

TRAVEL REPORT FORM

출장보고서

결 재	연구원	과장	부서장직 무대행	원장
	06/18	06/18	06/19	06/19
협 조	한수희	문상원	문상원	권원태
	과장	부서장		
	06/18	06/18		
	민영미	유진호		

I. Travel Overview 출장개요

1. Traveler(s) 출장자

Department 소속	Position 직위(직급)	Name 성명	Note 비고
APCC	원장	권원태	2019년도 국제 기후예측 워크숍 및 제3차 APCC MME 모델제공기관 회의 개최, 운영 및 참석
기후사업본부	본부장	유진호	
기후사업본부 예측운영과	과장	민영미	
기후사업본부 예측운영과	선임연구원	양유빈	
기후사업본부 예측기술과	선임연구원	함수련	
기후사업본부 예측기술과	선임연구원	이윤영	
경영지원실 대외협력과	사원	한수희	

2. Travel Period 출장기간

- 원장, 유진호, 민영미, 양유빈, 함수련 : 6/2(일) - 6/7(금) <5박 6일>
- 이윤영 : 6/2(일) - 6/5(수) <3박 4일>
- 한수희 : 6/1(토) - 6/7(금) <6박 7일>

3. Occasion and destination 행사 및 출장지

- 행사명 : 2019년도 국제 기후예측 워크숍 및 제3차 APCC MME 모델제공기관 회의
- 출장지 : 대만(Chinese Taipei), 타이페이(Taipei)

II. Major Activities 주요업무 수행내용

1. Main Contents and Activities 주요내용 및 활동

※ 국제 워크숍 및 모델제공기관 회의 회의록, 발표자료 및 세부사항은
2019년도 국제 기후예측 워크숍 및 제3차 APCC MME
모델제공기관회의 최종 결과보고를 통해 추후 보고 예정

□ 2019년도 국제 기후예측 워크숍

○ 행사 개요

- 행사명 : 2019년도 국제 기후예측 워크숍
 - 영문명 : 2019 International Workshop on Climate Prediction: Past, Present, and Future
- 주 제 : 계절 및 계절내 기후예측의 현재와 미래
 - 영문명 : Present and Future of Sub-Seasonal and Seasonal Climate Prediction
- 기 간 : 2019. 6. 3(월) - 4(화) <2일간>
- 장 소 : 대만 기상청 국제회의장
- 주 최 : APCC 및 대만기상청(Central Weather Bureau)
- 참가자 : 전세계 MME 생산 및 제공 기관, 기후예측 모델자료 생산 및 제공기관, 기후예측 연구진 등 100인 내외

○ 주요 활동

- 국제 워크숍 개최와 관련된 제반사항 운영 및 관리
 - ※ 총 15인의 발표자 및 100여명 참석자 참여
- 국제 워크숍 발표 및 세션 관리
 - 세션 1에서 민영미 예측운영과장, 세션 3에서 이윤영 선임연구원 발표
 - 유진호 기후사업본부장 기조연설 세션 좌장 및 세션 4에서 패널토론자로 참여
 - 민영미 과장, 함수련 선임연구원, 한수희 사원 세션 주요내용 기록
 - 포스터 세션에서 APCC 연구내용 발표(작성자 : 기후분석과 김선태 선임연구원, 예측운영과 임아영 연구원 / 발표자 : 예측기술과 함수련, 이윤영 선임연구원)

□ 제3차 APCC MME 모델제공기관 회의

○ 행사 개요

- 행사명 : 2019년도 국제 기후예측 워크숍
 - 영문명 : The 3rd APCC MME Model Providers' Meeting

- 기 간 : 2019. 6. 5(수) - 6(목) <2일간>

- 장 소 : 대만 기상청 회의실(614호)

- 참가자 : APCC MME 모델제공기관 담당자 11개기관 11인, 대만기상청 관계자, APCC 직원 등 21인

※ APCC MME 모델제공기관 총 14개 기관 중 호주기상청(BOM), 캐나다기상청(MSC), 일본기상청(JMA), 유럽지중해기후변화센터(CMCC), 국립기상과학원(NIMS), 부산대학교(PNU), 러시아수문기상센터(HMC), 러시아지구물리관측소(MGO), 대만기상청(CWB), 미국기상청(CPC/NOAA), APCC 11개 기관 참석

○ 주요 활동

- 모델제공기관 회의 운영에 관련된 제반사항 관리

- 국제 워크숍 발표 및 세션 관리

· 세션 1에서 민영미 과장, 양유빈 선임연구원, 함수련 선임연구원 발표

· 세션 1에서 민영미 과장이 세션 좌장 역할 수행

· 세션 2에서 유진호 기후사업본부장이 세션 좌장 역할 수행 및 토론 진행

· 민영미 과장, 함수련 선임연구원, 한수희 사원 회의 주요내용 기록

□ 프로그램 구성

구분	1일차 - 국제워크숍	2일차 - 국제워크숍	3일차 - MPM	4일차 - MPM
오전	• 개회식 • (기조연설) 기후예측의 현주소	• (세션3-1) 모델의 후처리: 검증 및 보정	• 개회식 • (세션1) 예측시스템 현황 및 개선사항, 향후 계획 발표	• (세션2) APCC 예측시스템 개선 방안 논의 • (세션3) Wrap-up • 폐회식
오후	• (세션1) MME 기후예측 시스템 현황 • (세션2) 기후모델의 한계점 및 개선사항	• (세션3-2) 모델의 후처리: 검증 및 보정 • (세션4) 패널토론 및 Wrap-up • 폐회식		• 현장견학 (대만기상청 주관)

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

○ 2019년도 국제기후예측워크숍(주제 : 계절 및 계절내 기후예측의 현재와 미래) 개최를 통하여, APCC 설립 이후 계절예측 MME를 선도해 온 APCC의 현주소를

파악하고 전 세계 양상블 예측 기반 정보제공기관과 기후예측의 미래 방향성을 함께 논의함. 현재 MME를 기반으로 계절예측정보를 생산하는 MME 그룹들이 다양해 지는 시점에서 이번 국제워크숍 개최는 APCC가 한발 더 도약하는 기반을 마련하였다고 판단됨

- 국제워크숍에 참석한 기조연설 및 발표자들은 우수한 내용으로 발표를 수행
 - 특히 APCC를 포함한 MME 기반 계절예측정보 생산 그룹의 발표는 MME의 현주소 및 한계점을 파악하고, 앞으로의 발전방향에 대한 토론으로 이어지면서 APCC의 현안에 대한 고민이 함께 논의되는 자리였음
 - 또한, 전 세계 기후정보 생산 및 기후서비스 제공 분야에서 APCC 연구 및 활동을 소개함으로써 APCC 인지도를 제고하는 기회였음
- 제3차 APCC MME 모델제공기관 회의는 대부분의 자료제공자가 참석(14개 기관 중 11개 기관 참여)하여 각 기관 예측시스템 현황, 최근 모델 개선사항 및 향후 계획을 공유함으로써 APCC 현업적 측면에서 참여 기관의 모델 개선에 따른 환경 변화에 유연하게 대체할 수 있는 기회를 제공함
- 모델제공기관 간 과학적 협력방안 가능성 타진 및 APCC BSISO 예측에 MME 모델제공기관의 참여 독려

3. Suggestions and Remarks 건의사항

- 국제워크숍의 우수한 발표내용과 특히 국제워크숍 및 모델제공기관 회의에서 논의된 MME 발전방향 및 참여모델 개선 계획 등에 관련된 토론 내용은 기후사업 본부에 공유, 향후 연구 및 업무 추진시 고려할 필요가 있음
- 또한 과거 모델제공기관 회의의 회의록 및 후속조치가 원활하지 않은 점을 상기하여, 이번 회의의 후속조치 및 회의록 등을 회의 참석자, APCC 예측운영과를 비롯한 관계자에게 공유하고 피드백이 원활히 이루어질 수 있도록 노력할 예정임
- APCC MME 모델제공기관의 참여모델로서 APCC 계절예측모델의 개선 및 발전 계획, 또는 활용성 논의가 필요하다고 판단됨

III. References (Presented and Collected Materials) 주요 수집자료

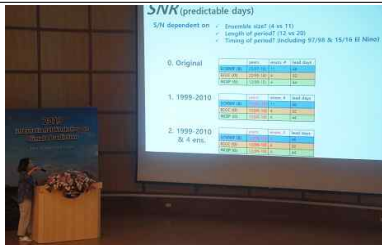
(with attachment of any information or report in case of attendance of conferences, workshops and meetings) 학술대회, 워크숍, 회의 등 참석 시 관련 정보 및 문서 첨부

- 국제워크숍 및 모델제공기관회의 참가자 Contact Information 취합·정리 및 관리 예정
- 국제워크숍 발표자료 및 회의록, 프로그램 책자 등은 APCC 홈페이지를 통해 게시

예정

- 모델제공기관회의 발표자료 및 회의록은 회의참가자 및 회원기관에 이메일로 공유 예정

IV. 출장사진

	
<국제기후예측워크숍 단체사진>	<국제기후예측워크숍 APCC 원장 개회사>
	
<국제기후예측워크숍 기초연설자 질의응답>	<국제기후예측워크숍 포스터 세션>
	
<국제기후예측워크숍 APCC 민영미 과장 발표>	<국제기후예측워크숍 APCC 이윤영 선임연구원 발표>
	
<모델제공기관회의 단체사진>	<모델제공기관회의 APCC 함수련 선임연구원 발표>
	
<모델제공기관회의 APCC 양유빈 선임연구원 발표>	<모델제공기관회의 APCC 유진호 본부장 토론 주제>

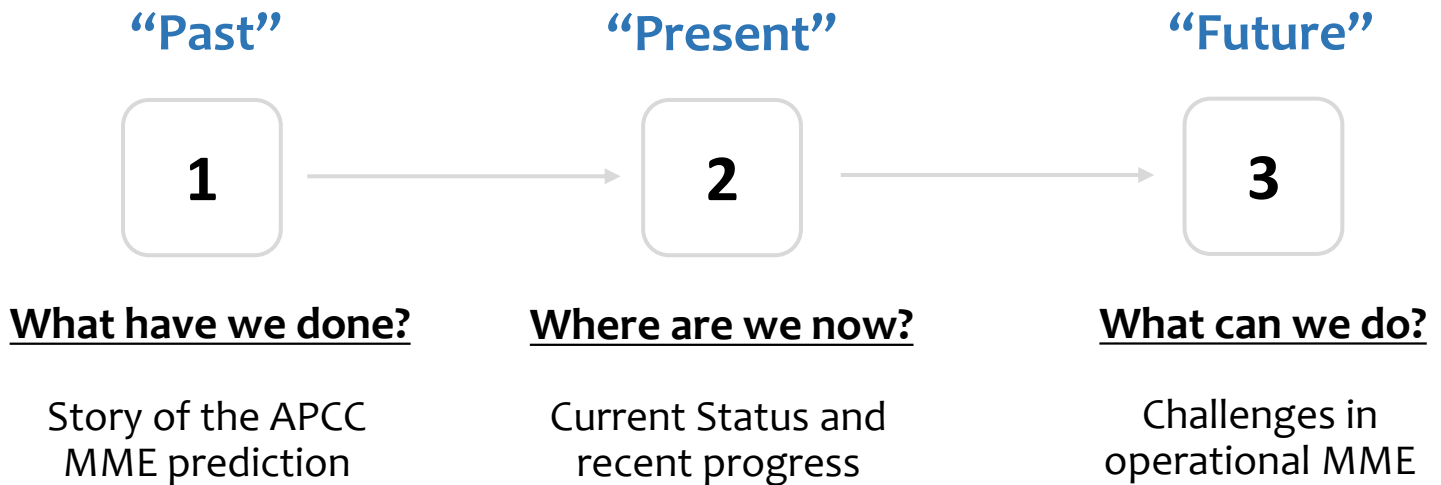
Current Status and Progress of MME Prediction System : Contribution of APCC to multi-model seasonal forecasting

Young-Mi Min

Climate Prediction Dept., Climate Services and Research Division
APEC Climate Center, Busan, Korea

- **Contributors:** SH Shin, D Jeong, CM Lim, Y Yhang, AY Lim, S Ham, Vladimir Kryjov (HMC), and APCC MME Producing Centers (PCs)

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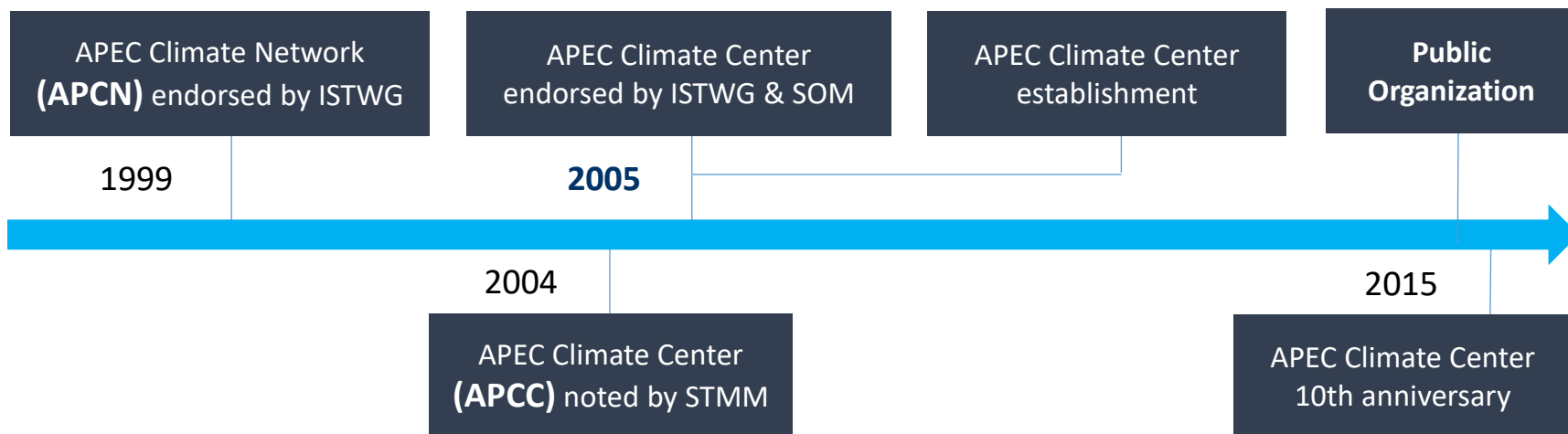


APCC OVERVIEW

History of the APEC Climate Center

Operational MME Initiatives

Need and scientific evidences for useful operational services of seasonal forecast based on Multi-Model Ensemble (MME)



2005 1st Senior Official Meeting (SOM) for the 17th APEC Ministerial Meeting Summary Report

41. SOM concluded that this was an important decision made by the ISTWG and endorsed the establishment of the APCC.



Overview of the APEC Climate Center

Vision and Goals

To contribute to economic growth in the APEC region and support the protection of lives and property, the reduction of economic losses, and enhance economic opportunities.

Mission

To enhance the socio-economic well-being of member economies by utilizing up-to-date scientific knowledge and applying innovative climate prediction techniques through



Climate Prediction

APCC products value-added, reliable, and real-time climate prediction information and provides the APEC region with it.



Climate Information Services

APCC leads in the development of interdisciplinary research and application techniques at the climate-environment-society nexus.



Interdisciplinary Research

APCC strives to be a key climate database center to distribute climate data, information products, and related tools.



International Cooperation

APCC guides developing countries from the APEC region toward building their own capacity to produce reliable climate prediction information.



Seasonal
Forecast



BSISO
Forecast



Climate
Monitoring



CLIK



Data
Service



CLIPs

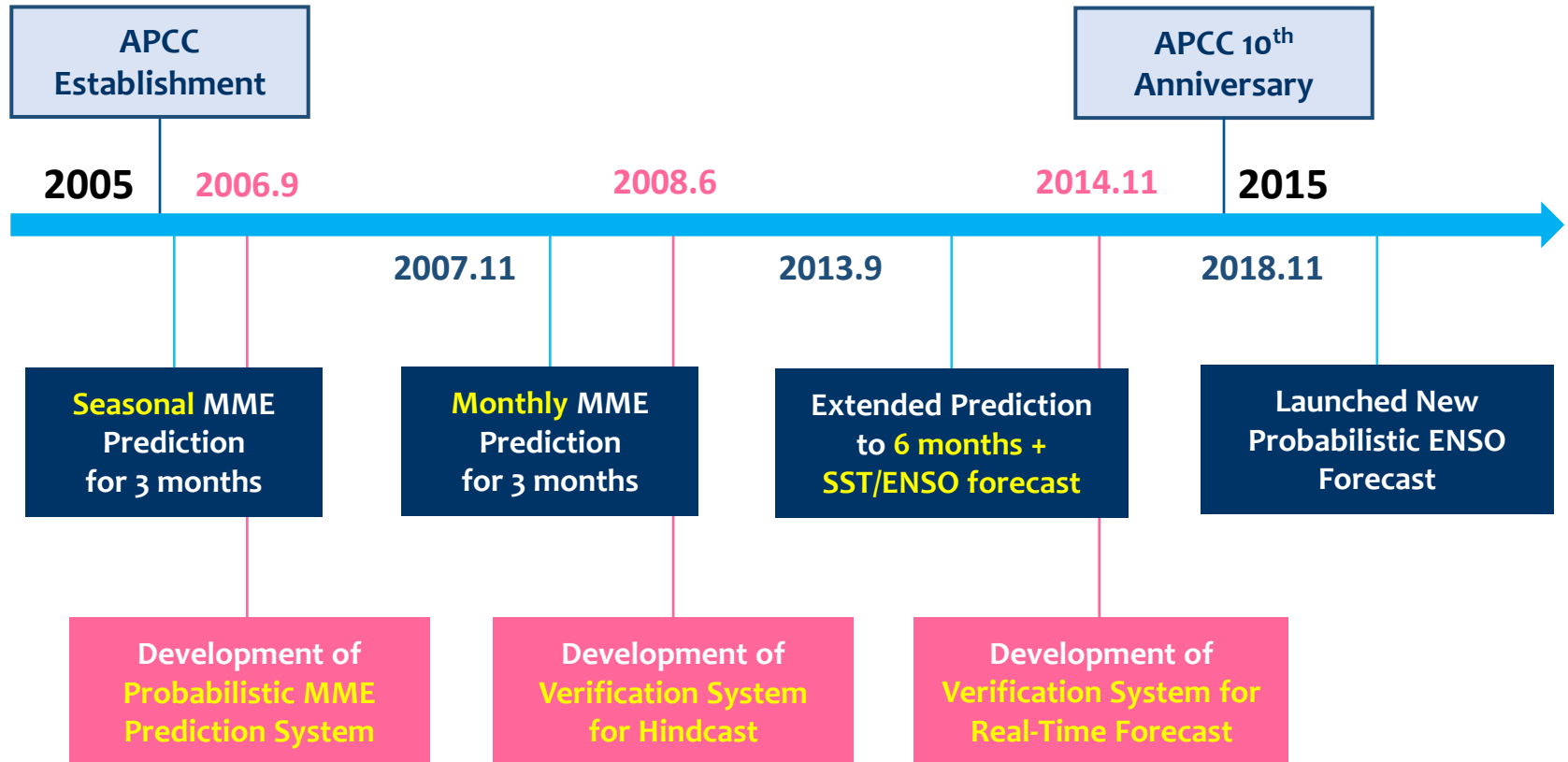


OpenWPS

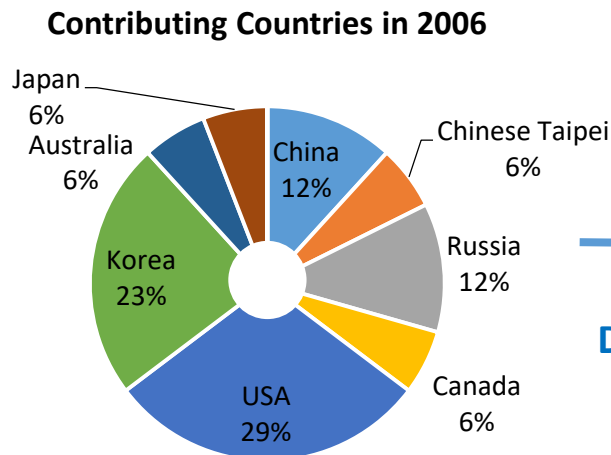
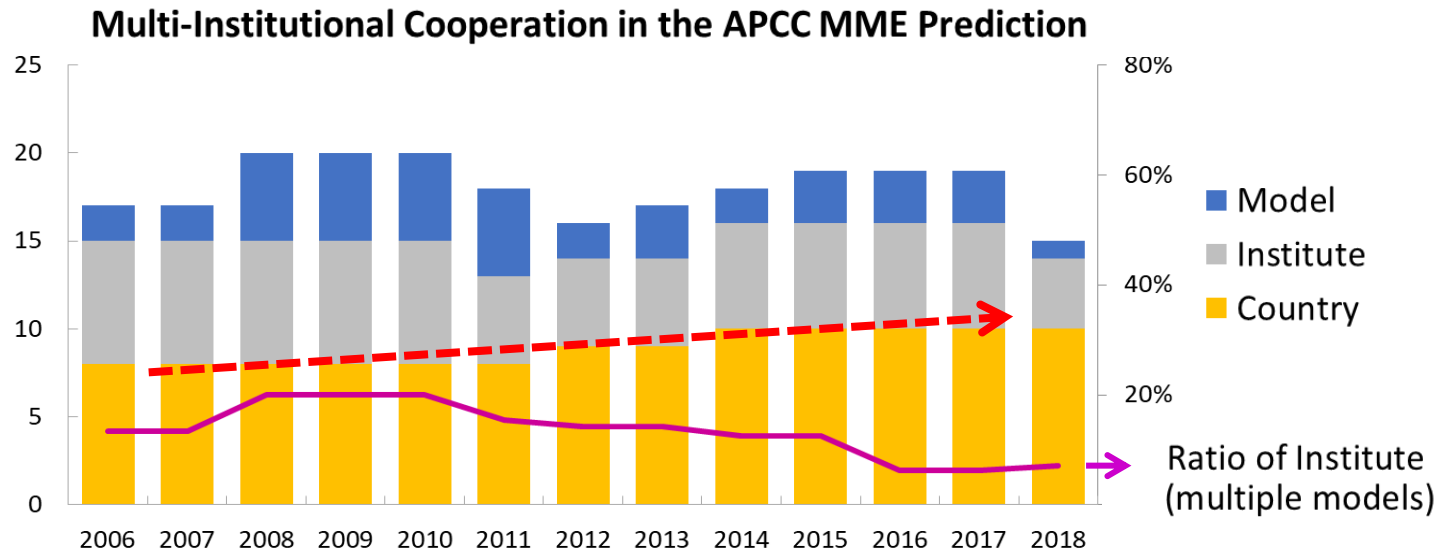
WHAT HAVE WE DONE?

Story of APCC MME Forecast on a seasonal time scale

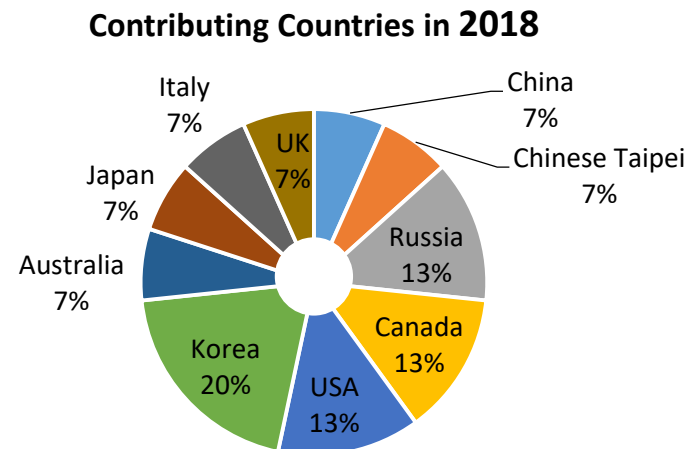
History of APCC MME Prediction System



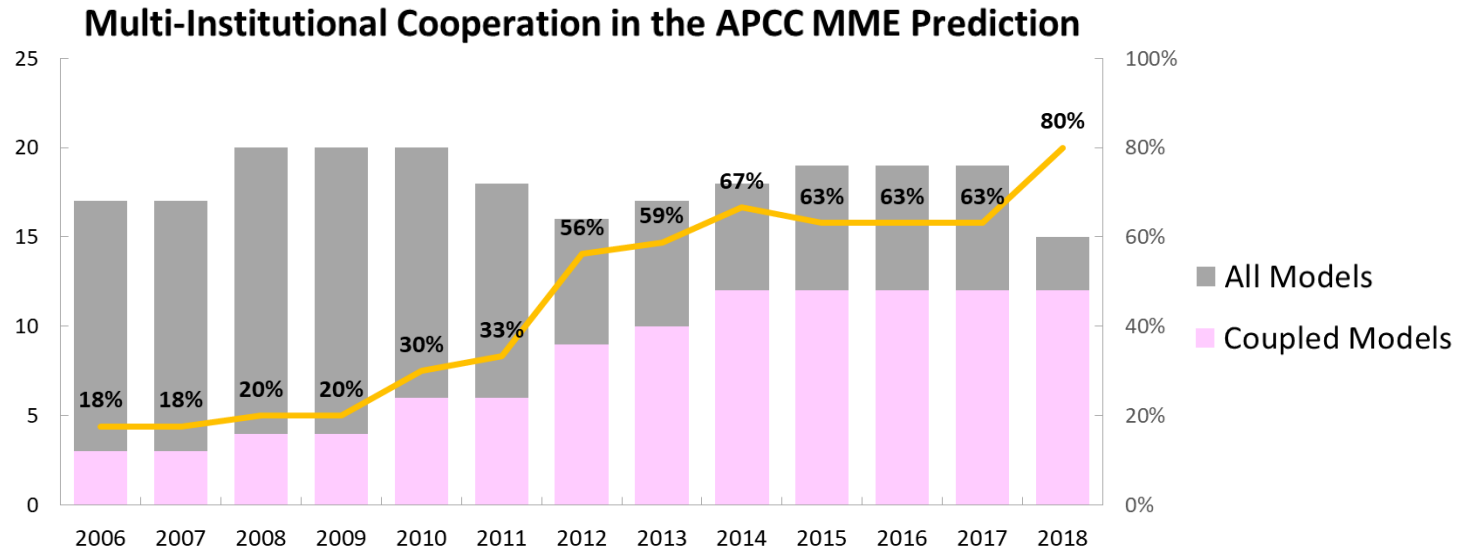
Models participating in APCC MME



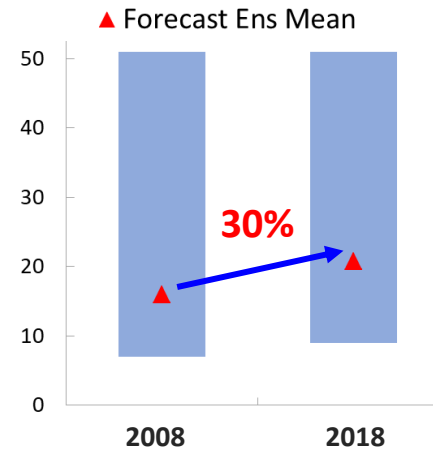
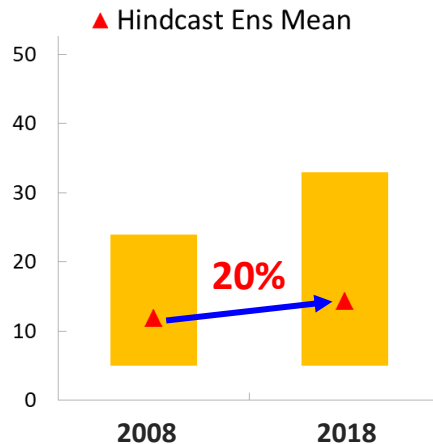
More
Diversified



Models participating in APCC MME



Changes in Ensemble Size



MME Schemes: Deterministic Forecast

SCM

(Simple MME)
Simple Composite
Method

- Simple composite of individual forecast with equal weighting

$$P = \frac{1}{M} \sum_i F_i'$$

SPM

(Calibrated MME)
Step-wise Pattern
Projection Method

- Calibrated MME which is obtained from the adjusted (or corrected) single-model predictions based on a stepwise pattern projection method (Kug et al. 2008)

$$P = \frac{1}{M} \sum_i \hat{F}_i'$$

MRG

(Weighted MME)
Multiple Regression
Method

- Empirically weighted MME with coefficient computed by multiple linear regression (Krishnamurti et al. 2000)

$$P = \sum_i a_i F_i'$$

SSE

(Weighted MME)
Synthetic Multi-Model
Super Ensemble Method

- Same as MRG, but with EOF-filtered dataset (Yun et al. 2003)

$$P = \sum_i \alpha_i \hat{F}_i'$$

Operationally implemented in the APCC MME Prediction

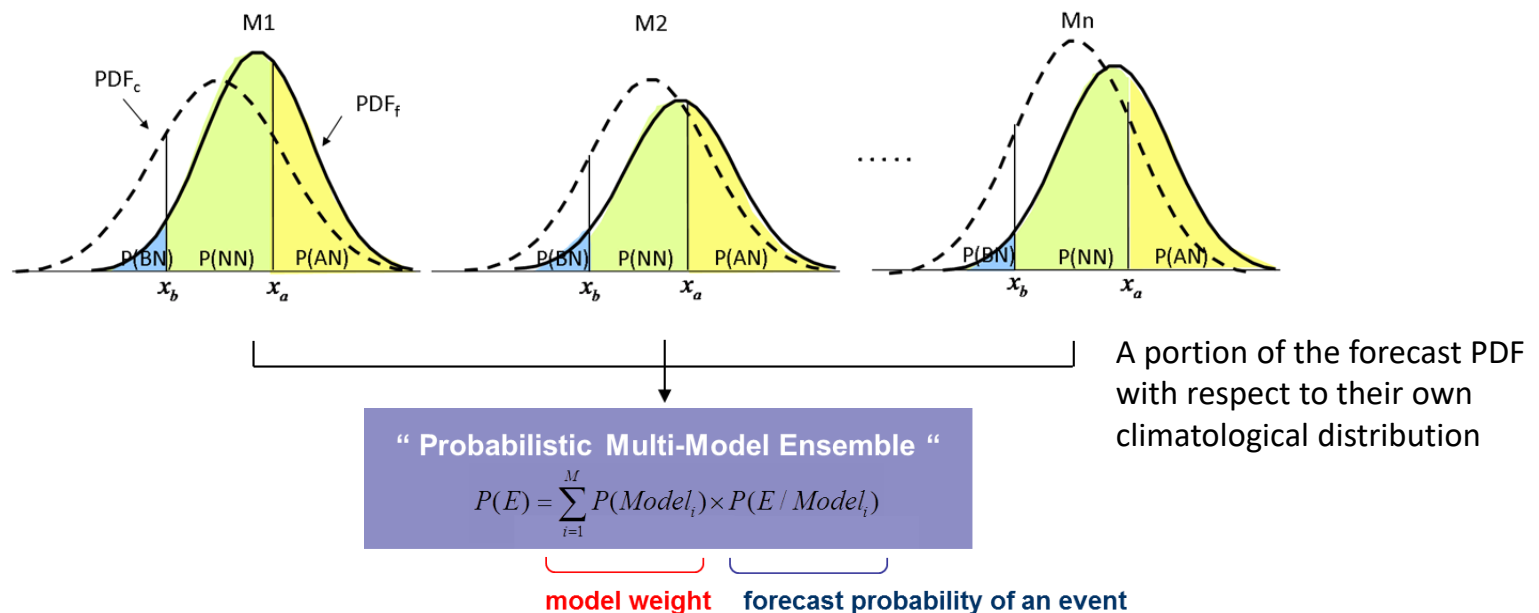
Kug et al. (2008) Optimal multi-model ensemble method in seasonal climate prediction, *Asia-Pac. J. Atmos. Sci.*, 44, 259-267.

Krishnamurti et al. (2000) Multi-model superensemble forecasts for weather and seasonal climate, *J. Clim.*, 13, 4196-4216.

Yun et al. (2003) Improvement of the multi-model superensemble technique for seasonal forecasts, *J. Clim.*, 16, 3834-3840.

MME Schemes: Probabilistic Forecast

- **(Problem): Inconsistencies** between the model ensemble sizes in hindcast and forecast, with the individual model ensembles essentially differing in size
- ↓
- **(Solution):** Forecast probability is estimated for each **Individual model** and then **combine** them with model weights proportional to the square root of ensemble size (Min et al. 2009)



MME Schemes: Probabilistic Forecast

- **(Problem): Inconsistencies** between the model ensemble sizes in hindcast and forecast, with the individual model ensembles essentially differing in size
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$$P(E_j) = \frac{1}{\sum_{i=1}^M \sqrt{n_i}} \sum_{i=1}^M \sqrt{n_i} P(E_j | mdl_i)$$

$P(E_j | mdl_i)$: probability of the model of the j event,
conditioned on the i model
 n : size of the sample

Operation



Model Development: In-House Coupled Model

('08) CCSM3: SST Nudging

- Simple Nudging method (Luo et al. 2005)
- Initiated 4 times a year (Feb, May, Aug, and Nov IC)
- Operationally Implemented in 2014 (Jeong et al. 2008)

('11-14) Ocean 3D Nudging

- Prescribed ocean subsurface TS and Currents
- Nudged ocean subsurface temperature
- Operationally implemented in 2016 (Kim et al. 2017)

('17) SCoPS

- High-resolution coupled model with improved initialization schemes (w/U. Hawaii)
- Operationally implemented in 2017 (Ham et al. 2019)

Luo et al. (2005) Seasonal climate predictability in a coupled OGCM using a different approach for ensemble forecasts. *J Clim*, 18(21), 4474-4497

Jeong et al. (2008) Experimental 6-month hindcast and forecast simulating using CCSM3-APCC. 2008 Technical Report, APCC

Kim et al. (2017) Mean bias in seasonal forecast model and ENSO prediction error. *Scientific Reports* 7, 6029

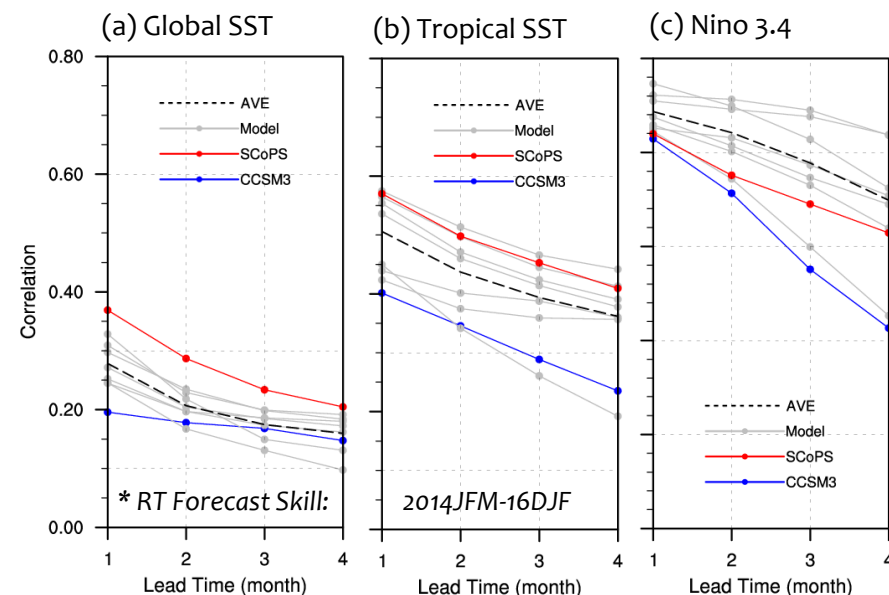
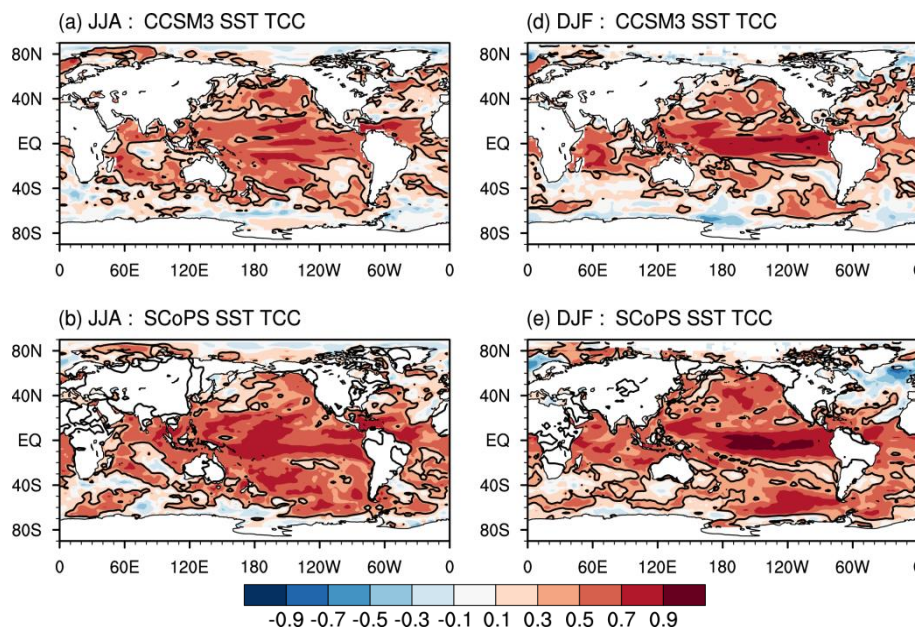
Ham et al. (2019) A newly developed APCC SCoPS and its prediction of East Asia seasonal climate variability. *Clim Dyn*, 52(11), 6391-6410

Model Development: APCC SCoPS

• Seamless Coupled Prediction System

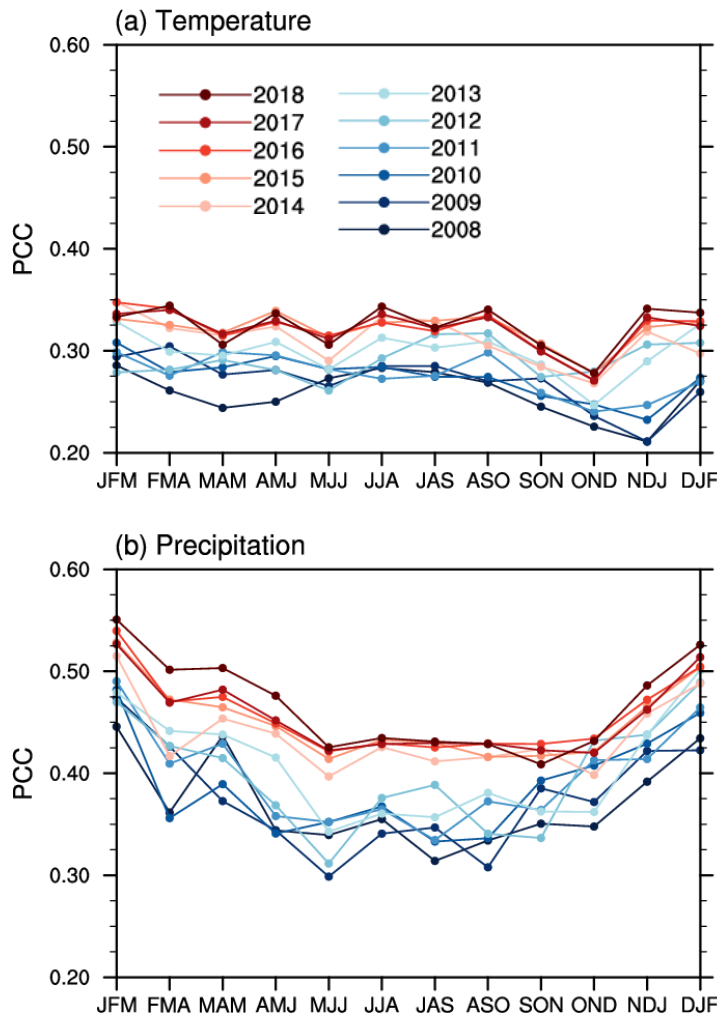
- SCoPS is more skillful than CCSM3 in predicting the seasonal climate variability.
- APCC in-house model has been replaced by SCoPS since Nov. 2017 (CCSM3: terminated).

		SCoPS	CCSM3
Model Description	Atmos.	ECHAM v5.3	CAM3
	Ocean	POP v2.0.1	POP v1.4.3
	Sea ice	CICE v4.1	CSIM4
Resolution	Atmos.	T159 // 31 levels	T85 // 26 levels
	Ocean	1° X 0.5° // 40 levels	
Initial condition	Atmos.	3D nudging from CFSR	—
	Ocean	EAKF from CFSR SST and profile data (WOD)	3D nudging from GODAS
Hindcast period		1982~2013	1983~2013
Ensemble configuration		Time lagged with perturbation on Gaussian noise	Time lagged
Ensemble		10	

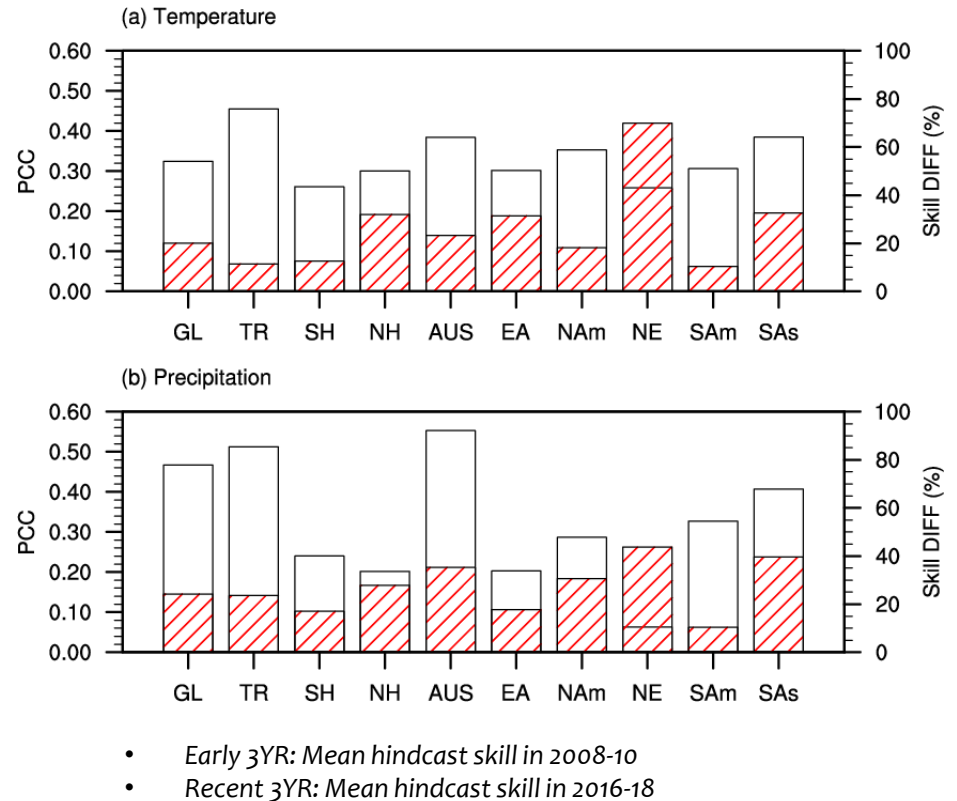


APCC MME Skill has been improved? Yes!

Hindcast Skill (83-05) of Each Year's Operational MME Prediction System



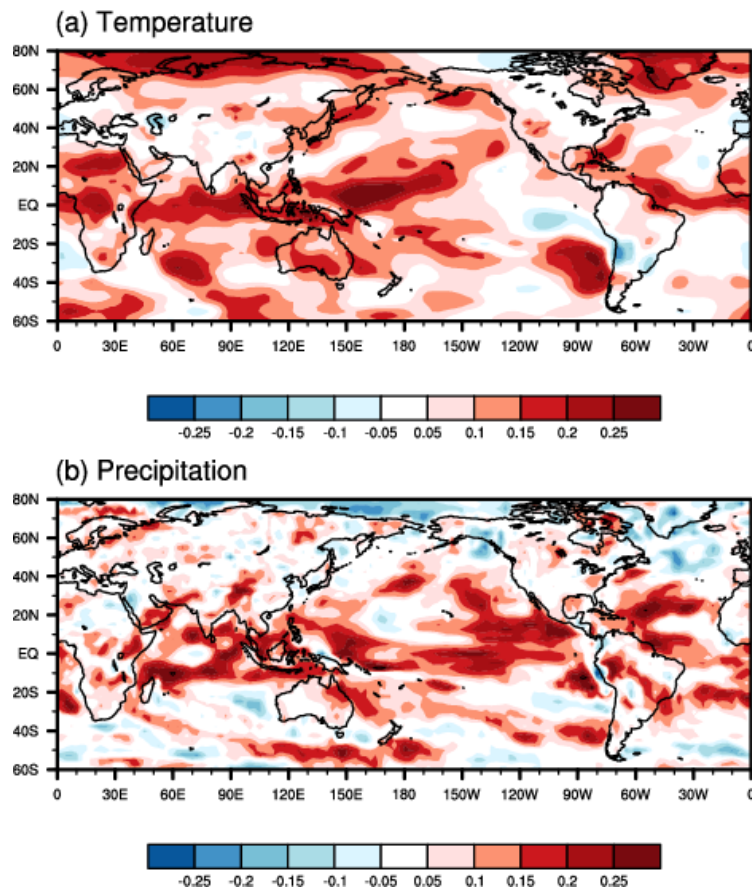
Hindcast Skill in 2018 and Skill Improvement (Recent 3YR compared with Early 3YR)



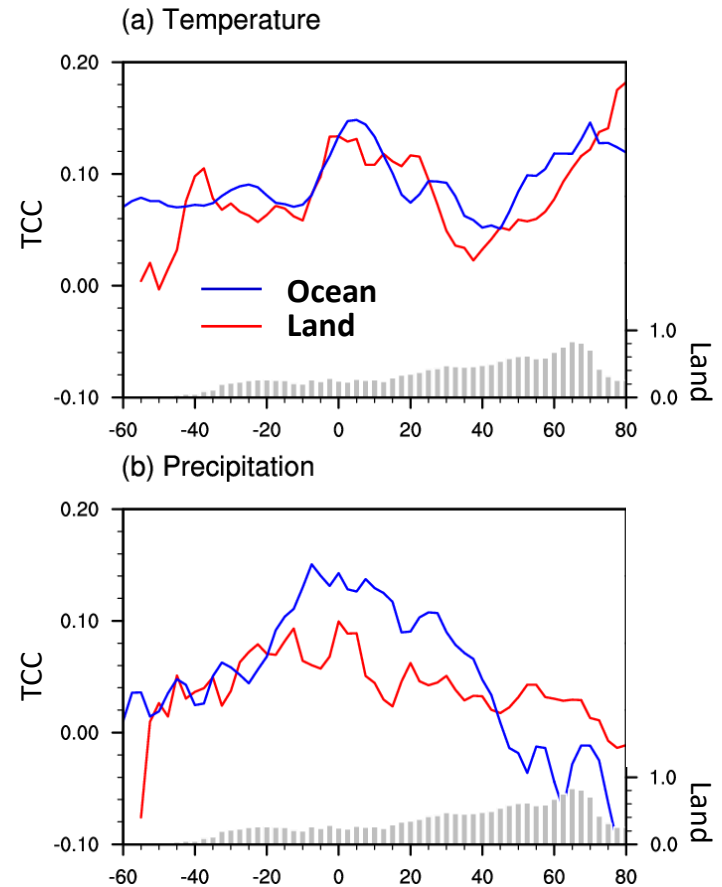
- Significant Increase: the northern Eurasia region for Temp.
- Increasing trend of temperature may contribute to increase of temperature forecast skill (Luo et al. 2011).

APCC MME Skill has been improved? Yes!

Hindcast Skill Difference: TCC
(Recent 3YR – Early 3YR)



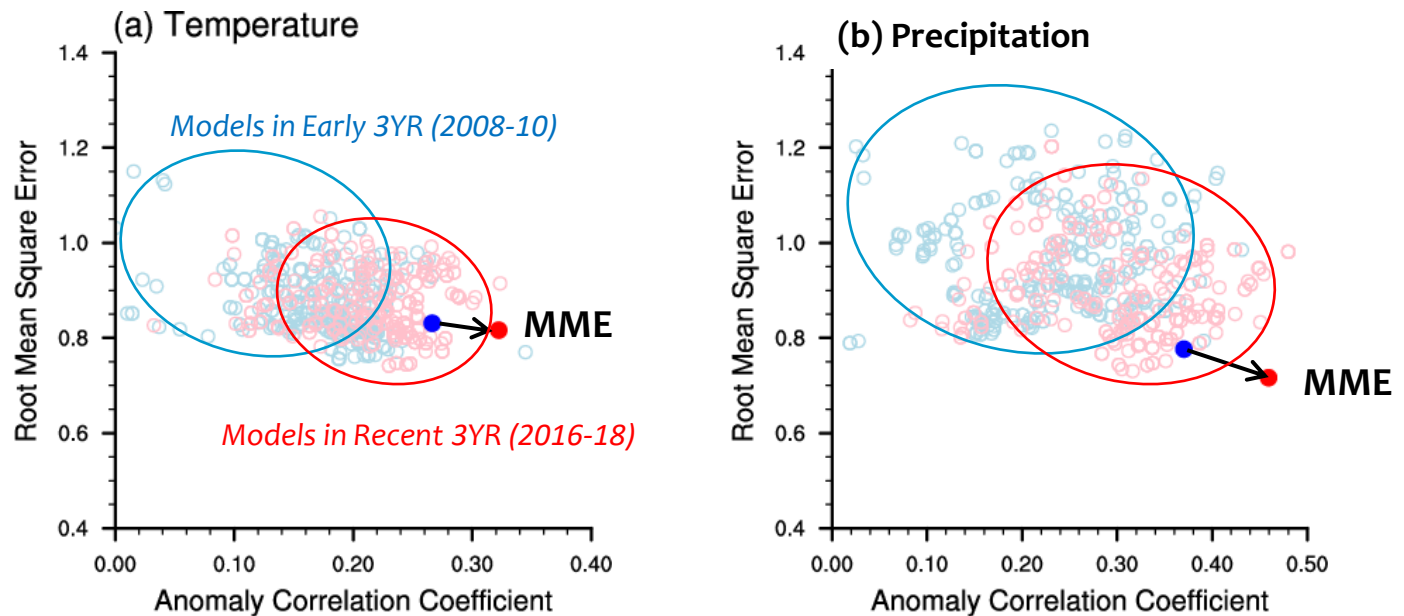
Zonal Mean of Hindcast Skill Difference



- Early 3yr: Mean Hindcast Skill in 2008-2010
- Recent 3yr: Mean Hindcast Skill in 2016-2018
- Bar: the fraction of land at each latitude

APCC MME Skill has been improved, Why?

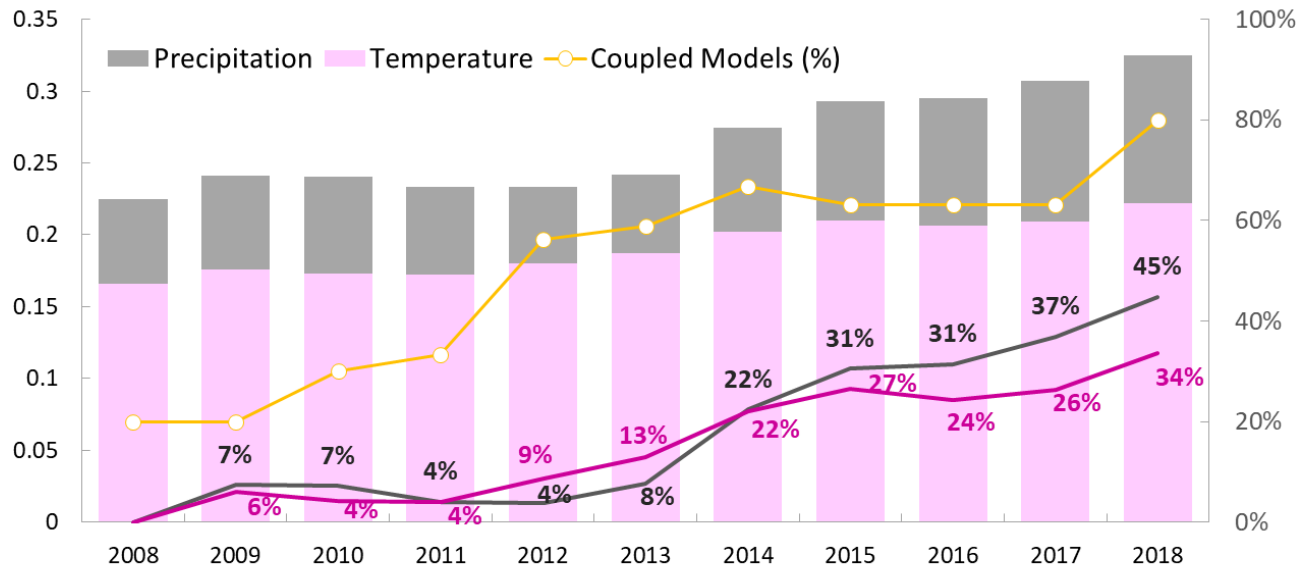
Hindcast Skill: PCC-RMSE, Contributing Models



- ✓ Due to the improvement of participating models in the MME

APCC MME Skill has been improved, Why?

