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Comparison of NEXRAD-Based and Observed Rainfall Data and TOPMODEL Simulations, McTier Creek Watershed, South Carolina

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Introduction

Rainfall is an important forcing function in most watershed models. As part of a previous investigation to assess interactions among hydrologic, geochemical, and ecological processes that affect fish-tissue mercury concentrations in the Edisto River Basin, the topography-based hydrological model (TOPMODEL) was applied in the McTier Creek watershed in Aiken County, South Carolina (Feaster and others, 2010; fig. 1). Measured rainfall data from six National Weather Service (NWS) Cooperative (COOP) stations surrounding the McTier Creek watershed were used to calibrate the McTier Creek TOPMODEL (fig. 2). Since the 1990s, the next generation weather radar (NEXRAD) has provided rainfall estimates at a finer spatial and temporal resolution than the NWS COOP network. For this investigation, NEXRAD-based rainfall data were generated at the NWS COOP stations and compared with measured rainfall data for the period June 13, 2007, to September 30, 2009. Likewise, these NEXRAD-based rainfall data were used with TOPMODEL to simulate streamflow in the McTier Creek watershed and then compared with the simulations made by using measured rainfall data.

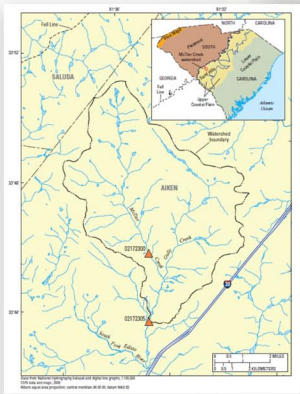

Figure 1. Location of the McTier Creek study area, Aiken County, South Carolina (from Feaster and others, 2010).

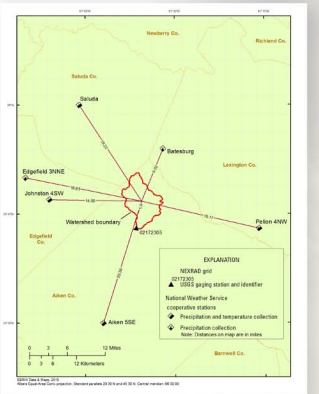

Figure 2. Location of National Weather Service Cooperative meteorological stations near the McTier Creek watershed, South Carolina, and NEXRAD grid locations (from Feaster and others, 2012).

Study Area

McTier Creek is a small headwater watershed that is a tributary to the South Fork Edisto River, which is one of the main tributaries to the Edisto River. The study area lies within the inland part of the Coastal Plain physiographic province known as the Sand Hills and encompasses about 31 square miles of the McTier Creek watershed. Two U.S. Geological Survey (USGS) streamflow-gaging stations were available for comparison of observed daily mean flow with simulated daily mean flow— station 02172300, McTier Creek near Monetta, SC, and station 02172305, McTier Creek near New Holland, SC (fig. 1). Meteorological input data (rainfall and average temperature included in the study were based on available data collected daily from six stations that are part of the NWS COOP stations network and are located near the McTier Creek watershed (fig. 2).

Refererences

Feaster, T.D., and Golden, H.E., Odom, K.R., Lowery, M.A., Conrads, P.A, and Bradley, P.M., 2010, Simulation of streamflow in the McTier Creek watershed, South Carolina: U.S. Geological Survey Scientific Investigations Report 2010-5202, 61 p., at http://pubs.usgs.gov/sir/2010/5202/.

Feaster, T.D., Westcott, N.E., Hudson, R.J.M., Conrads, P.A., and Bradley P.M., 2012, Comparison of TOPMODEL streamflow simulations using NEXRAD-based and measured rainfall data, McTier Creek watershed, South Carolina: U.S. Geological Survey Scientific Investigations Report 2012–5120, 33 p., at http://pubs.usgs.gov/sir/2012/5120/.

