SPACE AND GLOBAL ENVIRONMENT (ON THE RESULTS OF THE SCIENTIFIC SEMINAR HELD IN PARIS FROM 22 TO 23 JUNE, 1990 AND THE COSPAR SCIENTIFIC SESSION HELD IN HAGUE FROM JUNE 25 TO JULY 5, 1990)

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The International Seminar on Space and Environment organized under the sponsorship of the French Government, was held in Paris from 22 to 23 June, 1990. Its main task was the discussion of prospects for realization of international and national programs on application of the spaceborne means of exploring the global environment and biosphere. The Seminar Chairman was the director of the National Space Research Center J.–L. Lions; among the participants there were the Minister of Science and Technology Kuriene and the Minister of Communication and Cosmos P. Quilles. The similar problems were the major part of scientific program of the COSPAR Congress held in Hague from June 25 to July 5, 1990. Among the diverse problems of space ecology the most important remain, as before, the investigations of global climate and its changes.*

1. GLOBAL CLIMATE

Abundant information about the present–day state of climate and its future changes is involved in the part of the final report of the Intergovernmental Panel on Climate Change (IPCC) entitled *Scientific Estimate of Climate Change* (see Ref. 13) which was prepared by 170 leading specialists from 25 countries. The distinctive feature of this report was the rejection of the widespread opinion (not without the aid of mass media) that the rise of the mean global surface air temperature (SAT) within the limits 0.3–0.6°C and of the global sea level by 10–12 cm observed in the last century is associated with the growth of concentration of carbon dioxide and other greenhouse gases (GG) including first of all methane, chlorfluorocarbons (ClFC) and nitrous oxide. The weighted approach to the problem and the clear understanding of the necessity for further investigation of natural and anthropogenic factors of climate formation triumphed. Such an understanding of the problem leads in future (based on analysis of the observed data and numerical modeling) to the reliable estimates of the contribution of the climate formation factors and, in particular, to the detection of the greenhouse signal from the observed data (undoubtedly, the information solely about the SAT is insufficient: the substantiation is needed of the optimum set of the parameters characterizing the greenhouse signal in a most representative manner.[4,10]

Though the observed degree of global warming agrees, as a whole, with the estimates based on numerical modeling, this degree is close in value to the natural climatic variability (i.e., to the immanent noise of the climatic system). It is important to conclude from this fact that observed climate warming was primarily associated with natural variability of climate. Quite possibly the joint effect of the natural and some anthropogenic factors other than GG gave rise to weakening (because of the appropriate compensation) of more pronounced warming, which is not to be identified probably within the next decade and even longer.

There are no reliable evidences so far that the climatic variability became more pronounced of recent decades. Very likely, however, that as climate becomes warmer the time intervals with elevated temperatures will be more often encountered while that with reduced temperatures will be more seldom.

The impact of climate on ecosystems is undoubtedly of great importance as well as the back–action of ecosystem dynamics on climate. Fast climate variations will cause the changes of a specific composition of the ecosystems (they will be favourable for some of them whereas other ecosystems will perish incapable of adaptation). The growth of the CO_2 concentration can result in an enchanced bioproductivity and increased efficiency of the water use by vegetation. The effect of the climate warming on the ecosystems may lead to enhancement of natural emissions of the GG into the atmosphere (it concerns, for example, hydrates of gases in the permafrost which may enter the atmosphere under conditions of the climate warming and melting of the permafrost).

The report of the IPCC ascertains that the results of calculations made up to now allow one to formulate the following very reliable conclusions[13]:

1. It is necessary to take into account the multicomponent nature of the atmospheric greenhouse effect. The relative contribution of carbon dioxide to the formation of greenhouse effect was about 50% and this apparently will remain unchanged in future. As a result of the climate warming, the concentration of the principal GG–water vapor–will increase that will tend to the enhancement of the greenhouse effect (it is worth noting in this connection that the contribution of the water–vapor dynamics to the greenhouse effect has not yet been adequately studied).

2. The concentration of the long–living GG (CO_2, nitrous oxide, and ClFC) in the atmosphere reacts to the change in their emissions very slowly. Continuation of emissions will inevitably result in the growth of the GG concentrations for decades and centuries. Even after complete termination of emissions the stabilization of the acceptable value of the GG concentration will take a lot of time (as is well known, recently the intergovernmental resolution has been accepted on the complete termination of emission of the ClFC by 2000, thereby preventing their harmful effect on the ozone layer).

3. For stabilization of the long–living GG concentrations at the present–day value the immediate

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reduction of emissions at least by 60% is necessary. As for methane it must be reduced by 15–20%.

In the 21th century with the present–day amount of the GG emissions the rate of the SAT increase could be expected about 0.3°C for 10 years (with uncertainty within the limits 0.2–0.5°C by a decade) which exceeds the rate of climatic change observed for the last ten thousand years. The probable increase of the SAT (as compared with the present–day value) will have reached 1°C by 2025 and 3°C by the end of the next century. However, because of impact of other factors on climate formation (in addition to the GG) warming will not be uniform. When the scenarios of the GG concentration enhancement are outlined with an account of the limitations on their emissions of different scales in calculations of their possible dynamics, the rate of the SAT increase will be 0.2°C by a decade (scenario B), somewhat higher than 0.1°C by a decade (scenario C), and about 1°C by a decade (scenario D).

The numerical modeling led to the natural conclusion that the rate of warning of dry land will be higher than that of the oceanic surface, and warming at high latitudes of the Northern Hemisphere in winter would be more pronounced than the average global one (the response of the circumpolar zone of the Antarctic ocean appeares to be practically zero because of its braking at the expense of the deep oceanic circulation). Local climatic changes differed from the global, however, the reliability of calculations was insufficient in this case. Thus, for example, the degree of warming in South Europe and in the central part of North America, attendant to the decrease of the amounts of precipitations and soil moisture in summer, is to exceed the global one. Less pronounced results were obtained for the Tropics and for the Southern Hemisphere.

Estimates made under assumption of the present–day amount of emission of the GG showed that the average rate of rising the global oceanic level will be about 6 cm by a decade (with uncertainty within the limits 3–10 cm by a decade) and will be associated primarily with the thermal expansion of water masses and with melting of continental ice. It means the rise of the average global oceanic level by 20 cm by 2030 and by 65 cm by the end of the 21th century, and, what is more, the significant variations is to be observed on a regional scale.

As to the reliability of results of numerical modeling of climate the variety of the processes of climate formations and complicated interactions of them which have not yet been recognized should be taken into account. Among these climate–formation factors which have still received only insufficient study and require special concern are: 1) dynamics of sources and sinks of the GG determining their trends and scales of their impact on climate (in this case it is first of all the fundamental problem of global biogeochemical cycles and among them first is the carbon cycle), 2) cloudiness and its interaction with radiation; 3) interaction between the atmosphere and ocean, and 4) dynamics of the cryosphere (first of all of the polar ice–cups).

Of great importance is the problem of further improvement of the global system of climatic observations, especially its satellite part based on the analysis of the information content of various data, substantiation of priorities, and an optimum system of standard and satellite observations. Serious efforts are needed for quantitative substantiation of requirements for the observed data on the climatic parameters. All that and other questions were elucidated in detail in the scientific COSPAR program devoted to the global climatic change. Special session was devoted to the problem of early detection of enhancement of the greenhouse effect of the atmosphere and its impact on the climate.

