WORLD CLIMATE PROGRAMME

RESEARCH

INTERNATIONAL COUNCIL OF
SCIENTIFIC UNIONS

WORLD METEOROLOGICAL
ORGANIZATION

GLOBAL ENERGY AND WATER CYCLE EXPERIMENT

(GEWEX)

Report of the Third Session of the JSC Scientific Steering Group for GEWEX

(Hamilton, Bermuda, 21-25 January 1991)

July 1991

WCRP-57

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Report of the 1st Session WCRP-25
" " " 2nd " WCRP-44
" " " 3rd " WCRP-57 ... Scientific plan WCRP-49

The World Climate Programme launched by the World Meteorological Organization (WMO) includes four components:

The World Climate Data Programme
The World Climate Applications Programme
The World Climate Impact Studies Programme
The World Climate Research Programme

The World Climate Research Programme is jointly sponsored by the WMO and the International Council of Scientific Unions.

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LIST OF ACRONYMS

ABL	-	Atmospheric Boundary Layer
ACCP	-	Atlantic Climate Change Programme
ACRIM	-	Active Cavity Radiometer Irradiance Monitor
ADEOS	-	Advanced Earth Observation Satellite
AIRS	-	Atmospheric Infrared Sounder
ALADIN	-	Atmospheric Laser Doppler Instrument
ALT	-	Altimeter
AMI	-	Active Microwave Instrumentation
AMSU	-	Advanced Microwave Sounding Unit
ARM	-	Atmospheric Radiation Measurement
ATLID	-	Atmospheric Lidar
ATSR	-	Along-Track Scanning Radiometer
AVHRR	-	Advanced Very High Resolution Radiometer
AVNIR	-	Advanced Visible and Near-Infrared Radiometer
BAHC	-	Biospheric Aspects of the Hydrological Cycle
BEST	-	Bilan Energétique du Système Tropical
BOREAS	-	Boreal Ecosystems Atmosphere Study
CERES	-	Clouds and the Earth's Radiant Energy System
CNES	-	Centre National d'Etudes Spatiales
COARE	-	Coupled Ocean-Atmosphere Experiment
DIAL	-	Differential Absorption Lidar
DMSP	-	Defense Meteorological Satellite Program
ECLIPS	-	Experimental Cloud Lidar Pilot Study
ECMWF	-	European Centre for Medium-Range Weather Forecasts
EFEDA	-	European Field Experiment in Desertification Threatened Area
EMEX	-	Equatorial Monsoon Experiment
EOS	-	Earth Observing System
EOSP	-	Earth Observing Scanning Polarimeter
EPOP	-	European Polar Orbiting Platform
ERBE	-	Earth Radiation Budget Experiment
ERBS	-	Earth Radiation Budget Satellite
ERS	-	European Remote-sensing Satellite
ESA	-	European Space Agency
ESMR	-	Electronically Scanned Microwave Radiometer
ESOC	-	European Space Operations Centre
EUMETSAT	-	European Organisation for the Exploitation of Meteorological Satellites
FIFE	-	First ISLSCP Field Experiment
FIRE	-	First ISCCP Regional Experiment
GARP	-	Global Atmospheric Research Programme
GATE	-	GARP Atlantic Tropical Experiment
GBSRN	-	Global Baseline Surface Radiation Network
GCM	-	General Circulation Model
GCIP	-	GEWEX Continental-Scale International Project
GCTE	-	Global Change and Terrestrial Ecosystems
GEWEX	-	Global Energy and Water Cycle Experiment
GMCSS	-	GEWEX Multi-region Cloud System Study
GMS	-	Geostationary Meteorological Satellite
GOES	-	Geostationary Operational Environmental Satellite
GPCP	-	Global Precipitation Climatology Project
GPI	-	GOES Precipitation Index
GRDC	-	Global Runoff Data Centre
GRID	-	Global Resource Information Database
GSFC	-	Goddard Space Flight Center
HAPEX	-	Hydrological-Atmospheric Pilot Experiment

HIMSS - High-resolution Microwave Spectrometer Sounder
HIRIS - High Resolution Imaging Spectrometer
HIRS - High Resolution Infrared Sounder
IAHS - International Association of Hydrological Sciences
IAMAP - International Association of Meteorology and Atmospheric Physics
ICE - International Cirrus Experiment
IGBP - International Geosphere-Biosphere Programme
IGPO - International GEWEX Project Office
IMG - Interferometric Monitor of Greenhouse Gases
ISCCP - International Satellite Cloud Climatology Project
ISLSCP - International Satellite Land Surface Climatology Project
ITCZ - Inter-Tropical Convergence Zone
ITIR - Intermediate and Thermal Infrared Radiometer
JERS - Japanese Earth Resources Satellite
JGOFS - Joint Global Ocean Flux Study
JMA - Japan Meteorological Agency
JSC - Joint Scientific Committee for WCRP
LAWS - Laser Atmospheric Wind Sounder
LW - Longwave
MERIS - Medium Resolution Imaging Spectrometer
MIMR - Multiband Imaging Microwave Radiometer
MISR - Multi-angle Imaging Spectrometer
MOBILHY - Mobilisation du Bilan Hydrique
MODIS - Moderate Resolution Imaging Spectrometer
MSU - Microwave Sounding Unit
NASA - National Aeronautics and Space Administration
NASDA - National Space Development Agency of Japan
NCAR - National Center for Atmospheric Research (U.S.A.)
NESDIS - National Environmental Satellite, Data and Information Service
NMC - National Meteorological Center
NOAA - National Oceanic and Atmospheric Administration
NSCAT - NASA Scatterometer
NWP - Numerical Weather Prediction
OLR - Outgoing Longwave Radiation
POLDER - Polarisation and Directionality of Reflectances
RA - Radar Altimeter
RMS - Root Mean Square
SAR - Synthetic Aperture Radar
SBUV - Solar Backscatter Ultra-Violet instrument
SCANSCAT - Scatterometer
SCARAB - Scanner for Radiative Budget
SiB - Simple Biosphere Model
SMMR - Scanning Multichannel Microwave Radiometer
SRB - Surface Radiation Budget
SS - Space Shuttle
SSM/I - Special Sensor Microwave Imager
SST - Sea-Surface Temperature
SSU - Stratospheric Sounding Unit
SVAT - Soil-Vegetation-Atmosphere Transfer
SW - Shortwave
TOGA - Tropical Ocean-Global Atmosphere programme
TOMS - Total Ozone Mapping Spectrometer
TOPEX - Ocean Topography Experiment
TOVS - TIROS Operational Vertical Sounder
TRMM - Tropical Rainfall Measuring Mission
VOS - Voluntary Observing Ship

WCRP	-	World Climate Research Programme
WENPEX	-	Western North Pacific Cloud-Radiation Experiment
WGNE	-	Working Group on Numerical Experimentation
WMO	-	World Meteorological Organization
WOCE	-	World Ocean Circulation Experiment
WWW	-	World Weather Watch
XBT	-	Expendable Bathy-Thermograph
XCTD	-	Expendable Conductivity, Temperature and Depth

1. OPENING OF THE SESSION

The third session of the JSC Scientific Steering Group (SSG) for the Global Energy and Water Cycle Experiment (GEWEX) was opened at 9:00 a.m. on 21 January 1991, at the Hamilton Princess Hotel in Hamilton, Bermuda, by the Chairman, Dr. M. Chahine. The names and addresses of meeting participants are given in Appendix A. The agenda for the meeting is given in Appendix B.

The Chairman described the background for the meeting by calling attention to the many uncertainties in climate predictions especially with regard to the timing, magnitude and regional patterns of climate change and especially changes in precipitation. The impact of these uncertainties and the difficulty in reducing their influence on climate predictions has been clearly exhibited in recent analyses of large-scale environmental phenomena. Dr. Chahine concluded his opening remarks by focussing on the specific objectives of GEWEX which are to improve the knowledge of the processes at work in the "fast climate system" (the atmosphere, land surface and upper-ocean) and to provide the means to model these processes more effectively. Expectations are that GEWEX will provide an order of magnitude improvement in the ability to model global precipitation and evaporation, as well as an accurate assessment of the sensitivity of atmospheric radiation and clouds to climate change.

The Chairman then summarized national and international developments related to the planning of GEWEX, which have occurred since the second session of the GEWEX-SSG held in Paris, France, 15-19 January 1990. The Scientific Plan for GEWEX has been completed and distributed. Both an International GEWEX Project Office and a U.S.A. GEWEX Programme Office have been established in Washington, DC and it is confirmed that the central focus of the GEWEX build-up phase will be the GEWEX Continental-Scale International Project (GCIP) in the Mississippi River Basin of the U.S.A. The need for a number of detailed process studies of land surfaces and hydrology, cloud systems dynamics and cloud-radiation interactions was recognized. Two workshops one on water vapor and anoter on temperature/humidity retrieval were held in 1990. Several global data collection projects for clouds, radiation and precipitation are being designed to lead toward a GEWEX Global Observing phase in the late 1990's. Also of interest since the last SSG meeting was progress in the development of relevant satellite missions and in the definition of the relationship with other WCRP and ICSU activities, especially the International Geosphere Biosphere Core Project on the Biospheric Aspects of the Hydrological Cycle (BAHC).

2. REVIEW OF RELATIONSHIPS WITH OTHER WCRP AND ICSU ACTIVITIES

2.1 WMO/ICSU Joint Scientific Committee (JSC)

The Director of WCRP, speaking on behalf of the Chairman of the JSC, reviewed the recommendations of the Committee at its Eleventh Session (Tokyo, Japan, 5-10 March 1990) concerning GEWEX.

The JSC stressed the fact that support of GEWEX objectives in the international science community had grown in the past year because of the perception of the importance of tying together various aspects of climate and global change research relating to atmospheric energetics and hydrological and biological processes. The GEWEX Science Plan published by the GEWEX-SSG reflects that perception. The plan, covering the GEWEX build-up phase has

given impetus to refining the remote measurement techniques necessary for GEWEX purposes and to essential modelling and field studies that are required to exploit the next generation earth observing system to be implemented in the late 1990's.

The importance of expanding hydrological studies has been recognized, since the inception of GEWEX, as an essential step towards global models. The JSC has endorsed the concept of the GEWEX Continental-Scale International Project, recognizing that it would constitute a scientifically meaningful study of energy and water fluxes between atmosphere and land surface and a logical intermediate step in the development of the required global data management and assimilation schemes, leading to a future global Data and Information System.

2.2 Co-operation with the IGBP Core Project on the Biospheric Aspects of the Hydrological Cycle (BAHC)

The requirements for international programmatic linkages were discussed at length during the SSG session. The Group was informed that the intent was for BAHC to develop two main scientific thrusts:

(i) Long-term single-site studies of vegetation processes, including geo-biochemical fluxes and soil properties, in relation with activities of the IGBP core Project on Global Change and Terrestrial Ecosystems (GCTE);

(ii) The further development of hydrological-meteorological field studies on scales relevant to the investigation of dynamical and energy exchange processes undertaken by GEWEX.

Other specific projects of the BAHC would include the development of a "weather generator" aiming to simulate the variability and diversity of meteorological parameters of interest mainly realistic precipitation intensities for the development of ecosystem dynamics models and for climate impact studies, corresponding to given mean climate conditions, and the development of a global land-surface vegetation data set and (multi-parameter) map.

In the context of the GCIP presentation (see item 6), the potential for co-operation with the BAHC was discussed in more detail. The group noted a fairly clear difference of scientific emphasis between the studies of physical atmospheric-hydrological processes, in which atmospheric boundary layer (ABL) dynamics play a major role on the one hand, and the micro-scale studies of biospheric and biogeochemical processes on the other. The Group concluded that there was no scientifically compelling reason to combine the activities of GEWEX with those of the BAHC. Their considerations provided a clear basis for including in the overall objectives of GCIP the investigation of hydrological processes down to scales of about 10 km, where mesoscale ABL circulation systems become relevant, and the collection of all relevant data including appropriate documentation of the distribution and characteristics of vegetation.

The group, therefore, recommended that further co-ordination of GEWEX and BAHC should be pursued through the existing WCRP/IGBP Joint Working Group on Land Surface Experiments, chaired by Dr. J.C. André. A summary of Dr. André's comments on the progress of the Joint Working Group's activities is presented in item 7.

2.3 Co-operation with the International Association of Hydrological Sciences/World Meteorological Organization (IAHS/WMO) Working Group for GEWEX

The briefing was presented by Professor Gert A. Schultz, Chairman of the IAHS/WMO Working Group for GEWEX.

(i) Macroscale hydrological model development in support of GEWEX

It has been a long-standing proposal by hydrologists to create a pilot project for the development of macro-scale hydrological models in support of GEWEX. This proposal has now been developed by GEWEX into a major continental-scale field project, including hydrology, meteorology and perhaps some oceanography. The GEWEX Continental-Scale International Project (GCIP) in the Mississippi River basin is seen by the IAHS/WMO working group as the most attractive scientific initiative to foster and support the development of macroscale hydrological models driven by, or interacting with atmospheric general circulation analyses and models (GCMs). Further macro-scale hydrological modelling efforts proposed in Europe are outlined in item 10.2.

