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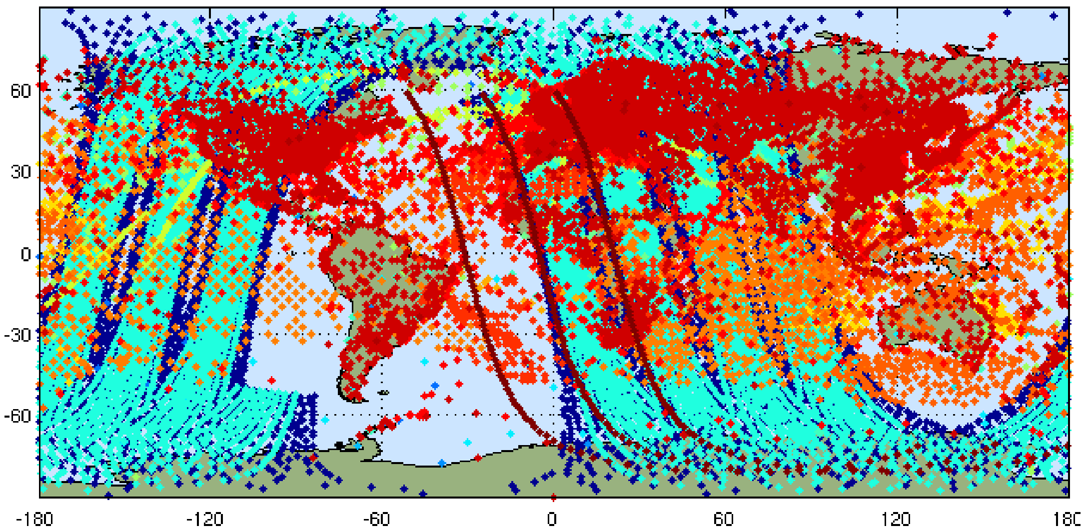

Observations are the critical resource used in producing reanalyses. They are diverse in frequency, distribution, and quality. As many as four million observations are analyzed during a 6-hour window in the 2000s. More than 50 billion observations can be analyzed over 30 years. See article by M. Bosilovich on page 3.

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4th WCRP International Conference on Reanalyses

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Commentary

Reanalyses and Their Applicability for Climate Research

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The upcoming 4th World Climate Research Programme (WCRP) International Conference on Reanalyses will address the applicability of the collection of existing and planned reanalysis archives for climate research and applications. It is tempting to consider these long-term data sets, with their favorable spatial and temporal coverage and basis on an optimized blend of observations and state-of-the-art Earth system models, as a useful proxy for real climate evolution. However, we need to be aware of the many well-known, but not always well-appreciated, limitations of these climate applications. These limitations are the inconsistencies in the observational inputs, the limited quality of the models, the subjectivity of the tuned statistical coefficients, and last but not least, the non-physical increments that are applied during the assimilation, which can destroy trends or important links between relevant processes.

A particularly bad example of using reanalysis data in a climate study was presented a year or so ago at the Royal Netherlands Meteorological Institute (KNMI) by a scientist who aimed to prove that surface warming is not at all related to changes in greenhouse gas composition. He referred to reanalyzed top of atmosphere (TOA) longwave radiation fluxes, which showed the opposite trends to what one would expect from the greenhouse gas theory. When the audience pointed this person to the well-known caveats of the radiation time series being used, the reply was that "these reanalyses cost billions of dollars" and "so must be worth something." This is not exactly a good motivation for using these data.

A much better example is the experiment where conditional sampling of surface temperature stations was applied to verify the statement that the poor and changing data density in the arctic region would be partly responsible for the observed global mean temperature. This conditional sampling experiment could successfully falsify this claim.

In the land-surface modeling community, a tremendous increase in the availability of global multi-year land-surface variables has occurred, mostly due to the successful GEWEX LandFlux Project and its predecessors, such as the Global Soil Wetness Project (GSWP-1 and -2). The multi-model mean evaporation from GSWP-2 is still used frequently as a benchmark or a best estimate of the truth over land, partly owing to the lack of a credible alternative with global coverage. The systematic comparison of these offline model data to satellite-derived estimates and reanalysis products shows that the uncertainty in this basic variable is still considerable, and, among others, quite dependent on the quality of the major forcings precipitation and radiation. Here one should be cautious of using offline or coupled reanalysis products as a true reference, but the increased availability of these products surely has advanced our understanding of the processes and interactions that govern the land-surface state.

One reason to be cautious about using land reanalysis data for climate applications, such as detection of trends in the hydrological budget terms is the possibility of large systematic increments in soil moisture and snow. From early experiments in the late 1990s at the European Centre for Medium-Range Weather Forecasts (ECMWF), it became evident that the relatively long time scale of the soil moisture reservoir makes this a likely receptor for systematic increments in the land-surface forcing such as precipitation or radiation. Systematic errors tend to accumulate in the slowest reservoir. Satellite observations of soil moisture or snow depth provide an additional observational constraint on these drifts, but introduce the risk of concealing the plain origin of the drift, which can be an imperfection in the model or observation system not at all related to the soil component of the system. Systematic inspection of the increments and execution of Observation System Simulation Experiments (OSSEs) remain important activities for the future.

Promising developments in the land component can be expected in the assimilation of novel quantities. Satellite products of vegetation cover or leaf biomass obtain useful information to constrain the global carbon cycle, or to include the important effects of slowly changing land cover on the surface energy or hydrological budget. However, the representation of more and more land-surface characteristics (urban areas, lakes, wetlands, irrigation areas) in modern Earth system models will require additional observations representative of the state of these components.

Where do we dream about going with reanalyses? A Model Data Fusion (MDF) system that perfectly compensates for observational shortcomings using perfect models and vice versa, and that can be considered a perfect representation of the historical state of the climate system for all relevant quantities and scales. We are not there yet, as long as the net influx of water to the ocean is different from the net outflux of water from the land; as long as data assimilation increments are not only a correction for random errors but also contain signatures of systematic errors; as long as spurious drifts dominate the poorly sampled parts of the domain, and as long as results are highly sensitive to tuning or subsampling. But the contribution of the wealth of reanalysis information to our understanding of the major drivers behind (regional) climate variability is considerable, and we should continue to work hard to optimize these important MDF-engines.

After Two Decades of Retrospective-Analysis: What's Next?

Michael G. Bosilovich

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Retrospective-analysis, or reanalysis, is the incorporation of long-term records of observations into an unvarying assimilation system to produce value-added data sets for a variety of applications, such as climate variability, chemistry, and process studies. Reanalyses were originally proposed for meteorological observations as a method to generate climate data sets from weather observations. As the satellite records of chemical, land and oceanic parameters build with time, reanalyses are developed for other types of observations and coupled reanalysis. The fundamental need for reanalyses was advocated by Trenberth and Olson (1988), and Bengtsson and Shukla (1988) as a way to provide continuous and consistent data sets for climate studies. Trenberth and Olson (1988) derived quantities for the atmospheric general circulation from observational analyses used in operational weather forecasting, finding that significant discontinuities in the time series of these derived quantities, such as changes in the forecast model, were related to changes in the analysis system. The logical conclusion was that reprocessing the analyses with a fixed analysis system would eliminate the spurious discontinuities prevalent in the operational analysis time series, and yield a global data set with a more consistent representation of the Earth's climate.

In this context, the first generation of reanalyses was developed. Aside from the well-known National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) reanalysis (Kalnay et al., 1996), the European Centre for Medium-Range Weather Forecasts (ECMWF) executed the ERA-15 Project (Gibson et al., 1997), and the Global Modeling and Assimilation Office (GMAO) at National Aeronautics and Space Administration's Goddard Space Flight Center provided a 17-year reanalysis (Schubert et al., 1993). These initial meteorological reanalyses have been cited in many studies, which document successes as well as identifying a series of shortcomings that will become the core of future research. There has been continual research and development on the quality of the observations (e.g., Kanamitsu et al., 2002; Uppala et al., 2005; and Haimberger, 2007), and numerical models and data assimilation (Dee and Uppala, 2009). In addition, the passage of time has led to more available computing power. The latest generation of reanalyses generally runs with finer spatial resolution and includes the following:

- Japanese 25-Year Reanalysis (JRA-25; Onogi et al., 2007)
- NCEP Climate Forecast System Reanalysis (CFSR; Saha et al., 2010)
- ECMWF Interim Reanalyses (ERA-Interim, Dee et al., 2011)
- NASA Modern-Era Retrospective analysis for Research and Applications (MERRA; Rienecker et al., 2011)

The recent reanalyses have improved on many aspects of the earlier-generation systems. Direct assimilation of the remotely sensed satellite radiances, rather than assimilation of retrieved state estimates, has become routine. Variational bias correction of the satellite radiances effectively anchors these data to high-quality observations from radiosondes and other sources (Dee and Uppala, 2009); used in ERA-Interim, MERRA, and CFSR. The recently completed CFSR is the first reanalysis to use a coupled ocean-atmosphere model, and it also assimilates precipitation data over land. In addition to the technical and scientific improvements of reanalysis systems, increased computational resources allow the use of higher-resolution models that better resolve the observations. These combined advances have lead to improved representations of many physical parameters in reanalyses, such as improved skill of the large-scale global and tropical precipitation (Bosilovich et al., 2009, 2011). In addition, the need for reanalyses to contribute to climate change studies has prompted significant innovations. For example, the 20th Century Reanalysis (20CR) Project carried out by NOAA and the Cooperative Institute for Research in Environmental Sciences (CIRES) uses reconstructed surface pressure observations and sea-surface temperature records going back to the 1870s, reproducing hemispheric weather patterns with the quality of a modern 3-day numerical forecast (Compo et al., 2011).

