

Climate Change Impact Assessment on Korean Water Resources

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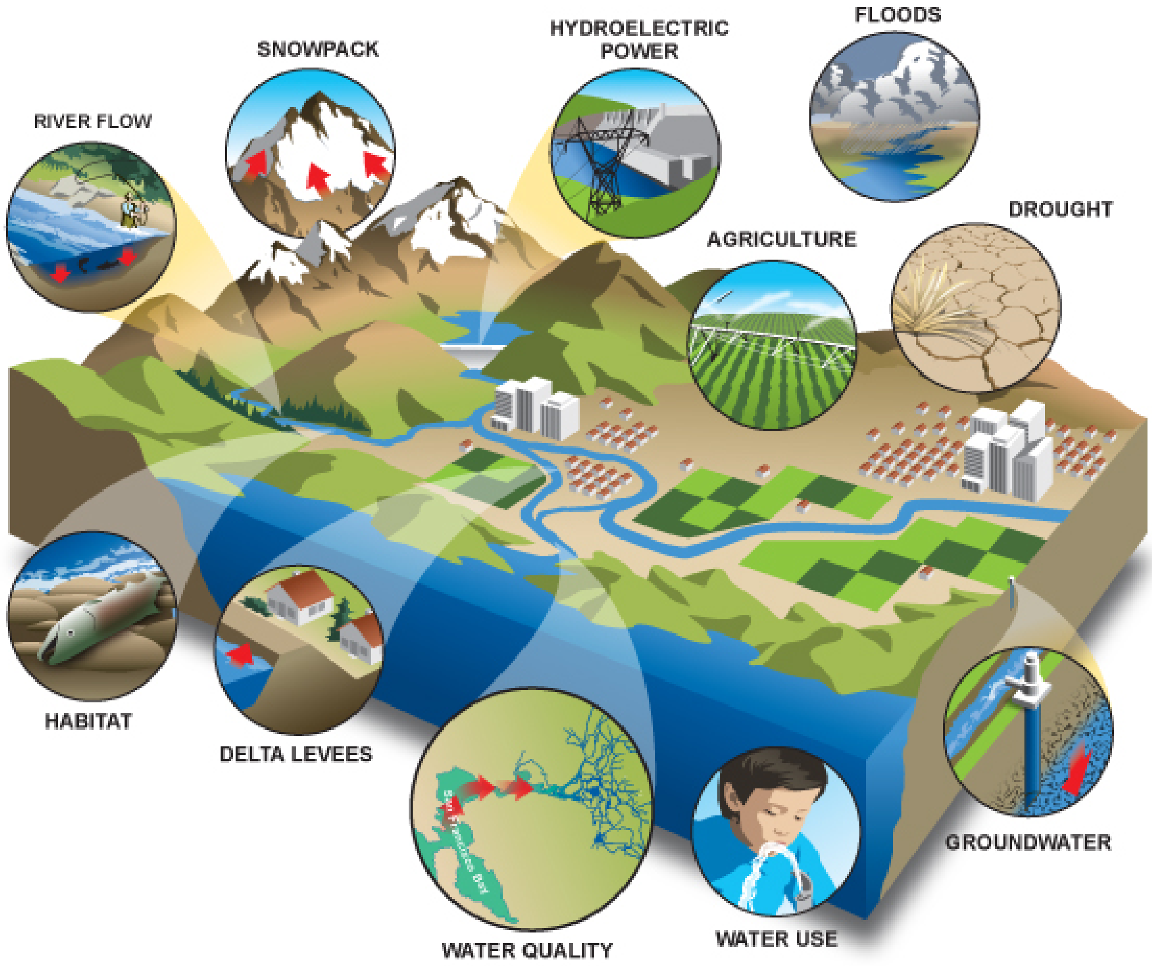
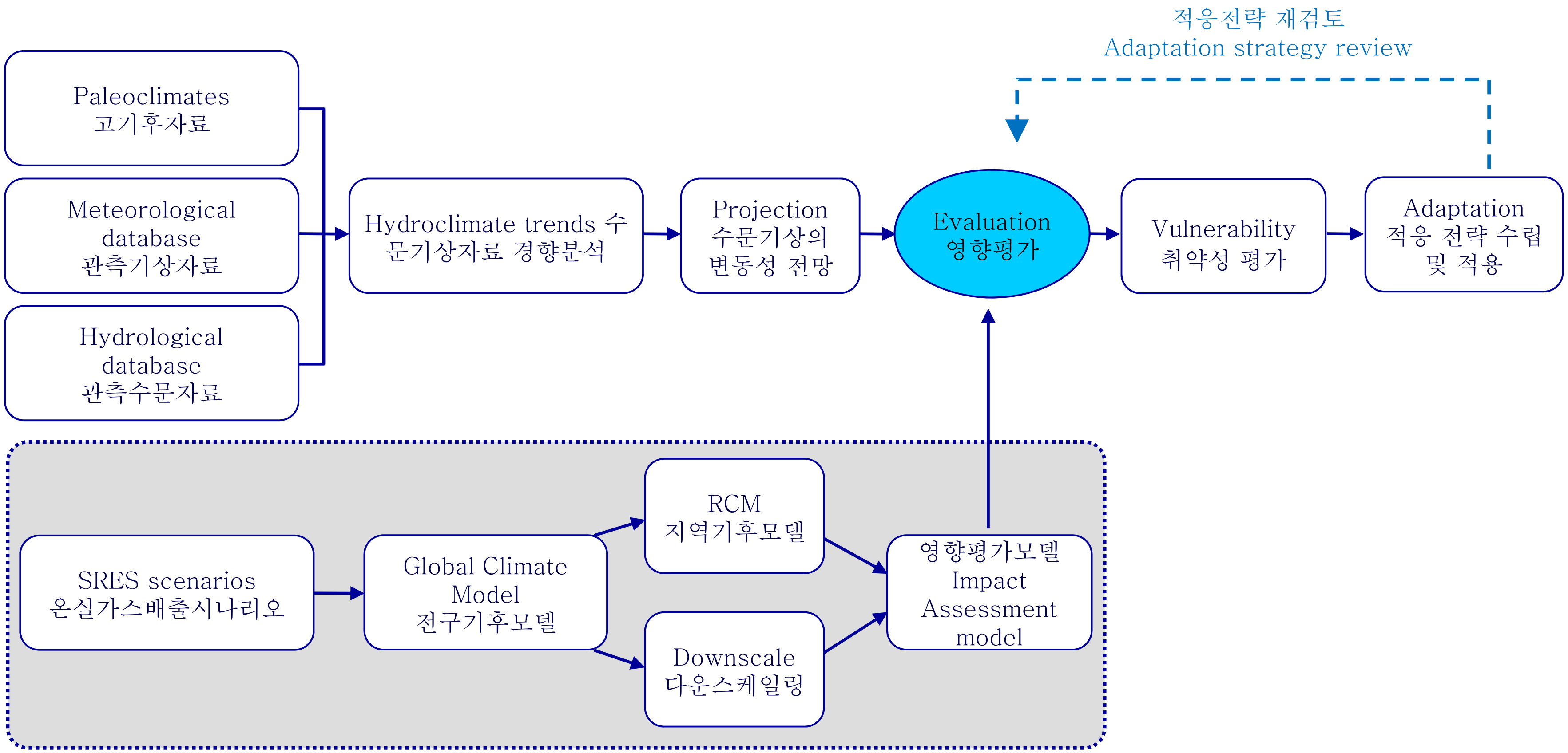
Introduction

The Impacts of Climate Change on Water Resources



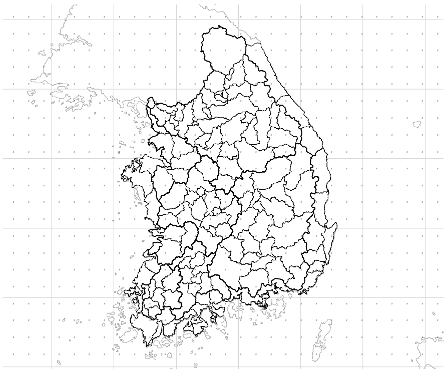
www.climatechange.water.ca.gov/

General procedure for climate change impact study

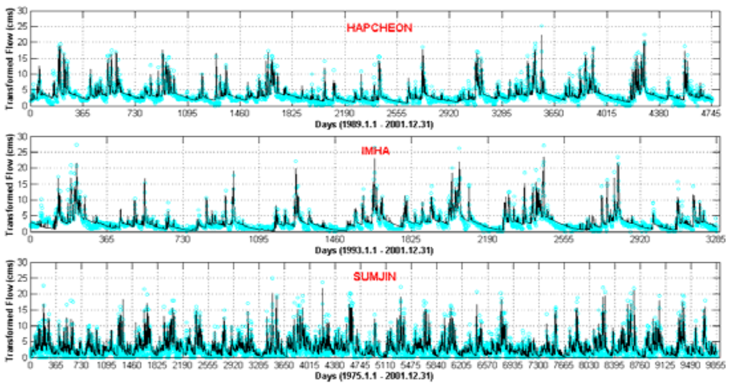


Possible Evidence of Climate Change on Water Resources

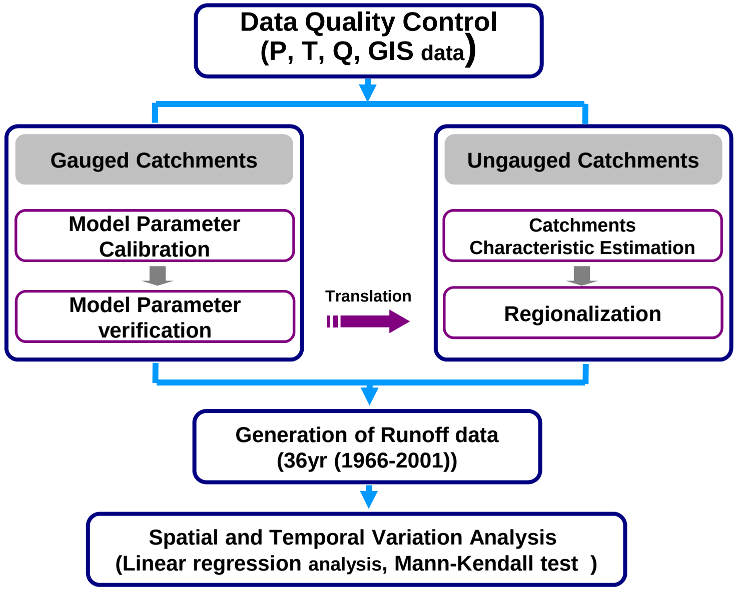
Evidence from the historical observation data



