Development of an Integrated Flood Analysis System (IFAS) for poorly-gauged rivers

Kazuhiko FUKAMI and Tomonobu SUGIURA

International Centre for Water Hazard and Risk Management (ICHARM) under the auspices of UNESCO, Public Works Research Institute (PWRI), Japan

Abstract The effect of the water-related disaster is increasing with population growth, concentration and increasing value of assets in the flood plain in recent years. In the countries where river improvements are not sufficient, smooth evacuation from flooding is important for decreasing loss of life and properties. However, in reality, development of a flood forecasting and warning system in these countries has not advanced properly because of financial difficulty, lack of rainfall data, etc. Therefore, ICHARM is developing a fundamental common toolkit for flood forecasting and warning system using rainfall data from satellites in order for the countries lack of surface rainfall data to establish flood forecast system rapidly and effectively. This system was named as Integrated Flood Analysis System, in short, IFAS. IFAS can utilize satellite-based rainfall data directly, and has modeling function with a default engine for runoff analysis, and graphical input-output interfaces, which enables runoff calculation necessary for issuing flood forecasts and alerts, which leads to a realization of the concept of GFAS-streamflow of IFNet.

Key Words : *GFAS-streamflow, satellite-based rainfall data, distributed hydrological model, GIS analytical toolkit, flood forecasting*

1. Background and concept of IFAS

In riparian areas with low flood safety due to slow river improvement, safe and smooth evacuation is crucial to protect human lives and property. Flood-prone developing countries, however, are suffering from major flood damages consecutively because of insufficient implementation of flood forecasting/warning systems due to financial constraints and limited hydrological observation facilities. However, we have big challenges for the implementation of flood forecasting/warning systems. Tsunami warning system is a good opposite example, many of which are currently being implemented in developing countries based on international cooperation coordinated by developed countries. Such a style of cooperation is working well because a tsunami warning systems can contribute to early evacuation if the timing of a tsunami wave's reaching is nicely predicted at a certain offshore point, which can be well predicted using regional observation network. On the other hand, flood forecasting/warning systems require detailed local data, such as topography, land use, river conditions, and rainfall distribution, etc. because their local heterogeneity greatly affect the flood conditions and its effect on flood-prone area. Thus, the accuracy and reliability of flood forecasting/warning can be ensured only when both the grasp of such local conditions and the operation of flood forecasting/warning system with continuous improvement are secured by local engineers themselves in a developing country with their sense of ownership.

ICHARM has therefore developed the Integrated Flood Analysis System (IFAS) Ver.1 as a common fundamental tool for flood forecasting/warning systems in developing countries through a joint research with private sectors (FY2005-2007). IFAS contains innovative information and technologies to encourage prompt and efficient implementation of flood forecasting/warning system even in developing countries. Furthermore, ICHARM will offer IFAS as a package with technical assistance in which 1) an executable of IFAS Ver.1 will be provided free of charge and 2) both technical training and dissemination activities are jointly promoted, so that developing countries can utilize provided information and technologies as easily as possible. The packaged assistance will help flood-disaster management administrators in implementing, operating and maintaining the flood forecasting/warning system by themselves with the strong sense of ownership, which will eventually lead to significant flood-risk reduction in developing countries.

IFAS was designed by the following basic technical concepts:

1) To prepare the capacity to utilize satellite-based rainfall information, which is available all over the world, as a quasi-real-time hydrologic data input to a rainfall-runoff model.
2) To prepare the capacity to analyze parameters of rainfall-runoff model with globally available GIS database.
3) To prepare a modeling framework and user-friendly interfaces which can be used for any grid-based parameter-distributed hydrologic model as the engine of the flood forecasting and warning system?
4) To make the system small & light as much as possible by focusing on flood runoff analyses

The details of these approaches are discussed below.

2. Utilization of satellite-based rainfall data

ICHARM proposes the utilization of satellite-based rainfall data in poorly-gauged basins. Recently, we have several data products which we can download through the internet. Although their temporal and spatial resolution is never enough fine for flood forecasting in relatively small-scale rivers, especially for flash flood, they seems significant for river basins more than around 5,000 km^2, especially for continental / transboundary rivers. Figure 1 shows an example of runoff analyses with 3B42V6 of NASA. The BTOPMC developed by the Yamanashi University was used here as a hydrologic model calibrated by ground-based rainfall data. This shows the high potential for large scale rivers to make quantitative runoff analyses with newer version of satellite-based rainfall data. Figure 2 shows another example of runoff calculations with 3B42RT of NASA (every 3-hour data, 25km-mesh) at the Oomagari station (6,840km^2) of the Kitakami River. The error of peak discharge was around 17% and the error of total runoff was just 5%. 3B42RT data has a good temporal resolution (3hr), therefore, IFAS beta version implemented not only ground-based rainfall data but also this product as a default input for rainfall. However, this product has relatively long delay of the delivery (more than 6 hours). Therefore, JAXA has recently developed another satellite-based rainfall product, “Real-time GSMaP” (http://sharaku.eorc.jaxa.jp/GSMaP/index). Digital data is planned to be open in this summer. This data has better temporal resolution (1hr) and spatial one (10km). However, according to ICHARM’s verification of the product, it seems that this satellite-based rainfall product often underestimates short-term heavy rainfall on the ground. Therefore, ICHARM is now developing a correction algorithm to improve the accuracy with/without ground-based data. IFAS Ver.1 implements this real-time GSMaP as well.

