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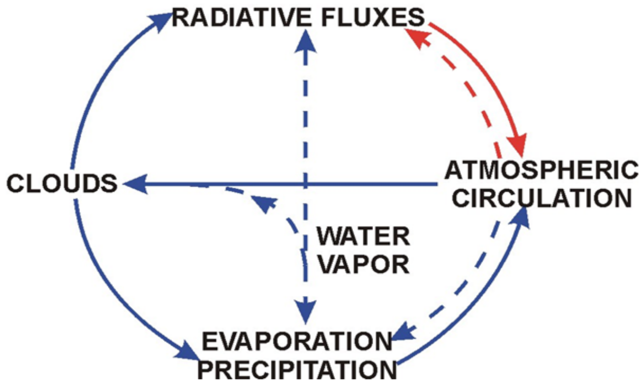
CLIMATE FEEDBACK:

CLOUDS COUPLE THE ENERGY AND WATER CYCLE

(IN A NONLINEAR PROCESS)



CLIMATE FEEDBACKS AS A PROBLEM OF COMPLEX, NON-LINEAR DYNAMICS

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The response of the climate to a change in forcing (or an imposed perturbation from equilibrium) is determined by internal processes that alter the relation between the forcing and the response. These processes are called feedback processes, in analogy with electrical circuit theory, where internal components interact to amplify or damp the system's response to forcing. This concept was applied to early studies of the climate represented by very simple, global energy-

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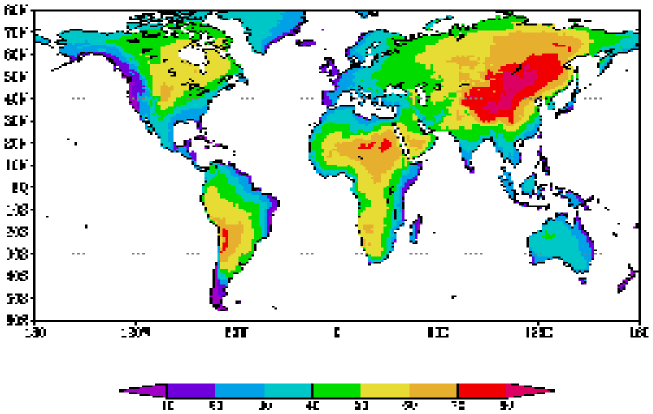
ANALYZING THE REGIONAL HYDROLOGICAL CYCLE



Percentage of precipitation over land that originated as continental evaporation, annually averaged over 15 years of simulation.

GEWEX CSE SOURCES OF PRECIPITATION USING GCM WATER VAPOR TRACERS

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Koster et al. (1986) used passive tracers to follow incoming atmospheric water from surface evaporation through the atmosphere, until it was precipitated. In this way, the geographical source of water for all precipitation could be identified. While these simulations were very coarse (8° x 10°) and short duration (only one season long), the work demonstrated a methodology of numerical calculation of the local and remote sources of precipitation within the model's simulation.

(Continued on Page 6)

What's New

- Joint GRP/WCRP Climate Feedback Workshop set for November.
- CliC/GEWEX Workshop on Solid Precipitation sets strategy for the future.
- GLASS/PILPS-C1 Experiment linking net CO_2, LH and SH underway in the Netherlands.
- GEWEX-IAHS Workshop builds links to water resource managers.

COMMENTARY

PAUL F. TWITCHELL RETIRES FROM IGPO

Paul D. Try, Director, IGPO

Over the last 12 years, Paul Twitchell has been assisting in developing and promoting GEWEX in a wide variety of venues and has been the driving force behind the GEWEX Newsletter. Because Paul has always been involved in following the latest developments in science and takes on any activity with great dedication and enthusiasm, I find it somewhat difficult to believe that he will actually be retiring and slowing down. Having served for many years as a program manager with the Office of Naval Research (ONR), Paul has always been excited about new research results and has a history of supporting promising new research. Paul received his Ph.D. in Oceanography from the University of Wisconsin and in addition to his serving with ONR, he has been a professor at the Naval Academy and also supported the US Air Force Air Weather Service as an Air Force Reservist, retiring as a Colonel.

So, with his third retirement (ONR, AF Reserve, and now from the International GEWEX Project Office), Paul will be moving back to his home in Wellesley, Massachusetts, but has said he will still be available to assist us in any way he can. I'm sure Paul will continue to follow developments within GEWEX, as well as the other areas of research he has always followed—polar lows, air-sea transfer, solar-terrestrial interactions, and satellite remote sensing of the atmosphere and ocean. Within the IGPO planning activities we have always counted on Paul to keep us up to date with international research since Paul has developed a remarkable number of contacts around the world following his many years at ONR tracking these activities.

I have known and worked with Paul for over 30 years in various situations and have never know anyone with such a high degree of dedication and loyalty. This is hard to replace. Whatever the task, Paul has always been ready and willing to take it on, even if it is not the most desirable activity. A true friend—we will miss his contributions.

Paul, best wishes to you and Eunice in your "latest" retirement.

EDITOR'S FAREWELL

An activity in 1990 at the International GEWEX Project Office (IGPO) addressed methods of communicating the GEWEX scientific objectives, plans, and results. A product of those early discussions was the establishment of *GEWEX News.* The first issue was published in early 1991 and a format developed for the November 1991 issue that is not too different from this August 2002 issue.

Now with over 11 years as editor, I will be moving on to other GEWEX related activities. I wish to thank all those who contributed science or news articles to *GEWEX News*, and particularly thank you for your patience with me. The production of *GEWEX News* has always been a team effort, including guidance from the GEWEX Scientific Steering Group, specifically Dr. Moustafa Chahine and Profesor Soroosh Sorooshian, and the Director of IGPO, Dr. Paul Try. The team included for many years at IGPO Ms. Carmelitta Riley and now Ms. Erin McNamara for typing, graphics, and layout assistance. In 1995 Ms. Dawn Erlich added significantly in producing *GEWEX News* in her role as Assistant Editor. The final excellent editing and supervision over printing was from the beginning accomplished by the Publications Division of Science and Technology Corporation (STC) under the professional leadership of Ms. Diana McQuestion.

