FINAL REPORT for APN F

Project Reference Number: ARCP2011-02CM

"River Management System Development in Asia Based on Data Integration and Analysis System (DIAS) under the GEOSS"

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"River Management System Development in Asia Based on Data Integration and Analysis System (DIAS) under the GEOSS"

Project Reference Number: ARCP2011-02CMY-Koike
Final Report submitted to APN

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OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

This project was launched under the GEOSS/Asian Water Cycle Initiative (AWCI) framework to develop an advanced river management system in AWCI member countries by exploiting the Data Integration and Analysis System (DIAS) data and data integration capabilities. The system is based on integration of data from earth observation satellites and in-situ networks with other types of data, including numerical weather prediction model outputs, climate model outputs, geographical information, and socio-economic data. Each country had nominated one demonstration basin for which in situ data were archived at DIAS and where a demonstration project was launched to generate information for making sound water resources management decisions while taking global climate change into account. The project included two meetings of AWCI International Coordination Group (ICG), which comprises representatives of water-related ministries and agencies of the participating countries, and one training course focused on techniques for climate change assessment. The meetings were organized with support of the two collaborating projects ARCP2011-05CMY-Bae and CBA2011-02CMY-Kaihotsu and provided good opportunities to present the capabilities of the targeted system to decision makers by showing the results of demonstration projects, which were carried out in cooperation between each country team and the experts of the AWCI collaborating organizations.

Objectives

The main objectives of the project were:

1. Implementation of a demonstration project in each AWCI basin that would include a distributed hydrological model by integrated in-situ and satellite data and model outputs, while considering regional and local specifics (e.g. snow and glaciers).
2. Assessment of climate change impacts on water resources in the demonstration basins using the developed basin models and development of optimization schemes for IWRM practices.
3. Presenting and communicating results of demonstration projects to policy and decision makers in order to promote the use of developed system in operational applications.

Amount received and number years supported

The Grant awarded to this project was:
US$ 45,000 for Year 1: 2010/2011
US$ 45,000 for Year 2: 2011/2012

Activity undertaken

Meeting events. The project included three AWCI ICG Meetings: (i) the 7th AWCI ICG Meeting in Tokyo, October 2010 that discussed the implementation strategy of the project and led to a whitepaper on the AWCI Climate Change Assessment and Adaptation (CCAA) study, (ii) the 8th AWCI ICG Meeting in Seoul, October 2011 that reviewed the project progress and initiated discussion on moving to the AWCI next phase focused on operational applications and further data integration; and (iii) the AWCI session at the 5th GEOSS AP Symposium in Tokyo, April 2012, which introduced draft implementation plan for the AWCI next phase based on each country input. In March 2011, a training course on downscaling techniques, hydrological modeling, and model output precipitation data bias correction method was held to kick off AWCI CCAA study.

Data collection and integration. Collection of in-situ data from the AWCI demonstration basins and archiving them in the DIAS database had continued and was completed. In addition to the basic dataset as agreed at the initial stage of AWCI, a long-term precipitation and temperature data from selected stations at the demonstration basins were collected for the CCAA study.

Hydrological model development. In AWCI demonstration basins hydrological models were developed using the Water and Energy Balance Distributed Hydrological Model (WEB-DHM; Wang et al., 2008). These models were used in the CCAA study and are basis for the demonstration projects.

Tools and techniques development. The AWCI countries represent a wide variety of geographical, climatic and hydrological conditions and thus various tools and methods are required to implement the targeted system. A hydrological model for cold regions was developed by incorporating a multi-layer energy-balance based snowmelt scheme into WEB-DHM. Also a method was developed for estimation snow depth spatial distribution in mountain areas using a radiative transfer model and microwave radiometer observations (AMSR-E satellite data). Moreover, an improved statistical method for GCM precipitation output bias correction was developed that cover extreme rainfall, normal rainfall and frequency of dry days. Furthermore, a dam operation optimization scheme (Saavedra et al., 2010) was incorporated into WEB-DHM and applied at some basins.

Climate Change Impact Assessment Study. The said whitepaper on the GEOSS/AWCI Climate Change Impact Assessment and Adaptation (CCAA) Study (see the Appendix) was developed in cooperation with Prof. Deg-Hyo Bae of the Sejong University, Korea, leader of the Project ARCP2011-05CMY-Bae. The necessary data was collected and WEB-DHM models for the basins developed prior to the March 2011 training course. The techniques explained at the training course were then applied to assess impact of climate change on water cycle in the AWCI basins.

Preparation for AWCI Phase 2 Plan. The Seoul meeting in October 2011 initiated preparation for drafting the AWCI Phase 2 implementation plan. A template for country inputs had been generated and contributions from all AWCI countries collected by March 2012. These proposals were reviewed at the 5th GEOSS AP Symposium, the AWCI parallel session and classified into three categories: (i) Framework based category - for collaboration between country and agencies (ii) Project based category (iii) Regional collaboration category or topic based collaboration category. Further discussions took place at the 9th AWCI ICG Meeting in Tokyo, 29 – 30 September 2012.

Results

In-situ data from the basins have been collected as planned including both, the AWCI Phase 1 dataset covering multiple stations observations in each of the AWCI basins over the period 2003 – 2004 or longer, and the long-term (1981 – 2000) precipitation and temperature dataset of selected stations in each basin requested for the CCAA study. The data have been archived at DIAS and while the basic Phase 1 dataset is fully open and accessible through the DIAS portal (http://www.editoria.u-tokyo.ac.jp/projects/dias/tools.php?locale=en), sharing policy of the long-term CCAA dataset is still under discussion.

Hydrological models at AWCI demonstration basins have been developed using WEB-DHM or other models as selected by national teams. A hydrological model for snow and glacier region (WEB-DHM-S) has been developed and used in cold region basins. An integrated modeling system for improved multi-objective reservoir operation was also developed. Demonstration projects have been carried out using these models and the results are discussed in the technical part of this report.

A whitepaper on AWCI CCAA study has been produced that has resulted from AWCI ICG discussions at previous meetings. Techniques for bias correction of climate model precipitation projections have been developed, which were necessary for the proposed CCAA study. At the focused training course in March 2011, the AWCI ICG members and leaders of CCAA study in each country acquainted with these tools and methodologies for assessment of possible impacts of climate change on water resources. Consequently, the CCAA study has been initiated in each AWCI basin using the mentioned tools and techniques. Results from the accomplished studies have been presented at the AWCI meetings and international conferences and are discussed in the technical part of this report.

A plan for the next phase of AWCI has been outlined that builds up on further data integration functions of so called "Water Cycle Integrator" (provided in Appendix below) and aims at extended cooperation with operational sector. The plan is based on individual inputs of AWCI countries that were reviewed at the 5th GEOSS AP Symposium in Tokyo, April 2012.

Relevance to the APN Goals, Science Agenda and to Policy Processes

The Project focused on specific issues related to water resources management and impacts of climate change on water resources as a way of addressing capabilities for sustainable development. The developed system is intended for an operational sector as a tool for transferring scientific knowledge to information required by policy and decision-making sectors. Its development was implemented through collaboration between research community and the members of AWCI ICG, which consists of representatives of water-related ministries and agencies of participating countries and of international science communities and space agencies members. The demonstration project implementation and results was thus supervised by policy- and decision-makers of participating countries, which has been helping to mainstream the developed/applied methodologies into operational IWRM applications in these countries.

Self evaluation

We believe the project has accomplished its objectives as given above. In-situ data from the basins have been collected as planned and stored at DIAS. Hydrological models have been developed in the AWCI demonstration basins including those with regional specifics, namely snow and glacier phenomena. The CCAA study and the demonstration projects using the developed models and collected in-situ data have been initiated in all basins. The work has advanced to different stages in individual basins, being completed for several of them. The remaining basins are expected to complete the work at the beginning of AWCI Phase 2. The policy and decision maker groups have been invited to the held meeting events and the developed system has been demonstrated, showing great potential of data integration approach for operational IWRM applications. Positive feedback has been received from AWCI countries and all the ICG representatives agreed to step in the AWCI Phase 2, aiming at further data integration and implementation in the operational sector.

Potential for further work

The project has moved the AWCI activities on to the 2nd phase, which targets closer cooperation with operational sector. The developed tools and methods and the results of pilot studies have been demonstrated to representatives from governmental sector of AWCI countries and all countries approved their participation in the next phase with intention to implement the introduced approach in operational applications. The AWCI meetings, held often in conjunction with other related international events, have facilitated to further strengthen the cooperative network of AWCI countries and collaborating organizations including ODA agencies, who may become strategic partners for activities in individual countries. An example of such collaboration is the Japanese International Cooperation Agency (JICA) project "The study of Water Security Master Plan for Metro Manila and its Adjoining Areas" (Jaranilla-Sanchez, 2013).

Publications

Duran-Ballen S., Tsutsui H., Koike, T, 2012: Snow Depth Spatial Distribution using Microwave Remote Sensing at the Puna Tsang River Basin in Bhutan, *AGU Fall Meeting*.

Jaranilla-Sanchez, P.A., T. Koike, C.T. Nyunt, M. Rasmy, I. Hasegawa, A. Matsumura, and D. Ogawada, 2013: Hydrological Impacts of a Changing Climate on Floods and Droughts in Philippine River Basins, Annual J. of Hydraulic Engineering, JSCE, Vol.57.

Nyunt, C.T., T. Koike, P.A. Jaranilla-Sanchez, A. Yamamoto, T. Nemoto, and M. Kitsuregawa, 2013: Bias Correction Method for Climate Change Impact Assessments in the Philippines, *Annual J. of Hydraulic Engineering, JSCE*, Vol.57.

Shrestha, M., L. Wang, T. Koike, Y. Xue, and Y. Hirabayashi, 2012: Modeling the Spatial Distribution of Snow Cover in the Dudhkoshi Region of the Nepal Himalayas, J. Hydrometeorology, Vol. 13, pp. 204 – 221.

Tsujimoto, K. and T. Koike, Requisite Conditions for Post-Monsoon Rainfall in Cambodia by Looking through 2009 Rainfall Data, 2012: *J. of Hydroscience and Hydraulic Engineering*, Vol.30, No.1.

Wang, L., and T. Koike, 2010b: Development of an integrated hydrological modeling system for near-real-time multi-objective reservoir operation in large river basins, *2010 AGU Fall Meeting*, San Francisco, December 2010.

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Jaranilla-Sanchez, P. A., L. Wang, and T. Koike, 2011: Modeling the hydrologic responses of the Pampangga River Basin, Philippines: A quantitative approach for identifying droughts, Water Resour. Res., doi:10.1029/2010WR009702.

Saavedra, O., T. Koike, K, Yang, T. Graf, X. Li, L. Wang, and X. Han, 2010: Decision support for dam release during flood using a distributed biosphere hydrological model driven by quantitative precipitation forecasts, *Water Resour. Res.*, 46, doi: 10.1029/2010WR009502

Wang, L., T. Koike, K. Yang, T. Jackson, R. Bindlish, and D. Yang, 2008: Development of a distributed biosphere hydrological model and its evaluation with the Southern Great Plains Experiments (SGP97 and SGP99), *Journal of Geophysical Research-Atmospheres*.

Awards

Results of research work undertaken as a part of this project by young scientists at the University of Tokyo has been awarded:

- Best Paper Award - International Session of the Japan Society of Civil Engineers (JSCE) 55th Annual Meeting of Hydraulic Engineering, 2011, to Mr. Maheswor Shrestha for the paper: "Simulation of interannual variability of snow cover at Valdai (Russia) using a distributed biosphere hydrological model with improved snow physics" published at the *Annual J. of Hydraulic Engineering*, *JSCE*, 2011.
- JSCE Young Scientists' Paper Award, 2012, to Dr. Kumiko Tsujimoto for the paper: "Two diurnal cycle systems with different spatial scales and their effects on the post-monsoon rainfall in the inland of the Indochina Peninsula" published at the *Annual J. of Hydraulic Engineering, JSCE*, 2012.
- SSMS (Society for Social Management Systems) Outstanding Paper Award, 2012, to Dr. Patricia Ann Jaranilla-Sanchez, Prof. Toshio Koike, and Prof. Lei Wang for the paper: "Towards Managing Droughts in a Changing Climate: A study of Southeast Asian Watersheds" published at the Journal of Society for Social Management Systems, 2011.

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TECHNICAL REPORT

Preface

The ever growing vulnerability that is induced by global and local changes such as population changes, climate changes and variability, socio-economic issues and environmental degradation, can result in increasing both the frequency and severity of extreme events, including droughts and floods. Today's challenges require the more holistic approach of the integrated water resources management (IWRM) process to help piece together the water management puzzle and to harmonize the plans of different water users. Implementing IWRM at the river basin level is an essential element to managing water resources in a more sustainable way, leading to long-term social, economic and environmental benefits.

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1.0 Introduction

The Global Earth Observation System of Systems Asian Water Cycle Initiative (GEOSS/AWCI) was established in 2007 as a response to the recognized needs for accurate, timely, and long-term water cycle information to implement Integrated Water Resources Management (IWRM) practices and with regards to the commonality in the water-related issues and socio-economic needs in the Asia-Pacific region. This well coordinated regional challenge of 19 countries in Asia was initiated and built up as a part of the APN ARCP 2006/2007 project called International Integrated Water Data Access and Transfer in Asia (IIWaDATA). With substantial support of further projects funded under the APN programmes ARCP and CAPaBLE, it has further evolved into a strong collaborative initiative focusing on convergence and harmonization of observation activities, interoperability arrangements for observed data and collected information, effective and comprehensive data management, and capacity building of the participating countries.

Implementing IWRM at the river basin level is an essential element to managing water resources in a more sustainable way, leading to long-term social, economic and environmental benefits. It requires wide range of disparate data from multiple disciplines and various sources and appropriate tools for processing these data and integrating and translating them into relevant information for water resources practitioners and policy decision makers. GEOSS/AWCI has been striving to develop an adequate database of local observations that complies with GEOSS interoperability standards. In-situ data from 18 selected basins of participating AWCI countries have been collected, quality controlled, equipped with appropriate metadata, and archived at the Data Integration and Analysis System (DIAS, http://www.editoria.u-tokyo.ac.jp/projects/dias/?locale=en), which was launched in 2006 as part of the Earth Observation and Ocean Exploration System, which is one of five National Key Technologies defined by the 3rd Basic Program for Science and Technology of Japan. By 2009, DIAS has begun its application phase and become ready to support IWRM practices in AWCI countries.

With GEOSS assuring an easy access to the global earth observations and datasets of local in-situ data readily available through the DIAS data portal, GEOSS/AWCI has proposed this project, River Management System Development in Asia Based on Data Integration and Analysis System (DIAS) under the GEOSS, which aims to develop an advanced river management system in member countries by exploiting the DIAS data and data integration capabilities. The system is based on integration of data from earth observation satellites and in-situ networks with other types of data, including numerical weather prediction model outputs, climate model outputs, geographical information, and socio-economic data to generate the required information for making sound water resources management decisions.

Moreover, in recognition of non-stationary nature of water cycle variability and considering growing evidence of climate change impacts on water resources in Asia, it is necessary to develop a clear consensus on how to best utilize model projections of climate and hydrology in conducting frequency analysis of future hydrological hazards. Hydrological regime shifts and changes in extreme events, including floods and droughts, are now fundamental threats. It is therefore essential to properly asses these changes as a basis for identifying effective responses and developing adequate adaptation strategies.

Reflecting on these needs, the main objectives of this project were:

1. Implementation of a demonstration project in each AWCI basin that would include a distributed hydrological model by integrated in-situ and satellite data and model outputs, while considering regional and local specifics (e.g. snow and glaciers).
2. Assessment of climate change impacts on water resources in the demonstration basins using

the developed basin models and development of optimization schemes for IWRM practices.

3. Presenting and communicating results of demonstration projects to policy and decision makers in order to promote the use of developed system in operational applications including design of measures for climate change adaptations.

2.0 Methodology

2.1 Project Coordination

The project implementation took advantage of the well coordinated GEOSS/AWCI framework of 19 countries including Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Japan, Korea, Lao PDR, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Thailand, Uzbekistan and Vietnam. The network has been maintained through a series of regular (once or twice a year) International Coordination Group (ICG) meeting events and conference calls. ICG consists of representatives of water-related ministries and agencies of the participating countries (one representative per country) and experts in specific focus areas including data integration, hydrological modeling, flood, drought, water quality, climate change, and capacity building to assure that the system is applicable to a complex set of water resources management issues. In addition, representatives of collaborating organizations providing expertise in these as well as other related disciplines are always invited and contribute to the AWCI ICG meetings. These meetings review the progress in the on-going activities, present the achieved results, and formulate proposals and plans for next steps. Involvement of scientists and modeling experts together with operational and governmental sector representatives in these events enables mutual communication among scientists and developers and policy- and decision-makers and thus facilitates to the process of implementing the developed tools and methodologies in operational applications.

To achieve the overall goal – implementation of the developed system in operation – an approach of demonstration studies have been adopted. Each country had nominated one demonstration basin for which data have been archived at the DIAS system and where the demonstration project (DP) was carried out by a country team in cooperation with other member countries and experts from the GEOSS/AWCI collaborating organizations and programmes. Implementation process was led and coordinated by AWCI ICG. By showing the success stories created through the demonstration projects to decision makers, the GEOSS/AWCI activities including this project have been shifting the emphasis from scientific challenges to operational applications to yield societal benefits and establish confirmed water management infrastructure against the water related problems.

2.2 Models, Tools, and Techniques

The AWCI countries represent a wide variety of geographical, climatic and hydrological conditions and thus various tools and methods have been required to implement the demonstration projects in individual basins although the overall approach is common among the countries. The technical aspect of the AWCI activities is greatly supported by the University of Tokyo, research team of Prof. Toshio Koike and DIAS, whose members have been continuously working on development and validation of relevant models and tools including hydrological models, snow models, data processing and archiving techniques, satellite observation algorithms, climate projection bias correction and downscaling techniques, land data assimilation system and others.

WEB-DHM and WEB-DHM-S

A core part of the developed River Management System is a Water and Energy Budget Hydrological Model (WEB-DHM) that was developed at the University of Tokyo and verified at various basins. It was developed by fully coupling a land-surface model, the Simple Biosphere Scheme (SiB2; Sellers et al. 1996) with a geomorphology-based hydrological model (GBHM; Yang et al., 2004). The WEB-DHM model enables consistent descriptions of water, energy and CO2 fluxes at the basin scale. It physically describes ET using a biophysical land surface scheme for simultaneously simulating heat, moisture, and CO2 fluxes in the soil-vegetation-atmosphere transfer (SVAT) processes (Wang and Koike 2009; Wang et al. 2009; Wang et al. 2010a). The basin and subbasins are delineated employing the Pfafstetter scheme, and subbasins are divided into a number of flow intervals based on the time of concentration. All external parameters (e.g., land use, soil type, hillslope properties, and vegetation parameters) and a meteorological forcing dataset including precipitation are attributed to each model grid, in which water, energy, and CO2 fluxes are calculated (Fig. 1). A hillslope-driven runoff scheme employing a kinematic wave flow routing method is adopted in calculating runoff.

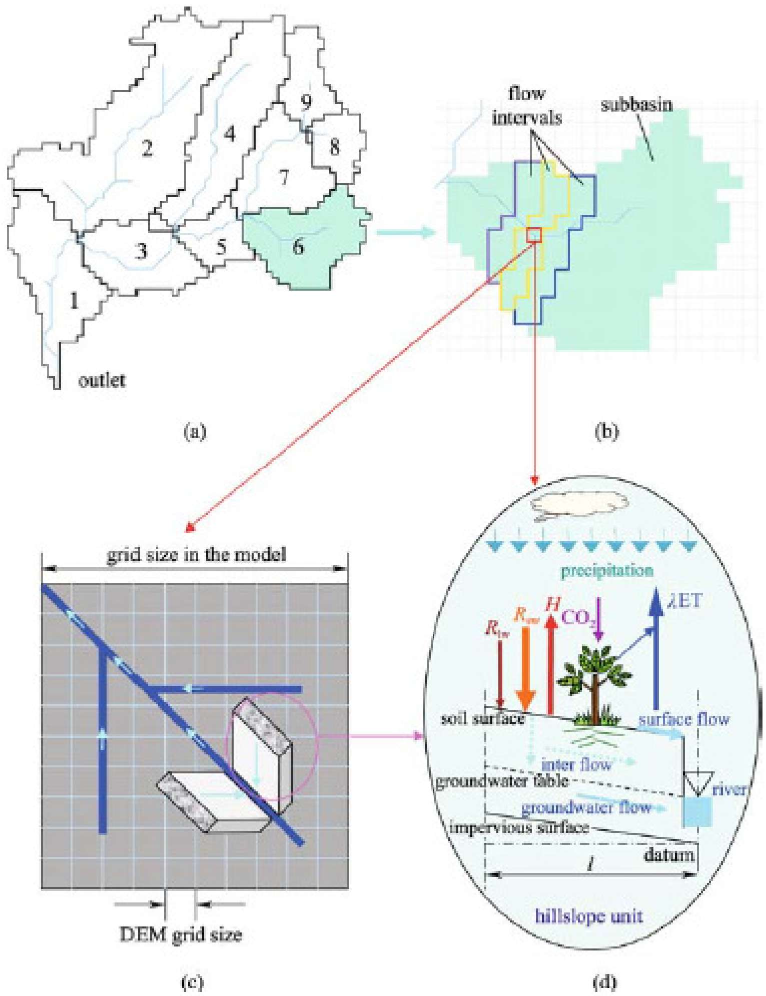

Figure 1: Overall structure of the WEB-DHM. (a) Division from a basin to subbasins; (b) subdivision from a subbasin to flow intervals comprising several model grids; (c) discretization from a model grid to a number of geometrically symmetrical hillslopes; (d) process descriptions of water transfer from atmosphere to river. Here, the land surface submodel is used to describe the transfer of turbulent fluxes (energy, water, and CO_2) between the atmosphere and land surface for each model grid, where R_{sw} and R_{lw} are downward solar radiation and longwave radiation, H is the sensible heat flux, and λ is the latent heat of vaporization. WEB-DHM simulates both surface and subsurface runoff using grid-hillslope discretizatino, and then simulates flow routing in the river network.

Seasonal snow cover and glacier phenomena are an important component of the environment in a number of AWCI countries, in particular (but not limited to) those in the Himalayan region. From a hydrological point of view, the temporal and spatial variability of the snow distribution on a basin scale plays a key role in determining the timing and magnitude of snowmelt runoff. Considering the effect of snow on land and atmospheric processes, it is essential that hydrological models accurately describe seasonal snow evolution. For applications in the AWCI basins such a model was developed by coupling the three-layer energy balance snow physics of the Simplified Simple Biosphere model, version 3 (SSiB3; Sun and Xue 2001; Xue et al. 2003) and the prognostic albedo scheme of the Biosphere-Atmosphere Transfer Scheme (BATS; Dickinson et al. 1993, Yang et al. 1997) into WEB-DHM. The resulting WEB-DHM with improved snow physics (WEB-DHM-S; Shrestha et al. 2010, 2012) adds more features to the WEB-DHM for simulating the spatial distribution of snow variables such as the snow depth, snow water equivalent, snow density, liquid water and ice contents in each snow layer, snow albedo, snow surface temperature, and snowmelt runoff. For snow-covered model grids, a three-layer energy-balance-based snow accumulation and melting algorithm is used when the simulated snow depth is greater than 5 cm; otherwise, a one-bulk-layer snow algorithm is used (Fig. 2). Each model grid maintains its own prognostic snow properties (temperature, density, and ice/water content) and/or land surface temperature and soil moisture content. The model was validated in the Dudhkoshi region of the Koshi basin, located in the northeast Nepal Himalayas (Shrestha et al. 2012).

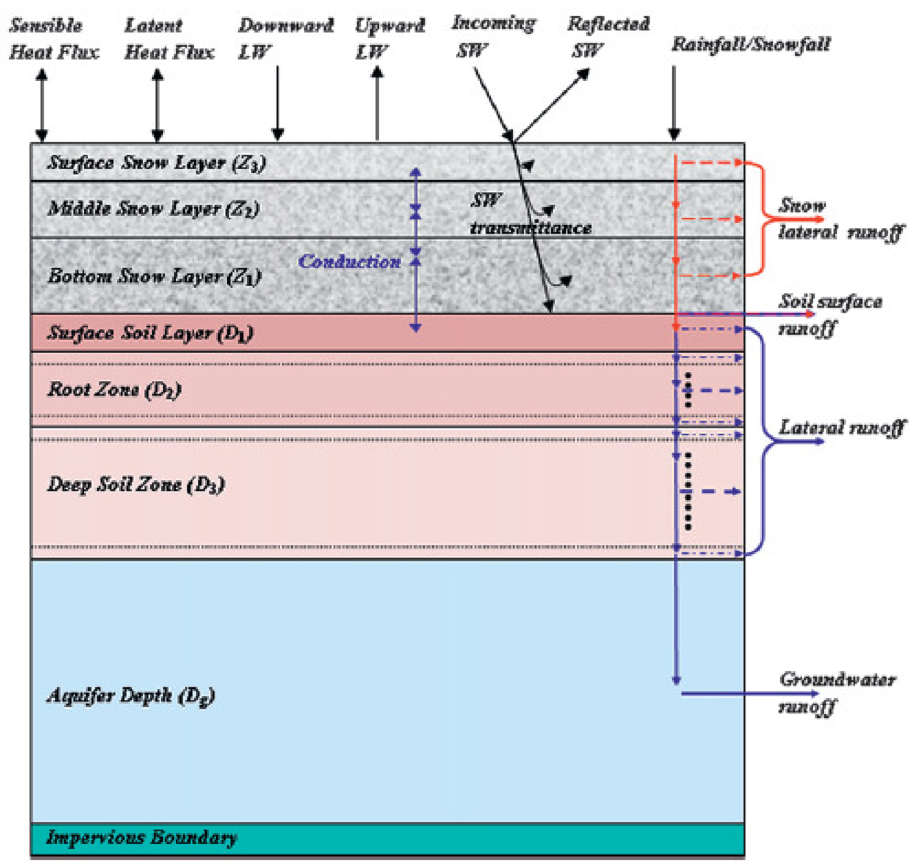

Figure 2: The soil model coupled with a three-layer snow model in WEB-DHM-S

Snow Depth Distribution Estimation Method for Mountain Regions using Remote Sensing

A new approach was developed to estimate snow amount using a microwave radiative transfer model (RTM) in mountain region, which takes into account local terrain slope and incidence angle of a readiometer scanner (Duran-Ballen et al. 2012). AMSR-E satellite observations of brightness temperature (Tb) at 18.7 GHz and 36.5 GHz frequencies were compared to calculated values of Tb in

Lookup Tables generated by the RTM model. The snow algorithm used to derive the snow depth and temperature spatial distribution was validated in a flat region using in-situ recorded snow depth data (Tsutsui and Koike 2009a, 2009b). However, remote sensing instruments are sensitive to the effects of the terrain slope, where the local incidence angle is different than the 55-degree incidence angle in case of a flat surface. In the developed method, the terrain DEM is used to calculate the slope and aspect of each grid and the local incidence angle is computed with the geolocation of the satellite as it passes over. To overcome the difference of spatial resolution between the AMSR-E data (25x25 km) and the DEM (resolution 1x1 km to express appropriately the terrain), Tb for the both frequencies is estimated with the local incidence angle for each terrain grid and then averaged for the larger satellite footprint grid using a weighted average based on the occurrence of the same local incidence angle. A uniform snow depth and temperature is assumed within each satellite footprint. The lookup tables are generated by inputting the snow depth and temperature into the RTM model for a range of local incidence angles (25° - 80°), snow depths (1 – 200 cm), and snow temperatures (223 – 273 K). One 18.7 GHz Tb and one 36.5 GHz Tb are calculated for each combination of snow depth and temperature and for each terrain grid. Then, the observed Tb is compared to the calculated average Tb in the lookup tables and corresponding snow depth and temperature of each footprint grid is estimated. The algorithm was validated at the Puna Tsang river basin in Bhutan (AWCI demonstration basin).