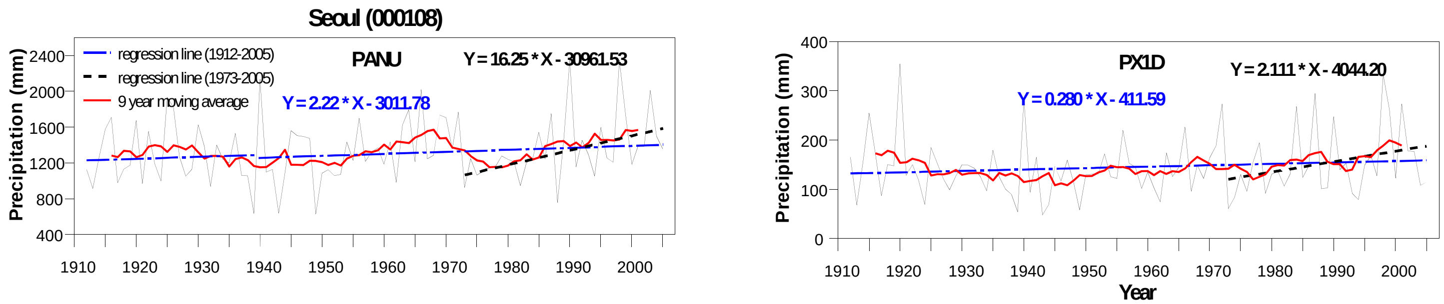
- Analysis overview
  - ✓ Analyze the spatial and temporal variations of the data
  - ✓ Use obs. data for P and model-driven data for Q
  - ✓ Use 325 station data for P and 135 subdivisions for Q
  - ✓ Use linear regression and Mann-Kendall test



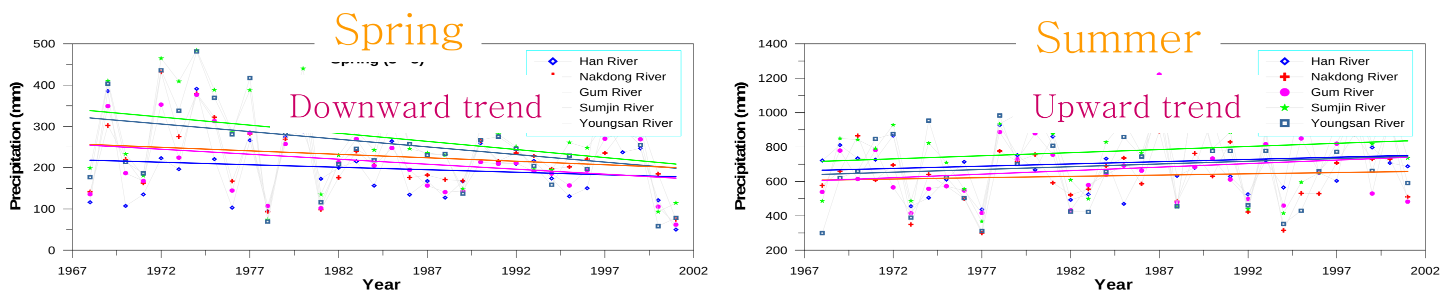
Hydrologic Model Calibration and Verification



Major Outcomes



Trends of annual precipitation and daily maximum precipitation

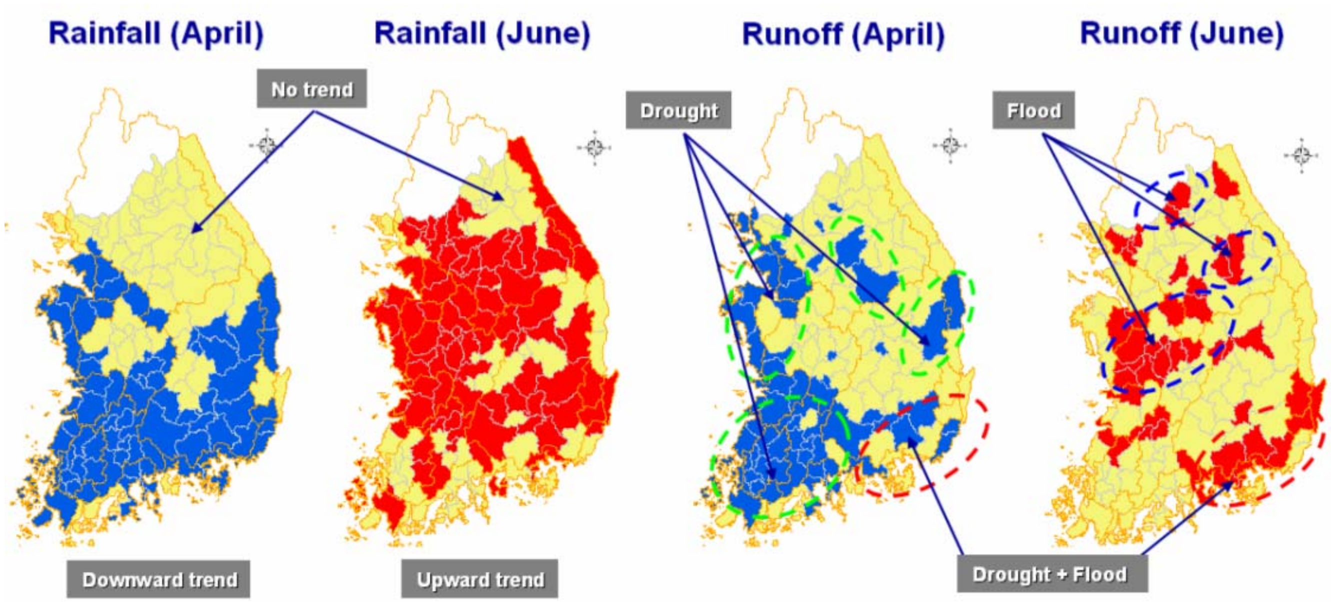


Trends of seasonal precipitation(1968-2001)- decreasing in spring, increasing in summer

Major Outcomes

✓ Spatial trend according to Mann-Kendall test for P & Q in April and June

- Decrease of P & Q in April is related to severe droughts in spring season
- Increase of soil moisture corresponding to the increase of P in June will lead to higher chance for summer flood

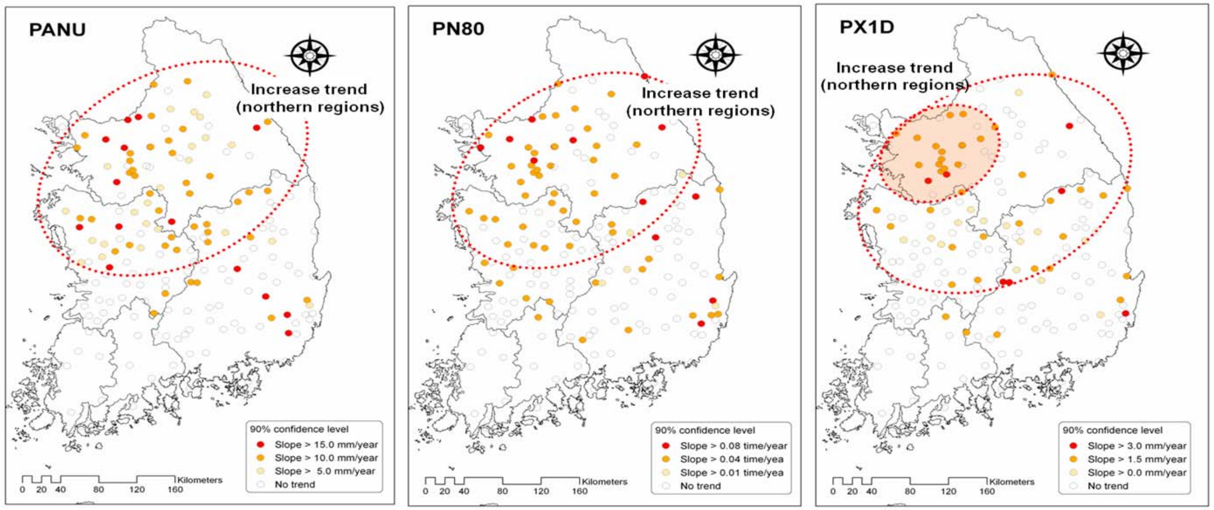


Vulnerability assessment-increasing possibilities for the damage occurrence from flood and drought

Major Outcomes

✓ Analysis for the extremes

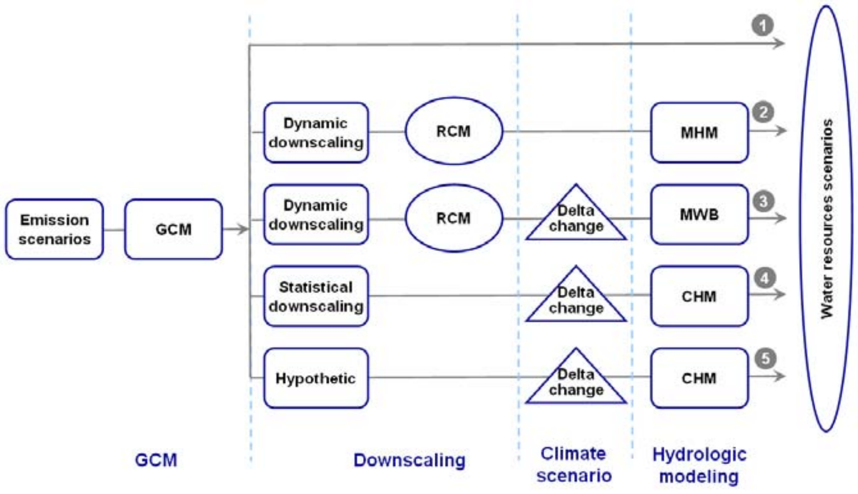
- The current 33-year (1973-2006) trends of rainfall intensity and frequency are much larger than those of past 94 years
- Those for northern part are larger than southern part

