NEW TREND AND APPLICATION OF RUNOFF ANALYSIS

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1. Introduction

Water-related disasters such as floods and droughts are increasing in the world and their scale of damage and impact is becoming increasingly serious. This may be caused by factors like climate change in global scale, rapid population growth, the high concentration of population and property in urban areas, etc. In Japan, flood risk is seriously high because of its special meteorological and geophysical conditions. Typhoons and Bay-u fronts bring heavy rainfall to Japan. Rivers are characterized by rapid runoff because of steep slopes of Japanese mountains. In addition, large fraction of the population and property are concentrated in floodplains which have the large potential of inundation.

In order to arrive at good flood simulation results, it is important not only to develop physically-based runoff models but also to clarify a runoff mechanism in a basin. A large number of refined physical models or theories were proposed to simulate runoff in real watersheds during the last several decades, and offered us a wealth of useful information about the mechanism of water flow in a catchment and its contribution to the runoff.

Two major developments transformed hydrology by making it more physical than empirical science. The first was the availability of increasingly-powerful computers which enabled the development of much more complex runoff models. The second was the recent developments in the remote sensing techniques. These technological developments have kindled a new interest in describing and modeling hydrological processes considering spatially distributed hydrological characteristics by using a distributed runoff model. Especially, over the last 10 years, remote sensing has emerged as a potential solution to many hydrological problems, and it holds out the possibility of a true distribution modeling capability in hydraulics. Pixel sizes for remotely sensed data are often the same as distributed model element scales.

2. Integrated Tools for the Water Cycle Simulation Based on Hydro-meteorology (Chuo University Model)

Over the last 10 years, joint research between Chuo University and DHI Water & Environment has been carried out to develop physically based flood forecasting system in Japan. We have developed a framework for simulation of flood flow based on meteorological and geophysical information. This is an integrated approach which covers part of water cycle from rainfall to flood inundation calculation. This method can be adopted for diverse scenarios including urban areas and mountainous terrains (**Fig.1**). In particular, the method is very promising for forecasting flood disasters in small basins and developing countries where the past hydrological data is insufficient. We continue developing our model and intend to eventually devise a method for utilizing the advanced remote sensing techniques in any region where the parameters concerning soil property, topographic characteristic, and land-use are available.

Total research activities have following features;

- ○Radar Hydrology: prediction and analysis of rainfall event
- ○Micro Cloud Physics: effects of aerosols on the cloud formation
- ○Urban Thermal Environment: mitigation effects of thermal environment by forest, river and watering
- ○Land Use Information: auto classification by using satellite images and GIS
- ○Runoff Analysis: distributed runoff models and flood routing models in river (MOUSE, MIKE SHE and MIKE 11)
- ○Flood Inundation Simulation (MIKE 21)
- ○Flood Control Method by Dam Gate Operation (MIKE 11)
- ○Theoretical Analysis of Fluid Dynamics: mathematical approach for analysis of ascending waves on a river based on generalized coordinate systems
- ○Mechanism of Sediment Transport and Variation of River Bed in Tidal Rivers

