Climate Change Impact on Agricultural Drought by Considering Uncertainty of CMIP5

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Jaepil Cho

APEC Climate Center

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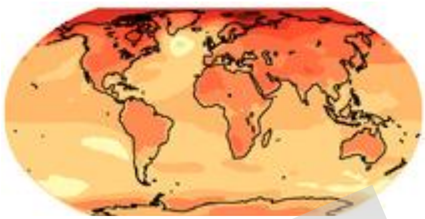
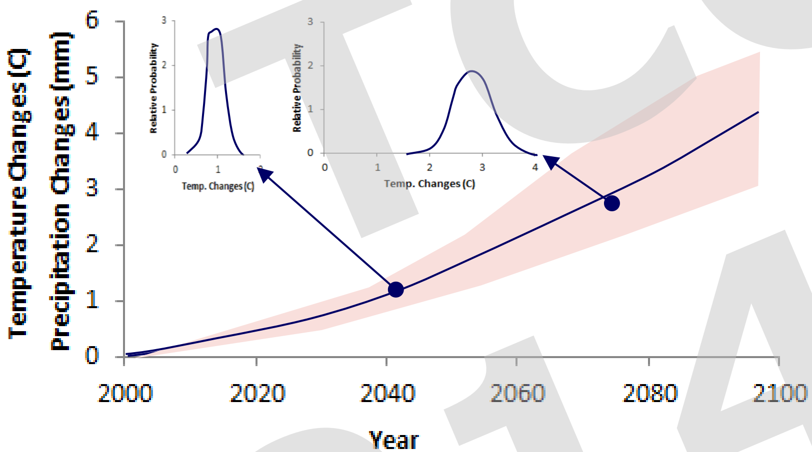
Presentation overview

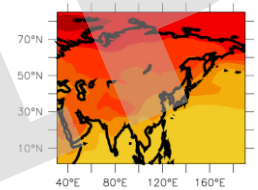
1. Things to be considered in using climate information
2. Downcaling and Bias Correction of Daily CMIP5 Data
3. Analysis of Precipitation Index
4. Assessment of Climate Change Impact on Agricultural Reservoirs
5. Suggestions

Uncertainty in Climate Change Research

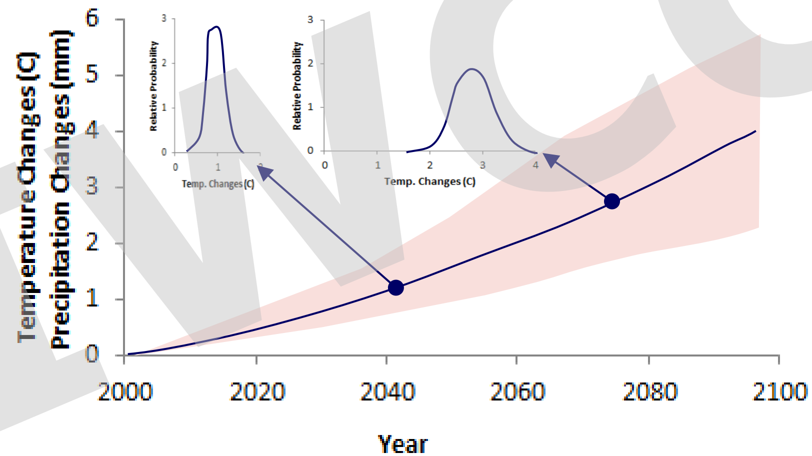


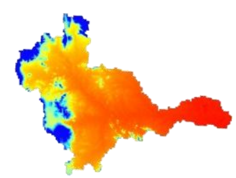
Global
Climate Change



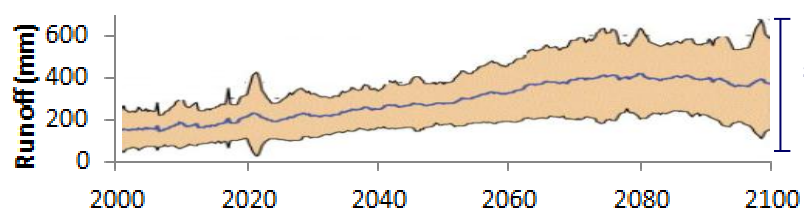


Regional
Downscaling





Watershed-scale
Hydrology Modeling



Ranges by several Models (processes)

Uncertainty =
f (GCMs, Time, Domain,
Variables, Processes)

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

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

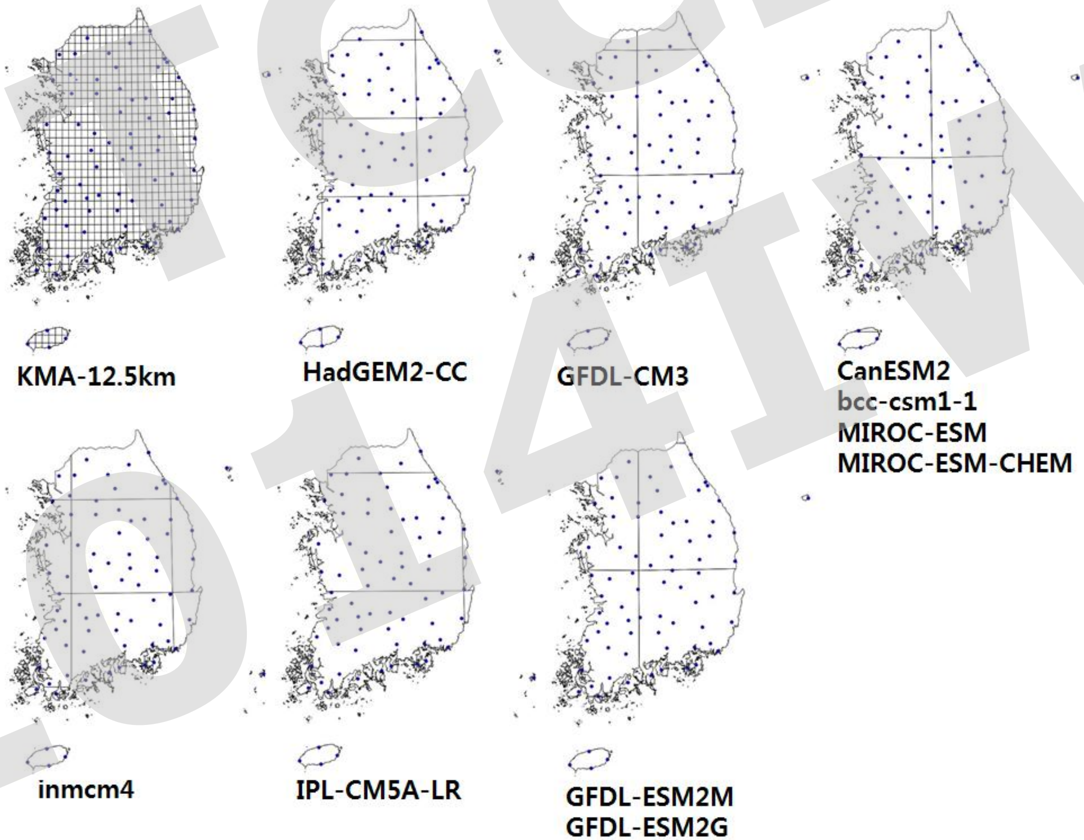
Even though we have same future projection ..

Uncertainty of future projections

Downcaling and Bias Correction of Daily CMIP5 Data

Used CMIP5 Data

- Daily 6 weather variables (Precipitation, Min/Max Temperature, Wind speed, Relative humidity, Solar radiation) ➔ 1 RCM & 33 GCMs



RCP8.5 Scenario

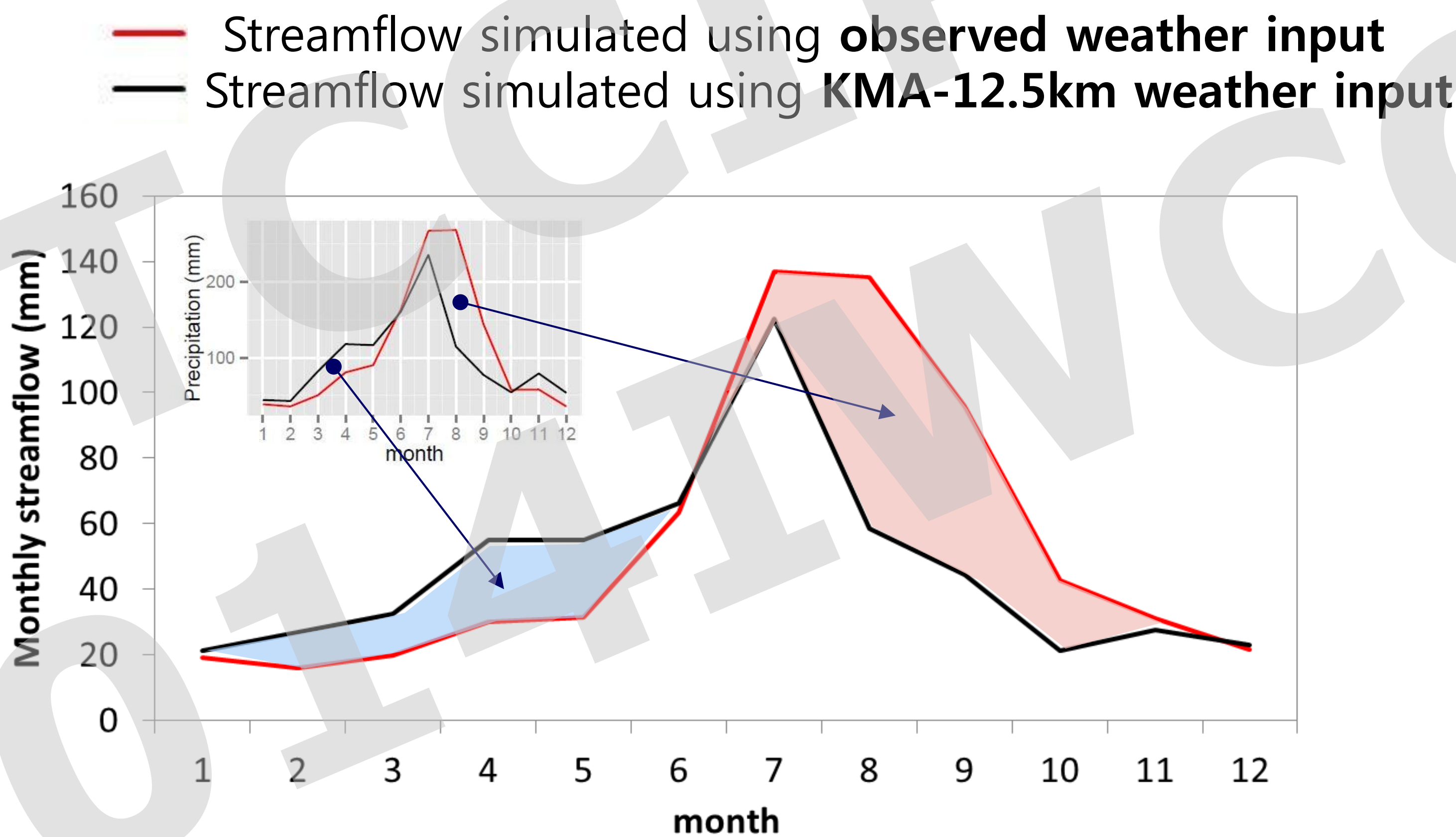
- KMA RCM
- 10 GCMs

Climate Data

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

➡ **Downscaling is required**

Why do we need a bias correction?

