GEWEX WCRP

Global Energy and Water Cycle Experiment

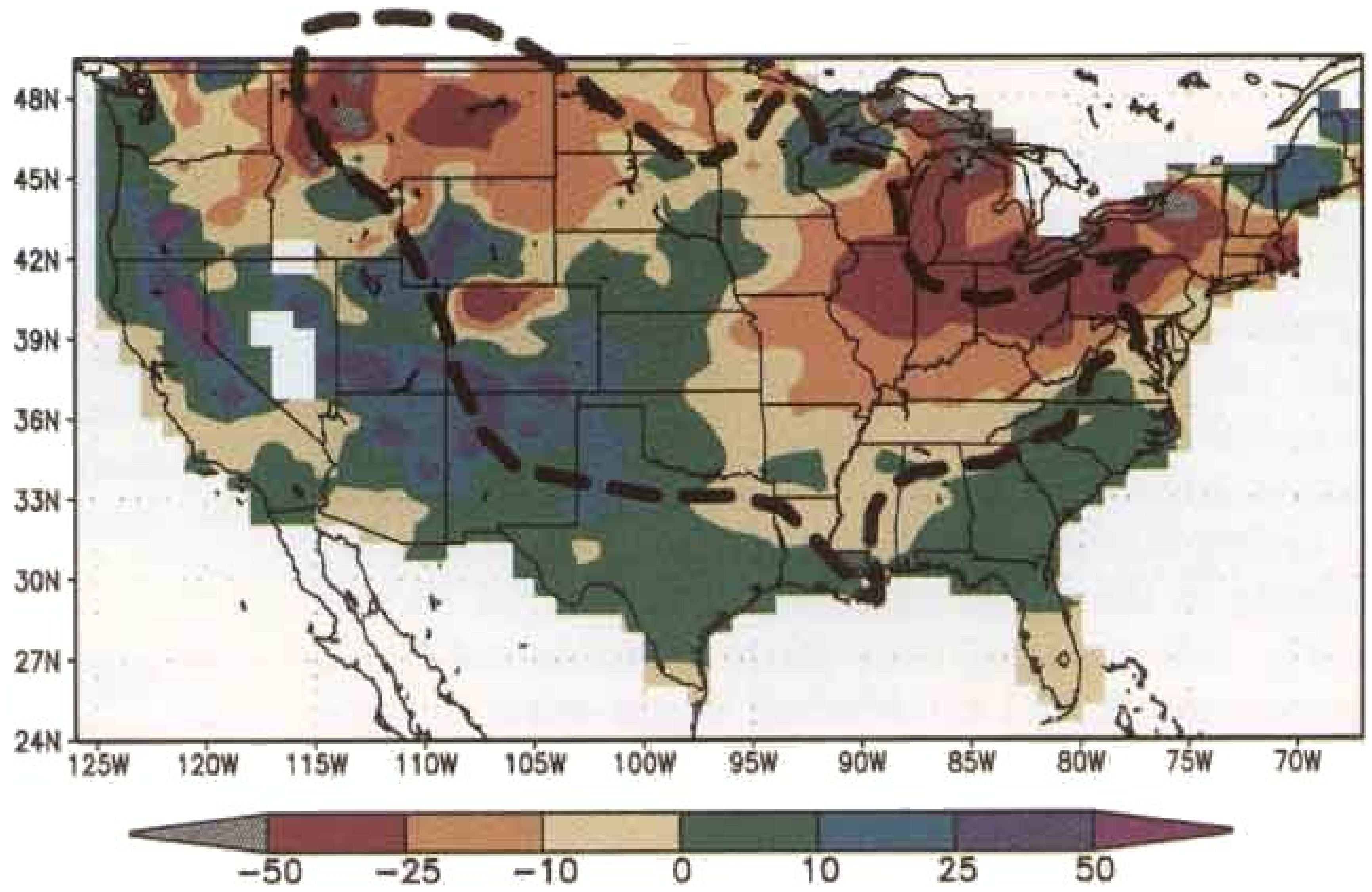
NEWS

Vol. 8, No. 2 May 1998

World Climate Research Programme–WCRP

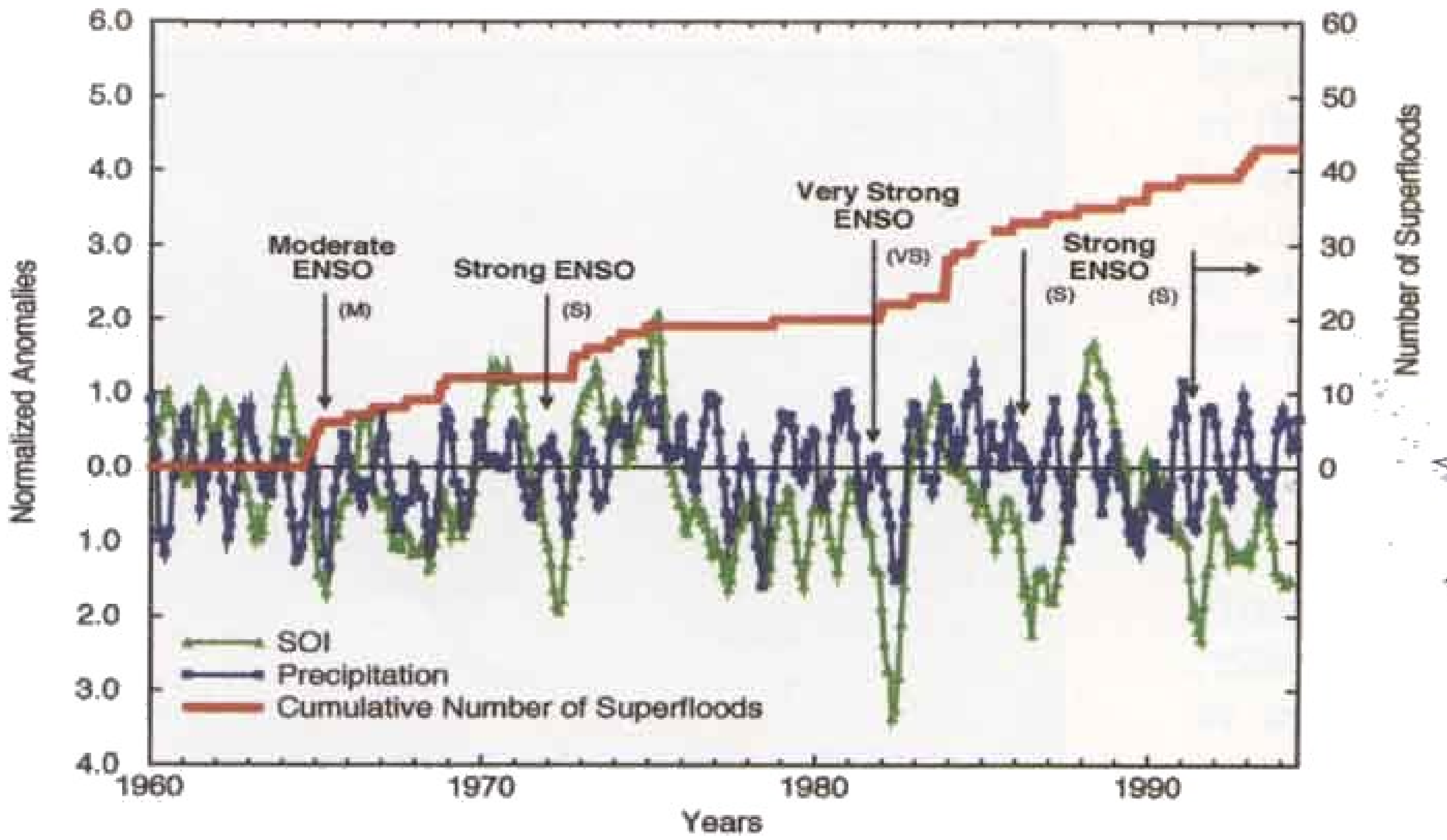
EL NIÑO IMPACTS GCIP REGION

Snowfall →



Forty-six years of data show below average snowfall for the northern United States during strong El Niño winters. (See article on Page 7.)

Superfloods ↓



Occurrence of extreme floods not necessarily related to precipitation anomalies—may link better to negative phase of SOI during El Niño events! (See article on Page 6.)

GAME IOPs UNDER WAY

7 Coordinated IOPs
80 RAOBs, 4 x day
See Pages 8-9

WHAT'S NEW IN GEWEX

- *New GEWEX Aerosol Project – Global Aerosol Climatology Project (GACP)*
- *Satellite Gravity Data Estimates Water Storage*
- *GCIP High Resolution Satellite Radiative Fluxes Now on World Wide Web*
- *GEWEX Coordinated EOP Planning Under Way (CEOP)*
- *Ten-Year AGCM climate runs show impact of land surface*
- *ARM to coordinate GVaP ground-based validation network*
- *3rd GEWEX International Scientific Conference set for Beijing, China in June 1999*

COMMENTARY

GEWEX CONTINENTAL-SCALE EXPERIMENTS COMMITMENT FOR CLOSER COORDINATION

Moustafa T. Chahine
GEWEX Scientific Steering Group

The GEWEX Continental-scale International Project (GCIP) was the first GEWEX large-scale land surface experiment. GCIP was established to improve understanding and demonstrate prediction of the variations of global and regional hydrologic processes and water resources and their response to environmental change. As a pathfinder project, and taking advantage of a wealth of data resources available in the Mississippi River Basin, GCIP was quickly followed by four more Continental-Scale Experiments (CSE) established world-wide in various climatic zones: (1) The Baltic Sea Experiment (BALTEX); (2) the Mackenzie River Basin GEWEX study in Canada (MAGS); (3) the Large-scale Biosphere-Atmosphere Experiment in Amazonia (LBA); and (4) the GEWEX Asian Monsoon Experiment (GAME), an experiment encompassing several areas in Asia. Establishment of a sixth experiment based on the study of the Coupling of the Tropical Atmosphere and Hydrological Cycle (CATCH) in West Africa is being considered. As Chairman of the GEWEX SSG, I am proud of the accomplishment of the international scientific community in organizing and conducting these major modeling and field-observing activities.

