Summary report on
The GEOSS Asian Water Cycle Initiative (AWCI) Training Course for the Climate Change Assessment and Adaptation (CCAA) Study

held
at the University of Tokyo, Hongo Campus, Tokyo, Japan
11 – 12 March 2011
(http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Mar2011/index.htm)

At the 7th AWCI ICG meeting held in Tokyo, Japan, in October 2010, the white paper (Attachment 1) on the Climate Change Assessment and Adaptation (CCAA) study was finalized and implementation steps and schedule were proposed. Subsequently, AWCI country representatives have proposed suitable basins and nominated leaders of the CCAA study in their countries. The first stage of the CCAA study includes assessment of the climate change impacts on water resources using the CMIP3 climate model projection outputs as forcing data and hydrological models to simulate water budget in a basin. Accordingly, a training course has been proposed for the CCAA study leaders to get familiar with the methods and tools necessary for accomplishing the goals of the assessment part of the study.

The AWCI training course for the CCAA study was planned in conjunction with other related events, namely the Global Terrestrial Network – Hydrology (GTN-H) meeting (12 – 13 March 2011, with a joint AWCI-GTN-H session on 13 March), the Integrated Global Water Cycle Observation (IGWCO) meeting (14 – 15 March 2011), and the 5th GEOSS AP Symposium (16 - 18 March 2011, with a full day parallel session on Water dedicated to AWCI on 17 March). Unfortunately, due to the Great East Japan Earthquake on 11 March 2011 and subsequent tsunami disaster and associated issues, the 5th GEOSS AP Symposium was postponed (India, March 2012) and other events adjusted to the extraordinary conditions.

About 25 attendees from 15 countries participated in the training course including the AWCI CCAA leaders and several students from Korea and Japan. The training course program included four main parts: (i) Climate projection rainfall bias correction method by the University of Tokyo, (ii) WEB-DHM hydrological model application method using the bias corrected rainfall data and other projection forcings by the University of Tokyo, (iii) Flood modeling system IFAS (Integrated Flood Analysis System) applications by

ICHARM, and (iv) Multi-model ensemble hydrologic modeling in use for Climate Change assessment by the Sejong University. Nevertheless, due to the earthquake, the ICHARM team could not come to the venue on 12 March and thus the IFAS course was cancelled and the morning session of 12 March was dedicated to the WEB-DHM training and two other related lectures. All the given presentations and some training material can be accessed through the internet at:
http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Mar2011/presentations.html

The final agenda was as follows:

Program of the AWCI training course for the Climate Change Assessment and Adaptation Study
March 11 – 12, 2011

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.

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 – 12:15 2.4 Rainfall Bias Correction
12:15 – 12:30 **Photo session (in front of the No. 1 Building)**

12:30 – 13:30 Lunch

13:30 – 14:40 2. Rainfall bias correction and downscaling methods by the University of Tokyo group – continue

14:40 – 15:45 BREAK and Earthquake

15:45 – 18:30 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
- Introductory lecture (Lei Wang)
- Practical training

Saturday 12 March 2011
09:30 – 12:00 3. **Hydrological model WEB-DHM (Water and Energy Budget Distributed Hydrological Model) use for the CCAA purposes - continued**
- Practical training
- Drought Indices and Climate Change Impact Assessment (Patricia Jaranilla-Sanchez)
- Development of spatially distributed energy balance snow model (WEB-DHM-S) and its application from point to basin scale (Maheswor Shrestha)

12:30 – 13:30 Lunch

13:30 – 17:00 5. **Multi-model ensemble hydrologic modeling in use for Climate Change assessment by Prof. Bae – Sejong University (including break)**
- Overview of Climate Change Impact Assessment on Water Resources
- Hydrologic Modeling
- Case Study: SURR Model

1. Training course preparation

Table 1: Data status for CCAA and preparation for bias correction and WEB-DHM courses just before the training course.