(ii) Methodology of precipitation measurement

The IAHS/WMO Working Group reported in 1990 its work toward improving the precision of precipitation measurements. A project led by Dr. Boris Sevruk (ETH, Zurich, Switzerland) had led to an "International Workshop on Precipitation Measurement" in December 1989. Further consultations are planned to discuss methodologies in relation to GEWEX precipitation data requirements.

(iii) Evaluation of methods for estimation of areal evapotranspiration

Another ongoing effort which could contribute to GEWEX is a project to intercompare existing schemes for estimating areal evapotranspiration, which is being conducted by the WMO Commission for Hydrology (CHy).

(iv) Global Runoff Data Center (GRDC)

Surface runoff is the hydrological parameter which can be measured with the highest degree of accuracy. For the purposes of comparing with GCM products, however, the runoff data collected as values from river gauges must be transformed into grid point values. Following a recommendation by the IAHS, the Global Runoff Data Center (GRDC) in Koblenz, Germany, will study this problem from a theoretical point of view. The SSG strongly endorsed this proposal.

(v) Models for assimilation of space based observations for validation of hydrological models

The IAHS/WMO Working Group meeting in Lausanne concluded that this project could be subsumed by GCIP.

A summary of the specific suggestions and recommendations which Professor Schultz presented to the SSG on behalf of the IAHS/WMO Working Group for GEWEX is given in Appendix C.

Dr. A. Hollingsworth, European Center for Medium Range Weather Forecasts (ECMWF), suggested that the hydrological modelling efforts be coupled with the atmospheric model development activities since four-dimensional assimilation of atmospheric and hydrological data may be expected to yield the most relibale estimations of energy and water fluxes which cannot be measured directly over extensive areas, i.e. net surface radiation, evapo-transpiration, precipitation, etc. The SSG agreed that macro-scale hydrological model development will be a most significant contribution of the IAHS Working Group to GEWEX. In order to assist with this IAHS undertaking, it was agreed that GEWEX will sponsor two joint WCRP/IAHS workshops to review and compare the hydrological codes in existing atmospheric circulation models. The proposed venues were, for the first ECMWF, Reading, U.K. in late 1991, and for the second, the IAHS Assembly in Tokyo in 1993.

The specific agenda of the 1991 workshop will be:

(i) To present the current status of macroscale meteorological modelling;

(ii) To review the current formulations and performance of hydrological codes in atmospheric circulation models and climate models, as well as ideas for assimilating hydrological data (e.g. use of rain data to modify soil moisture);

(iii) To formulate an 18-month workplan to document, evaluate and improve the formulations used in atmospheric circulation models.

An important purpose of this workshop is to offer to the hydrological community a convenient opportunity to familiarize themselves with GCMs and current data assimilation systems to be applied in GEWEX.

3. INTERNATIONAL GEWEX PROJECT OFFICE

The establishment of the International GEWEX Project Office (IGPO) in Washington, DC , U.S.A., was an essential step to expedite the implementation of the programme. The Project Office has received strong support from the Division of Earth Science and Application of the U.S.A. National Aeronautics and Space Administration (NASA) and the Office of Ocean Climate and Atmospheric Research of the U.S.A. National Oceanic and Atmospheric Administration (NOAA). A formal exchange of correspondence with the Permanent Representative of the U.S.A. has been initiated to confirm a commitment of the U.S.A. to:

(i) be the host country for the Office;
(ii) provide seconded professional staff persons to serve on a full time or part-time basis in the IGPO;
(iii) provide secretarial support and office accommodations for the Office
(iv) support local operating costs including telecommunications, office supplies and local travel (while international travel expenses will be covered by the Joint Climate Research Fund).

Dr. Paul Try has been nominated to be the Director of the IGPO. Details of Dr. Try's report on the current status of the Office are presented in Appendix D.

4. REVIEW OF SATELLITE MISSIONS RELEVANT TO GEWEX

The SSG was briefed on current plans of space agencies for future earth observation satellite missions. The Group was gratified by the progress made toward the development of the polar orbiting component of the space-based observing system for global change and climate research. This system will combine the NASA, ESA, and NASDA polar platforms and other related missions, such as the Tropical Rainfall Measurement Mission (TRMM), Earth Probes, etc., being planned for launch in the 1990's. The Steering Group, however, reaffirmed the crucial importance, for climate research and predictions, of two still missing components of the observing system:

(i) quasi-global or global wind measurements at all levels, as would be provided by the LAWS doppler lidar system;
(ii) non-sun-synchronous observations of radiation fluxes, clouds, and rainfall (TRMM and related follow-on missions).

4.1 WCRP Planning Meeting on Earth Observing Systems for Climate Research

The Steering Group perception, based on information provided at the recent WCRP Workshop on Space Observing Systems for Climate Research (WCRP-46), was that the gap now existing in current plans for winds, clouds, rainfall and radiation fluxes measurements from space could be filled, in the late 1990's, by a single GEWEX-dedicated satellite mission in a 55-60° orbit carrying a combined LAWS and radiation-cloud-rain measurement payload. Alternatively, the same observations could be obtained by means of a combination of smaller spacecraft.

In summarizing the Group's comments, the Chairman acknowledged the commitment by NASA to examine with other space agencies how these requirements could be fulfilled, either by an international GEWEX-dedicated space mission, or by a combination of specialized satellites, before the end of the century.

4.2 Statement by the representatives of the European Space Agency (ESA)

ESA's long term strategy in earth observation is focussing on four major themes:

(i) monitoring the earth environment;
(ii) monitoring and managing the earth's resources;
(iii) improvement of operational meteorology;
(iv) solid earth studies.

The programme is being implemented by means of a series of programmes. The European Remote Sensing Satellites ERS-1 and ERS-2 are the precursors to the ESA Polar Platform Programme. ERS-1 scheduled for launch in May 1991 will carry a scatterometer, radar altimeter and a synthetic aperture radar operable in both a wave mode and an image mode. Also included are an Along Track Scanning Radiometer (ATSR) and a micro-wave sounding instrument.

ERS-2 has been approved for a launch in principle during the second half of 1993. The satellite will be identical to ERS-1 with a slightly enhanced ATSR instrument and the addition of a Global Ozone Monitoring Experiment (GOME) sensor.

With these programmes well underway ESA's plans for the Polar Platform Programme are proceeding in parallel with two series of missions using the same spacecraft modular design. The modular approach is meant to accomodate relatively small as well as large payloads (up to 2400kg) and their power, communications and other resource requirements, as could be expected for an extensive period into the next century. The initial M-platform series has a three part payload, including an operational meteorological package, core facility payload instruments; and principal investigator instruments (to be selected at the outcome of the announcement of flight opportunity). Details are given in Appendix E.

4.3 National Space Development Agency of Japan (NASDA)

A scientific ad hoc committee of more than 70 investigators in earth system science have reviewed Japan's plans for an earth observation programme to be implemented in the late 1990's. The committee's recommendations gave highest priority to global and continuous observation of the earth from sun-synchronous polar orbit. The first polar platform mission will include only two major instruments: an advanced microwave scanning radiometer and a visible and infrared imager. Original plans to fly an experimental LIDAR were abandoned for this first mission. The committee did, however, recommend the measurement of essential climate parameters, such as wind field, precipitation and radiation, as the next highest priority for a further non-sun-synchronous satellite mission which would provide appropriate sampling of the diurnal cycle.

A list of candidate instruments for Japan's polar-orbiting platform programme is included in Appendix F with a brief description of each instrument.

4.4 National Aeronautics and Space Administration (NASA)

Final selection of the scientific payload for NASA's first Earth Observing System (EOS) mission EOS-A has been made. This line of large polar platforms planned by NASA will focus on the observation of global hydrological processes in the atmosphere, related radiation and cloud processes and land surface properties. The earliest launch date for EOS-A1 launch is now set in 1998. A list of selected instruments and a summary of NASA's ongoing earth observation programme is given in Appendix G.

The preparation of the joint Japan-U.S.A. Tropical Rainfall Measuring Mission (TRMM) is also being actively pursued. This mission is planned for a 1996 or 1997 launch (see item 9.2).

5. OCEANIC ENERGY AND WATER BUDGET STUDIES FOR GEWEX

The Group recognized the high scientific value of investigating the dynamics and thermodynamics of the coupled global atmosphere and ocean system, in order ultimately to predict climate variations by means of interactive models of the earth climate system and assimilation of global ocean and atmospheric data. The GEWEX-SSG further agreed that upper ocean observations, although not envisaged as a component of GEWEX initially, would provide essential information for constraining atmospheric and surface fluxes of heat and freshwater over the 70% of the earth's surface covered by the ocean.

Dr. K. Bryan, NOAA Geophysical Fluid Dynamics Laboratory, Princeton University, and Dr. R. Schmitt, Woods Hole Oceanographic Institution, briefed the group on the role of buoyancy forcing, caused by heat and fresh water inputs, in determining the circulation of the world ocean, and its consequences for global climate.

The role of fresh water inflow is most significant at high latitudes where surface temperatures are near the freezing point. In such locations, salinity rather than temperature controls the stratification near the ocean surface. Paleoclimatological data indicate that low frequency changes in salinity may have had important effects on the thermohaline circulation of the northwest North Atlantic. A cap of fresh water can strongly limit the depth of convective cooling, insulating the deeper waters from surface influences. Recent data describe a similar several-year reduction of deep convection by a large-scale, low-salinity anomaly in the North Atlantic. This shut-down of deep water renewal would limit the northward transport of warm surface waters which is a significant heat source at high latitudes. A possible source of fresh water which could generate the observed salinity anomaly is the export of sea-ice from the Arctic basin. For this reason, understanding the relative contributions of precipitation, run-off, ice-melt and sea-ice transport in the North Atlantic freshwater budget is a key climatological issue. Furthermore, strong local gradients in evaporation minus precipitation, and large seasonal variations may force a variety of oceanic responses in middle and low latitudes on timescales of many years.

The SSG reaffirmed the importance, for the study of ocean dynamics, of improving the determination of energy and water flux across the ocean-atmosphere interface and computing such fluxes reliably in climate models. The group further recognized the importance for GEWEX of acquiring sufficient surface and near surface salinity and temperature data to close the energy and freshwater budget (E-P) in the ocean, in order to provide a check on GEWEX derived fluxes over oceanic areas. As an initial response, the group endorsed the following proposals taken from Drs Bryan and Schmitt:

(i) Undertaking the development of a practical automatic salinity-measuring instrument for unattended operation on ships of opportunity;

(ii) Undertaking a pilot project to monitor surface salinity based on conventional measurements by voluntary observing ships (VOS) crossing the Atlantic;

(iii) Revisiting the estimations of the atmospheric heat and water budgets, based on operational meteorological analyses, for the purpose of estimating the divergence of freshwater and heat fluxes over the North-Atlantic basin (following the approach of the 1982 CAGE study).

At the request of the group Dr. Bryan agreed to assist in the formulation of the concept of a global climate variability research and prediction programme that would include the long-term science perspectives for further WCRP oceanographic activities following on the TOGA and WOCE programmes.

6. GEWEX CONTINENTAL-SCALE INTERNATIONAL PROJECT (GCIP)

The GEWEX Continental-scale International Project is considered as an essential component of the GEWEX science strategy to study the energy and water fluxes between atmosphere and land surface, and a logical intermediate step in the development of future global data and information systems. The GCIP will permit the systematic testing of atmospheric and hydrological models over an area covering the Mississippi river basin for a minimum of 5 years. This will provide the means to inter-compare the detailed performances of models under realistic time-dependent conditions, to ascertain their sensitivity to various possible estimates of forcing fluxes and to determine the degree of similarity with observed hydrological quantities (e.g., river runoff data). The continental-scale project will also facilitate the early development of global algorithms by acquiring, in a more limited area, many of the global data sets which are planned to be produced in the polar platform era of the late 1990's.

The choice of the Mississippi River Basin in the U.S.A. was guided by existing (approved) plans for an extensive upgrading of operational meteorological and hydrological networks covering the continental U.S.A., including the NEXRAD doppler radar system (see Figure 1), wind profilers and automatic weather stations operated by NOAA. It is believed the forthcoming aerological and hydrological network developments by NOAA will provide the best opportunity for collecting the required data sets to provide a meaningful scientific insight in coupled hydrological-atmospheric processes on a scale representative of climate-model results, and ground-truth for space-based estimates of precipitation, moisture, wind and other climate parameters. The principal goal of the project is to establish a bridge between scales which are significant in modelling individual processes of the hydrological cycle over land, and the scales at which it is practical to model the climate system for predictive purposes. Equivalent data are not likely to be available elsewhere on a similarly large-scale within the same timeframe, although the SSG stressed that scientific results of parallel efforts conducted in other areas would also be applicable.

The international workshop on GCIP, held in Reston, Virginia, in October 1990, produced a draft Science Plan which was reviewed by the GEWEX-SSG. The tentative schedule for further activities is as follows:

- Science Plan completed by mid-1991;
- Implementation Plan completed in early 1992;
- Announcement of opportunity (or equivalent) cycle ending in late 1992;
- Build-up phase between early 1993 and late 1994;
- Intensive observation phase from early 1995 when the NEXRAD network will be reasonably complete until start of GEWEX Global Observation Phase corresponding to the launchings of the U.S., European and Japanese polar platforms.