All CSEs have agreed to facilitate the exchange of scientific information and observational data, validate models and parameterization schemes and verify their transferability from one river basin to the other, and involve water resource agencies in order to better utilize prediction results. The CSEs will also engage the broader community through outreach efforts via a series of lectures on topics of regional and global climate variations and prediction of their impact on society.

The CSEs have now embarked on a field campaign designated as the Coordinated Enhanced Observing Period (CEOP). This campaign is a year-long effort to collect common data sets necessary to meet the common scientific objectives. The CEOP will start in the year 2001 and will be patterned after the First GARP Global Experiment. It will make effective use of the new generation of satellite data and global reanalysis schemes as well as other associated regional experiments. This coordinated effort will provide validation testbeds of models and remote sensing for GEWEX and other WCRP programs such as CLIVAR. It will also advance our understanding of several key processes of land surface and atmospheric interactions under different terrain and climate conditions, providing an important link in the transportability of data and models to larger scales. This coordinated effort will provide deeper insight into the coupled atmosphere-land surface interactions in the climate system and will improve our skill in predicting changes in precipitation and water resources on seasonal and annual time scales.

Through the efforts of the CSEs and the CEOP, GEWEX will measurably contribute to improved understanding and prediction of climate on a regional scale—a scale of importance and relevance to every citizen of our society. Ultimately, the legacy of GEWEX will be in the measure of this contribution. See related article on page 13.

Contents

INTER-ANNUAL VARIABILITY OF MACKENZIE RIVER DISCHARGE

Geoff Strong
GEWEX/MAGS Secretariat

The focus of the Canadian GEWEX Program is the Mackenzie GEWEX Study (MAGS). The Mackenzie is one of the largest northward-flowing rivers that empty into the Arctic, draining a basin of approximately 2 million km^2. The main objective of MAGS is to increase understanding of high latitude meteorological and hydrological processes and to improve capabilities to model such processes over the Mackenzie Basin. These processes include condensation and cloud processes in different seasons, precipitation mechanisms and types, redistribution of snow on the ground, evaporation, transpiration, and sublimation processes, energy, water and permafrost interactions.

Inter-annual variability in the climate and water balance of the Basin is large. In this relatively low precipitation region, spring snow melt and ice break-up lead to a sudden increase in discharge from the Mackenzie (see figure on the back page), which is prolonged by continued melt from higher elevations in the basin and rainfall during summer when almost 50% of the total annual precipitation occurs. **Variability of maximum discharge, which usually occurs in June, can be as large as 100%, and it appears to have a 3–4 year peak cycle**. Such variability impacts on the salinity of the central Arctic Ocean basin and its peripheral seas. The net surface water balance in any given year may not be zero, as substantial water storage can occur in the extensive wetlands, large lakes and in glacier ice. The major atmospheric moisture inputs to the basin come from the north Pacific Ocean, although evapotranspiration can make the basin a net source during summer. Moisture exports downstream are primarily to central Canada.

MAGS has been in progress for 3 years and involves some 35 government and university principal investigators, coordinated by a science committee with equal representation of hydrologists and meteorologists. Financial backing has been assured for the remaining 3 years of this first phase of the MAGS program (to mid-2001). A major thrust of the program is a concerted measurement program called CAGES (Canadian GEWEX Enhanced Study), in which most components of MAGS will be simultaneously undertaken for a "water year" commencing in early summer 1998. For future information, contact Geoff Strong at *Geoff.Strong@ec.gc.ca.*

Recent updates on MAGS can be viewed at the web site:

http://www.tor.ec.gc.ca/GEWEX/MAGS

NEW GEWEX AEROSOL PROJECT

Atmospheric aerosols, or fine particles, are one of the greatest sources of uncertainty in the interpretation and prediction of global climate change. Natural variations of aerosols, especially due to episodic eruptions of large volcanos, are recognized as a significant climate forcing, that is, a factor that alters the planetary radiation balance and thus may cause a global temperature change. In addition, aerosols from soil dust, biomass burning, and fossil fuel use are altering the amount and geographic distribution of atmospheric aerosols, and thus possibly affecting climate. The **GEWEX Global Aerosol Climatology Project (GACP)** is concerned with the climate forcing due to changing aerosols, including both the direct radiative forcing by the aerosols and the indirect radiative forcing caused by effects of changing aerosols on cloud properties.

In Phase I of GACP, a 20-year global climatology will be compiled of aerosol forcing data from satellite observations and field observations for use in climate models. To accomplish this, the Earth Science Enterprise (formerly called Mission to Planet Earth) of NASA Headquarters, has issued a research announcement NRA-97-MTPE-16. Principal investigators of the successful proposals will be included in the GACP Aerosol Radiative Forcing Science Team. This team will provide scientific guidance for a strategic approach toward definition of radiative forcing, encourage appropriate collaboration among research groups, and provide guidance to GACP. Phase II will consist of complementary field studies.

SATELLITE GRAVITY AND THE GEOSPHERE: CONTRIBUTIONS TO HYDROLOGY

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The cycling of water between and within the oceans, the atmosphere, and the continents, is a major source of mass re-distribution, with effects that should be readily detectable in satellite gravity data. In a National Research Council report (NRC, 1997), the Committee on Earth Gravity from Space explored the scientific questions that could be addressed with a better determination of the global gravity field, examined generic mission scenario, and deduced the expected advances that would flow from each. **The gravitational effects of changing water storage in continental regions are likely to be among the largest time-dependent signals. Gravity missions could provide estimates of changes in water storage over scales of several hundred kilometers and larger, with an accuracy of better than 10 mm of water equivalent everywhere over the globe**. For the GEWEX community, these results would be useful for connecting hydrological processes at the traditional scales of individual catchments (10's of kilometers and less) to those at larger scales. They would also be beneficial because of the impact of soil moisture on evapotranspiration and the exchange of latent heat between the continents and the atmosphere. The results could also aid in the ongoing evaluation of the Earth's water supplies by supporting the monitoring of aquifer depletion and snowpack, helping to predict floods and runoff available for irrigation and aiding in the assessment of agricultural productivity on a large scale. In addition there is a particularly exciting potential to study sea level changes and their causes (NRC, 1997; Dickey et al., 1988).

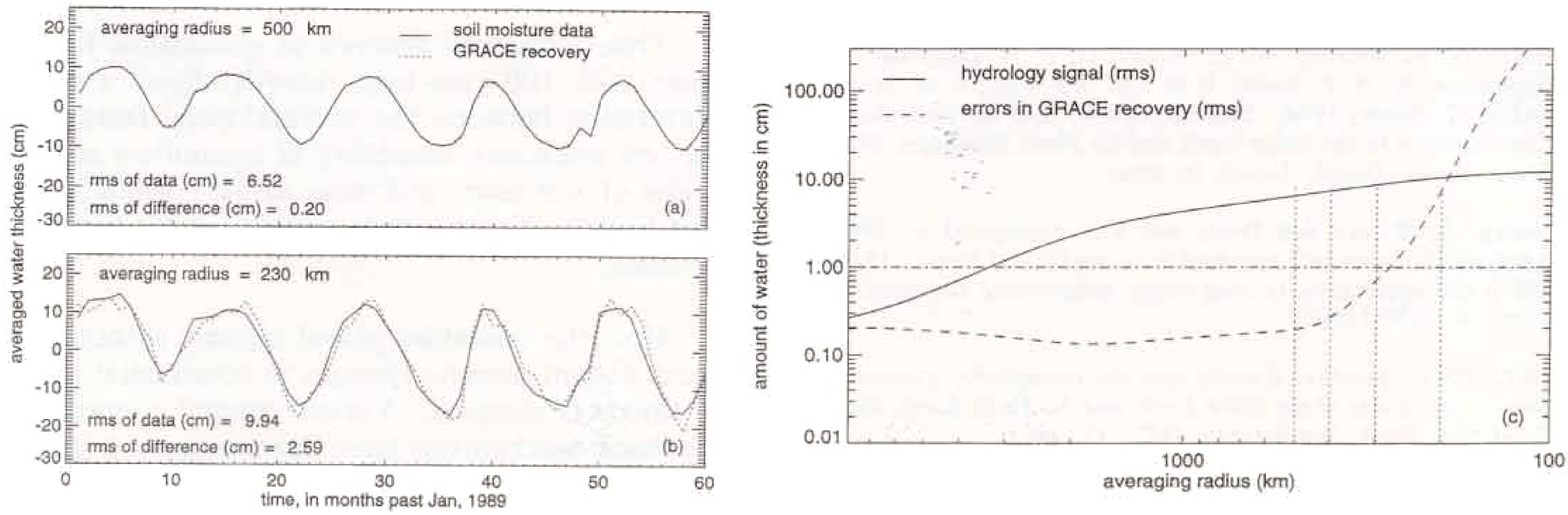
Satellite gravity data that have accumulated over several decades have been used to produce complex interpretive models of the Earth's gravity field (Nerem et al., 1995). Laser tracking of geodetic satellites augmented by satellite radar altimetry and GPS measurements have been the primary data source. The approval of two new missions opens a new era in the study of the global gravity field. The new missions are: (a) German-led mission CHAllenging Microsatellite Payload (CHAMP) for geophysical research and application, with U.S. involvement, scheduled for launch in 1999 and (b) NASA's Gravity Recovery and Climate Experiment (GRACE; launch date 2001). GRACE's low altitude (480 to 300 km), as well as its long lifetime (5 years), will provide measurements of both the static and temporal components of the gravity field with an unprecedented spatial and temporal accuracy.

The issue of whether GRACE gravity solutions can be inverted to solve for those changes in water storage depends on the amplitude of this hydrological gravity signal, and on whether the hydrological contributions can be separated from changes in gravity caused by other types of mass variability. The atmospheric signal is a particular problem because GRACE would be incapable of distinguishing between a change in water storage in a region and a change in atmospheric mass integrated vertically above that region. The atmospheric contributions will be removed from the GRACE results prior to the hydrological solutions by using the global pressure fields available from meteorological forecast centers. However, any errors in those pressure fields could degrade the hydrological results.

