Inclusion of New Probabilistic Forecasts to NAEFS

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Acknowledgements: EMC Ensemble team staffs
Presentation for 23rd Conf. Probability and Statistics in Atmos. Sci.
01/12/2016
New Orleans, LA

Highlights

- Background
  - Northern American Ensemble Forecast System – NAEFS
  - NAEFS Statistical Post Process (SPP)
- Current NAEFS status
- New variable for bias correction
- New for CONUS downscaling
- New for Alaska downscaling
- Conclusion

North American Ensemble Forecast System (NAEFS)

International project to produce operational multi-center ensemble products

Bias correction and combines global ensemble forecasts from Canada & USA

The National Oceanic and Atmospheric Administration
of the United States,

The Meteorological Service of Canada and

The National Meteorological Service
of Mexico

Recognizing the importance of scientific and technical international cooperation in the field of meteorology for the development of improved global forecast models;

Considering the great potential of model diversity to increase the accuracy of one to fourteen day probabilistic forecasts;

Noting the significant international cooperation undertaken to develop and implement an operational ensemble forecast system for the benefit of North America and surrounding territories;

The signatories, hereby inaugurate the North American Ensemble Forecast System at Camp Springs, Maryland, USA, on this 16th Day of November 2004.

Generates products for:
Weather forecasters
Specialized users and end users

It is part of NGGPS-ensemble post process
Strong connection to stakeholder
(WPC, CPC and et al)

NAEFS Milestones

- 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 – Q3FY16 — Version 5
- Applications:
  - NCEP/GEFS and NAEFS – at NWS
  - CMC/GEFS and NAEFS – at MSC
  - FNMOC/GEFS – at NAVY
  - NCEP/SREF – at NWS
- Publications (or references):
  - Cui, B., Z. Toth, Y. Zhu, and D. Hou, D. Unger, and S. Beauregard, 2004: *The Trade-off in Bias Correction between Using the Latest Analysis/Modeling System with a Short, versus an Older System with a Long Archive* The First THORPEX International Science Symposium. December 6-10, 2004, Montréal, Canada, World Meteorological Organization, P281-284.
  - Zhu, Y., and B. Cui, 2006: *"GFS bias correction"* [Document is available online]
  - Zhu, Y., B. Cui, and Z. Toth, 2007: *"December 2007 upgrade of the NCEP Global Ensemble Forecast System (NAEFS)"* [Document is available online]
  - Cui, B., Z. Toth, Y. Zhu and D. Hou, 2012: *"Bias Correction For Global Ensemble Forecast"* Weather and Forecasting, Vol. 27 396-410
  - Cui, B., Y. Zhu , Z. Toth and D. Hou, 2013: *"Development of Statistical Post-processor for NAEFS"* Weather and Forecasting (In process)
  - Zhu, Y., and B. Cui, 2007: *"December 2007 upgrade of the NCEP Global Ensemble Forecast System (NAEFS)"* [Document is available online]
  - Zhu, Y, and Y. Luo, 2015: *"Precipitation Calibration Based on Frequency Matching Method (FMM)"*. Weather and Forecasting, Vol. 30, 1109-1124
  - Glahn, B., 2013: "*A Comparison of Two Methods of Bias Correcting MOS Temperature and Dewpoint Forecasts*" MDL office note, 13-1
  - Guan, H., B. Cui and Y. Zhu, 2015: *"Improvement of Statistical Post-processing Using GEFS Reforecast Information"* Weather and Forecasting, Vol. 30, 841-854

NAEFS Statistical Post-Process (SPP)

- Purpose
  - Improve reliability while maintaining resolution in NWP forecasts
    - Reduce systematic errors (improve reliability) while
    - Not increasing random errors (maintaining resolution)
      - Retain all useful information in NWP forecast

- Methodology
  - Use bias-free estimators of systematic error
  - Need methods with fast convergence using small sample
  - Easy implementation for frequency upgraded forecast system

- Approaches – Computational efficiency
  - Bias Correction : remove lead-time dependent bias on model grid
    - Working on coarser model grid allows use of more complex methods
    - Feedback on systematic errors to model development
  - Downscaling: downscale bias-corrected forecast to finer grid
    - Further refinement/complexity added
      - No dependence on lead time

NAEFS Bias Correction (Decaying average method)

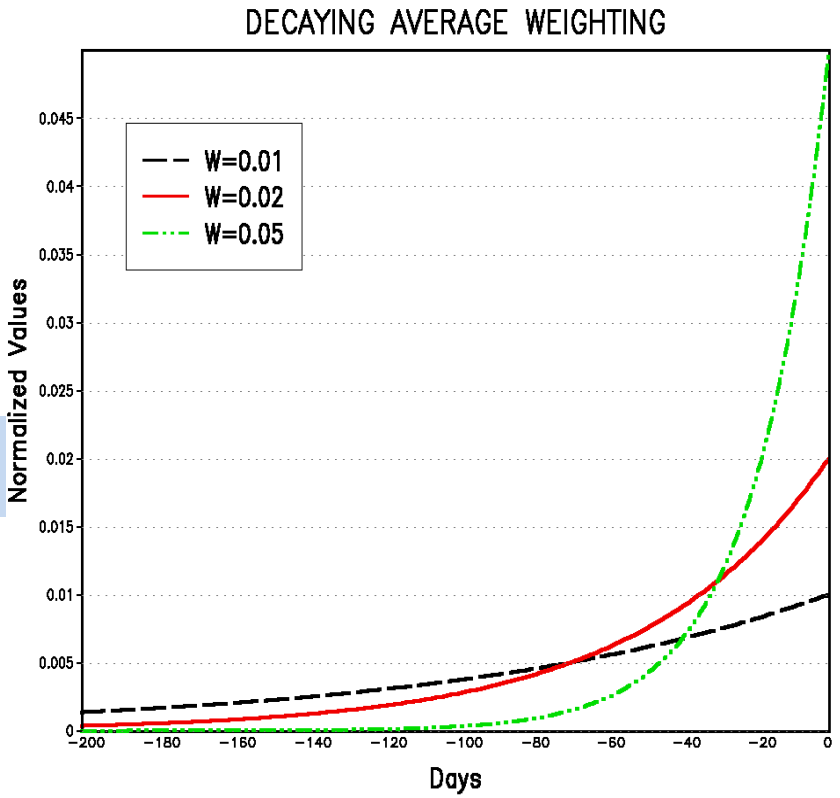
1). Bias Estimation:

$$b_{i,j}(t) = f_{i,j}(t) - a_{i,j}(t_0)$$

2). Decaying Average (Kalman Filter method)

$$B_{i,j}(t) = (1-w)\cdot B_{i,j}(t-1) + w\cdot b_{i,j}(t)$$

3). Decaying Weight: w =0.02 in GEFS bias correction (~ past 50-60 days information)

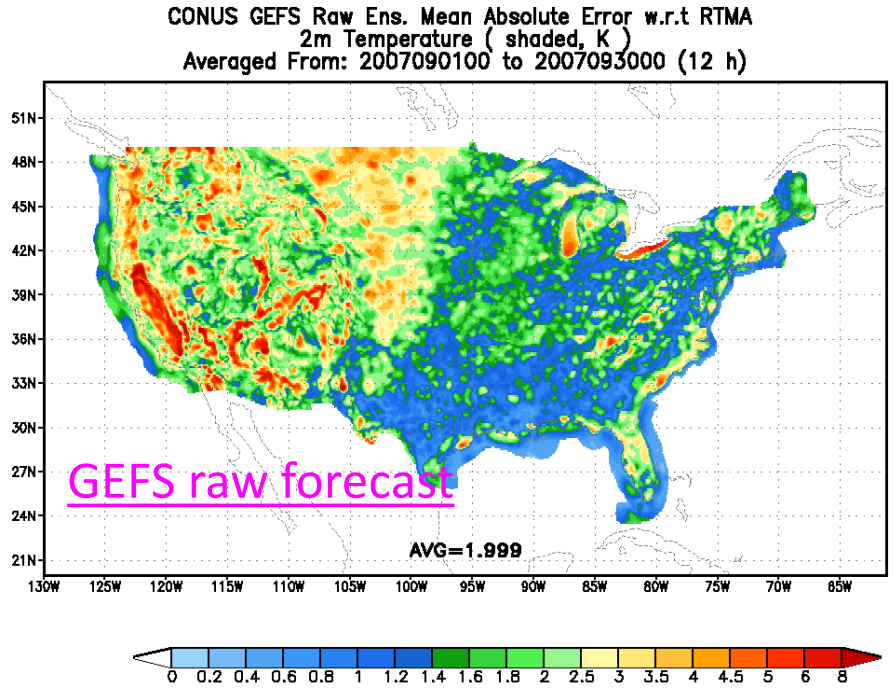


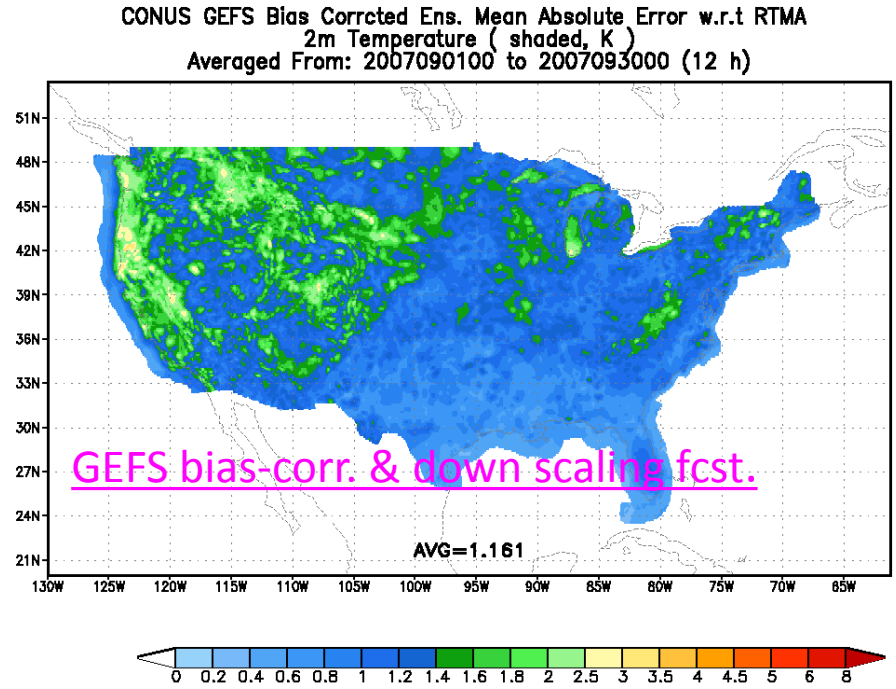
4). Bias corrected forecast:

