FINAL REPORT for APN PROJECT
ARCP2009-01CMY-Fukami

Flood Risk Management Demonstration Project under the Asian Water Cycle Initiative for the Global Earth Observation System of Systems (FRM/AWCI/GEOSS)

Asia-Pacific Network for Global Change Research

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Project Reference Number: ARCP2009-01CMY-Fukami
Final Report submitted to APN

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OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

This project is aiming to build up a scientific basis for sound decision-making and developing policy options for most suitable flood risk management in the Asia Pacific Region, through the full utilization of new opportunities on global, regional and in-situ dataset, knowledge and/or resources under the framework of Asian Water Cycle Initiative (AWCI) contributing to GEOSS (Global Earth Observation System of Systems). To attain the goal above, the following three objectives were specified:

1. To convert observations and data, both through space borne platforms and data integration initiatives, to usable information for flood reduction
2. To improve quantitative forecasts for coupled precipitation - flood-forecasting systems
3. To facilitate flood risk assessment through the provision of scenarios and data for exposure estimation

The research result is constructed by an aggregation of each voluntary research activity in each member country based on mutual intensive information/human exchanges and cooperative research activities. Several key technologies such as WEB-DHM, DRESS & FLOWSS of UT, IFAS of ICHARM, RegHCM-PM of NAHRIM, and so forth, and practical approaches were developed and validated. All of those technologies and practices will be the basis for sustainable flood risk management in the Asia Pacific Region in the future.

Objectives

This project was aiming at enhancing and utilizing regional cooperation to achieve the following three targets with the use of the resources and knowledge available at various specialized institutions in the Asia Pacific Region under the framework of Asian Water Cycle Initiative (AWCI) contributing to GEOSS (Global Earth Observation System of Systems).

1. To convert observations and data, both through space borne platforms and data integration initiatives, to usable information for flood reduction
2. To improve quantitative forecasts for coupled precipitation - flood-forecasting systems
3. To facilitate flood risk assessment through the provision of scenarios and data for exposure estimation

Amount received and number years supported

The Grant awarded to this project was:
US$ 42,000 for Year1, 2008-2009:
US$ 42,000 for Year 2, 2009/2010:

Activity undertaken

The researches of this project were conducted through utilizing the framework and activities of GEOSS-AWCI. Namely, the activities are composed by the following steps and cycles:

1) To exchange information/knowledge on studies in member countries relevant to the above goal and objectives through the GEOSS-AWCI regular meetings.
2) To develop (and/or adapt existing, with improvements) methodologies, tools and basic datasets related to the objectives, in each member country, as a demonstration project, referring to the above information/knowledge. Demonstration projects include the following two typical patterns:

a) To enhance in-situ field hydrological observations for each study basin, to apply the above methodology/tool to the basin, to validate and verify the applicability of the methodology/tool and to clarify the future subjects to make it from research phase to operational phase

b) To investigate historical water-related (in particular, flood) disaster events, to collect hydrological/meteorological/socioeconomic data for the extracted flood events, to apply the above methodology/tool to the past flood events as case studies, to validate and verify the applicability of the methodology/tool and to clarify the future subjects to make it from research phase to operational phase

3) To exchange research results/findings/experiences through the above demonstration projects and discuss the furthermore interactive cooperation among member countries through the above meetings.

The GEOSS-AWCI's regular meetings have been held as International Coordination Group (ICG) Meetings five times during the project period. In addition to that, another specifically-focused in-depth workshop titled 1st International Workshop on Application and Validation of Global Flood Alert System (GFAS)

Results

As a result of 2-year cooperative research activities under the framework of Flood WG of GEOSS-AWCI, there have emerged many promising technologies and practices for the future sustainable flood risk management. Most typical new technologies developed and/or validated through those activities are WEB-DHM, DRESS & FLOWSS of UT, IFAS of ICHARM, RegHCM-PM of NAHRIM, and so forth. Through repetitive meetings, discussions and cooperative activities, advanced technologies and many other innovative practices have been also shared among all the members of Flood WG of GEOSS-AWCI, which will be expected to lead to updating and enhancing a variety of science- & data-based foundations toward sound decision-making and developing policy options for effective flood disaster risk reduction in Asia.

Relevance to APN's Science Agenda and objectives

This project contributes to the Asian Water Cycle Initiative (AWCI) contributing to the Global Earth Observation System of Systems (GEOSS), which will assess regional vulnerability of natural and human systems from floods under changing environmental conditions, and contributes to the development of policy options for appropriate local and regional responses. These objectives are directly in line with the mission of APN and thus are relevant to the APN science and policy agenda. The project will directly contribute to enhancing regional cooperation, strengthen interaction between scientists and policy makers and will improve scientific and technical capabilities of Asian region nations, fitting very well to the APN activity framework.

Self evaluation

Several promising technologies have been developed and validated in this APN project such as WEB-DHM, DRESS, FLOWSS, IFAS, RegHCM-PM, and more that can be basic ones for efficient & effective integrated flood risk management in the Asian Pacific Region. Besides, a variety of practices and experiences of other case studies in many Asian countries using new emerging technologies, methodologies and data have been accumulated in each country, which will be the basis for the establishment of methodologies and systems for integrated flood risk management as well. There still remains relatively a long way from the present research phase to the future operational phase, it should be highly evaluated that each of three objectives are substantially met through such several key technologies and practices. Finally, the importance of human connections and confidence-building with each other among members of Flood WG of GEOSS-AWCI strengthened through cooperative activities should be emphasized. This will surely be useful for future further development of our mutual international cooperation and coordination toward real implementation of new-generation flood risk management system using GEOSS data.

Potential for further work

The same as the above (self evaluation) should be mentioned here. That is, the developed promising technologies and practices will be the basis for the establishment of methodologies and systems for integrated flood risk management. As mentioned above as well, there still remains relatively a long way from the present research phase to the future operational phase, which should be the future subject.

Publications

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Wang, L., C. T. Nyunt, T. Koike, O. Saavedra, L. C. Nguyen, T. V. Sap (2010) Development of an integrated modeling system for improved multi-objective reservoir operation, Frontiers of Architecture and Civil Engineering in China, 4(1), 47-55.

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References

There are ***many*** references for this report. They are listed in the "Reference" of the following "TECHNICAL REPORT".

Acknowledgments

I would like to express my sincerest thanks to all the members and collaborators of Flood WG of the GEOSS-AWCI for their kind provision of all the presentation materials t as references to this report. I would also like to express my warmest thanks to Dr. Toshio KOIKE, Dr. Petra Koudelova, Dr. Akiko GODA & Katsunori TAMAGAWA of UT, Dr. Srikantha Herath of UNU, Dr. Chu ISHIDA & Dr. Yoko INOMATA of JAXA for their outstanding cooperation and coordination to organize the regular GEOSS-AWCI ICG meetings.

TECHNICAL REPORT

Preface

Asian Pacific countries have been suffering from flood disasters every year, which have been big barriers not only to reduce natural disaster casualties/damages but also to promote social welfares and economy in those countries. This project was proposed to contribute to flood disaster reduction through enhancing sustainable flood risk management with GEOSS data. Under the cooperative framework of GEOSS-AWCI, information exchanges and cooperative studies were promoted, and lots of new developments and local studies were conducted in each AWCI member country. The report summarizes the outline of those research activities. Please refer to references for more details of each study.

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1.0 Introduction

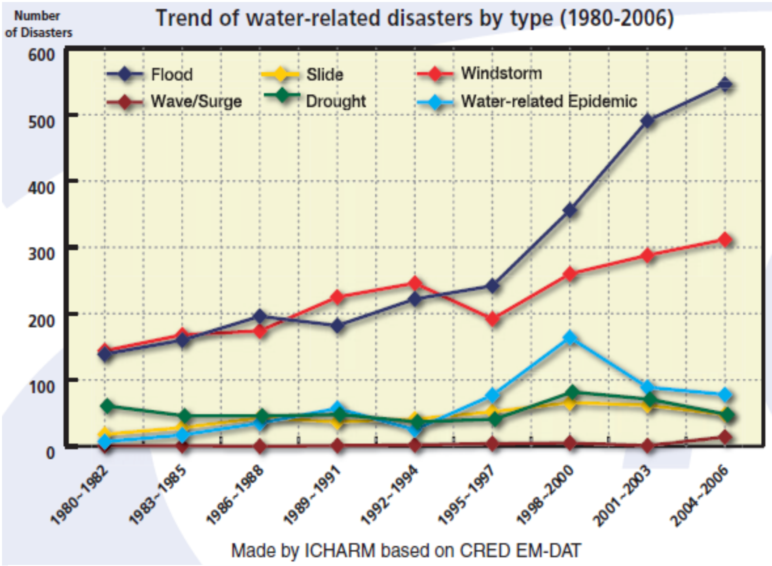


Fig.1 Trend of water-related disasters by type (1980-2006)

Asian countries have been still suffering from flood disasters repeatedly every year. Moreover, the number and influence of flood disasters are increasing recently (Fig.1 & 2). In order to mitigate flood disasters as much as quickly and efficiently, since it is almost impossible to prevent from flood hazards completely with sufficient structural measures due to its high cost and long time to finish, we should establish integrated flood management including flood forecasting systems and a best balance of structural (infrastructural) measures and non-structural ones for reducing vulnerability against flood risk and, on the contrary, for increasing coping capacity against it . Flood forecasting is a real-time reaction to mitigate flood disasters, while the consideration toward a best balance between structural and non-structural measures, such as hazard mapping, vulnerability assessing and its reduction, etc., are required for planning process at post- and/or pre-phase of flood disasters. Anyway, we need to plan suitably those measures considering the identification & prediction of the changing trend of floods & disasters induced by them. Thus, we need reliable historical and real-time databases of meteorology and hydrology to plan and establish those measures, based on the flood risk and vulnerability assessment, considering global change in terms of climate, urbanization, etc. However, such data are often lacking for many of developing countries in Asia. The goal of this proposed project was, therefore, to build up a scientific basis for sound decision-making and developing policy options for most suitable flood risk management for each country and region in Asia, through the full utilization of new opportunities on global, regional and in-situ dataset under the scheme of AWCI (contributing to GEOSS), which had been established in 2005. The goal of the proposed project was just linked with the mission of the APN's Second Strategic Plan (2005-2010).

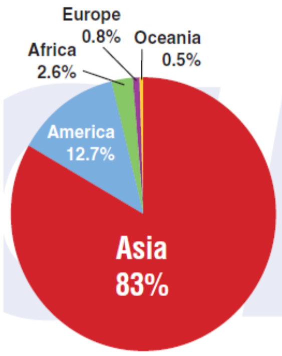


Fig.2 Percentage of casualties by water-related disasters (1980-2006)

To attain the goal, considering the two approaches stated in the above section, we need to provide methodologies, tools and basic datasets to derive such required information to convert both global-scale and local observations and data to really useful information and knowledge for flood risk management. On the basis of those fundamental technology and data, we need to improve real-time flood forecasting system for short-term crisis management and to assess flood risk and vulnerability and then to make flood scenarios for long-term integrated flood risk management. Namely, we set up our three objectives as follows:

1. To convert observations and data, both through space borne platforms and data integration initiatives, to usable information for flood reduction
2. To improve quantitative forecasts for coupled precipitation - flood-forecasting systems
3. To facilitate flood risk assessment through the provision of scenarios and data for exposure estimation

If we fulfill all the #1, #2 and #3 objectives, then we will be able to establish fundamental databases and capacity to effectively and suitably plan and realize the real-time based and long-term based measures to mitigate flood disasters promptly and efficiently. From technological point of view, it was expected to be possible for us to set those objectives, based on recent scientific achievements on climatology, meteorology and hydrology in the Asian monsoon regions such as those of GAME (GEWEX Asian Monsoon Experiments, WCRP) and on satellite-based observation of rainfall, physical & socioeconomic quantities of earth surfaces and numerical weather reanalysis, downscaling & prediction. It is, however, indispensable for us to consider the disparity in existing resources and capabilities among different countries/regions as well as their varied needs and environments. Therefore, we established the Flood Working Group in the framework of AWCI in 2006, to construct an international/inter-organizational cooperative field to promote research on a "demonstration project" for each different study basin to build up the first successful implementation about any of the above objectives and to make it a good showcase to strengthen appropriate interactions among scientists and policy-makers and to provide scientific input (corresponding to Policy Agenda of APN Strategic Plan) for the real implementation of the systems all over the flood-prone areas in Asia. Considering the disparity of capabilities of countries in Asia as above, the demonstration project will be coupled with capacity development offered by advanced global-change research network activities and organizations in Asia such as the University of Tokyo (UT), Japan Aerospace Exploration Agency (JAXA), the United Nations University (UNU), the International Centre for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM), Kasetsart University of Thailand and so forth. Those organizations were expected to facilitate the development of research infrastructure and the transfer of know-how and technology, even in poorly-gauged river basins, for converting the coupling of global-scale and local-scale observational data into any information and/or knowledge on flood risk management (objective #1), for promoting the implementation of flood forecasting system (objective #2), flood risk assessment and flood scenario generation (objective #3) in this proposed project. These activities will lead to improving the scientific and technical capabilities of nations in the regions of Asia in terms of hydrological forecasting and planning, and finally lead to (a) identify, refine and make available best practices, tools and methodologies for flood risk reduction in the Asia Pacific Region and to (b) develop training programs and modules on the use of global and regional data sets and observations.

Through the two-year project by the APN fund, the GEOSS-AWCI and its Flood-WG members have tried to understand realities and problems in flood risk management in each country, to consolidate those state-of-the-art technologies to couple global and local data, to apply them to a demonstration project in each country, and to share any interim results, findings and lessons among GEOSS-AWCI Flood Workings. Now we have accumulated and shared many practices in Asia for flood risk management, and some of them can be regarded as the best practices. However, most of such "top runners" are limited to well-financed cases by external funds. We should continue to make every effort to consolidate and customize our accumulated state-of-the-art know-how and technology in meteorological and hydrological science and engineering for real implementation of integrated flood risk management in Asia. The details of our achievements are described below.

2.0 Methodology

As mentioned in 1.0 Introduction, the activities of this project have been conducted under the framework of Flood WG in the GEOSS-AWCI (Implementation Plan for Global Earth Observation System of Systems Asian Water Cycle Initiative (GEOSS/AWCI)).

The AWCI was established in 2005 to develop an information system of systems for promoting the implementation of integrated water resources management (IWRM) through data integration and

sharing and improvement of understanding and prediction of the water cycle variation as a basis for sound decision making of national water policies and management strategies.
The objectives for AWCI are defined as follows:

- to develop Integrated Water Resources Management (IWRM) approaches;
- to share timely, quality, long-term information on water quantity and quality, and their variation as a basis for sound national and regional decision making;
- to construct a comprehensive, coordinated and sustained observational system of systems, such as prediction systems and decision support capabilities, under the GEOSS;
- to develop capacity building for making maximum use of globally integrated data and information for local purposes as well as for observation and collecting data.

The AWCI is a new type of an integrated scientific challenge in cooperation with meteorological and hydrological bureaus and space agencies. Its uniqueness is described as follows:

- Effective combination of the architecture and data and the capacity building;
- Advanced data infrastructure availability including a river basin meta-data registration system, a data quality control interface, and data-integration and downscaling methods;
- A clearly described data sharing policy agreed among the participating countries;
- Strong linkage among science communities, space agencies, and decision makers;
- Well coordination between the research communities and operational sectors with clear strategy for transferring scientific achievements to operational use;
- Effective cooperation with international projects and cooperative frameworks.

The above objectives and uniqueness of GEOSS-AWCI are very relevant to this project in terms of integrated flood risk management. This is the reason why this project has been conducted under the framework of GEOSS-AWCI.

Before starting this APN project, the Flood WG of GEOSS-AWCI had been established and two International Coordination Group meetings had been held in advance. Through those prior activities to the APN ARCP project, the GEOSS-AWCI implementation plan including the selection of "demonstration basin" was summarized in November 2008. Then in order to implement the AWCI implementation plan and this project proposal, Flood WG technical meetings have been conducted several times during the project period as one of the sessions of general AWCI International Coordination Group (ICG) meetings. The general AWCI-ICG meetings have been co-sponsored not only by this APN-ARCP project but also by two other APN-CAPaBLE projects (led by Dr. Ailikun of China and by Dr. Chu ISHIDA of JAXA). The list of the meetings during this APN project is as follows:

1. "The 4th Conference of the Asia Pacific Association of Hydrology and Water Resources (APHW) & the 3rd International Coordination Group meeting of the GEOSS-AWCI", Beijing, China, November 3-6, 2008.
Total Participants: 43 ICHARM support: 9

2. "The 3rd GEOSS Asia Pacific Symposium & the 4th International Coordination Group Meeting of the GWOSS-AWCI", Kyoto, Japan, February 4-7, 2009.
Total Participants: 66 ICHARM support: 5

3. "The 5th meeting of the GEOSS Asia Water Cycle Initiative (AWCI) International Coordination Group (ICG)", Tokyo, Japan, December 15-17, 2009.
Total Participants: 154 ICHARM support: 6

4. "The 4th GEOSS Asia Pacific Symposium and the 6th meeting of the GEOSS Asia Water Cycle Initiative (AWCI) International Coordination Group (ICG)", Bali, Indonesia, March 10-13, 2010.
Total Participants: 37 ICHARM support: 5 (including Cancel 1)

5. “The 7th Meeting of the GEOSS-AWCI International Coordination Group (ICG)”, Tokyo, Japan, October 5-6, 2010.

Total Participants: 79 ICHARM support:5

6. “The 1st International Workshop on Application and Validation of Global Flood Alert System (GFAS)”, Tsukuba, Japan, August 3-7, 2009

Total Participants: 6 (cancel 1) ICHARM support: 7 (including cancel 1)

The number of total participants includes other guests sponsored not only by the APN grants but also by other funds and general domestic participants. “ICHARM support” means the number of participants funded by this APN ARCP fund.

The last 6th workshop is not merely a general information-exchange & discussion meeting but a tightly-focused in-depth workshop on a specific technology: GFAS (Global Flood Alert System). GFAS is an initiative proposed by IFNet (International Flood Network) and is subdivided into the two: i) GFAS-Rainfall & ii) GFAS-Streamflow. GFAS-Rainfall is the original GFAS and a heavy rainfall alert (identification) on a global scale using satellite-based rainfall data (NASA-3B42RT and JAXA-GSMaP). GFAS-Streamflow is a conceptually-derived from the GFAS-Rainfall, i.e. an initiative to produce useful warning and forecasting information even for the basin where very limited (hydrologic & geophysical) in-situ data with securing the worldwide possibility to apply flood analysis and forecasting system in a wide variety of climatic and hydrologic conditions in the world. As a toolkit or platform for the GFAS-Streamflow, IFAS (Integrated Flood Analysis System) was developed. At the 6th workshop, the background, concept, theory, validations and applications of GFAS & IFAS were introduced, discussed and practiced. The detailed fruitful results of the workshop are also introduced and discussed in the next chapter (ex. Indonesia and Japan).

The common approaches in promoting this project utilizing the opportunities to hold the above meetings have been as follows:

1) To exchange information/knowledge on studies in member countries relevant to the above goal and objectives through the above meetings.
2) To develop (and/or adapt existing, with improvements) methodologies, tools and basic datasets related to the objectives, in each member country, as a demonstration project, referring to the above information/knowledge. Demonstration projects include the following two typical patterns:
   a) To enhance in-situ field hydrological observations for each study basin, to apply the above methodology/tool to the basin, to validate and verify the applicability of the methodology/tool and to clarify the future subjects to make it from research phase to operational phase
   b) To investigate historical water-related (in particular, flood) disaster events, to collect hydrological/meteorological/socioeconomic data for the extracted flood events, to apply the above methodology/tool to the past flood events as case studies, to validate and verify the applicability of the methodology/tool and to clarify the future subjects to make it from research phase to operational phase
3) To exchange research results/findings/experiences through the above demonstration projects and discuss the furthermore interactive cooperation among member countries through the above meetings.

The results of those cooperative research activities are described in the next chapter.

3.0 Results & Discussion

Taking the approaches explained in the previous chapter, this research project has been enhanced and progressed. The research result of this project is, therefore, an aggregation of each voluntary research activity in each member country in principle. Based on this understanding, the each-country's research result based on such mutual intensive information/human exchanges and cooperative activities is described, country by country, first of all. Then the overall findings and significance of the whole project are discussed later.

3.1 Demonstration researches and practices in each country

3.1.1 Bangladesh

Bangladesh is recognized as the most disaster prone area in the world. Since the half of the land of Bangladesh is less than 5m in altitude and the 68% of the land is vulnerable to flood, Bangladesh has suffered from many catastrophic cyclones floods historically since the great Bakerganj Cyclone in 1876.