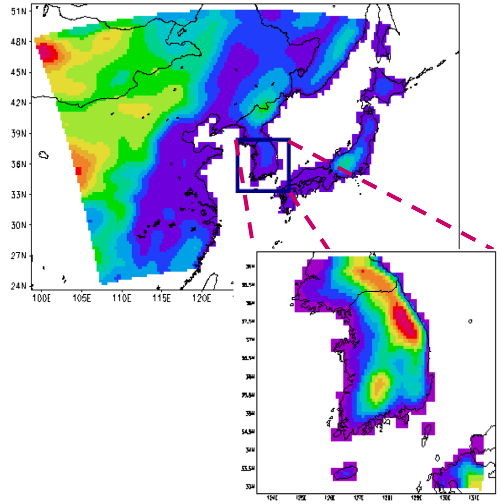


Trends of annual P, daily extremes greater than 80mm, daily max precipitation

Evidence from numerical simulation under climate change scenario

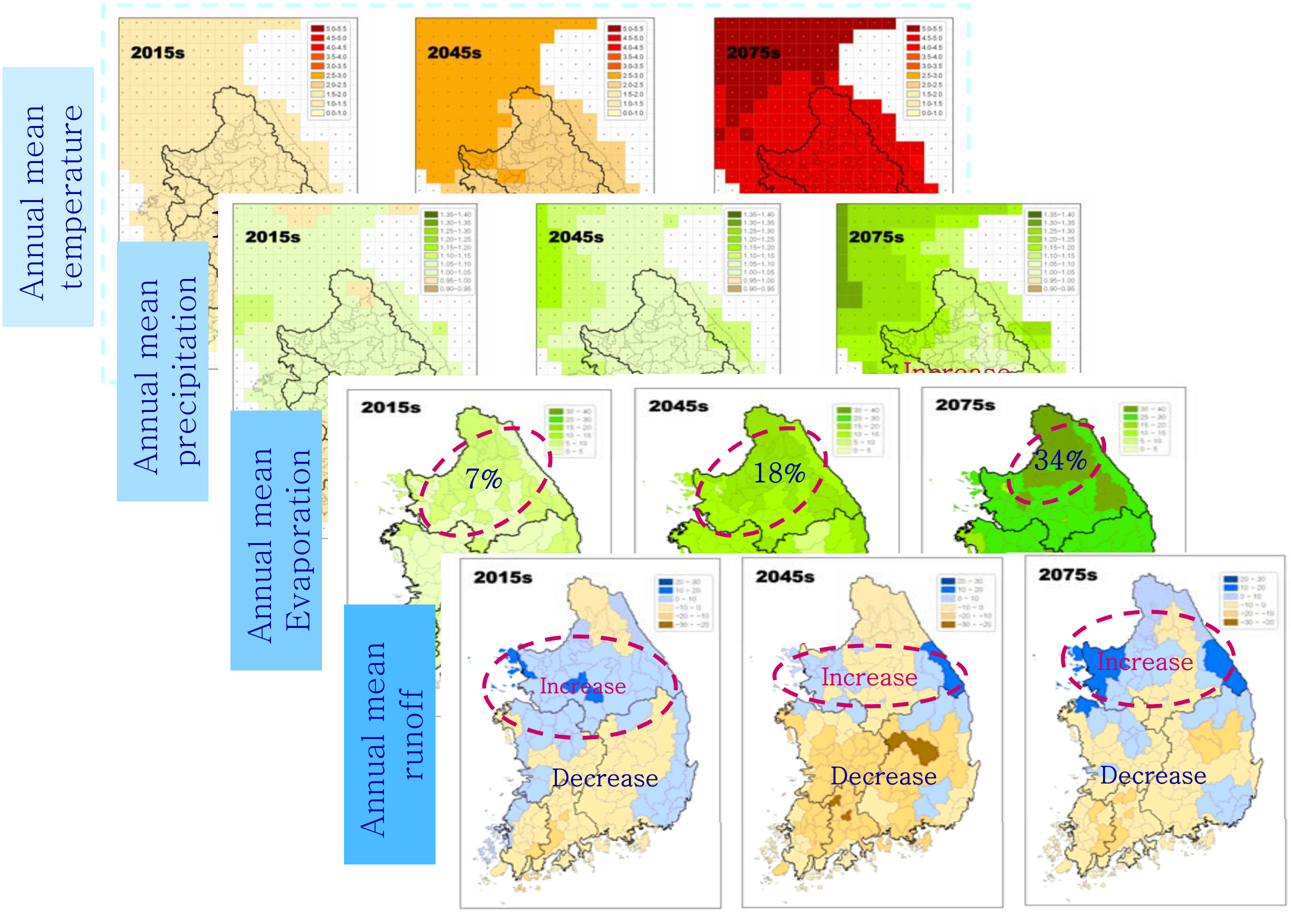
- Analysis overview
  - ✓ Emission scenarios: A2 (pessimistic scenario – CO_2, 820ppm at 2100)
  - ✓ GCM (ECHO-G), RCM (MM5)
  - ✓ Downscaling methods: Hybrid scheme (dynamic & statistical methods)
  - ✓ Resolution: 27km
  - ✓ Data periods : 1970 - 2100





Procedures for climate change impact assessments on water rsources(Xu and Singh, 2004)

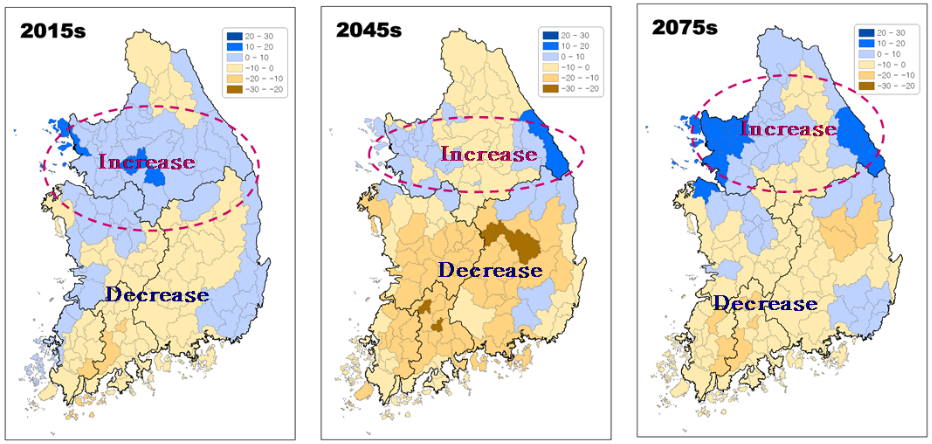
Major Outcomes



Annual variations of surface hydrology components under A2 climate change scenario

Backgrounds of this study

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

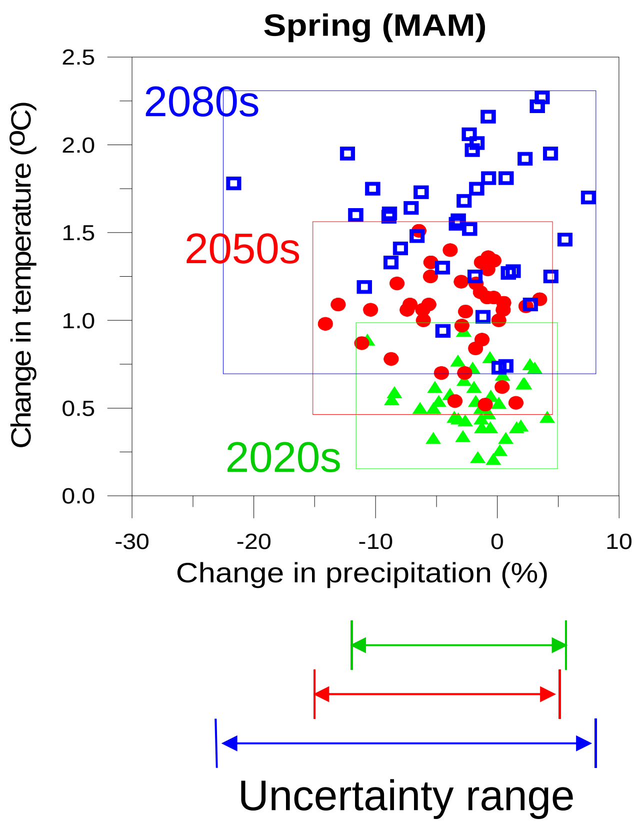


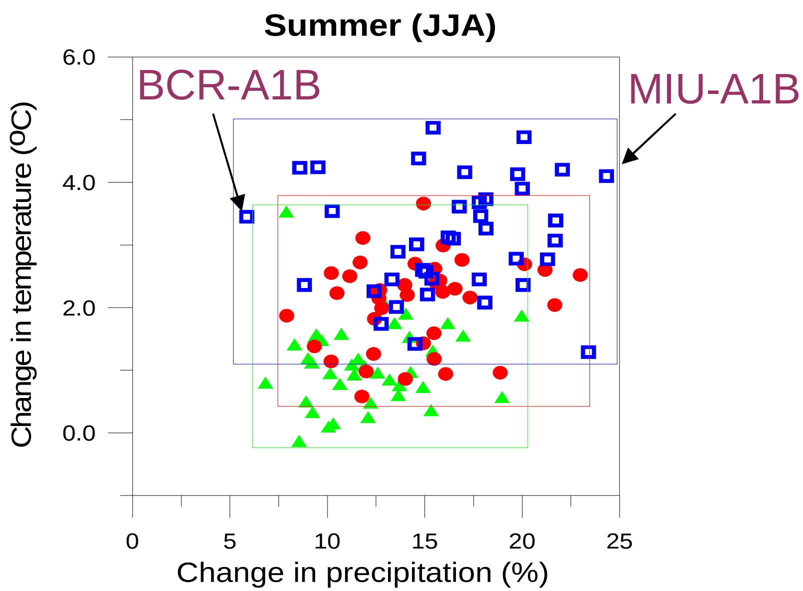
The objectives of this study

- Analyze the spatial and temporal variations in Korean water resources using multi-model ensemble scheme
- Quantify the uncertainty of the climate change impact assessment on surface hydrology

