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Progress and Prospects for Atmospheric Radiation: Summary of the Beijing International Radiation Symposium

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Symposium Cochairmen

1. Introduction

The Beijing International Radiation Symposium was held in Beijing, People's Republic of China, 26–30 August 1986. The symposium was sponsored by the Chinese Meteorological Society and American Meteorological Society and cosponsored by the Radiation commission of the International Association of Meteorology and Atmospheric Physics (IAMAP) and the World Meteorological Organization (WMO). The principal objective of the symposium was to provide a forum for scientific exchange between international (outside of China) and Chinese scientists in the fields of atmospheric radiation, remote sensing, and climate applications, and for the discussion of current progress and prospects in these areas. About 60 scientists from the United States, Europe, Japan, Canada, and Australia, and an approximately equal number of Chinese scientists participated in the presentation of papers and scientific discussion. Scientists from abroad were largely invited by the scientific organizing commitee. They represented a broad spectrum of authority and expertise in the field of atmospheric radiation and remote sensing of the atmosphere.

The unique features of the Tibetan Plateau and its radiative and heat-budget characteristics have been recognized as important factors affecting weather and climate processes in the earth-atmosphere system. Two scientific expeditions for surface and meteorological observations were conducted in 1979 and 1982 by Chinese scientists. Moreover, the well-known Asian dust storms originate in the Gobi Desert in western China. In addition to these two important features related to the radiative properties of the earth and atmosphere, the enthusiasm expressed by Chinese scientists for establishing their own satellite-based, remote-sensing program in the near future, made this symposium both exciting and significant from the standpoint of international exchange and cooperation.

This symposium also provided a platform for numerous experts and authorities in the field of atmospheric radiation and remote sensing of the atmosphere to review the state of the art in this field and, at the same time, explore the future direction of the atmospheric radiation discipline in the context of atmospheric sciences and meteorology. In particular, the presentations and discussions at the symposium shed some light on the challenges and prospects for atmospheric radiation in relation to remote sensing, weather prediction, and climate studies.

2. Opening addresses and overview

The symposium began with opening addresses by Zou Jingmeng, C. Murino, Ye Duzheng, and J. Lenoble. Zou, administrator of the State Meteorological Administration (SMA), which provided the logistics for the symposium, first welcomed the participating scientists on its behalf. Zou pointed out the importance of radiation observations and study for China in terms of climate research, remote sensing, and agricultural aspects. Murino, president of the University Corporation for Atmospheric Research (UCAR) and past president of the American Meteorological Society (AMS), addressed

FIG. 1. The title of the symposium in Chinese and English. The people in the photograph are, from left to right, Zhou Xiuji (cochairman), Kuo-Nan Liou (cochairman), Zou Jingmeng (administrator, SMA), Clifford Murino (president, UCAR), Ye Duzheng (president, CMS), and Jacquelin Lenoble (president, Radiation Commission, IAMAP).

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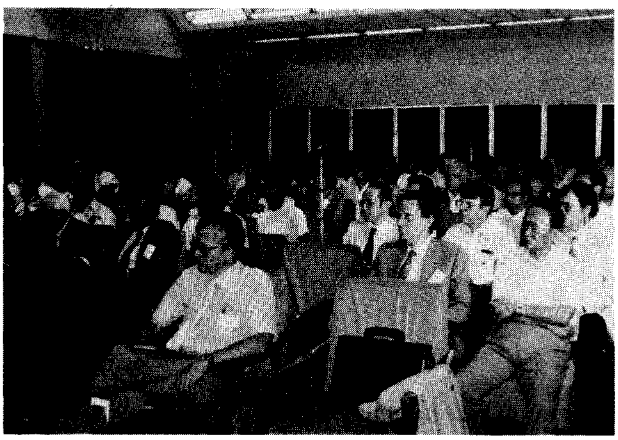

FIG. 2. A view of the participating scientists.

the symposium on behalf of AMS and stressed the importance of international research cooperation, as well as the significance of atmospheric radiation and remote sensing of the atmosphere in conjunction with climate studies and weather prediction. Ye, president of the Chinese Meteorological Society (CMS), welcomed the scientists attending and presenting papers at the symposium, and pointed out that because of its size and special features, the radiation budget over China will have a profound influence on global radiation problems, and hence, the climate. Finally, Lenoble, president of the Radiation Commission of IAMAP, addressed the symposium and described numerous activities of the commission. The four opening addresses are presented in their entirety following this summary in Appendix A.

In the keynote address, R. Goody of Harvard University, examined the prospects for atmospheric radiation in three general areas: numerical weather prediction, remote sensing, and climate studies. In terms of weather prediction, there is a question as to whether forecasts are likely to be improved by elaboration of existing computer codes for radiative transfer. Since radiative time constants for the troposphere lie between 15 and 150 days, radiative transfer does not contribute prime perturbations in three- to four-day forecasts. However, beyond the four-day time scales, there is the question of how new ideas may be introduced in radiative transfer to improve weather forecasts. In the past 50 years, significant research advances have occurred in the calculations of infrared radiative transfer for clear skies. A great deal of effort is now focused on the cloud problem, but the effect of clouds on radiation is very large and our understanding of cloud evolution is elementary. Even for clear skies, in order to achieve accuracies better than 80 or 90 percent in atmospheric calculations, we must consider a number of unsolved physical problems, including non-Lorentz line shapes, dimer formation, pressure-induced absorption bands of oxygen and nitrogen, and mixing of rotational wave functions. At present, although most of the radiation parameterization codes are credible, there is a tendency to construct overly complex schemes. Goody warned that the "black-box" approach to correlate radiative transfer and weather prediction has very little to offer. Radiative transfer would have a more-productive future for process and phenomenon studies with some emphasis on the use of approximate and analytic radiative equations. In the field of remote sounding, the increase in accuracy from advanced sounding systems is probably not enough to change the nature of forecasting. Major changes are likely to arise from the introduction of innovative techniques of measurement from space to monitor global biogeochemical changes. This may provide a context in which we can rethink the status of studies on atmospheric radiation. On the subject of climate studies, Goody pointed out that we know very little about a priori climate states. General-circulation models are not a priori calculations but are tuned to existing conditions. In the context of radiative topics, we must ask whether we understand the boundary conditions for a priori calculations and whether the states derived are necessarily unique. New ideas are needed if we wish to explore the field of climate catastrophies. The solution of climate change must involve the ocean, atmosphere, and surface chemistry predicted from fundamental principles. Finally, Goody pointed out that the atmospheric radiation community has the physical insights required to couple radiative and dynamical phenomena to make significant advances in meteorology and atmospheric sciences.