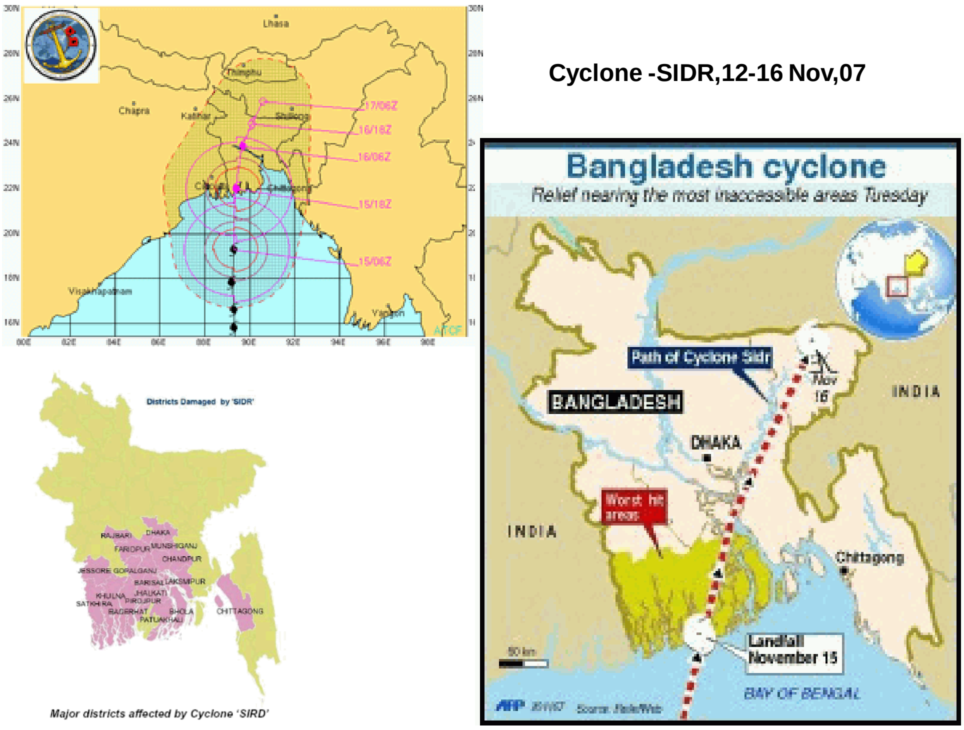


Fig.3 The track and affecting area of Cyclone Cider, 12-16 November, 2007 (Quadir, 2009)

Islam(2009, 2010) discussed the development of cyclone-induced disaster management in Bangladesh. The most famous cyclones are the Bhola Cyclone in 1970 that caused more than 300,000 fatalities, and the Bangladesh Cyclone in 1991 that caused 138,000 fatalities. Therefore, Bangladesh has tried to establish cyclone forecasting and warning. Bangladesh Meteorological Deparment (BMD) is mandated for tropical cyclone forecasting and warning, based on the information from 4 ground-based meteorological radars and satellite (MTSAT) images, and the Cyclone Preparedness Program (CPP) under the Bangladesh Red Crescent Society (BDRCS) established to forward cyclone warning bulletins to 42,675 coastal volunteers for saving coastal vulnerable people. High-floor shelters were constructed to save people living in vulnerable areas. As a result of those efforts, Bangladesh was successful to reduce casualties so much from the order of one hundred thousand to the order of several thousand including missed people, for the Cyclone

Cidr case in 2007 (Fig.3). Certainly this disaster was very big, but we should not forget the truth that the casualties were SO MUCH reduced compared with the past big high-tide disasters. It may have been relatively better for Bangladesh that the Cyclone Sidr landed around the time of low tide. But the strength of the cyclone in 1970 was 966hPa and 57m/s, therefore the cyclone itself was stronger in 2007. Consequently such a big (two-order!) decrease of casualties can be more properly explained by the prevailing of early warning system and high-floor shelters (around 2000). Of course, many lessons are still remaining but the point Bangladesh succeeded in such big disaster mitigation should be emphasized. Typical lessons indicated are as follows:

1) Early warning system coupling the Radar information of the Meteorological Department and local volunteers announcing flooding alerts (CPP: Cyclone Preparedness Program) played a big role to inform the central alert information to local municipal offices, and to reduce the disaster for most residential people, except for fishermen due to improper maintenance of communication system.
2) In many cases, the timing to start evacuation is still late. Beside, there were some cases residential people in floodplains did not escape because they were afraid their properties such as cattle were stolen.
3) The improvement of accuracy of high-tide and flood forecasting should be made for each local point to raise the reliability and credibility for local residential people. Firstly more water level stations are required. .
4) High-floor shelters, which have been often used as schools during ordinary times, were also very useful for reducing the disaster, but the number of them is apparently insufficient and a part of them has become old.
5) The embankment surrounding polders seemed useful to mitigate flooding flow as well, but the height of embankment are not necessarily enough against high-tide flooding flow. Proper design is required. Besides, trees over the embankment seem never good to protect embankments, because the shaking of trees by strong winds weakens the embankments.
6) More resilient house against flooding should be studied.

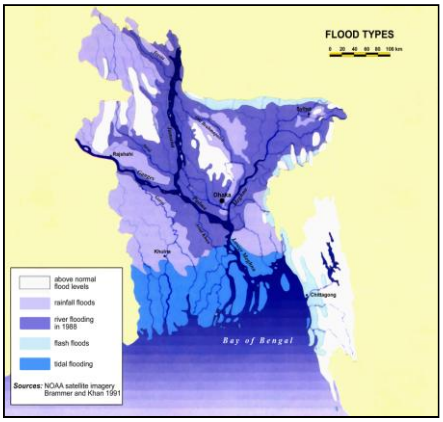


Fig.4 Flood types in Bangladesh (Islam, 2010)

Regarding the point 1), if regular CPP drills were conducted involving residential and fisherman people, then such improper situation could be detected in advance. The point 3) is true of developed counties, but the case above has much room to improve the system with existing methodology. The point 4) may be escapable if proper knowledge about the design of embankments were introduced. In this context, capacity building is indispensable and can play a big role for reducing disasters.

Other than tidal floods, three types of flood occur in Bangladesh: riverine flood, heavy rainfall flood and flash flood (Fig.4). Quadir (2009) discussed such flood disasters in Bangladesh. Recently, there were five major floods in 1987, 1988, 1996, 2004 and 2007. He showed a frequency analysis on flood-affected area. Islam (2010) showed us a detailed analysis on 2007 flood. He discussed the importance of the combination of structural & non-structural measures, and introduced a study for updating Dhaka Integrated Flood Control Embankment coupled with the Eastern Bypass Road Project. By means of numerical flood inundation modeling, he indicated the effect of the project on the reduction of flood inundation around the Dhaka area quantitatively and necessary structures for that. He also pointed out the importance and needs for long-term flood forecasting for riverine floods. This is a very typical example of studies for integrated flood risk management. Such a comprehensive study would be further promoted, including the demonstration river basin: Megna River.

Besides, every report indicated the possible adverse effect of climate change on flood disasters. Islam (2010) discussed climage-change impacts on not only flood but also salinity intrusion (drinking water) and drought (agriculture). These studies let to the new generation of the climate change adaptation WG in the GEOSS-AWCI.

Finally, the importance of sharing meteorological and hydrological data for integrated flood and water management in the three river basins: Ganges, Brahmaputra and Meghna (Fig.5). Most of floods and water resources for Bangladesh come from the upstream area of those basins in foreign countries. Referring to the objective of the GEOSS-AWCI activities, such data sharing should be promoted and enhanced from the perspective not only of disaster reduction and recovery but also of the social & economic development of the region of South Asia.

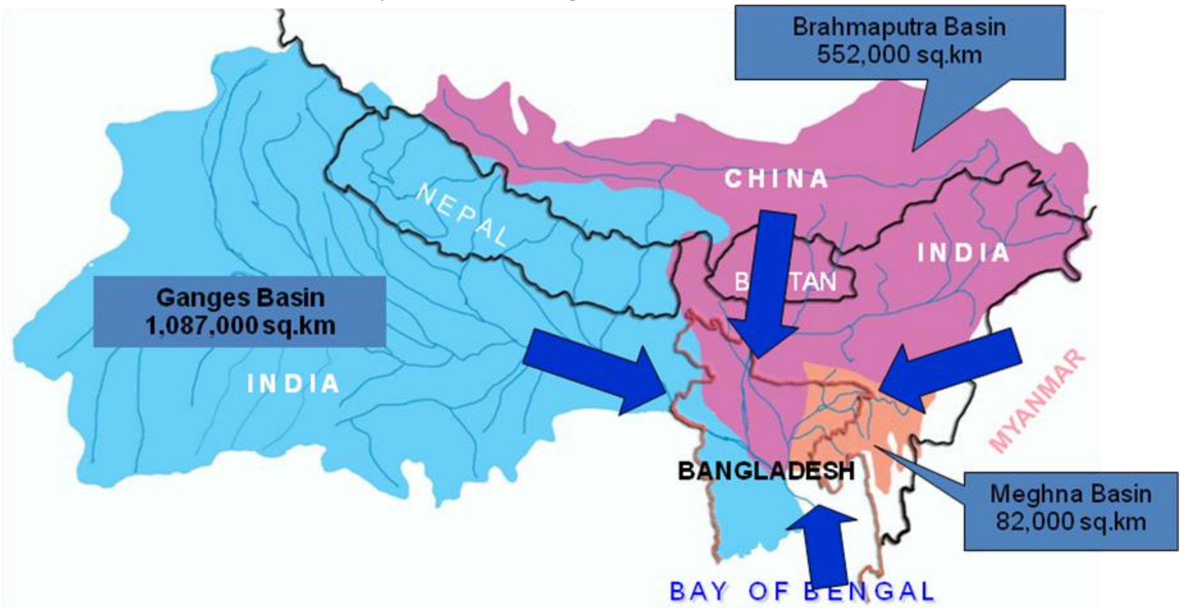


Fig.5 Three major river basins with big influence to Bangladesh (Quadir, 2009)

3.1.2 Bhutan

The Major issue for water resources management in Bhutan is flood management caused by GLOF (Glacier Lake Outburst Flood), heavy rainfall-induced flash flood, and/or landslide burst flood. To cope with this issue, Chhophel(2007) indicated capacity building needs and the concept of the demonstration project at the Punatsangchhu River (13,263 km^2). Its hydrological data during 1998 and 2009 are already shared on the DIAS. Chhophel (2010) reported the existence of many projects related to flood/water-resources management and climate change, and their priority ranking. Substantial progress report on the demonstration project is expected.

3.1.3 Cambodia

Cambodia is located in the upstream area of the Mekong River Delta. Therefore, Cambodia has suffered from seasonal flood from the Mekong River every year. If the flood is too big, then the flood causes flood disasters, as seen in 2000 flood. However, if the seasonal flood is too little, then this causes drought, since the flooding water is water resource for agriculture, fishery, domestic water, navigation, etc., especially in the area surrounding the Tonle Sap Lake. There sometimes happens flash floods in the tributaries of the Mekong River, induced by heavy monsoon rainfall and/or typhoons, which have often caused flood disasters. For example, Saravuth (2010) reported the damage of flood disasters caused by the Typhoon Ketsana in 2009 came up with the direct damage cost to water management and irrigation: USD 2.779 million, the indirect losses, which involve from farmer water user and selling fish in the reservoir: USD 0.013 million, and the total damage and losses thus reached USD 2.792 million (only for water sector). Therefore, flood forecasting is very important not only for disaster mitigation but also for planning agricultural activities such as seeding, harvesting, and all the other water-related life in Cambodia.

Saravuth et al.(2009) made a report on the historical evolution of meteorological and hydrological observational network in Cambodia. Due to the civil war in 1970's, there are almost no data during the period. After the middle of 1990s', systematic data collection has been enhanced. He reported 102 stations are in operation as of December 2006. The Mekong River Commission (MRC) is now enhancing real-time water-level data network using the GSM telephone (4 stations in Cambodia). The Department of Hydrology and River Works (DHRW) of the Ministry of Water Resources and Meteorology (MOWRAM) is now getting near real-time hydrologic data from 10 stations through telephone and sending flood forecasting information to mass media and 40 agencies/villages.

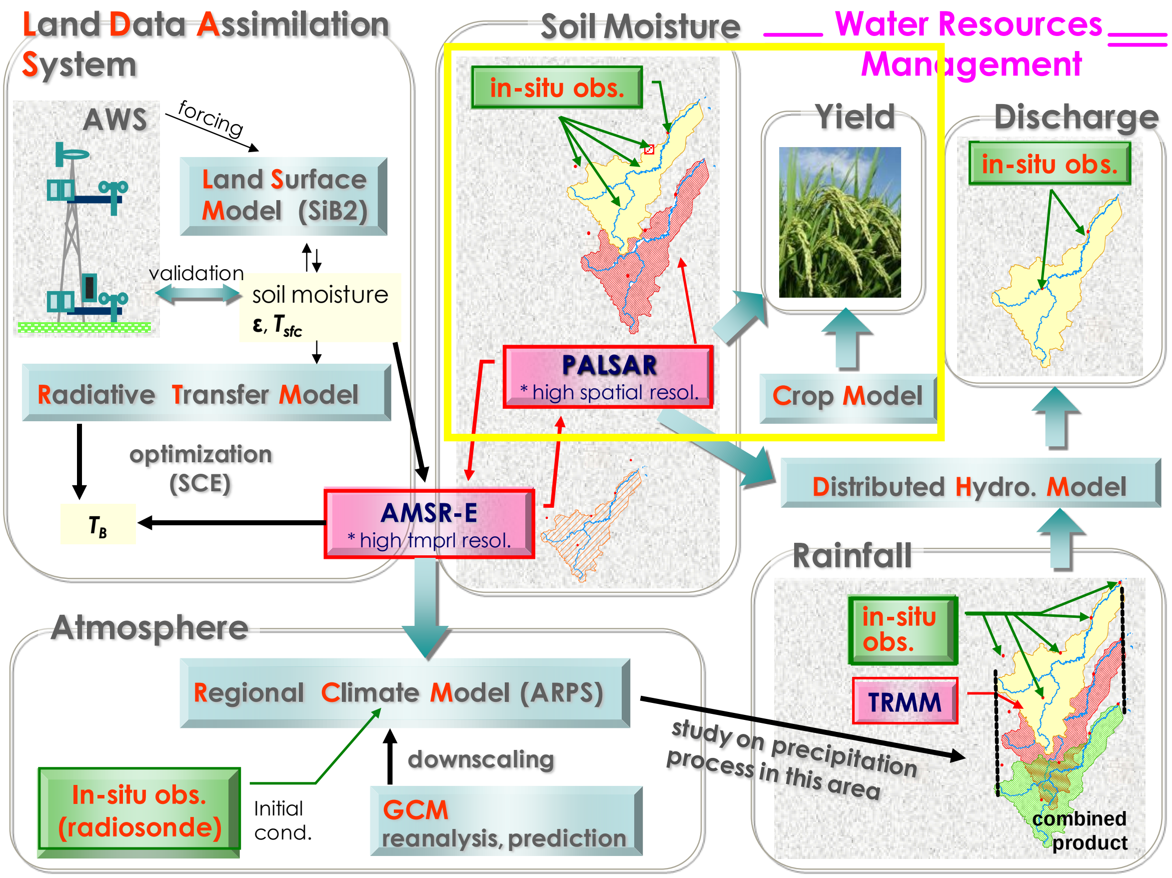


Fig.6 Proposed water resources management system coupled with GEOSS data (Monichoth et al., 2010)

Monichoth et al.(2010) introduced a study to make a prototype for state-of-the-art water-resource management using global and in-situ observational data coupled with meteorological and hydrological models(Fig.6). The target area is just the demonstration basin: Sangker River basin (2961 km^2). They installed an automatic weather station to measure not only meteorological but also soil-moisture data. By coupling land-surface model with remotely-sensed soil moisture data using microwave radiometric data (AMSR) and/or synthetic aperture radar (SAR) data, they produced a dataset for areal soil-moisture for the target area. They are going to manage agricultural activities such as irrigation, harvest, etc. on the basis of this system and to enlarge this system to a comprehensive flood/water-resource forecasting and management system. This study is one of the most typical examples of converting the combination of global and in-situ data to usable information for flood reduction and water resource management. The further development and verification are expected.

3.1.4 China

The demonstration projects and activities of China have been focused to drought and climate-change impact study issues under the GEOSS-AWCI.

3.1.5 India

Kumar (2008, 2009) overviewed the outline of flood disasters and flood disaster mitigation practices in India. The average annual rainfall of India is 1160 mm but it fluctuates very widely from place to place. The highest rainfall in India of about 11,690 mm was recorded at Mousinram near Cherrapunji in Meghalaya in the northeast of India. The average flood loss is more than 50 billion US dollars and 40,000 people were killed per year in the last decade of the 20th Century.

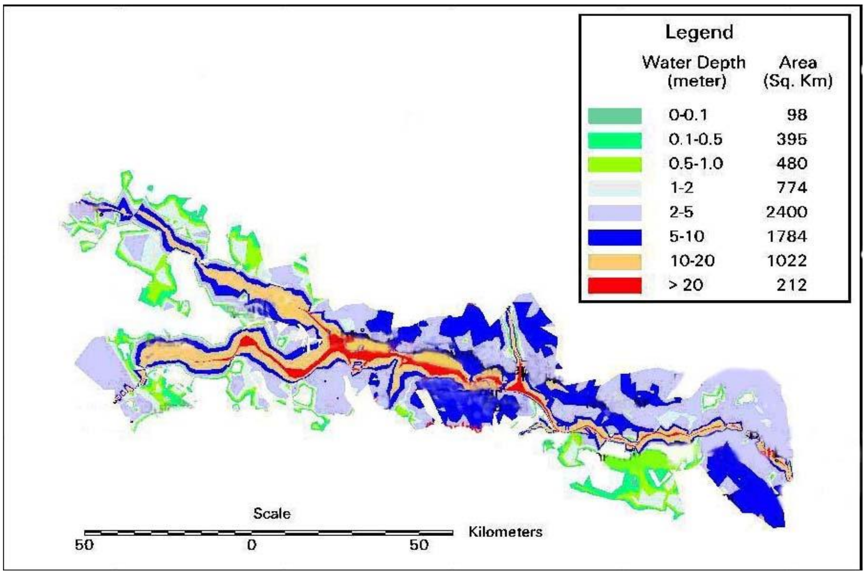


Fig.7 Example of flood inundation and depth mapping for 1000 year return period flood for the study area (Kumar, 2005)

Therefore, India pursued for a variety of the combination of structural & non-structural measures. He focused on flood hazard/risk zone mapping based on frequency analysis of streamflow data, numerical flooding simulation (Fig.7), and the verification of flooding patterns with satellite data. He also introduced typical flood forecasting technologies in India, including artificial neural network technique, and a plan to construct a decision support system for integrated water resources management.

Kaur (2010) reported a flash flood and mudflow on August 6, 2010, caused by extremely heavy storm ("cloud burst") at the Leh city in the Kashmir District, located in the upstream area of the Indus River. The Leh city was inundated with 1.2m-deep water and many buildings were destroyed (Fig.8). About 150 people were killed. The adjacent period had highly larger rainfall amount than the normal year. It is apparent this storm was one of the consecutive events to generate great 2010 flood in the Indus River. She mentioned a trial to apply WRF model to downscale macro-scale weather conditions for meteorological analysis on this event. This is a typical example to apply a global dataset to a local flood risk assessment.

India has been taking a variety of actions to mitigate flood disasters. It would be very beneficial to all the members of GEOSS-AWCI to share those experiences and lessons more intensively, since India has very unique experiences to manage rivers and water resources with a wide range of climatic, hydrologic, geologic and spatial-scale conditions.

Fig.8 Damaged houses by flash floods in Leh the City, India, August 6, 2010 (Kaur, 2010)

3.1.6 Indonesia

Indonesia has been leading GEOSS-AWCI Flood WG activities. First of all, Indonesia arranged the first training seminar and workshop under the framework of AWCI, as Dr. Loebis (2008) reported. This was the Seminar and Workshop on Use Satellite Based Information in Flood Risk Management, 21 – 24 July 2008. The Seminar was held at the Ministry of Public Works of Indonesia in Jakarta. Prof. Koike (UT), Dr. Herath (UNU), Mr. Fukami (ICHARM) and Dr. Saavedra (UT) made lectures on integrated water cycle prediction with remotely-sensed data, downscaling technology for rainfall prediction, integrated flood management practices in Japan, and distributed hydrologic modeling, respectively. Then the Training Workshop was held at the Research Center for Water Resources in Bandung. While Dr. Herath and Dr. Saavedra gave training exercises for their topics, respectively, Mr. Fukami gave training exercises on the Integrated Flood Analysis System (IFAS) as a basis for flood runoff modeling and forecasting. The selection of those topics of the seminar and workshop was just according to the mutual discussions and conclusions on the priority area of common requirements among AWCI member countries at the 3rd GEOSS Asian Water Cycle Symposium, Beppu, Japan, 2-4 December 2007. This seminar and workshop was a good chance for researchers and engineers in Indonesia to keep in touch with state-of-the-art meteorological and hydrological observational & modeling technologies, using global observational and modeling data, which have become available under the era of GEOSS.

