Understanding on utilization of weather and climate data with Agricultural model

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APCC APEC CLIMATE CENTER

[포토]최악의 가뭄에 고온현상까지 '타들어가는 農心'

임열수 기자　발행일 2017-05-31 제1면　글자

최악의 가뭄에 고온현상까지 겹치면서 농작물 피해가 속출하는 등 본격적인 영농철을 맞은 농촌에 비상이 걸렸다. 30일 오후 여주의 한 들녘에서 고온현상과 물 부족으로 인해 밭작물이 타들어 가고 있다. /임열수기자 pplys@kyeongin.com

Climate Change

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- Climate Variation
  - Uncertainty

- Long-term Climate
  - Adaptation
  - Mitigation

- Impact Assessment
  - Sensitivity
  - Vulnerability

Sustainable Development

Agriculture

- Farms, Fields, Crops, Livestocks…

Food Security

-

Soil Plant Atmosphere

- Soil – Plant – Atmosphere Continuum (SPAC)
  - normally mentioned SPAC is the Pathway for water moving from soil through plant to the atmosphere

Environment: *temporal & spatial*

- Planting > Growing > Harvesting
- Local Environment


Weather Station

- where crops are grown

Synoptic Weather Observation

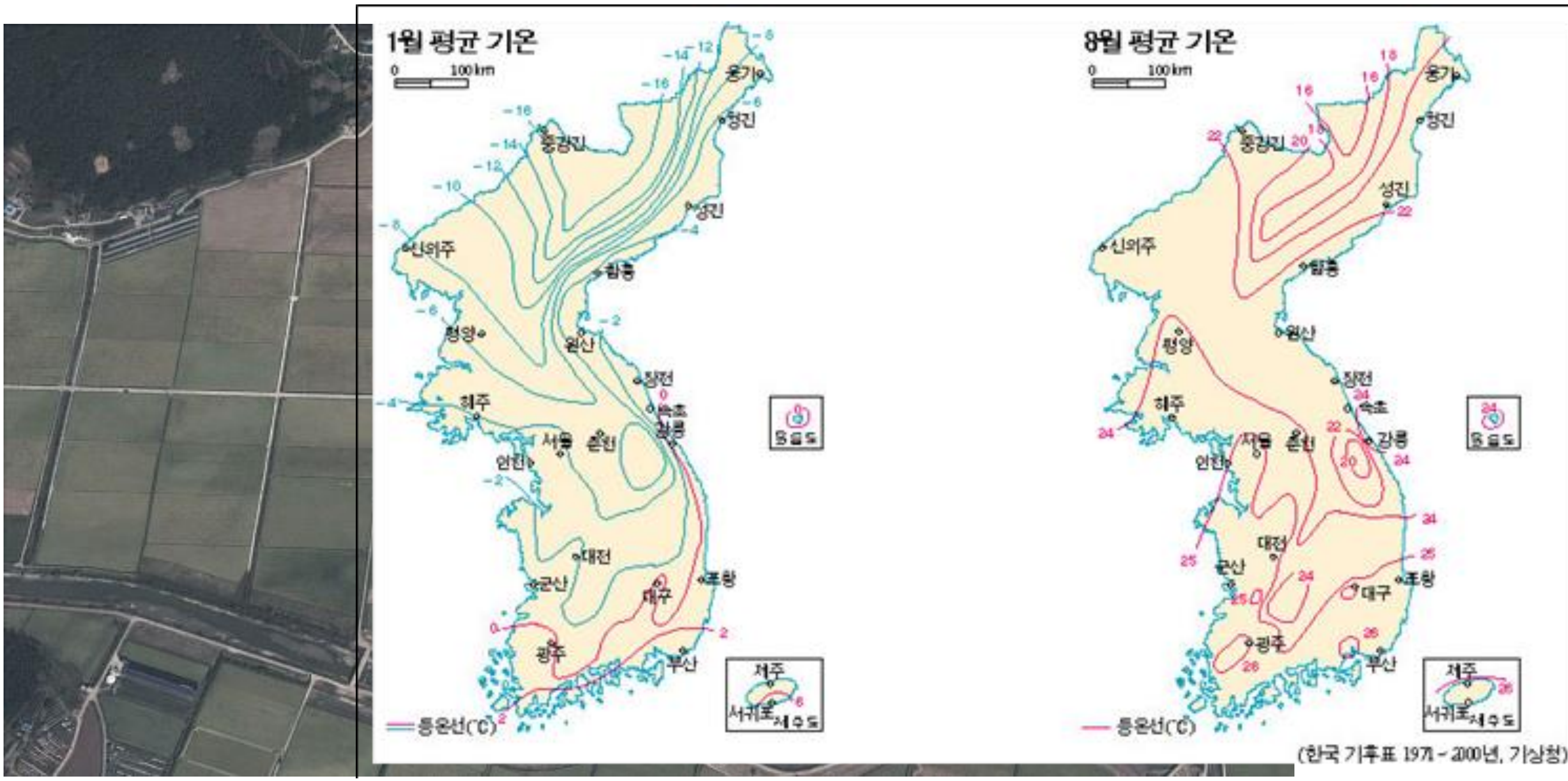
- Local Weather / Climate
  - Representative sites
  - Issues: homogenous terrains/land cover *vs*.
    various terrains/land cover

Terrain, Landuse

- Terrain : Land cover
  - Plain < Homogenous
  - Mountain (Highland) area, Urban < Complex, Various

Homogenous

- Synoptic weather station
  - isothermal line

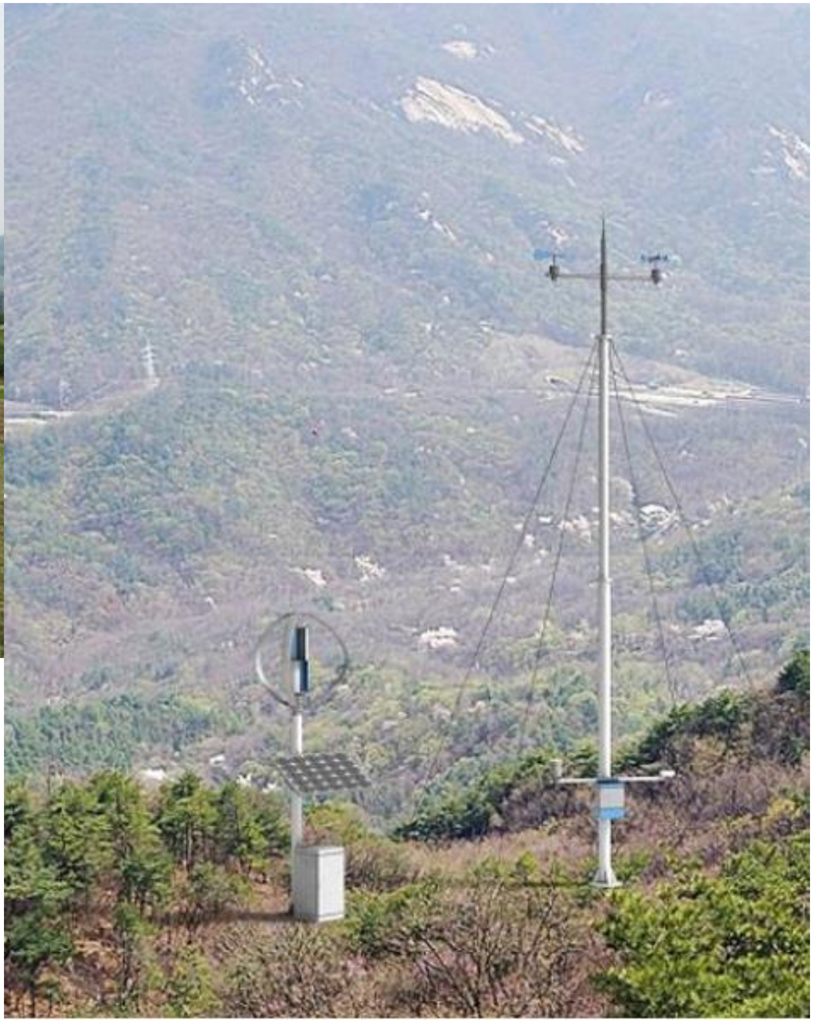


Various

- Mountain/Highland
  - various weather/climate; agro-, mountain- climate
  - not directly use synoptic weather/climate data

Local Weather

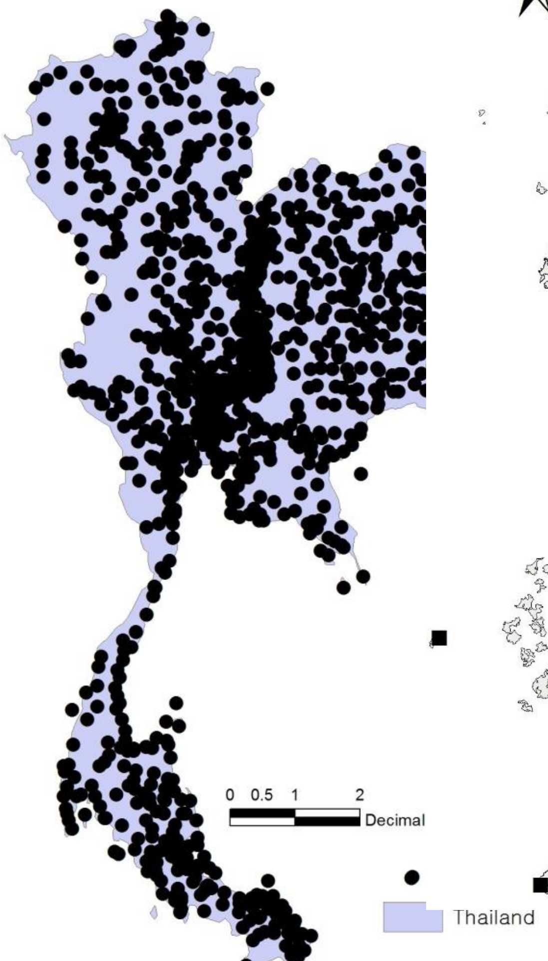
- where crops are grown, or where trees are grown

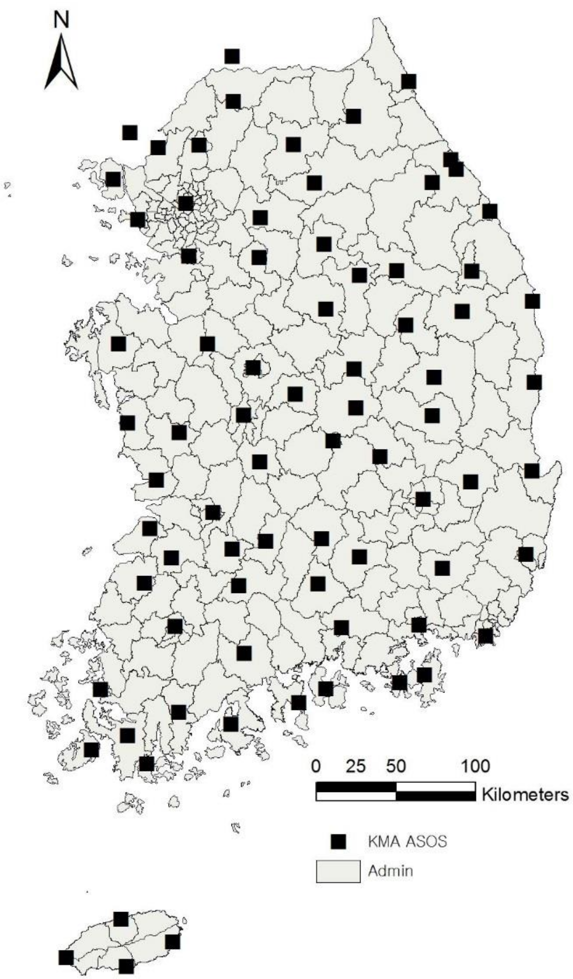


Climate Models

- Observation
  - synoptic weather stations
- Future Climate
  - forecasting models
  - .

Synoptic weather station maps of each countries (average distance over 50km, 100km)

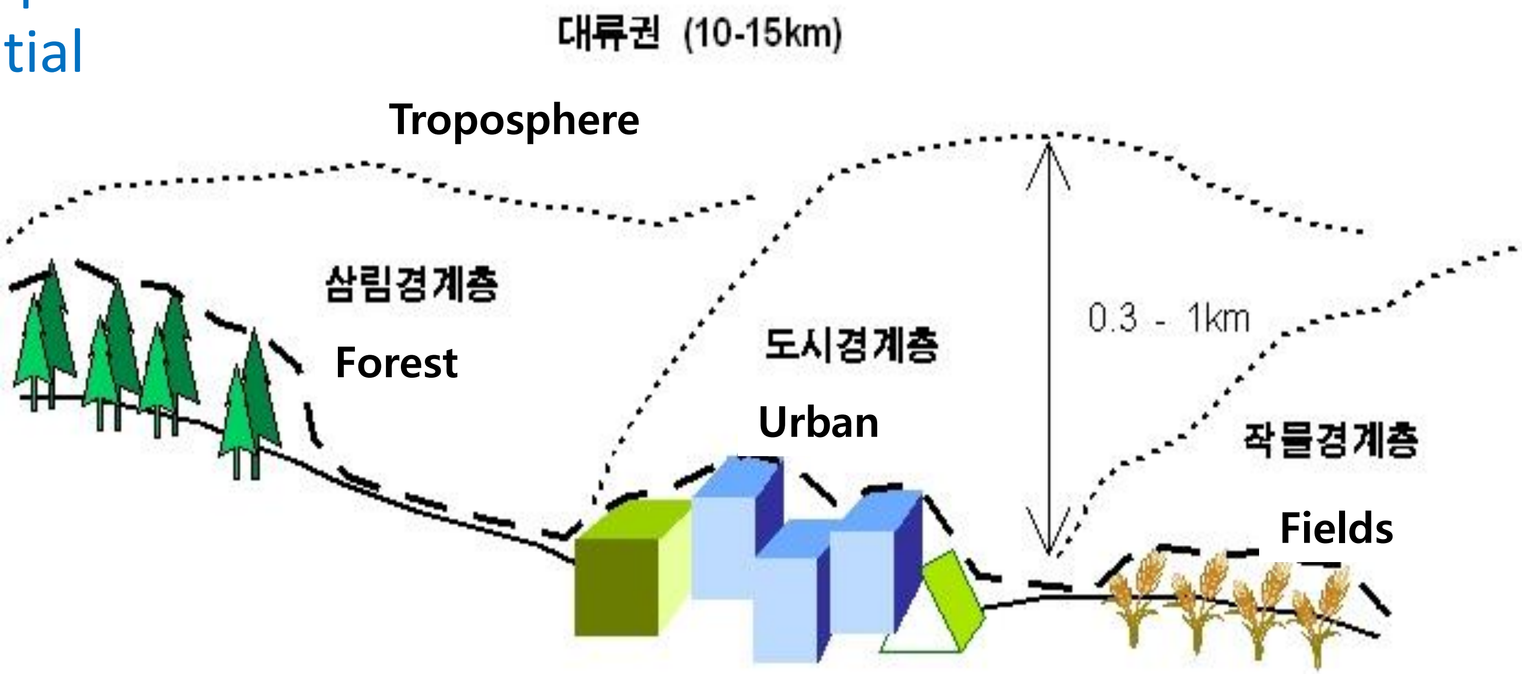




Local/Site-Specific Environment

- Site-specific climate: topography, vegetation, land cover
  - distance, elevation,
  - slope effect,
  - heat island effect, cold air drainage effect etc.

