3.1 AN EVALUATION OF A 30-YEAR LAND SURFACE MODEL SIMULATION USING OBSERVATIONAL FORCING

Hatim Sharif*[1], W. Crow[2], N.L. Miller[3], K.E. Bashford[3], and E.F. Wood[4]

[1]National Center for atmospheric Research, Boulder, Colorado
[2]ARS-USDA Hydrology and Remote Sensing Lab., Beltsville, MD
[3]Lawrence Berkeley Laboratory, Berkeley, CA
[4]Princeton University, Princeton, NJ

1. Introduction

Long-term basin-scale hydrologic response is related to physiographic descriptors and climate data. Multi-year land surface and subsurface processes are coupled to topography as well as large-scale atmospheric processes, soil memory, and vegetation change. The use of long records of observational data to determine the variability of land surface moisture fluxes and storages is instrumental in the search for answers to key science questions such as "Is the Global Hydrologic Cycle intensifying?", "To what degree?", "What is role of human activities?"`. The Arkansas-Red River basin has extensive data collection networks for meteorological and hydrological data. For this reason, these basins were the first large scale areas studied under the GEWEX Continental Scale International Project (GCIP). Portions of the basin were the site of the latest International H_2O Project (IHOP-2002) and the Department of Energy's Water Cycle IOP 2002 experiments. In addition, the basins contain a number of US Department of Agriculture Agricultural Research Service (USDA-ARS) experimental catchments, The US Department of Energy Atmospheric Radiation Cloud and Radiation Test Bed (ARM-CART) site, and the Cooperative Atmosphere-Surface Exchange Study (CASES) boundary layer facility.

*Corresponding author address:
Hatim Sharif
P.O. Box 3000
Boulder, CO 80307-3000
tel: (303)497-2832
fax: (303)497-8402
email: sharif@ucar.edu

2. The Study Area

The Arkansas and Red River basins are located in the Southern Great Plains of the United States. The two rivers are treated as one system because of similar climatologies. The Arkansas River basin has an area of 409,273 km^2 while the Red River basin has an area of 156,978 km^2. The headwaters of the basins come from the continental divide of the Rocky Mountains; both rivers, with almost parallel course, flow eastward to the Mississippi River. The Arkansas River joins the Mississippi near Little Rock, AR and the Red River near Shreveport, LA.
Figure 1 shows the location of the Arkansas-Red River basin in the United States Southern Great Plains (SGP) region. Rainfall climatologies of the basin display a strong east/west gradient, with drier conditions prevailing in the western part of the basin. The region generally sees precipitation maximums in the spring and fall and a relatively dry late summer. Significant orographic precipitation at the highest elevations in the west near the

continental divide is an exception. Snow accumulation has a significant contribution to the headwaters, but covers a relatively very limited area and does not have a significant influence on the climatology and hydrology of the basin. Runoff ratios in the basin are generally on the order of 10 to 20%. Typical seasonal cycles of soil moisture exhibit maximums during the late spring and minimums during the late summer and early fall. Late growing season minimums can be pronounced and soil moisture control on evapotranspiration is common during the summer months. Vegetation generally ranges from grassland in the drier western parts of the basin to deciduous forest in the east, although a large portion of the eastern region is cultivated.

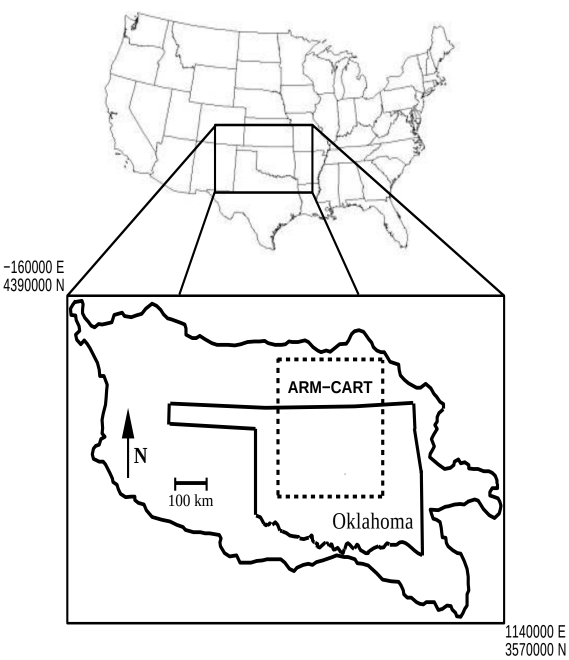

Figure 1

3. The Model

TOPMODEL-Based Land-surface Atmosphere Transfer Scheme (TOPLATS) (Peters-Lidard et al. 1997; *Famiglietti and Wood* 1994; *Famiglietti,* 1992) incorporates a TOPMODEL framework to account for lateral redistribution of subsurface water based on the local topography and soil transmissivity. TOPLATS is particularly well suited for such an analysis since it combines a detailed representation of surface water and energy balance processes while capturing the topographically induced horizontal redistribution of subsurface water. Spatial heterogeneities in soil moisture, which can be manifestation of heterogeneity in topography, soils, and vegetation, have been shown to be important controls on aggregated fluxes and boundary layer development.

