Hydro-meteorological Early Warning System for Urban Safety

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ABSTRACT

Hydro-meteorological early warning systems consist with the data acquisition in semi-real time, the water balance estimation using a land surface model, and the translation into risk evaluation of flood and land slide by comparing the estimates of river discharge and soil moisture against historical estimates, are underdevelopment on the global scale and on the regional scales in Japan and in Indo-China Peninsula, and on the local scale in the Mae Waang River Basin, in the south of ChiangMai, Thailand experimentally under GEWEX/MAHASRI project with support from GEOSS/JEPP. Digital information of meteorological forecast is crucial for longer lead time of forecast and warning, but real time monitoring of rainfall by in-situ observation with telemetering and/or by weather radar and earth observational satellites are helpful.

The proto-type of the hydro-meteorological early warning system under development on various scales performs fairly well regarding the collection of field data in real-time, and simulation of natural hydrological cycles. Developing interpretation, system which translate river discharge and soil moisture simulated by numerical models into disaster potentials of floods and land slides, and further integration of each component from data acquisition to information sharing e.g. through the Internet are required.

1. INTRODUCTION

As experienced in Japan during its rapid economical developing period in 1970's and 80's, concentration of population and land use change in urban area increases its vulnerabilities against urban flood disasters. Furthermore, it is anticipated that the precipitation pattern will be changed and generally intensified due to the climate change associated with the global warming. Even though a lot of mitigation measures to prevent the flood damages including the disaster due to land slide have been implemented in Japan in the last several decades, there were more than 200 casualties due to the flood disaster in 2004 in Japan. It has been pointed that soft measures such as integrated land use management considering the robustness against natural disasters and hydro-meteorological early warning system should be well associated with the hard measures, but research and development on these issues and practical application in the society were not incorporated enough. However, considering the rapid economical growth and concentration of the population to the urban area in Asian countries and the signs of changing climate, it is necessary to develop and implement soft measures such as hydro-meteorological early warning systems now.

2. BACKGROUND

Global Energy and Water Cycle Experiment (GEWEX) was organized to promote climate research related to global energy and water cycle, land-atmosphere interactions, application of climatic information for water resources management, etc., under the World Climate Research Project (WCRP), which was established in 1980, under the joint sponsorship of International Council for Science (ICSU) and the World Meteorological Organization (WMO), and has also been sponsored by the Intergovernmental Oceanographic Commission (IOC) of UNESCO since 1993. GEWEX Asian Monsoon Experiment (GAME) was proposed to organize an international research project corresponding to GEWEX in Asia. GAME-Tropics (or GAME-T) held a role to integrated hydro-meteorological research in South-East Asia with field observation, data base integration, satellite remote sensing, hydro-meteorological modeling, and prediction research. Through out the GAME/GAME-T project, a comprehensive research community was organized in South-East Asia in the field of hydro-meteorology and related disciplines, and it is the best time to propose a new project succeeding the heritage of GAME, and move forward the science and technology in the field.

Fortunately, Japan EOS (Earth Observation Systems) Promotion Program (JEPP) was proposed and approved to start in Japanese Fiscal Year in 2006 (starting from April 2006). In addition to the international circumstances such as the implementation of GEOSS (Global Earth Observation System of Systems), Japanese government recognized the needs to understand the earth system better, through collecting more data systematically by comprehensive global observation, dealing appropriately with global environmental problems, *e.g.* global warming and climate change, and forecasting the future change. Therefore the objects and scopes are set for the JEPP; the R&D on new observation contributing to the new global observation systems, and the realization and the operation of them, the observational research not only developing new observation systems but also bringing new social benefits, and contribution to GEOSS through establishing new observational systems. Based on these strategies, a competitive research funding by MEXT (Ministry of Education, Culture, Sports, Science, and Technology, Japan) was announced.

Corresponding to the research announcement, two research projects related to formulate the GAME-T follow-on program/projects were proposed and both of them were adopted. One of the projects was entitled “Pilot study on realizing an efficient water resources management through earth observation systems” lead by the first author. Since study period was practically only two and half year, the proposed research was focused on a very specific topic in a very small river basin in order to demonstrate the effectiveness of the utilization of earth observational data into local water resources management. Therefore the target was set to demonstrate the feasibility of hydro-meteorological forecasting in the Mae Waang river basin, south of Chiang Mai, Thailand.