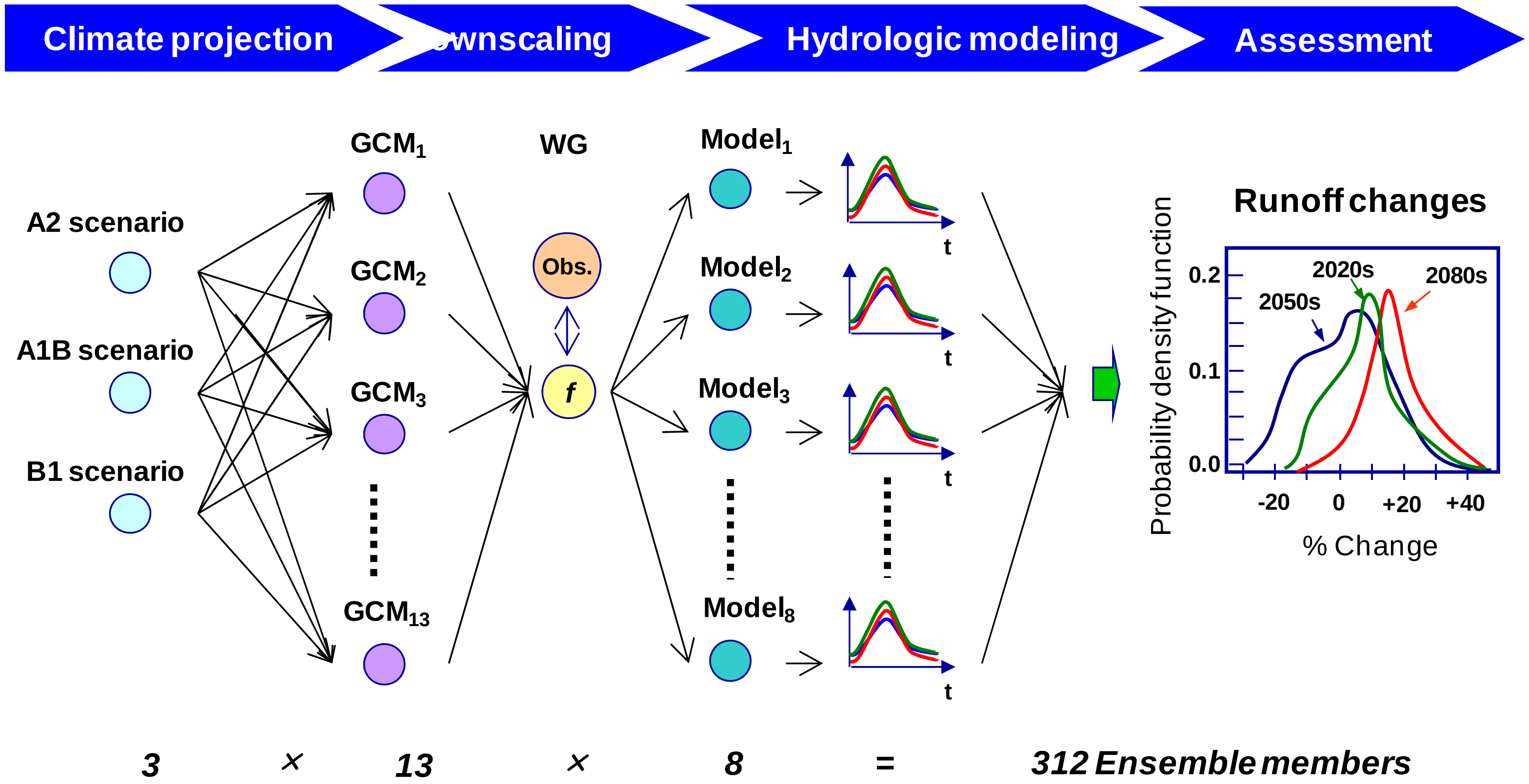
Methodology and Data

Why does multi-model ensemble need?



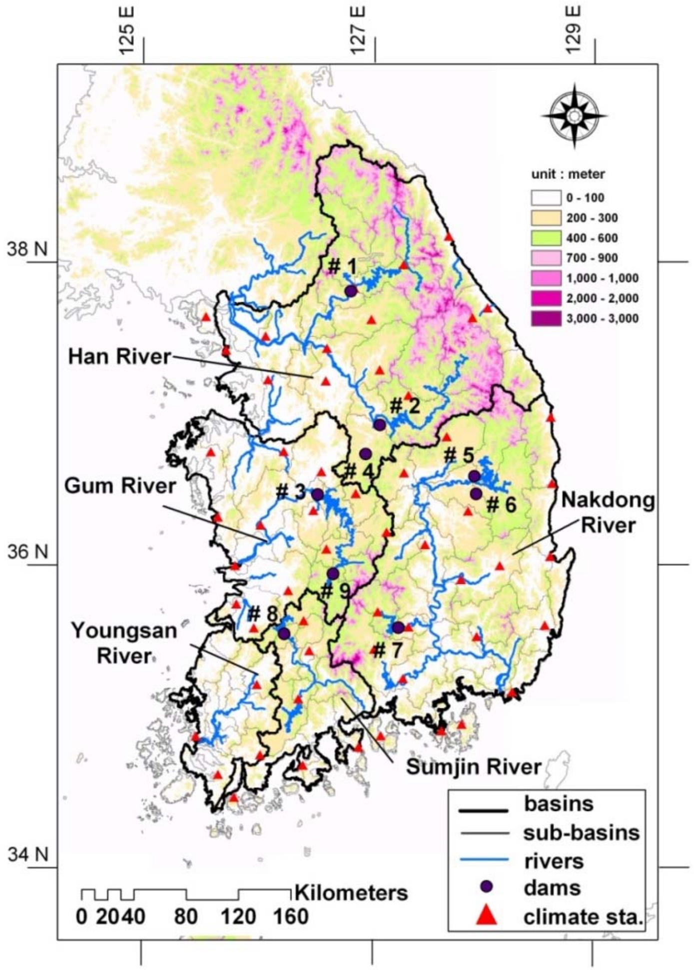


Multi - Model Ensemble



Study area

- The 109 sub-basins with 5 major river basins for climate change impact assessments on water resources
- The 56 climate stations in South Korea for statistical downscaling
- 6 dam sites for calibration and verification of hydrological models
- 3 dam sites for verification of regionalization method

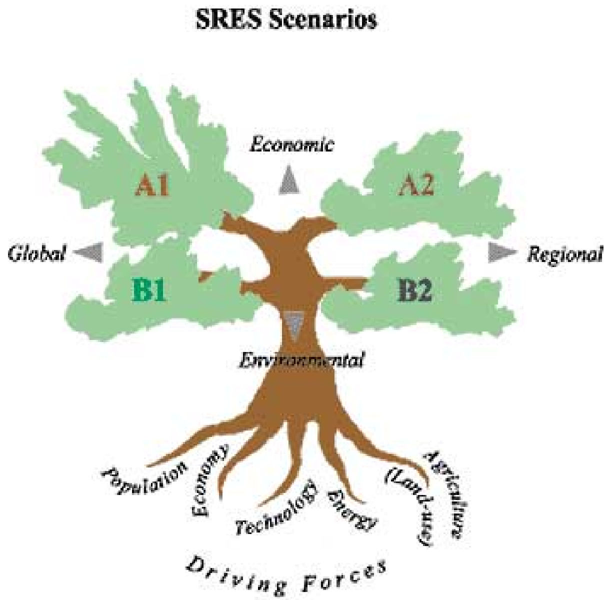


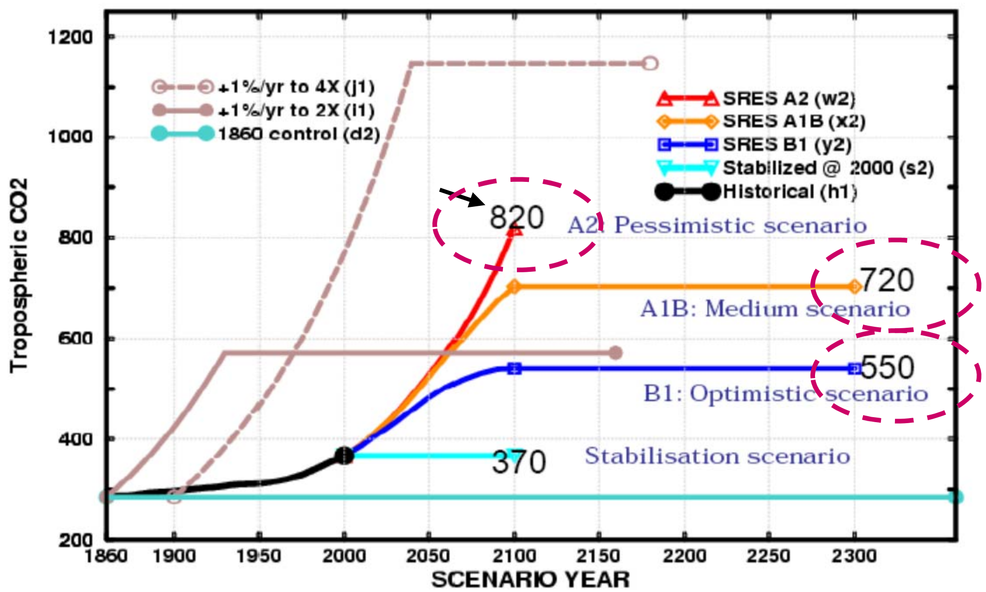
Data sources

- **Climate** – Daily precipitation, maximum & minimum temperature, relative humidity (KMA)
- **Streamflow** – Daily mean dam inflow (WAMIS, KWRC, KHNP)
- **Land use** – (WAMIS)
- **Soils** – Type, Depth, Water capacity, Hydrologic conductivity (NIAST)
- **Climate change simulations** – Monthly precipitation, Tmax and Tmin for 3 scenarios × 13 GCMs (IPCC DDC, NIMR)

Special report on emission scenario – A2, A1B, B1

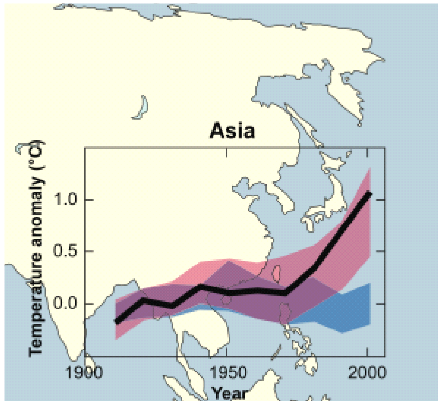
- "These scenarios cover a wide range of the main driving forces of future emissions, from demographic to technological and economic developments. The scenarios encompass different future developments that might influence greenhouse gas (GHG) sources and sinks, such as alternative structures of energy systems and land-use changes."- IPCC SRES report





Global Climate Models

- Used IPCC AR4 13 out of 23 GCMs simulation
- Data period : 200yr(1900-2099)
- IPCC SRES A2, A1B, B1
- Variables : precipitation, temperature, humidity et al.
- Data storage : approximately 1tera bite



Source: IPCC (2007)