In a follow-up invited presentation, Zhou Xiuji of the SMA, discussed several unique radiation characteristics over China. China covers an area of nine-million square kilometers and has one fourth of the world's population. Increasing industrialization and changes in agricultural practices in China have an important influence on the global environment. In terms of the impact on global radiation budgets, the unique features of the Qinghai-Xizang (Tibet) Plateau, with its complex geographical distributions, occupies almost a quarter of the continent of Asia. Characteristics of the general circulation, synoptic and climatic processes in eastern Asia are known to be a result of the dynamic and thermodynamic influences of the plateau. Two scientific expeditions for surface and meteorological observations were conducted in 1979 and 1982. Data are now available for the spectral surface albedo, surface emissivity, and other surface radiation parameters. Moreover, the famous Asian dust storms originate in the Gobi Desert and loess in the northwestern part of China. Chinese climatologists have extracted 1 156 dust-storm episodes for the last 1 700 years based on ancient Chinese historical records. The occurrence of the dust storm appears to depend on the season. The Chinese are now using ground-based lidar and satellite data to deduce the optical depth of the aerosols and their optical properties. The impact of these dust storms and on the long-lived, residual fine dust particles on cloud processes and radiation budgets, and hence on weather and climate processes, is certainly an area requiring in-depth studies. Finally, China, as a developing country, may be an important source area for the emission of infrared active trace gases such as CO, CH_4, O_3, CO_2, N_2O, SO_2, CCL_2F_2, CCL_3, F, etc. All of the three aforementioned aspects are uniquely associated with atmospheric radiation and remote sensing. Zhou pointed out that it is the intent of Chinese scientists to set up a comprehensive surface network to monitor solar radiation spectrally, especially the ultraviolet components, the physical and chemical structure of atmospheric aerosol particles, infrared-active trace gases, radiative properties of clouds, and surface albedo and emissivity.

R. Schiffer of the National Aeronautics and Space Administration (NASA), representing the Joint Planning Staff of the World Climate Research Program (WCRP), presented an overview of the scientific objectives of the WCRP and a number of scientific programs under its auspices. In particular, he described the cloud and radiation programs involving the ongoing International Satellite Cloud Climatology Project (ISCCP) and Earth Radiation Budget Experiment (ERBE). Schiffer indicated that particular opportunities exist for regional experiments to aid in validating satellite-derived estimates of cloud parameters and surface radiation fluxes and to develop and test new cloud and radiation parameterization methods for climate models. The Tibetan Plateau has been singled out as one of the highest priority test areas.

I. Rasool of the Laboratoire de Méteorologie Dynamique, France, and the Committee on Space Research (COSPAR), presented a discussion on remote sensing of global change. The goals of the Global Change Program are to expand our understanding of how the earth works as a total system, including physical, chemical, biological, and geological processes as they affect changes on a planetary scale. In order to meet these goals, data on many parameters, ranging from cloud cover, radiation balance, precipitation, and atmospheric and oceanic circulations, to vegetation type and density, atmospheric trace gases, and oceanic primary productivity and chemical and biological fluxes at the boundaries of land, ocean, and atmosphere, must be derived from international operational satellite systems. Satellite based remote-sensing programs should also be augmented with the technology developed by research missions and supported by validation experiments. Rasool pointed out that some of the basic elements of a global observing system are now available, while other equally essential elements, which are technologically feasible, need to be implemented in the future. The potential implementation of innovative techniques of measurement from satellite platforms in connection with global-change studies, presents a challenge and unique opportunity for scientists in the field of atmospheric radiation and remote sensing to make a greater scientific contribution.

3. Radiation budget

The session on the radiation budget over the Tibetan Plateau began with the presentation of global radiation and surface albedo over the east Asian continent by Raschke. He showed that downward solar radiation at the earth's surface can be estimated from the operational ISCCP data sets with spatial resolutions of better than 50 km. The computed results agree with simultaneous ground-truth data within about 5 to 8 percent. Shen Zhibao presented the observed surface-radiation balance from four heat-source observation stations and 18 pyranometer stations over the Qinghai-Xizang Plateau and its surrounding areas for August 1982 to July 1983. There was a discussion on the seasonal and spatial variations of the surface radiation budget. Stowe, on the other hand, used the Earth Radiation Budget (ERB) data from satellites, along with Temperature Humidity Infrared Radiometer (THIR) and Total Ozone Mapping spectrometer (TOMS) data, to study the radiation budget and cloud parameters over the east Asian region for a six-year period from 1 April 1979 to 31 March 1985. Variations in these parameters are related to the onset, intensity, and duration of the monsoon cycle. Zhu Fukang reported some unique characteristics of the seasonal transition of the surface radiation budget over the Qinghai-Xizang Plateau in 1979. Minnis discussed variations in the radiation budget over the plateau, utilizing data derived from the ERBE. He showed that the earth-atmosphere system over the plateau lost energy radiatively at a rate that was only 25 percent of the zonal average between 30° to 40°N, which is about $-80\ \mathrm{W \cdot m^{-2}}$.