I am confident the IGPO/STC team will continue to produce and improve *GEWEX News.*

Paul F. Twitchell, Ph.D., Editor

Contents

CLIMATE FEEDBACKS

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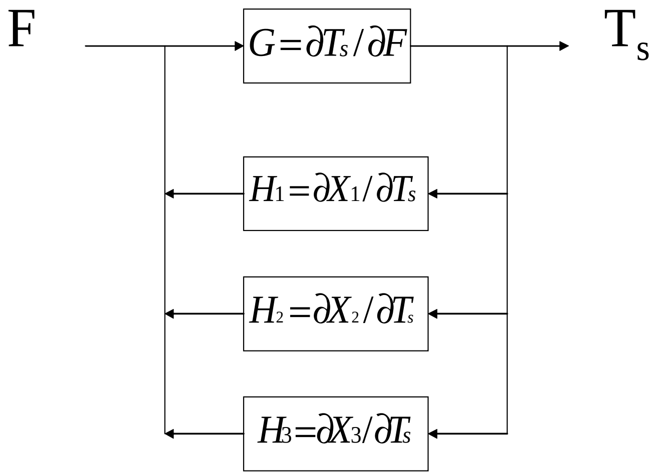
balance models. These simple models (see figure below) required that the state of the climate system be represented by one state variable (annual, global mean surface temperature, T_S) and be in near-equilibrium with the solar heating (the external forcing, S_0); and that one or more feedbacks involve internal variables (X_i) that are functions of T_S only and are independent of each other. Note also that the largest part of the climate's response to solar heating is an increase of temperature until the cooling by terrestrial radiation balances the solar heating. Thus, the net radiative balance or small deviations from it is not strictly the forcing for climate since it includes a major part of the climate response. The most studied feedbacks are cloud- and ice/snow-induced changes of planetary albedo (altering the forcing) and cloud- and water vapor-induced changes of the atmospheric opacity to terrestrial radiation (altering the response).



Feedback loops in system in parallel: F is external forcing, G is linear gain of system, T_S is surface temperature (or diagnosed variable). H and X represent feedback coefficients and internal variables, respectively.

If we consider the evolution of the planetary energy balance after a small perturbation from radiative equilibrium (or a small change in forcing), the change in the net radiative heating (solar heating minus terrestrial cooling), F, because of the feedbacks at time, $t_0 + 2\Delta t$, can be expressed as

$$F(t_0 + 2\Delta t) = F_0(t_0 + 2\Delta t) + \sum_i \frac{\partial F(t_0 + \Delta t)}{\partial X_i(t_0 + \Delta t)} \frac{\partial X_i(t_0 + \Delta t)}{\partial T_s(t_0)} \Delta T_s(t_0) \qquad (1)$$

where F_0 is the strictly external part of the forcing. This expression is obtained only if we assume that F acts only on T_S, even though it is a function of T_S and X_i, and that the X_i do not interact. These are crucial and very strong simplifying assumptions. Multiplying this expression by the system gain,

$$G = \frac{\partial T_s}{\partial F}$$

and assuming for small time intervals and constant $F = F_0$ that

$$GF = \Delta T_s$$

gives the familiar expression (cf. Peixoto and Oort, 1992; Curry and Webster, 1998):

$$\Delta T_s = \frac{G}{1 - G \sum_i H_i} F_0$$

where

$$H_i = \frac{\partial F}{\partial X_i} \frac{\partial X_i}{\partial T_s}$$

The classical feedback factors (Hansen et al., 1984) are then defined by

$$f = \sum_i f_i = G \sum_i H_i$$

Note that each feedback factor is the product of three partial first derivatives (in this case). If there are not too many variables and the relationships among them are very simple (usually linear), then the effects of the feedbacks can be calculated using these expressions as is still commonly done in current climate studies. However, to obtain the above expressions, several very strong assumptions about the climate had to be made: (1) a strict hierarchy of dependence is assumed (i.e., the forcing acts only on T_S, all the internal quantities are functions of T_S only and the internal quantities do not interact), (2) the external forcing, F_0, must be constant, (3) the system gain, G, must be constant (i.e., a linear dynamical system), and (4) the internal variables, X_i, are linear functions of T_S only. An important consequence of the last two assumptions is that the feedback factors are also constant.

If the dynamical system has many variables and the relationships among them are more complicated than linear, such a simple analysis no longer works. In particular, for the climate and our models of climate, none of the assumptions mentioned are true, even approximately. For example, the original energy balance models assumed that terrestrial radiation changes were linear in T_S (assumption 3), but it has become common to calculate the system gain without feedbacks using

$$G^{-1} = \frac{\partial}{\partial T_s}\left(\sigma T_s^{4}\right) = 4\sigma T_s^{3}$$

which is "more physically accurate" but not constant as required for the usual calculation of feedbacks. In other words, the simple Planck relationship for blackbody radiation already introduces a state-dependence to the climate's response: the climate is not as sensitive to the same forcing at all temperatures. Moreover, the actual situation we are confronted with is a climate that is changing in response to time-varying forcing (where human-induced changes are considered to be external forcing), violating assumption (2). Finally, the processes involving clouds, at the least, couple the energy and water cycle (see figure on front page) in ways that cannot be represented by independent and linear functions of T_S, violating assumptions (1) and (4). The most important consequence is that the climate feedbacks are state-dependent, implying both time and location dependence: they cannot be estimated as if they are constant "global" values.

What approach can we use instead to understand climate? Trying to answer this question raises two others: what do we actually want or need to know about the climate; and how do we evaluate how well we know it?

Returning to an evaluation of how a general, multivariate, nonlinear dynamical system responds to forcing suggests possible answers to these questions by highlighting the fundamental role played by the sensitivities (the partial first derivatives of each variable by the others) in the system's dynamics (remember that the classical feedback factors were products of these sensitivities). If we examine, in general, the changes at time $t_0 + 2\Delta t$ in a multivariate system described by the state variables **X** (arranged as a vector, where bold symbols are vectors and matrices), then expression (1) becomes

$$\Delta\mathbf{X}(t_0 + 2\Delta t) \approx F(t_0 + 2\Delta t) + \frac{\partial\mathbf{X}(t_0 + 2\Delta t)}{\partial\mathbf{X}(t_0 + \Delta t)}\,\mathbf{F}(t_0 + \Delta t) + \frac{\partial\mathbf{X}(t_0 + 2\Delta t)}{\partial\mathbf{X}(t_0 + \Delta t)}\,\frac{\partial\mathbf{X}(t_0 + \Delta t)}{\partial\mathbf{X}(t_0)}\,\mathbf{F}(t_0) \qquad (2)$$

where the approximation is that, for small Δt, the changes in all quantities are sufficiently accurately represented by the first derivatives (the sensitivities).