A review of the problem of recognizing the enhancement of greenhouse effect was given in two reports invited by Organizing Committee. T. Barnett et al. (USA) discussed the possibilities of using as a greenhouse signal (GS) the global set of aerological data on specific humidity and on the amount of clouds located at different altitudes in 1973–1986. The reference–points for searching the regions with the most significant variability were the computational results based on the model of the Goddard Institute of Space Research and on the changes in the examined parameters at a barometer altitude of 850 gPa for 100 years from the first to the last decade of the integration time due to the continuous growth of the CO_2 concentration. Calculations revealed, for example, the essential decrease of the Stratus amount near the equatorial latitudes given that the total cloud amount remained almost unchanged and the increase of the Cirrus amount. The spatial structure of calculated variability in humidity appeared to be coherent (self–consistent) in the tropical latitude belt; in addition, the most significant variations in humidity were found within the tongue of cold air in the tropical region of the Pacific ocean where the standard observations are unvailable (therefore it is planned to undertake the joint analysis of the data of IR and UHF satellite remote sensing using the HIRS/ MSU apparatus that can be considered to be reliable in the tropics). Recognizing the GS should be faciliated due to the fact that the precalculated variations of the cloudiness and humidity fields were rather significant and their natural spatial structure differed from the greenhouse one.

K.Ya. Kondrat'ev in his report noted that the ample review of the previous developments on the problem of the GS could be found in his monography.[4] The attempts made later to identify the GS from the observed data gave practically no results. It concerns, for example, the UHF satellite data on dynamics of extension of the sea ice cover for almost a decade which did not reveal any statistically significant trend. The corresponding values for Arctic, Antarctica and the globe were $-1.9 \pm 1.3\%$, $-0.3 \pm 1.4\%$, and $-1.0 \pm 0.9\%$. The same trends in the polynias and opening surfaces were equal to $-3.4 \pm 8.1\%$, $-0.7 \pm 5.7\%$, and $-1.0 \pm 3.4\%$.

The serious difficulty in detection of the GS is the insufficient reliability of reference points obtained on the basis of numerical modeling due to the above–mentioned imperfection of parametrization of cloudiness, interaction between the cloudiness and radiation, as well as the interaction between the ocean and atmosphere. So far the cycles of observations of the following parameters: the extension of ice and snow covers, the components of the Earth's radiation balance, the level of the global ocean, the river discharge, etc. are too short. This makes the detection of the GS difficult. Undoubtedly, actual are the searches for the most informative combination of the parameters and the regions of the Earth most sensitive to the increase in the GG concentration. The serious prospects can be associated with the observation of the biosphere dynamics that must be manifested in the greening of the globe under conditions of fertilization caused by the increase in the CO_2 concentration. In this connection data on the dynamics of biomass of continental plant canopy and marine phytoplankton could be important. It could be expected that the realization of the project planned as part of the program of the International Space Year on determination of the substantiation of approaches to the recognising the enhanced greenhouse effect on climate would mark a new stage in the solution of the GS problem.[6]

J. London and S. Warren (USA) performed a new analysis of data of ground–based observations of dynamics of the total cloud amount and the amount of different cloud types over oceans in the tropics during 1952–1981. This analysis led to the conclusion that the total cloud amount in the 20°S – 20°N latitude belt increases attendantly to the increase in the amount of Cirrus and Cumulonimbus clouds and to the decrease (or invariability) of Cumulus and Stratus. L. Stove et al. (USA) described a multi–purpose algorithm for retrieving the cloud amount from data of night– and daytime satellite observations using the AVHRR scanning apparatus capable to recognize the conditions of clear sky and broken and continuous cloudiness. The algorithm is planned to be tested by its implementation for real–time processing of the observed data. W. Buch (Chechoslovakia) presented data on the correlation between the SAT (during 1880 – 1980) and the index of geomagnetic activity. O. Kyarner (USSR) analyzed (using the NIMBUS–7 satellite over the period of 8 years) the effect of various factors of variability on the Eart's radiation balance.

A. Rimosz–Paal et al. (Hungary) discussed, by an example of the NIMBUS–7 data obtained over the period from May 1979 to May 1980 in the Carpathian region, the possibilities of retrieving the radiation balance of underlying surface (RBUS) and its components as well as the short–wave and long–wave radiation balances of the atmosphere (SWRBA and LWRBA). The comparison of these data with data of ground–based observations in Budapest has allowed them to provide an empirical foundation for the following correlation relation for the RBUS in the case of clear sky or continuous cloudiness:

$$R = -9.5 + 0.44R_s + 0.55F_\infty , \quad (1)$$

where R_s is the measurable radiation balance of the underlying surface–atmosphere system, F_∞ is the measurable outgoing long–wave radiation (OLWR). The correlation coefficient was equal to 0.98. Taking into account that

$$R_s = S_0(1 - \alpha_s) - F_\infty , \quad (2)$$

where S_0 is the extra–atmospheric insolation and α_s is the system albedo as well as the relation

$$R_s = R + R_a \quad (3)$$

the RBUS can be calculated from Eq. (1) while the RBA – from Eq. (3). In this case the relative value of the SWRBA (the solar energy absorbed by the atmosphere) is given by[15]

$$R_{a,s} = 1 - \alpha_s - \frac{G}{S_0}(1 - \alpha) . \quad (4)$$

Here G is the integrated radiation, whose values were derived from data of actinometric observations performed at six stations and α is the albedo of the underlying surface borrowed from the published data. When the relative value of $R_{a,s}$ given by Eq. (4) is known it is not difficult to calculate the absolute value of the SWRBA ($R_{a,s}$) and then to find the LWRBA ($R_{a,l}$) from the relation

$$R_a = R_{a,s} + R_{a,l} . \quad (5)$$

The average diurnal values of F_∞ and α_s were used as input data for calculations of R_s, R, R_a, $R_{a,s}$, and $R_{a,l}$. The results testified that R_s was negative during all the year, with its average–annual value being equal to – 74.3 W/m^2, whereas according to the earlier obtained data it was close to zero. Calculations of the ERB variations in summer with the CO_2 concentration increasing from 330 up to 430 ppm performed on the basis of the radiation convection model showed the increase of the integrated radiation, RBUS, and OLWR, but the decrease of the system albedo and the ERB. The SWRBA remained practically unchanged while the radiative cooling of the atmosphere intensified. Thus, under these conditions attendant to the growth of the CO_2 concentration the underlying surface received more heat whereas the atmosphere was getting cooler. The main reason for the change in the radiation regime was apparently the decrease of the cloud amount as a result of climatic warming.

H. Zwally (USA) having analyzed the radio–altimetric GROSAT, SEASAT, and SALT (satellite of USA navy) data revealed the thickening of the southern part of the Greenland ice sheet during last decade by 0.23 m a year that occurred within the zones of not only accumulation but also ablution and was to be a consequence of the intensification of perciptations in polar regions as a result of climate warming. The positive trend in the mass balance within the limits 20–40% is to be associated with the global lowering of the ocean level within the limits 0.2–0.4 mm a year (depending on the characteristic time scale of examined variations). In most Antarctica containing 91% of the planetary ice the annual increment of the ice mass exceeded only by 10% the increment observable in Greenland, and therefore the variations in the thickness of glacial sheet were smaller by an order of magnitude. The important means of following the dynamics of the polar glacial sheets is to become much more accurate satellite lidar altimetry (in this case the error in measuring the altitude can be decreased down to 10 cm) that apparently will have been realized by 1992 year.

2. GLOBAL AND REGIONAL ENERGETIC AND HYDROLOGICAL CYCLES

P. Monrel (World Meteorological Organization, Switzerland) presented the review of the Global Energy and Water Experiment (GEWEX) as part of WPCR, containing the well–known information.[4,10] The reporter noted, in particular, that the adopted estimate of permissible error in satellite measurements of radiation balance (10 W/m^2) ruled out the possibility of identification of variations caused by intensification of greenhouse effect (of the order of several W/m^2). However, it made possible to recognize anomalies (up to 50 W/m^2) engendered by El Niño. In connection with the recent conclusions based on numerical modeling of climate with an account of the atmosphere and ocean interaction (including the deep–water circulation) emphasized an important contribution of the inflow of sweet water (discharge of rivers) to the cold and salt water formation at large depths.

