Assessment of extended-range prediction capacity based on CMA-GEPS

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Report Outline

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1. Research Background

CMA-GEPS based probabilistic products are used widely in China and the ensemble data is also contributed to WMO THORPEX database. However, **CMA-GEPS possess limited progress related to its extended-range weather predictability and especially the study of MJO forecast is still vacant, which seriously lags behind the international development.** In order to improve extended-range prediction capacity based on CMA-GEPS further, firstly, we perform the experiments on the 1-year (Jan-Dec. 2021) period out to 35 days. And then, we try to answer the following questions.

Raise questions

- How is the extended-range prediction ability **related to the conventional meteorological elements**?
- What's **the system deviation** of CMA-GEPS related to the extended-range weather forecast?
- How well does the CMA-GEPS **predict MJO** including the intensity and phase? Further more, does the CMA-GEPS have the potential to **develop the extended-range weather forecast system**?

2. Model and Experiment

CMA-GEPS V1.2 configuration

The deterministic model	CMA-GFS V3.1
The horizontal resolution	50km, $0.5^{\circ} \times 0.5^{\circ}$
The vertical resolution	87 vertical levels (model top at 0.01hPa)
The initial perturbation method	The Singular Vectors (SVs) approach
The model perturbation approach	Stochastically Perturbed Parameterization Tendencies (SPPT) and the Stochastic Kinetic Energy Backscatter (SKEB) skems
Ensemble members	31 (30 perturbation members and 1 control member)
Model output frequency	**Every 24 hours**
Forecast Length	**35 days**
Initial analysis	4-Dimension Variational Assimilation Approach
SST forcing	SST is initialized with the OISST data set of NOAA and remains unchanged in the model running.

Experiment and Methodology

- All the experiments are initialized **on Wednesday 00 UTC every 7 days** from **Jan 1st, 2021 to Dec 31th, 2021**.
- **MJO is evaluated** using the traditional real-time multivariate (RMM) MJO index. (formula (1))
- **MJO skill is calculated** using the bivariate anomaly correlation between the forecast and analysis RMM index. (formula (2) and formula (3))
- **MJO amplitude errors** can be calculated as formula (4) and **MJO phase errors** can be calculated as formula (5) .

$$COR(\tau)=\frac{\sum_{t=1}^{N}[a_1(t)b_1(t,\tau)+a_2(t)b_2(t,\tau)]}{\sqrt{\sum_{t=1}^{N}[a_1^2(t)+a_2^2(t)]}\sqrt{\sum_{t=1}^{N}[b_1^2(t,\tau)+b_2^2(t,\tau)]}} \quad (1)$$

$$RMMA_{for}(t,\tau)=\sqrt{b_1(t,\tau)^2+b_2(t,\tau)^2} \quad (2)$$

$$RMMA_{obs}(t)=\sqrt{a_1(t)^2+a_2(t)^2} \quad (3)$$

$$ERR_{amp}(\tau)=\frac{1}{N}\sum_{t=1}^{N}(RMMA_{for}(t,\tau)-RMMA_{obs}(t)) \quad (4)$$