Mean skill of Contributing **Models** (Hindcast: 1983-2005)



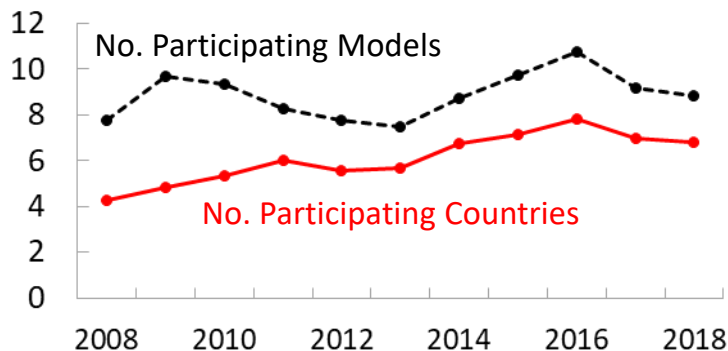
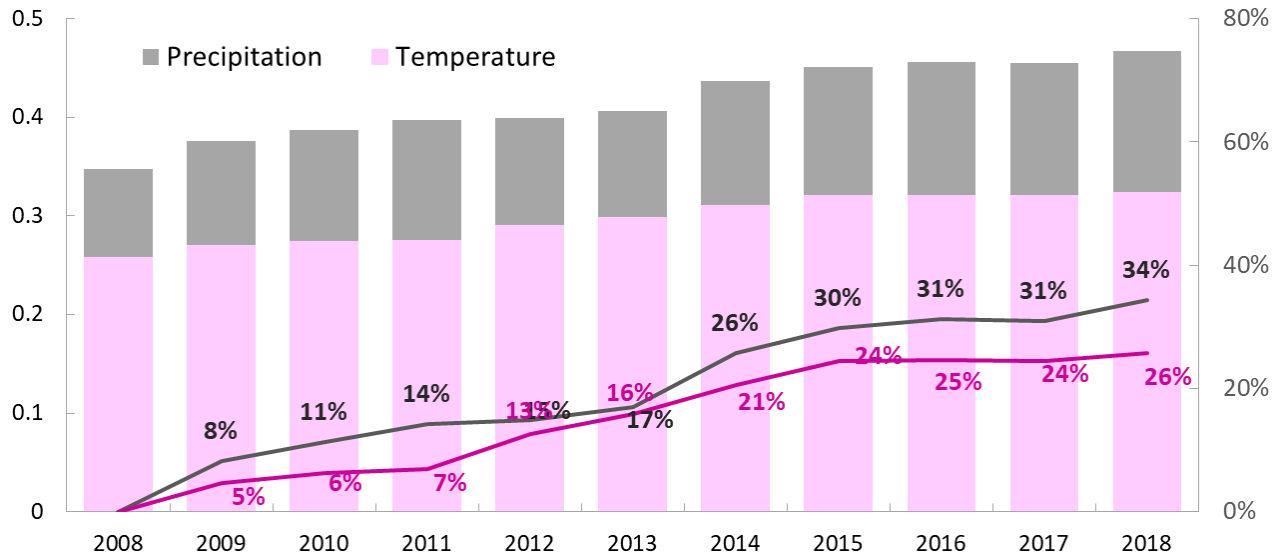
The rapid incremental improvement of the mean skill of individual models
= The rapid increase in participation of coupled models in the MME prediction system

The improvement of the MME prediction

- Mainly due to the collective improvement of individual models
- The increase of participation in coupled models may contribute to the significant increase in mean skill of individual models in the early of 2010s.

APCC MME Skill has been improved, Why?

MME Skill (Hindcast: 1983-2005)



Correlation	Temperature	Precipitation
No. Models	0.41	0.48
No. Countries	0.93	0.95

- ✓ The diversification of the models from independent groups contributes to the skill improvement in MME.

APCC MME Skill has been improved!

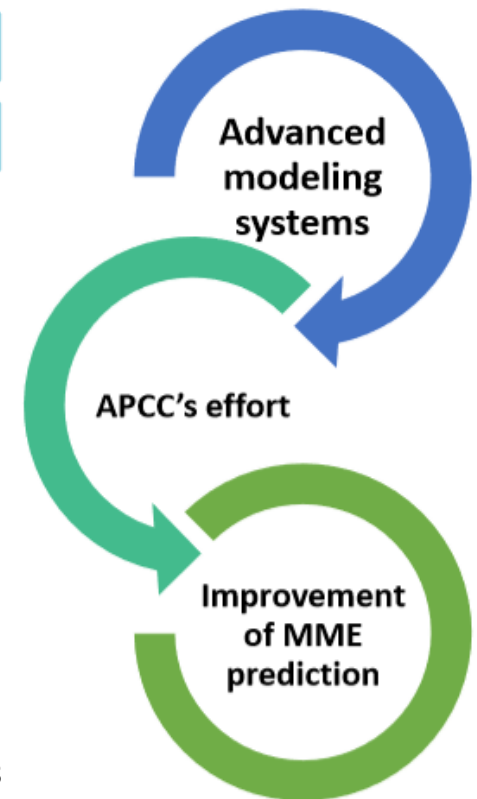
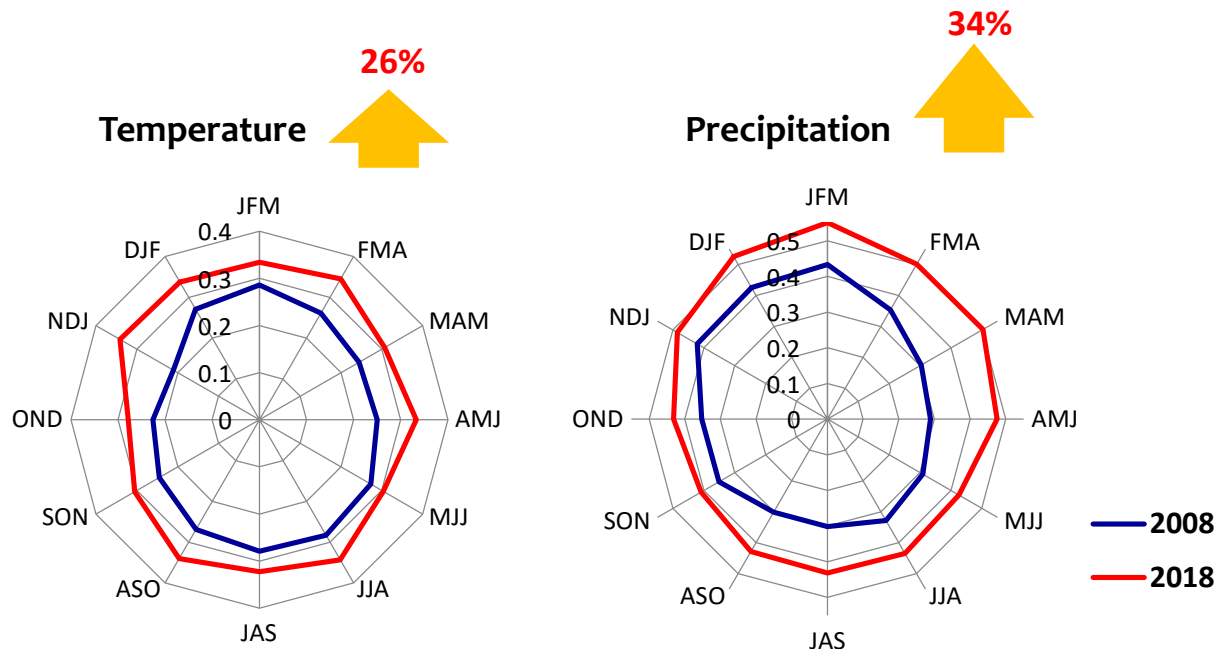
- MME System is doing a great Job!

Yoo and Kang (2005)

$$R_{MM} = \frac{\langle R \rangle}{\sqrt{V(\langle y \rangle)}} = \frac{\langle R \rangle}{\sqrt{\langle r \rangle}}$$

Average skill of all models

Inter-dependency among models



WHERE ARE WE?

Current Status and Recent Progress

APCC MME Seasonal Prediction

- APCC has provided seasonal forecast on a monthly basis, by multi-model ensemble for the upcoming two seasons on a global scale.
- At present, 14 leading operational centers and research institutes from 10 countries are participating in the APCC MME prediction.
- Climate outlook is disseminated to APEC member economies around 25th of every month, as well as climate monitoring and verification information.

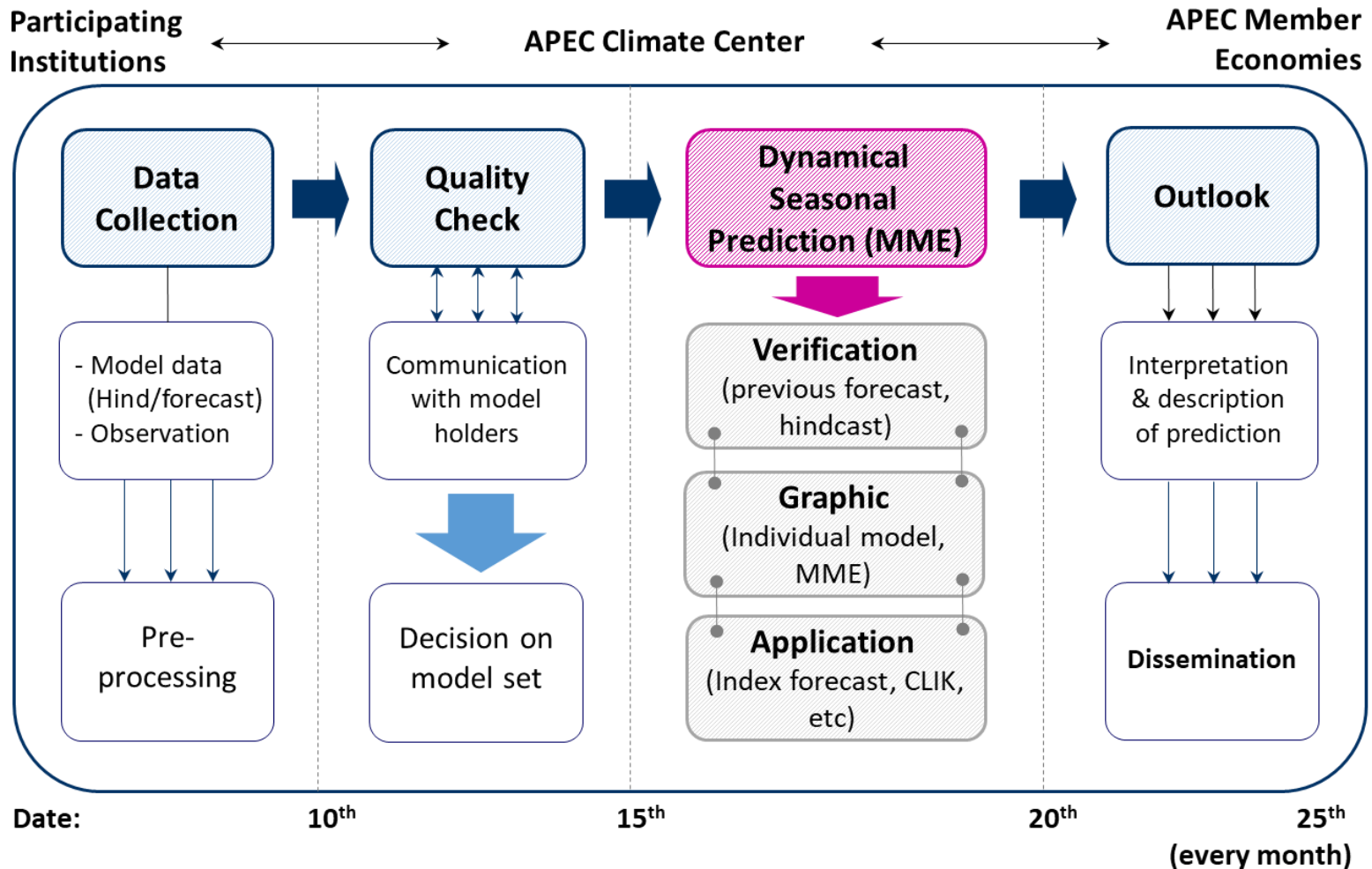


Participating Models

(as of May 2019)

Institute	Model Name	SST Specification (H/F)	Ens. (H/F)	Forecast Period	Hindcast Period
APCC	SCoPS	Predicted/Predicted	10/10	6-month	1982-2013
BCC	BCCV2	Persistent/Persistent	10/20	4-month	1991-2015
JMA	JMA/MRI-CPS2	Predicted/Predicted	10/51	6-month	1979-2014
MSC	CanCM	Predicted/Predicted	20/20	11-month	1981-2010
NASA	GMAO	Predicted/Predicted	10/11	8-month	1981-2010
NCEP	CFSv2	Predicted/Predicted	20/20	6-month	1982-2010
PNU	PNU CGCM v1.0	Predicted/Predicted	5/5	6-month	1980-2018
BOM	POAMA-M24	Predicted/Predicted	33/33	6-month	1983-2011
CMCC	CMCC-SPSv3	Predicted/Predicted	9/9	11-month	1993-2016
Met Office	UKMO	Predicted/Predicted	12/42	5-month	1993-2015
KMA	GLOSEA5	Predicted/Predicted	24/24	6-month	1991-2010
HMC	HMC	Predicted/Predicted	12/42	6-month	1985-2010
CWB	CWB	Predicted/Predicted	30/30	6-month	1982-2017
MGO	MGOAM2	Observed/Persistent	6/10	3-month	1979-2004

Operation Schedule

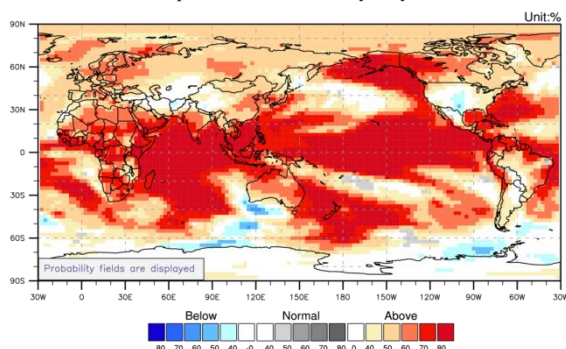


Seasonal Forecast Products

www.apcc21.org

- MME and individual model forecasts on a monthly basis
- Deterministic & Probabilistic
- T2M, T850, Prec, Z500, SLP, U/V wind at both global and regional scales
- Climate monitoring and verification information (hindcast, previous forecast)

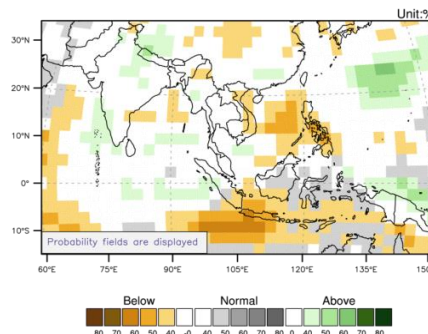
Temperature at 2m for May-July 2019



Issued: 25 Apr, 2019

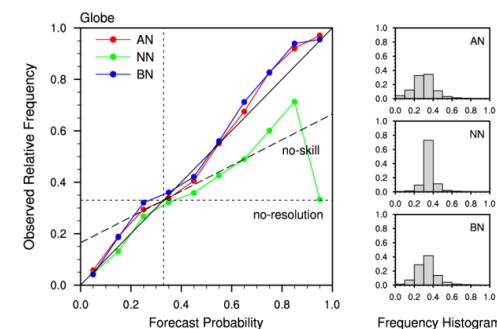
© APEC Climate Center

Precipitation for July-September 2018



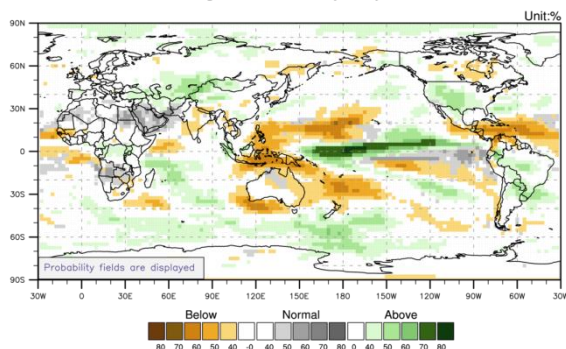
© APEC Climate Center

Reliability Diagram : PREC, JAS (1983-2005)



© APEC Climate Center

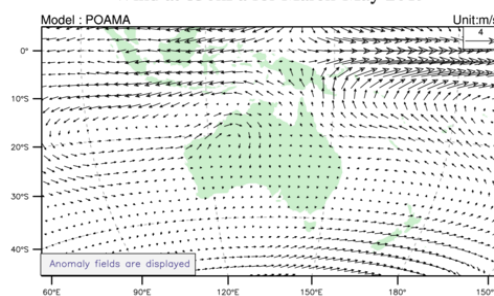
Precipitation for May-July 2019



Issued: 25 Apr, 2019

© APEC Climate Center

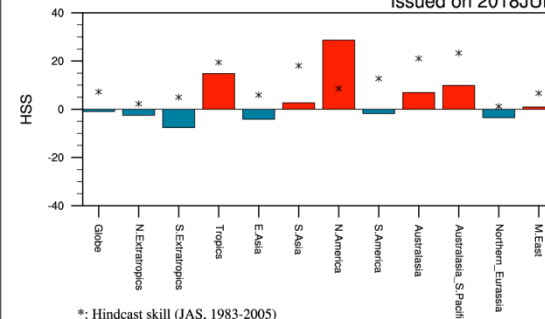
Wind at 850hPa for March-May 2019



© APEC Climate Center

Heidke Skill Score : PREC, JAS (2018)

Issued on 2018JUN



*: Hindcast skill (JAS, 1983-2005)

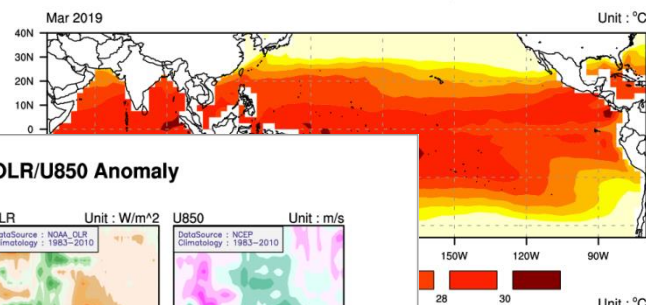
© APEC Climate Center

Recent Improvements: Climate Outlook

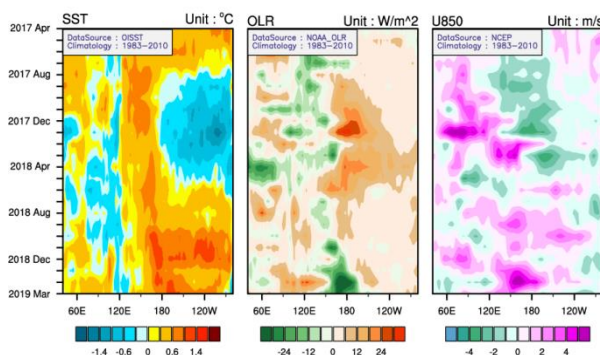
(Renewed the Contents/Structure)

- Provide more information on climate monitoring and prediction
- Change its structure for a more formal and easy-to-read form with suggestions/ comments from APCC Working Group

SST Total and Anomaly



SST/OLR/U850 Anomaly



* Anomalies are averaged between 5°S and 5°N.

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Website: www.apcc21.org

APCC Monthly Climate Outlook for May – October 2019¹⁾

(Issued: April 25, 2019)¹⁾

- During March 2019, El Niño conditions persisted with positive sea surface temperature anomalies across the equatorial Pacific Ocean.
- The latest APCC ENSO outlook suggests a greater than 53% probability for weak El Niño conditions during May – July 2019, and the probability for the conditions is likely to fall to 30% during August – October 2019.
- Positive temperature anomalies are likely to prevail over the tropical Pacific, subtropical western South Pacific, northern North Pacific, maritime continent, tropical Atlantic, Indian Ocean except the eastern part, and southern Africa for May – October 2019.
- Below normal precipitation anomalies are expected for the seas off the north coast of Australia, Caribbean Sea, off-equatorial North Atlantic, and Indian Ocean near southern Australia for May – October 2019.

Current Climate Conditions.

In March 2019, El Niño conditions continued. The positive equatorial sea surface temperature (SST) anomalies persisted across most of the tropical Pacific Ocean. Positive sub-surface temperature anomalies remained across most of the equatorial Pacific. Convection and the westerly wind anomalies near the Date Line slightly weakened. Positive monthly mean temperature anomalies exceeding +5°C prevailed over the central Russia, western Arctic Sea, Alaska, and northern Canada. Negative temperature anomalies were observed over northern USA, Greenland, North Africa, Middle East, and some austral seas. Positive precipitation anomalies prevailed over the western and central tropical Pacific, southwestern Indian Ocean, southern Australia, and North Africa. Negative precipitation anomalies spanned the western and central off-equatorial South Pacific, eastern Tropical North Pacific, North Atlantic, maritime continent, eastern Indian Ocean, East Asia, central Russia, western Canada, southern Europe, and southern Africa [Fig. 1, 2, and 3].

Discussion of Climate Forecast.

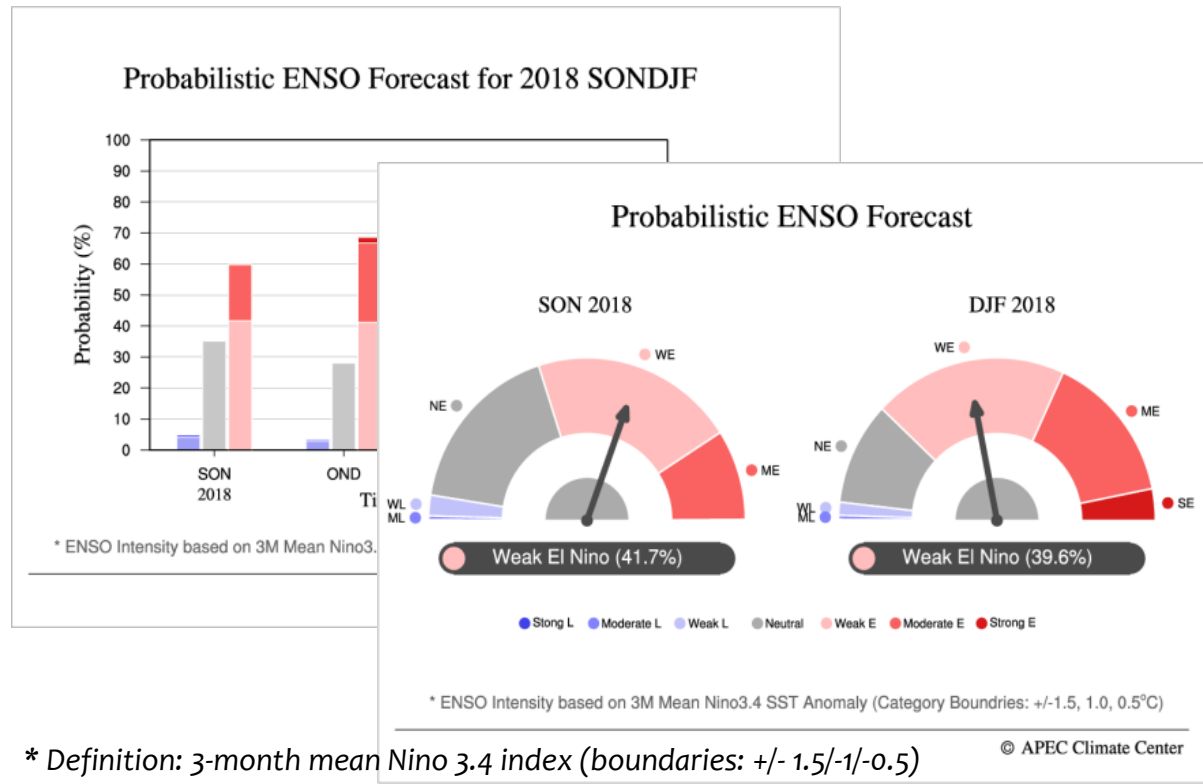
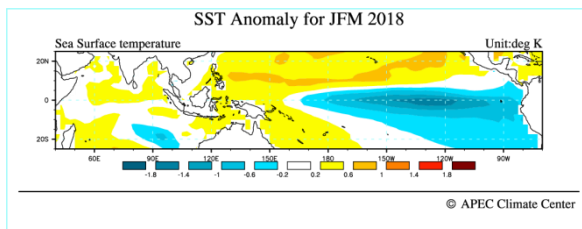
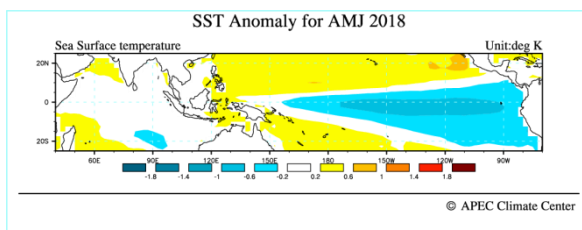
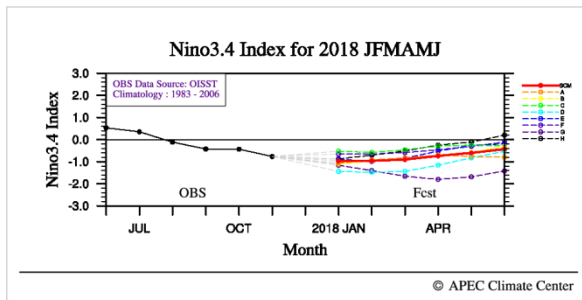
SST and ENSO Outlook:

Positive SST anomalies are likely to remain across most of the tropical Pacific Ocean for May – October 2019. Five out of six dynamical coupled models predict a Niño3.4 index exceeding +0.6°C to persist through the whole forecast period. Slightly warmer and cooler than normal SSTs over the western and eastern Indian Ocean are expected for the same period, which correspond to the weak positive phase of the Indian Ocean Dipole index. In summary, based on the running 3-month mean Niño3.4 index, the

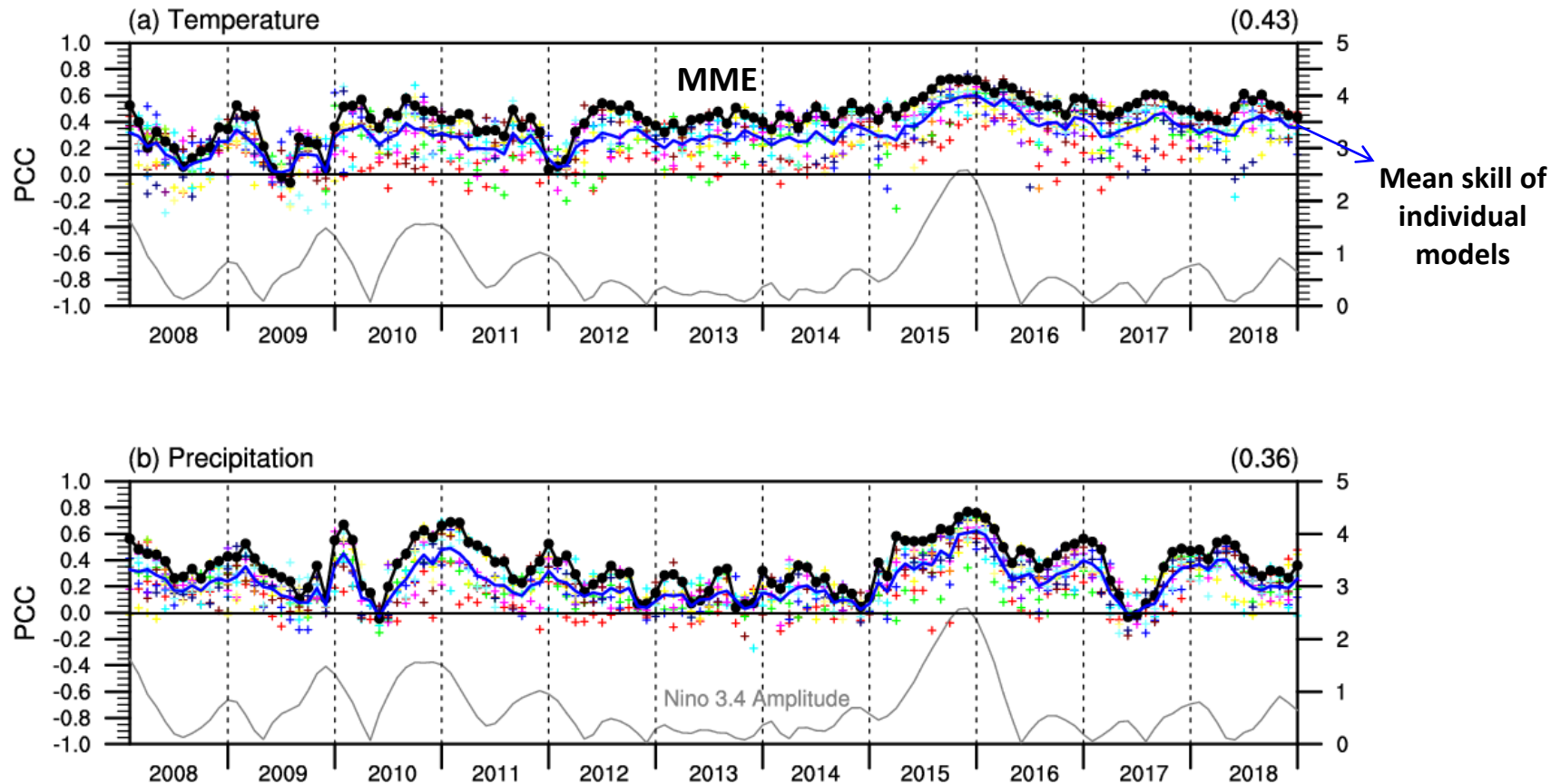
Recent Improvements: Diverse Contents

(Probabilistic Forecasts of ENSO Type & Intensity)

- Based on uncalibrated multi-model ensemble with equal model weights, and a Gaussian fitting method for estimation of forecast probability
- 7-Categorical forecasts: Strong/moderate/weak El Nino or La Nina, and ENSO-Neutral

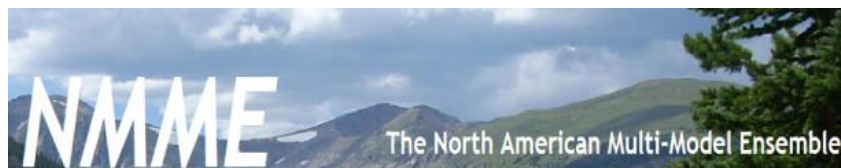


APCC MME Performance: Real-Time Forecast Skill



- ✓ APCC MME forecast shows a reasonably good level of prediction skill as compared with individual contributions.

MME Groups



International Research Institute
for Climate and Society



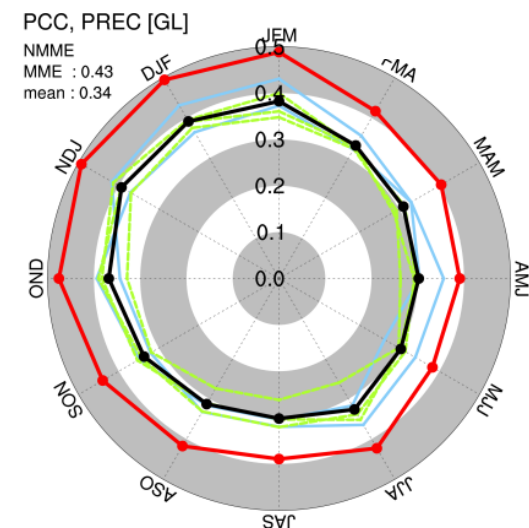
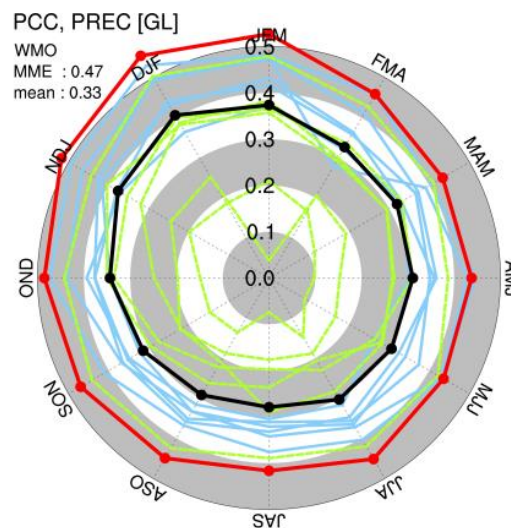
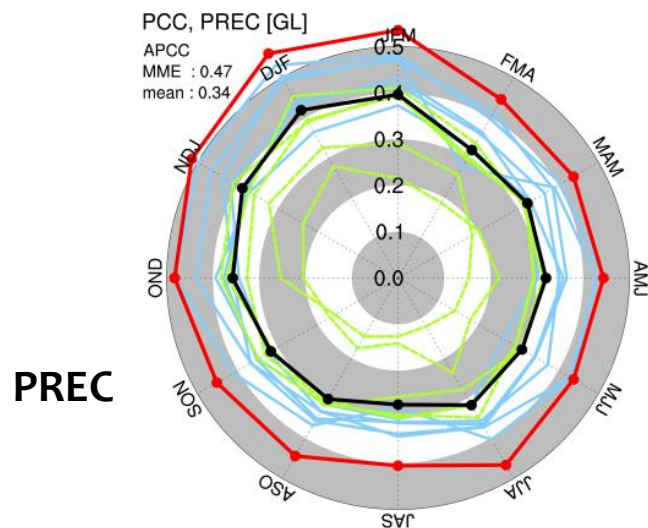
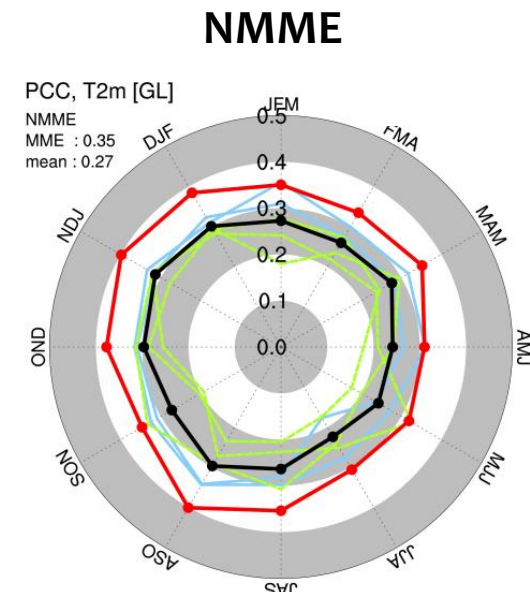
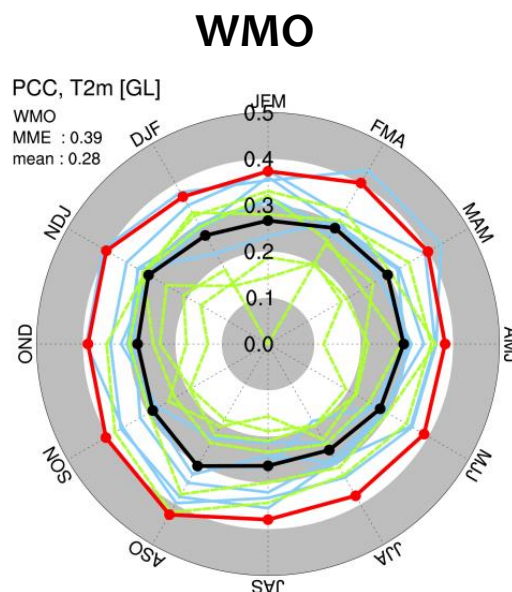
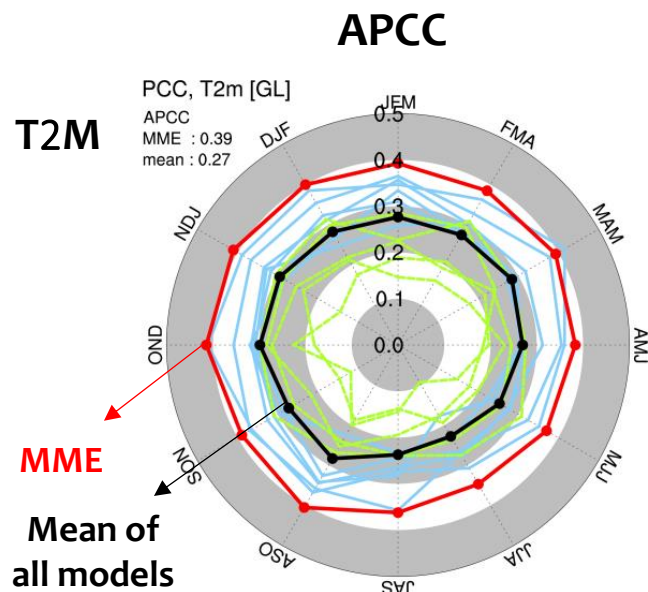
Skill Comparison with other MME Groups

- **Simple averaged MME** with equal weights
- Common hindcast period (1993-2005) on a common resolution (2.5 x 2.5 deg.)
- Observation: NCEP-R2 for Temperature at 2M, CMAP for Precipitation

	APCC	WMO	NMME	C3S	
Model	BoM_POAMA	BoM_POAMA			Common Model
	JMA_JRA55	JMA_JRA55			
	KMA_GLOSEA5	KMA_GLOSEA5			
	MSC_CANCM (2)	MSC_CANCM (2)	MSC_CANCM (2)		
	NCEP_CFSv2	NCEP_CFSv2	NCEP_CFSv2		
	UKMO_GLOSEA5	UKMO_GLOSEA5		UKMO_GLOSEA5	
	BCC_CSM	BCC_CSM			
	HMC_GCM	HMC_GCM			
	NASA_GEOSv2		NASA_GEOSv2		
		DWD_GCFS2		DWD_GCFS2	
		ECMWF_SEAS5		ECMWF_SEAS5	
	CMCC_SPSv2			CMCC_CPSv2	
	CWB_CWB	CPTEC_GCM	GFDL_FLOR	MF_SYS6	Independent Model
	PNU_CGCM	SAWS_EPS	NCAR_CESM1		
	APCC_SCoPS		NCARP_CCSM4		
	MGO_AM2		GFLD		
Hindcast Period	1993-2005	1993-2009	1982-2010	1993-2016	
Resolution	2.5x2.5	2.5x2.5	1x1	1x1	

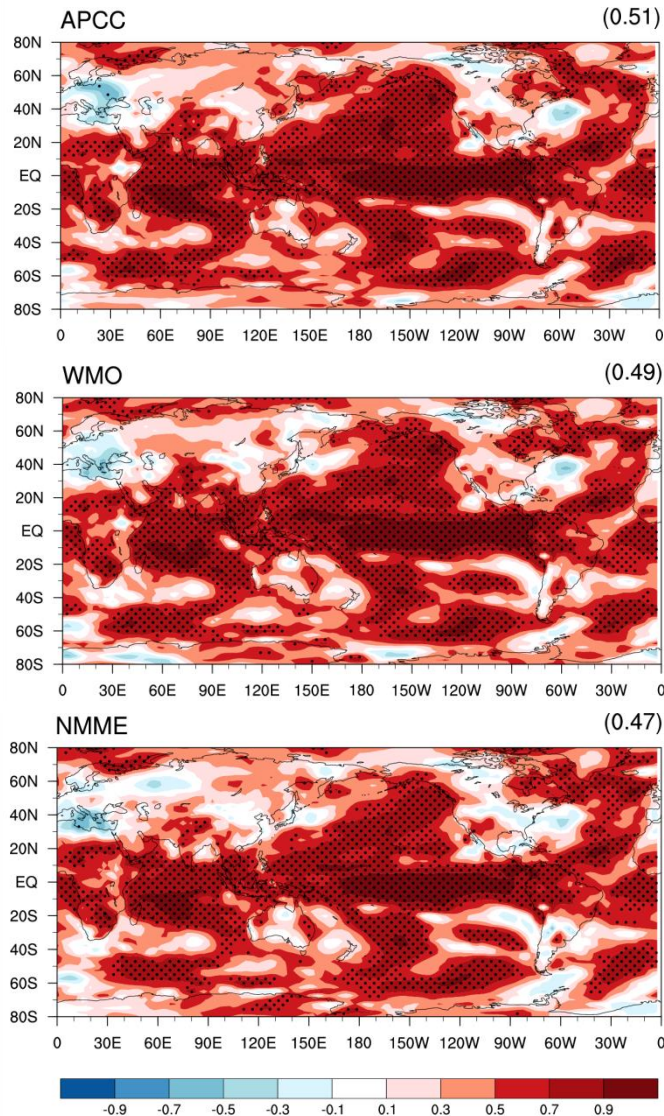
Skill Comparison with other MME Groups

- Common Model
- Independent Model

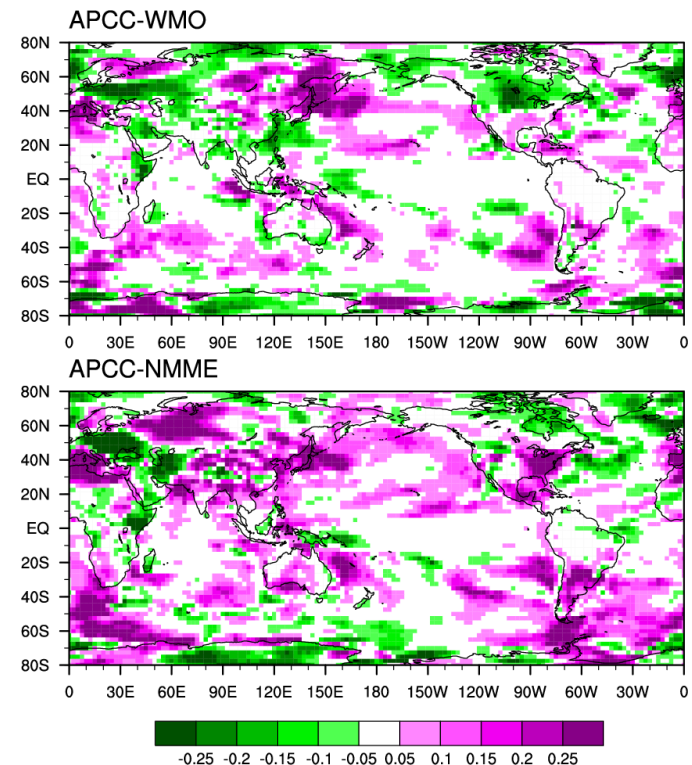


Skill Comparison with other MME Groups

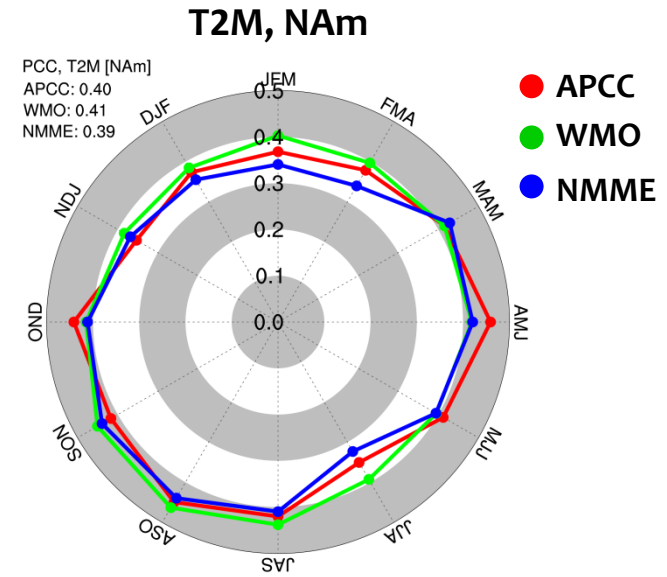
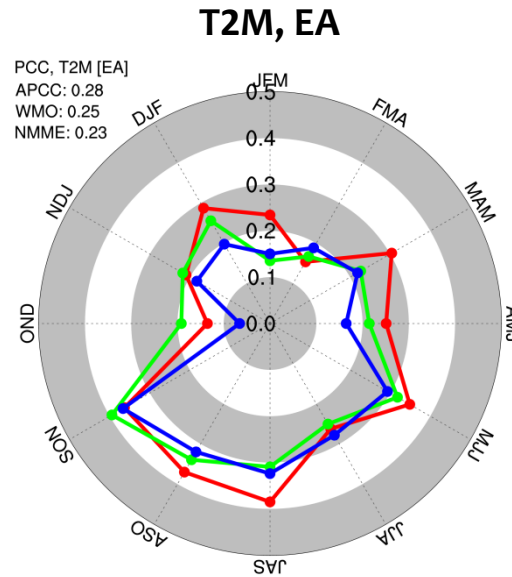
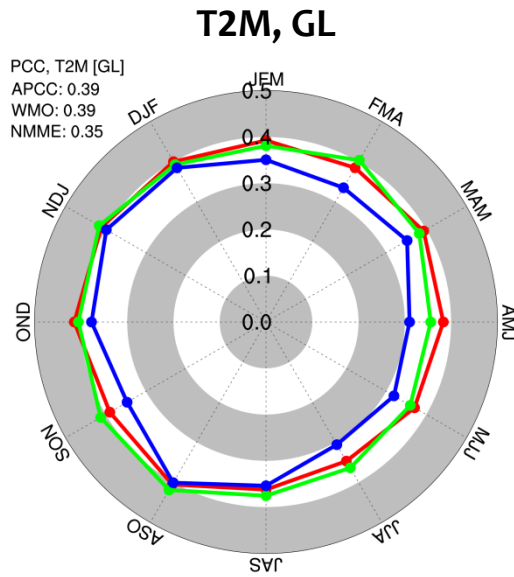
Hindcast Skill: T2M, DJF



- The global scale performance of boreal winter temperature are comparable.
- But, there are regional skill differences between them.



Skill Comparison: MME Skill



- The general skills of global temperature in APCC and WMO MMEs are quite comparable while NMME shows slightly lower skill than other two groups.
- The lower skill in NMME may be due to a smaller number of participating models.
- Overall, APCC MME shows comparable or slightly higher skill than other two MME groups.

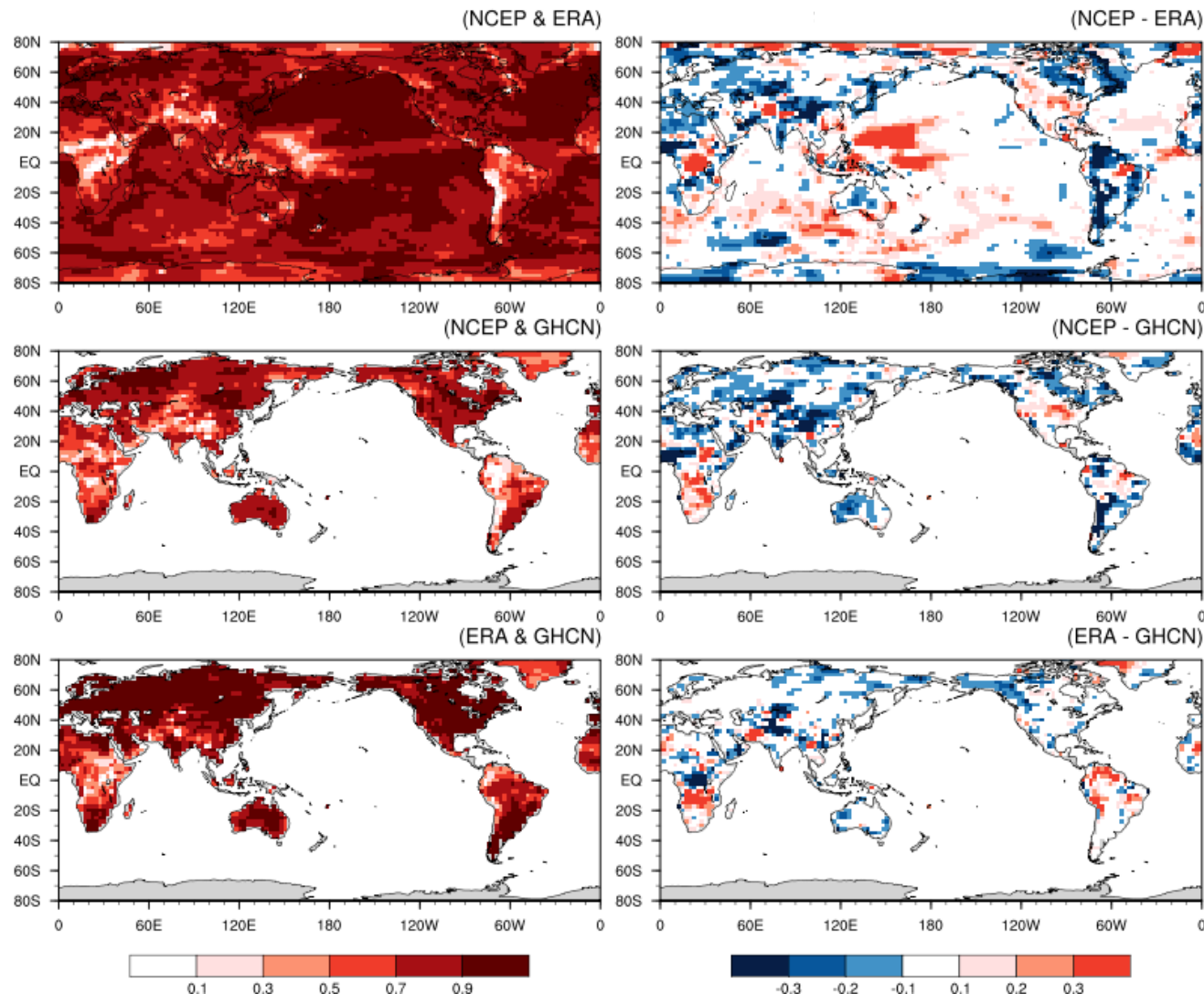
WHAT CAN WE DO?

Challenges in the MME operation

How to deal with **observational uncertainty**?

Correlation between OBSs

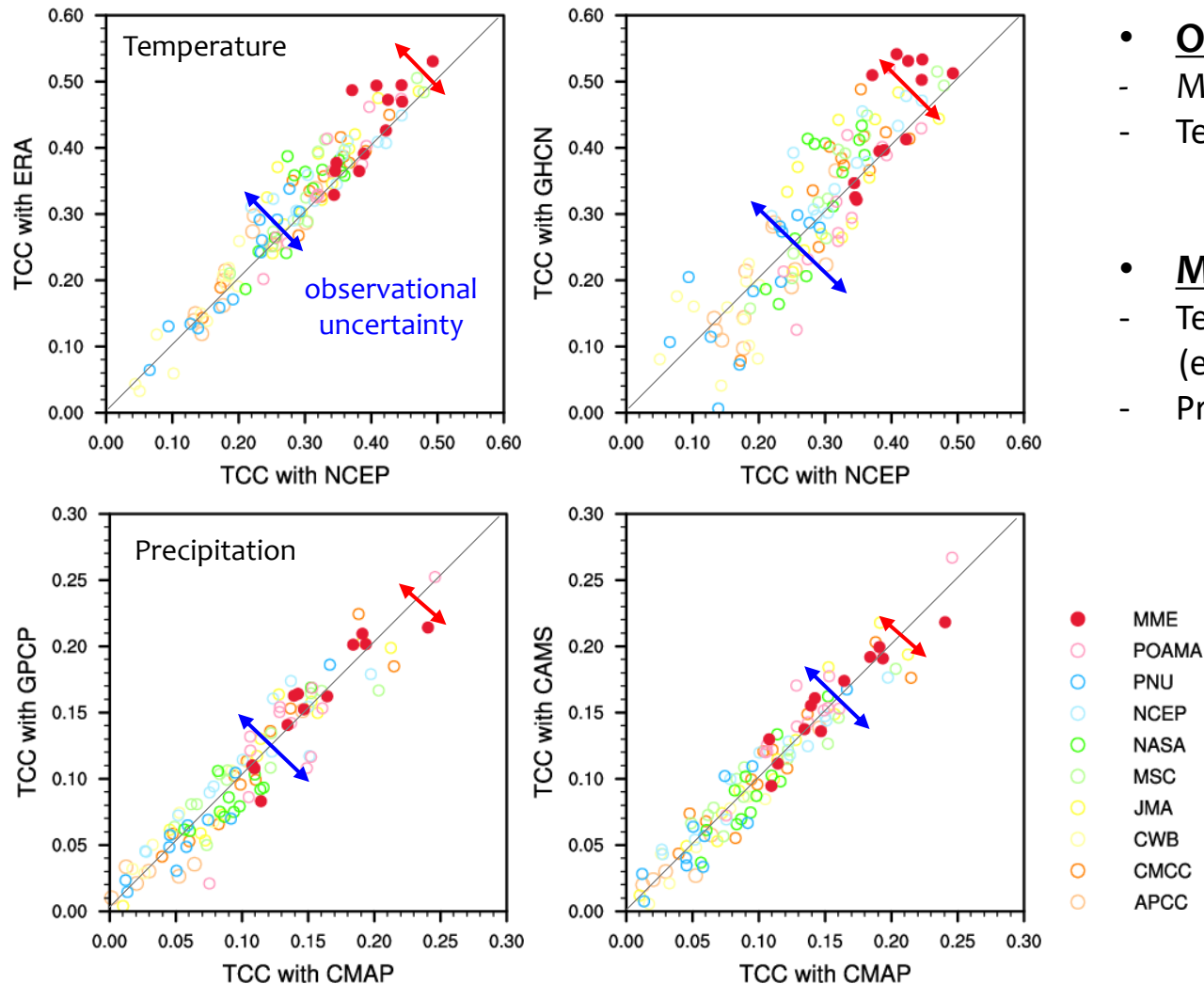
Correlation DF in APCC MME Prediction



- NCEP-R2, GHCN, ERA-II
- 1983-2005 (23 years)
- Common resolution (2.5 x 2.5 deg.)

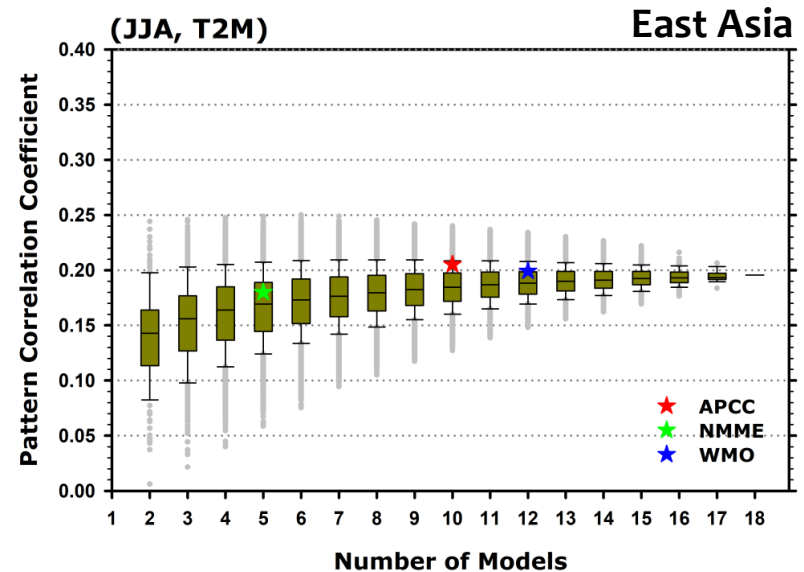
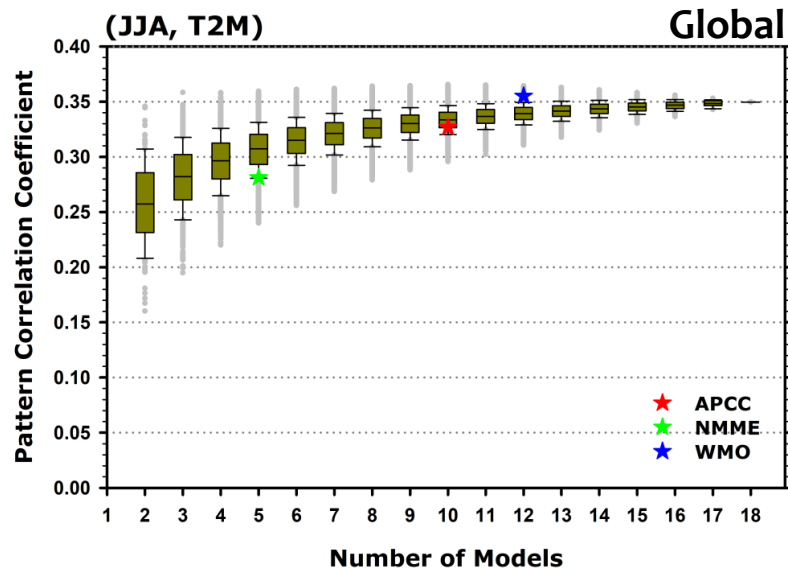
How to deal with observational uncertainty?