M. Chahine (USA) described the 4 000–channel apparatus for the IR sounding (AIRS) of the atmosphere intended for use on the polar platform (of the EOS polar–orbital satellite) and the AMSU advanced UHR apparatus intended for use onboard the NOAA satellites. Simultaneous processing of the IR and UHF data will allow one to reach the accuracy of retrieving the vertical temperature profile of the order of 1°C with altitude resolution about 1 km. Simultaneously information will be obtained about the relative humidity profiles, total atmospheric moisture content of the atmosphere, and various characteristics of clouds, ocean and dry land surface as well.

M. Debois (France) illustrated the possibility of interpretation of the METEOSAT data with the goal of following up the dynamics of the humidity field. The retrieval of the wind field from the cloud drift allowed one, in particular, to estimate the moisture convergence in the lower troposphere and the large–scale advection of water vapor. Quite satisfactory results were obtained when comparing the cloud and moisture content fields with field of the vertical velocity at a pressure altitude of 500 hPa above the surface. An example was given of successful application of these satellite observations with the aim of testing the reliability of the results of numerical modeling of climate. I. Mica et al. (Hungary) described a 16–level one–dimensional nonstationary heat–balance model of climate with an account of volcanic eruptions and the CO_2 concentration growth. M. Hrzanovska and L. Baranski (Poland) described the empirical procedure for retrieving the integrated radiation and the photosynthetically active radiation from the METEOSAT data on the cloud amount.

M. Hollingsworth (Great Britain) analyzed the information content of the present–day data of remote sensing of the atmosphere paying attention to, as a rule, unacceptably large errors in retrieving the parameters. It especially concerns the data on the wind field retrieved from dynamics of cloud or humidity fields. R. Gourney (Great Britain) drew attention to the same problem underlying the great importance of performing subsatellite observations in the key regions. P. Kabat (Netherlands) touched the complicated problem of analysis of simultaneous data of conventional and satellite observations with different spatial and temporal resolutions in studies of the atmosphere–biosphere interaction. E.T. Kanemasu et al. (USA) after the overview of the FIFE–87 and FIFE–89 field experiments paid attention to a rather high degree of correlation of the CO_2 flux between the atmosphere and plant canopy and the brightness ratio in near–IR and IR spectral ranges.

P. Martin (USA) formulated general understanding of impact of dynamics of plant canopy on climate manifested itself through the methane, isoprene and terpene emissions. An imitational model of forest dynamics was described suitable for the North America which was used for estimation of the evolution of the specific composition and vegetational phytomass during 500 years for prescribed climatic change. J. Wallas et al. (Great Britain) reported the results of gradient and direct measurements of heat and water vapor fluxes in the Sahel region which were used for substantiation of the procedure of reconstructing the evaporation taking into account the retrieved value of the underlying–surface temperature.

J. Lagard and E. Brune (France) suggested the empirical method of determining the average diurnal values of outgoing long–wave radiation according to the data of the AVHRR apparatus on the retrieved temperature of the underlying surface at early afternoon (the minimum SAT and the day length were also used as input data). C. Ottle et al. (France, Finland) provided a theoretical foundation for the simulation model of heat and water exchange in the soil–vegetation–atmosphere system with parameters determined from the satellite data of IR and UHR sounding. The application of this model allowed us to retrieve soil moistening or water supply within the root system of vegetation on spatial grid of the hydrological model. The successful experiment on retrieving the evapotranspiration was also performed.

B. Pinty et al. (France, USA) elaborated the method for retrieving the angular distribution of the underlying surface brightness from the satellite data with an account of atmospheric correction and filtering out the cloudiness contribution. A theoretical model was also proposed (the approximation of the semi–infinite absorbing and scattering layer) reproducing the observable angular distribution and making use of two optical parameters: albedo of single scattering and asymmetry of the scattering phase function (it is worth noting that the same approach was realized in the USSR a long time ago).

Ven Gang and Fu Kongbin (CPR) having processed the AVHRR data plotted the charts of geographical distribution of the normalized vegetation index (NDVI) for the Chinese territory, whose analysis allowed them to follow the variability of seasonal trends of plant canopy with monsoon variations being its dominant factor. The application of the technique of fundamental components for fitting the observable variability showed that the contribution of the first component to the variability was about 94% whereas the contribution of the second component of 1.4%. G. Gutman (USA) analyzed the factors making the interpretation of the NDVI data more difficult: the effect of the atmosphere, cloudiness, viewing geometry, drift of the instrumental sensitivity, and variations in the parameters of the satellite orbit. Correct interpretation of the data is possible only with reliable account of all the enumerated factors. D. Dunkel et al. (Hungary) shared their experience of using the LANDSAT data to estimate the water supply (water stress) of plant canopy and the flux of the latent heat during the vegetation season in Hungary. Since the important parameter prescribed for estimating the latent heat was the effective stomatal resistance, this quantity was measured and analyzed in sowings of maize, soya–beans, and potatoes. S. Nickolso et al. (USA) studied the NDVI dependence on various climatic parameters in a number of regions of Africa (East Africa, Bostwana, Sahel). The high degree of correlation was noted, in particular, among the NDVI, precipitations, soil moisture, and evaportantspiration.

Of great importance for studies of global and regional energetic and hydrological cycles are the observations of dynamics of the atmosphere and sea ice cover from data on the cloudiness and ice drifts. As to retrieving the wind velocity from the recorded drift of inhomogeneities of cloud cover or from water vapor distribution, this tendency of developments has now a rather long history. J. Schemetz and K. Holmlund (Germany) summerized their experience in real–time processing of the METEOSAT data based on the use of the series of three successive IR images with selection of nearly 2000 tracers for retrieval of the wind velocity. The method of spatial coherence provided the basis for retrieving the wind velocity field (automated processing of the three above–mentioned images yielded about 700 values of wind speed and direction). The application of the cloudy tracers at different altitudes allowed them to obtain data on wind at three altitudes. The difficulty that has not yet been overcome is their referencing to the Cirrus altitude.

H. Lorent and M. Debois (France) considered an example of retrieving the wind velocity field making use of the cross correlation method as applied to the METEOSAT–4 data on the drift of inhomogeneities of the horizontal water vapor distribution on July 21, 1989 (the pairs of successive images were processed). To monitor the reliability of the altitude referencing of the retrieved wind field, the aerological sounding data were compared with the results of numerical weather forecast. H. Woik (Germany) analyzed in general the SATOB data on the global fields of the wind–driven clouds having emphasized that the data of various geostationary satellites differ significantly. The comparison with data of the rawinsondes and numerical modeling showed that in the best case the errors in retrieving the wind speed were equal to 2–4 ms^{-1}. The account of the SATOB data in the short–range weather forecast revealed their positive effect on the forecast quality in the tropics and in the Southern Hemisphere; however, in the Northern Hemisphere the forecasting quality even deteriorated in some cases. The problem of improving the procedures for retrieving the wind field from the observations of the cloud drift remains important. T. Lachlan–Koup and J. Turner (Great Britain) noted that in Antarctica it is possible to have the routine data of the NOAA satellite in the form of three successive images of the cloud cover for a time of about 200 min. The most essential difficulty of data processing (especially automatical) is the identification of cloud tracers against the back–ground of snow cover. Taking into account gross errors in the wind fields retrieved from the cloud drift which are of primary importance in connection with progress in improving the numerical methods of weather forecast, the group of scientists of the Wisconsin University (P. Menzel et al.) discussed the possibilities of using the remote sensing data for more reliable altitude referencing of wind fields. Different aspects of reconstruction procedure (concerning mainly the representation of retrieved wind field) were discussed in a number of other reports.

