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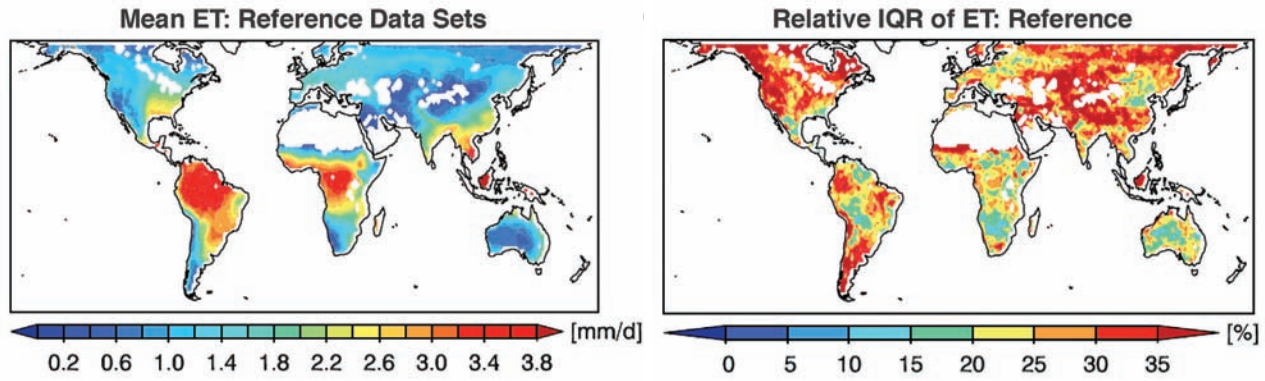
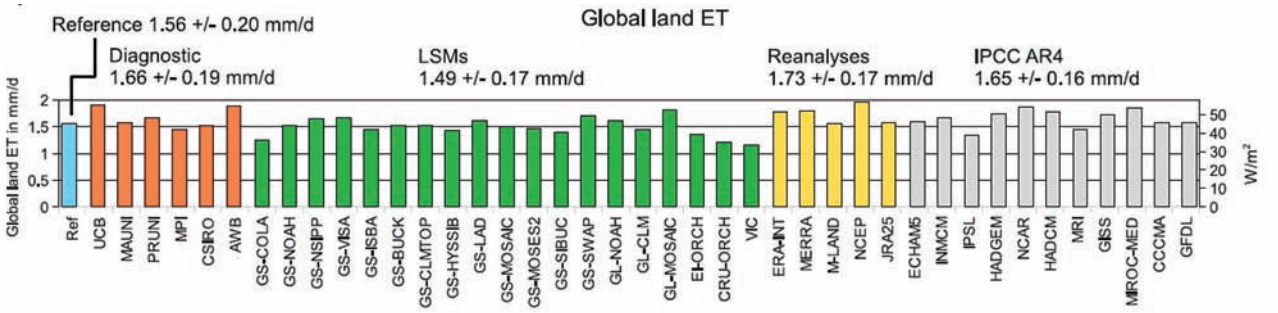
GEWEX LandFlux Project Plans Global Latent and Sensible Heat Flux Data Sets



The left panel shows the mean of 30 reference evapotranspiration (ET) data sets in mm/d. The data sets include remote-sensing-based estimates, reanalysis data, and output of land-surface models driven with observation-based forcing. The right panel shows the relative Interquartile Range (IQR) of the data sets in percentage. [From Mueller et al., 2011.] The data sets, as well as the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) simulations, are found to closely agree on the global-scale land ET (see figure below), but large regional differences are apparent. The LandFlux Project is currently preparing a synthesis benchmark data set based on existing global ET products (LandFlux-EVAL), as well as a targeted global GEWEX-based ET product. See article by S. Seneviratne et al. on page 18.



Mean annual global ET estimates in mm/d and W/m² from 30 reference data sets and IPCC AR4 simulations. [From Mueller et al., 2011.]

See These Articles Related to Evapotranspiration

- **Developing a Predictive Capability for Terrestrial Evapotranspiration: Ways Forward?** (page 10)
- **Evapotranspiration as a Regional Climate Priority: Results from a NASA/USDA Workshop** (page 15)
- **LandFlux-EVAL Workshop** (page 18)

Save the Date!

- **4th WCRP International Conference on Reanalyses, 7–11 May 2012, Silver Spring, Maryland, USA** (page 13)

Commentary

A Need for GEWEX Contributions to Regional Climate Issues

Peter J. van Oevelen
Director, International GEWEX Project Office

Early this May after a meeting in Oxnard, California, I was driving down Interstate 5 from Sacramento to Los Angeles when I noticed signs regularly posted along the road stating, "Stop the Congress-Created Dust Bowl." It immediately piqued my curiosity as to what was going on in this checkerboard of golden-brown hills flanked by mostly green valleys. The further south I got, the more and more land seemed to be left barren and dry. I thought immediately that it must have something to do with water not being transferred to these areas. The fact that quite a few properties (thousands of acres) were for sale indicated that it was not an easy thing to try to make a living from this land. Some research on the Internet* confirmed that much of the water from tributaries in Northern California is no longer diverted to the Central Valley in the south, and instead flows into the sea or is stored in reservoirs.

Stumped avocado trees in Valley Center, California. Stumping mimimizes the water use and the trees can be brought back into production after the drought ends. Source: California Department of Water Resources.

The primary reasons for this are global warming, drought mitigation, and the government's decision to protect endangered species (such as the Delta smelt). To many whose livelihoods are at stake, these reasons seem invalid: they feel that much of the water is currently just going into ocean without being used, while the reservoirs are full. The problem, of course, runs much deeper. California cannot just store enough water in the good years to make up for the bad years. On top of that, protecting the environment, including endangered species and their habitats, depends largely on the availability of fresh water. For an engineer it must seem possible to devise solutions to some of the problems, perhaps preventing the smelt from being caught in the pumps transporting the water, or increasing the water availability through desalinization and water conservation. Each of these solutions is within our capacity, but political and economical considerations often stand in the way. As a scientist, one can ask what the causes are for these problems and what the future outlook would be if they go unsolved. This in turn could help in providing sustainable long-term solutions, which will not be a single solution to all but a suite of measures addressing the various parts of the problem regarding fresh water use and availability.

The story above reminded me of a meeting held a few weeks ago in Silver Spring, Maryland, to explore the possibility of establishing a new North American hydroclimatology project. One of the possible themes under consideration for this project is the problems associated with water in the western part of the U.S., as well as Canada and Mexico. GEWEX, with its history of looking at the physical part of the energy and water cycle at regional and global scales, can play a fundamental role in establishing a concerted effort to tackle water problems in regions such as this.

Another example of this topic is the two recently held evapotranspiration (ET) related workshops described on pages 15 and 18. Better monitoring of ET at regional scales can help improve water resource management and support more efficient agricultural practices. ET is an important part of the energy and water cycle at the global scale, and very relevant for climate research and monitoring. Hence, what GEWEX can bring to the table is knowledge, experience, and expertise at the regional scale from various regions of the world with similar problems, as well as the ability to provide a global perspective. Naturally, this has to be done collaboratively with experts from other science and engineering disciplines, as the problems extend well beyond the physical part of the Earth system. In particular, disciplines dealing with social, economic, and legislative aspects will be crucial in providing sustainable solutions.

Of course, this is just one possibility, and the scientific community along with science funders have to decide what it wants to address and how to go about it. It is clear, however, that there are many scientific challenges where GEWEX could play a role in addressing societal needs. The new Imperatives established by the GEWEX community provide a clear path forward. GEWEX can and should be better at sharing its many successes with communities outside its own, an area where the International GEWEX Project Office should take the lead. We should also strengthen collaboration with other parts of the World Climate Research Programme, as well as groups beyond it. In my opinion, the best and most effective way to do this is at the working level. Some changes both organizational and scientific would be needed, and GEWEX is, with your support, already addressing these. We should keep in mind that the structure should fit the purpose and the means. This is probably best described by a quote that a dear colleague provided me not too long ago from Gaius Petronius (ca. 27–66 AD), the Roman Consul:

> *We studied hard, but it seemed that every time we were beginning to form up into teams, we would be reorganized. I was to learn later in life that we tend to meet any new situation by reorganizing: and a wonderful method it can be for creating the illusion of progress, while producing confusion, inefficiency, and demoralization.*

I am confident that we do not have to make that mistake!

*McChesney, John, 2009. Drought, Politics Trouble Farmers In California. National Public Radio, *http://www.npr.org/templates/story/story.php?storyId=103950335.*

GEWEX and ESA Have Developed a Process and an Integrative Platform for Ground-Based Soil Moisture Measurements to Support ISMN

An article profiling the International Soil Moisture Network (ISMN) appeared in the American Geophysical Union's weekly newspaper *Eos*, published on 26 April 2011. The piece covers the importance of soil moisture as an "essential climate variable" and explains the role of ISMN as a repository for standardized soil moisture data across the globe. GEWEX is highlighted as the catalyst for ISMN, developing the network with the support of the Group on Earth Observations (GEO) and the Committee on Earth Observation Satellites (CEOS).

Over 500 Years of BSRN Radiation Data Available

On May 3rd the central archive of the Baseline Surface Radiation Network (BSRN), which is housed at the World Radiation Monitoring Center, received exactly 6000 monthly station-to-archive files. In other words, 500 years of radiation data are now available at: *http://www.pangaea.de/PHP/BSRN_Status.php?q=LR0100*.

Contents

Moustafa Chahine, First GEWEX SSG Chair: An Extraordinary Gentleman and Scientist

Paul Try
International GEWEX Project Office, Silver Spring, Maryland, USA

We recently lost a great leader and scientist who had a significant impact on the GEWEX Project throughout its entire lifetime. Dr. Moustafa (Mous) Chahine, the first Chair of the GEWEX Scientific Steering Group (SSG) and former Chief Scientist at the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory, passed unexpectedly in late March of this year. I am sure he would also appreciate being remembered as the always-enthusiastic leader and driving force behind the Atmospheric Infrared Sounder (AIRS) Instrument and Science Team. The quote "always make progress" was his lead-in remark for every AIRS Science Team meeting. While it is difficult to summarize and give credit to one who has had such a long and distinguished career, this article provides key remembrances of his impact on GEWEX, climate science, and the entire Earth science community.

I first met Mous in 1990 when he was chosen as the initial Chair of the SSG and I was asked by NASA to help establish and lead the International GEWEX Project Office. We worked hard to pull together a few existing projects, establish some needed subprojects, and initiate a new large regional field campaign. Since the GEWEX objectives encompassed a very broad aspect of Earth science, Mous was instrumental in providing the necessary focus and organization of the many components that GEWEX managed. Always thinking ahead, Mous pushed us to obtain improved results in everything we were working on. Mous stayed continuously involved and provided direction to essentially all activities of GEWEX during the year between SSG meetings where the general guidance was formulated. His enthusiasm for the science advances he could see coming out of GEWEX was infectious, and he never seemed too busy to delve deeper into the science behind each of the efforts of its many components. Always a gentleman, and with a significant concern for the people behind the extensive efforts within the projects, Mous found ways to instill an urgency in our efforts to keep things on track and energized.

Mous always stayed abreast of GEWEX and its progress, as was shown in his comments for *GEWEX News* just last November, where he was encouraging a greater focus on process studies in the boundary layer and stronger emphasis on improvement in precipitation prediction. His own words —"my research work determines where I am going to be and what I am going to be doing during most of my daily life"—may be an understatement for his continued focus on and contributions to the Earth sciences. We will greatly miss this "Extraordinary Gentleman and Scientist."