As parallel to the implementation of JEPP, an international scientific panel on GAME follow on program was held at the end of August 2005, and it was agreed to promote the follow on program under a name of “MAHASRI” (Monsoon Asian Hydro-Atmosphere Scientific Research and Prediction Initiative). Even though there are many international programs and ongoing research projects, it was understood that “projects” correspond to individual research projects with funding and they may be related to one or more international programs, initiatives, etc., including MAHASRI. Since the name GAME-T was well known in the region, it was also proposed to call the sub-program under MAHASRI in tropical region as “GaME-T” namely GEOSS and MAHASRI Experiment in Tropics. It is believed that the disadvantage to confuse the GAME-T under GAME and GaME-T under MAHASRI is less than the advantage to use the popular wording which will easily understood the similar scientific objectives and international frameworks.

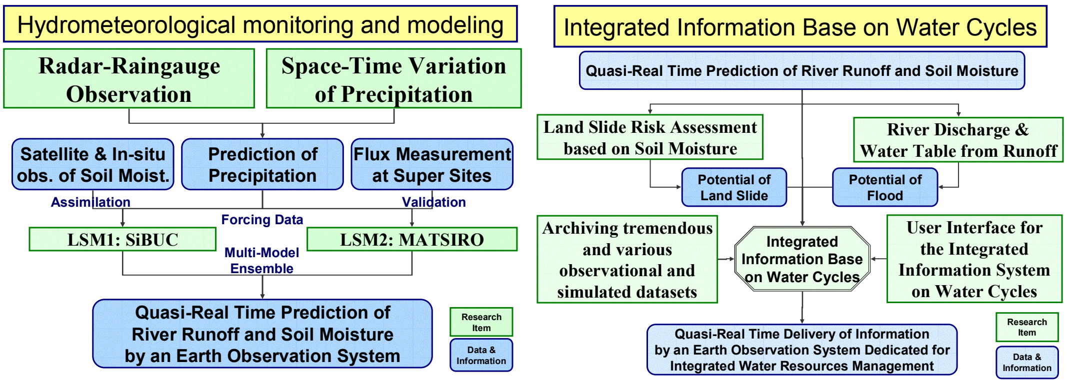

Figure 1: Frame work of the current pilot study of GaME-T; the feasibility of hydro-meteorological forecasting in the Mae Waang river basin, south of Chiang Mai, Thailand.

3. THE IMPLEMENTATION OF THE PILOT STUDY OF GAME-T

The framework of the current pilot study of GaME-T is illustrated in Figure 1. The project can be separated into two parts. First part is to obtain the earth observation data and utilize it as for the forcing input data for land surface models. Second part is the interpretation of the simulated river discharge and soil moisture information into flood and land slide potentials, respectively.

To enhance the current earth observation in the Mae Waang river basin, flux measurement fascilities associated with the telemetry capability were installed in the area under collaboration with Thai sub-committee for GaME-T, particularly with the Hydrological Center 1 of the Royal Irrigation Department, Thailand.

Sixteen hydrometeorological observational sites were installed and started their operation in summer 2006 (Figure 2). Among them two remote sites which cannot be accessed through automobile are equipped with raingauges and no telemetry because of security, lack of electric power, and out of range of the mobile phone service. Four key observational sites were developed and equipped with full hydrometeorological observational systems observing such as wind speed and direction, air temperature and humidity, downward and upward short and long wave radiometer, air pressue, soil moisture and temperature, and rainfall. Other sites have telemetry system with only rainfall measurement which is supposed have the strongest spatial variation.

