

Preparation for Implementation Plan for Climate Change Assessment & Adaptation

Hydrological Modeling

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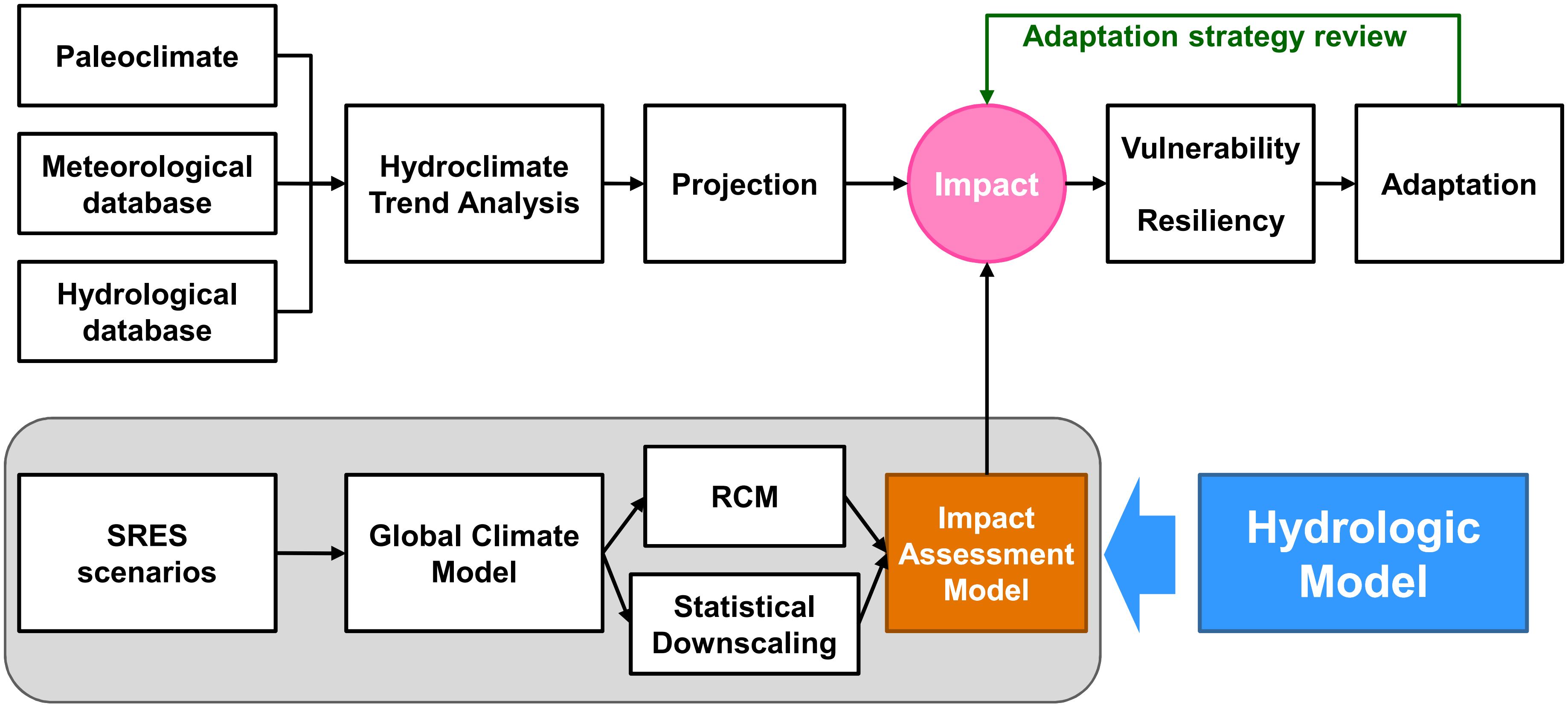
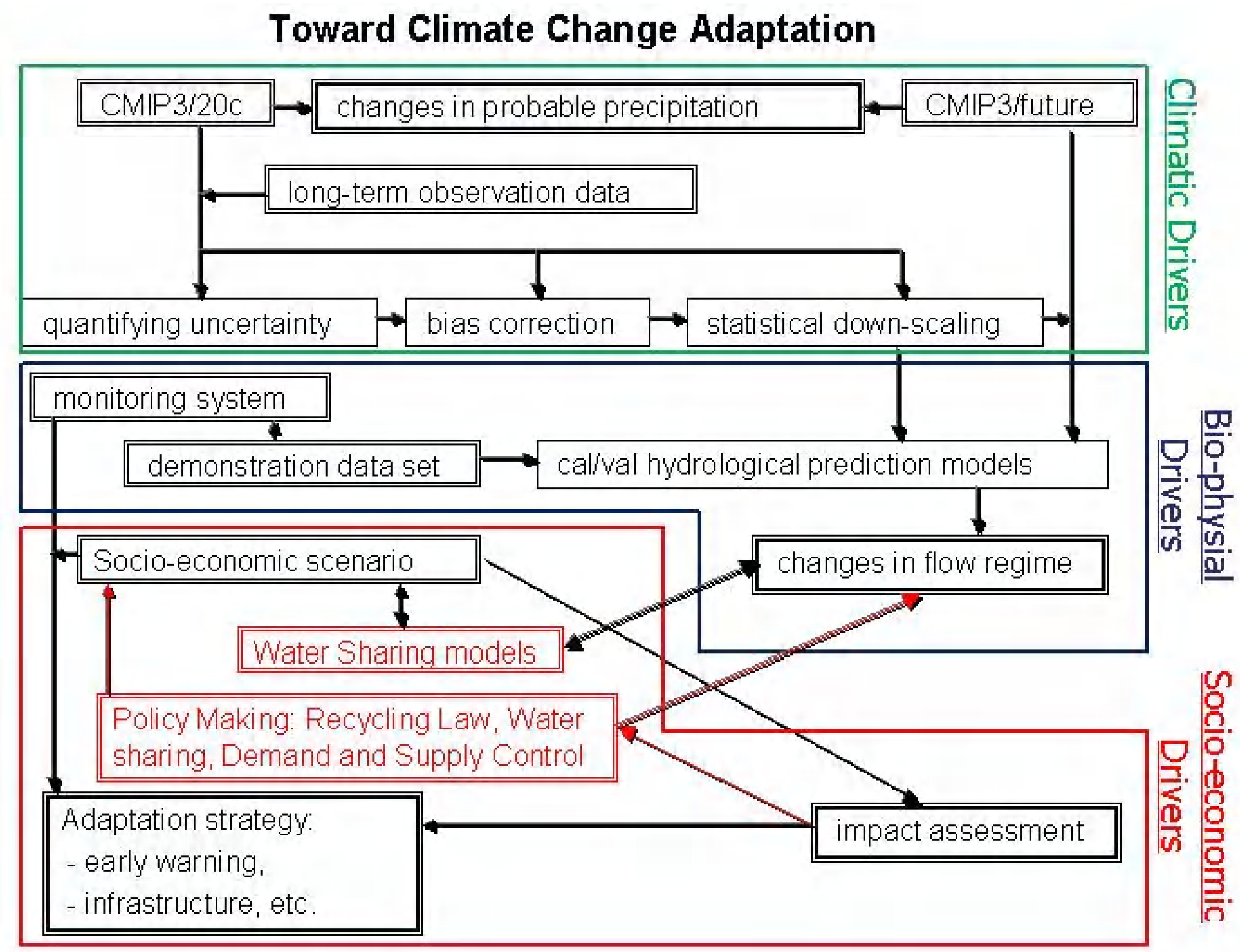
General Process for Climate Change Study

