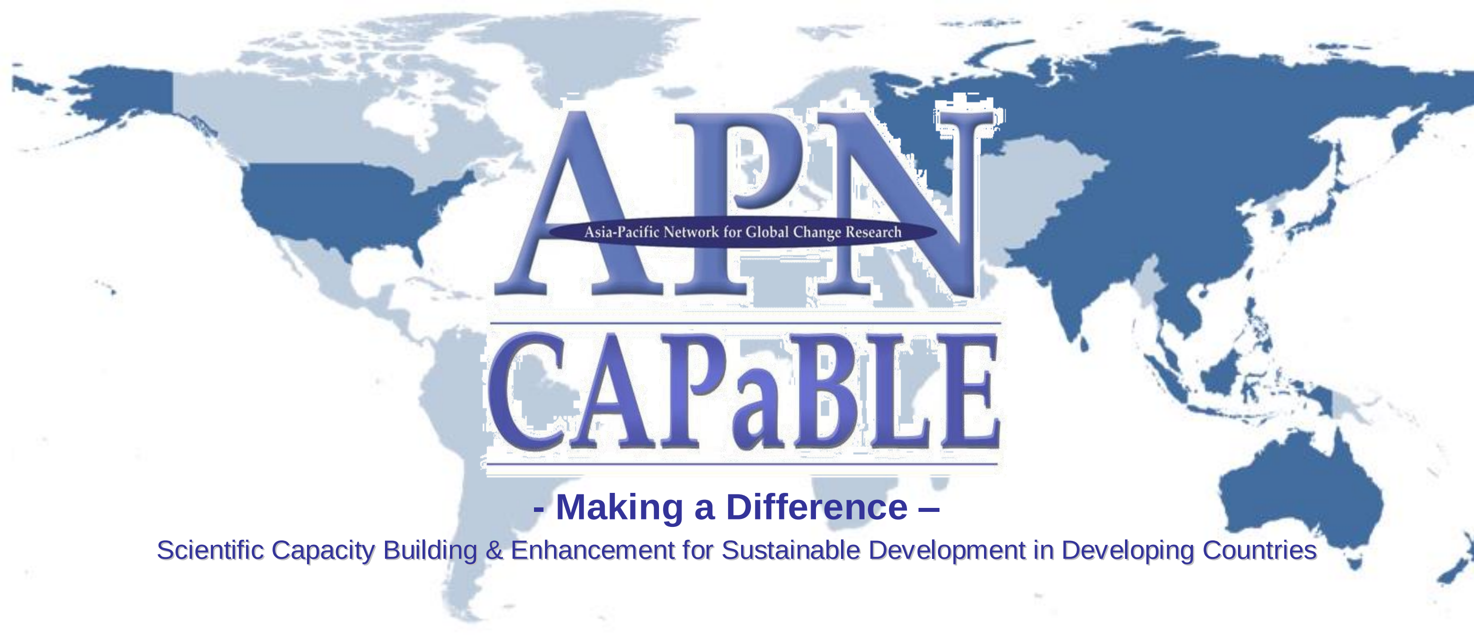
FINAL REPORT for APN PROJECT

Project Reference Number: CBA2013-01CMY-Rasul

Impact of Climate Change on Glacier Melting and Water Cycle Variability in Asian River Basins



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OVERVIEW OF PROJECT WORK AND OUTCOMES

Non-technical summary

This project is aimed at the capacity building of the scientists and institutions of participating member countries to cope with the foreseen situations due to climate change and for developing strategies to adapt the changes on scientific grounds. The activity was launched to jointly study the impact of climate change on the glacier melting process and water cycle variability in the Asian river basins. The kick-start of this project took place at the 9th Meeting of the GEOSS Asian Water Cycle Initiative-International Coordination Group (AWCI ICG) in Tokyo in September 2012. The project included three capacity building training workshops and also contributed to the AWCI ICG meetings which comprised representatives of water-related governmental and private agencies of the participating countries. The training workshops aimed at learning improved methods and tools necessary for processing climate model projections of future meteorological variables to be usable for assessment of climate change impacts on water resources, application of the processed GCM output as forcing data to run hydrological models and analyses of these hydrological simulations for possible future changes in intensities and frequencies of extreme events (floods and droughts). Special attention was paid to hydrological modelling and climate change impact assessment in cold regions with significant snow and glacier cover by using the WEB-DHM-S model.

Keywords

Climate Change, Water Cycle, Cold Region Hydrology, Glaciers, WEB-DHM-S.

Objectives

The project objectives included:

1. To improve the climate change assessment and downscaling techniques;
2. Building the capacity of member countries for the finest temporal and spatial resolution climate projections;
3. Training of professionals for application of WEB-DHM-S (Hydrological Model for cold regions including snow and glacier processes);
4. Assessment of glacier melt and hydrological regime shift in the light of climate change scenario;
5. Assessment of water cycle variability and development of drought early warning system.

Amount received and number years supported

The Grant awarded to this project was:
US$ 40,000 for Year 1: 2012/2013
US$ 36,000 for Year 2: 2013/2014

Activity undertaken

Capacity building. Three training workshops were organized that included: (i) the AWCI Training Course on Improved Bias Correction and Downscaling Techniques for Climate Change Assessment including Drought Indices held at University of Tokyo Hongo Campus, Tokyo, Japan, June 2013; (ii) the AWCI Training Workshop on Assessment of Climate Change Impact on a Watershed Hydrology including Hydrological Modeling in Cold Region Basins held in Islamabad, Pakistan, September 2014;

and (iii) an intensive WEB-DHM-S model training, Tokyo, Japan, March, 2015. The University of Tokyo has been providing the technical support on downscaling techniques, scenario development, climate impact assessment, hydro-climatic modelling, bias correction of models and use of hydrological models.

Data collection and integration. Contribution to the AWCI data collection and integration activities in the AWCI demonstration basins. Acquisition of cloud-free satellite imageries of selected glaciers. Selection of CMIP5 models and acquisition of baseline (1975-2005) and future (2010-2100) data of selected GCMs for 2 RCPs (4.5 and 8.5) (Moss, R.H et al., 2010). As part of the project activities in Pakistan, number of in-situ observation datasets from the Indus and Soan basins have been collected and shared with the UT research team but not opened publicly at this stage.

Research Activities. The project has contributed to the AWCI activity on climate change impact assessment on hydrological regime in nominated AWCI basins. The initial assessment with focus on drought has been carried out during the AWCI training course in June 2013. The project also supported development and validation of the WEB-DHM-S hydrological model, which includes advanced snow and glacier components, in the Hunza and the whole Upper Indus river basins by providing all available in-situ observations. Furthermore, the project has initiated a closer collaboration between the PMD and the University of Faisalabad and the University of Tokyo team targeting a comprehensive study in the Indus river basin addressing broad range of issues under the "water-climate-agriculture" nexus and considering also its socio-economy aspect. This set of studies include hydrological analyses by the WEB-DHM-S model in the Upper Indus basin, flood and flood inundation analyses by using the Ca-Ma Flood model along the whole Indus basin and combining these analyses with the DR^2AD economical model to estimate impact of disasters and the effect of disaster prevention investment on future economy growth. Similar economy impact study is carried out in the Soan basin and adjacent Pothohar area focusing on drought impact on agriculture produce. The intention is to plan similar complex of assessment studies in other AWCI countries.

Contribution to relevant meeting events and conferences. The project contributed to several events. (i) The 9th Meeting of the GEOSS Asian Water Cycle Initiative-International Coordination Group (AWCI ICG) and the 2nd AWCI Climate Change Assessment and Adaptation (CCAA) Study Workshop held in Tokyo in September 2012 included a kick-off session of this project. It was the first meeting of the project leader, co-leaders and collaborators to discuss the framework and future plan of activities to be undertaken during the first year. Prominent scientists of the region from Bhutan, India, Japan, Mongolia, Myanmar, Nepal, Pakistan and Uzbekistan have been collaborating to address the climate change issues in the cryosphere for assessing the water availability in large Asian river basins. (ii) An oral presentation on Integrated study of water resources management in Pakistan with focus on drought and impacts on agriculture production was presented at the MAIRS Open Science Conference held in Beijing, China in April 2014. (iii) The 10th AWCI ICG Session held in conjunction with the 7th GEOSS Asia-Pacific Symposium and the 10th GEO Integrated Global Water Cycle Observation (IGWCO) Community of Practice Meeting in Tokyo, Japan, in May 2014. Contributions to this event included oral presentations at the Water theme session of the GEOSS AP Symposium, discussion inputs at the AWCI ICG meeting and oral presentations on country activities by project participating countries at the IGWCO meeting. (iv) The Tokyo Conference on International

Study for Disaster Risk Reduction and Resilience in Tokyo, Japan in January, 2015. A poster presentation on the project activities and outcomes was provided at the Conference.

Results

- Data archived for four CMIP5 GCMs for Baseline (1975-2005) and future (2010-2100). Downscaled precipitation and temperature future scenarios were developed at 25km resolution for Indus river basin for four GCMs and both RCP4.5 and RCP8.5 (2010-2100) using advanced delta method.
- Results from preliminary climate change impact assessment studies in AWCI basins focusing on drought issues and results from a more complex assessment study carried out in the Soan basin in Pakistan.
- Initialization and first results of the comprehensive Indus basin set of studies including analyses addressing disaster risk reduction and other issues under the "water-climate-agriculture" nexus by using the WEB-DHM-S model, Ca-Ma Flood model, Hydro-SiB model, and DR^2AD economical model (includes early warning systems for flood and drought). Verification of the WEB-DHM-S model in the Upper Indus basin.
- At the three focused training courses, participants from each member country acquainted with tools and methodologies for assessment of possible impacts of climate change on water resources.
- Contributions to meetings and scientific conferences – presenting results of the activities and sharing the gained knowledge at international forums. Demonstrating the capabilities to policy- and decision makers and discussing potential implementation in operational use.

Relevance to APN's Science Agenda and Objectives

Drought and flood are the two hydrological extremes which emerge from meteorology and impact seriously on the food security not only on national level but influence the socio-economics of the regions. This is the common problem of the most of the Asian countries such as Pakistan, India, Bangladesh, Vietnam, Thailand and China. Ranging from the arid to the humid climate, the floods and drought occur as magnificent disasters affecting the socioeconomic activities and livelihoods. Both drought and flood related to the water issue in GEOSS Implementation Plan, has been getting more and more attention from the planners and policy makers.

This project has been trying to build a network of trained professionals at national levels integrated to AWCI responsible for effective monitoring, data integration, climate change impact assessment and modelling for guiding on adaptation strategies. The training focused on skills that professionals need to possess to be able to prepare guidelines (in the water resources arena) for policy makers on solid scientific grounds to devise strategies for adaptation to the climate change.

Self-evaluation

The participating countries and institutions played very active role by following the timelines and submitting the concerned assignments. All the collaborators have been collecting the relevant data sets on national scales and compiling to make their contribution to the project. A water-energy budget based distributed hydrological model (WEB-DHM-S) which incorporates snow and glacier processes has been developed by University of Tokyo and validated in the Himalayas and Hindu Kush regions and pilot study has been carried out in the Upper Indus river basin as originally intended. Work on climate change impact assessment, scenarios development was completed at Pakistan Meteorological Department. Project achievements were presented by the project collaborators during AWCI ICG meetings to exchange knowledge and experience with colleagues struggling to deal with the similar problems. Young professionals of AWCI member countries were trained on the climate change impact assessment techniques and the theory and applicability of the WEB-DHM-S model. In addition, two young professionals from PMD have received full training on WEB-DHM-S model. We feel the objectives of the project have been fulfilled except for the completion of the assessment of glacier melt and hydrological regime shift in the light of climate change scenario. This study has been initiated and is currently ongoing in the Upper Indus basin.

Potential for further work

The project has enabled AWCI activities to proceed further and develop a strong working relationship between member countries. The developed tools, methods and the results of studies have been demonstrated to representatives from governmental sector of AWCI countries and all countries approved their participation in future with intention to implement the introduced approach in operational applications. The set of studies initiated in the Indus basin have a great potential for similar activities in other AWCI countries.

Publications

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Shrestha M, Wang L, Koike T, et al. 2012. Modeling the spatial distribution of snow cover in the Dudhkoshi region of the Nepal Himalayas. J. Hydrometeorology, 13: 204-221.

DIAS Data Access: http://www.editoria.u-tokyo.ac.jp/projects/dias/tools.php?locale=en_US

DIAS GCM data tool: http://dias.tkl.iis.u-tokyo.ac.jp/model-eval/stable/index.html
http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Sep2012/index.htm
http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Jun2013/index.htm
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http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/IslamabadTraining_Sep2014/index.htm

Acknowledgments

The project leader and all collaborators sincerely thank Asian Pacific Network for the Global Change for the financial and other forms of support without which the initiation and implementation of the proposed work would not have been possible.

TECHNICAL REPORT

Preface

Climate change has been altering snow occurrence pattern, residency period, early melting process, and glacier melting process. Consequently, regions depending on snowmelt and glacier melt runoff experience erratic patterns in water availability including rise of droughts and floods. To address these challenging issues, knowledge sharing among communities at regional level is crucial. Lack of capacity to make effective use of Earth observation data, numerical model output, and analysis tools in some Asian countries do not allow them to deliver services to end users for prevention and mitigation of losses. AWCI has taken initiative to introduce and train professionals on integrated techniques for CC impact assessment and tools for extreme event analysis and forecast relevant for cold regions.

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1.0 Introduction

AWCI (Asian Water Cycle Initiative) of GEOSS, which has organized cooperation among the 18 Asian countries, is 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 as the most important elements. AWCI is trying to approach water issues in cooperation between global observations and local applications, between research communities and operational sectors, and/or among the different socio- economic benefit areas. AWCI has four components for capacity building: flood, drought, water quality and climate change. This project focused on the capacity building of drought analyses under the framework of AWCI of GEOSS considering also snow and glacier covered areas.

It is a well known fact that drought is a major disaster frequently experienced by Asian countries including Pakistan. In Pakistan, four years long drought afflicted the most parts of the country from 1998-2002 causing huge economic losses from household to national scale. Delayed winter rains did not allow the crop (wheat) sowing in rained areas 3 out of 10 years during the first decade of 21st century. At the same time unusual early summer heat waves triggered snow/glacier melting and produced downstream flooding in 2005 and 2009. As severe drought events occurred in Mongolia during the recent decade, increased expected probability may have drought influences on the decrease in vegetation and the pasture condition change, which in turn will have significant impact on livestock, the main agriculture commodity in Mongolia. Similarly, further AWCI countries have been reporting increasing risk of losses due to droughts. In cold region countries, glacier melting under warming thermal regime has been altering snow occurrence pattern, snow residency period, its metamorphic conversion to ice and early melting process. Consequently, water availability periods and water demand satisfaction erratic format give rise to drought and floods which demand knowledge sharing among communities at regional level to address the challenging issues related to the water cycle.

Reflecting on these issues, most of the AWCI countries have been calling for drought monitoring and early warning systems that could reflect on changing climate consequences. However, while some countries do have in-situ drought monitoring networks, usually the capacity to make effective use of remotely sensed data and numerical model output is minimal, which do not allow them to deliver services to end users for early warning and mitigation of drought losses. Moreover, in countries with snow and glacier areas, adequate hydrological models are lacking that are necessary for a robust and effective drought (as well as flood) warning system. Therefore, this project was proposed under the AWCI collaboration targeting to enhance capacities of AWCI countries for drought monitoring and early warning and for hydrological modelling in snow and glacier covered regions. The specific objectives of the project included:

1. To improve the climate change assessment and downscaling techniques;
2. Building the capacity of member countries for the finest temporal and spatial resolution climate projections;
3. Training of professionals for application of WEB-DHM-S (Hydrological Model for cold regions including snow and glacier processes);
4. Assessment of glacier melt and hydrological regime shift in the light of climate change scenario;
5. Assessment of water cycle variability and development of drought early warning system.

2.0 Methodology

The project focused mainly on capacity enhancement, but it has been also supported by research activities. The capacity building efforts were realized through three training courses organized in cooperation with the University of Tokyo and partly supported by the collaborative APN project ARCP2013-11CMY-Yabe. The courses were:

1. The AWCI Training Course on Improved Bias Correction and Downscaling Techniques for Climate Change Assessment including Drought Indices held at University of Tokyo Hongo Campus, Tokyo, Japan, June 2013 (http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Jun2013/index.htm).

2. The AWCI Training Workshop on Assessment of Climate Change Impact on a Watershed Hydrology including Hydrological Modelling in Cold Region Basins held in Islamabad, Pakistan, September 2014 (http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/IslamabadTraining_Sep2014/index.htm).

3. The intensive WEB-DHM-S model training, Tokyo, Japan, March, 2015 (no website).

The first two courses were dedicated to the climate change impact assessment techniques and their application for hydrological analyses under the climate change scenarios and also included sessions on hydrological models and their applicability for drought and flood forecasts. These two courses were designed considering the common needs among all the AWCI countries and all the AWCI countries were invited to nominate a suitable candidate for these courses. The June 2013 training focused on droughts and the September 2014 training included sessions on hydrological modelling in cold regions. The third course was an intensive training session dedicated to practical use of the WEB-DHM-S model – a hydrological model with advanced snow and glacier components and its participants acquired skills to fully utilize the model for various research activities and to provide this knowledge further. In such a manner, the capacity of AWCI country professionals has been gradually enhanced in the aspects of climate change impact assessment on watershed hydrology, drought analysis, and hydrological modelling for temperate as well as cold regions by using advanced techniques and tools. With these skills, the trained professionals are capable to further pursue research and practical application activities in the trained areas.

