NAEFS Upgrade (Version 5)

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Acknowledgements: EMC Ensemble team staffs

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Highlights of Changes

- New products
  - NAEFS (NCEP+CMC) ensembles
    - Bias corrected GEFS/NAEFS Total Cloud Cover (TCDC) at 1*1 degree resolution
      - NCEP GEFS only
      - Combined with CMC's, and downscaling???
    - CONUS downscaling to 2.5km resolution
      - Extend NDGD coverage to North – NAEFS project request/contribution
    - Alaska downscaling to 3.0km resolution
- Others – upgrade for NUOPC (FNMOC ensemble)
  - Direct distribute FNMOC's bias corrected forecast instead of NCEP produced bias corrected forecast
  - Total Cloud Cover (TCDC) will use "percentage (%)" instead of "fraction (0-1)

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 – Q2FY16 — 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 (in process)
  - 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 (Accepted: May 5 2015, http://dx.doi.org/10.1175/WAF-D-14-00126.1)

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:

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

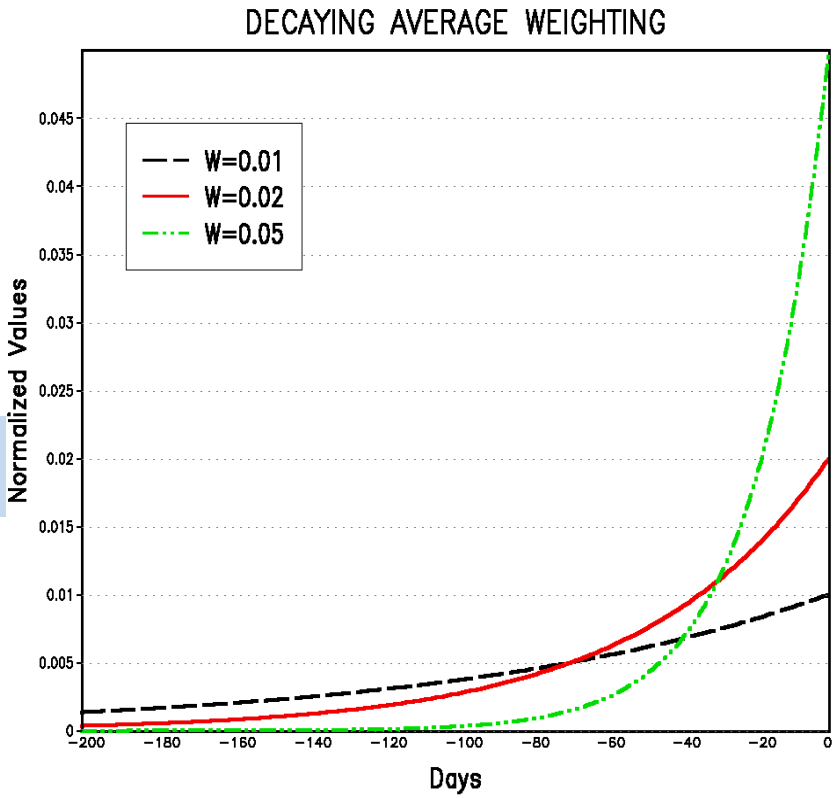
2). Decaying Average (Kalman Filter method)

