Section 7: NAEFS V6 Upgrade and Bias correction for 10 Meter Wind Speed

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North American Ensemble Forecast System (NAEFS) is an operational ensemble weather prediction system run jointly by Meteorological Service of Canada (MSC) and National Weather Service (NWS). It generates probabilistic products four times per day for North America, Alaska and the globe for up to 2 weeks in advance. As per NAEFS/NUOPC agreement, high resolution GEFS/NAEFS ensemble data will be exchanged and updated continually among the NAEFS/NUOPC participated centers once their ensemble system is upgraded.

The generation and improvement of NAEFS probabilistic guidance are maintained and continuously enhanced through the developments of NAEFS statistical post-processing (SPP) system. The coming NAEFS version 6 upgrade include high resolution (0.5*0.5 degree) GEFS/NAEFS data exchange among MSC, NWS and NAVY FNMOC, every 3 hours for 0-8 days, then 6 hours out to 16 days. The NAEFS SPP upgrade include: (1) the hybrid method of decaying bias and reforecast bias applied into the operational system, (2) bias correction for a new variable 10 meter wind speed, (3) precipitation downscaled product added, and (4) extreme forecast index (EFI), a new product, generated for 4 variables, 2 meter temperature, 10 meter wind speed, mean sea level pressure and precipitation.

Hybrid method for bias corrected forecast:

In NAEFS version 6 upgrade, high resolutions 0.5*0.5 degree NCEP/GEFS and CMC/GEFS ensembles will replace the current 1.0*1.0 degree data and send to the public and private users. Both NCEP/GEFS and CMC/GEFS will apply bias correction post-processing step on 0.5 degree resolution grids. CMC will keep the current decaying average bias correction method (Cui, Toth and etc. 2012), NCEP will upgrade its techniques to the hybrid method (Guan, Cui and Zhu, 2015) instead of the decaying average bias correction. CMC doesn't choose the hybrid method due to the lack of its own reforecast ensemble to support the new technique.

1.1 Methodology The new (or bias corrected) forecast (F) will be generated by applying decaying average bias (B) and reforecast bias (b) to current raw forecast (f) for each lead time, at each grid point, and each parameter.

$$F_{i,j}^{m} = f_{i,j}^{m} + (r_{i,j}^{2} - 1) \cdot b_{i,j} - r_{i,j}^{2} B_{i,j}$$

Where **r** could be estimated by linear regression from joint samples, the joint sample mean could be generated from decaying average (Kalman Filter average) for easy forward.

This method is applied to NCEP/GEFS ensemble 43 variables (red ones in Table 1). The other variables in Table 1 apply decaying average bias correction only.

1.2 Statistics and performance:

The performance of the hybrid bias correction method is verified against GFS analysis for different seasons. Many probabilistic verification tools such as CRPS, RMS, ensemble spread and etc. have been used for this validation. Figure 1 compares the GEFS 1.0 degree (black) and 0.5 degree (red) bias corrected ensembles for North American for a period from April 20, 2017 to June 10, 2017. Four variables including 500mb height field, 850mb temperature, 2-meter temperature, and 10-meter wind V component are compared. All of them apply the hybrid bias correction method. For the short lead time, the CRPS of 1.0 degree and 0.5 degree ensembles are much closed, and the 0.5 degree ensemble is a little bit better than the 1.0 degree ensemble. There is significant improvement for long lead time, when the reforecast bias calibration play important role for this period.

Figure 2 is the same as Figure 1, but it is for NAEFS 1.0 degree (black) and 0.5 degree (red) bias corrected ensemble CRPS comparison. The NAEFS is the equal-weighted combination of CMC and NCEP bias corrected ensembles. Because there is no methodology change for CMC ensemble bias correction, the week 2 improvement mainly comes from the NCEP/GEFS hybrid bias correction contribution.

Figure 3 displays the performance of GEFS final products after the bias correction and downscaling 2-step processing. The down-scaled 2-meter temperature is evaluated against CONUS RTMA from April 20, 2017 to May 31, 2017. The 2 curves are ensemble products with different resolution inputs for the down-scaling process, i.e. 1.0 degree (black) and 0.5 degree (red) bias corrected ensembles. Three verification plots are displayed including the CRPS, the root mean square error (RMSE) with ensemble spread, and the mean error (MERR) with mean absolute error (MAE).