Dependence of correlation on different OBSs
(12 seasons, 23 years, East Asia)



- **Obs Uncertainty:**
 - Models > MME
 - Temperature > Precipitation
- **MME (Model) Skill**
 - Temperature: ERA > NCEP (especially, land areas)
 - Precipitation: Similar

How to combine individual models in MME?



The more models, the better skill in MME?

Is there any optimal number of models in MME?

Is it better to use only good models and exclude bad models in MME?

How to Estimate Climatology?

- **MME Prediction System:** usually, common period from all the models

(Problems?)

- Relatively short hindcast period
- Missing the recent climate trends or variability (e.g., global warming)
- Missing advanced models in the MME that have been most recently developed

Participating Models in APCC MME Prediction System (as of 2018)

Institution	Models	Hindcast Period
WMO LC-LRF	Toulouse, CPTEC, SEAS5, EXTER, POAMA, MSC HMC, SAWS, GLOSEA5, TCC, BCC, NCEP, DWD	1993-2009 (17yrs)
NMME IRI	NCEP NASA, NCAR CFDL CM2.1, CFDL CM2.5, CanCM3, CanCM4	1982-2010 (29yrs)
EUROSIP	NCEP, ECMWF, METF, UKMO	1991-2010 (20yrs) (except for UKMO)
C3S	ECMWF METF, UKMO	1993-2015 (23yrs)

Institution	Models	Hindcast Period
APCC	SCoPS	1982-2013
CMCC	CMCC-SPSv2	1981- 2005
CWB	CWB	1982-2017
JMA	JMA/MRI-CPS2	1979-2014
MSC	CanCM	1981-2010
NASA	GMAO	1981-2010
NCEP	CFSv2	1982-2010
PNU	PNU CGCM v1.0	1980-2015
BOM	POAMA-M24	1983 -2011
Met Office	UKMO	1993-2015
BCC	BCCV2	1991-2014
KMA	GLOSEA5	1991-2010
HMC	HMC	1985-2010
MGO	MGOAM2	1979-2004

Seasonal MME Forecast, Where to go...?





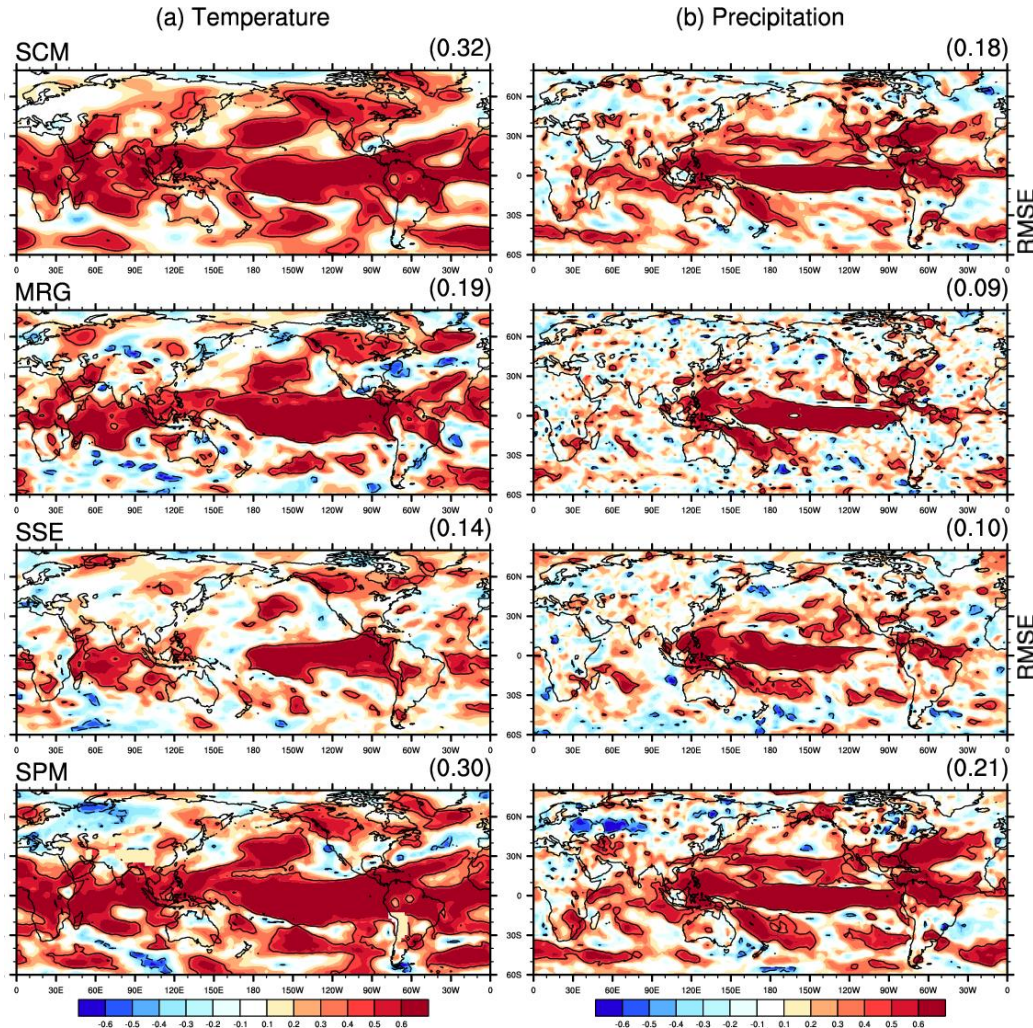
THANK YOU

(<http://www.apcc21.org>)

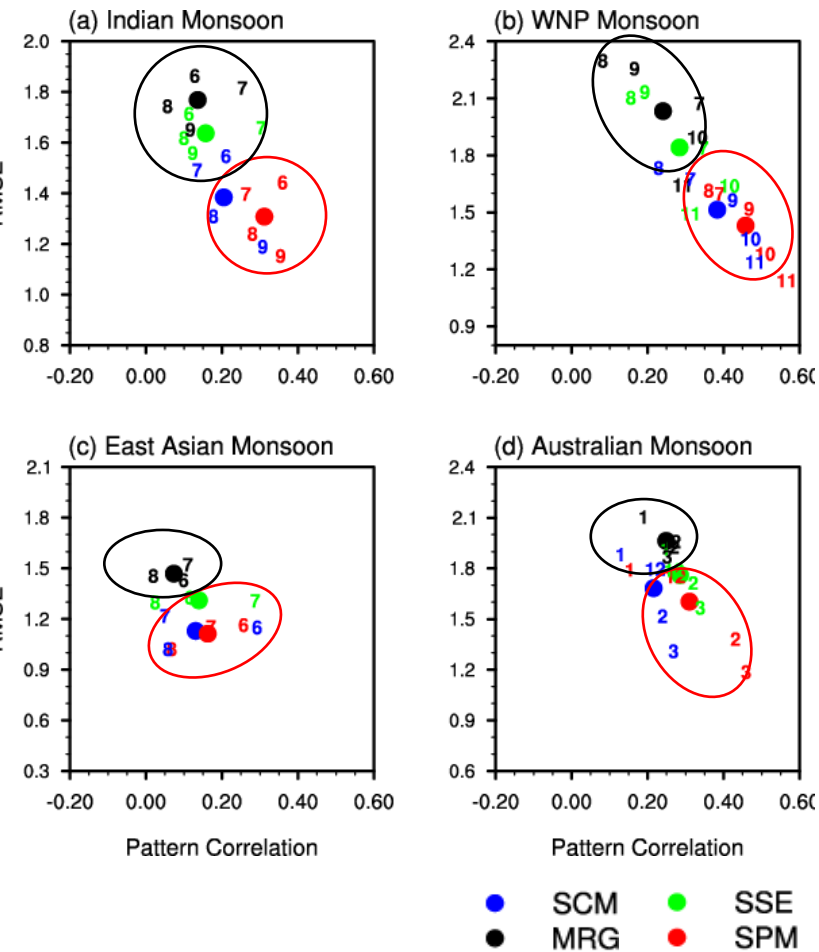


Simple MME is the best way?

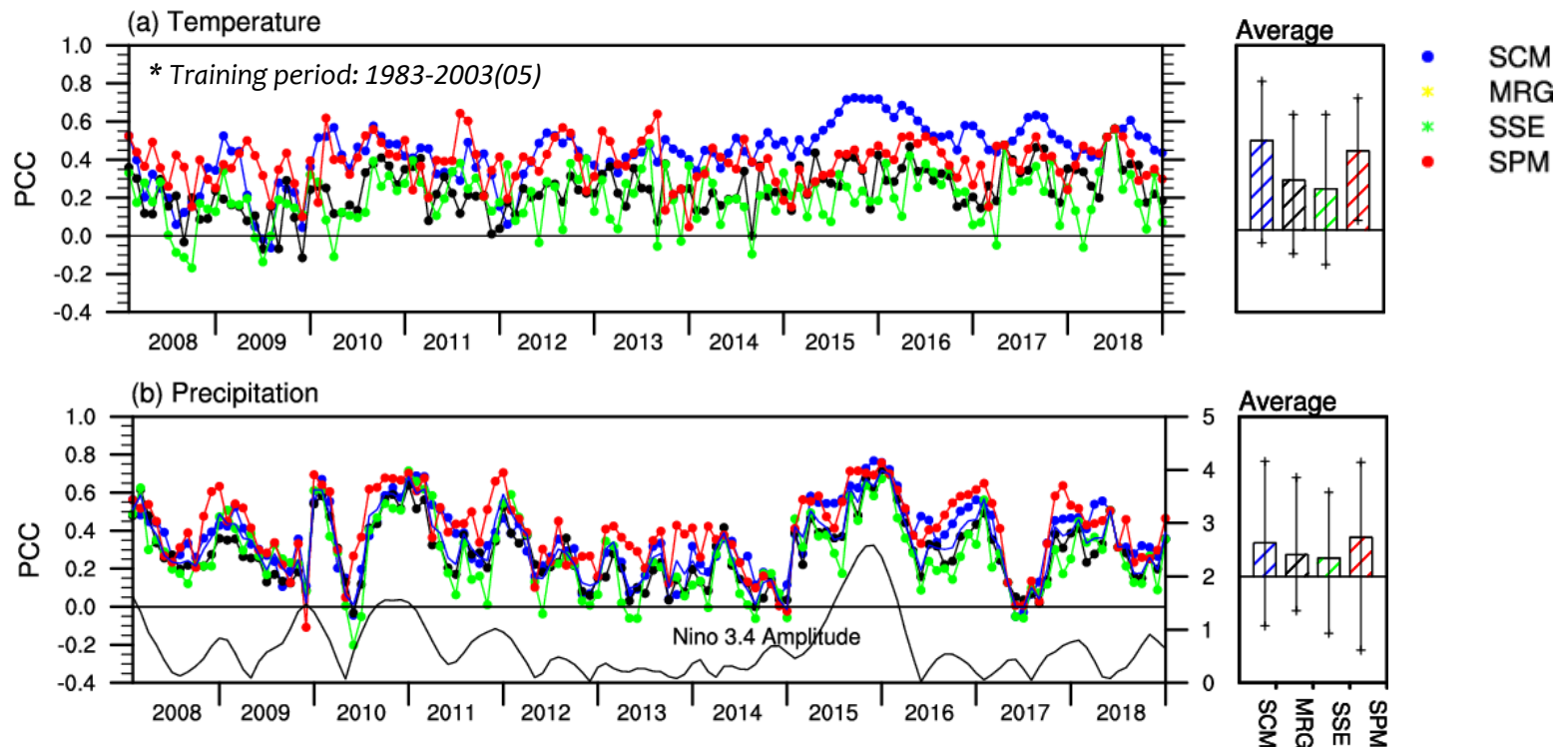
Hindcast Skill: TCC, 1983-2003



PCC-RMSE Diagram: Precipitation



Skill Comparison: RT Forecast (2008-18)



“Considering many issues from an operational point of view”

The use of **SCM method** is the most practical way of utilizing the multi-model approach in an operational environment.

Subseasonal Predictability : inter-model comparison and multi- model ensemble performance

Yun-Young Lee, Gayoung Kim, and Soon-Jo Yoon

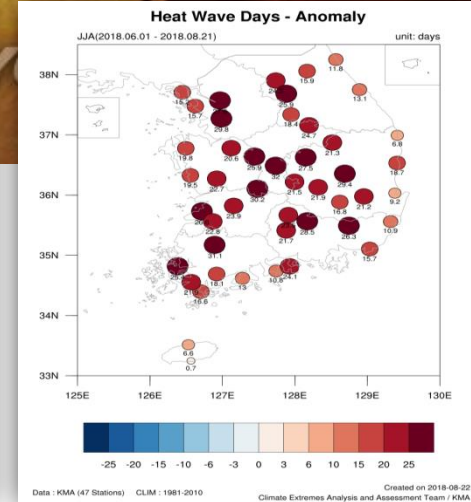
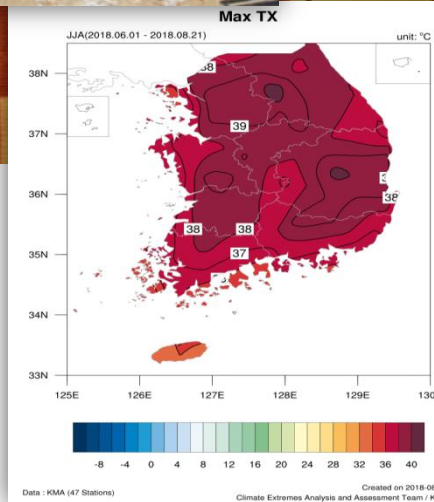
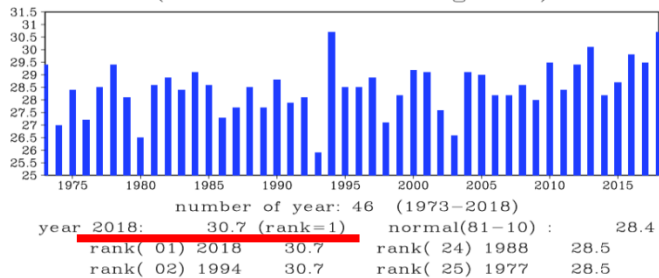
APEC Climate Center

2018 Korea Heat Wave



2018 Heat Wave related-	
Morbidity	4301
Fatality	48

Korea (45stn)
Maximum Temperature
(01Jun2018 ~ 21Aug2018)

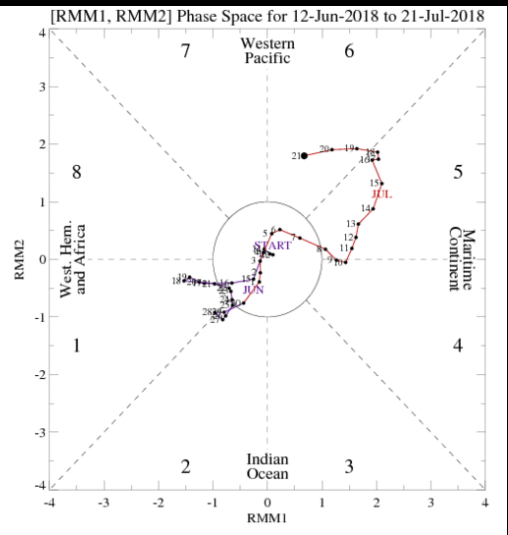


Monthly prediction fail case

Motivation

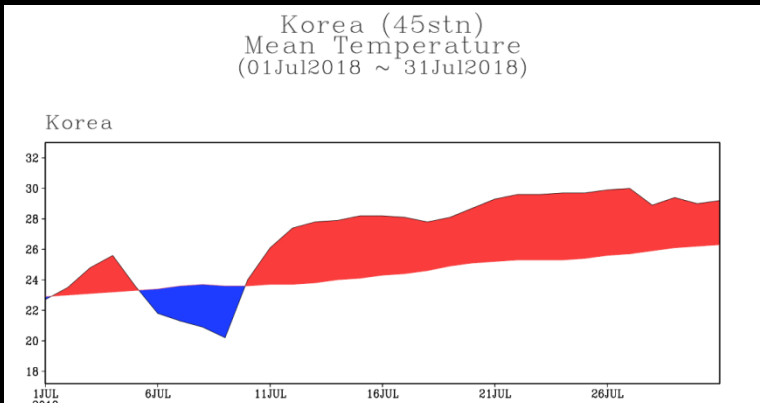
< 2018 July heatwave case >

MJO activity

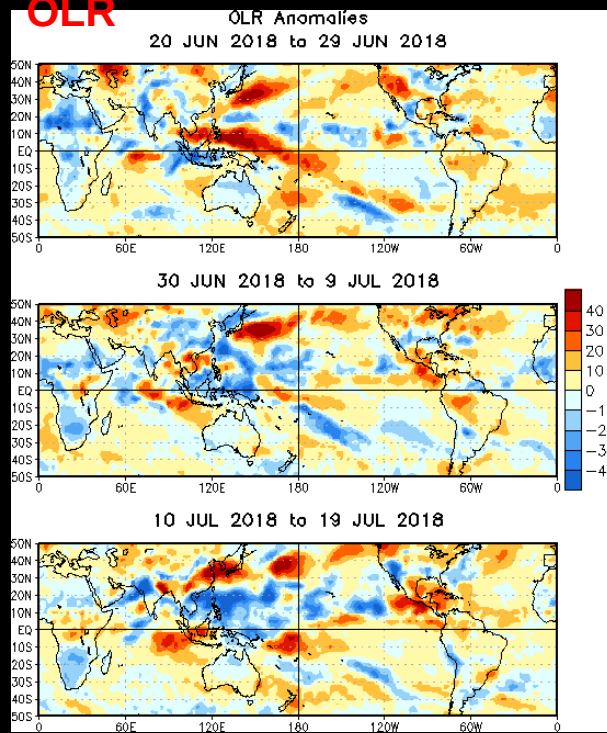


KMA Forecast	+/-0
OBS	+2.3degC (AN)

Korea Temp. (July)



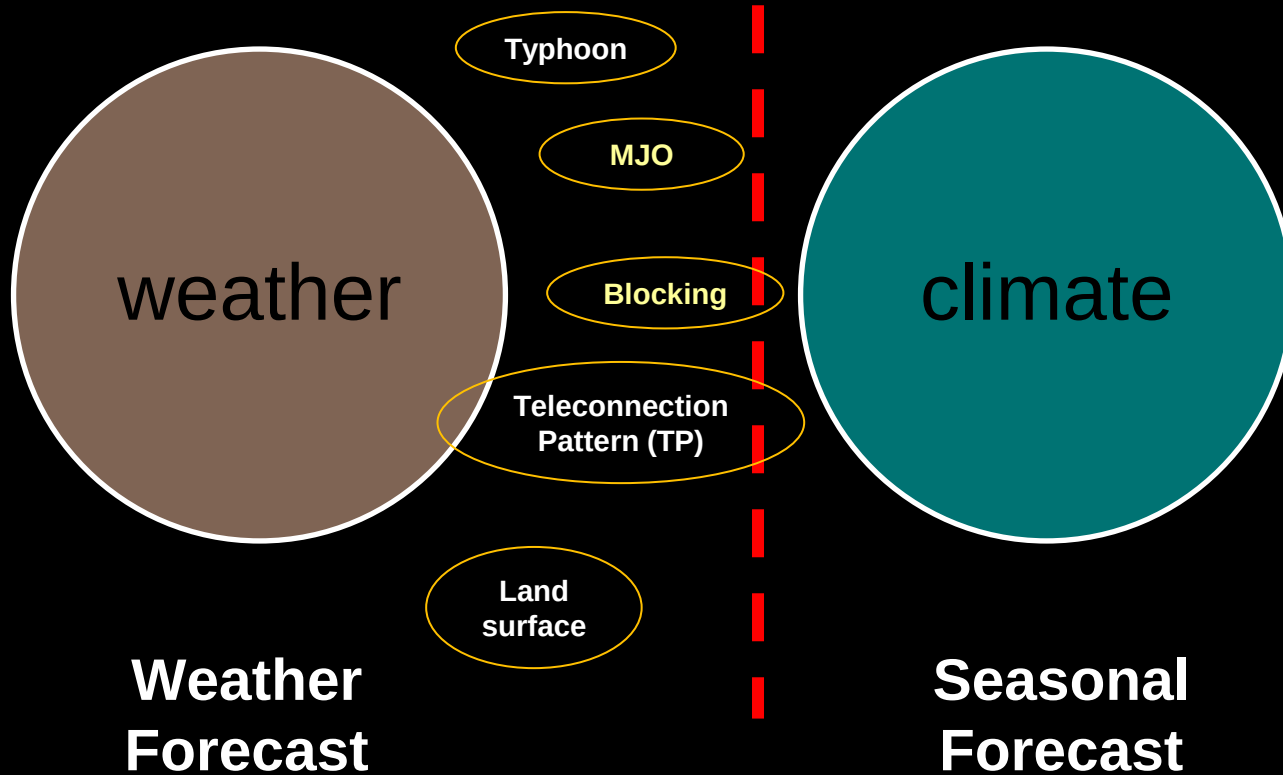
OLR



Subseasonal forecast necessity

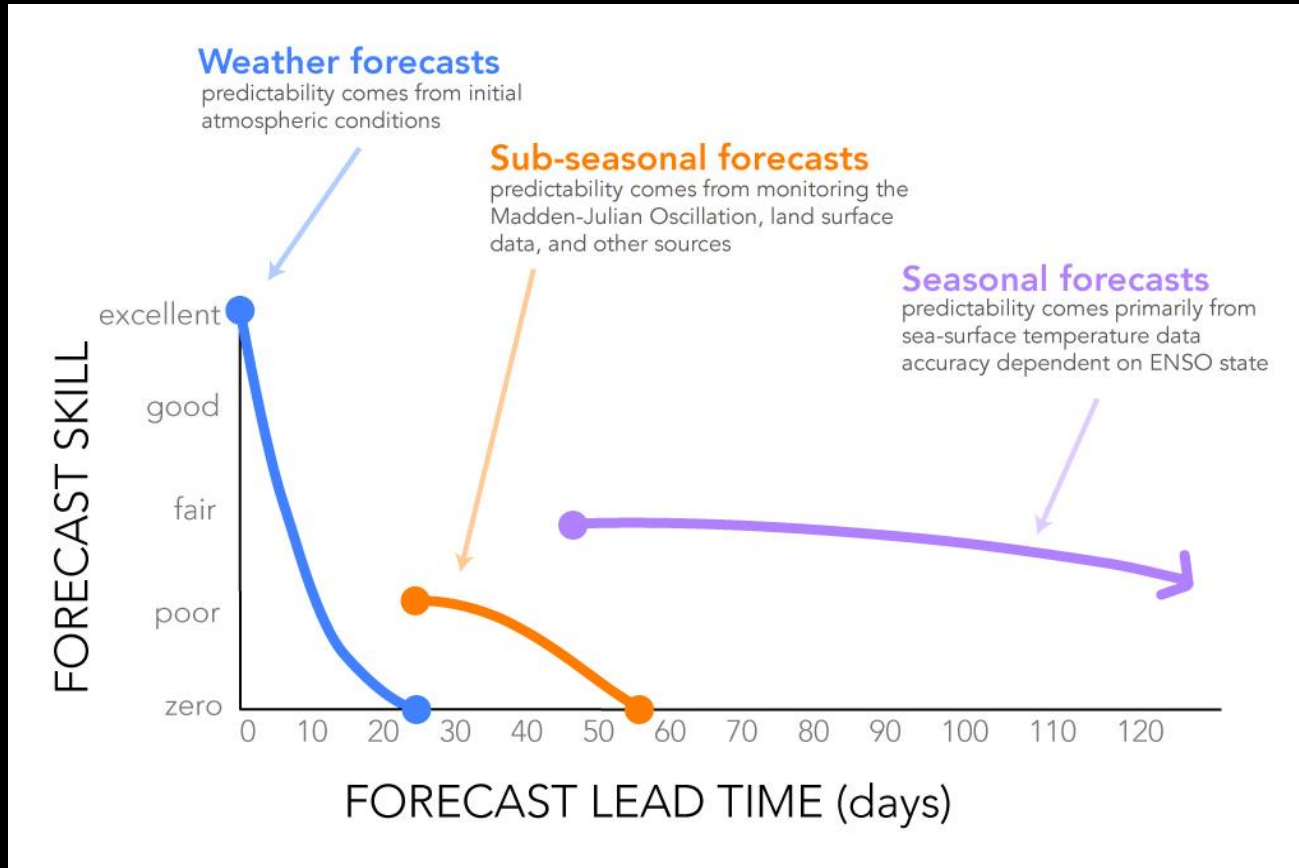
Motivation

- Bridge between weather & climate



Challenge of Subseasonal Prediction

Motivation



White et al. (2017)

Subseasonal scale merging (MME)

background

- S2S project
- NMME (SubX)

WMO Lead Center

- ✓ almost real-time S2S data processing (exception to 3 weeks embargo)
- ✓ only **WMO users** accessible
- ✓ weekly mean prediction (**release every week/ at most 6 weeks forecast**)
 - Probabilistic and Deterministic information (MME & 8 individual models)
 - SST, T2m, precipitation, mslp, u200, v200, h500, u850, v850 and OLR
 - MJO, BSISO prediction

❖ Specification of Models constituting WMO Lead-Center Subseasonal MME

WED	THU	FRI	SAT	SUN	MON	TUE	GPC / MME	Time range	Fcst. Week	Ens. Size	Avg. Day	Tot. Size
Merge 7days data							Beijing	4(10)-45(51) days	6	4	7	28
							ECMWF	5-46 days	6	51	1	51
Merge 7days data							Exeter	4(10)-45(51) days	6	4	7	28
							Melbourne	5-46 days	6	33	1	33
							Montreal	5-32 days	4	21	1	21
Merge 7days data							Seoul	4(10)-45(51) days	6	4	7	28
							Tokyo	6-33 days	4	25	1	25
							Washington	5-39 days	5	16	1	16
							MME	-	-	-	-	229

APCC Subseasonal MME initiative...

Inter-comparison of *individual models and MME*

← verification on

- ✓ Climatology (Q. how sensitive to lead days?)
- ✓ Predictability (Q. SNR, ensemble spread issue?)
- ✓ Prediction skill (Q. added-value from MME? footprint of LRF?)

Center	Time Range	Resolution	Ens. Size	Fcst. Freq.	Refcst. Period	Refcst. Ens. Size	Refcst. Freq.
ECCC	32 days	0.45x0.45, L40	21	weekly	1995-2014	4	weekly
ECMWF	46 days	*Tco639/319, L91	51	2/week	past 20 years	11	2/week
NCEP	44 days	T126, L64	16	daily	1999-2010	4	daily

**Triangular_cubic_octahedral*

ECMWF/ECCC/NCEP reforecast verification on

- **Climatological Mean Field**
 - ✓ Biases of LTM & LTS
 - ✓ PCC & RMSE of LTM (climatology)
- **Predictability (Model Potential)**
 - ✓ SNR (Signal to Noise Ratio)

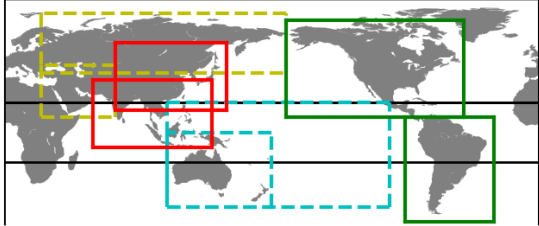
for **3** models (ECMWF, ECCC, NCEP)

for **v2016 & v2017** hindcast sets

for **4(11)** variables and **3(12)** regions

Reference: ERA-Interim

for extended/original period & short period

12 Regions	
	
11 Variables	12 Regions
TMAX	Globe
TMIN	Tropics
T2M	S. Extratropics
PREC	N. Extratropics
MSLP	East Asia
Z200	South Asia
Z500	North America
U200	South America
U850	Australia (or Australasia)
V200	Australia + S. Pacific
V850	Russia (or Northern Eurasia)
	East Middle

	years	ensm. #	lead days
ECMWF (B)	12(99-10)	11	46
ECCC (O)	12(99-10)	4	32
NCEP (G)	12(99-10)	4	44

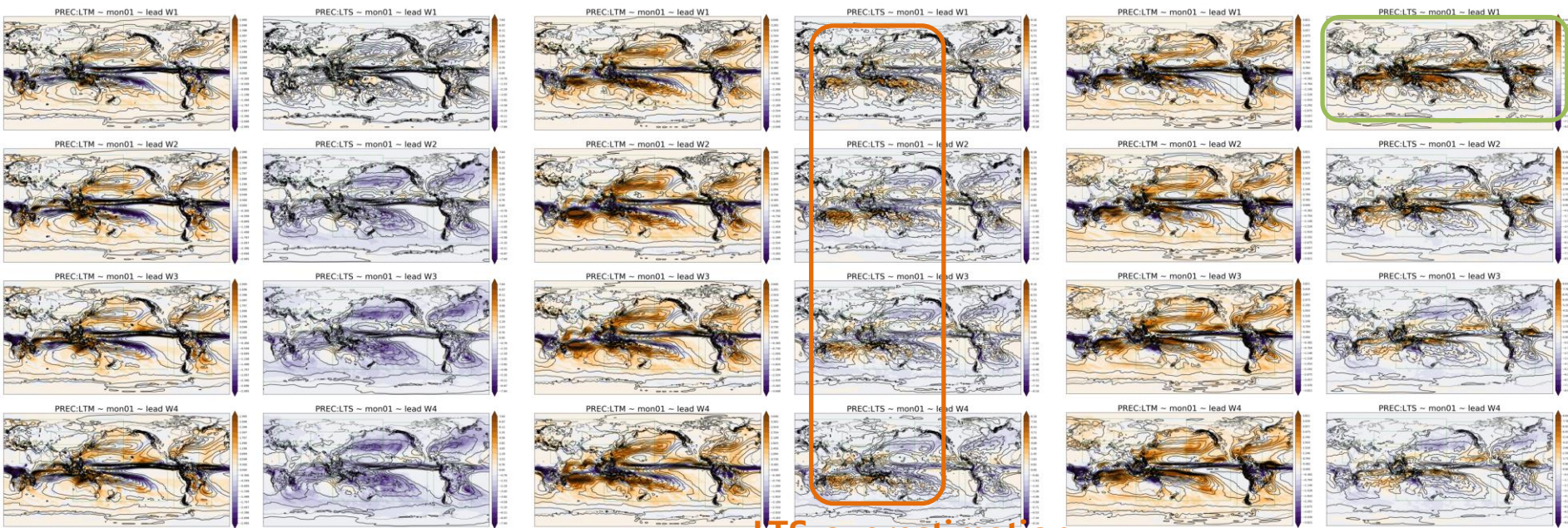
PREC LTM/LTS *bias*

Unresolved issues even in state-of-the-art climate models
: **Double ITCZ & Small Variance**

ECMWF

ECCC

NCEP



Less strong
double ITCZ

LTS
underestimation

LTS overestimation
over Indian Ocean
and through SPCZ

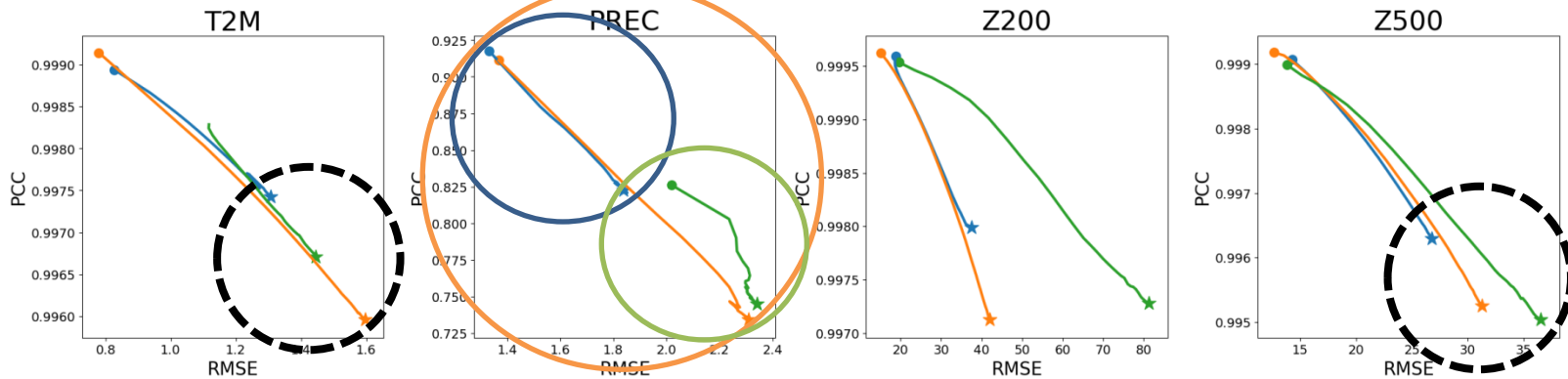
LTS overestimation
in lead W1

	years	ensm. #	lead days
ECMWF (B)	12(99-10)	11	46
ECCC (O)	12(99-10)	4	32
NCEP (G)	12(99-10)	4	44

PCC & RMSE of LTM

X: RMSE
Y: PCC

Expectation:
RMSE $\uparrow$ & PCC $\downarrow$ as lead $\uparrow$



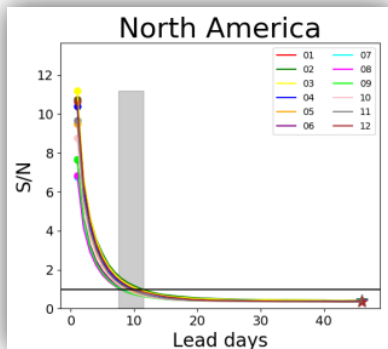
Roughly, LTM representation **ECMWF** > **ECCC** $\approx$ **NCEP**

	years	ensm. #	lead days
ECMWF (B)	20(97-16)	11	46
ECCC (O)	20(95-14)	4	32
NCEP (G)	12(99-10)	4	44

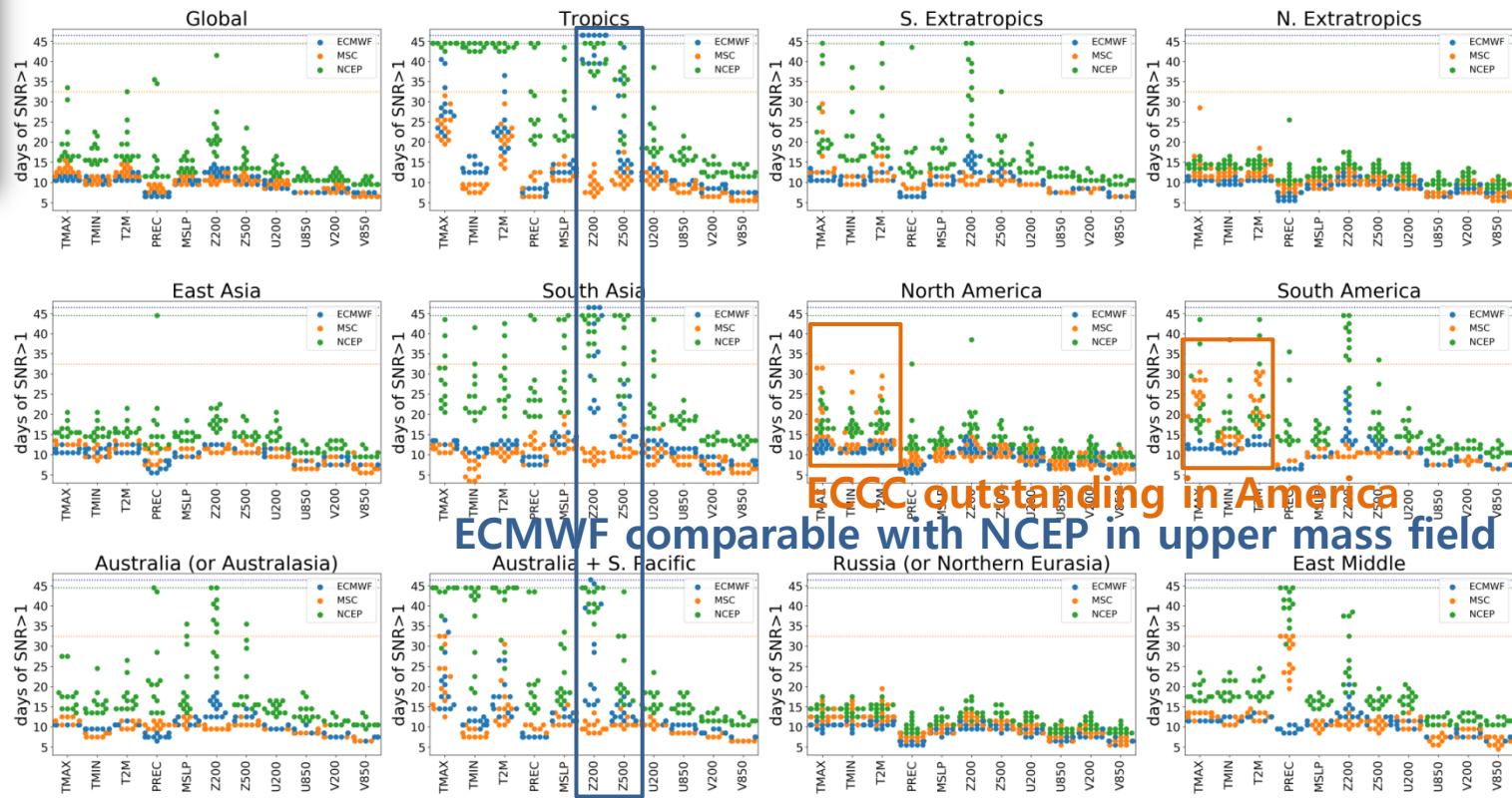
SNR (predictable days)

for most months & variables & regions...

NCEP defeats other two!



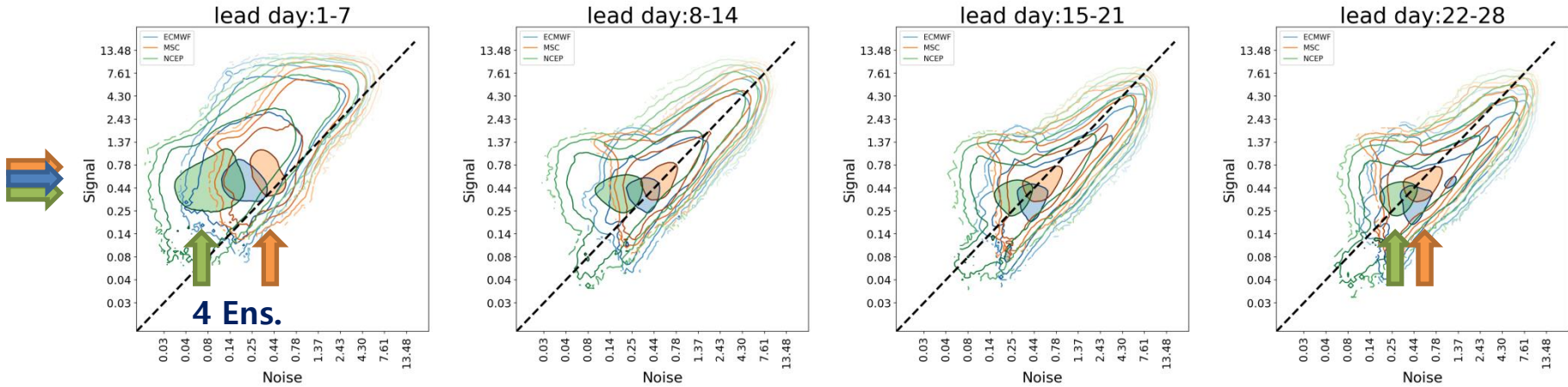
Predictable days
: when $S/N < 1$



	years	ensm. #	lead days
ECMWF (B)	20(97-16)	11	46
ECCC (O)	20(95-14)	4	32
NCEP (G)	12(99-10)	4	44

Q. *SNR: Signal vs Noise?*

T2M



NCEP & ECCC: different NOISE dist. with same ensemble #

NCEP: quite small NOISE during lead 1W

ECCC: quite large NOISE & it persists through whole lead days

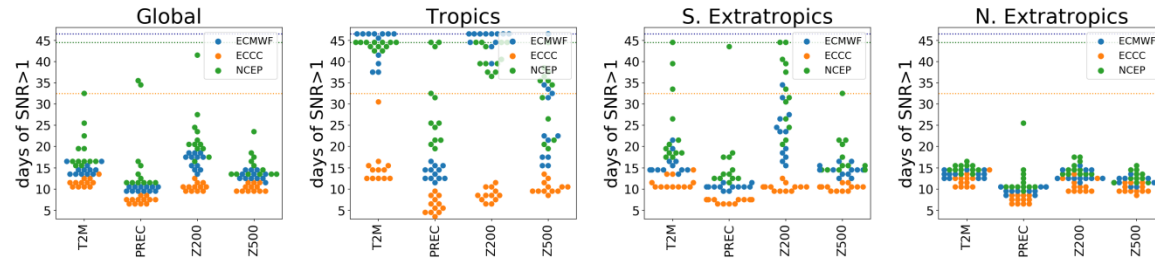
No clear difference in SIGNAL dist.

	years	ensm. #	lead days
ECMWF (B)	12(99-10)	4	46
ECCC (O)	12(99-10)	4	32
NCEP (G)	12(99-10)	4	44

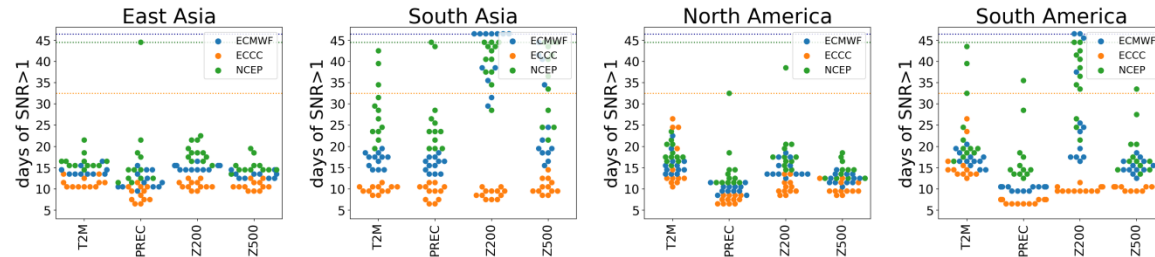
SNR (predictable days)

- S/N dependent on
- ✓ **Ensemble size? (4 vs 11)**
 - ✓ **Length of period? (12 vs 20)**
 - ✓ **Timing of period? (including 97/98 & 15/16 El Nino)**

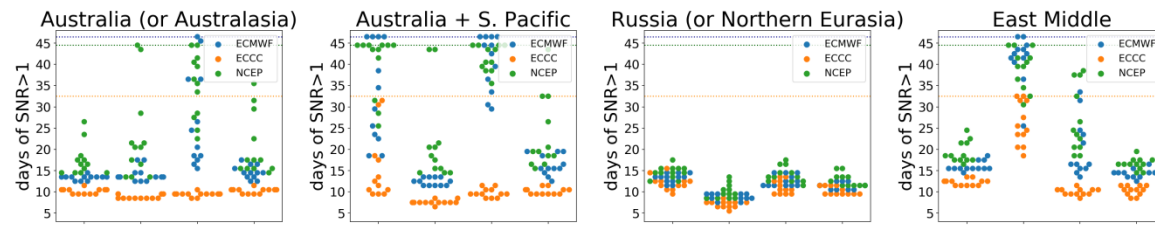
0. Original



1. 1999-2010



2. 1999-2010 & 4 ens.



Q. *SNR sensitivity?*

0. Original



1. 1999-2010



2. 1999-2010 & 4 ens.



Shorter $\longleftrightarrow$ longer

Globe

Tropics

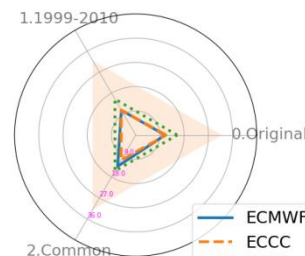
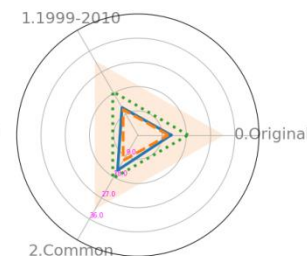
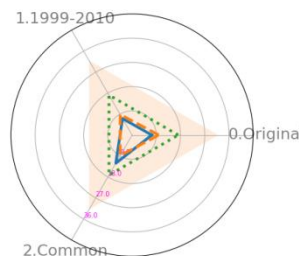
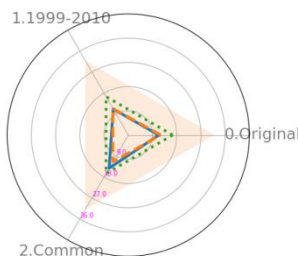
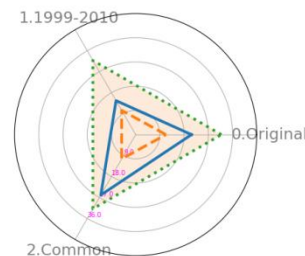
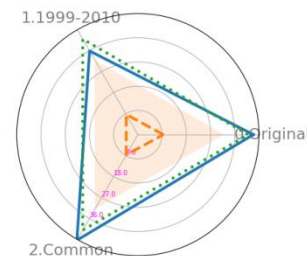
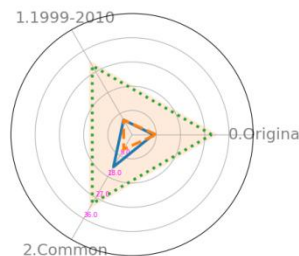
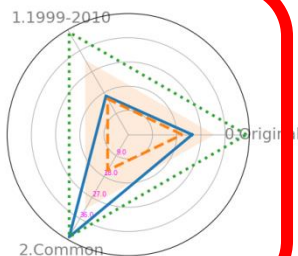
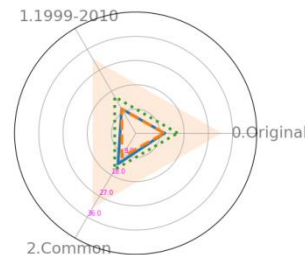
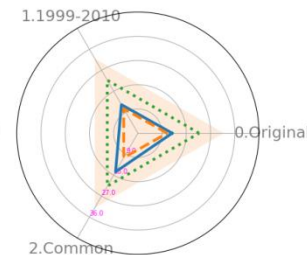
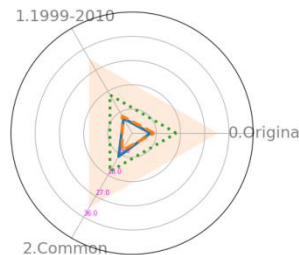
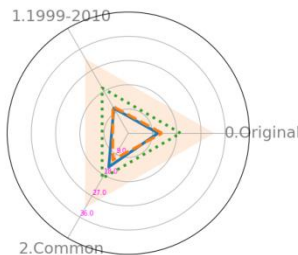
East Asia

T2M

PREC

Z200

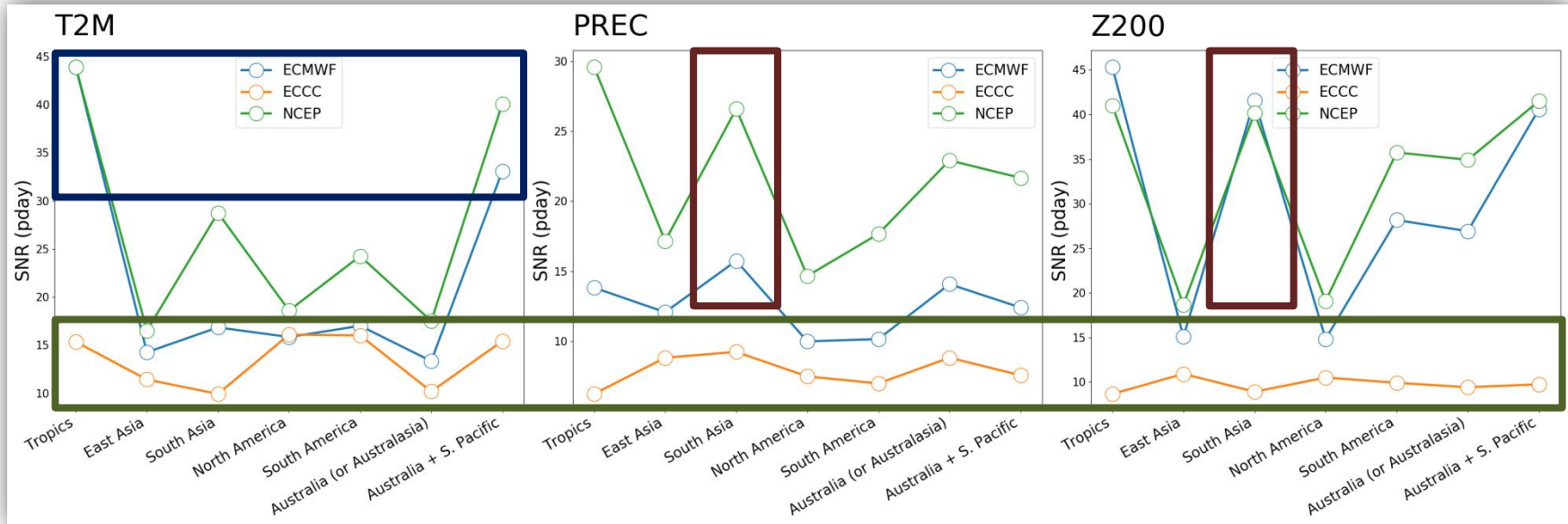
Z500



ECMWF
ECCC
NCEP

Dominant area of Subseasonal Predictability

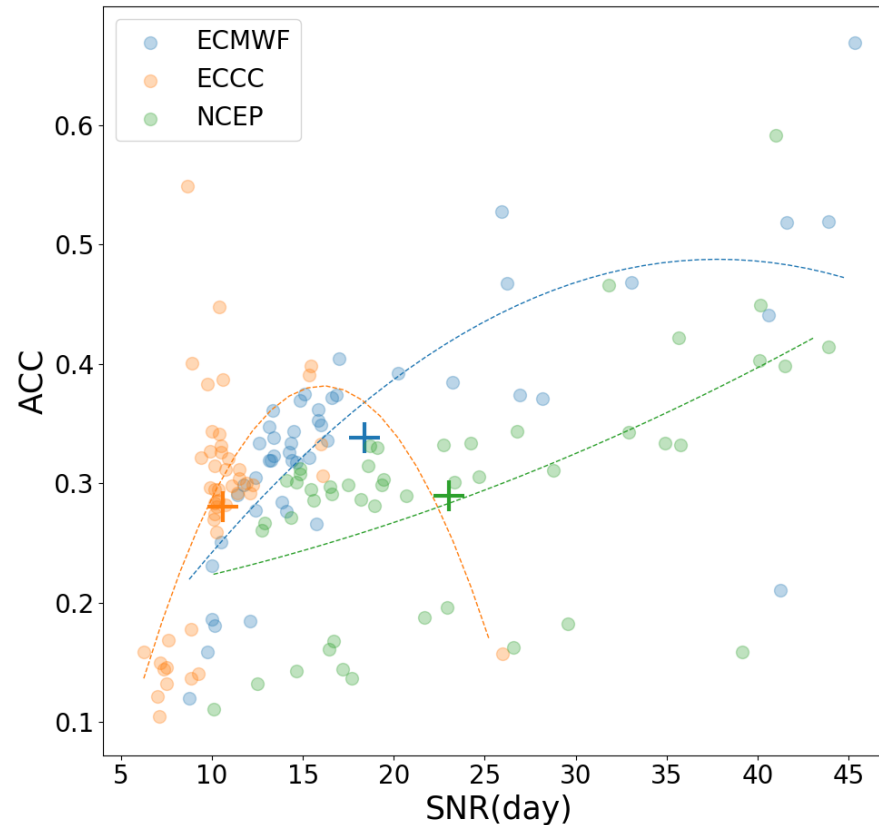
For common case,



- ✓ All three variables, dominant in Tropics and Australia+S.Pacific
- ✓ PREC & Z200: also dominant in the domain of South Asia
- ✓ ECCC: showing different feature from other two models, shorter predictability even in Tropics

SNR: affecting prediction skill (weekly ACC)?

Short period & 4ens case



Q. Ensemble Spread Issue!?!?!?

Under **the same** condition of **ensemble size & reference period**,



things we speculate at this moment,

- **Narrow** ensemble spread in **NCEP** leading to long lasting SNR:
NO model physics perturbation???
- **Wide** ensemble spread in **ECCC** leading to short lasting SNR:
Non-coupling atmospheric model issue?

