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NIES, Japan

Climate Change Impact Studies in APCC

Yonghee Shin/APEC Climate Center
Busan, South Korea

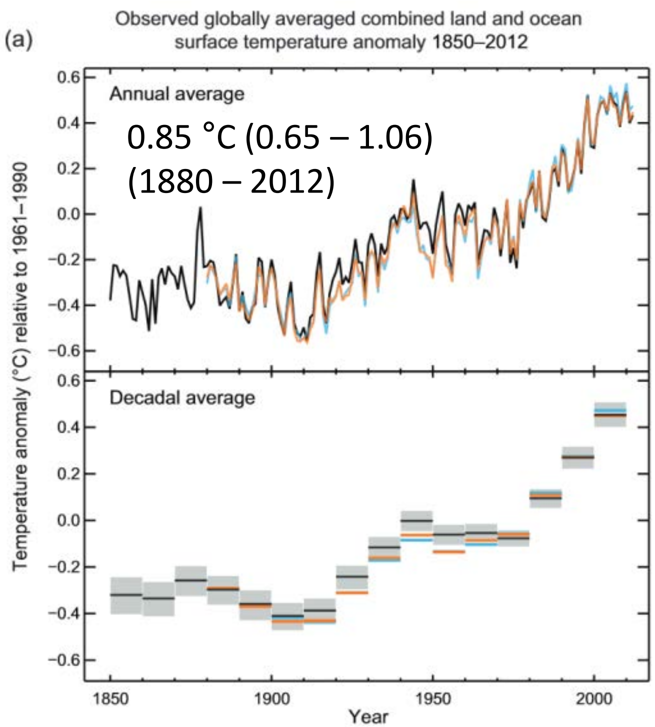
APCC APEC CLIMATE CENTER

Contents

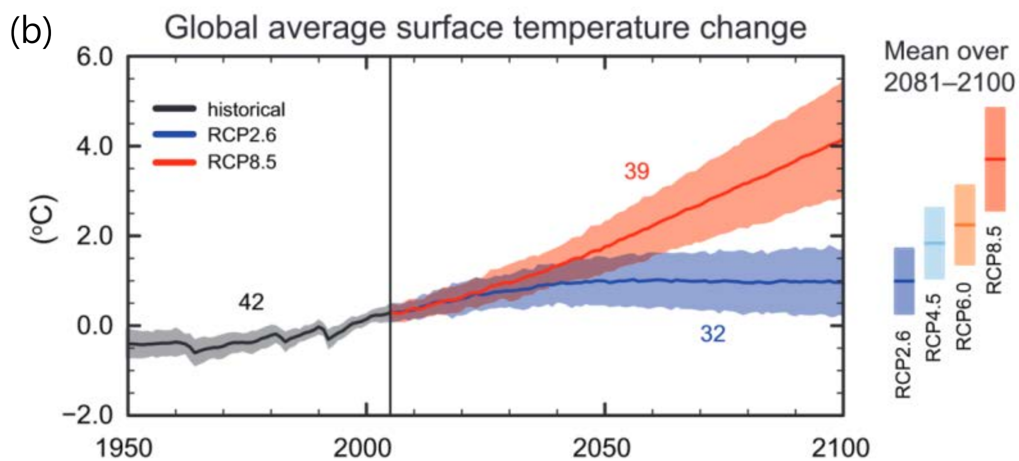
Climate Projection & Uncertainty (1)

➢ Higher global average surface temperature

3.7 °C (2.6 – 4.8)
(2081 – 2100, RCP8.5)



0.85 °C (0.65 – 1.06)
(1880 – 2012)

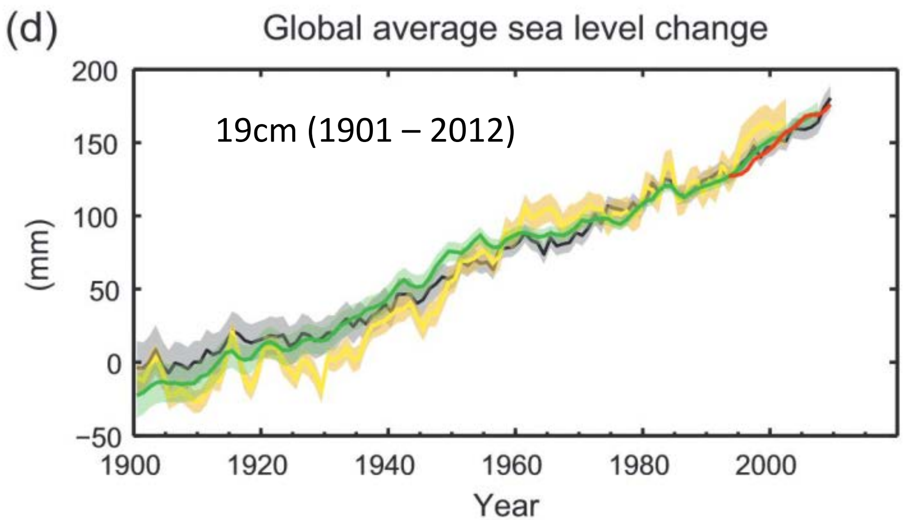


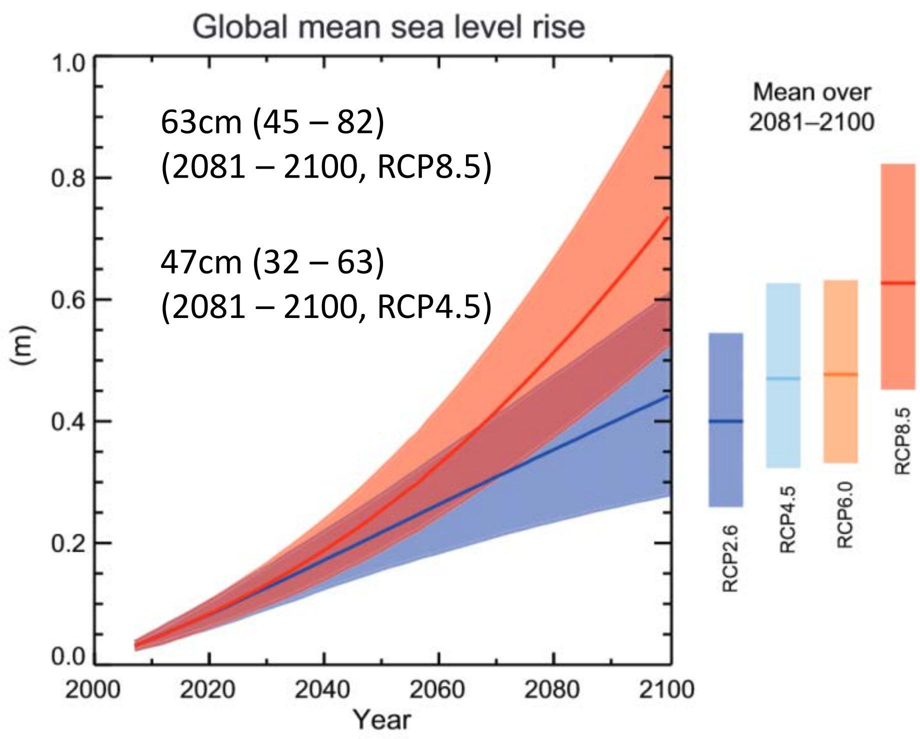
1.8 °C (1.1 – 2.6)
(2081 – 2100, RCP4.5)

Graphic courtesy of WG1 AR5 SPM (2013)

Climate Projection & Uncertainty (2)

➢ **Sea level rises**



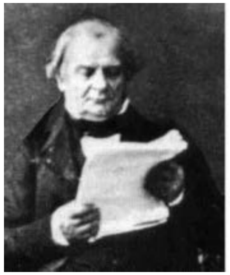


Graphic courtesy of WG1 AR5 SPM (2013), Picture courtesy of Google

Climate Projection & Uncertainty (3)

➢ More extreme rainfall

Clausius-Clapeyron law



$$k = \left(1 - \frac{\delta}{\varrho}\right) \frac{dp}{dt} C.$$

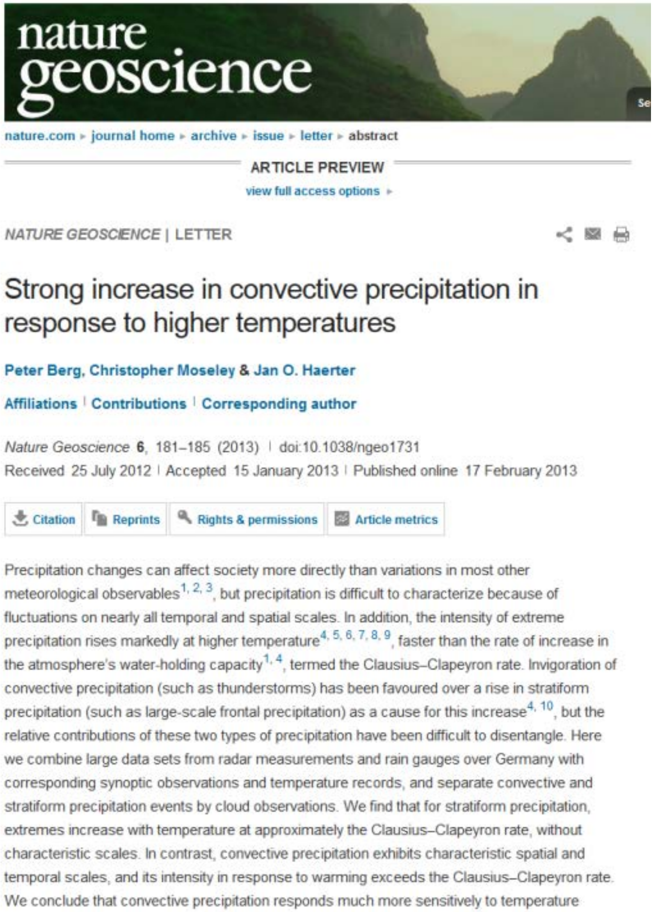
E. Clapeyron (1834)

$$r = C \cdot (s - \sigma) \frac{dp}{dt}.$$

R. Clausius (1850)

Warmer atmosphere is more likely to deliver heavy rainfall events.

1. For stratiform precipitation, extremes increase with temperature at approximately the Clausius–Clapeyron rate
2. Convective precipitation responds much more sensitively to temperature increases than stratiform precipitation



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NATURE GEOSCIENCE | LETTER

Strong increase in convective precipitation in response to higher temperatures

Peter Berg, Christopher Moseley & Jan O. Haerter

Affiliations | Contributions | Corresponding author

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Precipitation changes can affect society more directly than variations in most other meteorological observables[1, 2, 3], but precipitation is difficult to characterize because of fluctuations on nearly all temporal and spatial scales. In addition, the intensity of extreme precipitation rises markedly at higher temperature[4, 5, 6, 7, 8, 9], faster than the rate of increase in the atmosphere's water-holding capacity[1, 4], termed the Clausius–Clapeyron rate. Invigoration of convective precipitation (such as thunderstorms) has been favoured over a rise in stratiform precipitation (such as large-scale frontal precipitation) as a cause for this increase[4, 10], but the relative contributions of these two types of precipitation have been difficult to disentangle. Here we combine large data sets from radar measurements and rain gauges over Germany with corresponding synoptic observations and temperature records, and separate convective and stratiform precipitation events by cloud observations. We find that for stratiform precipitation, extremes increase with temperature at approximately the Clausius–Clapeyron rate, without characteristic scales. In contrast, convective precipitation exhibits characteristic spatial and temporal scales, and its intensity in response to warming exceeds the Clausius–Clapeyron rate. We conclude that convective precipitation responds much more sensitively to temperature

CMIP5 Summer Season Precipitation Change (1)

