DIGITAL WATERSHED AND ITS APPLICATION IN THE CONSTRUCTION OF DISTRIBUTED HYDROLOGY MODEL(DHM)

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Abstract – This paper proposes the concept and framework of digital watershed which is divided into three levels such as visual information platform, thematic application system and comprehensive decision-making support system. The construction of distributed hydrology model(DHM) based on digital watershed are discussed. It is shown that digital watershed makes it possible to construct DHM with the real meaning of "distributed on the whole scale of watershed". Digital watershed not only provides a new way to acquire, manage and analyze the complex input parameters of DHM, but also improves the visualization of the hydrological processes and results. It can play the role of the basic platform for the construction of DHM and the management of watershed.

Keywords: Digital Watershed, Distributed Hydrology Model(DHM), Spatial Information, Watershed Management

1. INTRODUCTION

Since Mr. Al Gore who was the former Vice President of the United States originally brought forward the concept of digital earth in 1998(Al Gore, 1998), the theories and methods of digital earth have been widely studied all over the world. So far, a lot of new versions of digital earth such as digital city, digital district and digital province have been come forth. As the cradle of human civilization, watersheds play very important roles in the economic and social sustainable developments. Because a watershed generally crosses over multi-administrative regions, it is best to consider the watershed as a whole in order to optimize its managements in the scale of watershed. Today, there have already been many watershed administrative organizations all over the world. In this situation, how to optimally manage the whole watershed has become a significant and urgent issue. As a branch or layer of digital earth, digital watershed is a very important node for the realization of digital earth (Zhang et. al, 2001), it can provide a new solution for the management of the whole watershed.

The water resources in watershed supply water for municipalities, agriculture and industry. If there are not enough water resources, drought will occur, while superfluous waters will cause flood hazard. So, the prediction and adjustment of water resources in watershed are very important for the watershed management. Hydrological model is one of the basic ways used to analyze and predict the water situation in watershed. So far, a lot of hydrological models have been developed, especially some distributed hydrological models(DHM) have begun to be proposed. However these hydrological models are not easy to be constructed by using conventional methods because of their complex input and output parameters.

This paper proposes the concept and framework of digital watershed, and discusses how to construct the distributed hydrological model based on digital watershed.

2. DIGITAL WATERSHED

2.1 Concept of digital watershed

Digital Watershed is an important branch of digital earth, Generally speaking, digital watershed is a large system which uses the modern technologies of remote sensing(RS), geographical information system(GIS), global positioning system(GPS), virtual reality(VR), database, network and

multimedia to capture, store, manage, process and analyze the information on geographical background, fundamental facility, natural resource, cultural scene, ecological environment, population distribution, social and economic condition in the scale of watershed, constructs a visual fundamental information platform, provides thematic application systems for administrative departments of different fields in the watershed, and on the bases of these, then develops a comprehensive decision-making system to optimize the managements of the watershed. So, digital watershed can not only model a watershed in the computer and provide visual query of information, but also simulate the thematic and comprehensive managements of the watershed(Zhang, 2001).

From the above descriptions, it is shown that digital watershed is the high integration of modern digital, network and information technologies in watershed. It provides a new way or tool to design, build, manage and serve the watershed. The construction of digital watershed plays a very significant role in improving the management efficiency and increasing the modernization level of the watershed(Zhang, 2001).

2.2 Framework of digital watershed

Digital watershed is a very huge system engineering. According to the above concept, it can be divided into three layers as follows.

(1) Visual information platform—Base Layer

The visual information platform is the basic layer of digital watershed. By using modern digital, information and network technologies, it collects different types of information in the watershed, constructs the spatial and attribution databases and makes up a visual fundamental information platform based on GIS, which models the watershed in the computer, realizes the visual storage, management, query and analysis of the information in the watershed and provides information services for the public.

(2) Thematic application subsystem—Thematic Layer

The thematic application subsystem is the applied layer of digital watershed. In a watershed, there are always many administrative and professional departments in different fields such as hydrology, natural resource and environment, which have their own corresponding requirements for automatic office(AO) and decision-making support system(DSS). On the base of the visual fundamental information platform, different thematic application subsystems should be developed for these professional departments so as to provide thematic application services.

(3) Comprehensive management and decision-making support system—Synthetical Layer

As the synthetical layer of digital watershed, the comprehensive management and decision-making support system is used to analyze different types of information in the watershed based on the visual information platform. In addition, it optimizes the macro-management and policy-making of the whole watershed according to the integration of many different results obtained from all the thematic application subsystems.

Among the above 3 layers of digital watershed framework, each of them has its own special functionality and is designed for corresponding users. The visual fundamental information platform is designed for everyone, including professional thematic users, as well as all public users. The thematic application subsystems are used by different administrative and professional departments in different fields in the watershed, and the comprehensive management and decision-making support system is designed for the top administrators of the watershed.

3. DISTRIBUTED HYDROLOGICAL MODEL(DHM)

3.1 Basic meaning of DHM

Hydrological model involves the mathematical simulation of the hydrographic responses to a hydrological event such as precipitation in a hydrologic unit. According to its structures and parameters, hydrological model can often be divided into two main types: lump hydrological model and distributed hydrological model.

By considering the whole watershed to be uniform, the lump hydrological model(LHM) describes the hydrological process in the watershed with average data. So, all the input parameters and the output results of the model are averaged. Different from the LHM, distributed hydrological

model(DHM) divides the whole watershed into a lot of subunits that have their own special parameters and are correlated with each other, and then the hydrological processes in each subunit of the watershed and the relationships between them are simulated. Compared with LHM, DHM pays more attentions to the non-uniformity of the watershed, and its descriptions of the hydrological process are distributed in the whole watershed area, which is more accordant with the actual hydrological process of the watershed. So, it is more appropriate to adopt DHM to simulate and analyze the water resources in the watershed.

