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An Integrated System for Water Budget Closure Over the Pan-Tropical Land Mass: A TRMM Validation Effort

J. Roads, University of California, San Diego/Scripps Institution of Oceanography (Scripps)

In collaboration with Charles Vorosmarty, University of New Hampshire (UNH)
Cort Willmott, University of Delaware (UDel)

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1. Analysis of the surface hydrologic cycle

Roads et al. (1999) compared characteristics of the National Centers for Environmental Prediction and National Center for Atmospheric Research (NCEP/NCAR) reanalysis surface water budget to the surface water budget characteristics in a long-term simulation with the NCEP global spectral model (GSM) used in the reanalysis. There are many geographic similarities. There are a few differences, though, mainly because the reanalysis has a source (artificial) of water from a seasonally varying damping (forcing) term. Because the GSM does not have this (forcing) term, the GSM surface becomes dryer and ultimately has decreased land evaporation and precipitation. Since evaporation variations are strongly related to surface air and skin temperature variations, this decreased GSM surface water is also associated with increased land temperature. However, the GSM surface water variability is greater because the reanalysis time constant (60 days) used to damp (force) the surface water back to the assumed climatology, is shorter than characteristic land surface parameterization hydrologic times, which are on the order of 6 months. In agreement with the decreased surface water variability, the reanalysis evaporation variability is also less than the evaporation variability in the GSM. This artificial time constraint may be a reason that the reanalysis temperature predictability by surface water is less than the demonstrated GSM predictability.

2. Long term CO2 sensitivity simulations with NCAR's CCM3 and global recycling rates

In a related effort, a number of climatological simulations and sensitivity experiments with the latest NCAR community climate model coupled to a sea-ice mixed layer model (Roads et al. 1998a) were compared to NCEP reanalysis and each other. In addition to a control run forced by observed sea surface temperatures for the period 1950-1994, there were a number of 20 year COs simulations developed, ranging from concentrations of 100 ppm to 3000 ppm. Global cycling rates were then calculated. A cycling rate was defined previously as the ratio of the precipitation to precipitable water, P/QT. Roads et al. (1998b) suggest that the cycling rate may ultimately decrease in the future and that the presumed intensification of the hydrologic cycle is due more to an increase in the water vapor storage than the cycling rate.

3. Tropical Atmospheric Hydrologic Cycle

Roads et al. (2001a) compared the National Centers for Environmental Prediction (NCEP) and Department of Energy (DOE) Reanalysis II tropical hydrologic cycle to TRMM products. Our eventual goal is to be able to utilize the global spectral model (GSM) used for the reanalysis as a predictive model for seasonal and longer climatic predictions. TRMM products provide a benchmark for comparison of the tropical hydrologic cycle terms. In particular, we can analyze the precipitation characteristics in the reanalysis to determine if we can replicate the TRMM observations. In addition, we can compare the parameterized evaporation to the evaporation deduced from a residual sum of TRMM precipitation and reanalysis moisture convergence. We found that the reanalysis precipitation certainly resembles, in many respects the TRMM observations. However, the biases were a bit larger and the correlations were a bit lower than we had hoped for originally. For example, the RII precipitation is larger than the TRMM precipitation (3.1 mm/day) by about .3 mm/day. The correlations were highest during the Boreal winter (.6) and lowest during the summer. Spatially the correlations were highest over the ocean and lowest over land, especially over Africa. Low correlations also occurred over the subtropical regions. The RII evaporation is about .2 mm/ day larger than the evaporation deduced as a residual of TRMM precipitation and moisture convergence (3.6 mm/day). For this field, the correlations were high only over the ocean. Over land regions the correlation was much lower and even highly negative. Perhaps not too surprising was that the net moisture convergence (-.44) is negative indicating that the tropics are a source of moisture for the rest of the globe. Also what may not be too surprising is that the equations have a residual moistening effect (.13), which is correlated highly with the difference between the TRMM and RII precipitation. This presumably indicates that most of this residual is due to RII precipitation being too strong initially; it is hypothesized that the balance would get better as spin down occurs.