The methodology of the research activities has followed the AWCI overall approach of data integration for addressing water cycle related issues. Pilot studies carried out mainly in the Indus river basin have employed various tools and methodologies developed at the University of Tokyo to support the data integration approach and the AWCI goals.

2.1 Drought Indices

A methodology for quantifying droughts was developed by Jaranilla-Sanchez, 2011 and firstly applied in the AWCI demonstration basin of Philippines, the Pampanga river basin. This methodology was adopted for drought analyses of this project and was demonstrated and exercised at the June 2013 training course. The method was derived from the standardized precipitation index, SI (McKee, 1993). The SI method has certain limitations for application to various hydrological parameters with various frequency distribution patterns (Jaranilla-Sanchez, 2011) and thus modification was suggested to use a Standard Anomaly index (SA) for temporal and spatial drought classifications. This index is based on a best-fitting distribution pattern of the monthly values of each hydrological parameter in consideration. These values may come from observation or hydrological models. In case of AWCI applications, outputs of the WEB-DHM and/or WEB-DHM-S simulations have been used, which allowed to analyze the drought spatially over the whole basin (for each grid of the model). This best-fitting distribution is transformed to the normal distribution according to Walpole, 2000 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. Classification of droughts was based on the SI categories (McKee et al., 1993). The effects of monthly and seasonal differences can be identified by SA. When using the physically consistent model as WEB-DHM, quantitative effects of evapotranspiration are integrated into calculation of other parameters. As different hydrological parameters may represent different types of drought (precipitation represents meteorological drought, runoff and groundwater table represent hydrological drought and soil moisture is relevant for agricultural drought), the SA for individual parameters may be combined to find out the most drought-prone areas of the investigated basin. The method can also be applied for future projections based on climate model projection outputs and thus analyze the possible changes in drought occurrence due to climate change.

2.2 WEB-DHM and WEB-DHM-S

A core tool of the AWCI River Management System is the Water and Energy Budget-based hydrological model (WEB-DHM) that was developed at the University of Tokyo and verified in various basins. It is being used for hydrological simulations in the investigated basins coupled with other tools to accomplish targeted objectives of a given study. The model 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 CO_2 fluxes at the basin scale. It physically describes evapotranspiration using a biophysical land surface scheme for simultaneously simulating heat, moisture, and CO_2 fluxes in the soil-vegetation-atmosphere transfer (SVAT) processes (Wang et al., 2009; Wang and Koike, 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 and vegetation parameters) and a meteorological forcing dataset including precipitation are attributed to each model grid, in which water, energy, and CO_2 fluxes are calculated. A hillslope-driven runoff scheme employing a kinematic wave flow routing method is adopted in calculating runoff.

Seasonal snow covers 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 (Liston, 1999). 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. 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).

2.3 Climate Change Assessment Framework

The schematic framework of the climate change assessment method and the data used are shown in Figure 1. The approach is to use the general circulation model (GCM) future climate projections as atmospheric forcing for hydrological models (WEB-DHM in case of AWCI study) to elucidate the impact of climate change on hydrological regime in the basin through comparison with historical simulations. In this case, the World Climate Research Programme's Coupled Model Intercomparison Project phase-3 (CMIP3) was considered but the same framework is going to be applied with the CMIP5 data that have already become available.

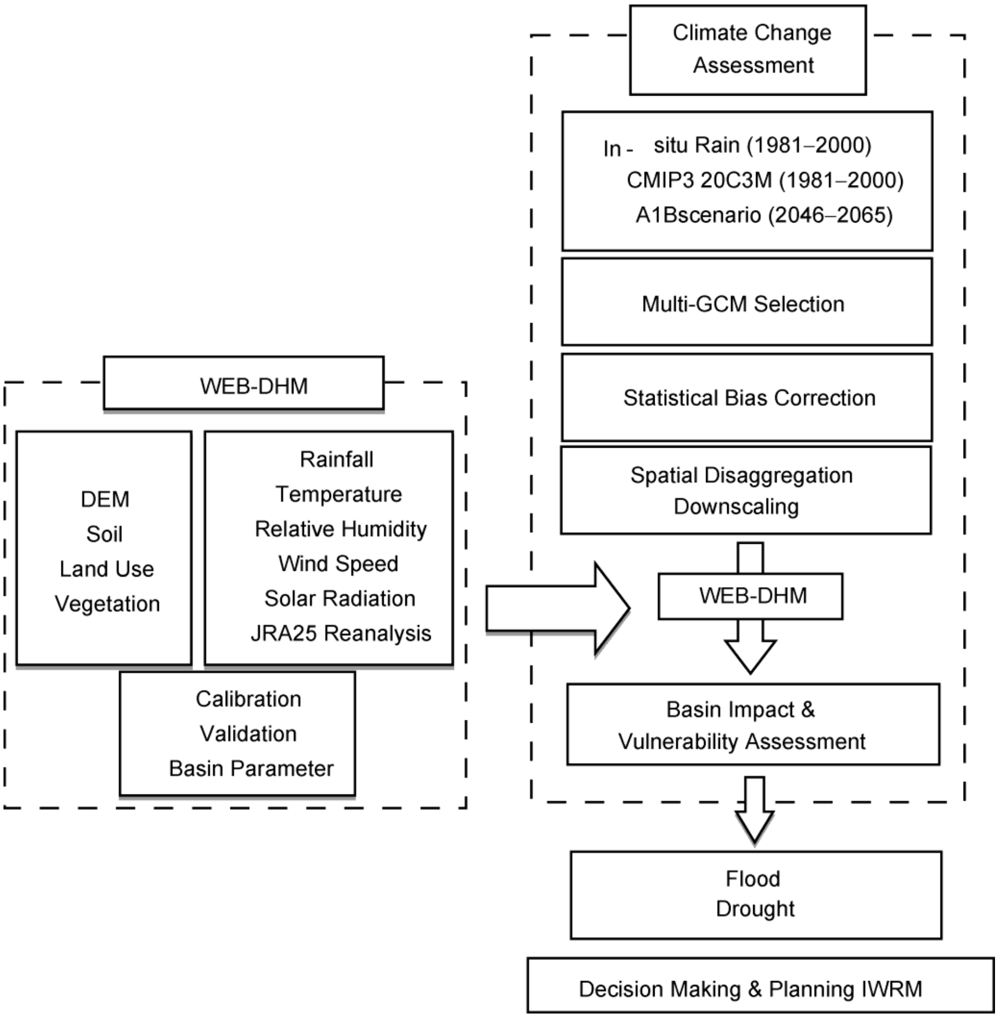

Figure 1 Climate Change Assessment framework, where CMIP3 is the World Climate Research Programme's Coupled Model Intercomparison Project phase-3, 20C3M is 20th Century Numerical Reproductive Experiment.

In the AWCI approach, a set of suitable GCM models for the investigated area are selected for the analysis rather than using the full ensemble of 24 GCMs of the CMIP3 project because some of the models cannot reproduce essential climatology of the subject region and their bias is too large to be correctible making their future projections irrelevant for this region. The selection method is based on model ability to represent regional climate during the base-line period. The key climatologic parameters (e.g. precipitation, air temperature, outgoing longwave radiation, meridional and zonal wind, sea surface temperature, and sea level pressure) produced by GCMs are compared with corresponding reference observation-based or reanalysis data. A simple index counter is used for identifying the models, which has above average spatial correlation and below average root mean square error (RMSE) prioritizing models with good rainfall patterns and seasonality. The output of selected models is subsequently corrected and downscaled using the *in-situ* observation following the method of Nyunt et al. (2013a, 2013b) described in Section 2.4. The corrected GCM outputs for the baseline period and the future analysis period are used as forcing data for the WEB-DHM, which produces hydrological response of the target basins.

2.4 Statistical bias correction method and downscaling for climate change impact assessment

The climate change impact assessment framework relies on General Circulation Models (GCMs) projection output as forcing data for hydrological models. However, there is substantial bias in GCMs precipitation output including the entire intensity spectrum (insufficient extreme events, biased mean intensity, extensive light intensity drizzle and too few dry days) and thus cannot be used to force hydrological or other impact models without some form of prior bias correction (Piani et al., 2010). Therefore, a comprehensive statistical bias correction method on the catchment scale was developed for applications in the AWCI basins (Nyunt et al. 2013a, 2013b). The daily precipitation output is corrected in three steps including extreme rainfall correction, correction of frequency of wet days (no-rain-day), and the bias of the inter-annual climatology monthly precipitation by using historical in-situ rainfall observation. The correction of extreme values 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).

The frequency of low-intensity rainfall wet days is corrected by using the ranking order statistics of 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 as no rain day. Finally, rainfall intensities between the extreme and no-rain-day thresholds are classified as normal rainfall in both observed data and GCM output. It is assumed that the cumulative distribution function (CDF) of monthly normal 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 and the CDF of daily GCM rainfall is mapped to the CDF of observed data for each month. In addition to the intensity and frequency bias, spatial downscaling of GCMs output is essential for regional and local impact studies. A statistical downscaling method was developed and employed in some demonstration basin cases (Nyunt et al., 2013b). It utilizes the Global Satellite Mapping of Precipitation (GSMaP; Kubota et al., 2007) product providing spatial rainfall pat-tern information (with resolution of 0.1°) and a correspond-ing rain gauge gridded dataset for correcting the GSMaP rainfall bias. A ratio of each GSMaP grid rainfall total at monthly scale with respect to the total over an area of a corresponding GCM grid is then used to downscale the bias corrected GCM rainfall output.

2.5 Data Integration and Analysis System (DIAS)

DIAS is a project for the creation of knowledge, which can be shared worldwide. With the goal of providing access to global and regional sensing data, a pilot system has been developed for the creation of an information storage infrastructure for public benefit applications and the deepening of scientific knowledge in the areas of climate, water cycle, for application in fisheries, agriculture and biodiversity management, particularly through the linking of information across disciplines. The mission of DIAS includes:

- to coordinate the cutting-edge information science and technology and the various research fields addressing the earth environment;

- to construct data infrastructure that can integrate earth observation data, numerical model outputs, and socio-economic data effectively
- to create knowledge enabling us to solve the earth environment problems
- to generate socio-economic benefits.

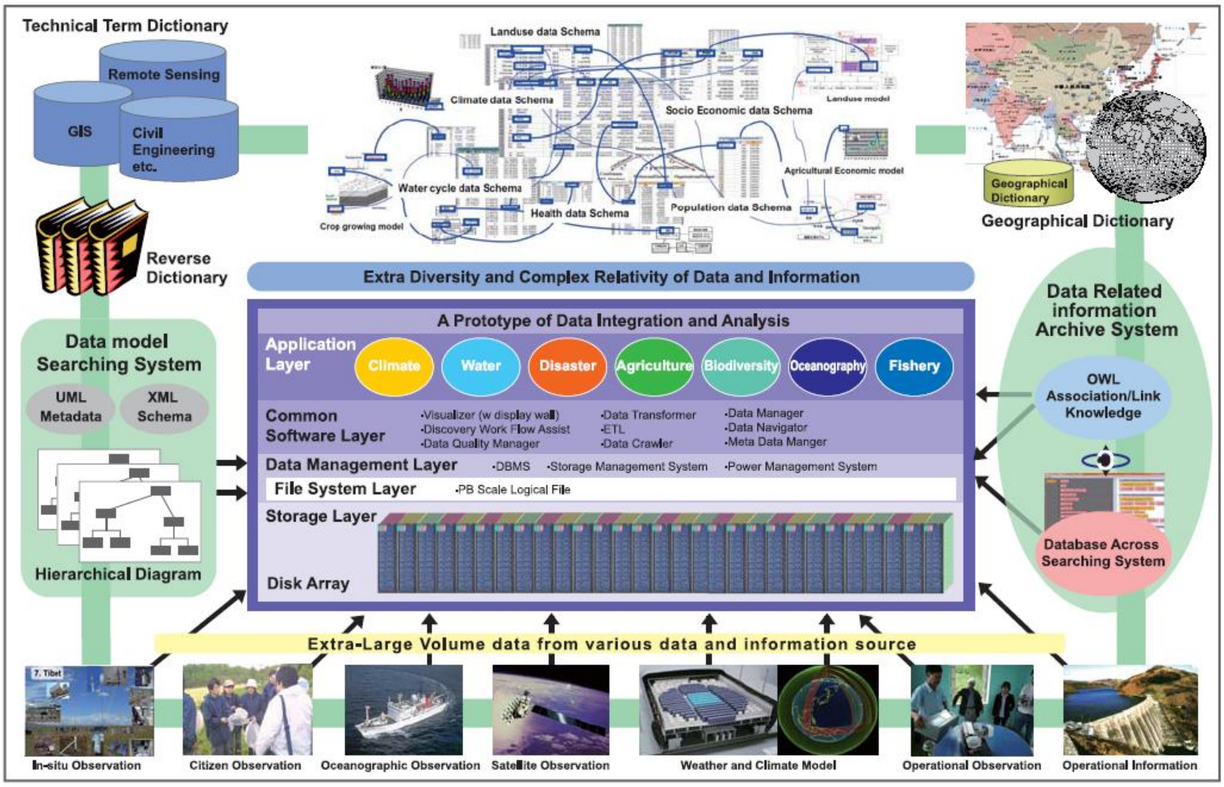

Figure 2 Structure of DIAS

The DIAS core system has been designed to accommodate a large volume and diversity of earth observations from inhomogeneous data sources and to provide functions for data analysis, integration and translation into information understood by wide communities including non-experts. DIAS provides supporting functions of life cycle data management, data search, information exploration, scientific analysis, and partial data down-loading. Essential is the DIAS ontology system for identifying the relationship between data and the cross-sectoral search engine for various databases. The interoperability portal provides an important function of data/metadata search, technical term search and visualization of relations among datasets registered in the DIAS core system. DIAS structure is shown in Figure 2. It consists of the data storage layer, data management layer, common software layer, and application layer, which encompasses various dedicated applications for analyzing and integrating the stored data. Among these applications are several data retrieving, visualization and integration functions designated for climate and water cycle analyses, some of them particularly devised based on AWCI requirements. These include the data archive and data management functions of the AWCI demonstration basin in-situ observations and the data uploading, data quality check and metadata registration functions; the archive and data retrieving and analyzing functions of the CMIP3 and CMIP5 data together with model selection and bias corrections functions (described below) and others. These functions are intended be widely available at no cost to the users and have been the subject of training during these project training sessions.

2.6 GCM archive, model selection and bias corrections functions on DIAS

The output of the CMIP3 and CMIP5 experiments are being stored at DIAS and a dedicated function for browsing, visualizing, analyzing and downloading selected data has been developed. The system is available on-line (http://dias.tkl.iis.u-tokyo.ac.jp/model-eval/stable/index.html), an interested user must open an own user account. The function allows browsing and analyzing only a selected portion of the data, which provides a great advantage to the user. For the purpose of climate change impact studies, other functions have been added on the system that includes the model selection support and model output bias correction function. The GCM output for a region in interest may be inspected against observation-based or reanalysis data to assess the suitability of each of the GCM models for this particular region as it is explained in Section 2.3 above. When the suitable models are selected, their precipitation output may be bias corrected using this on-line function, which employs the method described in Section 2.3 above. The corrected data may be viewed and analyzed on-line and also downloaded for further use.

2.7 Indus basin project

As a part of this project, a research activity in the Indus basin has been initiated carried out collaboratively by researchers from UT, PMD, Pakistan Agricultural Research Council (PARC), and the University of Agriculture, Faisalabad. The activity has built up on the previous achievements of AWCI as well as of this project and one of the foci was the Upper Indus basin, which is largely covered with snow and glaciers. The activity addresses potential impacts of climate change on water resources and their development in the Indus basin, in particular as it pertains to the food production and disaster risk reduction.

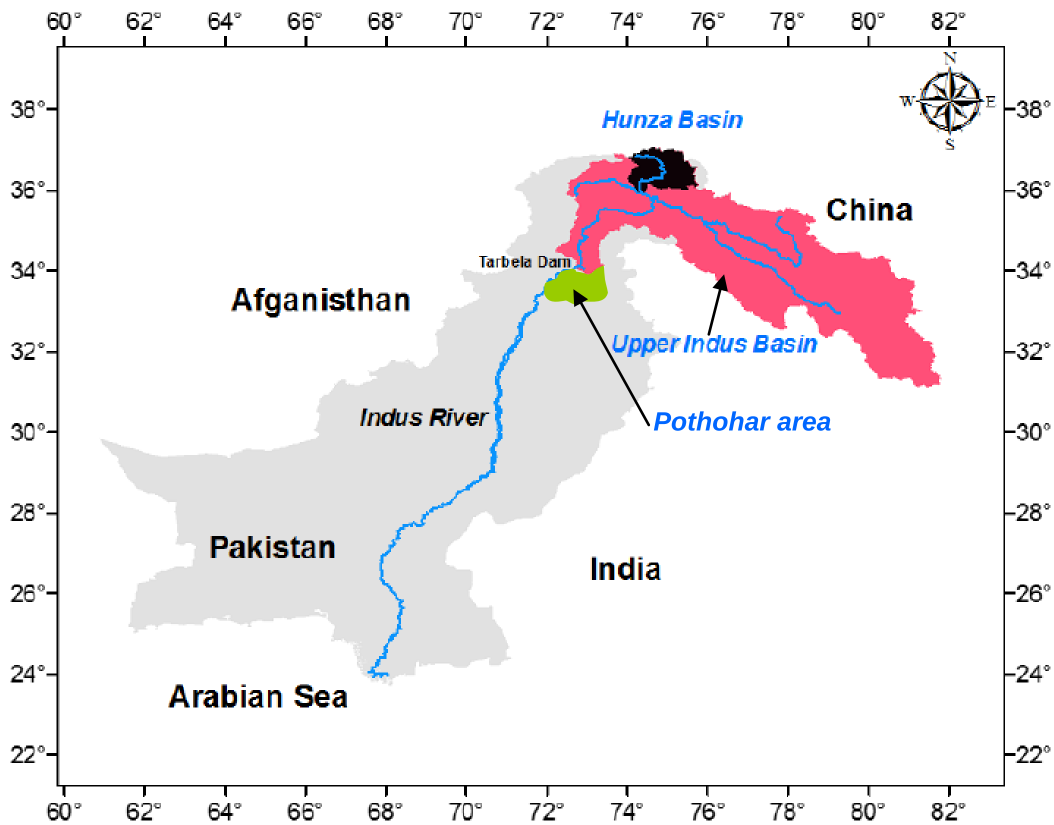

Figure 3: The Indus River basin with highlighted upper Indus Basin and Pothohar area – specific foci of the Indus study

The study encompasses three main foci.