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

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

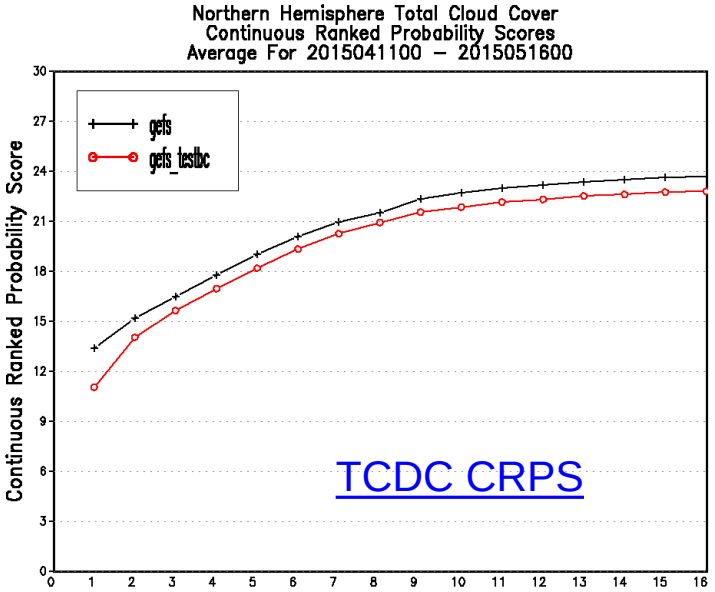
1. NAEFS upgrade

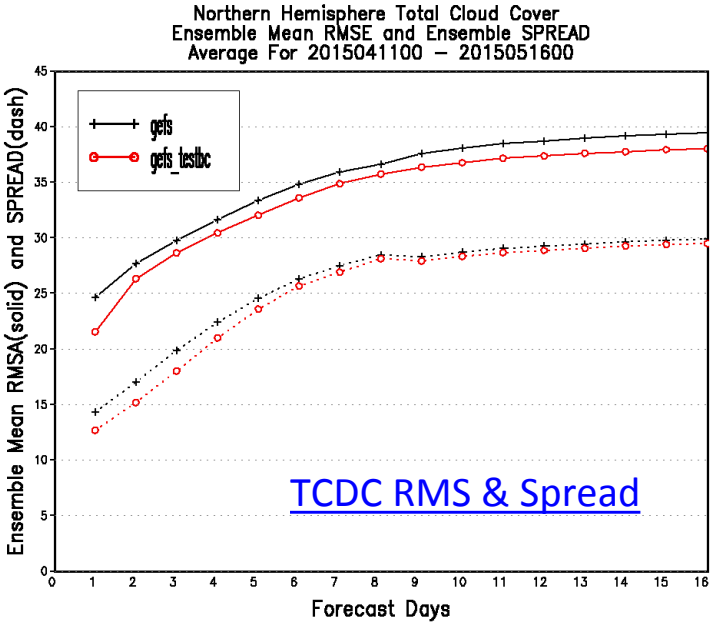
- Total could cover (TCDC) – bias correction
  - New variable for bias correction
  - Try to calibrate NCEP/GEFS first
  - Then combined with CMC/GEFS???
  - There is a challenge for proxy truth
- CONUS downscaling to 2.5km resolution
  - Replace current 5km resolution products
  - Extend NDGD coverage to North – NAEFS project request/contribution
- Alaska downscaling to 3km resolution
  - Replace current 6km resolution products

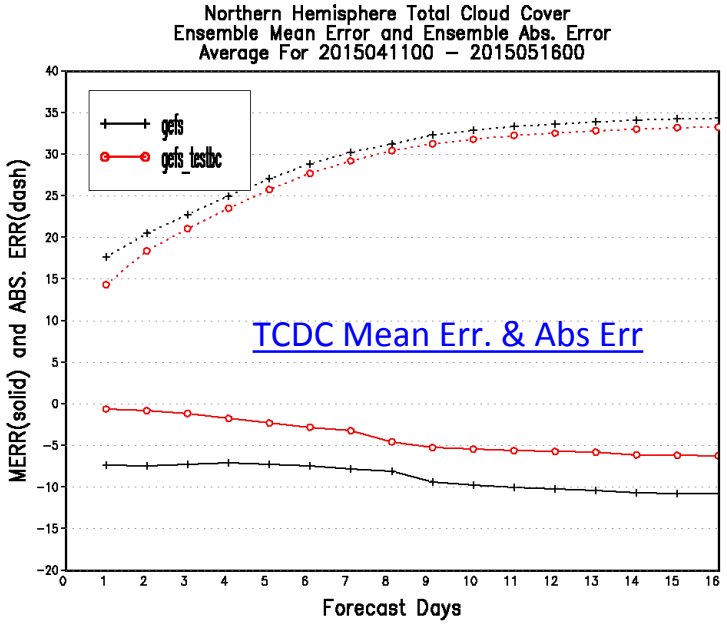
a. GEFS TCDC Bias Correction

- Based on GEFS operational ensemble systems
- For raw and bias corrected ensembles
- Bias estimation: against GEFS control and GFS 6-hr forecasts
- Period:
  - Spring – Apr. 11th 2015 – May 16th 2015
- Variables: TCDC (total cloud cover 6 hourly average)
- 1*1 degree resolution globally (verification only)
- Verify against GFS 6-hr forecast
- Comparison:
  - gefs: GEFS 20 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