Expression (2) is much more complete than expression (1) because the forcing, **F**, can act (in principle) on any of the state variables, **X**, and because all of the variables are (in principle) functions of all the others. The possibility of non-linear functional relationships among the state variables also means that the sensitivities are a function of the state of the system. Hence, the third term in expression (2), which resembles the feedback term in expression (1), is not constant: the feedbacks can, themselves, be functions of the state of the climate and vary in time (and with location). This creates the main problem of trying to understand how the climate works: since we can only observe the climate's behavior "in place" with all processes operating and interacting, it is very difficult to determine the state-dependent relationships among all the variables involved. We do not have the opportunity to simplify the system by conducting experiments, except in our climate models, where one variable at a time can be perturbed and the response measured.

As a result, the answers to our second two questions could be that we want/need to determine the sensitivities of the system and their state dependence; and that we can demonstrate their accuracy by comparing how well we can determine the (short-term) time-evolution of the system as a function of the climate's state. Returning to our first question: How can we determine the sensitivities given observations of the climate state at various times?

There are a number of powerful statistical analysis tools that might be applied to the problem of determining the climate sensitivities from observations, for example traditional autoregression models such as Auto-Regressive Moving Average. However, the one we are investigating (Aires and Rossow, 2002), neural networks, has three major advantages: it can represent very complex and nonlinear relationships, the sensitivities of the variables and their state dependence can be determined from the neural network in a straightforward way, and it can efficiently handle a very large number of variables. The analysis procedure has three steps: (1) the neural network is "trained" to represent all of the values **X** $(t_0 + \Delta t)$ given the values **X** (t_0), both obtained from extensive observations of the climate's time variations, (2) the accuracy of this representation is tested on other observations not used for the training, and (3) the sensitivities are calculated from the parameters of the "trained" neural network. Essentially, the training of the neural network performs a multivariate, nonlinear regression fit to the observational data set. Once trained, the parameters of the neural network can be used to calculate the sensitivities as a function of **X** (t).

Aires and Rossow (2002) illustrate the results from such an analysis approach by applying it to Lorenz' simple general circulation model (Lorenz, 1984). The sensitivities determined by the analysis of 200,000 observations of the model's time evolution are compared to the values calculated directly from the equations of the model. The neural network sensitivities are indistinguishable from the analytic ones: quantitatively, the rms differences at each time are one to two orders of magnitude smaller than the state-dependent variations of the sensitivities (except for one that is zero). **A crucial result is that the state-dependence of the sensitivities in the Lorenz system dynamics, which is a simple analog of the climate system, produces time-dependence of the sensitivities: in other words, the feedbacks in such nonlinear dynamical systems are time-dependent.**

This analysis approach is attractive because it also naturally defines several properties of the data set that are required for an accurate result: (1) the time (space) resolution of the dataset must be high enough that the approximation used to obtain expression (2) is accurate, i.e., the time (space) interval has to be small enough that all the variations in **X** (t) are represented accurately by only the first derivatives, (2) the range of climate states covered by the observations has to be statistically "complete", i.e., the data have to provide an adequate sample of all the states of the climate, all the possible relations of **X** (t), and (3) the variables included have to represent the complete state of the climate, otherwise the relations inferred by the analysis will be distorted by the variations of the "hidden" variables.

The example discussed here is meant to suggest a line of research; it is not yet a solution to our problem. Much more work is needed to investigate other approaches. For the neural network approach, research is needed to determine how to relate the sensitivities to physical processes. In particular, dealing with the effects of an "incomplete" observational prescription of **X** (t) is a major obstacle. At a minimum, application of the same analysis procedure to climate model output, limited to the same list of variables as available from observations, provides a much more "dynamic" and general way to compare the behavior of a model to the real thing.

A GEWEX Radiation Panel/Working Group on Coupled Modelling Workshop on Climate Feedbacks will be held 18-20 November 2002 in Atlanta, Georgia.

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GLOBAL PRECIPITATION CLIMATOLOGY PROJECT (GPCP) PRODUCTS AVAILABLE FROM THE SURFACE REFERENCE DATA CENTER

In 1987, the Surface Radiation Data Center (SRDC) was established under GPCP at the National Climatic Data Center in Boulder, Colorado. In 1998, the SRDC was transferred to the Environmental Verification and Analysis Center (EVAC) at the University of Oklahoma, 710 ASP Avenue, Suite 8, Norman, Oklahoma, 72009. One of the tasks of the SRDC is to collect surface measurements of precipitation on a variety of temporal and spatial scales and develop products that can then be used by the "satellite community" to verify their precipitation algorithms.

SRDC products are available to any researcher and can be downloaded at http://www.evac.ou.edu/srdc. Currently online are the up-to-date Pacific raingauge data, a digitized version of Taylor's rainfall atlas which contains Pacific island gauge prior to 1971. For the Tropical Rainfall Measuring Mission (TRMM) ground validation see http://trmm-fc.gsfc.nasa.gov/trmm_gv/index.html.

GEWEX CSE SOURCES OF PRECIPITATION

(Continued from Page 1)

In this methodology, each source requires a new three-dimensional prognostic array in the General Circulation Model (GCM), which is often not feasible with limited computational resources. Since that study, the tracer methodology has seen limited use (Druyan and Koster, 1989; Numagati, 1999). In recent years, there has been increasing focus on the atmospheric water cycle, especially with respect to the intensity and climate change of the regional water cycle (Morel, 2001). **The water tracers provide a diagnostic link between evaporation, precipitation, moisture transport and the timescale that water resides in the atmosphere.**

Recently, we have adapted the passive tracer methodology to the NASA Data Assimilation Office (DAO) Finite Volume GCM (FVGCM) to simulate the movement of regional sources of water (following Koster et al., 1986; and documented by Bosilovich and Schubert, 2002, in the NASA GEOS GCM). These passive tracers are termed Water Vapor Tracers (WVT) because they simulate the model's water vapor prognostic variable at the model time step. The model dynamics and physics compute tendencies for the WVT in proportion to the model's water vapor. While the WVTs evolve according to the model dynamics and physical parameterizations, they are entirely passive, in that they do not affect the simulated hydrological cycle. Evaporation within a limited region is used as the source for a WVT. The bottom figure on page 12 identifies 12 large-scale source regions. Each color-coded region represents a continental or oceanic source of water, in the form of evaporation, to the atmosphere. Following Bosilovich and Schubert (2002), we can diagnose the amount and location of precipitation that falls because of evaporation from each region.