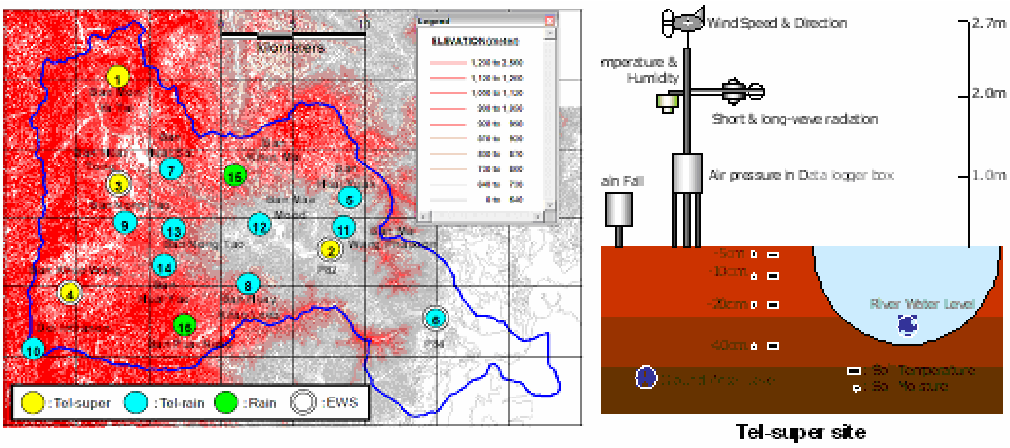

Figure2: The Hydrometeorological observational sites installed in the Mae Waang river basin, south of ChiangMai, Thailand. The locations are tentative and subject to revisions and changes.

Using the earth observational dataset consist with the field measurement dataset and satellite remote sensing data, and integrated with assimilated data which merges numerical model prediction and earth observational data optimally, land surface models will be run. Two land surface models (LSMs) will be used to calculate the surface energy and water balances; SiBUC (Simple Biosphere including Urban Canopy; Tanaka and Ikebuchi, 2004), and revised version of MATSIRO (Minimal Advanced Treatment of Surface Interaction and RunOff; Takata et al., 2003, Yoshimura et al., 2006).

Currently, proto-type of such a simulation system has been developed on global and regional scales in Japan and Indo-China Peninsula. Figure 3 illustrates the current data flow and how numerical models are used in the pilot system on the global scale.

For the particular case in the Mae Waang River basin, meteorological simulation using MM5 with initial and boundary conditions using global 4DDA (Four Dimensional Data Assimilation) data from NCEP and JMA in quasi real-time is under development. Research on the data integration between weather radar and ground raingauge data is also undergoing with the help of the weather radar at Omkoi operated by the Bureau of the Royal Rainmaking and Agricultural Aviation in Thailand. Final data flow which data to be used how is still uncertain and that will be the key of the pilot study.

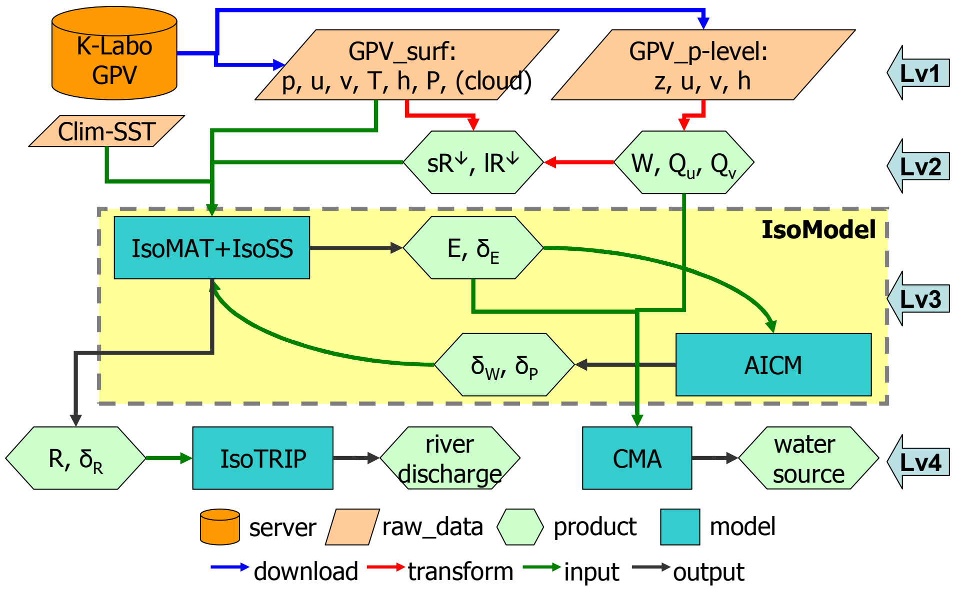

Figure 3: Schematic diagram illustrating the data flow and how numerical models are used to simulate energy and water balance in the pilot system.