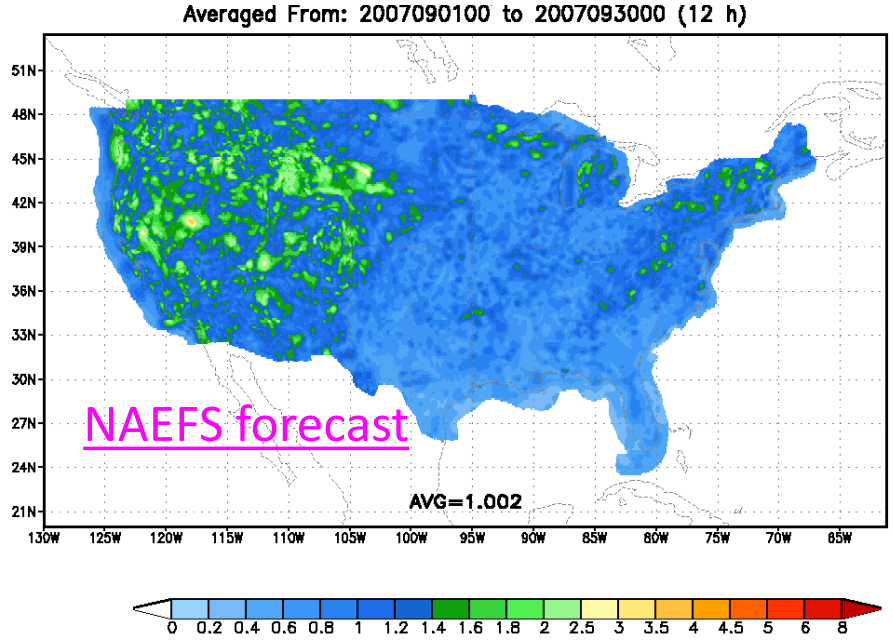
$$F_{i,j}(t) = f_{i,j}(t) - B_{i,j}(t)$$

Simple Accumulated Bias

Assumption: Forecast and analysis (or observation) is fully correlated







12hr 2m temperature forecast
Mean Absolute Error (MAE)
w.r.t RTMA for CONUS
average for September 2007

NAEFS bias corrected variables

Last upgrade: April 8th 2014 - (bias correction)

Variables	pgrba_bc file	Total 51
GHT	10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	10
TMP	2m, 2mMax, 2mMin, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	13
UGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11
VGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11
VVEL	850hPa	1
PRES	Surface, PRMSL	2
FLUX (top)	ULWRF (toa - OLR)	1
Td and RH	2m	2
Notes	CMC and FNMOC do not apply last upgrade yet	

NAEFS downscaling parameters and products

Plan: Q2FY2016 (NDGD resolutions)

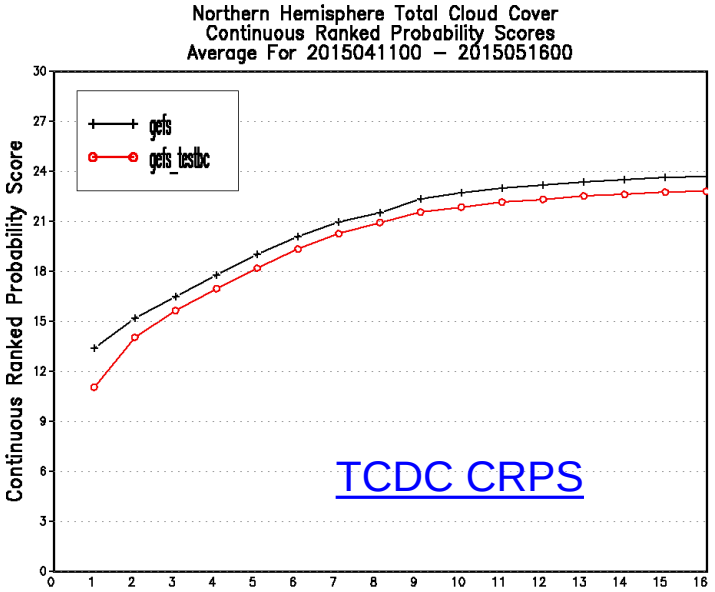
Variables	Domains	Resolutions	Total 10/10
Surface Pressure	CONUS/Alaska	2.5km/3km	1/1
2-m temperature	CONUS/Alaska	2.5km/3km	1/1
10-m U component	CONUS/Alaska	2.5km/3km	1/1
10-m V component	CONUS/Alaska	2.5km/3km	1/1
2-m maximum T	CONUS/Alaska	2.5km/3km	1/1
2-m minimum T	CONUS/Alaska	2.5km/3km	1/1
10-m wind speed	CONUS/Alaska	2.5km/3km	1/1
10-m wind direction	CONUS/Alaska	2.5km/3km	1/1
2-m dew-point T	CONUS/Alaska	2.5km/3km	1/1
2-m relative humidity	CONUS/Alaska	2.5km/3km	1/1
Total cloud cover?			
Wind Gust?			
Significant wave height			

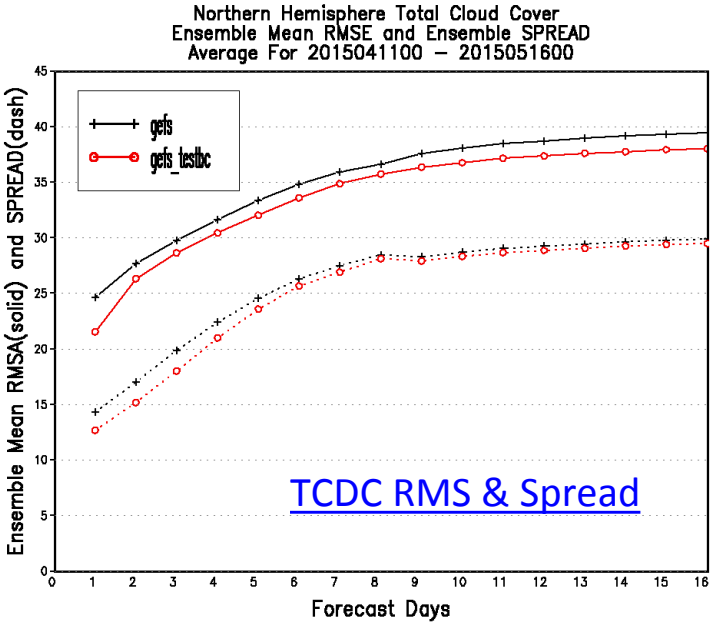
Downscaled products are generated from 1*1 degree probabilistic fcst globally
Products include ensemble mean, spread, 10%, 50%, 90% and mode

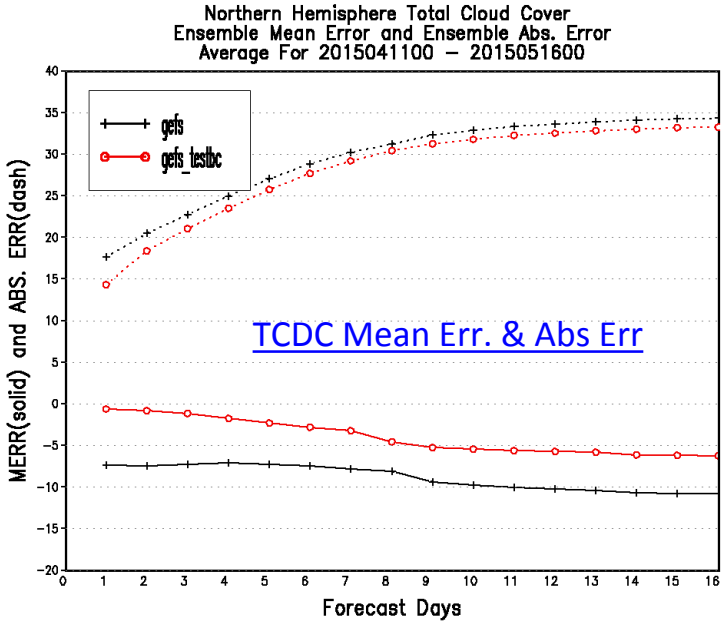
Bias Correction for Total Cloud Cover
(new variable)

- Variable: TCDC (total Cloud Cover – 6 hour average)
- Experiments: Current operational GEFS
- Resolution: 1*1 degree globally
- Period: Spring 2015 (April 11th – May 16th 2015)
- Bias estimation: against GEFS control
- Verification: Against GFS 6-hr forecast
- Comparison:
  - gefs: GEFS raw ensemble
  - gefs_bc: GEFS bias corrected ensemble
- More results:
  - http://www.emc.ncep.noaa.gov/gmb/wx20cb/conus_rtma2p5/crps_3line_raw_2015041100.2015051600_6h_gfsf06/GEFS_Spr2015.html