- Climate change impact, vulnerability and adaptation studies on water resources



Climate change studies on AWCI framework



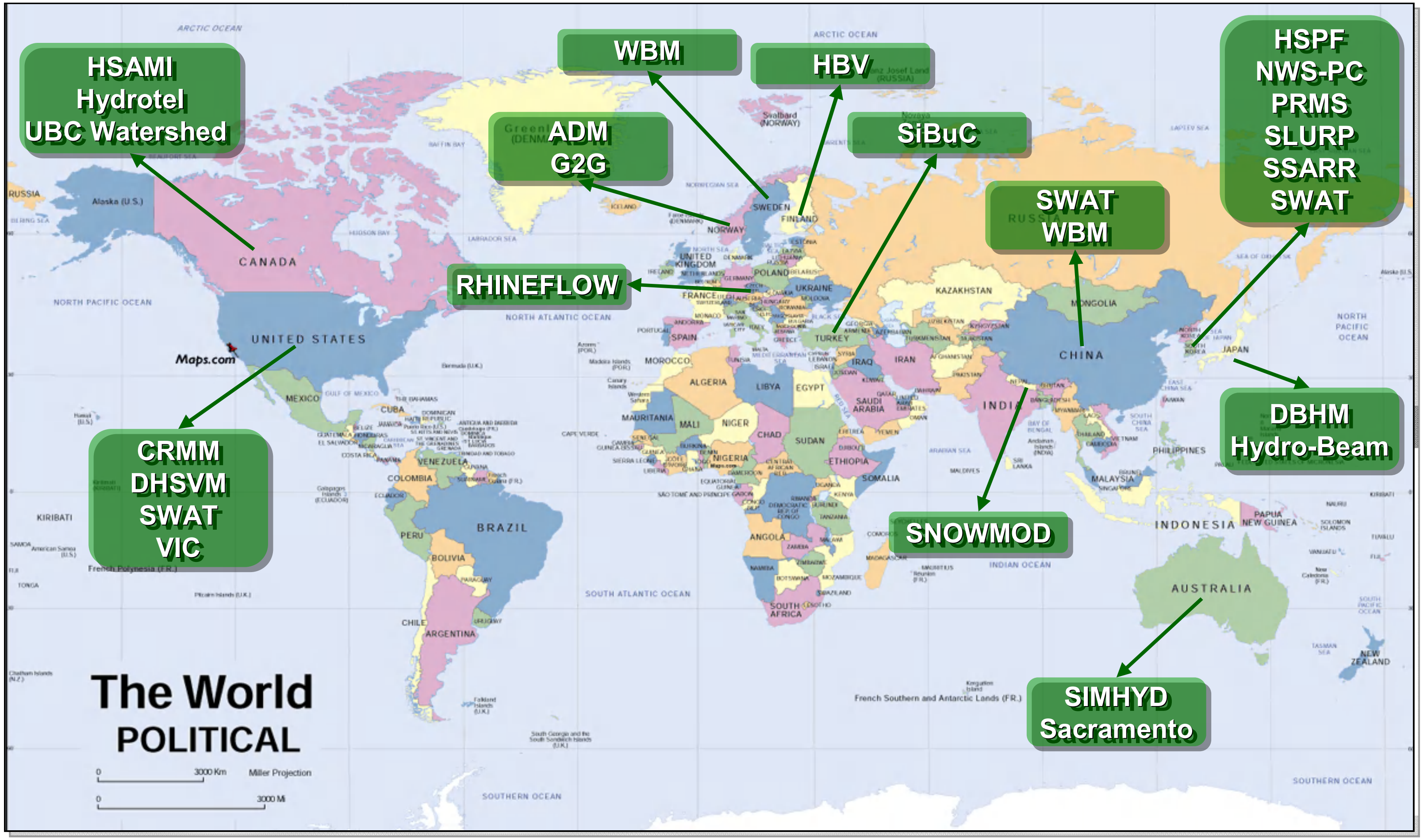
Flowchart of an implementation plan toward assessing impacts of climate change and preparing adaptation strategy – resulting version from breakout group discussions.

Adopted from T. Koike 2010

Review of Hydrologic Model

What kinds of hydrologic models used for CC study

- Keyword : climate change / water resources, water supply, hydrology
- Total number of paper : 56 (Journal of Hydrology, Water Resources Management, Climatic Change etc.)



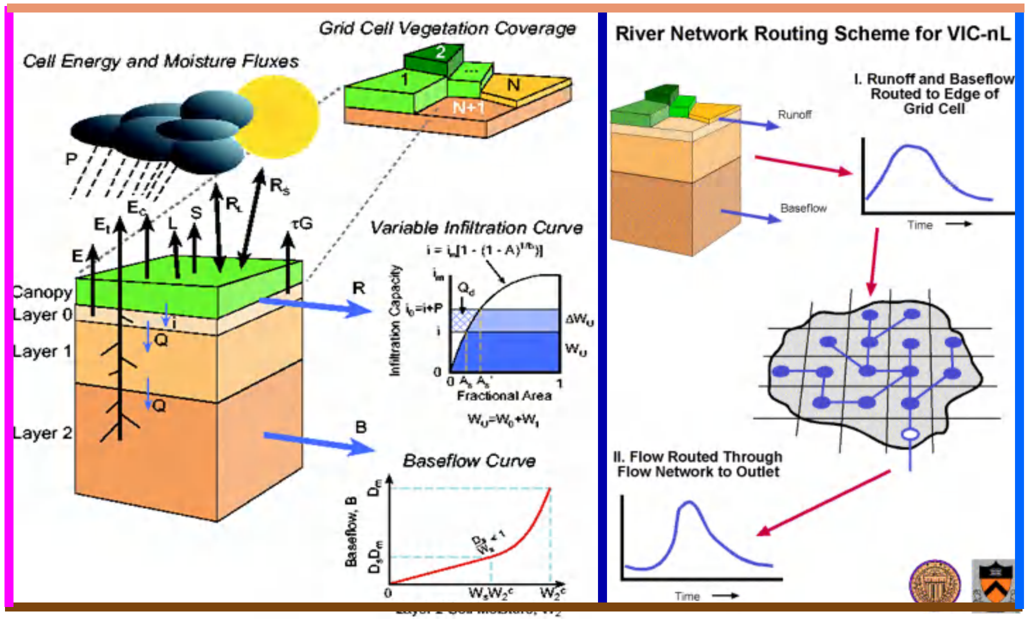
Characteristics of the selected hydrological models

Model	Agency	Model type	Evapotranspiration	Runoff
DBHM	University of Tokyo	Distributed	Penman-Monteith	Surface Groundwater
Hydro-BEAM	University of Kyoto	Distributed	Thornthwaite	Surface Subsurface Groundwater
PRMS	USGS (US)	Semi-dis.	Hamon Jensen-Haise	Surface Subsurface Groundwater
SIMHYD	University of Melbourne	Lumped	Input data	Surface Subsurface Groundwater
SLURP	Hydrologic-Solutions (UK)	Semi-dis.	Penman Monteith Spittlehous-Black Granger	Surface Subsurface Groundwater
SWAT	USDA (US)	Semi-dis.	Penman-Monteith Priestley-Taylor Hargreaves	Surface Subsurface Groundwater
VIC	University of Washington	Distributed	Penman-Monteith	Surface Baseflow

