

Korean Water Resources Changes under CMIP5 Projection

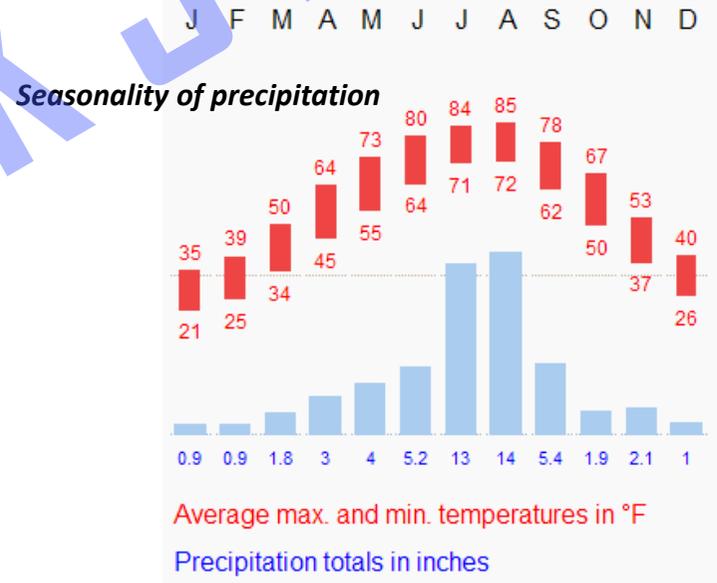
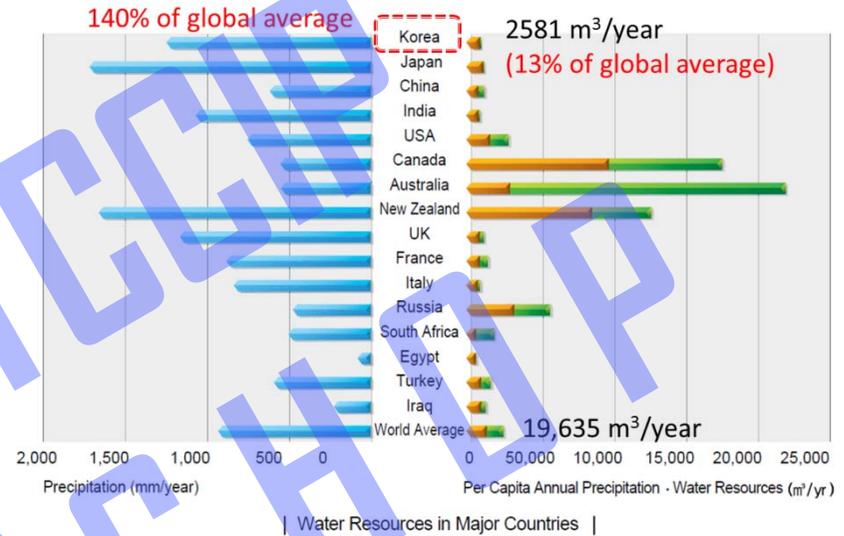
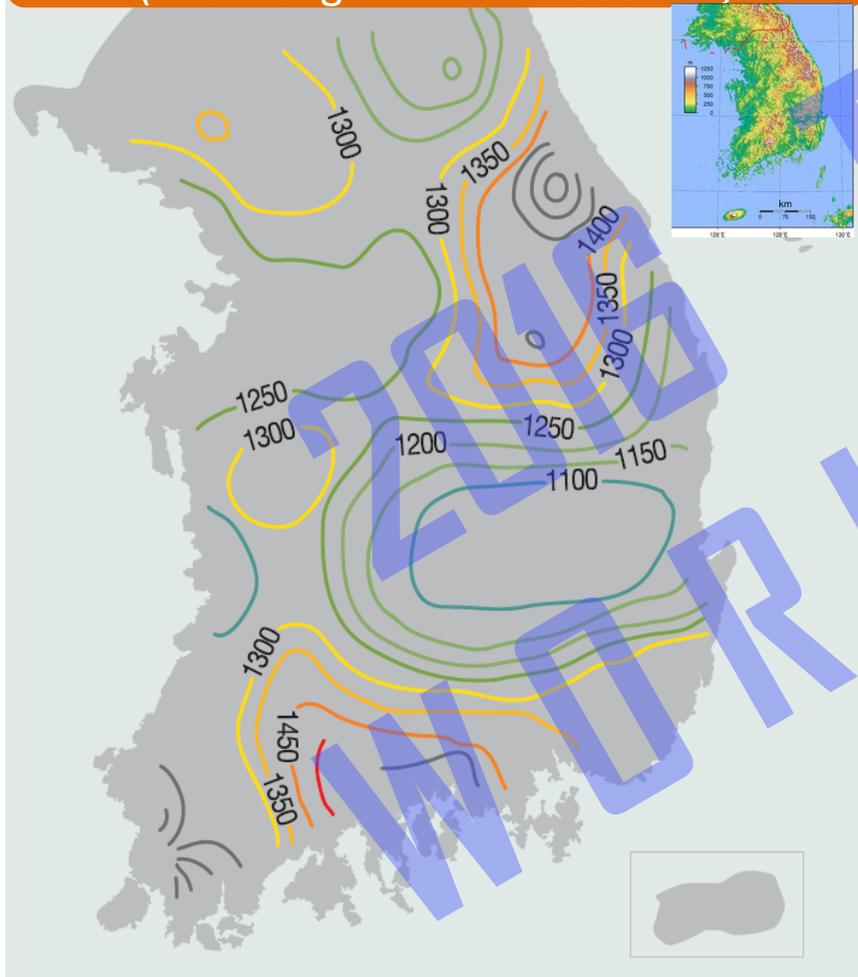
Il Won Jung, Hyung Il Eum, Ok-Yeon Kim, & Eunjeong Lee
Climate Research Dept., APEC Climate Center, Busan, Korea

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- I** Historical changes in Korean climate and water
- II** Climate Change Adaptation for Water Resources project
- III** Possible changes in water resources under CMIP5
- IV** Conclusions

Climate of South Korea

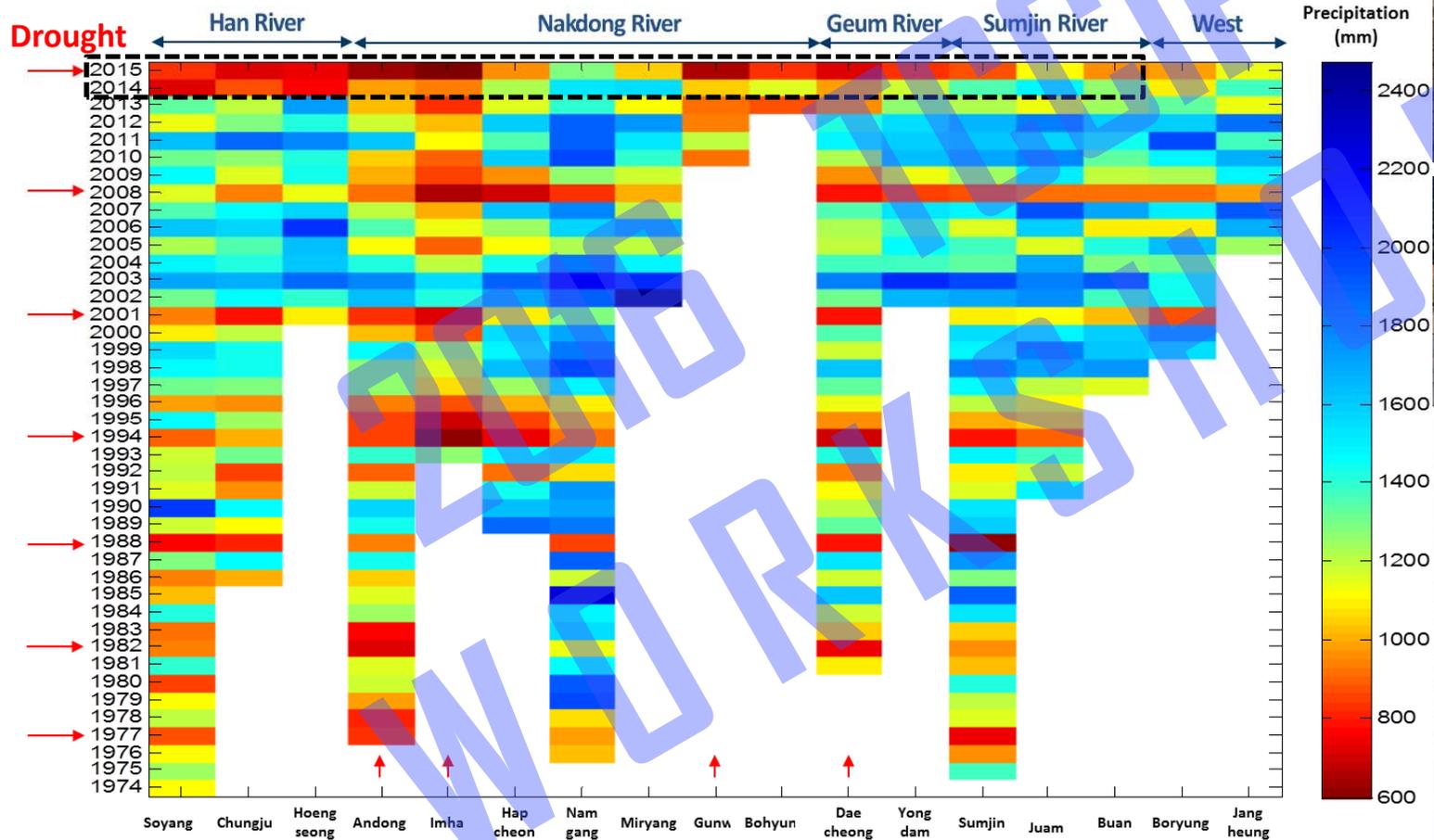
Annual mean precipitation :1,245 mm
(140% of global mean 880mm)



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)

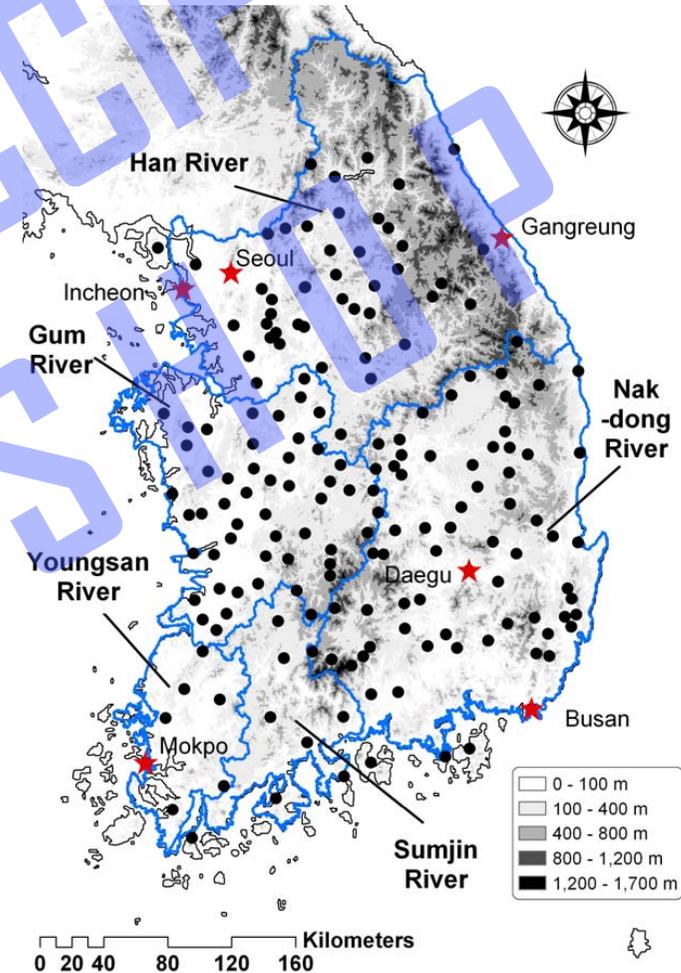
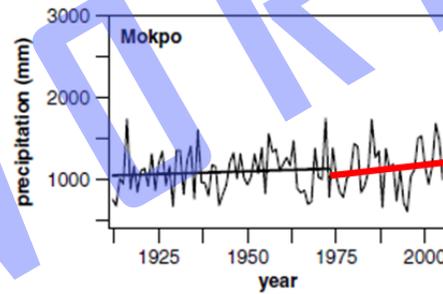
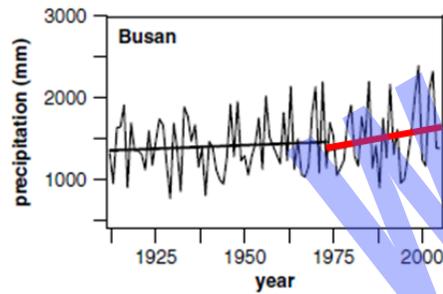
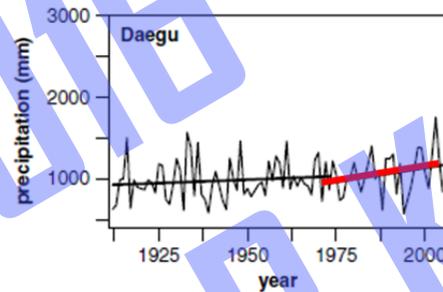
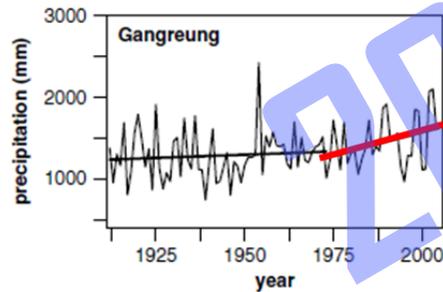
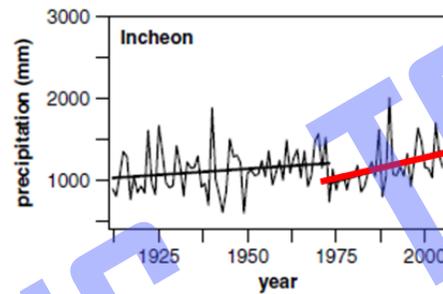
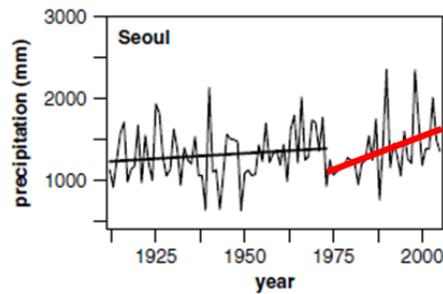