AWCI CCAA Data Status and training course preparation as of 11 March 2011

#	Country	CCAA Basin Name	Proposal	Basin Info	Historical data (1981 - 2000)	Bias Correction	WEB-DHM
1	Bangladesh	Meghna	Comp.	Complete	Complete	YES	YES
2	Bhutan	Punatsangchhu	Comp.	Complete	Partially (1986 ->)	YES	
3	Cambodia	Sangker	Comp.	Complete	Complete	YES	YES
4	India	Upper Bhima	Comp.				
5	Indonesia	Citarum	Comp.	Complete	Partially (1981 -> 1999)	YES	YES
6	Japan	Tone	Comp.	Complete	Complete	YES	YES
7	Korea						
8	Lao PDR						
9	Malaysia	Langat	Comp.	Complete	Complete	YES	YES
10	Mongolia	Tuul	Comp.	Complete	Complete	YES	YES
11	Myanmar	Shwegyin	Comp.	Complete	Complete	YES	YES
12	Nepal	Narayani	Comp.	Complete	Complete	YES	YES
13	Pakistan	Hunza	Comp.	Complete	Partially (1999 ->2008)	YES	YES
14	Philippines	Pampanga	Comp.	Complete	Complete	YES	YES
15	Sri Lanka	Kalu Ganga	Comp.	Complete	Complete	YES	YES
16	Thailand	Mae Wang	Comp.	Complete	Partially (1980 - 1991)	YES	YES
17	Uzbekistan	Chirchik-Okhangaran	Comp.	Complete	Complete	YES	
18	Vietnam	Huong	Comp.	Complete	Complete	YES	YES

Per agreed to schedule of the CCAA study, the CCAA leaders had been asked to provide historical observations in the and near to the selected basin – mainly daily rainfall, temperature, and discharge – by mid-February 2011. These datasets were then used for preparation of the rainfall bias correction and WEB-DHM application course, which allowed participants to use their own data during the training course. Those, who have not submitted sufficient data by the requested deadline, used the Japan Tone river basin data during training. The status of data submission and training course preparation is summarized in Table 1 above.

2. Opening and Rainfall bias correction

The event was opened by a brief welcome talk given by Prof. T. Koike, who acknowledged participants cooperation in submitting the 20-year historical data records that were indispensable for preparing the first part of the training course. He also appreciated special efforts of the IFAS team and Prof. D. Bae's group, who prepared other parts of the training course, providing more insights in the hydrological modeling for use in the CCAA study. Program of the two-day course was introduced and appreciation expressed to the sponsoring organizations including the University of Tokyo, the Hiroshima University, and the Seoul University, and other supporters.

The rainfall bias correction training course begun with a comprehensive introductory talk by Prof. Koike, who explained the scheme of the climate change impact assessment using (i) the multiple output of global climate models (GCM) for assessing the changing hazard and (ii) integrated hydrological models for assessing changing hydrology. Based on the assessment results and integrating them with relevant socio-economic data, valuable information can be produced for raising public awareness and undertaking effective actions towards adaptation. The methods and models developed at the University of Tokyo as well as applications in certain AWCI countries were introduced. The scheme of a complex CCAA study is shown in Figure 1.

