문서번호 APCC-출장-16-0261(2016-03-24)

결재	선임연구원	팀장	부서장	원장
	03/23 조재필	03/23 김옥연	03/24 김형진	03/24 정진승
협조				

TRAVEL REPORT FORM
출장보고서

I. Reporter 보고자

Department 소속	Position 직위(직급)	Name 성명	Travel Date 날짜	Note 비고
연구본부 기후변화연구팀	선임연구원	조재필	3/7~3/10	

II. Major Activities 주요업무 수행내용

1. Main Contents and Activities 주요내용 및 활동

1. APCC에서는 조재필 박사가 CMIP5를 이용한 한국의 농업용 저수지 운영에 대한 기후변화 영향평가 연구를, 정일원 박사가 기후변화로 인한 한반도 수자원의 과거와 미래 변화 가능성에 대해 발표하였음.

2. 김형진 박사, 조재필 박사, 정일원 박사는 학회 참가자 및 대만 NCDR 관계자와 기후변화에 따른 재난관리 분야의 적응 대책, 연구현황, 향후 협력 등에 대해 논의하였음(아래 NCDR Dr. Wei-Sen Li 미팅 부분 참조)

2. Relevance to APEC Climate Center's Activities 결론 및 소감

□ TCCIP 프로젝트

1. TCCIP는 대만 과학기술부의 지원 하에 NCDR(Natioanl Science and Technology Center for Disaster Reduction)에서 수행하는 기후변화 프로젝트임.

2. TCCIP 1단계(2010-2012)에서는 관측자료의 디지털화, 품질검증, 격자(gridded) 정보생산, 통계적 및 역학적 기법을 이용한 고해상도 기후전망 정보 생산을 수행하였음. 주요 연구결과를 바탕으로 대만 기후변화 보고서「Climate Change in Taiwan: Scientific Report 2011」를 발간하였음.

3. TCCIP 2단계(2013-2015)에서는 추가적으로 일본 MRI에서 제공하는 고해상도 기후전망 정보 활용하여 기후변화 영향평가(수자원, 재난관리, 환경, 보건, 농업 등)를 수행하였으며, 생산된 정보를 제공하기 위한 인터페이스 구축을 수행하였음.

4. TCCIP는 4개 팀으로 구성되어 있는데 첫 번째 팀에서는 관측과 기후모델 결과 분석, 두 번째 팀에서는 상세 기후변화 전망 정보 생산, 세 번째 팀에서는 상세 기후정보를 활용한 응용분야 연구 및 불확실성 분석, 네 번째 팀에서는 정보 제공, 커뮤니케이션, 결과 홍보 등의 역할을 담당하고 있음.

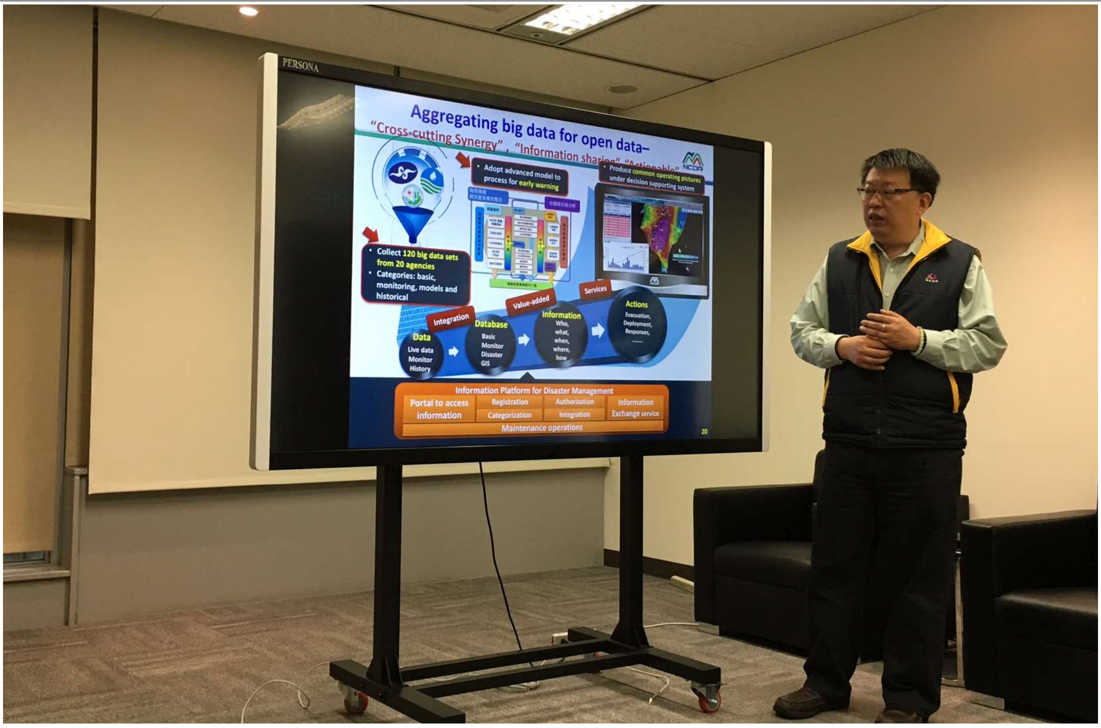
5. 2016 TCCIP 워크숍에서는 2단계에서 수행된 대만의 주요 결과를 발표하고, 아시아 태평양 국가들(호주, 일본, 한국, 태국, 필리핀 등)에서 추진하고 있는 기후변화 연구 현황을 공유하는 자리가 마련되었음.

6. 대만은 TCCIP 프로젝트를 통해 기후전망 분석, 상세 시나리오 생산, 응용분야 영향평가 및 불확실성 평가, 홍보 및 정보 제공 등의 일원화된 체계를 구축하고 있었음. 현재까지 기후변화 영향평가 및 불확실성 분석에 집중된 연구로, 적응정책 수립에 대한 연구는 아직까지 미흡한 것으로 판단됨.

7. 대만은 TCCIP Phase3 (Taiwan Climate Change simulation information and adaptation knowledge Integration Platform)를 통해 고해상도 미래전망 자료를 이용한 기후변화 적응연구를 향후 3년간 추진 예정

□ NCDR Dr. Wei-Sen Li 미팅

1. NCDR의 재난재해 예경보 시스템과 정보제공 플랫폼을 소개.
2. NCDR에서는 20개 재난관련 기관으로부터 120 종류가 넘는 정보를 수집하여, 재난 위험을 판단하고, 경보를 제공하는 체계를 구축하고 있음. 정보처리 절차는 데이터를 DB화하고, DB화된 데이터에서 정보추출, 핵심정보를 바탕으로 한 실행(action)계획 순으로 구성되어 있음.
3. NCDR의 재난재해 대응 사례 소개, 새벽에 발생할 것으로 예측된 호우에 대해 주민들의 대피시간까지 고려하여 인명피해를 예방한 사례가 감명 깊었음.
4. NCDR은 민간기업인 Google과도 협력하여 재난위험 정보를 제공하는 서비스를 운영중이며, 향후 보다 효과적이고 신속한 정보전달체계를 개선하기 위한 노력을 진행중임.
5. Wei-Sen Li는 양 기관의 연구협력 및 공동연구 발굴을 위한 세미나를 금년 내에 한국에서 추진할 것을 제안하였음.

1. 

III. References 참고사항

(with attachment of any information or report in case of attendance of conferences, workshops and meetings) 학술대회, 워크숍, 회의 등 참석 시 관련 정보 및 문서 첨부

1. Presented and Collected Materials 주요 수집자료

2. Suggestions and Remarks 건의사항

Program Structure

3 / 8 (Tuesday)

09:30-10:15	Opening Ceremony
09:45-10:45	Topic 1: Climate Projection: From High Resolution Climate Model to Extreme Weather Events Analysis
10:15-10:35	Tea Break
10:35-12:05	Topic 1: Climate Projection: From High Resolution Climate Model to Extreme Weather Events Analysis
12:05-12:35	Poster Introduction
12:35-13:30	Lunch
13:30-14:30	Topic 2: Climate Projection Applications: Hydrology and Hillslope Disaster
14:30-14:50	Tea Break
14:50-16:20	Topic 2: Climate Projection Applications: Hydrology and Hillslope Disaster
16:20-16:30	Short Break
16:30-17:50	Poster Session
18:00-	Reception

3 / 9 (Wednesday)

9:00-11:00	Topic 2: Climate Projection Applications: Hydrology and Hillslope Disaster
11:00-11:30	Tea Break
11:30-12:30	Topic 3: Climate Projection Applications: Public Health
12:30-13:00	Lunch
13:00-18:00	Field Trip (Invited only)

3 / 10 (Thursday)

9:00-11:00	Topic 1: Climate Projection: From High Resolution Climate Model to Extreme Weather Events Analysis Poster Session
11:00-11:20	Tea Break
11:20-12:20	Topic 3: Climate Projection Applications: Agriculture
12:20-12:30	Workshop Closure

Program Structure

2016 / 03/ 08	
Opening Ceremony	
09:30-09:40	Welcome Address Director *Hongey Chen* (陳宏宇) / National Science and Technology Center for Disaster Reduction, Taiwan
09:40-09:50	Opening Address MOST (tentative)
09:50-10:00	Photo All Participants
10:00-10:15	Introduction to TCCIP Deputy Director *Lee-Yaw Lin* (林李耀) / National Science and Technology Center for Disaster Reduction, Taiwan
10:15-10:35	***Tea Break***
Topic 1: Climate Projection: From High Resolution Climate Model to Extreme Weather Events Analysis **Chairman: Prof. Huang-Hsiung Hsu (許晃雄)**	
10:35-11:05	Climate change signal got from co-working between climate modelers and impact study researchers – the case of Japanese domestic projects – Dr. *Izuru Takayabu* / Meteorological Research Institute, Japan
11:05-11:35	CORDEX-East Asia: lessons and issues Dr. *Hyun-Suk Kang* / National Institute of Meteorological Research, Korea
11:35-12:05	Climate services that facilitate the development, delivery and uptake of projections Mr. *Kevin Hennessy* / CSIRO Oceans and Atmosphere Flagship, Australia

12:05-12:35	Poster Introduction
12:35-13:30	***Lunch***
Topic 2: Climate Projection Applications: Hydrology and Hillslope Disaster **Chairman: Prof. Keh-Chia Yeh (葉克家)**	
13:30-14:00	Future changes in extreme precipitation, rainfall erosivity and hillslope erosion in southeast Australia Dr. *Jason P. Evans* / University of New South Wales, Australia
14:00-14:30	Disaster loss assessment in Choshui river basin under climate change Dr. *Hsin-Chi Lee* (李欣輯) / National Science and Technology Center for Disaster Reduction, Taiwan
14:30-14:50	***Tea Break***
Topic 2: Climate Projection Applications: Hydrology and Hillslope Disaster **Chairman: Prof. Keh-Chia Yeh (葉克家)**	
14:50-15:20	Downscaling Future Climate Projections for Water Management Dr. *Surajate Boonya-aroonnet* / Hydro and Agro Informatics Institute, Thailand
15:20-15:50	Application on statistical downscaling data to assess hydrological impact due to climate changes in Taiwan Dr. *Yun-Ju Chen* (陳韻如) / National Science and Technology Center for Disaster Reduction, Taiwan
15:50-16:20	Korean water resources changes under CMIP5 projection Dr. *Il-Won Jung* / APEC Climate Center, Korea
16:20-16:30	***Short Break***
16:30-17:50	Poster Session
18:00-	**Reception (Invited Only)**

2016 / 03/ 09	
Topic 2: Climate Projection Applications: Hydrology and Hillslope Disaster **Chairman: To be confirmed**	
09:00-09:30	Hydrological impact of climate change in Japan and Taiwan using high-resolution AGCM Dr. *Yoshinobu Sato* / Ehime University, Japan
09:30-10:00	Modeling of urban inundation and its application potential to climate change impact Dr. *Kenji Kawaike* / Kyoto University, Japan
10:00-10:30	Climate change impact assessment on agricultural reservoirs in Korea under RCP Scenarios Dr. *Jae-Pil Cho* / APEC Climate Center, Korea
10:30-11:00	To be confirmed Dr. *Gemma Teresa T. Narisma* / Ateneo de Manila University, Philippine
11:00-11:30	***Tea Break***
Topic 3: Climate Projection Applications: Public Health **Chairman: Prof. Pei-Chih Wu (吳佩芝)**	
11:30-12:00	Dengue fever and global climate change Dr. *Simon Hales* / University of Otago, New Zealand
12:00-12:30	Evaluation of health impacts under climate change projection in Taiwan – Dengue fever and heat related mortality Dr. *Pei-Chih Wu* (吳佩芝) / Chang Jung Christian University, Taiwan
12:30-13:00	***Lunch***
13:00-18:00	**Field Trip (Invited Only)**

2016 / 03/ 10	
Topic 1: Climate Projection: From High Resolution Climate Model to Extreme Weather Events Analysis **Chairman: Prof. Cheng-Ta Chen (陳正達)**	
09:00-09:30	Probability distribution of tropical cyclone in large ensemble simulation by MRI-AGCM Dr. *Kohei Yoshida* / Meteorological Research Institute, Japan
09:30-10:00	Projection of Taiwan Climate Dr. *Huang-Hsiung Hsu* (許晃雄) / Academia Sinica, Taiwan
10:00-10:30	Nonparametric analysis of extreme precipitation with long return periods in Japan – using d4PDF Dr. *Kenshi Hibino* / University of Tsukuba, Japan
10:30-11:00	Projection of Northwest Pacific Typhoons in high-resolution AGCM Dr. *Cheng-Ta Chen* (陳正達) / National Taiwan Normal University, Taiwan
11:00-11:20	***Tea Break***
Topic 3: Climate Projection Applications: Agriculture **Chairman: Dr. Ming-Hwi Yao (姚銘輝)**	
11:20-11:50	The use of climate change projections and crop models for climate change impact assessment: TRF's Experiences in Thailand and Southeast Asia Dr. *Attachai Jintrawet* / Chiang Mai University, Thailand
11:50-12:20	Evaluation of rice production potential in Taiwan using SDSM future climate data Dr. *Ming-Hwi Yao* (姚銘輝) / Taiwan Agricultural Research Institute, Taiwan
12:20-12:30	**Workshop Closure**

Taiwan Climate Change Projection and Information Platform Project

Our Aim

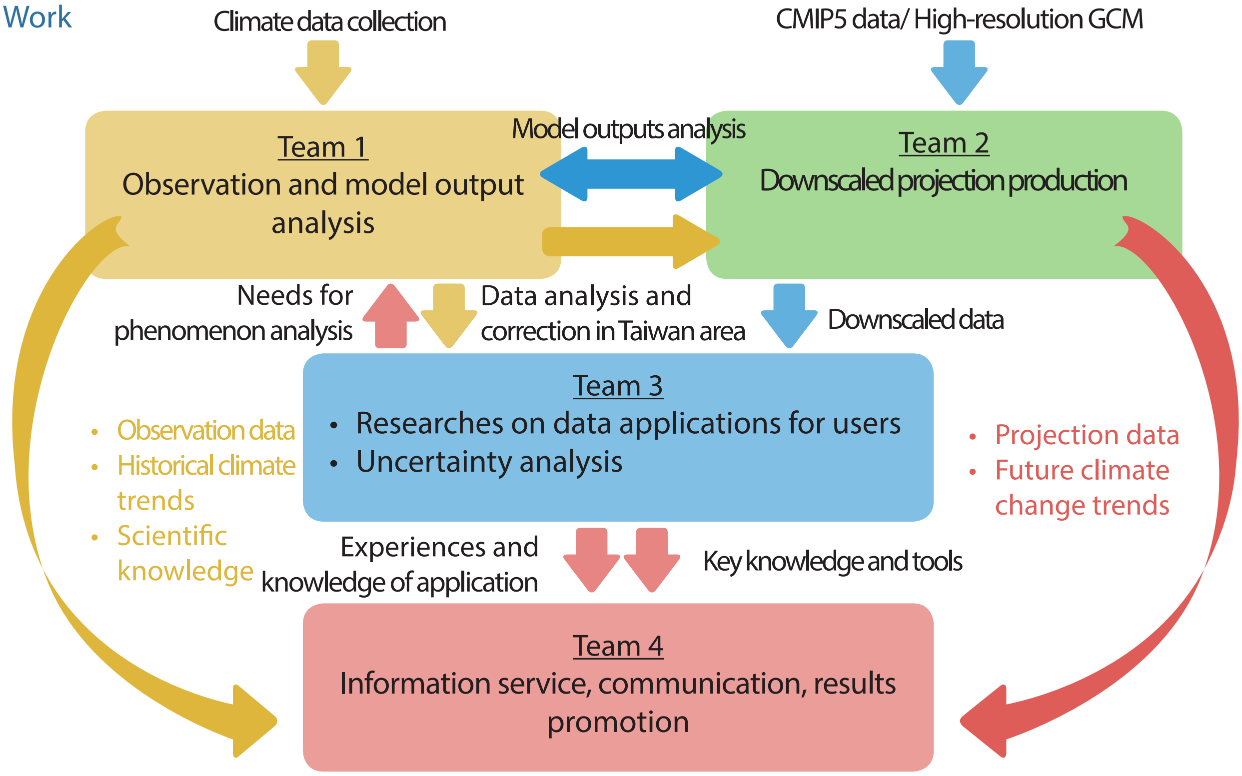
The Taiwan Climate Change Projection and Information Platform Project (TCCIP) coordinated by National Science and Technology Center for Disaster Reduction (NCDR) is one of three major climate change projects funded by Ministry of Science and Technology. The TCCIP project not only produces climate change data for impact assessments and adaptations but also aims to support national adaptation policy framework.

Our Mission

In TCCIP phase 1 (2010-2012) has produced substantial results for user service such as producing digitalized, homogenized, and gridded meteorological data sets; projecting climate change projection of Taiwan area; producing high spatial-temporal resolution data sets by statistical downscaling and dynamic downscaling; developing technologies to apply climate change data to the studies of disaster reduction and water resources management, publishing "Climate Change in Taiwan: Scientific Report 2011", and building the TCCIP website (tccip.ncdr.nat.gov.tw).

In TCCIP phase 2 (2013-2015), in addition to being a producer of high-resolution climate change projection data, the TCCIP also aims to be a good communication interface, effectively passing not only the data but also the related information to users.

Our Work



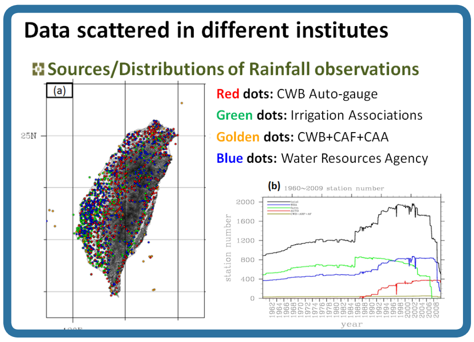
International Cooperation

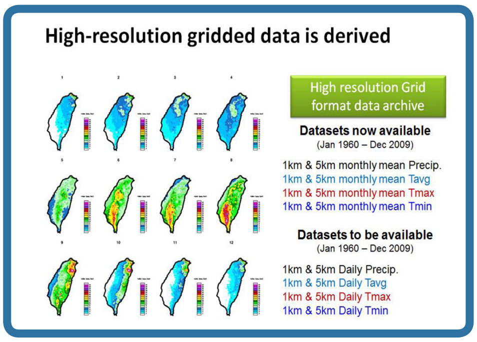
IPCC CMIP data	SOUSEI program, Japan Theme C (University of Tsukuba) High-resolution (20km) climate simulation Theme D (Kyoto University) Climate impact data
	High-resolution AGCMs GFDL HiRAM NCAR CAM5

科技部 Ministry of Science and Technology

Team 1

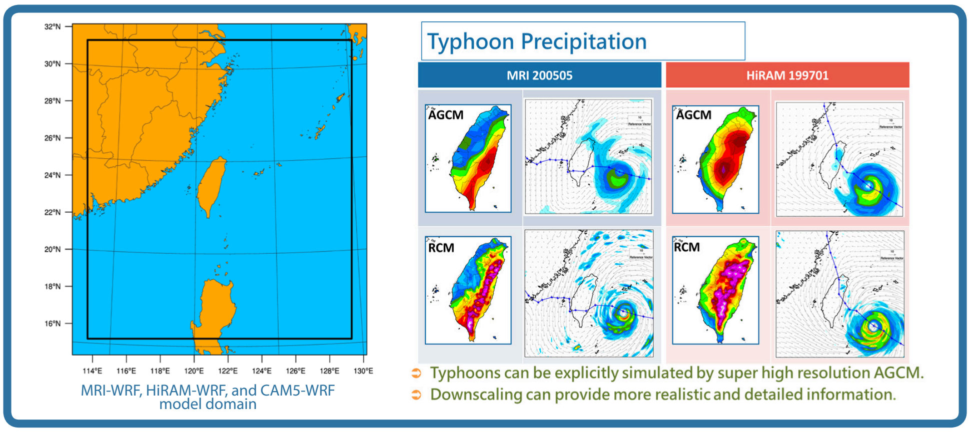
- Refinement of local climate change database and its reanalysis in Taiwan
- Developing Phenomenon Metric for climate study
- Developing Performance Metric for climate model evaluation





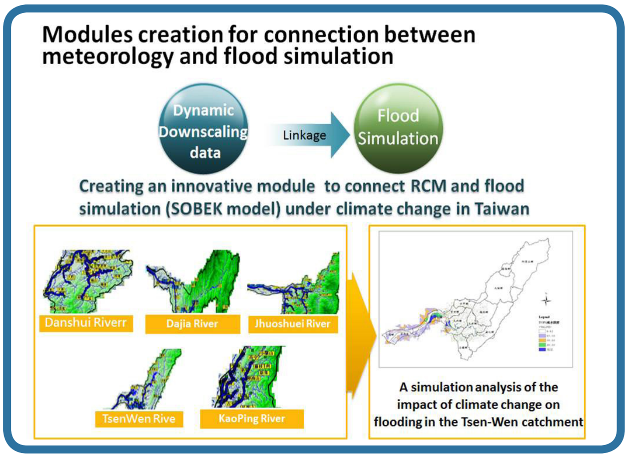
Team 2

- Producing statistical downscaling data sets (CMIP5)
- Producing dynamic downscaling data sets (3 high-resolution AGCMs)
- Studying the reasons of changes in seasonal rainfall and extreme events with dynamic downscaling data



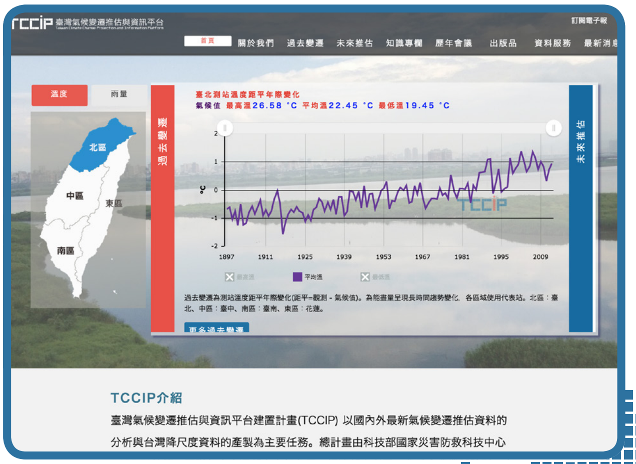
Team 3

- Developing applied technologies of downscaling data to disaster related studies
- Extending application on agriculture, public health, coastal area management
- Developing uncertainty assessment approaches



Team 4

- Communicating within scientific societies with climate data
- Updating the information platform and reinforcement of on-line service
- Writing and Publishing the “Climate Change in Taiwan: Second Scientific Report 2015”
- Translation and dissemination of climate change knowledge



Contact us

For data application and more detail, please visit website: http://tccip.ncdr.nat.gov.tw
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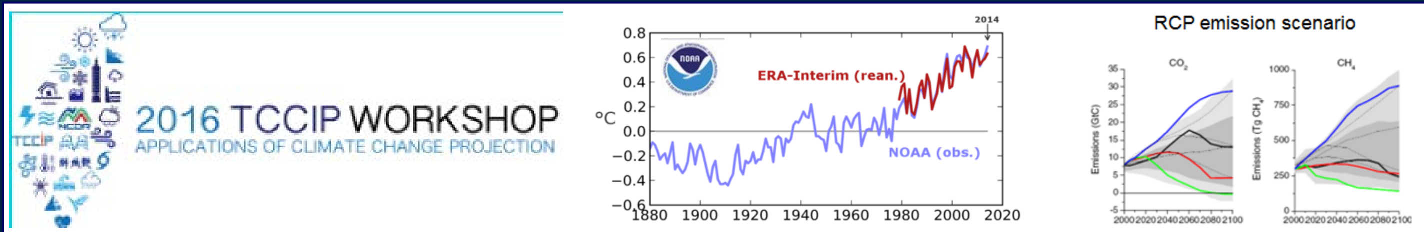


Korean Water Resources Changes under CMIP5 Projection

Il Won Jung, Hyung Il Eum, Ok-Yeon Kim, & Eunjeong Lee

Climate Research Dept., APEC Climate Center, Busan, Korea

APCC APEC CLIMATE CENTER

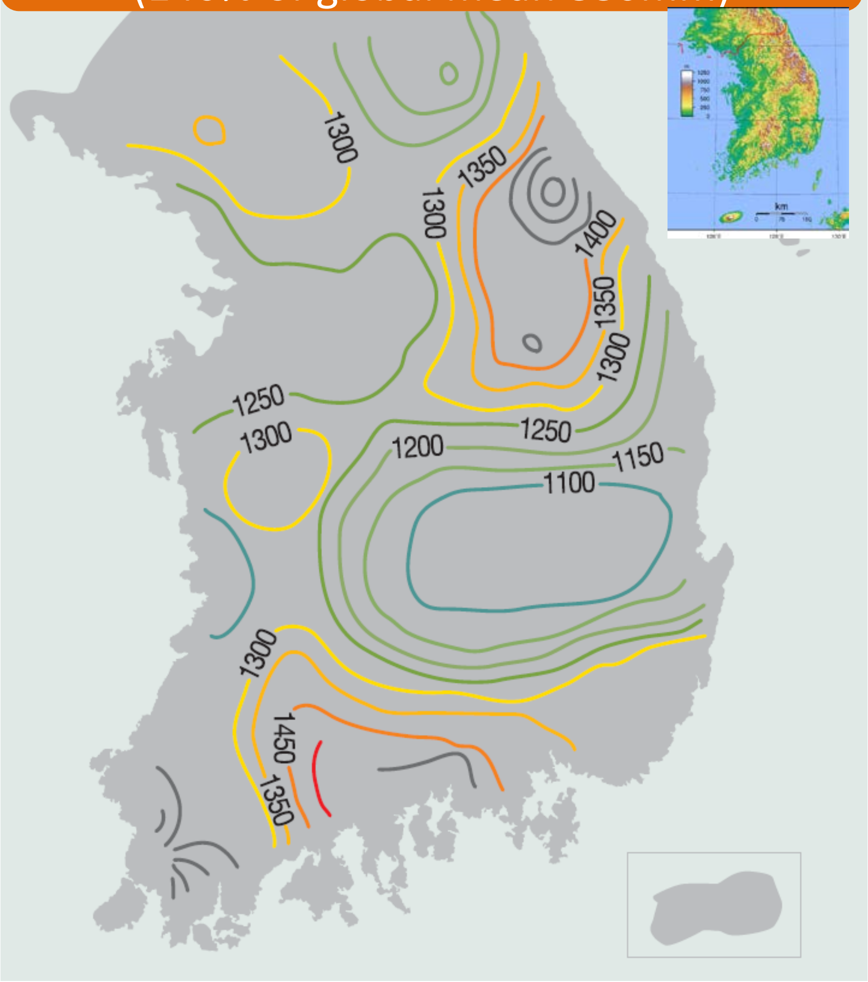
Climate Change Adaptation for Water Resources

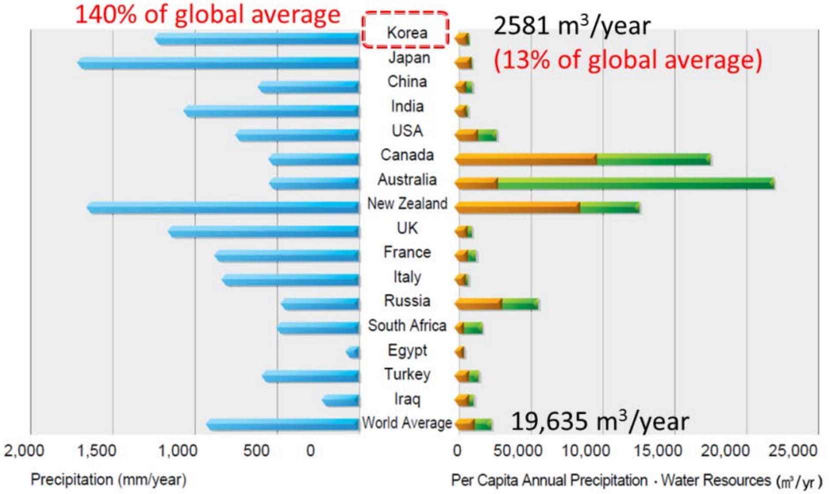
KAIA

Contents

Climate of South Korea

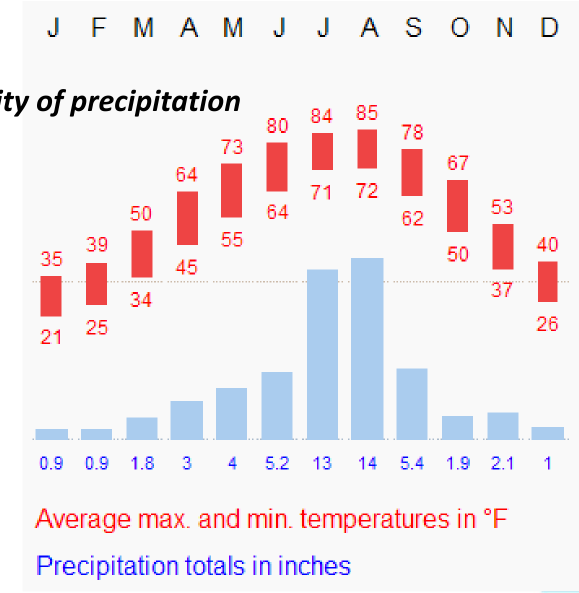
Annual mean precipitation :1,245 mm
(140% of global mean 880mm)





| Water Resources in Major Countries |

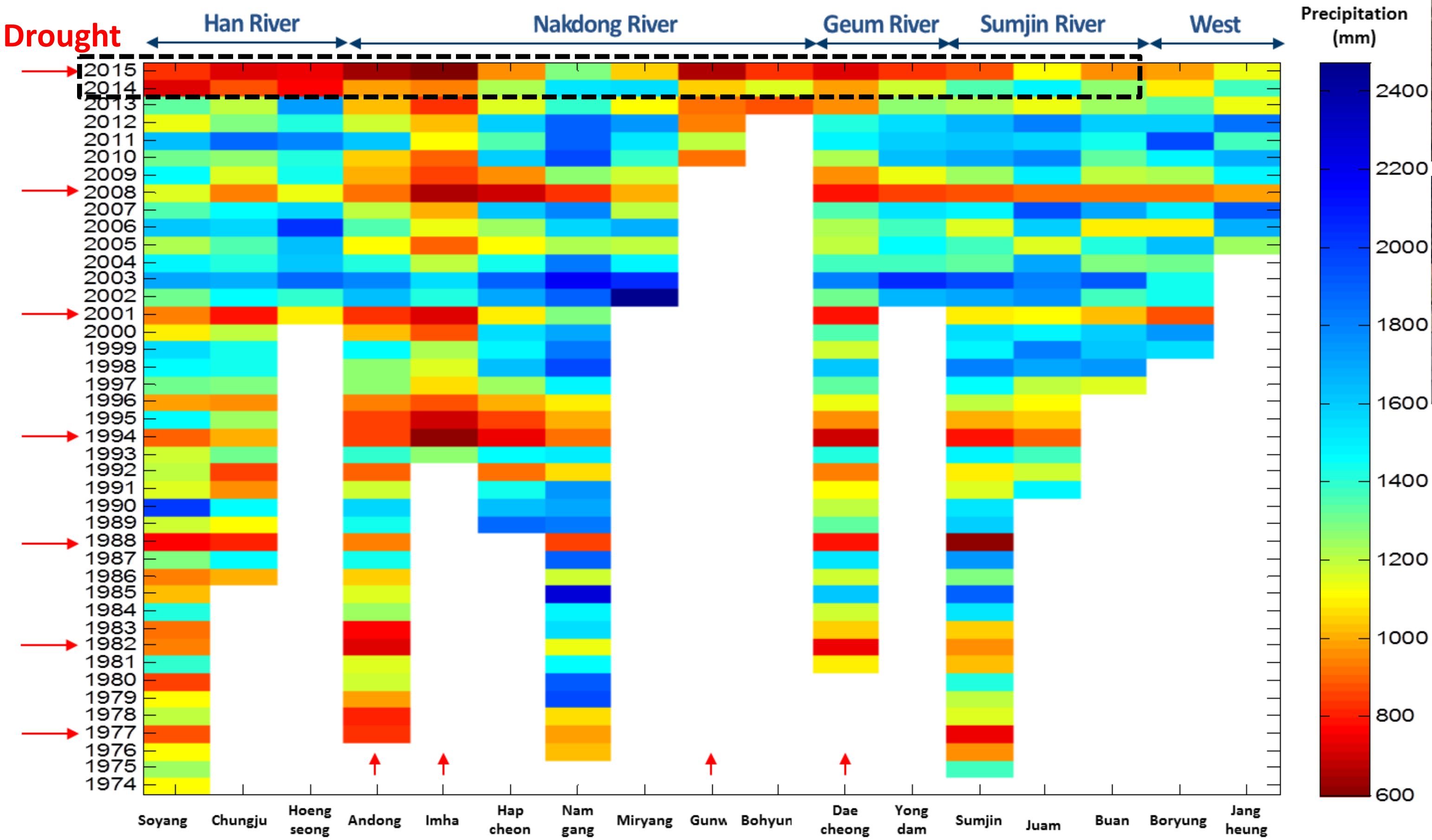
Seasonality of precipitation



Source: *Water resources in Korea 2007*. Water resources Bureau of MLTM

South Korea suffers periodic droughts

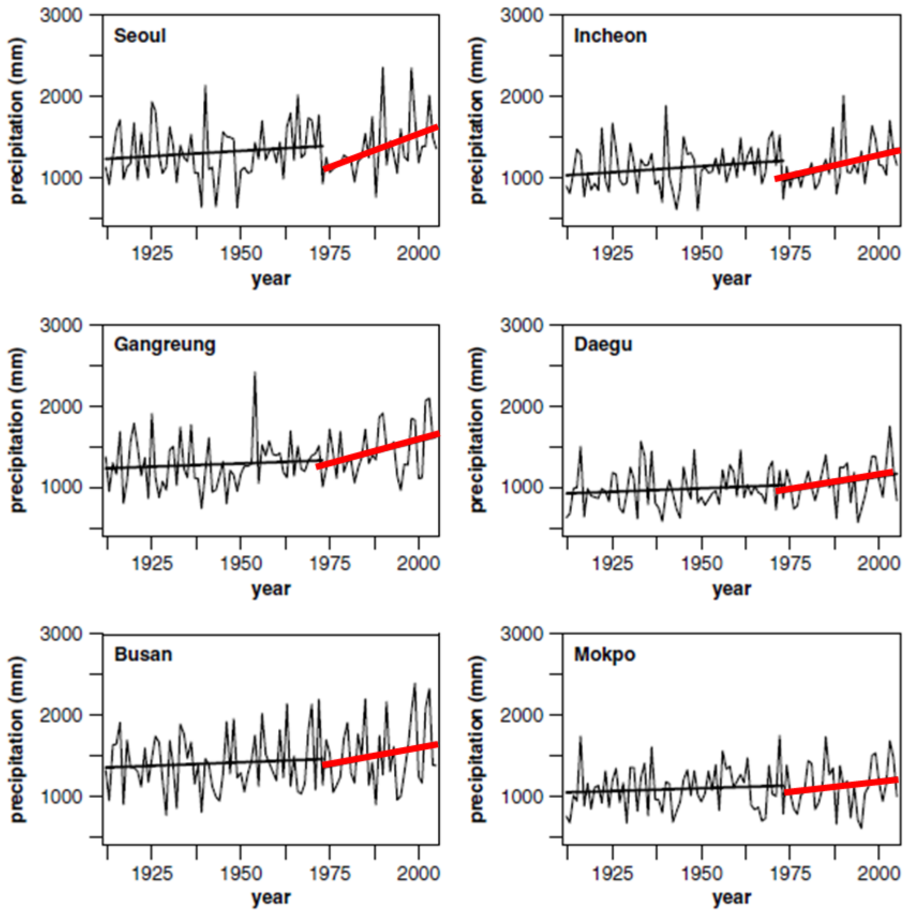
➢ **Annual precipitation of multi-purpose dams (K-water, 2016)**

