



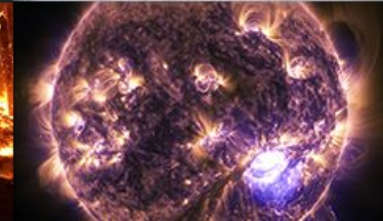
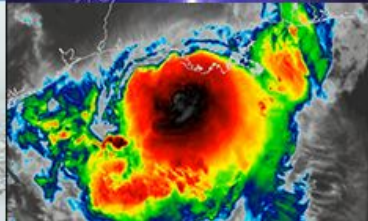
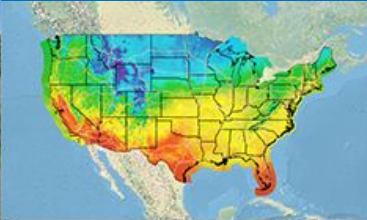
**NATIONAL
WEATHER
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Updates on UFS-based coupled GEFS

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Outline

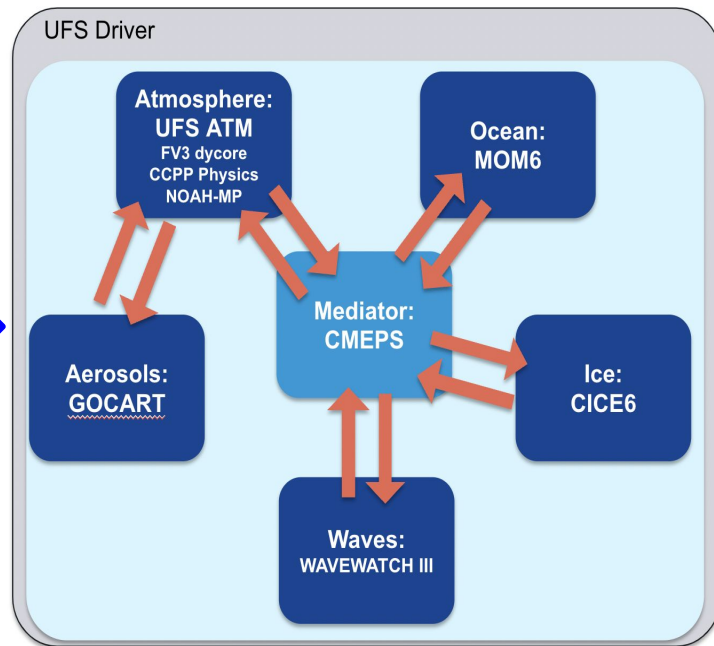
- A brief introduction of GEFSv13
- UFS global coupled model Ensemble Prototypes (EPs)
 - UFS coupled model prototypes and ensemble prototypes
 - Some results from EP1, EP2 and EP3
 - **EP4 and EP5 (miniset)**: experiments with aerosol coupling
- GEFSv13 status and what's next

Transitioning to a fully coupled model

NOAA's next global model updates



UFS fully coupled model



GEFSv13 Configurations (planned)

Components		V12 (Sep 23. 2020)	V13 (targeting FY26)
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		SOCA-Ens
	Model uncertainty		5-scale oSPPT and ePBL
Ice	Model		CICE6 (0.25°)
	Initial perturbation		SOCA-Ens
Wave	Model		WW3 (1-way) (0.5°)
Aerosol	Model	GOCART (1-way)	GOCART (2-way)

Timeline of the UFS coupled model prototypes

Coupled model prototype	Timestamp of the model tag
P5 ~~~~~> (EP1)	09/16/2020
P6 ~~~~~> (N/A)	02/19/2021
P7 ~~~~~> (EP2)	08/23/2021
P8 ~~~~~> (EP3)	05/31/2022
HR1~~~~~> (EP4)	01/30/2023
HR2 ~~~~~> (N/A)	07/24/2023
HR3~~~~~> (EP5)	01/11/2024

It usually takes **8 - 11** months to complete one ensemble prototype



Experiment design of the ensemble prototypes



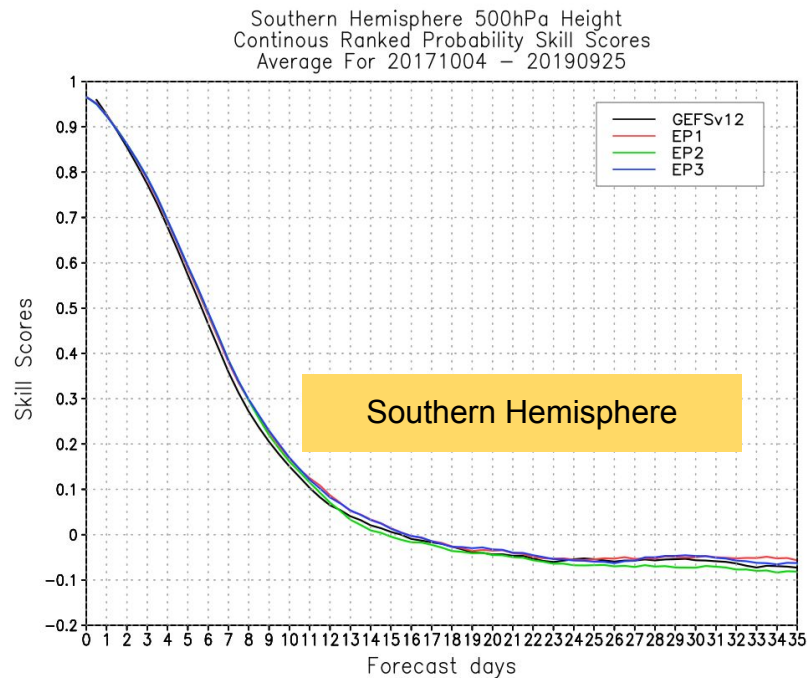
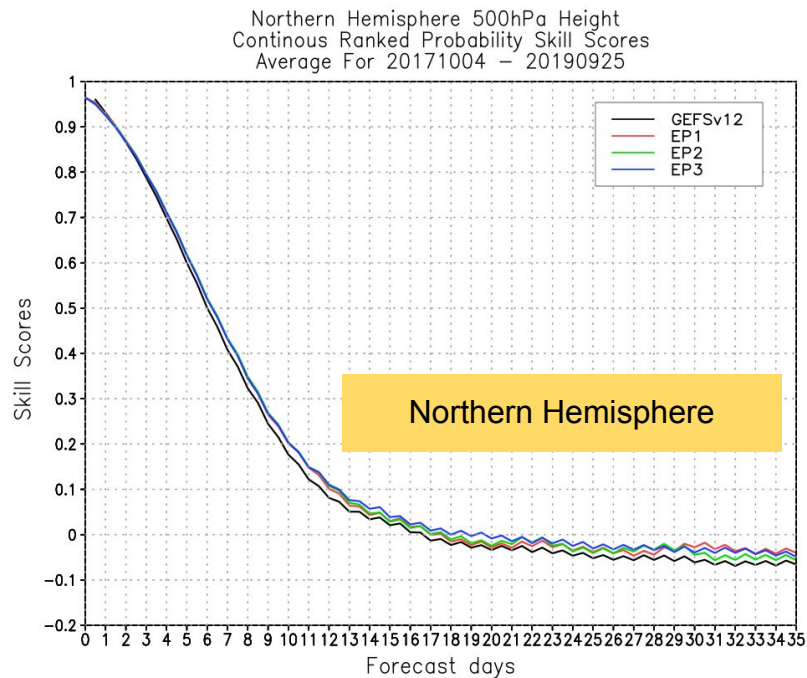
- ❖ Reference:
 - **GEFSv12 (reforecast)**, 10 perturbed members + 1 control member
- ❖ Ensemble prototype:
 - 10 perturbed members + 1 control member (not 31 members due to resources)
- ❖ Run period:
 - Full set: Oct 2017 - Sep 2019 (one more year (Oct 2020 - Sep 2021) for EP4 and EP5)
 - Miniset: 8 winter cases and 8 summer cases in 2018
- ❖ Initial conditions:
 - Analysis :
 - ATM: GFS v15/v16 analysis
 - OCN: CFSR T&S (EP1), ORAS5 (EP2 - EP5)
 - ICE: CPC ice analysis
 - WAV: GFSv15 wind/ice forcing (EP1 - EP3), GEFSv12 reanalysis (EP4-EP5)
 - Initial perturbations:
 - ATM: GFS v15/v16 EnKF f06
 - OCN: generated from 3 ocean analysis (EP3-EP5)
 - WAV: GEFS v12 reforecast (EP4-EP5)
 - GEFSv13 replay ICs (only for EP5 experiments)