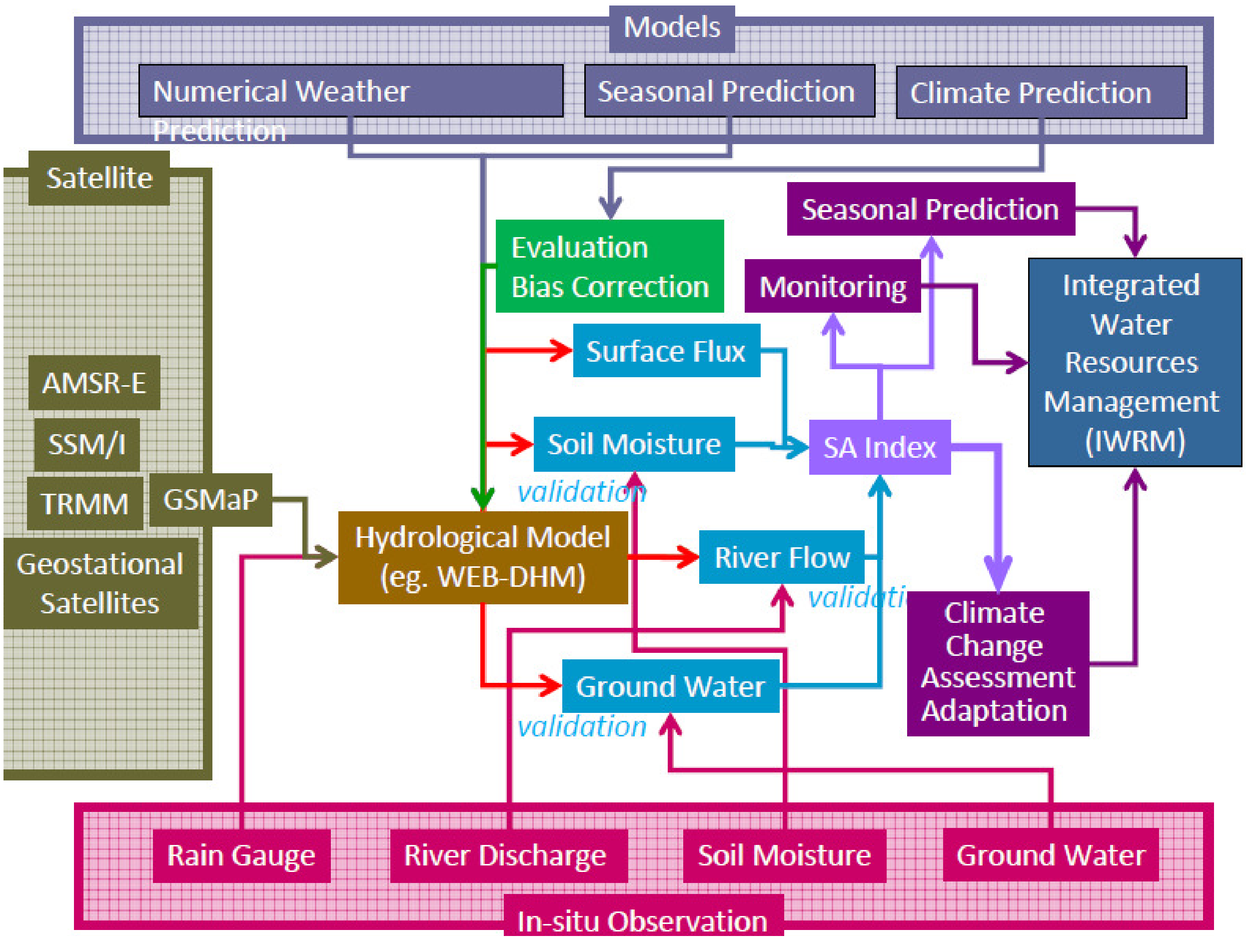


Figure 1: Scheme of a complex CCAA study depicting data integration.

The current GCMs have certain limitations resulting in significant uncertainties of their rainfall outputs. The main issues include large diversity among models, low extreme heavy rainfall, small number of no-rain days (producing long lasting, very low intensity drizzle), low seasonal representation, and low spatial distribution. Accordingly, the model output must be corrected for bias using the in-situ data, downscaled, and multiple model output must be considered in hydrological analysis.

