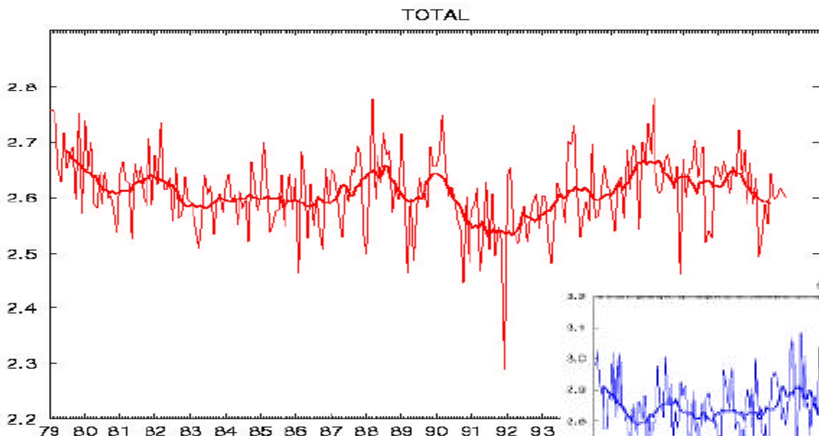
GEWEX WCRP

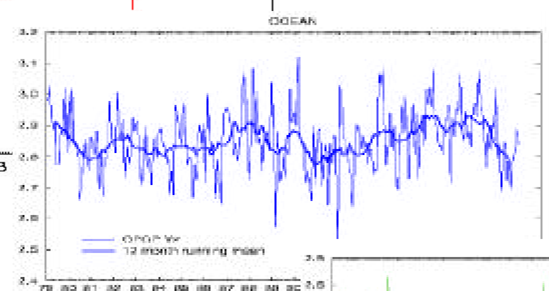
Global Energy and Water Cycle Experiment

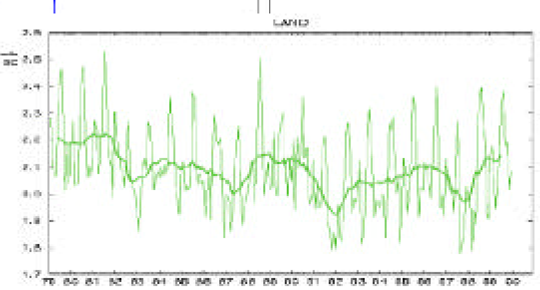
NEWS

Vol. 10, No. 3 August 2000

World Climate Research Programme–WCRP







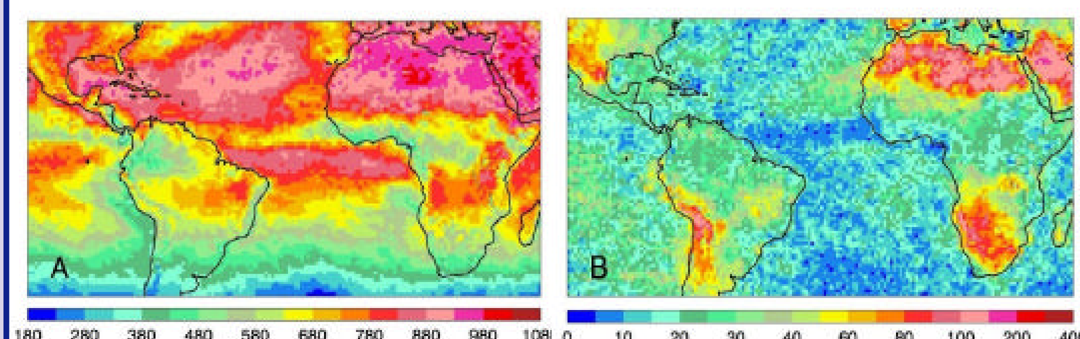
GPCP RELEASES THREE NEW PRECIPITATION PRODUCTS

Shown above is the new 20+ year GPCP monthly precipitation for 1979 to present. See examples on the back for the corresponding 5-day data set, along with an example of the new 1x1 degree daily product available for the last 3 years. Figures provided by NASA/GSFC. See http://orbit-net.nesdis.noaa.gov/arad/gpcp.

WHAT'S NEW

- GLASS to exploit new satellite data and begin carbon intercomparison study
- GCIP satellite products become operational
- New WCRP Director welcomed at GEWEX Phase II Strategy Meeting
- 100 years of data show teleconnection of precipitation between E. Asia and N. America
- AMIP-II study to show impact of land surface schemes

NEW SRB DATA SHOWING DIURNAL VARIATIONS



New results show monthly averaged diurnal range (max-min) of the surface net flux. Example above shortwave A, positive to surface, and longwave B, positive from surface for July 1986 for tropical/subtropical Atlantic and Mediterranean Basins. See Page 4.

COMMENTARY

GEWEX CHANGING EMPHASIS FOR PHASE II

Paul D. Try, Director
International GEWEX Project Office

With the advent of the new series of earth system satellites (e.g., TERRA, TRMM, AQUA, ENVISAT, ADEOS II, Cloudsat and PICASSO), and with the success of the projects developed within Phase I, GEWEX is moving into Phase II and building upon:

- new global descriptions of the earth's environment
- upgraded model representations on which to base predictions
- new local and regional descriptions of key processes
- an increasing focus on water resource applications

Our strategy for Phase I with its focus on the energy and water cycle and its processes was simple and straightforward: remain parameter focused and produce the best possible descriptions of the elements (and processes) of the energy and water cycle on a global basis; close the energy and water budgets on the continental scale; couple the hydrology/land/atmosphere at the mesoscale; model and predict globally with high-resolution upgraded Numerical Weather Prediction models; and apply results to water resources at the local scale.

As we move into Phase II, we need to modify this strategy somewhat, and the GEWEX Scientific Steering Group Chairman and members, along with the key GEWEX Panel and Project leaders, have been meeting to establish this modified strategy. In following newsletter issues we will provide more details, but I would like to provide some insight into the directions we are headed.

We will first be building upon the results from our Phase I efforts and begin shifting our emphasis toward more analysis and diagnostics of the processes driving the energy and water cycle. We will be working toward an integration of our global data into a more complete description of the processes along with developing the related model improvements necessary to enable improved representations of these processes and their prediction. The emphasis will be more focused on wet processes, linkages to carbon, greater exploitation of satellite data, and expanded efforts related to water resource applications.

During this key transition period, as we await the data from the series of new satellites, we will be moving ahead with this modified strategy. Several of our current GEWEX activities are key to these upcoming emphasis areas as we:

- provide for more intercomparison and analysis of our global data sets under the GEWEX Radiation Panel
- close the energy and water budgets and increase focus on water resource applications within the Water and Energy Budget Study (WEBS) and Water Resources Applications Project (WRAP) – both under the GEWEX Hydrometeorology Panel, which is also leading the effort to integrate the benefits of the regional experiments and the new satellite data through the Coordinated Enhanced Observing Period (CEOP) activities
- provide major advances in the development of new parameterization schemes and modeling for hydrology, land surface and cloud systems under the GEWEX Modeling and Prediction Panel along with a new focus on planetary boundary layer representations within all scales of models

Clearly many other GEWEX activities and projects will also be contributing substantially to this transition time and we hope to increase the participation of the international scientific community as we collectively join with the other WCRP projects (e.g., CLIVAR, SPARC, CLIC and WGNE/WGCM) to increase our knowledge of the earth system processes.

CHANGE AT GRDC

Dr. Thomas Maurer is the new head of the Global Runoff Data Centre (GRDC), Federal Institute of Hydrology (BfG), Koblenz, Germany. Dr. Maurer is a civil engineer with a background in hydraulic engineering, hydrology and numerical modeling. His e-mail is: thomas.maurer@bafg.de; GRDC address is: Global Data Runoff Centre (GRDC), P.O. Box 200253, D-56002, Koblenz, Germany; Telephone: +49(0)261 1306 5224; Fax: +49 (0) 261 1306 5280.

DAVID CARSON
NEW DIRECTOR OF WCRP

Dr. David John Carson assumed responsibility as Director of the Joint Planning Staff of the World Climate Research Programme in June 2000. He succeeds Professor Hartmut Grassl, who has returned to his director's post at Max-Planck Institute in Hamburg.