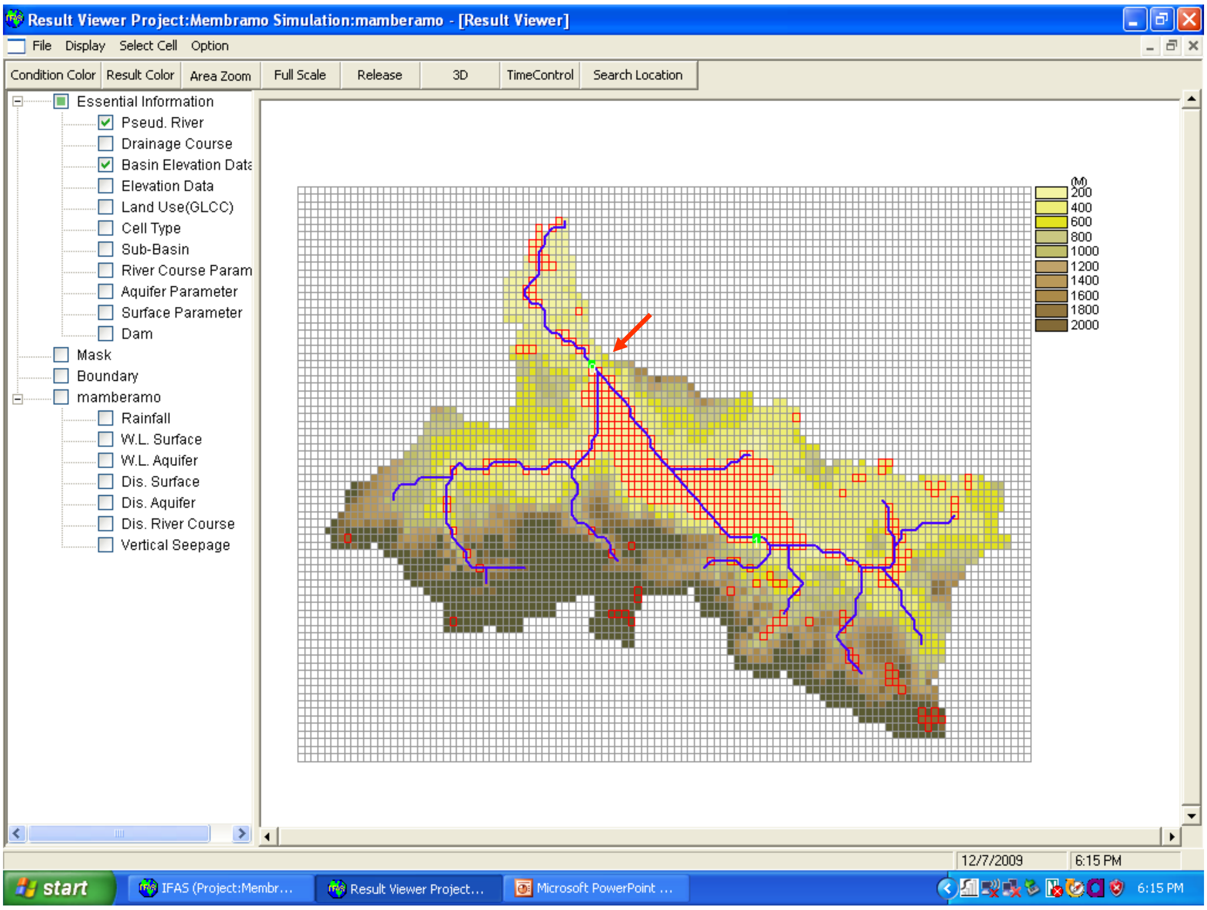


Fig.9 Basin boundary and major river channels delineated by IFAS (Memberamo River) (Loebis, 2009)

As described later, ICHARM organized the 1st International Workshop on Application and Validation of Global Flood Alert System (GFAS) at Tsukuba, Japan during 3-7 August, 2009. Representing Indonesia, Dr. Loebis attended this workshop. He learned how to apply and operate IFAS (Integrated Flood Analysis System, a tool for implementing "GFAS-Streamflow" concept) for flood runoff analysis under poorly-gauged conditions. After that, he reported their application of IFAS at the two river basins: Memberamo River Basin in the New Guinea Island (about 79,000 km^2, a demonstration basin, Fig.9) and Citarum River Basin in the West Java (about 4,500 km^2). In this study, the Research Center for Water Resources (RCWR) at Bandung played a big role. This has become a good example that the two core regional research institutes, namely, ICHARM and RCWR have jointly coordinated research and development activities in this APN-project members. Besides, those experiences became one of the backgrounds to start a new project to implement the IFAS-based operational flood forecasting and warning system for the Bengawan Solo River Basin in the East Java (about 16,000 km^2) as a Regional Technical Assistance Project sponsored by ADB during 2010-11 (fig.10). This ADB-RETA project is still now ongoing and being executed by ICHARM in cooperation with the Bengawan Solo River Basin Agency of the Ministry of Public Works of Indonesia. Since this project is not a research for the future but a real implementation project for now in terms of operational real-time flood risk management, there are quite a few challenges to solve. Despite of that, ICHARM and the Indonesian Agency have been making every effort to cope with them. This project will be one of the most typical showcases to pragmatize the concept of GEOSS-AWCI and this APN project.

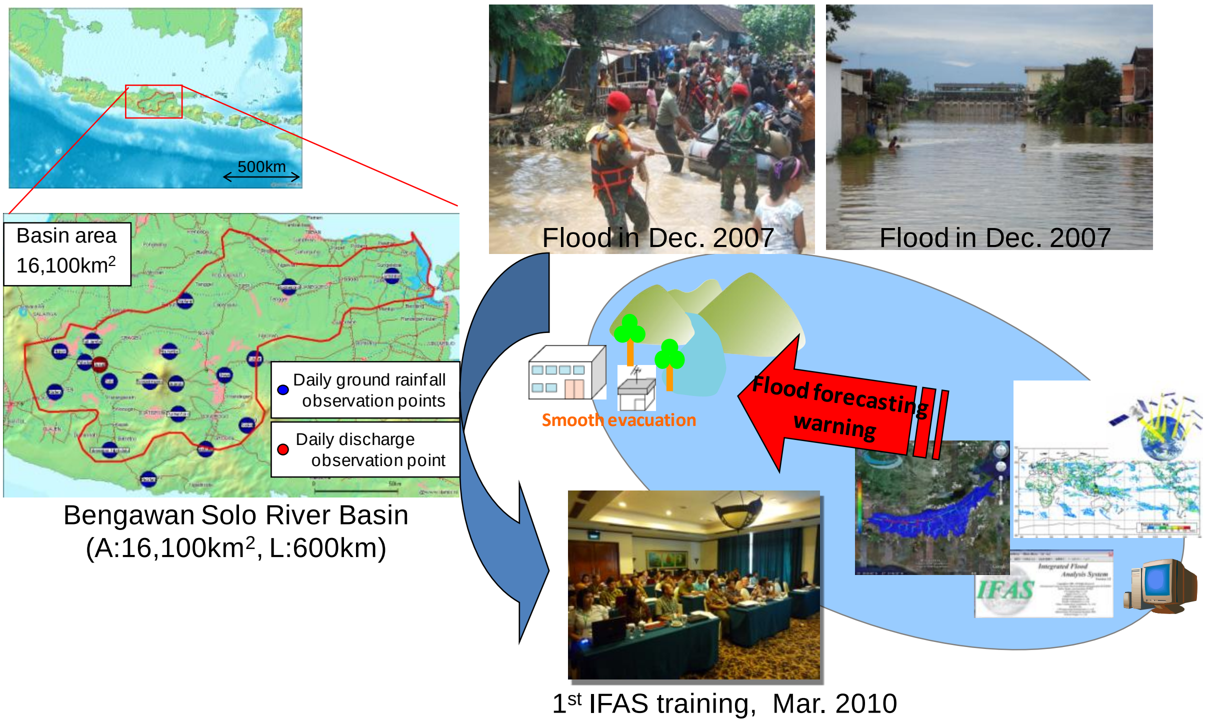


Fig.10 Concept of IFAS-based operational flood forecasting system of the Bengawan Solo River

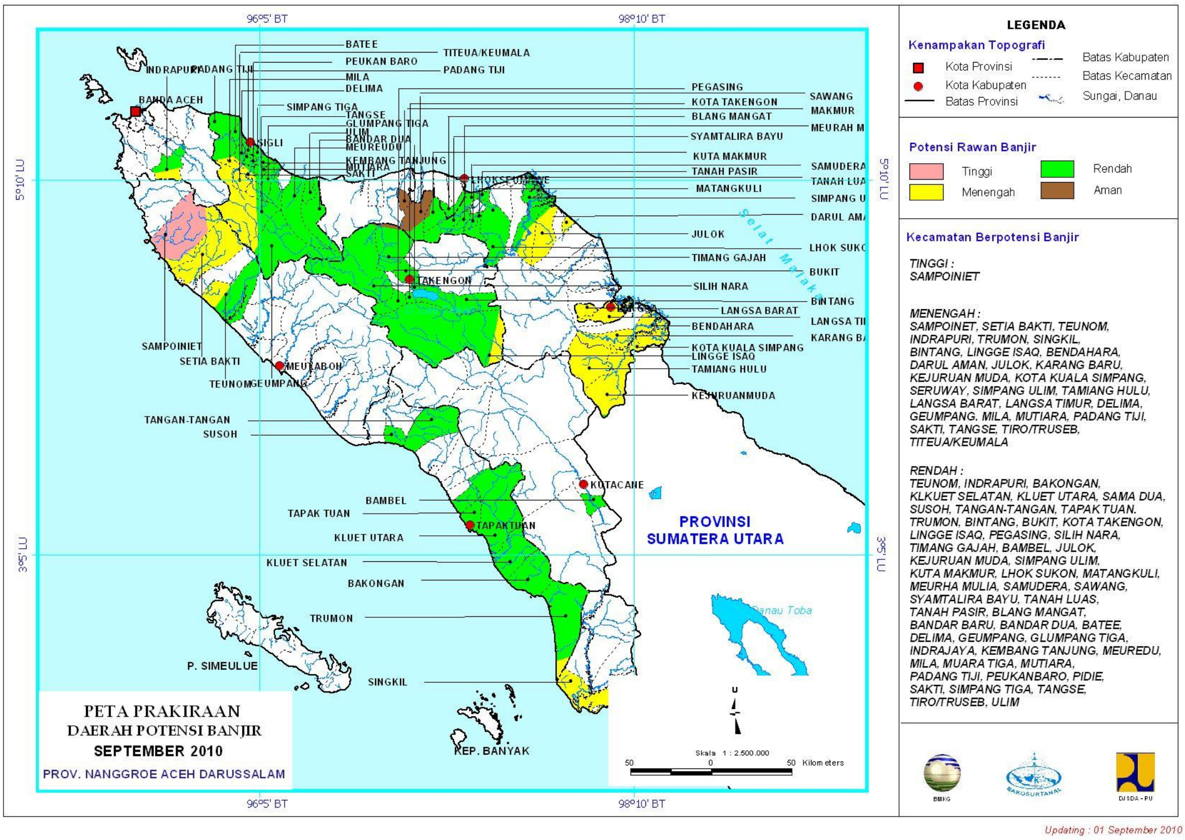


Fig.11 Example of flood disaster risk potential map based on historical experiences(Loebis, 2010)

Mulyantari (2010) described a fundamental framework for early warning system for floods. She indicated that flood forecasting system should be conducted on the basis of rainfall-runoff model with real-time rainfall data, including satellite-based one, for the upstream of a river, and on the basis of hydraulic model, including empirical water-level correlation model, and showed an example of water-level correlation models for the Bengawan Solo River. This idea will be followed by the above ADB-RETA project.

Kusuma (2010) reported an interesting diagnostic study on flood risk in the Citarum River. He described the importance of the river for the most productive area of the Java Island such as Jakarta, and he also described the natural and social history of the basin of the Citarum River and its inherent flood risk as a result.   He pointed out the flood risk assessment tools and mutual cooperation among stakeholders. In this sense, a trial of flood potential risk map based on past flood disaster experiences is very interesting, which Loebis (2010) reported.   The map is created for every district of Indonesia, for every month, in advance(Fig.11). This is not a real-time forecast, but will be very useful to raise awareness of residents living in the flood-prone areas against such flood disaster risks.

3.1.7 Japan

Japan is regarded as one of the countries with most severe natural water-related hazards in the world, such as floods, landslides, debris/mudflows, storm surges, etc. induced by the combination of extreme weather events such as typhoons, "Baiu"-fronts and convective storms, with its geophysical conditions such as tectonic and fragile geology with mountainous and alluvial conditions. Since 70% of the national land of Japan is mountainous, about a half of the population and three-fourths of the total property exist in alluvial plains, which account for only 10% of the area. Areas below sea level in the three major bays of Japan (Tokyo, Ise and Osaka Bays) occupy an area of 577 km^2, accommodating 4.04 million habitants. The combination of such high water-related hazards and highly-developed land use conditions results in high risk of water-related disaster risk if we don't take any actions. Therefore, water-related disaster prevention and mitigation has been always a "far-sighted policy", i.e. a top priority in national land administration in Japan since its long history, especially since 1890's.   However, long wars during latter part of 1930's and the former part of 40's depleted the resilience against flood risk, and extensive flood disasters consecutively occurred such as the extensive flood disaster in the Kanto Plain caused by the Typhoon Cathleen in 1947. Before 1965, annual flood disaster casualties had been almost more than 1,000 every year.   After 1965, i.e. after the enactment of the Basic Act for Disaster Countermeasures (1961), the diffusion of flood control infrastructures such as embankments, floodways, retarding basins, etc. and the spread of weather & flood warning information through radios and televisions, annual flood disaster casualties decreased to several hundreds. In particular, after 1985, the number of casualties was almost less than one hundred every year. This is regarded as a most prominent success story in the world to reduce flood disasters through strengthening coping capacities against flood risks in spite of very high flood hazards. Such historical evolutions of policies and experiences were introduced and shared among GEOSS-AWCI members by Okazumi (2009) and Ootsuki (2009, 2010).

However, as Okazumi (2009) and Ootsuki (2010) mentioned as well, Japan is now facing two types of new flood risk problems: one is flash flood typically on small to middle scale of river in urbanized or mountains, and the other is a emerging risk induced by climate change.

For example, we have to cope with very rapid water-level rise such as 134cm-rise in 10 minutes! which really happened at the Toga River, Hyogo Prefecture killing 5 people (including 3 children) in August, 2008. Similar flash flood disasters often occurred in 2008 & 2009, then the implementation of flood warning system for people in rivers and riversides has progressed. It was also realized that some of the specifications of conventional C-band radars covering all over Japan were not always enough to cope with such flash floods, especially in urban small-scale rivers, since the C-band radar's spatial resolution was 1km, the temporal resolution was 5 minutes and the data delivery time was almost 5 minutes after the real observation so as to make on-line calibration with ground-based telemeter raingauge stations. Therefore, the River Bureau of the Japanese Ministry of Land, Infrastructure, Transport and Tourism (MLIT) decided to implement X-band multi-parametric (MP) radars in high-flood-risk areas. This X-band MP radar will improve the spatial resolution (250m), the temporal resolution (1 minute) and the data delivery time (1-2 minutes after the real observation), since the MP radar does not necessarily require any on-line calibration system with ground-based rainfall data. The test-phase operation of X-band MP radars has started since July of 2010. New researches to improve short-term rainfall forecast using such a new-generation MP radar data have been also promoted by a new research grant scheme of the MLIT. This is really a new challenge in the field of hydrological forecasting.

Another challenge is how to cope with the increase of flood hazard and risk due to climate change. Japan has been continuously implementing flood-control infrastructures, including the construction of continuous levees and flood-storage structures, such as dams. These efforts steadily improved the flood safety level against medium-scale flood hazard. However, the construction of planned flood control structures has been slow due to the limitation of budget and still remains at a low completion level, only reaching about 60% of the government's current goal, which is set to implement flood control measures against rainfall with a return period of 30-40 years for large rivers and 5-10 years for small and medium rivers. According to a projection of the impact of climate change on hydrology in Japan as of 2009, annual maximum daily rainfall was evaluated to increase around 10% (20% in the northern part of Japan).

Those discussions highlight the two problems. One problem is how to make such a future projection reliable enough to change the authorized long-term flood control plan. Regarding this question, Ostuki (2010) proposed a concept of flexible approach considering not only long-term (~100 years) but also medium-term (25-30 years) projection. That is, the medium-term climate projection should be more reliable than the long-term projection since such near-future projections computed by most world-wide GCMs are very close with each other. Thus, first of all, taking some reasonable actions based on the medium-term projection, and some years later, evaluating the actions with monitoring data & updated future log-term & medium-term projection and taking the next actions based on such evaluations, monitoring & new projections are proposed (Fig. 12).

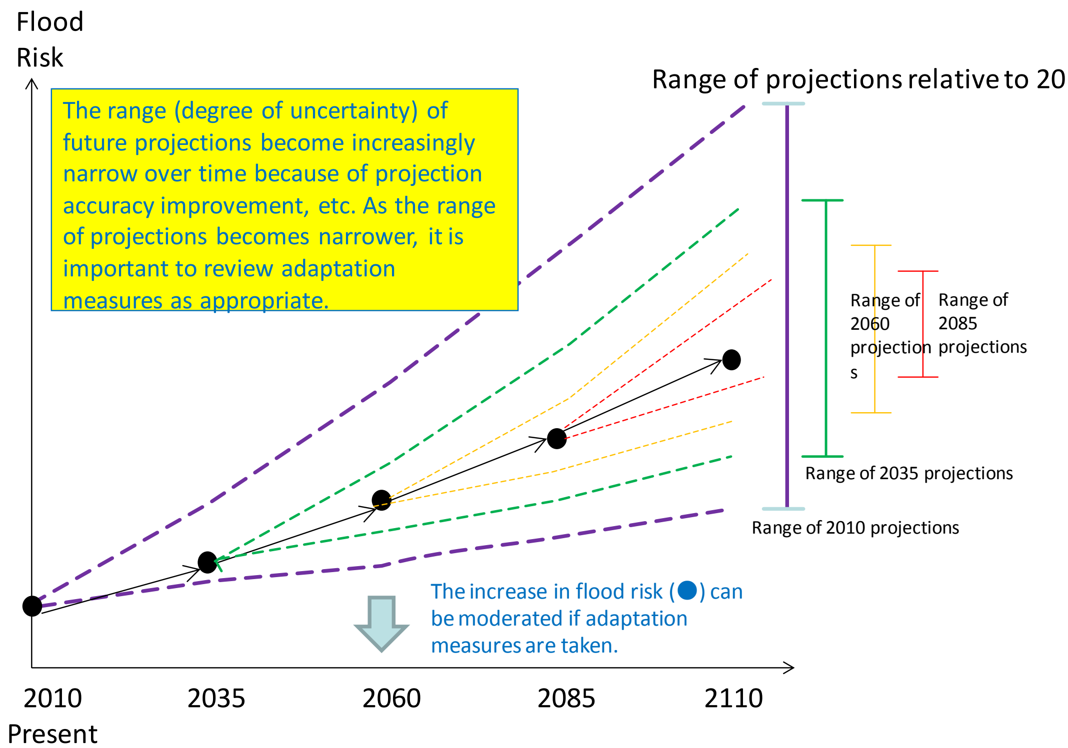


Fig.12 Concept to deal with uncertainty in long-term climate projections (Otsuki, 2010)

Another highlighted problem should be the recognition that the probable increase of extreme hydrological conditions will make it more difficult to fulfill the final goal (i.e. safety level) of flood control projects using only engineering measures. Therefore, the Panel on Infrastructure Development (2008) pointed out that we should aim at more disaster-resistant society through combining mitigation and adaptation in the future, since structural and engineering measures cannot fully meet the required safety level. Our next-step priority target should be to achieve "no loss of lives (zero casualty)" because ''zero damage'' from disasters is almost impossible under the era of climate change. Therefore, flexible adaptation measures and holistic approach to couple structural and non-structural measures should be taken at basin level to deal with all possible floods of different scales, based on flood disaster risk assessment. Those new approaches were summarized and discussed in the "Japan Practical Guidelines on Strategic Climate Change Adaptation Planning - Flood Disasters –" (MLIT, 2010).