- **Downscaling methods**
  - temporal
  - spatial



Models

- Climatic forecasting information produced in climate models

- need Application models in other sectors
  - Agricultural models
  - Hydrological models
  - Various models … etc.

Issues / Concerns

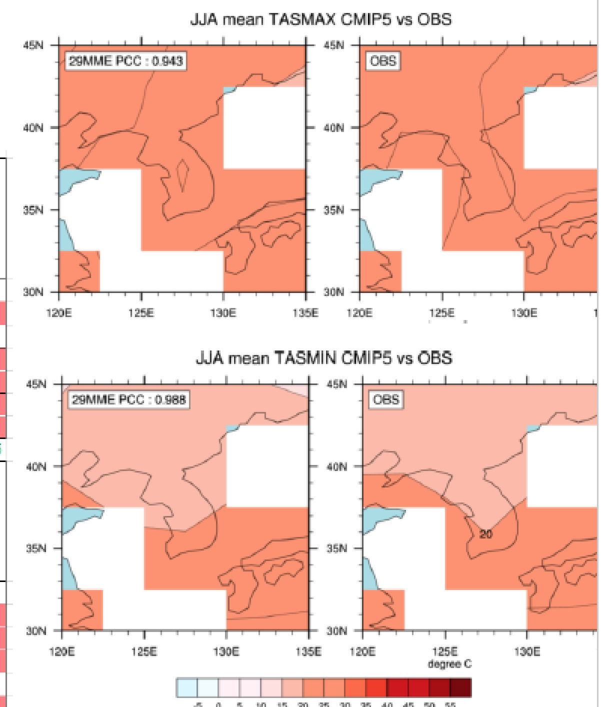
- When Applied to Other Models of Fields
  - using climate prediction information as input information
- Its Uncertainties
  - systematic
  - **downscaling**

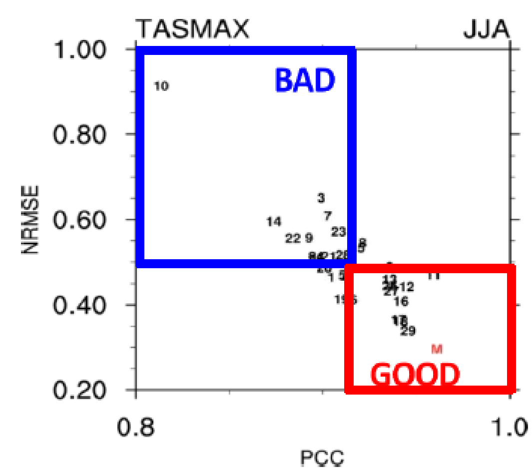
Uncertainty of Downscaling

- Model Evaluation

			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
			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
index		TX10p							1		-1	1	1	1		1			1	1	1					-1	-1	-1	-1		1
		TX90p	-1		1		1				-1	1				1					1										
		TN10p				1			-1				1			1		1	1	1		-1			1		-1		-1	1	1
		TN90p		-1			1	1		-1	-1	1	1	1		1	1	1		1						-1	1	-1			1
		R95p	1	1		-1						1	1			1	1						-1	-1	-1					1	1
		R99p	1									1	1			1	1						-1	-1	-1					1	1
			1	0	1	0	2	1	0	-1	-3	5	5	2	0	6	3	2	2	3	2	-1	-2	-2	-1	-2	-1	-2	-2	3	5

			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
			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
JJA	prcp	공간기후도			-1			1	1	1	1	-1	-1		-1	-1	-1	1	1	1						-1	-1	-1		1	1
		경년변동			-1	1	-1	1			1		-1	1	1	-1							-1	-1	-1	1	1	1		1	1
	tmax	공간기후도			1	1	1	1	-1	-1	1	-1		-1	-1	-1	-1	1		1	1		1	-1	-1	-1	-1		1	1	1
		경년변동	1		1				1		1		1	1	1		-1					-1	-1		1	1	-1	1		-1	
	tmin	공간기후도	-1	-1		1	1	1			1		-1	1	-1	1	-1		-1		-1	1	1			-1	-1	1	1	1	1
		경년변동			1		1	1			1		-1		1		-1		-1	1		1	1		1	1		1	-1	-1	
			0	-1	1	3	2	5	1	0	6	-2	-3	2	0	-2	-5	2	-1	3	0	1	1	-2	0	0	-3	3	1	2	4
			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
DJF	prcp	공간기후도	-1	1		1	1	1					1		1			-1	-1	-1		1		1		-1	-1		1	1	
		경년변동			1	1	1	1	-1		-1			1	1	1		-1	-1	-1		1	1	1					-1	1	
	tmax	공간기후도	1	-1	-1	1	1	1	-1		1	-1		1	1		-1	1	1	1	1		1	-1	1	-1	-1		1	1	
		경년변동	1	1	1	1	1			1	1	1	1		1	1		-1	-1	1					-1	1	1	1	1	1	1
	tmin	공간기후도		-1	-1	1	1	1	-1	1	1	-1	1	1	1	1	-1		-1		-1	1	1			-1	-1	1	1	1	1
		경년변동		1	1	1	1			1			1		1	1	-1		-1				1		-1	1	1	1	1	1	1
		AC1 (EA)	-1	-1	1	1	1	1	-1	-1	1	1	1	1	1		1	-1	-1	-1	1	1	1	-1		-1	-1	-1	-1	-1	1
			0	0	2	7	7	5	-4	2	3	0	5	4	7	4	-2	-3	-5	-1	1	4	5	0	-1	-2	-2	2	3	5	4
		Total score	1	-1	4	10	11	11	-3	1	6	3	7	8	7	8	-4	1	-4	5	3	4	4	-4	-2	-4	-6	3	2	10	13
		Ranking	20	22	13	4.5	2.5	2.5	24	20	10	16	8.5	6.5	8.5	6.5	27	20	27	11	16	13	13	27	23	27	29	16	18	4.5	1





Source: Dr. Eum Hyung-Il's research

Uncertainty of Downscaling

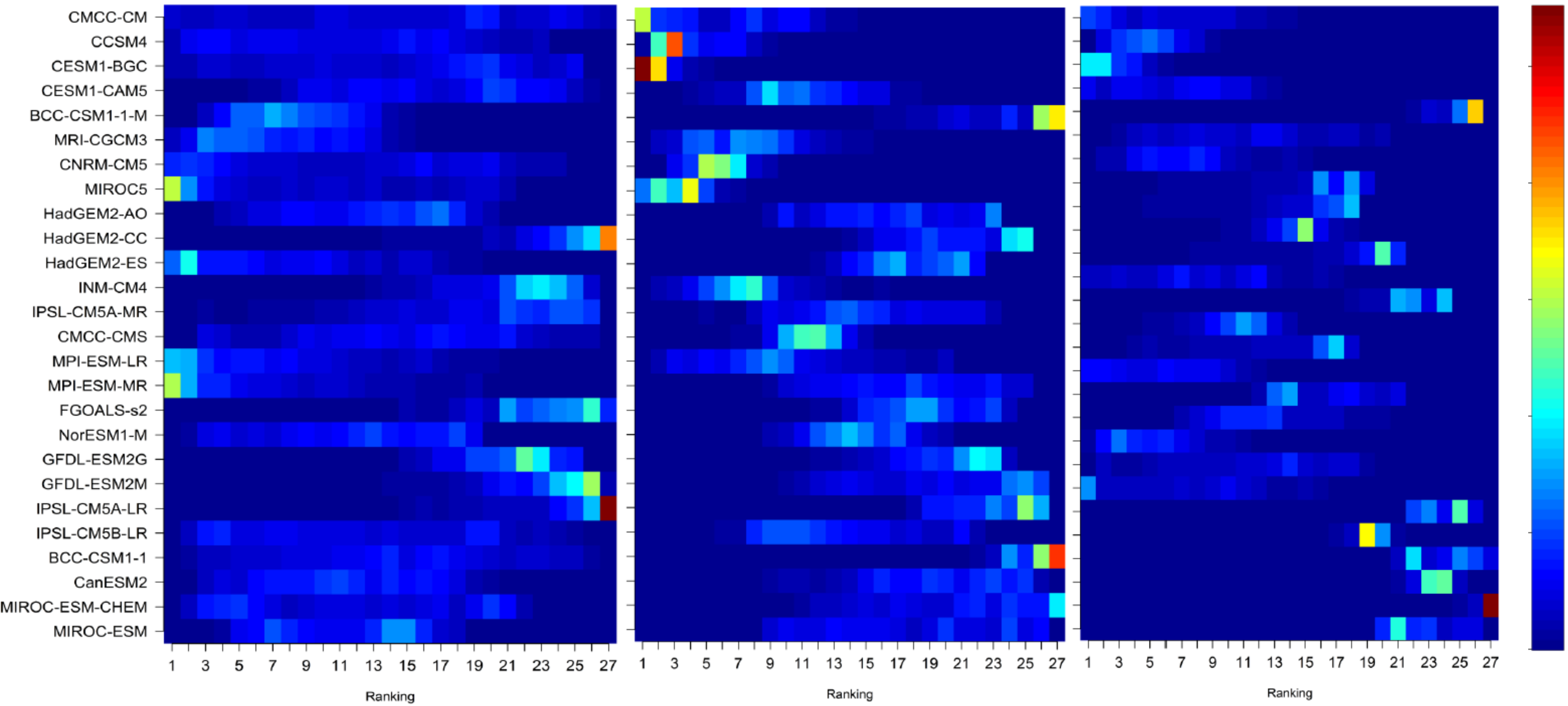
- Evaluation Framework

Criteria	Evaluation method					
	PRCP		TMAX		TMIN	
	Indicator	Evaluation method	Indicator	Evaluation method	Indicator	Evaluation method
Time-series Related (Criteria 1)	PRCPTOT SDII	Distance of RMSEs from the perfect value	SU ID DTR GSL	Distance of RMSEs from the perfect score	FD TR DTR GSL	Distance of RMSEs from the perfect value
	Tau, annual average	RMSE of tau between observed and simulated values	Tau, annual average	RMSE of tau between observed and simulated values	Tau, annual average	RMSE of tau between observed and simulated values
Distributed Related (Criteria 2)	Distribution of values	K-S D statistic	Distribution of values	K-S D statistic	Distribution of values	K-S D statistic
Multi-day Persistence (Criteria 3)	CDD & CWD	Distance of RMSEs from the perfect value	WSDI	Distance of RMSEs from the perfect value	CSDI	Distance of RMSEs from the perfect value
Extremes (Criteria 4)	Rx5day Rx1day R95pTOT R99pTOT		TXn TXx TX10p TX90p		TNn TNx TN10p TN90p	
Spatial structure (Criteria 5)	Spatial correlation between stations	RMSE of spatial correlations between observed and simulated values	Spatial correlation between stations	RMSE of spatial correlations between observed and simulated values	Spatial correlation b etween stations	RMSE of spatial correlations between observed and simulat ed values

Source: Dr. Eum Hyung-Il's research

Uncertainty of Downscaling

- PRCP
- TMAX
- TMIN



Source: Dr. Eum Hyung-Il's research

Agro-Climatology:

Agro-Climatic information

- Provide important information for cropping calendar (farming activities)
  - sowing/planting,
  - irrigation/spray schedule,
  - harvest crop

- Added value
  - to produce information to manage agricultural ecosystem

Agro-Climatic Index

- Growing Degree Days (GDD)

  - is a weather-based indicator for assessing crop development.

  - is a calculation used by crop producers that is a measure of heat accumulation used to predict plant and pest development rates such as the date that a crop reaches maturity (source: in google search).