Comparison of Measured and NEXRAD-Based Rainfall Data

Measured rainfall data were compared with NEXRAD-based rainfall data at six NWS COOP stations that surround the McTier Creek watershed (table 1). The comparison, using rainfall data for non-zero days at the NWS COOP station locations, indicated that the NEXRAD-based data were lower at all six locations with the total difference in rainfall ranging from –1.3 inches at the Batesburg COOP station to -21.6 inches at the Pelion COOP station. The estimation bias, which is a comparison of the total volume of rainfall for the comparison period, ranged from –1.6 percent at the Batesburg COOP station to –24.1 percent at the Edgefield 3 NNE COOP station. These findings are comparable with results reported for larger watersheds or coverage areas.

Table 1. Comparison statistics for days with non-zero rainfall for measured and NEXRAD-based daily rainfall for National Weather Service Cooperative stations near the McTier Creek watershed from June 13, 2007, to September 30, 2009.

Cooperative station		Total number of concurrent days	Number of non-zero days	Total measured rainfall (inches)	Total difference in rainfall (inches)	Estimation bias (percent)	Estimation efficiency	Root mean square difference (inches)
Number	Name							
380074	Aiken 5SE	501	139	62.3	–10.8	–17.3	0.53	0.38
380506	Batesburg	798	178	82.8	–1.3	–1.6	0.50	0.38
382712	Edgefield 3 NNE	754	144	85.6	–20.6	–24.1	0.42	0.58
384607	Johnston 4 SW	768	201	92.6	–16.6	–17.9	0.70	0.31
386775	Pelion 4 NW	822	209	101.4	–21.6	–21.3	0.59	0.33
387631	Saluda	833	209	92.4	–6.3	–6.9	0.68	0.30

Overview of TOPMODEL

TOPMODEL (a topography-based hydrological model) is a physically based watershed model that simulates streamflow based on the variable-source-area concept of streamflow generation. TOPMODEL systematically accounts for water as it enters the watershed as precipitation until it leaves the watershed through evapotranspiration, by direct withdrawal, or as streamflow.

In the water balance, rain on a given day is used first to satisfy the potential evapotranspiration for the day. The remainder moves overland to a stream if the rain falls on impervious surface that is connected to a stream (*qimp*), soil that is already saturated (*qof*), or soil through which the water cannot infiltrate rapidly enough (*qinf*) (fig. 3). Precipitation that falls on a surface-water body is added to the streamflow (*qsrip*). The remaining water infiltrates into the upper soil zone. Any water stored in the saturated subsurface zone is assumed to move downslope toward the stream channel and enters the stream as return flow (*qret*) in saturated areas and (or) subsurface flow (*qb*) at the streambanks. The portion of the subsurface water that drains into the stream depends on the volume in storage and the values of the TOPMODEL input parameters.

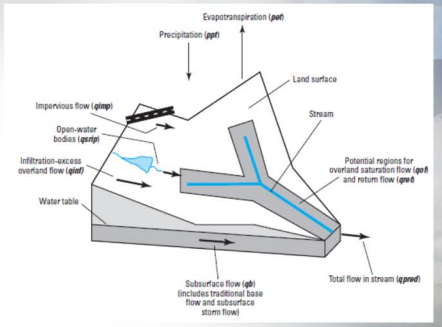

Figure 3. Definition of selected water-source variables from TOPMODEL.

Comparison of TOPMODEL Simulations

Streamflow simulations from the TOPMODEL using measured rainfall, which also was used in the calibration, were compared with simulations using NEXRAD-based rainfall data with the TOPMODEL that was calibrated using NEXRAD-based data. The comparisons were made at USGS stations 02172300, McTier Creek near Monetta, SC, and 02172305, McTier Creek near New Holland, SC (figs. 4 and 5). Several goodness-of-fit statistics that provide numerical comparisons of the timing and shape of simulated and observed streamflow hydrographs indicated similar results from the streamflow simulations using measured and NEXRAD-based rainfall data (tables 2 and 3). However, bias, which is the average of the residuals between the simulated and observed streamflow data, showed that streamflow simulations using the NEXRAD-based rainfall had a negative bias of –0.24 and –0.18 cubic feet per second (ft^3/s), respectively, compared to a positive bias of 0.24 and 0.07 ft^3/s, respectively, using the measured rainfall data. The equivalent percentage biases (PBIAS) were –2.3 and –0.87 percent, respectively, and 2.2 and 0.31 percent, respectively. The comparisons of TOPMODEL simulations using measured and NEXRAD-based rainfall for the McTier Creek watershed indicate that both rainfall datasets provide reasonable results with respect to matching the measured streamflow when the simulations are made using the same rainfall data that was used for the watershed model calibration. This is important because adjustment of calibration parameters for the TOPMODEL using NEXRAD-based data helped account for much of the bias indicated in table 1.