The presented rainfall bias correction method includes several steps that were explained in detail. Firstly, the available global model past simulation outputs (1981 – 2000) are checked against observation-based products for a selected region. Based on spatial correlation and root mean square error of monthly mean rainfall, individual models are "scored" and those with a low score excluded from further analysis. Secondly, the rainfall output of the selected models is then corrected for bias using the relevant in-situ observations for the same period (provided by CCAA leaders for the nominated basins). It includes three parts:

(i) extreme rainfall correction – using the plotting positions method considering multiple distributions and selecting the best fit distribution function
(ii) no rain days correction – determining threshold rainfall intensity of the model output, below which the projected rainfall is considered as "no rain"
(iii) moderate rain correction – finding a bias correction coefficient for each month of a year

All these steps had been elaborated in MS Excel sheets and templates for the training course participants prepared together with a reference document on the Excel sheets.

After the introductory lecture, the interactive training part was led by Dr. P. Koudelova. Participants were provided with fully equipped computers assuring that each participant had access to his/her country data and the Japan Tone river dataset only, because the longer historical data records are have not been subjected to the open AWCI policy yet.
The rainfall bias correction procedure was divided into three steps:

1. Selection of suitable model outputs for a particular region.
2. Downloading the selected model outputs, filling the gaps.
3. Inputting the downloaded data and corresponding in-situ data into the bias correction excel sheet and reading the results.

The participants followed the instructions and actively worked applying the method for their region and using their basin data. Assistance was provided by the University of Tokyo researchers and students to effectively complete all the necessary tasks. Participants got familiar with a special internet-based tool for viewing, comparing, and analyzing the CMIP3 model outputs and enabling also data download. They carried out the model scoring procedure using a pre-prepared template, which yielded a limited number of “suitable” models for their region. Rainfall of these models was downloaded including the past period corresponding to the available in-situ observation record as well as the future projection. Using another template sheet, the model output was checked and if necessary corrected for missing values that occur in some models due to a simplified calendar used for long-term simulations and projections. The gap-filled data were inserted into the bias correction sheet that automatically computed the corrected data. The main functions and approaches of the sheet were explained and the corrected future rainfall projection dataset stored for later use in the WEB-DHM part of the training.

3. Water and Energy Budget Distributed Hydrological Model (WEB-DHM)

The WEB-DHM training session was opened by a lecture given by Dr. Lei Wang, who explained the structure and main components of the WEB-DHM model and also provided examples of its application in the CCAA study. In the second part of the lecture, the design of the training course was outlined. As listed in the Table 1 above, for most of the nominated basins, the WEB-DHM model was developed in advance and forcing datasets prepared using the past (1981 – 2000) data from available sources (e.g. JRA25) as well as future projection data including the bias corrected rainfall. Thus most of the participants could work with own data in their river basin, using also the rainfall corrected output produced during the bias correction training course. The UT group researchers and students provided assistance to the participants, who learned how to initialize and run the WEB-DHM model and how to visualize and analyze the results, including comparison of discharge and basin water budget during the past and future.

In addition, two contributions were presented introducing applicability of WEB-DHM in the climate change related studies. The first one was dedicated to drought, introducing a standard anomaly index assessing various types of drought and integrating the information into a one index. Using the future projections or seasonal forecast as forcing data for WEB-DHM, drought tendencies in future and seasonal drought forecast can be produced.

The second presentation introduced an augmented version of WEB-DHM including an advanced snow cover and snowmelt model based on energy balance method (WEB-DHM-S). It has been validated against satellite data (for the snow cover) as well as against river discharge (snowmelt) and provided satisfactory results. It has a great potential for the climate change studies in the basins where snow-related phenomena are significant. The model is also being coupled with a glacier-melt model to be usable for glacier areas too.

