문서번호 APCC-출장-17-0294(2017-03-24)

TRAVEL REPORT FORM
출장보고서

결재	팀장	부서장	원장	
	03/23 조재필	03/24 김형진	03/24 정홍상	
협조				

I. Reporter 보고자

Department 소속	Position 직위(직급)	Name 성명	Travel Date 날짜	Note 비고
응용사업본부	선임연구원	조재필	2017.03.03. ~ 2017.03.09	

II. Major Activities 주요업무 수행내용

1. Main Contents and Activities 주요내용 및 활동

□ 13th International Drainage Workshop 참석
- KWPA, KRC 그룹 미팅 및 일부 발표 참석

□ KRC-KWPA JTC 미팅 참석
- 실질적인 파일럿 프로젝트에 대한 논의가 끝난 상황에서 형식적으로 진행됨.
- 교환 연구원 파견에 대한 KRC의 요청이 있었음
- 저수지 수면에 태양광 발전소 건설에 관하여 KRC 측의 요청이 있었음

□ 이란 KWPA 수탁사업 내용 구체화
○ 계약방법 변경
- 이란 기상청을 통한 기후서비스가 안되고 있는 상황에서 물관리 기관인 KWPA에서 외국기관인 APCC와 연구 중심의 계약을 단독으로 맺는 것은 어려움 (이란 내 전문가로는 불가능한 영역임을 설명해야 함)
- 농어촌공사와 협의되고 있는 파일럿 프로젝트의 일부로 연구를 진행할 것을 제안받음
- 농어촌공사의 파일럿 프로젝트의 경우도 아이에스테크놀로지(주)와 공동참여 방법에서 KRC와의 단독계약에 포함시켜 진행하는 방향으로 결정됨
- 전체 사업비의 경우 30개지점에 대한 200만불 규모에서 계측지점을 100개 지점으로 늘리고 250만불로 조정됨
- APCC의 연구비의 경우 KRC와 논의하여 결정하여야 하나 KRC의 경우 많은 사업비 조정으로 APCC에 2~3천만원 수준의 사업비를 제안함

○ KWPA-APCC 협의 내용
- 가뭄 모니터링/예측 및 유출량 예측을 중심으로 발표
- 가뭄 모니터링/예측은 Effective Drought Index (EDI)를 기반으로 진행하기로 결정
- 유량예측의 경우 현재 이란에서 사용하고 있는 모델과의 연계만을 고려하고 SWAT+ 등의 모델링은 향후 본 사업에 추가하여 진행
- 기 제출된 Concept Note 중에서 계절예측 상세화와의 연계성을 고려하여 Climate Zone 구분은 포함되어야 하며
- 시공간적으로 일관성 있는 관측자료의 생산을 위해서 격자 자료 생산 관련 내용을 추가할 것을 요청 받음 (프리즘기반의 외삽기법 기반)
- 연구비에 맞게 내용 조정을 하고 최소 비용 산정 (최소 8만불 이상이 최소경비이나, KWPA에서 생각하는 5만~6만불 수준의 연구비 산정)

- YSSP 및 위성자료기반 관측자료 생산 (IRI) 관련 내용을 추가적으로 고려해 줄 것에 대한 요청에 KRC 전체사업비 증액의 경우에 고려해 볼 것을 언급함
- 센터에서 제시한 MoU에 싸인을 하고 센터에서 이견이 없는 경우 메일로 MoU 원본을 KWPA에 보내 주기로 함

○ 향후 추진 방향
- 향후 1개월 이내에 계약서 검토 후 최종 계약 예정
- KWPA에서 요청한 추가적인 내용을 고려하여 연구비 증액여부 결정
- MoU 결정

○ 사업의 의미
- KRC와 APCC의 MoU 후속 조치로서의 의미 (APCC 단독 사업 추진이 어려운 상황에서 향후 KRC와의 협력관계를 통한 해외사업 추진)
- 파일럿 프로젝트 이후 계획되고 있는 본 사업에 공동 참여 가능성
- 해외에서의 수요자 중심의 사례 창출 (국내에서도 동일한 과정을 거쳤음)
- 태국 프로젝트의 경우 기후-응용분야 융합 측면에서 의미가 있는 반면, 이란 사업의 경우는 관측기반의 의사결정 시스템에 센터의 예측기반 의사결정 절차를 통합하여 하나의 시스템화 하는 데 의미가 있음

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

III. References 참고사항

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

1. Presented and Collected Materials 주요 수집자료

2. Suggestions and Remarks 건의사항

Climate Prediction and its Applications through KWPA-APCC Collaboration

08 March 2017

Jaepil Cho

Contents

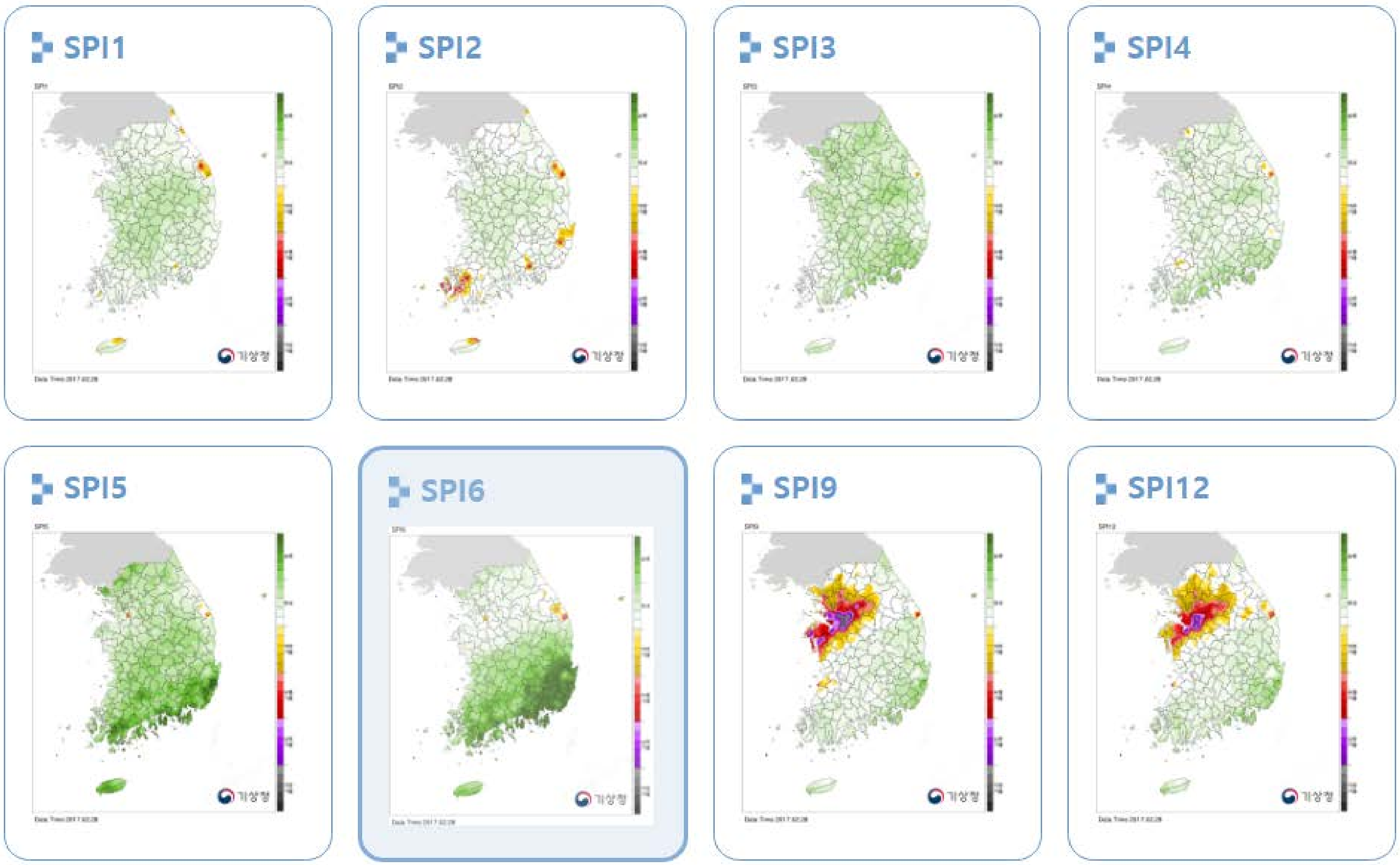
1. Drought Monitoring and Forecast in Korea
2. APCC's Seasonal Forecast
3. Hydrological Forecast
4. Cli-WARA project in Thailand
5. KWPA-APCC Collaborative Project

Drought Monitoring and Forecast in Korea

1. Drought monitoring
2. Drought forecast

Drought monitoring by KMA using SPI

Which one is representing current drought situation?



Drought monitoring in Korea using EDI

Objective Quantification of Drought Severity and Duration

HI-RYONG BYUN

Department of Atmospheric Sciences, Pukyong National University, Namku, Pusan, South Korea

DONALD A. WILHITE

National Drought Mitigation Center, University of Nebraska, Lincoln, Nebraska

(Manuscript received 17 March 1998, in final form 12 August 1998)

ABSTRACT

Common weaknesses of current drought indexes were analyzed. First, most of the current indexes are not precise enough in detecting the onset, end, and accumulated stress of drought. Second, they do not effectively take into account the aggravating effects of runoff and evapotranspiration, which build up with time. Third, they have a limited usefulness in monitoring ongoing drought because they are based on a monthly time step. Fourth, most of them fail to differentiate the effects of drought on surface and subsurface water supply.

A new series of indexes are proposed to solve these weaknesses and to improve drought monitoring. In the new indexes, daily, rather than monthly, time steps are used. A new concept, effective precipitation (EP), the summed value of daily precipitation with a time-dependent reduction function, is proposed as a basic tool.

Three additional indexes complement EP. The first index is each day's mean of EP (MEP). This index shows climatological characteristics of precipitation as a water resource for a station or area. The second index is the deviation of EP (DEP) from the MEP. The third index is the standardized value of DEP (SEP). By using these three indexes, consecutive days of negative SEP, which can show the onset, the ending date, and the duration of a water deficit period is categorized.

With the duration categorized, four additional indexes that can show drought severity are calculated: 1) accumulation of consecutive negative SEP, which shows the duration and severity of precipitation deficit together; 2) accumulated precipitation deficit, which shows precipitation departure from the normal during a defined period; 3) precipitation for the return to normal; and 4) effective drought index, a standardized index that can be used to assess drought severity worldwide. The merits and weaknesses of each index are compared. New quantified definitions on drought and its onset, end, and duration are proposed.

These indexes were tested in the High Plains region of the United States from 1960 to 1996. The results were compared to historical reports of drought. From this analysis, it was concluded that the new indexes not only advanced objectivity, but also offered a number of advantages in practical use. These are 1) a more precise determination of drought duration, 2) the usefulness in monitoring an ongoing drought, and 3) the variety of ways a drought's characteristics can be described.

EDI(Effective Drought Index, Byun and Wilhite, 1999)

Concept of EDI: Effective Precipitation

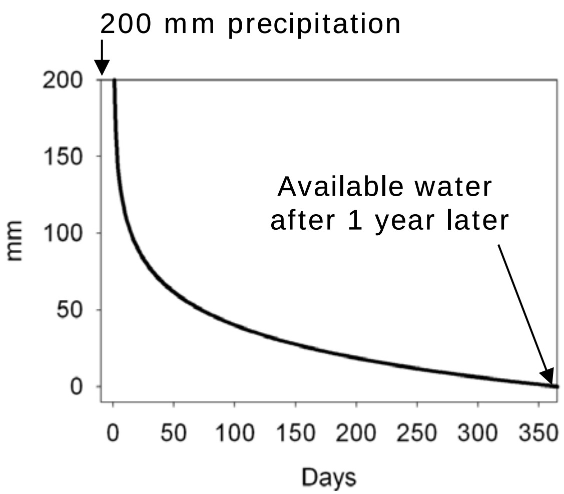
EP(Effective Precipitation)

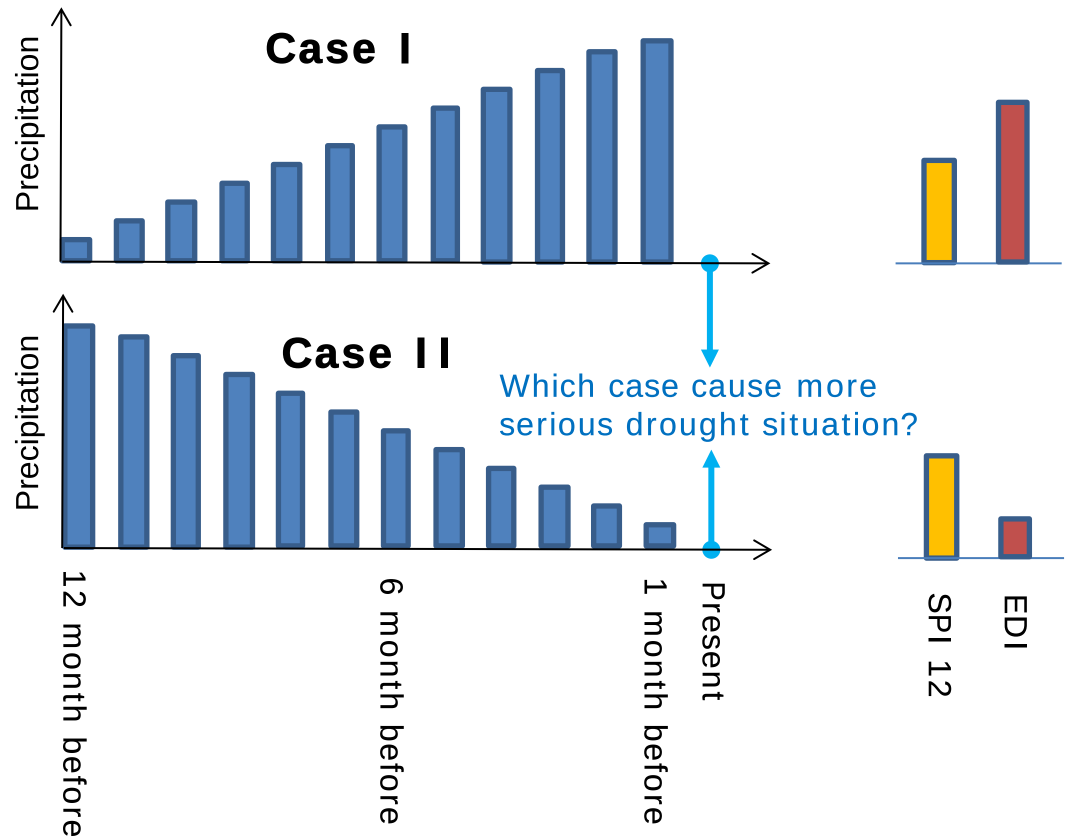
$$EP_i = \sum_{n=1}^{i}\left[\left(\sum_{m=1}^{n} P_m\right)/n\right]$$

$$DEP = EP - MEP$$

$$EDI = DEP/ST(DEP)$$

Available water decrease as time goes on





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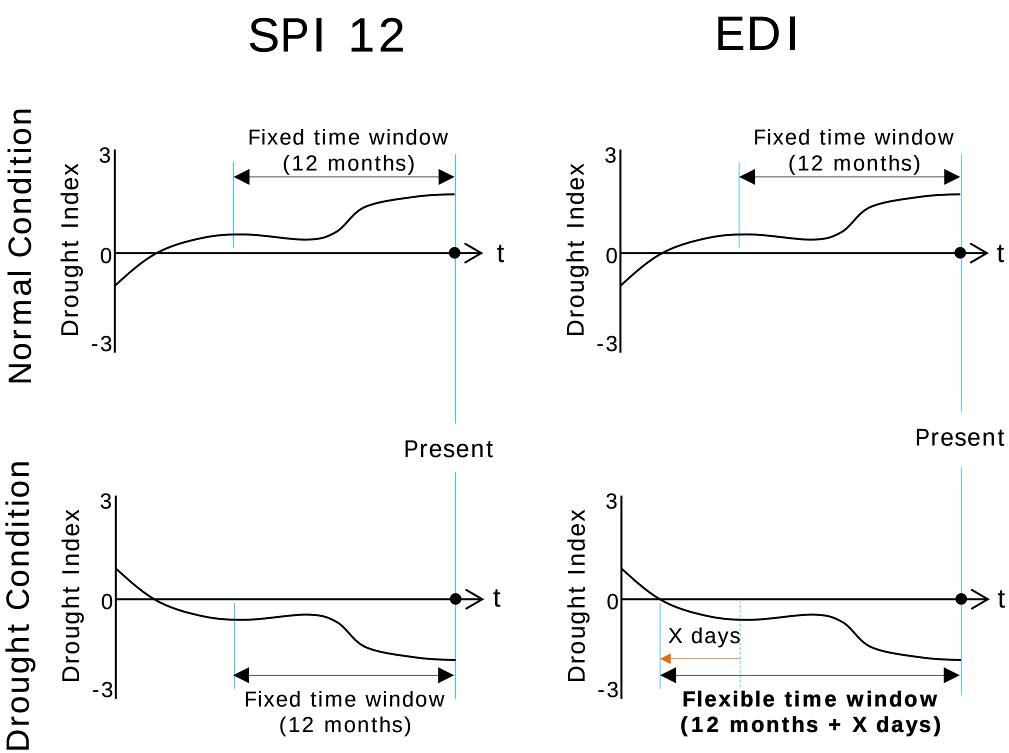
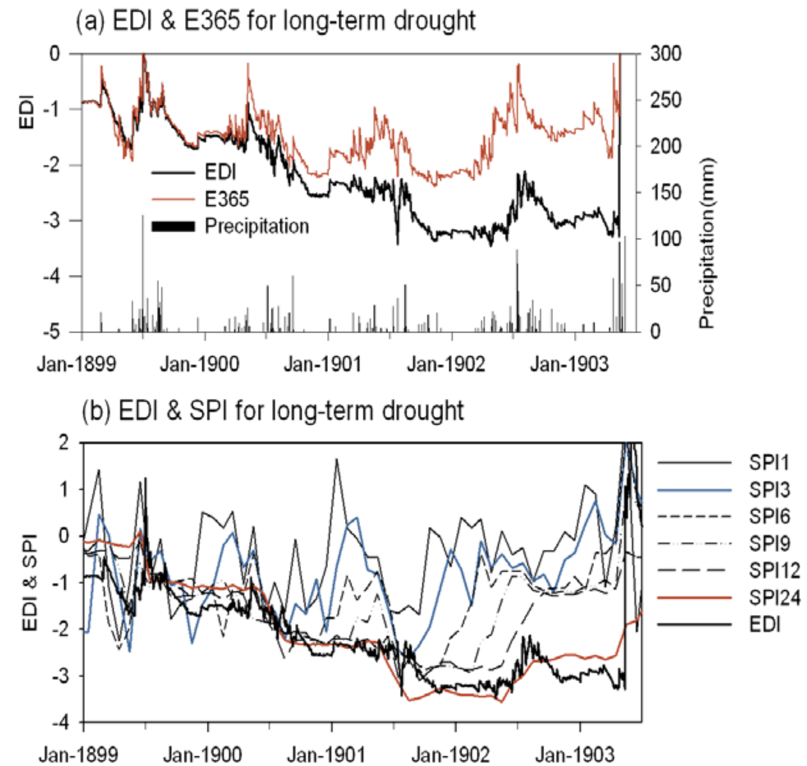
Concept of EDI: Flexible Time Window