New GPCC Full Data Reanalysis Version 5 Provides High-Quality Gridded Monthly Precipitation Data

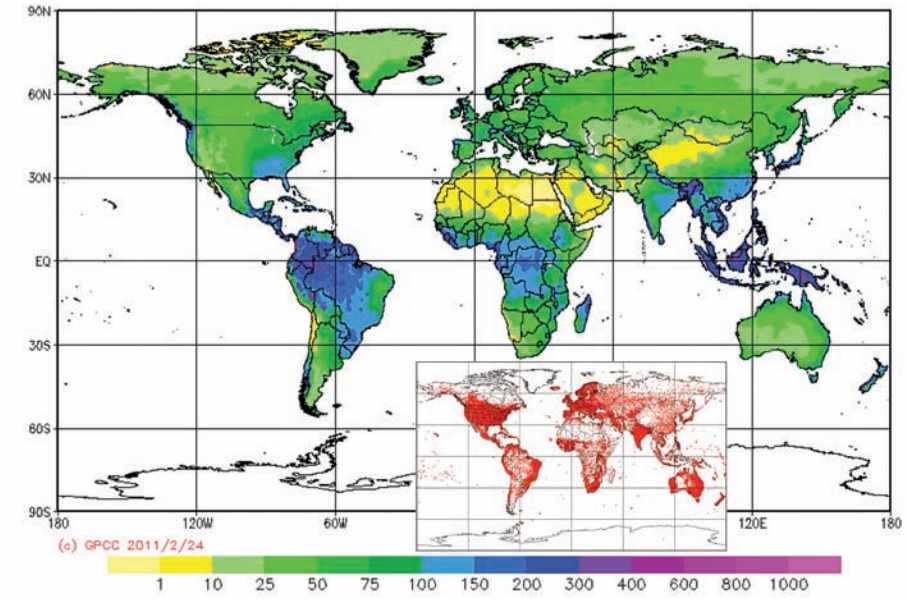
Bruno Rudolf, Andreas Becker, Udo Schneider, Anja Meyer-Christoffer, and Markus Ziese

Global Precipitation Climatology Centre, Offenbach, Germany

Since 1989, the Global Precipitation Climatology Centre (GPCC) has performed analyses of global land-surface precipitation distribution as the German contribution to the World Climate Research Programme (WCRP) and the Global Climate Observing System (GCOS). Many of the uses of GPCC data have been documented and published (e.g., Rubel and Kottek, 2010, and Gruber and Levizzani, 2008).

GPCC uses data obtained from worldwide observation networks operated by national meteorological services to develop products that address the broad spectrum of requirements from manifold users. Two GPCC products, First Guess and Monitoring, are delivered on a comparatively fast basis and are based upon measurements reported in near-real time. The Full Data Reanalysis Product is derived from a comprehensive data set covering a longer temporal range.

The ensemble of available observation data has grown substantially compared to the previous reanalysis, which was released in 2008. Following an intense test phase and four iterations of gridding and outlier evaluation, new gridded data sets, GPCC Climatology 2010 (mean monthly precipitation), and GPCC Full Data Reanalysis Version 5 (time series 1901–2009) were released in December 2010.



Plot of the annual precipitation in mm/month derived from the 12 monthly gridded GPCC climatologies. Underlying station locations are shown in the inset map.

Features of the New Release

The Full Data Reanalysis Version 5 provides monthly charts of gridded averages using data that have a minimum observation period of 10 years. These data are time dependent and vary for each grid cell, which provides the best possible area precipitation and serves as an optimum basis for regional climate mapping and hydrological budget studies.

The GPCC data set is composed of observed monthly totals from more than 80,000 stations worldwide, but only 65,000 stations satisfy the above mentioned 10-year limit so that their data series are long enough to derive temporal averages and climate parameters, respectively, to produce charts of gridded averages. For the monthly analysis of the gridded precipitation anomalies, maps of the GPCC Climatology 2010 (see figure below) provide the background values for precipitation anomalies. With access to a GPCC product for any single month, the user is automatically provided with grid cell specific information in addition to the precipitation values (such as the number of stations) and additional parameters suitable for accessing the reliability of gridded precipitation data.

For the aforementioned reasons the Full Data Reanalysis does not comply with the requirements on temporal data homogeneity as applicable for trend analysis studies and this product is not expected to serve climate change studies. To serve for this important use, a new homogenized product is in preparation and will cover a period of more than 50 years from 1951–2005. To generate this data set, the full data ensemble is reviewed to identify those stations with long data series. These series are subsequently subjected to a rigorous test for homogeneity. Based on the data series passing the homogeneity test, parameters of the global distribution of the temporal change of precipitation are calculated. Methodology and results will be published and become a part of the Fifth Intergovernmental Panel on Climate Change Assessment Report.

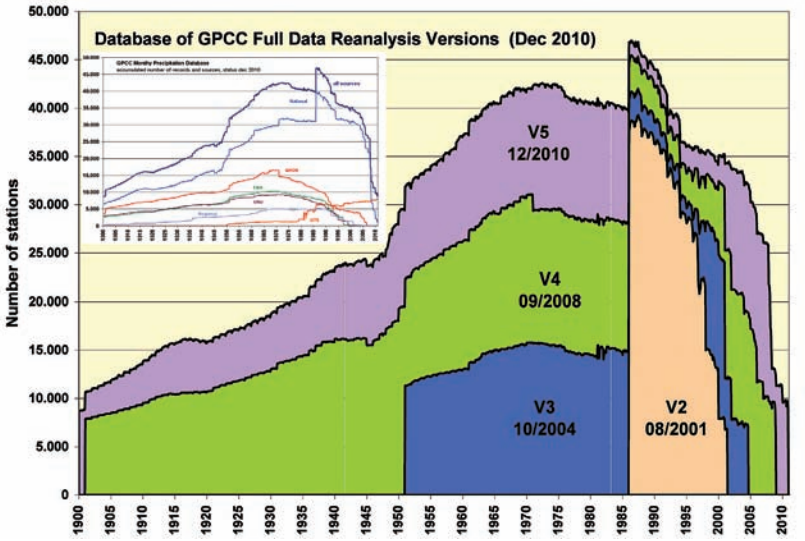
Data Sources

Data from the national weather centers in 190 countries are the primary data source for the data sets. In addition, GPCC receives daily surface synoptic (SYNOP) observations and monthly climate (CLIMAT) messages from the World Meteorological Organization's Global Telecommunications System (GTS). To be comprehensive in its approach, GPCC also integrates other global precipitation data collections from the Food and Agriculture Organization, the Climate Research Unit of the University of East Anglia, and the Global Historical Climatology Network, as well as several regional data sets. These efforts result in GPCC owning the largest and most comprehensive worldwide collection of precipitation data.

Data Processing

The collected data are imported into a relational data base, where they are kept in separate source specific slots. This methodology allows for cross-comparison of the data. As none of the sources are error free, each source provides reference information on a case-by-case basis.

As was done for the Full Data Reanalysis Version 4, the new GPCC data gridding method applies the spatial interpolation of the gridded anomalies that are subsequently added to the gridded global background. Prior to Version 4, this methodology was not feasible, as there were too few stations with sufficiently long data series to form a reliable gridded global background. However, since GPCC owns a sufficient number of stations providing climatic mean monthly precipitation totals, it is possible to interpolate them prior to the interpolation of the monthly data sets, providing the global background field. As before, a modified version of the Spheremap method for the interpolation was applied (Willmott et al., 1985).



Development of the database in terms of number of precipitation gauge stations integrated until 2001 (Version 2), 2004 (V3), 2008 (V4), and 2010 (V5). The inset shows the V5 data availability and the contributions from different data sources.

Scheduled GPCC Products

There are two scheduled GPCC products, the First Guess and the Monitoring Product. The First Guess product comprises an analysis of the monthly total precipitation at 1-degree horizontal resolution. The data for this product are solely recruited from SYNOP messages that are available in near real time, so they are available in due course for a comparatively fast (normally 3 to 5 days after the end of the observation period) generation of the analysis. For this product, only an automated quality control procedure is applied. If a temporal coverage of 70 percent of the month regarded is reached, the precipitation total is calculated and extrapolated to the total length of the month. Approximately 6,500 stations worldwide are available as data sources. For these stations all information available from the SYNOP messages (temperature, humidity, wind, snow and liquid water compartment of precipitation, level of systematic measurement error) are calculated according to a permanent schedule. All these parameters are also aggregated monthly and gridded.

Compared to the First Guess Product the data basis of the Monitoring Product is extended by the CLIMAT messages and other available data that are reported at regular intervals through the GTS, so that 7,000–8,000 stations are available for the analysis. The most recent monitoring products were based on more than 8100 stations. Moreover, there is a manual quality control performed by GPCC staff on top of the automated quality control. With the supplementary data to the First Guess product and the better quality of the resulting data set, the Monitoring Product becomes available approximately two months after the end of the observation period.

Pointer to the Gridded GPCC Data Products

GPCC gridded data products are available for download free of charge from the GPCC web portal at: *http://gpcc.dwd.de*. The data are available in different spatial resolutions that are described on the site. It is also possible to generate maps of the data by means of Visualizer Software.

Outlook

GPCC is continually updating its database and extending its coverage. The figure above shows the true success story of the GPCC database, namely its development in terms of the increasing number of precipitation gauge stations integrated up until 2011. Another product, the Homogenized Precipitation Analysis (HOMPRA), is scheduled to be released later in 2011.

Acknowledgements

GPCC is grateful for the contribution of Dr. Hermann Österle, Potsdam Institute for Climate Impact, who served as the de facto beta tester of Versions 4 and 5 of the Full Data, while checking them for the existence of inhomogeneities. His work has substantially supported the quality control and improvement of the GPCC products.

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North American Land Data Assimilation System Phase 2 (NLDAS-2): Development and Applications

Michael B. Ek[1], Youlong Xia[1,2], Eric Wood[3], Justin Sheffield[3], Lifeng Luo[4], Dennis Lettenmaier[5], Ben Livneh[5], David Mocko[6], Brian Cosgrove[7], Jesse Meng[1,2], Helin Wei[1,2], Victor Koren[7], John Schaake[8], Kingtse Mo[9], Yun Fan[10], Qingyun Duan[11], and Kenneth Mitchell[1*]

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The North American Land Data Assimilation System (NLDAS) is a multi-model land modeling and assimilation system that is run in an uncoupled mode on a common one-eighth degree grid covering the Continental United States (CONUS) along with northern Mexico and southern Canada, and driven by atmospheric forcing. NLDAS provides retrospective and real-time high-resolution water and energy cycle products, such as surface fluxes, soil moisture, snow cover, and runoff/streamflow, along with the near-surface atmospheric and precipitation data sets used as forcings for the NLDAS land models. These products support drought monitoring, seasonal hydrological prediction, weather and climate forecasting, model evaluation, and land-hydrology research within GEWEX and other communities. NLDAS has become a mature system and will be implemented into real-time National Centers for Environmental Prediction (NCEP) operations in the near future.

The retrospective component of Phase 2 of NLDAS (NLDAS-2) was completed in 2008 (*http://www.emc.ncep.noaa.gov/mmb/nldas*) and since then has continued in near real time. NLDAS-2 was developed at the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction/Environmental Modeling Center (NCEP/EMC) in collaboration with its NOAA Climate Program Office (CPO) Climate Prediction Program of the Americas (CPPA) partners. These partners include the National Aeronautics and Space Administration/Goddard Space Flight Center (NASA/GSFC), Princeton University, the University of Washington (UW), the NOAA National Weather Service/Office of Hydrologic Development (NWS/OHD), and the NCEP Climate Prediction Center (CPC). It can be considered as the follow-on to Phase 1 of NLDAS (Mitchell et al., 2004), which was supported through the NOAA Office of Global Programs (now CPO) GEWEX Americas Prediction Project (GAPP) and the NASA Terrestrial Hydrology Program.