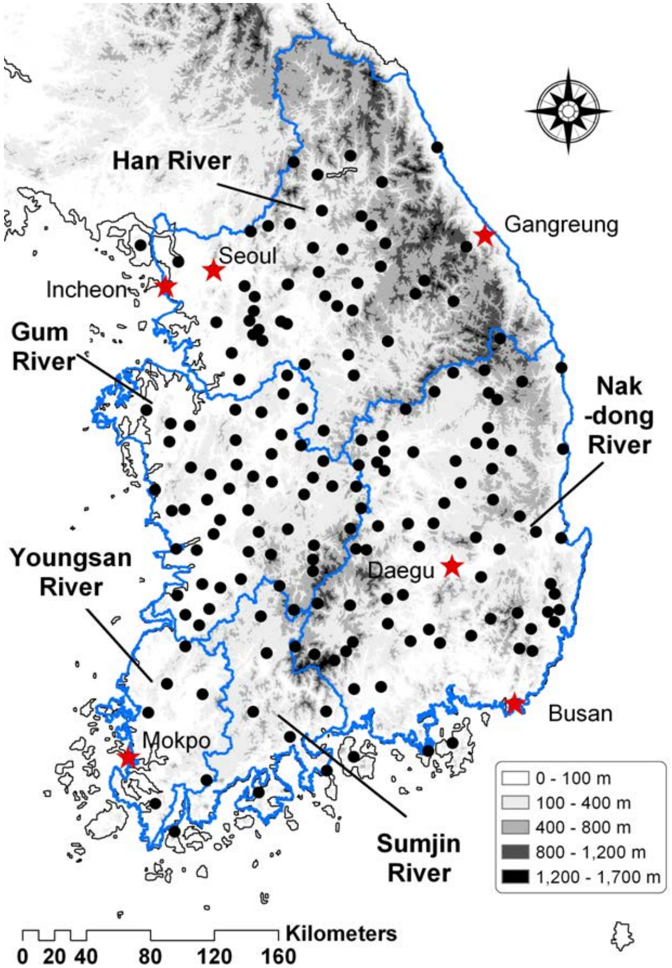


2015 summer precipitation was less than half of the average in Gyeonggi and Gangwon provinces

Historical changes in precipitation

➢ **Changes in annual precipitation (6 weather stations)**



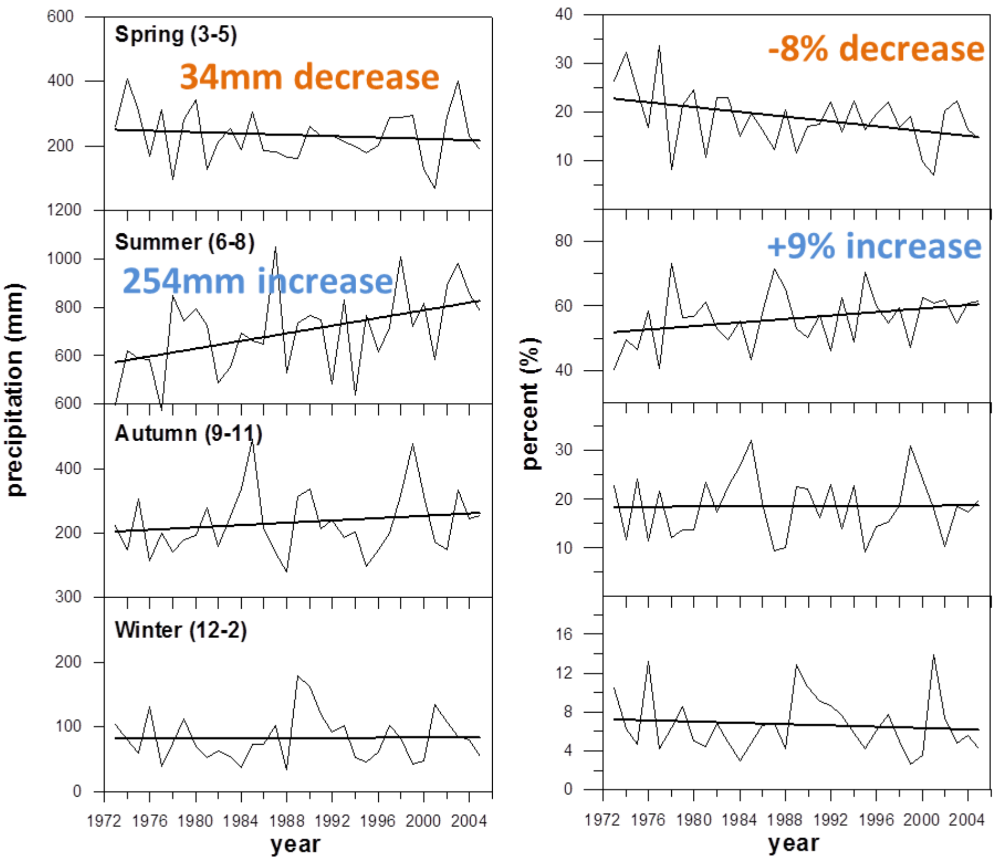


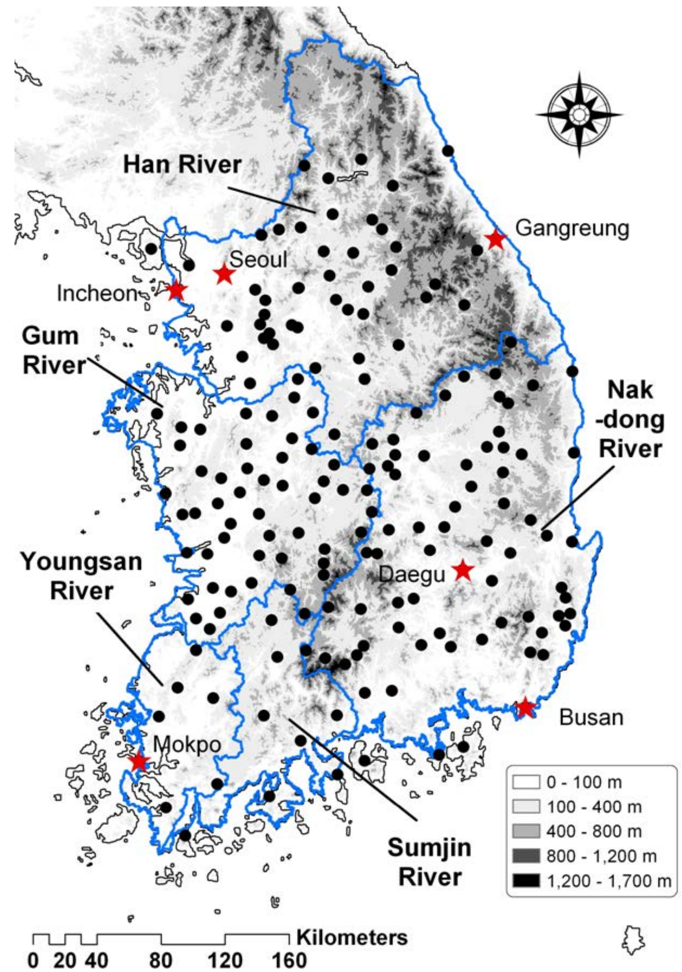
Source: *Jung et al. (2011) International Journal of Climatology*

Historical changes in precipitation

- **Changes in seasonal precipitation (183 weather stations)**

Recent 33yrs (1973 – 2005)

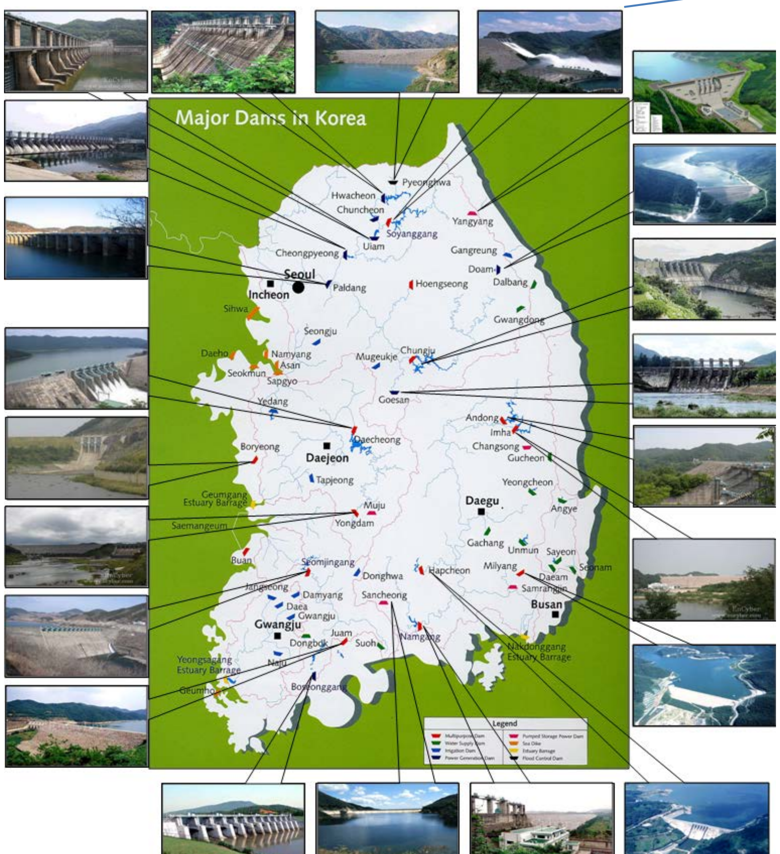




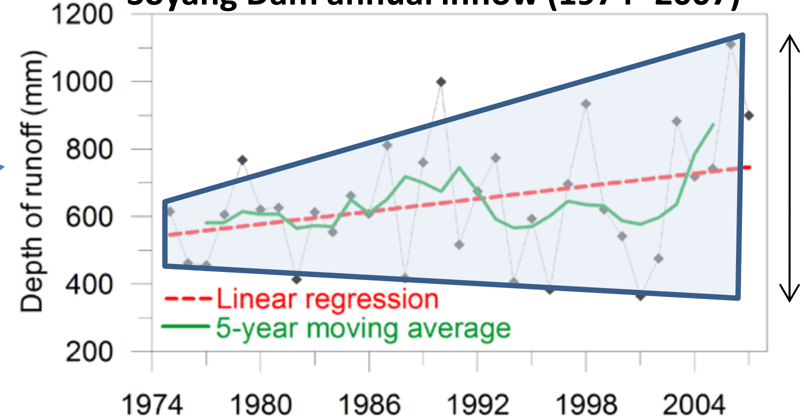
Source: *Jung et al. (2011) International Journal of Climatology*

Historical changes in streamflow

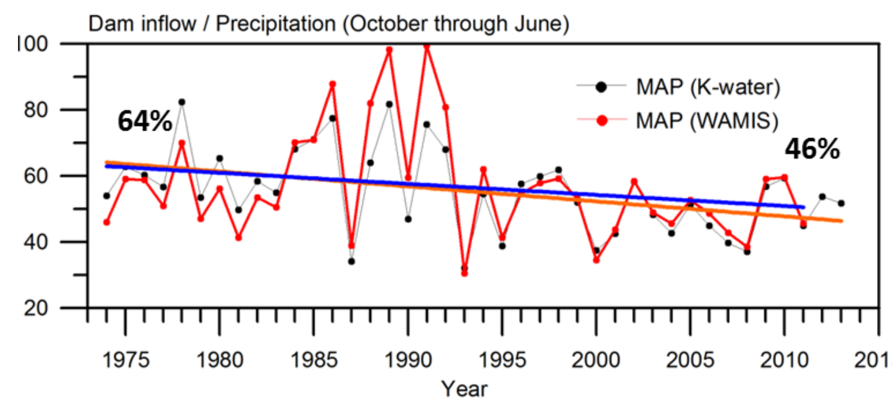
- **Changes in dam inflow**
  - ✓ **Dams contributes 65% of water supply (12.2 billion m^3)**



Soyang Dam annual inflow (1974 -2007)



Change in Dry-seasonal runoff rate



Source: Jung (2016) APCC annual report

CCAW Project (2014-2019): Climate Change Adaptation for Water Resources (CCAW)

APCC
APEC CLIMATE CENTER

➢ Project Overview

- ✓ Period/Budget : Sep. 15, 2014 ~ June 14, 2019 (4 years 9 months)/ 22 million USD
- ✓ Principal institute : Sejong university (Prof. Deg-Hyo Bae)
- ✓ Joint research institutes : 17 (K-water, APCC, Inha univ., Konkuk univ., etc.)

Final Goal

Development of technologies for national water resources management considering climate change impacts

CCAW Research Center

1. Extreme flood adaptation technology

- Development of guideline for flood defense standards and technologies for hydraulic structure management

2. Reliable water supply technology

- Development of techniques to secure water resources and provide reliable supply

3. Watershed management adaptation technology

- Comprehensive vulnerability assessment and development of integrated data system for establishing the efficient adaptation strategies

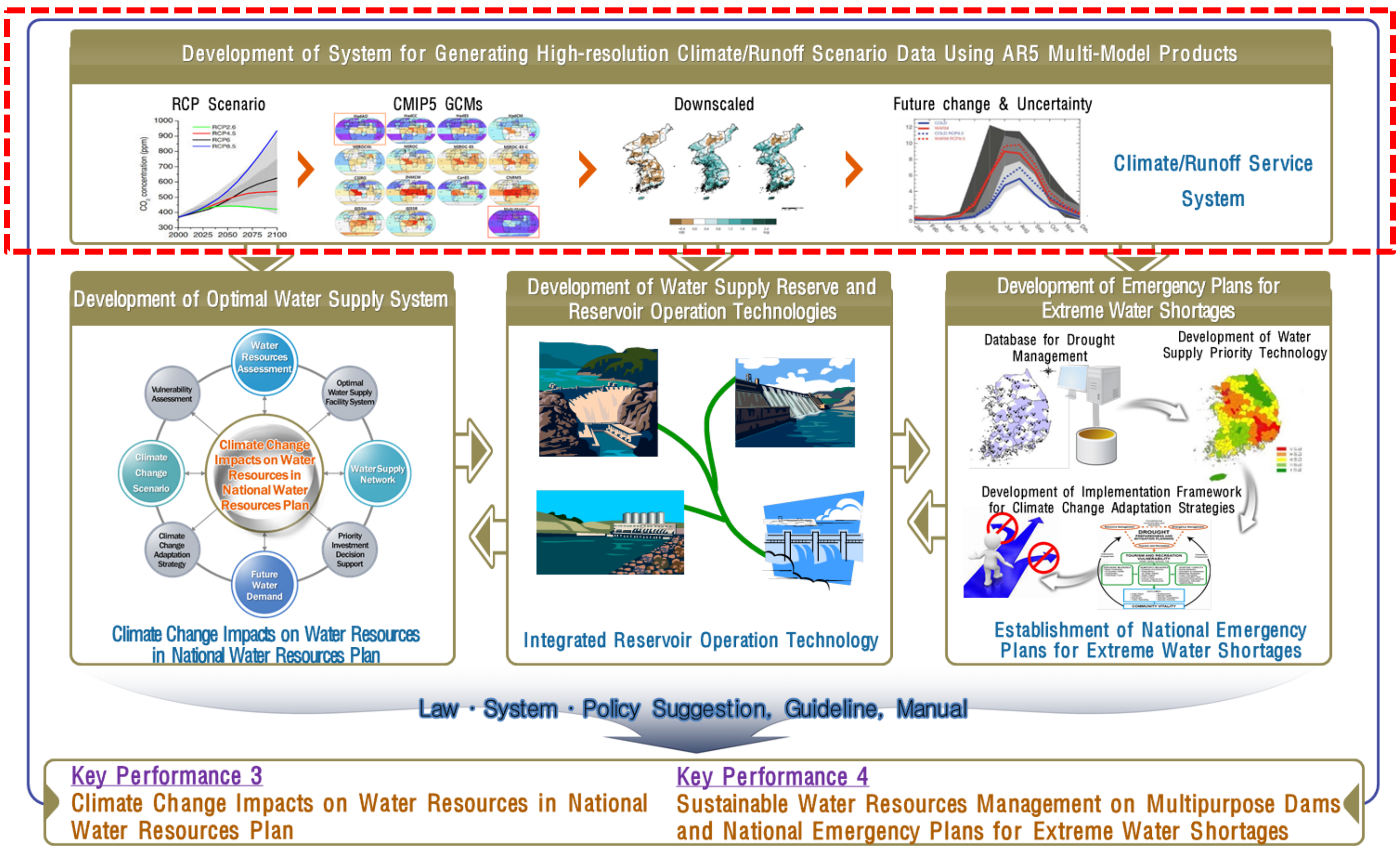
4. Water industry technology

- Development of water industry supporting technology for climate change adaptation

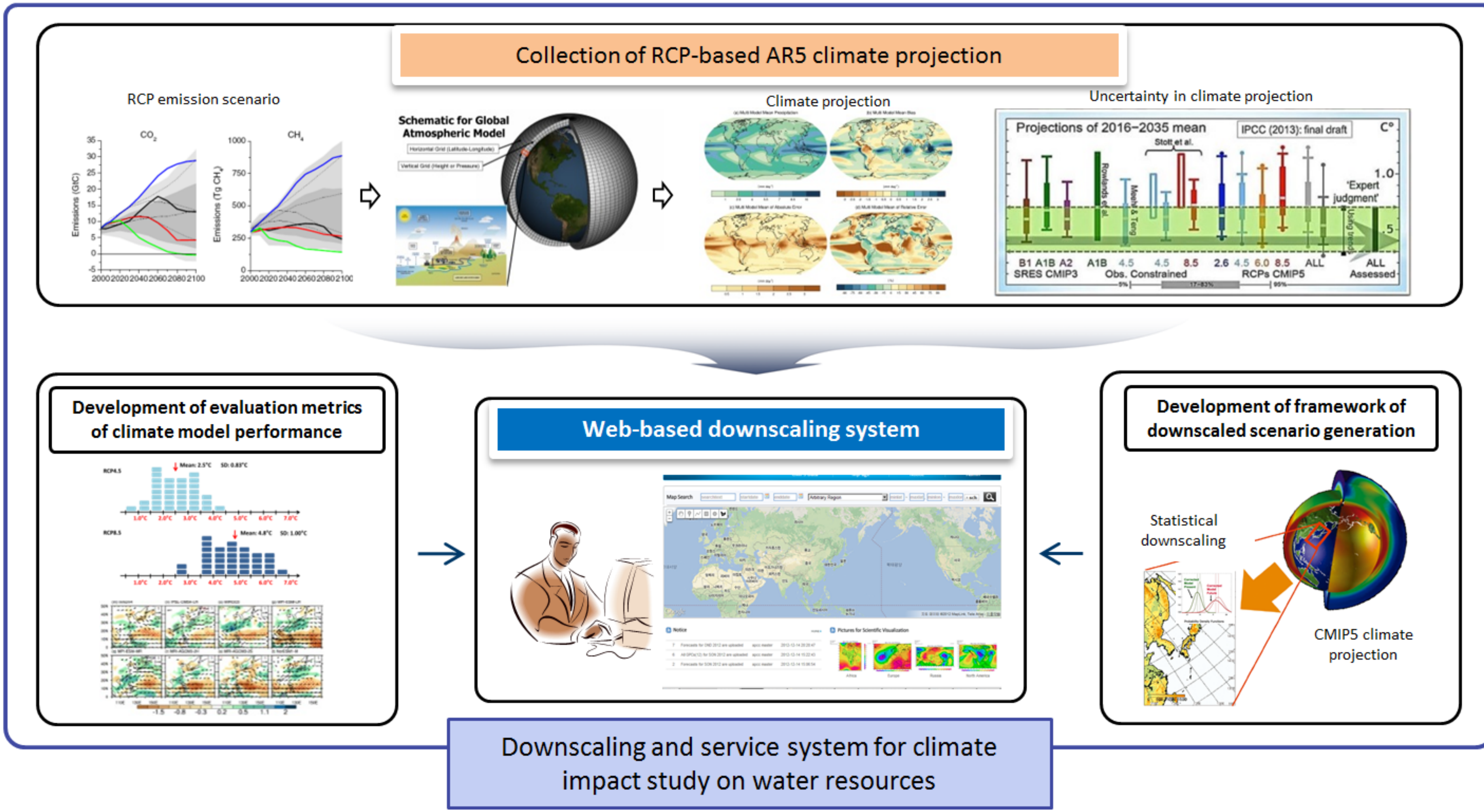
Research goal and framework

➢ Research goal

- ✓ **Assessment of climate change impacts** on Korean water resources under CMIP5 projection to **support for National Water Resources Plan (NWRP)** for establishing sustainable water resources management strategies in changing climate



Research structure for climate change impact assessment



Evaluation of performance of CMIP5

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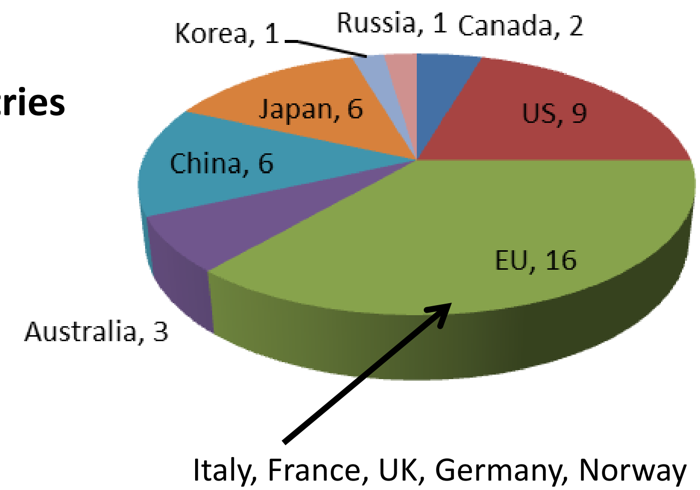
➢ Collection of CMIP5 projection

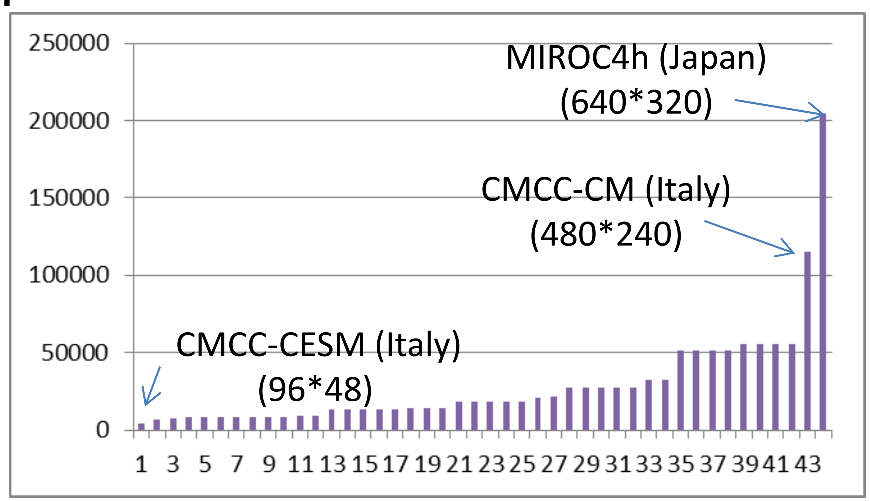
http://pcmdi9.llnl.gov/esgf-web-fe/

- CMIP5
  - Monthly (192.8 GB)
    - Historical 103 GB
    - RCP4.5 55 GB
    - RCP8.5 35 GB
  - Daily (4.78 TB)
    - Historical 2361 GB
    - RCP4.5 1348 GB
    - RCP8.5 1181 GB

Countries



Spatial resolution



No	Modeling group	Model name	Institute	Resolution
1	BCC	**BCC-CSM1-1-m**	Beijing Climate Center, China Meteorological Administration	320x160
2		**BCC-CSM1-1**		128x64
3	CCCma	**CanESM2**	Canadian Centre for Climate Modelling and Analysis	128x64
4	NCAR	**CCSM4**	National Center for Atmospheric Research	288x192
5	NSF-DOE-NCAR	**CESM1-BGC**	National Science Foundation, Department of Energy, National Center for Atmospheric Research	288x192
6		**CESM1-CAM5**		
7	CMCC	**CMCC-CM**	Centro Euro-Mediterraneo per I Cambiamenti Climatici	480x240
8		**CMCC-CMS**		192x96
9	CNRM-CERFACS	**CNRM-CM5**	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique	256x128
10	LASG-IAP	**FGOALS-s2**	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences	128x108
11	NOAAGFDL	**GFDL-CM3**	Geophysical Fluid Dynamics Laboratory	144x90
12		**GFDL-ESM2G**		
13		**GFDL-ESM2M**		
14	NASA GISS	**GISS-E2-R**	NASA Goddard Institute for Space Studies	144x90
15	MOHC	**HadCM3**	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)	96x73
16	NIMR/KMA	**HadGEM2-AO**	National Institute of Meteorological Research/Korea Meteorological Administration	192x145
17	MOHC	**HadGEM2-CC**	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)	192x145
18		**HadGEM2-ES**		
19	INM	**INM-CM4**	Institute for Numerical Mathematics	180x120
20	IPSL	**IPSL-CM5A-LR**	Institut Pierre-Simon Laplace	96x96
21		**IPSL-CM5A-MR**		144x143
22		**IPSL-CM5B-LR**		96x96
23	MIROC	**MIROC5**	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	256x128
24	MIROC	**MIROC-ESM-CHEM**	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	128x64
25		**MIROC-ESM**		
26	MPI-M	**MPI-ESM-LR**	Max Planck Institute for Meteorology (MPI-M)	192x96
27		**MPI-ESM-MR**		
28	MRI	**MRI-CGCM3**	Meteorological Research Institute	320x160
29	NCC	**NorESM1-M**	Norwegian Climate Centre	144x96
30	Multi Model Ensemble			

Hydroclimate Indicators for performance evaluation

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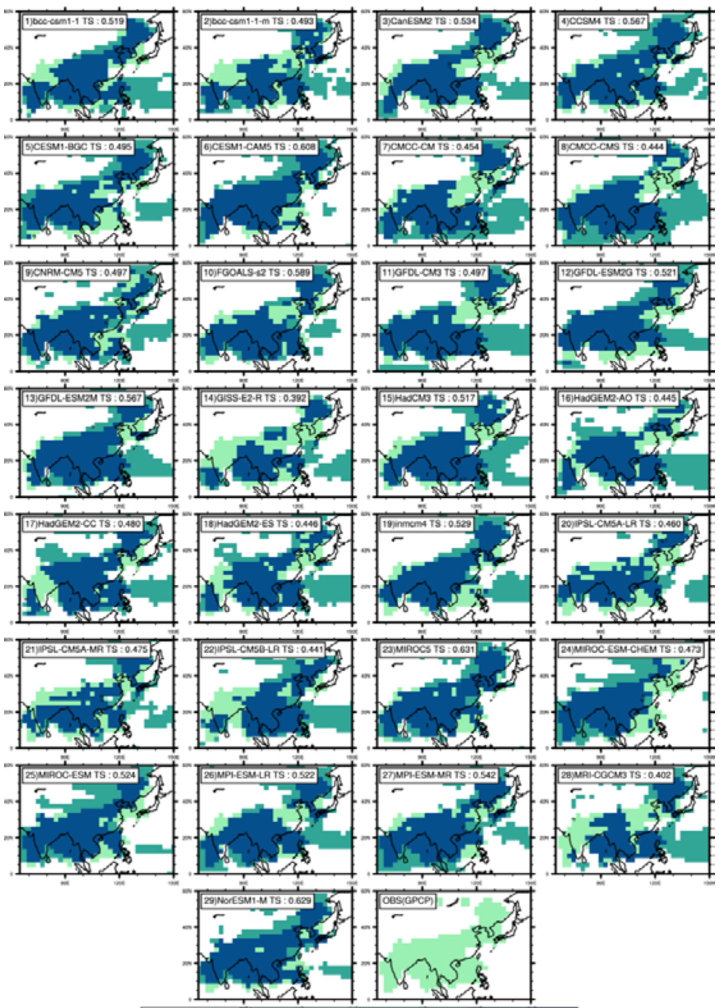
➢ **Expert Team on Climate Change Detection and Indices (ETCCDI) (WMO)**

No.	ID	Related variable	Description	Unit
1	SU	TMAX	Summer day, TMAX > 25°C	Days
2	ID		Ice days, TMAX < 0°C	Days
3	TX_n		Min TMAX	°C
4	TX_x		Max TMAX	°C
5	TX10p		Cool days, TMAX < 10^{th} percentile	%
6	TX90p		Warm days, TMAX > 90^{th} percentile	Days
7	WSDI		Warm spell duration, TMAX > 90^{th} percentile	Days
8	FD	TMIN	Frost days TMIN < 0°C	Days
9	TR		Tropical nights, TMIN > 20°C	Days
10	TN_n		Min TMIN	°C
11	TN_x		Max TMIN	°C
12	TN10p		Cool nights, TMIN < 10^{th} percentile	%
13	TN90p		Warm nights, TMIN > 90^{th} percentile	%
14	CSDI		Cold spell duration, TMIN < 10^{th} percentile	Days
15	DTR	TMAX & TMIN	Diurnal temperature range	°C
16	GSL		Growing season length	Days
17	CDD	PRCP	Consecutive dry days, PRCP < 1mm	Days
18	CWD		Consecutive wet days, PRCP ≥ 1mm	Days
19	PRCPTOT		Annual total PRCP in wet days (daily PRCP ≥ 1mm)	mm
20	Rx1day		Max 1-day precipitation	mm
21	Rx5day		Max 5-day precipitation	mm
22	R95pTOT		Annual total PRCP when daily PRCP > 95 percentile	mm
23	R99pTOT		Annual total PRCP when daily PRCP > 99 percentile	mm
24	SDII		Simple daily intensity index	mm/day

Results

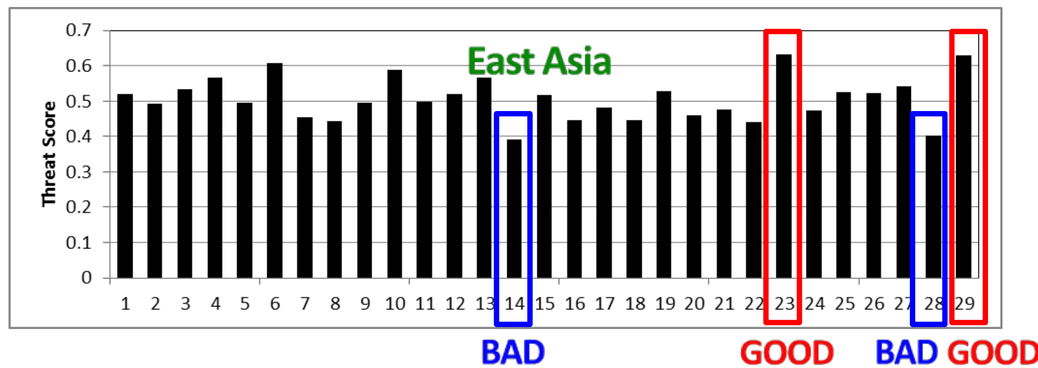
➢ **Performance of simulating East Asia Monsoon**

