Comparison of Watershed Streamflow by Using the Projected MIROC3.2hires GCM Data and the Observed Weather Data for the Period of 2000-2009 under SWAT Simulation

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Introduction

- Most water resources impact assessment studies using climate change scenarios have been conducted based on the IPCC GCM data.
- To aid accurate climate change and hydrologic modeling, quantitative descriptions of the uncertainty in climate outcomes are needed.
- This study traces back the past decade's (2000-2009) MIROC3.2hires GCM data that were projected in 2000 as of 2009, and compares the downscaled MIROC3.2hires data by LARS-WG with the ground observed climate data for the period to examine the degree of uncertainty in data used in impact assessment.

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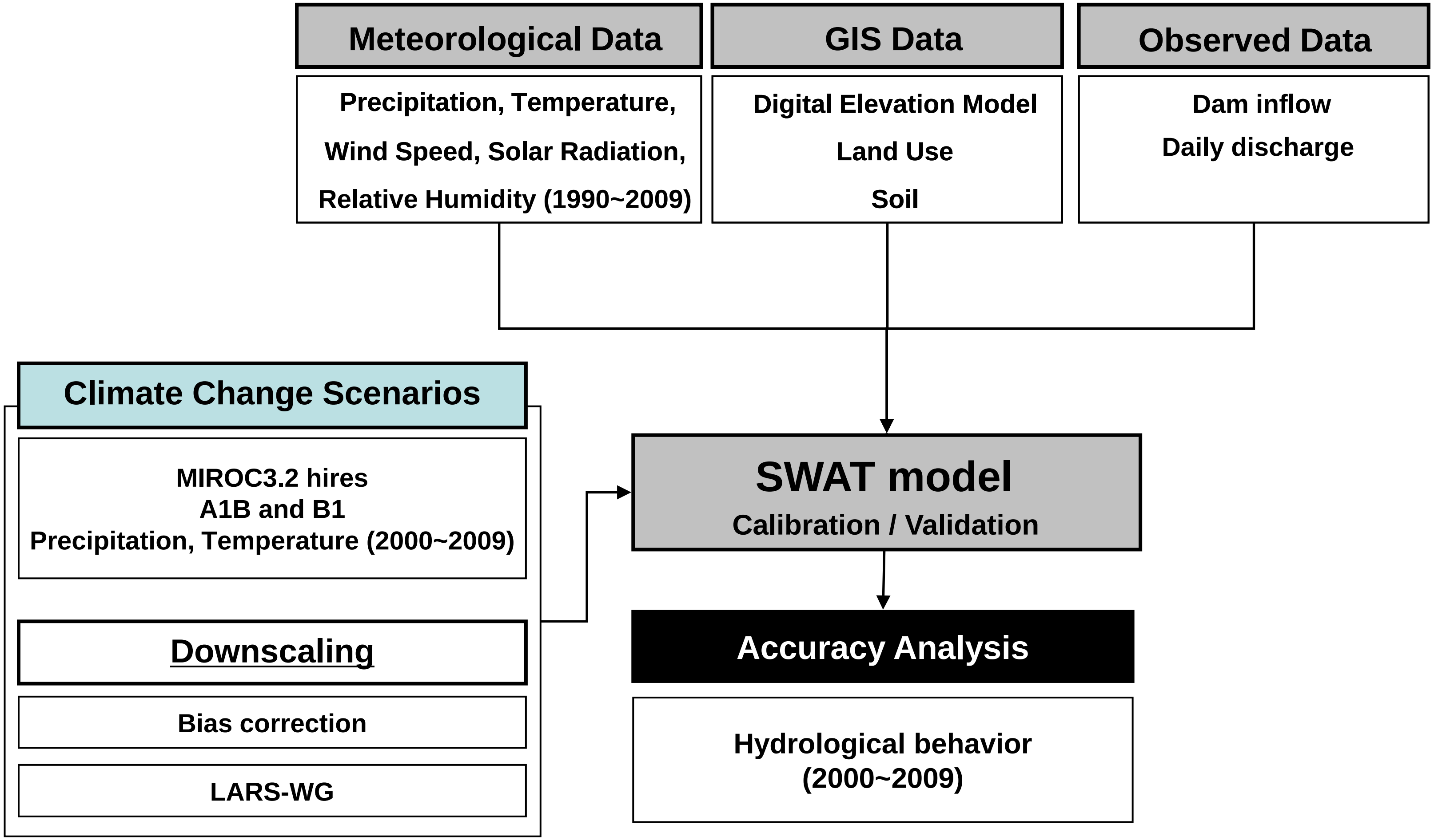
❑ The schematic diagram of this study