With so many reanalyses available, researchers naturally question which one is the best for a given project? The bottom line is that each has strengths and weaknesses, and these can also be regionally and temporally different. For many specific questions, a researcher will have to determine the suitability of reanalyses themselves, simply because there are so many possible applications of reanalyses. However, an effort has begun to develop an on-line reference for reanalysis information and knowledge. A wiki-based site at: *http://reanalyses.org* contains basic information on many reanalyses; however, the site will only thrive with input from the user community. As the community of users becomes more experienced with the strengths and weaknesses of reanalyses, it is important to provide more enhanced quantitative diagnostics from the data assimilation (e.g., Haimberger, 2007; Rienecker et al., 2011).

While the advancement and improved quality of reanalyses are substantial, there are significant challenges that remain in developing reanalysis data for higher order climate studies, such as global heating rates and trend analysis. For example, each of the latest satellite data reanalyses include spurious shifts in time series associated with the changes of observing systems (Bosilovich et al., 2011; Dee et al., 2011; Saha et al., 2010). This is a key challenge for the continuing development of reanalyses. Furthermore, ocean and land reanalyses have also become integral components of scientific research. As models become more advanced, they include coupled ocean, land, cryosphere, aerosol, and chemistry components, each of which has its own observations and data assimilation (Rodell et al., 2004; Xue et al., 2012). These coupled analyses, also called Integrated Earth

System Analyses, have the potential to show the interplay of the various Earth systems with respect to climate variability.

The World Climate Research Programme (WCRP) has supported the reanalysis community by organizing international conferences and panels designed to bring together the developer and user communities. On 7-11 May 2012, the 4th WCRP International Conference on Reanalysis will be held outside Washington, DC (*http://icr4.org*). The objective of the meeting is to evaluate the current status of reanalyses and discuss how they can be improved. The Conference will include sessions on the key atmospheric, ocean, and land processes, as well as observations and data assimilation. General topics of discussion will include the status and plans for near-term development, validation and intercomparison metrics, and climate research and applications. The program has been specifically designed to promote the exchange of information among developers and scientific users of the data, with a goal of outlining strategies for the continued advancement of reanalysis data for weather and climate studies.

References

Bengtsson, L., and J. Shukla, 1988. Integration of space and in situ observations to study global climate change. *Bull. Amer. Meteor. Soc.*, 69, 1130-1143.

Bosilovich, M.G., and coauthors, 2009. A Multimodel Analysis for the Coordinated Enhanced Observing Period (CEOP). *J. Hydrometeor.*, 10, 912–934.

Bosilovich, M.G., F.R. Robertson and J. Chen, 2011. Global Energy and Water Budgets in MERRA. *J. Climate*, 24, 5721–5739.

Compo, G.P., and coauthors, 2011. The Twentieth Century Reanalysis Project. *Quart. J. Roy. Meteor. Soc.*, 137, 1–28.

Dee, D.P., and S. Uppala, 2009. Variational bias correction of satellite radiance data in the ERA-Interim reanalysis. *Quart. J. Roy. Meteor. Soc.*, 135, 1830–1841.

Dee, D.P., and coauthors, 2011. The ERA-Interim reanalysis: Configuration and performance of the data assimilation system. *Quart. J. Roy. Meteor. Soc.*, 137, 553-597.

Gibson, J. K., P. Kallberg, S. Uppala, A. Nomura, A. Hernandez, and E. Serrano, 1997. ERA Description, ECMWF Reanalysis Final Report Series, 1.

Haimberger, L., 2007. Homogenization of Radiosonde Temperature Time Series Using Innovation Statistics. *J. Climate*, 20, 1377-1403.

Kalnay E., M. Kanamitsu, R. Kistler, and coauthors, 1996. The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, 77, 437-471.

Kanamitsu, M., W. Ebisuzaki, J. Woolen, and coauthors, 2002. NCEP-DOE AMIP-II reanalysis (R-2). *Bull. Amer. Meteor. Soc.*, 83, 1631-1643.

Onogi, K., and coauthors, 2007. JRA-25 Reanalysis. *J. Met. Soc. Japan*, 85, 369-432.

Rienecker, M.R., and coauthors, 2011. NASA's Modern-Era Retrospective analysis for Research and Applications. MERRA. *J. Climate*, 24(14), pp. 3624–3648.

Rodell, M., and coauthors, 2004. The Global Land Data Assimilation System. *Bull. Amer. Meteor. Soc.*, 85, 381–394. doi: http://dx.doi.org/10.1175/BAMS-85-3-381.

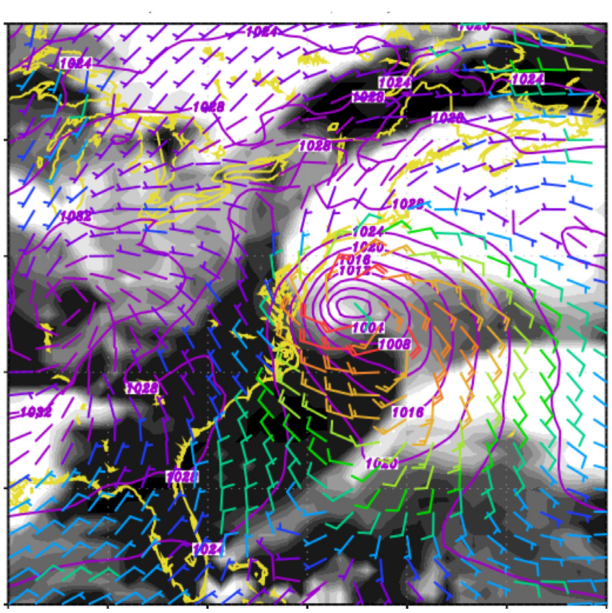
Saha, S., and coauthors, 2010. The NCEP Climate Forecast System Reanalysis. *Bull. Amer. Meteor. Soc.*, 91, 1015–1057.

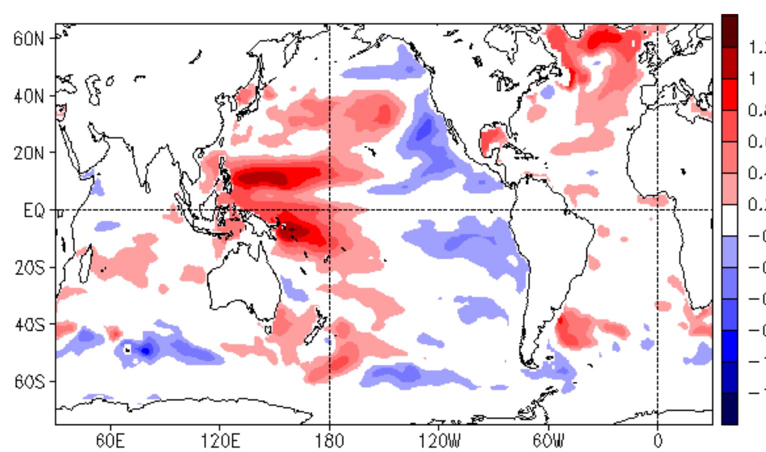
Schubert S.D., R.B. Rood, and J. Pfaendtner, 1993. An assimilated data set for earth-science applications. *Bull. Amer. Meteor. Soc.*, 74, 2331-2342.

Trenberth, K.E., and J.G. Olson, 1988. Evaluation and intercomparison of global analyses from NMC and ECMWF. *Bull. Amer. Meteor. Soc.*, 69, 1047-1057.

Uppala, S.M., P.W. Kallberg, A.J. Simmons, and coauthors, 2005. The ERA-40 re-analysis, *Quart. J. Roy. Meteor. Soc.*, 131 Part B, 2961-3012.

Xue, Y., M.A. Balmaseda, T. Boyer, et al., 2012. A Comparative Analysis of Upper Ocean Heat Content Variability from an Ensemble of Operational Ocean Reanalyses. Submitted to *J. Climate*.





Reanalysis products can provide continuous weather and circulation data. Additional parameters not routinely observed, if at all, are derived from the background forecast models. For example, (left) the 1979 President's Day Snowstorm depicted from MERRA sea-level pressure, surface winds and cloud fraction, and (right), the linear trend of 300-meter ocean heat content anomalies over the 1993-2009 period (°C/decade) from an ensemble mean of linear trends based on ten ocean reanalyses (Xue et al., 2012).

Regional Reanalysis for Climate Research Applications: South American Hydroclimate Reconstruction

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The concept of reanalysis is usually associated with climate assessment because of the global, gridded interpolated long-term records of atmospheric and surface variables available at regular time intervals. Roughly, a reanalysis system is a combination of several types of observations assimilated into an analysis system that is used to initialize numerical model short-term integrations that provide a set of diagnostic variables. This system produces an optimum description of the atmospheric conditions at a given time.