1. A development and application of WEB-DHM with snow and glacier component (WEB-DHM-S) in the Upper Indus Basin (see Fig. 3). The main objective of this study is to enhance the simulation capability of snow- and glacier- melt in the Upper Indus River based a distributed hydrological model coupled with an integrated snow scheme, satellite and in-situ observations, and numerical weather prediction model outputs. To fulfil the main objective, this study outlined the following sub-objectives:

a) To develop spatially distributed energy balance based multi-layer snow and glacier melt model (WEB-DHM-S) as described in Section 2.2 above.

b) To estimate the contribution of snow and glacier melt runoff to the total discharge, and to simulate the spatial distribution of snow cover area (SCA), and glacier mass balances in Upper Indus River.

c) To simulate long term hydrological processes (about 30 years) with the use of Japan reanalysis dataset (JRA-55).

d) To select the suitable GCM, to perform statistical bias correction, and to estimate future discharge and precipitation regime so that the impact of climate change on water resources of this basin would be quantified with a considerable accuracy.

2. The second focus is an innovative-approach study of flood disaster impacts on economy in the lower Indus Basin that targets effects on economy growth rather than a disaster impact snapshot in a particular time. The study employs an integrated flood simulation model (Catchment-based Macro-Scale Floodplain model, CaMa-Flood) and the economic model DR^2AD (Disaster Risk Reduction Investment Accounts for Development). The DR^2AD model is based on Dynamic Stochastic General Equilibrium (DSGE) model that expresses processes such as economic growth or stock accumulation as well as a process of getting out of a “poverty trap”. In combination with the disaster impact data and data on potential reduction of the risk by a certain investment in disaster prevention (IDP), the model can simulate the effect of the investment on a number of features (e.g. how people suffer from the disaster or how it is spread). The model outcome examples are shown in Figures 4 and 5.

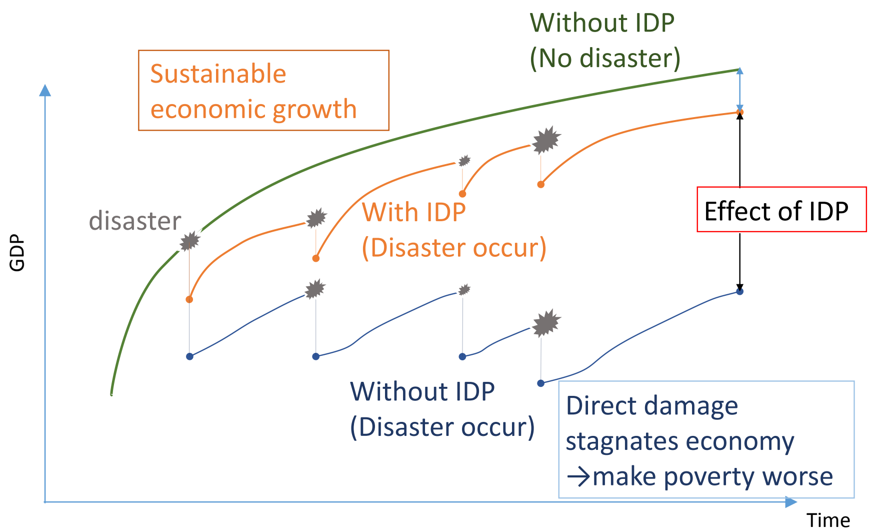

Figure 4: An example of the DR2AD model output showing an effect of investment in disaster prevention (IDP) on GDP.

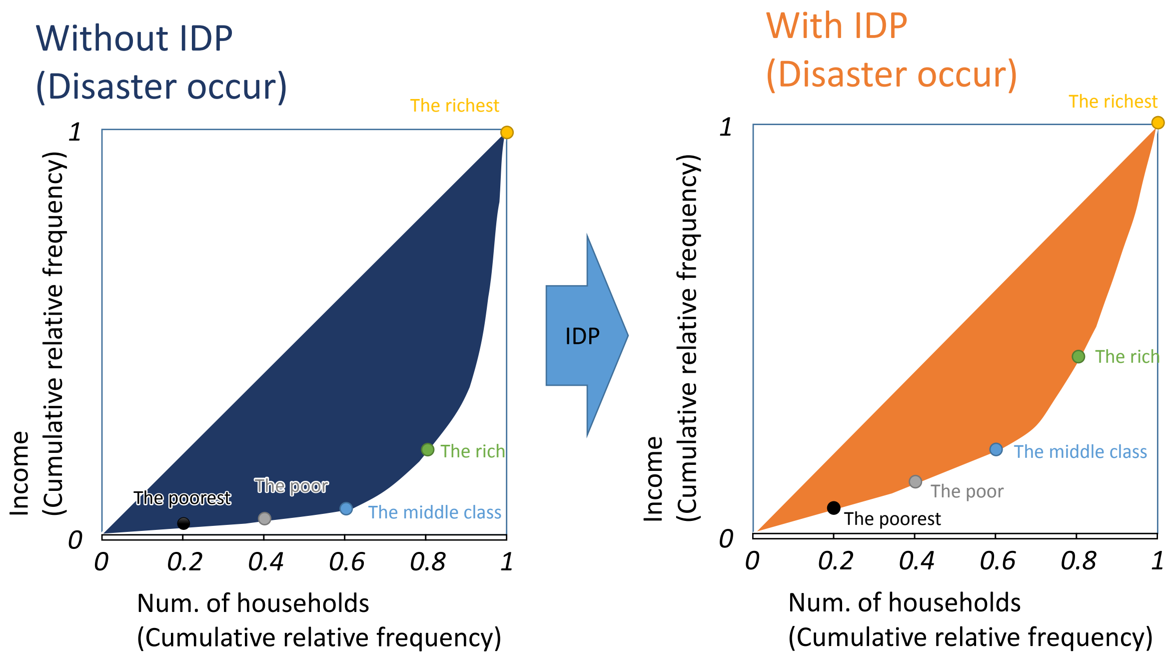

Figure 5: An example of the DR2AD model output showing an effect of investment in disaster prevention (IDP) on household income, i.e. possibility to escape from the poverty trap.

3. The third study targets droughts as a disaster and its impact on agriculture and subsequently on the economy. The pilot study is carried out in the Pothohar area (see Fig. 3). Numerical simulations of hydrological cycle and vegetation dynamics are helpful to predict and monitor severe droughts. However, it is still challenging to simulate both precise hydrological cycle and vegetation growth in the hydrological models. Moreover, data scarcity in many regions including some parts of Indus basin makes it difficult to calibrate and/or validate our modelling approach. We should also estimate the economic loss from the drought damage to contribute to decision making for the appropriate investment in drought prevention. These issues are solved by applying an eco-hydrological model that can calculate soil moisture, runoff, groundwater, and vegetation growth with the model parameter optimization technique assimilating satellite passive microwave observations. We also apply the economic model to integrate simulated droughts with economic losses in Pakistan (Fig. 6). We would like to answer the following questions: (1) how can we simulate hydrological and ecological responses to severe droughts in the nationwide scale of Pakistan including the ungauged area, and (2) how can we estimate economic losses from severe droughts and appropriate investment against them?

The strategy is to apply a new eco-hydrological model, called WEB-DHM-Veg, with in situ observed rainfall data and global-scale meteorological forcing products to the investigated river basin and the model performance is calibrated and validated against historical discharge and vegetation growth data and a historical drought is analyzed. This system has been successfully used in Africa in the Medjerda river basin in Tunisia (Sawada et al., 2014). Agricultural drought that is characterized by vegetation degradation occurred prior to hydrological drought characterized by river discharge and groundwater deficits. In addition, hydrological drought lasted longer than agricultural drought. Previous conceptual models have suggested these characteristics of severe droughts but we successfully simulated this process in the more quantitative way. The methodology given above is promising to analyze, monitor, and predict severe droughts. However, it is difficult to apply this approach in the ungauged area because we cannot have the access to field observations for model calibration and validation. Coupled Land and Vegetation Data Assimilation System (CLVDAS) addresses this issue by assimilating satellite passive microwave observations into model. Since satellite passive microwave observations are sensitive to both soil moisture and vegetation growth, we can optimize both hydrological and ecological parameters of our eco-hydrological model by using these satellite products that can be obtained everywhere. The CLVDAS method was successfully applied in West Africa, the Agoufou site showing that it can improve the model capability of simulating both surface soil moisture and leaf area index at the same time (Sawada and Koike, 2014). Finally, the economic DR^{2}AD will be run to evaluate the effect of investment in drought prevention.

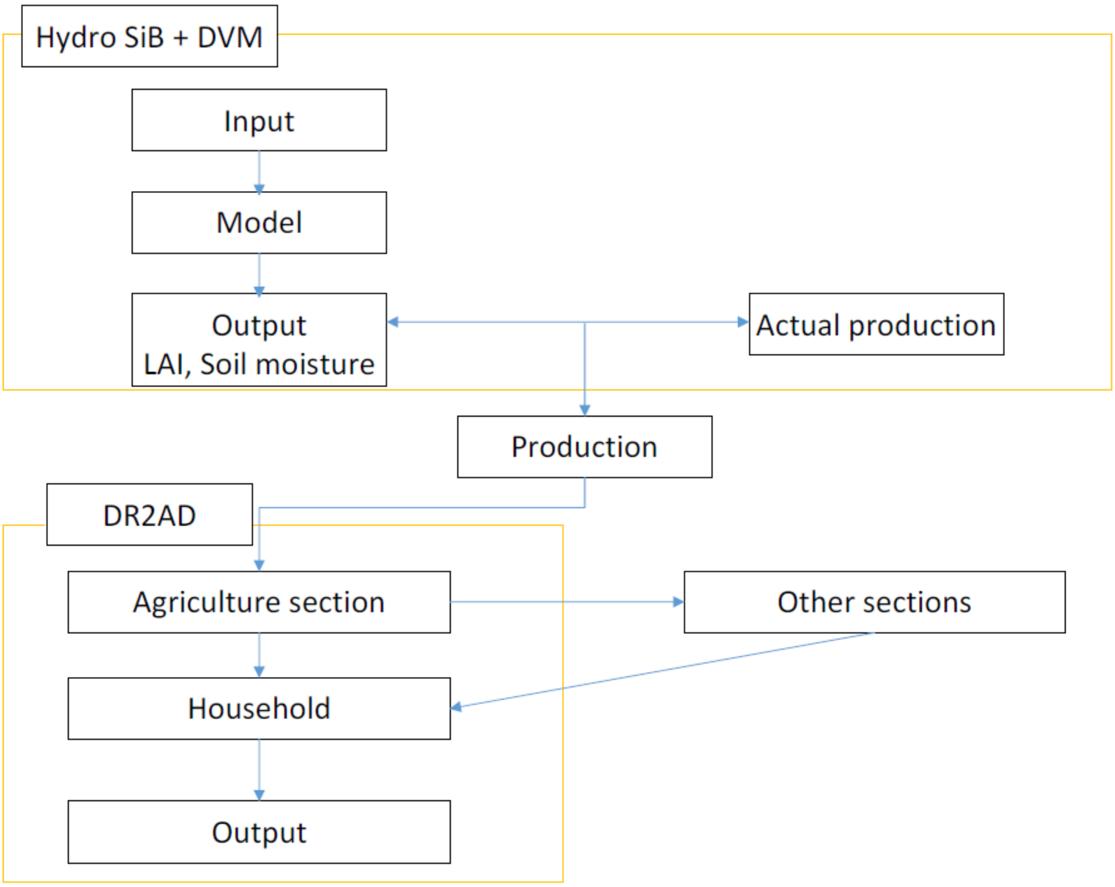

Figure 6: Schematic diagram of the model system to be used in the Pothohar area for drought analyses.

3.0 Results & Discussion

3.1 Data collected and available through DIAS

The data collection activities of AWCI have continued under this project. Additional in-situ datasets were submitted to DIAS for the purpose of the June 2013 training course and ensuing research activities. These data, however, have not been included in the publicly accessible database. Nevertheless, the data, in particular from Pakistan, have been utilized in several studies as it will be explained in following sections. Collaboration continued with satellite data providers, namely JAXA, who provided, e.g. the GSMaP data and soil moisture data. In addition, during the course of this project, the CMIP5 model output data has begun to be uploaded onto the DIAS system to be easily accessible similarly as the CMIP3 data. The CMIP5 data access with the DIAS dedicated functions will be available to public by July 2015.

3.2 Data provided for the Indus study (not available to public)

Overview of the in-situ data provided for the Indus study is provided in Tables 1 – 3 below.

Table 1: Data provided for the Upper Indus Basin

Location	Description	Period
Upper Indus basin	Glacier Inventory Data (PARC/ICIMOD)	
	Meteorological data by PMD (temperature T, precipitation P, solar radiation/sunshine hour SR, humidity R, wind speed WS): 7 stations 2 AWS stations (data for 2010 – 2012 only)	varies with each station and observed parameter – T and P usually from 1980-ties till 2012, others from 2007 ~ 2012
	Meteorological data of 3 stations by WAPDA	1995 - 2012
	Discharge data, 8 stations	Varies with station, about 1980-ties till 2008/2011
	Pakistan 2010 flood extent GIS files	
	Climatic data of upper Indus at 20 locations by the University of Agriculture, Faisalabad	2002-2011

Table 2: Data provided for the Lower Indus Basin

Location	Description	Period
Lower Indus basin	River discharge data at different gauges along the Indus River below the Tarbela dam	2006 - 2007

Table 3: Data provided for the Pothohar area

Location	Description	Period
Pothohar area	Daily/Hourly Meteorological Data in Pothohar area (8 stations)	1970-2012
	Discharge Datasets (6 stations)	1970(1992)-2003(2012)
	Flood prone area identification: Flood damage records	
	Drought prone area identification	
	Land use showing irrigated area, irrigation small dams and irrigation channel information	
	Historical Drought Years or Drought Seasons or Drought Months i) Agricultural Drought - If economic data or crop loss (or crop production) data is available ii) Meteorological Drought	1970-Present
	Regional annual crop production data (t/year)	1990-2012

3.3 Training courses outcomes and contributions to meetings

3.3.1 AWCI Training Course on Improved Bias Correction and Downscaling Techniques for Climate Change Assessment including Drought Indices (18 – 20 June 2013 at the University of Tokyo, Hongo Campus, Tokyo, Japan), http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Jun2013/index.htm

The training had two main objectives:

Capacity Building. The aim was to provide explanation of and teach how to apply improved climate change assessment techniques and tools including general circulation model (GCM) output selection, model output (precipitation) bias correction, downscaling of the corrected output to a basin scale and generation of drought indices and drought assessment.

Preliminary Climate Change Impact Analysis in AWCI participating basins. The results obtained during the training course are expected to be usable for regional analysis of climate change impacts on water resources, in particular droughts.

Total Number of AWCI Supported Participants was 21.

After the training course, the participants were asked to complete an evaluation questionnaire aimed at participants' perception of the course merits for their future work and also at their assessment of the course design and teachers' performance. In addition, the participants were asked to draft a brief technical report on their work and achievements during the course and also suggestions and plans for further research. The requested attachments included:

Part 1: Model Selection, Bias Correction and Downscaling:

- The **model selection excel sheet** that you have completed using the on-line system for model output evaluation at: http://dias.tkl.iis.u-tokyo.ac.jp/model-eval/stable/index.html
- If possible, any figure of the bias corrected and downscaled precipitation data using the GrADS software.

Part 2 & 3: WEB-DHM runs and drought indices:

- The Discharge and Drought SA analysis excel file (multiple sheets) as explained by at the course.

A one-month period was provided for the participants to complete their reports. The received inputs have been compiled in two files. The first one is an excel sheet summarizing the questionnaire answer, the second one is a compilation of technical reports.

The questionnaire answers showed that the training course met expectations of most of the participants and most of them felt they had learned some new and useful knowledge for their future work. On the other hand, the participants felt the time was rather limited to fully grasp all the details of the taught methods and thus further study (even self-study) or cooperation with the methodology authors would be necessary to be able use it for future applications in their countries. Nevertheless, many of the participants expressed their further interest in these climate change assessment techniques and intention of their institutions to use these techniques. In addition, more than half of the participants could derive at least some indicative results for their basin from the standard anomaly drought indices generated during the training course. These results will be further explored and appropriately published.