Long-term drought situation

Kim et al., 2009(Evaluation, modification, and application of the Effective Drought Index to 200-Year drought climatology of Seoul, Korea)

Jain et al.(2015) Comparison of drought indices for appraisal of drought characteristics in the Ken River Basin, Weather and Climate Extremes

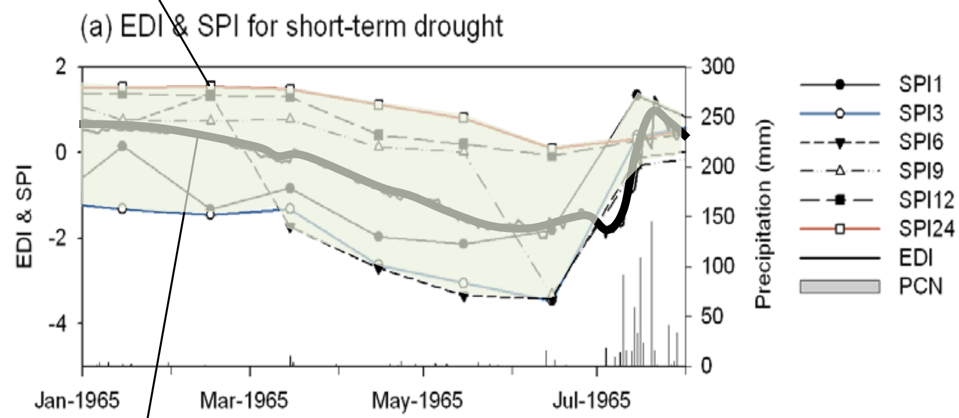
Consistent drought diagnosis for short-term drought

Table 3
Sample correlation matrix of Pearson product-moment correlation coefficients computed between paired values of drought index time series for Sagar district.

Row no.	Drought Index **1**	EDI **2**	SPI-1 **3**	SPI-3 **4**	↔	RDDI-6 **25**	RDDI-9 **26**	RDDI-12 **27**
1	EDI	1.00	0.45	0.64	… …	0.72	0.81	0.78
2	SPI-1	0.45	1.00	0.51	… …	0.34	0.27	0.23
3	SPI-3	0.64	0.51	1.00	… …	0.58	0.45	0.40
4	SPI-6	0.81	0.37	0.63	… …	0.91	0.68	0.60
5	SPI-9	0.92	0.30	0.50	… …	0.67	0.91	0.79
6	SPI-12	0.87	0.26	0.43	… …	0.61	0.78	0.91
↕	…	…	…	…	… …	…	…	…
	…	…	…	…	… …	…	…	…
19	RD-6	0.69	0.32	0.53	… …	0.77	0.51	0.44
20	RD-9	0.89	0.30	0.47	… …	0.60	0.84	0.70
21	RD-12	0.88	0.26	0.44	… …	0.59	0.76	0.88
22	RDDI-1	0.36	0.88	0.41	… …	0.30	0.23	0.19
23	RDDI-3	0.56	0.49	0.91	… …	0.57	0.45	0.39
24	RDDI-6	0.72	0.34	0.58	… …	1.00	0.69	0.61
25	RDDI-9	0.81	0.27	0.45	… …	0.69	1.00	0.81
26	RDDI-12	0.78	0.23	0.40	… …	0.61	0.81	1.00
27	Average correlation	**0.72**	**0.46**	**0.59**	… …	**0.60**	**0.60**	**0.57**
28	Average correlation of same time steps*		**0.92**	**0.95**	… …	**0.88**	**0.91**	**0.92**

* The average in column SPI-3 is computed from the average correlation of SPI-3 with 3-monthly time step of DIs such as SPI-3, Z-Score-3, CZI-3, RD-3, RDDI-3 and average in column RDDI-6 is computed from the average correlation of RDDI-6 with 6-monthly time step of DIs such as SPI-6, Z-Score-6, CZI-6, RD-6 and RDDI-6.

SPIs: incosistent drought diagnosis



Kim et al., 2009(Evaluation, modification, and application of the Effective Drought Index to 200-Year drought climatology of Seoul, Korea)

EDI: determined drought diagnosis

Effective Drought Index (EDI)
Standardized Precipitation Index(SPI)
China Z-Index (CZI)
Statistical Z-Score (Z-Score)
Rainfall deciles based drought index(RD)
Rainfall deciles based drought index (RDDI)

Jain et al.(2015) Comparison of drought indices for appraisal of drought characteristics in the Ken River Basin, Weather and Climate Extremes

Operational drought monitoring system

SOLA, 2010, Vol. 6A, 009−012, doi:10.2151/sola.6A-003 9

Introduction of East Asian Drought Monitoring System

Su-Bin Oh[1], Do-Woo Kim[1], Ki-Seon Choi[2], and Hi-Ryong Byun[1]

[1]*Department of environmental atmospheric sciences, Pukyong National University, Busan, Republic of Korea*
[2]*Korea Meteorological Administration, Seoul, Republic of Korea*

Abstract

This paper introduces the East Asian drought monitoring system that has been operational since 2008 (http://atmos.pknu.ac.kr/~intra2). It provides the spatial and temporal distribution of droughts using variables such as the drought intensity and duration. The main feature of this system is the effective drought index (EDI; Byun and Wilhite 1999) in which the drought intensity is calculated by considering cumulative precipitation as a weighting function of time. In addition, this system provides an available water resources index (AWRI; Byun and Lee 2002), which represents the hydrological index. These indexes were calculated using the monthly precipitation data obtained from 298 stations in East Asia (Republic of Korea, Democratic People's Republic of Korea, Japan, and China). Information on drought is provided in terms of monthly spatial distribution and is presented in the text and a time series. The period of data collection differs according to the observation start dates of the stations, and the longest period of data collection (Seoul, Korea) started in 1778. This system will contribute to drought prevention by diagnosing drought in real time. It will also provide fundamental data for further studies on drought by detecting the time and location of droughts.

1. Introduction

Drought has traditionally been the greatest natural disaster threatening the human population. According to the National Drought Mitigation Center (NDMC), drought causes the greatest damage among all disasters. Four worldwide droughts have been listed by the National Oceanic and Atmospheric Administration as being in the top five greatest natural disasters of the 20th century (www.bcc.cma.gov.cn) provides the spatial distribution information on droughts using the SPI and the percentage of precipitation anomaly. It also provides the spatial distribution of the drought index and the flood index globally and in the East Asian region. Boken et al. (2005) studied the monitoring system of each country.

However, the existing monitoring systems have limitations. First, they provide only limited data. Most systems currently provide only the spatial distribution of droughts and do not provide the time series and index value of drought. Therefore, we cannot obtain the exact drought index value and drought variability for each station. In addition, researchers are required to calculate the drought index for their studies.

Second, each monitoring system uses a different drought index, and the calculated index values are not identical. The most important factor is the technology used for drought quantification in order to monitor drought. However, there are problems with the PDSI and SPI, which are currently the most widely used indexes. Because the PDSI was developed for the Great Plains in the US, it is difficult to apply this index to other regions without modification. In addition, not only precipitation but also evapotranspiration and outflow are used for the calculation, which causes additional complications. The calculation of duration in the SPI method differs according to the subjective view of researchers, and thus, the state of drought can vary with different monitoring systems, even for the same date. Kim et al. (2009) have presented an in-depth comparative analysis of the weakness of SPI.

Third, the existing systems provide only short-term data. Most drought monitoring systems only show drought intensity since 2000, and some monitoring systems only show data in real time. This is inappropriate for studying drought on a long-term basis.

In this study, a new system is presented that overcomes the shortcomings of the existing monitoring systems. Importantly, the system calculates the drought index since 1778 (Seoul, Korea)

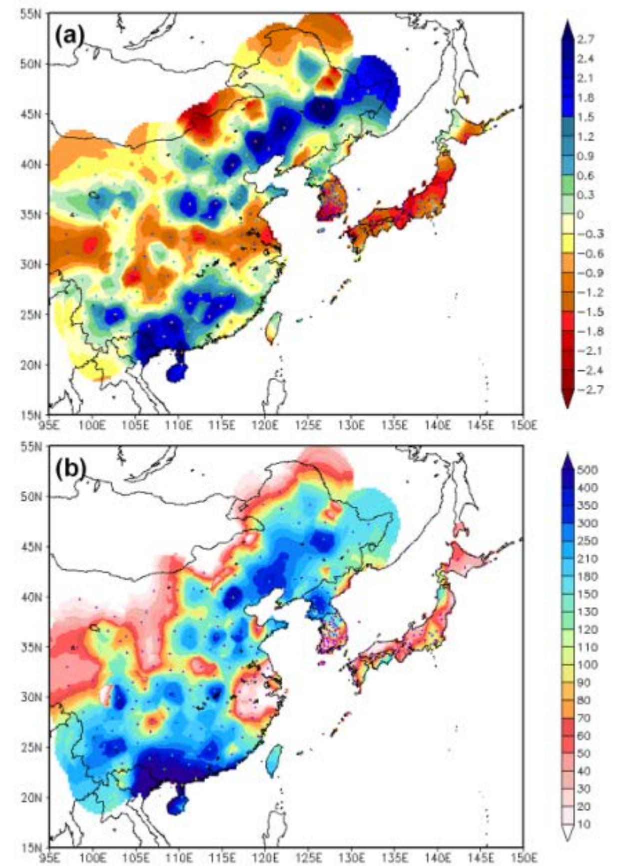


Fig. 5. The spatial distributions of (a) EDI and (b) precipitation in Jul. 1994.

http://atmos.pknu.ac.kr/~intra2

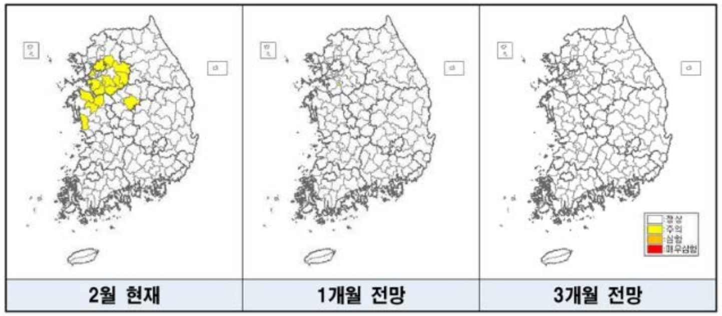
Drought forecast

2월 가뭄 예·경보

제 2017-2호

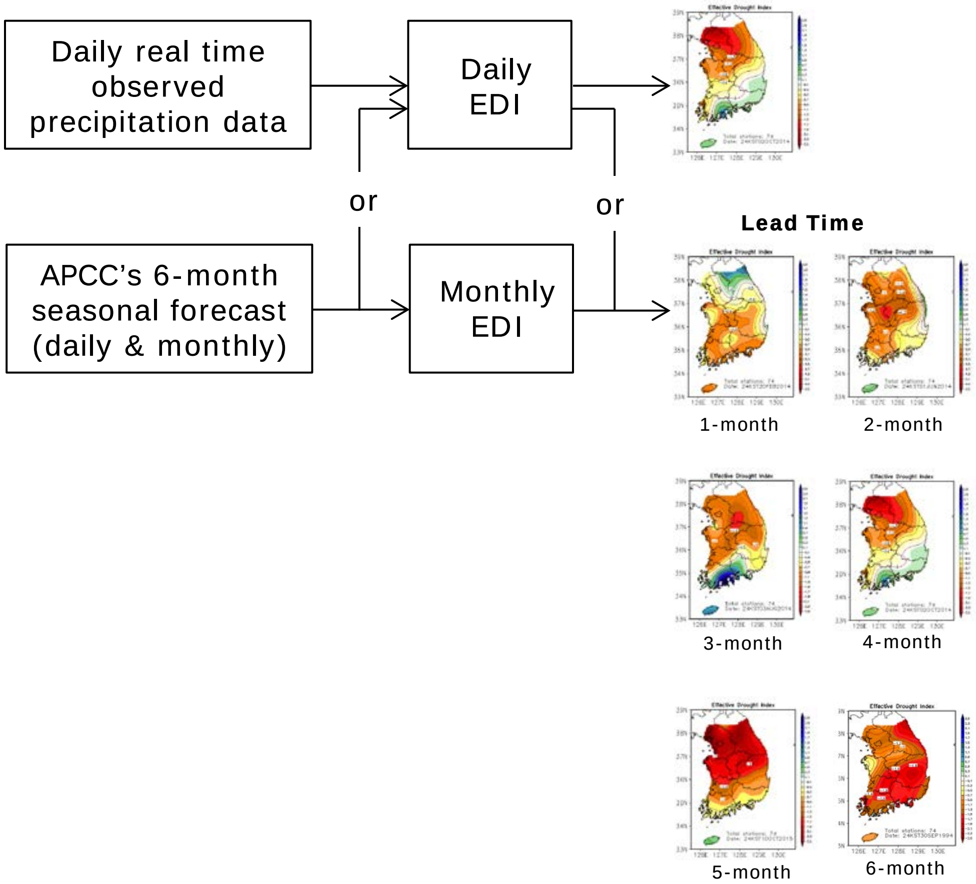
국민안전처, 농식품부, 환경부, 국토부, 기상청
2017년 2월 10일 발표

■ 기상 가뭄지도



구 분	2월 현재	1개월 전망	3개월 전망
주 의 (Yellow)	[서울·경기] 서울특별시, 광명시, 평택시, 구리시, 남양주시, 오산시, 시흥시, 하남시, 용인시, 이천시, 안성시, 화성시, 여주시, 양평군 [충북] 괴산군 [충남] 보령시, 아산시, 당진시, 예산군	[서울·경기] 오산시	-
심 함 (Orange)	-	-	-
매 우 심 함 (Red)	-	-	-

KMA's drought forecast (3 months)



For KWPA project

Other drought indices that KWPA might be interested

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. **26**: 971–985 (2006)
Published online 20 April 2006 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/joc.1264

COMPARISON OF SEVEN METEOROLOGICAL INDICES FOR DROUGHT MONITORING IN IRAN

SAEID MORID,[a,*] VLADIMIR SMAKHTIN[b] and MAHNOSH MOGHADDASI[c]
[a] *Tarbiat Modarres University, College of Agriculture, Tehran, Iran*
[b] *International Water Management Institute, Colombo, Sri Lanka*
[c] *Research Scholar, Tarbiat Modarres University, College of Agriculture, Tehran, Iran*

Received 11 January 2004
Revised 6 August 2005
Accepted 6 August 2005

ABSTRACT

Drought monitoring is an essential component of drought risk management. It is normally performed using various drought indices that are effectively continuous functions of rainfall and other hydrometeorological variables. A number of drought indices have been introduced and applied in different countries to date. This paper compares the performance of seven indices for drought monitoring in the Tehran province of Iran. The indices used include deciles index (DI), percent of normal (PN), standard precipitation index (SPI), China-Z index (CZI), modified CZI (MCZI), Z-Score and effective drought index (EDI). The comparison of indices is based on drought cases and classes that were detected in the province over the 32 years of data, as well as over the latest 1998–2001 drought spell. The results show that SPI, CZI and Z-Score perform similarly with regard to drought identification and respond slowly to drought onset. DI appears to be very responsive to rainfall events of a particular year, but it has inconsistent spatial and temporal variation. The SPI and EDI were found to be able to detect the onset of drought, its spatial and temporal variation consistently, and it may be recommended for operational drought monitoring in the Province. However, the EDI was found to be more responsive to the emerging drought and performed better.

KEY WORDS: drought monitoring; drought indices; Tehran province; Iran

<u>The EDI was found to be more responsive to the emerging drought conditions compared with the DI and the SPI</u>, particularly during the 1998–2001 drought spell. Also, compared to other indices, <u>the EDI was found to be able to describe developing drought conditions well – spatially and temporally</u>. The EDI efficiency can be related to the concept of effective precipitation (EP) that the index uses. However, <u>the requirement of a continuous daily precipitation record can be a serious limitation</u> for the wider use of the EDI.