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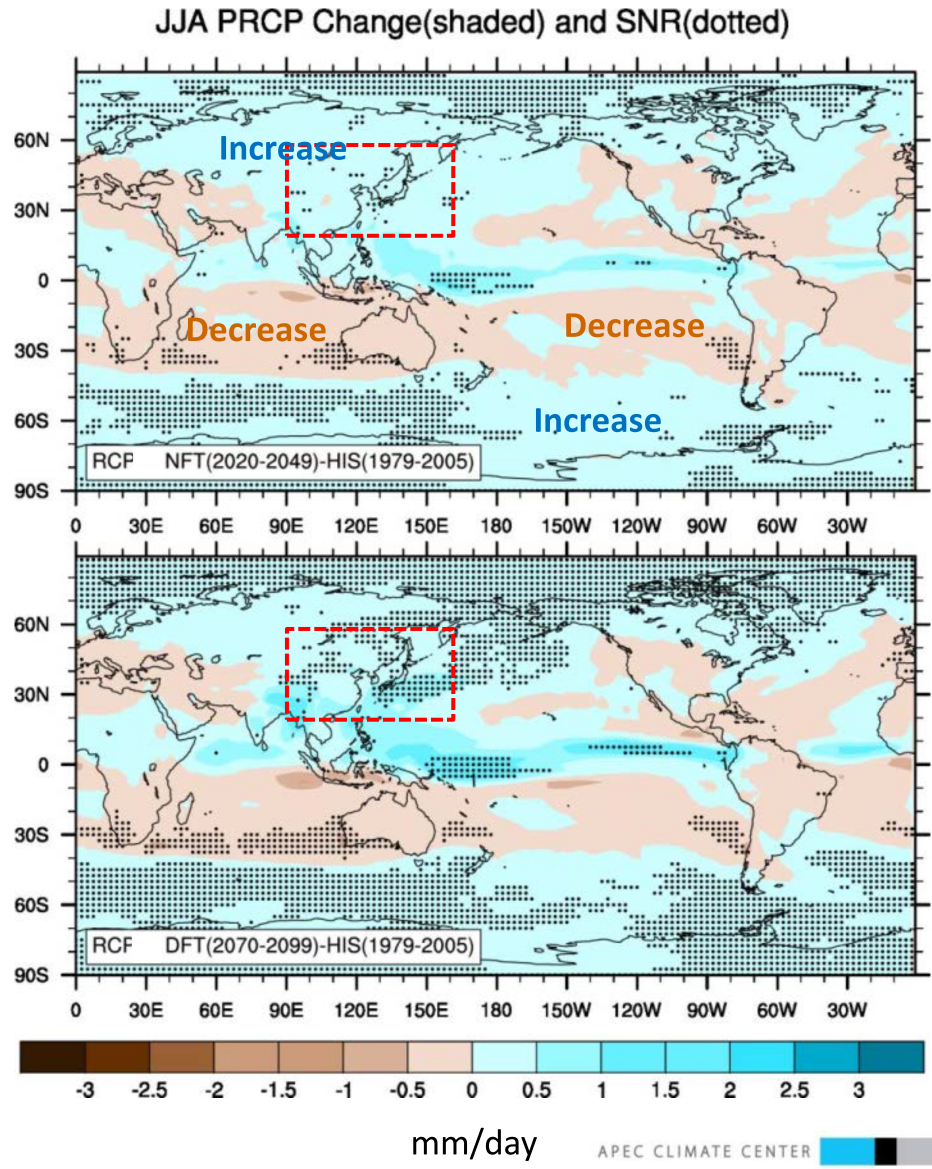
- **Consistency analysis**
  - ✓ 28 CMIP5 models
  - ✓ Signal to noise ratio (SNR)
  - ✓ RCP4.5
  - ✓ Reference 1979-2005
  - ✓ Near future 2020-2049
  - ✓ Distant future 2070-2099
  - ✓ June-July-August



CMIP5 Summer Season Precipitation Change (2)

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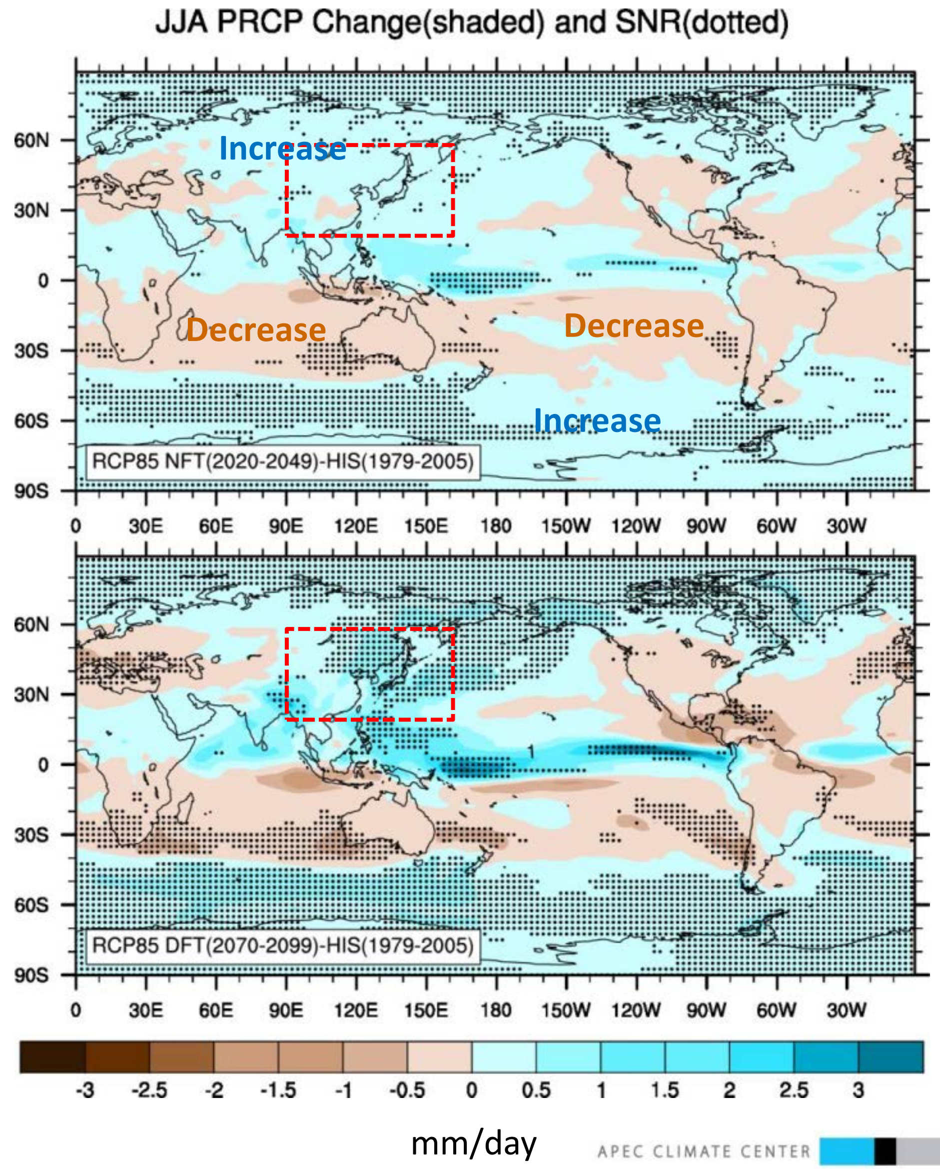
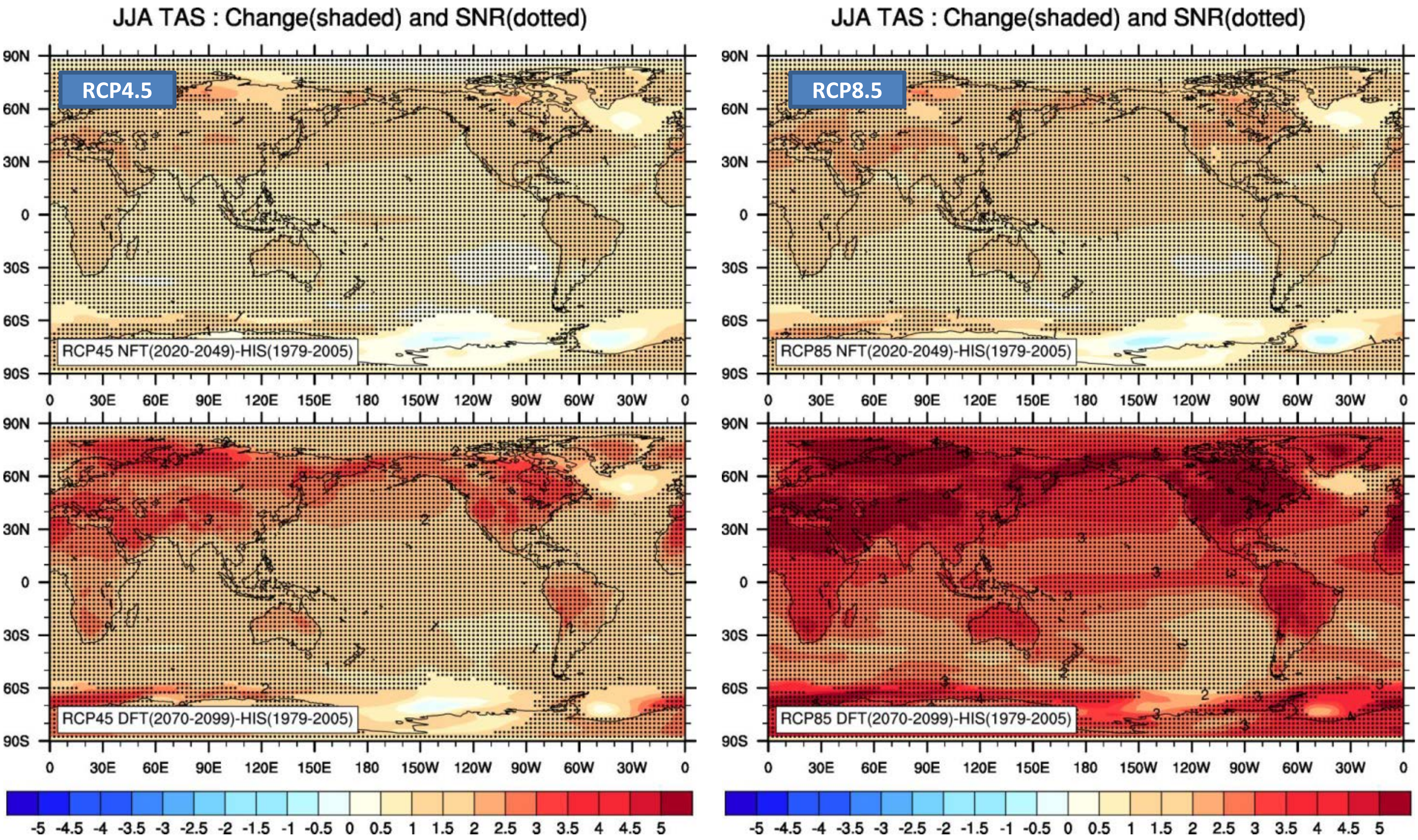
- **Consistency analysis**
  - ✓ 28 CMIP5 models
  - ✓ Signal to noise ratio (SNR)
  - ✓ RCP8.5
  - ✓ Reference 1979-2005
  - ✓ Near future 2020-2049
  - ✓ Distant future 2070-2099
  - ✓ June-July-August



CMIP5 Temperature Change



Degree Celsius

CMIP5 Temperature Changes in S.Korea (2081-00)