Several papers that followed were associated with the analysis of surface radiation budgets and albedo characteristics derived from scientific expeditions over the plateau covering a number of time periods: 1 December 1985–15 January 1986 (Pan Shouwen), August 1982–July 1983 (Ji Guoliang), and May–August 1979 (Xie Xianqun and Sun Zhi'an). Zhou Sisong presented results of the radiation budget over the plateau derived from data from the Advanced Very High Resolution Radiometer (AVHRR), while Zhong Qiang discussed a methodology for estimating the surface albedo of the plateau using these data. Computations of radiation budgets over the plateau were reported by Chen Yuejuan, Li Weiliang and Zhong Qiang and Cai Qiming.

In the subsession on the Radiation Budget, General, Cess discussed an idea for using a general-circulation model (GCM) to serve as a vehicle for suggesting and exploring means for converting narrow-band measurements of reflected solar radiation to broadband quantities. Chen Xing reported results from numerical computations of the tropospheric radiation budget over China. Charlock presented an approach to investigate the full dynamic response of GCMs. This approach involved comparing the synoptic space and time-scale fluctuation statistics of reflected solar and outgoing infrared (IR) fluxes derived from satellite observations with those computed by GCMs. Jiang Shangcheng presented the climatological feature of the ITCZ based on outgoing-longwave-radiation data derived from NOAA satellites for a ten-year period. He showed that annual variations in the ITCZ over tropical continents appear to follow the solar-declination cycle, whereas those over the Atlantic and Pacific oceans are related to the sea-surface temperature and affected by the Indian monsoon. Zhong Lingsheng reported ground-based observations of solar-spectral irradiance in the Kunming area of Yunnan Province. Pinker described a methodology for estimating surface-budget components from satellites and an investigation of the visible spectral and total planetary albedos. In subsequent papers, Gao Guodong and Weng Duming presented computational results for various components of the radiation budget at the top of the atmosphere over China.

Cheng Longxun then showed some potential relationships between the onset and dissipation of the Australian summer monsoon and seasonal cycles, utilizing results of harmonic analyses of outgoing longwave radiation. Xu Qun speculated that the persistent droughts of the Sahel, beginning in 1968, had a strong correlation with the persistent decreasing trend of direct solar radiation in the Northern Hemisphere due to more frequent volcanic eruptions and increasing anthropogenic aerosols. Chen Qiushi discussed a numerical model incorporating some aspects of cloud and radiation processes for the investigation of Walker circulation and planetary-scale physical processes. He pointed out that the effects of the coupling of radiation and clouds are important in determining the total heating variation along the latitude circle. Examinations of the regional climate and radiation characteristics in the desert region in northern China and over Shanghai, the largest city in China, were reported, respectively, by Wang and Chow Shudjen. Based on the analysis of outgoing longwave radiation Zhu Yuanjing showed that there is a correlation, with a three-month lag, between the summer rainfall in southern and eastern China and longwave radiation anomalies around Australia. Shi Guangyu discussed the effects of spectral data, band models, and pressure corrections on the calculation of atmospheric infrared cooling rates. On the basis of a three-dimensional model, Ding Yihui illustrated that incorporation of radiative processes and different patterns of cloudiness led to a more intense development of the tropical cyclone with a considerable enhancement of the maximum wind speed and upward motion in the eyewall region. He suggested that the structure and evolution of the tropical cycle simulated from the model with radiative processes were more realistic than in the case that did not consider radiative processes in the model.

4. Remote sensing of the atmosphere

On the subject of remote sensing of the atmosphere, Smith first reported on an advanced sounding system involving the High Spectral Resolution Interferometer Sounder (HIS). Results of theoretical analyses showed that the vertical resolution of atmospheric soundings obtained from HIS observations should be improved by a factor of two to four, depending on the altitude. Some reslts of HIS observations from the NASA U-2 aircraft during spring and summer 1986 were illustrated with respect to the expected advances in remote-sensing capabilities. Zhao Bolin described microwave–remote-sensing programs undertaken at Peking University for studies of the atmospheric temperature, cloud, liquid-water content, precipitation intensity, and surface reflection, and emission characteristics in the microwave region. In a follow-up paper, he described a methodology for inferring atmospheric-aerosol loading produced by the Asian dust storm from data derived from GMS visible infrared spin scan radiometer (VISSR) radiometer measurements. Chahine described the global distribution and accuracy of atmospheric and surface parameters derived from data acquired by the High Resolution Infrared Sounder (HIRS) and Microwave Sounding Unit (MSU). Huang Runheng reported results of the humidity profile and total precipitable water derived from ground-based microwave radiometers with 1.35-cm and 0.85-cm wavelengths. Liou presented a novel approach for deriving atmospheric infrared cooling rates from measurements of radiance at the top of the atmosphere based on the fundamental principles of infrared radiative transfer. To convert radiances to net fluxes and at the same time to achieve vertical profiling of cooling rates, a combined measurement of angular and wavenumber scans was proposed. Appropriate weighting functions in the rotational band of water vapor and some success in the inversion program for the retrieval of cooling-rate profiles were demonstrated.

