Update of GEFS Reanalysis/Reforecast

Hong Guan

Yuejian Zhu, Bing Fu, Xiaqiong Zhou, Eric Sinsky, Wei Li,
Dingchen Hou, Xianwu Xue, Bo Cui, Yan Luo and Jiayi Peng
and ensemble staffs

Environmental Modeling Center
NCEP/NWS/NOAA
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30-year FV3GEFS Reforecast Configuration

- **Forecast system**
  - FV3 GFSv15.1 and GEFSv12
  - Resolution – C384 (~25km) with 64 hybrid vertical levels

- **Frequency and ensemble size**
  - Initialized at 00UTC for every day
  - Run 5 members out to 16 days, except for 11 members out to 35 days every Wednesday

- **Initial conditions**
  - Phase I: 1989 – 1999 (11 years), CFS analysis, BV-ETR perturbation
  - Phase II: 2000 – 2018 (19 years), Hybrid FV3 GFS/EnKF reanalysis (ESRL/PSD) with Incremental Analysis Update (IAU) process, EnKF f06 perturbation
  - **Caution - Initial analyses and perturbations of 30 years are in-consistent**

- **Output data**
  - 3 hourly out to 10 days at 0.25 degree resolution
  - 6 hourly beyond 10 days at 0.5 degree resolution
  - Save all variables (**590**) in grib2 format at above resolution on HPSS for 5-year
  - Save selected variables (**77**) in grib2 format on disk for stakeholders (CPC, MDL, and NWC)
  - Save selected variables on project purchased disk (NCO, EMC and PSD are working this right now)

20-year FV3GFS Reanalysis (ESRL/PSD)

- **Real-time operational DA configuration:**
  - Hybrid 4D-En-Var, with control at C768 (approximately 0.125 degree grid spacing) and 80-ensemble members at C384 (approximately 0.25 degree grid spacing)
  - SPPT, SKEB, SHUM stochastic parameterizations in the ensemble to address model uncertainty

- **Reanalysis configuration:**
  - The same model version and stochastic parameterization as operational DA
  - Reduced resolution: C384 (control – 0.25degree) and C128 (ensemble members – 0.75degree)
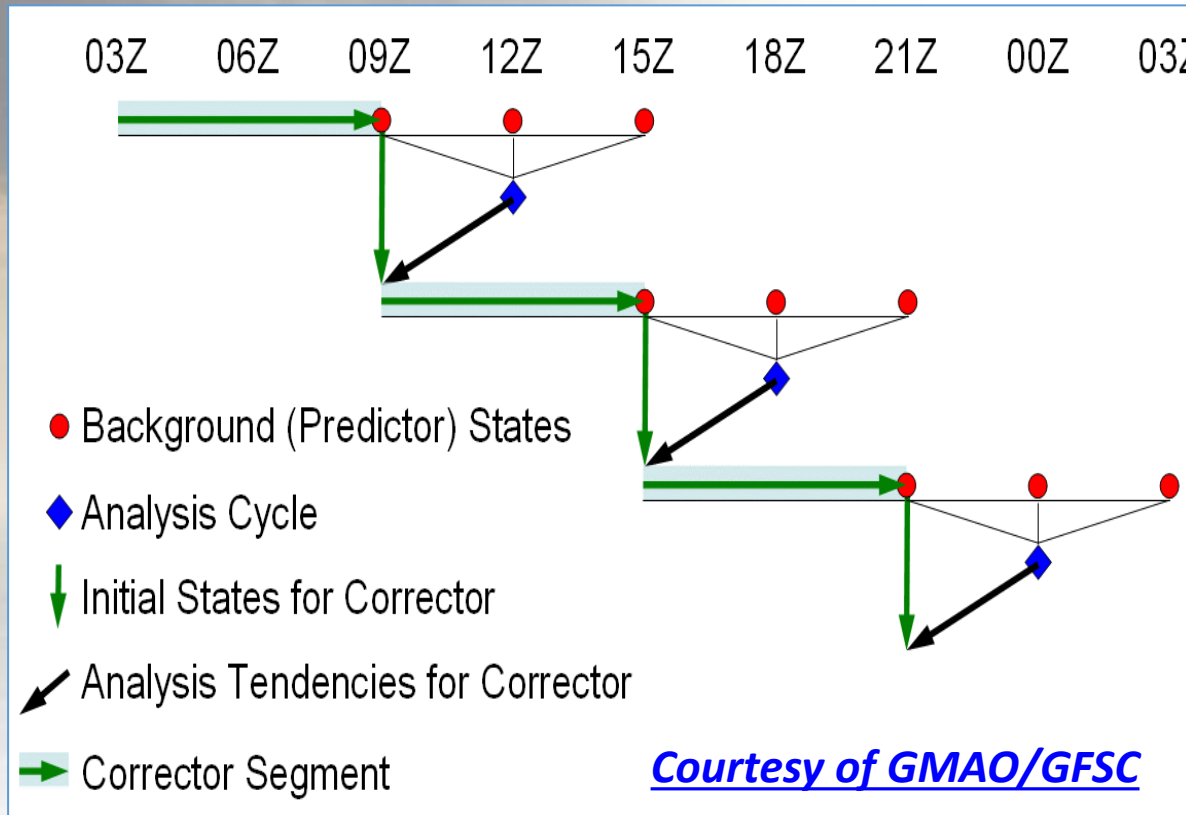 - **IAU** to control noise and improve accuracy

- Run 5 streams – each stream has 1-year spin-up
  - 1999 stream (1999 – 2003)
  - 2003 stream (2003 – 2007)
  - 2007 stream (2007 – 2011)
  - 2011 stream (2011 – 2015)
  - 2015 stream (2015 – 2019)

  Courtesy of Whitaker and Hamill

- Monitoring system – https://www.esrl.noaa.gov/psd/forecast-modeling/gefsrr/

Incremental Analysis Update (IAU) Process

Courtesy of GMAO/GFSC

The analysis increments are added to the model state over a period of time (IAU window) for each model time-step.