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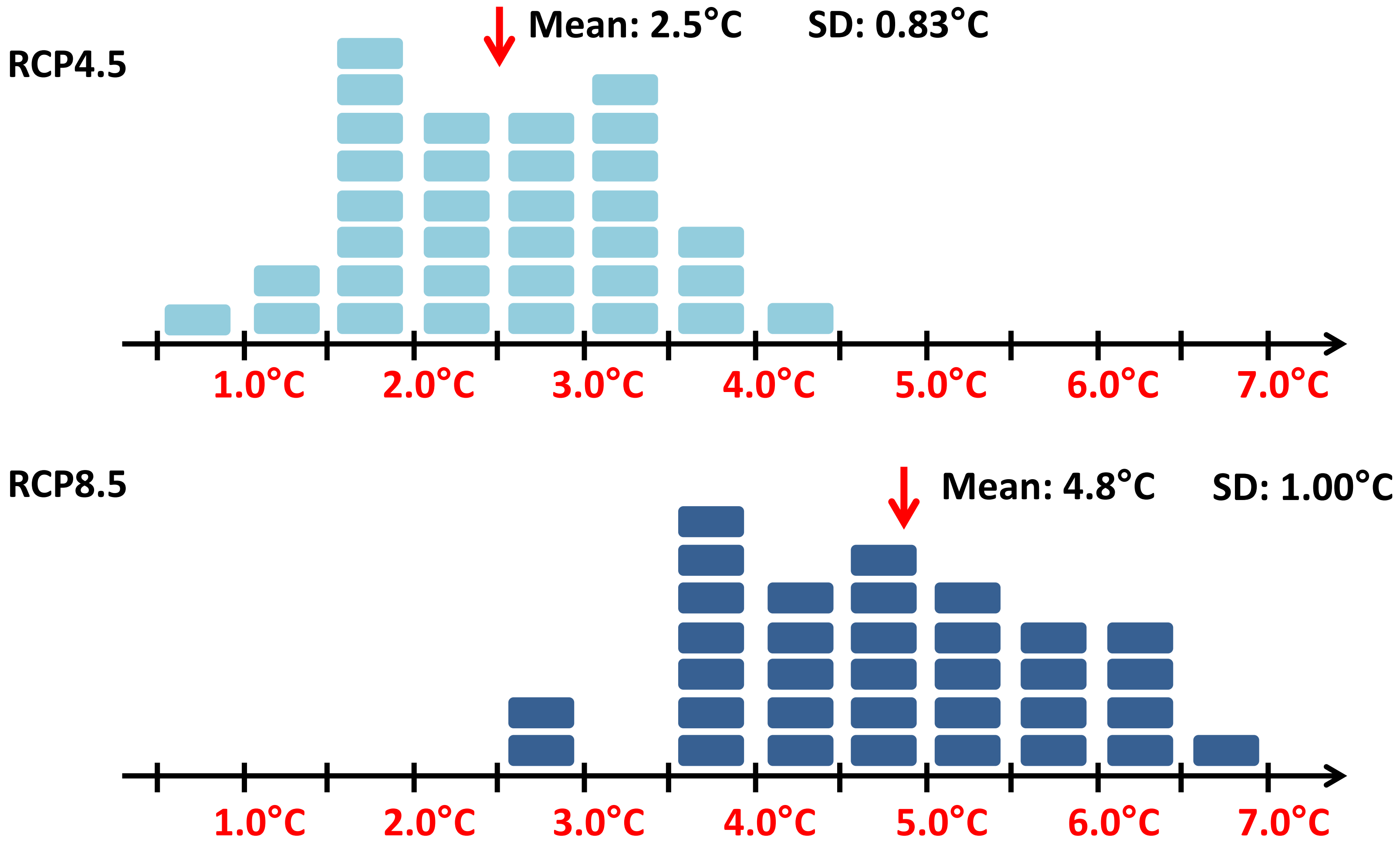
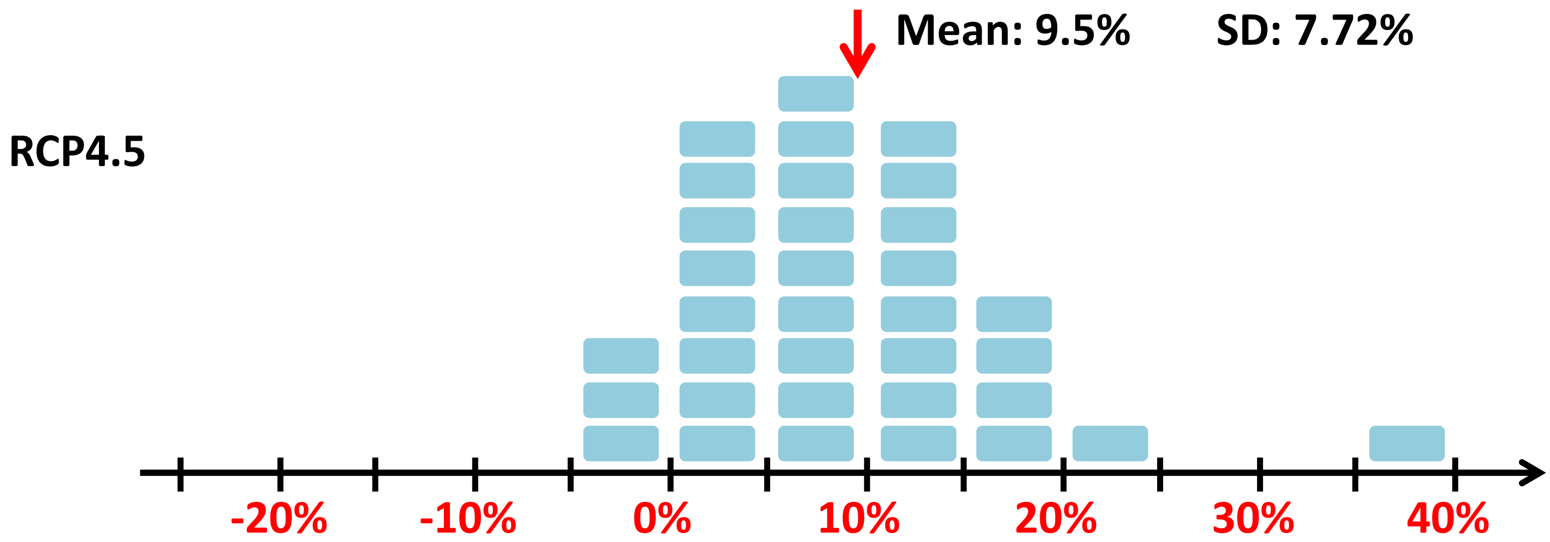
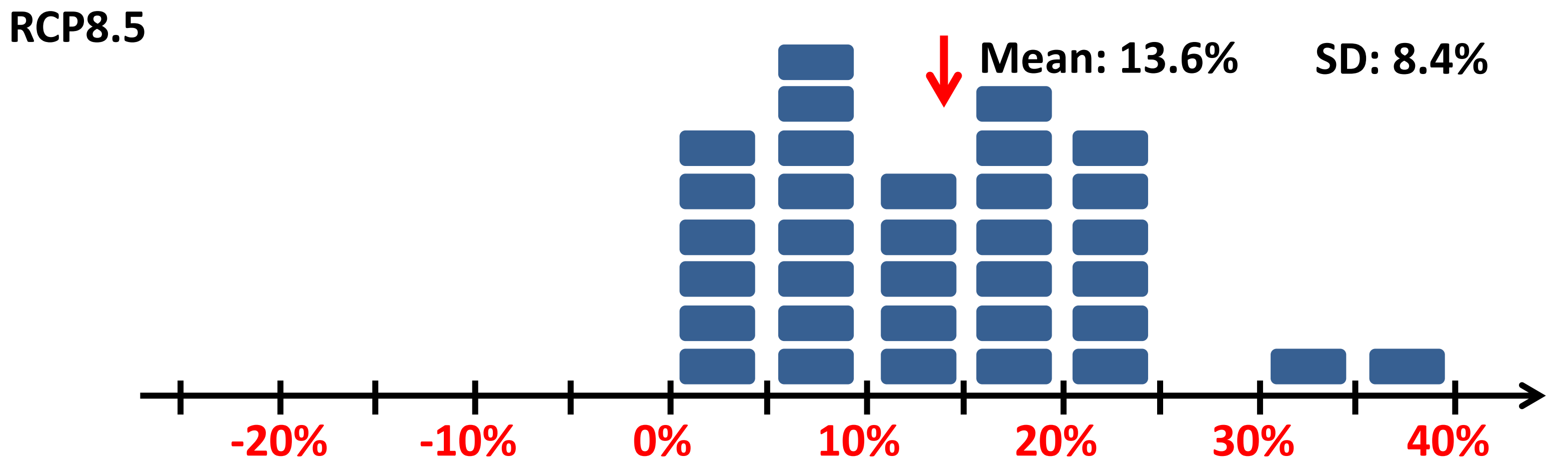


CMIP5 Precipitation Changes in S.Korea (2081-00)

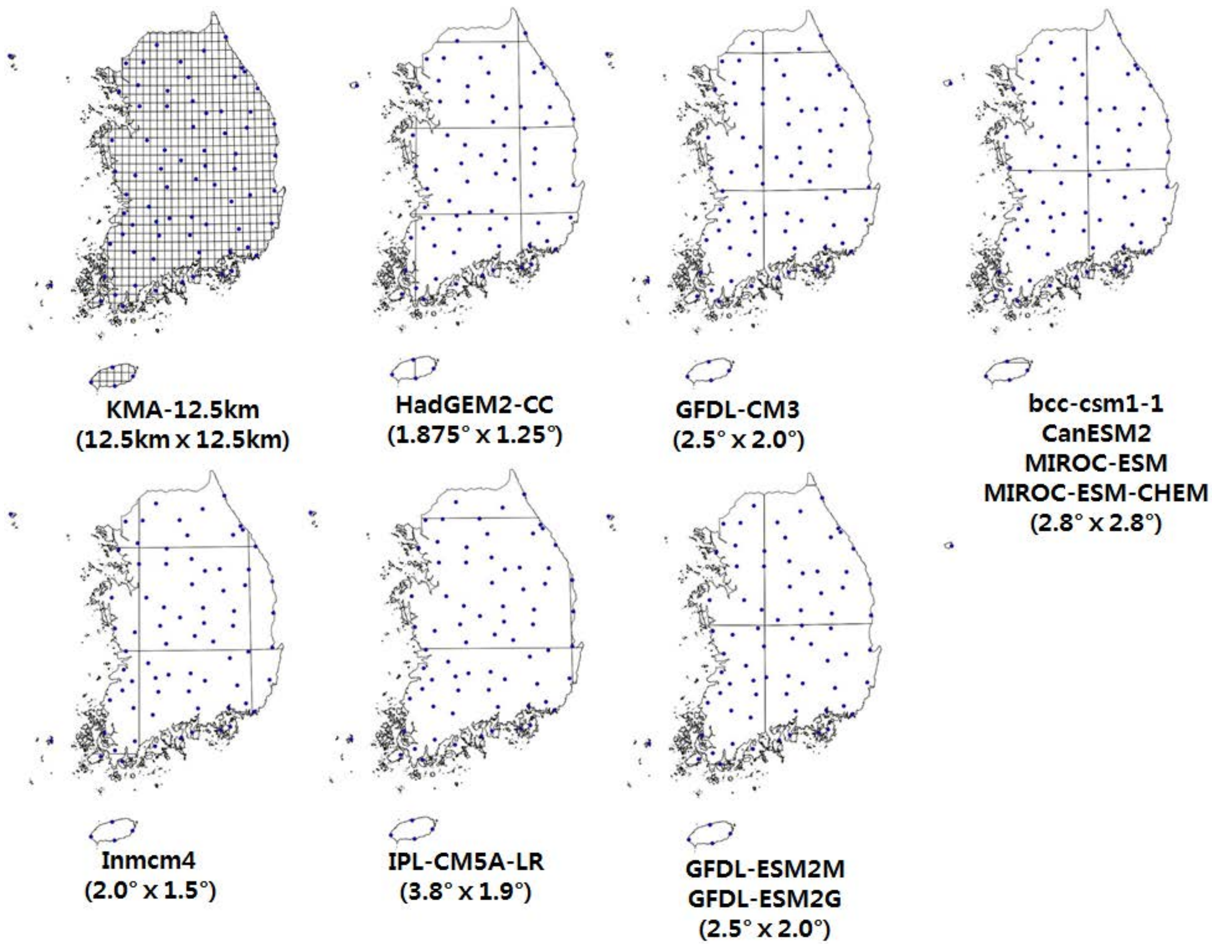




Assessment of Climate Change Impact on Agricultural Reservoirs

Climate Change Scenario (CMIP5) Data

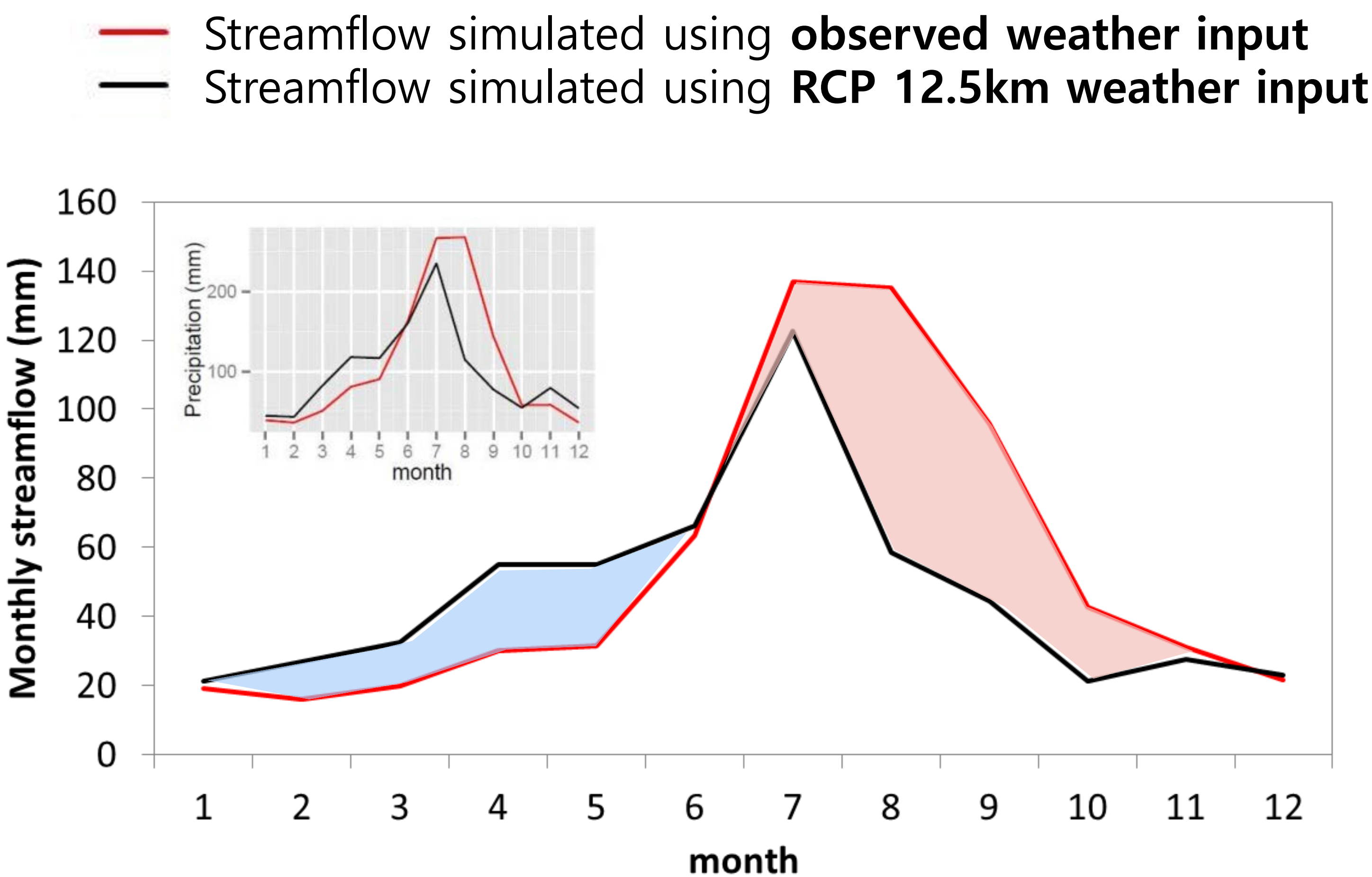
- **Daily 6 main climatic elements ➔ 34 GCMs**



RCP8.5 scenario
- KMA RCM
- 10 GCMs

Climate
- Precipitation
- Max.Temp
- Min.Temp
- Wind speed
- RH
- Solar radiation