The technical report included summary of the training course tasks:

- Selection of suitable GCM(s) for given study area

- Bias correction and downscaling of the selected GCM output(s) using the in-situ data
- Setting up the WEB-DHM runs and running WEB-DHM
- Processing and analyzing the WEB-DHM output
- Standard Anomaly (SA) drought indices generation from the WEB-DHM output

The climate change assessment studies are being done using an ensemble of GCM outputs, where the ensemble consists of "suitable" GCMs for the study area. The suitability of a GCM in the introduced methodology is assessed using a "scoring" method based on RMSE and Spatial correlation between the GCM output and a reference dataset (derived from observations or reanalysis). Using this method, which is incorporated in the on-line tool explained during the training course, the participants obtained a set of suitable models for their individual basins. For all basins, the model "gfdl_cm2_1" was either the first or second best and thus it was decided to use this model output for the training course purposes and only this one output due to the limited time available.

The GCM outputs cannot be used directly for hydrological simulations at the basin scale because of significant biases and coarse resolution and thus bias correction and downscaling methods must be applied to the GCM output. A user-friendly on-line tool has been developed for this purpose and was introduced at the training course. The participants used the tool to generate bias corrected and downscaled precipitation data for their respective basins. While the tool is very handy, some participants felt it would be useful to also see the procedure be done step by step with explanation of the theory behind each step. After producing the suitable precipitation data for the baseline historical period (1981 – 2000) and the investigated future period (2046 – 2060), the pre-prepared and calibrated WEB-DHM models for individual basins were set up using the generated precipitation data and other forcing data pre-prepared from JRA25 reanalysis. The participants run their WEB-DHMs on the distant server, generating necessary outputs for basin water budget assessment.

WEB-DHM was used to simulate past (1980-2000) and future (1946-1965) river discharge by using the selected GCM result as input. Although the simulation was conducted in daily time step, statistical analysis to capture river discharge variations throughout the year was computed in monthly basis. To evaluate the extreme event, simulation result was normalized based on the best-fit distribution for each monthly series. JMP software was used for this statistical analysis. By using the criteria of extreme event from standard deviation, the number of event with category "Extremely dry" (Stdev < -2.0), "Severely dry" (-2.0 $\leq$ Stdev < -1.5), and "Moderately dry" (-1.5 $\leq$ Stdev < -1.0) can be computed. In this way, most of the participants were able to generate the SA drought indices for the baseline historical period and the investigated future period. Due to the limited time, some participants were not able to complete the final step that involved the commercial statistical software JMP10 and thus were not able to finalize their work later if they were not able to obtain the software.

Tone (Japan)

The participants, who worked with the Japanese Tone river basin data (because the database for their country basin has not been fully developed for this kind of study yet, namely India, Lao, Uzbekistan), have concluded that the obtained results indicated **increase** in the river discharge in future and **decrease** of the frequency of "severe" and "moderate" drought events.

Citarum (Indonesia)

In general, the results indicated more extreme months in past scenario than in future scenario for both for dry or wet months. However, the event in future scenario tends to be more extreme than in the past scenario, especially for wet event. For example, there were only six events in past scenario with Standard Deviation > 2.5 (very extreme wet), while in future scenario, the number of event increased to 8 events, and there were 2 events with Standard Deviation > 4.0. The trend in extreme dry event seems not as clear as wet event. Although the average simulated discharge of future scenarios is lower than past scenarios, it seems still in range of 'near normal event'. The Indonesian participant provided two comments. The first one is regarding the reference precipitation data used for model selection, i.e. GPCP data: *Probably, GPCP is one the best data precipitation available for long term and large scale study. However, comparison with TRMM and station data in study area shows that GPCP data tend to be overestimate especially in Java Island, the location of Citarum River Basin.* Comparison of multiple GCM outputs with TRMM data showed that better results for other GCMs than the selected gfdl_cm2_1 model. Secondly: *WEB-DHM result showed that the average daily discharge in past scenario (1981-2000) is 89.7m3/s while in future scenario (2046-2065) the value is **decrease** to 66.2m3/s. This result is slightly different with figures in IPCC report which suggest that precipitation in South East Asia tend **increase** in the future.*

Langat (Malaysia)

From the standardized anomaly (SA) index analysis of Langat streamflow, most of the monthly temporal distribution of SA indexes for both past period 1981-2000 and future period 2046-2065 lies within the 'normal' category. In 1981-2000, there are twenty (20) occurrences of 'moderately dry' months with the lowest SA index of -1.377 in May 1986. However, there was no drought or water stress incidents reported for the year. Whilst the second lowest index is -1.33 which is in May 1998. From historical analysis it is known there was a prolonged dry month in 1998 in the basin, the event had caused major water crisis and shortage of water supply in Klang Valley and Langat basin, which had affected 1.8 million residents. However, the calculated indexes for the months are classified as 'moderately dry'. As for the future period, it is estimated that eighteen (18) 'moderately dry' months and two (2) 'severely dry' months would occur. The temporal distribution evaluated, although is inadequate, but could be a quick reference & rough estimate of future possible drought occurrences.

Soan (Pakistan)

The discharge in the past has peak values for the years 1985-1987 and in 1992-1998; in between these time slots the peak sometimes has decreasing and increasing trend otherwise. For the future simulation of discharge, the peak values appear in the year 2052-2054 and 2060-2062. However, the peak values are not much greater than the peak values of the past. This shows the moderate dryness of the basin in the future. The monthly discharge is prominently increasing for the August, September and October months in the future (2046-2065). The standardized anomaly index calculated for the past and future discharge simulated by WEB-DHM was calculated for three different categories (1) Extremely Dry, (2) Severely Dry and (3) Moderately Dry. The frequency of extremely dry conditions was higher for future as compared to the past whereas for the other two categories the values are equal or less to the past.

In addition, a more complex study was conducted in the Soan basin (Bhatti et al., 2014), which is summarized in the research outcomes Section below.

Kalu Ganga (Sri Lanka)

Monthly Discharges of each month in the Past and Future periods were fitted the bets statistical distribution using JMP10 software. The statistical parameters Location and Scale were derived for each month from the selected distribution. Drought indices were estimated. Number of months that extremely dry, severely dry and moderately dry conditions for past and future GCM discharge output was compared indicating **increase** in the river discharge in future and **decrease** of the frequency of “severe” and “moderate” drought events.

Mae Wang (Thailand)

The obtained results indicated **increase** in the river discharge in future and **decrease** of the frequency of “extremely”, “severe” and “moderate” drought events. Future work on this research should include a more extensive validation small-scale patterns with statistical methods involving height regressions, the differences of bias - corrected data. If this project has also developed algorithms combined with high resolution remote sensing and physically - based patterns, could greatly improve the realism of the resulting.

Huong (Vietnam)

The obtained results indicated **increase** in the river discharge in future and **decrease** of the frequency of “severe” and “moderate” drought events. Besides the work done during the training course, the introduction of satellite rainfall GSMaP and the exploitation of this data are useful for all participants when they return to their country to apply to mining operations as well as exploiting data sources for research. A stark example such as Vietnam, where network of hydro-meteorological observations is lack in some basins, affects strongly on forecast as well as research of the hydromet centers. Satellite rainfall GSMaP is a door where we can help solve this problem.

3.3.2 AWCI Training Workshop on Climate Change Impact Assessment (Held in Islamabad, Pakistan, 15 – 17 September 2014);

http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/IslamabadTraining_Sep2014/index.htm

The objectives of the Training Workshop included:

- Thematic lectures on Climate-Water-Food-Health Nexus and APN and AWCI related activities in Pakistan.
- Introduction, description and demonstration of capabilities of the Water and Energy Budget Distributed Hydrological Model for Snow and glacier basins (WEB-DHM-S), which is a novel and robust tool for cold region hydrological applications.
- In-depth explanation of the techniques for climate change impact assessment studies on water resources that are built in the Data Integration and Analysis System (DIAS) and available on-line (demonstration version).
- Explanation and Hands-on training on the use of these methods that include:
    - selection of suitable GCM outputs for the region of interest,
    - rainfall bias correction of these outputs,
    - downscaling of the GCM outputs for hydrological modelling at the basin scale

- hydrological runs by WEB-DHM (without the advanced snow and glacier component) – informative lecture on WEB-DHM will be provided but not full training of the model due to time constraints,
- analyses of the hydrological simulation results to assess possible impacts of climate change with focus on high flows and floods, and
- dynamical downscaling lectures.

The training began by a one-day plenary lecture session, which hosted a broader audience including representatives of Government of Pakistan and relevant institutions. The session provided an insight into the water related disasters in regions with considerable snow and glacier cover and highly dependent on agricultural production in terms of economical aspect. The climate-water-food nexus idea was introduced and possible solutions by utilizing data integration systems were presented and discussed, highlighting the need of inter-disciplinary and trans-disciplinary collaboration. The session also included lectures on the themes relevant to the training, in particular cold region hydrology, climate-water and climate-agriculture nexus in Pakistan, and data integration and analysis support services. The plenary session set the basis for the practical exercises of the training.

The practical training sessions were held at the PMD computing lab, where each participant was provided a PC and focused on the methods and techniques utilized for assessing the impact of climate change on hydrological regimes of a basin and thus on possible changes in water resources availability. The overall methodology of climate change impact assessment on hydrological regime was reiterated, that is using the climate projection model output for past and future periods as forcing data for a hydrological model to elucidate changes in the basin flows and soil moisture budgets. As the GCM output cannot be used directly to force basin scale hydrological models, several steps must be undertaken with the GCM output to prepare a suitable input for the hydrological simulations. All these steps were explained using the said techniques and these techniques were demonstrated on the Soan basin of Pakistan and all the participants focused on this basin in their individual work. The training included following sessions focused on climate change impact assessment on water resources:

1. Selection of appropriate climate projection outputs by GCMs (CMIP3 datasets) for desired assessment
2. GCM rainfall bias correction and statistical downscaling
3. Hydrological simulation preparation and analyses
4. Hydrological modelling in cold regions
5. Dynamical downscaling

The first session included a demonstration lecture with hands-on practices. The DIAS based on-line tool for accessing, analyzing and downloading the CMIP3 datasets was introduced, each participant followed the procedure individually. The step-by-step outline presented at the session is available through the workshop website. Participants mastered the use of this on-line tool for the purpose of selecting appropriate GCM output for a given region and completed the demonstration task. The second session explained the need of correcting the GCM precipitation output for hydrological analyses at the local scale (basin scale) and introduced the dedicated function of the said DIAS tool for statistical bias correction and downscaling of the GCM precipitation output. Participants followed the procedure and mastered the use of this function.

The results of the previous steps were bias corrected precipitation datasets for the past (current climate) and future (future climate) periods. In the third session the preparation for a hydrological analysis by using the WEB-DHM hydrological model and the obtained corrected precipitation data as forcing input was explained. More details of the WEB-DHM basis and physics were provided and the procedure of a basin's setting up and data preparation for simulation was explained. The case of WEB-DHM application in the climate change impact assessment study in the Soan basin was presented. The fourth session was dedicated to the details of the WEB-DHM-S model, a hydrological model for cold and high altitude regions that is based on the WEB-DHM model and adds sophisticated snow and glacier process simulation components. The session was designed by Dr. Maheswor Shrestha, the developer of WEB-DHM-S and provided an insightful lecture on the physics of the snow and glacier processes, possibilities of their simulations and details of the snow and glacier components in WEB-DHM-S. Examples of WEB-DHM-S applications were introduced including the upper Indus basin simulations.

At the last session, Dr. Mohamed Rasmy gave a comprehensive lecture on dynamical downscaling of the GCM outputs for regional and local scales. Details of the methodologies were introduced for the case of weather forecasts and for the case of climate projections. The weather forecast downscaling part included explanation of model calibration, downscaling/nesting technique using the mesoscale WRF model, initial conditions and boundary conditions and their improvement, and data assimilation technique. In the climate projection part, the so called Pseudo Global Warming Downscaling (PGW-DS) experiments were introduced. The training workshop was summarized and an assignment for the participants was introduced that targeted the feedback from the audience on the provided training and their views of its usefulness for their future work. The event was closed by the ceremonial awarding of participants with the Certificates of Accomplishment, handed out by Dr. Arif Mahmood, former Director General, PMD, Mr. Hazrat Mir, Director General, PMD, and Dr. Ghulam Rasul, Chief Meteorologist, PMD.

The assignment for the participants contained three parts including (i) a questionnaire on the participants' impression from the training, (ii) opening of the CEOS water portal account and considering its utilization for future work, and (iii) summary of the hands-on exercises outcomes of the training. The summary of the participants' responses indicated that the training was felt to be useful to improve the knowledge of concepts of Climate change modeling and hydrological modeling. The training was prepared and managed well, lecturers and trainers gave their presentations clearly and material was well organized. However, it was felt that more emphasis should be put on practical training on the tools but it was understood that such arrangements would require more time and would require much more technical preparations and support. With the given format, the training provided maximum and the effort of the organizers and financial support from sponsors (this APN project) was highly appreciated.

CEOS Water Portal

This system is more important to download required data to the research activities. It is user friendly and quite important system because the data are provided without any cost to the user (while various institutes usually asked money for the data). Therefore, this is an important system to learn. At the same time, it was felt that the system should continue to include further data and the database of studies using these data should be increased (which is solely on the data user will to do so).

Hands-on outcomes

The participants selected the most suitable models for the Soan basin, Pakistan using the on-line tools. These were

Models	Score (7 is max)
gfdl_cm2_1	7
mpi_echam5	7
cccma_cgcm3_1_t63	7
ingv_echam4	6

Then, the model precipitation output for the selected four models was corrected by using the on-line tool.

Correction plots showing climatology:

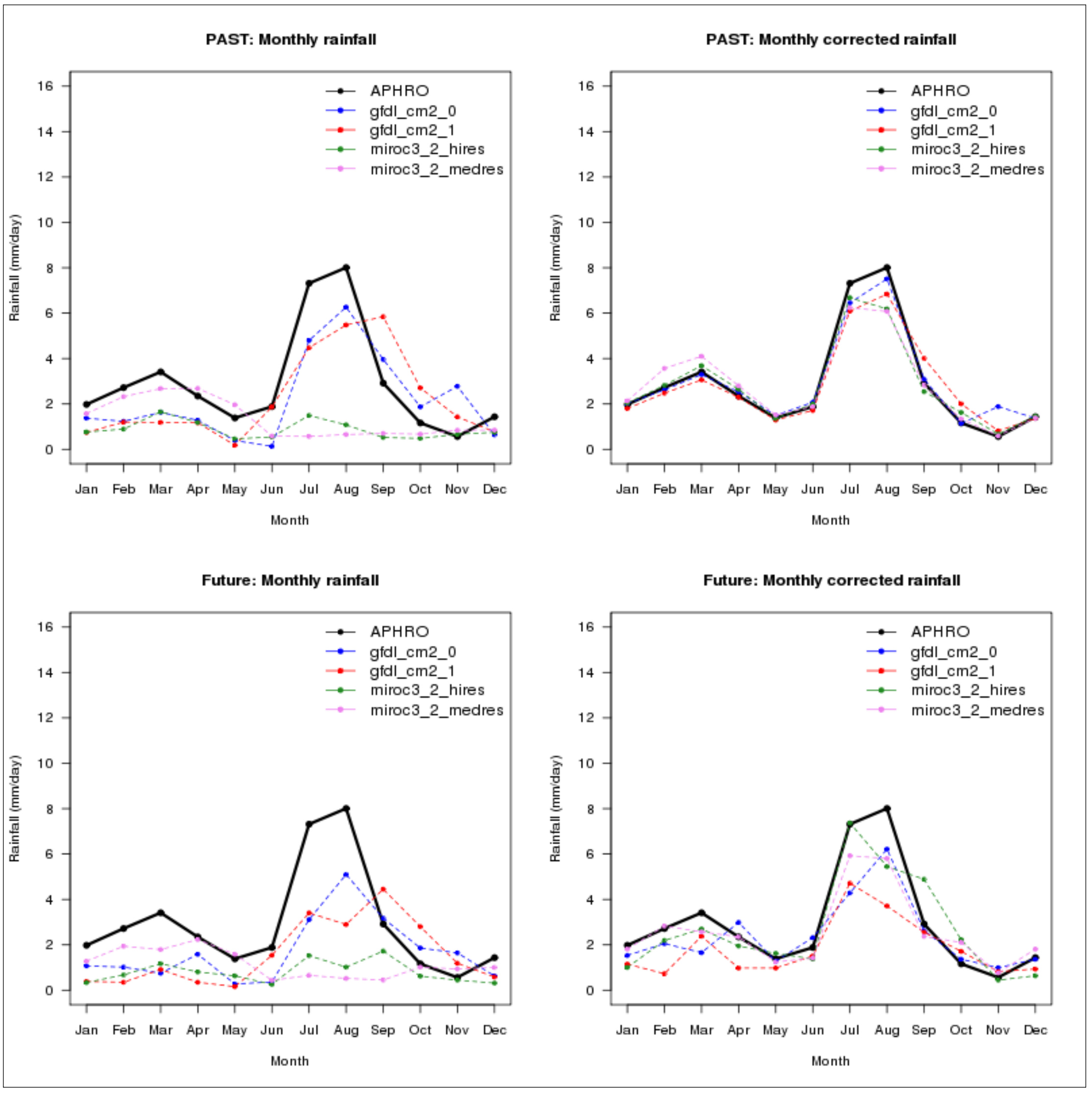

Figure 7: Climate model output (precipitation) bias correction: climatology. Left – before correction, right – after correction. Top – past simulation, bottom – future simulation. Black line is for observation-based data (APHRODITE), i.e. in all charts represent historical period.