4. Multi-model ensemble hydrologic modeling

This session was prepared by Prof. D. Bae and his colleagues at the Sejong University, Korea. Firstly, a lecture providing overview of climate change impact assessment on water resources was given. It reviewed the chronicle of climate change research and introduced general approaches of the impact assessment

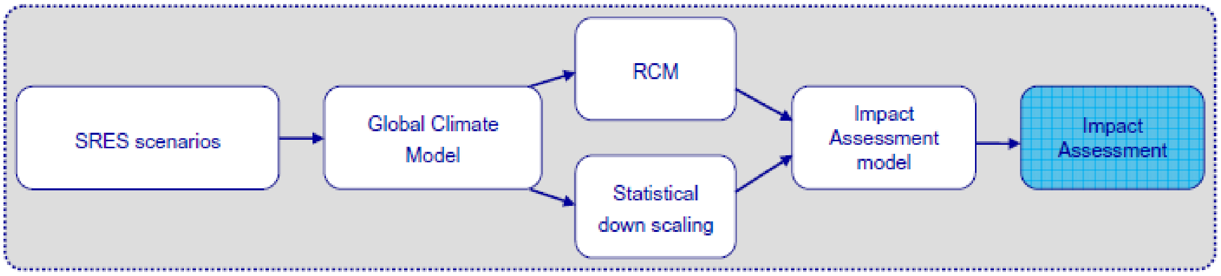


Figure 2: General processing of climate change impact assessment on water resources.

process (Fig. 2). Capabilities and limitations of GCMs were highlighted and various sources of uncertainties of the impact assessment explained that include Special Report on Emission Scenario (SRES) greenhouse gas emission scenarios, GCMs, downscaling technique, and impact assessment model. In order to cope with these uncertainties, multi model ensemble modeling approach has been developed, which was also introduced during the lecture. A study on quantifying magnitude of the uncertainties was presented, in which multiple hydrological models were run using multiple GCM outputs considering 3 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.

The second presentation focused on hydrological modeling, providing overview of available hydrological models all over the world, introducing hydrologic impact assessment process (Fig. 3) and explaining in detail two hydrological models representing (i) macroscale – global hydrological model VIC (Variable Infiltration Capacity) and (ii) microscale – Sejong University Rainfall – Runoff Model (SURR). Model

