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National Weather Service Interactive River Forecasting Using State, Parameter, and Data Modifications

Thomas Adams and George Smith [1]

Abstract

Interactive flood and river flow forecasting using the National Weather Service Interactive Forecast Program (IFP) is outlined. The IFP is an extension of the National Weather Service River Forecast System (NWSRFS), which has been used routinely in operational settings at NWS River Forecast Centers (RFCs) throughout the U.S., essentially in its existing form, since the mid-1980s.

Processing of the many hydrologic models and support routines that comprise NWSRFS have been made on mini- and mainframe computers in batch mode from NWS RFCs as remote job entries. The hydrologic component of NWSRFS has been ported from the mainframe environment to run on scientific workstations in a Unix and X Window System environment, this constitutes the NWSRFS-IFP. The features of the IFP: local processing, increased processing speed, improved visual display and output within a graphical user interface (GUI), and ease of use should significantly improve the forecaster's ability to visualize river conditions and detect errors in model simulations. The IFP will allow forecasters to quickly make state and parameter changes and modify input data to improve agreement between observed and simulated flows, and, consequently, improve forecasts.

Individual models are calibrated for each basin within the RFC drainage system area of responsibility during an initial calibration and NWSRFS system definition phase. Subsequently, during forecast periods, forecasters make state and parameter adjustments to models and modify input data in response to random errors manifested in simulation results that are due to imperfect model calibrations, errors resulting from model simplifications of complex physical processes, and space-time averaging and estimation of rainfall and other environmental variables.

Introduction

The NWS River Forecast System (NWSRFS) is a collection of integrated

[1]Research Hydrologists, National Weather Service, Hydrologic Research Lab., 1325 East-West Highway, Silver Spring, MD 20910

hydrologic and hydraulic FORTRAN subroutines used to model the continuous hydrologic response of river basins due to rainfall, snowmelt, and evapotranspiration, with hydrologic and hydraulic routing (Anderson, 1986 and Day, 1985). NWSRFS is part of a complex system that combines a national network of real-time raingage, streamgage, and climatic data acquisition platforms. Communication and database components handle the flow and storage of the raw data used as input to NWSRFS models (Page and Smith, 1993).

In the current operational environment at NWS River Forecast Centers (RFCs), significant time is spent coding model control input statements, waiting for batch processes to run remotely (possibly thousands of mile from the RFC), and return as line printer output. Forecasters must then sift through the output, comparing observed data against simulated results, decide what changes are necessary to improve the agreement between model output and observations, and recode and submit the model changes. Hydrologic forecasting in the NWS will change dramatically during the 1990's under NWS modernization and specifically the Advanced Weather Interactive Processing System (AWIPS). Under AWIPS operational forecasting within the NWSRFS at RFCs will migrate from a batch, remote-job-entry, and mini- and main-frame computer environment to desktop scientific workstations for local interactive processing and display of model output.

The Interactive Forecast Program (IFP) is the graphical user interface (GUI) for NWSRFS (Figure 1). The GUI programming code is written in the C programming language and is intended to run on computers using the UNIX operating system

