UTILIZING RADAR DATA TO IMPROVE STREAMFLOW FORECASTS

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ABSTRACT. This research investigates how the spatial distribution of rainfall within a basin influences the resulting streamflow forecasts. Specifically, the research evaluates fine scale (4 km x 4 km) hourly digital precipitation (HDP) data, provided by the WSR-88D Doppler radar, against rain gage data. The basin is divided into six sub-basins for the evaluation. The hypothesis is that the greater spatial resolution of the radar-derived rainfall, in combination with sub-dividing the basin, will provide a more accurate estimate of rainfall within the basin, thereby producing a more accurate streamflow forecast.

INTRODUCTION

In a typical year flooding kills more people in the United States than does any other weather phenomena. Major efforts have been underway for several years to improve flood forecasts. For example, technology has advanced the skill of river forecasting by allowing streamflow models to be run on local computers at the river forecast centers. The shortage of observations from the sparse rain gage network has been a limitation; however, today's forecasters have more available data, including observations at both a greater spatial and temporal resolution. We now are beginning to use fine scale rainfall data derived from Doppler radar. These finer scale data will be a great advantage to river forecasters when they are utilized effectively.

The National Weather Service River Forecast System (NWSRFS) is a comprehensive set of hydrologic techniques used by the National Weather Service River Forecast Centers to forecast streamflow during both flooding and non-flooding situations. Many factors are incorporated into the NWSRFS to produce the daily forecasts. Daily and hourly rainfall data from various types of observing stations are needed as input. Since there are more daily reporting stations than hourly sites, the hourly stations are used to distribute the daily amounts throughout the day. Also required are streamflow data obtained from stage gages operated by agencies such as the United States Geological Survey (USGS), National Weather Service (NWS), and the U. S. Army Corps of Engineers.

Most River Forecast Centers (RFCs) currently use the Sacramento Soil Moisture Accounting model (SACSMA) to forecast runoff (McIntire et al., 1998). Numerous parameters within SACSMA must be specified for a given basin before a streamflow forecast can be produced. These parameters, representing soil moisture characteristics such as percentage of impervious areas, vegetation cover, and percolation rates, must be defined for the various stream segments which constitute the basin drainage area.

The current procedure for estimating runoff utilizes rainfall expressed as a single 6-hour Mean Areal Precipitation (MAP) value over the river basin. MAP is calculated from rain gage data, and the single value is used for the entire basin regardless of its size, shape, and topography. However, Robert Davis at the NWS office in Pittsburgh, Pennsylvania showed that utilizing 1 hour radar-derived rainfall data over small watersheds (< 200 mi^2) increased the lead time for forecasting in flash flood events (Davis and Jendrowski, 1993). The procedure, called AMBER, divided a large basin into smaller sub-basins and defined characteristics for each. The flash flood forecasts then were produced by comparing rainfall patterns over these small watersheds to Flash Flood Guidance (FFG) generated by SACSMA at the RFCs. Mike Smith, at the NWS Office of Hydrology (OH), also has investigated the use of fine scale rainfall data from the WSR-88D Doppler Radar to improve streamflow forecasts (Smith et al., 1996a).

OBJECTIVES

The current study examines the influence that the spatial rainfall distribution within a basin has on resulting streamflow forecasts. The study consists of two components. The first consists of a statistical analysis for radar-derived mean areal precipitation and rain gage based mean areal precipitation. The second component uses rain gage data only to compare simulated streamflow for a total basin with simulated streamflow when the basin is subdivided into smaller components. This process is repeated using radar-derived rainfall to see how differently the model reacts. This research is an extension of that proposed by Smith (Smith et al., 1998). Our hypothesis is that by dividing a larger basin into smaller sub-basins, and then using either rain gage rainfall or radar-derived rainfall, a more accurate streamflow forecast should be produced.

METHODOLOGY

The river basin selected for this study corresponds to the headwater of the Flint River, specifically the Flint River at Culloden (Fig. 1). This basin was chosen because of its large impact on areas downstream, including the Hydrologic Service Area of the Tallahassee Weather Forecast Office (WFO). The headwater area includes large urban regions as well as sparsely populated agricultural regions. The Culloden basin has been divided into six sub-basins according to topography and data availability from the USGS.

Mean areal precipitation values derived from radar are called MAPX, and these values within each of the sub-basins will be used to simulate historical streamflow. A composite of radar-derived rainfall estimates and rain gage data (XMRG files) on a 4 x 4 km grid has been used to generate a time series of basin and sub-basin average values at 6-hour intervals. The XMRG files are created at the RFC on an hourly basis by using an interactive program and represent a snapshot of 1-hour rainfall (Table 1). MAPX is the result of overlaying the radar hourly digital precipitation (HDP) data and rain gage data. Each rain gage is given an area of influence on the composite which has been predetermined by the RFC. This area of influence helps the forecaster blend the gage and radar data, and assists in removing any erroneous radar data.