For 2-meter temperature, 0.5 degree product improves the CRPS (smaller values) and reduced RMSE (no change for the spread) for the long lead time (day 7 out to 16 days). The similar improvements are fund for verifications of the MERR and MAE. There is about 70.6% (1.2/1.7 *100%) overall MERR reduction for the 384-hour forecast.

10-meter Wind Speed:

This NAEFS v6 upgrade will introduce a new bias corrected variable, 10-meter wind speed. Based on 0.5*0.5 degree *U* and *V* at 10 meters, wind speed (*Ws*) has been generated according to following formula:

$$W_s = \sqrt{u^2 + v^2}$$

Once the 10-meter wind speed is available, its bias estimation is accumulated through the decaying average method with a 2% weight for the most recent forecast errors (Cui, Toth and etc. 2012).

Figure 4 shows the statistical results for 10-meter wind speed before and after bias correction. The three curves are from the raw 0.5 degree GEFS (black), bias corrected 0.5 degree GEFS (red), and the 0.5 degree NAEFS combined ensemble forecasts (green), respectively. The bias correction works well for variable 10-metere wind speed with the smaller CRPS, reduced RMSE and increased ensemble spread for NAEFS (green). The NAEFS has the best performance among the 3 ensembles. Such improvement comes from the bias correction step and multiple ensembles combination.

Variables	**Levels and Categories**	Total 86
GHT	10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	10/10
TMP	2m, 2mMax, 2mMin, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11/13
UGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11/11
VGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11 /11
VVEL	850hPa	0/1
PRES	Surface, PRMSL	0/2
FLUX (top)	ULWRF (toa - OLR)	0/1
Td and RH	2m	0/2
TCDC	Total cloud cover	0/1
WIND	10 meter Wind speed (NAEFS v6 upgrade)	0(1)

Table 1: NAEFS bias corrected variables for 0.5 degree.