The design of NLDAS-2 is based largely on that of NLDAS-1, and readers are referred to Mitchell et al. (2004) for details on land model and simulation configuration and design. The four NLDAS-2 land models are the Noah (Ek et al., 2003), Mosaic (Koster and Saurez, 1996), Sacramento Soil Moisture Accounting (SAC; Burnash, 1995), and Variable Infiltration Capacity (VIC, Liang et al., 1994) from, respectively, NOAA NCEP/EMC, NASA/GSFC, NOAA/OHD, and Princeton/UW. While the models require different combinations of forcing variables, they all draw from the same overall forcing data set produced as part of the NLDAS-2 Project.

The most important forcing input to the models is precipitation, where the underlying precipitation data set is a gauge-based daily one-eighth degree precipitation analysis from NCEP/CPC that is generated with a Parameter-elevation Regressions on Independent Slopes (PRISM)-correction method and a least-squares distance weighting analysis scheme. Since the PRISM-correction method considers the effects of topography on precipitation, this forcing data set partly reduces the underestimation of gauge precipitation noted in NLDAS-1, although wind-induced gauge undercatch remains an issue. The precipitation is temporally disaggregated to hourly, primarily using Stage II radar data and a combination of other observations, satellite retrievals, or model data when and where radar data are unavailable. Low-level winds, temperature, humidity, and radiation are taken from the North American Regional Reanalysis (NARR), where the downward shortwave radiation has a positive bias, so this field is bias-corrected in NLDAS-2 using 5 years (1996–2000) of Geostationary Operational Environmental Satellite (GOES) observations utilizing a ratio-based method developed by Cosgrove (see *http://ldas.gsfc.nasa.gov/nldas/NLDAS2forcing.php*).

Building on the results of NLDAS-1, many improvements in model physical processes and parameters were made for NLDAS-2. The physical processes of the Noah model have been upgraded and model parameters calibrated to improve the simulation of latent heat flux, total runoff, and skin temperature for the warm season. The snow model has been enhanced by adding melting/refreezing physics and a snow-age albedo algorithm, and by increasing the maximum snow albedo to improve snow water equivalent, sublimation, snowmelt, and snow cover simulation for the cold season. An efficient calibration method was used to calibrate Variable Infiltration Capacity (VIC) model parameters based on observed streamflow data from 1,130 small basins over the CONUS. This led to a reduction in mean annual positive bias for total runoff, in particular over the Southeast United States. While no SAC parameter values or model physics were changed for NLDAS-2, the source of potential evaporation forcing was altered from a Noah-based data set to a climatology-based data set. NLDAS-2 results show this change yielded a reduction in the model's large negative mean annual total runoff bias seen in NLDAS-1.

NLDAS-2 also differs from NLDAS-1 in terms of the two-step method used to minimize the impact of model spin-up.

To generate the initial conditions for each NLDAS-2 model, the last 8 years of output from the 11–year NLDAS-1 real-time simulation (October 1996 to December 2007) was first averaged together, and a mean state valid at 00Z on 1 October was generated. This first spin-up step disregarded the initial 3 years of output that were subject to spin-up effects in the NLDAS-1 simulation. The mean 00Z October 1 state from NLDAS-1 was then used to initialize a 15.25-year spin-up simulation for each model from October 1979 to January 1995 using NLDAS-2 forcing data. The 1 January land states for the last 10 years of this spin-up simulation were then averaged to provide initial states for NLDAS-2.

The NLDAS-2 products from the retrospective period (1979–2008) and the near-real-time analyses (2008–present) include soil moisture, soil temperature, energy fluxes, other land state variables, and forcing terms. They are available from *ftp://ldas3.ncep.noaa.gov/pub/raid0/nldas/* for the retrospective runs, and *ftp://nomad6.ncep.noaa.gov/pub/raid2/wd20yx/nldas/* for the real-time runs. The script used to download NLDAS-2 data sets is posted at *http://www.emc.ncep.noaa.gov/mmb/nldas/Download_Public_users.txt*. Additionally, the NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) also distributes retrospective and real-time forcing and Mosaic model output via ftp at: *http://disc.sci.gsfc.nasa.gov/hydrology/data-holdings* and a GrADS Data Server (GDS).

The evaluation of NLDAS-2 output shows that the energy flux terms from the equally weighted model ensemble mean compare favorably with the Ameriflux field measurements. Additionally, the ensemble mean soil moisture compares well with the soil moisture measurements of the Oklahoma Mesonet and the Illinois Water Survey. Operationally, the NLDAS-2 products have been used to derive drought indices over CONUS for drought monitoring, where the soil states and energy fluxes are used to assess the current hydroclimatic conditions.

In addition to support for the National Integrated Drought Information System (NIDIS, *http://www.drought.gov*), NLDAS-2 provides information to the authors of the NCEP/CPC operational Drought Monitor, Drought Outlook, and CPC monthly drought briefing. Displays of current drought conditions can be found on the NCEP/EMC NLDAS drought web page at: *http://www.emc.ncep.noaa.gov/mmb/nldas/drought*. The CPC drought briefing is available at: *http://www.cpc.noaa.gov/products/Drought/* and the seasonal drought outlook at: *http://www.cpc.ncep.noaa.gov/products/expert_assessment/seasonal_drought.html*.

The figure on page 20 shows an example of the total column soil moisture percentiles from each model and the ensemble mean. These and other NLDAS products have been used in numerous applications by researchers within the CPPA, as well as in GEWEX and other land-hydrology communities. Focusing on the modeling community, the NLDAS-2 system can provide land-surface initial conditions for regional climate forecasts and hydrologic predictions, and can be used for model verification. Also, while there are no long-term mesoscale soil moisture measurements available, NLDAS-2 products can provide useful estimates.

We recognize that the data assimilation system within NLDAS-2 is not complete because remotely sensed estimates of land-surface states such as soil moisture and snowpack are not yet assimilated as part of the system. This shortcoming is being actively addressed by NLDAS-2 participants in ongoing research. Meanwhile, NLDAS-2 models are being continuously upgraded, with significant progress being made on the next generation Noah model (Noah-MP) that features a multi-layer snowpack, ground water, dynamic vegetation, and representation of complex frozen soil processes. Future modeling efforts will seek to more fully unify atmospheric, land surface, and hydrologic processes. Also, NASA/GSFC HSB is collaborating with the NLDAS team at NCEP/EMC to integrate the NASA Land Information System (LIS) software into the current NLDAS (i.e., to make use of the LIS parallel processing capability) to add new and updated land-surface models to NLDAS, and to assimilate remotely sensed data such as snowpack and soil moisture. These efforts will form the basis of the next phase of NLDAS.

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GEWEX NEWS

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Increasing Desertification of Northwestern India Can Adversely Impact the South Asian Summer Monsoon

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Desertification is formally defined as land degradation in arid, semiarid, and dry sub-humid areas resulting from various factors, such as climatic variations and human activities (UNCCD, 2001). It is a complex process, contributed to by interactions among physical, biological, social, cultural, and economic factors. The human footprint is certainly influential, since deforestation, over-cultivation, soil salinization, overgrazing, and over-exploitation of natural resources contribute to land degradation. Desertification has long been recognized as a major environmental problem affecting the living conditions of people in many countries of the world. In India, nearly one-third of the area is undergoing land degradation, and about 25 percent is subjected to desertification.

The Thar (or Great Indian) Desert is located between northwestern India and Pakistan. It receives an average annual precipitation between 150 and 450 mm (west to east), mostly during the summer, and is the most densely populated desert region in the world, generating tremendous stresses on natural resources. This region underwent substantial agricultural expansion in the past decades, largely relying on the withdrawal of groundwater. Despite the weak positive trend in monsoon precipitation over the region, extensive agriculture has resulted in rapid depletion (0.33 m/yr) of groundwater over Northwestern India in recent years (Rodell et al., 2009). This could lead to several consequences, from a shortage of potable water, to a decline in agricultural productivity, to land degradation. Vast areas of Northwestern India are affected by rapid soil degradation and vegetation loss (e.g., Ravi and Huxman, 2009), and soil moisture has been drastically reduced (Singh et al., 2005). The region is under the threat of future desertification (e.g., Goswami and Ramesh, 2008). To the west of the Thar Desert, the relatively green Indus Valley has also been severely degraded and is suffering from water scarcity (WRI, 2003). Overall, the system appears unstable and potentially subject to a collapse in the near future (Tiwana et al., 2007; Tiwari et al., 2009).

Land-surface processes affect climate through the exchange of heat, moisture, and momentum between the Earth's surface and the atmosphere. The impact of vegetation change (due to anthropogenic activities or multidecadal variability) on climate has been widely investigated (Xue and Shukla, 1993; Dirmeyer and Shukla, 1996; Xue and Fennessy, 2002; Oyama and Nobre, 2004; Sen et al., 2004), especially for the Sahel. Vegetation degradation sustains three major regional positive feedbacks on the water cycle (i.e., leading to precipitation reduction which in turn increases desertification):

- Increased surface albedo leads to reduced absorption of solar radiation at the land-surface (which cools) and, other things being equal, to a net radiation loss at the top of the atmosphere. To maintain thermodynamic balance, compensating subsidence is generated (assuming thermal advection is negligible), inhibiting precipitation.

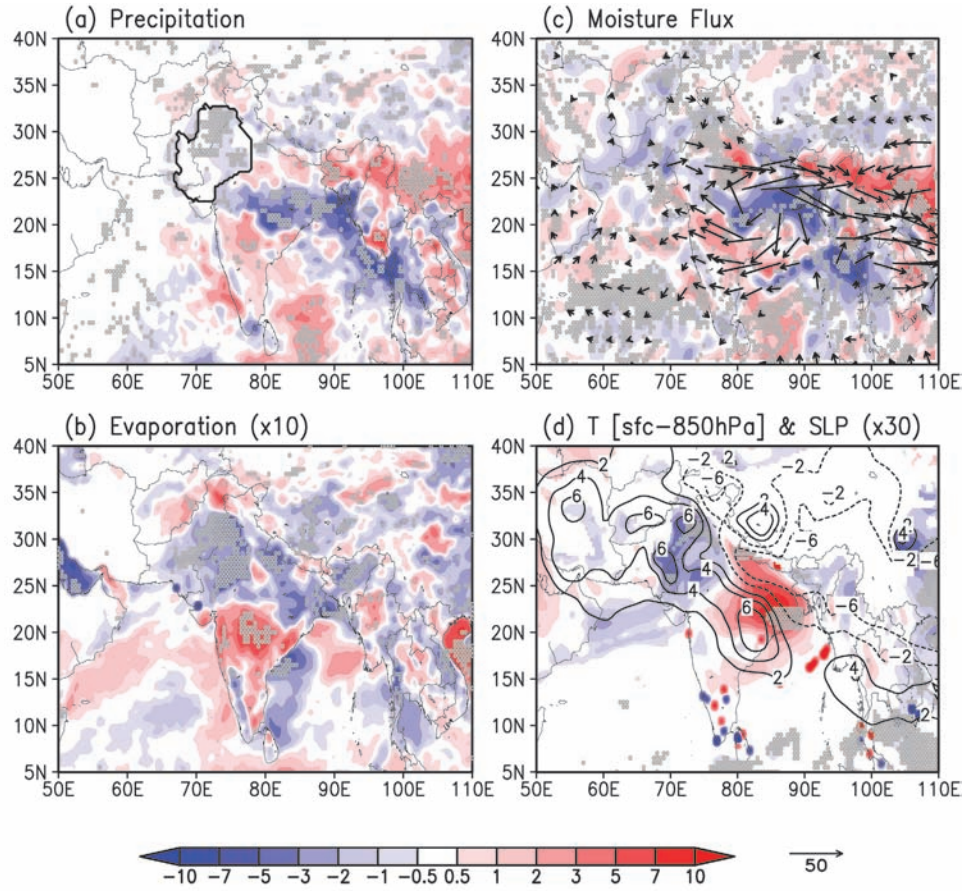
- Decreased surface roughness leads to reduced surface fluxes of heat and moisture, which can also weaken convection and precipitation. Reduced fluxes will, however, lead to surface warming.

