Introduction of the next Global Ensemble Forecast System for weather, subseasonal and monthly predictions.

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Acknowledgements:

- EMC ensemble team, coupling team, model team
- OAR/PSL; OAR/WPO; CPC/CTB; NWS/OSTI

Key Points

- Background and current operational GEFS
  - GEFSv11 vs GEFSv12
  - Accomplishments of 2020 implementation
- Next Global Ensemble Forecast System
  - GEFSv12 vs GEFSv13
  - Expectation: Weather, S2S, ocean, seaice, wave and aerosol
  - Summary

NCEP GEFS v12 Configurations

Components	V11 (Dec. 2015)	V12 (Sept. 2020)
GFS Model	Semi-Lagrangian, 2015	**FV3 (Finite-Vol Cubed-Sphere)**
Physics	GFS13 package (Zhao-Carr MP)	GFSv15 packages (**GFDL MP**)
Initial perturbations	EnKF f06	EnKF f06
Model uncertainty	STTP (Stoch. Total Tend. Pert)	**5-scale SPPT and SKEB**
Boundary forcing	SST - Climatology relaxation	**NSST + 2-tiered SST**
Tropical storm	Relocation for all members	No relocation
Horizontal Resolution	T_L574 (34km)/T_L382 (55km)	C384 (25km)
Vertical resolution	L64 (hybrid)	L64 (hybrid)
Daily frequency	00, 06, 12 and 18UTC	00, 06, 12 and 18UTC
Forecast length	16 days	16 days, 35 days (00UTC)
Members	Control + 20 pert members	**Control + 30 pert members**
Output resolution	0.5° x 0.5°	0.25° x 0.25° and 0.5° x 0.5°
Output frequency	3h the first 8 days; 6h the rest	3h the first 10 days; 6h the rest
Reforecast	EMC offline – 20 years	30 years (1989-2018)
Implementation	December 2nd 2015	September 2020

Examples of stochastic patterns for SPPT

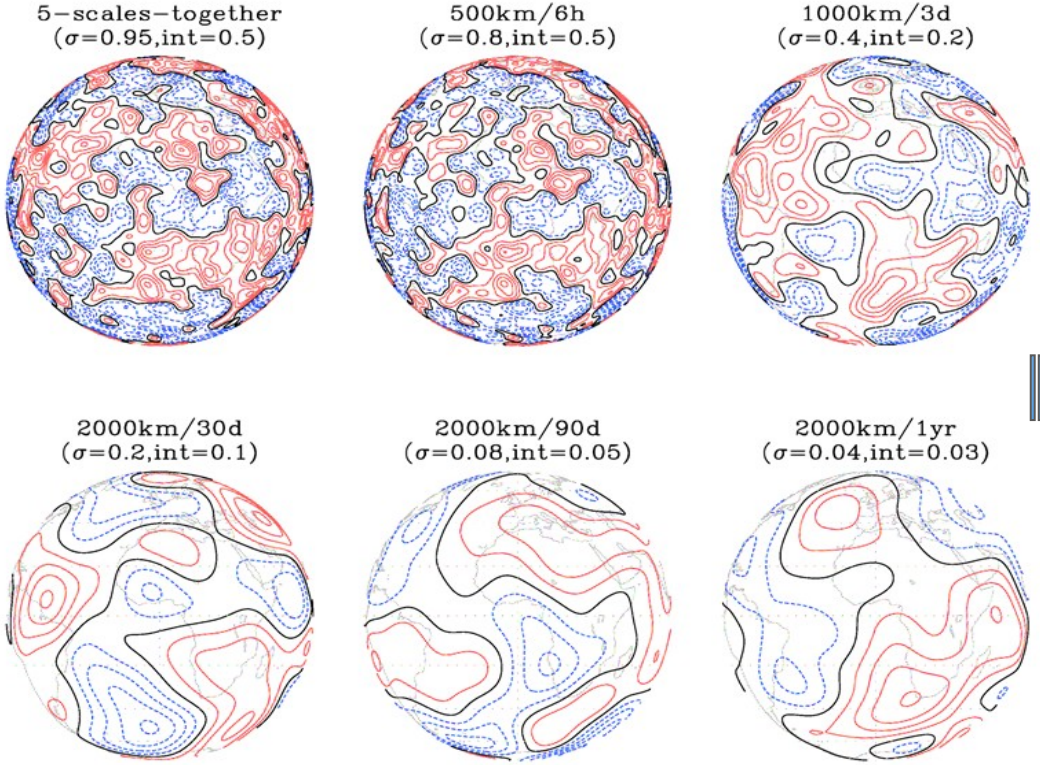
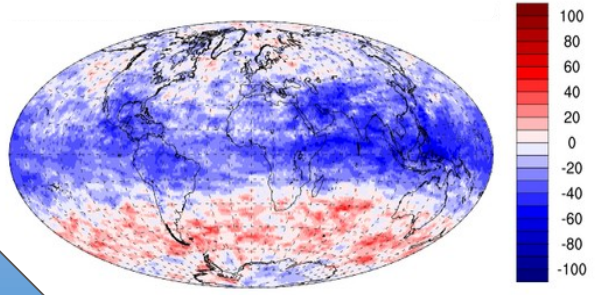