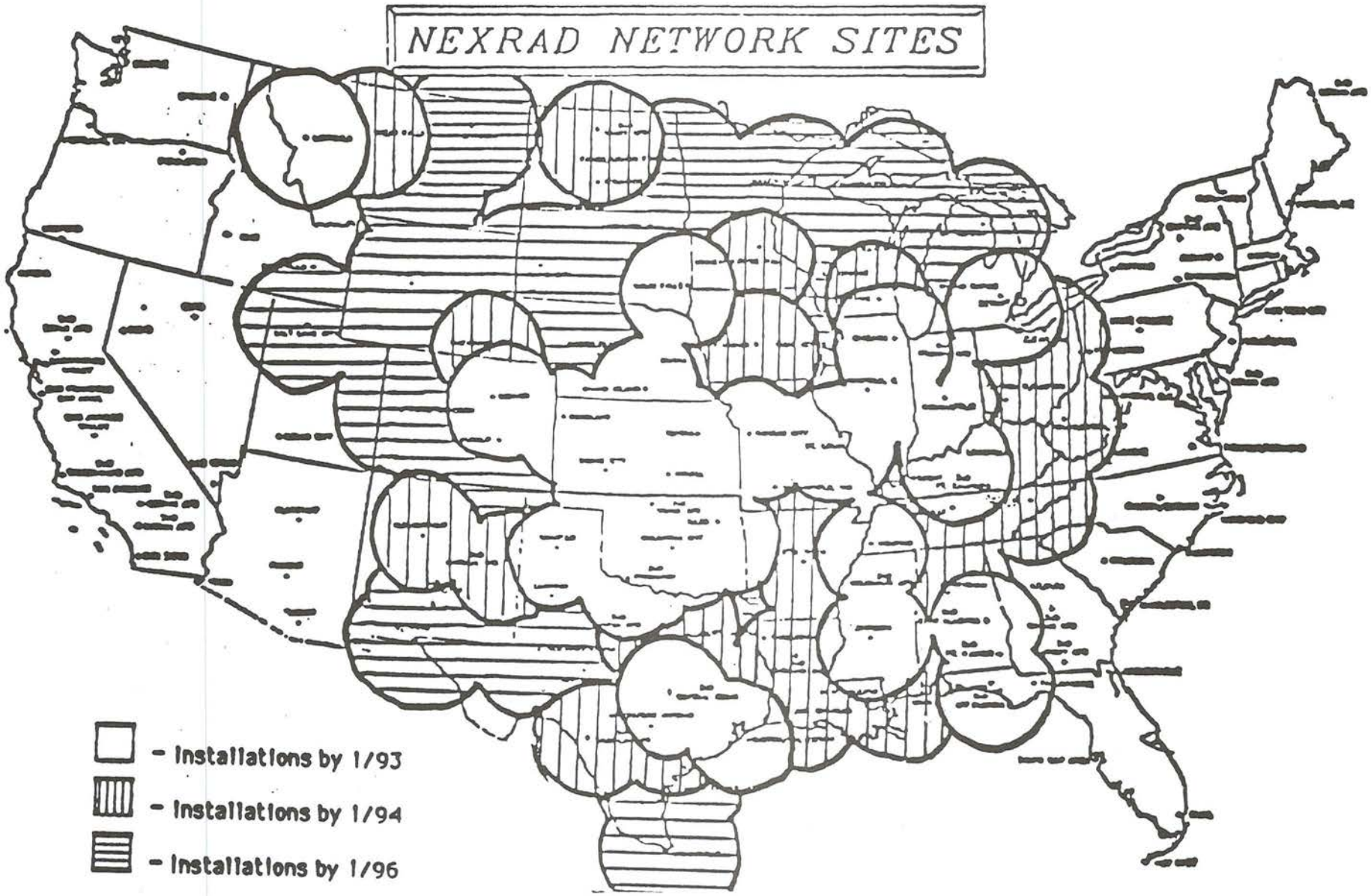

Figure 1. USA Nexrad Network Sites Planned within GCIP Area of Interest

In the ensuing GCIP discussion the SSG agreed that the relatively simple formulations of the role of vegetation in evapotranspiration as now embodied in "simple biospheric models", was probably adequate to consider the agregation of water and energy fluxes from mesoscale to GCM's grid scales. From the findings of the HAPEX-MOBILHY experiment, it appeared that the most significant contribution to variability on scales 10-100 km was associated with physical inhomogeneities in river catchment geometry, terrain properties, gross vegetation cover, rainfall and atmospheric mesoscale circulations. On those scales, local inhomogeneities in the range 1 to 10 km are amenable to weighted linear averaging, since they do not ellicit further non-linear feedbacks through driven mesoscale atmospheric circulations. This constatation provided the basis for orienting GCIP science objectives toward the study of processes on scales of 10 km and larger, while at the same time collecting relevant vegetation cover data.

The SSG also discussed the organizational structure of GCIP (see Figure 2), and especially, the proposed arrangement for scientific steering of the Project and co-ordination of international scientific views through a GCIP Science Panel. The Panel would be chaired by Dr. John Schaake of the National Oceanic and Atmospheric Administration, supported by leading experts from around the world in the fields of hydrological and atmospheric modelling, process studies, data analysis and data collection and management. Candidate members of the team were identified at the meeting (see figure 3) and the SSG recommended that action be taken to notify the proposed members and confirm the initial team structure by mid-March.

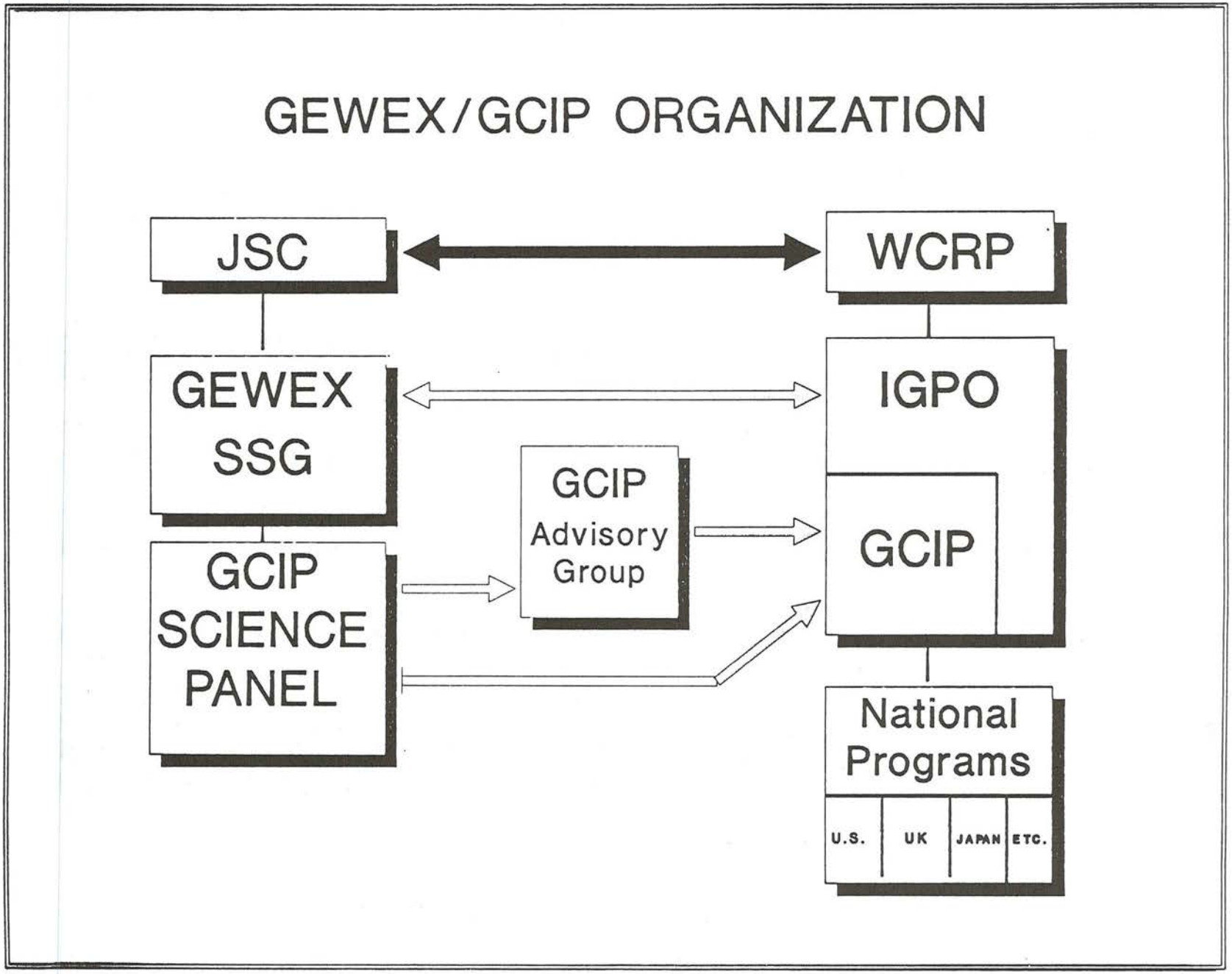

Figure 2. GEWEX/GCIP Organizational Structure

GCIP SCIENCE PANEL (GSP)

EX OFFICIO MEMBERS	HYDROLOGIC MODELLING	ATMOSPHERIC MODELLING	PROCESS STUDIES	DATA ANALYSIS	DATA COLLECT & MGMT
J. THEON (USA)	G. SCHULTZ (GERMANY)	P. ROWNTREE (UK)	P. SELLERS (USA)	E. RASMUSSEN (USA)	J. SMITH (USA)
M. COUGHLAN (USA)	R. BRAS (USA)	A. HENDERSON-SELLERS (AUSTRALIA)	J.C. ANDRÉ (FRANCE)	A. HOLLINGSWORTH (ECMWF)	E. NJOKU (USA)
P. TRY (USA)	R. GURNEY (UK)	K. LAVAL (FRANCE)	T. TAKEDA (JAPAN)	E. KALNAY (USA)	D. RENNÉ (USA)
D. VANE (USA)	E. ENGMAN (USA)	J. SHUKLA (USA)	S. SOROOSHIAN (USA)	J. SCHAAKE, CH. (USA)	A. GRUBER (USA)
H. LINS (USA)	R. LAWFORD (CANADA)	L. DUMENIL (GERMANY)	R. DICKINSON (USA)	T. CHARLOCK (USA)	G. LEAVESLEY (USA)
S. BENEDICT (WMO-WCRP)			E. RASCHKE (GERMANY)	A. OHMURA (SWITZERLAND)	
H. BOLLE (GERMANY)					
TBD (USSR)					

Figure 3. GCIP Science Panel Composition

7. HYDROLOGICAL-ATMOSPHERIC FIELD EXPERIMENTS

The Steering Group was briefed by Dr. J.C. André on the findings of the IGBP/WCRP Working Group on Land Surface Experiments. The working group held its first session 25 to 26 January 1990 in Wallingford (U.K.) at the invitation of the Institute of Hydrology (see WCRP-38). The initial topic of discussion at the meeting was the optimal design of future land-surface experiments, in the light of what had been learned during the HAPEX-MOBILHY and FIFE programmes. The Group concluded that it would be most helpful to have scale-1 (i.e. 10 km) and scale-2 (i.e. 100 km) components in future programmes. Scale-1 activities are better suited for detailed process studies of the interaction between the atmosphere, the vegetation and the surface hydrology, and are likely to be used as the basis for long-term studies of interest to plant physiology and ecology studies. Scale-2 field phases, of shorter duration than those at scale-1, are specifically designed to achieve GEWEX objectives on meso-scale interactions between atmospheric and hydrological processes and on spatial up-scaling. Having embedded scales 1 and 2 activities will allow interactions in the field between teams oriented toward either vegetation and biospheric processes or atmospheric and hydrological physical processes.

The Working Group considered plans for three major experiments being planned in the near future: HAPEX-SAHEL (1992), EFEDA-Spain (1994) and the Boreal Forest Study (1994). In subsequent discussions, it was decided that it was desirable to include a Tropical Rain Forest Experiment (1996) in Brazil to the Land-Surface Experiments plan. Each of these experiments (with the exception of the Rain Forest study) had both Scale 1 (10km) and Scale 2 (100km) components and each addressed an important climatic regime. A lack of detailed information prevented any discussion about similar experiments in the U.S.S.R. It was hoped that these activities could be addressed during the second meeting scheduled for 3-4 June 1991 following the AGU meeting in Baltimore, Maryland.

8. GEWEX CLOUD AND RADIATION RESEARCH ACTIVITIES

8.1 Multi-region Cloud Systems Study

The JSC agreed to co-sponsor a workshop to develop the scientific concept of a Multi-region Cloud System Study as proposed by the GEWEX-SSG in its January 1990 meeting. It is common knowledge that clouds and cloud systems are inadequately represented in atmospheric circulation models. As a result of these inadequacies the interactions of clouds and radiation, for example, are not properly reproduced by GCM's and climate models. There is also a need to improve the simulation of precipitation, including the vertical distribution of latent heat, by focussing on the mesoscale and smaller scale processes responsible for much of the heavier rain, and to improve the formulation of other important dynamical processes including the vertical transport of heat, water vapour and momentum by convective clouds, interactions between convective clouds and surface fluxes, etc. An integrated modelling and observational approach has been proposed to address these deficiencies.