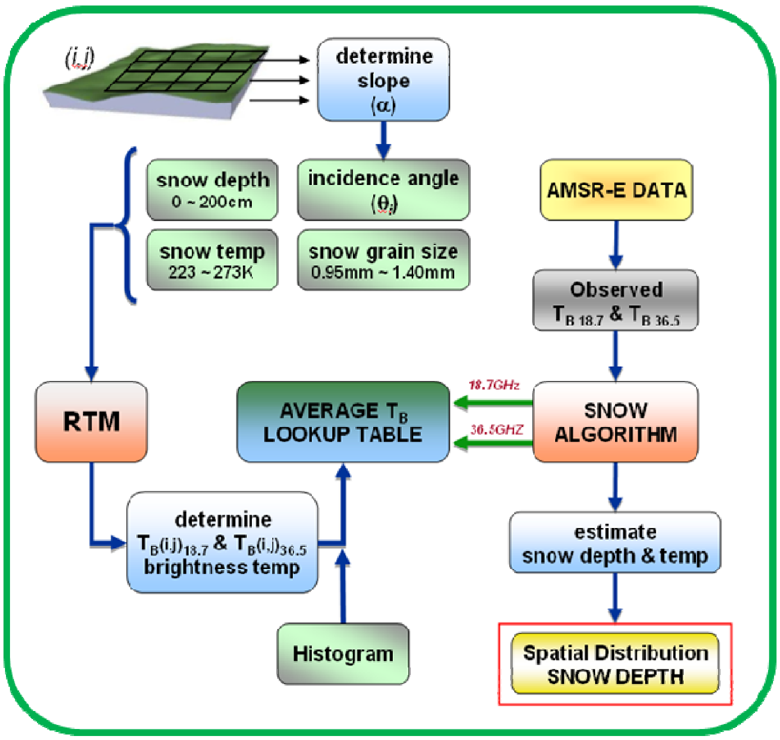

Figure 3: Framework overview of the snow depth distribution estimation method for mountain regions

Statistical Bias Correction Method and Downscaling for Climate Change Impact Assessment

Realistic representation of precipitation fields in future projections from climate models is crucial for climate change impact assessment. However, General Circulation Models (GCMs) often fail to simulate regional climate features required by basin-scale impact studies due to inadequate parameterization of several processes associated with cloud formation and land surface interactions with the atmosphere. To overcome this issue a comprehensive statistical bias correction method on the catchment scale was developed for applications in the AWCI basins (Nyunt et al. 2013). The method was validated in the Pampanga (AWCI demonstration basin), Angat, and Kaliwa basin in Philippines. The method uses an ensemble of available GCM outputs (daily values) and begins with selection of suitable GCMs for a given region. Then the daily precipitation output is corrected in three steps including extreme rainfall correction, correction of frequency of wet days (no-rain-day threshold), and correction of frequencies between the no-rain-day threshold and extreme events.

The GCM rainfall is corrected using historical in-situ rainfall observation. Moreover, there is a big gap of grid resolution between GCMs and catchment-scale hydrology models. To overcome this mismatch, downscaling of GCMs output (i.e. transforming information from climate models at coarse resolutions to a fine spatial resolution) is essential for regional and local impact studies. A statistical downscaling method based on Global Satellite Mapping of Precipitation (GSMaP; Kubota et al. 2007) spatial downscaling was employed for some AWCI demonstration projects.

GCM selection. GCM selection is based on historical simulation of daily rainfall and other atmospheric parameters of 24 GCMs from the Coupled Model Inter-comparison Project 3 (CMIP3) project over a targeted area. The scores are determined from spatial correlation coefficient (Scorr) and root mean square error (RMSE), which are derived from comparison of model outputs with reference datasets. Reference datasets include Global Precipitation Climatology Project (GPCP) products for precipitation and Japanese 25-year Reanalysis Project (JRA-25) for other atmospheric parameters.

Rainfall Bias Correction. The analysis of extremes has traditionally been tested using annual maximum series (AMS), and adjusted to suitable distributions (Gupta and Duckstein, 1975). However, this causes a loss of further high rainfall events within one year that may be considered extremes and that may exceed the maximum rainfall of other years. Therefore a new approach is employed to correct both intensity and frequency of extreme events. It is based on partial duration series (PDS), which are constructed using values above a threshold regardless of their year of occurrence, and permit inclusion of more than one event per year (Hershfield, 1973). The generalized Pareto distribution (GPD), which is the limit distribution of excess over a threshold series, is used to model PDS (Bobee and Rasmussen, 1995). A major issue of using PDS is the selection of threshold rainfall value to fit GPD. In this study, the lowest AMS from observed rainfall is defined as the first trial threshold of GPD series. The same number of extreme events is defined for GCM gridded series by ranking. Then, GCM series are fit to the GPD and bias-corrected GCM precipitation is calculated:

$$x'_{GCM}= F^{-1}_{OBS}\,(F_{GCM}\,(x_{GCM})) \quad (1)$$

where x'_{GCM} is bias-corrected extreme rainfall, F^{-1}_{OBS} is the inverse function of GPD probability of observed rainfall, F_{GCM} is the GPD probability of GCM rainfall, and x_{GCM} is the raw GCM output. Moreover, the corrected extreme rainfalls are calibrated by tuning the different thresholds to minimize RMSE between the corrected GCM and the observed extreme. The future projection rainfall is corrected by applying the same transfer function between GCM and observations during the historical period:

$$x'_{GCM\_fut}= F^{-1}_{OBS}\,(F_{GCM\_past}\,(x_{GCM\_fut})) \quad (2)$$

where x'_{GCM_fut} is the future bias-corrected rainfall F_{GCM_past} is the GPD probability of GCM rainfall for historical period, and x_{GCM_fut} is the raw GCM future projection.

The next step is to correct the frequency of wet days because most of the GCMs generate unrealistic low-intensity rainfall during a large number of wet days. This issue is resolved by using the ranking order statistics of the entire time series. The total frequency of wet days in the observed dataset is attained and applied to the GCM output to find the threshold rank and rainfall value, below which the GCM output is then considered be zero, i.e. no-rain day. For future projection, the same threshold for no-rain-day correction is used.

Finally, rainfall intensities between the extreme and no-rain-day thresholds are classified as normal rainfall in both observed data and GCMs. A two-parameter gamma distribution is used to correct bias of normal rainfall. It is assumed that the cumulative distribution function (CDF) of normal daily rainfall at a certain grid point follows the gamma distribution function. The daily GCM and observed rainfall data are fitted to a two-parameter gamma distribution for 12 months. Then, the CDF of daily GCM rainfall is mapped to the CDF of observed data for each month. The corrected normal rainfalls are calculated by the fitted gamma CDF using Eq. 1. This procedure adjusts only the rainfall intensity at monthly scale; it does not correct any errors in monthly frequency. The same transfer function for future projection is used (Eq. 2).

Statistical Downscaling using GSMaP. The employed downscaling method is based on GSMaP spatial downscaling. Firstly, GSMaP rainfall monthly correction is done between gauge station (in-situ observation) based gridded rainfall and GSMaP rainfall for a relevant period and areal average spatial weight for each grid of GSMaP is calculated for each month. Gauge based gridded rainfall is generated using Inverse Distance Weight (IDW) interpolation between the gauges and GSMaP grid centre. Then, bias-corrected GCMs rainfall is downscaled by using spatial weight distribution. This downscaling scheme is similar to a factor correction and does not correct the frequency of rainy days of GSMaP. The corrected GSMaP based spatial weights rather than the corrected GSMaP value itself are used for downscaling. The performance of downscaled map is then evaluated for target period in past (whole historical GCM simulation) and in future (targeted projection). Finally, downscaled rainfall is evaluated by annual average rainfall, inter annual variation, mean intensity, standard deviation, bias and root mean squared error of each GCM.

Drought Indices

Drought is a natural hazard causing severe damage in many regions globally including Asia. This has even worsened with the changing climate and has significant consequences for food, forestry production, and food security. GEOSS/AWCI has organized a working group on drought, which is focusing on (1) sharing and improving drought monitoring capabilities in AWCI countries; (2) establishment of a drought monitoring and research network; and (3) development of early warning systems of drought hazard in those countries (Kaihotsu 2012). For monitoring and studying drought, various types of drought indices have been developed and used.

For drought assessment in AWCI demonstration project a method was developed based on a standardized anomaly index (SA), a variation of the standardized precipitation index (SPI) (McKee et al. 1993), to quantify droughts. The SPI utilized an equation fitting a gamma distribution to the data set, and then converted it to a normal distribution. The method is limited to using only a single gamma distribution for the entire data set. Hence, variations in the mean monthly values resulting from the differences in distribution pattern of the data set are neglected. This assumption may be true for hydrological parameters such as rainfall, if it follows a gamma distribution. However, for other parameters with different land and atmospheric conditions (e.g. tropical conditions) monthly distributions patterns may vary. Another limitation is that it utilizes a simple average of precipitation for each period. This means that the SPI cannot accurately account for the effects of monthly differences or seasonality, nor for the fact that substantial water resources generated by rainfall that occurred many months ago have already been lost because of outflow and evaporation.

To differentiate the modifications made in the original method of calculating for SPI, standardized anomaly index (SA) was proposed for temporal and spatial drought classifications (Jaranilla-Sanchez et al. 2011). This index fits a distribution pattern to the monthly hydrological parameter values from the inputs and outputs of the WEB-DHM simulations. This is transformed to the normal distribution and then standardized by taking the anomaly (calculated as the difference of the parameter value from its climatic mean (long-term monthly mean)), divided by the standard deviation of the transformed parameter. The SPI categories (McKee et al. 1993) were used to classify droughts from SA outputs, ranging from extremely wet (SA > 2.0) to extremely dry (SA < -2.0). The effects of monthly and seasonal differences can be identified by SA, and the quantitative effects of evapotranspiration are integrated into calculations of other parameters using the physically consistent model WEB-DHM. Another advantage of the SA is the ease with which it can be combined with different parameters in spatially identifying the average effects contributing to drought at the basin scale.

Dam Operation Optimization

Another essential part of the developed river management system is a dam release support system (DRESS) intended for reservoir operators that is based on real-time observations and weather forecast data. The system has been developed at the University of Tokyo and validated at the Tone river basin (AWCI demonstration basin in Japan) and is in detail described in Saavedra et al., 2010. Main purpose of the system is optimal dam operation during heavy rainfall to reduce flood peaks downstream and at the same time, to maintain maximum possible storage in reservoirs for designed purposes (e.g. power generation, water supply, irrigation) during lower-flow periods.

The DRESS employs the WEB-DHM with an embedded dam operation module coupled to a heuristic algorithm for supporting release instructions. This comprehensive model solves the energy budget explicitly and can simulate the initial soil moisture properly, which might be critical for flood forecasting (Wang et al. 2009a). In normal runs, the model is forced by real-time observed radar products calibrated with a high-density rain gauge telemetry network. The radar calibration is based on a dynamic window, yielding a high-quality product almost free of shadows at high spatial and temporal resolutions. During heavy rainfall the model is driven by an operational nonhydrostatic mesoscale quantitative precipitation forecast (QPF) having four distinctive features: (1) forecast error weighting using a relatively wide domain according to location, intensity, and extent; (2) generation of ensemble flood forecasts using the evaluation of previous forecast errors; (3) use of the WEB-DHM forced by output from a non-hydrostatic mesoscale model; and (4) use of a heuristic algorithm for multi-reservoir operations with a multi-objective approach.

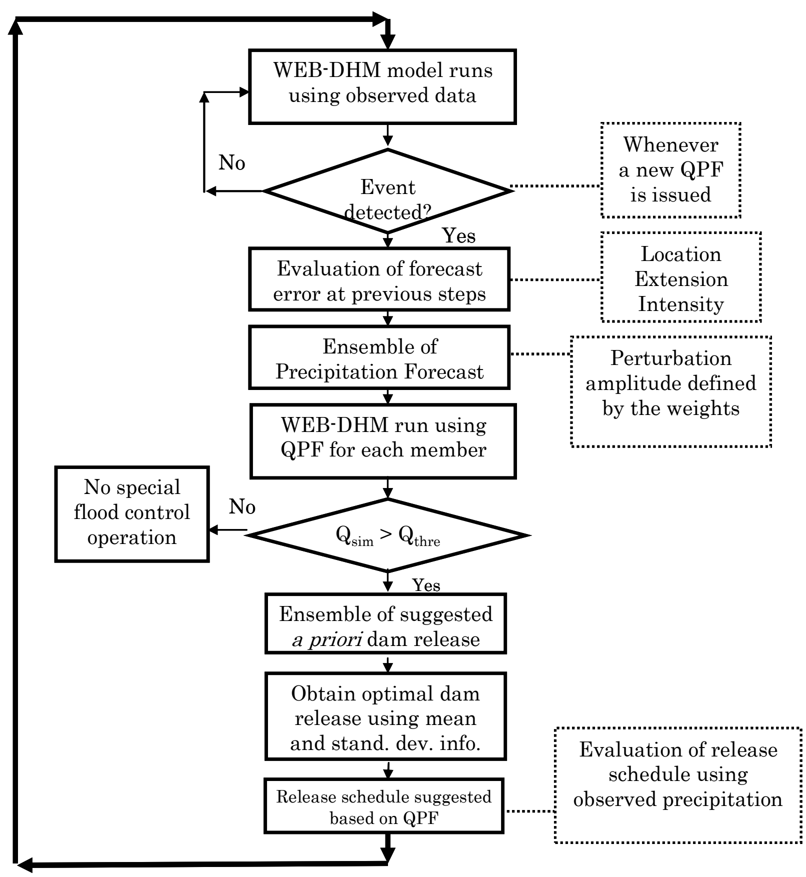

Figure 4: Steps of the dam decision support system DRESS for flood control under extreme events.

The DRESS is summarized in Figure 4. The WEB-DHM runs in normal mode forced by observed precipitation data until a heavy precipitation event is detected. At that point, the forecast error is evaluated. Recent observed precipitation and QPFs are compared over the previous time step window in terms of location, intensity, and extent. Next, a weighting method is used to calculate the weights in each zone. These weights define the amplitude of QPF perturbation to generate ensemble precipitation members over the total lead time. Then the WEB-DHM model is run to obtain the ensemble streamflow forecast. For special dam operations, a priori dam release is calculated for each ensemble member. Once the suggested optimal dam release schedule is determined using the QPF signal, the efficiency is evaluated using the observed precipitation.

2.3 Data

The developed system is based on integration of data coming from various sources including observation-based data (local in-situ and global satellite-borne observations) and model outputs (GCMs, regional climate models (RCMs), mesoscale atmospheric models) providing reanalyses, forecasts and climate historical simulations and future projections. Particular satellite and model datasets were selected as necessary and available for individual demonstration projects. Usually these include digital elevation model (DEM) data, land use and soil maps, leaf area index (LAI), meteorological variables if not available/usable from in-situ observations or in case of future projections and historical simulation evaluations, and others. Large amount of these data is available through the DIAS system or they have been gathered from their original sites.

Local in-situ data for demonstration basins were provided by participating countries. As agreed at the initial planning meeting of AWCI, the period of 2003/01/01 – 2004/12/31 was the basic period for demonstration projects and the countries committed to provide in-situ data at least for this period or longer based on the data availability and each country possibilities. Advanced on-line data upload, data quality control and metadata registration tools have been developed at DIAS to support data providers and facilitate the whole process of data submission and quality control, which therefore could be accomplished by individual data providers (i.e. country representatives) by themselves with kind assistance of the data management team at the University of Tokyo, DIAS. After the number and locations of observation stations and the list of observed parameters at a specific basin had been identified by the data provider, the data management team registered this information at the data upload system and created a user account for the provider. Then, the data provider could easily upload his data from his PC to the AWCI database on the DIAS server using a user-friendly, on-line tool (http://dias-d.tkl.iis.u-tokyo.ac.jp/AWCI/upload/).

When the data had been uploaded, the data provider could access his data at the AWCI database and quality control them using another on-line tool, the AWCI Data Online Visualization and Modifying System (http://ceop-qc.tkl.iis.u-tokyo.ac.jp/QC/AWCI.html). This system enables the user to view and correct his data using multiple visualization and analysis functions, all available on-line. The last step was metadata registration, an important element assuring data interoperability. This step encompasses two parts, metadata of observation data and metadata of documentation and was also supported by a sophisticated and user-friendly on-line tool (http://dias-d.tkl.iis.u-tokyo.ac.jp/awci_metadata/top/). Step-by step user manuals have been created for all these tools and are available for download at the mentioned websites. In addition, multiple presentations and training sessions on the use of these tools have been provided at the occasions of the AWCI meetings. The scheme of the data upload, quality control and metadata registration process is shown in Figure 5 below.

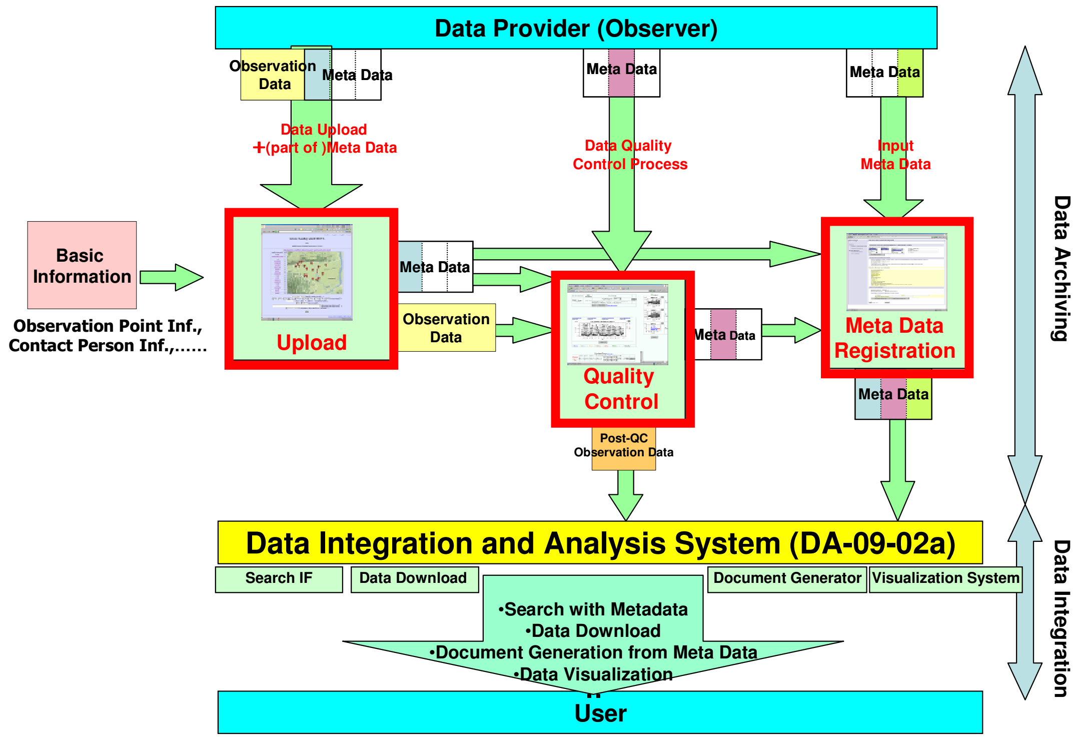

Figure 5: Web-based Data Archiving & Integration System at DIAS.

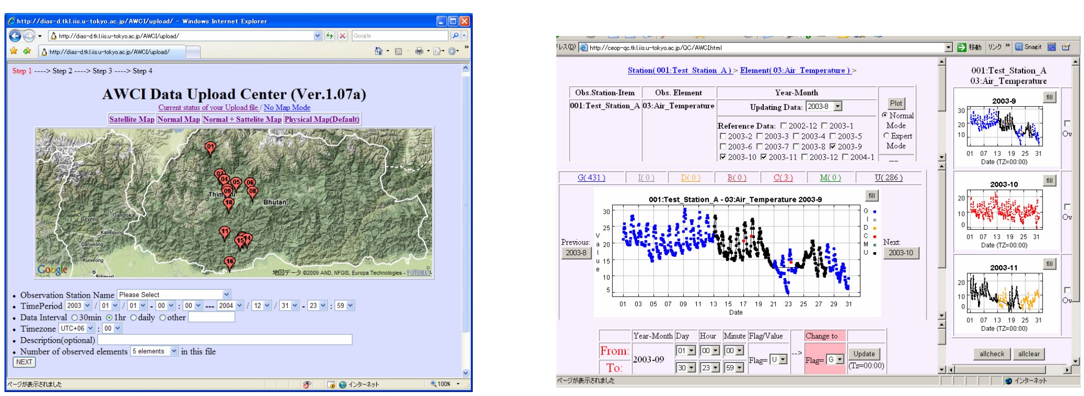

Figure 6: Example screens of the data upload (left) and data quality control (right) tools.

Being quality controlled, equipped with adequate metadata and relatively complex within each basin, the AWCI in-situ data represent top-quality datasets for multiple research activities related to water cycle. At the same time, these datasets were prerequisite for the development of the intended river management system. The data are open and accessible through the DIAS data portal:
DIAS Data Access: http://www.editoria.u-tokyo.ac.jp/projects/dias/tools.php?locale=en_US
DIAS Search and Discovery System: http://dias-dss.tkl.iis.u-tokyo.ac.jp/ddc/finder?lang=en
DIAS homepage: http://www.editoria.u-tokyo.ac.jp/projects/dias/?locale=en
The structure of the DIAS system is shown in Figure 7.

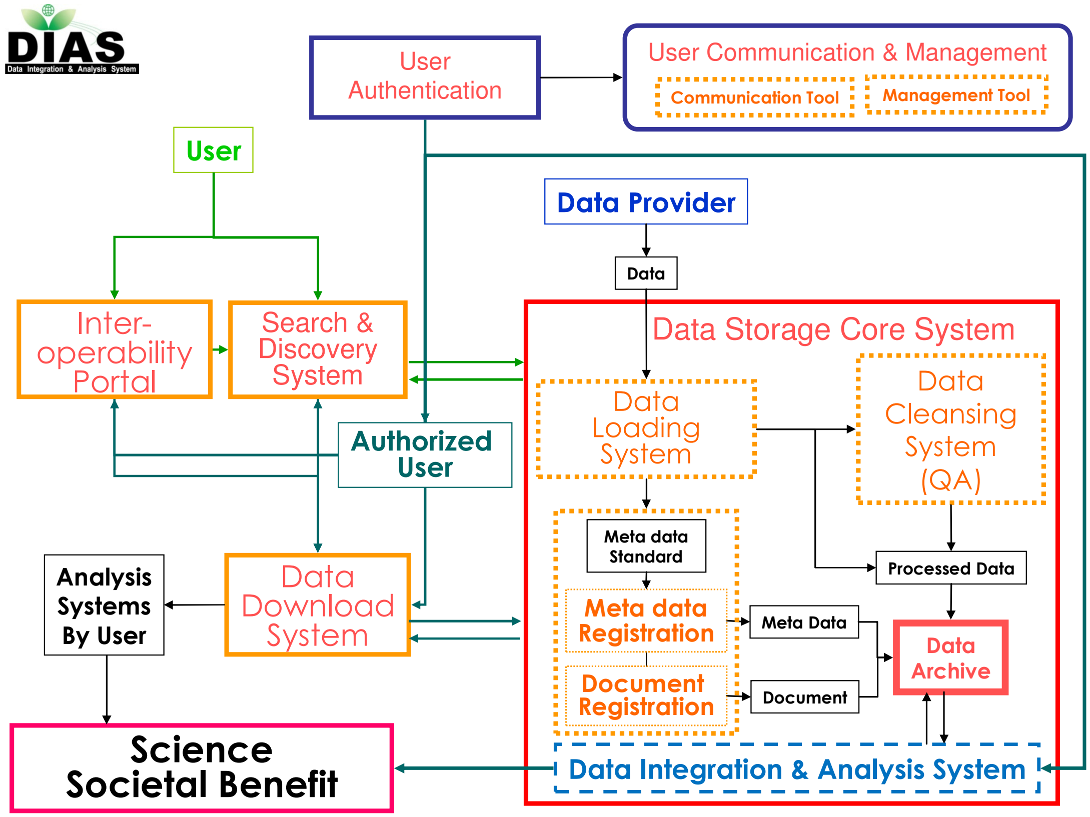

Figure 7: Schematic illustration of the DIAS structure.

2.4 Demonstration Projects

As mentioned in Section 2.1, this project adopted an approach of demonstration studies. Each country had nominated one demonstration basin for which data have been archived at the DIAS system and for which the demonstration project (DP) was carried out by a country team in cooperation with other member countries and experts from the GEOSS/AWCI collaborating organizations and programmes. While the main objective and implementation design might differ from basin to basin, the overall structure was similar. It included:

(a) Completion of the in-situ database at DIAS (data upload, data quality control, data and document metadata registration)
(b) Development of a distributed hydrological model, mostly WEB-DHM at each demonstration basin, its calibration using the provided in-situ observations (meteorological and streamflow) together with satellite observation and model data.
(c) Applications for preferred objectives (flood control, drought monitor, etc.)
(d) Preliminary Climate Change Assessment and Adaptation (CCAA) study as designed for the March 2011 training course with possible further extension of the study including further data and more complex assessment.
(e) Showing DP results and preparation for operational applications and moving to the next AWCI Phase supporting country project proposals under the GEOSS Water Cycle Integrator framework.

The demonstration basins with the basic data information are listed in the Table 1 below. The location of the basins is shown in Figure 8.

Table 1: List of AWCI Demonstration Basins and overview of collected data.