The FVGCM uses semi-Lagrangian advection that is particularly useful for tracer calculation (Lin and Rood, 1996). The model uses the NCAR CCM3 physical parameterizations. We have run the FVGCM at 1^{o} x 1.25^{o} resolution for 15 years using real time varying Sea Surface Temperatures (SST) from 1986–2000. **In this paper, we present the simulation of large-scale continental and oceanic sources of water for precipitation in GEWEX Continental Scale Experiments (CSE).** The area of each CSE is defined identically to Roads et al. (2002) (see bottom figure on page 12). The table below shows the annual contribution to each CSE precipitation from the large-scale geographical region's evaporation. An exact estimate of precipitation recycling cannot be identified in this table because the source regions are larger than the CSEs. However, **in all cases the local continental source of water is a major contributor to the precipitation**. Some CSEs are relatively simple to understand, such as the Mackenzie River Basin (GEWEX Mackenzie Study [MAGS]) where water comes either from the North American continent or from the Pacific Ocean. The Baltic Sea Experiment (BALTEX) seems to be more complicated with many sources of water contributing to precipitation, including European continental, North and Tropical Atlantic Oceanic and Polar (note that the Mediterranean Sea is included in Polar WVTs for convenience). The GEWEX Asian Monsoon Experiment (GAME)-Tibet and GAME-Siberia are the only two CSEs where the continental sources of water exceed oceanic sources. The figure on the right on page 1 shows the percentage of precipitation from continental sources over land. In general, coastal regions show less continental precipitation, especially where we would expect on-shore flow from the oceans. When averaged over all land points, 1.08 mm/day of precipitation from continental sources falls on land, while 1.50 mm/day precipitation from oceanic sources falls on land.

While the annual budgets of the moisture sources are useful, mean annual cycles can describe the seasonal variations of the moisture transport. On the back page, the figure shows the mean annual cycles of the major sources of each CSE. In the Mississippi River (GEWEX Continental International Project [GCIP]) and MacKenzie River basins, the North American continental source dominates during summertime, while in winter the Pacific Ocean source dominates. Likewise, BALTEX shows a transition from the local continental sources in summer to

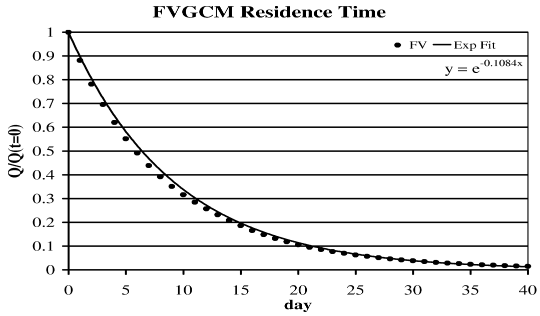
GEWEX CSE	Source Region														
	NA	SAM	AsA	Eur	Afr	Npa	Tat	INO	Sat	Nat	Spa	Pol	Cont	Oceanic	P(mm/dy)
GCIP	**43.9**	0.5	1.4	0.3	0.8	**19.7**	**28.9**	0.6	0.7	2.0	0.8	0.4	46.9	53.1	2.42
MAGS	**32.7**	0.1	7.9	1.1	0.3	**52.6**	1.0	0.9	0.1	0.9	0.4	2.2	42.0	58.0	1.52
LBA	0.0	**45.5**	0.1	0.1	4.3	0.4	**17.2**	2.5	**27.5**	0.4	1.3	0.5	50.2	49.8	5.98
BALTEX	6.2	0.1	1.8	**26.5**	1.1	4.2	**11.7**	0.3	0.2	**37.8**	0.1	**10.1**	35.6	64.4	2.44
CATCH	0.5	0.1	0.7	1.7	**41.0**	0.5	**21.7**	9.0	**20.0**	1.2	0.4	3.2	44.1	55.9	2.70
GAME-Tropics	0.2	0.1	**25.7**	0.6	3.3	**25.2**	0.5	**39.4**	0.4	0.2	3.8	0.5	29.9	70.1	4.75
GAME-HUBEX	0.2	0.1	**45.8**	0.8	1.7	**31.2**	1.0	**16.3**	0.2	0.5	1.7	0.6	48.6	51.4	3.30
GAME-Tibet	0.3	0.1	**53.1**	1.3	3.8	6.8	1.4	**30.5**	0.4	0.5	1.1	0.9	58.6	41.4	1.42
GAME-Siberia	2.6	0.0	**55.1**	**11.1**	1.1	8.1	3.3	1.2	0.1	8.4	0.2	8.8	69.9	30.1	3.80

Percentage of precipitation that occurs in each GEWEX CSE from each of the source regions shown on page 12. The sum of continental and oceanic sources is included for convenience. CSE annual mean precipitation is included in mm/day. Boldface indicates values greater than 10%. The percentages are computed from time averaged WVT precipitation divided by time averaged total precipitation.

oceanic sources in winter. With its maximum Mississippi contribution in late summer, the tropical Atlantic Ocean has a smaller annual cycle than the Pacific Ocean. However, summertime precipitation is larger than winter, so the tropical Atlantic has a larger impact on the annual budget than the Pacific Ocean (Table on page 6). Continental sources for Amazonian precipitation are large throughout the year, but the oceanic sources vary with the seasonal change of the easterly flow. In the GAME Tropics region, the moisture sources shift from the Pacific Ocean to the Indian Ocean. GAME-Siberia is largely dominated by the summertime Asia continental sources.