More recently, global reanalyses have been downscaled by dynamically consistent regional models to produce climate information at regional scales. For example, a well-known and valued regional effort is the 32-km horizontal, 45-layer resolution National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Prediction (NCEP) North American Regional Reanalysis (NARR; Mesinger et al., 2006). The NCEP Eta model and its three-dimensional data variational data assimilation (3DVAR) system (EDAS) set the basis for NARR, which was created to regionally access water variability. In that regard, all terms of the NARR water budget can be retrieved from the NARR outputs. The assimilation of observed precipitation is one of the most interesting features of NARR, as it is not usually seen in other reanalyses. NARR modifies the latent heat profiles according to the observed precipitation, successfully bringing the modeled precipitation closer to the observed. The Noah Land-Surface Model (Noah LSM; Mitchell et al., 2004; Ek et al., 2003) is an important part of the NARR system, and is driven by this improved model's precipitation, aiming for a superior hydroclimatology. The global NCEP-Department of Energy Atmospheric Model Intercomparison Project (AMIP-II) reanalysis (R2; Kanamitsu et al., 2002) provides the lateral boundary conditions for NARR.

Data assimilation schemes have greatly contributed to the achievement of better predictions over the past decades, and have been combined in order to improve results. For example, the traditional three-dimensional data assimilation scheme (3DVAR) has been used together with the ensemble Kalman Filter (EnKF) at the regional scale (Wang et al., 2008), mostly for weather prediction by regional models, such as the Weather Research and Forecasting Model (WRF). An ensemble filter has also been used in the global 20^{th} Century Reanalysis Project (Compo et al., 2006) to produce short-term analyses and to assess their uncertainties, suggesting that it might be successfully extended to regional reanalysis.

With the goal of producing a data set for the assessment of regional climate from global reanalysis for a time period of over 50 years, the NCEP/National Center for Atmospheric Research (NCAR) global reanalysis (R1; Kalnay et al., 1996) was dynamically downscaled to hourly, 10-km resolution over California (CaRD10; Kanamitsu and Kanamaru, 2007) and the Regional Spectral Model (RSM; Juang et al., 1997) was used for R1 downscaling. To preserve the transfer of large-scale features into the RSM solution driven by R1, the Scale-Selective Bias Correction (SSBC; Kanamaru and Kanamitsu, 2007) was applied to the RSM prognostic variables, mainly targeting the horizontal wind components at synoptic scale and above, similar to the spectral nudging technique in von Storch et al. (2000).

The Institute of Geosciences (IGEO) at the Universidade Federal do Rio de Janeiro (UFRJ) in Brazil is planning a 10-km resolution reconstruction of the South American hydroclimate that will use a combination of precipitation assimilation (PA; originally from Nunes and Roads, 2007a) and SSBC applied to a regional climate model. Considering the fully coupled regional modeling system (atmospheric and land-surface models), it is expected that the PA procedure will not only improve atmospheric characteristics, but also surface hydrology. More specifically, RSM, with a modified version of its original SSBC, will be used to assimilate precipitation rates from satellite-based products. This should correct both rotational and divergent parts of the horizontal wind using the combined schemes for downscaling a global reanalysis. Instead of improving low-resolution precipitation analyses by merging satellite data and reanalysis outputs (Sapiano et al., 2008), this approach will use high-resolution precipitation analysis over regions where skill has been demonstrated to improve the model's physics.

The pioneering work of Krishnamurti et al. (1991) in physical initialization applied to atmospheric general circulation model short-term predictions, and later its implementation in a regional spectral model by Nunes and Cocke (2004), has contributed to the formulation of a computationally low-cost precipitation assimilation algorithm (Nunes and Roads, 2005) at the Scripps Experimental Climate Prediction Center (ECPC). In that 2005 study, an earlier PA scheme was applied alone to an RSM extended integration over South America. The Large-Scale Biosphere-Atmosphere Experiment in Amazonia (LBA) wet season campaign of 1999 was chosen for the study. The result of that PA scheme applied to ECPC-RSM (hereafter referred to as PA) is shown in Figure 1 on page 6. Also displayed is the precipitation monthly mean produced by NCEP R2, which provided initial and lateral boundary conditions to the RSM downscaling. With the purpose of illustrating the uncertainty among reanalysis-based precipitation products, the NCEP (Coupled) Climate Forecast System Reanalysis (CFSR; Saha et al., 2010) and the National Aeronautics and Space Administration (NASA) Modern Era Retrospective-Analysis for Research and Applications (MERRA; Bosilovich, 2008) precipitation outputs are included.

Figure 1 shows that reanalysis resolutions vary. R2 has the coarsest resolution (approximately 200 km), followed by

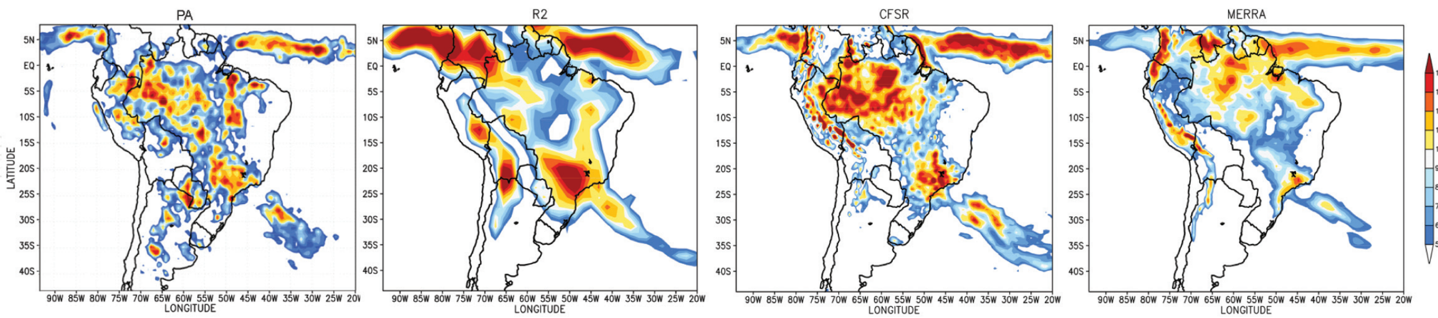

Figure 1. Monthly mean precipitation (mm/day) for January 1999 from PA (regional model), R2, CFSR, and MERRA reanalyses.

MERRA (two-thirds degree longitude by 0.5-degree latitude), with the finest resolution from the NCEP CFSR. The latter is available with a primitive horizontal grid of approximately 38 km on a 0.5-degree grid. Figure 1 also shows the 60-km resolution RSM with satellite-based PA. All panels show precipitation monthly means for January 1999. PA has improved precipitation in comparison to a model-controlled integration as well as prognostic variables (not shown; for details, see Nunes and Roads, 2005).

Precipitation estimates from the Special Sensor Microwave/Imager (SSM/I) radiometers flown on Defense Meteorological Satellite Program satellites are depicted in Figure 2 below. Precipitation estimates were obtained using the NOAA National Environmental Satellite, Data, and Information Service (NESDIS) SSM/I algorithm (Ferraro and Marks, 1995). In the absence of SSM/I data, NESDIS Outgoing Long-wave Radiation (OLR) data was blended into the rainfall data set (Gairola and Krishnamurti, 1992). The SSM/I-OLR precipitation estimates were provided on a Gaussian grid of about 70 km with defined values from 60°N to 60°S, and then bi-linearly interpolated to the RSM Mercator grid.

Figure 2 (center panel) shows the monthly mean precipitation from Version 1.1 of the One-Degree Daily (1DD) Global Precipitation Climatology Project (GPCP) product (Huffman et al., 2001). In these 1DD-GPCP estimates, the Threshold-Matched Precipitation Index (TMPI) algorithm is used for 40°N-40°S, and the rescaled daily Television and Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) for regions outside that belt.

The NOAA Climate Prediction Center (CPC) Merged Analysis of Precipitation (CMAP; Xie and Arkin, 1997) monthly rates are displayed in Figure 2 (right panel). The CMAP standard monthly rates shown do not contain reanalysis information, but combine satellite information from several sources. The precipitation analyses vary in resolution from roughly 0.7 to 2.5-degrees, from left to right. Despite their different resolutions, the good agreement seen in the satellite-based precipitation analysis features (Figure 2) is not observed among the global reanalyses shown in Figure 1. The small variations in the reanalysis monthly mean calculations were disregarded; however, this does not invalidate the overall results.

NCEP R2 uses a 5-day mean CMAP over land to adjust soil wetness, aiming for a positive impact on the modeled precipitation. In a first evaluation, the adjusted soil moisture in R2 does not show a positive influence on its South American tropical precipitation. The PA procedure efficacy—in bringing modeled precipitation closer to the assimilated SSM/I-OLR estimates—is measured here through both PA (R2-driven) and R2 linear correlation coefficients, which are 0.98 and 0.56, respectively.

