoelectric transmitters, and transmitters were also developed with small time constants, as well as new methods were proposed for their calibration. New thermoelectric instruments were developed for the measurement of illumination. Apparatus was constructed for the measurement of the long-wave albedo by the method of equalizing the temperatures of the transmitter and its field of view and for separating long-wave radiation during the day.

The late **I. P. Funk** (Australia) in a report "Measurements of the Radiation Balance on an Expanded Scale" discussed various types of balance meters.

Technical and organizational problems of instrument supply for network research in India were the subject of a communication by **A. Mani** (India).

G. V. Kirillova, Yu. K. Rossi, M. A. Sulev (USSR) reported results of a comparison of 17 balance meters and 8 pyrheliometers, carried out in March 1963 in Tartu and September 1963 in Tashkent. During the night time, the readings of the Yanishevskiĭ balance meters of the central Asiatic Hydrometeorological Institute, of the Ukrainian Hydrometeorological Institute, and of the Leningrad University, and also the pyrheliometer of Savinov and Yanishevskiĭ, coincide within 10%, whereas the pyrheliometer of Angstrom and the balance meter of Schulze exceed this error. During the daytime, the discrepancies of the balance meters reached 20% and more. Special comparison of the balance meters of Yanishevskiĭ, Schulze, and Courvoisier has shown that the latter cannot be used as a standard instrument owing to the large errors and that the selectivity of the Schulze balance meter reaches 30%.

L. Jacobs (England) described the operation of the network ship actinometric apparatus produced under his guidance. **F. A. Brooks** considered spectral corrections for black radiometers in the determination of the radiation heat exchange between thin layers of air and in an atmosphere with a temperature gradient. The sensitivity of thermocouples to variations of the pressure was investigated by **L. A. Ramdas** (India). **Yu. Reeman** (USSR) developed a new type of electronic integrator for automatization of actinometric measurements.

The paper of **K. Ya. Kondrat'ev, M. P. Burgova, M. V. Mikhaĭlov, V. S. Grishechkin, G. M. Petelin, A. N. Otto,** and **Z. R. Mironova** (USSR) was devoted to a description of spectral apparatus for the investigation of the field of short-wave radiation. Starting with the need for a comprehensive investigation of the radiation field in the atmosphere, the authors have produced, on the basis of standard spectroscopic apparatus, automatic spectrophotometers for the measurement of the following: 1) Spectral fluxes of total and scattered radiation in the 0.2—1.2 μ region. 2) Spectral fluxes of the direct, scattered, and total radiation, and also the polarization of the scattered light in the region 0.25—1.2 μ. 3) Spectral albedo of natural surfaces in the region 0.4—0.8 μ. 4) Spectral fluxes of total and scattered radiation in the region 0.28—1.0 μ from an airplane. 5) Spectrograph for the measurement of the spectral brightness of the sky.

D. N. Lazarev, N. I. Lukin, and **E. S. Petrova** (USSR) constructed a working model of a photoelectric photometer for the measurement of biologically active ultraviolet radiation. The use of photographic photometry for the measurement of the brightness of the sky and of the earth's surface was reported by **I. L. Kofsky** (USA).

In the concluding address, the president of the commission on radiation, **F. Moeller**, noted the fruitfulness of the symposium, which has contributed to a strengthening of existing scientific contacts between scientists of various countries, and to the creation of new contacts.

Translated by J. G. Adashko