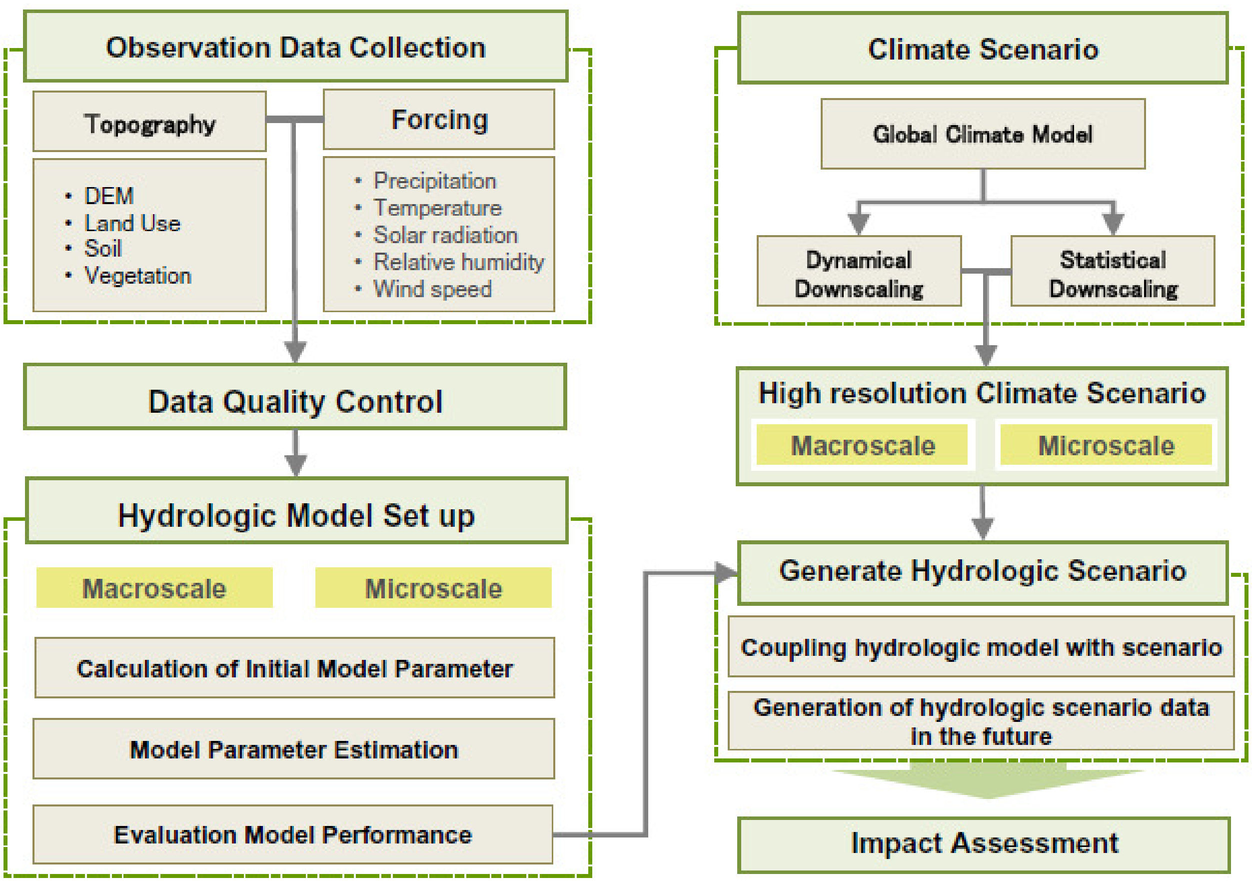


Figure 3: Hydrologic impact assessment process

structure and physics were introduced for both models and applications to Korean river basins were presented. The results indicated applicability of both the models for climate change assessment using hydrological analysis.

The third part of the session was dedicated to the application of the SURR model that was explained to the participants on a case study. Model simulation process (Fig. 4) was explained and step by step procedure shown. The sample simulation was done for the Korean AWCI demonstration basin, the Chungju dam basin.

