Establishment and verification of China Multi-Model Ensemble prediction system version 2 (CMMEv2.0)

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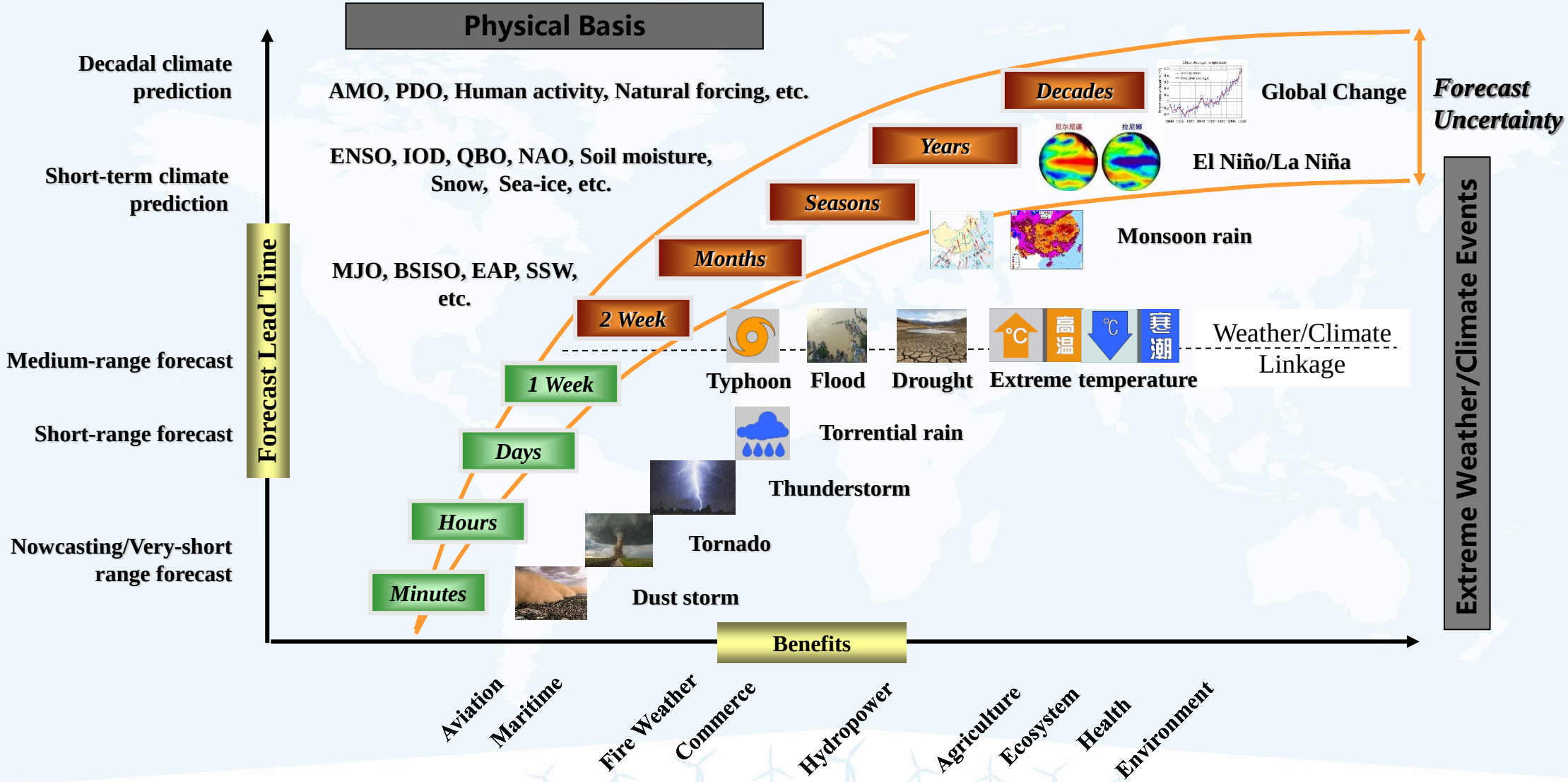
Outlines

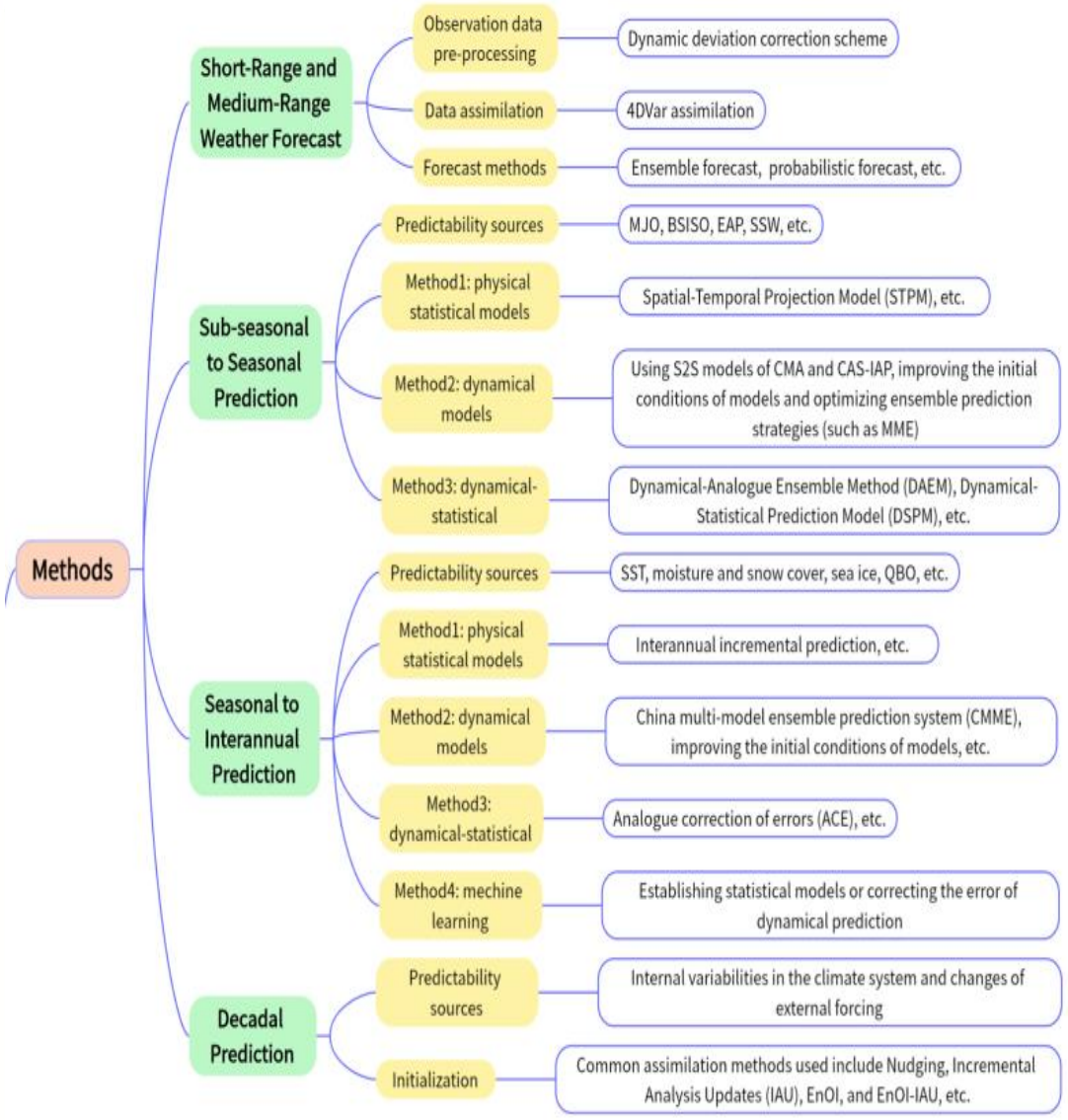
1. Backgrounds
2. Establishment and Product
3. Predictability Verification
4. Summary and discussions

The Target of Climate Prediction

Seamless Prediction: WWRP-WCRP



The Major Prediction Method



(Ren et al., 2023, AAS)

- Based on dominant predictability sources, physical statistical models, dynamical models and dynamical-statistical method has been widely used for prediction
- **Dynamical model** has become the most important foundation for subseasonal to decadal prediction

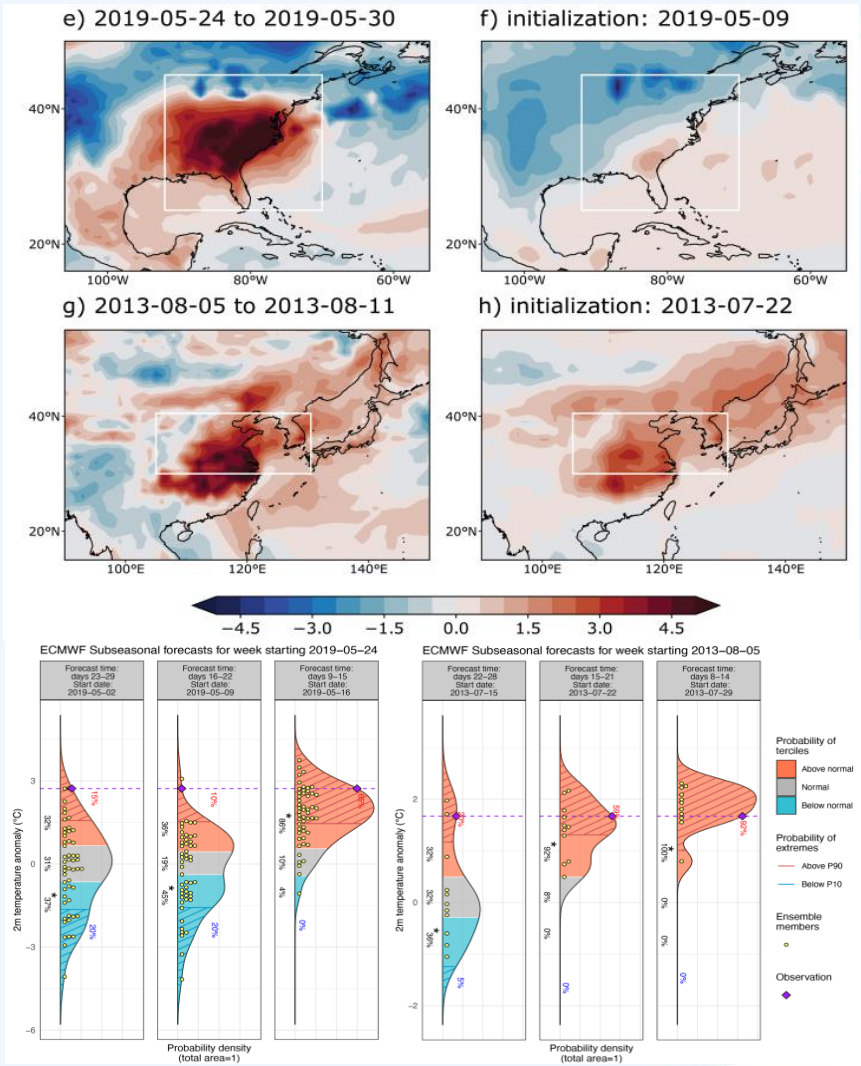
S2S Database

status on 2019-11-11	Time range	Resolution	Ens. Size	Frequency	Re-forecasts	Rfc length	Rfc frequency	Rfc size
BoM(ammc)	d 0-62	T47L17	3*11	2/week	fix	1981-2013	6/month	3*11
CMA(babj)	d 0-60	CMA (babj)	4	2/week	on the fly	past 15 years	2/week	4
CNR-ISAC(isac)	d 0-32	0.75x0.56 L54	41	weekly	fix	1981-2010	every 5 days	5
CNRM(lfpw)	d 0-32	T255L91	51	weekly	fix	1993-2014	4/month	15
ECCC(cwao)	d 0-32	0.45x0.45 L40	21	weekly	on the fly	1998-2017	weekly	4
ECMWF(ecmf)	d 0-46	Tco639/319 L91	51	2/week	on the fly	past 20 years	2/week	11
HMCR(rums)	d 0-61	1.1x1.4 L28	20	weekly	on the fly	1985-2010	weekly	10
JMA(rjtd)	d 0-33	Tl479/Tl319L100	50	weekly	fix	1981-2010	3/month	5
KMA(rksl)	d 0-60	N216L85	4	daily	on the fly	1991-2010	4/month	3
NCEP(kwbc)	d 0-44	T126L64	16	daily	fix	1999-2010	daily	4
UKMO(egrr)	d 0-60	N216L85	4	daily	on the fly	1993-2016	4/month	7

Imperfections of model directly prediction

- Skills for heat wave is about 3 weeks

OBS FCS（lead 3 weeks）

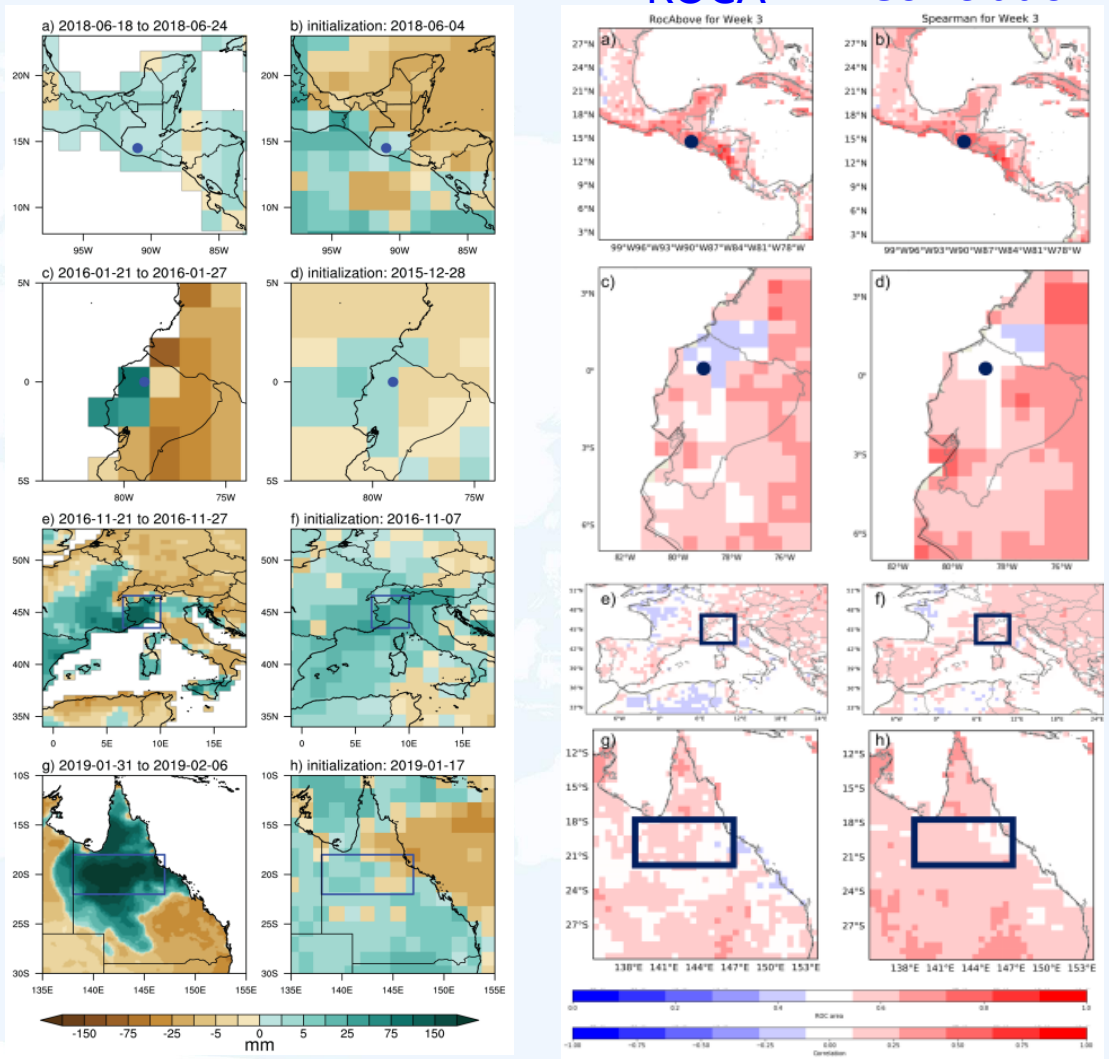


Ensembl e PDF

Lead 2-4 Weeks

- Skill for extreme rainfall is limited

OBS FCS（lead 3 weeks） ROCA Correlation



Base on ECMWF S2S model

（Domeisen etal., 2022,BAMS)

Developing of Multi-Model Ensemble

NMME

THE NORTH AMERICAN MULTIMODEL ENSEMBLE

Phase-I Seasonal-to-Interannual Prediction; Phase-2 toward Developing Intraseasonal Prediction

SubX BY THE NUMBERS

- 7 Global Models
- 1 Year of *Real-time* Forecasts
- 17 Years of *Retrospective* Forecasts
- 3-4 week guidance for Climate Prediction Center Outlooks

APCC

Table 1. The Participating Organizations and Institutes in the APCC MME Prediction

Country	Organization/Institute
Australia	Australian Bureau of Meteorology (BoM)
Canada	Meteorological Service of Canada (MSC)
China	Beijing Climate Center (BCC)
	Institute of Atmospheric Physics of China (IAP)
Japan	Japan Meteorological Agency (JMA)
Korea	Korea Meteorological Administration (KMA)
	National Institute of Meteorological Research of Korea (NIMR)
	Seoul National University (SNU)
	Pusan National University (PNU)
Peru	Meteorological and Hydrological Weather Service of Peru (SENAMHI)
Russia	Main Geophysical Observatory of Russia (MGO)
	Hydrometeorological Centre of Russia (HMC)
Chinese Taipei	Central Weather Bureau of Chinese Taipei (CWB)
USA	Center for Ocean-Land-Atmosphere Studies (COLA)
	International Research Institute for Climate and Society (IRI)
	National Aeronautics and Space Administration (NASA)
	National Center for Environmental Prediction (NCEP)

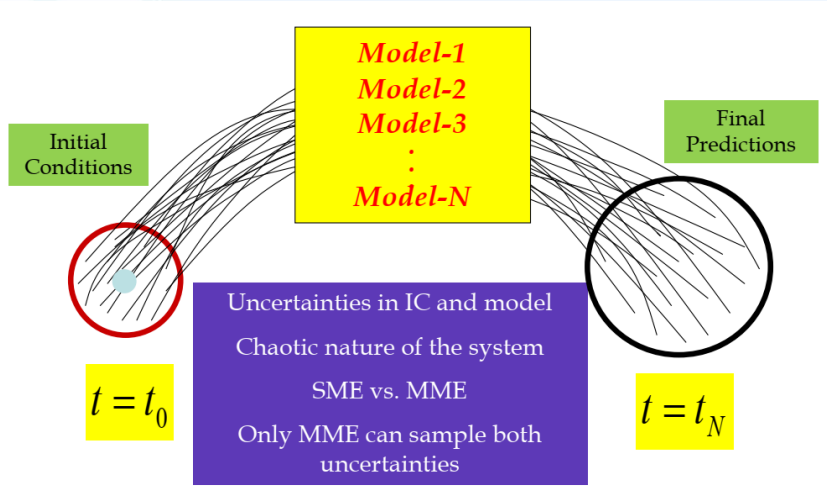
A few MME systems of climate prediction have been developed in the world, which can provide MME seasonal forecasts (e.g., the NMME, EUROSIP and APCC-MME).

ECMWF

The EUROSIP multi-model seasonal forecasting system

Operational from	System number					Effective hindcast period
	ECMWF	Met Office	Météo-France	NCEP	JMA	
September 2012	4	7	3	2		1991-2010
December 2012	4	8	3	2		1991-2010
January 2013	4	8	4	2		1991-2010
July 2013	4	9	4	2		1991-2010
July 2014	4	10	4	2		1991-2010
July 2015	4	11	4	2		1991-2010
June 2016	4	11	5	2		1991-2010
July 2016	4	12	5	2		1991-2010
March 2017	4	12	5	2	2	1991-2010

- Single model prediction is inevitably affected by the uncertainty from initial condition and physical process
- NMME, ECMWF, APCC has build up MME prediction system



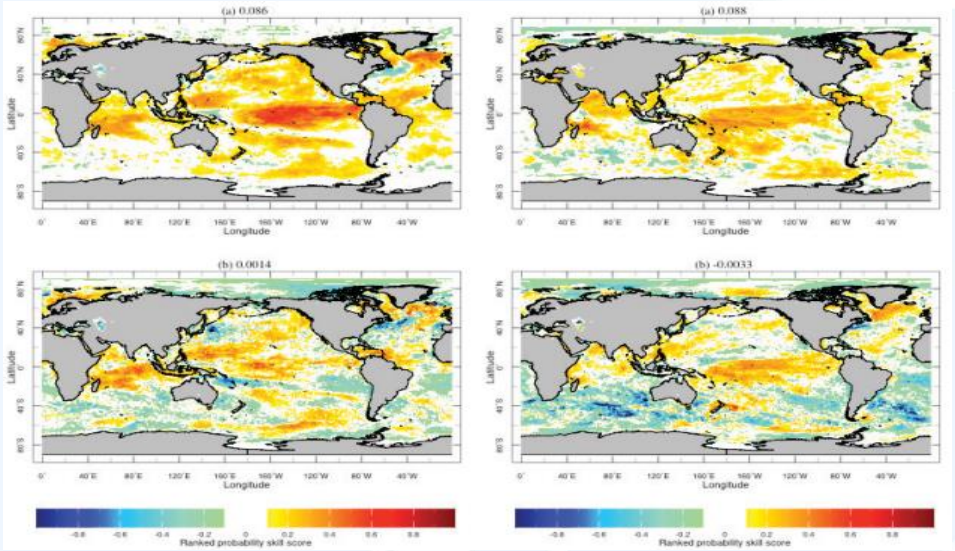
Krishnamurti et al., 1999, Science; Kirtman etal, 2014, BAMS; Mishra etal., 2019, CD)

Advantages of MME (e.g. NMME)

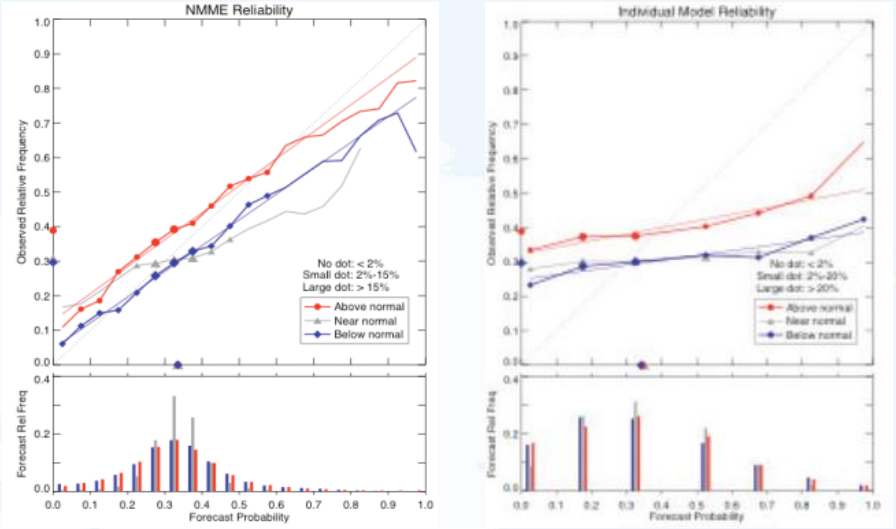
- **Enhance the prediction skills (SME)**

NMME

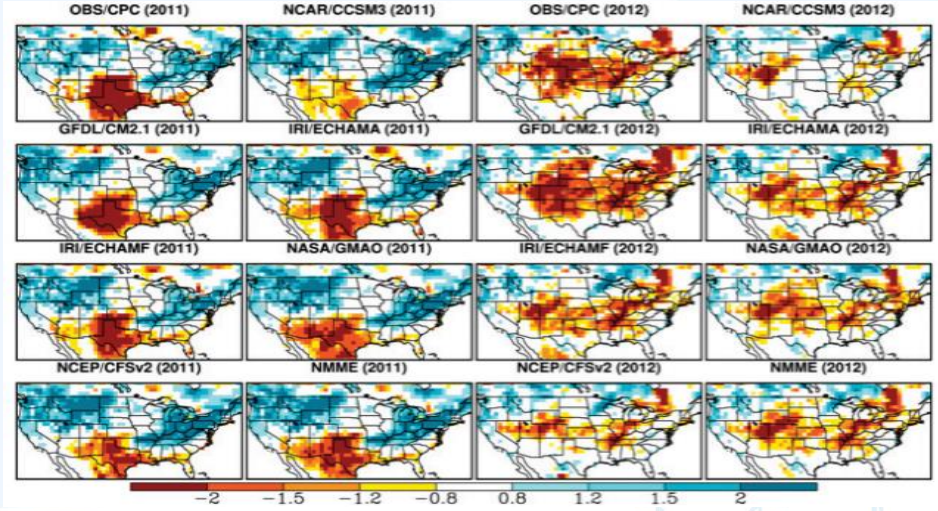
CFSv2



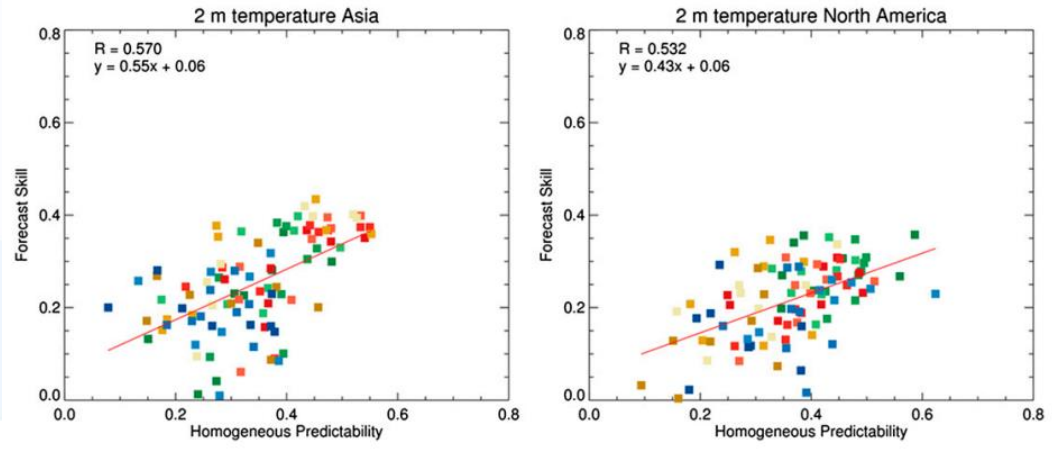
- **Improve the reliability for probabilistic prediction**