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Comparison of multi-monthly rainfall-based drought severity indices, with application to semi-arid Konya closed basin, Turkey

Selim Dogan[a,b,c,*], Ali Berktay[a], Vijay P. Singh[b,c]
[a] *Department of Environmental Engineering, Selcuk University, Konya 42031, Turkey*
[b] *Department of Biological and Agricultural Engineering, Texas A&M University, College Station, TX 77843, USA*
[c] *Department of Civil & Environmental Engineering, Texas A&M University, College Station, TX 77843, USA*

ARTICLE INFO

Article history:
Received 12 May 2012
Received in revised form 20 July 2012
Accepted 1 September 2012
Available online 12 September 2012
This manuscript was handled by Geoff Syme, Editor-in-Chief

Keywords:
Drought indices (DIs)
Drought severity
Effective Drought Index (EDI)
Konya closed basin
Rainfall

SUMMARY

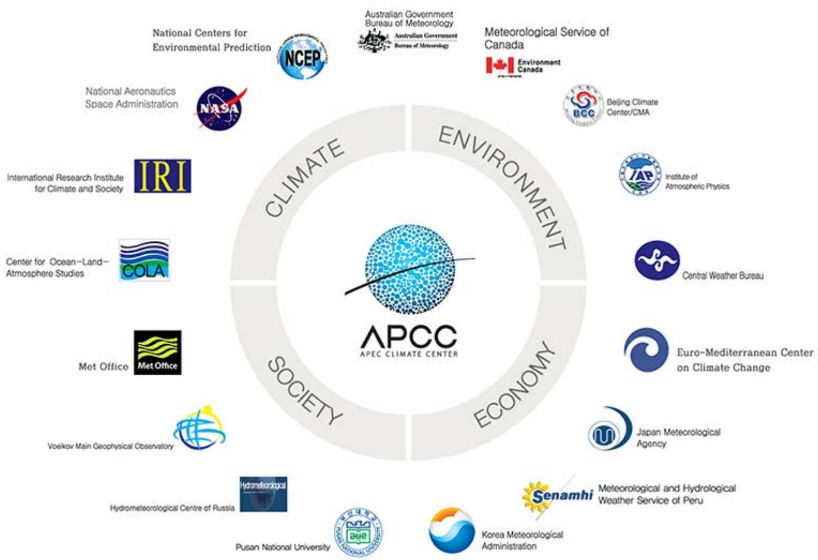
Many drought indices (DIs) have been introduced to monitor drought conditions. This study compares Percent of Normal (PN), Rainfall Decile based Drought Index (RDDI), statistical Z-Score, China-Z Index (CZI), Standardized Precipitation Index (SPI), and Effective Drought Index (EDI) to identify droughts in a semi-arid closed basin (Konya), Turkey. Comparison studies of DIs under different climatic conditions is always interesting and may be insightful. Employing and comparing 18 different timesteps, the objective of comparison is twofold: (1) to determine the effect of timestep for choosing an appropriate value, and (2) to determine the sensitivity of DI to timestep and the choice of a DI. Monthly rainfall data obtained from twelve spatially distributed stations was used to compare DIs for timesteps ranging from 1 month to 48 months. These DIs were evaluated through correlations for various timesteps. Surprisingly, in many earlier studies, only 1-month time step has been used. Results showed that the employment of median timesteps was essential for future studies, since 1-month timestep DIs were found as irrelevant to those for other timesteps in arid/semi-arid regions because seasonal rainfall deficiencies are common there. Comparing time series of various DI values (numerical values of drought severity) instead of drought classes was advantageous for drought monitoring. EDI was found to be best correlated with other DIs when considering all timesteps. Therefore, drought classes discerned by DIs were compared with EDI. PN and RDDI provided different results than did others. PN detected a decrease in drought percentage for

<u>EDI is preferable for monitoring long term droughts in arid/semi-arid regions</u> even if the input is monthly rainfall data. EDI is recommended for use in comparison studies, since <u>it is timestep independent index and has good correlations with various timesteps of other DIs</u>.

APCC's Seasonal Forecast

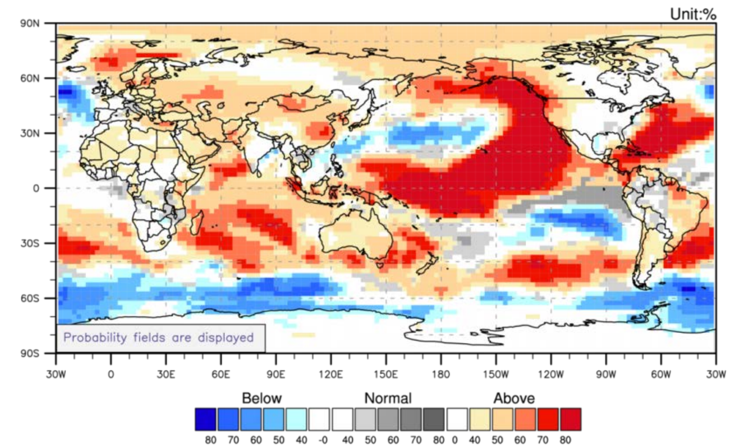
1. List of GCMs for real-time forecast
2. Added value of APCC-MME
3. Downscaling of seasonal forecast
4. User interface

Climate Prediction : APCC's Seasonal Forecast

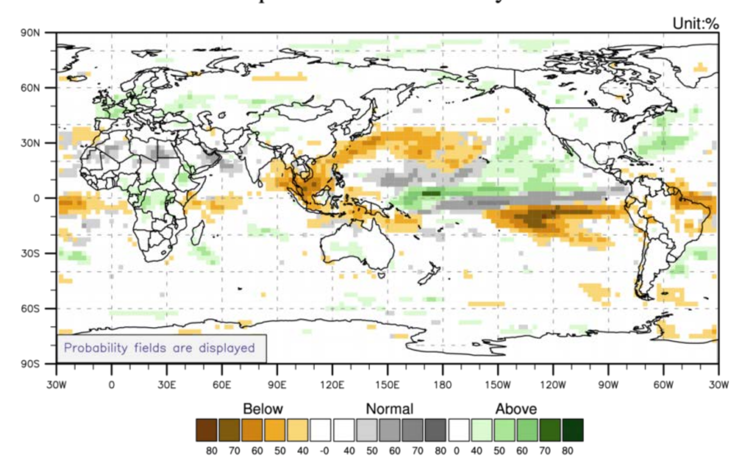


Multi-Model Ensemble (MME)

Temperature at 2m for March-May 2015



Precipitation for March-May 2015

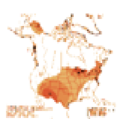
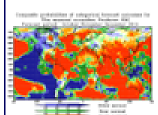
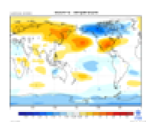


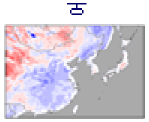
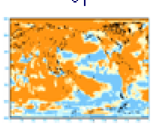
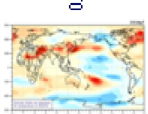
APCC has developed a climate prediction system based on a Multi-Model Ensemble (MME) technique, which collects seasonal forecast data from 17 institutes in 11 economies

- In order to enhance the reliability of its MME climate services, APCC continuously performs forecast verification against observational data

Climate Prediction : Predictability of APCC MME

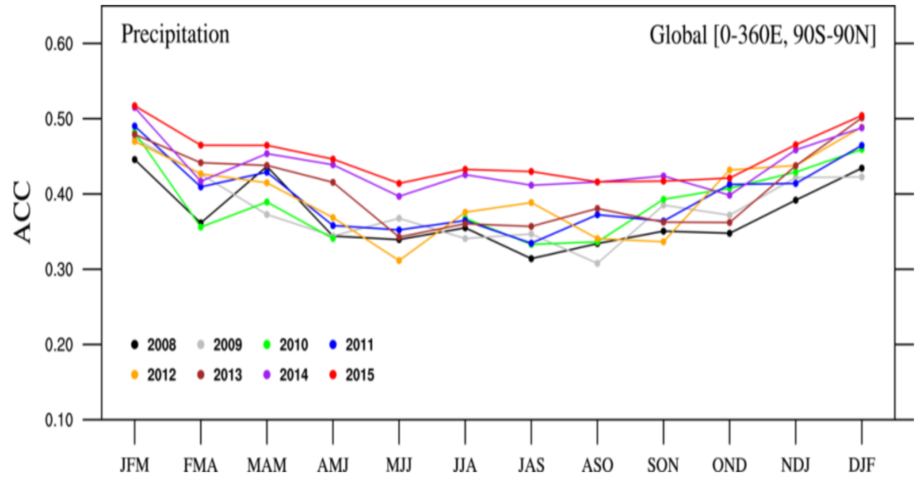
Predictability of APCC MME (2007)

	ECMWF[1]·영국	미국	러시아	WMO LRF[2]
대상	-	미국	전세계	전세계
예보기간	-	M+1,2,3 의 평균	M+1,2,3 의 평균	M+1,2,3
정확도 평가[6]	1, 2위	4위	10위	(3위↑)
접근성	접근불가	중	상	상
정밀도(해상도)	-		중 	상 

	일본	중국	한국	APCC[3]
대상	전세계	전세계	한국	전세계
예보기간	M+1,2,3	M+1	M+1,2,3	M+1,2,3
정확도 평가	3위	8위	7위	(3위↑)
접근성	상	상	상	상
정밀도(해상도)	중 	하 	상 	상 

1) European Centre for Medium-Range Weather Forecasts : 유럽중기예보센터
2) World Meteorological Organization LeadCentre for Long –Range Forecast : 세계기상기구 중장기예보센터
3) APEC Climate Center) : APEC산하 기후연구기관
출처 : 07년 세계기상기구 보고서, 08년 기상청 국정감사보고서

Rainfall hindcast ACC (08-15)



Real time rainfall forecast ROC score (12-15)

	APCC	WMOLC	ECMWF	NCEP	UKMO	JMA
AN	0.57	0.54	0.54	0.53	0.53	0.53
NN	0.52	0.52	0.54	0.52	0.52	0.51
BN	0.57	0.53	0.52	0.54	0.52	0.53

Available individual models for real-time forecast

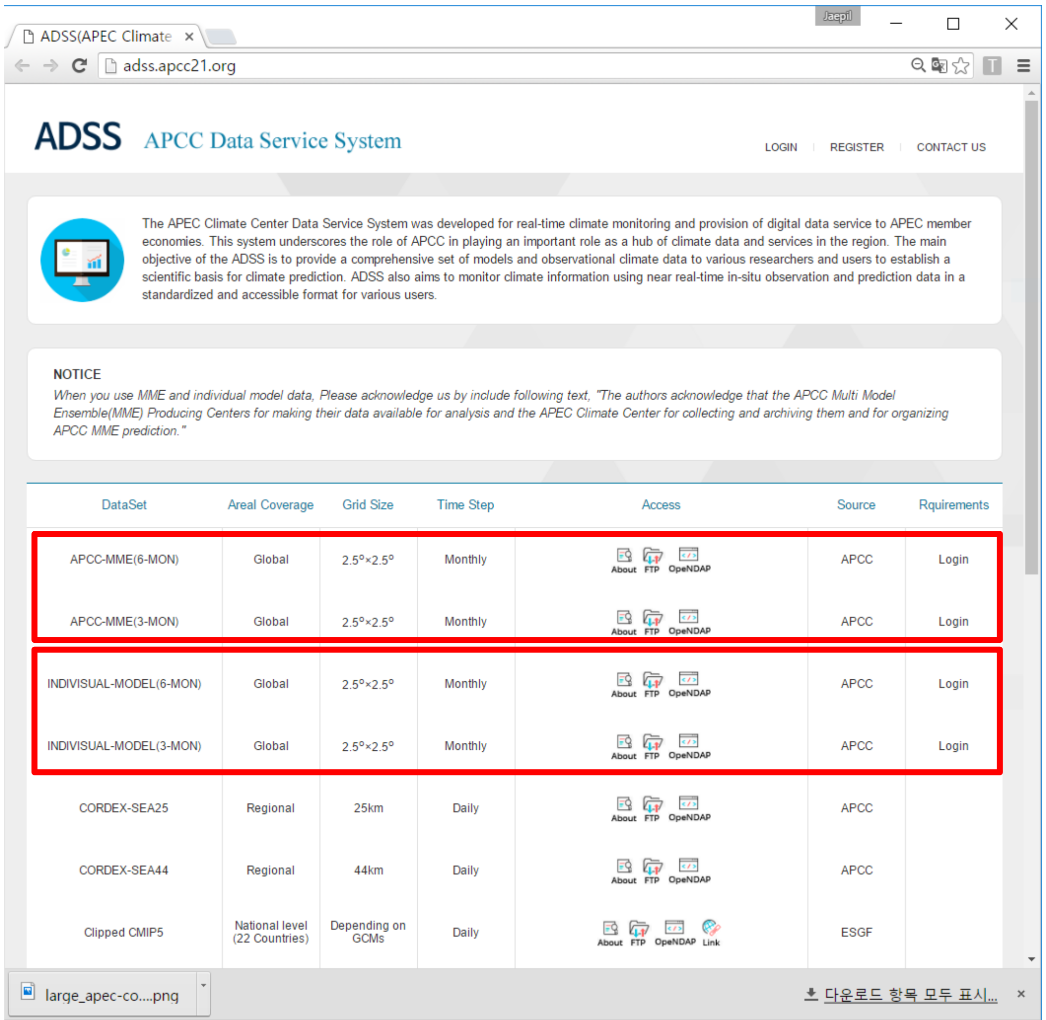
Model acronym	Institution(country)	Lead time	Ensemble size
BCC	Beijing Climate Center (China)	3 month	8
CWB	Central Weather Bureau (Taipei)	3 month	10
HMC	Hydrometeorological Centre of Russia (Russia)	3 month	20
IRI_CA	International Research Institute for Climate and Society (USA)	3 month	24
APCC	APEC Climate Center (Korea)	6 month	10
CMCC	Centro Euro-Mediterraneo sui Cambiamenti Climatici (Italy)	6 month	9
MSC	Meteorological Service of Canada (Canada)	6 month	20
NASA	National Aeronautics and Space Administration (USA)	6 month	9
NCEP	NCEP Climate Prediction Center (USA)	6 month	15
PNU	Pusan National University (Korea)	6 month	5
POAMA	Centre for Australian Weather and Climate Research /Bureau of Meteorology (Australia)	6 month	10

3MON: 4 GCMs, 6MON: 7 GCMs (1983~ current)

➡ Data can be downloaded from ADSS using sforecast package

Seasonal Forecast Data Services

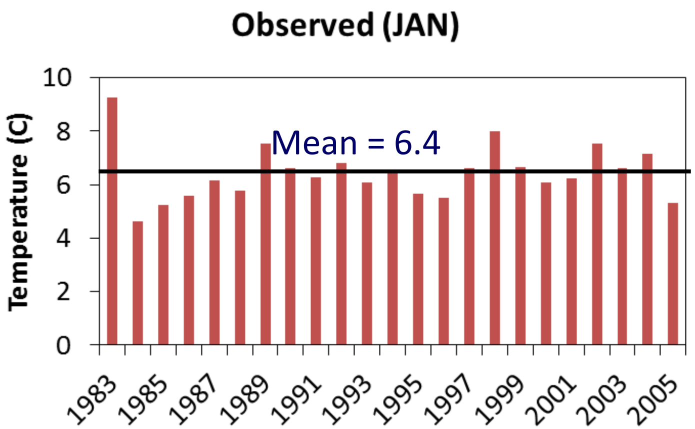
✓ APEC Climate Center Data Service System (ADSS)

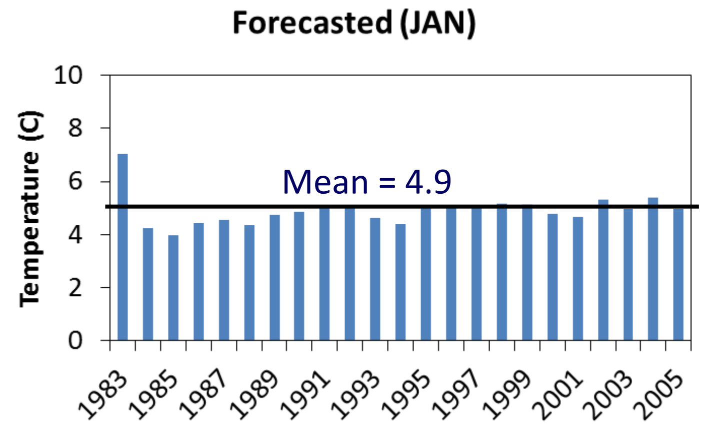


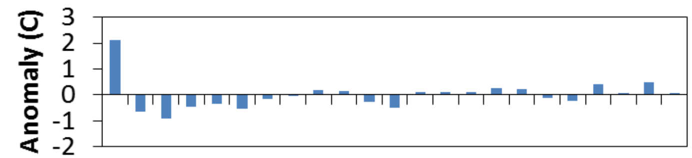
DataSet	Areal Coverage	Grid Size	Time Step	Access	Source	Rquirements
APCC-MME(6-MON)	Global	2.5°×2.5°	Monthly	About FTP OpenNDAP	APCC	Login
APCC-MME(3-MON)	Global	2.5°×2.5°	Monthly	About FTP OpenNDAP	APCC	Login
INDIVISUAL-MODEL(6-MON)	Global	2.5°×2.5°	Monthly	About FTP OpenNDAP	APCC	Login
INDIVISUAL-MODEL(3-MON)	Global	2.5°×2.5°	Monthly	About FTP OpenNDAP	APCC	Login
CORDEX-SEA25	Regional	25km	Daily	About FTP OpenNDAP	APCC	
CORDEX-SEA44	Regional	44km	Daily	About FTP OpenNDAP	APCC	
Clipped CMIP5	National level (22 Countries)	Depending on GCMs	Daily	About FTP OpenNDAP Link	ESGF	