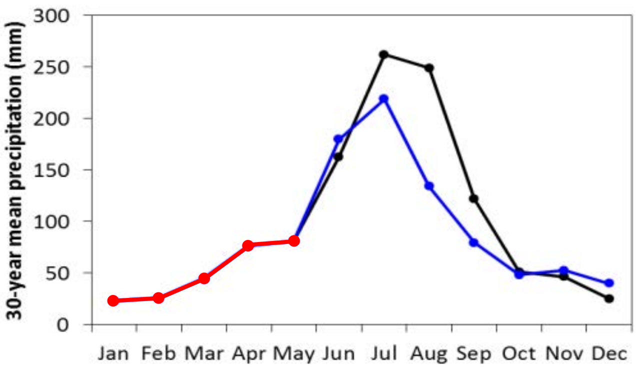
Sensitivity Analysis of Streamflow



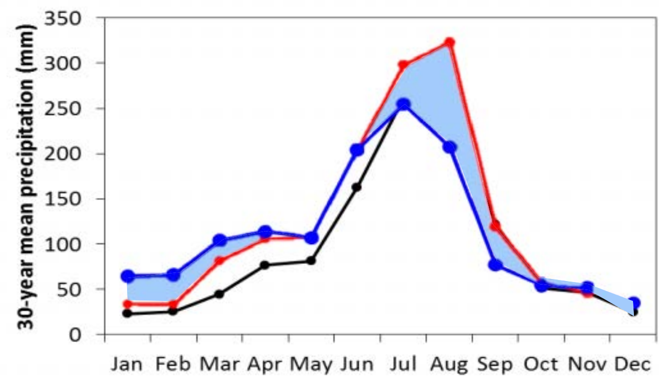
Streamflow is decided by monthly rainfall: Need bias correction

Bias Correction of Climate Data (Non-parametric Quantile Mapping methods)

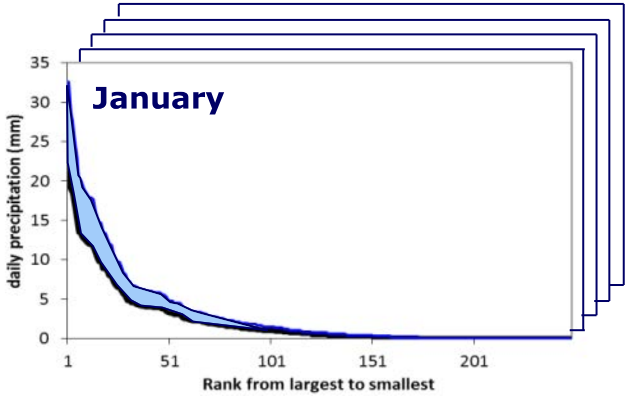
Historical (1976~2005)



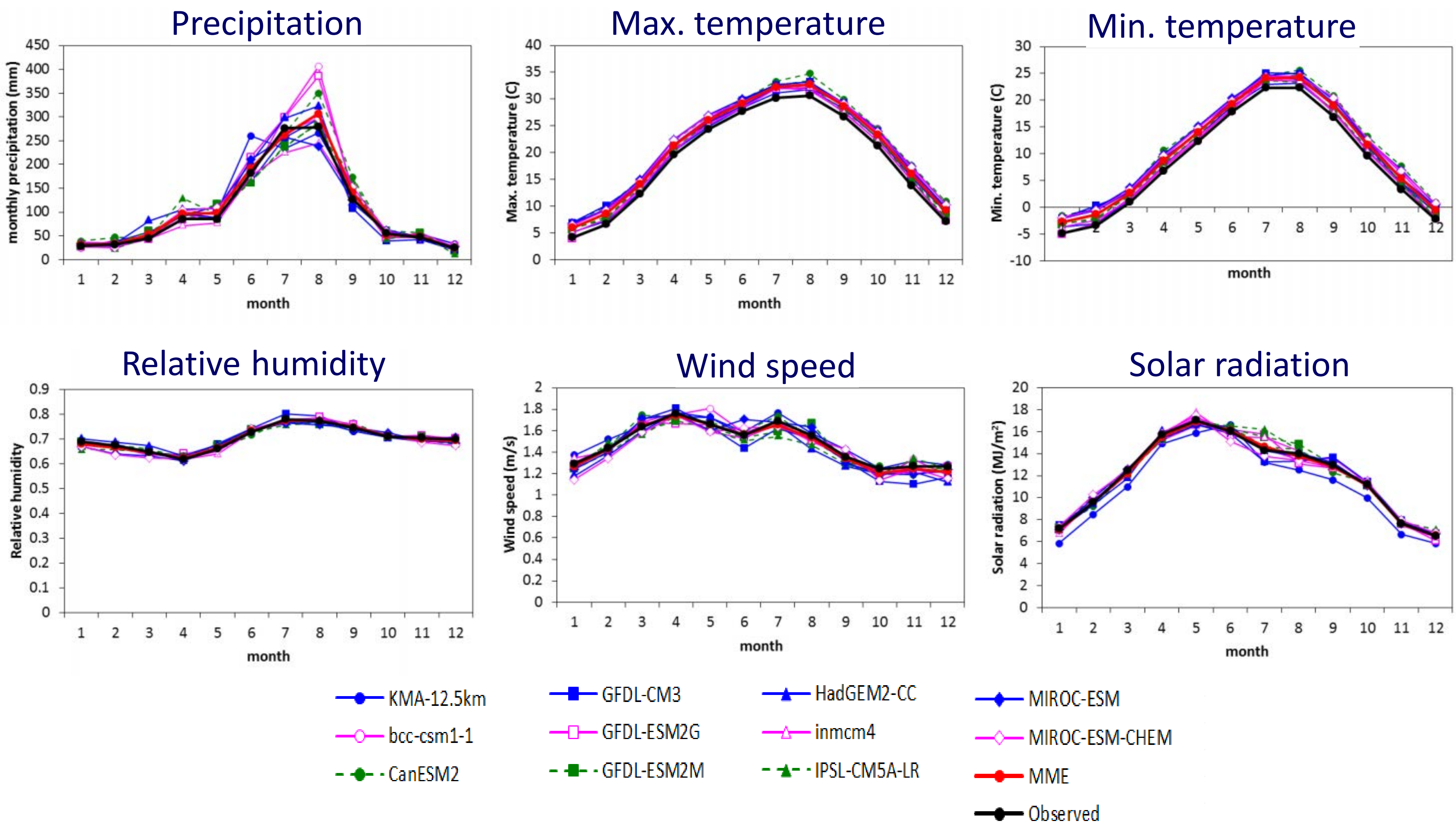
Future (2011~2040)



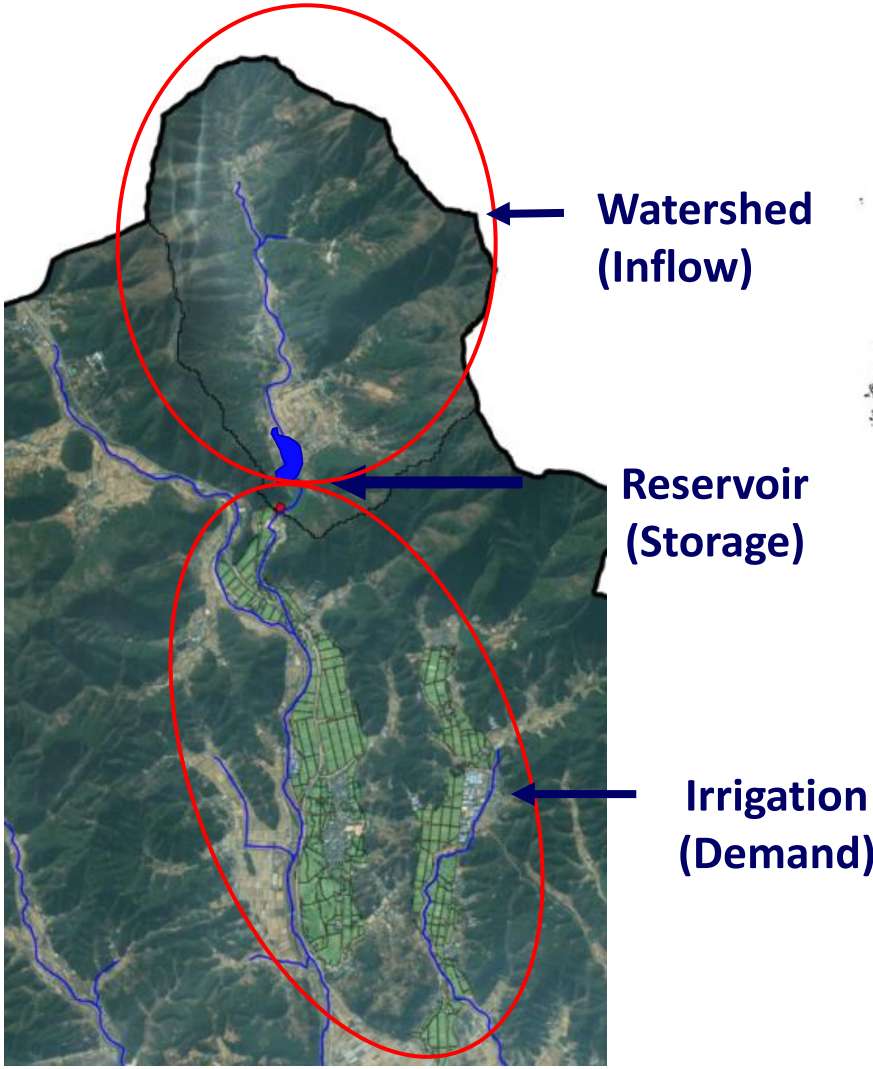
Observed
Before quantile mapping
After quantile mapping
Quantile mapping information



After Bias Correction (RCP8.5, Jeonju)



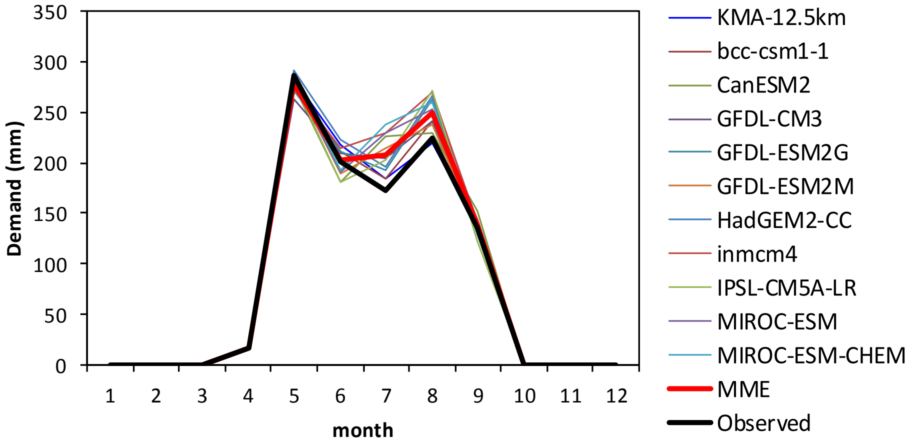
Representative Watershed for Analysis



- **HOMWRS**
  - Inflow: 3 step tank model
  - Demand: ET + Sowing + Transplanting + Loss
  - Water storage

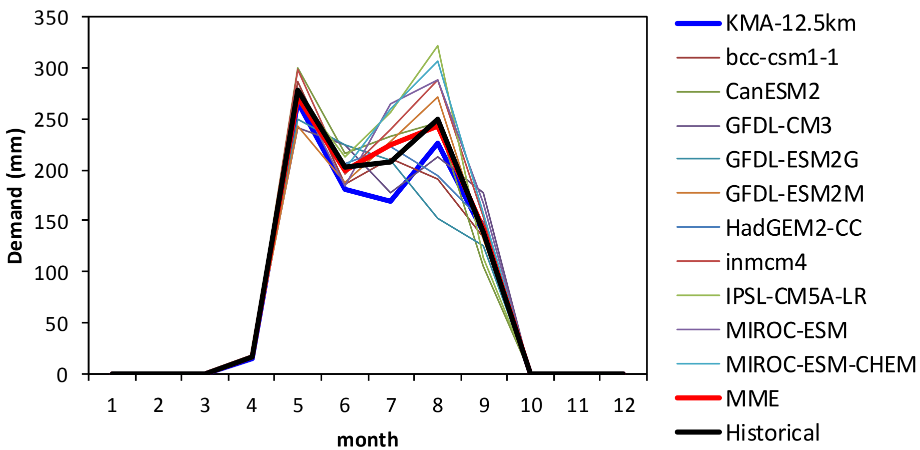
Monthly Water Demand Reproduction & Prediction

1976-2005



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

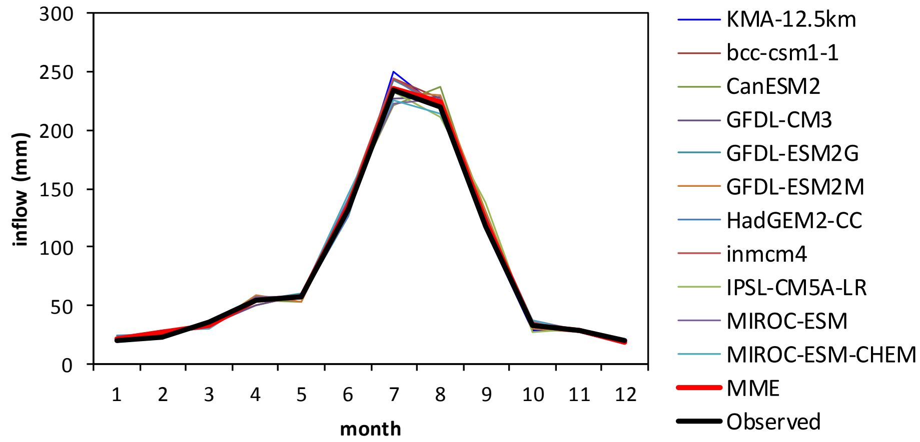
2011-2040



Models	Demand (mm)	% difference	Rank
MME	1099		
KMA-12.5km	**997**	**-9.3**	**10**
bcc-csm1-1	1026	-6.7	9
CanESM2	1117	1.6	5
GFDL-CM3	1051	-4.4	8
GFDL-ESM2G	979	-11.0	11
GFDL-ESM2M	1079	-1.9	6
HadGEM2-CC	1062	-3.4	7
inmcm4	1195	8.7	4
IPSL-CM5A-LR	1196	8.7	3
MIROC-ESM	1197	8.9	2
MIROC-ESM-CHEM	1210	10.0	1