Upper Air Variables– 0.5degree

	U	V	T	RH	Height	VV	O3MR
10hPa	C,E	C,E	C,E		C,E		C
50hPa	C,E	C,E	C,E		E		C
100hPa	E	E	E		E		C
200hPa	C,M,E	C,M,E	C,M,E	C,M	C,M,E		
250hPa	M,E	M,E	M,E	M	M,E		
500hPa	C,M,E	C,M,E	C,M,E	C,M	C,M,E		
700hPa	C,M,E	C,M,E	C,M,E	C,M	C,M,E		
850hPa	C,M,E	C,M,E	C,M,E	C,M	M,E	E	
925hPa	M,E	M,E	M,E	M	M,E		
1000hPa	M,E	M,E	M,E	M	M,E		
0.995 (hybrid)	C	C	C	C			

Total: 55 variables to support CPC, MDL and EMC (NAEFS), but not for MDL's BMOS

C – CPC; M – MDL; N – NWC; E - EMC (the same for next slide)

Surface and Other Variables – 0.25degree

Variables	Requested	total	Notes
PMSL, Surface Pressure	C,M,N,E	2	
T2m, Tmax, Tmin	C,M,N,E	3	Tmax and Tmin for 6-hr
2m RH	M,N,E	1	Could convert to Td or q
U10m, V10m	C,N,E	2	
QPF	C,M,N,E	1	3-hr accumulation
Precipitation Types	C,M,E	4	Rain, Freezing rain, Ice Pellets, Snow
PWAT	M	1	
CAPE	C,M,E	1	
CIN	C,M,E	1	
Helicity 0-3000km	C	1	
Total sky cover (TCDC)	M,E	1	
Snow water equivalent	C	1	
OLR	C,E	1	
SDLR	N	1	
SDSR	N	1	

Total 22 variables, the BMOS variables are not counted in this list

Reforecast has been running ......

- Dec. 21st 2018 – Started Phase I reforecast later afternoon
- Dec. 22nd 2018 – government shutdown
- Dec. 22nd 2018 – Jan. 27th 2019
    - Cron job was continuously running
    - Approximately, one year reforecast/per week without stopping (7/24)
- Jan. 28th 2019 – government reopen
    - Continue Phase I reforecast
    - Made up all missing/fail forecasts
    - April 30 2019 - Finished phase I reforecast
- Between later April – mid-June 2019
    - Both of EMC and PSD worked on the consistence of the forecasts from reanalysis and future operation.
- June 24th 2019 – Started Phase II reforecast
    - However, we have limited HPC resources, runs are much slower than phase I
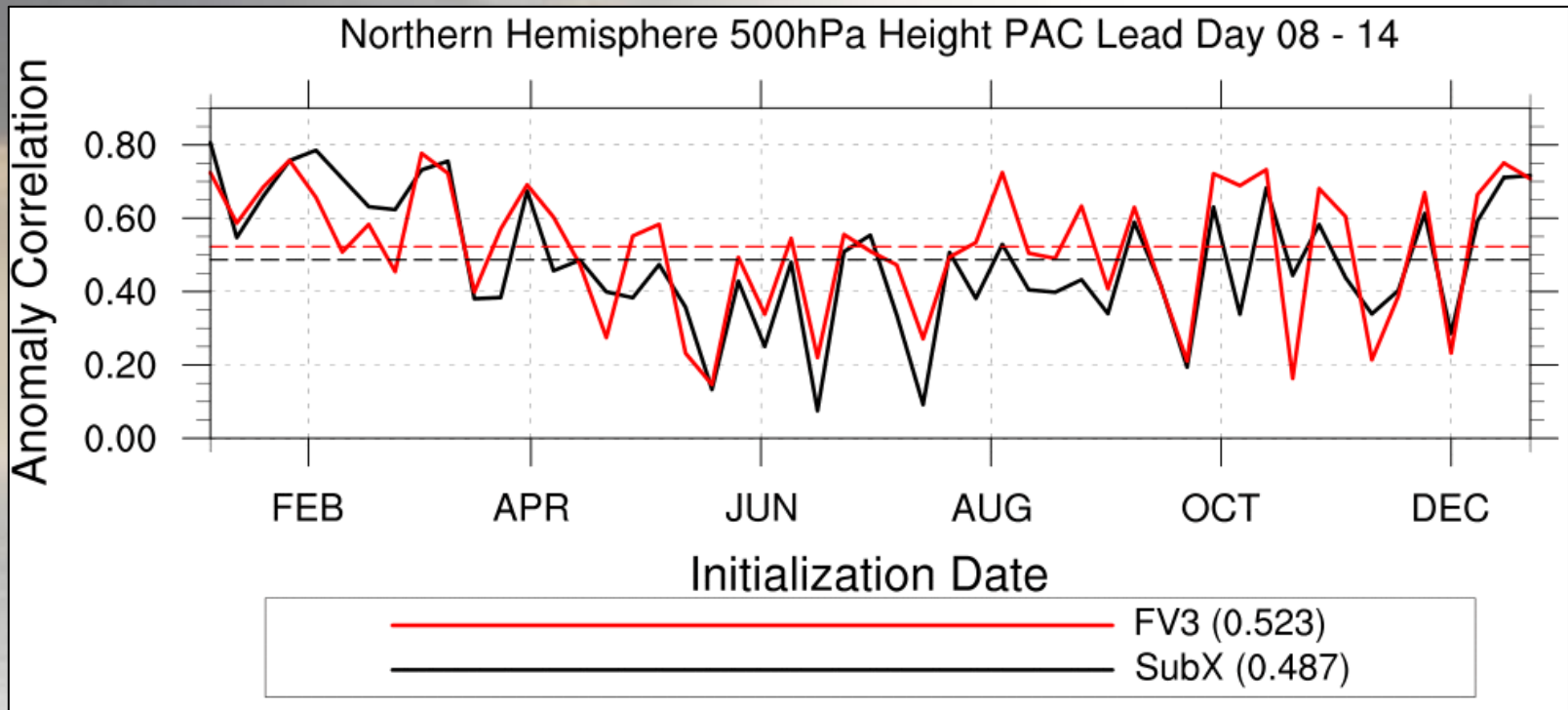   - Target date to finish – Dec. 31 2019