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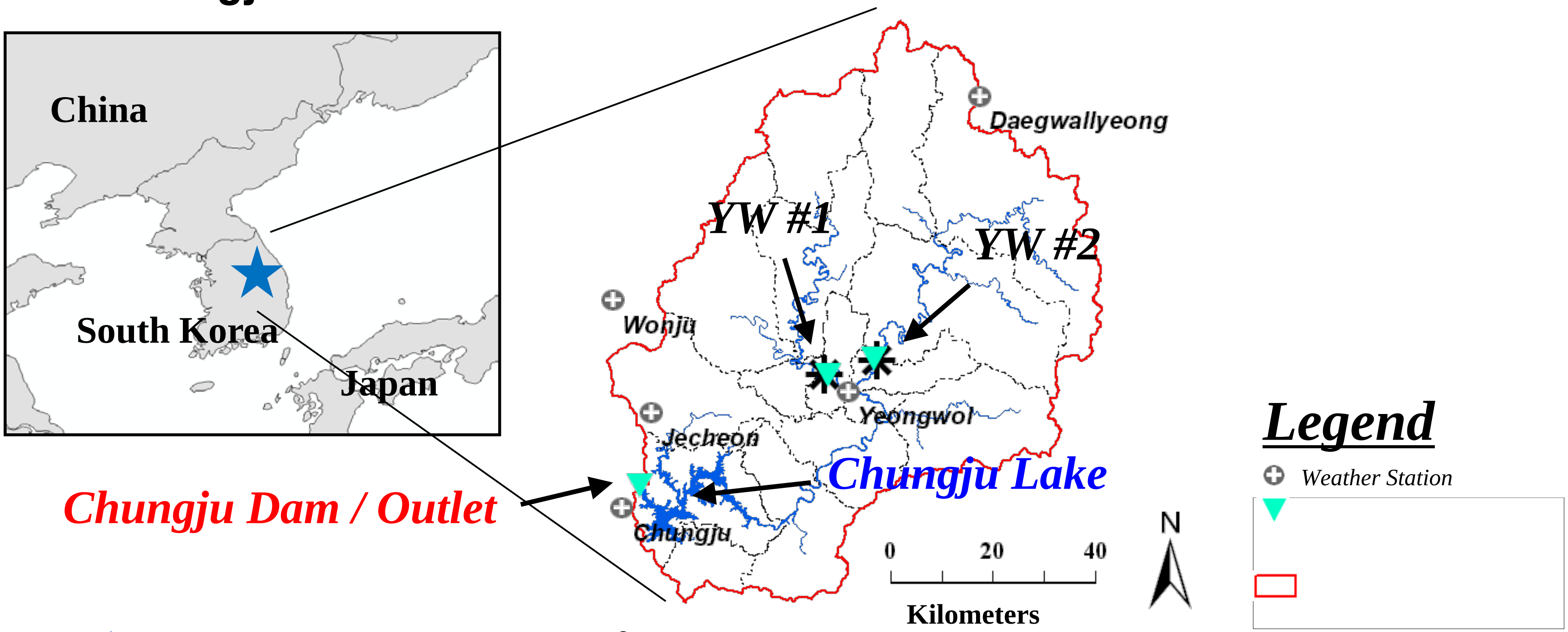
❑ Study watershed

◆ Chungju dam watershed



- ✓ Watershed area : 6,661.6 km^2
- ✓ Annual average precipitation : 1,359.5 mm
- ✓ Annual average temperature : 9.4 ℃
- ✓ Forest area : 84.6 % (5573.1 km^2)
- ✓ Latitude range : 36.8 °N ~ 37.8 °N
- ✓ Longitude range : 127.9 °E ~ 129.0 °E

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SWAT Model description

- **SWAT (Arnold et al., 1998) is a well-established, distributed eco-hydrologic model operating on a daily time step.**

- **It was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time.**

- **Model theory**
  - **Penman-Monteith method**

$$\lambda E = \frac{\Delta \cdot (H_{net} - G) + \rho_{air} \cdot c_p \cdot [e_z^0 - e_z] / r_a}{\Delta + \gamma \cdot (1 + r_c / r_a)}$$

λE = Latent heat flux density (MJ/㎡•d)

E = Depth rate evaporation (mm/d)

Δ = Slope of the saturation vapor pressure-temperature curve de/dT (kPa/℃)

H_{net} = Net radiation (MJ/㎡•d)

G = Heat flux density to the ground (MJ/㎡•d)

c_p = Air density (kg/㎥)

ρ_{air} = specific heat at constant pressure (MJ/ kg•℃)

e_z^0 = Saturation vapor pressure of air at height z (kPa)

e_z = Water vapor pressure of air at height z (kPa)

Γ = Psychrometric constant (kPa/℃)

r_c = Plant canopy resistance (s/m)

r_a = Aerodynamic resistance (s/m)

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Model setup

Data set for SWAT model

Data Type	Source	Scale	Data Description / Properties
Terrain	National Geography Institute	1/5,000	Digital Elevation Model (DEM)
Soil	Rural Development Administration	1/25,000	Soil classifications and physical properties viz. texture, porosity, field capacity, wilting point, saturated conductivity, and soil depth
Land Use	Water Management Information System	30 m	Landsat land use classification (2000 year, 9 classes)
Weather	Meteorological Administration	-	Daily precipitation, minimum and maximum temperature, mean wind speed and relative humidity data of **5 stations** from 1977 to 2009
Streamflow	Flood Control Office	-	Daily streamflow data from 1998 to 2003

