CHINA COUNTRY REPORT: NATIONAL FLOOD FORECASTING SYSTEM IN CHINA

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Abstract

This paper focuses on the key technologies for structure of flood forecasting model-base and flood forecasting schemes, and the coupling mechanism of model calibration with optimization algorithms as well as the interactive operational forecasting which fully exerts forecaster's knowledge and experience, enhances the efficiency of forecasting analysis and improves quality of forecasting production. Meanwhile, a technical system of the universal flood forecasting i.e. National Flood Forecasting System (NFFS) is built.

Key Words: Flood Forecasting, Forecasting Scheme, Parameter Calibration, Interactive Forecasting

1. INTRODUCTION

The Bureau of Hydrology (BOH) is a non-profit agency affiliated to Ministry of Water Resources (MWR) with administrative function. BOH takes the following responsibilities: managing hydrological sector all over China; organizing and providing guidance to monitor and analyze water quantity and quality of surface water and ground water as well as assessing water resources; collecting, processing and forecasting precipitation information and water regime for state key flood control areas and important large-sized reservoirs and providing decision-making support to State Flood Control and Drought Relief Headquarters. The division of hydrological information and forecasting (DHIF) supports this mission not only by providing flood forecasting and warning for the protection of life and property and but also basic hydrological information for improvement of economy and environment. The hydrological experts of DHIF have been designing, developing, testing and implementing a hydrological forecasting system i.e. the National Flood Forecasting System (NFFS). In future, NFFS will be developed and applied in hydrological forecasting sectors of BOH in 31 provinces and 7 large river authorities as well as 244 local hydrological centres in China. It will improve significantly the modernization level of hydrological information and forecasting in whole country and provided a great deal of flood forecasting achievements with long lead time and high accuracy to the flood control and decision-making sectors in recent years.

2. BACKGROUND

After late 1980s, with the popularity and evolution of computer technology, varied flood forecasting software were developed respectively by hydrological information and forecasting sectors in different levels. However, owing to lack of uniform management, these locally developed software programs introduced three major problems into flood forecasting. First, this independent software was developed according to specifically requirement and objectives. With the hydroclimatic variation in China from humid to arid conditions, there is no flood forecasting system which include all the features needed to model the flow in rivers in the varied hydrometeorologic regimes. Second, this software had a rigid program structure which made it difficult to add new modules as additional features were developed. The hydrological modelling structure required that all basins use the same models in a fixed sequence. Third, the software was dependent on the individual who did the initial development. When that person changed jobs or retired, much of the knowledge of how to run the programs, or how to maintain or enhance the programs was lost. Hence, by 1998 there is no a uniform flood forecasting system to be developed and applied in China.

3. NATIONAL FLOOD FORECASTING SYSTEM

In late 1990s, with the implementation of National Flood Control Command System project, the uniform standard real-time database has been built in hydrological information centres of national, provincial and local BOH. It supports the technique basis for NFFS. In 1998, the BOF of MWR began a project to design the structure of NFFS. A major objective of the project was to develop a system structure which looked toward the future of flood forecasting. The basic design requirement for NFFS is (1) to found standard advanced software and hardware configuration based on the uniform standard real-time database and client/server environment, (2) to adopt modular structure to easily add new models and procedures to keep up with technological changes, (3) to let the user control the selection of models and the sequence of use, (4) to have a model calibration system which combined manually and automatically calibration method, (5) to allow the user to flexibly control real-time processing and use graphical and tabular interface for interactive forecasting, (6) to efficiently process large amounts of data to produce forecasts at hundreds or thousands of locations, (7) to have integrated powerful flood forecasting management function.

At present, the major parts of NFFS is shown as following:

(1) Software and hardware configuration of NFFS

The software and hardware configuration of NFFS includes computer hardware platform, computer operating system above Windows 95/98 and standard real-time database as well as client/server environment. The NFFS software can be installed in client computer. There are two supporting database i.e. IDBS and FDBS which be constructed in server (see Fig1). IDBS is the real-time database. FDBS is forecasting database to store the model code, parameter, state, flood forecasting scheme, forecasting result, historical hydrometeorologic data, basin geography information system (GIS) and user information. NFFS is developed based on GIS which have a powerful capacity to display and manage river, topography, basin boundary, gauging station distribution, Thiessen polygon boundary, real-time and forecasting information query for forecasting location.