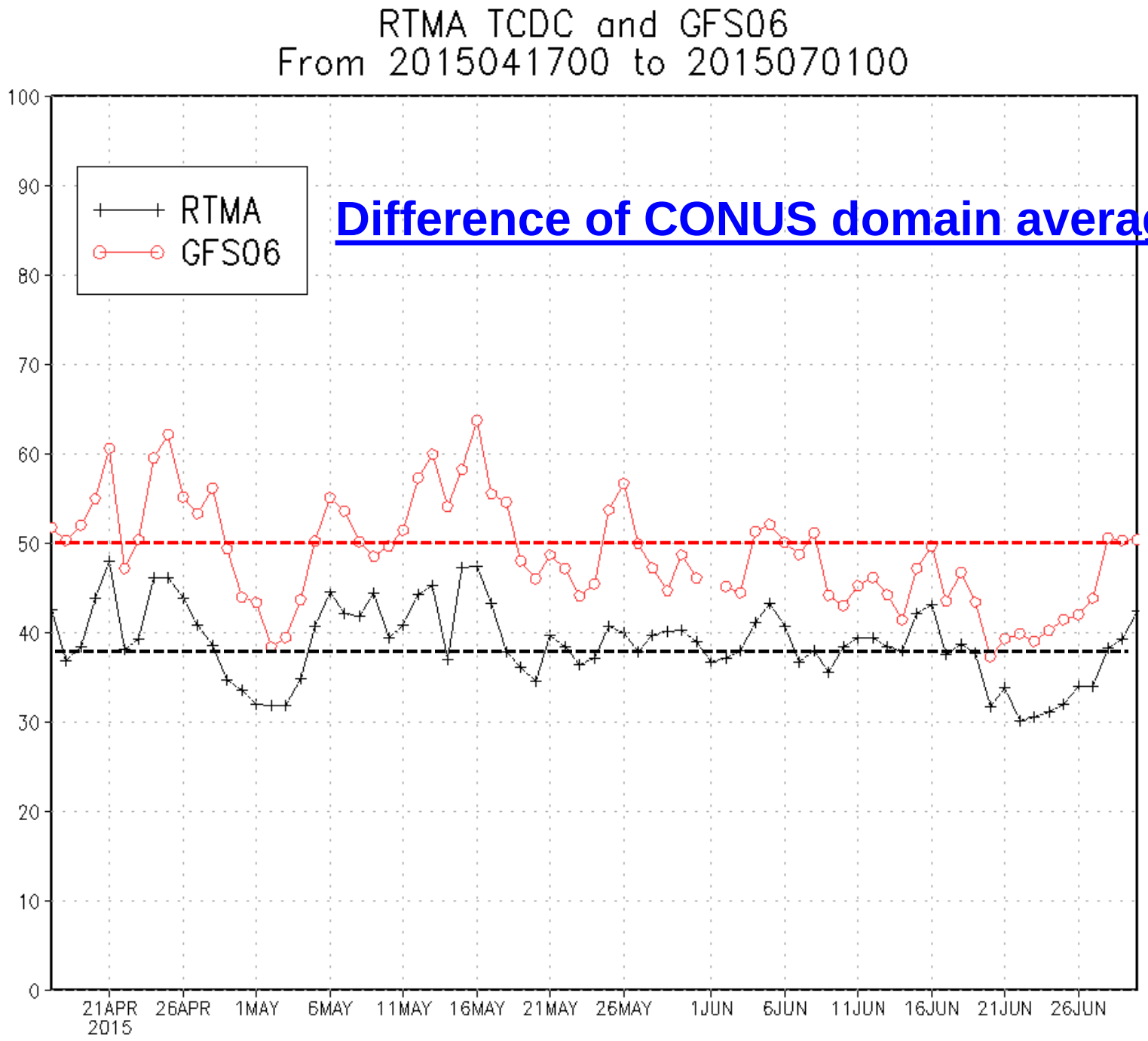




gefs: production GEFS raw forecast
gefs_testbc: GEFS bias corrected forecast

w.r.t gfsf06

There are large uncertainty of GFS 0-6hr forecast
With model spin-up???
Large diff: RTMA and GFS 0-6hr