In connection with the paper presented by Huang Runheng, Wei Cong described a technique for the simultaneous determination of the precipitable water-vapor content and cloud liquid-water content from two microwave frequencies. McClatchey reviewed the current state of the art in remote sensing, principally from satellite platforms. In particular, he raised questions regarding the accuracy of retrieving cloud parameters, temperatures, water vapor, winds, aerosols, and precipitation with today's technology and interpretive techniques. The role of ground-based active systems in the context of global numerical weather prediction and mesoscale functioning was also examined. Li Quangqing discussed errors in the kernel function and observations on temperature profile retrievals and proposed an algorithm to remove the effect of kernel function errors. Gille reviewed the method and advantages of infrared "limb" sounding, along with the required instrumentation. Some results of global fields of temperature, ozone, water vapor, nitric acid, and nitrogen dioxide retrieved from limb-sounding instruments on board *Nimbus 6* and *Nimbus 7* was presented and future applications of the limb-sounding technique for flight on the Upper Atmosphere Research Satellite were discussed. A ground-based, angular-scanning, broadband sounding system in the 15 μm CO_2 band was proposed by Liu Changsheng for remote sounding of the temperature profile in the boundary layer.

Isaacs reported on the future of remote-sensing systems, including microwave temperature and millimeter-wave moisture sensors for the Defense Meteorological Satellite Program (DMSP) spacecraft of the 1990s. There was a discussion on the potential applicability of these sensors for retrieving water-vapor profiles, clouds, precipitation, and surface conditions. Ma Xialin presented a physical model for deriving the total-ozone amount from HIRS radiance data from TIROS-N satellites. Spinhirne described two instruments involving the Cloud Lidar System and Multispectral Cloud Radiometer flown on NASA ER-2 for mapping cirrus and stratus clouds. Gal-Chen presented a technique to deduce the vertical temperature for initialization of mesoscale models from a combined use of observed wind and radiance and the equations of motion. Qiu Kangmu reported a statistical method to account for atmospheric attenuation in deriving the sea-surface temperature. J. King presented an innovative inversion technique for the temperature profile by virtue of Laplace-transform operations associated with the solution of the radiative-tansfer equation. He illustrated that the inferred temperature at a given level depends solely on the observed radiance and the derivatives of the radiance function at that level. Qiu Jinhuan discussed an application of near-horizontal sky radiance measurements for the determination of aerosol depths and cloud-optical depths. Finally, Gall described the mesoscale structure of the Arizona monsoon through the use of temperatures and cloud track winds derived from satellite data.

5. Clouds, radiation and climate

In this session, Wetherald first presented results of GCM experiments involving the change in soil moisture and cloud feedback in response to an increase in CO_2 concentration. The cloud cover was fixed in one experiment and was computed in another. It was shown that soil moisture reduces in summer over extensive midcontinental regions and high latitudes. Moreover, this summer dryness is enhanced by a positive feedback due to the reduction of total cloud amount produced in the experiment. Fu Yixian gave the results of estimated cloudiness and albedo over the Northern Hemisphere for the period 1851–1984 utilizing a one-dimensional energy-balance climate model. Raschke reported a field experiment with aircraft, satellite and ground-based measurements planned by several research groups in Europe for the fall of 1987 and 1988. The radiative properties of boundary-layer stratocumulus clouds from aircraft observations were then discussed by Stephens, who also related them to atmospheric diabatic heating and their potential role in climate. The effects of low, middle, and high clouds on solar and infrared radiation over China using empirical calculations were discussed by Jiang Zhihong, who replaced Lu Yurong in the presentation.

Ou presented results derived from one- and two-dimensional climate models with an interactive–cloud-formation program. Overall, the incorporation of an interactive–cloud-formation program in simplified climate models reduces the sensitivity of temperature increases caused by positive radiative forcings, such as the anticipated increase in CO_2 concentration. Based on these model results, clouds appear to stabilize the perturbed climate system. In a follow-up study using a one-dimensional energy-balance climate model, Fu Yixian further showed that an increase in cloudiness in the model has a cooling effect at low latitudes and middle latitudes, but has a warming effect at high latitudes. Rossow discussed an investigation of the importance of cloud geometry, including such factors as fractional cover viewed from satellites, inhomogeneous cloud optical properties, and angular dependence of multiple-scattered radiation. Illustrations were made by comparing coincident retrievals from satellites with different resolutions and viewing geometries. Utilizing NOAA AVHRR data, Lin Xijian presented results of cloud-retrieval exercises based on a bispectral-clustering technique. London showed that the total cloud cover over the globe should be 16 percent rather than the previously suggested 50 percent. This conclusion was derived from analyses of ground observations of total cloudiness for a ten-year period from 1972 to 1981. He reported that during this period, there was an apparent decrease in reported cumulus and an increase in both stratus and cumulonimbus, but the total cloud amount showed no significant trend. Coakley discussed the radiative properties of layered cloud systems derived from analyses of NOAA AVHRR data. In particular, he illustrated that observations of 3.7-μm solar radiation reflected by clouds indicated that broken cloud fields often have higher reflectivities than do extended uniform clouds. This appears to suggest a possible influence of cloud sides on reflected radiation and a difference between these clouds in terms of liquid-water content and cloud-droplet sizes.