Theoretical Overview of selected models

Global hydrologic model

- The VIC(Variable Infiltration Capacity) model is soil vegetation atmospheric transfer scheme that considers both energy and water balances
- A grid-based macro-scale model that is usually implemented at various spatial scales from 1/8 °to 2°
- Widely used for analyzing the variations of water resources due to climate change



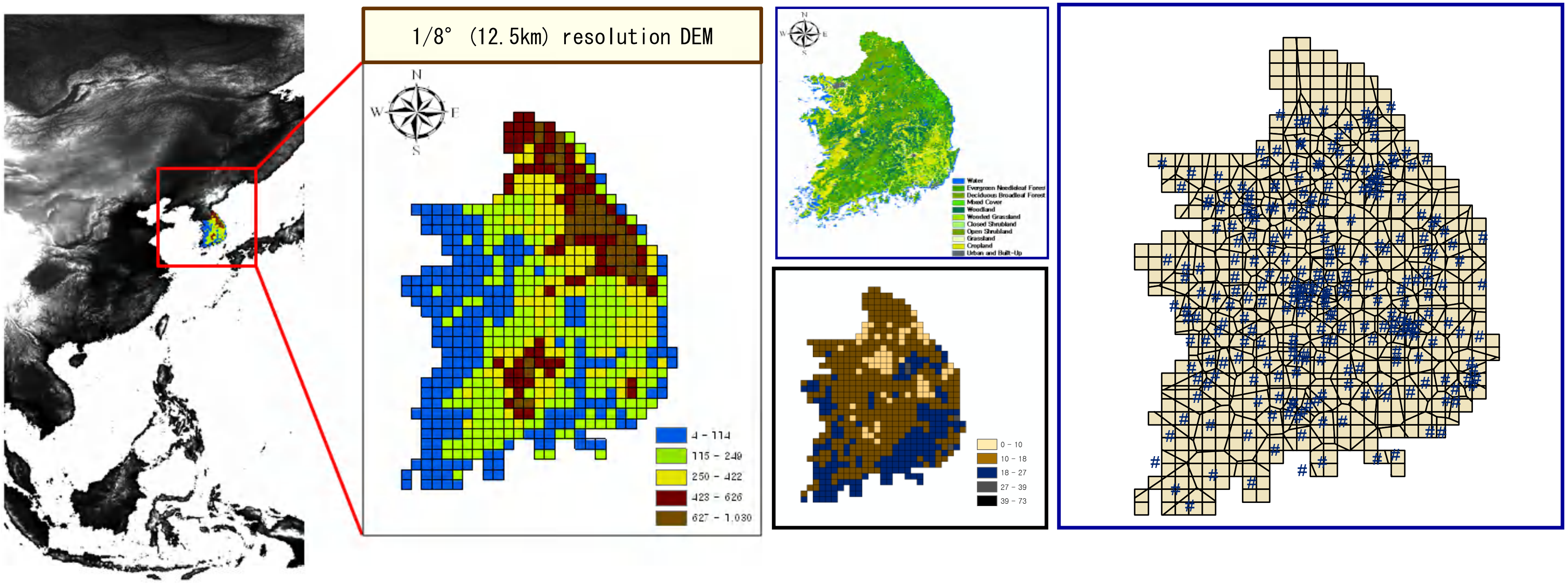
Parameter	Input Data
Basin	DEM
Forcing	Precipitation Maximum Temperature Minimum Temperature Wind Speed
Soil	Soil Properties
Vegetation	Landuse

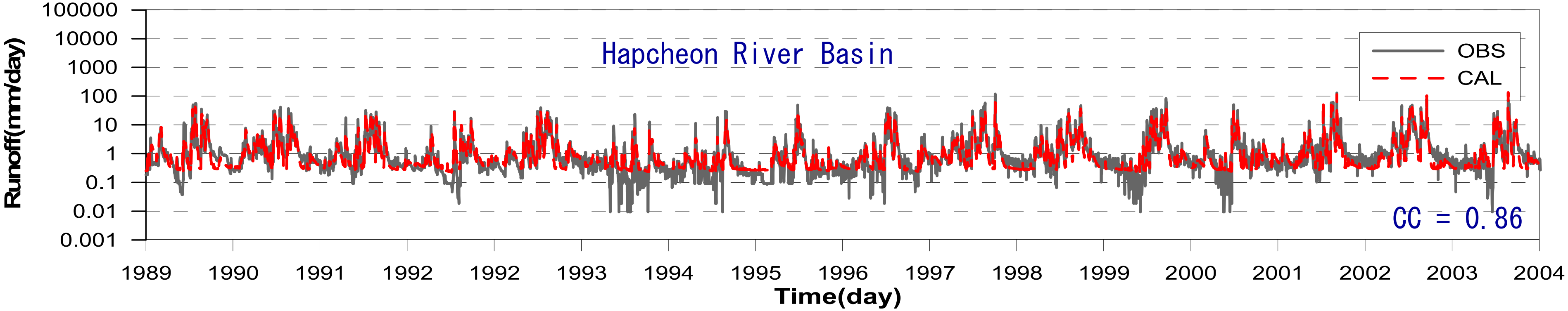
Application domain

GEOSS/AWCI Regions

East Asia Domain

Model applications on Korean domain with global/local data





Hydrological models for demonstration basin/national level

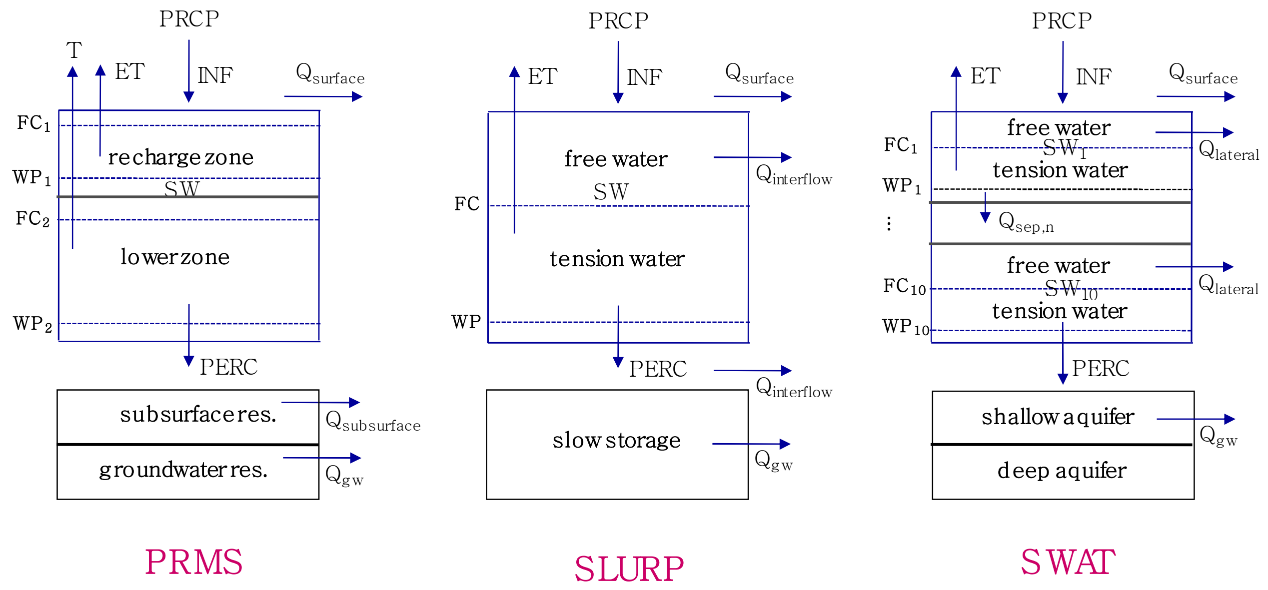
- **SWAT (Soil and Water Assessment Tool)**
  - Developed by USDA-ARS (Arnold et al., 1998)
  - Applied to predict the effects of climate and vegetative change, groundwater withdrawals and reservoir management