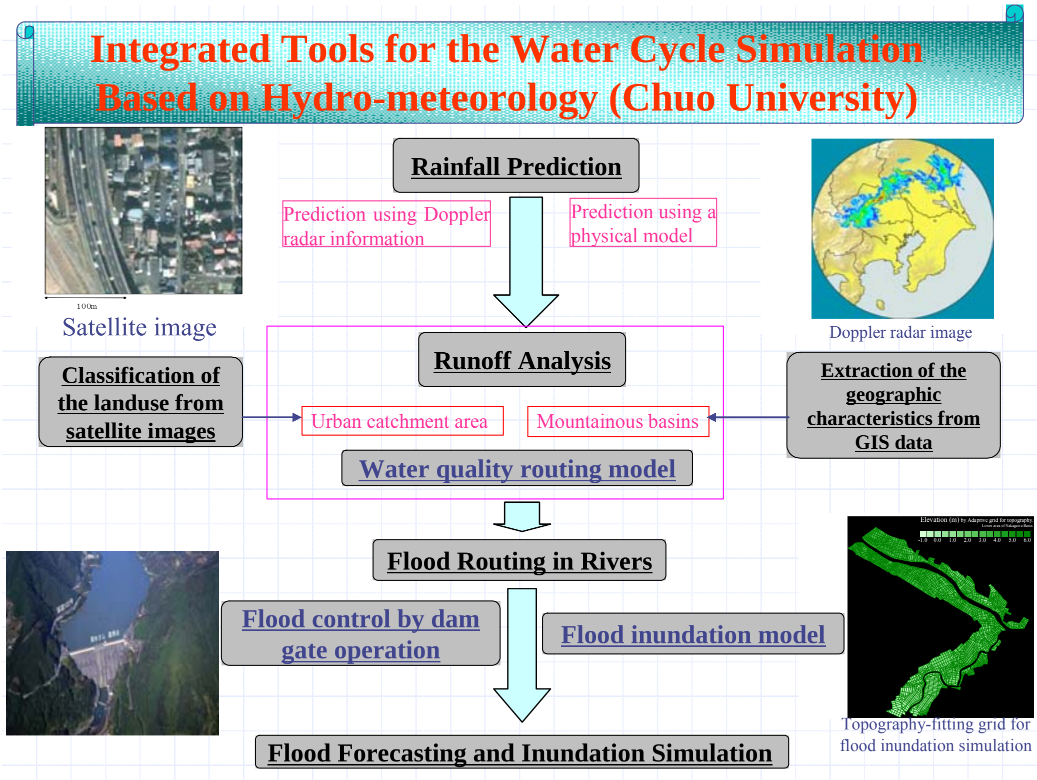

Figure 1. Schematic representation of flood simulation outline

○Field Observation and Numerical Analysis of Water Quality in Reservoirs, Lakes and Tidal rivers

Our laboratory has a Doppler radar for meteorological observations, whose detection range is 256km, and it covers all of the Kanto plain. Radar information is used: 1) to analyze the rainfall characteristics of growth and decay; 2) input rainfall data for runoff calculation considering the temporal and spatial distribution of rainfall; and 3) predict rainfall. There are two methods to predict rainfall using Doppler radar information. One is to predict rainfall by visual Doppler radar images. The other method is to predict rainfall by using physical models together with Doppler radar information.

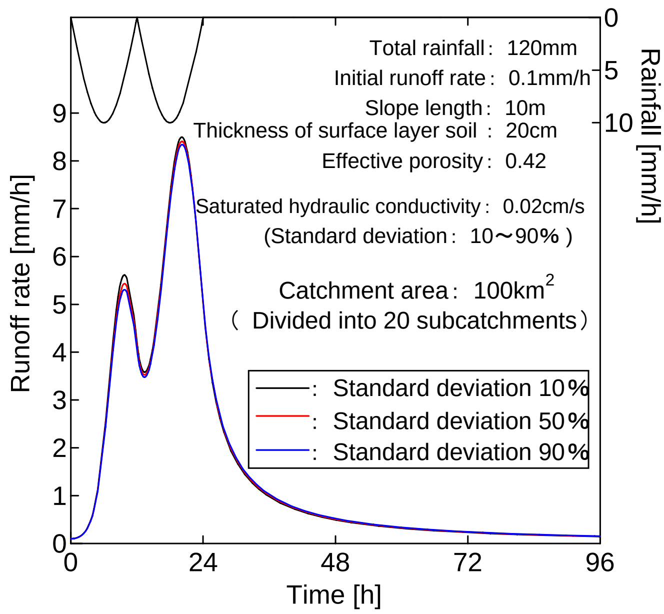

Figure 2. Relationship between spatial distribution of saturated hydraulic conductivity and runoff rate

The land use is automatically classified by using satellite images, and the information is provided as the ground surface data regarding urban areas. Geographic characteristics like river networks and basin boundaries in mountainous terrains are extracted from GIS data including Digital Elevation Models. For runoff analysis in urban areas, MOUSE model consisting of surface and pipe-flow components is being used. In mountainous basins, a lumped model based on the Kinematic wave scheme is proposed. From the relationship between unsaturated flow theory and Kinematic wave equation, the parameters of this model are determined based on topographic and geographic characteristics. This is extremely important for flood prediction in ungauged basins where hydrologic data is insufficient. Also this model can demonstrate surface flow, subsurface flow, vertical infiltration flow and ground water flow, depending on differences in soil properties. At the same time, water quality hydrographs, which illustrate change in the concentration of various substances in river water during a rainfall event, are simulated by using a new theory based on the law of conservation of mass. With regarding to flood routing in rivers, one-dimensional