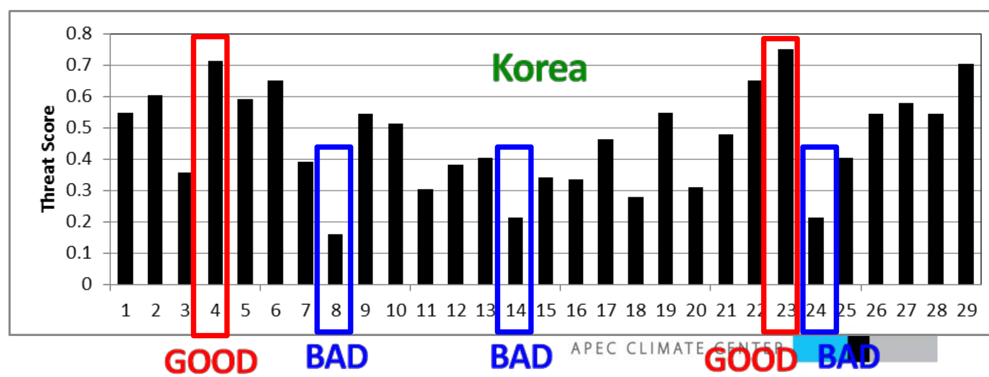
GM domain OBS vs CMIP5



$$Threat\ score = \frac{hit}{(hit + missed + falsealarm)}$$

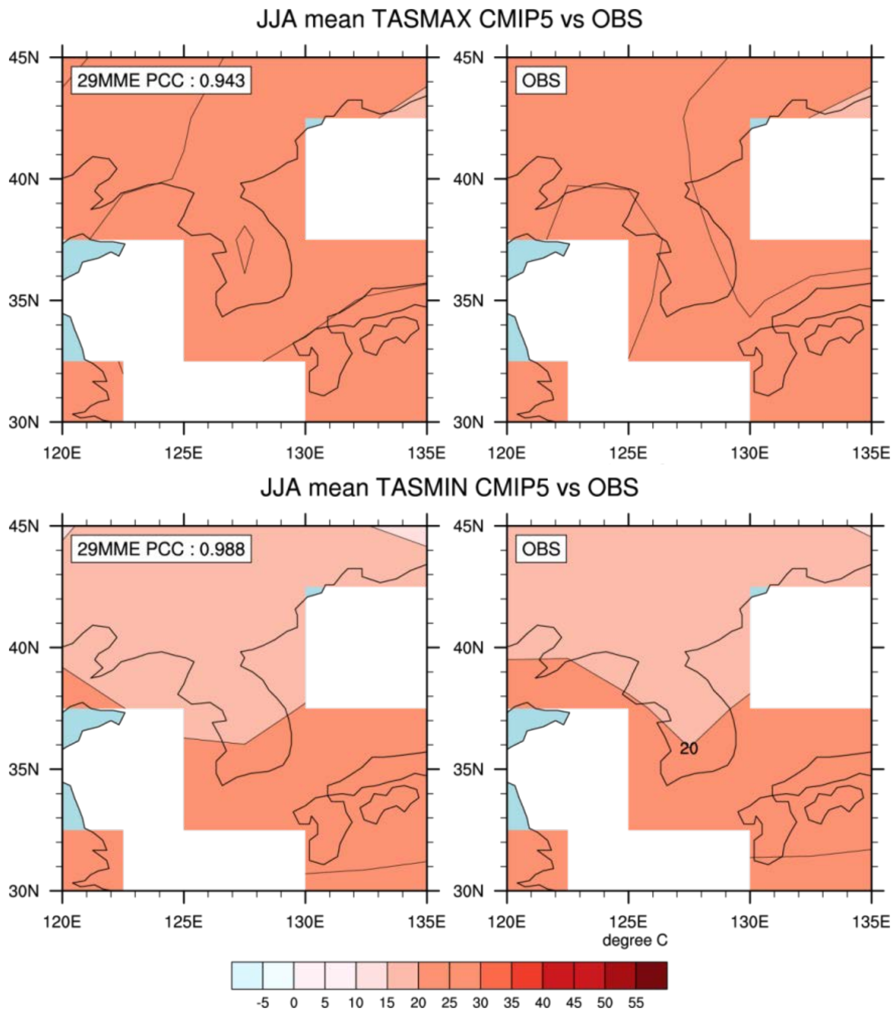
missed : obs O, sim X
false-alarm : obs X, sim O
hit : obs O, sim O

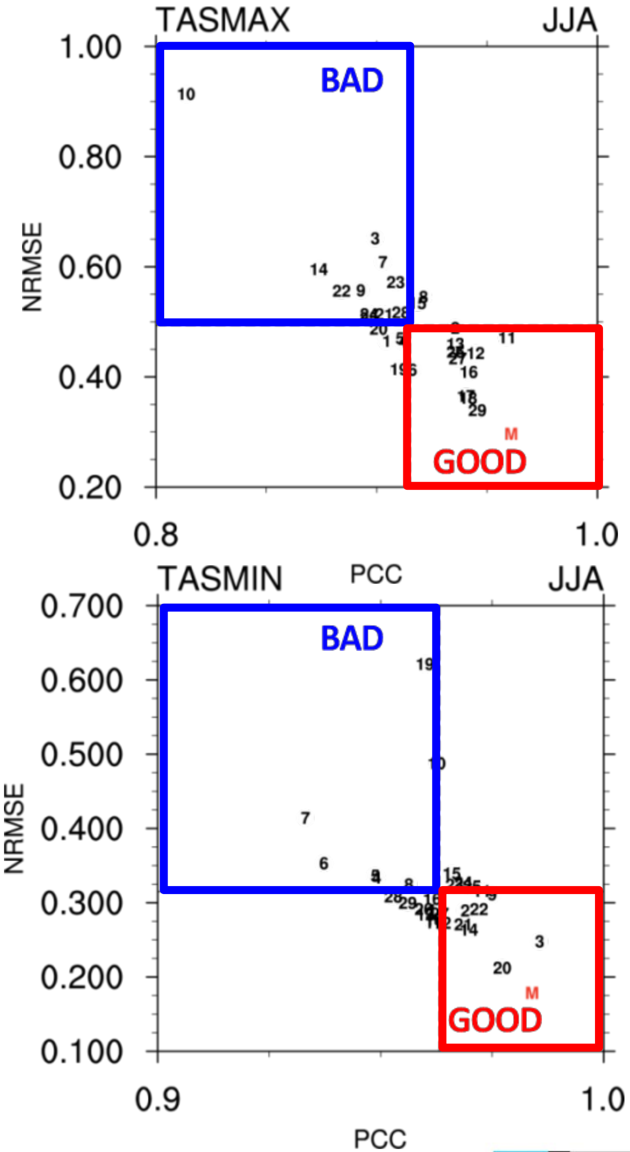




Results

- **Performance of simulating Max. & Min. temperature**

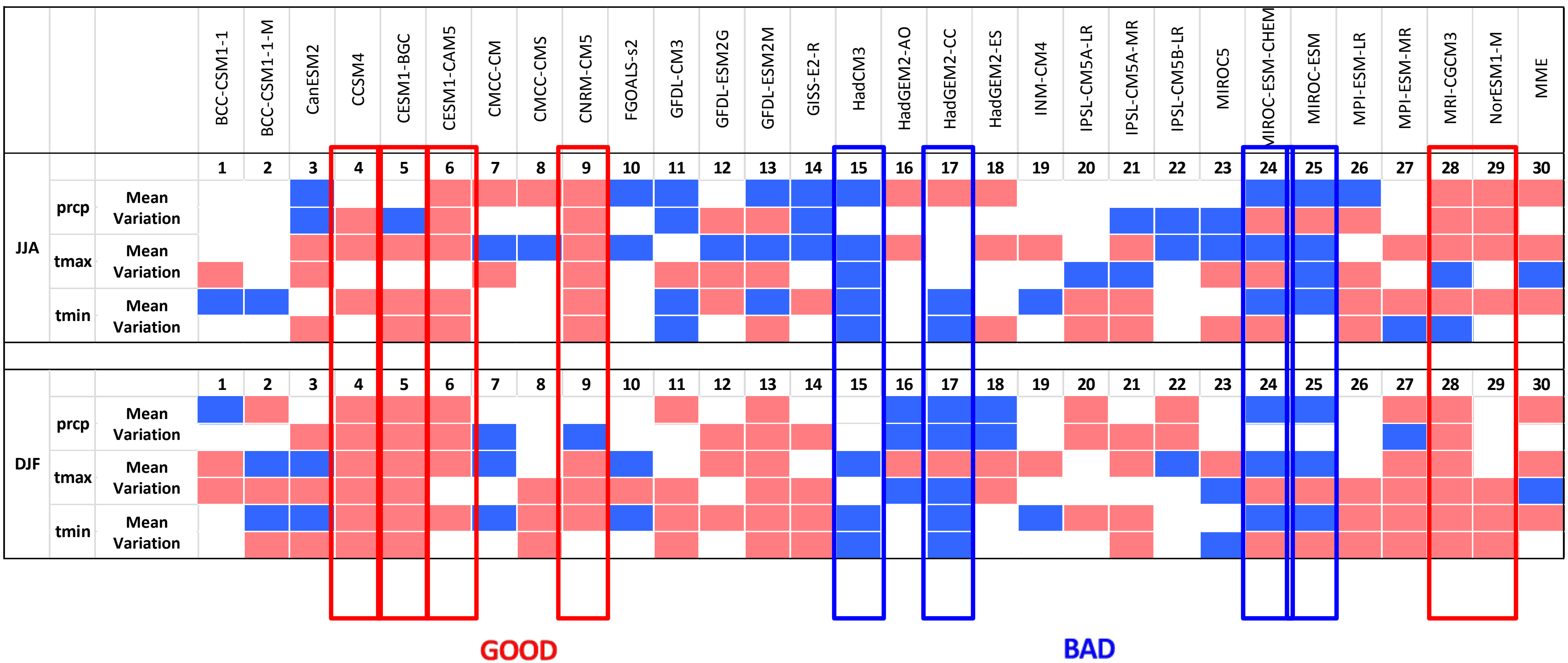




Results

➢ **Performance of seasonal mean precipitation, Tmax & Tmin**

GOOD : NRMSE↓ PCC↑ BAD : NRMSE↑ PCC↓



Results

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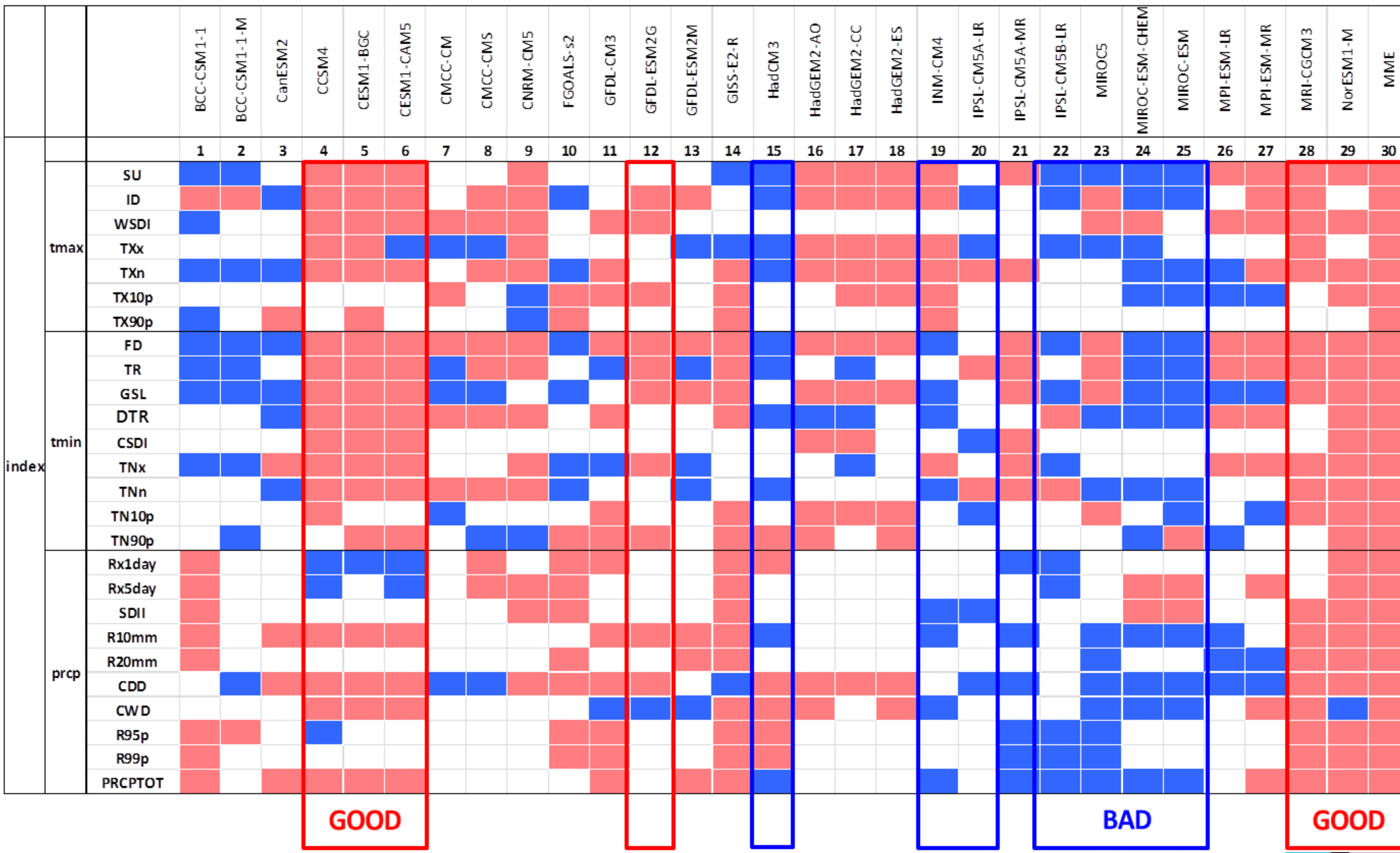
➢ Performance evaluation using ETCCDI



Results

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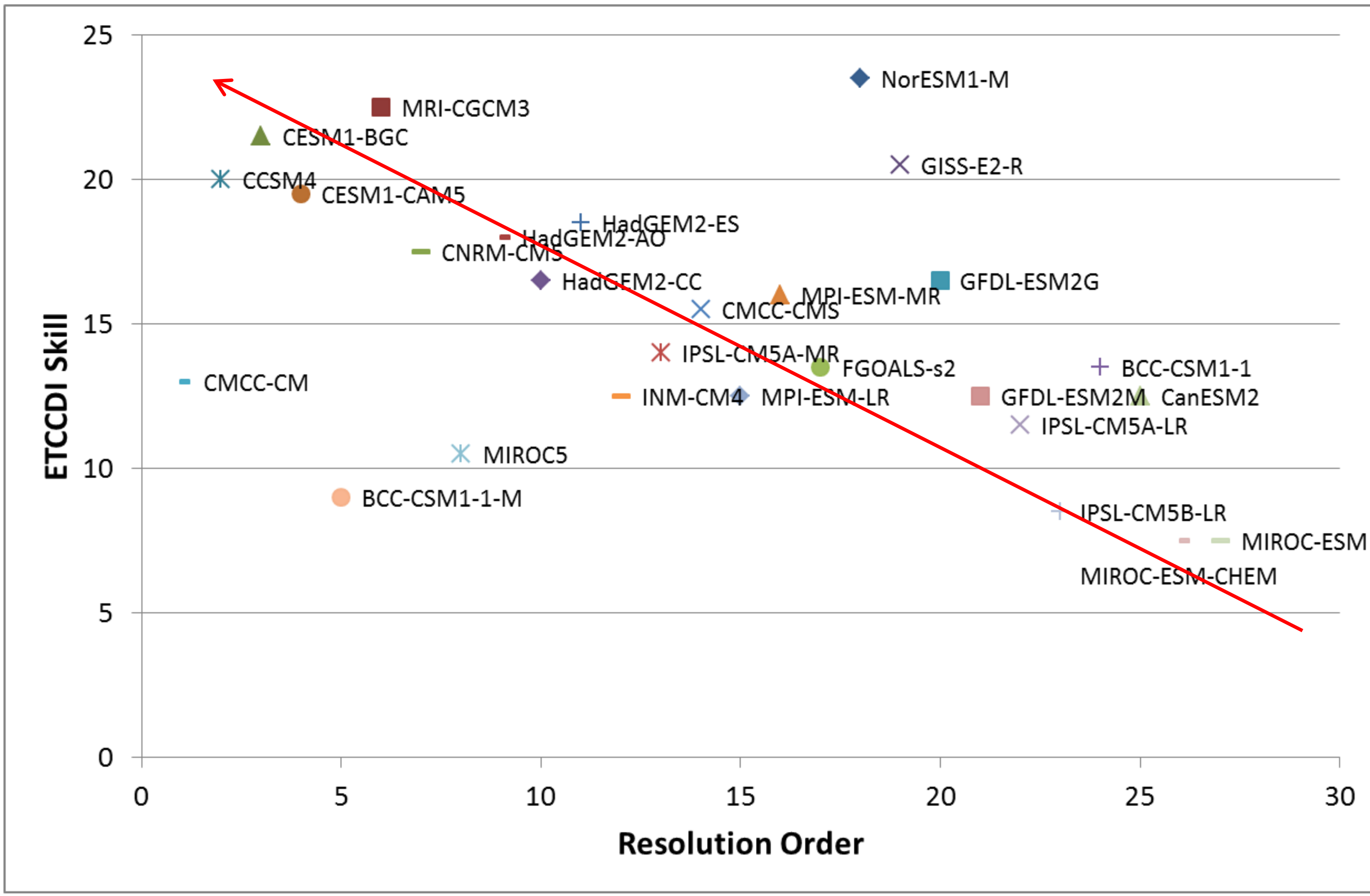
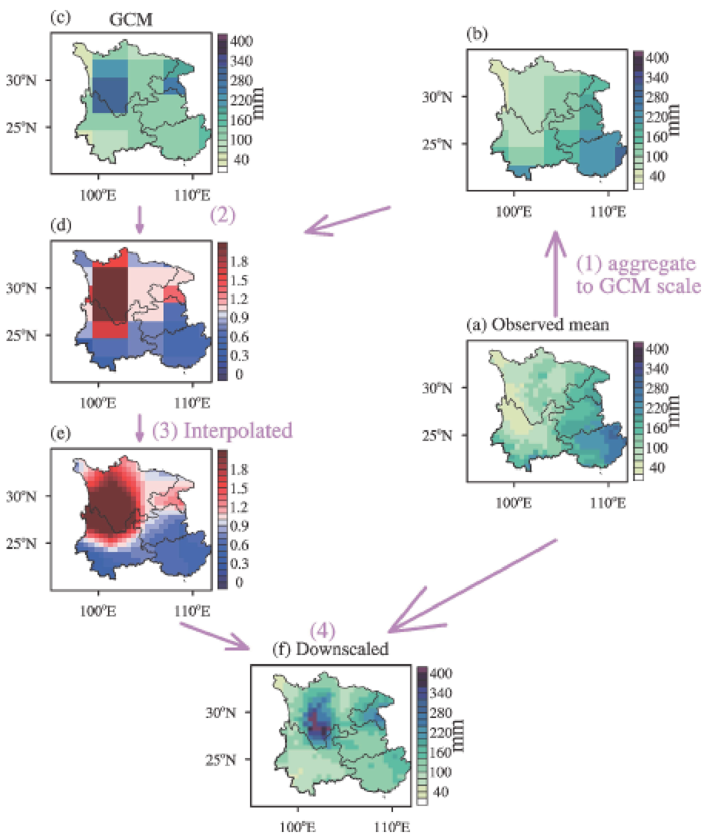
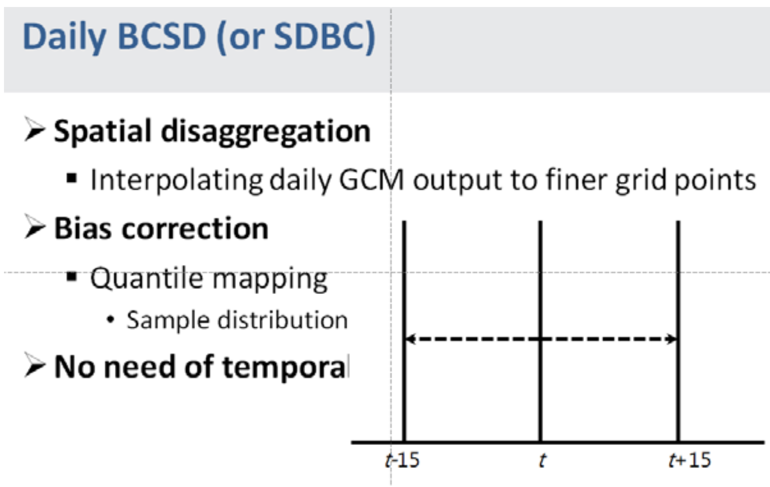
➢ **Performance by the spatial resolution of climate models**



Statistical downscaling

➢ Bias Correction & Spatial Disaggregation (BCSD)



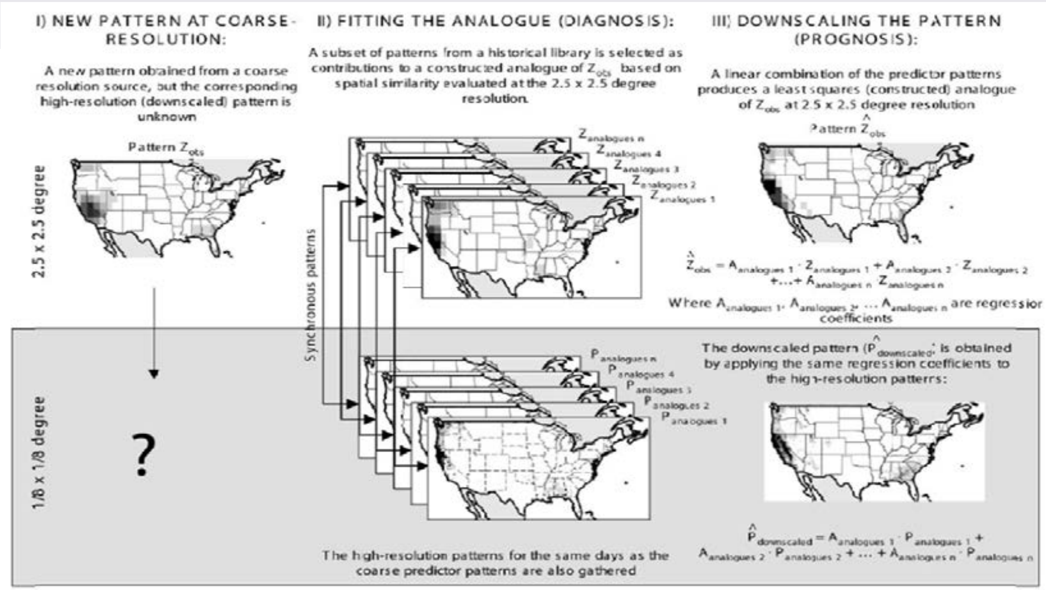


✓ Bias-Correction/Constructed Analogue (BCCA)

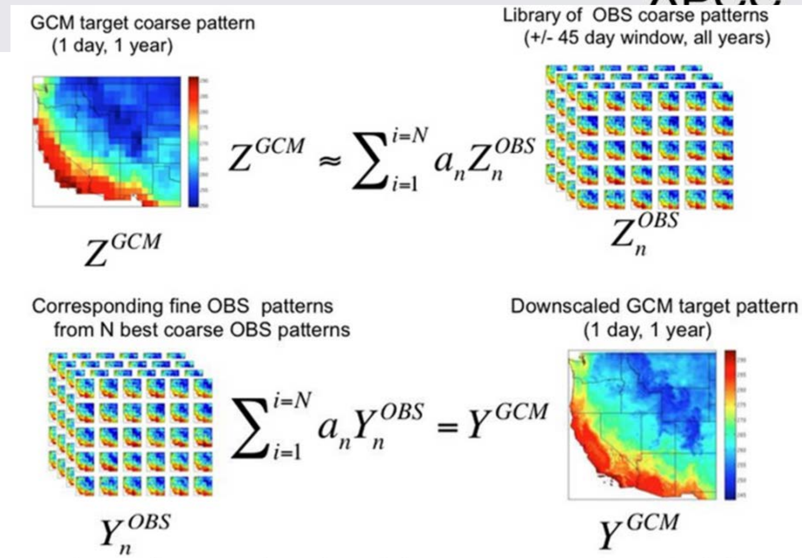
✓ Multivariate Adaptive Constructed Analogs (MACA)

✓ Bias-Correction/Climate Imprint (BCCI)

Source: Lin W, Wen C, Wen Z. (2014) Advances in Atmospheric Sciences



Source: Hidalgo et al. (2008)



Source: http://climate.northwestknowledge.net/MACA/MACAmethod.php

Multivariate Adaptive CA (MACA)

http://climate.northwestknowledge.net/MACA/index.php


Multivariate Adaptive Constructed Analogs(MACA) Statistical Downscaling Method

University of Idaho

MACA Home | ABOUT THE DATA | VISUALIZATIONS | GET THE DATA | GUIDANCE | CONTACT

CMIP5 Statistically Downscaled for Coterminous USA (CONUS)

The Multivariate Adaptive Constructed Analogs(MACA)(Abatzoglou, Brown, 2011) method is a statistical downscaling method which utilizes a training dataset (i.e. a meteorological observation dataset) to remove historical biases and match spatial patterns in climate model output.

We have used MACA to downscale the model output from 20 global climate models (GCMs) of the Coupled Model Inter-Comparison Project 5 (CMIP5) for the historical GCM forcings (1950-2005) and the future Representative Concentration Pathways (RCPs) RCP 4.5 and RCP8.5 scenarios (2006-2100) from the native resolution of the GCMS to either 4-km or ~6-km.

The MACA dataset is unique in that it downscales a large set of variables making it ideal for different kinds of modeling of future climate (i.e. hydrology, ecology, vegetation, fire, wind). We currently have data for the following variables:

- tasmax - Maximum daily temperature near surface
- tasmin - Minimum daily temperature near surface
- rhsmax - Maximum daily relative humidity near surface
- rhsmin - Minimum daily relative humdity near surface
- huss - Average daily specific humidity near surface
- pr - Average daily precipitation amount at surface
- rsds- Average daily downward shortwave radiation at surface
- was - Average daily wind speed near surface
- uas - Average daily eastward component of wind near surface
- vas - Average daily northward component of wind near surface

We are currently dispensing 3 data products: MACAv1-METDATA, MACAv2-METDATA and MACAv2-LIVNEH.

- MACAv1-METDATA is available for the Western USA, while MACAv2-LIVNEH/MACAv2-METDATA are available over the entire coterminous USA.
- MACAv2-LIVNEH/MACAv2-METDATA both use the newest version of the MACA method (version 2), while MACAv1-METDATA uses version 1. Both methods are very

Bias Correction/Climate Imprint (BCCI)

- **Bias correction at coarse grid: Quantile mapping**
- **Adjustment by long-term average climate maps**
  - E.g. 30-year average ($P_{monthly}$ & $T_{monthly}$) at stations

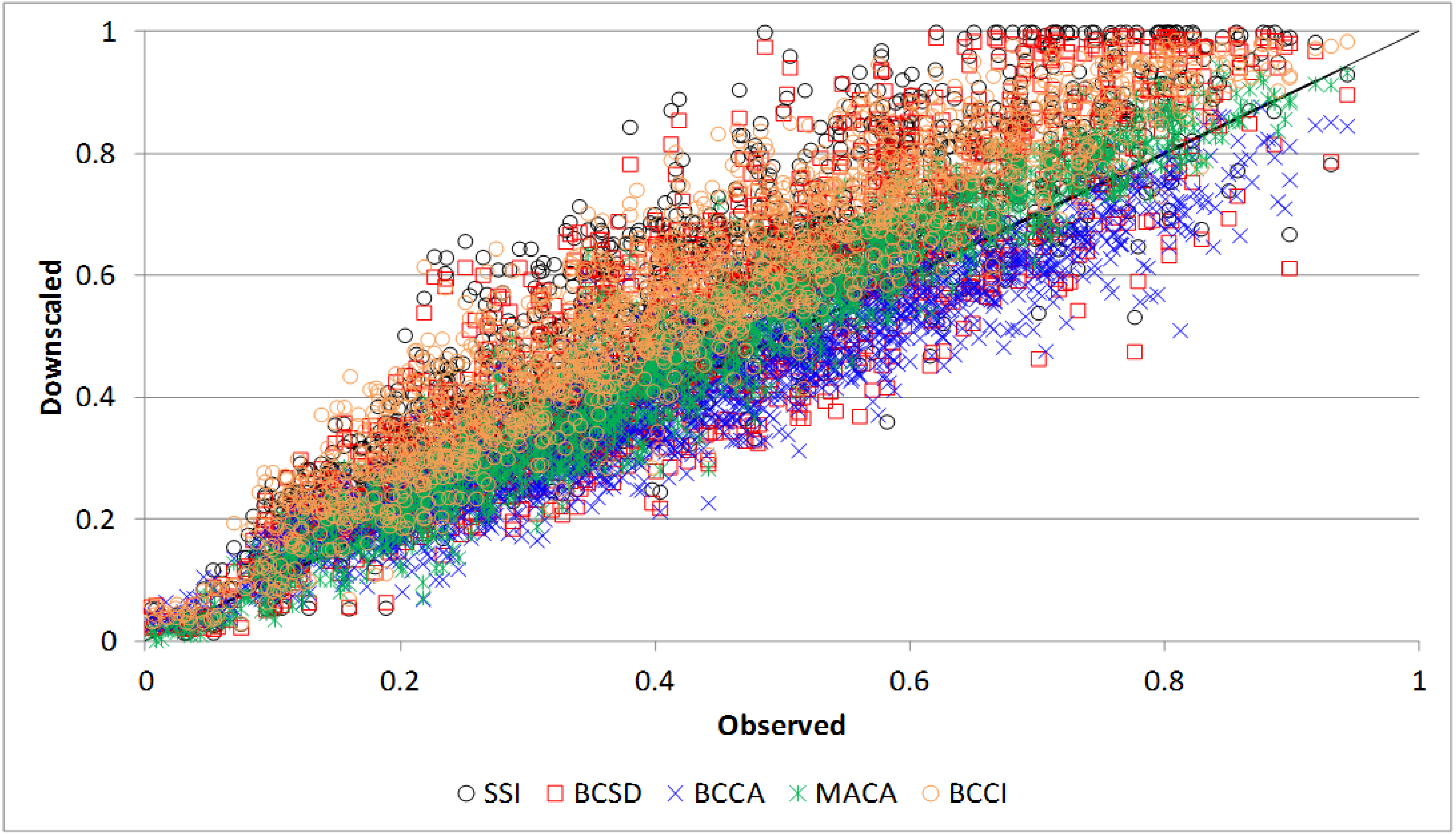
$$P_{ratio} = \frac{P_{daily}}{P_{monthly}} \quad \text{at a large grid}$$

$$P_{daily} = P_{interpolated\ ratio} P_{monthly} \quad \text{at a fine grid}$$

$$T_{difference} = T_{montly} - T_{daily} \quad \text{at a large grid}$$

$$T_{daily} = T_{monthly} - T_{interpolated\ difference} \quad \text{at a fine grid}$$

➢ **Spatial correlation of summer (JJA) precipitation**



➢ Seasonal correlation of each variable

	TMAX				TMIN				PRCP			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
SSI	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BCSD												
BCCA												
MACA												
BCCI												

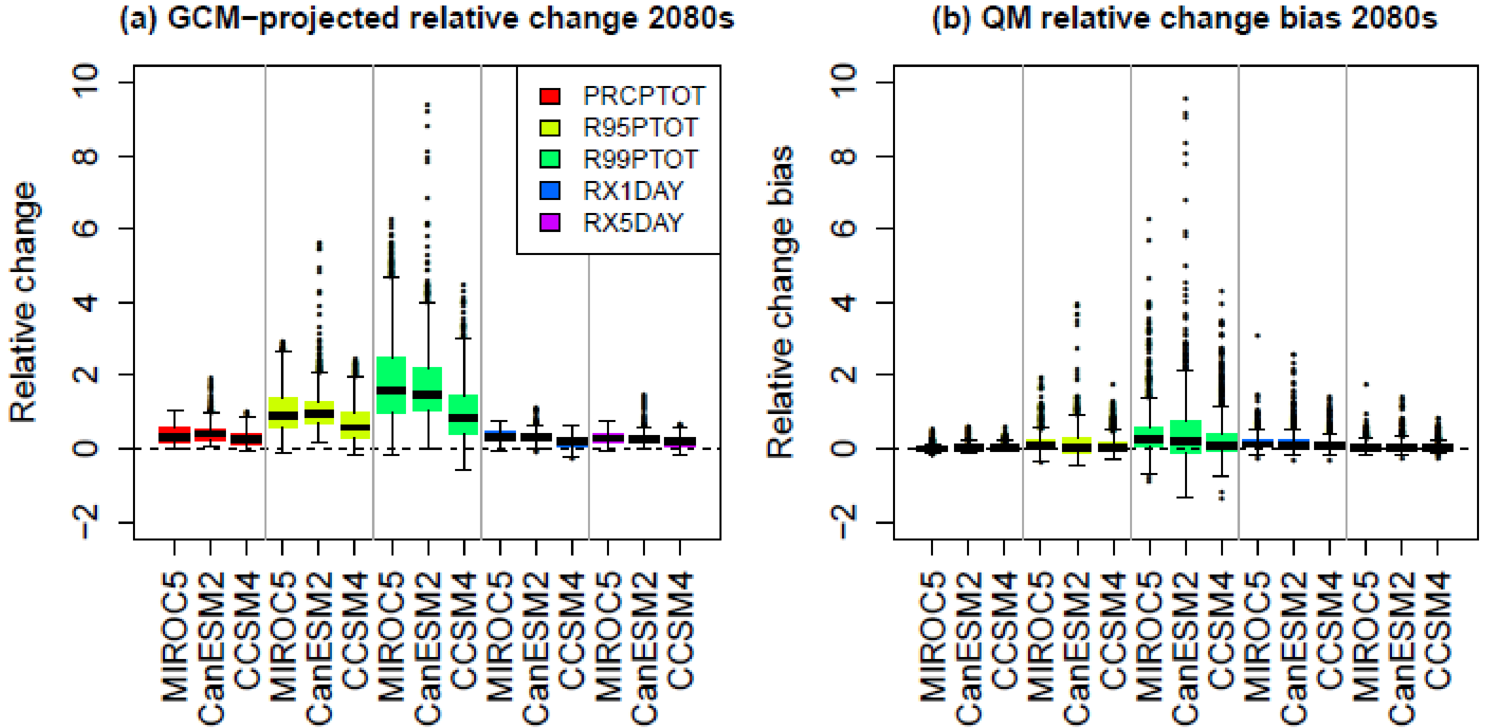
➢ K-S D statistic

	TMAX				TMIN				PRCP			
	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter
SSI	0.195	0.279	0.165	0.188	0.119	0.174	0.122	0.216	0.276	0.379	0.303	0.353
BCSD	**0.051**	0.053	**0.044**	**0.094**	**0.054**	**0.053**	**0.053**	**0.099**	0.020	**0.027**	**0.022**	0.034
BCCA	0.053	**0.052**	0.045	0.097	0.055	**0.053**	0.054	0.101	**0.019**	0.028	0.023	**0.033**
MACA	0.053	**0.052**	0.045	0.097	0.055	0.054	0.054	0.101	0.020	0.028	0.023	**0.033**
BCCI	0.053	**0.052**	0.045	0.099	0.056	**0.053**	**0.053**	0.102	**0.019**	**0.027**	0.023	**0.033**