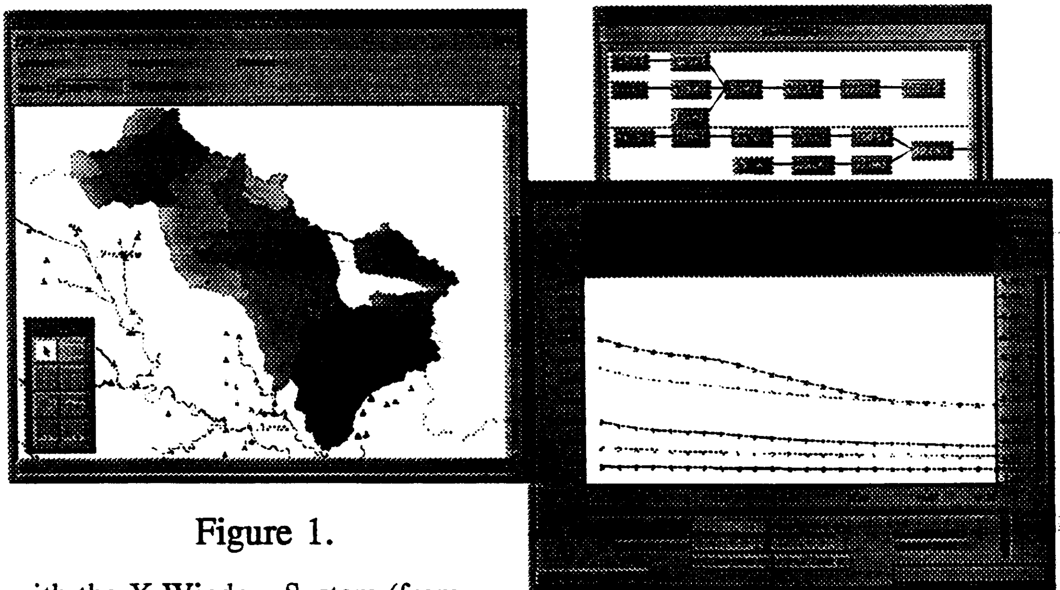

Figure 1.

with the X Window System (from the Massachusetts Institute of Technology and the X Consortium) and Open Software Foundation (OSF) Motif toolkit, which is an X based object library used to create the graphical interface objects on computer screens. The IFP gives an RFC hydrologic forecaster the means to issue commands through menu and button selections using a mouse connected to a computer in the manner that is available commercially using an Apple Macintosh, IBM compatible PC using Microsoft Windows, or OS/2 from IBM. The IFP is used to control and monitor NWSRFS execution, make model changes, and visualize hydrographs, hyetographs, and other time-series, as well as streamgage rating curves. Watershed, county, and state boudaries, streams and rivers, forecast point locations, and cities can be shown as map overlays in the IFP.

The IFP was designed to meet the following goals:

(1) improve river flow and flood forecasts,
(2) reduce the length of time needed to issue forecasts,
(3) ease the use of NWSRFS,
(4) reduce forecaster data input errors while making model adjustments,
(5) make the use of NWSRFS interactive.

The primary goal of the IFP is, obviously, to improve forecasts and to make them more timely. This is accomplished by simplifying NWSRFS interaction and by making it interactive with local processing and graphical display of the observed data and model output. The result is that the forecaster begins with headwater basins, iteratively running the models defined for the basin, comparing simulated results against observed data, making model adjustments to improve agreement, and re-running NWSRFS. When the forecaster is satisfied that simulation errors have been minimized within reasonable bounds, the forecaster directs NWSRFS to proceed to the next downstream basin. Consequently, the hydrograph from the basin just completed serves as an upstream time-series input to the next downstream basin, which becomes the current basin for modeling purposes. These steps are repeated until the forecaster has completed NWSRFS simulation of the most downstream basin in the set of topologically connected basins, called Forecast Groups (Figure 2). Each RFC divides its area of responsibility into collections of Forecast Groups based on basin divides, stream network topology, and what seems manageable within a forecast context.

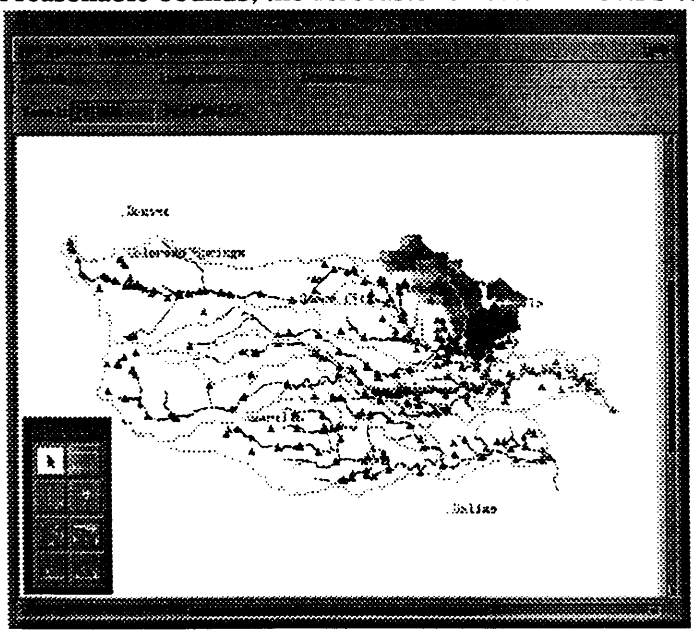

Figure 2.

