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GEWEX NEWS

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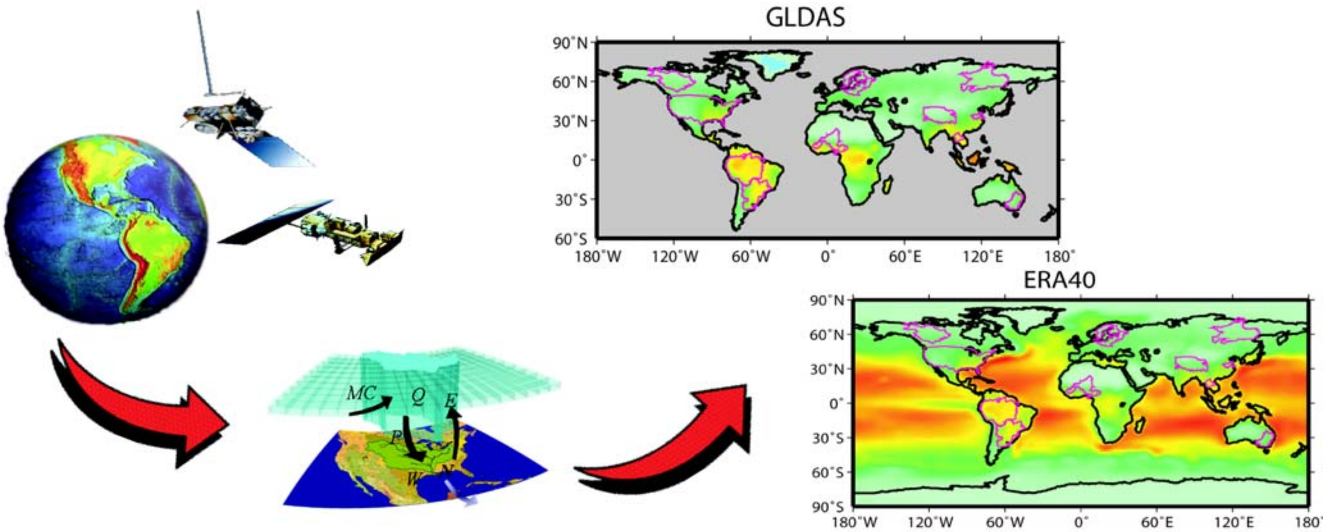
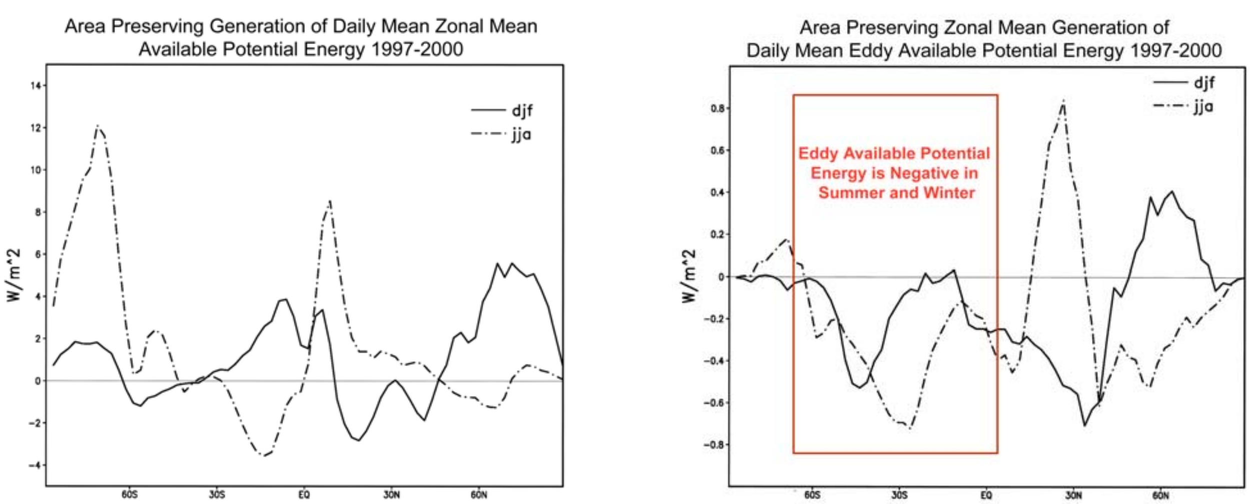
GEWEX ADDRESSES WATER AND ENERGY BUDGETS USING SATELLITES AND MODELS



1986-1995 latent heat flux (wm^{-2}) climatology from GLDAS and ERA-40 with CSEs outlines for analysis and intercomparison. *See articles by Roads and Trenberth, et al. on pages 6 and 9.*

NEW SATELLITE ESTIMATES OF AVAILABLE POTENTIAL ENERGY SUPPORT THE VIEW THAT ATMOSPHERIC EDDIES ARE A NET SINK OF ENERGY



Left panel shows zonal, seasonal average generation of available potential energy, and right panel shows eddy available potential energy. Both were determined from observation-based calculations of atmospheric heating/cooling by radiation, precipitation and surface fluxes. *See article by Rossow, et al. on page 4.*