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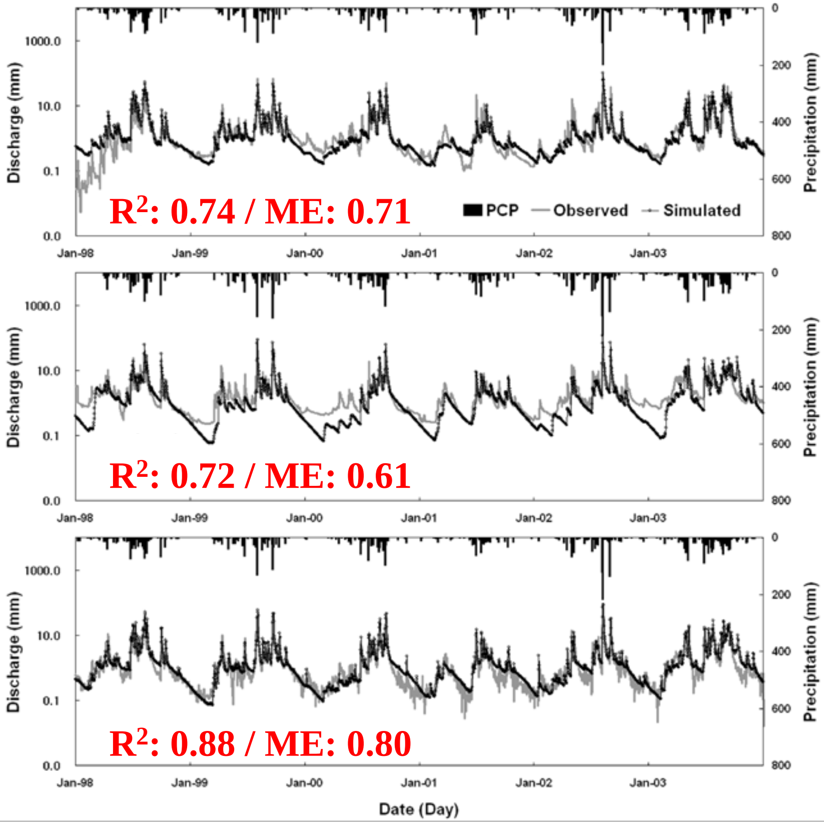
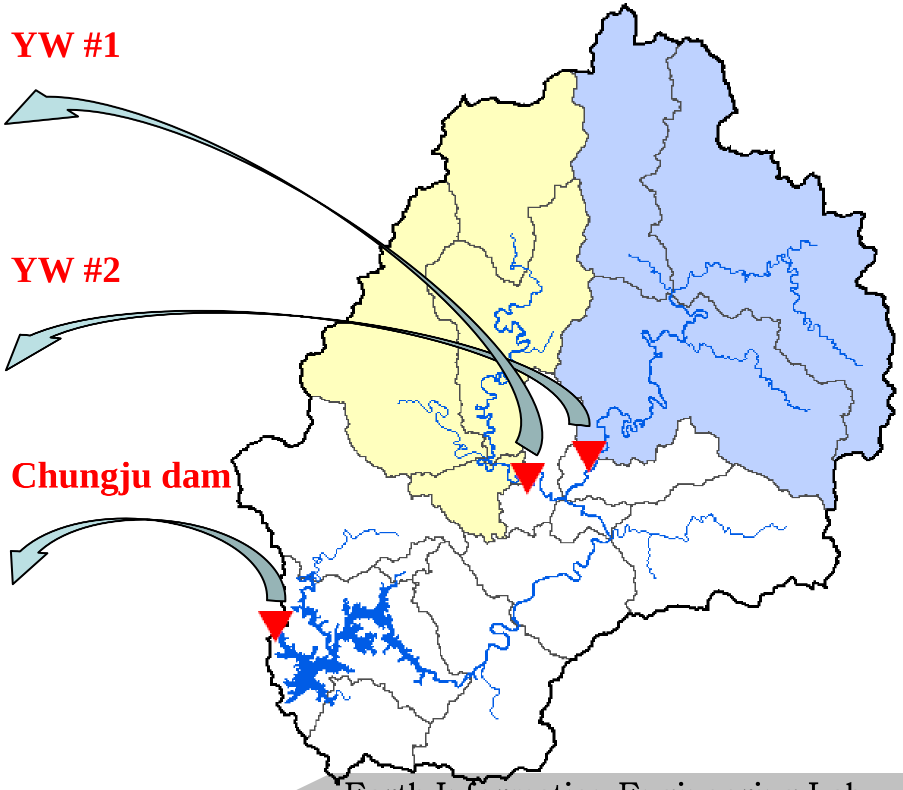
Calibration and Validation

Discharge

- Calibration period : 1998-2000 / Validation period : 2001-2003
- Using daily discharge records at three calibration points
- ME : Nash and Sutcliffe model efficiency





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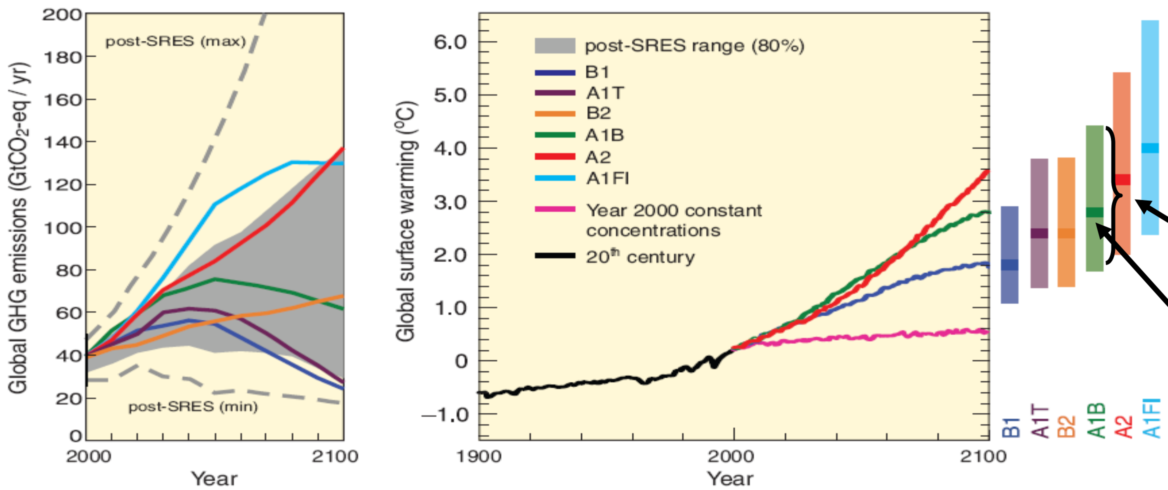
Climate Change Scenarios

