NAEFS Upgrade at NCEP

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# North American Ensemble Forecast System (NAEFS)

- *International project to produce operational multi-center ensemble products*
- *Bias corrects and combines global ensemble forecasts from Canada & USA*
- *Generates probability products for global and regional for weather forecasters, specialized users and end users*
  - *global forecasts at 0.5 degree, 384 hours, 4 times per day*
  - *downscaled products, CONUS(2.5km) and Alaska(3km)*

- **Implementations**

First NAEFS implementation – bias correction – IOC, May 30 2006	Version 1
NAEFS follow up implementation – CONUS downscaling - December 4 2007	Version 2
Alaska implementation – Alaska downscaling - December 7 2010	Version 3
CONUS/Alaska new variables expansion – April 8 2014	Version 4
CONUS/Alaska NDGD (2.5km/3km) and expansion – March 29th 2016	Version 5
CMC/GEFS/NAEFS high resolution (0.5 deg) upgrade – July 18 2018	Version 6
GEFS v12 Reforecast bias upgrade – September 23, 2020	Version 6.1
GEFS/NAEFS utilize all 31 GEFS members instead of 21 – Q1 2024	Version 7

Motivation of NAEFS Upgrade

courtesy of Yuejian Zhu
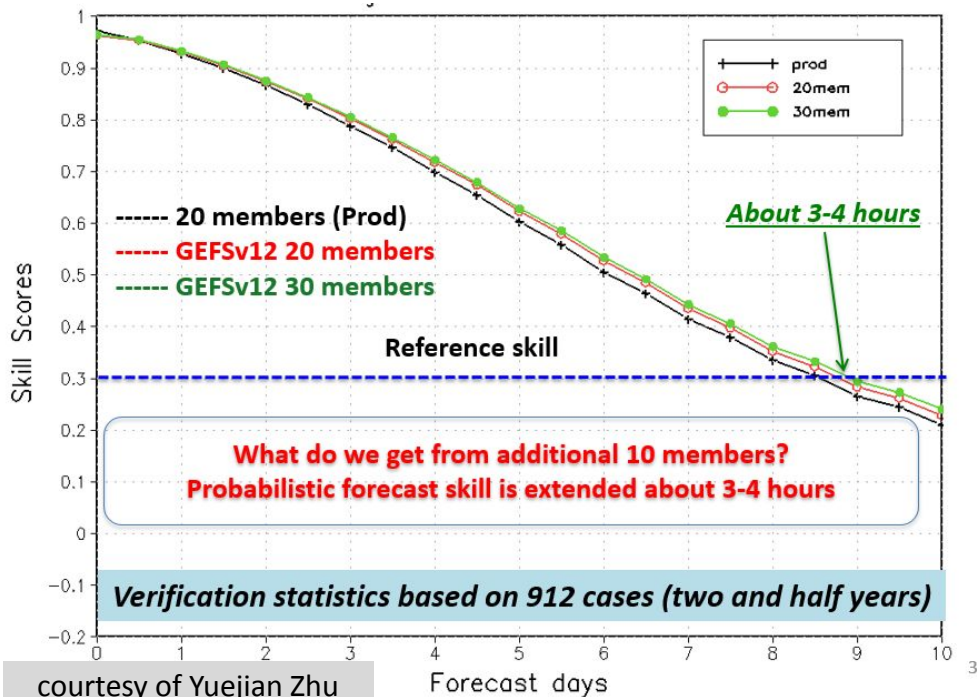
Value demonstration for GEFS members
- *Cont. Ranked Prob. Skill Scores of NH 500hPa height*
- *GEFSv11(prod) vs. GEFSv12*
- *Raw forecasts without bias correction*
- *Extend about 3-4 hours skill*

NAEFS v6.1:
- *GEFS: 21 calibrated members*
- *NAEFS: 42 calibrated members(21 GEFS + 21 CMCE)*

NAEFS v7:
- *GEFS: 31 calibrated members*
- *NAEFS: 52 calibrated members (31 GEFS + 21 CMCE)*