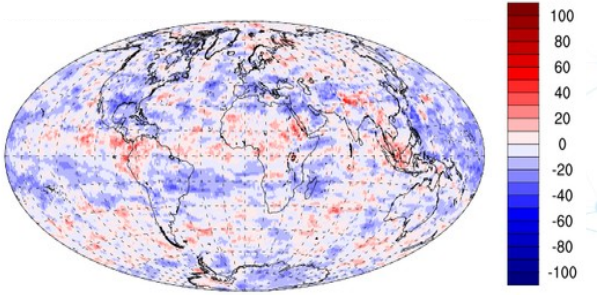
Fig.: 5-scale random patterns used in Stochastic Perturbed Physics Tendencies (SPPT). On the top of each plot, the numbers (except for upper left) represent the scales of spatial and temporal perturbations with the maximum amplitude and contour intervals in the bracket.

500hPa zonal wind

Error/Spread ratio



GEFSv11 with STTP



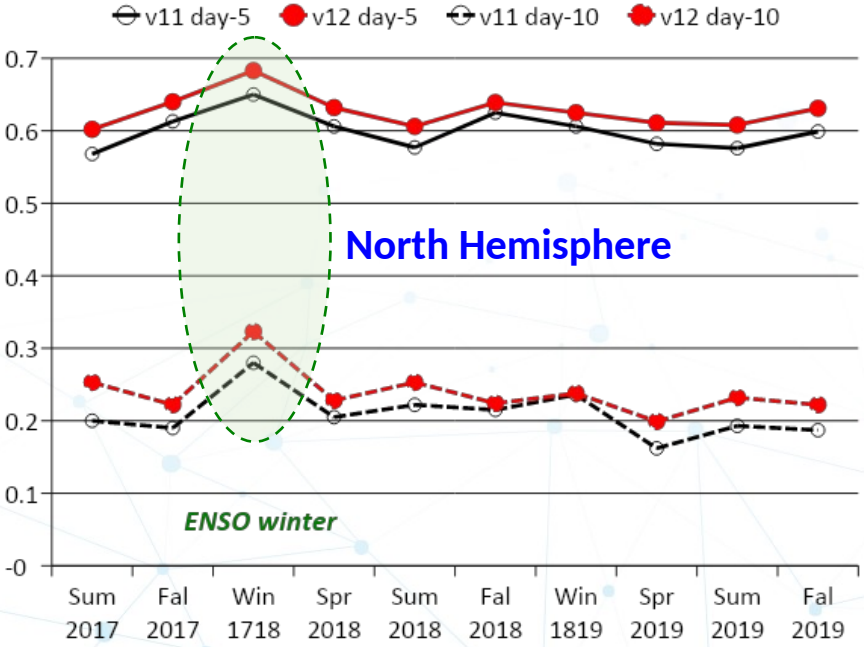
GEFSv12 with SPPT + SKEB

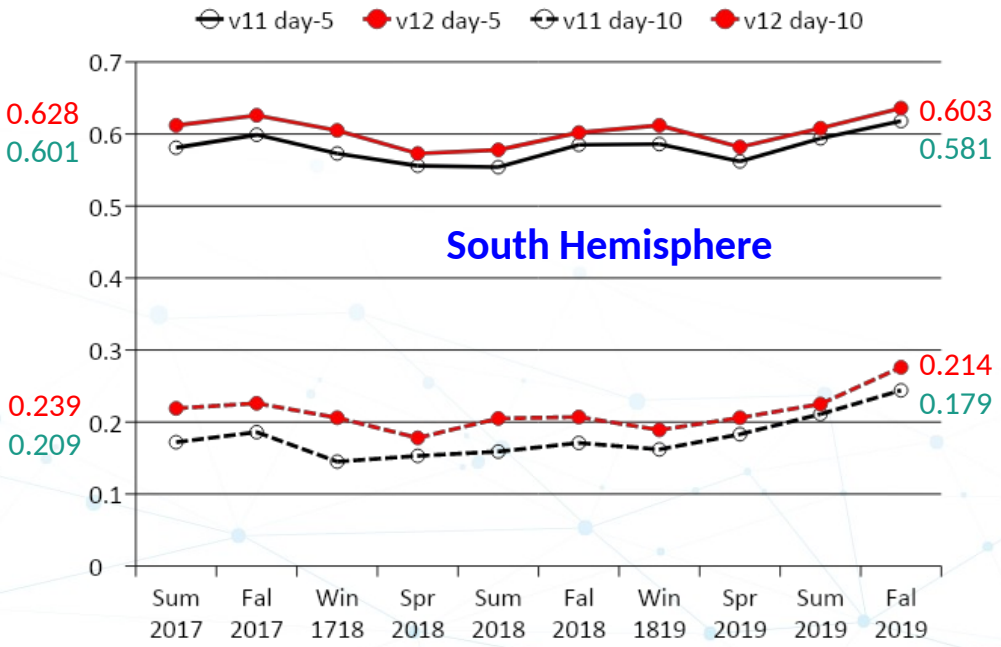
- No radiative perturbation for clear sky
- No perturbation under divided streamline

Accomplishments of GEFSv12 (highlights)

- Weather -
  - Improved probabilistic forecast skill and predictability
  - Improved PQPF and T2m
  - Improved TC tracks and spread
- Week-2; Weeks 3&4 -
  - An improvement for temperature, precipitation, 500 hPa heights tropical cyclone and stratosphere.
- Wave -
  - Reduce bias and RMSE; An improvement of wave spread.
- Aerosol (control member only) -
  - Improvement in the dust predictions (signals and errors)
- 31-year Reforecasts
  - Support forecast calibration and validation of hydrometeorological application

CRPS Skill of 500hPa geopotentoal height





CRPSS – *Continuous Ranked Probabilistic Skill Score is one of evaluation tools to measure ensemble based probabilistic forecast. CRPSS=1 is for perfect forecast, CRPSS=0 is for no skill from reference, CRPSS=0.25 is similar to PAC=0.6 (pattern anomaly correlation of ensemble mean). GEFS v12 has better CRPSS for both hemispheres, day-5 and day-10, all two and half years.*