- Decreased soil moisture by vegetation reduction affects evapotranspiration and therefore moisture availability in the atmosphere, which in general also negatively impacts precipitation.

The large-scale picture can be complicated as these regional processes interact not only with each other but potentially with larger-scale processes, especially over South Asia where ocean-atmosphere-land coupling plays an important role in summer monsoon evolution. A common aspect of almost all desertification studies is the use of low-resolution general circulation models. More importantly, only Dirmeyer and Shukla (1996) appear to have investigated the effects of desertification over the Indian subcontinent, albeit in an idealized scenario.

Our study (Bollasina and Nigam, 2011) seeks to investigate the impact of the realistic expansion of the Thar Desert on the South Asian summer monsoon hydroclimate, and to elucidate the main physical processes at play. The Weather Research and Forecasting (WRF-ARW) Version 3.1.1 regional climate model was used to conduct ensemble simulations [control (CTL) and sensitivity (DES) experiments] for seven months (February–August) at a 36-km horizontal resolution. Desert conditions were prescribed by changing the distribution of vegetation types and associated parameters (e.g., albedo, vegetation fraction, roughness length) over the most exploited area between Pakistan and northwestern India. The new values do not, however, represent a drastic change with respect to the control experiment since the area is already partially dry and relatively bare at the beginning of the simulation. Initial soil moisture is differently initialized in the two experiments but this difference is not consequential in view of the substantial dryness of the initial state (February/March).

Over the desert area, the atmospheric water cycle weakens (i.e., precipitation, evaporation, and moisture convergence decrease, as well as soil moisture and runoff), further reinforcing the driving mechanism (see the figure at the top of the next page). Air temperature cools due to the overall impact of albedo change and because of the reduction of surface fluxes. Subsidence is generated by thermodynamic balance and increasing sea-level pressure. An anomalous low-level northwesterly flow over the Indo-Gangetic Plain weakens the moisture advection from the Bay of Bengal, leading to a precipitation decrease over Eastern India and consequent cooling of the middle troposphere (but heating of the ground) with the for-

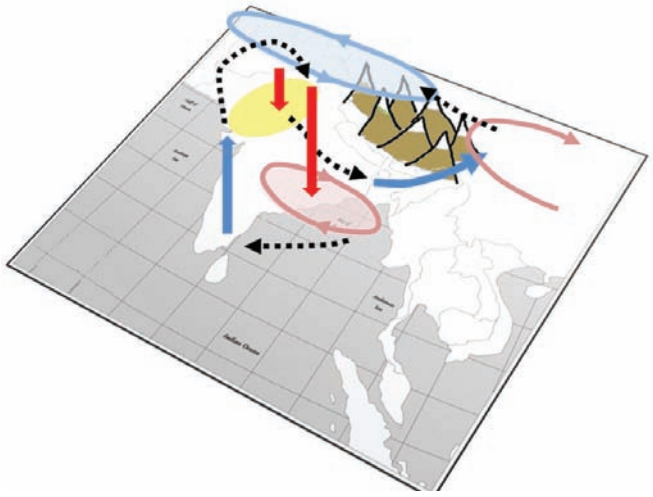


Average difference of the desertification scenario control run (DES-CTL) in June, July, and August for: (a) precipitation (P, mm/day); (b) evaporation (E, x 10 mm/day); (c) vertically integrated mass-weighted moisture flux (kg m/s) and its convergence (shaded, positive red, mm/day); and (d) surface-850 hPa vertically averaged temperature (shaded, °C) and sea level pressure (x30 hPa, contours). The light grey hatching is for statistically significant areas at the 80 percent (a) and 90 percent (b-d) confidence level. The black contour in (a) denotes the area of the expanded desert in DES.

mation of an anomalous anticyclone. The cooling over Northwestern India extends throughout the troposphere, and the upper-tropospheric Tibetan High weakens as a result of the anomalous subsidence over the desert area. On the east, the anomalous flow from the Indo-Gangetic Plain intensifies and deviates toward the Eastern Himalayas and Southern China, producing more precipitation by orographic uplift (see figure at right).

Decreasing evaporation over the desert should contribute to controlling the cooling due to the increase in albedo. Interestingly, this feedback appears to be marginal over this region.

In a holistic investigation of the changing monsoon, the changes brought about by the expansion of the Thar Desert can interact with other large-scale changes induced by other forcings (e.g., aerosol loading over South Asia, greenhouse gas warming), leading to amplification or dampening of the desert related effects. Our findings nonetheless suggest that increasing desertification of northwestern India and the related expansion of the Thar Desert can profoundly impact the summer monsoon hydroclimate and circulation over the Indian subcontinent, potentially redistributing precious water over South Asia.



A schematic picture of the average circulation anomalies (DES-CTL) in June, July, and August over the Indian Subcontinent induced by the expanded desert (represented by the yellow area). The Himalayas and Tibetan Plateau are also drawn. Colored circular areas represent high (red) and low (blue) pressure. Large-scale vertical motion is indicated by red (subsidence) and blue (ascent) thick arrows. Black dotted arrows represent approximately horizontal winds (i.e., mainly associated with horizontal transport).

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Developing a Predictive Capability for Terrestrial Evapotranspiration: Ways Forward?

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In April 2011, two workshops were held that focused on the development of improved observation and modeling capabilities for terrestrial evapotranspiration (ET). The workshop held in Silver Spring, Maryland (see page 15) focused more on regional ET issues related to water availability, while the Vienna, Austria workshop (see page 18) focused on ET issues as an integral component of the global water and energy budgets. Reading the reports, two challenges emerge for the community: (1) how can irrigated agriculture and water management be improved through better, real-time information on ET, and what data and ET modeling systems need to be developed? and (2) given the central role of ET in the climate system, are quality data sets available for the development of ET as an Essential Climate Variable (ECV) for the Global Climate Observing System (GCOS) that allows for "climate trend quality" ET estimates for climate studies? Neither challenge can be solved easily, but community collaboration and space agency cooperation can take us a long way towards meeting both.

Meeting the first challenge requires data at the sub100 m scale—farm-scale irrigation management to 1–2 km for irrigation district water management. Most ET algorithms for irrigation and water management over large areas are based either on land-surface temperature (LST) data from the highest resolution thermal satellite sensors available (e.g., Landsat) or on shortwave vegetation indices (VIs) that are used to specify crop coefficients applied to a reference or potential ET and adjusted by crop type. While some algorithms have gained acceptance within the user community, widespread application of these methods has not yet taken hold. VI methods typically require extensive local calibration and are unable to handle transient stress conditions, while the accuracy of water-use estimates from LST-based methods is hampered by lack of high spatial and temporal resolution radiation and LST data available in near real time, and by reasonable confidence in continuity. Both funding agencies and users (irrigation districts, water managers) need to commit to programs in a sustained manner for progress. Future technical advances in merging data sources from in situ to satellites at multiple scales offer potential improvements, but require support from sustained research and application programs.

Meeting the second challenge is equally complicated. ET algorithms depend on radiation, meteorological, and biospheric data. Current data sets continue to have issues that preclude them from achieving "climate quality," and ECVs (e.g., albedo) are fraught with temporal quality problems making derived ET uncertain. The LandFlux-EVAL Workshop report on page 18 shows a high level of coordination among the input data set providers and the ET product producers, as well as intercomparison studies of climate-scale ET data sets. Continued progress and success will depend on international program support for accelerating the development of the underlying ECVs on which any ECV ET product must depend.

Meeting/Workshop Reports

GEWEX/ESA Data User Element GlobVapour Workshop on Long-Term Water Vapor Data Sets

8–10 March 2011
ESA/ESRIN, Frascati, Italy

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The GEWEX Radiation Panel (GRP) has initiated a Water Vapor Assessment Project intended to both quantify the state of the art in water vapor products as well as to eventually select a product for use by GRP in its production of globally consistent water and energy cycle products. The activity started with a dedicated workshop on long-term water vapor data sets and their quality assessment that was strongly supported by the European Space Agency's (ESA) GlobVapour Project. The GlobVapour Project is developing multi-annual global water vapor data sets based on calibrated and inter-calibrated satellite radiances for long time series satellite observations.

The joint Workshop brought together the producers and users of water vapor and temperature data sets, as well as validation experts, with the goal of developing a strategy for an assessment procedure for water vapor and temperature data sets, and the identification of critical gaps in the existing and planned data sets for climate applications. Representatives from the following universities and research organizations attended the Workshop, which was hosted by the ESA European Space Research Institute (ESRIN): Collecte Localisation Satellites, Centre National de la Recherche Scientifique, Colorado State University, Danish Meteorological Institute, Free University of Berlin, University Corporation for Atmospheric Research, United Kingdom Met Office; the satellite retrieval communities [German Aerospace Center, Deutscher Wetterdienst, Max-Planck Institute]; the ground-based community [Jet Propulsion Laboratory, Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN), University of Cologne]; and space agencies [ESA, European Organization for the Exploitation of Meteorological Satellites, National Oceanic and Atmospheric Administration]. Presentations are available: at *http://due.esrin.esa.int/meetings/meetings247.php*.

Participants at the GEWEX/ESA Data User Element GlobVapour Workshop on Long-Term Water Vapor Data Sets and their Quality Assessment.

The Workshop consisted of one and a half days of presentations about the various activities in water vapor data set generation and validation, and these emphasized the need for a water vapor assessment to provide consistent and well-characterized data records for use across GEWEX. This was followed by one day of working group discussions on total column water vapor and water vapor profiles, and data records with deep layer humidity information (often called upper or free tropospheric humidity). Because many water vapor data sets are currently being constructed with essential climate variable/climate data record characteristics, Joerg Schulz, GRP vice-chair, provided a summary of relevant questions and issues related to the ongoing GRP assessments on clouds, aerosols, and precipitation.

At the core of the GRP assessment is the need of GEWEX to gain insight into water vapor products that are now being constructed for climate applications. Because each product has slightly different users and objectives, it was thought counterproductive to rank algorithms in terms of quality alone, as the usefulness of a product ultimately depends upon the application. The assessment instead should focus on overall characteristics of each product as determined from comparisons against various in situ observations, comparisons with other products, analyses of other properties (e.g., representation of the diurnal cycle), and dependence on a priori information. This approach is currently being used for the Infrared Atmospheric Sounding Interferometer instrument algorithm comparison, involving eight algorithm teams within the ESA GlobVapour Project (*http://www.globvapour.info*).

There was consensus at the Workshop that total column water vapor, as well as water vapor profiles and their related temperature profiles, should be assessed. As such, the assessment should not include stand-alone temperature profiles or deep-layer temperature data sets like those derived from the Microwave Sounding Unit (MSU) or the Advanced MSU. It also should not include sea-surface temperature or land-surface temperature unless these are integral parts of the vapor profile. Nor should the assessment include 2-m temperature or humidity unless these levels are part of an overall water vapor profile.

The discussion groups agreed that an important service provided by the water vapor assessment activity should be building and maintaining a total column water vapor and a water vapor profile validation database that includes data of sufficient quality and long-term stability to be of use to the assessment and future producers. GRUAN (*http://www.gruan.org*) could be an important part of this activity, but until such databases are fully available, products such as the frost point hygrometers, Analyzed RadioSoundings Archive radiosondes, microwave radiometers, surface and space-based global positioning systems, Raman Lidar, and Fourier Transform Infrared Spectrometers, as well as Baseline Surface Radiation Network (BSRN) and Clouds and the Earth's Radiant Energy System (CERES) observations, should be made available in a coherent fashion to aid in the water vapor validation effort.