- **Provide skillful prediction for extreme event**



- **Achieve the common deficiencies for model update**



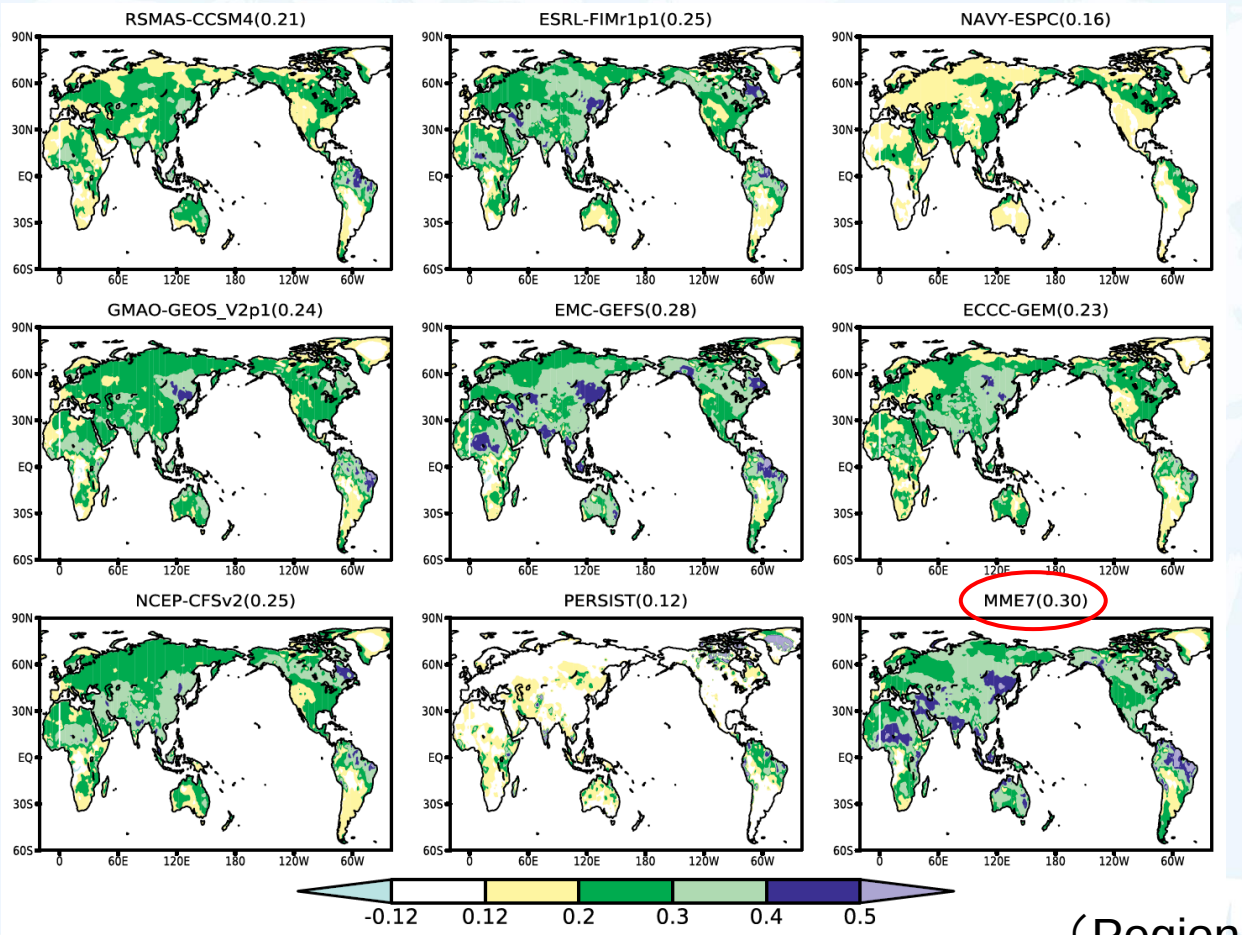
（Kirtman etal, 2014, BAMS; Becker etal, 2014 JC)

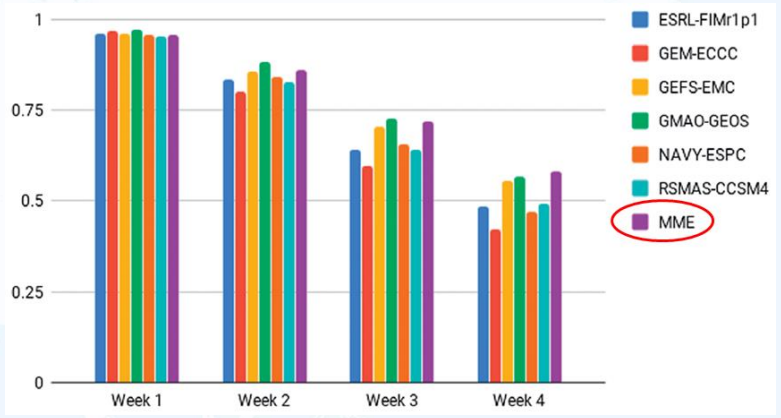
Prediction skills of SubX

SubX（**A Multimodel Subseasonal Prediction Experiment**）

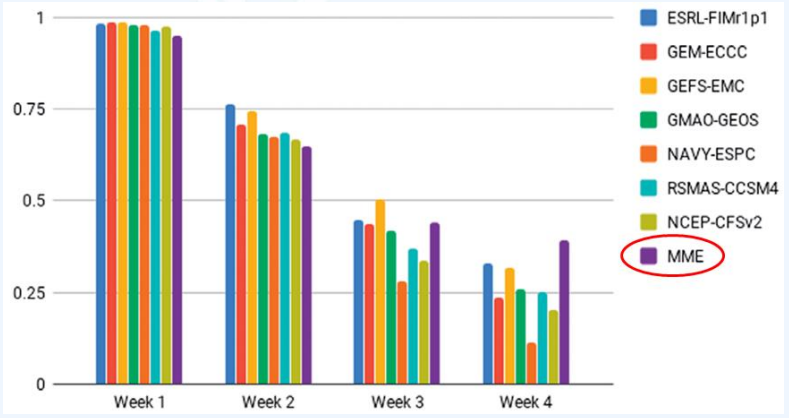
NCEP-CFSv2 | EMC-GEFS | ECCC-GEM | GMAO-GEOS | NAVY-ESPC | RSMA-CCSM4 | ESRL-FIM

TCC of T2m





MJO

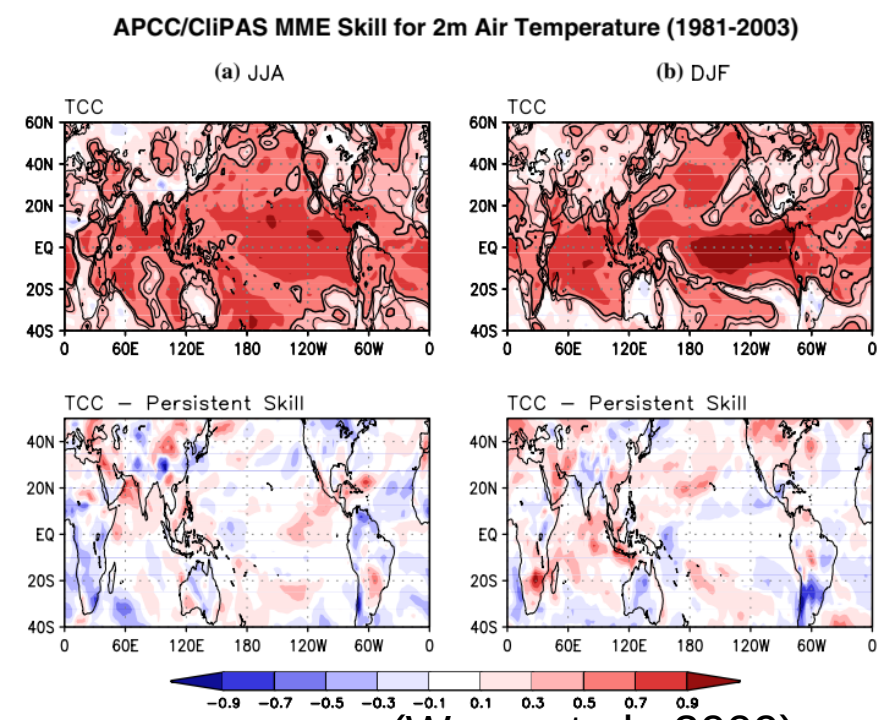


NAO

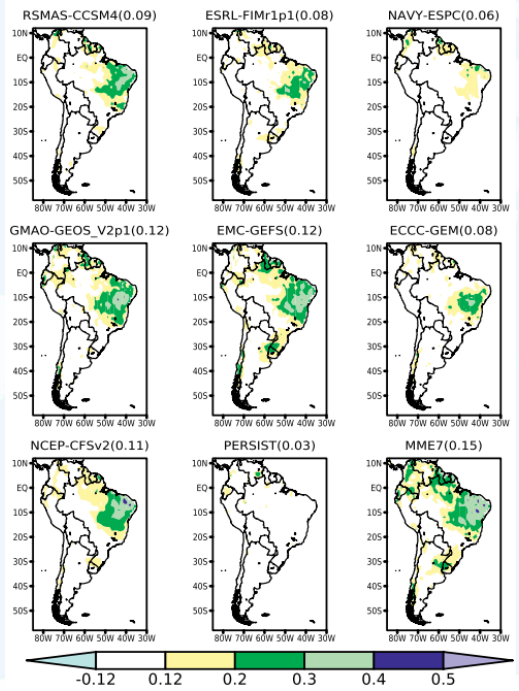
（Pegion etal, 2019, BAMS）

Questions and Challenges

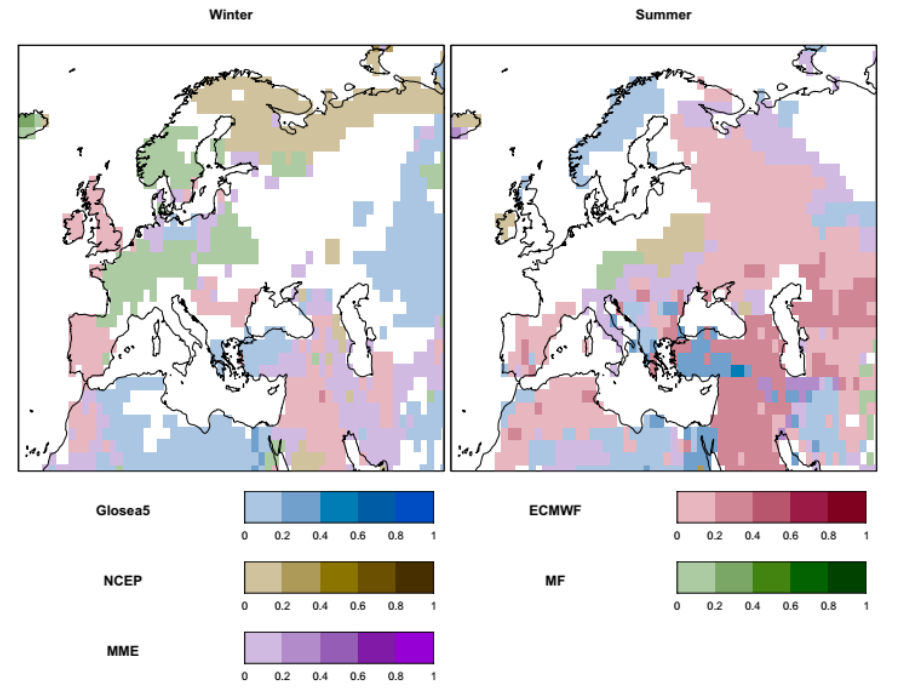
- Number of Chinese domestics dynamical models have been developed recently (CMA, IAP, NUIST, FIO et al), most of them optimize the simulation over East Asian specifically
- It is necessary to establish China Multi-Model Ensemble (CMME) system and focus on the prediction skill of East Asian especially



(Wang et al., 2009)



(Pegion et al., 2019, Subx)



(Mishra et al., 2019, EUROSIP)

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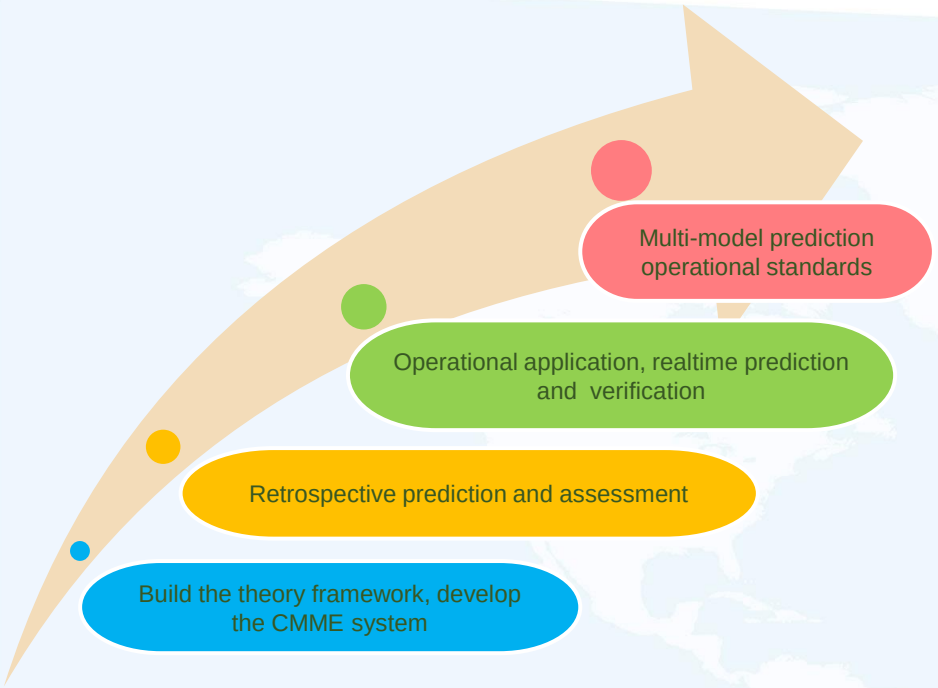
Introduction of CMMEv2.0

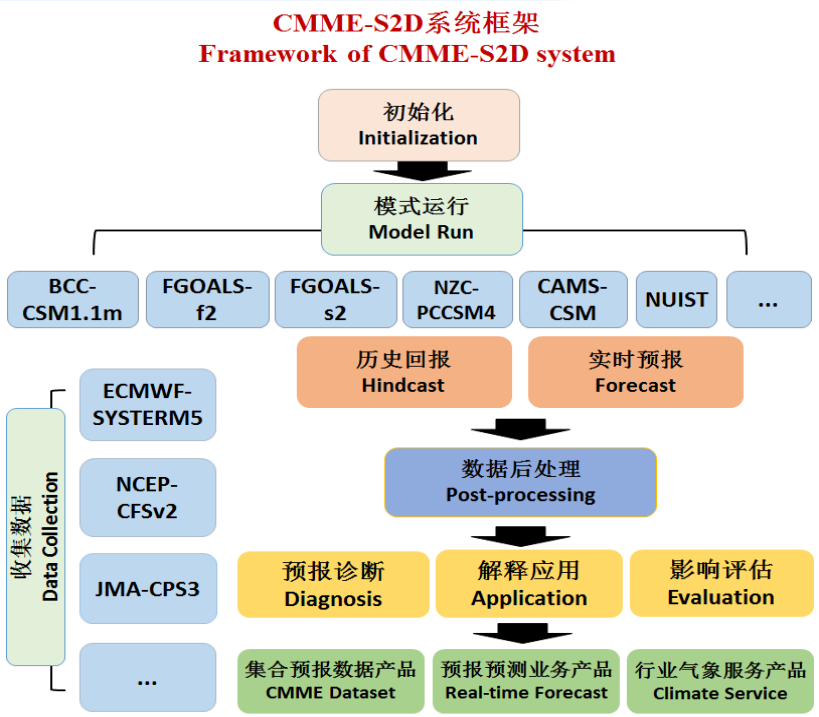


中国多模式集合预测（CMME）系统2.0版本
China Multi-model Ensemble Prediction System v2.0

CMME-CPPS	CMME-S2D	CMME-S2S	CMME-VECOM
气候现象 Climate Phenomena Prediction	季节-年代际 Seasonal to Decadal	次季节-季节 Subseasonal to Seasonal	预测检验 Verification and Evaluation
厄尔尼诺、热带大气季节内振荡、北极涛动、太平洋副热带高压等 ENSO, MJO, AO, WPSH, et al.	年际年代际(建设中)、滚动季、逐月 Interannual & Decadal (under construction), Seasonal, Monthly	次月、逐旬 逐候、日（过程） Next month, Ten days, Pentad, Daily	历史回报、实时预测 确定性、概率预测 Hindcast, Forecast, Deterministic Prediction, Probabilistic Prediction

Based on several domestic operationally-run climate models and internationally imported data, Beijing Climate Center has established the China Multi-model Ensemble Prediction System(CMME). It consist of 4 sub-systems and provides the prediction and verification products of basic climate elements such as temperature and precipitation, as well as the primary climate variability modes.

2.1 CMME-S2D sub-system



- CMME-S2D subsystem consists of 9 climate models, (6 domestic running models and 3 internationalal import data model) 207 ensemble members.
- CMME-S2D provides the monthly and seasonal prediction products of the air temperature, precipitation and sea surface temperature in the next six months. (currently)
- Compared to CMMEv1.0, 3 new models (CAMS, NUIST, JMA) are added and EC model has been updated to S5

模式 Models	机构 Organization	大气分辨率 Atmosphere Resolution	海洋分辨率 Ocean Resolution	集合数 Ensemble Size	预报时长（月） Forecast lead month
BCCCSM1.1m	国家气候中心 BCC	T106, L26	1/3°~30km, L40	24	13
FGOALS-f2	大气所 IAP/CAS	1×1, L32	1×1, L50	35	6
FGOALS-s2	大气所 IAP/CAS	R42, L26	1×1, L30	4	6
NZC-PCCSM4	大气所 IAP/CAS	2.5×1.9, L26	1×1	8	6
CAMS-CSM	气科院 CAMS	T106, L31	1×1, L50	8	6
NUIST	南信大 NUIST	T106, L19	2×2(赤道0.5), L40	9	24
ECMWF-S5	欧洲中心 ECMWF	T319, L91	ORCA 0.25, L75	15	6
NCEP-CFSv2	美国国家环境预报中心 NCEP	T126, L64	1×1, L40	4	10
JMA-CPS3	日本气象厅 JMA	TL319, L100	0.25 x 0.25, L60	100	6

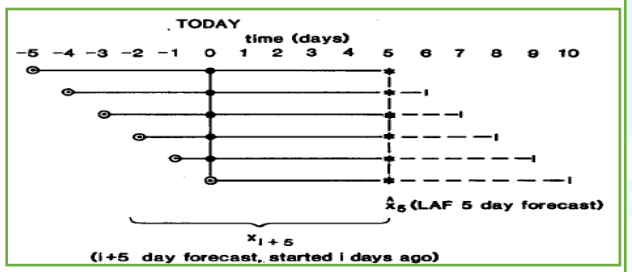
Initialization of domestic running models

Initialization

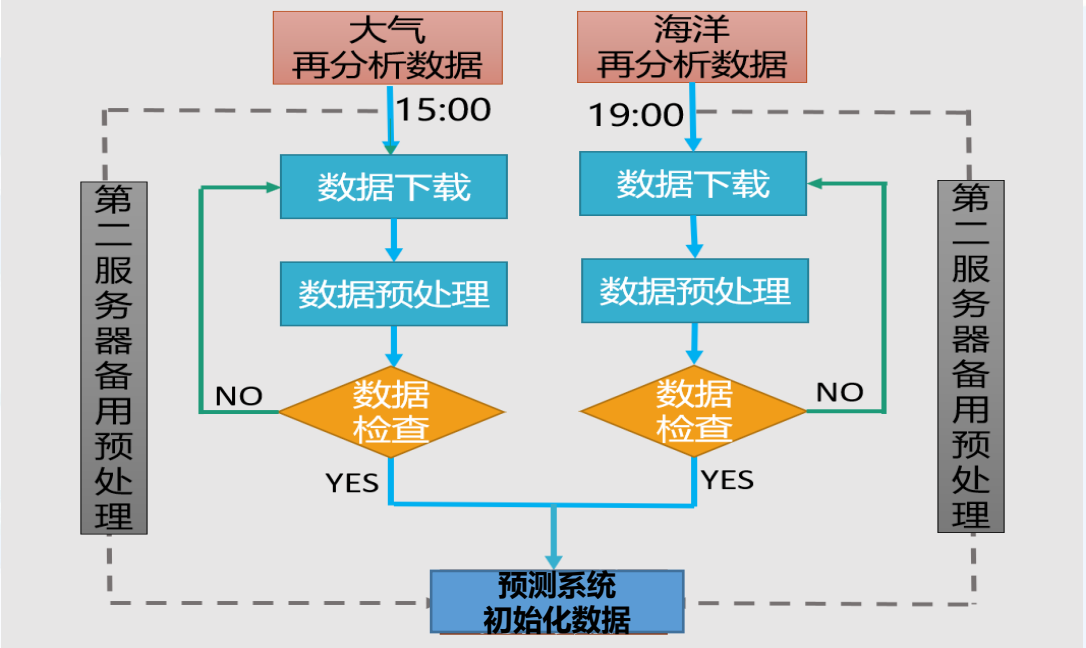
Newtonian relaxation nudging

$$\frac{\partial \alpha}{\partial t} = F(\alpha, X, t) + G_\alpha \cdot W_\alpha \cdot \varepsilon_\alpha(X) \cdot (\bar{\alpha}_0 - \alpha)$$

Lagged Averaged Forecast (LAF)



Atmosphere：CRA-40 reanalysis data
Ocean：GODAS-pentad



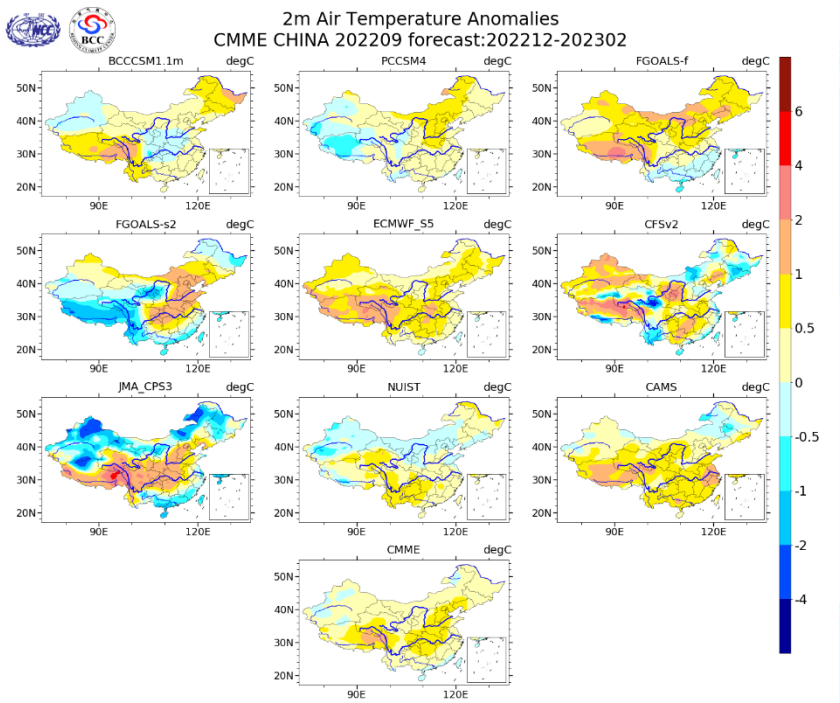
- For the 3 domestic running models (FGOALS-f2, FGOALS-s2 and NZC-PCCSM4), the Newtonian relaxation Nudging is used to assimilate atmospheric and oceanic reanalysis data。The standard isobaric surface wind field, temperature field and altitude field data of CRA-40 reanalysis were selected for the atmospheric assimilation, and multi-layer ocean temperature data of GODAS reanalysis data were selected for ocean assimilation.

- The assimilation time window of atmospheric reanalysis is 6 hours, and that of ocean data is 1 day. The lagged averaged forecast (LAF) method is used to generate the ensemble members .

Products of CMME-S2D sub-system

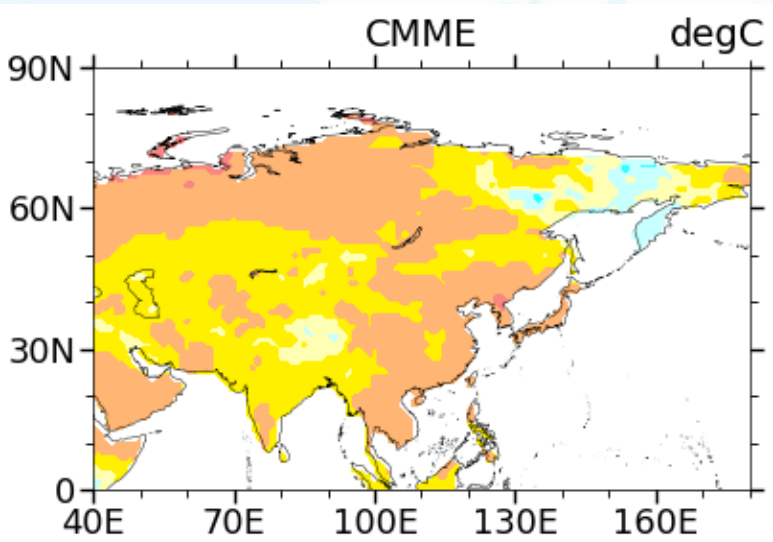
- Predictand: T2m anomaly, Precipitation anomaly percentage, SST anomaly
- Multi-timescale (Month and Rolling-seasonal) and Multi-domains (Global, Continent and China) ensemble prediction (9 single models and 1 ensemble mean)
- The products are real-time updated monthly on the NCC official website.

http://cmdp.ncc-cma.net/pred/cn_cmme_s2d.php?cmmeCat=CMME-S2D

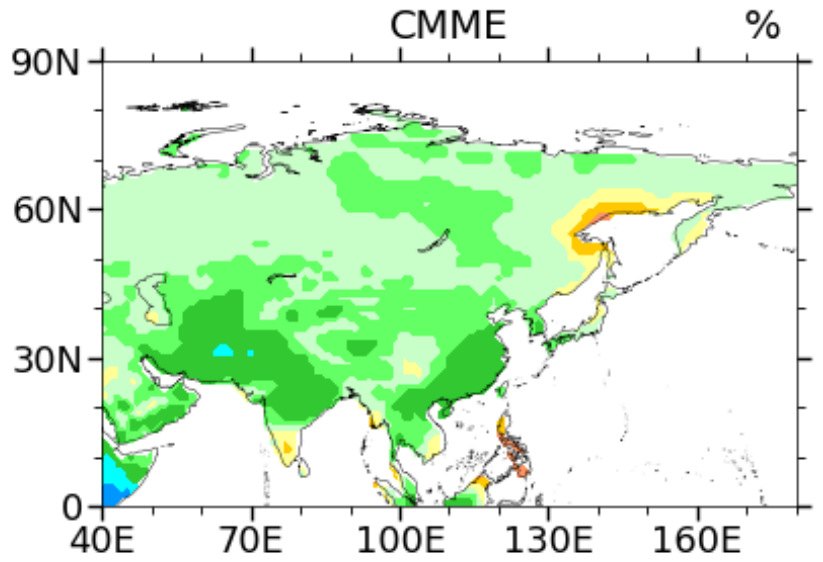


T2m in China

23/23 DJF (Ini from Oct)



MME T2m in Asian



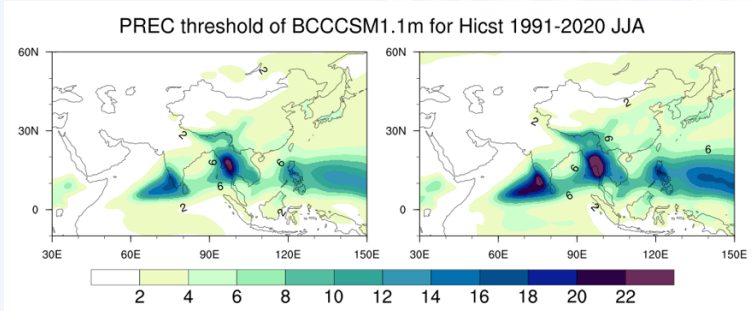
MME PREC in Asian

Probabilistic Prediction (new!)