Previous studies have shown some evidence of improvement in the near-surface variables due to the precipitation assimilation's continuous interaction with the land-surface scheme (Nunes and Roads, 2007a), as well as in model representation of transverse ageostrophic circulations that are mainly induced by the

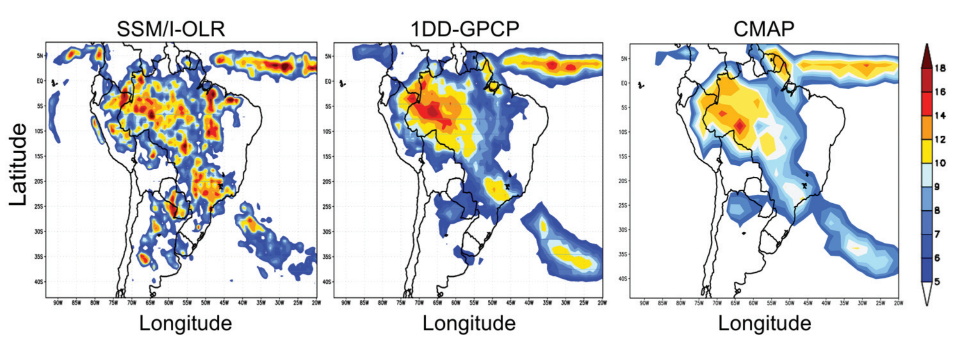

Figure 2. Monthly mean precipitation (mm/day) for January 1999 from the following satellite-based products: SSM/I-OLR, 1DD-GPCP, and CMAP.

large-scale circulation (Nunes and Roads, 2007b, 2009).

This IGEO-UFRJ climate reconstruction effort is seeking international partnerships, especially through GEWEX participation. The goal is to assimilate the best precipitation analyses possible from new satellite products and gauge data sets to validate the scheme through comparisons with the GEWEX data sets. These outputs will be made available for climate research and applications.

Acknowledgments
NOAA/NCEP/National Weather Service provided the R2 and CFSR data sets. MERRA data sets were obtained from the Modeling and Assimilation Data and Information Services Center (MDISC), managed by the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC). Florida State University provided the SSM/I-OLR estimates. CMAP data were provided by the NOAA Office of Oceanic and Atmospheric Research Earth System Research Laboratory Physical Sciences Division at: *http://www.esrl.noaa.gov/psd/*. 1DD data were provided by the NASA/Goddard Space Flight Center's Laboratory for Atmospheres, which develops and computes the 1DD as a contribution to GPCP.

References

Bosilovich, M., 2008. NASA's Modern Era Retrospective-analysis for Research and Applications: Integrating Earth Observations. *Earthzine.org.*

Compo, G.P., J.S. Whitaker, and P.D. Sardeshmukh, 2006. Feasibility of a 100-year reanalysis using only surface pressure data. *Bull. Amer. Meteor. Soc.,* 87, 175-190.

Ek., M.B., and coauthors, 2003. Implementation of Noah land surface model advances in the National Centers for Environmental Prediction operational mesoscale Eta model. *J. Geophys. Res.*, 108, 8851, doi:10.1029/2002JD003296.

Ferraro, R.R., and G.F. Marks, 1995. The development of SSM/I rain-rate retrieval algorithms using ground-based radar measurements. *J. Atmos. Oceanic Technol*. 12, 755-770.

Gairola, R.M., and T.N. Krishnamurti, 1992. Rain rates based on SSM/I, OLR and raingauge data sets. *Meteorol. Atmos. Phys*., 50, 165-174.

Hufmann, G.J., R.F.A. Adler, M.M. Morrissey, D.T. Bolvin, S. Curtis, R. Joyce, B. McGavock, and J. Susskind, 2001. Global precipitation at one-degree daily resolution from multisatellite observations. *J. Hydrometeor*. 2, 36-50.

Juang, H.-M. H., S.-Y. Hong, and M. Kanamitsu, 1997. The NCEP Regional Spectral Model: An Update. *Bull. Amer. Meteor. Soc.*, 78, 2125-2143.

Kalnay, E., and coauthors, 1996. The NCEP/NCAR 40-Year Reanalysis project. *Bull. Amer. Meteor.* Soc., 77, 437-471.

Kanamaru, H., and M. Kanamitsu, 2007. Scale-selective bias correction in a downscaling of global analysis using a regional model. *Mon. Wea. Rev*., 135, 334-350.

Kanamitsu, M., E. Wesley, J. Woollen, S.-K. Yang, J.J. Hnilo, M. Fiorino, and G. L. Potter, 2002. NCEP-DOE AMIP-II reanalysis (R-2). *Bull. Amer. Meteor. Soc*. 83, 1631-1643.

Kanamitsu, M., and H. Kanamaru, 2007. 57-Year California Reanalysis Downscaling at 10-km (CaRD10) Part 1. System Detail and Validation with Observations. *J. Climate*, 20, 5527-5552.

Krishnamurti, T.N., J. Xue, H.S. Bedi, K. Ingles, and D. Oosterhof, 1991. Physical initialization for numerical weather prediction over the tropics. *Tellus*, 43AB, 53-81.

Mesinger, F., and coauthors, 2006. North American Regional Reanalysis. *Bull. Amer. Meteor. Soc*., 87, 343-360.

Mitchell, K.E., and coauthors, 2004. The multi-institution North American Land Data Assimilation System (NLDAS): Utilizing multiple GCIP products and partners in a continental distributed hydrological modeling system. *J. Geophys. Res.*, 109, D07S90, doi:10.1029/2003JD003823.

Nunes, A.M.B., and S. Cocke, 2004. Implementing a physical initialization procedure in a regional spectral model: impact on the short-range rainfall forecasting over South America. *Tellus*, 56A, 125-140.

Nunes, A.M.B., and J.O. Roads, 2005. Improving regional model simulations with precipitation assimilation. *Earth Interactions*, 9, No. 20, pp. 1-44.

Nunes, A.M.B., and J. Roads, 2007a: Influence of precipitation assimilation on a regional climate model's surface water and energy budgets. *J. Hydrometeor.*, 8, 642-664.

Nunes, A.M.B., and J. Roads, 2007b. Dynamical influences of precipitation assimilation on regional downscaling. *Geophys. Res. Lett.*, 34, L16817, doi:10.1029/2007GL030247.

Nunes, A.M.B., and J.O. Roads, 2009. Dynamical downscaling of short-term climate fluctuations: On the benefits of precipitation assimilation. *J. Geophys. Res.*, 114, D12108, doi:10.1029/2008JD010933.

Saha, S., and coauthors, 2010. The NCEP Climate Forecast System Reanalysis. *Bull. Amer. Meteor. Soc.*, 91, 1015-1057.

Sapiano, M.R.P., T.M. Smith, and P.A. Arkin, 2008. A new merged analysis of precipitation utilizing satellite and reanalysis data. *J. Geophys. Res*., 113, D22103, doi:10.1029/2008JD010310.

von Storch, H., H. Langenberg, and F. Feser, 2000. A spectral nudging technique for dynamical downscaling purposes. *Mon. Wea. Rev.*, 128, 3664-367.

Wang, X., D.M. Barker, C. Snyder, and T.M. Hamill, 2008. A hybrid ETKF–3DVAR data assimilation scheme for the WRF Model. Part I: Observing system simulation experiment. *Mon. Wea. Rev.*, 136, 5116-5131.

Xie, P., and P.A. Arkin, 1997. Global precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs. *Bull. Amer. Meteor. Soc.*, 78, 2539-2558.

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Atmospheric Moisture Transports from Ocean to Land in Reanalyses

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The essence of the overall hydrological cycle is the evaporation of moisture in one place and precipitation in other places. Evaporation exceeds precipitation over the oceans, which allows moisture to be transported by the atmosphere onto land where precipitation exceeds evapotranspiration, and the runoff flows into streams and rivers, and discharges into the ocean, completing the cycle. There have been many estimates of the various components that enter into the hydrological cycle but the most comprehensive estimates are available from atmospheric reanalyses. The capabilities of eight recent modern atmospheric reanalyses (Table 1) were assessed based on four-dimensional data assimilation to provide reliable estimates of the vertically integrated moisture transports and other components of the hydrological cycle (Trenberth et al., 2011).

The atmospheric conservation of the moisture equation, when vertically integrated in flux form, relates the change in moisture storage in an atmospheric column to the atmospheric moisture divergence and the freshwater flux into or out of the column *E-P*, where *E* is the surface evaporation and *P* is the net surface precipitation rate. Because the tendency term is small, the primary balance is between the freshwater flux *E-P* and the moisture divergence.

Reanalyses provide a synthesis of all available data and can correct the bias in errors from radiosonde measurements. Moisture fields have greatly improved in reanalyses, especially over the ocean, which have been helped by the direct assimilation of radiances. Nonetheless, there are continual changes over time in the observations that lead to large spurious apparent changes in the fields that affect the hydrological cycle in assimilating models. Of particular note is the introduction of Special Sensor Microwave Imager (SSM/I) observations in mid-1987, the advances made in going from the Television and Infrared Observation Satellite (TIROS) Operational Vertical Sounder (TOVS) to Advanced TOVS (ATOVS), along with the Advanced Microwave Sounding Unit–B (AMSU-B) water vapor channels from late 1998 [the National Oceanic and Atmospheric Administration (NOAA-15) satellite replaced the NOAA-12 satellite] to 2001 (NOAA-16 replaced NOAA-14 on March 20, 2011), the Atmospheric Infrared Sounder (AIRS) observations in about late 2002, and Global Positioning System Radio Occultation (GPS RO) measurements from about 2002 on, increasing in volume after the Constellation Observing System for Meteorology Ionosphere and Climate (COSMIC) was launched in April 2006.