The procedures applied currently for retrieving the characteristics of ice cover dynamics from the radar shooting data (the results of passive radio observations were not considered because of their low spatial resolution) rely on two approaches which realized the cross–correlation method (similar to the case of cloud drift data processing) or the tracking on the drift of the margin of ice cover. J. Rothrock et al. (USA) after processing the SEASAT data made a conclusion that the former procedure was more convenient and reliable in the case of broken ice. Analysis of observed data (simultaneously with the numerical modeling data) allowed them to obtain the information about such characteristics as advection, momentum balance, deformation of openings, ice cover in general (hummocking, etc.), and some other properties of the ice cover.

The creation of stations for receiving the satellite radar information in Fairbanks (USA), Ottawa (Canada) and Kiruna (Sweden) has opened the prospects for observing dynamics of ice cover in the whole Arctic. The similar set of three receiving stations exists in Antarctica as well. J. Iohannessen and R. Flesche (Norway) in their report considered an example of data processing of an airborne radar of side viewing (SV) pertaining to the Barents sea. J. Marco et al. (USA) discussed the experience of simultaneous interpretation of pairs of successive images obtained with the help of the SV radar and AVHRR apparatus using the procedure of spatial cross–correlation.

The special scientific session devoted to the analysis of the information contribution of the satellite remote sensing data to the weather forecast was of considerable interest. The situation in this field is so far characterized, as it has been already noted, by the positive contribution to the quality of numerical weather forecast within the equatorial zone alone and in the Southern Hemisphere whose standard meteorological information is fragmentary. In this connection W. Smith (USA) characterized the functional capabilities of the remote sensing systems developed for the EOS satellites. The basis of these systems will be an IR–interferometer and spectrometer capable of obtaining data in about six and five thousands of channels, respectively, with very high spectral resolution in the range 1–10 km. Even the UHF systems of remote sensing will ensure the spatial resolution of about 15 km. Numerical simulation and flight tests of the entire complex onboard ER–2 and U–2 high–altitude aircrafts allow us to believe that the errors in retrieving the vertical temperature profile would be reduced down to 1 K. A. McDonald (USA) pointed out that the most stringent requirements were imposed by the ultra–short–range weather forecast and this fact called for the integrated use of the standard (especially radar) and satellite information. Forecasting for 1 hour, the computer processing of large amount of data (during 1958–1990 the amount of data has became 20–30 times larger) requires the application of parallel processors with rate of calculations of the order of 8 billions of operations a second. Computers which will appear by 2000 allow us to make global numerical weather forecasts on the grid with a step of about 4 km and regional forecasts of 1.4 km.

D. McGilli (USA) underlined that both the promise of standard and satellite means of meteorological observations and improved software would yield the unprecedented possibilities for detailed account of meso–scale processes in the case of the super–short–range weather forecast. Practical results attained in this field are shown by an example of a system of local objective analysis and forecast developed by the NOAA collaborators.

J. Lewis (USA) shared the experience of using the adjoint equation method and the importance function for meso–scale analysis and forecast (note that analogous approach was used by G.I. Marchuk in the USSR 15–20 years ago). H. Leglo et al. (France) demonstrated fruitfulness of an account of the supplemental data of the AVHRR for identification of low cloudiness over dry land and ocean, detection of high thick clouds and thin cold Cirrus, as well as snow and cloud cover for ultra–short–range weather forecast from the METEOSAT data. H. Al Hafeed and P. Singh (Iraq) discussed the methodical peculiarities of retrieving the vertical profile of the moisture content and the total water content of the atmosphere from data of the UHF–radiometry. Sharov (Bulgaria) presented the results of theoretical studies of the von Karman eddies and line clouds compared with satellite data.

D. Palleo (European Medium––Range Weather Forecast Center –– EMWFC, Great Britain) characterized the experience, accumulated in the EMWFC, of using the routine data of satellite thermal sounding (SATEM) having emphasized that forecasting for periods more than three days is required to be global. The daily global set of the SATEM data involves 5–6 thousand observations which is about an order of magnitude greater than the amount of aerological information. Though, as earlier, the impact of satellite data was of minor importance for forecasting the Northern Hemisphere there was, nevertheless, some progress consisting in the radical decrease of the number of cases with negative impact (these cases can be mainly explained by insufficiently reliable control of the data quality). To solve the problem of the error minimization the method of adjoint equations was used. The basic conclusion was that in future the scheme of retrieving should become a fundamental part of the objective analysis. In this connection C. Kelly (EMWFC) drew attention to the fact that still existing serious disadvantages of the retrieving algorithms engendered gross errors in data of satellite thermal and wind (from the cloud drift) sounding. Inadmissibly large were the systematic errors in retrieving the wind velocity from the data of the HIMAWARI Japanese geostationary satellite. It is natural that information contribution of the wind data (SATOB) appeared to be especially considerable in the tropics. The expediency was underlined of direct use of the satellite spectrometric observations in prognostic schemes instead of the intermediate stage of solving the problems of retrieving the profiles of meteorological elements. The same conclusion was done by A. Lorentz (Great Britain).

Analyzing the errors in retrieving the vertical profile of moisture content in the atmosphere, L. Tahani et al. (France) showed the primary importance of the reliable assignment of *a priori* data. C. Klod et al. (France, USA) having applied an advanced method of initiation of remote sensing data developed by the scientists of the Laboratory of

Dynamic Meteorology (France) on the basis of the recognition methodology demonstrated its efficiency for the analysis of the meso–scale processes. W. Heakly (ECMWF) used the METEOSAT data on the cloud cover for testing the reliability of the cloud cover characteristics calculated with the help of the prognostic scheme of the EMWFC.

3. PROCESSES IN THE MIDDLE ATMOSPHERE

The observations of the middle atmosphere composition can yield an important information about the global change since, as G. Brassear (USA) fairly noted, the chemical composition of the atmosphere is formed, to a considerable extent, under the impact of processes in the biosphere (it especially concerns the concentration of greenhouse gases in the atmosphere). In this connection G. Brassear made a review of data on spatial and temporal variability of concentration of such atmospheric trace gases as CH_4, CFC, CO, N_2O, nonmethane hydrocarbons, isoprene, terpene, etc. underlying in addition the important role that hydroxyl played as a factor determining the lifetime of the trace gases in the atmosphere as well as the urgency of investigations of gas exchange between the atmosphere and ecosystems.

Analyzing the present–day concept on the formation of the spring minimum in the total ozone content (TOC) in Antarctica, M. McElroy (USA) paid attention to the two–fold role of the polar stratospheric clouds (PSC) consisting originally of the crystals of trihydrate of nitric acid. On the one hand, the chemical reactions running on the surface of the PSC particles ensure the conversion of chlorine and bromine compounds from chemically inactive forms to the active ones. On the other hand, the clouds make a significant contribution to the removal of the nitric acid by the precipitations. Ozone is destructed in both Antarctic and Arctic stratosphere as a result of catalytic gas–phase reactions in which ClO and BrO take part. Rapid formation of the minimum in the TOC in the Antarctica is promoted by the relative isolation (due to stable circumpolar circulation) and by low stratospheric temperature in winter and in spring. As an effective indicator of stratospheric dynamics, the potential eddy can be considered, whose values are maximum within the zone of the TOC minimum.