Special Report on Emission Scenarios (SRES)



2100 year

A2 (high) → CO_2 **830 ppm**
A1B (middle) → CO_2 **720 ppm**
B1 (low) → CO_2 **550 ppm**

'Likely range'

'Best estimate'

- ✓ In this study, GHG emission scenario adopted SRES "A1B" (warming middle) and "B1" (warming low) scenarios.

- ✓ **A1B** : A future world of very rapid economic growth, low population growth and rapid introduction of new and more efficient technology.
  B1 : A very heterogeneous world. The underlying theme is that of strengthening regional cultural identities, with an emphasis on family values and local traditions, high population growth, and less concern for rapid economic development.

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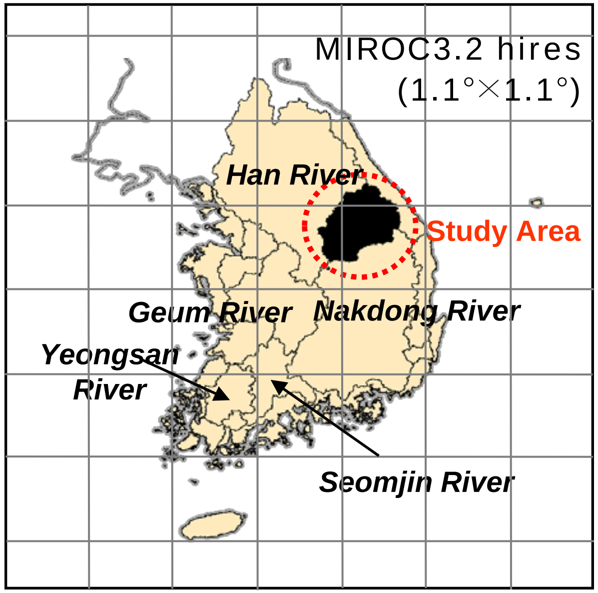
General Circulation Models (GCMs)

Climate Data from GCM (MIROC3.2 hires)



Model	MIROC3.2 hires
Center	NIES (National Institute for Environmental Studies)
Country	Japan
Scenario	A1B, B1
Grid size	320 × 160 (1.1° × 1.1°)

- ✓ The GCM (MIROC3.2 hires) data by two SRES climate change scenarios of the IPCC AR4 (fourth assessment report) were adopted.
- ✓ The MIROC3.2 hires model, developed at the NIES of the Japan, had the highest spatial resolution of approximately 1.1° among the GCM of IPCC.

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Error Correction

Bias Correction Method (Droogers and Aerts, 2005)

- The GCM data was corrected to ensure that 30 years observed data (1977-2006, baseline period).
- GCM model output of the same period have similar statistical properties among the various statistical transformations.

For temperature

$$T'_{GCM,fut} = T_{GCM} + (\overline{T}_{meas,his} - \overline{T}_{GCM,his})$$

For precipitation

$$P'_{GCM,fut} = P_{GCM} \times (\overline{P}_{meas,his} / \overline{P}_{GCM,his})$$

GCM	Scenario	Bias correction factor	
		Temperature	Precipitation
MIROC3.2 hires	A1B	-2.20	1.08
	B1	-2.19	1.10

