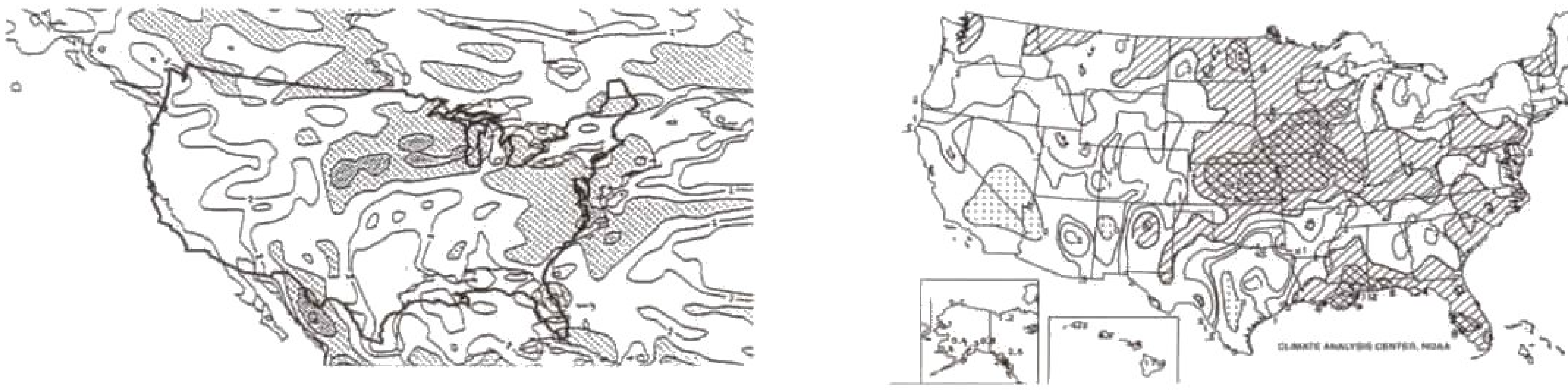
GEWEX WCRP
Global Energy and Water Cycle Experiment
NEWS

Vol. 3, No. 3 October 1993

World Climate Research Programme–WCRP

30 Day Experimental Forecast **Observed**



Comparison of 30-day forecast precipitation by the new ECMWF model, Cycle 48, to NOAA Climate Analysis Center analysis (see article below).

A NEW SURFACE BOUNDARY LAYER FORMULATION AT ECMWF and EXPERIMENTAL CONTINENTAL PRECIPITATION FORECASTS (JULY 1993)

A.C.M. Beljaars, P. Viterbo, and M.J. Miller
ECMWF, Reading, England
and
A. K. Betts and J.H. Ball
Atmospheric Research, Pittsford, VT USA

INTRODUCTION

On 4 August 1993, Cycle 48 of the European Centre for Medium-Range Weather Forecasting (ECMWF) model was implemented with a new soil hydrology and atmospheric boundary layer formulation. This article will: (1) summarize recent activities to identify contemporary model deficiencies in the atmospheric boundary layer and land surface parameterizations; (2) outline the changes to the ECMWF model; and (3) compare July 1993 total precipitation forecasts to the precipitation observed over the flood region of the continental United States.

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WHAT'S NEW IN GEWEX

- GCIP Brochure Published
- GEWEX Supports Amazonia Project (LBE)
- First PILPS Results Released
- GEWEX Canada Plans Extended Visit to IGPO
- ISLSCP CD-ROM Planned for June 1994
- GCIP Research Implementation Plan (Vol II) (Final Draft Distributed)

In This Issue

COMMENTARY

THE KEY ROLE OF THE INTERNATIONAL GEWEX PROJECT OFFICE

Dr. Moustafa T. Chahine
Chairman, GEWEX Science Steering Group

In less than three years of operation, the International GEWEX Project Office (IGPO) has played a significant role in furthering international climate and global change research by fostering the development of the GEWEX program. The IGPO is the focal point for all GEWEX project activities (see Table 1), coordinating new initiative support, acting as the center for all GCIP efforts to date and expanding international communications exchange to nearly 1500 scientists. These activities and more (see accompanying article in this newsletter) have helped establish GEWEX as a major global change project.

The IGPO contributes significantly to GEWEX leadership on a broad international scientific front in global climate change research and provides a vitally important focus for all GEWEX activities.

I encourage all scientists working in the GEWEX areas of interest to support and make use of the capabilities of our International GEWEX Project Office.