The figure on the next page (from Wahr et al., 1998) shows synthetic water storage solutions obtained by inverting simulated GRACE gravity data. The gravity data include estimated signals of soil moisture plus snowpack (using a global data set constructed as described by Huang et al., 1996), as well as gravity contributions from the atmosphere and oceans, and a realization of the expected GRACE measurement errors. The gravity data are used to infer monthly changes in water storage averaged over a disc centered at Manaus, Brazil (in the Amazon River Basin), and the results are compared with the results computed directly from the soil moisture data set used in the simulation. The results are shown in terms of the thickness of a water layer. The results in panels (a) and (b) show comparisons for 5 years of monthly values for two different averaging discs (radii of 500 and 230 km). Panel (c) shows the rms both of the predicted signal at this location and of the errors in the GRACE recovery of this signal, as a function of averaging radius. Note that the GRACE errors are smaller than the signal at radii of about 200 km and larger (smaller than 1 cm at radii in excess of about 280 km), and reduce to about 2–3 mm at radii of 400 km and larger. The 2–3 mm limit comes from the estimated atmospheric pressure errors, and is equivalent to a 0.2–0.3 mbar rms pressure error. The degradation of the results with decreasing radius is due to the increase in GRACE measurement error with decreasing scale.

The inferences are that GRACE should be able to provide useful estimates of changes in continental water storage at scales of a few hundred kilometers and larger and at time scales of two weeks and longer, and that GRACE has the potential of delivering monthly values of water mass with accuracies approaching 2 mm in water thickness at large scales. The GRACE results can also complement space-based microwave and infrared soil moisture measurements. The latter provide information on only the upper few centimeters of water in the soil, whereas the GRACE estimates reflect changes in water storage throughout the water column. What GRACE does allow is closure of the total water budget over large regions. This should permit the assessment and improvement of regional-scale hydrological models and of the hydrological components of atmospheric and climate models.

The sources of global sea-level rise are uncertain; most, but not all, of the likely mechanisms involve the redistribution of mass from the continents to the ocean. From a GRACE-type mission, an increasing mass of water in the ocean equivalent to 0.1 mm/yr of sea-level rise can be measured. Changes in the masses of the Antarctic and Greenland ice sheets are the major unknown contributors to sea-level change—even the sign of ice-sheet mass



The results of simulations in which synthetic GRACE data are used to recover the hydrological signal at Manaus, Brazil (in the Amazon River Basin). The simulated geoid data include the GRACE geoid errors, as well as contributions from hydrology and oceanography, and our estimated errors in the atmospheric pressure data. Panels (a) and (b) show 5 years of monthly values for two averaging radii. The solid line is the hydrology signal that went into the simulation, and the dotted line is the signal inferred from the synthetic GRACE data. Panel (c) shows the rms of 5 years of monthly data as a function of averaging radius. The solid line is the estimate from the hydrology data. The dashed line represents the accuracy of the GRACE results, estimated as the rms of the difference between the GRACE recovered values and the hydrology signal (from Wahr et al., 1998).

change is in dispute. Gravity measurements over the ice sheets (particularly, in combination with a laser-altimeter mission) would lead to a determination of those contributions with an accuracy of a very few tenths of a millimeter per year.

In summary, satellite gravity measurements expected in the next few years will provide unprecedented views of the Earth's gravity field and, given sufficient duration, its changes with time. Gravity changes directly reflect changes in the masses of the ocean (thus allowing the separation of steric and non-steric contributions to sea-level rise), the Greenland and Antarctic ice sheets, and the water stored in the continents. Not only can measurements of those changes provide a truly global integrated view of the Earth, they have, at the same time, sufficient spatial resolution to aid in the study of individual regions of the Earth. These data should yield information on water cycling previously unobtainable and be useful to both fundamental studies of the hydrologic cycle and practical assessments of water supply and distribution.

For further information contact Jean Dickey, Tel: 818-354-3235; Fax: 818-393-6890; E-mail: jean.dickey@jpl.nasa.gov.

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ENSO INFLUENCE ON THE OCCURRENCE OF EXTREME FLOODING

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Pennsylvania State University

The relationship between El Niño Southern Oscillation (ENSO) events and superfloods over the GEWEX Continental-scale International Project (GCIP) domain of the Upper Mississippi River Basin is shown on the front cover (lower figure). Superfloods are defined as those that occur with return periods in the order of 10 years for river basins exceeding 10^4 km^2, as shown by the red line in the figure. The surface pressure difference between Tahiti and Darwin over the Pacific Ocean is known as the Southern Oscillation Index (SOI), and is shown in purple. Shown in green are the monthly anomalies of precipitation. **Note that superfloods are not necessarily related to the high precipitation anomalies, but the data suggest a link between high precipitation anomalies to the negative phase of SOI during El Niño.**

The substantial increase in the number of superfloods after the 1982–1983 events through 1994 is consistent with the strengthening of ENSO activity during this period. Similar patterns can be found in the early and mid-century decades.

Time frequency analysis of streamflow for stations with 100-year-long records shows a strong correlation between the nonstationary features of the low frequency variability of streamflow at timescales of 7–9 years, and those of the Eastern Pacific Sea Surface Temperature anomalies for the same decades.

How the uncertain global climate system connects distant oceanic changes to continental events as floods is complex. Various natural connectivity feedback mechanisms have been suggested including land-atmosphere processes and the impact of clouds. It is clear that modeling and interdisciplinary assessments must be pursued to develop a science basis to provide decision makers with reliable information.

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THE RELATIONSHIP OF SNOWFALL IN THE UNITED STATES TO ENSO

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The relationship of Mississippi River Basin snowfall to the El Niño Southern Oscillation (ENSO) was investigated using data from more than 1,000 cooperative observer stations for the period 1951–1997. For each station, total seasonal snowfall was computed for each of the 46 cold seasons from 1951–1952 to 1996–1997. Statistical relationships involving the ENSO were based on seven strong El Niño events (1957–1958, 1965–1966, 1968–1969, 1972–1973, 1982–1983, 1991–1992, and 1994–1995) and five strong La Niña events (1955–1956, 1970–1971, 1973–1974, 1975–1976, and 1988–1989). These events were identified based on sea surface temperature anomalies (SSTA) averaged over the central Pacific region bounded by 180° to 150°W and 5°S to 5°N, following Livezey et al. (1997). To be included in our analysis, SSTAs had to exceed 1°C for each of the winter months of December, January, and February. This set of cold seasons excludes weaker events. Snowfall for seven strong El Niño and five strong La Niña events were compared with snowfall occurring during the other 34 (base period) winters.

The upper figure on page 1 shows the difference between the mean snowfall of the seven El Niño cold seasons and the 34-year base set for the Upper Mississippi River Basin. **The average snowfall for the seven El Niño winters exhibited a coherent pattern with below average snowfall across the eastern portions of the basin and near average snowfall over the rest of the basin.** On the lee side of the Great Lakes, negative anomalies of greater than 70 cm are seen. Application of the modified Welch two-sample t-test (Snedecor and Cochran, 1980) indicates that these snowfall anomalies are significantly different (at the 10% level) from the base period snowfall over Illinois, Indiana, and Ohio. These results are consistent with the model experiments of Livezey et al. (1997), who examined the response of the general circulation to SSTAs in the central Pacific. They found that middle tropospheric pressure anomalies were positive in southern Canada and negative in the southern United States. This decreases the pressure gradient across the northern U.S., which might be expected to result in less frequent and/or less intense extratropical cyclone activity. Other work (e.g., Montroy et al., in press) has shown that El Niño events are associated with below average total precipitation during January and February in the Great Lakes and Ohio River valley. This is also consistent with these snowfall results.

These results suggest the potential to make snowfall forecasts several months in advance of winter in the above areas by capitalizing on recent advances in the capability to forecast El Niño events. However, this snowfall signature was not present in an analysis that included weak El Niño events. Also, during the strong La Niña winters, there was no tendency for above or below average snowfall.

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GAME INTENSIVE OBSERVING PERIOD UNDER WAY

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The overall goal of GAME is to understand the role of the Asian monsoon in the global climate system, with a particular focus on diurnal, seasonal and interannual time scales.

The GAME strategy for achieving this goal consists of three components:

1) Monitoring by satellites and *in situ* surface observations

2) Process studies based on four regional experiments in the Chao-Praya River Basin of Thailand (GAME-Tropics), the Huaihe River Basin in central China (HUBEX), the Tibetan Plateau (GAME-Tibet) and the Lena River Basin in Siberia (GAME-Siberia).