P. McCormick (USA) considered, based on data of the SAGE–2 satellite functioning from 1984, the interannual variability of the ozone and aerosol concentrations in the stratosphere and revealed the high degree of correlation among the PSC dynamics, TOC minimum, and their quasibiennial oscillations (QBO). After the eruption of the El Chichon volcano the aerosol optical thickness was gradually and continuously decreasing having reached the background value only by 1990. K. Labitzke (Germany) drew attention to the difficulty of recognizing the long–term trends, which was associated with the multifactor variability of the stratosphere. These difficulties must be overcome, in particular, in the study of the effect of the solar activity on the temperature and pressure fields in the stratosphere. Reliable filtering–out the effect of the QBO and El Niño/Southern oscillation made it possible to find a rather high degree of correlation among the pressure altitudes of 30 hPa and 100 hPa and the 10.7–cm solar radio wave considered as the index of solar activity. Analogous correlation was also found for the temperature at a pressure altitude of 30 hPa (however, the distinctive many–year trend was not found). The report by H. Cisneros (Spain) was devoted to the same problem of the effect of solar activity on the stratosphere. He demonstrated the existence of the 11–year cycle of the TOC variability. D. Heath (USA) analyzed the long–term variability in the TOC using the NIMBUS–7 data obtained in 1978–1986 and showed that the long–term variability of the ozone content in the layers above a pressure altitude of 2 hPa and below a pressure altitude of 30 hPa disagreed with data calculated on the basis of a two–dimensional model since the zonal symmetry assumed in the model was absent.

4. DYNAMICS OF GLOBAL BIOSPHERE

If the climate investigations are performed predominantly as part of the World Programme of Climate Research (WPCR), the problems of the biosphere are covered by the International Geosphere–Biosphere Programme (IGBP)[3,5,17,18] and by the corresponding national programmes. In the USSR it is the Programme of Biospheric and Ecological Researches[1,2,12] while in USA it is the US Global Change Research Program which relies on the Earth Observing System (EOS) Programme and on more extensive Mission to the Planet Earth Programme.[16]

The IGBP has been put into action from September 10, 1990. It provides for seven key directions of development discussed by the Chairman of the Special Committee of the IGBP J. McCarthy at the Paris Seminar[14,18]:

1. Regularities of chemical processes in the global atmosphere and the contribution of biological processes to the cycles of trace gas components.[26]

The developments of this direction involve:

(a) International Global Atmospheric Chemistry (IGAC) Project providing:

– Studies of processes determining a change in the chemical composition of the atmosphere.

– Investigation of interactions between the chemical composition of the atmosphere and biospheric and climatic processes.

– Prediction of the effect of natural and anthropogenic factors on the chemical composition of the atmosphere.

(b) Stratosphere––troposphere interactions for the biosphere (STIB) investigation.

In this case the following actions are planned:

– To analyze the effect of variations of the ozone content in the stratosphere on the penetration of the biologically harmfull UV–radiation to the Earth's surface.

– To obtain the qualitative evaluations of the processes of the stratosphere––troposphere interaction.

– To estimate the natural variability of the stratosphere and the impact of anthropogenic factors on it.

– To obtain the qualitative evaluations of the impact of aerosol on climate.

– To estimate the impact of the stratospheric processes on climate.

2. Impact of biogeochemical processes in the ocean on climate change and climate ocean feedback.

Two projects are provided:

(a) Integrated investigations of global gas exchange between the ocean and atmosphere as part of the JGOFS programme.

– Studies of global scale of the processes governing the dynamics of entering the carbon and other related biogenic element fluxes into the ocean as well as the evaluations of the gas exchange of the atmosphere, sea bottom, and continental boundaries.

– Development of prognostic methods of global scale of the response of the ocean on the anthropogenic perturbations, especially associated with the climate change.

(b) Global Ocean Euphotic Zone Studies (GOEZS) with an account of the interaction between physical, chemical, and biological processes.

3. The effect of the land tenure change on the resources of coastal zones of seas and oceans as well as the effect of the ocean level variations and climate on the coastal ecosystems.

This direction will be realized in the project:

(a) Land––ocean interaction in the coastal zone (LOICZ) aimed at the development of the methods for predicting the effect of climate change, land tenure, and ocean level on functioning and stability of coastal ecosystems on global scale with an account of the priority of the interactions of variations in the conditions on the land and in the ocean and the possible feedback of physical processes on the environment.

4. Interaction of the plant canopy with physical processes being responsible for the formation of the global hydrological cycle.

Biospheric aspects of the hydrological cycle (BAHC) involve:

– Studies of the biospheric impact on the hydrologic cycle on the basis of field observations aimed at the elaboration of models of the energetic and hydrologic exchange in the soil–plant canopy–atmosphere system on the spatial and temporal scales varying from the elements of the plant canopy to the cells of the models of general atmospheric circulation.

– The development of databases that can be used to describe the interactions between biosphere and physical processes in the environment as well as to verify the reliability of simulation models of the above–mentioned interactions.

5. The impact of global change on terrestrial ecosystems.

(a) Global changes and terrestrial ecosystems (GCTE) provide for:

– The development of procedure for predicting the impact of the climate change, CO_2 concentration, and land tenure on ecosystems as well as the evaluation of the contribution of these effects to the biosphere––environment feedback.

(b) Global changes and ecological complexity (GCEC):

– The development of procedure for predicting the relations between global changes and biovariety (ecological complexity).

6. Paleoecological and paleoclimatic variations and their consequences.

Past Global Ecoclimate Studies (PAGES).

– Reconstruction of the detailed history of global climate changes and the environment over the period from 2000 BC to our era with temporal resolution at least of the order of a decade, but preferably up to a year and a season.

– Reconstruction of the history of climate changes and environment during the entire glacial cycle aimed at close examination of the natural processes governing the climate change.

7. The system approach to the imitation modeling of the Earth's system aimed at prediction of its evolution in future.

Global Analysis and Imitation Modeling (GAIM).

– Quantitative evaluation of the interaction of the global physical, chemical, and biological interactive processes in the Earth's system during the last 100 thousand years bearing in mind the analysis of possible changes in future.

Five from six enumerated projects (IGAC, JGOFS, BAHC, GCHC, and PAGES) pertaining to the practically approved key projects have been formulated in a sufficiently concrete form. The implementation of two of them (JGOFS and IGAC) has been already started while three other projects (BAHC, GCTE, and PAGES) are still at a stage of detailed elaboration. The same concerns the STIB, LOICZ, and GAIM projects.

In the context of the IGBP it is of interest the substantion of the priorities in the American Global Changes program,[16] which provides for a definite sequence of the priorities (in the order of their lesser significance):

(1) Climatic and hydrologic systems: the cloud contribution; the ocean circulation and heat fluxes; interaction between the land, atmosphere, and ocean; energetic and hydrologic exchange; quantitative interelations in the interactive climatic system; and, the ocean–atmosphere and ocean–cryosphere interactions.

(2) Dynamics of biogeochemical processes: exchange of trace gas components (TGC) between biosphere, atmosphere, and ocean; conversion of the TGC by the atmosphere; biochemistry of water masses near the surface and in large depths; processes in the terrestrial biosphere; carbon and biogenic cycles; and, influence of land processes on marine ecosystems.

(3) Ecosystems and their dynamics: long–term observations of the structure and functioning of the ecosystems; the response of the ecosystem to climate change and other perturbing effects; interactions between physical and biological processes; models of interactions, feedbacks, and response of ecosystems to perturbing effects; and, the models of productivity and resources of ecosystems.

(4) History of the Earth's system: paleoclimate, paleoecology, atmospheric composition, composition and circulation in the ocean, ocean productivity, changes of the ocean level, and paleohydrology.

(5) Social and economic aspects: development of the database; elaboration of the models describing the interrelations of the population growth; requirements for energy generation, land tenure, and industry.

(6) Geophysical processes: coastal erosion, volcanic processes, permafrost and marine gas hydrates, heat and energy fluxes at the ocean bottom, dynamics of the ocean level, and marine tectonic processes.