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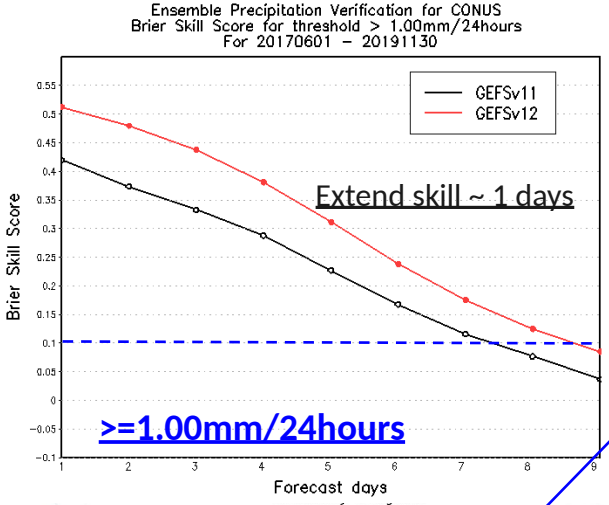
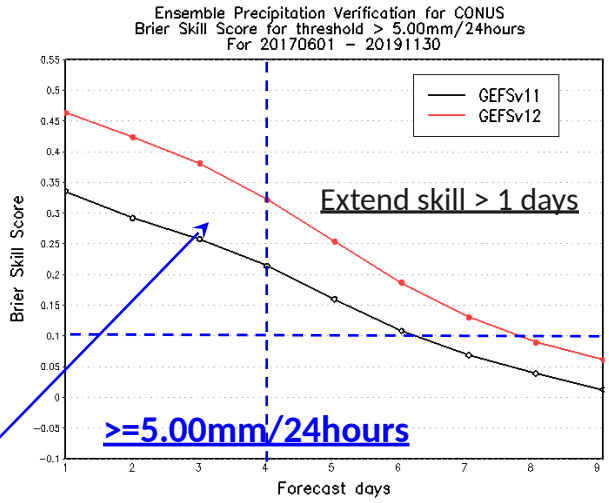
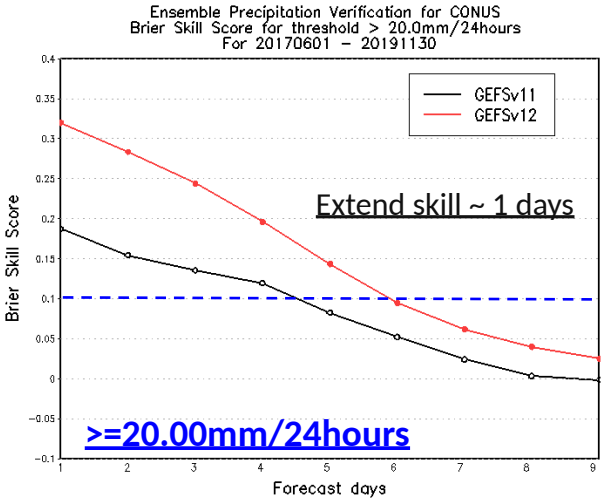
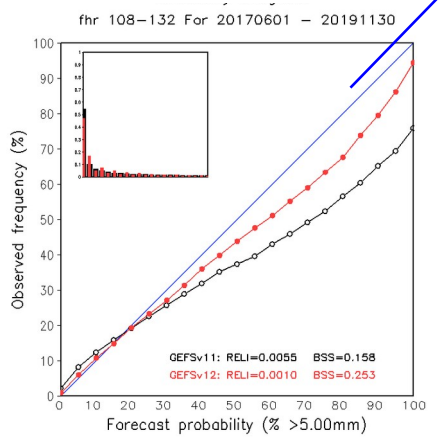
Brier Skill Scores of the CONUS PQPF









Brier Score – *Brier score is a very popular verification tool to evaluate (probabilistic) forecast performance. It is easy to decompose to three components (resolution, reliability and uncertainty). BSS=1 is for perfect forecast, BSS=0 is for no skill from reference of climatology. GEFSv12 probabilistic Quantitative Precipitation Forecast (PQPF) is over performance than GEFSv11 for all forecast categories, all forecast lead-time. Statistically, GEFSv12 has extended one more day(s) probabilistic forecast skills over GEFSv11. The forecast is much reliable (left plot) than GEFSv11.*

Example of impact: Spatial and Time-Lag Correlation at tropical equator OLR and 850 hPa Zonal Wind