The validation strategy should begin with Level 1 data sets used to produce water vapor products. While this is not generally viewed as part of the assessment itself, the Level 1 stability and usefulness for climate data records should be documented via

the data providers and verified as best as possible. Level 2 data should be compared to the validation data described above. These comparisons should allow for the characterization of product uncertainties as well as a product's strengths and weaknesses. Suitability for climate trends and product differences are difficult to assess from Level 2 comparisons alone. An important additional validation step at this level is the use of radiative fluxes, which can be computed both in the up- and downwelling directions, and in turn be compared directly to CERES and BSRN flux observations.

Level 3 monthly global and regional intercomparisons would be most useful to elucidate differences among products and should focus on parameters such as probability density functions (PDFs) in addition to means. Radiation reacts to the PDF of water vapor rather than the mean. Level 3 validation data may be added if deemed useful at these space/time scales.

There was agreement that the assessment should be performed in two phases. Phase I would begin with 3 years of recent data, when more satellite data sets and more validation data sets are available. This should also shed some light on the properties of the longer term data sets that will be useful when longer time series with less validation data are assessed in Phase II.

The working groups also discussed the type of expected errors; in particular, systematic errors that lead to differences of water vapor Level 3 data sets. The group followed a list based on the work of the GEWEX aerosol assessment team, and added some additional bias sources that are specific to water vapor.

- Radiometric Bias: biases due to uncharacterized or ill-applied sensor calibration.
- Retrieval Bias: related to shortcomings in a retrieval itself.
- Sampling/Contextual Bias: related to where a retrieval is/is not performed or contextually related uncertainty in a scene. This leads to a skewed data population relative to what is thought to have been collected.
- Aggregation/Data Reduction Bias: loss of required information during analysis or conversion to a gridded product.
- Cognitive Bias: withholding or framing data/results contrary to the full nature of the data.
- Topography Bias: stemming from uneven topography and vapor below profile sensitivity.
- Diurnal Bias: thought to be particularly prevalent over land but also observed over the oceans.
- A priori Biases: stemming from the water vapor profiles, all using some form of a priori information in the retrieval.
- Spectroscopy Bias: while no longer thought to be a leading source of error, it is a potential source of small biases.

While the actual assessment experiment design was left to a committee that is in its formative stages, the timetable is to finish Phase I in 1–2 years. The first deadline is the upcoming GRP meeting in Tokyo, Japan, from 30 August–2 September. The participants agreed that a good start would be to have this document fully elaborated and product developers contacted regarding potential participation.

7th Annual GEO Integrated Global Water Cycle Observations Theme Planning Meeting

13–14 March 2011
Tokyo, Japan

Rick Lawford[1], Toshio Koike[2], Wolfgang Grabs[3], and Belazs Fekete[4]

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The seventh annual Planning Meeting of the Group on Earth Observations (GEO) Integrated Global Water Cycle Observations (IGWCO) Theme Community of Practice (COP) was held at the University of Tokyo. Thirty-four people from 15 countries participated. The Global Terrestrial Network-Hydrology (GTN-H) Meeting was held before the IGWCO Meeting and the majority of these participants stayed for the IGWCO Meeting. Although both meetings were held in relatively calm conditions on the University of Tokyo campus thanks to the effort of our hosts, Prof. Toshio Koike and Ms. Akiko Goda, uncertainty was evident elsewhere as aftershocks from the March 11th 9.0 earthquake were felt regularly. We were very grateful to our hosts for letting us proceed with the meeting under these conditions, and we also benefitted from the contributions of attendees from an earlier Asian Water Cycle Initiative (AWCI) Training Workshop who remained in Tokyo for the IGWCO Meeting.

The objectives of the IGWCO Meeting included: (1) reviewing progress on the water and water-related tasks in the GEO Water Societal Benefit Area (SBA); (2) refining proposed actions and tasks for the 2012–2015 GEO Work Plan; (3) exploring possible links between the GEO Water SBA and the activities of other GEO SBAs; and (4) reviewing other IGWCO activities and plans not connected to the GEO Work Plan.

Progress on the tasks in the 2009–2011 GEO Work Plan was reviewed and those tasks requiring attention and encouragement were noted. A template submitted by Dr. George Huffman, based on his experience in developing precipitation products, was reviewed to see if it provided a useful basis for creating other satellite data products. New variables were also considered, including evapotranspiration, which was the focus of a National Aeronautics and Space Administration (NASA)/United States Department of Agriculture (USDA) workshop held in April 2011 (see report on page 15).

Several projects reported on progress in the area of data integration. It is clear that the Data Integration and Analysis System has provided a model for development activities, although work remains to be done. A basis was agreed upon for improved collaboration between the Committee on Earth Observation Satellites (CEOS) Water Portal Project and GTN-H data centers. The Portal could play a central role in the new Global Water Cycle Data Integrator that was introduced by Prof. Koike. When implemented, this structure will serve as a basis to extend data services to other GEO SBAs, such as Food, Health, Biodiversity, and Energy, and will provide a

broader range of data products. This system will also distribute new data products from the CEOS precipitation constellation and the planned Global Change Observation Mission-Water (GCOM-W) satellite, which was described by the Japan Aerospace Exploration Agency representatives.

Drought activities were discussed in light of emerging plans for a GEO global drought monitor and the conclusion of the Canadian Drought Research Initiative (DRI), which has provided new approaches to drought monitoring, user engagement, and data legacies. Plans for a global drought monitor are building on the Architecture Implementation Pilot-3 (AIP-3) Initiative, which brought together contributions from National Integrated Drought Information System (NIDIS), the Princeton Drought Monitor, and European drought monitoring activity to demonstrate how an integrated system could work. There was also some discussion about the potential for a flood monitoring system building on the activities of the World Meteorological Organization (WMO).

Within the Capacity Building cluster there has been substantial progress related to the African Water Cycle Coordination Initiative (AfWCCI). As a result of the February Symposium in Addis Ababa, there has been a decision to select two large transboundary basins in Africa (one under the management of a well developed River Basin Authority and possibly a second under a lesser developed River Basin Initiative) and to develop plans for sets of projects in each basin to demonstrate the value of GEO principles for regional water management. In addition, the AfWCCI has developed a draft capacity building strategy that will guide demonstration projects and education related to water issues. During the past year, the AWCI has made progress in its three scientific areas (drought, floods, and water quality) and has held several training workshops. The latest workshop, held just before the IGWCO Meeting, addressed issues such as downscaling and data analysis in support of climate change impact studies. The Hydrological and Space Network of Information for Latin America and the Caribbean (CIEHLYC) has implemented a website and is now beginning to accumulate information on projects and activities in Latin and Caribbean America. Topics of interest to the water managers from this region include glacier dynamics, land use changes, natural disasters of hydrometeorological origin, soil quality, and the identification of ecosystem loss and areas for reforestation. The Institute of Electrical and Electronics Engineers (IEEE) has launched a "Water for the World" Project in Lake Nicaragua to demonstrate how remote sensing can support water quality monitoring. European efforts under the Seventh Framework Programme (FP-7)'s European GEO Network (EUGENE) have led to an inventory of GEO Water Activities in Europe and the possible formation of a regional COP in that region.

Recent studies undertaken in conjunction with the Earth System Science Partnership Global Water System Project (GWSP) have identified some of the world's rivers and ecosystems that are under threat. Indicators are used to represent the relative magnitude of these threats. Based on the assessment of both the natural and the built environments, it is possible to assess the degree to which different regions and nations have ameliorated the impacts of natural water cycle variations by the construction of water controls, leading to the possibility of developing an integrated and coordinated approach for societal benefit creation.

Based on these discussions, a number of other activities were proposed for the 2012–2015 GEO Work Plan. New deliverables were proposed for Evapotranspiration and Indicators. Efforts will be made to have the Global Environmental Monitoring System (GEMS, the United Nations Environmental Programme's global in situ water quality program) included in GEO water quality discussions. It is anticipated that the new Work Plan will likely separate water quality, floods, and drought from the other GEO water cycle activities.

It was recommended that GTN-H and IGWCO work together to develop an integrated product that mobilizes both the benefits of integrated products from IGWCO (possibly precipitation) and the data center holdings of GTN-H (e.g., the Global Runoff Data Center, GRDC). There was recognition that more convergence between the IGWCO Capacity Building activities in different regions could accelerate some developments in IGWCO. To this end it was agreed that the AWCI and the CIEHLYC will explore ways to accelerate the development of the Latin and Caribbean Americas activities. On a broader scale, IGWCO will develop a plan for approaching development agencies with success stories and proposals for integrated data delivery systems to seek directed funding for GEO water cycle target areas. In a related effort, WMO and other United Nations agency water projects will be reviewed to assess how Water SBA activities could supplement their efforts. Based on the recent GEO-Intergovernmental Panel on Climate Change (IPCC) meeting, water cycle priorities that influence IPCC goals will be documented for the benefit of the IPCC program. IGWCO also plans to contribute to the preparations for the Rio+20 United Nations Conference on Sustainable Development to be held in Rio de Janeiro, Brazil, on 4–6 June 2012.

Save the Date!

4TH WCRP INTERNATIONAL CONFERENCE ON REANALYSES

7–11 May 2012
Silver Spring, Maryland, USA

http://reanalyses.org/meetings/4th-wcrp-international-conference-reanalyses

Conference Objectives:

- Share understanding on the major challenges facing reanalyses: the changing observing system and Integrated Earth System.
- Assess the state of the disciplinary atmospheric, ocean, and land reanalyses including the needs of the research community for weather, ocean, hydrology, and climate.
- Review the new developments in the reanalyses, models, and observations for study of the Earth System.
- Explore the international collaboration in reanalyses including their role in regional and global climate services.

Final Workshop on the Water Cycle Multimission Observation Strategy (WACMOS)

3 April 2011
Vienna, Austria

Peter J. van Oevelen
International GEWEX Project Office, Silver Spring, Maryland, USA

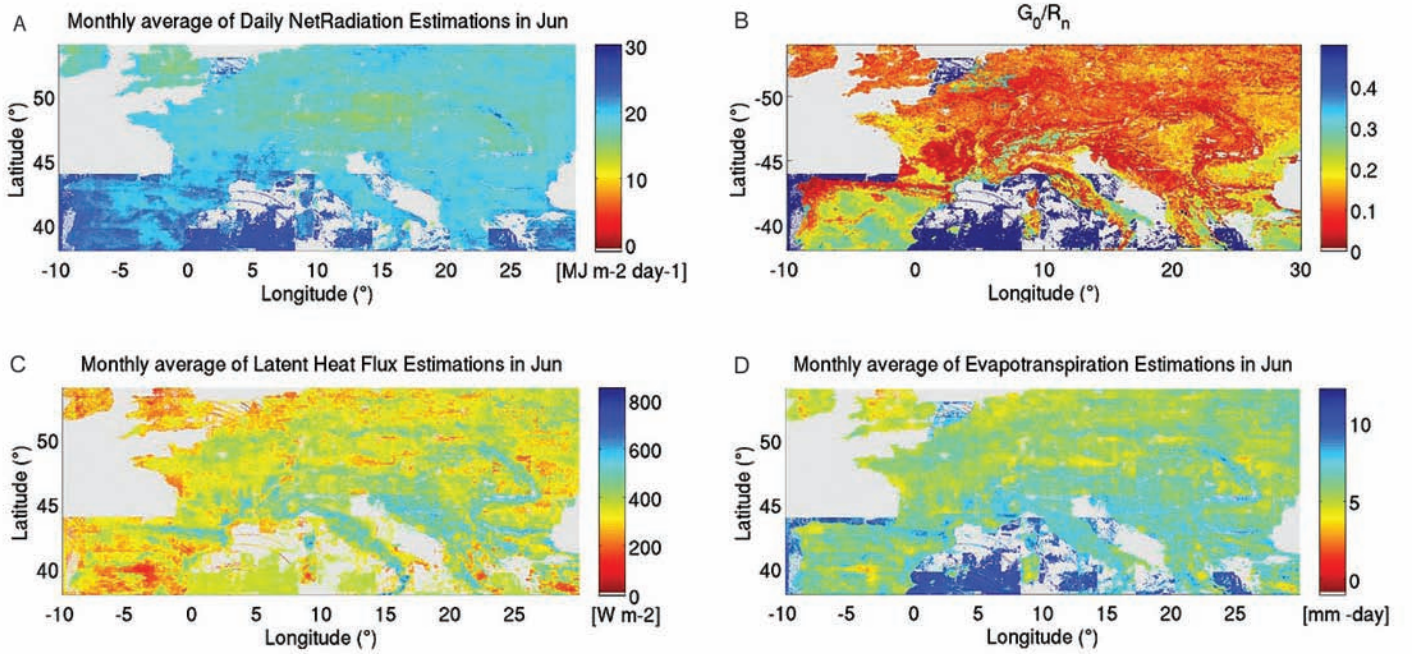
Forty people attended the final Water Cycle Multimission Observation Strategy (WACMOS) Workshop, where the results of the Project were presented to the science community, followed by a panel discussion. The Workshop was hosted by the Technical University of Vienna.