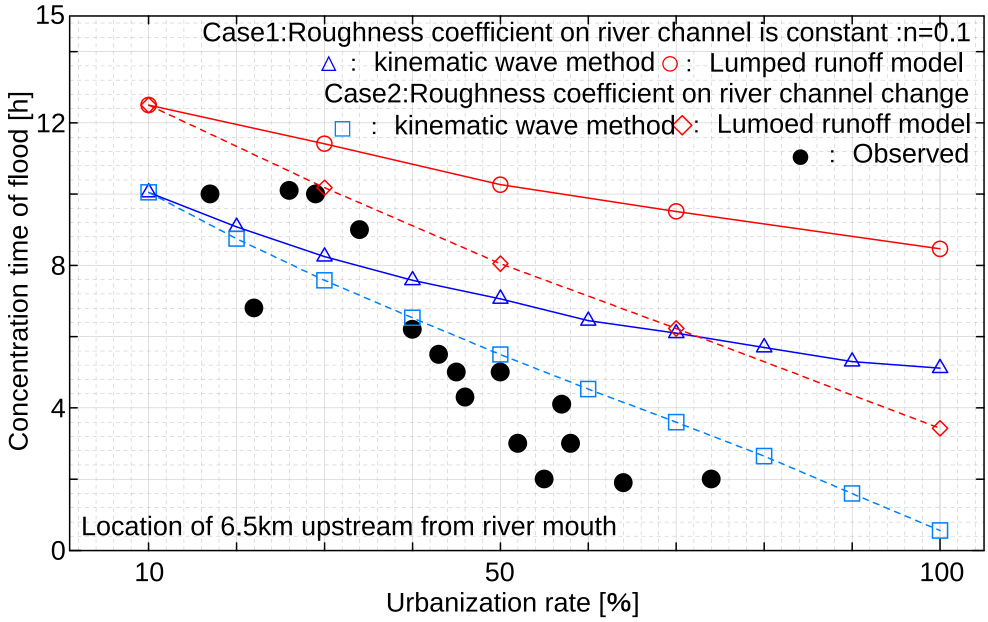

Figure 3. Relationship between concentration time of flood and urbanization rate

unsteady flow calculation is carried out in a large-scale channel networks. In small mountainous basins where the effect of river channels is small, a lumped model using Kinematic wave theory is used. It is not important to carry out the unsteady flow model in small mountainous basins in case their spatially scale is in the order of $100km^2$.

3. Effects of Spatial Distribution of Hydrological Characteristics on Flood Runoff

In order to clarify the effects of spatial distribution of hydrological characteristics on flood runoff, we carried out rainfall-runoff calculation using MIKE SHE considering spatially distributed hydrological characteristics in a catchment scale and saturated hydraulic conductivity in a slope. With regarding to flood routing in rivers, one-dimensional unsteady flow calculation using MIKE11 is carried out in a large-scale channel networks. Hydrological characteristics were given as the random number which followed normal distribution for each sub catchments under the condition that the mean value of hydrological characteristics was set to equal in all calculations.

The calculation result is shown in **Fig.2**. It is clear that there is a little difference about calculated runoff rate at the end of the catchments considering the spatially distributed hydrological characteristics. From these results, it is found that the effect of the spatial distribution of hydrological characteristics on rainfall runoff can neglect in catchment scale of about $100km^2$ and hydrological characteristics can deal with a mean value in runoff calculation.

4. Impacts of Urbanization on Flood Runoff in an Urban Catchments Area

In order to evaluate quantitatively the effects of urbanization on flood runoff characteristics in an urban catchment area, we carried out runoff calculations using Mike11 for *Tsurumi* river catchment which is one of typical urban river in Japan. In surface runoff calculation, urbanization rate is treated as impervious area rate for catchments, initial loss, manning roughness coefficient for each catchments and effective rainfall.

Fig.3 shows the results of calculation and observation of relationship between concentration time of flood and urbanization rate in Tsurumi river catchment. It was found that concentration time of flood is dramatically decreased with increase of the urbanization rate.

5. Flood Control by Dam Gate Operation

A new method of flood control by dam gate operation based on runoff characteristics of a basin using MIKE 11 will also be presented. This method is based on the idea that there is no risk to reduce reservoir level if the amount of anticipatory release equal to the amount of inflow which flows into a dam certainly from the rainfall that has already fallen. In this method, rainfall data of upstream and downstream catchments is also used to determine the amount of outflow discharge from the dam reservoir.