2015 summer precipitation was less than half of the average in Gyeonggi and Gangwon provinces



Historical changes in precipitation

➤ Changes in annual precipitation (6 weather stations)

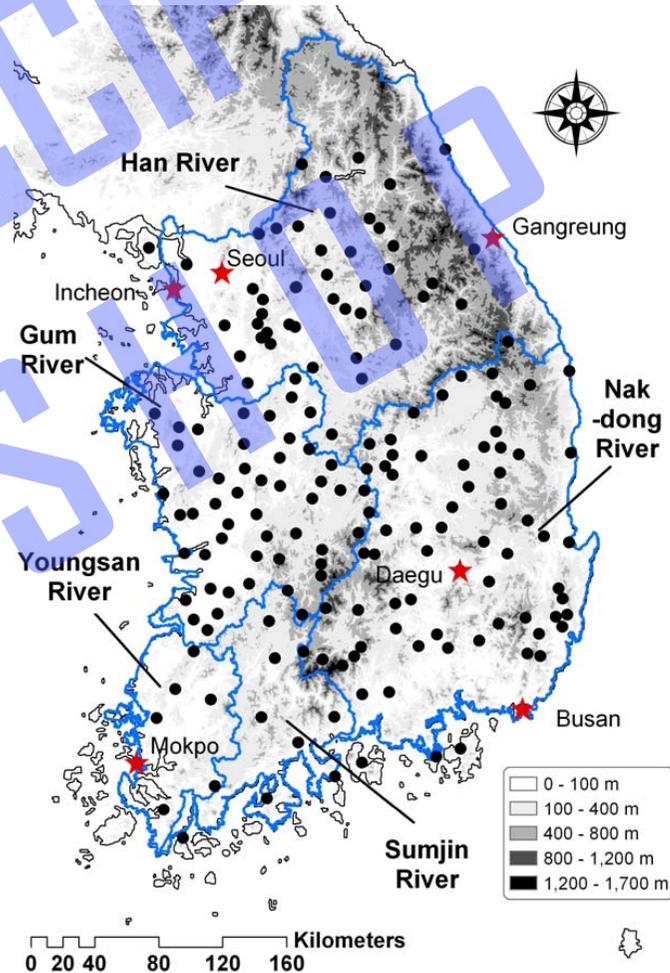
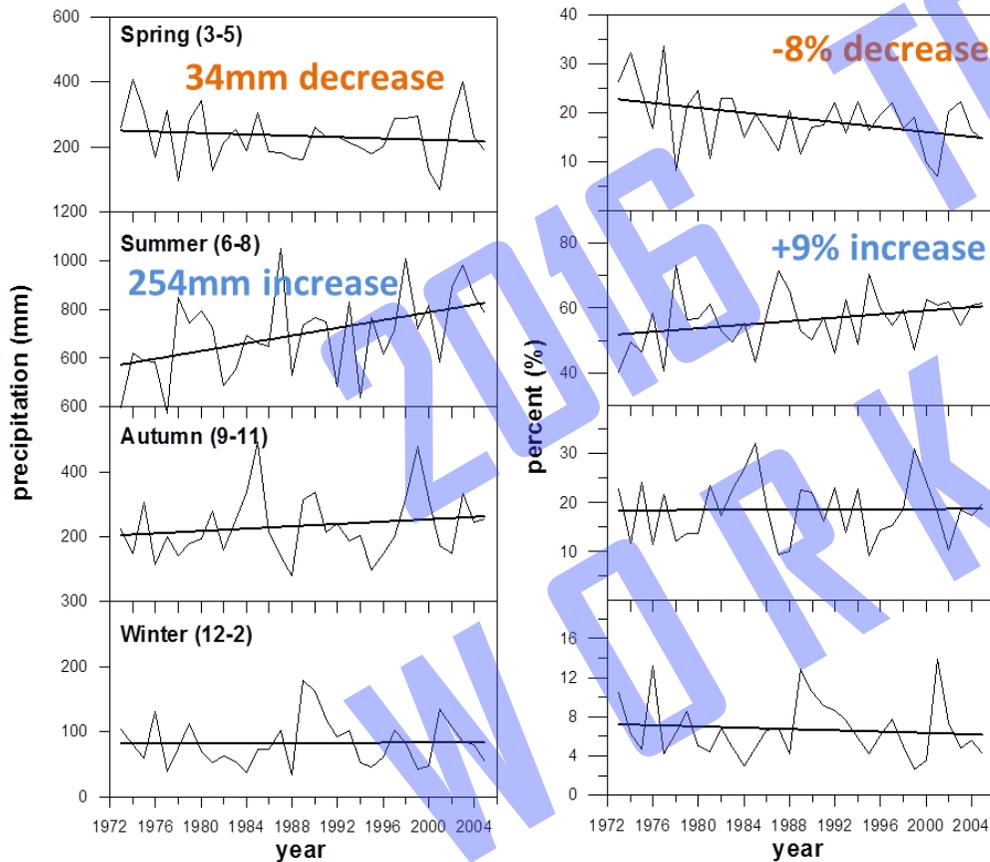


Source: Jung et al. (2011) *International Journal of Climatology*

Historical changes in precipitation

➤ Changes in seasonal precipitation (183 weather stations)

Recent 33yrs (1973 – 2005)

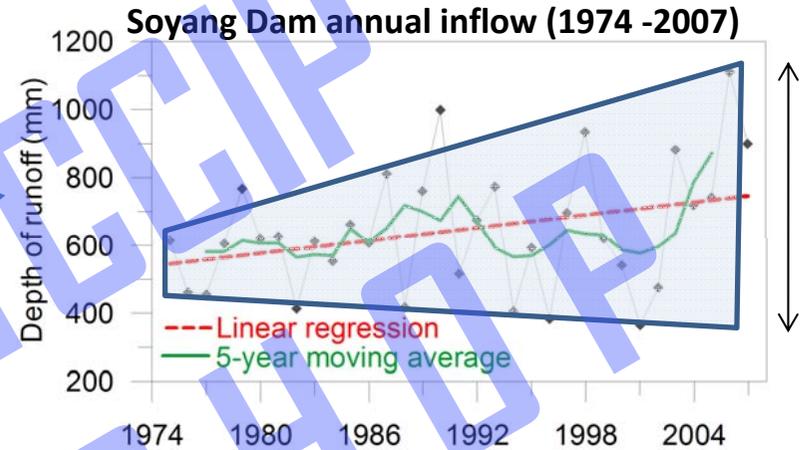


Source: Jung et al. (2011) International Journal of Climatology

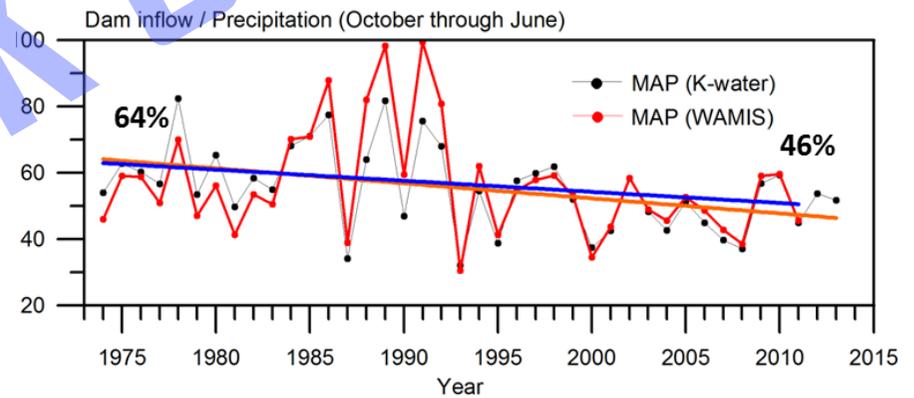
Historical changes in streamflow

➤ Changes in dam inflow

✓ Dams contributes 65% of water supply (12.2 billion m³)



Change in Dry-season runoff rate



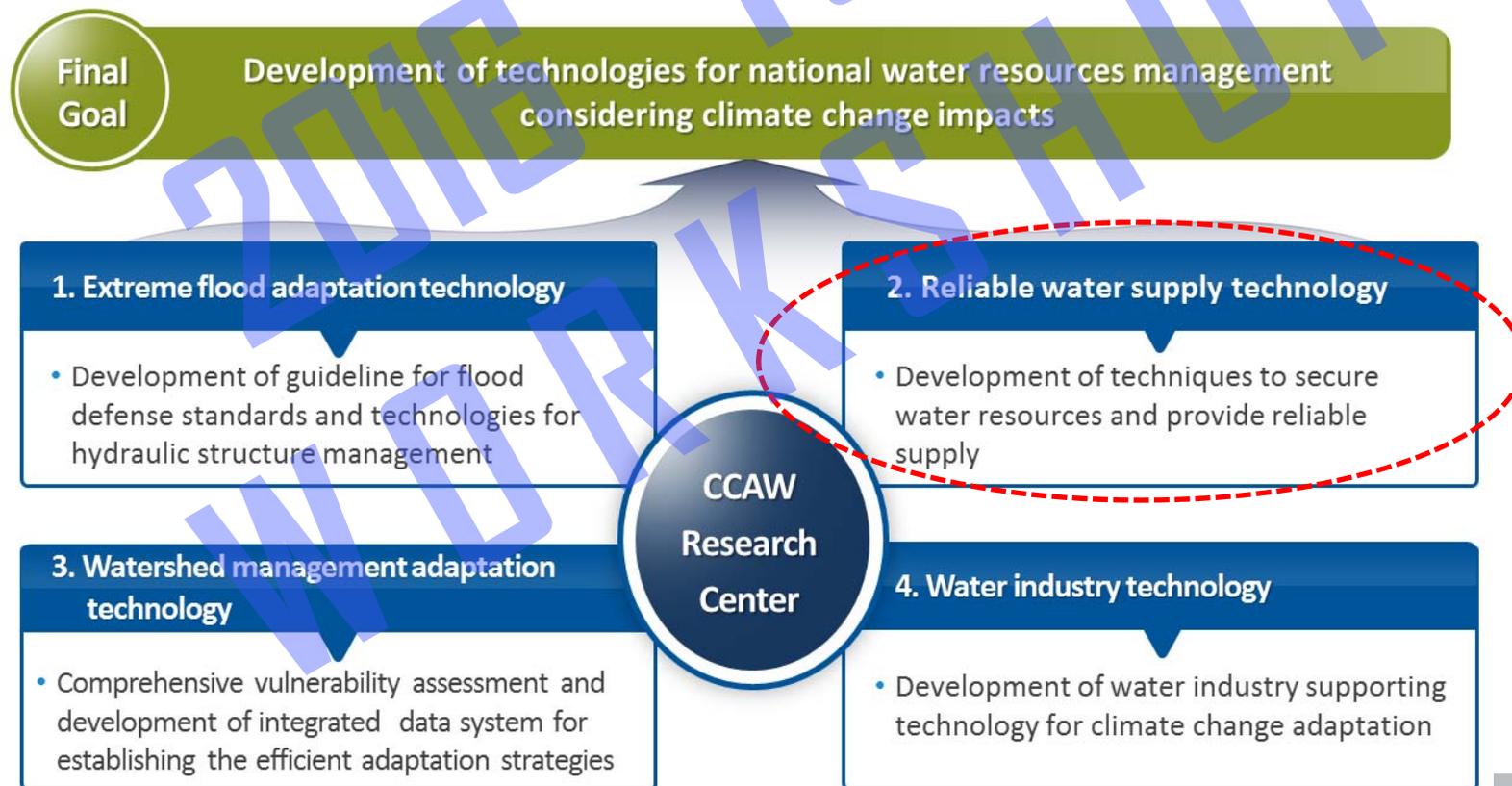
Source: Jung (2016) APCC annual report

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



➤ Project Overview

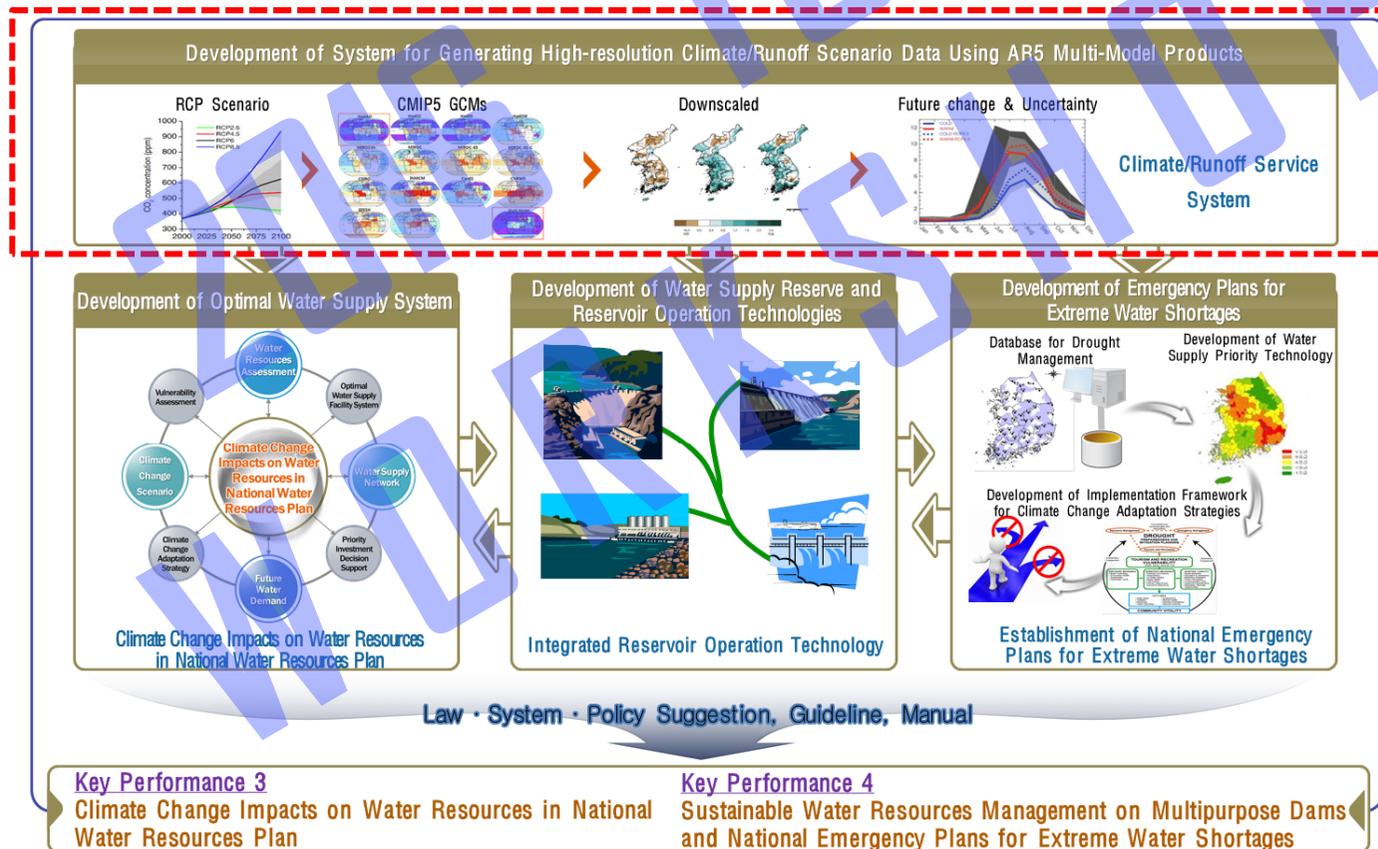
- ✓ Period/Budget : Sep. 15, 2014 ~ June 14, 2019 (4 years 9 months)/ 22 million USD
- ✓ Principal institute : Sejong university (Prof. Deg-Hyo Bae)
- ✓ Joint research institutes : 17 (K-water, APCC, Inha univ., Konkuk univ., etc.)