Table 1

Reanalysis	Horizontal Resolution	Dates	Vintage
NCEP/NCAR R1	T62	1948–Present	1995
NCEP-DOE R2	T62	1979–Present	2001
CFSR (NCEP)	T382	1979–Present	2009
C20r	2°	1871–2008	2009
ERA-40	T159	1957–2002	2004
ERA-I	T255	1989–Present	2009
JRA-25	T106	1979–Present	2006
MERRA (NASA)	0.5°	1979–Present	2009

Summary of the main atmospheric reanalyses that are current, with the horizontal resolution (latitude; T159 is equivalent to about 0.8°), the starting and ending dates, and the approximate vintage of when the analyses became available.

The moisture budget is generally not closed in reanalyses owing to the analysis increment arising from errors in the state variable fields and observational uncertainties. A step forward in some recent reanalyses is the use of either a four dimensional data assimilation system for the European Centre for Medium Range Weather Forecasts (ECMWF) Interim Reanalysis (ERA-Interim) or an incremental analysis update technique for the Modern Era Retrospective-Analysis for Research and Applications (MERRA). Both of these allow the analyzed fields to evolve smoothly in time instead of with jumps at times of analyses, which has a major advantage of largely eliminating the spin-up problem of the hydrological cycle.

E and *P* from reanalyses were used to derive a value of *E-P* over the ocean and a value of *P-E* over land. The analyses were also used to estimate a value for the transport of atmospheric moisture from ocean to land. Another independent estimate (from Dai and Trenberth, 2002; Dai et al., 2009) is the value of the return flow in rivers and at the surface. Ideally these four estimates would be identical for averages (where the storage tendency is small); however, in practice they are not. In reanalyses, differences among the first three estimates arise from the analysis increment which precludes reanalyses from satisfying physical closure constraints in either the energy or water cycles. Moreover, specified sea-surface temperatures (SSTs) in the reanalyses provide an "ocean" that has infinite heat and water capacity to take up or provide energy or water to the atmosphere. The degree to which the reanalyses satisfy physical constraints and the extent of the imbalances provides a useful commentary on the quality and usability of the reanalyses for many purposes.

Atmospheric reanalyses are produced by the major meteorological centers, including the National Center for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR; R1); NCEP/Department of Energy (DOE; R2) and NCEP Climate Forecast System Reanalysis (CFSR); ECMWF-40 Year Reanalysis (ERA-40); and ERA-Interim; the Japanese Meteorological Agency (JMA) 25-year Reanalysis (JRA-25); and the National Aeronautics and Space Administration (NASA) MERRA. The first generation of atmospheric reanalyses in the mid to late 1990s had substantial problems that limited their use, particularly for global climate change and variability studies. Two second generation global reanalyses, ERA-40 and JRA-25, addressed some of the shortcomings of the earlier reanalyses, but many of the problems tied to observing system changes and model deficiencies remain. CFSR is a new NCEP reanalysis of the atmosphere, ocean, sea ice, and land over 1979-2009. ERA-Interim is a global reanalysis extending from 1979 onward. MERRA is a new reanalysis from NASA Goddard from 1979 to the present. A different kind of reanalysis, the Twentieth Century Reanalysis (C20r) for the entire 20th century and beyond, is based only on specified SSTs and analysis of surface or sea level pressures.

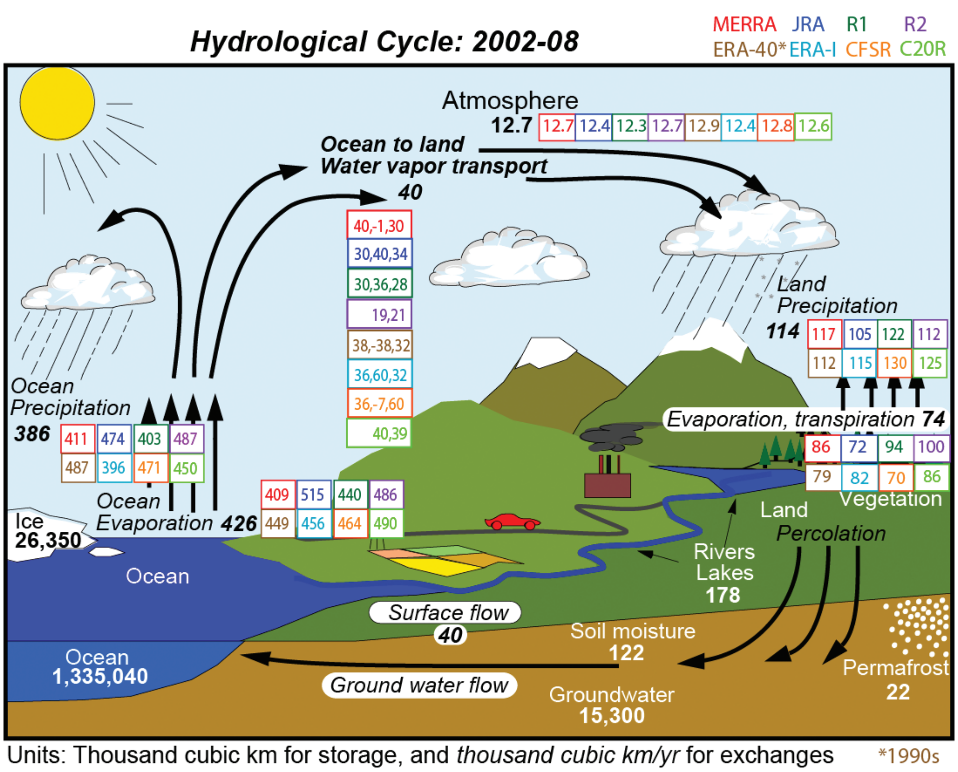
The results from all of the available reanalyses (Table 1) for the main atmospheric components of the hydrological cycle are given in the figure below for 2002-2008. Here the "observed" value stems mainly from Trenberth et al., 2007 (henceforth T07). All *P - ocean* estimates in the figure are high compared to the T07 estimate or that of the Global Precipitation Climatology Project (GPCP) (386). MERRA, R1, and ERA-Interim values are within seven percent while JRA, R2, ERA-40, CFSR, and C20r are clearly excessive. Aside from MERRA, *E - ocean* values from reanalyses are also high compared with the estimated values from T07 and JRA. R2, CFSR, and C20r are clearly much too high, even allowing for uncertainties or adjustments in observed estimates.

The older NCEP reanalyses contain limited moisture information over the ocean and the moisture fields are largely model values. For MERRA, ERA-40, and CFSR (see figure below), *P* exceeds *E* over ocean, a result that cannot be physically correct, highlighting the fact that the moisture for precipitation comes from the analysis increment and is then precipitated out. These models were evidently not capable of holding the observed levels of moisture, and promptly activated convective parameterization, which gets rid of the excess. This is evidently also true for R2 once the transport onto land is taken into account. Big changes in ERA-Interim vs. ERA-40 are evident.

Transport of moisture onto land from the moisture budget (see figure below) is less than *E-P* for the ocean in JRA and R1, suggesting that some precipitation occurs prematurely in those models over the oceans, while MERRA is the same, CFSR is slightly higher, and ERA-Interim is slightly less than the river discharge estimate.

On land, aside from JRA, which is low, precipitation is generally close to observed values, presumably because this quantity is tuned to match observations to some degree. For CFSR on land, the analysis increment evidently supplies some moisture for precipitation as evapotranspiration is slightly low compared with the estimate of 74, while precipitation is unduly high. *E* is high for MERRA, R1, R2, and C20r over land. As a result, *P-E* is generally too low except in C20r, while the value from CFSR is much too high. Hence there is a rough balance between the onshore transport and land *P-E*, with the largest differences for MERRA and CFSR.

There are quite substantial changes for 2002-2008 vs. the 1990s in several reanalyses, mainly for the ocean and especially in JRA, CFSR, and MERRA, owing to the TOVS to ATOVS transition, while ERA-Interim is sensitive to changes in SSM/I



Estimates of the observed hydrological cycle adjusted from Trenberth et al. (2007) to apply to the 2002-2008 period, with units in 1000 km³ for storage and 1000 km³/yr for exchanges. Superposed are values from the eight reanalyses for 2002-2008, color-coded as given at top right. The exception is for ERA-40, which is for the 1990s. For the water vapor transport from ocean to land, the three estimates given for each are: (i) the actual transport estimated from the moisture budget (based on analyzed winds and moisture), (ii) the E-P from the ocean; and (iii) P-E from the land, which should be identical.

data. The land values are more stable overall, signifying the more stable observing system over land, where radiosondes control values.

The low value of *P-E* on land in most reanalyses (except CSFR and C20r) is consistent with past studies showing that the lifetime of moisture in models is too short and recycling is too large, so that the contribution from advection is too low. For CSFR, the moisture for precipitation must come from the analysis increment but the implication is again that the model prematurely precipitates. In general, the precipitation and evaporation over oceans in reanalysis models are too large (except in MERRA). The errors relate to excessive evaporation. Chronically premature precipitation from models provides little reason for faith in the model estimates of *P* or *E*, and it is not uncommon for the balance to be between the analysis increment (instead of *E*) and precipitation in wet areas, or *E* and the analysis increment in dry regions (e.g., where the soil moisture has been specified incorrectly). For instance, this seems likely over Australia for ERA-40 (see T07) and also ERA-Interim.

Previously we found that the atmospheric moisture budget generally provides a better estimate of the hydrological cycle components, and this finding still holds with the latest reanalyses. Indeed, *E-P* from the moisture budget is considerably more stable in time and consistent across the reanalyses. Hence our observational best estimates of the energy and water budgets and components of the hydrological cycle generally provide a key test of the fidelity of both the reanalyses and climate models. The results also inform our knowledge about *E-P*.