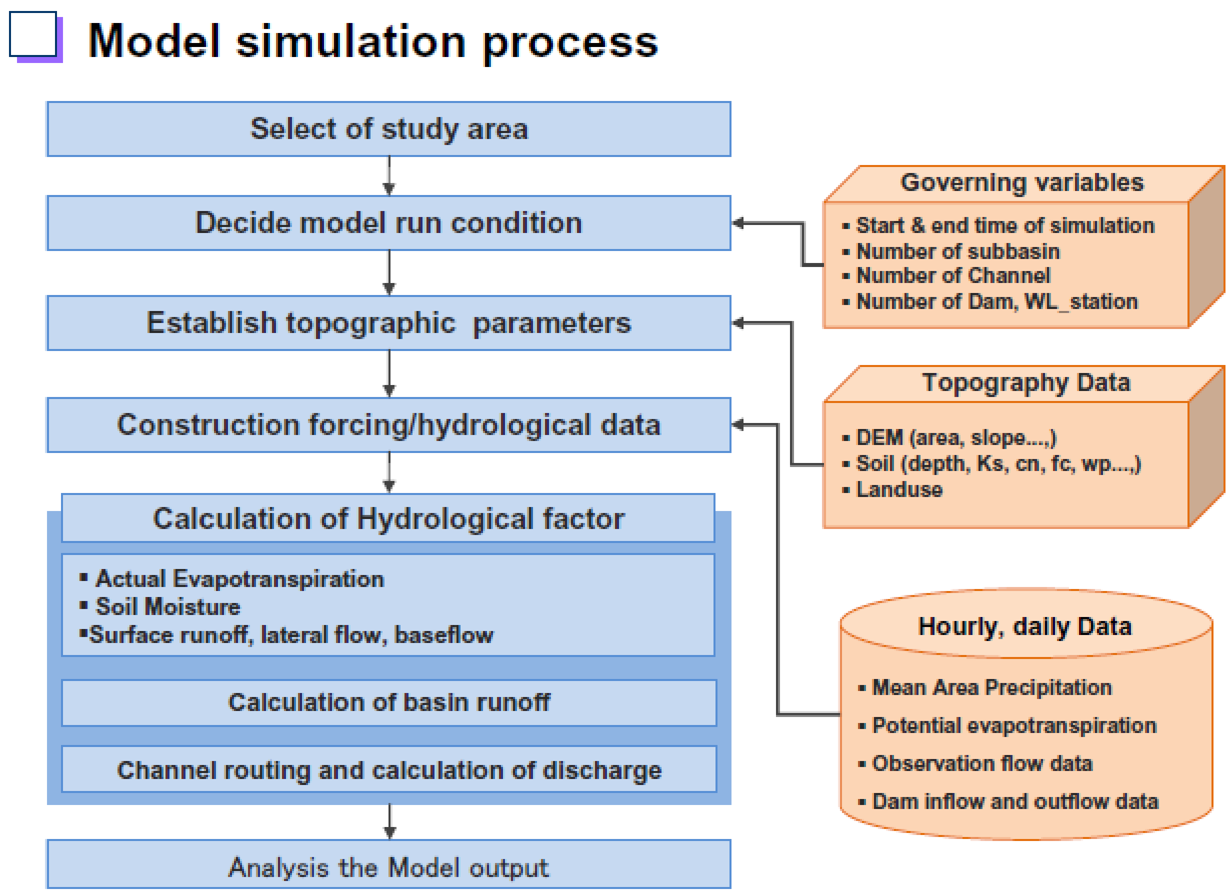


Figure 4: SURR model simulation process

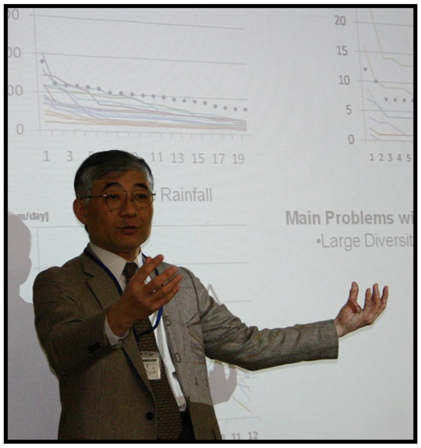
5. Closing

At the end of the two-day event, Prof. T. Koike summarized the achievements and acknowledged participant's diligent work during the working sessions. He appreciated participants' focus on the course subject and their kind cooperation regardless the difficult situation after the earthquake.

This training course was understood to be a kick-off event for the CCAA activities and the CCAA leaders were asked for continued cooperation and timely data submissions.

The participants were invited to attend the subsequent events, namely the GTN-H and IGWCO CoP workshops. Several AWCI country representatives contributed a country report during these events.

The next AWCI event was proposed in October and subsequently it was confirmed that the next AWCI meeting will be held in Seoul, South Korea on 6 – 8 October 2011.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ATTACHMENT 1