From multi-model inter-comparison,

- ✓ **What determines the ensemble spread?**
- ✓ **How is it connected to prediction skill?**

MME prediction skill assessment

- **Prediction skill** for hindcast & real-time forecast
 - ✓ ACC (Anomaly Correlation Coefficient)
 - ✓ LEPS, ROC, SR

for v2016 & v2017 sets

for 4(11) variables and 3(12) regions

For 3 models (ECMWF, ECCO, and NCEP) &
4 MME variations

MME_e (extended/original reference period, equal weighted MME)

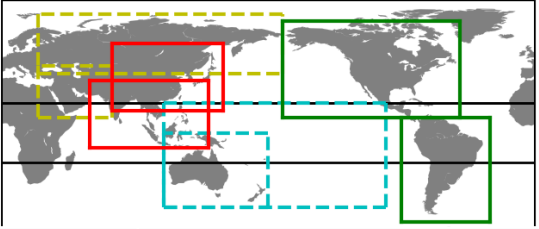
MME_c (common reference period, equal weighted MME)

MME_g (common period, grand ensemble MME, pooling)

MME_w (common period, root ensemble size weighted MME)

Reference: ERA-Interim (short period)

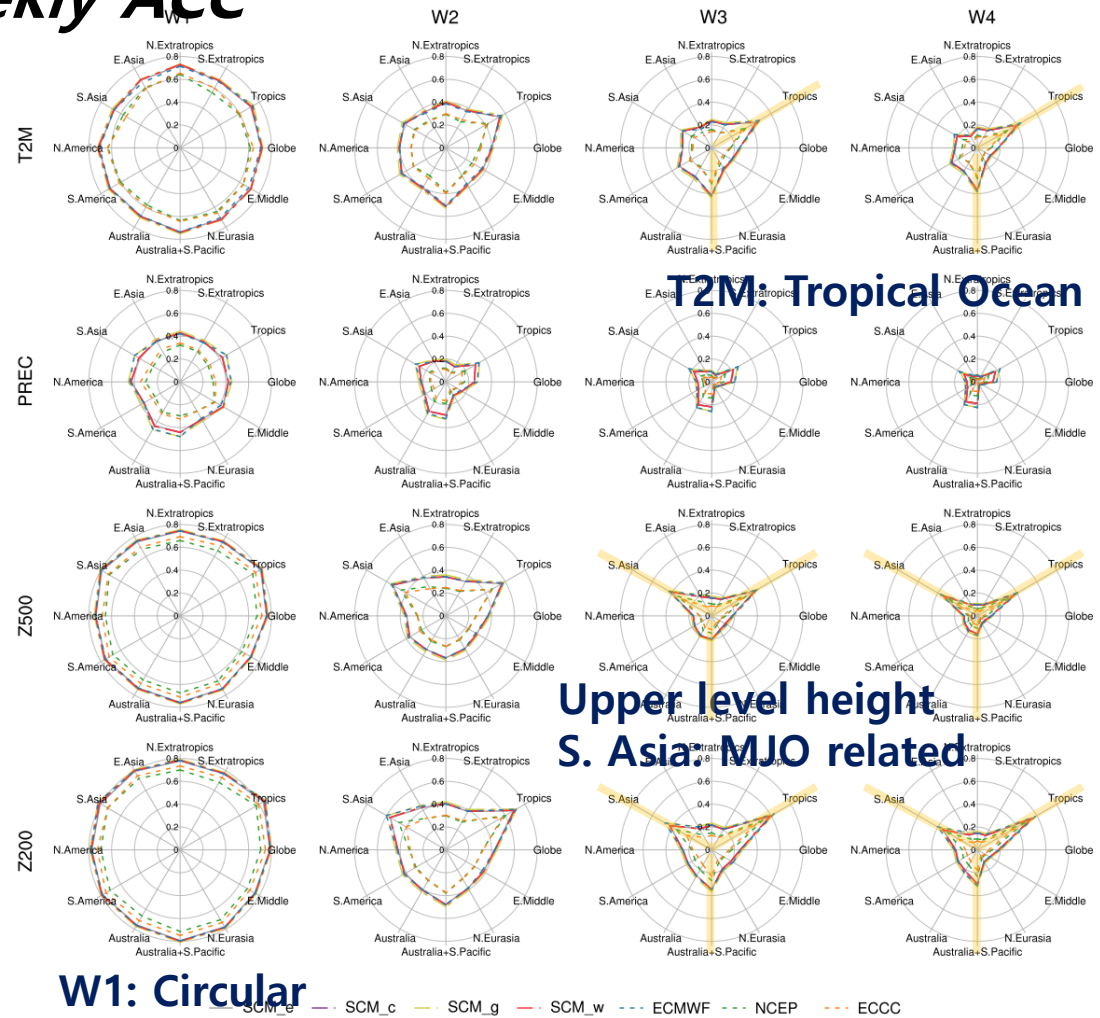
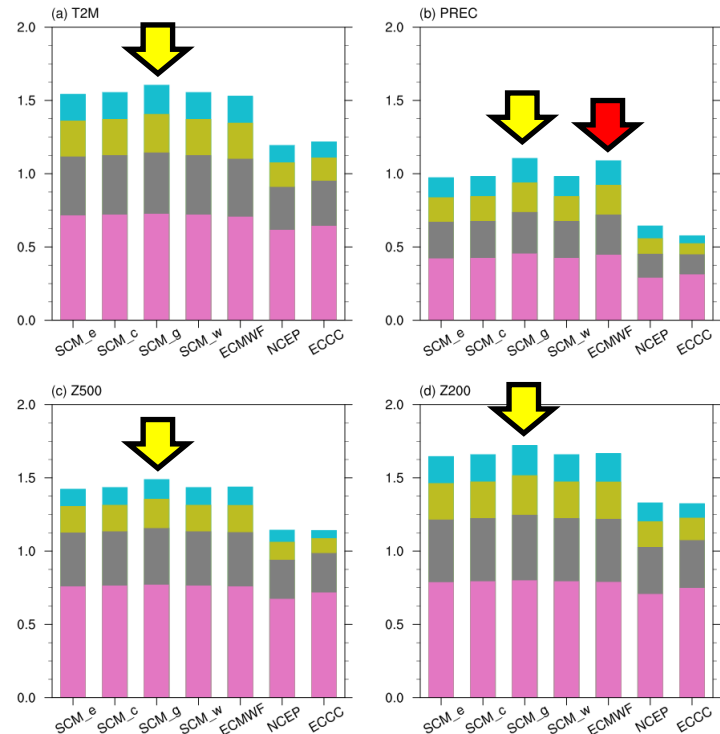
- Relationship with ENSO & QBO year-to-year variation

12 Regions	
	
11 Variables	12 Regions
TMAX	Globe
TMIN	Tropics
T2M	S. Extratropics
PREC	N. Extratropics
MSLP	East Asia
Z200	South Asia
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	East Middle

	years	ensm. #	lead days
ECMWF (B)	12(99-10)	11	46
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NCEP (G)	12(99-10)	4	44

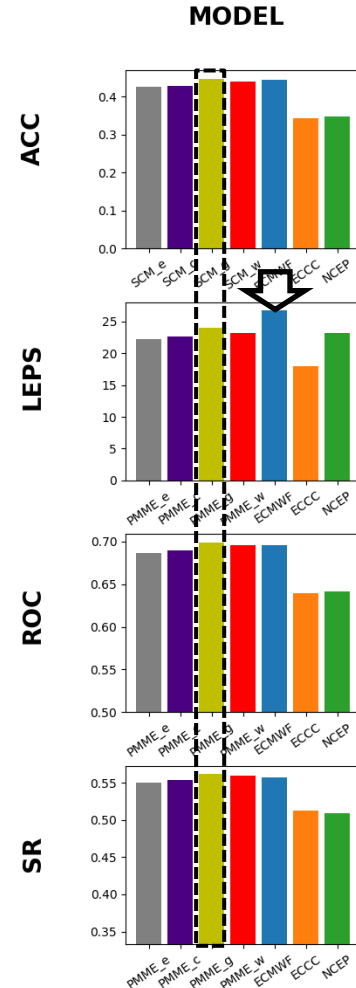
HINDCAST: Weekly ACC

Weekly ACC: Globe



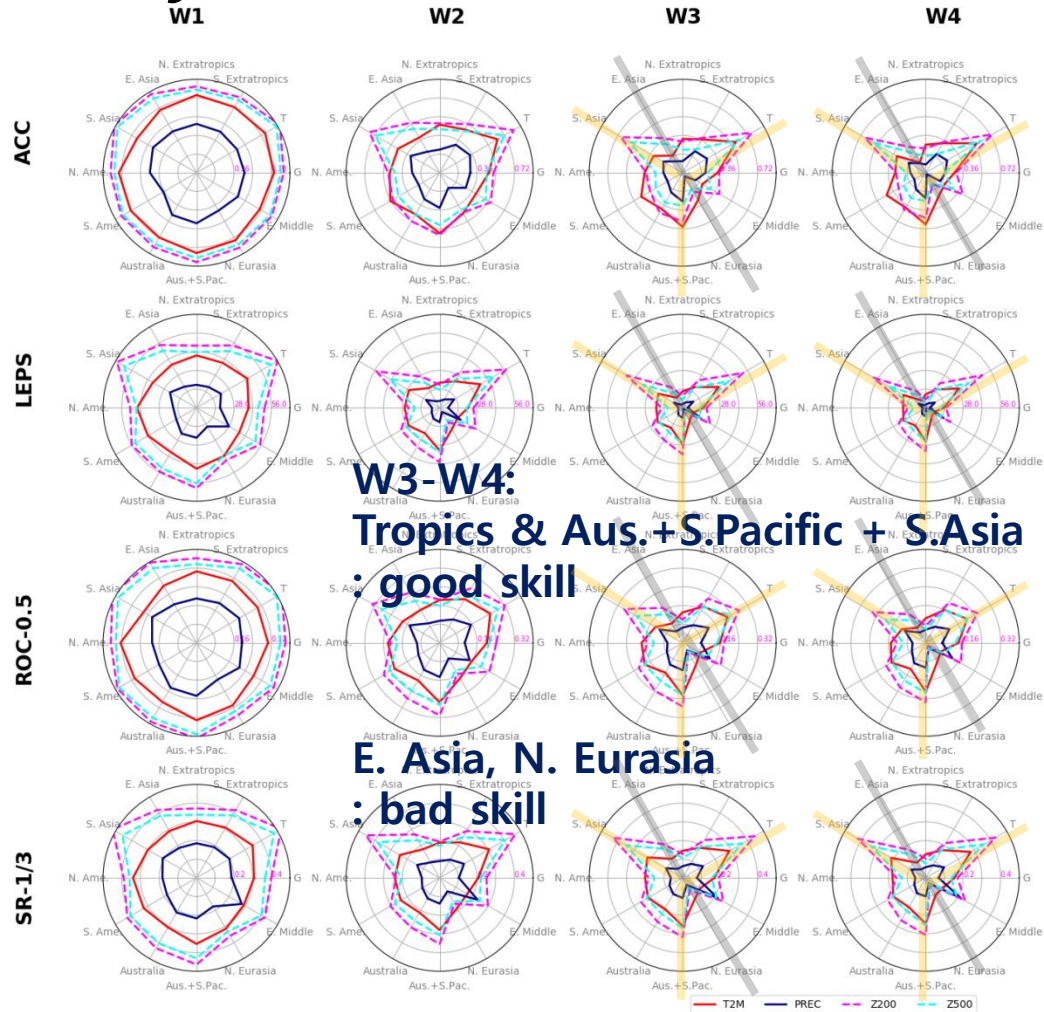
	years	ensm. #	lead days
ECMWF (B)	12(99-10)	11	46
ECCC (O)	12(99-10)	4	32
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R. Forecast: dependency on variable



MME_g

Metric exception

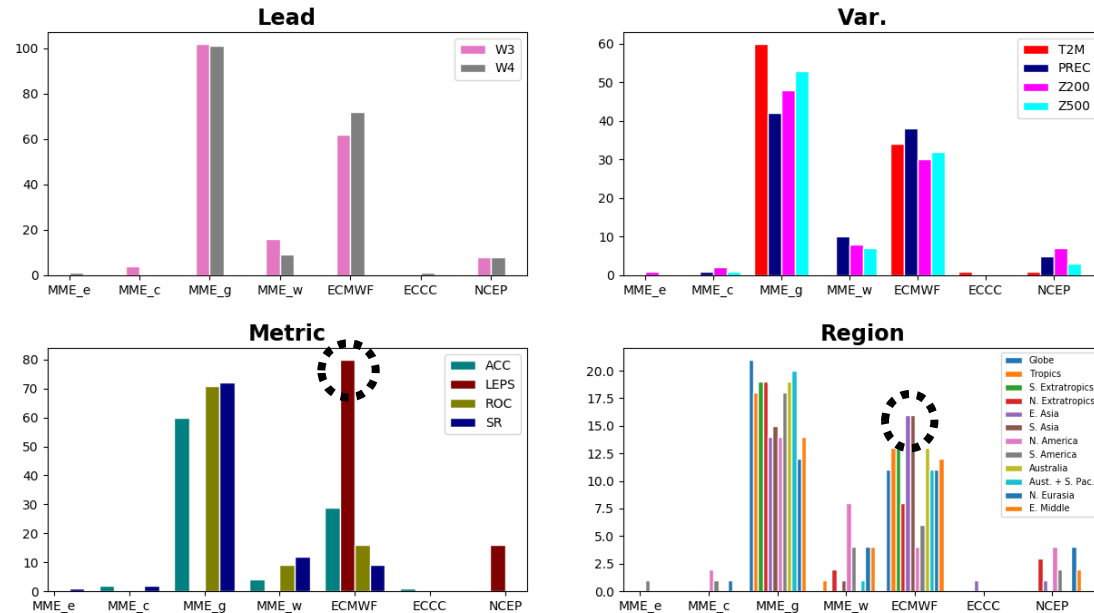


	years	ensm. #	lead days
ECMWF (B)	12(99-10)	11	46
ECCC (O)	12(99-10)	4	32
NCEP (G)	12(99-10)	4	44

Q. MME defeats ECMWF?

Partly **YES**

Top ranker counts



**** W3 & W4 only**

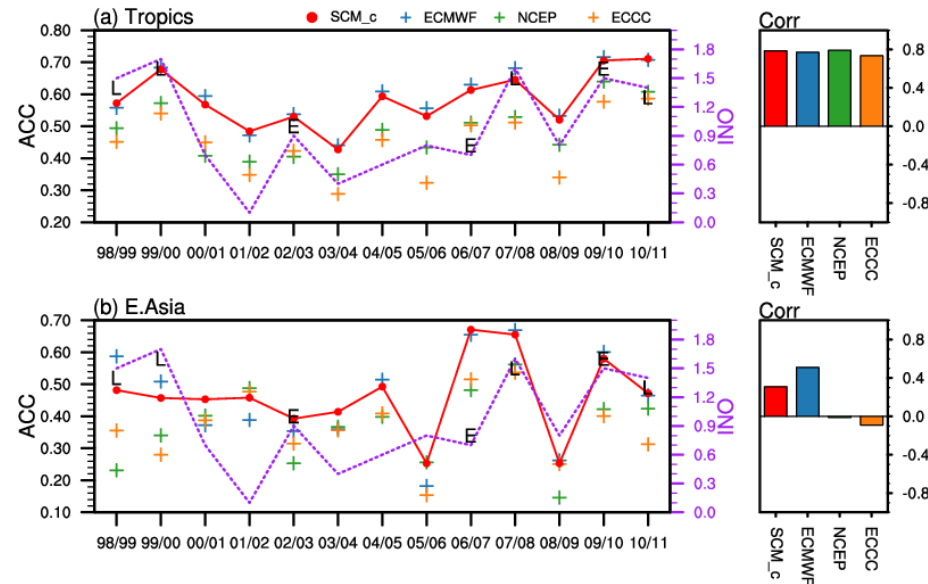
- Grand ensemble **MME_g** is most frequently counted as a top ranker (more than ECMWF).
- Region exception: over E. Asia, ECMWF > MME_g.
- Metric exception: in LEPS, ECMWF is the most.

	years	ensm. #	lead days
ECMWF (B)	12(99-10)	11	46
ECCC (O)	12(99-10)	4	32
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ACC and ONI during DJF

T2M

Weekly ACC: T2M, DJF, Week 2



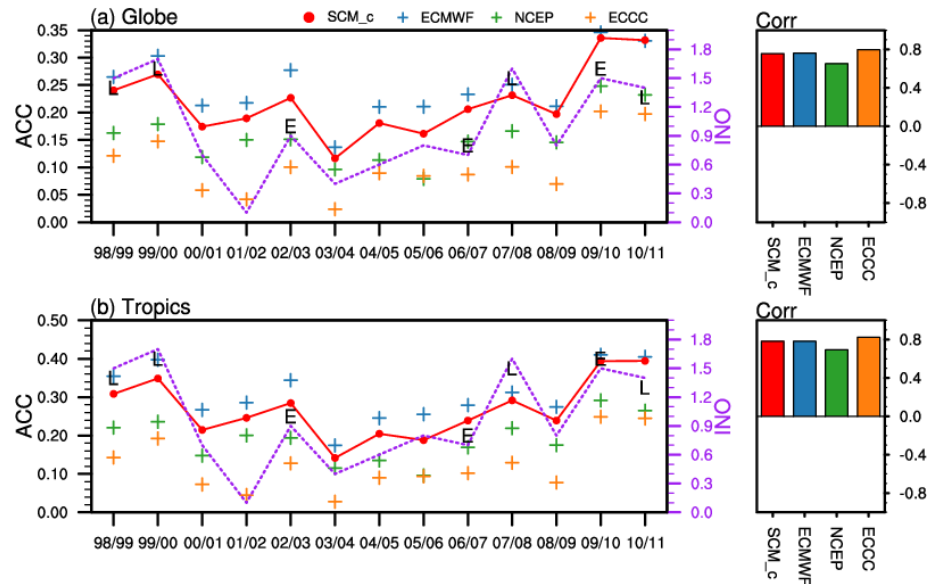
* ONI: ONI magnitude (absolute value of ONI)

** E: El Nino year / L: La Nina year

*** only forecasts of initial data within DJF are verified.

PREC

Weekly ACC: PREC, DJF, Week 3



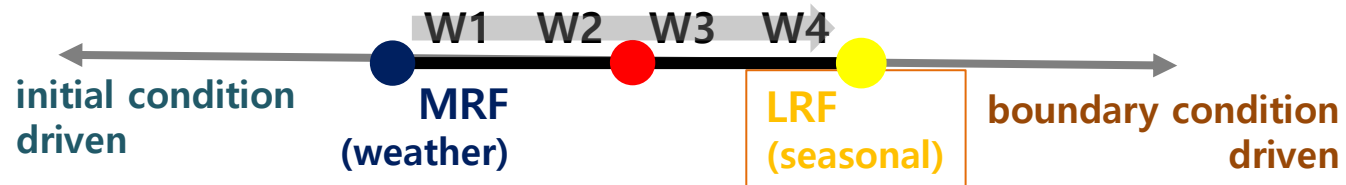
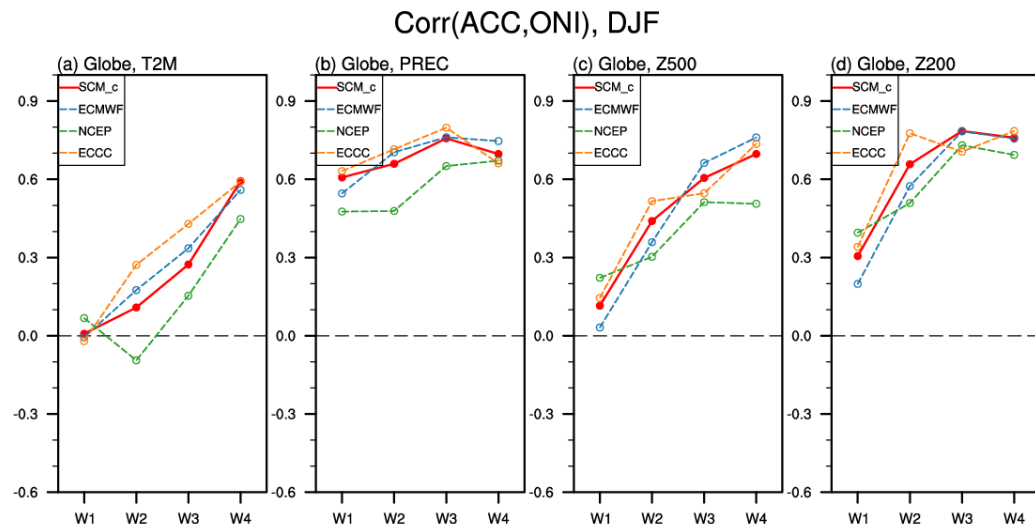
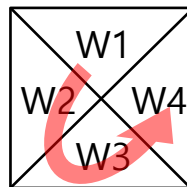
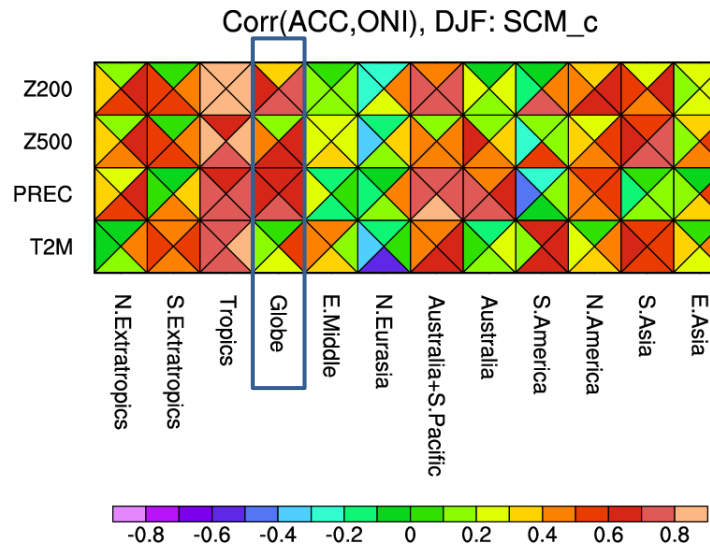
Subseasonal prediction skill

- dependent on ENSO strength
- ACC skill is very low in W34 though...

	years	ensm. #	lead days
ECMWF (B)	12(99-10)	11	46
ECCC (O)	12(99-10)	4	32
NCEP (G)	12(99-10)	4	44

Q. *S2S: MRF~LRF*

ocean boundary cond. dependent???

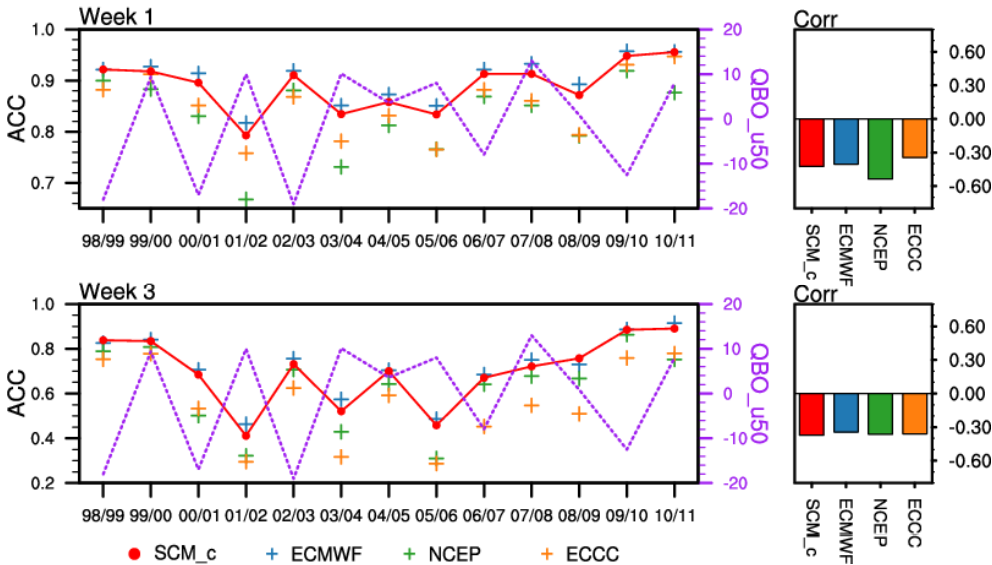


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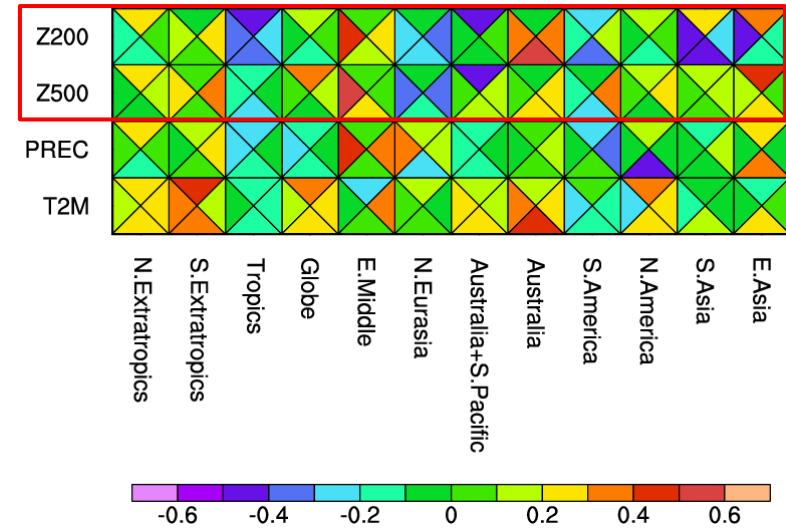
ACC and QBO during DJF

: upper air boundary cond. dependent???

Weekly ACC: Z200, Tropics, DJF



Corr(ACC, QBO_u50), DJF: SCM_c



* -QBO: Easterly/ +QBO: Westerly

** only forecasts of initial date within DJF are verified.

* Lim, Y., Son, SW., Marshall, A.G. et al. Clim Dyn (2019). <https://doi.org/10.1007/s00382-019-04719-y>

Subseasonal prediction skill

- dependent on QBO phase
- for upper level variable over limited regions (Tropics, S. Pacific, S. Asia).

Summary

When it comes to three models' reforecast, real-time forecast and their multi-model ensembles (MMEs) for 11 variables and 12 verification regions:

- Models display disorganized pattern of long-term mean (LTM) for some regions and variables and they tend to underestimated interannual variation. LTM spatial pattern similarity decreases but absolute biases increase as lead time increases in all three models.
- **Predictability** measured by **signal to noise ratio (SNR)** is **longest in NCEP but shortest in ECCC** under the same condition of ensemble size and reference period, which does not agree with the order of prediction skill.
- **Prediction skill varies with months, regions, and variables** and the features are very similar between reforecast and real-time forecast. Overall prediction skill rapidly decreases as lead time increases but ECMWF has the longest skill among three models.
- From the comparison of four MME method variations with different combinations of reference period and weighting, it is found that the **grand ensemble merging MME (MME_g) has a skill at least comparable to, and perhaps even better than, the ECMWF.**
- Global subseasonal prediction skill during boreal winter season is shown to be largely **dependent on the ENSO strength** and the association becomes clearer in longer lead weeks. For the limited regions and variables, the prediction skill tends to be high (low) when **easterly (westerly) QBO is prevailing.**

3rd APCC MME Model Providers' Meeting

5 June 2019		
Time	Agenda	Speaker
9:00–9:30	Registration	
Opening Ceremony		MC: Suhee Han (APCC)
9:30–9:35	Welcome Remarks	Dr. Won-Tae Kwon (Executive Director, APCC)
9:35–9:40	Group Photo	
Session I: Current Status and Improvement of Seasonal Prediction System Chair: Young-Mi Min (APCC)		
9:40–9:45	Overview of APCC MME Model Providers' Meetings	Dr. Young-Mi Min (Research Fellow, APCC)
9:45–10:10	Overview of Current APCC MME Prediction System	Dr. Yoobin Yang (Research Fellow, APCC)
10:10–10:35	Bureau's seasonal prediction system – POAMA & ACCESS-S	Dr. Aihong Zhong (BOM, Australia)
10:35–11:00	Coffee Break	
11:00–11:25	The Canadian Seasonal to Interannual Prediction System version 2 (CanSIPS-v2)	Dr. Ryan Muncaster (MSC, Canada)
11:25–11:50	Seasonal Forecasting Activities at CMCC: current status and future developments	Dr. Silvio Gualdi (CMCC, Italy)
11:50–12:15	Current Status and Future Plan of JMA's Seasonal Ensemble Prediction System	Mr. Takashi Yamada (JMA, Japan)
12:15–12:40	Current Status and Plan for APCC Seasonal Prediction System	Dr. Suryun Ham (APCC, Korea)
12:40–14:00	Lunch	
14:00–14:25	Current Status and Plan of KMA's Climate Prediction System	Dr. Seon-Yong Lee (NIMS, Korea)
14:25–14:50	Introduction to PNU 40-member ensemble long-range prediction system	Ms. Sera Jo (PNU, Korea)
14:50–15:15	HMC LRF Production: Current status and future plans	Dr. Vladimir Kryjov (HMC, Russia)

15:15–15:45	Coffee Break	
15:45–16:10	The current state of the MGO climate model for seasonal forecasts	Dr. Vadim Matyugin (MGO, Russia)
16:10–16:35	The Current Status of Climate Forecast System in Central Weather Bureau	Dr. Jyh–Wen Hwu (CWB, Chinese Taipei)
16:35–17:00	NCEP Climate Forecast System: current version operational forecast skill assessment and next version development	Dr. Mingyue Chen (NOAA, USA)
17:30–19:00	Welcome Dinner	
6 June 2019		
Session II. Discussion on Improving APCC MME Prediction System Chair: Jin Ho Yoo (APCC)		
9:00–11:10	Discussion	
11:10–11:20	Selection of Co–Vice–Chair	
11:20–11:30	Closing	
11:30–12:00	Lunch	
12:40–18:00	Field Trip (Yeh–Liu Park)	

CWB observer

- Jen-Her Chen, Senior Meteorologist, Meteorological Information Center, CWB
- Ching-Teng LEE, Associate Researcher, Research and Development Center, CWB
- Meng-Shih Chen, Chief, Long-range Weather Forecast Section, Weather Forecast Center, CWB
- Yun-Lan Chen, Technical Specialist, Research and Development Center, CWB

Programme



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14:00-14:25	Current Status and Plan of KMA's Climate Prediction System	Dr. Seon-Yong Lee (NIMS, Korea)
14:25-14:50	Introduction to PNU 40-member ensemble long-range prediction system	Ms. Sera Jo (PNU, Korea)
14:50-15:15	HMC LRF Production: Current status and future plans	Dr. Vladimir Kryjov (HMC, Russia)
15:15-15:45	Coffee Break	
15:45-16:10	The current state of the MGO climate model for seasonal forecasts	Dr. Vadim Matyugin (MGO, Russia)
16:10-16:35	The Current Status of Climate Forecast System in Central Weather Bureau	Dr. Jyh-Wen Hwu (CWB, Chinese Taipei)
16:35-17:00	Seasonal Prediction using the GEOS S2S System: Impacts of NASA's Satellite Observations	Dr. Steven Pawson (GMAO/NASA, USA)
17:00-17:25	NCEP Climate Forecast System: current version operational forecast skill assessment and next version development	Dr. Mingyue Chen (NOAA, USA)
18:00-20:00	Welcome Dinner	

Overview of APCC MME Model Providers' Meeting (MPM)

Young-Mi Min
(5 June, 2019)





APCC MME Model Providers' Meeting (MPM)



- **APCC MME Producing Centres (PCs)**
 - Coordinate efforts on the implementation of multiple climate science activities and better support to socio-economic development process
- **Objectives of the APCC MME MPM**
 - To share the current status, recent progress and plans in the operational practices and scientific studies
 - To discuss technical issues faced in the APCC MME operations and future directions to improve the APCC MME prediction system
 - To strengthen towards advancing communication and interaction among APCC MME PCs

1st APCC MME MPM



Country	Organization	Representative (2014)
Australia	1. BoM	Ms. Aihong Zhong
Canada	2. MSC	Dr. Bertrand Denis
China	3. BCC	Dr. Ke Zongjian
Chinese Taipei	4. CWB	Dr. Jyh-Wen Hwu
Italy	5. CMCC	Dr. Silvio Gualdi
Japan	6. JMA	Dr. Kazutoshi Onogi
Korea	7. APCC	Dr. Hyung-Jin Kim
	8. KMA	Mr. Duk-Jin Won
	9. PNU	Ms. Joonlee Lee
Russia	10. HMC	Dr. Dmitry Kiktev
	11. MGO	Dr. Vadim Matyugin
UK	12. Met Office	Dr. Peter McLean
USA	13. IRI	Dr. Nicolas Vignaud
	14. COLA	Mr. Dan Paolino
	15. NCEP/NOAA	Dr. Jae-Kyung E. Schemm
	16. NASA	Dr. Siegfried Schubert



- Aug 18-19, 2014, APCC, Busan, Korea
- 12 participants from 11 MME PCs



1st APCC MME MPM

APCC

(Outcome)

- Establishment of APCC MME Producing Centres (PCs)

Chair	APCC	Director	Permanent
Vice-chair	APCC	Representative, Climate Services and Research Div.	Permanent
	BOM	Representative, APCC MME PCs (Dr. Aihong Zhong)	Changeable (2014. 8 – 2016.4)

** Elected among the participating PCs at the MPM meeting*

- Agree on forming Terms of Reference (TOR) of the group and operational modalities
- Share a plan to hold the MME MPM every two years on a regular basis



2nd APCC MME MPM (May 24-25, 2016, Busan, Korea)



Country	Organization	Representative (2014)
Australia	1. BoM	Ms. Aihong Zhong
Canada	2. MSC (video conference)	Dr. Bertrand Denis Dr. Marko Markovic Dr. Bill Merryfield
China	3. BCC	Dr. Ke Zongjian
Chinese Taipei	4. CWB	Dr. Jyh-Wen Hwu
Italy	5. CMCC	Dr. Silvio Gualdi
Japan	6. JMA	Mr. Yoshiaka Sato
Korea	7. APCC	Dr. Seon-Ta Kim
	8. KMA	Mr. Duk-Jin Won
	9. PNU	Ms. Joonlee Lee
Russia	10. HMC	Dr. Dmitry Kiktev
	11. MGO	Dr. Vadim Matyugin
UK	12. Met Office	Dr. Peter McLean
USA	13. IRI	Dr. Nicolas Vigaud
	14. COLA	Mr. Dan Paolino
	15. NCEP/NOAA	Dr. Jae-Kyung E. Schemm
	16. NASA	Dr. Siegfried Schubert



- May 24-25, 2016, APCC, Busan, Korea
- 12 (9) participants from 9 MME PCs



2nd APCC MME MPM

APCC

(Outcome)

- Update the Membership of the APCC MME PCs

Chair	APCC	Director	Permanent
Vice-chair	APCC	Representative, Climate Services and Research Div.	Permanent
	CMCC	Representative, APCC MME PCs (Dr. Silvio Gualdi)	Changeable (2016. 5 – 2019.5)

** Elected among the participating PCs at the MPM meeting*

- Share the current status and future of APCC MME and its members
- Discuss seasonal forecast limitations and improvement
- Discuss better climate information services based on APCC MME



3rd APCC MME MPM (June 5-6, 2019, Chinese Taipei)

(Topics)

- ***Session I: Current Status and Improvement of Seasonal Prediction System***
 - To share the progress of operational and research developments related to climate prediction on a seasonal time scale, as well as plans of participating models in near future
- ***Session II: Discussion on Improving APCC MME Prediction System***
 - To discuss some technical issues faced in the APCC MME operations and future directors
 - To propose recommendations on the way to advance further operational prediction
 - To strength interaction and enhance cooperation among the APCC MME PCs



Session I:

Current Status and Improvement of Seasonal Prediction System

(5 June, 2019)

Overview of Current APCC MME Prediction system

Yoo-Bin Yhang, Young-Mi Min, Sun-Hee Shin, Bong-Geun Song
Daeun Jeong, Chang-Mook Lim, A-Young Lim

Climate Prediction Department



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Current APCC-MME Prediction Skill

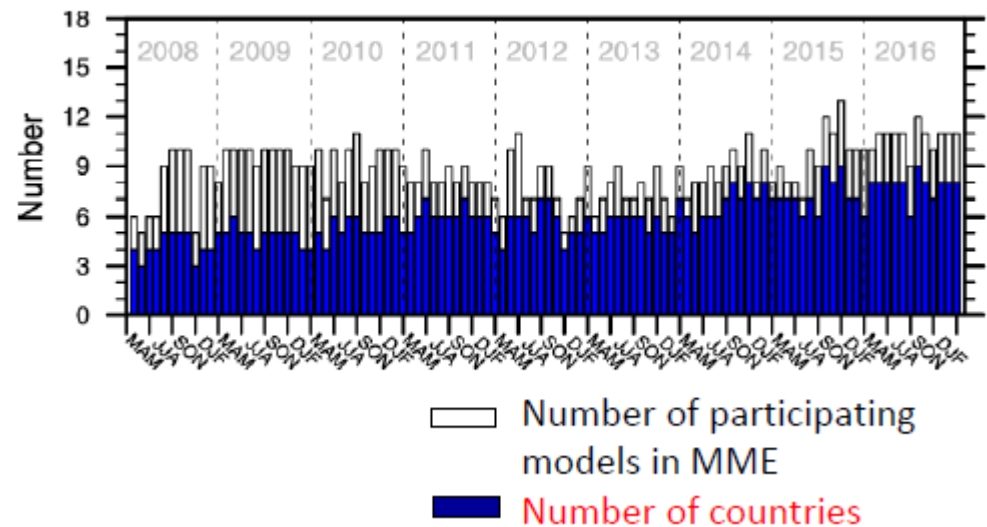
APCC MME Seasonal prediction

- Based on ensembles of dynamical seasonal climate prediction from 14 leading operational and research centers in 10 different countries

Multi-institutional Cooperation



Number of Models and Countries



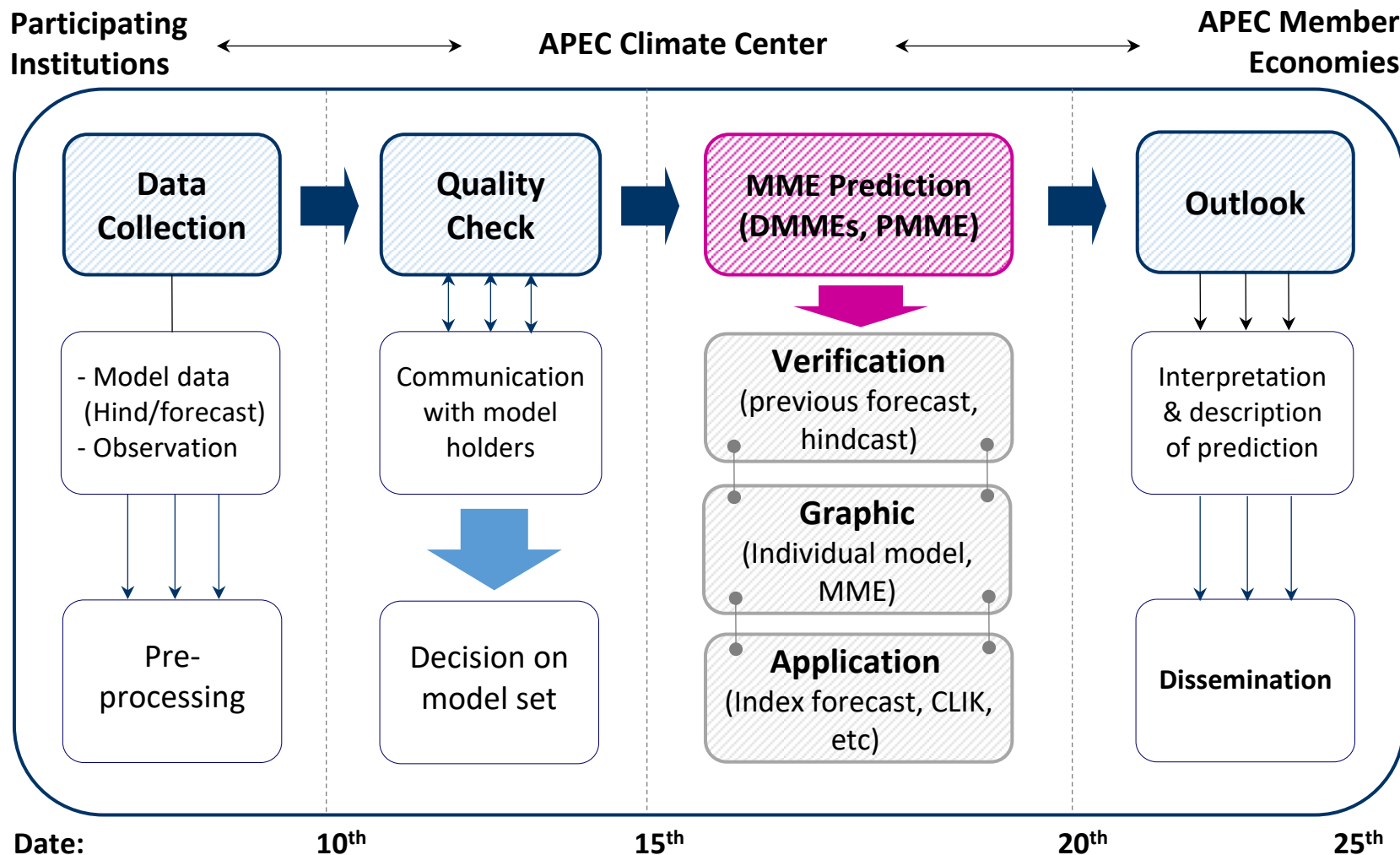


APCC MME Participating Models

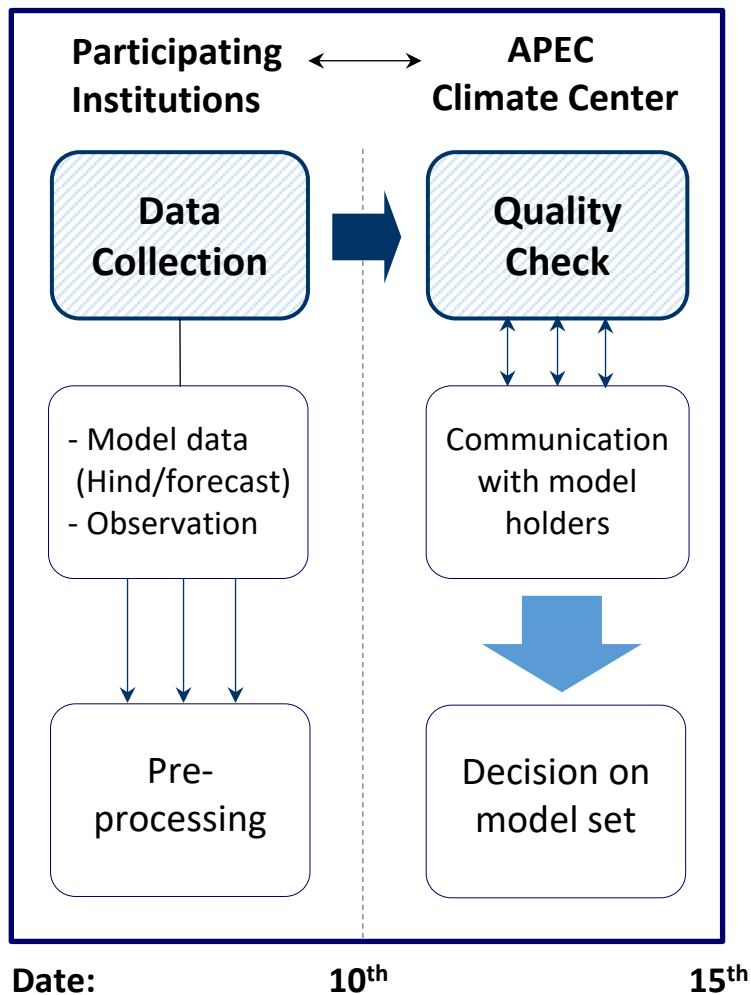
Institute	Model Name	SST Specification (H/F)	Ens. (H/F)	Forecast Period	Hindcast Period	Resolution
APCC	SCoPS	Predicted/Predicted	10/10	6-month	1982-2013	T159, L31
CMCC	CMCC-SPSv2	Predicted/Predicted	9/9	11-month	1981-2016	T63, L19
CWB	CWB	Predicted/Predicted	30/30	6-month	1982-2017	T119, L40
JMA	JMA/MRI-CPS2	Predicted/Predicted	10/51	3(6)-month	1979-2014	T159, L60
MSC	CanCM	Predicted/Predicted	20/20	11-month	1981-2010	T63, L35
NASA	GMAO	Predicted/Predicted	10/11	8-month	1981-2010	288x181, L72
NCEP	CFSv2	Predicted/Predicted	20/20	6(9)-month	1982-2010	T126, L64
PNU	PNU CGCM v1.0	Predicted/Predicted	5/5	6-month	1980-2015	T42, L18
BOM	POAMA-M24	Predicted/Predicted	33/33	6-month	1983-2011	T47, L17
Met Office	UKMO	Predicted/Predicted	12/42	5-month	1993-2015	1.875x1.25, L85
BCC	BCC	Predicted/Predicted	24/24	6-month	1991-2015	T106, L26
KMA	GLOSEA5	Predicted/Predicted	12/42	6-month	1991-2010	0.83°x0.56°, 85L
HMC	HMC	Persistent/Persistent	10/20	4-month	1985-2010	1.125x1.40625, L28
MGO	MGOAM2	Observed/Persistent	6/10	3-month	1979-2004	T42, L14
MME				3(6)-month	1983-2010	2.5° x 2.5°

* Grey: participating models in MME; yellow: not available owing to their hindcast period or experiment type

Operation Schedule

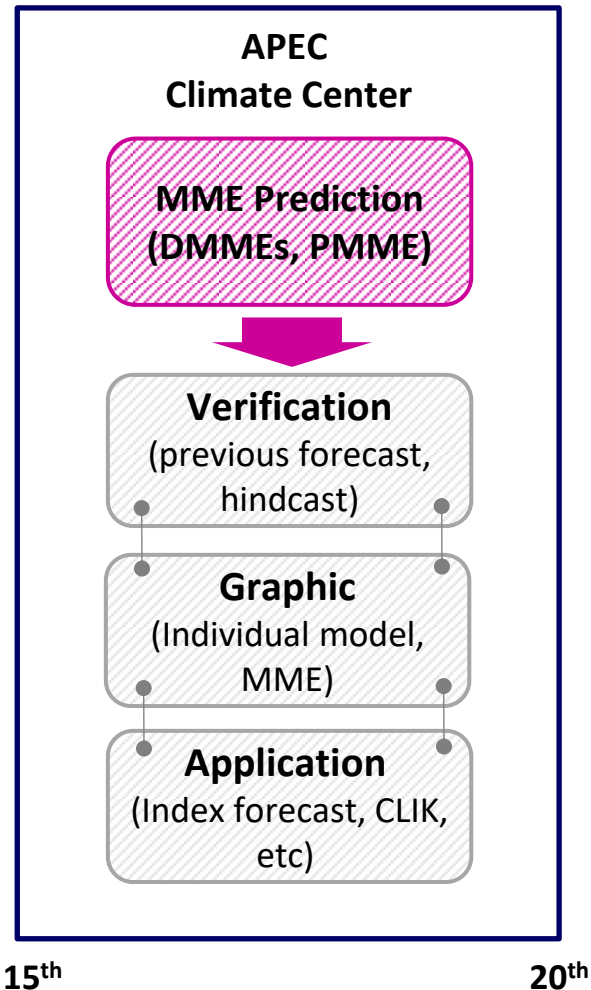


Procedure of Operations: **Data Request**



- Schedule: 1st ~ 15th every month
- Data requirement:
 - (1) Hindcast and forecast data
 - Period: 1979 ~ present (more than 6 months)
 - SMIP-2/HFP or CMIP-type experiments in hindcast
 - (2) Data Provision/Submission
 - Type: monthly mean data for individual ensemble members
 - Format: 2.5°x2.5° degree interval over global domain
 - Grid or NetCDF formats are encouraged.
 - (3) Variables
 - At least 11 variables are strongly recommended.
(T2m, SST, Prec, SLP, T850, Z200, Z500, u/v850, u/v200)

Procedure of Operations: **MME production**



- Schedule: 15th ~ 20th every month
- **Deterministic forecast (DMME)**
 - [SCM: Simple Composite Method](#)
 - MRG: Multiple Regression Method
 - SPM: Stepwise-pattern Projection Method
 - SSE: Synthetic multi-model Super Ensemble method
- **Probabilistic forecast (PMME)**
 - [Tercile-based categorical probabilities](#)
- **Verification:** in terms of skill score recommended by WMO Standard Verification System for Long-Range Forecast (SVS-LRF)
- Application: CLIK, statistical downscaling

Verification Information

- The APCC verification system is based on recommendations from WMO SVS-LRF in terms of verification metrics and regions.
- Metrics used to measure prediction skill: deterministic (ACC, RMSE, TCC, MSSS), probabilistic (ROC, HSS, RPSS, BSS, RD)

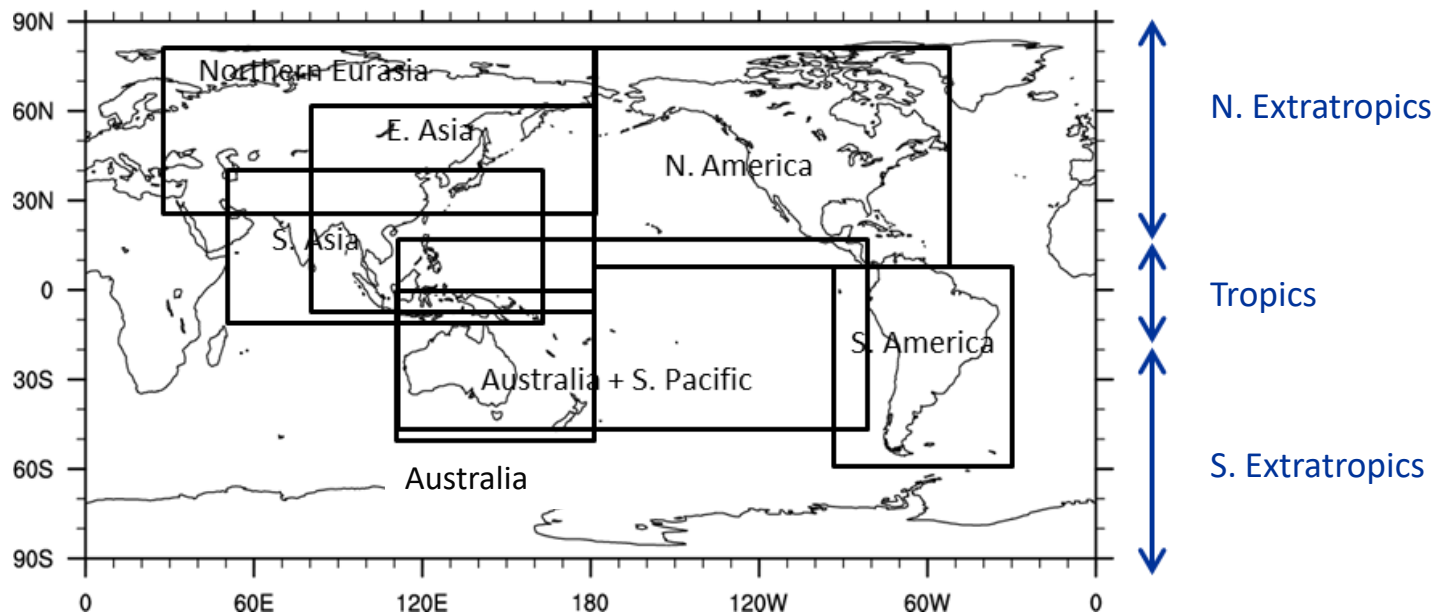
Parameters	Region	Deterministic forecast	Probabilistic forecast
<i>Diagrams and scores to be produced for regions</i>			
Basic variable (T850, T2m, PREC, Z500, SST)	GL, TR, NE, SE	MSSS	ROC curve
		ACC	ROC score
		RMSE	Reliability diagram
	EA, SA, NAm, SAm, AUS, AUS+SP, NEu, ME	ACC	HSS
		RMSE	RPSS
			BSS
Nino Index	Nino1+2/3/3.4/4	TCC	N/A
ENSO-Modoki index	EMI	TCC	N/A
IOD index	IOD	TCC	N/A
<i>Grid-point data for mapping</i>			
Basic variable	Grid-point verification on a 2.5° x 2.5° grid	MSSS	ROC score
		Difference map	HSS
		Ensemble spread map	RPSS
			BSS

- ✓ **Lead time:**
 - Monthly mean
 - Seasonal mean
- ✓ **Variable:**
 - Basic variables
 - SST indices
- ✓ **Observation**
 - NCEP II Reanalysis
 - CAMS-OPI
 - NOAA OISST

* CAMS-OPI: Climate Anomaly Monitoring System and Outgoing longwave radiation Prediction Index

Verification Information

- Recommendations from WMO SVS-LRF and CORDEX.
- Large-scale statistics: Globe, Tropics, N. Extratropics, S. Extratropics
- Sub-region statistics: E. Asia, S. Asia, N. America, S. America, Australasia, Australia + S. Pacific, Northern Eurasia, Middle East.