[GEFS ensemble prototypes and experiments](#)



Skills of 500hPa geopotential height

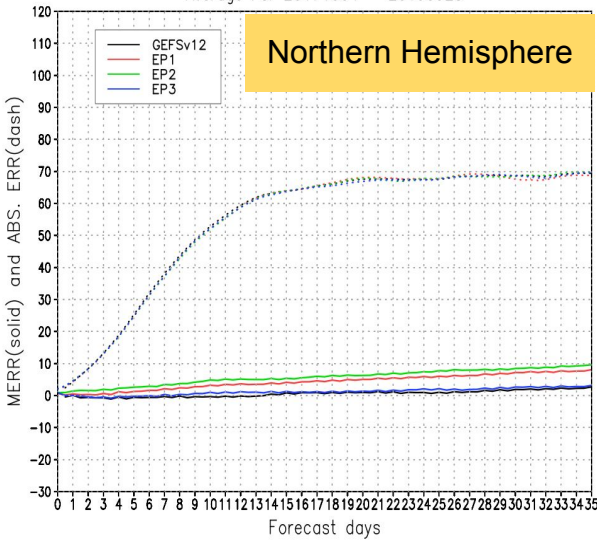


- For short lead-time: all three experiments are very similar and better than GEFSv12 up to week 2.
- For week-3 and beyond: EP3 is best in the NH, mixed in the SH.

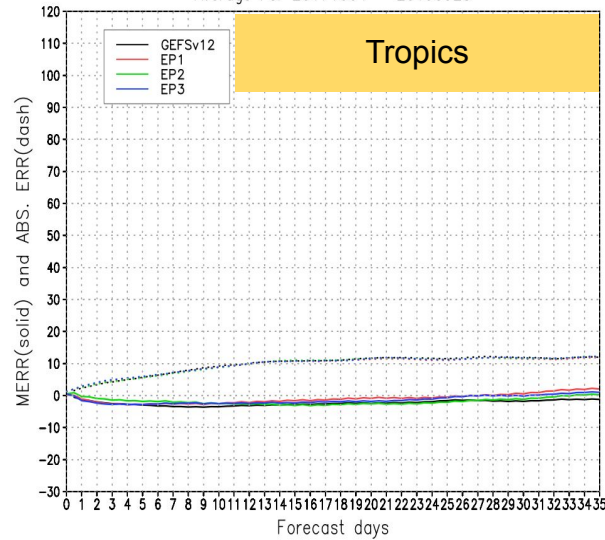


Bias of 500hPa geopotential height

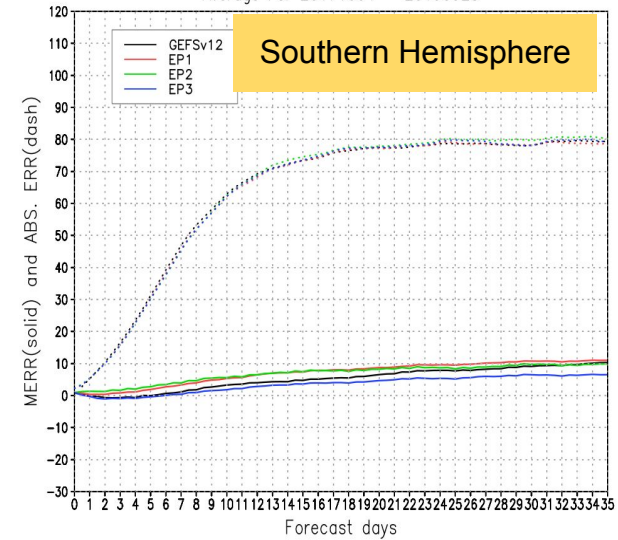
Northern Hemisphere 500hPa Height
Ensemble Mean Error and Ensemble Abs. Error
Average For 20171004 – 20190925



Tropical 500hPa Height
Ensemble Mean Error and Ensemble Abs. Error
Average For 20171004 – 20190925



Southern Hemisphere 500hPa Height
Ensemble Mean Error and Ensemble Abs. Error
Average For 20171004 – 20190925

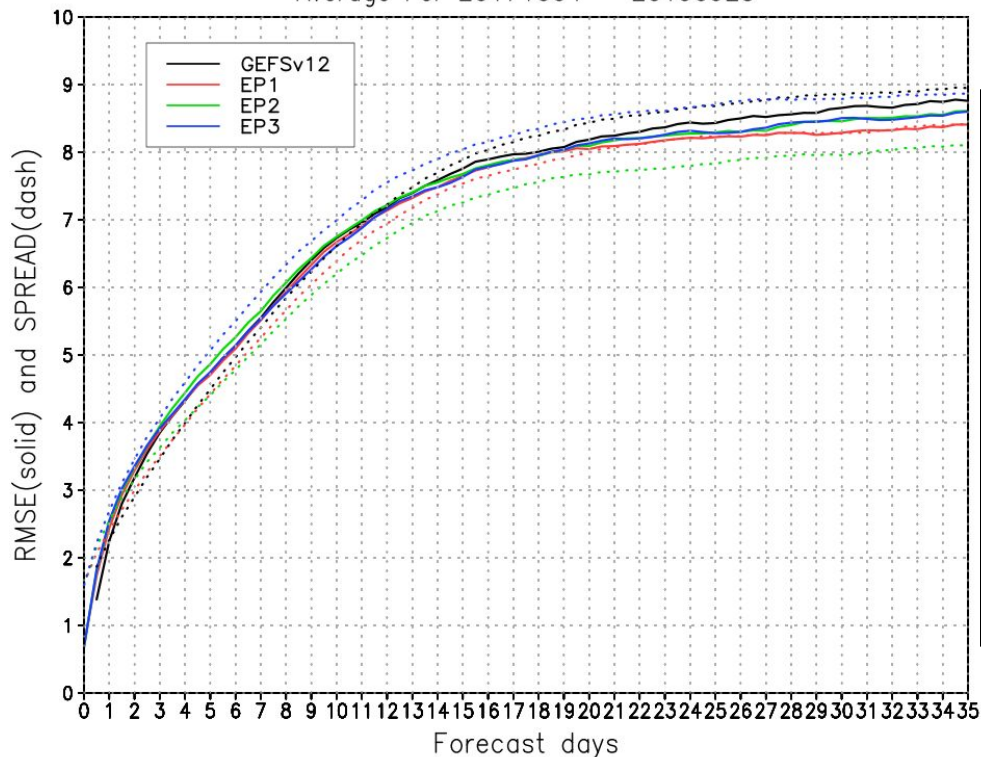


- Overall - EP3 shows **the best bias** for three domains
- EP1/EP2 introduces warm bias for all three domains



RMSE/SPRD for U250 tropical zonal winds

Tropical 250hPa U.
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20171004 – 20190925



- Ensemble spread changes following the updates of ensemble prototype.
- An indication of the changes of the physical tendency