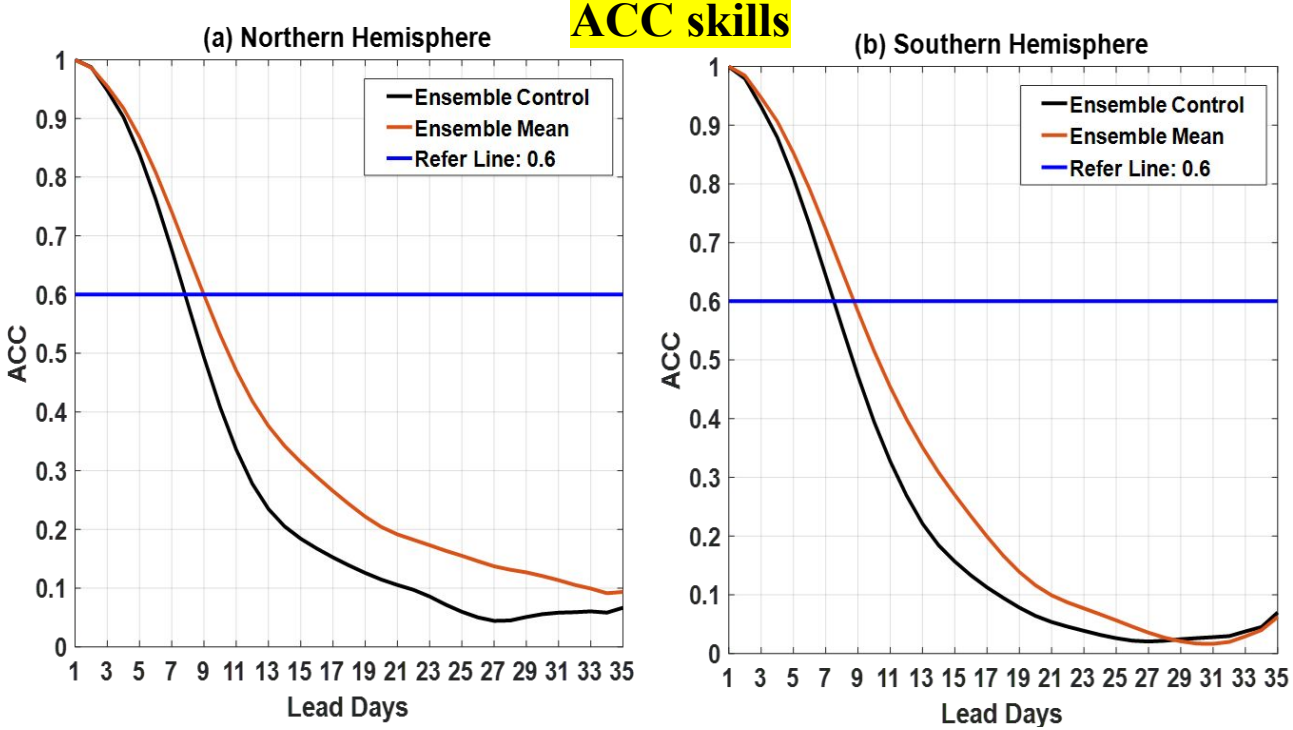
$$ERR_{phs}(\tau)=\frac{1}{N}\sum_{t=1}^{N}\tan^{-1}\left(\frac{a_1b_2-a_2b_1}{a_1b_1+a_2b_2}\right) \quad (5)$$

in which $a_1(t)$, $a_2(t)$ is RMM1 and RMM2 based on the observations and $b_1(t,\tau)$, $b_2(t,\tau)$ is the predicted RMM1 and RMM2 leading τ days at time t