Statistical Verification for TCDC from 20150411 to 20150516



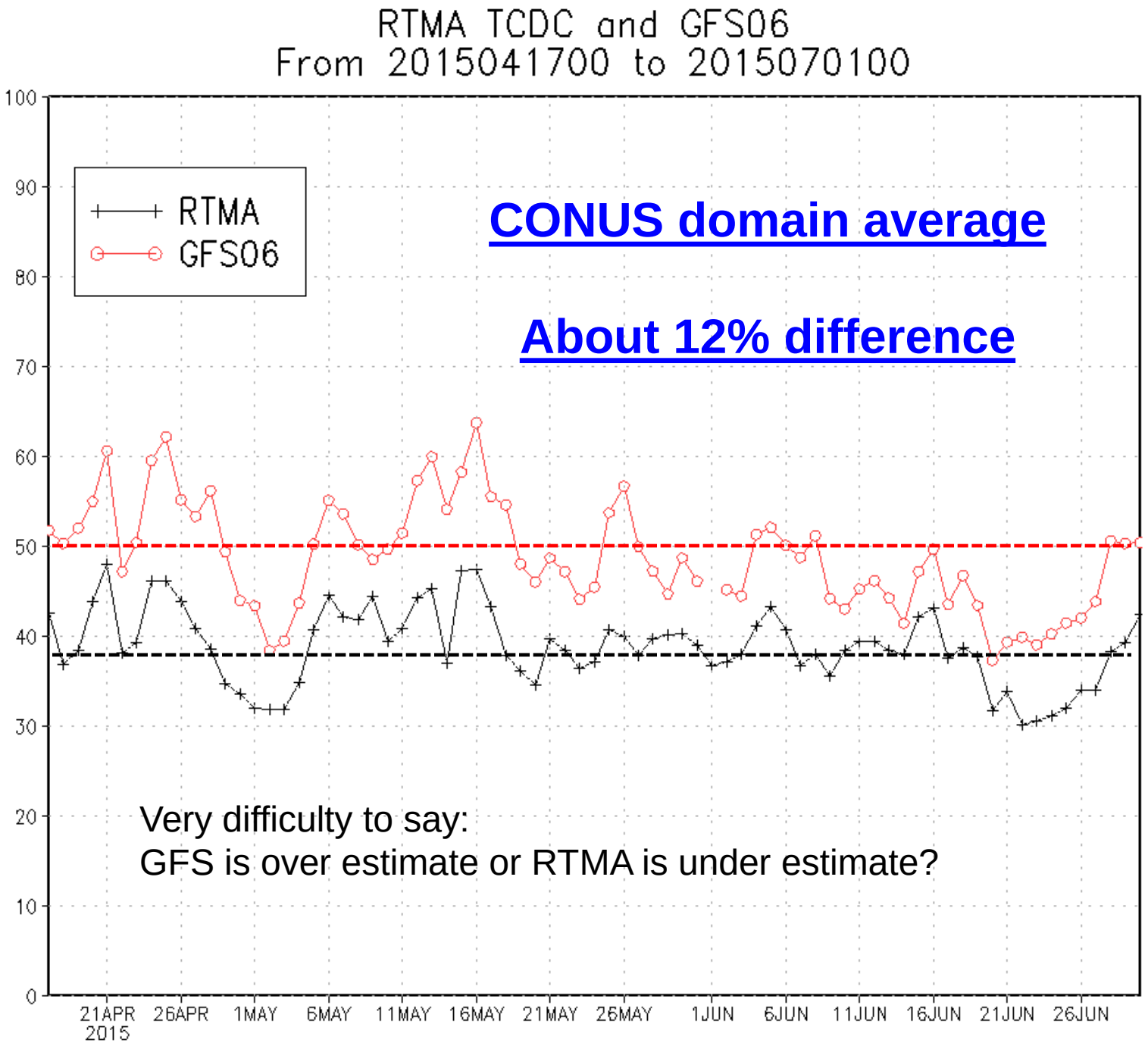


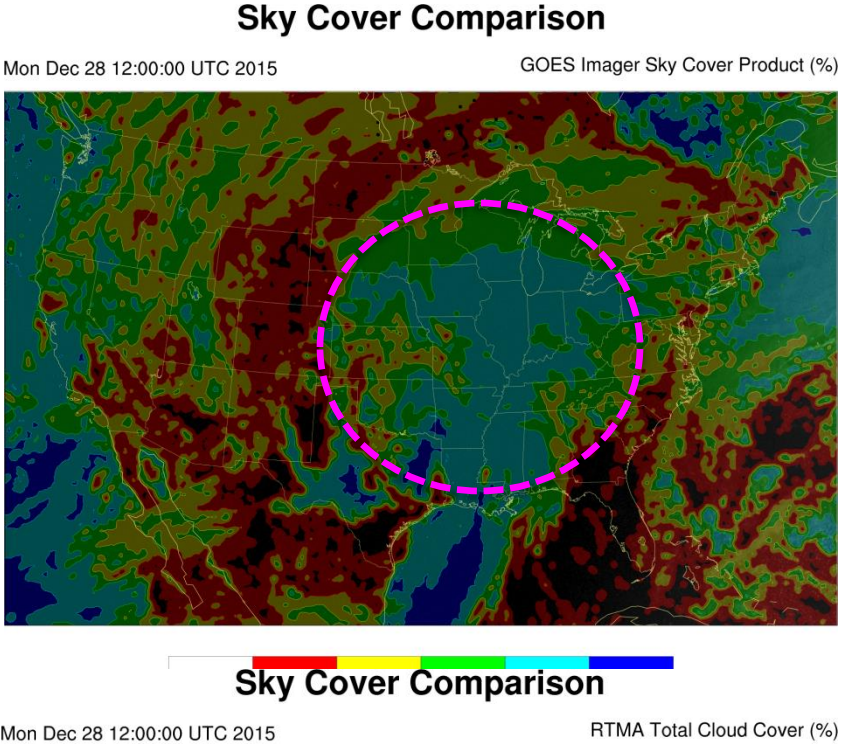


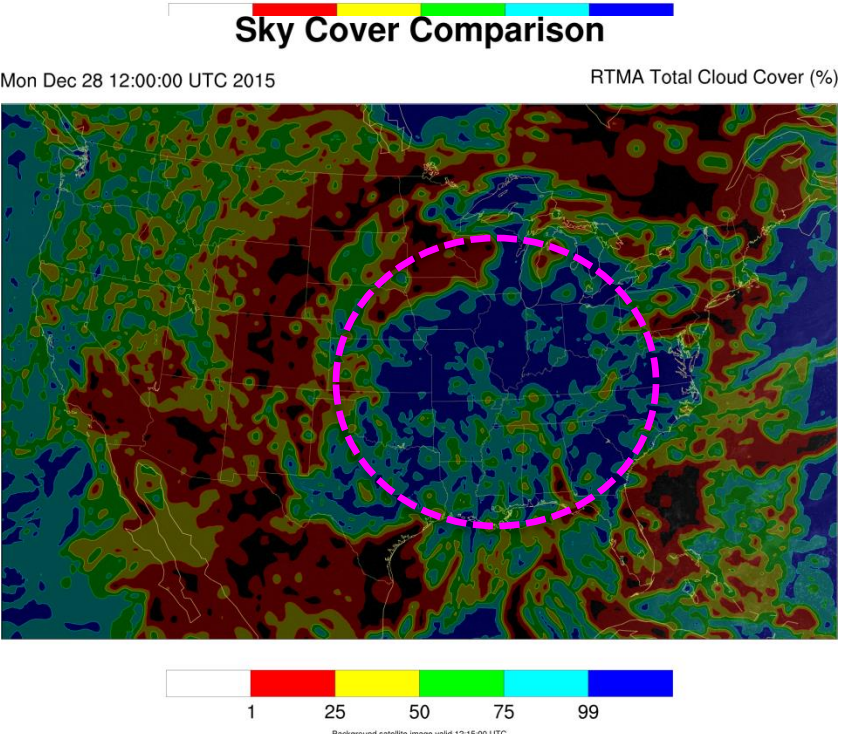
gefs: production GEFS raw forecast
gefs_testbc: GEFS bias corrected forecast

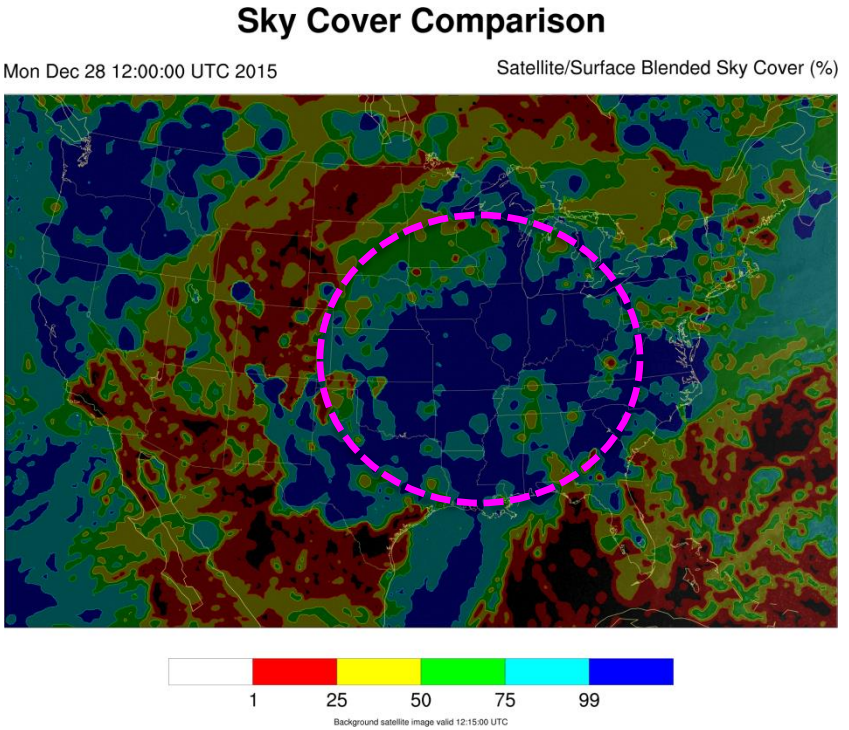
w.r.t gfsf06

There is an improvement based on this verification, but we need to understand the uncertainties of TCDC analysis (or 6hr average).


RTMA TCDC and GFS06
From 2015041700 to 2015070100
RTMA
GFS06
CONUS domain average
About 12% difference
Very difficulty to say:
GFS is over estimate or RTMA is under estimate?
100
90
80
70
60
50
40
30
20
10
0
21APR
2015
26APR
1MAY
6MAY
11MAY
16MAY
21MAY
26MAY
1JUN
6JUN
11JUN
16JUN
21JUN
26JUN







Total cloud cover:

1. Global analysis
   a. NESDIS 0.5*0.5d every 6hr analysis
   b. AFWA 1.0*1.0d every hr(?) analysis
2. Regional analysis
   a. RTMA 2.5km CONUS every hr
3. U. of Wisconsin CMISS
   a. GOES imager
   b. Satellite/surface blended
   c. …….

