The Development of Coupled GEFS: Status and Challenges

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Outline

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Introduction

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- NOAA/NCEP is planning to implement a fully coupled UFS global forecast system (GFS) and Global Ensemble Forecast System (GEFS) in 2025. This is the first time for a fully coupled global model to be implemented in NOAA's operational modeling suite for medium range prediction.
- Significant changes of model behavior are expected given the fact that model is upgraded from a ATM-only model to a fully coupled ATM-LAND-OCN-ICE-WAV-CHM model. There is a critical need to test and evaluate the fully coupled GEFS in preparation for the next model upgrade.

Status of the coupled GEFS

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- Four ensemble prototypes (EP1 - EP4) have been developed along with the development of UFS coupled model prototypes (P1-P8, HR1, HR2...)
- For each EP, a 2-year (Oct 2017 - Sep 2019) weekly run experiment has been conducted to evaluate the model performance.
- EP4a (EP4 aerosol) is being planned now, and probably EP5 (HR2 based) will be the next in the row if time allows.
- Overall, all the EPs show improvements compared with GEFSv12, some results from the latest EPs (EP3 and EP4) will be showed in this talk.

ICs in the Ensemble Prototypes (EPs)

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	EP1(p5) (C384L64, OCN_L75)	**EP2(p7)** (C384L97,OCN_41)	**EP3(p8)** (C384L97,OCN_41)	**EP4(HR1+)** (C384L127,OCN_75)
ATM	GFSv15 EnKF&ANL (L64)	GFSv15 EnKF&ANL (L97) sfc spinup (NOAH-MP)	GFSv15 EnKF&ANL (L97) (new oro) sfc spinup (NOAH-MP) updated	GFSv15 EnKF&ANL (L127) (new oro) sfc spinup (NOAH-MP) HR1 updated
OCN	CFSR Salinity and T	CFSR Salinity and T	ORAS5 anl + pert	ORAS5 anl + pert
ICE	CPC ice analysis	CPC ice analysis	CPC ice analysis	CPC ice analysis
WAV	CFSv2 wind/ice forcing	GFSv15 wind/ice forcing	GFSv15 wind/ice forcing	GEFSv12/GFSv16 wind/ice forcing

Model physics and perturbations

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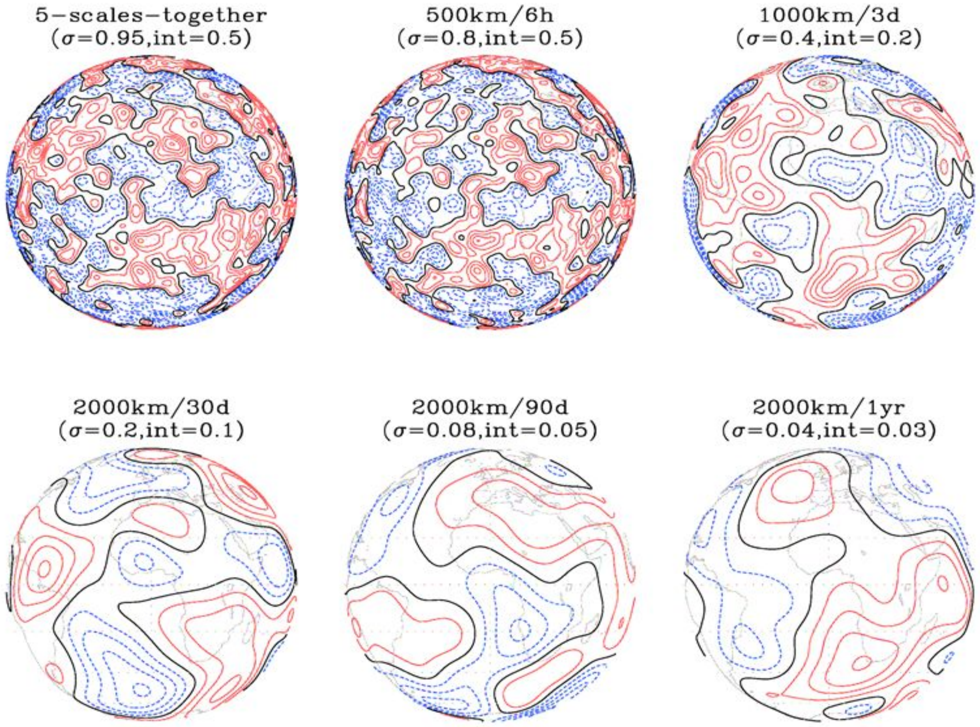
	EP1(p5) (C384L64, OCN_L75)	EP2(p7) (C384L97,OCN_41)	EP3(p8) (C384L97,OCN_41)	EP4(HR1+) (C384L127,OCN_75)
phy	Hybrid-EDMF Sa-SAS GFDL-MP GWD (stationary oro) NOAH-LSM …	Sa-TKE-EDMF Sa-SAS GFDL-MP GWD (stationary oro) NOAH-MP NSST …	Sa-TKE-EDMF Sa-SAS Thompson-MP uGWDv0+GSL NOAH-MP NSST …	Sa-TKE-EDMF Sa-SAS Thompson-MP uGWDv0+GSL NOAH-MP NSST …
stoch	SPPT (25% off) SKEB (0.7)	SPPT(30% off) SKEB (0.7) CA pert_mp, radtend ocnSPPT(100%) ePBL(100%)	SPPT (25% off) SKEB (0.8) CA pert_mp, radtend ocnSPPT(100%) ePBL (100%)	SPPT (30% off) SKEB (0.8) CA pert_clds ocnSPPT(100%) ePBL (100%)

