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Comparing the operational capabilities of the site specific hydrologic predictor (SSHP) and a fully distributed hydrological model (MIKE SHE) using WSR-88 radar rainfall inputs over a small basin in Florida

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1. INTRODUCTION

The Black Creek Basin in North Florida has been the site of flash flooding during the 1990's. WSR-88 derived rainfall rates were applied to the Systeme Hydrologique Europeen distributed hydrological model (MIKE SHE) and to the Site Specific Hydrologic Predictor (SSHP) to compare the relative operational and diagnostic advantages of using either model in forecasting of flash flood events. The results focus on inter-model comparisons between the SSHP using the Missouri Basin River Forecast Center-Antecedent Precipitation Indices (MKC-API) rainfall-runoff model, and the MIKE SHE distributed model. Both sets of calculations are compared to observations of discharge at USGS gauging stations in the basin for January and July 1998. We discuss the differences in results and analyze the relative operational usefulness of using WSR-88 rainfall rates as inputs to a distributed model and the Site Specific model over such a small (1253 km^2) basin on short time scales.

Black Creek Basin in North Florida is a small basin (1253 km^2) located southwest of Jacksonville Florida. It consists of two main tributaries, the North Fork and the South Fork, which merge near Middleburg, Florida, and from there empties into the St. Johns River. In this paper, WSR-88-derived rain rates are input to MIKE-SHE, the Systeme Hydrologique Europeen distributed hydrological model (Refsgaard and Storm 1995; Refsgaard 1997) to examine the comparative operational and diagnostic advantages of using fully distributed versus Thiessen-derived rainfall rates over this small basin of modest topography under convective and synoptic scale weather conditions. The analysis is performed during two months, February and July 1998, to obtain a better understanding of how WSR-88 data might aid distributed hydrological modeling during wintertime widespread rainfall regimes, and under summertime conditions of quasi-tropical, small-scale convective activity. Figure 1 shows the perimeter of the Black Creek Basin and the positions of rain gauges, Thiessen Polygons, WSR-88 radar grid points and the river gauging stations operated by the USGS. The St. Johns River runs from south to north on the eastern side of the basin. The southernmost river gauge is the

HRAP grid and Thiessen polygons

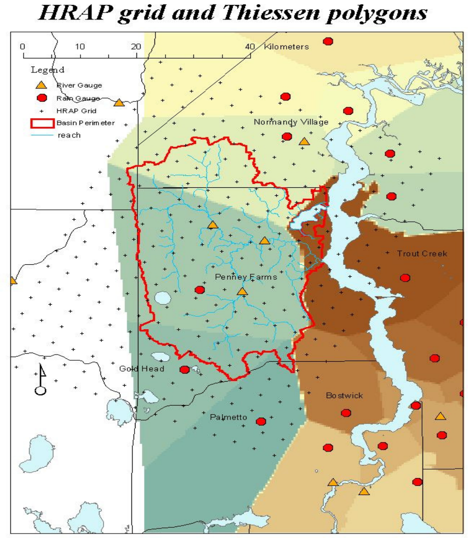

Figure 1: The Black Creek Basin, WSR-88 grids, Thiessen Polygons, and river and rainfall instrumentation. The red solid circles are rain gauges; the orange triangles are river gauges. Inside the basin perimeter (red solid line) the northernmost river gauge is at Middleburg; the southernmost river gauge is Penney Farms; and the easternmost gauge is at Doctor's Inlet, which was inoperable during 1998, and which monitors the main outlet into the St. Johns river to the east. The Penney Farms rain gauge near the center of the basin dominates the Thiessen calculations.

Penney Farms gauge; the northernmost river gauge is at Middleburg; and the easternmost river gauge is at Doctor's Inlet. The river gauge at Doctor's Inlet was inoperable during 1998, which was the only year that the rain gauge near Penney Farms was operating. The Penney Farms rain gauge dominates the Thiessen Polygon estimates of rainfall over the basin. The basin includes most of Clay County, with a significant portion in Duval County to the north, including the city of Jacksonville, Florida. Black Creek consists of two main branches, the South Fork and the North Fork. Discharge from the South Fork passes through the Penney Farms gauge, while discharge from the North Fork passes through the Middleburg gauge. The combined discharge from both streams passes the gauge at Doctor's Inlet, and thence to the main basin outlet at the St. Johns River.

The basin is approximately 40x40 km^2 (484 square miles) in area. Each WSR-88 grid is 4x4 km^2.