Problem of BCSD downscaling

- ✓ Strongly rely on an assumption of stationarity
- ✓ Extrapolation required for values outside of historical range
- ✓ Inflation of projected values from GCMs

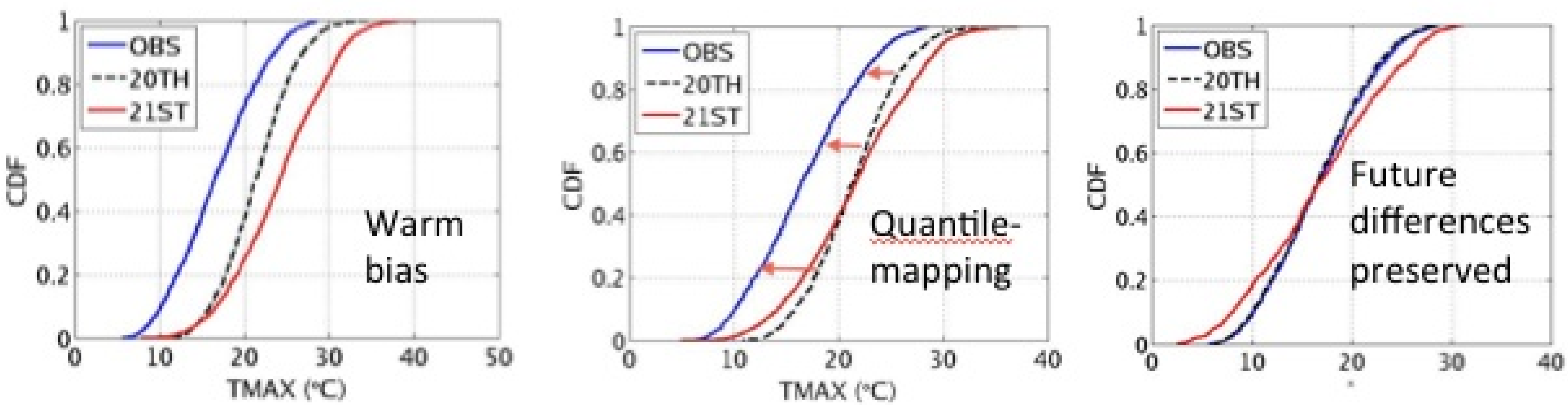
Relative change bias =
change in GCM (%) – change in downscaled data (%)



Source: Cannon et al. (2015)

➢ BCSD-Detrended Quantile Mapping (DQM)

- ✓ **Account for changes in the projected values**
- ✓ **Removing the modelled trend in the long-term mean**
- ✓ **Re-imposing it after QM**
- ✓ **Reflecting only mean change between reference and future periods**



Raw GCM Data

After Epoch Adjustment

After Bias Correction

Source: http://climate.northwestknowledge.net/MACA/MACAmethod.php

➢ BCSD-Quantile Delta Mapping (QDM)

- ✓ **Preserving model-projected relative changes in all quantiles**
- ✓ **Correcting systematic biases in quantiles**

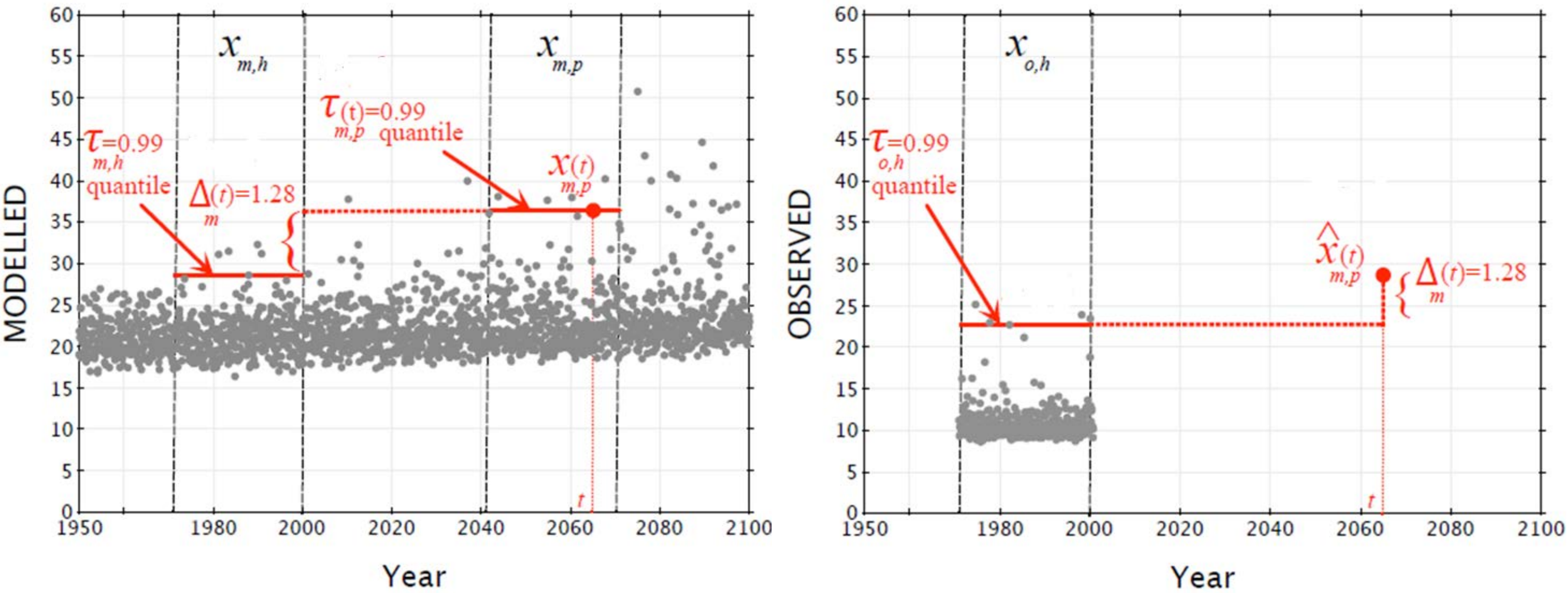


Figure from Cannon et al. (2015)

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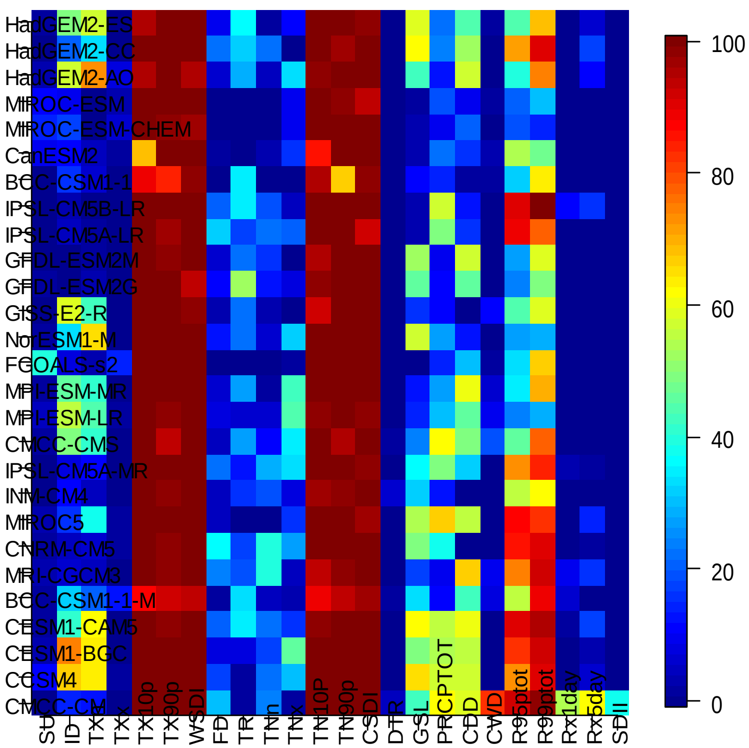
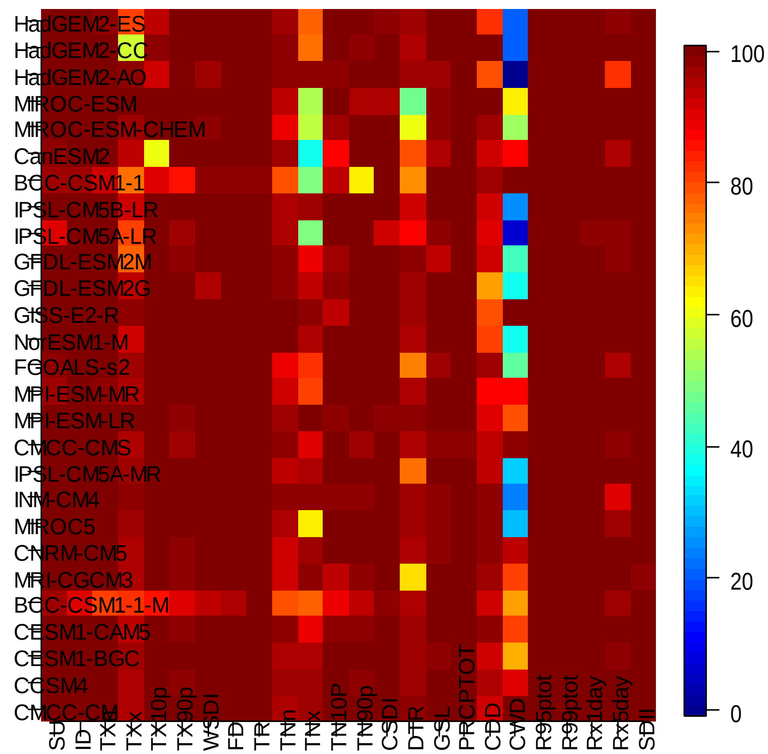
➤ Proportion of passing K-S test (60 weather stations)



Before BCSD-QDM

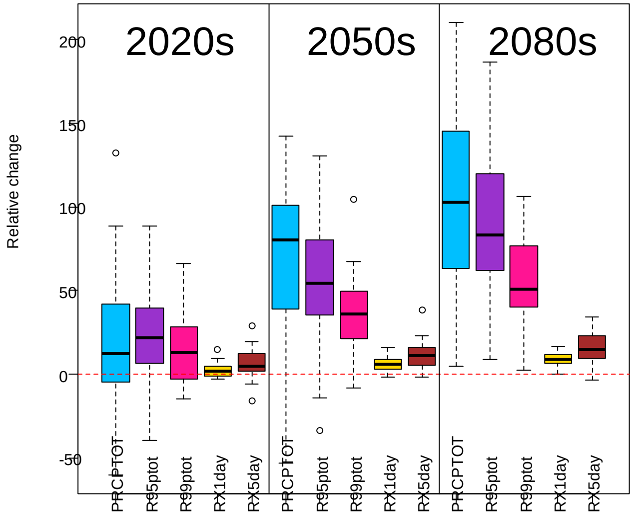


After BCSD-QDM

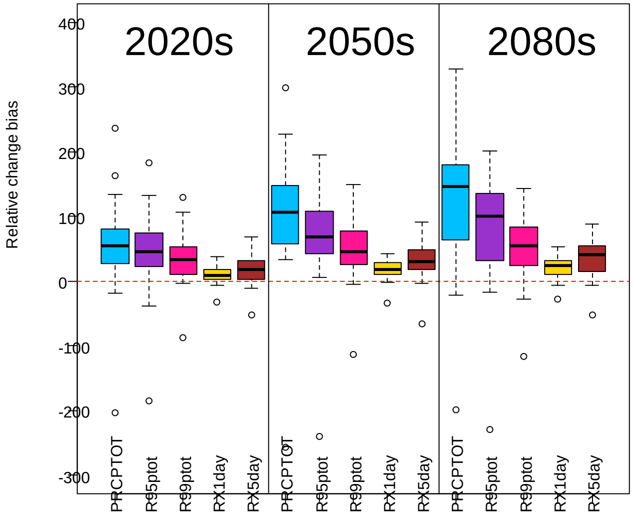
➢ ETCCDI related to PRCP

Relative change bias = change in GCM (%) – change in downscaled data (%)

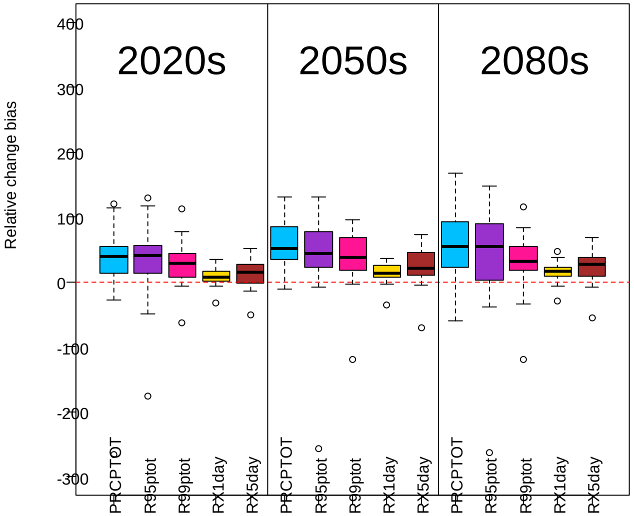
GCMs



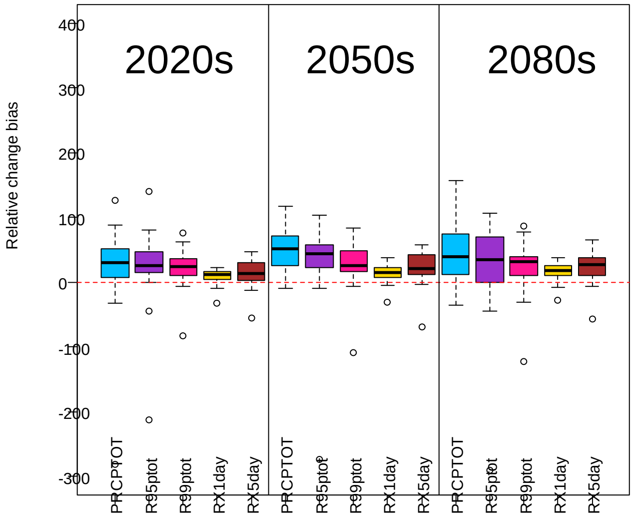
QM



DQM



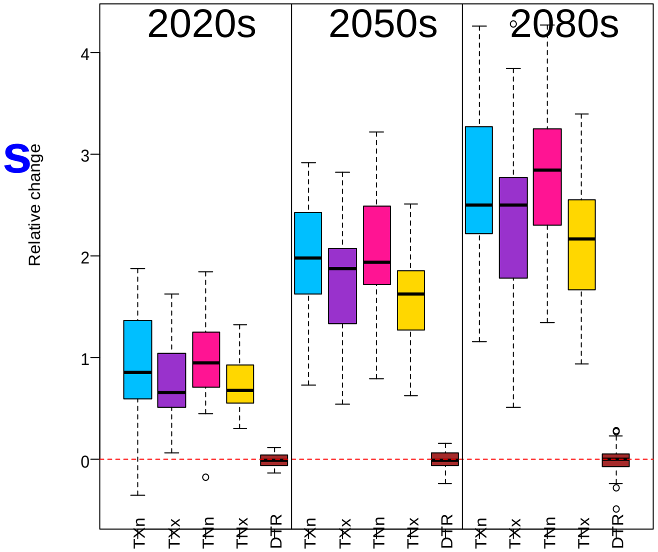
QDM



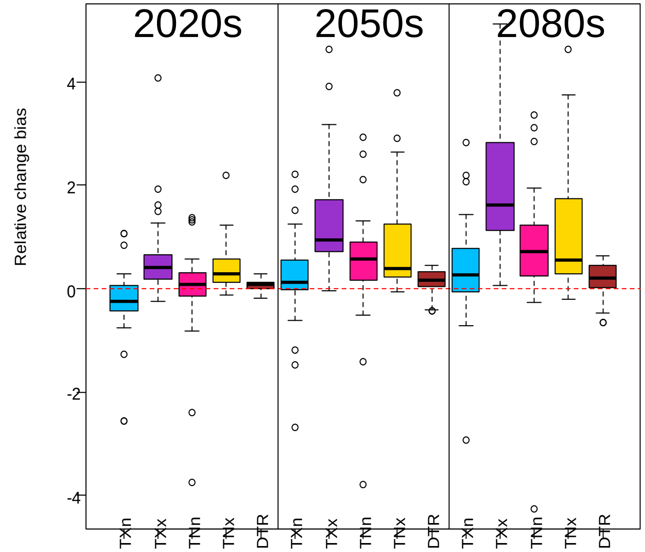
➢ ETCCDI related to Tmax & Tmin

Relative change bias = change in GCM (%) – change in downscaled data (%)

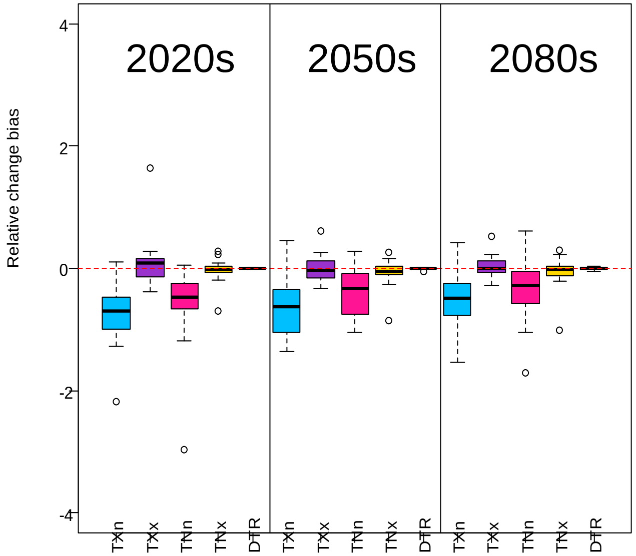
GCMs



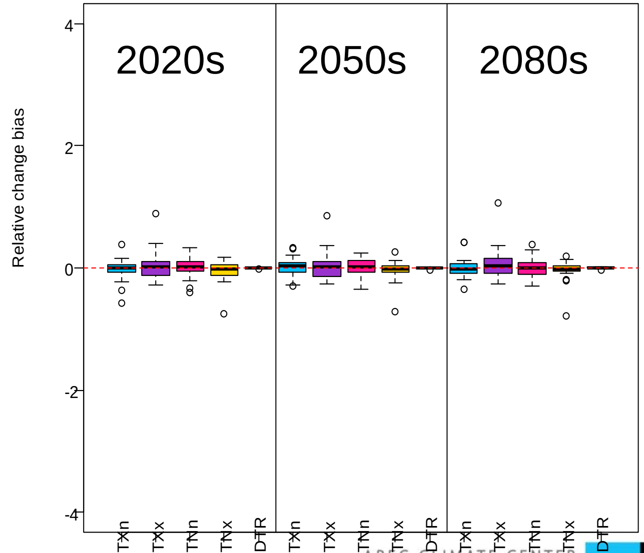
QM



DQM

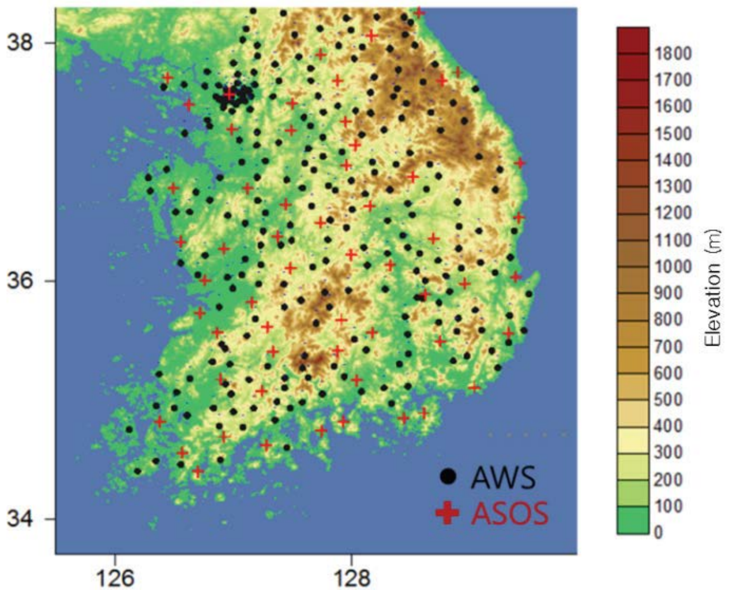


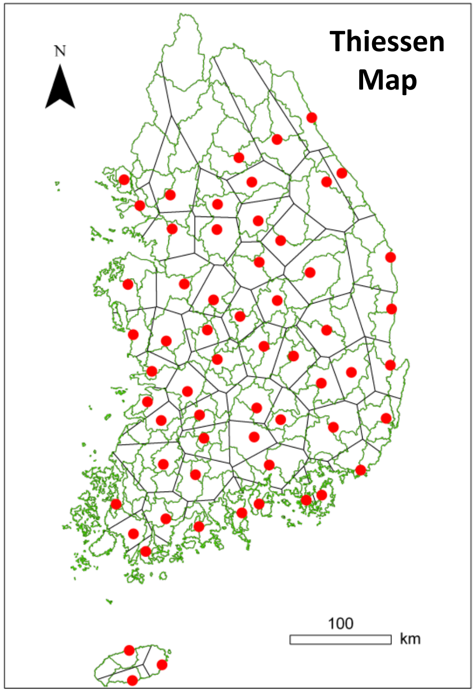
QDM



➢ Statistically-downscaled scenarios

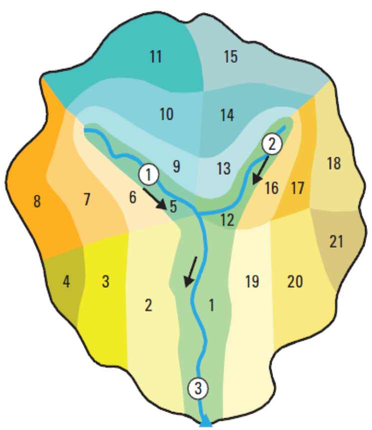
- ✓ Spatial scale : 60 ASOS weather stations
- ✓ Climate variables : daily precipitation, max. temperature and min. temperature
- ✓ Data period : Reference (1976-2005), Future (2006-2099)
- ✓ RCP 4.5 scenario (done) & RCP 8.5 scenario (ongoing)
- ✓ Basin-areal averaged scenarios for 109 mid-size watershed

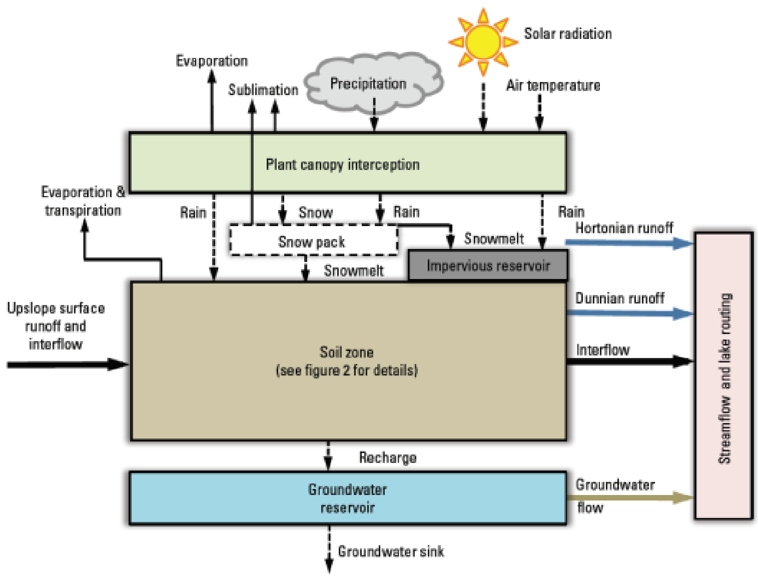




Hydrologic modeling

- **Precipitation-Runoff Modeling System (PRMS)**
  - ✓ **U.S. Geological Survey (USGS)**
  - ✓ **Deterministic, Physically-based semi-distributed model**
  - ✓ **Simulation of hydrologic response according to climate and land use changes at watershed scales**





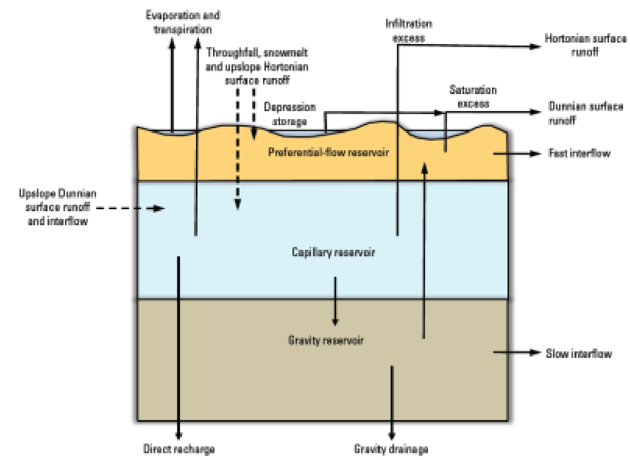
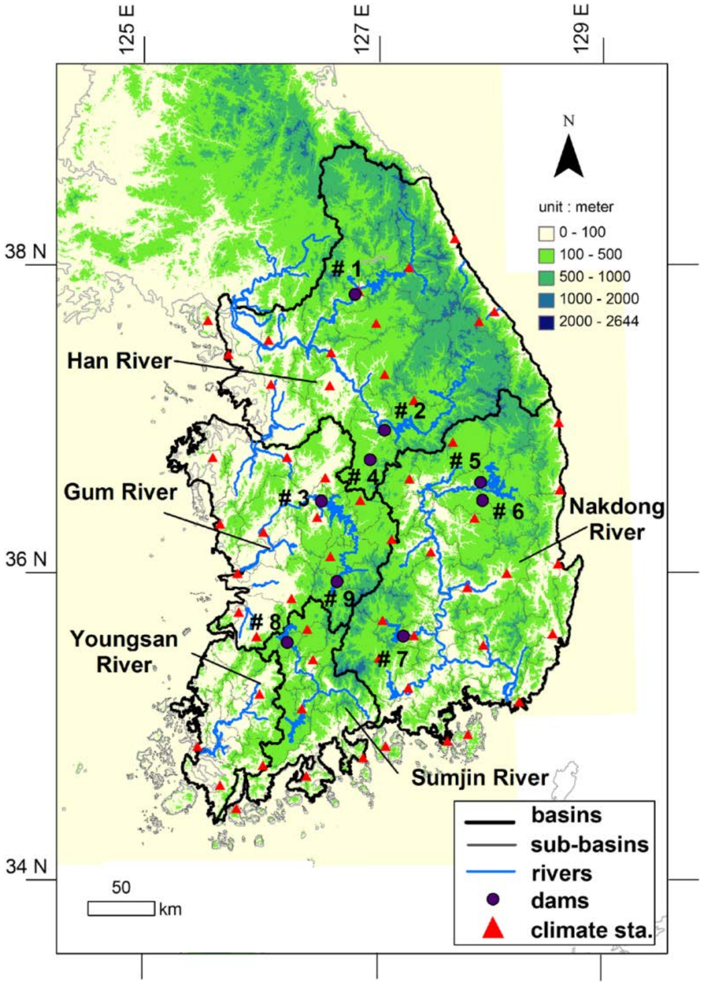


Figure 2. Details of the Precipitation-Runoff Modeling System Soil Zone.

Figure from USGS (2008)

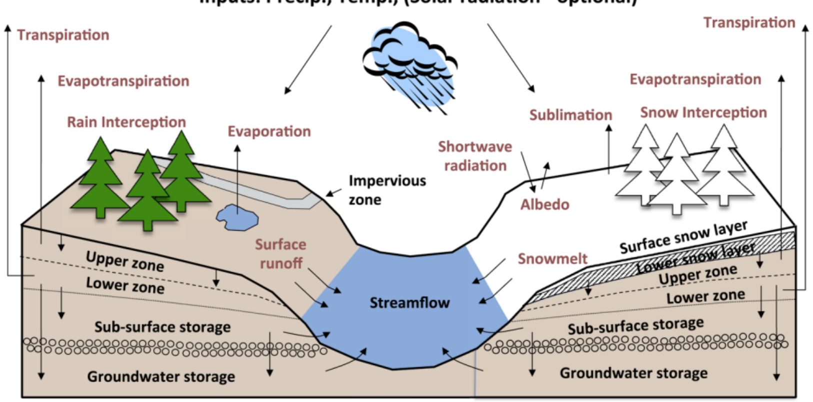
➢ PRMS model parameters calibration and regionalization



- ✓ Extract geophysical parameters associated with GIS layers (DEM, Soil, Land use etc.)
- ✓ Optimization sensitive parameters (21) which are associated with linear or non-linear equations to compute surface, subsurface, and groundwater using SCE-UA (NSE > 0.6) (Jung et al., 2013)
- ✓ Regionalization of calibrated parameters for ungauged basins. This study used a regionalization method based on physical similarity (Lee et al., 2009; Jung et al., 2013)

Description of PRMS model parameters for optimization

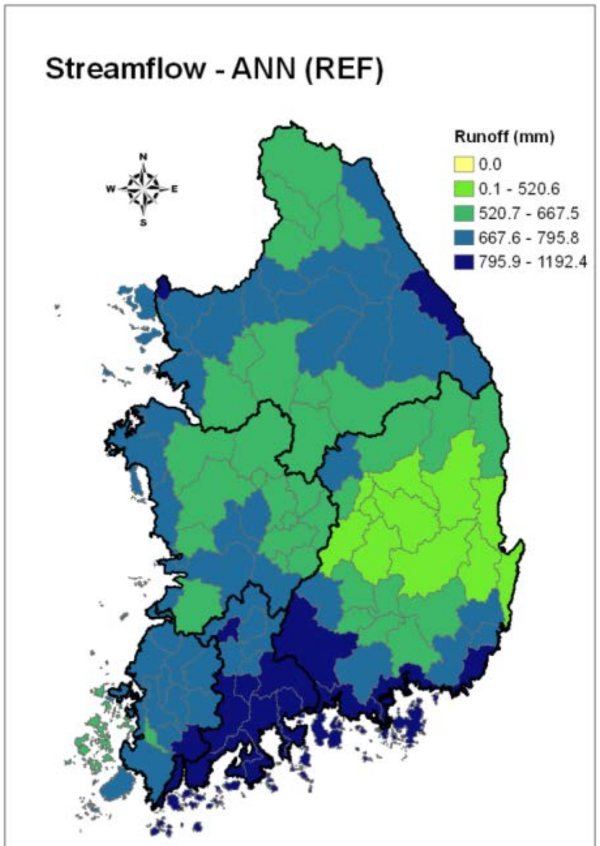
PRMS Model Structure

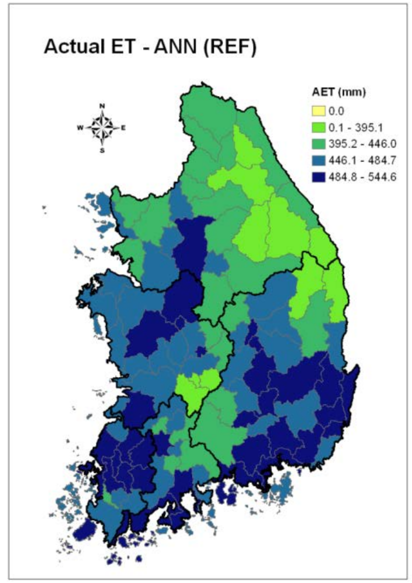


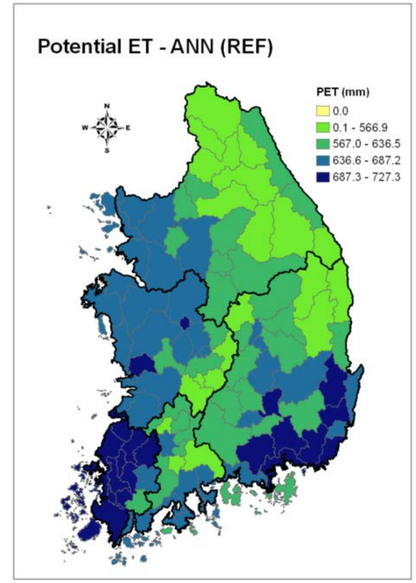
Source: USGS open-file Report 2012-1274

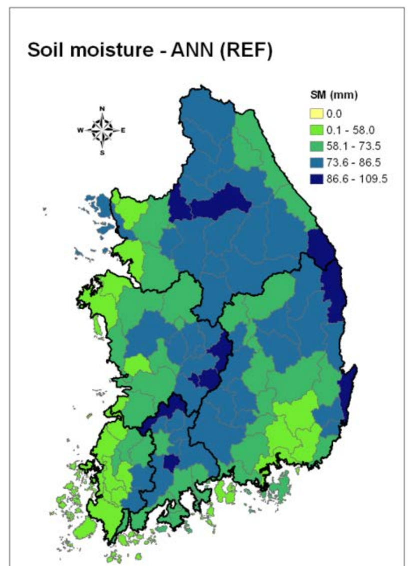
Parameter	Description	Range
adjmix_rain	Monthly factor to adjust rain proportion in a mixed rain/snow event	0.0001 ~ 3.0
cecn_coef	Monthly convection condensation energy coefficient	0.0001 ~ 20.0
emis_noppt	Average emissivity of air on days without precipitation	0.757 ~ 1.0
freeh2o_cap	Free-water holding capacity of snowpack	0.01 ~ 0.2
potet_sublim	Fraction of potential ET that is sublimated from snow in the canopy and snowpack	0.1 ~ 0.75
tmax_allrain	Monthly maximum air temperature when precipitation is assumed to be rain	20.0 ~ 50.0
tmax_allsnow	Monthly maximum air temperature when precipitation is assumed to be snow	20.0 ~ 40.0
snowinfil_max	Maximum snow infiltration per day	1.0 ~ 20.0
soil_moist_max	Maximum available water holding capacity	3.0 ~ 10.0
soil2gw_max	Maximum amount of the capillary reservoir excess	0.0001 ~ 5.0
sat_threshold	Water holding capacity of the gravity and preferential flow reservoirs	1.0 ~ 20.0
smidx_coef	Fraction percolating from upper to lower zone free water storage	0.0001 ~ 1.0
smidx_exp	Exponent in non-linear contributing area	0.2 ~ 0.8
fastcoef_lin	Degree-day factor	0.0001 ~1.0
fastcoef_sq	Temperature criteria at which snow begin to melt	0.0001 ~ 1.0
slowcoef_lin	Linear coefficient in equation to route preferential flow storage	0.0001 ~ 1.0
slowcoef_sq	Non-linear coefficient in equation to route gravity reservoir storage	0.0001 ~ 1.0
ssr2gw_exp	Non-linear coefficient in equation used to route water from the gravity reservoirs to the groundwater reservoir	0.8 ~ 1.2
ssr2gw_rate	Linear coefficient in equation used to route water from the gravity reservoir to the groundwater reservoir	0.0001 ~1.0
pref_flow_den	Fraction of the soil zone in which preferential flow occurs	0.1 ~ 1.0
gwflow_coef	Linear coefficient in the equation to compute groundwater discharge	0.0001 ~1.0