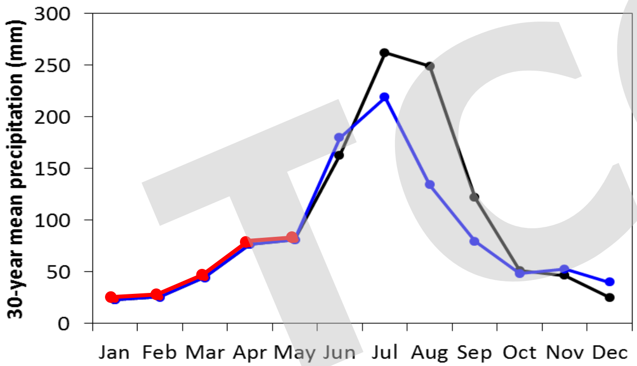


Monthly streamflow pattern follows the precipitation pattern

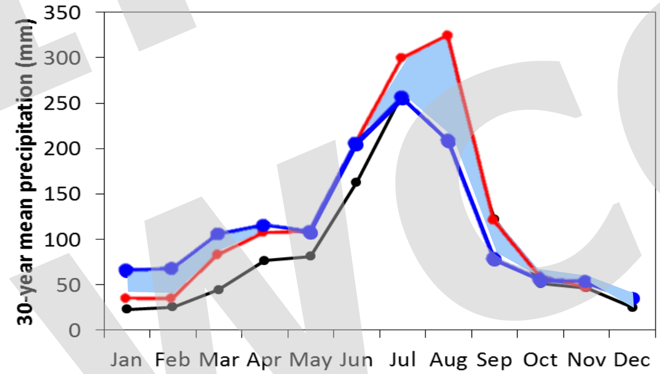
➡ **Bias Correction (BC) is necessary**

Bias Correction of Daily CMIP5 Data (Non-paramtric Quantile Mapping methods)

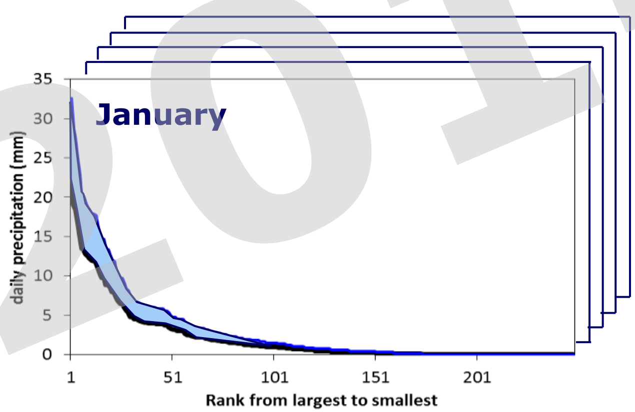
Historical (1976~2005)

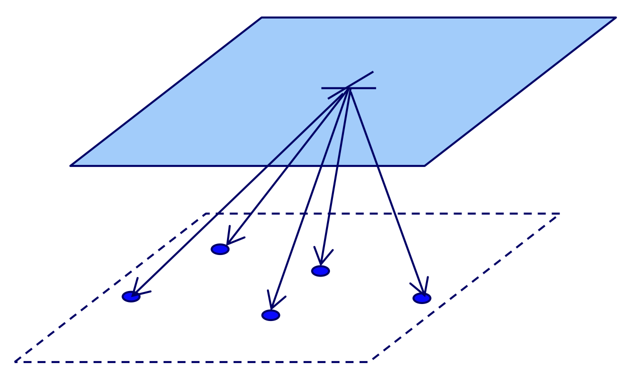


Future (2011~2040)

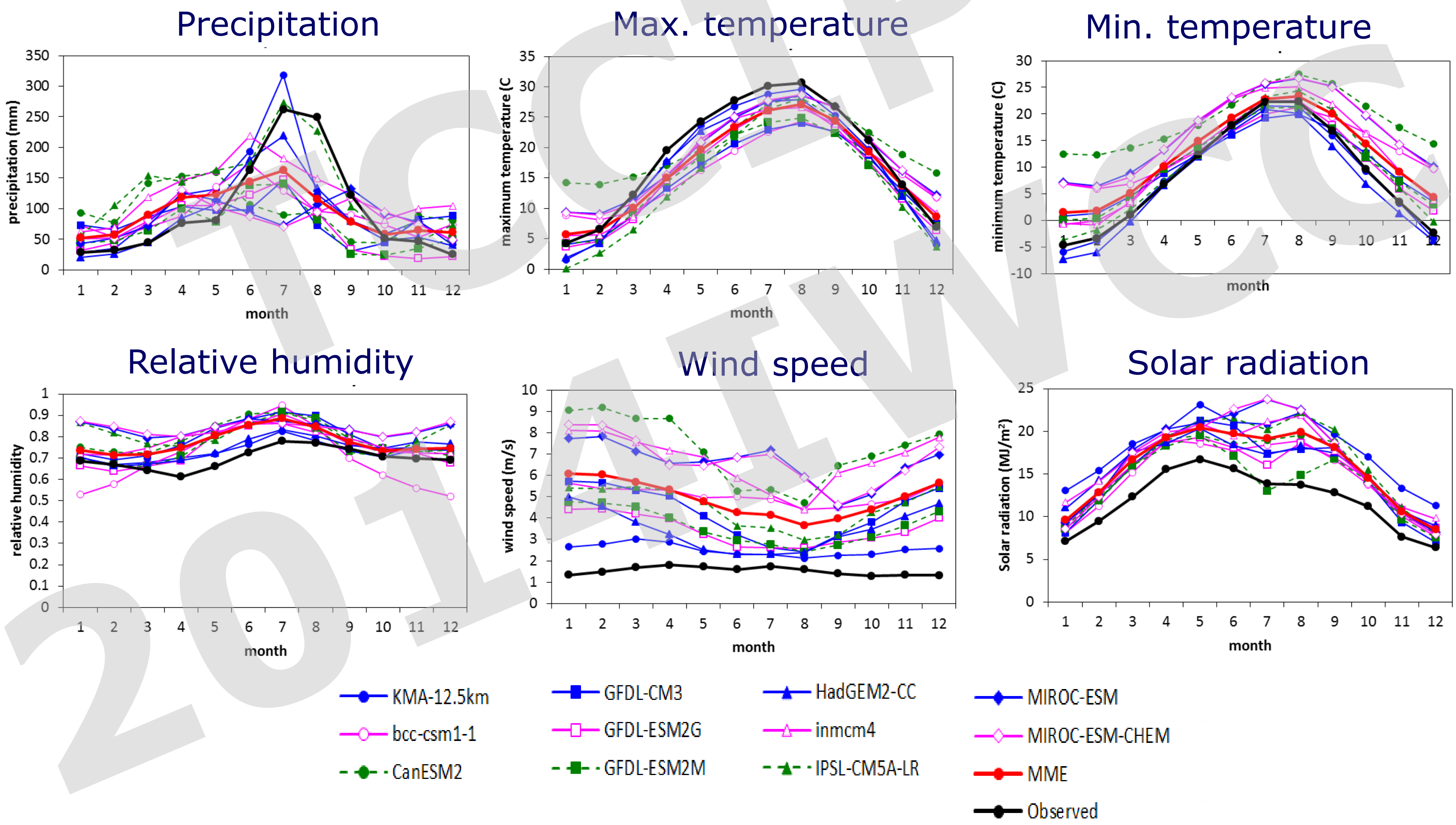


- Observed or Historical
- Before quantile mapping
- **Quantile mapping information**
- After quantile mapping

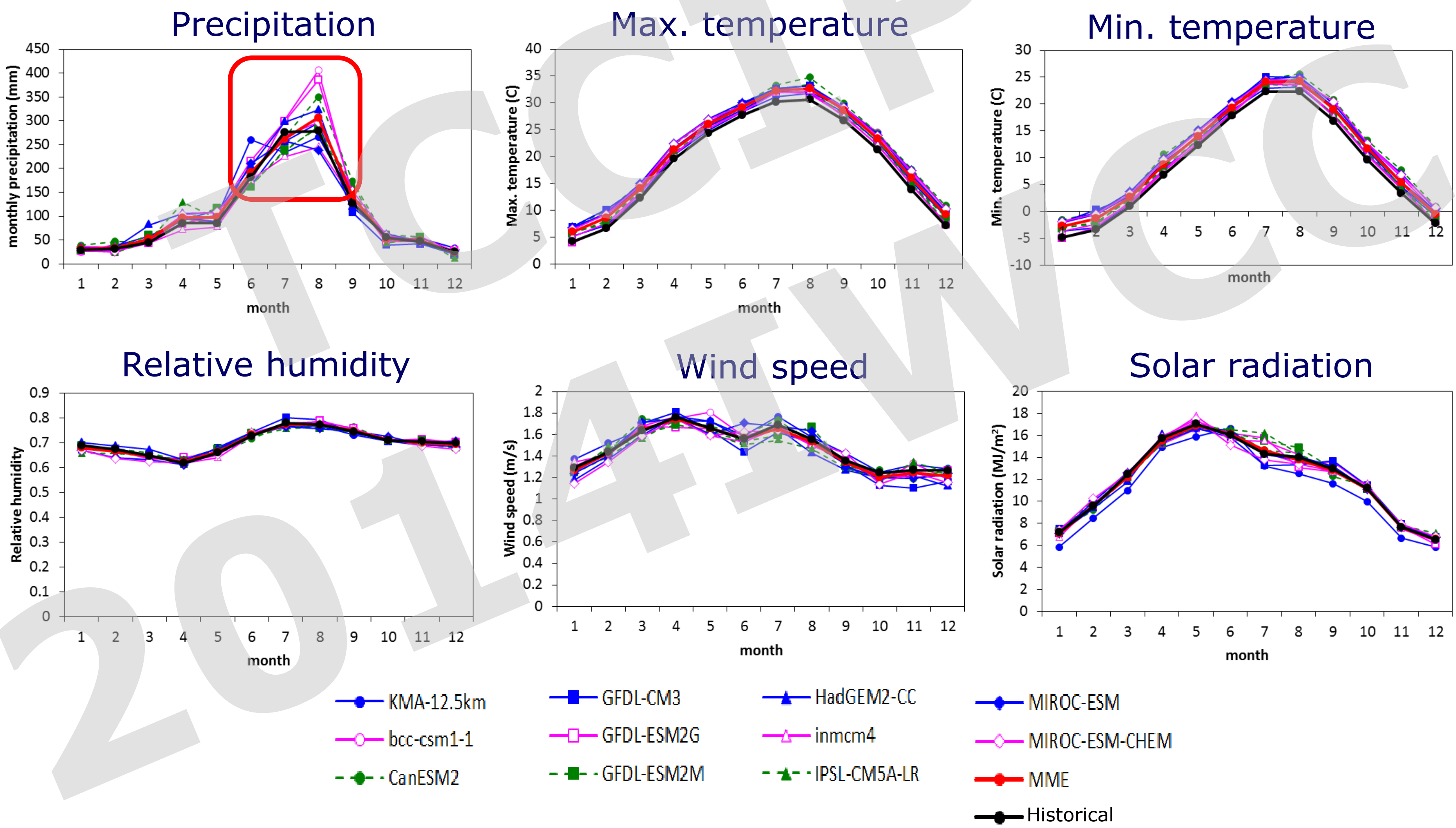




Uncertainties of weather variables before bias corection (Historical, Jeonju)



Uncertainties of weather variables after bias corection (RCP8.5, Jeonju)