- **PRMS (Precipitation-Runoff Modeling System)**
  - Developed by USGS (Leavesley et al., 1983)
  - Designed to analyze the effects of precipitation, climate and land use on streamflow and general basin hydrology

- **SLURP (Semi-distributed Land Use-based Runoff Processes)**
  - Conceptual model which is capable of use as a fully-distributed hydrologic model (Kite, 1978)
  - Developed for use in meso-scale basins as an alternative to the use of larger models

Comparison of soil moisture accounting methods

- It generally perform as an algebraic summation of all moisture accretions and depletions from the soil profile

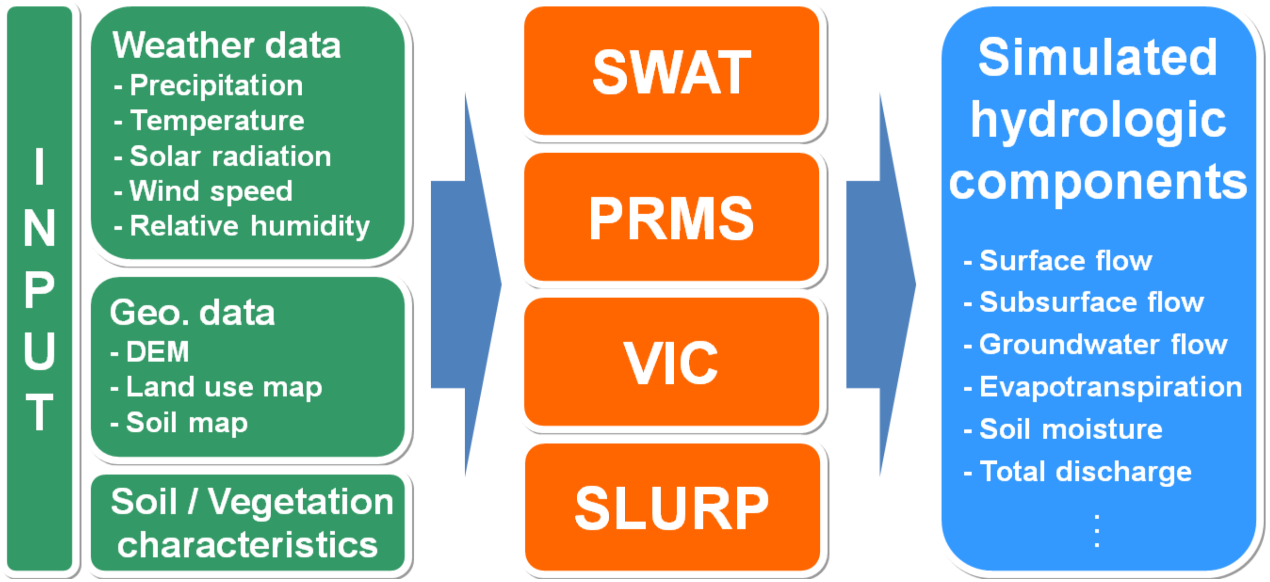


- The depletions usually include evapotranspiration, lateral flow and percolation, while the accretions consist of rainfall and snowmelt input to the system
- The models have different structures on their model development purposes
  - Maximum number of layers: 10 with free & tension field each for SWAT, 2 with recharge zone and lower zone for PRMS, 1 with free water and tension water

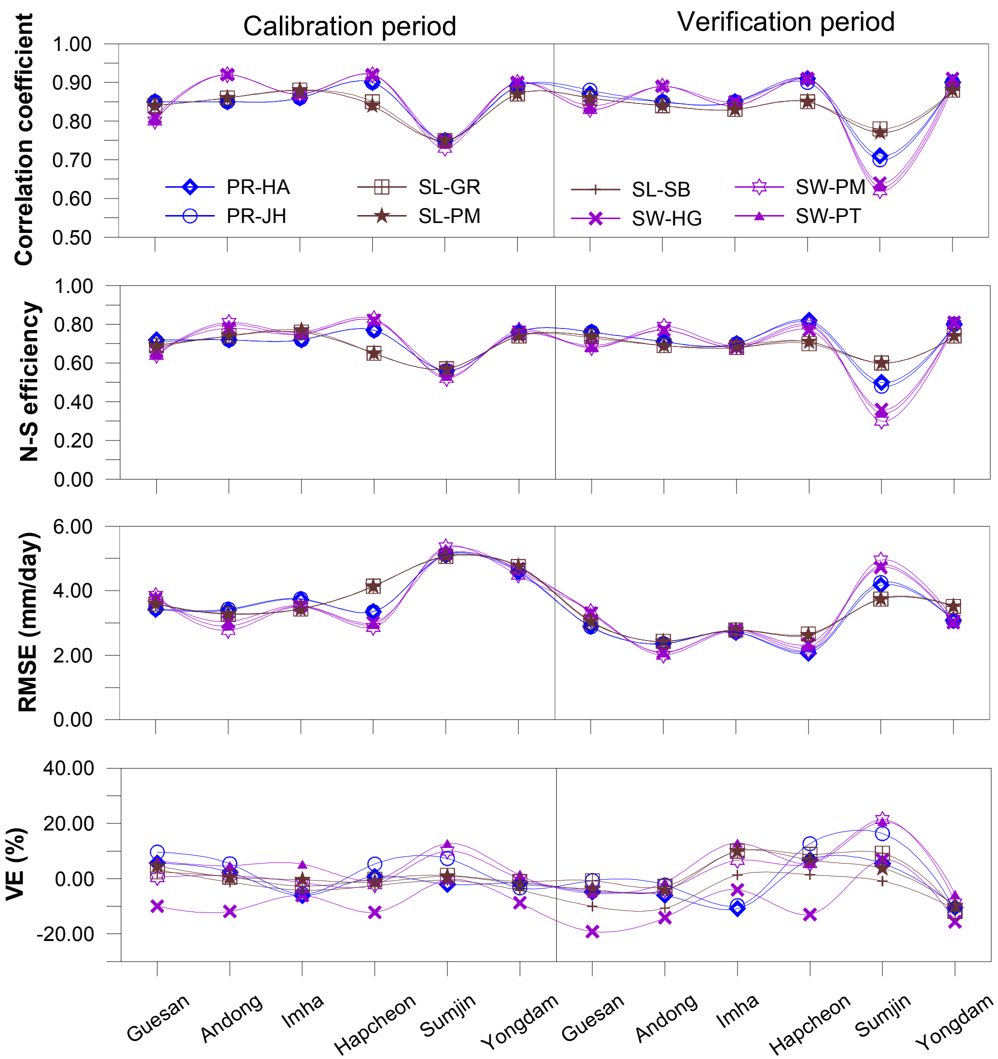
Potential evapotranspiration computation methods