Obtained simulation results especially stream flow and soil moisture will be translated into disaster potentials of floods and land slides by comparing with the historical estimates obtained through simulation archive in the past, even though how long it will be possible to carry out the hind cast for this region is uncertain.

Finally, all the information obtained from the field, simulated by numerical models, and translated into disaster potentials will be put on the web and opened for public in quasi real-time. Proto-type of the web pages are already developed and observational information from the field measurement in the Mae Waang river basin can be accessible even now at http://geoss.tkl.iis.u-tokyo.ac.jp/geoss/ even though password may be applied temporarily for some adjustment and development.

4. EXAMPLE FROM A PILOT STUDY ON REGIONAL SCALE

The framework of the hydro-meteorological warning system illustrate in Figure 3 is implemented on global and regional scales, and regional scales are in Japan and in South East Asia. Data flows and numerical models such as atmospheric circulation model, land surface model, and river routing model are the same for various scales at this moment, however, available forcing data, such as surface temperature, humidity, wind speed, downward solar radiation and long wave radiation, and precipitation, derived from meteorological observation and/or prediction as for initial and boundary conditions, and model parameters such as land cover/land use are different for various spatial scales and target regions.

In the case of the proto-type of the Japanese local hydro-metrological warning system, forcing data are obtained from the prediction and four dimensional data assimilation data of Mesoscale Spectral Model (MSM). Precipitation, which is one of the most dominant forcing data for land surface hydrology, can be replaced by the radar-AMeDAS composite, which merges the advantages of the high spatial distribution of weather radar and the accuracy of telemetry raingauges (AMeDAS; Automated Meteorological Data Acquisition System).

River channel network, named as Total Runoff Integrating Pathways (TRIP; Oki and Sud, 1998), is used to integrate the simulated runoff into river discharge. Original TRIP was developed on global scale with 1 degree by 1 degree global grid boxes, and 0.1 degree by 0.1 degree longitudinal and latitudinal grids developed for Japan are used for the current hydro-meteorological warning system in Japan. Further higher scale river channel network is under development now.

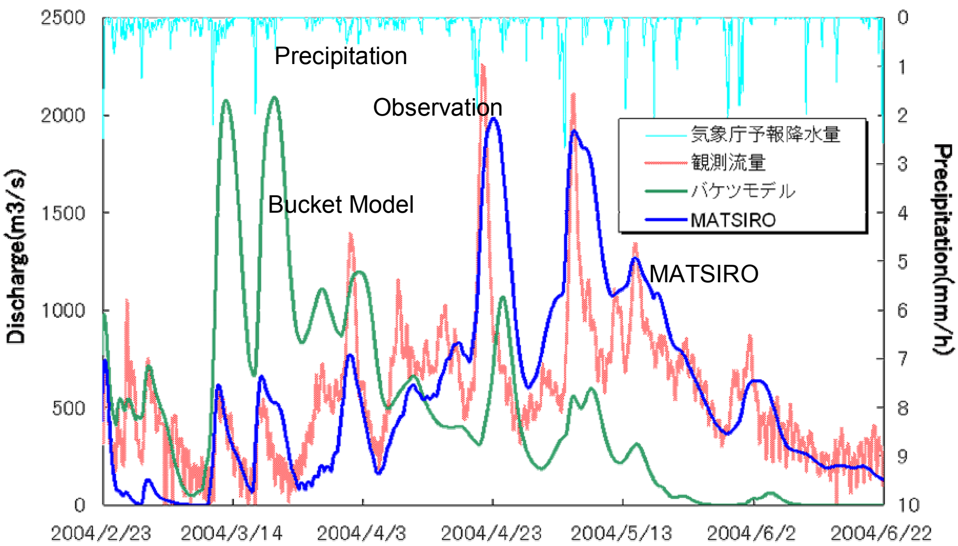

Figure 4: An example of the hydrological simulation of the current proto-type of hydro-meteorological warning system in Japan. Line from top to downward indicates predicted precipitation, and other three lines indicate river discharge of observed, simulated by Bucket Model, and MATSIRO model, respectively.