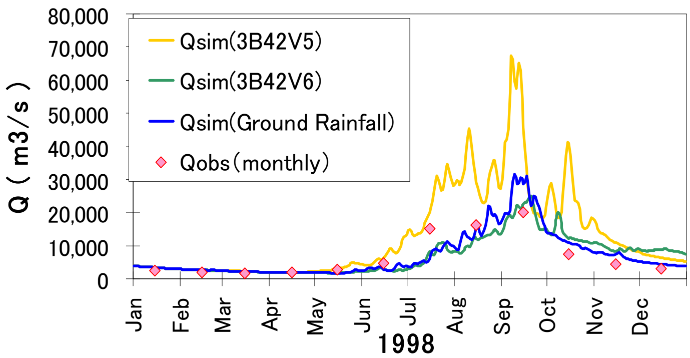

Figure 1: Comparison of runoff simulations with ground-based and satellite-based rainfall data at Pakse in the Mekong River (Area=545,000km^2) using the BTOPMC model

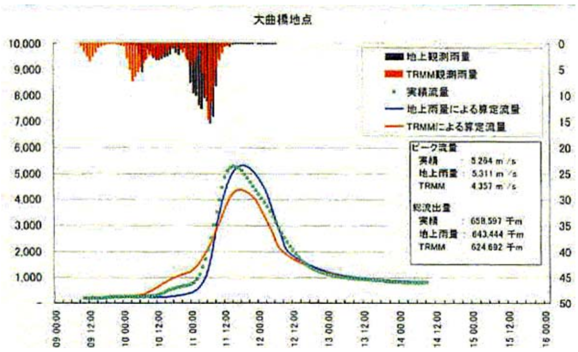

Figure 2: Comparison of runoff simulations with ground-based and satellite-based rainfall data at Oomagari in the Kitakami River (Area = 6,400km^2) using the storage function method

Ground-based rainfall data can also be input and converted to mesh-based data with the Thiessen-polygon, the inverse distance-squared, or the Krigging methods. The satellite-based rainfall data assimilation with the ground-rainfall data is a future subject.

3. Utilization of globally-available databases with GIS analytical toolkits and a distributed-parameter hydrologic model

The scarcity of hydrologic observational network means the lack of historical hydrologic database. The parameters of a rainfall-runoff hydrologic model are usually determined by historical hydrologic (rainfall & river discharge) data. Therefore, the lack of hydrologic data is a question of vital importance for flood forecasting and warning. Of course, if we do not have any data at all, it is almost impossible to make flood forecasting. Here, the authors assume the situation that there are some data but not enough. In such a situation, the usage of distributed-parameter hydrologic model, the parameters of which are related with geophysical conditions, is to be considered.

ICHARM selected the PWRI-distributed hydrologic model tentatively as a default hydrologic model (Fig.3). The PWRI-distributed model was excellent in terms of the data requirement & performance, stability, easiness & lightness to use, linkage with GIS and free right to use for ICHARM. The model does not have enough applications in the world, but this can be compensated with ongoing researches considering a variety of experiences in Japan. In near future, BTOP model will be also implemented as another default distributed-hydrologic model, which has had a variety of examples of applications all over the world.

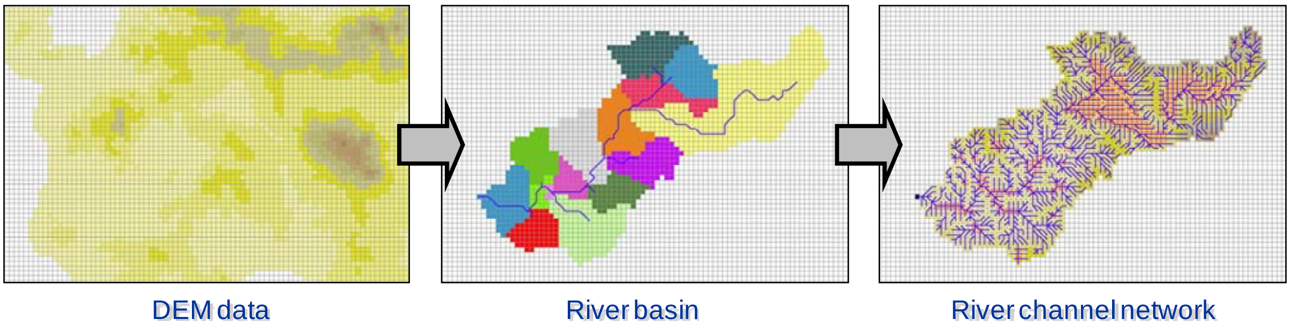

Figure 3: Automatic delineation of flow and river channel network from global DEM

IFAS uses the DEM data given as input data, and creates a basin divide automatically according to the topography. When a user chooses the cell of the outlet of the river, the flow direction of each cell is determined automatically, and river channel network is delineated based on the DEM (Fig.3). If a depressed cell is created in a basin and a river channel is divided, modification of the altitude of a cell is automatically performed so that the flow direction of all the cells may become settled toward the outlet.