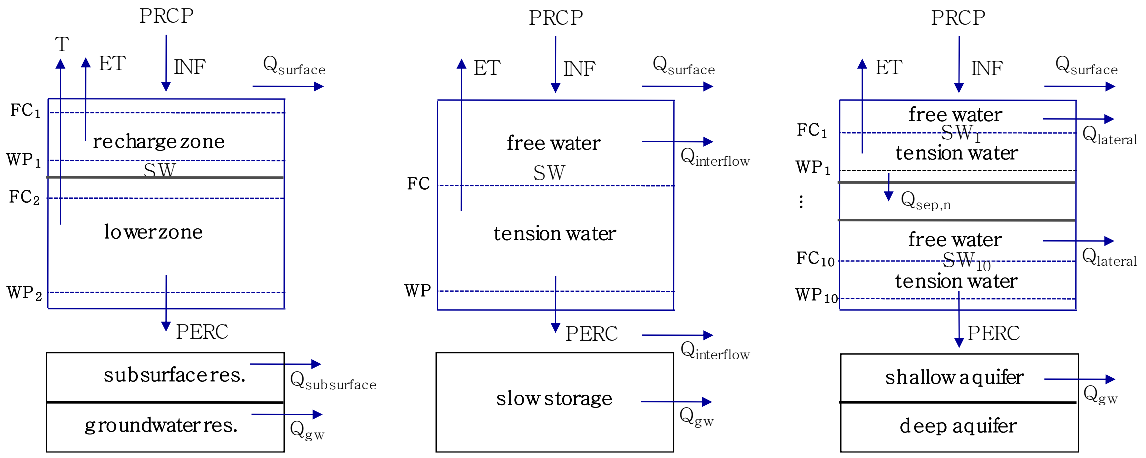
No.	ID	Model (agency: version)	Country	Resolution	
				Atm.	Ocn.
1	a	BCC: CM1	China	128X96	128X96
2	b	BCCR: BCM2	Norway	128X64	360X180
3	c	CCCMA: CGCM3_1-T47	Canada	96X48	192X96
4	d	CCCMA: CGCM3_1-T63	Canada	128X64	256X192
5	e	CNRM: CM3	France	128X64	180X170
6	f	CSIRO: MK3	Australia	192X96	192X189
7	g	GFDL: CM2	USA	144X90	360X200
8	h	GFDL: CM2_1	USA	144X90	360X200
9	i	NASA: GISS-AOM	USA	90X60	90X60
10	j	NASA: GISS-EH	USA	72X46	360X180
11	k	NASA: GISS-ER	USA	72X46	72X46
12	l	LASG: GFOALS-G1_0	China	128X60	360X170
13	m	INM: CM3	Russia	72X45	144X84
14	n	IPSL: CM4	France	96X72	180X170
15	p	NIES: MIROC3_2_HI	Japan	320X160	320X320
16	q	NIES: MIROC3_2_MED	Japan	128X64	256X192
17	r	CONS: ECHO-G	Germany/Korea	96X48	128X117
18	s	MPIM: ECHAM5	Germany	192X96	360X180
19	t	MRI: CGCM2_3_2	Japan	128X64	144X111
20	u	NCAR: CCSM3	USA	256X128	320X395
21	v	NCAR: PCM	USA	128X64	360X180
22	w	UKMO: HADCM3	UK	96X73	288X144
23	x	UKMO: HADGEM1	UK	192X144	360X216

Bias correction and disaggregation

- WXGEN (Sharply and Williams , 1990), a well-known and popularly used weather generator for climate study
- Daily precipitation, maximum temperature and minimum temperature, relative humidity, wind speed

Weather status	WXGEN (Sharpley & Williams, 1990)
Precipitation status Definition of wet day Determination of precip. status a given day	 Precipitation > 0mm Transition probabilities of a first-order Markov chain applied to the previous day¡¯s status
Precipitation Daily distribution parameters Correlation	 Skewed distribution Separate parameters are calculated for each month None.
Max. & Min. temperature Daily distribution Parameters Conditioned on precip. Correlation	 Normal distribution Mean and standard deviation of the normal vary daily Yes Constant lag auto-correlation Constant cross-correlation between Tmax, Tmin, and radiation
Radiation Daily distribution Parameters	 Normal distribution Mean and standard deviation of the normal vary daily
Wind & Relative humidity Daily distribution Parameters	 Normal distribution Mean and standard deviation of the normal vary daily

3 Semi–Distributed Hydrologic Models



PRMS SLURP SWAT

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

Regionalization method

- **Regionalization method using multivariate statistical analysis (Lee et al. 2009 JKWRA)**

Selection of physical characteristics of catchments

Principle Component Analysis

Cluster analysis using principle components

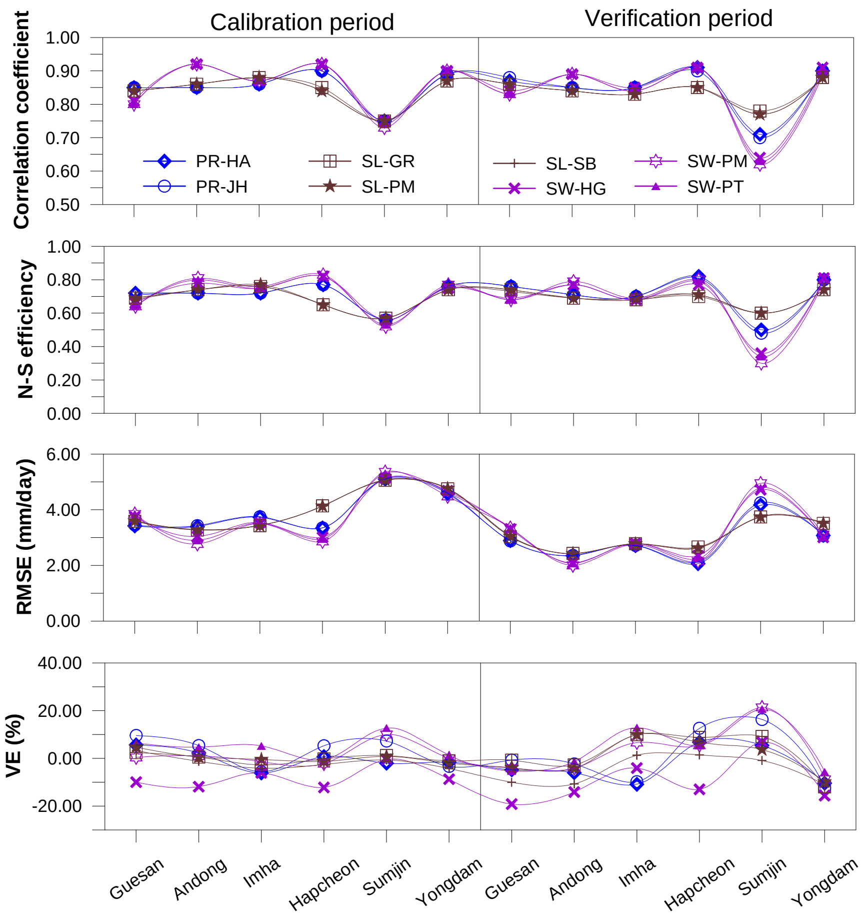
Regionalization of model parameters

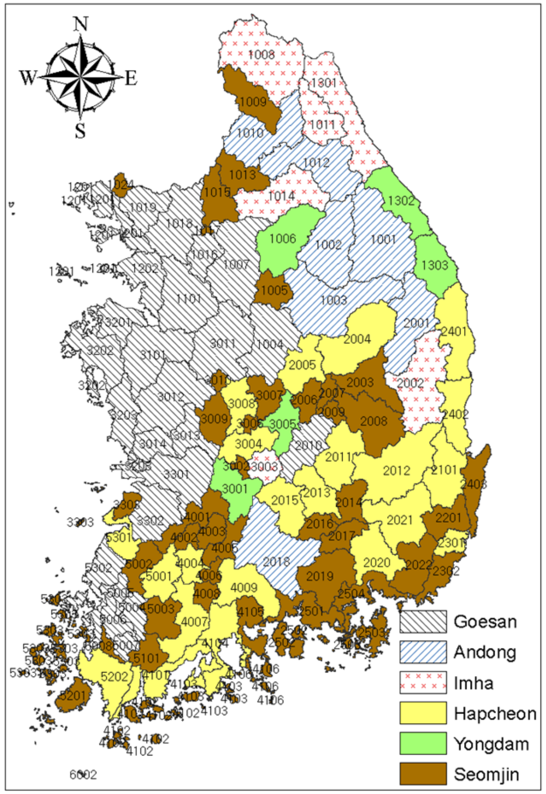
Performance verification of regionalized model parameters

Result and Analysis

Hydrologic model performances

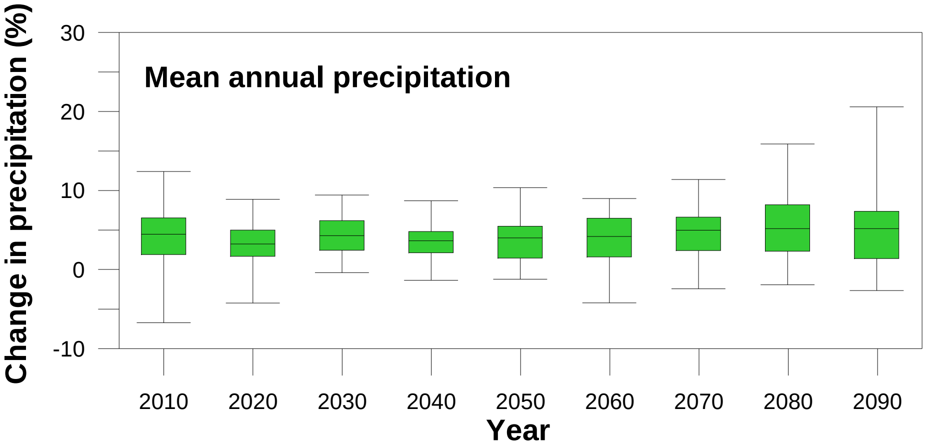
- Statistical results for the 8 model performance