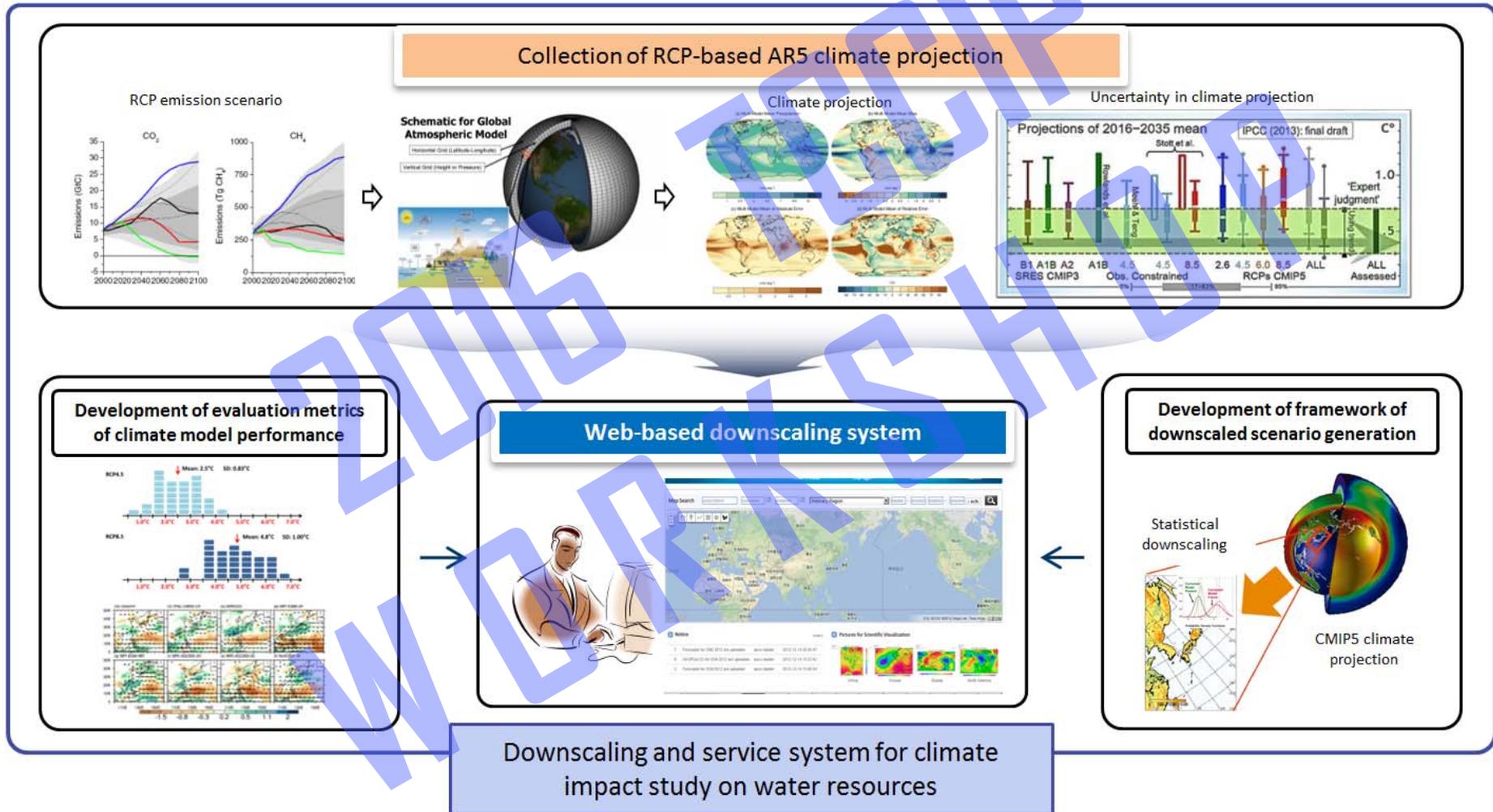
Research goal and framework

➤ 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

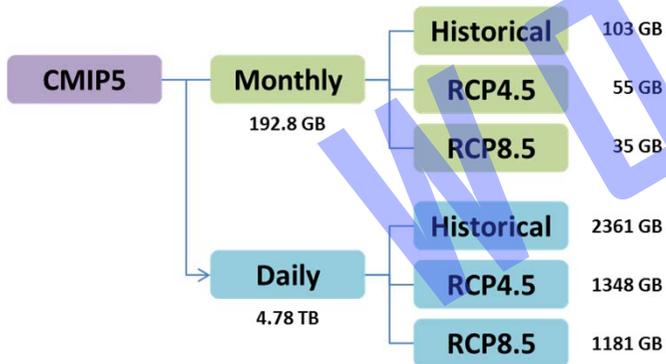


Evaluation of performance of CMIP5

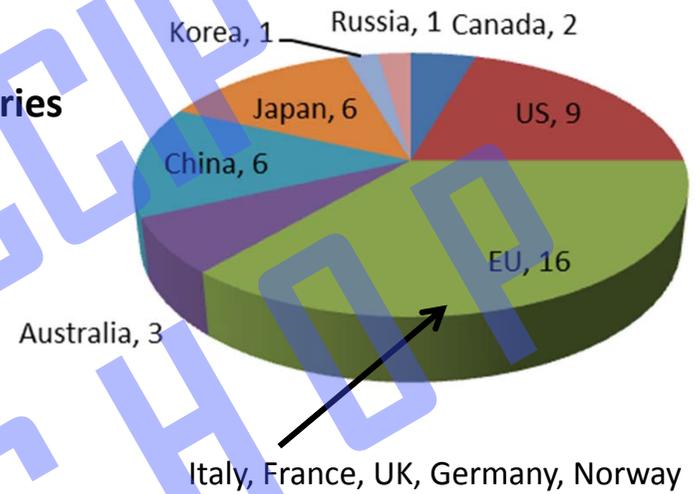
➤ Collection of CMIP5 projection



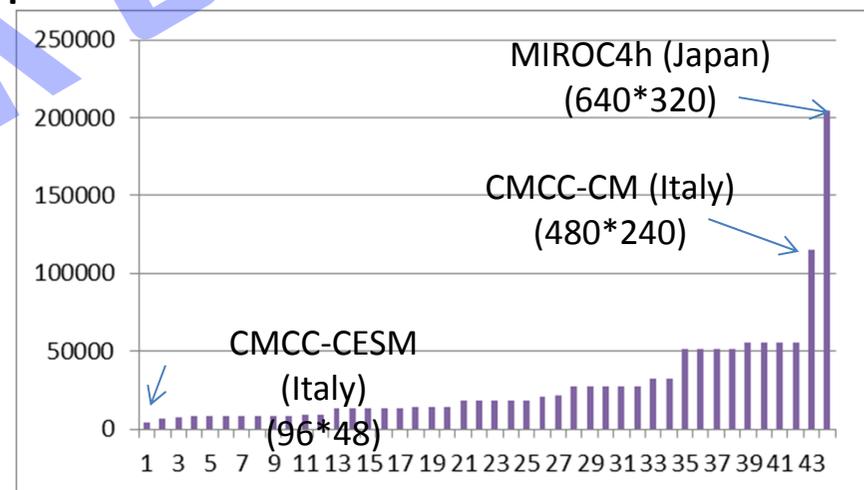
<http://pcmdi9.llnl.gov/esgf-web-fe/>



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

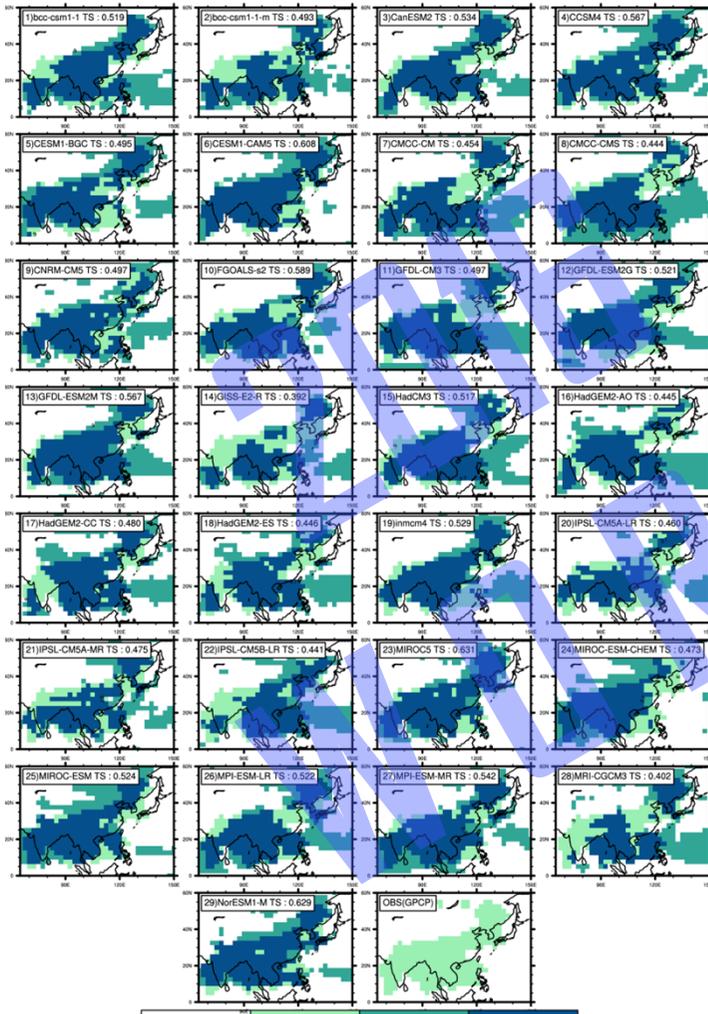
➤ Expert Team on Climate Change Detection and Indices (ETCCDI) (WMO)

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

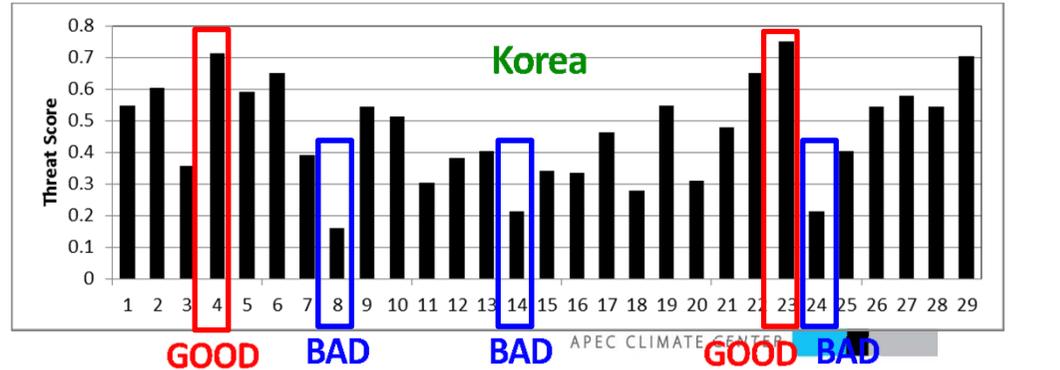
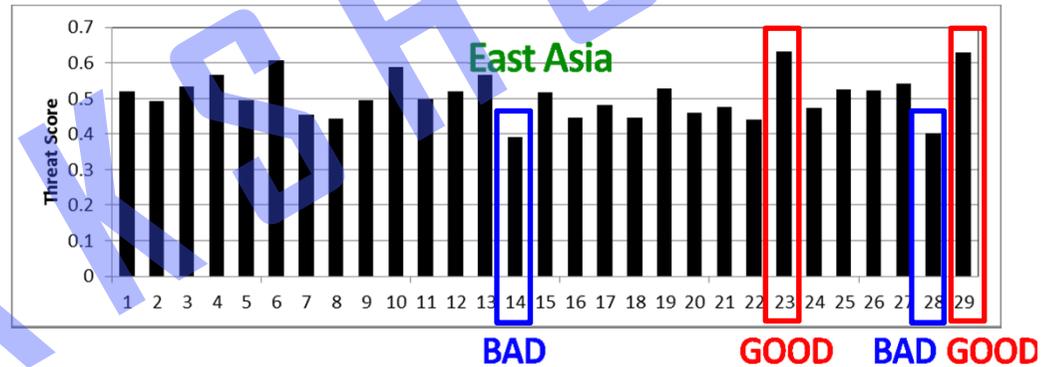
➤ Performance of simulating East Asia Monsoon