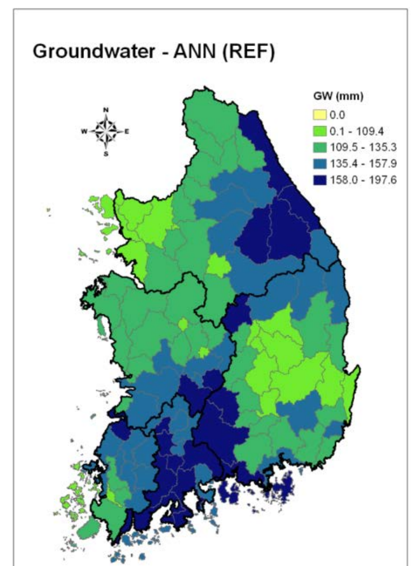
- **Streamflow simulation for 1976-2005 using PRMS**





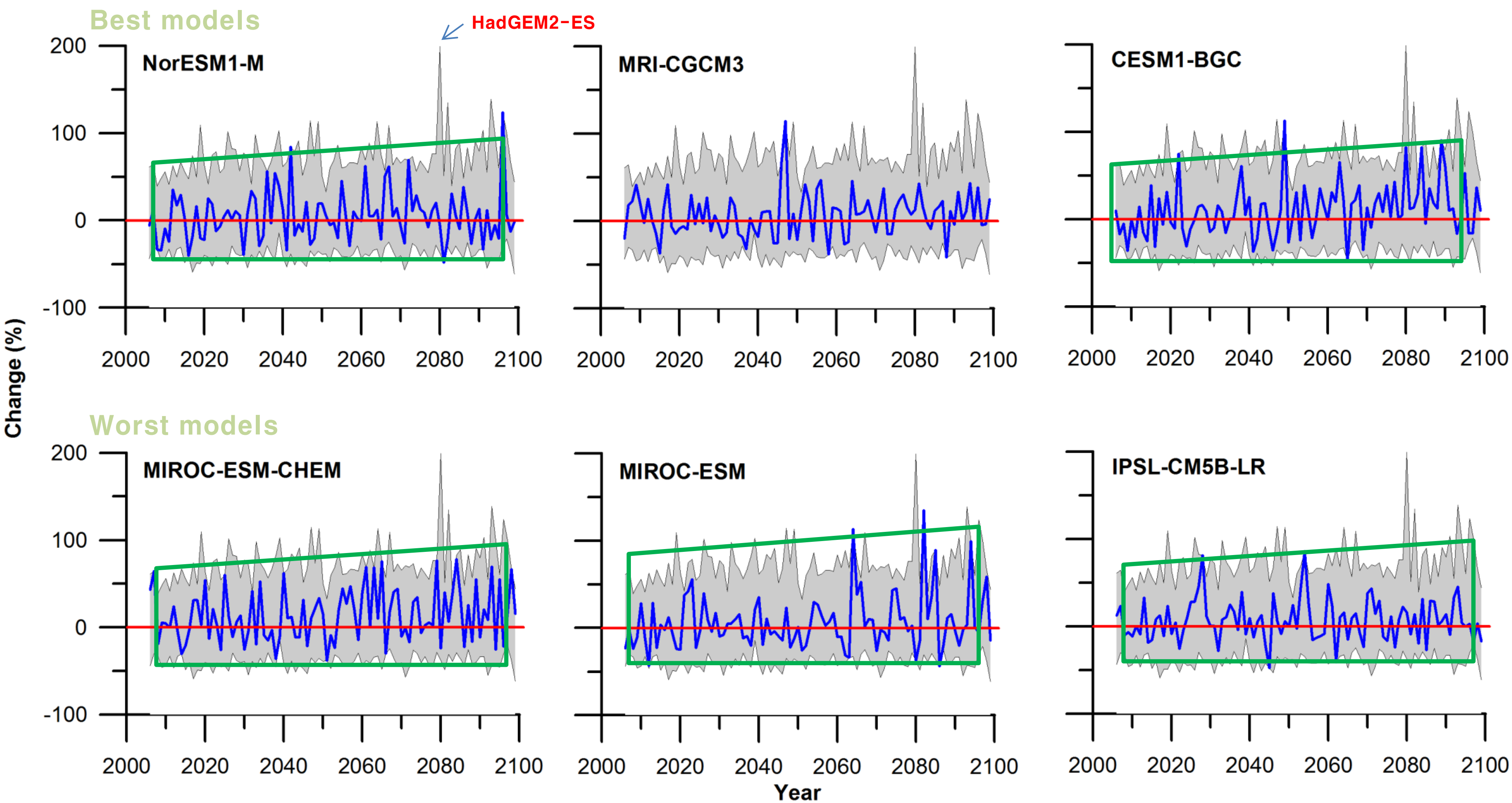




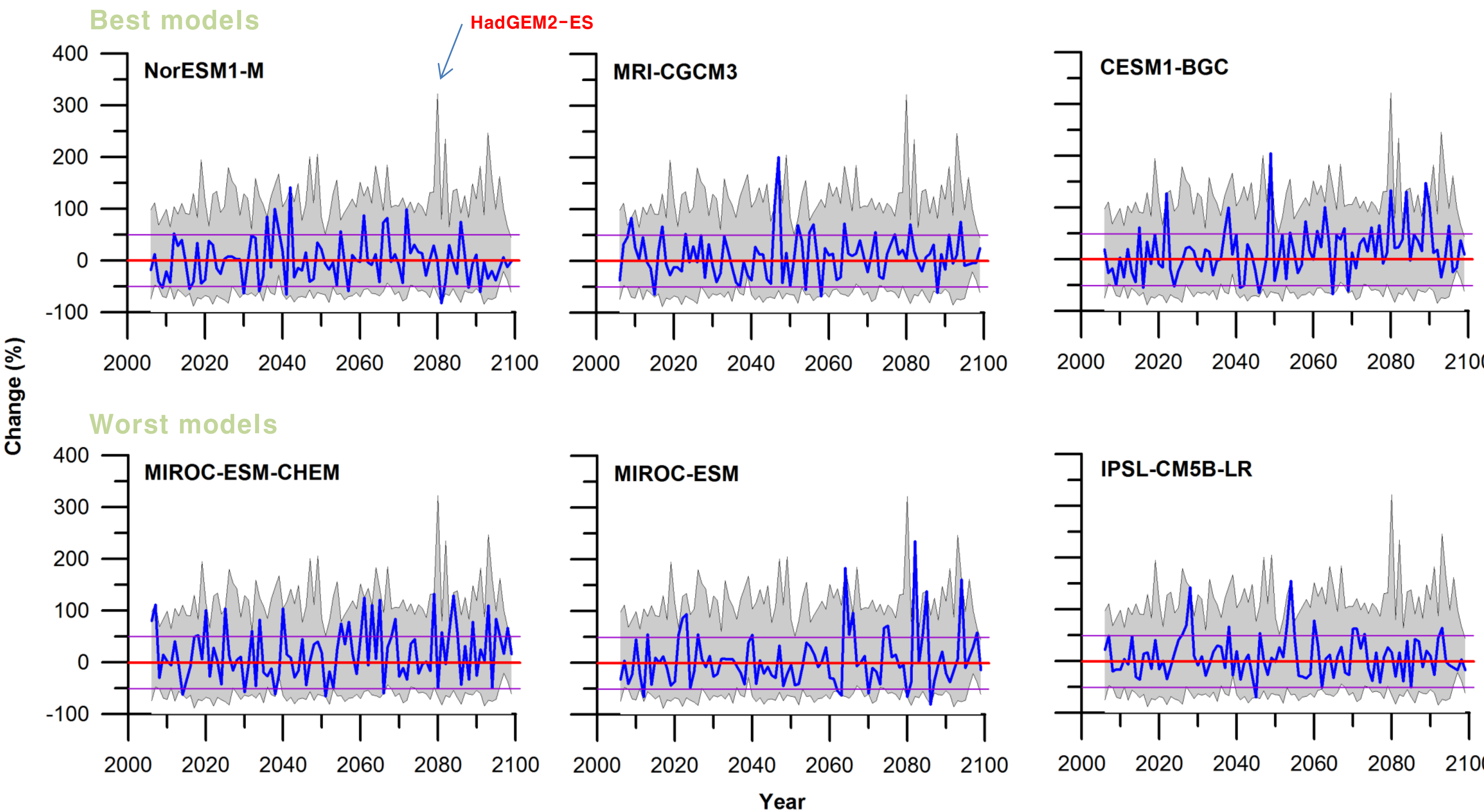


Change in annual precipitation (Nakdong)

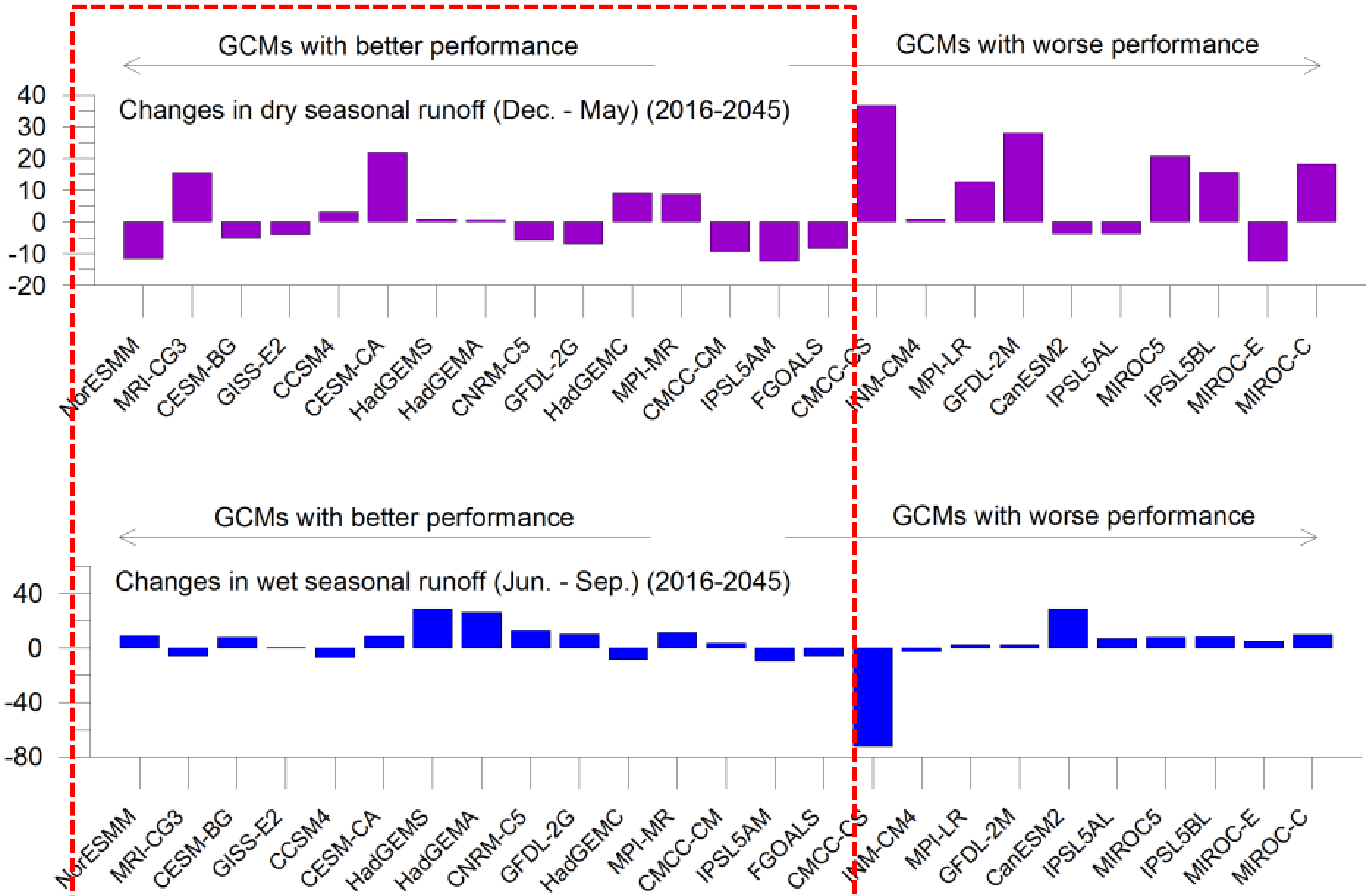
APCC
APEC CLIMATE CENTER



Change in annual streamflow (Nakdong)

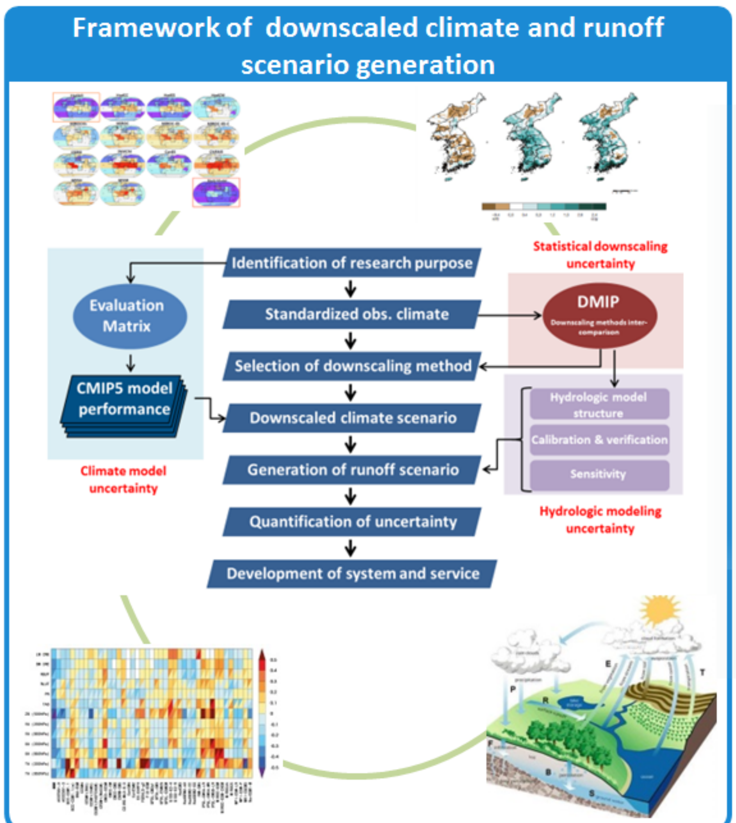


Change in seasonal streamflow (Nakdong)



Expectation and utilization

- ✓ Improving the reliability of climate change research through generating scenarios by a systemized downscaling process
- ✓ Preventing inefficient and redundant investment for producing downscaled climate and runoff scenarios for climate impact and vulnerability assessments
- ✓ Timely updating of downscaled climate and runoff scenarios when a new scenario (e.g., IPCC AR6) is developed



Development of downscaling and service system

Project Agency

Related organizations

Providing downscaled climate and runoff scenarios

- Support other research teams to be able to conduct impact and vulnerability assessment and to develop adaptation strategies
- Support to develop better multipurpose dam operation rules under climate change and to establish national long-term planning for sustainable water resources management

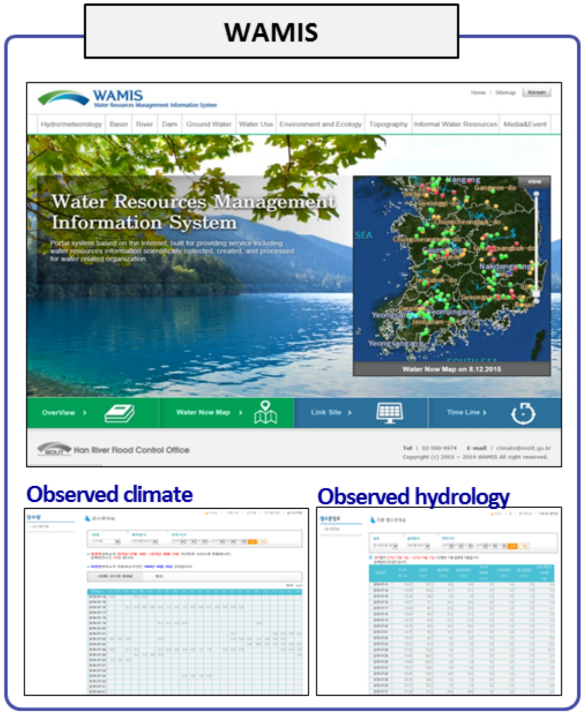
Service through the developed system

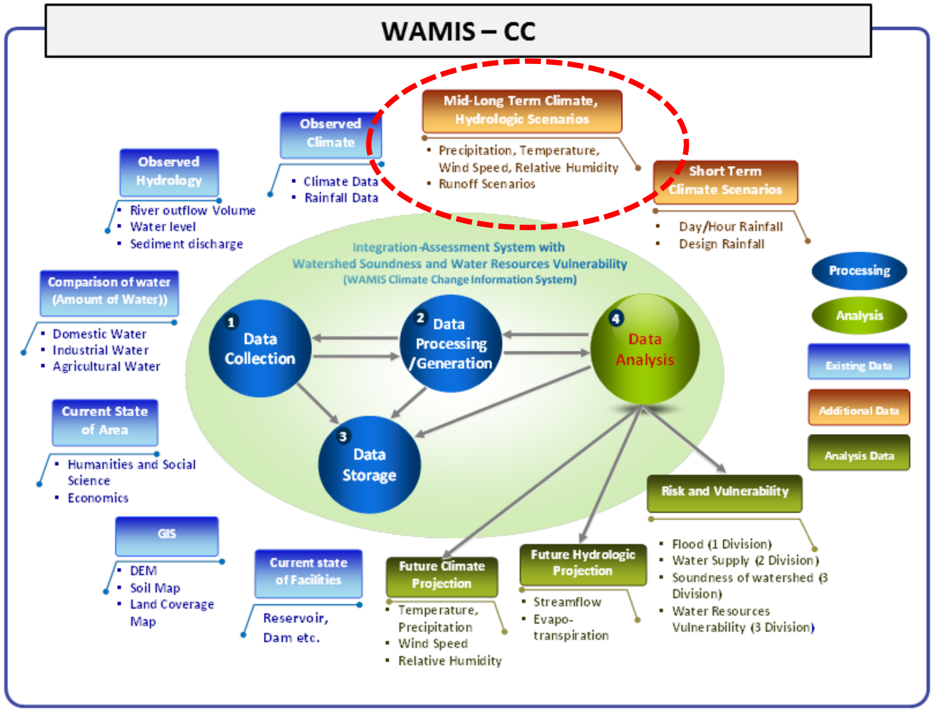
- Provide enhanced accessibility to downscaled climate change information through a web-based system
- Provide useable and useful climate information for developing adaptation strategies of central and local governments
- Provide climate information to climate-sensitive sectors such as agriculture, environment, and forestry

Expectation and utilization

National WAMIS extension including water-related climate change information

- WAMIS (Water Management Information System) : the water resources information scientifically collected, created, and processed for water related organization
- WAMIS-CC : the system that provide climate change scenario, climate change impact and vulnerability assessment result in addition to existing WAMIS data

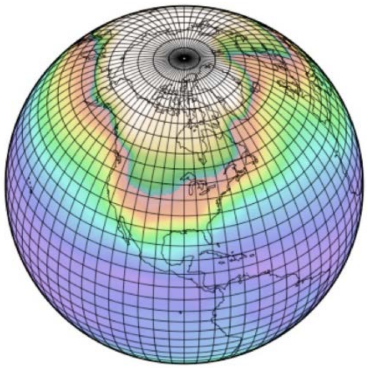


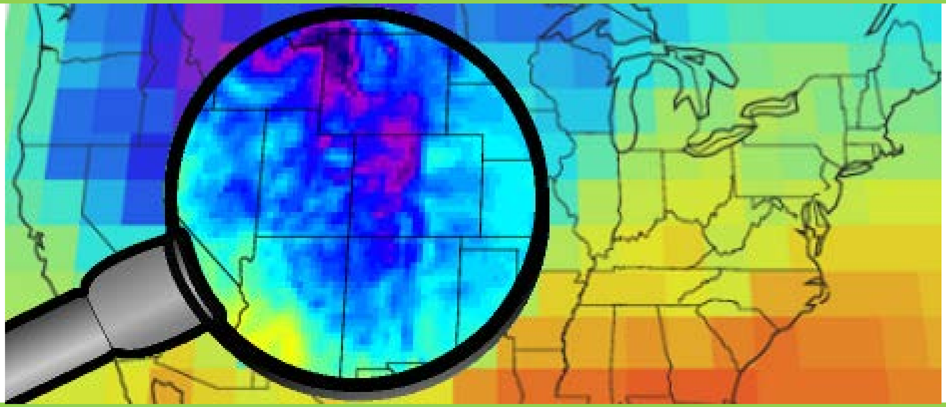


Source: CCAW (2015)

Thank you for your attention !

Climate Change Impact Assessment on Agricultural Reservoirs in Korea under RCP Scenarios





2016/03/09

Jaepil Cho (APEC Climate Center)

Overview

1. **Background information**

2. **Downscaling and Data Analysis**

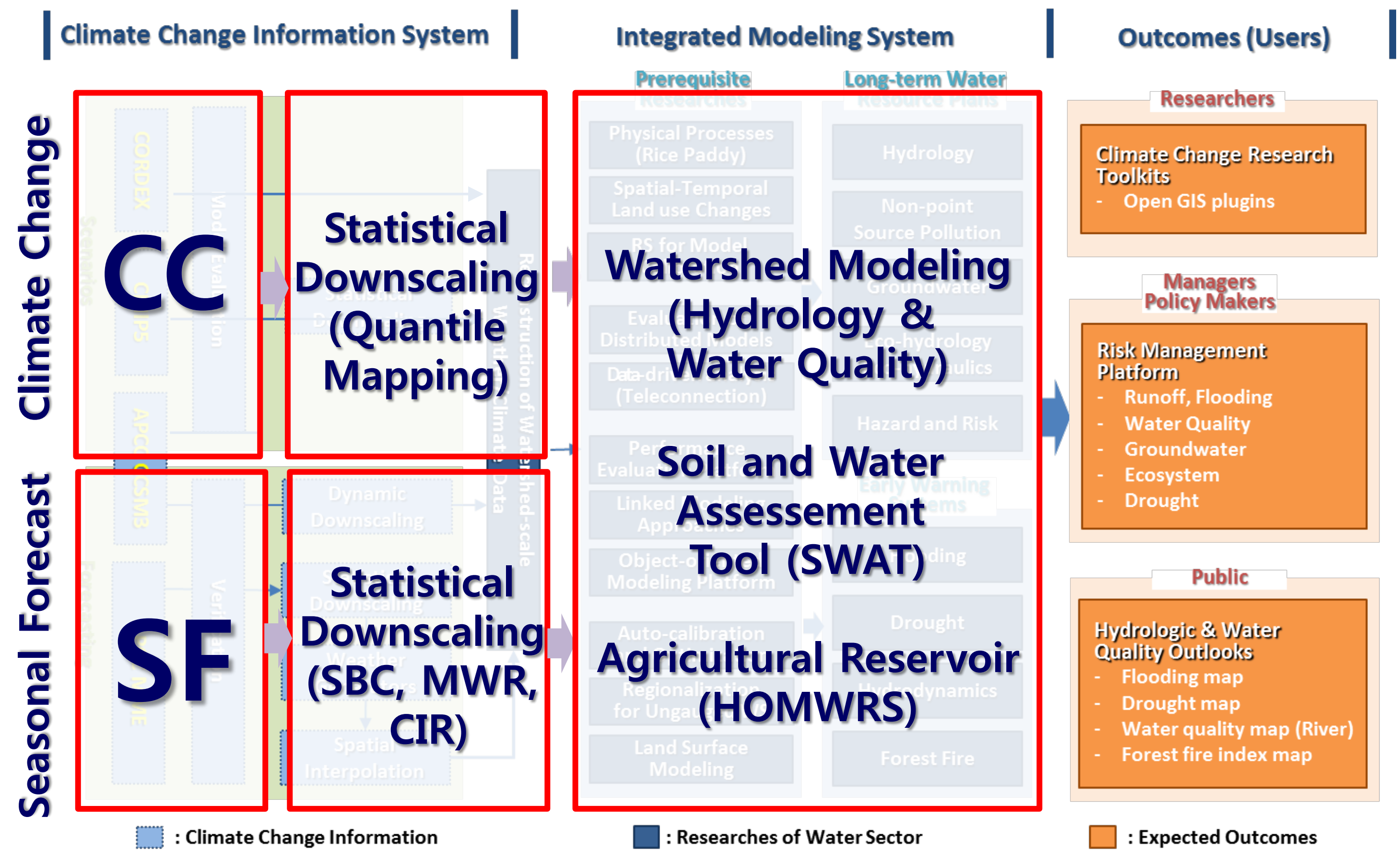
❖ Statistical downscaling (daily & Monthly)

❖ Precipitation index

3. **Impact Assessment on Reservoirs**

Background Information

❖ Framework of APCC Water Sector



Facilities for Agricultural Water Supply

(Source; KRCC, 2011)

Agricultural Facilities	Managed by KRC		Managed by Local Government		Total	
	Count	Area(ha)	Count	Area(ha)	Count	Area(ha)
Reservoirs	3,363	340,984 (65.4%)	14,206	112,327 (39.3%)	**17,569**	**453,311 (56.2%)**
Pumping Stations	4,077	166,142 (31.9%)	3,390	34,611 (12.1%)	7,467	200,753 (24.9%)
Weirs	5,887	13,669 (2.6%)	38,401	138,742 (48.6%)	44,288	152,411 (18.9%)
Total	13,327	520,795	55,997	285,680	69,324	806,475

- ❖ 62% of total water resources are used for agricultural water (2007)
- ❖ 80% of agricultural water are used for paddy irrigation during Apr-Sep.
- ❖ 80% of irrigation water for paddy areas are supplied from agricultural facilities
- ❖ 56% of total irrigated areas are supplied by agricultural reservoirs

Agricultural drought with respect to reservoirs

❖ Small agricultural reservoirs are vulnerable to climate change

Source: http://blog.daum.net/sangkunlee/969

Uncertainty in Future Projections of Climate Change

❖ How reliable are projections of future climate change scenarios?

Scenarios	Inflow	% Change
Historical	988.5	
RCP8.5: GFDL-ESM2G	1198.0	21.2
RCP8.5: inmcm4	953.7	-3.5

- **How decisions can be utilized when opposite signals are projected in the same watershed?**

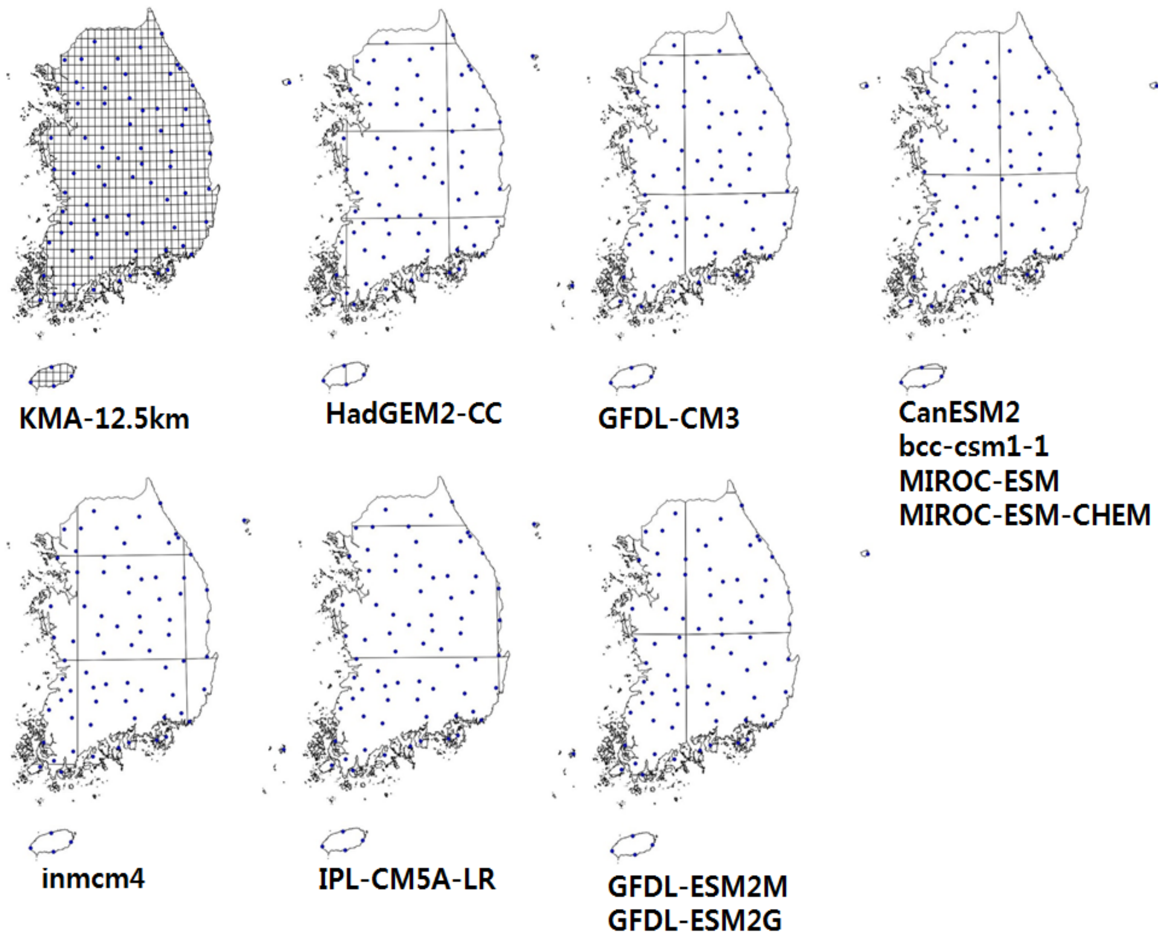
- **Even though MME-based projection shows same projection, what kind of additional information should be provided for decision-making?**

Scenarios	Inflow (mm)	% change
Historical	988.5	
RCP8.5	1078.1	9.1

Even though we have same future projection ..

Uncertainty
of future projections

Spatial resolution of GCMs in CMIP5



RCP8.5 Scenario

- KMA RCM
- 10 GCMs

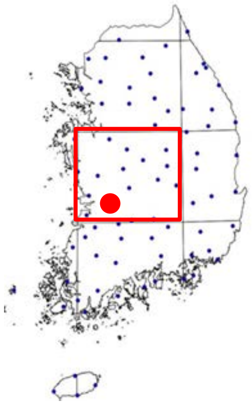
Climate Data

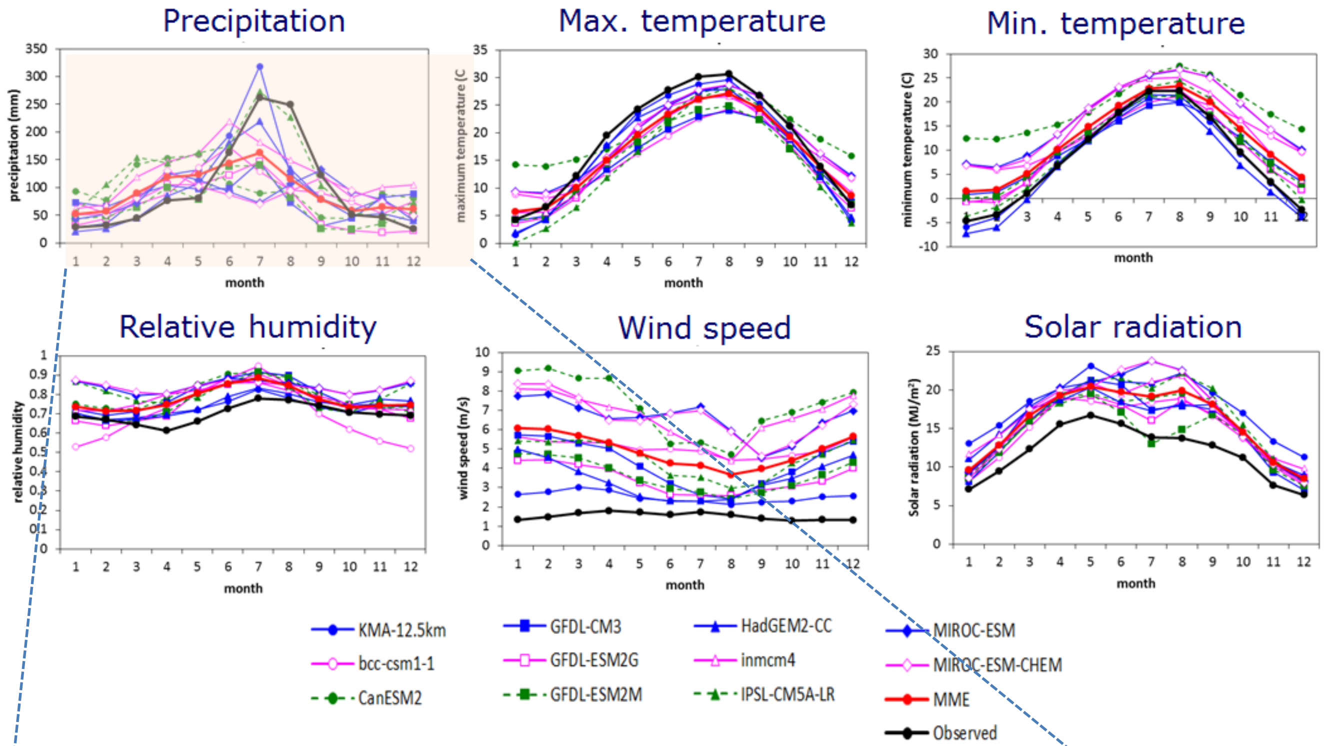
- Precipitation
- Min. temperature
- Max. temperature
- Wind speed
- Relative humidity
- Solar radiation

➡ **Downscaling is required**

Temporal comparison of monthly mean values

❖ Jeonju (1976~2005, Before Bias-Correction)





Historical (1976~2005) after Bias-Correction

?