1989 - 1999

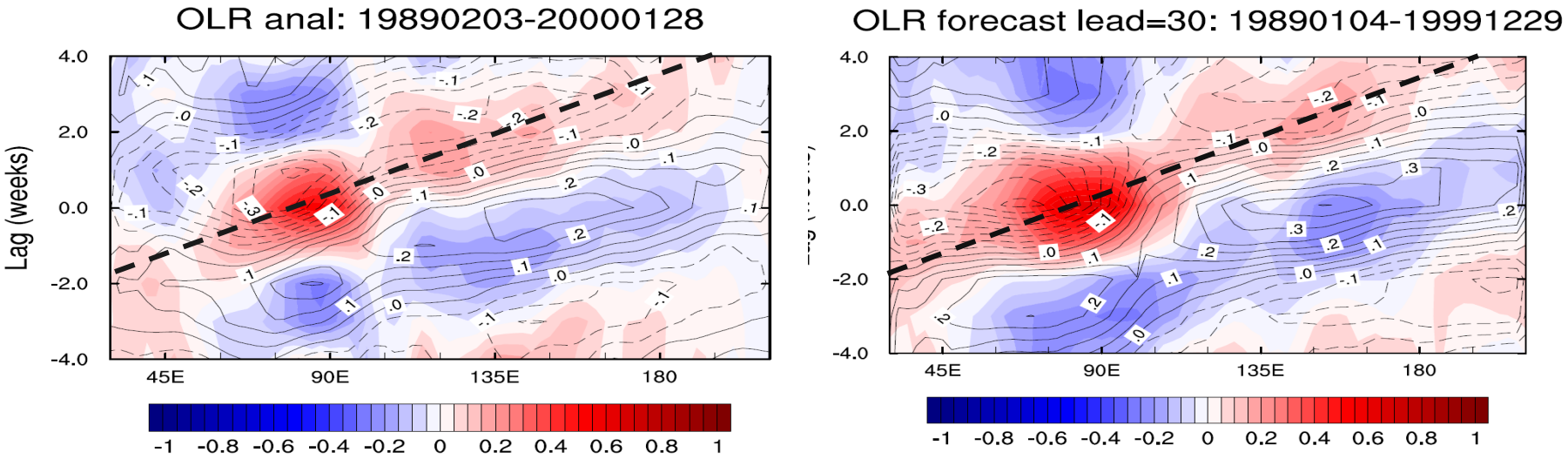


Figure: *Spatial and time correlation (anomaly) between Centre* ***India Ocean*** *and different longitudes/time-lag of 11 years analysis (CFSR; left) and 30-day forecast (GEFS ensemble mean; right). The correlation coefficient of OLR is in shaded and 850 zonal wind is in contours.*

The statistics indicate that there is a very good eastward propagation of signal (or MJO) from Indian Ocean. However, it is challenge for northward propagation of India Ocean (Not show).

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Key Points

- Background and current operational GEFS
  - GEFSv11 vs GEFSv12
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NCEP Global Ensemble Forecast System (Configuration)

Components		V12 (Oct. 2020)	V13 (Q2FY25)
Atmos	Dynamics	FV3 (Finite-Vol Cubed-Sphere) GFSv15	FV3 (Finite-Vol Cubed-Sphere) GFSv17
	Physics	saSAS, GFDL-MP, K-EDMF, oroGWD	saSAS, Thompson-MP, sa-TKE-EDMF, uGWD
	Initial perturbation	EnKF f06 (previous cycle)	EnKF f00 (early cycle)
	Model uncertainty	5-scale SPPT and SKEB	5-scale SPPT, SKEB, SPP, CA
	Boundary (ocean surface)	NSST + 2-tiered SST	NSST
	Resolutions	C384L64 (25km)	C384L127 (25km)
Land	Model	NOAH-LSM	NOAH-MP
	Initial perturbation	N/A	Soil moisture
Ocean	Model	N/A	MOM6 (0.25°L75)
	Initial perturbation	N/A	SOCA-Ens
	Model uncertainty	N/A	5-scale oSPPT and ePBL
Ice	Model	N/A	CICE6 (0.25°)
	Initial condition	N/A	SOCA-Ens
Wave	Model	WW3 (one way)	WW3 (2-way) (0.25° lat/lon grid)
Aerosol	Model	GOCART (one way)	GOCART (2-way)

new

NCEP Global Ensemble Forecast System (Support)