Model perturbations: SPPT/SKEB

- **SKEB**: Estimate energy lost each time step and inject this energy in the resolved scales. a.k.a stochastic energy backscatter (SKEB; Berner et al. 2009)
- **SPPT**: perturb the results from the physical parameterizations (or tendency) (Palmer et al. 2009)
- CA: Cellular Automata - A Stochastic Parameterization of Organized Tropical Convection (Bengtsson et al. 2021).
- oSPPT: Perturb the ocean temperature, Salinity and thickness of ocean layer
- ePBL: Perturb the KE generation and dissipation of ocean PBL

Examples of stochastic patterns for SPPT



Skill Scores: RMSE/SPRD

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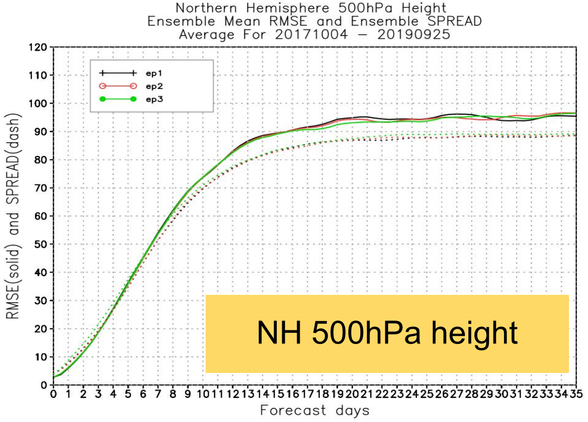