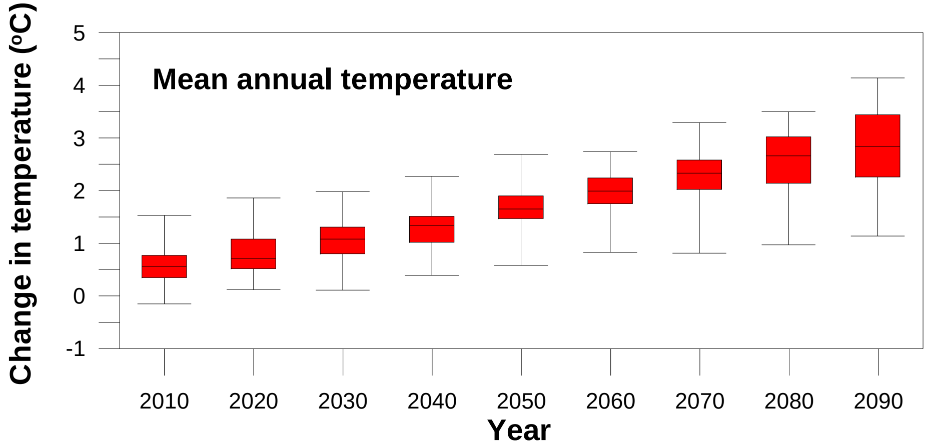
Application of regionalization method

Change in annual precipitation and temperature



Slightly increase

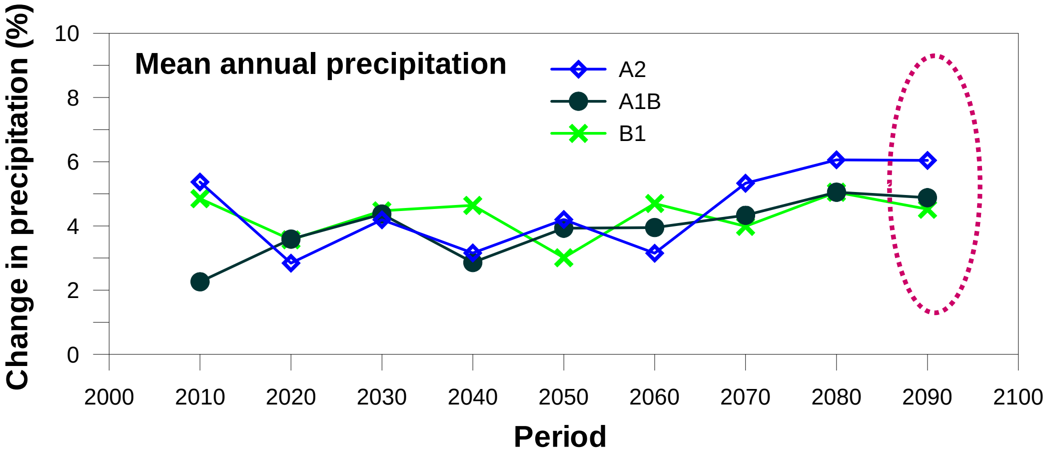
+3% - +5%



Steeply increase

+2.8℃

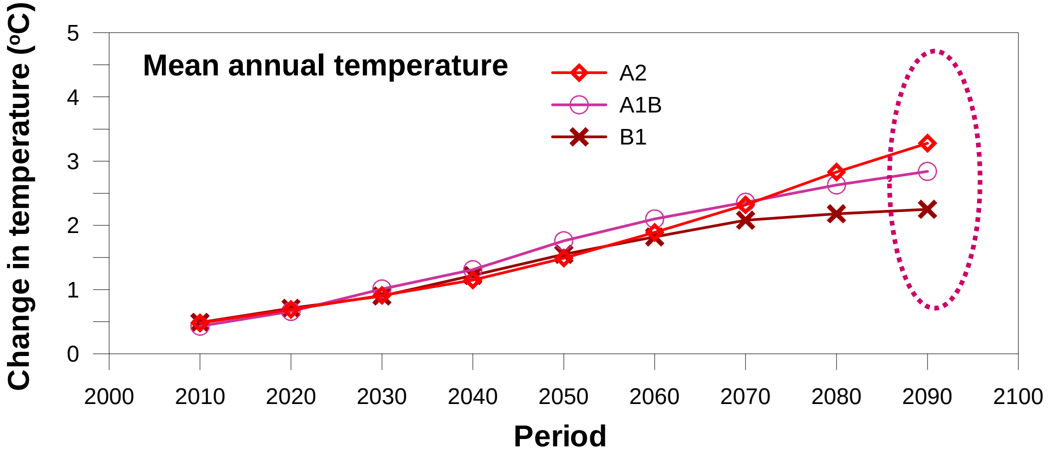
Variations of P & T according to emission scenarios