	Country	Basin Name	Data Period	# of Sta. (Rec. Int.)	Observed Elements
1	Bangladesh	Meghna	2003/01-2008/12	9 (Daily)	Ta, Pr, Discharge, WL
2	Bhutan	Punatsangchhu	1989/01-2008/12	16 (Daily)	Pr, Discharge
3	Cambodia	Sangker	2003/12-2010/01	5 (Hourly)	Pr, WL
4	India	Seonath	2000/06-2004/12	30 (Daily)	Pr
5	Indonesia	Mamberamo	1958/01-2007/12	3 (Daily, Monthly)	Ta, RH, Pr, sun, ET
6	Japan	Tone	2002/12-2004/12	16 (Hourly)	Ta, WS, WD, Pr, sun, Dis.
7	Korea	Upper Chungju-dam	2003/01-2004/12	68 (Daily)	Ta, RH, WD, Pr, sun, Dis.
8	Lao PDR	Sebangfai	2003/01-2007/12	6 (Daily)	Pr, WL, AWS
9	Malaysia	Langat	2003/01-2004/12	24 (Daily)	Pr, Dis, Ta
10	Mongolia	Selbe	2004/01-2006/12	4 (Daily)	Ta, WL, Dis, Pr
11	Myanmar	Shwegyin	2003/01-2004/12	1 (Daily)	WL, Dis, Pr
12	Nepal	Bagmati	2003/01-2004/12	22 (Daily)	Ta, RH, Pr, WS
13	Pakistan	Gilgit	2000/01-2008/12	17 (Daily)	Ta, RH, WD, WD, Pr, Dis
14	Philippines	Pampanga	1961/10-2005/12	4 (Daily, Monthly)	Pr, Dis, WL
15	Sri Lanka	Kalu Ganga	2003/01-2004/12	12 (Daily)	Pr, Dis
16	Thailand	Mae Wang	2006/05-2008/12	14 (10 min)	Ta, Pr, WL
17	Uzbekistan	Chirchik-Okhangaran	2003/01-2004/12	18 (Daily)	Ap, Ta, DueTa, RH, WS, Pr, SD, SkinT, Sun, Dis, snow, Aqueous_Tension, etc
18	Vietnam	Huong	2003/12-2008/12	8 (Hourly, every event)	WL, Pr

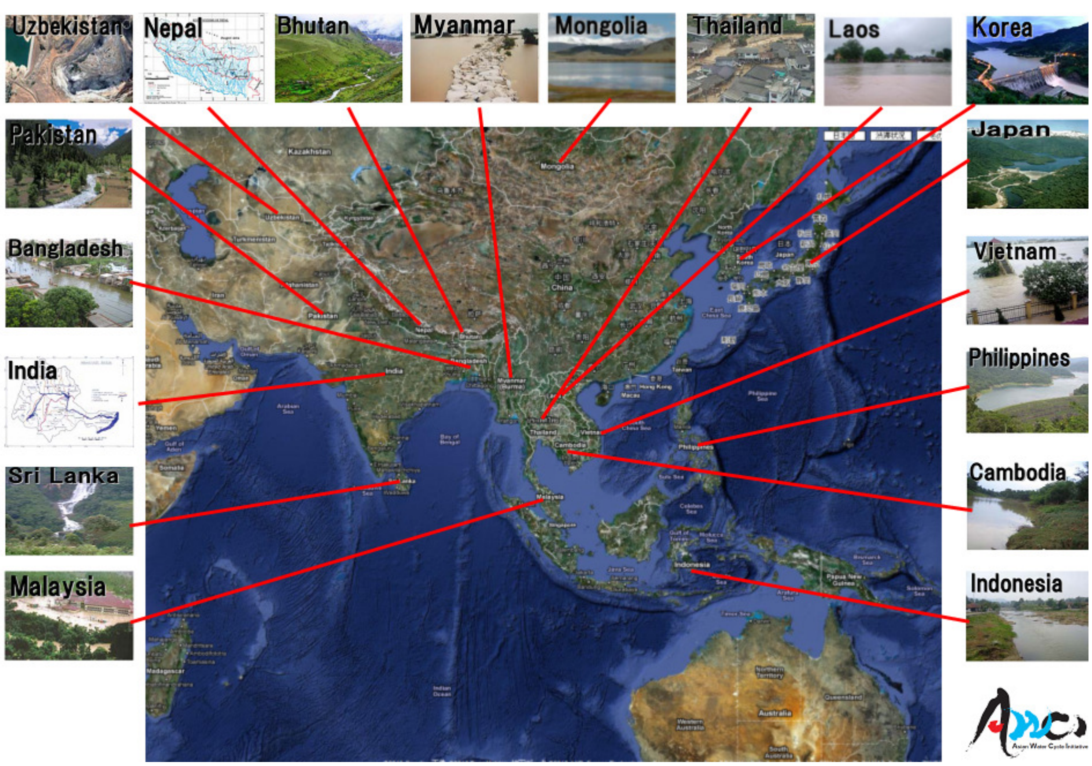

Figure 8: AWCI Demonstration Basins.

In addition to the demonstration project objectives, a preliminary climate change assessment and adaptation study (CCAA) has been carried out. The detailed proposal of the study including the methodology is described in the white paper on the GEOSS/AWCI Climate Change Impact Assessment Activity in Appendix A. The preliminary study was undertaken as the part of the AWCI Training Course for the Climate Change Assessment and Adaptation Study held on March 11 – 12, 2011. For this purpose, additional data has been collected covering the baseline historical period 1980 – 2000. For this study, some countries nominated different basin from that selected for the demonstration project. These additional datasets, which will become basis for the second phase of AWCI, have not been opened for public sharing though discussion on such possibility has been initiated. An overview of the status as of 27 September 2012 is given in Table 2.

Table 2: List of AWCI CCAA Basins and overview of collected historical baseline data – AWCI phase 2 database as of 27 September 2012. To be completed/augmented during AWCI phase 2.

#	Country	Basin Name	Identical with DP basin?	# Sta.	Observed Elements	Data Period
1	Bangladesh	Meghna	yes	8	Precipitation	1980 - 2000
2	Bhutan	Punatsangchhu	yes	14	Precipitation	1985 - 2010
3	Cambodia	Sangker	yes	5	Precipitation	1981 - 2008
4	India	Upper Bhima	no	36 17 10	Precipitation Discharge Air Temperature	1970 – 2006 1973 – 2001 1985 - 2002
5	Indonesia	Citarum	no	37	Precipitation	1991 - 2009
6	Japan	Tone	yes	4	Precipitation	1901 - 2000
7	Korea	Upper Chungju-dam	yes	*CCAA study carried out using tools developed by Sejong university, Korea. Refer to the APN ARCP project of Prof. Deg-Hyo Bae: ARCP2011-05CMY		
8	Lao PDR	Sebangfai	yes	pending		
9	Malaysia	Langat	yes	19	Precipitation	1980 - 2000
10	Mongolia	Tuul	no	8	Precipitation	1980 - 2000
11	Myanmar	Shwegyin	yes	3	Precipitation	1980 - 2000
12	Nepal	Narayani	no	1	Precipitation	1978 - 2007
13	Pakistan	Hunza	no	2	Precipitation	1999 - 2008
14	Philippines	Pampanga	yes	3 6	Precipitation AWS	1961 – 2000 1961 - 2011
15	Sri Lanka	Kalu Ganga	yes	8	Precipitation	1980 - 2010
16	Thailand	Mae Wang	yes	1	Precipitation	1979 - 1992
17	Uzbekistan	Chirchik-Okhangaran	yes	11	Precipitation	1979 - 2005
18	Vietnam	Huong	yes	9	Precipitation	1976 - 2009

3.0 Results & Discussion

3.1 AWCI Database at DIAS

Collection of the in-situ data from the selected AWCI demonstration basins (Table 1) has been completed as committed by each participating country. All the data has been quality checked and equipped with adequate metadata, which includes both metadata of observation and documentation metadata (Fig. 9). The data has been archived at the DIAS database and is freely accessible through the DIAS data portal (http://dias-dss.tkl.iis.u-tokyo.ac.jp/ddc/finder?lang=en).

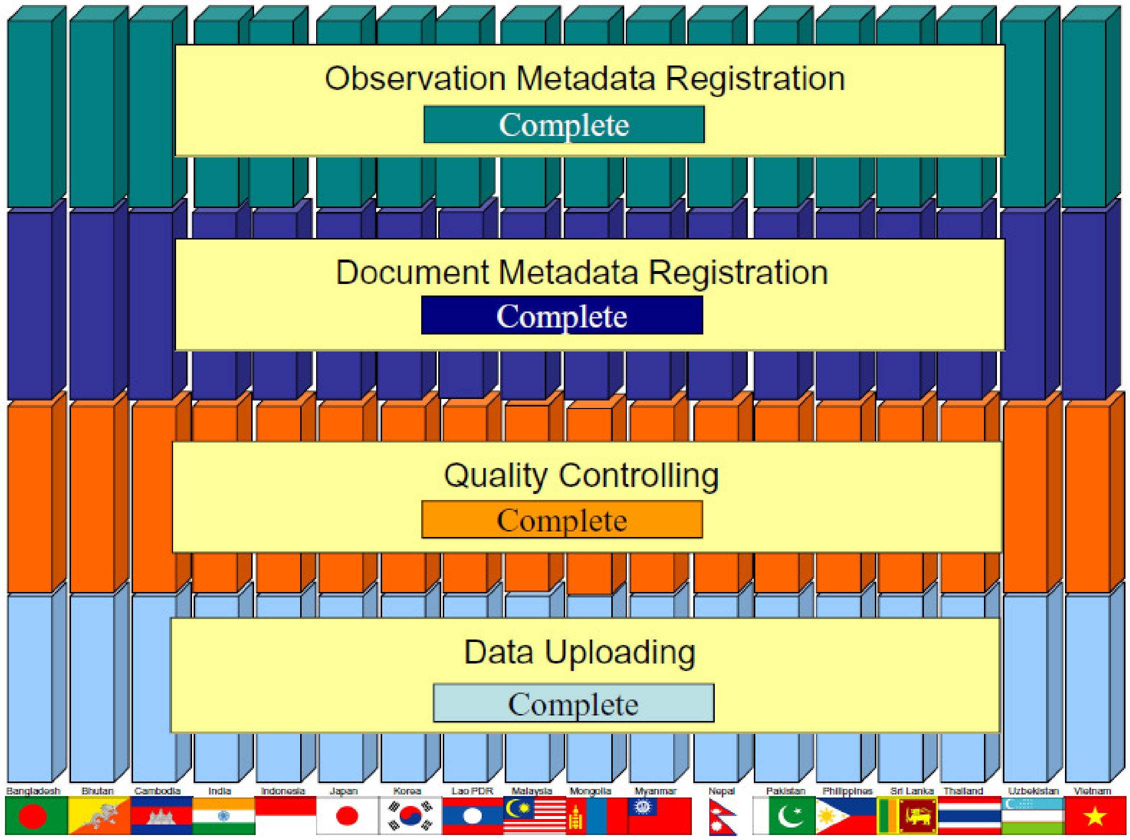

Figure 9: Bar chart of the AWCI in-situ data submission, quality control and metadata registration status.

In addition to the basic dataset for the demonstration projects as listed in the Table 1 above, data covering a baseline historical period of 1980 – 2000 for climate change assessment has been provided by the AWCI countries in order to carry out the preliminary CCAA study (Table 2). These additional data has not been agreed for public sharing yet but have been stored at the University of Tokyo database for the purpose of the AWCI CCAA study and the associated training course. The database should be completed and augmented during AWCI Phase 2 and the intention is to achieve agreement for public sharing.

3.2 Demonstration Projects and CCAA study at Individual Basins

The Demonstration Projects have been initiated in all the AWCI countries and the data collection, quality control and metadata registration is one substantial achievement for each participating country as well as the AWCI data management group at the University of Tokyo. Further development of DPs has progressed very individually, which was mainly caused by a different status of water resources management practices in individual countries. While some countries have already had implemented certain advanced computing tools for IWRM support in operational use, other countries have just initiated such process.

Most of the demonstration projects had begun with development and calibration of WEB-DHM at the demonstration basins and if different, also at the basins nominated for the CCAA study. Fulfillment of this task is summarized in Table 3 below. In many cases, the CCAA study has become part of the country DP and in some countries DP and/or CCAA study has advanced to the development of a complex project involving country authorities, experts from AWCI collaborating organizations as well as Official Development Assistance (ODA) agencies assuring adequate funding.

These countries include Philippines, Pakistan, Cambodia, Indonesia, and Vietnam. Further results are described for each country separately in following sub-sections.

Table 3: AWCI basins where WEB-DHM was developed and calibrated.

No.	Country	Basin Name	WEB-DHM + calibration
1	Bangladesh	Meghna	yes
2	Bhutan	Punatsangchhu	yes
3	Cambodia	Sangker	yes
4	India	Seonath	pending
4a		Upper Bhima (CCAA)	pending
5	Indonesia	Mamberamo	pending
5a		Citarum (CCAA)	yes
6	Japan	Tone	yes
7	Korea	Upper Chungju-dam	Different hydrological model *
8	Lao PDR	Sebangfai	pending
9	Malaysia	Langat	yes
10	Mongolia	Selbe	pending
10a		Tuul (CCAA)	yes
11	Myanmar	Shwegyin	yes
12	Nepal	Bagmati	pending
12a		Narayani (CCAA)	yes
13	Pakistan	Gilgit	pending
13a		Hunza (CCAA)	yes
14	Philippines	Pampanga	yes
15	Sri Lanka	Kalu Ganga	yes
16	Thailand	Mae Wang	yes
17	Uzbekistan	Chirchik-Okhangaran	pending
18	Vietnam	Huong	yes

Bangladesh

Meghna Basin Introduction. Surma-Meghna River System is one of the three major river systems of Bangladesh. It is the longest river (669 km) system in the country. It also drains one of the world's heaviest rainfall areas (e.g. about 10,000 mm at Cherapunji, Meghalaya, India). The **Surma** river originates in the hills of Shillong and Meghalaya of India. The main source is the **Barak** river, which has a considerable catchment in the ridge and valley terrain of Naga-Manipur hills bordering Myanmar. Barak-Meghna has a length of 950 km of which 340 km lies within Bangladesh. Parts of Meghna Basin remain in 3 countries, of which Bangladesh covers 31,859 km^2 or 41.1%, India 44,934 km^2 or 58.0%, and Myanmar 690 km^2 or 0.9% area. The Meghna Basin area in the north-east zone of Bangladesh (Fig.10) is mostly flash flood prone, which occur by spring reversal. Spring reversal is characterized by rainfall ~490 mm in the SW to ~1290 mm in the NE. The area has a tropical monsoon climate characterized by twice-yearly reversal of air movement. Meghna Basin consists of mosaic of wetland habitats, including rivers, streams and irrigation canals and large areas of seasonally flooded cultivated plains. The annual average flow of Meghna is 500 ~ 30,000 m^3/s. But in wet season the flow rises above 160,000 m^3/s in the northern portion. Annual Sediment Transport is around 10^6 tons.

Main goal of the DP

- Developing information system for improved modeling and disaster forecasting
- To make a bridge between regional and global scale data and information for sound decision making and resource allocation.

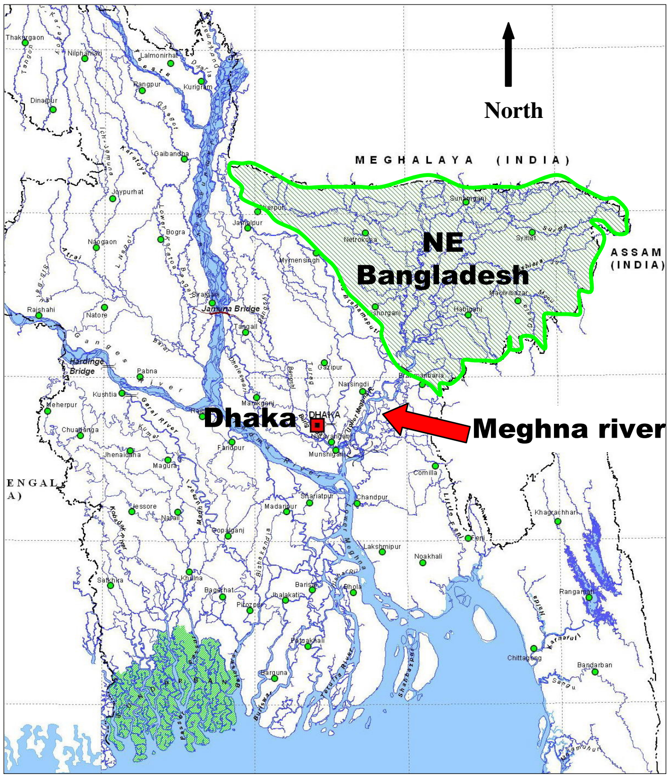

Figure 10: Meghna river in Bangladesh and the flash flood prone area in the north-east Bangladesh.

- Transfer output of joint research achievements to formulate adaptation strategy and enhancing social capacity building technique against disaster.

Collaborators in Bangladesh
Ministry of Defense (MOD), Bangladesh Meteorological Department (BMD), Space Research and Remote Sensing Organization (SPARRSO), Bangladesh University of Engineering and Technology (BUET), SAARC Agricultural Centre (SAC), Bangladesh Water Development Board (BWDB), Disaster Management Bureau (DMB) etc.

Project status. Flash flood forecasting studies have been carried out in the north-east region of the Meghna basin. These studies were conducted by the Bangladeshi authorities using ECMWF weather forecast data and the forecasting system currently in use in Bangladesh (Fig. 11).

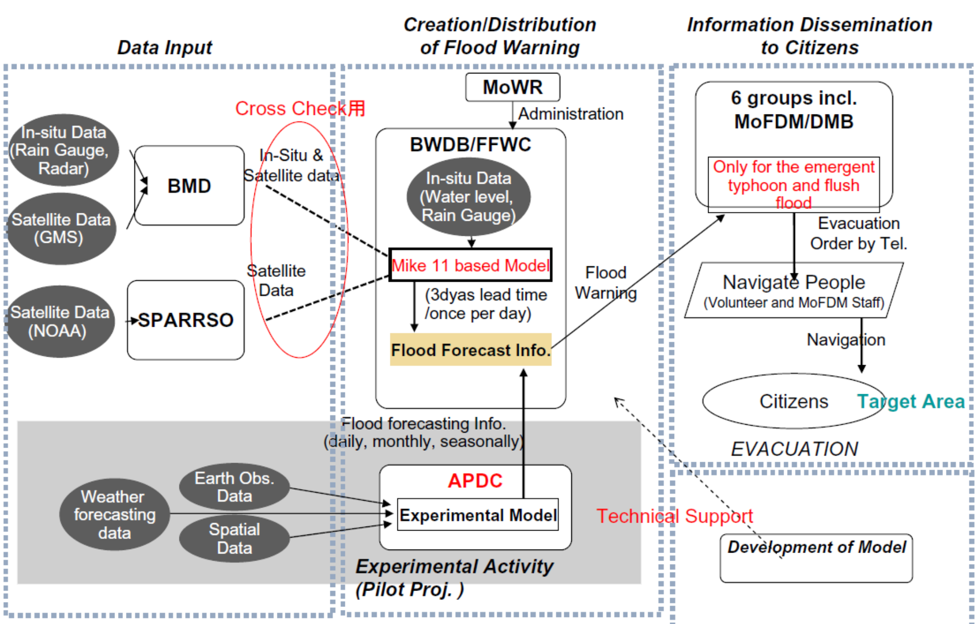

Figure 11: Current Flood warning system in Bangladesh

In addition, a study using WEB-DHM has been carried out in cooperation with the University of Tokyo. In this study, the global dataset including corrected TRMM precipitation data was employed to reproduce flood peaks in the Meghna river basin. The results showed suitability of the WEB-DHM model for flood forecasting (Saavedra and Koike, 2008). The WEB-DHM is thus a candidate model for improving the current system, which needs to be updated and upgraded including local level information for better local level flood forecasting with increased lead-time.

Climate change impact assessment research has been intensively carried out in Bangladesh showing the probable increase of risk associated with floods (extent and frequency), more frequent and intensive cyclones, river bank erosion, drought, sea level rise and salinity intrusion. CCAA study following the AWCI proposal has been initiated by a preliminary work at he March 2011 training course and is expected to continue during the 2nd phase of AWCI.

Bhutan

Bhutan is small country with a population of 695,822 with an area of 38, 394 km^2 located on the eastern fringes of the Himalayas. The landscape is mountainous with elevations ranging from 100m to 7000m and the terrain is very rugged. The landscape is dominated with high forest cover (70.46%) along steep slopes with very little land available for agriculture (2.93%). Bhutan's Climate is dominated by the monsoon which is very active from June to October. Monsoon contributes more than 70% of the rainfall in Bhutan. But spatial distribution of rainfall is varied with the southern foothills receiving more rain than the inner valleys.

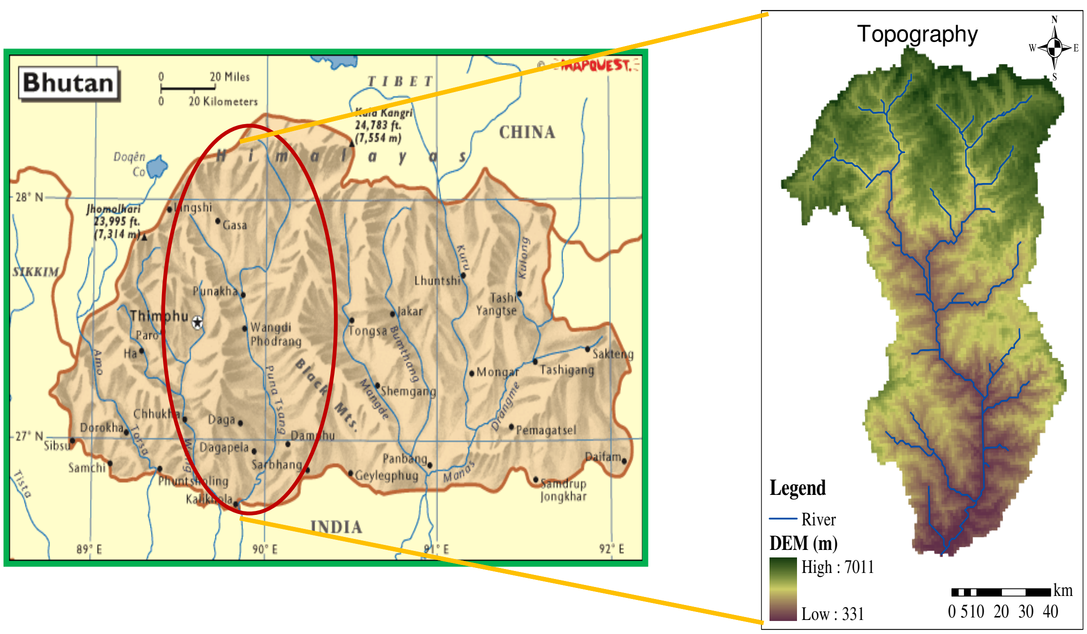

Figure 12: Location of the Punatangchhu basin in Bhutan and its topography.

The data available in Bhutan is considered very short for any meaningful analysis. However an analysis of observed data from 2000-2009 shows an increasing trend for both maximum and minimum temperatures but no apparent trends in precipitation pattern. The temperature records from the meteorological stations located in the study basin indicate this trend. Despite the inadequacy of data, various studies have been carried out such as the recently study for Bhutan's Second National Communication UNFCCC. Some of the programmes identified under the National Adaption Programme of Action (NAPA) to Climate Change have been implemented. The notable ones being the artificial lowering of the Thorthormi lake, identified as one of the dangerous glacial lake. This lake is located at the headwaters of the Punatsangchhu. A GLOF Early Warning System has also been put in place. On the legislation front, the Royal Government of Bhutan recently enacted the Bhutan Water Act and the provisions of this Act will enable setting up mechanisms for proper basin management.

The Punatsangchhu Basin (Fig. 12) was chosen as the demonstration basin on account of being the largest single river basin, as the basin severely threatened by glacial lake outburst floods and also due to huge developments taking place, with particular reference to the mega-hydropower projects. The tasks undertaken and completed under this project include (i) in-situ data provision to the DIAS as shown in Tables 1 and 2 above, (2) development and calibration of WEB-DHM, and (3) development and validation of the method for estimation of snow depth spatial distribution using microwave remote sensing as it is described in Section 2.2 above. Due to the lack of in-situ snow observation in the Punatsangchhu basin, it was validated against the outputs of snow depth of the WEB-DHM-S. WEB-DHM-S outputs of stream discharge and snow cover area were validated with measured flow discharge at 4 gauge stations and MODIS snow cover area, respectively. As indicated by comparison in Figure 13, the RTM successfully estimates the snow depth trend and seasonal behaviour of the snow cover areas. The best spatial correlation of 0.3 was for Feb. 26, 2006.
The developed method is a useful tool for snow depth estimation from satellite observations in the snow-melt dependent basins. Together with the WEB-DHM-S model, these tools are essential for further research on climate change impacts on water cycle in the AWCI countries with cold regions.

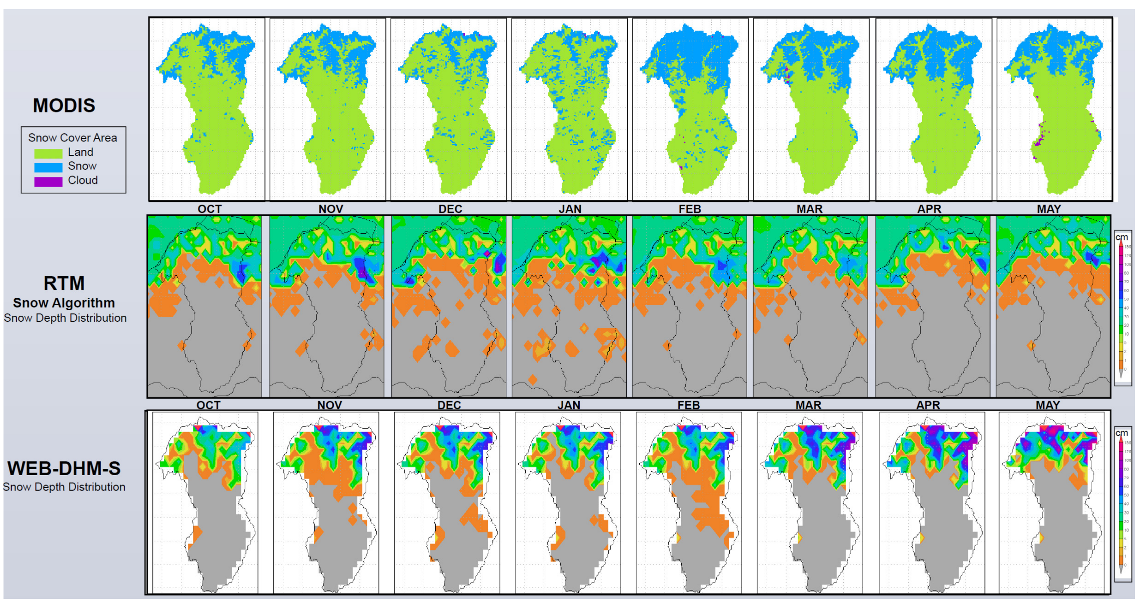

Figure 13: Snow depth spatial distribution over the Punatsangchhu basin from October 2005 to May 2006.

Cambodia

The Sangker river basin is one of the tributaries of Tonle Sap Lake, located in Battambang Province at southwest of Cambodia (Fig. 14). The middle basin is covered with mixed agriculture and urban area and suffers from flash flood. The downstream region is inundated for 6 months in a year by the flood from Tonle Sap Lake and floating rice is cultivated. However, there is no large-scale systematic irrigation system and thus it is difficult to manage rain-fed paddy fields in tropical monsoon climatic areas with distinct dry and rainy seasons (Tsujimoto and Koike, 2012).The productivity of the crops is thus highly dependent on the amount and variability of the rainfall and the stream flow. Since most of the paddy fields are rain-fed and most of the farmers rely only on their experience (not science-based), they would not accommodate themselves to the changing rainfall and water resources under the climate change and thus food security in this region would be threatened. The main objectives of DP included study of precipitation patterns and prediction technology of agricultural water resources considering also the impacts of climate change. The Cambodian DP has evolved into a complex project being implemented through cooperation among the Cambodian governmental authorities, namely Ministry of Water Resources and Meteorology (MOWRAM), the University of Tokyo, and JAXA (Space Applications For Environment (SAFE) project).