Agro-Climatic Index: GDD

- GDD by calculating from daily temperature data

$$\text{GDD} = \frac{(T_{max} - T_{min})}{2} - T_{base}$$

- T_{max}: daily Maximum Temperature
- T_{min}: daily Minimum Temperature
- T_{base}: base temperature which a crop starts growth

Agro-Climatic Index: GDD

- GDD by calculating with monthly temperature data

$$\mathrm{GDD} = N \times \frac{(T_{max} - T_{min})}{2} - T_{base} + L \times \sigma \times \sqrt{N}$$

- N : the number of month
- T_{max}: monthly Maximum Temperature
- T_{min} : monthly Minimum Temperature
- T_{base}: base temperature which a crop starts growth
- L : constant
- σ : the standard deviation of the monthly Average temperature

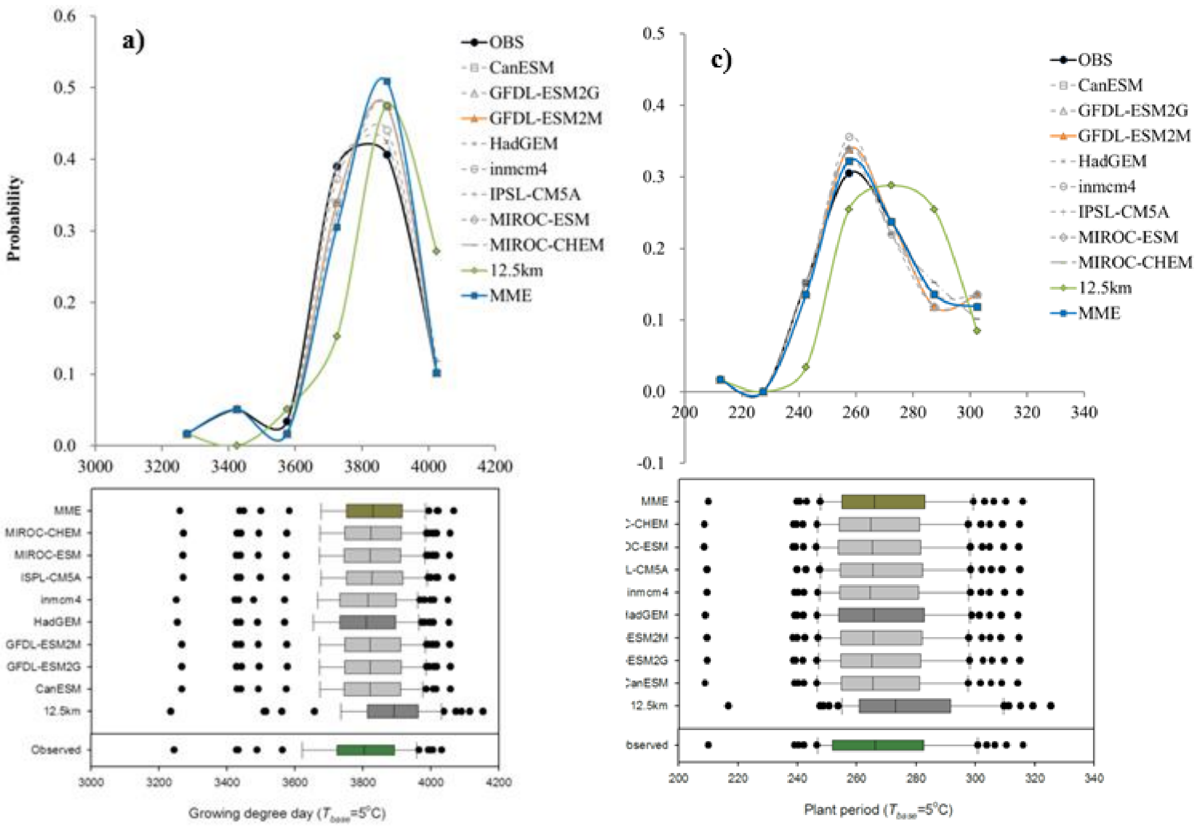
Agro-Climatic Index: GDD

- 8 GCMs and one RCM used in the calculation of GDD

Model	Origin	Country	Resolution
KMA-12km	Korea Meteorological Administation	Korea	12.5km x 12.5km
CanESM2	Canadian Centre for Climate Modeling and Analysis	Canada	2.8^o x 2.8^o
GFDL-ESM2G GFDL-ESM2M	NOAA/GFDL (Geophysical Fluid Dynamic Laboratory)	USA	2.5^o x 2.0^o
HadGEM2-CC	Meteorological Office Hadley Center	UK	1.88^o x 1.25^o
inmcm4	Institute for Numerical Mathematics	Russia	2^o x 1.5^o
IPSL-CM5A-LR	Institute Pierre Simon Laplace	France	3.75^o x 1.8^o
MIROC-ESM MIROC-ESM-CHEM	Atmosphere and Ocean Research Institute, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	Japan	2.8^o x 2.8^o

Agro-Climatic Index: GDD

- T_{base}: 5°C GDD by calculating from daily temperature data

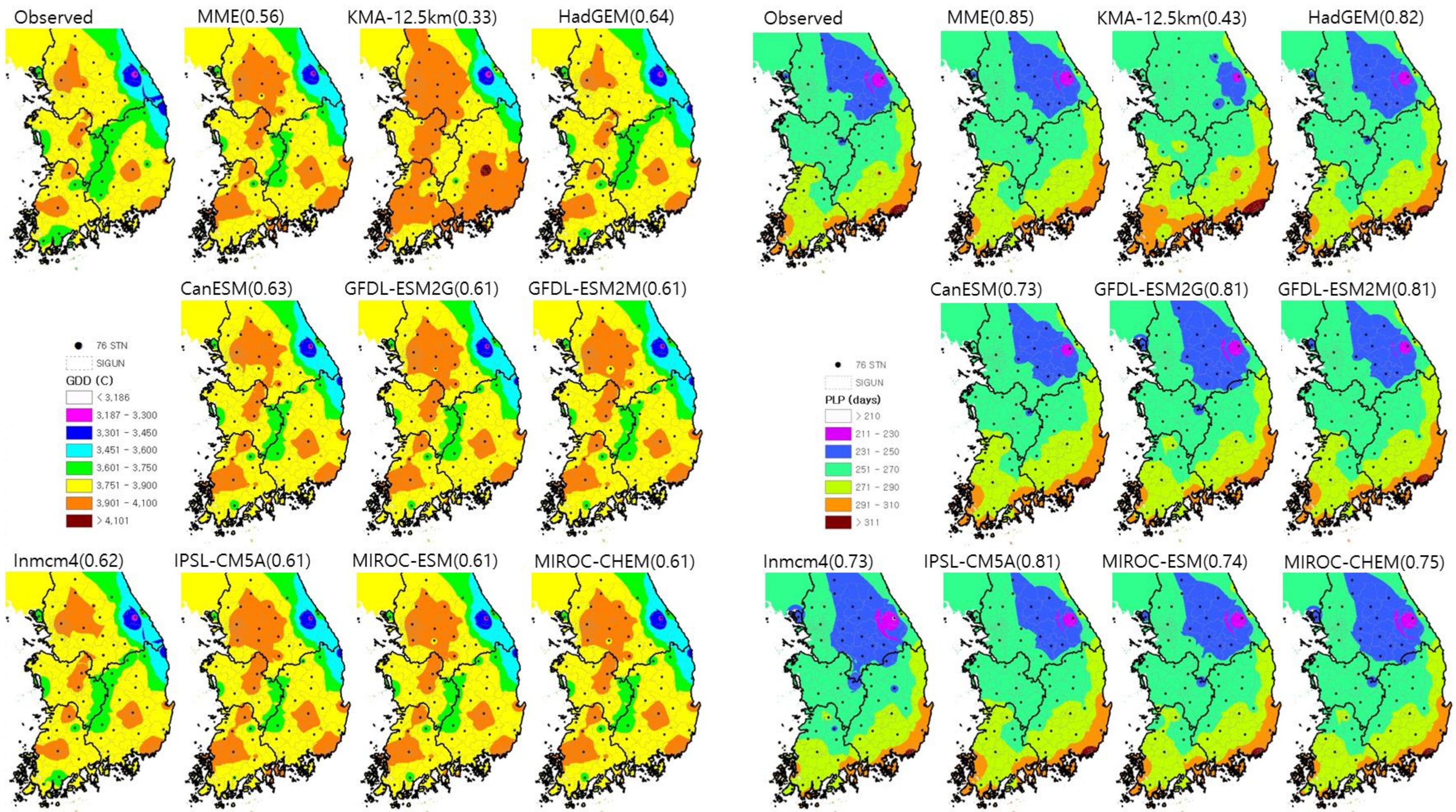


Probability density function (up) and boxplot (down) of growing degree days (right) and plant period (left) on base temperature 5°C under each GCM during 1976-2005. In each box plot, horizontal lines represent, from left to right, the 10th percentile, 25th percentile, median, 75th percentile and 90th percentile of calculations on each climate sets (from observed to each 8 individual GCM and one RCM).

Reference: Chung U, Cho JP, Seo MC, Jung WS (2015) Evaluation of Agro-Climatic index in Korean Peninsular using multi-model ensemble downscaled climate prediction of CIMP5. Abstract book of International Scientific Conference, 7-10 July 2015 Paris, France, pp316-317.

Agro-Climatic Index: GDD

- T_{base}: 5°C GDD by calculating from daily temperature data



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Crop Model:

Growth and Development Stage, Potential yield

Agricultural Models

- Soil models

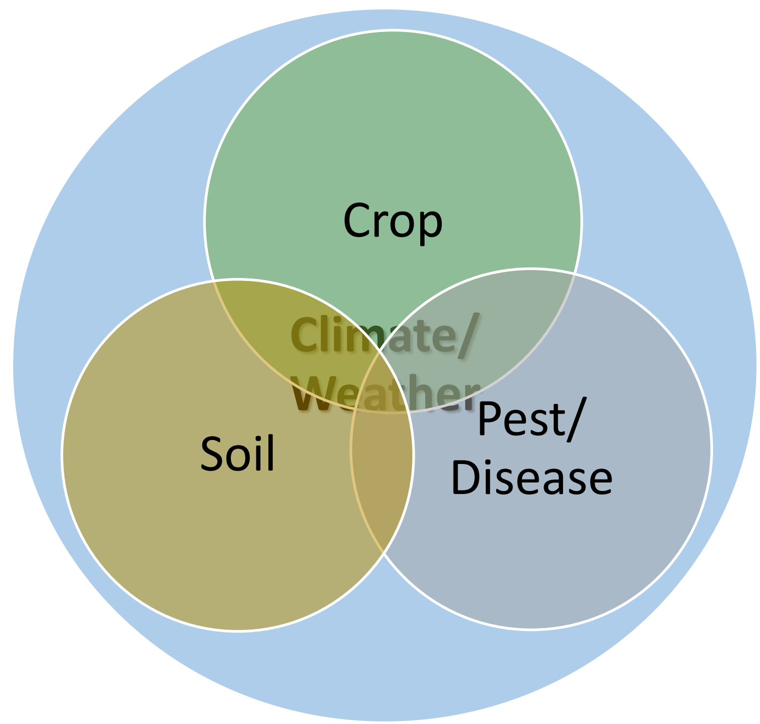
  - roots

Climate/Weather Data

- Crop models

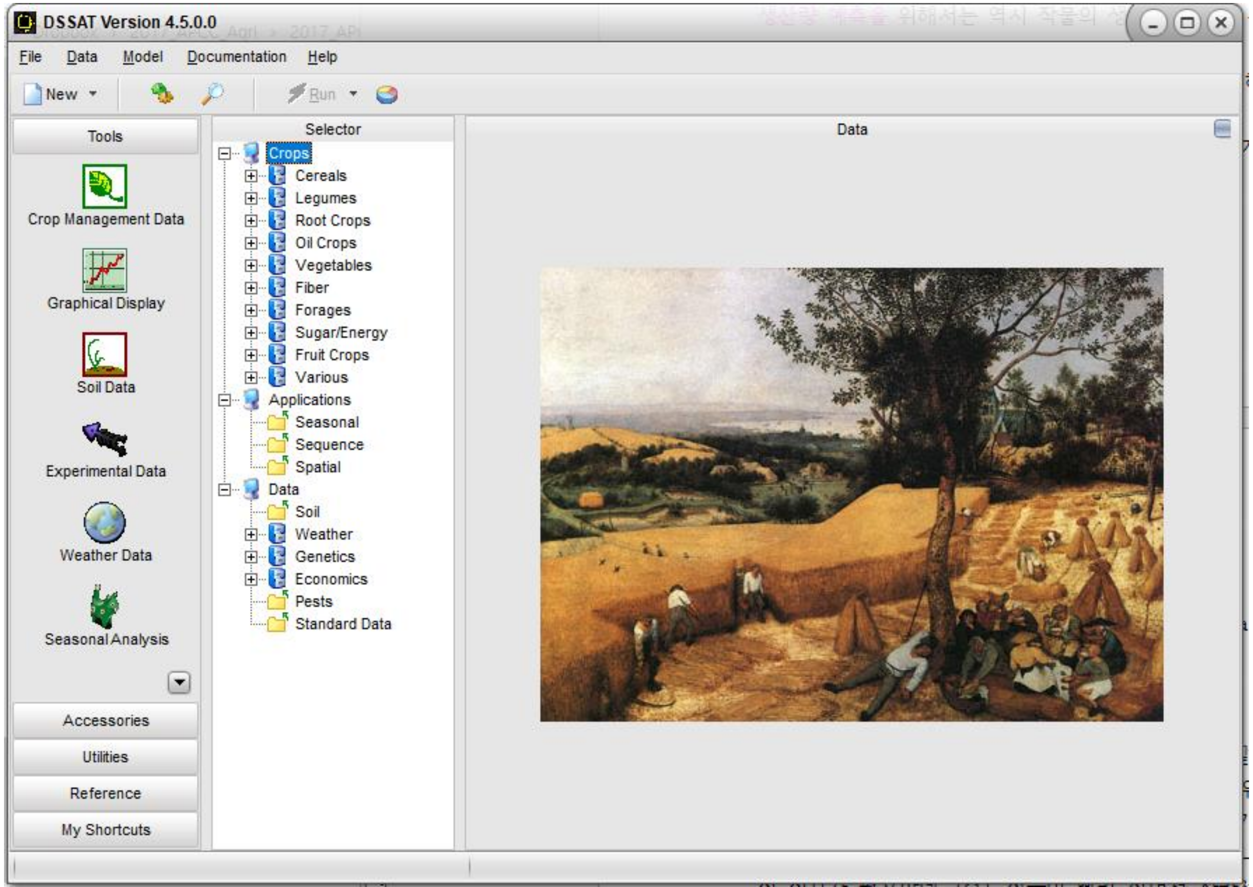
  - phonological/genetic

- Pest/Disease models



Crop models

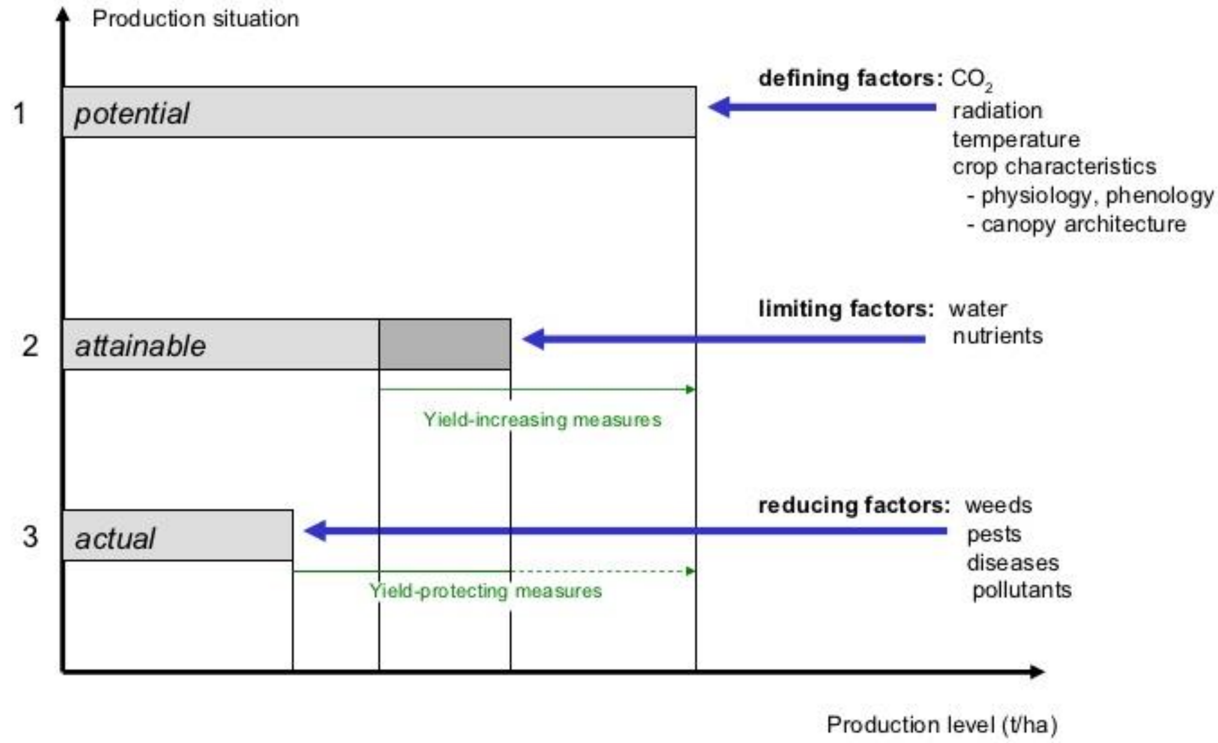
- DSSAT package
  - various crops
  - even vegetables and fruit crops



Crop models

- Crops
  - Cereal crops: Rice, Maize,
  - Legume crops: Soybean, Peanut …
  - Root crops: Potato, Taro …

- Potential Yield



Objectives of Case Study-1

- High temperature Impacts on Growth Stages

  - (Obs.1) Assess the reproducibility of temperature on each growth stage and growth periods

  - (Obs.2) Assess the impact of high temperature on yield of soybean?

-

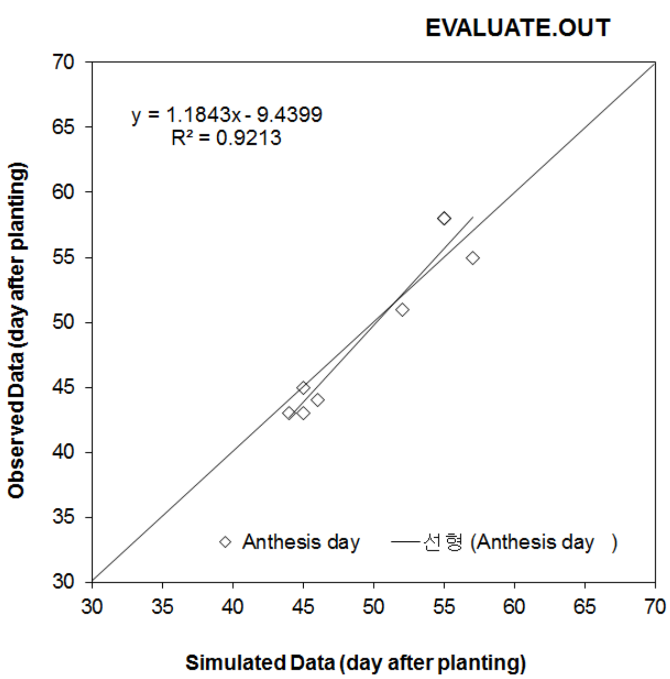
Materials and Methods of Case Study

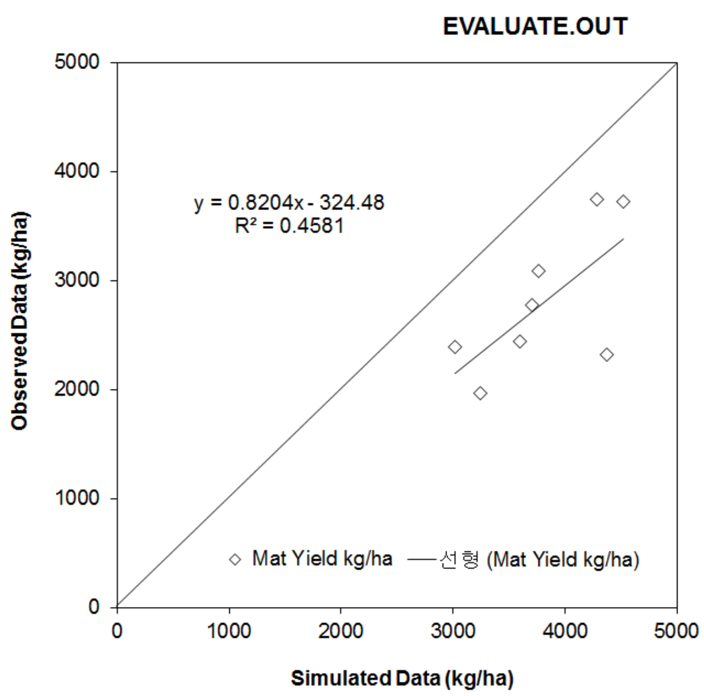
- CROPGROW-Soybean
  - Cultivars: TaeGwang (medium-late maturity)
  - Genetics information from GenCalc
  - Applied sites: Jeonju and Miryang + 14 fields
- Critical growth stages
  - Vegetative: before flowering
  - Reproductive: after flowering
- Criteria abnormal temperature on each growth stage

Genetic Information

- TaeGwang (medium and late maturity)
  - Korean soybean cultivar

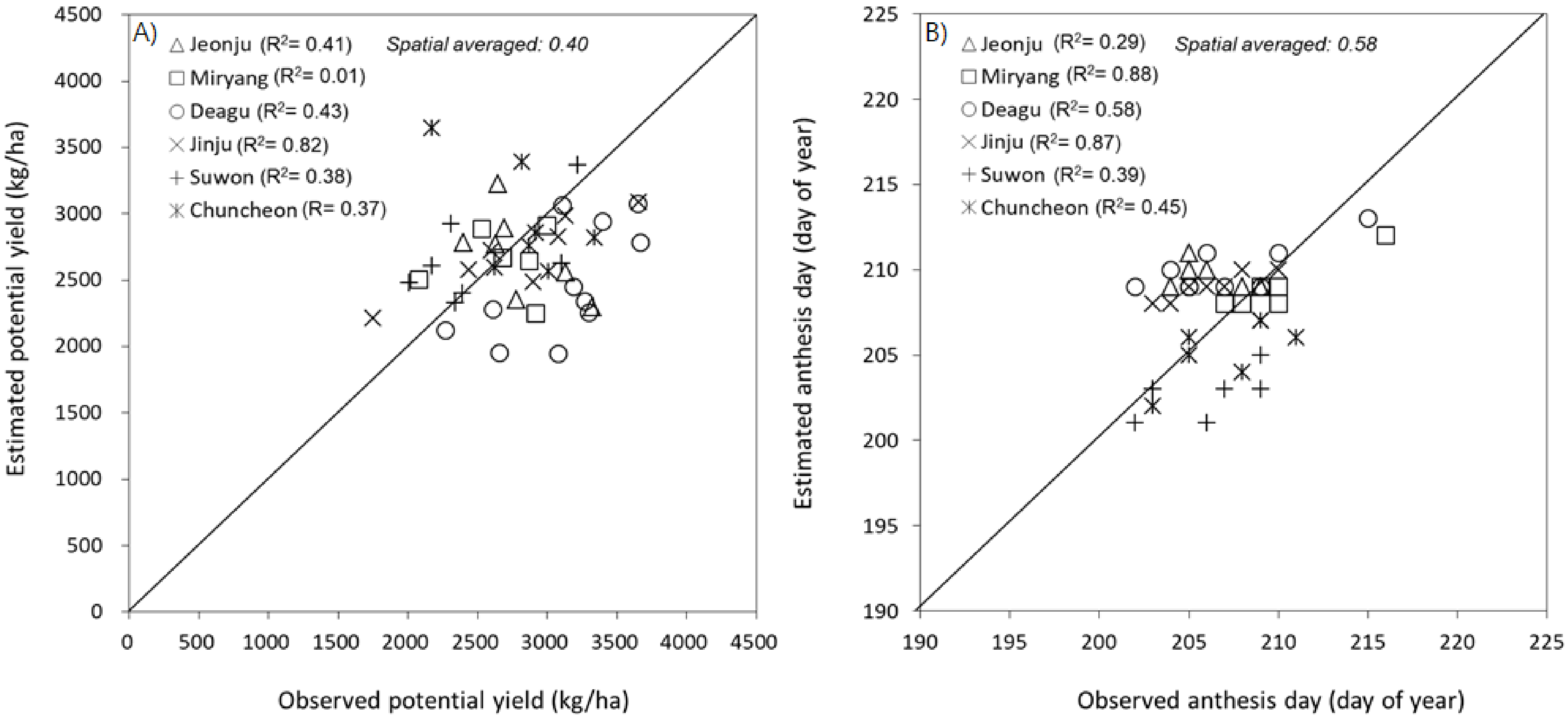
	CSDL	PPSEN	EM-FL	FL-SH	FL-SD	SD-PM	FL-LF	LFMAX	SLAVR	SIZLF	XFRT	WTPSD	SFDUR	SDPDV	PODUR	THRSH	SDPRO	SDLIP
Taegwang	12.70	0.32	18.71	4.92	9.52	35.84	9.56	1.03	350.00	300.00	1.00	0.19	10.10	1.35	29.28	78.00	0.40	0.20





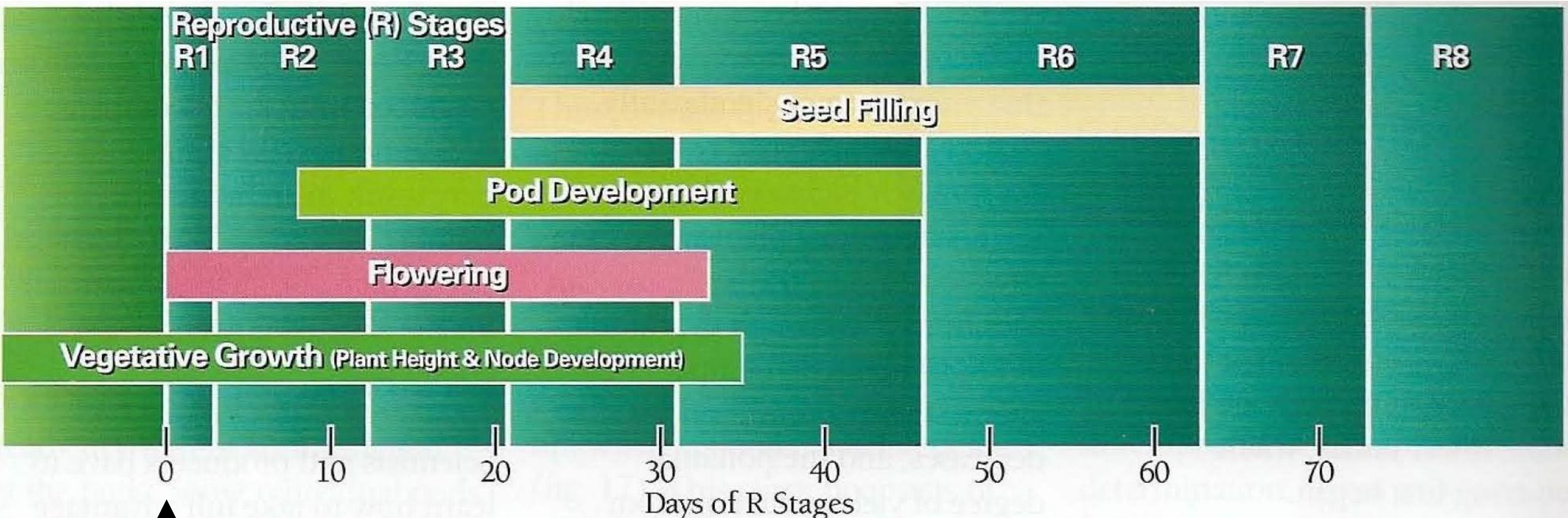
Genetic Information

- Evaluation genetic properties of TaeGwang
  - 16 sites



Growth Stage of Soybean

- Growing season: timing of planting, flowering, pod development, and seed filling