* CORDEX: Coordinated Regional Climate Downscaling Experiment

Climate Information (<http://www.apcc21.org>)

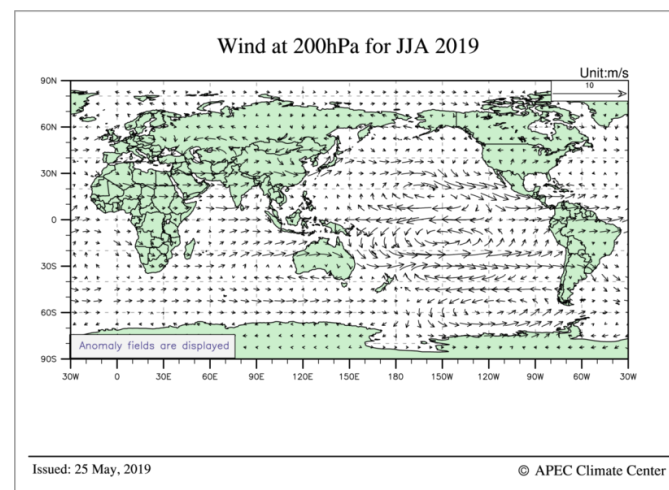
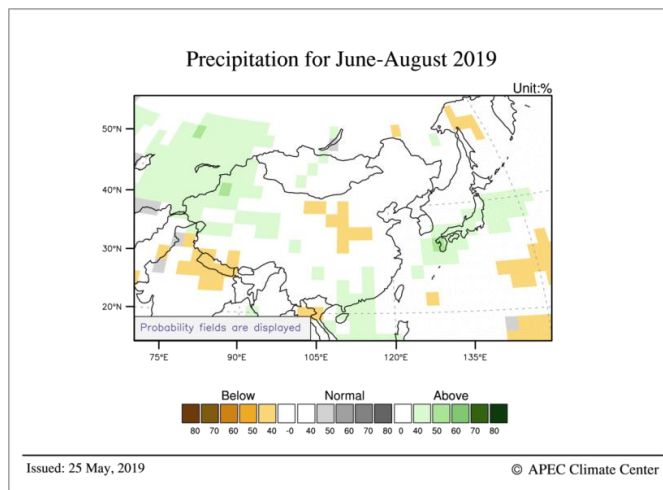
Climate Information Service

–	Seasonal Forecast
▸	Outlook
▸	ENSO
▸	Verification
–	Forecast
–	Hindcast
+	BSISO Forecasts
+	Applied Forecast
+	Current Climate Conditions
+	CLIK
+	CLIPs
+	ADSS
+	OpenWPS

✓ Outlook

- MME and individual model forecasts on a monthly basis
- 6-month forecasts with 1-month lead time
- Deterministic & probabilistic
- T2m, T850, Prec, Z500, SLP, U/V wind
- Both global and regional scales

Outlook	Deterministic MME Forecast	Probabilistic MME Forecast	Deterministic Forecast
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Climate Information (<http://www.apcc21.org>)

Climate Information Service

—

Seasonal Forecast

▸

Outlook

▸

ENSO

▸

Verification

-

Forecast

-

Hindcast

+

BSISO Forecasts

+

Applied Forecast

+

Current Climate Conditions

+

CLIK

+

CLIPs

+

ADSS

+

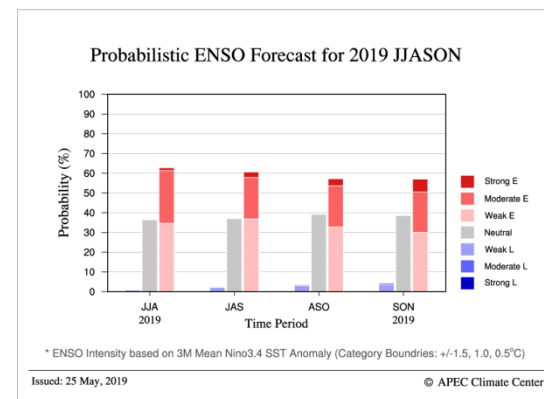
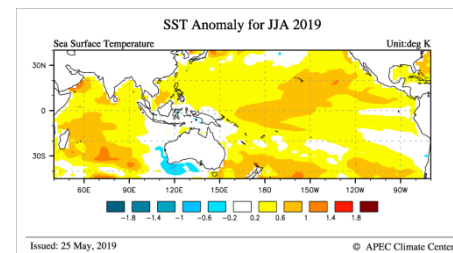
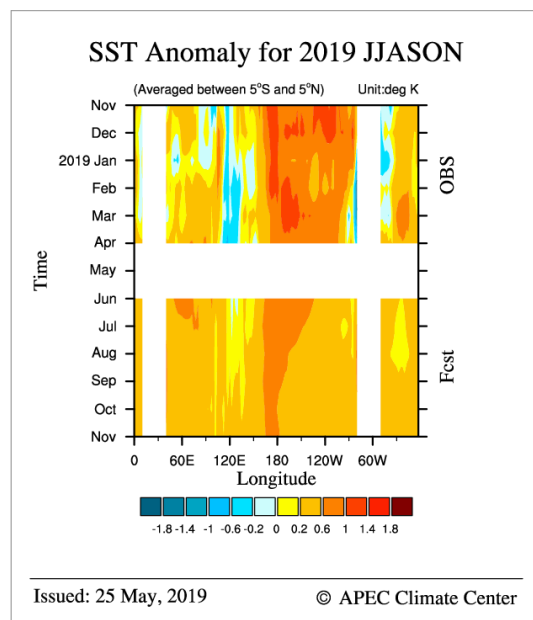
OpenWPS

✓ ENSO

MME Predictions

ENSO, Modoki and IOD Indices	Probability of ENSO state	Spatial distribution	Time-longitude Cross Section
------------------------------	---------------------------	----------------------	------------------------------

- MME and individual model predictions
- SST, ENSO & IOD indices (Nino 1+2/3/3.4/4, EIOD)
- Spatial distribution, time-longitude cross section, time series



Climate Information (<http://www.apcc21.org>)

Climate Information Service

Seasonal Forecast

▸ [Outlook](#)

▸ ENSO

▸ **Verification**

- Forecast

- Hindcast

+ BSISO Forecasts

+ Applied Forecast

+ Current Climate Conditions

+ CLIK

+ CLIPs

+ ADSS

+ OpenWPS

✓ Verification

■ Verification for Deterministic MME method

Anomaly Correlation Coefficient

Root Mean Square Error

■ Verification for Probabilistic MME method

Reliability Diagram

Relative Operating Characteristics Curve

Heidke Skill Score

Ranked Probability Skill Score

■ Verification for SST Forecast

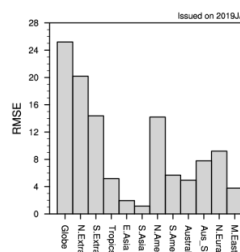
Anomaly Correlation Coefficient

Root Mean Square Error

ENSO Index

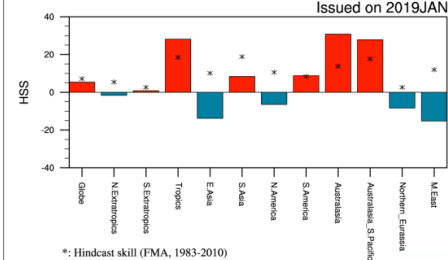
- Season
- Variable
- Region
- Lead

Root Mean Square Error : Z500, FMA (2019)



© APEC Climate Center

Heidke Skill Score : PREC, FMA (2019)



*: Hindcast skill (FMA, 1983-2010)

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Climate Information (<http://www.apcc21.org>)

Climate Information Service

–	Seasonal Forecast
▸	Outlook
▸	ENSO
▸	Verification
	- Forecast
	- Hindcast
+	BSISO Forecasts
+	Applied Forecast
+	Current Climate Conditions
+	CLIK
+	CLIPs
+	ADSS
+	OpenWPS

✓ Verification

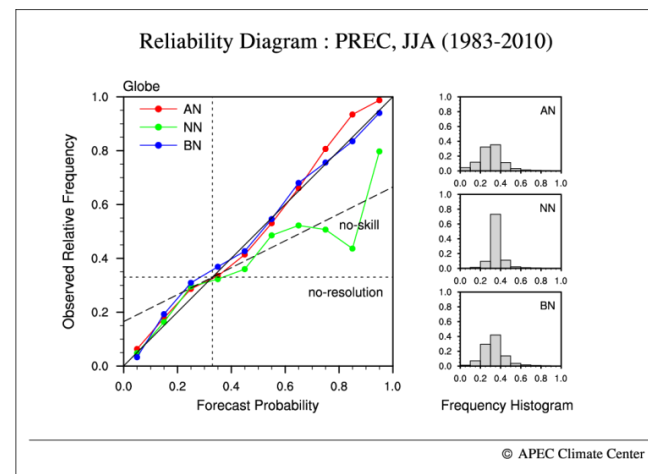
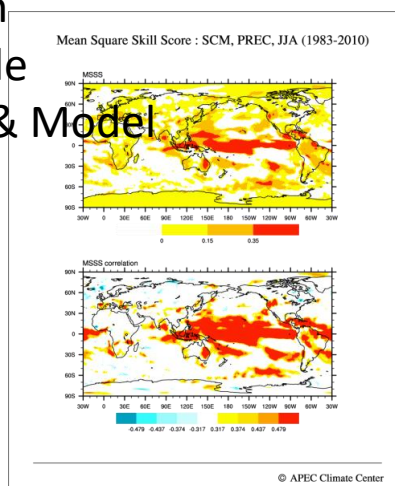
■ Verification for Deterministic MME method

Anomaly Correlation Coefficient	Root Mean Square Error	Mean Square Skill Score (MSSS) and MSSS Correlation	Gerrity Skill Score
---------------------------------	------------------------	---	---------------------

■ Verification for Probabilistic MME method

Reliability Diagram	Relative Operating Characteristics Curve	Relative Operating Characteristics Score	Brier Skill Score
---------------------	--	--	-------------------

- Season
- Variable
- MME & Model
- Region





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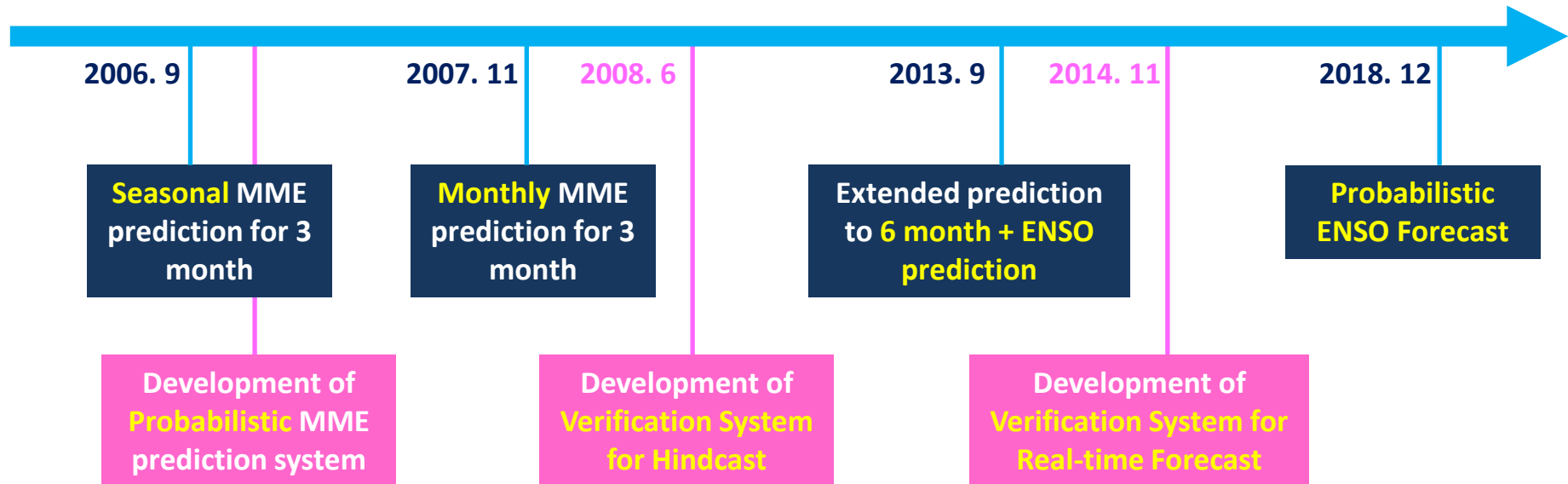
III.

Current APCC-MME Prediction Skill



Improvement of APCC MME Forecast System

❖ History of APCC MME Operation System



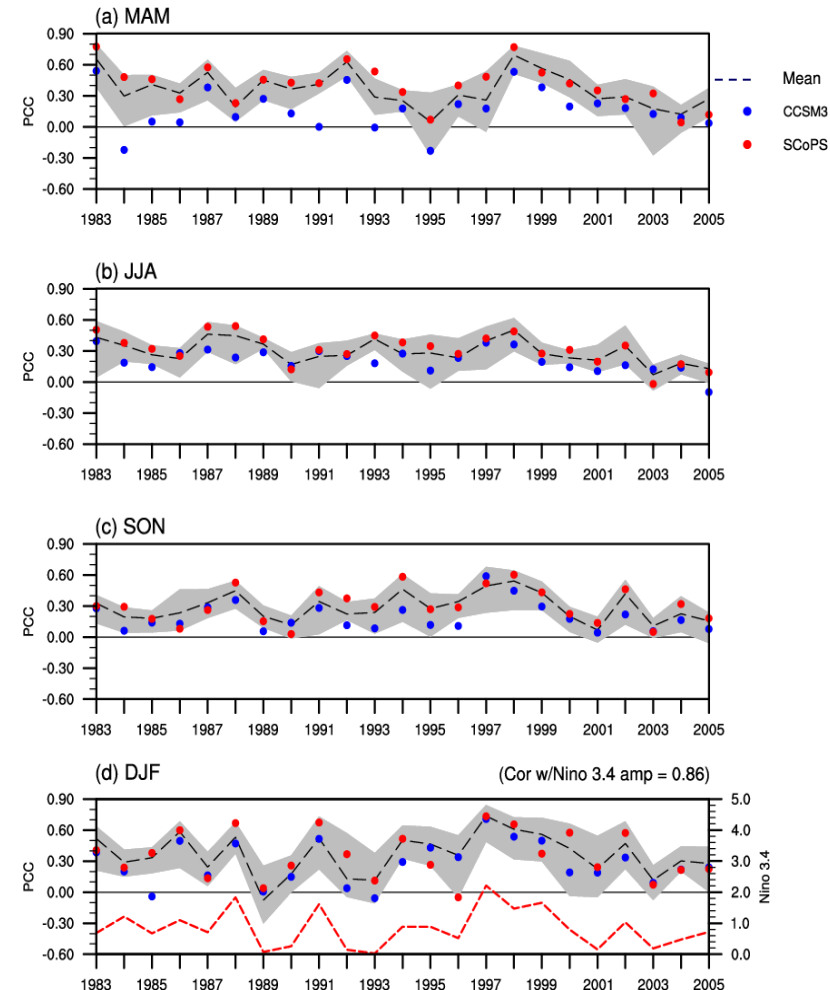
Development of in-house model

❖ Upgrading APCC in-house forecast system

- SCoPS model has participated in the APCC MME prediction since Nov. 2017.

		SCoPS	CCSM3
Model Description	Atmos.	ECHAM v5.3	CAM3
	Ocean	POP v2.0.1	POP v1.4.3
	Sea ice	CICE v4.1	CSIM4
Resolution	Atmos.	T159 // 31 levels	T85 // 26 levels
	Ocean	1° X 0.5 // 40 levels	
Initial condition	Atmos.	3D nudging from CFSR	—
	Ocean	EAKF from CFSR SST and profile data (WOD)	3D nudging from GODAS
Hindcast period		1982~2013	1983~2013
Ensemble configuration		Time lagged with perturbation on Gaussian noise	Time lagged
Ensemble		10	

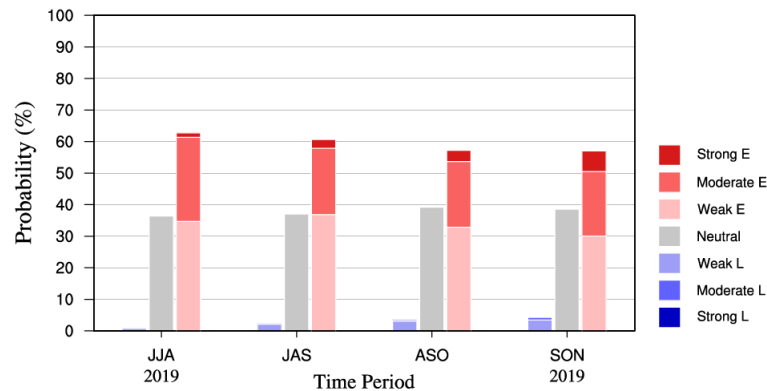
Interannual Variation: GL, PREC



Diverse contents : ENSO intensity

❖ ENSO intensity

Probabilistic ENSO Forecast for 2019 JJASON

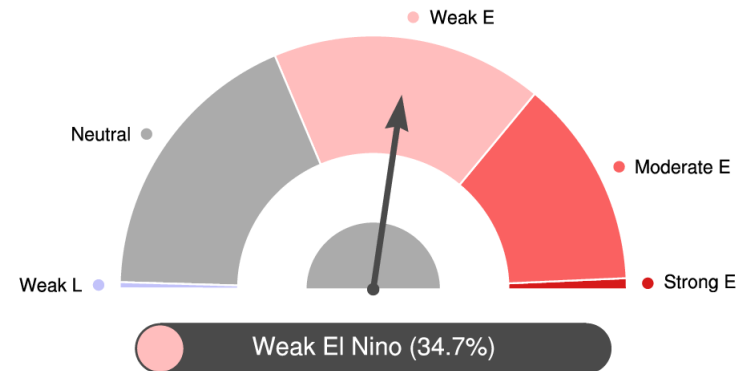


* ENSO Intensity based on 3M Mean Nino3.4 SST Anomaly (Category Boundries: +/-1.5, 1.0, 0.5°C)

Issued: 25 May, 2019

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Probabilistic ENSO Forecast for JJA 2019



* ENSO Intensity based on 3M Mean Nino3.4 SST Anomaly (Category Boundries: +/-1.5, 1.0, 0.5°C)

Issued: 25 May, 2019

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Probabilistic MME forecast of the status and intensity based on 3-month mean Nino3.4 index for four overlapping 3-month mean period.

Improvement of seasonal forecast outlook



The APEC CLIMATE CENTER
Climate Outlook for December 2018 – May 2019

BUSAN, 26 November 2018 – The synthesis of the latest model forecasts for December 2018 to May 2019 (DJFMAM) from the APEC Climate Center (APCC), located in Busan, South Korea, indicates a positive El Niño-Southern Oscillation (ENSO) phase. The positive temperature anomalies are likely to prevail over the globe, with highly probable above normal temperatures over the tropical Pacific and Atlantic, the northwestern and northeastern North Pacific, and the western and central Indian Ocean. Below normal precipitation over the Philippine Sea is predicted to be highly probable for the same period.

Current Climate Conditions

Enso-neutral conditions continued during October. Normal sea surface temperature (SST) anomalies prevailed. Negative seasonal mean temperature anomalies exceeding 1°C prevailed over Africa, the Middle East, and the Indian Ocean. Precipitation anomalies spanned the Laptev Sea, the Pacific and Atlantic, South China Sea, eastern Indian Ocean, and the western North Pacific.

Forecast

Sea Surface Temperature and ENSO Outlook:

The prevailing ENSO phase is expected to be positive. The Niño3.4 index is predicted to be around 1°C for the boreal winter and above 0.5°C for the boreal spring, which means that El Niño conditions are expected for the whole forecast period. Slightly positive SST anomalies are expected over the Indian Ocean basin, which corresponds to the neutral phase of the Indian Ocean Dipole for the whole forecast period.

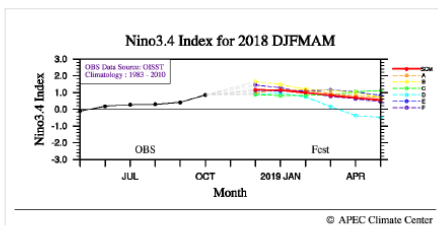


Fig. 3. Predicted Niño 3.4 Index from individual models (A, B, C, D, E, and F) and the simple composite Multi-Model Ensemble (MME) method (SCM).

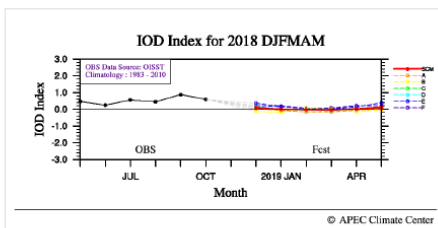


Fig. 4. Predicted Indian Ocean Dipole mode index (IODMI) from individual models (A, B, C, D, E, and F) and the SCM.



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APCC Monthly Climate Outlook for April – September 2019

(Issued: March 25, 2019)

- During February 2019, El Niño conditions were strengthened with positive sea surface temperature anomalies across the equatorial Pacific Ocean.
- The latest APCC ENSO outlook suggests a greater than 55% probability for moderate El Niño during April – June 2019, and a greater than 80% probability for El Niño conditions during July – September 2019.
- Positive temperature anomalies are likely to prevail over the tropical Pacific, northern North Pacific, maritime continent, Indian Ocean, southern Africa, northern South America, and the western North Pacific.
- Below normal precipitation anomalies are expected for the seas off the north coast of Australia, and above normal precipitation is expected for the equatorial Pacific for April – September 2019.

Current Climate Conditions

In February 2019, El Niño conditions developed. The equatorial Pacific remained warmer than average across most of the tropical Pacific. Positive temperature anomalies were strengthened across most of the tropical Pacific. Negative seasonal mean temperature anomalies were observed over the western Arctic. Negative seasonal mean temperature anomalies were observed over the western tropical Pacific, northeastern North Pacific, and the central tropical Pacific, northeastern North Pacific near Canada. Precipitation anomalies spanned the maritime continent, central tropical Pacific, northeastern North Pacific near Canada, and the western North Pacific.

Discussion of Climate Forecast

SST and ENSO Outlook:

Positive SST anomalies are likely to remain across most of the tropical Pacific, and strengthen for July – September 2019. Four out of five Niño3.4 index exceeding +1°C to persist through April – June 2019. Positive SST anomalies are predicted to persist through April – June 2019. Positive SST anomalies are predicted to persist through April – June 2019.

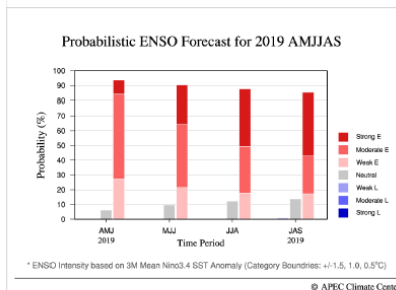
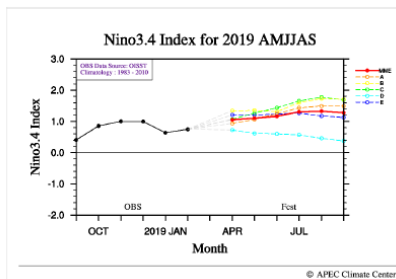


Fig. 5. Predicted monthly mean Niño3.4 index from individual models (A, B, C, D, and E) and the MME for April – September 2019 (top). Probabilistic MME forecasts of the status and intensity based on 3-month mean Niño3.4 index for four overlapping 3-month mean periods (bottom). Anomalies are computed with respect to the common base period of participating models in the APCC MME prediction (1983-2010).



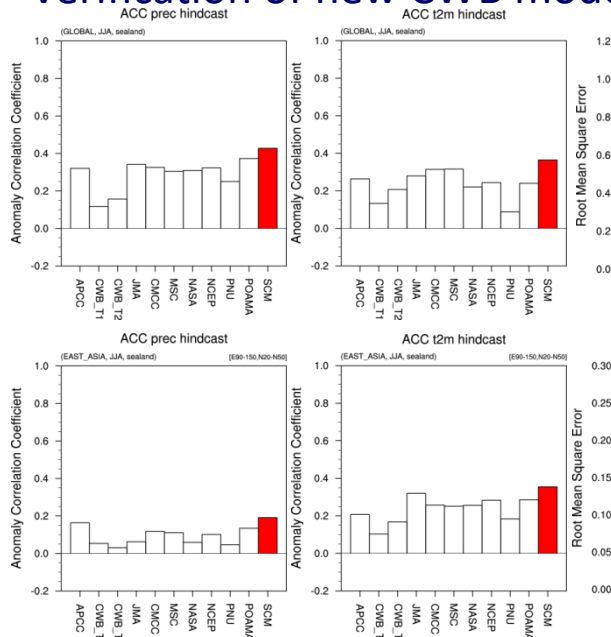
Improvement of participating models

❖ Upgrading the forecast model

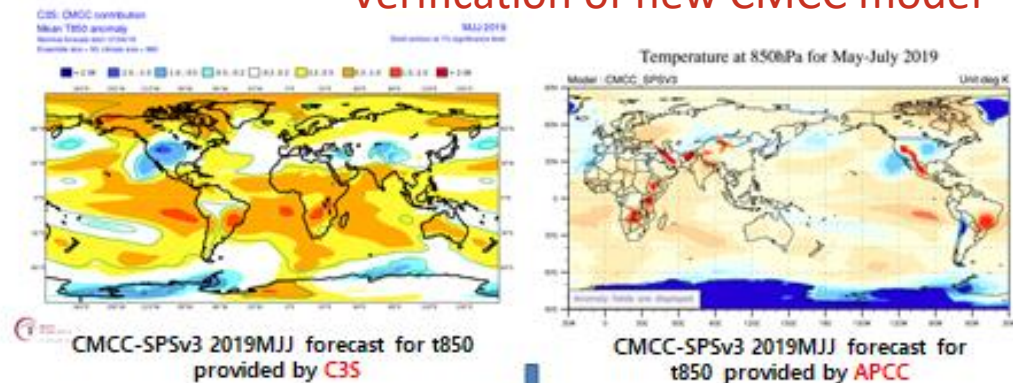
- BCC : improved BCCv2.0 to 1-tier prediction system from 2-tier [2016]
- CWB : improved model resolution from T42 → T119 [Jan 2018]
- NASA : model upgrade GEOS-S2S-1 → GEOS-S2S-2 [Jan 2018]
- CMCC : model upgrade CMCC-SPSv2 → CMCC-SPSv3 [Oct 2018]
- BOM : ACCESS-S (60km) will replace POAMA (250km)

APCC's effort to provide MME

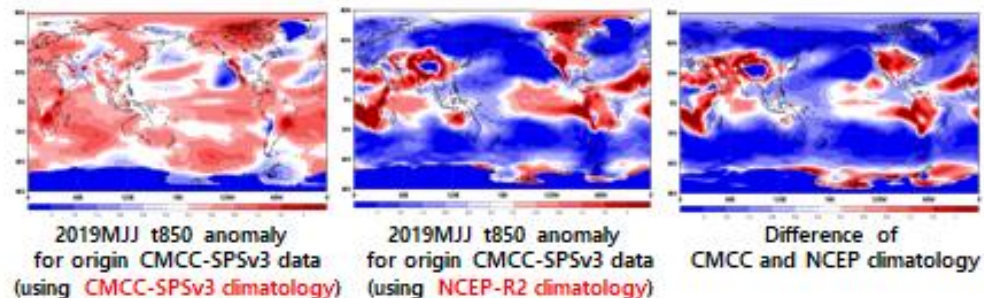
Verification of new CWB model



Verification of new CMCC model



Analysis origin CMCC-SPSv3 data





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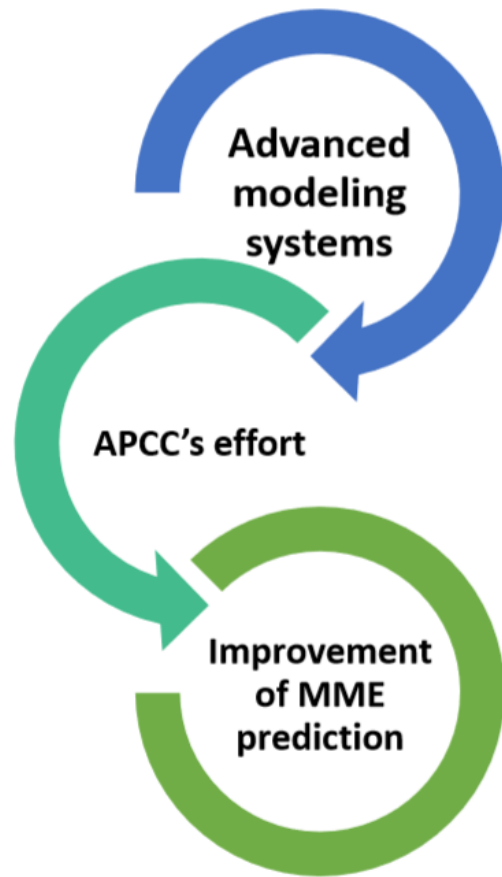
II.

Recent Improvements

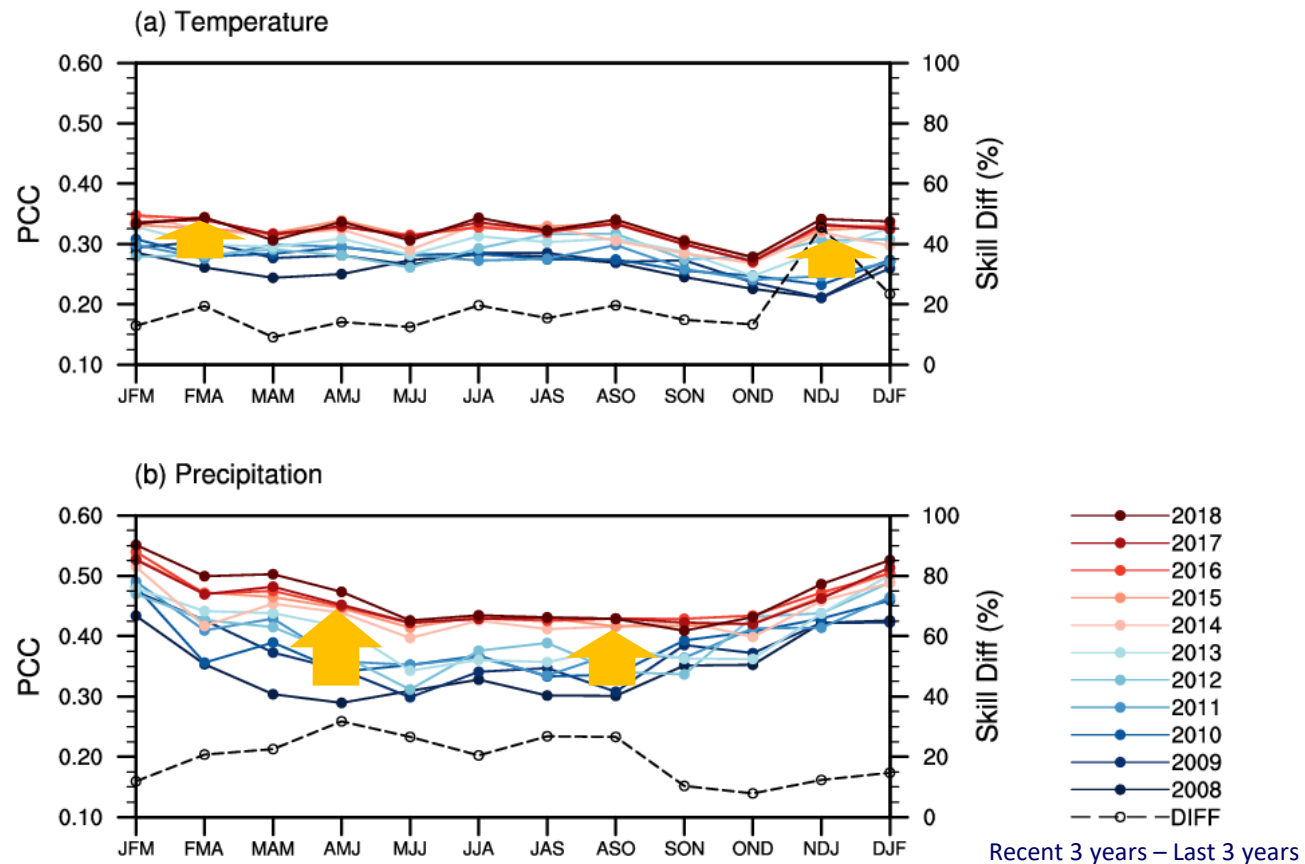
III.

Current APCC-MME Prediction Skill

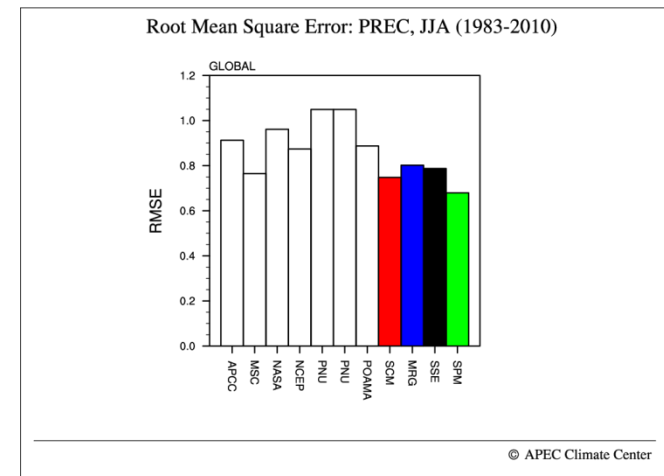
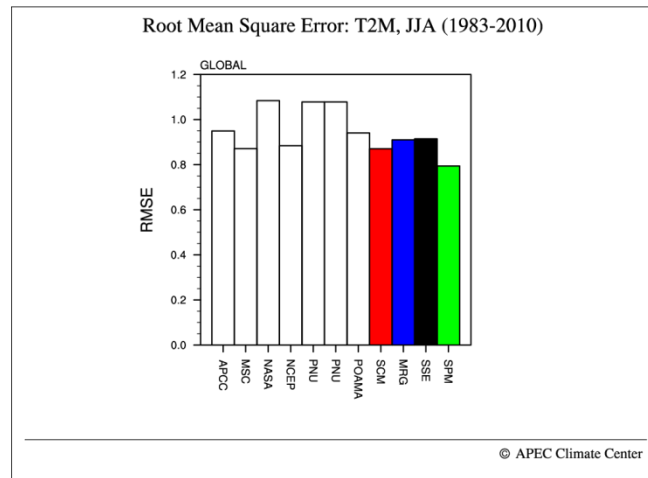
APCC MME Prediction skill



Hindcast Skill of APCC MME



Current APCC MME Prediction skill : Hindcast

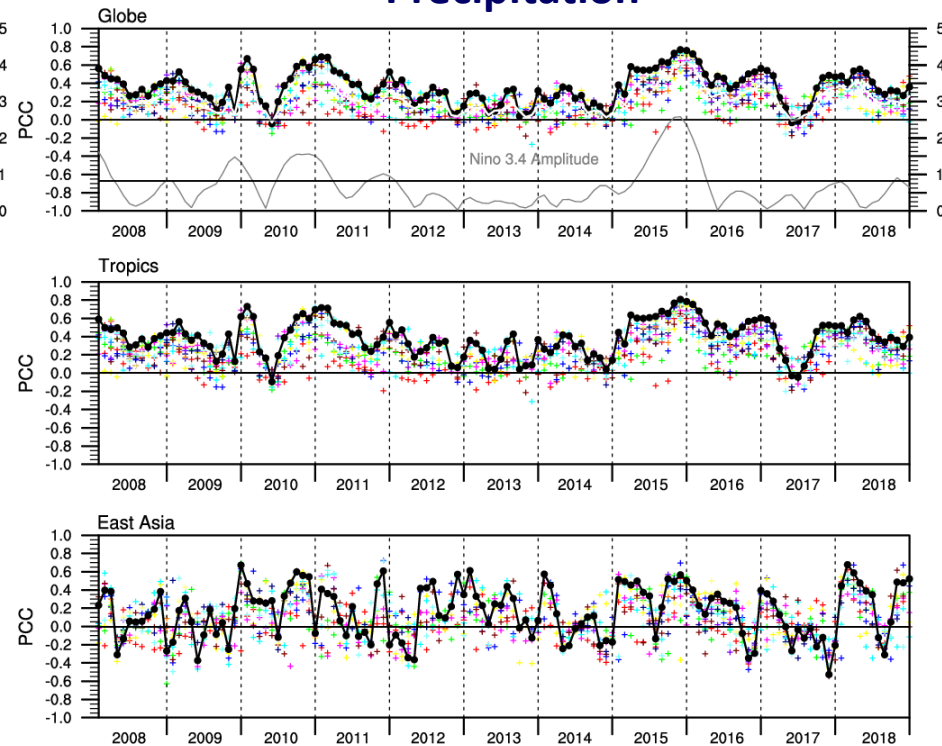
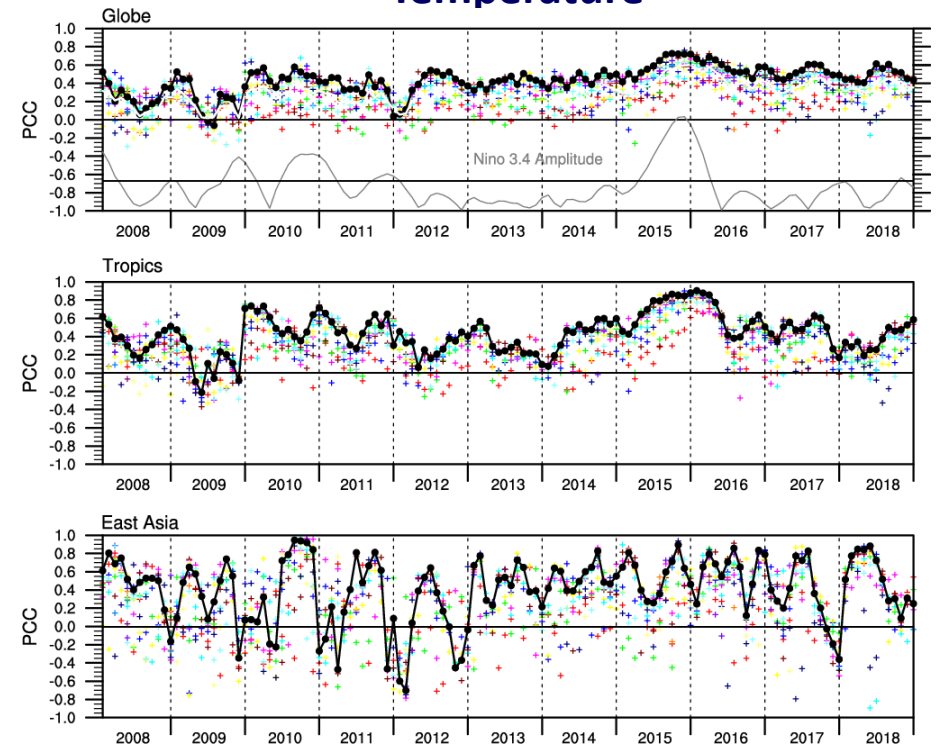


- The simple averaged MME (SCM) and calibrated (or corrected) MME (SPM) methods show consistently better performance than two weighted MMEs (MRG and SSE) in hindcast.
- SPM has positive effect in reducing errors and improving the multi-model prediction in a large proportion of cases.
- Considering many issues from an operational point of view, the use of SCM method is the practical way of utilizing the multi-model approach in an operational environment.

Current APCC MME Prediction skill : **RT forecast**

Temperature

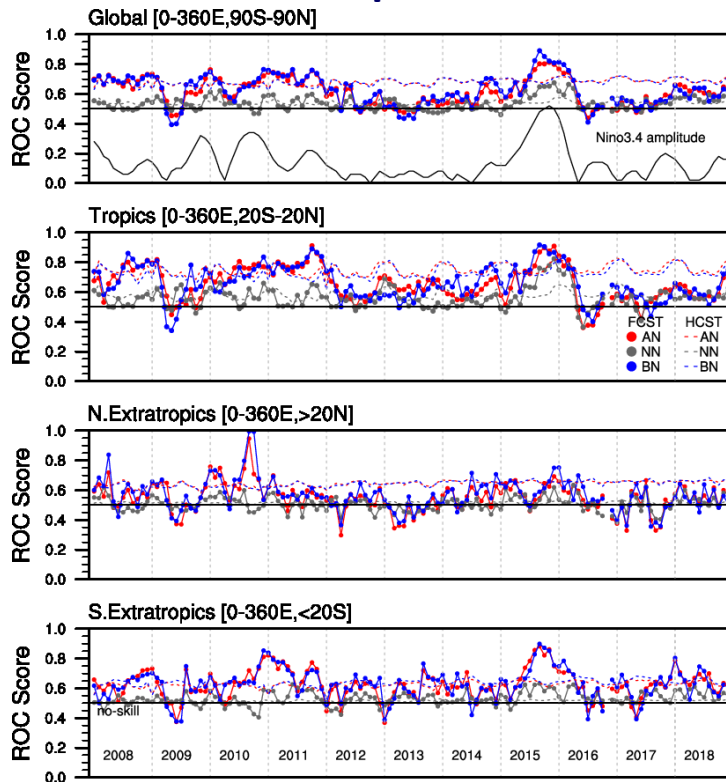
Precipitation



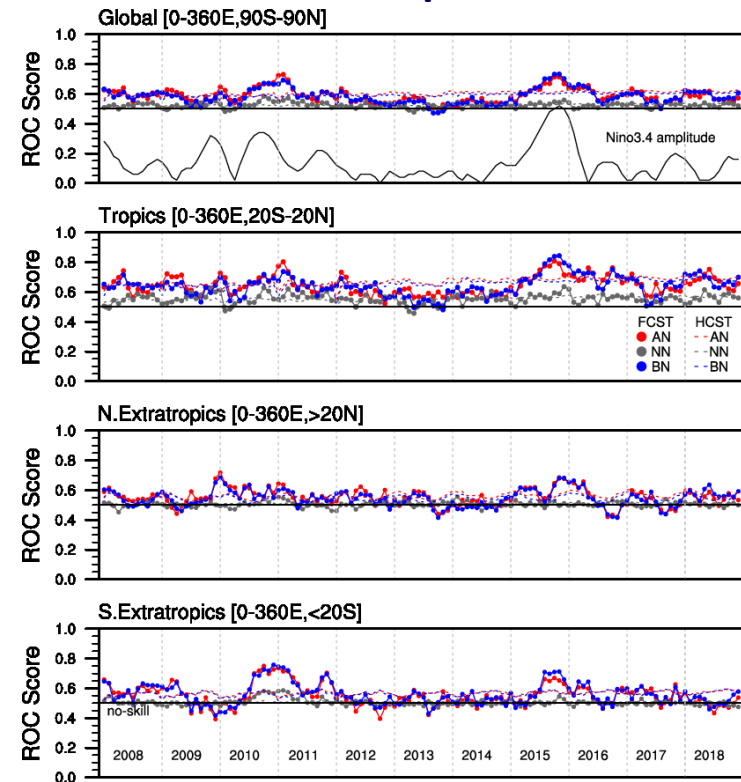
- Strong ENSO contribute the improvement of the forecast skill.
- ACC skill is dependent on ENSO index in recent years.

Current APCC MME Prediction skill : **PMME**

Temperature



Precipitation

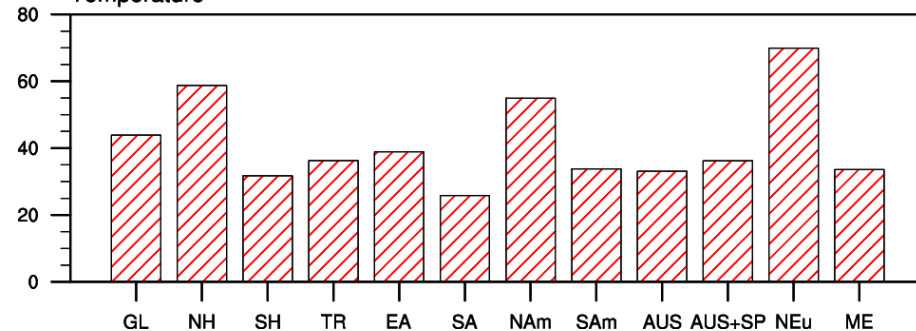


- Skill score for above normal and below normal category follows Nino 3.4 amplitude.
- SST forcing is very important to seasonal prediction.
- The relationship is stronger in temperature prediction than precipitation.

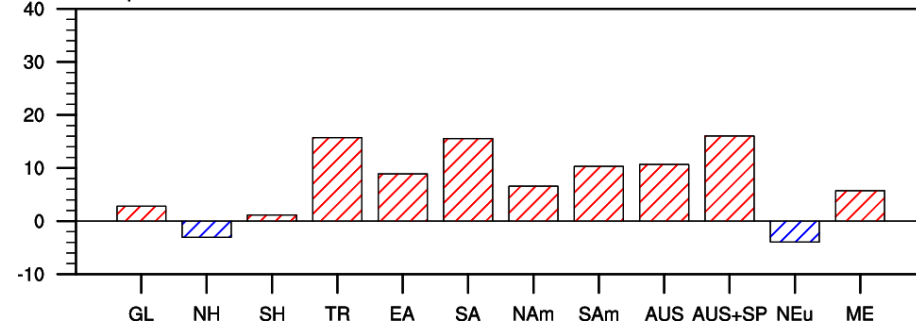
Current APCC MME Prediction skill : **RT forecast**

Heidke Skill Score (2008-2018)

Temperature

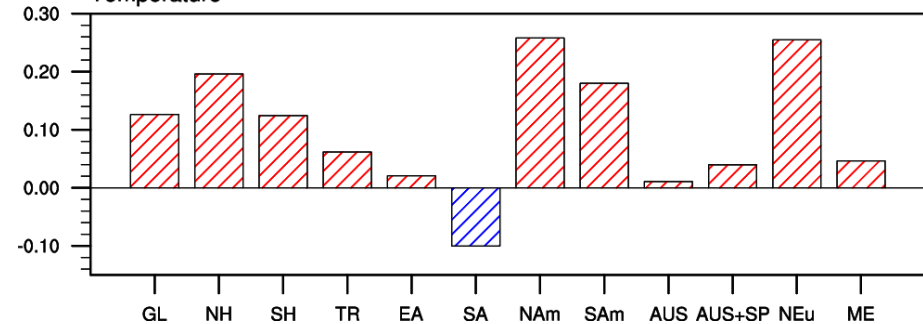


Precipitation

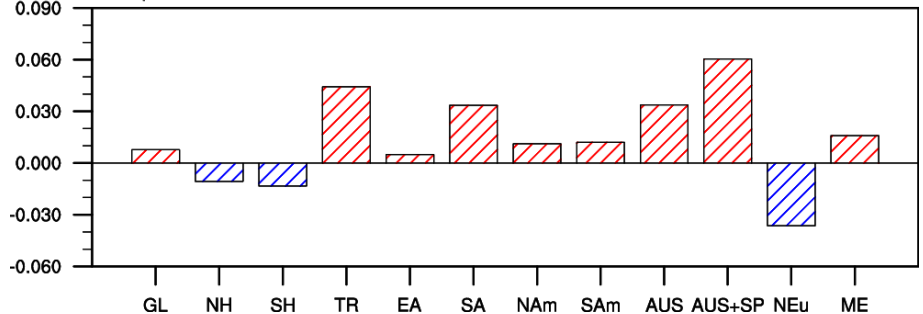


Ranked Probability Skill Score (2008-2018)

Temperature



Precipitation



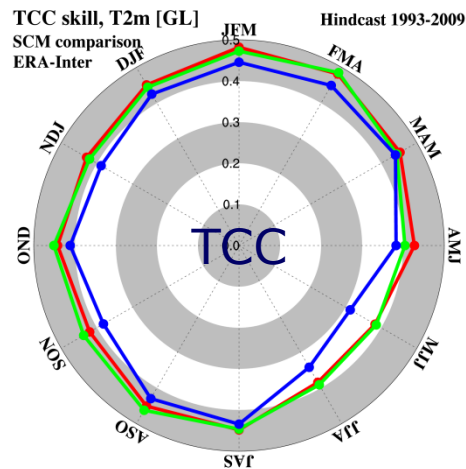
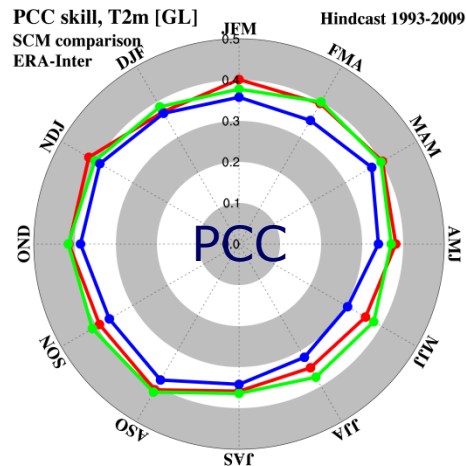
- For temperature, higher skill is shown in northern hemisphere, especially, in North America and Northern Eurasia.
- For precipitation, MME show relatively higher skill near the Equator, Tropics, South Asia, and Australia.



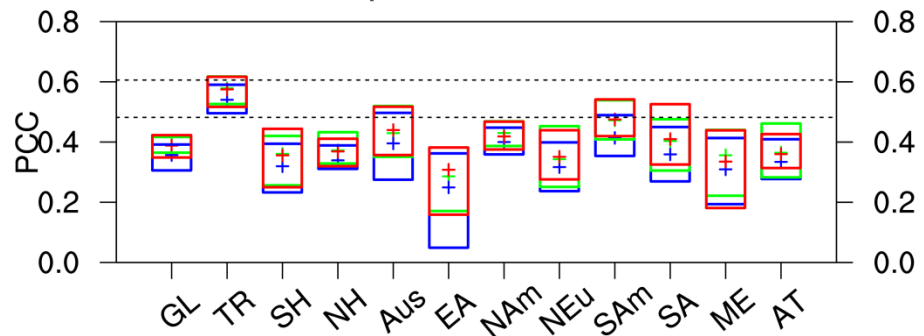
Comparison of SCMs from APCC/WMO/NMME

MME	APCC	WMO	NMME (IMME)
Hindcast Period	1983-2010	1993-2009	1982-2010
	1993-2009 (17 years)		
Participating Model	10 models	12 models	5 models
	BOM_POAMA	BOM_POAMA	MSC_CANCM NCEP_CFSv2
	JMA_JRA55	JMA_JRA55	
	KMA_GLOSEA5	KMA_GLOSEA5	
	MSC_CANCM	MSC_CANCM	
	NCEP_CFSv2	NCEP_CFSv2	
	UKMO_GLOSEA5	UKMO_GLOSEA5	
	APCC_SCOPS	BCC_CSM	GFDL_FLOR(CM2.1)
	CWB_CWB	CPTEC_GCM	NCAR_CESM1
	NASA_GEOSv2	DWD_GCFS2	NASA_GEOSv2
	PNU_CGCM	ECMWF_SEAS5	
		HMC_GCM	
		SAWS_EPS	

Comparison of SCMs from APCC/WMO/NMME: Seasonal PCC & TCC skill (T_{2m})

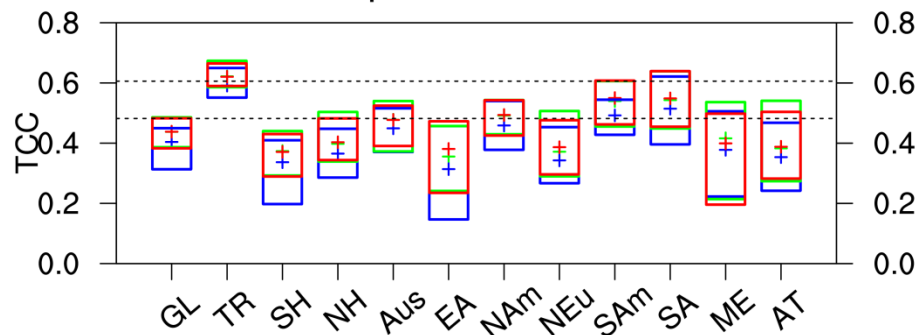


MME skill comparison ,T_{2m}

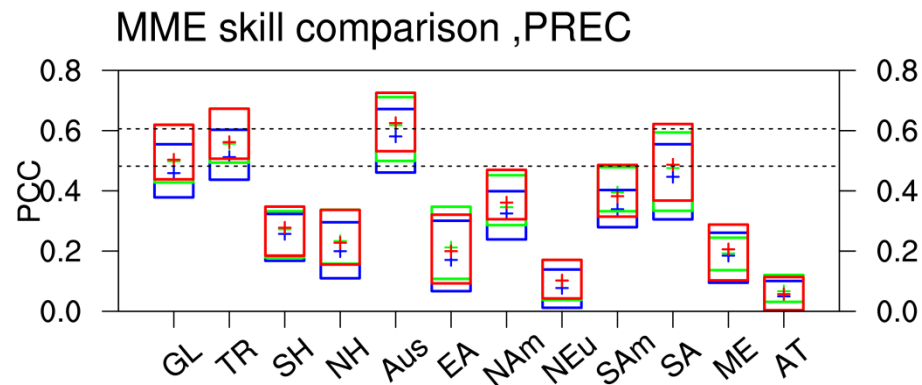
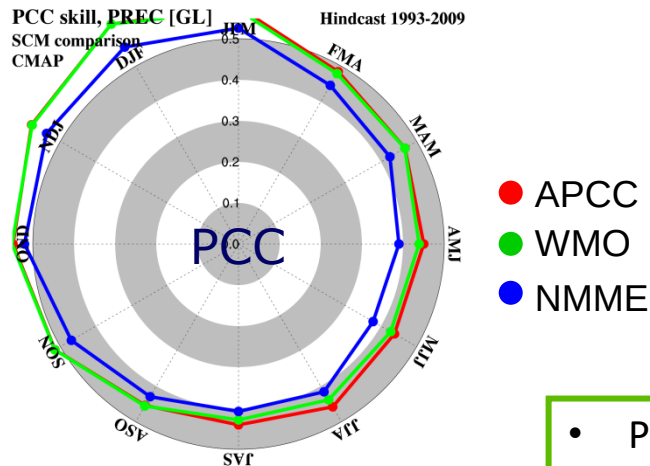


- The SCM is applied to participating models of APCC, WMO, NMME.
- APCC, WMO, NMME have relatively low skill in summer.
- APCC, WMO, NMME show similar regional variation.
- APCC shows comparable prediction skills to other MMEs.

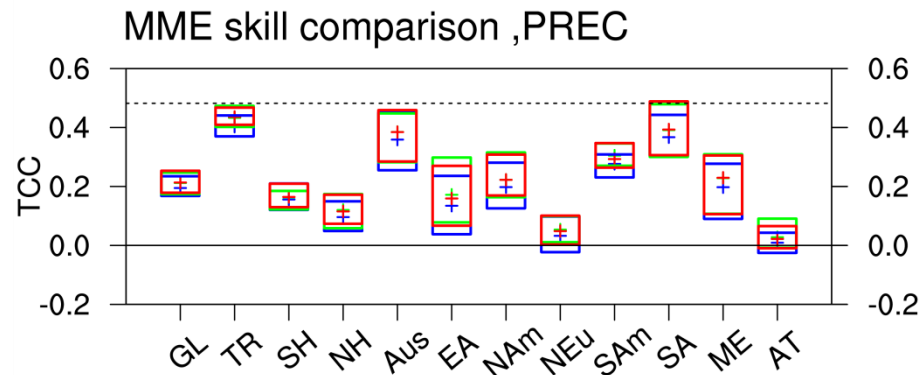
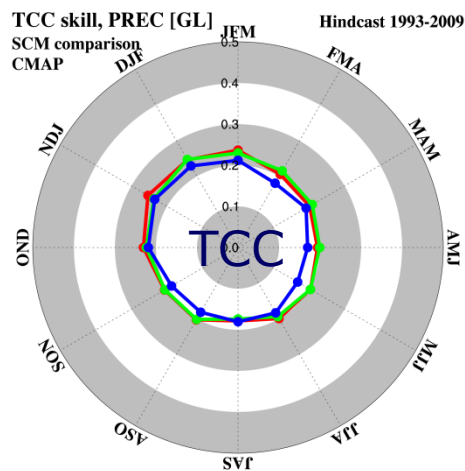
MME skill comparison ,T_{2m}



Comparison of SCMs from APCC/WMO/NMME: Seasonal PCC & TCC skill (PREC)



- Prediction skill depends on sub-regions.
- MMEs have better skill in tropics, Australia, and South Asia.
- MMEs have worse skill in East Asia, Northern Eurasia, and Middle East.
- APCC show comparable prediction skill to other MMEs.





Summary

- Since its establishment, APCC has been issuing operational monthly seasonal forecasts based on a well-validated MME seasonal prediction system.
- The APCC MME seasonal prediction system consists of four deterministic (SCM, SPM, MRG and SSE) and one probabilistic methods along with relevant verification.
- The APCC-MME forecast skill has been improved since 2008.
 - Improvement of individual model's performance
 - Quality control of the APCC
- APCC has been made an effort to provide diverse contents (e.g., probabilistic ENSO forecast)
- APCC MME shows comparable prediction skill to other MMEs.