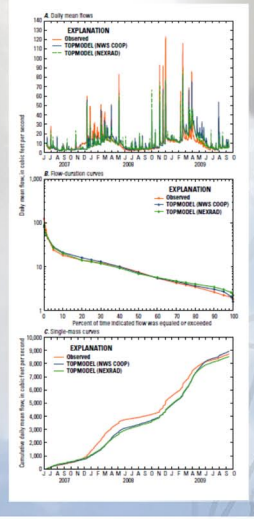

Figure 4. TOPMODEL streamflow simulations in relation to *A*, daily mean flows, *B*, flow-duration curves, and *C*, single-mass curves at McTier Creek near Monetta (02172300), for June 13, 2007, to September 30, 2009.

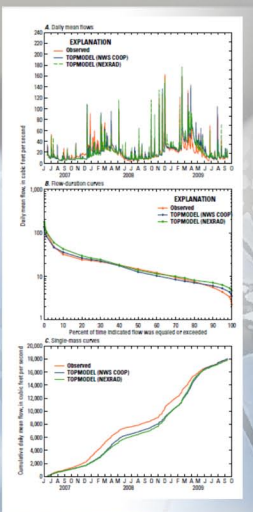

Figure 5. TOPMODEL streamflow simulations in relation to *A*, daily mean flows, *B*, flow-duration curves, and *C*, single-mass curves at McTier Creek near New Holland (02172305), for June 13, 2007, to September 30, 2009.

Table 2. Goodness-of-fit statistics for McTier Creek near Monetta for the June 13, 2007, to September 30, 2009 simulation.

Statistic	Observed	TOPMODEL (Calibrated and simulated using measured rainfall)	TOPMODEL (Calibrated and simulated using NEXRAD-based rainfall)
Maximum (ft^3/s)	123	80	87
Mean (ft^3/s)	10.4	10.6	10.2
Median (ft^3/s)	7.5	7.2	6.8
Minimum (ft^3/s)	1.8	1.6	2.2
Standard deviation (ft^3/s)	12.0	9.9	9.5
Bias (ft^3/s)		0.24	-0.24
PBIAS (percent)		2.2	-2.3
RMSE (ft^3/s)		6.9	6.4
MAE (ft^3/s)		3.9	3.5
r		0.82	0.85
NSE		0.67	0.71

Table 3. Goodness-of-fit statistics for McTier Creek near New Holland for the June 13, 2007, to September 30, 2009 simulation.

Statistic	Observed	TOPMODEL (Calibrated and simulated using measured rainfall)	TOPMODEL (Calibrated and simulated using NEXRAD-based rainfall)
Maximum (ft^3/s)	163	159	177
Mean (ft^3/s)	21.8	21.5	21.2
Median (ft^3/s)	17.0	14.6	13.8
Minimum (ft^3/s)	2.6	4.1	4.7
Standard deviation (ft^3/s)	19.9	18.8	19.7
Bias (ft^3/s)		0.07	-0.18
PBIAS (percent)		0.31	-0.87
RMSE (ft^3/s)		11.1	10.9
MAE (ft^3/s)		6.8	6.6
r		0.82	0.85
NSE		0.67	0.68

[ft^3/s, cubic foot per second; RMSE, root mean square error; MAE, mean absolute error; r, Pearson's correlation coefficient; NSE, Nash-Sutcliffe coefficient of model-fit efficiency]