EP4 results

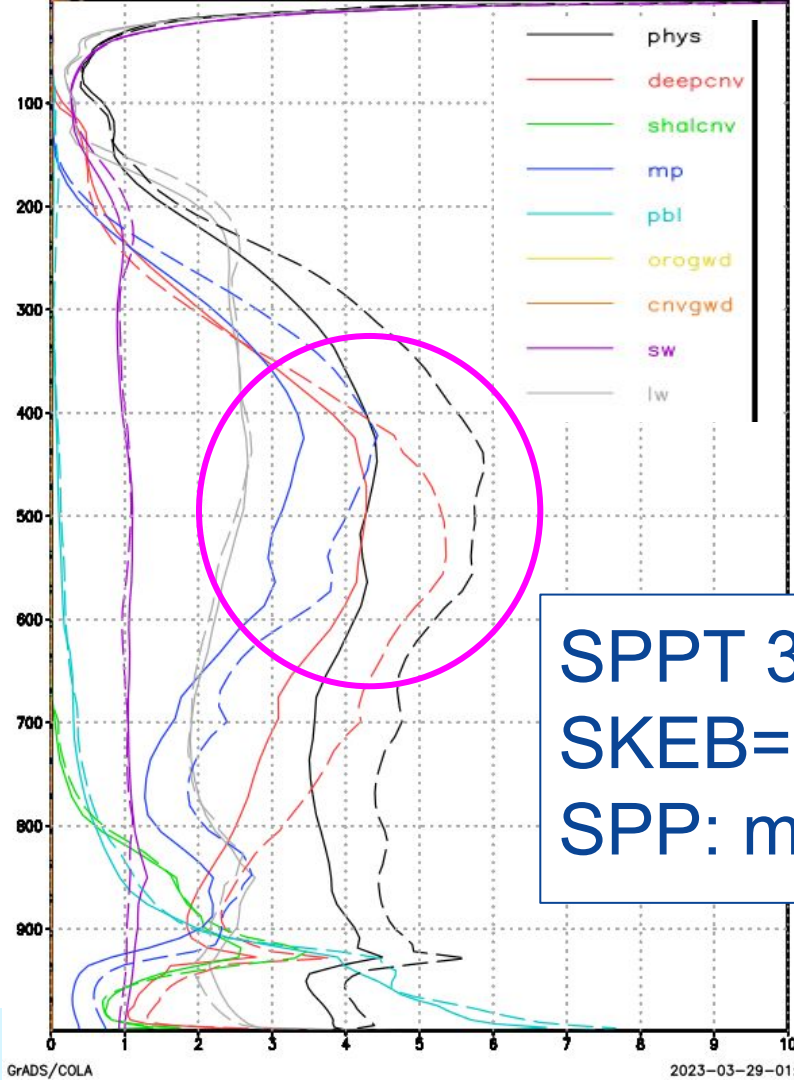


Physical tendency comparison:
EP3 (solid) vs EP4 (dash)

(p02: 20171004 00Z 252h forecast)

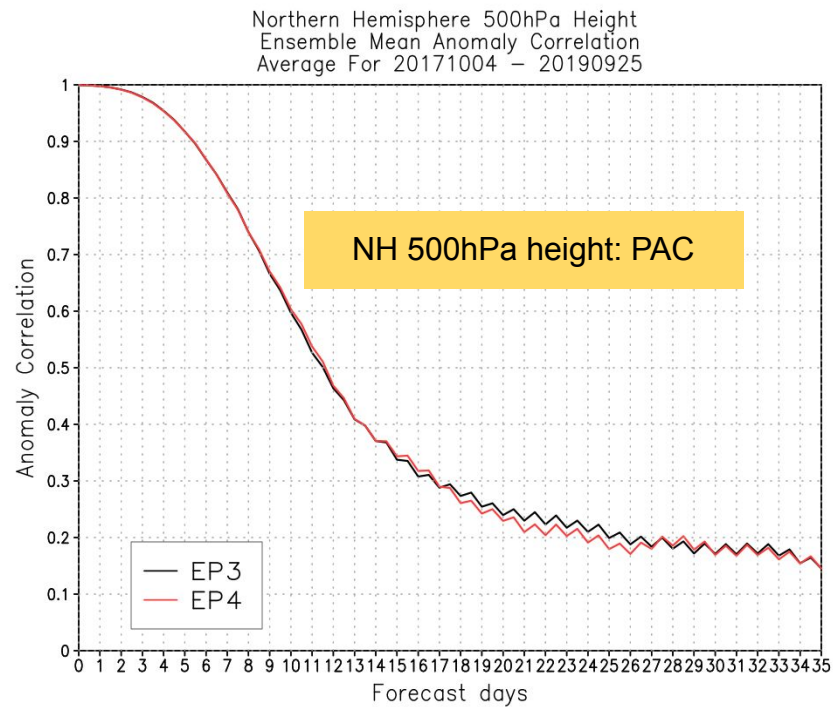
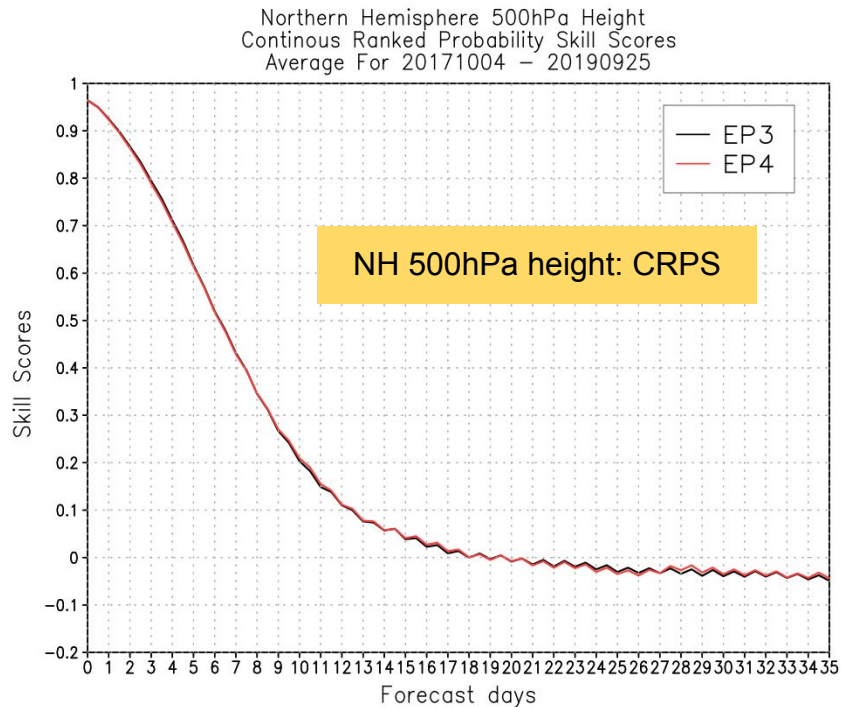
Averaged absolute DT/Dt ($1e-5$)
Over (40E-150W,20S-20N)

- Large difference of total physical tendency caused by mp and deep convection
- PBL is the major contributor for total tendency at lower level.
- PBL taper added from EP4



SPPT 30% off
SKEB=0.8
SPP: mp_cld

Skills of 500hPa geopotential height (NH: CRPS and AC)

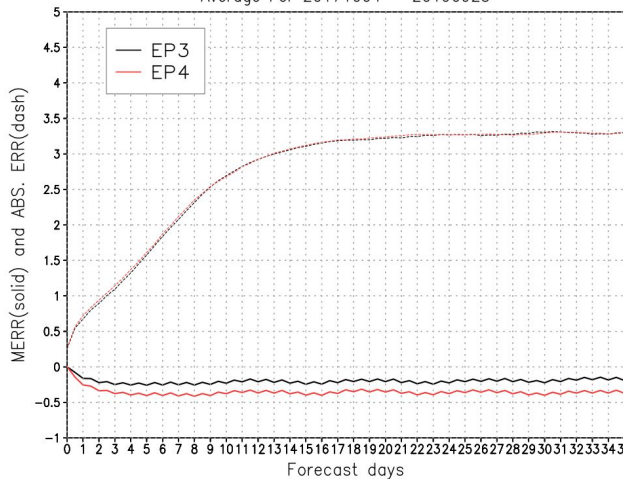


- For short lead-time: EP4 is similar to slightly worse (CRPS) better (AC) than EP3
- For week-2 and beyond: EP3 and EP4 are very similar, especially for CRPS, EP4 is slightly degraded from EP3 for ACC

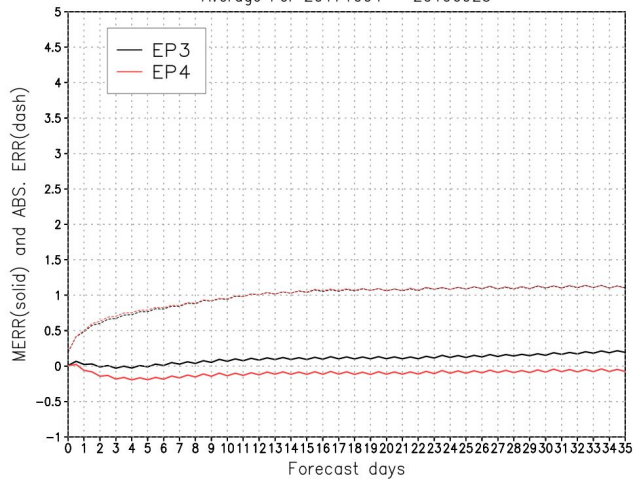
Skills of 850hPa temperature (bias)