The figure on the back page suggests that in some regions, significant amounts of water are transported very long distances. For example, the Asia continental source for the Mackenzie basin in summer, and the North American source for BALTEX must traverse entire oceans. While a map of moisture transport may suggest the possibility that these are potential sources, the tracers provide a quantitative diagnostic. **This also raises the question of residence time of the atmospheric water in the GCM.** To evaluate the residence time, we initialized a special WVT equal to the initial atmospheric water content, but provide no source at the surface. This allows the precipitation to deplete the WVT atmospheric water content in time without being replenished. Again, this WVT is a diagnostic and the simulated precipitation and hydrologic cycle continue normally. The figure in the next column shows the time series of the WVT water content as it is depleted. **Fitting the data points with an exponential curve shows that the e-folding time of the atmospheric water is 9.2 days.** The more traditional way of determining the residence time of water in the atmosphere uses a time constant equal to atmospheric water over precipitation (Trenberth, 1998). For this period, the global mean precipitation is 3.33 mm/day and the global mean total precipitable water is 24.9 mm, which suggests a moisture depletion estimate (e-folding time of the water content) of 7.5 days. Trenberth (1998) points out that this estimated value of depletion is quite sensitive and neglects moisture transport (inherently included in the WVT estimate).

The WVTs provide a diagnostic tool to evaluate the hydrologic cycle in atmospheric numerical models. **The diagnostic considers the instantaneous evaporation and precipitation rates as well as transport processes.** Such diagnostics should be useful in evaluating the water cycle of extreme conditions such as flood and drought, as well as the intensity of regional water cycles in climate change experiments. Of course, the quality of the WVT diagnostics depends on the veracity of the GCM simulation. At present, we are implementing the WVT diagnostics in the NASA DAO Data Assimilation System to evaluate real data case studies and the impact of water vapor assimilation on the hydrologic cycle. These diagnostics may be useful in other studies, such as synoptic meteorology, mesoscale meteorology and paleoclimatology. It may also be possible to validate the WVT diagnostic data with precipitation isotope data. (This work is supported in part under the GEWEX Americas Precipitation Project (GAPP), Pan-American Climate Study Warm Season Precipitation Initiative, and the NASA Global Water and Energy Cycle Program.)



Model simulated globally averaged WVT with no evaporative sources (daily average) divided by the initial water (dots) and the exponential fit of the model data (line). This indicates an average global residence time of 9.2 days from this simulation.

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MAGS SPECIAL ISSUE OF ATMOSPHERE-OCEAN

The Canadian Meteorological and Oceanographic Society (CMOS) journal, Atmosphere-Ocean, has published a Mackenzie GEWEX Study (MAGS) special issue with a collection of papers that address key aspects of the water and energy features of the Mackenzie River basin. This special issue is concerned with the 1994/95 water year, a period characterized by one of, if not the lowest, discharge from the Mackenzie River into the Arctic Ocean on record. Copies of this issue (Volume 40, No. 2, June 2002) may be obtained through the CMOS web site at: http://www.meds-sdmm.dfo-mpo.gc.ca/cmos/pubs.html or from Dr. Ronald Stewart, Climate Processes and Earth Observation Division, Meteorological Service of Canada, 4905 Dufferin Street, Downsview, Ontario M3H 5T4 Canada, E-mail: Ron.Stewart@ec.gc.ca.

COUPLING CHEMISTRY AND PHYSICS IN THE TERRESTRIAL BIOSPHERE: THE PILPS-C1 EXPERIMENT

Nicolas Viovy
French Atomic Energy Commission

In the past, models of the land surface have been developed for two different purposes: as boundary conditions for the atmosphere (with an emphasis on biophysical processes), and for a better understanding of the carbon cycle (with an emphasis on biochemical processes). These separate developments have lead to relatively independent intercomparison projects, in the framework of WCRP (e.g. Project for Intercomparison of Land Surface Parameterization Schemes (PILPS), Henderson-Sellers et al., 1993, 1995) and International Global-Biosphere Program programs, (e.g. Potsdam model intercomparison, Cramer et al., 1999; EMDI, Olson et al., 2001).

But it is now established that geochemical and physical processes are highly coupled at the land surface, on time scales of seconds to centuries. For instance, **it has been demonstrated that the feedback of atmospheric CO_2 concentration on stomatal conductance induces changes in the hydrologic cycle, with important consequences for the climate, and vice versa** (Sellers et al., 1996; Betts et al., 1997). The recent evolution of land surface representations, for the study of both the carbon cycle and climate, have lead to improvements in the coupling between biophysical and biogeochemical processes. At the same time, since 1995 several sites have been instrumented for the continuous measurement of fluxes of both net CO_2 and energy. Thus, we are able now to go further in our understanding of the coupling between the CO_2 and water cycles, by comparing simulated fluxes with *in situ* data collected in the frame of fluxnet project.

The PILPS-C1 experiment, an initiative of the GEWEX/Global Land-Atmosphere Systems Study (GLASS), was launched in May 2002, with the aim of comparing land surface model fluxes of net CO_2, latent and sensible heat with *in situ* measurements at a selected site. This site, called Loobos, is a part of the Euroflux network. Loobos is a 80-year-old coniferous forest located in the center of The Netherlands. Fluxes of CO_2, latent and sensible heat have been measured there continuously for the years 1997 and 1998 using the eddy correlation method. The flux tower is 27 meters in height, and measurements are made every 30 minutes.

In the comparison of *in situ* net CO_2 fluxes with model simulations, one major problem concerns soil carbon spinup. In fact, a part of the CO_2 net flux arises from decomposition of soil organic matter which can be more than one century old. Thus, a valid comparison between the simulated and observed CO_2 fluxes requires that the model be initialized over a period of several centuries. This in turn requires a knowledge of both climate and land use during the spinup period. Such knowledge is generally not available. An interesting feature of the Loobos site is that the forest was planted 80 years ago on sand (i.e., on soil containing no organic matter), meaning that the initial condition of the soil carbon pool is known. Moreover, near the Loobos site there is a meteorological station which has been recording data since the beginning of the 20th century. Thus, Loobos offers a unique opportunity for testing model simulations of the carbon cycle. Can our models simulate the carbon sink observed on this site?

As explained previously, different types of land surface schemes have been developed, some more oriented toward biophysical, others toward biogeochemical processes. The carbon-type intercomparisons and biophysical intercomparisons have largely happened independently and interactions between these groups have been limited. PILPS-C1 offers the first opportunity to bring these groups together using carbon. As a result, participation in the project is open to a wide scientific community, including those working with traditional land surface schemes, and workers utilizing more carbon-oriented models.

In summary, the two main scientific questions addressed by this project are: (1) What is the ability of models of different types to correctly reproduce both biophysical and biogeochemical processes; and (2) Taking into account the long-term history of the site, are the models able to reproduce the observed sink of carbon?