Start flowering

Growing Period or Growing Season

Criteria abnormal temperature

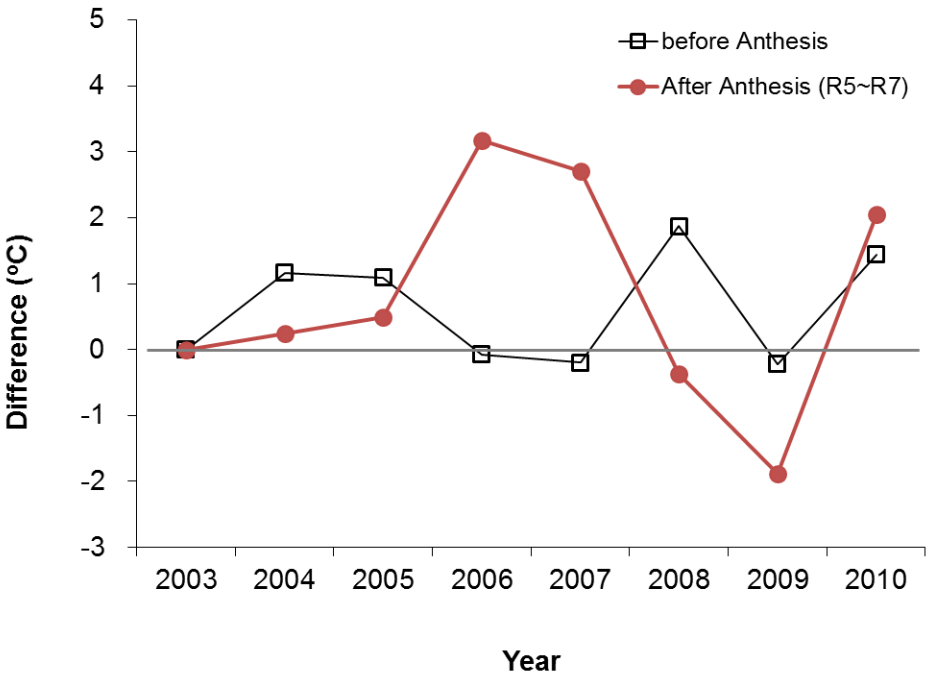
- Critical growth stages

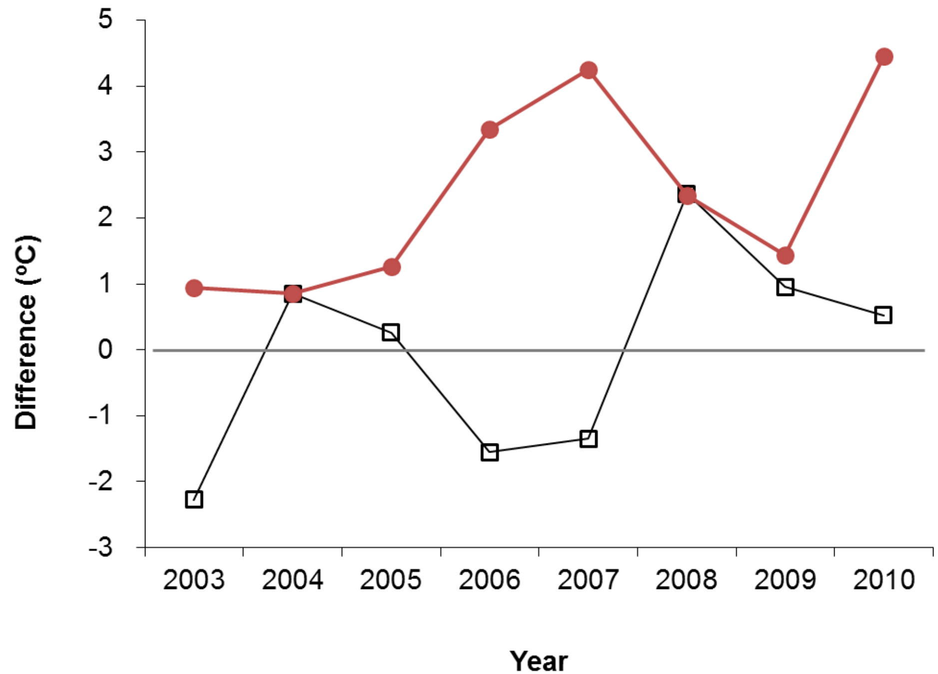
Crop	Vegetation period		Reproduction period	
	Base Temp.	Range of Opt. Temp.	Range of Opt. Temp.	Failure Temp.
Soybean	10	25-30 (DT), 19-24 (NT)	26-32 (DT), 22-27 (NT)	37

(*Holmberg, 1973; Gibson and Mullen, 1996*)

Abnormal temperature

➢ before and after Anthesis



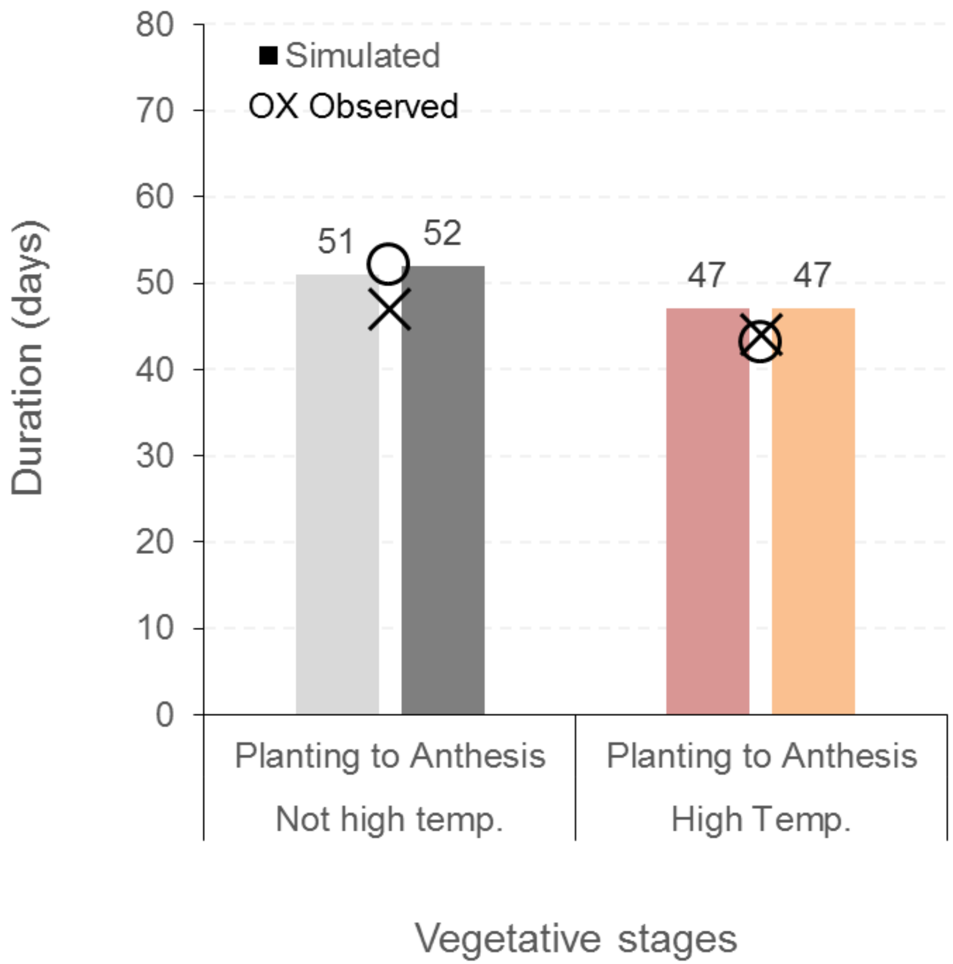


Jeonju

Miryang

Impact on growth period

- During Vegetative stage

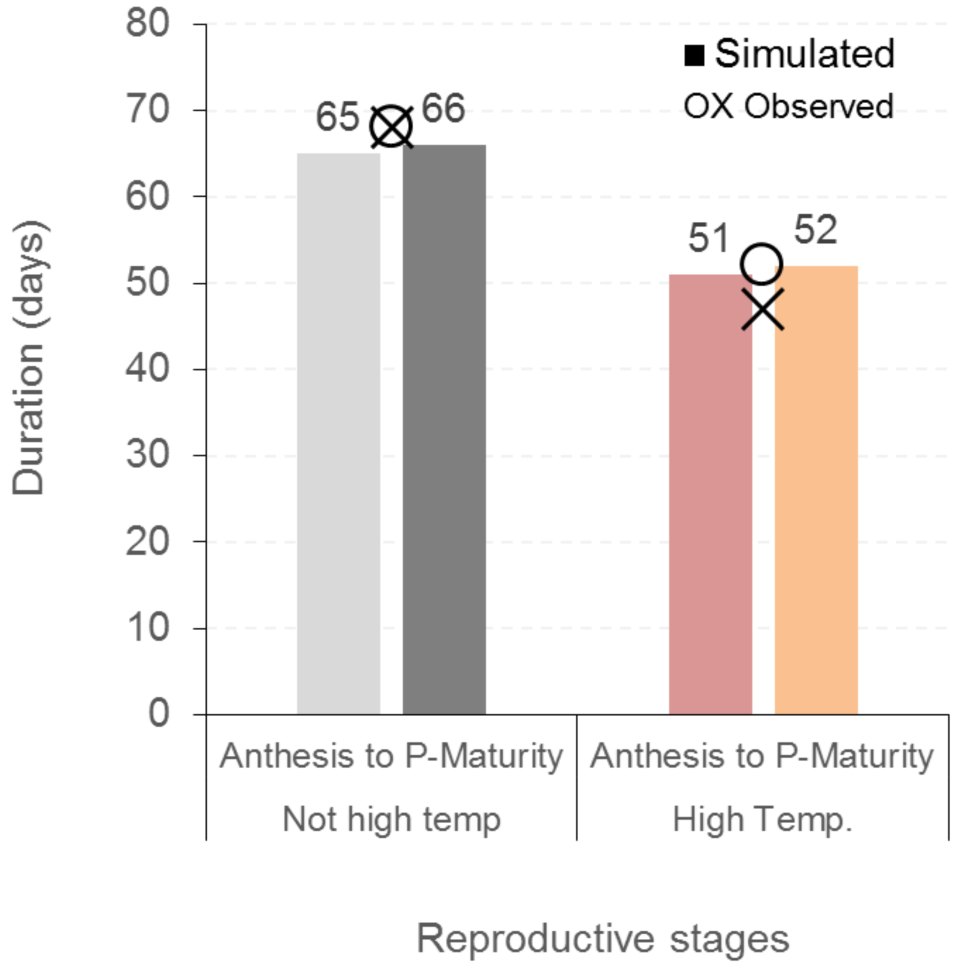


O: Miryang
X: Jeonju

Within 4~5 days

Impact on growth period

- During Reproductive stage



O: Miryang
X: Jeonju

14~16 days
(two weeks)

Summary (Obs.1.)

- Period of vegetation stages (before flowering) is shortened

- Reproductive stages is also shortened, especially high temperatures occur in the period of R4(R3) to R6, and it’s shorter, and also affects decreasing yield
  - $1.5^{o}C$ ~ $2.0^{o}C$ compared with criteria temperature

Yield Components (Obs.2)

- How much the impact of high (abnormal) temperature on yield of soybean?

Shift growth stages

- Planting Season
  - May to June

May June

Range: one month or 1.5 month

Shift growth stages

- **Shift Planting time**: easy way to avoid extreme case, such as high temperature or no rainy days (i.e., conditions in which crops can not grow/cultivate well)

- In the case of Korean soybean, usually plant June 10 in the southern region

  - shift (+/-) 5 days (shorten / delay)

  - for example,

    - ➢ shorten – May 25, June 5 with based on June 10
    - ➢ delay – June 15 etc…

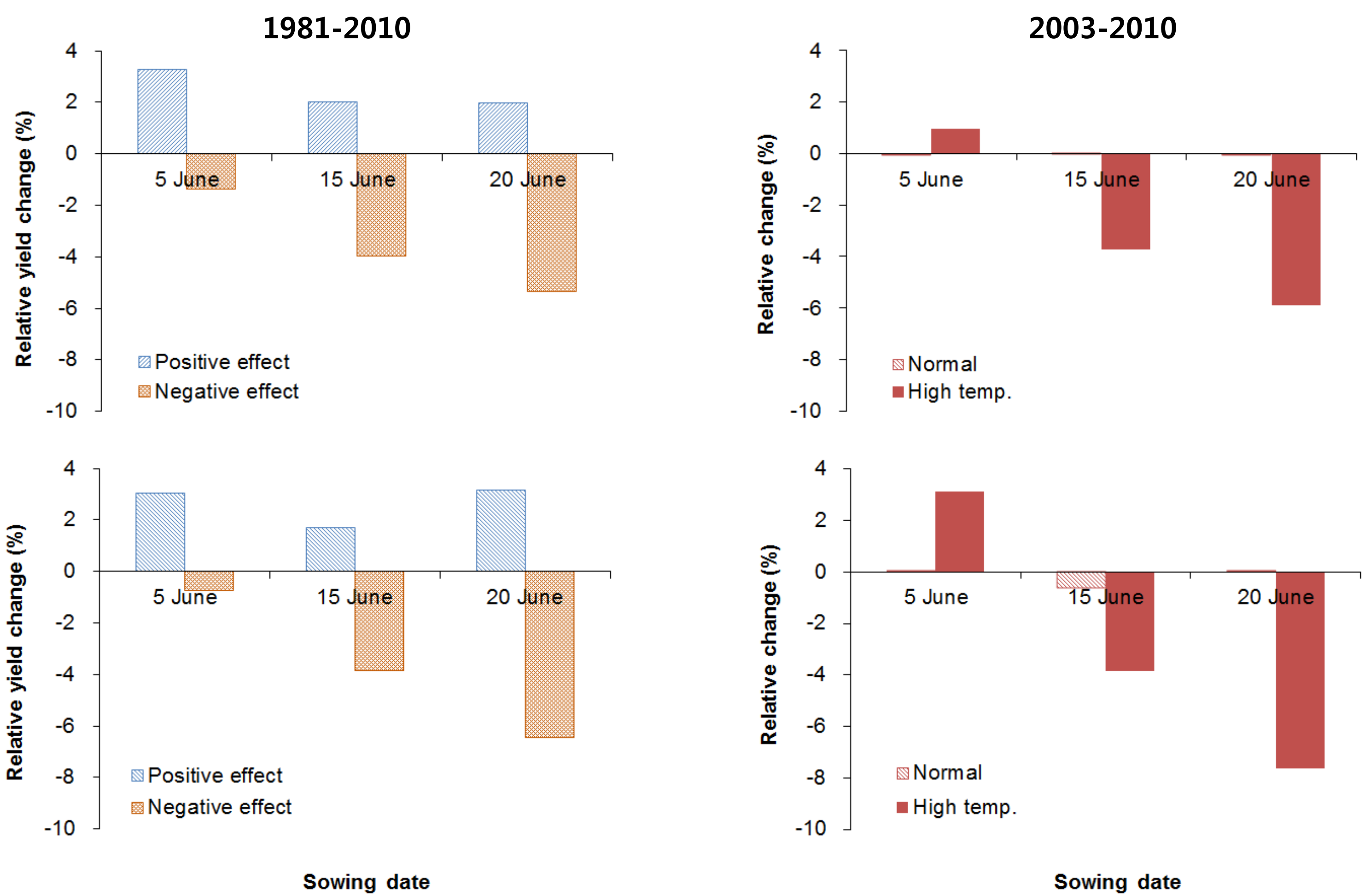
Results

Chung et al., 2016: Responses of soybean yield to high temperature stress during growing season: A Case study of the Korean soybean. *Korean Journal of Agricultural and Forest Meteorology*, 18(4), 188~198 (doi: 10.5532/KJAFM.2016.18.4.188)