- NCEP GEFS ensemble members increased from 21 to 31 during GEFSv12 upgrade in 2020
- Increasing ensemble size from 20 to 30 leads to significant improvements

NAEFSv7 Products and Changes

- **NCEP GEFS**: calibrate 51 variables globally, downscale 10 variables on ndgd
    - Bias correct all **31 GEFS members** instead of 21
    - Create GEFS probabilistic forecasts and anomaly forecasts from **31 calibrated members**
    - Downscaled products (CONUS & Alaska) from GEFS probability forecasts

- **NAEFS** : calibrated 51 variables globally, downscale 10 variables on ndgd
    - Create NAEFS probabilistic forecasts and anomaly forecasts from **52 members**
    - Downscaled products (CONUS & Alaska) from NAEFS probability forecasts

- **NCEP GEFS precipitation**: calibrated products
    - Bias correct **31 GEFS members**, 6hr & 24hr bias corrected QPFs/PQPFs for CONUS
    - Downscale **31 GEFS calibrated members,** 6hr & 24hr downscaled QPFs/PQPFs for CONUS

- FNMOC – Fleet Numerical Meteorology and Oceanography Center ensemble
    - Upgrade FNMOC ensemble products from 1 degree to 0.5 degree
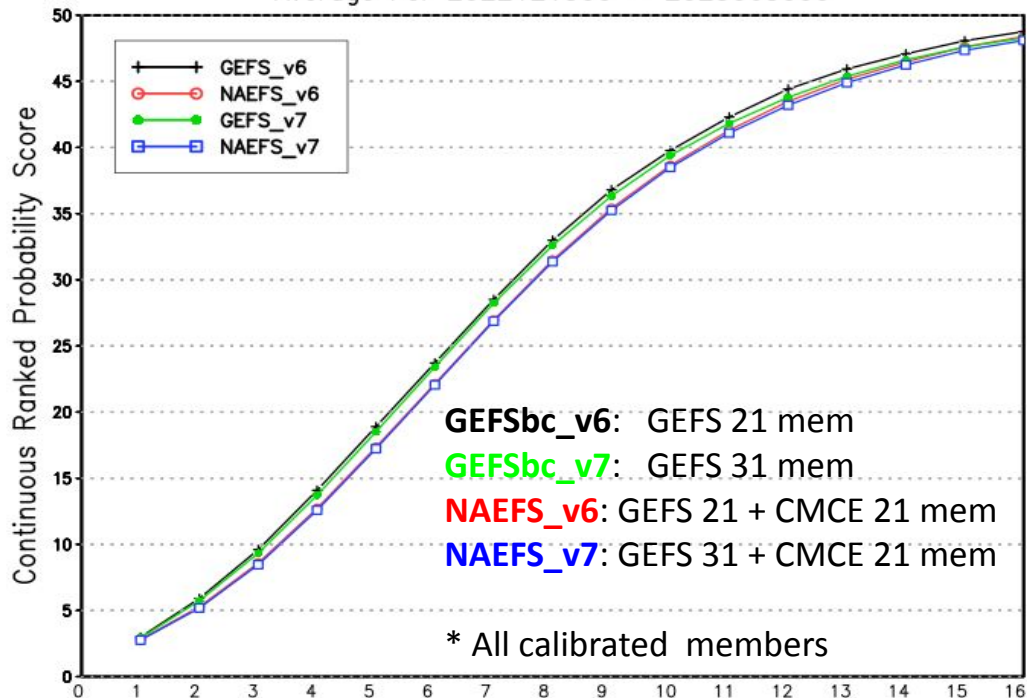
NAEFS FLOW CHART
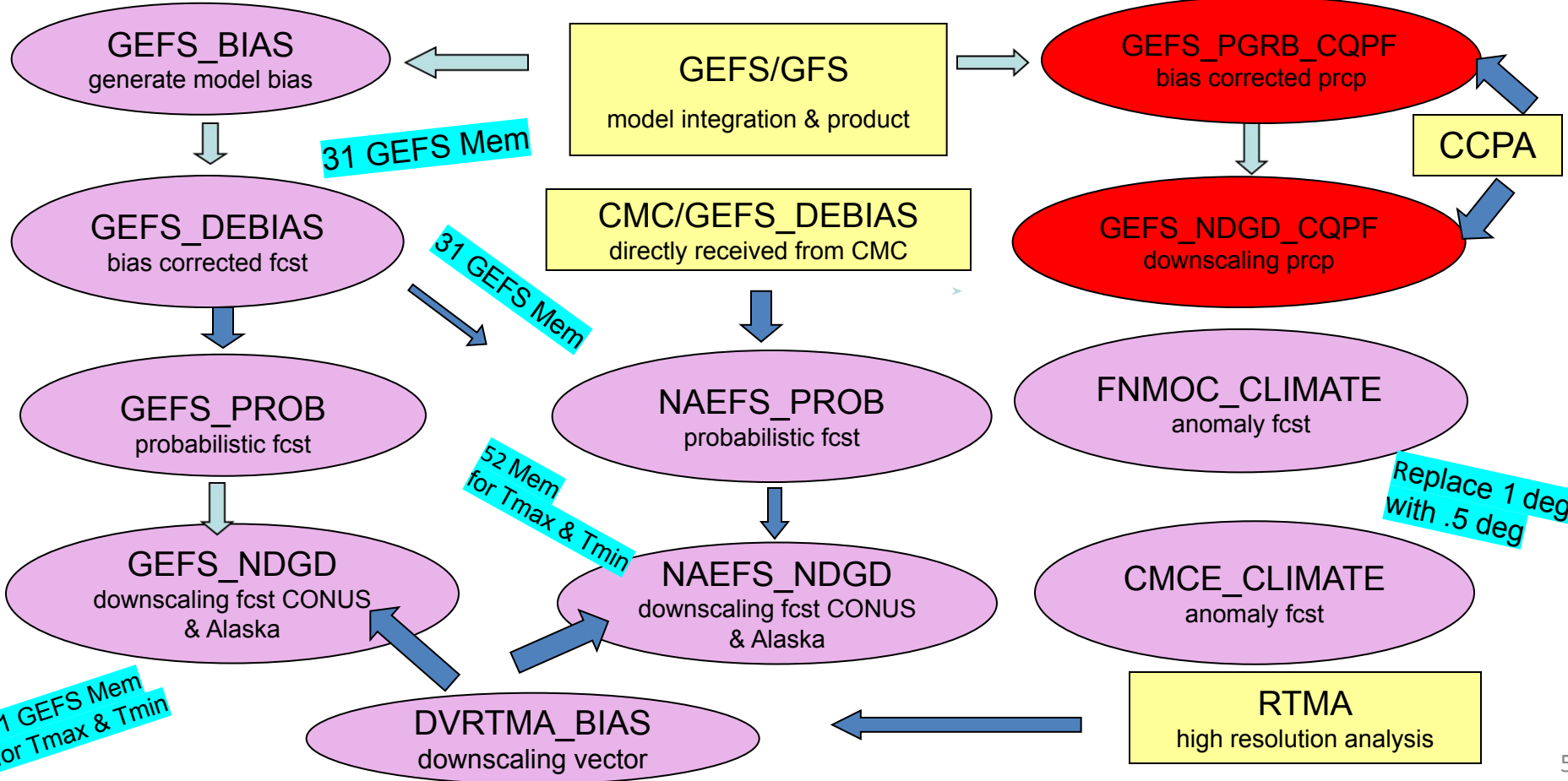
NAEFSv7 Evaluation Outline

- **Value demonstration of 31 GEFS calibrated members in NAEFSv7**
  - Experiment period: 6 months from December 17, 2022 to June 30, 2023
  - Verification graphics showing the NAEFSv7 parallel, NAEFSv6, GEFSbc with 21 members & GEFSbc with 31 members
    - Part I: GEFS & NAEFS Bias Corrected products (0.5 degree global)
    - Part II : GEFS & NAEFS Downscaled Products, CONUS 2.5km & Alaska 3km
    - Part III: GEFS Precipitation Bias Corrected Products, CONUS 0.5 degree