CONUS downscaling to 2.5km

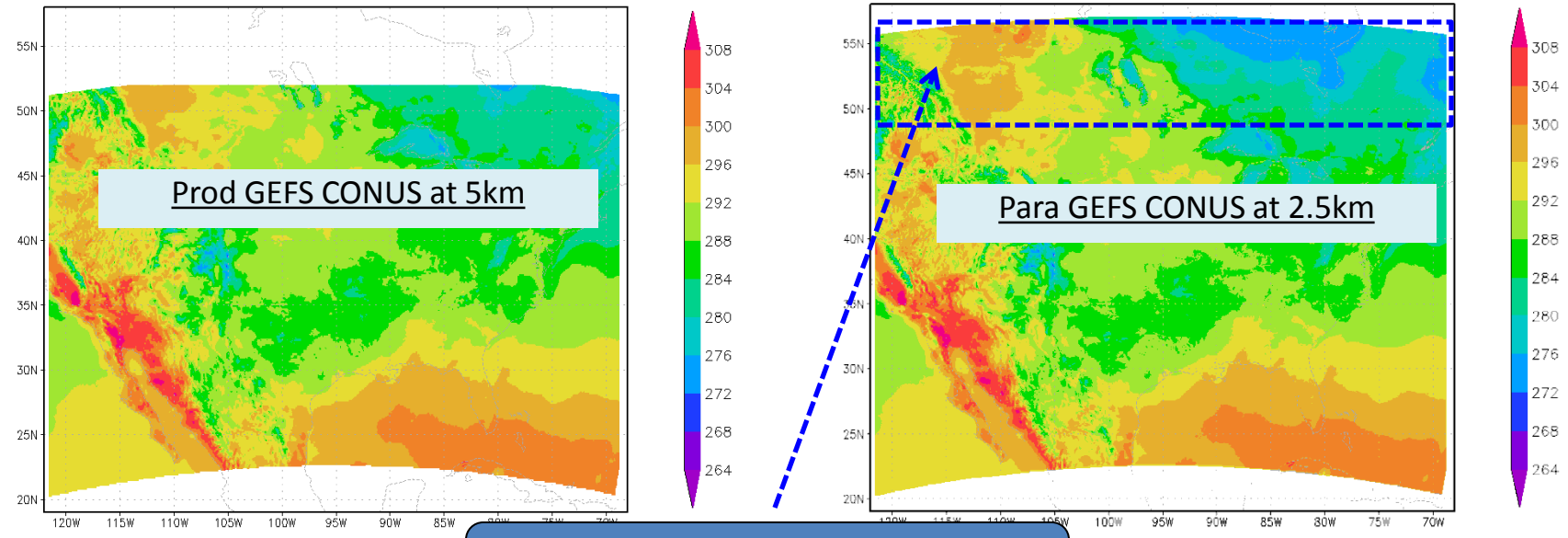
Changes:

- ✓ Resolution from 5km to 2.5km
- ✓ Domain extend to North about 5degree
- ✓ Improve probabilistic skills slightly

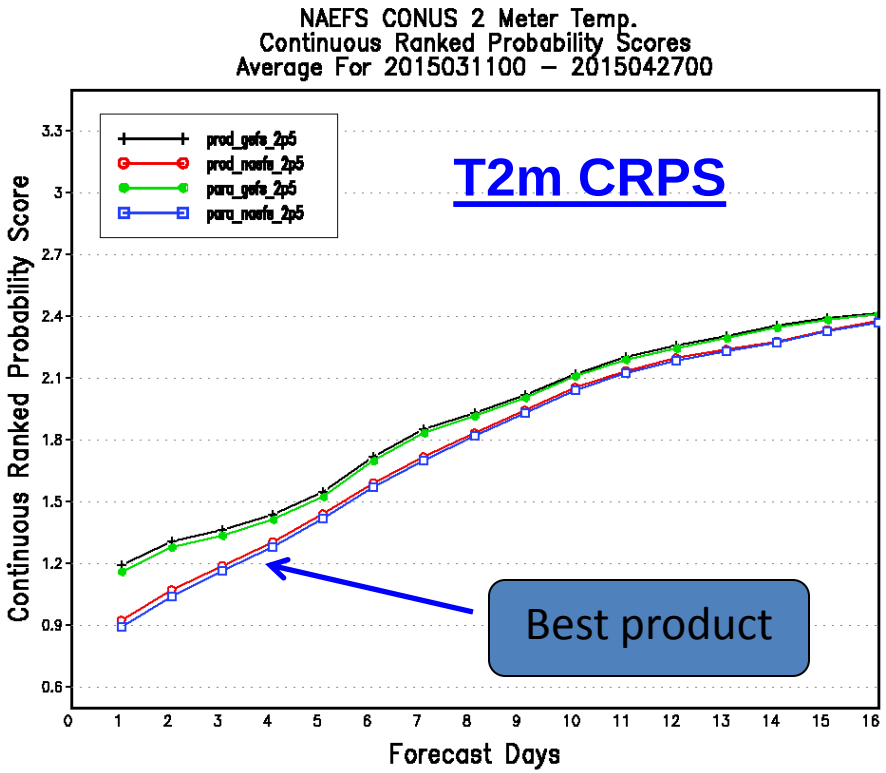
CONUS Downscaled Product Samples (T2m 48hr Fcst)

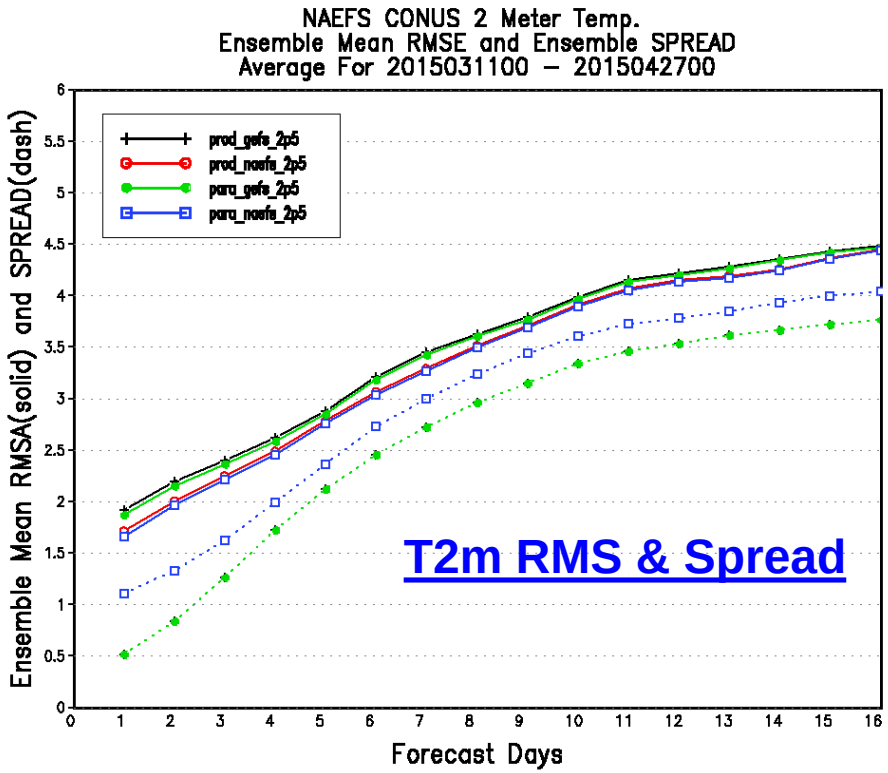
Current

Upgrade



Statistical Verification from 20150311 to 20150427





prod_gefs: production GEFS downscaled product interpolated to 2.5km

prod_naefs: production NAEFS downscaled product interpolated to 2.5km

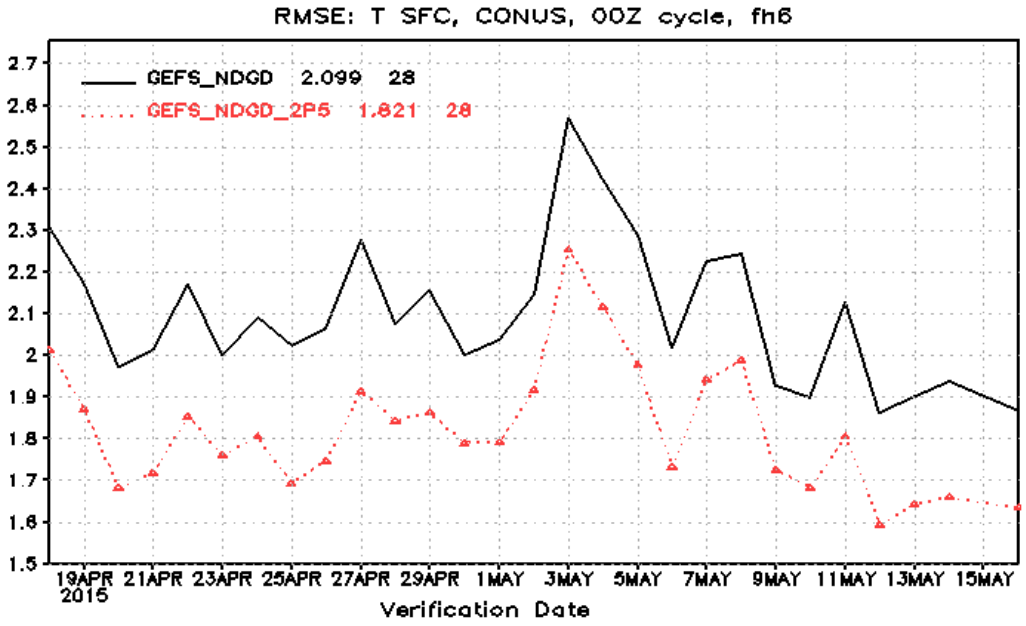
para_gefs_2p5: parallel GEFS downscaled product at 2.5km

para_naefs_2p5: parallel NAEFS downscaled product at 2.5km

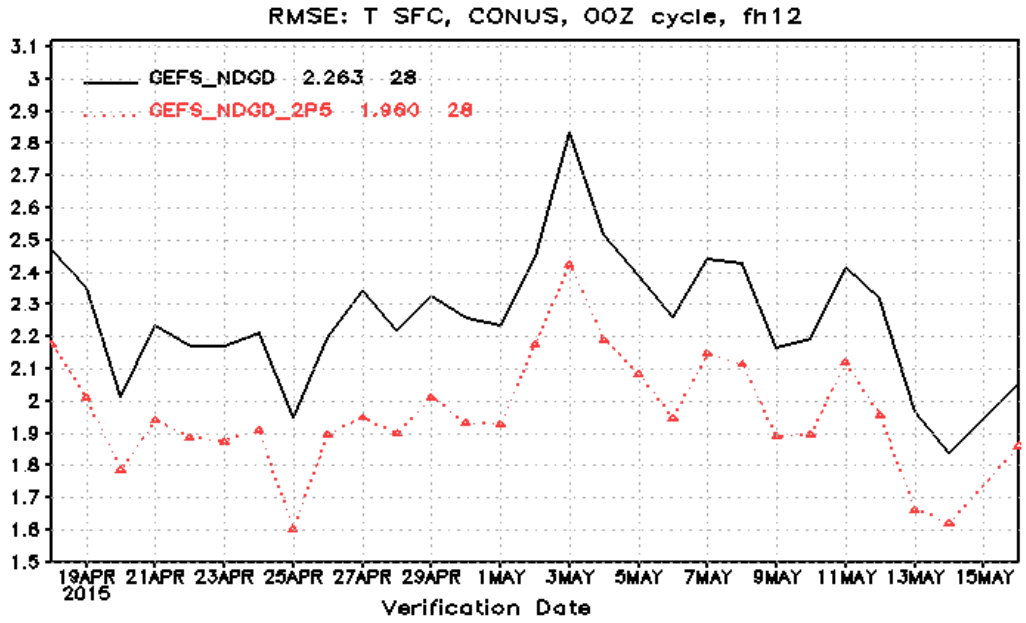
CONUS at 2.5km (prod_gefs_2p5 & prod_naefs_2p5 from interpolation of 5km forecasts)