NWSRFS must cycle through an entire forecast group beginning in the headwater basins, or the most upstream basin in the case of downstream forecast groups, and terminate with the last downstream basin when it executes in a batch mode. Errors encountered upstream are propogated downstream through channel routing. Thus, any model changes made to upstream basins are felt downstream, which leads to wasted computational cycles through downstream basins until good model results are obtained in upstream basins. However, during actual forecast sessions, when forecast schedules must be met, shortcuts are made to minimize the number of NWSRFS runs. Consequently forecast accuracy suffers until forecasts are updated during a subsequent session. The IFP circumvents this problem by allowing the forecaster to make as many iterations as needed on each basin before proceeding to downstream basins in the forecast group. The forecaster must still exercise hydrologic judgement and skill in making *good* model adjustments to minimize the number of iterations on each basin, but on fast Reduced Instruction Set Computer (RISC) -based scientific workstations, the time spent on model computations for individual basins is small (on the order of a second or two, at most) and results are displayed immediately.

The kind of NWSRFS model changes that can be made during forecast operations, using a mechanism of *runtime modifications*, are limited to certain state and parameter variables and observed time-series when they are found to be erroneous. These changes have no lasting effect on the underlying calibration of the NWSRFS models and have limited periods over which they affect simulations.

State, Parameter, and Data Modifications

Typically when hydrologic models are used for research or in engineering practice, if simulations appear to be *systematically* under or over predicting observations, some change is made to an indivdual parameter value or a few parameter values of the underlying model to improve model agreement over most of the model simulations. However, in a predictive mode no observations are available for comparison and none will be available, in all likelihood, until well after the time of interest. Parameter tweaking may take the form of a slight increase or decrease in the value of an infiltration or soil moisture storage coefficient, Manning's *n* value, etc. There are many sources of model errors.

Some errors are artifacts of model structure and conceptualization, they are the result of simplifications of physical systems in order to achieve a predictive model. We attempt to minimize these errors during model calibration. At some scale all models are lumped, either explicitly or implicitly, whether they are conceptual or are physically based (Bevan, 1989). Lumped conceptual models approximate the real world and introduce errors through their structure. Also, spatial averaging of parameters at many model scales likely will not reflect heterogeneities in the response of the physical system very well. Additionally, during model calibration and verification there is the question of the source of input and output errors, whether they are due to measurement uncertainty or are introduced through spatial and temporal averaging. Physically based models invariably make assumptions of homogeneity over sub-grid scales, which also leads to errors, but also raises questions concerning the applicability of equations that are valid at small (microscopic) scales to grid areas on the order of tens of meters.

The fundamental point remains that once achieved, model calibration represents an optimized set of parameters (based on the observed data over the calibration period) that should be left unchanged unless underlying assumptions related to the condition of the basin or climate, etc., change. If conditions change within the basin, which most often is related to landuse changes or the construction of flow control structures, the assumptions are altered and a re-calibration is warranted and necessary. However, other factors may influence the modeling process that could justify temporary changes to some model parameters, particularly in an operational forecast setting.

Some modifications are easy to identify during forecast operations, such as correcting erroneous observations or marking periods within time-series as missing data if the correct values are not available. But in algorithms such as that found in NWSRFS which automatically identifies incident precipitation as either rainfall or snowfall according to whether or not the observed temperature is above or below some threshold temperature value, allowances are made to let the forecaster explicitly identify precipitation as either rain or snow. For instance, field reports could indicate rainfall is falling in an area that a NWSRFS model has identified as snowfall. The IFP and NWSRFS allows the forecaster to override model results and force precipitation within the basin simulations to be rainfall rather than snowfall over the affected period (Figure 3).