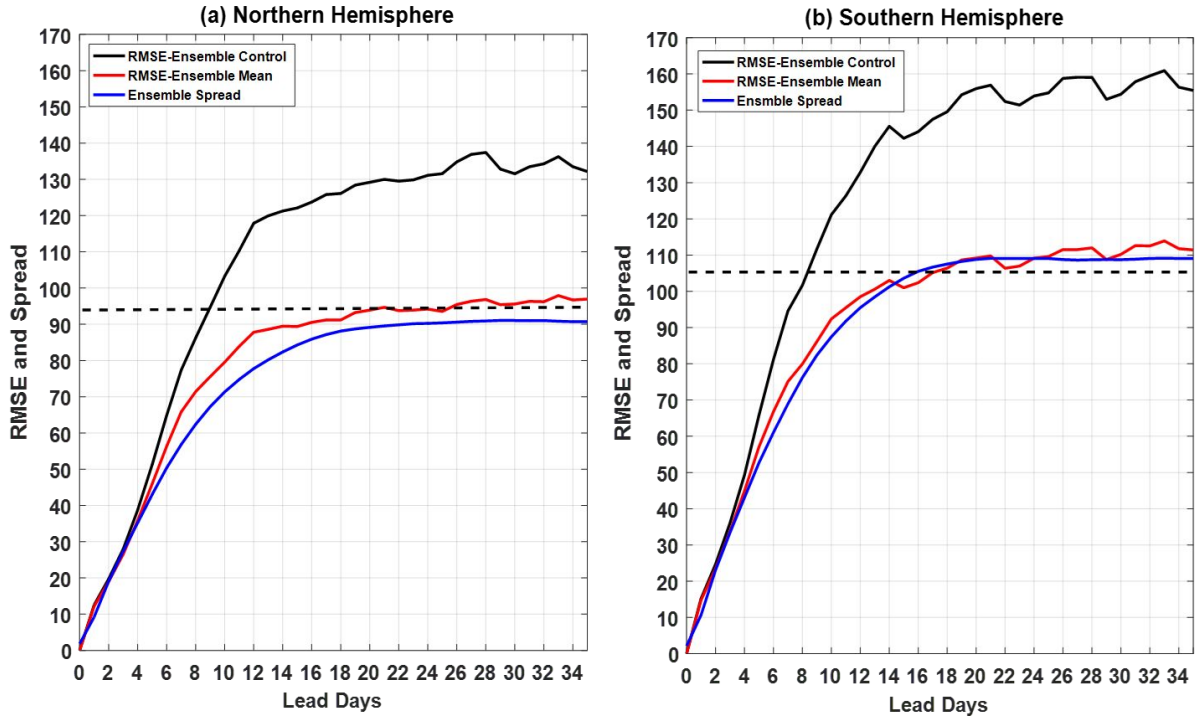
3. Analysis of extended-range weather forecast ability related to the conventional meteorological elements