- Relative change on yield planted at June 10

Jeonju

Miryang



Apply to future climate scenarios

- Compare two cases:

  - Occurrence of high temperature during critical periods *Vs*.

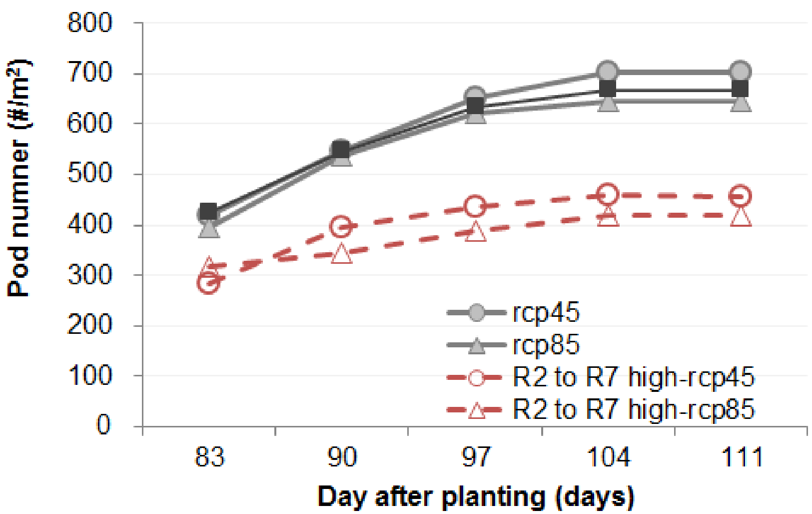
  - Just common temperature as Normal year

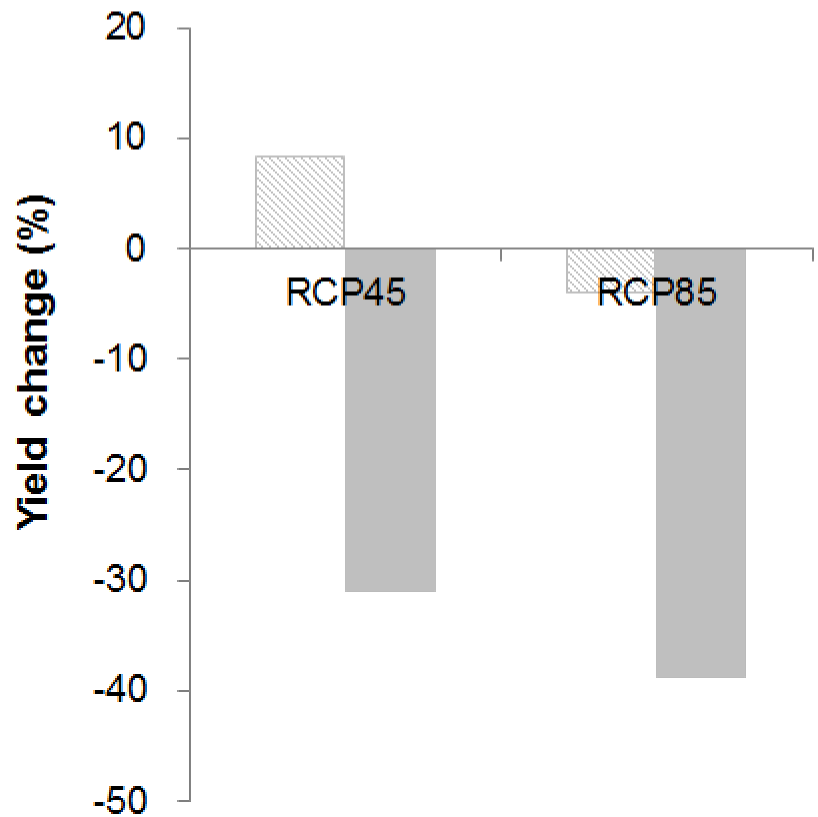
- Future Climate Scenarios

  - a preliminary result of KMA-125km

Results

- Relative change on a yield component in Normal vs. High temperature

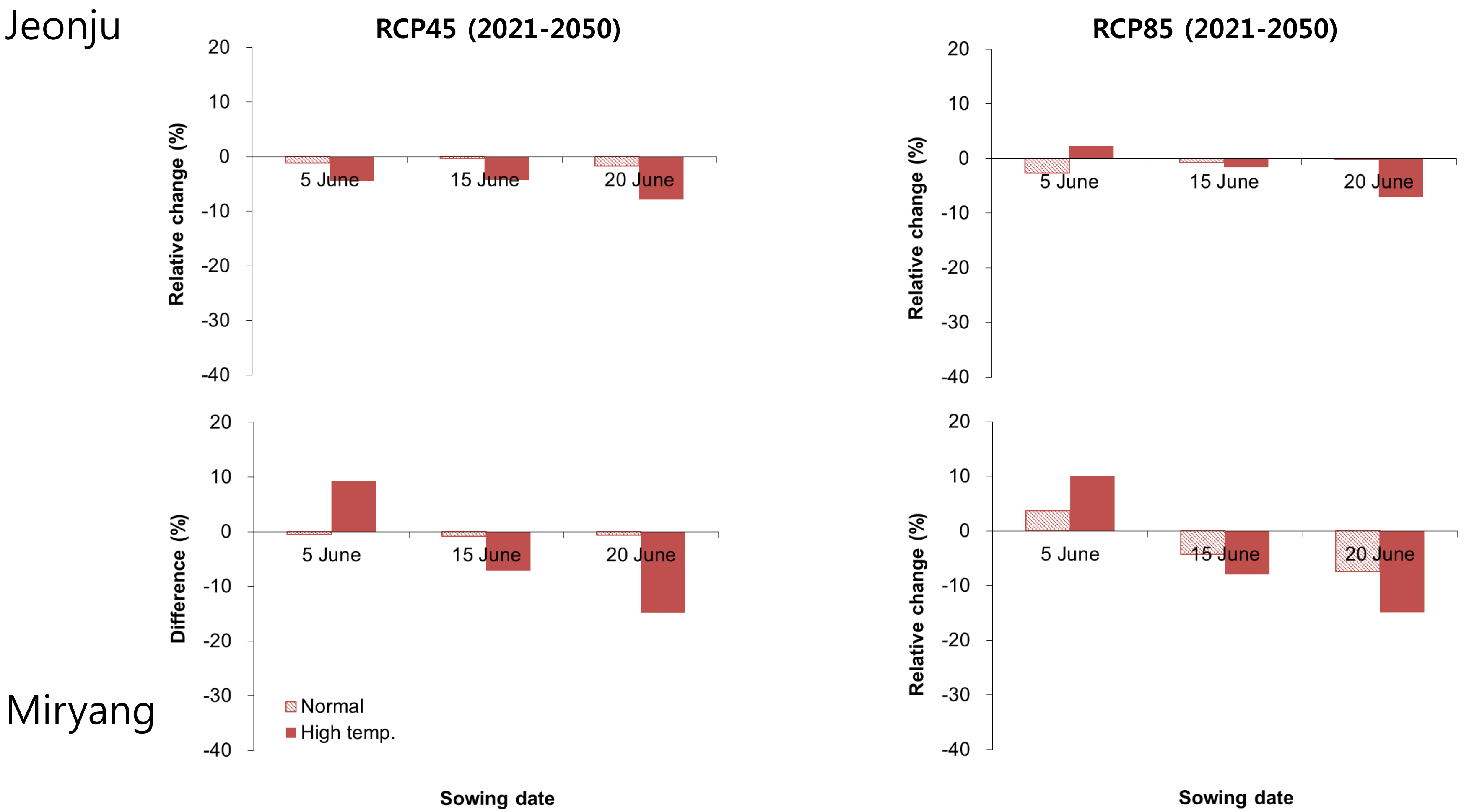




밀양

Results

- Relative change on yield planted at June 10



Summary (Obs.2.)

- by shortening the planting time, it is possible to avoid the decrease of the yield of soybean by avoiding the high temperature during critical growth stage (e.g., grain filling period)

- more negative impact on delay of the planting time

Multi Model Ensemble Simulation:

Reproducibility of yield in CROP Model

Objectives of Case Study-2

- Multi Models Ensemble Simulation

  - (Obs.3)

  evaluate yield reproducibility, & investigate appropriate ensemble averaging method to average the predicted yields from various climate models, &

  build database for multi models ensemble simulation of crop model

Climate (Weather) Information

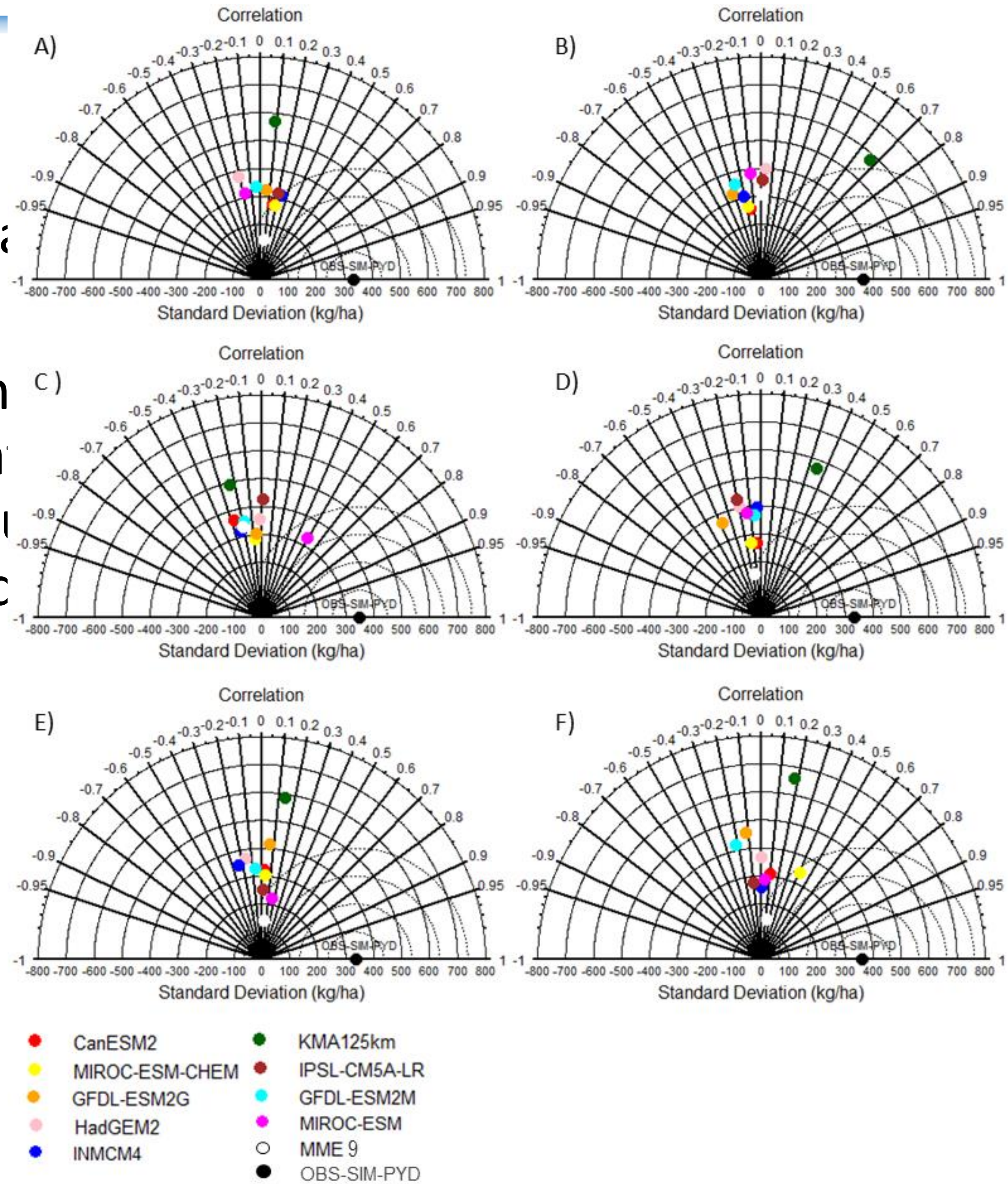
- 9 Scenarios
  - 8 GCMs
  - 1 RCM
- Quantile mapping

mdlnms	Historical						RCP4.5						RCP8.5					
	PR	TX	TN	WD	SR	RH	PR	TX	TN	WD	SR	RH	PR	TX	TN	WD	SR	RH
ACCESS1-0	1	1	1				1	1	1				1	1	1			
bcc-csm1-1-m	1	1	1				1	1	1				1	1	1			
bcc-csm1-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CanESM2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CCSM4	1	1	1				1	1	1				1	1	1			
CESM1-BGC	1	1	1				1	1	1				1	1	1			
CESM1-CAM5	1	1	1				1	1	1				1	1	1			
CMCC-CM	1	1	1				1	1	1				1	1	1			
CMCC-CMS	1	1	1				1	1	1				1	1	1			
CNRM-CM5	1	1	1				1	1	1				1	1	1			
CSIRO-Mk3-6-0	1	1	1				1	1	1				1	1	1			
FGOALS-g2	1	1	1				1	1	1				1	1	1			
FGOALS-s2	1	1	1				1	1	1				1	1	1			
GFDL-CM3	1	1	1				1	1	1				1	1	1			