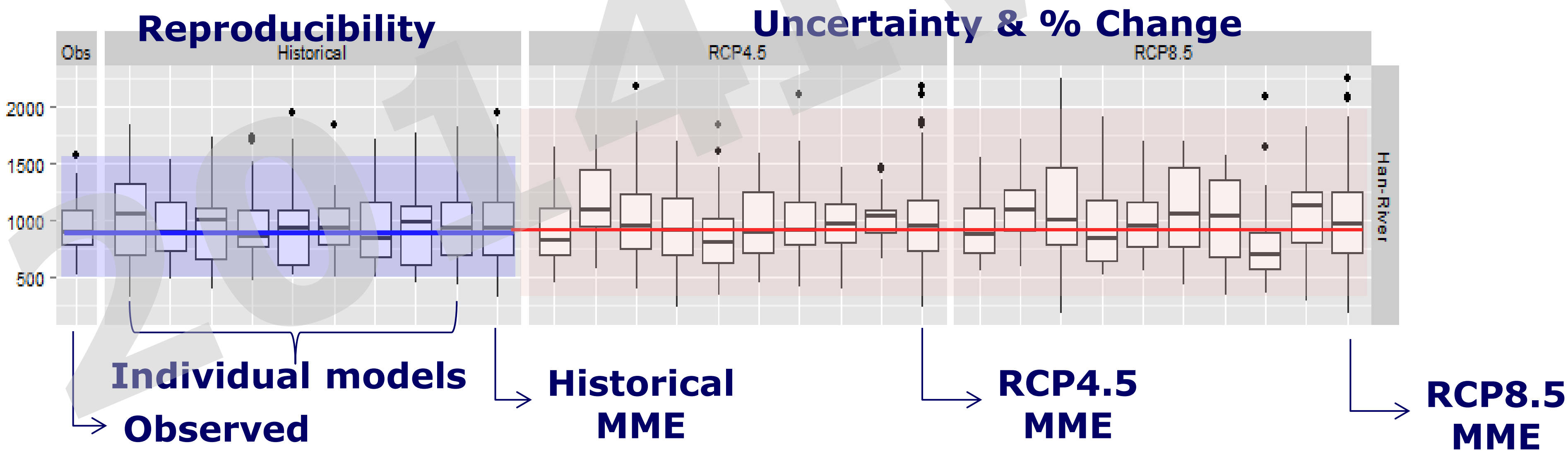
Analysis of Precipitation Index

Precipitation index

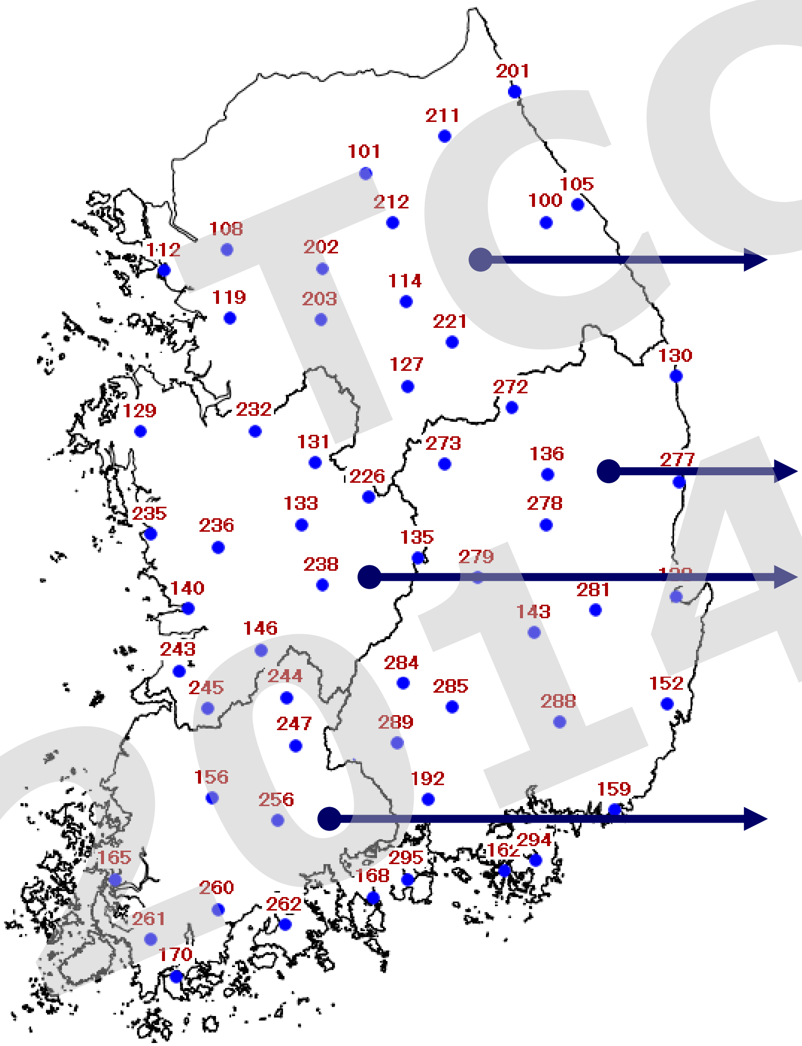
- Wet season(Jun~Sep) precipitation
- Max. daily precipitation
- Number of days daily precipitation ≥ 80mm
- Dry season(Oct~May) precipitation
- Maximum number of consecutive dry days

Flood (first three items)

Drought (last two items)



4-River Basins



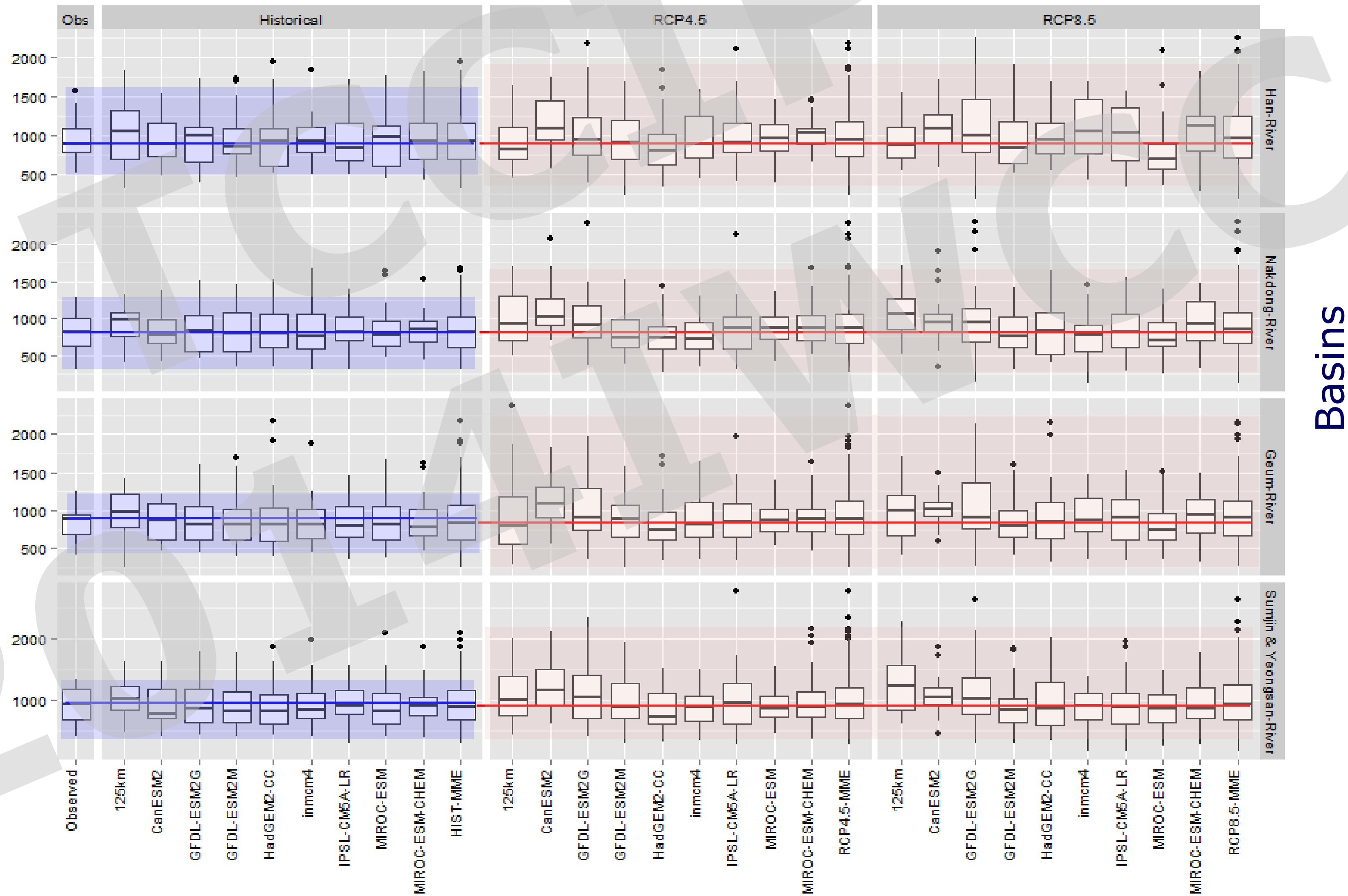
Han-River Basin
(15 stations)

Nakdong-River Basin
(21 stations)

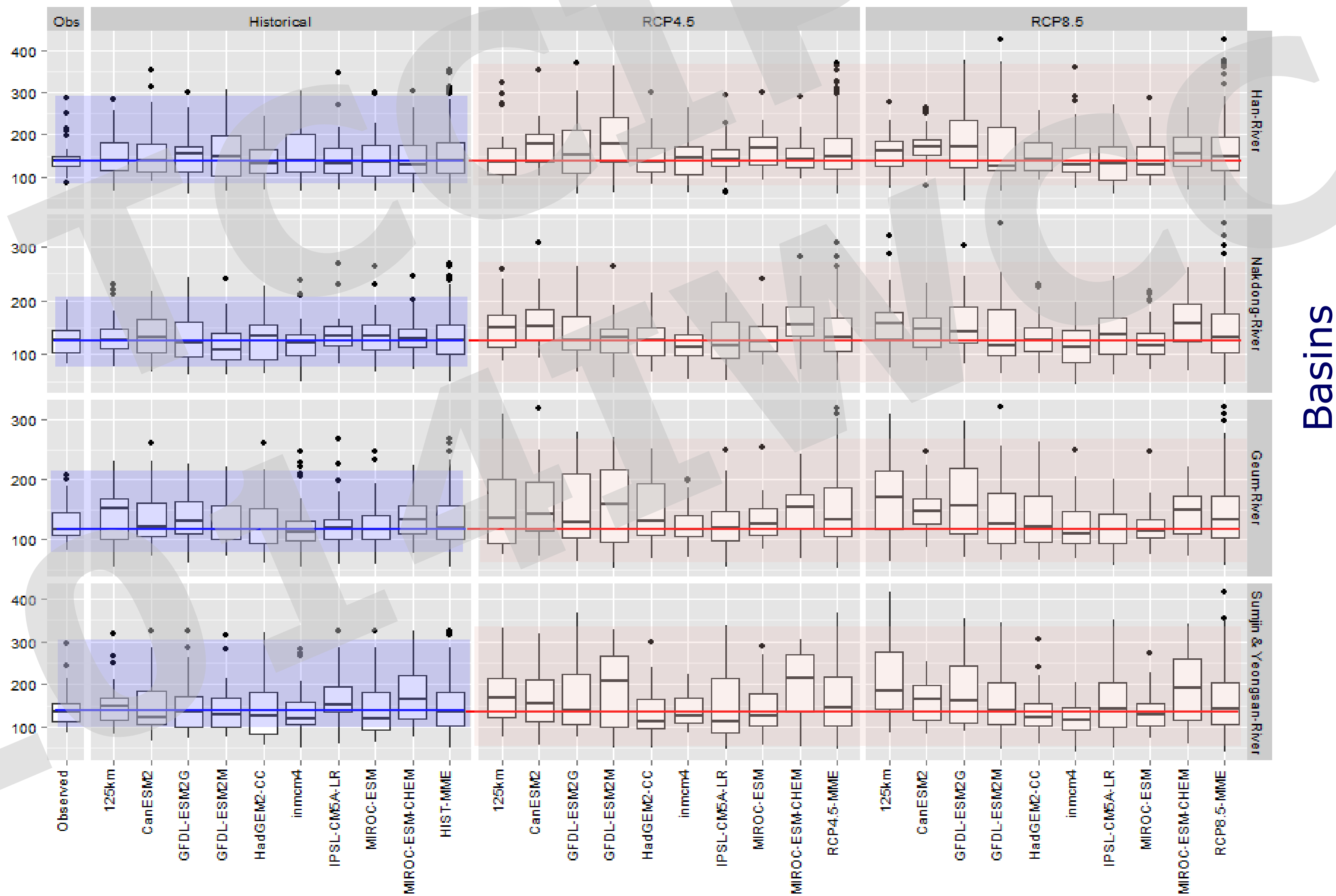
Geum-River Basin
(13 stations)

Sumjin/Yeongsan-River Basin
(10 stations)

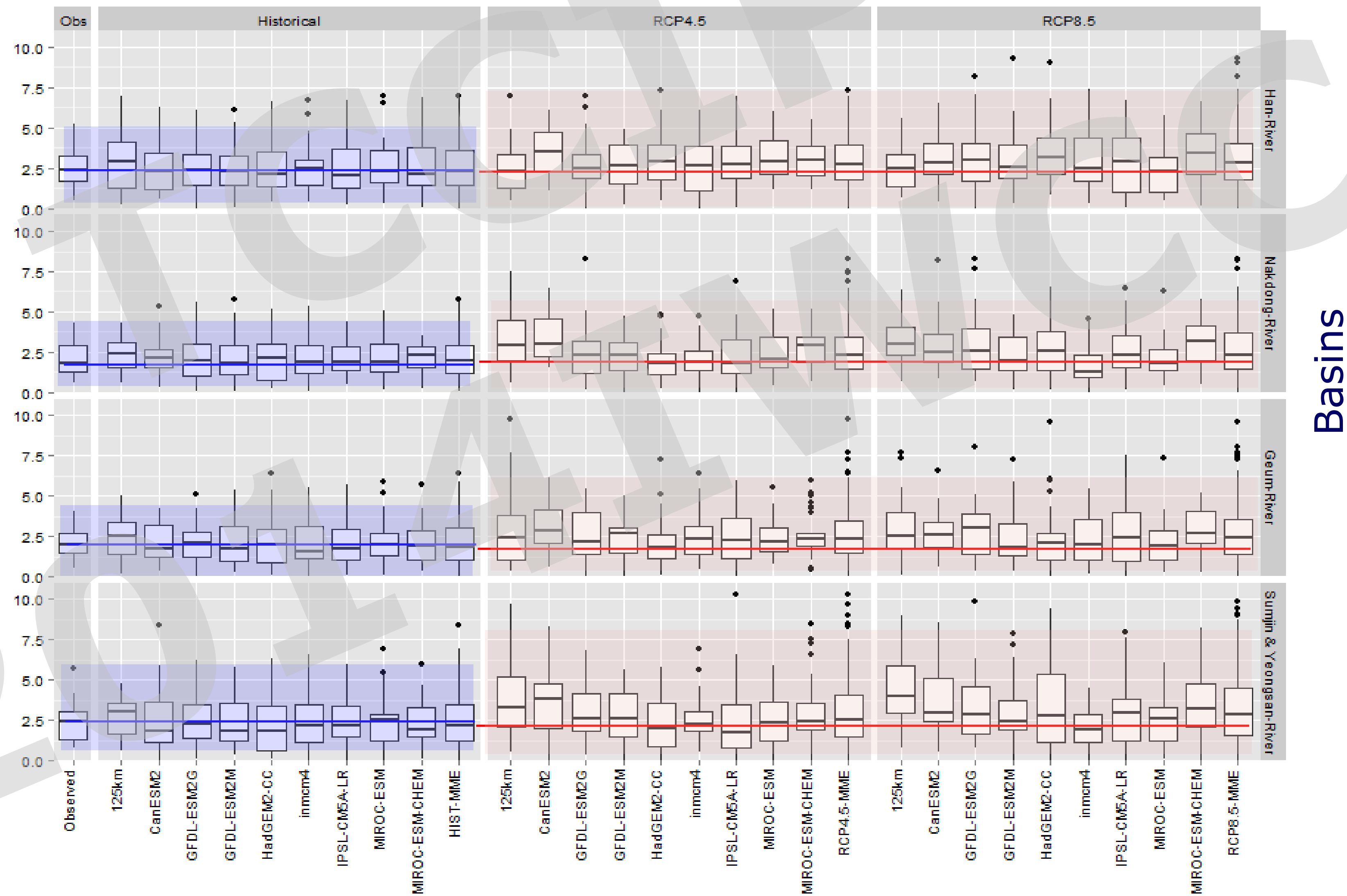
Wet season (Jun~Sep) Precipitation (mm)