Results are consistent with the view that recycling of moisture is too large in most models and the lifetime of moisture is too short. For the energy cycle, most reanalyses have spurious imbalances of approximately 10 W/m^2 within the atmosphere, and approximately 5-10 W/m^2 in net fluxes into the surface and to space. Major improvements are needed in model treatment and assimilation of moisture, and surface fluxes from reanalyses should only be used with great caution.

Acknowledgments
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References

Dai, A., and K.E. Trenberth, 2002. Estimates of freshwater discharge from continents: Latitudinal and seasonal variations. *J. Hydrometeor.*, 3, 660–687.

Dai, A., T. Qian, K.E. Trenberth, and J.D. Milliman, 2009. Changes in continental freshwater discharge from 1949-2004. *J. Climate*, 22, 2773–2791.

Trenberth, K.E., L. Smith, T. Qian, A. Dai, and J. Fasullo, 2007. Estimates of the global water budget and its annual cycle using observational and model data. *J. Hydrometeor.*, 8, 758–769.

Trenberth, K.E., J.T. Fasullo, and J. Mackaro, 2011. Atmospheric moisture transports from ocean to land and global energy flows in reanalyses. *J. Climate*, 24, 4907-4924.

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Lessons Learned from Conducting Assessments of Global Water and Energy Data Sets

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An important evolving role in GDAP has been conducting assessments of global data sets produced by the international community. These assessments include all global water and energy products, as well as radiative transfer codes that form the basis of the retrievals as well as model simulations (see: *http://gewex.org/gdap/gdap_assessment_wgs.html*). In the hope of providing helpful guidance to other groups planning to undertake assessment activities, we provide the following summary of the lessons learned by GDAP.

The assessments discussed here refer primarily to spaceborne data sets for which there are a variety of data sources produced by individual investigators, agencies, and nations. These products often have no simple ground-based equivalents to define "truth" and the best products often cannot easily be identified unless an application is defined. For new users, this data set diversity can be confusing, and without the proper background information and understanding of the limitations of available data, there is a danger that these data may be incorrectly applied or misinterpreted. Assessments in the GDAP sense therefore consist primarily of documented expert opinions on data products for use by the research and the user communities. An example is the soon-to-be-released GEWEX Radiative Flux Assessment, which involved 75 participants representing nearly all the space and weather agencies around the world.

Assessments, like the products they assess, should not be viewed as static but rather as dynamic activities that may need to be repeated every 5-10 years depending upon the rate at which products are being added or modified within a given discipline.

It is often difficult to define a single best climate data source. Data sets are instead most often complementary in nature with varying strengths and weaknesses. Essential elements that define the usefulness of a data set are certainly its accuracy and error characterization, but data products can be evaluated too favorably by the developers themselves in order to encourage data usage. Comparisons to data products from alternative sources are not undertaken often enough. In contrast, comprehensive evaluations against reference data and side-by-side comparisons among all available data sets (at different spatial and temporal scales) are prerequisites for smart data choices in user applications. In addition to error characterization and comparisons among available products, data usefulness depends upon factors such as spatial or temporal coverage, data access, length of record and supporting documentation, both project-type documentation and peer-reviewed product description and analysis, and a listing of peer-reviewed research reports that have used the data product. The publicly available information on these elements is usually rather limited and should be made explicit in assessment reports.

It is the task of the assessments to conduct objective and independent evaluations and intercomparisons. The basic goal is to point out differences and limitations and, if possible, to provide reasons for them. In that context, it helps to involve the scientists who created the data so that sufficient background information on instruments, applied methods, and underlying assumptions and limitations can be more fully understood and conveyed to the user. When possible, it is better if comparisons are conducted by investigators with expertise in the field who did not create a product being evaluated in the assessment. This avoids potential aliasing of the results by someone who may have an interest in a particular assessment outcome. While desirable, this has not been possible with all of the GDAP assessments. Having more than one investigator directing the assessment was found to mitigate these concerns.

When product developers are involved, there is a tendency to broaden the goal of the assessment from its original intent of informing the user community to one of using the assessment itself as a diagnostic to help investigators improve their respective products. The second objective clearly requires broad participation from the data producers. GDAP has found that these two objectives are, in fact, compatible with one another but should always be kept distinct in the assessment. GDAP has also found that including model data sets in the comparisons is often useful in that it immediately incorporates the needs of an eventual user community.

Assessments often create specialized data products that can be of great value to the community after the assessment is completed. This includes any validation data assembled for the assessment as well as any common gridded products created from the original data sets. In addition to easy access to the assessment report, and the detailed methodology used in the analysis, the data sets created specifically for the assessment were found to be particularly helpful as data sets often get revised and updated even over the relatively short period of the assessments. Having assessment-specific data sets and procedures available allows new products to be evaluated in a consistent manner.

The assessment of geophysical products should cover the following elements (see figure on page 12):

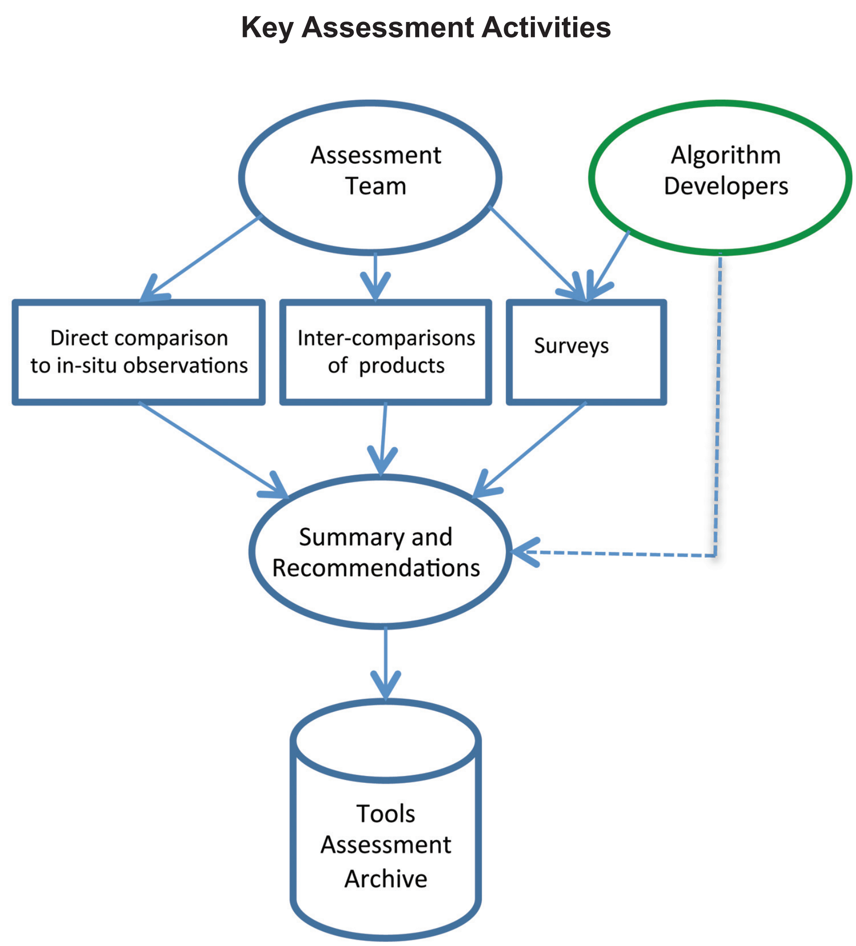
- A survey of available data and background information about these.
- A quantitative examination of strengths and limitations against reference data (especially if data of higher accuracy and higher maturity are available).

- Intercomparisons of different data sets (at different scales).
- Recommendation for intended data uses and areas for which data should "not" be applied.
- Easy access to the assessment report and all examined data sets and methods.

Assessments usually rely on voluntary efforts, which can take considerable time to finish and can collapse unless there is strong leadership. Assessments should also include:

- A dedicated, motivated, and respected person to lead the effort.
- Complementary assessment team members with specialized knowledge.
- Regular team meetings.
- A centralized data depot for data sets created specifically for the assessment (e.g., validation data or common gridded products) that can be used to facilitate assessments by new products or new versions of existing products.
- Seed funding for the centralized activities.

Assessments, like the products they assess, should not be viewed as static but rather as dynamic activities that may need to be repeated every 5-10 years, depending upon the rate at which products are being added or modified within a given discipline. Even if the validation data, procedures, and previously assessed data are archived for interim use by new product developers, comprehensive assessments are critical to move the field forward in a systematic way.



Key assessment activities include not only the classical comparisons to in situ observations, but also intercomparisons among products and detailed surveys related to the intended uses of products. In addition to recommendations, assessments should strive to save procedures and data sets that allow future product developers to repeat the assessment for their product.

Benefits of Assessments

To Product Providers:

- Allow objective selections of appropriate data products.
- Provide background information on available products.
- Provide easy access to data in a common user-friendly format.
- Establish reference data test-beds and tools for external evaluations.

To Science and User Communities:

- Provide independent and transparent quality assurance for products.
- Endorse the use and the credibility of products to a broader community.
- Identify key limitations in products to stimulate improvements.