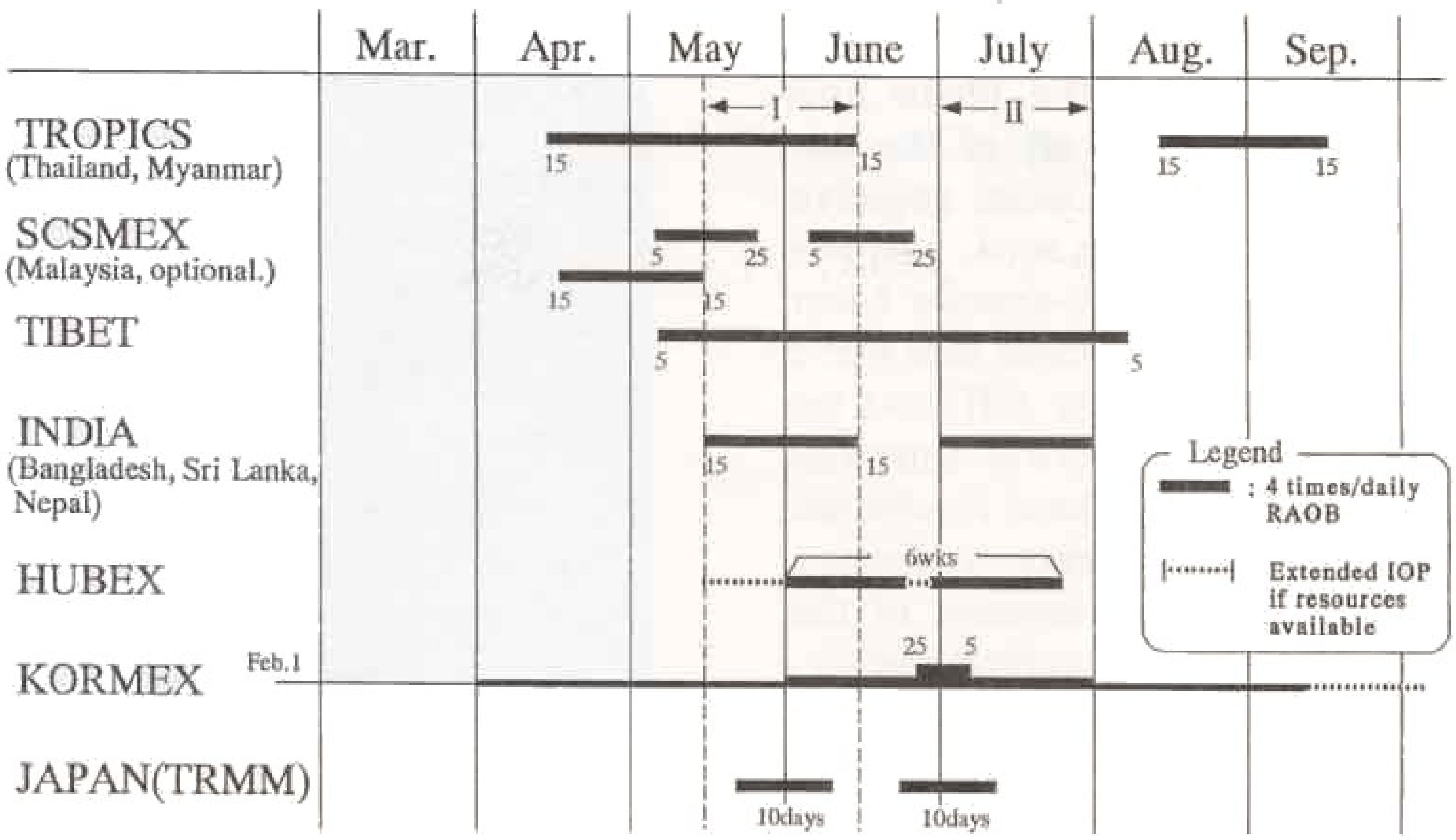
3) Modeling of hydrometeorological processes in the climate system.

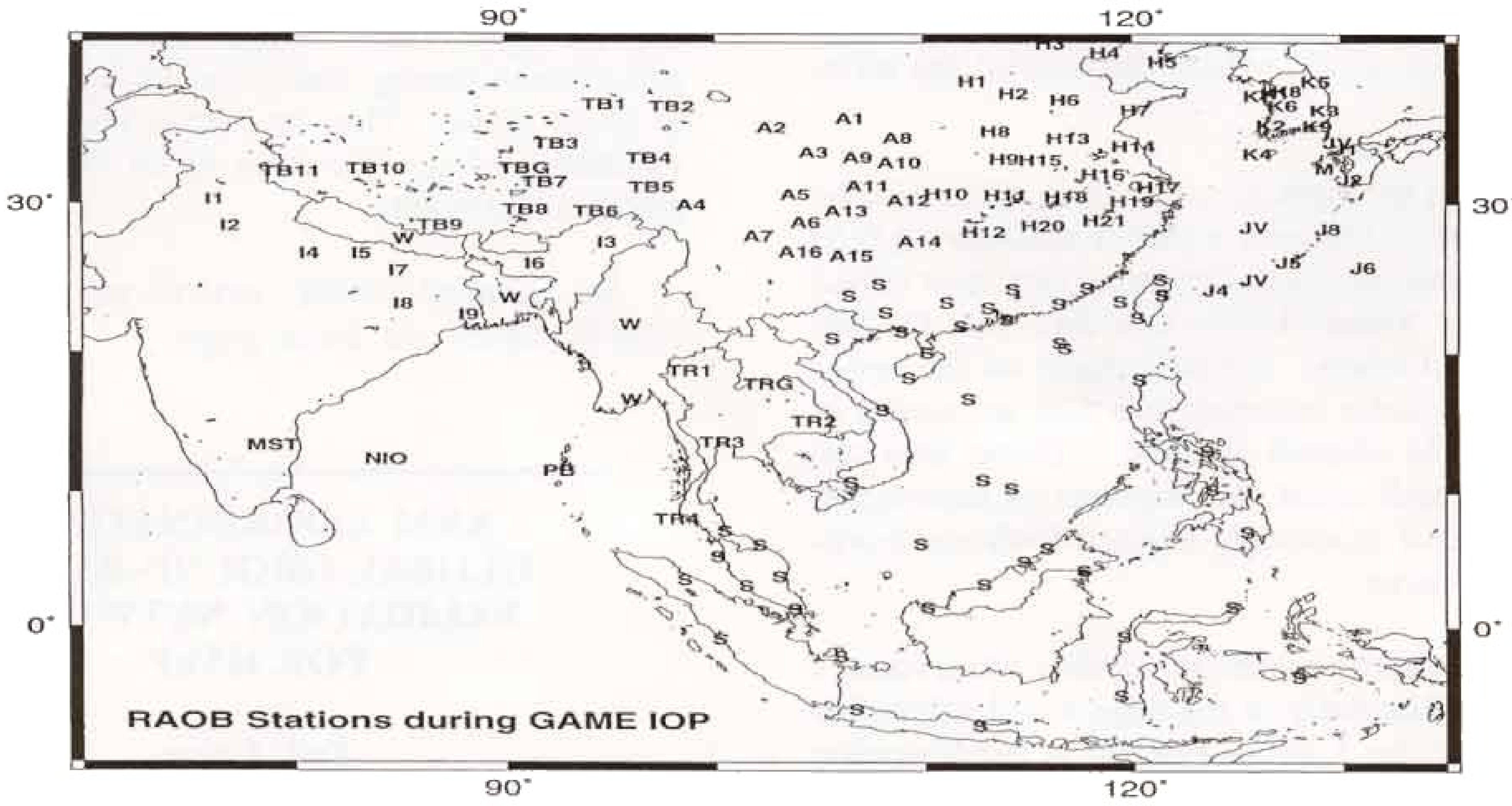
To resolve the diurnal cycle of energy and hydrological processes of the Asian monsoon system, GAME is conducting an Intensive Observing Period (IOP) from April through September 1998 for the four regional experiments. The IOP is coordinated with the South China Sea Monsoon Experiment (SCSMEX) (see article in February 1998 issue of *GEWEX News*) and will include 4 times/day enhanced radiosonde observations, which will be combined with measurements from the Tropical Rainfall Measuring Mission (TRMM). **In addition, long-term monitoring of surface radiation and energy budgets will be started at 12 sites in the monsoon Asian region from Siberia to the tropical rainforest, as part of GAME-AAN (Asian AWS Network).**

Phase I (April) of the IOP focuses on the processes in the pre-monsoon season, and will study the land-surface/atmosphere interaction, including snow cover over the Tibetan Plateau, and soil moisture/evaporation and pre-monsoon rain processes in the tropics and subtropics. Land surface hydrological process, surface radiation and heat fluxes and PBL processes will be intensively observed. In Southeast Asia, particularly over the Indo-China peninsula, this stage includes the onset of the summer monsoon and the role of soil moisture changes from the dry pre-monsoon condition to the post-onset conditions.

Phase II (May to June) corresponds to the onset phase of the monsoon over the major part of the Asian monsoon region, including India, the Tibetan Plateau, and the South China Sea. In east Asia (China, Japan, Korea) this phase also corresponds to the onset of the frontal rain season. The full onset of the monsoon over the South China Sea is nearly consistant with this phase. In Siberia,

GAME-IOP (year 1998)





rapid snow melt and seasonal warming of the surface and atmosphere occur nearly concurrently.

Phase III (July to September) corresponds to the mature phase of the monsoon in the tropics and Tibetan Plateau. In east Asia, this phase is nearly consistent with the withdrawal phase of the frontal rain season. Precipitation reaches its maximum in the northern part of the continent.

In these phases, the roles of surface-atmosphere interaction and convective activity in the continental as well as regional scale fields should be solved in time scales of the diurnal cycle, intraseasonal variability and seasonal cycle.

The intensive upper air sounding of temperature, humidity, pressure and wind fields over the entire Asian monsoon area will provide essential data for estimating the atmospheric energy and water budget during the IOP. The aerial coverage of the radiosonde network for the GAME IOP is shown in the figure above. **GAME and SCSMEX will coordinate enhanced radiosonde observation 4 times per day (every 6 hours) at more than 80 stations**. The unified enhanced observation period for the whole domain includes one month from May 16 to June 15 (onset phase) and one full month in July (mature phase). Each regional project or country will have a different schedule of enhanced radiosonde observations, depending upon the regional monsoon conditions and the scientific objectives of their own. GAME-Tropics will implement longer enhanced radiosonde observation because Southeast Asia has the longer monsoon season with two major rain spells in May to June and August to September. The time schedules of the enhanced observation for each region and country is shown on Page 8. The countries involved include Japan, China, Korea, Taiwan, Philippines, Vietnam, Thailand, Malaysia, Singapore, Indonesia, Myanmar, India, Bangladesh, Sri Lanka, and Nepal.

Sixteen upper air stations in China will be involved in the IOP as part of the Japan-China cooperative study on the Asian monsoon. Korea will implement the enhanced radiosonde observations during the IOP as part of the KORMEX enhanced observation. The mesoscale meteorological research group of the Meteorological Research Institute in Tsukuba is going to cooperate with this IOP by deploying the enhanced radiosonde and radar observations over the East China Sea. The Japanese Meteorological Agency will also implement the enhanced observations at some stations in southwestern part of Japan in cooperation with the TRMM validation program in the Okinawa Islands.