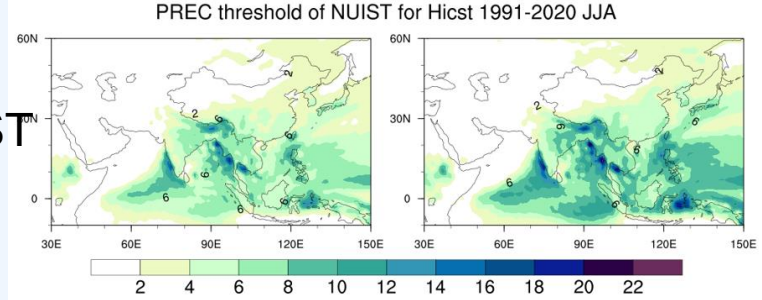
Threshold of prec tercile

33% 66%

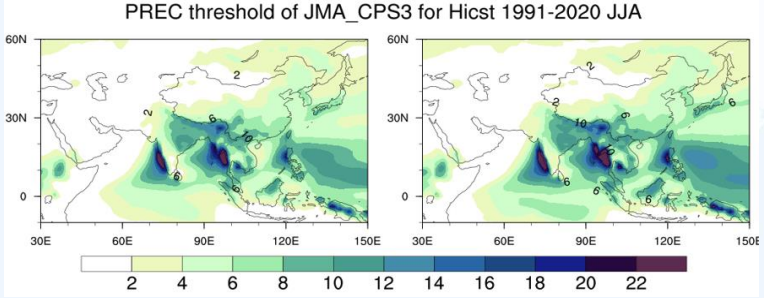
BCC



NUIST

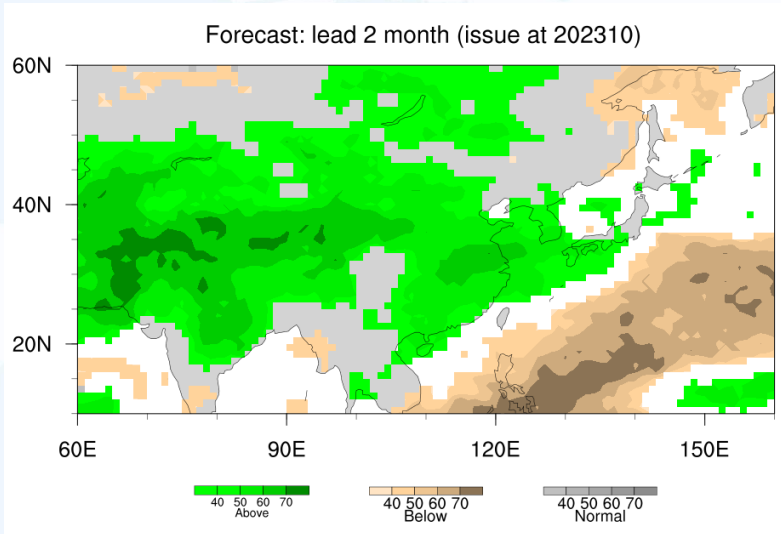


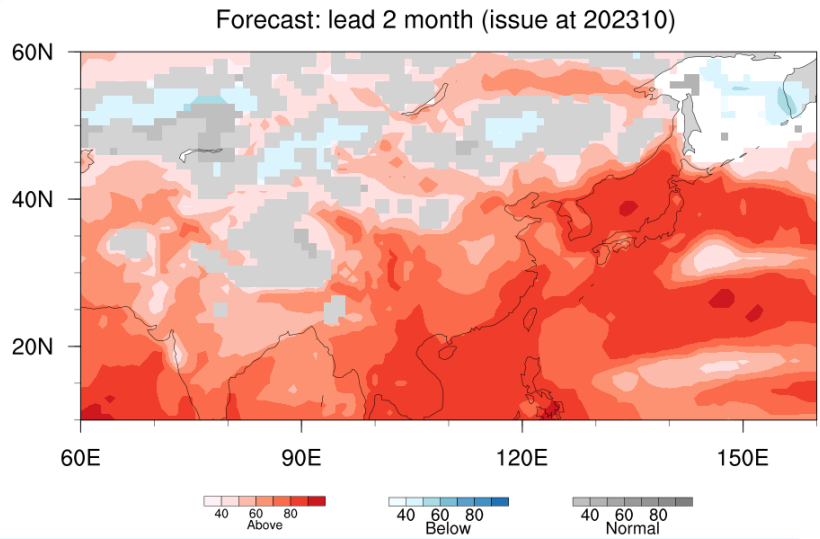
JMA



- Use 3 models (BCCCSM、JMA_CPS3、NUIST) and 53 members
- Identified tercile threshold based on the hindcast of each model
- Plot AN, BN and NN according to the similar neritics of NMME

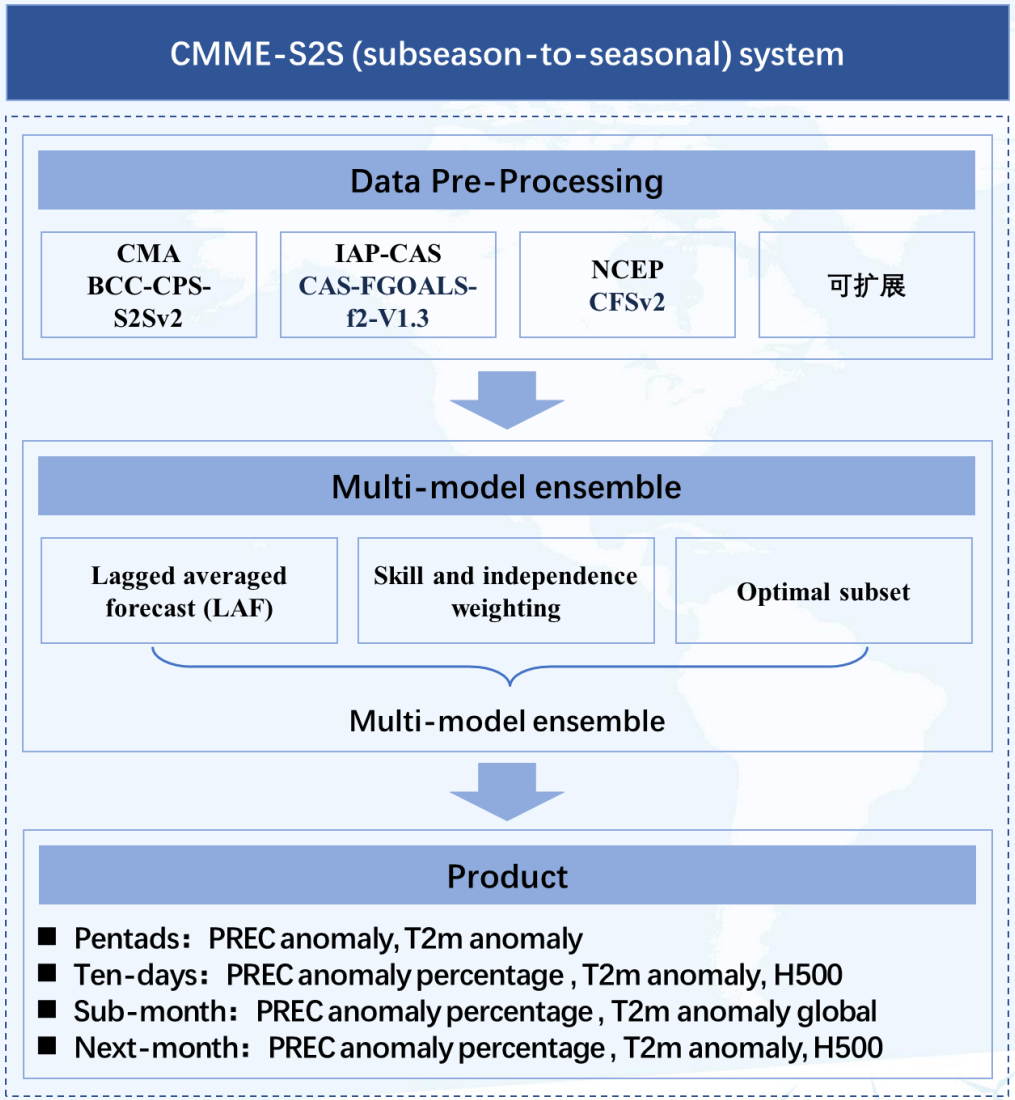
Prediction on DJF(23-24) ini from OCT



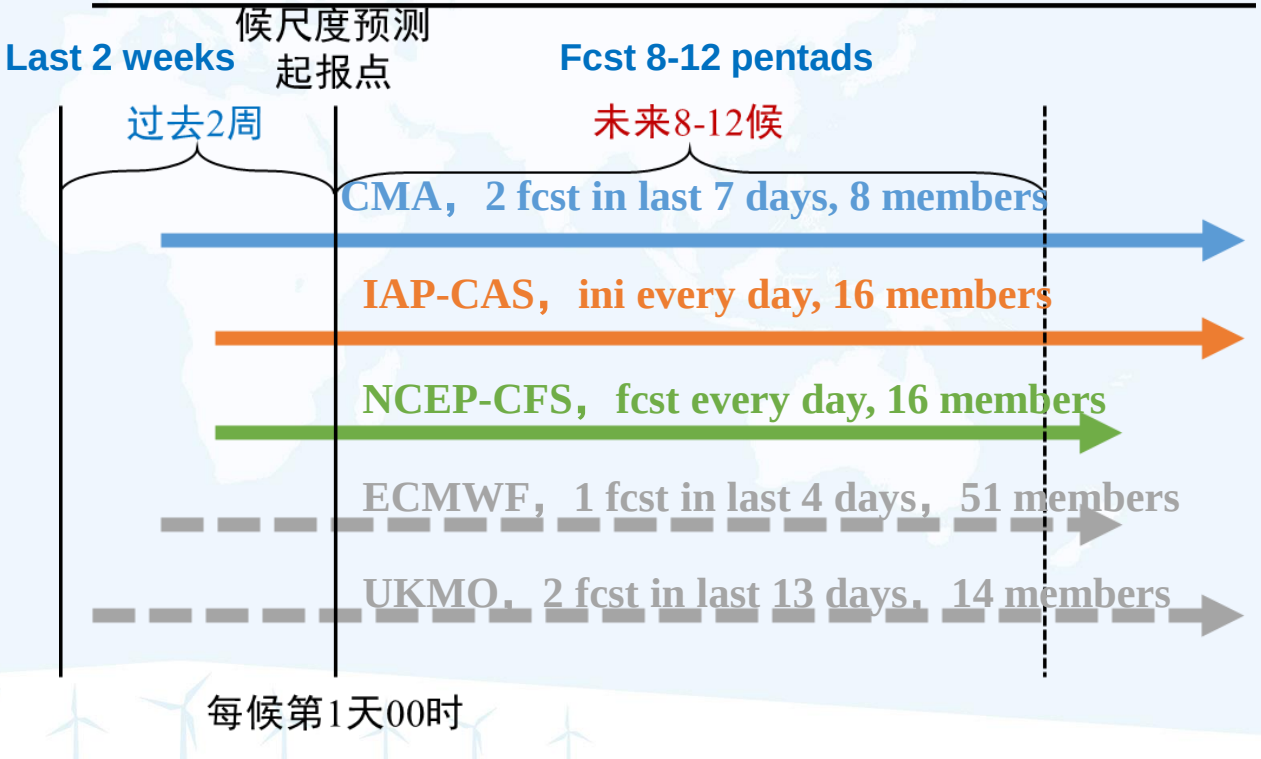


2.2 CMME-S2S sub-system (new!)

Farmwork of CMME-S2S



Data source	Forecast leading time (d)	Ensemble size	Forecast frequency	Forecast period	Hindcast strategy	Hindcast period	Model version
CMA	60	4	2/week	2020-present	On the fly	Past 15 years	BCC-CPS-S2Sv2
IAP-CAS	65	16	1/day	1999-present	Fix	1999-2018	Fgoals-f2
NCEP	44	16	1/day	2016–present	Fix	1999–2010	NCEP ensemble
ECMWF	46	51	2/week	2018-present	On the fly	Past 20 years	CY46R1



Products of CMME-S2S

中国多模式集合预测系统（CMMEv2.0）

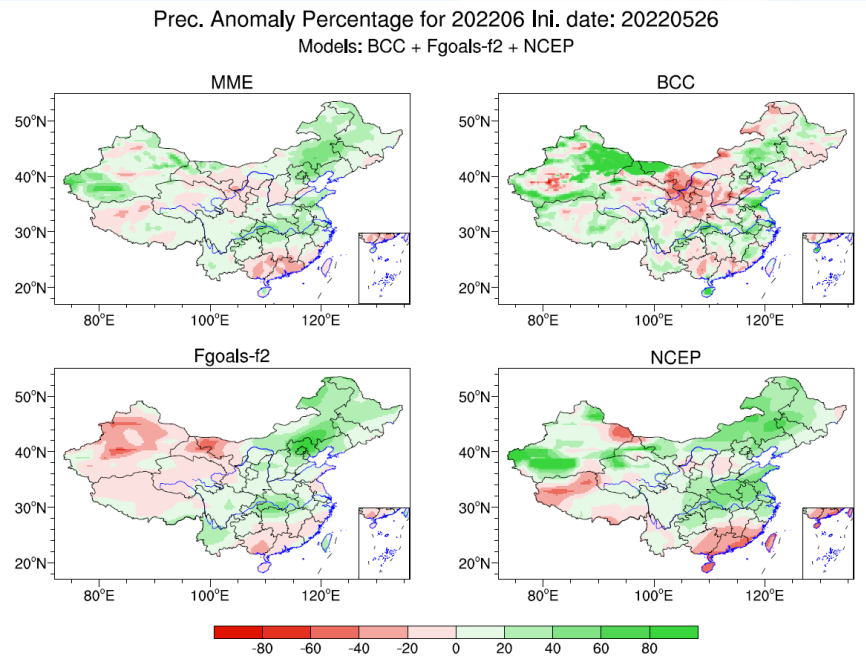
系统介绍	季节至年代际（CMME-S2D）	次季节至季节（CMME-S2S）	气候现象（CMME-CPPS）	预测检验（CMME-VECOM）

subsystem

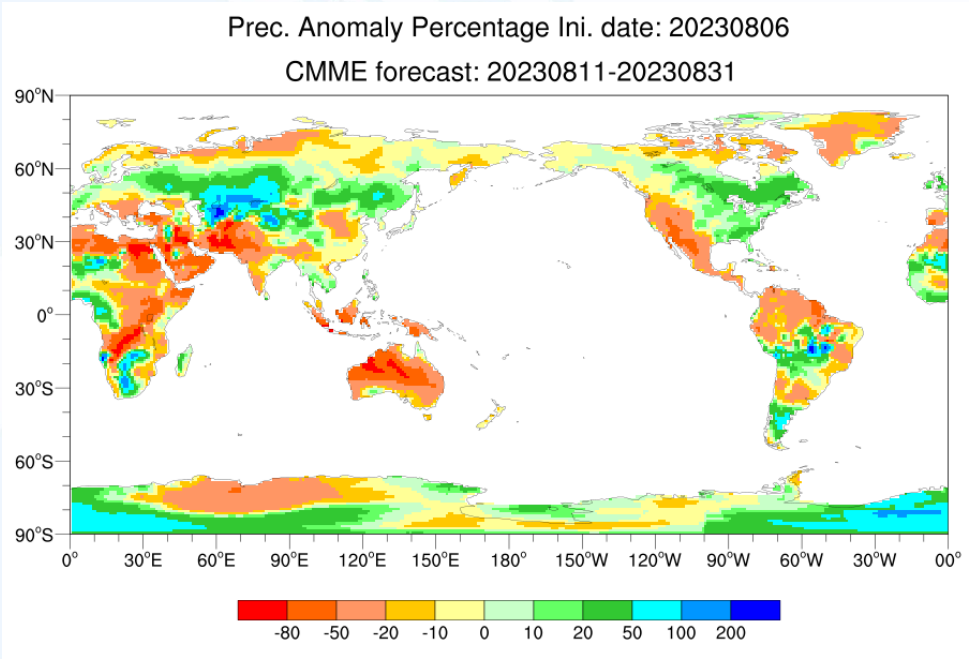
月尺度预测产品			旬尺度预测产品					候尺度预测产品		过程预测产品	
降水距平百分率	2米气温异常	500hPa位势高度场异常	降水距平百分率	2米气温异常	500hPa位势高度场异常	全球每月中下旬降水距平百分率	全球每月中下旬2米气温异常	降水异常	2米气温异常	降水异常	2米气温异常

Timescale & element

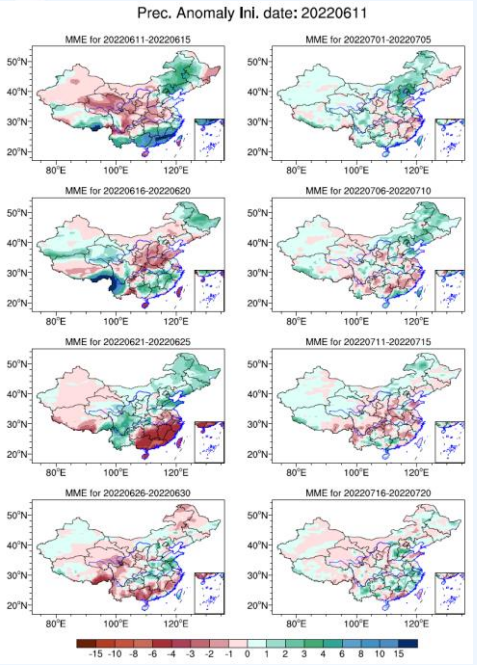
■ Next month prediction



■ Ten-days prediction



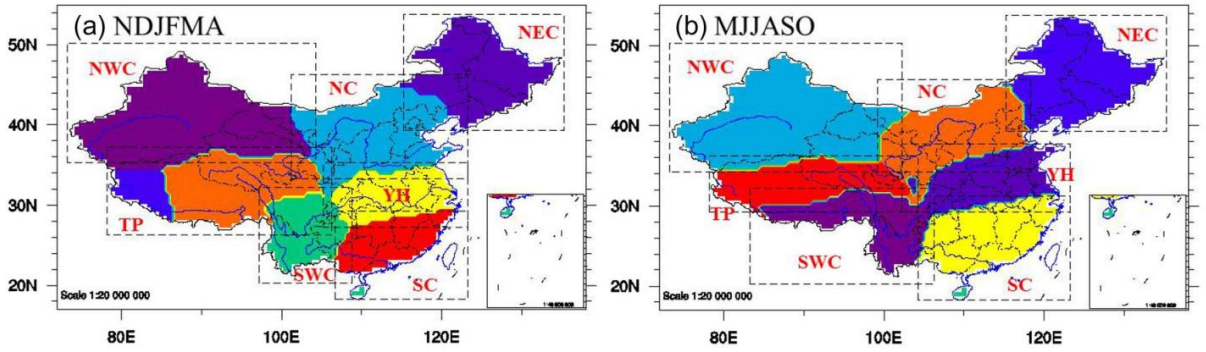
■ Pentad Prediction



http://cmdp.ncc-cma.net/pred/cn_cmme_v2.php?cmmeCat=CMME-S2S

Dynamical-Statistical Prediction Model (DSPM)

Divided China into 7 sub-regions based on K-means method



Establish DSPM for each sub-region in summer and winter

Training Period

Predictor Standardized $X_o(t, i_1 \times j_1 \times 6_{panteds})$

Predictant Standardized $Y_o(t, i_2 \times j_2 \times 6_{panteds})$

Extend-Singular Value Decomposition (E-SVD)

$$X_o(t, i_1 \times j_1 \times 6_{panteds}) \approx \sum_{k=1}^{K} L_k (i_1 \times j_1 \times 6_{panteds}) l_k(t)$$
$$Y_o(t, i_2 \times j_2 \times 6_{panteds}) \approx \sum_{k=1}^{K} R_k (i_2 \times j_2 \times 6_{panteds}) r_k(t)$$

Linear Regression (LR)

$$r_k(t) = akl_k(t) + b_k$$

Prediction Period

BCC-CSM2-HR Forecast Standardized $X_f(t, i_1 \times j_1 \times 6_{panteds})$

Projection

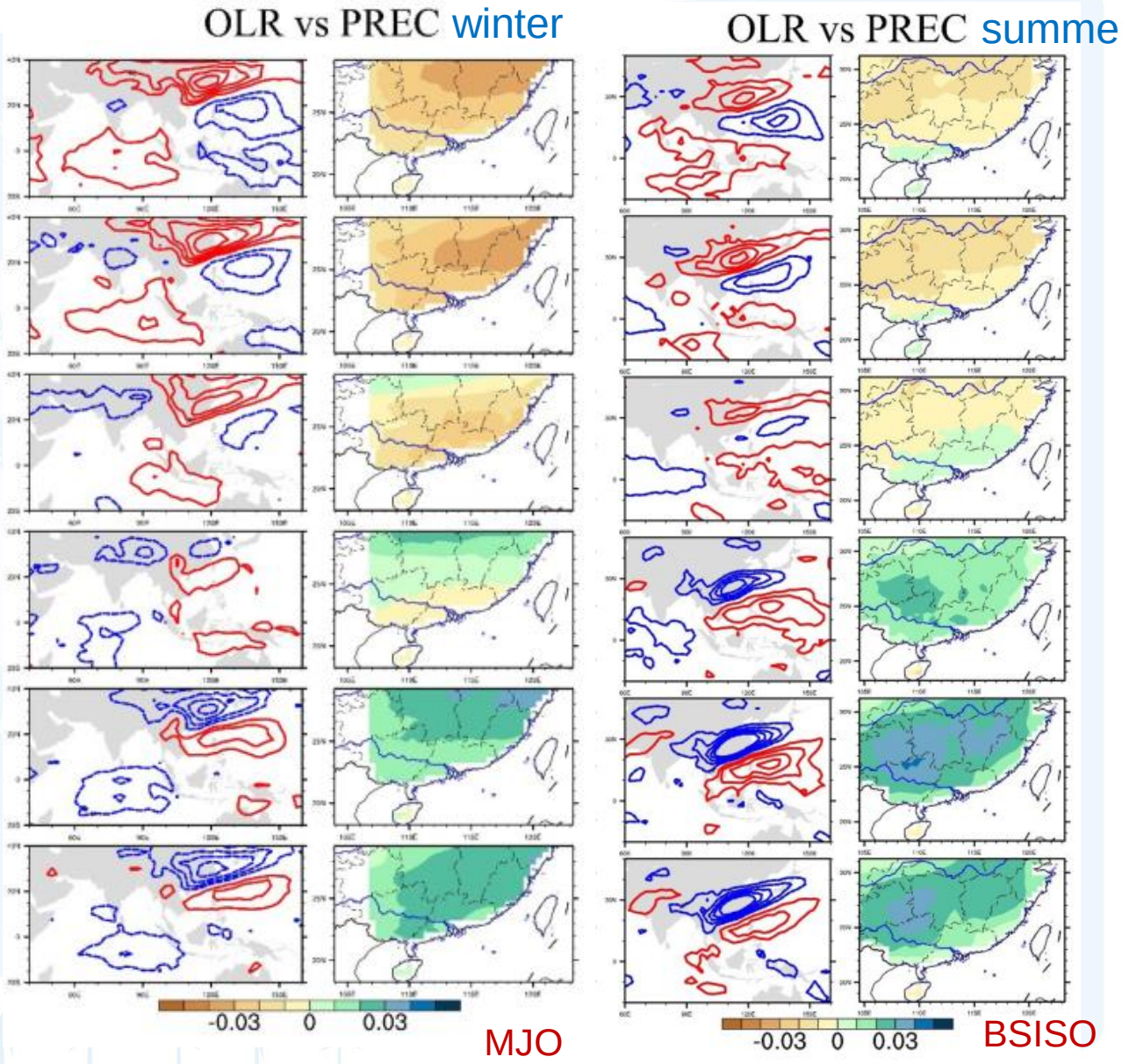
$$l_{kf}(t) = \sum_{s=1}^{i_1 \times j_1 \times 6_{panteds}} X_f(t, s) \times L_k(s)$$
$$r_{kf}(t) = akl_{kf}(t) + b_k$$

Reconstruction

$$Y_f(t, i_2 \times j_2 \times 6_{panteds}) = \sum_{k=1}^{K} R_k (i_2 \times j_2 \times 6_{panteds}) r_{kf}(t)$$

Predictor: HGT, UWND, SHUM, OLR, SLP et al

The subseasonal couple evolution mode

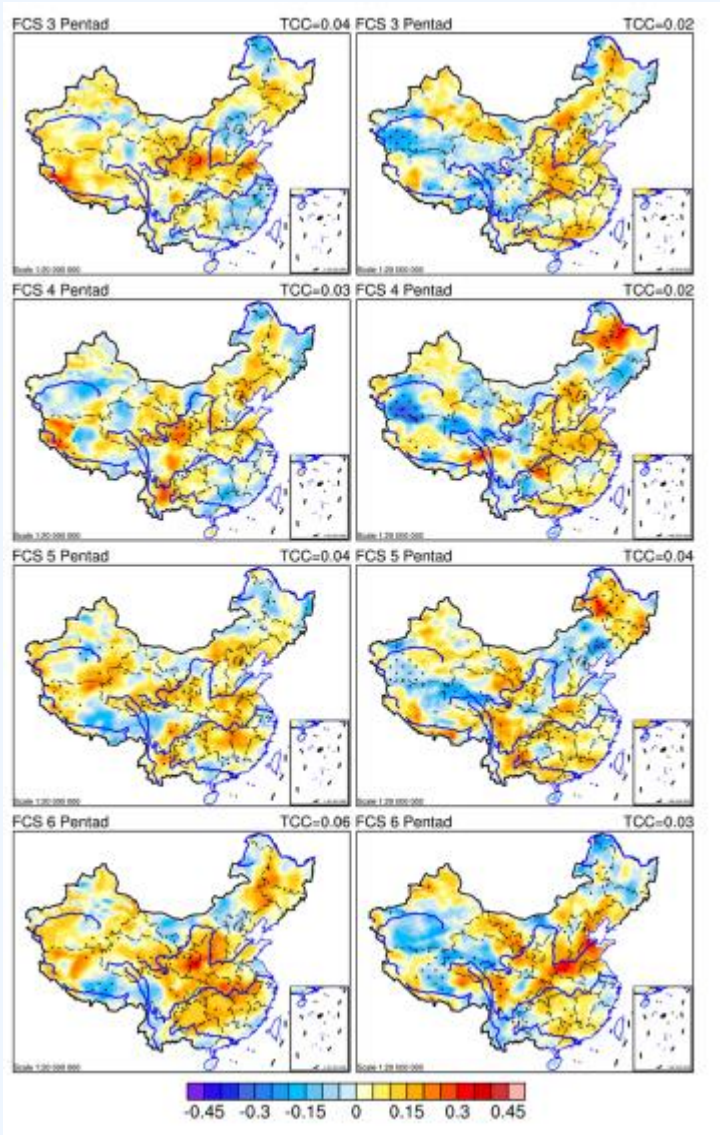


MJO

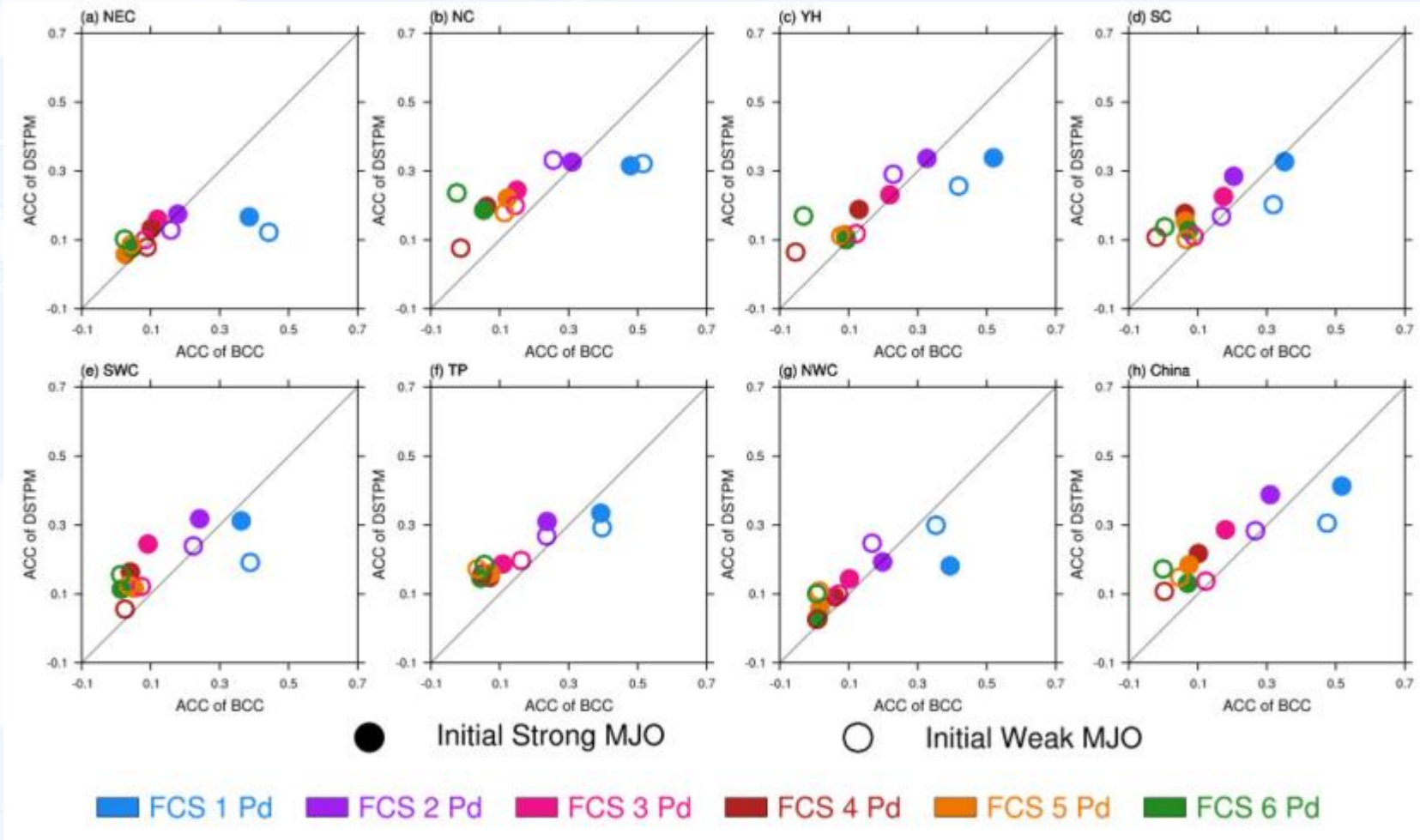
BSISO

Prediction skills and sources of DSPM

Skill improvements (DSPM-BCC)