Meeting/Workshop Reports

9th Global Water System Project SSC Meeting

18-20 October 2011
Xi'an, China

Rick Lawford[1] and Janos Bogardi[2]

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The Global Water System Project (GWSP) Science Steering Committee (SSC) Meeting was chaired by Dr. Claudia Pahl-Wostl of the University of Osnabruck, Germany. Dr. Jun Xia, the Director of the Key Laboratory of Water Cycle and Related Land Surface Processes at the Chinese National Academy of Sciences in Beijing, hosted the meeting at the University of Science and Technology in Xi'an.

During the past year, the GWSP International Project Office (IPO) together with members of the SSC have contributed to the preparations for a number of meetings, and have carried out research, outreach, and data stewardship activities. GWSP is organizing a session at the upcoming 6th World Water Forum in Marseille, France in March 2012, and partnering with GEWEX and other organizations in organizing a session on "the integrated assessment, governance and management of water in a changing world at global, regional and transboundary levels" at the Planet Under Pressure conference being held in London in March 2012.

Dr. Janos Bogardi, the GWSP Executive Officer, has been leading the preparation of a book based on the 2010 Global Catchment Initiative (GCI) Conference. The IPO published a new flyer, developed a computer-based information show, and supported an exhibit at the World Water Week Conference in Stockholm in August 2011. Dr. Bogardi and a number of SSC members prepared a policy paper for the Rio+20 Conference in June 2012. The IPO also arranged for the transfer of the GWSP Digital Water Atlas to the Global Runoff Data Centre. In addition, the GWSP IPO, acting on behalf of the project scientists, has applied for partnership status with UN-Water.

Phase-2 of the GCI Project has been launched and will address some of the core science questions related to the impact of integrated water-energy-food security issues on major river basins, and in turn, the changes in water management that have arisen to address these emerging challenges, particularly in the context of climate change and increases in the demand for water. Rick Lawford reported that survey questionnaires were being distributed to experts on 18 basins in five continents and included questions dealing with climate change, land use change, river channel modifications, water quantity and quality issues, agricultural and energy drivers and tradeoffs, biodiversity, extremes and risk management, legal frameworks and ownership, environmental services, conflict and conflict resolution, government intervention, and governance. A GCI Phase II Workshop is being planned in conjunction with a Water-Energy-Food Security Conference in Winnipeg, Manitoba, 1-4 May 2012.

Dr. Stuart Bunn provided an overview of a number of Global Scale Initiative activities, which use the indicators study (Vörösmarty et al., 2010) on global threats to human water security and river biodiversity, and moves them into the forecast mode through use of future scenarios. In addition to the threat mapping that has been carried out, ecosystem services are being tabulated and their changes evaluated over time using an econometric model. Work on river health in Asia is continuing using the indicators that have been tested in other environments.

Dr. Claudia Pahl-Wostl described the Twin2go Project (*http://www.twin2go.uos.de/*), which involved comparative studies between basins in different geographical areas. The Project has resulted in methodological innovations with respect to knowledge integration, improved understanding on water governance regimes, reports, scientific publications, policy briefs, and an online database.

Dr. Sharad Jain described the problems related to designing dams and new water infrastructure when upstream flow data are not considered. In India, this is complicated by the special management considerations that must be addressed when rivers are used for religious and cultural reasons. He advocates the integration of monitoring, evaluation, and adjustment (adaptive management) into water resources development plans.

Research in the Philippines is currently underway to assess the impacts of climate change on extreme events. The research described by Dr. Falino Lansigan includes downscaling of climate scenarios, conducting hydrologic frequency analysis in a changing climate, assessing the implications of updating engineering standards (e.g., drainage, flood control, water resources management), and exploring climate change adaptations. A conference on water and agriculture is planned in the Philippines in November 2012.

Priorities for water management in China are shifting from water quantity management to water quality management, and from water supply management to water demand management. Dr. Jun Xia reported on a new project to study the impacts of climate change on water resources in China. The study, entitled "Impact of Climate Change on Water Cycle, Regional Water Resources Security and the Adaptation Strategy for the Eastern Monsoon Area of China," is designed to provide assessments of the vulnerability of water resources to climate change and advice on the adaptive management steps to be taken.

Dr. Hong Yang described studies being undertaken to assess the virtual water flows across sectors and geographical regions including China, and modeling studies in Africa to assess the impacts of climate change on freshwater availability (and food security) with a focus on the Niger, Congo, and Nile rivers. These studies provide an analysis of the extent to which water can be considered as an economic resource and highlight the major challenges facing sustainable catchment water management in the context of globalization, based on the experiences of different countries and regions. Drought and its consequences are featured in these studies in terms of the extent of drought impacts on crop yield and the value of this information for a "drought hotspots" map.

GWSP continues to build linkages to GEWEX and the Global Earth Observing System of Systems (GEOSS) through the Water Societal Benefit Area (SBA). A recent survey by the Group on Earth Observations (GEO) on data needs in its nine SBAs showed that precipitation is the most frequently requested variable, followed by soil moisture. GEWEX is leading scientific initiatives in these two key areas. Other areas where GEWEX can provide a scientific and observational basis for the applications that GWSP may undertake include the GEWEX Regional Hydroclimate Projects and the GEWEX Hydrologic Applications Project (HAP)'s work on drought. The GEO Capacity Building efforts in Asia, Africa, and Latin America could form the basis for an effective network of hydrologists with interest and expertise in issues that are being addressed by GWSP.

GWSP is making progress on completing its commitments in its 10-year research plan, although some uncertainties exist. The IPO had a sudden decrease in its staffing with the departure of Andrea Meyn and the death of Konrad Vielhauer. IPO funding was extended to June 2012, which will enable the office to support meetings and activities until that time. The IPO is planning to submit a multi-year follow-on proposal to the German government. A GWSP wrap-up conference is planned for 2013 that would pave the path for a new water initiative within the evolving International Council for Science (ICSU) framework.

Reference

Vörösmarty, C.J., P.B. McIntyre, M.O. Gessner, D. Dudgeon, A. Prusevich, P. Green, S. Glidden, S.E. Bunn, C.A. Sullivan, C.R. Liermann, and P.M. Davies, 2010. Global threats to human water security and river biodiversity. *Nature*, 467, 555-561.

GEWEX NEWS

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Third Cloud Retrieval Evaluation Workshop (CREW-3)

13-17 November 2011
Madison, Wisconsin, USA

Rob Roebeling[1], Bryan Baum[2], Ralf Bennartz[2], Ulrich Hamann[3], Andy Heidinger[4], Anke Thoss[5], and Andi Walther[2]

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Clouds strongly modulate the energy balance of the Earth and its atmosphere through their interaction with solar and thermal radiation (Cess et al., 1989). However, because cloud properties vary on timescales of seconds to days, and also spatially on scales from meters to thousands of kilometers, clouds are represented in a rudimentary way in climate and weather forecast models and contribute largely to the uncertainty in climate predictions. The radiative behavior of clouds depends predominantly on cloud cover and cloud micro- and macrophysical properties, such as the cloud height, cloud thermodynamic phase, and cloud ice/water path. Measurements of the global distributions of these properties, and their diurnal, seasonal, and interannual variations are critical for improving our understanding of the role of clouds in the weather and climate systems.

Cloud Retrieval Evaluation Workshops (CREWs) provide an international forum for sharing state-of-art cloud parameter retrievals obtained from passive imaging satellite observations, and provide a path towards optimizing these retrievals for both climate monitoring research, as well as for climate and weather model analysis. The overarching objectives of CREWs are to identify and address research questions related to cloud parameter retrievals; to enhance communication among scientists; to develop international partnerships; to provide a comparison and validation platform; and to provide retrieval verification and validation statistics. An important component of the workshops is the discussions on the results of the algorithm and sensor comparisons and validation studies.

Twenty-five participants attended the first CREW, which was held in 2006 in Norrköping, Sweden. In 2009, 45 attended CREW-2, and almost 70 participants from universities, research institutes, and satellite agencies in Europe and the United States participated in CREW-3.