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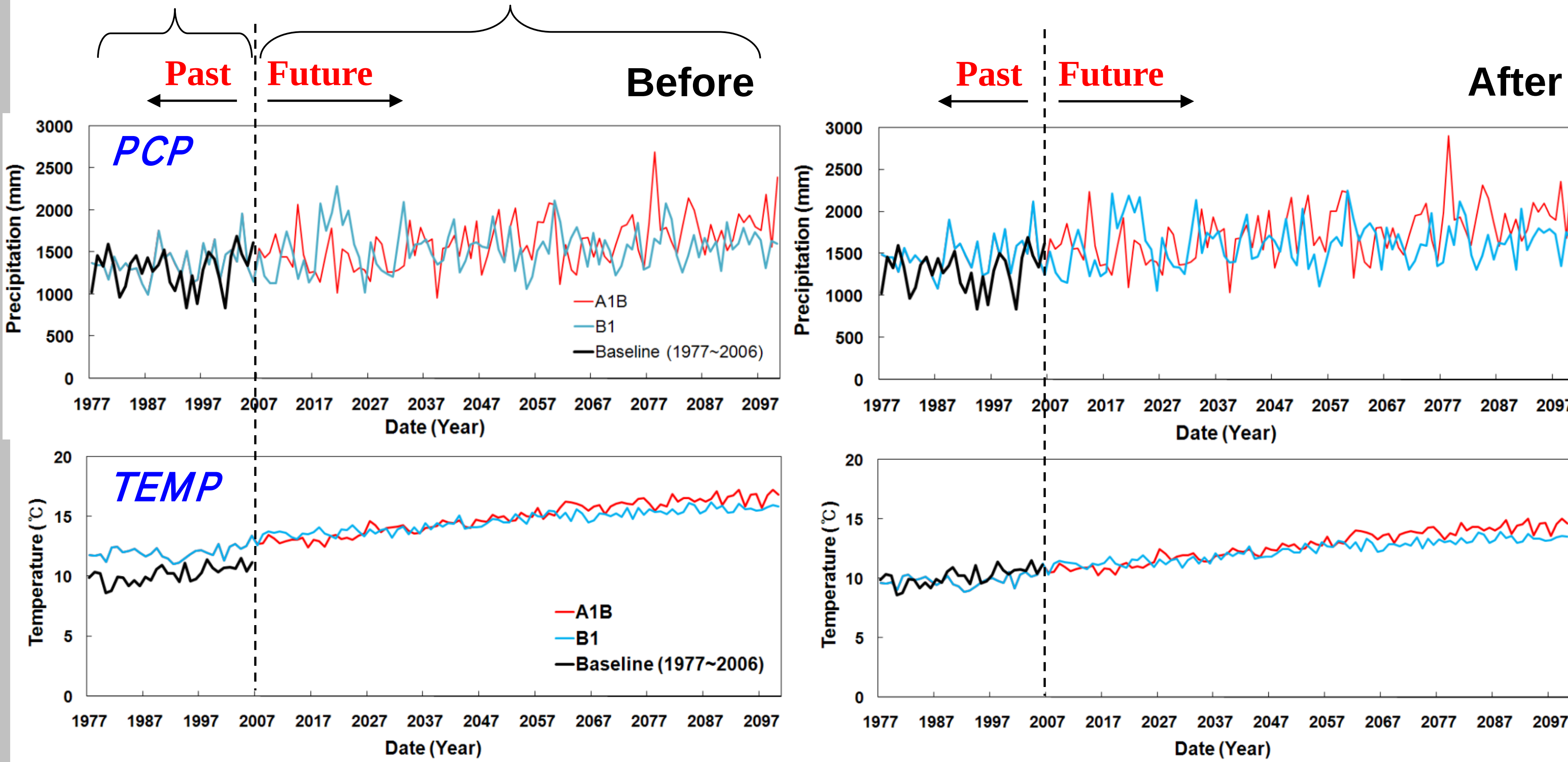
Error Correction

20th Century Simulations (20C3M) : 1977 - 2000

21th Century Simulations (A1B and B1) : 2001 - 2100



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Downscaling

LARS-WG (Long Ashton Research Station – Weather Generator)

- A stochastic weather generator which can be used for the simulation of weather data at a single site under both current and future climate conditions.
- Developed by Mikhail A. Semenov, 1997
- Statistical downscaling
  - Empirical downscaling, employing statistical relationships between the large-scale climatic state and local variations derived from historical data records.
  - Strengths: Cheap, computationally undemanding and readily transferable.
  - Weakness: Requires high quality data for model calibration, Low-frequency climate variability problematic.
- Precipitation (mm), maximum and minimum temperature (°C) and solar radiation ($MJm^{-2}day^{-1}$)

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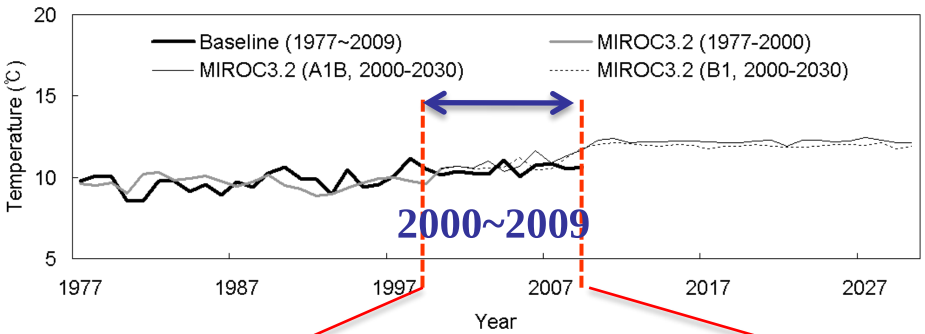
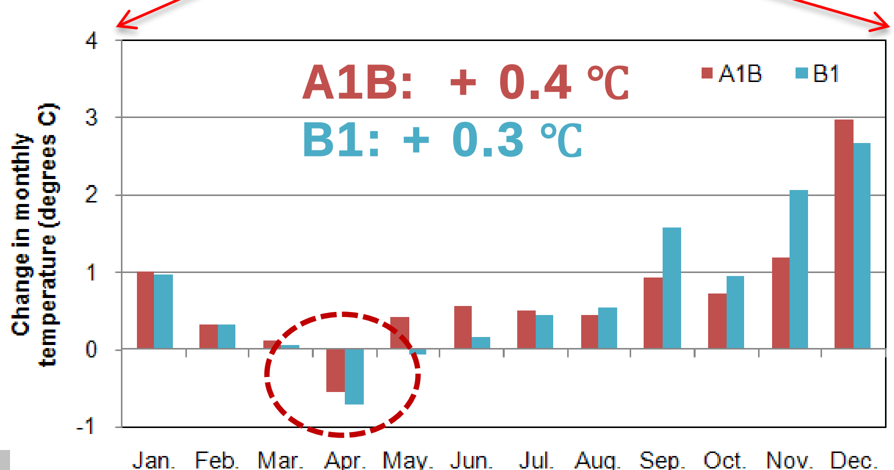
Downscaling