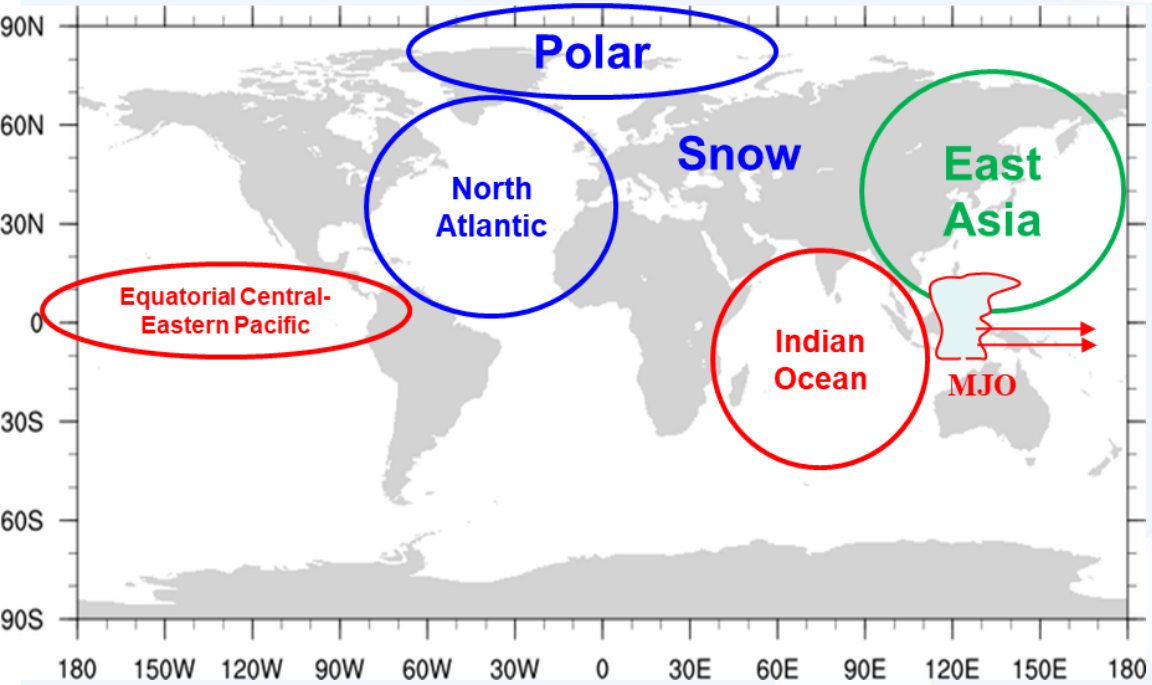


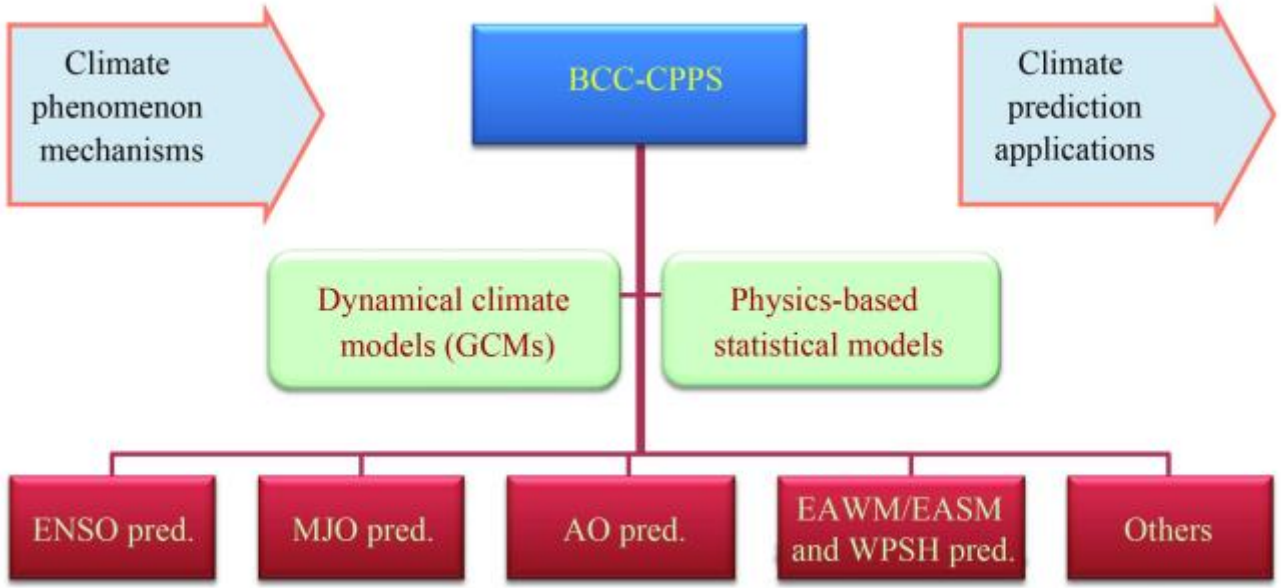
The skills relations of BCC against DSPM under differentt MJO condition



(Wu et al, 2022, Clim Dyn)

2.3 CMME-CPPS sub-system (improve!)





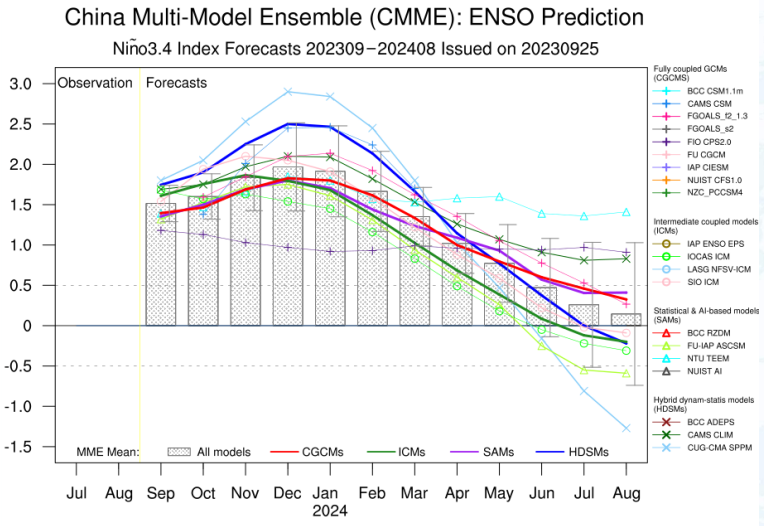
Climate Phenomenon Prediction System (CPPS):

- System off ENSO Monitoring, Analysis and Prediction (**SEMAP**)
- ISV/MJO Monitoring and Prediction System (**IMPRESS**)
- Mid-high-latitude-polar Atmospheric TEleconnections and Sea ice-snow variations (**MATES**)
- A prediction system of Primary East-Asian Circulation pattErns (**PEACE**)

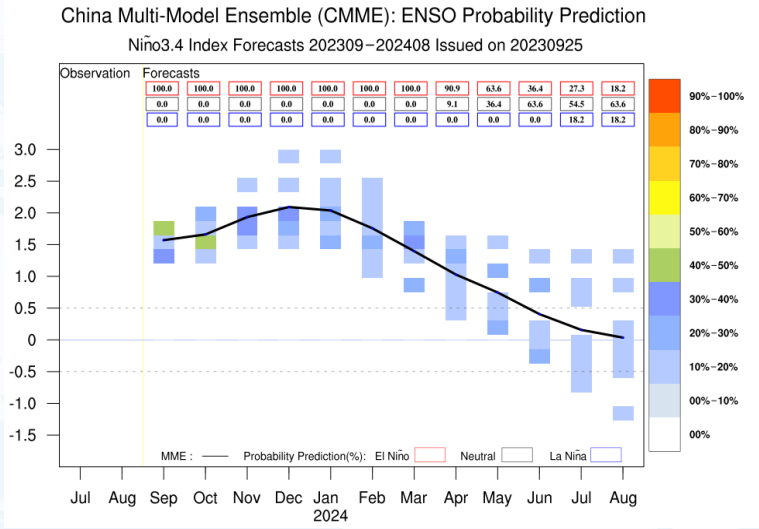
（Ren etal, 2017, JMR)

CMME-ENSO

Deterministic Prediction



Probabilistic Prediction



Participant Models or Methods

Fully coupled GCMs (CGCMS)
- BCC CSM1.1m
- CAMS CSM
- FGOALS_f2_1.3
- FGOALS_s2
- FIO CPS2.0
- FU CGCM
- IAP CIESM
- NUIST CFS1.0
- NZC_PCCSM4

Intermediate coupled models (ICMs)
- IAP ENSO EPS
- IOCAS ICM
- LASG NFSV-ICM
- SIO ICM

Statistical & AI-based models (SAMs)
- BCC RZDM
- FU-IAP ASCSM
- NTU TEEM
- NUIST AI

Hybrid dynam-statis models (HDSMs)
- BCC ADEPS
- CAMS CLIM
- CUG-CMA SPPM

模式名称	所属单位
BCC_CSM1.1m	国家气候中心（NCC）
CAMS_CSM	中国气象科学研究院（CAMS）
FGOALS-f2_1.3	中科院大气物理研究所（IAP）
FGOALS_s2	中科院大气物理研究所（IAP）
FIO_CPS	自然资源部第一海洋研究所（FIO）
FU_CGCM	复旦大学（FU）
IAP_CIESM	中科院大气物理研究所（IAP）
NUIST_CFS	南京信息工程大学（NUIST）
NZC_PCCSM4	竺可桢-南森国际研究中心（NZC）
IAP_ENSO_EPS	中科院大气物理研究所（IAP）
IOCAS_ICM	中国科学院海洋研究所（IOCAS）
LASG_NFSV-ICM	中科院大气物理研究所（IAP）
SIO_ICM	自然资源部第二海洋研究所（SIO）
BCC_RZDM	国家气候中心（NCC）
FU_IAP_ASCSM	复旦大学（FU）
NTU_TEEM	台湾大学（NTU）
NUIST_AI	南京信息工程大学（NUIST）
BCC_ADEPS	国家气候中心（NCC）
CAMS_CLIM	中国气象科学研究院（CAMS）
CUG_CMA_SPPM	中国地质大学 武汉（CUG）

- Provide multi-model deterministic and probabilistic prediction
- **Grouped** by fully coupled GCM, intermediate coupled model, statistical-AI based models and Hybrid dynamical-statistical models
- It shows a **medium-strength El nino** event will be formed during this winter （2.0C）

（Dr. Ren Hong-Li）

http://cmdp.ncc-cma.net/pred/cn_cmme.php?Elem=CMME-ENSO

Products of other CPPS

中国多模式集合预测系统（CMMEv2.0）

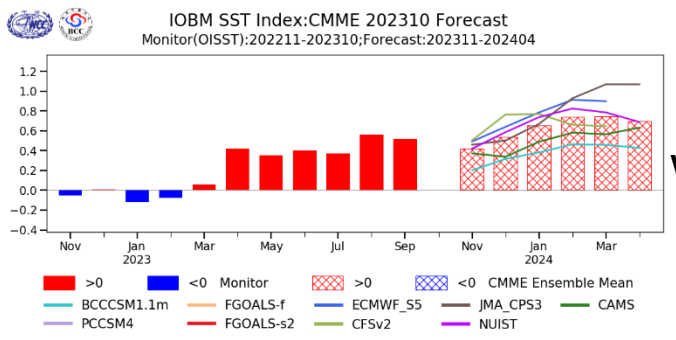
系统介绍	季节至年代际（CMME-S2D）	次季节至季节（CMME-S2S）	气候现象（CMME-CPPS）	预测检验（CMME-VECOM）

Sub-system

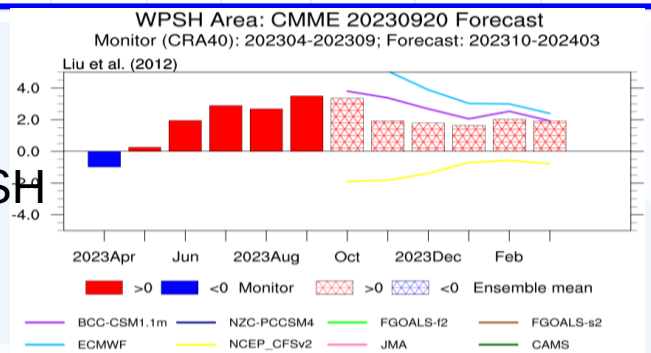
太平洋海温指数							印度洋海温指数			大西洋海温指数			西太副高				南亚高压			MJO	AO
Nino34	Nino3	Nino4	Nino12	NinoEP	NinoCP	NinoA	IOBM	IOD	SIOD	NASTI	NTASST	AtlNino	面积	强度	西伸脊点	脊线位置	强度	中心纬度	中心经度	MJO	AO

CPPS

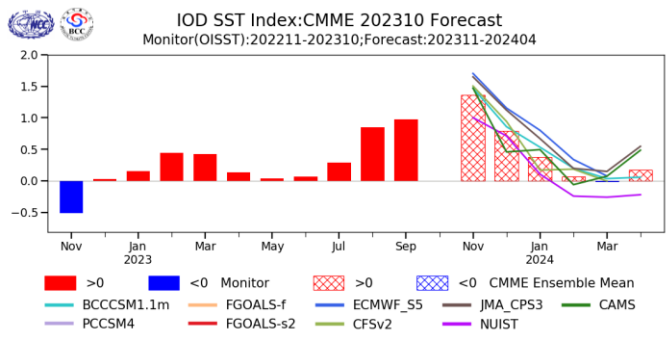
IOBM



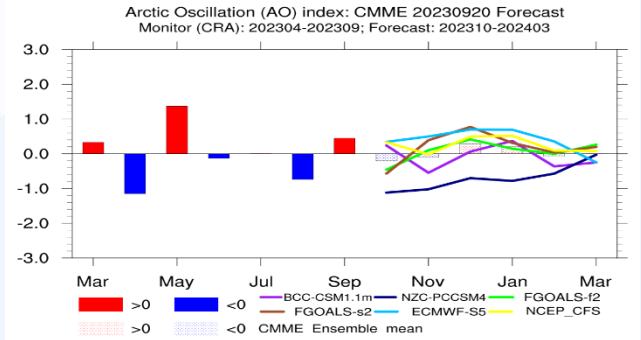
WPSH



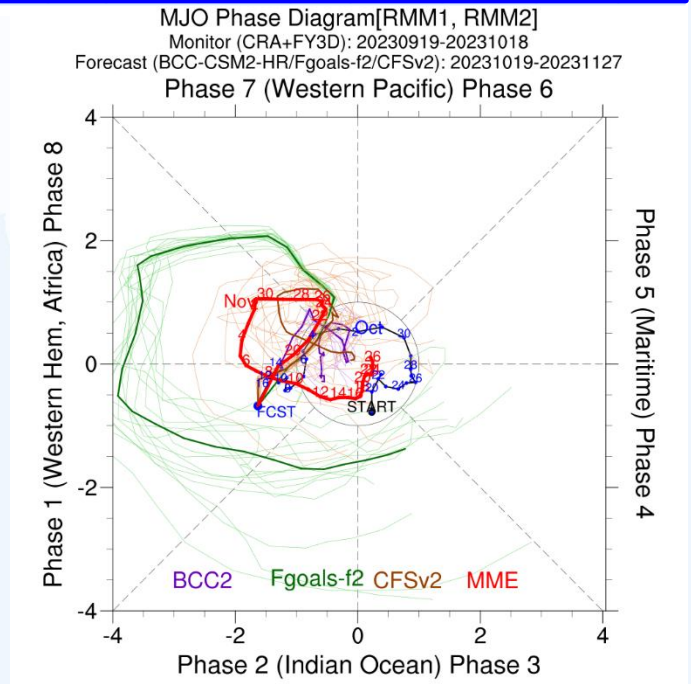
IOD



AO



MJO



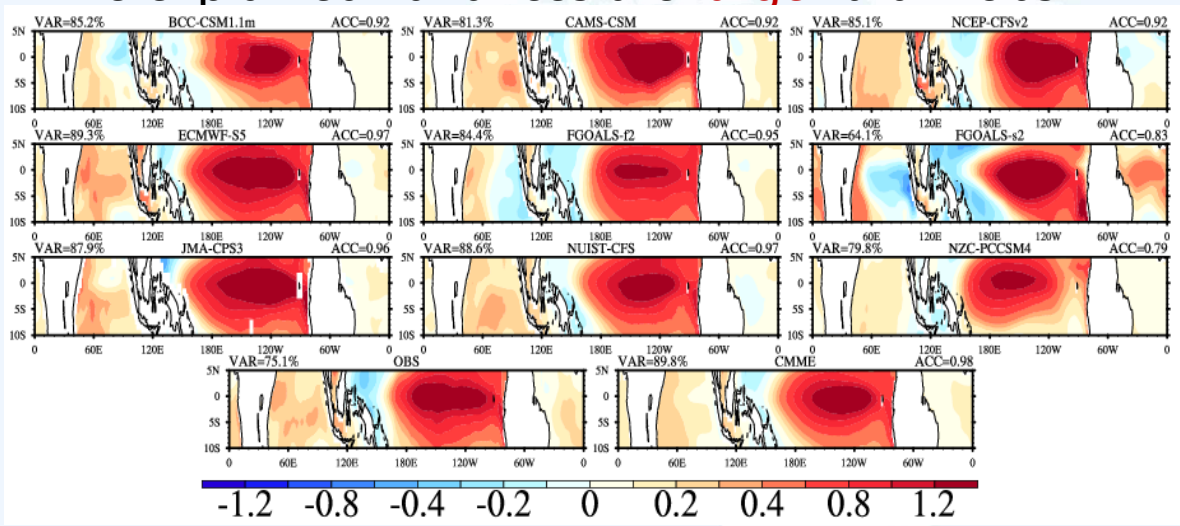
http://cmdp.ncc-cma.net/pred/cn_cmme_v2.php?cmmeCat=CMME-CPPS

Outlines

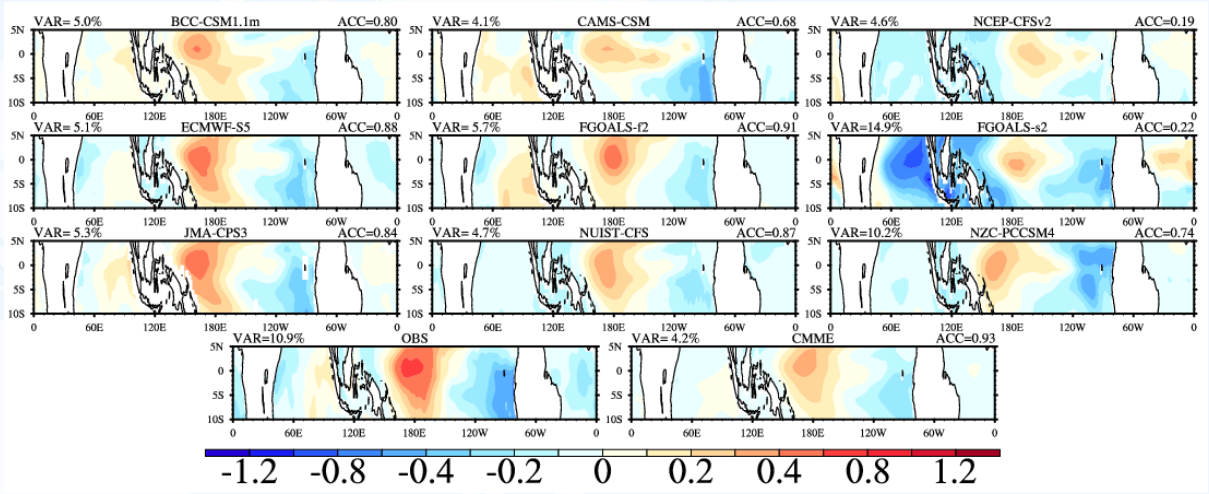
1. Backgrounds
2. Establishment and Product
3. Predictability Verification
4. Summary and discussions

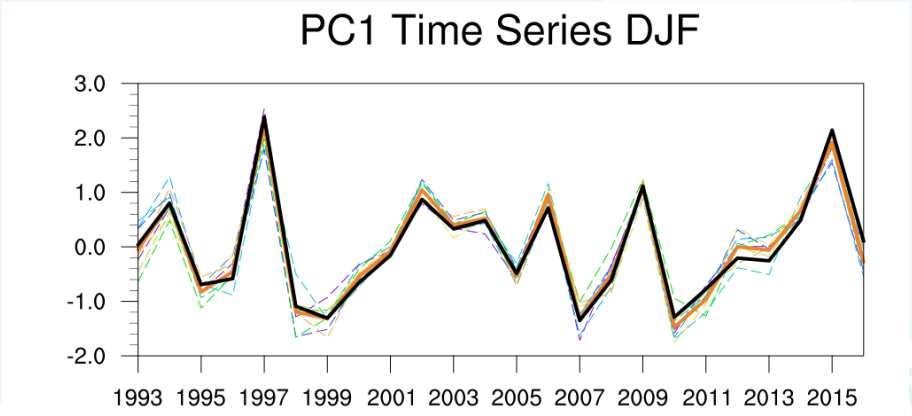
Extraction of Dominant SST patterns

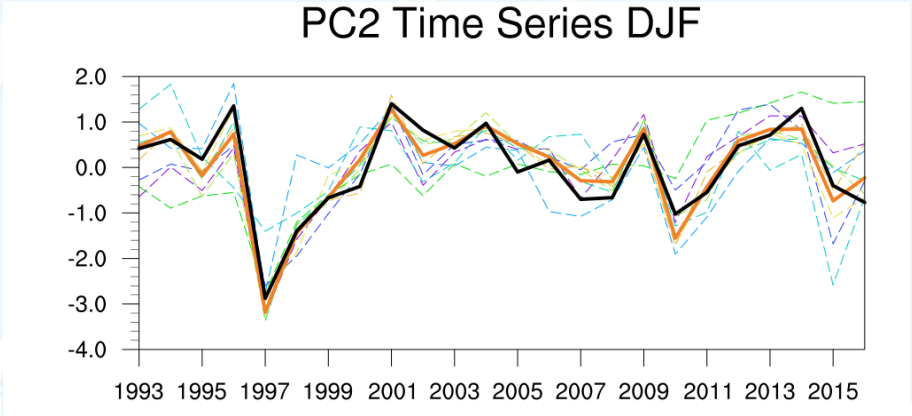
- **EOF1**
  - The spatial distributions of EOF1 are generally well captured even at 3-month lead time
  - The explained variances are larger than obs



- **EOF2**
  - Most models can capture the CP ENSO, except for a westward shift of maximum positive SSTA



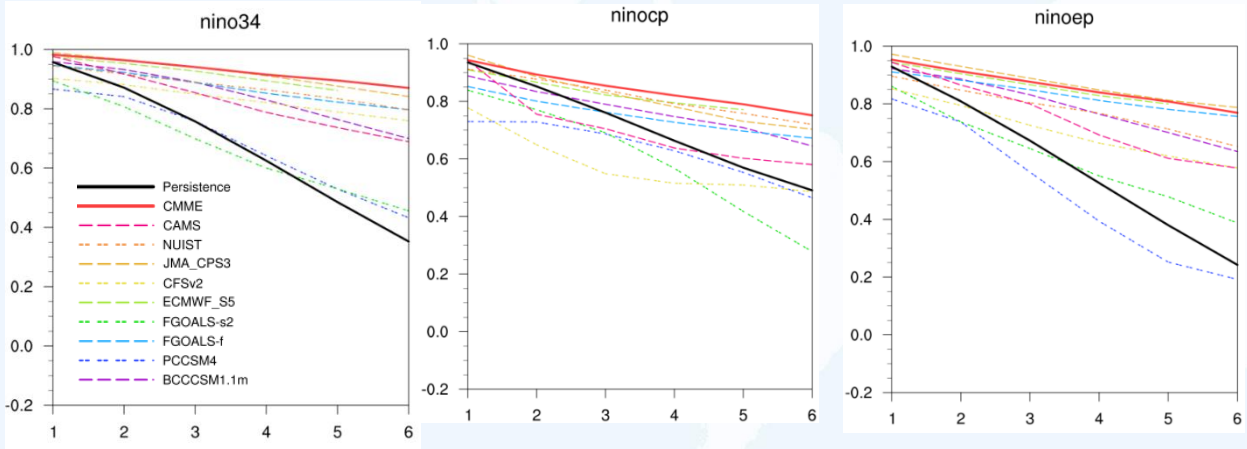




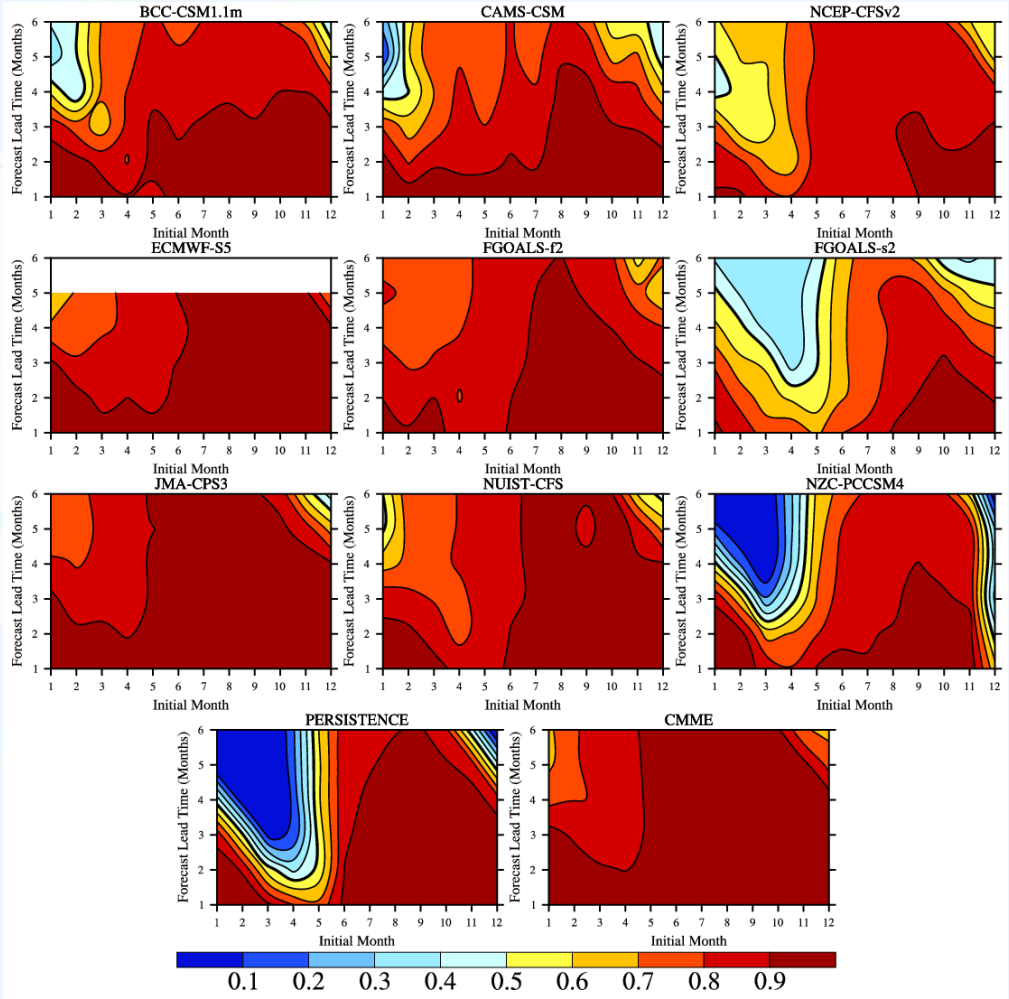
Prediction skills of Niño Index

- Correlation skills of CMME for **Niño3.4 index reach 0.87** at **6-month lead**, and reach 0.77 and 0.75 for EP and CP ENSO index, which are higher than all individual models
- The spring prediction barrier still exist, but become relieved than single model