Model	Evapo-transpiration	Snowmelt	No. of soil zones	Runoff components	Routing	Members
PRMS	Hamon Jensen-Haise	energy balance method	2	surface flow subsurface flow groundwater	None	PR-HA PR-JH
SWAT	Penman-Monteith Priestley-Tayor Hargreaves	degree-day method	2	surface flow Interflow groundwater	Muskingum	SW-PM SW-PT SW-HG
SLURP	Penman-Monteith* Morton CRAE Granger * Spittlehouse/Black * Linacre	modified degree-day method	1-6	surface flow subsurface flow groundwater	Muskingum	SL-PM SL-GR SL-SB

Applications of the models



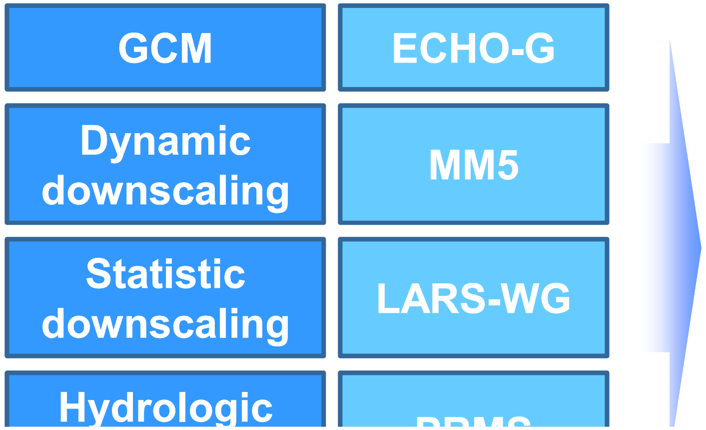
Performance of SWAT, PRMS and SLURP on 6 dam basins



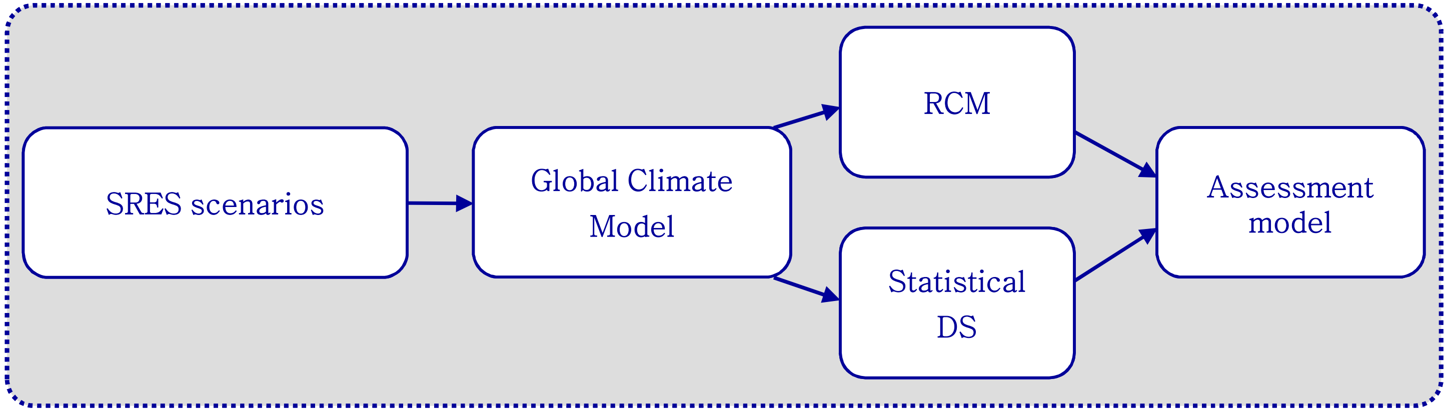
Several Hydrologic Issues on CC Study

Uncertainties on climate change impact assessment

- **Several studies have assessed the climate change impact on Korean water resources (Bae et al. 2008, Climate Research 35, pp.213-226)**



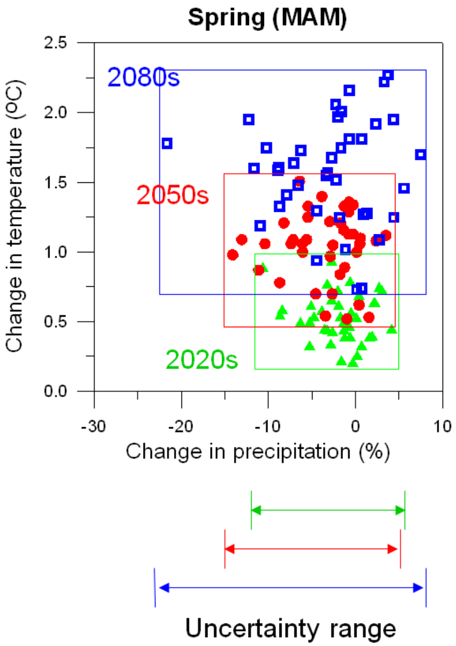
Uncertainties sources on CC impact assessment

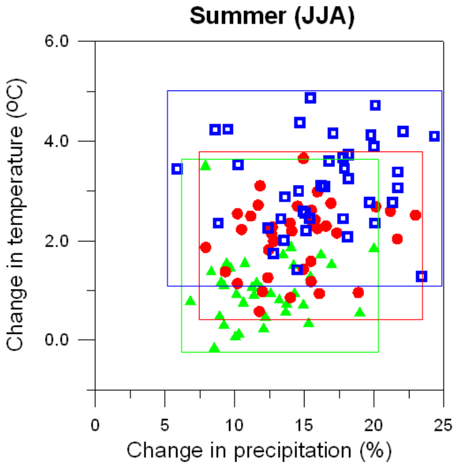


- **Uncertainties are existed within the whole process, namely GCM projection, downscaling and hydrologic modeling process**
- **Hydrologic uncertainties of climate change on IPCC AR4 GCM simulations in Chungju basin, Korea (submitted to J. of hydrology)**

  - The 8 hydrologic models having similar performance of runoff simulations during past observation periods show different results when GCM outputs are used
  - In particular, the difference are significant for the winter season in this study area
  - It represents that except for winter season, the uncertainties from the selection of hydrologic models are smaller than those of GCM outputs