With regard to the retrieval of cloud parameters from satellites, Arking reviewed a number of approaches involving the use of a threshold in one or more channels, the statistical distribution of radiances within an area that encompasses many fields of view, and the introduction of new channels. The latter approach could use channels in the 15 μm CO_2 band or solar H_2O bands, which could help reduce the nonuniqueness in the retrieval problem. M. King presented a methodology and instrumentation for measuring a cloud's single-scattering albedo and asymmetry factor, and preliminary results derived from aircraft observations. Davies discussed the radiative budget at the cloud top using a detailed radiative-transfer model and the effects of this budget in the context of a cloud's thermodynamic equilibrium. In another cloud remote-sensing study, Wu described a program using data from the Multispectral Cloud Radiometer, Cloud Lidar System, and Advanced Microwave Moisture Sounder flown on NASA ER-2 aircraft. To understand cloud-radiation feedbacks from observations, Somerville discussed a study using multi-year time series of ERB and sea-surface temperature data. Finally, Paltridge presented some results of spectral and total solar albedo for ice clouds and water clouds in terms of liquid-water contents obtained during Aspendale ISCCP Regional Experiment.

6. Aerosols and radiation

The stratospheric aerosol-size distribution and refractive indexes inferred from the Stratospheric Aerosol and Gas Experiment (SAGE) and balloon-borne polarimetric observations were presented by Lenoble in this session. It was pointed out that the determination of tropospheric aerosol characteristics has been less successful than stratospheric aerosols. Hu Huanling reported aerosol size distributions measured over a number of locations in China using an 18-channel–single-particle counter. In a subsequent paper, he described the effects of the refractive index on the determination of the aerosol-size distribution. Fiocco then presented results of lidar observations of El Chichon aerosol clouds in Frascati, Italy and found negative correlations between the stratospheric aerosol concentrations and ozone concentrations. Qiu Jinhuan described a forward scattering technique for determining the aerosol-size distribution, refractive index, and surface albedo from multiwavelength radiation observations. An approach to the inverse problem was reported by Herman, who used a set of mathematical functions to form the orthogonal basis functions for the retrieval of aerosol size distributions. Wu Beiying presented results of computed intensity and polarization from a spherical atmosphere using the Monte Carlo program with particular emphasis on polarization characteristics when the sun is near the horizon. Reagan described the effects of temporal variations in optical depth on the determination of the solar constant from the Langley method and the methods that would minimize these variations. Zhao Fengsheng further discussed a technique for deducing the aerosol refractive index from an inversion of the Stokes parameters at certain scattering angles.

Along a similar line, Tanaka reported ground-based observations, as well as aircraft observations made in Japan of the upward solar flux and downward solar flux from special pyranometers from which the single-scattering albedo of aerosols and surface albedo can be estimated. In a follow-up paper, he described a program for monitoring the atmospheric turbidity using a five-channel scanning radiometer in the suburbs of Sendai, Japan for the period from September 1981 to May 1985. Moreover, Tanaka studied the composition and optical properties of a yellow sand episode over Japan on 21 April 1982 and found that the sand storm is composed of large, irregular particles with an asymmetry factor of about 0.7. Wang Bingzhong reported on the atmospheric turbidity over China from solar spectral radiation observations. Zhou Jun presented values of aerosol optical depths measured from a nine-wavelength solar radiometer in Hefei and at Huangshan Mountain, China, as well as typical aerosol-size distributions inferred from these measurements. Nakajima described an airborne solar spectral radiatometer and data-analysis algorithm for the inference of the aerosol optical depth. Yin Hong showed the importance of aerosol absorption based on multiple-scattering calculations. The results of spectral measurements of solar radiation using a sun photometer at Syowa Station, Antarctica during a research expedition, were reported by Shiobara. Quenzel presented a method for determining the aerosol-size distribution by means of solar-aureole radiance measurements. Subsequently, he discussed the potential of a spaceborne lidar for cloud and aerosol studies. Schotland discussed the bias encountered in the determination of the solar constant from the Langley method due to the effects of aerosols and suggested concurrent use of lidars to minimize this bias. Finally, Valero described a multichannel radiometer for determining the atmospheric optical depth and total to diffuse solar-flux ratio. The instrument has been used successfully to infer the optical depth and absorption of solar fluxes by Arctic haze.

7. Trace gases, chemistry and climate

In the final session of the symposium, a number of papers were devoted to the discussion of the chemistry and radiation of various trace gases and their impact on climate. Liu pointed out that, in addition to carbon dioxide, the most important species are methane and ozone. It is believed that the increase in ozone is a result of photochemical production due to anthropogenic emissions of nitrogen oxides and nonmethane hydrocarbons, while the increase in methane is partly due to the changing tropospheric chemistry induced by anthropogenic emissions of carbon monoxide, nitrogen oxides, and nonmethane hydrocarbons. Through greenhouse effects and feedbacks, these trace gases could have a significant impact on climatic temperature perturbations. Chang discussed the importance of the in-cloud–radiation flux due to increased scattering on the photodissociation of many atmospheric-chemical species present in the cloud. It is necessary to have more-precise formulations and further studies on the effect of the in-cloud increase of photolysis on atmospheric acid formation. Mao Jietai reported results of the distribution of average ultraviolet flux in a stratiform cloud based on multiple-scattering calculations. Finally, Vuppurturi presented results of potential temperature and ozone perturbations caused by past and projected future anthropogenic emissions of trace gases using a one-dimensional radiative-convective-photochemical model.