TABLE 1. GEWEX Projects

	NAME	ACTIVITY
HYDROMETEOROLOGY	GEWEX CONTINENTAL-SCALE INT'L PROJECT (GCIP)	Intensive study of hydrological and energy budgets in Mississippi River basin
HYDROMETEOROLOGY	GLOBAL RUNOFF DATA CENTER (GRDC)	Compile global river dishcarge data
HYDROMETEOROLOGY	INT'L SATELLITE LAND SURFACE CLIMATOLOGY PROJECT (ISLSCP)	Provide global data, experiments, and modelling on land-surface interactions, emphasising satellite remote sensing
RADIATION	GEWEX WATER VAPOR PROJECT (GVAP)	Improve measurement of water vapor and accuracy and availability of global data
RADIATION	INT'L SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP)	Produce a global data set on the Earth's radiance
RADIATION	SURFACE RADIATION BUDGET (SRB)	Provide global data set on the radiation budget of Earth's surface
RADIATION	BASELINE SURFACE RADIATION NETWORK (BSRN)	Provide measurements and validation data worldwide
CLOUD/PRECIP	GLOBAL PRECIPITATION CLIMATOLOGY PROJECT (GPCP)	Provide monthly global estimates of area-averaged precipitation
CLOUD/PRECIP	GEWEX CLOUD SYSTEM STUDY (GCSS)	Develop prototype models of cloud dystems that can be incorporated into large climate models

THE INTERNATIONAL GEWEX PROJECT OFFICE

HISTORY AND ACCOMPLISHMENTS

The IGPO was established by the World Climate Research Programme (WCRP) in 1990 to support the planning of the GEWEX program, coordinate international implementation activities, and facilitate collaboration between the components of GEWEX and other related scientific efforts. The IGPO, hosted by the United States under U.S. National Aeronautics and Space Administration sponsorship, is located in Washington, DC and operates as a component of the Joint Planning Staff of the WCRP, with Dr. Paul D. Try serving as its Director.

Specific tasks of the IGPO include preparing and updating detailed implementation and/or operational plans for the program; ensuring the timely flow of operational and other relevant information to GEWEX participants; developing documentation for the international coordination of GEWEX projects and providing information on GEWEX activities to the international scientific community; and providing organizational support for the expanding GEWEX activities.

Early IGPO efforts were focussed on the development of the new GEWEX Continental-scale International Project (GCIP), supporting the project through the organization of the Science Panel and Sub-Panels with nearly 100 participating scientists; development of the experiment concepts; publication of the Science Plan and three volumes of the Implementation Plan; and formation of the GCIP Project Office. Organizing this new project is an example of the type of task successfully pursued by the small IGPO staff. This project became the first major effort for the 1990s to be conducted by GEWEX. Progress on GCIP-Mississippi has now led to NOAA plans for establishing a separate project office for GCIP in Washington, DC.

The IGPO has been involved in significant interagency as well as international activities. For example, a joint Memorandum of Participation with the Atmospheric Radiation Measurement Project of the U.S. Department of Energy has been established to facilitate cooperative efforts between these two projects.

The IGPO Publication Series was initiated to provide more detailed technical and planning information to the international scientific community on GEWEX activities. Examples include:

- Implementation Plan for the Pilot Phase of the GEWEX Water Vapor Project (GVaP)
- Science Plan for the Project for Intercomparison of Land-Surface Parameterization Schemes (PILPS)
- GCIP Implementation Plan
- GCIP workshop reports

The IGPO also provides information to the broad international science community through an electronic bulletin board and with the publication of this Newsletter. The *GEWEX NEWS*' growing distribution (nearly 1500) and the increasing frequency of publication (now quarterly) is a measure of its success in providing information on GEWEX activities.

Some of the routine activities for the IGPO are the organization and hosting of international meetings, conferences, workshops, and special sessions or symposia at professional scientific meetings. For example, there will be two special GEWEX sessions at the American Meteorological Society's Fifth Symposium on Global Change Studies at the 1994 Annual Meeting (see page 10 of this issue). Also, there is direct IGPO staff participation in all nine GEWEX component activities from planning through implementation elements. Assisting in the initiation of the GEWEX cloud radar and the Amazonia projects, the development of new CD-ROMs for the International Satellite Land Surface Climatology Project, processing letters of intent for GVaP, and coordinating Surface Radiation Budget support for other projects are just some of the IGPO activities in addition to the efforts involved with GCIP. The Global Precipitation Climatology Project (GPCP) planning meeting is a recent example where the IGPO Director was directly involved (see photo on page 12).

As described above, the IGPO has been actively involved with a full complement of GEWEX projects and will continue to provide a broad spectrum of support activities as these efforts expand and move into their next phase.

PRELIMINARY WORKSHOP SUMMARY ON THE BIOSPHERE-ATMOSPHERE FIELD EXPERIMENT IN THE AMAZON (LAMBADA/BATERISTA)

Carlos A. Nobre, INPE

During the period 8–11 September 1993, a workshop was convened to discuss a large-scale biosphere-atmosphere field experiment in Amazonia. The goals of this experiment, proposed to take place in the 1997–1998 time frame, are to answer the following questions:

(i) How does Amazonia currently function as a regional entity?—with emphasis on interactions with the Earth System in the form of exchanges of energy, water, carbon and other trace gases via atmospheric and river systems.