ANALYZING THE VARIATIONS OF THE GLOBAL ENERGY AND WATER CYCLE

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The core of the Earth's climate system is an energy cycle that converts absorbed solar radiation into heat and associated terrestrial radiation into the circulations of the atmosphere and ocean. A key exchange of energy within this system, which also couples the circulations of the atmosphere and ocean, is between the surface and the atmosphere, primarily through evaporation cooling of the surface and precipitation heating of the atmosphere, thereby intimately linking the energy and water cycle. Because of the Earth's spherical shape, its rapid rotation, and its elliptical orbit about the sun, the solar heating is neither uniform nor constant. Because of the turbulent nature of the atmospheric and oceanic motions that transport heat and water, the response of the system is not steady. Hence, the "climate," which is usually portrayed as a static state of a single system, is actually an amalgam of variations of energy and water exchanges among several climate system components that respond on a broad range of space-time scales and are coupled by the exchanges of energy and water. Although some statistics of these variations may be static, the energy-water cycle is fundamentally dynamic.

Basic questions about the climate are: (1) how variable is the climate with a "statistically steady" forcing (natural variability)? and (2) how sensitive is the climate to systematic changes in the forcing (climate change)? The latter is determined by numerous feedback processes that operate to alter the exchanges of energy and water within the system and outside but, in a truly dynamic climate system, the former is also influenced by these same processes. To learn the answers to these questions, therefore, we must observe the varying relationships among the components of the climate system and diagnose the variations of their exchanges of energy and water to determine how they regulate and modulate the climate response to forcing. For this purpose, the observations must have a combination of high space-time resolution and global, long-term coverage that can only be provided, in practice, by systematic satellite observations. The former is required to accurately resolve the energy and water exchange variations at the weather-process-level and the latter is required to provide enough examples of the different possible configurations of the climate system to understand the range of multi-variate, non-linear relationships that are produced by the interactions of the processes.

To describe the complete energy-water cycle requires measurements of the thermodynamic state of all of the climate components and the hydrodynamic state of the atmosphere and ocean, as well as all the properties of them that affect the energy and water exchanges. The state is described by the 4-dimensional distribution of temperature, humidity and winds in the atmosphere, of the temperature, salinity and currents in the ocean and the temperature and "water content" of the land and ice. To calculate the exchanges of energy requires determination of the tendencies of the state variables and their atmospheric and oceanic transports which are functions of spatial derivatives of these variables. Additional properties that are needed to calculate radiative exchanges are the gas composition of the atmosphere (including the main greenhouse gases), aerosols, clouds and surface spectral albedo/emissivity. The main additional quantities to determine the water cycle are precipitation (rain and snow), water storage on the land as snow/ice and in the deep aquifer, as well as water runoff from the land to the ocean.

The state of the atmosphere has been observed and analyzed for many of the past decades by the operational weather and national climatolgical services, but these data were not compiled specifically for climate studies until the concept of reanalysis was developed. The World Climate Research Program (WCRP) was established, in part, to coordinate activities to develop a number of data sets that were missing for describing the energy-water cycle (Global Atmospheric Research Program, 1975). The first three activities organized were projects to compile observations of the properties of clouds (the International Satellite Cloud Climatology Project, ISCCP), the thermodynamic state of the world ocean (the World Ocean Circulation Experiment, WOCE) and precipitation (the Global Precipitation Climatology Project, GPCP). The cloud data set, when combined with the atmospheric state data sets, has now been used by the Surface Radiation Budget (SRB) Project to reconstruct the complete radiation budget at the surface and top of atmosphere, supported by a series of satellite Earth Radiation Budget (ERB) satellite missions [Nimbus-7, ERB Experiment (ERBE), Scanner for Radiation Budget (ScaRab), Clouds and the Earth's Radiant Energy System (CERES), Geostationary ERB Experiment (ERBE)] and establishment of a Baseline Surface Radiation Network (BSRN).

NASA also began measuring the properties of the stratosphere, particularly to monitor volcanic aerosol, ozone and water vapor variations. Now these various compilations are being brought together with efforts to estimate the remaining surface fluxes of heat and water under the auspices of the GEWEX Radiation Panel (GRP) to foster analyses of the global energy-water cycle. The table on the right summarizes some of the data products available and their characteristics.