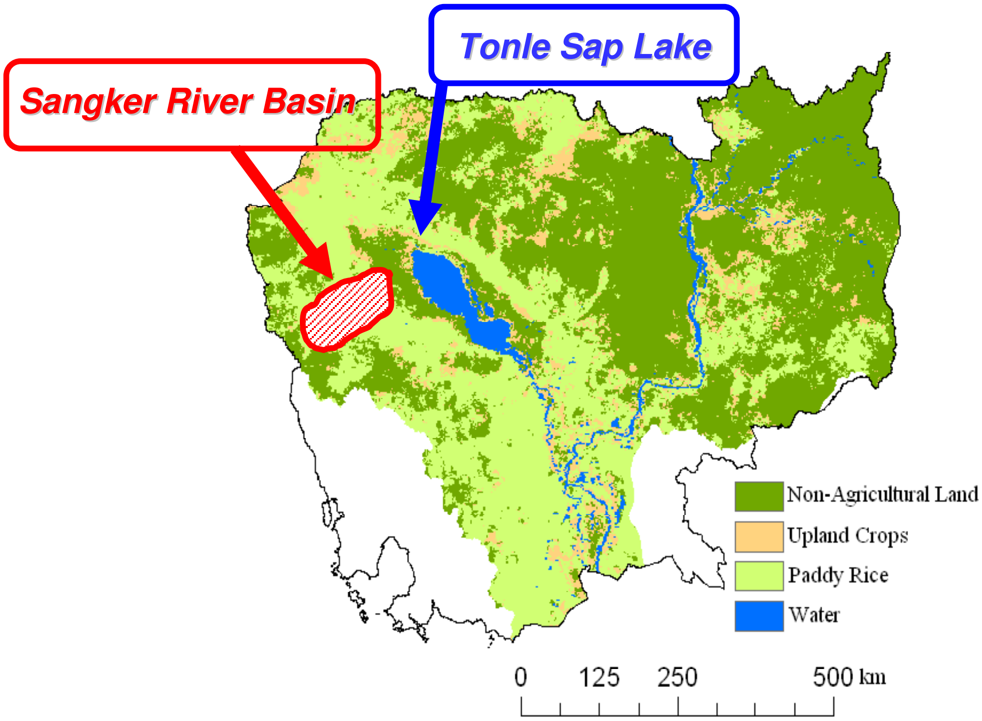

Figure 14: Location of the Sangker river basin and Tonle Sap Lake in Cambodia

The in-situ data from the basin has been provided as committed (see Tables 1 and 2). One of the issues in Cambodia is very limited number of observation stations. Through cooperation with the University of Tokyo, new precipitation gauges have been installed and the local staff trained to be able to maintain the stations and collect good quality data. In addition, an Automated Weather Station (AWS) has been installed. Using the precipitation gauge and AWS data, satellite TRMM data and numerical simulations by atmospheric models, a comprehensive study on precipitation patterns in western Cambodia has been carried out (Tsujimoto and Koike 2012) that clarified the mechanism of post-monsoon rainfall and suggested three requisite conditions for these rainfall events: (i) abundance of precipitable water, (ii) development of a land breeze from the southwest of the Tonle Sap Lake, and (iii) large-scale northeasterly wind of moderate strength.

In addition, a study was carried out with coupled WEB-DHM and the rice growth model SIMRIW-rainfed to grasp the required hydro-meteorological information for rain-fed agriculture. The results of the coupled model were validated by the LAI and soil moisture in the Sangker River Basin. The sensitivity analysis showed that rainfall prediction at the beginning of the dry season is very important (Tsujimoto et al. 2013). Moreover, the preliminary CCAA study undertaken following the March 2011 training course methodology indicated possible increase of flood peaks. Such understanding is important for developing the targeted methodology for prediction of rainfall and agricultural water resources, which aims to make maximum use of knowledge, technologies, infrastructures, and real-time and archived satellite data which are indispensable for development, validation and application of the developed prediction system (Fig. 15).

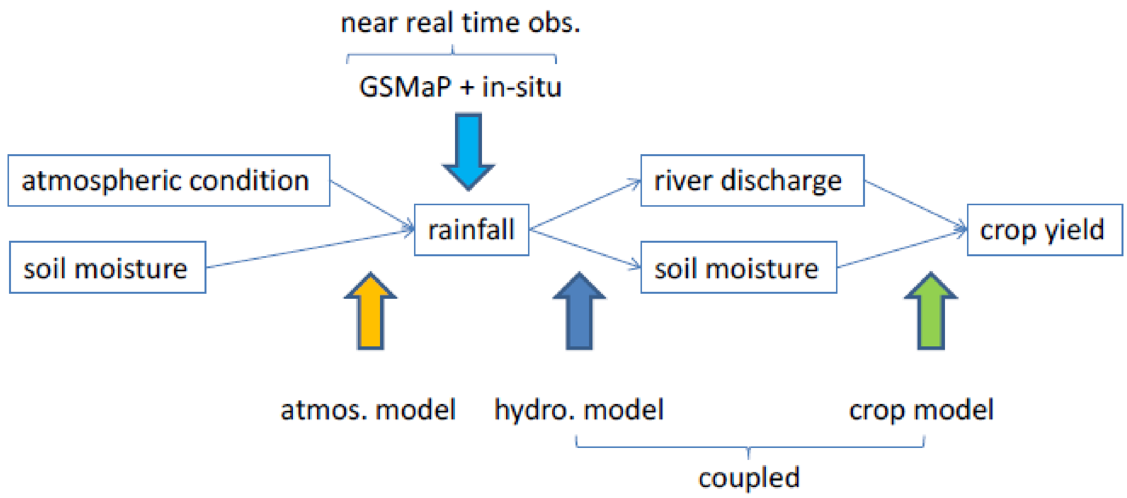

Figure 15: Schematic chart of the developed system in Cambodia

India

The Seonath River Basin, which was selected for DP, is the largest tributary of Mahanadi basin where the Indian Meteorological Department (IMD) had been pursuing an effort to establish estimation of quantitative precipitation forecast by using dynamical downscaling technique. Accordingly, the objective of the demonstration project was also to provide Quantitative Precipitation Forecast (QPF) and Probability of Precipitation (POP) of the basin by a dynamical downscaling technique using the

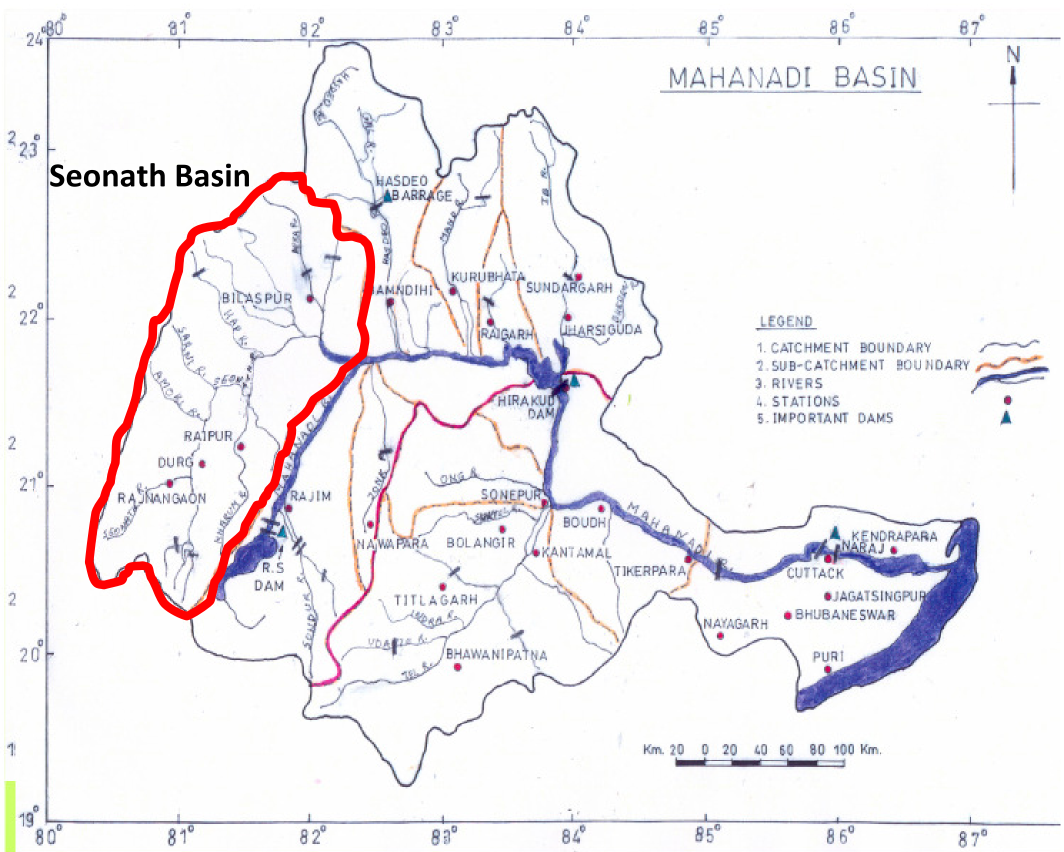

Figure 16: Location of the Seonath basin at upstream of the Mahanadi basin.

NWP model products and other data to the station/basin level. The accuracy of QPF should be high enough so that it can be used in flood forecasting model (at least 80%). The basin rises in the Chandrapur district of Maharashtra at an elevation of about 532m and meets Mahanadi river after traversing a distance of about 383 km (Fig. 16). In-situ precipitation data of the 30 gauging station within the catchment have been provided to the DIAS database, however WEB-DHM has not been developed at this basin yet. The project at the Mahanadi basin has been implemented by IMD, independently on AWCI.

For the CCAA study, the Upper Bhima Basin was nominated, which has a geographical area of 14,712 km^2 and lies in western India in the state of Maharashtra (Fig. 17). Length of the Bhima River up to Ujjani Dam is 275 km. The average annual rainfall is 700 mm and it decreases from west to east with three regions of varying rainfall: the extreme western region of heavy annual rainfall (2,300 mm), the foot hill region where annual rainfall is moderate (800 to 1,000 mm) and the central and eastern region of lowest annual rainfall (400 to 600 mm). About 25% of the area in the Basin is hilly and highly dissected, 55% is plateau and 20% plain and valley filled. Forestry covers 10.1% of the basin and agricultural use in the basin makes up 76.3 %. Of the crops grown in the basin, 64.8% are under irrigation. Soils in the basin range from reddish brown on sloping land (basalt 38%), coarse shallow soils (12%), medium black soils (26%), and Deep black soil (24%).

There are 18 projects with gross storage greater than 17.4 million m^3 in the basin. The original purpose of these projects was to catch the runoff from the Western Ghats to be used for irrigation during the non-monsoon period. However, since the development of these projects, municipal and industrial demands have since accounted for much of this supply of water as has the need for flood protection. Six hydropower projects have a total installed capacity of 318MW. The other reservoirs service the command areas. The water resources are managed by the Surface Water and Ground

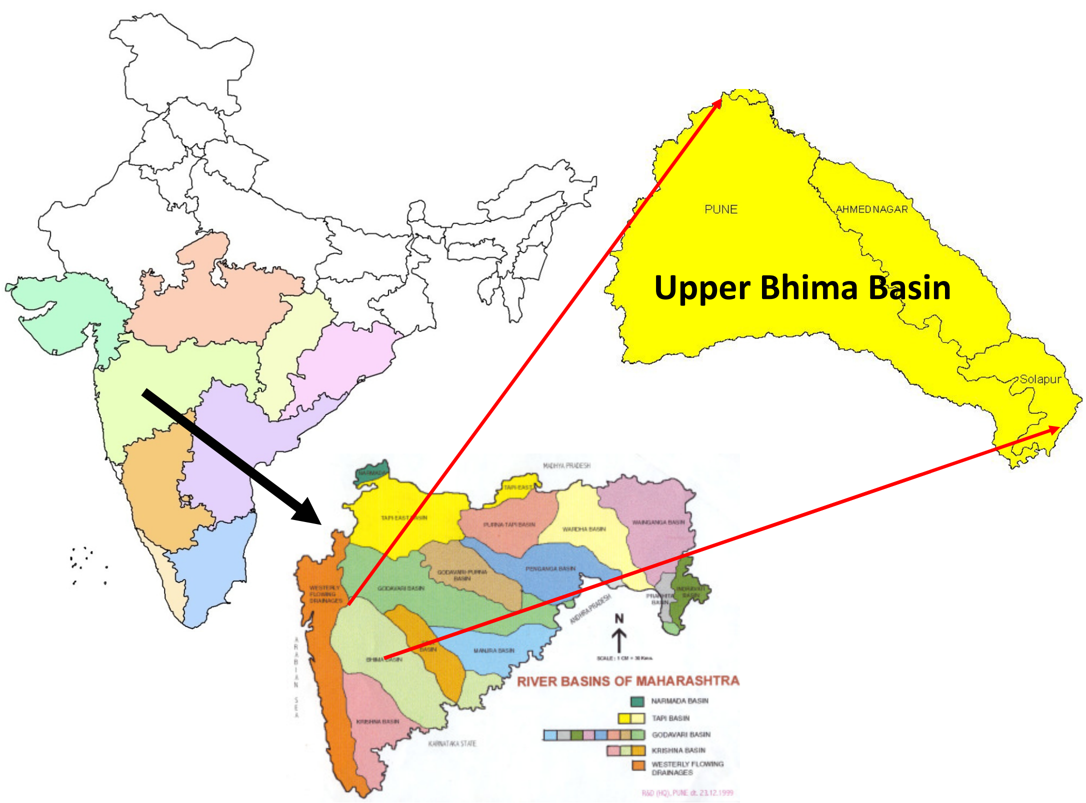

Figure 17: Location of the Upper Bhima Basin in India

Water Resources Departments of the Maharashtra state. Quantification of the impacts and vulnerabilities and assessment of adaption strategies with combination of climate projections and integrated assessment models by utilizing comprehensive data of climate water cycle and resources are required for integrated water resources development and management of water resources of the basin.

Under the CCAA study, the rainfall and temperature data of Upper Bhima basin has been entered in the DIAS network of Tokyo University for AOGCM quantitative evaluation. The suitable GCM output for the region would be accepted after gap filling and bias correction of historical simulation precipitation output and future projection precipitation output of selected models using observed precipitation data. These future scenarios would be linked with hydrological model for assessing the impact of climate change on water resources. Studies are required to be taken up for developing the modified methodologies for the assessment of water resources, hydrological design practices, flood and drought management, operation policies for the existing as well as proposed water resources projects and assessment of available water for irrigation including the land uses and cropping patterns. This work is ongoing.

Indonesia

The main objective of the Indonesian DP was flood forecast and support for flood decision-makers and to improve the predictive capability for key water cycle variables and feedbacks through improved parameterization to better represent hydro-meteorological processes at the Mamberamo river basin. This is relatively large basin (78,992 km^2) on the New Guinea island. The in-situ data was provided to the DIAS database as committed and WEB-DHM model development was considered. However, the in-situ data in particular river discharge observation is rather sparse (some variables only monthly) and was not adequate for developing the desired flood forecasting system.

Considering the issues above, the Citarum river basin was nominated for the CCAA study. It is one of the strategic Basins in West Java and flows from the mountainous area in Bandung, through the three cascade dams: Saguling, Cirata, and Jatiluhur, before reaching the Java Sea. Upper Citarum River Basin is the main water supply contributor (49% inflow of Jatiluhur) for drinking water of Jakarta (capital city) and the most developed industrial area of Indonesia (Bekasi, Kerawang and Cikarang).

Figure 18: Location of the Citarum River Basin on the Java Island, Indonesia.

The data for the Citarum basin was submitted to the AWCI database and the WEB-DHM was developed. Rainfall and discharge variability analysis in Upper Citarum River Basin (CRB) was done by comparing discharge stations data in Nanjung (near Saguling Dam inlet) with rainfall area in upper CRB. The results suggested the Upper Citarum River Basin tends to have higher discharge in wet season and lower discharge in dry season in recent year compared to 10 to 15 years ago. Change in Upper Citarum River Basin condition is not only affected by anthropogenic factor (land cover change, urban area development), but also affected by changes in climate conditions. Rainfall data also showed that average monthly rainfall in wet season tends to increase, while average monthly rainfall in dry season tends to decrease (Kusuma 2012).

The Citarum River Basin project is another one, which has advanced to the stage of preparation of a complex multidisciplinary project covering fields of Flood and Drought, Water Quality, Water Policy, Water Availability (Agriculture, Drinking, Industry, and Domestic) and Implementation of Technology. It involves multiple partners including Indonesian Government institution, local stakeholders and relevant research and funding organizations:

- Government Institution: BAPPENAS (State Ministry of National Development Planning), BAPPEDA (Regional Body of Planing and Development) and BBWSC (Board of Authority for Citarum River).
- State Own Company: PDAM (Regional Water Utility Company) Bandung and Reservoir Operator/Authority of Jatiluhur, Cirata and Saguling
- Related University/Research Institution: University of Tokyo, Institute of Technology Bangung (ITB), UNPAD and PUSAIR (Center for Research of Water)
- International Funding Institutions: Asian Development Bank (ADB), Japan International Cooperation Agency (JICA)
- Non-Government Organization (NGO) represent the Citarum River Community

Planning of the project has been initiated through focused workshops in which participation of all the involved parties is assured.

Japan

The Upper Tone River basin was selected for DP in Japan (Fig. 19). It is located in the northern headwaters of the Tone river basin. The Tone River is a very important source of water supply, irrigation and power generation for the Tokyo area. Therefore its management is crucial for the region. According to Japan Meteorological Agency (JMA), the trend of frequency and intensity of heavy rainfall in this region has been increasing on average from 1961-2001. The main target to be addressed through demonstration was development of a system able to (i) reduce flood peaks at downstream and (ii) replenish water levels in reservoirs after a flood event by using quantitative precipitation forecast, which would be implemented as a support tool for dam operators.

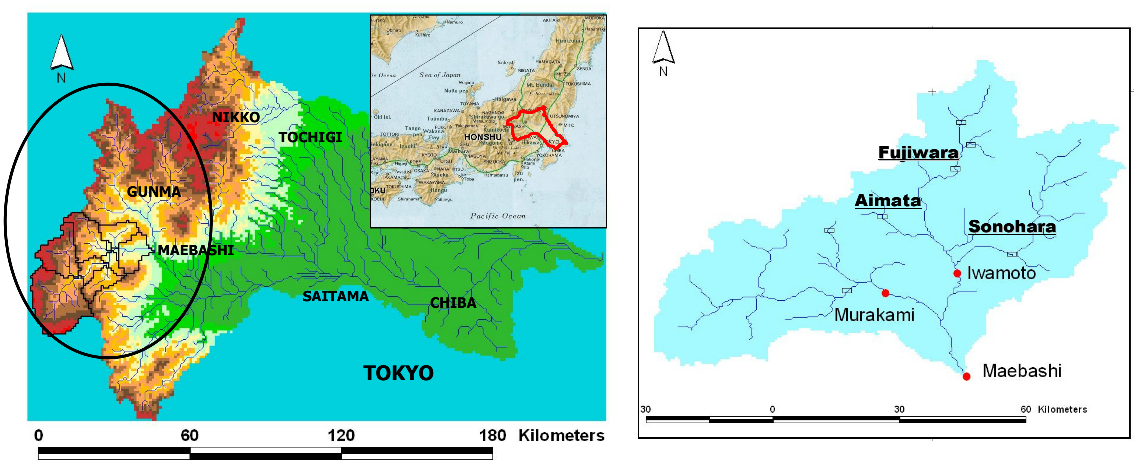

Figure 19: Location of the Tone River Basin on the Honshu Island, Japan with the Upper Tone Basin highlighted by a black oval (left) and the Upper Tone Basin with discharge gauging stations (red dots) and dams (black rectangles) on the right side.

The in-situ data from the basin have been provided to the DIAS database including also the long-term precipitation record for the CCAA study. The targeted system was developed as briefly introduced in Section 2.2, full description is given in Saavedra et al. 2010. Currently, the University of Tokyo research team is implementing the system into real-time operational use. In addition, the Upper Tone basin was used for development and testing of the WEB-DHM model as described in Section 2.2 and fully explained in Wang et al. 2010a. The preliminary CCAA study has confirmed findings of JMA that it is very likely that heavy rainfall will be increasing in future.

Korea

The Republic of Korea nominated the Upper Chungju-dam Basin (Fig. 20) for the DP as well as CCAA study. The main objectives were (i) utilization of an integrated hydrological and meteorological forecast system for the optimal dam operation and flood risk reduction and (ii) understanding of the regional and global water cycle mechanisms in case of climate change. The in-situ data have been submitted to the DIAS database as committed for both, the DP and CCAA study. The work was carried out by the Sejong University team and presented at the AWCI meetings (e.g. Bae et al. 2008; Bae et al. 2011) and would be summarized in details in the final report of the ARCP2011-05CMY-Bae project, which is a collaborative project under the AWCI framework.

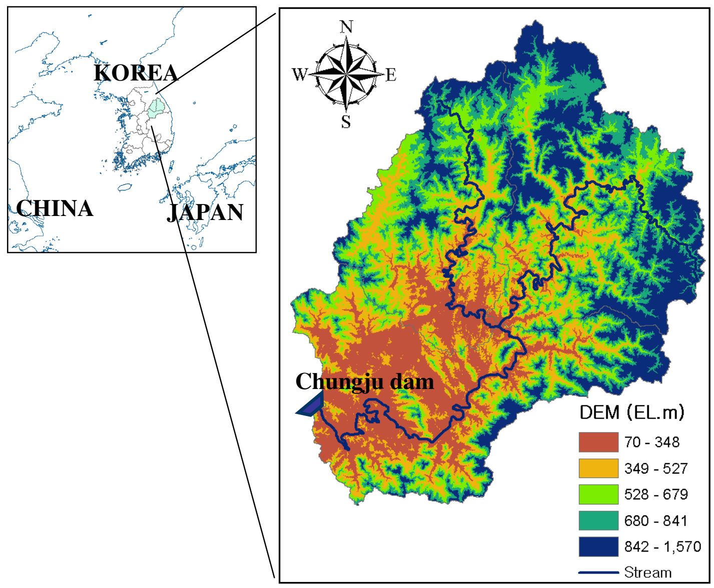

Figure 20: Location of the Upper Chungju-dam Basin in Korea.

The methodology employed includes multi model ensemble modeling approach, which had been developed to cope with uncertainties produced by individual models. In this approach, not only the ensemble of GCM outputs was used but also multiple hydrological models were run using these GCM outputs considering various emission scenarios. The results showed great uncertainty that increased for more distant future, however, certain conclusions in terms of impact on water resources in South Korea could be made, namely that spring runoff is projected to decrease and summer and winter runoff amounts are projected to increase and water resources management and practices in South Korea is likely to be distressed by climate change.

Lao PDR

The Sebangfai River Basin, selected for the DP as well as CCAA in Laos, is located in the Khammouane Province. At the source, the river flows from the Vietnam border in the southeast-northwest direction to Boualapha District and changes direction to the west to Mahaxay District and then turns from the northeast-southwest into the Mekong (Fig 21). The main focus of DP was capacity building in flood forecasting and analysis as well as improving the data transmission system. The in-situ data for the DP has been provided to the DIAS database as committed. Further activities on the Sebangfai basin include routine observations, monitoring, forecasting and early warning towards adverse weather and river floods. This service has been provided by DMH to people at risk communities and to the decision making body such as National Disaster Management Committee (NDMC) in order for

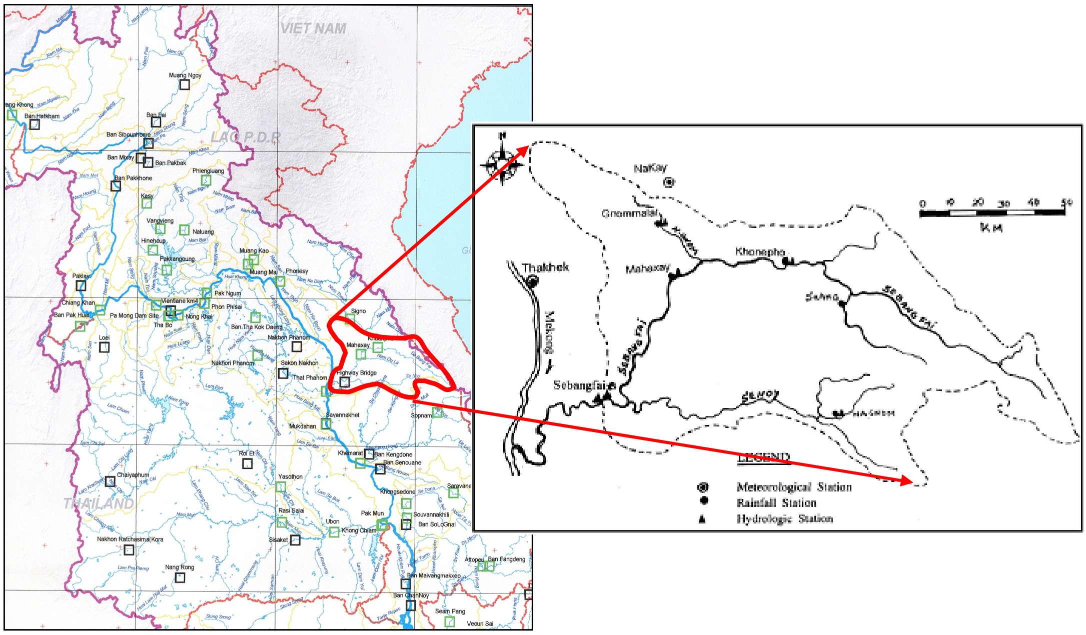

Figure 21: Location of the Sebangfai River Basin in the Mekong River Basin in Laos.

commands of taking appropriate actions. The tools utilized for these tasks the Water Resources and Environment Research Institute (WERI) include the Decision Support Framework (DSF) tools developed by the Mekong River Commission (MRC) Programmes. With regards to the further implementation of AWCI activities, Lao PDR has encountered many challenges and gaps to be filled up. To fulfill the roles and overcome those challenges, Lao PDR is expecting to be part and benefit from the accelerated coordination and integration efforts, which urgently focus on capacity building of both personnel expertise and sciences and integration of various fields.

Malaysia

The Langat River Basin, Malaysia DP and CCAA basin, is located in the mid western part of Peninsular Malaysia and encompasses areas within the states of Selangor, Negeri Sembilan and Putrajaya Federal Territory (Fig. 22). It lies adjacent to the south of Klang Valley, the most highly developed urban conurbation in Malaysia. The total land area of the basin is estimated to be about 2,350 km^2. Two major dams namely Langat and Semenyih Dam are located in the upper basin as it provides domestic and industrial water supply for Kuala Lumpur, Putrajaya and areas joining to it. During the past decades, the Langat Basin experienced intensive urbanization, which resulted not only in rapid creation of large impervious areas producing significant problems, such as regular flooding due to inadequate drainage facilities and managements, but also the increase of water demand for domestic and industrial purposes. The frequency of water stress (droughts) and excess of water (floods) are expected to magnify in the near future which is mainly due to climate change and variability.