GM domain OBS vs CMIP5



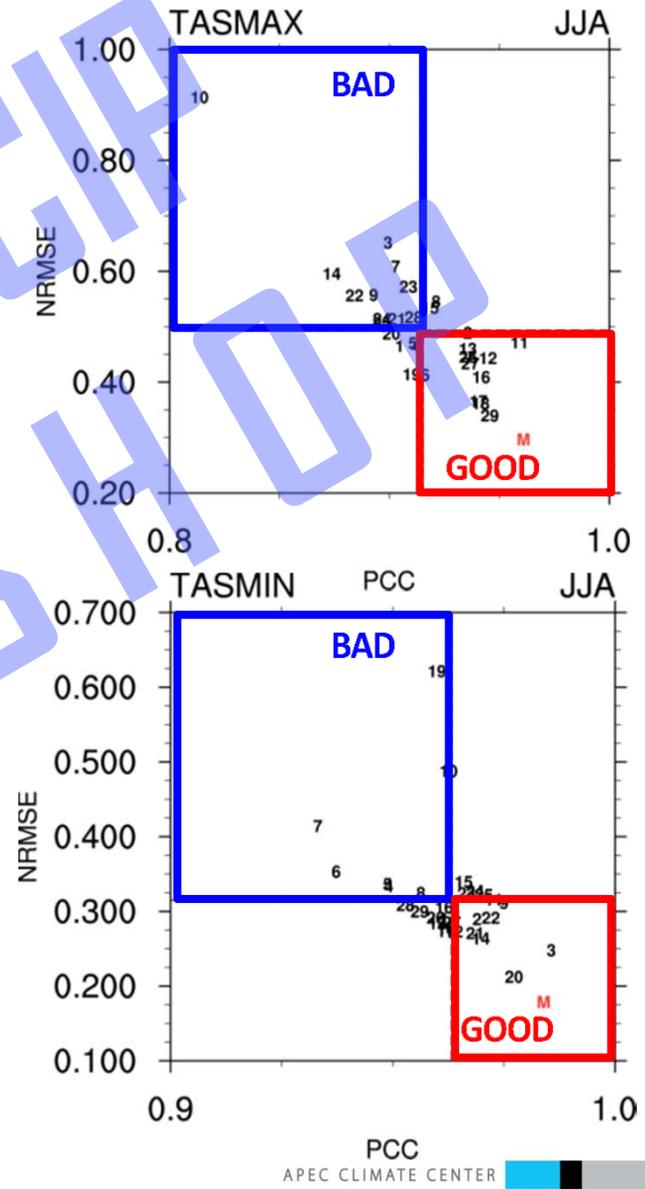
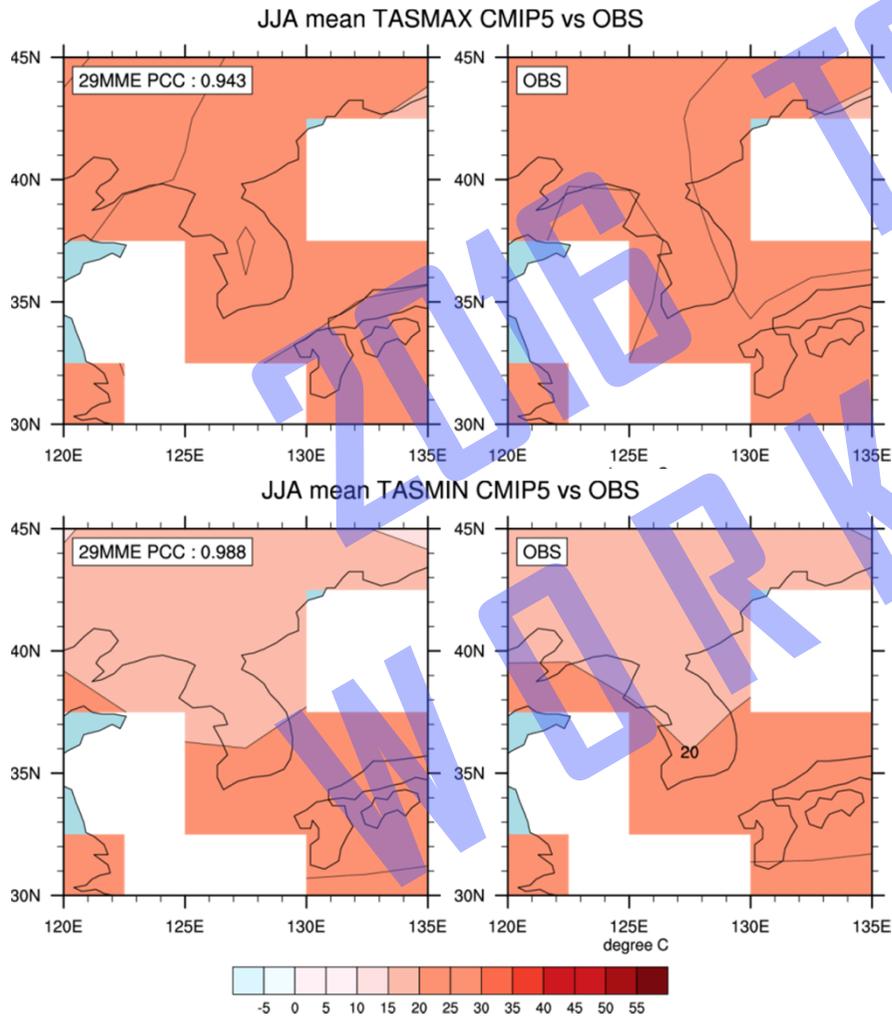
$$\text{Threat score} = \frac{\text{hit}}{(\text{hit} + \text{missed} + \text{falsealarm})}$$

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 ↓

		BCC-CSM1-1	BCC-CSM1-1-M	CanESM2	CCSM4	CESM1-BGC	CESM1-CAM5	CMCC-CM	CMCC-CMS	CNRM-CM5	FGOALS-s2	GFDL-CM3	GFDL-ESM2G	GFDL-ESM2M	GISS-E2-R	HadCM3	HadGEM2-AO	HadGEM2-CC	HadGEM2-ES	INM-CM4	IPSL-CM5A-LR	IPSL-CM5A-MR	IPSL-CM5B-LR	MIROC5	MIROC-ESM-CHEM	MIROC-ESM	MPI-ESM-LR	MPI-ESM-MR	MRI-CGCM3	NorESM1-M	MME		
JJA	prcp	Mean Variation	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
		Mean Variation																															
		Mean Variation																															
	tmax	Mean Variation																															
		Mean Variation																															
		Mean Variation																															
tmin	Mean Variation																																
	Mean Variation																																
	Mean Variation																																

GOOD

BAD

Results

➤ Performance evaluation using ETCCDI

		BCC-CSM1-1	BCC-CSM1-1-M	CanESM2	CCSM4	CESM1-BGC	CESM1-CAM5	CMCC-CM	CMCC-CMS	CNRM-CM5	FGOALS-s2	GFDL-CM3	GFDL-ESM2G	GFDL-ESM2M	GISS-E2-R	HadCM3	HadGEM2-AO	HadGEM2-CC	HadGEM2-ES	INM-CM4	IPSL-CM5A-LR	IPSL-CM5A-MR	IPSL-CM5B-LR	MIROC5	MIROC-ESM-CHEM	MIROC-ESM	MPI-ESM-LR	MPI-ESM-MR	MRI-CGCM3	NovESM1-M	MME	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
tmax	SU	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	
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	WSDI	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
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tmin	TX90p	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
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	TR	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
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prcp	Rx1day	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	Rx5day	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	SDII	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
	R10mm	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
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	R95p	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
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GOOD

BAD

GOOD

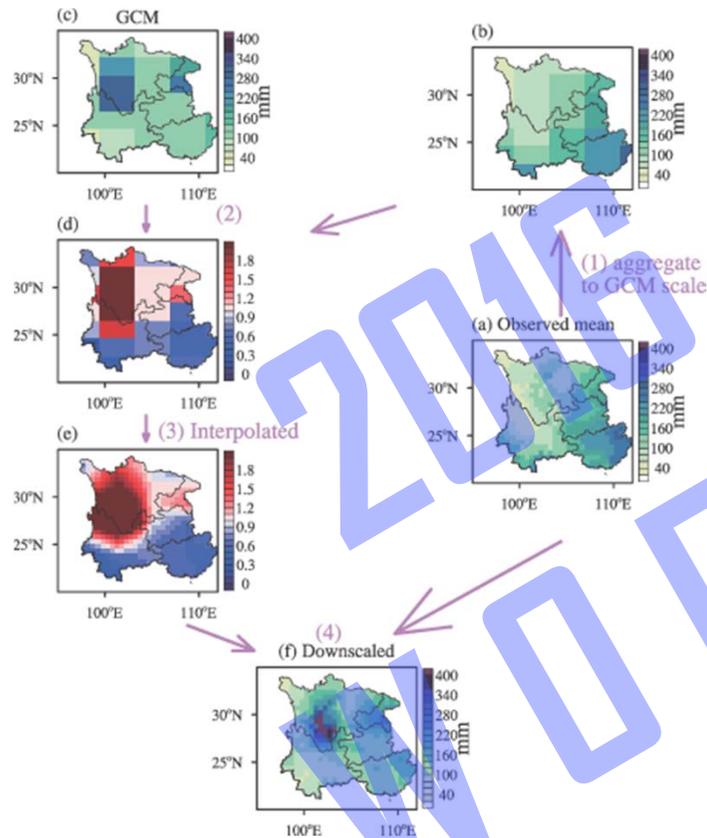
Results

➤ Performance by the spatial resolution of climate models



Statistical downscaling

➤ Bias Correction & Spatial Disaggregation (BCSD)



Daily BCSD (or SDBC)

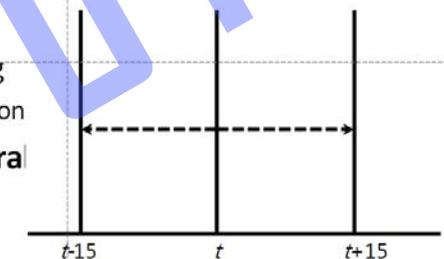
➤ Spatial disaggregation

- Interpolating daily GCM output to finer grid points

➤ Bias correction

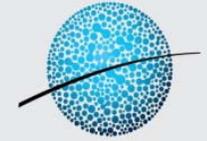
- Quantile mapping
- Sample distribution

➤ No need of temporal



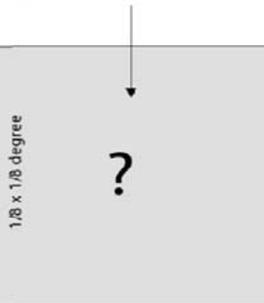
- ✓ Bias-Correction/Constructed Analogue (BCCA)
- ✓ Multivariate Adaptive Constructed Analogs (MACA)
- ✓ Bias-Correction/Climate Imprint (BCCI)

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



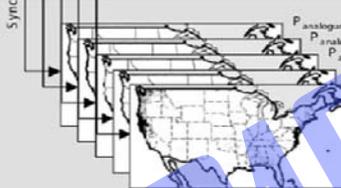
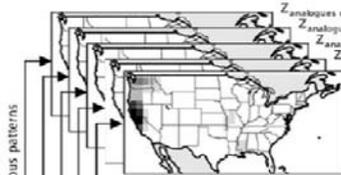
I) NEW PATTERN AT COARSE-RESOLUTION:

A new pattern obtained from a coarse resolution source, but the corresponding high-resolution (downscaled) pattern is unknown



II) FITTING THE ANALOGUE (DIAGNOSIS):

A subset of patterns from a historical library is selected as contributions to a constructed analogue of Z_{obs} based on spatial similarity evaluated at the 2.5 x 2.5 degree resolution.



The high-resolution patterns for the same days as the coarse predictor patterns are also gathered

III) DOWNSCALING THE PATTERN (PROGNOSIS):

A linear combination of the predictor patterns produces a least squares (constructed) analogue of Z_{obs} at 2.5 x 2.5 degree resolution



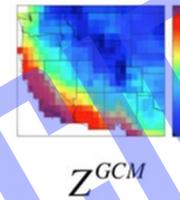
$$Z_{obs} = A_{analogues 1} Z_{analogues 1} + A_{analogues 2} Z_{analogues 2} + \dots + A_{analogues n} Z_{analogues n}$$

Where $A_{analogues 1}, A_{analogues 2}, \dots, A_{analogues n}$ are regressor coefficients

The downscaled pattern ($P_{downscaled}$) is obtained by applying the same regression coefficients to the high-resolution patterns:

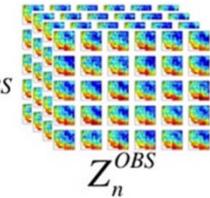
$$P_{downscaled} = A_{analogues 1} P_{analogues 1} + A_{analogues 2} P_{analogues 2} + \dots + A_{analogues n} P_{analogues n}$$

GCM target coarse pattern (1 day, 1 year)

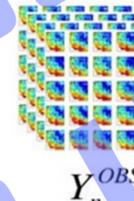


$$Z^{GCM} \approx \sum_{i=1}^{i=N} a_n Z_n^{OBS}$$

Library of OBS coarse patterns (+/- 45 day window, all years)

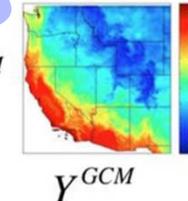


Corresponding fine OBS patterns from N best coarse OBS patterns



$$\sum_{i=1}^{i=N} a_n Y_n^{OBS} = Y^{GCM}$$

Downscaled GCM target pattern (1 day, 1 year)



Source: <http://climate.northwestknowledge.net/MACA/MACAMethod.php>

Source: Hidalgo et al. (2008)

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 VISUALIZATION GET THE DATA ADVANCE CONTACT

CMIP5 Statistically Downscaled for Conterminous USA (CONUS)

The Multivariate Adaptive Constructed Analogs (MACA) (Hidalgo, 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 Intercomparison Project 5 (CMIP5) for the historical GCM forcings (1950-2005) and the future Representative Concentration Pathways (RCPs) RCP 4.5 and RCP 8.5 scenario (2006-2100) from the native resolution of the GCMs to either 4 km or 16 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, etc.). We currently have data for the following variables:

- tmax - Maximum daily temperature near surface
- tmin - Minimum daily temperature near surface
- rhmax - Maximum daily relative humidity near surface
- rhmin - Minimum daily relative humidity near surface
- havg - Average daily specific humidity near surface
- pr - Average daily precipitation amount at surface
- rds - Average daily downward shortwave radiation at surface
- vs - Average daily wind speed near surface
- us - Average daily eastward component of wind near surface
- vs - Average daily northward component of wind near surface

We are currently developing 3 data products: MACA v1-METDATA, MACA v2-METDATA and MACA v1-LIVNH. MACA v1-METDATA is available for the Western USA, while MACA v2-LIVNH/MACA v2-METDATA are available over the entire conterminous USA. MACA v2-LIVNH/MACA v2-METDATA both use the newest version of the MACA method (version 2), while MACA v1-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