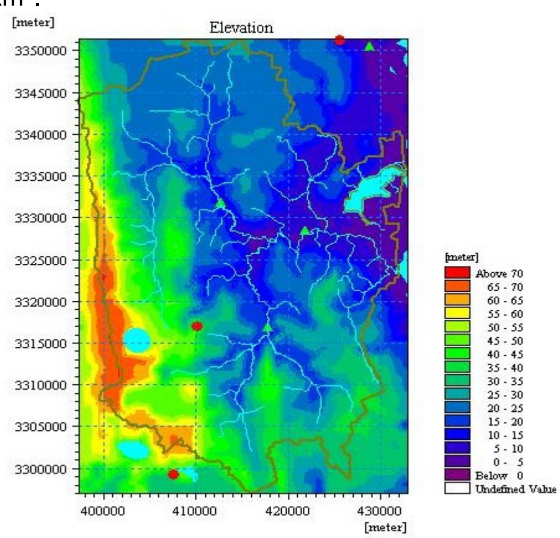

Figure 2: Topography of Black Creek Basin. The green triangles are river gauges. The river gauge at Penney Farms responds mostly to flows from the southern part of the basin, while the Middleburg gauge records flows mostly from the western and northern reaches. The red solid circles represent rain gauges at Gold Head State Park (southernmost), Penney Farms (middle), and at Normandy Village (northernmost).

Based on the STATGO soils database, the surface layer of soils in the basin is mostly fine sand, with some fine sandy loam, loamy sand and muck in the river valleys. A surficial aquifer system approximately 50 meters thick above a confining layer (the Hawthorn Formation)

There is a significant topographical component to flows in the Black Creek Basin (see Figure 2). There is a 60 - 70 m MSL ridge lining the western side of the basin along which the North Fork flows from south to north. This fork curves to the east before emptying into the main branch at the junction of the North and South forks between Middleburg and the Doctor's Inlet gauge. Gentler topography drives the flow in the South Fork through Penney Farms toward the intersection with the main branch just west of Doctor's Inlet. Thus, the gauge at Middleburg records flow mostly from the western and northwestern basin, while the gauge at Penney Farms records flow from the southern part of the basin.

separates the surficial aquifer from the Floridan aquifer below (USACE, 2000). The vegetation in the basin is more than 60% coniferous forest, either natural or in silviculture; 20% of the basin is in water or wetlands; and the rest is a mixture of residential (~10%), commercial mining, crops and dairy farms (USACE, 2000).

2.0 Hydrological modeling case studies
2.1 MIKE-SHE Model Configuration

The MIKE-SHE model was set up to calculate flow within the Black Creek Basin using MPE rainfall values for July and February 1998. The rainfall data sets provided distributed hourly rain rates at 4x4 km^2 resolution during both months.

MIKE-SHE was applied in its simplest two-layer soil mode, an unsaturated soil layer overlying a saturated layer. The depth of the unsaturated layer was determined from the rooting depth of the vegetation and the soil matrix saturated potential in the saturated zone that is the surficial aquifer. Soils were considered saturated below the bottom of the unsaturated layer. Boundary conditions for inflow to the basin were set in steady state to the minimum discharge observed at each river gauge over the last 30 years, and tide gauge observations at Red Bay Point across from the mouth of Black Creek were used to assign the oscillating stage conditions at the main outlet to the St. Johns River.

The initial depth to saturation for soils was set to one meter. The vegetation types, soil hydraulic conductivities, Manning numbers, Leaf Area Index (LAI) and rooting depths were held constant over the entire model domain and were selected based on nominal published values (Bonan 1996). The generic soil types were obtained from the STATSGO soils shape files and soil hydrological properties based on Clapp and Hornberger 1978, Hornberger et al. 2003;

and Pielke, 2002. A basin mean Manning's M of 5.0 was selected from the range of values reported in USACE (2000). Thus, topography and soils were the only permanent properties of the basin that were distributed in space. No attempt was made to calibrate the model, or to assess the antecedent saturation of soils for initialization. Under these conditions, one cannot expect the distributed model to calculate accurately the discharge at the USGS river gauges. However, our purpose includes an attempt to understand the differences between model outputs that may result from distributed MPE rainfall data as input to MIKE SHE and area mean rainfall inputs to the Site Specific model.