CONUS Statistical Verification again Observation (T2m)

RMSE @ 6 fhr



RMSE @ 12 fhr

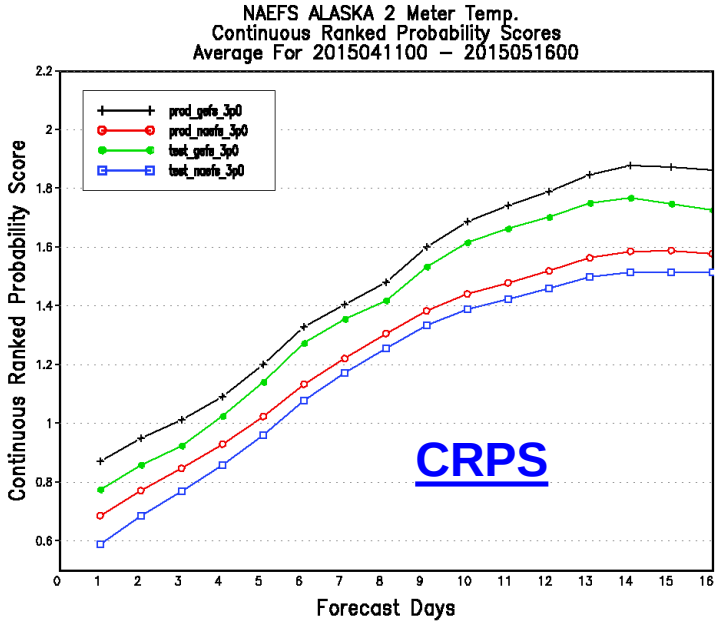


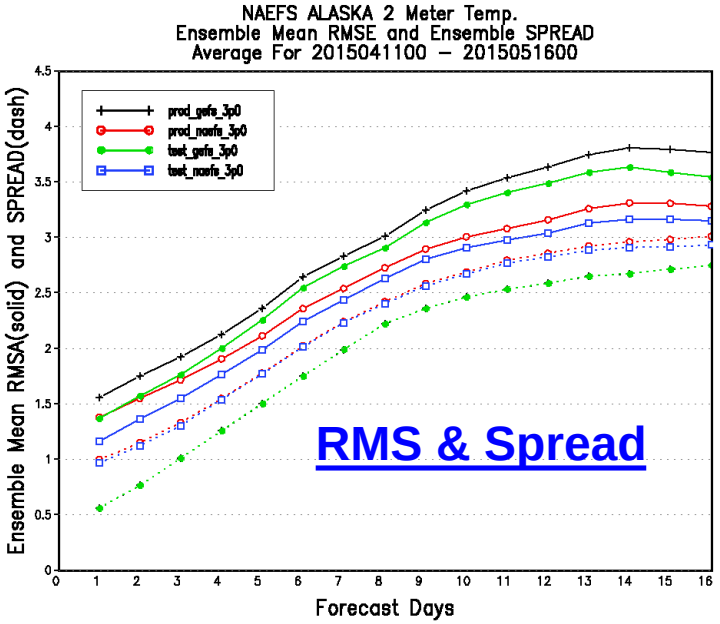
Alaska downscaling to 3km

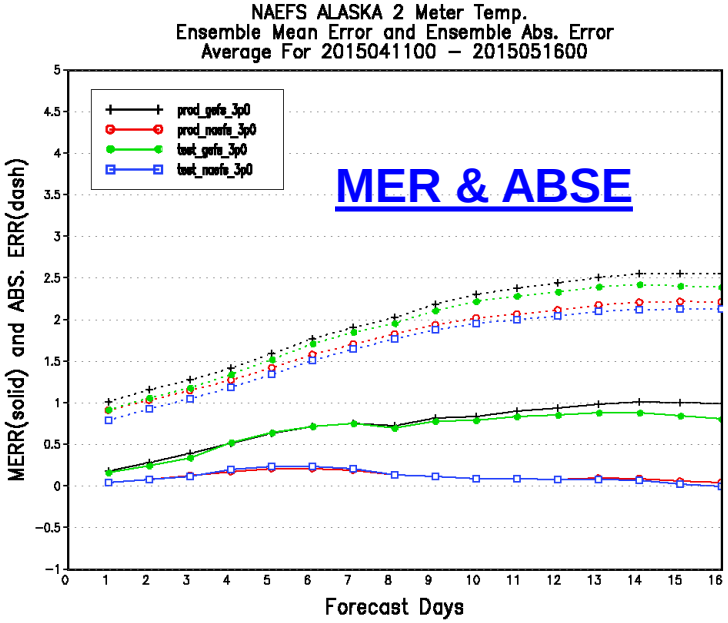
Changes:

- ✓ Resolution from 6km to 3km
- ✓ Improve probabilistic skills

Alaska Statistical Verification for T2m







prod_gefs: production GEFS

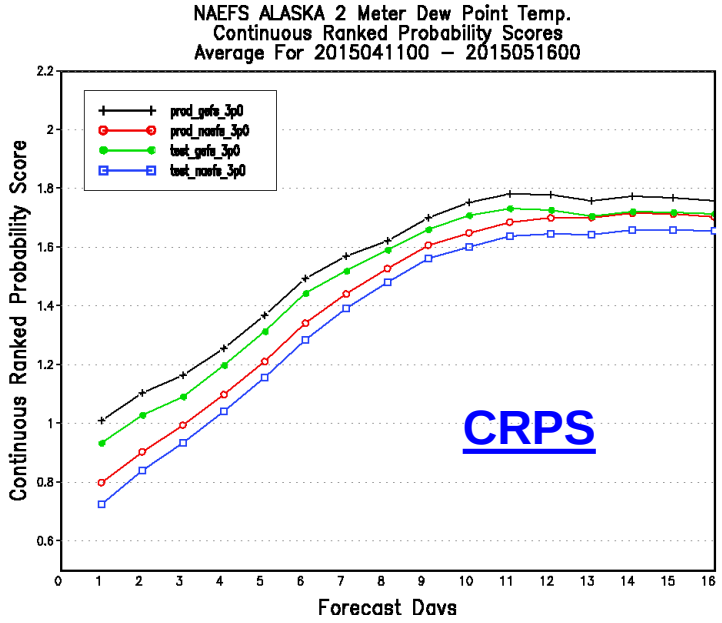
prod_naefs: production NAEFS

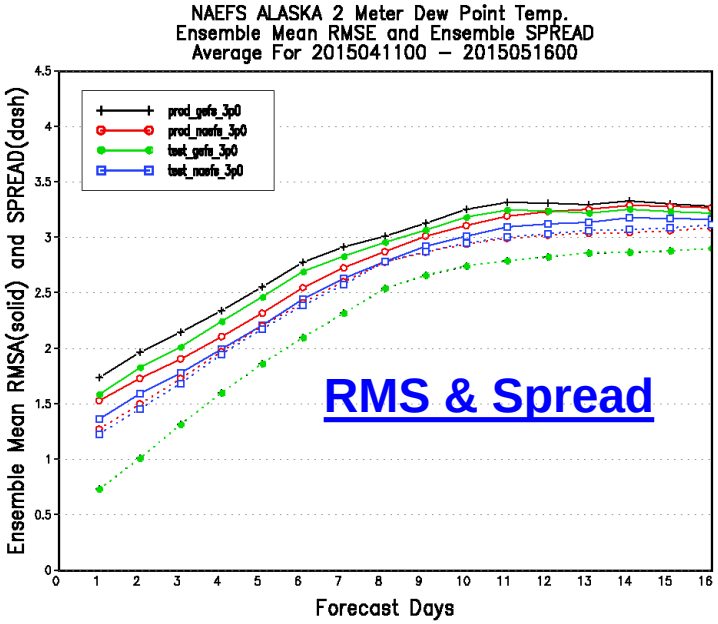
test_gefs_3p0: parallel GEFS

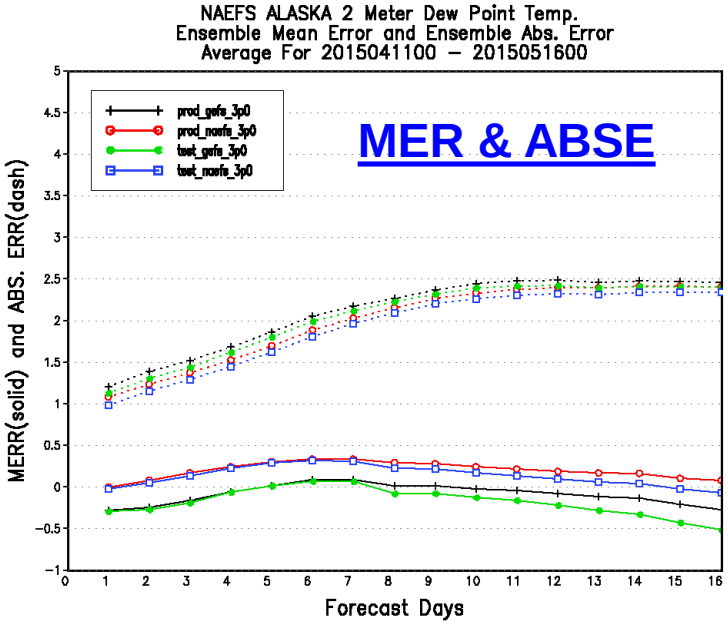
test_naefs_3p0: parallel NAEFS

Period: 20150411 to 20150516

Alaska Statistical Verification for Td2m







prod_gefs: production GEFS

prod_naefs: production NAEFS

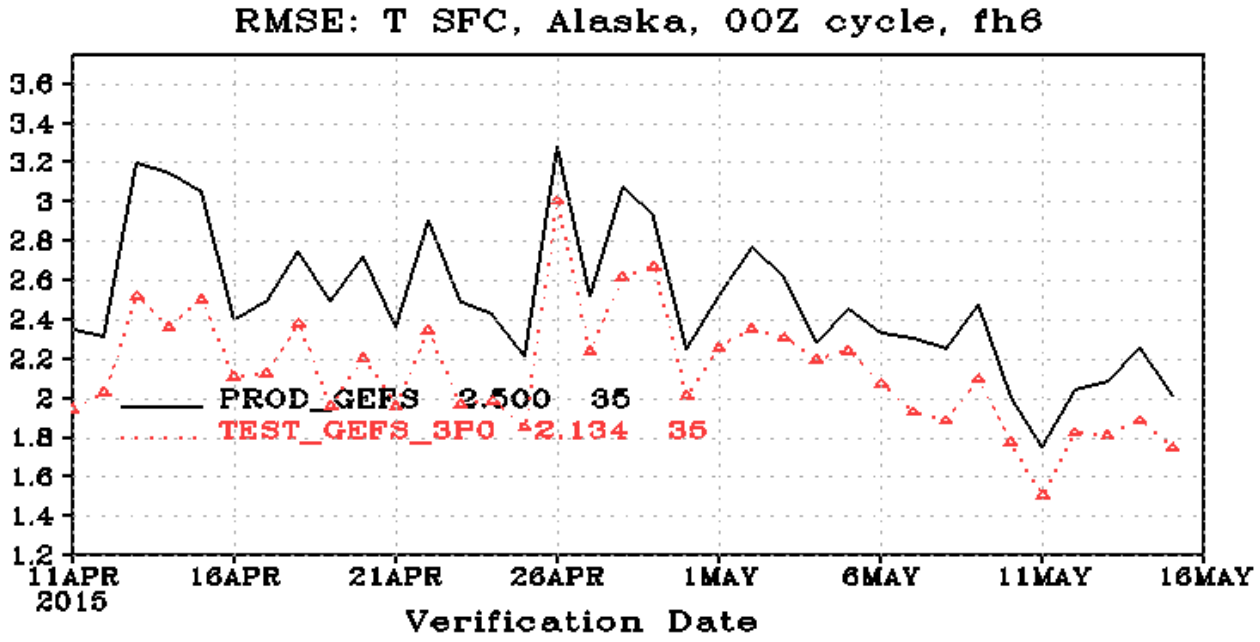
test_gefs_3p0: parallel GEFS

test_naefs_3p0: parallel NAEFS

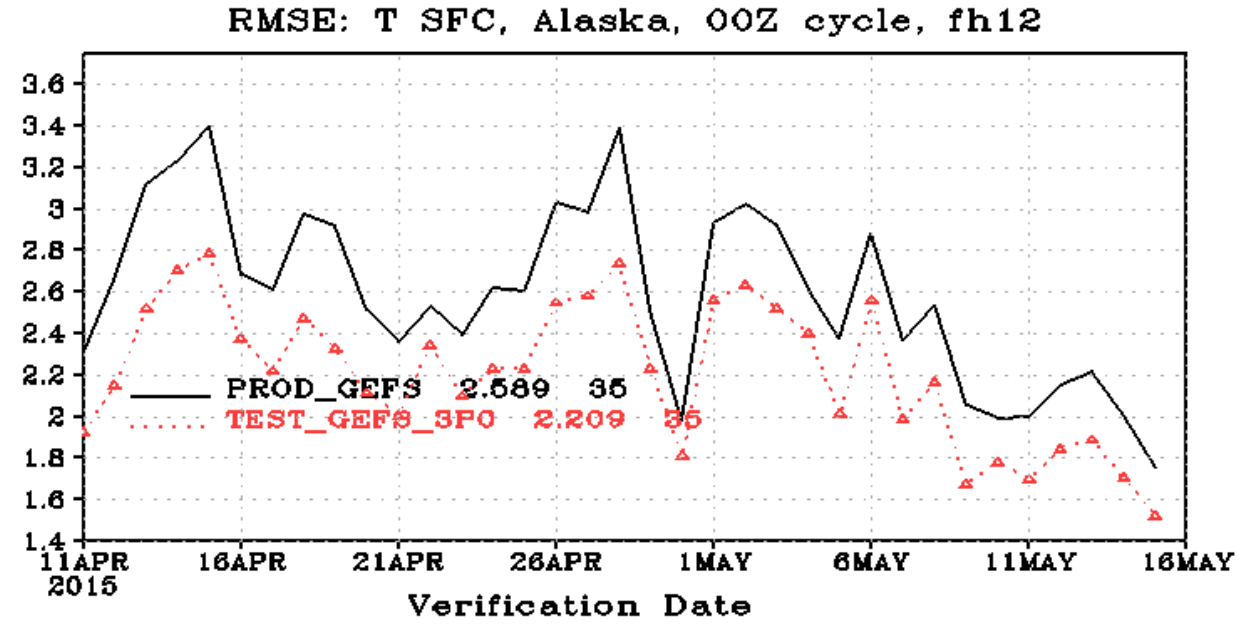
Period: 20150411 to 20150516

Alaska Statistical Verification again Observation (T2m)

RMSE @ 6 fhr



RMSE @ 12 fhr

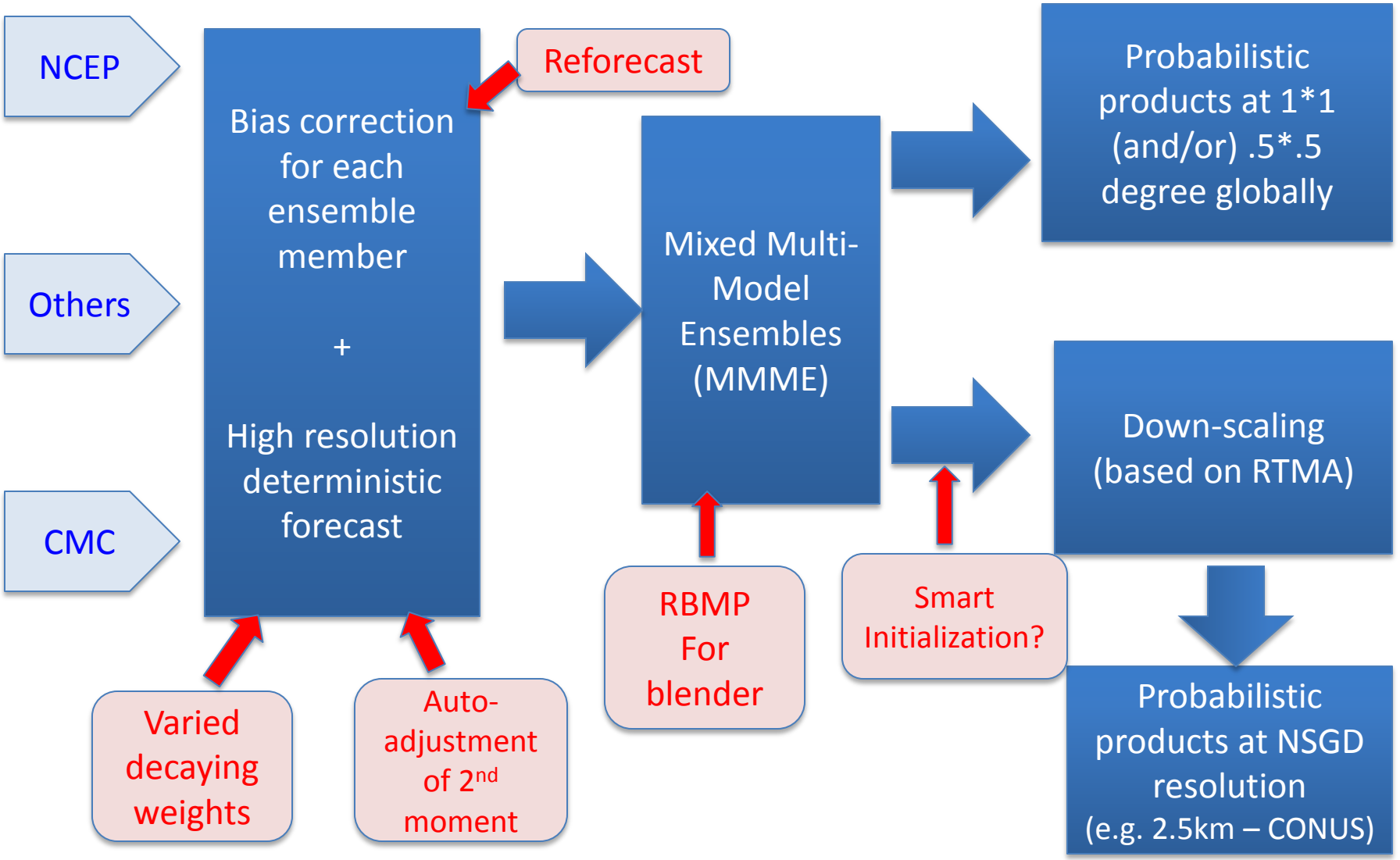


Summary of downscaling

- CONUS
  - 2.5km (finer) resolution to match up NDGD resolution
  - Extend coverage of large Canadian portion for NAEFS project
  - Slightly better skills for all downscaled variables

- Alaska
  - 3.0km (finer) resolution to match up NDGD resolution
  - Much better skills (or improvement) for T2m, Tmax, Td2m
  - Less improvement for U10m