(7) Effect of solar activity: the observations of variations of the extra–atmospheric UV solar radiation, interaction between the solar radiation and the atmosphere, spectral and integral solar constant, effect on climate, indirect indicators of the effect of solar activity on the environment, development of the long–term database. It should be noted that conceptual aspects of the USA program have been examined deeper than in the current version of the IGBP[3–6]; however, the substantiation of priorities necessitates further efforts. Undoubtedly, for example, that the problems of the ecosystem dynamics and global biochemical cycles are of primary importance in comparison with the climatic and hydrologic processes.[1,2,7] Thus, of primary importance is the fact that the growth of greenhouse gas concentration affects the climate rather than otherwise, though the interactivity of the total combination of processes is indisputable. Of primary importance is the problem of processing, archiving, and distributing the observed data of unprecedented volume, the solution of which is considered in USA to be very important. Naturally, the key role in the global system will be played by satellite observations. In this connection extremely unfavorable is the fact that up to now there are no agreements on data exchange coordinated on the international level. The satellite observations should be

combined with the integrated routine observations in the representative ground–based and marine polygons (key regions). Although the IGBP involves some recommendations on this question, the criteria of choosing the key regions still remain, as a rule, intuitive and qualitative. There were practically no attempts so far to substantiate their choice on the basis of the results of imitation. The only exception is the concept of energy–active zones being developed in the USSR.[9–11]

In the COSPAR Programme much attention is focused on the problem of large–scale interaction between biological and physical processes in the ocean and at the ocean–atmosphere boundary. Discussing the problem of the global carbon cycle, B. Nattl et al. (USA) underlined the decisive role of the ocean as a carbon reservoir in the biosphere which determined the urgency of investigation of the CO_2 exchange between the atmosphere and ocean functioning as a biological pump exhausting CO_2 from the atmosphere. For better understanding of the way of functioning of this pump much more complete data on dynamics of primary productivity are needed. In this connection the possibilities were discussed of retrieving the phytoplankton content from the NIMBUS–7 data obtained in the region of the Atlantic ocean and of applying the empirical methods of the primary productivity estimates from these data. One of the difficulties of solving this problem was associated with the fact that the remote sensing allowed one to retrieve the phytoplankton content only in the upper part (about 20%) of the euphotic zone. A profound model of a marine ecosystem was briefly described with an account of entering of biogenes, phyto– and zooplankton dynamics, ocean circulation, and other factors.

L. Mervilat et al. (France) performed the calculations of the CO_2 exchange between the atmosphere and ocean from the difference between the CO_2 concentrations in the atmosphere and ocean with an account of the exchange coefficient K obtained with the use of the near–water wind data retrieved from the satellite scatterometric and UHF observations. The spatial and temporal variability of K, the difference between the CO_2 concentrations, and, cosequently, the CO_2 flux were found which testifies to the urgency of the above–mentioned IGOFS Programme being a part of the IGBP. Launching of the ERS–1 satellite equipped with the scatterometer will allow us to obtain the global data set on the near–water wind velocity and consequently more information about the CO_2 flux. In accordance with the available estimates the average annual CO_2 flux absorbed by the ocean varied within the limits 0.9–1.4 Gton for carbon (depending on the input data used for calculation).

A.G. Grankov and A.M. Shutko (USSR) considered the role of various factors in the formation of the radio–brightness temperature of the ocean surface at different wavelenghts (10–100 cm), namely, the sea foam, state of sea roughness, and salinity substantiate an optimum choice of the wavelengths for retrieving the ocean surface temperature (OST). D. Minster et al. (France) discussed the methodological aspects of interpretation of the GEOSAT altimetric observations for retrieving the altitude of the mean ocean surface, its tidal variations, as well as the characteristics of macro– and mesoscale variability of the ocean. The possibilities of the radioaltimetry were illustrated from the viewpoint of retrieving the topography of continental ice cover. Having in mind the preparation to processing of the ERS–1 and TOPEX/POSEIDON radioaltimetric data, K. Wakker et al. (Netherlands) checked their procedure by considering by way of example the GEOSAT data obtained in the South–East Atlantic (averaged over a year) and in the North Atlantic (averaged over two years). The results obtained were illustrated by the charts of the retrieved values of the altitude of the ocean level averaged over one (or two) year. The analysis of their deviations from the average level allowed them to reveal the topographic variability of the ocean surface which appeared to be especially large in the regions of Agulhas and the Gulf Stream. The available information about the relative dynamics of the ocean topography allowed them to calculate the stream fields (in relative units) the analysis of which showed the existence of a number of eddies. The determination of their trajectories, velocities, and values opened the possibilities of following the eddy dynamics (their movement appeared to be verey complicated).

5. SATELLITE OBSERVATIONAL SYSTEMS

In a number of countries national programmes provide for the completion of the creation of the huge system of satellite ecological observations by the end of the current century. Since these programmes were widely elucidated in the literature,[3,5,6,8,16] let us restrict ourselves to a short comment about the discussion of this problem on the COSPAR congress solely.

W. Hantress (USA) presented the general characteristics of the EOS system being developed in USA which is a key element of the Mission to the Planet Earth Programme and of the more extended Global Change Programme. During 15 years of planned functioning the scientific instrumentation placed onboard six EOS satellites (including the Freedom piloted space station) is capable of obtaining the enormous amount of information about the environment and biosphere with diurnal amount being equal to about 2 Tbytes. The data obtained previously have already made it possible to posess the charts of distributions of the ground and ocean surface temperature, ozone content, phytoplankton concentration, near–water wind, and other quantities. Much importance is attached to the development (before the beginning of the EOS system functioning) of the effective system of data processing, archiving, and distributing. As to the problem of data storage, the most expedient is acknowledged a distributed system equipped with the computer communication means which guarantees users the accessibility of information.

A.V. Karpov (USSR) described the USSR system of meteorological (Meteor) and oceanographical (Ocean) satellites as well as the satellites employed in the exploration of natural resources (Resurs–01) intended for routine observations which were also employed for some developments within the framework of international collaboration (the SCARAB Soviet–French project of measurements of the Earth's radiation balance and of installation of the American ozonometric apparatus onboard the Meteor satellite). K.Ya. Kondrat'ev amplified this report informing about developments associated with the use of the data of the Almaz satellite and the preparation of the module intended for exploration of natural resources onboard the Mir orbital station. B. Holomew (Great Britain) briefly reported on the plans of the European Space Agency devoted mainly to the prospects for using the data of the ERS–1 satellite, which was launched in 1990 (the decision has already been accepted about the financial support launching of the ERS–2 satellite in 1994). Of great importance was the launch of the METEOSAT–4 geostationary satellite on June 3, 1990. The geostationary satellites of the next generation are developing now, first of which is scheduled to be launched in 1998.

T. Tanaka (Japan) discussed the plans of Japanese Space Agency (NASDA) dwelling mainly on the description of the JERS–1 satellite employed in the exploration of natural resources (at the beginning of 1992 injected in the solar–synchronized orbit at a slope angle of the flight path of 97.7° and an altitude of 568 km with the expected lifetime of about 2 years) and the ADEOS satellite employed in the exploration of natural resources (at the beginning of 1995, the solar–synchronized orbit with the parameters: 98.59°; 796.75 km; 3 years). The instrument used onboard the last satellite includes a 12–channel ocean color and temperature scanner (OCTS), a 5–channel scanning advanced visible and near–IR range radiometer (AVHRR), an interferometric monitoring system (IMS) for greenhouse gases, an improved limb atmospheric spectrometer (ILAS), a laser retroreflector (RIS), a POLDER French spectrophotometer–polarimeter, as well as an American total ozone measurement system (TOMS) and a 13.995 GHz scatterometer.