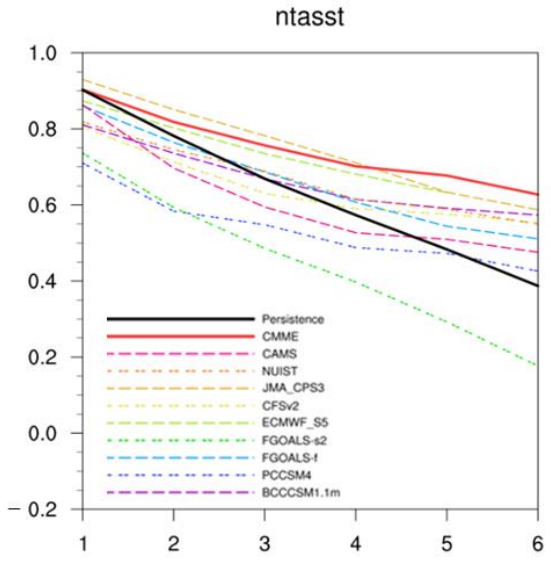
Prediction skill of Niño Index



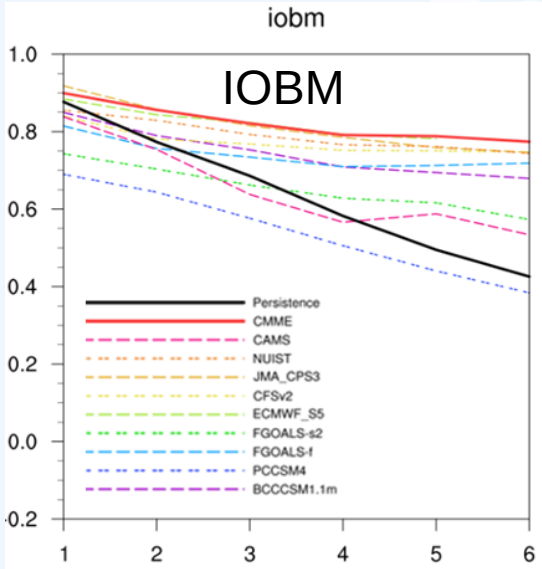
Skills' dependences on initial month

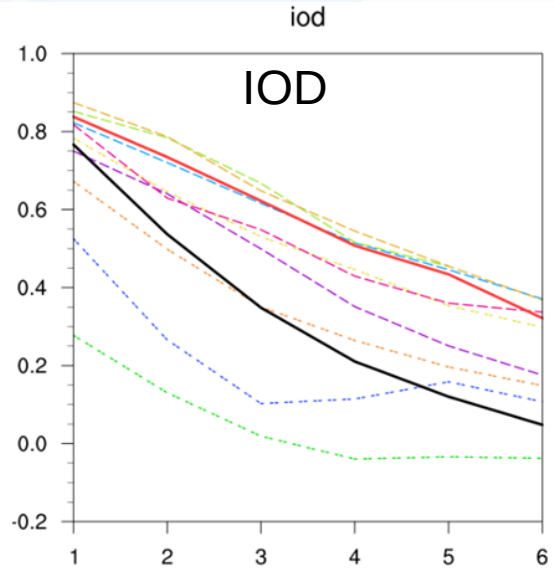


Prediction Skills of dominant ocean modes

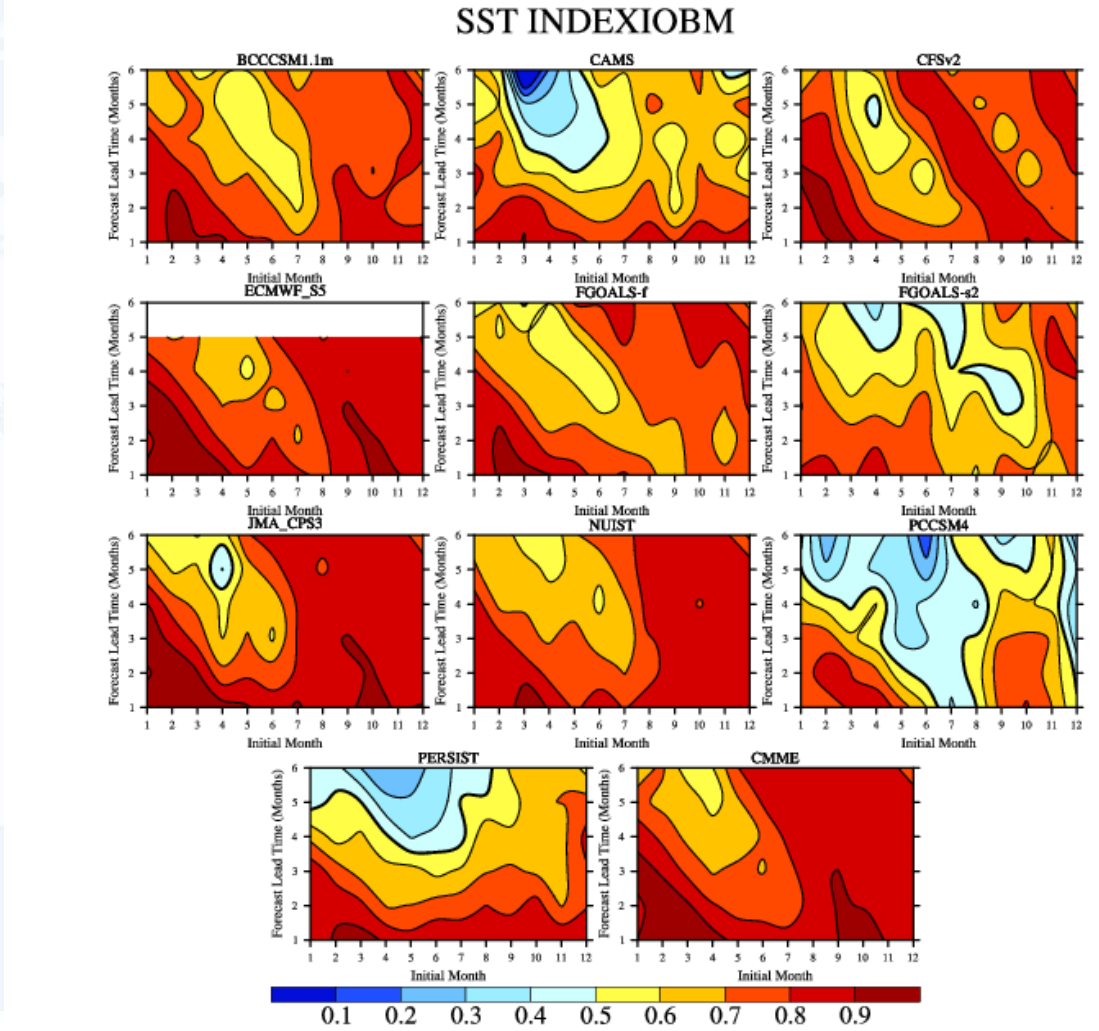


NAT



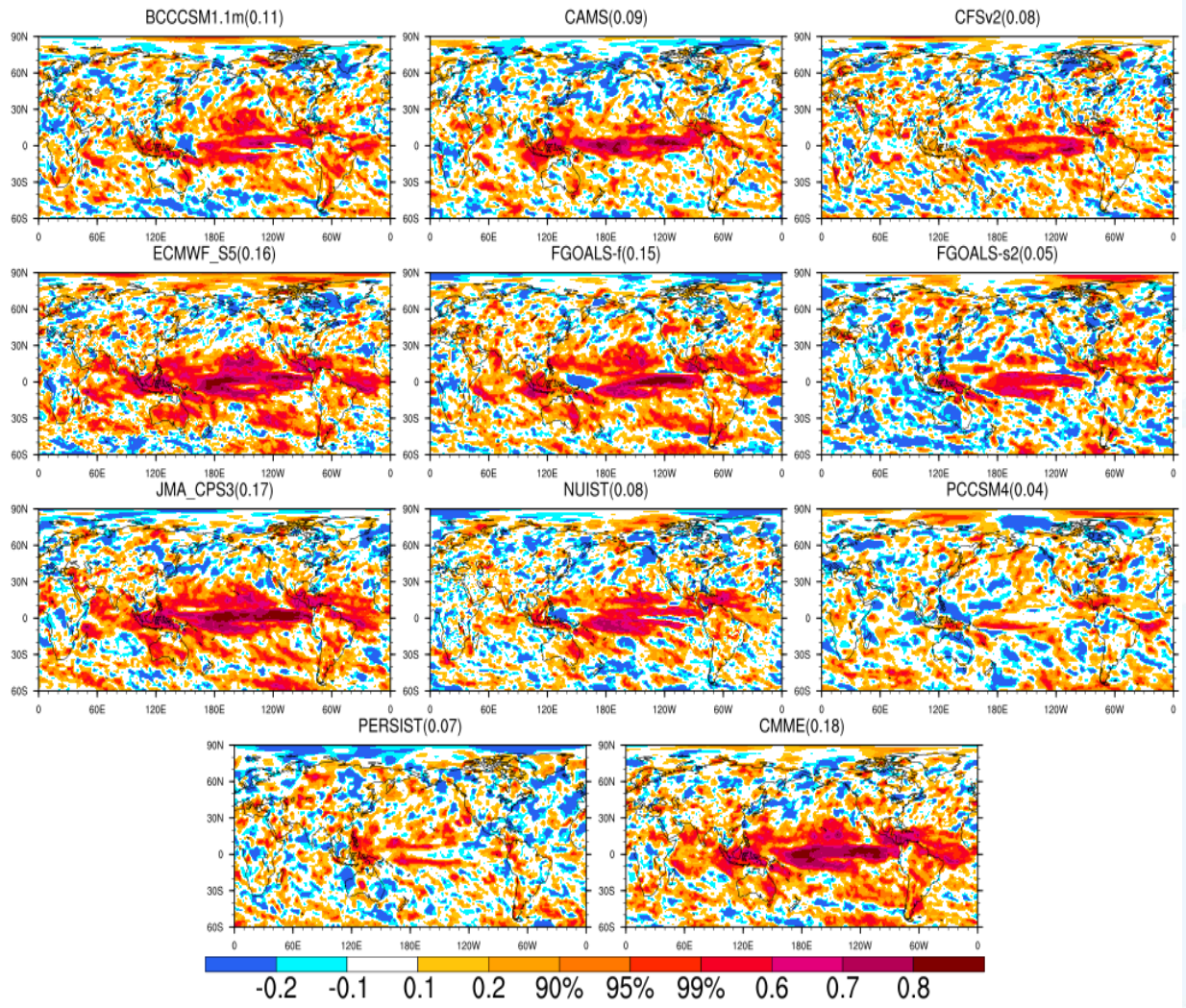


Skill of IOBM for different ini months

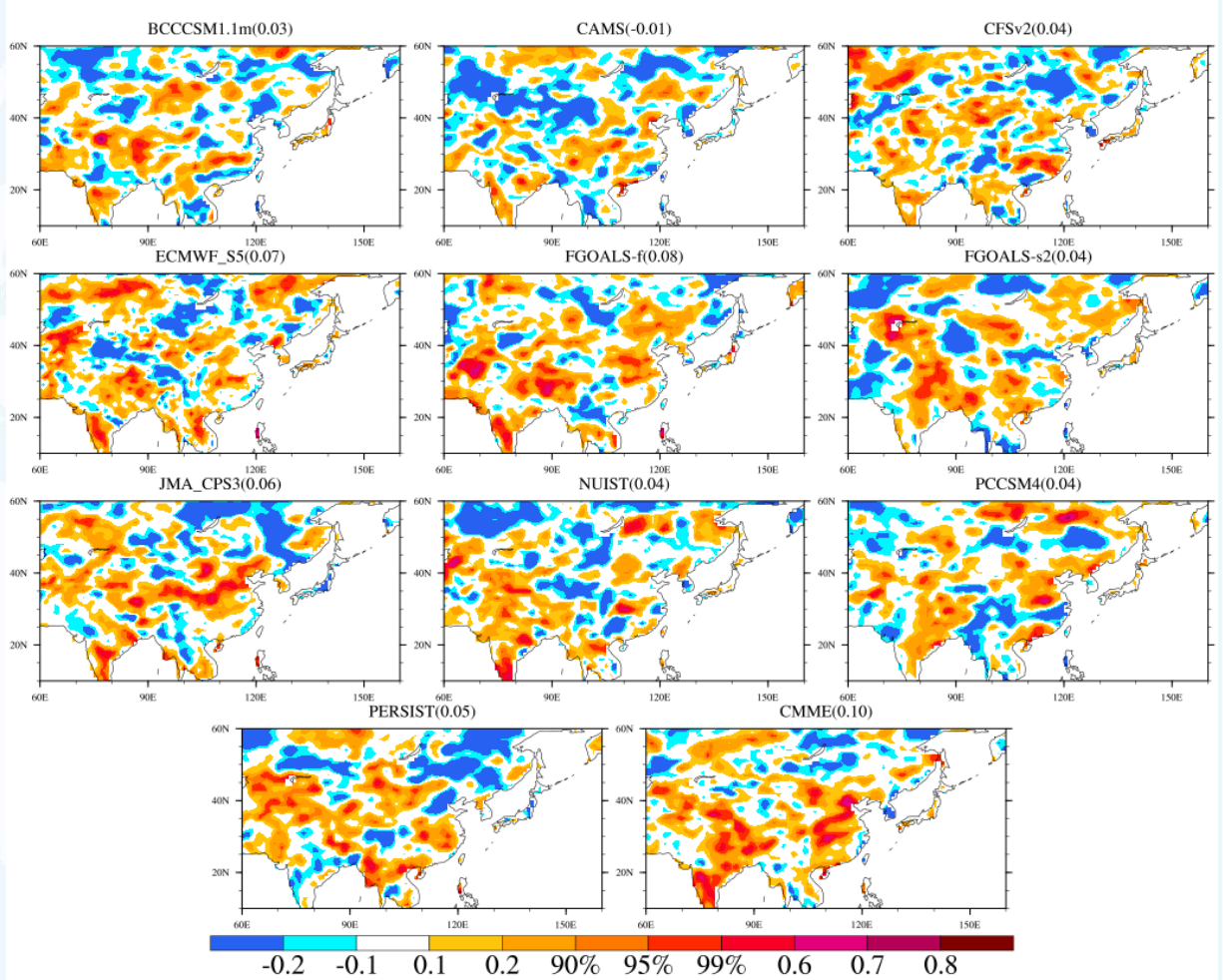


Prediction skills for PREC anomaly

TCC skills for JJA at 3-month lead (ini from Mar)



TCC skills over East Asian (Land)

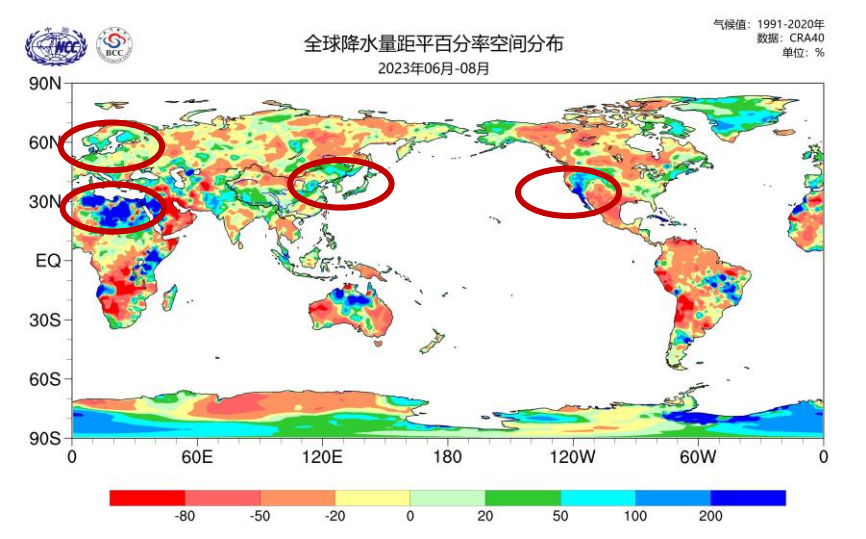


The skill of CMME is better than any single model, especially over East Asian

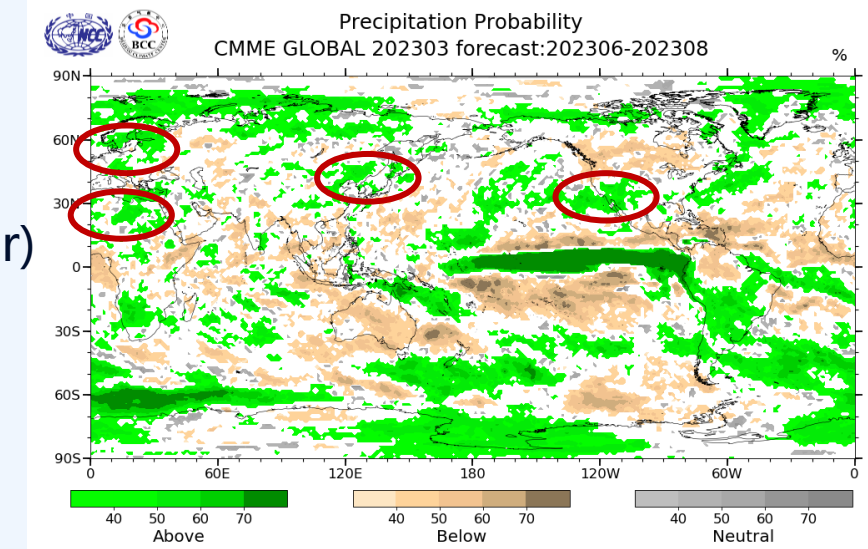
Real-time Verification of CMME

Global PREC in 2023

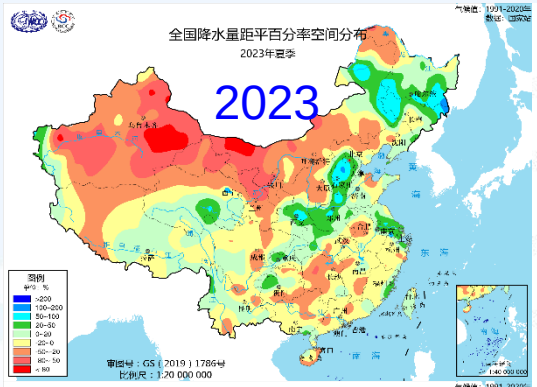
OBS (CRA-40)

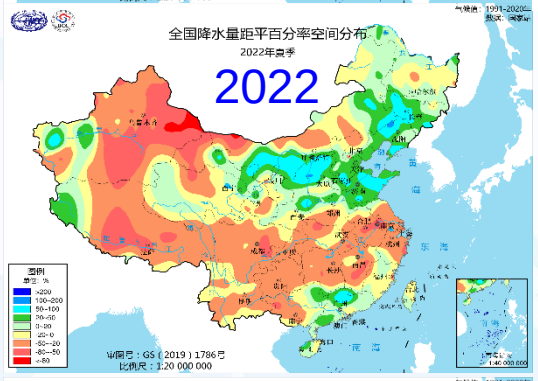


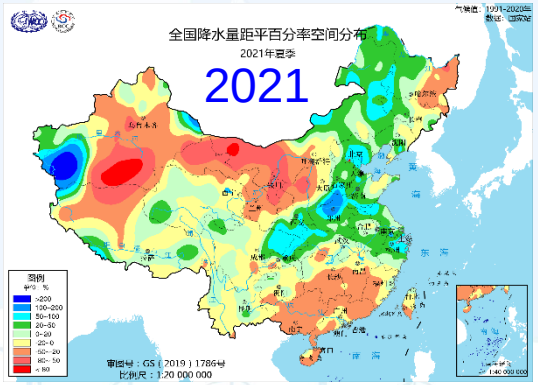
FCS (from Mar)



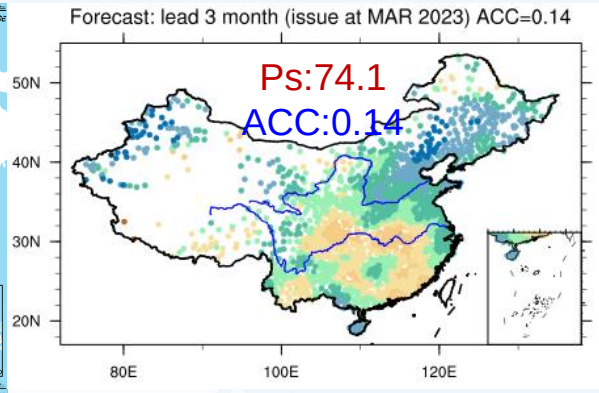
OBS

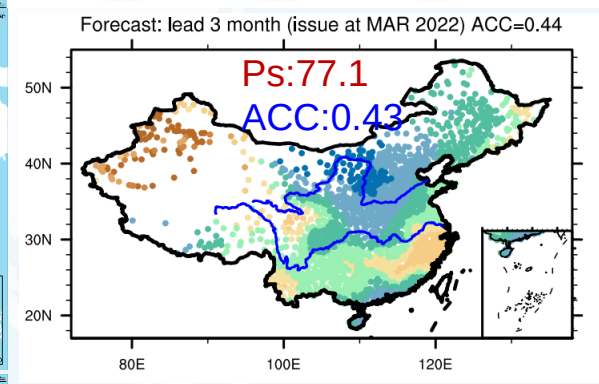


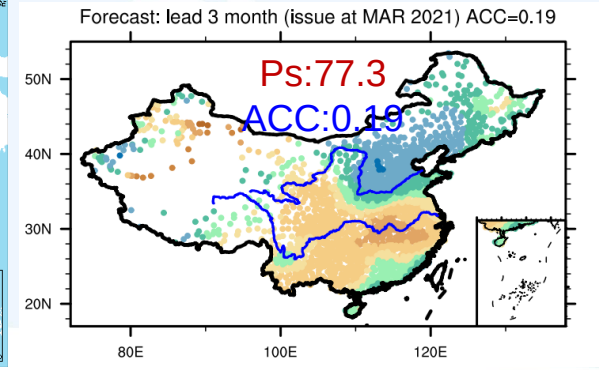




FCS(from Mar)