Referring to the importance of non-structural measures against floods, the University of Tokyo has been developing a decision support system for real-time optimal operation of multiple dam reservoirs, including flood forecasting system coupled with numerical weather forecast data (GPV), as Oliver and Koike (2010) reported and summarized. The system consists of 1) Dam Release Support System (DRESS) for dam release decision support to reduce flood peaks and store volume for water-use and 2) Flood Warning Support System (FLOWSS) for dissemination of flood warning to perform evacuation timely. DRESS is a combination of ensemble of precipitation forecasts and WEB-DHM (Water and Energy Budget-based Distributed Hydrological Model, Fig.13). The model was

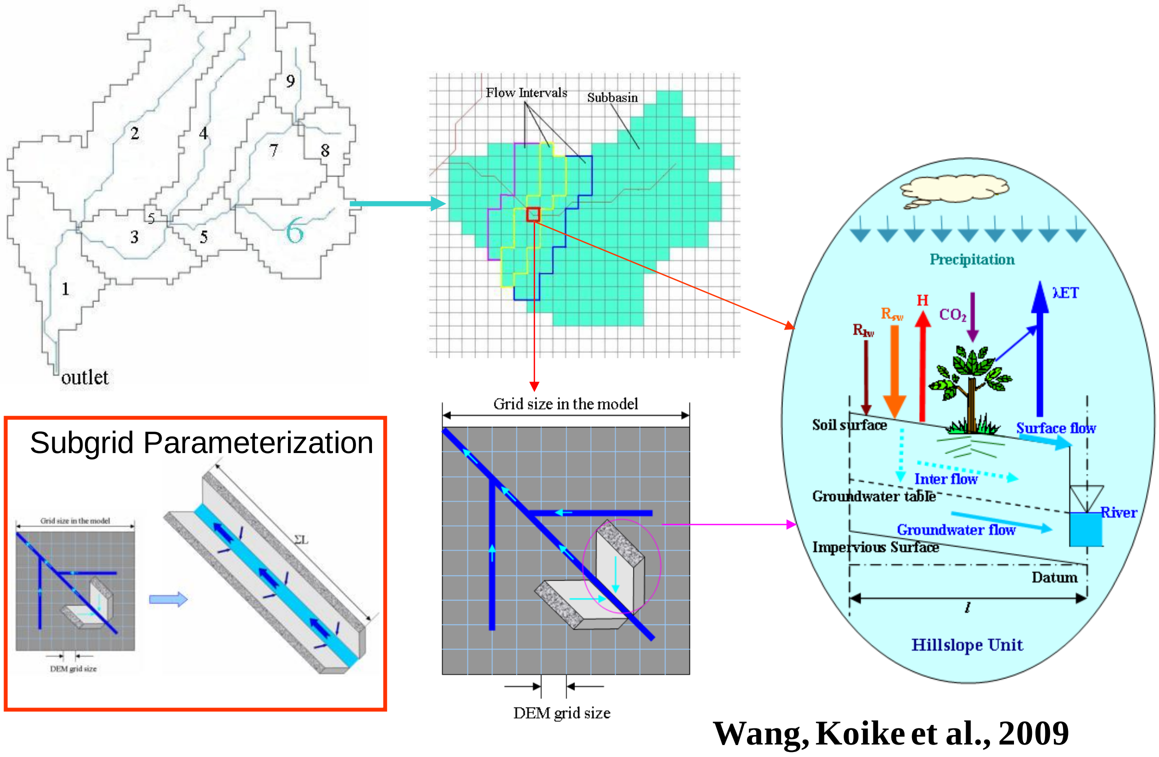


Fig.13 Concept of WEB-DHM of UT (Saavedra et al., 2010)

originally developed for the Upper Tone River (a demonstration basin) and was verified. Fig.14 shows an example of results of optimal operation of multiple dam reservoirs based on the DRESS, reducing flood peak level and saving water storage in dams from normal operations. FLOWSS is an integrated flood forecasting system using not only ground-based raingauge and numerical precipitation forecast data but also satellite-based rainfall data. The FLOWSS was applied to the Huong River and the Red River in Vietnam, as mentioned later. This is one of the most advanced hydrological forecasting examples, fully utilizing global numerical & satellite data for integrated flood management on a local scale and therefore a typical achievement of GEOSS-AWCI flood-WG activities and this APN project, i.e., 1) to convert observations and data, both through space borne platforms and data integration initiatives, to usable information for flood reduction, and 2) to improve quantitative forecasts for coupled precipitation - flood-forecasting systems.

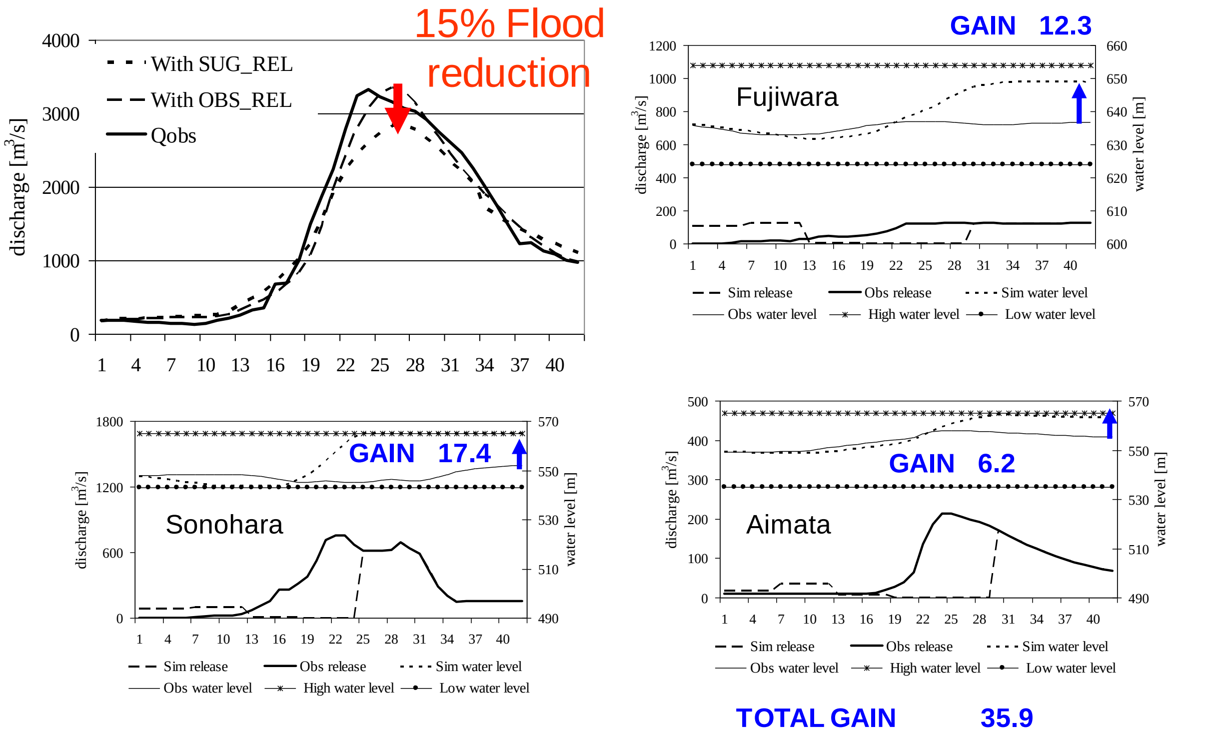


Fig. 14 Effect of DRESS on effective flood-peak reduction and water-storage saving through optimal dam reservoirs operation, Upper Tone River, Japan (9-11 July 2002). (Saavedra et al., 2010)

In parallel to the above, International Centre for Water Hazard and Risk Management under the auspices of UNESCO (ICHARM) has been making every effort how to transfer high technology to use global databases for local management to developing countries and how to lead to real implantation of the state-of-the-art technology for integrated flood management under the condition of limited in-situ observational network and resources (budget and capacity) in those countries. In this context, ICHARM has been developing a fundamental common toolkit for flood runoff analysis and forecasting system using not only ground-based but also satellite-based rainfall data in order for the countries lack of surface rainfall data to establish flood forecast system rapidly and effectively, as Fukami et al.(2008) introduced. This system was named as Integrated Flood Analysis System (IFAS, Fig.15). The design concepts of IFAS were as follows:

1. To prepare interfaces to get satellite-based rainfall data in addition to ground-based rainfall data, to secure the worldwide availability of input data for flood forecasting/analysis system.
2. To adopt two types of distributed-parameter hydrologic models, PWRI Distributed Hydrologic Model (PDHM) Ver.2 and Block-wise TOP (BTOP) model, the parameters of which can be estimated as the first approximation based on globally-available GIS databases to secure the worldwide availability of hydrologic models for flood forecasting/analysis.
3. To implement GIS analysis modules in the system to set up the parameters for the flood forecasting/analysis model, therefore no need to depend on external GIS softwares.
4. To prepare a series of easy-to-understand graphical user interfaces for data input, modeling, runoff-analysis, and displaying the outputs.
5. To distribute the executable program, free of charge, from the ICHARM/PWRI website.

The IFAS Ver.1 was developed under a joint research with the Infrastructure Development Institute (IDI) and nine major civil-engineering consultancy companies during FY2005-2007.

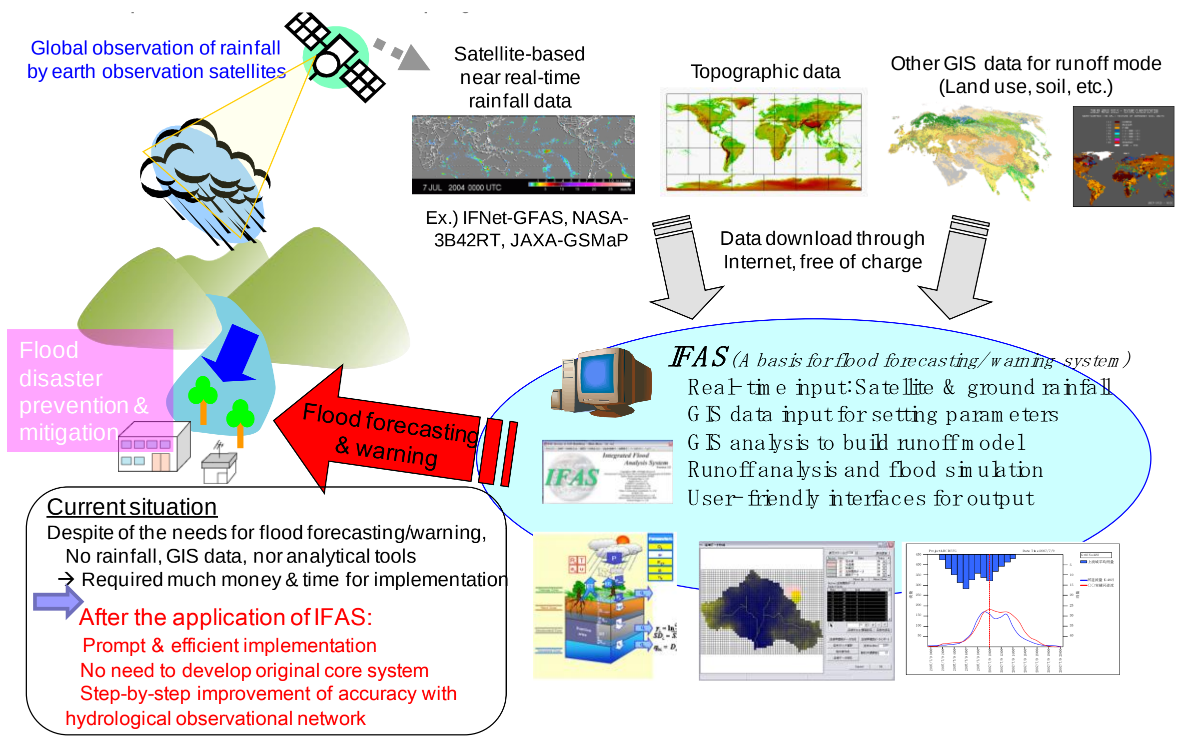


Fig.15 Concept of Integrated Flood Analysis System (IFAS)

Consequently, IFAS can incorporate not only ground-based rainfall data (csv data) but also satellite-based near-real-time rainfall products such as NASA-3B42RT, NOAA-CMORPH, JAXA-GSMaP_NRT, etc. as shown in Table 1.

Table 1 Major satellite-based global rainfall data products available thought the internet

Product name	3B42RT	CMORPH	**GSMaP_NRT**
Developer and provider	NASA/GSFC	NOAA/CPC	JAXA/EORC
Coverage	N60° - S60°		
Resolution	0.25°	0.25°	**0.1°**
Resolution time	3 hours	3 hours	**1 hour**
Time lag	10 hours	15 hours	**4 hours**
Coordinate system	WGS		
Historical data	Dec 1997-	Dec 2002-	Dec. 2007～
Sensors	TRMM/TMI Aqua/AMSR-E AMSU-B DMSP/SSM/I IR	Aqua/AMSR-E AMSU-B DMSP/SSM/I TRMM/TMI IR	TRMM/TMI Aqua/AMSR-E ADEOS-Ⅱ/ AMSR SSM/I IR AMSU-B

From the table, GSMaP_NRT seems more promising for the purpose of flood forecasting due to its high temporal & spatial resolution and its quick delivery. According to some validation studies, however, it was clarified that GSMaP_NRT tended to underestimate rainfall intensity, in particular, for heavy cases. Then Shiraishi et al.(2009) found out an empirical relationship between spatial correlation factor (presumably corresponding to the movement speed of precipitation cells) and the degree of underestimation. Based on this empirical relationship, they developed a self-correction

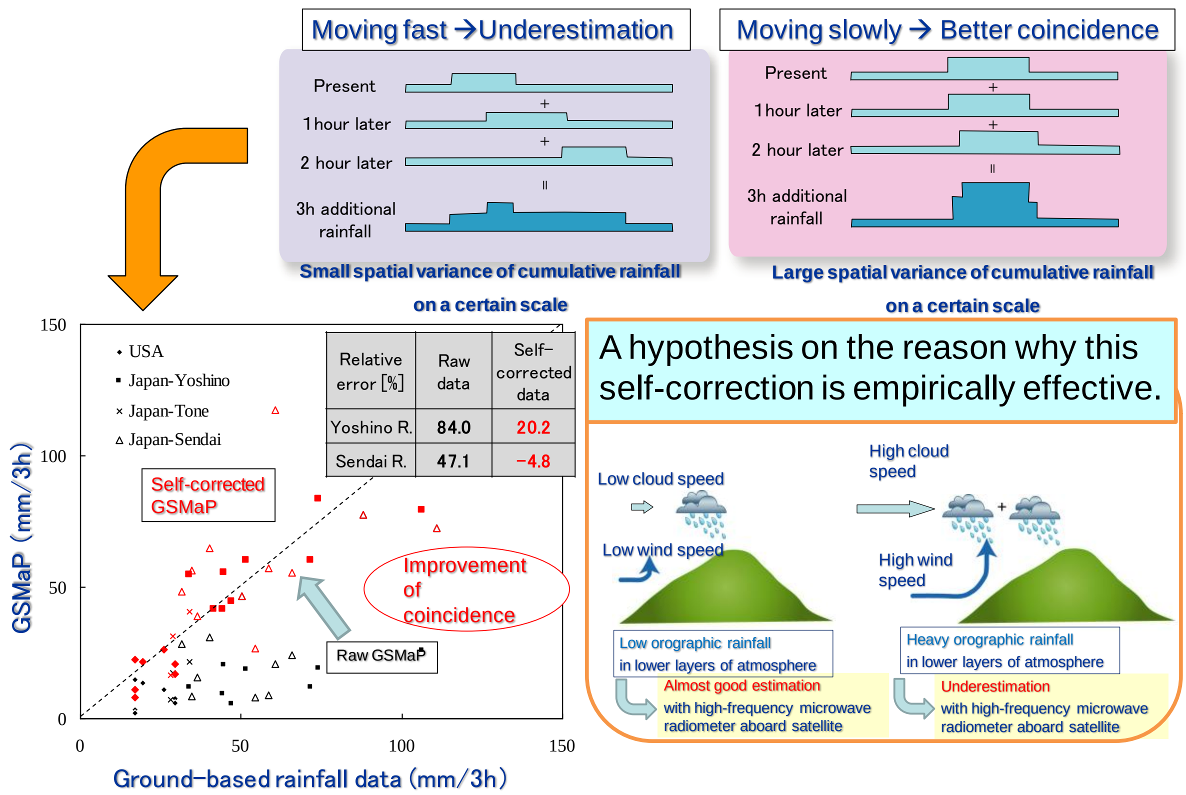


Fig.16 Concept, validity and background of self-correction algorithm for GSMaP_NRT without any ground-based data

method for GSMaP_NRT without any ground-based rainfall data (Fig.16). This method is expected to be very practical and useful for poorly-gauged river basins to use satellite-based rainfall data for flood forecasting purpose since it is difficult to implement fully-designed network of telemeterred raingauges. According to another study for the case of Typhoon Morakot in Taiwan in 2009, this method seemed effective to get the first-order approximated areal rainfall distribution in poorly-gauged river basins (Fig.17). However, we have also found out some cases which self-corrected satellite-based rainfall data cannot reproduce flood hydrographs properly (Fig.18). It was clarified that such bad results could happen if the frequency of real observation of rainfall field from the space was not enough during the rainfall increasing period. To minimize this influence, we would strongly desire and anticipate the real implementation of GPM (Global Precipitation Measurement) mission, which has been planned by JAXA, NASA and other space agencies in the world and will make it possible to observe any area in the world once in three hours. If this project is realized, the temporal resolution and reliability of satellite-based rainfall data would be expected to be much improved. In

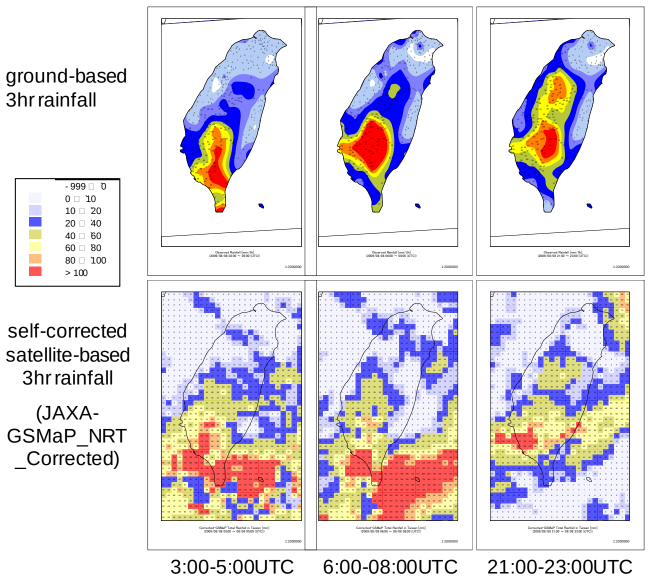


Fig. 17 Comparison of self-corrected JAXA-GSMaP_NRT rainfall data with ground-based rainfall data (Taiwan, Typhoon Morakot, 8 August 2009)

reality, it would not be likely the case to implement an operational flood forecasting and warning system just only based on satellite-based rainfall data even with the self-correction method. In spite of that, this satellite-based rainfall information would be useful to understand the effectiveness and the limitation of global data for each local river basin. This kind of analysis is to be conducted at the first phase of flood runoff analysis and to be a milestone to upgrade the flood runoff analysis and/or forecasting system, step by step, to improve the reliability and accuracy with the implementation of in-situ hydrological observation network, which will surely lead to the enhancement of local ownership of the system.