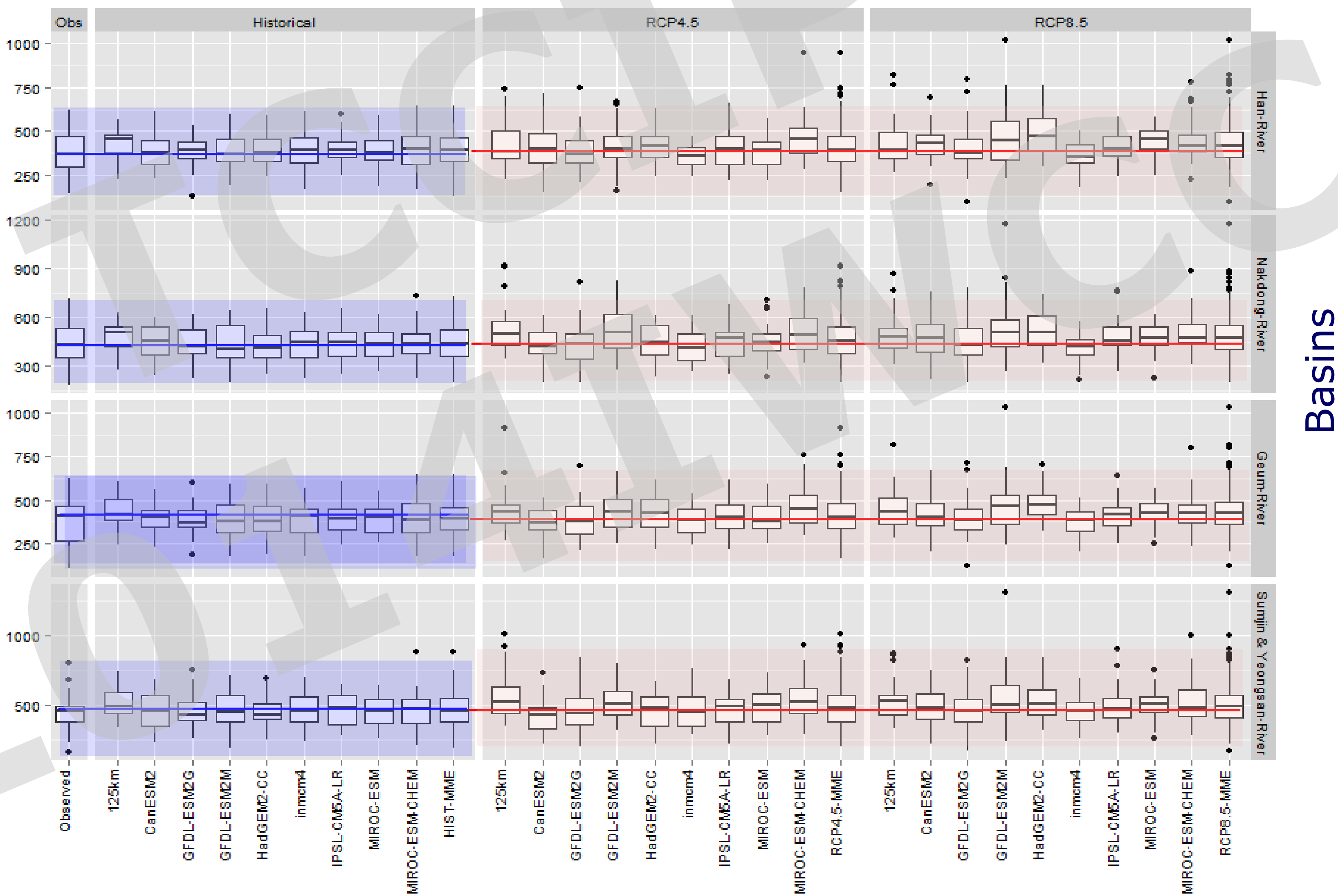
Daily maximum precipitation (mm)



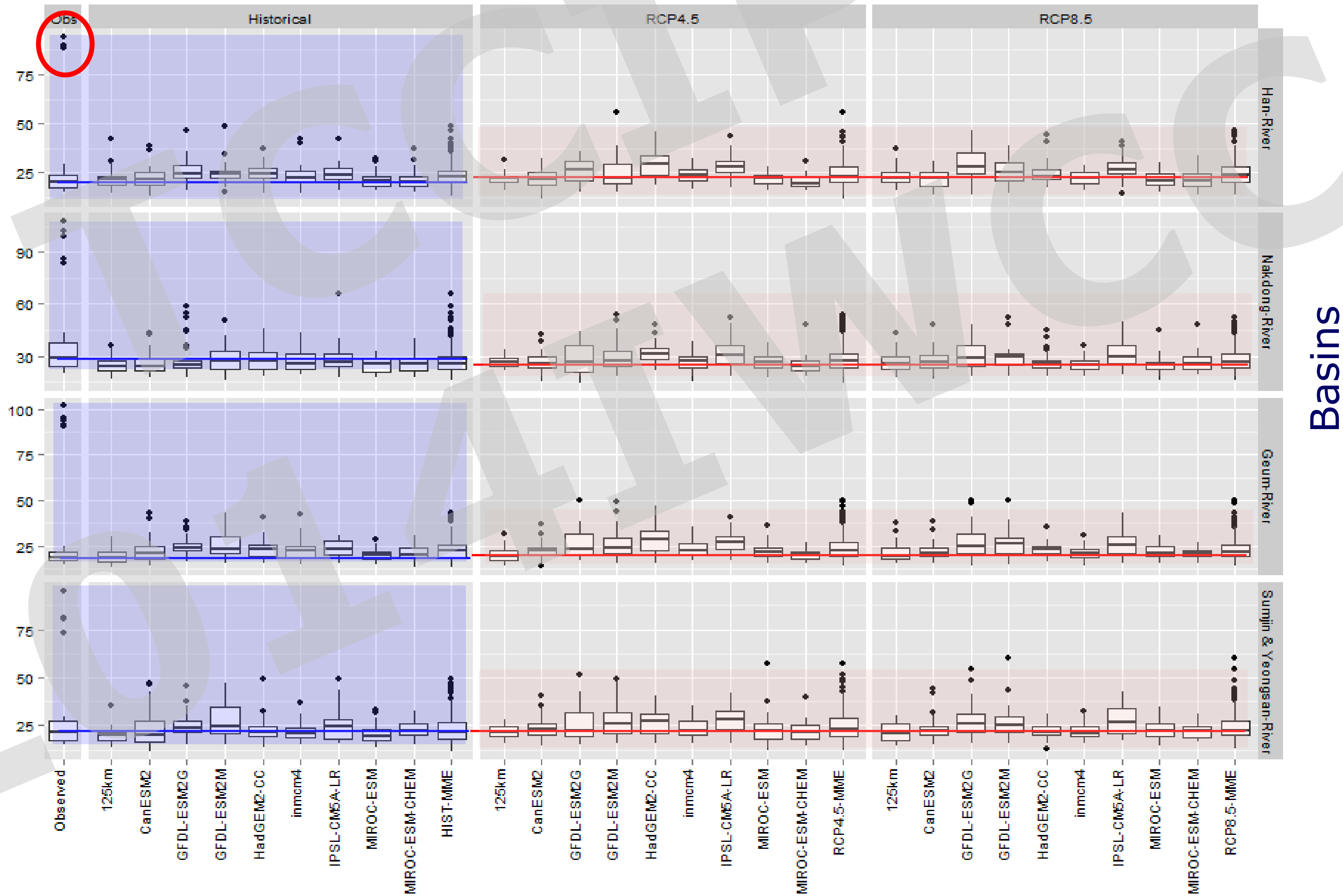
Number of days daily precipitation ≥ 80mm



Dry season (Oct ~ May) Precipitation (mm)



Maximum dry days
= maximum number of consecutive dry days



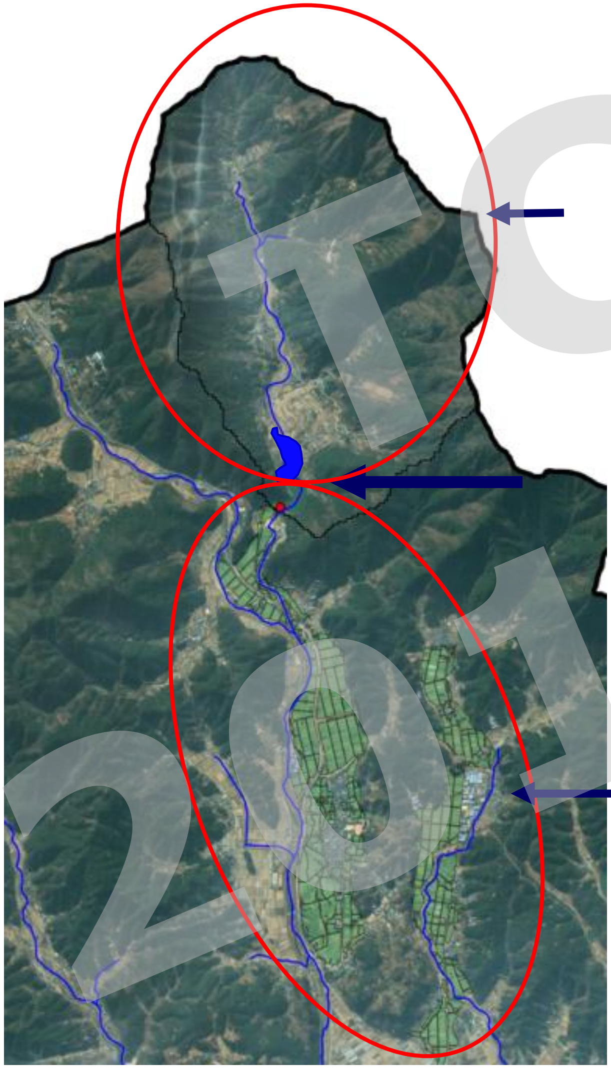
Assessment of Climate Change Impact on Agricultural Reservoirs