+6.0% for A2

+4.9% for A1B

+4.5% for B1

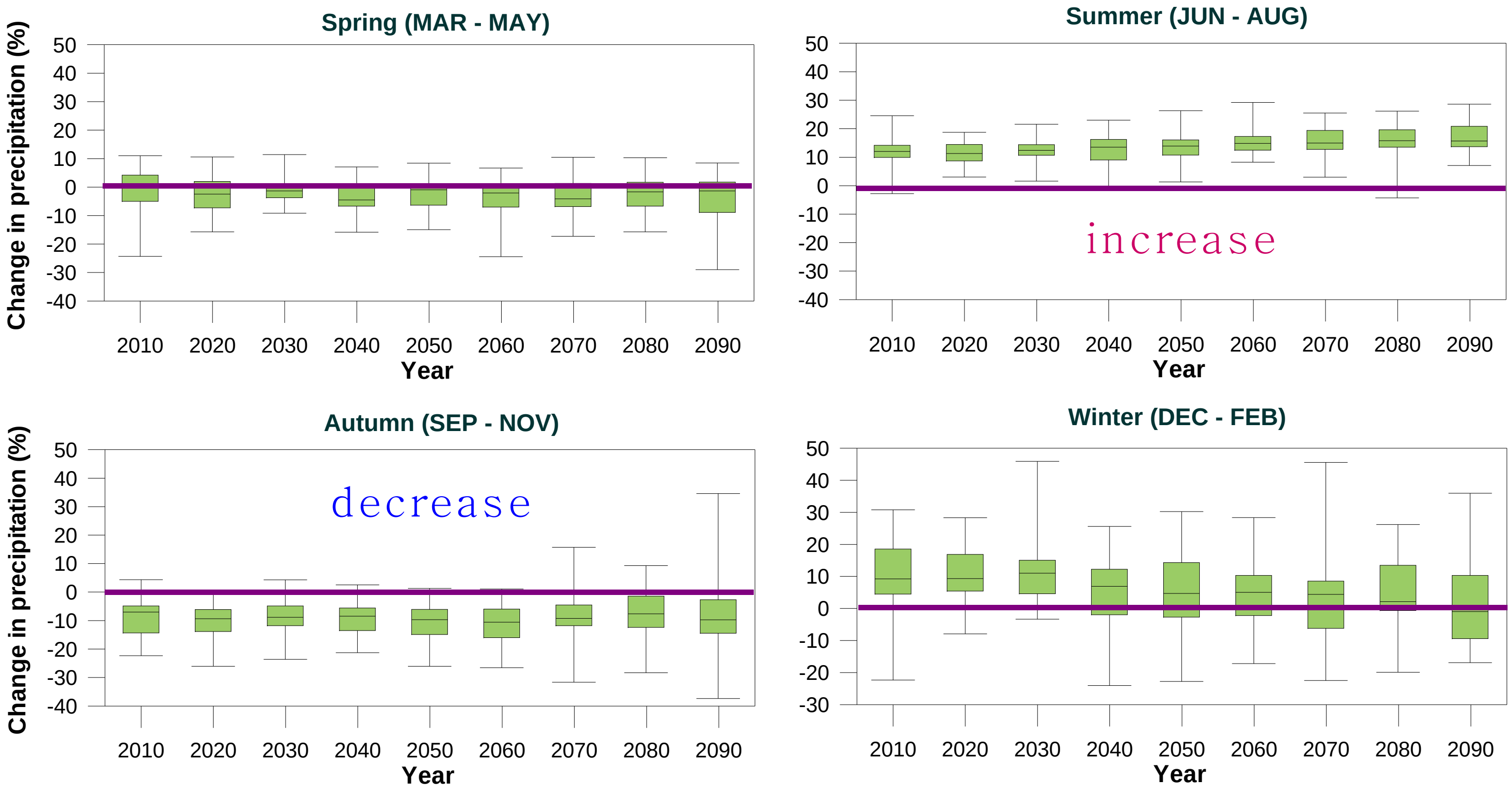


+3.3 ℃ for A2

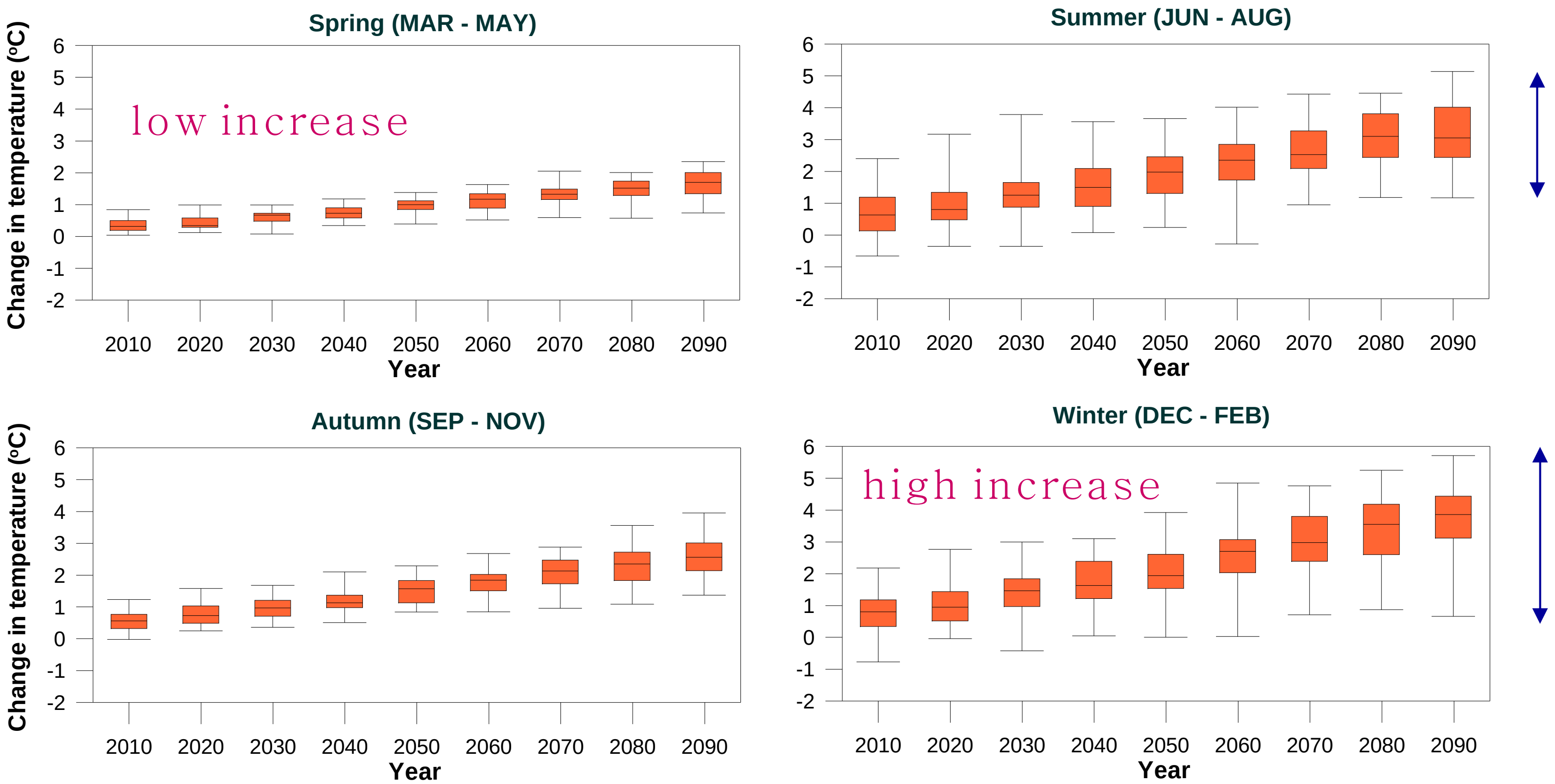
+2.8℃ for A1B

+2.3℃ for B1

Change in seasonal precipitation



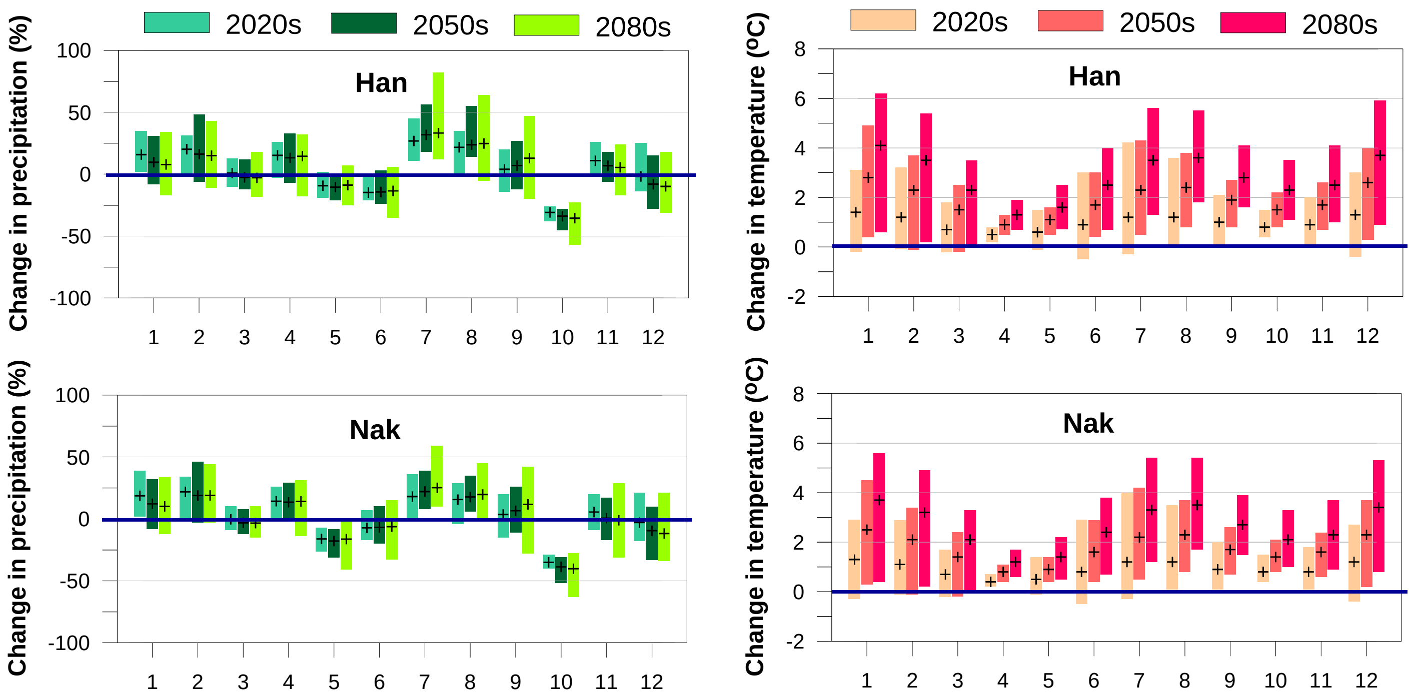
Change in seasonal temperature

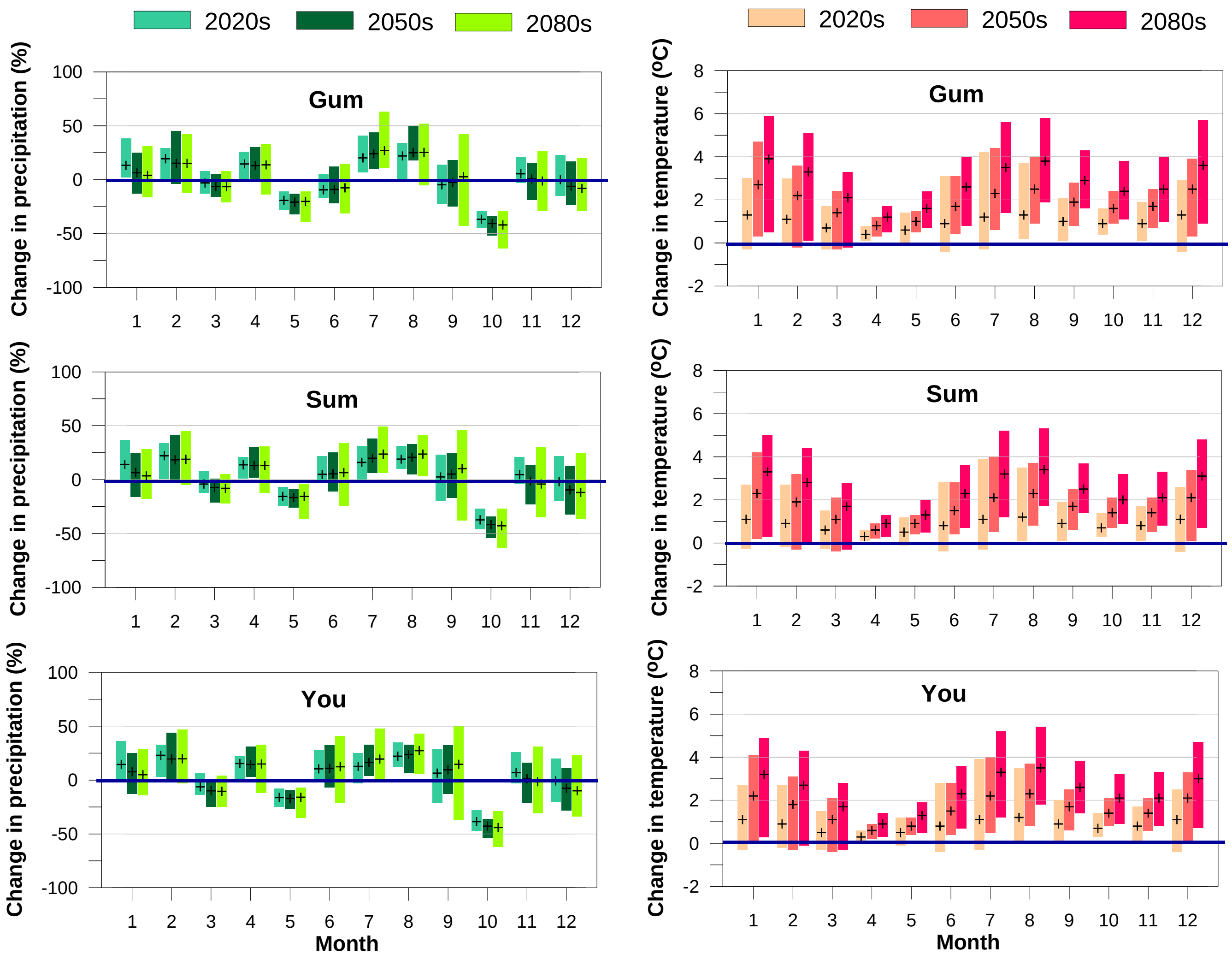


Lower uncertainty < Higher uncertainty

Change in monthly precipitation and temperature

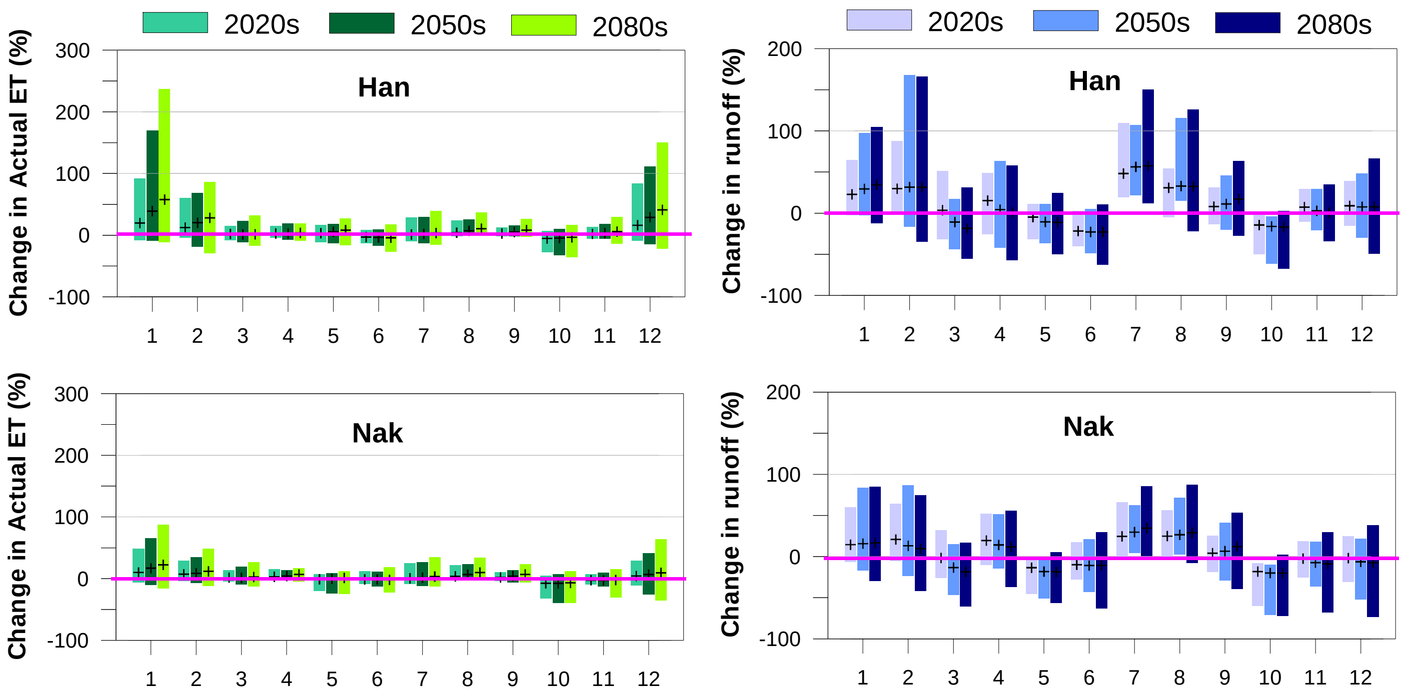
- The precipitation is expected to increase on July & August and decrease on October in most basins.
- The temperature is expected to more increase in summer and winter than in fall and winter.