4. GCIP WEBS

Roads et al. (2001b) are developing a water and energy budget synthesis (WEBS) for the Global Energy and Water Cycle Experiment's (GEWEX's) Continental Scale International Project (GCIP) over the Mississippi River Basin from observations and models for the period 1996-1999. The synthesis includes a general description of the Basin climate, physiographic characteristics, a brief description of available observations, types of models used for GCIP investigations, and a comparison of water and energy variables and budgets from models and observations. Observations cannot adequately close budgets since too many fundamental observations are missing. Models, especially analysis models are required for many individual processes that are not really measured in any meaningful way on a continental scale. For example, soil moisture and evaporation are measured at only a few sites, although there are intensive efforts to develop satellite-derived products. High-resolution atmospheric moisture and dry static energy convergence cannot easily be derived from radiosonde observations. Models that properly represent complicated interactions may ultimately provide better overall descriptions of the budgets than any attempt to grid observations of a single variable from only knowledge of only the observations. Models will also be required for predictions. Therefore, as part of the general synthesis, the purpose of this paper is to compare different classes of models with available observations. We compare a global general circulation model with a regional climate model along with global and regional analyses, a macroscale hydrologic model and observations. There does appear to be a clear advantage to using a regional analysis over a global analysis or a regional simulation over a global simulation to describe the budgets. There also appears to be some advantage to using a macroscale hydrologic model for at least the surface water budgets although the surface energy budgets may still be better simulated by the atmospheric analyses.

5. The Impact of Precipitation Uncertainties on Global Water Balance Calculations

Water balance calculations are becoming increasingly important for a various earth system studies. Precipitation is a critical variable for such calculations since it is the immediate source of water in the land surface hydrological budget. Numerous precipitation data sets have been developed in the last two decades, but these data sets often show marked differences in depicting the spatial and temporal distribution of the precipitation. Fekete et al. (2001a) describe five global monthly precipitation data sets (Climate Research Unit of University of East Anglia, Global Precipitation Climate Center, Global Precipitation Climatology Project, NCEP/NCAR Reanalysis, Willmott-Matsuura) to assess the uncertainties these data sets represent in depicting the spatial and temporal distribution of the precipitation and its impact on the water balance model calculations. The five data set tested here were climatologically averaged and compared regionally by calculating various statistics of the differences.

Fekete et al. (2001b) used the different precipitation data sets in a water balance model context to demonstrate the impact of the uncertainties in precipitation on the estimated runoff. A water balance model operating globally at 30-minute resolution was applied with different configuration representing the evapotranspiration processes. The different runoff estimates calculated by varying the input precipitation data sets and the configuration of the water balance calculations were compared to each other and measured discharge. This comparison revealed clear spatial patterns in the runoff biases. Precipitation uncertainties result in increased uncertainties in the runoff estimation. The magnitude of the uncertainties in runoff calculation due to uncertainties in precipitation was found to be equal or greater than the uncertainties in the formulation of the evapotranspiration processes in the water balance calculations.

Fekete and Vorosmarty (2001a) also compared four gridded mean monthly time series of air temperature and precipitation covering the South American continents for the 1960-90 period. The different data sets were tested in the context of a water balance model and mean annual estimated runoff was compared to observed runoff at selected gauging sites. Fekete and Vorosmarty (2001b) described the impact of these uncertainties on water balance calculations. In particular, the water balance results were compared against measured river discharge in a simulated river network context. River discharge is one of the most accurately measured components of the hydrological cycle and therefore can serve as an excellent source of information for validating water balance calculations. A procedure which combines measured river discharge with water balance modeled runoff to produce composite fields of high spatial resolution but mass-constrained by the observational record for discharge was also described.

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