Preliminary Evaluation of GEFSv12 (FV3GEFS) Reforecast

Comparison of TS Track between GEFSv10 and GEFSv12 (FV3GEFS) Reforecast (1989-1999)

2nd generation of GEFS reforecast
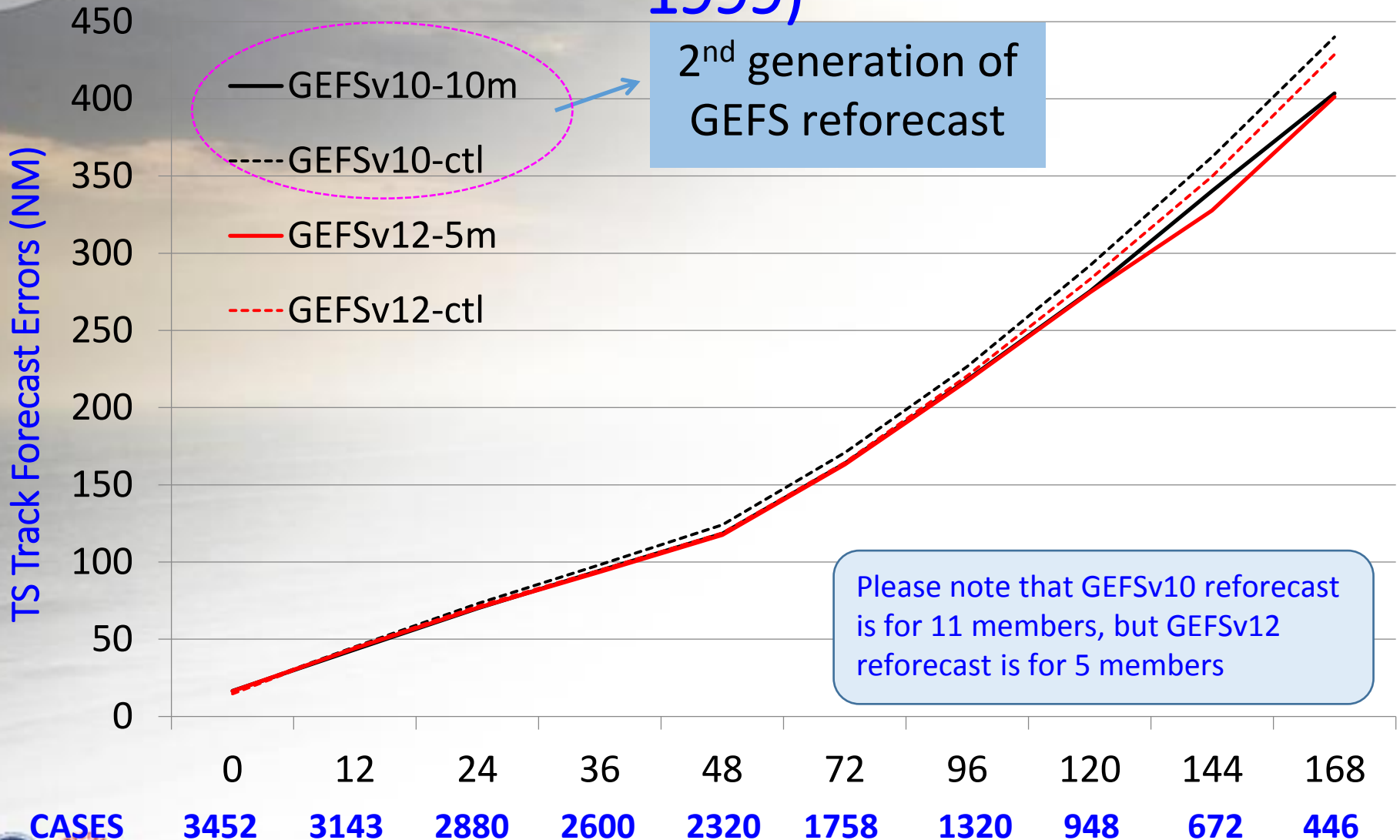
Please note that GEFSv10 reforecast is for 11 members, but GEFSv12 reforecast is for 5 members