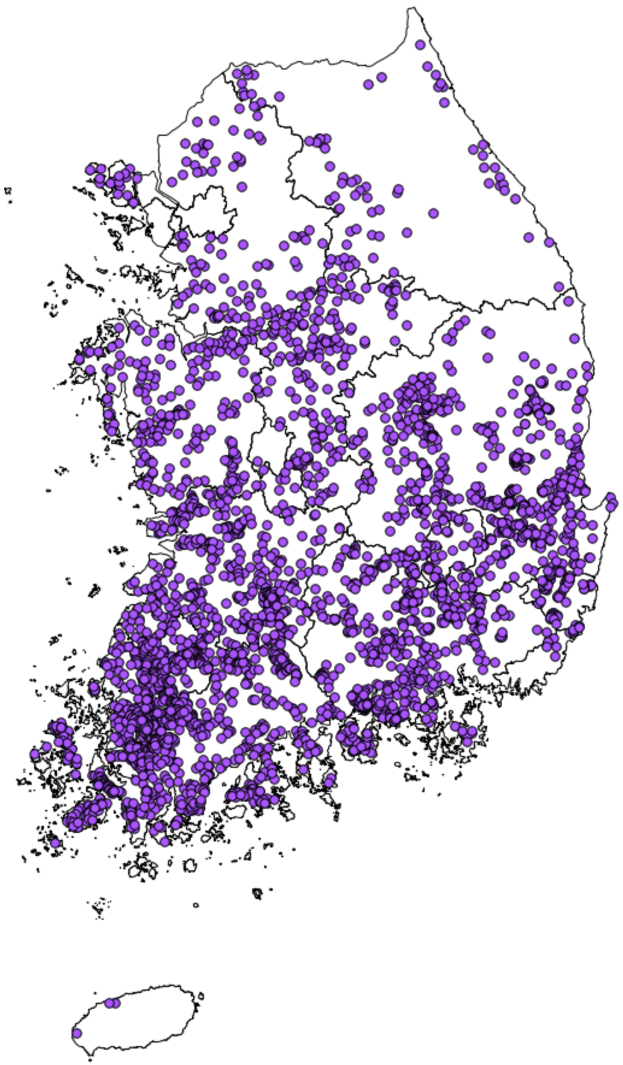
Future (XXXX~XXXX5) after Bias-Correction

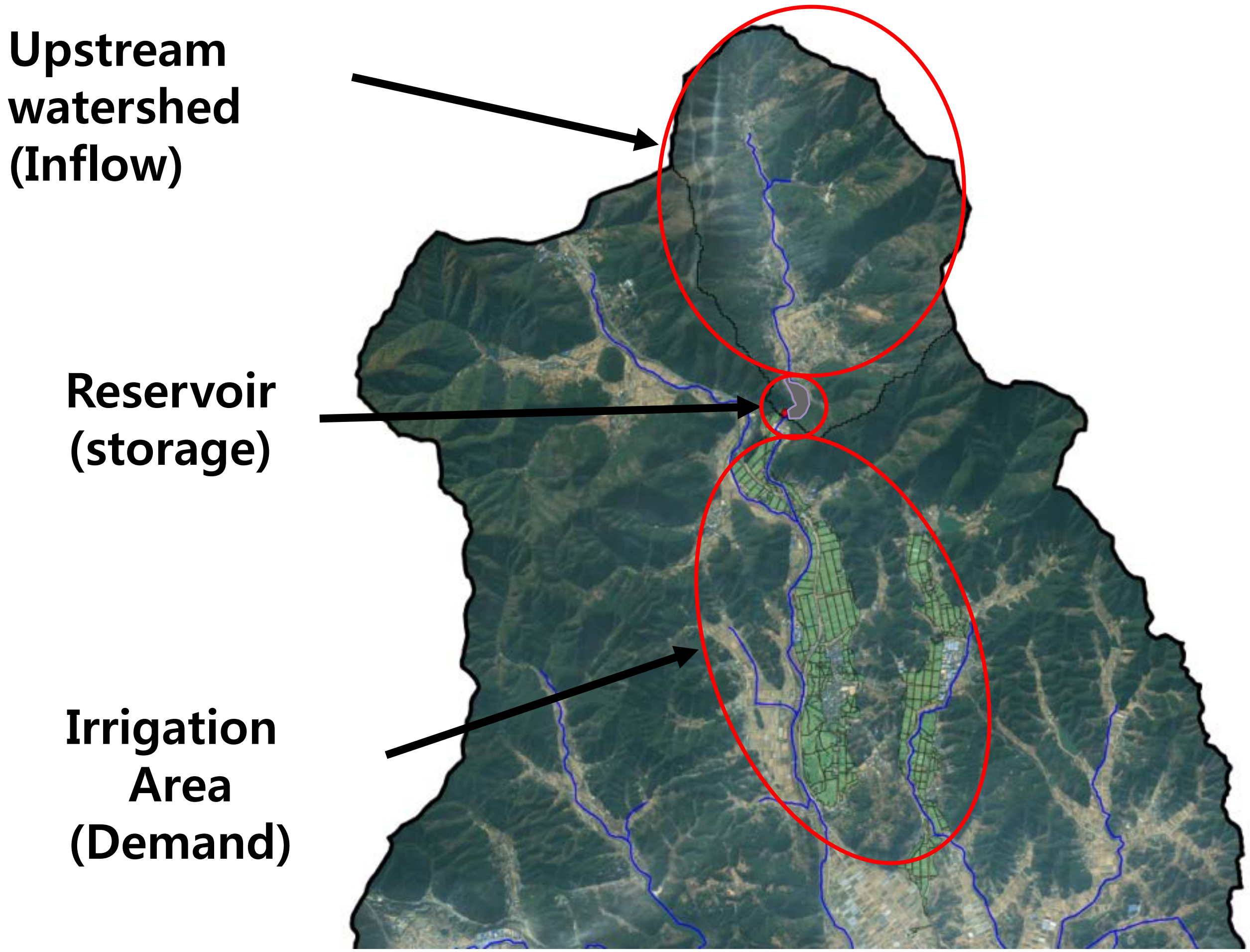
?

➡ **Bias Correction (BC) is necessary**

Selected Agricultural Reservoirs

❖ 3372 reservoirs managed by Korea Rural Community Corporation (KRC) were selected





Available Models in CMIP5 Data Portal

- http://cmip-pcmdi.llnl.gov/cmip5/availability.html
  - 28 Modeling Centers and 61 Models

Availability
Data Portal
FAQs
For Data Providers
More Info
CMIP5 Status
CMIP5 Errata
CMIP5 Publications
Obs4MIPs Wiki
Contact

Important information concerning some models and simulations can be found by clicking on the "Modeling Center" name.

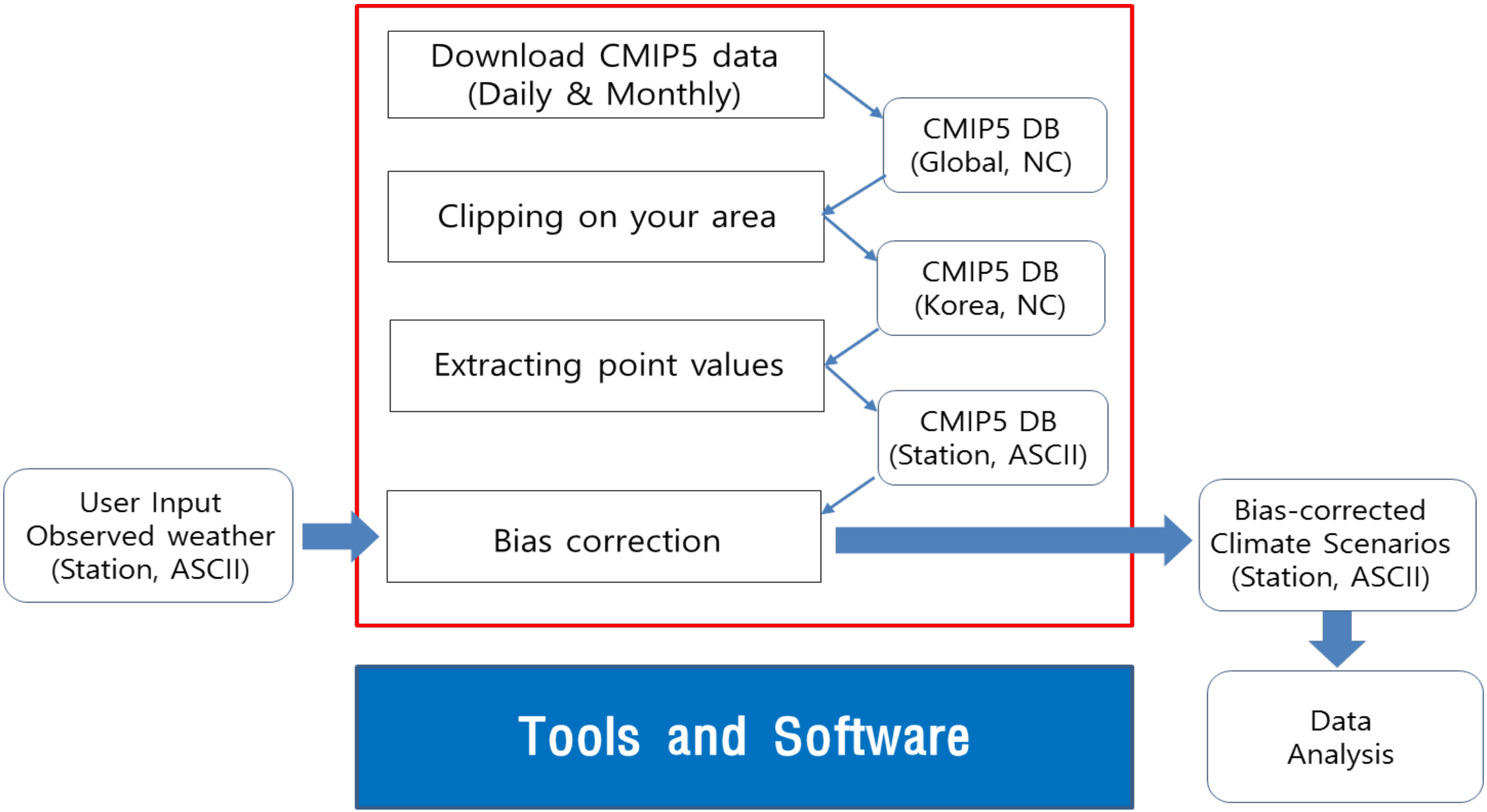
Modeling Center	Model	Institution	terms of use
BCC	BCC-CSM1.1 BCC-CSM1.1(m)	Beijing Climate Center, China Meteorological Administration	unrestricted
CCCma	CanAM4 CanCM4 CanESM2	Canadian Centre for Climate Modelling and Analysis	unrestricted
CMCC	CMCC-CESM CMCC-CM CMCC-CMS	Centro Euro-Mediterraneo per I Cambiamenti Climatici	unrestricted
CNRM-CERFACS	CNRM-CM5	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique	unrestricted
CNRM-CERFACS	CNRM-CM5-2	Centre National de Recherches Meteorologiques / Centre Europeen de Recherche et Formation Avancees en Calcul Scientifique	unrestricted
COLA and NCEP	CFSv2-2011	Center for Ocean-Land-Atmosphere Studies and National Centers for Environmental Prediction	unrestricted
CSIRO-BOM	ACCESS1.0 ACCESS1.3	CSIRO (Commonwealth Scientific and Industrial Research Organisation, Australia), and BOM (Bureau of Meteorology, Australia)	unrestricted
CSIRO-QCCCE	CSIRO-Mk3.6.0	Commonwealth Scientific and Industrial Research Organisation in collaboration with the Queensland Climate Change Centre of Excellence	unrestricted
EC-EARTH	EC-EARTH	EC-EARTH consortium	unrestricted
FIO	FIO-ESM	The First Institute of Oceanography, SOA, China	unrestricted
GCESS	BNU-ESM	College of Global Change and Earth System Science, Beijing Normal University	unrestricted
INM	INM-CM4	Institute for Numerical Mathematics	unrestricted
IPSL	IPSL-CM5A-LR IPSL-CM5A-MR IPSL-CM5B-LR	Institut Pierre-Simon Laplace	unrestricted
LASG-CESS	FGOALS-g2	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences; and CESS, Tsinghua University	unrestricted
LASG-IAP	FGOALS-gl FGOALS-s2	LASG, Institute of Atmospheric Physics, Chinese Academy of Sciences	unrestricted
MIROC	MIROC4h MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	non-commercial only
MIROC	MIROC-ESM MIROC-ESM-CHEM	Japan Agency for Marine-Earth Science and Technology, Atmosphere and Ocean Research Institute (The University of Tokyo), and National Institute for Environmental Studies	non-commercial only
MOHC (additional	HadCM3 HadCM3Q HadGEM2-A	Met Office Hadley Centre (additional HadGEM2-ES realizations	unrestricted

Selected GCMs and variables

- 14 GCMs
- 6 variables: Precipitation, Temperature (Min. & Max.), Relative humidity, Wind speed, Solar radiation

NO	Models	Historical		RCP4.5		RCP8.5	
		Monthly	Daily	Monthly	Daily	Monthly	Daily
1	BNU-ESM	O		O		O	
2	IPSL-CM5A-MR	O		O		O	
3	IPSL-CM5B-LR	O		O		O	
4	MIROC5	O		O		O	
5	MRI-CGCM3	O		O		O	
6	bcc-csm1-1	O	O	O		O	O
7	MIROC-ESM-CHEM	O	O	O	O	O	O
8	MIROC-ESM	O	O	O	O	O	O
9	IPSL-CM5A-LR	O	O		O	O	O
10	CanESM2		O		O		O
11	GFDL-ESM2G		O		O		O
12	GFDL-ESM2M		O		O		O
13	HadGEM2-CC		O		O		O
14	inmcm4		O		O		O

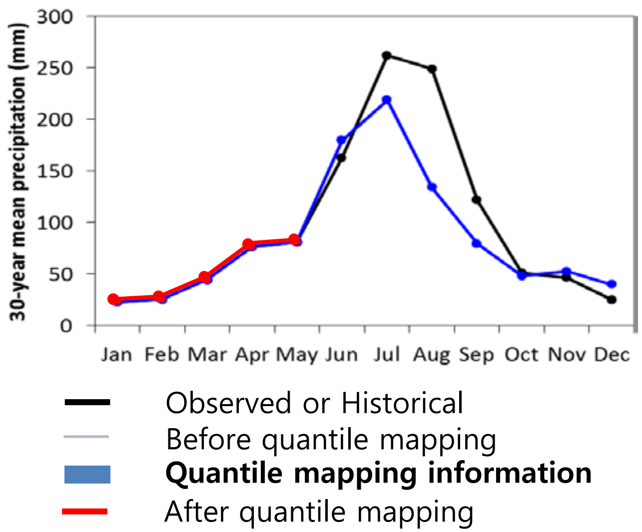
Statistical downscaling and Analysis of precipitation index



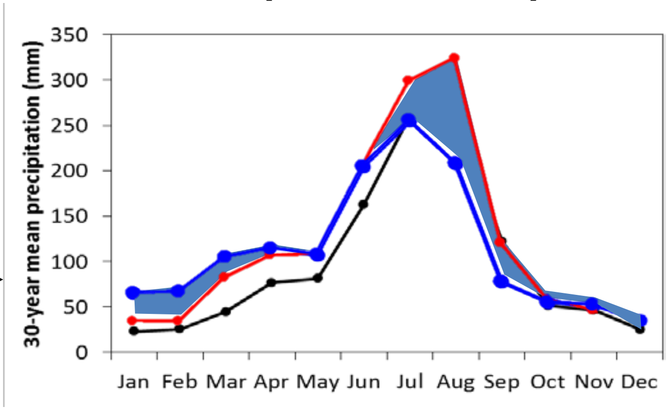
Downscaling of Daily CMIP5 Data

❖ Non-parametric Quantile Mapping methods

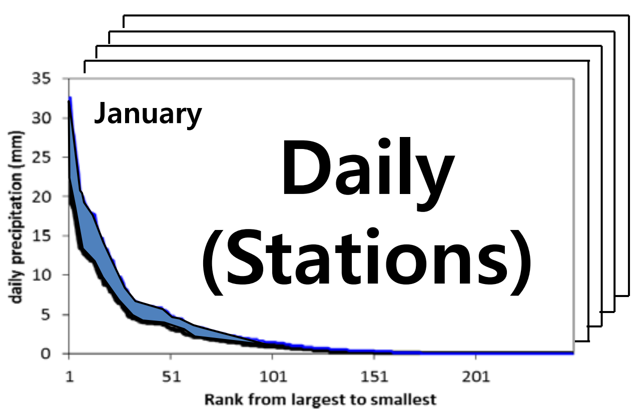
Historical (1976~2005)

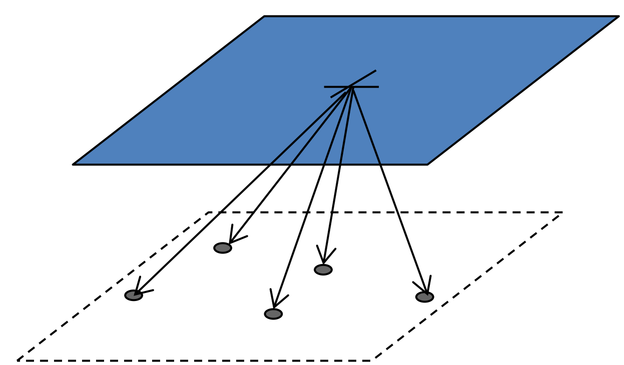


Future (2011~2040)



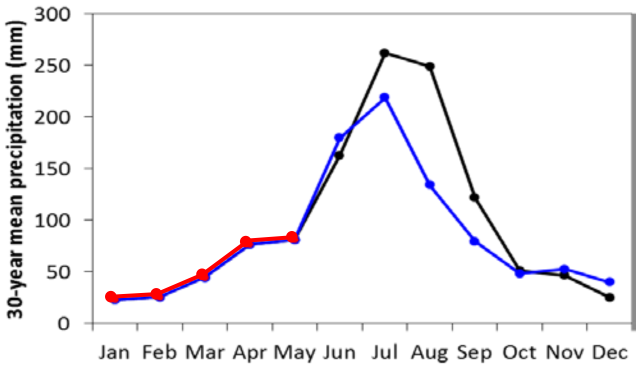
Non-parametric Quantile Mapping methods



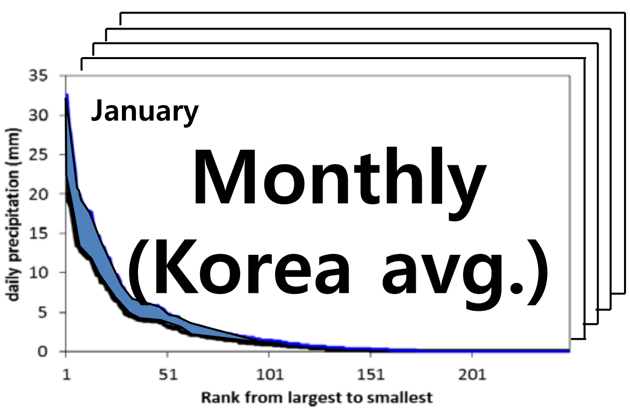


Downscaling of Monthly CMIP5 Data

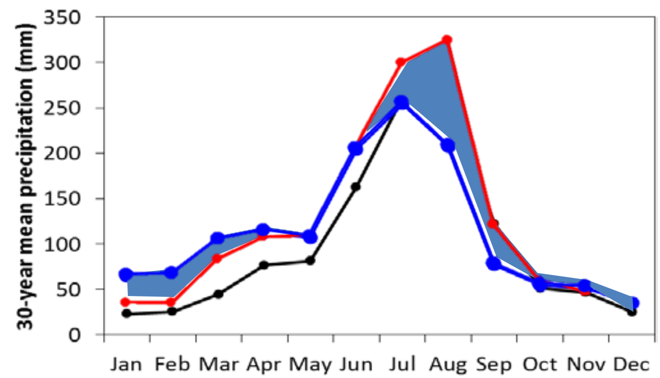
Historical (1976~2005)



Observed or Historical
Before quantile mapping
Quantile mapping information
After quantile mapping



Future (2011~2040)



Temporal Downscaling

Temporal downscaling (Monthly to daily)

GCM's Korea avg.

yearmon	prec	t2m
Jan-83	0.623	-2.182
Feb-83	1.622	2.326
Mar-83	1.452	7.280
Apr-83	3.505	11.880
May-83	2.701	
Jun-83	3.572	
Jul-83	8.453	
Aug-83	9.573	24.774
Sep-83	7.755	20.920
Oct-83	2.115	14.774
Nov-83	2.419	6.643
Dec-83	0.221	1.669
Jan-84	0.189	-1.225
Feb-84	0.017	0.270
Mar-84	0.912	3.338

Jan−81

Mahalanobis distance = f(prec, t2m)

Ovserved Korea avg.

yearmon	prec	t2m
Jan-73	0.673	-1.631
Feb-73	1.789	2.631
Mar-73	1.428	7.052
Apr-73	3.586	12.139
	2.619	17.243
	3.681	21.332
	7.041	23.314
Aug-73	8.509	24.722
Sep-73	7.145	20.680
Oct-73	2.092	14.745
Nov-73	2.375	7.133
Dec-73	0.151	1.442
.	0.076	-1.409
.	0.123	-0.368
Jan-11	0.997	-1.826
Feb-11	2.313	1.354
Mar-11	2.659	5.750
Apr-11	0.904	12.704
May-11	4.124	17.254
Jun-11	6.330	20.626
Jul-11	10.191	25.146
Aug-11	4.078	27.135
Sep-11	6.269	20.657
Oct-11	3.736	14.392
Nov-11	0.783	8.224
Dec-11	0.972	1.381

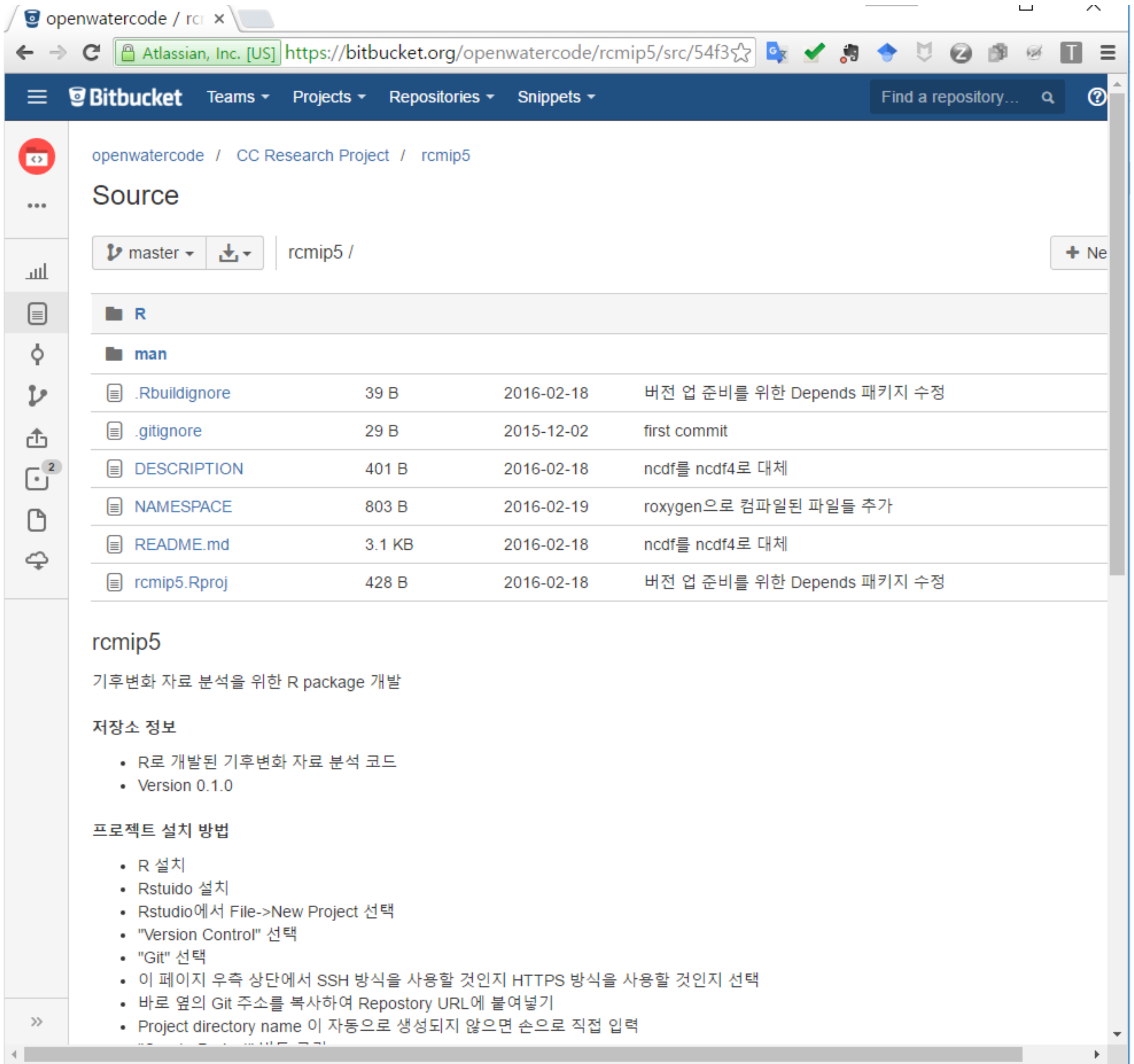
ID135

ID136

ID137

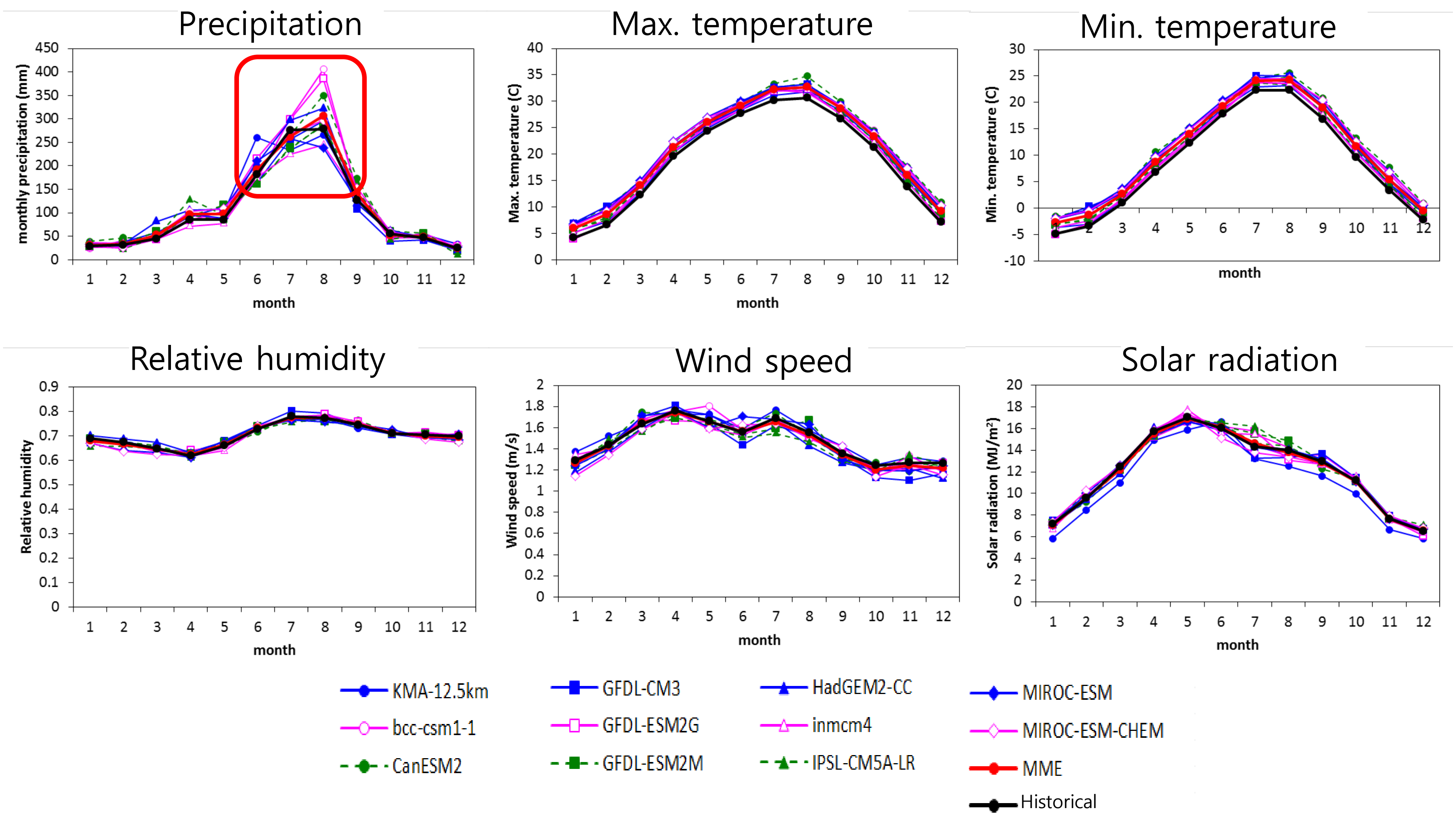
date	prcp	tmax	tmin	wspd	rhum	rsds
1981-01-01	0.8	1.4	-2.8	3.81	0.62	2.5
1981-01-02	0	-1.7	-7.9	9.43	0.47	5
1981-01-03	0	-3.2	-9.7	9.61	0.39	5.4
1981-01-04	0	-1.5	-9.7	5.05	0.34	7.1
1981-01-05	0	-2.7	-9.2	7.61	0.26	5.4
1981-01-06	0	0.8	-8.8	7.07	0.27	8.1
1981-01-07	0	3.6	-4.4	6.43	0.26	7.1
1981-01-08	0	6.4	-3	4.35	0.36	8
1981-01-09	0	7	-2.8	7.98	0.46	8.3
1981-01-10	0	0	-7	6.35	0.41	6.2
1981-01-11	0	0	-8.8	7.96	0.44	7.8
1981-01-12	0	0.8	-5.5	6.59	0.35	5.4
1981-01-13	0	-1.4	-8.4	5.18	0.39	6.3
1981-01-14	0	0.6	-10.4	3.1	0.45	8.9
1981-01-15	15.9	-1.7	-6	2.7	0.81	2.8
1981-01-16	0.1	0.3	-6.2	2.65	0.71	5.7
1981-01-17	0	2.6	-6.9	3.03	0.51	8.5
1981-01-18	0	3.2	-4.5	4.52	0.48	7.1
1981-01-19	0	0.9	-6.4	2.88	0.64	6.8
1981-01-20	0	2.4	-5.4	4.58	0.39	7.4
1981-01-21	0	0.3	-6.4	4.36	0.44	6.2
1981-01-22	0	-0.2	-9.1	2.43	0.5	8.5
1981-01-23	0	2.8	-6.7	1.52	0.58	9
1981-01-24	0	3.1	-1.5	3.16	0.72	3.4
1981-01-25	0	2.4	-4.6	3.82	0.62	6.9
1981-01-26	0	-0.2	-7.9	3.02	0.47	7.9
1981-01-27	0	0.6	-6.1	3.12	0.41	6.6
1981-01-28	0	3.1	-6.5	2.71	0.46	9.4
1981-01-29	0	4.2	-4.1	3.8	0.48	8.6
1981-01-30	0	5.6	-6.3	2.69	0.5	10
1981-01-31	0	3.2	-5.8	1.93	0.53	9.3

Downscaling package (rcmip5) in R



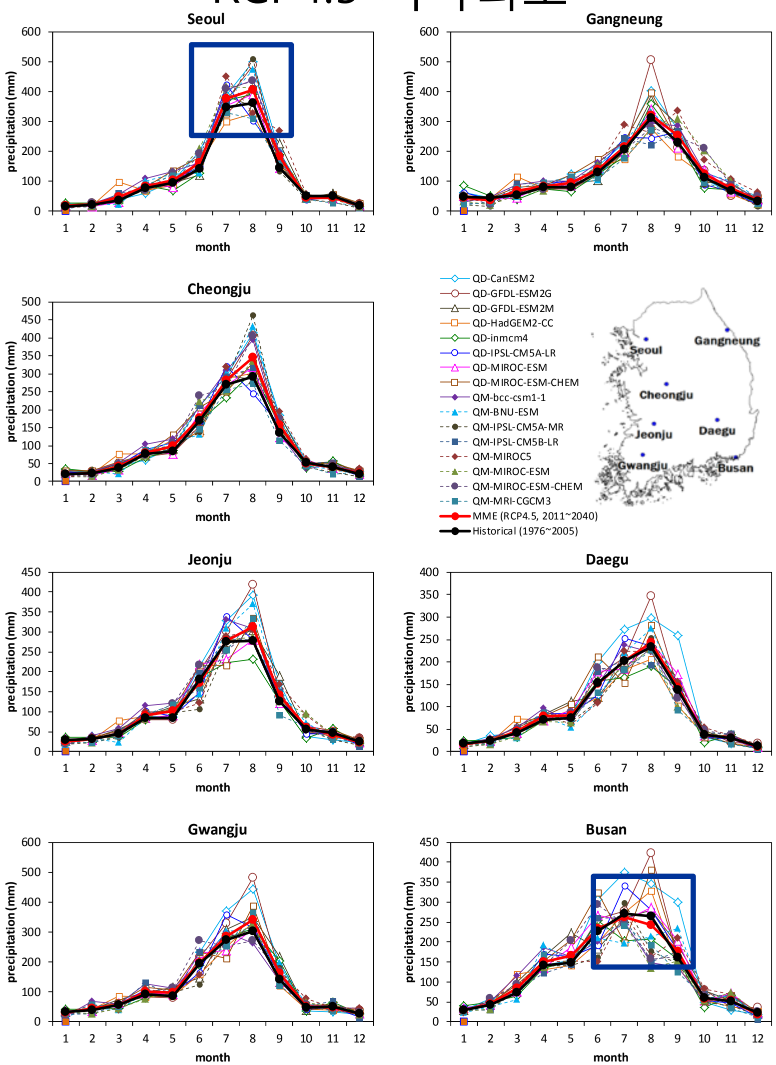
Uncertainties of weather variables after bias correction

❖ RCP8.5 (2011~2040, Jeonju)