- **NAEFSv7 official verification from EMC Model Evaluation Group (MEG)**
  - Started on March 3, 2023 – August 5, 2023
  - <u>NAEFSv7 Official Verification Webpage:</u> https://www.emc.ncep.noaa.gov/users/meg/naefsv7

- Comments and recommendations from NWS Centers/Regions
  - NWS Southern Region, Alaska Region, Western Region, Central Region, Pacific Region & WPC

CRPS of North Hemisphere 500hPa Height

Northern Hemisphere 500hPa Height
Continuous Ranked Probability Scores
Average For 2022121500 – 2023063000

Legend:
- GEFS_v6
- NAEFS_v6
- GEFS_v7
- NAEFS_v7

GEFSbc_v6: GEFS 21 mem
GEFSbc_v7: GEFS 31 mem
NAEFS_v6: GEFS 21 + CMCE 21 mem
NAEFS_v7: GEFS 31 + CMCE 21 mem

* All calibrated members

Verification statistics based on 198 cases

Bias Corrected Forecast

Continuous Rank Probability Score
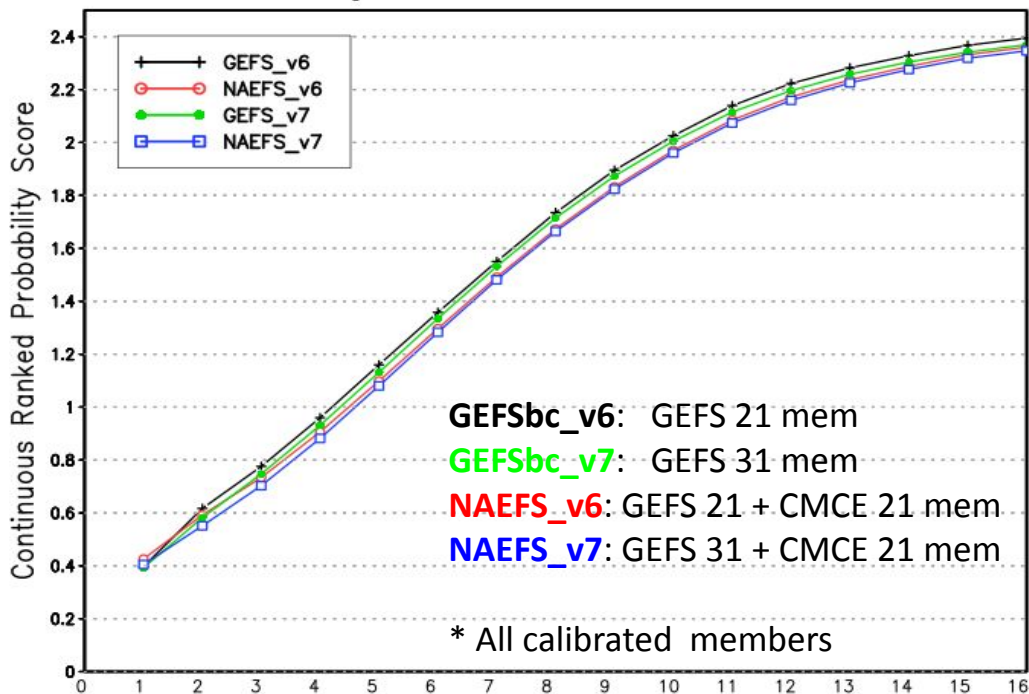*CRPS measures the reliability and resolution (the lower the CRPS, the better)*

- GEFSbc with 31 members performed better than 21 members from Days 1-16

- NAEFSv6 and NAEFSv7 are better than individual GEFS ensemble

- NAEFSv7 and NAEFSv6 were very similar at Days 1–11; NAEFSv7 are slightly better at Days 12-16

CRPS of North Hemisphere 850hPa Temperature

Northern Hemisphere 850hPa Temp.
Continuous Ranked Probability Scores
Average For 2022121500 – 2023063000

GEFSbc_v6: GEFS 21 mem
GEFSbc_v7: GEFS 31 mem
NAEFS_v6: GEFS 21 + CMCE 21 mem
NAEFS_v7: GEFS 31 + CMCE 21 mem