David began his research career in the UK Meteorological Office (the Met. Office) in 1969, following his Ph.D from the Department of Applied Mathematics, University of Liverpool. Early in his career he conducted and directed research on the structure and evolution of the atmospheric boundary layer, followed by research on the development and testing of atmospheric general circulation models, with particular emphasis on the representation of physical processes and devising methods for the application of numerical weather prediction models for extended-range forecasting.

In 1982, he was appointed to Assistant Director level within the Met Office, and led the Boundary Layer Research Branch and later the Dynamical Climatology Branch. For 3 years (1987–1989), David was seconded to the Natural Environment Research Council (NERC) as their first Programme Director for atmospheric sciences, to formulate and implement a NERC Strategy for Atmospheric Sciences.

On return to the Met. Office in January 1990, he became Director of Climate Research and, in that capacity, the first Director of the Hadley Centre for Climate Prediction and Research. After almost 9 years at the Hadley Centre, he moved in November 1998 to become the Director of Numerical Weather Prediction in the Met. Office.

David has been an active Fellow of the Royal Meteorological Society since 1971, including being its President in 1997–98. His Presidential addresses on Seasonal Forecasting and Climate Modelling: Achievements and Prospects have both been published in the Quarterly Journal of the Royal Meteorological Society (in January 1998 and January 1999, respectively).

GLASS TO EXPLOIT NEW SATELLITE DATA AND BEGIN CARBON INTERCOMPARISON STUDY

At the first meeting of the GEWEX Global Land-Atmosphere System Study (GLASS) held July 19–21, 2000 in Sydney, Australia, the science panel added two new emphasis areas to their on-going off-line and coupled Land Surface Scheme (LSS) modelling activities — one specifically focused on the exploitation of the new satellite sensor data sets and the other focused on the coupled land/atmosphere aspects of the carbon cycle. The first will involve the production of satellite-sensed parameters by the LSSs for improved cross-validation, and the latter an off-line Project for Intercomparison of Land-surface Parameterization Schemes (PILPS) study focused on the carbon uptake and respiration. More details will be provided in the GLASS implementation Plan to be summarized in the next issue of *GEWEX News*.

CONTENTS

THE SRB PROJECT RELEASE 2 DATA SET: AN UPDATE

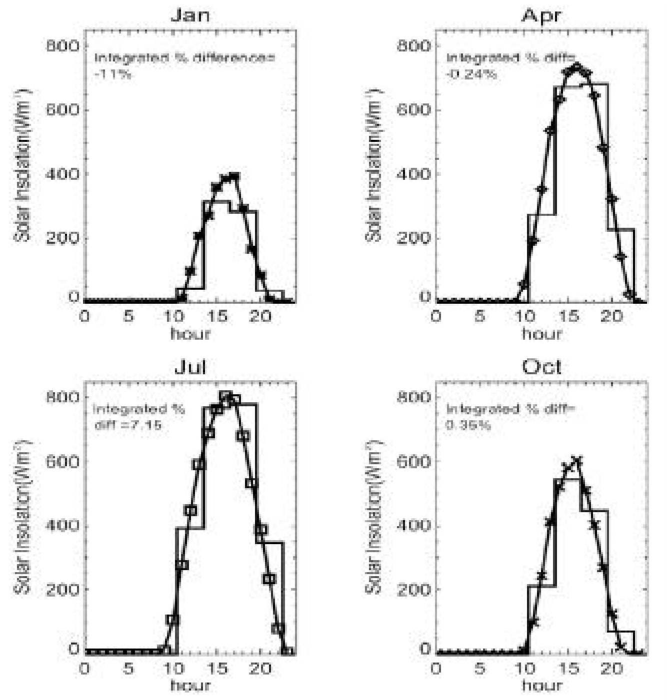
P. W. Stackhouse, Jr.
NASA Langley Research Center

S. K. Gupta, S. J. Cox,
M. Chiacchio and J. C. Mikovitz
Analytical Services and Materials, Inc.

The WCRP/GEWEX Surface Radiation Budget (SRB) project at NASA was initiated, in association with the WCRP and later GEWEX, to focus research on quantifying the radiative energy exchange at the Earth's surface over time. NASA has recently renewed support for GEWEX SRB to archive a new data set, to provide for continued development and improvements, and to overlap with Earth Observing System era data sets. GEWEX SRB Release 2 (R2), a significant upgrade from the V1.1 WCRP SRB Shortwave (SW) 4-year data set (Whitlock *et al.*, 1995), is now being prepared for processing and archival at the NASA Langley Atmospheric Sciences Data Center.

Among the many upgrades to algorithms and input data sets, the most important are: the addition of longwave (LW) flux algorithms, the increase of resolution from the 280 km x 280 km equal area grid system to 1°x1° using the ISCCP DX pixel data set (Rossow and Schiffer, 1999), and the use of reanalysis meteorology from a data assimilation project. Column ozone is obtained from Total Ozone Mapping Spectrometer (TOMS) data and a surface emissivity map is introduced (Wilber *et al.*, 1999). This R2 data set will provide global SW and LW surface and top-of-atmosphere radiative fluxes for a 12-year period (July 1983 – June 1995). The fluxes will be produced at a variety of time resolutions including 3-hourly, daily, monthly and a monthly averaged 3-hourly product.

An example of R2 output showing the higher spatial and temporal resolution is shown on page 1. This figure gives the difference between the maximum and minimum monthly averaged 3-hourly net SW and net LW surface fluxes in July 1986. The differences represent the monthly averaged diurnal ranges. The maps show how clouds, surface types, and boundary layer meteorology determine the range of net energy incident to and emitted from the surface for this month.



Monthly averaged SW diurnal cycles for Bermuda in 1992 for SRB (3-hourly) and BSRN (hourly).

The validation of data such as displayed on page 1 remains a central part of SRB activity. Shown above is an example of the monthly averaged diurnal cycles of surface insolation from R2 compared with hourly averaged Baseline Surface Radiation Network (BSRN) measurements from Bermuda for the mid-seasonal months of 1992. The results indicate that the diurnal cycle is well captured at this site, despite its island location.

More information on the SRB algorithms, processing status and data release will be made available on the GEWEX SRB homepage:
http://srb-swlw.larc.nasa.gov/Pilot_homepage.html

References

Rossow, W.B. and R. Schiffer, 1999. Advances in understanding clouds from ISCCP. *Bull. Amer. Meteor. Soc.*, **80**, 2261-2287.

Whitlock, C.H., and co-authors, 1995. First global WCRP shortwave surface radiation budget dataset. *Bull. Amer. Meteor. Soc.*, **76**, 905-922.

Wilber, A. C., D. P. Kratz, S. K. Gupta, 1999. Surface emissivity maps for use in satellite retrievals of Longwave Radiation. NASA Technical Publication 1999-209362, 35 pp.

ANALYSIS OF AMIP II MODELS' SIMULATIONS OF LAND SURFACE CLIMATES

Parviz Irannejad[1], Ann Henderson-Sellers[1], Tom Phillips[2], and Kendal McGuffie[3]

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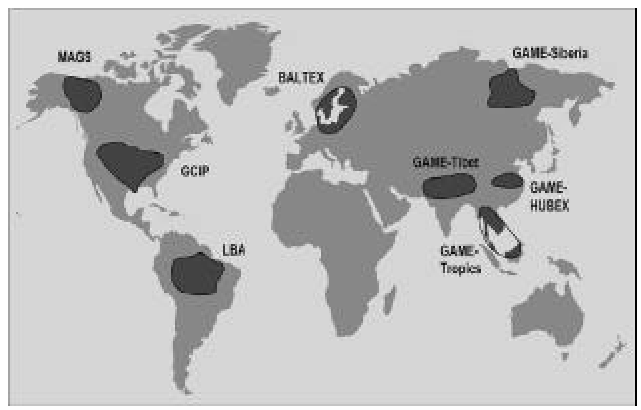
The first phase of the Atmospheric Model Intercomparison Project (AMIP I) saw the participation of some 30 modelling centres and nearly as many diagnostic subprojects that analysed various aspects of model simulations of climate in the decade 1979-1988. The Project for Intercomparison of Land-surface Parameterization Schemes (PILPS) was responsible for AMIP Diagnostic Subproject 12 on Land-surface Processes and Parameterizations. Subproject 12 (DSP12) analysed those AMIP simulations in which the associated land-surface schemes (LSS) were participating in PILPS off-line experiments. Subproject 12 performed its work in the context of several significant limitations: little global land surface validation data; the limited set of model "standard output variables"; and the small range of LSS complexity represented. In these circumstances, DSP12 carried out a "zero-order" evaluation in the sense that it identified problematical and/or unexpected features in the simulations of various aspects of the simulated land surface climates (Irannejad et al., 1995; Love et al., 1995; Qu and Henderson-Sellers, 1988).

