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# The NCEP GEFS-v12 Reforecasts to Support Subseasonal and Hydrometeorological Applications

Hong Guan[1], Yuejian Zhu[2], Eric Sinsky[3], Bing Fu[3], Xiaqiong Zhou[3], Wei Li[3], Xianwu Xue[1], Dingchen Hou[2], Bo Cui[3], and Jiayi Peng[3]

[1]*SRG at Environment Modeling Center, NCEP/NWS/NOAA, College Park, MD*
[2]*Environmental Modeling Center, NCEP/NWS/NOAA, College Park, MD*
[3]*IMSG at EMC, NCEP/NWS/NOAA, College Park, MD*

## 1. Introduction

For the incoming implementation of National Centers for Environmental Prediction (NCEP) Global Ensemble Forecast System version 12 (GEFSv12), which is based on Finite Volume 3 (FV3) dynamical core and referred as FV3-GEFS, the 30-year (1989-2019) reforecast was generated to support forecast validation and calibration for various stakeholders, private sectors, and public users. The service areas cover weather, week-2, subseasonal forecast, and hydrometeorological application. This dataset was produced from NOAA's Weather and Climate Operational Supercomputing System (WCOSS) in NCEP. This study summarizes the configuration and dataset of the FV3-GEFS reforecast and presents some preliminary evaluations for 500hPa geopotential height, tropical storm (TS) track, and 2-meter temperature. These results were also compared with GEFSv10 or Subseasonal experiment (SubX) GEFS reforecasts.

## 2. Reforecast system configuration and dataset

The NCEP FV3-GEFS will be implemented in September 2020. This real-time forecast system is based on the Global Forecast System vervion 15.1 (GFSv15.1). The resolution of the forecast system is ~25 km (C384 grid) with 64 vertical hybrid levels. More detail on the GEFSv12 forecast system can be found in Zhou *et al.* (2019). The reforecast was integrated once per day out to 16 days except on Wednesday when the forecast was extended to 35 days. In contrast to the real-time forecast system, the reforecast system has a smaller ensemble size (5 (11) members for the 16-day (35-day) run and 31 members for the real-time forecasts). Boundary condition was derived from a two-tiered SST and Near Sea Surface Temperature (NSST) approach that accounts for both day-to-day variability and diurnal cycle of SST.

For the Phase I reforecast (1989-1999), the Climate Forecast System Reanalysis (CFSR) (Saha *et al.* 2014) was used as the initial control analysis. The breeding vector and ensemble transform with rescaling (BV-ETR) technique (Wei *et al.* 2008) was used to produce initial perturbations. For the Phase II reforecast (2000-2018), initial conditions were taken from the FV3 GFS/Ensemble Kalman Filter (EnKF) hybrid analysis and EnKF 6-hour forecasts, recently generated by the NOAA Earth System Research Laboratories (ESRL). The FV3 reanalysis has several differences compared to the current operational analysis. 1. Incremental Analysis Update (IAU) process was applied to reduce noise and improve accuracy. 2. NSST was replaced by Optimum Interpolation Sea Surface

**Table 1** Fifty-five upper air variables **at** 0.5° resolution.

| | U | V | T | RH | Height | VV | O3MR |
|---|---|---|---|---|---|---|---|
| 10 hPa | x | x | x | | x | | x |
| 50 hPa | x | x | x | | x | | x |
| 100 hPa | x | x | x | | x | | x |
| 200 hPa | x | x | x | x | x | | |
| 250 hPa | x | x | x | x | x | | |
| 500 hPa | x | x | x | x | x | | |
| 700 hPa | x | x | x | x | x | | |
| 850 hPa | x | x | x | x | x | x | |
| 925 hPa | x | x | x | x | x | | |
| 1000 hPa | x | x | x | x | x | | |
| 0.996 (hybrid) | x | x | x | x | | | |

Correspondence to: Hong Guan, SRG at Environment Modeling Center, NCEP/NWS/NOAA, College Park, MD 20740; E-mail: hong.guan@noaa.gov

Temperature (OISST). 3. Both control and perturbed analyses (C384 and C128) have a coarser resolution than the real-time analyses (C768 and C384) due to the limited computational resource.

The 30 years of reforecast dataset are currently archived on the High Performance Storage System (HPSS). All 590 variables in grib2 format are saved 3 (6) hourly at 0.25° (0.5°) resolution for the first 10 days (beyond 10 days) of forecasts. The 77 selected variables from 590 are requested to store on WCOSS disk for the stockholders quick access. The upper air and single-level variables are separately listed in Table 1 and 2, respectively. More selected variables will be saved on project purchased disk for the broader community uses in the future.