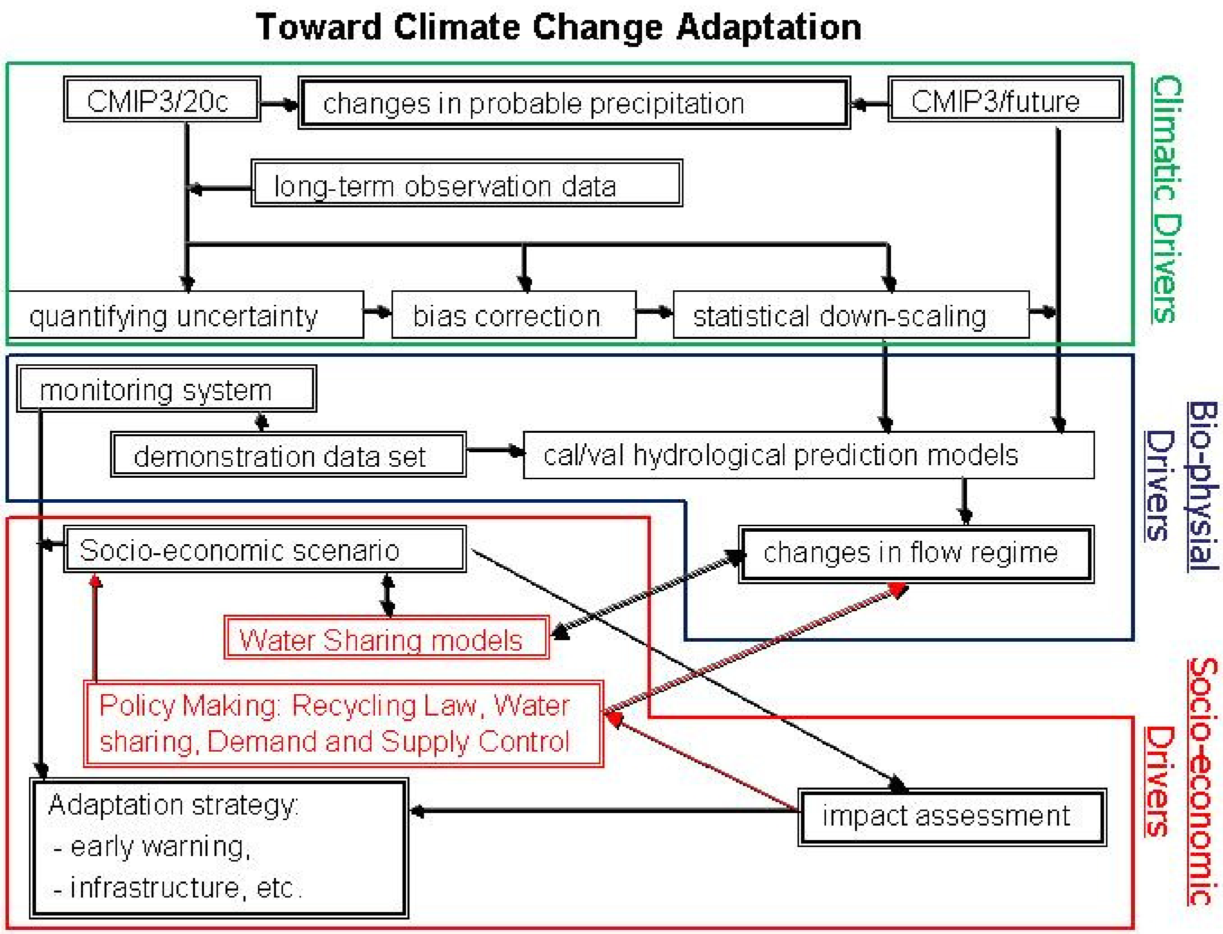
Whitepaper on the GEOSS/AWCI Climate Change Impact Assessment Activity

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.

2. Mission



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

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

Step I for Climate & Bio-Physical Drivers

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 and is currently beginning its activities (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.

1. Flood

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.

2. Drought

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.

<u>Step II for Socio-Economic Drivers</u>

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.

<u>1. Risk Assessment</u>

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.

<u>2. Multilayered Risk Management</u>

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.

6. Timeline

30 October 2010:	Proposing a river basin for the Climate Change Assessment and Adaptation (CCAA) study by each AWCI member country and providing information on the available observation.
30 November 2010:	Review of available bias correction and downscaling methods (Japan)
February 2011:	Data submission to DIAS
March 2011:	Workshop and training session on downscaling, bias correction, and hydrological modeling at the occasion of GEOSS AP Symposium and Asian Water Cycle Symposium
March - October 2011:	Conducting the step I activities – impact assessment (climate and bio-physical drivers
October 2011:	Discussion on socio-economic drivers and related activities, planning