In the current AMIP (Phase II), the experimental design remains fundamentally the same (i.e., commonly specified radiative forcing and ocean boundary conditions), but the simulation period has been extended by 7 years (from 1979 to 1995) and several refinements of the experimental protocol have been made to attempt to address concerns expressed by land surface specialists in AMIP I. These include a greater emphasis on adequate initialization/spin-up of soil moisture stores; conservation of continental surface energy and water; and a more extensive set of land surface variables output. In addition, the spectrum of LSS complexity included in AMIP II AGCMs is expected to be broader than in AMIP I. Thus, DSP12 plans to continue its analysis of the relationship among land surface simulations, processes and parameterization schemes under these more auspicious conditions (Phillips et al., 2000). This paper reports on the methodology to be applied in this Diagnostic Subproject (Phillips et al., 1998). The analysis of the AMIP II land-surface simulation will be performed globally and regionally. Analyses have been planned for GEWEX/Continental Scale Experiment (CSE) regions, shown below, and for different climate zones, defined by the de Martonne aridity index: $I = P / (T+10)$, where P is mean annual precipitation in mm and T is mean air temperature in degrees Centigrade. PILPS experiments have demonstrated that the bucket scheme behaves differently from complex land surface schemes (Chen et al., 1997). AMIP I showed that increased LSS complexity alters surface energy partitioning. **Given the wider range of LSS employed in AMIP II, DSP12 aims to analyse the surface energy and water budgets as a function of LSS complexity (Shao and Henderson-Sellers, 1996)**.



GEWEX Continental-Scale Experiment (CSE) Regions

An important difficulty in assessing the performance of climate models is the lack of high quality global data sets. Until this data drought improves, for example, by future provision of the International Satellite Land Surface Climatology Project (ISLSCP) Initiative II data sets, validation of the AMIP II models will necessarily rely heavily on possibly less reliable model-derived estimates of land-surface variables such as those provided by various reanalyses. It must be emphasised that reanalysis data contain any biases of the respective analysis model and, therefore, should not be regarded as absolute reality. Having this caveat in mind, model-derived estimates such NOAA's National Centers for Environmental Prediction (NCEP), the Department of Energy (DOE), the National Center for Atmospheric Research (NCAR), and Variable Infiltration Capacity (VIC) data, will be used as validation data sets to try to account for any possible biases. NCEP-DOE is not fundamentally different from NCEP-NCAR, but it is an updated global analysis that fixes the known processing errors in NCEP-NCAR and uses an improved forecast model and data assimilation system (Kanamitsu et al., 1999). The VIC data set consists of monthly (derived from daily) global terrestrial (excluding Greenland and Antarctica) data for the period 1979–1993. This data set has been generated using the VIC land surface scheme driven by forcing from station observations of precipitation (where available) and maximum and minimum surface air temperature and humidity (Nijssen et al., 2000).

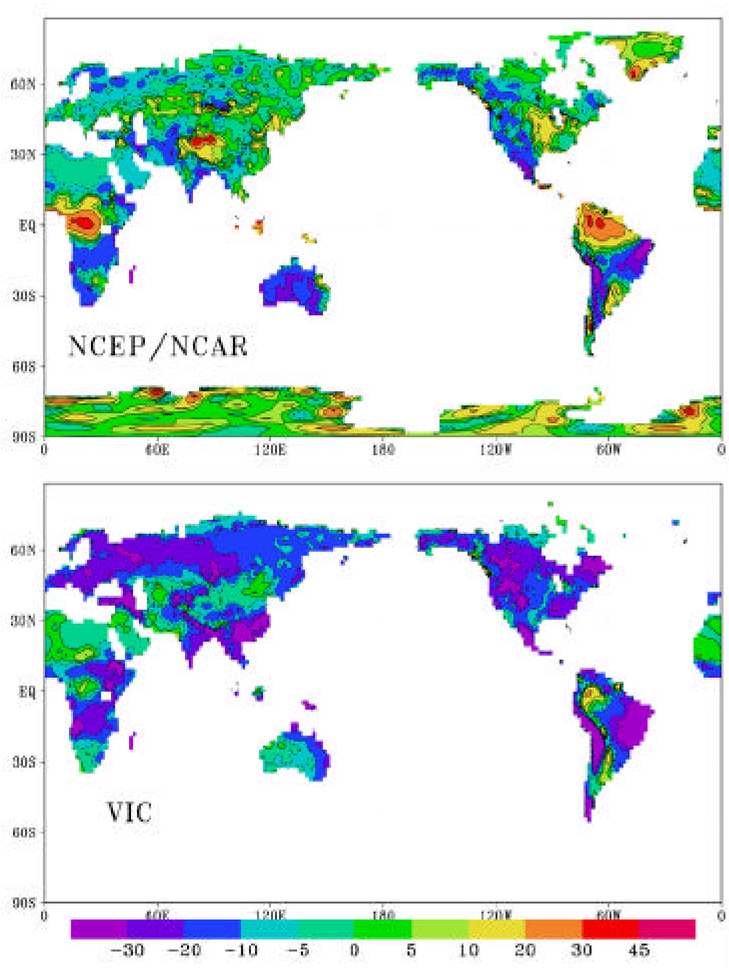
Some 30 AGCMs are participating in AMIP II. To date, simulations by five models have been quality controlled and are available for analysis. In DSP 12, all the reanalysis and model results will be interpolated into T62 resolution for analysis. Here, the latent heat fluxes (LH) derived from NCEP-DOE, NCEP-NCAR and VIC are presented in order to illustrate the analysis approaches to be employed in Diagnostic Subproject 12. NCEP-DOE is used as the 'control' data set here. However, it should be emphasised that this selection is arbitrary and does not imply any superiority of NCEP-DOE over other reanalyses.

The upper left panels of the figure on the opposite page illustrate the distribution of the deviations of 14-year (1980–1993) mean LH of the NCEP-NCAR and VIC data from the control (NCEP-DOE) over the continental surfaces. The mean latent heat flux of NCEP-NCAR generally agrees with that of the control, presumably because the two reanalyses are derived from the same origin. For instance, the NCEP-NCAR's grid-averaged LH is within 10 W/m^2 of that of the control in about 67 percent of the land grid points and within 5 W/m^2 of it in about 42 percent of the land grid points. NCEP-NCAR tends to underestimate LH in many arid and semi-arid subtropical regions (Middle East, northern Mexico and south-western United States, Australia); to overestimate it both in very humid tropical regions (Amazon Basin, Indonesia, central Africa) and in cold regions (Greenland, Antarctica, Himalayas). In half of the grid points the LH flux of NCEP-NCAR has positive and in the other half negative biases relative to NCEP-DOE. VIC, on the other hand, greatly underestimates LH over almost all land surfaces, except for relatively small areas in the Middle East, South America and northern Africa. Globally in about 88 percent of the land grid points (except for Antarctica and Greenland) the LH from VIC is less than that from NCEP-DOE. In only 41 percent of the land grid points the mean LH estimated by VIC is within 10 W/m^2 of that of the control, and in about 25 percent of the grid points it is within 5 W/m^2.

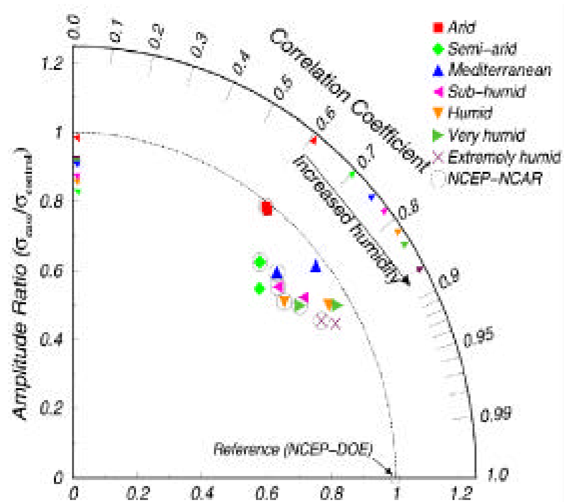
The lower panel on the opposite page compares the mean latent heat flux derived from NCEP-NCAR and VIC for continental surfaces overall and in different climate zones with fluxes from NCEP-DOE. Globally, NCEP-NCAR slightly and VIC greatly underestimate mean latent heat flux compared to NCEP-DOE. However, the relative differences are climate dependent, so that the global underestimation is mainly due to the underestimation in wetter climates by VIC and in drier climates by NCEP-NCAR. Furthermore, the grid-average LH relative to NCEP-DOE varies across the climate zones. For instance, in 95 percent of the arid grid points the VIC's mean LHs are within 10 W/m^2 of that of NCEP-DOE, but only 14 percent for the extremely humid grid points. The inter-climate variability of mean LH is larger in NCEP-NCAR and much smaller in VIC compared to NCEP-DOE.