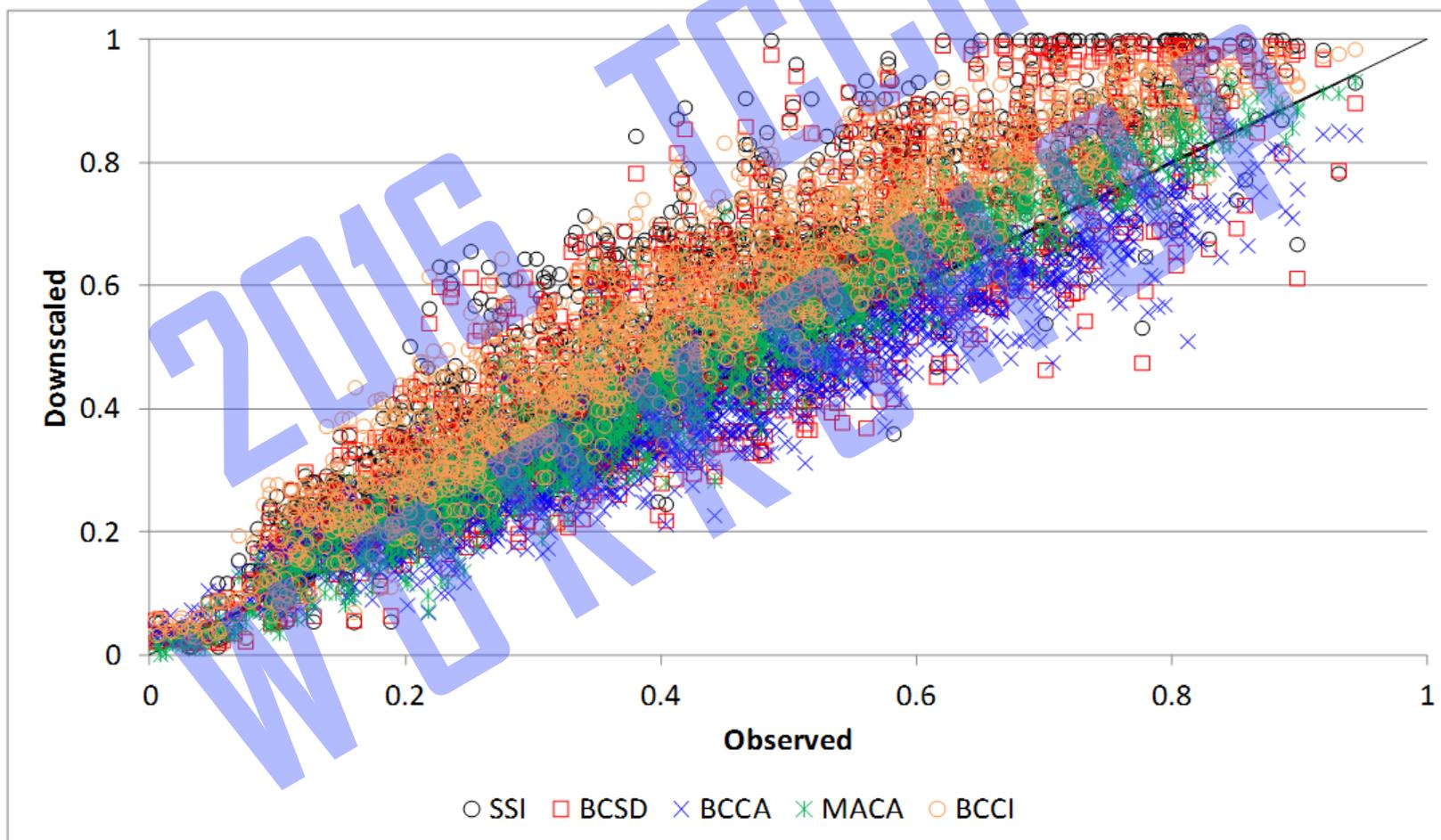
$$P_{ratio} = \frac{P_{daily}}{P_{monthly}} \text{ at a large grid}$$

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

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

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

➤ 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	0.850	0.857	0.866	0.813	0.845	0.825	0.804	0.713	0.614	0.520	0.623	0.617

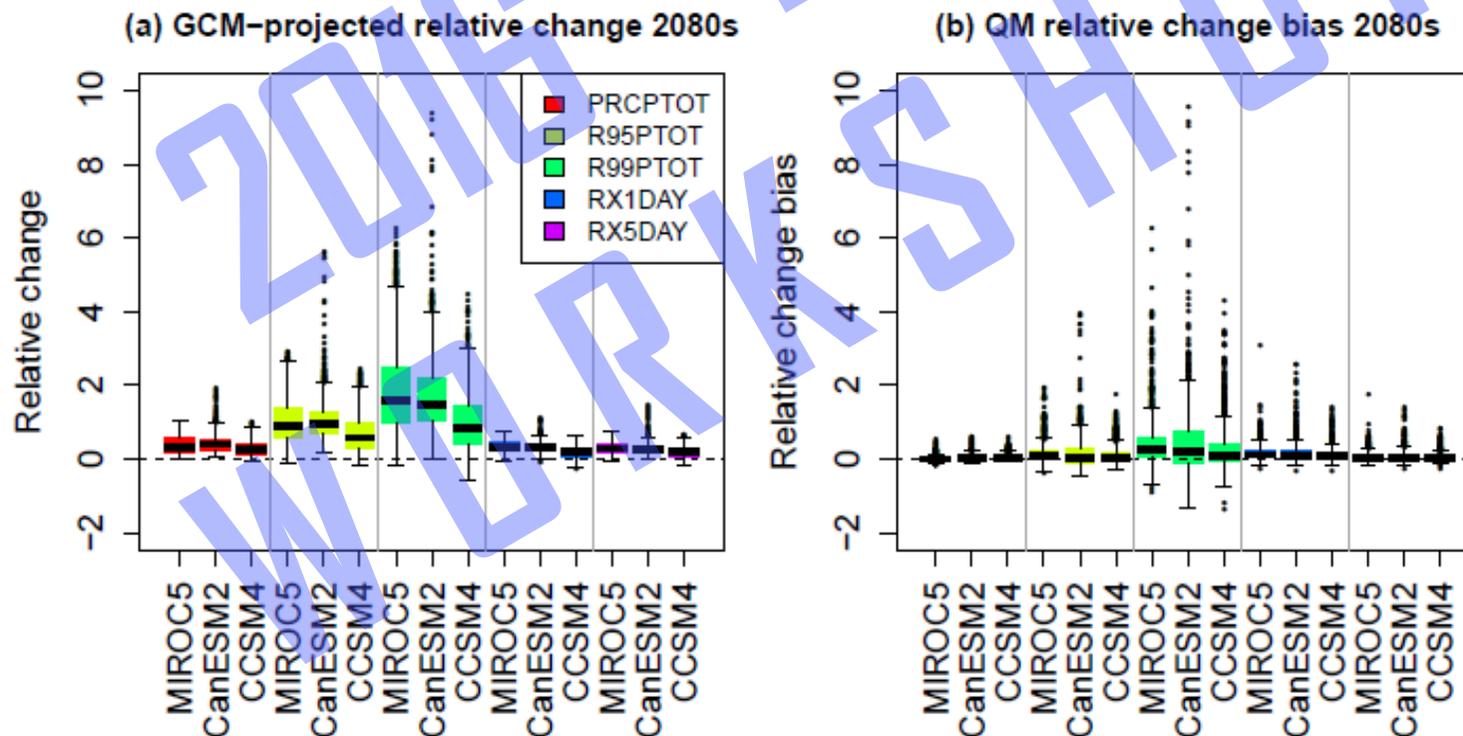
➤ K-S D statistic

	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

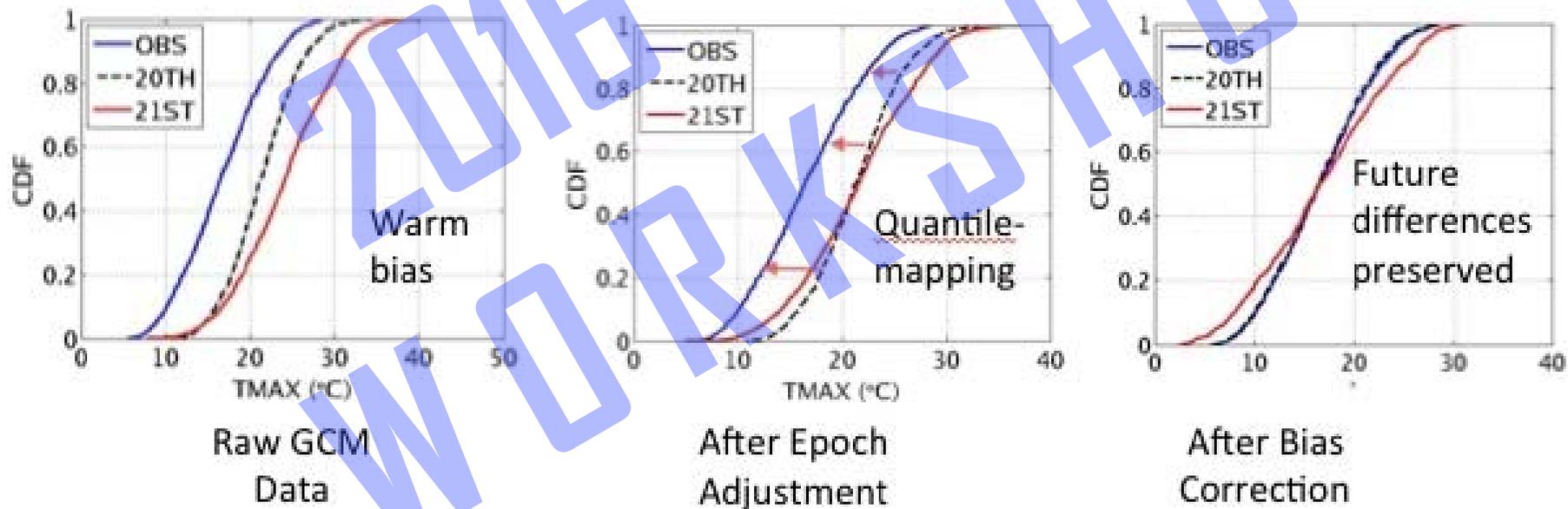
Relative change bias =
change in GCM (%) – change in downscaled data (%)



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



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

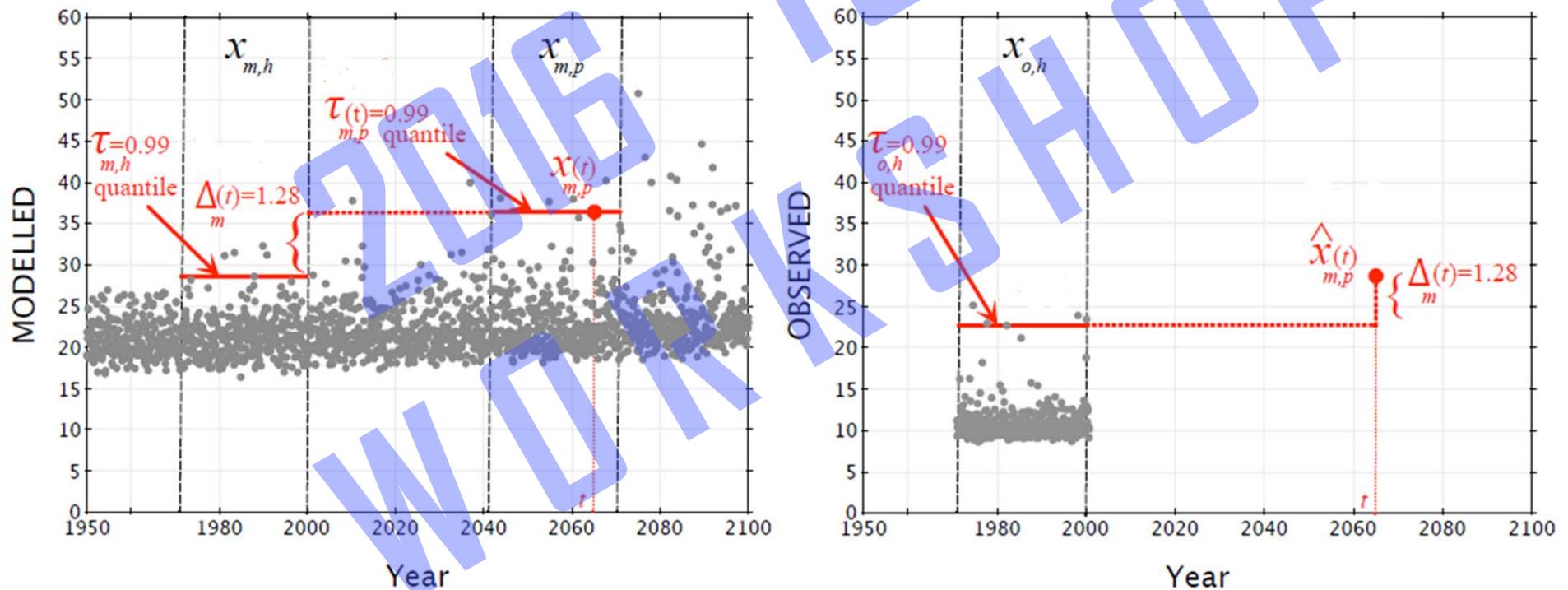
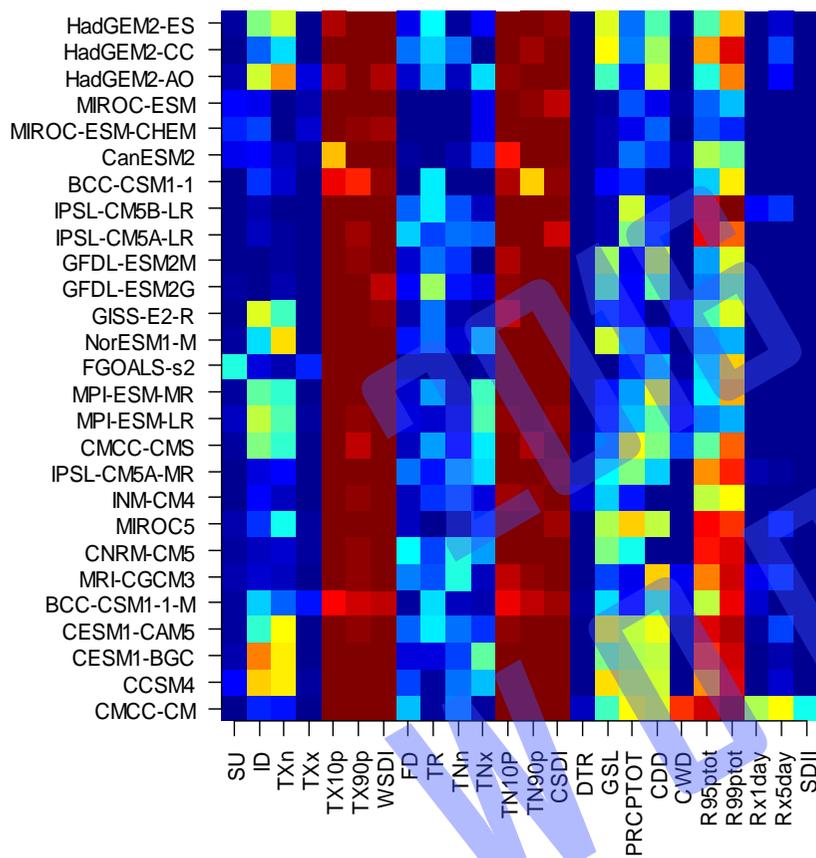
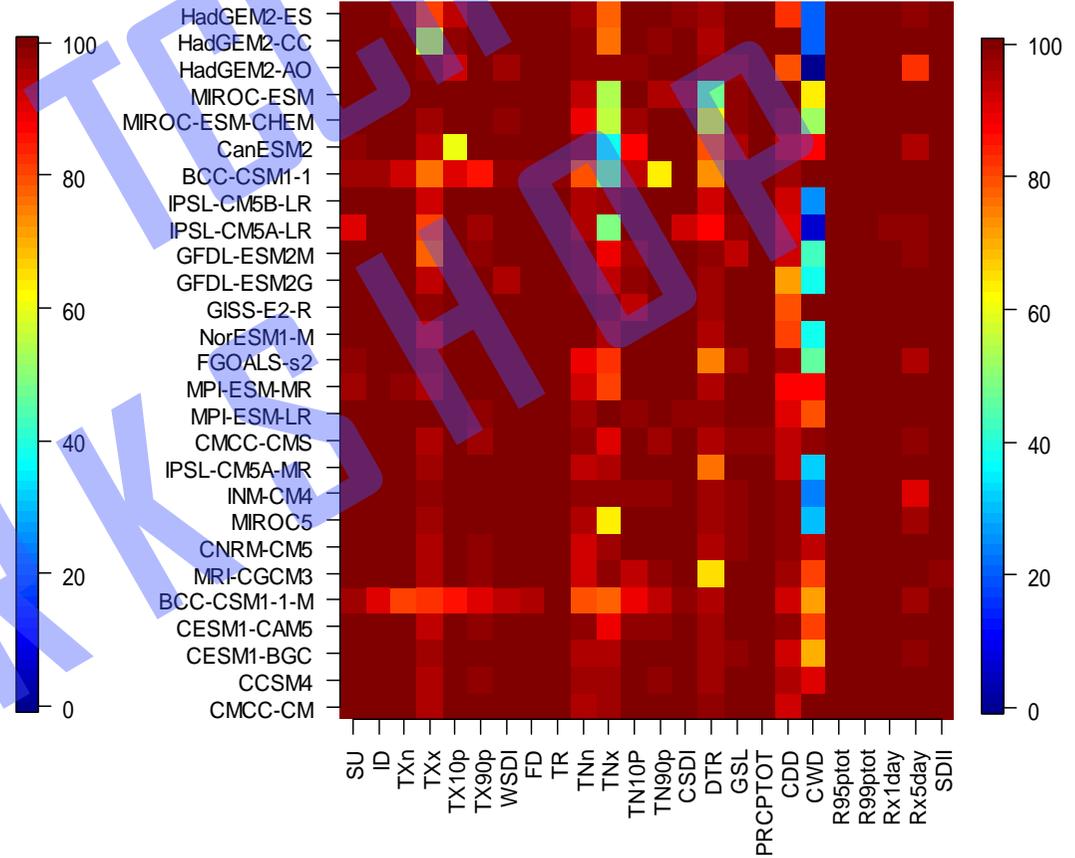