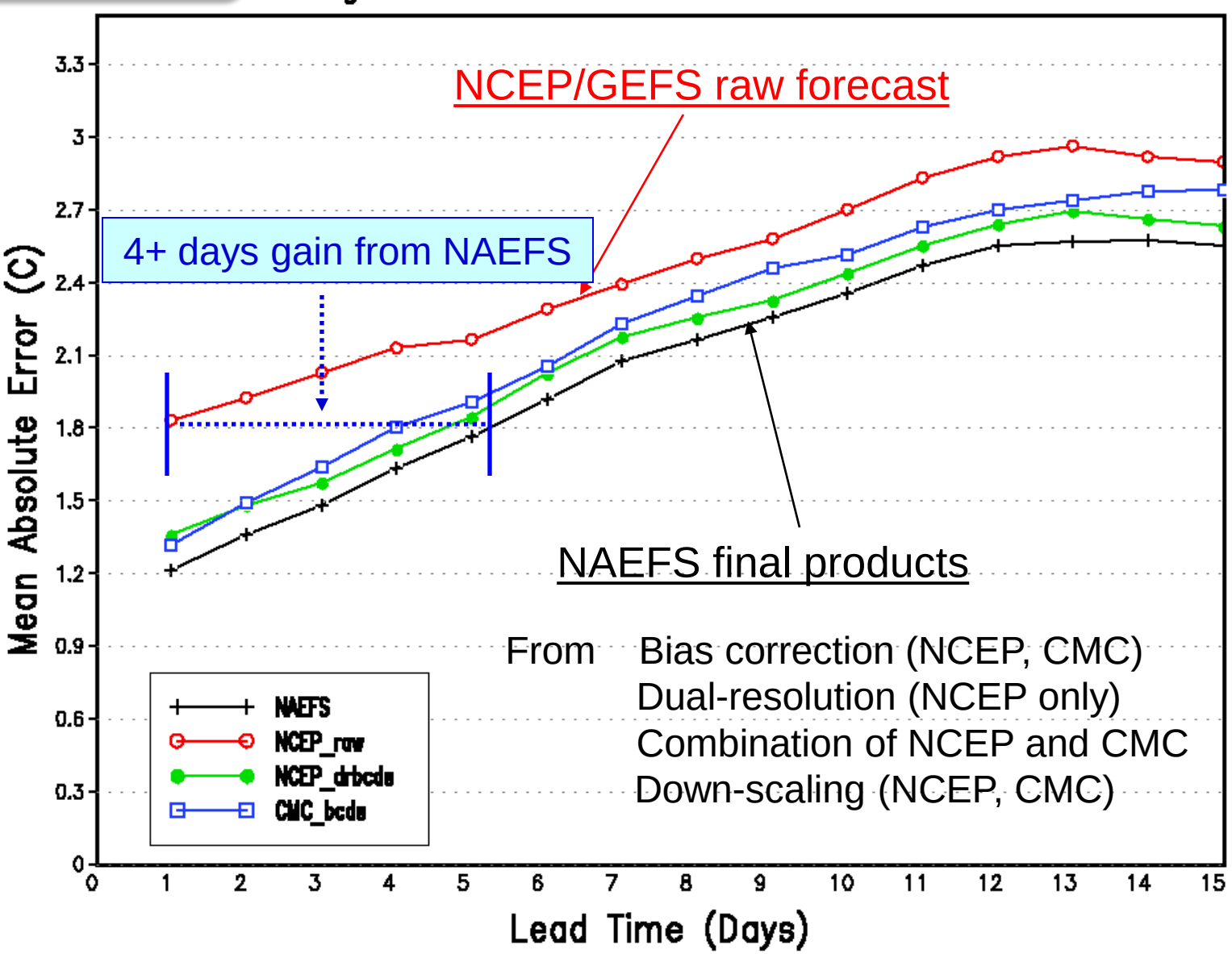
Future NAEFS Statistical Post-Processing System



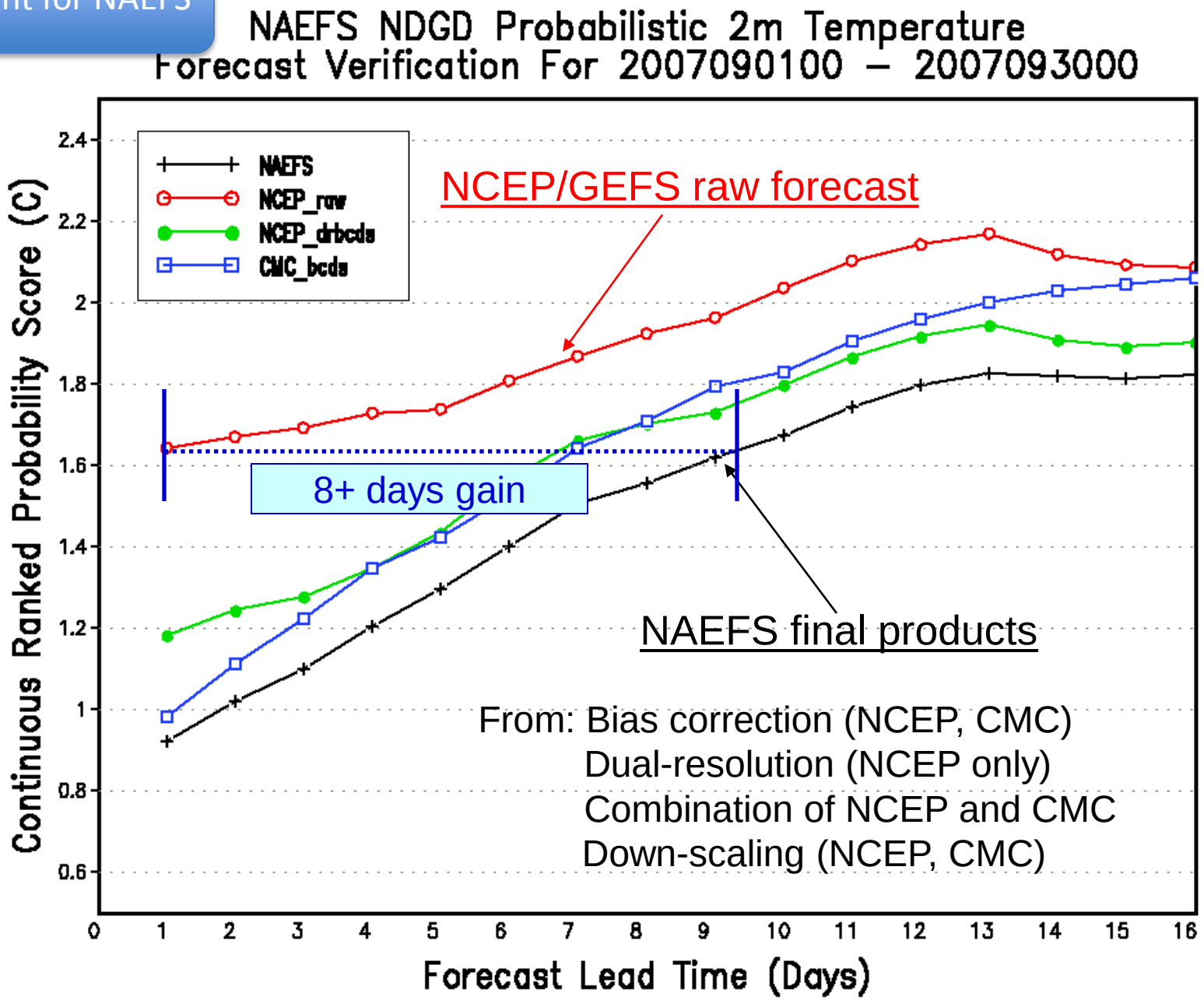
Thanks and questions?