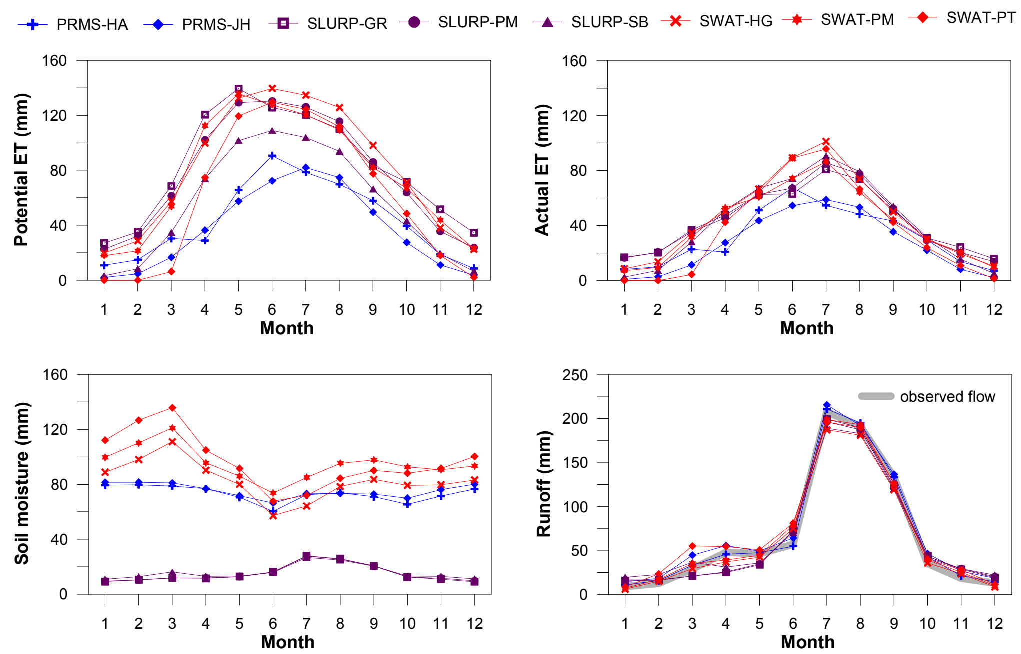
Why does multi-model ensemble is needed?





GCM

Hydrologic model



Estimation of hydrologic model parameters for ungauged basins

➢ Regionalization method based on basin characteristic relationship

Determine basin characteristics on calibration basins

Basin Area(Ao), River Length(Lo), Basin Slope(So), etc

↓

Determine the relationship between river flows and basin characteristics

Qoi = f(Ao, Lo, So, ···), i=1,2, ···,n

Determine basin characteristics on ungaged basins

Basin Area(Au), River Length(Lu), Basin Slope(Su), etc

↓

Determine the estimated flows from basin characteristics

Qsj = f(Au, Lu, Su, ···), j=1,2, ···, m

↓

Regionalization of model parameters

Determine model parameters on ungauged basin for Min[Qoi-Qsj]

➢ Regionalization method using multivariate statistical analysis (Lee et al., 2009 JKWRA)

Selection of physical characteristics of catchments

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Principle Component Analysis (PCA)

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Cluster Analysis (CA) using principle components

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Regionalization of model parameters

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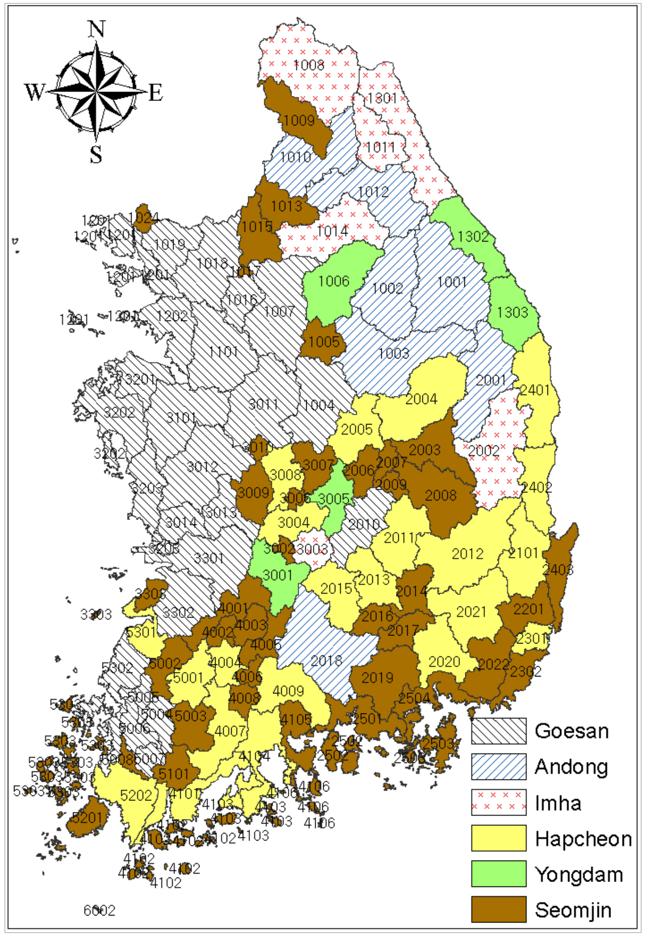
Performance verification of regionalized model parameters