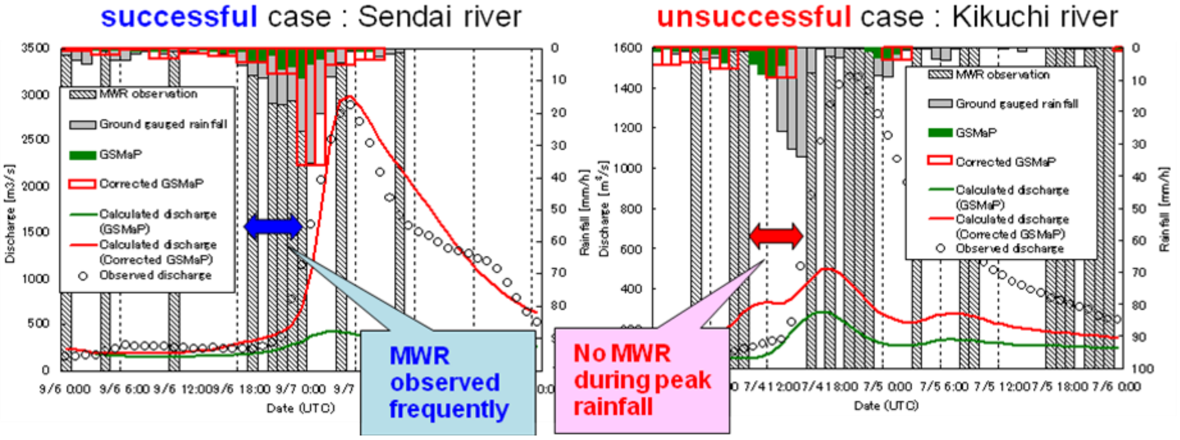


Fig.18 Successful & unsuccessful cases of self-correction algorithm for GSMaP_NRT and its relationship with the frequency of direct microwave radiometric observations from the space

In order to spread this IFAS system widely and to apply it effectively for flood management issues to contribute to the reduction of flood disaster in the world, ICHARM has organized quite a few workshops/sessions to train local practitioners/engineers of developing countries since 2008. Most typical one is the 1st International Workshop on Application and Validation of Global Flood Alert System (GFAS), jointly organized/sponsored by ICHARM, IFNet (IDI), APN, held at ICHARM, Tsukuba, Japan, during 3-7 August 2009 (Fig. 19). The objective of the workshop was to study how to undertake hydrological forecasting in poorly-gauged river basins through initiating GFAS/IFAS validation and to discuss issues regarding the accuracy and applicability of the system in each area. This workshop was planned according to the agreement on the necessity of it at the Flood WG in the 4th International Coordination Group Meeting of the GEOSS-AWCI, Kyoto, Japan, February 4-7, 2009, although this workshop had been originally planned to be held at AIT (Asian Institute of Technology) in Thailand. The participants were recruited through the network of GEOSS-AWCI Flood WG, and consequently, six people were invited from Bangladesh, India, Indonesia, Lao PDR, Nepal, and Viet Nam. Some of them were members of GEOSS-AWCI Flood WG. Many of the participants took their in-situ hydrological data with them and tried to validate hydrological modeling with IFAS with the in-situ data. This workshop was very successful to share IFAS technology and its applications & problems among APN countries and led to enhancing case studies by their own capacities in some countries, such as Indonesia, as mentioned above, and Vietnam, as mentioned later. Moreover, a project to implement IFAS-based operational flood forecasting/warning system in the Bengawan Solo River of Indonesia has been sponsored by ADB, as mentioned above as well.

Fig.19 Participants of the 1st international Workshop on Application and Validation of GFAS, at ICHARM, Tsukuba, Japan, August 3-7, 2009.

Such development, applications, disseminations and implementations of IFAS are also typical achievements of GEOSS-AWCI flood-WG activities and this APN project, i.e., 1) to convert observations and data, both through space borne platforms and data integration initiatives, to usable information for flood reduction, and 2) to improve quantitative forecasts for coupled precipitation - flood-forecasting systems.

3.1.8 Korea

Korea is also focusing on the impact analysis of climate change on hydrology and water resources. Lee et al.(2008) demonstrated a comparative study on soil moisture modeling with hydrological models based on global data at the demonstration basin in Korea. Bae (2009) discussed the importance of local data for hydrologic modeling even for such hydrologic models based on global data. Bae (2010) proposed a next-step climate change impact assessment and adaptation study for water resources. He discussed that there were sources of uncertainty of climate change impact assessment in every process such as GCM projection, downscaling and hydrologic modeling, and that the importance of consideration of uncertainty of hydrologic modeling which had not been incorporated very well so far. He proposed a multi-model ensemble approach (Fig.20). Those reports will be the basis for the activities of climate change WG of AWCI in the future.

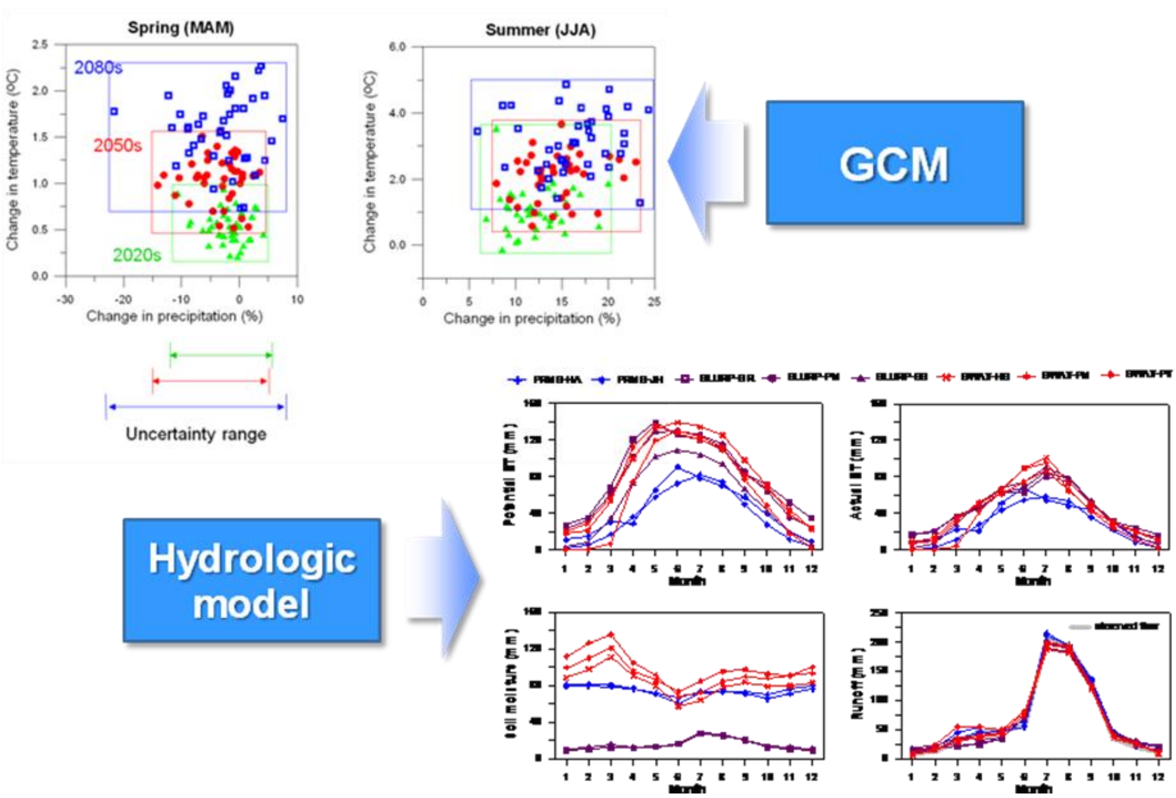


Fig.20 Scatter plots of GCM outputs(precipitation) and runoff analysis with different models to show the necessity of multi-model ensemble approach

3.1.9 Lao PDR

Lao PDR has also suffered from flood disasters caused by floods from the Mekong River and its tributaries (flash floods & landslides). Amphaychih (2010) mentioned there were 28 notable floods from 1966 to 2007. In particular, there were 6 large floods (1966, 1971, 1978, 1995, 1996, 2000 and 2002). He also mentioned flash flood in the mountainous area was becoming common. A typical example occurred in the Luangnamtha Province (Fig.21) in 2006 as mentioned below.

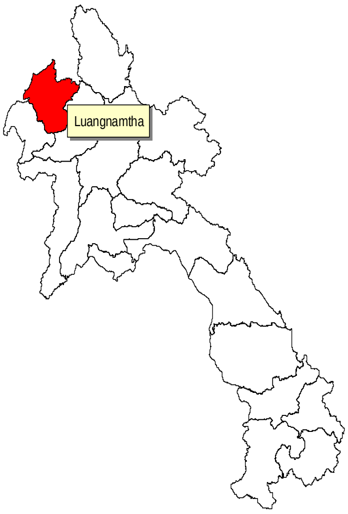


Fig.21 Location of the Luangnamtha Province in Lao PDR

Amphaychih et al.(2008) also described the characteristics of flash flood disasters. Flash floods in Lao PDR have occurred in the northern part of Lao PDR and around the border between Lao PDR and Vietnam. Especially, the Luangnamtha Province often experiences flash floods. Significant flash floods occurred in the Namtha River in 2002, 2005, 2006, 2007 and 2008 by 2008, almost annually. Regarding the case of 2006 flood (August 6-7), heavy daily rainfall with 52.8 – 112.6 mm occurred at many stations during 6-7 August 2006, which caused destructive high-flow flash floods. Flood inundation occurred at the Hongleuai water-level station around noon of August 7 and flood overflowed the Namtha Dam around 1-3pm of August 7 (Fig. 22). As a result, 132 villages were inundated with 1.2m depth. He summarized the lessons learned, as follows:

- The unplanned human settlements which were developed into mountainous area caused significant damages.

Fig.22 Overflow from theNamtha Dam(7 August 2006)

- Since the resources are limited, public mobilization in flood management and mitigation is very important.
- Short and medium term flood forecasting, warning and dissemination are very crucial for flash flood preparedness activities.

In order to cope with those issues, Lao PDR established the provincial disaster management committee with the objective to implement flood management and mitigation measures. Integrated flood management based on the quantitative understanding of flood hazards and risks utilizing global GEOSS and local data are expected to go well.

3.1.10 Malaysia

Malaysia is located in the tropical monsoon region, and suffering from a variety of floods (Kuala Lumpur, 1926). According to Shaaban (2009), flood prone area is around 26,720km^2, about 9% of the total land area of Malaysia, affecting 4.9 million people. The average annual flood damage is around 1 billion RM (263 million USD). He indicated the causes of floods were as follows:

1) Natural phenomena
   - Heavy rainfall caused by the northeast monsoon from November to February
   - High tide
2) Human activities
   - Landuse change, rapid development and urbanization
   - inadequate drainage facilities and obstacles in rivers

Therefore, climage change impact assessment on floods is one of the major concerns for hydrologists in Malaysia.

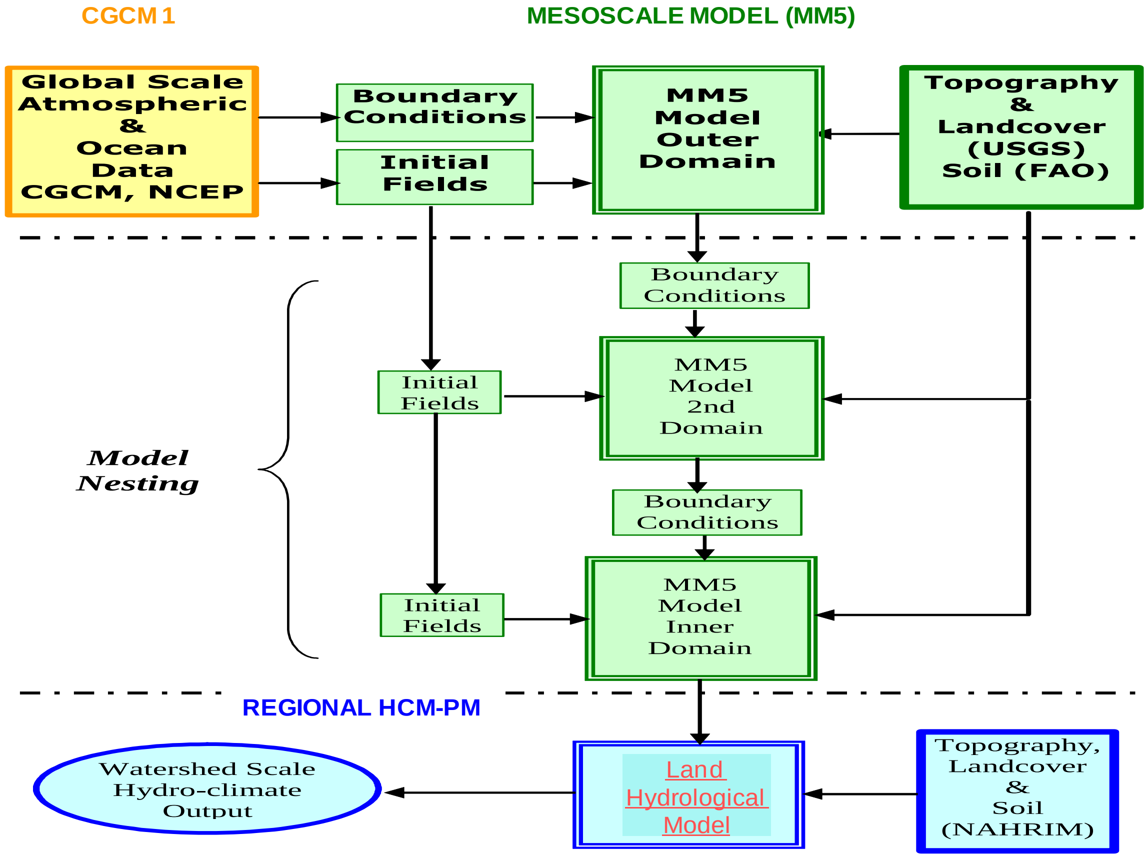


Fig.23 Flowchart of climate change impact assessment on a river watershed scale with RegHCM-PM

Malaysia is one of the leading countries in the climate change impact assessment studies. The National Hydraulic Research Institute of Malaysia (NAHRIM) has an outstanding downscaling technology for hydrometeorological projection of future climate on a regional scale, i.e. the Regional Hydroclimate Model of Peninsular Malaysia (RegHCM-PM) (Shaaban et al., 2008, Fig.23). The atmospheric component of RegHCM-PM is the MM5 (5th Generation Mesoscale Model) developed by NCAR (US National Center for Atmospheric Research), a non-hydrostaticmodel which can be downscaled even to 0.5km spatial resolution, which makes it very desirable for downscaling climate study results to the scale or river watersheds. The land hydrology component of RegHCM-PM is taken from the Integrated Regional Scale Hydrologic-Atmospheric Model (IRSHAM), a fully physically-based regional land surface hydrology model, which was jointly developed by the Hydrologic Research Laboratory, University of California at Davis, USA and by the Public Works Research Institute of Japan (PWRI). By using the RegHCM-PM, NAHRIM downscaled global climate change simulation data (Canadian GCM1 = CGCM) at very coarse resolution (-410km) to fine spatial resolution (-9km) via medium resolution (-27km) for the future period of 2025-2050 (2025-2034 & 2041-2050), including the past climate during 1984 and 1993. Those downscaled data have been archived as the Future Hydroclimate Data Retrieval System, which enables very flexible climate-change impact assessment studies in Malaysia (Amin, 2010). For example, Amin (2010) assessed the possible future changes of monthly rainfall anomaly, annual maximum 1-3 day rainfall, probable maximum precipitation (PMP using statistical Hershfield method) and flood hydrographs at the Bekok Dam for examining the impact on its spillway based on real flood events of December 2006 and January 2007 (Fig.24). His conclusion is as follows, regarding flood issues:

- It can be seen that in general future flooding is going to be worse but there are slight variations. But if we consider more exceptional flood events such as the PMF (Probable Maximum Flood), the impact is more significant as compared to conventional design floods of 10, 50 and 100-year return period.

Reducing uncertainties of those projections will be the next-step subject for the climate change impact assessment studies. Climate change adaptation studies are also expected to be enhanced and shared among flood WG of GEOSS-AWCI.

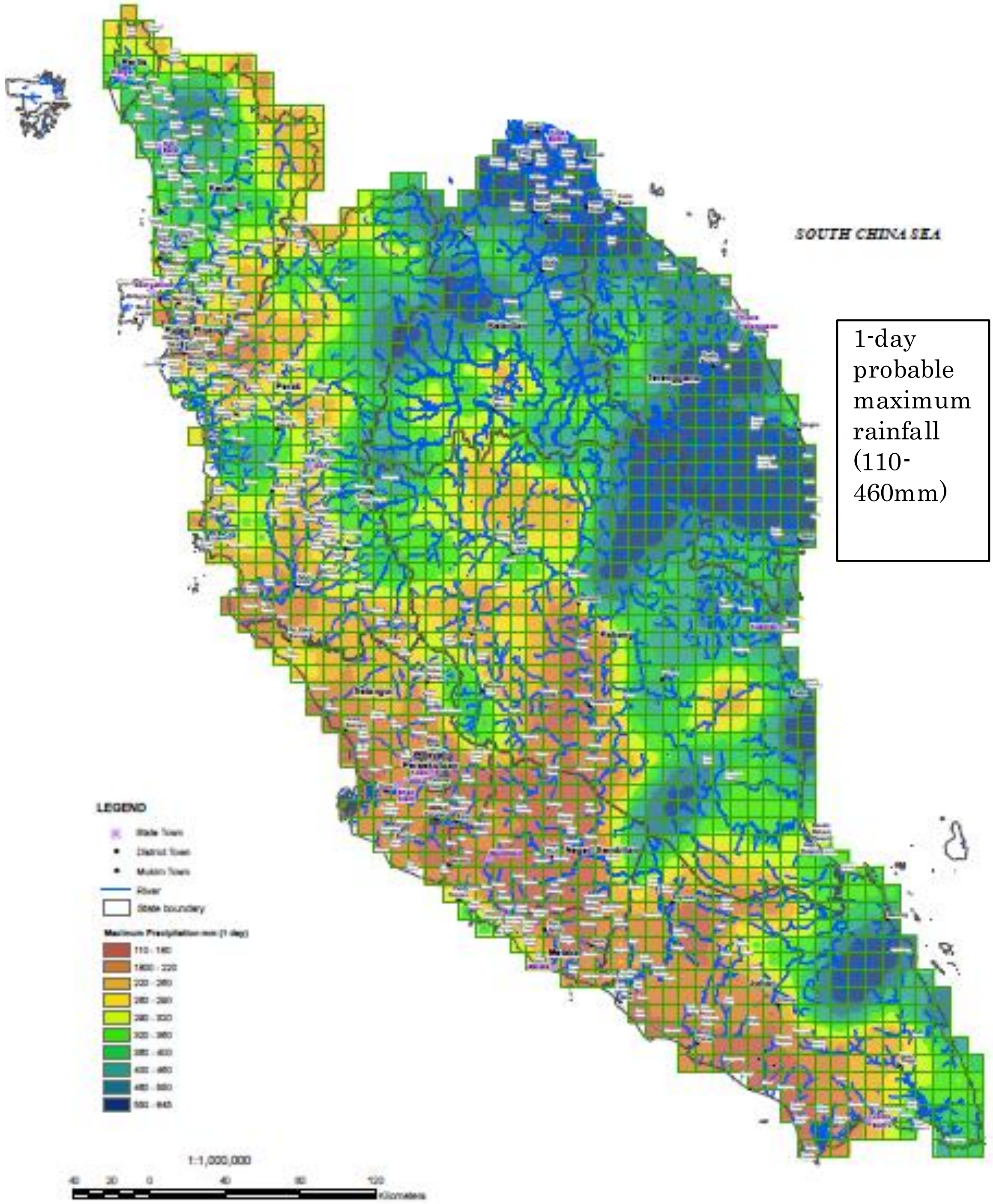


Fig.24 Maximum 1-day rainfall estimation over the peninsula of Malaysia in the future (2025-2034 & 2040-2050) (Amin, 2010)

3.1.11 Mongolia

Fig.25 Flash floods in the Ulaanbaatar City, 18 July 2005) (Oyunbaatar, 2009)

Mongolia is an arid and semi-arid country with annual average precipitation of 224mm and only 9.9% of it forms surface runoff, partially recharging into groundwater aquifers (Oyunbaatar, 2009). However, Mongolia has also severe storm and flood. Through the GEOSS-AWCI meetings, those flood issues and possible future countermeasures have been discussed. Oyunbaatar (2009) divided floods in Mongolia into three categories: snowmelt flood (spring flood), rainfall flood and flash flood. Davaa (2010) showed the climate change impact assessment in Mongolia. According to him, the annual mean temperature of Mongolia increased by 2.14 degree during the last 70 years whereas the number of occurrence of natural disasters related with convective storm increased two times in 70 years. According to the future projection with the Hadley Center GCM (HadCM3), annual rainfall will be decreased by 2-4% in 2011-2030 but increased by 7-11% in 2080-2099. However, temperature and evaporation will also increase in the future, and as a result of that, river flow will be decreased in the future. Consequently, rain flood may decrease, but flash flood may still increase in the future. Historically the maximum daily rainfall at Ulaanbaatar is 103.5mm in July 1966. On 15 August 1982, 44mm rainfall was recorded in 20 minutes at Ulaanbaatar. This intensive rainfall caused severe flash flood and several tens of casualties (Fig.25). Considering such a recent situation, climate change may increase such flash flood risk, especially around the Ulaanbaatar City, since many hillslopes around the city have been being urbanized rapidly. It is now recognized that the Ulaanbaatar City should prepare more capacity for draining flash flood for hillslopes and early flood forecasting/warning system utilizing a radar raingauge installed in the vicinity of the Ulaanbaatar City.