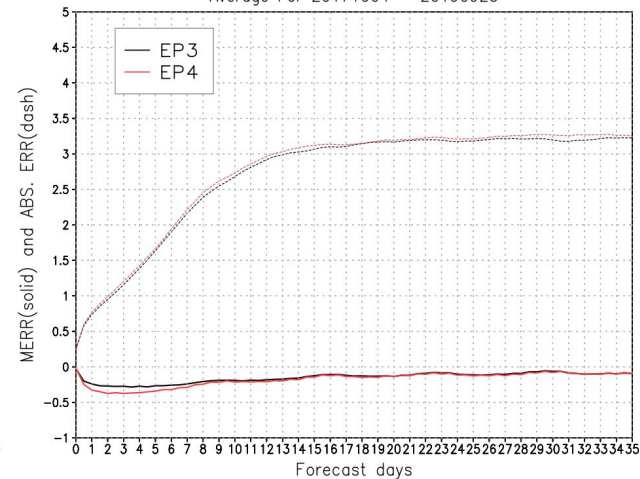
Northern Hemisphere 850hPa Temp.
Ensemble Mean Error and Ensemble Abs. Error
Average For 20171004 – 20190925



Tropical 850hPa Temp.
Ensemble Mean Error and Ensemble Abs. Error
Average For 20171004 – 20190925



Southern Hemisphere 850hPa Temp.
Ensemble Mean Error and Ensemble Abs. Error
Average For 20171004 – 20190925



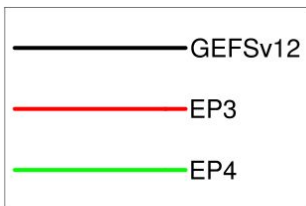
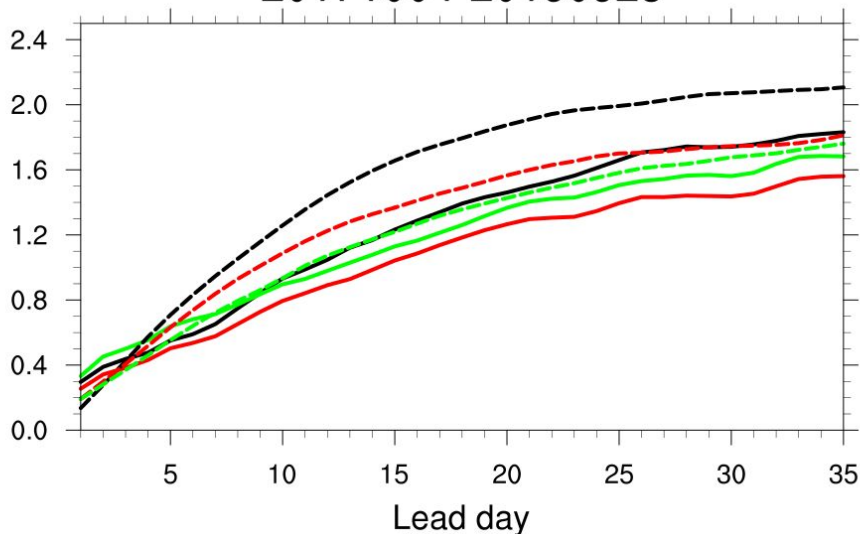
- It is similar to 500hPa height, EP4 shows colder bias from NH to tropical, less difference for SH



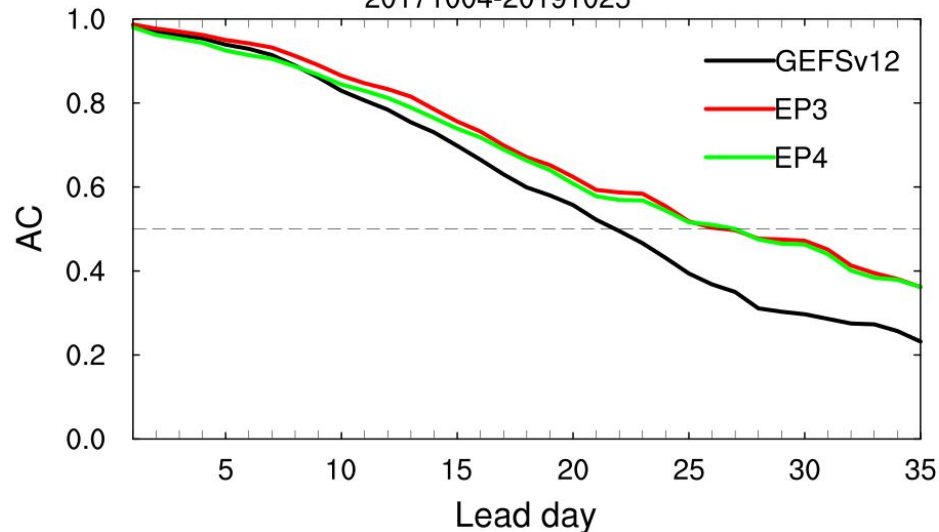


Latest Experiments - EP4 (2 years)

MJO RMSE/Spread
20171004-20190925



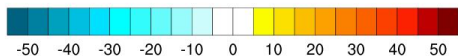
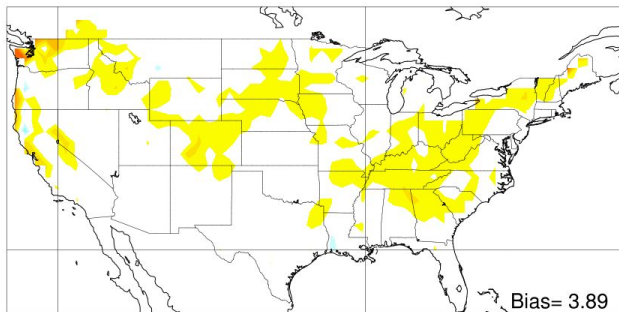
MJO skill: RMM1+RMM2
20171004-20191025



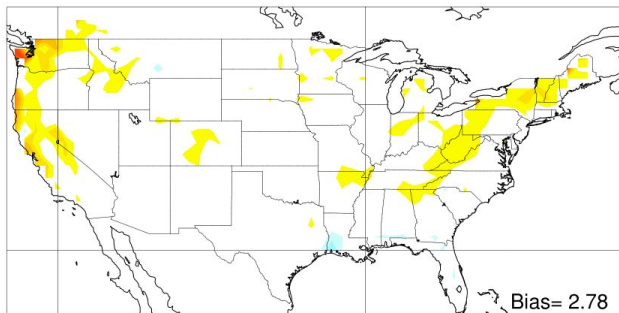
- EP4 experiments demonstrated reduced MJO spread, but increased RMS error from EP3.
- EP4 experiments have similar MJO skill (RMM1+RMM2) for longer lead-time, but it is degraded for short lead time.