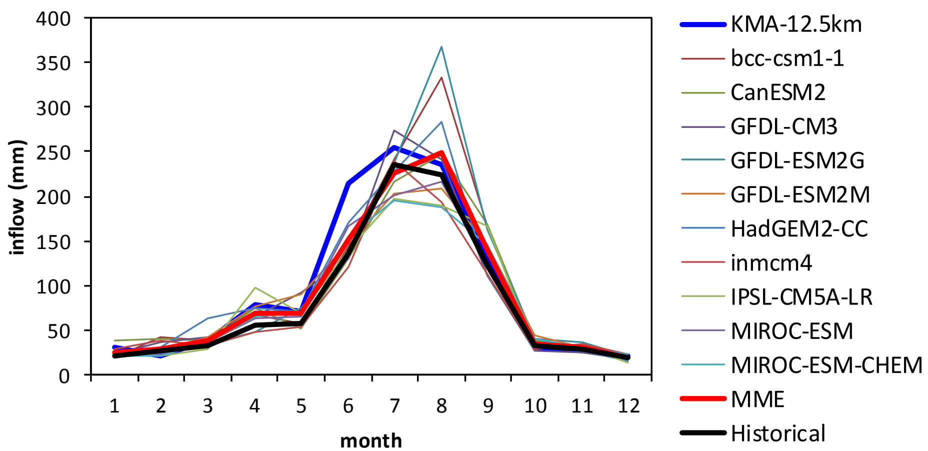
Monthly Inflow Reproduction & Prediction

1976-2005



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

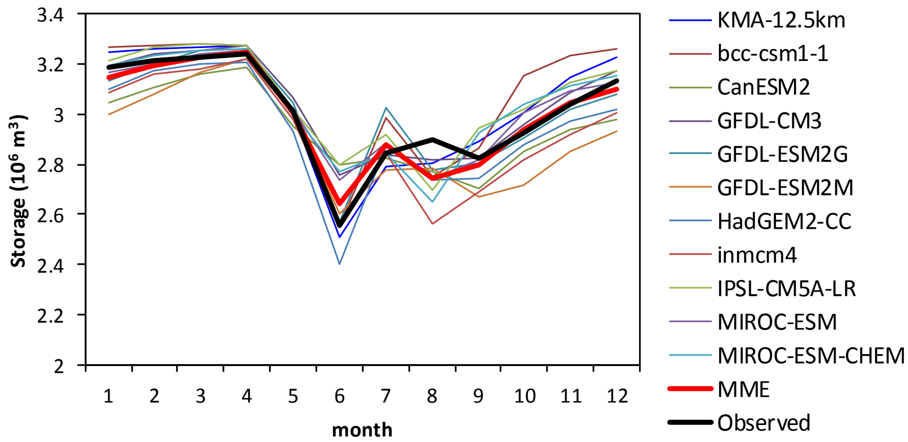
2011-2040



Models	Inflow (mm)	% difference	Rank
MME	1078		
KMA-12.5km	**1153**	**7.0**	**3**
bcc-csm1-1	1192	10.6	2
CanESM2	1088	0.9	5
GFDL-CM3	1083	0.4	6
GFDL-ESM2G	1198	11.1	1
GFDL-ESM2M	1052	-2.5	7
HadGEM2-CC	1125	4.3	4
inmcm4	954	-11.5	11
IPSL-CM5A-LR	1009	-6.5	8
MIROC-ESM	1003	-6.9	9
MIROC-ESM-CHEM	993	-7.9	10

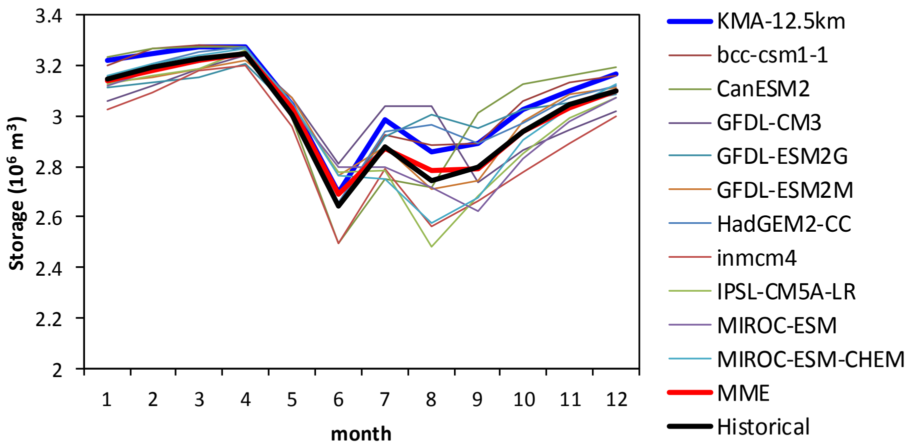
Monthly Water Storage Reproduction & Prediction

1976-2005



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

2011-2040



Models	Storage (10^6 m^3)	% difference	Rank
MME	3.00		
KMA-12.5km	**3.07**	2.1	**1**
bcc-csm1-1	3.06	2.0	2
CanESM2	3.04	1.3	4
GFDL-CM3	3.01	0.3	6
GFDL-ESM2G	3.03	0.8	5
GFDL-ESM2M	3.00	0.0	7
HadGEM2-CC	3.04	1.4	3
inmcm4	2.89	-3.9	11
IPSL-CM5A-LR	2.95	-1.7	10
MIROC-ESM	2.97	-1.2	9
MIROC-ESM-CHEM	2.98	-0.8	8

Assessment of Climate Change Impact on Rice Yields

Multiple Scale Crop Yield Modeling

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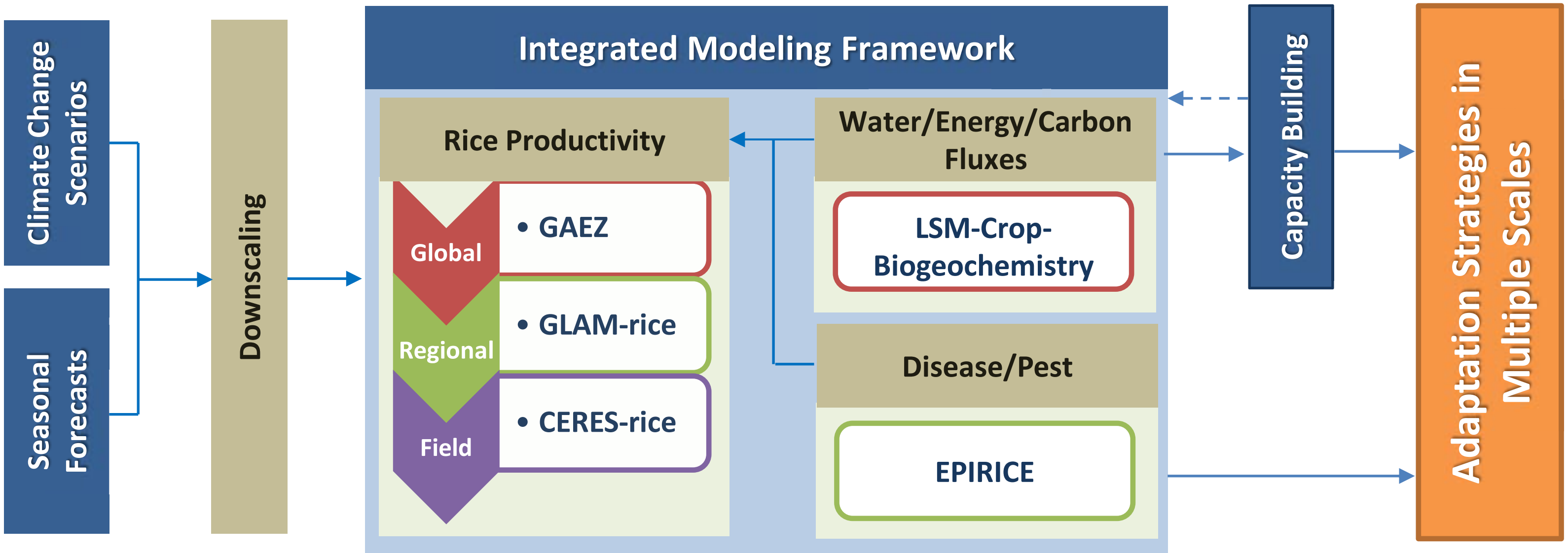
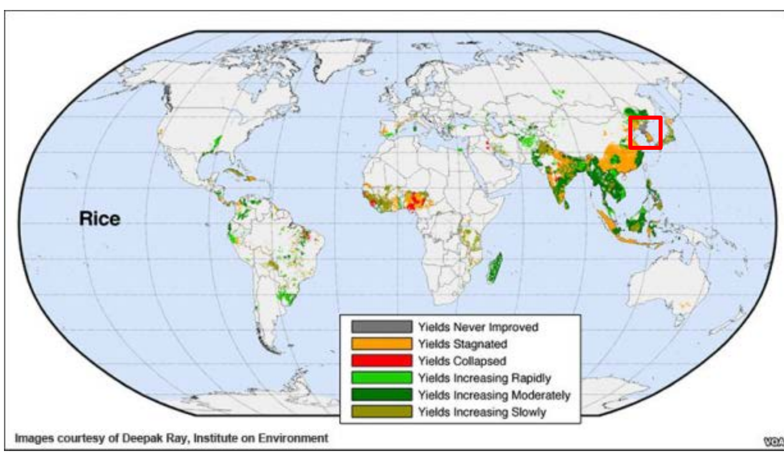
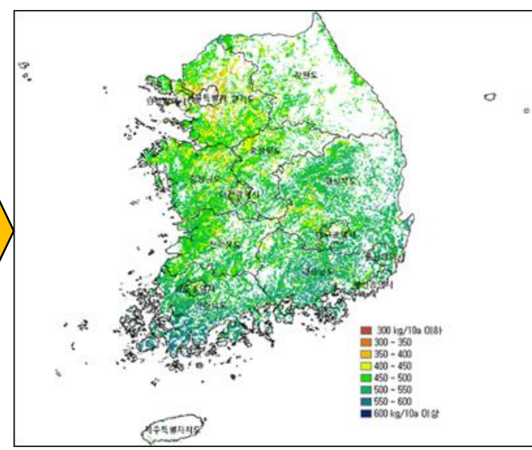




Global scale



Regional scale

Field scale

CMIP5 Climate Change Scenarios

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Model	Code	RCP Scenario				Spatial Resolution (lon. X lat.)
		2.6	4.5	6.0	8.5	
ACCESS1-0	ac10	×	◎	×	◎	192 X 145
ACCESS1-3	ac13	×	◎	×	◎	192 X 145
BCC-CSM1-1-M	b11m	◎	◎	◎	◎	320 X 160
BNU-ESM	bne1	◎	◎	×	◎	128 X 64
CanESM2	ce21	◎	◎	×	◎	128 X 64
CCSM4	csm4	◎	◎	×	◎	288 X 192
CESM1-BGC	c1bg	×	◎	×	◎	288 X 192
CESM1-CAM5	c1ca	◎	◎	◎	◎	288 X 192
CMCC-CM	cccm	×	◎	×	◎	480 X 240
CNRM-CM5	cc51	◎	◎	×	◎	256 X 128
CSIRO-Mk3-6-0	cm36	◎	◎	◎	◎	192 X 96
FGOALS-g2	fgg2	◎	◎	×	◎	128 X 60
FGOALS-s2	fgs2	◎	◎	◎	◎	128 X 108
FIO-ESM	fie1	◎	◎	◎	◎	128 X 64
GFDL-CM3	gc31	◎	◎	◎	◎	144 X 90
GFDL-ESM2G	ge2g	◎	◎	◎	◎	144 X 90
GFDL-ESM2M	ge2m	◎	◎	◎	◎	144 X 90
GISS-E2-R	ge2r	◎	◎	◎	◎	144 X 90
HadGEM2-AO	hg2a	◎	◎	◎	◎	192 X 145
HadGEM2-CC	hg2c	×	◎	×	◎	192 X 145
HadGEM2-ES	hg2e	◎	◎	◎	◎	192 X 145
INM-CM4	in40	×	◎	×	◎	180 X 120
IPSL-CM5A-LR	ic5l	◎	◎	◎	◎	96 X 96
IPSL-CM5A-MR	ic5m	◎	◎	◎	◎	144 X 142
IPSL-CM5B-LR	icbl	×	◎	×	◎	96 X 96
MIROC5	m501	◎	◎	◎	◎	256 X 128
MIROC-ESM	mes1	◎	◎	◎	◎	128 X 64
MIROC-ESM-CHEM	mesc	◎	◎	◎	◎	128 X 64
MPI-ESM-LR	mpel	◎	◎	×	◎	192 X 96
MPI-ESM-MR	mpem	◎	◎	×	◎	192 X 96
MRI-CGCM3	mc31	◎	◎	◎	◎	320 X 160
NorESM1-M	ne1m	◎	◎	◎	◎	144 X 96