The India Meteorological Department (IMD) agreed to implement the enhanced radiosonde observations of 9 stations in Northern India. In addition, the National MST Radar Facility at Gandaka will implement continuous MST radar observations to monitor vertical wind profiles throughout the monsoon season.

In addition to upper air operations there will be a network of automated weather stations (AWS) providing surface and planetary boundary layer (PBL) observations. Shown below is a flux-type GAME meteorological tower. All equipment on the tower is powered by solar batteries and data are stored in the stand-alone control module. These data are archived and will assist investigators to resolve the diurnal cycle of mesoscale surface hydrometeorological phenomena.

One of the most essential satellite observations for GAME, particularly in the tropics and subtropics and including the Tibetan Plateau is precipitation

Flux type GAME Tower located at Arvaikheer, Mongolia. Photo taken on 19 March 1998, surface temperature –10°C, smoke in background from town of Arvaikheer. Photograph courtesy of Dr. Rikie Suzuki.

rate measurements by TRMM, which was launched in November 1997 (see example of TRMM measurements on back page). The 5-day mean through 1-month mean rainfall amounts over the GAME area including the surrounding oceans need to be validated based on *in situ* intensive observations and other satellite-derived atmospheric moisture quantity such as from SSM/I, some of which will be deployed as part of the GAME regional experiments. These rainfall data will be used for aerial mean energy and water budget analysis and/ or basin scales. This data set is also important for validation of precipitation in GCMs and regional model experiments.

See related GAME article on page 14 and TRMM figure on back page.

ARM COORDINATING GLOBAL GROUND-BASED VALIDATION NETWORK FOR GVaP

Ted Cress
Pacific Northwest Laboratories

The GEWEX Global Water Vapor Program (GVaP) plans to acquire data from a worldwide network of ground sites in order to validate global water vapor distribution data sets derived from satellite remote sensing. The purposes of the global ground-based validation network are strikingly similar in many respects to the measurement and data quality objectives of the Department of Energy's Atmospheric Radiation Measurement (ARM) Program. ARM will coordinate the establishment of the GVaP ground-based network, based largely on its experience in establishing its existing three highly instrumented sites and its data distribution and archival capabilities. ARM's current sites in Oklahoma, Alaska, and the Tropical Western Pacific Ocean will form a backbone for the GVaP validation network. Additionally, ARM's own concentration on water vapor measurements has established a level of experience in instrument performance and capability as well as data analysis and intercomparison that will aid GVaP in establishing its satellite data validation methodology. To date, ARM has conducted two intensive measurement periods focused on water vapor, in September 1996 and 1997. The key instruments involved have included Raman Lidar, microwave radiometers, balloon sondes, chilled mirrors at the surface and on a tower, airborne *in situ* measurements and the high resolution (one wave number) atmospheric emitted radiance interferometer (AERI). More information on these measurement periods and ARM are available from the ARM web site at http://www.arm.gov.

IMPORTANCE OF LAND-SURFACE PROCESSES FOR THE UNCERTAINTIES OF CLIMATE CHANGE: A EUROPEAN PROJECT

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[4]University of Reading, United Kingdom

In the contribution of Working Group I to the second assessment report of the Intergovernmental Panel on Climate Change (Houghton et al., 1996) land-surface/atmosphere interactions were considered to be one of the major uncertainties attached to current climate projections. The disparity between soil moisture, latent and sensible heat fluxes simulated by current land-surface schemes in intercomparison projects such as PILPS (Henderson-Sellers et al., 1994) was taken as an indicator for this uncertainty. To measure the impact of land-surface schemes on the sensitivity of atmospheric general circulation models (AGCM) one would need to compare it to the uncertainties linked to the other processes in these models. This can only be achieved with a coordinated set of experiments using a number of AGCMs. **In 1996 the European Commission financed a project with the aim of determining the uncertainty linked to land-surface processes in climate change simulations.** Preliminary results from this project are presented here.

The experimental design selected for this project was rather simple and tried to impose as few constraints on the modelling groups as possible. Four groups chose to participate with their AGCM; the Hadley Centre, the Laboratoire de Météorologie Dynamique du CNRS, Météo-France and the University of Reading. It was decided to perform with all AGCMs time-slice experiments of at least 10 years using a transient climate change run available at the Hadley Centre (Mitchell et al., 1995). This was accomplished by applying the temperature and sea-ice changes obtained from this coupled experiment to the climatological sea-surface temperatures used by the AGCMs. Each of the participating groups performed 1 x CO_2 and 2 x CO_2 time-slice experiments with their standard land-surface scheme and also a modified scheme. The choice of this modification was left to the groups but most chose to alter only the hydrological part of the scheme (see table below). The experiments of the Hadley Centre also includes a change in the soil thermodynamics. Thus only a small section of the uncertainties associated to land-surface modelling is explored in this project.

The monthly means of the last 10 years for the four experiments of each group (2 control and 2 double CO_2 experiments) are being archived at LMD. Before the completion of the database we decided to perform a preliminary analysis on a limited number of regions and variables. The aim was to guide and plan the work on the full data set. **The initial results of the preliminary analysis indicate that land-surface modelling may result in uncertainties in climate change predictions that are comparable to those caused by other processes.**

To try to depict the relative importance of the uncertainty related to land-surface processes a simple diagram was developed. As all the 2 x CO_2 experiments used the same sea surface temperature change we can measure the difference in sensitivity between the AGCMs by plotting on the horizontal

Hadley Centre	Exp A Exp B	Old land-surface scheme (Jones et al.) The MOSES scheme
Laboratoire de Météorologie Dynamique	Exp A Exp B	The SECHIBA scheme (Ducoudre et al.) A simple bucket hydrology
Météo-France	Exp A Exp B	The ISBA scheme (Noilhan and Planton) Surface conductance was reduced
University of Reading	Exp A Exp B	The ECMWF scheme (Viterbo and Beljaars) The rooting depth was increased

A brief description of the time-slice experiments performed for this project.

axis the deviation in percentage of the annual mean response from the average of all eight experiments. This encompasses for instance the uncertainties linked to the water vapor or cloud/radiation feedbacks as these processes are modeled differently in all four AGCMs. The deviation in percentage of each experiment from the average response for its AGCM gives a measure of the change in sensitivity induced by the modification of surface processes. This anomaly is plotted on the vertical axis. Thus, in these graphs a clustering of points around the 1:1 line means the impact of land-surface processes representation on climate sensitivity is similar to the impact of the other differences among the participating AGCMs, while a horizontal line may lead to the conclusion that land-surface processes will not have a dominant role in the model's response.

Figure 1 shows the relative importance of the land-surface schemes for the sensitivity of annual mean surface temperature over all land points. The experiments A and B for each model form distinct pairs along the horizontal axis. This means that the various changes performed by the four groups to their land-surface scheme affect the surface temperature increase by only a small amount compared to the differences between the AGCMs. The radiative fluxes at the surface exhibit a similar behaviour. The result is very different for annual mean precipitation over all land points. **Figure 2 shows that the difference in sensitivity between the two experiments performed with one AGCM can be as large as between two models.** The uncertainty linked to surface processes is in this case important for the sensitivity of the AGCM. The same result is obtained for evaporation and moisture convergence. We noted in this preliminary analysis that the magnitude of the impact of the land-surface change on the control climate did not give good guidance as to its impact on climate sensitivity.

Previous studies have shown that projections of the surface conditions in a greenhouse gas enhanced climate will depend on our ability to model the surface (Thompson and Pollard, 1995) but this dependence was not compared to other sources of uncertainties. The preliminary results presented above included only four models; nevertheless they suggest that our ability to project the changes in the hydrological cycle of the atmosphere for a changed