Components		V12 (Oct. 2020)	V13 (Q2FY25)
Forecast frequency and leads		35 days (00UTC); 16 days (06, 12, 18UTC)	35/48 days (00UTC); 16 days (06, 12, 18UTC)
Atmos	Output (GRIB2)	Day 1-10, every 3 hours	Day 1-10, every 3 hours
		> day-10, every 6 hours	> day-10, every 6 hours
		Top level : 10 hPa	Top level: 1 hPa
Land	Output (GRIB2)	Day 1-10, every 3 hours	Day 1-10, every 3 hours
		> day-10, every 6 hours	> day-10, every 6 hours
Ocean	Output (GRIB2)	N/A	Average for 24 hours
	Output (NetCDF)	N/A	Average for 24 hours
Ice	Output (GRIB2)	N/A	Average for 24 hours
	Output (NetCDF)	N/A	Average for 24 hours
Wave	Output (GRIB2)	Out to 16 days	The same as atmosphere
Aerosol	Output (GRIB2	Day 1-5, every 3 hours	The same as atmosphere
Reanalysis		20 years (2000 - 2020)	30 years (1994 - 2023)
Reforecast		31 years (1989 - 2020)	30 years (1994 - 2023)

new

Expectations

- The benefits from coupled GEFS (Global Ensemble Forecast System)
- Further improvement of probabilistic weather forecasting
  - Including PQPF, T2m and TC
- Improvement of MJO predictions
  - Including propagation, intensity and skill
- Improvements from two way coupling between atmosphere/waves/aerosol
- New products for the ocean and sea ice
- 30 years GEFSv13 reforecast

GEFSv13 Prototype Experiments - EOS highlights

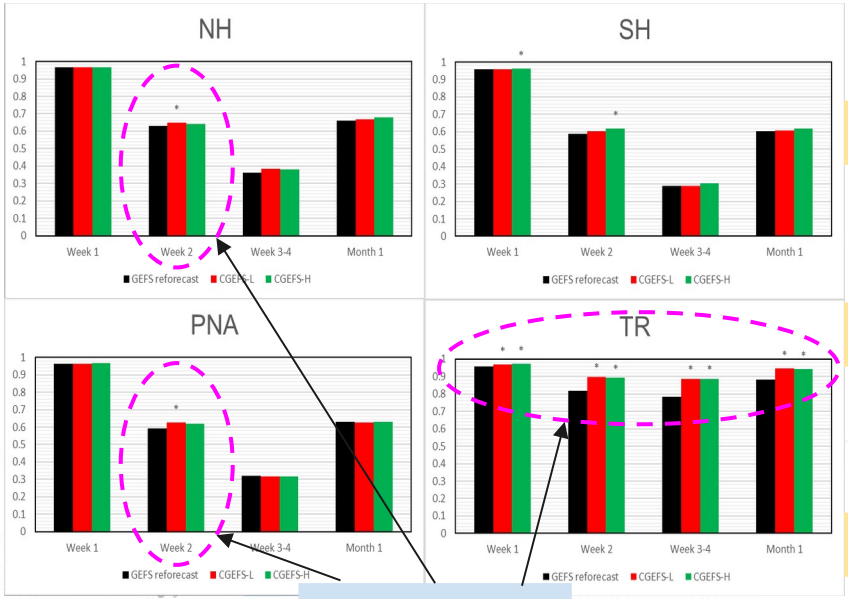
Editor's highlights - JGR Atmosphere (2023) --- Zhu, Y., B. Fu, B. Yang, H. Guan, E. Sinsky, W. Li, J. Peng, X. Xue, D. Hou, X.-Z. Liang and S. Shin, 2023: Quantify the Coupled GEFS Forecast Uncertainty for the Weather and Subseasonal Prediction.