(ii) How will human-induced change alter the function of the Amazon region?—with emphasis on modifications within Amazonia associated with replacing tropical forest with mixed replacement vegetation, and on indirect modification of the vegetation gradient in areas surrounding Amazonia.

To answer these questions, an experiment consisting of two linked field activities is being proposed. One activity is a large-scale regional component of long-term monitoring, the other a set of process oriented field studies.

The first activity is known as the Large-scale Atmospheric Moisture Balance of Amazonia using Data Assimilation (LAMBADA). This program would set in place a radiosonde network around and within the basin; precipitation, hydrography and surface meteorological networks within the basin; long-term monitoring stations of CO_2 and trace gases in at least six research sites within the basin; and a comprehensive satellite remote sensing program. The field observation phase of LAMBADA would continue for around 1–2 years, probably in the 1997–1998 time frame. In conjunction with meteorological fields provided by a mesoscale model 4-dimensional data assimilation (4DDA) scheme, LAMBADA would provide the data that would permit quantification of the energy, moisture, and carbon budgets of the region and their dependence on the large-scale atmospheric circulation.

The second activity is known as the Biosphere-Atmosphere Transfers and Ecological Research In situ STudies (BATERISTA). This program is proposed as a coordinated set of process studies aimed at better understanding the micrometeorological, ecophysiological and biogeochemical controls on the exchange of energy moisture, trace gas, and momentum between the atmosphere and the vegetated land surface. The BATERISTA studies would also provide opportunities for the validation of remote sensing techniques and provide a framework for associated ecological studies. As proposed, six research areas located in different ecoclimatic regions of the Amazon basin and surrounding regions are to be equipped with arrays of surface sampling equipment, flux towers and other hardware. Three of the research areas are to be the axis of an ecological gradient transect study.

The LAMBADA and BATERISTA Experiment (LBE) Workshop was held at the Brazilian Space Research Institute (INPE), in Sao Jose dos Campos, Brazil. More than 80 scientists from a number of countries (Bolivia, Brazil, Colombia, France, Germany, Holland, Peru, UK, USA, and Venezuela) and from international agencies and programs (WCRP, International Geosphere-Biosphere Program [IGBP], Inter-American Institute, WCRP/GEWEX ISLSCP) attended the meeting. The timeliness of the proposed research and the international, interagency and interdisciplinary nature of LBE was widely recognized by the participants. As a result of the meeting a "Preliminary Science Plan" was refined and a organizational structure to carry out LBE was outlined.

EDITOR'S NOTE

GEWEX investigators are encouraged to submit short articles on their findings for consideration in the Newsletter. Concise illustrations summarizing results are requested. The publication schedule for 1994 is:

ITEMS DUE	PUBLICATION
15 Dec.	January 1994
15 April	May 1994
15 July	August 1994
15 Sept.	October 1994

PROJECT FOR INTERCOMPARISON OF LAND-SURFACE PARAMETERIZATION SCHEMES (PILPS) FIRST RESULTS FROM PHASE 2

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The first results from the PILPS project (Henderson-Sellers and Brown, 1992) Phase 2 were discussed at the International Association of Meteorology and Atmospheric Physics (IAMAP) Assembly in Yokohama in July 1993. A full day of the GCIP Symposium was devoted to PILPS presentations related to the results of Phase 2. This was followed by an evening discussion meeting on the development of the PILPS Science Plan attended by about 100 scientists.

PILPS, which is cosponsored by GCIP and the Working Group on Numerical Experimentation (WGNE) (Henderson-Sellers and Dickinson, 1992) has moved from Phase 1, in which schemes were described and existing sensitivity studies reported (e.g., Henderson-Sellers et al., 1993), to the first stage of Phase 2. In Phase 2 the same set of stand-alone simulations are being conducted by all the participating models.

Using atmospheric forcing data generated from a general circulation climate model, 22 participating land surface schemes were run to equilibrium. Forcing data for a tropical forest and a grassland grid point were used. The land surface parameters (roughness, length, albedo, soil depth, etc.) for both locations were provided for each scheme so that any differences in the results should be due to physical differences between the models rather than differences in the surface characterization. Results were collected, quality controlled, and interpreted at Macquarie University, Australia, on annual, monthly, and selected daily time scales.

At the July meetings in Japan only results for surface temperature, evaporation, sensible heat flux, snow depth and runoff were reported and compared. It is found that there is some agreement between the models in the prediction of annually averaged temperatures with a range, among all the models, of 2.5 K in the case of the tropical forest and 3.8 K for the grassland. Evaporation and sensible heat, averaged over 1 yr, show less inter-model agreement. The model predictions for the tropical forest range from –40 to +50 W m^{-2} for evaporation. For the grassland, predictions range from –22 to +22 W m^{-2} for the sensible heat flux and +25 to +62 W m^{-2} for the latent heat flux. Monthly averaged results show considerable divergence: Figure 1 is an example of the mean monthly evaporative and sensible fluxes as residuals from the average of the most central 50% of the participating models. All these results are available via anonymous ftp from pilps@mqmet.cic.mq.edu.au, and a report on the control simulation phase of PILPS will be forthcoming as an IGPO publication.