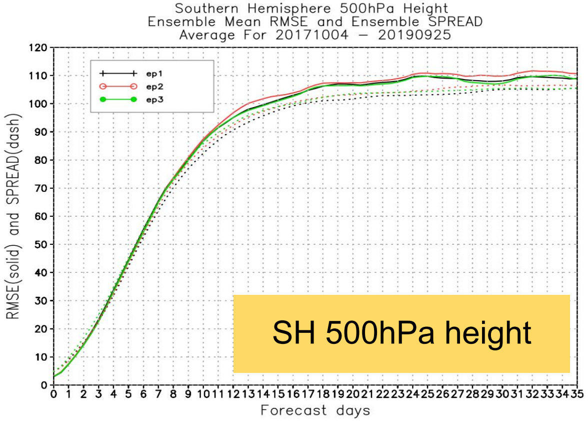

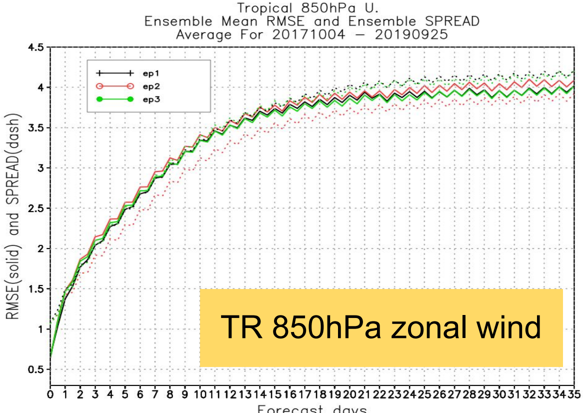

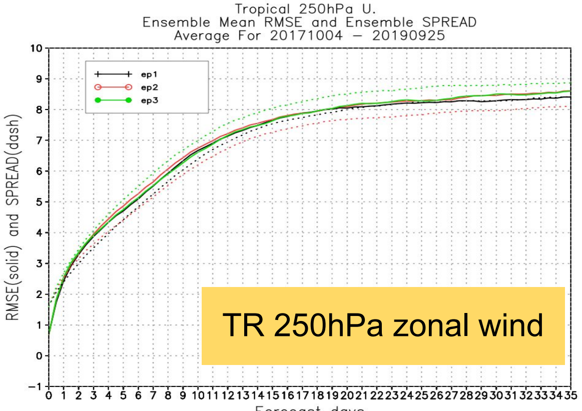

- Ensemble spread is highly dependent on the stochastic perturbations. It is tunable by adjust the coefficients of SKEB and SPPT
- Ex-tropical: contributed mainly from SKEB; all three EPs are very similar