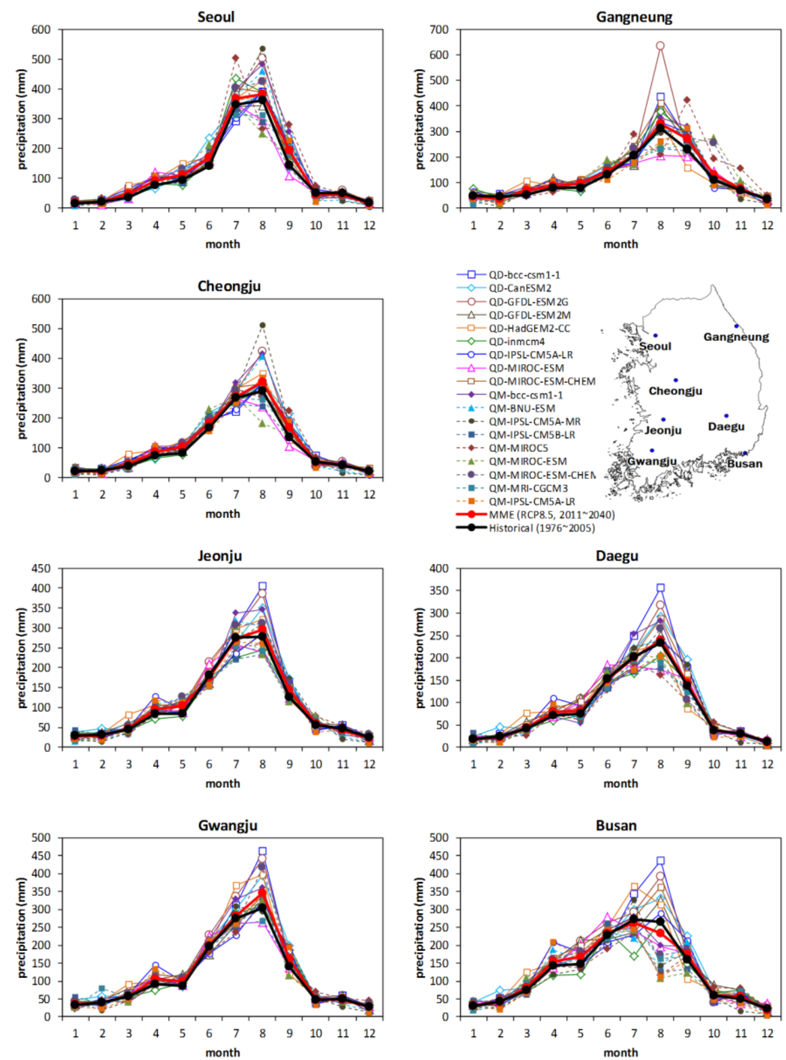


Spatial pattern of monthly precipitation changes

RCP4.5 시나리오



RCP8.5 시나리오

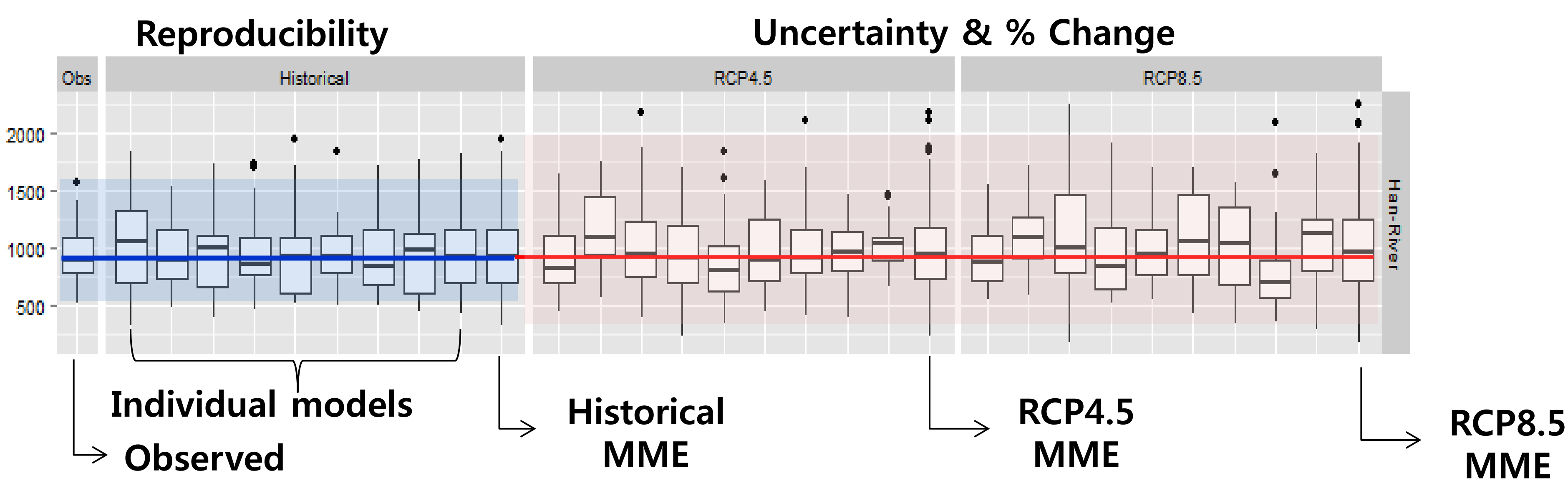


Precipitation index

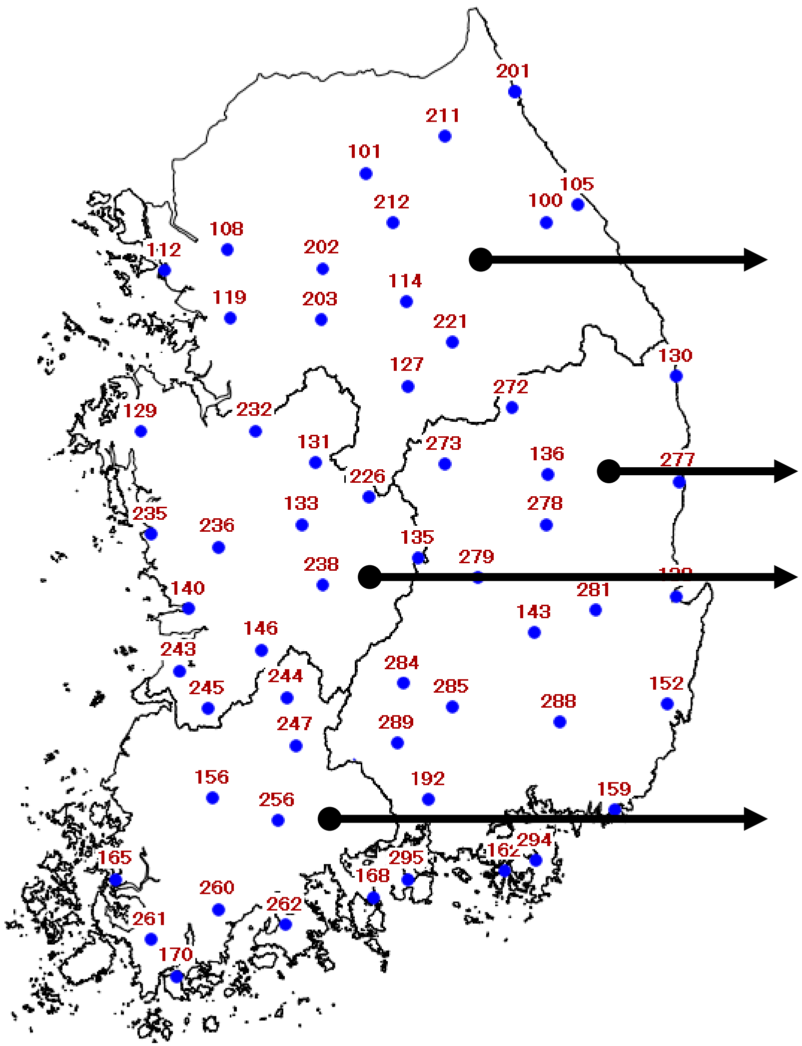
❖ Wet season(Jun~Sep) precipitation
❖ Max. daily precipitation
❖ Number of days daily precipitation ≥ 80mm
❖ Dry season(Oct~May) precipitation
❖ Maximum number of consecutive dry days

Flood

Drought



4-River Basins



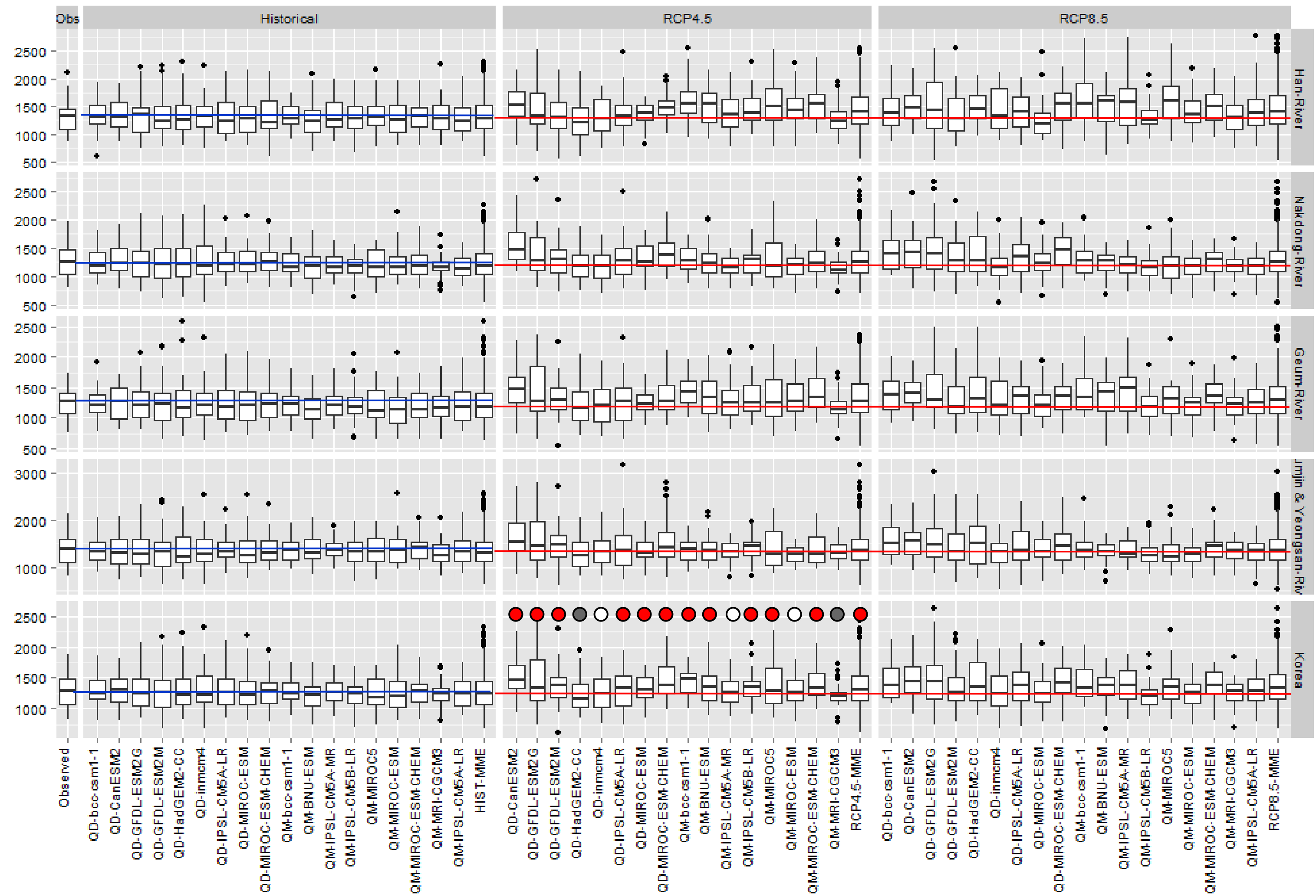
Han-River Basin
(15 stations)

Nakdong-River Basin
(21 stations)

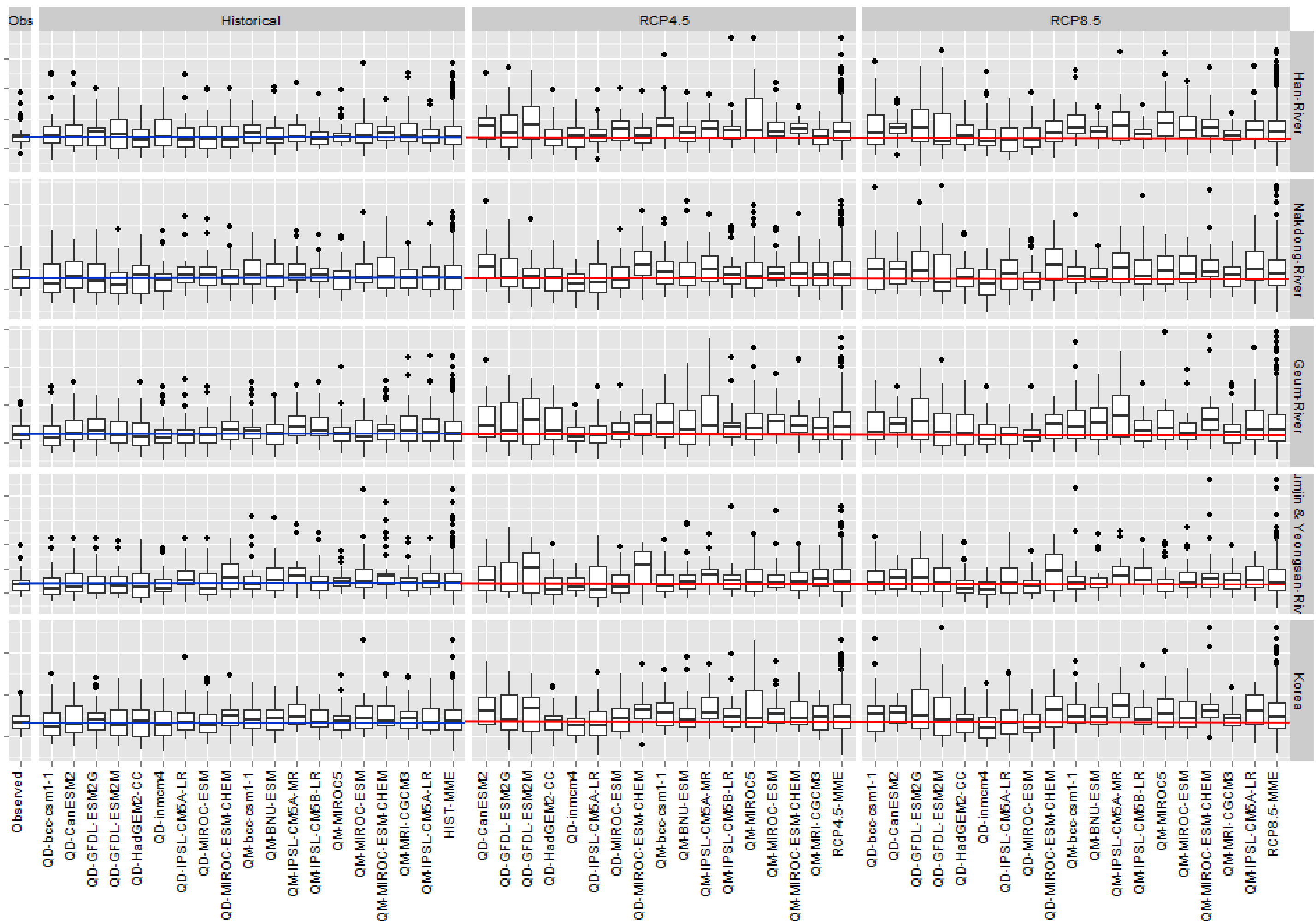
Geum-River Basin
(13 stations)

Sumjin/Yeongsan-River Basin
(10 stations)

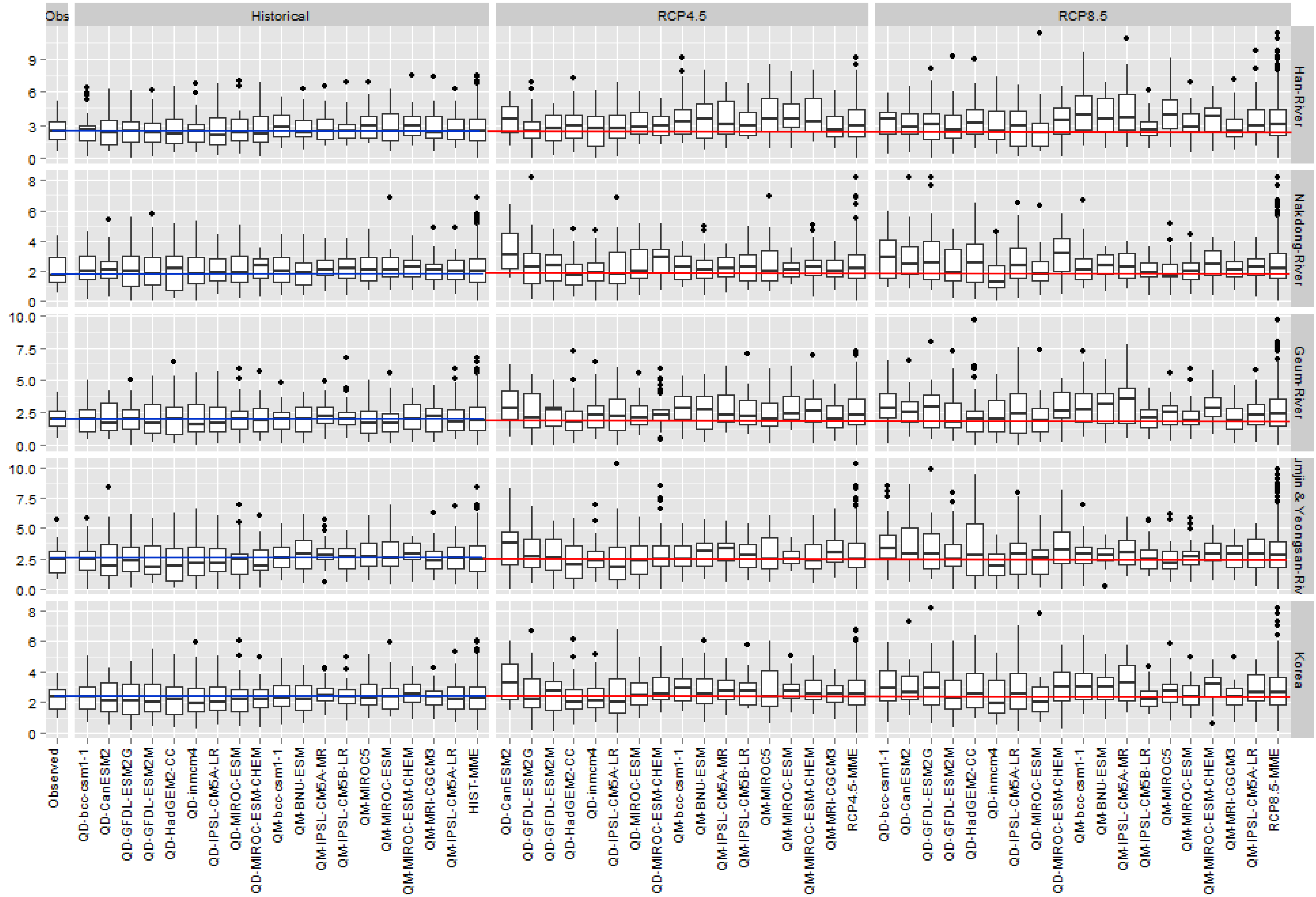
Annual precipitation amount



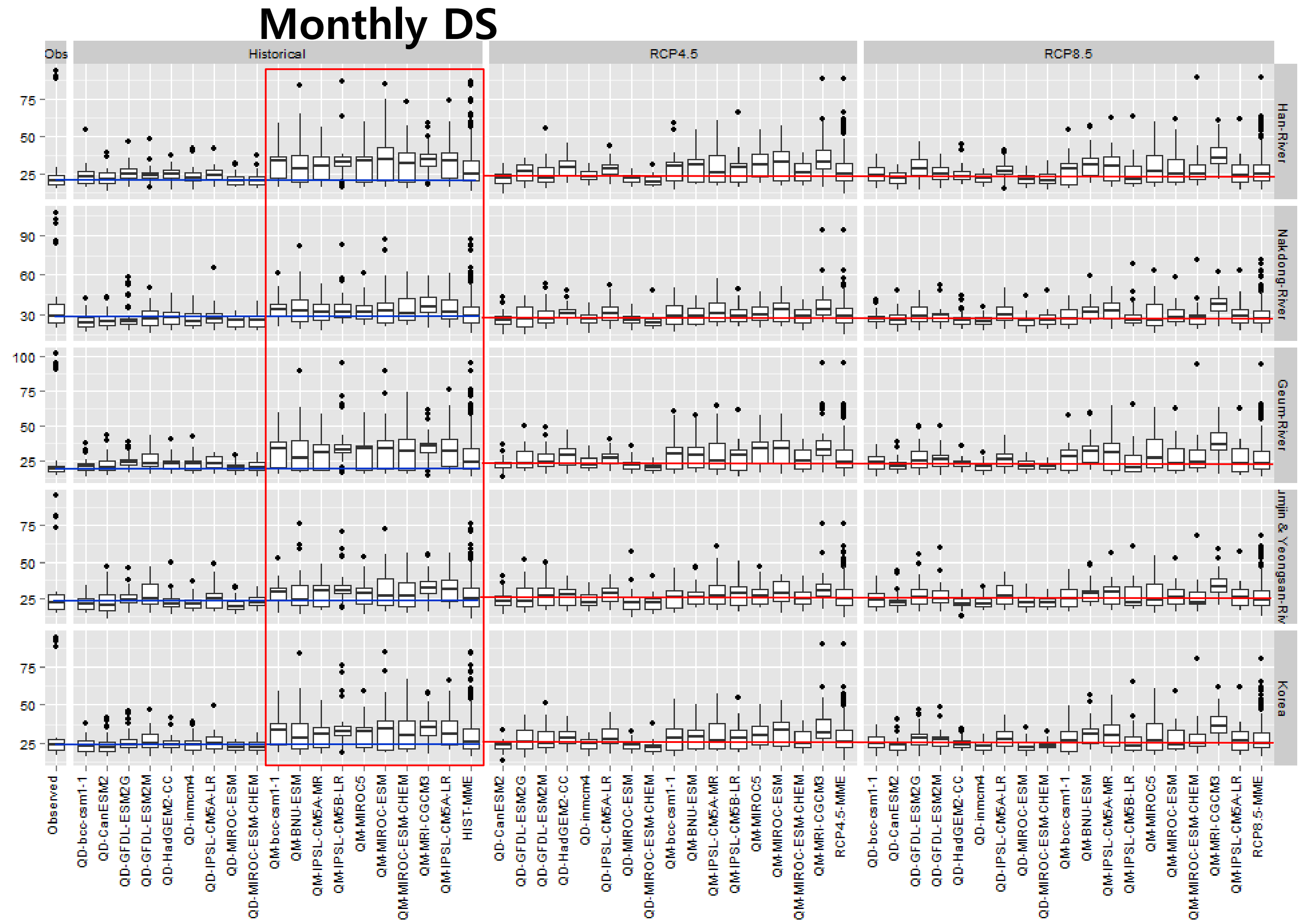
Daily maximum precipitation (mm)



Number of days daily precipitation ≥ 80mm

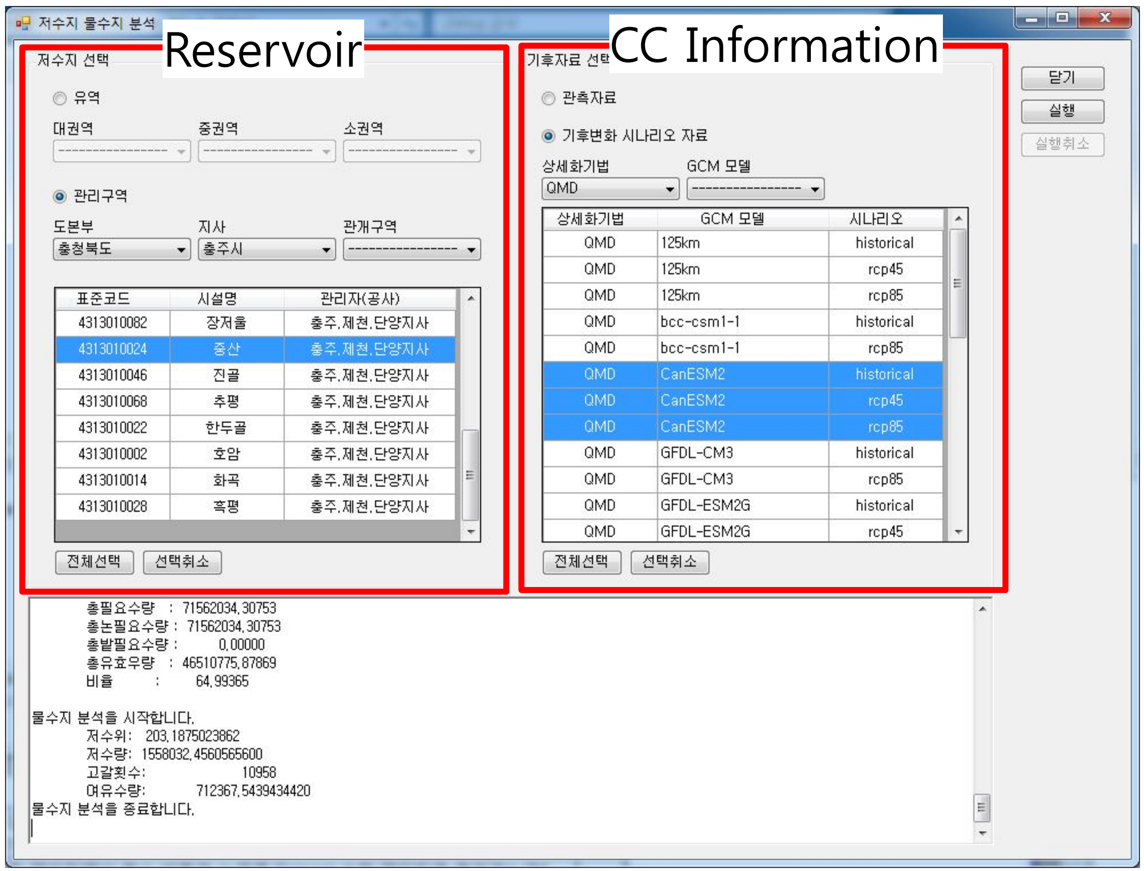


Maximum number of consecutive dry days



Assessment of Climate Change Impact on Agricultural Reservoirs

❖ Hydrological Operation Model for Water Resources System (HOMWRS)



Reproducibility for historical period

How well dose a climate change scenario reproduce the spatial and temporal pattern during the historical period?

Scenarios	Inflow (mm)	% change
Historical	988.5	
RCP8.5	1078.1	9.1

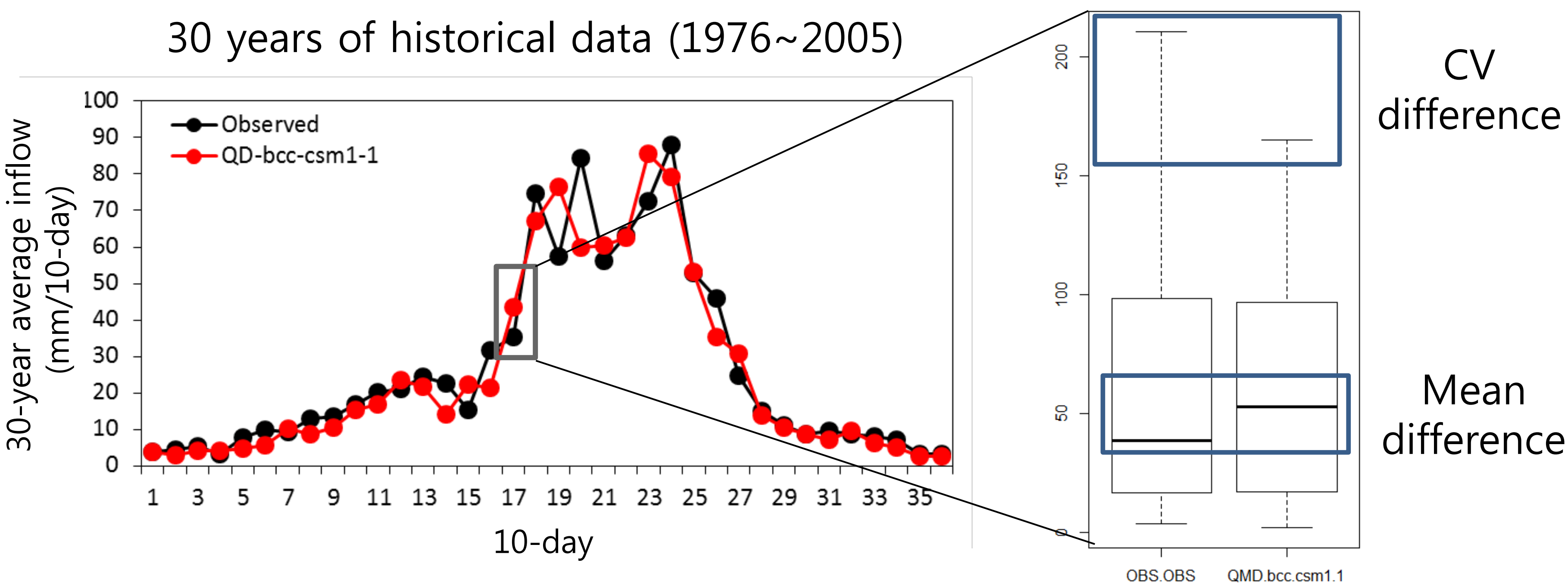
Even though we have same future projection....

- ❖ What should be premised in order to have significant meanings within the future climate change projections?
- ❖ Does scenario-based data reproduce the characteristics of rainfall (extreme, spatial/temporal patterns) during the historical period, compared to the observations ?