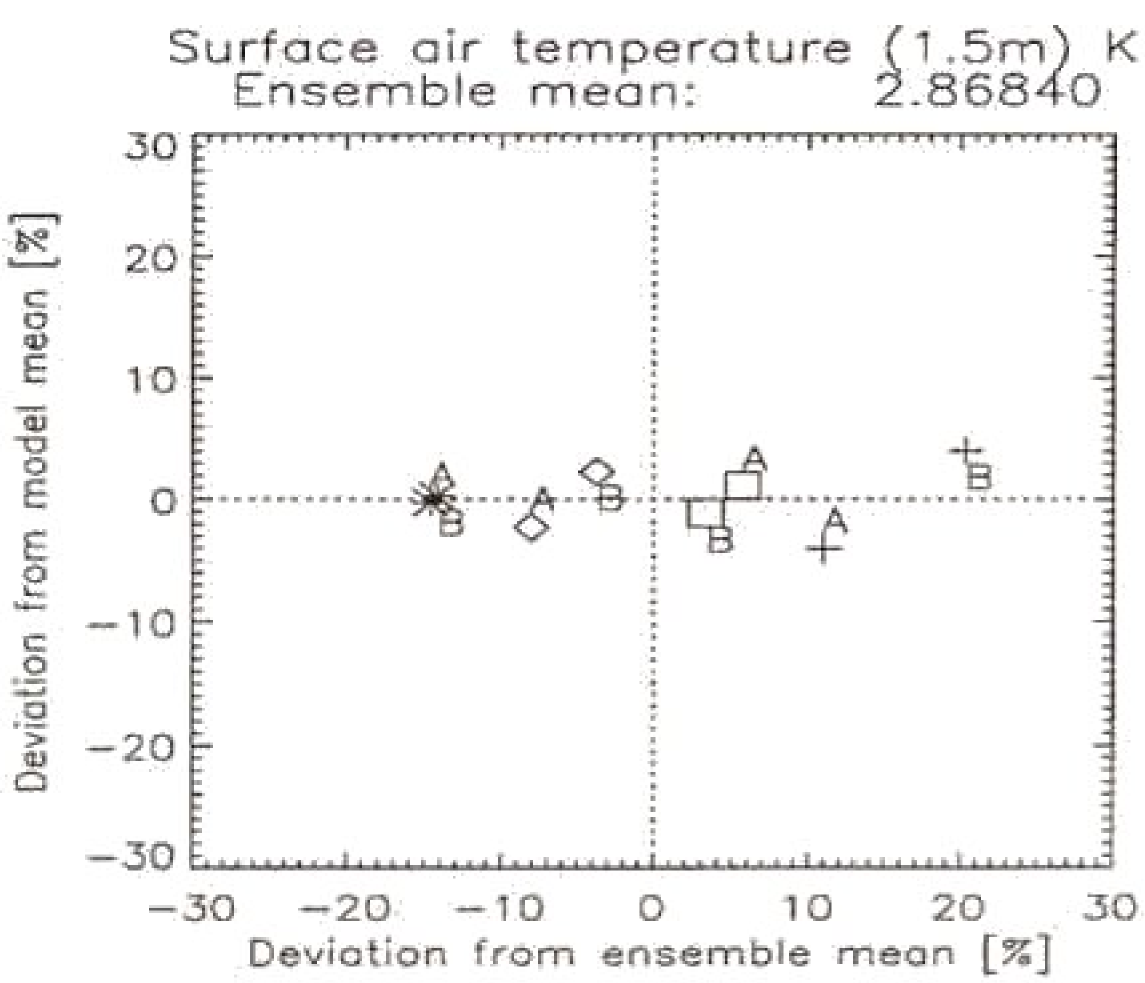

Figure 1. Comparing the variations of the increase in annual mean surface air temperature averaged over all land points for four AGCMs against the impact of a change in land-surface processes to this warming. The vertical axis is the deviation of the temperature increase in one experiment from the average of Exp A and Exp B obtained with this AGCM. The horizontal is deviation from the average sensitivity of all ACMs and experiment.

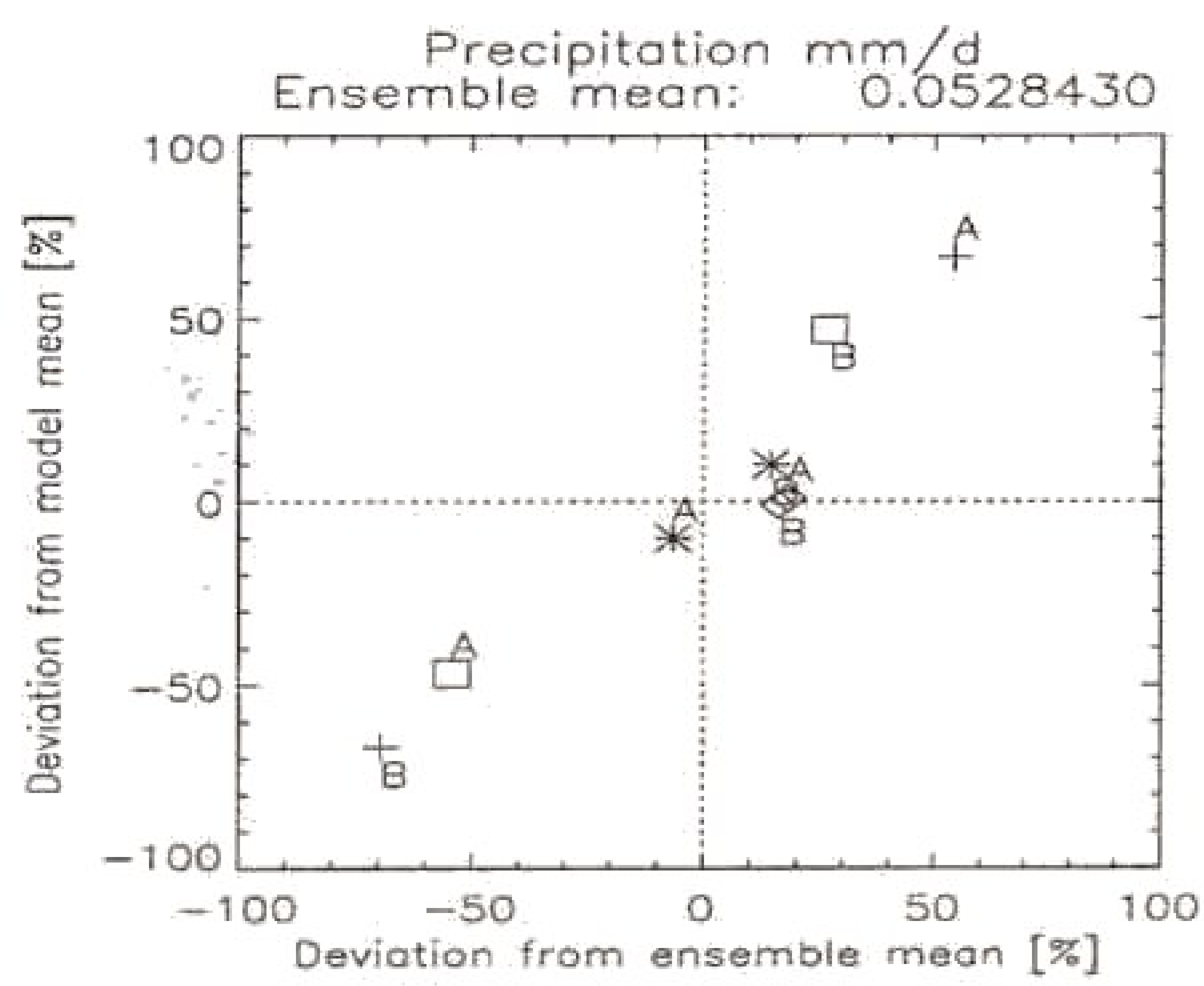

Figure 2. Same as Figure 1 except for precipitation. Ten-year climate change runs (2 x CO_2) for four AGCMs show that variations in the treatment of land-surface processes within one model cause impacts larger than the difference between AGCMs for precipitation, evaporation and moisture convergence. Each AGCM is attributed a symbol and the letter designates the experiment.

climates will have to take into account our ability to model the land-surface. For the uncertainties linked to the cloud/radiation feedbacks, it was recognized early on by the community that comprehensive intercomparison projects were needed for their assessment (Cess et al., 1993). Considering the importance of the hydrological cycle for human activities it might be meaningful to extend the intercomparisons performed in this project to a wider sample of AGCMs.

This project will continue the preliminary analysis by studying the uncertainty in different regions and by extending it to a larger number of variables. Once the database is complete the analysis will focus on the mechanisms behind the changes in the hydrological cycle, how they vary from one experiment to the other and how robust they are. Once the project is completed the database will be made available to the community.

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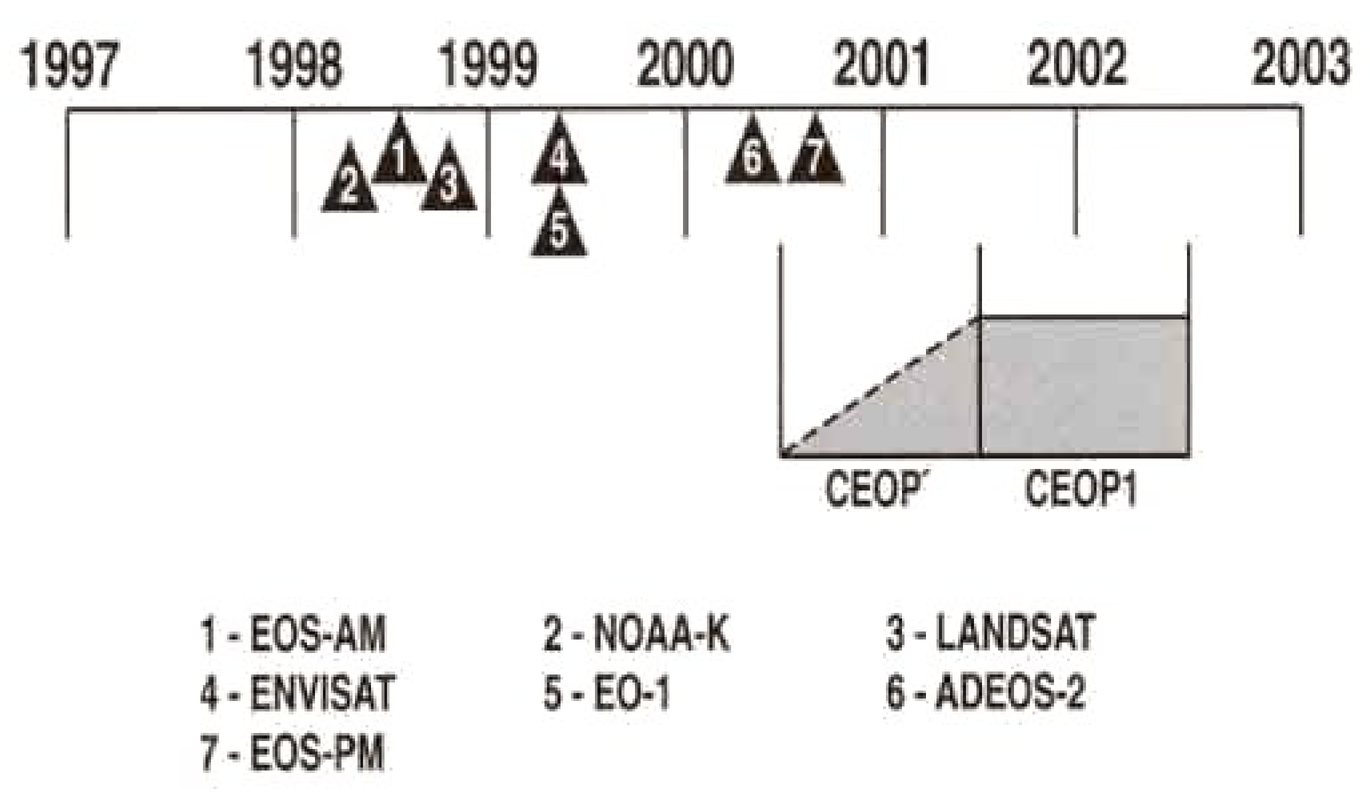
COORDINATED ENHANCED OBSERVING PERIOD PLANS AND PROGRESS

Rick Lawford
GCIP Project Office

On March 26 and 27, 1998, representatives from four of the Continental-Scale Experiments (CSE) met at the University of Arizona to develop GEWEX Hydrometeorology Panel (GHP) plans for a Coordinated Enhanced Observing Period (CEOP). Participants agreed that the next decade represents the first real opportunity for continental data sets to be developed on a global scale based on the new generation satellites. Consequently, they are recommending that the GHP carry out a case study of the influence of continental hydroclimatic processes on the predictability of global atmospheric circulation patterns and changes in water resources on time scales up to seasonal using data sets collected from the CSEs and other strategic areas. To fulfill these plans the CSEs plan to enhance their observing programs during the period 2001 to 2002 after the launch of the EOS-PM satellite. It is recognized that this initiative needs to be much broader than just the CSEs; consequently, linkages are being sought with global hydrology initiatives and other components of GEWEX. The CEOP will be an important element of the transferability and global applications strategy also being developed by the GHP. Those interested in more information about opportunities for involvement in the CEOP should contact the CEOP Working Group Chair, Toshio Koike at tkoike@nagaokaut.ac.jp or Rick Lawford at lawford@ogp.noaa.gov.