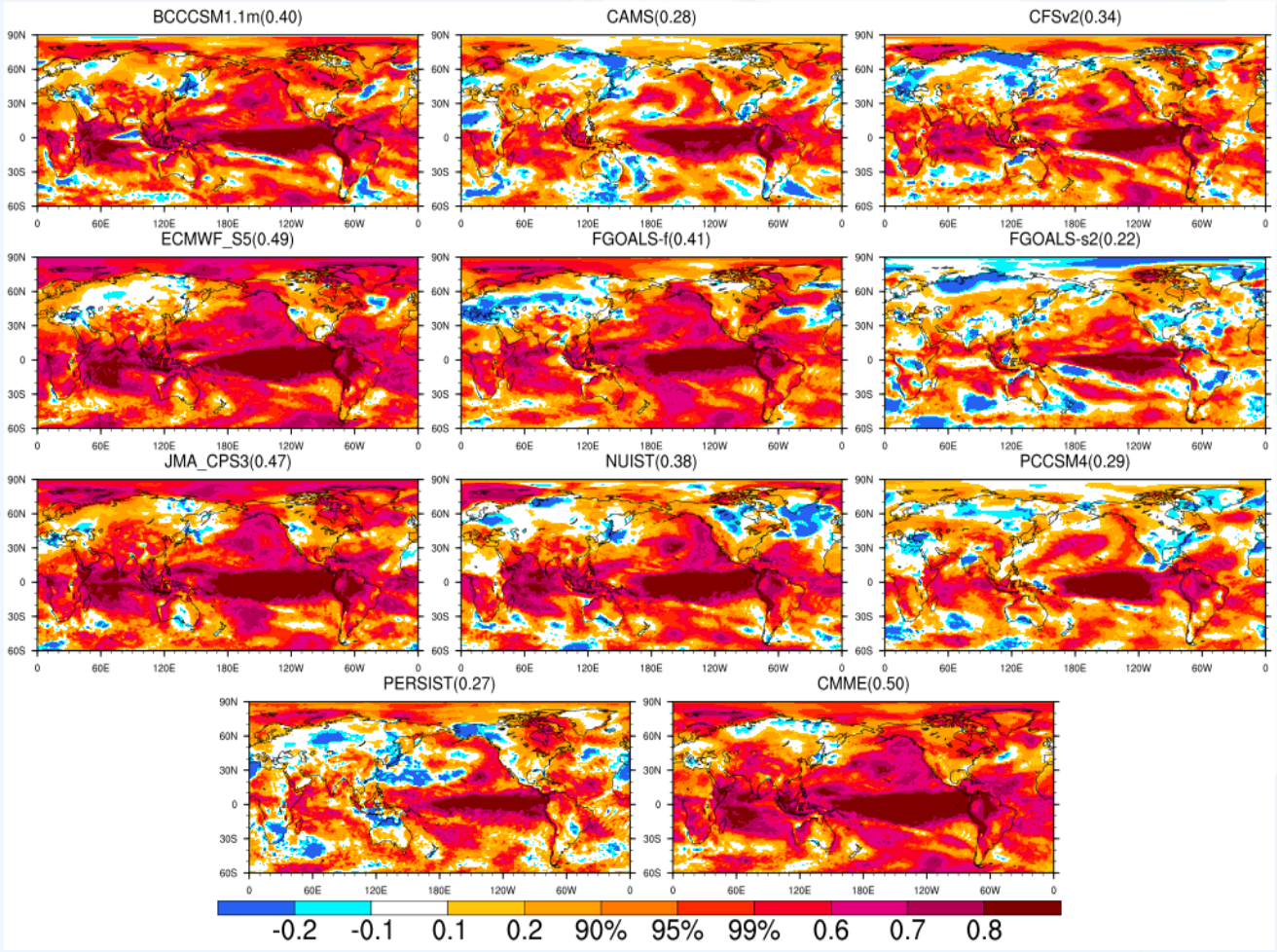




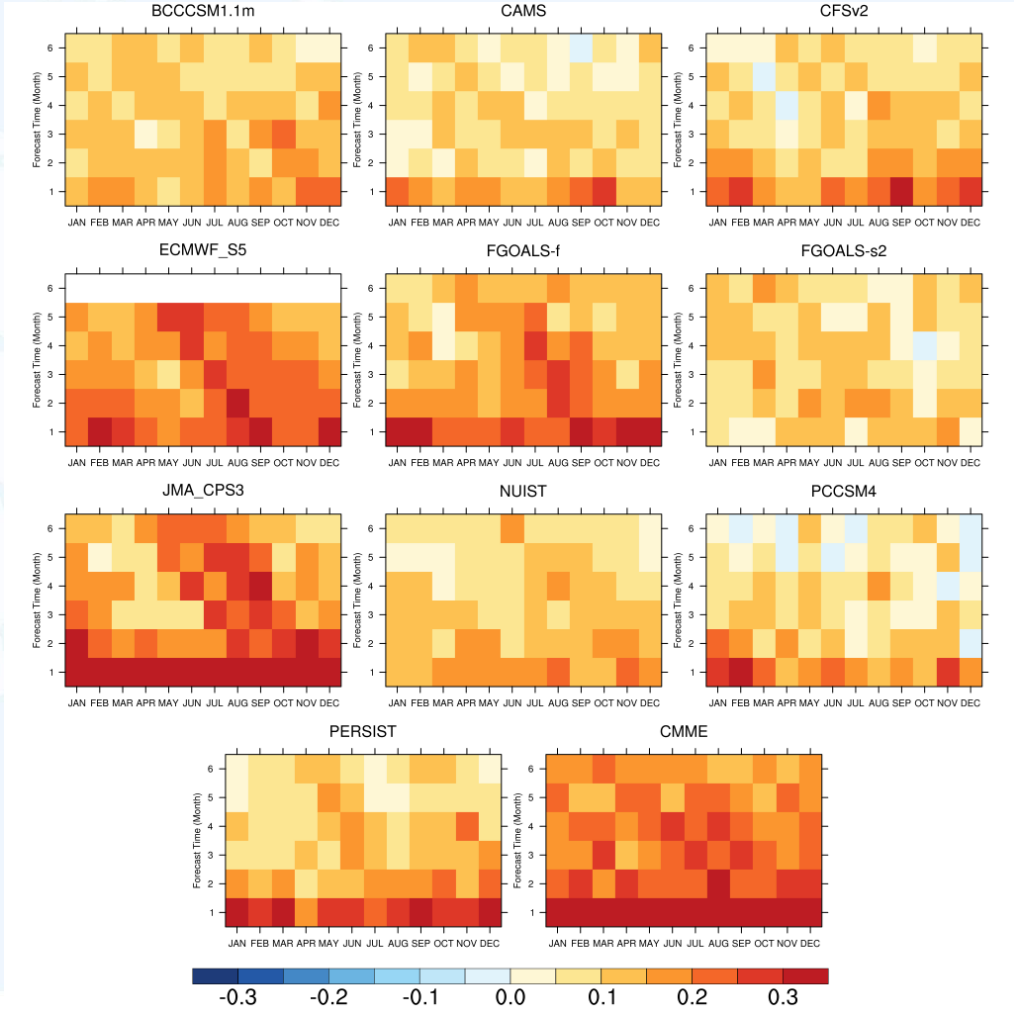


Prediction skills for T2m anomaly

- Skill of CMME is higher than each single mode and persistent prediction, es over Mid-high latitude
- The predictions that target on Oct to Jan are higher than the other months



TCC skills for DJF ini from Sep



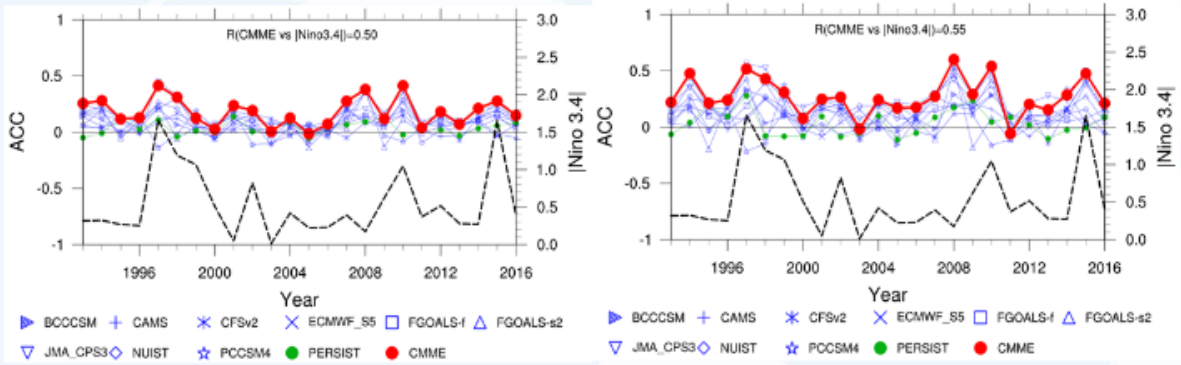
Skills dependence for initial month

Interannual variation of Prediction Skills

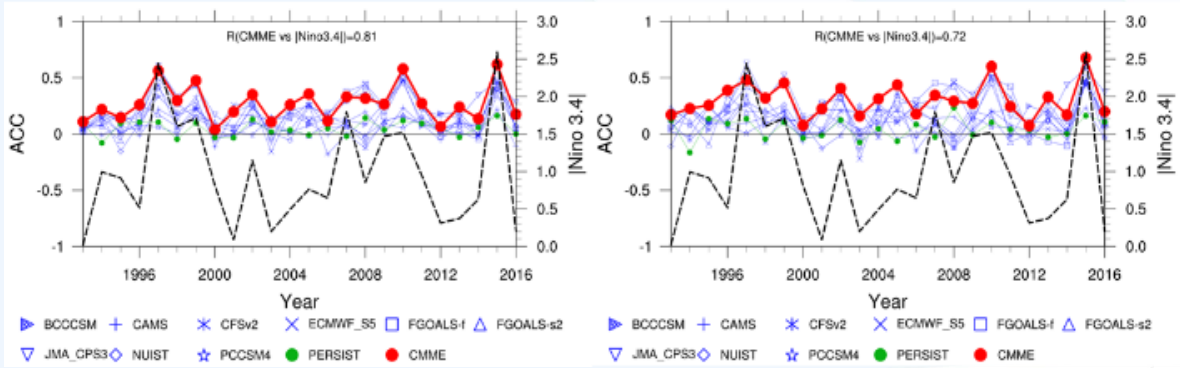
- Interannual variations of PCC skills are **depended on the amplitude** of ENSO event
- CMME can **better capture** the modulations of ENSO event, but model tend to over-estimate the influence of ENSO

Global | Tropics

Ini Mar for JJA

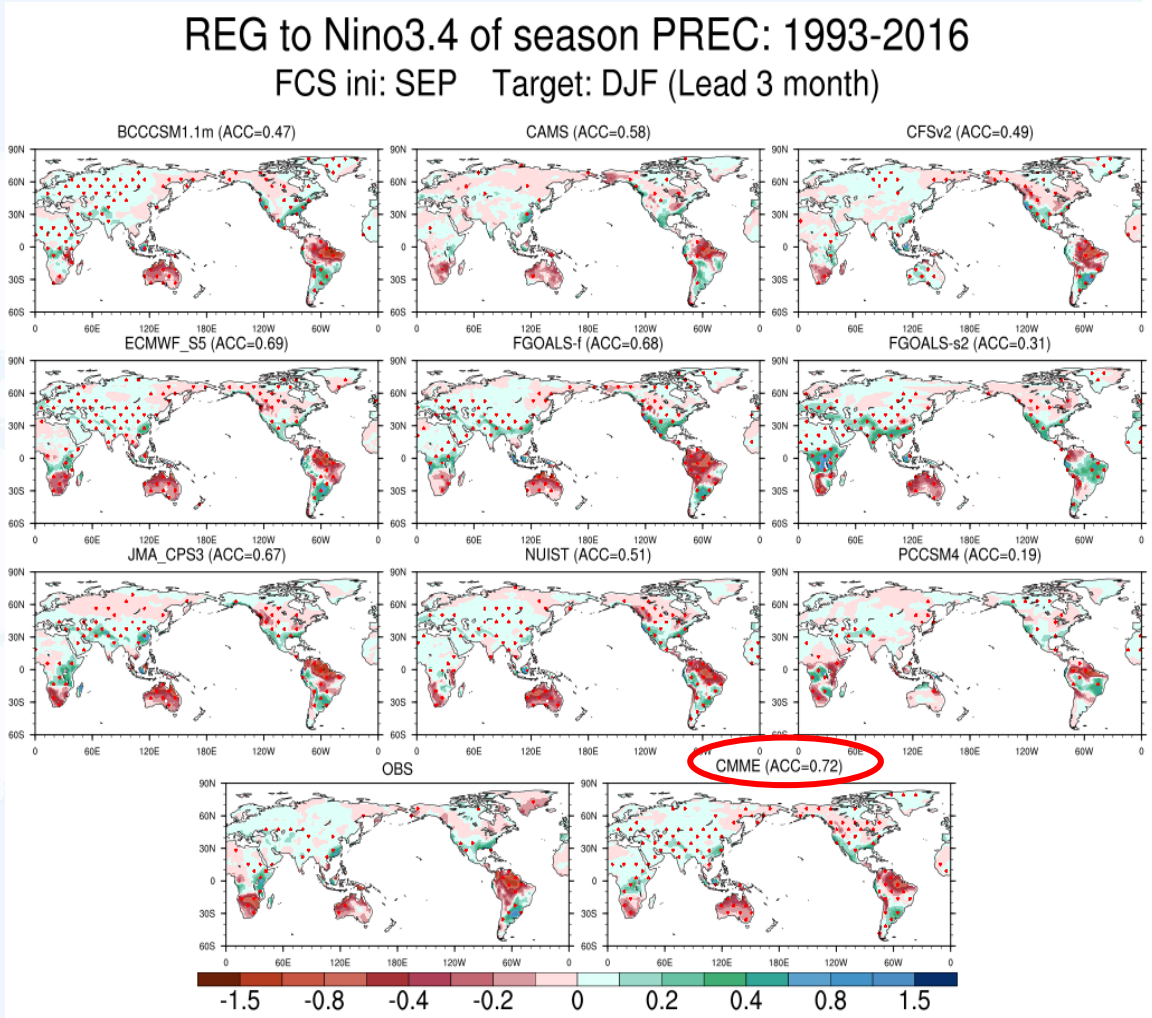


Ini Sep for DJF



Yearly variation of PCC and abs(Niño3.4)

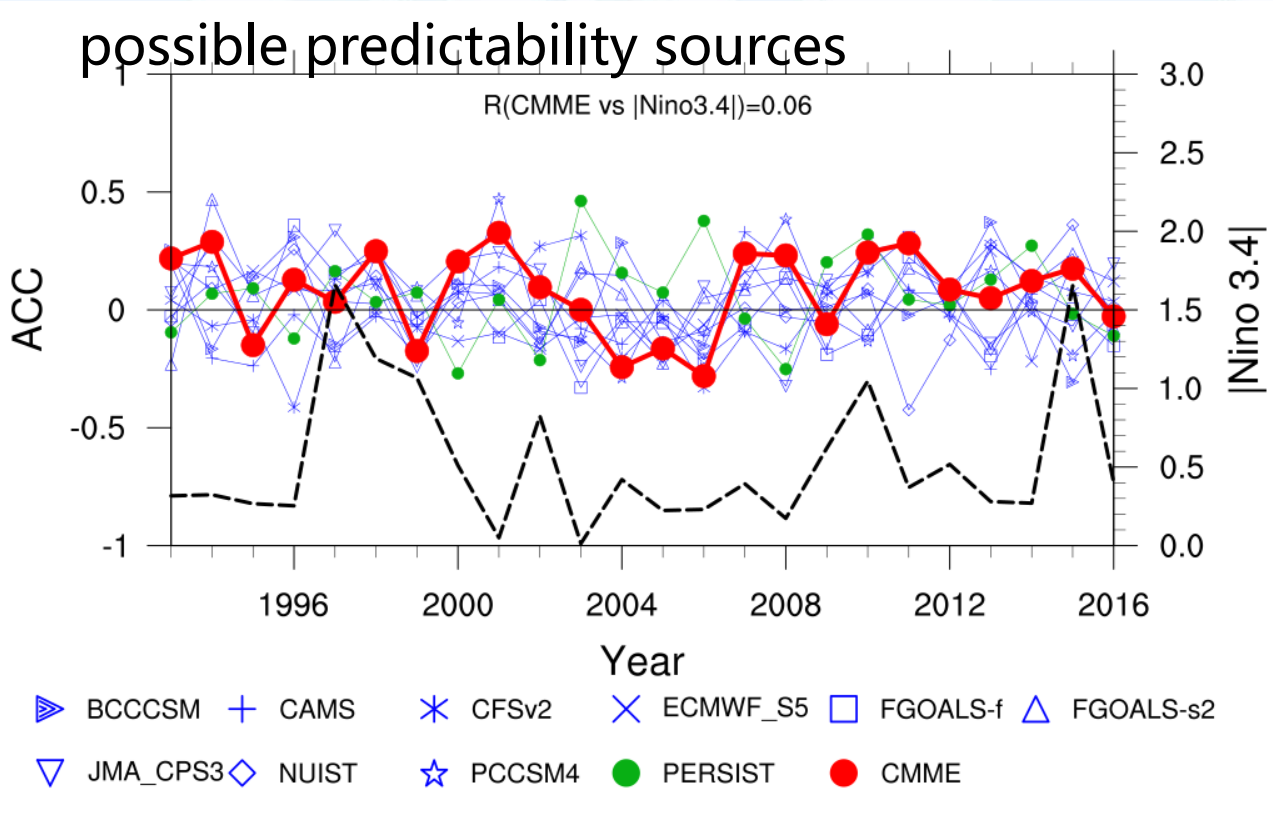
Regression of DJF PREC against Niño3.4



Initial from Sep

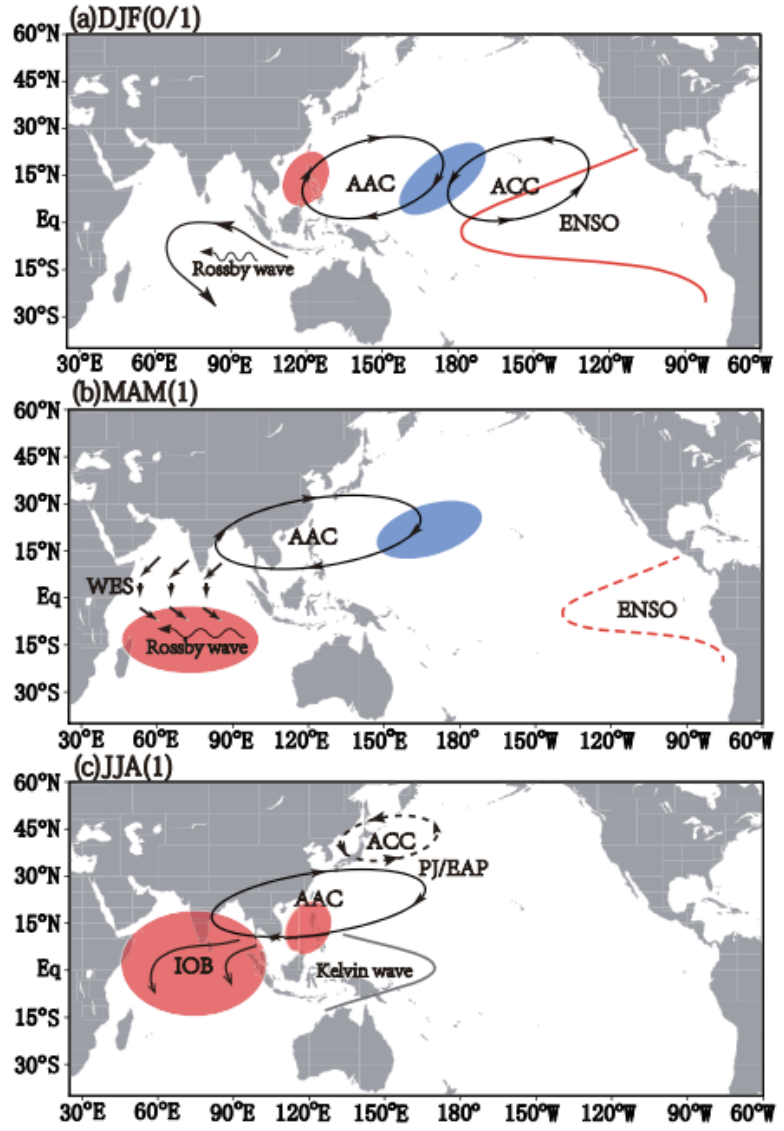
Predictability sources of East Asian

- Relation between Skill over EA in JJA and ENSO is quite weak in CMME
- SST over North Indian Ocean could be possible predictability sources



Yearly variation of PCC **over EA** and abs(Niño3.4)

Indo-western Pacific ocean capacitor (**IPOC**) effect



Xie et al 2016,AAS

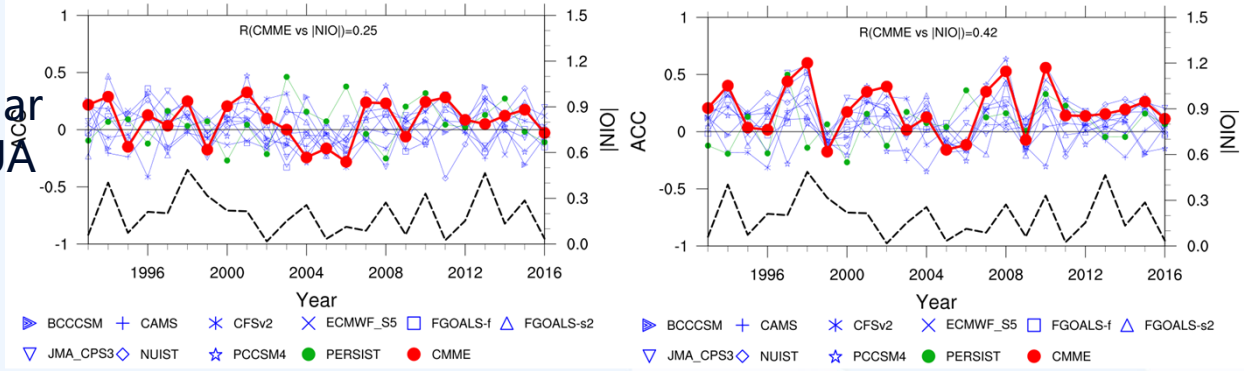
Predictability sources of East Asian

- Yearly PCC skills over EA and SA are related with SSTA **amplitude of NIO**
- The response pattern of NIO warming, such as stronger Meiyu front are better simulated by CMME

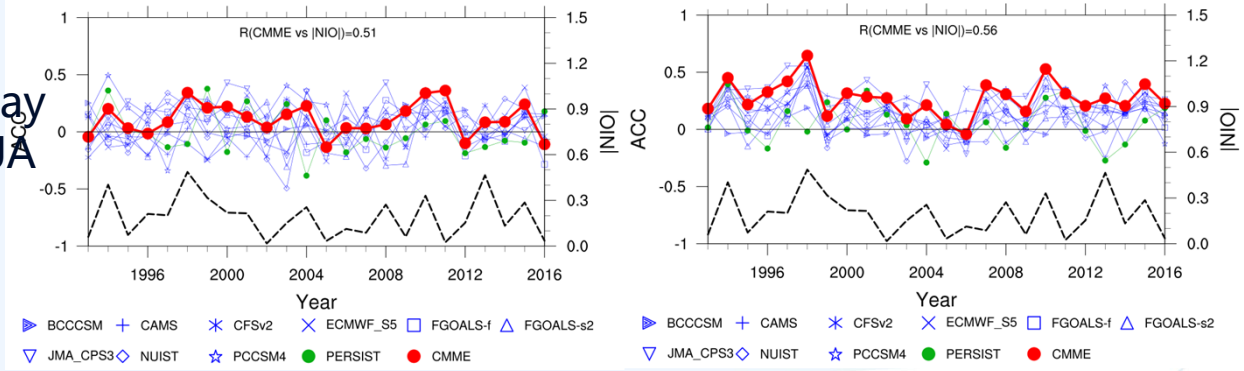
East Asian

South Asian

Ini Mar for JJA

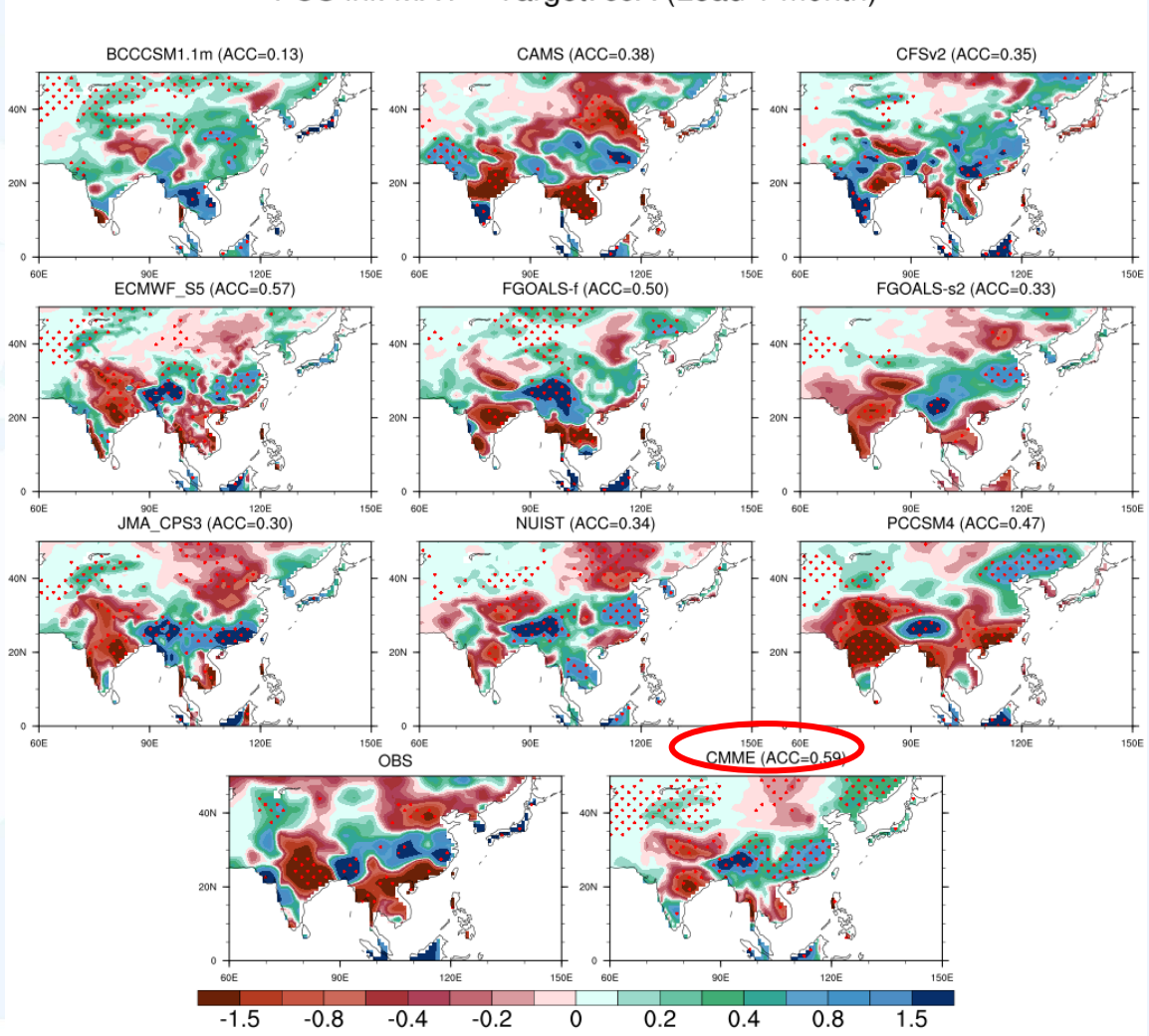


Ini May for JJA



Yearly variation of PCC and abs(NIO)

Regression of JJA PREC against NIO



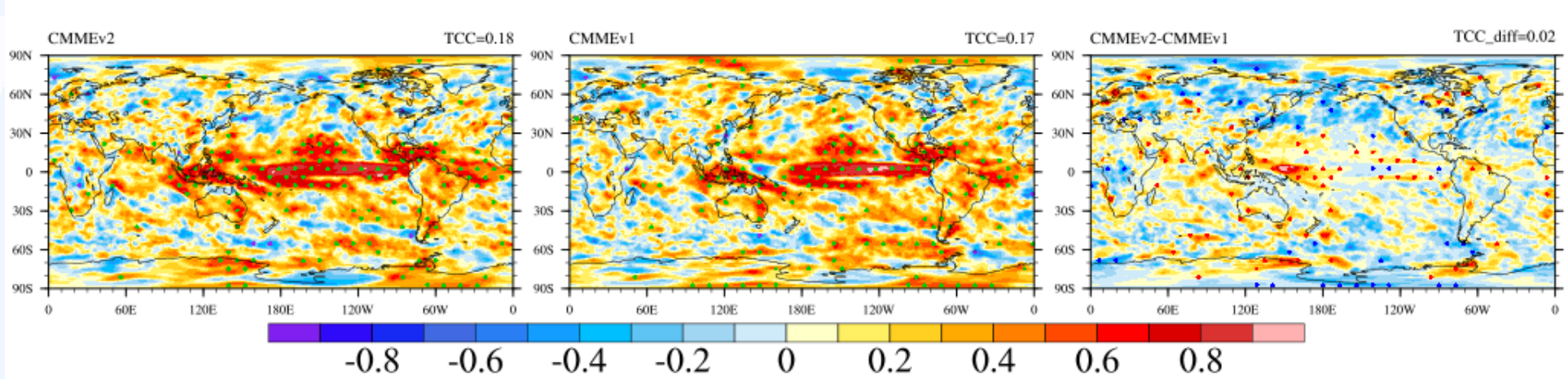
Initial from May

Skill differences between CMMEv2 and v1

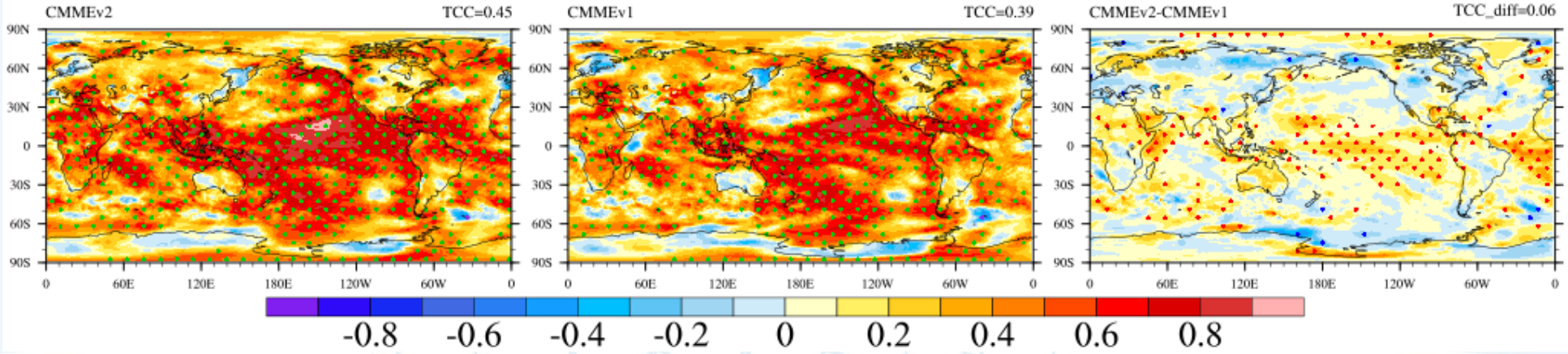
- Compared to its previous version, the **improvement of T2m** over tropics are more significant
- The **PREC skill over East Asia** during JJA has also been enhanced