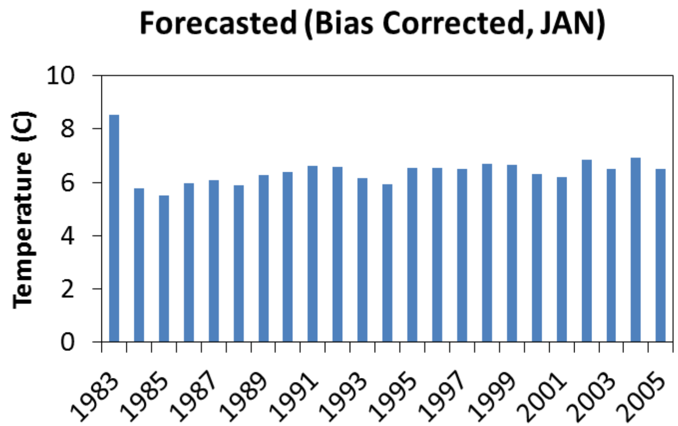
- ❖ Global scale data
- ❖ 2.5° x 2.5° spatial resolution
- ❖ Monthly time-scale
- ❖ 3- and 6-month lead time
- ❖ MME and Individual models
- ❖ Login is required

Simple Bias Correction (SBC)









- **Temporal**: same
- **Spatial**: same
- **Variable**: same

$$T'_{y,m} = (T_{y,m} - T_{hist,m}) + T_{obs,m}$$

$$P'_{y,m} = \begin{cases} (P_{y,m} - P_{hist,m}) + P_{obs,m} & \text{for } P_{y,m} \geq P_{obs,m} \\ (P_{y,m} \div P_{hist,m}) \times P_{obs,m} & \text{for } P_{y,m} < P_{obs,m} \end{cases}$$

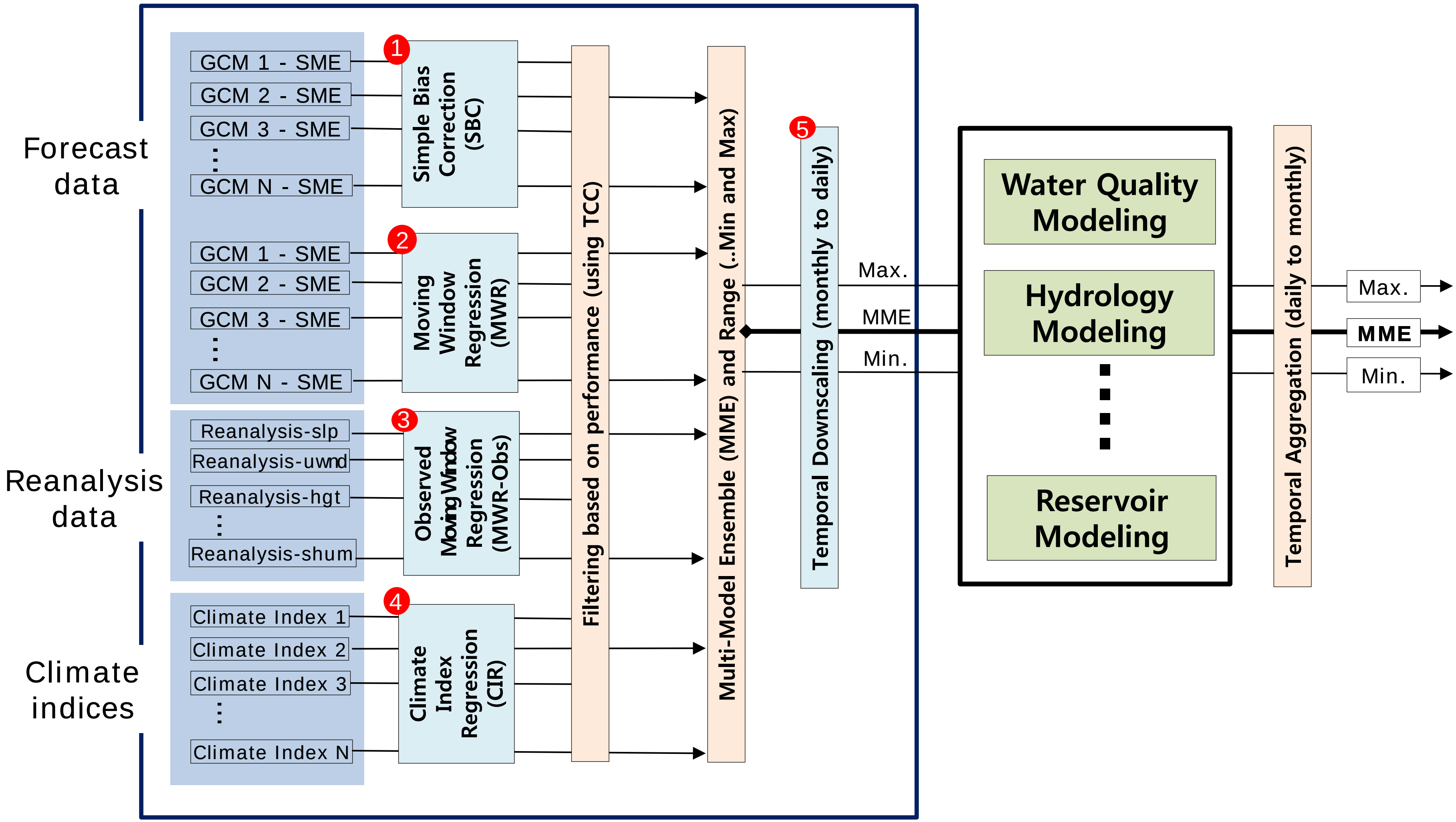
What is the added value of APCC MME?

Prediction skill for monthly precipitation on NorthEastern region in Thailand after bias correction using SBC

TCC	Lead Time											
	1-month		2-month		3-month		4-month		5-month		6-month	
	NCEP	MME	NCEP	MME	NCEP	MME	NCEP	MME	NCEP	MME	NCEP	MME
JAN		0.42		0.42								
FEB	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45		
MAR	0.48	0.48	0.48	0.48								
APR	0.44	0.72	0.69	0.72	0.42	0.70	0.46	0.70	0.45	0.64	0.45	0.65
MAY	0.42	0.60	0.42	0.57	0.42	0.53	0.42	0.52	0.42	0.49	0.44	0.44
JUN		0.44		0.44		0.44		0.44		0.44		0.44
JUL		0.62		0.40		0.40		0.40		0.40		
AUG		0.81		0.81		0.77		0.77		0.50		0.50
SEP												
OCT		0.43		0.43		0.43		0.43				
NOV		0.72		0.72		0.63		0.55		0.55		
DEC		0.40		0.40		0.40						

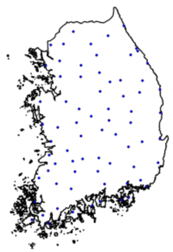
TCC: Temporal correlation coefficient
NCEP: CSFv2

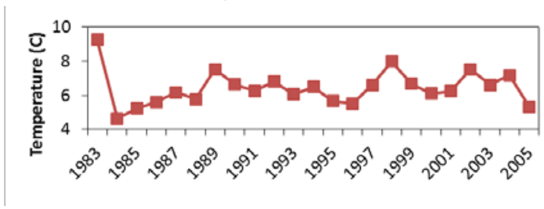
Integrated Downscaling System
- 3 more approaches to the SBC



Moving Window Regression (MWR): Indirect use of forecasts

Observed





Temperature
(JAN, 1983~2005,Korea)

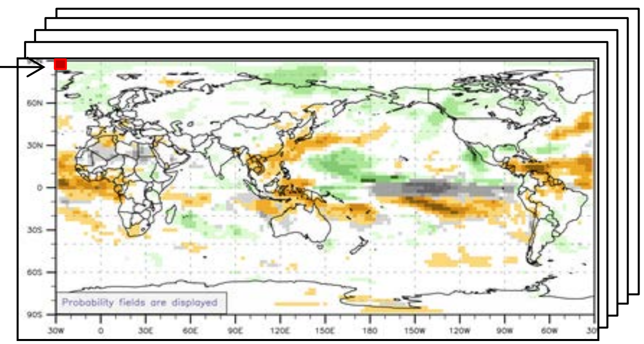
Temp = a *SLP + b

- **Temporal**: same
- **Spatial**: different
- **Variable**: different

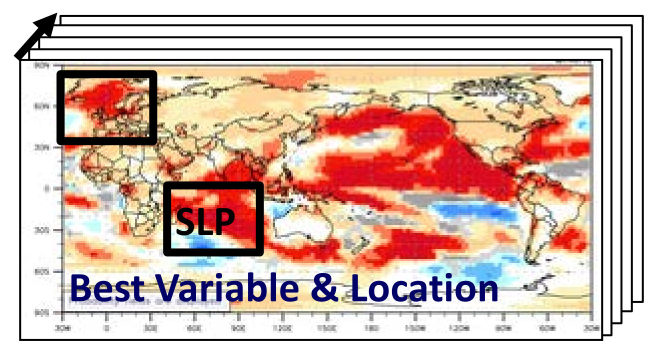
Forecasted

Models: BCC, CWB, HMC, IRI_CA, APCC, CMCC, MSC, NASA, NCEP, PNU, POAMA

Variables: PREC, T2M, T850, U200, V200, U850, V850, Z500, SLP, SST (JAN, 1983~2005)

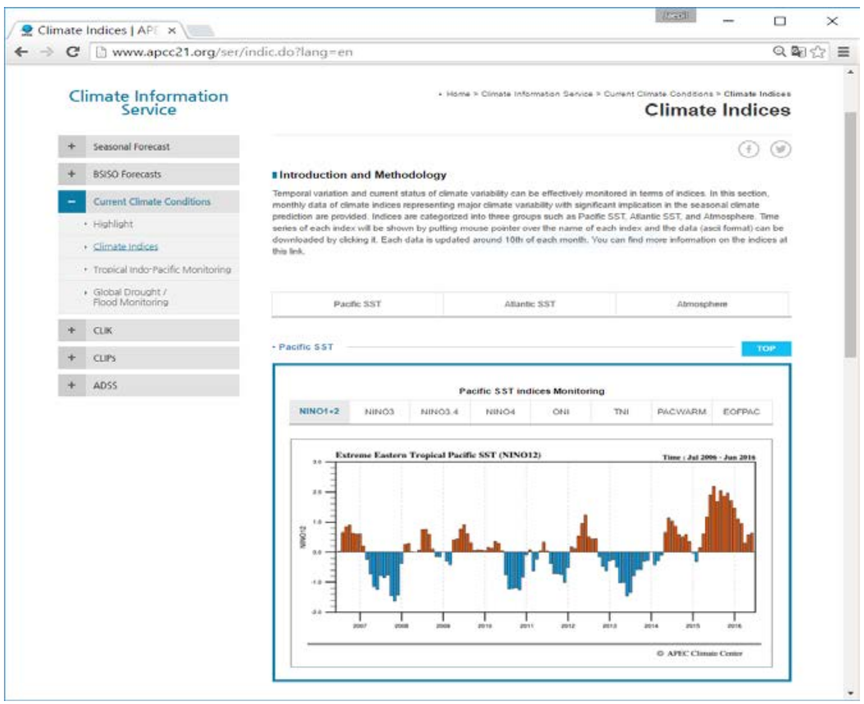


Temporal Correlation Coefficient (TCC)

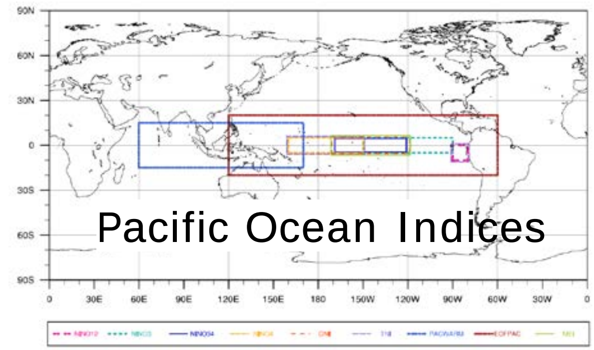


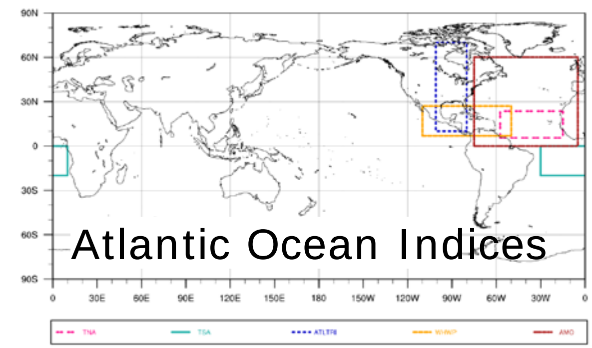
Climate Monitoring: Climate Indices

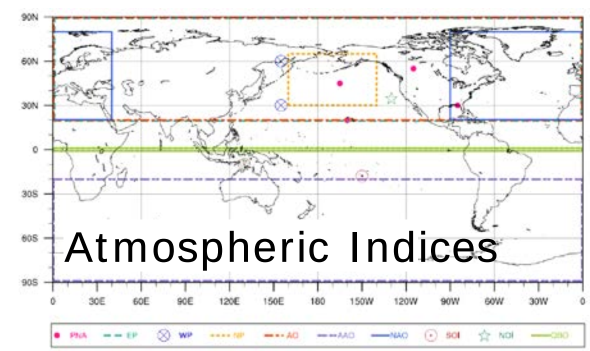
Temporal variation and current status of climate variability are effectively monitored in terms of indices. Monthly data of climate indices representing major climate variability with significant implication in the seasonal climate prediction are provided.



http://www.apcc21.org/ser/indic.do?lang=en

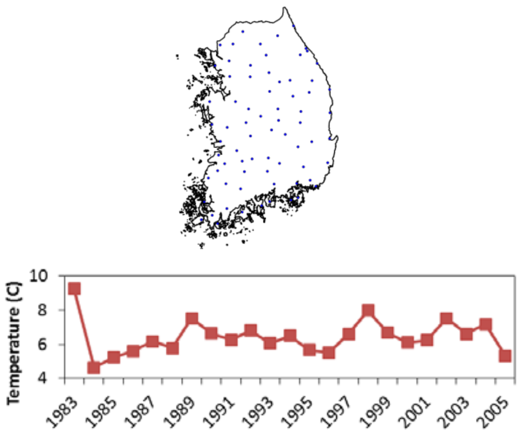






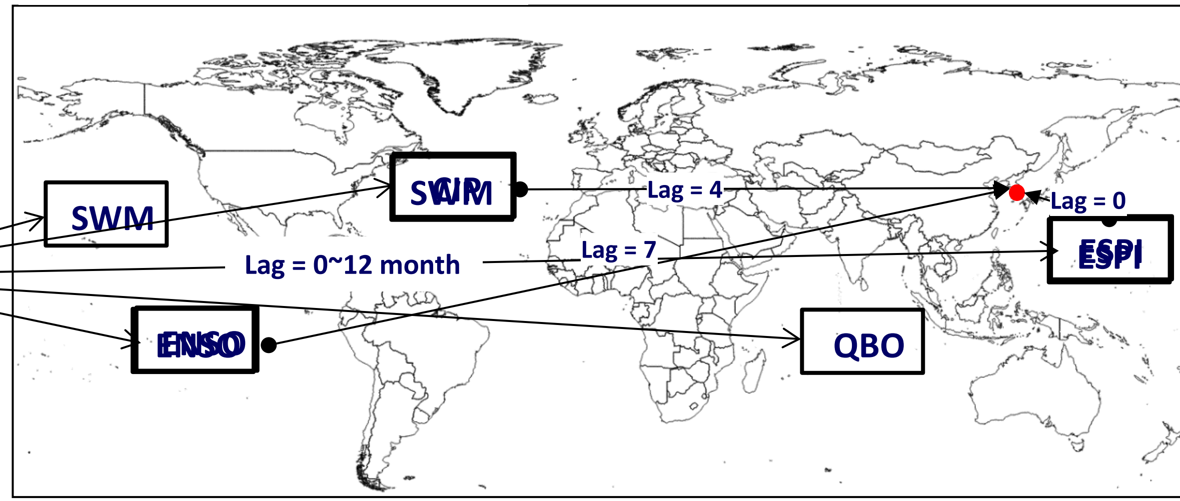
Climate Index Regression (CIR)

Observed



Temperature
(JAN, 1983~2005,Korea)

Climate Index from CPC



1. Linear regression (all CIs * Lags)
2. Select N best CIs and Lags
3. Decide multivariate regression model
   Y = a *ENSO_lag7 + b*ESPI_lag0 + c

Temporal Downscaling Method

Forecasted Area Average

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

Jan-81

Mahalanobis distance = f(prec, t2m)

Observed Area Average

yearmon	prec	t2m
Jan-73	0.673	-1.631
Feb-73	1.789	2.631
Mar-73	1.428	7.052
Apr-73	3.586	12.139
[illegible]	3.619	17.243
[illegible]	3.681	21.332
[illegible]	7.041	23.314
Aug-73	8.509	24.722
Sep-73	7.145	20.680
Oct-73	2.092	14.745
Nov-73	2.375	7.133
Dec-73	0.151	1.442
.	0.076	-1.409
.	0.123	-0.368
Jan-11	0.997	-1.826
Feb-11	2.313	1.354
Mar-11	2.659	5.750
Apr-11	0.904	12.704
May-11	4.124	17.254
Jun-11	6.330	20.626
Jul-11	10.191	25.146
Aug-11	4.078	27.135
Sep-11	6.269	20.657
Oct-11	3.736	14.392
Nov-11	0.783	8.224
Dec-11	0.972	1.381