Descriptions of participating models

Model	Ens.	Source of atmospheric initial conditions	SST Specification	Sea Ice Specification
APCC	10 (hcst) 10 (fcst)	3D initialization from NCEP CFSR	Predicted	Forecasted from climatology
CMCC				
CWB	30 (hcst) 30 (fcst)	CFSR & CDAS from NCEP	OPGSST 2.0 from CWB	NCEP climatology
JMA	10 (hcst) 51 (fcst)	JRA-55	predicted (1-tier method)	Interactive sea ice model
MSC	20 (hcst) 20 (hcst)	The CMC Global 4D-var analysis	Predicted (OGCM4)	Continuous nudging
NASA	4 (hcst) 4 (fcst)	MERRA reanalysis	Predicted (MOM4)	GEOS ODAS-2
NCEP	20 (hcst) 20 (fcst)	CFS data assimilation system each day at 00, 06, 12, 18Z	Predicted (MOM4)	Predicted (2-layer model)
PNU	5 (hcst) 5 (fcst)	NCEP/NCAR R2 in AGCM OISST in OGCM	Predicted	Predicted
POAMA	33 (hcst) 33 (fcst)	ALI scheme based on nudging atmospheric fields from Bureau NWP		
GLOSEA5		UM ERA-interim (1991-2010) & KMA NWP	NEMO-CICE NEMOVAR from Met Office	NEMO-CICE
UKMO		UM ERA-interim (1993-2015) & Met Office NWP (2010-)	NEMO-CICE NEMOVAR from Met Office	NEMO-CICE

Climate Information (<http://www.apcc21.org>)

Climate Information Service

Seasonal Forecast

▸ [Outlook](#)

▸ ENSO

▸ Verification

- Forecast

- Hindcast

+ BSISO Forecasts

+ Applied Forecast

+ Current Climate Conditions

+ CLIK

+ CLIPs

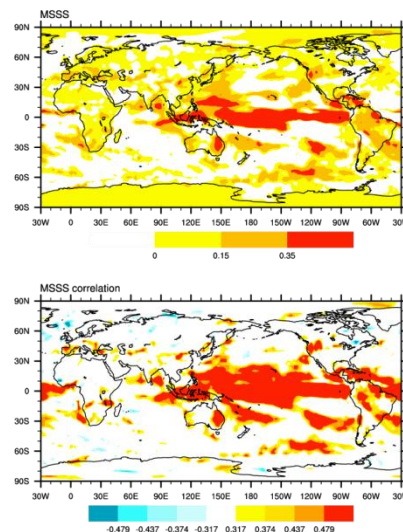
+ ADSS

+ OpenWPS

✓ Verification

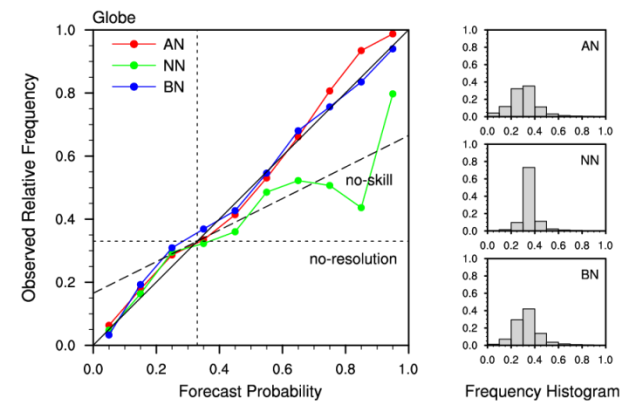
- Verification information for Hindcast and Real-time forecast
- Deterministic: ACC, RMSE, MSSS
- Probabilistic: Reliability diagram, ROC curve, HSS, RPSS, BSS

Mean Square Skill Score : SCM, PREC, JJA (1983-2010)



© APEC Climate Center

Reliability Diagram : PREC, JJA (1983-2010)



© APEC Climate Center

Sensitivity test : Hindcast period

❖ MME skill comparison : MME (common-period) vs MME(own-period)

$$R_{MM} = \frac{\langle R \rangle}{\sqrt{V(\langle y \rangle)}} = \frac{\langle R \rangle}{\sqrt{\langle r \rangle}}$$

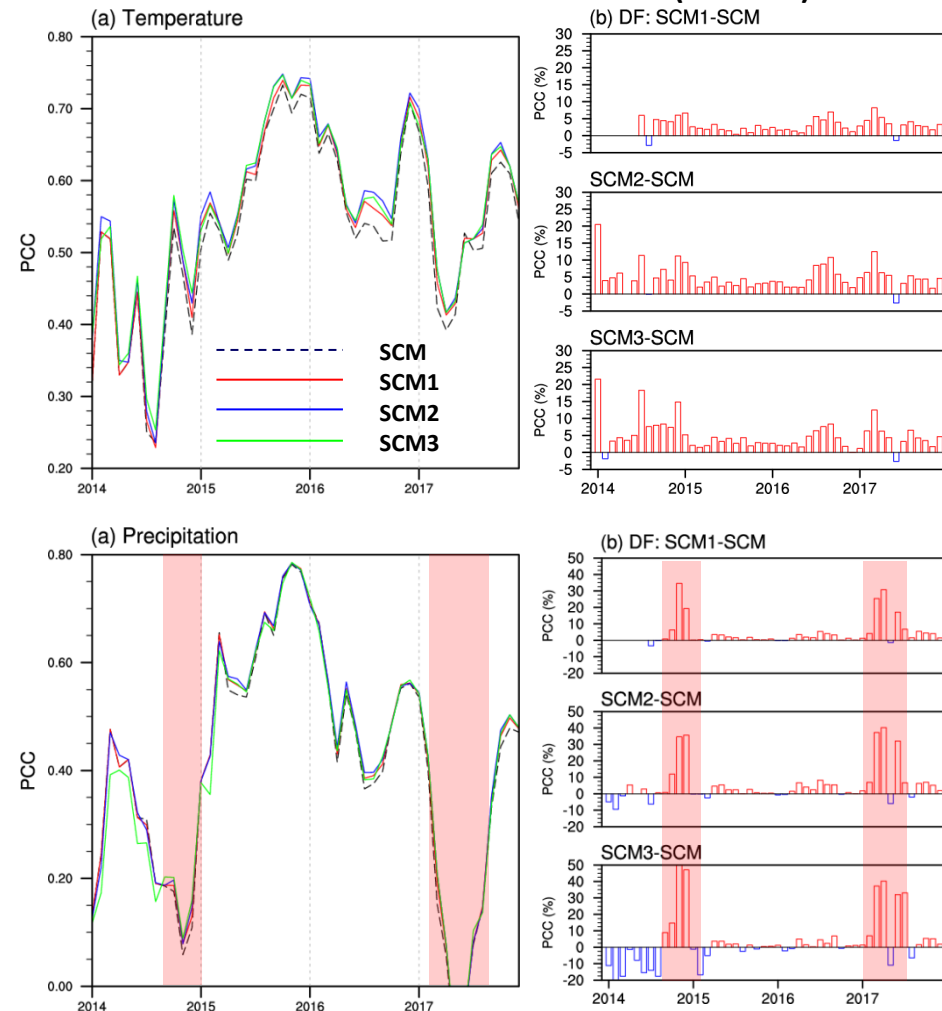
Average skill of all models

Inter-dependency among models

Exp.	Participating Models
SCM	Simple average of 9 models with equal weight (APCC, CMCC, CWB, JMA, MSC, NASA, NCEP, PNU, POAMA)
SCM1	SCM + GLOSEA5 (10 models)
SCM2	SCM + GLOSEA5 + UKMO (11 models)
SCM3	SCM + GLOSEA5 + UKMO + HMC (12 models)

- APCC MME 공통 Hindcast 기간(1983-2005)
- ➔ 기후값에 따른 민감도가 상대적으로 작은 **28년(1983-2010)으로 확장 가능**
- 개별모델의 자체 Hindcast 기간 활용
- ➔ **APCC MME 참여모델 확대 가능**

Pattern Correlation Coefficient (2014-17)



Climate Information (<http://www.apcc21.org>)

Climate Information Service

✓ ENSO

- MME and individual model predictions
- SST, ENSO & IOD indices (Nino 1+2/3/3.4/4, EIOD)
- Spatial distribution, time-longitude cross section, time series

—

Seasonal Forecast

▸

Outlook

▸

ENSO

▸

Verification

-

Forecast

-

Hindcast

+

BSISO Forecasts

+

Applied Forecast

+

Current Climate Conditions

+

CLIK

+

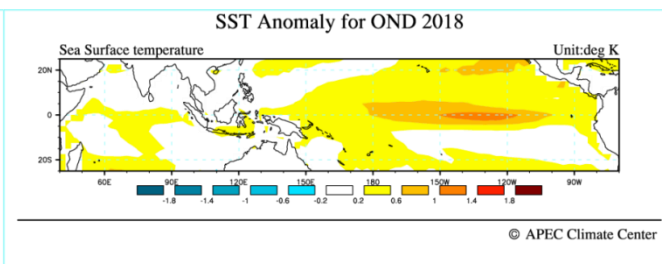
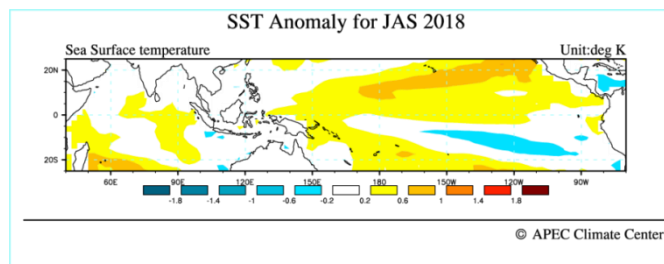
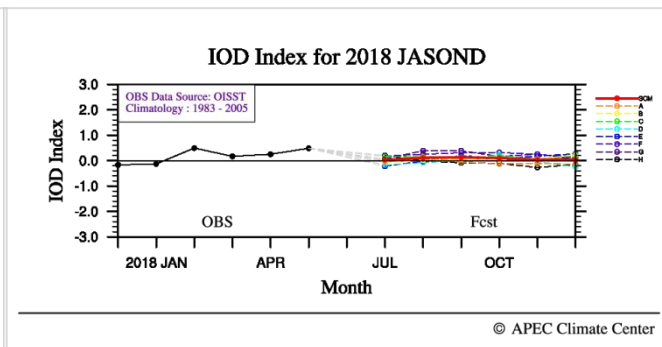
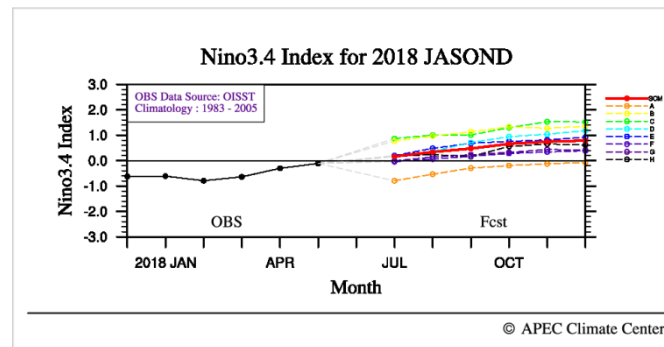
CLIPs

+

ADSS

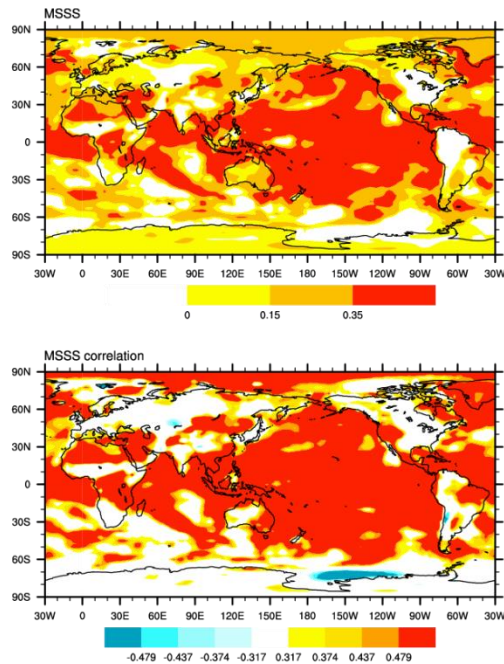
+

OpenWPS



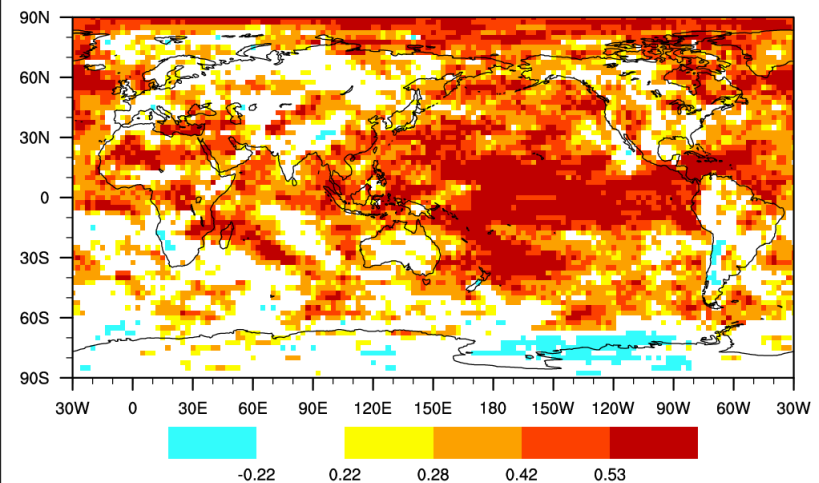
Current APCC MME Prediction skill : Hindcast

Mean Square Skill Score : SCM, T2M, JJA (1983-2010)



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Gerrity Skill Score : SCM, T2M, JJA (1983-2010)

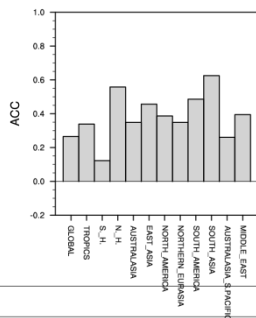


Issued: 25 May, 2019

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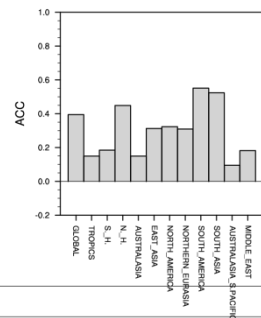
Current APCC MME Prediction skill : Hindcast

Anomaly Correlation Coeff. : T2M, JJA (1983-2010)



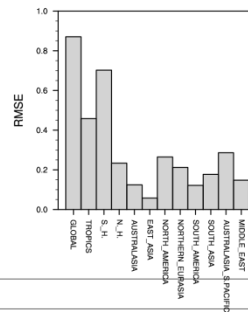
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Anomaly Correlation Coeff. : PREC, JJA (1983-2010)



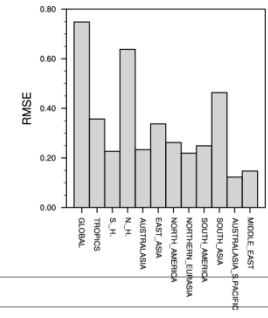
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Root Mean Square Error: T2M, JJA (1983-2010)



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Root Mean Square Error: PREC, JJA (1983-2010)

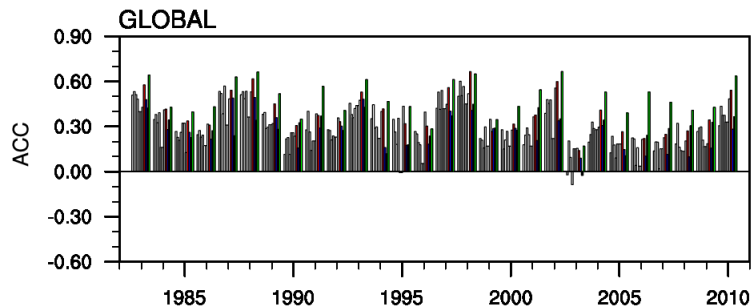


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- (i) The simple averaged MME (SCM) and calibrated (or corrected) MME (SPM) methods show consistently better performance than two weighted MMEs (MRG and SSE) in both hindcast and forecast.
- (ii) SPM has positive effect in reducing errors and improving the multi-model prediction in a large proportion of cases.

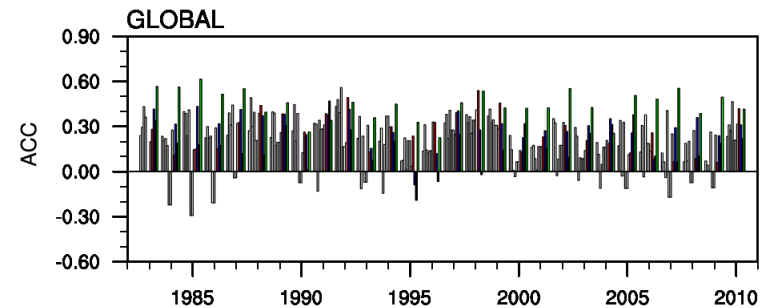
Current APCC MME Prediction skill : Hindcast

Anomaly Correlation Coeff. : PREC, JJA (1983-2010)



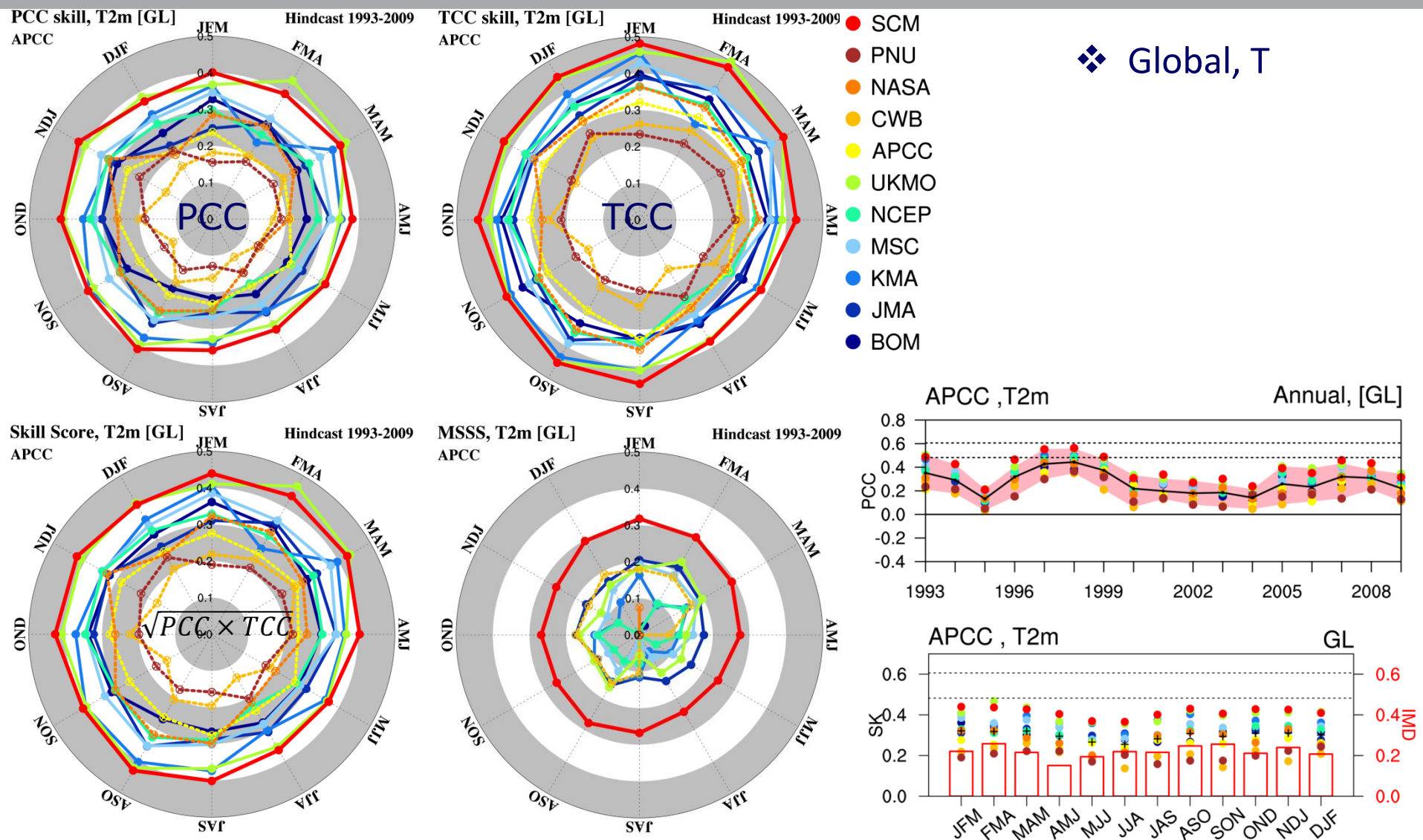
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Anomaly Correlation Coeff. : T2M, JJA (1983-2010)

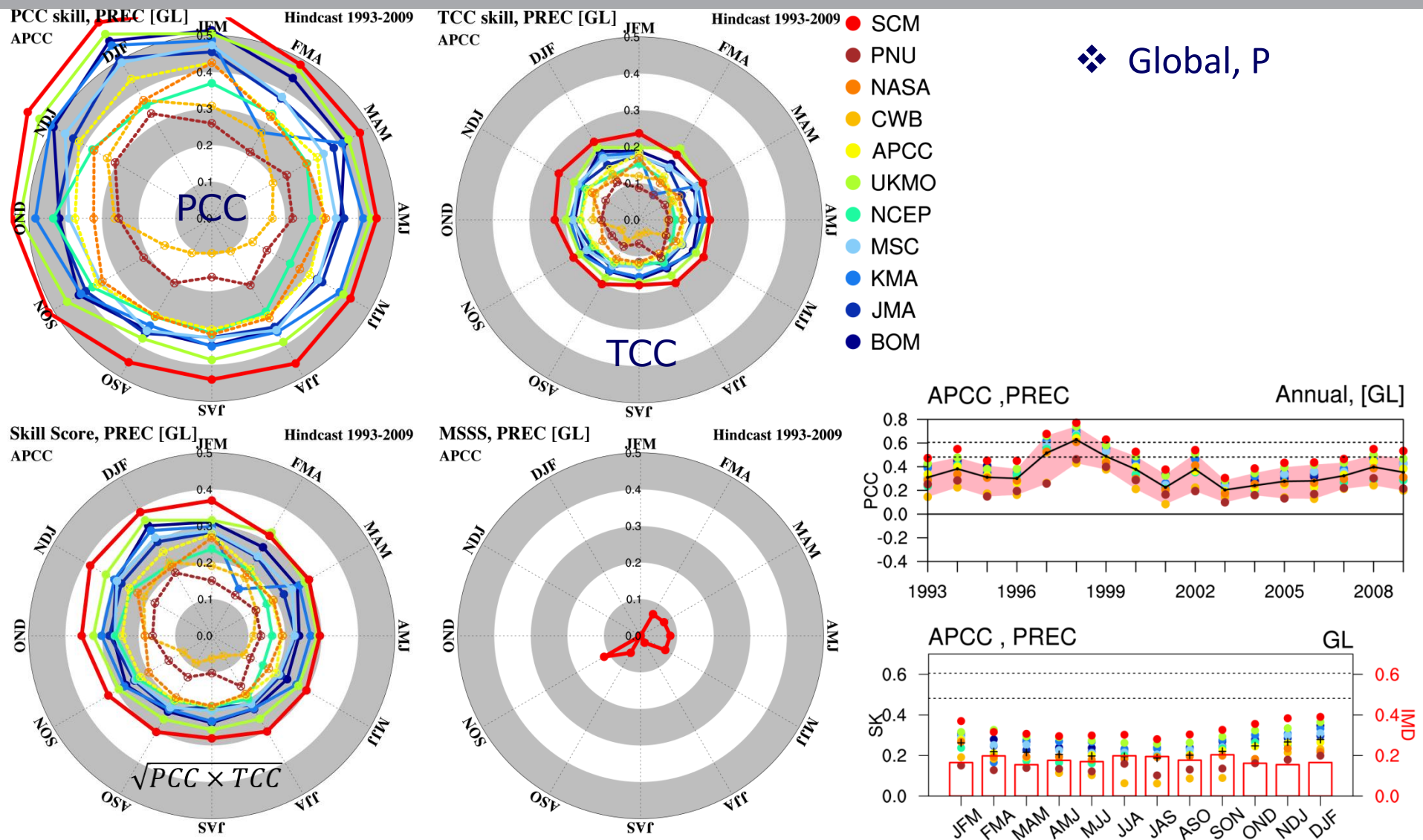


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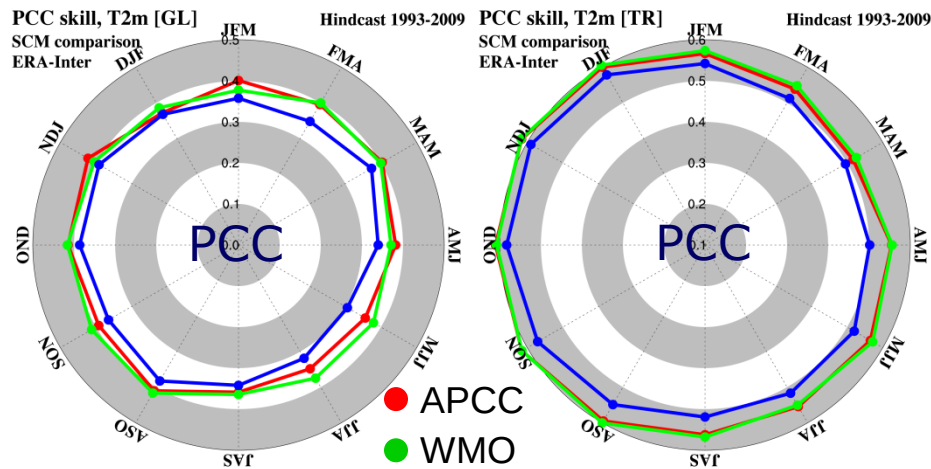
Current APCC MME Prediction skill : Hindcast



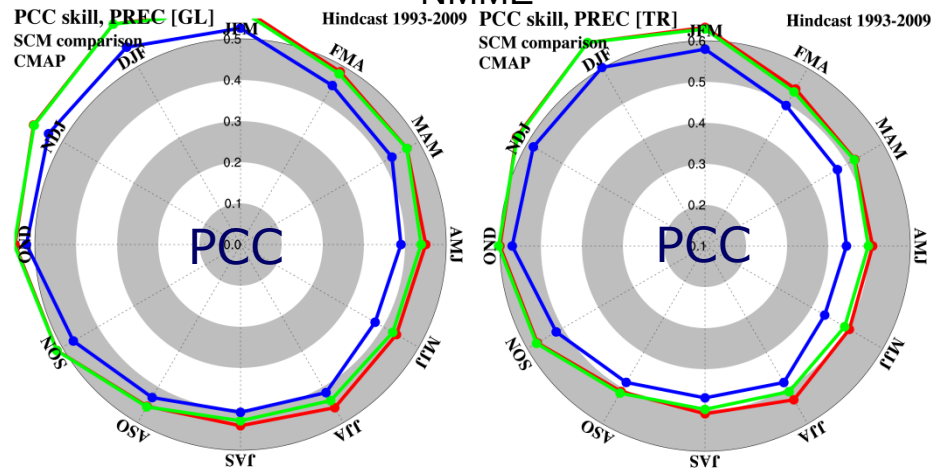
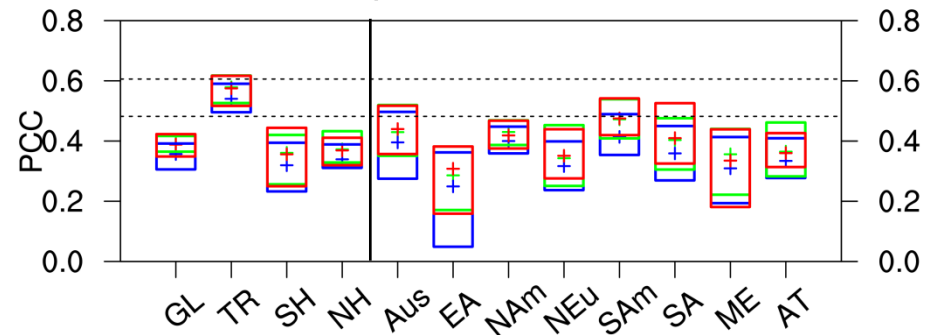
Current APCC MME Prediction skill : Hindcast



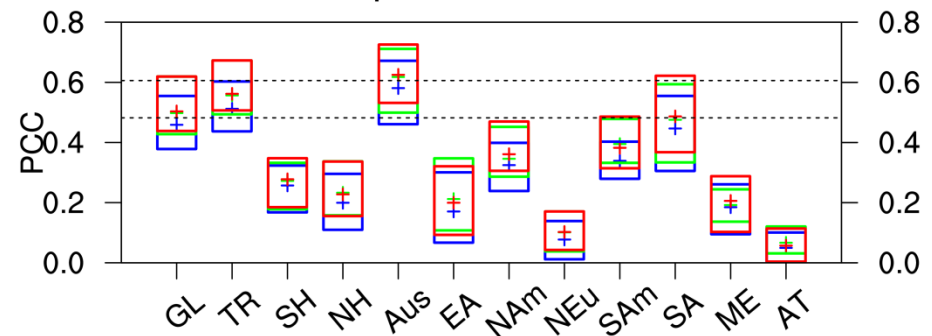
Comparison of SCMs from APCC/WMO/NMME



MME skill comparison ,T2m



MME skill comparison ,PREC

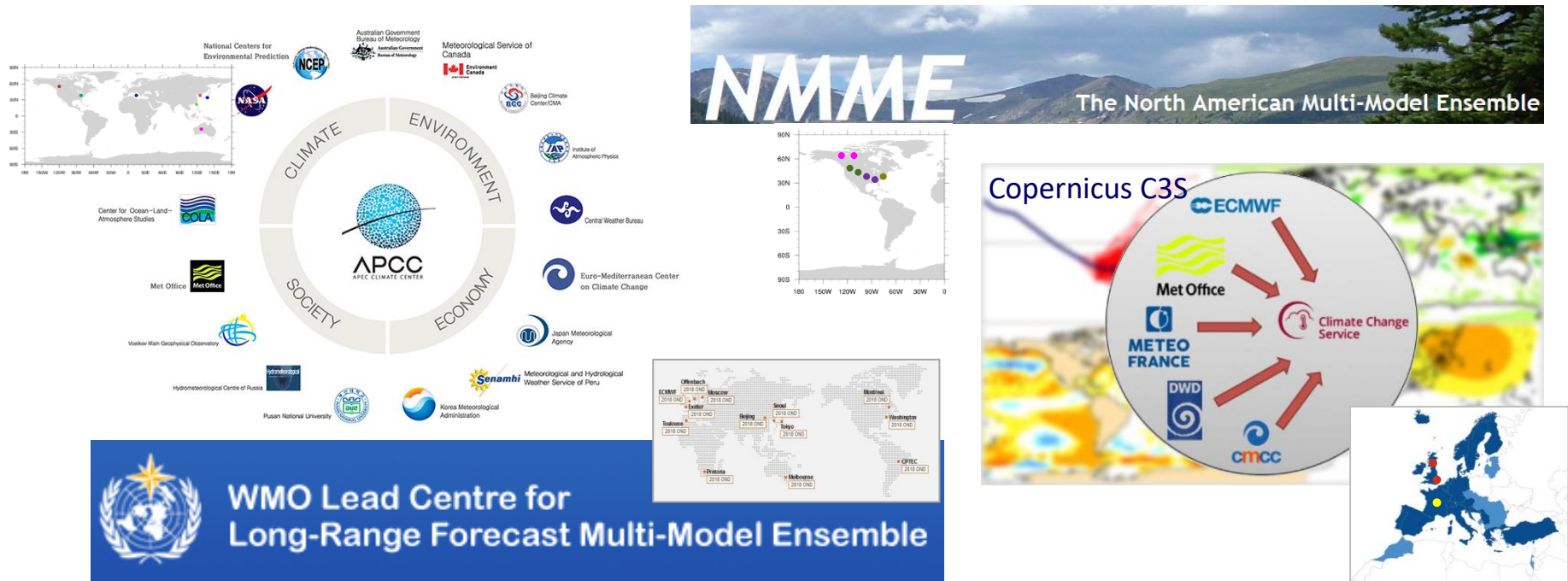


연구배경 및 현황

Part III

MME 자료개선 기반연구

MME 예측 정보를 제공하는 기관들



현재 다양한 기관에서 MME를 활용한 계절예측정보가 제공되고 있으며, 참여모델들이 점차 중복되고 있는 시점임. 다른 기관과의 차별성 및 우위확보를 위한 노력이 필요함

→ MME 자료 개선 기반 연구

APCC Seasonal Prediction system

June 5, 2019

Suryun Ham*, Young-Mi Min, A-Young Lim, Yeomin Jeong, Yoo-Bin Yhang
APEC Climate Center

Part 1:

Introduce to APCC Seasonal prediction model

Background

Since Nov.2017, APCC seasonal prediction model:

CCSM3 → SCoPS

SCoPS: Seamless Coupled Prediction System

- Newly developed coupled system with a research group of Univ. of Hawaii
- For predicting subseasonal to seasonal climate
- High resolution atmosphere-ocean-land-seaice model
- Improved Integrated AO initialization

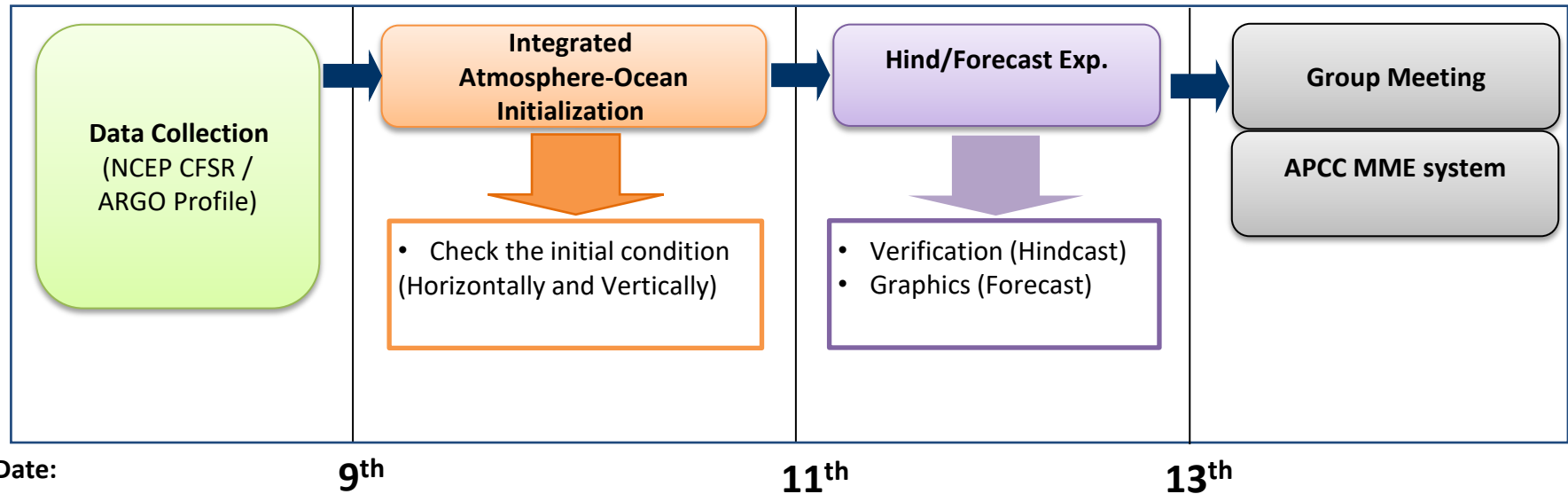
Ham, S., A-Y. Lim, S. Kang, H. Jeong, and Y. Jeong, 2019: A newly developed APCC SCoPS and its prediction of East Asia seasonal climate variability. *Clim. Dyn.*, 52(11), 6391-6410

Seamless Coupled Prediction System

		SCoPS	CCSM3
Model	Atmos.	ECHAM v5.3	CAM3
	Ocean	POP v2.0.1	POP v1.4.3
	Sea ice	CICE v4.1	CSIM4
Resolution	Atmos.	T159L31	T85L26
	Ocean	$\sim 1.0^\circ \times 0.5^\circ / L40$	
Initialization	Atmos.	3D nudging from CFSR U, V, T, Q	-
	Ocean	EnKF from CFSR SST and profile Temp & Salinity data (ARGO)	3D nudging from GODAS Temp

- Hindcast Simulation
 - Total Ensemble members : 10
 - Time lagged forecasting (1st, 5th with 5 perturbation ensemble spread by ENKF)
 - - ATM/OCN/ICE ICs: Daily
 - Hindcast period: 1982~2013 (32 years) / Forecast period: 2014~
 - 7month integration

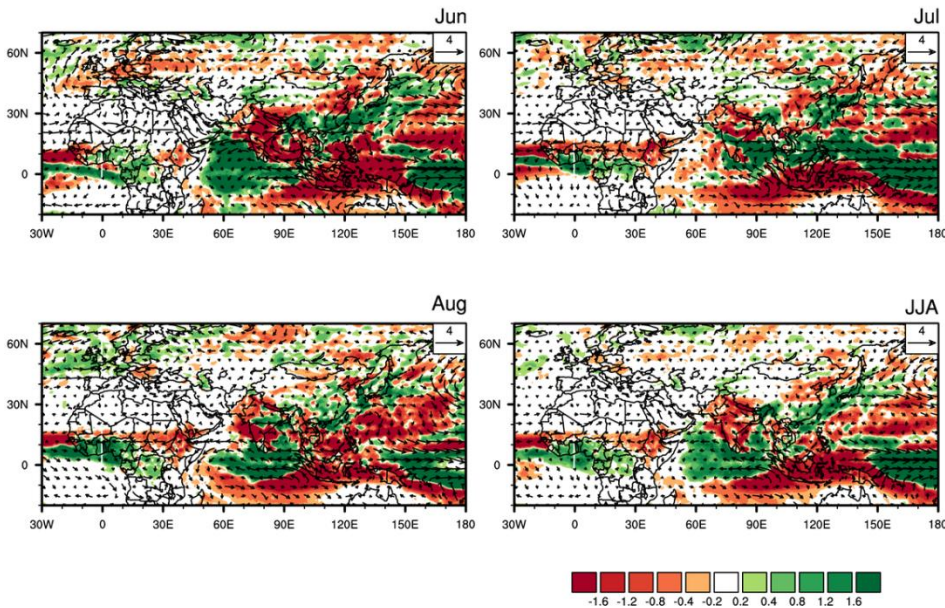
Forecast time schedules (SCoPS)



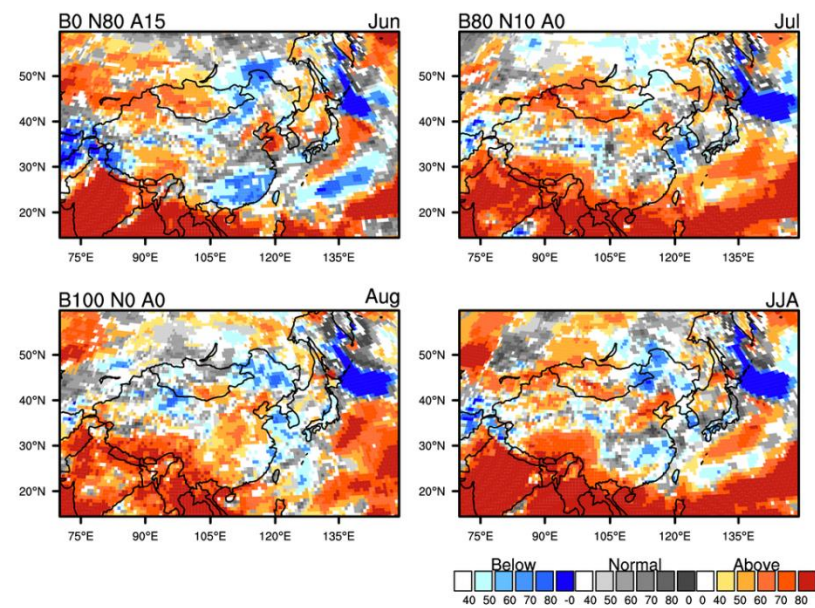
1. Collecting **NCEP CFSR (u,v,t,q,sst)** and **ARGO T & S vertical profile data**
2. Integrated Atmosphere-ocean initialization → 1st, 5th day **Restart files** for ATM., OCN., Seaice models
3. Seasonal **Forecast for 7-mon.**
4. Discuss some characteristics of seasonal forecast data in **Group meeting** with hindcast verification and forecast Graphics
5. Providing the forecast data to **APCC MME system**

Forecast outputs

UV850 and Precipitation Anomaly 2019JJASON (Deter.)



2m Temperature Anomaly 2019JJASON (Prob.)



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- **Deterministic as well as probabilistic Forecast for East Asia seasonal temperature and precipitation from SCoPS.**
 - ex) SCoPS predict Wet and cool summer for Korea.
 - Typical El Nino response, but note that SCoPS has systematic errors that usually overestimated El Nino intensity due to warm biases in subsurface at western Pacific.

Seamless Coupled Prediction System



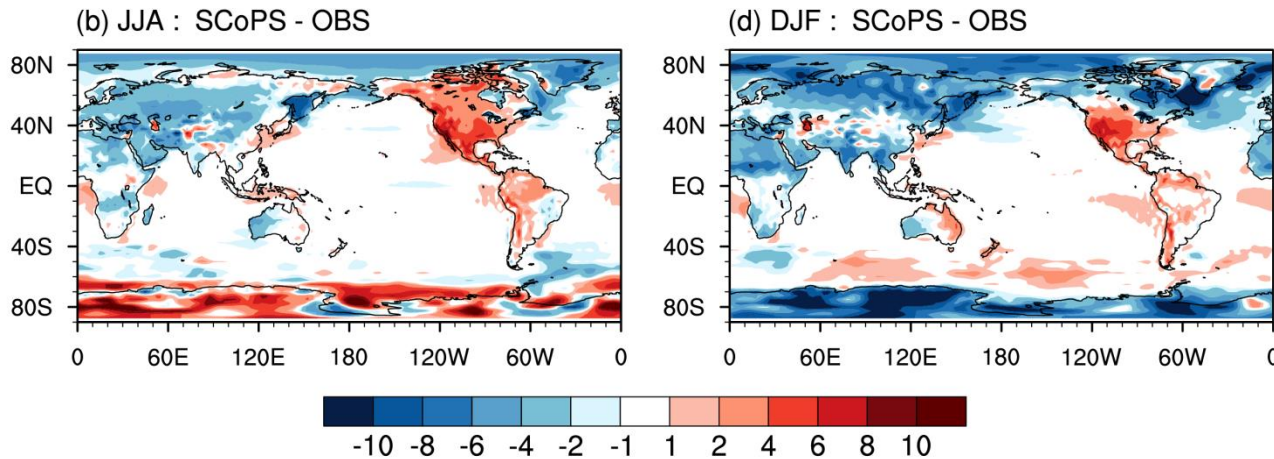
Part 2: Assessment of seasonal prediction skill

Hindcast (1982-2013)

Prediction skill: Biases (JJA, DJF)

2mTemperature

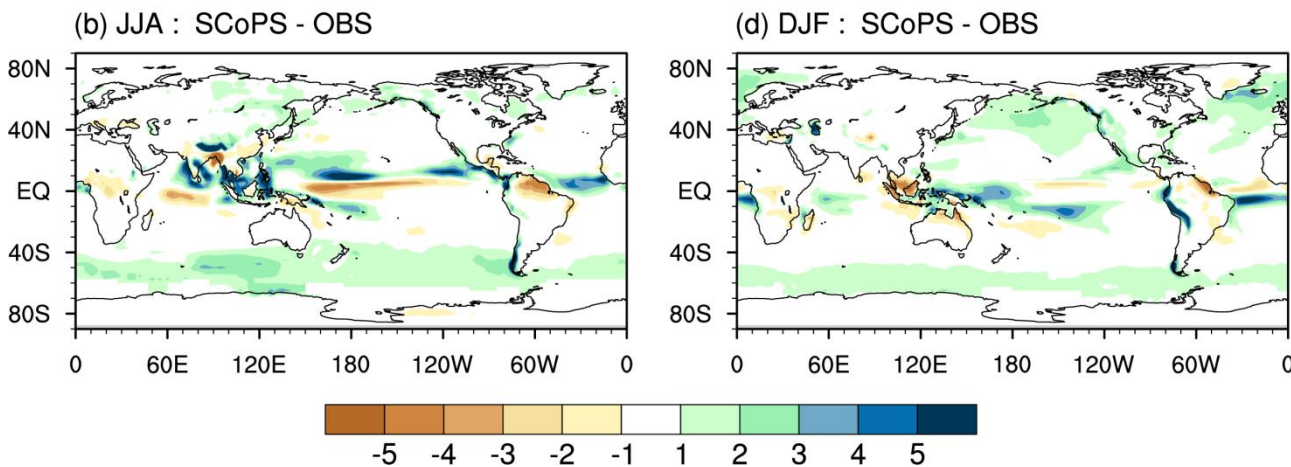
1-mon lead 3-mon mean forecast biases



Both season:

- **Warm** biases over North and South America
- **Cold** biases over the Eurasian

Precipitation



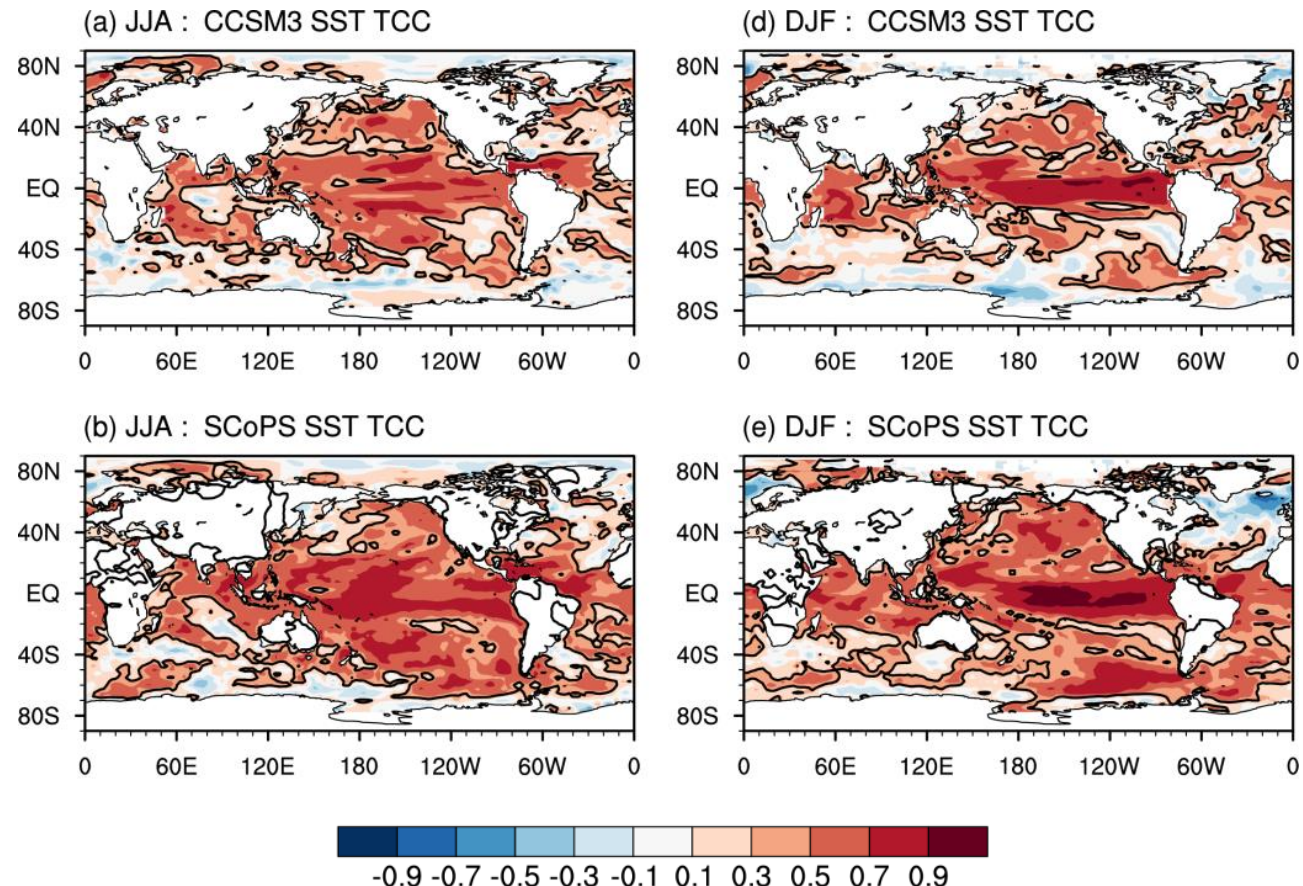
- **Wet** biases over the ITCZ,
- Wet(Dry) biases over Maritime continental regions in JJA (DJF)
- Dry biases over the central equatorial Pacific (JJA),

Hindcast (1982-2013)

Prediction skill: TCC (JJA, DJF)

Temporal Correlation Coefficient

SST

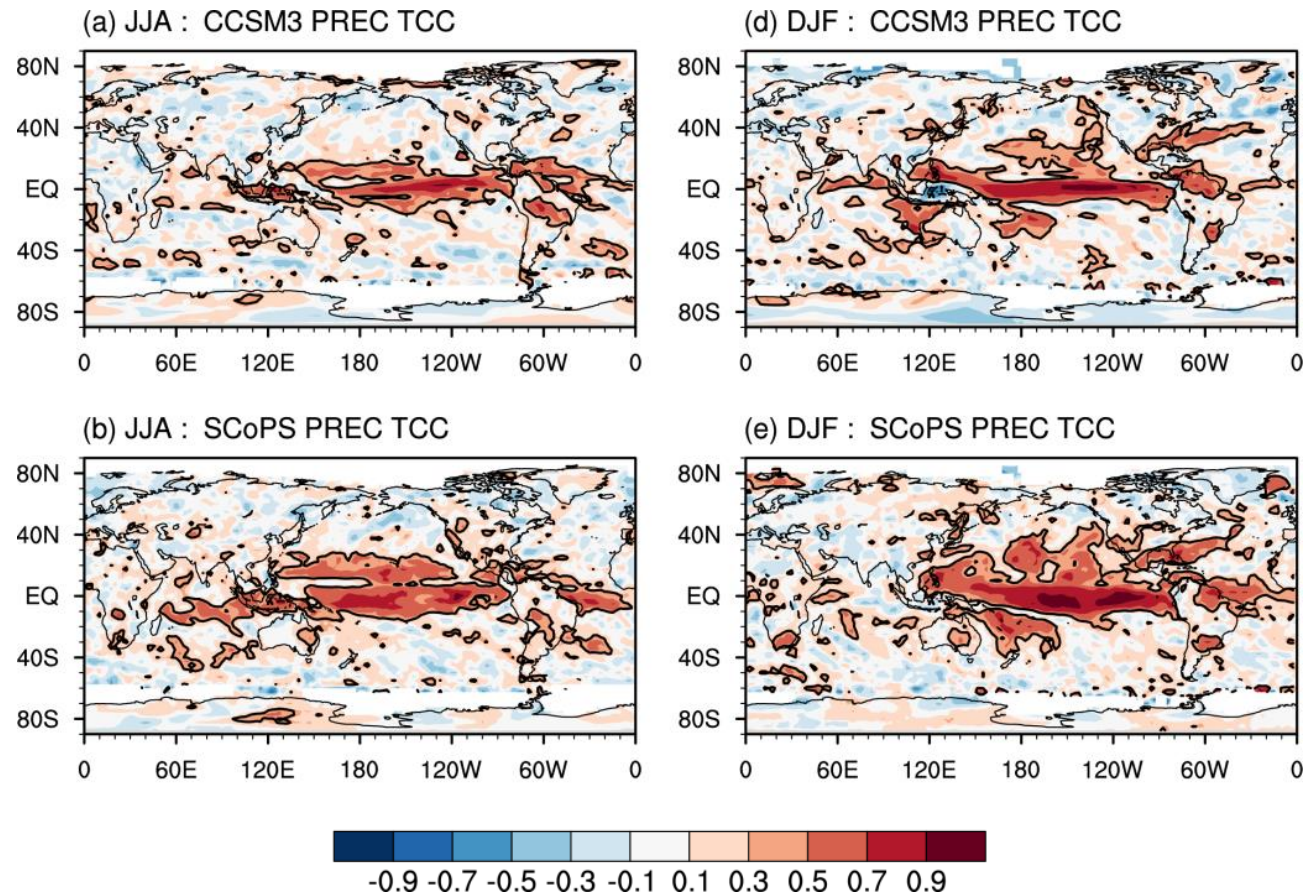


- **Great skill in the tropics**, regions related to the ENSO
- An impressive feature of SCoPS is that it **maintains a higher TCC skill over the western northern Pacific and Indian Ocean** than CCSM3.

Hindcast (1982-2013)

Prediction skill: TCC (JJA, DJF)

Temporal Correlation Coefficient Precipitation



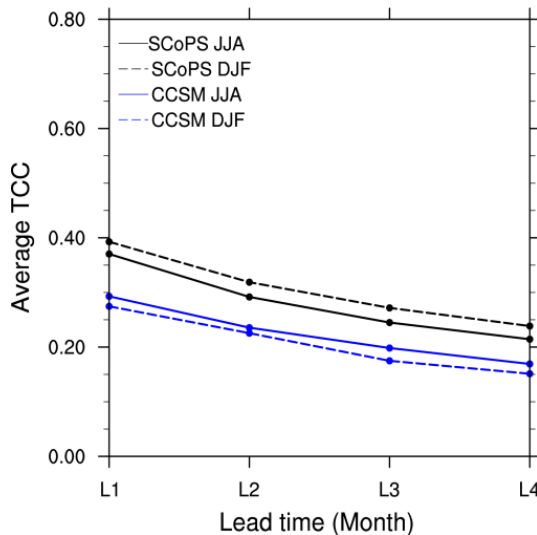
- Greater skill over the Tropics than the extra-tropics, over ocean than land
- Skill of SCoPS is higher than that of CCSM3 over the Indian Ocean and northern western Pacific, although some regions have lower skill.