3.1.12 Myanmar

Myanmar has the area of 678,000km^2 and its annual rainfall ranges from 600mm in the central area to 4,000mm in the coastal areas. Myanmar has suffered from many flood disasters every year, including riverine floods along large-scale continental rivers such as Ayeyarwaddy River, Thanlwin River, etc. and flash/storm floods along smaller-scale rivers. Ms. Htay Htay Than (2009) reported past maxmimum flood records for each river system

Table 2 Flood records in Myanmar since 1966

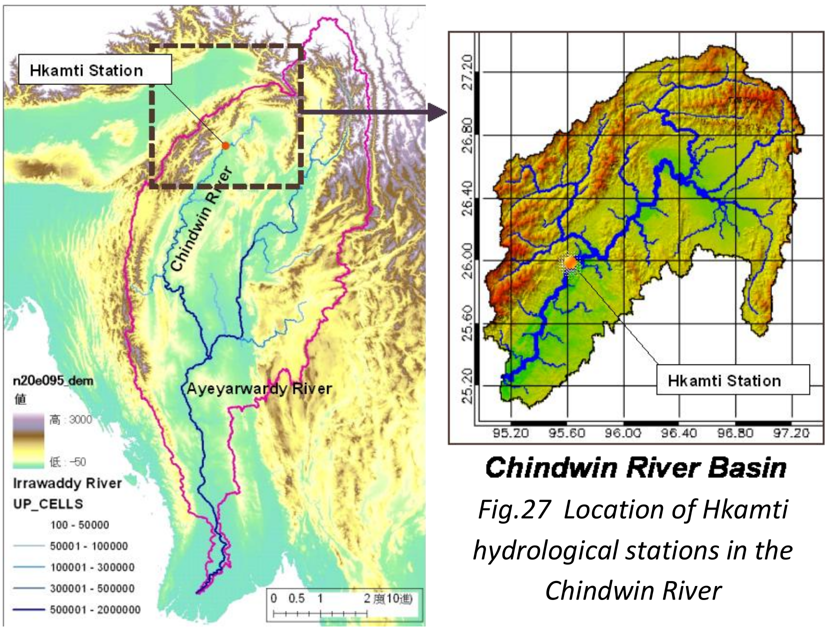
Stations	DangerLevel (cm)	Max. WL (cm)	Flood Duration	above DL (m)	Year
Ayeyarwady					
Myitkyina	1200	1411	4 days 12 Hrs	2.11	1979
Bhamo	1150	1338	8 days 2 Hrs	2.38	2004
Katha	1040	1154	7 days 6 Hrs	1.14	1979
Mandalay	1260	1382	16 Days	1.22	2004
Sagaing	1150	1274	17 Days 6 Hrs	1.24	2004
Nyaung Oo	2120	2263	16 Days 12 Hrs	1.43	2004
Chauk	1450	1532	12 Days 12 Hrs	0.82	1974
Minbu	1700	1982	17 Days 12 Hrs	2.82	1974
Aunglan	2550	2737	15 Days	1.87	1974
Pyay	2900	3025	13 Days	1.25	1974
Hinthada	1342	1461	13 Days 6 Hrs	1.19	1966
Chindwin					
Hkamti	1360	1771	18 Days 6 Hrs	4.11	1991
Homalin	2900	3107	18 Days 6 Hrs	2.07	1968
Mawlaik	1230	1608	15 Days 12 Hrs	3.78	1976
Kalewa	1550	1920	10 Day 12 Hrs	3.70	2002
Monywa	1000	1099	9 Days 6 Hrs	0.99	2002

as shown in Table 2.

It is apparent that big floods beyond the danger water level for more than 1 to 4m have happened. Therefore, Myanmar has made the following implementation plan for the demonstration river basin, Shwegyin River (1,700km^2).

1) To install two telemetering stations and one receiving station in the Shwegyin river basin, in order to get early warning system
2) To develop forecasting technique for flash flood Requirement:-
   - Advance technology for satellite rainfall estimation
   - Advance technology transfer for flash flood forecasting
3) To display the hydrological behavior of watersheds after estimation the geomorphologic parameters from digital elevation model
4) To develop the design flood and design rainfall for different return periods and probable maximum precipitation for duration of one to three days
5) To produce the unit hydrograph, which is of great use in the development of flood hydrograph for extreme rainfall magnitudes for use in design of hydraulic structure and development of flood forecasting and warning systems based on rainfall
6) To develop accurate flood risk maps based on flows the hydrologic model using all available data including GIS data sources

Fig.26 Photos at the IFAS Training Seminar, 22-24 June 2010, Nae Pyi Taw, Myammar



Chindwin River Basin

Fig.27 Location of Hkamti hydrological stations in the Chindwin River

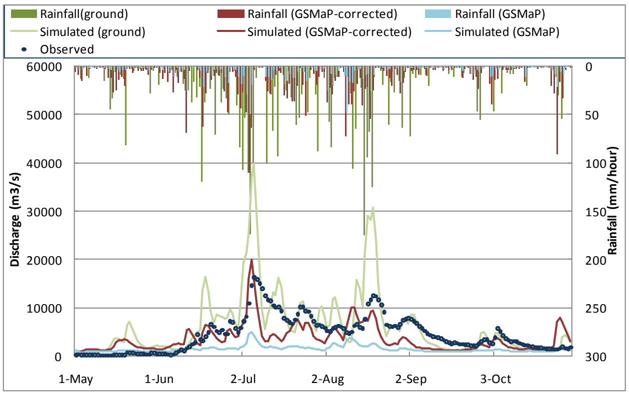


Fig.28 Comparison of IFAS simulation for 2008 using ground-based and satellite-based rainfall data with observed river flow (Htay Htay Than, 2009)

According to the implementation plan, river morphologic parameters, observed 1-3day maximum rainfall, probable 1-3day maximum rainfall with non-exceedance probability with 1/10, 1/20, 1/50, 1/100, 1/200, and 1/500 , and probable maximum water level with the same sets of non-exceedance probabilities were estimated (Htay Htay Than, 2009). Besides, an IFAS Training Seminar was held during June 22-24, 2010 at the Deparment of Meteorology and Hydrology (DMH), Ministry of Transport in the Nae Pyi Taw City, Myanmar, to develop capacities for satellite rainfall estimation and flood forecasting (Fig.26). This

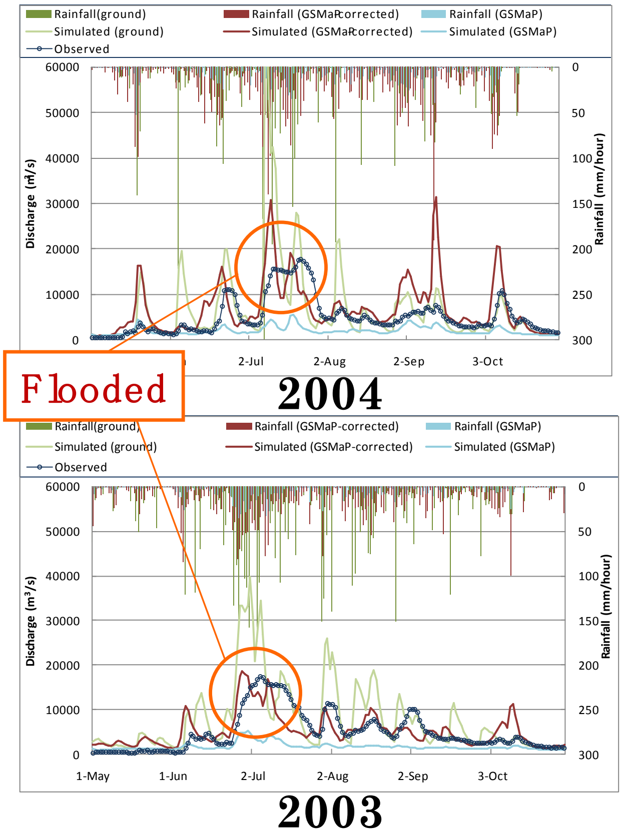


Fig.29 Comparison of IFAS simulation for 2003 & 2004 using ground-based and satellite-based rainfall data with observed river flow (Htay Htay Than, 2009)

IFAS Seminar was sponsored by JAXA under the framework of Flood Monitoring WG for the Sentinel Asia Project of the APRSAF (Asia-Pacific Regional Space Agency Forum). Mr. Mizumoto (JAXA), Mr. Fukami and Dr. Miyamoto (ICHARM) and Mr. Matsuki (IDI) attended the seminar as lecturers. From the DMH side, 15 engineers participated in this seminar. Mr. Mizumoto explained JAXA's activities in earth observations from satellites and Mr. Matsuki of IDI (Infrastructure Development Institute) explained the IFNet (International Flood Network) activities such as heavy-rainfall alert e-mails through GFAS (Global Flood Alert System). Then Mr. Fukami and Dr. Miyamoto were engaged in IFAS trainings. At first, an exercise was conducted with a set of demonstration data from a Japanese river. Then another exercise was conducted with Myanmar's original data from the Hkamti Station of the Chindwin River (upstream area: 27,420km^2, Fig. 27). The preliminary result of this exercise was shown in Figs. 28 and 29. In this basin, there is only one ground-based rainfall station at the Htkami Station. As a result of this, the runoff simulation with ground-based rainfall data was never good. The runoff simulation with raw satellite-based rainfall data (JAXA-GSMaP) was too little compared with observation. Finally, the runoff simulation with the ICHARM's self-corrected GSMaP_NRT attained the best result. Although this best result among three-type simulation cannot necessarily be referred as enough good result compared with examples of best simulations in fully-gauged river basins, especially in terms of low-flows, the Figure 26 showed the satellite-based IFAS simulation clearly identified two biggest flood events in the beginning of July and middle of August, 2008. Besides, Fig. 29 showed the potential to identify flood inundation in the upstream of the Hkamti Station through the comparison of the satellite-based IFAS simulation with real observation. These results show the high potential and practicability of satellite-based rainfall data (especially, JAXA-GSMaP_NRT corrected by the ICHARM's algorithm) and IFAS (PDHM) as a flood runoff analysis system with world-wide availability, minimum cost and very easy operation. Of course, we have to emphasize the importance of in-situ local data to verify and further improve the flood analysis system lastly. The number of participants of this IFAS Seminar from Myanmar was 15, each one pair of participants from major river work offices in each region of Myanmar. They went back to their own office, pair by pair, with a PC in which the IFAS had been installed during the Seminar. Therefore, this IFAS system is expected to be prevailed nationwide including the demonstration basin.

Myanmar has also paid much attention to the impact of climate change on floods and water resources. Tin Yi (2010.03) reported the detailed analysis on past trends in monsoon onset, monsoon withdrawal, number of monsoon depressions, monsoon rainfalls, etc. Tin Ang Tun (2010) reported most recent flood situations.

We hope those analytical efforts and experiences will raise capacities for flood risk management not only for the demonstration basin but also all over the Myanmar territory and will lead to reduce flood damages in Myanmar.

3.1.13 Nepal

Nepal has a variety of geographical conditions from the Terai Plain to the Himalayan high mountains, and from very dry to wet areas, and very steep hydraulic conditions (Sharma, 2009, Fig.30).

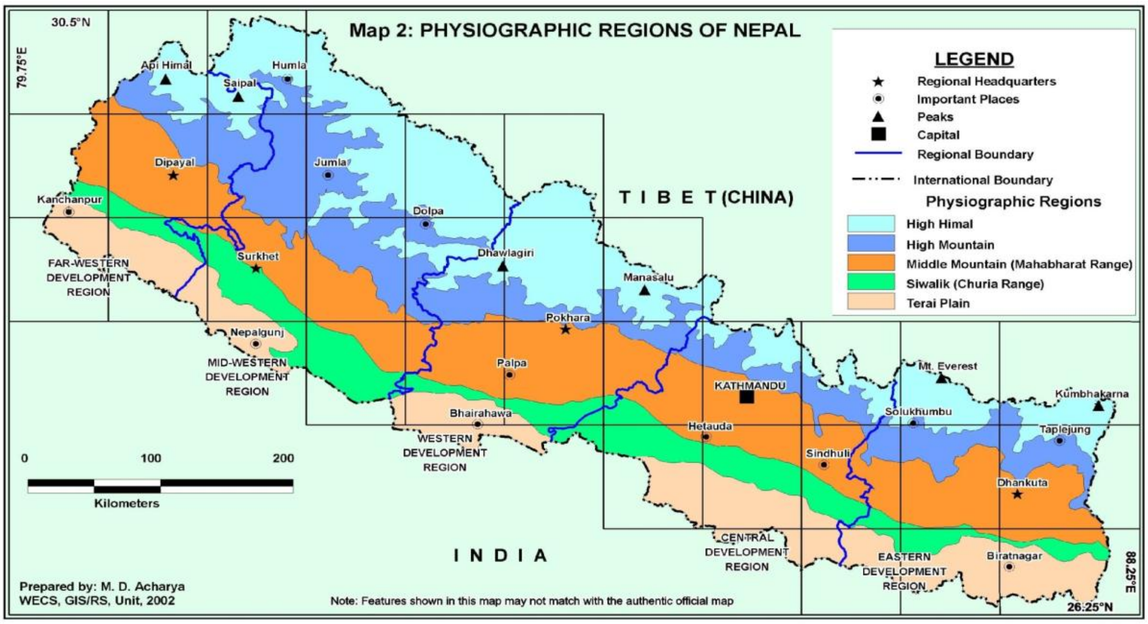


Fig.30 Five regions of Nepal (Sharma, 2009)

Nepal has heavy monsoonal rain during June to September and relatively weak geological formation. Therefore, water-related disasters are associated with landslides and debris flows in high and mid mountain areas, sediment deposit and bank erosion in lower mountains and upper plain areas, and bank erosion and flooding in lower plain areas. Nepal has also 3,252 glaciers covering 5,324 km^2. 20 glacier lakes are said to be potentially dangerous and the risk of Glacier Lake Outburt Flood (GLOF) would be increased under global warming (Sharma, 2009.12). Sharma (2009.02) reported that Nepal had a few hundred casualties due to floods and landslides and that the loss of properties was increasing year by year (more than 288 million NRs in 2006). On the other hand, water is a very important natural resource of Nepal as water resources for agricultural irrigation and 43,000 Mw of hydropower. Therefore, Nepal is going to promote integrated water resources management and flood management for flood disaster mitigation, navitation improvement and economic development.

Sharma (2009) discussed the issues of GLOF. Historically, there are 16 GLOFs so far, and its risk is increasing due to climate change, he indicated. Typical mitigation measures are 1) reducing volume of water, 2) protecting infrastructure, 3) monitoring system, and 4) preventive measures against avalanches. He introduced such an example around the Imja Lake, using satellite images. This is an example of the utilization of GEOSS for local flood management. He indicated the importance of collaborative & systematic investigation.

Shresta (2010) showed an intensive study at the Bagmati River Basin, a demonstration area of Flood WG of GEOSS-AWCI in Nepal. The Bagmati River has the about 3,700 km2 of watershed area up to the India-Nepal boarder. It originates from the Shivapuri Hill (2731 m amsl) and flows down south into the plain (75 m amsl). Rainfall is influenced by mainly south-west monsoon during June and

September. Orographic effect is pronounced and governs the rainfall pattern. Average annual rainfall in the southern part of the basin is 1500mm whereas in the northern part is around 2000 mm. There are 26 raingauge stations in the basin, especially in the Kathmandu Valley area and therefore the basin has relatively a good network of rainfall observation in Nepal. Two streamflow gauging stations were focused and the annual/monthly average flow, expected flow for some specific probabilities, and probable flood corresponding to 2-, 10- and 200-year return period. This is another example of flood risk assessment based on in-situ database. For the basin, Sharma (2008) discussed further implementation plan as follows:

- Establish a network of real-time data transmission using CDMA commercially available;
- Integrate this network to the central processing system;
- Develop tools to automate processing
- Integrate techniques of downscaling global met info to the rainfall runoff model
- Constantly validate the flood warning to the observed data
- Extend this system Appropriate for IWRM

Information exchange, capacity building and funding efforts through GEOSS-AWCI would be expected to make it possible to implement the above plan on the basis of their own resources in near future.

3.1.14 Pakistan

Sheikh(2009) described the Pakistan's wide variety of geographical, climatic and hydrological conditions. The northern mountains comprise parts of the Himalayan and Karakoram ranges with a small part of the Hindukush range. Pakistan has more glaciers than any other land outside north and south Poles and covers some 13,680 km^2 as glaciated area. Karakoram is the abode of sizable glaciers and as high as 37% of Karakoram area is under its glaciers against Himalayas' 17% and Alps' 22%. Areas below approximately 31°N constitute deserts. Thar desert spans the border between India and Pakistan. Hamun-e-Mashkhel, some 87 km long and 35km wide is the largest desert found in Balochistan. The Dasht and Kharan deserts of Balochistan lie towards the western border of Pakistan with Iran. Regarding the climate, the northern half of Pakistan above 31°N is semi-arid to humid with a sub-humid belt running along the southern slopes of the sub-mountainous regions. The southern half of Pakistan below 31°N is mostly arid to hyper arid. The weighted precipitation in the southern half (~175mm) is one-third of the precipitation in the northern half (~600mm) and is almost one half of the Pakistan's weighted precipitation (around 330 mm). Pakistan receives around 50% of the rainfall during the monsoon (JJAS) season while about 30% is received in the winter (DJFM) season.

Sheikh(2009) also discussed the past trend of climate and water, and probable impacts of climate change on hydrology. The area averaged mean annual temperature over Pakistan increased by 0.57C (in agreement with the global trend) over the period 1901-2000. The 48-year period 1960-2007 recorded a slope of mean annual temperature as 0.24C per decade as compared to 0.06 per decade during 1901-2000 reflecting much increased rate of warming in recent years. This increase of air temperature has caused the retreat of many glaciers in the upstream of Indus as Rasul (2009) mentioned. The areally-averaged mean annual precipitation over Pakistan increased by 25% during the previous century. Monsoon precipitation increased elsewhere except in coastal regions (where there was a significant drop) and the Western Balochistan Plateau during 1951-2000. During the above period, the winter rains decreased in most of the districts, in particular by 13-20% in Sindh and western Balochistan. El Nino years generally tend to be in drought conditions whereas La Nina years behave the other way round and bring excess rains.

Besides, Rasul(2009) discussed several extreme events by that time such as 1) five-year prolonged severe drought (1998-2003), 2) heavy downpour record in the Capital in July 2001 (620mm in 10

Fig.31 Location of Gilgit & Hanza River Basins (Ahmad, 2010)

hours), 3) the heaviest rainfall in an arid zone, Karachi City in July 2003 (120mm in 14 hours), 4) snowmelt flood in the upstream of Indus in June 2005, 5) tropical cyclones, Gonu & Yemyin in 2007 and 6) two GLOF events in 2008.

Therefore, it may be very probable that Pakistan would be threatened under the climate change era by severer and more frequent extreme events such as floods due to heavy downpour, snowmelt and/or GLOF, droughts due to the retreat of glaciers and the decrease of rainfall in winter.

The great Indus Flood in 2010, affected more than 20 million people, may be a typical example of future extreme events under the increasing climate variability.

Considering the importance as a source area of floods including snowmelt & flash floods and water resources from glaciers, two of the upper Indus River Basin, the Gilgit & the Hunza River Basins (Fig. 31) were selected as demonstration basins in Pakistan, and the Pakistan Meteorological Department implemented an

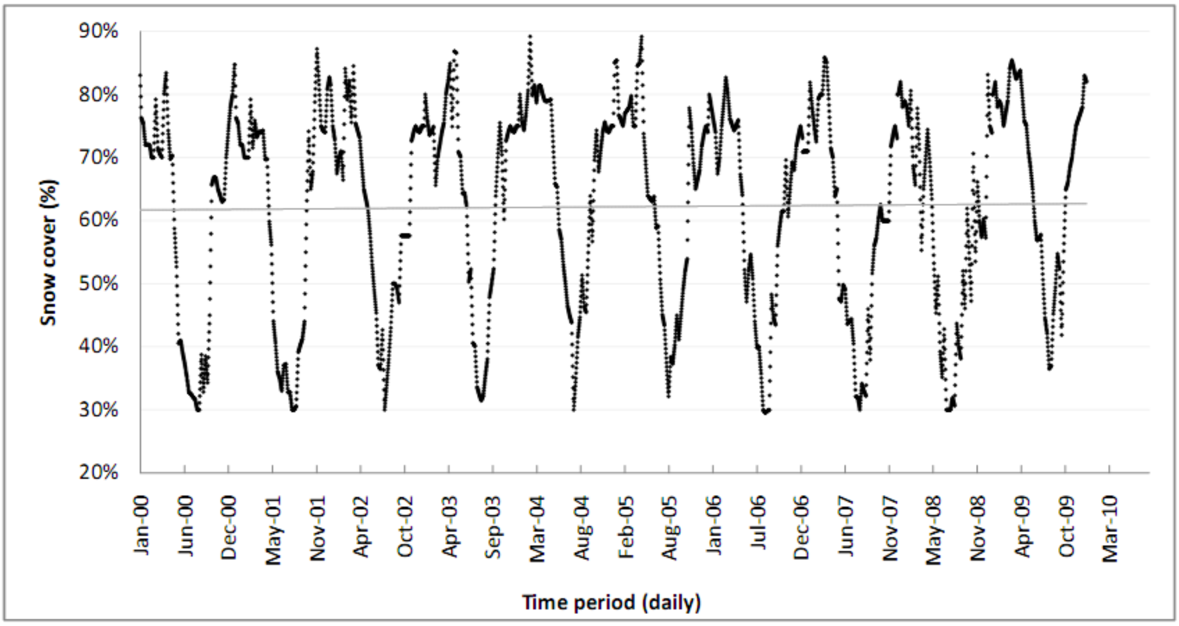


Fig.32 Temporal variation of snowcover in the Hunza River Basin over 10 years from 2000 to 2009, where the daily data were estimated by the linear interpolation of 8-day MODIS images, with a slight increasing trend line during the period. (Ahmid, 2010)

intensive meteorological & hydrological observational network for the basins. Ahmad (2010) reported a study on snowcover and snowmelt modeling in the Hunza Basin using a snowmelt runoff model, SRM, using snowcover monitoring data with MODIS (Fig.32). The simulation results were quite successful for 2003-2004 season(Fig.33). This is another typical example of the output of GEOSS-AWCI concept and is expected to lead to better understanding and management of flood and water resources in the upper Indus River Basin.