Standardization of spatial resolution
(Longitude 1°, Latitude 1°)

Historical data : 1961-2005
Scenario data : 2006-2100

Rice Yield Simulation Setting

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Items	Settings
Model	M-GAEZ model (Modified by NIES)
Crops	Rice(8 varieties)
Study area	Asia-Pacific Region (20 countries)
Periods	1990s (1991-2000), 2020s (2021-2030), 2050s (2051-2060), 2080s (2081-2090)
GCMs	CMIP5 GCMs (32 GCMs)
Scenarios	RCP (RCP2.6, RCP4.5, RCP6.0, RCP8.5)
Adaptations	Planting dates, Varieties
Climate observations	CRU time-series datasets
Climate conditions	Surface Air Temperature [℃], Precipitation [mm/day], Surface Downwelling Shortwave Radiation [W/m^2], Wind Speed [m/s]

Rice Yield Changes in the Asia-Pacific Region Countries (1)

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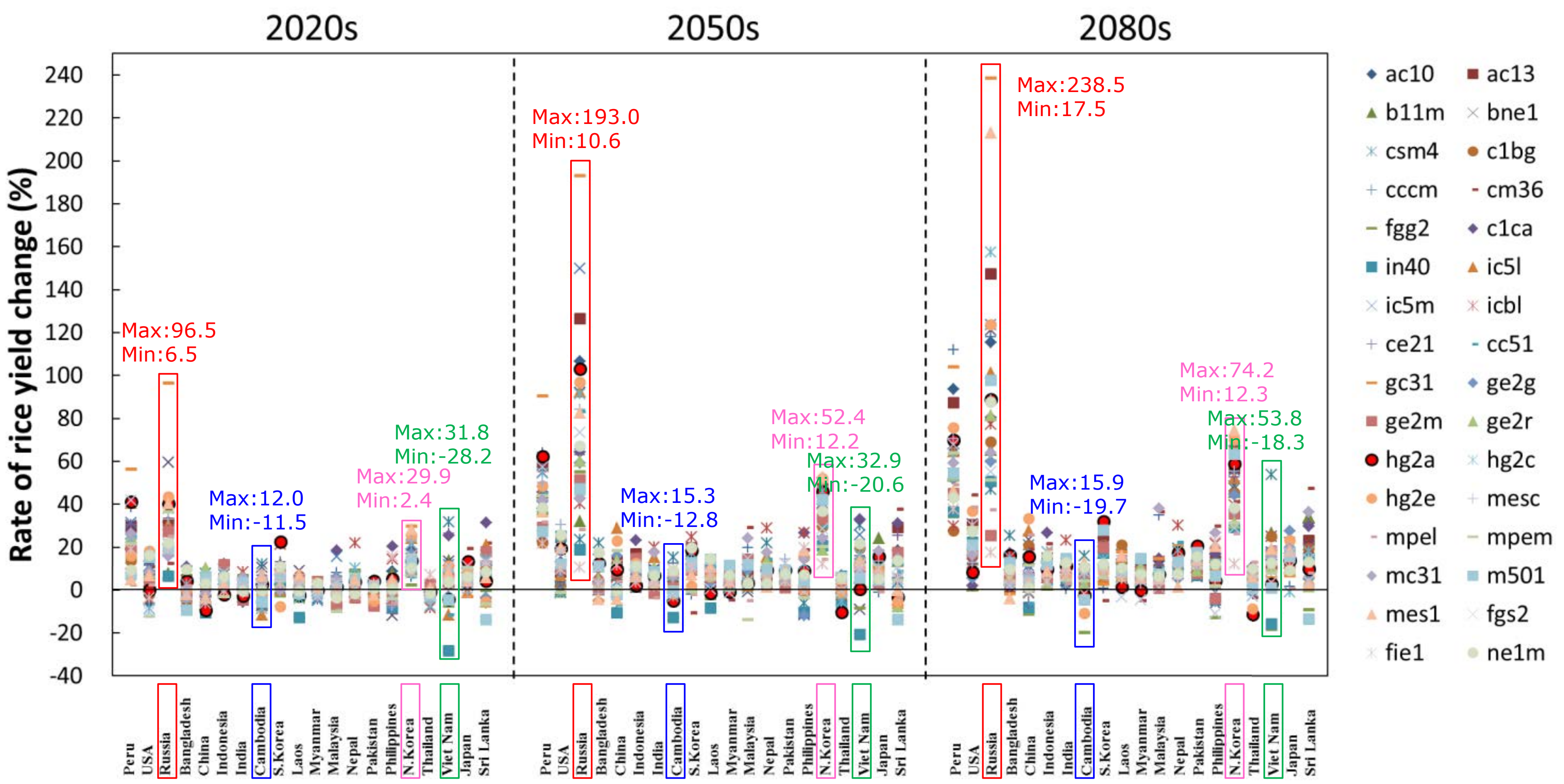
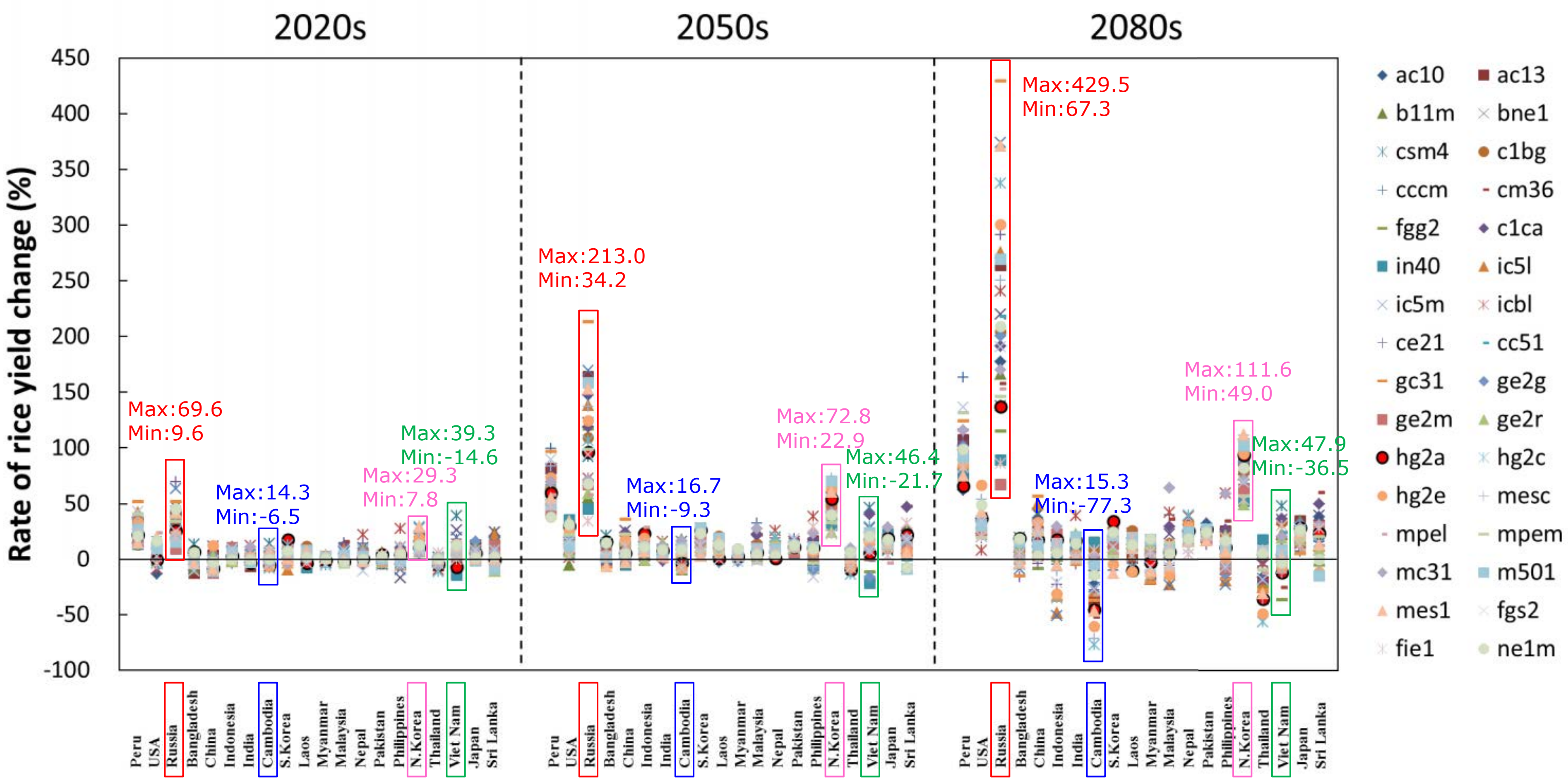
RCP 4.5 Adaptation(ON)



Rice Yield Changes in the Asia-Pacific Region Countries (2)

RCP 8.5 Adaptation(ON)



Uncertainty of Rice Yield Changes (China and India)

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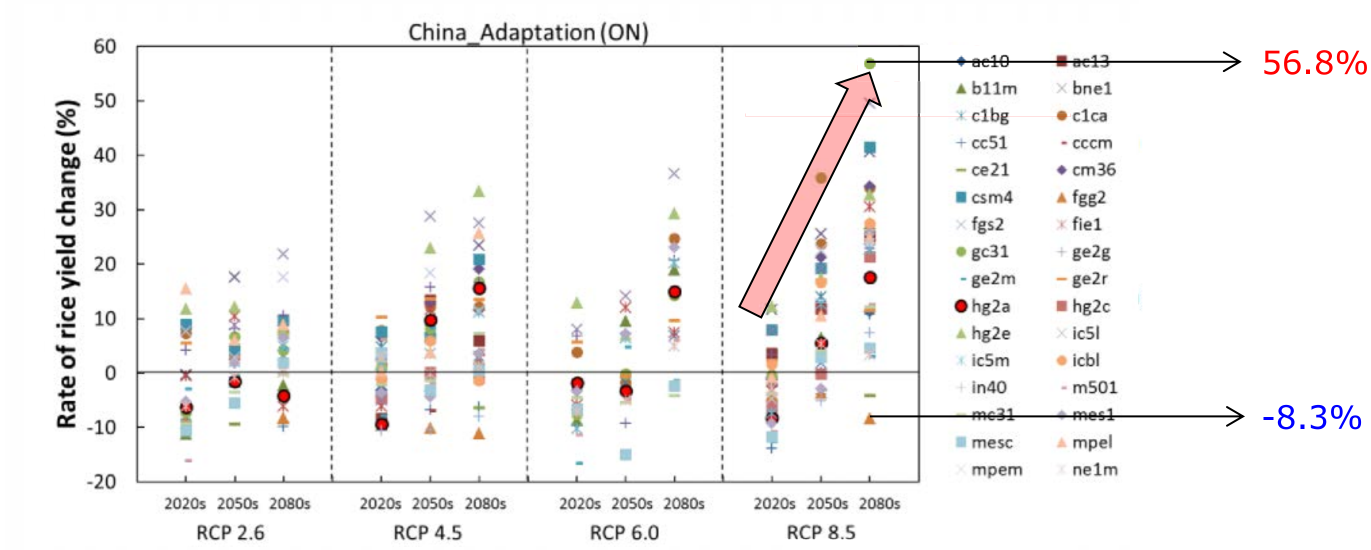

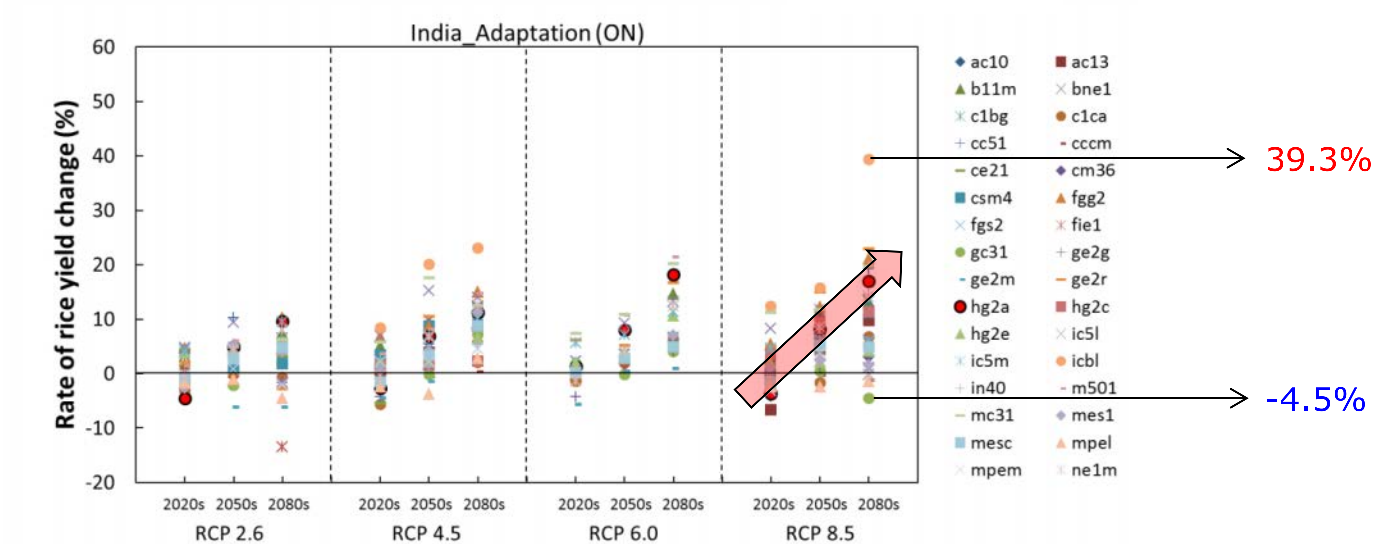

Uncertainty of Rice Yield Changes (Russia and Cambodia)