Figure from Cannon et al. (2015)

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



Before BCSD-QDM

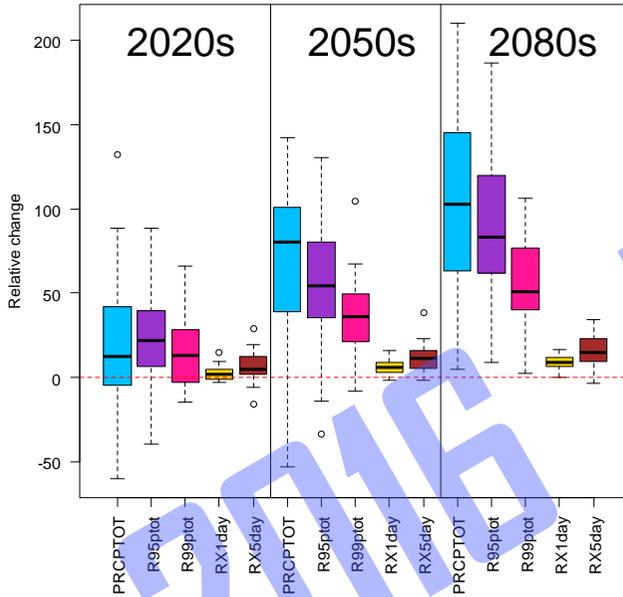


After BCSD-QDM

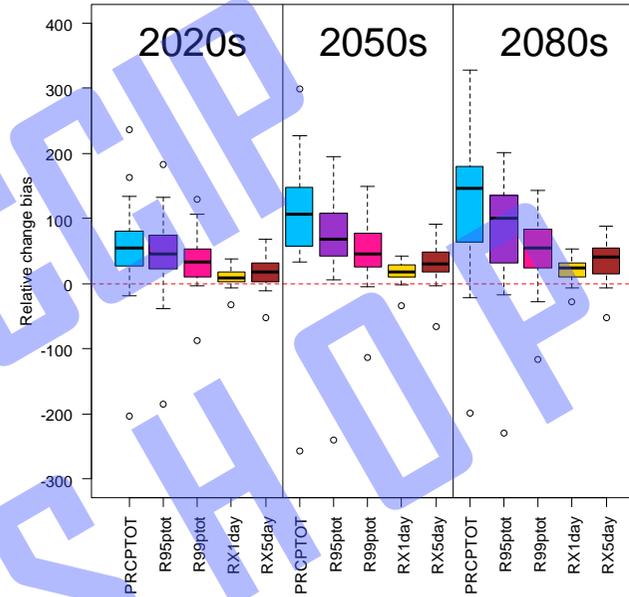
➤ ETCCDI related to PRCP

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

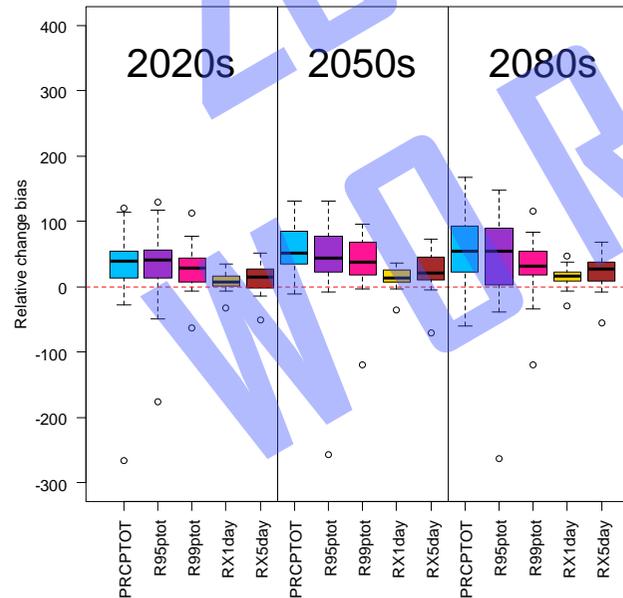
GCMs



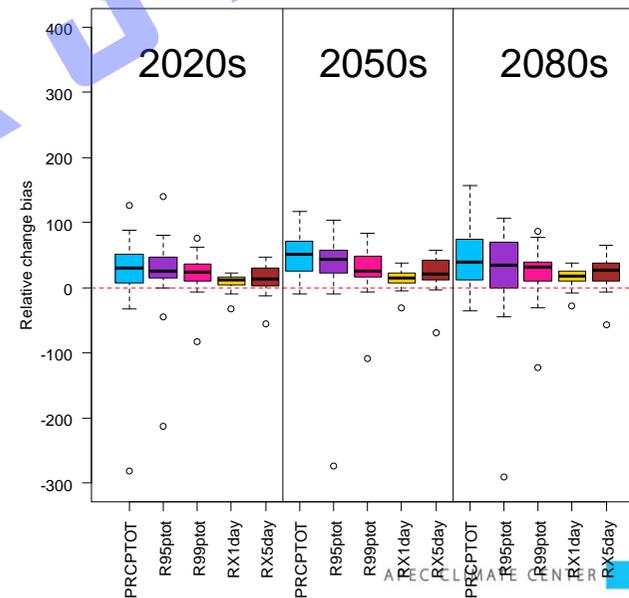
QM



DQM



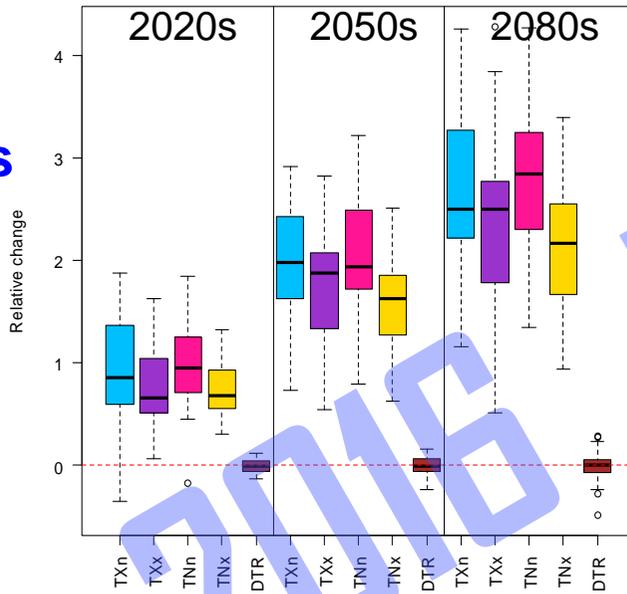
QDM



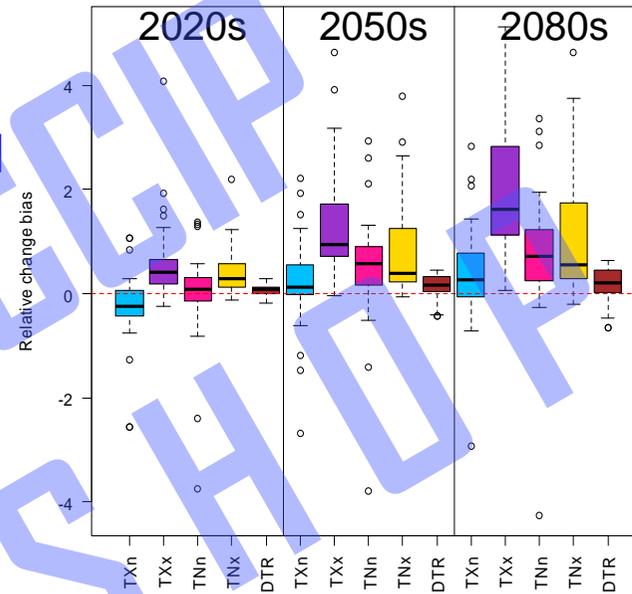
ETCCDI related to Tmax & Tmin

Relative change bias = $\frac{\text{change in GCM (\%)} - \text{change in downscaled data (\%)}}{\text{change in downscaled data (\%)}}$

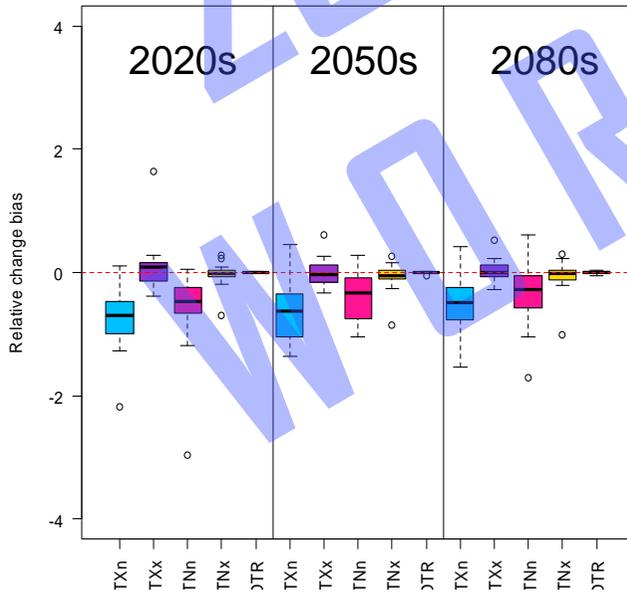
GCMs



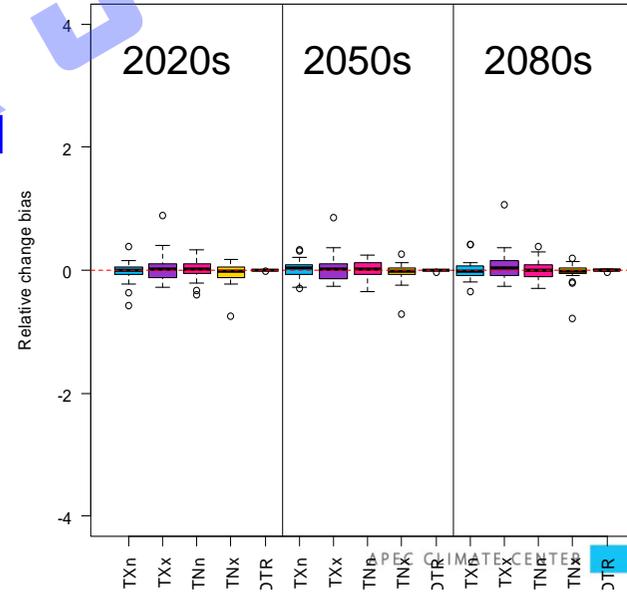
QM



DQM

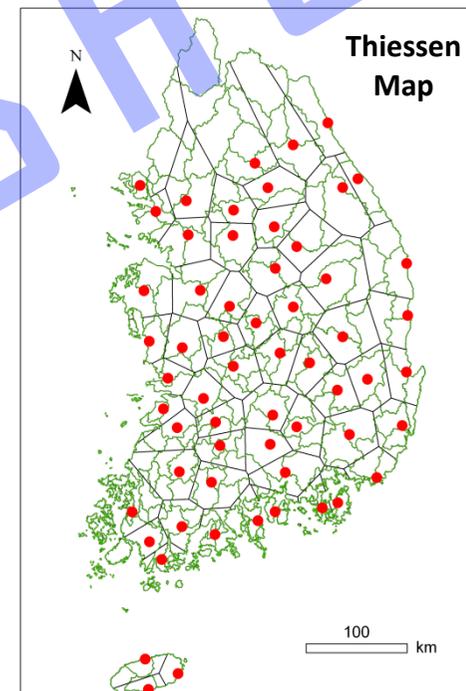
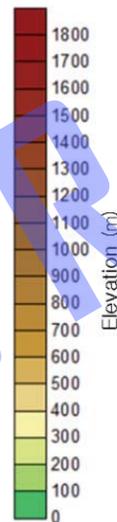
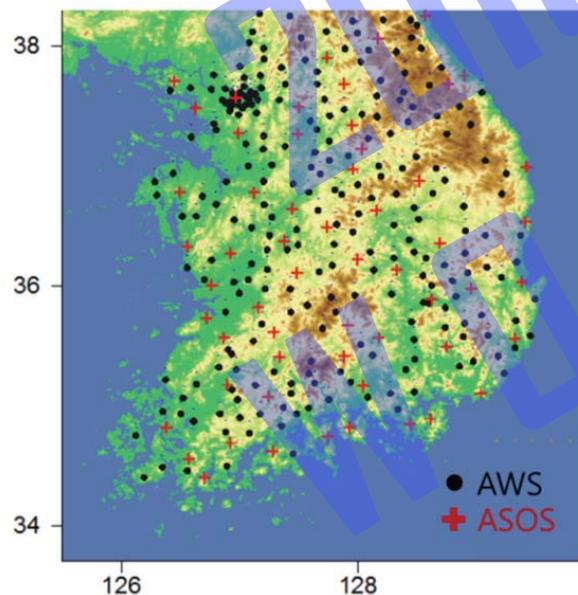