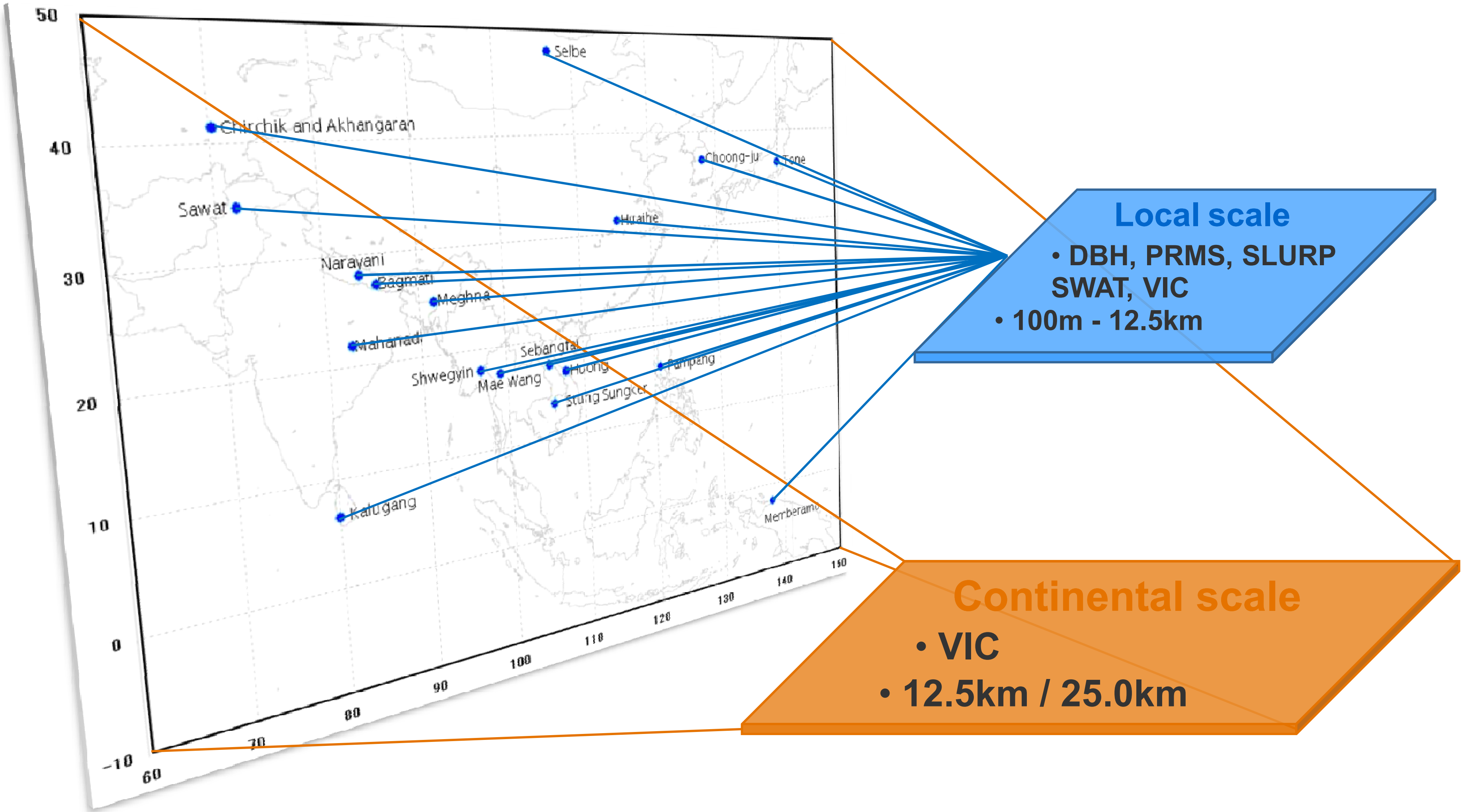


Application of regionalization method

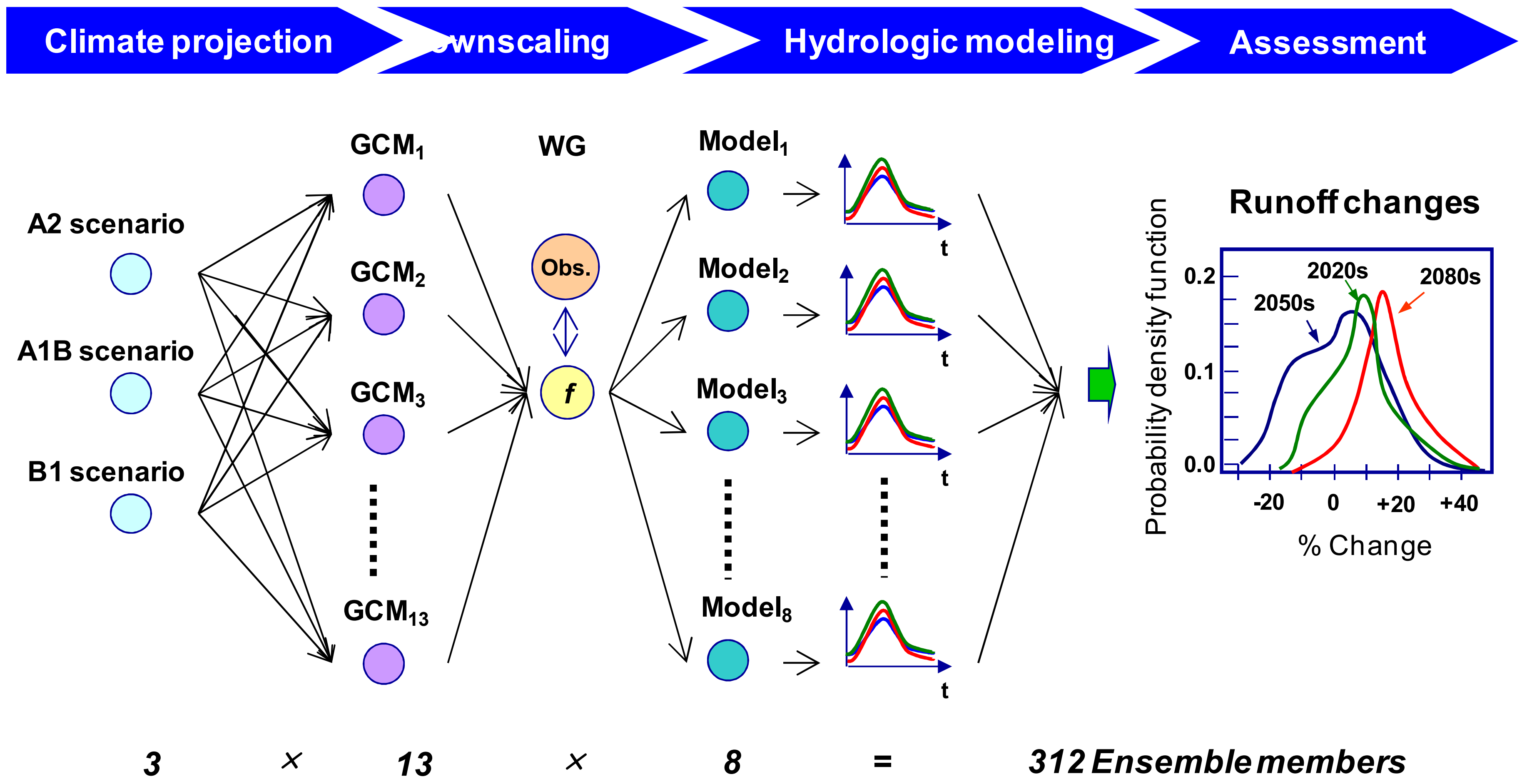
Proposed hydrologic models for CC Adaptation