8. Panel discussion on international research cooperation

In the panel discussion chaired by London, short presentations were made by a number of international and Chinese scientists on research subjects and progress of mutual interest. Among these presentations, Ye Duzheng of the Chinese Academy of Sciences described his ideas and plans for an observational research program to study earth-atmosphere interactions over the western part of China. The objectives of this observational research program are to understand the physical processes governing the exchange of heat, water vapor, momentum, and other substances between the surface and atmosphere over various kinds of surfaces, to establish ground-truth data for the development of satellite sounding techniques for the inference of surface parameters, and to establish a network of global monitoring stations for global change research.

Ye's proposed program is scientifically unique in two respects. First, the proposed observation region, the Hei-He Basin in the Hexi Corridor of Gansu Province, is located at the eastern edge of the Tibetan Plateau. The scientific investigation of its dynamic and thermodynamic influences on global weather and climate is of critical importance. Second, north of the observation region is the large Gobi Desert, which is one of the most significant dust sources in the world. The surface data, which will combine the characteristics of the Tibetan Plateau and Gobi Desert, would be of fundamental value to the development of satellite sounding techniques and to the modeling and understanding of climate processes.

Ye's presentation was favorably received by the international scientists present. Goody, who summarized the panel discussion, noted the importance of such a field observational program over complex terrain in connection with research on global surface-exchange processes and the necessity for international cooperation and assistance in such a program. Moreover, Goody pointed out that, in order to initiate an international cooperative research program to assist Ye's proposed experiment, it is important to produce a document that outlines the rationale and strategy for the involvement and participation of a group of interested scientists outside of China. A number of scientists expressed an interest in initiating an international cooperative program based on Ye's proposed experiment.

Appendix A. Addresses to Beijing International Radiation Symposium

Address given by: Zou Jingmeng

Administrator, State Meteorological Administration, China

Mr. Chairman, ladies, and gentlemen:
Today, the International Radiation Symposium, cosponsored by the Chinese Meteorological Society and the American Meteorological Society, and supported by the WMO, begins. With great pleasure, I would like to congratulate all of you on the opening of the Symposium as scheduled.

As you know, the energy source of atmospheric motion is solar radiation, and the radiation budget of the atmosphere-ocean-land system is a primary physical process responsible for world climatic variations. Since the 1960s severe climate disasters, such as floods and droughts, have seriously affected food production, water, energy, and the livelihood of mankind. As a result, climate issues have drawn worldwide attention and concern. Meteorologists in the world have the feeling that it is their responsibility to solve these problems. The 1988–1997 World Climate Research Program reflects the great importance scientists attach to these issues. This research program incorporates the monitoring and study of radiation. Furthermore, the physics of atmospheric radiation transmission are the theoretical basis for remote sensing. In turn, remote-sensing techniques provide a very important means to better understand atmospheric motion. Research into atmospheric radiation, therefore, has become an indispensible subject in modern atmospheric science.

Chinese meteorologists pay great attention to the monitoring of and research on radiation. Soon after the founding of the People's Republic of China, solar radiation stations were established and gradually developed into a network for radiation monitoring. The valuable data accumulated over the last 30 years of observations have provided a reliable basis for research into atmospheric radiation. At the beginning of the 1960s, along with the development of radiation observations, research on the atmospheric radiation budget in east Asia was carried out in China. In the summer of 1979, the first meteorological experiment on the Qinghai and Tibetan Plateau was cosponsored by the State Meteorological Administration and the Academy Sinica. Six radiation observation stations were set up on the Plateau and the *Atlas of Qinghai and Tibetan Plateau Radiation and Thermal Equilibrium* was published. The atlas filled a gap in the climate research in this area. This summer, in the course of the Sino-American joint experiment on the Plateau boundary layer, radiation observations were added to the programs at another two stations. Thanks to the friendly cooperation between the scientists of the two nations, the experiment, which lasted for two months, was smoothly carried out. At the beginning of 1986, A Sino-American joint investigation cruise under the TOGA program in the west Pacific Ocean was undertaken, in which radiation measurements were conducted. In the second forthcoming cruise, observations in this field will also be included.

In order to strengthen the coordination of climate research in China, the National Climate Committee will be established. We will continue our research primarily on the impact of carbon dioxide, aerosols, and ozone on climate; secondly on the feedback mechanisms of the stratosphere and troposphere in relation to flux variations in solar radiation; and finally, on the radiation equilibrium over the Qinghai-Tibetan Plateau.

Like other developing countries, agriculture in China accounts for a great proportion of the national economy. Along with economic growth, various departments such as aviation, transportation, water and electricity generation, and architecture are in dire need of accurate meteorological predictions. Chinese leaders have a clear view of the economic benefits from the weather service in various sectors. The State Meteorological Administration is one of the subordinate bodies directly under the leadership of the state council. Our governmental leaders often show their concern over meteorological issues. Now, the meteorological development program has been listed in the 7th national five-year plan. We are fully aware that meteorology knows no boundaries, and presents us with a good basis for international cooperation. Today, in a spirit of cooperation, we have gathered here. I believe that you will bring many creative research results to this meeting. I also believe that the symposium held in Beijing will be a great boost to the meteorological work of our country and will be very helpful in the exchange of ideas and to the promotion of cooperation between China and other nations.

Finally, I would like to take this opportunity to express my heartfelt thanks to the WMO for its support and to the experts who contributed greatly to the preparations for the symposium.

My best wishes for the success of the symposium. Thank you.

Address given by: Clifford J. Murino

President, University Corporation for
Atmospheric Research
and
Past President, American Meteorological Society,
United States

Mr. Zou, Professor Ye, Dr. Lenoble, participants and guests:
I am honored to have been invited to address this distinguished group of leading atmospheric scientists at the Beijing International Radiation Symposium. I am also especially pleased to do so because it gives me cause to return to this beautiful country and to see once again my many good friends in China and, on this occasion, to meet with friends from distant lands.