ID135

date	prcp	tmax	tmin	wspd	rhum	rsds

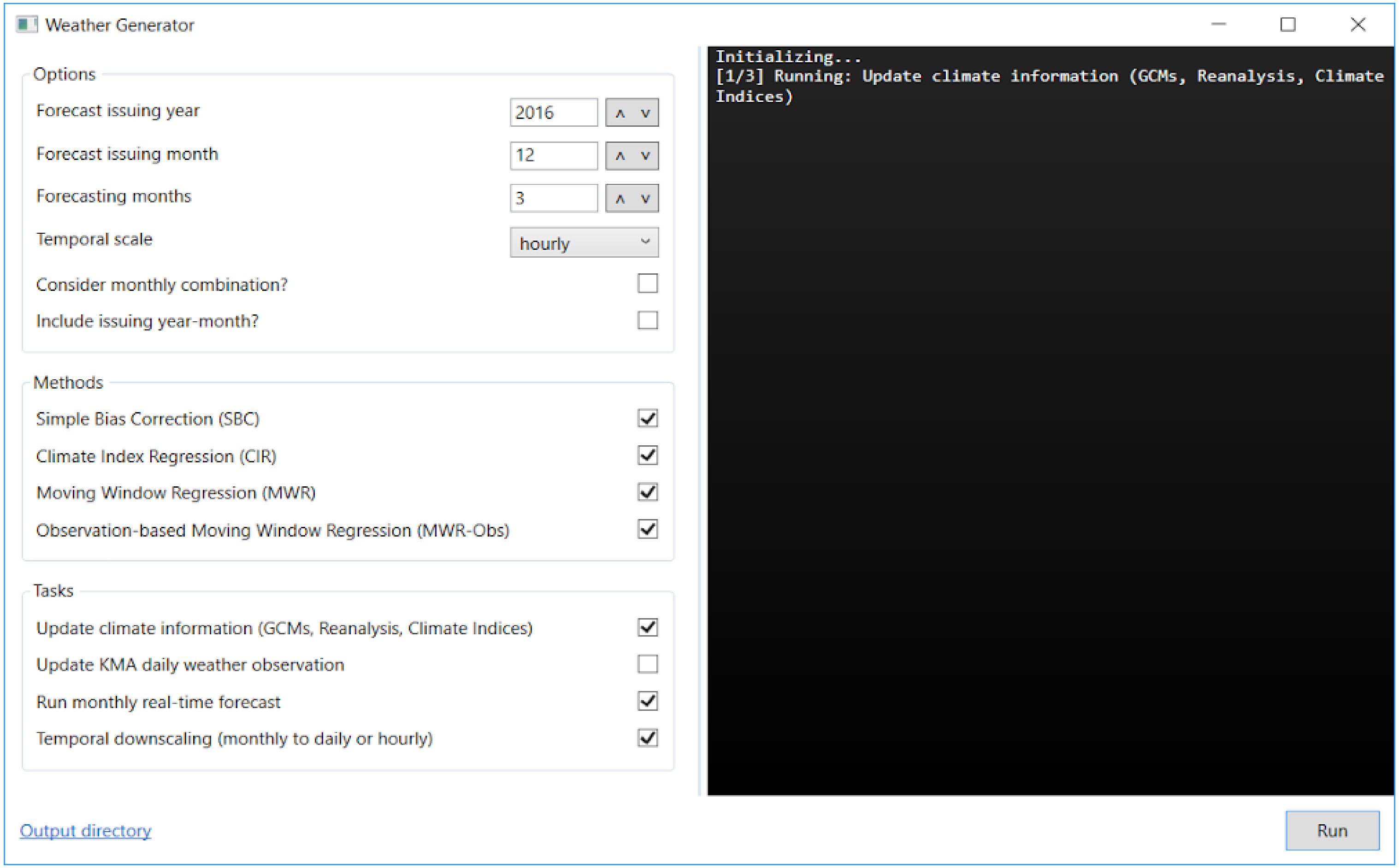
ID136

date	prcp	tmax	tmin	wspd	rhum	rsds

ID137

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

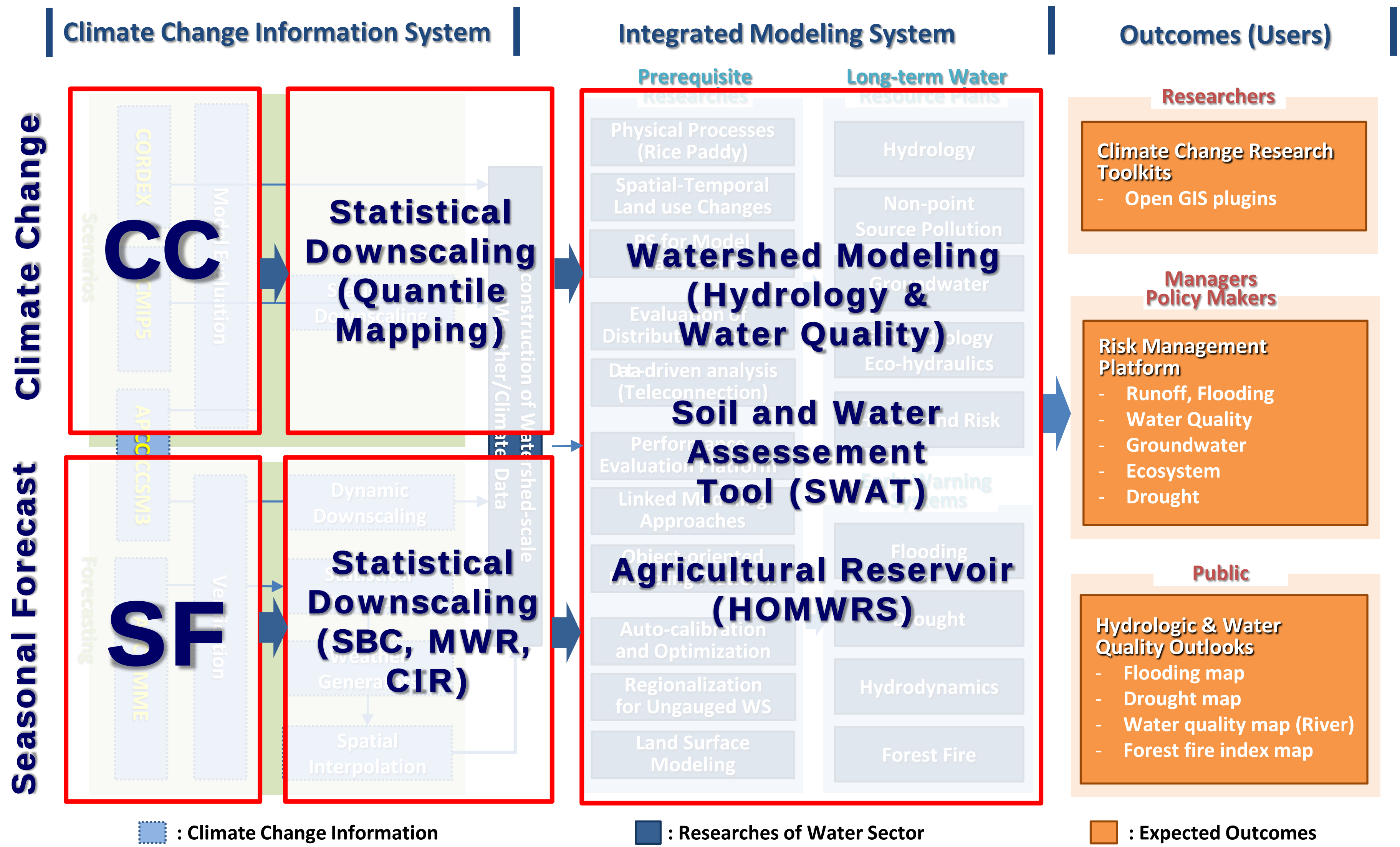
User interface for real-time forecast



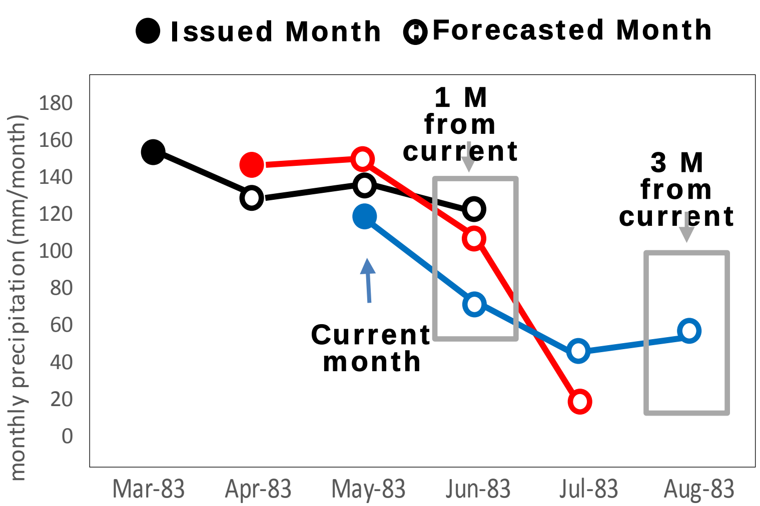
Hydrological Forecast

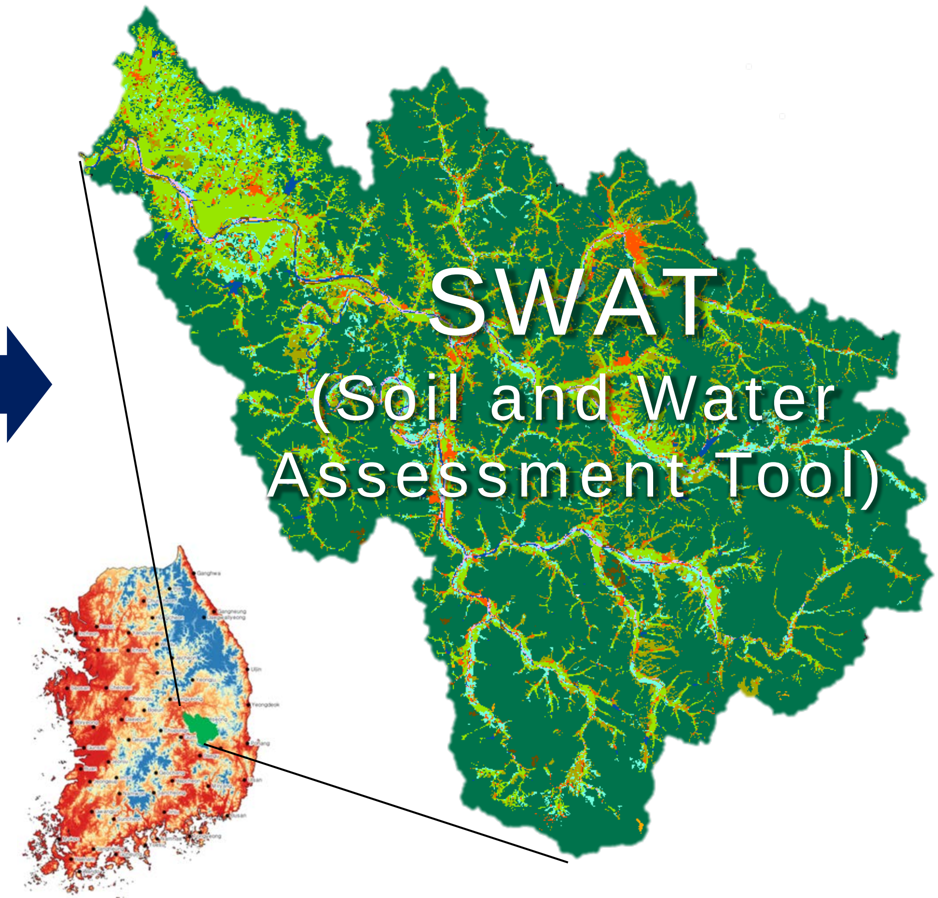
1. Water quality forecast
2. Storage level forecast

Framework of APCC Water Sector



Watershed modeling for WQ forecasting

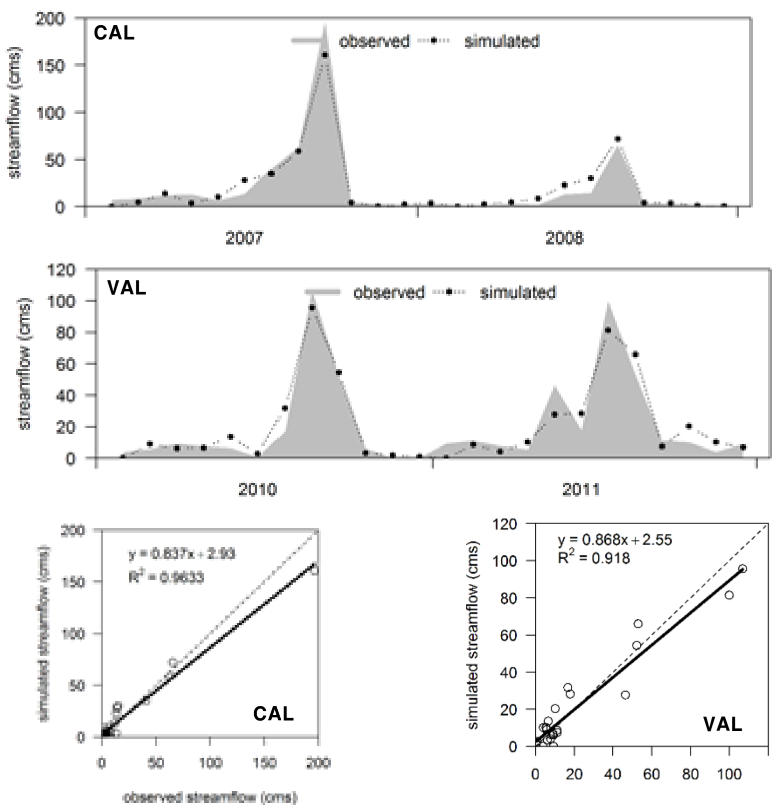




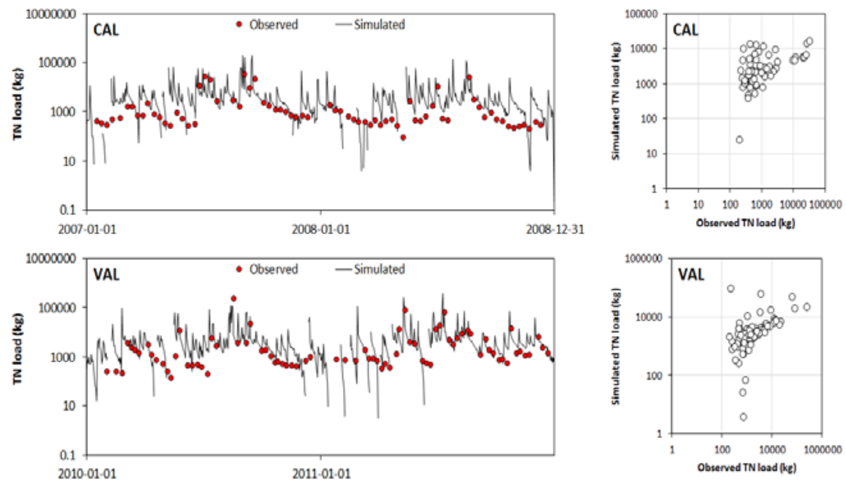
- **Initialization of streamflow and water quality was not considered**

SWAT Verification Results

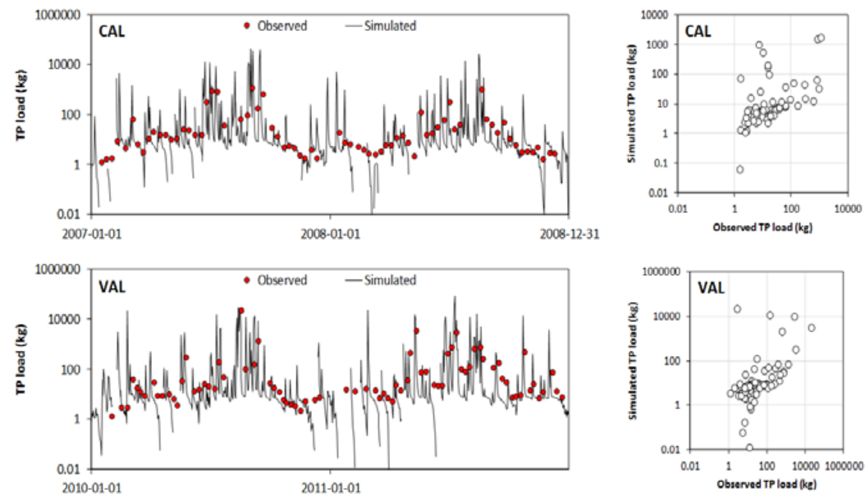
Performance measures	Calibration	Validation
% Error	-1.6	-1.1
Monthly NSE	0.95	0.92