The aim of the modelling, which will include very fine mesh numerical simuation with gridscales down to 1 km or less, is to improve understanding, provide synthetic data for parameterization development and testing, and to assess how results can be generalized for different types of cloud systems in different regions and seasons. The aim of the observations is to test hypotheses related to parameterization development and to provide anchor points for evaluating the credibility of the very fine mesh cloud system models.

A set of archetypal cloud system realizations on a 1 km grid would be developed for convective systems in low and high latitudes, over ocean and continents, to aid the development of parameterization schemes for larger-scale models that cannot resolve convection. Such realizations would also aid the development of algorithms for space observing techniques.

The SSG has endorsed this approach and asked Dr. Browning to proceed with efforts to organize a Cloud System Science Team that will produce a detailed Science Plan. The purposes of the plan are primarily to:

(i) Promote the scientific approach, based on cloudscale modelling of convective and other cloud processes, rainfall, radiation and related physical properties and ABL processes.

(ii) Indicate potential data sources from planned field studies or campaigns of opportunity (such as TOGA COARE and GCIP) and identify gaps in observational field programmes.

8.2 Radiation Projects in the Context of GEWEX

The SSG reviewed briefly the progress made in the various WCRP radiation projects of interest to GEWEX, including the International Satellite Cloud Climatology Project (in relation with GEWEX's multi-region cloud study),

earth radiation budget measurements at the top-of-the-atmosphere (e.g. ERBE and follow-on programmes) and the Surface Radiation Budget project, including the long-awaited development of a WCRP Baseline Surface Radiation Network. The Group noted that radiation transfer processes constituted an essential aspect of the global energy budget and that proper formulation of radiation fluxes, in the presence of various atmospheric constituents and clouds, was an integral part of the GEWEX science goals. The studies, undertaken by GEWEX, to characterize and predict the thermodynamical and optical properties of cloud systems call for closer co-operation with WGNE on modelling studies and ISCCP on cloud observations. An important consideration is the further improvement of cloud diagnostic methods, taking advantage of new instrument developments being implemented for EOS.

The Group agreed that, although the first attempts to refine the formulation of the cloud-radiation feedback in climate models have been mostly based on "cloud-forcing" information deduced from ERBE data, the time will soon come when more complete cloud-distribution information, such as provided by ISCCP, could be applied for further work. A related topic is identifying means to acquire reliable water vapor concentration statistics at all levels of the atmosphere (especially around tropopause level where the greenhouse effect of water molecules is most significant).

Furthermore, determining the time-dependent area-averaged net radiation flux at the earth surface (over oceans as well as over land) is an essential GEWEX requirement to develop better determinations and predictions of evaporation and sensible heat fluxes. The Group was briefed on progress made toward systematic production, at Langley Space Research Center, of a monthly-mean shortwave (solar) surface radiation flux climatology derived from the global ISCCP visible radiances data set. To a fair degree of approximation, solar radiation incident upon the surface is that which has not been diffused upward by the cloud deck and is therefore highly correlated with the planetary albedo measured by satellites.

This does not apply to longwave (earth) radiation, however, as IR radiances measured at TOA are essentially independent of longwave radiation fluxes between the surface and the lower layers of the atmosphere (or cloud-base). It is therefore to be expected that estimation techniques, based on remote sensing information only, are bound to fail. The SSG considered there was little point in pursuing, at the present stage of space instrumentation, the search for alternate remote-sensing techniques to estimate the incident or net longwave radiation at the surface, and that the most promising approach would be to infer the net IR radiation from the best available analysis of meteorological fields, as done for the sensible and latent heat fluxes. A degree of optimism is allowed in view of the relatively small values and limited space-time variability of the net IR radiation flux, compared to the highly variable solar radiation flux reaching the surface.

In consideration of the breadth and multi-disciplinary nature of atmospheric radiation issues confronting GEWEX, the SSG expressed the wish to take direct responsibility for WCRP Radiation Projects directly relevant to GEWEX and accordingly, to complement the range of scientific expertise available to the Group by adding two to three appropriate atmospheric

radiation experts to its membership. The SSG recognized that taking this step would not, by a considerable margin, exhaust the range of important radiation physics problems in climate research and that further consideration of these problems would still be needed by an appropriate WCRP Working Group on Radiation Science or through closer co-operation with the IAMAP International Radiation Commission.

8.3 Temperature and Water Vapour Retrievals

The accuracy of atmospheric temperature and humidity profiles inferred from satellites observations was assessed by a workshop, held in Greenbelt, Maryland, 23 to 26 October 1990, which was attended by more than fifty scientists. The workshop identified the steps that could be applied to improve the accuracy of current retrieval by improved algorithms, using existing observations and appropriate ancillary data. The proceedings of the workshop are currently being drafted by the International GEWEX Project Office.

In a related but separate effort, a workshop on the Role of Water Vapor in Climate was held under the auspices of GEWEX in Easton, Maryland, from 30 October to 1 November 1990. The workshop proposed a "GEWEX Water Vapor Research Project" to improve the measurements of atmospheric water vapor and its impact on meteorological, hydrological and climatological processes. After discussion concerning the definite need for good water vapour data and the potential for success of the proposed GEWEX Water Vapour Project (GVaP), the SSG endorsed the implementation of a GVaP Pilot Study with the objectives below and recommended co-ordination of the efforts of interested scientists and government agencies through an international Science Panel. The initial objectives for the GVaP Pilot Study are:

(i) Intercomparison of water vapour measurements from balloons with results from active and passive remote sensing techniques, including ground-based, airborne and spaceborne observations. This activity is being designed to result in improved standards of measurements.

(ii) Establishment of one or two ground-based reference stations (Raman Lidar) for long-term observation of temporal variations of water vapour over given locations, to help understand water vapour variability and validate satellite retrievals.

(iii) Compilation of an experimental global water vapour data set, including total column precipitable water (PW) and some information on vertical profiles, based on existing satellite observations.

8.4 ECMWF/WCRP Workshop on Clouds, Radiation Transfer and the Hydrological Cycle

Noting that two years of Earth Radiation Budget Experiment (ERBE) data, one year of International Satellite Cloud Climatology Project (ISCCP) C2 level data and five and a half years of ISCCP B3 data have been released during the last few months, the SSG was interested to learn how the climate modelling community envisaged the exploitation of these new radiation data sets over the next few years.

A WCRP-supported Workshop on Clouds, Radiation Transfer and the Hydrological Cycle was held at ECMWF, in November 1990, to compare experiences in using climatological datasets to improve the representation of clouds, radiation and the hydrological cycle in GCMs and in operational NWP assimilation/forecast systems. A striking result was the variety of ways in which the new satellite products are being used to validate not only the time mean ERB diagnostics, but also the spatial and temporal variability of the cloud fields, radiation fields and oceanic surface fluxes. Studies based on the direct comparison of derived model products with satellite measurements appeared the most promising approach.

Net radiation fluxes at the top of the atmosphere, as measured by satellites, provide an excellent first estimate of the quality of the simulation of the hydrological cycle in numerical models and have been widely used for this purpose. The clear sky radiative fluxes from ERBE are relevant for the validation of GCM radiation parameterizations and for validation of the thermal and moisture structures of the model atmosphere, as well as surface albedo and the parameterization of land and ocean temperature. However the uncertainties in the observed clear-sky fluxes need to be better documented on a regional basis. There is a 3-fold variation in the cloud-feedback factors estimated in experiments with 19 different atmospheric GCMs, from weakly negative to strongly positive. Different definitions of clouds and methods for calculating cloud forcing may also contribute to this assessment of the dispersion of model results.

There are large differences between TOVS and SSM/I monthly mean estimates of total precipitable water content over the sub-tropical and tropical oceans, which need to be resolved. There are also large uncertainties in current climatological estimates of cloud liquid water. However, this problem is simplified by the fact that modelled cloud optical depth can be directly compared with cloud optical parameters derived from ISCCP. Prognostic cloud schemes are highly sensitive to cloud microphysics in both the ice and water domains, and a better understanding of these processes is urgently required. Sensitivity of model parameterizations to spatial resolution also needs to be explored more fully. High resolution cloud system models with detailed dynamics and microphysics would also be quite valuable for interpretation of field measurements. The SSG concurred with the workshop proposal for a literature survey of existing cloud microphysical data. Documentation of this type would help provide reasonable limits within which the prognostic schemes should operate.

Short-time fluctuations (diurnal to a few days) were considered important in testing the response of cloudiness and convection to different radiative and dynamical forcing. Study of the diurnal cycle, as allowed by ISCCP data, was thought essential. While a full range of studies of variability of the radiation fields on periods of 1-10 days, 30-60 day waves and seasonal cycles also would constitute important tests of model performance. The broadband ERBE global dataset, can only be used with care since day to day variability had not been explicitely validated. It was concluded that the 3-hourly radiative fluxes from ISCCP could be used for this problem.

No consensus emerged from the workshop regarding the relative benefits of prognostic and diagnostic cloud parameterization schemes. The SSG was told that the workshop had emphasized physical uncertainties in the representation of cloud microphysics and underlined computational difficulties associated with the rapid variations of moist quantities in the atmosphere. There was general agreement, however, that prognostic cloud schemes hold promises for the future.

The list of recommendations issued by the workshop and under consideration by the radiation science community, included:

- Intercomparison of precipitation datasets
- Intercomparison of Surface Radiation budgets in models
- Limited re-assimilations, with state-of-the-art models, of periods with overlapping ERBE, ISCCP and FIRE data (e.g. Oct.'86, July'87)
- Formal archiving of FIRE, ICE, WENPEX, etc. data, thus making the data generally available
- Validation of total precipitable water estimates and cloud liquid water estimates (from TOVS, SSM/I, etc.)
- Investigation of biases in clear sky calculations, and better documentation of regional uncertainties in ERBE clear sky estimates
- Validation of diurnal variability models using ISCCP or ERBE data
- Development of prognostic cloud schemes and associated assimilation schemes.

9. RAINFALL MEASUREMENTS AND DATA

9.1 Global Precipitation Climatology Project (GPCP)

The Climate Analysis Center (Washington) has been producing precipitation maps in the tropical belt 40N-40S, based on estimates deduced from the analysis of infrared cloud cover imagery produced by geostationary satellites. Maps on a 2.5 x 2.5 degree grid are available for each 5-day period from 1 January 1986 through the end of September 1990. This activity is now operational and products are regularly available for distribution in digital form. The Goddard Space Flight Center has produced about 2 years of monthly precipitation analyses from SSM/I microwave (18 GHz) radiance data. They cover the oceanic zone 50N-50S only and are mapped on a 5 x 5 degree grid. The processing is now proceeding systematically. Finally, the Global Precipitation Climatology Centre in Offenbach is producing experimental rainfall maps based on raingauge station data using automatic and manual analysis processes.

The Algorithm Intercomparison Programme (AIP) was instituted, as part of the GPCP, to assess current rainfall retrieval algorithms against high-density in situ data (raingauge, digital radar). The first project was conducted over Japan during the period June-August 1989. The Japanese Meteorological Agency (JMA) has made available high resolution IR and visible data from the GMS satellite as well as corresponding JMA model precipitation forecasts and radar/raingauge validation data (see Figures 4 and 5). The Climate Analysis Center (Washington) added SSM/I observations and distributed the data to participating scientists around the world. Results were to be reviewed at a workshop on 22-24 May 1991.

The SSG concluded that the GPCP was making excellent progress in developing its calibration-validation programme. It reaffirmed the view that precipitation estimates derived from four-dimensional atmospheric data assimilation and rainfall forecasts with state-of-the-art NWP models have reached the stage where they could be combined with GPCP products to infer an optimal "blended" precipitation climatology data set for WCRP.

9.2 Rainfall Measuring Satellite Mission

Dr. J. Theon of NASA Headquarters reported on the status of the Tropical Rain Measuring Mission (TRMM). The objective of this joint project of the United States and Japan is to produce a 3-year data set of monthly averaged rainfalls, to 15% accuracy, each in 5 x 5 degree grid box for the portion of the Earth between 37N and 37S latitudes. TRMM is expected to make possible a significant advance in understanding the general circulation of the atmosphere by characterizing the essential process of latent heat conversion to buoyant force in tropical latitudes.

TRMM's instrument complement includes a rain radar, a microwave scanning radiometer and a visible and infrared imager that will make possible a precise quantification of rainfall. The spacecraft is expected to orbit at a nominal altitude of 350 km with an inclination of 35 degrees. Japan is to provide the precipitation radar and the H-II launch vehicle, while the U.S.A. will contribute the visible, infrared and passive microwave sensors. The acquisition of ground validation data is being co-ordinated over a variety of sites in Australia, Japan, Indonesia, Thailand, China, Israel, Kwajalein, the U.S.A. and possibly India. A research announcement process was begun in August 1990 and selected projects will be announced in the first quarter of 1991. A launch date in 1996 or 1997 is currently planned.