Reproducibility
for historical period

Considering factors for reproducibility test

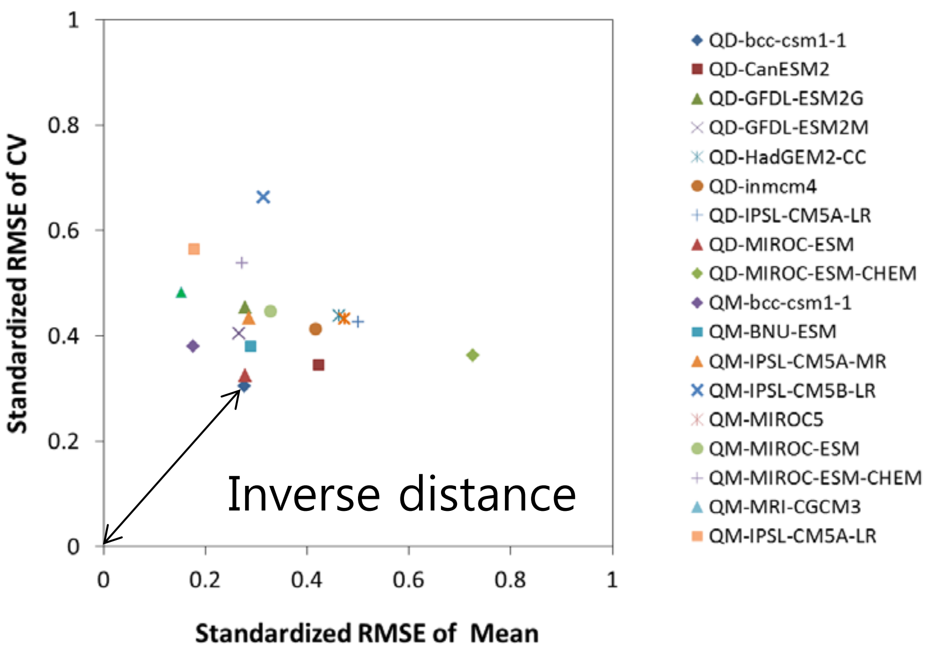
- Comparing observed and modeled (GCM) 10-day inflow, demand, and storage for historical period
- RMSE in mean and coefficient variation (CV) are used

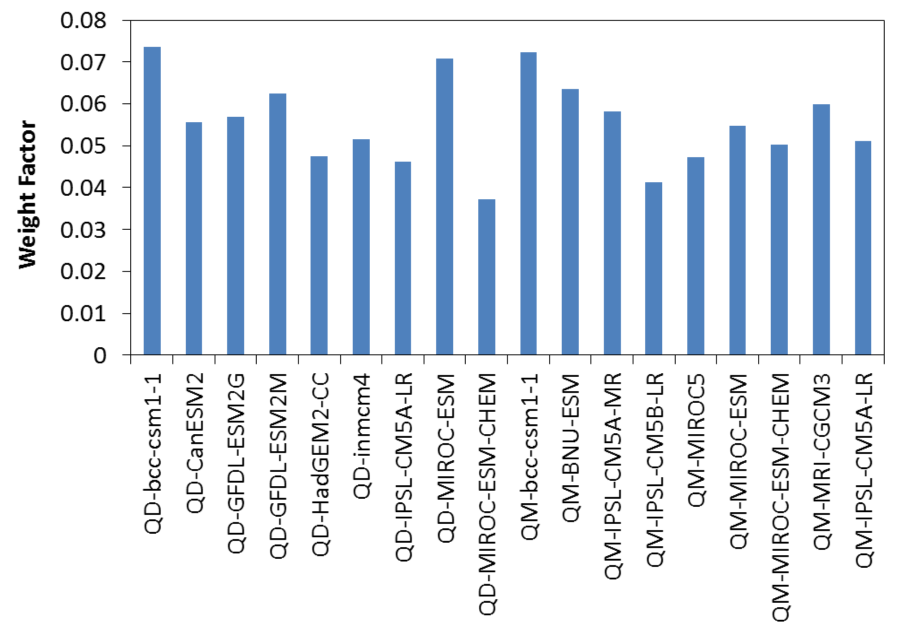


Weighting factor based on reproducibility

❖ Inflow from upstream watershed

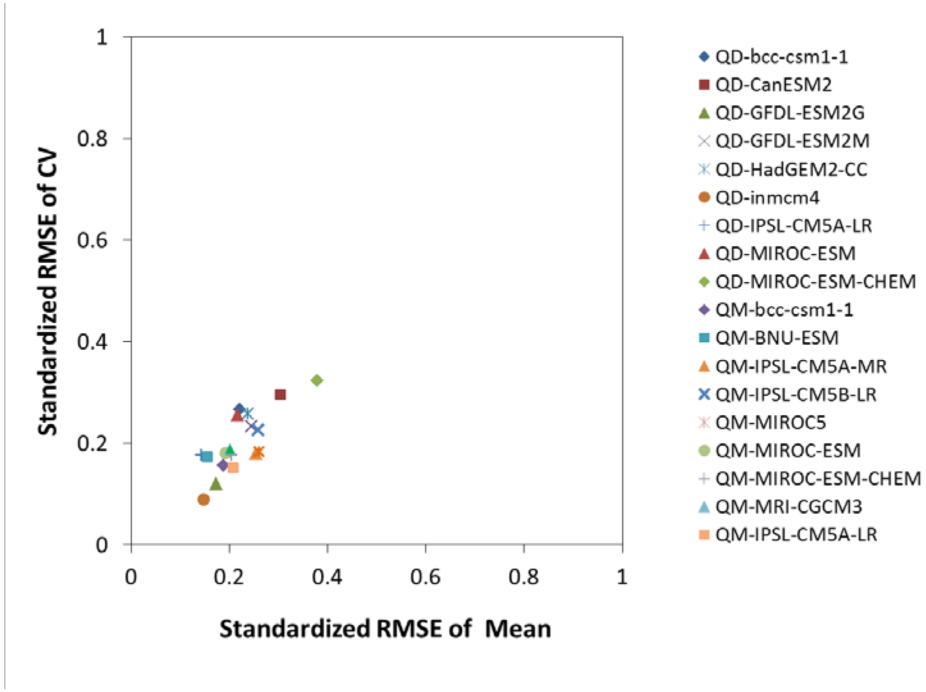
- Standardization using mean and coefficient of variation (CV)
- Inverse distance weighting factor for MME estimation

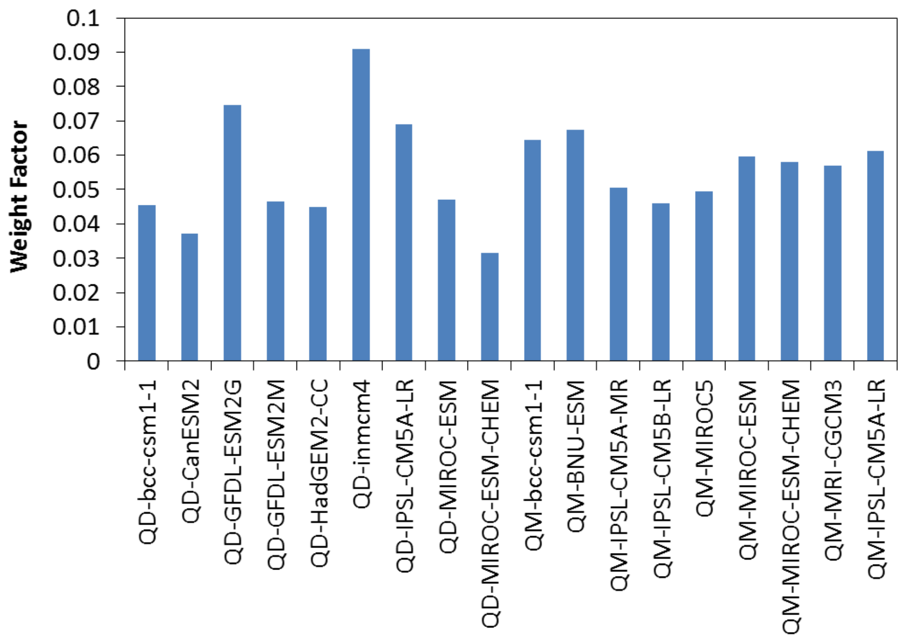




Weighting factor based on reproducibility

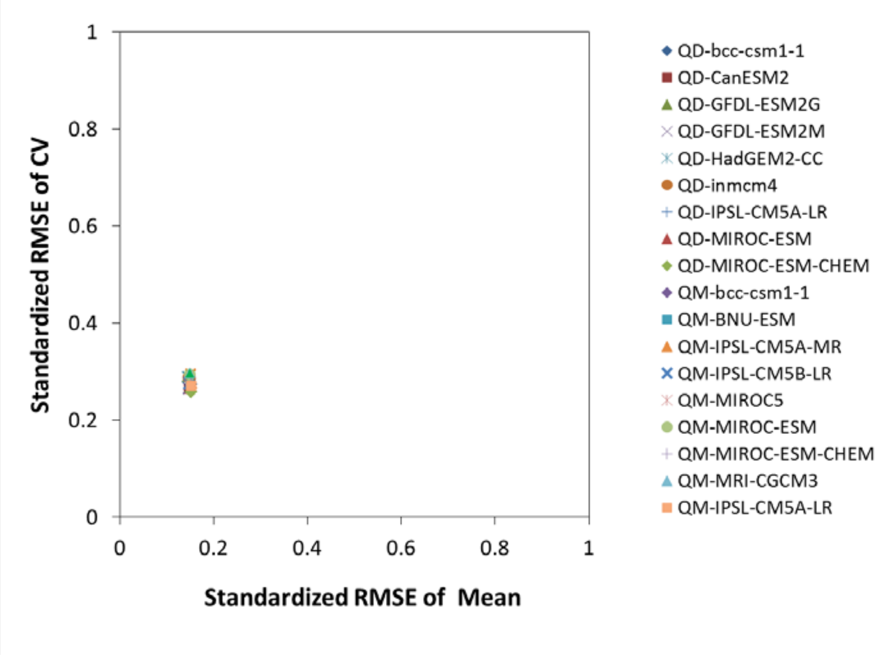
❖ Irrigation Water Demands

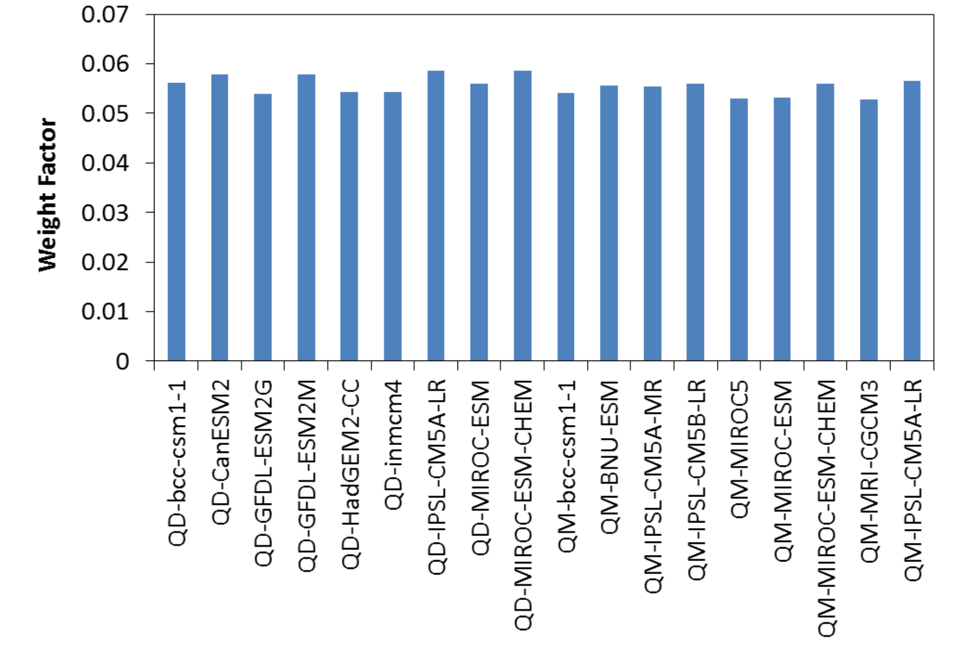




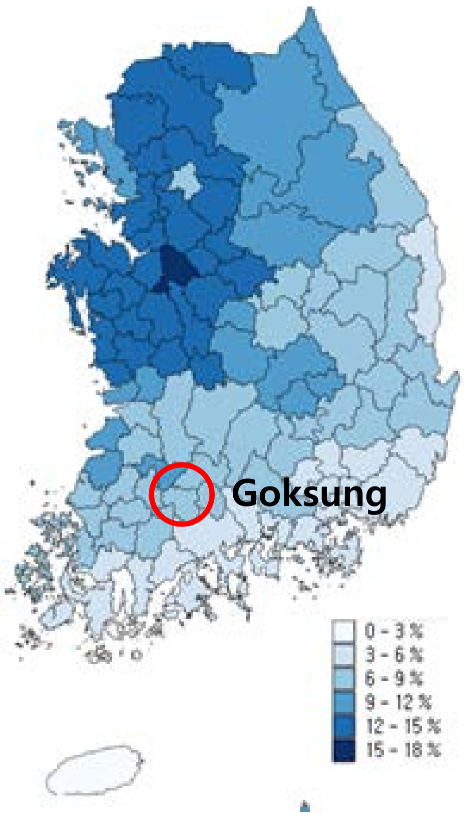
Weighting factor based on reproducibility

❖ Storage

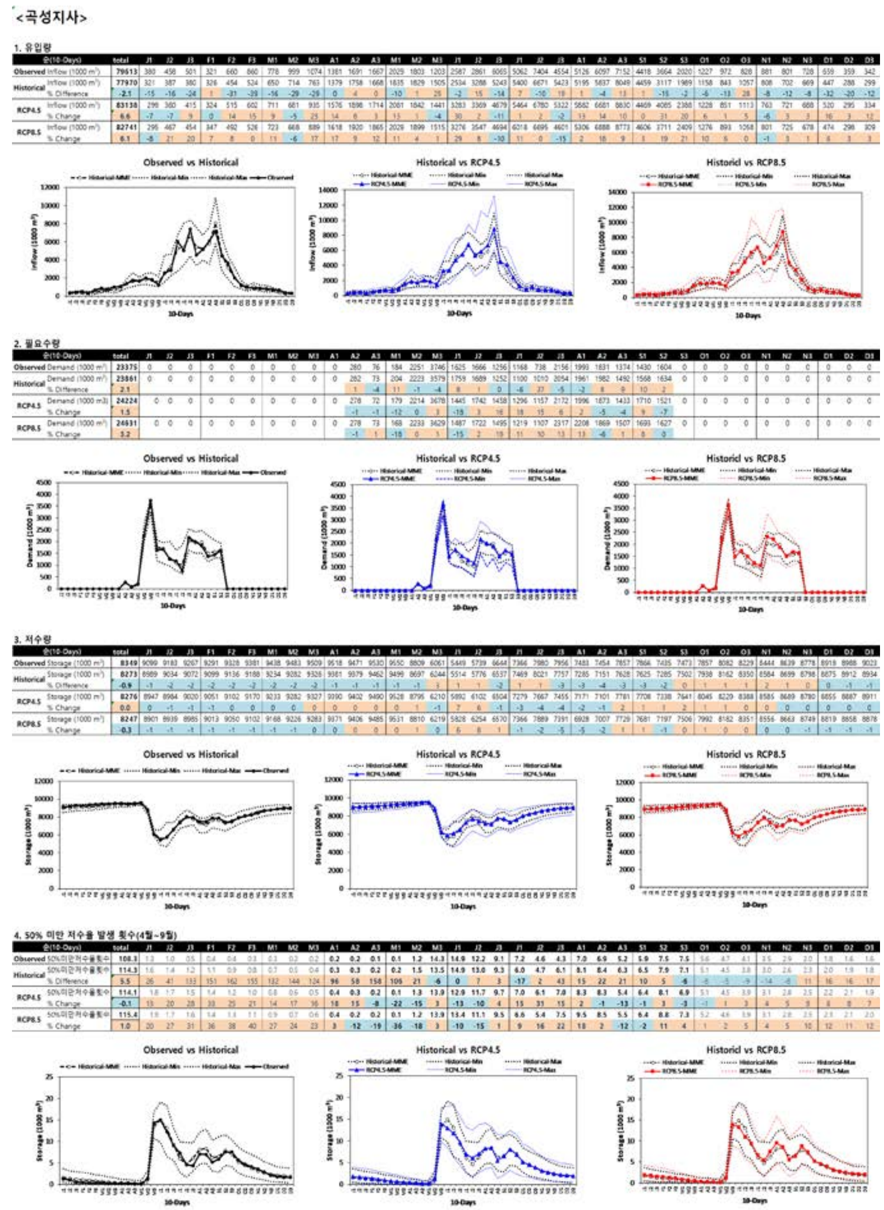




Impact Assessment Report at Branch Level



❖ Report template for impact assessment



Inflow

Demand

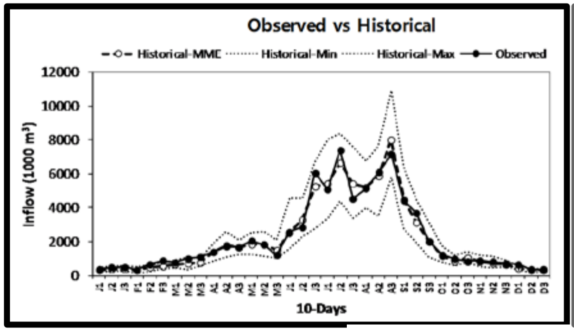
Storage

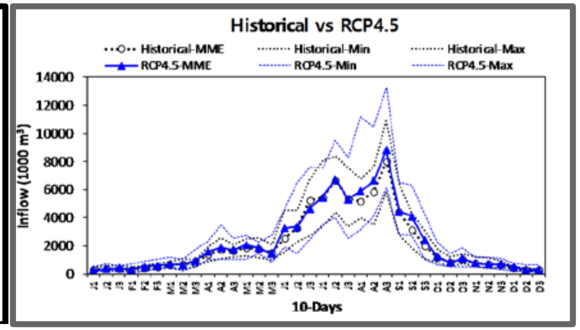
Drought

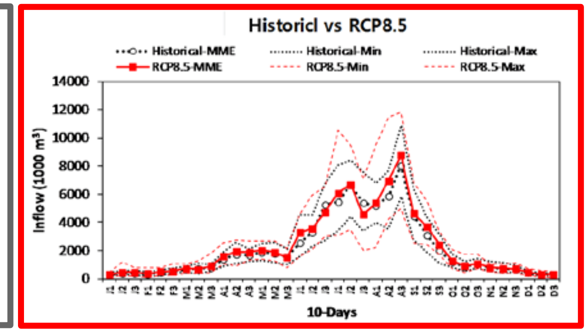
Impact assessment on 10-day inflow (Goksung)

1. 유입량

순(10-Days)		total	J1	J2	J3	F1	F2	F3	M1	M2	M3	A1	A2	A3	M1	M2	M3	J1	J2	J3	J1	J2	J3	A1	A2	A3	S1	S2	S3	O1	O2	O3	N1	N2	N3	D1	D2	D3
Observed	Inflow (1000 m³)	**79613**	380	458	501	321	660	860	778	999	1074	1381	1691	1667	2029	1803	1203	2587	2861	6065	5062	7404	4554	5126	6097	7152	4418	3664	2020	1227	972	828	881	801	728	659	359	342
Historical	Inflow (1000 m³)	**77983**	323	385	379	328	456	523	655	717	767	1379	1753	1670	1834	1813	1513	2521	3302	5251	5447	6651	5413	5192	5874	8001	4453	3116	2006	1159	840	1051	807	701	668	447	290	300
	% Difference	**-2.0**	-15	-16	-24	2	-31	-39	-16	-28	-29	0	4	0	-10	1	26	-3	15	-13	8	-10	19	1	-4	12	1	-15	-1	-6	-14	27	-8	-13	-8	-32	-19	-12
RCP4.5	Inflow (1000 m³)	**83104**	301	360	415	326	518	602	712	681	941	1579	1889	1717	2082	1845	1446	3274	3385	4643	5471	6758	5338	5904	6659	8795	4461	4096	2407	1233	847	1100	756	714	694	521	296	335
	% Change	**6.6**	-7	-7	10	0	14	15	9	-5	23	15	8	3	14	2	-4	30	3	-12	0	2	-1	14	13	10	0	31	20	6	1	5	-6	2	4	17	2	11
RCP8.5	Inflow (1000 m³)	**82835**	296	460	453	352	496	525	724	667	896	1623	1900	1869	2027	1891	1523	3282	3566	4682	6086	6678	4555	5361	6941	8741	4614	3716	2409	1260	886	1057	806	728	684	474	300	311
	% Change	**6.2**	-9	20	20	7	9	0	11	-7	17	18	8	12	11	4	1	30	8	-11	12	0	-16	3	18	9	4	19	20	9	5	1	0	4	2	6	3	3

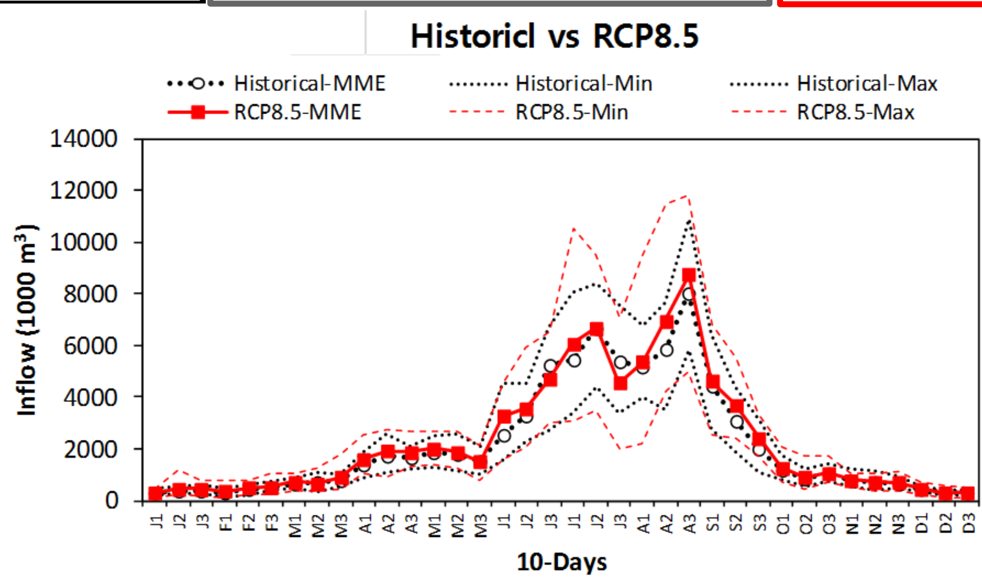






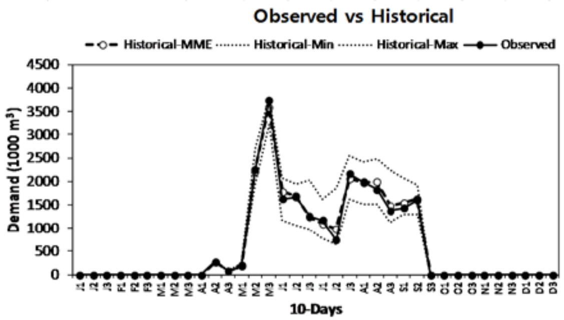
Reproducibility

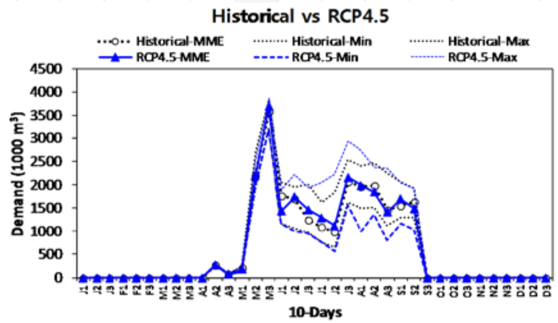
Future climate change impact assessment

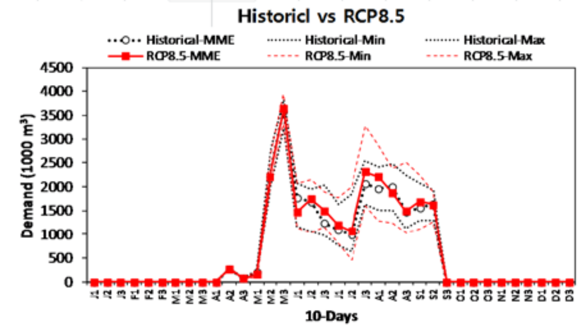


Impact assessment on 10-day demand (Goksung)

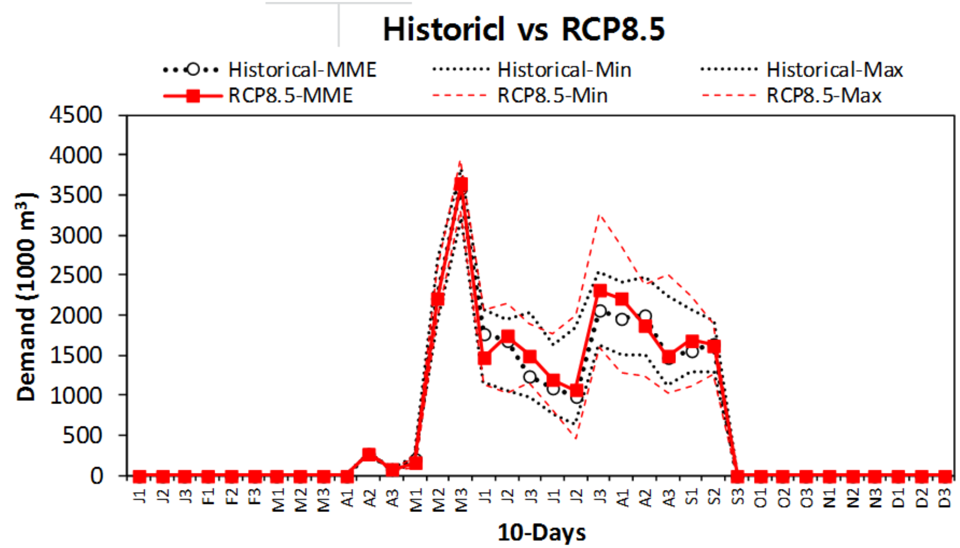
순(10-Days)		total	J1	J2	J3	F1	F2	F3	M1	M2	M3	A1	A2	A3	M1	M2	M3	J1	J2	J3	J1	J2	J3	A1	A2	A3	S1	S2	S3	O1	O2	O3	N1	N2	N3	D1	D2	D3
Observed	Demand (1000 m^3)	**23375**	0	0	0	0	0	0	0	0	0	0	280	76	184	2251	3746	1625	1666	1256	1168	738	2156	1993	1831	1374	1430	1604	0	0	0	0	0	0	0	0	0	0
Historical	Demand (1000 m^3)	**23819**	0	0	0	0	0	0	0	0	0	0	282	73	205	2208	3589	1775	1694	1241	1095	979	2066	1963	1994	1469	1550	1637	0	0	0	0	0	0	0	0	0	0
	% Difference	1.9											1	-4	11	-2	-4	9	2	-1	-6	33	-4	-2	9	7	8	2										
RCP4.5	Demand (1000 m3)	**24086**	0	0	0	0	0	0	0	0	0	0	278	72	177	2208	3692	1438	1742	1465	1300	1126	2159	1986	1847	1410	1691	1494	0	0	0	0	0	0	0	0	0	0
	% Change	1.1											-1	-1	-14	0	3	-19	3	18	19	15	5	1	-7	-4	9	-9										
RCP8.5	Demand (1000 m^3)	**24540**	0	0	0	0	0	0	0	0	0	0	277	73	164	2216	3639	1472	1738	1499	1199	1070	2313	2209	1874	1486	1688	1623	0	0	0	0	0	0	0	0	0	0
	% Change	3.0											-2	1	-20	0	1	-17	3	21	10	9	12	13	-6	1	9	-1										







순(10-Days)		total
Observed	Demand (1000 m^3)	**23375**
Historical	Demand (1000 m^3)	**23819**
	% Difference	1.9
RCP4.5	Demand (1000 m3)	**24086**
	% Change	1.1
RCP8.5	Demand (1000 m^3)	**24540**
	% Change	3.0

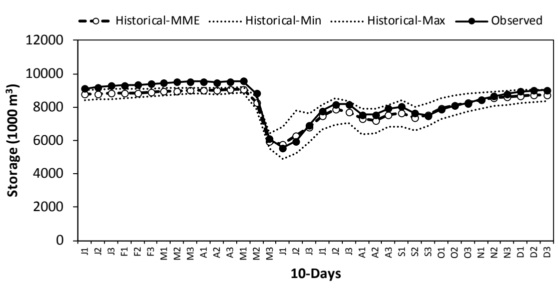


Impact assessment on 10-day storage (Goksung)

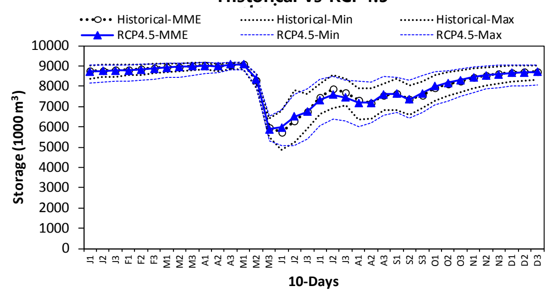
순(10-Days)		total	J1	J2	J3	F1	F2	F3	M1	M2	M3	A1	A2	A3	M1	M2	M3	J1	J2	J3
Observed	Storage (1000 m^3)	**302883**	9110	9194	9278	9302	9339	9392	9448	9494	9519	9528	9481	9541	9561	8818	6088	5545	5942	6913
Historical	Storage (1000 m^3)	**292767**	8760	8791	8816	8834	8862	8901	8935	8968	8998	9032	9002	9047	9076	8295	5965	5750	6284	6778
	% Difference	**-3.3**	-4	-4	-5	-5	-5	-5	-5	-6	-5	-5	-5	-5	-5	-6	-2	4	6	-2
RCP4.5	Storage (1000 m^3)	**292455**	8728	8753	8774	8792	8830	8880	8927	8959	8991	9023	9000	9078	9093	8351	5890	5983	6506	6751
	% Change	**-0.1**	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-1	4	4	0
RCP8.5	Storage (1000 m^3)	**291719**	8686	8713	8744	8762	8789	8828	8878	8922	8960	9011	9003	9054	9090	8372	5918	6021	6575	6846
	% Change	**-0.4**	-1	-1	-1	-1	-1	-1	-1	-1	0	0	0	0	0	1	-1	5	5	1

순(10-Days)		J1	J2	J3	A1	A2	A3	S1	S2	S3	O1	O2	O3	N1	N2	N3	D1	D2	D3
Observed	Storage (1000 m^3)	7782	8177	8176	7559	7551	7925	8041	7634	7485	7869	8094	8241	8456	8650	8789	8929	8999	9034
Historical	Storage (1000 m^3)	7471	7865	7680	7317	7199	7543	7643	7347	7535	7926	8120	8272	8459	8552	8627	8684	8710	8722
	% Difference	-4	-4	-6	-3	-5	-5	-5	-4	1	1	0	0	0	-1	-2	-3	-3	-3
RCP4.5	Storage (1000 m^3)	7331	7600	7449	7185	7197	7612	7625	7348	7655	8017	8177	8306	8450	8536	8605	8664	8687	8701
	% Change	-2	-3	-3	-2	0	1	0	0	2	1	1	0	0	0	0	0	0	0
RCP8.5	Storage (1000 m^3)	7342	7744	7431	7010	7085	7614	7628	7258	7570	7969	8129	8270	8435	8517	8581	8633	8660	8672
	% Change	-2	-2	-3	-4	-2	1	0	-1	0	1	0	0	0	0	-1	-1	-1	-1

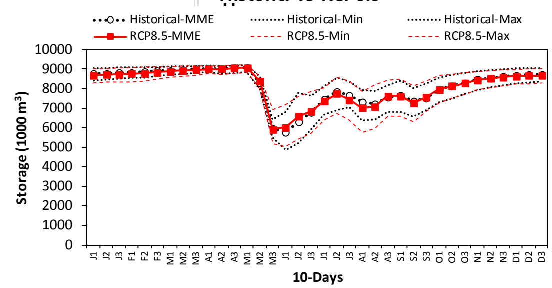
Observed vs Historical



Historical vs RCP4.5

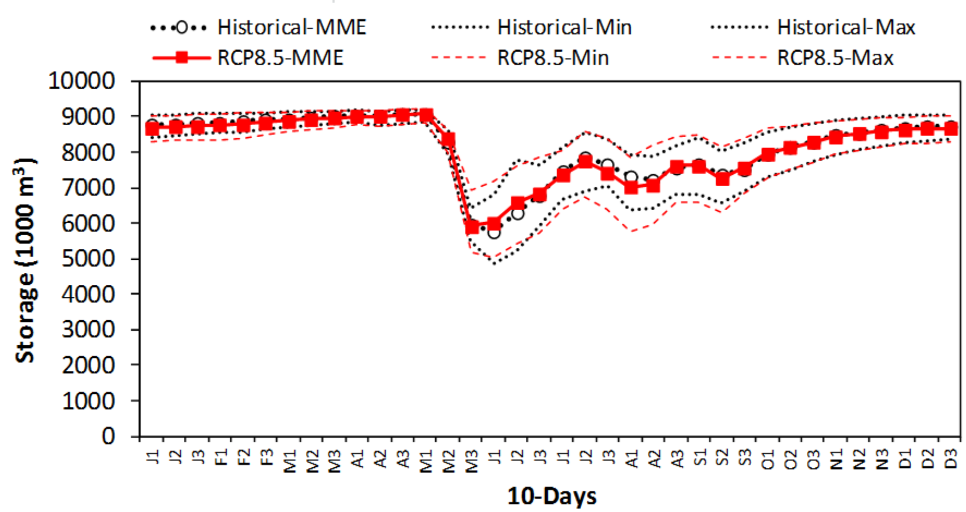


Historicl vs RCP8.5



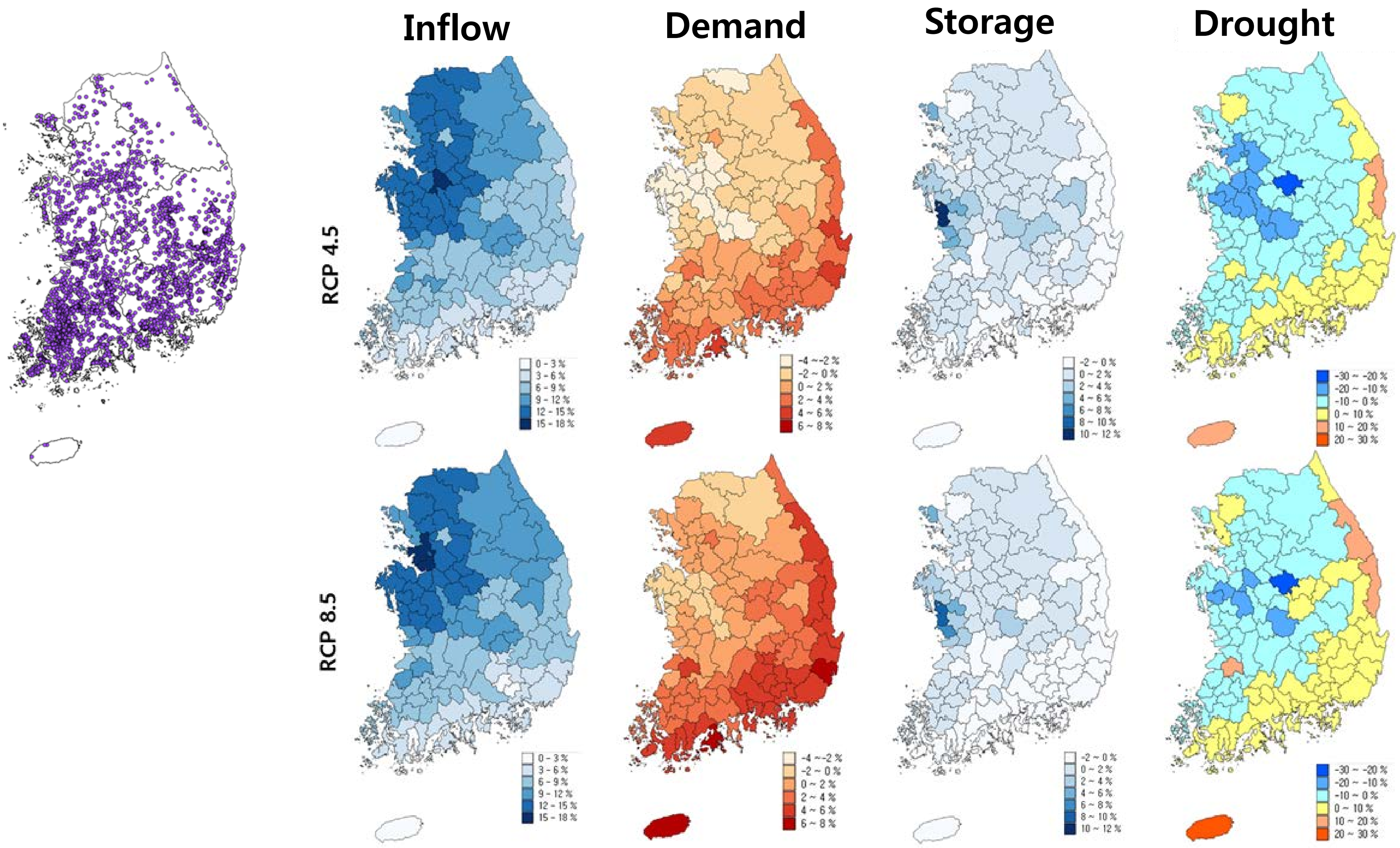
순(10-Days)		total
Observed	Storage (1000 m^3)	**302883**
Historical	Storage (1000 m^3)	**292767**
	% Difference	**-3.3**
RCP4.5	Storage (1000 m^3)	**292455**
	% Change	**-0.1**
RCP8.5	Storage (1000 m^3)	**291719**
	% Change	**-0.4**

Historicl vs RCP8.5



Climate Change Impact on Agricultural Reservoir

❖ Spatial distribution of impact assessment results



Concluding Remarks

- Weighting factor method based on the reproducibility test (ten-day mean and variation) of individual GCMs was developed for estimating MME for upsteam inflow, demand of water supply, and storage level of reservoirs.
- Future projection according to climate changes predicted highest changes in upsteam inflow by showing that: 1) 8.5% and 8.1% increase in upstream inflow, 2) 0.6% and 2.6% increase in demand, 3) 0.7% and 0.4% increase in storage level, and 4) 1.6% and 0.4% decrease in the number of occurrence of 50% or less storage level, respectively, for RCP4.5 and 8.5 scenarios as compared to the past period.
- However, result of the spatial distribution analysis at 93-Jisa level shows that the Midwest region can be changed to positive direction while Southeast region can be changed to negative direction for water management purpose by showing significant increases in demands compared to the upstream inflow.

Thank You!