Streamflow

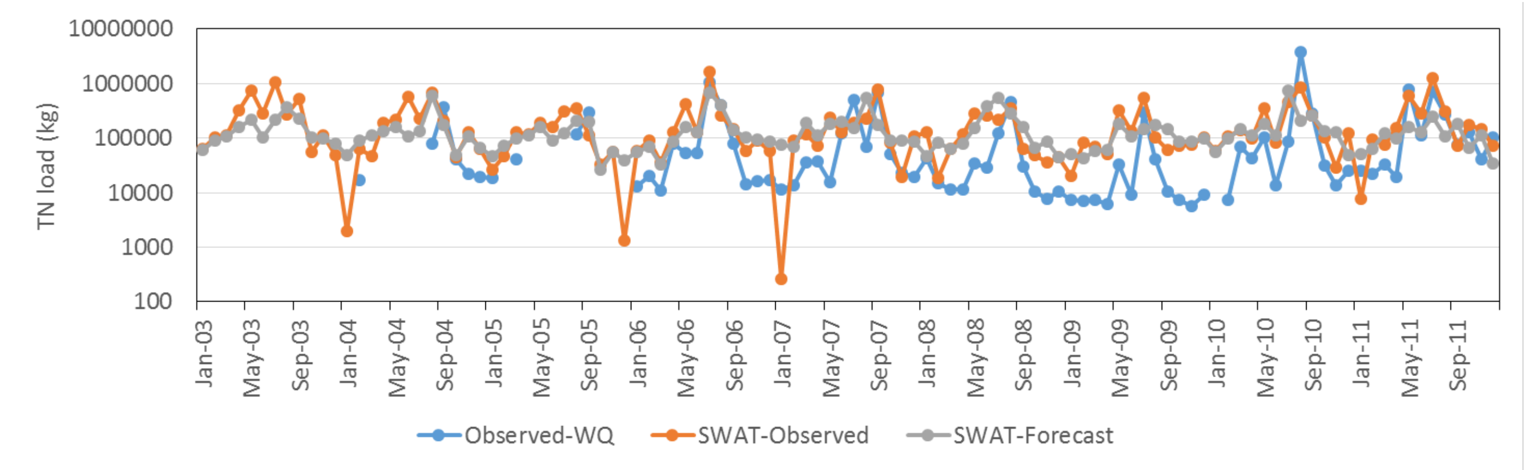


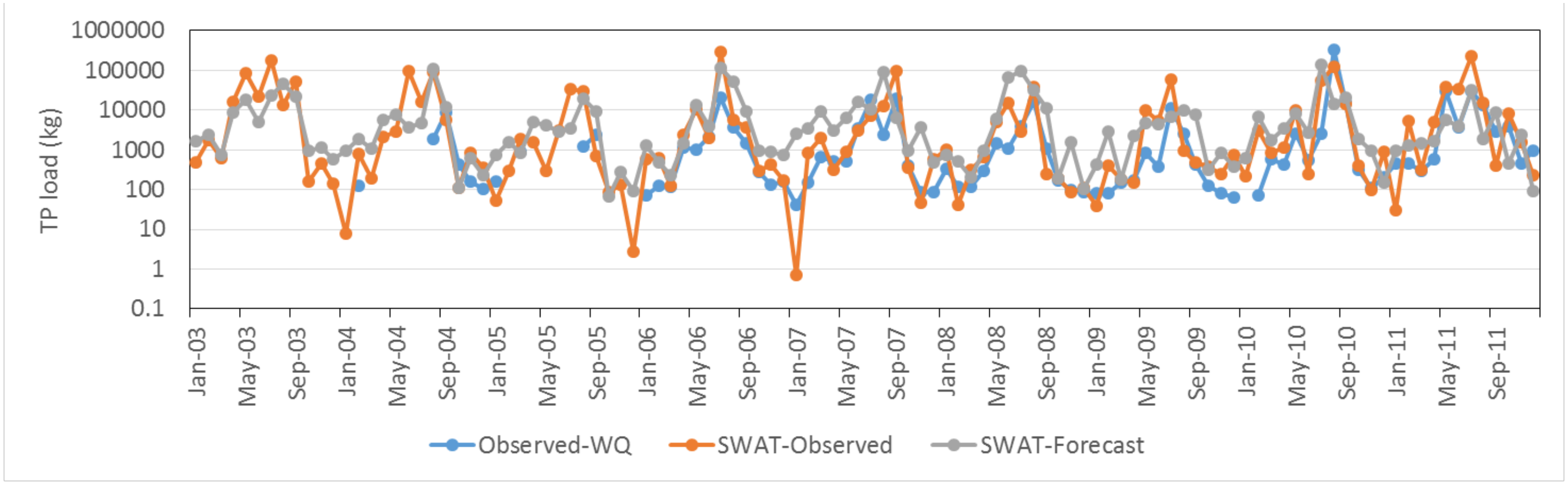
Total Nitrogen (TN) Loads



Total Phosphorus (TP) Loads

Monthly prediction of TN and TP Loads

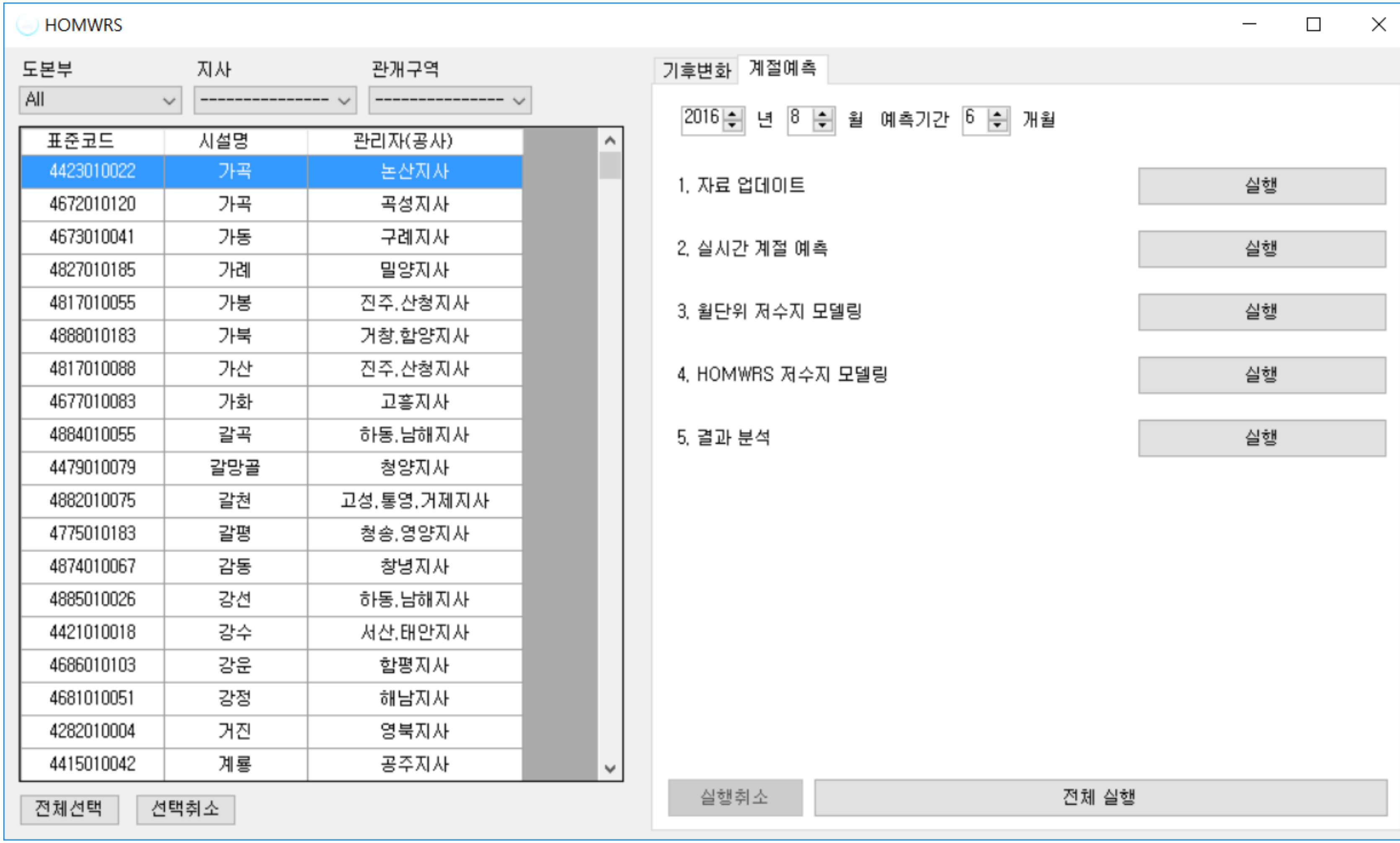




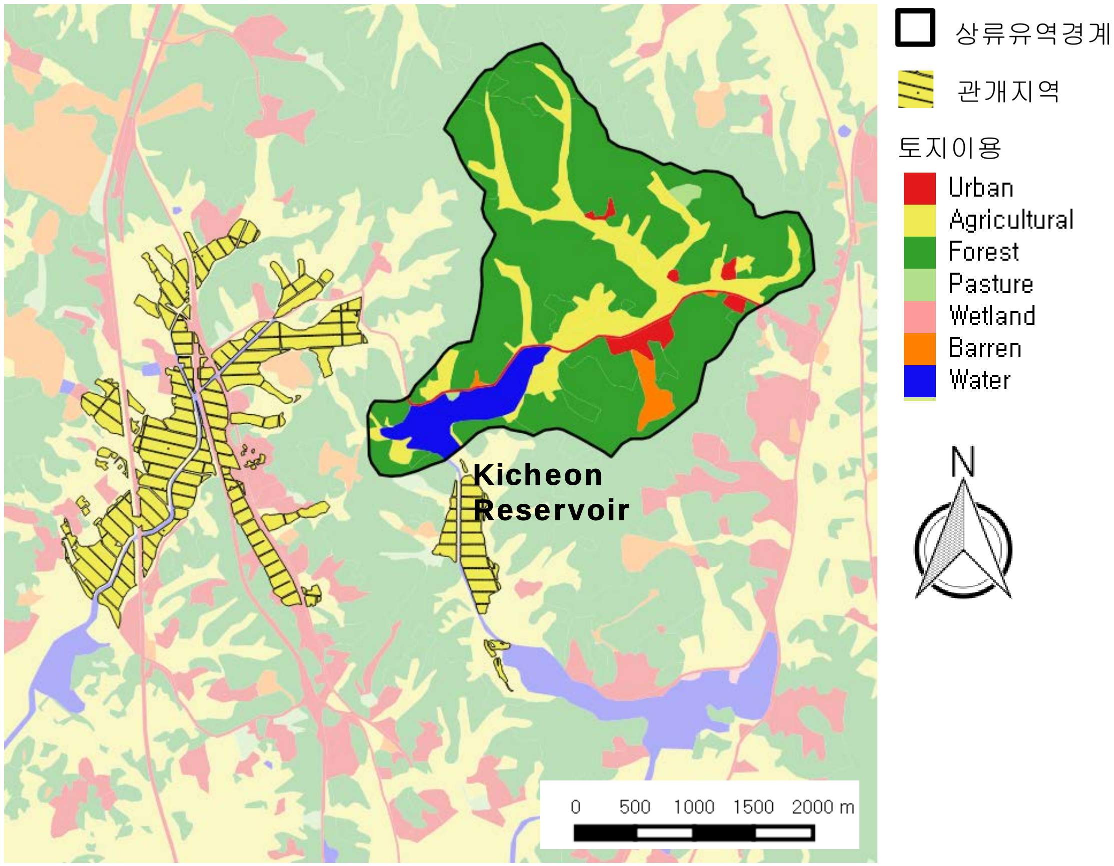
Monthly Temporal Correlation Coefficient

Month	Total Nitrogen (TN)		Total Phosphorus (TP)	
	SWAT-Forecast vs. Observed-WQ	SWAT-Forecast vs. SWAT-Observed	SWAT-Forecast vs. Observed-WQ	SWAT-Forecast vs. SWAT-Observed
JAN	-0.47	-0.27	-0.38	-0.08
FEB	0.01	0.00	-0.34	0.26
MAR	**0.72**	**0.67**	0.45	**0.68**
APR	0.40	**0.80**	-0.20	**0.71**
MAY	-0.34	**0.58**	-0.26	**0.74**
JUN	-0.05	0.00	-0.15	-0.10
JUL	-0.04	0.30	-0.46	0.27
AUG	-0.25	0.14	-0.30	0.14
SEP	0.31	0.29	0.31	0.07
OCT	-0.30	0.25	-0.14	-0.09
NOV	0.37	0.22	0.24	0.13
DEC	-0.62	0.37	-0.39	-0.02

HOMWRS for Long-term Water Level Prediction



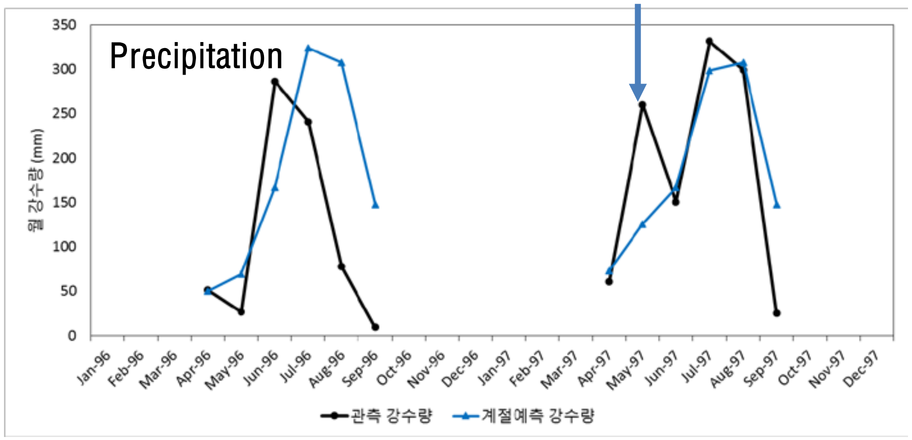
Seasonal Forecast Application for Kicheon Reservoir

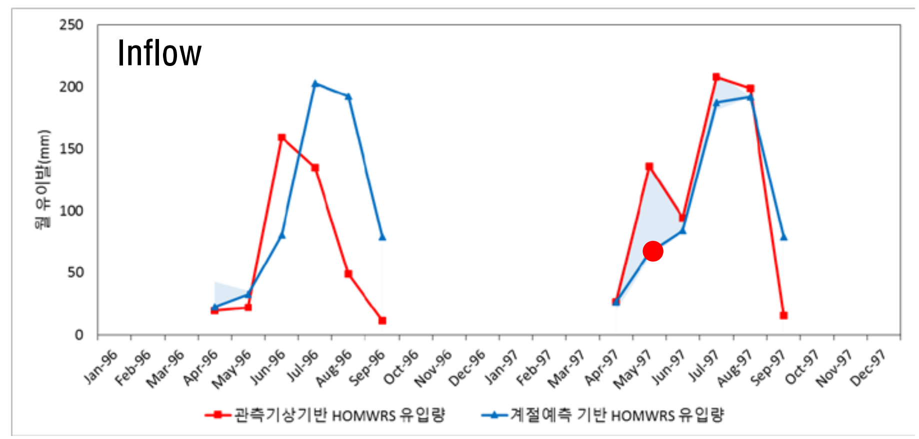


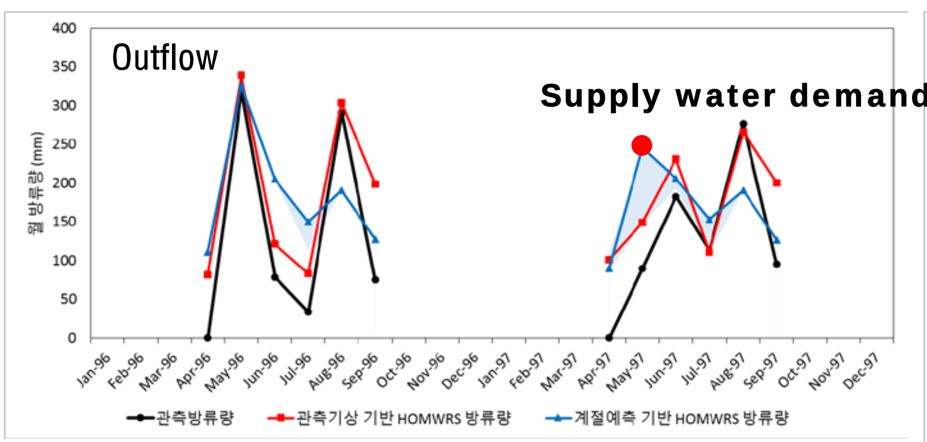
- **Kicheon reservoir**
  - Watershed area: 755 ha
  - Irrigation area: 270.7 ha
- **HOMWRS modeling**
  - Period: 1996 ~ 1997
  - 6 months forecast at every March

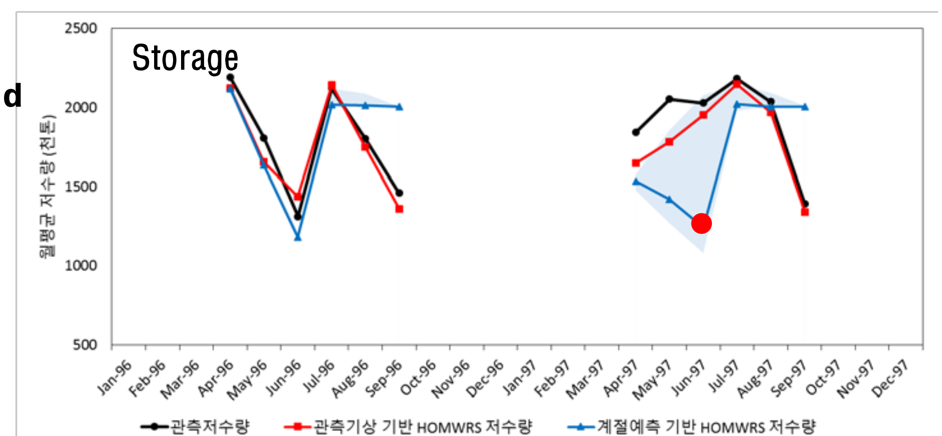
Seasonal forecast application result for Kicheon reservoir