Proposed Schedule for the GHP Coordinated Enhanced Observing Period (CEOP)



MEETING SUMMARIES

THIRD GAME INTERNATIONAL SCIENCE PANEL

Kenji Nakamura
GAME International Project Office

The Third GAME International Science Panel (ISP) was held from 12 to 14 January 1998 at the Japan Meteorological Agency (JMA), Tokyo, Japan, with the kind support of JMA, the National Space Development Agency of Japan and the World Climate Research Programme (WCRP). Twenty-three ISP members or representatives and 42 observers/experts from 13 countries participated.

After opening addresses from Prof. T. Yasunari, Chairperson of GAME; Mr. T. Ono, Director of JMA; Mr. W. Iwamoto, Ministry of Education, Science, Sports, and Culture, Japan; and Mr. T. Tanaka, NASDA/EORC; the panel started. The current status of each component of GAME and related projects was introduced. Initial images from the recently launched Tropical Rainfall Measuring Mission (TRMM) were presented and were very impressive.

Enhanced radiosonde observation is one of the most important keys for the success of GAME. We need as many harmonized radiosonde observations as possible. Prof. Yasunari proposed the establishment of an IOP operational center in JMA. This center would promote enhanced radiosonde observations in each regional project. The quality of the radiosonde data was one of the issues discussed. Dr. Kuma, JMA, pointed out a difference between the first JMA forecast and observations around the tropopause in China. An additional radiosonde observation in China may be required for data comparison to clarify the difference.

GAME data management was another big issue. A guideline was proposed by Dr. Takahashi from the Meteorological Research Institute of JMA. Taking into consideration that each regional project has its own problems with its budget and the number of the field workers, and that this is also the case with the GEWEX Continental-scale International Project (GCIP), the following data release schedule was adopted. IOP data will be made available to the participating institutes and scientists by the end of June 1999, and to the international research community by the end of June 2000. Non-IOP data will be available to the participating institutes and scientists at the end of 1 year after the observations, and to the international community 2 years after the observations.

Along with the regional experiments which are focused in the IOP, long-term monitoring using the Asian AMeDAS Network (AAN) is also an important component of GAME. A working group (WG) for AAN was proposed by Prof. Yasunari to consider the maintenance of the facilities of AAN after the IOP (after the year 2000), and for successive observations. GAME also needs an international network to lead the AAN activity into the future. The AAN WG proposed a plan for (1) long-term monitoring, (2) data information management, and (3) coordination with other international activities (IGBP/FLUXNET). After several comments including a possibility to contribute to GTOS and GCOS, the proposal was adopted.

The future of GAME was the last subject. Prof. Ohata proposed creating a working group for the Second IOP, which is planned from 1999 to 2000. The objectives of the WG would be to: (1) determine detailed scientific objectives and focused issues; (2) determine the basic direction of implementation; and (3) seek cooperation from other international projects. The WG would meet in the Autumn of 1998. After several comments on the time frame and the importance of new satellite data such as TRMM and ADEOS II, and cooperation with the GEWEX framework, the proposal was finally adopted.

In the wrap up session, finalization of the IOP section of the implementation plan (IP) was discussed. After several requests for modification, the IP was adopted. Radiosonde observations will be implemented from the beginning of April to the end of October. The unified enhanced observations have two phases: (1) the onset phase from May 16 to June 15, and (2) the mature phase for the full month of July. Each regional project or country will have a different schedule of enhanced radiosonde observations. The regions and countries involved are Japan, China, Hong Kong, Taiwan, Korea, Philippines, Sri Lanka, Vietnam, Thailand, Malaysia, Singapore, India, Bangladesh, Myanmar, and Nepal.

The last business of the panel was to reconfirm current ISP members, and to appoint Dr. Kuma, as the JMA member of ISP. Finally, the next ISP was proposed to be held in conjunction with the 4th GAME International Study Conference and 3rd International GEWEX Conference tentatively scheduled for mid-1999 in Beijing, China.

NEW GCIP SATELLITE RADIATIVE FLUXES WEB SITE

A web site (**http://www.meto.umd.edu/~srb**) has been established to provide information on surface and top-of-atmosphere shortwave radiative fluxes, as produced by National Oceanic and Atmospheric Administration (NOAA)/ National Environmental Satellite, Data and Information Service (NESDIS). At this time, information based on 5 months of the NOAA product is provided at instantaneous, hourly, daily, and monthly time scales with 0.5° resolution.

The satellite inferred surface fluxes were evaluated against ground truth at the University of Maryland, and selected results are included. It is planned to provide this type of information close to the time it becomes available. Any comments on the web site should be e-mailed to Rachel Pinker at *pinker@metosrv2.umd.edu*.

WCRP/GEWEX MEETINGS CALENDAR

For calendar updates, see the GEWEX Web Site: http://www.cais.com/gewex/

2–3 June 1998—GLOBAL WATER VAPOR PROJECT UPPER TROPOSPHERIC HUMIDITY COMPARISON WORKSHOP, Darmstadt, Germany.

2–4 June 1998—GEWEX CLOUD SYSTEMS STUDY WORKING GROUP III WORKSHOP, Geesthacht, Germany.

8–12 June 1998—GCIP MISSISSIPPI RIVER HYDROMETEOROLOGY CONFERENCE, St. Louis, Missouri, USA. For information contact Adrienne Calhoun or Rick Lawford, GCIP Project Office, NOAA Office of Global Programs, 1100 Wayne Avenue, Suite 1210, Silver Spring, Maryland, 20910, USA. Tel: 301-427-2089 ext. 511; Fax: 301-427-2222, or for general information on the Mississippi River Celebration visit the web site at: http://www.ogp.noaa.gov/gcip/miss/missceleb.html.

24–29 June 1998—OCEAN CIRCULATION AND CLIMATE, THE WOCE CONFERENCE, Halifax, Nova Scotia, Canada. For information, contact the WOCE IPO at 44-1703-5967789; Fax: 44-1703-596204; E-mail: woceipo@soc.soton.ac.uk.

29 June–2 July 1998—ECMWF/GMPP WORKSHOP ON MODELLING AND DATA ASSIMILATION FOR LAND-SURFACE PROCESSES, Reading, UK.

7–10 July 1998—COUPLED OCEAN-ATMOSPHERE RESPONSE EXPERIMENT (COARE 98) DATA ANALYSES, AND MODELLING TRANSFER TO GEWEX/CLIVAR PROGRAMMES, Boulder, Colorado, USA.

12–19 July 1998—32ND COSPAR SCIENTIFIC ASSEMBLY–40TH ANNIVERSARY, Nagoya, Japan. For information contact Copernicus Gesellschaft, E-mail: COSPAR@COPERNICUS.ORG.

3–7 August 1998—ARCTIC BUOY AND SEA ICE CHARTS CONFERENCE, Seattle, Washington, USA. For information contact: http://www.npolar.no/acsys/seattle98/index.htm.

17–21 August 1998—INTERNATIONAL CONFERENCE ON SATELLITES, OCEANOGRAPHY AND SOCIETY, Lisbon, Portugal. For information contact D. Halpern, Jet Propulsion Laboratory, MS 300-323, California Institute of Technology, Pasadena, California 91109-8099; Fax: 818/393-6720; E-mail: halpern@pacific.jpl.nasa.gov.

24–26 August 1998—GCSS WORKING GROUP I WORKSHOP ON TRANSITIONAL CUMULUS CASE FROM ASTEX, Madrid, Spain. Local organizer Joan Cuxart Rodamilans (j.cuxart@inm.es); Fax: 34 1 544-5823.

25–27 August 1998—GHP/ACSYS WORKSHOP ON COLD REGIONS MODELING, Quebec City, Canada. For information e-mail contacts are V. Vuglinski: admin@vggi.spb.nu and R. Lawford: lawford@ogp.noaa.gov.

26–28 August 1998—GVAP/SPARC WORKSHOP ON UPPER TROPOSPHERE/LOWER STRATOSPHERE WATER VAPOR, Boulder, Colorado, USA.

31 August–4 September 1998—GEWEX RADIATION PANEL MEETING, St. Andrews, Scotland.

14–18 September 1998—GEWEX HYDROMETEROLOGY PANEL MEETING, Boulder, Colorado, USA.

25–28 October 1998—AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, Fairbanks, Alaska, USA. Topics include ocean-atmosphere-land-ice interaction and international collaboration on global change research. For information visit: http://www.gi.alaska.edu.

2–6 November 1998—JOINT JSC/CAS WGNE AND GEWEX MODELING AND PREDICTION PANEL, Montreal, Canada.

9–13 November 1998—GEWEX CLOUD SYSTEM STUDY AND WORKING GROUP ON NUMERICAL PREDICTION WORKSHOP ON CLOUD PROCESSES AND FEEDBACKS OF LARGE-SCALE MODELS, European Centre for Medium-Range Weather Forecasts, UK.