A scientific research by means of climate change modeling and projection that has been conducted in Peninsular Malaysia indicates a possible increase in inter-annual and intra-seasonal variability with increased hydrologic extremes which is higher high flows and lower low flows at various northern watersheds in the future. Therefore, the primary objective of Langat demonstration project was to carry out climate change assessment and adaptation (CCAA) on the resources, environment and socio-economics of the basin. It intends to quantify the potential climate change impacts on water resources and also to determine appropriate adaptation options for minimizing the impacts. The CCAA has been carried out into two components: water supply (droughts) and floods analysis. The

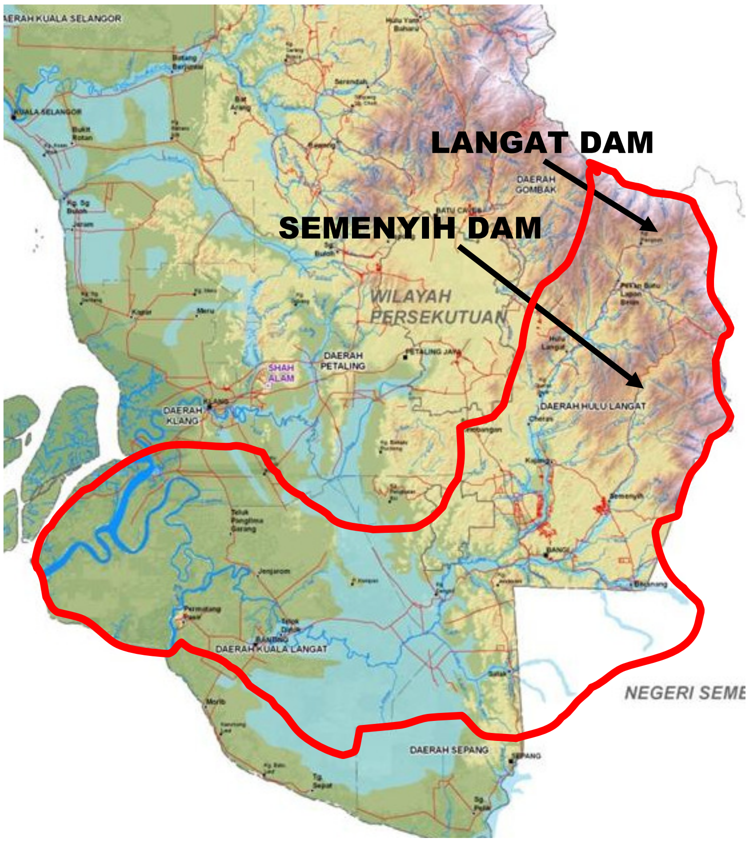

Figure 22: Location of the Langat River Basin in Peninsular Malaysia.

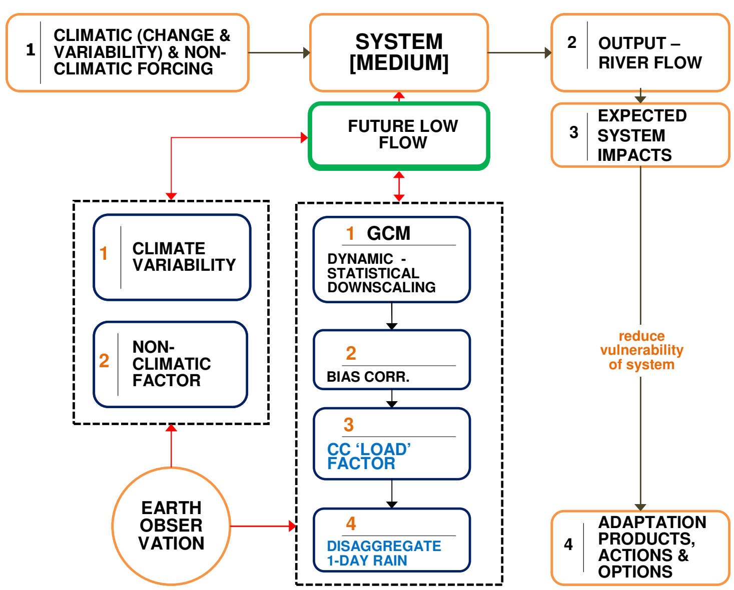

Figure 23: Framework of the CCAA project of AWCI Phase 2 in Malaysia.

CCAA for drought and water supply included storage-yield analysis and water supply and water demand modeling up to the segmented time horizon of 2050. As for floods, particularly for river flood protection, analysis has been carried out among others are to examine structural integrity of existing or near future proposed floods related infrastructures at the protection level of 100-year average recurrence interval (ARI). Subsequently, the cost and options of adaptation for water resources will be determined, and it is defined by a combination of the cost of providing flood protection and water supply, which are estimated based on three scenarios: (1) socio-economic baseline, (2) baseline and climate change, and (3) climate change scenario only.

The in-situ data from the Langat basin have been submitted to the DIAS database as committed. As to utilize the DIAS system, the basin climate change factor of rainfall was derived from 18 GCMs with respect to 20 years recorded data of 7 rain gauges for the segmented time horizon of 1981-2000 (historical) and 2046-2065 (future). The results showed increase of the 1-day design rainstorm at 100-years average recurrence interval (ARI) by average factor (over the ensemble of GCMs) ranging from 1.04 – 1.23 in different part of the Langat basin. In addition, it has also been derived from National Hydraulic Research Institute of Malaysia (NAHRIM) Regional Hydroclimate Model (RegHCM) 9km grid for the period of 2025-2034 and 2042-2050. The analysis of future water availability over the peninsular Malaysia showed that in number of areas, less water is expected while in others it may increase. The CCAA study continues to be carried out by NAHRIM and has been evolving into a more complex project participating in the AWCI Phase 2. The concept of the project is in Figure 23.

In line of Integrated Water Resources Management (IWRM), Integrated River Basin Management (IRBM) and Integrated Floods Management (IFM) which would accommodate and support the concept of 'green growth with blue' (GGB), the CCAA is definitely able to assist and connect the knowledge generated by the scientific community and the specific needs of stake holders. There is a need to re-examine the conventional practices of planning methodology which requires of imposing the CCAA into planning methodology in order to achieve sustainable development of water resources and to reduce future hydro-climate hazards. In addition, the adaptation actions could be strengthened by means of the economics of adaptation to climate change (EACC) through cost benefit analysis (CBA) as to justify and determine adaptation cost and options. In this context, the Malaysian Government through the Economic Planning Unit (EPU) of Prime Minister's Department embarked with the economics of climate change study for Malaysia (ECCM) which aims to assess the economic costs and benefits of adaptation and mitigation measures in water resources, agriculture and energy sectors.

Mongolia

The selected Selbe River Basin is located in center of Mongolia, in the north of Ulaanbaatar. It is the upper basin of the Tuul Stream basin (6300 km^2). In past 20 years, settling area and population have been rapidly increasing, which resulted in substantial increase of number of house buildings, paved areas, groundwater wells and livestock pasture. In addition forest cut and cultivation took place in some extent. The main goals of the DP included surface and ground water monitoring and modeling to assist better management in light of anthropogenic influences and climate change impact and

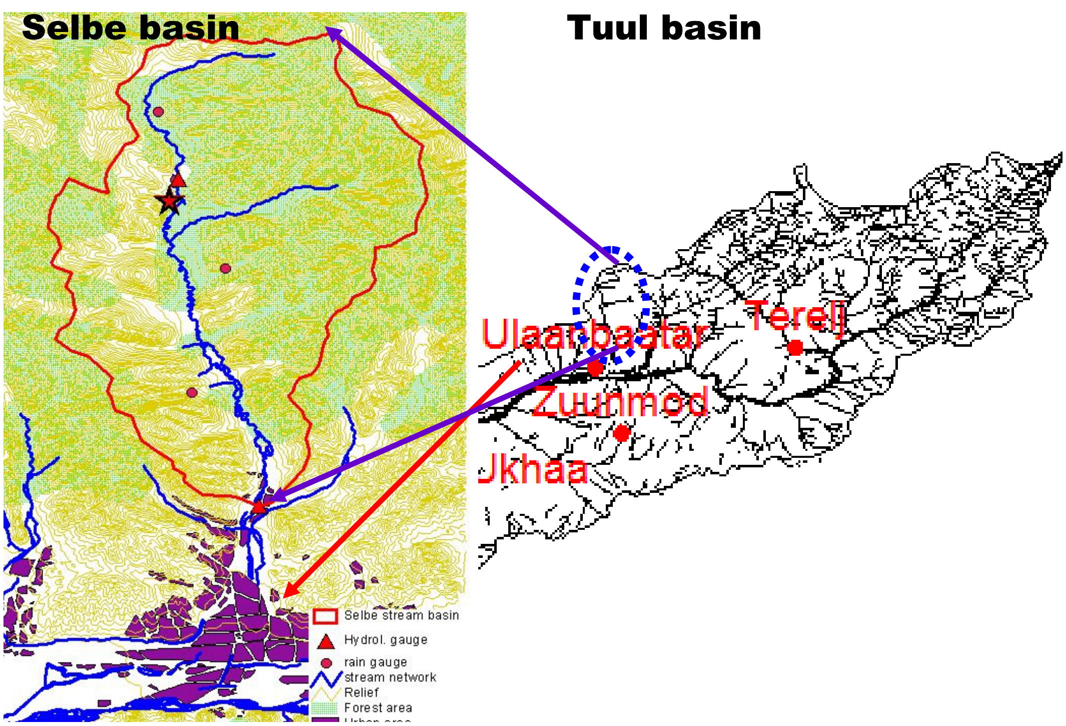

Figure 24: Selbe River and Tuul River Basins in Mongolia.

flood control, assistance in development of information systems for promoting the implementation of IWRM in the Selbe and Tuul River Basins. While the Selbe Basin was the focus of DP, the Tuul Basin above the city of Ulaanbaatar was nominated for the CCAA study.

The in-situ data have been submitted and quality checked as committed for both, the DP and CCAA. The WEB-DHM has been developed for the Tuul basin, but it is yet to be prepared for the Selbe basin. A preliminary CCAA study was carried out using HadCM3 model output for future periods 2046-2065 and 2080-2099. The results showed increase in annual mean temperature as well as annual mean precipitation. In addition, the Mongol AMSR/AMSR-E/ALOS Validation Experiment (MAVEX) is going on in Mongolia, which includes extensive and intensive in-situ measurement of soil moisture for validation of satellite soil moisture observation algorithms. A few stations of MAWEX are also contributing to the AWCI activities, namely the objectives of the Drought working group as provided in detail in the final report of the CAPaBLE project CBA2011-02CMY-Kaihotsu.

Myanmar

The demonstration basin of Myanmar is the Shwegyin Basin, a relatively small basin of about 1697.9 km^2. There is only one meteorological and hydrological observation station in this basin. The main goal of DP was to promote the flood forecasting system in the basin and this basin has also been nominated for the CCAA study. Daily mean water level, discharge and daily rainfall during 2003 and 2004 and also daily water level (1991-2010) were provided to the DIAS database as committed. Accomplished activities of DP include:

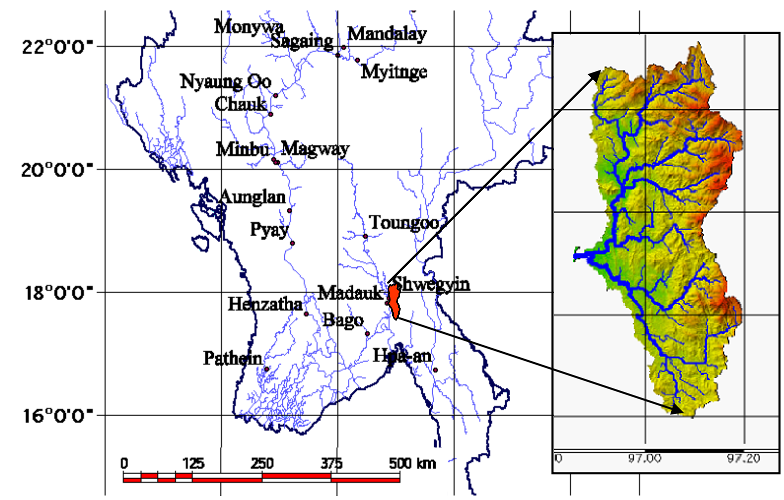

Figure 25: Shwegyin Basin in Myanmar.

(a) The geomorphologic parameters were determined by using River Tools Software.
(b) The design flood and design rainfall for different return periods and probable maximum precipitation for duration of one to three days were calculated.
(c) The unit hydrograph was calculated, which is useful in the development of flood hydrograph for extreme rainfall magnitudes for use in design of hydraulic structures and development of flood forecasting and warning systems based on rainfall.
(d) Capacity building was also done by purchasing the GIS software (River tools and TNTmips Image Processing Software), holding the training to develop the GIS application and also training workshop on the IFAS model during June 2010. The IFAS training was held as part of the AWCI Flood Working Group activities, supported by ICHARM (see also the final report of the ARCP2009-01CMY-Fukami).

As for the CCAA study, the Department of Meteorology and Hydrology (DMH) of Myanmar carried out studies on the climate change impacts using the MAGICC 5.3 model focusing on temperature and precipitation during 3 periods (2001 – 2020, 2021 – 2050, and 2051 – 2100) and also using the ECHAM5 Model with Global Warming Experiment. The results, which were presented at the 8th AWCI ICG meeting in Seoul, Korea, October 2011, suggested that during the 21st century:

- Annual, April, and May temperature of Myanmar will increase.
- Rainfall for SW Monsoon period is also expected to increase.

- Late onset will be at deltaic area, central Myanmar and northern Myanmar and early withdrawal from whole country.
- Predicted length of rainy season showed that it will be shorter than normal (144 days).
- Monsoon intensity will be generally moderate along the Myanmar coast.

(See: http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Seoul_Oct2011/pdf/3-06_Yi.pdf)
In addition, the WEB-DHM was developed for the Shwegyin basin in cooperation with the UT team and applied for a preliminary CCAA assessment at the March 2011 training course.

The Myanmar DMH has been involved in the Initial National Communication (INC) project of Myanmar under UNFCCC as well as in the National Adaptation Plan of Action (NAPA) project, which is commencing in Myanmar for vulnerability assessment and measures for reduction of impact and strategy for adaptation.

Nepal
Nepal has proposed two river basins namely the Bagmati River Basin for the DP and the Narayani River Basin for the CCAA study (Fig. 26). Bagmati is a medium type of river of Nepal with drainage area of 3700 km^2. It originates from Shivapuri Hill (2731 m) and flows down to south through Kathmandu valley up to Indo – Nepal border. Nakhhu, Kulekhani, Kokhajor, Marin and Chandi rivers

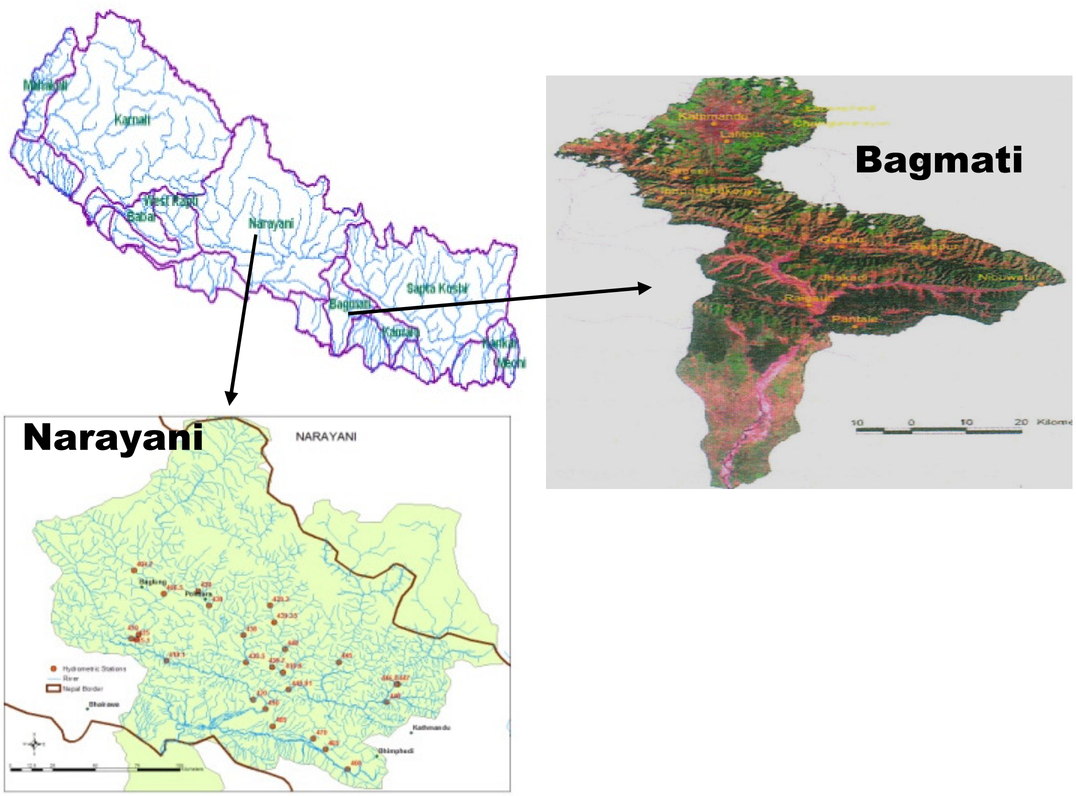

Figure 26: River Basins of Nepal and locations of the Bagmati and Narayani Basins.

are its major tributaries. Flood damages, landslides, bank erosion and water pollution are acute problems in the river basin. There are 21 meteorological stations and two hydrometric stations within and around the basin. The main objectives of the DP were (i) to assist in preparing the formulation of improved River Management Plans, (ii) to set priority activities and projects to increase water security in the river basin which are expected to include flood forecasting and management, drought management, water allocation, and pollution control, and (iii) to develop an effective rainfall – runoff simulation Model. Among major issues with regards to IWRM practices is the lack of a basin wise single institution responsible for water resources decision making. Accordingly, one of the priority tasks is to address this issue and set up a single institution within the basin, which can take water related decision based on IWRM principles. Such efforts are now ongoing in Nepal. As for the technical part, the in-situ data has been provided to the DIAS database and quality assured as committed. While the WEB-DHM-S model has been developed and validated using in-situ observations in Nepal, its development and application in the Bagmati basin is yet to be done.

The Narayani River Basin is a major river basin of Nepal. It has total drainage area of 34960 km^2 out of which 29626 km^2 lies in Nepal and 5334 km^2 lies in Tibet, China. The basin contains 1025 glaciers and 338 glaciers lakes out of which 4 are potentially dangerous for GLOF. It has 2030 km^2 area under ice and snow cover. Budhi Gandaki, Trishuli, Marsayndi, Kali Gandaki and Seti are major tributaries of the Narayani River. GLOF, landslides, flash flood and flood inundation are severe problems in the river basin. There are 58 metrological and 26 hydrometric stations in and around the basin. The precipitation data for the CCAA preliminary study has been submitted to the AWCI database as committed. The WEB-DHM has been developed for the purposes of the preliminary work at the March 2011 training course. Nevertheless, the full study requires application of WEB-DHM-S model suitable for glacier and snow areas.

As mentioned above and in Section 2.2, WEB-DHM-S model was developed and validated using observations from Nepal (Shrestha et al. 2012). Namely, it was the Dudhkoshi region of the eastern Himalayas using the observed data of the Global Energy and Water Cycle Experiment (GEWEX) Coordinated Enhanced Observing Period (CEOP) for the snow season 2002/2003. Point evaluations (snow depth and upward short- and longwave radiation) at Pyramid (a station of the CEOP Himalayan reference site) confirm the vertical-process representations of WEB-DHM-S in this region. The simulated spatial distribution of snow cover is evaluated with the Moderate Resolution Imaging Spectroradiometer (MODIS) 8-day maximum snow-cover extent (MOD10A2), demonstrating the model's capability to accurately capture the spatiotemporal variations in snow cover across the study area. Through these evaluations, WEB-DHM-S has demonstrated its capacity to address basin-scale snow processes in the Himalayan region.

Pakistan

The Gilgit Basin consisting of two main rivers, Gilgit and Hunza, located in the upper Indus River Basin has been nominated for the DP and the Hunza basin also for the CCAA (Fig. 27). These basins are located in the Karakoram mountain region with steep slopes and large extent covered with glaciers and snow. The upper part of the whole Indus basin represents about 20% of its extent but contributes about 80% of all discharge of the Indus River. Majority of the flow is produced by snow and glacier melting during the summer season. Accordingly, the main focus of the DP and CCAA was on snow and glacier processes, in particular better ability to simulate and predict discharge for flood forecasting and warning, including glacier lake outburst floods (GLOF), and to assess possible impacts of climate change on glacier and snow water reservoirs in the area.

The in-situ data of the both, Gilgit and Hunza river basins have been provided to the DIAS database as committed (Table 1 and 2 above). Considering the natural conditions in the area, the snow-cover and snowmelt modeling capability is essential for any water cycle studies in this region and thus a hydrological model capable of snow and glacier processes simulation was required to implement the DP and CCAA studies and implement the intended river management system. With coming of WEB-DHM-S in 2011 and its fully validated version in 2012, this has become possible.

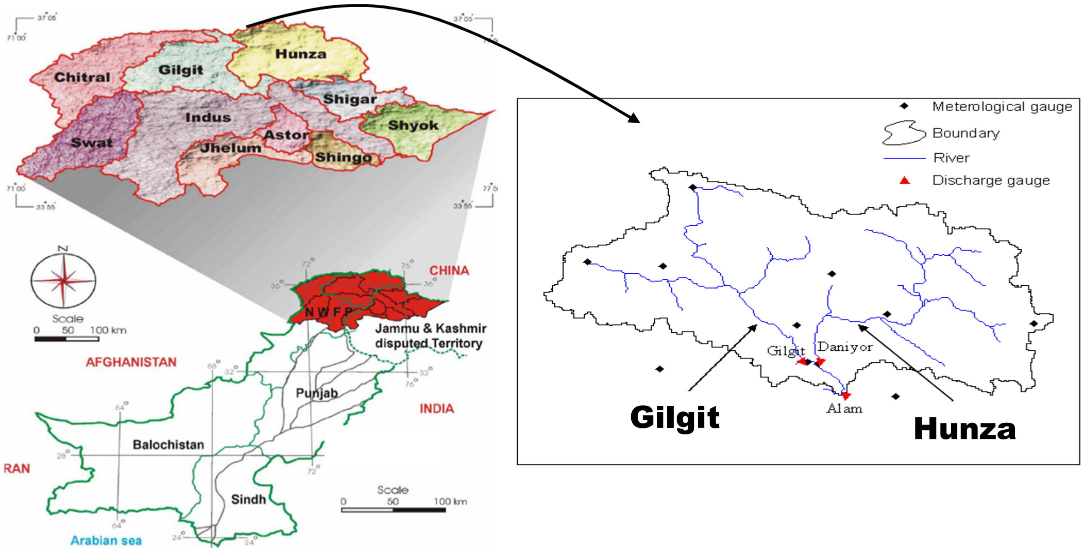

Figure 27: The Gilgit and Hunza River Basins in the Upper Indus River region in Pakistan.

In addition, at the beginning stage of the ARCP2011-02CMY-Koike project, Pakistan experienced benefits of the AWCI collaborative framework in a practical case. Serious damage happened in Pakistan in August 2010 due to floods and mudslides caused by heavy rains which occurred continuously since July 29, 2010. The flood damage spread from north to south in Pakistan along the Indus River and its tributaries. The Japan Aerospace Exploration Agency (JAXA) has made observations using the Advanced Land Observing Satellite (ALOS, "Daichi") to monitor the state of the damage and provided them to the responsible Pakistani institutions to support the disaster management efforts. First analysis of those ALOS images is available at the AWCI website at: http://monsoon.t.u-tokyo.ac.jp/AWCI/data.htm. In addition, the AWCI collaborating institute, International Centre for Water Hazard and Risk Management (ICHARM), carried out a prompt flood analysis using the IFAS system promoted by the AWCI Flood working group (http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Oct2010/pdf/4-8.pdf).

Through the demonstrations at the AWCI meetings and training courses and positive experiences with the AWCI framework, the original DP has evolved into a comprehensive project on assessment of possible climate change impacts on water resources in selected basins in Pakistan, including the Hunza basin representing the mountain region and Soan River Basin, which originates in the foothills of Muree, north-east of Islamabad and passing through the steep slopes, it enters the plains near Islamabad and follows to the west until it reaches the Indus River. The plains of the Soan Basin are largely utilized for agriculture, which depends on received precipitation and assessment of the climate change impacts is highly desirable. The project has been implemented with support of the JAXA’s SAFE program (Satellite Applications for Environment) and University of Tokyo providing expertise in hydrological modeling and climate change assessment. The study in the Soan River followed the AWCI CCAA methodology introduced in Section 2 and including bias correction of GCM output, downscaling it and using it to run WEB-DHM to assess future water budgets. The results showed that it is virtually certain that floods will occur more often but at the same the basin will also very likely suffer from droughts in future. The Hunza Basin study focused on simulation of the snowcover and snow- and glacier-melt runoff at current time, because methodology to correct snowfall projections has yet to be developed. The model results showed acceptable accuracies in simulating the snow cover area and discharge. The contributions of glacier melt, snow melt runoff and rainfall to total discharge were estimated showing minor contribution from rainfall (~10%) and dominant contribution by snowmelt (~40%) and glaciermelt (~50%). These studies should be published in peer reviewed journals in 2013 or 2014.

Philippines

The Pampanga River Basin was selected for DP, which is the forth largest basin in the Philippines (Fig. 28). The total length of the main river is about 260 km. The basin is drained through the Pampanga River and via the Labangan Channel into the Manila Bay. The main river is supported by several tributaries. It has a relatively low-gradient channel at the middle and lower sections. There are two dams within the river basin and the main objective of DP was optimal multi-purpose reservoir operation as well as downscaling techniques for IWRM and CCAA. The same basin was chosen for the CCAA study.

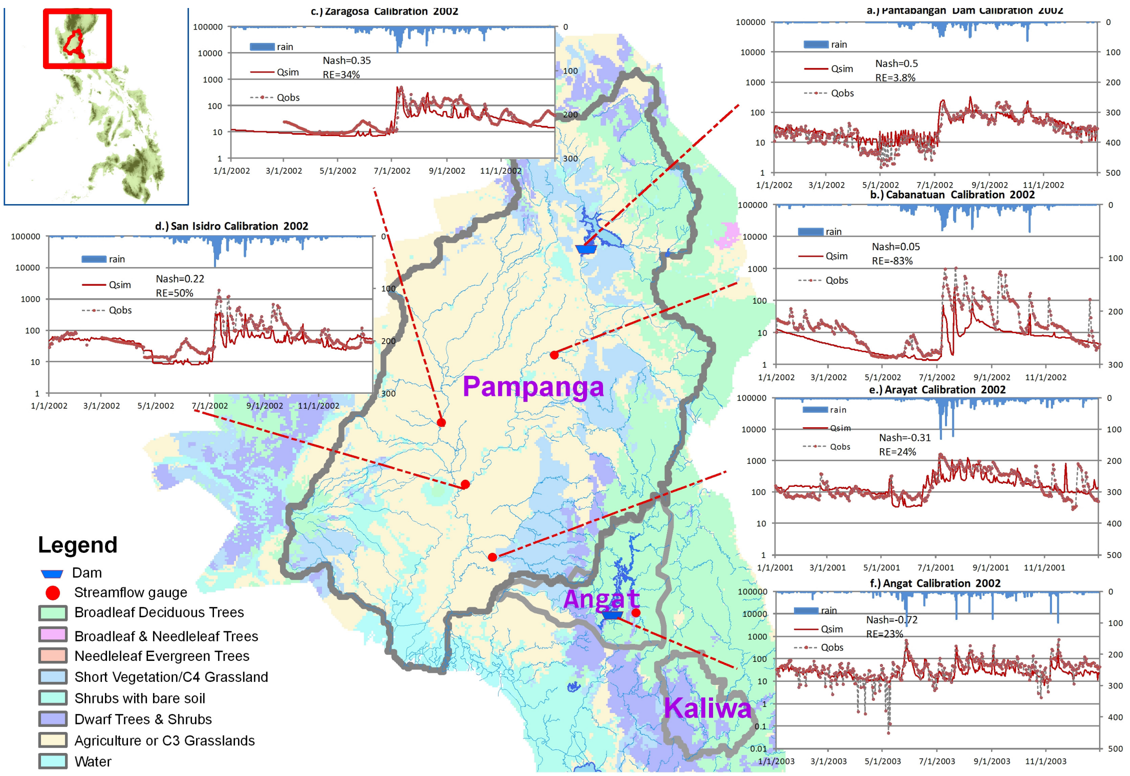

Figure 28: The Pampanga, Angat and Kaliwa River Basins in Philippines.