Legend:
- GEFSv10-10m
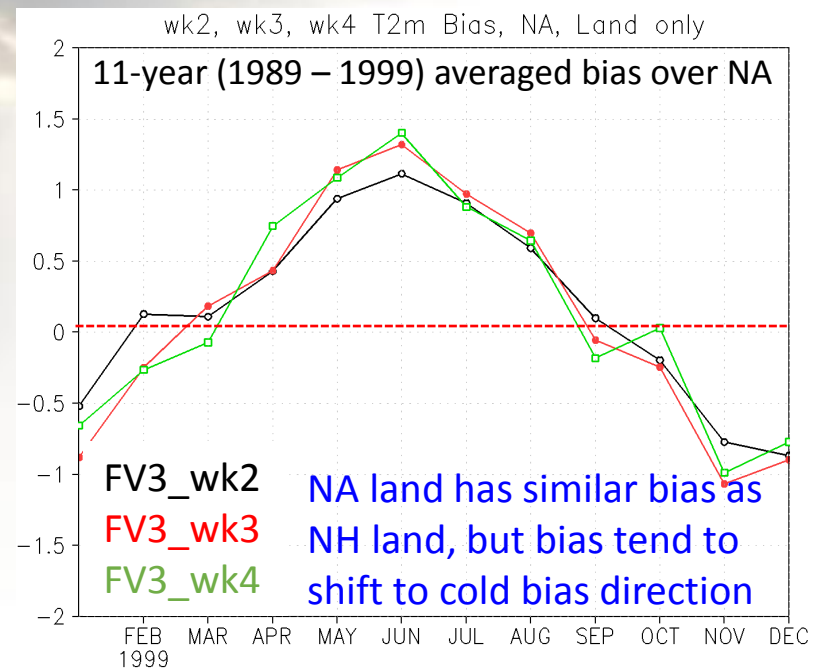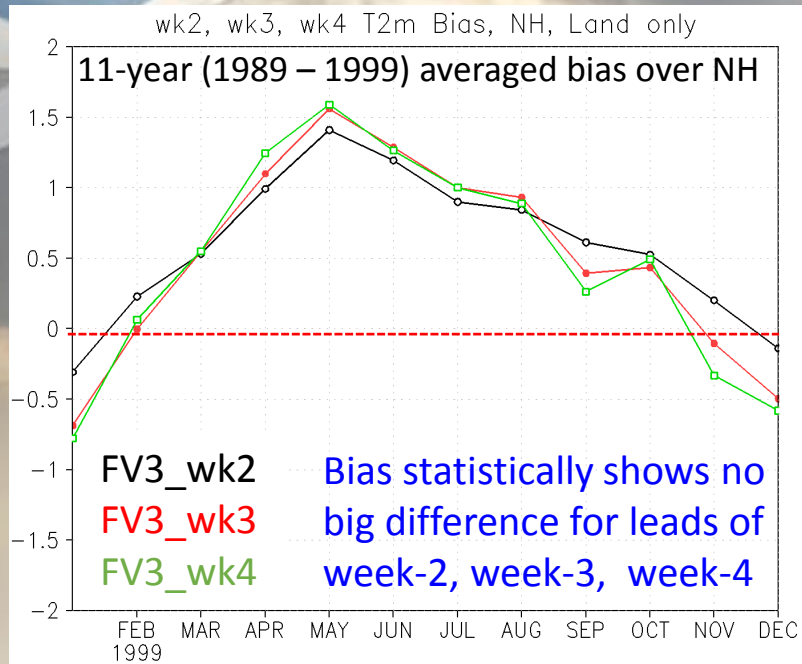- GEFSv10-ctl
- GEFSv12-5m
- GEFSv12-ctl

Y-axis: TS Track Forecast Errors (NM)

CASES	3452	3143	2880	2600	2320	1758	1320	948	672	446
Hour	0	12	24	36	48	72	96	120	144	168

GEFSv10 reforecast: the 2nd generation of reforecast

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Comparison of 500mb Height between SubX and FV3GEFS (1999)

Northern Hemisphere 500hPa Height PAC Lead Day 08 - 14

FV3 (0.523)
SubX (0.487)

SubX --- 0.487

FV3   --- 0.523

2-m Temp. Bias for FV3GEFS Reforecast (1989-1999)

wk2, wk3, wk4 T2m Bias, NH, Land only

11-year (1989 – 1999) averaged bias over NH

FV3_wk2
FV3_wk3
FV3_wk4

Bias statistically shows no big difference for leads of week-2, week-3, week-4

wk2, wk3, wk4 T2m Bias, NA, Land only

11-year (1989 – 1999) averaged bias over NA

FV3_wk2
FV3_wk3
FV3_wk4

NA land has similar bias as NH land, but bias tend to shift to cold bias direction

360hr Reforecast Bias, T2m, NA, Land only

Year-by-year bias over NA (land only)