Difference of CONUS domain average

b. CONUS downscaling to 2.5km

Changes:

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

NAEFS downscaling parameters and products

Plan: Q2FY2016 (NDGD resolutions)

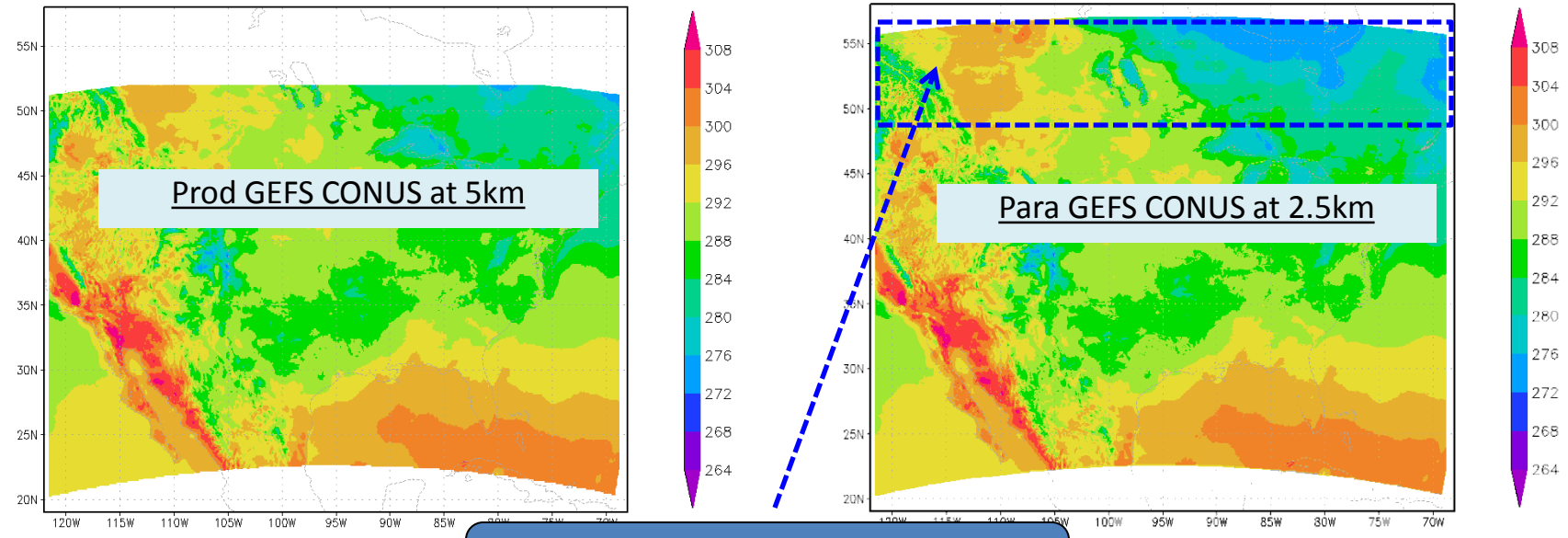
Variables	Domains	Resolutions	Total 10/10
Surface Pressure	CONUS/Alaska	2.5km/3km	1/1
2-m temperature	CONUS/Alaska	2.5km/3km	1/1
10-m U component	CONUS/Alaska	2.5km/3km	1/1
10-m V component	CONUS/Alaska	2.5km/3km	1/1
2-m maximum T	CONUS/Alaska	2.5km/3km	1/1
2-m minimum T	CONUS/Alaska	2.5km/3km	1/1
10-m 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