Correction plots showing extreme rainfall

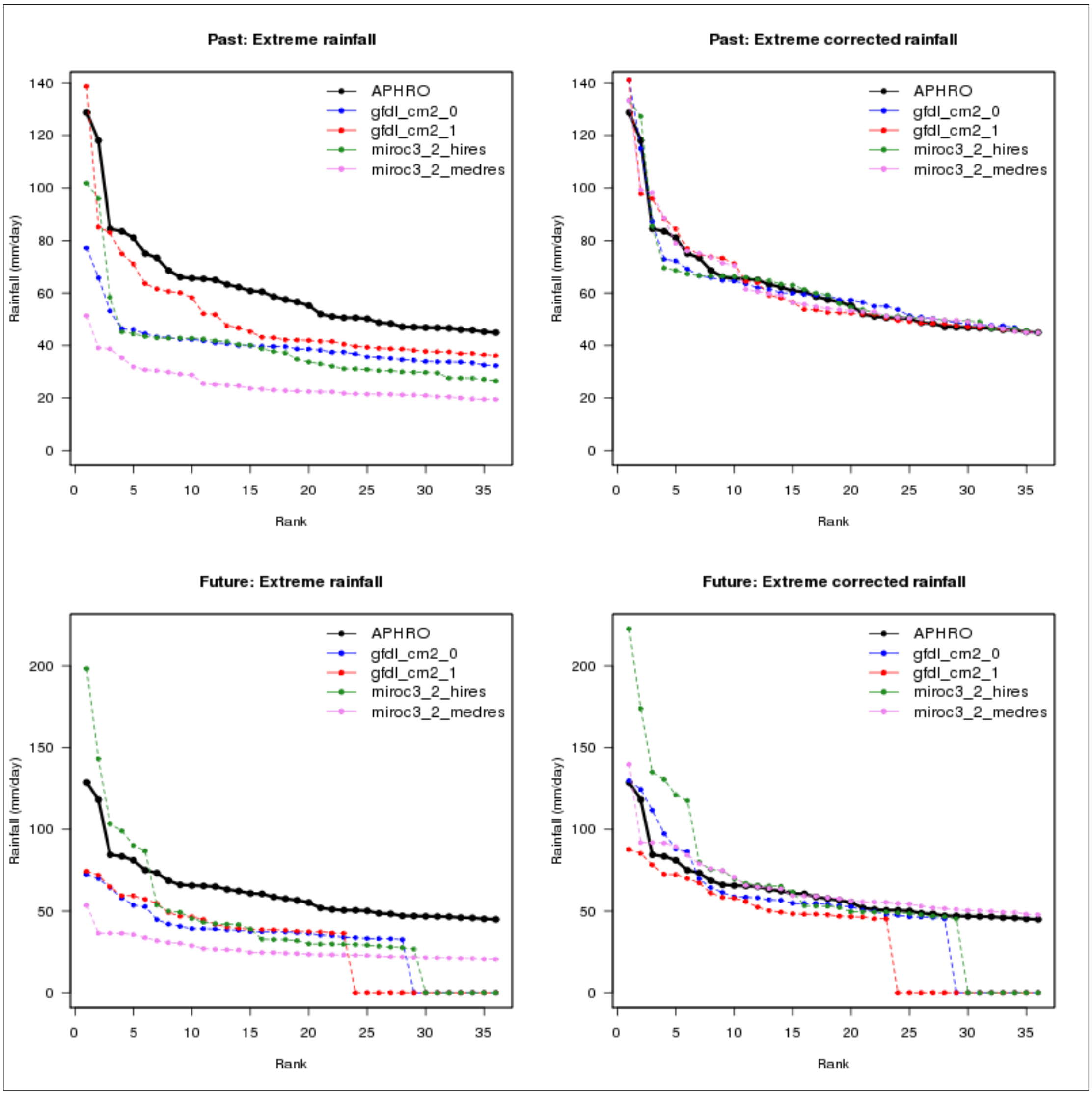

Figure 8: Climate model output (precipitation) bias correction: extreme rainfall. Left – before correction, right – after correction. Top – past simulation, bottom – future simulation. Black line is for observation-based data (APHRODITE), i.e. in all charts represent historical period.

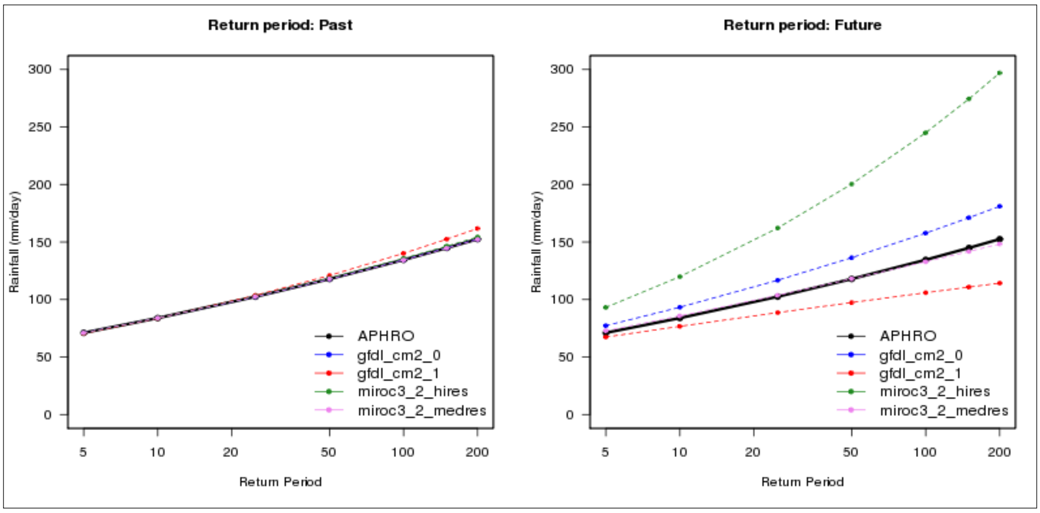

Figure 9: Return period rainfall intensity after bias correction for past (left) and future (right). Black line shows APHRODITE data (past period observation).

Figure 9 shows comparison of precipitation intensity return period between past (current) climate) and future climate conditions. This indicates possible change in frequency of high intensity rainfall in future. It also shows how different models project different changes in rainfall patterns due to climate change, and thus this uncertainty in climate projections must be considered in adaptation recommendations.

3.3.3 An intensive WEB-DHM-S training (held at the University of Tokyo, Tokyo, Japan, 23-27 March, 2015)

The aim was to provide explanation of and teach how to apply on the Water and Energy Budget Distributed Hydrological Model for cold regions (WEB-DHM-S). Training course was designed to train two PMD experts on the use of hydrological model for simulation of climate change impacts on water resources. The course started from the basics of hydrological modelling leading towards complete understanding of model setup. The goal during the training program was to learn techniques necessary to carry out assessment analyses for target basins, with focus on floods and droughts and including snow and glacier areas. While the snow and glacier components of the model were explained, the Soan Basin without the snow and glaciers was used as a test case for training purpose.

Three main learning modules were completed:

1. Water and Energy Budget Distributed Hydrological Model (WEB-DHM-S) – model understanding, definition of target basin and required geographical fields, preparation of meteorological forcing data for hydrological model.
2. Running pre-set simulations using the precipitation prepared in the Section 1.
3. Analysis of model output and qualitative results of model tuning

The participants are expected to be able develop the WEB-DHM-S for snow and glacier containing basin with a moderate help from the UT experts in the future.

3.3.4 Contribution to relevant meeting events and conferences (see the event websites for further details and presentation material)

The project contributed to several events.

(i) http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Sep2012/index.htm

The 9th Meeting of the GEOSS Asian Water Cycle Initiative-International Coordination Group (AWCI ICG) and the 2nd AWCI Climate Change Assessment and Adaptation (CCAA) Study Workshop held in Tokyo in September 2012 included a kick-off session of this project. It was the first meeting of the project leader, co-leaders and collaborators to discuss the framework and future plan of activities to be undertaken during the first year. Prominent scientists of the region from Bhutan, India, Japan, Mongolia, Myanmar, Nepal, Pakistan and Uzbekistan have been collaborating to address the climate change issues in the cryosphere for assessing the water availability in large Asian river basins.

(ii) http://mairs.csp.escience.cn/dct/page/1

An oral presentation on Integrated study of water resources management in Pakistan with focus on drought and impacts on agriculture production was presented at the MAIRS Open Science Conference held in Beijing, China in April 2014.

(iii) http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_May2014/awci/index.htm

http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_May2014/igwco/index.htm

The 10th AWCI ICG Session held in conjunction with the 7th GEOSS Asia-Pacific Symposium and the 10th GEO Integrated Global Water Cycle Observation (IGWCO) Community of Practice Meeting in Tokyo, Japan, in May 2014. Contributions to this event included oral presentations at the Water theme session of the GEOSS AP Symposium, discussion inputs at the AWCI ICG meeting and oral presentations on country activities by project participating countries at the IGWCO meeting.

(iv) http://monsoon.t.u-tokyo.ac.jp/AWCI/TokyoConf/en/index.htm

The Tokyo Conference on International Study for Disaster Risk Reduction and Resilience in Tokyo, Japan in January, 2015. A poster presentation on the project activities and outcomes was provided at the Conference by Dr. Ghulam Rasul.

3.4 Research Activities Outcomes

3.4.1 Assessment of climate change impacts on hydrological regime in the Soan river basin, Pakistan

Summary description

The Soan river is a tributary of the Indus river, that originates in the foothills of Muree, east of Islamabad, and flows from east to west through the Pothohar area. The area drained down to the Dhok Pathan, a control discharge gauge of this study, comprises 6,487 km^2 (Fig. 10). The basin is semi-arid with annual total rainfall of 750 – 1400 mm and its climate is driven by the Indian monsoon with a wet season from July to September. To support agriculture, numerous multipurpose rainwater storage ponds have been constructed. Accordingly, the pond function was introduced in the WEB-DHM model to account for water stored in these ponds. The model was calibrated against observed discharge at the Dhok Pathan gauge for the year 1997 and validated for the year 1998 (Fig. 11). In addition, the model performance was evaluated for soil moisture by using surface soil moisture data produced by Land Data Assimilation System of the University of Tokyo (LDAS-UT; Yang et al., 2007). The model grid size was 1000 m. The input data is summarized in Table 4. The APHRODITE rainfall data was used for baseline simulation in 1981 – 2000 because of limitations of local observation network.

Table 4: Input data of the Soan basin study

Data	**Spatial Resolution**	**Temporal Res.**	**Source**
DEM	50 m	Static	SRTM
Land Use	1000 m	Static	Global, USGS
Soil type/local	1000 m	Static	FAO
Discharge	Point (Dhok Pathan gauge)	Daily	Pakistan Meteorological Department (PMD)
Precipitation	Gridded (0.25 degree)	Daily	APHRODITE (provided by Japan Meteorological Agency (JMA))
Meteorological data (Shortwave and longwave radiation, wind speed, humidity, air pressure, air temperature)	Gridded	6-hourly	Japan Reanalysis JRA-25, JMA
Vegetation indices: LAI, FPAR	Gridded (1 km)	8-day average	MODIS Terra

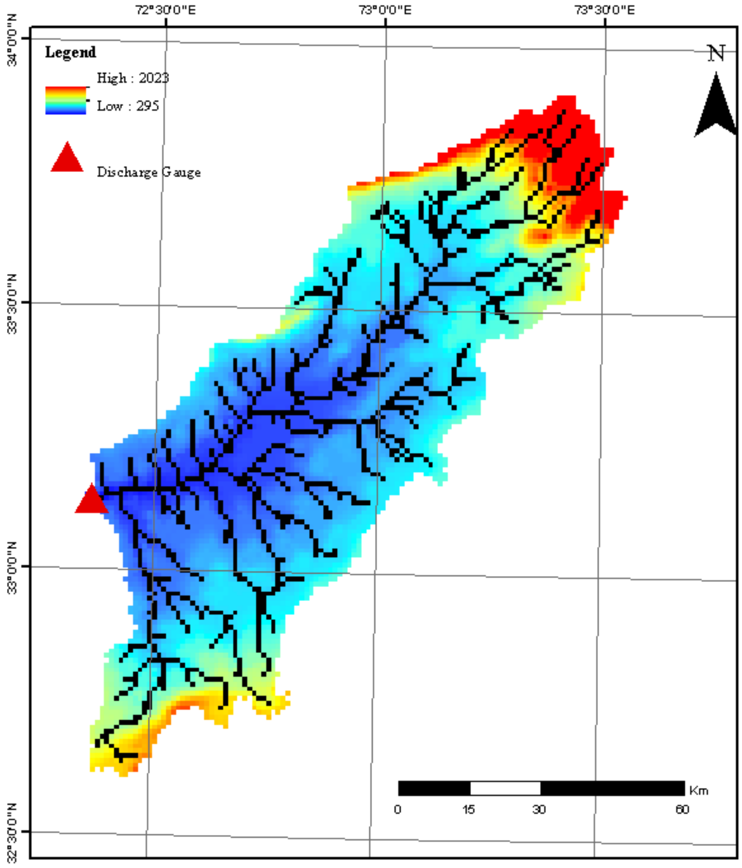

Figure 10: The Soan River Basin, Pakistan: river network and elevation.

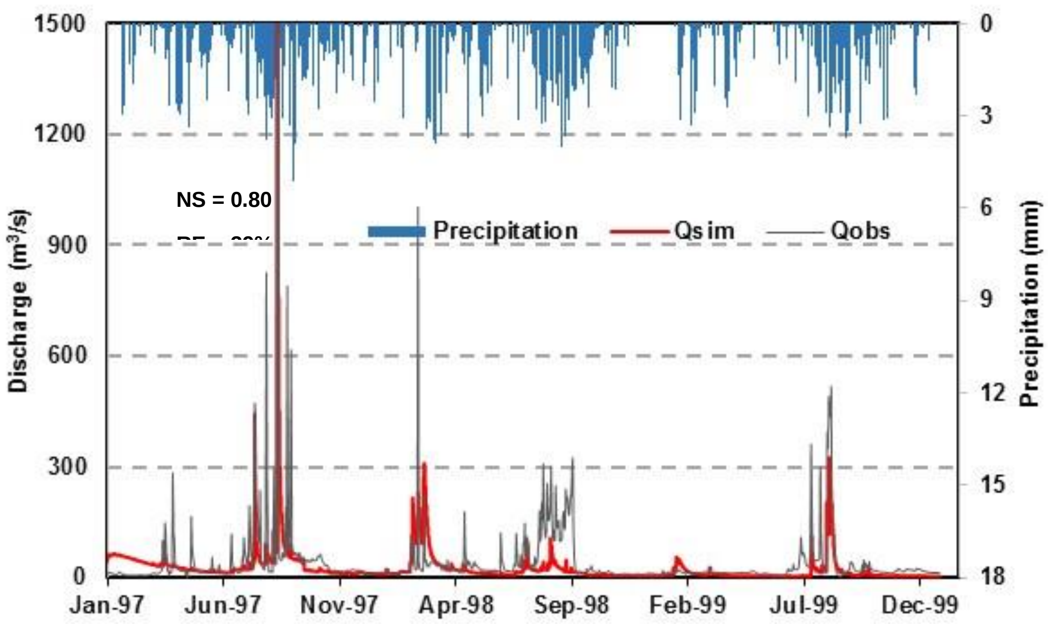

Figure 11: WEB-DHM calibration (1997) and validation in the Soan basin, Pakistan. Qsim is simulated discharge, Qobs is observed discharge, NS is Nash coefficient, and Re is relative error of the calibration.

Results

Four GCMs were selected as suitable for the region of the Soan river, namely gfdl_cm2_0, gfdl_cm2_1 (both by US Dept of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, USA), miroc3_2_medres, and miroc3_2_hires (both by Center for Climate System Research, University of Tokyo (CCSR UT)/National Institute for Environmental Studies (NIES) /Frontier Research Center for Global Change, Japan Agency for Marine-Earth Science and Technology (FGCGC JAMSTEC), Japan). The analysis of peak flows trends is shown in Figure 12. Three of the four selected GCMs (gfdl_cm2_0, miroc3_2_medres, and miroc3_2_hires) showed similar trends with substantial increase in magnitude of peak discharges in the future, while the gfdl_cm2_1 model showed decrease in peak discharge in the future. This indicates that is likely that floods will increase in the future.