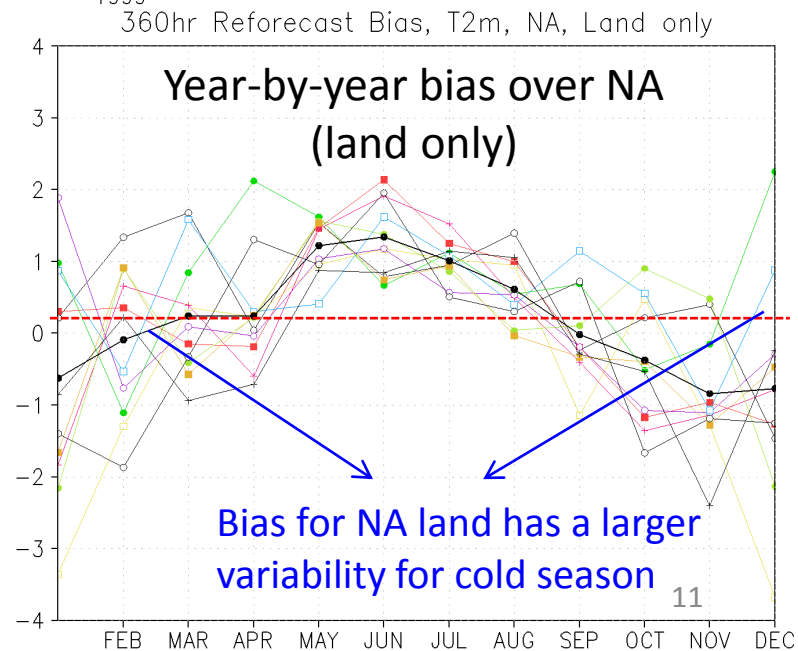Bias for NA land has a larger variability for cold season

Reference: CFS reanalysis

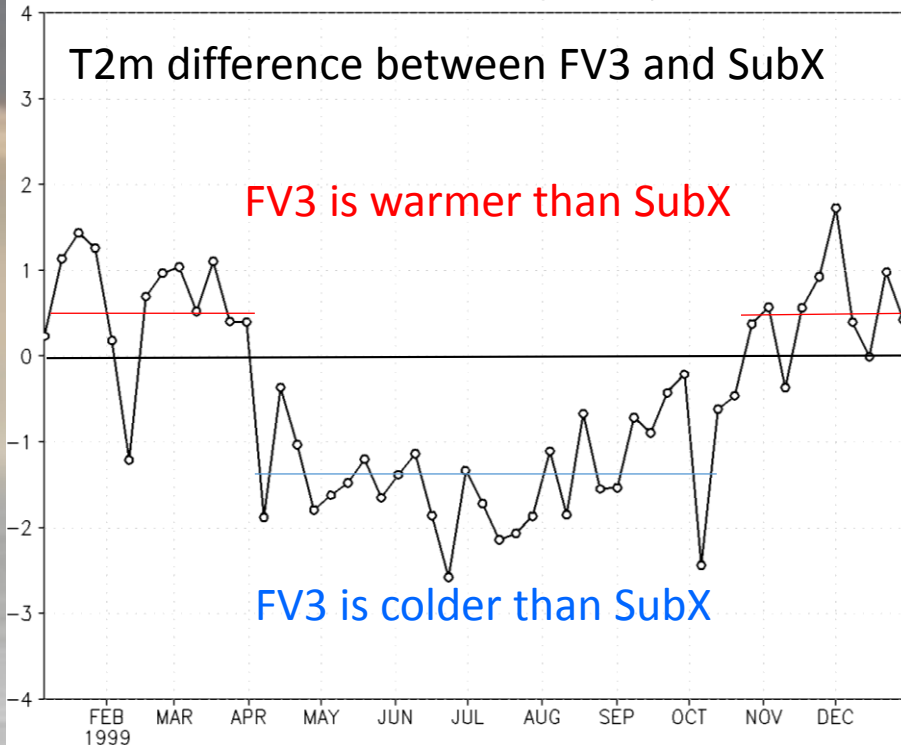Top left: NH (land only) weeks-2; -3; -4 bias

Top right: NA (land only) week-2; -3; -4 bias

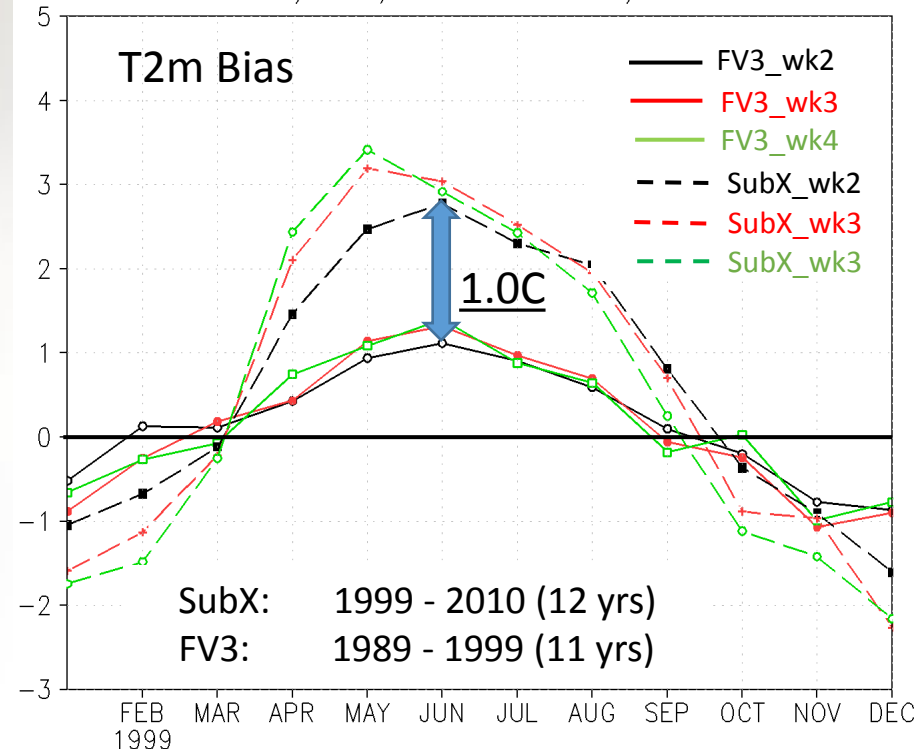Bottom right: NA (land only) 240-hour year-by-year bias