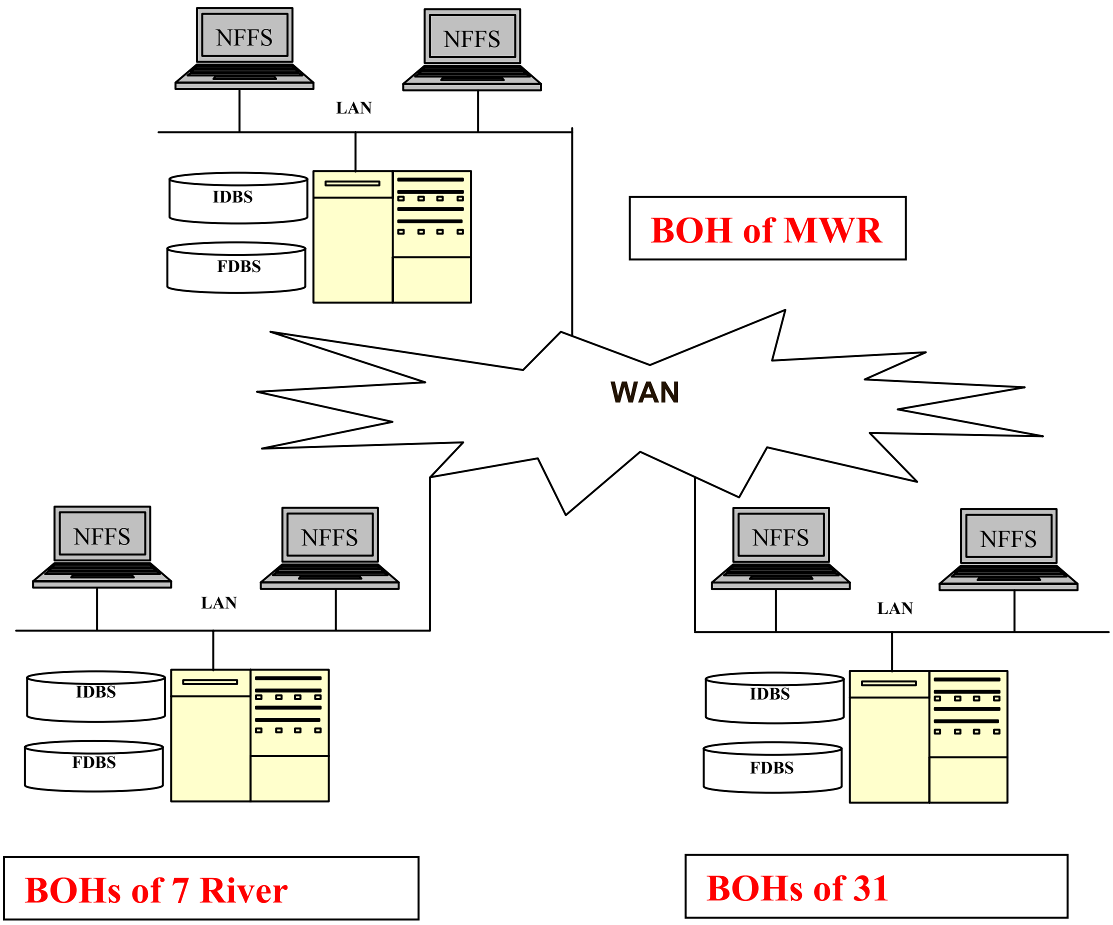


Fig 1. NFFS's Environmental Structure

(2) Flood forecasting models and methods

NFFS adopts complete modular structure so that modules can be independent of system and components could be developed by a number of individuals. The user can easily add new models and methods based on standard I/O files form and flexibly select a set of models and methods to build a forecasting scheme for any basin. At present, hydrological models in NFFS can be selected from the following list:

Soil	Xinanjiang Soil Moisture Accounting	SMS_3
	Sacramento Soil Moisture Accounting	SAC
	Rain-Runoff correlation Method	P_RZHJR
Channel	Lag and K Routing	LAG_3
	Muskingum Routing	MSK
	Unit Hydrograph	UH_B
	Diffusion Wave Model	KSB
Utility	Empirical Model	P######

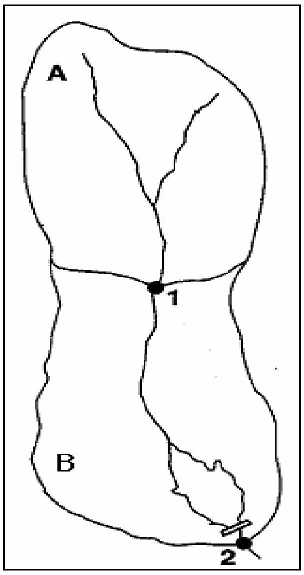
Reservoir regulation	Independently controlled reservoir regulation under various modes of operation	RES_SNGL

These hydrological models were compiled to dynamic link libraries with 32 bit as outer function.

In NFFS, there are 9 variety of standard I/O files including model parameter file, model initial state file, water level and discharge input in same interval time file, observed water level and discharge input file, point rainfall input file, areal rainfall input file, net rainfall I/O file, model terminal state file, water level and discharge output in same interval time file. These 9 files can be stored in one file according to fixed sequence of use as module interface parameter. If any I/O of conceptual model or empirical model can be programmed based on above description, it will be a general standard forecasting model.