**Table 2** Twenty-two surface and other single-level variables at 0.25° resolution.

| Variables | Total | Notes |
|---|---|---|
| Pressure at Mean Sea Level (PMSL), Surface Pressure | 2 | |
| 2-meter Temperature; Maximum and Minimum | 3 | Tmax/Tmin for 6-hr |
| 2-meter Relative Humidity | 1 | |
| 10-meter wind (U10m, V10m) | 2 | |
| Precipitation | 1 | 3-hr accumulation |
| Precipitation Types | 4 | Rain, Freezing rain, Ice Pellets and Snow |
| Perceptible Water | 1 | |
| Convective Available Potential Energy (CAPE) | 1 | |
| Helicity at 0-3000m | 1 | |
| Convective inhibition (CIN) | 1 | |
| Total Cloud Cover (TCDC) | 1 | |
| Snow Water Equivalent (SWE) | 1 | |
| Outgoing Long-wave Radiation (OLR) | 1 | |
| Surface Downward Long-wave Radiation (SDLR) | 1 | |
| Surface Downward Sort-wave Radiation (SDSR) | 1 | |

## 3. Preliminary evaluations

Figure 1 compares the Northern Hemisphere (NH) anomaly correlation (AC) scores of 500 hPa geopotential height between the SubX-GEFS and FV3-GEFS week 2 forecasts in 1999, which is only overlap year during the Phase I reforecast period. Here, the CFSR is used as reference for both datasets. Obviously, FV3-GEFS outperforms the SubX-GEFS with a higher AC score (0.523 versus 0.487).

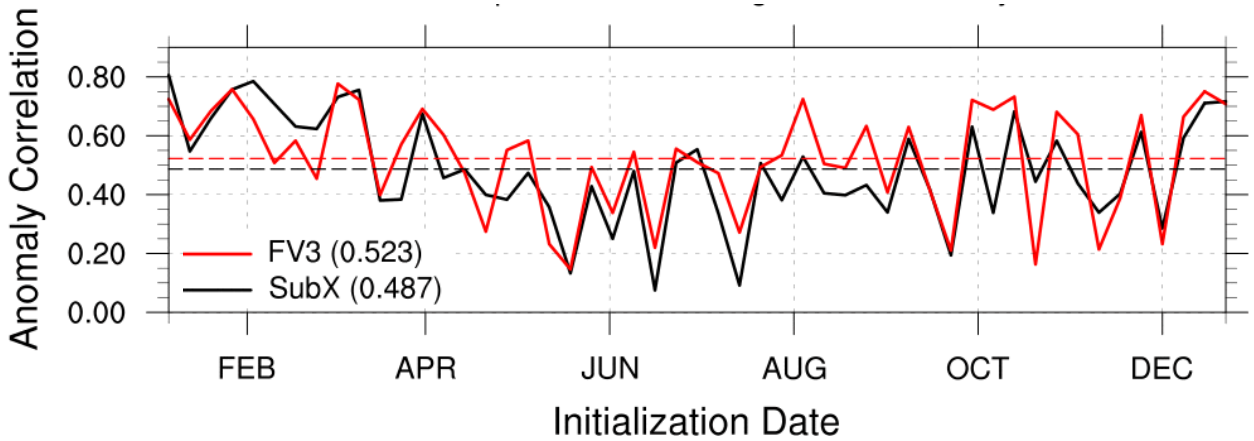


**Fig. 1** Pattern Anomaly Correlation (PAC) for Northern Hemisphere 500 hPa geopotential height for week 2 forecast in1999. Black and red colors denote SubX and FV3 forecasts, respectively.

The tropical storm (TS) track forecasting has been challenging. To evaluate the ability of FV3-GEFS on TS track forecast, the track errors between the FV3-GEFS and GEFSv10 are compared during the Phase I reforecast period (Fig. 2). The National Hurricane Center (NHC)/ Joint Typhoon Warning Center (JTWC) best (observed) track data is used as reference for evaluating two sets of dataset. For control forecast, the track errors for FV3-GEFS are slightly smaller than GEFSv10, especially for the longer lead times. The errors for ensemble mean forecasts are very similar although the FV3-GEFS (5 members) has much less ensemble number than GEFSv10 (10 members).