Parameters are needed to set up about all the cells in the runoff model. In IFAS, it is possible to set the parameter of each cell automatically based on the classification of GLCC given as input data. At present, a default guideline parameter set for each land use condition is included in IFAS to setup parameters without the past hydrological information. An example of the calculational result using this parameter set is shown in Fig.4. In order to improve the accuracy of runoff analyses, we need tune the parameter set with in-situ observational data for areal rainfall and flood discharge.

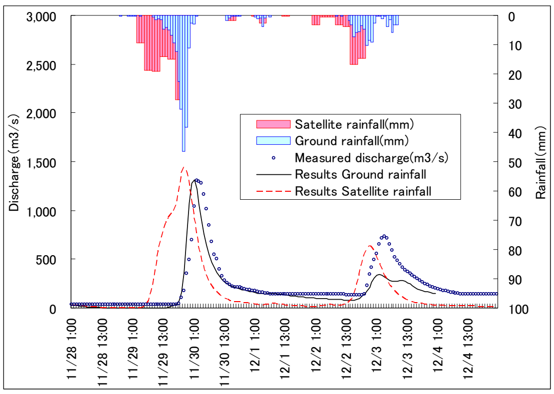

Figure 4: Example of runoff simulations with a default guideline parameter set of IFAS

IFAS prepares common output interfaces for both hydrological & GIS input and output data with hyetgraphs, hydrographs, plan views, tables, etc. (Fig.5). Hydrologic variables for each cell can be also displayed. The time series display using animation is also possible. The details of the interface will be introduced at the Seminar.

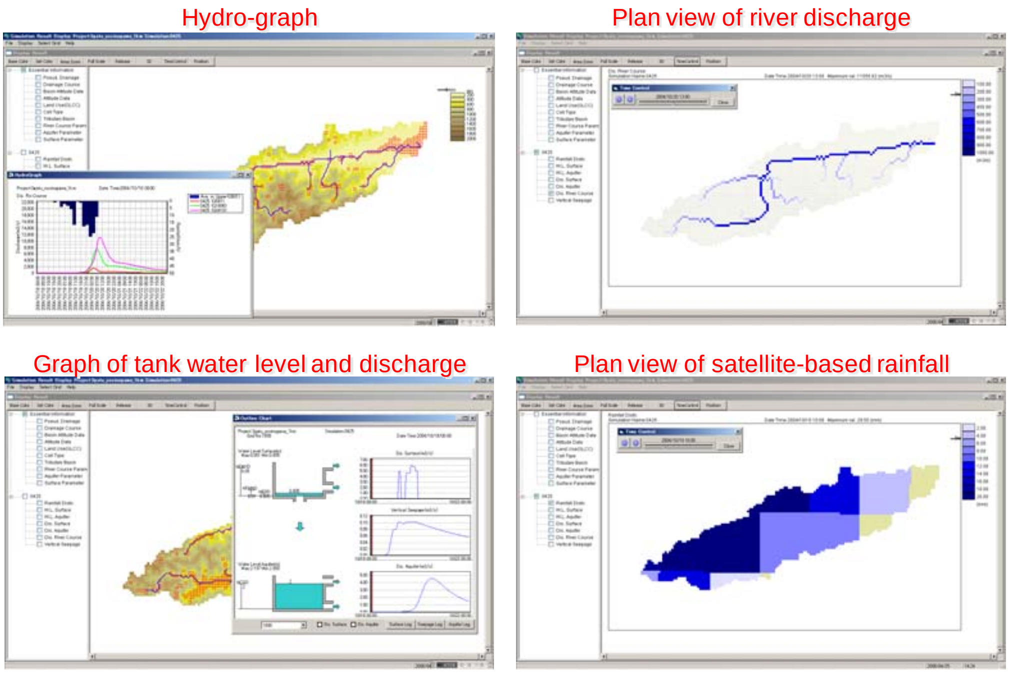

Figure 5: Example of output interfaces for simulation results of IFAS

4. Conclusion

The IFAS Ver.1 has already been released officially at the GFAS Training Workshop for the Global Flood Alert System (GFAS) Validation, which was held at Tsukuba in Japan from 3 to 8 October 2008, organized by IFNet and ICHARM in cooperation with WMO. ICHARM wishes IFAS would be utilized as a basic tool to realize the concept of GFAS-streamflow by IFNet, i.e. for flood-control planning and flood forecasting widely in developing countries. ICHARM would use it as well through technical assistance projects in developing countries and activities such as researches, information networking and training courses. Through such activities, ICHARM likes to contribute to flood disaster mitigation in the world.

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