CONUS Precipitation Bias for Week-1 average (2 years)

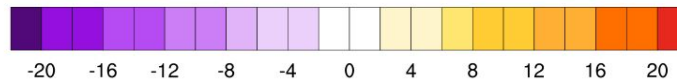
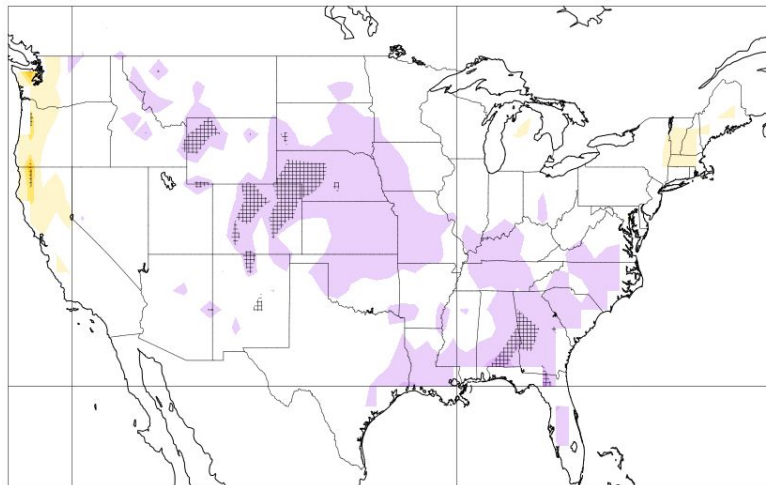
CONUS GEFSv12 Week 1 APCP bias: 20171004-20190925



CONUS EP4 Week 1 APCP bias: 20171004-20190925

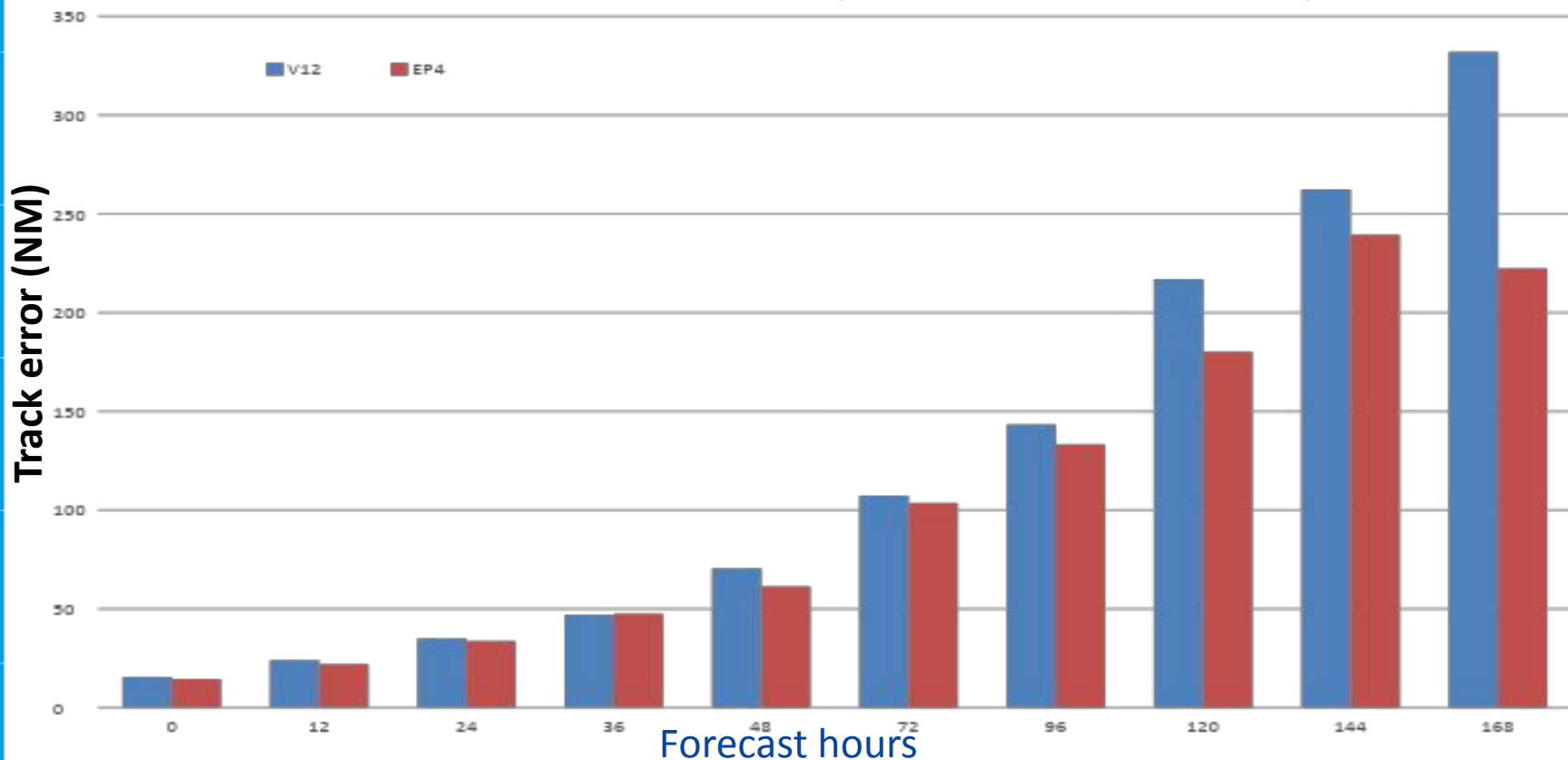


CONUS_GEF5_EP4_APCP_minus_GEF5v12_bias_stat_w1_20171004_20190925



- ACP bias reduced in EP4 compared to GEF5v12

Track error, 2020-2021, AL/EP/WP(Atlantic, East/West Pacific)



CASES 52

46

39

36

30

24

16

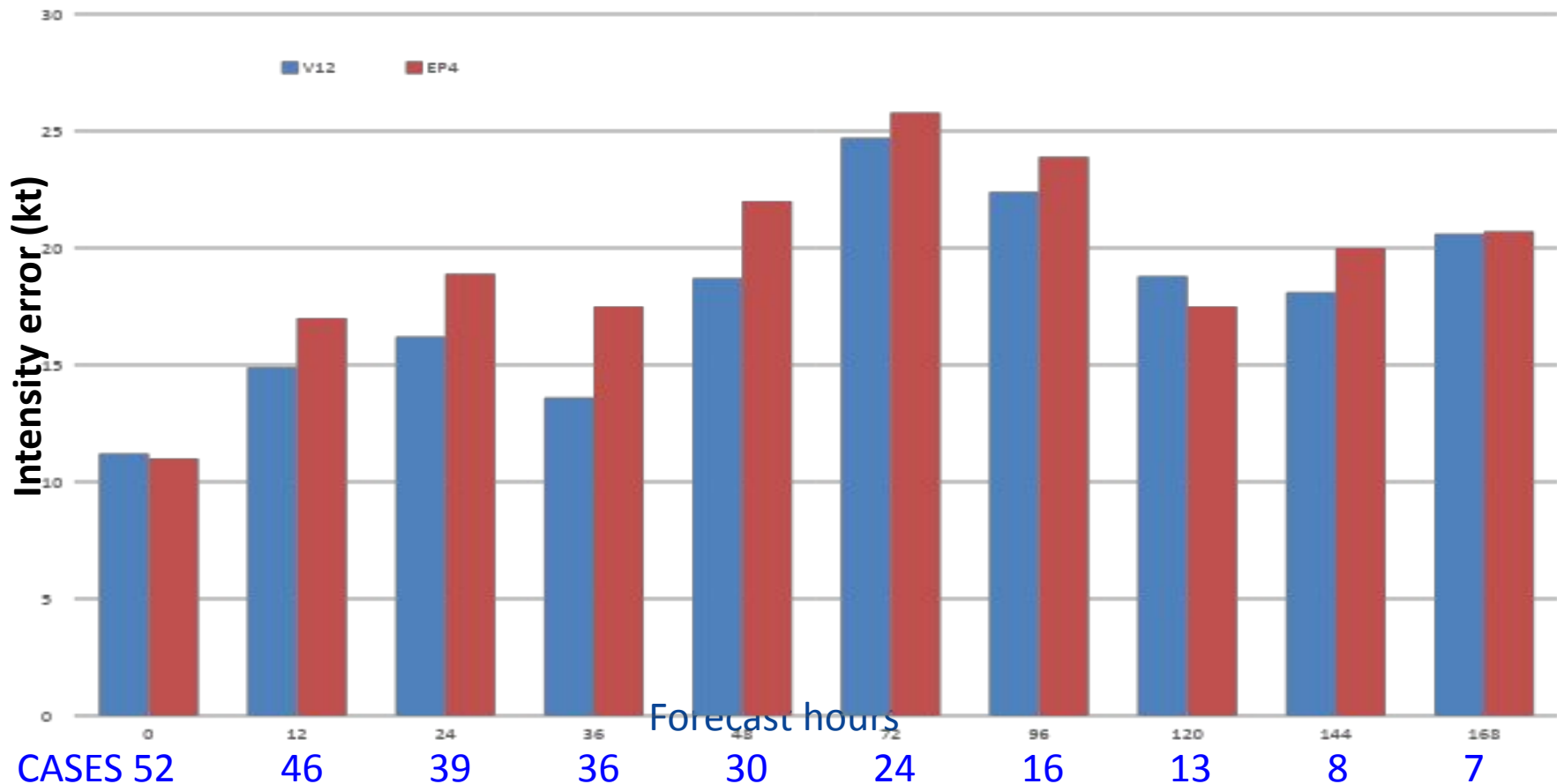
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8