Agricultural reservoirs

Small agricultural reservoirs are vulnerable to climate change

- 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

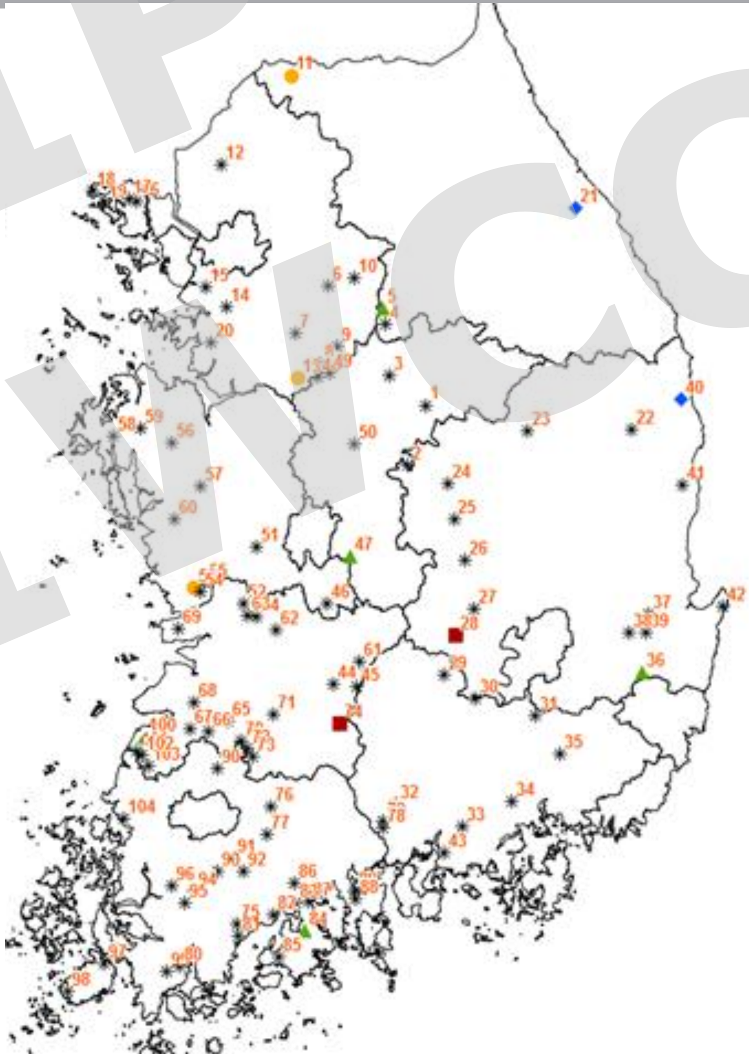
Selected Agricultural Reservoirs



Upstream watershed (Inflow)

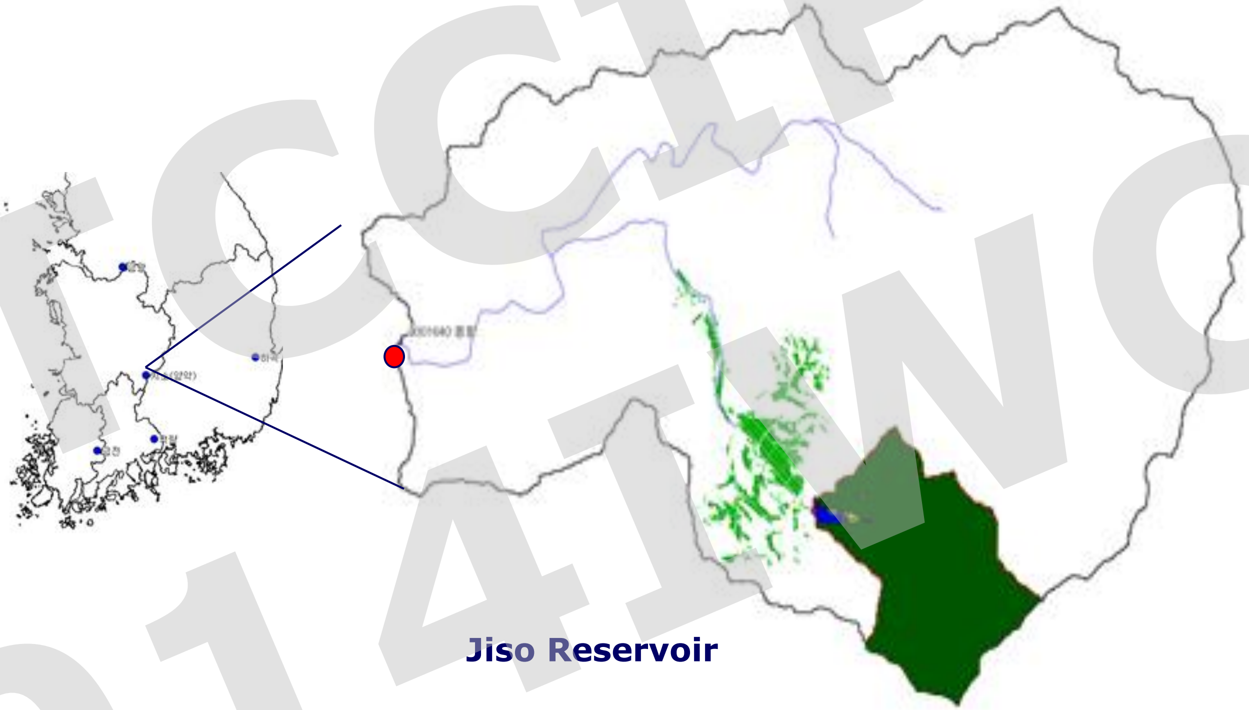
Reservoir (storage)

Irrigation (Demand)



104 reservoirs

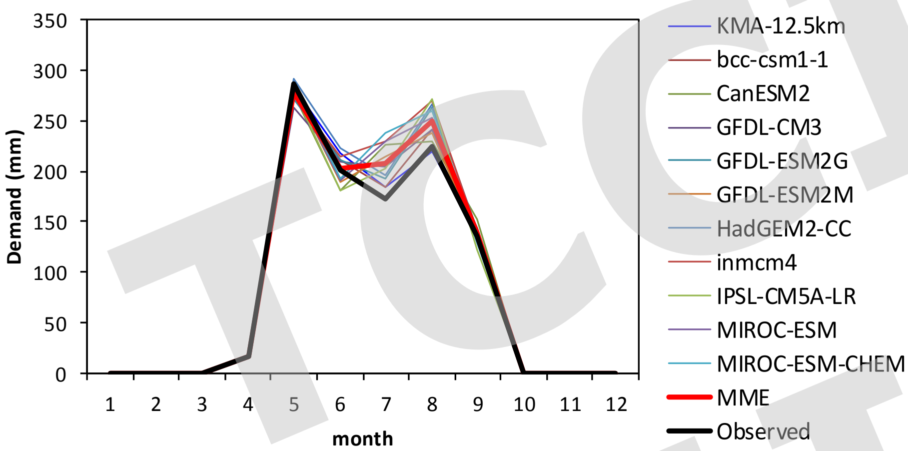
Representative Reservoir for Reproducibility/Uncertainty Analysis



- **HOMWRS**
  - Inflow: 3-Tank model
  - Demand: ET + water supply for Sowing, transplanting + loss
  - Storage based on water balance

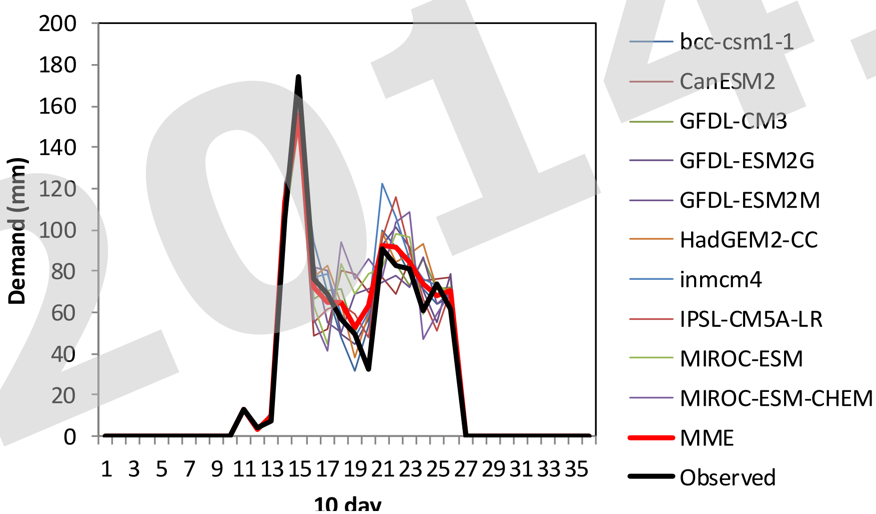
Reproducibility of irrigation demand

Monthly



Models	Demand (mm)	% difference	R^2
Observed	1038		
MME	1094	5.4	0.989
KMA-12.5km	1057	1.9	0.997
bcc-csm1-1	1066	2.8	0.997
CanESM2	1082	4.2	0.975
GFDL-CM3	1077	3.8	0.986
GFDL-ESM2G	1090	5.0	0.987
GFDL-ESM2M	1073	3.4	0.986
HadGEM2-CC	1135	9.4	0.994
inmcm4	1146	10.5	0.976
IPSL-CM5A-LR	1074	3.4	0.976
MIROC-ESM	1116	7.5	0.977
MIROC-ESM-CHEM	1119	7.9	0.97

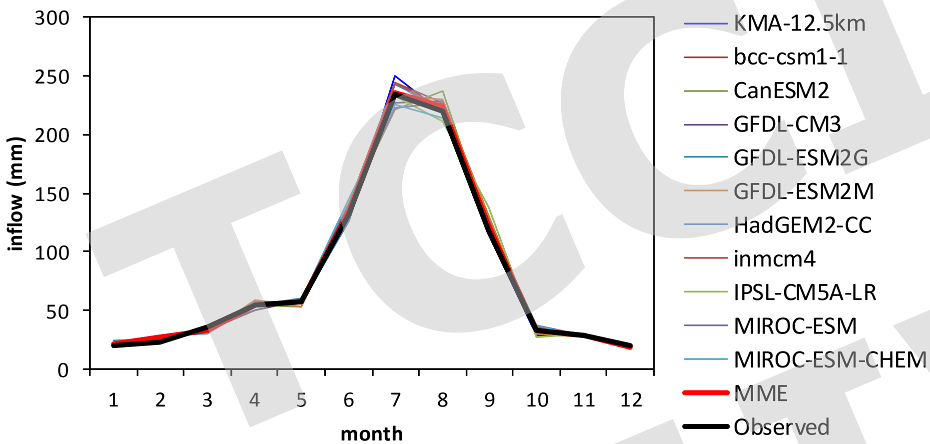
10-day



Models	demand (mm)	% difference	R^2
Observed	1038		
MME	1094	5.4	**0.972**
KMA-12.5km	1057	1.9	0.962
bcc-csm1-1	1066	2.8	0.961
CanESM2	1082	4.2	0.916
GFDL-CM3	1077	3.8	0.967
GFDL-ESM2G	1090	5.0	0.964
GFDL-ESM2M	1073	3.4	0.939
HadGEM2-CC	1135	9.4	0.967
inmcm4	1146	10.5	0.967
IPSL-CM5A-LR	1074	3.4	0.957
MIROC-ESM	1116	7.5	0.931
MIROC-ESM-CHEM	1119	7.9	0.887

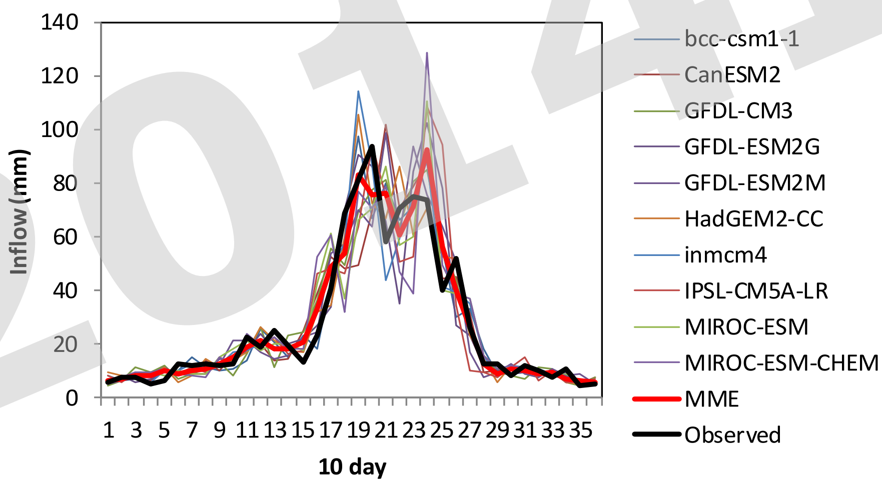
Reproducibility of upstream inflow

Monthly



Models	Inflow (mm)	% difference	R^2
Observed	976		
MME	988	1.3	0.999
KMA-12.5km	980	0.5	0.996
bcc-csm1-1	989	1.4	0.998
CanESM2	982	0.7	0.992
GFDL-CM3	989	1.4	0.996
GFDL-ESM2G	990	1.5	0.998
GFDL-ESM2M	997	2.2	0.996
HadGEM2-CC	987	1.1	0.997
inmcm4	997	2.2	0.998
IPSL-CM5A-LR	992	1.7	0.991
MIROC-ESM	984	0.9	0.996
MIROC-ESM-CHEM	989	1.4	0.995