Shown on the upper right panel, the spatio-temporal statistics of NCEP-NCAR and VIC estimates of LH compared to NCEP-DOE for different climate zones are plotted on a Taylor Diagram (Taylor 2000). The "Reference" is the land surface LH from NCEP-DOE for the period 1980–1993. In this polar plot, the radical distance is proportional to the spatio-temporal amplitude ratio, where the dotted quarter-circle denotes a perfect match of the standard deviations of the evaluated and the control. The angular dimension is scaled to be proportional to the cosine of the spatio-temporal pattern correlation. The coloured arrows show the average values for each de Martonne climate zone. The mean correlation coefficient of the available data is smaller in the arid zone and increases towards the wetter climates. There is no clear association between the magnitude of the mean amplitude ratio and the aridity index. Although the mean latent heat flux of NCEP-NCAR agrees better with NCEP-DOE in most climates, its coefficients of correlation are smaller and its amplitude ratios are shifted further (inwards) from the unit quarter circle compared to those of VIC. The smaller-than-one amplitude ratios show that both

(Continued on page 8)

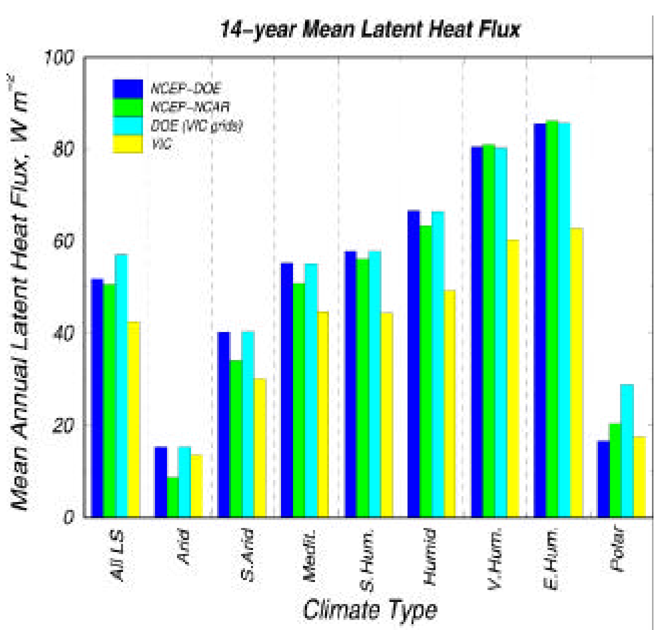


Global distribution of the deviations (W/m²) of 14-year mean latent heat flux of NCEP-NCAR and VIC reanalyses from NCEP-DOE over the continental surfaces.



Shown in the structure of spatio-temporal variability of NCEP-NCAR (circled) and VIC (not circled) of the reanalyses monthly mean latent heat flux for the perid 1980–1993 in different climate zones, with reference to the corresponding NCEP-DOE reanalysis data set. (The colored arrow heads show the average (of NCEP-NCAR and VIC) values for the de Martonne climate zones.

Comparison of mean land-surface estimated latent heat flux (W/m²). The all LS shows the overall LH over continents. The climate zones are arid, semi-arid, Mediterranean, sub-humid, humid, very humid, extremely humid, and polar. Due to lack of VIC data over Antartica and Greenland, the values for NCEP-DOE have been calculated separately for comparison with NCEP-NCAR and VIC.



Simulations of Land-surface Climates

(Continued from page 6)

NCEP-NCAR and VIC have smaller intra-climate variability than NCEP-DOE.

Preliminary analysis so far has revealed that:

- Large-scale variations of LH are captured by all reanalyses considered. However, there are considerable differences among the three data sets.

- Compared to NCEP-DOE, the global mean LH over the land surfaces is underestimated greatly by VIC, mainly due to lower LH in wetter climates, and is underestimated slightly by NCEP-NCAR, due to underestimation in drier climates.

- NCEP-NCAR has a larger and VIC has a smaller inter-climate variability of mean LH than NCEP-DOE. The intra-climate variability of both is smaller than that of NCEP-DOE.

- The spatio-temporal correlation coefficient of estimated LH by NCEP-NCAR and VIC relative to NCEP-DOE is small in drier climates and increases towards wetter climates.

In summary, the AMIP DSP12 methodology for the intercomparison of the land-surface simulations as a function of LSS complexity and by evaluation agains pseudo-observations (reanalyses) is planned to include: (a) Analysis of global and geographical variability; (b) Focused analysis for GEWEX-CSE regions and for areas where the inter-model differences are large and/or simulations considerably differ from reanalyses; and (c) Analysis in different climate zones and across different latitudes.

References

Chen, T.H., and co-authors, 1997. Cabauw experimental results from the Project for Intercomparison of Land-surface Parameterization Schemes. *J. Clim.,* 10(7), 1194–1215.

Love, P. K., A. Henderson-Sellers, and P. Irannejad, 1995. AMIP Diagnostic Subproject 12 (PILPS Phase 3): Land surface processes. Proceedings of the First International AMIP Scientific Conference, Monterey, California, USA, 15–19 May 1995, WCRP-92, WMO/TD-No. 732.

Irannejad, P., A. Henderson-Sellers, Y. Shao, and P.K. Love, 1995. Comparison of AMIP and PILPS off- line land surface simulation. Proceedings of the First International AMIP Scientific Conference, Monterey, California, USA, 15–19 May 1995, WCRP-92, WMO/TD-No. 732, 465-470.

Kanamitsu, M., W. Ebisuzaki, J. Woolen, J. Potter, and M. Fiorino, 1999. Overview of NCEP/DOE Reanalysis-2. The Second International Conference on Reanalyses, Reading, UK. Accessible online at http://wesley.wwb.noaa.gov/reanalysis2/kana/Overview.htm.

Nijssen, B., R. Schnur, and D.P. Lettenmaier, 2000. Global retrospective estimation of soil moisture using the VIC land surface model, 1980–1993. Accepted *J. Climate*.

Phillips, T.J., A. Henderson-Sellers, P. Irannejad, K. McGuffie, and H. Zhang, 2000. On validation and diagnosis of land-surface climate simulations. *Climate Change Newsletter*, 12(1), 3–5.

Phillips, T.J., A. Henderson-Sellers, A. Hahman, and A.J. Pitman, 1998. AMIP II diagnostic subproject 12: Landsurface processes and parameterizations (a joint AMIP/PILPS project). Accessible online at http://www.pcmdi.llnl.gov/pilps3/proposal/.

Qu, W.Q. and A. Henderson-Sellers, 1998. Comparing the scatter in PILPS off-line experiments with those in AMIP I coupled experiments. *Global Planet. Change*, 19, 209–224.

Taylor, K.E. (2000). Summarizing multiple aspects of model performance in a single diagram. *J. Geophys. Res. (submitted).*

Shao, Y., and A. Henderson-Sellers, 1996. Modeling soil moisture: PILPS Phase 2(b). *J. Geophys. Res.*, 101, 7227-7250.

GCIP SATELLITE PRODUCTS BECOME OPERATIONAL

The National Environmental Satellite Data and Information Service (NESDIS) of NOAA recently approved a set of products developed for GCIP. The quantities made operational are insolation, photosynthetically active radiation, and surface temperature. These products were developed and used to validate and force the land surface components of regional numerical weather prediction models. The cloud cover, cloud fraction, cloud and surface brightnesses derived from geostationary satellite data are used to estimate incident solar radiation (insolation) at hourly intervals and at a resolution of 0.5^o latitude/longitude resolution. For clear scenes, a surface (skin) temperature is estimated using split-window retrieval from the 11 and 12 µm bands of the imager. The first use of the insolation and surface temperature was to validate the radiation and surface physics schemes of regional forecast models. The model soil moisture is expected to be greatly improved from the use of these products.