In the analysis of monthly and diurnal results, it is shown that there is no consensus between the model predictions of energy fluxes, snow depth, or runoff. There is a marginally better agreement in the prediction of temperature. The major differences in the monthly total runoff must have implications for the soil moisture distribution and thereby the partitioning of available energy.

These PILPS Phase 2 results, showing that the currently available land surface models do not agree on

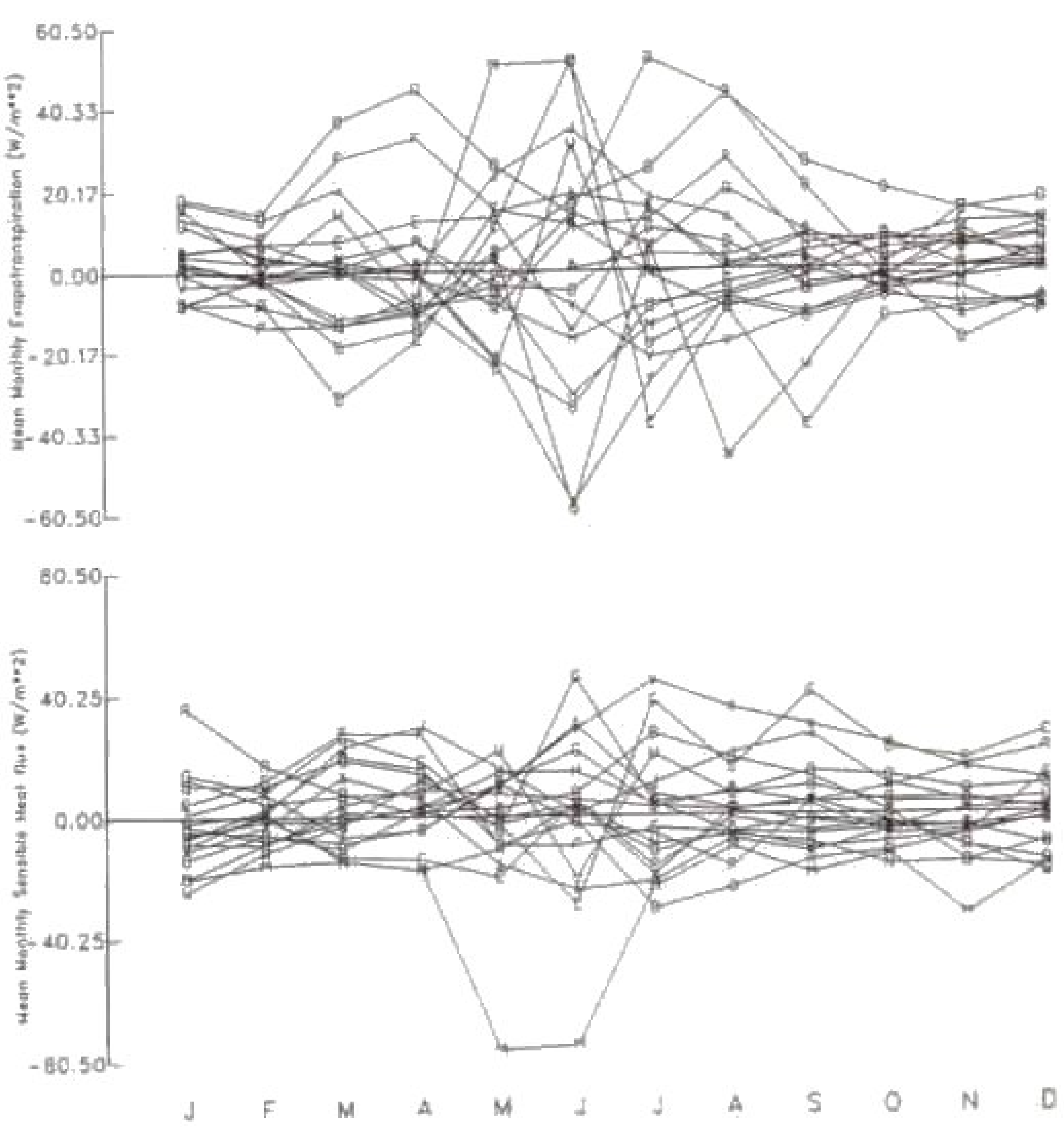

Fig. 1. Seasonal PILPS difference from rms-mean grassland.

the land surface climate even when all the atmospheric forcings are identical, were debated in some detail at the July meetings in Yokohama. Results were presented by many of the participating PILPS groups in which sensitivity studies for their schemes had been conducted in order to improve understanding of the wide scatter in the results of PILPS Phase 2.