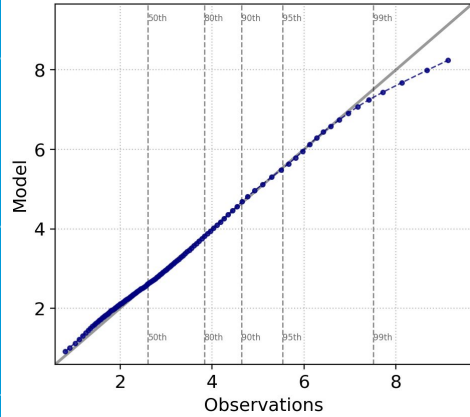
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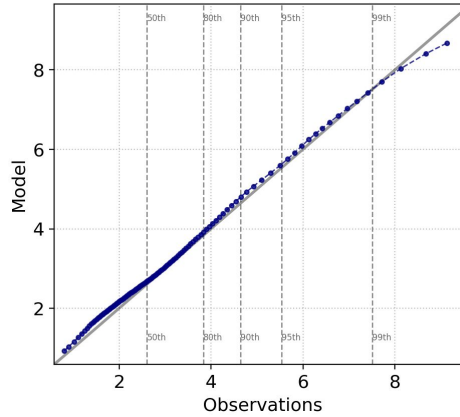
Intensity error, 2020-2021, AL/EP/WP(Atlantic, East/West Pacific)



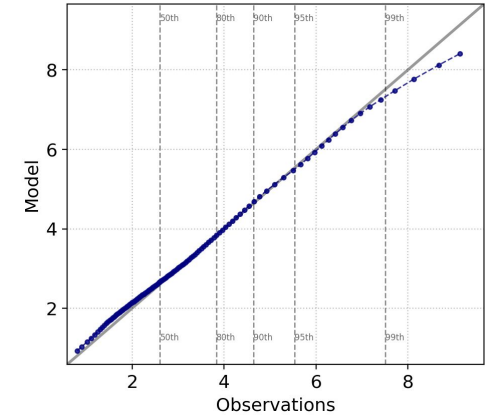
QQ plots, Hs(m) -Week 2, (8 winter cases)



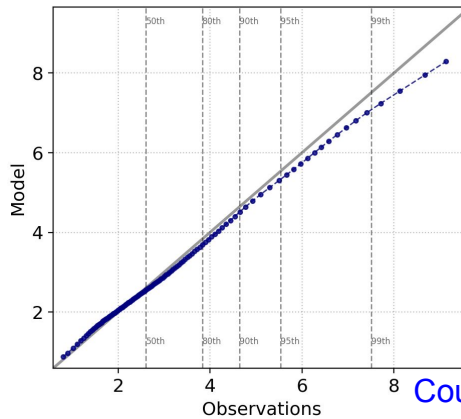
NOCUR



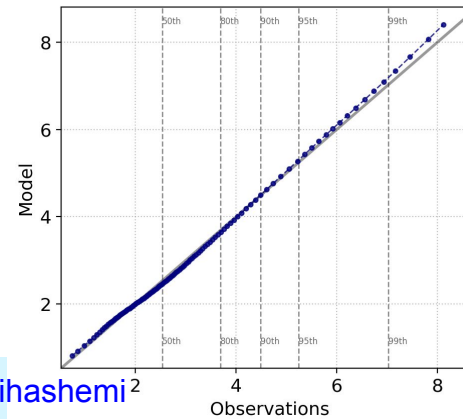
BMax_1.5



BMax_1.45



EP4



GEFSv12

Experiments with aerosol from EP4 and EP5

- **EP4 (HR1 based):**
 - EP4: (aerosol: climatology): 2-year full set
 - EP4b: (aerosol: prognostic, observed emission): 2-year full set
- **EP5 (HR3 based): only miniset completed**
 - EP5d: (aerosol: prognostic, blending emission):
 - EP5r2: (aerosol: prognostic, blending emission):
 - replay ICs (UFS coupled model replay ERA5/ORAS5)

Weekly averaged AC of GEFSv12/EP4/EP4b

<u>Z500: NH</u>	GEFSv12	EP4	EP4b
Week 1	0.965	0.967	0.967
Week 2	0.629	0.656	0.648
Week 3-4	0.356	0.378	0.386

<u>Z500: SH</u>	GEFSv12	EP4	EP4b
Week 1	0.958	0.961	0.962
Week 2	0.586	0.584	0.604
Week 3-4	0.291	0.278	0.243

- Blue text: higher AC than GEFSv12 (bolded text: significant improvement from GEFSv12 at a 95% confidence interval)
- Red text: lower AC than GEFSv12 (bolded text: significant degradation from GEFSv12 at a 95% confidence interval)

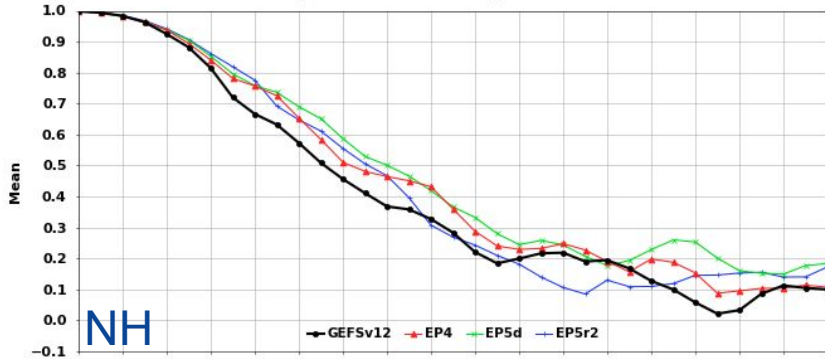


EP5 miniset results

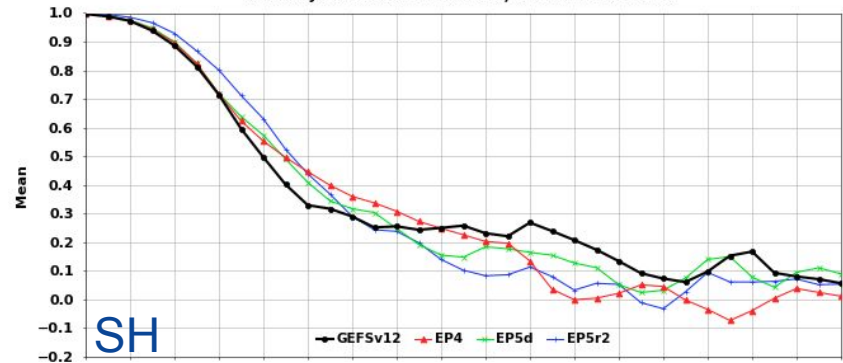


Z500 ACC: Winter

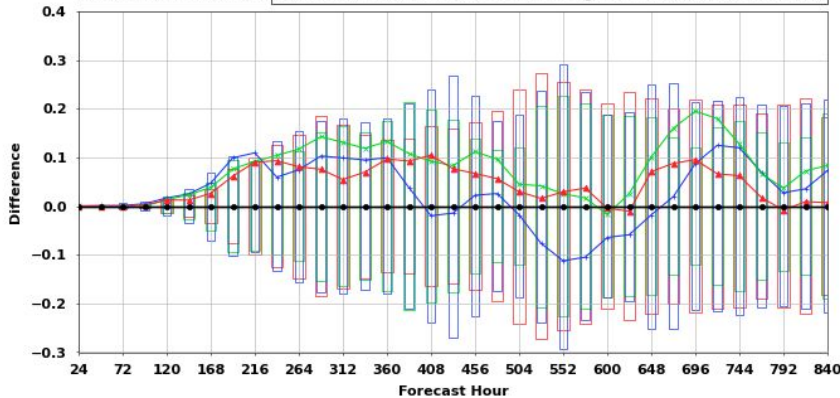
Anomaly Correlation Coefficient
500 hPa Geopotential Height (gpm), Northern Hemisphere 20N-80N
valid 03Jan2018-28Mar2018 00Z, forecast hour means