* All calibrated members

Verification statistics based on 198 cases

Bias Corrected Forecast

Continuous Rank Probability Score

- GEFSbc with 31 members are improved in skill for all lead times than GEFSbc 21 members

- NAEFSv6 and NAEFSv7 are better than individual GEFSbc ensemble

- NAEFSv7 performed better than NAEFSv6 for all lead time
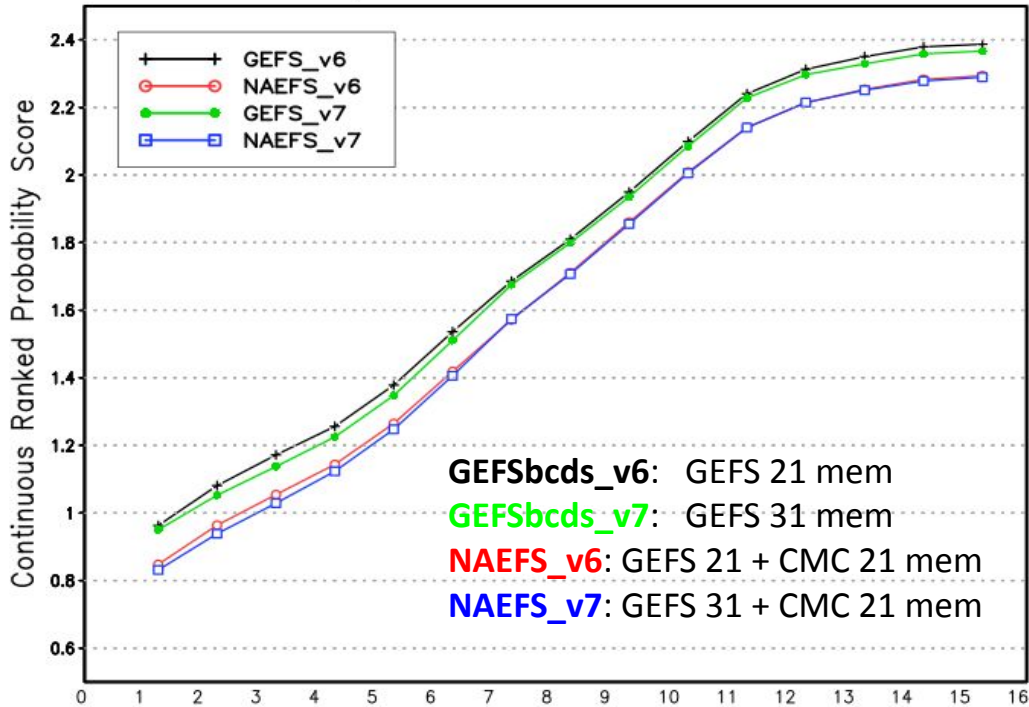
More evaluation are available

- Overall NAEFSv7 is good or slightly better than NAEFSv6

CRPS of CONUS Tmax

NAEFS CONUS Tmax
Continuous Ranked Probability Scores
Average For 2023010700 − 2023063000

GEFSbcds_v6: GEFS 21 mem
GEFSbcds_v7: GEFS 31 mem
NAEFS_v6: GEFS 21 + CMC 21 mem
NAEFS_v7: GEFS 31 + CMC 21 mem