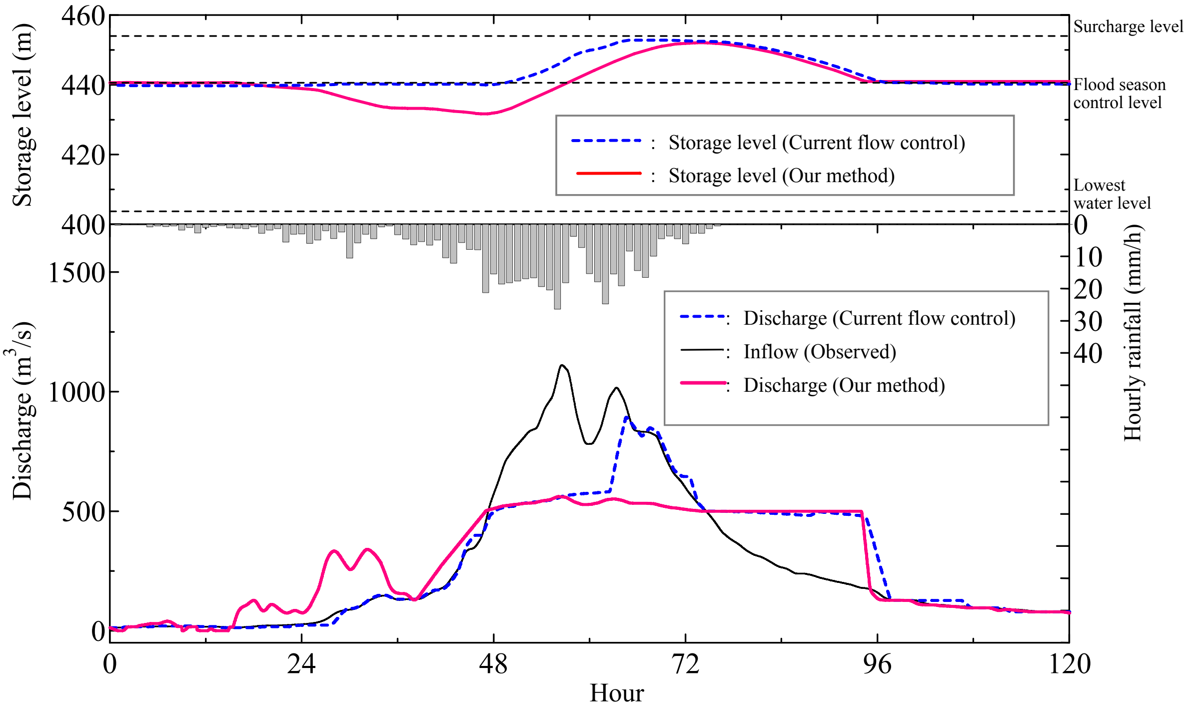

Figure 4. Comparison between flood control by dam gate operation based on our method and present operation

Fig.4 shows time series of an inflow, outflow and the reservoir level for Kusaki dam reservoir in Japan and comparison of flood control based on our proposed method and present method. It can be said that it is very effective for anticipatory release based on the flood control method proposed in this research, as we did not have to perform 'Proviso Operation (Inflow = Outflow)'.

6. Conclusions

The purpose of this presentation is to introduce the Integrated Tools for the Water Cycle Simulation Based on Hydro-meteorology (Chuo University Model) and to clarify the effects of spatial distribution of hydrological characteristics and urbanization on flood runoff in a catchment. The conclusions obtained in the present study are as follows.

1) Framework for simulation of flood flow based on meteorological and geophysical information is proposed in this research. This is an integrated approach which covers part of water cycle from rainfall to flood inundation calculation. DHI Software such as MOUSE and MIKE11 is used in some parts of flood simulation frame.
2) The calculation of rainfall runoff and unsteady flow in large-scale river channel network is carried out in this research. From the calculation results, the effect of spatial distribution of hydrological characteristics on rainfall runoff is small, and hydrological characteristics can be dealt as a mean value in catchment scale of about $100km^2$.
3) A new method of flood control by dam gate operation based on runoff characteristics of a basin using MIKE11 is proposed and applied to Kusaki dam reservoir in Japan. Using our method, water level in target point is reduced more than present level by the use of present operation. From these, it can be said that it is very effective for anticipatory release based on flood control method proposed in this research.

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