WACMOS was launched in early 2009 as a joint European Space Agency (ESA) and GEWEX collaboration within ESA's new Support to Science Element Programme. The goal of the Project was to support the development of novel techniques to study the water cycle using Earth observations. Four themes were identified for exploring the development of global water cycle data sets: (1) evapotranspiration, (2) soil moisture, (3) clouds, and (4) water vapor. WACMOS was executed by a consortium composed of the International Institute for Geo-Information Science and Earth Observation (lead, The Netherlands), the Technical University of Vienna (Austria), VrijeUniversiteit (The Netherlands), the Royal Netherlands Institute for Meteorology (The Netherlands) and the German Weather Services.

The primary objective of the Workshop was to present the results from WACMOS to the GEWEX community, and collect feedback on these. The workshop was divided into two parts where the first five presentations described the Project and each of the four developed methodologies and experimental data sets. It was clear from the presentations that the water vapor and cloud data sets were the most developed but that both of these could benefit from more interaction with other ongoing international efforts, such as the recently started GEWEX Radiation Panel Water Vapor Assessment Initiative.

The soil moisture component of WACMOS represents a significant step forward in developing suitable methodologies to advance the development of a long-term global data record that merges the different passive and active microwave data sets now available. The work done on evapotranspiration (ET) explored the potential of using ESA data to contribute to ET retrievals and identified the limitations and the work needed to develop mature global products. The aforementioned ET product would link well with the efforts ongoing in the GEWEX Landflux Initiative (see the LandFlux-EVAL Workshop report on page 18).

The overall impression from the presentations and the panel discussion was that WACMOS is a successful start of a new type of collaboration with ESA to explore innovative approaches and new methodologies that will contribute to GEWEX efforts towards the generation of enhanced data set products and deserves continuation. More detailed information about the Workshop can be found at: *http://wacmos.itc.nl/?q=node/24*.



Surface heat fluxes and evapotranspiration in June 2008. The monthly average of daily net radiation (MJ/m²/day), ratio of soil heat flux to net radiation (-), monthly average of latent flux (W/m²) and monthly average of evapotranspiration (mm/day) is shown respectively in figure A, B, C, D. Note some data are missing near the coasts. The impact of the European Centre for Medium-Range Forecasts forcing fields can be seen as tiles.

Evapotranspiration as a Regional Climate Priority: Results from a NASA/USDA Workshop

5–7 April 2011
Silver Spring, Maryland, USA

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Seventy-six experts participated in the Workshop sponsored by the National Aeronautics and Space Administration (NASA) and the United States Department of Agriculture-Agricultural Research Service (USDA-ARS). The Workshop was held in response to a recommendation by the Group on Earth Observations (GEO) Work Plan that a meeting on evapotranspiration (ET) be held to discuss ET products and services, and the potential for incorporating ET activities into the 2012–2015 GEO Work Plan. Although the Workshop had a regional emphasis, there were several excellent international and global presentations, including one on the GEWEX LandFlux Project. The different scales of these activities suggests that a framework is needed that can accommodate both regional and global ET activities.

Specific objectives of the Workshop included: (1) defining the needs and requirements for evapotranspiration data in weather and climate studies, in natural and agro-ecosystem monitoring, and in water resource management; (2) reviewing the methods used to measure and model ET; (3) assessing surface and satellite observation systems required to support ET measurement, modeling, and evaluation; (4) assessing the feasibility of developing a proposal for a task on evapotranspiration for the 2012–2015 GEO Work Plan; and (5) exploring the level of support and consensus for developing a strategy for establishing evapotranspiration as an Essential Climate Variable (ECV) within the Global Climate Observing System (GCOS) Framework.

The Workshop featured a combination of oral and poster presentations and breakout group sessions focused on the above objectives. Presentations by users of ET data set the tone for the Workshop. In the U.S. at the national and regional levels, water rights issues represent a major opportunity for ET applications. ET data play a key role in estimating water loss due to irrigation, the largest cause of consumptive water loss in the U.S., particularly in the West. Irrigation requirements are relatively specific since the needs are clearly defined by the geometry and number of the irrigation systems and can be monitored with high resolution satellite data. There was a strong consensus that land-surface temperature (LST) at high resolution is critical for monitoring irrigation. State governments have made commitments to more efficient water management in the western U.S., but they need full access to improved and more timely ET data and applications to implement this plan. Water managers also reported that in spite of the recent development of new techniques, the procedures used in some of the water balance calculations in some states are out-of-date and do not take advantage of new observational and data assimilation systems. The development of ET forecasts for water management is also seen as a priority. Although they are currently being produced on an experimental basis, they could be improved by using ET as a dynamic prediction variable in models and by increasing the time resolution.

ET data are also required for international applications. The famine warnings distributed through Famine Early Warning Systems Network (FEWS NET) in Africa rely on accurate ET estimates. In some cases, the estimates of ET are critical for water budget computations and the management of transboundary basins. In the case of transboundary basins shared by countries that are unwilling to exchange data, global ET products could have substantial benefits. In addition, the climate modeling community has a need for reliable ET data on a global basis to validate GCM estimates. At present, there are no long-term homogenous ET data sets suitable for evaluating the trends of ET estimated by models; however, NASA is developing data sets for closing water budgets over land areas of the globe through its NASA Energy and Water Cycle Study (NEWS).

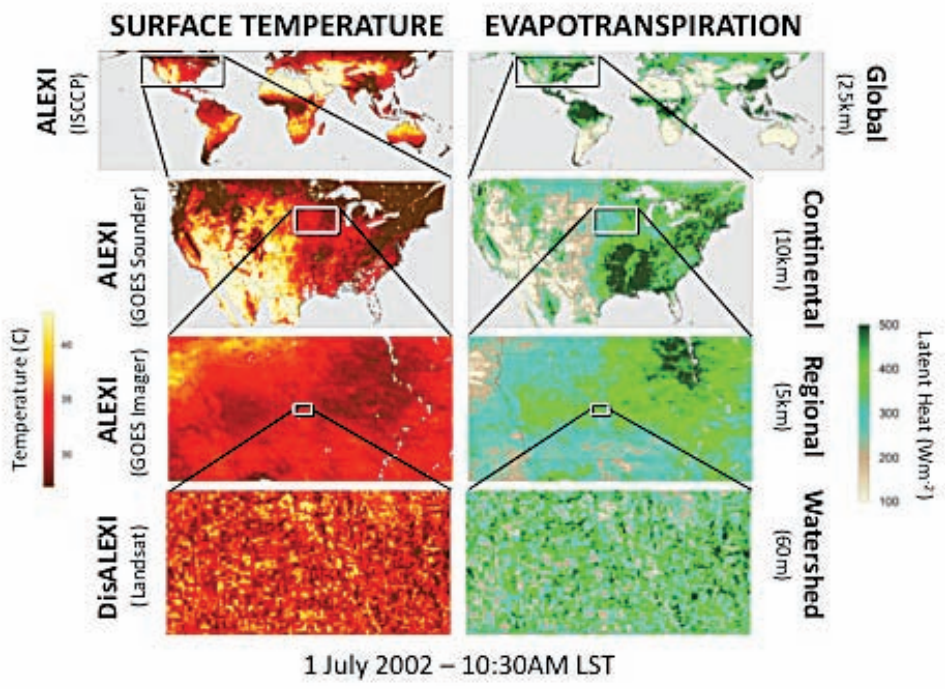
The review of existing observational systems to meet user needs identified deficiencies. At present, the large uncertainties in flux measurements, primarily using the eddy covariance (EC) technique, are addressed through extensive post-processing. These requirements make it difficult to move EC flux measurements from the research arena to the operational domain. In terms of in situ systems there is a range of instruments available for measuring ET. However, other than FLUXNET, which employs the EC technique, it does not appear that other measurement systems have been coordinated in a network. Scintillometry offers a source of observations that may provide reliable ET for Cal/Val and model development activities at larger spatial resolutions than FLUXNET. The planned National Ecological Observatory Network (NEON) is an exciting U.S. opportunity that will provide more ET data and a plethora of ancillary information on vegetation, soil, and ecosystem services. Efforts should be made to integrate NEON measurements into FLUXNET plans. Some FLUXNET towers have had a long-standing problem in closing the energy budget although recent findings presented at this workshop suggested this problem was largely the result of undermeasurement of the vertical velocity and soil heat flux. The various FLUXNET programs around the world could constitute a candidate reference network for ET measurements if the flux towers had a more uniform distribution over the Earth's land surface and followed more comprehensive observational protocols.

Satellites provide measurements that are critical boundary conditions for estimating ET on spatially uniform girds at different resolutions for the Earth's land areas. Thermal observations providing LST are deemed essential for developing robust

techniques in quantifying ET because LST is fundamentally coupled to the energy state of the land surface. Although cloud cover prohibits continuous coverage of LST over the globe, creative data processing techniques can maximize the information value of these observations. For example, it was shown that high resolution products at finer time scales can be produced with good interpolation schemes that fuse infrequent high resolution data with more frequent moderate to coarse resolution data. New satellites such as the Geostationary Operational Environmental Satellite (GOES)–R combined with other geostationary satellites (e.g., Meteosat) covering other continents will provide new opportunities to obtain global estimates of ET. In addition, microwave sensors such as the future Soil Moisture Active Passive (SMAP) satellite will also provide a new ET product that may be very useful in the development of a continuous product since clouds do not obscure microwave observations of the land surface. There is a role for the science community to assist in developing and testing new products as data from these satellites come online.

The modeling community also needs support to develop better ET parameterizations and products. Evidence was presented showing that major differences in ET estimates occur when different sources of radiation data are used. These sensitivities highlight the importance of having access to high quality and relevant data sets as inputs for ET calculations. Furthermore, there are many different methodologies and parameterizations developed for computing ET in prognostic (e.g., numerical weather prediction models) and diagnostic (remote sensing-based models) models. There are also significant uncertainties in key inputs to prognostic models (e.g., precipitation), as well as diagnostic models (e.g., LST). However, evidence was presented showing that for remote sensing-based approaches using LST, it is possible to significantly reduce uncertainty in ET computations due to errors in LST by defining wet and dry ET extremes and associated LST values to internally calibrate model parameterizations for a given satellite scene or to use a time-differencing approach with geostationary satellite-derived LST observations coupled to a land-atmosphere model of morning boundary layer growth (see figure below).