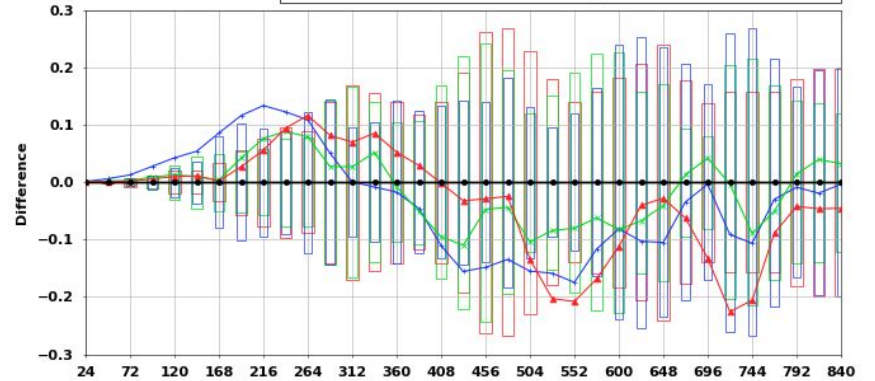
Anomaly Correlation Coefficient
500 hPa Geopotential Height (gpm), Southern Hemisphere 20S-80S
valid 03Jan2018-28Mar2018 00Z, forecast hour means



Difference from GEFSv12 Note: differences outside the outline bars are significant at the 95% confidence level



Difference from GEFSv12 Note: differences outside the outline bars are significant at the 95% confidence level

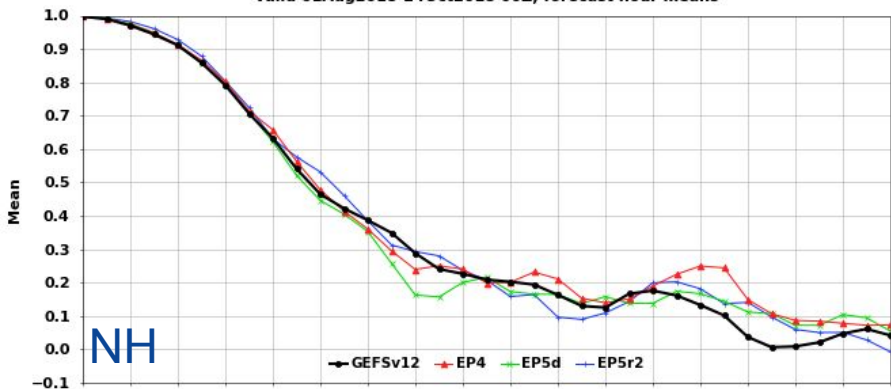


For NH, EP5r2 is comparable to other EPs, and all EPs perform better than GEFSv12
For SH, EP5r2 performs significantly better than other EPs and GEFSv12 for first 10 days

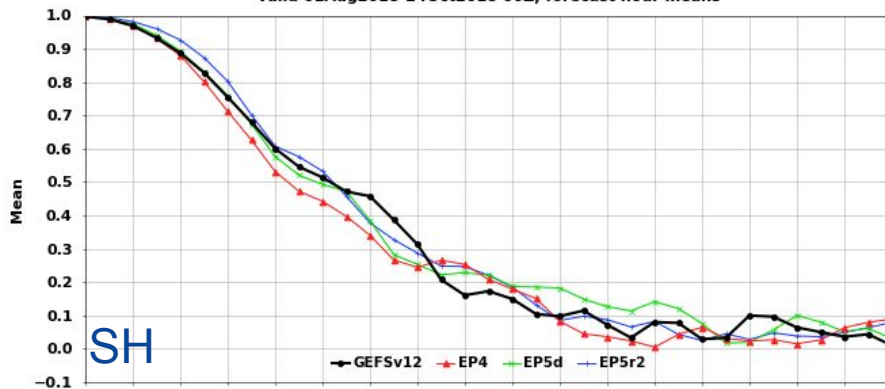


Z500 ACC: Summer

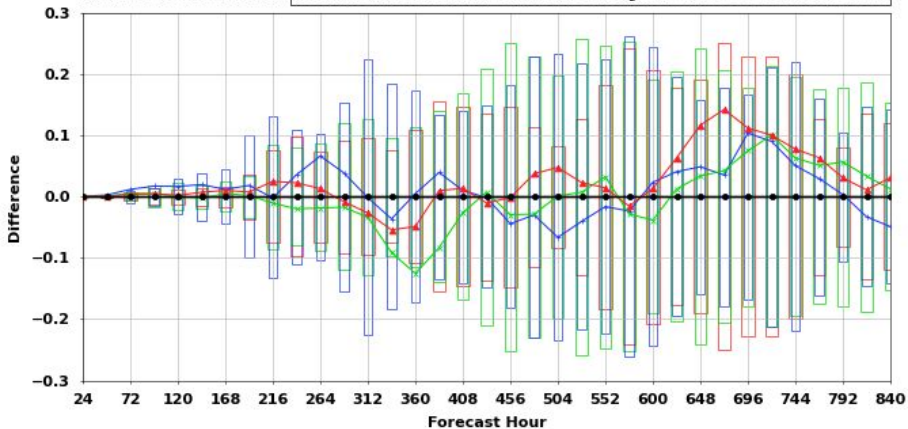
Anomaly Correlation Coefficient
500 hPa Geopotential Height (gpm), Northern Hemisphere 20N-80N
valid 01Aug2018-24Oct2018 00Z, forecast hour means



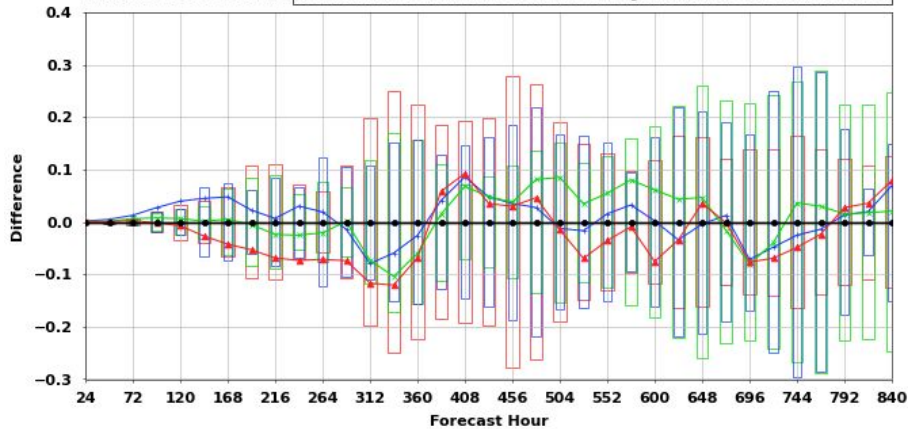
Anomaly Correlation Coefficient
500 hPa Geopotential Height (gpm), Southern Hemisphere 20S-80S
valid 01Aug2018-24Oct2018 00Z, forecast hour means



Difference from GEFSv12 Note: differences outside the outline bars are significant at the 95% confidence level