I greet you in two capacities. First, as immediate past president of the American Meteorological Society, a cosponsor of this symposium, I greet you on behalf of the nearly 10 000 members of the American Meteorological Society. Last year, as president of the AMS, I had the good fortune to work closely with Professor Ye in his role as president of the Chinese Meteorological Society in the planning of this conference. On behalf of the AMS, I want to thank the Honorary Chairmen, Professor Ye, and Professor London; the Chairmen, Professor Liou and Professor Zhou; and the Program Committee for their tremendous effort in organizing this symposium. I congratulate them on putting together such a magnificent program and on making the symposium such an outstanding success.

I also greet you in a second capacity, that of president of the University Corporation for Atmospheric Research: UCAR. As a consortium of 55 universities with Ph.D. programs in atmospheric and oceanic science, we are increasingly involved in international scientific activities. This derives in part from our management, on behalf of the National Science Foundation, of the National Center for Atmospheric Research: NCAR, and in part from programs conducted within UCAR itself. For example, I note on the symposium program that my colleague, Dr. Julius Chang, is scheduled to speak on research that is an outgrowth of the NCAR program on regional-scale acid deposition modeling. Dr. Chang recently has been establishing collaborations with scientists in Europe as part of a cooperative European-community program of research on acid deposition being advanced under the banner EUROTRAC, "European Experiment on Transport and Transformation of Environmentally Relevant Trace Constituents of Anthropogenic and Natural Origin." He is exploring similar cooperative arrangements with scientists here in China and stands ready to do so with interested scientists in other countries.

In a different but related vein, one notes that advances in research in the atmospheric sciences have carried our field ever deeper into the domains of adjoining disciplines, resulting in increasing pressures for collaboration and cooperation with working scientists in other fields. Ready examples are found in areas of atmosphere-ocean interactions, climate modeling, and atmospheric chemistry, where increasing demands are placed on inputs that are often biological, hydrological, or geological in nature. This natural expansion of the field coincides with emerging national and international initiatives to mount new organized research endeavors that are both global and interdisciplinary in nature, such as the ICSU Geosphere-Biosphere Global Change Program. These programs call for an enhanced collaboration between scientific disciplines to understand the earth as a coupled system. Behind them is a recognition that the major environmental problems that face the world today can only be addressed through concerted, multidisciplinary, international efforts. Human activities have reached the stage where they perturb the global environment, with consequences that are often unpredictable, given our present, limited understanding of the interactions that maintain the necessary conditions for life on this planet.

These growing initiatives seem destined to coalesce to produce a large-scale, international, multidisciplinary thrust in the decade of the 1990s.

We atmospheric scientists look forward to playing a central leadership role in these imminent, emerging programs. We should be pleased that we have not only the opportunity to lead but the responsibility to lead. This mandate for leadership falls to us for at least two reasons. First, the atmosphere is global and is the connective element in these multidisciplinary programs. In my view, progress in developing alliances among the other disciplines will be seriously hampered unless the connecting thread—the atmosphere—is woven into the entire fabric of a program on global change.

Second, we have a distinguished record of success in international cooperation, both in the areas of operations and in research. In operational meteorology, we long ago learned that we simply could not do our jobs without such cooperation. Data obtained in, and collected from, all parts of the world are routinely exchanged so that they may serve as the basis for weather predictions produced in countries the world over.

Parenthetically, I should mention that in June I had the opportunity to attend, as an official delegate, the two-week-long meeting in Geneva of the Executive Council of the WMO. As you know, the permanent representatives to the WMO are the heads of weather services in some 150 participating nations. Mr. Zou, who shares this platform today, has been an extraordinarily effective leader in the highest councils of the WMO. As an outsider to this august body, I can report objectively how impressed I was with the fervor, skill, and true spirit of cooperation with which the Executive Council worked. While surely there were differences of opinion expressed, in no case did I detect anything but the purest of motives—each delegate was working for what he or she believed was in the best interest of the science and the worldwide community of people our science tries to serve. And out of the discussions came an outstanding, balanced, four-year plan of activities that will be proposed for formal adoption by the WMO Congress next May.

In the area of international cooperation in reserach, no other science can match the magnitude and complexity of our successful program in the 1970s called the Global Atmospheric Research Program. Currently, we are carrying forward the World Climate Research Program under WMO auspices.

To be successful in the new program on global change, new and augmented institutional arrangements on many levels and of many types will be needed. For example, within individual governments, there will be a need to develop appropriate mechanisms for properly reviewing research objectives and research plans and for ensuring that the necessary financial resources are provided to worthy efforts. As another example, the American Meteorological Society, on Dr. Kenneth Spengler's initiative, has been working to establish ties with sister meteorological societies the world over. And recently, the AMS Executive Committee put into place a new mechanism that will focus on establishing ties with sister societies in the other relevant disciplines. As a final example, UCAR is in the process of broadening ties with atmospheric research institutions outside of our continent to foster an enhanced level of cooperative research.

All of this is why I am so pleased to see this symposium come about. Virtually all of the program is central to the critically important scientific issues we will have to deal with in these emerging programs. To name but a few topics to be discussed this week: the radiative properties of clouds and their role in climate and climate change; the roles of aerosols and trace gases in climate and climate change; global observing systems and new techniques for assimilating remotely sensed data into our models. All are key issues in any program on global change.

In conclusion, I am truly impressed with this symposium: with how important its substance is; with how timely it is as we plan these major new programs; and with how appropriate it is in that we are an international group convened to share what we have learned, and, together, to plan for the future.