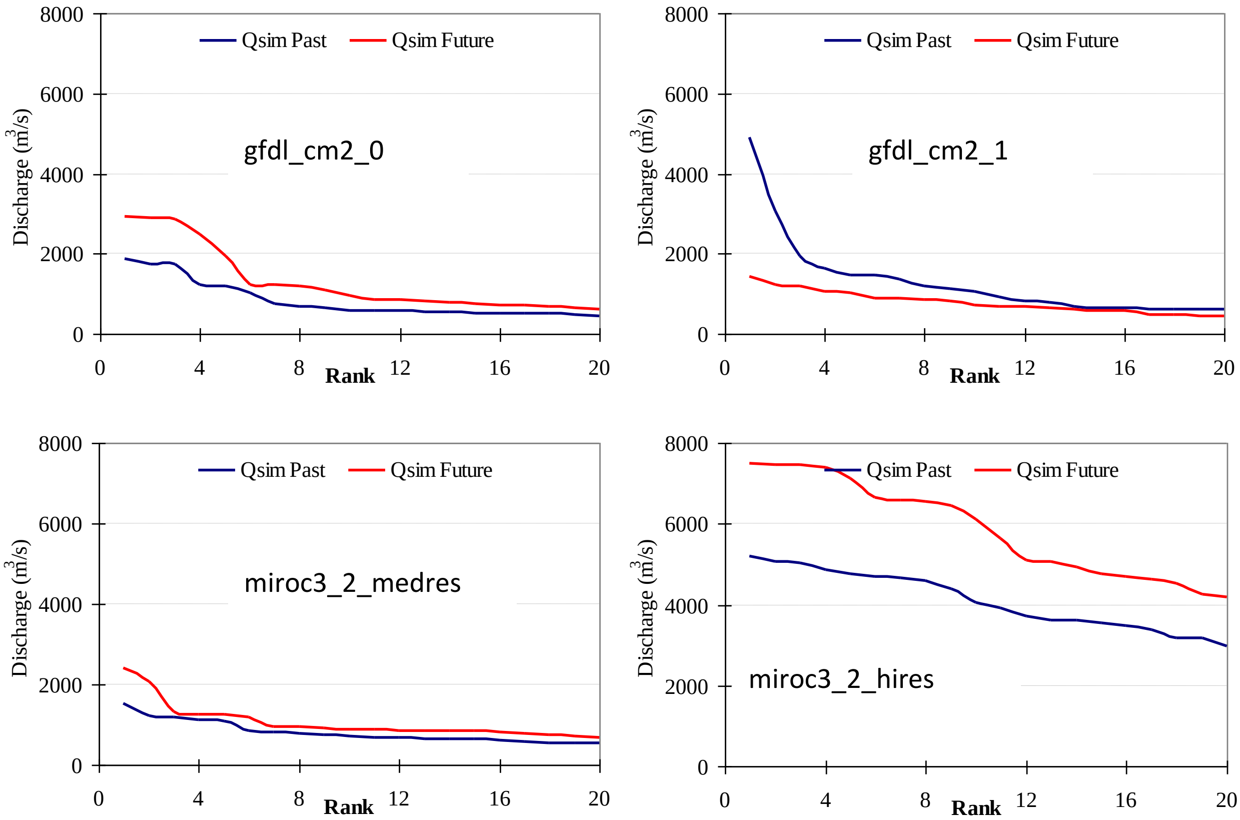

Figure 12: Climate trends of the top 20 peak discharges during 20 years for past and future. The Soan river basin, Pakistan.

The results of drought analysis were not consistent for selected GCMs as it is summarized in Table 6. Outputs of two GCMs (gfdl_cm2_0 and miroc3_2_hires) resulted into slightly higher average daily discharge (ADavg) with higher standard deviation (larger discharge fluctuation) in the future, while the other two models (gfdl_cm2_1 and miroc3_2_medres) indicated rather significant decrease in ADavg with smaller standard deviation (less fluctuation) in the future. In case of drought discharge, three models (gfdl_cm2_0, gfdl_cm2_1 and miroc3_2_medres) predicted slight decrease in DDavg in the future showing more intense drought in the future as compared to past. The standard deviations of these values have similar range of values for both the past and the future indicating that there is little difference in the fluctuations of the DDavg. Moreover, two models have shown decrease (gfdl_cm2_0 and gfdl_cm2_1) and two models (miroc3_2_medres and miroc3_2_hires) have predicted increase in the longest number of days per year below DDavg. The results are thus rather inconclusive in terms of future droughts.

Table 5: Summary of drought trends in the Soan River Basin, Pakistan (average values calculated over the 20 years of baseline period (past) and future projection period (future) and mentioned with standard deviation).

Models	*Average Daily Discharge, ADavg (m^3/sec) (Average of average daily discharge for 20 years)*		*Drought Discharge, DDavg (m^3/sec) (Average of 355th Rank for twenty years)*		*Longest no. of days/year below DDavg*	
	Past	Future	Past	Future	Past	Future
gfdl_cm2_0	29.13±12.52	30.51±12.98	8.18±6.06	5.44±2.13	272	177
gfdl_cm2_1	32.32±20.00	22.08±11.29	8.25±5.75	7.65±6.14	357	354
miroc3_2_medres	37.88±15.74	28.37±14.30	8.77±7.08	7.63±5.88	319	348
miroc3_2_hires	22.19±9.83	23.11±12.57	7.13±5.89	7.34±6.02	288	307

This study was carried out and published by Bhatti et al., 2014.

3.4.2 Indus Project

Upper Indus Basin (above Tarbela dam)

This study focused on developing a suitable hydrological model for the upper part of the Indus river basin that is largely covered by snow and glaciers and whose runoff is mainly generated from snowmelt and glaciermelt. The WEB-DHM-S model has been developed that is an adapted version of the WEB-DHM hydrological model and which can simulate snow processes, glacier processes and forest snow processes simultaneously in a basin scale. Its structure is shown in Figure 13 (prepared by Dr. M. Shrestha).

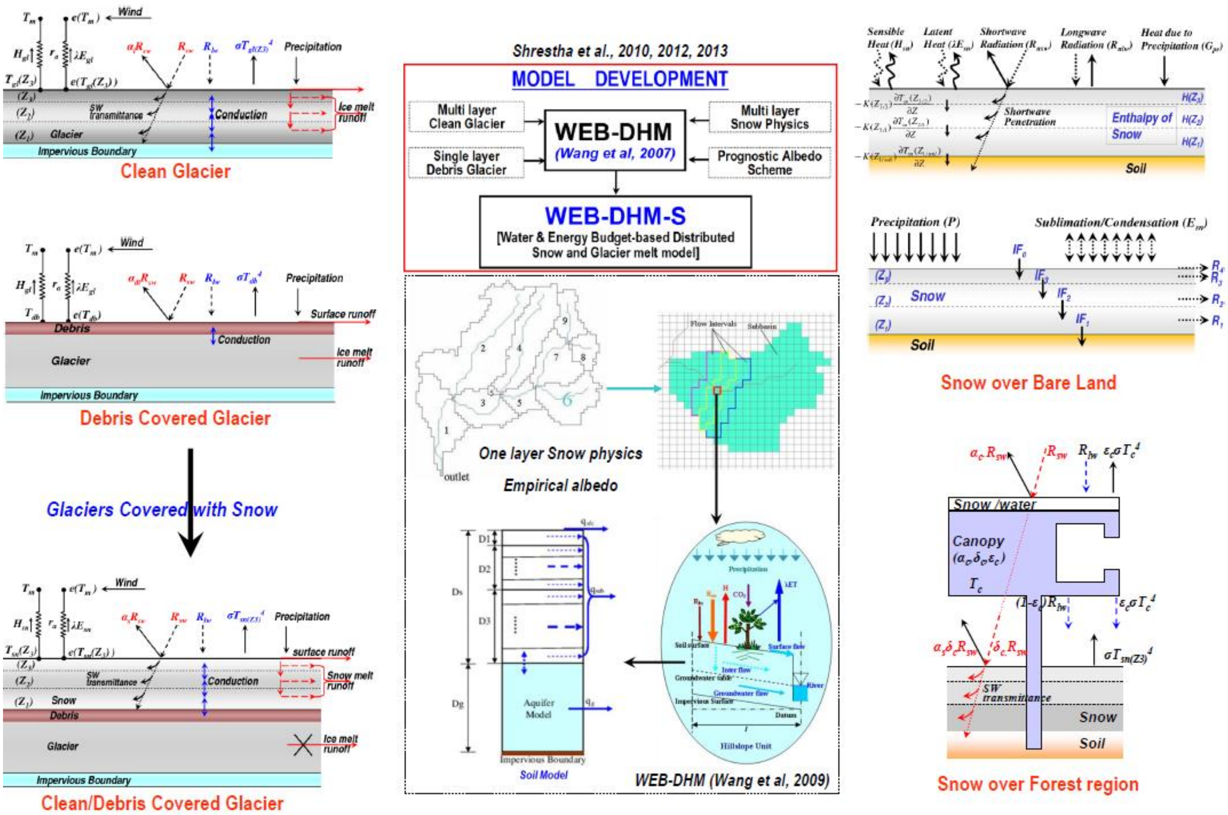

Figure 13: Schematic diagram of the WEB-DHM-S model.

For calibration and validation of the model, the available in-situ data from the local observation stations, GLDAS output and APHRODITE precipitation products were used. Calibration and validation of the model were accomplished with acceptable accuracy despite of large data scarcity (Fig. 14). After the validation, a longer-term simulation was carried out that showed the model ability to reproduce snowmelt and glaciermelt processes, snowcover and glaciercover distribution and intraseasonal changes that were checked agains MODIS and ICIMOD glacier data. The advantage of the model is also the information of the discharge origin – whether from rainfall, snowmelt or glaciermelt. The results showed that in the Hunza basin (a subbasin of the upper Indus), snowmelt and glaciermelt contribution to the total runoff is about 80 – 85% while rainfall contributes only about 15 – 20% of the total. Further results and more details will be included in the publication in preparation by Dr. M. Shrestha.

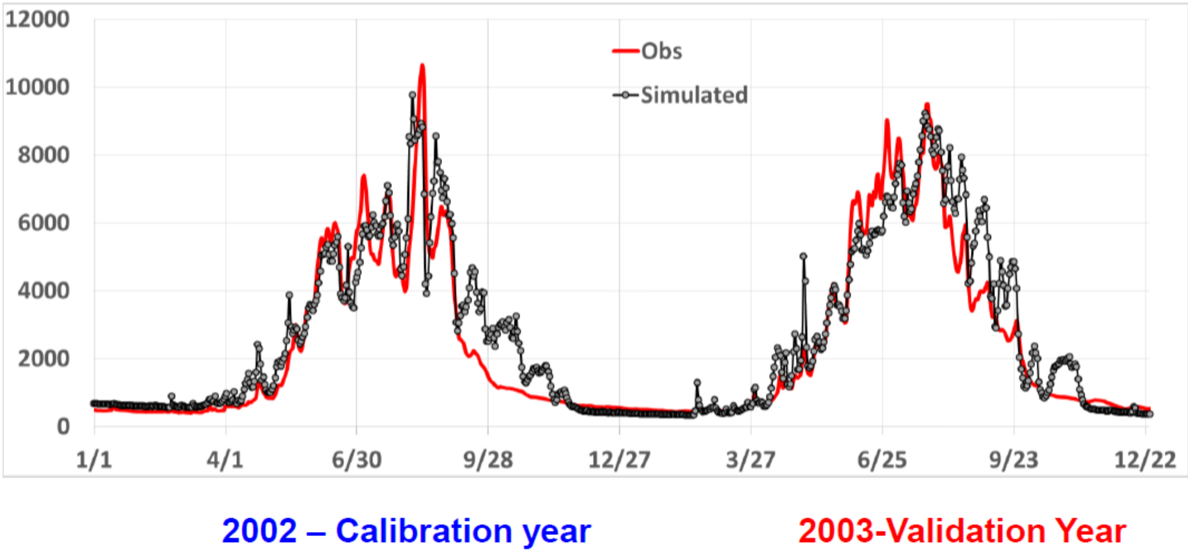

Figure 14: Calibration and validation of the WEB-DHM-S model in the Upper Indus basin (up to Tarbela dam).

Middle and Lower Indus Basin (below Tarbela dam)

This study (Ohta, 2014) has developed a framework for quantitative economical assessing of the impact of flood protection investment on reducing the losses due to a flood disaster and applied the system in the Lower Indus Basin. The system has been developed by combining the flood inundation simulation model CaMa-flood and the economic model DR^2AD and establishing a method to calculate input values for the economic model from the output of the flood model. The first investigated parameter was a number of affected people due to flood inundation and its reduction by constructing levees in certain parts of the basin, in particular in the lower reach and in the cities. The simulations also showed that confining the river by levees along upper reaches or excessively, would lead to increase of flooded areas and thus of number of victims downstream. Furthermore, the impact of levee construction on Gini (inequality index between rich and poor) and GDP indices was investigated. The residence pattern of people with respect to their income level was considered according to 2 different scenarios. It was found that construction of levees in the middle reach would lead to increase of Gini but also a greater increase of GDP (comparing to the situation without any flood protection), while construction of levees in the lower reach would lower Gini (which is desirable) but the GDP would not increase that much. In this manner, with further data and more factors considered, the developed system may support policy-decision process in flood protection planning. The system may be augmented, used in various applications (future projections of floods due to climate change, land use changes, etc.), and also is transferable to other countries. When also coupled with a physically-based hydrological model as WEB-DHM and WEB-DHM-S, the runoff and thence flood flow generation may be better simulated.

This study has been carried out as a Master Degree research and is in detailed described in Ohta, 2014, Master Degree Thesis, University of Tokyo, March 2014. (in Japanese).

Pothohar Area

This study (Suzuki, 2015) has developed a framework for assessing the impact of a drought disaster on the economy, in which the agriculture plays the key role and applied the system in the Pothohar area of Pakistan (see Section 2.7). The framework has been developed by combining the eco-hydrological model (WEB-DHM-Veg, the WEB-DHM hydrological model with vegetation dynamic scheme embedded) with the Coupled Land and Vegetation Data Assimilation System (CLVDAS) and a multi-regional, multi-sector economic growth model (DR^2AD). To adapt the CLVDAS system for the irrigated areas of Pakistan, an irrigation model has been incorporated. Irrigation total amount is determined using the data of the surface water intake and the pumped groundwater amount and the spatial and temporal distribution of water is determined based on the water demand according with the land use.

The index of vegetation amount resulting from the eco-hydrological coupled system was converted to the variables corresponding to those of the economic model, i.e. into a production function depending on land-use (crop) and water. Then, the economic model was calibrated using the results of the eco-hydrological system and crop production yields in historical period. Finally, the long-term evaluation was carried out by the calibrated economical model. The results indicated that a drought with the return period of 50 years may lead to economic losses up to 7% of GDP. Though this calculation considered a closed economy (i.e. not possible import from abroad as an emergency measure) the results should be taken seriously in future planning for drought disaster risk reduction. The developed framework may be used in other areas and in other applications, e.g. climate change impact assessment (with climate projections), scenarios with groundwater depletion due to overexploiting, etc.

This study has been carried out as a Master Degree research and is in detailed described in Suzuki, 2015, Master Degree Thesis, University of Tokyo, March 2015. (in Japanese).

4.0 Conclusions

This project was proposed under the AWCI collaboration targeting to enhance capacities of AWCI countries for drought monitoring and early warning and for hydrological modelling in snow and glacier covered regions. The specific objectives of the project included:

1. To improve the climate change assessment and downscaling techniques;
2. Building the capacity of member countries for the finest temporal and spatial resolution climate projections;
3. Training of professionals for application of WEB-DHM-S (Hydrological Model for cold regions including snow and glacier processes);
4. Assessment of glacier melt and hydrological regime shift in the light of climate change scenario;
5. Assessment of water cycle variability and development of drought early warning system.

Capacity building. Three training workshops were organized that included: (i) the AWCI Training Course on Improved Bias Correction and Downscaling Techniques for Climate Change Assessment including Drought Indices held at University of Tokyo Hongo Campus, Tokyo, Japan, June 2013; (ii) the AWCI Training Workshop on Assessment of Climate Change Impact on a Watershed Hydrology including Hydrological Modeling in Cold Region Basins held in Islamabad, Pakistan, September 2014; and (iii) an intensive WEB-DHM-S model training, Tokyo, Japan, March, 2015. The University of Tokyo has been providing the technical support on downscaling techniques, scenario development, climate impact assessment, hydro-climatic modeling, bias correction of models and use of hydrological models.

The first two courses were dedicated to the climate change impact assessment techniques and their application for hydrological analyses under the climate change scenarios and also included sessions on hydrological models and their applicability for drought and flood forecasts. These two courses were designed considering the common needs among all the AWCI countries and all the AWCI countries were invited to nominate a suitable candidate for these courses. The June 2013 training focused on droughts and the September 2014 training included sessions on hydrological modelling in cold regions. The third course was an intensive training session dedicated to practical use of the WEB-DHM-S model – a hydrological model with advanced snow and glacier components and its participants acquired skills to fully utilize the model for various research activities and to provide this knowledge further. In such a manner, the capacity of AWCI country professionals has been gradually enhanced in the aspects of climate change impact assessment on watershed hydrology, drought analysis, and hydrological modelling for temperate as well as cold regions by using advanced techniques and tools. With these skills, the trained professionals are capable to further pursue research and practical application activities in the trained areas.

Data collection and integration. Contribution to the AWCI data collection and integration activities in the AWCI demonstration basins. Acquisition of cloud-free satellite imageries of selected glaciers. Selection of CMIP5 models and acquisition of baseline (1975-2005) and future (2010-2100) data of selected GCMs for 2 RCPs (4.5 and 8.5) (Moss, R.H et al., 2010). As part of the project activities in Pakistan, number of in-situ observation datasets from the Indus and Soan basins have been collected and shared with the UT research team but not opened publicly at this stage.

Research Activities. The project has contributed to the AWCI activity on climate change impact assessment on hydrological regime in nominated AWCI basins. The initial assessment with focus on drought has been carried out during the AWCI training course in June 2013. The project also supported development and validation of the WEB-DHM-S hydrological model, which includes advanced snow and glacier components, in the Hunza and the whole Upper Indus river basins by providing all available in-situ observations. Furthermore, the project has initiated a closer collaboration between the PMD and the University of Faisalabad and the University of Tokyo team targeting a comprehensive study in the Indus river basin addressing broad range of issues under the "water-climate-agriculture" nexus and considering also its socio-economy aspect. This set of studies include hydrological analyses by the WEB-DHM-S model in the Upper Indus basin, flood and flood inundation analyses by using the Ca-Ma Flood model along the middle and lower Indus basin and combining these analyses with the DR^2AD economical model to estimate impact of disasters and the effect of disaster prevention investment on future economy growth. Similar economy impact study was carried out in the Soan basin and adjacent Pothohar area focusing on drought impact on agriculture produce. In both these cases, the framework for the disaster impact on economy and the effects of investment into disaster countermeasures have been developed and successfully tested. The intention is to plan similar complex of assessment studies in other AWCI countries. Also a climate change impact assessment study was carried out in the Soan basin in the Pothohar area, Pakistan using the techniques that were taught at the held training courses and that are described in this report.