(3) Forecasting scheme

The flood forecasting schemes embody that a set of models and methods selected considering the features of related rivers. The user can found and manage easily forecasting schemes for consecutive forecasting from upstream to downstream by friendly human-machine interface in NFFS. The processing include inputting basin code, lead time of forecasting scheme, basin boundary, code of gauging stations selected, weights of precipitation stations, parameter, state, interval time, warming time of models selected, rating curve, warning threshold and illumination (see Fig. 2).



SMS_3	Area A
LAG_K	Area A to Point 1
MSK	Point 1 to Point 2
SMS_3	Area B
LAG_K	Area B to Point 2
ADD/SUB (Runoff)	Area A + B
ADJUST-Q	Point 2
STAGE-Q	Point 2 (Q→H)

Fig 2. The Process of Forecasting Scheme Foundation

(4) Model calibration

Calibration of model parameters can be completed well by error-trial and automatic calibration methods based on human-machine interface in NFFS. The Simplex and Rosenbroke optimization methods were adopted in calibration module of NFFS. The independent calibration module is only related to parameters optimized and objective function selected so that the module can be easily updated (see Fig 3.).

Two objective functions i.e. coefficient of determination and water balance can be selected. Threshold of objective function can be selected according requirement of user.

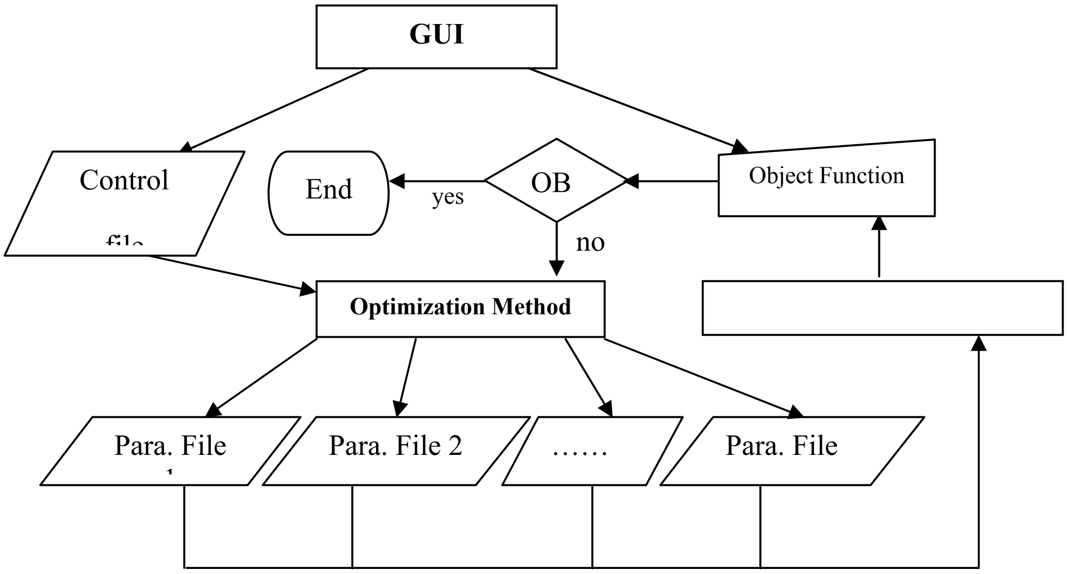


Fig 3. The Process of Parameter Optimization Calibration

(5) Real-time operational forecasting

In NFFS, there are interactive forecasting and automatic timing forecasting. The automatic timing forecasting means NFFS can automatically accomplish forecasting by forecasting scheme and sequence selected, even every hour. Interactive forecasting can provide the information to forecaster for the correction of data and simulated results. The interactive forecasting module can deal with rainfall input, rainfall in lead time, runoff input, model parameter, model state, rating curve, results and adjustment optimization by graphical interface (see Fig.4). Forecasting error statistic module can analyze all forecasting results for any forecasting location to compare the accuracy of forecasting schemes and assess capacity of forecaster.