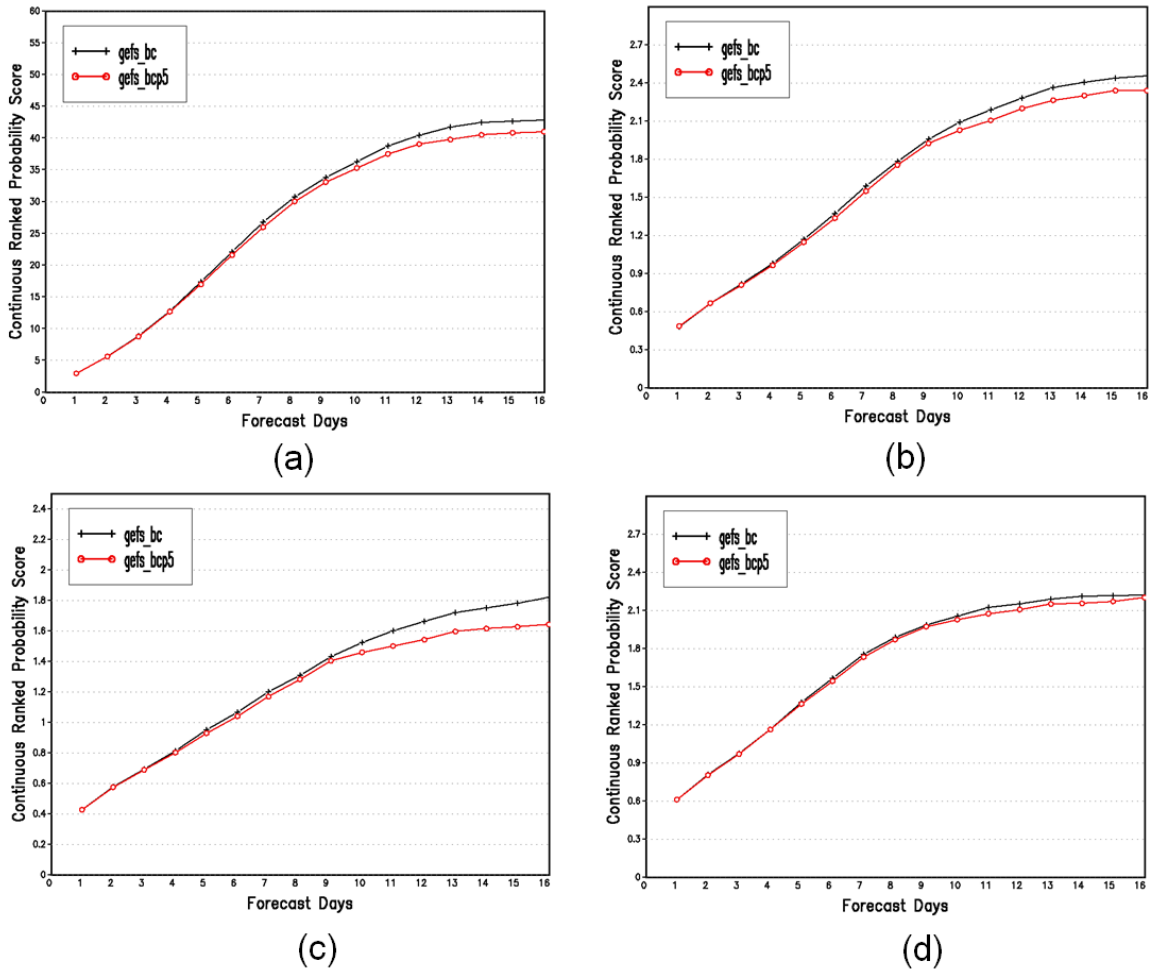

Figure 1: CRPS for GEFS 1.0 degree (black) and 0.5 degree (red) bias corrected ensemble for North American averaged from April 20, 2017 to June 10, 2017. (a) 500mb height field, (b) 850mb temperatures, (c) 2-meter temperature, and (d) 10-meter wind V component.