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Comparison of 2-m Temp. between FV3GEFS and SubX for NA land only

360h T2m FV3−SubX, 1999, NA

T2m difference between FV3 and SubX

FV3 is warmer than SubX

FV3 is colder than SubX

wk2, wk3, wk4 T2m Bias, NA

T2m Bias

- FV3_wk2
- FV3_wk3
- FV3_wk4
- SubX_wk2
- SubX_wk3
- SubX_wk3

1.0C

SubX: 1999 – 2010 (12 yrs)
FV3:   1989 – 1999 (11 yrs)
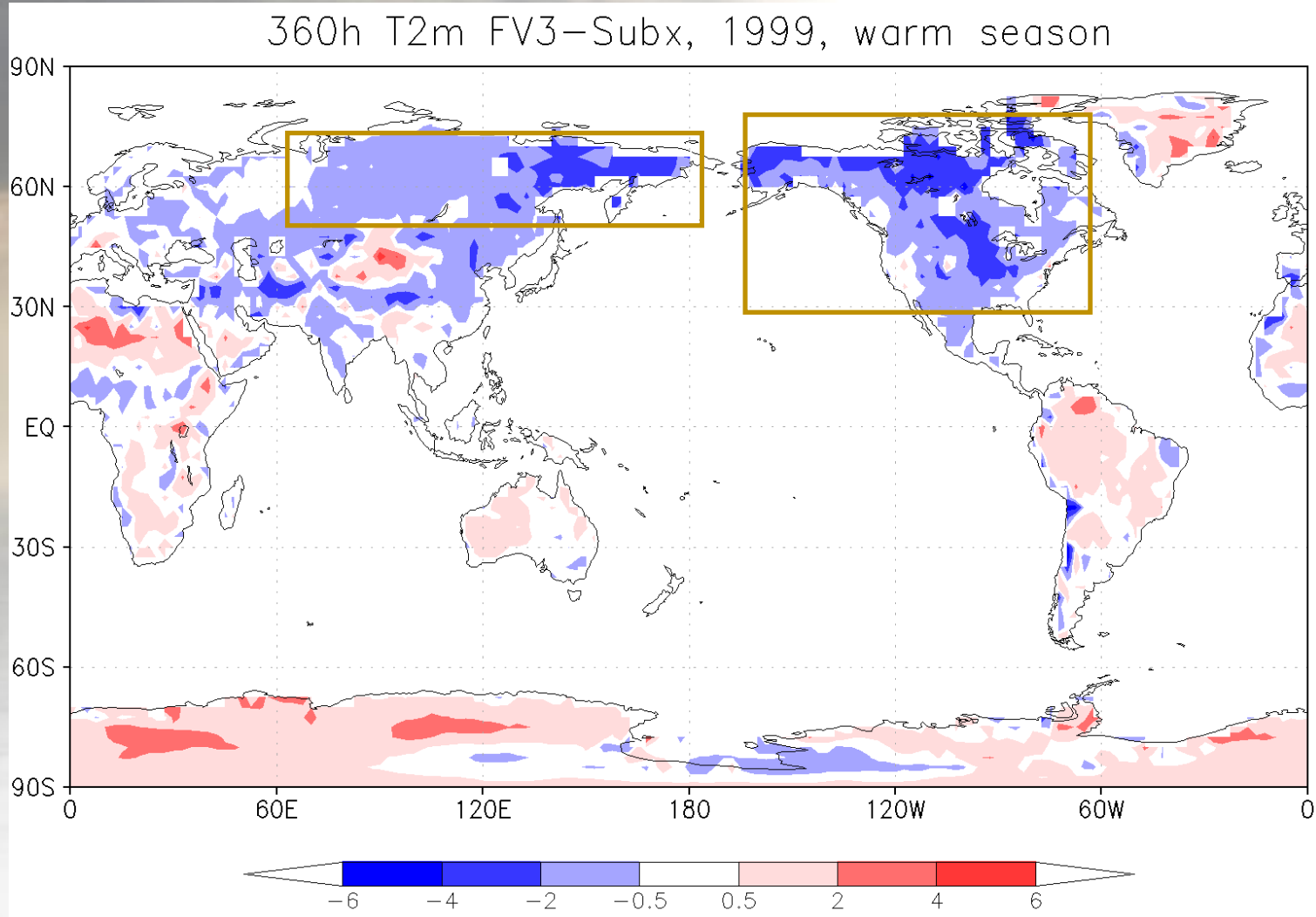
Only one year overlap (1999)