The 2002 timeline for the project is as follows: (1) Submission of the forcing data in June to the participants, (2) Deadline for submission of results in August and (3) Convene a workshop for analysis of preliminary results in November.

As of now, nine groups are participating in PILPS-C1, but new groups are encouraged to join the project.

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WORKSHOP/MEETING SUMMARIES

WCRP WORKSHOP ON DETERMINATION OF SOLID PRECIPITATION IN COLD CLIMATE REGIONS

Fairbanks, Alaska, USA
9–14 June 2002

Paul Louie
Meteorological Service of Canada

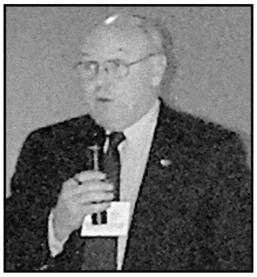
Over 50 invited scientists representing 13 countries participated in this international workshop organized by CliC and GEWEX and hosted by the University of Alaska Fairbanks. The workshop was sponsored by: WMO/WCRP and WMO/Global Climate Observing System programmes; Meteorological Service of Canada; NOAA Arctic Research Office and NOAA/NASA GEWEX Americas Prediction Project; and the International Arctic Research Centre and the Water and Environmental Research Centre both at the University of Alaska Fairbanks.

The objectives of this workshop were:

- Review the current status of measuring or determining precipitation, especially solid precipitation, in cold climate regions;
- Identify gaps and issues; and
- Recommend actions that will allow us to determine precipitation over a range of time and space scales for climatological and hydrological analyses, regional water budgets, validation and process experiments and models.

Invitees brought a wide range of expertise in cold climate precipitation, representing both *in situ* measurement and remote sensing techniques; the development of precipitation adjustment techniques and implementation of them on regional and global scales; major field programs; global data archives; and the modeling community. There was representation of the major cold regions of the world including North and South America, Scandinavia, Eurasia, China and the Arctic and Antarctic.

The workshop was organized in five sessions which included both oral and poster presentations. The session topics were: 1) Precipitation Measurement, 2) Measurement Errors and Adjustment Procedures, 3) Precipitation Data for Major Projects, 4) Regional and Global Precipitation Analysis, and 5) Precipitation Modeling and Model Validation. A short special session was convened to present related information on Major Projects. These included presentations on the research and observation activities of GEWEX and a very comprehensive description of the scientific agenda of the Global Precipitation Measurement (GPM) Mission.



Barry Goodison opening WCRP CliC/GEWEX workshop.

The workshop program and the abstracts for all the presentations are available at: http://acsys.npolar.no/meetings/precip/ws.htm. The proceedings for the workshop will be published by WMO/WCRP by the end of 2002.

Three breakout sessions were organized to discuss more fully the topics of: Precipitation Measurement; Measurement Errors and Adjustments; and Global Precipitation Data Sets. The groups were tasked to identify gaps and issues and to recommend actions.

The working group on Precipitation Measurement had three sub groups to address Conventional Measurement Methods, Alternative Strategies and New Technologies. Some of the common issues identified by these sub working groups were:

- The impact of automation on precipitation measurement and related challenges; and
- The need to blend (fuse or combine) data from different sources (*in situ*, model, satellite)

Some of the common recommendations included:

- Establish a WCRP working group to develop guidelines on the minimum station density required for climate research studies on solid precipitation in cold climate regions; and
- Conduct urgently needed research to determine how to obtain climate quality data from automated weather observing systems—need to define and attribute "climate"-quality to operational weather observing systems/sites.

The working group on Measurement Errors and Adjustment Procedures addressed several questions, including:

- What are the errors in gridding and creating gridded products?
- What must be done to provide consistent adjustments to facilitate comparisons among national, regional and global climatologies?

Findings from this group included:

- There is real value in reporting adjusted precipitation and there is a continuing need for ongoing intercomparisons.

The working group dealing with Global Precipitation Data Sets addressed such questions as:

- What research and development is needed to prepare for these new measurement and data systems (for example, the Satellite Global Precipitation Measurement Mission);
- What are the limitations in merging satellite and *in situ* products; and
- Is there a role for a data-model mix in producing global precipitation data products?

Some of the research needs identified by this group included:

- Development of models for downscaling to topography, blending strategies for data assimilation (e.g. define error characteristics), and interpolation to determine large-scale precipitation patterns in the absence of data.

Some recommendations put forward by this group:

- Develop a strategy for exploiting new technologies in the development of algorithms and models for third and fourth generation precipitation climatologies; and
- Use daily precipitation as a building block for precipitation climatologies.

The closing session provided an opportunity for further discussion of issues by participants. The CliC Implementation Plan (available at the ACSYS/CliC website, http://clic.npolar.no) had identified issues, needs and proposed actions and those identified by GEWEX GHP were reviewed in the context of the workshop discussion. This workshop provided a good start at tackling these issues. Some issues that were not fully covered or still in need of resolution were also identified. Examples include:

- Precipitation measurement in mountainous regions and Antartica;
- Solid precipitation over sea ice and ice covered Arctic Ocean;
- How to improve the linkage to the GCM community and determining modeling needs.

After three and half days of presentations and intense discussions, there were several afternoon/evening field trips to local research sites. On the following day, about half of the participants traveled to Barrow to visit the Climate Monitoring and Diagnostics Laboratory, which included the University of Alaska-Fairbanks – Japan Frontier Institute snowfall/blowing snow observation site; the U.S. Department of Energy Atmospheric Radiation Measurement (ARM) site; a tour of the Barrow Arctic Science Consortium facilities; the Weather Office at Barrow; and a tour of the Automatic Weather Observation System site at Barrow Airport.