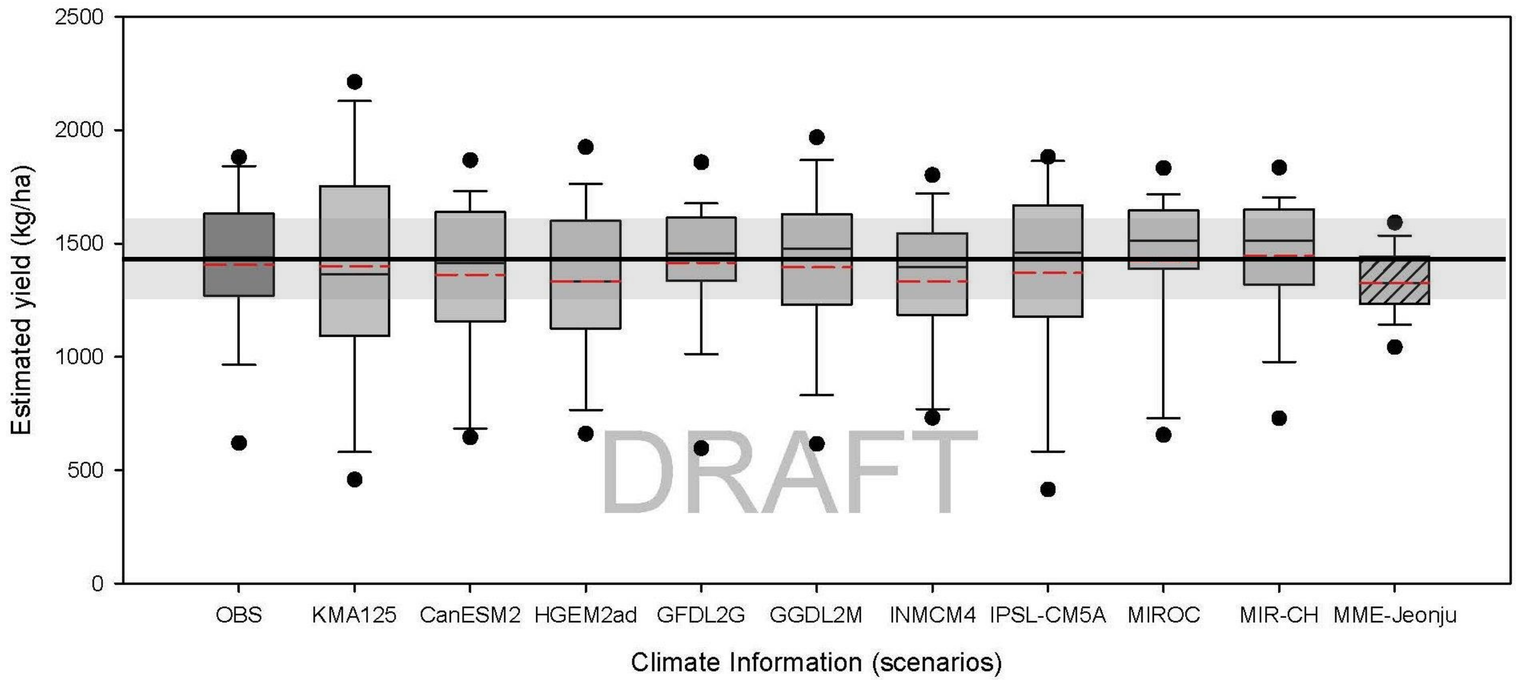
Model	Origin	Country	Resolution
KMA-12km	Korea Meteorological Administation	Korea	12.5km x 12.5km
CanESM2	Canadian Centre for Climate Modeling and Analysis	Canada	2.8° x 2.8°
GFDL-ESM2G GFDL-ESM2M	NOAA/GFDL (Geophysical Fluid Dynamic Laboratory)	USA	2.5° x 2.0°
HadGEM2-CC	Meteorological Office Hadley Center	UK	1.88° x 1.25°
inmcm4	Institute for Numerical Mathematics	Russia	2° x 1.5°
IPSL-CM5A-LR	Institute Pierre Simon Laplace	France	3.75° x 1.8°
MIROC-ESM MIROC-ESM-CHEM	Atmosphere and Ocean Research Institute, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology	Japan	2.8° x 2.8°

Reproducibility of yield

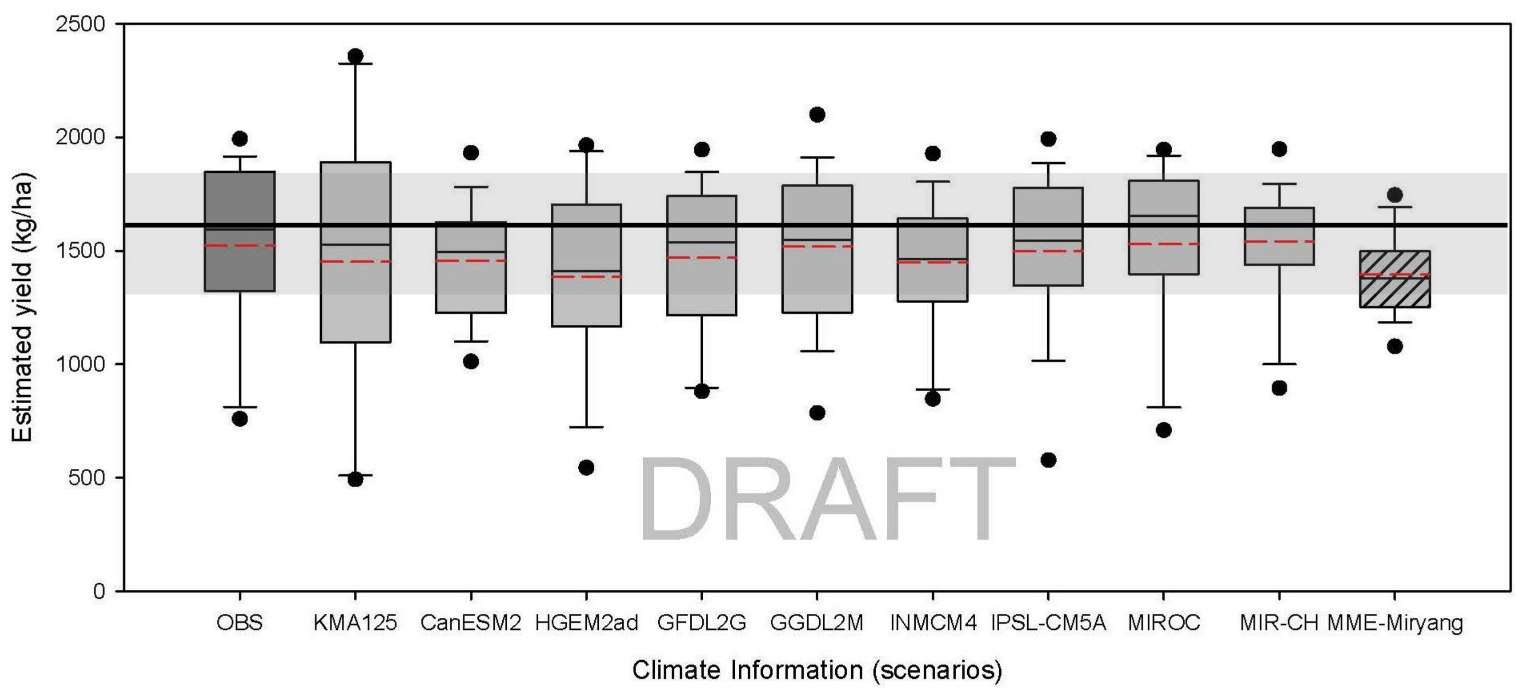
- Reproduce
  - past climate(weather) a
  - necessary to analyze in
    downscaled climate da
    growth periods reprodu
    accurately enough, and
    the crop model.



Jeonju



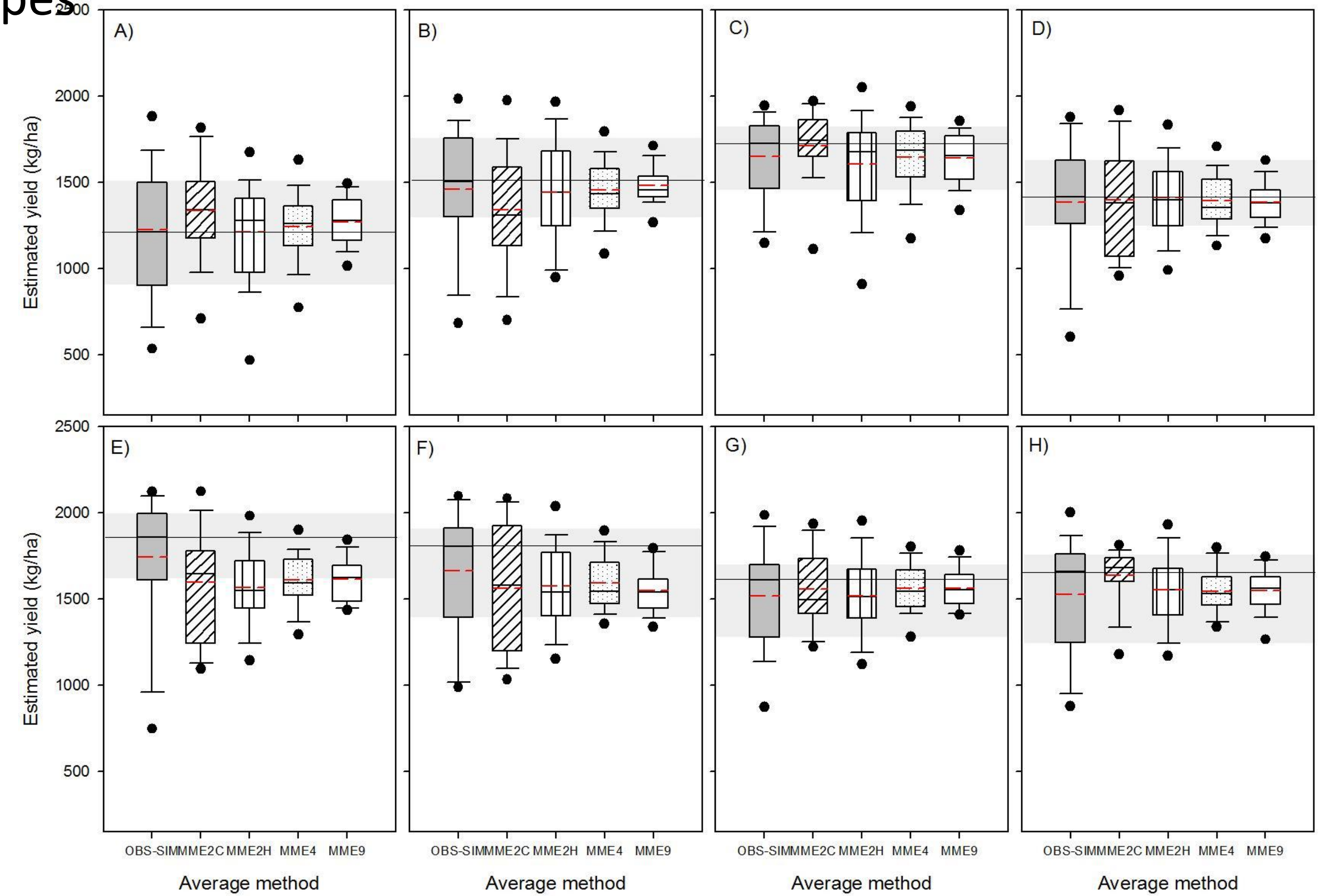
Miryang



Multi Model Ensemble Methods

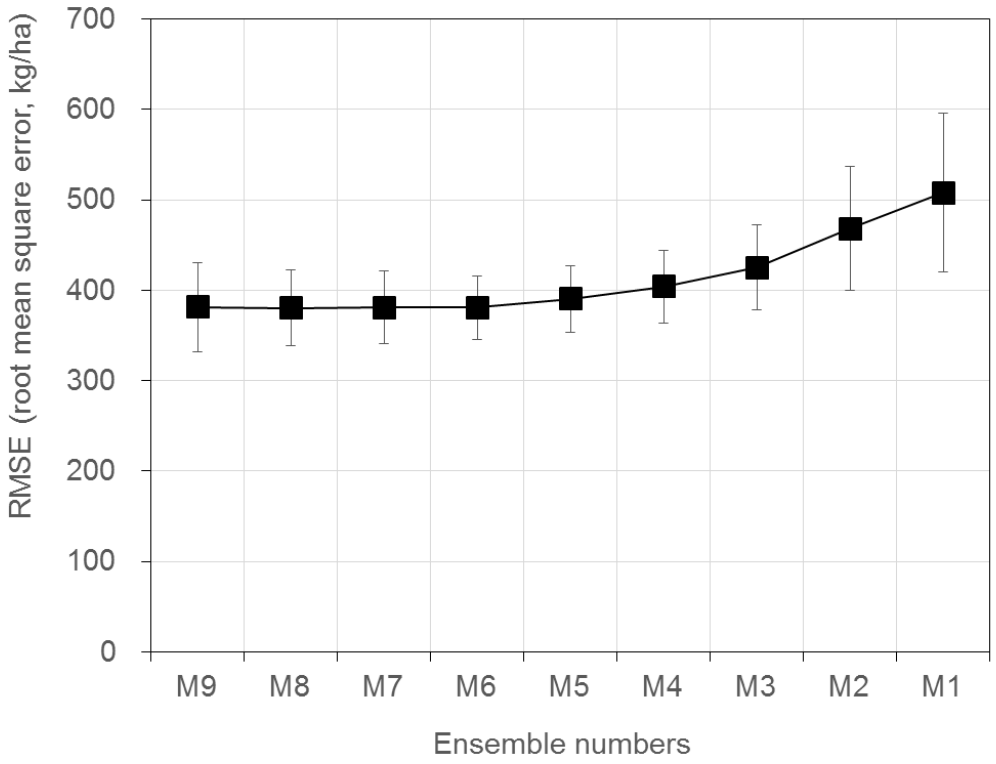
Chung U, Kim YU, Seo BS, Seo MC (2017) Evaluation of Variation and Uncertainty in the Potential Yield of Soybeans in South Korea Using Multi-model Ensemble Climate Change Scenarios. Agrotechnology 6: 158. doi: 10.4172/2168-9881.1000158)