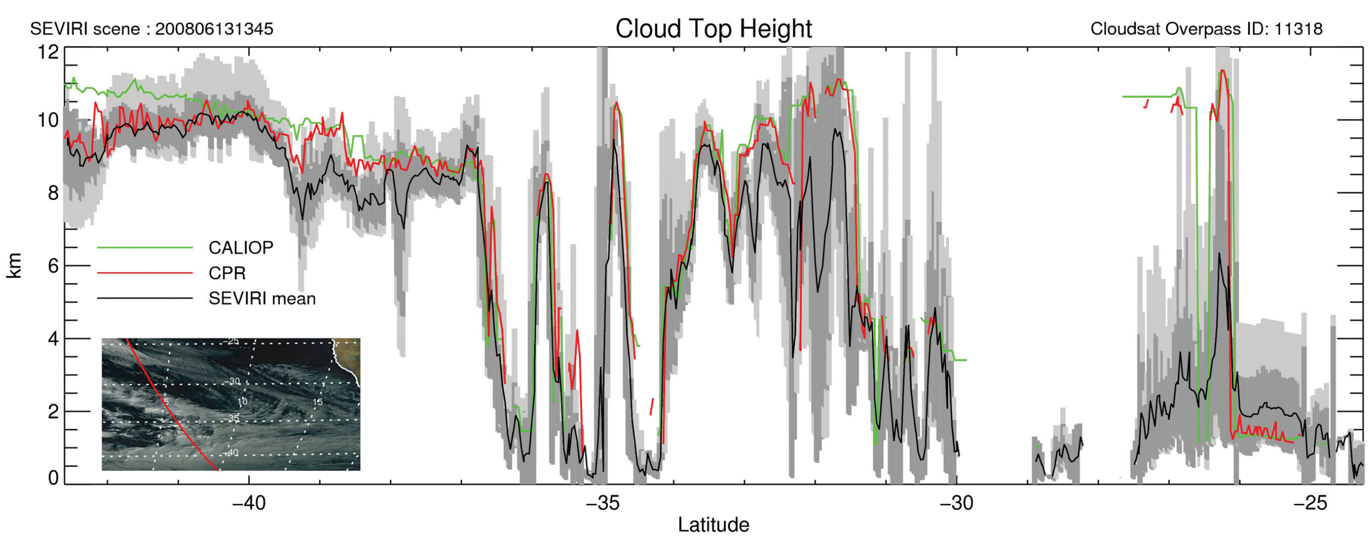
A topic of great interest at CREW-3 was how each team filtered their global results for detailed analysis and comparison with other products. A common database was built to organize cloud property retrievals from different algorithms for passive imagers [Meteosat Second Generation (MSG), Moderate Resolution Imaging Spectroradiometer (MODIS), Advanced Very High Resolution Radiometer (AVHRR), POLarization and Directionality of the Earth's Reflectances (POLDER) and/or Atmospheric Infrared Sounder (AIRS)]. These were complemented with cloud measurements that serve as a reference [CloudSat, Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), Advanced Microwave Sounding Unit (AMSU), Multi-angle Imaging SpectroRadiometer (MISR)] for a number of "golden days." Prior to the Workshop, the data were evaluated by a European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) Fellow and several workshop participants. It is now common to compare individual products from passive sensors with the active sensor measurements from the A-Train constellation of satellites. In this way more knowledge may be gained on the behavior of the different retrieval schemes over different cloud conditions.

In the session on instrument calibration, presentations were given on methods to obtain calibrated satellite radiances, stressing the importance of these Fundamental Climate Data Records (FCDRs) as input to cloud parameter retrieval algorithms. The session on cloud reference observations included several presentations on the capabilities of recent active satellite instruments, such as CloudSat, CALIPSO, and the passive microwave instrument, AMSR, for the observation of cloud parameters. Besides the value of these observations for cloud research in general, they are also an important source of information for the validation of passive imager retrievals. Comparison of passive to active cloud properties is increasingly important in the framework of CREW. In the sessions on cloud detection, cloud properties retrievals, and intercomparison and validation, many talks addressed the physical fundamentals of cloud remote sensing with results provided from comparison and validation studies. Presentations were also given on conditions and requirements that need to be satisfied for the generation of "well understood" cloud parameter data records, and on the use of these Thematic Climate Data Records (TCDRs) in several climate monitoring and climate model evaluation studies.

A more focused analysis of cloud retrieval principles and the validation of cloud parameters was made within three parallel breakout sessions. The topics of these sessions were: (i) cloud vertical placement; (ii) cloud physical properties; and (iii) cloud climatologies.

All working groups stressed the necessity of long-term, well-calibrated and homogenized (i.e., common grid and format) data sets of satellite products. These data sets are needed to ensure the quality of instantaneous cloud parameter retrievals, whereas they are inevitable for developing TCDRs that are suitable for detecting climate trends. They also expressed the intent to actively contribute to the workshop's cloud parameter assessment, aiming to quantify the sensitivities of cloud parameter retrievals to different sources of error and to increase our scientific understanding of the different physical (assumptions) and philosophical approaches adopted by the retrieval teams. More specifically, the Working Group on Cloud Vertical Placement suggested that cloud height and temperature retrievals be complemented with information on the cloud type (i.e., opaque, semi-transparent, or multiple-layer clouds). In addition, this group strongly supported the recent developments towards better detection of multiple-layer clouds in an atmospheric column.

The Working Group on Cloud Physical Properties discussed in detail the differences between cloud property retrievals from infrared (IR) observations, and the microphysical properties of ice cloud models that should be used to retrieve ice cloud parameters from visible (VIS) and shortwave infrared (SWIR) observations. They concluded that IR-only cloud



Example of the comparison between ten Meteosat Spinning Enhanced Visible and Infra-Red Imager (SEVIRI) cloud top height retrievals and corresponding Calipso CALIOP and CloudSat Cloud Profiling Radar (CPR) observations for the A-Train overpass on 13 June 2008 around 13:45. The gray shades represent the 66th and 95th range of the SEVIRI retrievals.

optical thickness retrievals appear to have better skill than VIS/SWIR techniques for clouds with optical thicknesses smaller than three. Based on comparisons between the active sensor Cloud-Aerosol Lidar with Orthogonal Polarisation (CALIOP), VIS/SWIR, polarized measurements from the Polarization and Anisotropy of Reflectances for Atmospheric Sciences coupled with Observations from a Lidar (PARASOL), and IR-only retrievals of optical thickness, the retrievals for ice cloud seem to match best with nature when roughened particles are assumed.

Finally, the Working Group on Cloud Climatologies discussed ways forward to accommodate a common approach for generating global gridded (Level 3) cloud climatologies with respect to methods used for spatial sampling and methods for calculating uncertainty information. Moreover, the need was stressed for uniformity among the cloud parameter data sets.

The collaboration initiated at CREW-3 will be continued. The attending scientists strongly support the proposal to establish working groups on the three research topics of the breakout sessions, and through these, enhance exchange and collaboration on these topics in the future. In support of the GEWEX Cloud Assessment, the Work Group on Cloud Climatologies will seek to advance the aggregation methods used to derive Level-3 cloud parameters from Level-2 instantaneous retrievals, and help to produce climate data records with sufficient quality and error characterization for studying trends on seasonal, interannual and decadal time scales. The attending scientists acknowledged the need for preservation of their data in formats that are widely accessible, and increase the use of their data by adopting common data formats. The goal of working towards traceability and uniformity in data products includes discussions on data quality, analytical standards, and strategies for data interpretation. To work towards these goals, it was suggested that connections be established with international programs that coordinate these type of activities, such as the Sustained Co-Ordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM).

More detailed information on the workshop can be found on the CREW website at: *http://www.icare.univ-lille1.fr/crew/*. The passive imager retrievals and the reference data in the common database are available via the CREW FTP site, and can be downloaded after registering at: *http://www.icare.univ-lille1.fr/register/register.php*. When asked for a "short description of your project," please state that you have an account request for the Cloud Retrieval Evaluation Workshop.

Reference

Cess, R.D., G.L. Potter, J.P. Blanchet, G.J. Boer, S.J. Ghan, J.T. Kiehl, H. Le Treut, Z.-X. Li, X.-Z. Liang, J.F.B. Mitchell, J.-J. Morcrette, D.A. Randall, M.R. Riches, E. Roeckner, U. Schlese, A. Slingo, K.E. Taylor, W.M. Washington, R.T. Wetherald, and I. Yagai, 1989. Interpretation of cloud-climate feedback as produced by 14 atmospheric general circulation models. *Science*, 245, 513-516.

GEWEX/WCRP Calendar

For the complete Calendar, see the GEWEX website: http://www.gewex.org/

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

2–4 April 2012—WCRP Polar Climate Initiative Workshop—Toronto, Canada

11–13 April 2012—Global Drought Information System Workshop—Frascati, Italy

22–27 April 2012—EGU General Assembly 2012—Vienna, Austria

7–10 May 2012—6th HyMeX Workshop—Primosten, Croatia

7–10 May 2012—SOLAS Open Science Conference—Cle Elum, Washington, USA

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

14–16 May 2012—GEWEX/GRACE Workshop on application of GRACE data to climate modeling and analysis—Woods Hole, Massachusetts, USA

14–17 May 2012—GDAP Water Vapor Assessment Workshop—Frankfurt, Germany

16–19 May 2012—YOTC International Science Symposium and 8th AMY International Workshop—Beijing, China

22–25 May 2012—5th WMO Workshop on the Impact of Various Observing Systems on Numerical Weather Prediction—Sedona, Arizona, USA

28 May – 2 June 2012—5th International Conference BALWOIS 2012 on Water, Climate and Environment—Ohrid, Republic of Macedonia

5–8 June 2012—16th International Symposium for the Advancement of Boundary Layer Remote Sensing—Boulder, Colorado, USA

6–9 June 2012—MedCLIVAR Final Conference—Leece, Italy

2–6 July 2012—4th AMMA International Conference—Toulouse, France

16–20 July 2012—33rd Session of the WCRP Joint Scientific Committee—Beijing, China

1–3 Aug 2012—12th Meeting of the GEWEX Baseline Surface Radiation Network (BSRN) Project—Potsdam, Germany

3–7 Sept 2012—2012 EUMETSAT Meteorological Satellite Conference—Sopot, Poland

10–14 Sept 2012—1st GEWEX Pan-Global Atmospheric System Studies (GASS) Meeting—Boulder, Colorado

10–14 Sept 2012—GEWEX/GLASS LoCo Workshop and Panel Meeting—Boulder, Colorado

1–3 Oct 2012—GEWEX Data and Applications Panel (GDAP)Meeting—Paris, France

15–19 Oct 2012—25h Session of the GEWEX SSG—Sydney, Australia