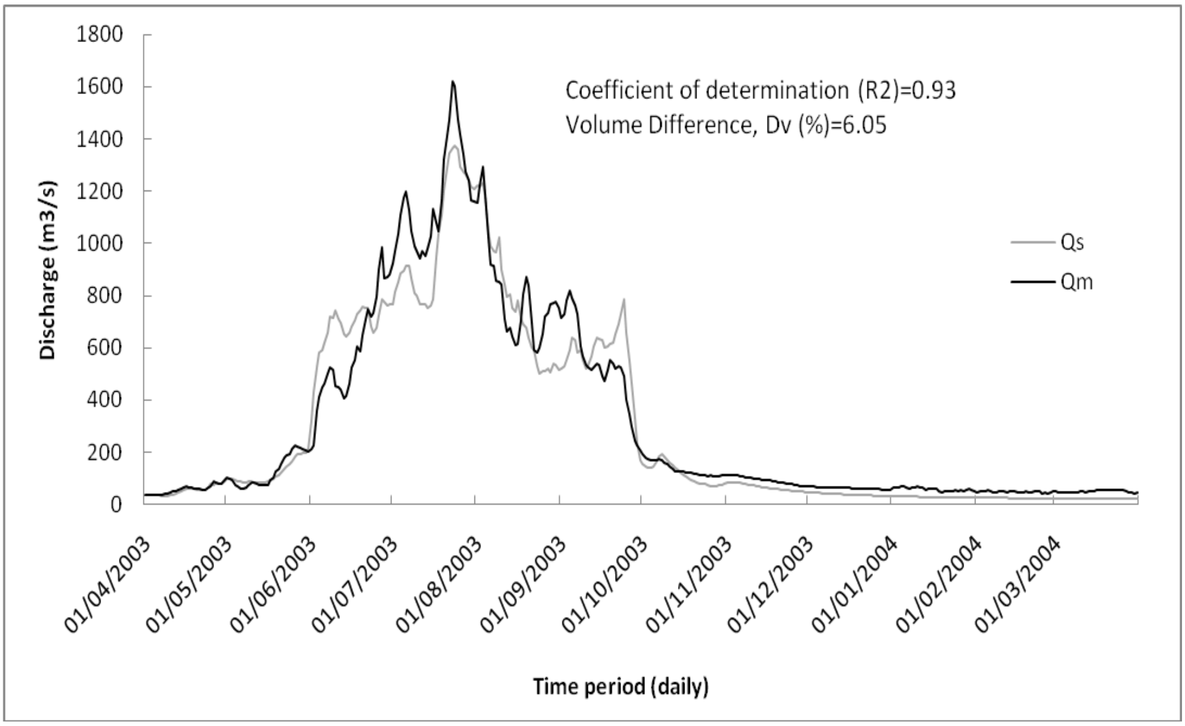


Fig.33 Comparison of SRM simulations with observed hydrograph during the hydrological year of 2003-04 in the Hunza River Basin (Ahmid, 2010)

Fukami (2010) reported a study to apply satellite-based rainfall data to the flood runoff & flash-flood-inundation simulation in the Kabul River, where the biggest number of casualties was recorded in the Indus Flood 2010. The flood runoff simulation using IFAS with the ICHARM's self-corrected GSMaP seemed apparently quite matched with the observed streamflow data at the Nowshera station. But, if six ground-

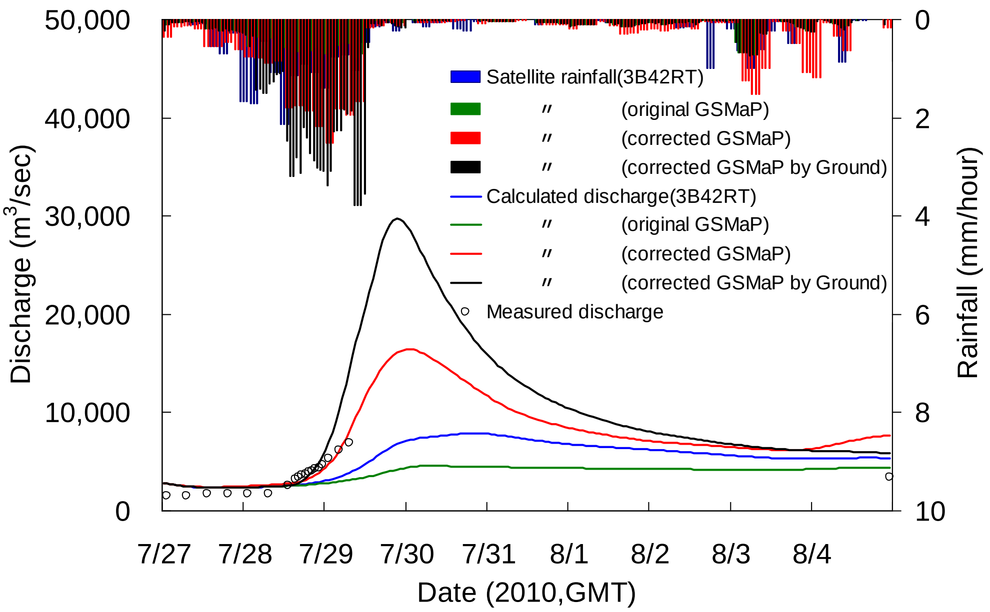


Fig.34 Comparison of IFAS simulations using various rainfall-data sources with observed riverflow (Fukami et al, 2010)

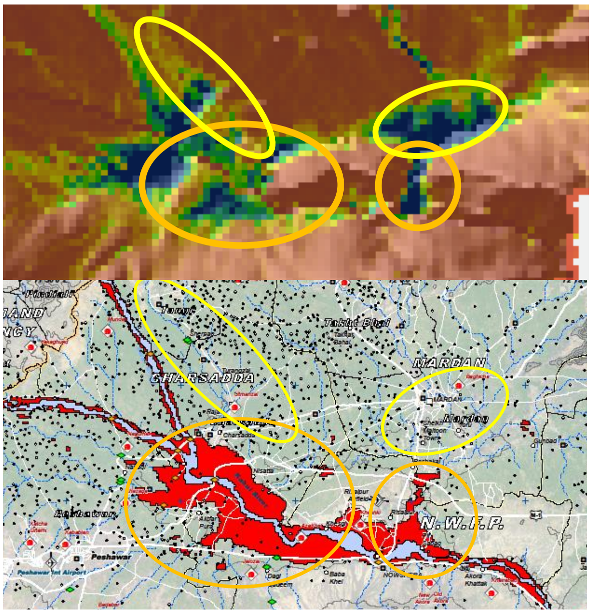


Fig.35 Comparison of flood inundation areas estimated from ICHARM's RRI model with satellite-based rainfall (above) and monitored from MODIS (below) (Fukami et al., 2010)

based daily rainfall data were incorporated to correct the original GSMaP data directly, which were expected to be more reliable than the self-corrected GSMaP since the data were based on the real ground rainfall data, the result of the simulation became overestimated (Fig.34). This may be caused by the decrease of flood peak due to flood inundation in the upstream of the gauging station or by some observational error, and so forth. In any case, those simulations showed the high potential of satellite-based rainfall as one of the source of flood-runoff simulation even in poorly-gauged river basins. He also showed a comparison between a flood inundation simulation using a rainfall-runoff-inundation coupled model (RRI model, Sayama et al.,2010) with GSMaP and the flood inundation area monitored by MODIS. The simulation of RRI model reproduced severe flash flooding in minor valleys but the MODIS images could not monitor such flash flood occurrences, the existence of which was confirmed by house-damage data (Fig.35). This example shows us another potential of global-GIS-based hydrologic simulation with satellite-based rainfall data to reveal the reality of flood disasters under very limited real-time hydrologic-data conditions.

3.1.15 Philippines

The Philippines is a country composed of about 7,100 islands, located in the boundary of the Eurasian Plate and the Filipino Plate. Therefore, the Philippines is a typical example of a mobile belt area (or a tectonic zone) with very vulnerable geology and many volcanos & earthquakes. Besides, the Philippines is very close to the North-West Pacific Ocean where a lot of typhoons are generated every year and is just under the Intertropical Convergence Zone with the northeast & southwest monsoons. Therefore, the Philippines, like Japan, has lots of sources of natural hazards, including floods, landslides, etc.

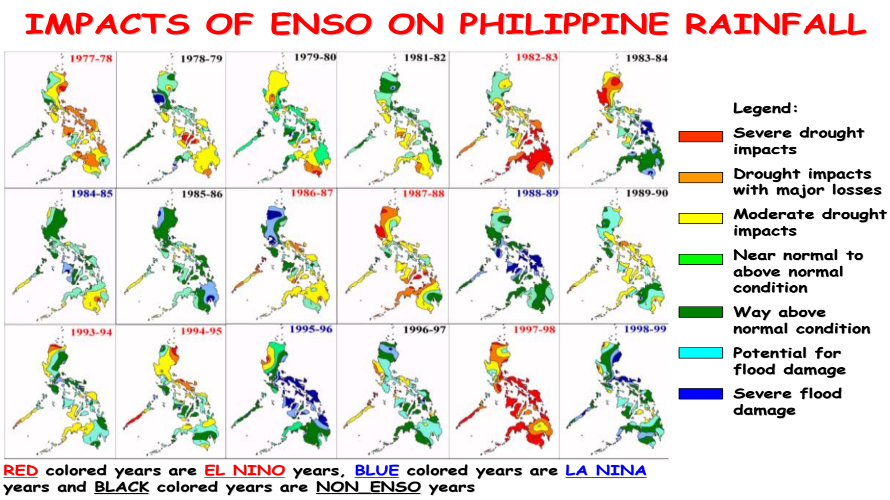


Fig.36 Interannual variation of hydrological impacts from 1977 to 1988 in the Philipines (Hilario, 2009)

Hilario (2009) reported a study on the relationship between hydrological extreme events and the ENSO (El Niño -Southern Oscillation). El Niño has caused droughts in many areas and, on the other hand, La Niña has often caused extreme rainfall events (Fig.36). For example, in February 2006, a huge-scale landslide occurred at the town of Guinsaugon after a heavy rainfall event and the town was almost buried by the landslide with about 1,000 people. She mentioned the damage of typhoons such as "Milenyo (September 2006)" and "Frank (Fengshen, June 2008)". Janillo (2009) reported the damage of Typhoon "Ketsana (Ondoy, October 2009), which recorded the highest 24-hr rainfall amount (455mm) in the Metro Manila. The number of casualties was around 300.

Janillo (2009) mentioned also the PAGASA (Philippine Atmospheric Geophysical Astronomical Services Administration) activities to cope with those flood hazards. The PAGASA implemented meteorological stations including 35 automatic weather stations and 10 Doppler Radars (in plan). She indicated the major challenges as follows:

a) Extreme Event (Flood and drought) management system
b) Rainfall downscaling and forecast (short and long term)
c) Flood Simulation
d) Climate Change Scenario building and Impact Assessment

Hilario (2010) reported a national project for the climate change impact assessment and adaptation in the Philippines during 2009-2011. This is a joint project among may sectors of the government and the United Nations. The total cost of the project is 8 million US dollars. The project includes five demonstration projects in each region of the country. The downscaling of GCM outputs are also included. Through those projects and the incorporation of GEOSS-AWCI knowledge and information, more effective flood disaster management system is expected to be developed and be used in operation.

3.1.16 Sri Lanka

According to Weerakoon (2009), flood disaster is the most typical natural disaster since the percentage of flood disasters among natural disasters is more than 80%. For example, 488 thousand people were affected and 48 people were killed by floods. Therefore, flood disaster prone area has been identified and mapped.

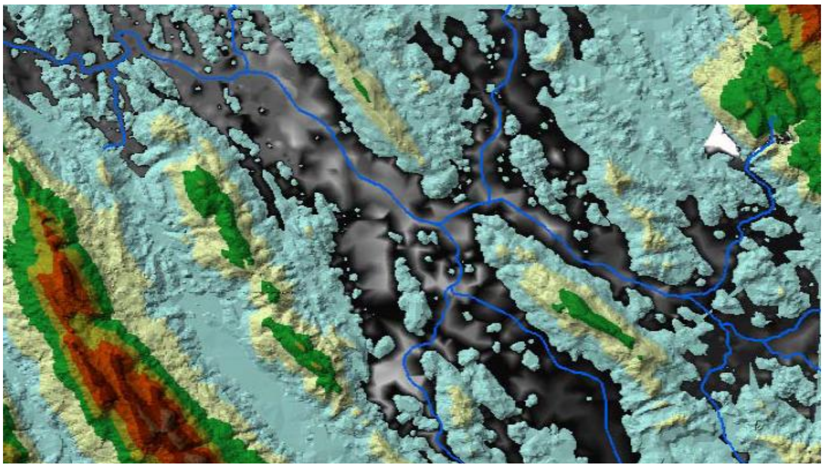


Fig.37 Flood inundation risk area corresponding to 50-year return period around the Rathapura City in the Kalu Ganga Basin

At the demonstration basin of Sri Lanka, the Kalu Ganga River basin (catchment area: 2,690km^2, annual rainfall: more than 4,000mm), a flood inundation & damage simulation around the Rathnapura City in the basin was conducted using HEC-RAS and HEC-GeoRAS, including flood risk assessment corresponding to 5-year and 50-year floods (Fig.37). To conduct similar studies in other flood-prone areas, the importance and difficulty to secure accurate DEM were indicated and discussed through the report of the study at the AWCI-ICG meeting.

3.1.17 Thailand

The demonstration basin of the GEOSS-AWCI is the Mae Wang River Basin in the northern Thailand. Therefore, flood disasters in the northern part of Thailand have been mainly discussed at the AWCI-ICG meetings. Flash floods and riverine floods occurs mostly in the wet season from May to October when continuous heavy rain influenced by southwest monsoon from the Indian Ocean, tropical

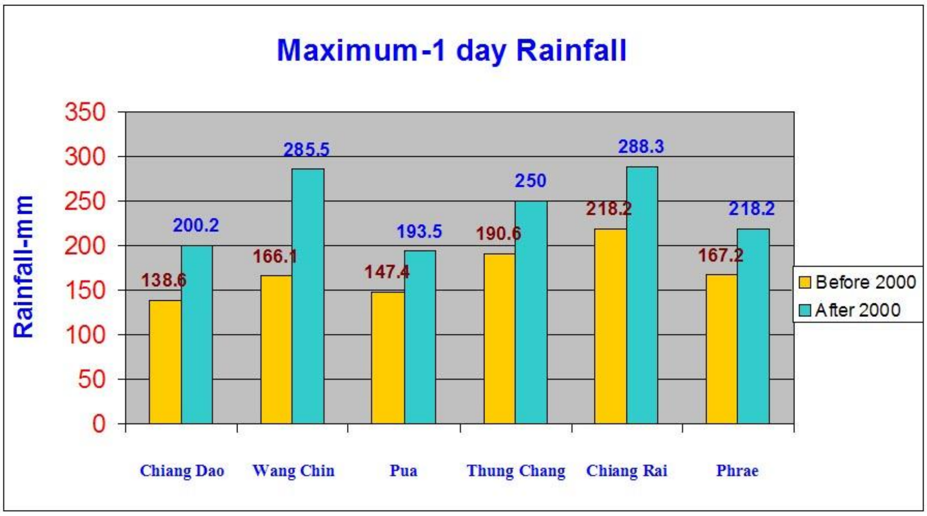


Fig.38 Comparison of maximum 1-day rainfall record before 200 and after 2000 (Thada, 2009)

storm from the South China Sea, low pressure trough or frontal encounter of different pressure air masses. Thada (2009) reported that typical flood disasters in the Mae Wang River Basin are in September 2006, September 2007, & November 2008. He mentioned the increasing trend of maximum 1-day rainfall in the northern Thailand was identified through the comparison between the period before 2000 and that after 2000 (Fig.38). The flooding area has also increased. Under such a condition, the Royal Irrigation Department (RID) of Thailand implemented 13 rainfall stations & 5 water level stations in the Mae Wang River Basin, in cooperation with the Institute of Industrial Science of the University of Tokyo. The major flood prone area is located around the downstream of the Mae Wang River, and a water level station, 18km-upstream from the water level station near the flood prone area, is located at the confluence point of the most part of the mountainous areas

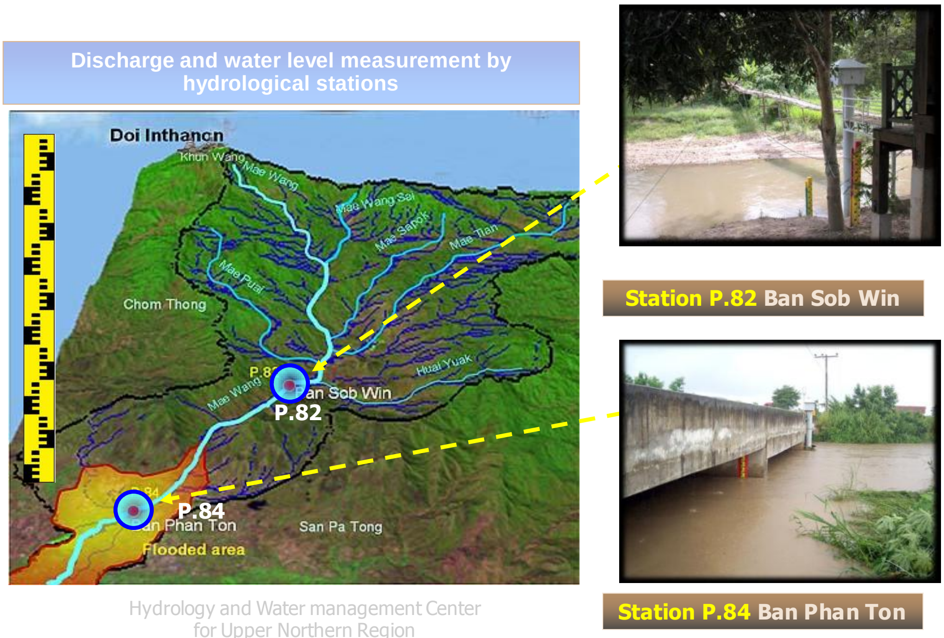


Fig.39 Two correlated hydrological stations of the Mae Wang River for flood forecasting (Thada, 2009)

(Fig.39). Therefore, the correlation between the two water level stations enabled to make flood forecasting with 4-5 hour lead time. The RID paid also attention to the way how to raise public awareness and preparedness against floods there. Water-level measuring staff gauges were colored with green, yellow & red corresponding to the range of safety level (Fig.40), and a flood information board with the display of real-time digital numbers (Fig.41) was installed to let the public know the updated information about the upcoming flood. This is a typical successful showcase not only in the implementation of flood warning system but also in flood risk management including the raise of public awaren ess & preparedness in flood prone areas of the Asian monsoon region in the GEOSS-AWCI activities. At the next stage, RID is going to study how to utilize raingauge

Fig.40 Colored staff gauge to easily identity flood risk (Thadu, 2009)

network and distributed-parameter hydrologic model for the demonstration basin and to apply the developed technology to other flood-prone areas of Thailand. This study will make another good showcase of GEOSS-AWCI activities in the implementation of flood warning system with GEOSS information.