- MME types
  - 4 types
  -



Number of participating

- Number of participating in MME simulation
  - the estimation error decreased as the number of GMCs included in the MME increased



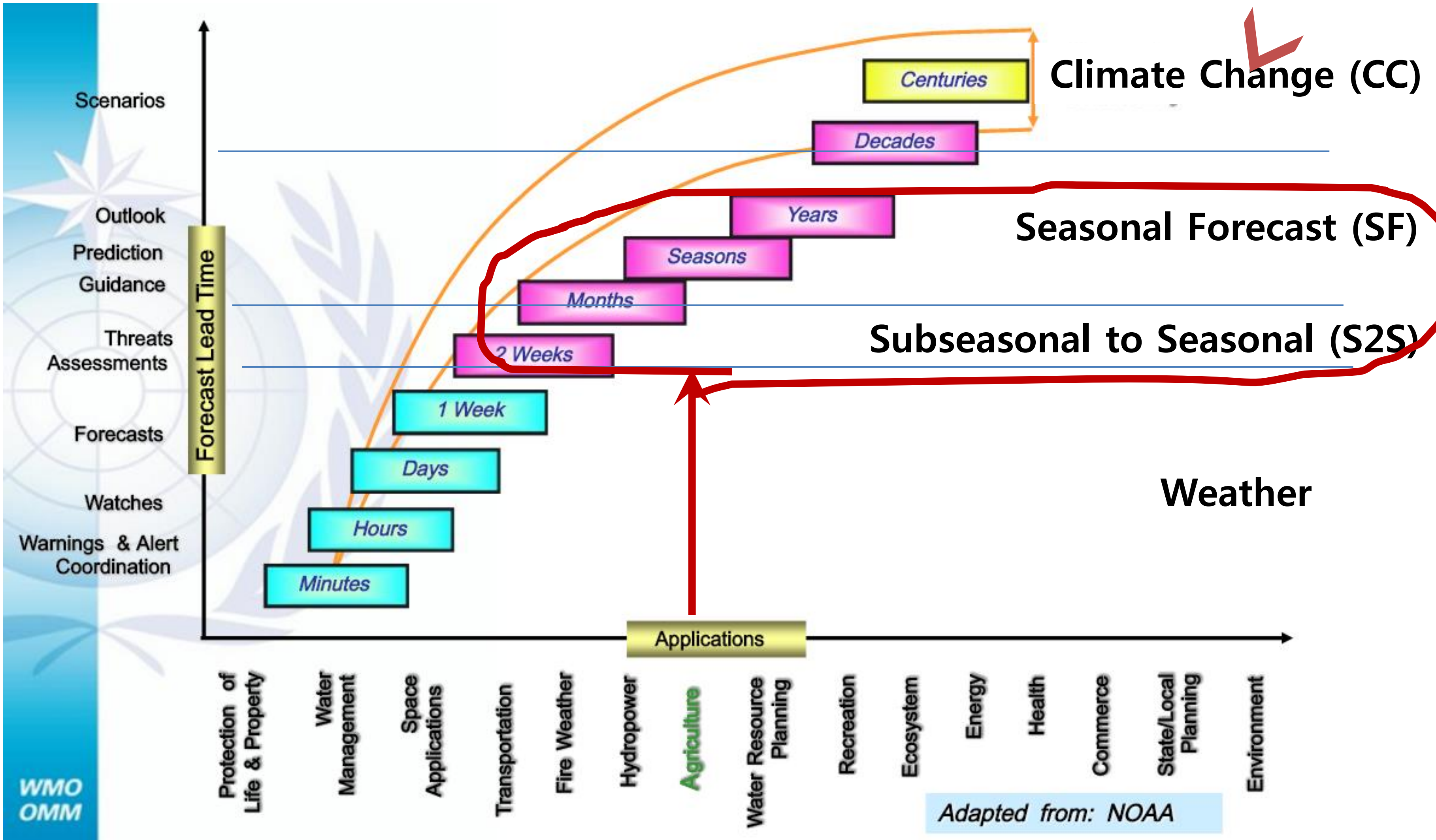
Summary (Obs.3.)

- the mean of the MME4 averaged potential yields or the MME9 averaged potential yields were similar to the OBS-SIM-PYD, but the range of variations (interquartile range) of the predicted potential yield was small and showed the typical features of the statistical method, so that the potential yield could not be predicted for any given climate change scenario, such as high temperature events

- necessary to provide information on the type and number of individual GCMs that can reduce the estimation error by as much as possible, rather than including arbitrarily large numbers of GCMs in the MME

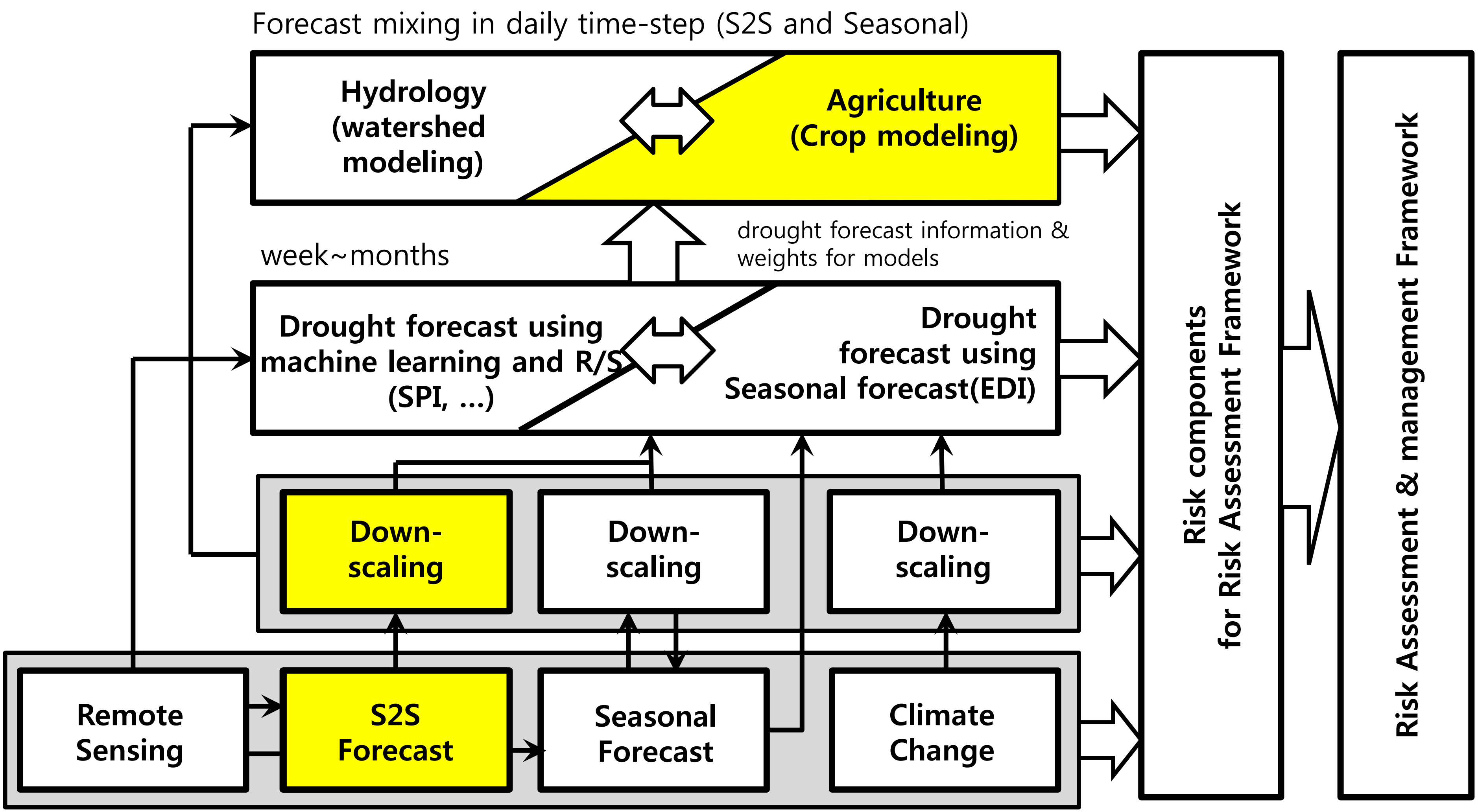
Additional

➢ Multi-range climate information



Source: http://slideplayer.com/slide/1447561/

Project Overview

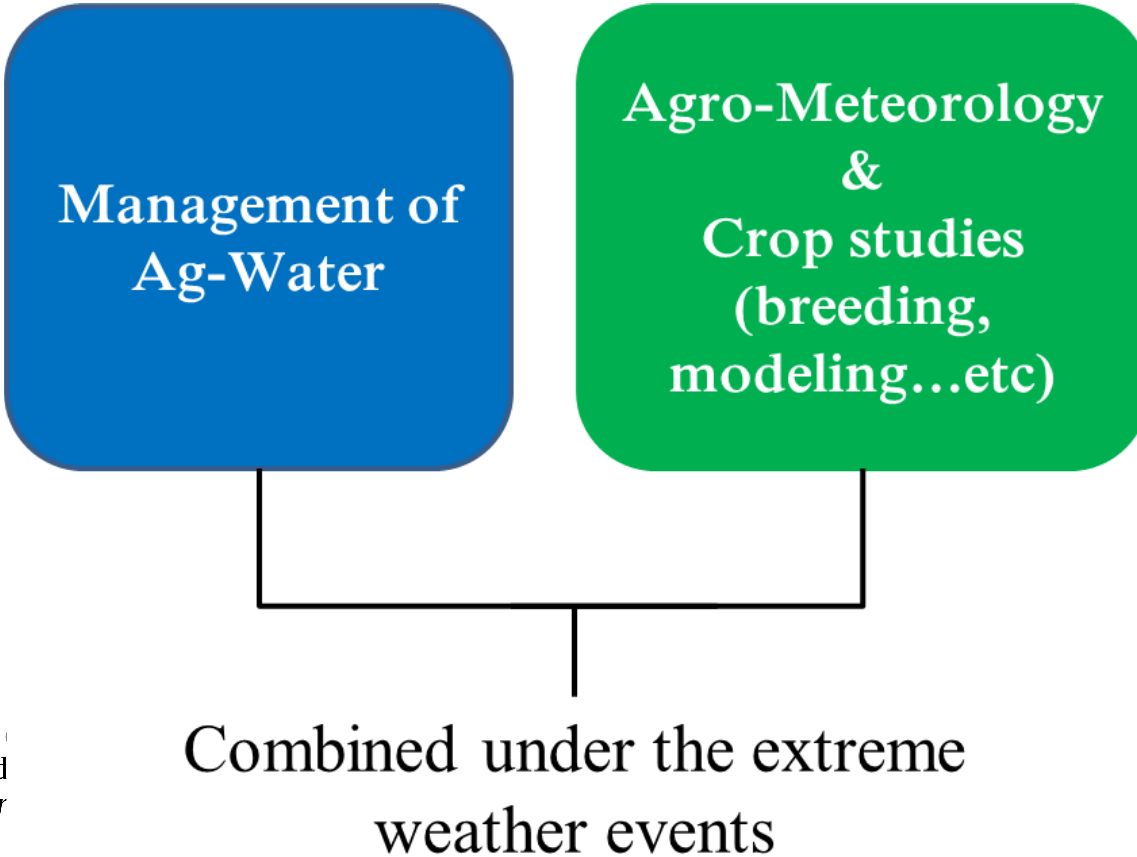


Crop modeling (S2S)

2) Assessment critical growth stages of crop from S2S Information
   - in cropping season: 1~2 weeks (within 7 ~ 15 days)
   - 3 critical periods (e.g., 1~2 weeks after sowing or planting, flowering period and grain filling period during reproductive period. Those periods are within 7~15 days)

multi-disciplinary research

- multi-sectors combined approach
  - breeding
  - plant physiology
  - crop modeling
  - socioeconomics
  - hydrology modeling results



Chung et al., 2014: Modeling the effect of a heat wave production in the USA and its implications on food in the developing world. *Weather and Climate Extr* 6, 67-77. (doi: 10.1016/j.wace.2014.07.002)

Thank you so much for attention

APEC CLIMATE CENTER