Both use cfsr as initial condition

For cold (warm) season, cold (warm) bias in FV3 is smaller (much smaller) than that in SubX. The smaller bias in FV3 is possibly due to more sophisticated GFDL MP.
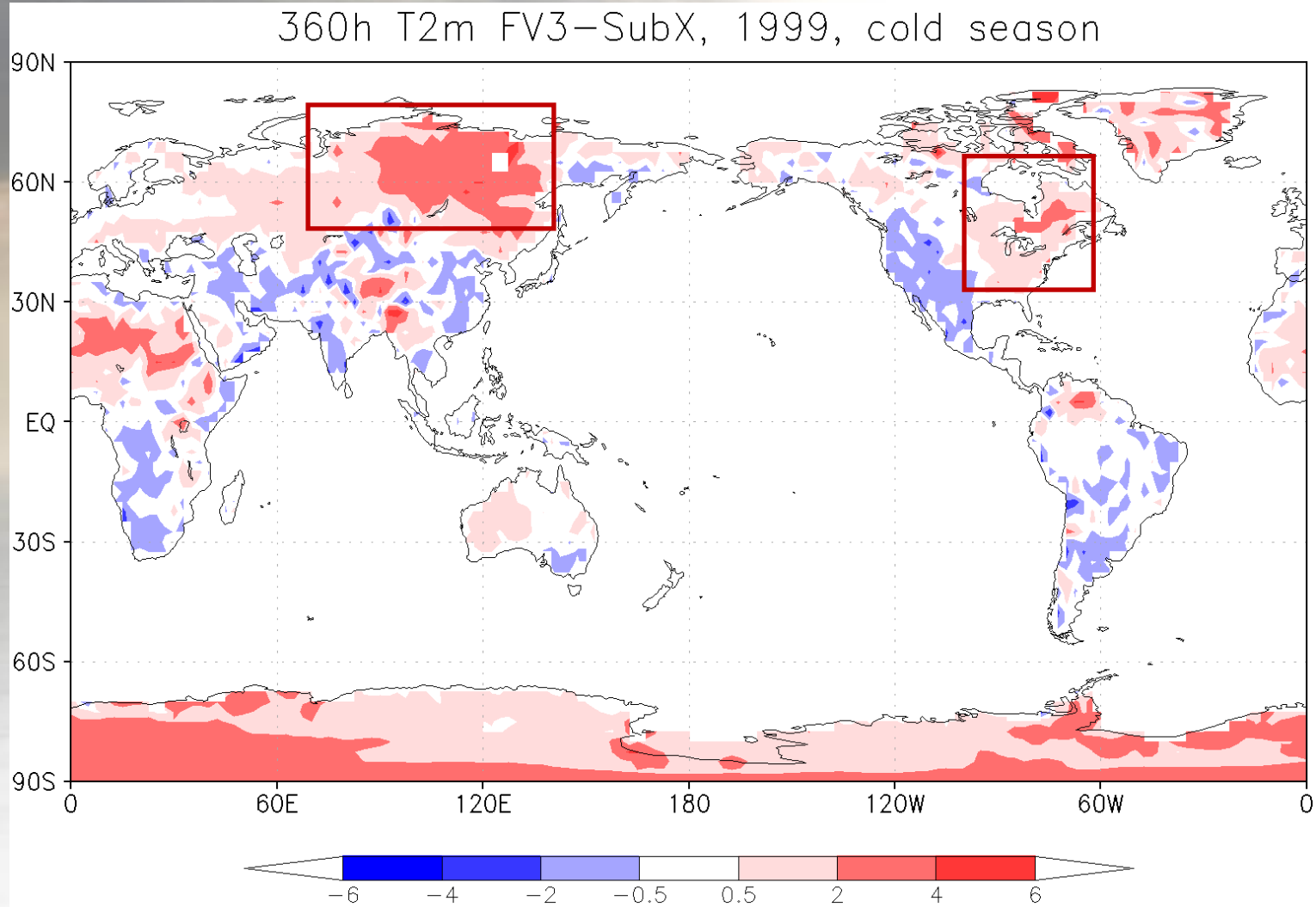
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Comparison of 2-m Temp. between FV3GEFS and SubX (1999, Warm Season)

360h T2m FV3-Subx, 1999, warm season

FV3 is colored for NA and high latitude to reduce warm bias for warm season

Comparison of 2-m Temp. between FV3GEFS and SubX (1999, Cold Season)