2.2 SITE SPECIFIC

The Site Specific model used at the local Weather Forecast offices is designed for headwaters application. However it is a major step forward towards bringing sophisticated data management tools normally associated with the complex National Weather Service River Forecast System (NWSRFS) into the Weather Forecast Office (WFO) environment. Site Specific offers the choice of using either Antecedent Precipitation Index (API) known as API-MKC input developed by the Missouri Basin River Forecast Center (MBRFC) or the Sacramento Soil Moisture Accounting Model (SACSMA). Soil moisture parameters may set either by the supporting River Forecast Center, or set locally by the WFO. These values consist of either Headwaters Guidance (FFH) values for use by the API rainfall runoff model or the actual soil moisture states for the basin generated by SACSMA using the NWSRFS at the RFC. In either case, these values are created by the RFC and sent to the WFOs to support the WFO Site Specific model. The rainfall runoff models are driven by the input Mean Areal Precipitation (MAP) time series which may be generated in any manner locally, but can also be automatically created from the National Weather Service (NWS) Multi-Sensor-Estimator (MPE) program based upon gage biased radar rainfall for the Site Specific Basin being modeled. The model inputs include (observed and forecast) rainfall, stage, and discharge and allows for use of evapotranspiration. During the forecast run process, adjust flow operations are allowed to calibrate the model to current flow conditions to improve forecast flow. The forecast hydrograph is generated using a unitgraph developed by the supporting RFC for that forecast point. Rating curve data enable conversion of flow to stage and stage to flow and are displayed with the hydrograph window in Site Specific. Site Specific is integrated with and supported by same Informix database structure and system in use by the RFCs for NWSRFS and the WFOs for the WFO Hydrologic Forecast System (WHFS). The Site Specific forecast runs for Black Creek were accomplished using the MBRFC-API model using historical MPE gage biased radar rainfall estimations generated by Dr. Henry Fuelberg and his students at Florida State University. This data including the supporting rain gage data has undergone rigorous quality control and cross-checks by Dr. Fuelberg and his students. The rating curves, unitgraph and historical hydrograph data for Black Creek were provided by the Southeast River Forecast Center. It is the goal of the collaboration to improve the quality of Site Specific forecasts by using Mike-She distributed presentation of soil-moisture conditions over a basin, to better evaluate current and forecast small stream responses by lumped models such as Site Specific and NWSRFS.

2.0 PRELIMINARY RESULTS

As expected, the models respond differently to the different rain inputs. The models were run for two months at hourly time steps for February 1998 (not shown), which represents a high-flow period, and for July 1998, which represents a relatively low flow period.

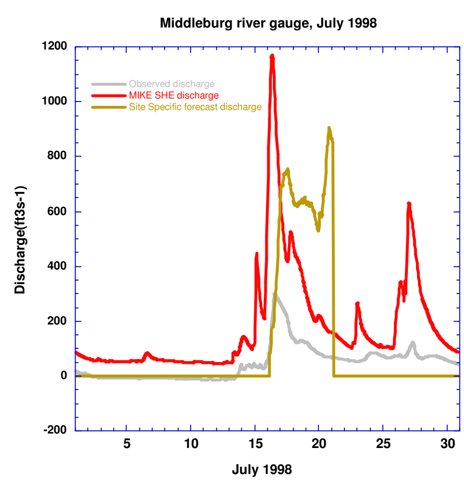

Figure 3: Calculated and observed discharge at the Middleburg gauge for July, 1998.

Figure 3 shows a comparison of calculated and observed discharges at the Middleburg gauge for July1998. The red line is the discharge calculated at the MIddleburg gauge using MIKE SHE and the orange line is that calculated by Site Specific. The gray line is the observed hourly discharge recorded by the gauge. Both MIKE SHE and Site Specific overestimate the observed discharge, but the distributed model emulates the decline in discharge better than the lumped model (Site Specific). MIKE SHE was uncalibrated in Figure 1 and more attention to calibration is expected to produce better results.

Further calculations are being undertaken with both models using both historical radar-derived rainfall data and forecast rainfalls downloaded from the South East River Forecast Center. An approach to real- ime application of distributed models, using displays of current basin wide soil moisture content as depicted by MIKE SHE, the spatial distribution of accumulated rainfall and predicted river discharge at the gauges are being examined for February 1998 in order to elucidate the relative merits and value of using a distributed model to gain insight into using such a distributed model and Site Specific in understanding and forecasting the hydrological behavior of small flashy basins such as Black Creek.

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