It was recognized that a number of the schemes had used different characterization of the vegetation and soils. In particular, the need to homogenize definitions of "soil moisture holding capacity" and "runoff" was underlined. It was agreed that a short series of additional stand-alone simulations will be conducted by the "PILPers" before beginning comparisons based on field observations in 1994.

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ECMWF Cycle 48 and Precipitation

(Continued from page 1)

Several components of GEWEX, including the GEWEX Continental-scale International Project (GCIP) and International Satellite Land Surface Climatology Project (ISLSCP), address climate change problems by investigating the land surface interaction with atmospheric processes. Investigation of soil moisture impact (feedback) on precipitation at different spatial and time scales is a key GCIP activity.

From comparisons to field data sets, such as those assembled during the First ISLSCP Field Experiment (FIFE), it was possible to identify the changes needed to improve the ECMWF Cycle 47 model. FIFE was conducted in mid-continent United States, a site within the domain of GCIP (see Betts et al., 1993a, and Beljaars and Betts, 1992). Cycle 47 problems identified were:

- The ground heat flux over land surfaces was too large by a factor of 2 to 3 and had a phase error in the diurnal cycle.

- The diurnal cycle of the sensible and latent heat flux has a phase error of about 2 hr due to thermal inertia of the 7 cm surface soil layer in the model.

- The boundary layer depth was generally too small, indicating a lack of boundary layer entrainment.

- The boundary layer was too moist, even if the surface fluxes were correct. This was again due to lack of boundary layer entrainment.

- The evaporation from the surface was too large in wet conditions and too small in dry conditions.

- The soil moisture was excessively controlled by the climate layer.

- Runoff tended to be a constant fraction of precipitation, resulting in relatively large runoff even when the soil was dry.

Changes in formulation relevant to GCIP include the introduction of the four predictive layers for land surface hydrology, a new concept on skin temperature, and greater entrainment at the top of the unstable daytime atmospheric boundary layer. The latter finding highlights the need expressed in GCIP planning for daytime measurements of the atmospheric boundary layer diurnal cycle to reduce uncertainties in entrainment formulations.

In addition to the changes in boundary layer parameterization and land surface parameterization, Cycle 48 of the ECMWF model included a modification of air-sea parameterization as described by Miller et al., (1992).

Model Changes

For a more detailed description of the changes to Cycle 47, see Beljaars and Viterbo (1993). For Cycle 48 boundary layer changes above the surface layer two regimes have been distinguished, the stable and unstable.

For the stable regime in Cycle 47 a Monin-Obukhov (MO) formulation (Beljaars and Holtslag, 1991) was used above the boundary layer height. An iterative procedure is used to calculate the Obukhov length given the Richardson number (Ri). The diffusion coefficients used by the model are much smaller in the free troposphere than below the boundary layer height. The new model (Cycle 48) stable regime follows the same approach; the only difference is that the stability functions of the new MO formulation are slightly modified to get a better Richardson-dependence of the turbulent Prandtl number (ratio of turbulent diffusivities for momentum and heat) in the range of 0.2 to 1 Ri.

The formulation of vertical diffusion in Cycle 47 (Louis, 1979; Louis et al., 1982) in the unstable regime is similar to the stable regime, with Richardson number dependent stability functions below the boundary layer height. The diffusion coefficients in the unstable regime are large, leading to rapid dry adiabatic adjustment. This process is relatively insensitive to the formulation since mixed profiles of dry static energy are always produced, provided that the diffusion coefficients are sufficiently large.

It was shown with the help of FIFE data that the lack of entrainment through the stable capping inversion results in mixed layers that are too shallow and too moist. An entrainment parameterization has been introduced in Cycle 48 by specifying the diffusion coefficient in the capping inversion such that the buoyancy flux in the entrainment layer becomes proportional to the surface buoyancy flux. A profile of diffusion coefficients is prescribed in the mixed layer as proposed by Troen and Mahrt (1986). Details of how this scheme performs in comparison with FIFE data are given by Beljaars and Betts (1992).

The Surface Layer

In Cycle 47, the transfer coefficients for heat, momentum, and moisture were based on the Richardson number formulation, and a single roughness length was used for all the fluxes (Louis, 1979). In Cycle 48, the transfer coefficients which are used to parameterize the surface fluxes of momentum, heat, and moisture consist of a neutral part determined by the logarithmic profile and separate roughness lengths for momentum and heat (the moisture roughness length is identical to that for heat), plus a stability correction. The roughness lengths over land have been recomputed from vegetation, urbanization, and orographic distributions, where new empirical formulae have been used for the orographic contribution (see Mason, 1992). Where an orographic contribution applies to the roughness length for momentum, the neutral transfer coefficients for heat and moisture are kept constant. This results in orders of magnitude reduction of the roughness for heat and moisture, when compared to the momentum values.