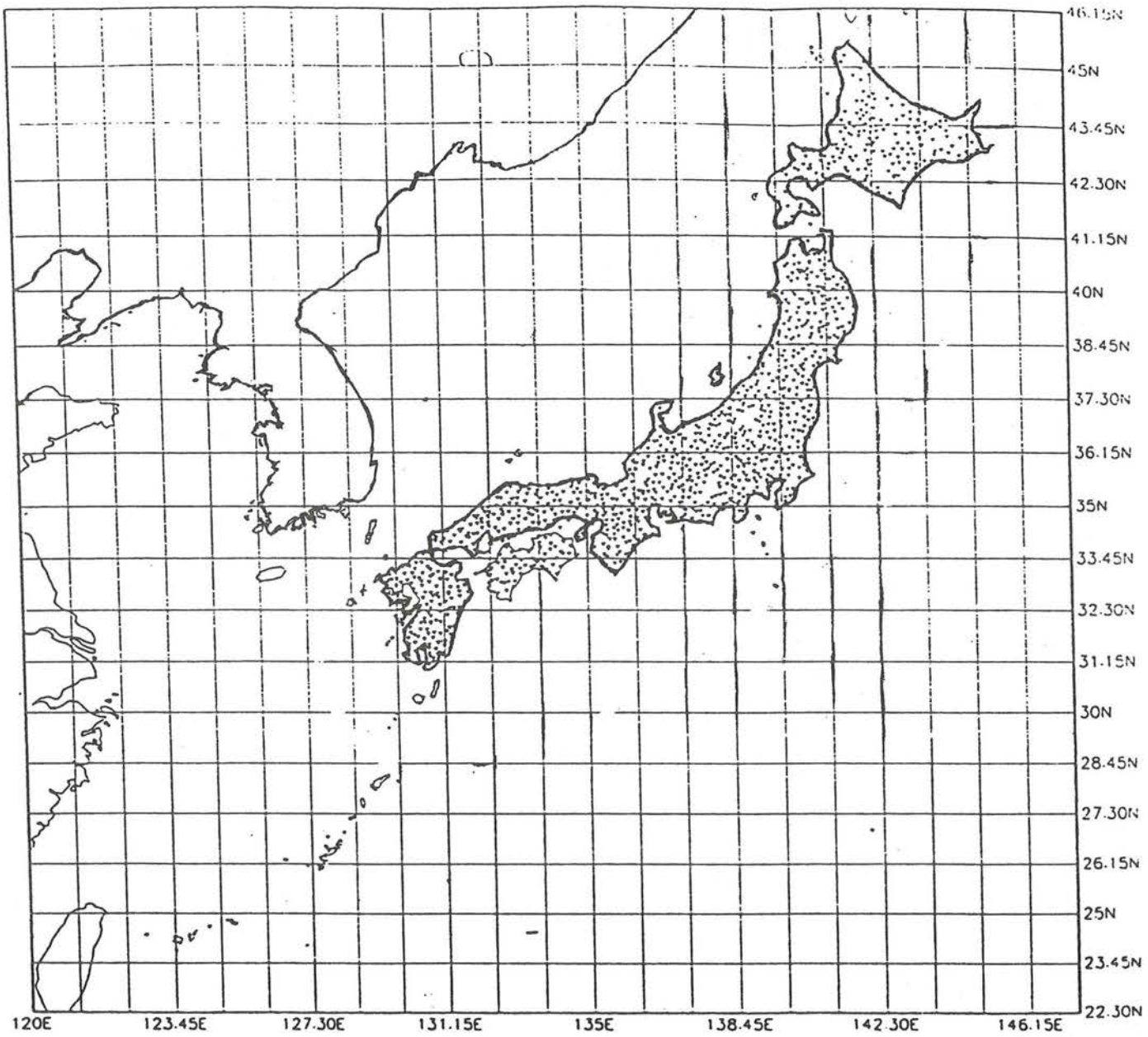

Figure 4. AmeDas: Automated Raingauge Data Network locations contributing to GPCP Algorithm Intercomparison Programme

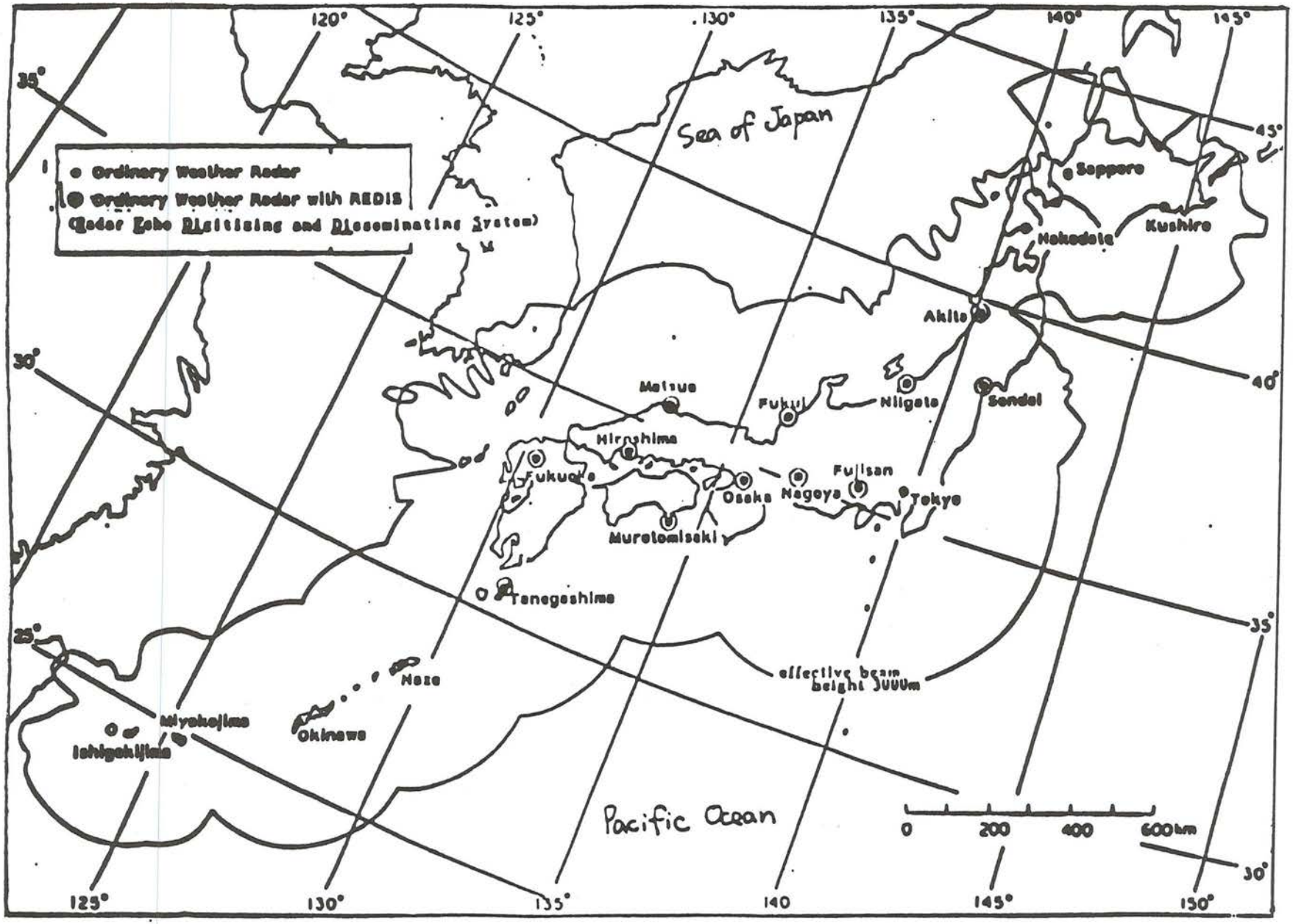

Figure 5. Weather Radar Network of JMA

10. GEWEX MODELS

10.1 Surface-Vegetation-Atmospheric Transfer (SVAT) Models

Current climate models contain excessive simplifying assumptions and neglect the quantitative effects of various feedback processes on surface-vegetation-atmosphere interactions. A more comprehensive approach integrating information from intensive field studies or large-scale analyses of aerological, radiation and hydrological fields with fine-mesh model products will be the preferred GEWEX methodology.

Nevertheless, use will also be made of state of the art one-dimensional SVAT schemes, even though the development of such models was not specifically considered part of GEWEX. The GEWEX/GCIP application of SVAT models will be based on the premise that hydrological processes on scales resolved by macro-scale hydrological or global climate models are mainly affected by physical inhomogeneities in precipitation, net radiation, soil properties, surface roughness, topography, etc. and relatively insensitive to the formulation of microscale vegetation processes.

Therefore, planning for GCIP modelling data acquisition/assimilation will include the elements needed to simulate all coupled atmosphere-surface processes on scales of 10 km or larger, including land cover data and type of vegetation, with the appropriate level of detail.

The SSG concurred with this concept and endorsed further collaboration between GCIP and SVAT modellers concerning the quantification of the hydrological properties of selected vegetation types and their role in energy and moisture exchanges. At the direction of the SSG, a proposal for a workshop on high resolution modelling and SVAT parameterization studies is being developed by the GCIP Project Scientist.

Dr. Dickinson observed that there is a great deal of interest in sharing algorithms and comparing computer softwares among land surface modellers, resulting in the incorporation of advanced interfacing schemes in the new Community Climate Model or CCM-2 of NCAR. The effort to characterize the fine spatial structure over land processes is reflected in various "up-scaling" schemes. For example, advanced mesoscale models are now being "embedded" in GCM's to investigate year to year differences in climate over a region as a function of the global GCM boundary conditions in that region. In a similar way, high resolution land maps are being placed "underneath" a GCM, so that integration over a large number of land sub-grid elements takes place before average exchanges with the atmosphere are computed.

Dr. Dickinson's remarks confirmed that continued improvement in SVAT schemes at the microscale level is necessary to develop more realistic area-averaged formulations for implementation in general circulation and climate models.

10.2 Macroscale Hydrological Modelling and Data Assimilation

The growing interest in the hydrological science community for the development of macro-scale models is concurrent with the planning of GCIP and therefore naturally focusses on hydrological modelling on the scale of large river catchments. The most ambitious projects will be related to the Mississippi basin study discussed in item 6. The SSG was briefed on the development of such macro-scale hydrological models by Professor G. Schultz.

One project is being organized by Austria, Switzerland, France, Germany, Belgium, Luxemburg and the Netherlands who together constitute the "International Commission for the Hydrology of the River Rhine" (KHR). Starting in 1990 the KHR concentrated on developing mesoscale models for the sub-catchment of the Mosel river and other rivers which can later be combined into a common hydrological model for the river Rhine. It is intended that the hydrological model for the Mosel river and later the Rhine river be used for evaluating potential changes in climate, in a coupled mode in the atmospheric GCMs, such as that at the Max Planck Institute for Meteorology in Hamburg.

Another example of this type of analysis was begun at the International Institute of Applied Systems Analysis (IIASA) at Laxenburg, Austria, under the aegis of the WCP-Water Project B.3. Plans were laid for a joint effort to develop grided estimates of runoff data over central Europe. The rivers under consideration for macro-scale modelling are the Elbe river, Odra and Vistula. It is expected that four-dimensional data assimilation will be used for verification of these macro-scale modelling experiments in the same way as for GCIP. The SSG concurred with Professor Schultz's assessment of the importance of each of these activities in terms of their potential for forecasting not just climate change but, even more significantly, the effects of climate change on hydrological resources.

11. NEXT SESSION

An invitation was extended by Dr. Takao Munenaga, on behalf of the National Space Development Agency of Japan (NASDA), to host the fourth session of the GEWEX-SSG in Tokyo in conjunction with the Geophysical Institute of the University of Tokyo (Dr. Taroh Matsuno). The invitation was accepted by the Chairman on behalf of the entire group. It was agreed that arrangements be made by the Director of the WCRP in concert with Japanese authorities for a meeting during the week 27-31 January 1992.

12. SUMMARY OF NATIONAL GEWEX PROGRAMMES

Time was alloted for representatives of the U.K. and Japan to summarize the elements of their national programmes contributing to GEWEX.

12.1 United Kingdom National GEWEX Programmes

The proposed components of the U.K. national programme that are meant to contribute to GEWEX were outlined by Dr. Browning, including the following topics:

- The Role of Water Vapour in the Global Atmosphere
- GEWEX Multi-Region Cloud System Study
- Radar Observations of the Troposphere from Space
- Mesoscale Field Experiments
- GCIP Related Data Analyses

See Appendix H for a more detailed description of the U.K. activities in each of these areas.

12.2 Japanese National GEWEX Programmes

The activities being undertaken in Japan in support of GEWEX were outlined by Dr. A. Takeda. The list of proposals currently being evaluated included:

(i) Cloud-Scale Energy and Water Cycle Processes, including both cloud-radiation processes (STA Project 1991-2000) and meso-scale precipitation processes (TRMM). The radiation studies would address the cloud dynamics at low and high levels over the ocean, the parameterization of radiative effects of cloud systems and other issues. The meso-scale precipitation studies will primarily concern microscale precipitation effects in tropical, subtropical, or arid climates;

(ii) Land Hydrology studies to investigate, on scales from 10-100 km, evaporation and runoff processes for the improvement of modelling and parameterization schemes related to land hydrology;

(iii) Continental-scale Energy and Water Cycle Studies, based on the co-ordination of a number of scientific studies related to the Asian monsoon cycle, which would contribute to the GEWEX continental scale project especially from the observational and data analysis point of view.