- 1996 shows good agreement in storage level
- Underestimation of precipitation on May, 1997 resulted in overestimated water supply and underestimated storage level







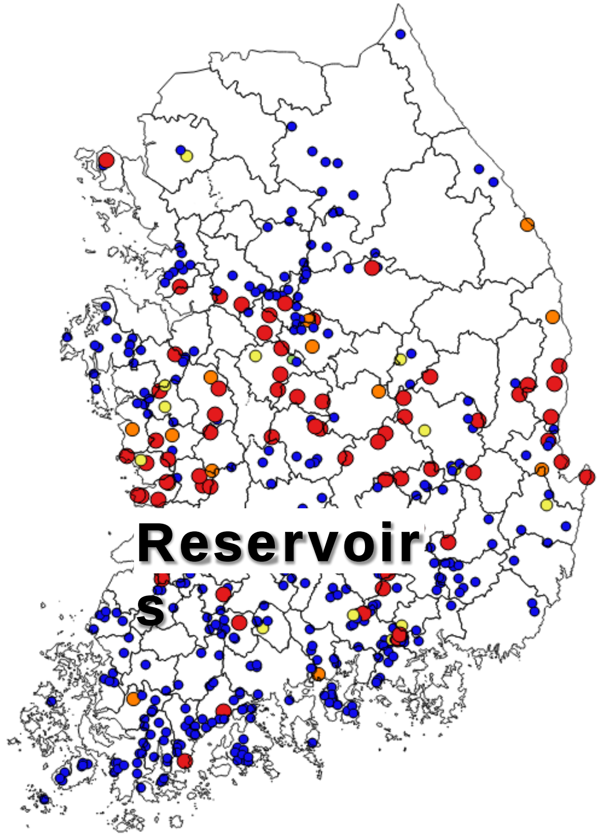


Expected outcome for decision-making

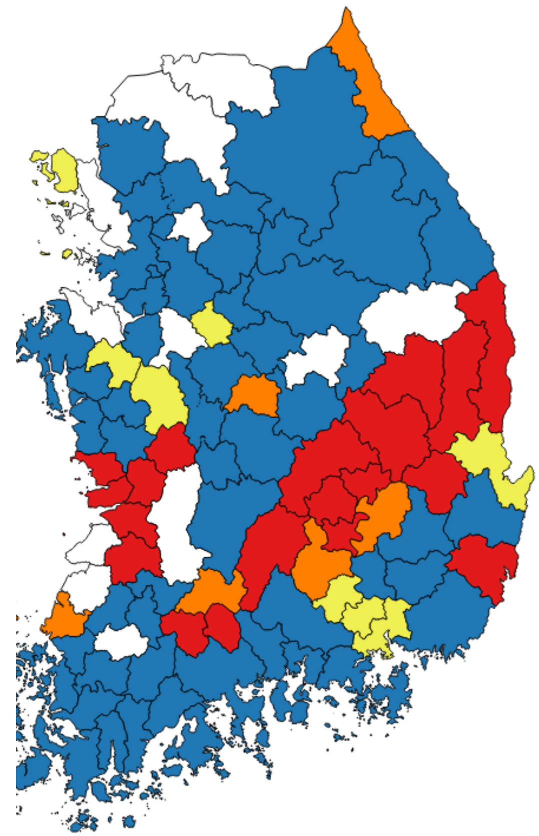
Drought alerting level for June 20th
(Forecast issued on January 15th)

Drought alerting levels

구분	농업용수 가뭄지표 정의(농어촌공사)
관심 (Blue)	농업적 가뭄발생 시기(4월~9월)
주의 (Yellow)	최근 2개월 누적강수량이 평년 대비 70% 미만이고, 농업용 저수지 저수율이 평년 대비 70% 미만인 때
경계 (Orange)	최근 2개월 누적강수량이 평년 대비 60% 미만이고, 농업용 저수지 저수율이 평년 대비 60% 미만인 때
심각 (Red)	최근 2개월 누적강수량이 평년 대비 50% 미만이고, 농업용 저수지 저수율이 평년 대비 50% 미만인 때

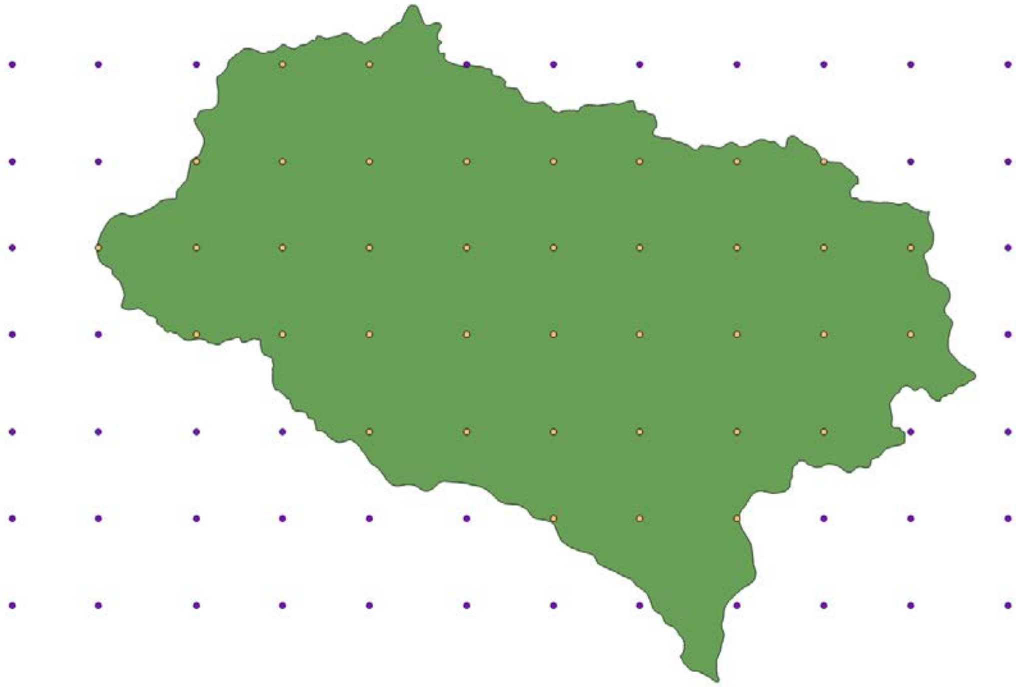


Individual reservoirs



KRC Branchs

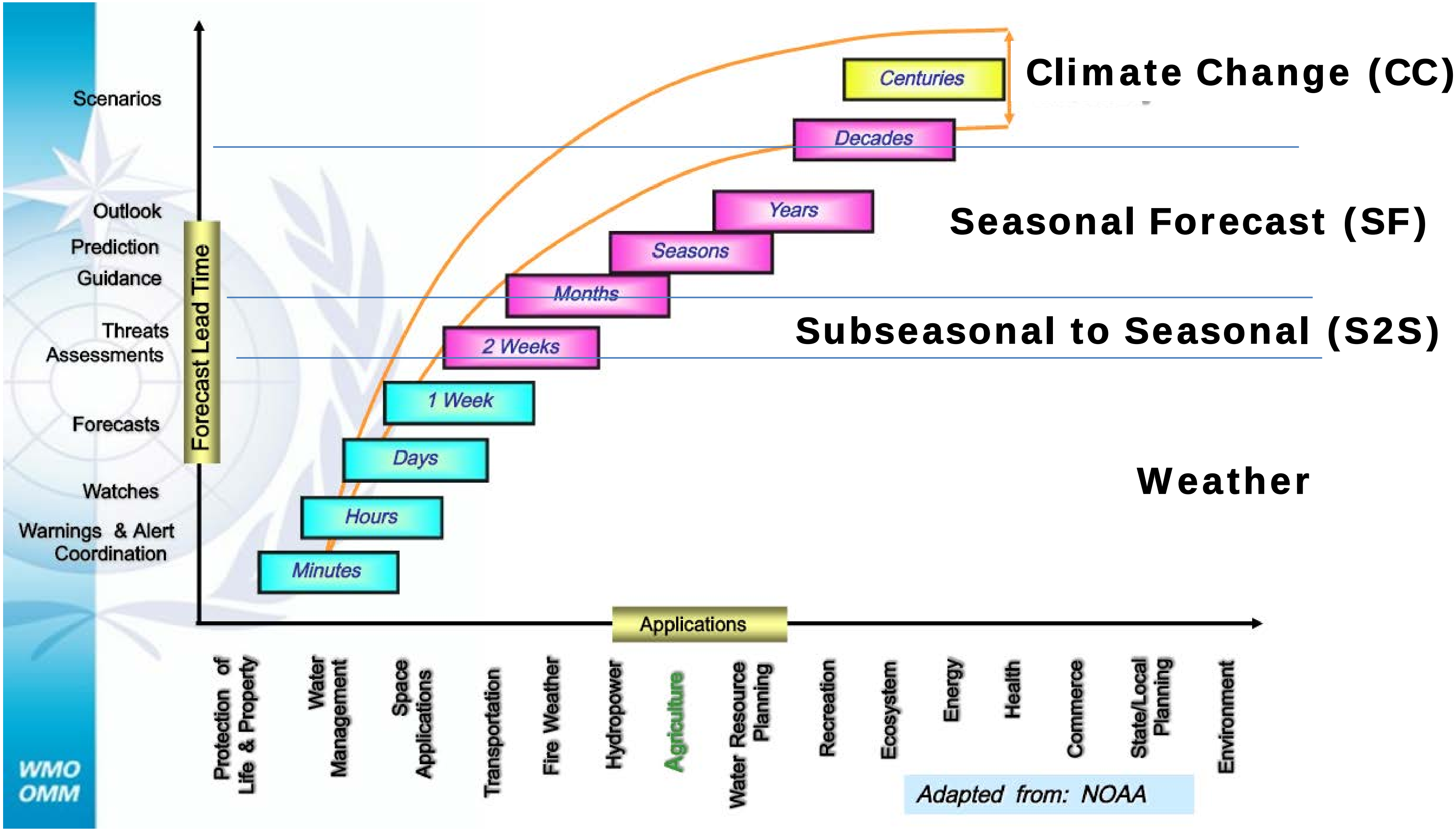
SWAT+



Introduction to Cli-WARA

Climate information-based Water-Agriculture Risk Assessment

Seamless Prediction and Services Framework

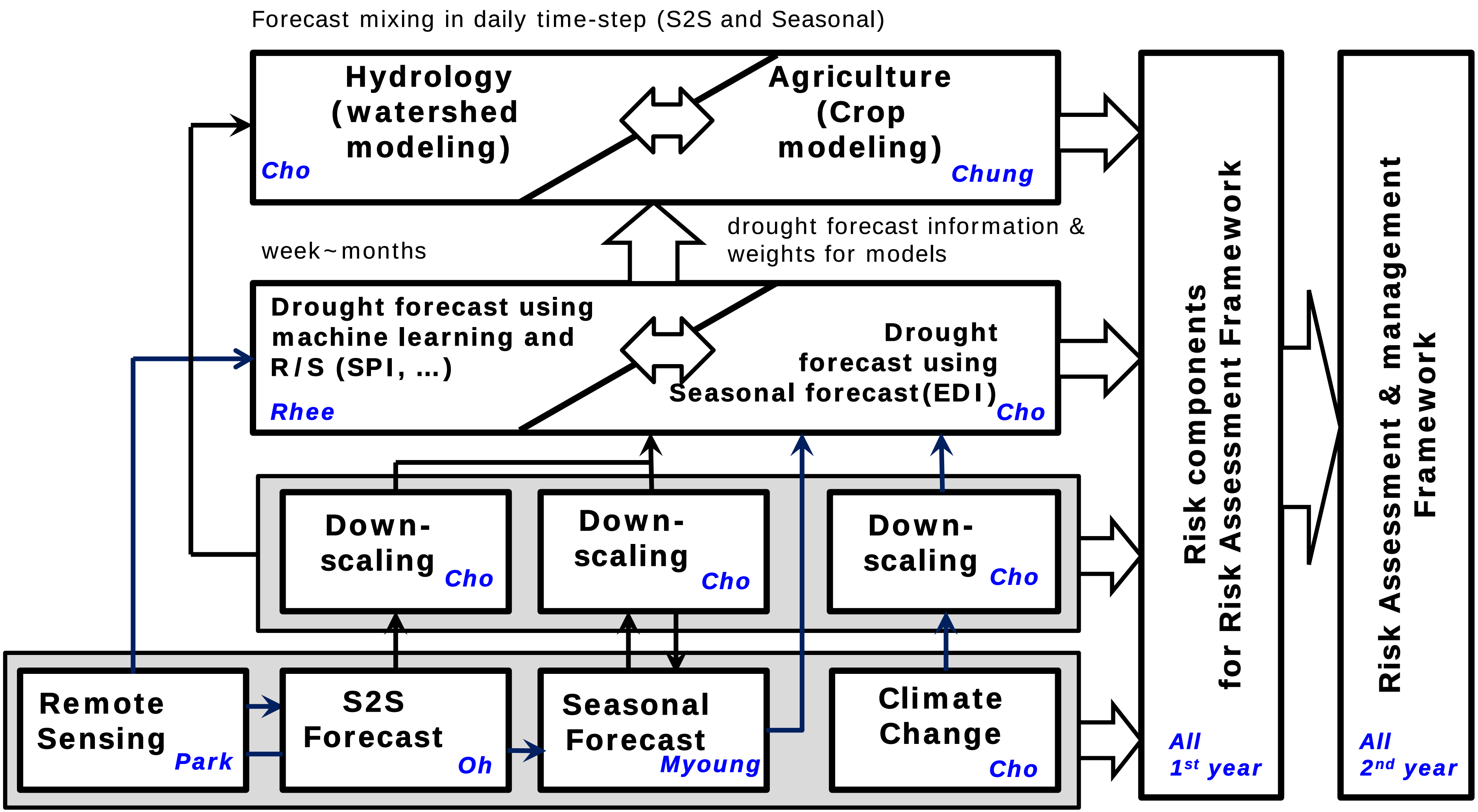


Source: http://slideplayer.com/slide/1447561/

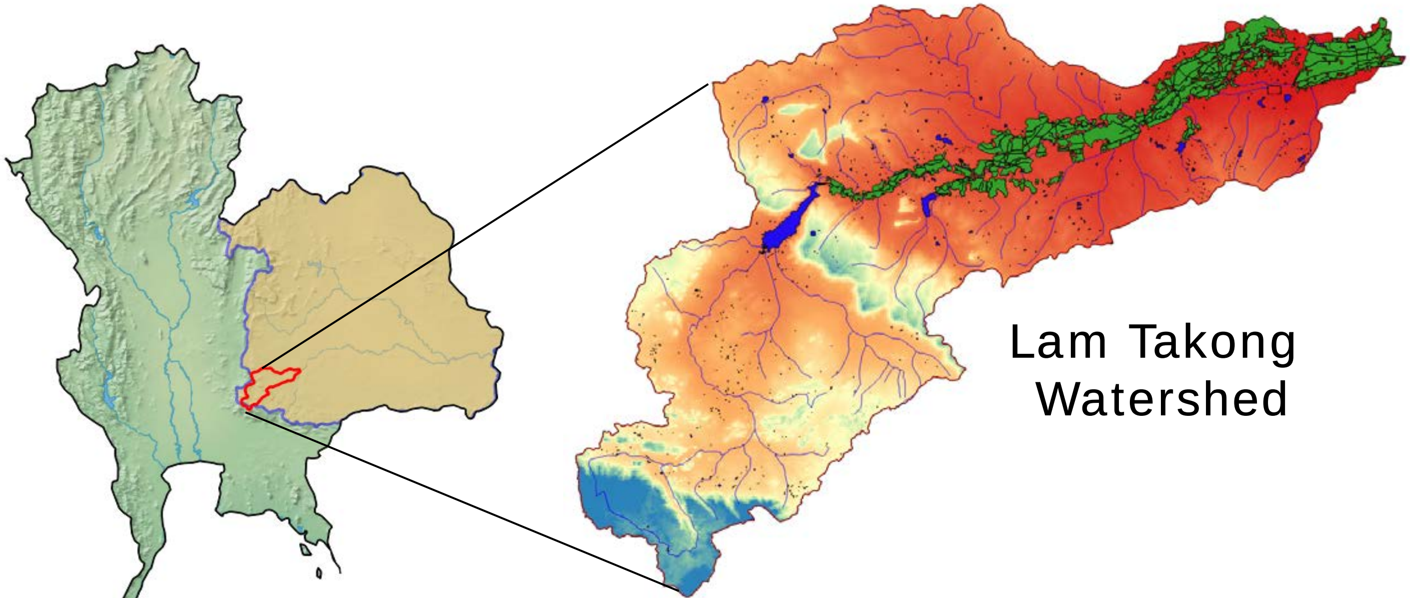
Objectives

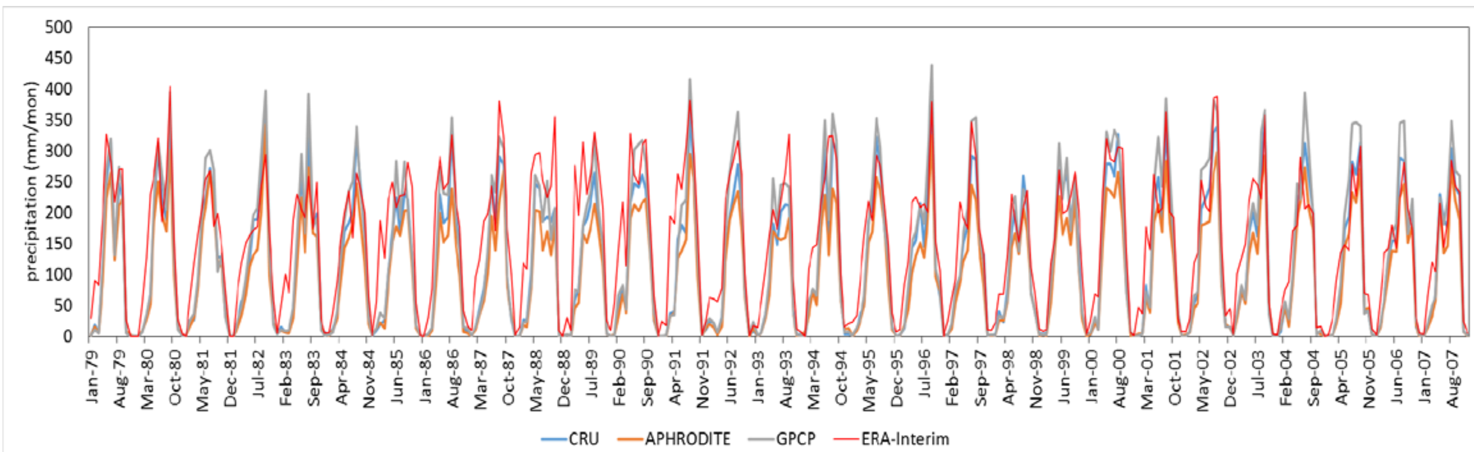
1. **To analyze the impact of various scales of climate variability**, e.g., BSISO, Indian Ocean Dipole (IOD), and El Nino Southern Oscillation (ENSO), and climate change on droughts in Thailand
2. **To apply downscaled climate information to agriculture and water resources** for understanding the impacts of climactic variability on Thailand's agricultural-water system
3. **To test improvement of the predictability** of drought, water resources, and agricultural production by employing probabilistic climate information in regional applications **based on the combined inputs of drought prediction, S2S, and seasonal forecasts**
4. **To develop a drought risk assessment (1st year) and management (2nd year) framework** to support decision-making for water management and agricultural production improvement
5. **To disseminate the representative multi-disciplinary case study** that can be applied or extended to other regions, **including other parts of Thailand**