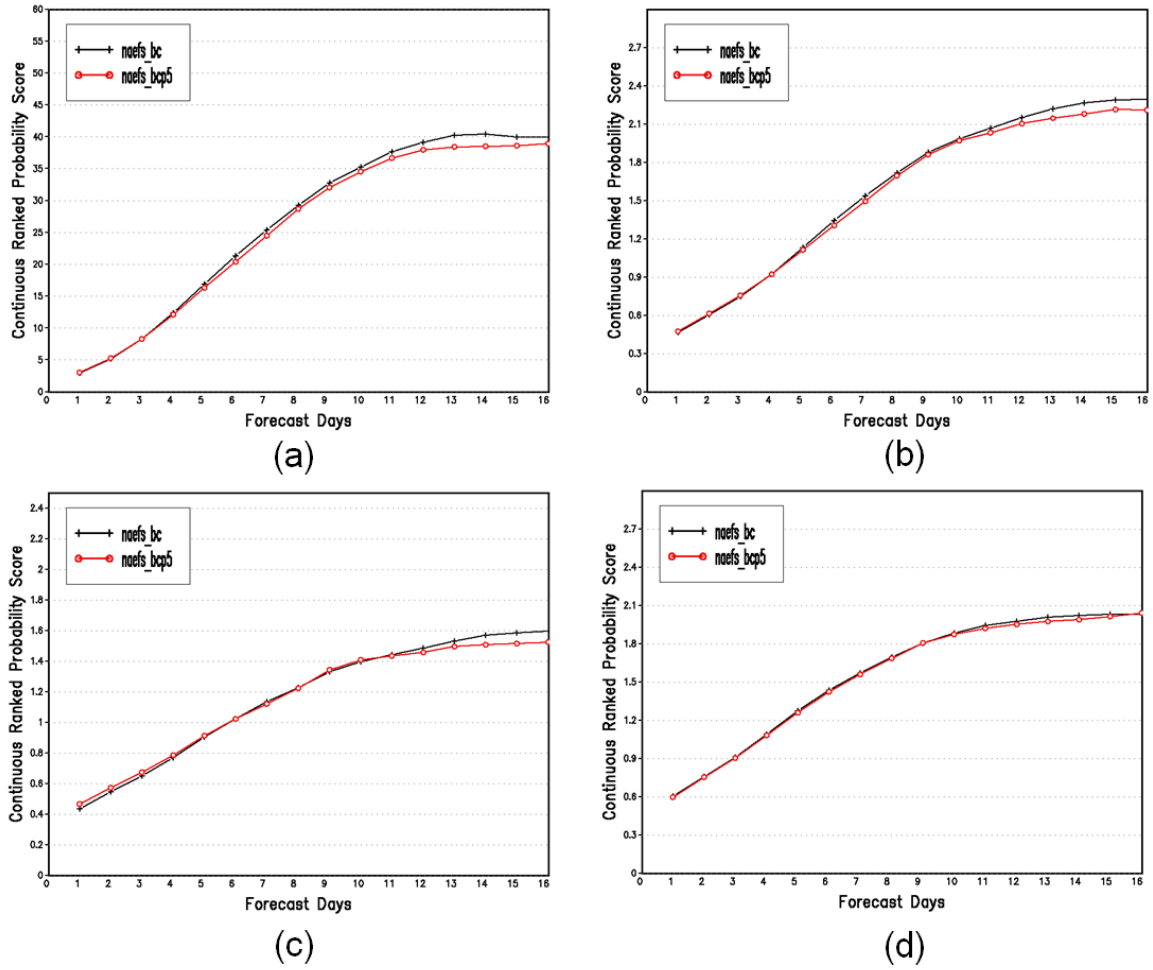

Figure 2: The same as Figure 1, but for NAEFS 1.0 degree (black) and 0.5 degree (red) bias corrected ensemble CRPS.