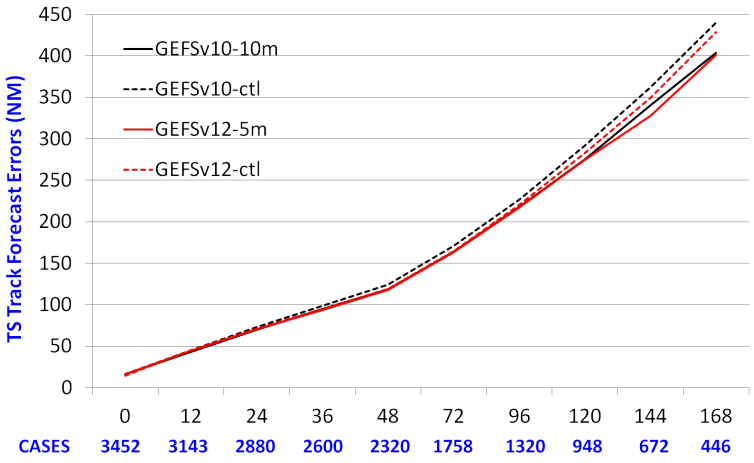


**Fig. 2** Errors of TS tracks over the Atlantic, East Pacific and West Pacific basins during the Phase I reforecast period for GEFSv10 (black lines) and FV3-GEFS (red lines). Dash and solid lines denote control and ensemble mean forecasts, respectively.

To characterize the systematic errors of 2-m temperature, we first examined 2-m temperature bias for week 2, week 3, and week 4 forecasts over North America (NA) land only (Fig. 3). Obviously, FV3-GEFS during the 1989-1999 period has a very similar bias feature as the SubX-GEFS during the 1999-2010 period with a warm bias for the warm season and cold bias for cold season. However, the magnitudes of the bias are much smaller in FV3-GEFS than the SubX-GEFS. The maximum bias reduction in FV3-GEFS is more than 2°c in May for week 3 and week 4 forecasts. It should be noted that the time period for this comparison is inconsistent. The corresponding comparison (not shown) for the overlap year (1999) also draws the same conclusion.

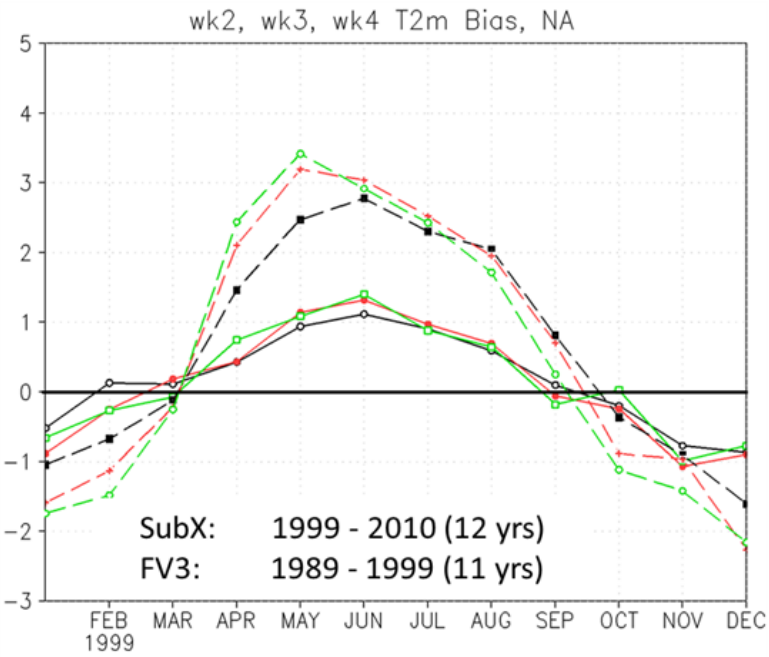


**Fig. 3** The 2-m temperature bias (land only) for the raw FV3 (solid lines) and SubX (dash lines) forecasts. Black, red, and green colors represent week 2, week 3, and week 4 forecasts, respectively.

Week 3 and 4 probabilistic temperature forecasts are also evaluated over 4 geographic domains for 2016 using Ranked Probability Skill Score (RPSS) (Fig. 4). The reference analyses for the FV3-GEFS and SubX-GEFS are their own initial analyses, FV3 and GDAS reanalysis, respectively. The skill of FV3-GEFS shows the considerable improvement over the NA for the warm season and tropical (TR) region for all the seasons. For the other two regions, the skills are very similar between the two sets of data.