Extra slides

Equal weight for NAEFS

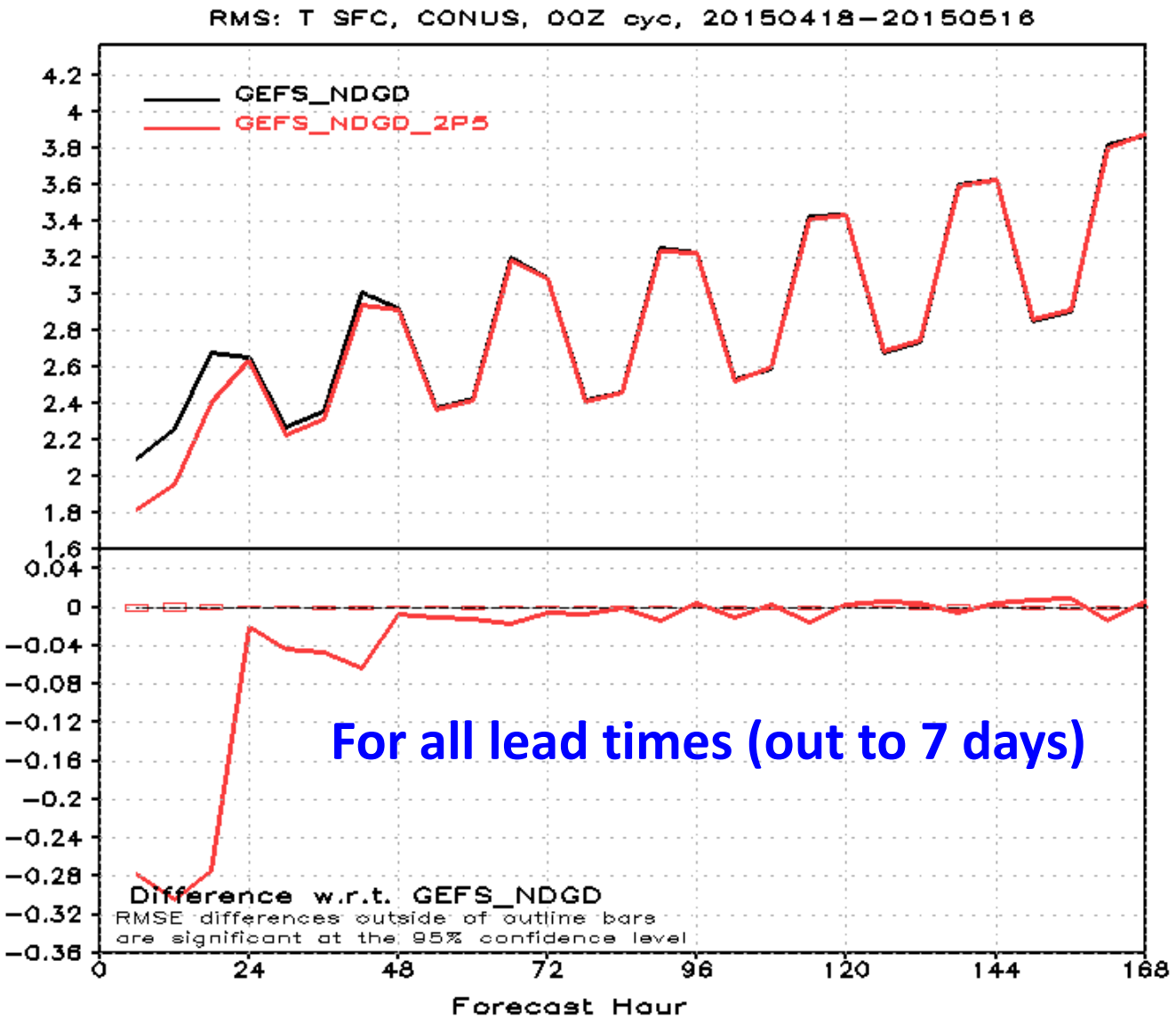


Equal weight for NAEFS



CONUS Statistical Verification again Observation

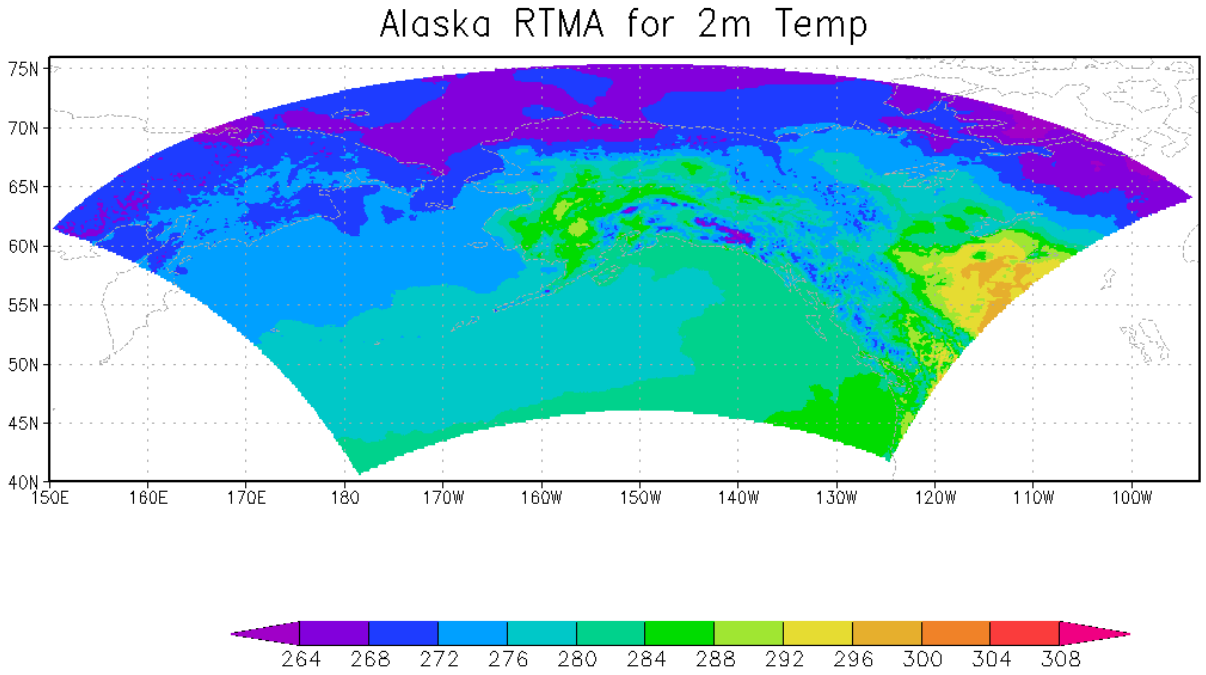
(T2m RMS error)



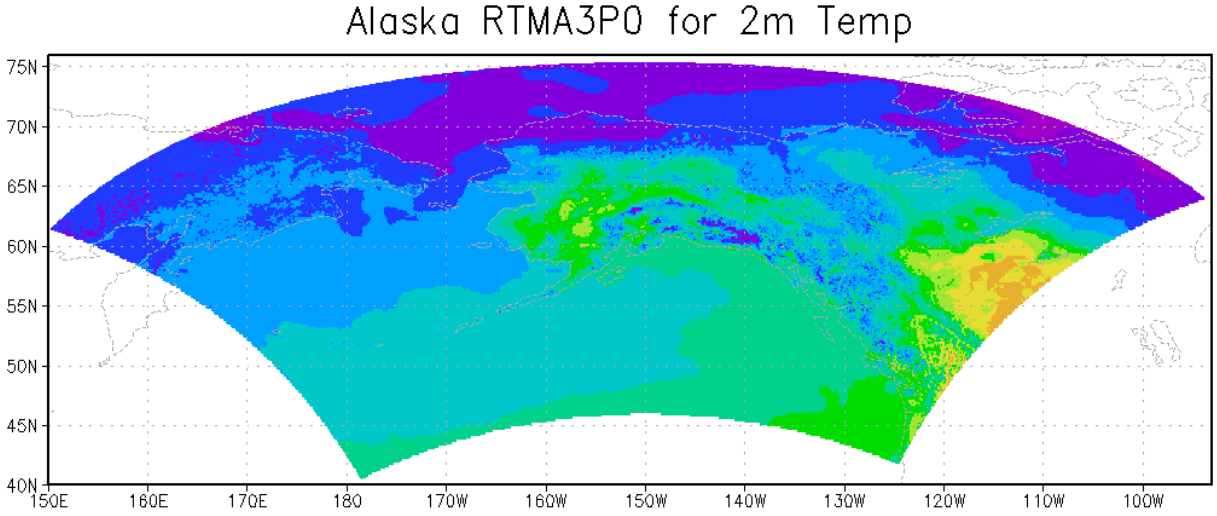
For all lead times (out to 7 days)

Alaska Downscaled Product Samples (NAEFS T2m 48hr Fcst)

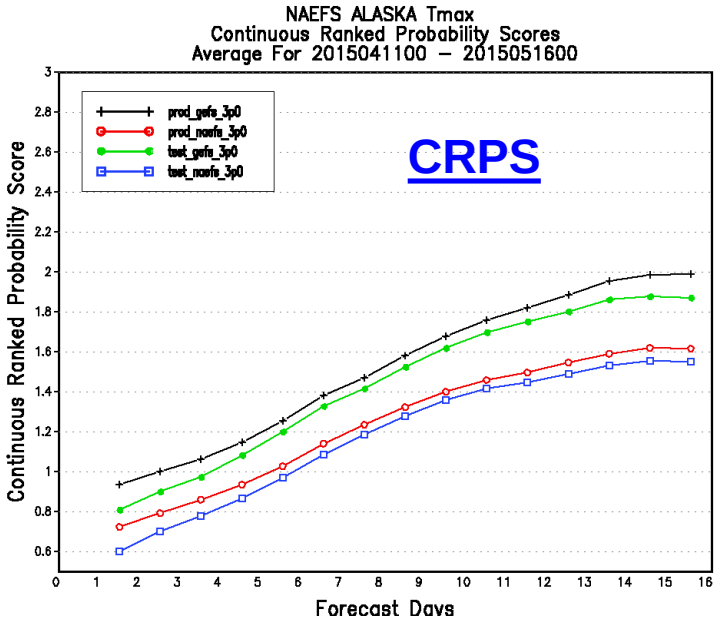
Production - 6km

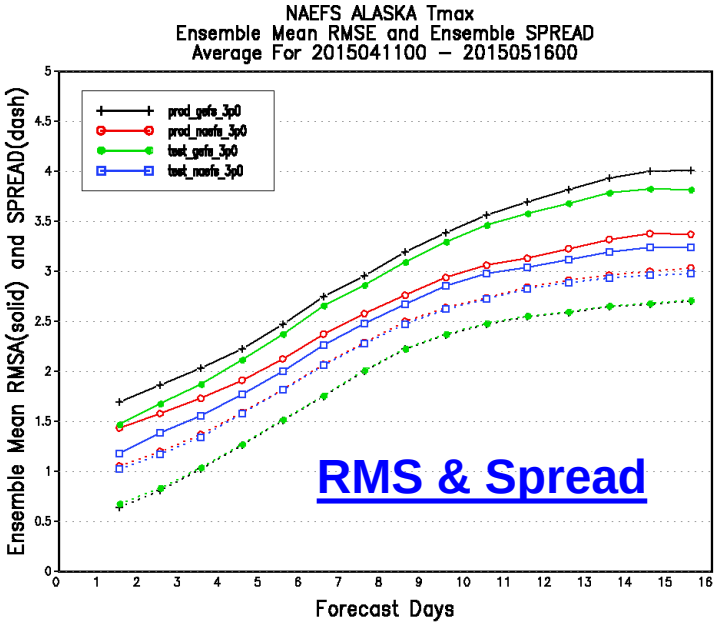


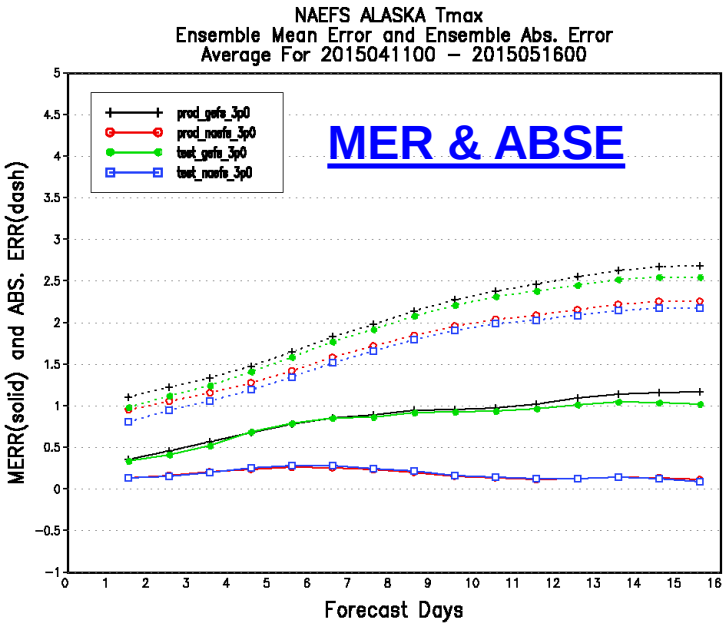
Parallel - 3km



Alaska Statistical Verification for Tmax







prod_gefs: production GEFS

prod_naefs: production NAEFS

test_gefs_3p0: parallel GEFS

test_naefs_3p0: parallel NAEFS

Period: 20150411 to 20150516

Alaska Statistical Verification again Observation (T2m RMS)