The stability corrections applied to the neutral transfer coefficients are now expressed as a function of the Obukhov length instead of the Richardson number. This allows for a consistent treatment of different roughness lengths for heat and momentum in combination with stability corrections.

The Skin Temperature

In order to have a faster response of the sensible and latent heat fluxes to the radiative forcing and to reduce the heat flux into the ground, the concept of a skin layer has been introduced. The skin layer has no heat capacity and adjusts its temperature instantaneously to the radiative forcing. The heat transfer to the underlying soil is parameterized with the help of an empirical conductivity, the value of which determines the amplitude of the diurnal cycle in the soil heat flux.

Clouds

The entrainment in shallow cumulus clouds has been increased and the relative humidity criterion for inversion clouds has been modified. The effect of increased entrainment in shallow convection is to have a more rapid mixing of the updrafts with surrounding air, resulting in less deep penetration.

Land Hydrology

The Cycle 47 surface scheme was based on the heat and water budget of two active soil layers plus an additional "climate" layer underneath (Blondin, 1991; Viterbo and Illari, 1993). The fluxes of water and energy between the layers are based on constant diffusion coefficients. The climate values, kept constant during the forecasts, were used as lower boundary conditions and updated at the beginning of every month. The "Mintz and Serafini" climate (Mintz and Walker, 1993) is used for soil moisture, while for climate temperature the RAND climatology is used (Brankovic and van Maanen, 1985).

From comparisons with FIFE data it was concluded that the land hydrology in Cycle 47 was inaccurate and dominated excessively by the climate fields. This was confirmed by single column simulations where the model's atmospheric forcing is replaced by observational data.

The new Cycle 48 has four prognostic soil layers, that represent time scales from the diurnal to the annual. The diffusivities and conductivities of soil moisture are nonlinear functions of the soil moisture. This allows precipitation to penetrate fairly quickly into the soil, and in dry conditions the upward diffusion of water becomes slower. The runoff in the new model is mainly due to gravitational drainage. Boundary conditions at the bottom are zero energy flux and free percolation. The new hydrology scheme has been extensively tested in one column mode with the help of long data sets such as FIFE. The main conclusion is that the new scheme maintains evaporation in the drying season for a longer time and that it loses less water in runoff when the soil is dry. In general, the new scheme tends less to extremes. It produces less evaporation in wet conditions and the soil dries out less quickly.

Soil Moisture and Rainfall

Betts et al. (1993b) discuss the coupling between land-surface, boundary layer parameterization and rainfall at a local diurnal time scale and a regional seasonal time scale. Analyses of monthly precipitation forecasts for July 1993 with different soil moisture suggest that the coupling between regional soil moisture and rainfall may have played a role in Mississippi River basin flooding. A large sensitivity of monthly and seasonal precipitation over the United States to initial soil moisture was discovered. Also, at a local scale a diurnal link between soil moisture, boundary layer equivalent potential temperature, and precipitation was noted.

The month of July 1993, a flooding time in the Mississippi River basin, provided an opportunity to show the impact of the new land surface parameterization in the ECMWF Cycle 48 model. Figure 1 is the 30-day average precipitation forecast (T106) for July 1993 using a wet soil condition for 1 July, representing unstressed evaporation by vegetation. Figure 2 shows the difference field between the wet simulation and a dry simulation representing vegetation under stressed evaporation (not shown) for the same month. Note a mean increase of precipitation of 4 mm/day over the central United States. The July rainfall published by the National Oceanic and Atmospheric Administration Climate Analysis Center (see Fig. 3) depicts a

Fig. 1. 30-day average precipitation (mm/day) from ECMWF Cycle 48 (T-106) forecast from 1 July 1993, using wet 1 July soil moisture, corresponding to unstressed evaporation. Contours are at 1, 2, 4, 8 mm/day.

Fig. 2. Difference between wet 1 July soil moisture (Fig. 1) and for forecast initialized on 1 July with dry soil moisture corresponding to stressed evaporation. The increase in monthly mean precipitation resulting from increase in initial soil moisture is shown in mid continent.

similar pattern over the central United States to that shown in Fig. 1 (4 mm/day is approximately 5 in./month). The simulation suggests that the coupling of the atmospheric boundary layer and precipitation with soil moisture has a long time scale, which suggests the possibility of long-term (monthly or seasonal) prediction of precipitation. The increase in precipitation has not come from simple evaporation of the initial soil moisture, but is probably due to feedback processes, with the modified atmospheric boundary layer driving enhanced moisture convergence. This large-scale feedback requires further study as do strategies for determining soil moisture fields to initialize models.

Fig. 3. NOAA Climate Analysis Centre map: observed July precipitation in inches (from **Weekly Weather and Crop Bulletin**, *Vol. 80, No. 32, page 10, Washington, DC).*

A similar picture emerged from short- and medium-range forecasts during the parallel run of ECMWF model cycles 47 and 48 in July 1993 (prior to operational implementation). The 48-72 hr precipitation averaged over all forecasts in July verifies much better over the USA with Cycle 48 than with Cycle 47. More detailed results will be published elsewhere.