Other areas of research and operations include the modelling of water cycle processes in GCM's, analytic studies of global change and specific observations and data analyses.

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JSC Scientific Steering Group for the
Global Energy and Water Cycle Experiment
(Third Session, Hamilton, Bermuda, 21-25 January 1991)

AGENDA

1. Opening of the session

2. Review of relationships with other WCRP and ICSU activities

   2.1 Recommendations of the Joint Scientific Committee for WCRP

   2.2 Co-operation with the IGBP on the Biospheric Aspects of the Hydrological Cycle (BAHC)

   2.3 Co-operation with the IAHS/WMO Working Group for GEWEX

3. Establishment of an international GEWEX Project Office

4. Review of satellite missions relevant to GEWEX

   4.1 WCRP Planning Meeting on Earth Observing Systems for Climate Research

   4.2 Statement by the representatives of ESA

   4.3 NASDA

   4.4 NASA

5. Air-sea interaction problems for GEWEX

6. GEWEX Continental-scale International Project (GCIP)

7. Hydrological-atmospheric field experiments

8. GEWEX cloud and radiation research activities

   8.1 Multi-region Cloud Systems Study

   8.2 Radiation Projects in the context of GEWEX

   8.3 Temperature and Water Vapour Retrievals

   8.4 ECMWF/WCRP Workshop on Clouds, Radiation Transfer and the Hydrological Cycle

9. Rainfall measurements and data

   9.1 Global Precipitation Climatology Project (GPCP)

   9.2 Rainfall Measuring Satellite Mission

10. GEWEX models

   10.1 Surface-Vegetation-Atmosphere Transfer (SVAT) Models

   10.2 Macroscale Hydrological Modelling and Data Assimilation

11. Next session

12. Summary of national GEWEX programmes

   12.1 United Kingdom

   12.2 Japan

Suggestions and Recommendations of the IAHS/WMO Working Group for GEWEX

The IAHS/WMO Joint Working Group made the following suggestions and recommendations to the Scientific Steering Group for GEWEX:

(i) The International GEWEX Project Office (IGPO) in Washington, DC, U.S.A., should be made a truly international institute. It should be announced that national experts from outside the U.S.A. would be welcome to work on the project. It is hoped that hydrologists would submit proposals to their national bodies for support of such joint activities. The U.S.A. would provide office and laboratory space and facilities but could not be expected to pay the salaries of the overseas experts. Members of the Working Group had contacted their national authorities for funding such research work and several Working Group members reported that their home countries are prepared to finance experts from these countries for temporary activity within the IGPO.

(ii) The IAHS/WMO Working Group suggests that close links should be established between the GEWEX organization (e.g. SSG, GCIP, etc.) and the persons responsible for IAHS/WMO working group supported projects. This is particularly relevant for the project on precipitation measurement (Dr. Sevruk) and the WMO project on evaluation of methods for estimation of areal evapotranspiration (Dr. Askew, WMO).

(iii) It is hoped that members of the IAHS/WMO Working Group will be invited to participate in the scientific guidance of the GCIP.

(iv) It is hoped that the scientists involved in the GCIP will keep in contact with other hydrological macro-scale modelling efforts elsewhere in the world, particularly in Europe.

(v) Hitherto the design of satellite systems and sensors as well as the planning of experiments (e.g. ISLSCP) was done by experts in fields other than hydrology. It would improve the situation of hydrology as well as the potential achievements of experiments if hydrologists were incorporated into teams which plan such experiments in the future.

(vi) Although the activities required for GEWEX in the field of hydrology are of a type which so far had rather low priority in hydrological sciences, the international hydrology community recognizes the needs and importance of hydrological activities relevant to GEWEX. Hydrological science is prepared to play the role which is expected from it within the GEWEX programme.

Status of the International GEWEX Project Office (IGPO)

1. Establishment

The office was established in Washington, DC, in September 1990. The mailing address and telephone of the office are as follows:

OMNET -- INTL.GEWEX

Mail -- IGPO
Dr. Paul D. Try
Science & Technology Corporation
600 Maryland Ave S.W., Suite 1, Plaza
Washington, DC 20024

Phone -- 202-863-1435 or 202-863-0012
Fax -- 202-488-5364

2. Staff

Director	Dr. Paul Try
Executive Manager	Dr. Warren Spaeth
Science Advisor	Dr. Paul Twitchell (part-time)
GCIP Manager	Dr. Michael Coughlan (part-time)

3. Initial activities

The Office is assisting in co-ordinating and publishing the GCIP workshop report and both the GCIP Science Plan and GCIP Implementation Plan. Support has also been provided in planning, implementing and publishing the results from the GEWEX Temperature and Humidity Workshop

The Office has been involved in programme co-ordination within the U.S.A. and throughout the international community. An electronic database and GEWEX bulletin board have been established and a newsletter and GEWEX brochure are currently being developed.

The GEWEX.STATUS bulletin board will be used to pass on announcements, meeting schedules and agendas, and information notices as well as provide a forum for others to pass on GEWEX related information.

4. Terms of Reference

Terms of Reference for the Office as approved by the SSG are given in Annex 1.

5. Call for Distribution List Update

IGPO is establishing an updated distribution list for GEWEX matters and would appreciate receiving updated mailing addresses, E-mail, telephone, and fax numbers. If you are not receiving GEWEX or GEWEX Continental-scale International Project (GCIP) mailings now, we may need your updated mailing information.

INTERNATIONAL GEWEX PROJECT OFFICE (IGPO)

Terms of Reference

The International GEWEX Project Office (IGPO) is established to support the planning of the GEWEX programme as well as the international co-ordination of activities contributing to the implementation of GEWEX.

The following guidelines are applicable:

(a) The IGPO operates a component of the Joint Planning Staff (JPS). The Director of the IGPO (D/IGPO) is responsible to the Director of the World Climate Research Programme (D/WCRP).

(b) The IGPO is the main office for initiating international correspondence and for carrying out international liaisons at the working level, as required for the implementation or further development of GEWEX systems.

(c) The specific tasks of the IGPO also include:

(i) Preparing and updating detailed implementation and/or operations plans for the programme;

(ii) Ensuring the timely flow of operational and other relevant information to GEWEX participants and members of the Joint Scientific Committee (JSC) and GEWEX Steering Group (SSG);

(iii) Preparing documentation concerning the international co-ordination of GEWEX projects and providing information on GEWEX activities for the broad scientific community;

(iv) Other organizational duties as may be required during the course of the programme;

(d) The Director of the IGPO attends the sessions of the SSG and SSG Officer's meetings.

(e) The IGPO will be located in Washington, DC, and will include staff members detailed from participating agencies, as appropriate.

(f) Support for international travel, as required for discharging the responsibilities of the office, will be provided from the WCRP Joint Climate Research Fund under the responsibility of the D/WCRP.

The Programme Proposal for the First European Polar Platform Mission

1. Mission and Design Requirements

The following information was provided as the most recent set of mission and design specifications:

(i) Payload Gross Weight
- Up to 2400KG

(ii) Payload Power
- Sunlight average 2.1KW (growth 2.4KW)
- Eclipse average 1.9KW (growth 2.2KW)

(iii) Data Transmission
- Up to 3 KA-Band at 50/100MBPS
- Up to 3 X-Band at 50/100MBPS

(iv) Data Recording
- Up to 4 tape recorders with capacity greater than 25 gigabits, a record rate of 3.5 MBPS and a replay rate of 50 MBPS.

(v) Data Interfaces
- Up to 3 high rate channels at 100 MBPS
- A minimum of 15 low to medium rate channels at up to 32 MBPS

2. Major components

The first M-series platform (M-1) will be an unserviced, free-flying spacecraft with three major instrument packages:

(i) Operational Meteorological Instruments
(ii) Core Facility Payload Instruments
(iii) Announcement of Opportunity Instruments

2.1 The Operational Package

Current planning includes the following instruments in the operational package:

(i)	Visible/Infrared Image	(AVHRR)
(ii)	Infrared Sounder	(HIRS)
(iii)	Microwave Sounder	(AMSU)
(iv)	Meteorological Communications Package	(MCP)
(v)	Data collection and Location System	(ARGOS)
(vi)	Search and Rescue	(S & R)

2.2 The Core Facility Payload Package

The following instruments currently make up the core facility payload:

(i)	Synthetic Aperture Radar	(ASAR)
(ii)	Scatterometer	(ASCATT)
(iii)	Radar Altimeter	(RA)
(iv)	Medium Resolution Imaging Spectrometer	(MERIS)
(v)	Interferometric Limb sounder	(MIPAS)

Recent engineering feasibility studies have verified that it is not technically viable to include the backscatter LIDAR (ATLID) in this mission.

2.3 Other Earth Observation Instruments

An additional Earth observation package has been divided into three major areas of investigation:

(i) Positioning
- Precise Range and Range Rate Equipment (PRARE)

(ii) Chemistry and Dynamics of the Atmosphere
- Global Ozone Monitoring by Occultation of Stars (GOMOS)
- Scanning Imaging Absorption spectrometer for Atmospheric chartography (SCIAMACHY)

(iii) Radiation and Sea Surface Temperature
- Advanced Along-Track Scanning Radiometer (AATSR)
- Clouds and the Earth's Radiant Energy Systems (CERES)

3. Mission Schedule

A tentative time-line indicates launch of the first platform (M-1) occurring in the last quarter of calendar year 1997, the second (M-2) and third (M-3) platforms follow in the second quarter 2002 and the fourth quarter 2006 respectively. To help ensure continuity it is proposed to make the second platform (M-2) a complete copy of the first (M-1) ready for launch 18 months after the launch EPOP-M1. There are plans for parallel development of a second set of polar platforms (N-series). The first of these platforms (N-1) would not be ready for launch before year 2000.

4. Other Approved and Future Earth Observation Programmes

The total earth system science programme of the European Space Agency includes the following satellite missions and activities:

Type	Approved	Future
Geostationary	Meteosat Operational Programme	Meteosat Second Generation (MSG)
Sun-Synchronous	European Remote-Sensing Satellites (ERS-1 and ERS-2)	European Polar Platforms
Inclined Orbits		Aristoteles
Data Acquisition and Handling	Earthnet	
Technological Development	Earth Observation Preparatory Programme (EOPP)	EOPP Extension

Candidate Payload for Japan's Earth Observation Polar Platform Programme

1. Candidate Instrument Payload

The tentative list of candidate instruments for Japan's polar orbiting Earth Observation Platform included the following sensors:

(i)	Advanced Microwave Scanning Radiometer	(AMSR)
(ii)	Global Imager	(GLI)
(iii)	Tunable Etalon Remote Sounder of Earth	(TERSE)
(iv)	Three-dimensional Ozone Mapping with UV Image Spectrometer	(TOMUIS)
(v)	Stratospheric Limb Infrared Emission Spectrometer	(SLIES)
(vi)	Investigation of the Micro-Biosphere	(IMB)
(vii)	Advanced Radar Altimeter (ADALT)	
(viii)	Precipitation Radar	(PR)

2. Instrument Descriptions

2.1 Advanced Microwave Scanning Radiometer

This instrument is a multi-frequency microwave radiometer for measurement of various atmospheric and oceanic parameters including precipitation, water vapor content, cloud water content, sea surface temperature, sea ice and wind velocity at the ocean surface. The performances of the instrument can be characterized as follows:

Frequency	-	6 GHz to 90 GHz (6 frequencies) (extension to 1.4 GHz and 180 GHz as an option)
Polarization	-	vertical and horizontal
Temperature resolution	-	0.2 - 1K (Goal)
Radiometric accuracy	-	1 K (Goal)
Antenna aperture	-	2 m

2.2 Global Imager

GLI is an imaging spectrometer for global monitoring of biological and physical processes, as well as stratospheric ozone, in a spectral range from ultraviolet to thermal infrared. Instrument performances are characterized as follows:

Number of channels	-	more than 20 bands from UV to thermal IR
Bandwidth	-	10 to 20 nm
Swath	-	greater than 1800 km
IFOV	-	less than 1 km

2.3 Atmospheric Chemistry Monitoring Instruments

The three instruments TERSE, TOMUIS and SLIES are all designed for atmospheric chemistry investigations. TERSE is a high spectral resolution near-infrared spectrometer which uses a scanning tunable interferometric etalon system to obtain highly accurate global measurements of minor

tropospheric species (CH_4, H_20, N_20, CO_2). TOMUIS is an imaging spectrometer which measures backscatter in the UV spectrum for two-dimensional mapping of stratospheric ozone distribution. SLIES measures the infrared emission of minor stratospheric and tropospheric constituants by looking at nadir and the earth's limb with a Fourier-transform Michelson interferometer.

2.4 Investigation of the Micro-Biosphere

IMB is a high spatial resolution multi-band imaging radiometer for observing the global environment from the visible through the near infrared.

2.5 Advanced Radar Altimeter

ADALT is a two-frequency radar altimeter for ocean circulation studies and analysis of the extent and volume of sea-ice and ice sheets.

2.6 Precipitation Radar

The proposed instrument is an active microwave sensor based on the heritage of the Tropical Rain Measurement Mission (TRMM), to determine the three-dimensional distribution of precipitating rain drops.