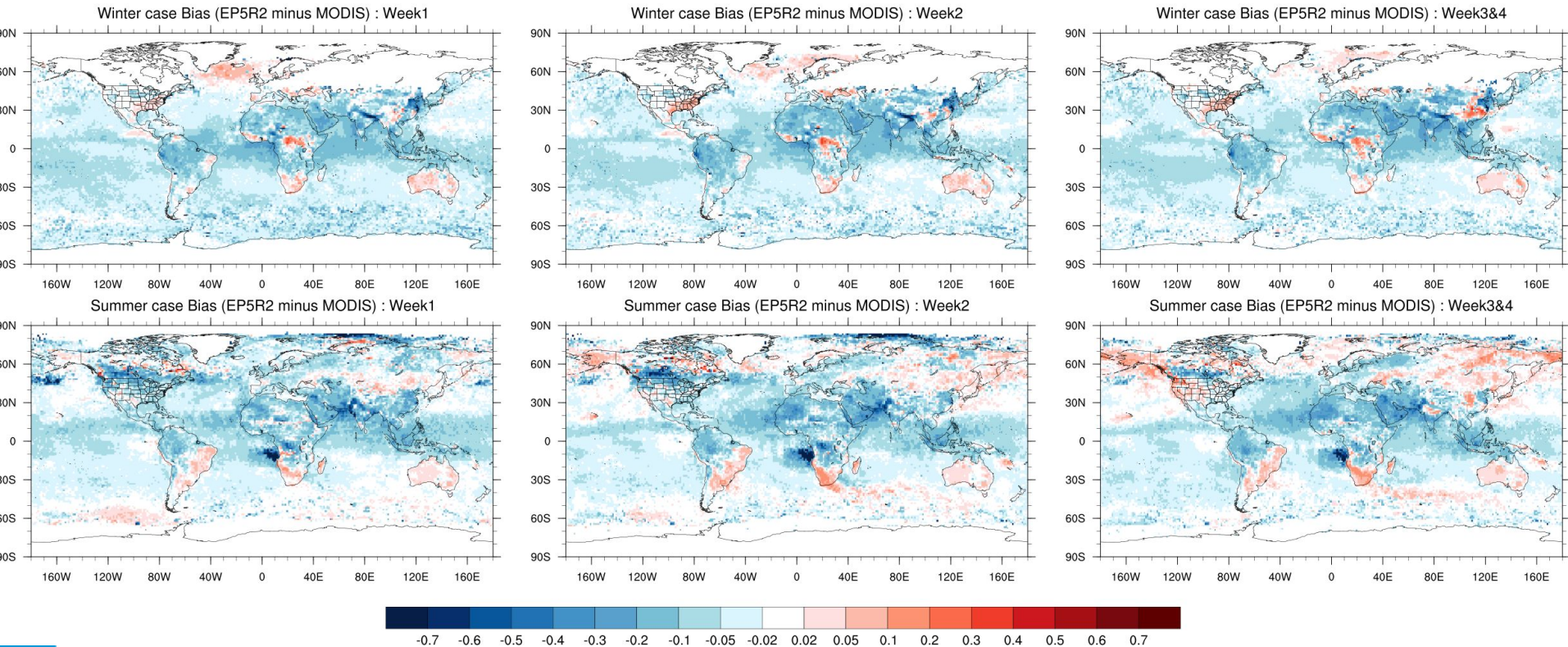
Difference from GEFSv12 Note: differences outside the outline bars are significant at the 95% confidence level





AOD bias in EP5r2 for winter (top) and summer (bottom)

8 winter cases and 8 summer cases in 2018



Green: EP5r2 significantly improved from GEFSv12
 Red: EP5r2 significantly degraded from GEFSv12

EP5r2 vs. GEFSv12 AC/RMSE: Days 1-10

Winter

		N. America					N. Hemisphere					S. Hemisphere					Tropics											
		Day 1	Day 3	Day 5	Day 6	Day 8	Day 1	Day 3	Day 5	Day 6	Day 8	Day 1	Day 3	Day 5	Day 6	Day 8	Day 1	Day 3	Day 5	Day 6	Day 8	Day 1	Day 3	Day 5	Day 6	Day 8		
Anomaly Correlation Coefficient	Heights	250hPa	▲				▲					▲	▲	▲		▲												
		300hPa	▲				▲					▲	▲	▲		▲												
		700hPa	▲				▲					▲	▲	▲		▲												
		1000hPa	▲			▲		▼	■				■	■	■		■											
	Vector Wind	250hPa	▲				▲					▲	▲	▲		▲												
		500hPa	▲				▲					▲	▲	▲		▲												
		850hPa	▲				▲					▲	▲	▲		▲												
	Temp	250hPa	▲			▲		▲			▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		500hPa	▲			▲		▲			▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		850hPa	▼					▼	■				▼	■	■		▼											
MSLP	MSL	▲			▲		▼	■				▼	■	■		▼												
RMSE	Heights	10hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		20hPa	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
		50hPa	▲					▲					▲					▲					▲					
		100hPa	▲					▲					▲					▲					▲					
		200hPa	▲					▲					▲					▲					▲					
		500hPa	▲				▲						▲					▲					▲					
		700hPa	▲				▲						▲					▲					▲					
		850hPa	▲				▲						▲					▲					▲					
		1000hPa	▲				▲						▲					▲					▲					
		Vector Wind	10hPa	■					■				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
20hPa	M		M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	
50hPa	▼						▼					▼					▼					▼						
100hPa	▼						▼					▼					▼					▼						
200hPa	▲						▲					▲					▲					▲						
500hPa	▲						▲					▲					▲					▲						
700hPa	▲						▲					▲					▲					▲						
850hPa	▲						▲					▲					▲					▲						
1000hPa	▲						▲					▲					▲					▲						
Temp	10hPa		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	20hPa	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	
	50hPa	▲					▲					▲					▲					▲						
	100hPa	▼					▼					▼					▼					▼						
	200hPa	▲					▲					▲					▲					▲						
	500hPa	▲					▲					▲					▲					▲						
	700hPa	▲					▲					▲					▲					▲						
	850hPa	▼					▼					▼					▼					▼						
	1000hPa	▼					▼					▼					▼					▼						

Summer

		N. America					N. Hemisphere					S. Hemisphere					Tropics											
		Day 1	Day 3	Day 5	Day 6	Day 8	Day 1	Day 3	Day 5	Day 6	Day 8	Day 1	Day 3	Day 5	Day 6	Day 8	Day 1	Day 3	Day 5	Day 6	Day 8	Day 1	Day 3	Day 5	Day 6	Day 8		
Anomaly Correlation Coefficient	Heights	250hPa	▲				▲					▲	▲	▲		▲												
		300hPa	▲				▲					▲	▲	▲		▲												
		700hPa	▲				▲					▲	▲	▲		▲												
		1000hPa	▲				▲					▲	▲	▲		▲												
	Vector Wind	250hPa	▲				▲					▲	▲	▲		▲												
		500hPa	▲				▲					▲	▲	▲		▲												
		850hPa	▲				▲					▲	▲	▲		▲												
	Temp	250hPa	▲				▲					▲	▲	▲		▲												
		500hPa	▲				▲					▲	▲	▲		▲												
		850hPa	■					■					■					■					■					
MSLP	MSL	▲				▲					▲					▲					▲							
RMSE	Heights	10hPa	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
		20hPa	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
		50hPa	▲	▲				▲					▲					▲					▲					
		100hPa	▲					▲					▲					▲					▲					
		200hPa	▲					▲					▲					▲					▲					
		500hPa	▲					▲					▲					▲					▲					
		700hPa	▲					▲					▲					▲					▲					
		850hPa	▲					▲					▲					▲					▲					
		1000hPa	▲					▲					▲					▲					▲					
		Vector Wind	10hPa	▼					▼				▼	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
20hPa	M		M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	
50hPa	▼						▼					▼					▼					▼						
100hPa	▼						▼					▼					▼					▼						
200hPa	▲						▲					▲					▲					▲						
500hPa	▲						▲					▲					▲					▲						
700hPa	▲						▲					▲					▲					▲						
850hPa	▲						▲					▲					▲					▲						
1000hPa	▲						▲					▲					▲					▲						
Temp	10hPa		▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
	20hPa	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	
	50hPa	▲					▲					▲					▲					▲						
	100hPa	▼					▼					▼					▼					▼						
	200hPa	▲					▲					▲					▲					▲						
	500hPa	▲					▲					▲					▲					▲						
	700hPa	▲					▲					▲					▲					▲						
	850hPa	▲					▲					▲					▲					▲						
	1000hPa	▼					▼					▼					▼					▼						

- ACC/RMSE differences are overall favorable (especially over SH) except for 1000 hPa temperature RMSE



Summary

- ❖ Five ensemble prototypes (EP1 - EP5) have been developed following the development of UFS coupled model
- ❖ Overall the coupled ensemble model outperformed the current operational GFSv12
- ❖ The latest EP (EP5r2) is running for the full set. We only have some results from the miniset, waiting for the evaluation for the full set (expected to be finished by early July)

Future plan

- ❖ Finish the EP5r2 full set run by July 1.
- ❖ Evaluation of EP5r2 full set run from July 1 - 31.
- ❖ Launch the GEF5v13 reforecast in August
 - If global-workflow for ensemble is ready
 - If the results from EP5r2 is satisfactory