GEWEX – IAHS WORKSHOP ON THE APPLICATION OF GEWEX SCIENTIFIC RESEARCH TO WATER RESOURCES MANAGEMENT

Dresden, Germany
22–26 July 2002

Lawrence Martz[1] and Alan Hall[2]

[1]University of Saskatchewan, Canada
[2]IAHS, Australia

The Workshop was held in conjunction with the 3rd International Conference on Water Resources and Environment Research (ICWRER) at the Dresden University of Technology. It was organized by the GEWEX Water Resources Applications Project (WRAP) Committee and the International Association of Hydrological Sciences (IAHS)/World Meteorological Organization (WMO) Working Group on GEWEX. The broad objective of the Workshop was to initiate a dialogue with water managers on their needs and the GEWEX data/model products that are available to address those needs. This was intended to identify useful forecast/modeling products for water managers; understand how these are used in decision-making; and determine preferred product delivery mechanisms

The Workshop program consisted of three keynote presentations, six presentations on water resource applications in GEWEX Continental Scale Experiments (CSE) and a panel discussion with the keynote speakers from the Workshop and the ICWRER Conference. The keynote presentations were:

- GEWEX and Water Resources Applications Project Overview: Lawrence Martz, Chair WRAP.
- Relevance of Predictions (short-, medium-, long-term) of Water Availability for Water Resources Management: Martin Kaupe and Mathias Schmitt, Wassergewinnung (W), GEW RheinEnergie AG, Germany.
- Current Research on the Application of Meteorological Forecasts to Water Resources Management: John Schaake, Jr., NOAA National Weather Service, USA.

The CSE presentations were:

- Toward Water Resources Assessment and Management in Thailand with GAME-T Datasets: Shinjiro Kanae (GAME).
- GEWEX Related Water Resources Applications in the Baltic Sea Drainage Basin – Contribution from BALTEX: Sten Bergström (BALTEX).

- The Value of Seasonal Climate Forecasts for Reservoir Management: Aris Georgakakos (GAPP).
- Application of Seasonal Climate Forecasts to Water Management in the Tennessee River: Ruby Leung (GAPP).
- Hydrometeorological data availability issues in west Africa: a challenge to understand the African Monsoon): Christian Depraetere (CATCH).
- Restoring Ice-Jam Floodwater to a Drying Delta Ecosystem, Terry Prowse: presented by Lawrence Martz (MAGS).

The Panel Discussion component of the Workshop involved the Workshop keynote speakers (with Gert Schultz substituting for Kaupe and Schmitt) and keynote speakers from the ICWRER Conference—Uri Shamir (Israel), PeteLoucks (USA), and Keith Hipel (Canada). The panel addressed wide-ranging issues:

- The uncertainty of forecasts and the need for measures to describe this uncertainty.
- Integration of hydrological and climate models to reduce complexity and model parameterization requirements.
- Water managers find it difficult to respond to high levels of uncertainty.
- As water becomes more scarce, reliable water supply together with the opposite problem of flood protection are seen as key issues.
- The potential value of the Global Soil Wetness products and the Prediction of Ungauged Basins (PUBS) initiative.
- The value of hydrological observations to the Coordinated Enhanced Observing Period (CEOP).
- One day workshops with water managers and water scientists at regional/local/basin scale by the CSEs as a way of developing greater use of GEWEX products.

The Dresden Workshop presentations and discussions will be reviewed at the upcoming WRAP meeting in New York on September 9, 2002. They will also serve as useful base for the second WRAP Workshop planned for the IUGG General Assembly in Sapporo in July 2003 (JWH02 - The Role of GEWEX Hydrological Science in Improved Water Resources Management).

GEWEX/WCRP MEETINGS CALENDAR

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

2–6 September 2002—WMO/WWRP INTERNATIONAL CONFERENCE ON QUANTITATIVE PRECIPITATION FORECASTING, Reading, UK.

9–13 September 2002—8TH SESSION OF THE GEWEX HYDROMETEOROLOGY PANEL AND ASSOCIATED MEETINGS (WRAP, WEBS, CEOP), IRI, Palisades, New York, USA.

30 September – 2 October 2002—GSWP-2 KICKOFF WORKSHOP, COLA, Calverton, Maryland, USA.

1–3 October 2002—GOES USERS' CONFERENCE II, NIST, Boulder, Colorado, USA.

2–4 October 2002—GLASS PANEL MEETING, COLA, Calverton, Maryland, USA.

8–9 October 2002—ISLSCP FUTURE STRATEGY AND INITIATIVE III MEETING, Washington, DC, USA.

9–10 October 2002—CEOP SATELLITE DATA INTEGRATION MEETING, Tokyo, Japan.

10–19 October 2002—34TH COSPAR SCIENTIFIC ASSEMBLY (Special Session on Properties of the Earth-Atmosphere-Ocean System as Inferred from the New Generation of Earth Science Satellites), Houston, Texas, USA.

6–10 November 2002—8TH ANNUAL MAGS MEETING AND SCIENCE COMMITTEE MEETING, Jasper, Canada.

12–15 November 2002—2ND INTERNATIONAL ATMOSPHERIC MODEL INTERCOMPARISON PROJECT (AMIP) CONFERENCE, Meteo-France, Toulouse, France.

18–20 November 2002—GRP/WGCM WORKSHOP ON CLIMATE FEEDBACKS, Atlanta, Georgia, USA.

18–22 November 2002—WGNE/GMPP MEETING, Météo-France, Toulouse, France.

6–10 December 2002—AGU FALL MEETING, San Francisco, California, USA. Special theme session on research in climate and hydrology in the Southern Hemisphere.

15–17 January 2003—US-JAPAN WORKSHOP ON CLIMATE CHANGE, Irvine, California, USA.

20–25 January 2003—15TH SESSION OF THE GEWEX SSG, Bangkok, Thailand.

9–13 February 2003—83RD AMERICAN METEOROLOGICAL SOCIETY ANNUAL MEETING, Long Beach, California, USA.

17–21 March 2003—WCRP JOINT SCIENTIFIC COMMITTEE MEETING, Reading, UK.

2–4 April 2003—CEOP SECOND FORMAL INTERNATIONAL IMPLEMENTATION PLANNING MEETING, Berlin, Germany.

30 June – 11 July 2003—XXIII GENERAL ASSEMBLY OF THE INTERNATIONAL UNION OF GEODESY AND GEOSCIENCES (IUGG), Sappora, Japan.