- Tropical area: contributed mainly from SPPT; EP2 is underdispersion for both 850hPa and 250hPa, but EP1 and EP3 are slightly over-dispersion
- The spread of tropical wind is highly impacted by model physics

Vertical cross-section: RMSE/SPRD

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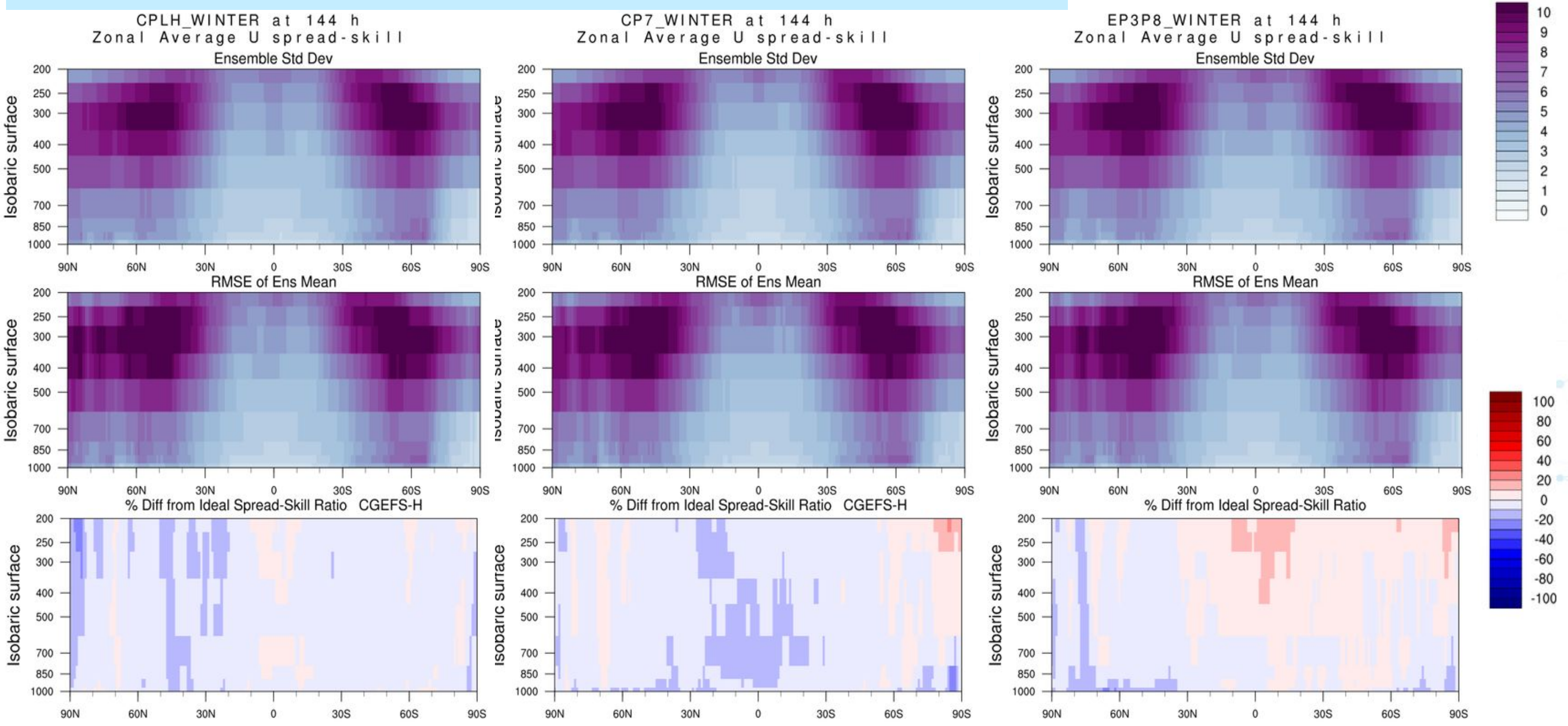