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COLD CLIMATE STUDIES

Dr. Terry Krauss, Head, GEWEX Secretariat, National Hydrology Research Centre, Canada will be at IGPO for an extended period of time in November 1993 to discuss and plan collaborative cold climate studies. The focus will be links between GCIP and the Mackenzie GEWEX Study and the coordination of implementation activities.

FORTHCOMING MEETINGS OF INTEREST

GEWEX in Asia International Symposium
Beijing, China
3–6 March 1994

An International Symposium on the Global Energy and Water Cycle Experiment, with the main topic *GEWEX IN ASIA*, will be held at Peking University, Beijing, China. It is being organized by the Chinese Liaison Group of GEWEX, which was founded in October 1991.

This Symposium will consist of both invited and contributed papers on the continental-scale energy and water cycle and the impact on the global, regional or basin-scale hydrological balance including observational studies. For further information contact: Prof. Zhao Bolin, Chairman of the Organizing Committee, c/o Dept. of Geophysics, Peking University, Beijing 100871, P.R. China; Tel: (86-1) 2501131; Fax: (86-1) 2564095.

The Role of Water and the Hydrological Cycle in Global Change
Pisa, Italy
27 May – 6 June 1994

This is a NATO Advanced Study Institute (ASI) course to be held at the international hotel complex Il Ciocco, Pisa, Italy. Lecture notes will be provided for the meeting and the complete lectures by leading scientists will subsequently be produced in book form. This course is designed for young researchers at the post-doctoral level.

Topics to be covered will include:

- Water in global change processes and global water budgets
- Hydrology in climate models
- Soil moisture studies
- Evaporation measurement, modelling, and effects of climate change
- Ice and snow factors in global change
- Water in the atmosphere, clouds, and modelling
- River runoff, lakes, wetlands, and climate
- Continental scale hydrological modelling

Climate change scenarios and impact assessment
Potential changes to hydrological systems, water courses, and aquifers
Implications for water resources
Consequences to society

Those interested in the course should prepare a typed application (one side of sheet only) that includes name, age, address, telephone and fax numbers, brief outline of academic background and current work. If attendance is conditional on some financial support, please indicate the amount.

Applications should be sent to Dr. Howard R. Oliver (NATO ASI), Institute of Hydrology, Wallingford, Oxfordshire OX10 8BB, UK. Tel.: (+44) 491 838800. Fax: (+44) 491 832256.

WCRP/GEWEX MEETINGS CALENDAR

18–20 October 1993—INTERNATIONAL WORKSHOP ON CLOUD-RADIATION INTERACTIONS AND THEIR PARAMETERIZATION IN CLIMATE MODELS, Washington, D.C. For information contact S. Benedict, WMO (WCRP) 41, Avenue Giuseppe Motta, 1211 Geneva 2, Switzerland. PHONE: 41-22-730-8247; FAX: 41-22-734-0357; E-MAIL/OMNET: S.Benedict.

20–22 October 1993—THE FOURTH ANNUAL GCIP SCIENCE PANEL MEETING, Norman, Oklahoma, USA, by invitation only.

10–12 November 1993—GEWEX SURFACE RADIATION BUDGET SCIENCE WORKSHOP, Langley, Virginia, USA. For information contact Thomas P. Charlock, NASA Langley Research Center, Mail Stop 420, Hampton, Virginia 23665. PHONE: (804) 864-5687; FAX: (804) 864-7996.

7–10 December 1993—GEWEX CLOUD SYSTEM STUDY MEETING, Reading, UK. For information contact Dr. Keith Browning, University of Reading, P.O. Box 238, Early Gate 3, Reading, Berkshire, RG6 2AL, UK; FAX: 44 734 318791.

17–22 January 1994—SIXTH SESSION OF GEWEX SCIENTIFIC STEERING GROUP, Frascati, Italy, by invitation only.

23–28 January 1994—AMERICAN METEOROLOGICAL SOCIETY FIFTH SYMPOSIUM ON GLOBAL CHANGE STUDIES to be held in conjunction with the 74th AMS Annual Meeting in Nashville, Tennessee, USA. Sessions on GEWEX Continental-scale International Project (GCIP) and GEWEX Water Vapor Project (GVaP) are scheduled. Agenda published in October 1993 Bulletin of the American Meteorological Society.

21–27 March 1994—THE SCIENTIFIC STEERING COMMITTEE of both the International Satellite Land Surface Climatology Project (ISLSCP) and the IGBP Core Project Biological Aspects of the Hydrological Cycle (BAHC) will hold sequential committee meetings in Tucson, Arizona.