Similarly, within NWSRFS' snow modeling algorithm (SNOW-17), there is the capability to adjust the rate of snowmelt using a snowmelt correction factor, owing to the complexity of snowmelt thermodynamics, the observed characteristics of the snow pack, and forecaster's experience (Figure 4). NWSRFS-IFP has the added capability that allows forecasters to adjust the amount of incident precipitation over a basin, which currently only accepts basin average values. Mean areal precipitation estimates in NWSRFS are calculated for each basin from surrounding raingages and those located within basins using Thiesen and similar weighting schemes. Given the high areal variability of rainfall, especially during summer months, and the relative sparcity of recording raingages, intense rainfall could be easily missed and often is during forecast operations. So when reports from local observers indicate higher rainfall amounts than the automated system is reporting, the NWSRFC forecaster can adjust the incident rainfall by using a RRICHNG modification based on amounts that come from local observers (Figure 5). Within the AWIPS environment, the availability of detailed radar rainfall estimates using WSR-88D radar (Shedd, 1993) will dramatically improved the scale at which precipitation estimates (on a 4x4 km grid) are available for NWSRFS hydrologic modeling purposes.

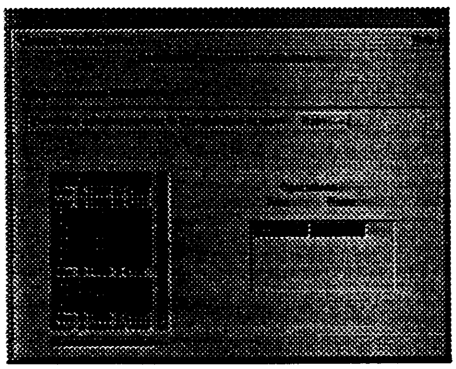

Figure 3.

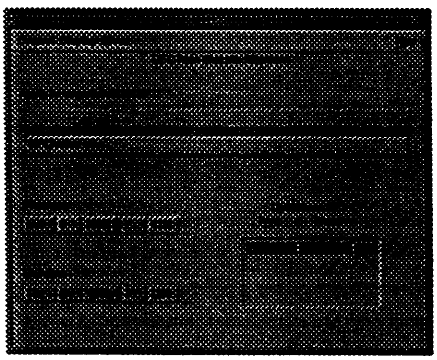

Figure 4.

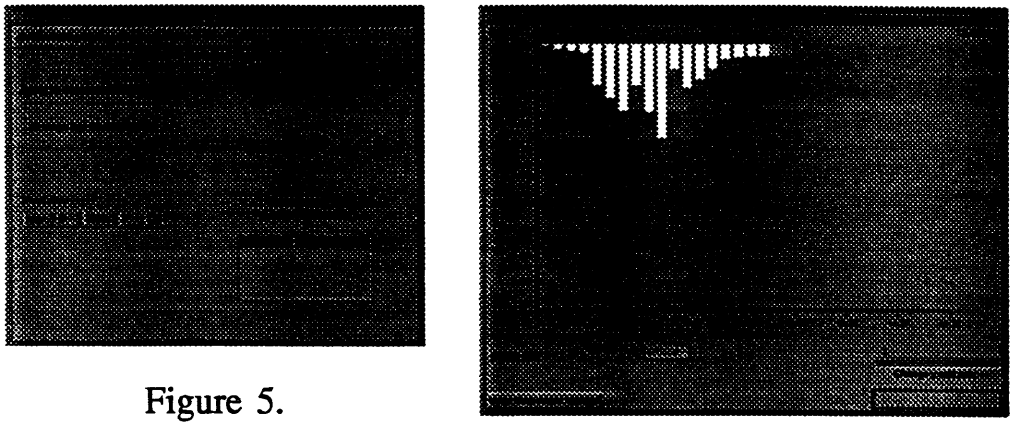

Figure 5.

Summary/Conclusions

NWSRFS has proven itself to be a robust system for NWS operational hydrologic forecasting over the last decade. With IFP ehancements the system has proven to be significantly easier to use, leading to improved and more timely forecasts. NWSRFS' capability that allows forecasters to make operational (runtime) modifications to state, parameter, and input data is a crucial element in producing reliable accurate river flow and flood forecasts.

Appendix I. References

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