These products may be viewed at: **http://orbit-net.nesdis.noaa.gov/goes/gcip/**. They are being archived at the University of Maryland: **http://metosrv2.umd.edu/~srb/gcip/gcipsrb.htm**.

GEWEX ACTIVITIES AT OPEN SCIENTIFIC MEETINGS

Reports on GEWEX results are increasing in refereed literature and at major scientific conferences, such as the European Geophysical Society (EGS) XXV Assembly, April 2000, in Nice, France. At the EGS meeting there was a GEWEX session that focused on water cycles over large and medium-sized drainage areas as well as a number of other presentations related to GEWEX in hydrology and ocean-atmosphere sessions. At the recent meeting of the American Geophysical Union (AGU), 30 May–2 June 2000, sessions were held throughout the week reporting on GEWEX research in hydrology, land-surface processes, atmospheric modeling, and discussions on water resource and hydrology policy.

One example of GEWEX sessions at scientific meetings is summarized on page 14. Also, at the same AGU Meeting was a session titled "Advances in GEWEX Continental-scale International Project (GCIP) Research," an update on research reported in the special issues of the *Journal of Geophysical Research* (Vol. 104, No. D10, 1999) on GCIP. The focus of this AGU GCIP session was on seasonal and interannual variability in moisture sources, precipitation (including two papers on snow), soil wetness, and water resource management. From the papers in the GCIP session, it was evident that GCIP investigators have continued to make good progress in developing their understanding of regional water and energy budget components. Several GCIP principals were also involved in a special interdisciplinary Union Session on linking the hydrological sciences to water resource policy and applications. The large audience heard how GEWEX, the GCIP follow-on, called the GEWEX American Prediction Project (GAPP), and the US Global Water Cycle Initiative will make important contributions to society's needs during the next decade. It was clear that expectations are growing both within and outside the GCIP community for a strong GAPP science program with substantive links to water resource applications.

Another example of GEWEX activities at major meetings is the forthcoming American Meterological Society Meeting (14–19 January 2001), where there are sessions reporting scientific results on aerosol research (GEWEX Global Aerosol Climatology Project) and the impact of precipitation extremes (GEWEX Global Precipitation Climatology Project). Also, at the Fall AGU meeting, cold season land processes research will be presented.

TELECONNECTION OF PRECIPITATION BETWEEN EAST ASIA AND NORTHWESTERN NORTH AMERICA

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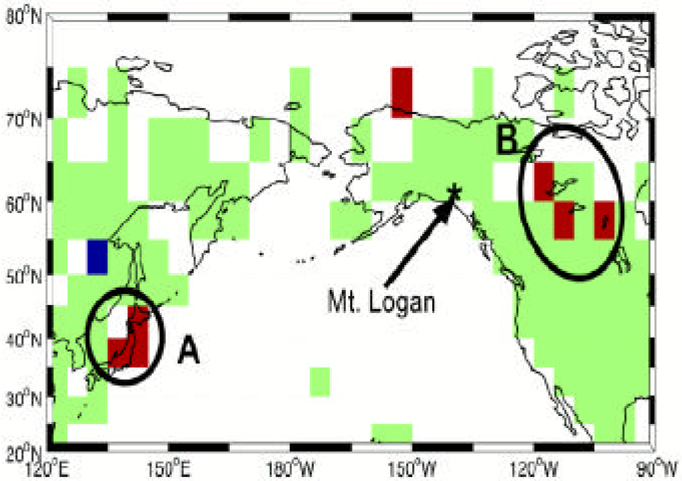
Mount Logan, elevation 5,957 m, is the highest mountain in Canada and only 160 m shorter than Denali-Mount McKinley. It is situated 100 km from the Gulf of Alaska in a region that has supported near-continuous human settlement for over 10,000 years. Yet, there is no evidence that it was named or sighted by either aboriginals or Europeans prior to 1890. Notwithstanding our ignorance of its existence, the mountain has been accumulating, in its snow and ice, climatic information over a period extending back to the 17th century and perhaps earlier. **The mountain's strategic location makes this information especially important.** It is situated at the end of the major North Pacific storm track along the main atmospheric pathway by which water vapor enters the Mackenzie River Basin (Smirnov and Moore, 1999). In addition, **it is in the center of the region that experiences one of the largest extra-tropical responses to ENSO (Horel and Wallace, 1981). Its extreme height allows it to sample the mid-tropspheric flow where these processes have their largest amplitudes.** In this paper, we report on some of the findings obtained from the analysis of ice cores obtained at a height of 5,340 m on Mount Logan (Holdsworth et al.,1992).

Various stratigraphic techniques were applied to date the core (Holdsworth et al., 1992), resulting in a time series of annual net snow accumulation extending from 1736 to 1985. It is important to recognize that total annual precipitation cannot be retrieved from the ice core data. However, under the assumption that deposition and scour at the site have been approximately uniform over time, the data, nevertheless, contain useful climatic information. For example, its power spectrum has statistically significant power at the ENSO and decadal periods (Holdsworth et al.,1992).

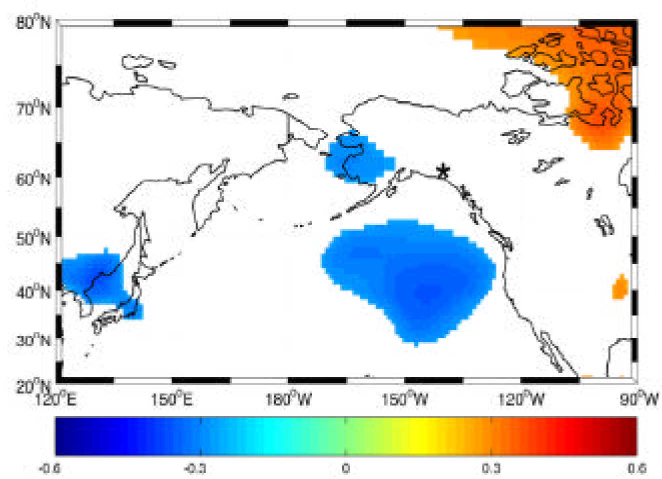
The motivation for this paper was to determine the regions in which the annual precipitation is



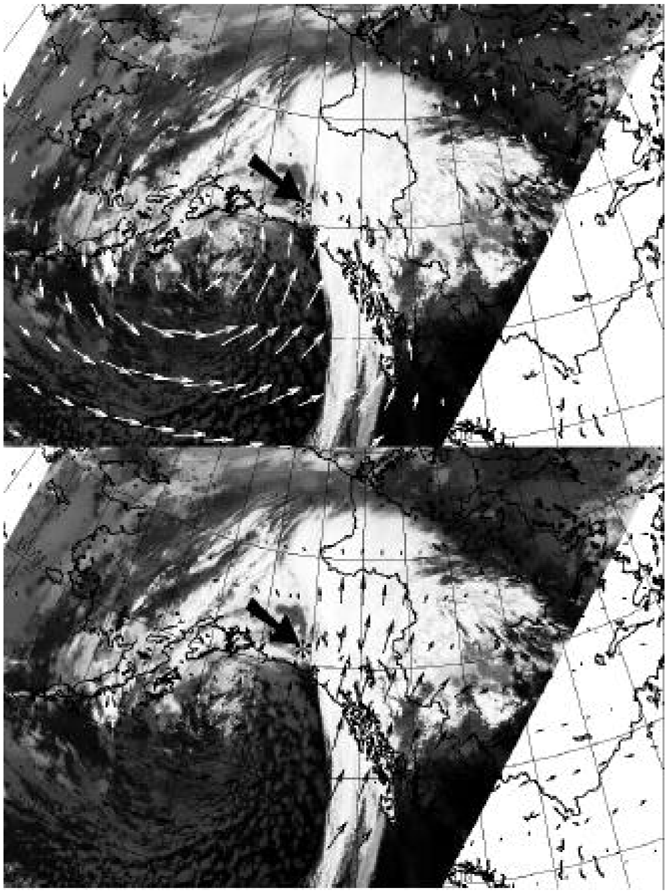
Spatial cross-correlation of gridded annual precipitation time series with Mount Logan time series. Japan (A) and McKenzie River (B) area locations where the cross correlation is positive and statistically significant at the 99 percent confidence level (indicated in red).

correlated with the Mount Logan time series. To this end, we made use of a gridded global precipitation data set derived from the Global Historical Climatology Network (GHCN) covering the period from 1851 to 1985 (Vose et al., 1992; Baker et al., 1995). The figure above shows the Pearson cross-correlation coefficient of the gridded GHCN annual precipitation data with the Mount Logan time series. An overlap of at least 50 years was required for inclusion in the analysis. Only those locations where the cross correlation is statistically significant at the 99 percent confidence interval are shown. **The figure above clearly shows a number of locations (shown in red) where there is a statistically significant positive correlation with the Mount Logan time series. These locations (circled) include the Mackenzie River Basin of Northern Canada, the North Slope of Alaska, Japan and the Sichuan region of China.** A statistically significant anti-correlation exists with a location in Siberia (shown in blue). Japan and the Mackenzie River Basin are of particular interest as they are regions where there is clustering of locations with statistically significant correlations. The average length of the overlap for the regions in which there was a statistically significant cross-correlation was 101 years. No significant correlation of either sign was identified with neighboring locations. This result holds even at significance levels as low as 90 percent.