## 4. Conclusion

The 30-year FV3-GEFS reforecast dataset was generated in NCEP/EMC to support a variety of applications. The preliminary evaluations in this study demonstrate that FV3-GEFS outperforms SubX-GEFS or GEFSv10 for 500 hPa geopotential height, TS track, and 2-m temperature forecasts. In the future, we will extend the

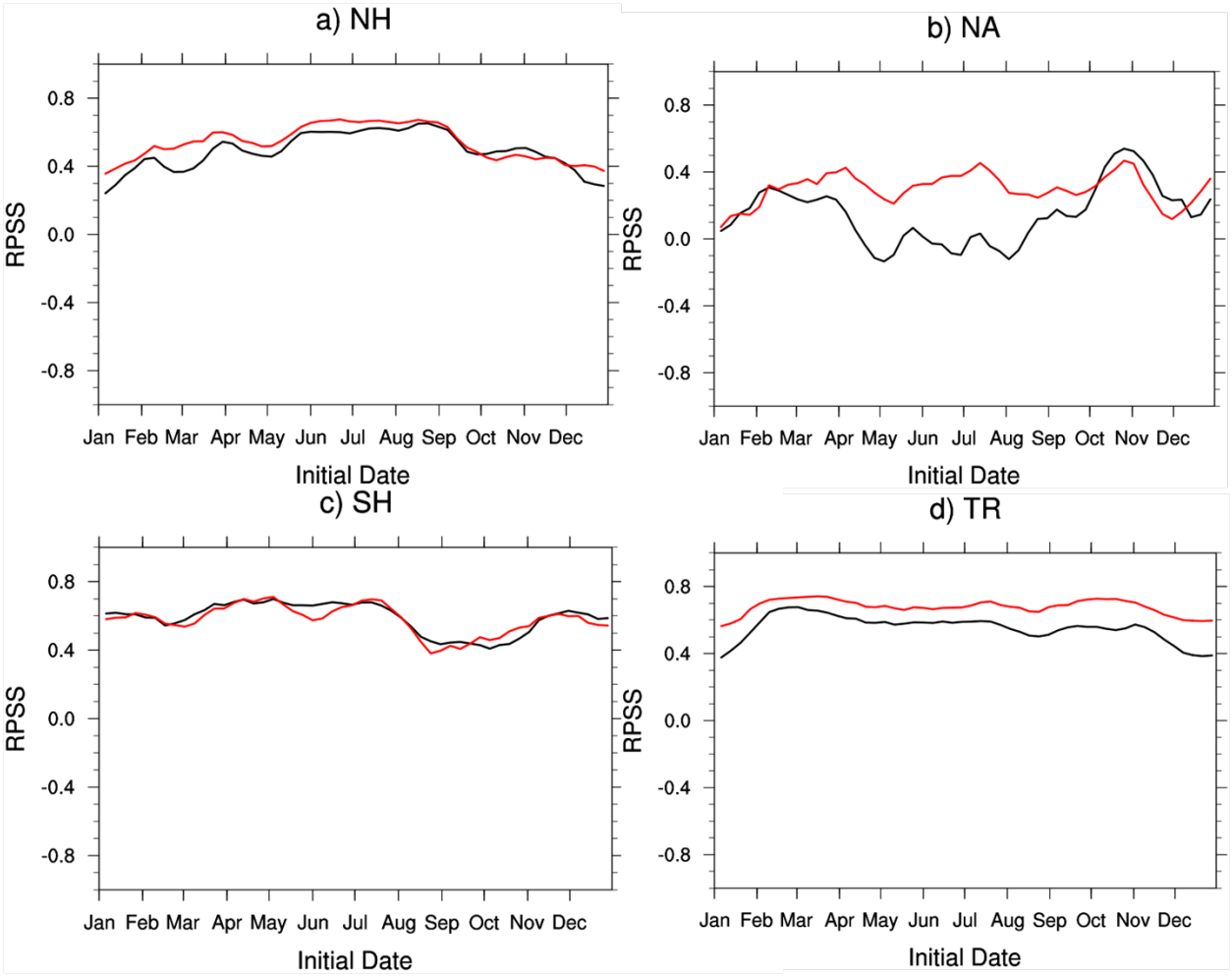


**Fig. 4** RPSS of 2-m temperature forecasts for weeks 3 and 4 in 2016 (land only) averaged over (a) the NH, (b) NA, (c) the Southern Hemisphere (SH), and (d) the TR for the raw SubX (black) and FV3 (red) forecasts.

evaluations to the entire reforecast period and more variables. The impact of inconsistent initial analyses between the two reforecast phases on the forecasts will be also explored.

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