Verification statistics based on 175 cases

Bias Corrected & Downscaled Forecast

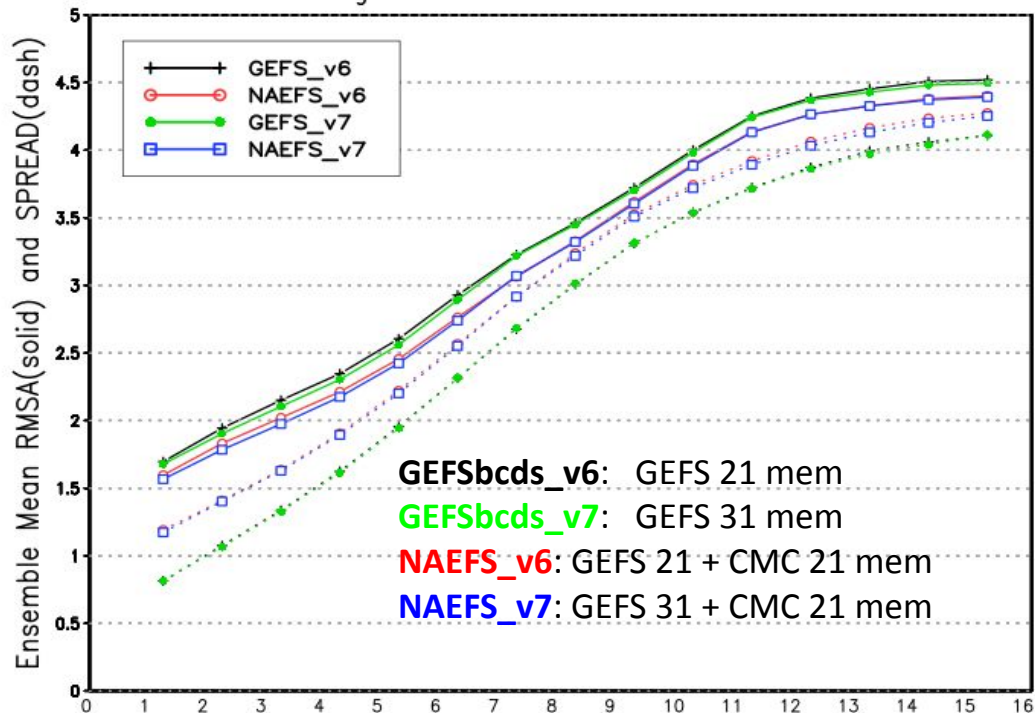Tmax: pick up the maximum value from bias corrected and downscaled forecasts

Continuous Rank Probability Score

- GEFSbcds with 31 members performed notable better than GEFSbcds 21 members for all lead time

- NAEFSv7 performed better at Days 1-7. NAEFSv7 and NAEFSv6 were very similar at Days 8–16

RMS & Ensemble Spread of CONUS Tmax

NAEFS CONUS Tmax
Ensemble Mean RMSE and Ensemble SPREAD
Average For 2023010700 – 2023063000

Verification statistics based on 175 cases
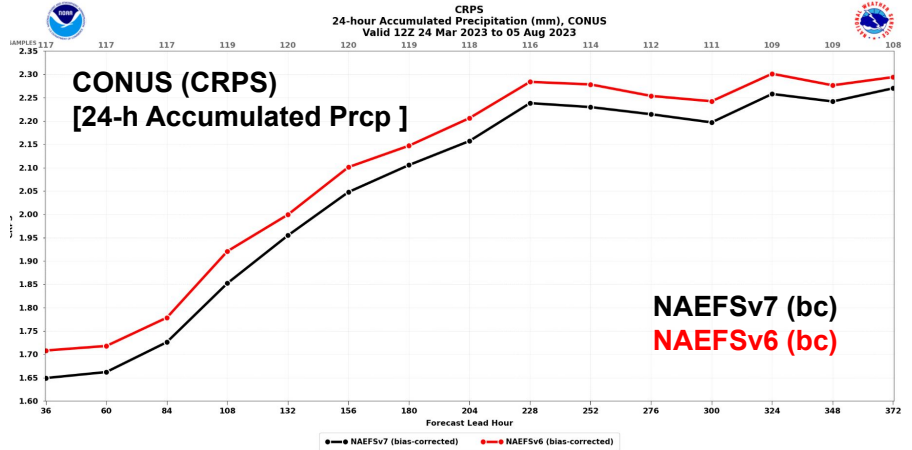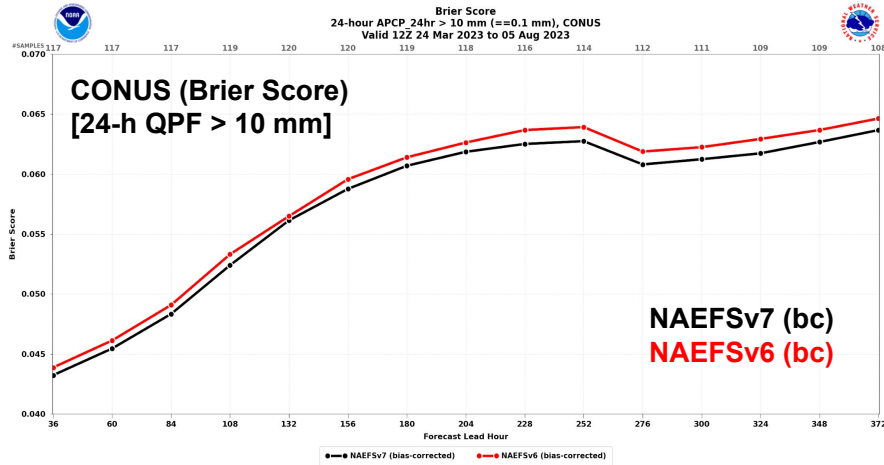
Bias Corrected & Downscaled Forecast