Figure 4 compares the simulated river discharge by Bucket Model (Manabe, 1969) and MATSIRO (Takata et al., 2003) with observed river discharge at Ishikari-Ohashi Station in the Ishikari River Basin, Hokkaido, Japan for Feburary through June in 2004. Hokkaido is located in the North of Japan and a lot of snow is observed in winter. MATSIRO is incorporated with a detailed snow model and simulates overall seasonal variation of river discharge very well even quantitatively. Short term temporal variation found in the observed river discharge is thought to be due to the anthropogenic impact on hydrological cycles, such as reservoir operation associated with hydropower generation, and current system cannot simulate it. However, recently a integrated numerical hydrological model has been developed which is incorporated with such human activities as reservoir operation (Hanasaki et al., 2006; Haddeland et al., 2006) and water withdrawals considering the water demand in crop fields which is estimated by a crow growth simulation (Hanasaki et al., 2006b).

Even though the simulation is quantitatively good, it is still uncertain whether such a modeling system can capture the unprecedented extreme event can be captured since all the models are calibrated and validated based on past experiences. Therefore it is designed to classify the potential level of disaster by comparing the hazard level, such as extent of the maximum flood volume and soil moisture content in the surface layer, with historical values obtained through hind casting (simulating past). If the hazard level is identified as once in 10 years, a serious situation is anticipated and warning can be made accordingly. Of course, change in the capacity to cope with hazard and mitigate disaster in the society can be taken into account when disaster potentials are estimated.

5. Application for Urban Safety

Basically the similar hydro-meteorological warning system is expected to be applicable for urban areas in terms of disasters such as urban floods and land slides. However, the system should require substantial modification from two points of views.

Firstly, from estimating hazard potential side, prompt monitoring with high spatial resolution is required for urban areas. Most of urban river basins are small and due to the urban land cover, concentration time of floods in urban system is generally quite short. Therefore prompt monitoring and data transfer is inevitable for urban areas. Installation of weather radar and telemetry raingauges would help this aspect, and also weather forecast will help expanding the lead time of the hazard forecast.

Other aspect is the high influence of the artificial structures in urban areas, such as houses (roofs), road (embankment), sewage system, etc. These artificial structures substantially modify the hydrological cycles in urban areas and they should be included in the simulation of hydrological cycles in urban area. Stabilities of slopes are largely controlled by artificial enforcement in the urban areas, and change of such measures should be considered when levels of disaster potentials are warned.

Currently high resolution Japan regional system of hydro-meteorological warning is under development in 1km by 1km horizontal spacing or equivalent. They should be a nice start to targeting hydro-meteorological warning in urban areas but higher spatial resolution, down to 10m spacing, may be necessarily for practical applications.

6. REMARKS

GEOSS and other international circumstances pushed to promote the GAME-T follow-on program and a new project on hydrometeorological studies in South East Asia, namely GaME-T under MAHASRI, but it should definitively be basically owing to the success of the GAME-T and the deep discussions, enthusiasms, and willingness to continue the program/project in the region by all the stakeholders such as researchers, governmental officers in Japan, Thailand, and neighboring countries such as Vietnam, Malaysia, Laos, Cambodia, and Myanmar.

Even though current pilot study focuses on a short-term prediction study in a comparatively small river basin, but such a system will be a basis for longer-term studies applicable for water resources management, such as drought. Regional studies with higher temporal dataset are also very important to develop a tool to assess realistic vulnerabilities of water resources management against the anticipated impact of climate change (Oki and Kanae, 2006). Further development and continuation of the hydrometeorological studies are expected in the region.

Regarding the urban safety, nesting into warning systems on larger spatial scales will be necessary, and at the same time, the instantaneous observational measures, such as weather radar and telemetries are essential for accurate and timely issues of hydrometeorological warnings in addition to the better numerical models predicting natural and anthropogenic hydrological cycles and the consideration of social capacity to mitigate the hydrometeorological disasters. Remote sensing and detailed GIS in urban areas will help for these.

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