Vertical cross-section: RMSE/SPRD

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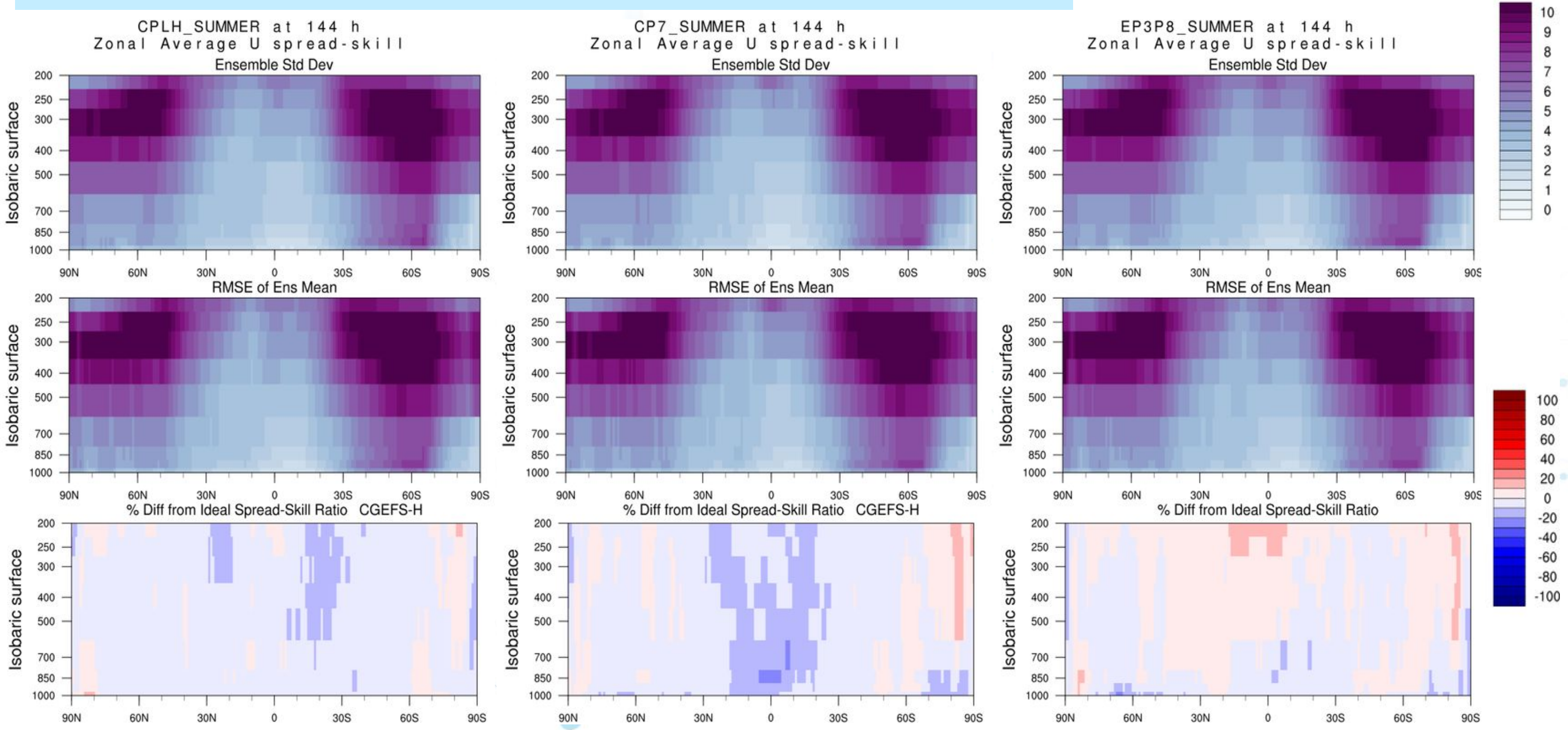