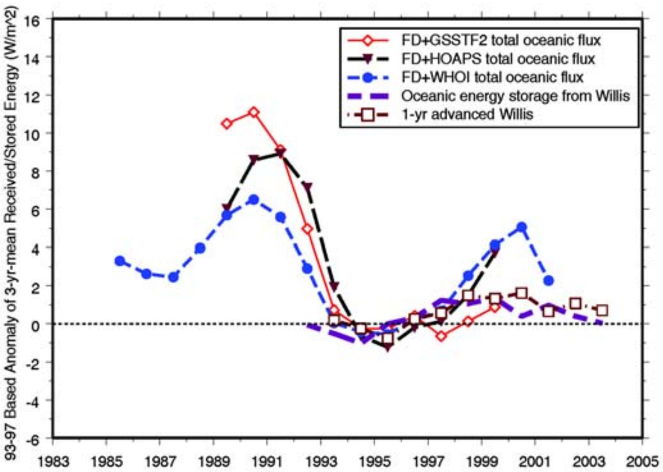
As an illustration of the type of analyses that can be performed with such a compilation of data sets, we show the first direct observation-based determination of the generation of zonal mean and eddy available potential energy (G_Z and G_E, respectively) as defined for one form of the atmospheric energy cycle suggested by Lorenz (1967). These quantities are determined from the atmospheric heating/cooling by radiation (ISCCP-FD, Zhang *et al*., 2004), precipitation (GPCP, Adler *et al.*, 2003) and surface sensible heat fluxes oceans and land (GSSTF2, Chou *et al.*, 2003, GLDAS, Rodell *et al.*, 2004). The period covered is 1997-2000 because that is the only common period for which daily results are available from all sources. A land surface model was used for the surface sensible heat fluxes over land because no data set is available for this quantity as yet. The figures at the bottom of page 1 summarize the results and show very interesting features. First, as suggested by Lorenz, but contradicted by the results of Peixoto and Oort (1992), G_E is generally negative, (i.e., the atmospheric eddies are a net sink of energy). Second, the largest values of G_Z appear in the tropics and polar regions: the "baroclinic wave" zone exhibits almost no net energy change in the zonal mean. Third, the largest absolute values of G_E are associated with the tropical monsoons in the summer hemisphere and midlatitude storms in the winter hemisphere. With these results we can now study the individual contributions to these energy generation terms.

As another illustration, the decadal variations of the surface energy fluxes over the ocean (GSSTF2, Chou *et al.*, 2003, ISCCP-FD, Zhang *et al.*, 2004) are compared in the figure on page 6 with an independent estimate of variations of the heat content of the upper ocean (Willis *et al.*, 2004). Given the uncertainties associated with these data products, the results show a (lagged) correlation of more than 0.5. Again, with these results in hand we can diagnose the separate contributions to the heat budget of the ocean influenced by different atmospheric processes.

To stimulate more extensive analyses of the variations of the global energy-water cycle and the processes

Energy and Water Cycle Element/ Data Set Names	Period Covered	Sampling Spatial (km)	Time (hrs)
Atmospheric State			
*TOVS (no winds)	1979-Present	280	24
*NCEP/NCAR	1948-Present	280	6
ERA-40	1963-2003	280	6
Clouds			
*ISCCP	1983-2005	280	3
SOBS	1971-1996	280-560	3-24
Ozone			
TOMS	1978-2003	110	24
*SBUV	1978-2005	280	24
SAGE II	1979-2005	560	Monthly
Trace Gases			
CO_2, CH_4, etc.	1958-Present	Global	Monthly
Aerosols			
*GACP (ocean only)	1981-2004	280	Monthly
*NOAA aerosol (ocean only)	1995-2005	110	24
SAGE II (strat.)	1984-2005	560	Monthly
Radiation			
NIMBUS-7 (TOA)	1978-1985	280	12
ERBE (TOA)	1984-2002	280	24
CERES (TOA)	2000-Present	110	3
*SRB (TOA-SRF)	1983-2004	110	3
*FD (TOA-SRF)	1983-2005	280	3
Precipitation			
*GPCP	2002-Present	280	3
*GPCP	1997-Present	280	24
*GPCP	1979-Present	280	Pentad
Surface Fluxes			
GSSTF2 (oceans)	1989-2000	110	24
HOAPS (oceans)	1987-2000	110	24
Oceanic State			
*Reynolds (SST)	1982-2005	110	Weekly
*World Ocean Atlas (Levitus)	1948-1998	110-560	Monthly
*WOCE	1990-1997	----	----
Ocean Surface Winds			
Wentz	1987-2005	110	24
Ocean Currents			
T/P-Jason	1992-2005	50-110	5-Day
GRACE	2002-2005	----	----
Key Supporting Data Sets			
Baseline Surface Radiation Network	1994-2005	35 sites	5 Min
Global Precipitation Climatology Centre	1951-2004	50	Monthly
Global Runoff Data Centre	1970-2005	4500 Sites	Daily

Some available global, long-term data sets that can be used to quantify variations of the global energy-water cycle. References and relevant web site addresses for these data sets can be found on the GEWEX Radiation Panel web site at http://grp.giss.nasa.gov/gewexdsets.html. Asterisks indicate data sets to be provided on the National Climatic Data Center (NCDC) active server.



Comparison of the decadal-scale anomaly in net surface fluxes and the variations of annual upper-ocean heat content.

that influence them, the GRP proposes organizing a complete set, at least one data set for each of the components of the energy-water cycle, in two forms. The first is a summary of the data sets in the form of monthly mean global maps, all in the same grid covering the same time period, posted on and downloadable from the GRP web site (*http://grp.giss.nasa.gov/gewexdsets.html*). The second is to begin providing access to the original versions of these data sets (with a variety of map grids, sampling intervals and periods covered), starting with the four GRP products for radiation, precipitation, clouds and aerosols, on an active server to be hosted by NCDC. The online summary is now available and the data sets are being assembled for the server and should be available by the summer of 2006.

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