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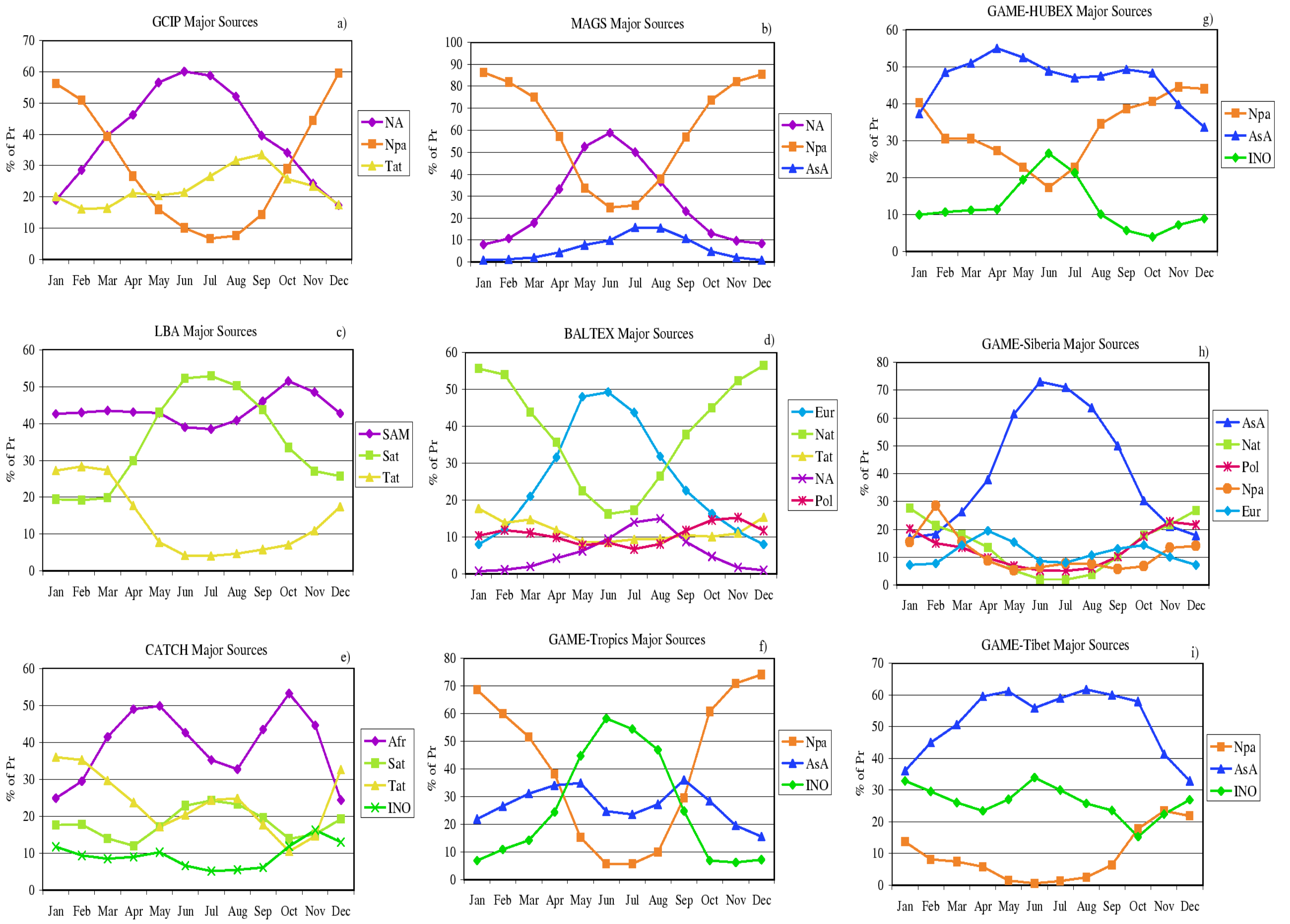
LINKING CLOUD FEEDBACK, WATER VAPOR SOURCES, AND TERRESTRIAL BIOSPHERE TO THE ENERGY AND WATER CYCLE (SEE ARTICLES ON PAGES 1 AND 8)



a) GCIP Major Sources

b) MAGS Major Sources

g) GAME-HUBEX Major Sources

c) LBA Major Sources

d) BALTEX Major Sources

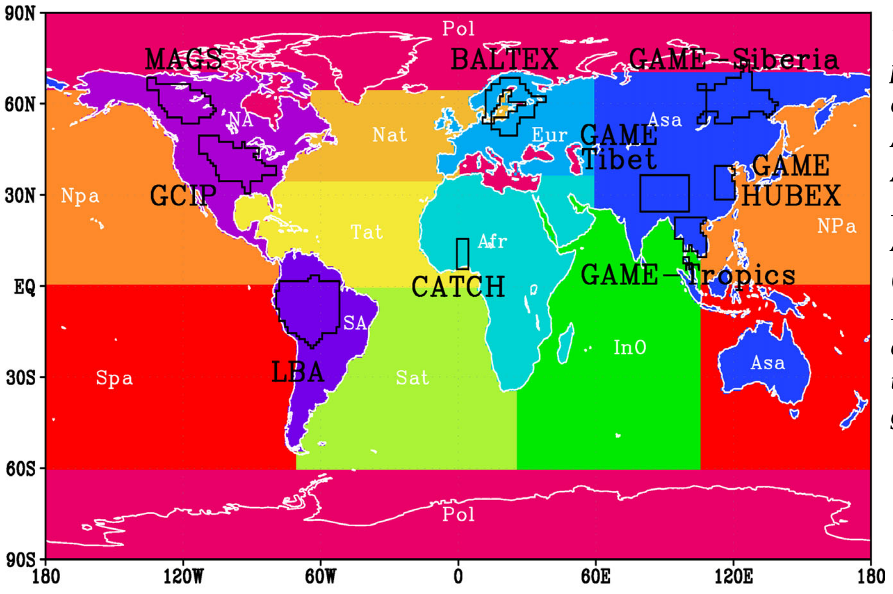
h) GAME-Siberia Major Sources

e) CATCH Major Sources

f) GAME-Tropics Major Sources

i) GAME-Tibet Major Sources

Mean annual cycle of the dominant sources of water that occurred as precipitation in each of the CSEs. Colors correspond to the geographical regions as shown below.



The source regions of water vapor for precipitation from continental and oceanic regions. NA, North America; SA, South America; Eur, Europe; Afr, Africa; Asa, Asia-Australia; Npa, North Pacific; Spa, South Pacific; Nat, North Atlantic; Tat, Tropical Atlantic; InO, Indian Ocean; and Pol, Polar (both north and south are also included). Figure above and to left are referenced in article "GEWEX CSE Sources Of Precipitation Using GCM Water Vapor Tracers" beginning on page 1.