500hPa geopotential height

ACC skills



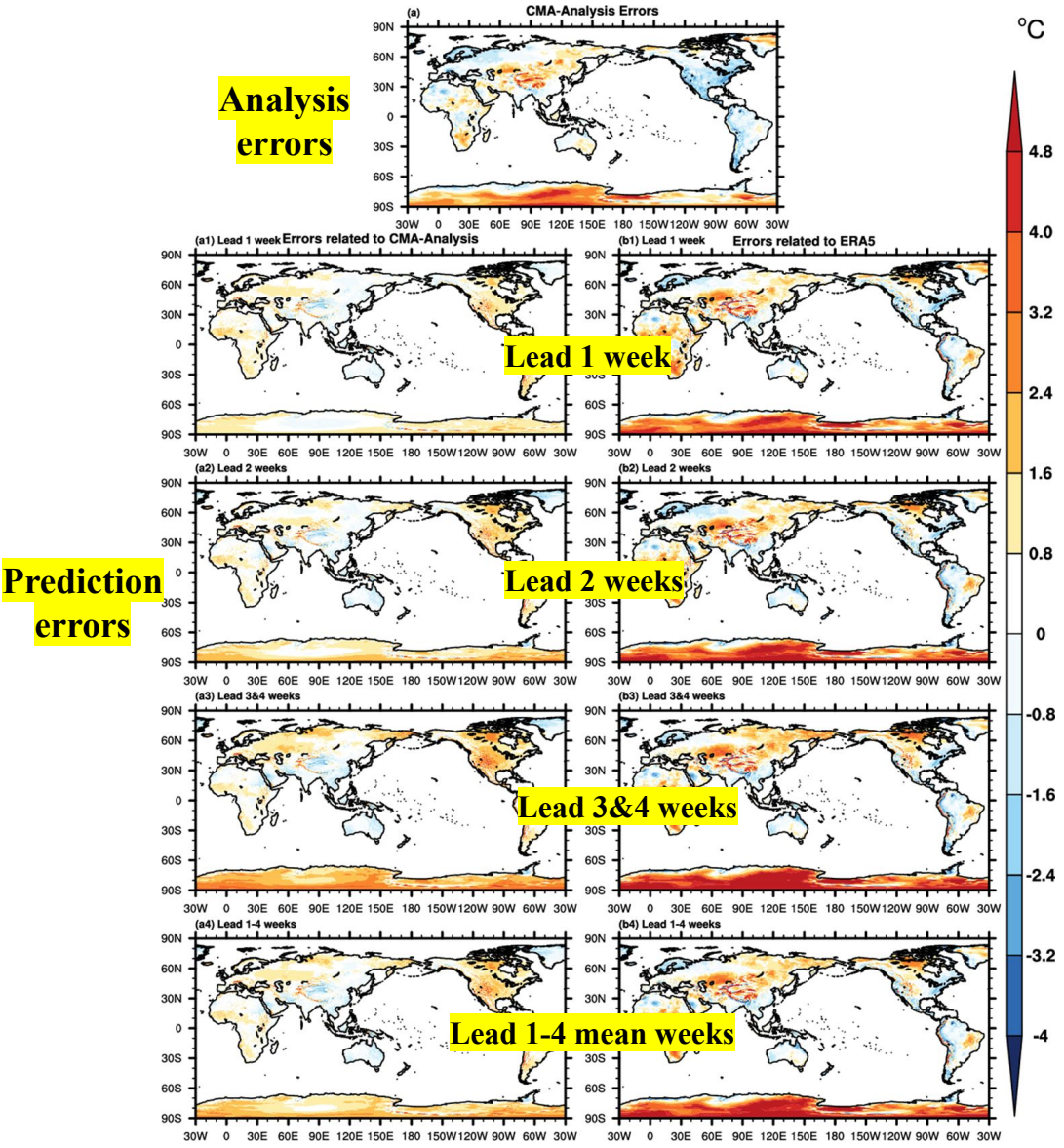
RMSE and Ensemble Spread



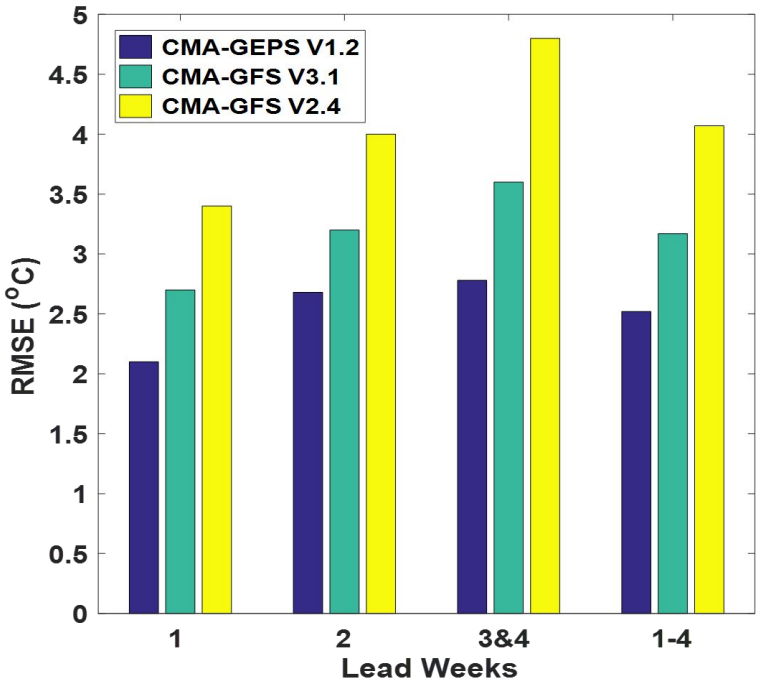
- The ACC skills were 9 days and 8.7 days and the effective forecast days of ensemble prediction are 1.2 days and 1.3 days rise than that of the control prediction in the northern and southern hemisphere respectively .
- The ensemble forecasting system is more predictable than the deterministic prediction on the extension scale, and the potential forecast days in the northern and southern hemispheres are 18 and 16 days, respectively.