4. The Data

The main source of soil properties is the US Soil Conservation Service State Soil Geographic database (STATSGO). STATSGO include soil texture, residual moisture and total soil depth to bedrock from which other properties were derived. Parameters related to vegetation were obtained from the ISLSCP global data. 30 year daily 1/8th degree gridded meteorological forcings data were obtained from the Surface Water Modeling group at the University of Washington from their web site at http://www.hydro.washington.edu/Lettenmaier/gridded_data/, the development of which is described by *Maurer et al*. (2002). The daily forcings were then disaggregated to hourly gridded data using a disaggregation technique based on *Maurer et al*. (2002).

5. Preliminary Results

A 30-year simulation using the fully distributed version of TOPLATS at 1km resolution for the Arkansas-Red River basin is being preformed. Forcing data (precipitation, incoming radiation and

surface meteorology) interpolated from meteorological and rain gauge observations are used. Preliminary modeling work was based on modeling results for the 1994 growing season over the Arkansas-Red River basin presented by *Crow* (2001). Domain-averaged water and energy balance modeling results are shown in Figures 2 and 3 respectively. Soil moisture traces show the distinct mid- to late-summer dry-down that is typical of the region. Simulated runoff results give a runoff ratio of 15% - near climatological expectations for the basin. More detailed calibration of the model versus stream flow observations was conducted for given small catchments distributed in the eastern portion of the basin. July 1994 was usually wet with several large-scale precipitation systems wetting the basin. The strongest dry-down during the simulation period was in late June.
This dry-down is reflected in modeled surface energy fluxes shown in Figure 3 – especially the peak of sensible heating during late June. Relatively lower sensible heating values during July are consistent with the usually large amount of precipitation observed during the month. Ground heat flux decreases steadily during the simulation period due to the steady thickening of vegetation cover throughout the growing season. Large-scale validation of modeled energy flux observations occurred within the ARM-CART study area (see Figure 1). During the simulation period the spatial averages of TOPLATS energy flux results and ARM-CART observation within the study area match to within a root-mean-square error of about 30 W/m^2.

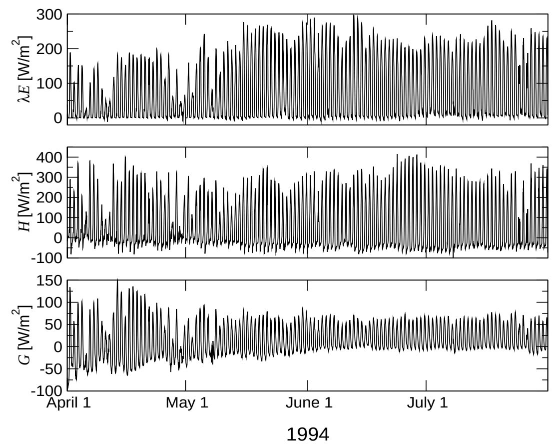

Figure 2

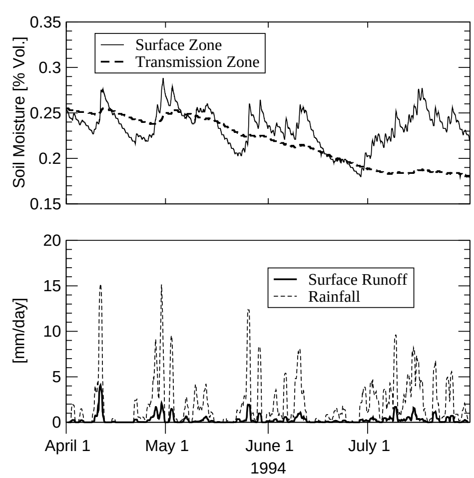

Figure 3

6. Work in Progress

Analysis of mean-monthly, seasonal, and annual changes in soil moisture, latent and sensible heat, as correlated to large-scale patterns is being performed. The correlation between mean-monthly, seasonal, and annual variations in surface energy fluxes, soil moisture, and stream flow and large-scale atmospheric and surface patterns is examined.

The impact of dry growing seasons on vegetation health and crop growth dynamics has been clearly documented in NDVI imagery of the Great Plains during droughts in 1988 and 1995/1996. Given the importance of transpiration on the overall hydrologic cycle of the region, capturing these feedbacks is a key component of representing the impact of long-term atmospheric variability on the hydrology of the southern Great Plains. A simple dynamic vegetation model that updates leaf area index based on water stress conditions is being included in TOPLATS to capture these dynamics.

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