Fig.41 Flood information board for public

3.1.18 Uzbekistan

Major water-related problems for Uzbekistan seem drought and the impact of climate change on water resources apparently, but mudflows and floods caused by rain storm, snowmelt, GLOF, etc. are also the issues of interest and attention. Dergacheva (2010) reported that five ministries and province/city administrations have been cooperating, since 2007, to monitor hydrometeorological situations to define dangerous hydrometeorological phenomena, to assess the future potential threat of hazards, to make short-term (up to 5 days) or long-term forecast on such hazards and to archive those data. The monitoring system contains 78 meteorological stations, 145 hydrological stations, remote sensing (from NOAA), cameras, geophysical information system based on ACCESS, ArcView and MAPOBJECT (Fig.42). This system is one of the most advanced hydrological monitoring and archiving system. She summarized the next steps to improve the monitoring system as follows:

1) To ensure the infrastructure for the collection, transmission and processing of hydrometeorological data (air temperature, precipitation, snow accumulation, water levels, etc.) directly from the object and the representative mountain glacier basin;
2) To develop criteria for operational assessment of the stability of the object and the risk of an emergency situation according to the comprehensive monitoring of the state of the object;
3) To carry out the practical implementation of theoretical concepts for the formation and movement of the flood formed after outburst of glacial lake, speed of movement of flood wave and areas of possible flooding;

4) To develop the concept of the practical implementation of an early warning system and preventive measures on the basis of the integrated monitoring.

It is expected that this monitoring system will provide us not only with water-related disaster forecast but also with monitoring & modeling the probable impact of climate change on hydrology and water resources.

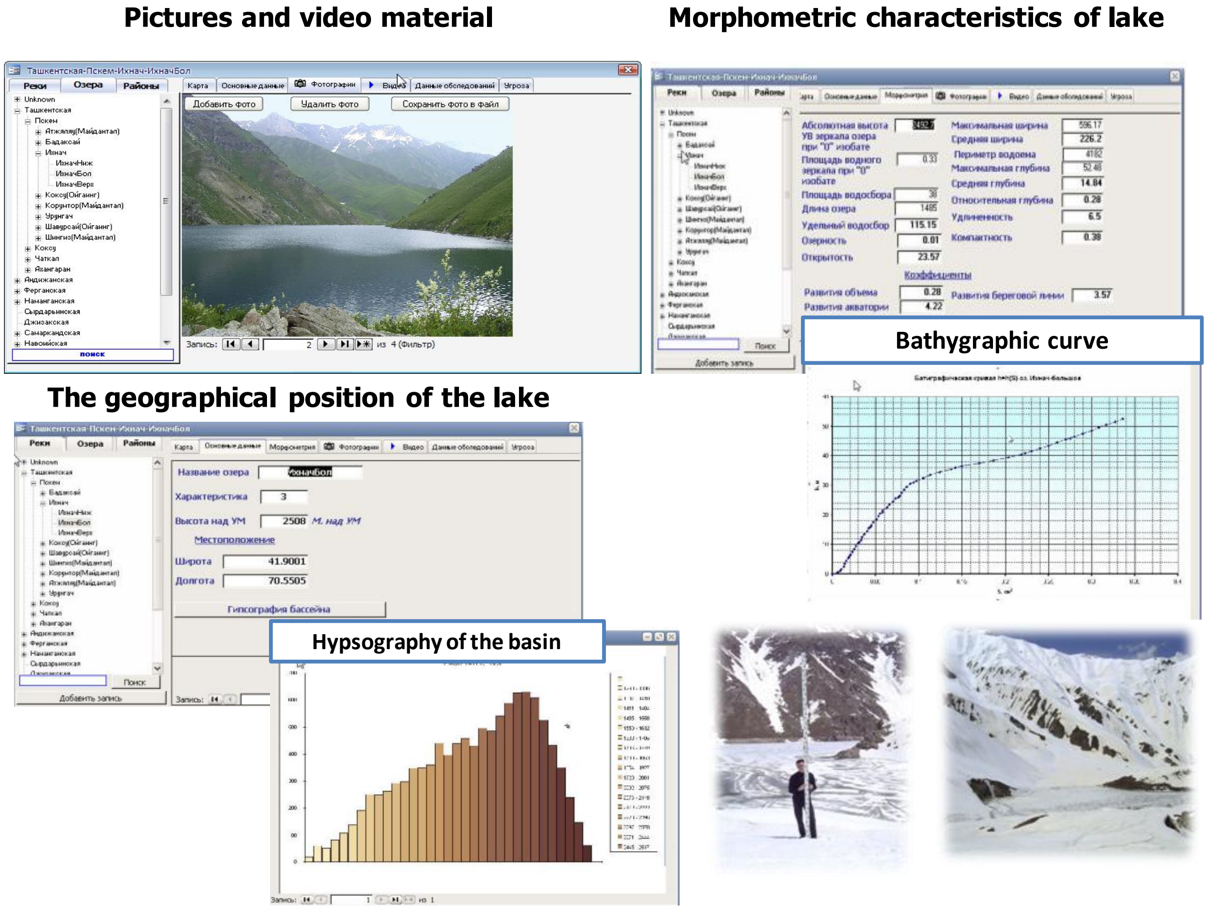


Fig.42 Uzbekistan's hydrometeorological monitoring system (Dergacheva, 2010)

3.1.19 Vietnam

Vietnam is also a country exposed to typical flood disasters caused by typhoons and heavy rainfall storm affected by Asian monsoons. Tinh(2009) reported the biggest floods on the Red River in August and November of 2009. The former flood caused 120 casualties and the latter was the biggest flood in the 60-year record which caused the damage of about 3 billion US dollars. According to Tinh(2010), in recent years, there were more typhoons with higher intensity affecting Vietnam. Typhoon track has a tendency of moving southward and the typhoon season tends to end later. There were more typhoons with abnormal movement. Since drought is expected to be severer under climate change, drought would be the first priority to cope with in Vietnam, but flood is also another issue of big concern.

Tinh(2009) mentioned that Vietnam planned to spend over 1.95 trillion VND for the National Climate Change Adaptation Programme until 2015. Around the half of the budget will be mobilized from foreign sources. The State budget will cover 30 percent of the remaining half of the fund and an additional 20 percent will be drawn from local budgets and private economic sectors.

Under the circumstances above, Vietnam and Japan started a joint demonstration project on the sustainable water management in the Huong River Basin (2,830km^2) of Vietnam, a GEOSS-AWCI demonstration basin, under the framework of GEOSS-AWCI and APRSAF-SAFE (Space Application for Environment). Saavedra(2010) reported that the UT's DRESS and FLOWSS based on WEB-DHM (see the Japan's paragraph 3.1.7) was applied for real-time flood forecasting of the Huong River. If the rainfall prediction data of the GPV (Grid Point Value) calculated by a global numerical prediction model was used as the rainfall input to the WEB-DHM, then the forecasted river discharge was underestimated. On the other hand, both the flood forecast results with the 6-hr lead-time downscaled rainfall prediction and with the satellite-based (TRMM) rainfall data were almost coincident with the observed river discharge in terms of flood peak's timing and level (Fig.43). The same modeling system was also applied to the Red River Basin (160,000km^2) successfully, including the flood-control function through three dam reservoirs. These results show the high potential of downscaled forecasting and satellite-based rainfall data. This is also a typical example of integrated flood management with GEOSS data.

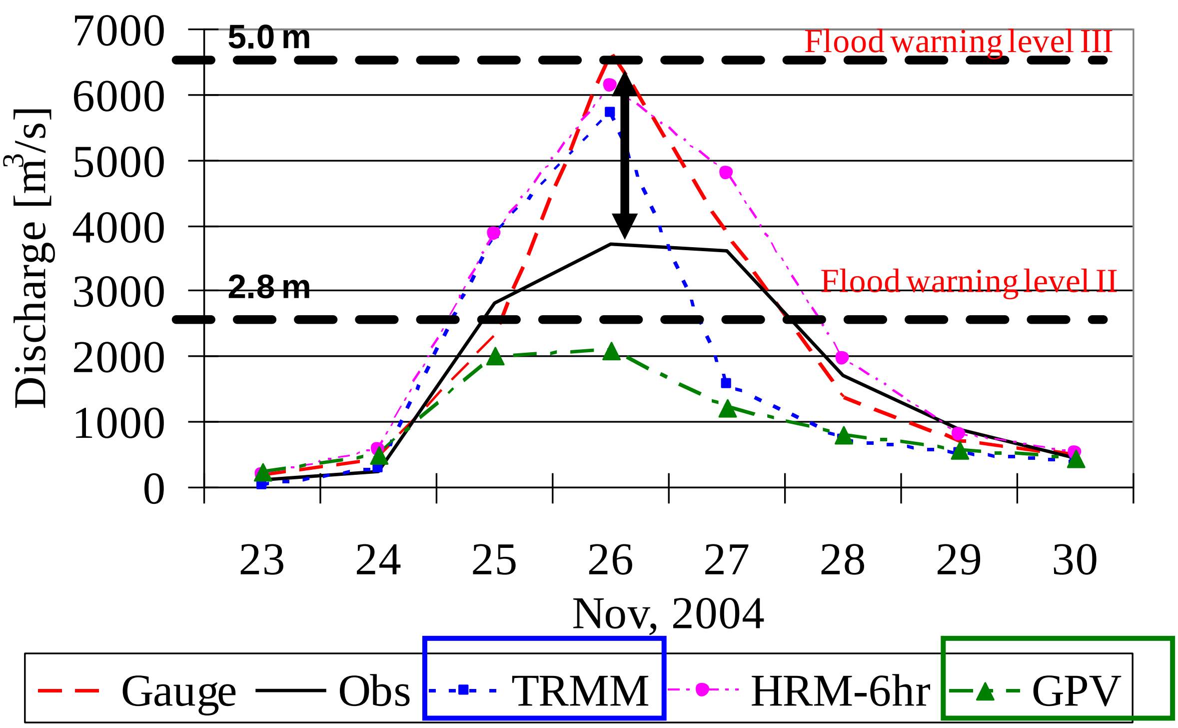


Fig.43 Comparison of flood runoff simulations of Flowss using various rainfall forecasting & monitoring data with observed riverflow in the Huong River (Saavedra et al., 2010)

3.2 Discussions

As described and summarized above, each member country of Flood WG of GEOSS-AWCI has been making every effort to build up a scientific basis for sound decision-making and developing policy options for most suitable flood risk management. To attain the goal above, we set up the following three objectives:

1. To convert observations and data, both through space borne platforms and data integration initiatives, to usable information for flood reduction
2. To improve quantitative forecasts for coupled precipitation - flood-forecasting systems
3. To facilitate flood risk assessment through the provision of scenarios and data for exposure estimation

Namely, each representative of the International Coordination Group (ICG) for GEOSS-AWCI has had regular meetings, on average twice a year, reported new developments, new research findings, trials-and-errors of each country and conducted information exchanges to share them, based on the APN fund. Sometimes, some workshops or training seminars, to understand new technologies/

approaches more and to activate joint cooperative activities more, were held. The 1st International Workshop on Application and Validation of Global Flood Alert System (GFAS)", Tsukuba, Japan, during 3-7 August 2009 is a typical example of such workshops.

As a result of those mutual cooperative activities, a variety of research activities including demonstration projects with demonstration basins' data and/or historical flood events' data have been conducted to attain the goal and objectives above.

For example, the University of Tokyo has developed 1) Dam Release Support System (DRESS), a combination of ensemble of precipitation forecasts and WEB-DHM (Water and Energy Budget-based Distributed Hydrological Model), for dam release decision support to reduce flood peaks and store volume for water-use and 2) Flood Warning Support System (FLOWSS) for dissemination of flood warning to perform evacuation timely. Those models were applied to the Tone River, the demonstration river basin of Japan, the Huong River, the demonstration basin of Vietnam, and more, and were validated. This research and development is the most typical and advanced example toward the objectives 1) & 2) above, directly, in the sense that the system is one of the most state-of-the-art science-oriented inventions in the world to cope with uncertainties of hydrological forecasts through ensemble simulation with downscaled numerical weather prediction data updated by satellite-based rainfall data.

The above approach of the UT has definitively the very high potential to solve many problems in flood forecasting and risk analysis, but it may require highly-skilled human resources, state-of-the-art computer environments and relatively high cost & long time to implement. Therefore, UT is now going to implement the WEB-DHM systems on DIAS, which is now being developed as a platform to share GEOSS-AWCI databases.

The UNESCO-ICHARM's approach will give us another choice. That is, ICHARM has developed IFAS (Integrated Flood Analysis System) as a toolkit to enhance flood forecasting and analysis system in poorly-gauged river basins through combining not only ground-based but also satellite-based rainfall data and already-existing hydrologic modeling technologies such as simplified distributed-parameter hydrologic models, the parameters of which can be estimated from global GIS data. The executable system of IFAS has been distributed to the world through the ICHARM's website, free of charge. The workshops and training seminars of IFAS were held in Japan, Indonesia, Myanmar under the framework of GEOSS-AWCI. Then IFAS was applied and validated in the participating countries including those three countries. This is also another typical example of the activities toward the objectives 1) & 2) directly, in the sense that IFAS would enable us to promptly & efficiently build up a flood runoff analysis and/or flood forecasting system, without developing a basic core system for them from the beginning, and to improve the accuracy of forecast, step by step, in accordance with the availability of resources to implement in-situ ground-based hydrological observational network.

The developments of integrated water resource management system with satellite & AWS data in Cambodia, WRF model applications to analyze extremely heavy storm in the Kashimir district of India, snowmelt runoff forecasting system with satellite-based snowcover monitoring with MODIS in Pakistan are also one of such examples toward the objectives 1) & 2). The development of hydrometeorological monitoring system in Uzbekistan is an example toward the objective 1). The development of flood forecasting system at the Mae Wang River of Thailand is another example toward the objective 1) with a practical approach to raise public awareness & preparedness against flood disasters.

On the other hand, a variety of comprehensive and intensive studies toward the objective 3) have been also being tried and conducted, such as the detailed analysis of flood forecasting procedures and effects at the Cyclone Cidr and of climate change impacts in Bangladesh, flood hazard mapping with hydraulic models in India, flood risk mapping based on past experiences in Indonesia, climate change impact study with multi-model ensemble approach in Korea, climate change impact study with an advanced fully-coupled downscaling mesoscale model (RegHCM-PM) in Malaysia, diagnostic studies on historical & probable floods (& climate change impacts) in Bhutan, Lao PDR, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, & Sri Lanka. In particular, the studies in Korea and Malaysia are regarded as the most typical state-of-the-art science-based climate change impact studies on hydrology and its extreme events.

As discussed above, there have emerged many promising technologies and practices for the future sustainable flood risk management in these APN-funded Flood-WG activities of GEOSS-AWCI since the middle of FY2008.

4.0 Conclusions

The Flood WG of GEOSS-AWCI has been promoting mutual cooperative research activities, through regular meetings & human/information exchanges, to build up a scientific basis for sound decision-making and developing policy options for most suitable flood risk management. To attain this goal, we set up the following three objectives:

1. To convert observations and data, both through space borne platforms and data integration initiatives, to usable information for flood reduction
2. To improve quantitative forecasts for coupled precipitation - flood-forecasting systems
3. To facilitate flood risk assessment through the provision of scenarios and data for exposure estimation

As a result of 2-year cooperative research activities among Flood WG of GEOSS-AWCI, there have emerged many promising technologies and practices for the future sustainable flood risk management. Most typical new technologies developed and/or validated through those activities are WEB-DHM, DRESS & FLOWSS of UT, IFAS of ICHARM, RegHCM-PM of NAHRIM, and so forth. Through repetitive meetings, discussions and cooperative activities, advanced technologies and many other innovative practices have been shared among all the members of Flood WG of GEOSS-AWCI, which will be expected to lead to updating and enhancing a variety of science- & data-based foundations toward sound decision-making and developing policy options for effective flood disaster risk reduction in Asia.

5.0 Future Directions

The referred technologies above such as WEB-DHM, DRESS & FLOWSS of UT, IFAS of ICHARM, RegHCM-PM of NAHRIM and other emerging innovative practices will surely be some typical candidates of the best choices to effectively couple global / in-situ observational and numerical data with state-of-the-art hydrological & meteorological analyzing & forecasting methodologies and to enhance and promote sustainable flood risk management. However, most of them are still at the stage of case-study or validation phase and the dissemination and effective applications of them throughout Asia has never been enough yet. Therefore, the Flood WG activities of GEOSS-AWCI, including not only human/information exchanges but also capacity building, should still continue so that such progressive approaches are prevailed among administrators and engineers in charge of flood risk management and flood disaster reduction.

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Tinh, D. (2010) Country report, Presentation at the 7th AWCI-ICG Meeting, Tokyo, Japan, October 5-6, 2010.

Appendix

Conferences/Workshops

1. "The 4th Conference of the Asia Pacific Association of Hydrology and Water Resources (APHW) & the 3rd International Coordination Group meeting of the GEOSS-AWCI", Beijing, China, November 3-6, 2008.

2. "The 3rd GEOSS Asia Pacific Symposium & the 4th International Coordination Group Meeting of the GWOSS-AWCI", Kyoto, Japan, February 4-7, 2009.

3. "The 5th meeting of the GEOSS Asia Water Cycle Initiative (AWCI) International Coordination Group (ICG)", Tokyo, Japan, December 15-17, 2009.

4. "The 4th GEOSS Asia Pacific Symposium and the 6th meeting of the GEOSS Asia Water Cycle Initiative (AWCI) International Coordination Group (ICG)", Bali, Indonesia, March 10-13, 2010.

5. "The 7th Meeting of the GEOSS-AWCI International Coordination Group (ICG)", Tokyo, Japan, October 5-6, 2010.

6. "The 1st International Workshop on Application and Validation of Global Flood Alert System (GFAS)", Tsukuba, Japan, August 3-7, 2009

Agenda/Programme and participants list are attached as PDF files below, separately.

Glossary of Terms

ADB	Asian Development Bank
AMSR	Advanced Microwave Scanning Radiometer
APN	Asia-Pacific Network for Global Change Research
AWCI	Asian Water Cycle Initiative
BDRCS	Bangladesh Red Crescent Society
BMD	Bangladesh Meteorological Department
BTOP	Block-Wise TOPMODEL
CPC	Climate Prediction Center of NOAA
CPP	Cyclone Preparedness Program
DIAS	Data Integration & Analysis System
DHRW	Department of Hydrology and River Works of Cambodia
DRESS	Dam Release Support System
ENSO	El Niño -Southern Oscillation
FLOWSS	Flood Warning Support System
FRM	Flood Risk Management
GAME	GEWEX Asian Monsoon Experiment
GCM	General Circulation Model
GEOSS	Global Earth Observation System of Systems
GEWEX	Global Energy and Water Cycle Experiment
GFAS	Global Flood Alert System
GIS	Geographical Information System
GLOF	Glacier Lake Outburst Flood
GPV	Grid Point Value
GSMaP_NRT	Global Satellite Mapping of Precipitation – Near Real Time

ICHARM	International Centre for Water Hazard and Risk Management under the auspices of UNESCO
ICG	International Coordination Group
IDI	Infrastructure Development Institute, Japan
IFAS	Integrated Flood Analysis System
IFNet	International Flood Network
IRSHAM	Integrated Regional Scale Hydrologic-Atmospheric Model
JAXA	Japan Aerospace Exploration Agency
MLIT	Ministry of Land, Infrastructure, Transport and Tourism of Japan
MM5	5th Generation Mesoscale Model
MODIS	Moderate Resolution Imaging Spectroradiometer
NAHRIM	National Hydraulic Research Institute of Malaysia
NASA	National Aeronautics and Space Administration of USA
NCAR	US National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration of USA
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PDHM	PWRI Distributed Hydrologic Model
PWRI	Public Works Research Institute of Japan
RCWR	Research Center for Water Resources of Indonesia
RegHCM-PM	Regional Hydroclimate Model of Peninsular Malaysia
RETA	Regional Technical Assistance (of ADB)
RID	Royal Irrigation Department of Thailand
RRI	Rainfall-Runoff-Inundation (Model of ICHARM)
SAR	Synthetic Aperture Radar
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNU	United Nations University
UT	University of Tokyo
WCRP	World Climate Research Programme
WEB-DHM	Water and Energy Budget-based Distributed Hydrological Model

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List of demonstration river basin of each AWCI member country

Country	Demonstration river basin
Bangladesh	Meghna River
Bhutan	Punatsangchhu River
Cambodia	Sangker River
India	Seonath River
Indonesia	Mamberamo River
Japan	Upper Tone River
Korea	Upper Chungju-dam
Lao PDR	Sebangfai River
Malaysia	Langat River
Mongolia	Selbe River
Myanmar	Shwegyin River
Nepal	Bagmati River
Pakistan	Swat River
Philippines	Pampanga River
Sri Lanka	Kalu Ganga River
Thailand	Mae Wang River
Uzbekistan	Chirchik-Okhangaran River
Vietnam	Huong River

Major PDF slides of presentations at GEOSS-AWCI-ICG meetings and workshop

Attached as PDF files below, separately.