Address given by: Ye Duzheng

President, Chinese Meteorological Society

Dear friends, ladies and gentlemen:
First of all please allow me, on behalf of the Chinese Meteorological Society, to express our warm welcome to all the participants here. Attending this symposium, besides the Chinese scientists, are scientists from many different countries. There are scientists from the American, European, and Australian continents, and, of course, also from the Asian continent. To all the scientists from foreign countries, we offer our special welcome. This symposium is jointly sponsored by the Chinese Meteorological Society, the American Meteorological Society, the International Association of Meteorology and Atmospheric Physics and the World Meteorological Organization. To the latter three organizations, the Chinese Meteorological Society would like to offer our sincere thanks for joining with us to hold this symposium. Their participation in cosponsoring it is greatly appreciated.

Atmospheric radiation, as a branch of meteorological science, has been developing steadily in China since the 1950s, although not as rapidly as in more developed countries. The achievements in atmospheric radiation in China have already been talked about by Mr. Zou, the director of SMA. I will not go into them again. However, I would like to mention the following two points. First, China is a big country. It occupies a fairly large percentage of the world's land, so the overall features of atmospheric radiation over China will play a role in global radiation problems. Secondly, we have the world's highest and largest plateau, the Qinghai-Xizang (Tibet) Plateau, which is a unique geographical feature. The radiative problems of this plateau are certainly a matter of scientific interest, but they are practically important as well. The radiative conditions of the plateau will not only play an important role in the atmospheric circulation over China but also over a very wide region. As Mr. Zou stated a little while ago, we have already started observational studies on the atmospheric radiation over the plateau. But it is only a start, and maybe only a small start. From these two points we can see that China can make contributions to knowledge of atmospheric radiation in the international family. But I am sorry to say that we have not been particularly active in the international radiation community in the past. So I am very pleased to see an international radiation symposium now being held in China. This symposium is the first international radiation symposium ever held in our country. I hope that in the future we can hold more international radiation meetings like this one, and even bigger ones. I hope also that this symposium will be an indication that China will be more active in the international radiation community in the coming years. We shall do our best to make this symposium a good start toward that goal.

To close my talk, I would like to wish our foreign friends success in the scientific meeting and a happy stay in China in the coming few days. Thanks to all.

Address given by: J. Lenoble

President, Radiation Commission of IAMAP

On behalf of the Radiation Commission of IAMAP, I would like to address my best wishes for the success of this Beijing International Radiation Symposium (BIRS). I am very grateful to our Chinese colleagues, who organized this symposium and made such a wonderful preparatory work. I wish also to extend my thanks to the American colleagues who worked with the Chinese scientists from the origin of this International Radiation Symposium, which is the first to be held in China. It is a great pleasure and a great honor for the International Radiation Commission (IRC) to cosponsor the BIRS.

I would like to take this opportunity to briefly present the activities of IRC, for those who are not familiar with it. The IRC is one of the ten commissions of the IAMAP. Its role is part of the broader charter of IAMAP concerning the earth-atmosphere system and the atmosphere of other planets. The IRC is concerned with all problems involving radiative energy transfer, radiative properties of the surface and atmosphere, and remote sensing. Its responsibilities include but are not limited to the following, which are summarized in terms of reference:

1) a) To stimulate improvement in the standards for calibration of instruments concerned with measurement of atmospheric radiation; b) to encourage the development of new and more accurate instruments, which are needed for measurement of atmospheric radiation; and c) to help develop high quality standards in network measurements of atmospheric radiation.
2) a) To advise other scientific bodies on matters of atmospheric radiation when requested; b) to develop, when necessary, formal recommendations for the promotion of particular aspects of atmospheric radiation; and c) to join with other scientific bodies in any activity, which will promote the discipline of atmospheric radiation.
3) a) To summarize and publish, as needed, the status, research, and measurement requirements of particular aspects of atmospheric radiation; b) to provide a forum for the scientific community to exchange relevant results and ideas and to encourage international cooperation; and c) to organize the quadrennial International Radiation Symposium.

Most of the IRC activity is performed by its working groups. These are established for a limited time and with a very specific task. The membership of the working groups is very flexible and not limited to IRC members. In fact, they are widely open to all those who want to contribute to their work. The present working groups (WG) are as follows:

- WG on Intercomparison of Transmittance and Radiance Algorithms (ITRA);

- WG on Intercomparison of Radiation Codes for Climate Models (ICRCCM);
- WG on TOVS;
- WG on ISCCP;
- International Coordination Group on Laser Atmospheric Studies (ICLAS);
- WG on Earth Radiation Budget;
- Joint WG with the Commission of Cloud Physics on an International Aerosol Climatology Project (IACP); and
- Joint WG with the Ozone Commission and the Commission on Planetary Atmospheres and their Evolution on Atmospheric Spectroscopy Applications (ASA).

The IRC also nominates reporters to follow particular problems, such as the functioning of the World Radiation Data Center or cloud-base observations.

The IRC has about 45 members, which cover different fields in atmospheric radiation. We also try to have a membership that is as international as possible. This policy leads to some underrepresentation of the large countries (ten American members, six Soviet members, and four or five for small European countries like France or Germany). But I am ashamed that we have only one Chinese member, who is our distinguished friend, Professor Zhou Xiuji. We will elect new members next year during the IUGG General Assembly in Vancouver. A nominating committee has been organized and it is chaired by Professor J. London. I hope very much that this committee will be able to propose several new Chinese members. I am sure that their contribution to the future activities of the IRC will be of the highest level. ●