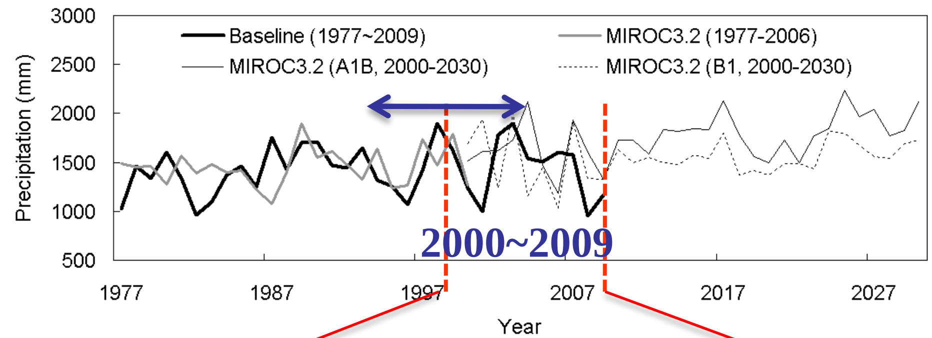
- Comparison of observed (1977-2009) and MIROC3.2 hires projected (1977-2030) annual and monthly mean temperature and precipitation

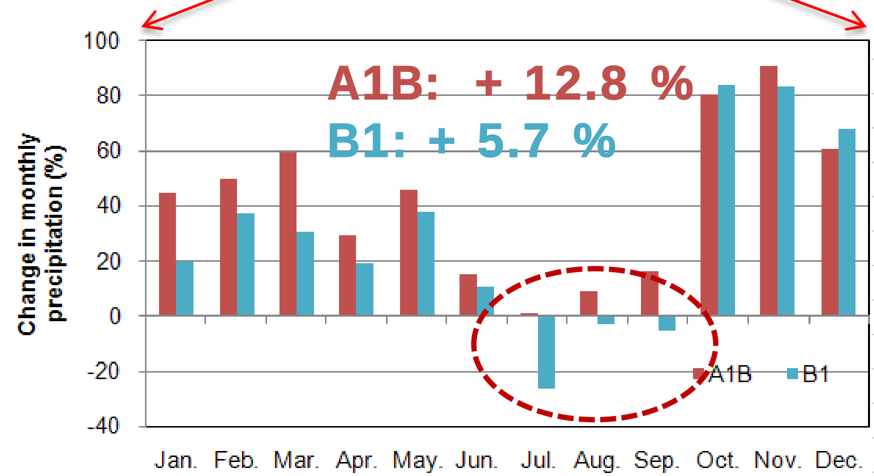
Temperature change (℃)





Precipitation change (mm)





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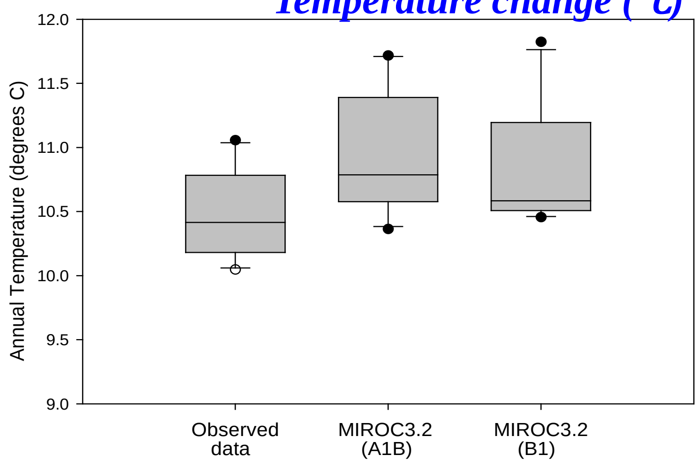
Downscaling

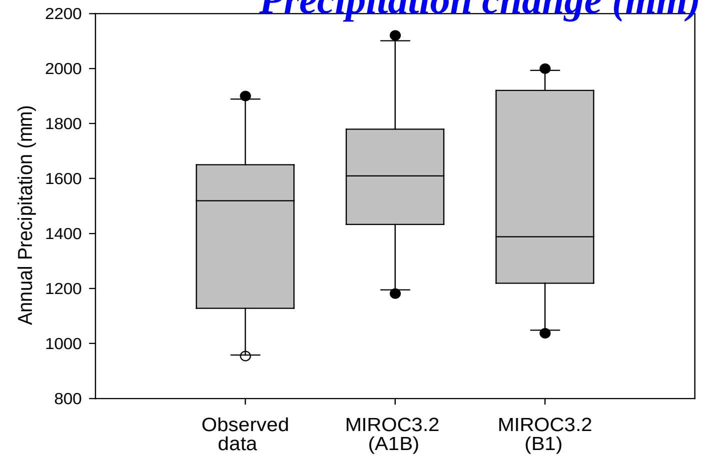
- Temperature and precipitation of Observed and MIROC3.2 hires projected for 10 years (2000~2009)

Temperature change (℃)