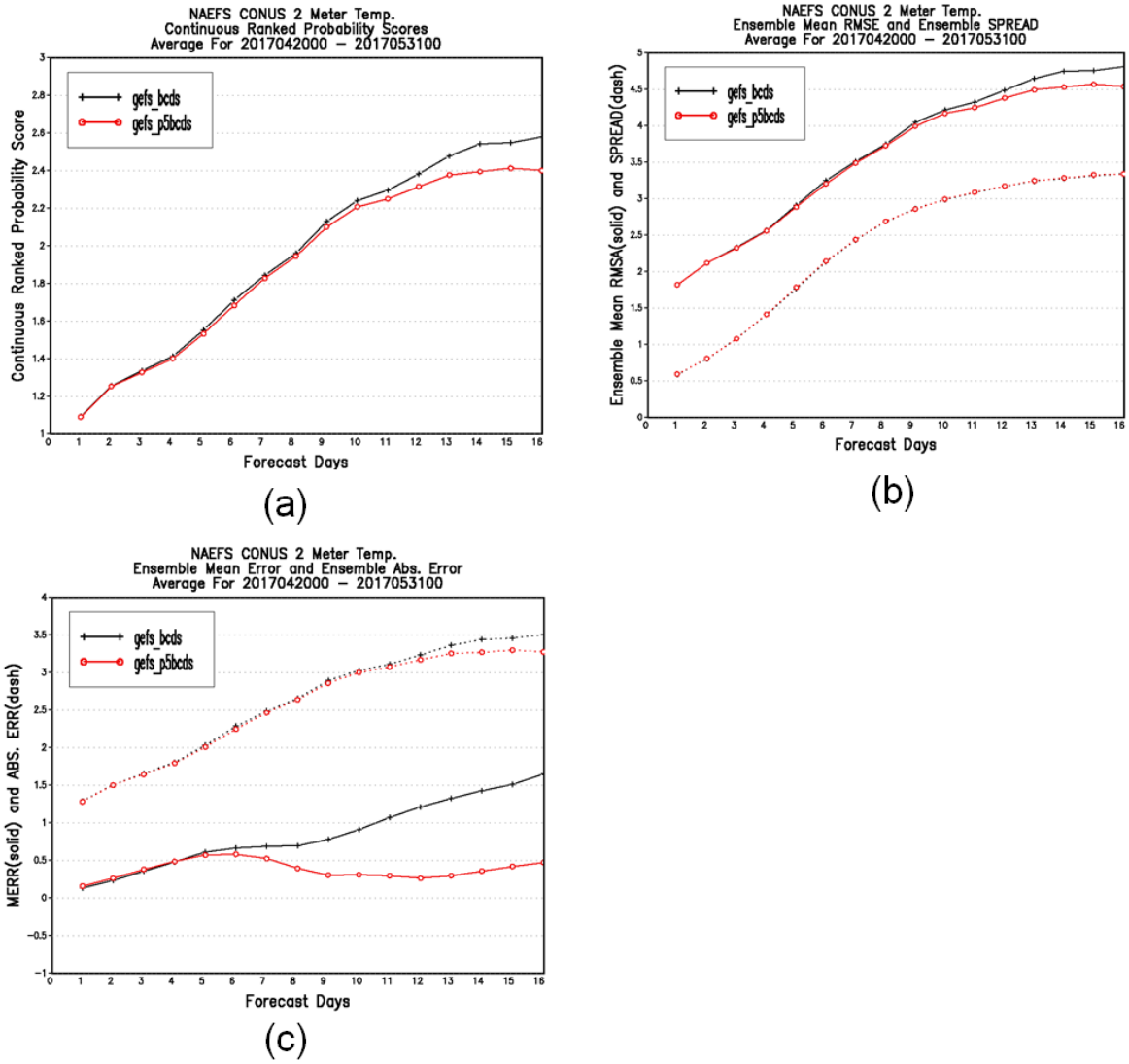

Figure 3: GEFS down-scaled probabilistic forecasts evaluation for 2-meter temperature for CONUS averaged from April 20, 2017 to May 31, 2017. The black and red curves are for ensembles with 1.0 degree and 0.5 degree bias corrected ensemble inputs. Verifications include (a) CRPS, (b) root mean square error (solid) and ensemble spread (dash), and (c) mean error (solid) and absolute error (dash).

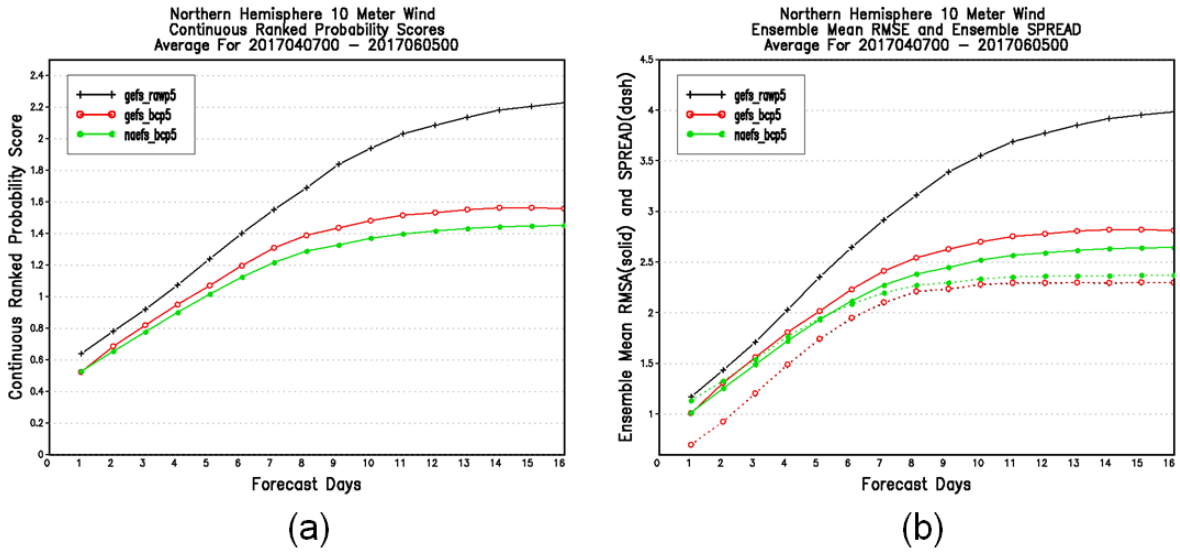

Figure 4: Statistical results for 10m wind speed before and after bias correction for 2017 spring. The gefs_rawp5 is for 0.5 degree GEFS raw ensemble (black), the gefs_bcp5 is for 0.5 degree GEFS bias corrected ensemble (red), and the naefs_bcp5 is for 0.5 degree NAEFS bias corrected ensemble (green). Verifications include (a) CRPS, and (b) root mean square error (solid) and ensemble spread (dash).

References

Cui, B., Z. Toth, Y. Zhu and D. Hou, 2012: Bias correction for global ensemble forecast. *Weather and Forecasting*, Vol. 27 396-410.

Guan, H., B. Cui, Y. Zhu, 2015: Improvement of statistical post-processing using GEFS Reforecast Information, *Weather and Forecasting*, Vol. 30, 841-854.