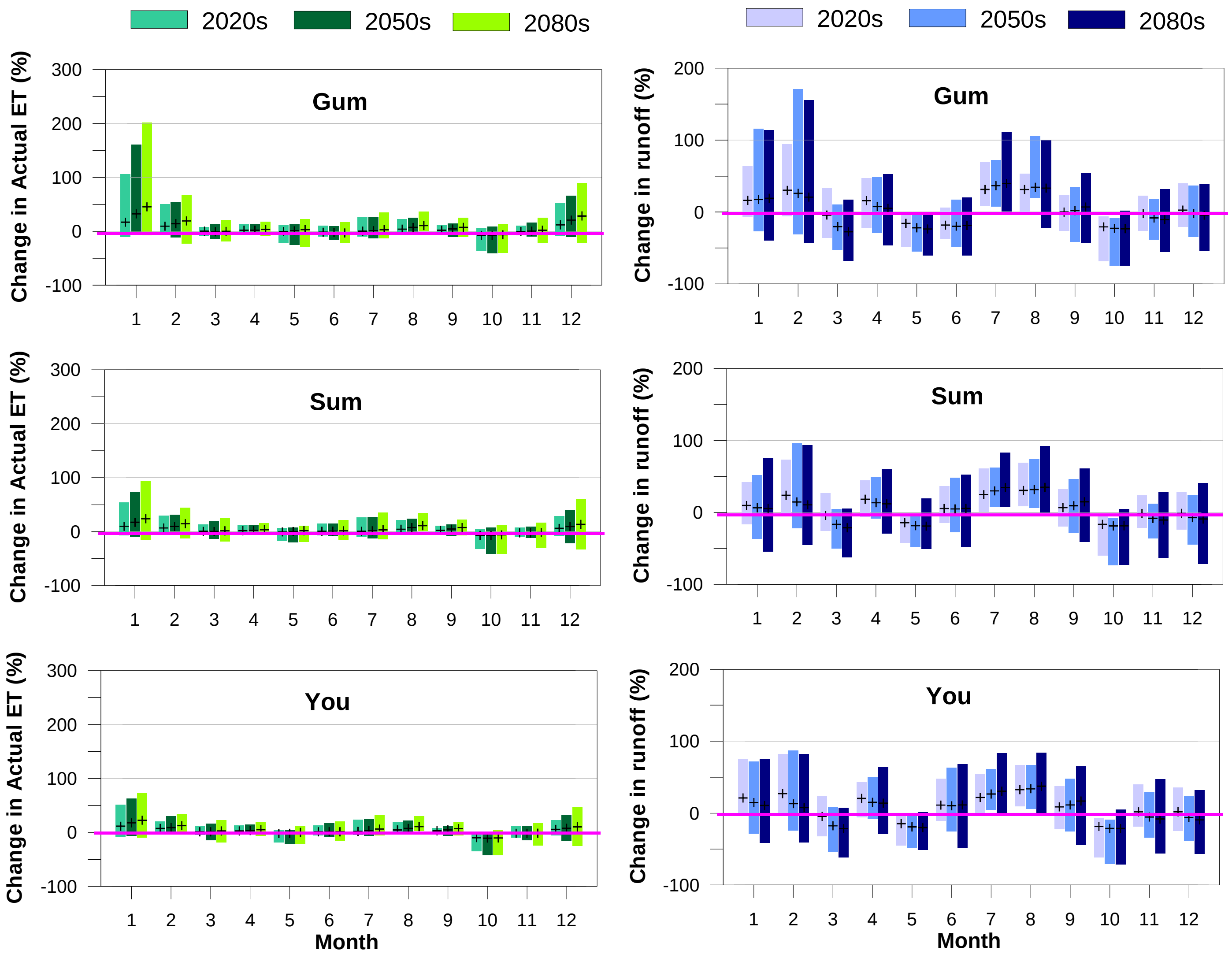



2020s
2050s
2080s
Gum
Sum
You
Change in precipitation (%)
Change in temperature (ºC)
Month

Change in monthly evapotranspiration and runoff

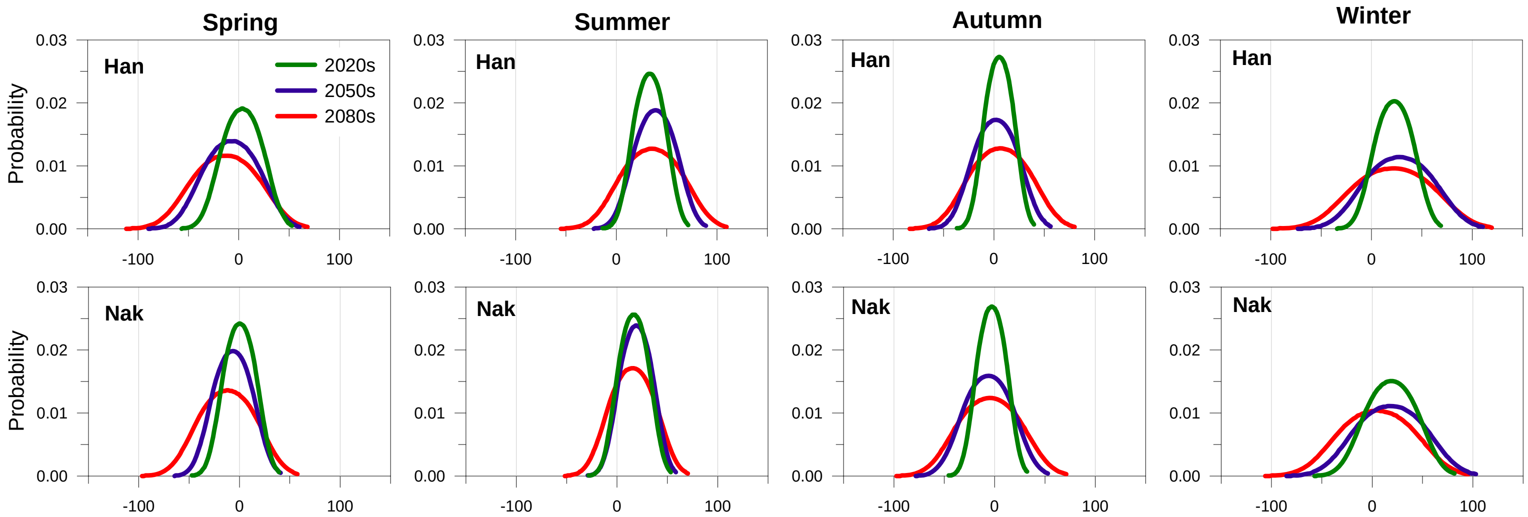
- The AET is expected to high increase in winter
- The runoff is expected to increase on July & August and decrease on October in most basins.
- Uncertainty of runoff change is higher than precipitation change

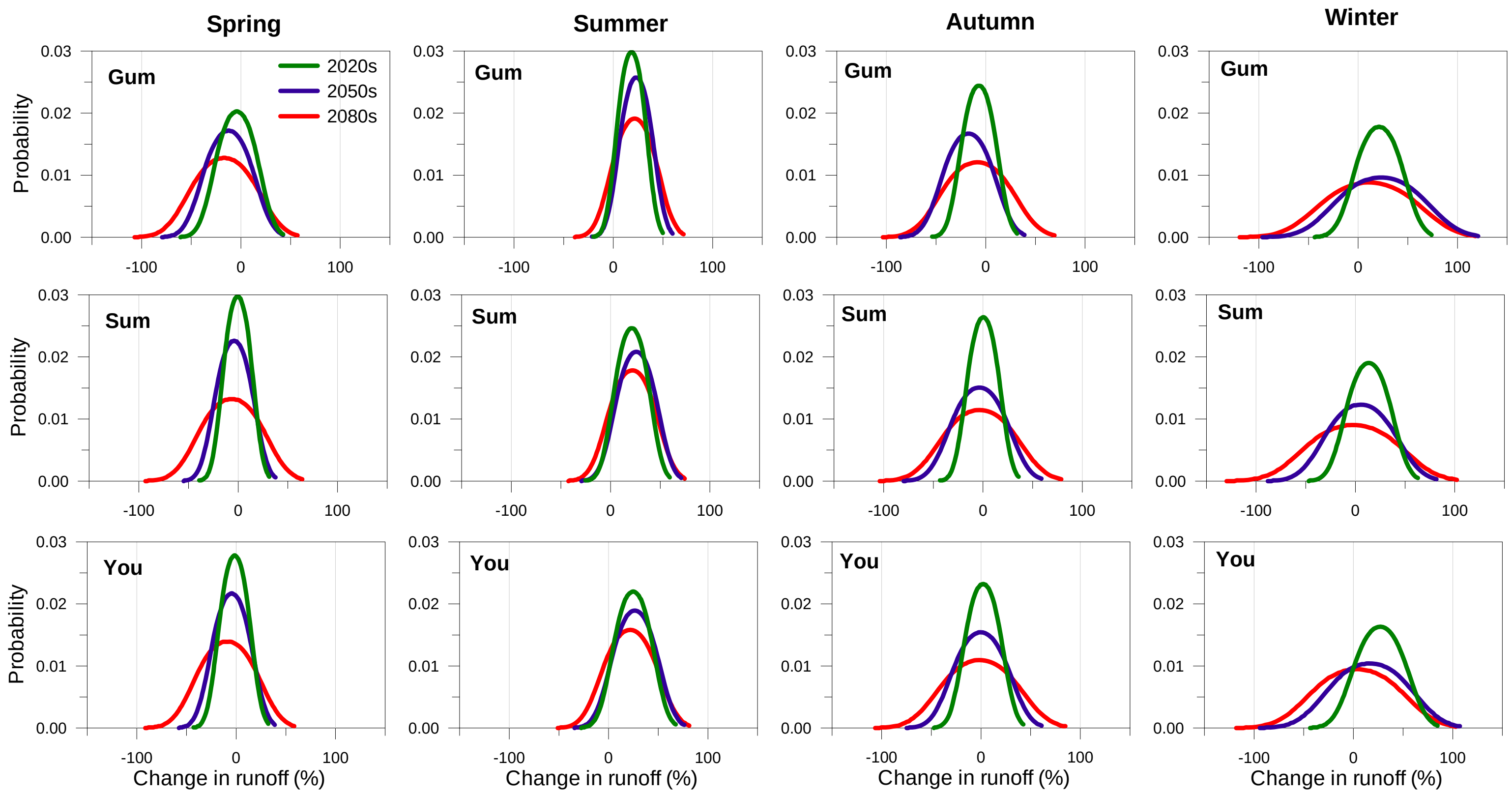



2020s
2050s
2080s
Change in Actual ET (%)
Change in runoff (%)
Gum
Sum
You
300
200
100
0
-100
1 2 3 4 5 6 7 8 9 10 11 12
Month

Uncertainty of change in runoff

- Kernel density function of seasonal runoff changes
  - ✓ In most basins, the mean runoffs in summer increase in 2020s, 2050s, 2080s.
  - ✓ Runoff in spring and fall decrease in 2050s, 2080s
  - ✓ The uncertainty of runoff changes are the largest in winter and the lowest in summer
  - ✓ The 2080s than 2020s and 2050s period shows higher uncertainty




Spring
Summer
Autumn
Winter
Gum
Sum
You
2020s
2050s
2080s
Probability
0.03
0.02
0.01
0.00
-100
0
100
Change in runoff (%)