# Distributed Parameter Hydrologic Modeling and NEXRAD for River Forecasting: Scale Issues Facing the National Weather Service

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**Abstract**

With the advent of NEXRAD (Next Generation RADar), the National Weather Service has the opportunity to move from current lumped parameter modeling to more of a distributed parameter hydrologic modeling approach for river forecasting. However, this high resolution precipitation data poses the problem of calibration at one spatial and temporal scale while using the models operationally with NEXRAD data at a finer spatial and temporal scale. Until national NEXRAD coverage exists for a long enough time period to prove useful for calibration, understanding must be gained as to how to adjust calibrated model parameters to account for runoff volume differences resulting from using high resolution rainfall inputs. To examine this, a synthetic watershed was modeled using various sized computational elements using 9 months of archived NEXRAD rainfall data. Results indicate that finer spatial and temporal scales result in the generation of more total runoff and fast response runoff. Tests indicate that hydrologic model parameters are not transferrable across scales. When calibrating at a lumped scale and then disaggregating the basin for operational forecasting, certain parameters must be adjusted in order to recalibrate the hydrologic model.

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## Introduction

The Hydrologic Research Lab of the National Weather Service (NWS) has embarked on a program to move towards distributed parameter hydrologic modeling for flood and long-term river forecasting. Currently, the 13 River Forecast Centers (RFC) of the NWS use continuous hydrologic models with spatially lumped parameters and precipitation inputs to provide daily stage/discharge forecasts at over 4,000 locations across the Nation (Fread, 1995).

Given the high resolution and quality of NEXRAD data, the NWS has an opportunity to depart from lumped parameter modeling and more effectively account for the spatial and temporal variability of precipitation. For example, current procedures at RFC's usually involve the generation of mean areal precipitation (MAP) values derived from point raingage data. These average inputs are normally for 6 hour computational time increments and for watersheds several hundred square miles in area. These models are calibrated using up to 45 years of historical streamflow and precipitation data, with the result that the hydrologic model parameters are inherently related to the spatial and temporal scale of calibration. In contrast, NEXRAD will provide hourly rainfall measurements over a 4 x 4 km grid, representing unprecedented resolution for the United States.

Rather than moving directly to a gridded or other high resolution distributed parameter hydrologic model that is based on the NEXRAD grid, a semi-distributed modeling approach has been adopted in HRL as a first step towards utilization of the NEXRAD data (Smith, 1995). In this format, a basin currently being modeled by an RFC would be disaggregated into several constituent sub-basins. Instead of using point raingage measurements to compute MAP values for each entire basin, MAP values for each sub-basin would be derived from the gridded NEXRAD values. Unit hydrographs would be developed from standard methods or geomorphological analysis and used to convert runoff volumes to discharge values. A Muskingum-Cunge routing operation will be used to translate hydrographs to the next downstream computational point. The goal of the overall research is to provide RFC personnel with: 1) hydrologic tools to model sub-basins, 2) guidelines as to what degree to disaggregate a lumped basin to capture essential spatial rainfall variability, and 3) guidelines as to the adjustment of calibrated model parameters to account for finer operational modeling scale. Future research will address the development of gridded distributed parameter models.

## Scaling Issues

As with distributed parameter models in general, problems arise when the issue of calibration is considered. The conceptual model currently used by the NWS that would be applied to each sub-basin is the Sacramento Soil Moisture Accounting Model (SAC-SMA) (Burnash, 1995). Practical experience and statistical analyses have shown that this model requires a minimum of 5 to 8 years of data for proper calibration (University of Arizona, 1995). Current NWS calibration procedures call for a 6 hour time step and are limited to the basin scale. However, only a few years of NEXRAD data is available as of the current date. Until enough NEXRAD data is available for calibration, it is proposed that the hydrologic model parameters be calibrated at a lumped basin scale and 6-hour time step and then uniformly applied to each constituent sub-basin.

However, in this approach, some adjustment must be made to the hydrologic model parameters as they are derived at a basin scale and 6-hour time step and then used operationally at sub-basin scale with 1-hour NEXRAD data. Runoff volumes generated at the calibration scale will be different than those generated at the operational scale. Thus, the NWS must understand how to adjust model parameters when calibrating at one scale and operationally forecasting at a different spatial and temporal scale.

## Current Research

Modeling efforts have been carried out to investigate the runoff volume differences resulting from lumped versus semi-distributed operational scales. Tests were conducted to identify SAC-SMA model components having the greatest scale dependency. In the testing, a 64x64 matrix of NEXRAD gridded precipitation values was obtained for an area near the Oklahoma-Arkansas border. This data was collected for a 9-month period. SAC-SMA model parameters were obtained from a calibrated basin within the geographic extent of the 64 x 64 matrix.