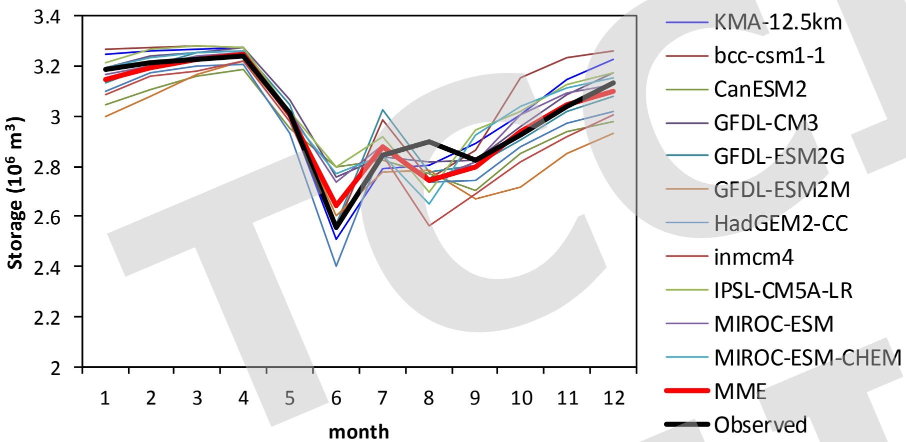
10-day



Models	Inflow (mm)	% difference	R^2
Observed	976		
MME	988	1.3	**0.913**
KMA-12.5km	980	0.5	0.891
bcc-csm1-1	989	1.4	0.887
CanESM2	982	0.7	0.804
GFDL-CM3	989	1.4	0.881
GFDL-ESM2G	990	1.5	0.836
GFDL-ESM2M	997	2.2	0.823
HadGEM2-CC	987	1.1	0.911
inmcm4	997	2.2	0.906
IPSL-CM5A-LR	992	1.7	0.739
MIROC-ESM	984	0.9	0.779
MIROC-ESM-CHEM	989	1.4	0.678

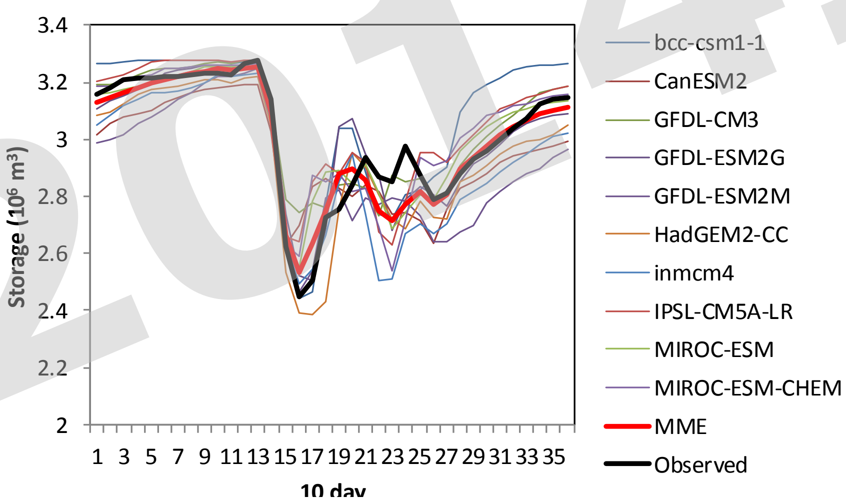
Reproducibility of reservoir storage level

Monthly



Models	Storage (10^6 m^3)	% difference	R^2
Observed	3.009		
MME	2.997	-0.4	0.93
KMA-12.5km	3.036	0.9	0.95
bcc-csm1-1	3.077	2.3	0.84
CanESM2	2.943	-2.2	0.76
GFDL-CM3	3.041	1.1	0.91
GFDL-ESM2G	3.006	-0.1	0.89
GFDL-ESM2M	2.901	-3.6	0.84
HadGEM2-CC	2.937	-2.4	0.96
inmcm4	2.920	-3.0	0.84
IPSL-CM5A-LR	3.061	1.7	0.77
MIROC-ESM	3.025	0.5	0.87
MIROC-ESM-CHEM	3.036	0.9	0.74

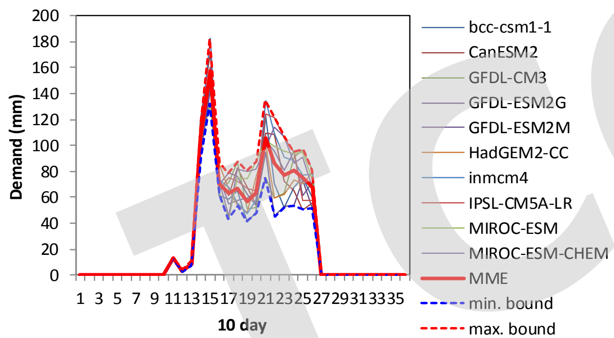
10-day



Models	Storage (10^6 m^3)	% difference	R^2
Observed	108		
MME	108	-0.4	**0.922**
KMA-12.5km	109	0.9	0.92
bcc-csm1-1	111	2.3	0.818
CanESM2	106	-2.2	0.767
GFDL-CM3	109	1.1	0.871
GFDL-ESM2G	108	-0.1	0.857
GFDL-ESM2M	104	-3.6	0.841
HadGEM2-CC	106	-2.4	0.923
inmcm4	105	-3.0	0.82
IPSL-CM5A-LR	110	1.7	0.789
MIROC-ESM	109	0.5	0.856
MIROC-ESM-CHEM	109	0.9	0.745

Uncertainties in RCP8.5 scenario (2011~2040)

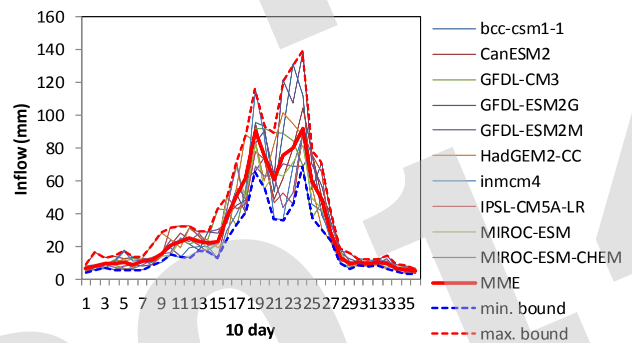
Demand



Models	Demand (mm)	% Change
MME	1099	
bcc-csm1-1	1026	-6.7
CanESM2	1117	1.6
GFDL-CM3	1051	-4.4
GFDL-ESM2G	979	-11.0
GFDL-ESM2M	1079	-1.9
HadGEM2-CC	1062	-3.4
inmcm4	1195	8.7
IPSL-CM5A-LR	1196	8.7
MIROC-ESM	1197	8.9
MIROC-ESM-CHEM	1210	10.0
KMA-12.5km	997	-9.3

-11.0% ~ 10.0%

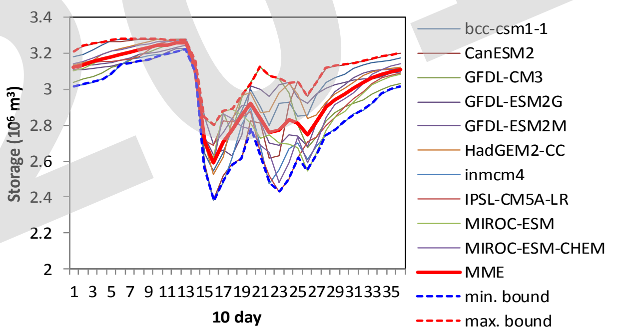
Inflow



Models	Inflow (mm)	% Change
MME	1078	
bcc-csm1-1	1192	10.6
CanESM2	1088	0.9
GFDL-CM3	1083	0.4
GFDL-ESM2G	1198	11.1
GFDL-ESM2M	1052	-2.5
HadGEM2-CC	1125	4.3
inmcm4	954	-11.5
IPSL-CM5A-LR	1009	-6.5
MIROC-ESM	1003	-6.9
MIROC-ESM-CHEM	993	-7.9
KMA-12.5km	1153	7.0

-11.5% ~ 11.0%

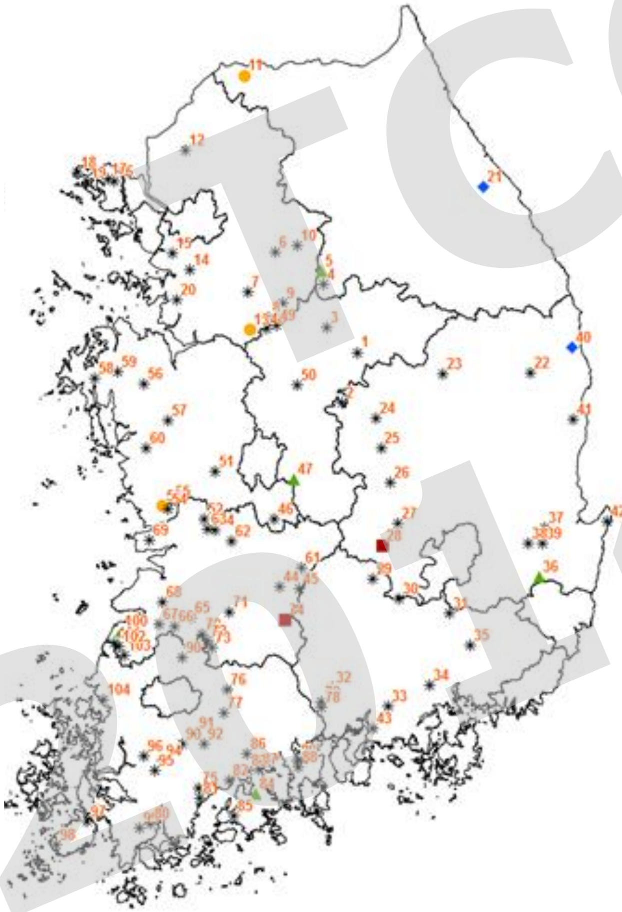
Storage



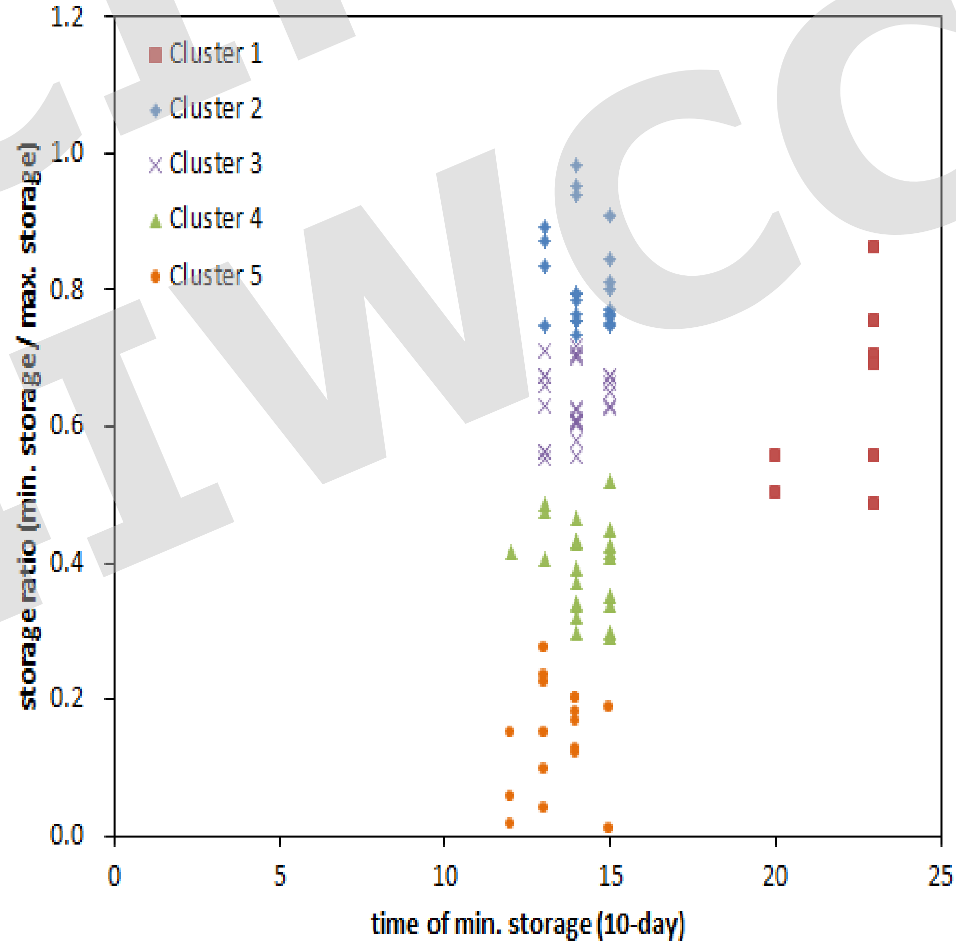
Models	Storage (10^6 m^3)	% Change
MME	3.003	
bcc-csm1-1	3.062	2.0
CanESM2	3.042	1.3
GFDL-CM3	3.011	0.3
GFDL-ESM2G	3.027	0.8
GFDL-ESM2M	3.004	0.0
HadGEM2-CC	3.045	1.4
inmcm4	2.887	-3.9
IPSL-CM5A-LR	2.953	-1.7
MIROC-ESM	2.968	-1.2
MIROC-ESM-CHEM	2.980	-0.8
KMA-12.5km	3.066	2.1