Eos

A New Coupled Modeling System Improves Forecast Skills

Building on older versions, the new Global Ensemble Forecast System with coupled atm

By Minghua Zhang
27 February 2023



Significantly improve the skills

Built on top of the current operational Global Ensem… system is developed by fully coupl… skills are assessed by using anomalies of 500 hectop… nds at different heights, tracks and Oscillation (MJO) among others. The new system is s… d times than the uncoupled syster…

Citation: Zhu, Y., Fu, B., Yang, B., Guan, H., Sinsky, E., Li, W., et al. (2023). Quantify the coupled GEFS forecast uncertainty for the weather and sub… Atmospheres, 128, e2022JD037757. https://doi.org/10.1029/2022JD037757

—Minghua Zhang, outgoing Editor in Chief, JGR: Atmospheres

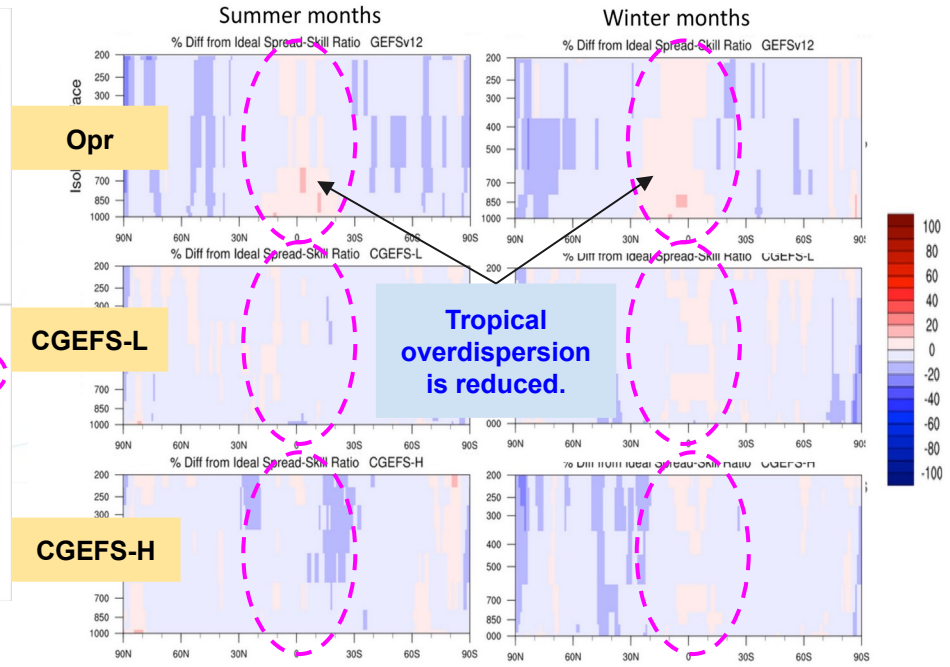


Figure 9: The vertical cross section of the ratio for boreal summer six months (left column) and boreal winter six months (right column) of zonal wind from surface (1000hPa) to 200hPa in vertical, for 144 hours (6 days) forecasts, and for the GEFSv12 reforecast (top), CGEFS-L (middle) and CGEFS-H (bottom).