Extended-Range prediction skills of 2-m temperature

Relative errors



RMSE with different group of test

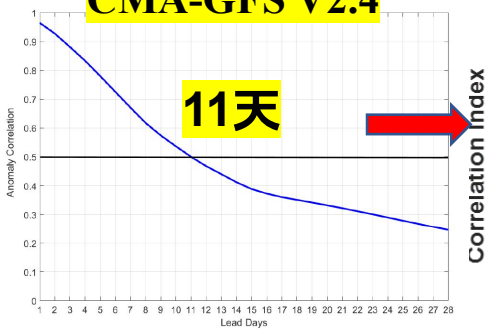


- Compared to the control prediction and the CMA-GFS V2.4, the system deviation of 2-m temperature with CMA-GEPS V1.2 was significantly reduced on each prediction time scale.

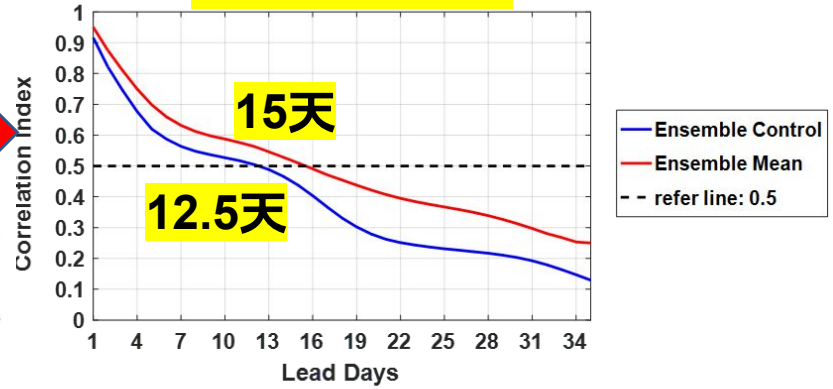
- CMA-GEPS could describe the spatial distribution characteristics of 2-m temperature field well on the extension period scale.
- 2-m temperature prediction errors mainly concentrate in the desert or plateau areas where there exist significant thermal forcing effects.