The in-situ data from the Pampanga basin has been provided to DIAS as committed for the DP and CCAA study. The WEB-DHM was developed and applied in a study on quantification drought following the diagram in Figure 29 (Jaranilla-Sanchez et al. 2011). Following up on this study and a preliminary climate change assessment efforts at the March 2011 training course, the original DP has been expanded and evolved into a comprehensive project contributing to the Water Security Master Plan for Metro Manila and its Adjoining Areas. The project was proposed by the Metropolitan Waterworks and Sewerage System (MWSS) of Philippines and supported by the University of Tokyo, Japan International Cooperation Agency (JICA), and Nippon Koei Co., Ltd., who carried out a study on Climate Change Assessment and Runoff Simulation. The project includes the Pampanga basin and also the Angat Basin with the multipurpose Angat dam and the Kaliwa Basin (Fig. 28) as water supplying basins for Metro Manila. There were two main objectives of the study:

- To assess the effects of climate change on the water cycle in Metro Manila and its adjoining areas, including the Angat, Kaliwa and Pampanga river basins, as a basis of the water balance analysis and associated project assessment.
- To propose optimized operations of the water resources management facilities.

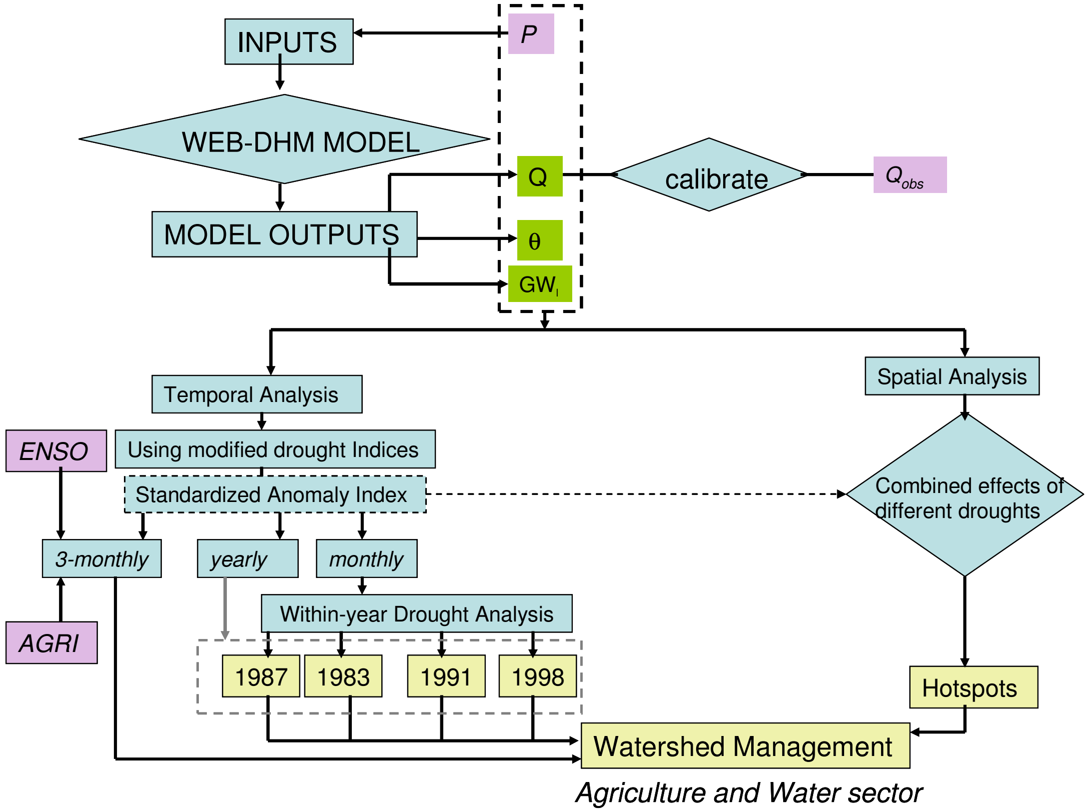

Figure 29: Diagram on methodology for quantifying drought. P = precipitation; Q = discharge (simulated and observed); θ = soil moisture (root zone and surface); GWl = groundwater level measured from the soil surface; AGRI = agricultural production de-trended and normalized; ENSO = Niño 3.4 Index

It has been acknowledged that the water supply balance in Metro Manila should be analyzed in a comprehensive manner, and that a comprehensive development project for the surrounding regional development was needed to prioritize the individual issues unique to each project with respect to the water resources development. Under climate change with frequent heavy rainfall events, larger drought-affected areas and severe typhoons as pointed in the IPCC Forth Assessment Report (2007), it is important to evaluate the vulnerability of long-term water resources and the merits of employing multiple water-use facilities. An integrated water cycle analysis during both the low-water and high-water periods is needed, and such analyses should be conducted quantitatively, continuously, and comprehensively. Furthermore, optimized operation of multiple water-use facilities should be examined as a part of climate change adaptation. To accomplish these targets, this study included

- Water supply analysis and climate change impact assessment;
  - Collection of climate prediction simulation results in Metro Manila and its adjoining river basins
  - Evaluation of the effects of climate change in Angat River Basin, Kaliwa River Basin, and Pampanga River Basin following the methodologies outlined in Section 2.2 above (GCM output selection, bias correction, downscaling)
  - Hydrological model development and river runoff simulation
  - Simulation of stream flow under the effects of climate change in the future
- Examination of the optimized operation of water-use facilities

The study has been completed and the results partly published (Jaranilla-Sanchez et al. 2013) including the climate change assessment component. It indicated very likely increase in flood intensities and frequencies in all the basins. On the other hand, the results also suggested that severe droughts will very likely to occur in the Pampanga river basin but about as likely as not in Angat and Kaliwa basins with local conditions playing a very important role in how floods and droughts affect them. However, careful consideration of uncertainty should be considered for water resource management planning factoring in future changes in climate in these basins. The results of the dam operation optimization study using the DRESS scheme introduced in Section 2.2 showed that appropriate in-advance dam release based on QPF with reasonable accuracy can achieve flood risk reduction and effective water use both and should be published in a peer reviewed journal in the near future.

Sri Lanka

The demonstration basin selected in Sri Lanka for AWCI is the Kalu Ganga basin, the fourth largest river basin on the island covering the area of 2720 km^2. It is located at the South-Western part of Sri Lanka (Fig. 30) and contains regions of high rainfall receiving an annual average rainfall of 3000 mm. The Kalu Ganga is about 130 km long and discharges into the Indian Ocean at the coastal city of Kalutara. The Kalu Ganga floods, which are inflicting heavy damages to properties and lives in the Districts of Ratnapura and Kalutara, is an annual phenomenon of national importance. Though several attempts have been made to reduce the flood risks by the river, the flood disasters continue in the basin due to climatic, hydrologic, topographic and land use characteristics in the basin.

The broad objective is to minimize the damages caused to the lives, economy and the environment due to floods in the basin. The project demonstrates how distributed hydrological models incorporated with remotely sensed data could be useful in flood disaster reduction. Specifically, the project focused on (i) effect of alternative structural methods and non structural methods on flood risk reduction and (ii) identification of inundation levels of different floods and the possibility of implementation of early warning systems based on real time flood forecasting.

The in-situ data of the Kalu Ganga basin has been submitted to DIAS and quality controlled as committed for both, the DP and CCAA study. The WEB-DHM model has been developed and used for the preliminary CCAA efforts at the March 2011 training course. In addition, the following has been accomplished by the national team in Sri Lanka (see presentation at the 8th AWCI ICG Meeting in Seoul, Korea, October 2011: http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Seoul_Oct2011/pdf/3-03_Weerakoon.pdf):

- Flood Modelling of Kalu-Ganga river basin has been carried out by the application of HEC-HMS and HEC-RAS models.
- Weather modeling by WRF and downscaling rainfall at local scale from regional climate models.
- Analysis of variation of extreme rainfall in future due to climate change and application adaptation techniques for reducing flood damages. The extreme rainfalls over the Kalu-Ganga river basin have increased and therefore, more severe floods could be expected to occur in the basin in future.
- In addition, identification of future extreme rainfall and flood conditions for proposing suitable adaptation measures to minimize the risks of damages and losses caused by the floods affected by climate change was carried out in the lower Kelani Basin (located north of the Kalu Ganga and containing the capital city of Colombo) using the following models:
    - Statistical Downscaling Model (SDSM) for rainfall forecasting under A2 & B2 scenarios
    - Hydrologic Engineering Center – Hydrologic Modeling System (HEC–HMS) – for rainfall runoff simulations
    - FLO–2D model for flood and inundation analysis at lower catchment

  The possible inundation maps for future flooding were developed.

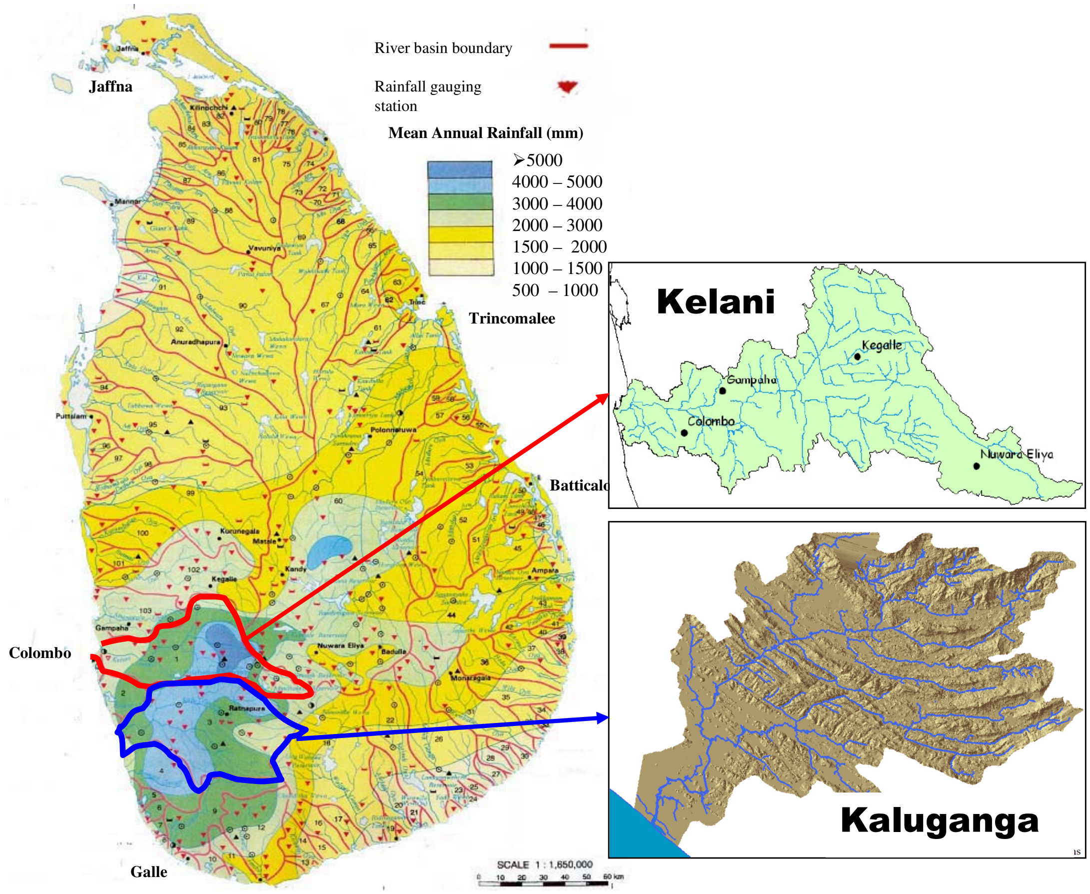

Figure 30: Location of the Kalu Ganga and Kelani River Basins in Sri Lanka

Thailand

Affected by global climate change and related factors, the problems of flood hazards, landslide and debris flow in most regions of Thailand have obviously increased in recent years and still have trend to occur with more frequency, severity and area extension. These disasters cause economic and life losses nationwide in each year. The main cause of the floods comes from the same source that is the rainfall. During the wet season, humidity brought from the ocean onto the land by southwest monsoon influences upon the region is the main source of rainfall meanwhile tropical storms and depression troughs with high intensive rainfall are the triggers of the floods. Deforestation, encroachment of the upstream area for settlement and cropping including the extended settlement into the vulnerable part of the urban area resulted by the population growth are also the antecedent factors that support flood problem. Moreover the infrastructure development such as road construction in the mountain areas and plains, bridge piers, dam and weir could become the obstructions against runoff drainage during the storm events and reinforce the severity of flood.

With realization of the flood hazard which causes suffer and losses each year, the Royal Irrigation Department (RID) with cooperation and supports by AWCI, including the relevant APN projects, set up the telemetering network system in the Mae Wang Basin, the upstream sub-basin of Chao Phraya Basin in Chiang Mai province, northern Thailand (Fig. 31) as a part of the AWCI DP in Thailand. The network consists of 16 automatic rain gauge stations (4 super-telemetering sites and 12 normal rain gauge sites) to survey and collect the meteo-hydrological data related with flooding such as rainfall, runoff, water level, air temperature, soil humidity and ground water level etc. The data collected by

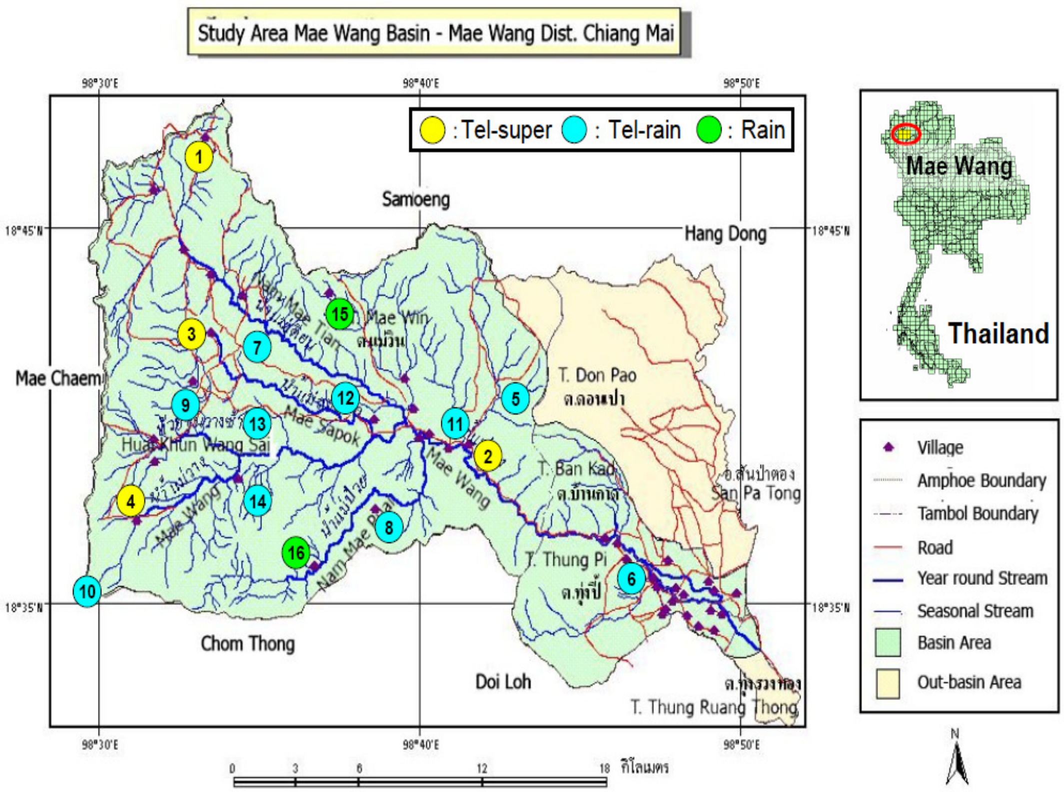

Figure 31: Mae Wang Basin in the North Thailand with locations of observation stations including telemetric super sites (yellow dots) observing a set of hydro-meteorological variables, telemetric rain gauges (turquoise), and ordinary rain gauges (green).

automatic data-logger transferred directly to the center office by cell phone modem connection is helpful for real-time flood monitoring and early warning. Besides, the available information from other sources such as the weather map, weather forecasting, storm-track satellite images, daily rainfall reports and regional hourly rainfall radar images are also employed for concurrent analysis before disseminating the flood forecating and warning. Anyway, although flood warning announcement or flood information may be prepared from advance sources or some multiple high technology instruments but in the stage of dissemination to the public through any type of media, it should be simplified into the friendly interfaces for the people to access and understand conveniently. Flood information board installed at the landmark point of the community is one of the simple channels for public relation that people can monitor the current river situation by themselves, symbolic colour painted staff gauge at the riverside could be a clear and simple concrete water level indicator and the information broadcasted on radio and television or even on internet websites should not to be too complicated to understand.

The model of flood warning system from Mae Wang Basin DP now applied to The Chao Phraya Basin, the main basin of the central region, but there are still some parameters to be adjusted for appropriate application due to the differences of physical factors and area characteristics. The warning system aims to prevent and mitigate the hazard of flood disaster from any losses. People need to be informed with quick, accurate and reliable information and be able to estimate the scale of flood for preparation and dealing with the situation in any stages of pre-flood, during flood or post-flood without panic or careless. Furthermore the results from the warning system research and development may partly lead us to find the resolution for global warming and climate crisis in comprehensive dimensions and sustainability.

In addition to the development of the above system, Thailand has submitted the DP and CCAA data for the Mae Wang Basin as committed. The WEB-DHM has been developed for the purposes of the March 2011 training course. The CCAA study is now on-going.

Uzbekistan

The selected Chirchik-Akhangaran basin is located in northeastern part of Uzbekistan. There are two rivers – Chirchik (161 km) and Akhangaran (223 km) and the basin has 67 lakes with different genesis type. Snowmelt induced runoff generates 60-75% of the total streamflow, which is exploited for hydropower generation at 19 hydropower plants within the basin. Floods including mudslides and sediment transportation are the major issue in the basin. The main objective of the DP was determination of an adequate flood warning system in the basin. In addition, possible changes of the flow regime due to climate change impacts are also of great interest in this basin, which contains remarkable mountain area covered with glaciers and seasonal snowcover.

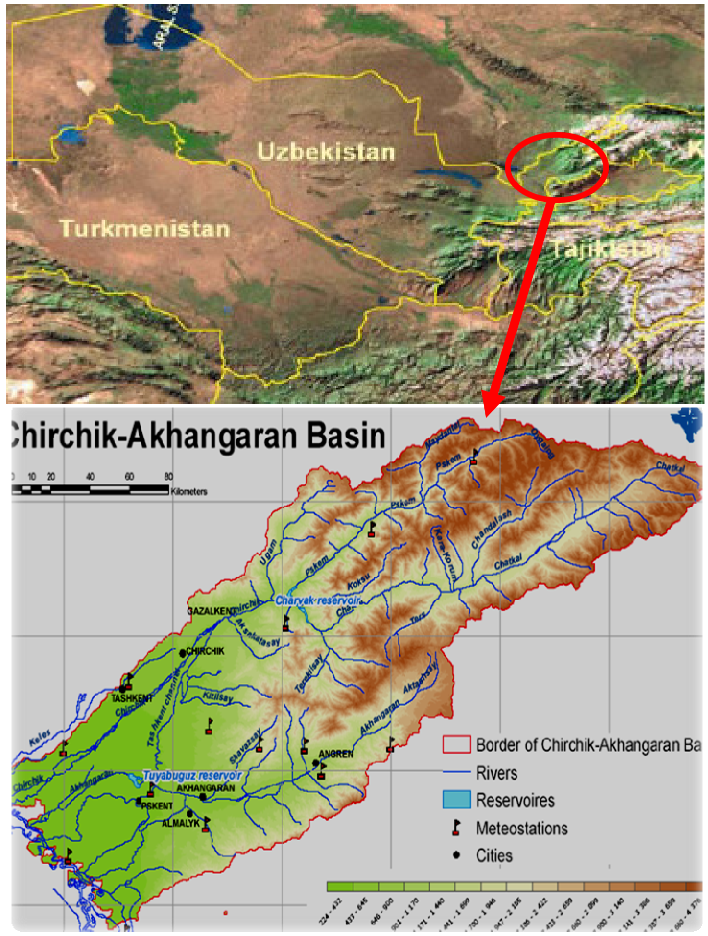

Figure 32: The Chirchik-Akhangaran Basin in Uzbekistan

The data for DP and CCAA study in the nominated basin has been provided as committed. The WEB-DHM has not been developed yet but climate change impact assessment study in the basin was undertaken by Uzhydromet, the Center of Hydrometeorological Service (NIGMI). Various scenarios of greenhouse gases emission were considered by a set of GCM for two periods in future, namely 2015 – 2030 and 2020 – 2050. The results showed possible seasonal changes in the precipitation regime with decrease of spring precipitation and increase in other seasons. It was also found that large valley glaciers are rather vulnerable to unfavorable meteorological conditions like air temperature rise and that the present-day weather conditions are extremely unfavorable for the existence of these glaciers. Moreover, reduction of glaciations in foreseeable future will have negative consequences on the volume and regime of flow, as well as the quality of fresh waters in the basin. If the contribution of glacier and snow component in the flow of the Chirchik river is evaluated as 60-75% at present time, then its value will be decreased by 15-30% when realizing different scenarios of climate change.

In addition, the mathematical model of small mountain river flow generation, which had been developed by NIGMI, allowed evaluating the reaction of the flow of small water collections to the possible climate changes in different height and climatic zones of Uzbekistan according to the changes of meteorological parameters. The range of reactions of small rivers to the climatic changes is rather wider. Differentiated analysis based on the sources of feeding and regularity of flow generation in different altitude zones showed that greater changes should be expected in the zone of mountains, which are close to glaciers. These changes will be accompanied with the increase of glacial component of flow and with the decrease of glaciations. The equality of volumes of snow and ice feeding is usually observed on the rivers, where the glaciers occupy at least one third of the basin area. The flow of these basins will be increased at the expected warming according to the chosen gradations of precipitation change. In case of realization of scenarios causing moderate reduction of precipitation simultaneously with air temperature increase, the flow from the middle and low altitude zones will be decreased.

Viet Nam

The Huong River Basin was selected for the DP and CCAA study in Viet Nam (Fig. 33). It belongs to the Thua Thien Hue province in the coastal part of the Central Viet Nam and covers the area of 2830 km^2, of which over 80% are mountains. The Huong River system contains three main rivers: Ta Trach, Huu Trach and Bo River. The Huong River is rather short and steep; it runs from mountains to the low plain area. Time of concentration is short and the basin has low storage capacity. Floods and inundation often occur very quickly and severely. The main goal of the DP was to improve accuracy of flood forecast and to get efficient flood warning system.

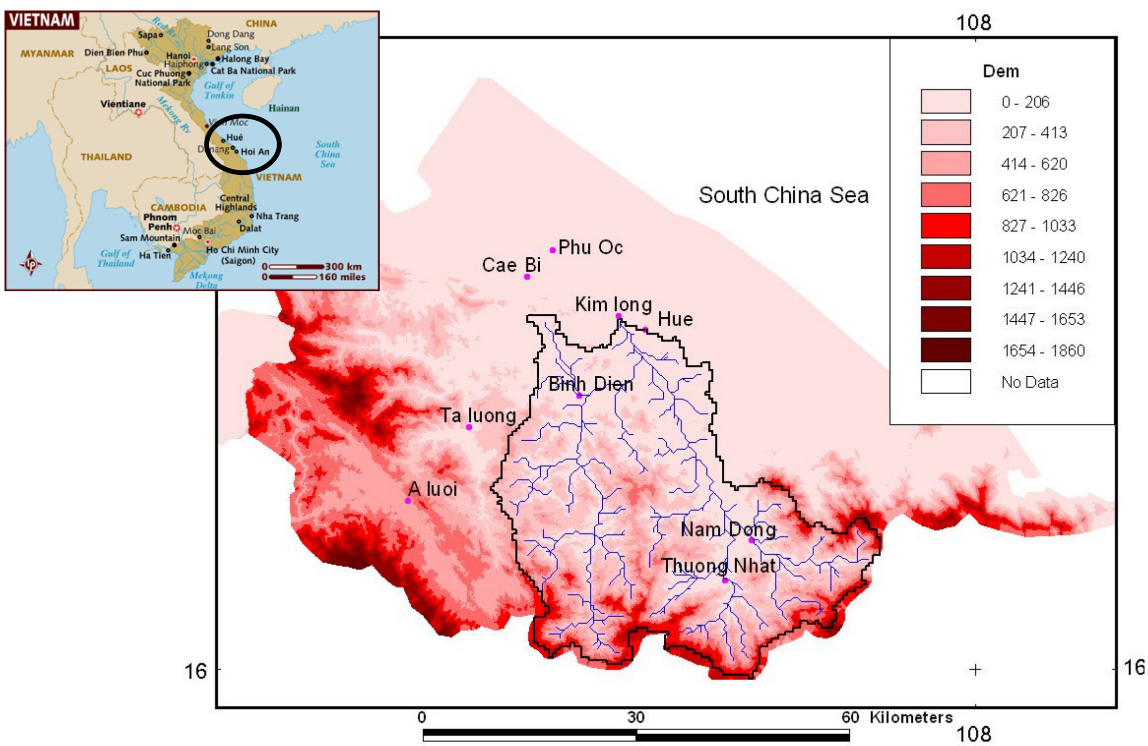

Figure 33: The Huong River Basin in the Central Vietnam.