Programme Proposal for the First NASA Earth Observing System Polar Platform

1. Confirmed Instruments

The first EOS-A series polar platform (-A1) will be an unmanned, free flyer. The following is a list of instruments which have been confirmed for placement on the platform:

(i)	Atmospheric Infrared Sounder (AIRS is a facility instrument with which, together with the Advanced Microwave Sounding Units AMSU-A and AMSU-B, will constitute the advanced operational sounding system)	(AIRS)
(ii)	Intermediate Thermal Infrared Radiometer	(ITIR)
(iii)	Clouds and Earth's Radiant Energy Systems	(CERES)
(iv)	Earth Observing Scanning Polarimeter	(EOSP)
(v)	High-Resolution Dynamics Limb Sounder	(HIRDLS)
(vi)	Lightning Imaging Sensor	(LIS)
(vii)	Multi-angle Imaging Spectro-Radiometer	(MISR)
(viii)	Moderate-Resolution Imaging Spectrometer - Nadir/Tilt	(MODIS-N/T)
(ix)	Six Stick Fan-Beam Scatterometer	(STIKSCAT)

2. Other Approved and Future Earth Observation Programmes

(See annex to this Appendix).

Approved and Future Earth Observation Programmes with NASA Involvement

Mission (Approved)	Launch	Country (s)	Date (Approximate)
TOMS	METEOR-3	USSR/US	August '91
UARS	SHUTTLE/ATLANTIS	US/UK/CAN/FR	October '91
TOPEX/POSEIDON	ARIANE	FRANCE/US	June '92
SeaWIFS	-	US	June '93
TOMS	-	US	August '93
NSCAT	ADESO/H1	JAPAN/US	April '95
TOMS	ADEOS/H1	JAPAN/US	April '95
RADARSAT	DELTA	CANADA/US	1996
TRMM	H2	JAPAN/US	1996/97
TOMS	-	-	1997
EOS-A	TITAN-IV	US/ESA/JAPAN/CAN	1998
ESA-M	ARIANE	ESA/US	1997
JPP-1	H2	JAPAN/US/EUROPE	1998
Shuttle Missions (Approved)			
ATLAS (1),(2),(3),---		US/GER/UK/ BELG +	1992/93/---
SIR-C (1),(2),(3),---		US/GER/ITA	1993/94--
LITE (LASER RANGING)		US	
SSBUV (3),(4),(5),---		US	1991/92/93/--
Future Missions (Pending approval)			
ATLAS	DELTA CLASS	GER	1997
ARISTOTELES	DELTA CLASS	ESA	1998
EOS-B series	-	US/UK/ESA/OTHERS	2001
EOS-SAR	-	US/GER/ITA/OTHERS	-

Summary of Proposals for National GEWEX Programmes of the United Kingdom

1. Background

In recent months, active consideration has been given to developing proposals for a United Kingdom contribution to various aspects of GEWEX. Five complementary proposals emerged from a meeting of the interested scientific community from Universities, Research Council Institutes and Government Departments at the Royal Society in London in January 1991.

2. Specific GEWEX Related Projects

The essence of the proposals is conveyed in the following descriptions, which summarize the fuller supporting documents now in preparation. Together they outline a broad national programme of research covering aspects of meteorology, hydrology, and space-instrument development. The next stage, that of securing funding, will proceed over the coming months.

2.1 Role of Water Vapor in the Global Atmosphere

Reliable general circulation statistics for moist variables are not in general available and diagnosis of the general circulation both observed and simulated have tended to add moist effects on rather than view them as basic. With the prospect that many more observations should be made to fit the new observations into a conceptual framework, it is important to put a fresh effort into diagnosing the moist general circulation of the atmosphere. Current data and models should be investigated using moisture budgets on pressure, isentropic and, perhaps, moist isentropic surfaces. The budgets should be understood in terms of air trajectories and the sources and sinks of moisture. Particular emphasis should be placed on regions where the water vapour distribution is important and currently poorly simulated and understood, e.g. the sub-tropical mid- and upper-troposphere, the top of the tropical convective boundary layer and the lower stratosphere. Developments and application of Lorenz's notion of moist available potential energy could be considered.

Most modern diagnoses of the observed general circulation are based on the routine analyses produced by forecast centres for NWP. Four-dimensional assimilation techniques are designed to provide fields on regular grids of variables used in NWP models, at a sequence of times, which are consistent with the observations distributed in time and space. By using a forecast model, assimilation techniques incorporate information about the atmosphere not present in the observations alone. Hence the values produced can be more useful for many purposes than the raw observations, or fields produced directly from the observations without incorporating this additional information. This approach is essential if we are to provide a representation of the atmosphere which is sufficiently detailed in time and space for uses such as global flux calculations. Physically consistent fields are especially important for studying the hydrological cycle over the oceans (as suggested by Kirk Bryan) where observations are relatively sparse. However, in order to be reliably useful for diagnosis of climate and atmospheric processes in the context of GEWEX, assimilation techniques need to be further developed.

For certain types of derived values, such as low-resolution long-term averages, simple non-assimilation processing of the observations alone may produce more accurate results. Assimilated fields must be carefully compared with model-independent estimates before being used for diagnostic studies. Estimates of the expected errors of the assimilated fields are also required before they can be applied effectively; these may arise from the assimilation process, from the model or from the observations themselves. Information on error sources is not normally stored in NWP archives in an easily usable way.

Statistics (derived during the assimilation process) on the fit between model and observations, will be useful for improving the model itself. This is particularly relevant to the representation of moist processes, cloud and precipitation; complete, assimilation independent, information for these parameters is not available, so validation is best done with the data as observed.

These considerations make it essential that there is close collaboration between those developing the data assimilation techniques, the representation of moist processes within the NWP and general circulation models, and the uses of assimilated fields for climate, general circulation and process studies. The U.K. has strength in all these areas, and is perhaps unique in the level of collaboration which already exists. Groups at Reading University and the Meteorological Office are particularly well placed to make a significant contribution to GEWEX in this area.

2.2 Contribution to GEWEX Multi-Region Cloud System Study (GMCSS)

The World Climate Research Programme has proposed a Global Energy and Water Experiment (GEWEX) to study a variety of atmospheric and hydrological processes. Amongst these processes the description of the properties of convective clouds has high priority. The properties of convective clouds involve the cloud physics, radiative transfer, turbulence and mesocale dynamics. The scales on which these processes occur are so diverse that a combination of numerical simulation and observational programmes will be the preferred approach to determine these required properties. A numerical model which explicitely describes the main boundary layer and convective scale dynamics and only parameterises the microscale processes is technically feasible in the 1990's. Such a model itself requires much parameterization but, in contrast to climate models, on a much smaller scale that matches the scales of cloud physics, turbulence and radiative transfer observables. The MCSS proposal noted this opportunity and would foster its development. As itemised below, the U.K. Meteorological Office and universities (e.g. UMIST) have top-level expertise in this field and are well placed to undertake a major thrust. By building upon existing facilities and expertise, a substantial return is possible from the relatively small resources needed to develop a new modelling initiative and link in existing expertise.

The GEWEX scientific plan proposes two complementary elements (i) a mesoscale programme using models with resolution of order 20 km and (ii) a cloud-scale programme using models with resolution 1 km and less. The mesoscale programme is intended to focus on the observed tendency for deep convective clouds to become organized on a scale of the order of hundreds of kilometres. A major initiative will involve storms located over the central U.S.A. The cloud scale programme is seen as critical to the development of

the models used in mesoscale studies and is expected also to be of direct use in climate models when large scale organization is absent. The suggested new U.K. focus is on the cloud-scale study, but it will be important to sustain links with the mesoscale programme both in this country, within the Joint Centre for Mesoscale Meteorology at Reading University (JCMM), and elsewhere.

Objectives of Programme

(i) To develop and make available for multiple applications, a three-dimensional convective-scale model describing motions in the range of scales 100m to 300km.

(ii) To develop and test cloud physics and radiative transfer formulations for local application within modelled clouds and test these against cloud-scale observations.

(iii) To undertake mesoscale observational projects to check the model's ability to correctly "integrate" the various processes. This will include collaboration in international field experiments.

(iv) To apply the complete convective-scale model to a wide range of regions and conditions, with a view to generating climate model parameterizations. These parameterizations will include vertical mixing, momentum transfer, latent heating profiles and radiative tranfers.

(v) To use the cloud realizations from the model to develop remote sensing retrieval algorithms.

2.3 Radar Observations of the Troposphere from Space

This is a proposal for a major U.K. contribution led by the Rutherford Appleton Laboratory, the Meteorological Office and universities, to the science and technology of observations from space of rainfall and clouds in the troposphere.

The programme would have two main thrusts the first of which would be to seek a comprehensive involvement in the scientific support and exploitation of the US/Japan "Tropical Rainfall Measuring Mission" (TRMM) due for launch in 1996, whose objectives are well aligned with those of the GEWEX programme. Also, where relevant, the possibilites will be explored for participation in other on-going spaceborne radar programmes such as ALT-2 for the first ESA Polar Platform mission. The second thrust would be to undertake an in-depth study of the technical feasibility of a millimetre-wave radar system to observe clouds from space.

In all important aspects of this programme, there is substantial expertise, facilities and experience in the U.K. research community. The areas of expertise include: interaction of e.m. waves with hydrometeors, interpretation of radar echoes, modelling of cloud and rainfall structures in the atmosphere and, of course, the exploitation of data through data-assimilation and other means of analysis. This is complemented by substantial expertise in the relevant aspects of space instrument

development. The facilities available in the U.K. include a 25-metre steerable dish antenna which is in frequent use at S-band for dual-polarisation studies of rainfall radar echoes (a topic which is of central importance to the correct interpretation of the single-polarisation data from TRMM), research aircraft (including a comprehensively instrumented C-130 Hercules operated by the U.K. Meteorological Office) plus airborne and other radar instrumentation for specialised ground-based and airborne studies of radar echoes from rainfall.

The scientific benefits from this will be in the area of improved monitoring of rain and clouds, derived from an improved understanding and validation of data from TRMM which, although limited in coverage, is the only planned space mission which is likely to provide data of this kind in the GEWEX time-frame. It is anticipated that this work will quickly lead to a clearer view of the potential of space-borne radar for the monitoring of cloud structure and motions and will lead naturally to a major programme proposal for space instrument development. If the feasibility is convincingly demonstrated in the early stages, a comprehensive proposal for instrument development will be produced.

2.4 GEWEX Mesoscale Field Experiments

The U.K. has noteworthy and productive history of participation in observational and modelling studies to investigate mesoscale aggregation of land surface properties, both independently and through the HAPEX and the ISLSCP international field experiments. Led by the Institute of Hydrology it seeks now to take an expanded role in the research area through the programme of mesoscale field experiments proposed under GEWEX, following the priorities and experimental format developed by the joint IGBP/WCRP Working Group on Land Surface Experiments.

The proposed expansion will exploit the substantial relevant expertise in the U.K., and will take the form of:

(i) Increased participation by the U.K. hydrological community, which have formed the major U.K. input to previous studies;

(ii) More broadly-based participation, to include observational inputs by the ecological, meteorological, remote sensing and trace gas measurement communities; and

(iii) Development of expertise in the area of coupled hydrological/ecological/atmospheric modelling, at both mesoscale (10 km grid) and microscale (1 km grid and less), to investigate the aggregation problem at these scales.

The U.K. will participate at a significant level in all the proposed experiments - EFEDA, HAPEX-Sahel and BOREAS - but expects to take its most significant role in the mesoscale experiment investigating tropical deforestation, which is to take place in Amazonia in the mid 1990s. This reflects substantial historical involvement in tropical forest research, and ongoing collaborative research links on this topic with the Brazilian scientific community.

This expanded activity is conditional on securing increased national funding, which is required mainly to cover the marginal costs of the enlarged participating community, but also for provision of national pool of instrumentation for successive use in the experiments, and to co-ordinate and manage this national participation.

2.5 GEWEX Continental-Scale International Project

The aim of the project is to develop physically-based models of evaporation and the runoff generation process which will:

(i) Contribute to the further refinement of climate models, and

(ii) Provide a link between climate models and studies of the impact of environmental change on hydrological resources of larger river basins.

Physically-based simulation of the runoff generation process can provide a number of benefits to climate models (relating to the representation of sub-grid scale variability and the addition of catchment lags, routing and between-cell transfers), and the GEWEX Continental Scale International Programme (GCIP) has accordingly been established to provide a framework for a comprehensive investigation. The long-term goal of GCIP is to produce models which can be applied anywhere without the need for regional calibration (but with regional parameters), although developmental work will be concentrated in the Mississippi catchment. This covers a wide range of climatic and hydrological conditions, and has abundant data.

The Institute of Hydrology and other parts of the U.K. hydrological community have a vital role to play in the GCIP. The U.K. is a leader in the development and application of physically-based hydrological models, the assimilation of spatially-variable input data and their linkage with simulation models, and, through collaboration between hydrologists and the Meteorological Office, the coupling of links between climate and hydrological models. U.K. hydrologists have studied the effect of spatial scale on hydrological modelling, and are well placed to develop methodologies for the transfer of data from the scale most appropriate for hydrological modelling to that used in global climate models. U.K. scientists will also be involved in the selection of the study regions, the estimation of selected climate change impacts, and the development of procedures for transferring models to regions with limited ground data.