Vertical profile: physical tendency

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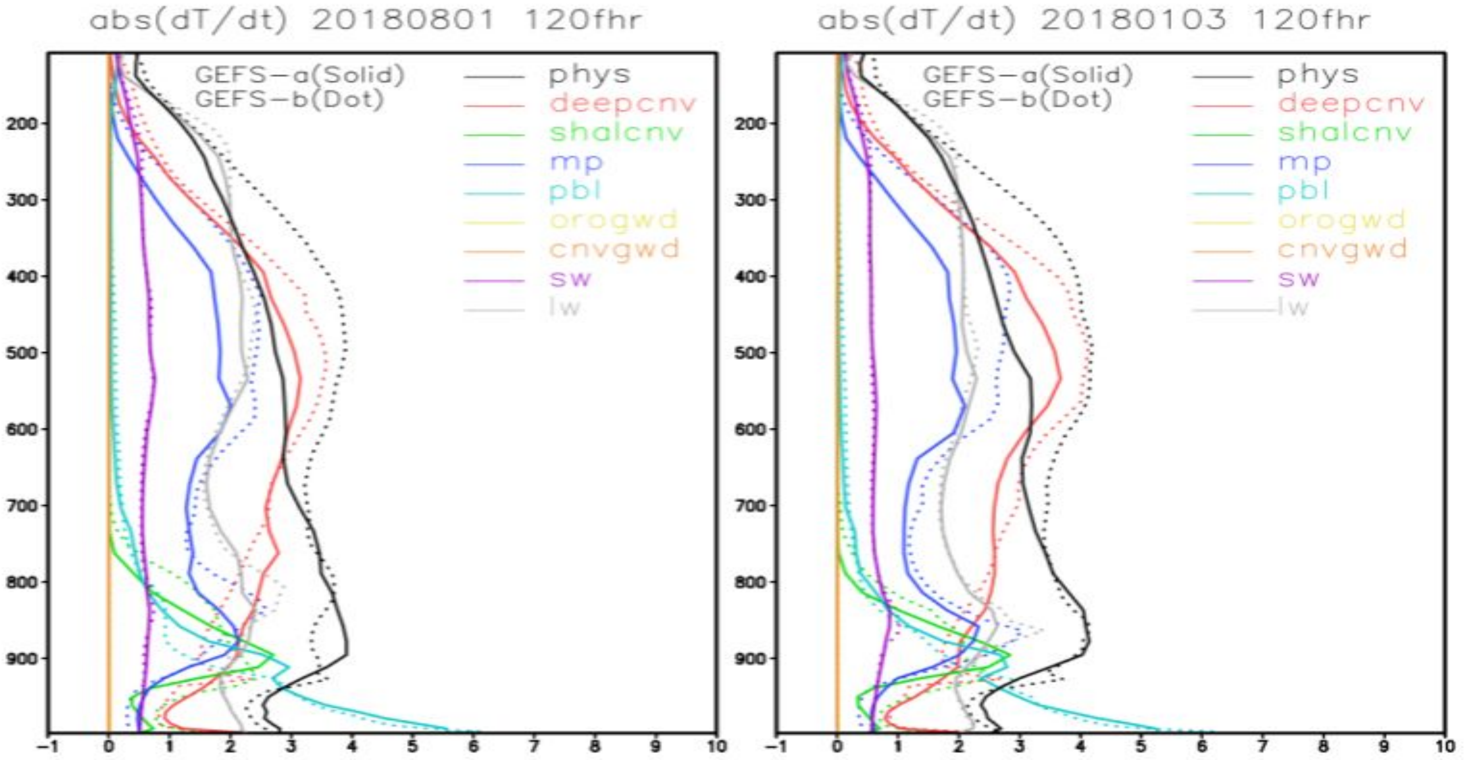