A significant outcome of the Workshop is the decision to generate two white papers by the fall of 2011. One paper will focus on the benefits and applications of routine ET observations in the user community. The second paper will be a state-of-the-art review of measurement and modeling of ET and will serve as the basis for a scientific journal article. In addition, a document will be derived providing specific criteria for a GCOS Essential Climate Variable (ECV), and a short proposal for incorporating ET as an ECV in the GCOS Implementation Plan is being prepared. If deemed appropriate, a small list of activities will be developed for consideration in the 2012–2015 GEO Work Plan. Consideration will also be given to holding several follow-on ET workshops: one in conjunction with users, primarily in the Western U.S., a second in Europe to engage the broader international community in the efforts initiated at this workshop, and a third in conjunction with the LandFlux Project to ensure these regional/continental activities are mutually supportive to their global initiative. The science community also needs to ensure that it takes advantage of the interest of U.S. and international water resource agencies concerned with water availability for competing needs such as crop production, human consumption, energy production and ecosystem services. These agencies need access to ET databases and decision support tools to address these issues. They also have requirements for continuity and reliability in the products that they use. In addition, they should be able to demonstrate in concrete terms the benefits of Earth Observations for decision-making purposes. To this end, consideration is being given to establishing an ET Working Group to discuss data needs, to promote the development of ET databases, and to address ET issues.



Multi-scale ET maps for 1 July 2002 produced with the Atmosphere-Land Exchange Inverse (ALEXI) modeling scheme and flux disaggregation algorithm (DisALEXI) using surface temperature data from Landsat (60 m), GOES Imager (5 km), GOES Sounder (10 km), and the international constellation of geostationary satellites, zooming into the Walnut Creek Watershed near Ames, Iowa, site of the Soil Moisture Experiment (SMEX02). The global and continental-scale ET maps are 14-day composites of clear-sky model estimates.

GEWEX Hydroclimatology Panel Meeting

8 April 2011
Vienna, Austria

Dennis Lettenmaier[1] and Jan Polcher[2]

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The newly formed GEWEX Hydroclimatology Panel (GHP) met for the first time at the Vienna University of Technology (TU Wien). The meeting was hosted by Prof. Wolfgang Wagner, who also kindly sponsored a joint dinner for the GHP and LandFlux Project members.

One objective of this meeting was to identify urgent issues requiring attention prior to the formal GHP meeting that is planned in Boulder on 17–19 October 2011. By previous agreement, all discussions were for information purposes only and no actions were taken. Specific GHP topics addressed at the meeting are given below.

Regional Hydroclimate Projects (RHPs)

Historically, the RHPs have been the cornerstone of GHP, but the activity levels of some RHPs have declined in recent years. Accordingly, there is a need to revisit RHP qualification criteria and to evaluate the activities of the current RHPs. There was a lengthy discussion of how best to assure a vibrant RHP program that is consistent with the new GEWEX Imperatives (Trenberth, 2010) and that can foster the emergence of new RHPs and provide for an orderly retirement of RHPs when they have been completed. A set of criteria will be drafted for discussion at the October GHP meeting and these will focus mostly on the scientific contributions of the RHPs to overall GEWEX goals, especially with respect to water cycle modeling and prediction. The previous requirement of close interaction with a weather center is now less critical than it once was; on the other hand, stronger evidence of plans for coordination and cooperation with other RHPs has become more critical. To facilitate such cooperation, the GHP Panel is considering formation of an RHP Council that would consist of representatives of all of the RHPs. The Council would coordinate day-to-day interactions among the RHPs (e.g., via periodic teleconferences and/or cross-RHP meetings).

Reference Sites

The Coordinated Energy and Water Cycle Observations Project (CEOP) implemented a set of global references sites where surface radiative, turbulent, and ground heat fluxes, as well as various ancillary variables, were archived. Many of these sites are associated with the RHPs, and in fact, one view was that the primary responsibility of the RHPs to CEOP was the provision of reference site data. The data sets, which were intended to be used for evaluation and testing of land-surface and coupled land-atmosphere models, have been plagued by record incompleteness (Lettenmaier, 2010) and have not been as widely used as had been hoped. On the other hand, the data that are in the archive have been much more carefully quality controlled than similar data (in some cases from the same sites) that are held in archives like AmeriFlux and FLUXNET. Funding for data archiving and quality control had been provided by the National Oceanic and Atmospheric Administration (NOAA) but has been discontinued. How to proceed, and the extent to which already-archived data can be maintained, is a concern for GHP. There were strong feelings by the Panel that GEWEX should ensure that high quality reference sites are operated over the long term and that the data archives are complete, quality controlled, and freely available, but it is unclear at this point how best to achieve this goal.

Interaction with Satellite Missions and Products

As GHP moves to focus more on climate model evaluation and testing, and regional to global scale water cycle prediction, satellite data sets will be of increasing importance. The CEOP satellite data archive, and the Model Output Location Time Series (MOLTS) from several weather prediction and reanalysis products, will be key elements. There was a discussion of whether and how GHP might facilitate more widespread use of the Gravity Recovery and Climate Experiment (GRACE) data in this context, as well as other existing and future sources of land-surface data such as precipitation [Global Precipitation Mission (GPM)], soil moisture [Soil Moisture and Ocean Salinity (SMOS) mission and Soil Moisture Active-Passive (SMAP) mission], and surface water [Surface Water Ocean Topography (SWOT) mission].

Interaction with GLASS and CORDEX

Regional climate models are an underutilized source of information about ongoing and future land-surface water cycle changes. GHP, because of its regional focus within GEWEX, needs to foster collaborations here. With encouragement from both the GEWEX Scientific Steering Group and the World Climate Research Programme, GHP is exploring the Coordinated Regional Climate Downscaling Experiment (CORDEX) and the Global Land Atmosphere System Study (GLASS) as the most suitable options for enhancing exchanges between these modeling projects and the RHPs and other GHP activities, given the common interests in land-surface processes.

Broader Project Coordination Issues

GHP, in its previous incarnation as CEOP (and before that as the GEWEX Hydrometeorological Panel), has had a fairly inclusive approach to projects that are broadly related to its (and/or the GEWEX) charge. This led to a large family of activities linked to the Panel but which are in some cases not well coordinated. As GHP moves forward, it will become more focused on the post-2013 GEWEX Imperatives related to the GHP charge of addressing "scientific issues associated with water cycle processes involved in the coupling of the atmosphere and the land surface, including the distribution of water and potential impacts on water resources." As this focus evolves, there is concern that some existing programs under GHP may become orphaned, and GHP will need to consider how best to address such situations.

References:

Lettenmaier, D., 2010. New Directions for GEWEX. *GEWEX News*, Vol. 20, No. 3, p. 1–2.

Trenberth, K., 2010. Moving Forward: Process for Planning the Future of GEWEX Begins at 2nd Pan-GEWEX Meeting. *GEWEX News*, Vol. 20 No. 4, p. 10–13.

LandFlux-EVAL Workshop

8–9 April 2011
Vienna, Austria

Sonia I. Seneviratne[1], Carlos Jimenez[2], Chris Kummerow[3], Matthew McCabe[4], William B. Rossow[5], Eric F. Wood[6], Martin Hirschi[7], Brigitte Mueller[1], and Adriaan J. Teuling[8]

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The GEWEX Radiation Panel (GRP) LandFlux Project is focused on the development and routine production of a multi-decadal global reference land-based surface turbulent heat flux data set, primarily for evapotranspiration (ET), but also for sensible heat flux. The motivation for this is the historical lack of consistent evaluation and intercomparison of existing land ET products and long-term and reliable estimates for these quantities. Within this overall effort, the LandFlux-EVAL Project (*http://www.iac.ethz.ch/url/research/LandFlux-EVAL*) aims to evaluate and compare related recently developed data sets to provide a benchmark for the upcoming product and other applications. Following meetings held in Melbourne, Australia in 2009 and Tokyo, Japan in 2010, this two-day workshop with data producers was organized to coincide with the General Assembly of the European Geosciences Union. The Institute of Photogrammetry and Remote Sensing at the Vienna University of Technology (TU Wien) hosted the Workshop, the Swiss Federal Institute of Technology Zurich (ETH Zurich) coordinated the overall organization, and GEWEX and the integrated Land Ecosystem-Atmosphere Process Study (iLEAPS) of the International Geosphere-Biosphere Programme (IGBP) provided logistical support. Over 20 participants from international institutions attended the workshop.

Chris Kummerow (Colorado State University), Sonia Seneviratne (ETH Zurich), and Wolfgang Wagner (TU Wien) provided introductory words at the Workshop, the main objectives of which were to: (1) review state-of-the-art global ET and auxiliary data sets (radiation, precipitation, soil moisture, surface meteorology, and ancillary data); (2) develop a design for the LandFlux-EVAL benchmarking database using existing global ET data sets; and (3) develop a strategy and timeline towards the development of a GEWEX Version 0 global ET (and sensible heat flux) product(s).

The first session, chaired by Eric Wood (Princeton University) and Matthew McCabe (University of New South Wales), was dedicated to the review of challenges, current status, and outlook in the development of new satellite-based global ET products. It included introductory presentations on these products by the two chairs, including inputs from several data contributors, as well as short overviews on specific current products. Z. (Bob) Su (University of Twente) presented the Surface Energy Balance System; Han Dolman and Diego Miralles (Vrije Universiteit Amsterdam) presented the Global Land-surface Evaporation: the Amsterdam Methodology (GLEAM); and Markus Reichstein (Max-Planck-Institute for Biogeochemistry, Jena) presented an empirically upscaled FLUXNET-based data set. Two conclusions of the first session were that major uncertainties in current satellite-based ET products stem from uncertainties in forcings (e.g., radiation, wind) and that most available ET data sets are not fully independent.

The second session, chaired by William Rossow (City College New York) and Eleanor Blyth (Centre for Ecology and Hydrology), assessed possible forcing and land parameter data sets for GEWEX ET products and multi-model intercomparisons. Prof. Rossow provided an overview of GEWEX products, including the International Satellite Cloud Climatology Project (ISCCP), the Global Precipitation Climatology Project (GPCP), and the Surface Radiation Budget (SRB) Project, which was followed by a presentation on ground radiation observations by Martin Wild (ETH Zurich) and an evaluation of satellite radiation data sets using ground observations by Taiping Zhang [National Aeronautics and Space Administration/Goddard Space Flight Center (NASA/GSFC)]. Prof. Kummerow presented the status of current satellite-based precipitation data sets. Multivariable forcing data sets prepared as input for model simulations or data product generation were presented by Fulco Ludwig [Wageningen University, European Union Integrated Project Water and Global Change (WATCH Project)] and Justin Sheffield (Princeton University). An overview of the current status of reanalysis data sets from the National Centers for Environmental Prediction (NCEP), the European Centre for Medium-Range Weather Forecasts (ECMWF), and the NASA/GSFC Global Modeling and Assimilation Office (GMAO) was provided by Brigitte Mueller (ETH Zurich) based on inputs from the respective centers. Dr. Seneviratne also briefly reported on the planned Coupled Hydro-Energy-Eco System Experiment (CHEESE)/Global Soil Wetness Project-3 (GSWP3) initiative to be led by the University of Tokyo and the University of California at Irvine. The general conclusion of this second session was that SRB was adequate for ET applications, although aerosols represent an important source of uncertainty. With respect to precipitation, several short-term products exist, such as the Tropical Rainfall Measuring Mission (TRMM) Multisatellite Precipitation Analysis (TMPA), the Climate Prediction Center Morphing Technique (CMORPH), the Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks (PERSIANN), and the Global Satellite Mapping of Precipitation (GSMAP) that perform well, but GPCP currently has the best long-term climate record.