Selection of hydrologic model

- Selection of hydrologic model depends on area scale and model performance

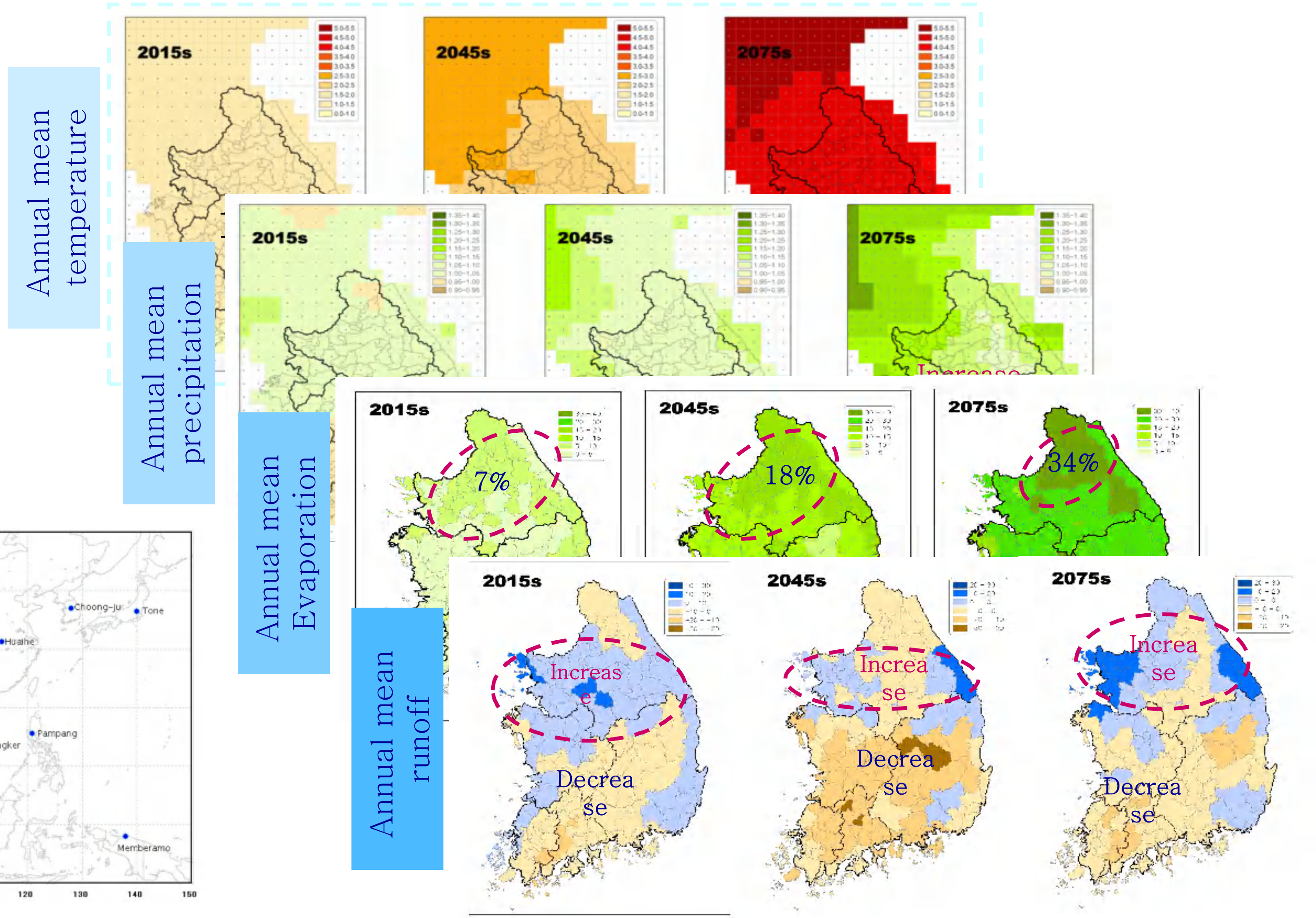


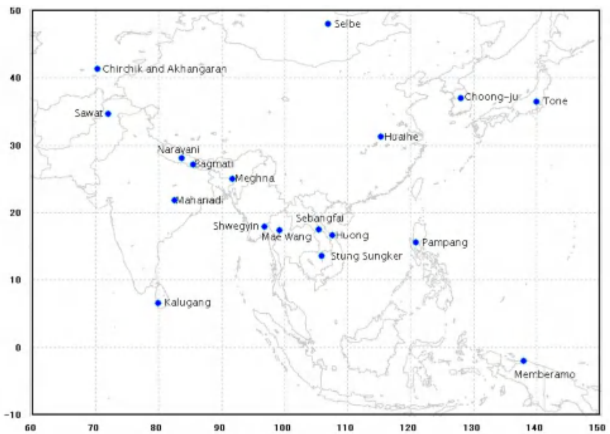
Multi Model Ensemble (MME) approach



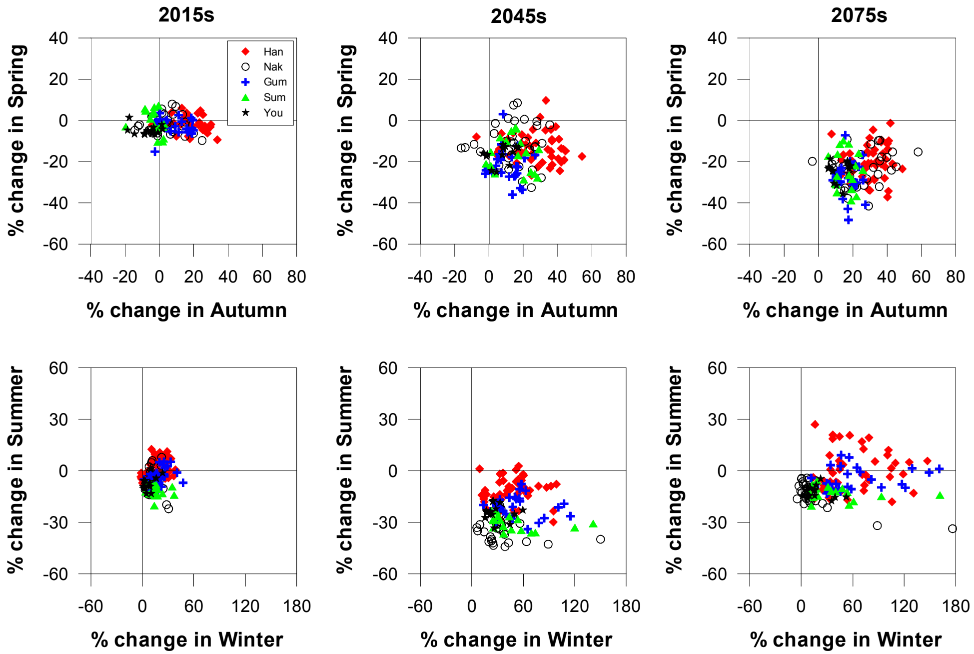
Expected major outputs

➢ Annual variations of water cycle components under A2 climate change scenario





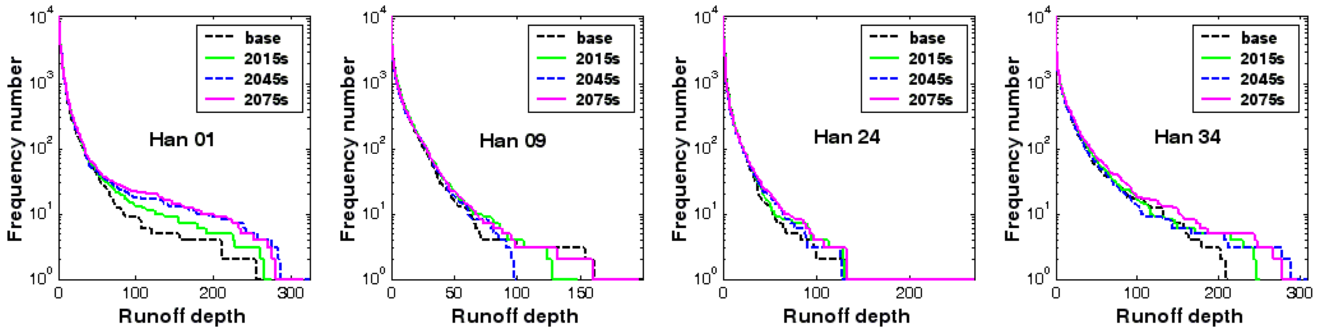
➢ Changes in seasonal runoff



- Significant increasing trends of runoff in fall and winter, decreasing in spring and summer

➢ Variations of extreme events

- Extreme discharge increases in the future periods, especially for the runoff depth more than 100 mm



Concluding Remarks for Future Study

Data Collection & Quality Control (18 river basins and Asia)	**Topography data**: • DEM • Land Use • Soil • Vegetation **Forcing data**: • Precipitation • Temperature • Solar radiation • Relative humidity • Wind speed **Climate scenario**: • Climate scenarios using GCM • High resolution
Hydrologic Model Set Up	• Calculation of initial model parameters • Evaluation of model performance
Generation of Hydrologic Scenario	• Coupling hydrologic model with climate scenario • Generation of hydrologic scenario data in the future
Impact Assessment	• Trend analysis on the temporal and spatial patterns
Capacity Building	• Sharing methodology, experience and outcome

Thank you