MJO prediction

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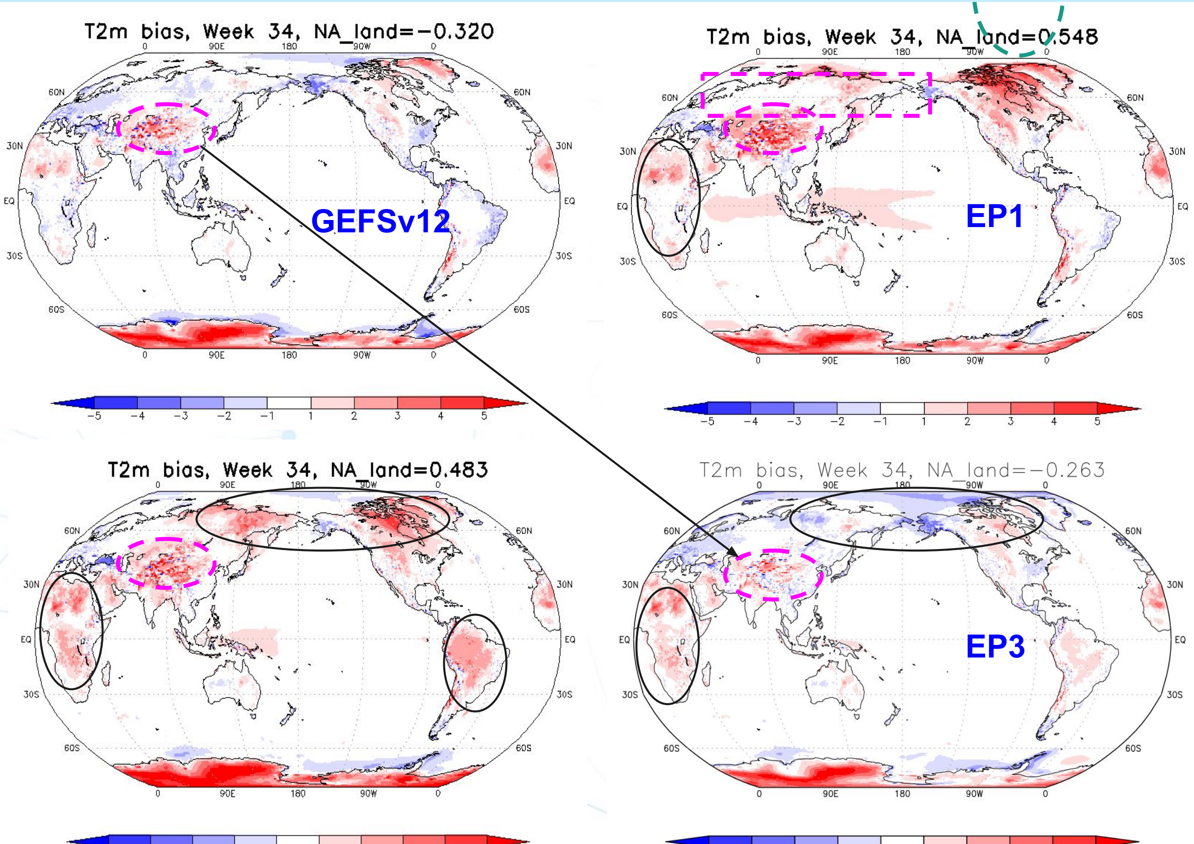
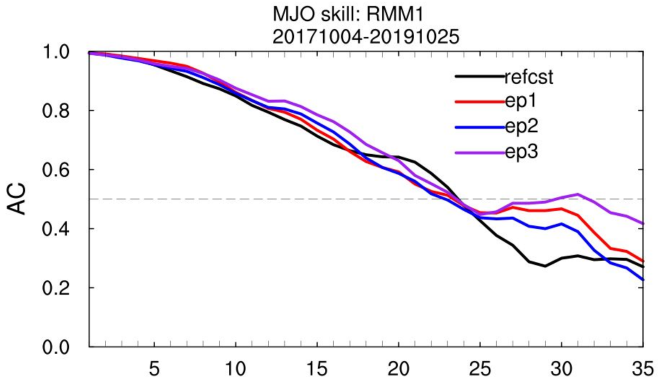
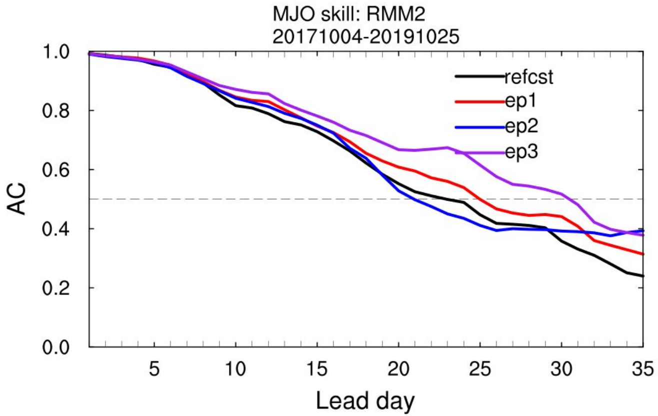
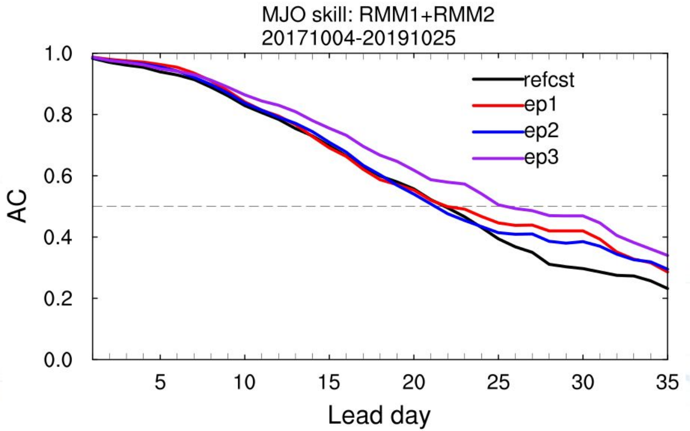