-3.9% ~ 2.1%

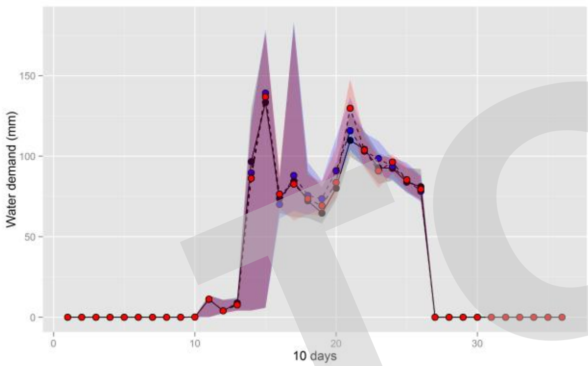
Assessment of Climate Change Impact on Agricultural Reservoirs



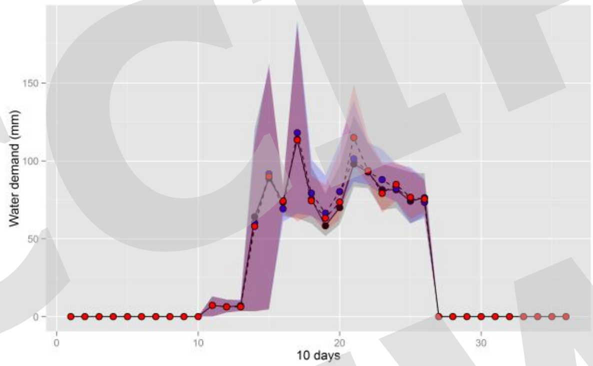
104 reservoirs



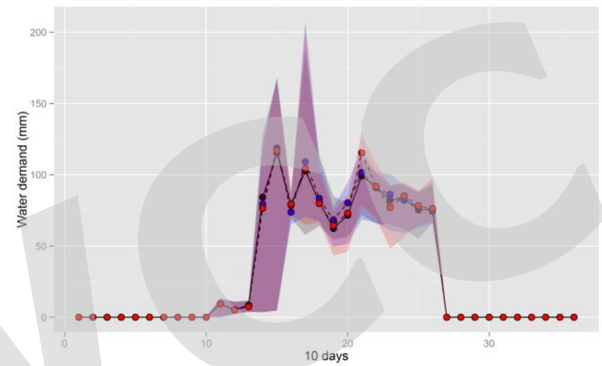
Irrigation demand projection (2011~2040)



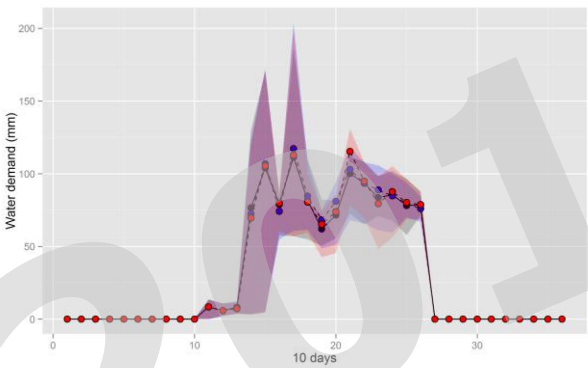
Cluster 1



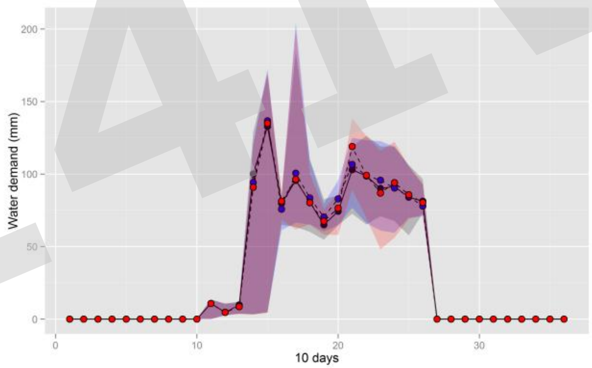
Cluster 2



Cluster 3



Cluster 4

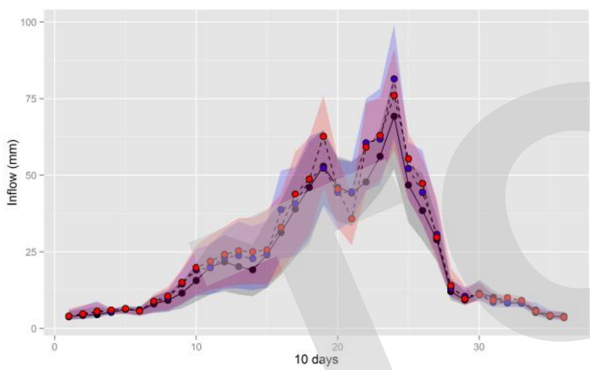


Cluster 5

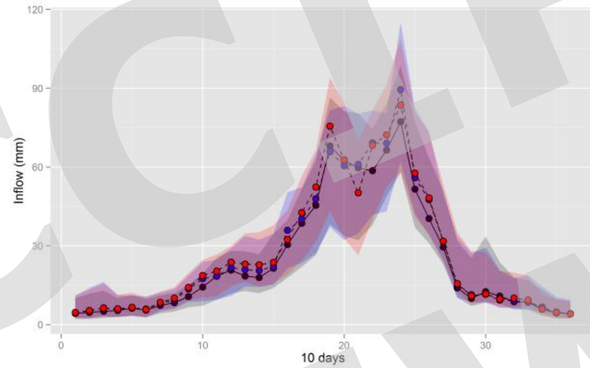
Clusters		Historical	RCP4.5	RCP8.5
1	Inflow(mm)	1194	1226	1218
	% change		2.7	2.0
2	Inflow(mm)	1069	1099	1092
	% change		2.8	2.1
3	Inflow(mm)	1126	1148	1140
	% change		2.0	1.3
4	Inflow(mm)	1128	1153	1145
	% change		2.2	1.5
5	Inflow(mm)	1202	1223	1217
	% change		1.8	1.3

1.3% ~ 2.1%

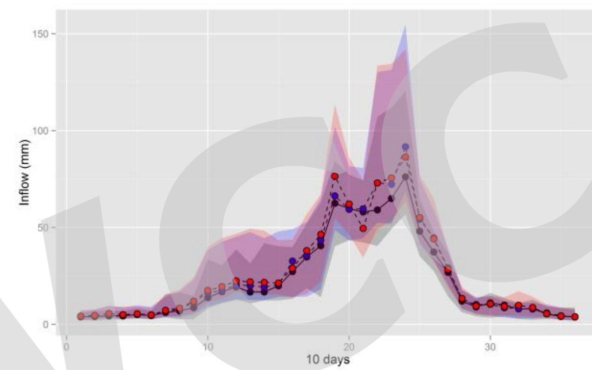
Inflow projection (2011~2040)



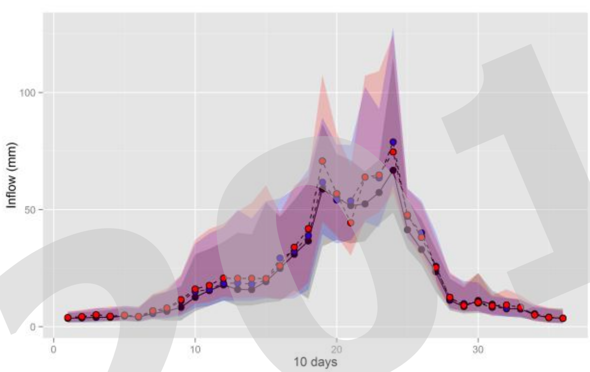
Cluster 1



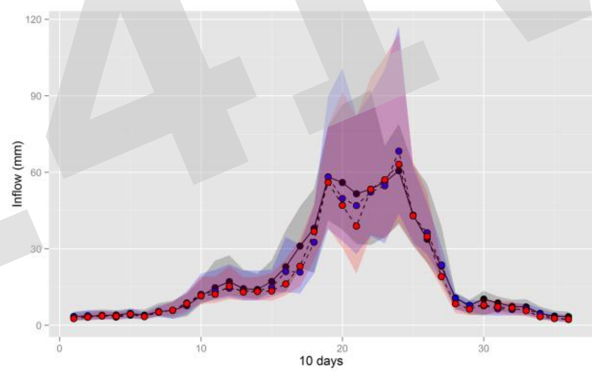
Cluster 2



Cluster 3



Cluster 4

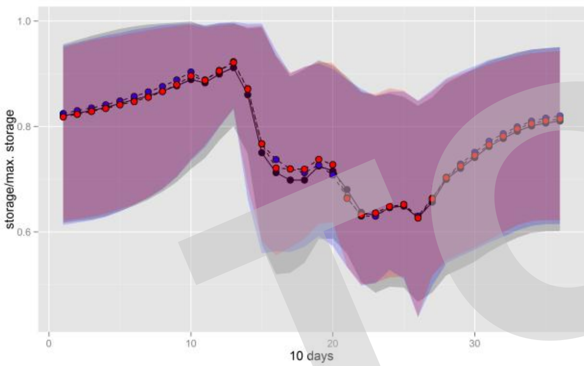


Cluster 5

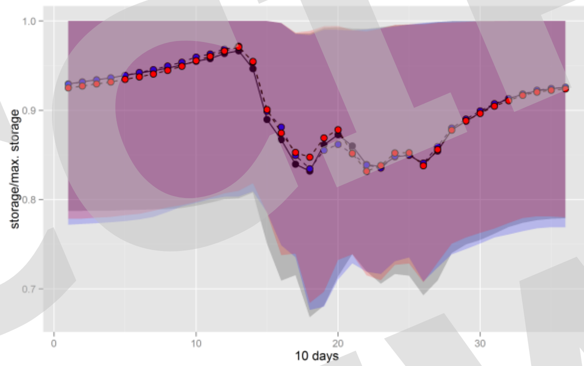
Clusters		Historical	RCP4.5	RCP8.5
1	Inflow(mm)	799	871	885
	% change		9.0	10.8
2	Inflow(mm)	876	940	959
	% change		7.3	9.5
3	Inflow(mm)	817	902	919
	% change		10.4	12.5
4	Inflow(mm)	742	815	829
	% change		9.8	11.7
5	Inflow(mm)	722	796	806
	% change		10.2	11.5

9.5% ~ 12.5%

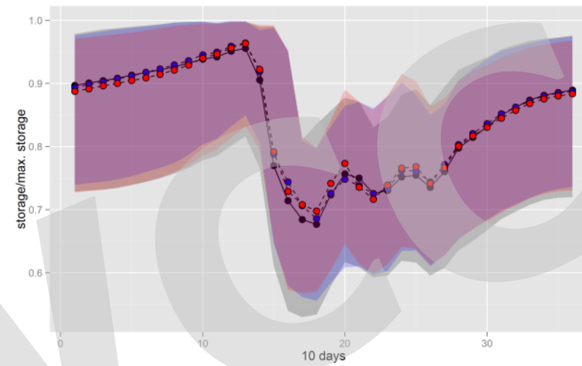
Storage ratio projection (2011~2040) (current storage / total storage)