The absence of any correlation with nearby locations is consistent with surface snow pit samples from Mount Logan (Holdsworth et al., 1991). These data show a discontinuity in the isotopic ratio of oxygen and hydrogen with elevation that suggests a different source region for the precipitation that falls at low elevations as compared to that at higher elevations. This finding is supported by the meteorology of the region. Extra-tropical cyclones in the Gulf of Alaska are responsible for much of the precipitation that falls on Mount Logan and in the Mackenzie River Basin, the Mackenzie GEWEX Study (MAGS) region, to the east (Smirnov and Moore, 1999). Shown on the next page is an example of one such cyclone and the water vapor transport associated with it is illustrated in the satellite imagery. The transport at 925 hPa clearly shows that the low-level circulation associated with the system advects moisture from the Bering Sea into the Gulf of Alaska. The moisture at this level is intercepted by the topography. At 700 hPa, one can see the inflow of moisture that intercepts Mount Logan and which enters the Mackenzie River Basin. At this height, the moisture is associated with the system's frontal zone and as such has been lifted to this level along its warm conveyor belt from a source region to the southwest. Smirnov and Moore (2000) argue that this source region is in the subtropical north Pacific.



Spatial cross correlation of the annual mean sea-level field from the NCEP reanalysis with the Mount Logan (indicated by the asterisk) net annual snow accumulation time series (1948–1985). Only those locations where the cross correlation is statistically significant at the 95 percent confidence level are shown.



Water vapor transport at 925 hPa (upper) and 700 hPa (lower) at 18 GMT on September 24, 1994 as diagnosed from the ECMWF objectively analyzed fields. The fields are superimposed on an infrared image from a pass of the NOAA 12 polar orbiting satellite that occurred at 17:51 GMT on the same day. The location of Mount Logan (60°37'N, 140°31'W) is indicated by the large arrows.

For the remainder of this paper, we will focus our attention on elucidating the meteorological processes responsible for the correlation that exists with annual precipitation in Japan and the Mackenzie River Basin. They were identified in the first figure shown as being regions where there was a clustering of grid points with a high degree of correlation with the Mount Logan time series. The correlation with the Mackenzie River Basin (MAGS) region is relatively easy to understand. As discussed above, extra-tropical cyclones are responsible for much of the moisture that is transported into the basin (Smirnov and Moore, 1999; 2000). The dominant route for this transport is from the southwest and as such is intercepted by Mount Logan. It, therefore, seems reasonable, given the common moisture source, that there should exist a high degree of correlation between precipitation in the basin and the snow accumulation on Mount Logan. No such correlation exists with coastal stations near Mount Logan.

The correlation with precipitation in Japan, at a distance of some 6,000 km, is at first glance remarkable. The lower figure on the opposite page shows the Pearson cross correlation coefficient of the annually averaged sea-level pressure field from the NCEP/NCAR reanalysis with the Mount Logan data for the period 1948–1985. The field has regions of negative (blue) correlation on the western and eastern boundaries of the North Pacific Ocean. It follows that above average snow accumulation on Mount Logan is associated with lower than average sea-level pressures and hence enhanced cyclonic activity in the Gulf of Alaska and along the coast of Japan or vice versa. Such a pattern is consistent with the observed correlation of precipitation in Japan with the Mount Logan data. The mechanism that leads to this *teleconnection* in the sea-level pressure field has not yet been identified. Spectral and coherence analysis indicates a strong El Niño Southern Oscillation (ENSO) signal in the Mount Logan time series (Holdsworth et al.,1992; Moore et al., 2000). Recently, it has been shown that precipitation in east Asia is also modified by ENSO (Wang et al., 2000). It is, therefore, possible that the observed *teleconnection* may be an indirect one due to ENSO. Alternatively, Lau and Wang (2000) have identified a "Pan-Pacific" wave-train with centers of action off east Asia and western North America. Still unresolved is the relationship of this mode with ENSO.

The present Mount Logan time series is nearly 300 years in length and there is the potential with new drilling to extend it back further. The long range and robust correlation of precipitation with the time series that has been identified is evidence of its usefulness as a source of climate information. A key to unlocking this understanding is improved knowledge of:

- the impact of teleconnections and ENSO on Pacific Ocean storm tracks
- the structure of extra-tropical cyclones in the Gulf of Alaska/Mount Logan region

- the sources of and pathways through which moisture is transported by these weather systems

- the interaction of these cyclones with the topography in northwestern North America

Such research will add to our understanding of the Mount Logan ice core as well as the physical processes responsible for atmospheric teleconnections. **The proposed Coordinated Enhanced Observing Period (CEOP) with its links to various GEWEX programs and regional experiments would be an ideal vehicle to study the linkages identified in this paper.**

Acknowledgments: NCEP reanalysis data provided by the NOAA-CIRES Climate Diagnostics Center, Boulder, Colorado, USA. GHCN data provided by the NOAA National Climate Data Center, Asheville, North Carolina, USA.

References

Baker, C.B., J.K. Eischeid, T.R. Karl, and H.F. Diaz, 1995. The quality control of long-term climatological data using objective data analysis. Preprints of AMS Ninth Conference on Applied Climatology. (available at www.ncdc.noaa.gov/gcps/papers/qc1/qc.html)

Holdsworth, G., S. Fogarasi, and H.R. Krouse, 1991. Variation of the stable isotopes of water with altitude in the Saint Elias Mountains of Canada. *J. Geophys. Res.*, 96 (D4), 7483–7494.

Holdsworth, G., H.R. Krouse, and M. Nosal, 1992. Ice core climate signals from Mount Logan Yukon 1700–1987 in *Climate Since A.D. 1500*, ed by Bradley R.S. and Jones, P.D. Routledge UK.

Horel, J.D., and J.M. Wallace, 1981. Planetary scale atmospheric phenomena associated with the Southern Oscillation. *Mon. Wea. Rev.* 109, 813–829.

Lau, K.M., and H. Wang, 2000. Remote forcing of summertime U.S. Draughts and floods by the Asian monsoon. *GEWEX News* 10:2 pg 5–6.

Moore, G.W.K., G. Holdsworth, and K. Alverson, 2000. Climate variability since 1736 as expressed in an ice core from the Saint Elias mountain range in northwestern North America, manuscript in preparation.

Smirnov,V.V., and G.W.K. Moore, 1999. Spatial and Temporal Structure of Atmospheric Water Vapour Transport in the Mackenzie River Basin, *J. Climate.* 12,681–696.

Smirnov,V.V., and G.W.K. Moore, 2000. Short-term and Seasonal Variations of the Atmospheric Water Vapor Transport through the Mackenzie River Basin, manuscript submitted to *J. Hydromet.*

Vose, R.S., R.L. Schmoyer, P.M. Steurer, T.C. Peterson, R. Heim, T.R. Karl, and J.K. Eischeid, 1992. The Global Historical Climatology Network: Long-term monthly temperature, precipitation,sea level pressure, and station pressure data. NDP-041. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge,Tennessee.

Wang, B., R. Wu, and X. Fu, 2000. Pacific-east Asian teleconnections: How does ENSO affect east Asian Climate? *J. Climate.* 13,1517–1525.

WORKSHOP/MEETING SUMMARIES

WORKSHOP ON SOIL MOISTURE FOR HYDROMETEOROLOGICAL AND HYDROCLIMATOLOGICAL APPLICATIONS

16–19 May 2000
Norman, Oklahoma

John A. Leese
GCIP Project Office

The GEWEX Scientific Steering Group, noting the rapid progress in modeling land surface processes and developing a coupled land-hydrology/atmosphere model for weather and climate prediction, recommended holding a workshop on soil moisture. In parallel with this GEWEX effort on soil moisture, the International Geosphere Biosphere Programme/Biospheric Aspects of the Hydrologic Cycle (IGBP/BAHC) was developing plans to hold a workshop on modeling root water uptake in hydrological and climate models. Discussions among scientists led to the joining of efforts for two workshops.