- Reforecast - a warm bias for central Asia.
- Coupling EP1- the warm bias for NA, and around tropical indian ocean and west central Pacific.
- Coupling EP2 - similar to EP1 except the larger warm bias over South America and Southern Africa and less bias over the tropical oceans
- Coupling EP3 - Overall, it is better than EP1 & EP2.
- NA land only, EP3 shows it closed to refcast, less bias than EP1 & EP2.

MJO prediction



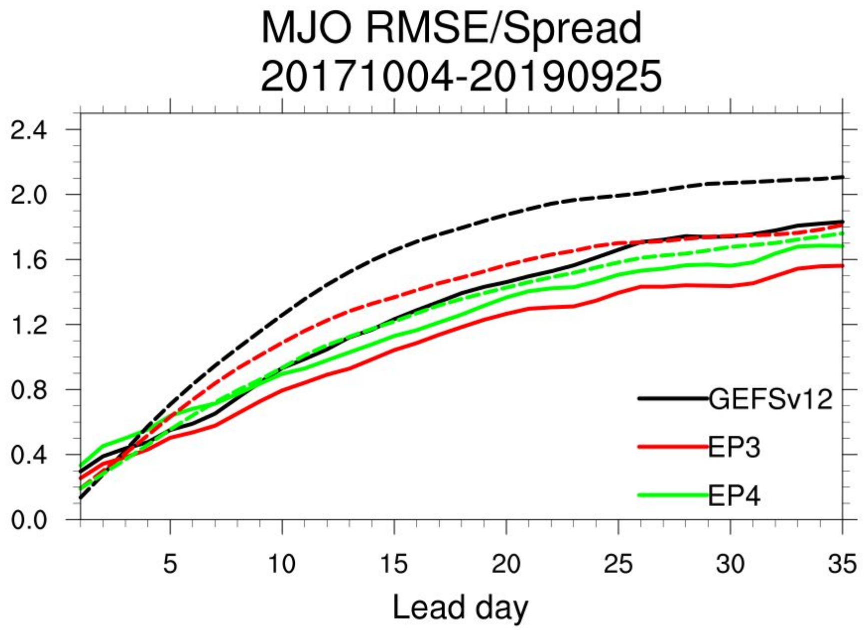


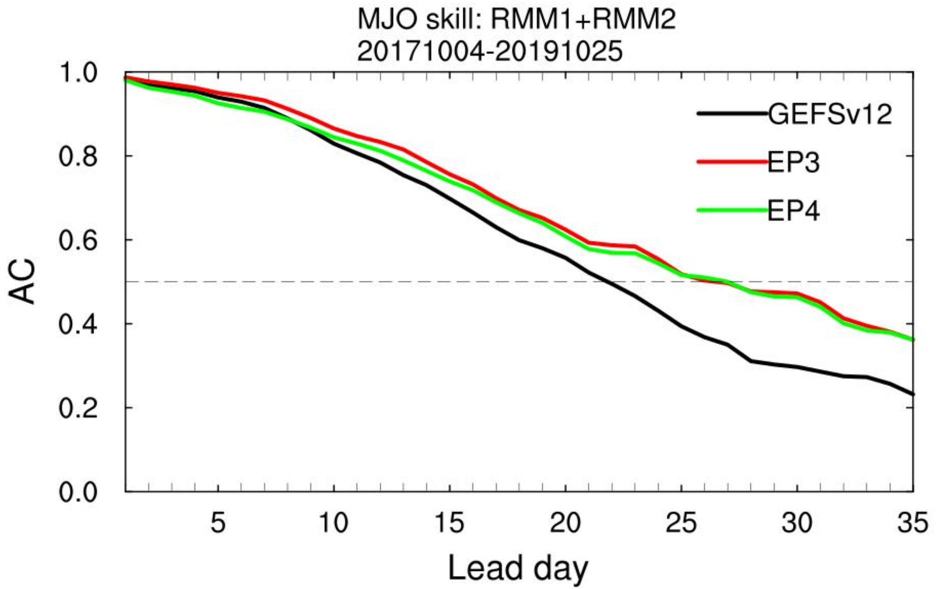


Discussion:

- Both model and analysis climatology - NCEP/NCAR reanalysis
- **Overall - EP3 MJO skills are better than reforecast, EP1 and EP2. The total skills (RMM1+RMM2) reaches 26 days which is mainly from RMM2 (30+ days).**
- Please note that the MJO skill for “reforecast” (or GEFS SubX version was excellent when compared to other national/international models which participated SubX project (Ref: Pegion, K., and co-authors, 2019: The Subseasonal Experiment (SubX): A multi-model subseasonal prediction experiment, Bull. Amer. Meteor. Soc. 100 2043-2060)

MJO prediction





- Both EP3 and EP4 are better than GEFSv12
- EP4 shows reduced MJO spread, but increased RMS error from EP3.
- EP3/EP4 shows similar MJO skill for longer lead time, but EP3 is better for short lead time

Summary and Challenges

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- Summary
  - In most categories, coupled GEFSs (EP1, EP2 and EP3) are better than uncoupled GEFS (or GEFSv12 reforecast).
  - EP1 shows very good results - significantly better than uncoupled GEFS for 500 hPa height for most lead-time, and all domains
  - EP2 shows less skills, and more bias of 2-meter temperature
  - EP3 demonstrates better temperature bias, best MJO skills. CONUS precipitation is closed to reforecast and EP1, tropical precipitation is improved from reforecast.
  - EP4 - completed. Full evaluation is ongoing!
- Challenges
  - 11-member ensemble is not sufficient to represent full uncertainties
  - GEFS 30-year reforecast requires model be frozen about 1 year earlier
  - Sample initial conditions are not available

References for GEFSv13 development

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