The proposed work programme builds not only upon established U.K. expertise, but also on large-scale hydrological modelling work contained in the "Terrestrial Initiative in Global Environmental Research" (TIGER) proposal. The TIGER studies can be seen as essential building blocks for the more comprehensive GCIP investigations. Substantial resources will be required to implement the U.K. contribution to GCIP, due primarily to the large staff effort required but also to the necessary investment in computing facilities to handle and manipulate the complex models to be developed and their input data.

LIST OF REPORTS

WCRP-1 VALIDATION OF SATELLITE PRECIPITATION MEASUREMENTS FOR THE GLOBAL PRECIPITATION CLIMATOLOGY PROJECT (Report of an International Workshop, Washington, D.C., 17-21 November 1986) (WMO/TD-No. 203)

WCRP-2 WOCE CORE PROJECT 1 PLANNING MEETING ON THE GLOBAL DESCRIPTION (Washington, D.C., USA, 10-14 November 1986) (WMO/TD-No. 205)

WCRP-3 INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP) WORKING GROUP ON DATA MANAGEMENT (Report of the Sixth Session, Fort Collins, USA, 16-18 June 1987) (WMO/TD-No. 210)

WCRP-4 JSC/CCCO TOGA NUMERICAL EXPERIMENTATION GROUP (Report of the First Session, Unesco, Paris, France, 25-26 June 1987) (WMO/TD No. 204)

WCRP-5 CONCEPT OF THE GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (Report of the JSC Study Group on GEWEX, Montreal, Canada, 8-12 June 1987 and Pasadena, USA, 5-9 January 1988) (WMO/TD-No. 215) (out of print)

WCRP-6 INTERNATIONAL WORKING GROUP ON DATA MANAGEMENT FOR THE GLOBAL PRECIPITATION CLIMATOLOGY PROJECT, (Report of the Second Session, Madison, USA, 9-11 September 1988) (WMO/TD-No. 221) (out of print)

WCRP-7 CAS GROUP OF RAPPORTEURS ON CLIMATE, (Leningrad, USSR, 28 October-1 November 1985) (WMO/TD-No. 226)

WCRP-8 JSC WORKING GROUP ON LAND SURFACE PROCESSES AND CLIMATE, (Report of the Third Session, Manhattan, USA, 29 June-3 July 1987) (WMO/TD-No. 232)

WCRP-9 AEROSOLS, CLOUDS AND OTHER CLIMATICALLY IMPORTANT PARAMETERS: LIDAR APPLICATIONS AND NETWORKS, (Report of a Meeting of Experts, Geneva, Switzerland, 10-12 December 1985) (WMO/TD-No. 233)

WCRP-10 RADIATION AND CLIMATE: (Report of the First Session, JSC Working Group on Radiative Fluxes, Greenbelt, USA, 14-17 December 1987) (WMO/TD-No. 235)

WCRP-11 WORLD OCEAN CIRCULATION EXPERIMENT - IMPLEMENTATION PLAN - DETAILED REQUIREMENTS (Volume I) (WMO/TD-No. 242)

WCRP-12 WORLD OCEAN CIRCULATION EXPERIMENT - IMPLEMENTATION PLAN - SCIENTIFIC BACKGROUND (Volume II) (WMO/TD-No. 243)

WCRP-13 RADIATION AND CLIMATE (Report of the Seventh Session of the International Satellite Cloud Climatology Project (ISCCP) Working Group on Data Management, Banff, Canada, 6-8 July 1988) (WMO/TD-No. 252)

WCRP-14 AN EXPERIMENTAL CLOUD LIDAR PILOT STUDY (ECLIPS) (Report of the WCRP/CSIRO Workshop on Cloud Base Measurement, CSIRO, Mordialloc, Victoria, Australia, 29 February-3 March 1988) (WMO/TD-No. 251)

WCRP-15 MODELLING THE SENSITIVITY AND VARIATIONS OF THE OCEAN-ATMOSPHERE SYSTEM (Report of a Workshop at the European Centre for Medium Range Weather Forecasts, 11-13 May 1988) (WMO/TD-No. 254)

WCRP-16 GLOBAL DATA ASSIMILATION PROGRAMME FOR AIR-SEA FLUXES (Report of the JSC/CCCO Working Group on Air-Sea Fluxes, October 1988) (WMO/TD-No. 257)

WCRP-17 JSC/CCCO TOGA SCIENTIFIC STEERING GROUP (Report of the Seventh Session, Cairns, Queensland, Australia, 11-15 July 1988) (WMO/TD-No. 259)

WCRP-18 SEA ICE AND CLIMATE (Report of the Third Session of the Working Group on Sea Ice and Climate, Oslo, 31 May-3 June 1988) (WMO/TD-No. 272)

WCRP-19 THE GLOBAL PRECIPITATION CLIMATOLOGY PROJECT (Report of the Third Session of the International Working Group on Data Management, Darmstadt, FRG, 13-15 July 1988) (WMO/TD-No. 274)

WCRP-20 RADIATION AND CLIMATE (Report of the Second Session of the WCRP Working Group on Radiative Fluxes, Geneva, Switzerland, 19-21 October 1988) (WMO/TD No. 291)

WCRP-21 INTERNATIONAL WOCE SCIENTIFIC CONFERENCE (Report of the International WOCE Scientific Conference, Unesco, Paris, 28 November to 2 December 1988) (WMO/TD No. 295)

WCRP-22 THE GLOBAL WATER RUNOFF DATA PROJECT (Workshop on the Global Runoff Data Set and Grid estimation, Koblenz, FRG, 10-15 November 1988) (WMO/TD No. 302)

WCRP-23 WOCE SURFACE FLUX DETERMINATIONS - A STRATEGY FOR IN SITU MEASUREMENTS (Report of the Working Group on In Situ Measurements for Fluxes, La Jolla, California, USA, 27 February-3 March 1989) (WMO/TD No. 304)

WCRP-24 JSC/CCCO TOGA NUMERICAL EXPERIMENTATION GROUP (Report of the Second Session, Royal Society, London, UK, 15-16 December 1988) (WMO/TD-No. 307)

WCRP-25 GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (GEWEX) (Report of the First Session of the JSC Scientific Steering Group for GEWEX, Pasadena, USA, 7-10 February 1989) (WMO/TD-No. 321) (out of print)

WCRP-26 WOCE GLOBAL SURFACE VELOCITY PROGRAMME (SVP) (Workshop Report of WOCE/SVP Planning Committee and TOGA Pan-Pacific Surface Current Study, Miami, Florida, USA, 25-26 April 1988) (WMO/TD-No. 323)

WCRP-27 DIAGNOSTICS OF THE GLOBAL ATMOSPHERIC CIRCULATION (Based on ECMWF analyses 1979-1989, Department of Meteorology, University of Reading, Compiled as part of the U.K. Universities Global Atmospheric Modelling Project) (WMO/TD-No. 326)

WCRP-28 INVERSION OF OCEAN GENERAL CIRCULATION MODELS (Report of the CCCO/WOCE Workshop, London, 10-12 July 1989) (WMO/TD-No. 331)

WCRP-29 CAS WORKING GROUP ON CLIMATE RESEARCH (Report of Session, Geneva, 22-26 May 1989) (WMO/TD-No. 333)

WCRP-30 WOCE - FLOW STATISTICS FROM LONG-TERM CURRENT METER MOORINGS: THE GLOBAL DATA SET IN JANUARY 1989 (Report prepared by Robert R. Dickinson, Eddy Statistics Scientific Panel) (WMO/TD-No. 337)

WCRP-31 JSC/CCCO TOGA SCIENTIFIC STEERING GROUP (Report of the Eighth Session, Hamburg, FRG, 18-22 September 1989) (WMO/TD-No. 338)

WCRP-32 JSC/CCCO TOGA NUMERICAL EXPERIMENTATION GROUP (Report of the Third Session, Hamburg, FRG, 18-20 September 1989) (WMO/TD-No. 339)

WCRP-33 TOGA MONSOON CLIMATE RESEARCH (Report of the First Session of the Monsoon Numerical Experimentation Group, Hamburg, FRG, 21-22 September 1989) (WMO/TD-No. 349)

WCRP-34 THE GLOBAL PRECIPITATION CLIMATOLOGY PROJECT (Report of the Fourth Session of the International Working Group on Data Management, Bristol, UK, 26-28 July 1989) (WMO/TD-No. 356)

WCRP-35 RADIATION AND CLIMATE (Report of the Third Session of the WCRP Working Group on Radiative Fluxes, Fort Lauderdale, USA, 12-15 December 1989) (WMO/TD-No. 364)

WCRP-36 LAND-SURFACE PHYSICAL AND BIOLOGICAL PROCESSES (Report of an ad-hoc Joint Meeting of the IGBP Co-ordinating Panel No.3 and WCRP Experts, Paris, France, 24-26 October 1989) (WMO/TD-No. 368)

WCRP-37 GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (Report of the Workshop to Evaluate the Need for a Rain Radar in Polar Orbit for GEWEX, Greenbelt, USA, 25-26 October 1989) (WMO/TD-No. 369)

WCRP-38 GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (Report of the First Session of the WCRP-GEWEX/IGBP-CP3 Joint Working Group on Land-Surface Experiments, Wallingford, UK, 25-26 January 1990) (WMO/TD No. 370)

WCRP-39 RADIATION AND CLIMATE (Intercomparison of Radiation Codes in Climate Models, Report of Workshop, Paris, France, 15-17 August 1988) (WMO/TD No. 371)

WCRP-40 GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (Scientific Plan), August 1990 (WMO/TD-No. 376)

WCRP-41 SEA-ICE AND CLIMATE (Report of the fourth session of the Working Group, Rome, Italy, 20-23 November, 1989) (WMO/TD-No. 377)

WCRP-42 PLANETARY BOUNDARY LAYER (Model Evaluation Workshop, Reading, U.K., 14-15 August 1989) (WMO/TD-No. 378)

WCRP-43 INTERNATIONAL TOGA SCIENTIFIC CONFERENCE PROCEEDINGS (Honolulu, USA, 16-20 July 1990) (WMO/TD-No. 379)

WCRP-44 GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (Report of the 2nd Session of the JSC Scientific Steering Group, Paris, France, 15-19 January 1990) (WMO/TD-No. 383)

WCRP-45 SEA ICE NUMERICAL EXPERIMENTATION GROUP (SINEG) (Report of the First Session, Washington, D.C., 23-25 May 1989) (WMO/TD-No. 384)

WCRP-46 EARTH OBSERVING SYSTEM FOR CLIMATE RESEARCH (Report of a WCRP Planning Meeting, Reading, U.K., 2-3 July 1990) (WMO/TD-No. 388)

WCRP-47 JSC/CCCO TOGA SCIENTIFIC STEERING GROUP (Report of the Ninth Session, Kona, Hawaii, USA, 23-25 July 1990) (WMO/TD-No. 387)

WCRP-48 SPACE OBSERVATIONS OF TROPOSPHERIC AEROSOLS AND COMPLEMENTARY MEASUREMENTS (Report of experts meeting at Science and Technology Corporation, Hampton, Virginia, U.S.A., 15-18 November 1989) (WMO/TD-No. 389) (out of print)

WCRP-49 TOGA MONSOON CLIMATE RESEARCH (Report of the 2nd session of the Monsoon Numerical Experimention Group, Kona, Hawaii, U.S.A., 26-27 July 1990) (WMO/TD-No. 392)

WCRP-50 TOGA NUMERICAL EXPERIMENTATION GROUP (Report of the 4th Session, Palisades, New York, U.S.A., 13-14 June 1990) (WMO/TD-No. 393)

WCRP-51 RADIATION AND CLIMATE (Report of the 1st Session, International Working Group on Data Management for WCRP Radiation Projects, New York City, U.S.A., 21-23 May 1990) (WMO/TD-No. 398)

WCRP-52 THE RADIATIVE EFFECTS OF CLOUDS AND THEIR IMPACT ON CLIMATE (Review prepared by Dr. A. Arking at request of IAMAP Radiation Commission) (WMO/TD-No. 399)

WCRP-53 CAS/JSC WORKING GROUP ON NUMERICAL EXPERIMENTATION (Report of the sixth session, Melbourne, Australia, 24-28 September 1990) (WMO/TD-No. 405)

WCRP-54 RADIATION AND CLIMATE (Workshop on Implementation of the Baseline Surface Radiation Network, Washington, DC, U.S.A., 3-5 December 1990) (WMO/TD-No. 406)

WCRP-55 GLOBAL CLIMATE MODELLING (Report of first session of WCRP Steering Group on Global Climate Modelling, Geneva, Switzerland, 5-8 November 1990) (WMO/TD-No. 411)

WCRP-56 THE GLOBAL CLIMATE OBSERVING SYSTEM (Report of a meeting convened by the Chairman of the
oint Scientific Committee for the WCRP, Winchester, U.K., 14-15 Jan uary 1991) (WMO/TD-No. 412)

WCRP-57 GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (Report of the 3rd session of the JSC Scientific Steering Group, Hamilton, Bermuda, 21-25 January 1991) (WMO/TD-No. 424)