3.2 Theory of DHM Construction

From the above definitions of LHM and DHM, it can be found that DHM is more complex in structures and parameters, and therefore more difficult to be constructed than LHM. In the construction of a hydrological model, input parameters, initial and boundary conditions, as well as governing equations are always needed to simulate the hydrological process so as to obtain the hydrological outputs in the watershed(Fig.1). In order to construct a DHM, the watershed has to be firstly divided into some subunits, and then the input parameters of the model in every subunit should be obtained respectively. Although there might be different input parameters for different DHMs, some input parameters are common, including rainfall, interception, evapotranspiration, infiltration and so on. With these parameters, as well as the initial and boundary conditions being input into the governing equations, the outputs such as water discharge in every subunit and the water accordant junction of all the subunits in the whole watershed are calculated and simulated.

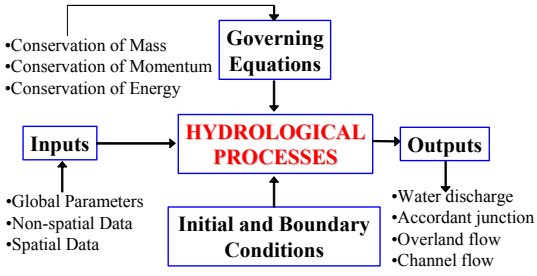

Fig.1 General theory and workflow to construct DHM

4. CONSTRUCTION OF DHM BASED ON DIGITAL WATERSHED

It seems that the construction of DHM is very simple in theory, however in practice, it is not easy to be realized. One of the most important reasons is that the input parameters of every subunit in the whole watershed are quite difficult to be obtained, managed and analyzed in conventional methods because of the large area of the watershed and the spatial complexity of these parameters. So, although at the end of 1960s, the concept of DHM has been firstly proposed, there are less practical DHMs that have the real meanings of "distributed on the whole scale of watershed". It is necessary to probe into new ways to conveniently construct DHM. With digital Qinjiang watershed in China for an example, we try to technically apply digital watershed in the construction of DHM.

4.1 Information platform of digital Qinjiang watershed

According to the concept of digital watershed, the information platform of digital Qinjiang watershed, including the basic and thematic information databases are constructed. In the basic information platform, the fundamental information on geographical background, ecological environment, society and economy in the watershed are collected and digitized. In addition, the hydrology thematic information such as water system, precipitation, land over/use, vegetation, soil moisture and evapotranspiration that are needed to be used to construct DHM are also integrated onto the basic information platform. All these information are managed by the databases based on GIS, which can be visually displayed and queried.

Since the watershed is always very large and spatially non-uniform, it is quite difficult to acquire, collect and manage the above information if only using traditional methods. In addition of the conventional investigations on site of the watershed, remote sensing is also applied to inverse the information because of its macro-field, quick and economical advantages. Figure 2 is an example to acquire the water system of the Qinjiang watershed by applying the remote sensed SRTM dataset(Farr, 2000).

Fig.2 Water systems in Qinjiang watershed inversed from the remote sensed SRTM dataset

4.2 Spatial information grid(SIG) construction based on information platform

On its basic and hydrology thematic information platform, the Qinjiang watershed is divided into a lot of subunits, and the parameters in every subunit needed to construct DHM are visually digitized respectively. Because all the subunits are spatially distributed in the whole watershed and each of them has its own corresponding information, they are called spatial information grid(SIG) which is managed by using GIS(Fig.3).

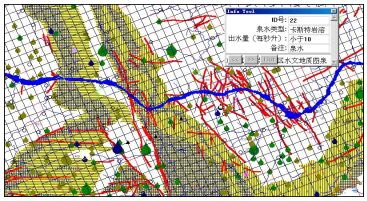

Fig.3 SIG construction based on digital Qinjiang watershed

4.3 Construction of DHM and hydrological analysis

Read out from the spatial information grid of digital Qinjiang Watershed, the parameters needed to construct DHM are input into the governing equations, and along with the initial and boundary conditions, the water discharge in each subunit and the run off in the whole Qinjiang watershed can be calculated and simulated. Figure 4 is the simulation of the flood going forward in Qinjiang watershed.

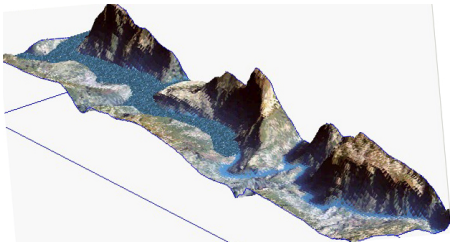

Fig.4 Flood going forward simulation in Qinjiang watershed

5. CONCLUSIONS

With the high integration of modern digital, network and information technologies in watershed, digital watershed is an important regional branch of digital earth. Digital watershed is a very huge system engineering which can be divided into base layer, thematic application layer and synthetical layer. Digital watershed provides a new way for the management of the watershed.

Because of the spatial complexity of its input and output parameters, it is not easy to construct DHM only in conventional methods. Digital watershed makes it possible to construct DHM in practice with the real meaning of "distributed on the whole scale of watershed", it not only provides a new method to acquire, manage and analyze the complex input parameters of DHM, but also improves the visualization of the simulated hydrological processes and results. Digital watershed can play the role of the basic platform for the construction of DHM, and the hydrological simulation in the watershed is one of the thematic application systems of digital watershed.

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