4 MJO prediction capacity assessment and error analysis with CMA-GEPS

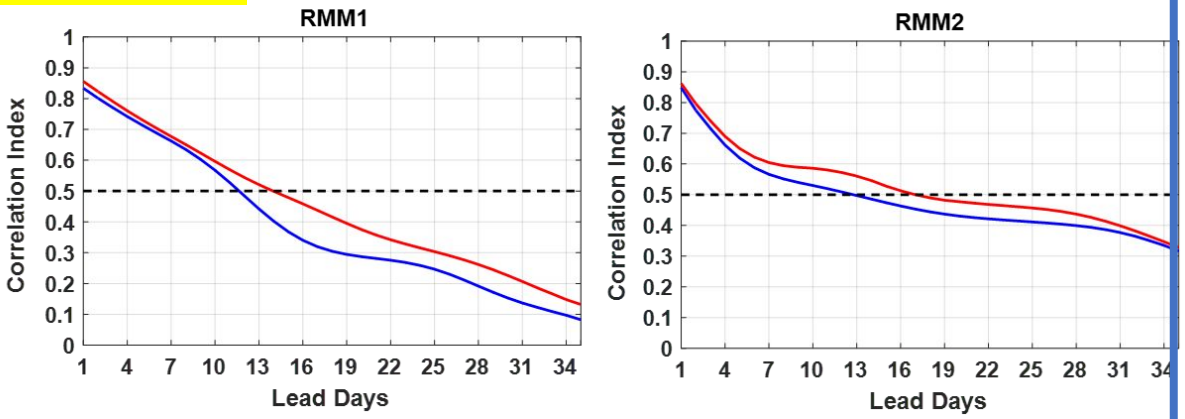
CMA-GFS V2.4



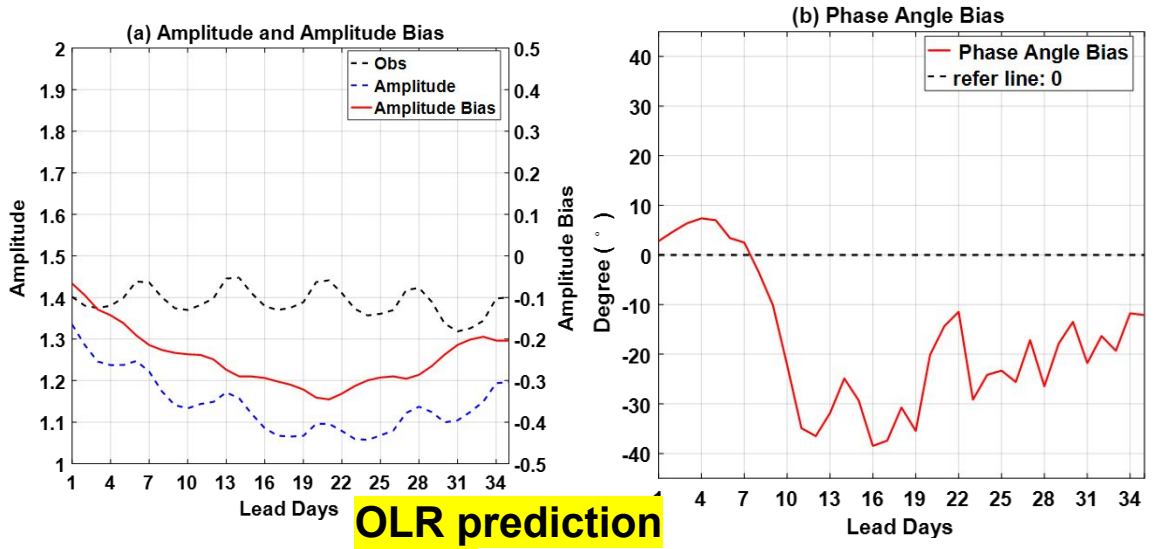
CMA-GEPS V1.2



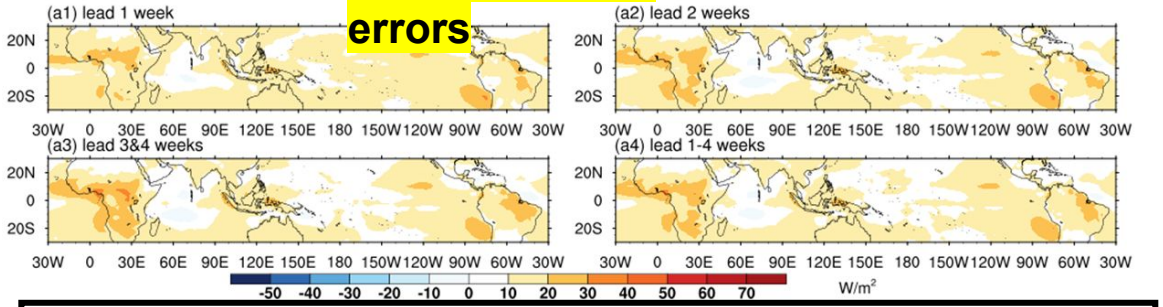
MJO prediction skill



MJO amplitude and phase bias



OLR prediction errors

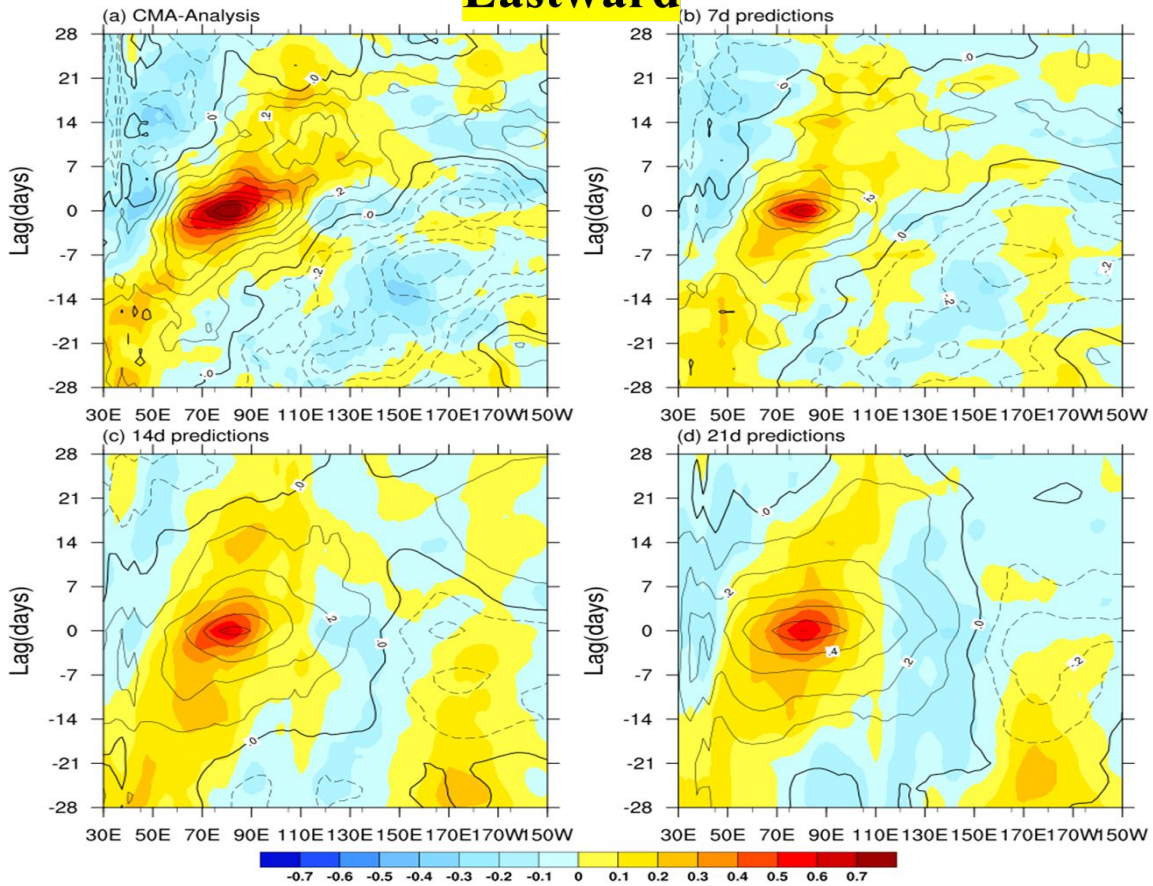


- The improvement of MJO prediction skills can be resulted from the model's development including the assimilation system and the physical process in the model. Also, the ensemble skills can greatly improve MJO prediction ability.
- CMA-GEPS has the capacity to further develop the extended-range ensemble predictions.