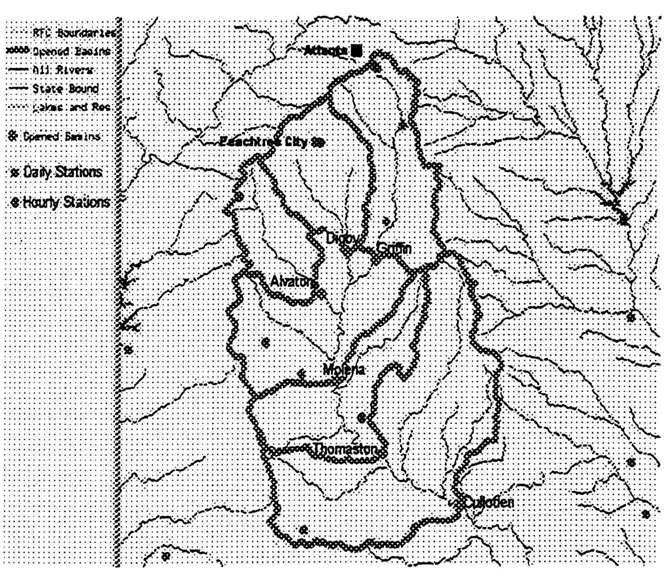

Figure 1. Map of the Culloden basin showing the daily and hourly rain gage sites that are used in the MAP calculation. Also shown is the sub-divided Culloden basin. There are a total of 8 hourly rainfall sites and 13 daily rainfall collection sites.

Since the NWSRFS will be used to simulate streamflow for the basin and sub-basins, the different operations comprising the system must be defined. The rainfall/runoff model and unit hydrograph define basic hydrologic operations for a headwater sub-basin. In the case of a sub-basin further downstream, it is necessary to employ a routing scheme. In this study there are both headwater as well as downstream sub-basins.

Rainfall/runoff models will be used to compute the amount of rainfall that reaches the stream. We utilize the Sacramento Soil Moisture Accounting (SACSMA) rainfall/runoff model, specifying its various parameters for the whole basin and maintaining their values for the sub-basins.

Unit hydrographs are used to convert runoff, generated with the rainfall/runoff model, to a direct runoff hydrograph. Unit hydrographs can be developed using streamflow data, synthetic methods, or conceptual analysis. Synthetic unit hydrographs usually are derived from characteristics of the basin. Observed data exist for only one of the sub-basins (Culloden, Fig. 1), and this historical data set will be used to generate a unit hydrograph at this site. Synthetic unit hydrographs will be generated for the remaining five sub-basins. A software package called the Integrated Hydrologic Automated Basin Boundary System (IHABBS) is used to generate synthetic unit hydrographs for the sub-basins (NWS-OH et al., 1998). This tool utilizes high resolution topographic maps and offers several methods of generation. The Soil Conservation Service (SCS) method of generating synthetic hydrographs will be used for this study.

Routing methods will be defined for each of the sub-basins. This operation is needed to move the water to the outlet of the complete Culloden basin. Many routing methods are available, but those most commonly used within NWSRFS are storage routing models, including the Muskingum model, Lag and K, and Layered coefficient routing (Fread, 1985). These models are based on conservation of mass and an approximate relation between flow and storage. Operationally, Lag and K has been, and continues to be a widely used routing method, mainly because of its flexibility. However, due to the lack of streamflow data in the sub-basins, routing parameters will be defined using the Muskingum-Cunge method. Muskingum-Cunge uses physical characteristics of the basin to determine the coefficients that the other methods determine from historical data.

Once the basin and sub-basins are defined in NWSRFS, the model will be run for 42 years (1955-1996) using 6-hour MAP rain gage data to calibrate the model and determine the

Table 1. Time Series Definitions

	XMRG	MAPX	MAP
Gridded or Basin Averaged	Gridded	Basin Averaged	Basin Averaged
Radar and Gage Data or Gage Only	Radar and Gage	Radar and Gage	Gages Only

basin parameters. Then, beginning in June 1996, MAPX at 6-hour intervals and MAP at 6-hour intervals will be used separately to simulate streamflow using ICP (Interactive Calibration Program) (Smith et al., 1996a). Specifically, MAP and MAPX for each sub-basin will be used to calculate separate estimates of simulated streamflow at the Culloden (final) river gage and at the five sub-basin gage sites. Simulated stream flows from both the entire basin, and from the separately calculated sub-basins, will be compared to observed data at the Culloden river gage. If the routing methods and synthetic unit hydrographs are appropriate, the greater spatial resolution provided by the sub-divided basin approach will produce a more accurate streamflow simulation (Smith et al. 1996b).

To summarize, the following will test the utility of these methods:

1) Statistical Analysis of (MAP) and Basin (MAPX)
2) Calibration of the basin using historical (MAP)
3) Comparison between sub-divided basin streamflow (MAPX/MAP) and Basin streamflow (MAPX/MAP)

1) Statistical analysis of basin (MAP) and basin (MAPX) will be used to determine the degree of agreement between gage (MAP) and radar-derived (MAPX) precipitation.
2) The entire basin will be calibrated using historical MAP and streamflow data to determine the SACSMA parameters which then will be used for the sub-basins.
3) Sub-divided streamflow (MAPX and MAP) vs. Basin streamflow (MAPX and MAP) is the most important comparison because it will prove or disprove the hypothesis that sub-dividing a basin into smaller components yields better streamflow estimates. Preliminary results show large differences between MAP and MAPX. Thus, it may not be appropriate to compare MAP simulated streamflow with MAPX simulated streamflow. Preliminary results will be presented at the conference.

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