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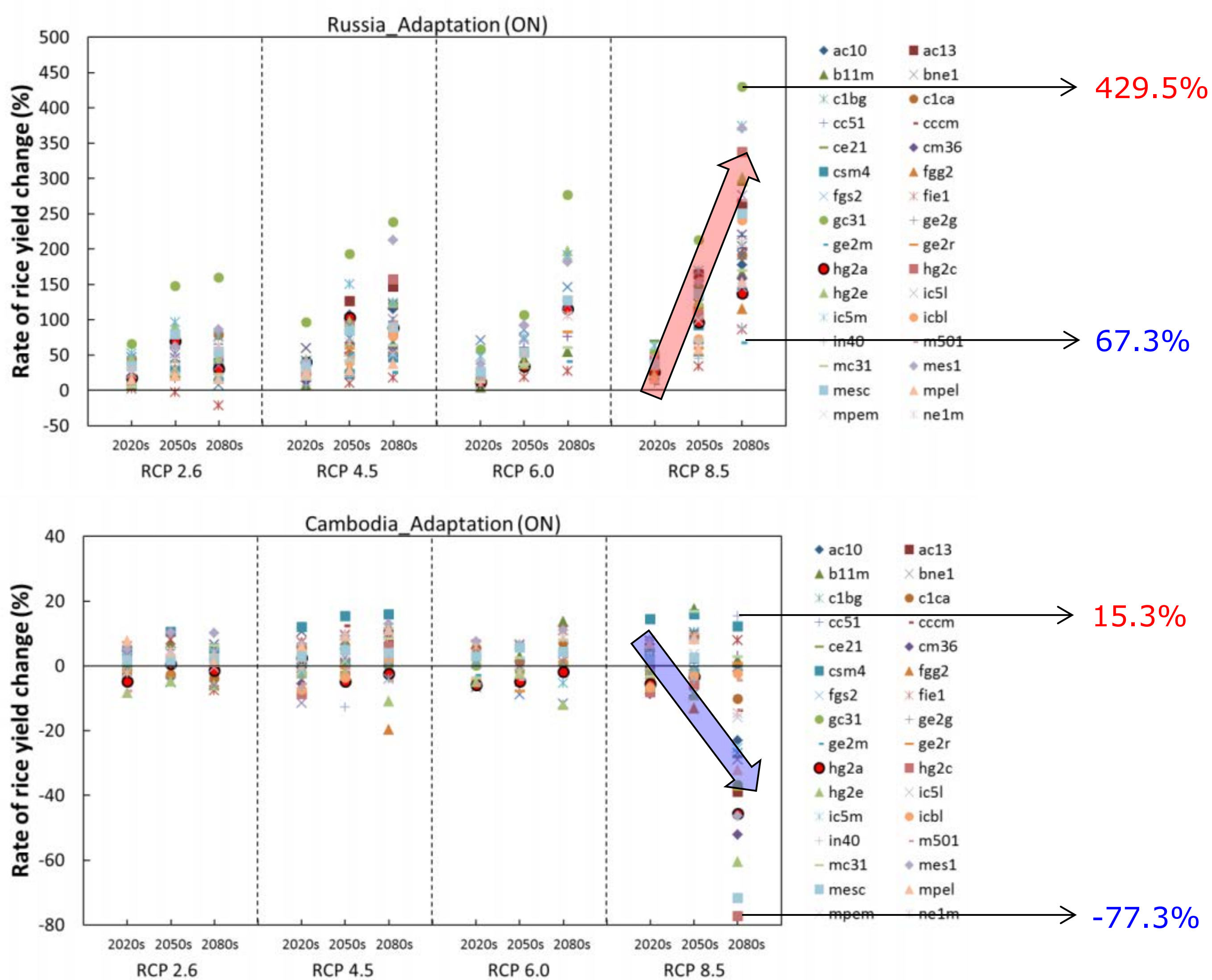
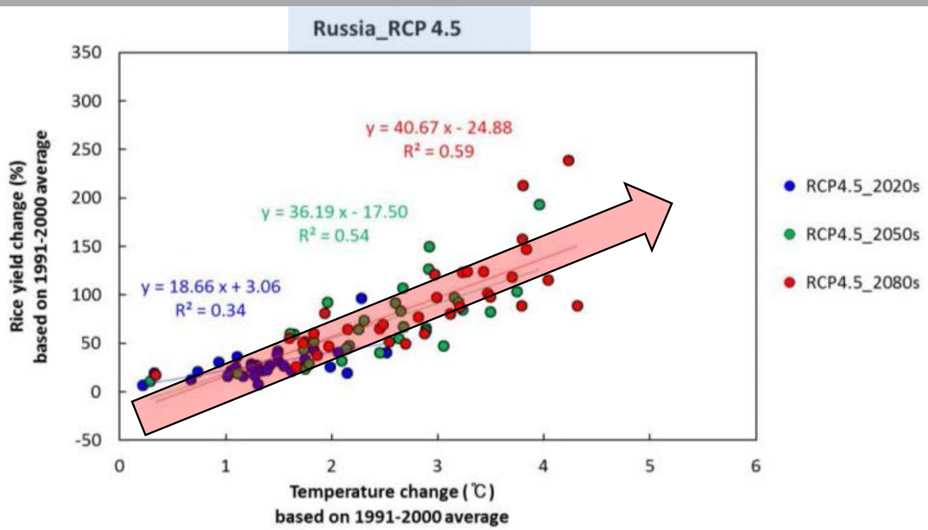
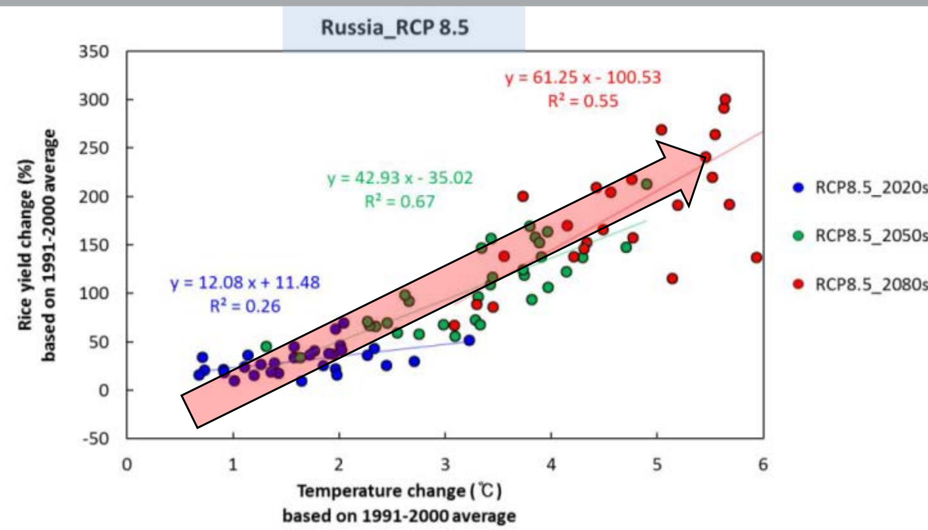
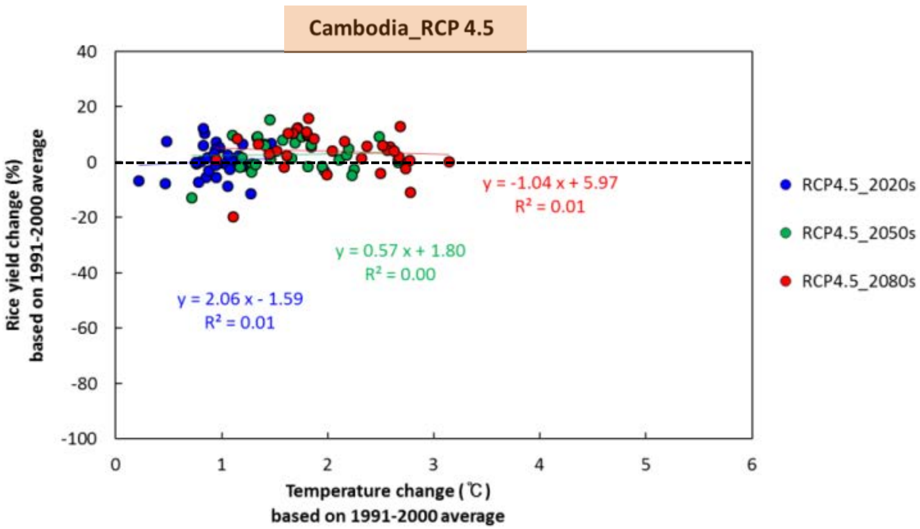
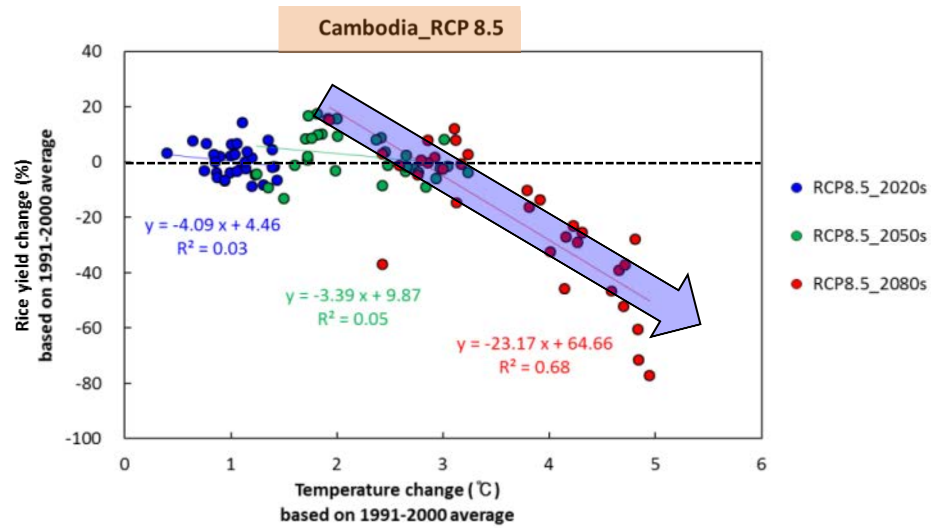