The first workshop was held from 30 September to 2 October 1999 at Gif-sur-Yvette, France. The principal objective was to develop a research strategy for the next 3–5 years, aiming at a systematic description of root functioning, rooting depth, and root distribution for modeling root water uptake at regional to global scales. A summary report on this workshop was published in *BAHC News*, No. 7 in May 2000.

This is a brief summary on the second workshop held at the University of Oklahoma in Norman Oklahoma. The full meeting report will be published as *International GEWEX Project Office Publication Series No. 34* in September 2000.

In considering the progress in land surfaces processes and modeling, which entails the complex aspects of soil moisture, it was decided that **the Workshop needed to focus on an overall objective designed to develop a strategic plan for the next 5 years in soil moisture monitoring, analysis and prediction for hydrometeorological and hydroclimatological applications,** which: (a) identifies and recommends priorities for research; (b) demonstrates the scientific and technical feasibility of implementing a global system through one or more pilot projects or an evolutionary series of pilot projects; and (c) contributes to the design of a global system which could be operational by the end of this decade.

Soil moisture is an environmental descriptor that integrates much of the land surface hydrology and is the interface between the solid earth surface and the atmosphere. As important as this seems to our understanding of hydrology, the related ecosystem dynamics, and biogeochemical cycles, it is a descriptor that has not had widespread application in the modeling of these processes. The main reason is it is a very difficult variable to measure, not at a point in time, but on a consistent and spatially comprehensive basis. The large spatial and temporal variability that soil moisture exhibits in the natural environment is precisely the characteristic that makes it difficult to measure and use in earth science applications.

There have been a number of field experiments during the decade of the 1990s. Noteworthy is a series of field experiments in the state of Oklahoma in the USA in 1992, 1997, 1999 and plans for another in 2001. The focus of the first three field experiments was on the algorithm development for deriving soil moisture estimates from microwave data. The main elements of a planned 2001 experiment are validation of the Advanced Microwave Scanning Radiometer (AMSR) brightness temperature and soil moisture retrievals, extension of instrument observations and algorithms to more challenging vegetation conditions, and the evaluation of new instrument technologies for soil moisture remote sensing. Two versions of the AMSR instrument will be launched in the 2001–2002 time frame on the AQUA and ADEOS-II platforms. A primary science objective is the study of the interaction of soil moisture and the atmospheric boundary layer.

A plenary discussion was held to achieve a common understanding about the characteristics of a global system for soil moisture monitoring, analysis and prediction. The initial characteristics of such a system are to provide measurements and/or estimates of volumetric soil water content on at least a daily basis at a 50-km resolution and at vertical resolutions consistent with vegetative rooting depths within the resolution grid. The participants agreed that assessments of the utility of soil moisture data products at 25 and 10 km horizontal resolution would also be helpful as inputs to the design of a future global operational system.

It was generally agreed that a soil moisture monitoring system will be model based with the *in situ* and remotely sensed measurements used primarily for validation and evaluation of the model-derived fields. One can consider a coupled land-hydrology/atmosphere model as the basis for producing soil moisture analysis and prediction data products. However, the current weakness in General Circulation Models (GCM) in accurately predicting precipitation could necessitate the use of uncoupled models to produce these data products. The Workshop focused on applications in agriculture, hydrology and meteorology.

Based on considerations of the workshop presentations, it was agreed that a global system for soil moisture is needed and, furthermore, a rudimentary system could be implemented on an experimental basis with tools currently available. This system should have the ability to monitor soil moisture on a daily basis, should provide data sets and analyses for diagnostic studies and applications and should provide predictions and, possibly, future scenarios of soil moisture conditions. However, many future improvements would be essential to make such a system successful and operational. The priority research topics within the areas of soil moisture monitoring, analysis and prediction and applications will appear in the IGPO report mentioned above. This report will address a specific recommendation on developing a global monitoring system for soil moisture, providing a strategy for developing (*in situ* and remote) instruments, identifying deficiencies in models and producing long-term soil moisture data sets for use in climatological studies and applications.

This Workshop succeeded in bringing together the scientists working on different aspects of soil moisture monitoring, analysis and prediction. The results can provide a solid foundation for the design and implementation of a global system for hydrometeorological and hydroclimatological applications.

U.S. GEWEX RESEARCH PROGRESS PRESENTED AT THE AGU SPRING MEETING

John Roads
Scripps Institution of Oceanography

30 May – 3 June, 2000
Washington, DC

The National Research Council's (NRC) Global and Water Cycle Experiment (GEWEX) Panel held special sessions on GEWEX at the Spring American Geophysical Union meeting in Washington, DC, on 31 May and 1 June. The main purpose of these sessions, chaired by John Roads, Chairman of NRC GEWEX Panel, and Peter Schultz, NRC, was to review U.S. contributions to GEWEX. Presentations were made on research pertaining to the earth's radiation balance, hydrologic cycle, and modeling and observations of the coupled land-atmosphere system.

Paul Try, International GEWEX Project Office, stated that the goal of the GEWEX Program is to reproduce and predict, by means of suitable models, the variations of the global hydrological regime, its impact on atmospheric and surface dynamics, variations in regional hydrological processes and water resources and their response to changes in the environment. (See Commentary on page 2 of this issue for GEWEX plans). Nancy Ritchey, NASA Langley Research Center (LaRC), presented a poster on a number of GEWEX data sets available from the LaRC Atmospheric Science Data Center, including products from the Surface Radiation Budget (SRB) Project, International Satellite Cloud Climatology Project (ISCCP), NASA Water Vapor Project (NVAP), the International Satellite Land-Surface Climatology Project (ISLSCP) Initiative I, and the Earth Radiation Budget Experiment.

Joyce Penner, University of Michigan, discussed the Global Aerosol Climatology Project (GACP), which aims to build an accurate understanding of the abundance of aerosols by comparison of satellite, as well as ground-based observations with models. Paul Stackhouse, NASA Langley Research Center, discussed the importance of accurately determining the surface radiation budget at the earth's surface. The SRB Project aims to use a newly developed processing and analysis system to supply long-term accurate surface and top-of-atmosphere (TOA) radiative budget quantities to meet user research and industrial needs, the most pressing of which is the need to support the GEWEX ISLSCP Initiative II data set. Istuam Laszlo, University of Maryland, discussed a new research version of the shortwave algorithm that uses the vertical structure of the atmosphere including multiple layers of clouds.

Thomas Vonder Haar, Colorado State University, discussed how water vapor feedback processes within the earth's climate system require new scientific observations, analyses and modeling experiments. The GEWEX Global Water Vapor Project (GVaP) is an international collaboration to address the role of water vapor in variations of the water and energy cycle.

B. Sohn, University of Seoul, Korea, showed how indirect calculation methods in which horizontal divergence of water vapor is balanced by the evaporation minus precipitation and thus transports could be calculated from remotely sensed products and compared to transports from numerical weather prediction analyses. Clouds are also critical components affecting the atmospheric hydrologic cycle, David Starr, and Ruei-Fong Lin, NASA Goddard Space Flight Center (GSFC), gave presentations on the GEWEX Cloud Systems Study (GCSS) systematic comparison and evaluation of cirrus cloud models.

Robert Adler, NASA/GSFC, discussed climatological projects of the Global Precipitation Climatology Project (GPCP). These data are now being used to validate general circulation models. George Huffman, NASA/GSFC, discussed a new 1-degree daily GPCP precipitation data set (see page 1). Scott Curtis also showed how GPCP data could be used to study intraseasonal fluctuations over the tropics. Pete Robertson, NASA Marshall Space Flight Center, then discussed some new results of precipitation estimation from satellites and how some of the variations were different from current GPCP data sets. Brian Soden, NOAA Geophysical Fluid Dynamics Laboratory, suggested that global climate models, forced with observed sea-surface temperatures (SST) accurately reproduce the observed tropospheric temperature, water vapor and outgoing longwave radiation changes. However, the predicted variations in tropical-mean precipitation rates are substantially smaller than observed.