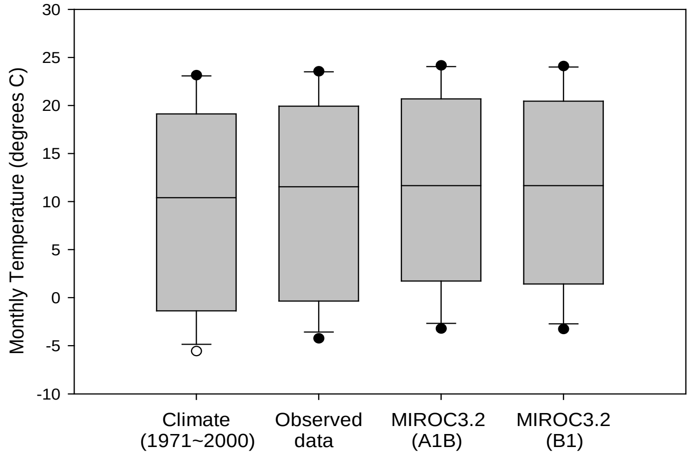
Precipitation change (mm)

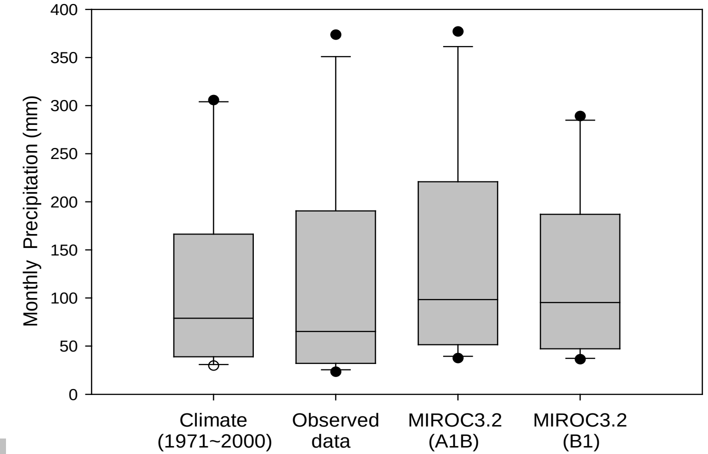
Annual





Monthly





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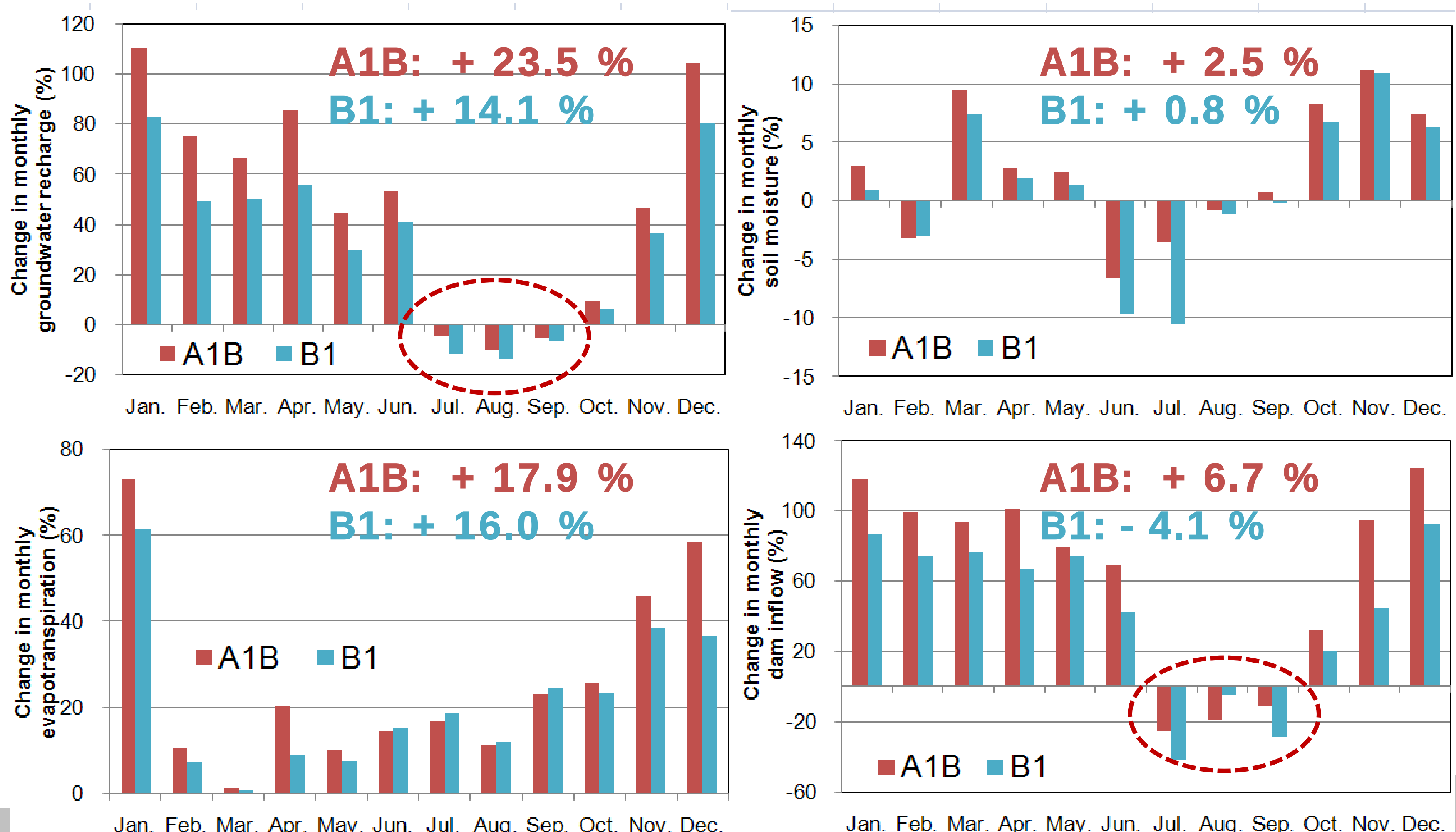
❑ Results