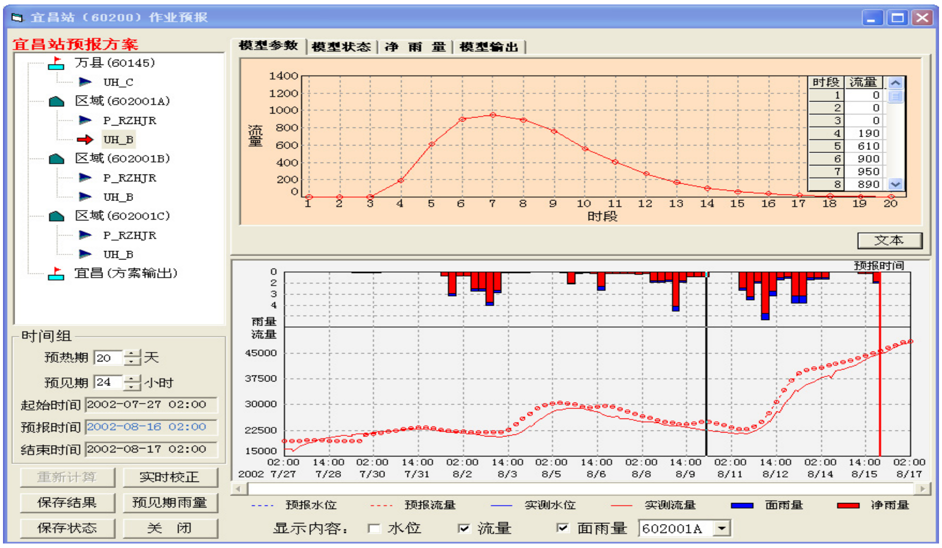


Fig 4. Interface of real time operational forecasting

(6) Utility modules

In NFFS, a number of data processing modules were developed, including model parameter file production module, model state file production module, three-dimension map display and query module, automatic generation of catchment boundary module (see Fig.5), Thiessen polygon area calculation module, point rainfall in same interval time calculation module, rainfall distribution module, water lever and discharge conversion module, forecasting error adjustment module and forecasting scheme I/O module etc.

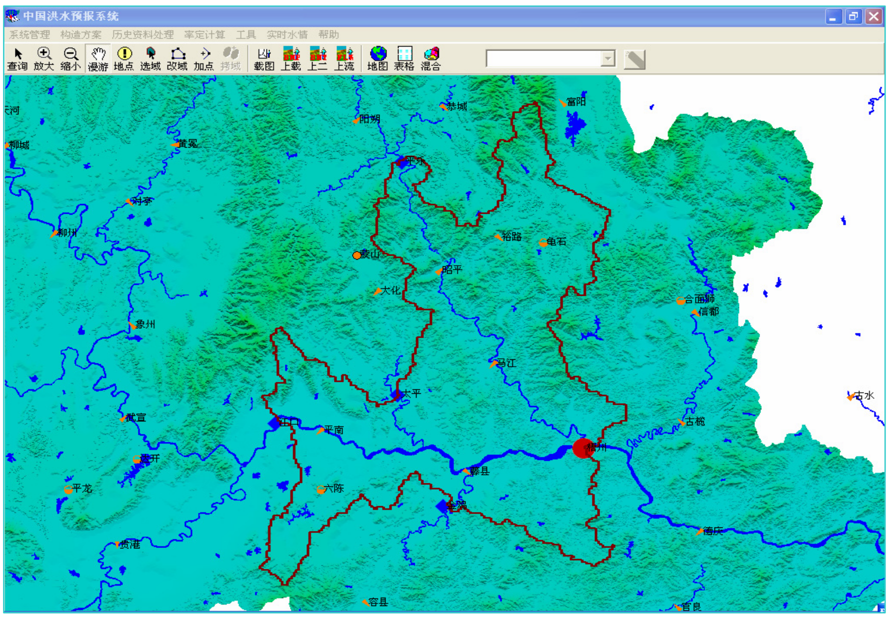


Fig 5. The module of automatic generation of catchment boundary

(7) System management

NFFS has powerful system management function including user management, forecasting model management, forecasting scheme management, hydrological station management.

User management includes administrator, general user. Administrator can add, delete and modify forecasting model, distribute forecasting scheme, manage automatic timing forecasting, user information; General user can construct, delete, modify, calibrate and operate its own forecasting scheme. Hydrological station management includes system station management and scheme station management. System station management can add, delete, modify the feature of hydrological station in electronic map by SA; Scheme station management can add, delete modify the precipitation station used in scheme by general user.

4. SUMMARY

The main conclusions are summarized as follows:

(1)The paper studies a set of unified standard data interface and management system to found flood forecasting model-base which possesses the basic characteristics of software reuse, independence, unification and expansion.

(2)The paper presents the management system of forecasting scheme, indicates the structure of flood forecasting scheme which can be finished easily and quickly based on man-machine interface.

(3)The paper shows the standard data interface between coupling mechanism of model parameters calibration with optimization algorithms.

(4)The paper demonstrates all kinds of man-machine interactive interface in the process of manual flood forecasting so that it is helpful to quicken the speed of forecasting analysis and to promote the quality of forecasting production.

Based on the key technology frames mentioned in this paper, the National Flood Forecasting System has been developed and applied successfully to 22 kinds of hydrologic sectors in both Ministry of Water Resources and provinces.

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