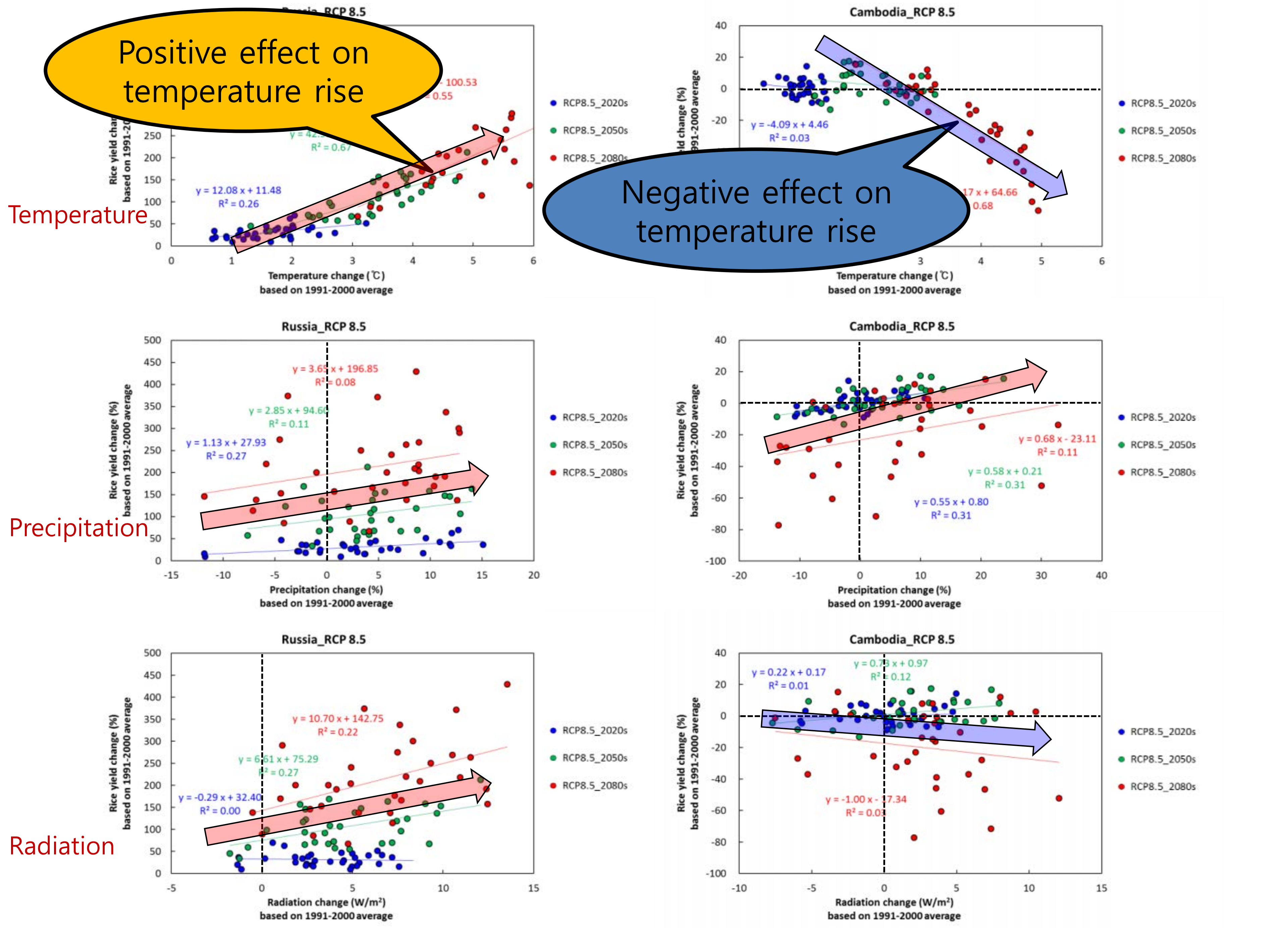
Climatic Sensitivity for Rice Yield











Positive effect on temperature rise
Negative effect on temperature rise
Temperature
Precipitation
Radiation
Russia_RCP 8.5
Cambodia_RCP 8.5
RCP8.5_2020s
RCP8.5_2050s
RCP8.5_2080s
y = 12.08 x + 11.48
R² = 0.26
R² = 0.67
0.55
y = -4.09 x + 4.46
R² = 0.03
0.68
Temperature change (℃)
based on 1991-2000 average
Rice yield change (%)
based on 1991-2000 average
y = 3.65 x + 196.85
R² = 0.08
y = 2.85 x + 94.60
R² = 0.11
y = 1.13 x + 27.93
R² = 0.27
y = 0.68 x - 23.11
R² = 0.11
y = 0.58 x + 0.21
R² = 0.31
y = 0.55 x + 0.80
R² = 0.31
Precipitation change (%)
based on 1991-2000 average
y = 10.70 x + 142.75
R² = 0.22
y = 6.61 x + 75.29
R² = 0.27
y = -0.29 x + 32.40
R² = 0.00
y = 0.22 x + 0.17
R² = 0.01
y = 0.73 x + 0.97
R² = 0.12
y = -1.00 x - 17.34
R² = 0.03
Radiation change (W/m²)
based on 1991-2000 average

Uncertainty Range for RCP Scenarios (1)

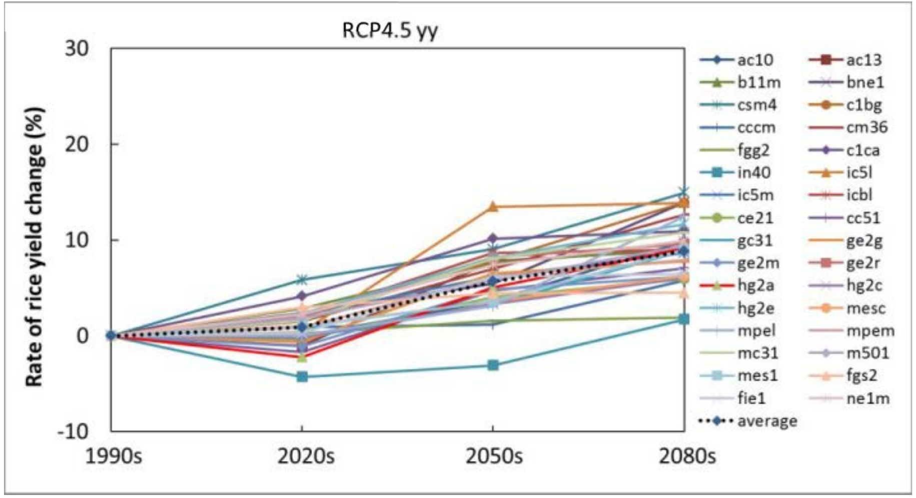
APCC

Adaptation(ON) **Average of 20 countries**

RCP 4.5

Average change(Uncertainty range)

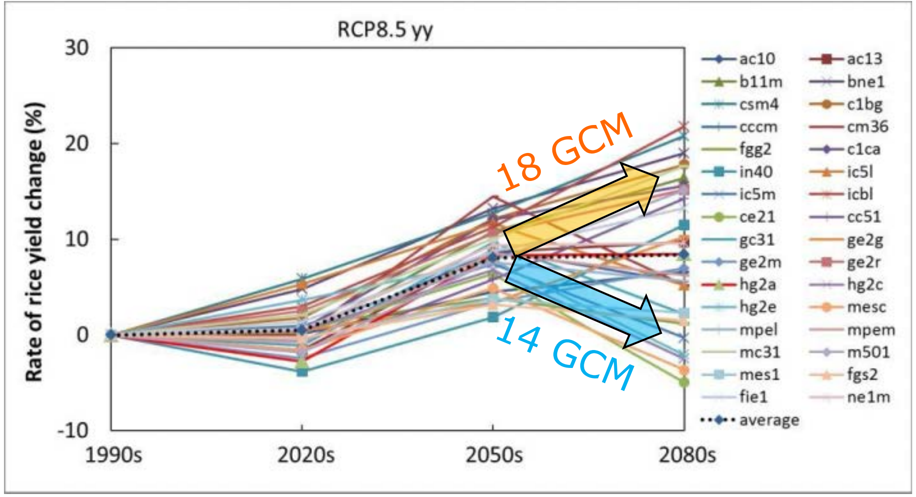
- 2020s: 0.8% (5.8%~-4.3%)
- 2050s: 5.6% (13.5%~-3.1%)
- 2080s: 8.7% (14.9%~1.7%)



RCP 8.5

Average change(Uncertainty range)

- 2020s: 0.5% (5.9%~-3.8%)
- 2050s: 8.0% (14.4%~1.9%)
- 2080s: 8.4% (21.8%~-5.0%)



Uncertainty Range for RCP Scenarios (2)

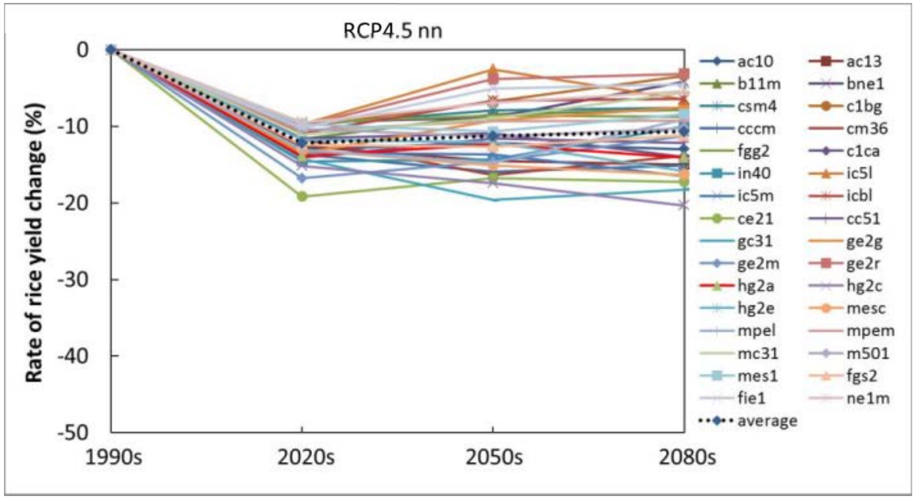
APCC

Adaptation(OFF) **Average of 20 countries**

RCP 4.5

Average change(Uncertainty range)

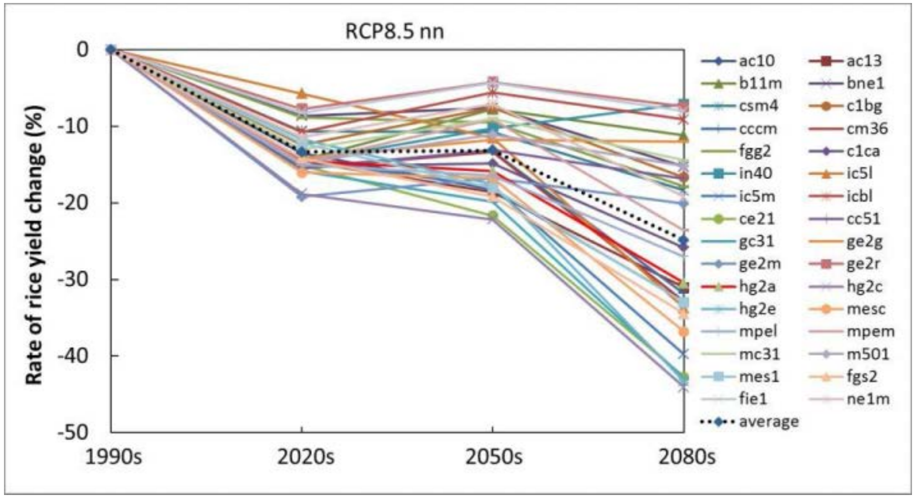
- 2020s: -12.2%
  (-9.5%~-19.2%)
- 2050s: -11.3%
  (-2.6%~-19.6%)
- 2080s: -10.7%
  (-3.1%~-20.3%)



RCP 8.5

Average change(Uncertainty range)

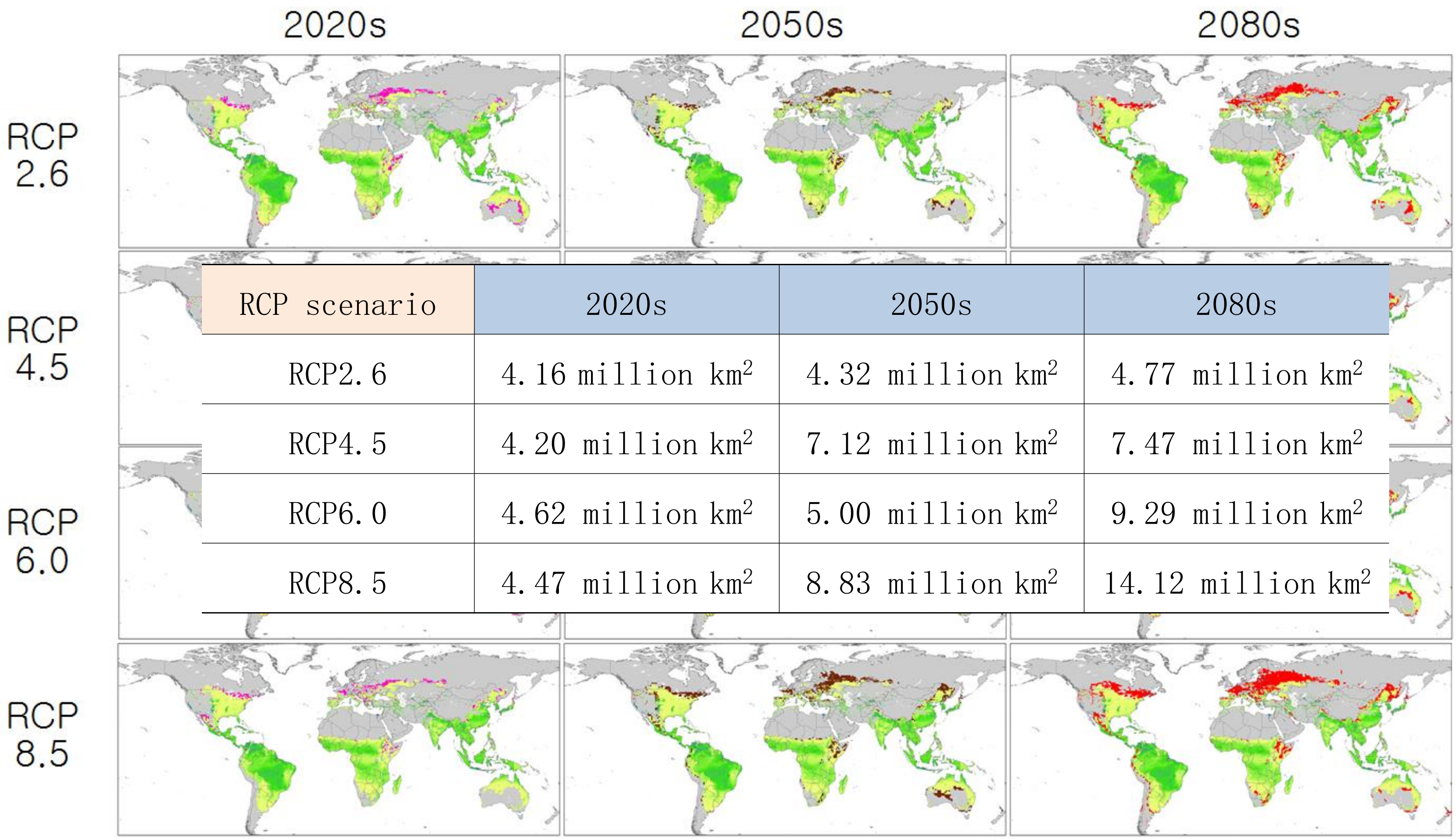
- 2020s: -13.4%
  (-5.7%~-19.2%)
- 2050s: -13.2%
  (-4.2%~-22.1%)
- 2080s: -24.9%
  (-7.0%~-44.0%)



Extension of Rice Cultivation Area

Adaptation(ON)

HadGEM2-AO Model



RCP scenario	2020s	2050s	2080s
RCP2.6	4.16 million km^2	4.32 million km^2	4.77 million km^2
RCP4.5	4.20 million km^2	7.12 million km^2	7.47 million km^2
RCP6.0	4.62 million km^2	5.00 million km^2	9.29 million km^2
RCP8.5	4.47 million km^2	8.83 million km^2	14.12 million km^2

THANK YOU!