The in-situ data for DP and CCAA has been submitted to the DIAS database as committed. The WEB-DHM model has been developed in the basin and applied in several activities including the targeted flood forecasting system using satellite data and numerical rainfall forecast. In a test case, the flood inundation at Hue City was predicted for flood alarming and preparedness using weather forecast by a High Resolution Model (HRM) with 6 hours lead-time (Saavedra and Koike 2008). Two experts have been trained in using distributed hydrological models including WEB-DHM in collaboration with the University of Tokyo. In addition, inter-disciplinary collaborative research in the Huong River has been

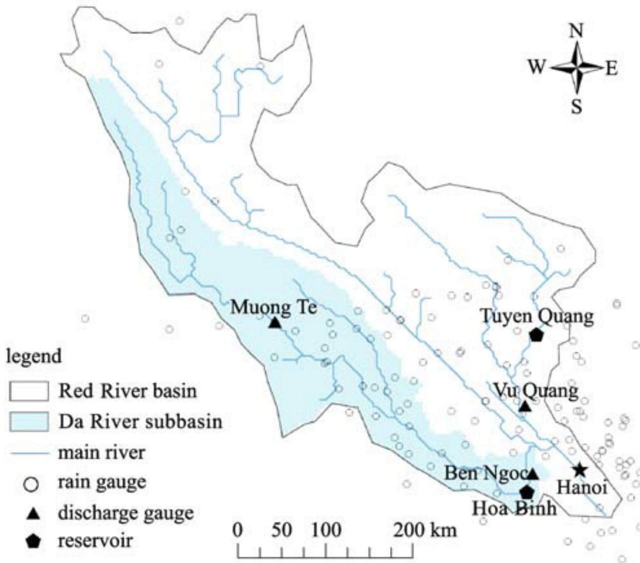

Figure 34: The Red River Basin in China and Viet Nam.

initiated and advanced that uses WEB-DHM and includes water quality component and involves water quality and health science groups under the frameworks of the GEOSS/AWCI and The Global Center of Excellence (GCOE).

A preliminary CCAA study activities were undertaken and the March 2011 training course and plans are for further assessment for the basin based on trained models and intensive research work followed by testing some modeling in water quality management and improvement flood forecasting system in line with climate change.

In addition, WEB-DHM coupled with the reservoir routing module and dam operation optimization scheme (DRESS) was applied to the Red River basin in the northern part of Viet Nam (Fig. 34) for optimization of the Hoa Bihn reservoir operation as a contribution to the IWRM practices implementation process in Viet Nam. This was a pilot study using the observed data for a historical flood event, which was carried out in cooperation with the University of Tokyo (in detail described in Wang et al 2010c). Spurring from this pilot study a complex project has been proposed under the framework of Asia-Pacific Regional Space Agency Forum (APRSAF)/SAFE in collaboration with JAXA and the University of Tokyo, which aims to develop a robust dam operation support system utilizing weather forecast in the Red River basin. Furthermore, a proposal was placed for Regional Capacity Development Technical Assistance (R-CDTA) for applying remote sensing technology in river basin management for Philippines, Bangladesh, Viet Nam with support of ADB. The project preparation activities have advanced and a draft implementation plan is underway.

3.3 Implementation Plan for the Next Phase of AWCI

At the 8th AWCI ICG meeting in Seoul, Korea in October 2011, strategies for the 2nd phase of AWCI were discussed. The concept of the GEOSS Water Cycle Integrator (WCI, see Appendix B) was introduced that aims at establishment of “work benches” where partners can share data, information and applications in an interoperability way, exchange knowledge and experiences, deepen mutual understanding and work together effectively. Country reports at this meeting (http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Seoul_Oct2011/presentations_files.htm) included country view on their possible involvement in the next AWCI phase. All AWCI countries expressed their interest to continue to participate in the AWCI activities and welcomed the WCI concept as the direction for AWCI. Based on the outcomes of two breakout group sessions, a template for country inputs to the AWCI 2nd phase implementation plan was drafted and its structure introduced during the closing session. Subsequently, the template was refined and sent to the ICG country representatives to elaborate their contribution (see Appendix C).

All countries submitted their inputs by the end of February 2012 and these drafts have been collated into a reference document for the AWCI parallel session of the 5th GEOSS AP Symposium held in Tokyo in April 2012. The country proposals for the 2nd phase were presented at the Symposium:

http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Apr2012/AWCIpresentations_files.htm and classified into three categories:

(i) Framework based category - for collaboration between country and agencies
(ii) Project based category
(iii) Regional collaboration category or topic based collaboration category

Further discussions took place at the 9th AWCI ICG Meeting in Tokyo, 29 – 30 September 2012 (http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Sep2012/index.htm), which focused on synthesizing the provided inputs into an implementation plan and it has been decided that the country inputs will be organized in a set of Project Design Matrices (PDMs), one matrix per country project proposal including clear explanation of:

1. Overall Goal
2. Project Purpose
3. Outputs
4. Activities and Key Leaders

From these matrices, each country project implementation plan will be elaborated in cooperation with involved partners and key leaders. Some countries have already begun this stage as explained in the country reports in Section 3.2 (e.g. Cambodia, Indonesia, Philippines, Pakistan, Viet Nam). The development of the Project Design Matrices will be undertaken as a part of the follow-up project funded under the APN ARCP programme, namely the GEOSS/Asian Water Cycle Initiative/Water Cycle Integrator (ARCP2012-16NMY-Ochiai; led by Dr. O. Ochiai, Japan Aerospace Exploration Agency, JAXA).

4.0 Conclusions

This project was launched under the GEOSS/Asian Water Cycle Initiative (AWCI) framework to develop an advanced river management system in AWCI member countries by exploiting the Data Integration and Analysis System (DIAS) data and data integration capabilities.

The main objectives of the project were:

1. Implementation of a demonstration project in each AWCI basin that would include a distributed hydrological model by integrated in-situ and satellite data and model outputs, while considering regional and local specifics (e.g. snow and glaciers).
2. Assessment of climate change impacts on water resources in the demonstration basins using the developed basin models and development of optimization schemes for IWRM practices.
3. Presenting and communicating results of demonstration projects to policy and decision makers in order to promote the use of developed system in operational applications.

The project has accomplished all these objectives, even though not for all the AWCI demonstration basins as it is described in the country reports above.

A particular success was full completion of the AWCI in-situ data archive at DIAS that includes observed data of the 18 AWCI demonstration basins over the certain period that have been rigorously quality checked and equipped with metadata to assure interoperability (http://dias-dss.tkl.iis.u-tokyo.ac.jp/ddc/finder?lang=en). In addition, the data have been provided in compliance with GEOSS data sharing policy, i.e. available for fully open access. Several tools have been developed that are necessary for implementation of the targeted system. These tools include the advanced Water and Energy Budget Distributed Hydrological Model (WEB-DHM), which enables consistent descriptions of water, energy and CO_2 fluxes at the basin scale, and its upgraded version WEB-DHM-S incorporating a three-layer energy-balance-based snow accumulation and melting algorithm as well as a glacier-melt submodel that makes the WEB-DHM-S feasible for applications in basins with snowcover and glaciers. The WEB-DHM and WEB-DHM-S have been validated at AWCI basins. In addition, a method for estimation of snowcover distribution in the mountainous areas using satellite AMSR-E data has been developed and validated in Bhutan. Furthermore, a comprehensive method for bias correction and downscaling of climate model precipitation output (rainfall only, the method for snowfall is now under development) for assessment of climate change on water resources has been developed and validated. For drought assessment in AWCI demonstration project a method was developed based on a standardized anomaly index (SA), a variation of the standardized precipitation index. Finally, a support system was developed for dam operation optimization utilizing weather forecast data and thus suitable for real-time operational applications. The system was successfully validated in the Tone river basin in Japan and applied in the Pampanga River Basin (Philippines), and Huong River Basin and Red River Basin (Vietnam).

The WEB-DHM or WEB-DHM-S have been developed at 14 basins and in 7 of them applied toward the goals of country demonstration project (namely Bangladesh, Bhutan, Cambodia, Japan, Pakistan, Philippines, and Viet Nam. In some of the basins, other hydrological models have been used, namely in Korea, Malaysia, Myanmar, Sri Lanka, and Thailand. Moreover, in case of Cambodia, Indonesia, Pakistan, Philippines, and Viet Nam, the demonstration project activities have resulted into initiation of a complex project involving strategic partners from country's governmental sector, international ODAs and academia and considering operational use of the developed system as one of the project outcomes. All these projects include assessment of impacts of climate change and then development/expansion of the IWRM support tools with specific focus according to each country needs, e.g. agriculture water availability prediction in Cambodia, multipurpose reservoir operation for flood reduction in Vietnam, and assessment of hydrological regime under the climate change in basins in Pakistan and Philippines. Research activities of the projects in Cambodia, Philippines and Pakistan have been already initiated and first conclusions derived suggesting that it is very likely that more frequent and more intense floods will be occurring in all the studied basins in future, while the frequency of occurrence and intensity of droughts significantly depends on local geographical and landcover conditions in each basin.

The project organized a training course for the Climate Change Assessment and Adaptation Study (http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Mar2011/index.htm). The training course kicked-off the AWCI CCAA study, which in many cases has been (is) carried out at the same basins as country DP. The participants learnt how to use the global model precipitation output of future climate projections for assessment of climate change impacts on hydrological regime in the basin. The participants worked with their own data during the course and carried out preliminary assessment using the corrected GCM output and applying the WEB-DHM model to their basin.

Furthermore, three meetings were held that involved AWCI ICG members and served the purpose of reviewing activity progress, further implementation planning and also presentation of demonstration project results to policy- and decision-makers of participating countries. This is why an effort is always made to organize the AWCI meeting in conjunction with a larger relevant event like GEOSS Asia Pacific Symposium, for example. During the meetings, poster and/or exhibition sessions were held to facilitate promotion of the AWCI and collaborating organizations' achievements and their applications for operational use. Namely, these meetings were:

- The 8th AWCI ICG Meeting and the 1st Climate Change Assessment and Adaptation (CCAA) Workshop, Seoul, Korea, October 2011 (http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Seoul_Oct2011/index.htm)
- The AWCI Parallel Session at the 5th GEOSS AP Symposium, Tokyo, April 2012 (http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Apr2012/AWCIpresentations_files.htm)
- The 9th AWCI ICG Meeting, Tokyo, September 2012 (http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Sep2012/index.htm)

Implementation planning for the 2nd phase of AWCI has been initiated and all participating countries have submitted proposal for their involvement. These country inputs were presented at the AWCI parallel session of the 5th GEOSS AP Symposium and will be elaborated into a set of Project Design Matrices. The original country inputs have been collated and made accessible at: http://monsoon.t.u-tokyo.ac.jp/AWCI/doc/AWCI_IP2_Country_drft.pdf.

5.0 Future Directions

At the 8th AWCI ICG meeting in Seoul, October 2011, it was concluded that AWCI had completed the first phase focused on research, system development and demonstration activities and was ready to step in to the next phase, aiming at operational applications of the first phase achievements. It was agreed that the strategy would be in compliance with the GEOSS Water Cycle Integrator (WCI) concept introduced at the meeting (see Appendix B below). All the participating countries expressed their interest to continue their active involvement in the AWCI framework and submitted a proposal for their specific contribution according to the WCI concept.

The intension is to prepare and initiate in each participating country a complex project involving governmental sector, local stakeholders, and strategic partners including ODAs, academia and other research institutions. Several such projects have been already established and developed to various stages (Cambodia, Indonesia, Pakistan, Philippines, and Viet Nam) as explained above. In a similar way, projects in other countries will be established while considering specific needs and current stage of technical and institutional advancement of each country. The main focus will be on the system for IWRM support while considering climate change impacts. This includes completion of the CCAA study objectives (see Appendix A) in those basins, where only preliminary work has been undertaken.

As a part of this process, two AWCI projects funded under the Asia Pacific Network for Global Change Research (APN) programmes had been proposed and accepted for funding: (i) Impact of Climate Change on Glacier Melting and Water Cycle Variability in Asian River Basins (led by Dr. G. Rasul, Pakistan Meteorological Department, PMD) and (ii) GEOSS/Asian Water Cycle Initiative/Water Cycle Integrator (led by Dr. O. Ochiai, Japan Aerospace Exploration Agency, JAXA), which will built up on the achievements of this project and that were kicked-off at the 9th AWCI ICG meeting in Tokyo, September 2012.

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Appendix

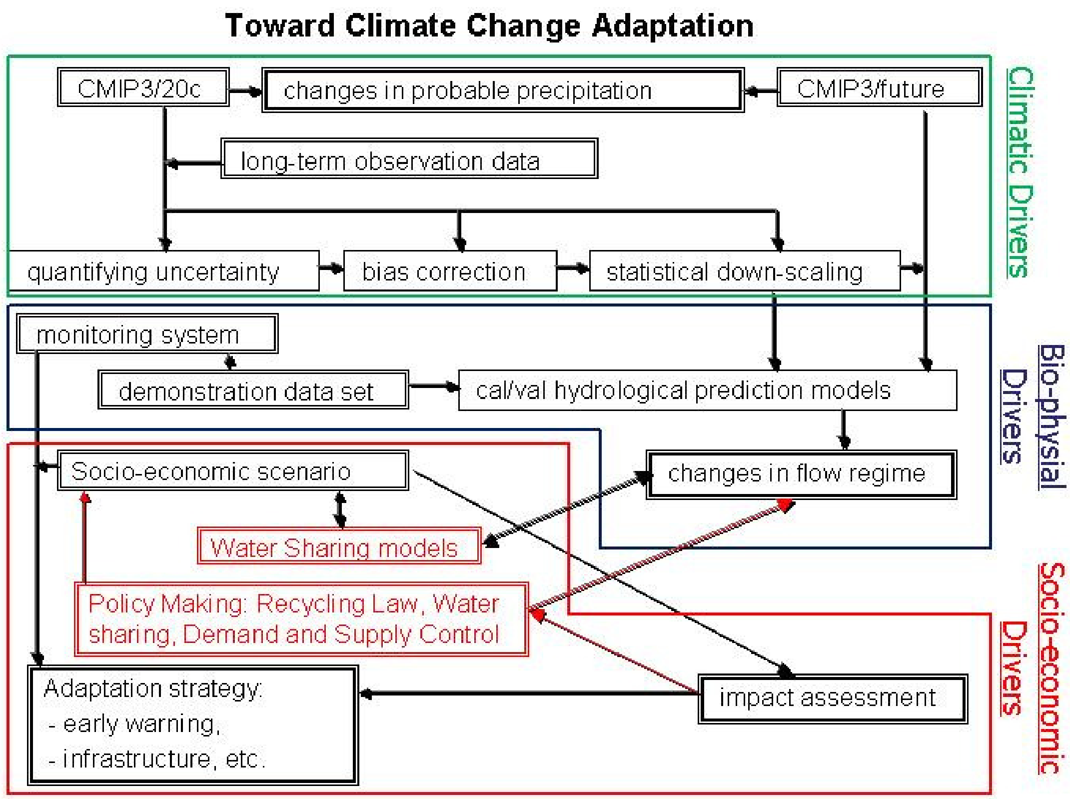
Appendix A:

Whitepaper on the GEOSS/AWCI Climate Change Impact Assessment Activity

1. Background

Impacts of climate change on water resources and water-related hazards in the Asia-Pacific region have already become evident, as both scientific observations and the experiences of the region's inhabitants confirm. In confronting the risks and challenges posed by changing climate, it is essential to properly asses its impacts as a basis for identifying effective responses and developing adequate adaptation strategies.

In recognition of these challenges, the GEOSS Asian Water Cycle Initiative (AWCI) has proposed activities focusing on climate change impact assessment in three specific areas including flood, drought, and snow and glacier phenomena. At the 6th AWCI International Coordination Group (ICG) Meeting in Bali, March 2010, an approach toward assessing impacts of climate change using the Climate Model Intercomparison Project (CMIP) data was proposed and accepted as illustrated in the chart below. This Whitepaper is an elaboration of that proposal.



Flowchart of an implementation plan toward assessing impacts of climate change and preparing adaptation strategy – resulting version from breakout group discussions.

2. Mission

The main goal of the proposed activity is to set up a methodology for assessment of climate change impacts on the water resources and water-related hazards that will be applicable in the AWCI member countries and by using this methodology to carry out such assessment studies on the demonstration basins in each country focusing on the three identified areas including flood, drought, and snow and glaciers phenomena.

3. Objectives

1. To set up a methodology for quantifying uncertainty of climate projection focusing on forcing variables for hydrological models.
2. To set up a methodology for correcting bias of the projected forcing variables.

3. Produce projections of water resources and water hazard related variables by employing a proper hydrological model forced by the corrected projected forcings.
4. Assess the impacts of climate change on changes in water resources and water-related hazards.
5. Recommendations for adaptation strategy.

4. Methodology

<u>Step I for Climate & Bio-Physical Drivers</u>

The activities will take an advantage of the CMIP3 (and later CMIP5) output including past simulations and future projections that are stored on the Data Integration and Analysis System (DIAS) of Japan. Close collaboration is envisioned with the AWCI project "Climate Change Impact Assessment on the Asia-Pacific Water Resources under GEOSS/AWCI" that is led by Prof. Deg-Hyo Bae, was approved for funding by APN in April 2010 (http://monsoon.t.u-tokyo.ac.jp/AWCI/projects.htm#change). Approaches toward accomplishment of the listed objectives may differ according to the focus area, i.e. whether the phenomena under assessment will be related to flood, drought, or snow and glaciers.

<u>1. Flood</u>

Key mission for flood:

Impact analysis on PMF, flood frequency, dam safety, optimal dam operation, etc.

As heavy rainfall is the key factor in floods, the flood-oriented activities will focus on change in heavy rainfall events and associated changes in flood peaks. Using available long-term historical records (at least 20-years) of rainfall in the AWCI demonstration basins and the CMIP3 (or later CMIP5) precipitation outputs for the corresponding period, the uncertainty in CMIP precipitation outputs will be identified. Consequently, the bias in the daily rainfall data will be corrected in the model projections. The corrected data together with other forcing variables taken from the CMIP projections will be used to run suitable hydrological models in the demonstration basins that will generate projected river flow. The projected heavy rainfall events and flood peaks will be compared with the historical series and studied for possible trends and/or changes in intensity and frequency of occurrence.

Method:

1. Data registration of demonstration basin to DIAS
2. Capacity building for bias correction & downscaling – e.g. UNU seminar on downscaling in May 2011
3. Application of multiple (hopefully!) hydrologic models such as WEB-DHM, IFAS-PDHM or BTOP, any locally-used model at the demonstration basin, etc.

<u>2. Drought</u>

Key mission for drought:

1. To carry out a long term monitoring of soil moisture, precipitation, air temperature, and snow by in-situ and satellite with studying the definition of drought for climate change assessment.
2. To present an early warning system including seasonally forecasting for adaptations.

In case of drought, set of drought indices will be investigated. Similarly as for flood, available long-term historical records of rainfall and CMIP3 precipitation output will be analyzed, the uncertainty identified for heavy rain, moderate rain, and low rain events, and the bias corrected. The observed in-situ precipitation and JRA25 output will be used to force an adequate hydrological model (e.g. Web-DHM) in the demonstration basins to derive the drought indices for the historical period. Consequently, the projected forcing variables by CMIP3 including the bias-corrected precipitation will be used to force the hydrological model for the future period and projection river flow and basin states will be generated. Drought indices for the future period will be derived and compared with those for the historical period. Possible trends and/or changes in drought occurrence, severity and frequency of occurrence will be studied.

In addition to the above study involving numerical model experiments, the focus will also be on strengthening the monitoring system and data analysis of precipitation, soil moisture phonological elements, evapotranspiration, air temperature, land use, discharge, and groundwater.

<u>3. Snow and Glaciers</u>

Regarding the snow and glaciers focus, the abovementioned approaches are currently not applicable due to (i) lack of sufficient historical in-situ observation of snow and glacier variables (insufficient in terms of length of record, density of observation network, temporal resolution of the observation) and (ii) lack of adequate hydrological model coping with the snow and glacier processes. Since quantifying uncertainty and bias correction is difficult without long-term observation data, it is proposed to use satellite data for snow cover and glacier change monitoring, namely Landsat data and the high resolution ASTER GDEM. A statistical value of a snow covered area will be generated from the CMIP3 output for the historical period using a hydrological model designed for cold regions. This statistical value will be compared with such a value resulting from Landsat data and in this way the CMIP3 output will be evaluated and bias corrected.

Step II for Socio-Economic Drivers

To make a sound decision in water policy responding to changing political and socio-economic needs and demands under climate change, it is vital to develop a comprehensive risk assessment method that covers political and socio-economic aspects as well as natural scientific aspects. The method should be able to reflect the effects of climate prediction uncertainty in an appropriate way.

1. Risk Assessment

With the socio-economic background, it is important to develop a comprehensive assessment system that can quantify socio-economic impacts induced by climate change on comprehensive societal benefits, including complacency about the risks to life and environmental safety. To design an adaptive measure, it is necessary to evaluate currently available technology and its future direction, to consider the socio-economic and cultural characteristics of each target river basin, and then to quantify how much the risk to society can be reduced by combining various measures.

The first step will be to review existing studies in each participating country. Cooperation with experts on socio-economic studies in each country will be sought.

2. Multilayered Risk Management

We must identify and implement approaches that improve water security over a wide range of potential conditions, including current climate variability. Multilayered approaches, including both structural and non-structural ones, should be promoted. Also early warning systems either for flood or drought or other water-related hazards are important elements of the scheme. Effective management as a whole can be achieved by shifting the capacities for specific purposes among existing reservoirs. Effective water demand management, including proper water distribution for different objectives of water use and negotiation among different stakeholders during severe drought, should be promoted. It is undoubtedly effective to control urban land use in flood plains and local low-lying lands where serious damage is caused by flooding and localized torrential rainfall respectively.

3. Governance

Adaptation measures involve a wide range of stakeholders. We must build the capacity of society to demonstrate resilience in the face of changing climate through strengthening the adaptation capacities of stakeholders of society as a whole for operationalizing the multilayered risk management with climate change adaptation measures. It is also important to recognize water quality as an inseparable determinant of sustainable environment and people's well being. It is important to establish a platform consisting of stakeholder organizations, experts, and academics at the early stages of planning where making decisions, sharing information, providing advice, and clarifying each organization's role are conducted.

5. Implementation strategy

For the step I, we had better take an aggregation approach on observation capability, data sets, data infrastructure, models, prediction capabilities and knowledge.

1. *Sharing observation capability*
2. *Sharing long tem data, especially long-term daily rainfall data and hourly data even short periods.*
3. *Sharing data infrastructure and climate projection data sets – an easy access to the GCM products needs to be provided.*
4. *Sharing hydrological models including down scaling methods.*
5. *Sharing regional characteristics of the climate change impacts on river flow regimes.*

For the step II, the shared ideas, data, experiences and knowledge should be applied to each demonstration river basin considering its locality.

Appendix B

GEOSS Water Cycle Integrator

A proposal to CEOS and GEO
Toshio Koike, Japan GEO WG Chair

Background

World Bank Vice President, I. Serageldin, recently observed "Many of the wars of the 20th century were about oil, but wars of the 21st century will be over water." In reference to the growing global and regional water issues. In 2001, the International Conference on Freshwater in Bonn identified "managing risks to cope with variability and climate change" as one of its primary actions in dealing with governance issues. Recent climate-related water catastrophes, such as floods in Pakistan, Australia, Brazil and South Africa, serve to remind us that the most significant and harmful impacts of climate change will be experienced through alterations in the water cycle. Climate change adds another formidable challenge, especially in water which is essential in the natural climate system and the human society. Although the impacts are currently far from certain, they are unlikely to be favorable.

Concept Design

Water is key which makes a bridge between the climate processes in atmosphere, oceans, cryosphere, terrestrial carbon cycle, ecosystems and sea level rise, and the socio benefit areas including agriculture and forestry, health, energy, human settlement and infrastructure and the economy.

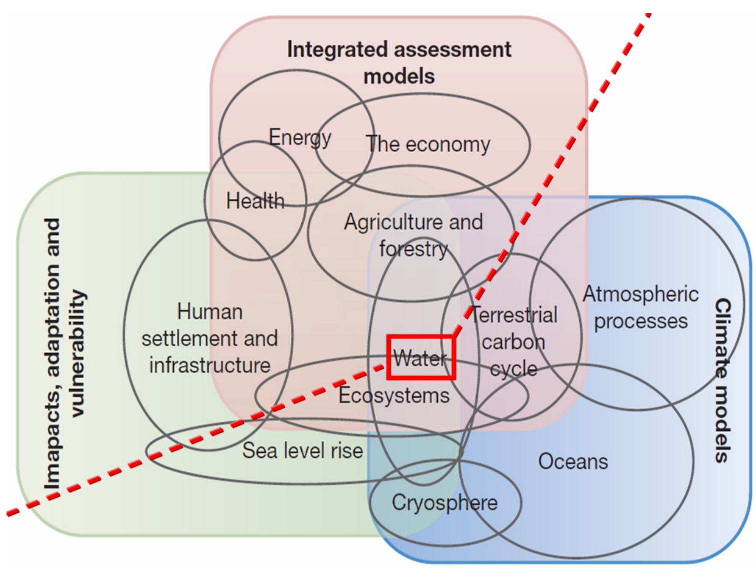


Figure 1. Model Integration for Assessment, Richard H. Moss, et al., Nature, 2010, modified by Author.

The global water cycle, which includes the transport and distribution of large amounts of water associated with its constant phase changes among solid, liquid and gaseous states, is a critical component of the Earth's climate system. Due to the effects of the atmospheric and ocean circulations and the variations of water stored as snow and soil moisture, local and regional water cycle variations are correlated across areas and seasons.

People have been developing water cycle management systems considering the water cycle variability as a stationary process. But now, under the current conditions this concept has been shown to be misleading resulting in a need for radical change in approach to develop a clear consensus on how best to utilize model projections of climate and hydrology in conducting frequency analysis of future hydrological hazards. Hydrological regime sifts and changes in extreme events, including floods and droughts, are now fundamental threats to human beings all over the world.

Increased water cycle variability impacts primarily through water, biological processes and human dimensions with implications for land use and societal development. It is critically important to recognize the fundamental linkages among water; land use, including deforestation; carbon cycle and ecosystem services; and food-, energy- and health- securities. By sharing coordinated, comprehensive and sustained water cycle and related Earth observations and information for sound decision making, GEOSS could lead in developing effective interdisciplinary collaborations for working together based on coordinated and integrated efforts and subsequently to both mitigation and adaptation benefits. Building resilience to the climate change and variability is essential for establishment toward the final goal, the sustainable development of Earth's societies and ecosystems.