In the testing, the 64 x 64 matrix was considered to represent a synthetic watershed. For the 9 month period, runoff volumes from the SAC-SMA were computed for the watershed at 7 different spatial scales as shown in Table 1. At the coarsest level, the entire 64 x 64 matrix was considered to be a lumped basin. For each time step, 64 x 64 elements were used to compute a single mean areal precipitation value as input into the hydrologic model. At the next level, the watershed was disaggregated into 4 sub-basins, each consisting of 32 x32 NEXRAD elements. At the finest scale, each of the 4056 NEXRAD cells was considered to be a sub-basin.

| Scale | Size of Sub-basin in NEXRAD 4-km. Cells | Number of Sub-Basins |
|---|---|---|
| 1 | 64 x 64 | 1 |
| 2 | 32 x 32 | 4 |
| 3 | 16 x 16 | 16 |
| 4 | 8 x 8 | 64 |
| 5 | 4 x 4 | 256 |
| 6 | 2 x 2 | 1024 |
| 7 | 1 x 1 | 4056 |

Table 1. Sub-Basin Size for 7 Modeling Scales

**Results**

Computations for the 7 scales were performed for each of 3 time steps: 1, 3, and 6 hour. Runoff volumes from the SAC-SMA components for each scale and each time step were depth-averaged for the entire 9 month period. Figure 1 presents the depth-averaged runoff volumes for each major SAC-SMA component for the 1-hour time step scenario.

From Figure 1 it can be seen that some of the component runoff volumes are dependent on the size of the constituent sub basin. This indicates that hydrologic model parameters are not transferrable across scales.

In particular, surface flow displays a marked scale dependency. At the coarsest scale, no surface runoff was computed. Surface runoff occurs in the SAC-SMA model when the two reservoirs representing the upper soil layer are filled and the rainfall rate exceeds the rate of percolation and interflow generation. Tests of the 9-month NEXRAD

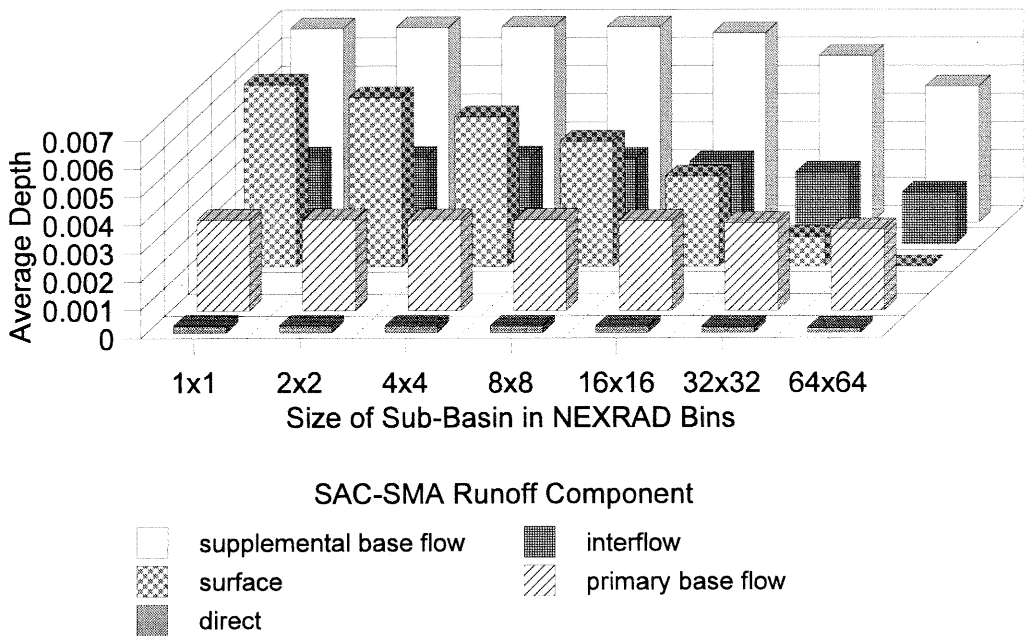


Figure 1. 1-Hour Mean of Runoff Components Vs. Size of Computational Area using 9 Months of NEXRAD Data.

data set indicate that only one rainfall event achieved 100% coverage of the entire 64 x 64 synthetic watershed. Due to this partial coverage, computations of mean areal precipitation at the coarsest scale include many NEXRAD cells with zero rainfall, resulting in smaller MAP values being input to the SAC-SMA representing the entire basin. Consequently, the two reservoirs in the upper soil layer never fill so as to produce surface flow.

The greatest surface runoff was computed when the watershed was modeled at the finest spatial scale. Thus, as a basin is disaggregated into smaller sub-basins to capture the spatial variability of rainfall as measured by NEXRAD, more surface flow would be generated if the same hydrologic model parameters were used as in calibration. The sub-basin representation would no longer represent a calibrated system; the SAC-SMA parameters governing the generation of surface flow would need adjustment. Figure 1 also shows that parameters associated with the generation of interflow and supplemental base flow would need adjustment.

## Conclusions and Further Research

From the series of runoff volume tests at different spatial and temporal scales, it is clear that hydrologic parameters for the SAC-SMA are not constant across scales. If parameters are derived during calibration at a lumped scale, they must be adjusted when the lumped basin is disaggregated into a collection of sub-basins. It is envisioned that parameter adjustment guidelines will be developed during testing that involves generating discharge hydrographs from sub-basins. Five watersheds in Oklahoma have been selected for initial testing. Historical streamflow data and precipitation data have been assembled. Calibration at a lumped scale is in progress. These basins will be disaggregated to various levels of sub-division and resultant discharge hydrographs will be compared to observed streamflow records.

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