GEFSv13 ensemble prototype performances

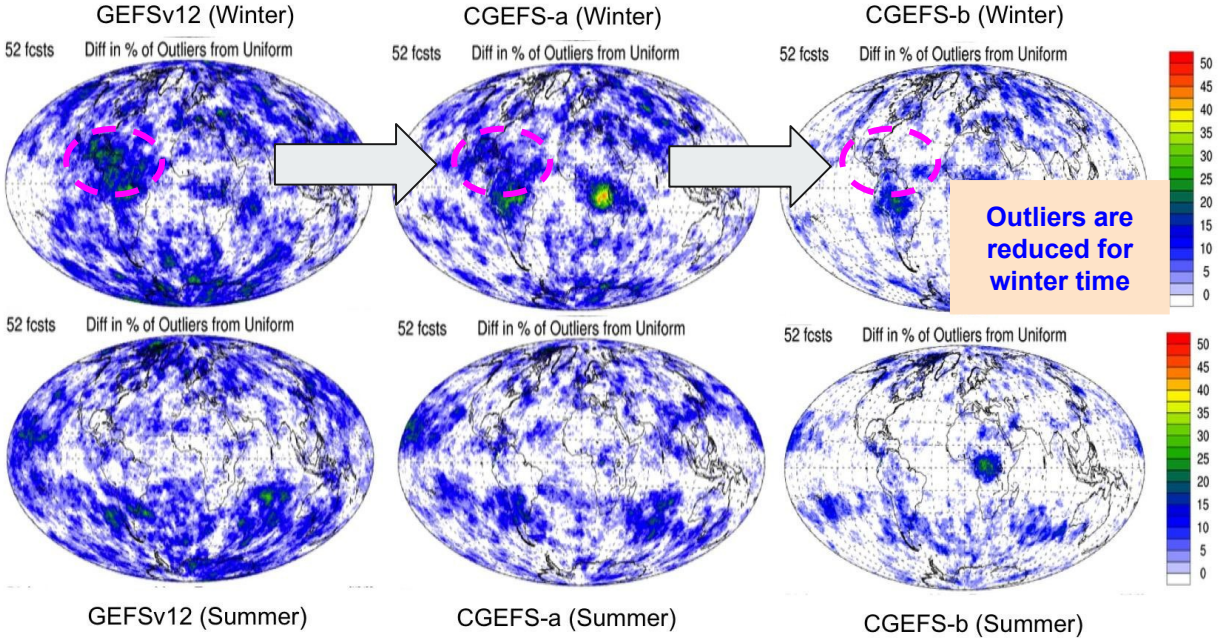


Figure 3. Distribution of the ratio of 500 hPa height 120h forecast outliers from uniform (in percentage) in GEFSv12 (left), CGEFS-a (middle) and CGEFS-b (right) for summer (bottom) and winter (top).

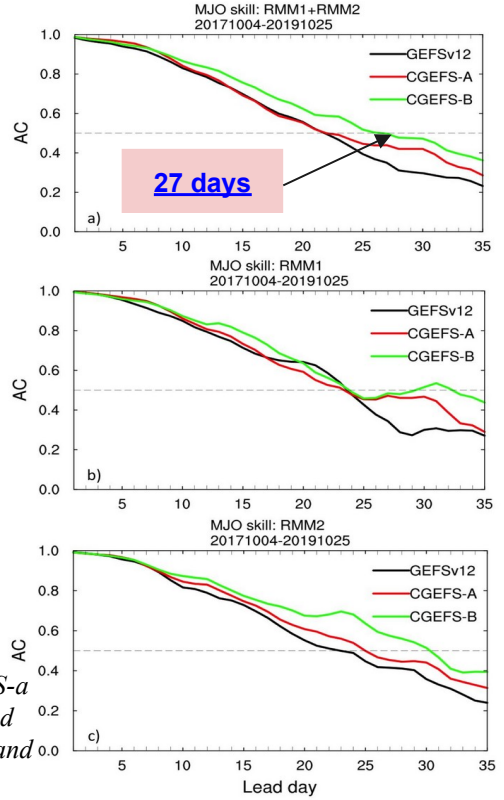


Figure 11. The MJO index for the GEFSv12 (black), CGEFS-a (red) and CGEFS-b (green).The MJO forecast skill is defined as the bi-variate anomaly correlation between the analysis and forecast real-time multivariate MJO index 1 and 2

Bing Fu et al. 2023: Weather to subseasonal prediction from the UFS coupled Global Ensemble Forecast System

Summary

- GEFSv12 implementation
  - 1st UFS one-way coupled (wave and aerosol) system for operation since Sep. 23 2020
  - 31 years reforecast to support GEFS applications
- GEFSv13 configurations
  - GEFSv13: Atmosphere (C384L127), Ocean (0.25^{o}L75), Sea Ice (0.25^{o}), wave and aerosol fully coupled model.
- Expectations from GEFSv13
  - Benefits of fully coupled GEFS (Global Ensemble Forecast System)
  - Improved probabilistic weather forecast and MJO predictions
  - New ocean and sea ice products
  - 30 years replay-reforecasts
- Timelines for GEFSv13 implementation
  - Q2FY24 - Frozen GEFSv13 and start GEFSv13 reforecast
  - Q1FY26 - GEFSv13 implementation

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Thanks for your attention!!!

Questions?