The third session, chaired by Sonia Seneviratne and Carlos Jimenez (Observatoire de Paris), assessed the status and development of the LandFlux-EVAL benchmarking database. Dr. Seneviratne highlighted the objectives of the LandFlux-EVAL Project, which, beside the evaluation of current data sets, also includes the derivation of a benchmarking database. Prof. Jimenez and Dr. Mueller provided overviews on two recent LandFlux-EVAL publications and ongoing analyses

(Jimenez et al., 2011; Mueller et al., 2011). The figure at the top of page 1 shows the mean fields and relative Interquartile Range (IQR) from 30 ET data sets analyzed in Mueller et al., 2011. The data sets, as well as the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) simulations, are found to closely agree on the global-scale land ET (see figure at the bottom of page 1), but large regional differences are apparent. Dr. Blyth highlighted current ongoing benchmarking initiatives, in particular, the new International Land Modeling Benchmarking (ILAMB) Project. It was concluded that the LandFlux product and LandFlux-EVAL database would both be of high relevance to ILAMB. It was agreed that the first LandFlux-EVAL database would be compiled based on different data sources, including remote-sensing based data sets, reanalysis products, and land-surface models driven with observation-based forcing. This database will also include measures of uncertainty, including median and IQR, reflecting uncertainties induced by the different methodologies, which is seen as a valuable addition to previous studies on global ET. Dr. Seneviratne's group will lead its development.

The final session on a strategy for the development of the GEWEX Version 0 ET and sensible heat flux products was chaired by Prof. Kummerow, who provided a presentation on the vision and timeline for the GEWEX LandFlux product, including how it should be made compatible with other GEWEX products. Contributions by the groups of Bob Su, Markus Reichstein, Hans Dolman, and Eric Wood were confirmed. Additional contributions are possible and these will be clarified by GRP. The timeline for the first version of the LandFlux data set is fall 2011. Short presentations on consistency analyses and process-based evaluations for the resulting product were provided by Drs. Seneviratne and Reichstein. Prof. Wagner gave a presentation on the status of current soil moisture data sets and possible intercomparisons with the resulting LandFlux ET product. At present only the GLEAM product makes use of soil moisture information. In the final discussion, decisions regarding common forcing products were reached. It was concluded that forcing should be based as much as possible on GPCP and SRB, and that the ECMWF ERA-Interim product meets all requirements as a basis for wind speed. At present it appears difficult to have a common land cover data set for all products.

In conclusion, there was significant progress at the Workshop towards the development of a LandFlux-EVAL database and a LandFlux ET product. First versions of these two products are planned for Northern Hemisphere fall 2011 and will be critical for several research communities, in particular for hydrological and climate change research.

References:

Jiménez, C., et al., 2011. Global intercomparison of 12 land surface heat flux estimates. *J. Geophs. Res.*, 116, D02102, 27 pp.

Mueller, B., et al., 2011. Evaluation of global observation-based evapotranspiration data sets and IPCC AR4 simulations. *Geophys. Res. Lett.*, 38, L06402, 7 pp.

GEWEX/WCRP Calendar

For the complete listing, see the GEWEX web site: http://www.gewex.org

6–10 June 2011—EUCLIPSE/GCSS/CFMIP Meeting on Cloud Climate Feedback—Met Office, Exeter, UK.

13–17 June 2011—US CLIVAR/NCAR ASP Researcher Colloquium: Statistical Assessment of Extreme Weather Phenomena under Climate Change—Boulder, Colorado, USA.

28 June–7 July 2011—IUGG XXV General Assembly—Earth on the Edge: Science for a Sustainable Planet—Melbourne, Australia.

11–14 July 2011—11th Global Conference on Global Warming—Lisbon, Portugal.

24–29 July 2011—IGARSS 2011—Vancouver, Canada.

22–26 August 2011—8th Baltic Sea Science Congress—St. Petersburg, Russia.

30 August–2 September 2011—GEWEX Radiation Panel Meeting—Tokyo, Japan.

5–9 September 2011—EUMESAT Meteorological Satellite Conference—Olso, Norway.

13–16 September 2011—2011 SORCE Science Meeting, Symposium on the Decadal Variability of Earth's Climate, Solar Irradiance and Sun-like Stars—Sedona, Arizona, USA.

16–17 September 2011—iLEAPS Early-Career Scientist Workshop: Challenges and Opportunities of Interdisciplinary Collaboration in Land-Ecosystem-Atmosphere Science—Garmisch-Partenkirchen, Germany.

18–23 September 2011—Third iLEAPS International Science Conference—Garmisch-Partenkirchen, Germany.

25–29 September 2011—International Water Resources Association's World Water Congress—Porto de Galinhas/PE, Brazil.

19–21 October 2011—GEWEX Hydroclimatology Panel Meeting—Boulder, Colorado, USA.

23 October 2011—GEWEX GLASS Meeting—Denver, Colorado, USA

25 October 2011—GEWEX Executive Meeting—Denver, Colorado, USA

24–28 Oct 2011—WCRP Open Science Conference: Climate Research in Service to Society—Denver, Colorado, USA

7–10 November 2011—ECMWF-GEWEX/GABLS Workshop on Diurnal Cycles and the Stable Atmosphere Boundary Layer—Reading, UK.

14–18 November 2011—24th GEWEX SSG Meeting—CNR, Rome, Italy.

5–9 December 2011—AGU Fall Meeting—San Francisco, California, USA.

22–26 January 2012— 92nd Annual AMS Meeting— New Orleans, Louisiana, USA.

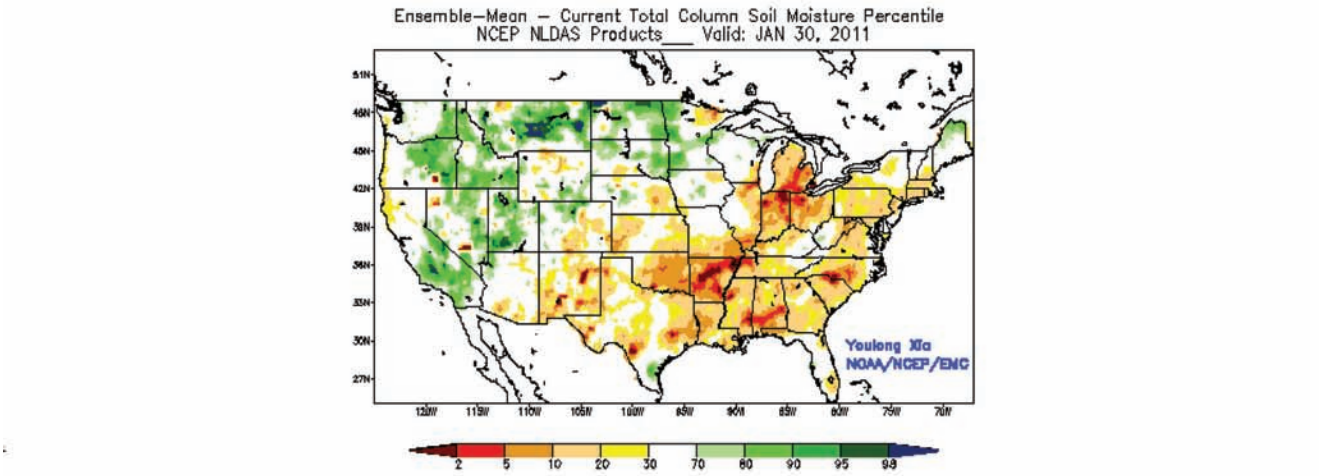
20–23 March 2012—Workshop on the Physics of Climate Models—Caltech, Pasadena, California, USA.

26–29 March 2012—ICSU/IGBP/IHDP/WCRP Conference: Planet Under Pressure: New Knowledge, New Solutions—London, UK.

7–11 May 2012—4th WCRP International Conference on Reanalyses—Silver Spring, Maryland, USA.

NLDAS Drought Monitor Soil Moisture

ENSEMBLE MEAN LSM OUTPUT



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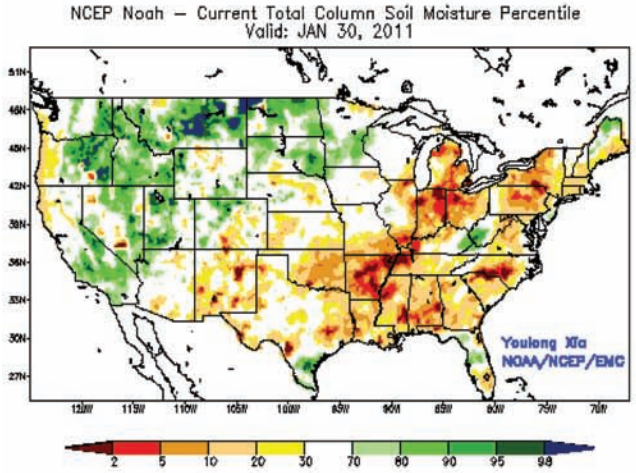

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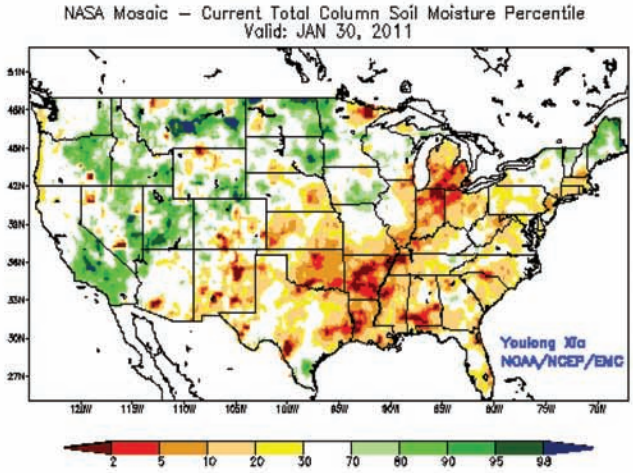

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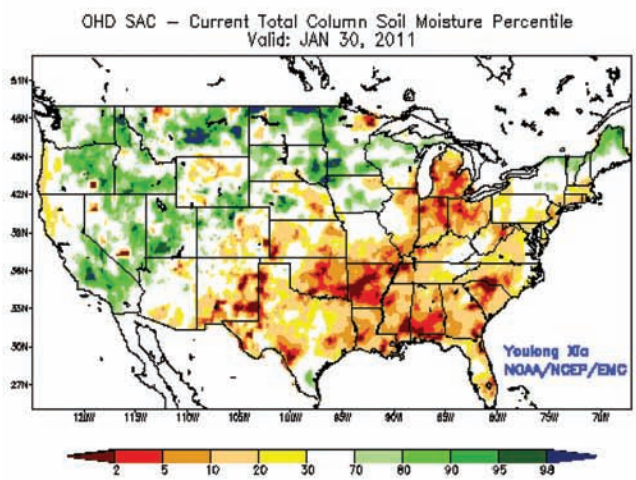
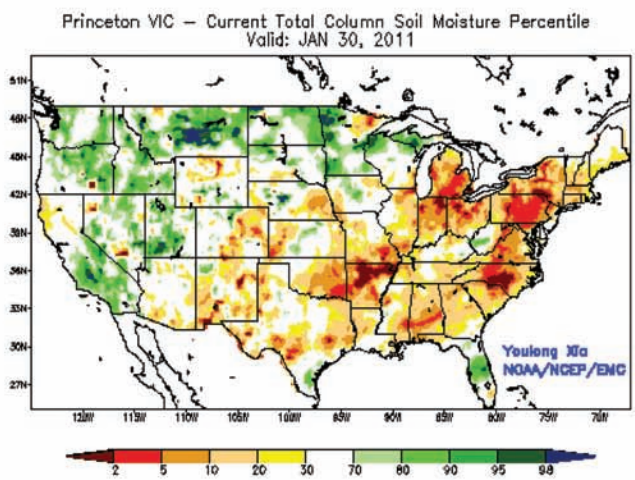


VIC LSM OUTPUT:



Total column soil moisture percentiles on 30 January 2011 for each of the four NLDAS land models as well as the ensemble mean (red: drought/dry; green: flood/wet), taken from the NLDAS web page at: http://www.emc.ncep.noaa.gov/mmb/nldas. See article by M. Ek et al. on page 6.