QDM



➤ 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

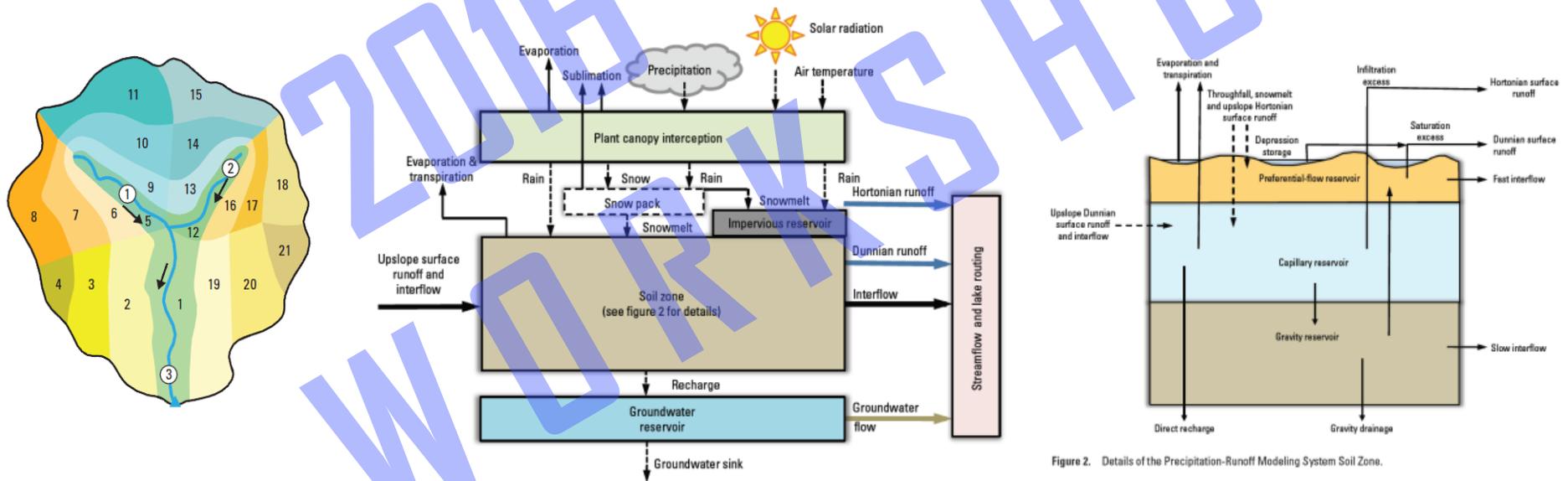
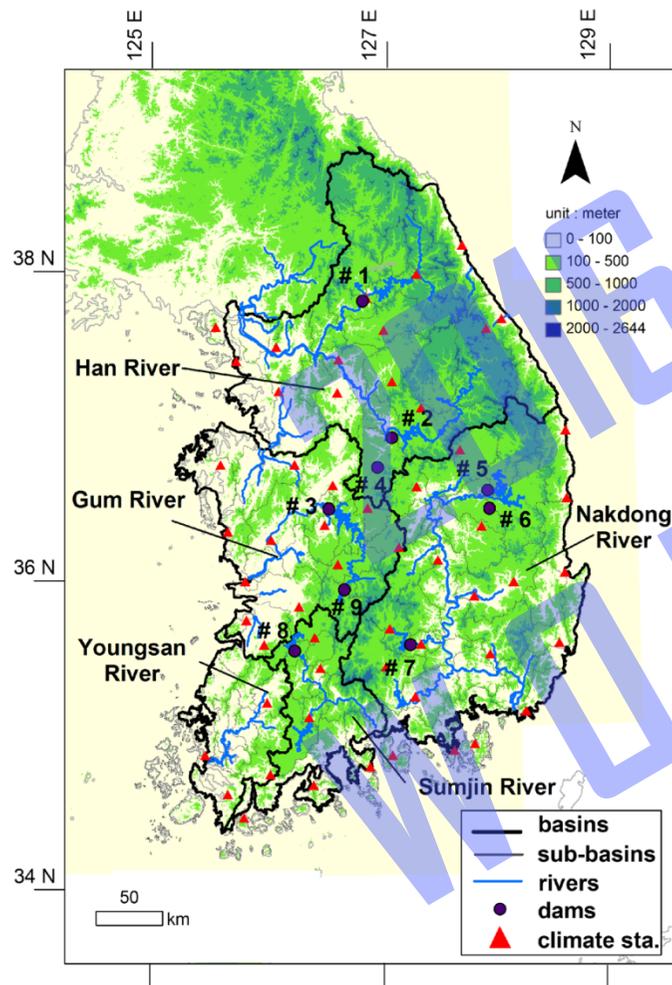


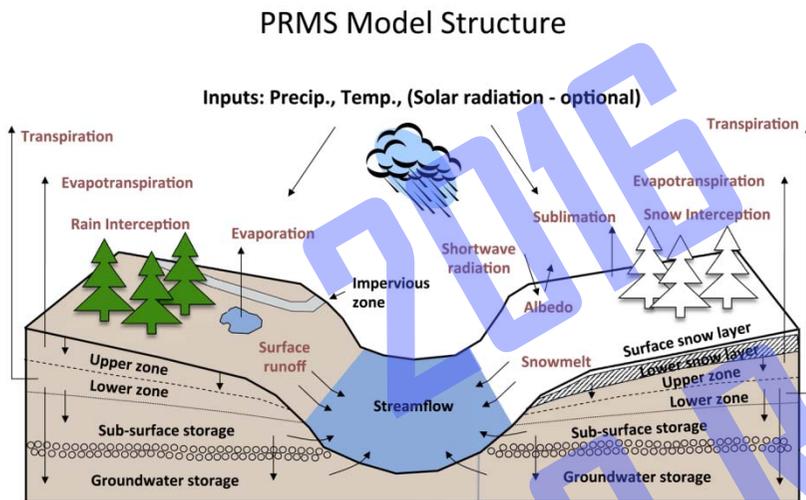
Figure from USGS (2008)

➤ 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)

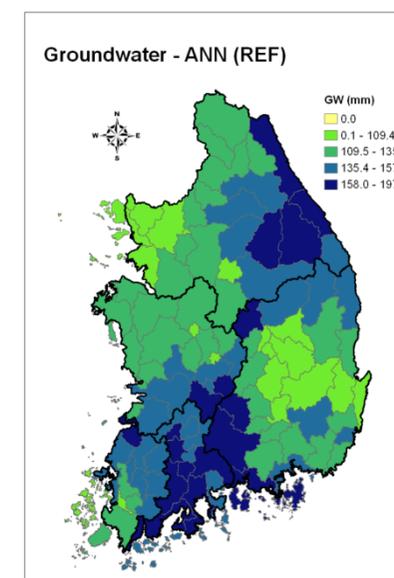
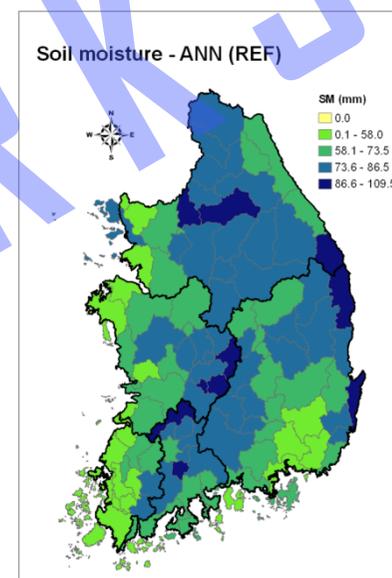
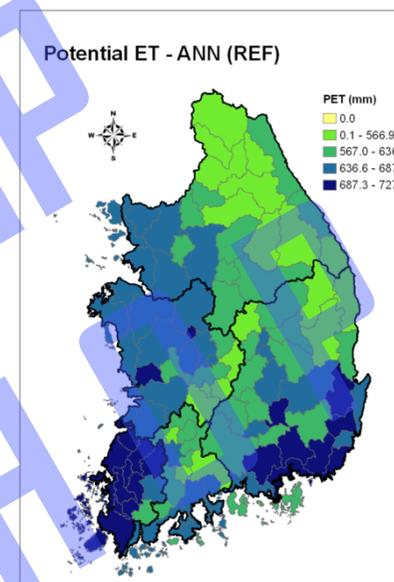
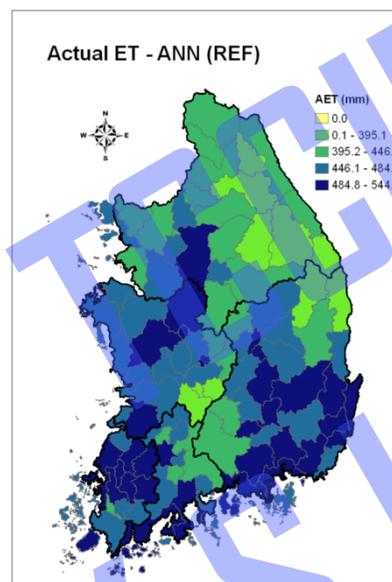
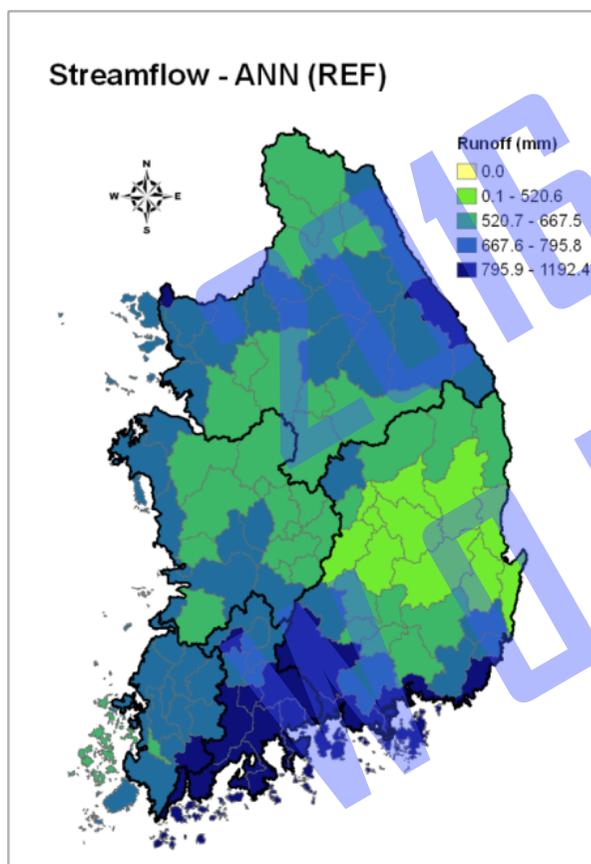
➤ Description of PRMS model parameters for optimization