Tmax: pick up the maximum value from bias corrected and downscaled forecasts

RMS and Ensemble Spread

- GEFSbcds with 31 members has smaller RMS than GEFSbcds 21 member at Day 1-16, ensemble spread is similar

- NAEFSv7 has smaller RMS at Days 1-7 and similar values at Days 8-16

Brier Score & CRPS of GEFS 24-h Precipitation

- Of the parameters evaluated, bias-corrected 24-h precipitation showed the most improvement in **NAEFSv7**
- Brier Scores for various 24-h QPF thresholds (>1, 5, 10, 25, 50 mm) were notably better in **NAEFSv7**
- CRPS for 24-h accumulated precipitation was significantly improved in **NAEFSv7**
- Brier Score & CRPS were also notably better in **NAEFSv7** in all four CONUS sub-regions (West, Central, East, South)

courtesy of Alicia Bentley and Geoff Manikin

EMC MEG Official NAEFSv7 Evaluation

Parameter	Remarks	Improvement Neutral Degradation
500-hPa Geo. Height	Comparable in the NH and SH; slight improvement in the tropics at all forecast lead times	
1000-hPa Geo. Height	Slight improvement in the NH in the short range; comparable in the SH; slight improvement in the tropics at all forecast lead times	
250-hPa U/V Winds	Slight improvement in the NH at all lead times; comparable in the SH and tropics	
850-hPa U/V Winds	Slight improvement in the NH at all lead times; comparable in the SH; slight improvement in U wind in the tropics with comparable V wind	
850-hPa Temperature	Slight improvement in the NH warm bias at all lead times; slightly larger cold bias in the SH; comparable in the tropics	
2-m Temperature	Comparable over CONUS-West and Alaska; slight decrease in the warm bias over CONUS-Central/East/South at longer lead times; slight increase in the cold bias over CONUS-East at shorter lead times	
10-m U/V Winds	Comparable over CONUS-Central, CONUS-South, and Alaska; slight improvement in U wind low bias over CONUS-West; slight increase U wind high bias over CONUS-East	
24-h Precipitation	**Improvement over all CONUS sub-regions and thresholds,** modest skill at >50 mm; comparable frequency bias for most CONUS sub-regions	

Summary & Project Status

- **Overall Impressions**
  - This upgrade will allow utilizing GEFS 31 calibrated members in the NAEFS
  - Both GEFS calibrated and downscaled guidance are improved for most metrics, most parameters with 10 more members, especially for the majority of precipitation stats
  - NAEFSv7 is as good or slightly better than NAEFSv6
  - The similar performance of NAEFSv7 and NAEFSv6 is not surprising
    - Notable improvement when ensemble size increases from 21 to 31, slightly small from 42 to 52
    - Consistent with many studies that optimum (ratio of cost/value) ensemble membership is about 40-60

- **Project Status**
  - Evaluators from NWS Centers/Regions support the proposed NAEFSv7 upgrade
  - Request approval from EMC Director to proceed with implementation
  - Planned implementation date: ~11/28/2023