The OCTS apparatus has the following channels (their band width is indicated in parenthesis): 0.412; 0.443; 0.490; 0.520 (0.02); 0.565; 0.665 (0.002); 0.765; 0.865 (0.04); 3.7 (0.3); 8.5 (0.5); 11.0; and, 12.0 μm (1.0 μm), whereas the channels of the AVHRR are centered at the following wavelengths: 0.45; 0.57; 0.67; 0.87 (0.1); and, 0.62 μm (0.2 μm). The spatial resolution of the scanners is, respectively, 700 m (the width of the viewing swath is equal to 1400 km) and 16 m (or 8 m at a wavelength of 0.62 μm) with 80 km width of the viewing swath. The IMG apparatus designed for retrieving the vertical profiles of the GG within the 10–60 km altitude range provides the spectral measurements of the outgoing radiation in the range 3–15 μm at the instantaneous field of view $0.75 \times 0.75°$ with the 20 km width of the viewing swatch. The ILAS is functioning in three spectral intervals: 0.753–0.784, 4.1–6.9 and 7.3–11.8 μm at the field of view angles ±15° (in the vertical direction) and ±10° (in the horizontal direction).

Japanese experts take part in the meteorological observations in the tropics (aiming at measuring the precipitations) with the help of the instruments installed onboard the TRMM satellite (1986), which will be injected in orbit at small slope angle of the flight path (about 35°) and an altitude of 350 km. The instrumental complex is developed the JPOP satellite employed in the exploration of natural resources which is scheduled to be launched in 1988.

Highly extensive is the French Programme of Exploration of Natural Resources and Ecological Investigations presented by J.–L. Fellow and A. Ratier and tailored toward the solution of the IGBP and WPCR problems. The essential developments of the programme are: preparation of launching of the SPOT–3 satellite (probably, in 1993 depending on functioning of the SPOT–2) and of the SPOT–4 (tentatively, in 1995), participation in the French–American Mission TOPEX/POSEIDON (radioaltimetric observations), whose realization is scheduled in the middle of 1992, when the full–scale realization of the World Ocean Circulation Experiment (WOCE) start. The French experts make an significant contribution to the realization of programmes of the ERS–1 (first of all, UHF sounding of the atmosphere) and UARS (retrieving the wind and temperature fields from the data of videointerferometer) satellites. The BEST satellite is developing, the program of which is analogous to that of the TRMM and relies on the use of such an apparatus as a meteorological radar, Doppler lidar, and DIAL. Some Soviet–French developments have already been mentioned which incorporate the Alisa Project (lidar sounding of the cloud cover from onboard the Mir station) as well. The development of the Globsat satellite employed for investigations in the field of the atmospheric chemistry, climatology, etc., is promising.

J. Oring (USA) described the developments of the NOAA which involve: modification of the algorithms for retrieving the ocean surface temperature, the substantiation of the correct interpretation of data on normalized vegetation index, estimates of the cloud–radiation effect on climate, reconstruction of the cloud–radiation balance of the underlying surface, retrieval of the total ozone content from the IR data, use of the remote sensing data in weather forecasting, etc.

In a number of reports of particular character various types of apparatus were described intended for satellites of different application: V. Salomonson (USA) described a MODIS videospectrometer (for the EOS system); M. Sander and D. Way (USA) – a radar with a synthesized aperture (EOS); J. Bertaux et al. (France) – an ozonometric component of the GOMOS spectrometer (European polar platform); A. Gode et al. (Netherlands) – a SCIAMACHY spectrometer.

R. Bowler (Great Britain) informed about the development of a videospectrometer with a comb–like scanner for the visible and near–IR spectral ranges. This apparatus consisting of two identical telescopes directed (in the plane of the sattellite orbit) at the angle ±20° is capable of obtaining the stereoscopic images of the area with 5–m spatial resolution and 60–km viewing swath which can be displaced within the limits of the 300–km subsatellite swath. This apparatus is projected to be installed on the European polar platform which will be injected in the orbit at slope angle of the flight path 98.7° and an altitude of 824 km. The accuracy of the satellite orientation (along three axes) will be ±0.03°, that of the wandering – ±0.15°, which ensures the accuracy of determining the viewing direction of ±0.03°. The stereoimages under discussion may be used, in particular, for the construction of digital topographic maps. To minimize the effect of the atmospheric haze, the channel 0.7–0.9 μm was used to obtain the stereoimages. For channels in the visible range the spatial resolution of images will be equal to 10 m. A 40–channel videospectrometer was developed (the spatial resolution was equal to 20 m at the 7.5–km width of the viewing swath) capable of obtaining the images or spectra and intended for scientific investigations. The possibility is considered of obtaining the images with 2.5 m spatial resolution.

J. Wain (USA) described the results of the test flights (onboard the C–130 and ER–2 aircrafts) of the set of various instruments developed for the EOS system giving, by way of example, data of the flight over the region of the Yukatan peninsular (Central America) covered with forests of moist tropics. I. Kudo et al. (Japan) described an 8–channel optical scanner (OPS) and the radar with side view equipped with synthesized apparatus for the L band with horizontally horizontal polarization which had the 18–m spatial resolution and the 75–km width of the viewing swath, and was intended for use onboard the ADEOS satellites. The OPS provided the 18×24 km resolved element (at the ground level) with the 75–km width of the viewing swath. The following channels were used: 0.52–0.60; 0.63–0.69; 0.76–0.86; (for obtaining the stereoimages); 1.60–1.71; 2.01–2.12; 2.13–2.25; and, 2.27–2.40 μm.

I. Bodechtel and S. Sommer (Germany) discussed the results of airborne observations in different regions of West Europe over the land and sea using a multi–channel three–range scanner in the spectral regions: 450–865 (31 channels), 1440–1800 (4 channels), and 2000–2500 nm (28 channels). The channel bandwidth was equal to 12.3, 120.0, and 16.3 nm, respectively. An 8–channel videospectrometer was also used (in the wavelengths range 400–850 nm). The flights were carried out over the key regions where the various synchronous ground–based obsevations were performed. A. Ono and H. Fujisada (Japan) described a videospectrometer (ITIR) made for American Polar Platform in Japan. Having two telescopes differently oriented (to obtain stereoimages), the ITIR is capable of obtaining the images in 14 wavelengths ranges with the spatial resolution of 15 (channels 1–3), 30 (channels 4–9), and 90 (channels 10–14). The following set of channels was used (in order of their serial numbers): 0.52–0.60; 0.63–0.69; 0.76–0.80; 1.60–1.71; 2.02–2.12; 2.12–2.19; 2.19–2.26; 2.29–2.36; 2.36–2.43; 8.125–8.475; 8.475–8.825; 8.925–9.275; 10.25–10.95; and, 10.95–11.65 μm. K. Maeda et al. (Japan) analyzed the results of the data interpretation of the MOS–1 Japanese oceanographic satellite from the viewpoint of its efficiency for preparing and processing of data of the ERS–1 and TERS–1 satellites.

6. CONTROL OF GLOBAL DATA ARRAY

In connection with the fact that the volume of the accumulated data of satellite observations is enormous and by the end of the century it will have increased by several orders of magnitude the problem of the control of global data array acquires a key significance. It is this circumstance which caused the decision to hold a special session on the data control.

The report by T. Townsend (USA) was aimed at the general characteristics of the data and information systems as part of the IGBP consisting of a number of Regional and three World Data Centers. The related problems were illustrated by the search–for project for following the Earth's surface changes manifested themselves in diminishing the biovariety and bioproductivity which produce the grave (and interactive) impact on climate. The satellite information whose main source is the AVHRR data with 1–km spatial resolution should be supplemented by integrated observational programs for a number of key places in different representative regions of the globe (including Ubsu–Nur). V. Hantress (USA) having described the scheme of the data control as part of the EOS program emphasized the choice of the distributed system of data processing and archiving given that the reliable computer communications are available. It has a possibility to update technically in every five years. Up to now the global data arrays have been accumulated with the use of various satellite instruments (indicated in parenthesis) during rather long time intervals: 1978–1986 (CZCS), since 1987 (SSM/I), since 1978 (TOVS), since 1981 (AVHRR), and since 1978 (GOES). The large amount of work on the data archiving is carried out by the NOAA which posessed the archives of the cloud cover, aerosol, ozone, snow and ice covers, ocean surface temperature, ozone content, etc.