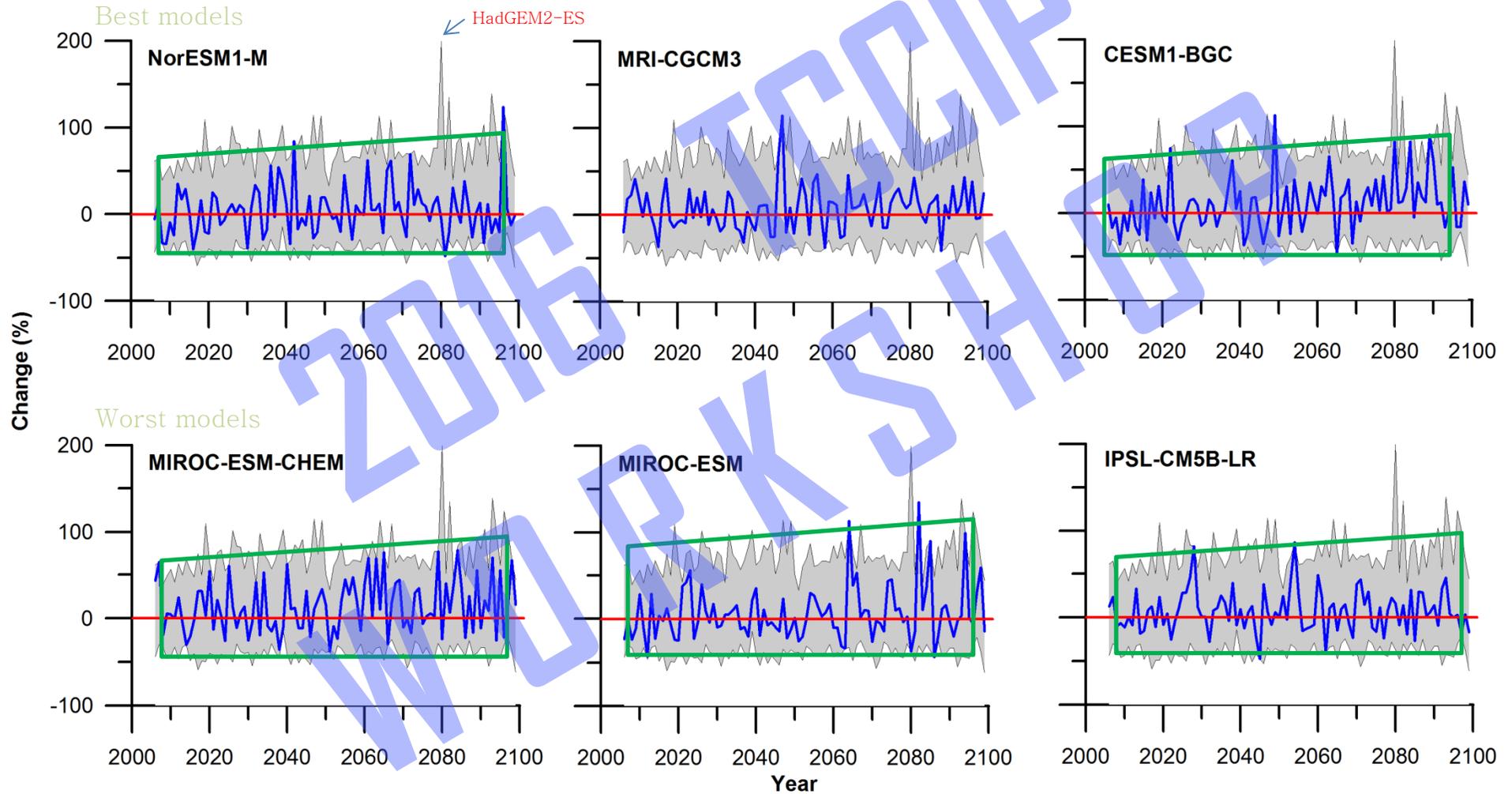
Source: USGS open-file Report 2012-1274

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

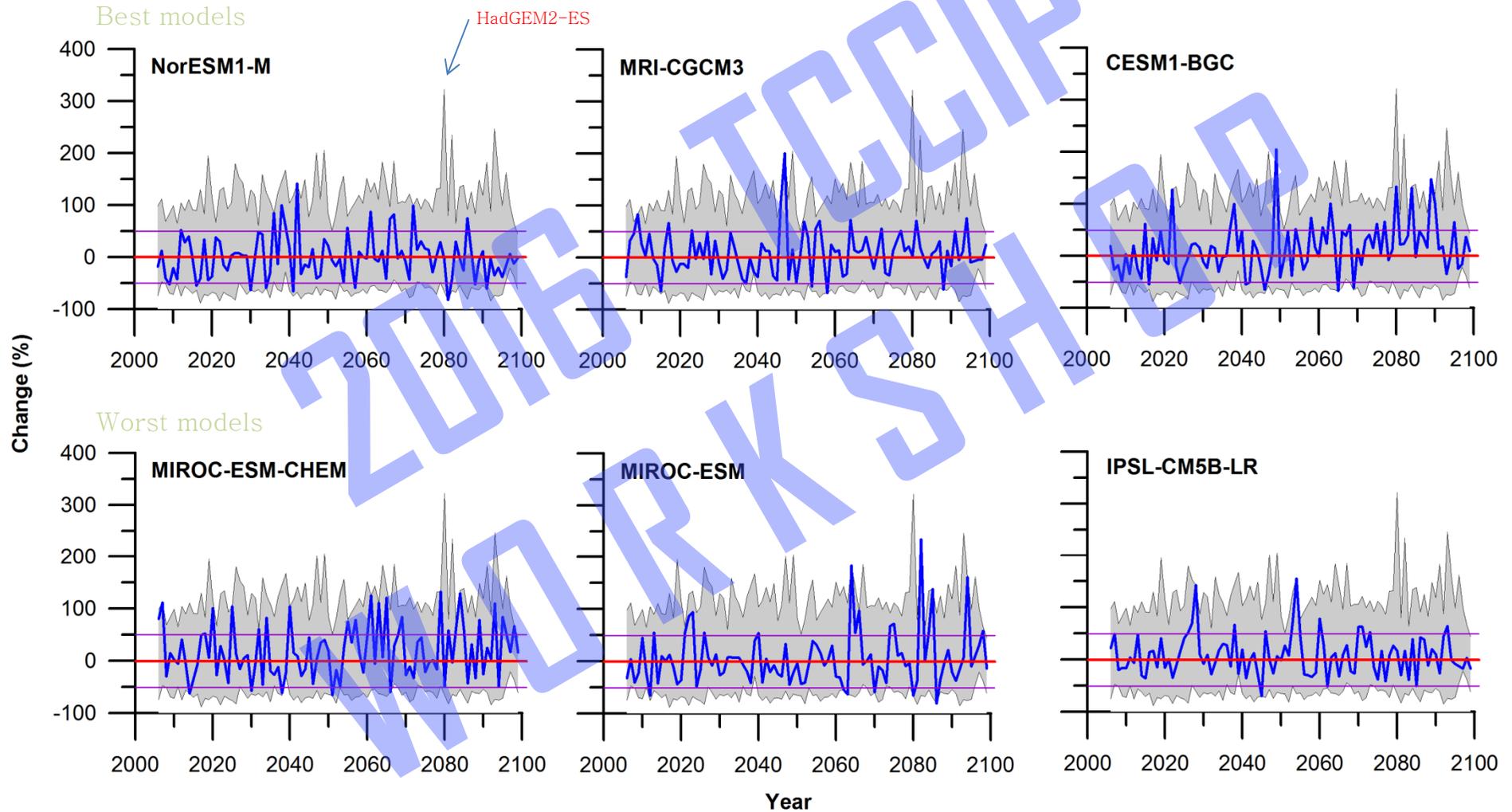
➤ **Streamflow simulation for 1976-2005 using PRMS**



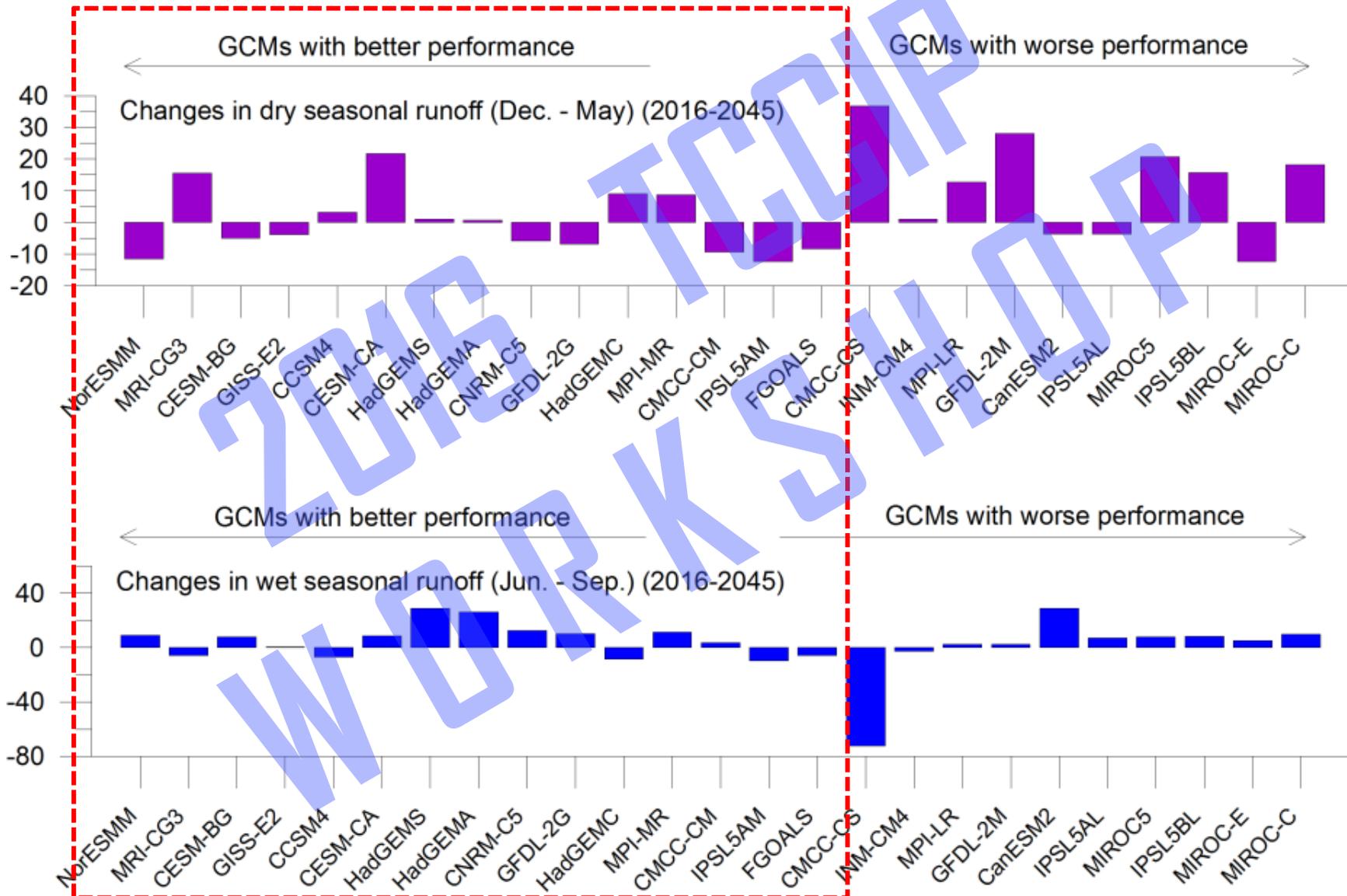
Change in annual precipitation (Nakdong)



Change in annual streamflow (Nakdong)

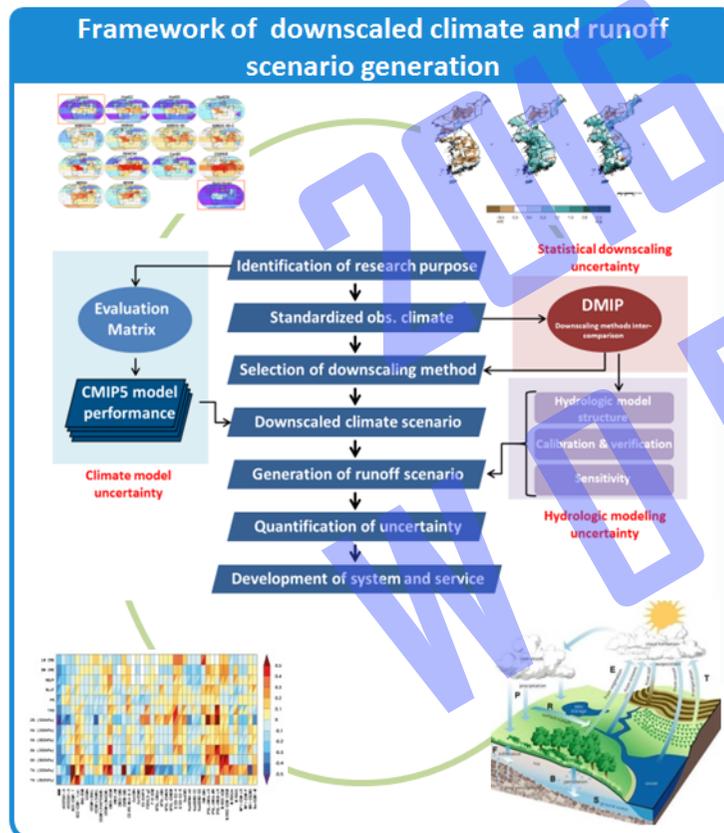


Change in seasonal streamflow (Nakdong)



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



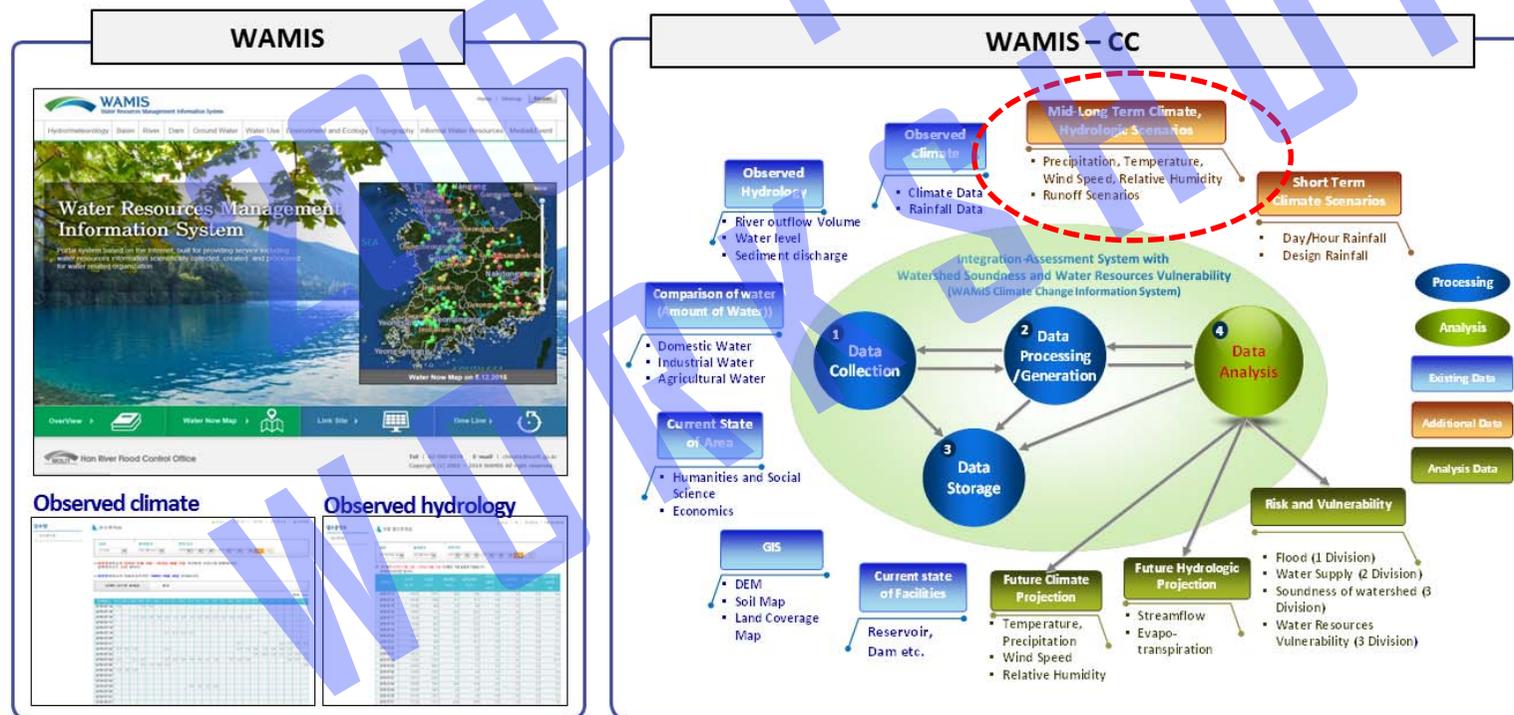
Service through the developed system

- 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 !