Contribution to relevant meeting events and conferences. The project contributed to several events. (i) The 9th Meeting of the GEOSS Asian Water Cycle Initiative-International Coordination Group (AWCI ICG) and the 2nd AWCI Climate Change Assessment and Adaptation (CCAA) Study Workshop held in Tokyo in September 2012 included a kick-off session of this project. It was the first meeting of the project leader, co-leaders and collaborators to discuss the framework and future plan of activities to be undertaken during the first year. Prominent scientists of the region from Bhutan, India, Japan, Mongolia, Myanmar, Nepal, Pakistan and Uzbekistan have been collaborating to address the climate change issues in the cryosphere for assessing the water availability in large Asian river basins. (ii) An oral presentation on Integrated study of water resources management in Pakistan with focus on drought and impacts on agriculture production was presented at the MAIRS Open Science Conference held in Beijing, China in April 2014. (iii) The 10th AWCI ICG Session held in conjunction with the 7th GEOSS Asia-Pacific Symposium and the 10th GEO Integrated Global Water Cycle Observation (IGWCO) Community of Practice Meeting in Tokyo, Japan, in May 2014. Contributions to this event included oral presentations at the Water theme session of the GEOSS AP Symposium, discussion inputs at the AWCI ICG meeting and oral presentations on country activities by project participating countries at the IGWCO meeting. (iv) The Tokyo Conference on International Study for Disaster Risk Reduction and Resilience in Tokyo, Japan in January, 2015. A poster presentation on the project activities and outcomes was provided at the Conference.

5.0 Future Directions

The project has enabled AWCI activities to proceed further and develop a strong working relationship between member countries. The developed tools, methods and the results of studies have been demonstrated to representatives from governmental sector of AWCI countries and all countries approved their participation in future with intention to implement the introduced approach in operational applications. The undertaken training courses have contributed to this purpose by enhancing skills of participating researchers in conducting the climate change impact assessment studies by exploiting the DIAS archive and data integration functions and in hydrological modeling with focus on drought and on cold regions. With completion of the CMIP5 datasets access and analysis function on DIAS, the AWCI member will be able to carry out further analyses of possible impacts of climate change on water resources and also to establish early warning systems for flood and drought disasters. The AWCI countries have confirmed such intentions at the 10th AWCI ICG meeting in Tokyo, May 2014.

The pilot studies in the Indus basin have shown a great potential for (i) expansion of the investigated features and (ii) transferability to other countries. Considering all the modeling systems and tools developed under the AWCI framework so far, each country may establish a unique system tailored to address their actual issues. A great contribution of a high importance was the development of the frameworks for coupling the hydrological analyses with economic model as it provides outcomes in the form relevant for policy- and decision-making. Accordingly, the intention is to further develop these capabilities to be able to consider more complicated economical situations and relationships in the AWCI countries.

From the water cycle scientific point of view, further work is planned on capability to assess the impact of climate change on snow and glaciers, which requires a sophisticated bias correction method for GCM snowfall output. Figure 15 shows a proposed framework for such challenge.

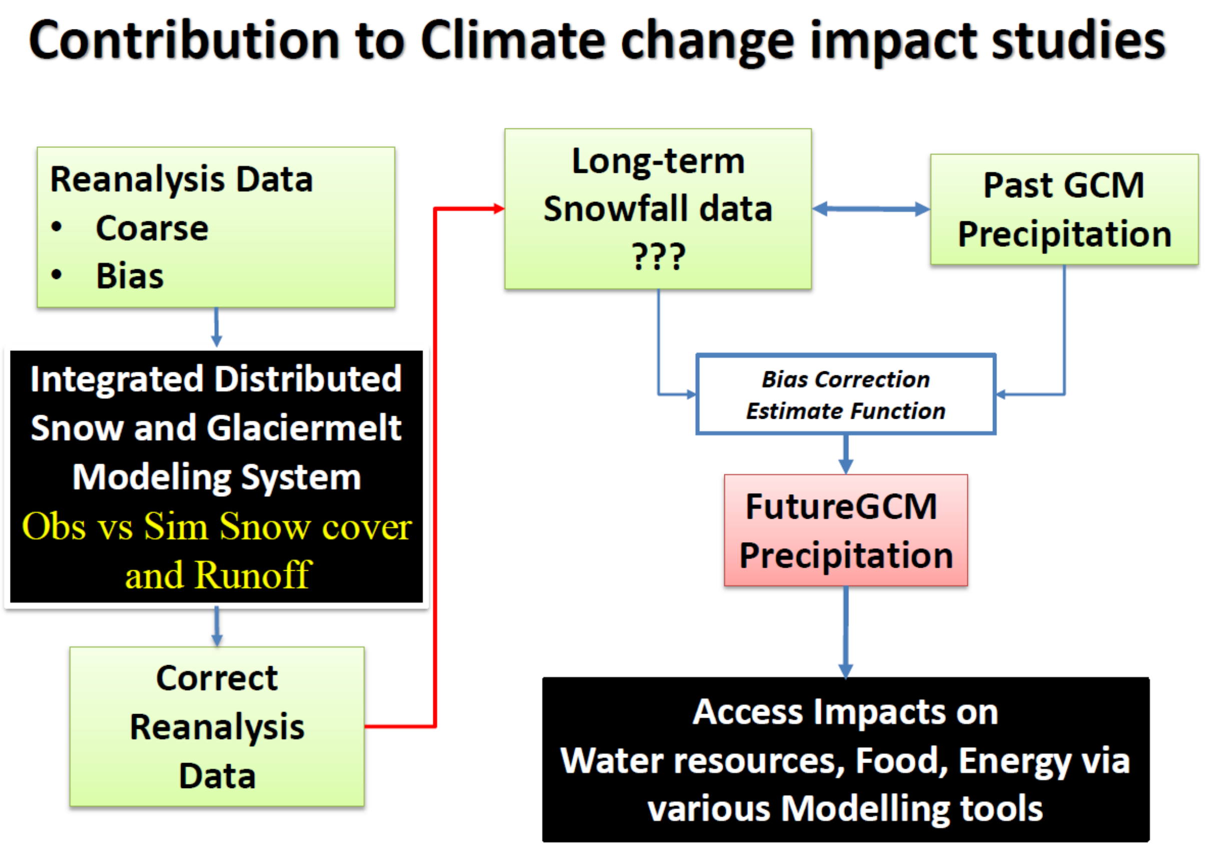

Figure 15: Framework of the climate change impact study in cold regions with significant amount of snowfall using the WEB-DHM-S hydrological model. Future challenge for AWCI.

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Event websites:

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Appendix

Conferences/Symposia/Workshops

1. AWCI Training Course on Improved Bias Correction and Downscaling Techniques for Climate Change Assessment including Drought Indices

- held at the University of Tokyo, Tokyo, Japan, 18 – 20 June 2013

Training Course Agenda

Tuesday 18 June: GCM Selection, Bias Correction, Downscaling

08:00 – 08:30 Registration
08:30 – 09:10 Opening Session
08:30 – 08:40 Welcome remarks: Toshio Koike (UT)
08:40 – 09:10 Opening Lecture: Climate Change Impact Assessment in Asia (Toshio Koike, UT)
09:10 – 10:45 Lectures
09:10 – 09:20 The training course design (Petra Koudelova, UT)
09:20 – 09:40 Development of Statistical Bias correction and Downscaling scheme for climate change impact assessment at a basin scale (Cho Thanda Nyunt, UT)
09:40 – 10:00 BREAK
10:00 – 10:30 Introduction of Global Satellite Mapping of Precipitation (Satoshi Kida, JAXA)
10:30 – 10:45 Asia Pacific Network for Global Change Research (APN) Activities (Taniya Koswatta, APN Secretariat)
10:45 – 18:00 Training, part 1: GCM Selection, Rainfall Bias Correction, Downscaling
10:45 – 12:00 Hands-on training session: GCM selection (DIAS on-line system, Excel sheets)
12:00 – 12:10 Group Photo (Kentaro Aida, UT)
12:10 – 13:15 LUNCH
13:15 – 18:00 Training, part 1: GCM Selection, Rainfall Bias Correction, Downscaling: Continue
13:15 – 14:00 Hands-on training session: GCM selection (DIAS on-line system, Excel sheets) – continue
14:00 – 14:15 Introduction of the on-line system for the bias correction and downscaling (Mohamed Rasmy, UT)
14:15 – 15:30 Hands-on training session: Rainfall bias correction and Downscaling for the historical baseline period (1981 – 2000) and future projection period (2046 – 2065) (DIAS on-line system) and preparation of the WEB-DHM precipitation forcing data
15:30 – 15:50 BREAK
15:50 – 17:30 Hands-on training session: Rainfall bias correction and Downscaling (DIAS on-line system) and preparation of the WEB-DHM precipitation forcing data – continue
17:30 ADJOURN
18:00 – 20:00 Cocktail and Discussion Session (UT Café)

Wednesday 19 June: WEB-DHM running for historical and future periods; Drought Indices

08:30 – 12:00 Training Part 2: WEB-DHM
08:30 – 09:05 Hydrological modeling for climate change impact assessment – importance of in-situ precipitation data and Drought under the climate change (Toshio Koike, UT)
09:00 – 09:15 Climate change impact assessment on water resources sector in Malaysia (Nurul Huda Md. Adnan, NAHRIM)
09:15 – 09:30 Hydrological Modeling (WEB-DHM) for the AWCI/CCAA Climate Change Impact Assessment Studies (Patricia Ann Jaranilla-Sanchez, UT)
09:30 – 09:45 WEB-DHM with an advanced, energy balance based snow-melt scheme and glacier-melt component: WEB-DHM-S (Maheswor Shrestha, UT)
09:45 – 10:00 BREAK
10:00 – 11:30 Hands-on training session: Visual analysis of bias corrected and downscaled rain (Grads); Off-line preparation for running WEB-DHM
11:30 – 12:45 LUNCH
12:45 – 13:30 Hands-on training session: Running WEB-DHM
13:30 – 14:00 In-siu data management system for AWCI - Introduction and the on-line tool demonstration (Katsunori Tamagawa, Hiriko Kinutani, Misa Oyanagi, UT)

14:00 – 17:30 Training Part 3: WEB-DHM outputs, Drought Indices & Presentation on JRA55
14:00 – 14:30 Drought Indices: methodology and applications for drought assessment (Patricia Ann Jaranilla- Sanchez)
14:30 – 16:00 Hands-on training session: WEB-DHM and Drought Indices generation using the bias corrected precipitation and WEB-DHM historical baseline and future period outputs
16:00 – 16:30 BREAK
16:30 – 16:45 JRA55 reanalysis by JMA (Kazutoshi Onogi, JMA)
16:45 – 17:30 Hands-on training session: Drought Indices generation using the bias corrected precipitation and WEB-DHM historical baseline and future period outputs. Continue.
17:30 ADJOURN

Thursday 20 June: WEB-DHM output review, Drought Indices, Excursion to IIS
08:30 – 11:00 Training Part 3 - Continue: WEB-DHM outputs, Drought Indices
08:30 – 09:45 Hands-on training session: Drought Indices generation – continue; Review and discussion on the WEB-DHM results of the previous day runs.
09:45 – 10:00 BREAK
10:00 – 11:00 Hands-on training session: Result analysis, conclusions, Q&A.
11:00 – 11:20 Change of precipitation and soil moisture on the Mongolian Plateau from 2001 to 2012 (Ichirow Kaihotsu, Hiroshima University)
11:20 – 12:10 Closing Session
11:20 – 11:30 Closing Remarks
11:30 – 12:00 Certificate Ceremony
12:00 – 12:10 Logistics of the afternoon excursion
12:10 – 13:50 LUNCH
14:20 – 18:00 Visit to the DIAS core system at the Komaba Campus of the University of Tokyo
14:20 Meeting in front of the Engineering Bldg. No.1 (ginkgo tree)
14:30 Departure to the Komaba campus (subway)
16:00 – 17:30 Visit of the DIAS core system
17:30 ADJOURN

2. The 7th GEOSS AP Symposium, the 10th AWCI ICG Meeting and the 10th IGWCO Workshop

- held at the KFC Hall and the University of Tokyo, Tokyo, Japan, 26 – 30 May 2014

Agenda of the AWCI Parallel session at the Symposium

GEOSS Asian Water Cycle Initiative (AWCI)

Water is essential for human life and wellbeing. It provides a bridge among atmospheric, oceanic and terrestrial natural sciences and socio-economic benefit areas including agriculture, forestry, health, energy, economy and human settlement. More than 60 percent of the world population lives in Asia. The Asian monsoon brings a rich-water environment. However, the Asian monsoon often causes serious floods, landslides, droughts, water scarcity, and water pollution problems. Climate change is now a fundamental threat in Asia.

To address the Asian water-related issues, the GEOSS Asian Water Cycle Initiative (AWCI) was established in 2005. Responding to the data needs, eighteen GEOSS/AWCI member countries collected and archived hydrological data under the open data policy of the GEOSS. The Data Integration and Analysis System (DIAS) contributes to this data integration. Soil moisture, ground water, inundation, drought, snow- and glacier- melt, vegetation growth, and rice production are simulated and predicted in demonstration river basins in Asia. GEOSS/AWCI supports capacity building through a wide range of training courses for practitioners and policy makers.

GEOSS/AWCI has stepped into the second phase. In November 2013, GEO organized the joint "GEOSS Asia - Africa Water Cycle Symposium" in Tokyo. The members introduced their ideas and the draft Project Design Matrix (PDM) and exchanged knowledge and experience with countries and river basin authorities in Africa, donors, space agencies and other key collaborators.

The objective of this breakout session will focus on the cross-cutting and inter-related nature of challenges in water nexus. By sharing planning and on-going case studies, we would identify benefits obtained by mutual linkages between water and the related socio benefit areas, including climate, agriculture, ecosystem, health and economy, and consider how to promote water-centric inter-linkage as a goal to be more widely pursued.

GEOSS/AWCI is addressing regional water-related problems in Asia as an important component of its sustainable development priority.

Co-Chairs:

Richard Lawford (GEO Water)
TBD
Toshio Koike (The University of Tokyo)

09:45-10:15 **1. Opening GEOSS/AWCI Breakout Session**

1) Opening Address
2) Report on the 1st GEOSS Asia-Africa Water Cycle Symposium

10:15-12:00 **2. Introduction to Global and Regional Water-related Activities**

1) Integrated Global Water Cycle Observations (IGWCO)
2) Observations from Space
   - Shizuku
   - GPM
   - GSMaP Real-time Correction for Water Resources Management
3) International Centre for Water Hazard and Risk Management (ICHARM)
4) Network of Asian River Basin Organizations (NARBO)
5) Post-MDGs/ SDGs, Hyogo Framework Action 2

12:00-13:00 ***Lunch Break***

13:00-15:00 **3. Inter-linkage Case Studies**

1) Indonesia
2) Pakistan
3) Sri Lanka
4) Vietnam

15:00-15:20 ***Break***

15:20-17:00 **4. Discussion towards Promoting Inter-linkages**

1) Needs, Issues and Benefits
2) Linkage to Regional and Global Coordination Framework
3) Building capacity
4) Planning Strategy

17:00-17:30 **5. Closing GEOSS/AWCI Breakout Session**

1) Session Summary
2) Concluding Remarks

Agenda of the AWCI ICG Meeting (afternoon of 28 May 2015; http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_May2014/awci/index.htm)

Discussion on:

(i) reorganization of the AWCI structure to suit the needs of Phase 2 targets
(ii) suggestions for further steps in pursuing the country PDMs towards implementation

Agenda of the IGWCO Workshop (29 – 30 May 2015; http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_May2014/igwco/index.htm)

Thursday, May 29:

08:30 – 09:00: Registration

09:00 – 10:20: A. Opening Session

1. Welcoming Remarks of Local Host (Toshio Koike)
2. GEO Overview (Douglas Cripe)
3. IGWCO Highlights of the past year and Expectations for this meeting (Rick Lawford)
4. Summary of the Highlights from the AP GEOSS Symposium (Toshio Koike)

10:20 -10:45 Coffee/ Health Break

10:45 – 12:30: B. Review of Water Task Activities

SB Implementation Board (Rifat Hossain)
Review of Component 1 activities (Integrated Data Products and Services)
Presentations (These presentations should emphasize the goal of the activity, how the activity contributes to the Water Target, what will be delivered in 2015; the obstacles encountered and (possibly) overcome in producing the integrated products).