Hindcast (1982-2013)

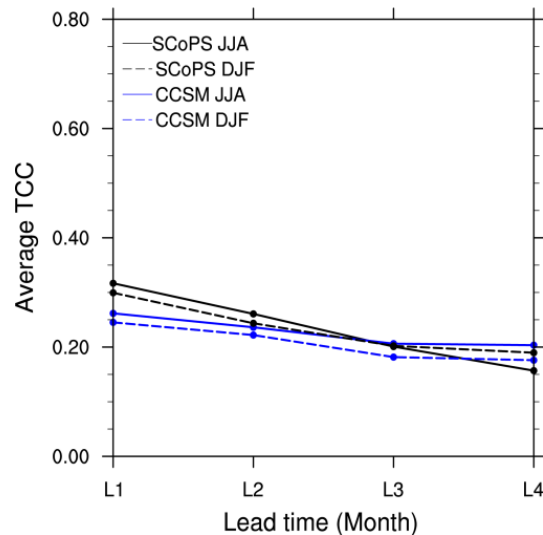
Prediction skill: TCC (JJA, DJF)

Global

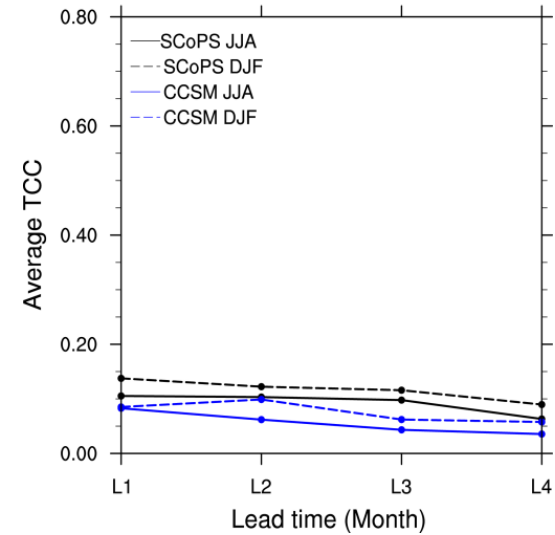
SST



2mTemp



Precipitation

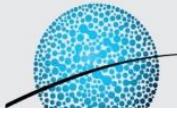


- Averaged TCC

: Prediction skill generally decreases to the forecast lead time

: SST skill is slightly higher than the t2m and precipitation

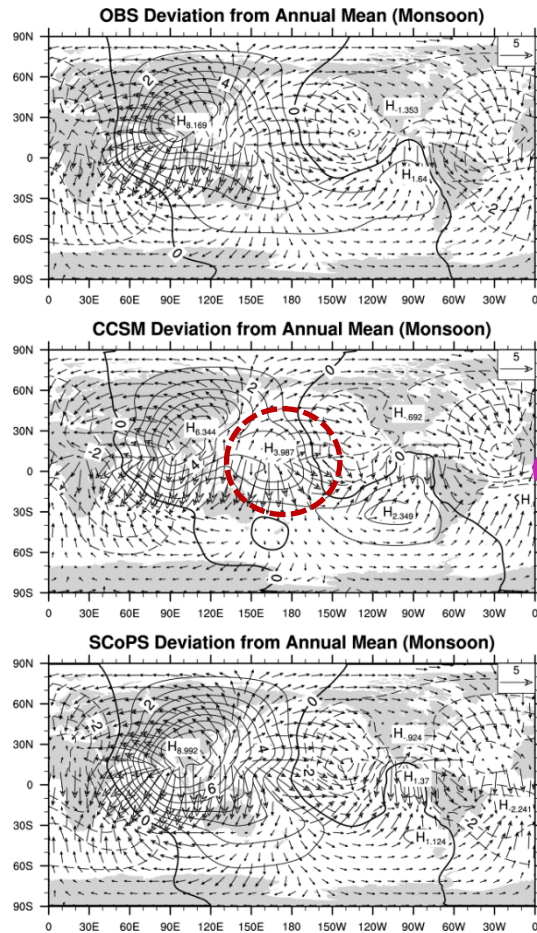
: Generally SCoPS prediction skill for all variables is higher than CCSM3 for both season and regions, although some variables show lower skill for a long lead time.



Hindcast (1982-2013)

Monsoon circulation (JJA, DJF)

JJA

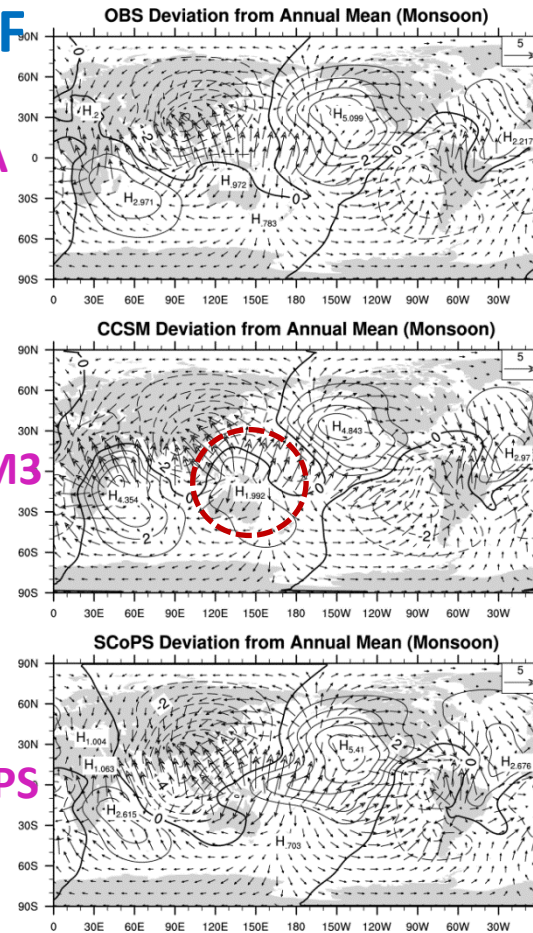


DJF

ERA

CCSM3

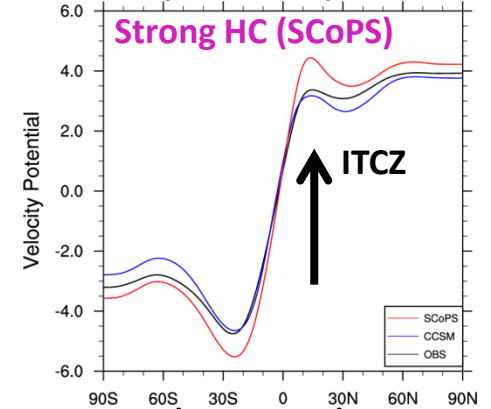
SCoPS



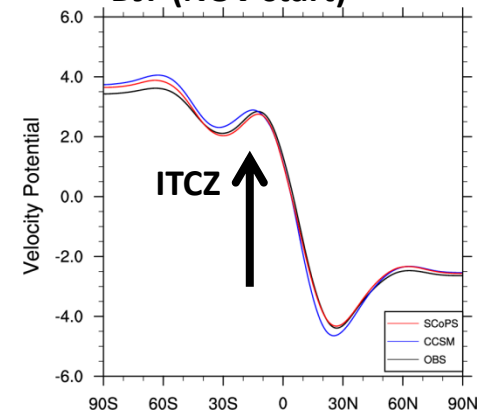
Hadley circulation intensity

JJA (MAY start)

Strong HC (SCoPS)



DJF (NOV start)



EASM: upper air divergence over East Asia and upper air convergence over the Pacific and Atlantic ocean, Convection center is located near the Philippines.

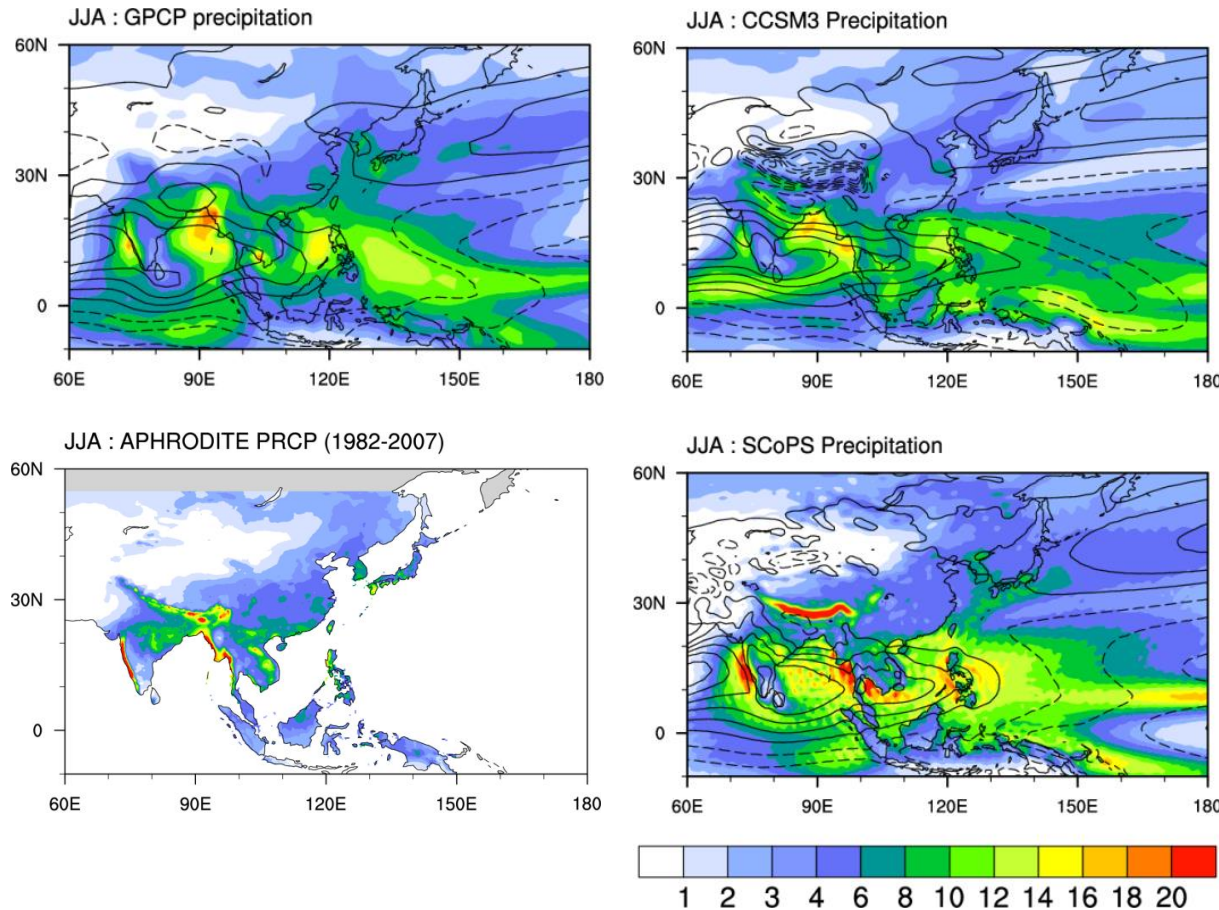
- CCSM3: additional peaks over the Tropics (JJA), and Australia (DJF).
- SCoPS: closer pattern to the observation than those from the CCSM3. but, HC intensity is overestimated.



Hindcast (1982-2013)

East Asia summer climate variability: Precipitation

JJA mean precipitation and 850hPa zonal wind



- **Narrow and strong bands of precipitation** are indicated over the western areas of India, Indochina, and the Philippines in the APHRODITE data

- SCoPS well represented these observed pattern due to the higher resolution

- Also, SCoPS captures the **zonally elongated rainband** associated with the EASM.

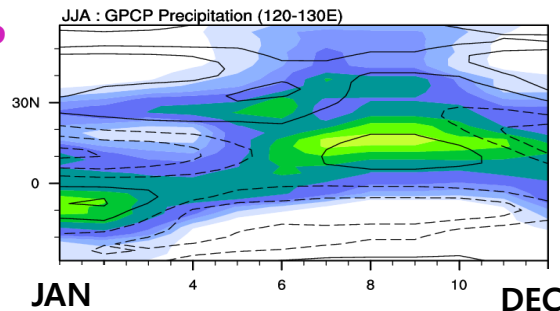


Hindcast (1982-2013)

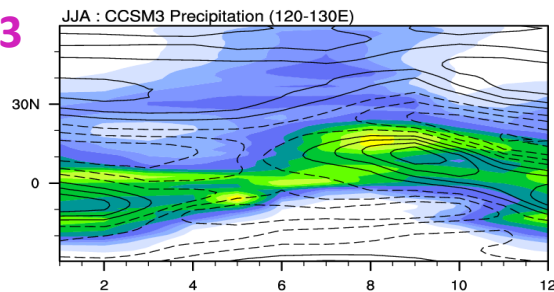
East Asia summer climate variability: Precipitation

Latitude-time cross sections for precipitation annual cycle and 850hPa zonal wind
120-130E (East Asian region)

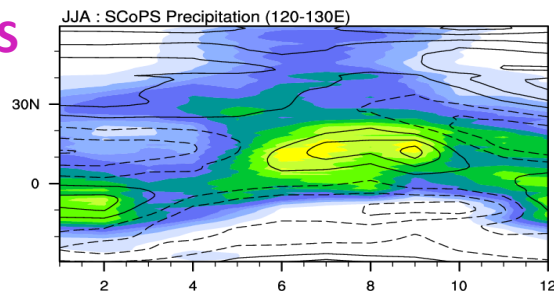
GPCP



CCSM3



SCoPS

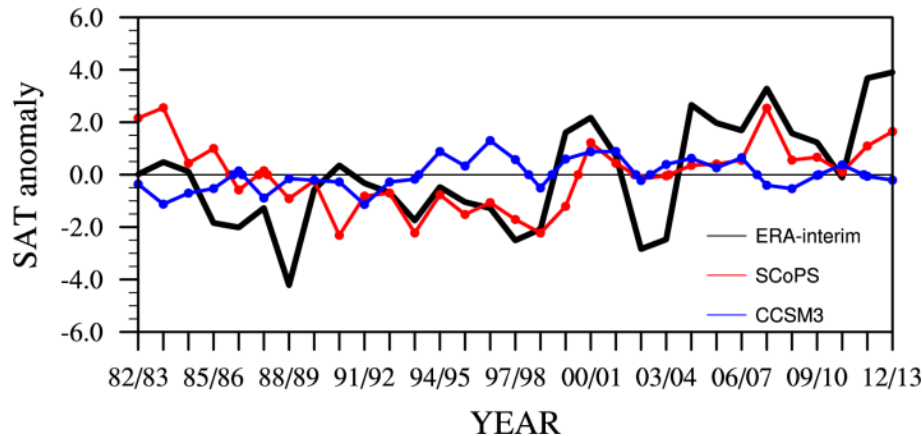


- Both hindcasts generally represent rain peak over the ITCZ.
- **CCSM3 exaggerated precipitation** over the equatorial rainband, even in winter
- SCoPS well represent the two peak rain season, slightly overestimated.
- Remarkably, the **northward migrated rainband related to the EASM is captured by SCoPS**

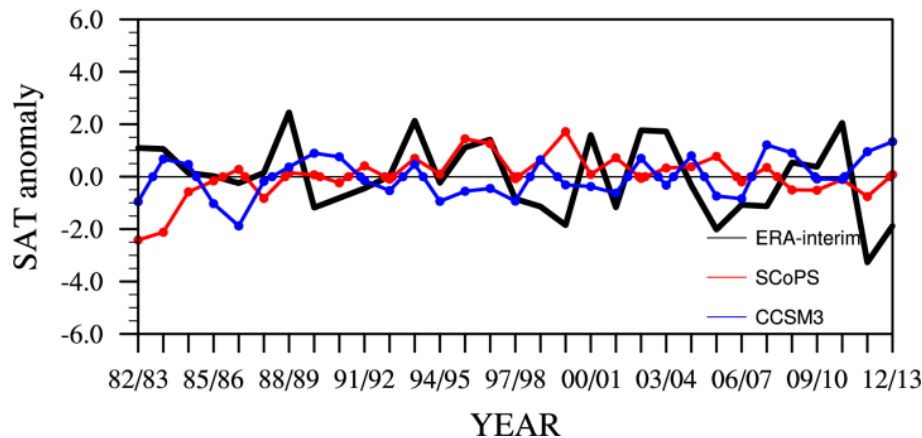
Hindcast (1982-2013)

East Asia winter climate variability: Arctic-EA feedback

Winter SAT over the K-B



Winter SAT over the S-C



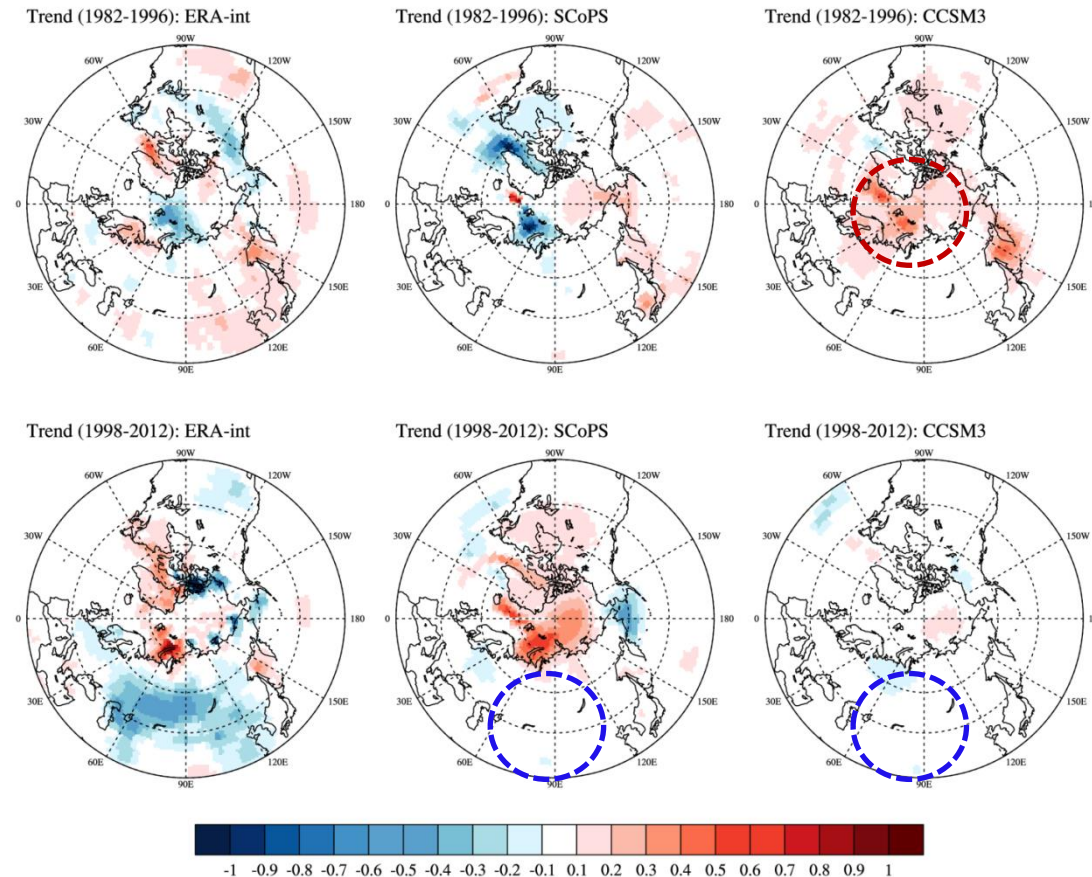
East Asia winter climate variability is significantly related to Arctic climate variability, especially sea ice.

- Recently, Kara-Barents Sea and East Siberian-Chukchi sea regions have marked **reductions in sea-ice concentration**
- Since 1998, **Arctic surface warming** has progressed rapidly, especially K-B sea region.
- **ERA-interim** data show recent trend very well, the progressed arctic surface warming, especially K-B region.
- **CCSM3** shows a pattern that is somewhat different from observation.
- **SCoPS** generally well represent the warming trend in K-B region.

Hindcast (1982-2013)

East Asia winter climate variability: Arctic-EA feedback

Linear trend in the arctic temperature for the periods 1982-1996 and 1998-2012



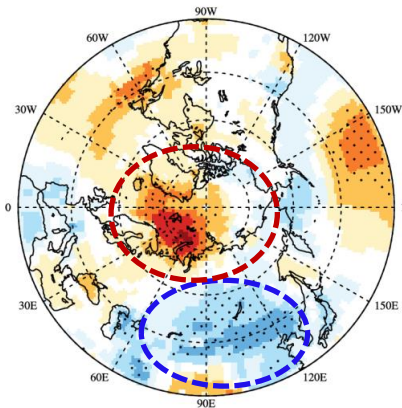
- In earlier epoch the Arctic was actually **cooling slightly** whereas in the later epoch it was **warming**.
- SCoPS generally well represent the warming trend in Arctic, but missed Eurasian cooling pattern.
- CCSM3 do not capture the **Arctic warming trend**.

Hindcast (1982-2013)

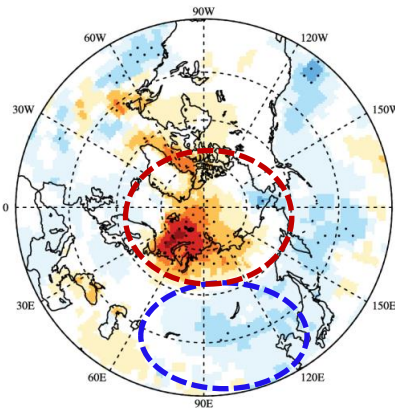
East Asia winter climate variability: Arctic-EA feedback

Correlation coefficients of SAT anomalies with respect to detrended monthly Arctic temperature

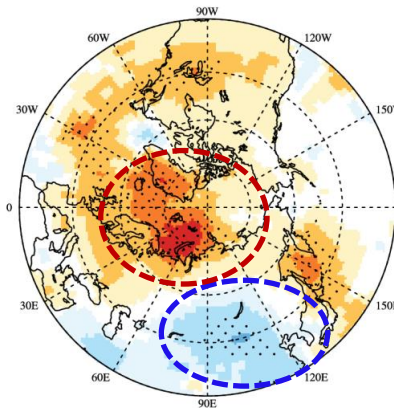
Cor K-B SAT: ERA-interim



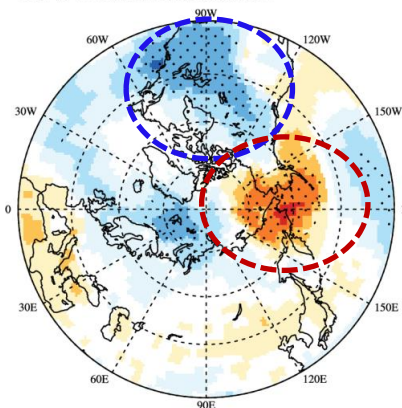
Cor K-B SAT: SCoPS



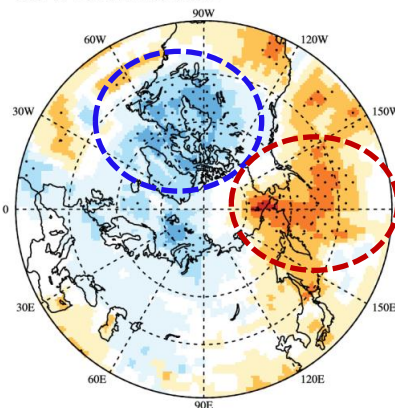
Cor K-B SAT: CCSM3



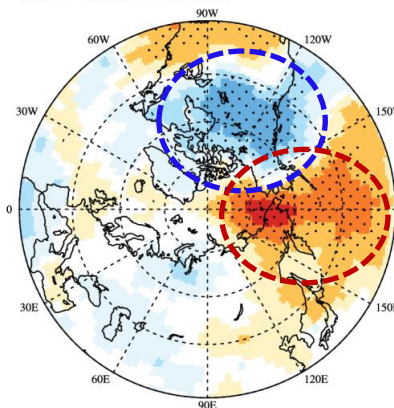
Cor S-C SAT: ERA-interim



Cor S-C SAT: SCoPS



Cor S-C SAT: CCSM3



When the Arctic SAT gets warmer over the K-B region, East Asia experiences cold winters

→ **Warm Arctic-Cold Eurasian pattern; WACE**

North American winter SAT anomalies **are strongly negatively correlated** with SAT anomalies in the East Siberian-Chukchi Sea region

SCoPS: well represented these pattern, but slightly weak Eurasian cooling pattern

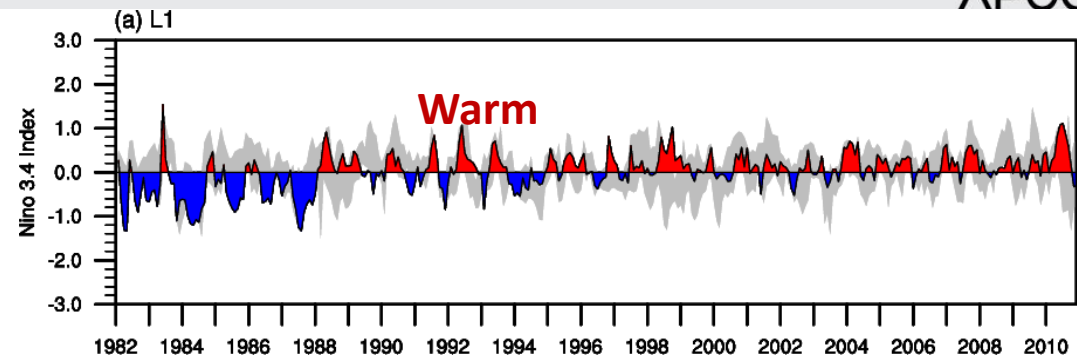
CCSM3: well capture the WACE pattern, but with strong positive correlated pattern

Seamless Coupled Prediction System

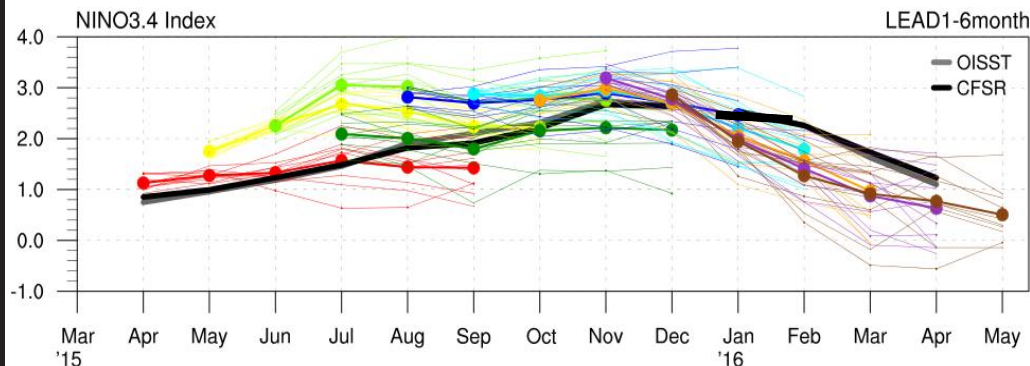
Part 3: To reduce systematic errors

Systematic error in SCoPS

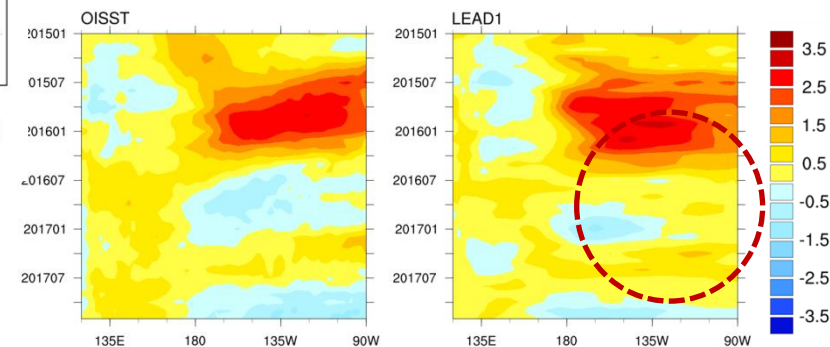
Error of 3mon. mean Nino 3.4 Index



Evolution of 2015-2016 Nino 3.4 Index



Evolution of observed and predicted SST anomalies along the equatorial (5°S-5°N) in the Pacific from 2015 to 2017



- First few years, **cold biases** in Nino 3.4 region are prominent, after warm biases are significant.
- In realtime forecast, evolution of predicted Nino 3.4 index from SCoPS is **overestimated** that from observation.
- Especially, SST anomalies in the **eastern Pacific show warm biases** compare to the observation

Seamless Coupled Prediction System

#1: Minor error fix

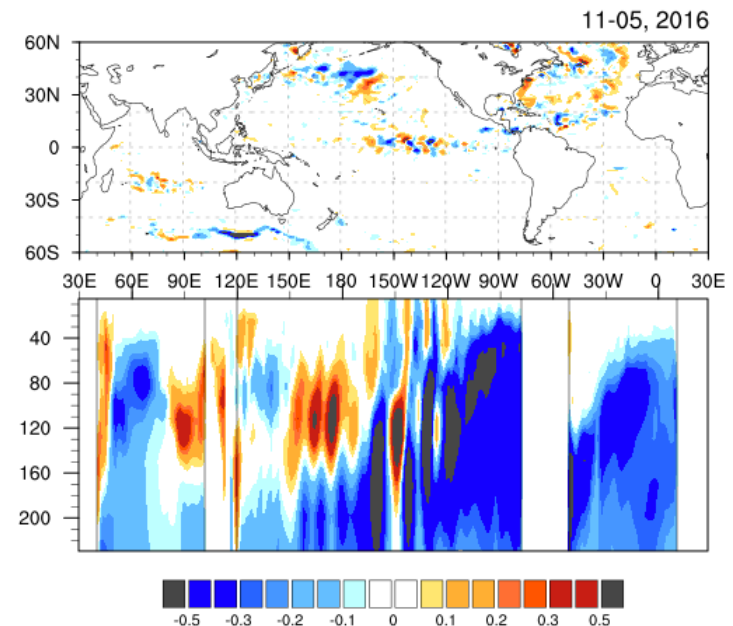
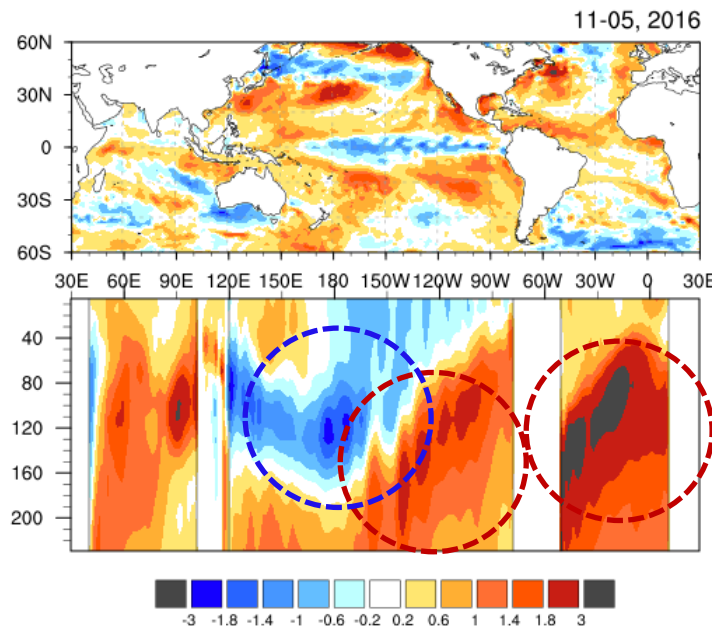
ORG

NEW - ORG

Ocean Initial Condition for 2016DJFMAM

SST anomaly

Sub-Surface
temperature
anomaly
(5S – 5N)



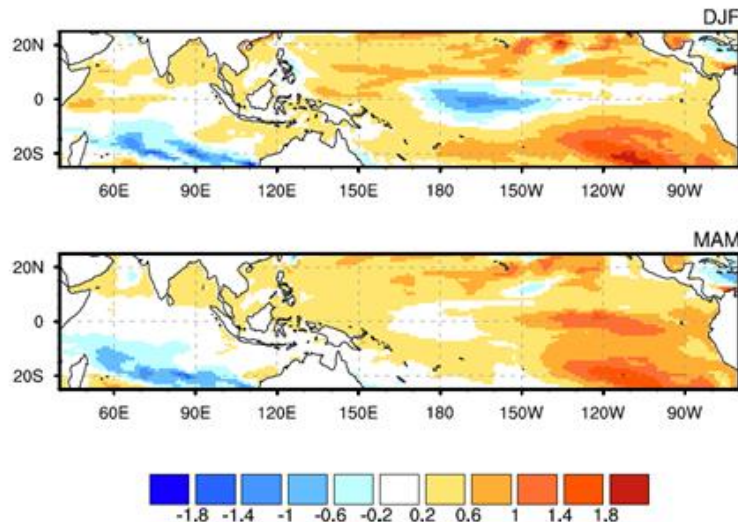
- Too much warm subsurface anomalies over the eastern Pacific, cold subsurface anomalies over the central Pacific
- 1) vertical ocean variables MPI dimension code error fix, 2) code clean-up, etc.
 ➔ **warm and cold anomalies biases are slightly reduced!**

Seamless Coupled Prediction System

#1: Minor error fix

ORG

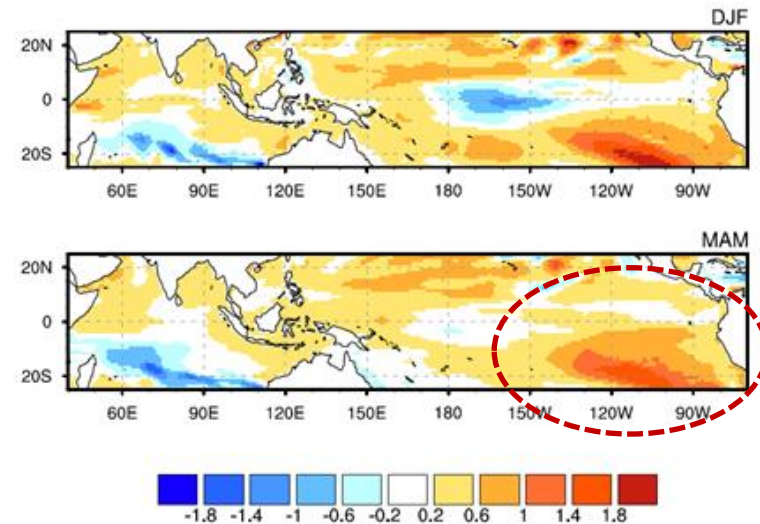
SST Anomaly 2016DJFMAM (Deter.)



© Climate Research

NEW

SST Anomaly 2016DJFMAM (Deter.)



© Climate Research

- Short lead time forecast (1-3 month): Two predicted SST anomalies are almost same.
- **Long lead time** forecast (4-6 month): The SST anomalies over Eastern Pacific is significantly **decreased** in NEW forecast.

SCoPS: Ocean model (POPv2.0.1)

#2: Ocean diffusivity

Background diffusivity (in KPP mixing)

- $1 \text{ cm}^2/\text{s}^1$ (Munk 1966)
- subsurface 0.3, deep $1.3 \text{ cm}^2/\text{s}^1$ (Gregg 1977, Bryan and Lewis 1979) → SCoPS
- $0.1 \text{ cm}^2/\text{s}^1$ (Ledwell et al. 1993, 1998, Large et al., 1994)
- $0.17 \text{ cm}^2/\text{s}^1$ (Moum et al. 2002, Stammer 2005)
- Depends on latitude: $0.01 - 0.5$ (Jochum 2009)

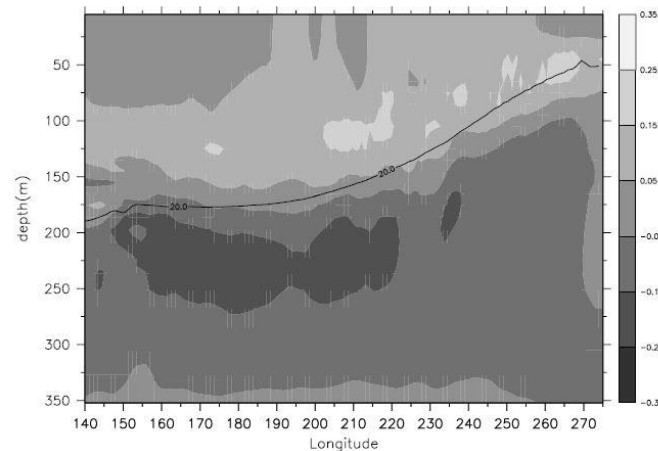
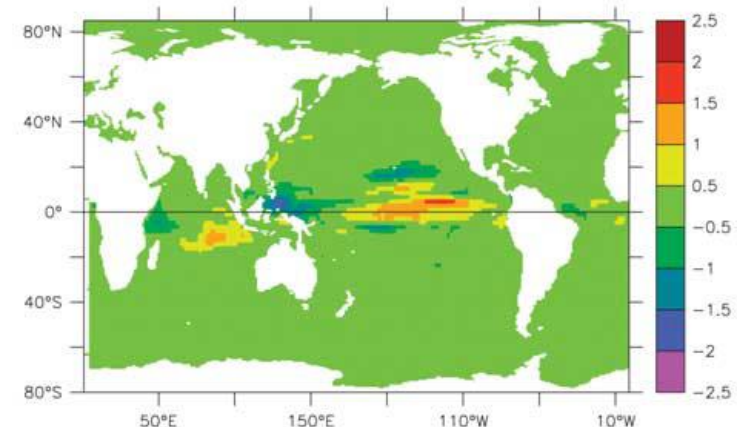


Figure 2. Temperature difference along the upper equatorial Pacific between a run with $k = 0.01 \text{ cm}^2 \text{ s}^{-1}$ and a run with $k = 0.03 \text{ cm}^2 \text{ s}^{-1}$. Superimposed is the mean position of the 20°C isotherm in LEQUAE. Lower diffusivity reduces diffusion across the thermocline and thereby reduces deeper and increases upper layer temperatures.



a) EQUA - CONT

SCoPS: Ocean model (POP)

#2: Ocean diffusivity

Simple sensitivity test for background diffusivity

- **subsurface 0.3, deep 1.3 cm^2/s^1** (Gregg 1977, Bryan and Lewis 1979)
→ **0.17 cm^2/s^1** (Moum et al. 2002, Stammer 2005)

Test simulation

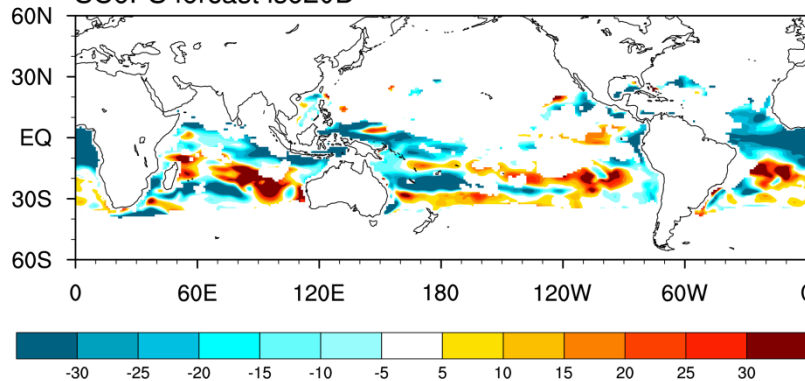
2015. 11. Initial → 2016. 1. Forecast (2mon lead)

Test period: 2016JAN (2mon. Leadtime)

20Deg Isotherm depth (thermocline)

ORG – GODAS

SCoPS forecast iso20D

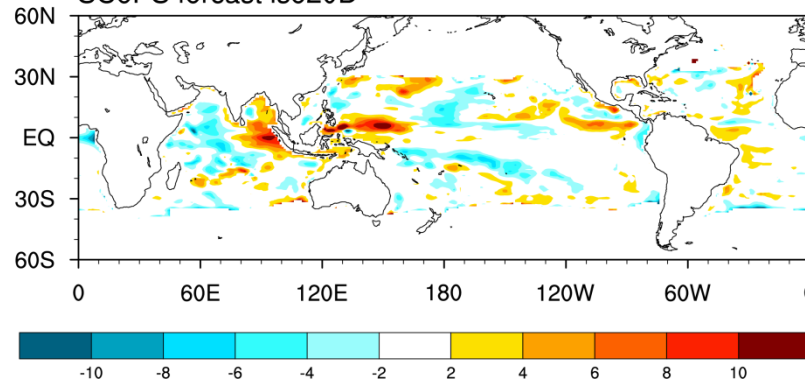


SCoPS:

- Shallow thermocline over western Pacific, Atlantic, northern Indian ocean
- Deep thermocline over southern western Pacific, part of Indian ocean.

VMIX – ORG

SCoPS forecast iso20D

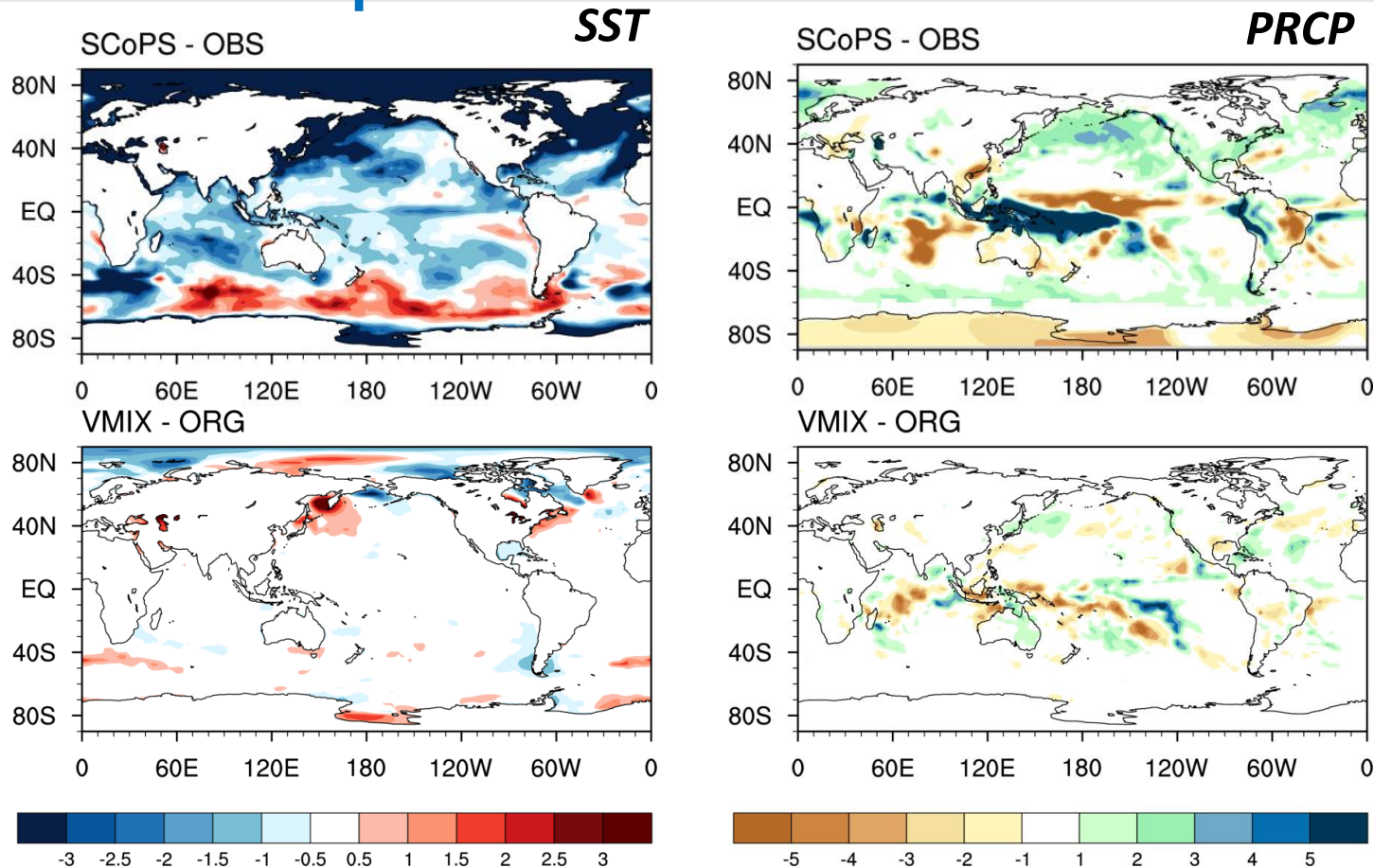


New exp.:

- **Reduced biases** of thermocline depth, especially, western Pacific

Test period: 2016JAN (2mon. Leadtime)

SST & Precipitation



SCoPS:

- Cold biases are dominant.
- Wet biases over western Pacific following ITCZ, and Dry biases over the central Pacific.

New exp.:

- SST is not much changed, but **wet and dry biases is reduced** by diffusion change.

Summary & Plan

Summary

Since Nov.2017, APCC seasonal prediction model:

CCSM3 → SCoPS

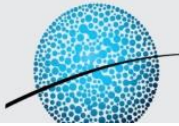
- SCoPS shows higher prediction skill than the CCSM3
- Systematic errors: Cold Sea surface temperature, Warm Subsurface temperature

Plan

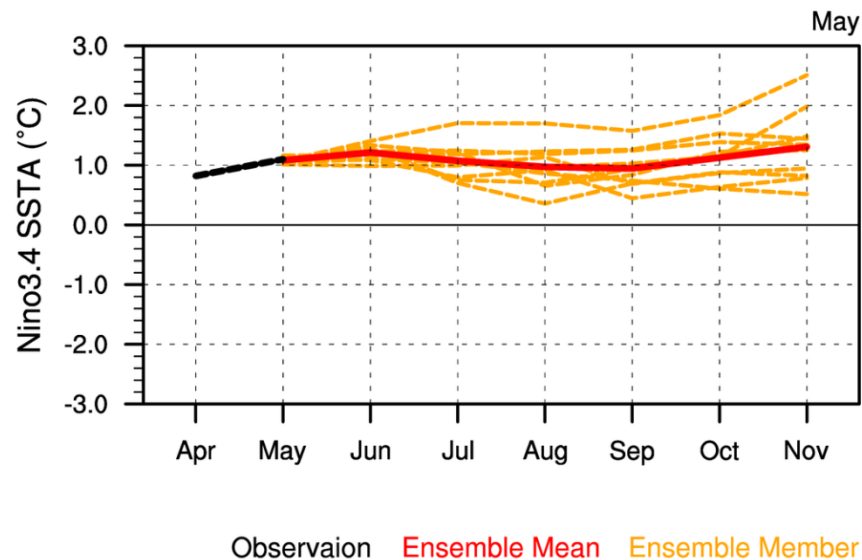
- More sensitivity test for ocean processes for forecast and Initialization system
- To find the reason related to cold SST biases

Thank you for your attention !!

Forecast outputs

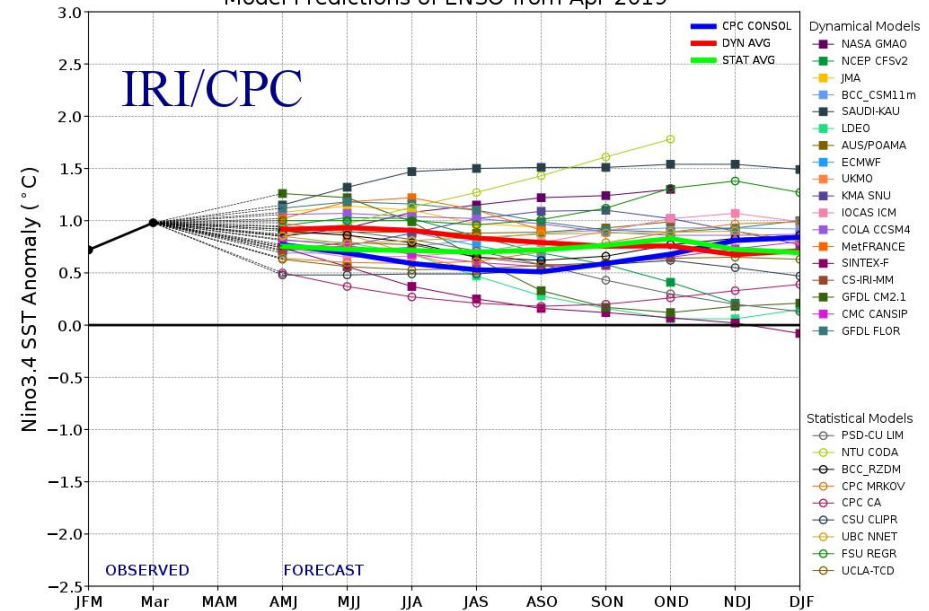


ENSO (Nino3.4) 2019JJASON (Deter.)



© Climate Prediction Team

Model Predictions of ENSO from Apr 2019



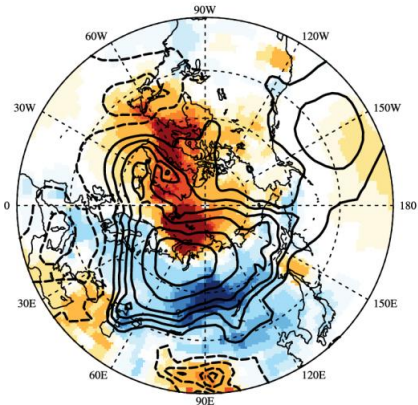
- Check the **ENSO Forecast** from SCoPS compare to the IRI/CPC providing models
ex) SCoPS predict El Nino to continue through 2019, it is stronger pattern than that from averaged IRI/CPC models (also, APCC MME).

Hindcast (1982-2013)

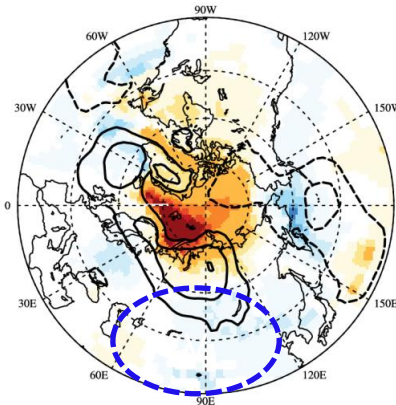
East Asia winter climate variability: Arctic-EA feedback



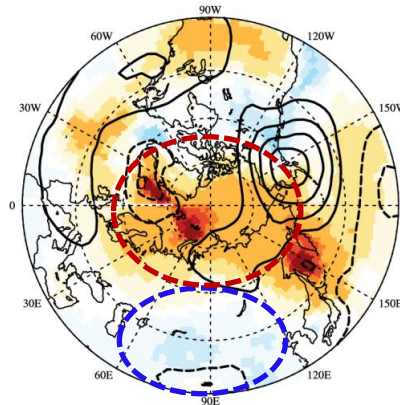
SAT regressed on ERA-int PC1 27.3%



SAT regressed on SCoPS PC1 29.3%



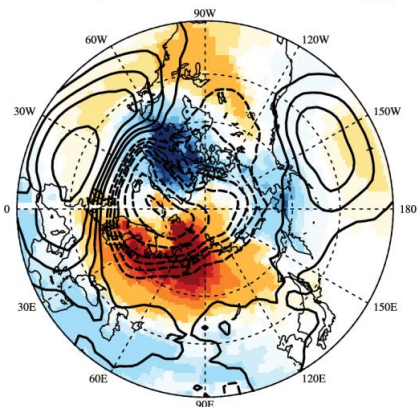
SAT regressed on CCSM3 PC1 43.9%



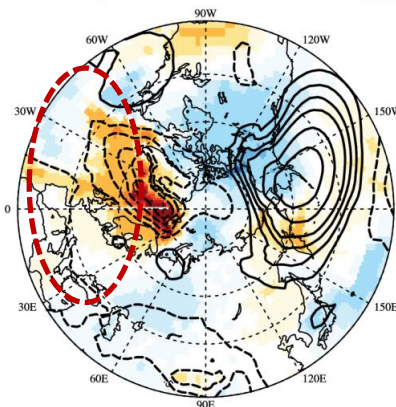
DJF-mean SAT (shaded) and SLP (contour) regressed on normalized two leading modes (PC1, PC2) governing winter SAT anomalies

- Warm Arctic Cold Eurasia pattern & strong SLP over the Arctic to Eurasia (intensified Siberian High)
- Warming over Eurasian continent & meridional SLP Dipole over the North Atlantic (NAO, AO)

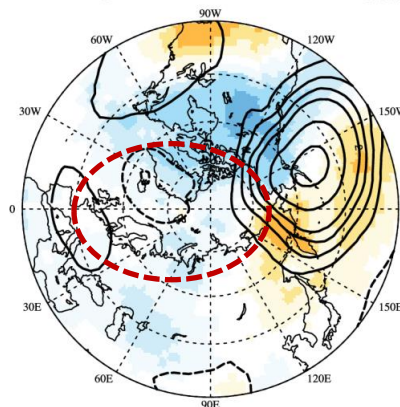
SAT regressed on ERA-int PC2 18.4%



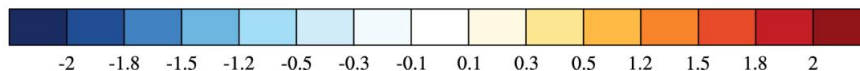
SAT regressed on SCoPS PC2 16.5%



SAT regressed on CCSM3 PC2 15.2%



- SCoPS: generally well captured, but Eurasia cooling (PC1) and arctic warming (PC2), North Atlantic positive SLP do not captured
- CCSM3: too weak SLP pattern, especially AO (PC2) and Eurasia warming is missed

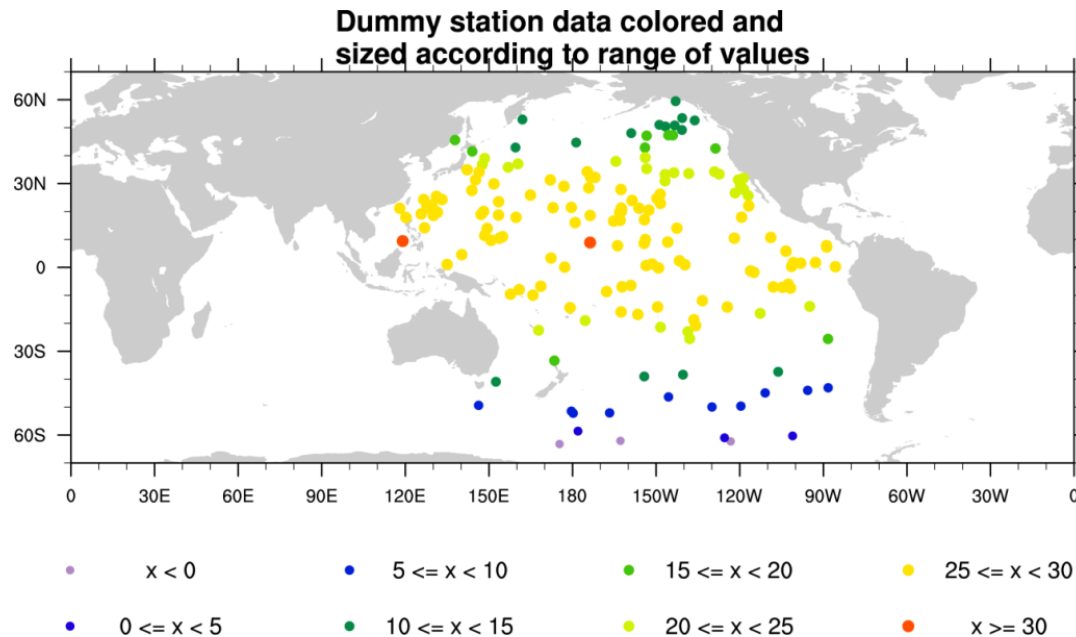


→ Arctic-EA feedback is difficult to represented in Seasonal prediction model. (limitation of East Asia winter forecast using diagnostic model only)

Ocean initialization

해양 자료 동화

- 해양 연직 400m까지, 40S-40N, Temperature & Salinity ENKF
- weighting factor를 주어 동화.
- 임계값 두어, 현재 값과 너무 많이 차이나는 값은 무시
:quality check전 ARGO자료의 튀는 값 제거

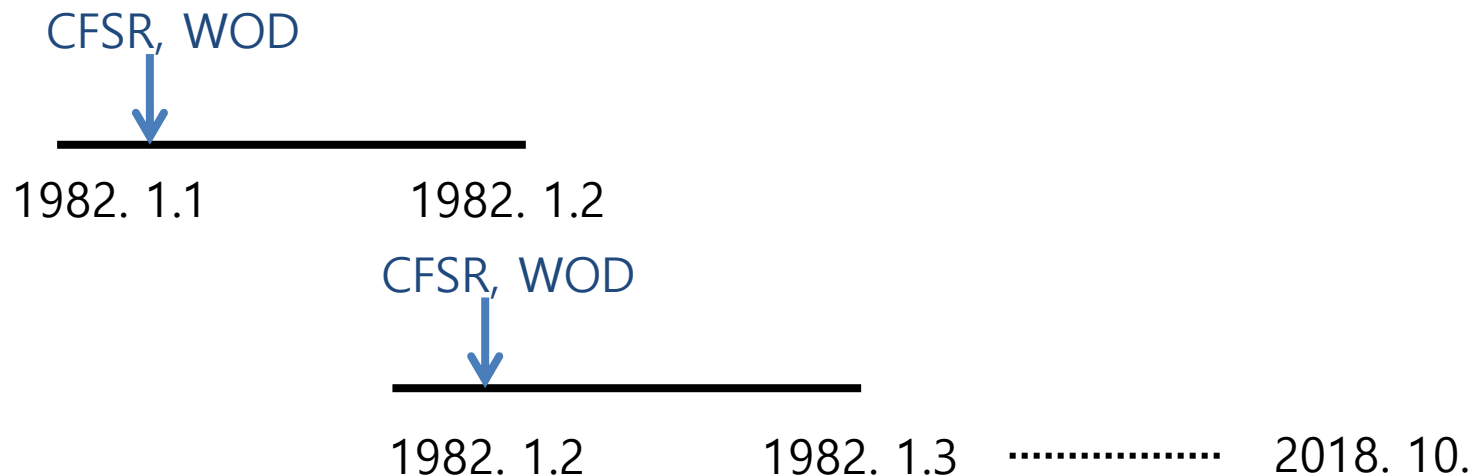


Ocean initialization

Model error!!!