360h T2m FV3-SubX, 1999, cold season
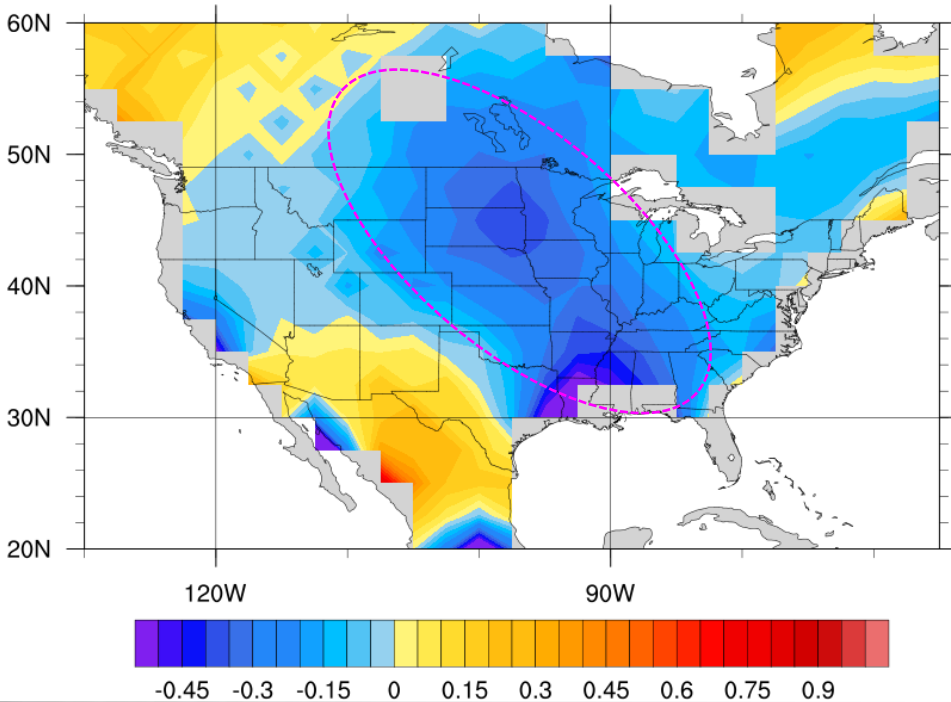
FV3 is warmer for east CUNUS and high latitude to reduce cold bias for cold season
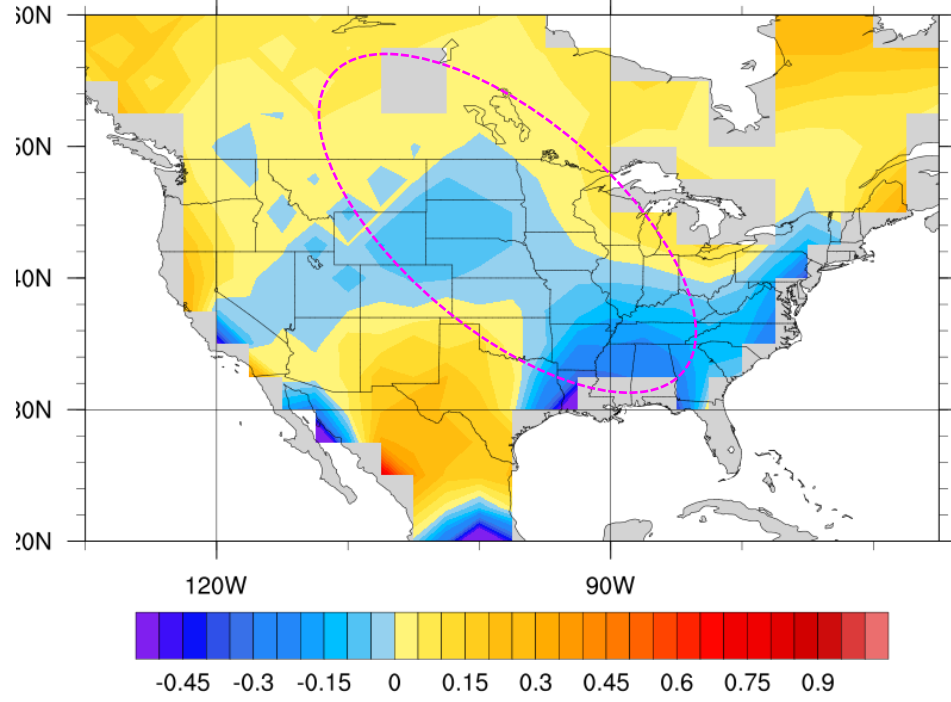
RPSS of 2-m Temp. for Weeks 3&4 Average (2017-2018)

a) Subx T2m RPSS 20170401to20180327

a) FV3 T2m RPSS 20170401to20180327

FV3GEFS indicates a big improvement for T2m over CONUS

For raw ensemble forecast (no calibration)
Truth: own analysis or f00 at 2.5d resolution

Summary

- Phase I (1989-1999) reforecast has been finished
  - 2-m temp. bias is much smaller than SubX version
  - TC tracks get improved from v10 reforecast
  - Week 2 PAC score for Z500 is better than SubX version
- Phase II (2000-2018) reforecast has been running since June 24, 2019
- GEFSv12 implementation schedule:
  - Finish 30-year reforecast by the end of this year (Dec. 31th). Only 4 months left!!!
- Challenges
  - HPC resource for reforecast, still seeking for cloud computation
  - HPSS to store forecasts and transfer data between PSD and EMC
  - Progress for generating the reanalysis and restart files through extra IAU replay process
- Keep updated on our progress!!!

Thanks for your attention!!!

GEFSv10, v11+, and v12 configuration

	V10	V11+ (SubX)	V12 (FV3)
GFS model	Spectrum model	Spectrum model	FV3 dynamics
Resolution	T254L42 (0-8day) ~50km T190L42 (8-16day)~75km	T574L64 (0-8day) ~33km T382L64 (8-35day) ~55km	C384L64 (0-35day) ~25km
Stochastics scheme	STTP	SPPT (5 scales), SHUM and SKEB (0.6)	SPPT (5 scales), SKEB (0.6)
SST	RTG SST	2-tier SST	2-tier SST
Run frequency	Once per day(00UTC)	Once per week(00UTC)	Once per day(00UTC)
Initial analysis	CFSR (1985- present)	CFSR (1999-2010) GDAS (2011-2016)	CFSR (1989-1999) Reanalysis IAU(2000-2019)
Perturbation	ETR (1985- present)	ETR (1999-2010) ENKF 6-h forecast	ETR (1989-1999) ENKF 6-h forecast
Membership	10+1	10+1	4+1 and 10+1

Reforecast Runs

11/5 members, every day at 00UTC

35d (11m)   **Reforecast leads**   **35d (11m)**

5 members

16d   **16d**   **16d**   **16d**   **16d**   **16d**

Repeat this every 7 days

Phase I: 1989 – 1999 (11 years)

Phase II: 2000 – 2018 (19 years)

Project 650 Dell nodes for 1 year