CMMEv2 CMMEv1 CMMEv2-CMMEv1

PREC
Ini Mar
fcs JJA

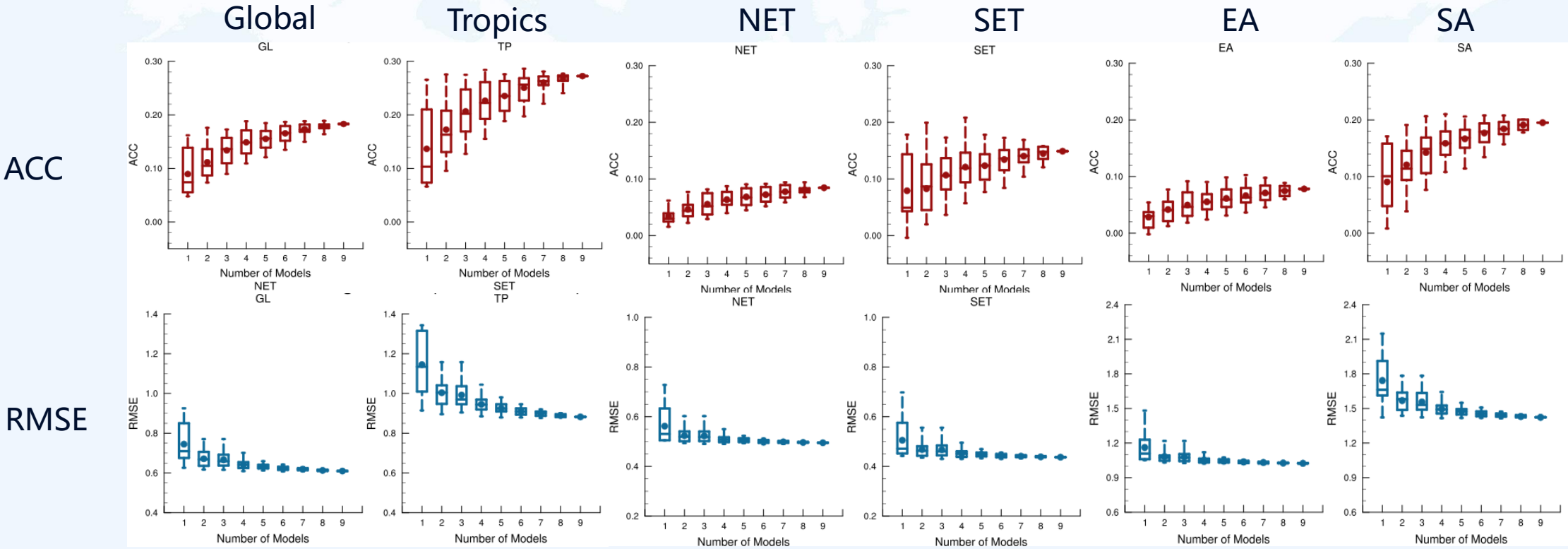


T2m
Ini Sep
fcs DJF



Skill Dependence on Ensemble members

- Question：Whether the ensemble model numbers should be further increased?
- The best skills become saturation after the ensemble models increased to 5-6 models, but the median skill of random ensemble mean is still increasing
- The **optimal sub-group ensemble** of 5-6 models could have better skill than 9-model equal-weighted ensemble mean

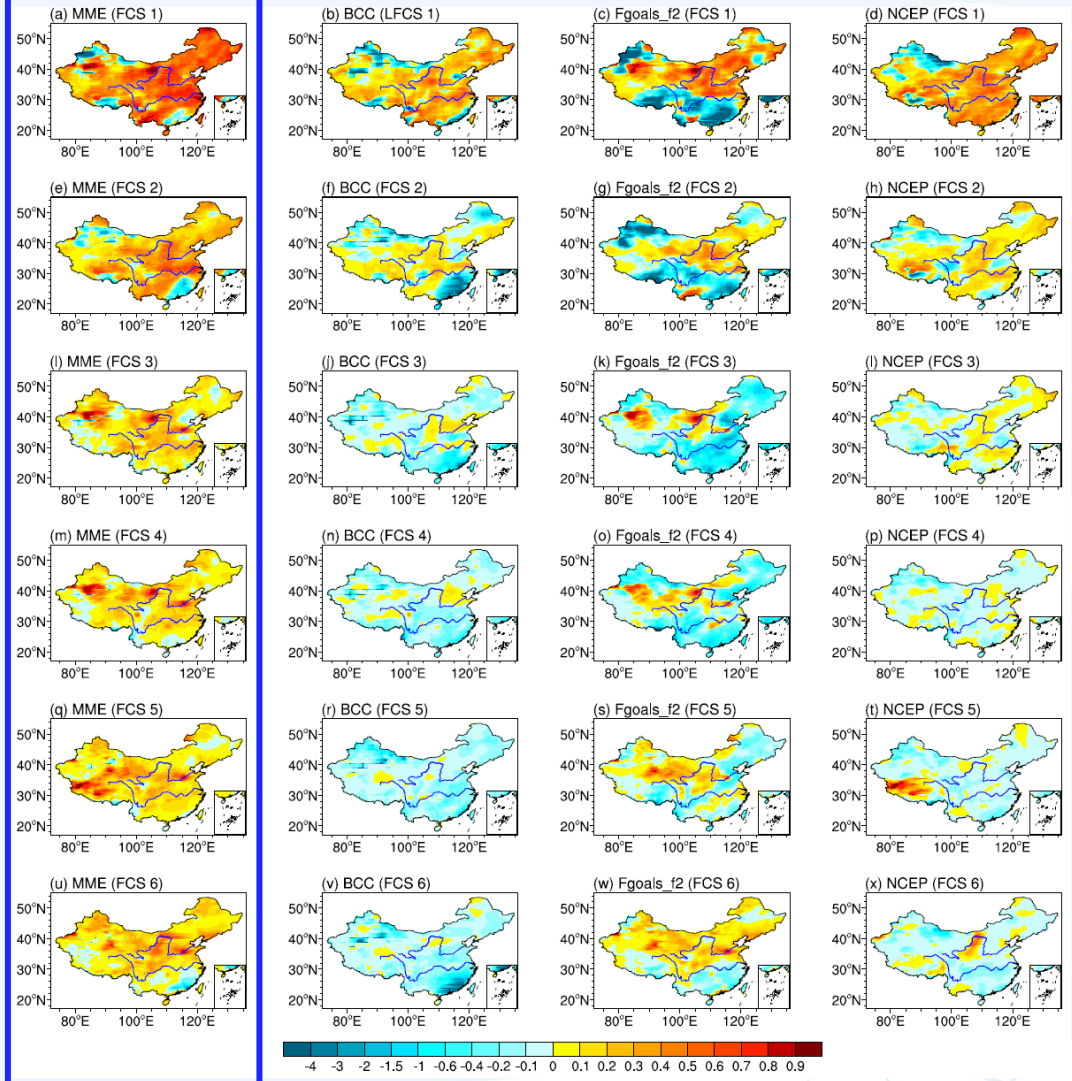


Dependence of MME skills on the numbers of models for 3-month lead JJA PREC

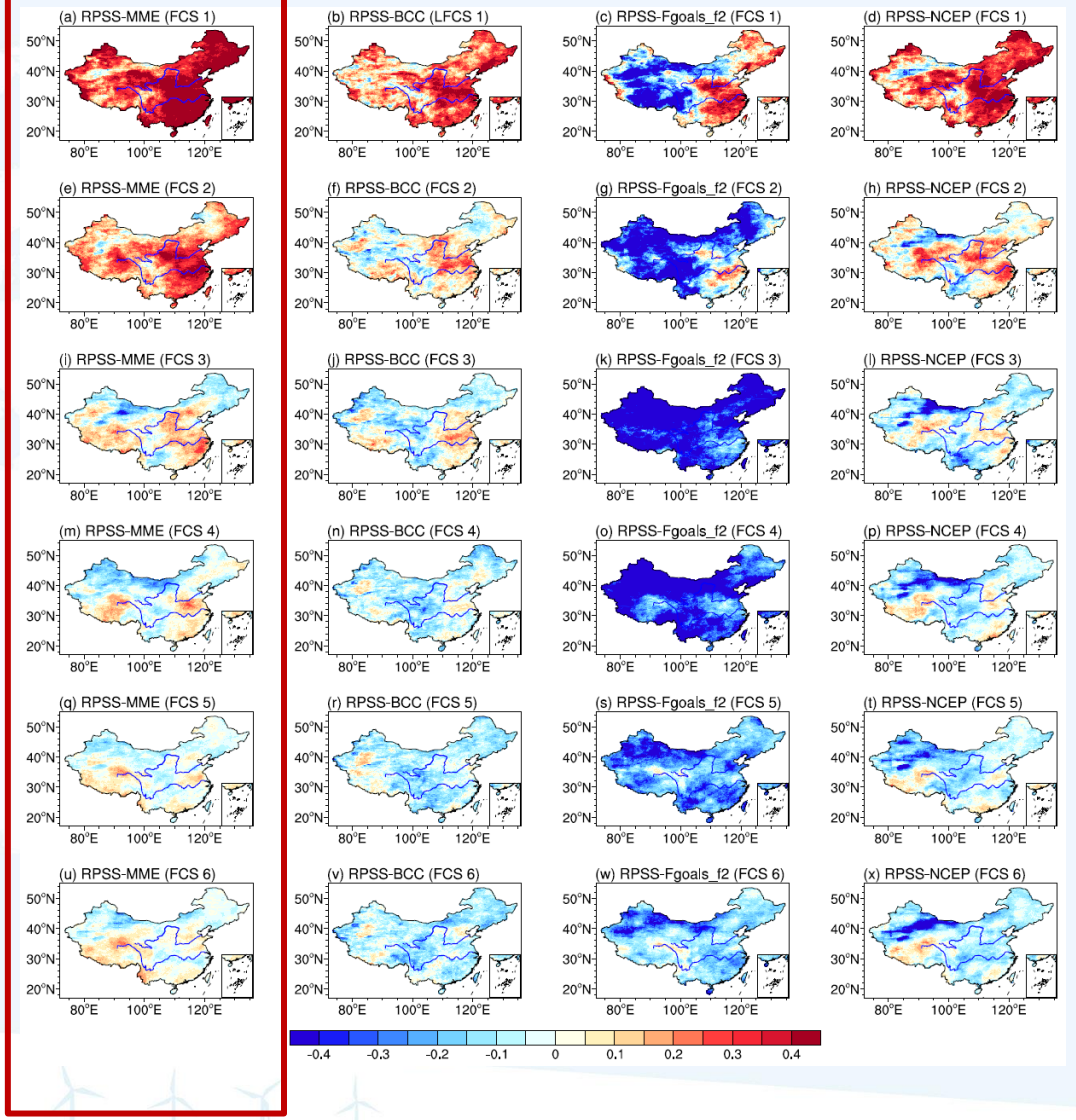
Prediction Skills of CMME-S2S

- Reduce the deterministic forecast error
- **Improve the probabilistic** skill significantly

MSSS of pentad PREC FCST

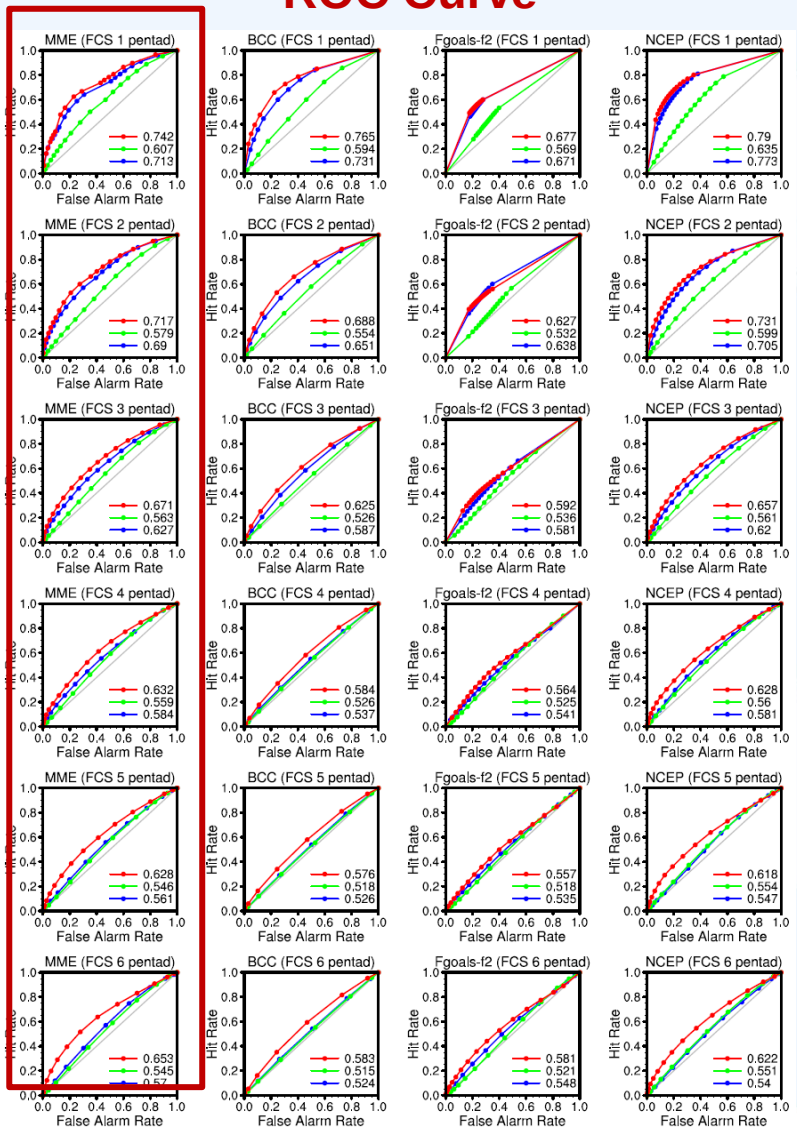


RPSS of pentad PREC FCST

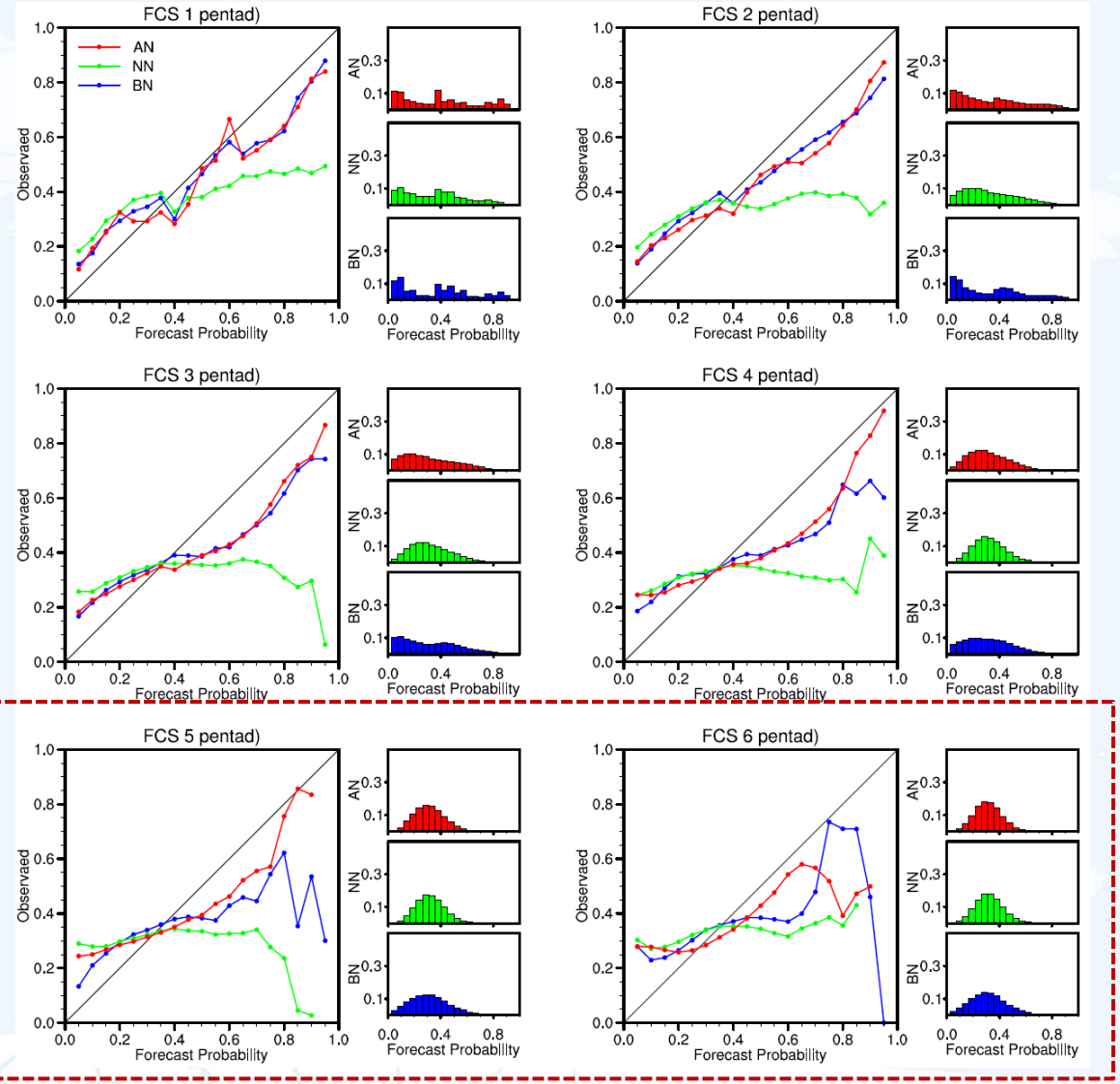


Probabilistic Skill of CMME-S2S

ROC Curve



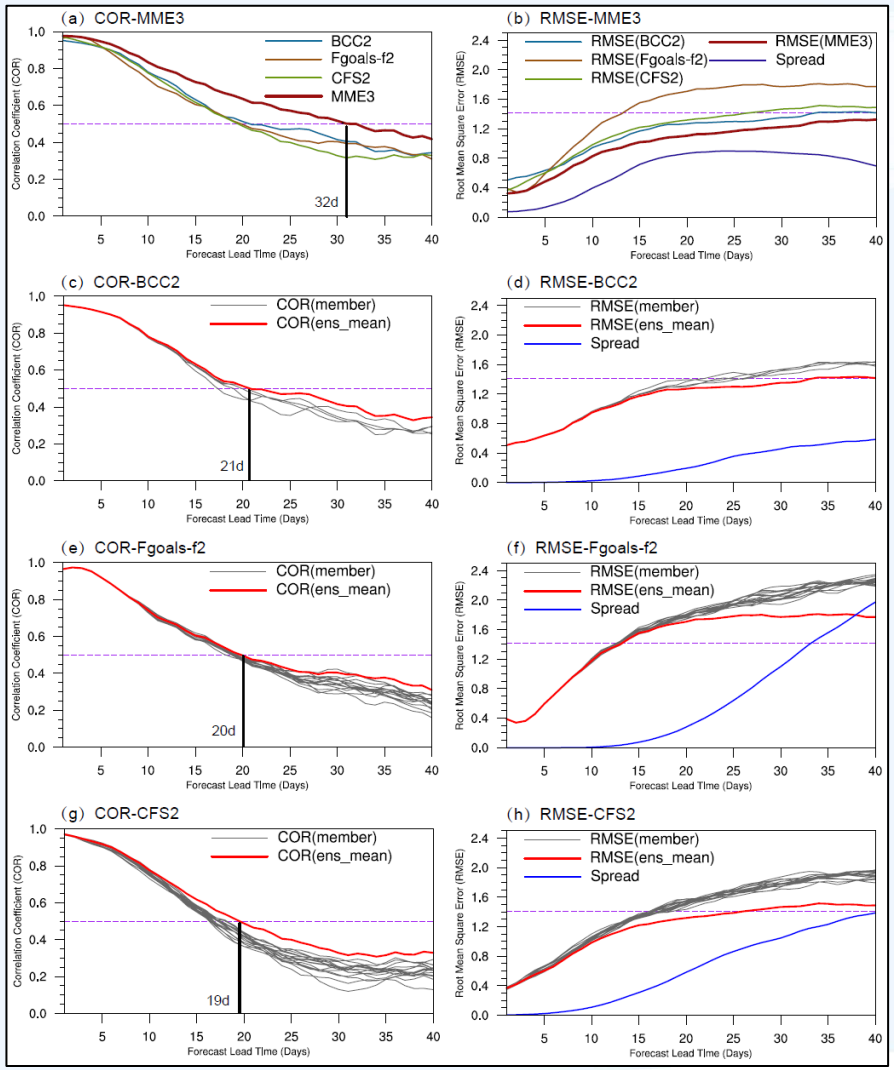
Reliability Diagram and Frequency Histogram



Under longer forecast lead time, MME still exhibit higher prediction Reliability

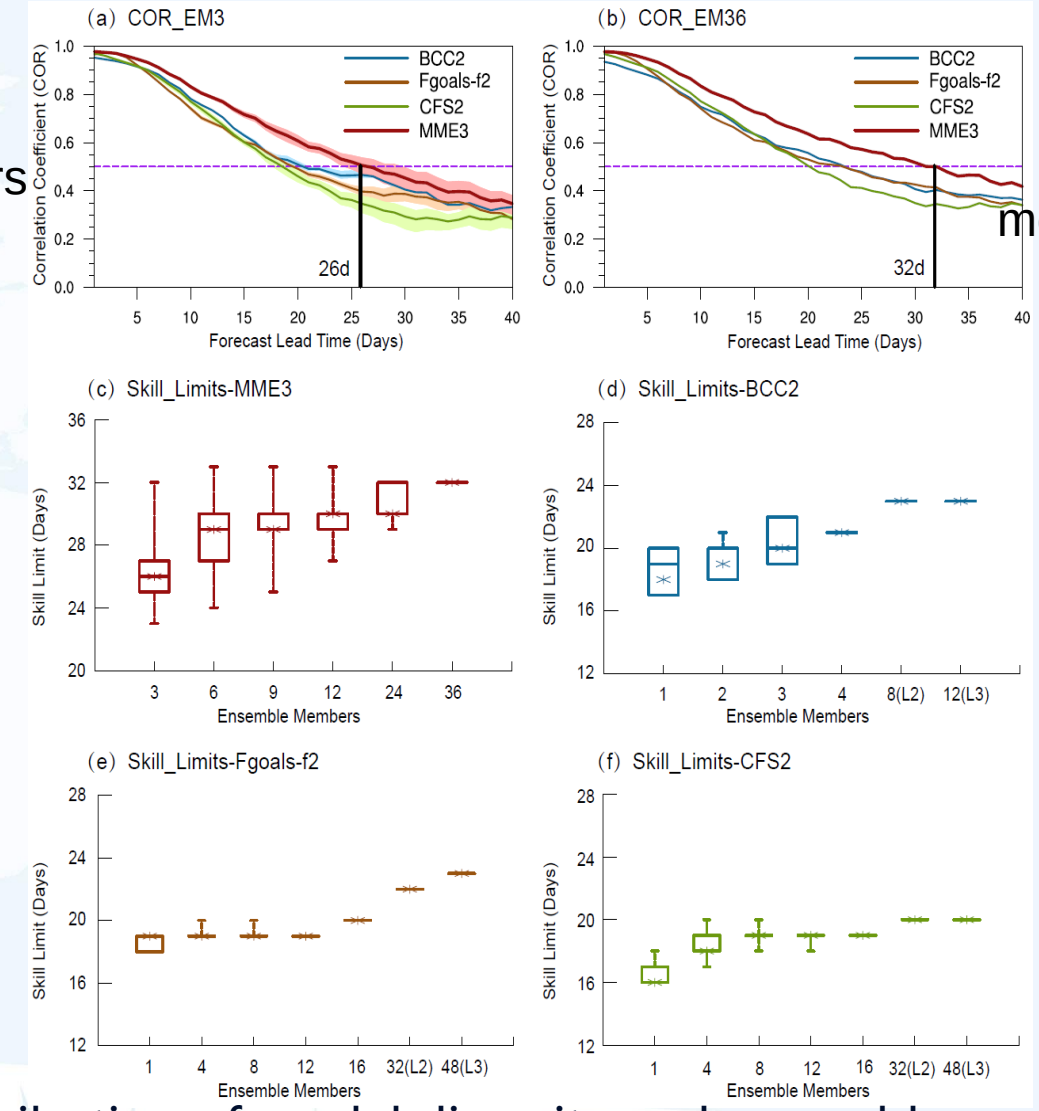
Verification of MME prediction of MJO

- Useful skills **extend to 27d** after MME



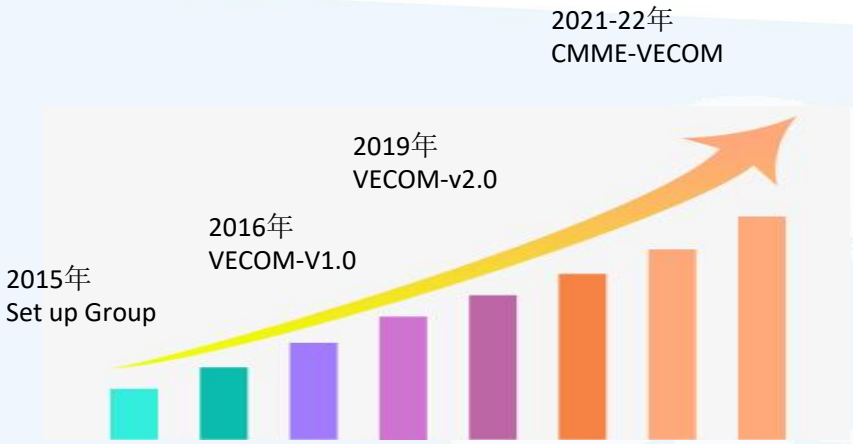
Skill verification of realtime MJO perdition

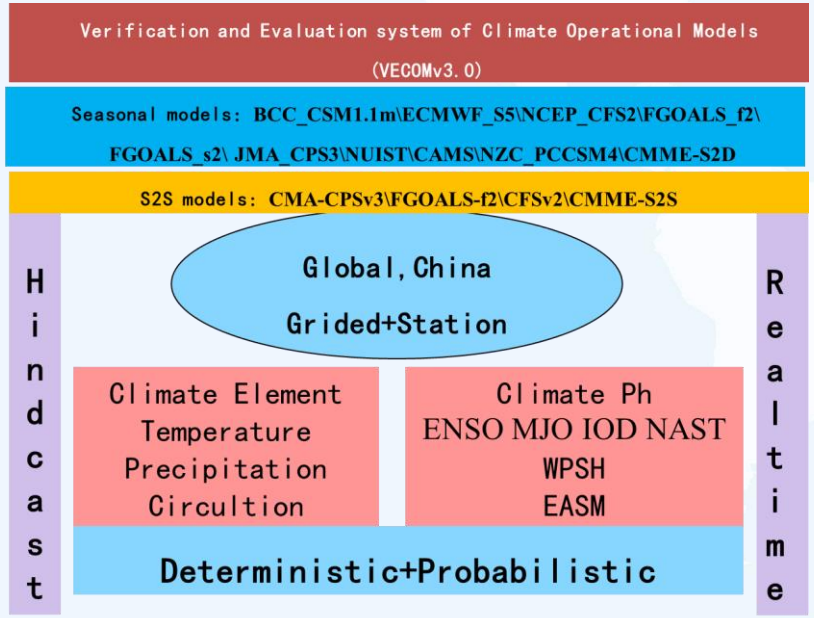
- Improvements mainly come from **model diversity**, and the increase of ensemble members also contribute