- 자료동화 수행시 **1day integration** 수행

➔ Model balance vs. initial accuracy

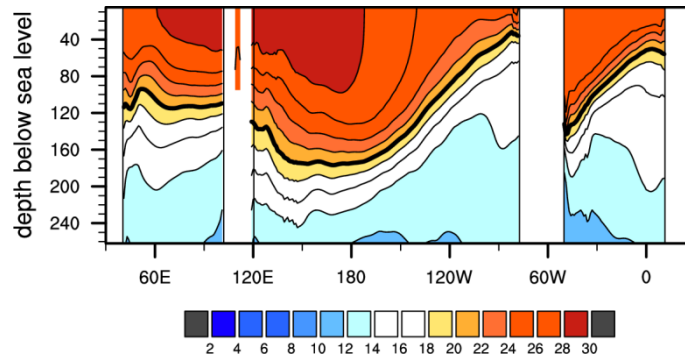


- 결국 모델 error를 배제할 수 없음!

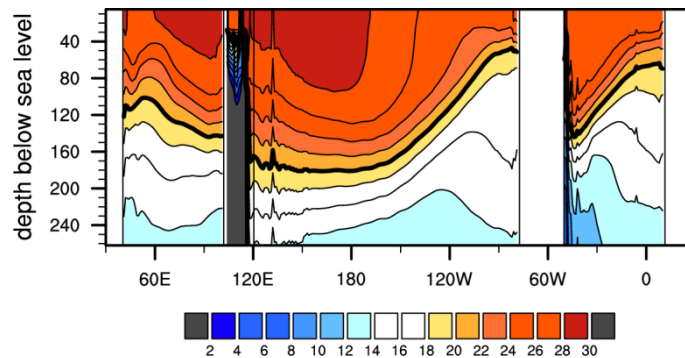
Hindcast period: JAN. 1982 – 2013

Vertical temperature (5S-5N)

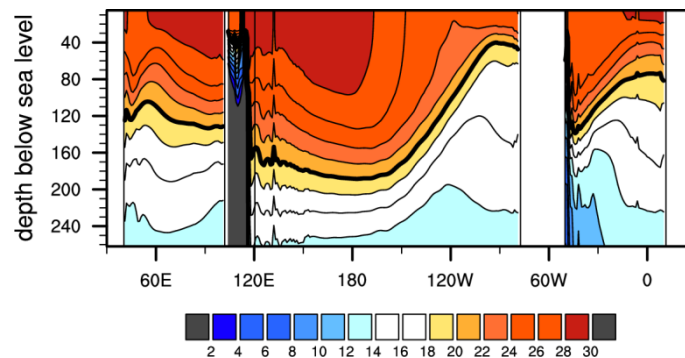
GODAS



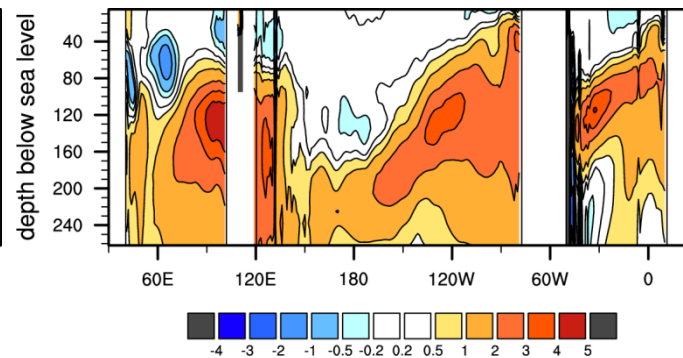
SCoPS initial



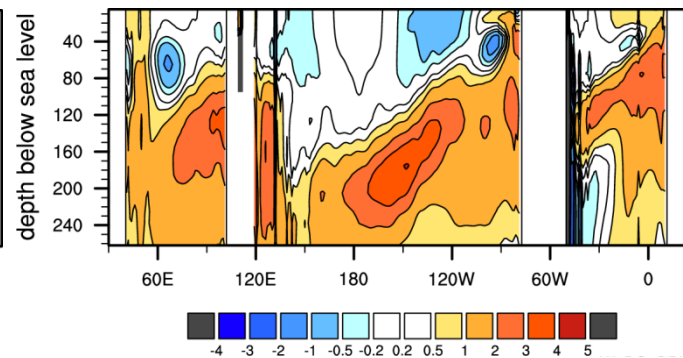
SCoPS 2mon lead



SCoPS initial – GODAS



SCoPS 2mon lead – GODAS

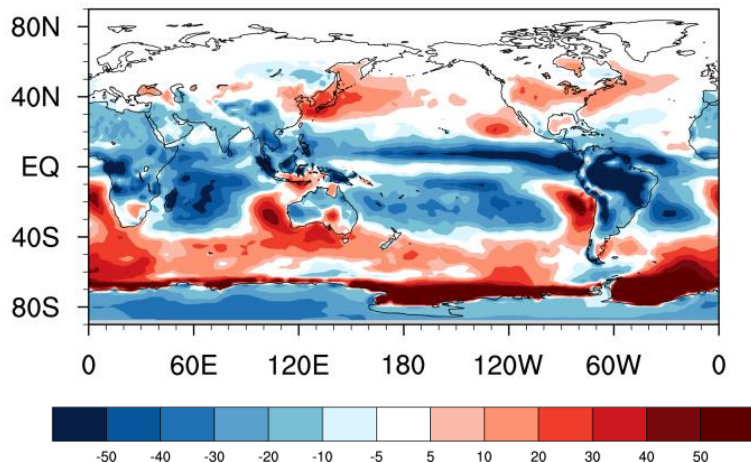


Hindcast period: JAN. 1982 – 2013

Fluxes

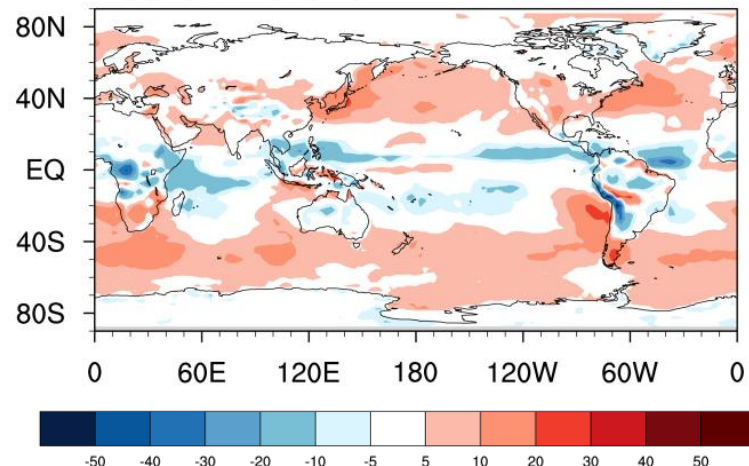
Net SFC SW fluxes

initial SCoPS-OBS



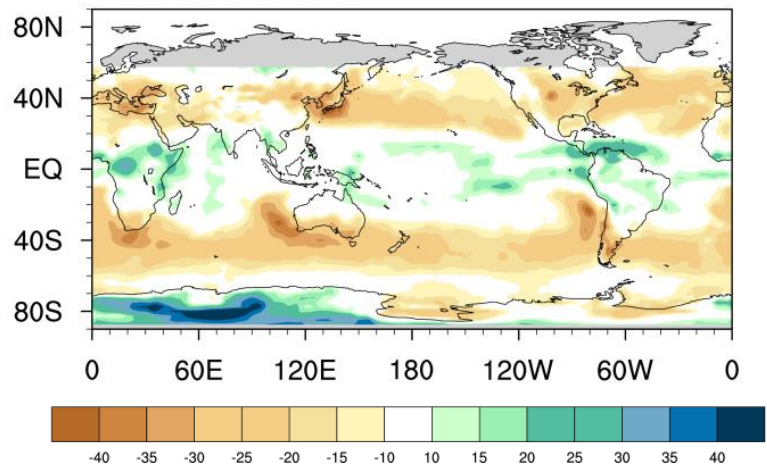
Net TOA LW fluxes

initial SCoPS-OBS



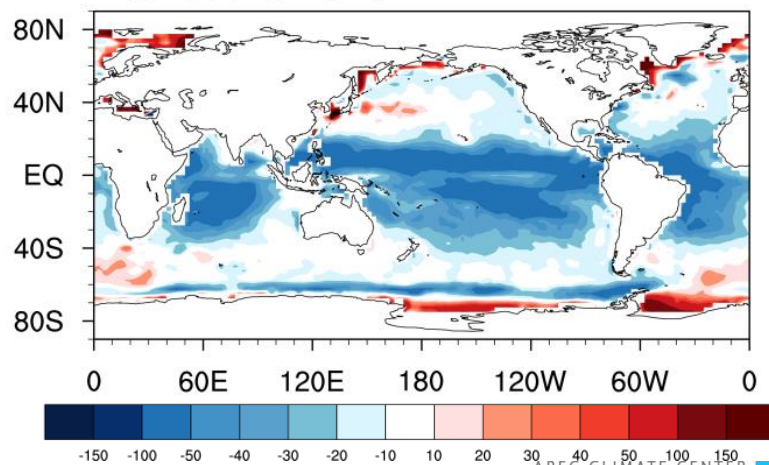
Total cloud amount

initial SCoPS-OBS



Net sfc. Heat flux

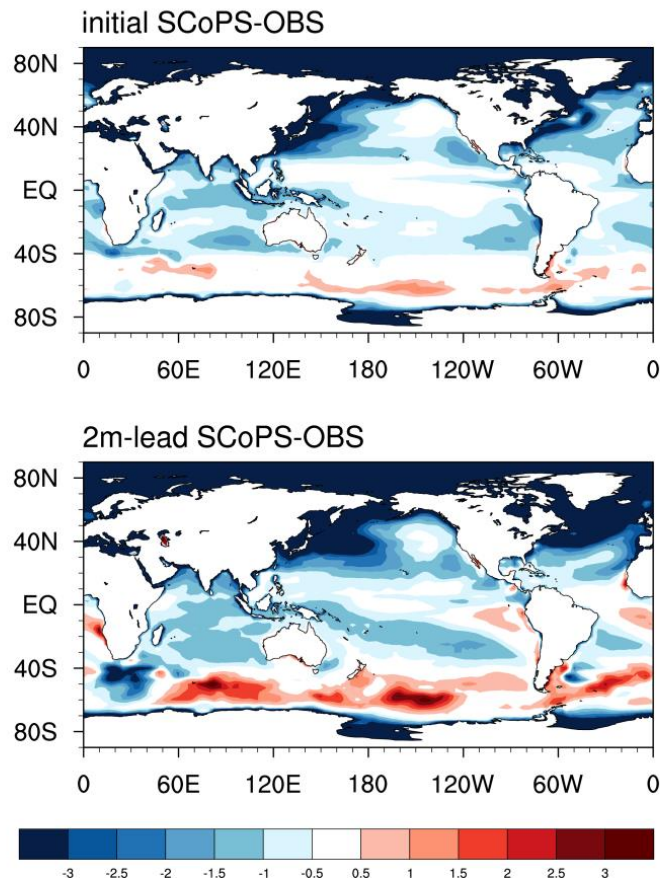
initail SCoPS - OBS



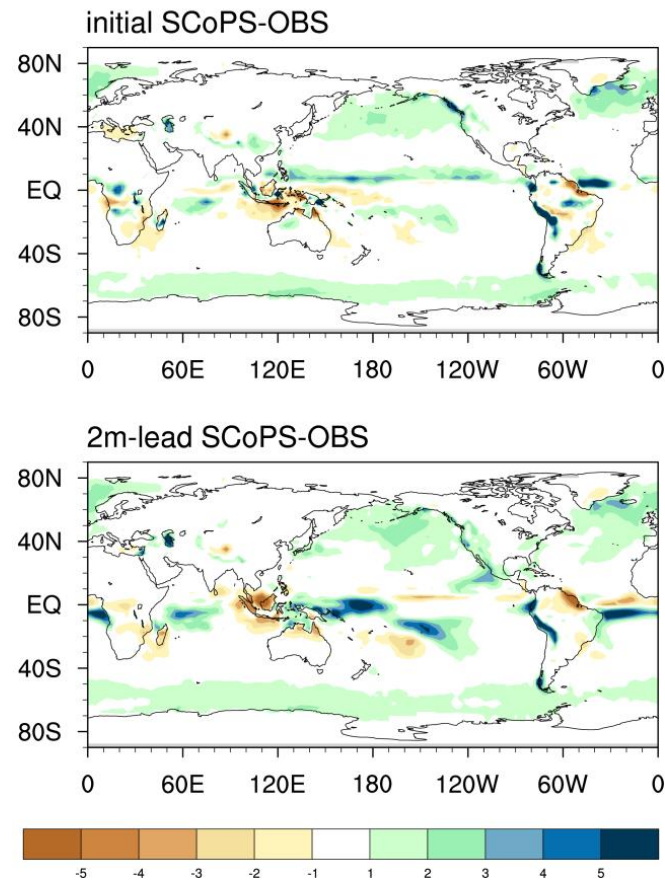
Hindcast period: JAN. 1982 – 2013

Surface current & wind

Sea surface temperature



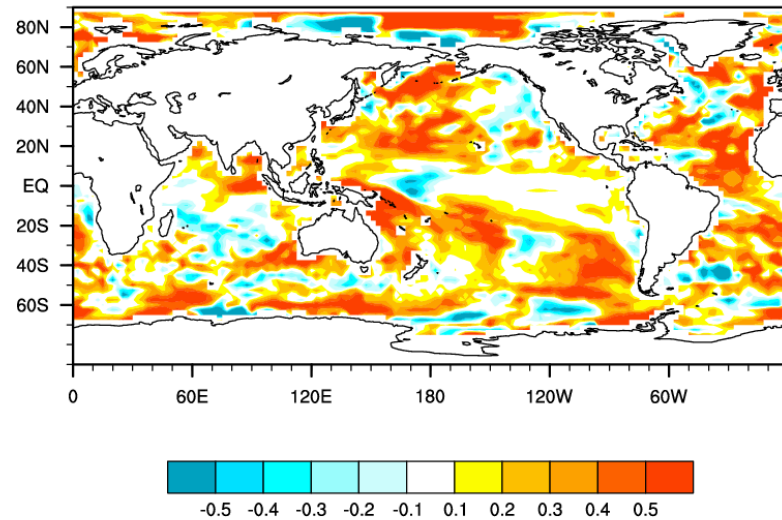
Precipitation



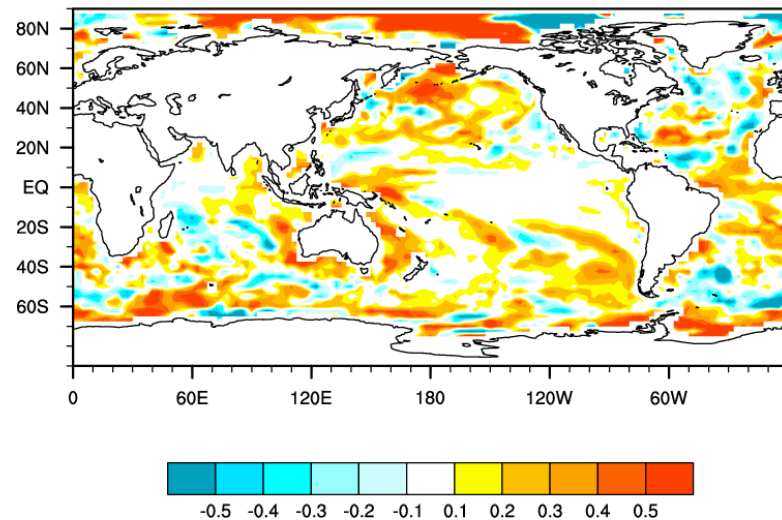
Realtime (2014-2016)

SST Skill Difference: TCC

(a) SCoPS-CCSM3



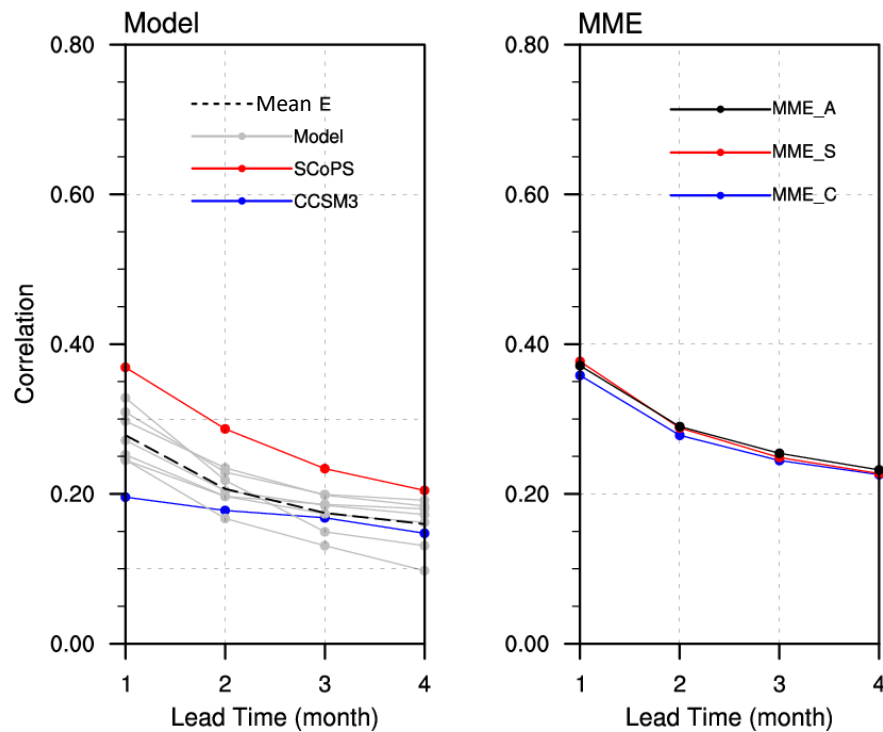
(b) SCoPS-MEAN



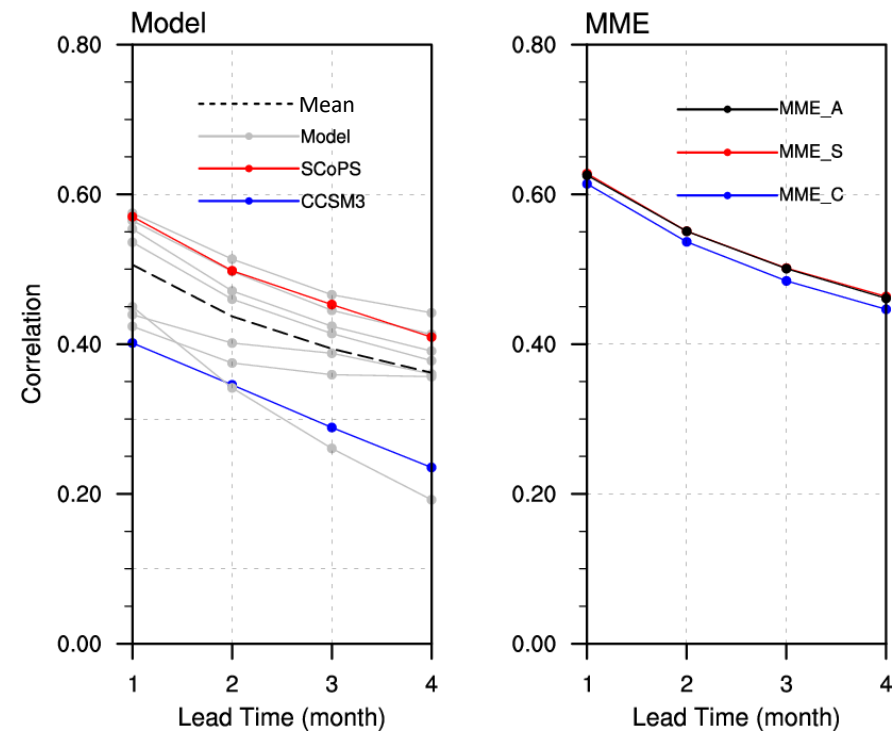
Realtime (2014-2016)

SST Skill: Averaged TCC over GL and TR

Global SST



Tropical SST (20°S-20°N)

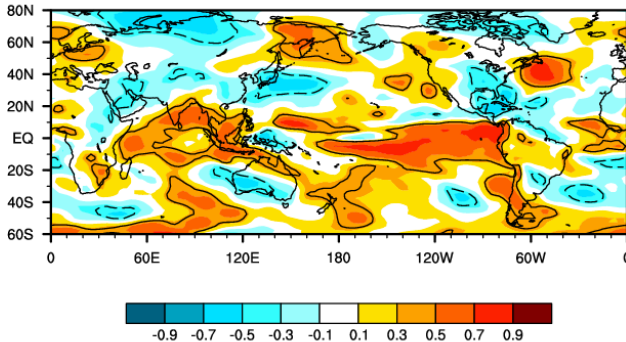


Realtime (2014-2016)

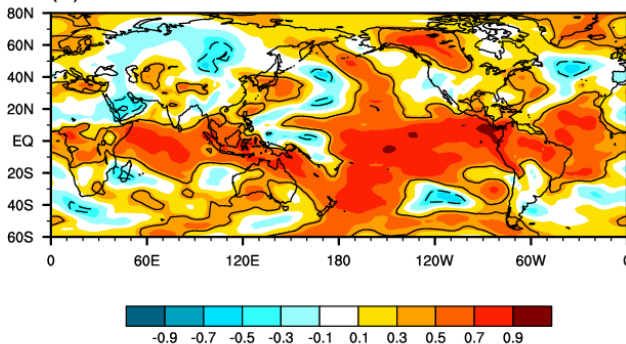
Skill of Atmos. Variable: TCC (CCSM3, SCoPS)

T850

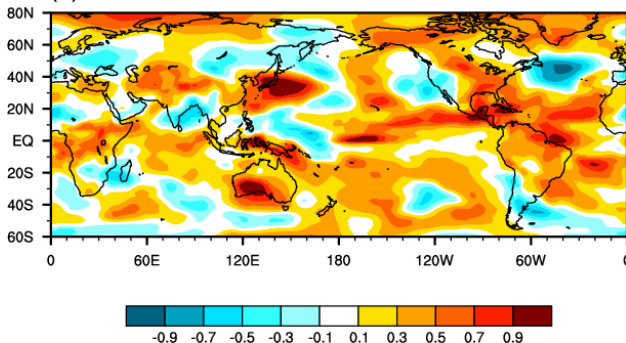
(a) CCSM3



(b) SCoPS

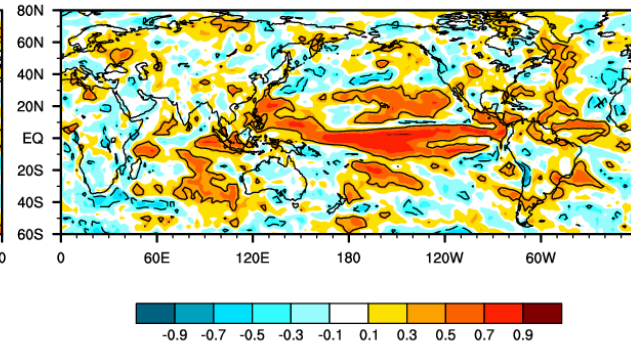


(c) DF: S-C

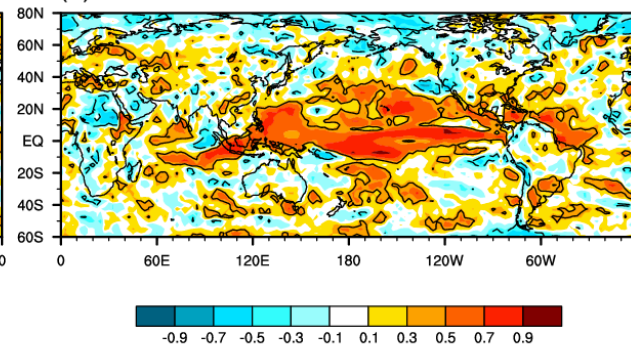


PREC

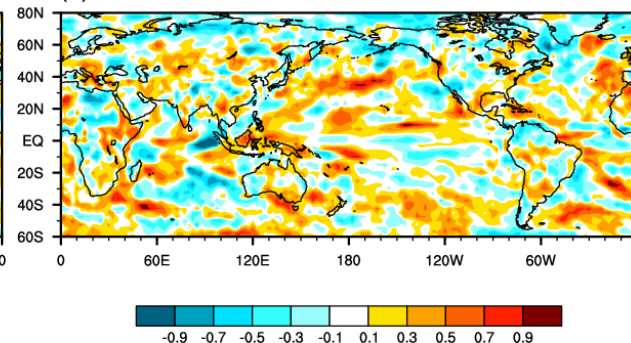
(a) CCSM3



(b) SCoPS

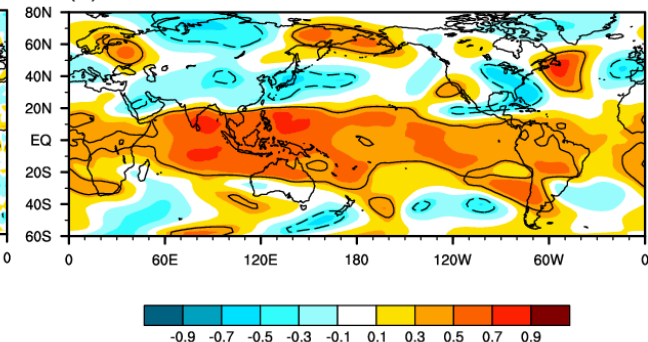


(c) DF: S-C

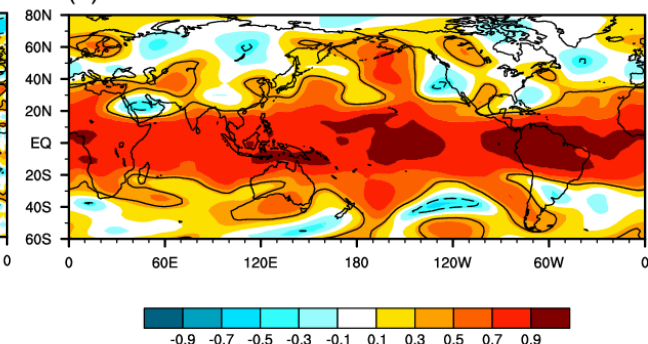


Z500

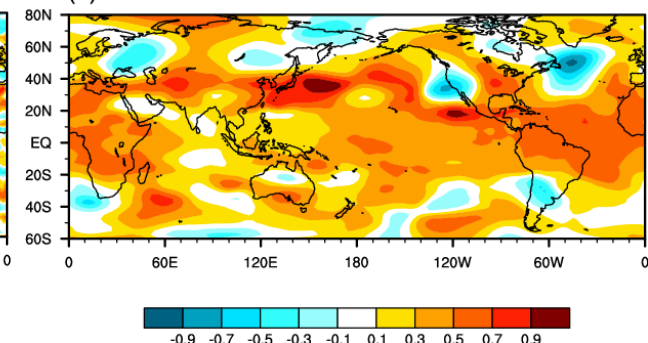
(a) CCSM3



(b) SCoPS

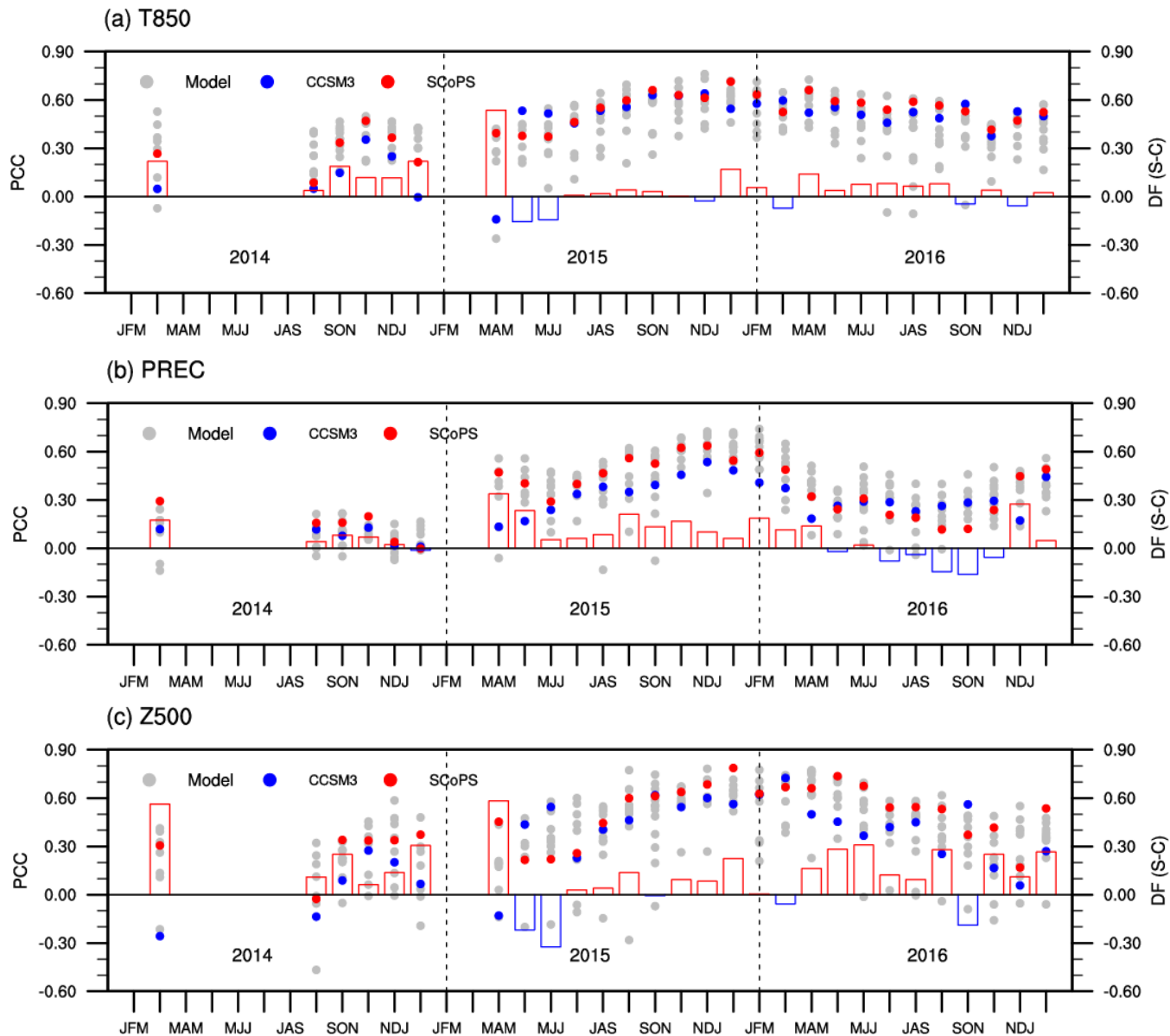


(c) DF: S-C



Realtime (2014-2016)

Skill of Atmos. Variable: PCC, GL



Part 1: Subseasonal prediction

SCoPS Subseasonal prediction

- 2014-2015 MJJSO 예보장 생산
- BSISO 예측 성능 검증
- 계절내 예측성능 검증

담당: 김해정, 정유림, 정여민, 함수련

SCoPS: Subseasonal prediction

WCRP/WWRP S2S Project

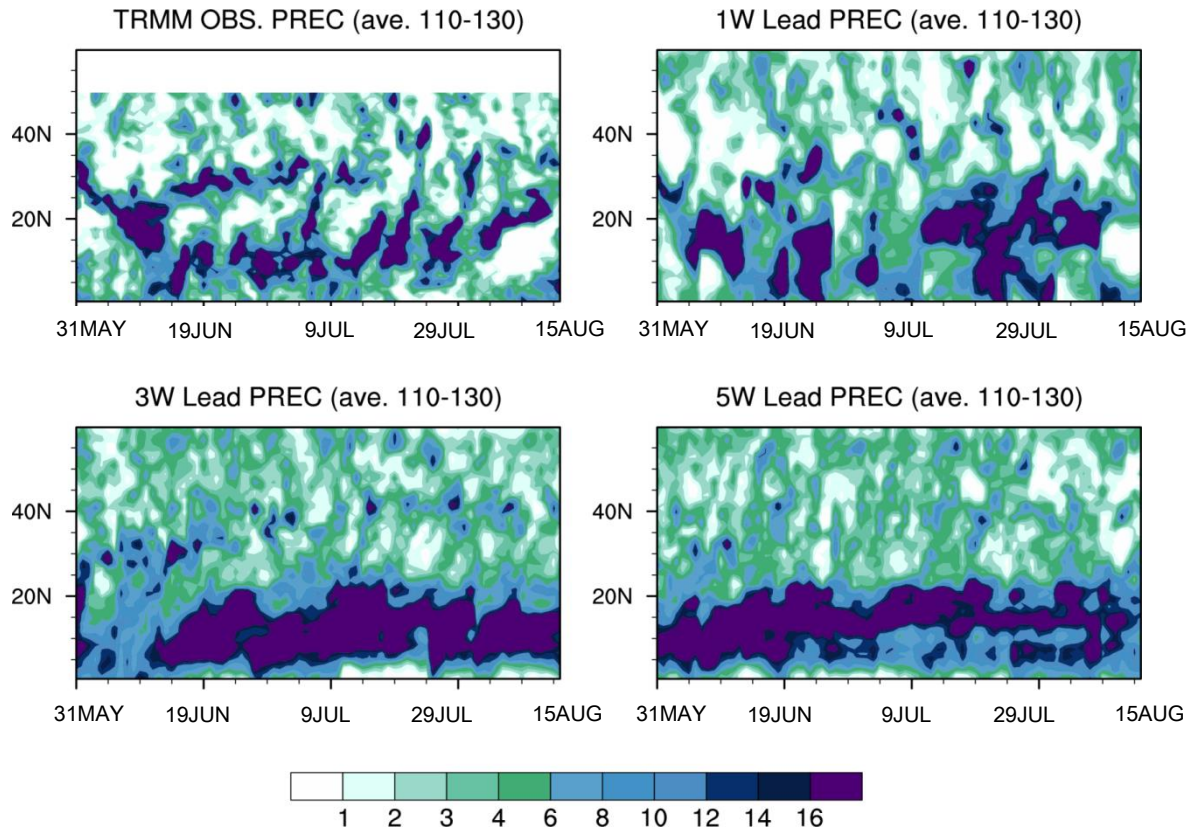
	Time-range	Resol.	Ens. Size	Freq.	Hcsts	Hcst length	Hcst Freq	Hcst Size
ECMWF	D 0-32	T639/319L91	51	2/week	On the fly	Past 20y	weekly	5
UKMO	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
NCEP	D 0-45	N126L64	4	4/daily	Fix	1999-2010	4/daily	1
EC	D 0-35	0.6x0.6L40	21	weekly	On the fly	Past 15y	weekly	4
CAWCR	D 0-60	T47L17	33	2/week	Fix	1981-2013	6/month	33
JMA	D 0-34	T159L60	25	2/week	Fix	1979-2009	3/month	5
KMA	D 0-60	N216L85	4	daily	On the fly	1996-2009	4/month	3
CMA	D 0-45	T106L40	4	daily	Fix	1992-now	daily	4
Met.Fr	D 0-60	T127L31	51	monthly	Fix	1981-2005	monthly	11
CNR	D 0-32	0.75x0.56 L54	40	weekly	Fix	1981-2010	6/month	1
HMCR	D 0-63	1.1x1.4 L28	20	weekly	Fix	1981-2010	weekly	10

❖ SCoPS Subseasonal prediction

- T159L31
- 10 ensemble member
- Forecast period: D 0-60
- Update frequency: Weekly (Initial time: Monday)
- Forecast period: 2014-2017 → 2014-2015
- Testing season: May to October
- Hindcast period: TBD

SCoPS: Subseasonal prediction

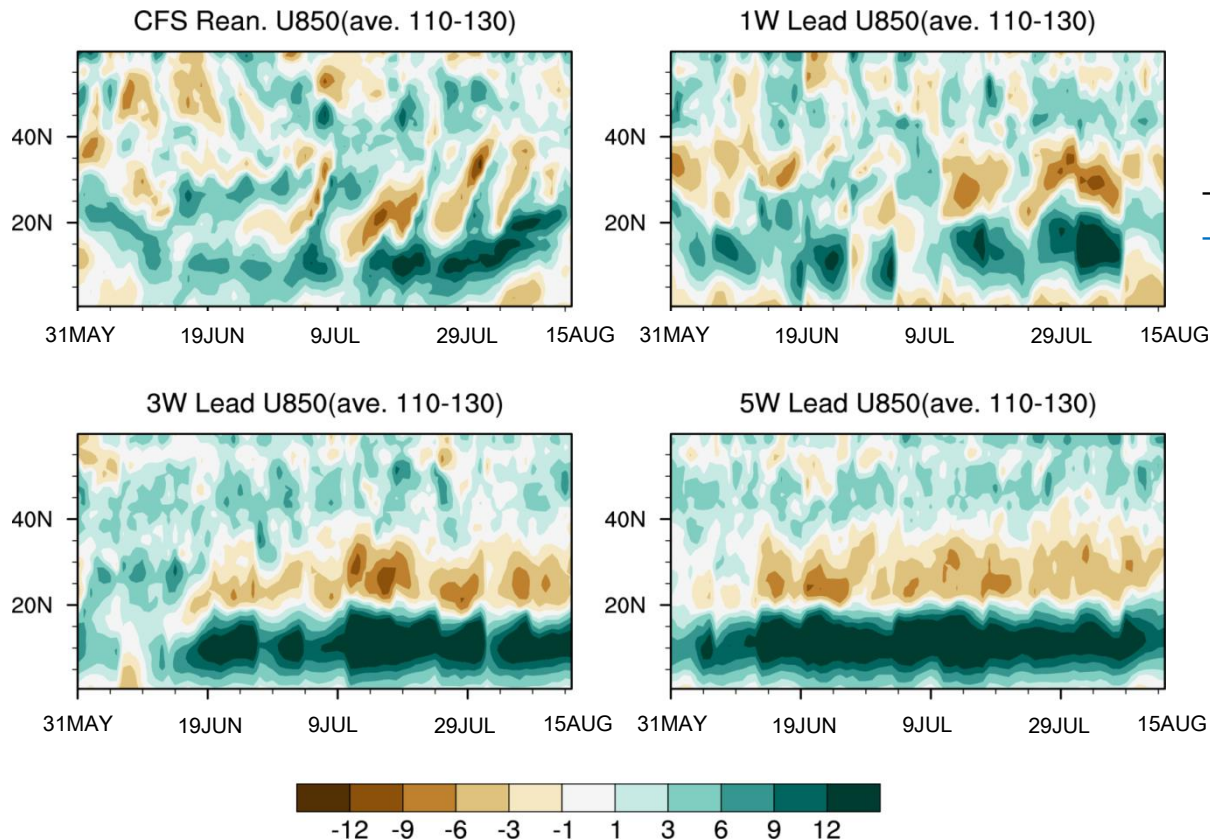
Time-Latitude cross section of Precipitation over EA region



- 리드별 오차 증가
- 적도-중위도로 전파되는 패턴 사라짐
- 7월-8월 적도지역 오차 감소

SCoPS: Subseasonal prediction

Time-Latitude cross section of 850hPa Uwind over EA region

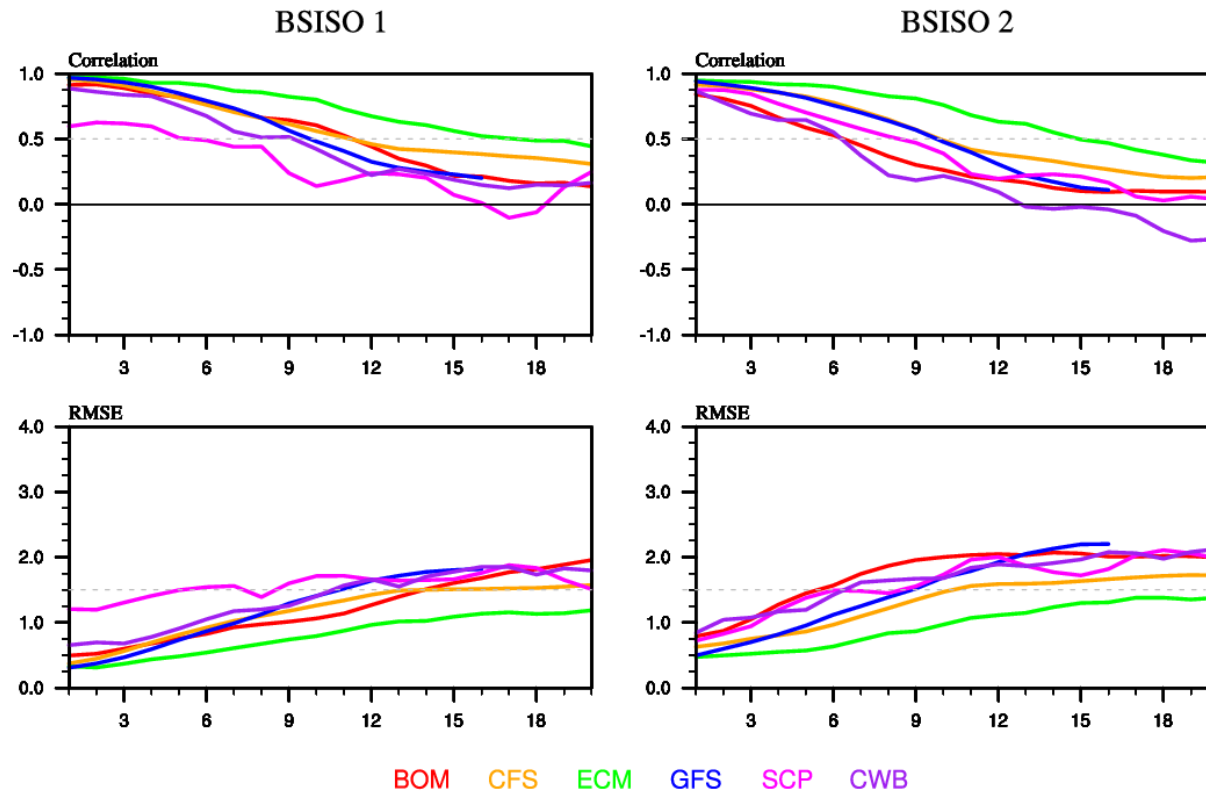


- 리드별 오차 증가
- 적도-중위도로 전파되는 패턴 사라짐

SCoPS: Subseasonal prediction

BSISO verification (2014-2015 MJJAS)

BSISO verification



BSISO1 skill 불안정,
BSISO2가 BSISO1보다 skill 다소
높게 나타남

Lee et al. (2013)

- BSISO1: 아시아 여름 몬순 지역에서의 북쪽으로의 전파, 30-60일 주기를 표현
- BSISO2: 북/북북동 방향의 전파, 30일 주기 및 10-20일 주기를 모두 표현

Part 2: Seasonal prediction

✓ Ocean diffusivity

- Background diffusivity (in KPP mixing)
 - Large et al. 1994/ Ledwell et al. 2000
 - $VDC = vdc1 + vdc2 * \text{atan}((|z| - \text{depth}) * \text{linv})$
vdc1 = 0.524
vdc2 = 0.313
depth = 250m
linv = $4.5e-5$
- 지표: $0.1 \text{ cm}^2/\text{s}^1$, 250m: 0.524, 수온약층~심해: $1.0 \text{ cm}^2/\text{s}^1$

Part 2: Seasonal prediction

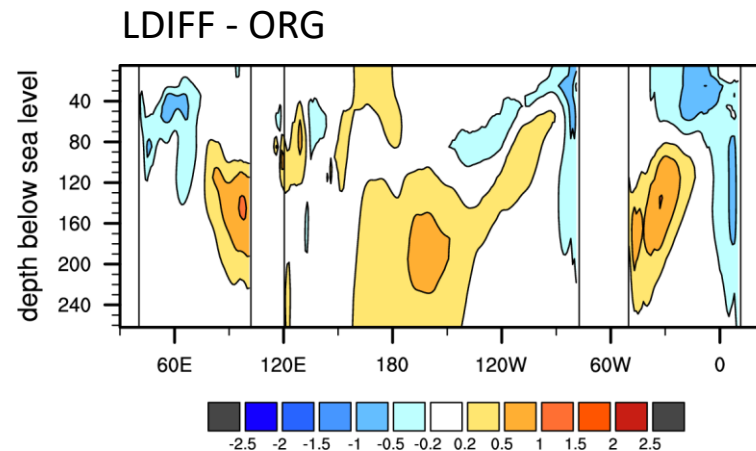
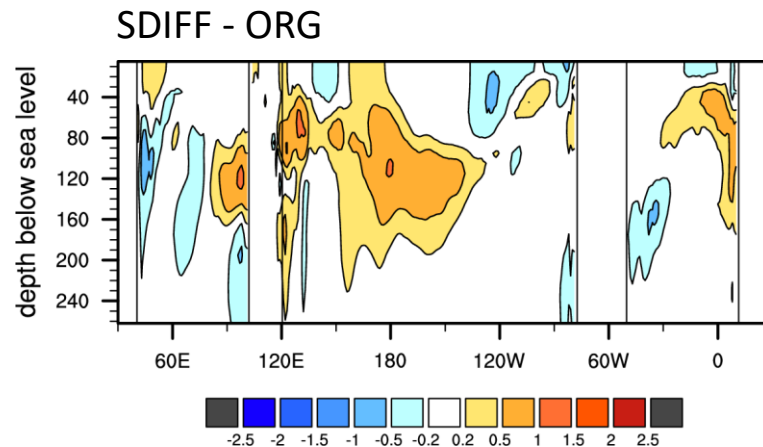
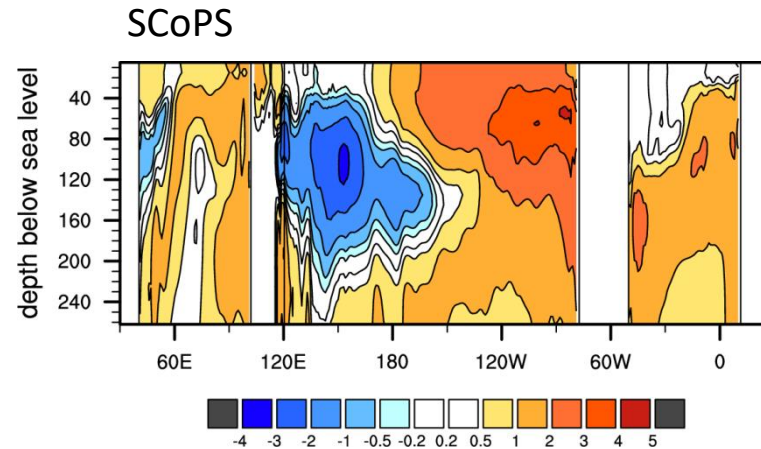
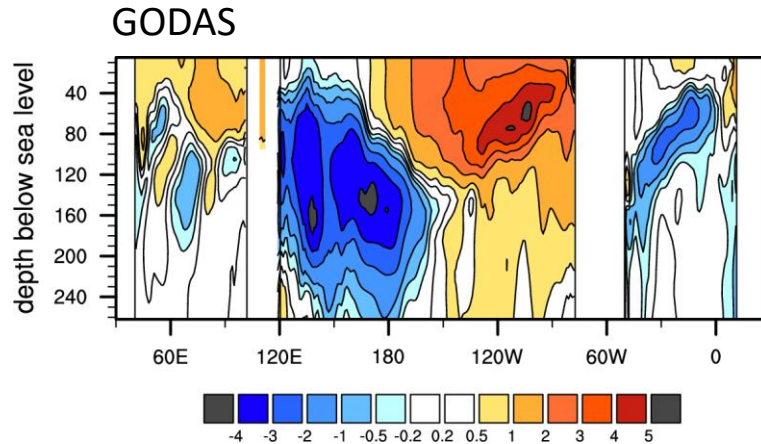
✓ Ocean diffusivity

- 2015. 11. Initial → 2016. 1. Forecast
 - SDIFF: vdc1 = 0.262 (min. = 0.01)
 - LDIFF: vdc1 = 0.786 (max. = 1.0)

Test period: 2016JAN (2mon. Leadtime)

Vertical temperature (5S-5N)

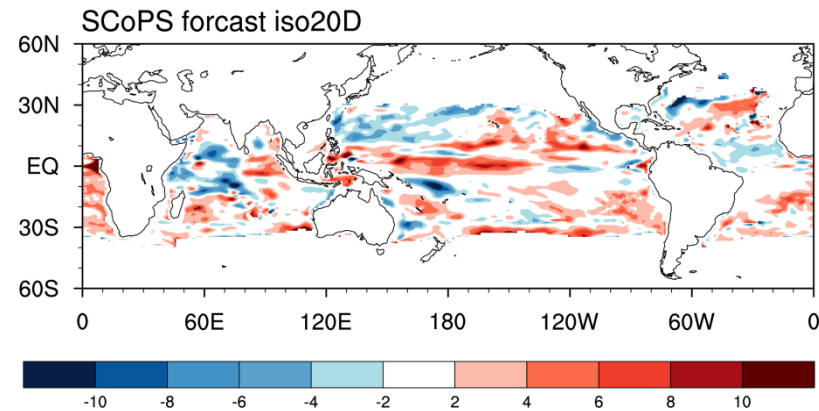
SCoPS Original



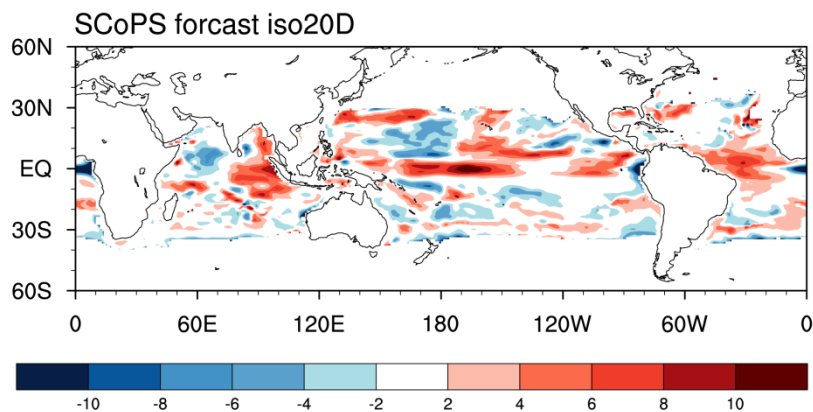
Test period: 2016JAN (2mon. Leadtime)

20C Isotherm depth (thermocline)

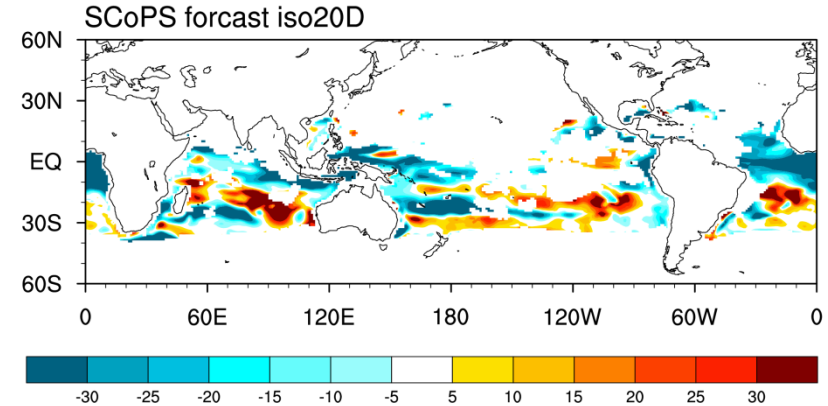
SDIFF - ORG



LDIFF - ORG



ORG - GODAS



Test period: 2016JAN (2mon. Leadtime)

SST & Precipitation