Project Overview



Study Area and grid-observations





Outcomes

- **Climatic Analysis**
  - Climatic knowledge information (physical/dynamical mechanism verification, etc.) for improving predictability of seasonal forecasting
  - S2S Predictability Assessment in Thailand
  - S2S and seasonal variability of rainfall and key factors in Thailand
  - Meteorological evaluation of statistically-driven seasonal predictors
  - Drought case analysis and key factors
- **Downscaling**
  - Downscaling methods of S2S prediction and mixing methods of S2S and seasonal prediction downscaled
  - Generation of downscaled climate projections that preserve multivariable correlations
  - Assessment of future projections of the downscaled climate change scenario data
  - Estimate and evaluate various future extreme climate indices
- **Drought Forecasting**
  - Assessment on utilization watershed drought information of ESA Sentinel Satellite
  - Prediction module for Effective Drought Index (EDI) based on downscaled precipitation forecasting
  - Drought forecasting information using spatial information of satellite data in Thailand / the weights between models for application of agriculture and water resource modeling
  - Estimation and comparison of drought indices based on forecasted precipitation and machine learning
- **Agricultural and Hydrological Modeling**
  - Assessment of agricultural production using downscaled data and drought information which are improved predictability
  - The modeling of agricultural production according to change of agricultural managements (e.g., rotation)

KWPA-APCC Collaborative Project

1. Original concept note
2. Preliminary seasonal predictability (SBC)
3. Discussions

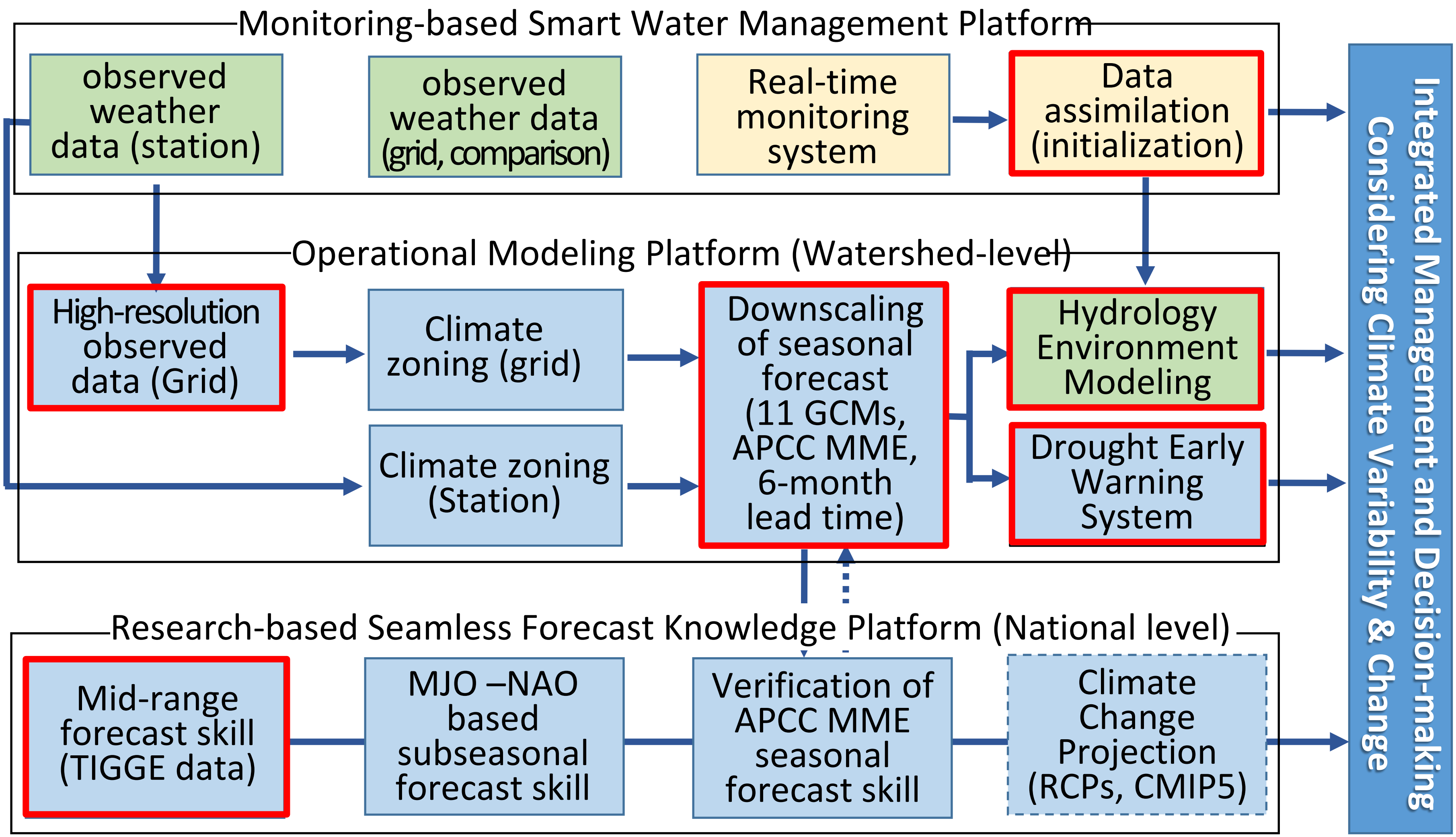
Applying Climate Expertise toward Tailored Forecasts in Agriculture and Water Resources Management

- **Any <u>reliable climate forecasts will be highly valuable for real-time decision making</u> for all sectors impacted by climatic conditions in Iran, specifically Khuzestan province.**
- **Located in a semi-arid area, Khuzestan province is highly influenced by repetitive droughts, severe floods, high temperature and frequent dust storms.**
- **Having a wide range of responsibilities followed by <u>complexities associated with uncertain weather and climate however, decision makers face serious challenges</u> in management side.**
- **Therefore, reliable data especially in terms of hydroclimate forecasts having appropriate spatiotemporal resolution plays a substantial role in several aspects**

Objectives and Contents

- **Understanding of physical mechanisms** contributing to climate variability at sub-seasonal to interannual time scale
- **Evaluating predictability at sub-seasonal to interannual time range** over 6 main river basins in Iran will be analyzed
- **Climate zones will be determined** over three river basins Khuzestan province
- **Producing high resolution gridded datasets** for precipitation and temperature at daily and monthly time scale
- **Statistical downscaling** of dynamic seasonal climate model outputs
- **Developing a system to detect and forecast drought** based on several meteorological drought indices
- **Capacity building programs** that might include organizing training programs, research exchange

Strategic plan on the collaborative project



Project scope that KWPA is interested

- Understanding of physical mechanisms contributing to climate variability at sub-seasonal to interannual time scale
- Evaluating predictability at sub-seasonal to interannual time range over 6 main river basins in Iran will be analyzed
- Climate zones will be determined over three river basins Khuzestan province
- Producing high resolution gridded datasets for precipitation and temperature at daily and monthly time scale
- Statistical downscaling of dynamic seasonal climate model outputs
- Developing a system to detect and forecast drought based on several meteorological drought indices
- Capacity building programs that might include organizing training programs, research exchange
- Hydrological forecast

Possible Team Members

Dr. Jaepil Cho (PI)

Dr. KyungWoon Park

Dr. Boksoon Myoung

Dr. Jinyoung Rhee

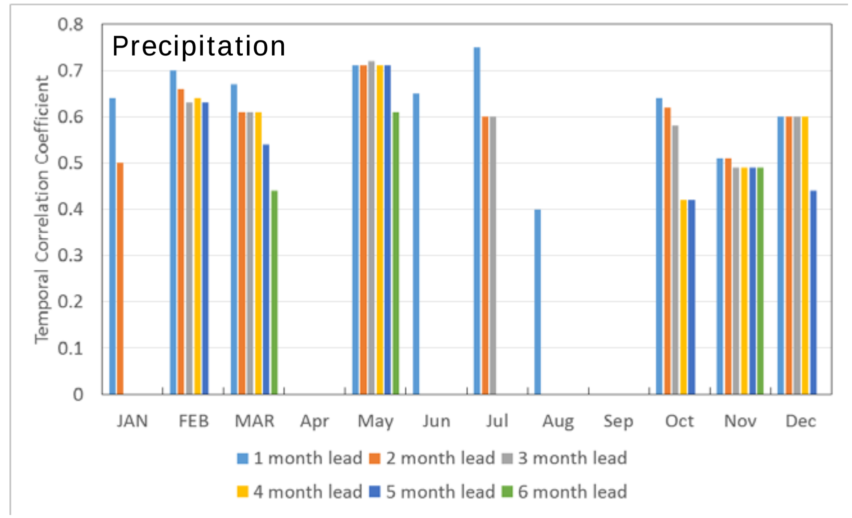
Dr. Ji-Hyun Oh

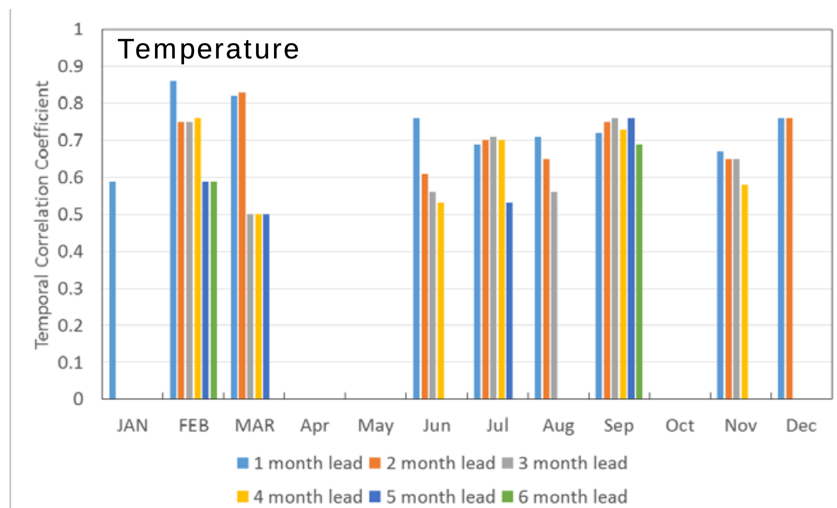
SWAT Group

PKNU Group
(Dr. Byun and Kim)

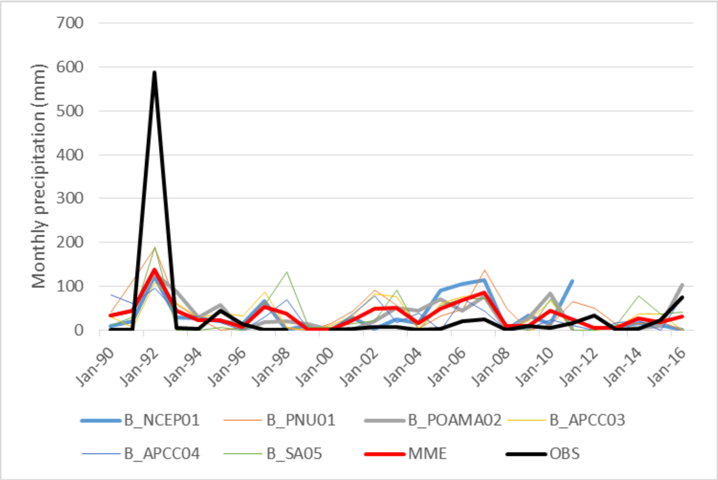
Preliminary predictability of seasonal forecast on Ahwaz region

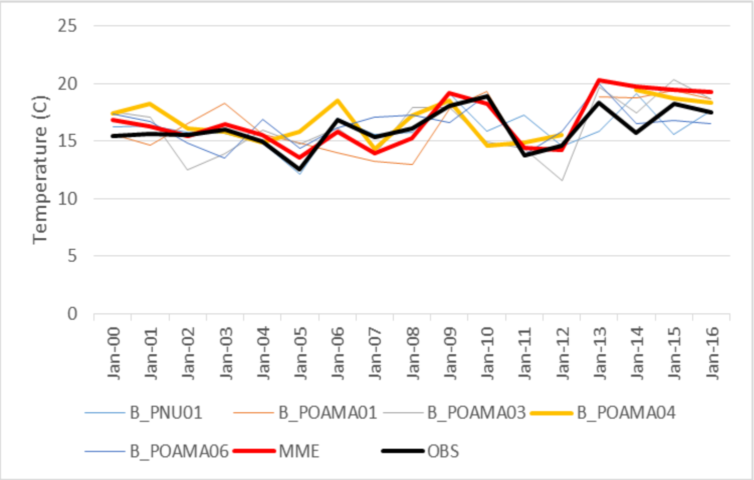
- Observed data from GHCN
- Using SBC method



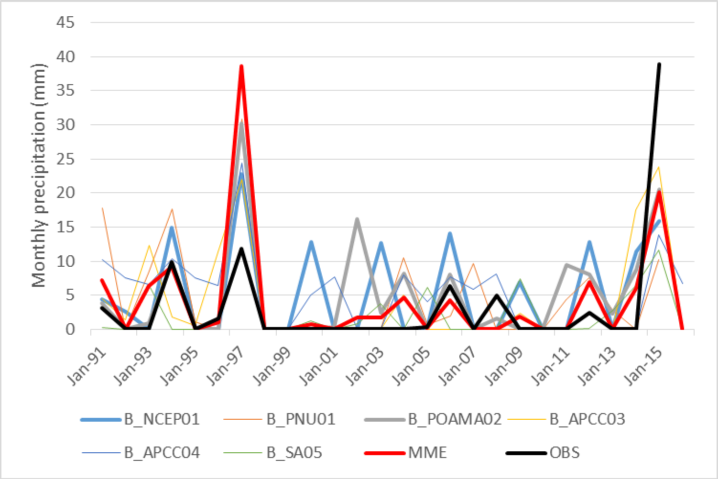


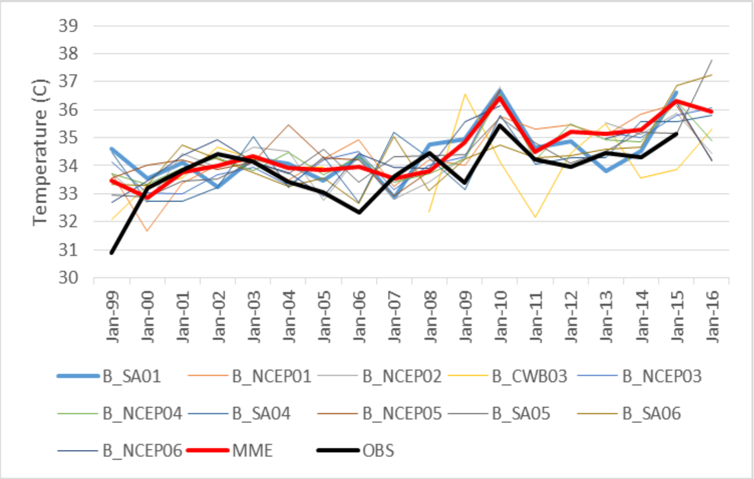
Preliminary predictability of seasonal forecast on Ahwaz region





Feb- 1LT





Sep- 1LT

Precipitation **Temperature**

감사합니다
تشكر