- The Accuracy of Hydrologic Components for 10 Years (2000-2009) SWAT Simulated Results (Annual)



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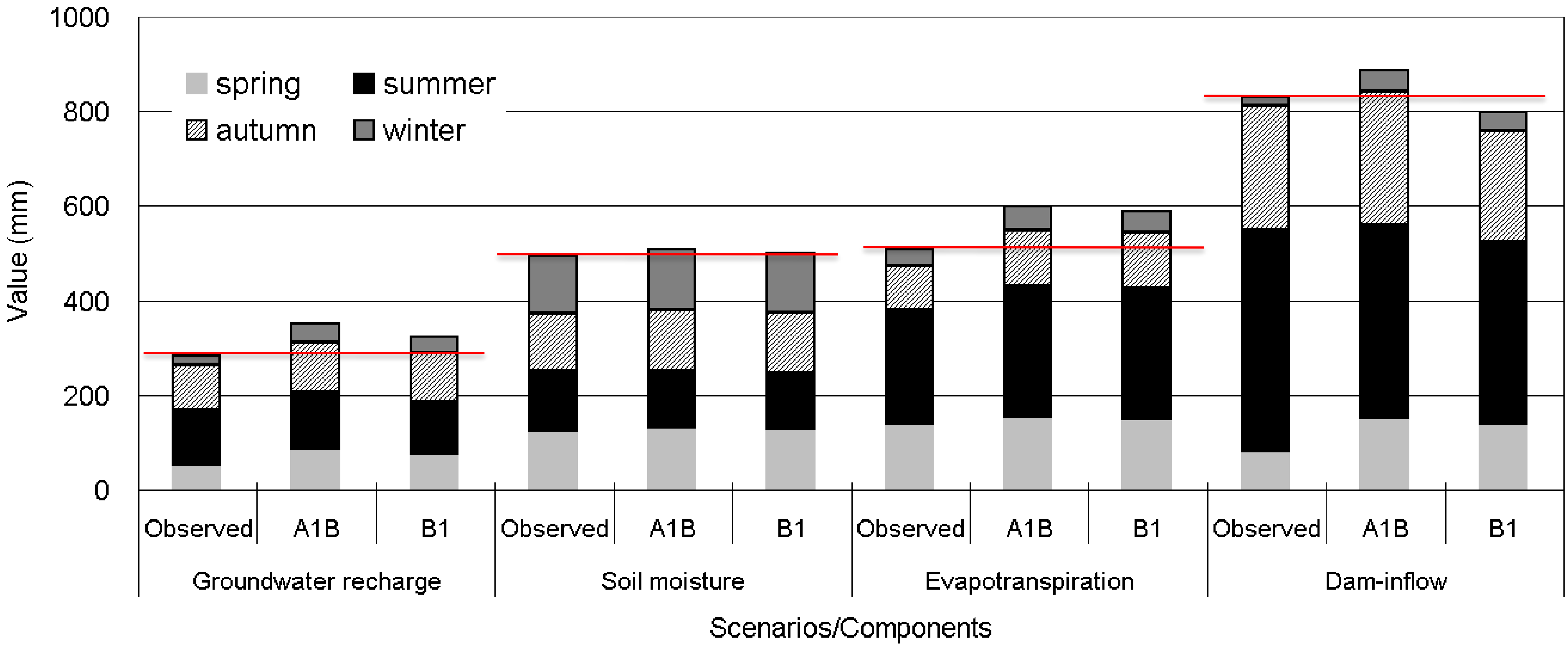
Results

- The Accuracy of Hydrologic Components for 10 Years (2000-2009) SWAT Simulated Results (Seasonal)



Groundwater recharge	Soil moisture	Evapotranspiration	Dam-inflow
A1B: + 23.5 %	A1B: + 2.5 %	A1B: + 17.9 %	A1B: + 6.7 %
B1: + 14.1 %	B1: + 0.8 %	B1: + 16.0 %	B1: - 4.1 %

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❑ Conclusions

❑ The mis-projected results in annual average hydrologic components

Components/ Scenarios	Temperature (℃)	Precipitation (%)	Ground water recharge (%)	Soil moisture contents (%)	Evapotranpiration (%)	Dam inflow (%)
A1B	+ 0.4	+ 12.8	+ 23.5	+ 2.5	+ 17.9	+ 6.7
B1	+ 0.3	+ 5.7	+ 14.1	+ 0.8	+ 16.0	- 4.1

❑ We checked the disagreement between future projected climate data and the observed weather data for the past decade (2000-2009), and the mis-projected climate data affected the evaluation of future hydrological behavior of a watershed.

❑ We found that the time span selection for bias-correction affects the the projection of climate data. For example, data with 10 yrs or 20 yrs rather than over 30 years for bias correction study is necessary to reflect the recent changes in temp. and precp.

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Thank you

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