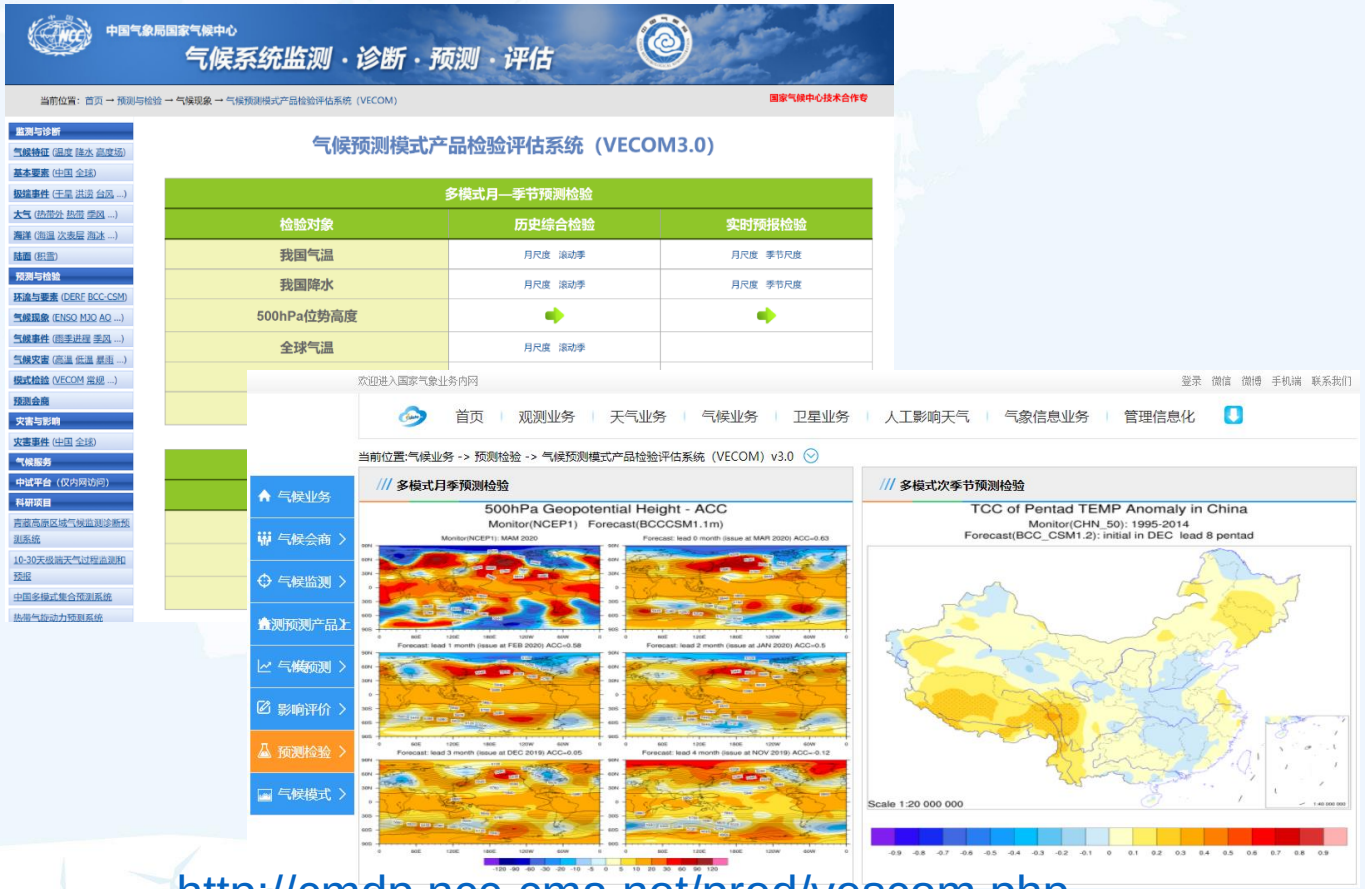
Contribution of model diversity and ensemble members

Establishment of CMME-VECOM Sub-system





- VECOM provide hindcast and realtime verification product of PREC, T2m, SST, and dominant climate phenomenon (ENSO, MJO, IOD, WPSH, EASM etal)
- Both of deterministic and probabilistic verification method are applied for CMME models



http://cmdp.ncc-cma.net/pred/vescom.php

Verification Products of Hindcast and realtime

国家气候中心
National Climate Centre

首页 | 中心概况 | 工作动态 | 业务服务 | 科技创新 | 气候科普 | 公告通知 | 技术合作

当前位置：首页 → 预测与检验 → 气候现象 → 气候预测模式产品检验评估系统（VECOM）

- 监测与诊断
  - 气候特征 (温度 降水 高度场)
  - 基本要素 (中国 全球)
  - 极端事件 (干旱 洪涝 台风 ...)
  - 大气 (热带外 热带 季风 ...)
  - 海洋 (海温 次表层 海冰 ...)
  - 陆面 (积雪)
- 预测与检验
  - 环流与要素 (DERF BCC-CSM)
  - 气候现象 (ENSO MJO AO ...)
  - 气候事件 (雨季进程 季风 ...)
  - 气候灾害 (高温 低温 暴雨 ...)
  - 模式检验 (VECOM 常规 ...)
  - 预测会商
- 灾害与影响
  - 灾害事件 (中国 全球)
- 气候服务
- 中试平台 (仅内网访问)
- 科研项目

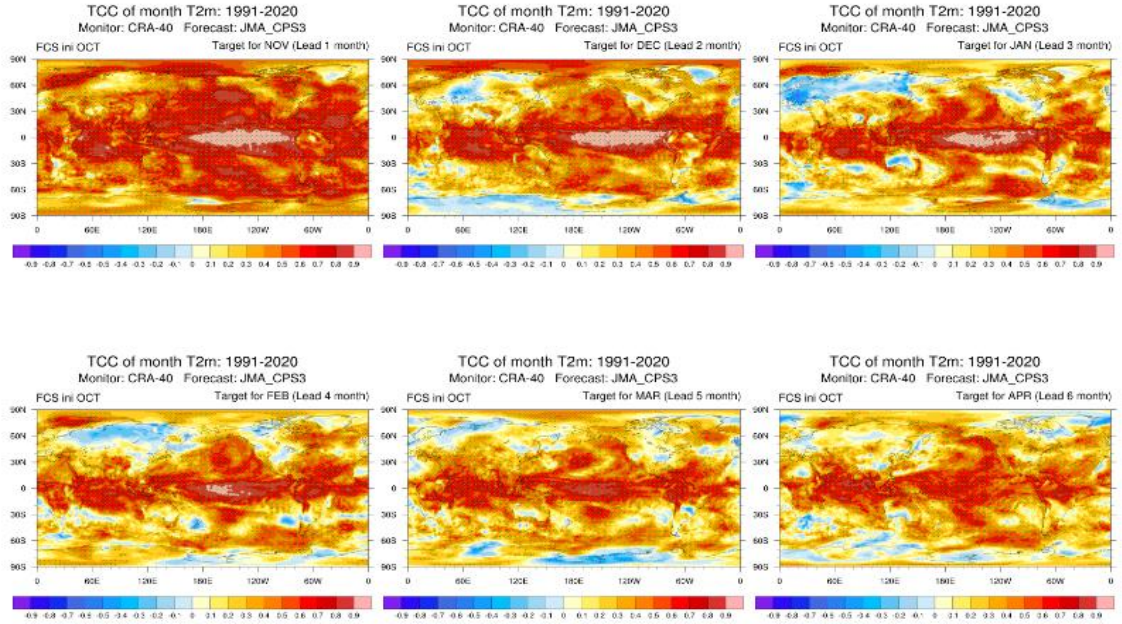
全球气温

9个models+CMME

BCC-CSM1.1m | CAMS | CFSv2 | ECMWF_S5 | FGOALS-f | FGOALS-s2 | JMA_CPS3 | NUIST | PCCSM4 | CMMEv2.0

时间距平相关系数(TCC) | 均方技巧评分(MSSS)

起报月：Oct

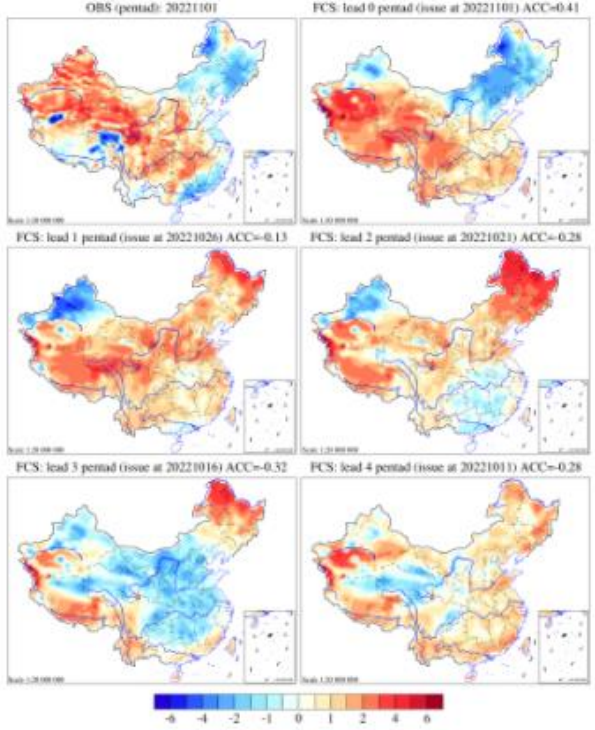


我国格点气温

BCC-CSM2-HR | CMME

系数（ACC） | 不同leadtime预报技巧对比

2022 | 11 | 01 | 显示结果图形



Outlines

1. Backgrounds
2. Establishment and Product
3. Predictability Verification
4. Summary and discussions

Summary

1) System Establishment: The China Multi-Model Ensemble (CMME) prediction system has been established and updated to its second version (CMMEv2.0), which include 4 sub-systems (CMME-S2D, CMME-S2S, CMME-CPPS and CMME-VECOM 4). Dynamical-statistical method has also been developed to further improve the prediction skills.

2) Skill verification: Compared to SME, MME effectively reduce the prediction uncertainty and improved the reliability for deterministic and probabilistic prediction. The skills for Niño3.4 reach **0.87** at 6-month lead and above **27 days** for MJO

3) Predictability sources: The predictability sources mainly come from ENSO, but also from NIO for East Asian. Both of the increasement of model diversity and ensemble members contribute to the skills improvement of MME, especially for the former one.

Further Development of CMME

Establish MME Platform

Operational models
（CESM、GFDL)

Domestics models
（FIO et al）

Model update and
feedback

Improve Prediction Skills

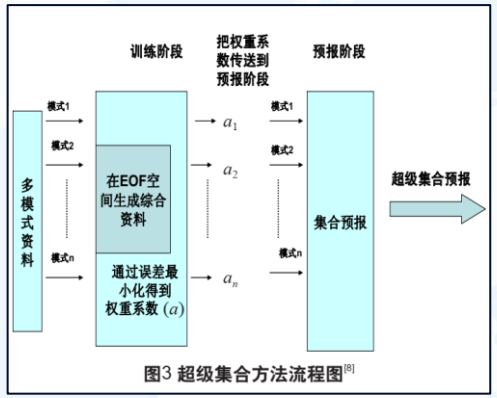
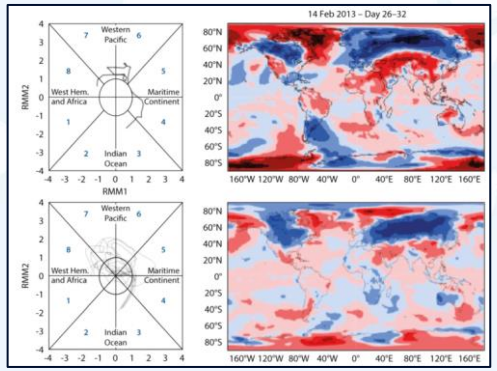


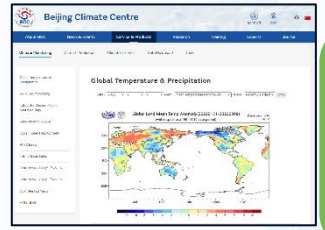
图3 超级集合方法流程图[8]

Ensemble method

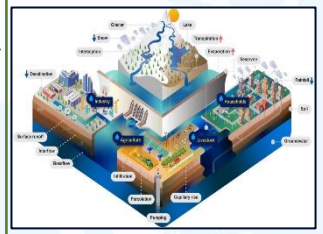


Extreme event

Expand Application



BCC
Global
Forecast

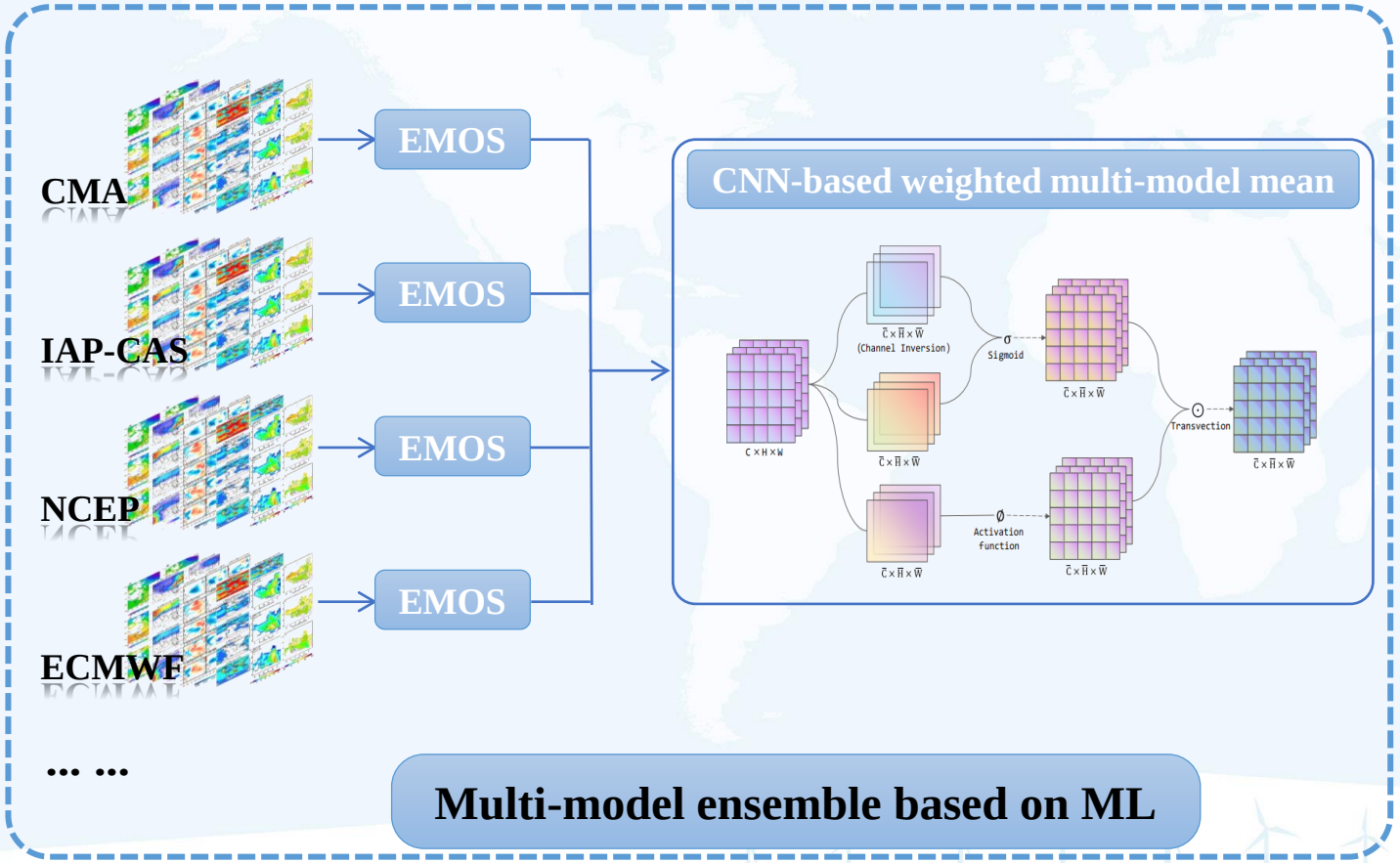


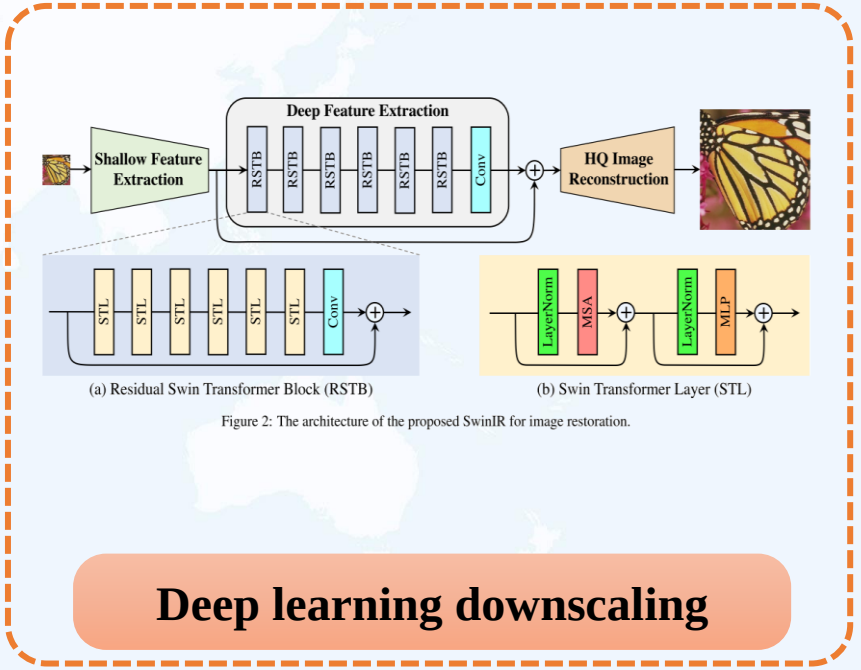
Coupled
hydrological
model

Wind & solar
Prediction

Combined with ML and DL model

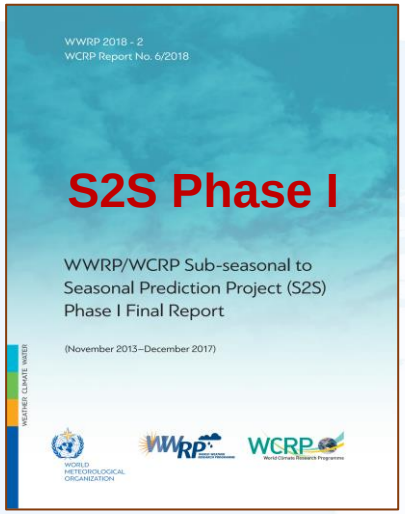
- Combine MME with artificial intelligence methods such as machine learning and deep learning,
- Build model error correction, optimal ensemble and intelligent downscaling schemes.
- Form **seamless** (subseaonal to decadal) intelligent grided climate prediction products.

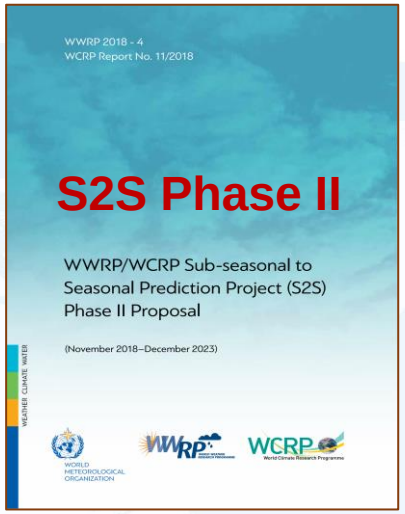




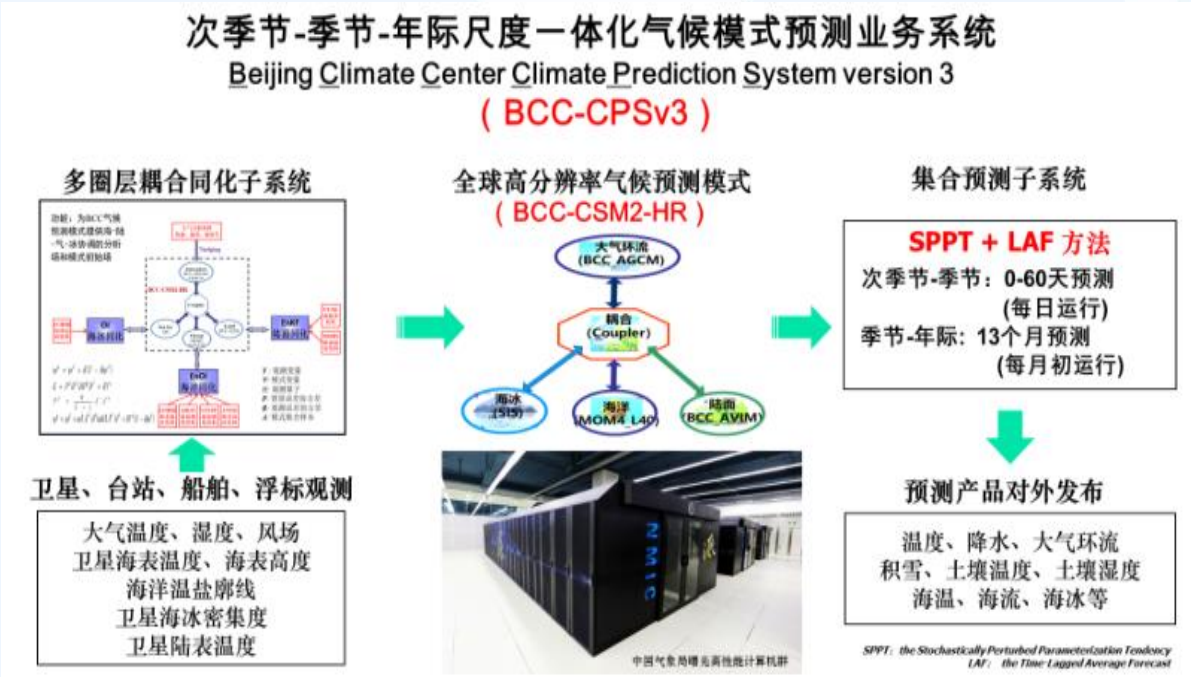

Thank you!

The major prediction method





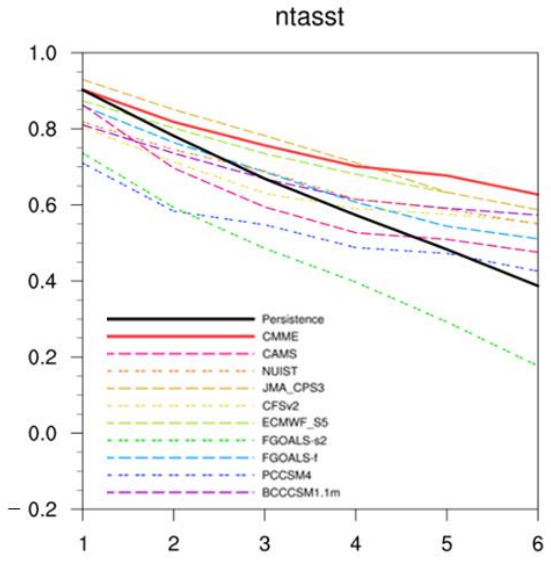
- Based on dominant predictability sources, physical statistical models, dynamical models and dynamical-statistical method has been widely used for prediction
- Dynamical model has become the most important foundation for subseasonal to decadal prediction



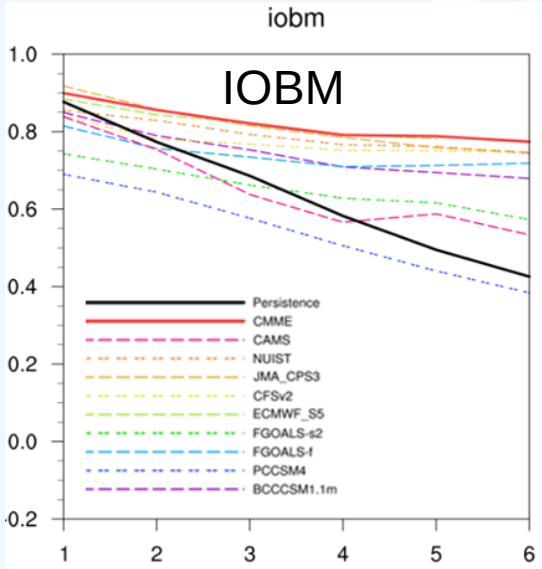
S2S Database

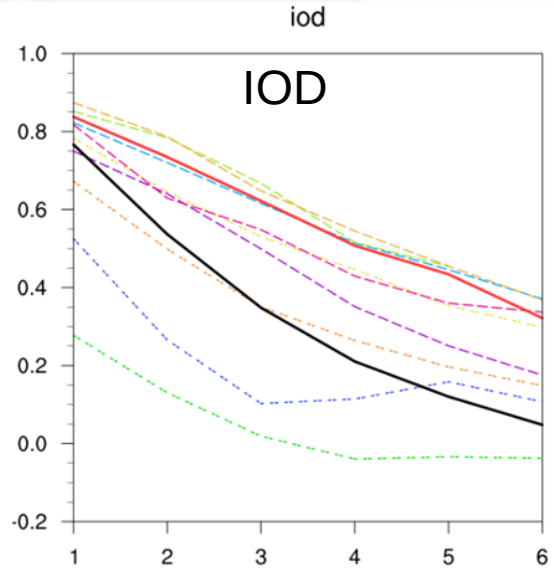
status on 2019-11-11	Time range	Resolution	Ens. Size	Frequency	Re-forecasts	Rfc length	Rfc frequency	Rfc size
BoM(ammc)	d 0-62	T47L17	3*11	2/week	fix	1981-2013	6/month	3*11
CMA(babj)	d 0-60	CMA (babj)	4	2/week	on the fly	past 15 years	2/week	4
CNR-ISAC(isac)	d 0-32	0.75x0.56 L54	41	weekly	fix	1981-2010	every 5 days	5
CNRM(lfpw)	d 0-32	T255L91	51	weekly	fix	1993-2014	4/month	15
ECCC(cwao)	d 0-32	0.45x0.45 L40	21	weekly	on the fly	1998-2017	weekly	4
ECMWF(ecmf)	d 0-46	Tco639/319 L91	51	2/week	on the fly	past 20 years	2/week	11
HMCR(rums)	d 0-61	1.1x1.4 L28	20	weekly	on the fly	1985-2010	weekly	10
JMA(rjtd)	d 0-33	Tl479/Tl319L100	50	weekly	fix	1981-2010	3/month	5
KMA(rksl)	d 0-60	N216L85	4	daily	on the fly	1991-2010	4/month	3
NCEP(kwbc)	d 0-44	T126L64	16	daily	fix	1999-2010	daily	4
UKMO(egrr)	d 0-60	N216L85	4	daily	on the fly	1993-2016	4/month	7

Prediction Skills of dominant ocean modes



NAT





Skill of IOBM for different ini months