D. Halpern et al. (USA) presented the review of oceanographic information. The special attention was paid to the accumulation of radiometric, scatterometric, and UHF data obtained over the open ocean surface, as well as of the data on dynamics of snow and ice covers, and ocean color and surface temperature. As an example of a new data array presented were the global charts of differences between the CO_2 concentrations in the atmosphere and upper ocean layer characterizing the CO_2 fluxes between the atmosphere and ocean. As G. Bartoc and G. Witti (France) reported, the Special Interdepartment Workshop was formed in the USA to coordinate the efforts on the data control.

7. COMBINED PROCESSING OF DATA OBTAINED FROM SATELLITES WITH HIGH SPATIAL RESOLUTION

This direction of integrated developments aiming at processing of satellite data on natural resources, ecology, etc. attracted especially great attention of Japanese experts, and the corresponding session was organized by Prof. K. Tsuchia (the Tokio University), the initiator of making the MOS Japanese oceanographic satellite.

K. Tsuchia and M. Tokuno considered the results of simultaneous analysis of radiometric data of a VTIR (MOS–1) radiometer for the visible and thermal spectral regions, of a MESSR (MOS–1) 4–channel (0.51–0.59; 0.61–0.69; 0.72–0.80; and, 0.80–1.10 μm) radiometer with electronic scanning, of a VISSR (the GMS–3 Japanese geostationary satellite) 2–channel (10.5–12.5 μm) scanning radiometer for the visible and IR spectral regions, and of the AVHRR (NOAA–9) 5–channel (0.58–0.68; 0.725–1.1; 3.55–3.93; 10.3–11.3; 11.5–12.5 μm) radiometer to retrieve the temperature and albedo of the ocean surface having found only quite acceptable discrepancies between the retreieved quantities, though the most complicated atmospheric conditions were chosen with Cirrus or small Cumulus clouds whose recognition was provided by the MESSR data.

I. Nishimura et al. gave an example of retrieving the ocean surface temperature and the concentration of suspended substance (SS) in the Arnane sea from the data of an airborne multi–channel scanner, an apparatus of the thematic mapping of the LANDSAT satellite and the AVHRR radiometer with the use of the empirical regression procedure attaching these data to the results of the control observations. Thus, for example $SS = 0.0015\exp(55.838X)$, where $X = B3/(B1 + B2 + B3 + B4)$ and B are the LANDSAT data in different channels. The results obtained were used for mapping the OST and the concentration of the suspended substance. Y. Suga demonstrated the efficiency of complex analysis of a multi–dimensional data of multi–spectral photographing from onboard the LANDSAT and SPOT satellites in the region Hiroshima and of the array of information obtained with the use of the geographic informational system to analyze the dynamics of the land tenure and the landscape mapping. S. Chehara and T. Morohoshi gave an example of how important is the nonsimultaneous photography from onboard of different satellites (MOS–1, LANDSAT, and SPOT) in combination with the ground–based observations for following the consequences of volcanic eruption (lava flows, vegetation damaging, ash ejections, etc.), taking place on the Island Miyakejima on October 3, 1983. S. Tanaka discussed the possibilities for the analysis of local ecological consequences of anthropogenic effects from data of space photography with a very high resolution (up to some meters and better), which would be possibly achieved by 2020. The examples were considered of the forest injure by acid precipitations and insects and the effect of fertilizing the golf areas to maintain them in a proper state (it is worth noting that it is better to solve problems using the airborne photographing).

In a number of reports of Japanese experts the problems were discussed of geometric (T. Osuti et al.) and atmospheric corrections. S. Mukai and T. Mukai considered the problem of atmospheric correction as applied to retrieving the chlorophyll concentration from data of a CZCS apparatus (the NIMBUS–7 satellite). The calculation procedure was based on the calculation of the appropriate corrections for the given model of atmospheric aerosol with their subsequent adaptation to the brightness of the ocean surface–atmosphere system measured from onboard the satellite. Bearing in mind the solution of the atmospheric correction problem, K. Tsuchia and M. Matzumoto proposed the procedure of retrieving the aerosol number density from data of the IR channels of the VTIR apparatus (MOS–1 satellite) under conditions of the dry atmosphere. S. Garstl (USA) made a general review of the problem of atmospheric correction, however, without pointing out the concrete solutions.

H. Revercomb et al. (USA) discussed the advantages of geostationary satellites for following the spatial and temporal variability of natural phenomena and processes, having illustrated the general conclusions by the imitation analysis of the GPHIS Fouirier spectrometer data in the range 3.7–16.1 μm with spectral resolution up to 0.1 cm^{-1} (for the nonapodized spectrum). The GPHIS apparatus may functioning in one of two regimes: (1) recording spectra over a wide range of wavelengths with spectral resolution of 0.33 cm^{-1} and (2) recording spectra in narrow wavelength ranges with super–high resolution. The main purpose of the apparatus was to retrieve the vertical temperature profiles (with an error of about 1°C) and the mixing ratio of some trace gas components. J. Dozier (USA) described the results of a complex work with the use of remote sensing data and conventional observations for studies of formation of a river discharge under conditions of snow melting in mountains which were determined first of all by dynamics of radiation balance of the underlying surface. The calculations of the snow cover albedo agree well with the observations if the adequite effective radius of snow particles assumed spherical, will be introduced.

CONCLUSIONS AND RECOMMENDATIONS

Having participated in the COSPAR congress after the 10–year interval, I consider it is necessary to note:

1. In spite of the high scientific level of the congress, the International Organizing Committee did not make its best to join the sessions on the study of ecological and natural resources lasted all 11 days of the congress into the logically united whole and to reduce the number of accidental (and poor) reports.

The main tendencies in the field of remote sensing (RS) are characterized by unprecedented increase of the instrument complexity and information volume (only by the end of our century supercomputers will be available for processing of the informational data array having a volume of several Tbytes). In this connection our lag in the field of the instrumental developments appears to be even more catastrophic. For example, up to now we do not have even the scanning apparatus analogous to the AVHRR 4– (and now 5–) channel radiometer with reliable calibration (which determines possible digital data processing) which has been already used onboard the NOAA satellites for a long time. Unfortunately, our leading research institutes in the field of remote sensing have not yet been used the possibilities for accumulating experience in interpteration of data directly transmitted from the polar orbital and geostationary satellites.

2. There is no doubt that the studies of ecological and natural resources represent the main part of the COSPAR scientific program; however, this fact has practically no influence on the list of the members of Soviet delegation. Although the delegation was unprecedentally large (for the tour to a capitalist country) – more than 60 members – the Space Physical Geography was represented by none of leading Soviet specialists. The results were shameful: even small Hungary was represented more numerously.

3. Since the comission was recently formed for the preparation of the COSPAR and IAF congresses, it is necessary to make it hard working and solving the problems of a competitional choice of the reports and the reporters as well as of an advanced preparation of recommendations concerning the programs and personalities (for the COSPAR officials). The expert functions could be realized by the appropriate sections of the ISTC on SR.

4. It is the very time to stop the practice of sending the specialists not mastering English at the international conferences without simultaneous interpretation.

5. Careful analysis is required of the state of the art in the field of international cooperation as applied to remote sensing in which the departamental isolation, (sometimes) the irresponsibility, and the lack of organization are still existing. It is necessary to raise essentially the role of the ISTC on SR and Interkosmos in coordination of international collaboration providing the necessary conditions for that.

6. Unfortunately, it is poorly known in the west countries (or completely unknown) about the access to the information obtained with the use of radars with side view operated onboard the Kosmos–1500 and Kosmos–1870 satellites. Bearing in mind our unquestioned priority in this field (in the west countries analogous information will be available only after launching the ERS–1 and JERS–1 satellites), a more active advertising the corresponding developments are urgently needed.

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