- Soil Moisture (Peter van Oevelen)
- GEOWOW (Adrian Strauch)
- Precipitation (George Huffman), Great Lakes Water System (Gail Faveri) (RL to summarize)
- ➢

System Integration:

- GEO Water Cycle Integrator (Toshio Koike)
- EartH2Observe (Jaap Schelluemer)
- DIAS and the CEOS Water Portal (Satoko Miura)

12:30 – 13:30 Lunch
13:30 – 14:30 B. **Review of the Task**
Component 2: Droughts and floods (Will Pozzi)

- Floods from ICHARM (Y. Iwami (TBC))

Component 3: Cold Regions (Dr. Shi)
Component 4: Water Quality Remote presentation on Friday morning)

- Sediments (Adrian Strauch)

Component 5: Capacity Development (AWCI and AfWCCI will be addressed in the introduction of the Country Reports)

- CIEHLYC (Angelica Guiterrez-Magness (TBC))

14:45 – 15:15: C. Introduction to the Asian Water Cycle Initiative and the African Water Cycle Coordination Initiative

- ➢ Introduction and overview of AWCI and AfWCCI (Toshio Koike)
- ➢ DRAGON (Yijian Zeng)

15:15 – 15:30 Coffee/ Health Break
15:30 – 18:00: D. Introduction to Phase II Asian Water Cycle Initiative

1. Individual country contributions to AWCI:
   a. Bangladesh – Mafizur Rahman
   b. Bhutan – Karma Chhophel
   c. Cambodia – Kumiko Tsujimoto
   d. Laos – Bounteum Sysouphanthavong
   e. India - Cancelled
   f. Indonesia – Muhammad Syahril Badri Kusuma
   g. Mongolia – Dambarvavjaa Oyunbaatar
   h. Myanmar – Than Zaw
   i. Pakistan – Ghulam Rasul
   j. Philippines – Analiza Solis
   k. Sri Lanka – S.B. Weerakoon
   l. Thailand – Thada Sukhapunnaphan
   m. Viet Nam – Dang Ngoc Tinh
   ➢ Discussion

Friday, May 30:

08:30 – 10:00: E. Continued review of the Task Components with remote presentations (08:30 – 10:00 – Speakers are still being confirmed)

- Water Quality – Steven Greb
- Evapotranspiration - David Toll
- World Water Services and AIP-7 - David Arctur
- WMO/GTN-H – Wolfgang Grabs (TBC)
- Morocco Country Report – Kamal Labassi

➢ **10:00 – 10:30 Break**
10:30 – 11:15: F. Implementing the GEOSS Water Strategy:

- Overview of the GEOSS Water Strategy and the status of its Implementation (Rick Lawford)

- Possible contributions to ID-05 Study
- Discussion (touching on all of the major recommendations that the IGWCO COP can help address directly)

11:15 – 12:00: G. Agency contributions to GEO Water and the GEOSS Water Strategy

- JAXA (Shizu Yabe)
- NASA (David Toll or Substitute)
- ITC – University of Twente (Yijian Zeng)

12:00 – 13:00: Lunch

13:00 – 14:45: H. New Directions and Synergies with other GEO activities

- Blue Planet (Douglas Cripe)
- GEOGLAM and water linkages (Will Pozzi)
- Wetlands (GEOBON) (Adrian Strauch, Shin-ichi Nakano)
- Climate (Toshio Koike, Peter van Oevelen)
- Water and Water Borne Diseases (Rifat Hossain)
- Water-Energy-Food Nexus and Sustainable Water Futures (Future Earth) (Rick Lawford)
- Discussion

14:45 – 15:30: I. Moving forward

1. Ideas for IGWCO COP and GEO Water Outreach
2. Thoughts on potential Water contributions to the next GEO Implementation plan (Toshio Koike)
3. Meeting Summary and Preliminary Action Items (Rick Lawford)
4. Next Meeting

15:30 – 16:00 Coffee/Health Break

16:00-17:30: I. Special Session on Water and SDGs, Health and UN Programs

1. Introduction to opportunities for water in activities related to SDGs, Health and UN programmes (Rifat Hossain)
2. Discussion on links to SDGs
3. Short presentations on Water-Health connections at the U of Tokyo (Toshio Koike and others)
4. Discussions on water and health and other UN activities

3. The AWCI Training Workshop on Assessment of Climate Change Impact on a Watershed Hydrology including Hydrological Modeling in Cold Region Basins

- held in Islamabad, Pakistan on 15 – 17 September 2014
- organized by the Pakistan Meteorological Department (PMD) in cooperation with the University of Tokyo, Japan supported by the Asia Pacific Network for Global Change Research (APN).

Agenda (Final version)

DAY 1: Monday 15 September 2014

09:30 – 09:55 Registration

10:00 – 11:30 1. Opening and Welcome Remarks (*Chair: TBD*)

Mr. Hazrat Mir, Director General, *Pakistan Meteorological Department*: Welcome Address (10min)
Dr. Ghulam Rasul, *PMD*: APN Project led by PMD (10min)
Dr. Qamar-uz-Zaman Chaudhry, Special Envoy of WMO Secy Gen for Asia-Pacific (10min)
Dr. Amir Muhammad, APN Representative of Pakistan (10min)
Keynote Speech:
Prof. Dr. Toshio Koike, *University of Tokyo*, (30 min)
Remarks by the Chief Guest: Iftikhar Ahmed Mir, Senior Joint Secretary (10min)

11:30 – 11:40 Group Photo

11:40 – 11:50 BREAK

11:50 – 12:00 2. Training Workshop Outline (Dr. Petra Koudelova, *University of Tokyo*)

12:00 – 12:30 3. Pakistani Contributions to AWCI (*Chair: Dr. Arshad M. Khan*)

20 minutes' presentation and 5 min questions/answers

1. Pakistani activities under AWCI – overview of past, present, and future (Dr. Bashir Ahmad, *PARC*)

12:30 – 14:00 LUNCH

14:00 – 14:50 3. Pakistani Contributions to AWCI – continue (*Chair: Dr. Arshad M. Khan*)

2. Indus project – climate and water nexus (Dr. Ghulam Rasul, *PMD*)
3. Indus project – water and food (agriculture) nexus (Prof. Dr. Ashfaq Chatta, *University of Agriculture, Faisalabad*)

14:50 – 16:15 **4. Hydrological modeling in cold region watersheds** (*Chair: Prof. Dr. Ashfaq Ahmad Chattha*)
20 minutes' presentation and 5 min questions/answers

1. UNESCO Flood Project (Mr. Muhammad Riaz*, FFD/PMD*)
2. Distributed hydrologic modeling in cold region and high elevation watersheds in an integrated approach (Dr. Maheswor Shrestha*, UT*)
3. Brief on September 2014 Floods in Pakistan (Mr. Aleem ul Hassan, *National Weather Forecasting Center*)

16:15 – 16:45 *BREAK*

16:45 – 18:00 **5. Data Integration and Analysis System (DIAS) and Data Support Services** (*Chair: Mr. Ahmad Kamal, NDMA*);
20 minutes' presentation and 5 min questions/answers

1. Expansion and Linkages of Water Cycle Initiative (Prof. Dr. Toshio Koike)
2. DIAS data upload, quality control and metadata support system (Dr. Petra Koudelova*, UT*)
3. CEOS Water Portal data service (Dr. Petra Koudelova*, UT*)

18:00 *Adjourn*
20:00 Discussion dinner

DAY 2: Tuesday 16 September 2014

Training Workshop on Climate Change Assessment: GCM Bias Correction and Statistical Downscaling, Hydrological Analyses – using a demo case of the Soan Basin, Pakistan

08:00 – 08:30 Registration and Arrangements

08:30 – 12:00	**6. Training Part 1.1: GCM Selection**
08:30 – 08:50	Introductory Lecture (Dr. Petra Koudelova)
08:50 – 10:40	Hands-on: Selection of suitable GCM output for the Soan basin region – using an on-line tool and MS Excel sheet (Dr. Petra Koudelova)
10:40 – 11:00	*BREAK*
11:00 – 12:00	Hands-on: Selection of suitable GCM output for the Soan basin region – using an on-line tool and MS Excel sheet - continue
12:00 – 13:30	*LUNCH*
13:30 – 15:00	**7. Training Part 1.2: GCM Rainfall Bias Correction, Statistical Downscaling**
13:30 – 14:00	Introductory Lecture (Dr. Mohamed Rasmy)
14:00 – 15:00	Hands-on: Correction of the rainfall data of the selected GCMs and downscaling them using an on-line tool; visual inspection and discussion (Dr. Mohamed Rasmy)
15:00 – 15:30	*BREAK*
15:30 – 17:30	**8. Training Part 2**: **Hydrological Simulation Preparation and Analyses**
15:30 – 16:00	Introductory Lecture (Dr. Asif M. Bhatti)
16:00 – 17:30	Hands-on: Preparing hydrological simulation, WEB-DHM demonstration, Analysis of results including high and low flows, Discussion (Dr. Asif M. Bhatti)

17:30 *Adjourn*

DAY 3: Wednesday 17 September 2014

Training Workshop on Climate Change Assessment: WEB-DHM-S, Dynamical Downscaling
08:00 – 08:30 Registration and Arrangements

08:30 – 09:30	**9. Hydrological Modeling in Cold Regions: WEB-DHM-S model – physical and technical details, applicability discussion** (Dr. Maheswor Shrestha)
09:30 – 12:00	**10. Dynamical Downscaling** (Dr. Mohamed Rasmy)
09:30 – 10:30	Methodology Introduction Lecture (Dr. Mohamed Rasmy)
10:30 – 10:50	*BREAK*
10:50 – 12:00	Case studies presentation, Discussion (Dr. Mohamed Rasmy)
12:00 – 12:30	**11. Certificate Ceremony**
12:30 – 13:00	**12. Closing Remarks**
13:00 – 14:00	*LUNCH*

14:00 – 17:00 EXCURSION
17:00 Adjourn

4. The Intensive training seminar on WEB-DHM-S at the University of Tokyo, 23 – 27 March 2015

The purpose of this seminar is to train the experts of Pakistan Meteorological Department in the theory and use of the hydrological model for the cold region that was developed at the University of Tokyo by the research team of Prof. T. Koike. The training is carried out under the project funded by APN under the CAPaBLE programme, titled: "Impact of Climate Change on Glacier Melting and Water Cycle Variability in Asian River Basins" and led by Dr. Ghulam Rasul, PMD. The trained experts will be using the subject WEB-DHM-S model for hydrological applications and climate change assessment studies.

Agenda:

March 23, Monday :Energy balance & water balance concept in WEB-DHM-S
March 24, Tuesday: Snow and glacier melt modular system
March 25, Wednesday: Basic Programming of Fortran
March 26, Thursday: Model configuration
March 27, Friday: Model run and calibration/Validation

Participants:

Mr. Syed Ahsan Ali Bokhari	Pakistan	Pakistan Meteorological Department
Mr. Atif Irshad	Pakistan	Pakistan Meteorological Department

Funding sources outside the APN

Activity	**Organization**	**In-kind**	**Cash US$**
Travel support and meeting organizations	University of Tokyo (Source: Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Japan)		**25,000**
Training course support (technical, educational)	University of Tokyo, Pakistan Meteorological Department	Monetary equivalent not specified	
Satellite data provision	Japan Aerospace Exploration Agency (JAXA)	Monetary equivalent not specified	
Data archiving and integration functions – DIAS system	University of Tokyo (Source: Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Japan)	Monetary equivalent not specified	
Project management and coordination functions	University of Tokyo, Pakistan Meteorological Department	Monetary equivalent not specified	
Data management and application planning	Each member country	Monetary equivalent not specified	
	Total	**Not specified**	**25,000**

List of Young Scientists trained in climate change assessment, bias correction and hydrological modeling

S.No	Full Name	Affiliation	Email Address
1	Prof. Md. Mafizur Rahman	BUET, Bangladesh	mafizur@gmail.com
2	Mr. Md. Shameem Hasan Bhuiyan	Bangladesh Meteorological Department (BMD), Bangladesh	shameem_dd@yahoo.com
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20	Ms. Wereya Witaya	Royal Irrigation Department, Hydrology Division, Thailand	wereya@gmail.com
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Testimonials/Feedback from participants

Tone (Japan)

The participants, who worked with the Japanese Tone river basin data (because the database for their country basin has not been fully developed for this kind of study yet, namely India, Lao, Uzbekistan), have concluded that the obtained results indicated **increase** in the river discharge in future and **decrease** of the frequency of "severe" and "moderate" drought events.

Citarum (Indonesia)

In general, the results indicated more extreme months in past scenario than in future scenario for both for dry or wet months. However, the event in future scenario tends to be more extreme than in the past scenario, especially for wet event. For example, there were only six events in past scenario with Standard Deviation > 2.5 (very extreme wet), while in future scenario, the number of event increased to 8 events, and there were 2 events with Standard Deviation > 4.0. The trend in extreme dry event seems not as clear as wet event. Although the average simulated discharge of future scenarios is lower than past scenarios, it seems still in range of 'near normal event'.

The Indonesian participant provided two comments. The first one is regarding the reference precipitation data used for model selection, i.e. GPCP data: *Probably, GPCP is one the best data precipitation available for long term and large scale study. However, comparison with TRMM and station data in study area shows that GPCP data tend to be overestimate especially in Java Island, the location of Citarum River Basin.* Comparison of multiple GCM outputs with TRMM data showed that better results for other GCMs than the selected gfdl_cm2_1 model.

Secondly: *WEB-DHM result showed that the average daily discharge in past scenario (1981-2000) is 89.7m3/s while in future scenario (2046-2065) the value is **decrease** to 66.2m3/s. This result is slightly different with figures in IPCC report which suggest that precipitation in South East Asia tend **increase** in the future.*

Langat (Malaysia)

From the standardized anomaly (SA) index analysis of Langat streamflow, most of the monthly temporal distribution of SA indexes for both past period 1981-2000 and future period 2046-2065 lies within the 'normal' category. In 1981-2000, there are twenty (20) occurrences of 'moderately dry' months with the lowest SA index of -1.377 in May 1986. However, there was no drought or water stress incidents reported for the year. Whilst the second lowest index is -1.33 which is in May 1998. From historical analysis it is known there was a prolonged dry month in 1998 in the basin, the event had caused major water crisis and shortage of water supply in Klang Valley and Langat basin, which had affected 1.8 million residents. However, the calculated indexes for the months are classified as ‘moderately dry’.

As for the future period, it is estimated that eighteen (18) 'moderately dry' months and two (2) 'severely dry' months would occur. The temporal distribution evaluated, although is inadequate, but could be a quick reference & rough estimate of future possible drought occurrences.

Swan (Pakistan)

The discharge in the past has peak values for the years 1985-1987 and in 1992-1998; in between these time slots the peak sometimes has decreasing and increasing trend otherwise. For the future simulation of discharge, the peak values appear in the year 2052-2054 and 2060-2062. However, the peak values are not much greater than the peak values of the past. This shows the moderate dryness of the basin in the future. The monthly discharge is prominently increasing for the August, September and October months in the future (2046-2065).

The standardized anomaly index calculated for the past and future discharge simulated by WEB-DHM was calculated for three different categories (1) Extremely Dry, (2) Severely Dry and (3) Moderately Dry. The frequency of extremely dry conditions was higher for future as compared to the past whereas for the other two categories the values are equal or less to the past.

Kalu Ganga (Sri Lanka)

Monthly Discharges of each month in the Past and Future periods were fitted the bets statistical distribution using JMP10 software. The statistical parameters Location and Scale were derived for each month from the selected distribution. Drought indices were estimated. Number of months that extremely dry, severely dry and moderately dry conditions for past and future GCM discharge output was compared indicating **increase** in the river discharge in future and **decrease** of the frequency of “severe” and “moderate” drought events.

Mae Wang (Thailand)

The obtained results indicated **increase** in the river discharge in future and **decrease** of the frequency of “extremely”, “severe” and “moderate” drought events. Future work on this research should include a more extensive validation small-scale patterns with statistical methods involving height regressions, the differences of bias - corrected data. If this project has also developed algorithms combined with high resolution remote sensing and physically - based patterns, could greatly improve the realism of the resulting.

Huong (Vietnam)

The obtained results indicated **increase** in the river discharge in future and **decrease** of the frequency of “severe” and “moderate” drought events.

Glossary of Terms

ADB	Asian Development Bank
AWCI	Asian Water Cycle Initiative
CaMa-flood	Flood inundation simulation model
CCAA	Climate Change Assessment and Adaptation
CEOS	Committee on Earth Observation Satellites
CLVDAS	Coupled Land-Vegetation Data Assimilation System
DIAS	Data Integration and Analysis System
DR^2AD	Economic Model
GCM	General Circulation Model
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GSMaP	Global Satellite Mapping of Precipitation
ICG	International Coordination Group
IIWaDATA	International Integrated Water Data Access and Transfer in Asia
IWRM	Integrated Water Resources Management
ICHARM	International Centre for Water Hazard and Risk Management
JAXA	Japan Aerospace Exploration Agency
JICA	Japan International Cooperation Agency
MEXT	Ministry of Education, Culture, Sports, Science, and Technology
PARC	Pakistan Agricultural Research Center
PDM	Project Design Matrix
PMD	Pakistan Meteorological Department
UT	University of Tokyo
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)
WEB-DHM-Veg	Eco-hydrological model based on WEB-DHM with dynamic vegetation growth component
WMO	World Meteorological Organization
WCDRR	World Conference on Disaster Risk Reduction

Appendix

Participant reports, agenda, photographs and presentations of the activities are provided separately and available online as well.

1. The Asian Water Cycle Initiative (AWCI) Training Course on Improved Bias Correction and Downscaling Techniques for Climate Change Assessment including Drought Indices held at the University of Tokyo, Hongo Campus, Tokyo, Japan,18 – 20 June 2013.
   Folder **TrainingCoursesDocuments\June2013** contains all related material including agenda, participant's reports, photos and training materials.
   Training material is also available online at.
   http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_Jun2013/index.htm

2. 10th Asia Water Cycle Initiative International Coordination Group (AWCI ICG) Meeting held at the Kokusai Fashion Center in Tokyo, 28 May 2014.
   Folder **TrainingCoursesDocuments\May2014** contains related material and available online

   http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/Tokyo_May2014/awci/presentations.htm.

3. AWCI Training Workshop on Climate Change Impact Assessment Held in Islamabad, Pakistan, 15 – 17 September 2014
   Folder **TrainingCoursesDocuments\ September2014** contains related material and available online
   http://monsoon.t.u-tokyo.ac.jp/AWCI/meetings/IslamabadTraining_Sep2014/index.htm

4. Intensive training seminar on WEB-DHM-S at the University of Tokyo, Dept. Civil Engineering, Japan,23-27 March, 2015
   Folder **TrainingCoursesDocuments\ March2015** contains related material.