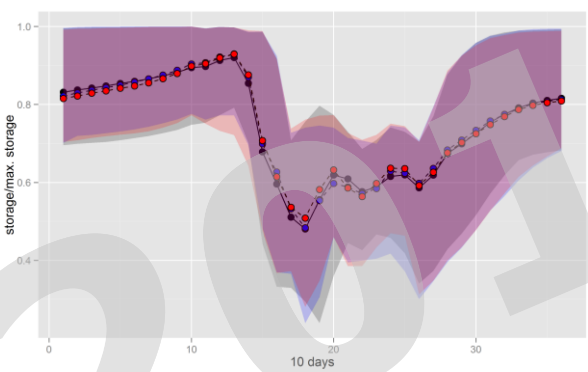
Cluster 1



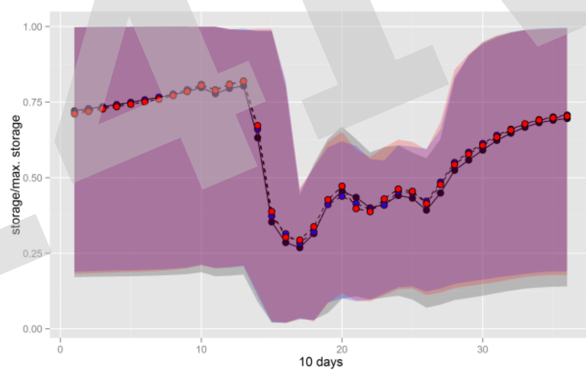
Cluster 2



Cluster 3



Cluster 4



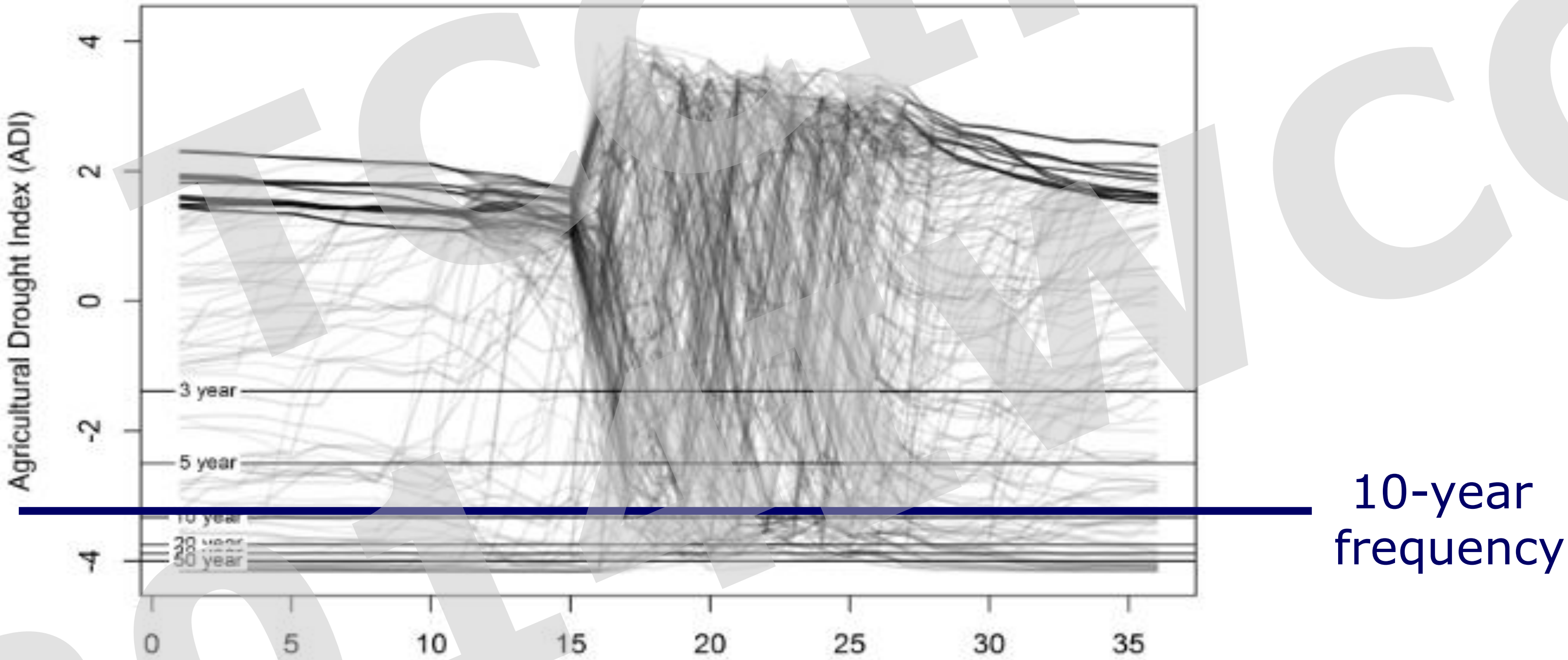
Cluster 5

Clusters		Historical	RCP4.5	RCP8.5
1	Storage ratio	0.77	0.78	0.78
	% change		0.9	0.5
2	Storage ratio	0.90	0.90	0.90
	% change		0.2	0.1
3	Storage ratio	0.84	0.84	0.84
	% change		0.5	0.3
4	Storage ratio	0.74	0.74	0.74
	% change		0.4	0.3
5	Storage ratio	0.59	0.60	0.60
	% change		1.6	1.6

0.1% ~ 1.6%

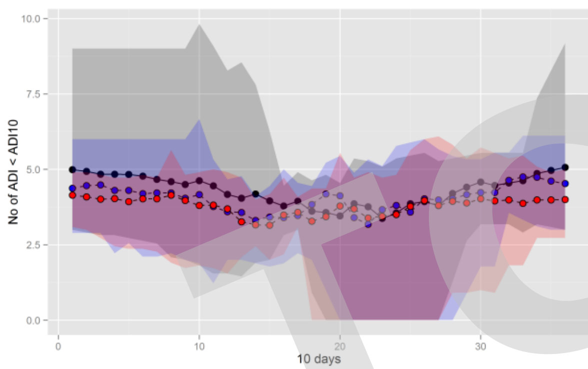
Agricultural drought index based on storage level

- **Storage → Agricultural Drought Index (ADI)**

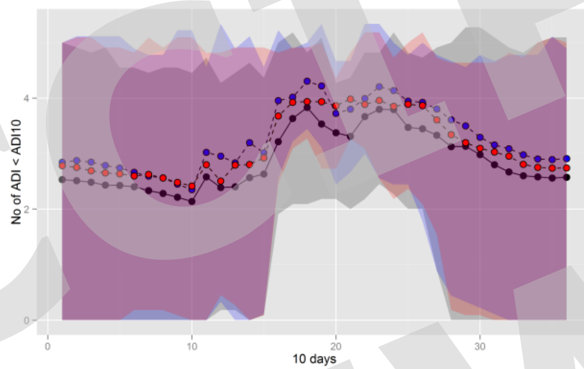


Frequency(yr)	~3	3	5	10	20	30	50	50~
P(X≤x)		0.33	0.20	0.10	0.05	0.03	0.02	
ADI		-1.39	-2.50	-3.33	-3.75	-3.89	-4.00	
Classification	Normal		Moderate drought		Severe drought			Extreme drought

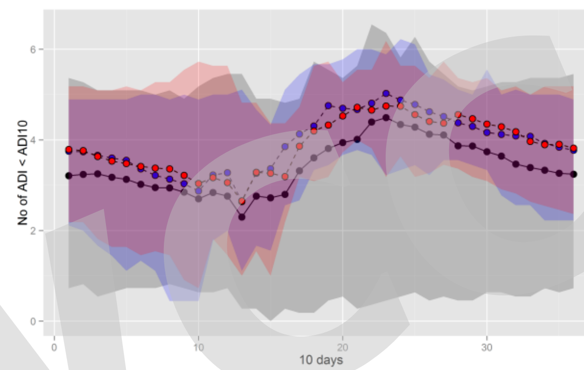
ADI projection (2011~2040)



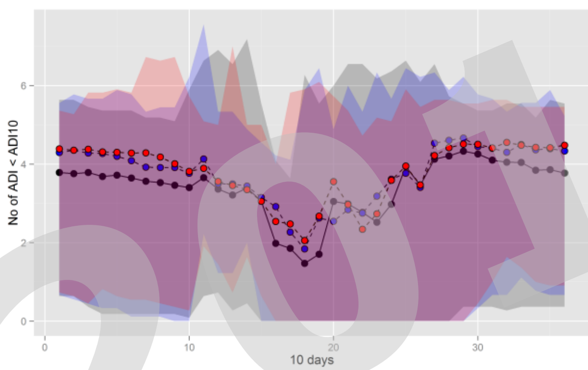
Cluster 1



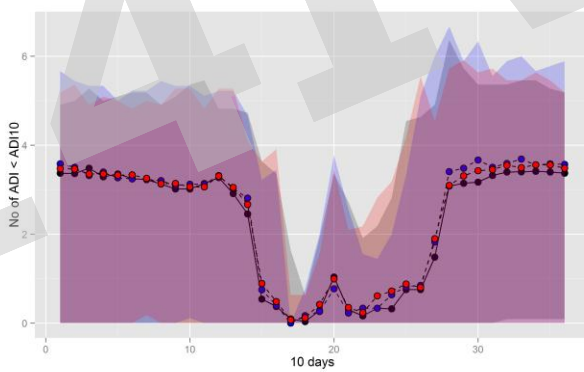
Cluster 2



Cluster 3



Cluster 4



Cluster 5

Clusters		Historical	RCP4.5	RCP8.5
1	No of $ADI<ADI_{10}$	154.6	145.0	136.0
	% change		-6.2	-12.0
2	No of $ADI<ADI_{10}$	103.7	118.1	113.0
	% change		13.8	8.9
3	No of $ADI<ADI_{10}$	122.9	141.4	139.8
	% change		15.1	13.8
4	No of $ADI<ADI_{10}$	122.3	135.0	136.4
	% change		10.4	11.5
5	No of $ADI<ADI_{10}$	80.4	84.7	84.4
	% change		5.3	4.9

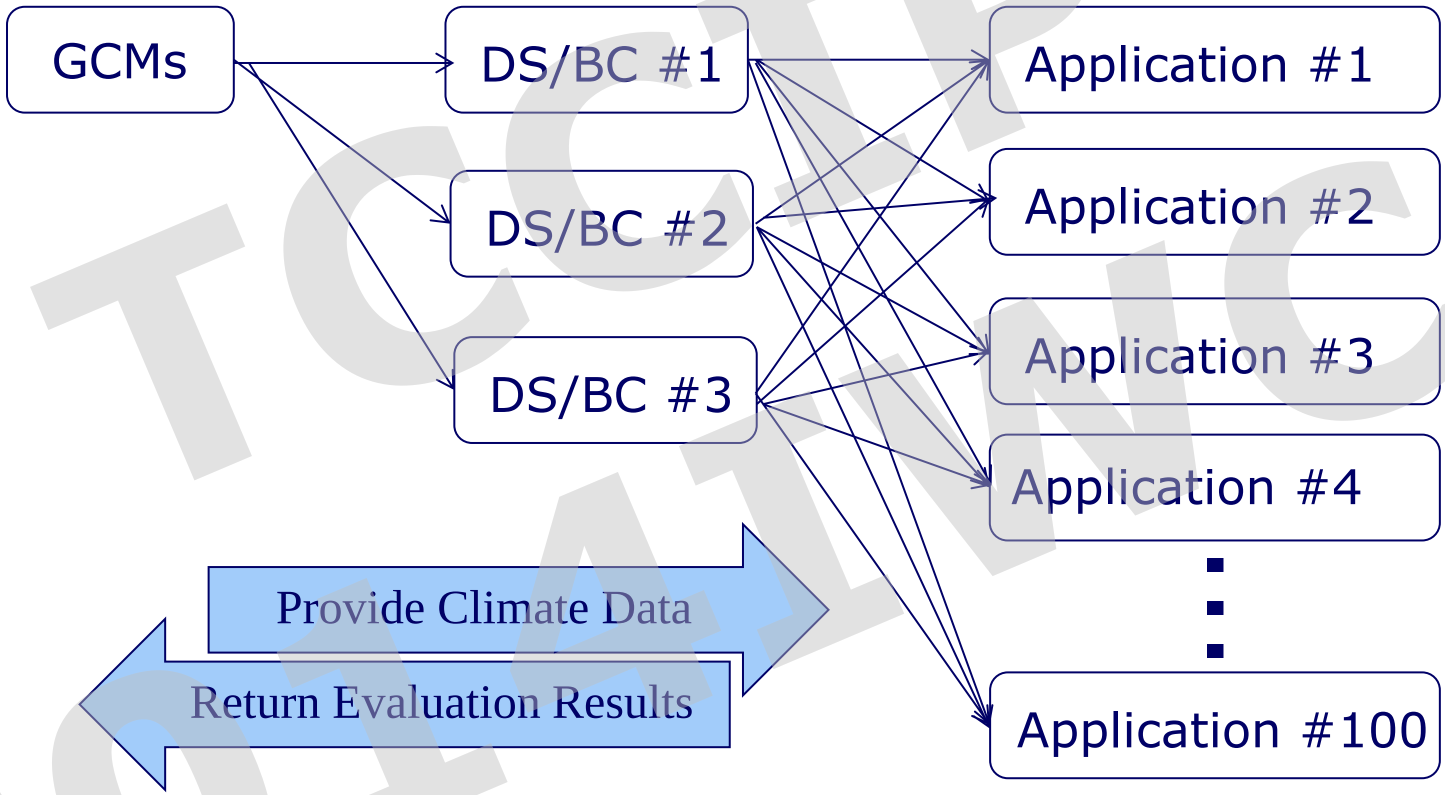
-12.0% ~ 13.8%

Concluding Remarks

Within a climate change impact assessment ....

- Upsteam Inflow, irrigation demand, and water storage level increased for the future period.
- However, frequency of agricultural drought based on the reservoir storage level showed the increase trends.
- Precipitation shows the higher uncertainty compared to the other weather variables.
- Reproducibility-related information for the downscaled/bias-corrected scenario data should be provided.
- Multi-model ensemble (MME) is necessary in order to consider uncertainty.

- **Process-based evaluation of GCMs and DS methods is necessary**



- **Concerns in Downscaling**
  - Spatial/variable coherence, Hourly data, Grid data