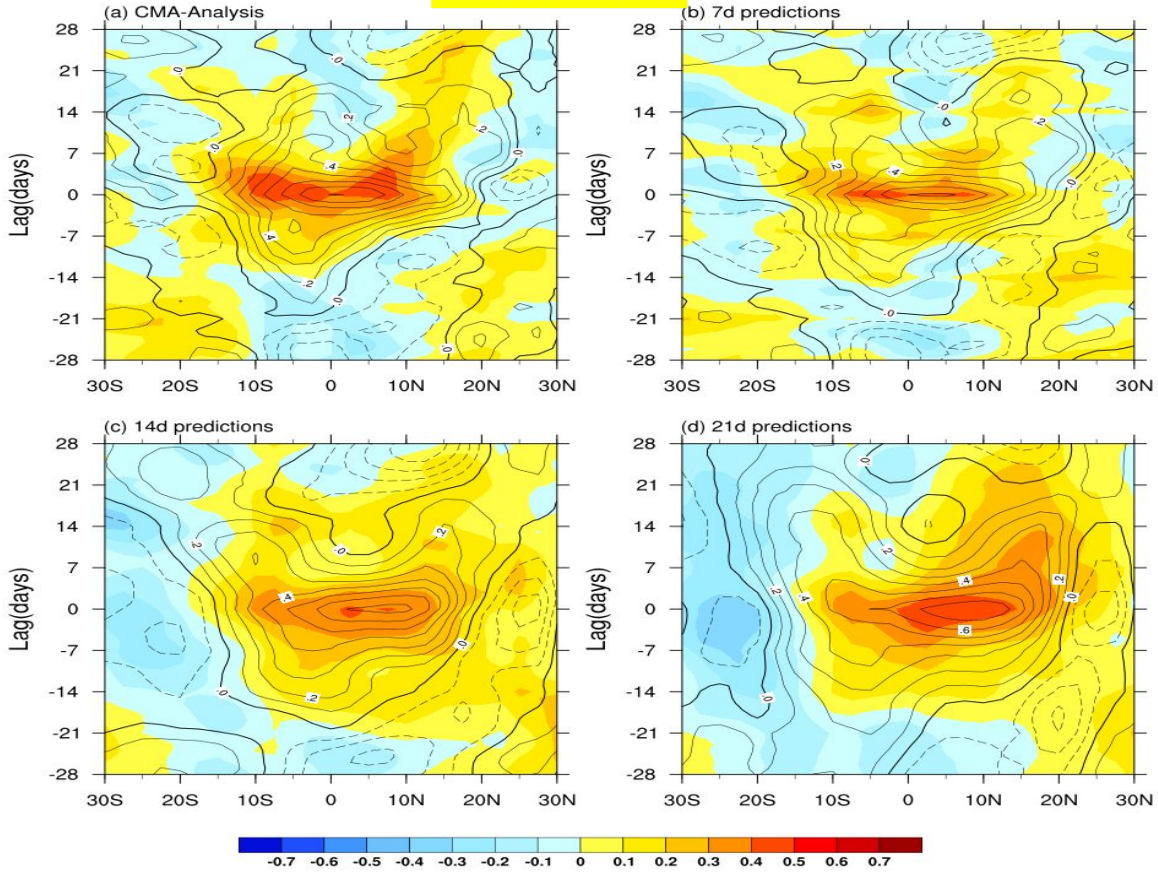
- The intensity prediction was weaker than the analysis, which may be due to the weak tropical convective system.
- The propagation speed of 1-8 days leading prediction was a little faster and that of 9-35 leading days was slower than the analysis.

MJO Propagation Characteristics Analysis

Eastward



Northward



Similarity coefficients

Propagation Direction	7 天预报	14 天预报	21 天预报
Eastward	$R_{U850} = 0.95$	$R_{U850} = 0.79$	$R_{U850} = 0.54$
	$R_{OLR} = 0.8$	$R_{OLR} = 0.61$	$R_{OLR} = 0.58$
Northward	$R_{U850} = 0.93$	$R_{U850} = 0.76$	$R_{U850} = 0.53$
	$R_{OLR} = 0.78$	$R_{OLR} = 0.59$	$R_{OLR} = 0.54$

- CMA-GEPS could predict the eastward and northward signal well.
- The prediction of circulation signal propagation characteristics is better than that of convective signal.
- MJO eastward propagation characteristics are better than those of northward propagation.

5 Summary and Further Work

- The ensemble forecasting system **is more predictable than the deterministic prediction** on the extension scale related to 500hPa geopotential height.
- CMA-GEPS could **describe the spatial distribution of the temperature field well** on the extension period scale.
- CMA-GEPS could skillfully **forecast MJO with 15 leading days**, which were superior to other general circulation models.
- The intensity prediction of MJO **was weaker** than the analysis; the propagation speed of **1-8 days leading** prediction **was a little faster** and that of **9-35 leading days was slower** than the analysis.
- The prediction of **circulation signal propagation characteristics is better than that of convective signal**, and MJO **eastward** propagation characteristics **are better** than those of **northward** propagation for CMA-GEPS.
- In the following study, the impact of **SST forcing** on the extended range temperature, accumulated precipitation and MJO skills are examined using CMA-GEPS V1.2 with **various SST forcing configurations**.

Thank you!