Rick Lawford, GCIP Project Office, introduced the U.S. GEWEX Continental-scale International Project (GCIP) and its transition to GEWEX America Prediction Project (GAPP). Rick Lawford noted that specific GCIP successes included a better understanding of land processes and heterogeneity, more accurate water budget estimates, development of advanced land-surface schemes and the incorporation of these schemes into prediction systems, new data sets using remotely sensed data and new in situ measurement systems, and advanced data assimilation systems. Specific aspects were discussed in the companion AGU special session on GCIP.

Chris Milly, Geophysical Fluid Dynamics Laboratory, discussed how GEWEX had contributed to an increased focus on the land surface and how these investigations were being facilitated by products from the SRB data set, the ISLSCP Initiative I CD-ROM, the GRDC database, and by the Project for Intercomparison of Land-Surface Parameterization Schemes (PILPS).

Eric Wood, Princeton University, discussed macroscale hydrological models, which predict fluxes and runoff at continent and subcontinent scales. Hideki Kanamaru, Boston University, discussed another estimate of runoff, from net top-of-atmosphere radiation via the coupled water and energy balance of the atmosphere. John Roads discussed surface water and energy budgets over the continental United States. Vasubandhu Misra, Center for Ocean-Land-Atmosphere (COLA) Studies, discussed similar budget terms for Brazil. Oreste Realle, COLA, discussed how the impact of land variability on climate variability can be made and compared to the role of ocean variability in general circulation models. Kaye Brubaker, University of Maryland, showed how back trajectory analysis could be used to analyze evaporative sources for moisture in the Mississippi River Basin.

GEWEX/WCRP MEETINGS CALENDAR

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

11–15 September 2000—GEWEX HYDROMETEOROLOGY PANEL, Angra dos Reis, Brazil.

27–29 September 2000—ERB2000 CONFERENCE ON MONITORING AND MODELLING CATCHMENT WATER QUANTITY AND QUALITY, Ghent, Belgium.

11–13 October 2000—THIRD MEETING OF THE GLOBAL AEROSOL CLIMATOLOGY PROJECT (GACP), Lanham-Seabrook, Maryland, USA.

16–20 October 2000—WORKING GROUP ON NUMERICAL EXPERIMENTATION (WGNE)/BUREAU OF METEOROLOGY RESEARCH CENTRE (BMRC) WORKSHOP ON SYSTEMATIC ERRORS, Melbourne, Australia. The workshop web site is: http://www.bom.gov.au/bmrc/admin/syserr.html

23–27 October 2000—GEWEX MODELING AND PREDICTION PANEL (GMPP)/WORKING GROUP ON NUMERICAL EXPERIMENTATION (WGNE), Melbourne, Australia.

6–10 November 2000—SECOND GENERAL ASSEMBLY OF SPARC: STRATOSPHERIC PROCESSES AND THEIR ROLE IN CLIMATE, Mar del Plata, Argentina.

15–17 November 2000—ISLSCP INITIATIVE II MEETING, NASA/GSFC, Greenbelt, Maryland, USA.

15–17 November 2000—6TH MAGS SCIENCE WORKSHOP, Saskatoon, Canada.

29 November – 1 December 2000—GEWEX CLOUD SYSTEM STUDY (GCSS) SCIENCE PANEL MEETING, Tokyo, Japan.

11–13 December 2000—INTERNATIONAL SATELLITE CLOUD CLIMATOLOGY PROJECT (ISCCP) WORKING GROUP ON DATA MANAGEMENT (WGDM) AND SCIENCE ADVISORY TEAM MEETING, NASA Goddard Institute for Space Studies, New York City, NY, USA.

15–19 December 2000—AMERICAN GEOPHYSICAL UNION FALL MEETING, San Francisco, California, USA. Land-surface and cold season processes to be addressed. For information: www.agu.org/meetings.

14–19 January 2001—81ST AMERICAN METEOROLOGICAL SOCIETY MEETING, Albuquerque, New Mexico, USA. Special symposia include: Global Aerosol Climatology; 12th Symposium on Global Change Studies and 5th Symposium on Integrated Observing Systems. For information consult: www.ammetsoc.org/meetings.

29 January – 2 February 2001—GEWEX SCIENTIFIC STEERING GROUP MEETING, Barcelona, Spain.

19–24 March 2001—WCRP JOINT SCIENTIFIC COMMITTEE MEETING, Boulder, Colorado, USA.

GEWEX NEWS
Published by the International GEWEX Project Office (IGPO)
Dr. Paul D. Try, Director

Editor: Dr. Paul F. Twitchell
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Silver Spring, MD 20910, USA

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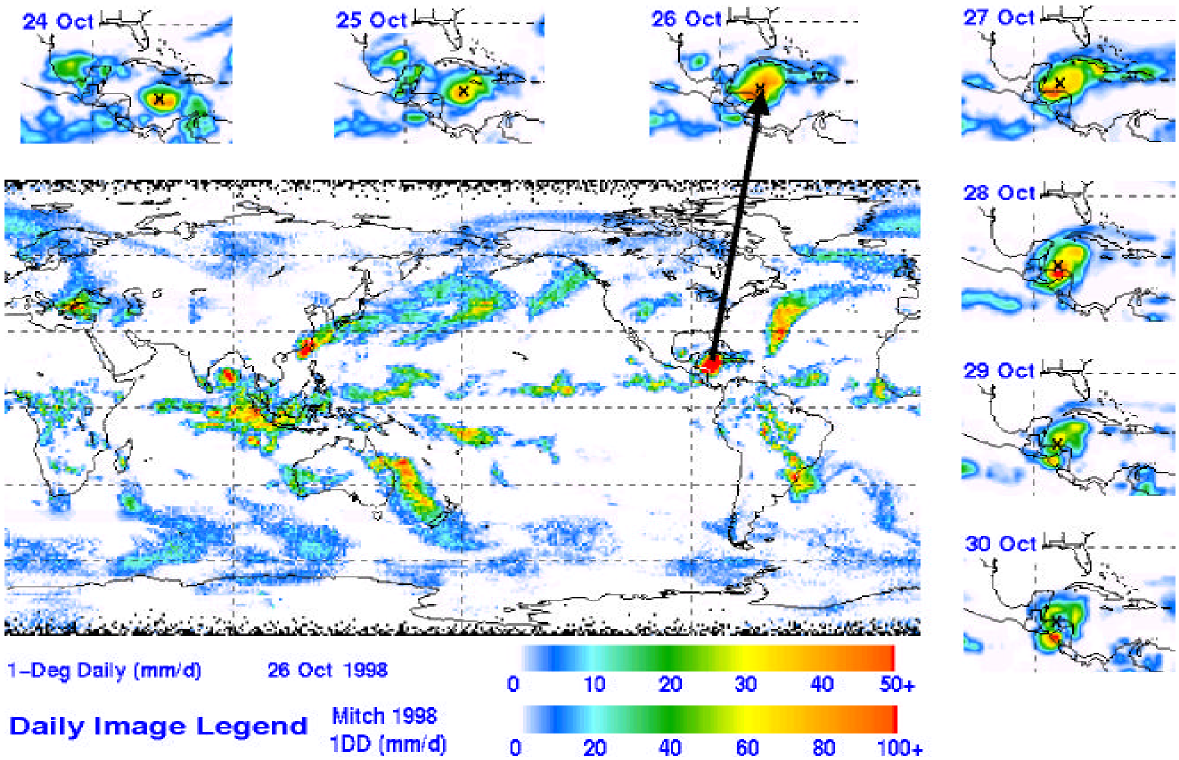
GPCP DAILY 1X1 DEGREE IMAGES OF HURRICANE MITCH



The above example of the new GPCP 1x1 degree daily preciptation product (available from 1997 to present) for 26 October 1998, illustrates the global coverage for 26 October 1998 and daily changes in the precipitation associated with Hurricane Mitch from 24–30 October 1998. The black X's denote Mitch's 12Z daily position. (G. J. Huffman et al., 2000; Global Precipitation at 1-Degree Daily Resolution from Multi-satellite Observations; submitted to J. Hydromet.)

NEW GPCP PENTAD (5-DAY) PRODUCT SHOWS MJO

Time-longitude plots of estimated precipitation anomalies during June–December 1996 in mm/day units. Dashed lines on the GPCP pentad analysis (left panel) indicate periods of increased convective precipitation associated with Madden-Julian Oscillation activity. Such oscillations are not apparent in the monthly analysis (right panel). Attribution: Dr. Pingping Xie, Climate Prediction Center/NCEP/NWS.