16–18 May 1994—EIGHTH SESSION OF THE GPCP WORKING GROUP ON DATA MANAGEMENT (WGDM), Offenbach, Germany (tentative dates).

5–8 July 1994—WORKING GROUP ON RADIATION FLUXES (WGRF) Meeting, Luneburg, Germany.

11–14 July 1994—WGDM FOR WCRP RADIATION PROJECTS, Budapest, Hungary.

18–22 July 1994—EUROPEAN CONFERENCE ON THE GLOBAL ENERGY AND WATER CYCLE. For registration information on this conference write: The Executive Secretary, Royal Meteorological Society, 104 Oxford Road, Reading, Berkshire RG1 7LJ, UK.

12–14 December 1994—GPCP THIRD ALGORITHM INTERCOMPARISON PROGRAMME (AIP-3) WORKSHOP, Melbourne, Australia (tentative dates).

GEWEX REPORTS/DOCUMENTS (Available from IGPO)

GCIP BROCHURE (Tri-fold Glossy)

IMPLEMENTATION PLAN FOR THE GEWEX CONTINENTAL-SCALE INTERNATIONAL PROJECT (GCIP), Volume I—Data Collection and Operational Model Upgrade, May 1993, IGPO Publication Series No. 6.

A PRELIMINARY SCIENCE PLAN FOR A LARGE-SCALE BIOSPHERE-ATMOSPHERE FIELD EXPERIMENT IN AMAZON BASIN, Report on Workshop convened 18–20 June 1992 at NASA Goddard Space Flight Center, Greenbelt, Maryland, USA.

INTERNATIONAL SATELLITE LAND SURFACE CLIMATOLOGY (ISLSCP) WORKSHOP REPORT, 23–26 June 1992, Columbia, Maryland, USA.

PROJECT FOR INTERCOMPARISON OF LAND-SURFACE PARAMETERIZATION SCHEMES (PILPS): Report on PILPS Workshop, 24–26 June 1992, Columbia, Maryland and First Science Plan. September 1992, IGPO Publication Series No. 5.

GEWEX CONTINENTAL-SCALE INTERNATIONAL PROJECT (GCIP) DATA WORKSHOP: Summary report on 5–8 May 1992 Workshop. June 1992, IGPO Publication Series No. 4.

GEWEX CONTINENTAL-SCALE INTERNATIONAL PROJECT (GCIP) ATMOSPHERIC SCIENCE COMPONENT; Report on Atmospheric Subpanel Workshop 18–19 March 1992. May 1992, IGPO Publication Series No. 3.

IMPLEMENTATION PLAN FOR THE PILOT PHASE OF THE GEWEX WATER VAPOR PROJECT (GVaP), March 1992, IGPO Publication Series No. 2.

SCIENTIFIC PLAN FOR THE GEWEX CONTINENTAL-SCALE INTERNATIONAL PROJECT (GCIP)-WCRP-67, February 1992 (WMO/TD/No. 461). (Second Printing now available)

THE ROLE OF WATER VAPOR IN CLIMATE, A STRATEGIC RESEARCH PLAN FOR THE PROPOSED GEWEX WATER VAPOR PROJECT (GVaP), Report of Workshop, Easton, MD, U.S.A., 30 October – 1 November 1991. NASA Conf. Pub. 3210.

GLOBAL ENERGY AND WATER CYCLE EXPERIMENT (GEWEX)—REPORT OF THE FIRST GEWEX TEMPERATURE/HUMIDITY RETRIEVAL WORKSHOP, WCRP-XX, Greenbelt, MD, U.S.A., 23-26 October 1990.

GEWEX CONTINENTAL-SCALE INTERNATIONAL PROJECT (GCIP). REPORT OF THE FIRST GCIP PLANNING WORKSHOP. RESTON, VIRGINIA, U.S.A., 8_10 October 1990. April 1991, IGPO Publication Series No. 1.

SCIENTIFIC PLAN FOR THE GLOBAL ENERGY AND WATER CYCLE EXPERIMENT—WCRP-40, AUGUST 1990. (WMO/TD - No. 376).

GLOBAL CLIMATE CHANGE—A SCIENTIFIC REVIEW PRESENTED BY THE WORLD CLIMATE RESEARCH PROGRAMME (WCRP), January 1990. The WCRP is the international scientific program chartered jointly by the International Council of Scientific Unions and the World Meteorological Organization to provide a quantitative understanding of climate and predictions of global and regional climate changes on all time scales. This document is a review of global climate change as of 1990.

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Working Group on Data Management for the Global Precipitation Climatology Project at the July 1993 meeting in Tokyo, Japan. In the center of the first row is the Director General of Japan Meteorological Agency, Dr. Kozo Ninomiya, and to his right Dr. Phil Arkin, Project Manager for WCRP of GPCP. Next to Dr. Arkin (third from right) is Sam Benedict WMO/WCRP and second from left (also in front row) is Dr. Paul D. Try, Director, IGPO.

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