16–18 November 1998—4TH CANADIAN GEWEX/MAGS WORKSHOP, Montreal, Canada. See web site or contact Secretariat; E-mail: Geoff.Strong@ec.gc.ca.

30 November–4 December 1998—GEWEX CLOUD SYSTEM STUDY SCIENCE PANEL, Kauai, Hawaii, USA.

10–15 January 1999—AMERICAN METEOROLOGICAL SOCIETY ANNUAL MEETING, Dallas, Texas, USA. The meeting theme is "Climate and Global Change: Focus on the Americas". Call for papers found in Bull. American Meteorological Society. Abstracts due at AMS Headquarters, 45 Beacon Street, Boston, MA 02108-3693, no later than 1 October 1998.

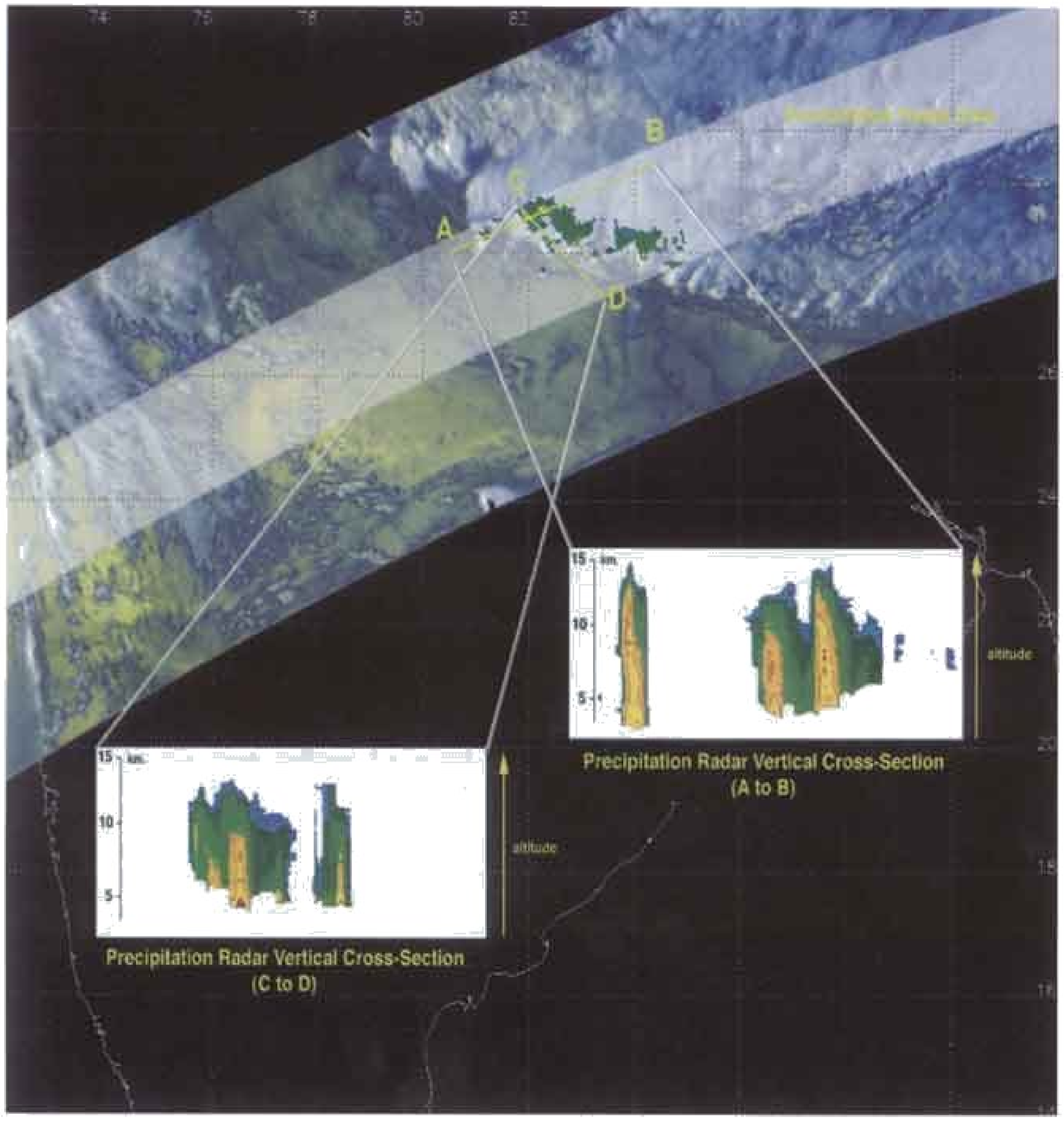
February 1999—GEWEX SCIENTIFIC STEERING GROUP, Tuscon, Arizona, USA.

15–20 March 1999—WCRP JOINT STEERING COMMITTEE MEETING, Kiehl, Germany.

9–12 June 1999—THE THIRD INTERNATIONAL SCIENTIFIC CONFERENCE ON THE GLOBAL ENERGY AND WATER CYCLE, Beijing, China.

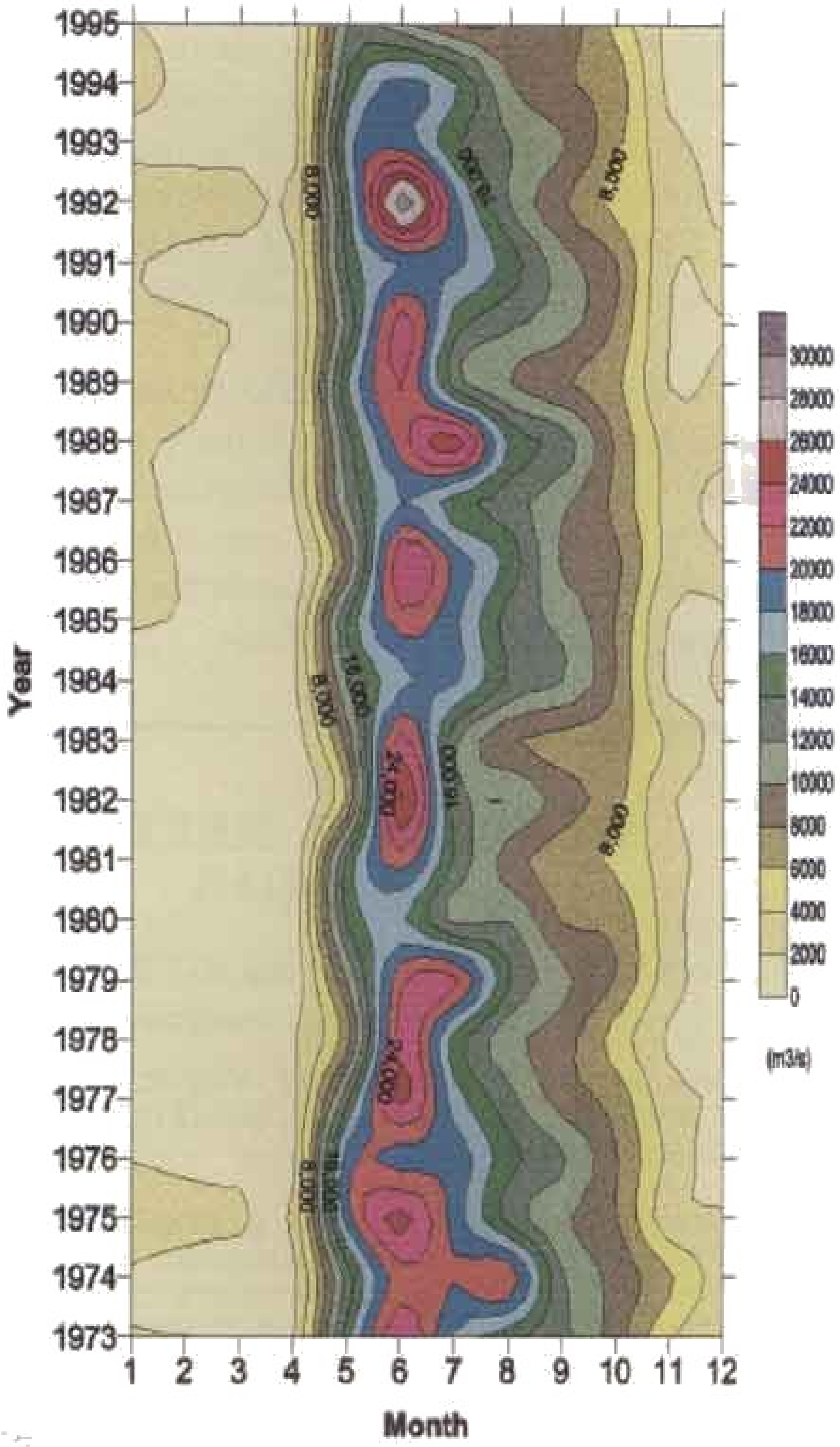
19–30 July 1999—GHP-RELATED SYMPOSIA AND WORKSHOPS AT THE 22ND GENERAL ASSEMBLY OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS (IUGG), Birmingham, UK. Further information contact School of Earth Sciences, Univ. of Birmingham, Edgbaston, Birmingham B15 2TT, UK; Fax: 44 121 414 4942; E-mail: IUGG99@bham.ac.uk.

EXAMPLE OF TROPICAL RAINFALL MEASURING MISSION (TRMM) SUPPORT FOR GAME-TIBET



A TRMM overflight of Tibet (upper right landscape) and precipitation over Northern India on 18 March 1998 at 11:19 UTC. The clouds and landscape are observed by combining visible and near-infrared measurements. The precipitation radar measurements are shown by the bright green, and by the two vertical cross sections along the lines AB and CD indicate convective structure of the precipitating cells. Courtesy of TRMM Group at NASA Goddard Space Flight Center.

VARIABILITY OF MACKENZIE RIVER DISCHARGE INTO THE ARCTIC OCEAN



Variability of maximum discharge, which usually occurs in June, can be as large as 100 percent, and it appears to have a 3–4 year peak cycle. *(See page 3)*

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