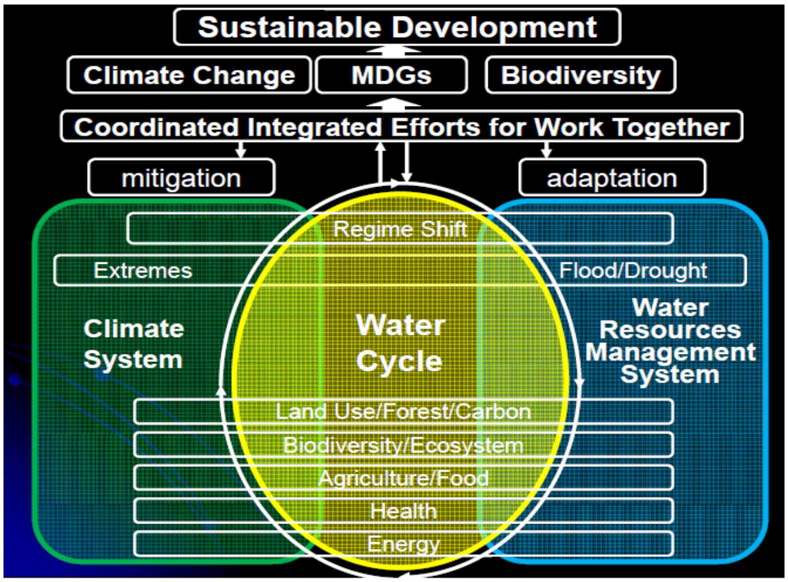


Figure 2 Concept Design

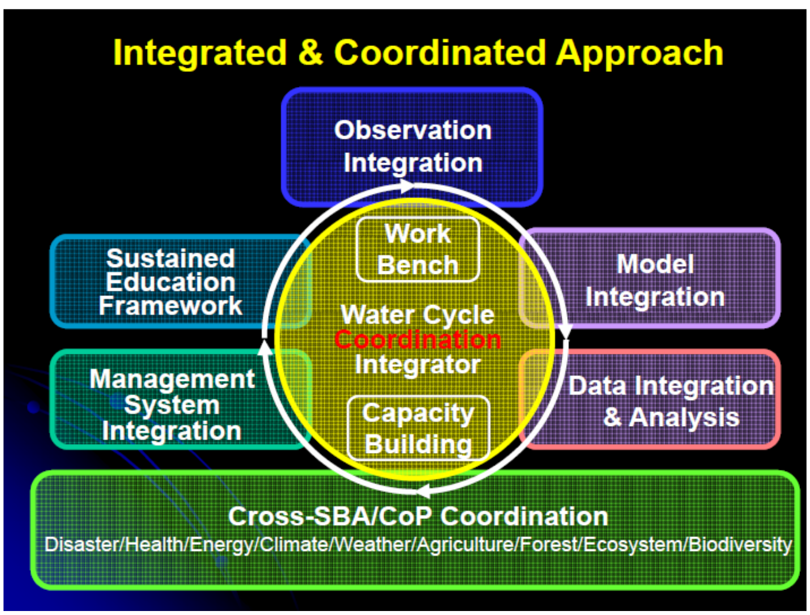


Figure 3 Implementation Design.

Implementation Design

To accelerate the coordinated and integrated efforts, we need to develop "GEOSS *Water Cycle Integrator (WCI)*", which develops a holistic coordination capability of the following function in cooperation with various partners:

- observation integration
- science and model integration
- data integration & analysis
- cross-Socio Benefit Areas and Community of Practices
- management system integration
- sustained education framework

GEOSS/WCI will set up "work benches" where partners can share data, information and applications in an interoperability way, exchange knowledge and experiences, deepen mutual understanding and work together effectively. (A work bench is a virtual geographical or phenomenological space where experts and managers work together to use information to address a problem within that space). GEOSS/WCI enhances the coordination of efforts to strengthen individual, institutional and infrastructure capacities, especially for effective interdisciplinary coordination and integration.

CEOS's Key Roles in GEOSS/WCI

In order to implement GEOSS/WCI CEOS would be expected to lead "satellite observation integration" and "data integration" for GEOSS/WCI. These elements are essential components for the technical and

Figure 4 Coordinated Observation and data integration.

architectural elements of WCI. To quantify the impacts and vulnerabilities and develop and assess adaptation options, it is important to combine climate projections with integrated assessment models by utilizing comprehensive data of the climate, water cycle and resources for each societal benefit area observed by satellites. This effort would address the need for a Bridge between the current CEOS constellation projects and promote the development of a new observational and analysis integration capability.

This effort will build on the mutual cooperation between CEOSS/WGISS and WCRP/GEWEX, which successfully implemented the Coordinated Enhanced Observing Period (CEOP) was and its integration capability for in-situ and satellite observation data and numerical model outputs. The CEOS Water Portal is now developing a wider and deeper data integration capability under GCI framework. A GEOSS/WCI data integration function will be developed by accelerating the effort and incorporating developments and expertise of other systems including those in NASA, ESA and other CEOS members. Other efforts will be needed to build the networks and to involve the experts and managers who will test and utilize this system.

GEO has established GEOSS Asian Water Cycle Initiative (AWCI) and GEOSS African Water Cycle Coordination Initiative (AWCCI). In Latin America, the GEOSS water capacity building programs are now on going. Through regional, inter-disciplinary and inter-agency coordination, and integrated efforts, GEOSS/WCI will lead to effective actions and public awareness toward water security and sustainable development.

Appendix C

Template for Country Input to the AWCI Phase 2 Implementation Plan

(based on the outcomes of the Seoul meeting breakout sessions)

1. Issues and Needs

1. Issues related climate system - water cycle - water use

- Regionally common issues - identify which of the common issues are relevant to your country:
  - changes in climate and consequences – quantitative assessment
    - ✓ intensification of variability (heavy rainfall and dry spells), cyclones
    - ✓ frequency of extremes: flood (localized + social)and drought
    - ✓ seasonal climate pattern (precipitation, dry and wet, maxima,)
  - Identify available capability/resources in your country – specify clearly
  - Identify lack of capability – specify clearly, including more details, which capability out of the following ones is missing: monitoring, modeling, inventory of water resources, understanding planning & management
- Describe critical and specific issues in your country, include more details:
  - landslides / erosion
  - Sea level rise
  - Temperature rise→GLOF
  - Depletion of ground water
  - Hydropower
  - Trans-boundary and international coordination (MRC)
  - Shifting snow residency, melting period, snow-line→biodiversity

2. Issues related to Water Nexus: agriculture, energy, health – water quality, biodiversity, and ecosystem

A. Introduce issues related to Water Nexus in your country and identify two directions (see the example below):

1. Water and Climate Change affect each Socio-Benefit Area (SBA)
2. Each SBA affects water and environment

B. Introduce on-going projects and programs related to Water Nexus in your country

SBA	**CC, Water, and Environment**
• Agriculture:	←water scarcity and surplus, crop failures → quality of surface and ground water (fertilizer, pesticide)
• Energy:	←hydropower
• Urban:	→water quality, ground water depletion, increase of municipal water demand, inefficient municipal water management (low tariff, unplanned conjunctive), decrease of flood plains,
• Ecosystem and Biodiversity:	←change in flow pattern, water diversion
• Health	←water bone diseases (dry and wet spells: Malaria, Dengue, flood: Diarrhea)
• Infrastructure:	←design and management

C. Respond to each of the following questions by considering water and climate change specifically for your country:

- How can we address seasonal variability at national level?
- How can we manage water resources in proper way between upstream and downstream and among different sector uses: hydropower, irrigation, water supply?
- How can we give the right information to these different sectors? They are demanding for more customized climate information?
- How can we adapt the design criteria to changing characteristics and magnitude of water hazards, e.g. for new drainage?
- How can we share the data to the different sectors beyond laboratories?

3. Needs for functions and/or tools of WCI to address the identified issues

Specify needs for your country:

- Observations:
  - in-situ telemetric network (mountain areas)
  - remote sensing (satellite, radar) currently and in future
- Data Access
  - satellite data access (operationally coupled with in-situ near real-time data)
  - global data access (Numerical Weather Prediction, Reanalysis, Climate Projection)
- Models
- Management systems
  - Forecasting
  - Early Warning
  - Decision support
    - ✓ National/local government (climate proofing, urban management, risk reduction measures, adaptation strategies)
    - ✓ community-based
- Platform for sharing data and knowledge and exchanging ideas and experiences
- Capacity building – describe in other section (Part 2: Implementation Proposal)

4. Needs for collaboration framework at the national level: inter-agency, interdisciplinary

Please introduce existing activities and what kind of activities/framework is needed in your country with regards to each of the following points:

- We need to show a holistic view of water and climate change and their impacts on water nexus to all the stakeholders through sharing data and information, exchanging ideas and experiences, and working together.
- We need a well-organized interdisciplinary and inter-sectoral body at professional- and/or policy making- levels by involving academia and civil societies.
- We need to implement demonstrations and exchange good (failure) practices through regional conferences/workshops.
- We need criterion to maintain data quality, at least for rainfall, water level and hopefully river discharge and technical standards to design infrastructures in terms of water.

2. Implementation proposal

1. Please describe Steps and Strategy following the three approaches:

Framework development approach – describe desirable framework in your country

- Demonstration design ←→ infrastructure integrity
- Introducing legislation→high level coordination body→research promotion→Improvement of awareness→private sector involvement

Strategic approach

- Showcase: intention, background, objectives, collaborations, achievements with accuracy and feasibility, benefits to other sectors, interest → involvement one by one starting with existing inter-agency collaborations)
- Demonstrations → regional and general commonality
- Expansion of the AWCI demonstration studies to a whole region → sharing experiences →a holistic understanding and technology.

Technical approach – propose a technical approach considering your target basin/country

Monitoring→understanding→Climate change assessment including downscaling, bias correction→detail assessment→model→demonstration→ mainstreaming→ creation of regional knowledge

2. Additional resources – suggestion of potential collaborators

- Please identify local, national, regional, and worldwide (including UN) collaborators in the field of research, operation, administration, financial and human resources supports. Please fill the matrix:

Collaborators ----------- **Field**	Local	National	Regional	Worldwide
Research				
Operation				
Administration				
Financial res.				
Human res.				

- Mainstreaming water and climate change within the national policy by getting supports from water nexus. Please describe mainstreaming strategy suitable for your country.

3. Specific request to GEOSS and to international community (data/tools accessibility)

Describe in a concrete way and specifically for your country needs:

- Inventory and summary directory – what kind is needed in your specific case
- Data request function responding to new needs – what kind of function
- Data access and information exchange
- Models and Tools: analysis, prediction, early warning, risk assessment, decision support – what kind for what purpose
- Regional office and/or data center – what kind of function you expect for the office

4. Coordination between water cycle integration and capacity development strategy

- Identify contents of capacity development needs in your country
- Introduce existing and on-going activities and the needs and support related to these five items:

- Synchronize capacity development with national implementation programme coordinated by the regional programme.
- Training for not only researchers but also practitioners from top level to operator/technician's level, with appropriate standards depending on the level (various kinds of training) including trainer's training to be followed by practice and identify it as a postgraduate program in collaboration with international educational framework (e.g. UNU, UN-CECAR).
- Short term capacity development workshops on specific observation and modeling skills and medium to long term supports to regional resource centers.
- Coordinate with national and regional centers of excellence (ex. WMO centre in Hanoi on WR)
- Organize capacity development workshops in each country for the agencies involved in the project at national level on the WCI implementation. Identify agencies and participating organizations for making such an opportunity.

5. Schedule

Apr. 2012 5th GEOSS AP Symposium: Preparation for Implementation Plan
Oct. 2012 4th AWCI Symposium: Approval of the 2nd stage implementation plan

2013-2015: Step 1 - demonstration project (feasible study) at each basin
2016-2018: Step 2 - project implementation at national and/or regional scale
Please make a rough design for step 1 and step 2.

Due date for the input: 27 JANUARY 2012

Conferences/Symposia/Workshops

1. The AWCI training course for the Climate Change Assessment and Adaptation Study March 11 – 12, 2011

Agenda

The course is designated for the CCAA study leaders to get acquainted with several methods useful and necessary for carrying out the proposed CCAA study in nominated river basins. The course will last for two days.

First day: Friday 11 March 2011

~09:20 Registration

09:20 – 09:30 1. Welcome and Introduction
09:30 – 12:00 2. Rainfall bias correction and downscaling methods by the University of Tokyo group
09:30 – 10:00 2.1 Method introduction – lecture (Prof. Koike)
10:00 – 10:30 2.2 Climate Model Output Evaluation and Selection
10:30 – 11:00 2.3 Climate Model Output Download and gap-filling
11:00 – 11:15 Break
11:15 – 12:00 2.4 Rainfall Bias Correction
12:00 – 12:15 **Photo session (in front of the No. 1 Building)**
12:15 – 13:30 Lunch
13:30 – (14:30) 2. Rainfall bias correction and downscaling methods by the University of Tokyo group – continue if necessary
If the session is completed earlier, the WEB-DHM part will begin earlier.
(14:30) – 18:00 3. Hydrological model WEB-DHM (Water and Energy Budget Distributed Hydrological Model) use for the CCAA purposes by Dr. Lei Wang and the University of Tokyo team
The session will include a break when appropriate

Second day: Saturday 12 March 2011
09:00 – 12:30 4. Flood modeling system IFAS (Integrated Flood Analysis System) applications by Dr. Fukami and the ICHARM team (including break)
12:30 – 13:30 Lunch

13:30 – 17:00 5. Multi-model Hydrological modeling in use for Climate Change assessment by Prof. Bae – Sejong University (including break)

List of Participants

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2. The 8th Meeting of the GEOSS Asian Water Cycle Initiative International Coordination Group (AWCI ICG) and the 1st AWCI Climate Change Assessment and Adaptation (CCAA) study Workshop

Seoul, South Korea, 6 – 8 October, 2011

Agenda

Thursday 6 October

09:00 – 09:30 Registration
09:30 – 10:00 1. Opening Session, Welcome Remarks, Photo

09:30 – 09:40 Deghyo Bae (Sejong University)
09:40 – 09:50 Jae Heyon Park (Water Resources division, Ministry of Land, Transport and Maritime Affairs)
09:50 – 10:00 Photo session
10:00 – 12:00 2. AWCI Working Group Activity Review Session
10:00 – 10:20 General review of the AWCI status: *Toshio Koike*
10:20 – 10:40 BREAK

10:40 – 10:55	Flood WG report:	*Kazuhiko Fukami and Srikantha Herath*
10:55 – 11:10	Drought WG report:	*Ichirow Kaihotsu and Ghulam Rasul*
11:10 – 11:25	Water Quality WG report:	*Bilqis Hoque*
11:25 – 11:40	Climate Change WG report:	*Deghyo Bae and Mafizur Rahman*
11:40 – 12:00	Capacity Building report:	*Srikantha Herath*

12:00 – 13:00 Lunch
13:00 – 17:00 3. Country Activity Review and Possible Contributions to the AWCI Next Stage Session

In this session, country and expert reports will be presented. The country reports should cover two main items: (i) Report on current country activities related to AWCI, which includes demonstration projects, Climate Change Assessment and Adaptation (CCAA) study and other activities, and (ii) Ideas and views of possible country involvement in and contribution to the next stage of AWCI that is envisioned in line with the GEOSS Water Cycle Integrator (WCI). Introduction of the WCI mission and concept as well as instructions for presentation preparation have been provided to the presenters in advance. **One report per country** is expected, presented by either the ICG country representative or CCAA leader.

The expert reports include presentations on research and technical achievements related to the AWCI activities that are not included in the country reports. Presentation time 15 min, i.e. 13 min presentation and 2 min discussion; i.e. four contributions in an hour

13:00 – 15:30 First part (10 country reports)

13:00 – 13:15	Vietnam:	*Tinh Dang Ngoc*
13:15 – 13:30	Thailand:	*Thada Sukhapunnaphan*
13:30 – 13:45	Sri Lanka:	*S.B. Weerakoon*
13:45 – 14:00	Philippines:	*Rosalina de Guzman*
14:00 – 14:15	Nepal:	*Shiv Kumar Sharma*
14:15 – 14:30	Myanmar:	*Tin Yi*
14:30 – 14:45	Mongolia:	*Gombo Davaa*
14:45 – 15:00	Malaysia:	Mohd *Zaki Mat Amin*
15:00 – 15:15	Laos:	*Singthong Pathommady*
15:15 – 15:30	Korea:	*Deg-Hyo Bae*

15:30 – 16:00 BREAK

16:00 – 18:00 Second part (4 country reports and 3 expert presentations)

16:00 – 16:15	India:	*Rakesh Kumar*
16:15 – 16:30	Cambodia:	*Long Saravuth*
16:30 – 16:45	Bhutan:	*Karma Chhophel*
16:45 – 17:00	Bangladesh:	*Ashfakul Islam*
17:00 – 17:15	Water Quality Challenges in Bangladesh:	*Bilqis Hoque*
17:15 – 17:30	Community Based Management of Agricultural Resources at Watershed Level for Sustainable Livelihoods:	*Thaworn Onpraphai*
17:30 – 17:45	Climate Change Assessment and Adaptation:	*Cho Thanda Nyunt*
17:45 – 18:00	Discussion	

18:00 Adjourn
18:30 Reception

<u>**Friday 7 October**</u>
09:00 – 10:30 3. Country Activity Review and Possible Contributions to the AWCI Next Stage Session – continue: Third part (6 expert presentations)
Presentation time 15 min, i.e. 13 min presentation and 2 min discussion; i.e. four contributions in an hour

09:00 – 09:15	Thailand 2011 Experiences on Flood Monitoring:	*Hansa Vathananukij*
09:15 – 09:30	Flood Predictability and Optimization of Water Resources Management:	*Oliver Saavedra*
09:30 – 09:45	Introduction of GIT4CC (Green Infrastructure Technology for Climate Change):	*Hyoungkwan Kim*
09:45 – 10:00	Drought Monitoring and Prediction:	*Patricia Sanchez*
10:00 – 10:15	Modeling of Snow- and Glacier- melt Runoff Simulation:	*Maheswor Shrestha*
10:15 – 10:20	Discussion	

10:20 – 10:50 BREAK

10:50 – 12:30 4. Capability of Observation, Data Integration and Prediction Session

The presentations will focus on capabilities possibly contributing to the GEOSS WCI framework. Each will be allocated ~ 20 minutes (including questions).

10:50 – 11:10 JAXA: *Toru Fukuda*
11:10 – 11:30 JMA: *Hirotaka Kamahori*
11:30 – 11:50 KMA: Climate Change Projections using Representative Concentration Patheays and HadGEM2-AO Climate Model: *Kyung-On Boo*
11:50 – 12:10 ICHARM: *Kazuhiko Fukami*
12:10 – 12:30 UNU-CECAR: *Srikantha Herath*

12:30 – 13:30 Lunch

13:30 – 14:30 4. Capability of Observation, Data Integration and Prediction Session - continue

13:30 – 14:30 GEOSS Water Cycle Integrator toward Asian regional coordination: *Toshio Koike*

14:30 – 16:00 5. Breakout discussion session 1 – GEOSS WCI: needs and capabilities

14:30 – 14:45 Introduction and instructions for the breakout groups: *Toshio Koike*

Individual groups (3 – 4) are to be decided. Reference material includes the WCI document and the "Green growth with blue" document. Downloadable from the meeting website at:
http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Seoul_Oct2011/agenda.htm

14:45 – 16:00 **Breakout group discussion**

The groups will discuss several points including (i) possible scope of involvement in the WCI framework identifying needs and capabilities, (ii) coordination and integration of activities across the working groups under the WCI framework, (iii) possible contribution to Rio+20.

16:00 – 16:20 BREAK

16:20 – 18:30 6. Breakout discussion session 2 – GEOSS WCI: practical implementation ideas

The groups will discuss practical implementation of the WCI targets at the AWCI demonstration basins. Ideas for particular projects should be formed that will be complied into an Implementation plan before the January 2012 GEOSS Asia-Pacific Symposium.

Individual groups (3 – 4) are to be decided.

18:30 Adjourn

<u>**Saturday 8 October**</u>

09:00 – 09:30 7. Breakout session summary

09:30 – 10:30 8. Implementation planning for a regional coordination project targeting Climate Change Adaptation

This is a discussion plenary session, synthesizing the outcomes of the meeting into suggestions/instructions for an implementation plan of the AWCI next step.

10:30 – 11:00 BREAK

11:00 – 11:30 9. Regional Proposal to Rio+20

This is a discussion plenary session that will produce a proposal of AWCI contribution to Rio+20

11:30 – 12:00 10. Summary and Closing session

12:30 Adjourn

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3. The GEOSS Asian Water Cycle Initiative (AWCI) Parallel Session of the 5th GEOSS AP Symposium, Tokyo, Japan, 2 – 4 April, 2012

Agenda (AWCI Session on 3 April)

Floods and droughts are a recurring problem in Asia. Rapid population and economic growth is straining existing water resources and the ecosystem. The expansion of urbanization and the climate change is considered to make considerable impacts on such a vulnerable region. The AWCI aims to develop an Integrated Water Resources Management (IWRM) by exploiting the Global Earth Observation System of Systems (GEOSS) to address the water-related issues described above.

The AWCI member country reports presented at the 8th AWCI meeting in Seoul in October 2011 showed a great progress in the AWCI demonstration projects and good preparedness of individual countries to step into the next phase that envisions further integration and inter-disciplinary collaboration through the GEOSS Water Cycle Integrator (WCI) concept of "work benches". Following this concept, the member countries have initiated preparation of a draft implementation plan for the 2nd stage of AWCI.

The objective of this breakout session is to introduce each draft implementation plan and to establish make an integrated cooperative framework among the member countries, the Earth observation communities, science communities and the related international activities.

Co-Chairs:
Richard Lawford (GEO Water)
Syahril Badri Kusuma (Institute of Technology Bandung (ITB))
Toshio Koike (The University of Tokyo)

09:30-09:40 Opening GEOSS/AWCI Breakout Session

- Opening Remarks D. Cripe, *GEO Secretariat*

09:40-10:30 GEOSS/AWCI Activity Reports *10min. each*

1. Working Group Reports by Chair(s):

- Flood WG K. Fukami, *ICHARM*
- Droughts WG G. Rasul, *PMD*, I. Kaihotsu, *HU*
- Water Quality WG P. Koudelova, *UT*
- Climate Change WG M. Rahman, *BUET*

2. Capacity Building Activities by Lead(s): S. Herath, *UN Univ.*

10:30-12:30 Brief introduction to Draft Implementation Plans: Part1

5min. presentation + discussion

1. *Bangladesh:* M.A. Islam
2. *Bhutan:* K. Chophel
3. *India:* R. Kumar/S. Kaur
4. *Indonesia:* S.B. Kusuma
5. *Japan:* T. Koike
6. *Laos:* S.Pathoummady
7. *Malaysia* M.Z.M. Amin
8. *Mongolia:* G. Davaa
9. *Myanmar* : S. Lin
10. *Nepal:* S.K. Sharma
11. *Pakistan:* G. Rasul/B. Ahmad
12. *Philippines:* F. Hilario
13. *Sri Lanka:* G.R.A.S. Gunathilake
14. *Thailand:* T. Sukhapunaphan
15. *Uzbekistan:* I. Dergacheva
16. *Vietnam:* D.N. Tinh

12:30-13:30 *Lunch Break*

13:30-15:15 Inputs from Agencies *15min. each including discussion*

1. Asia-Pacific Network for Global Change Research (APN)
2. United Nations Educational, Scientific and Cultural Organization (UNESCO) T. Sonoda
3. Network of Asian River Basin Organizations (NARBO) T. Kawasaki
4. Japan International Agency (JICA) Y. Amano
5. Japan Aerospace Exploration Agency (JAXA) R. Oki
6. Japan Meteorological Agency (JMA) K. Oonogi
7. International Centre for Water Hazard and Risk Management(ICHARM) K. Fukami

15:15-15:30 *Break*

15:30-17:15 Discussion towards an Integrated Cooperative Framework *All*

- Common Targets and Fields:
- Regional Coordination Framework
- Linkage to Global Coordination Framework
- Building capacity
- Planning Strategy

17:15-17:30 Closing GEOSS/AWCI Breakout Session

- Session Summary
- Concluding Remarks

Participants (AWCI Session on 3 April)

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<u>Funding sources outside the APN</u>

1. University of Tokyo (Source: Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Japan)

- In kind support: (i) Data archiving and integration functions – DIAS system
  (ii) Project management and coordination functions
  (iii) Expertise in hydrological modeling and Climate change assessment
- Monetary support: Travel support of AWCI members to attend meeting events; roughly 60,000 USD

2. Japan Aerospace Exploration Agency (JAXA)

- In-kind support: (i) Expertise in remote sensing data
  (ii) Provision of satellite data and appropriate tools for their processing

3. Japan Meteorological Agency

- In-kind support: Atmospheric model data (forecast and reanalysis)

4. Hiroshima University

- In-kind support: Expertise in drought and satellite soil moisture data

5. Sejong University

- In-kind support: Expertise in hydrological modeling and climate change assessment

6. Each AWCI member country

- In-kind support: In-situ data from selected river basins

List of Young Scientists

In addition to the AWCI ICG members including representatives of governmental institutions (ministries and meteorological and hydrological services), this project involved a number of researchers, doctoral and master students affiliated with AWCI collaborating institutions and organizations. At the University of Tokyo, Prof. Koike's laboratory, certain activities of this project and generally of AWCI (mostly the tools and techniques development and pilot studies in some basins) were undertaken as part of PhD. or Master Course research of several international students coming from AWCI participating countries (e.g. Indonesia, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka). Among those are also Dr. M. Shrestha (Nepal), Dr. K. Tsujimoto (Japan), and Dr. P.A. Jaranilla-Sanchez (Philippines), who received the awards listed in the non-technical summary.

Glossary of Terms

ADB	Asian Development Bank
AIT	Asian Institute of Technology
AOGCM	Atmosphere-Ocean General Circulation Model
APRSAF	Asia-Pacific Regional Space Agency Forum
AWCS	Asian Water Cycle Symposium
AWCI	Asian Water Cycle Initiative
BATS	Biosphere-Atmosphere Transfer Scheme
CB	Capacity building
CCAA	Climate Change Assessment and Adaptation
CDF	Cumulative Distribution Function
CEOP	Coordinated Energy and Water Cycle Observations Project
CMI	Crop Moisture Index
DHM	Distributed Hydrological Model
DIAS	Data Integration and Analysis System
DP	Demonstration Project
DRESS	Dam Release Support System
GCM	General Circulation Model
GCOE	Global Center of Excellence
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GEWEX	Global Energy and Water Cycle Experiment
GGB	Green Growth with Blue
GPD	General Pareto Distribution
GSMaP	Global Satellite Mapping of Precipitation
ICG	International Coordination Group
IFM	Integrated Floods Management
IIWaDATA	International Integrated Water Data Access and Transfer in Asia
IRBM	Integrated River Basin Management
IWRM	Integrated Water Resources Management
ICHARM	International Centre for Water Hazard and Risk Management
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
LAI	Leaf Area Index
MEXT	Ministry of Education, Culture, Sports, Science, and Technology
ODA	Official Development Assistance
OCDI	Observation Convergence and Data Integration
NDVI	Normalized Difference Vegetation Index
NGO	Non-Governmental Organization
NWP	Numerical Weather Prediction

PDS	Partial Duration Series
PDSI	Palmer Drought Severity Index
PMD	Pakistan Meteorological Department
PP	Probability of Precipitation
QPF	Quantitative Precipitation Forecast
R-CDTA	Regional Capacity Development Technical Assistance
RS	Remote Sensing
SA	Standardized Anomaly Index
SAFE	Space Application for Environment
SPI	Standardized Precipitation Index
SVAT	Soil-Vegetation-Atmosphere Transfer
SWSI	Surface Water Supply Index
TRMM	Tropical Rainfall Measurement Mission
TVDI	Temperature Vegetation Dryness Index
UT	University of Tokyo
UNU	United Nations University
WCRP	World Climate Research Project
WEB-DHM	Water and Energy Budget Distributed Hydrological Model
WEB-DHM-S	Water and Energy Budget Distributed Hydrological Model – Snow (with advanced snow and glacier scheme)
WMO	World Meteorological Organization
WSSD	World Summit on Sustainable Development

Access to the data, meeting presentations and reports:

Access to the AWCI in-situ data is available through the DIAS portal:
http://dias-dss.tkl.iis.u-tokyo.ac.jp/ddc/finder?lang=en

Access to the meeting presentations and reports is through the AWCI website at:
http://monsoon.t.u-tokyo.ac.jp/AWCI/

- page “Meetings”
- page “Publications, Documents”