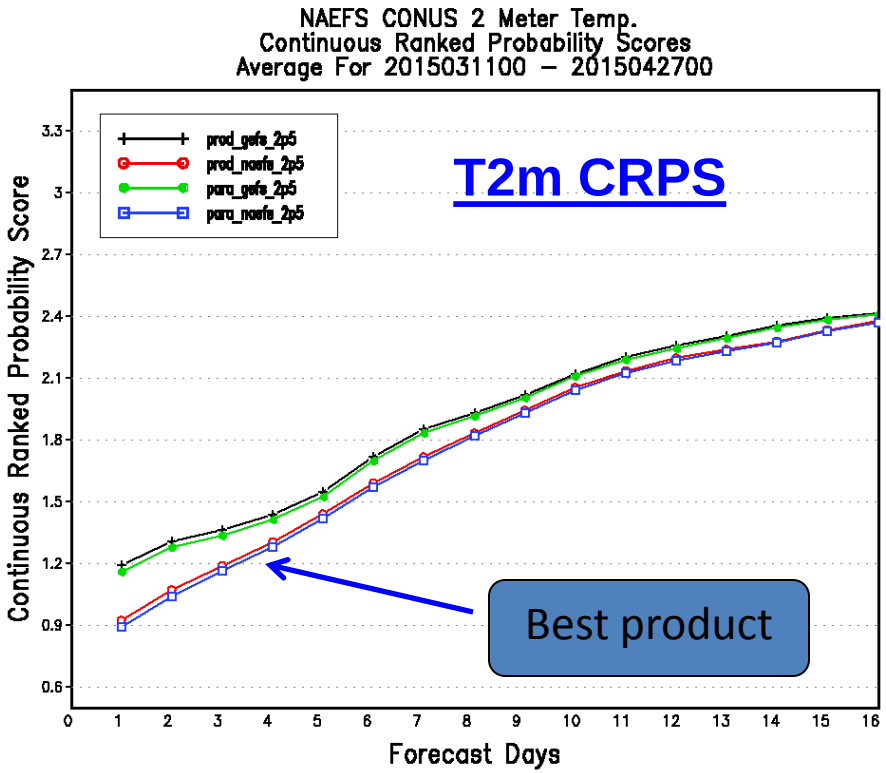
CONUS Downscaled Product Samples (T2m 48hr Fcst)

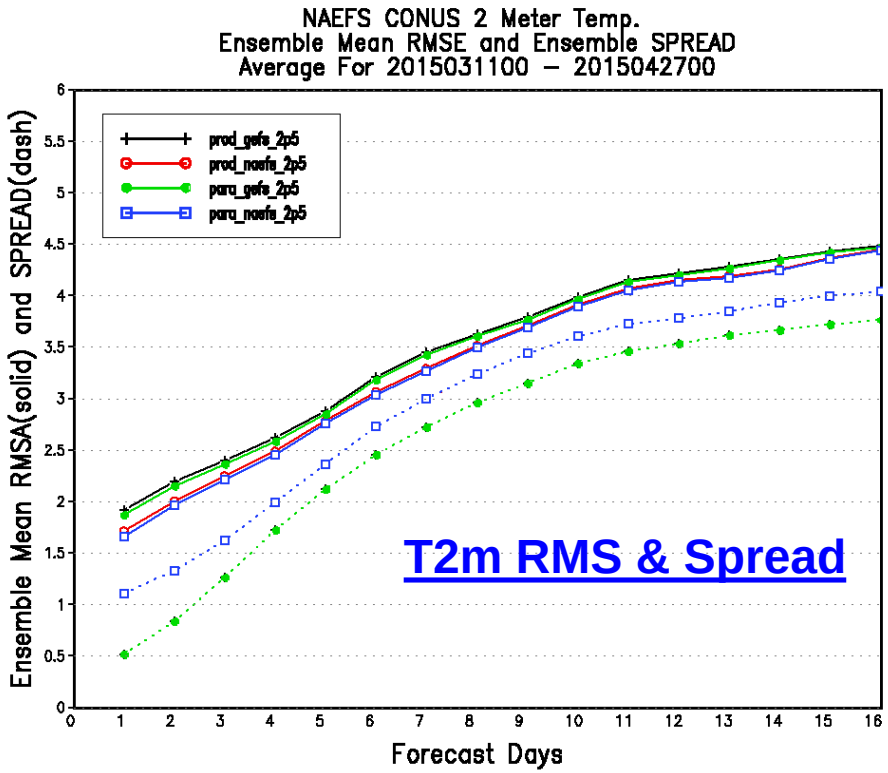
Current

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

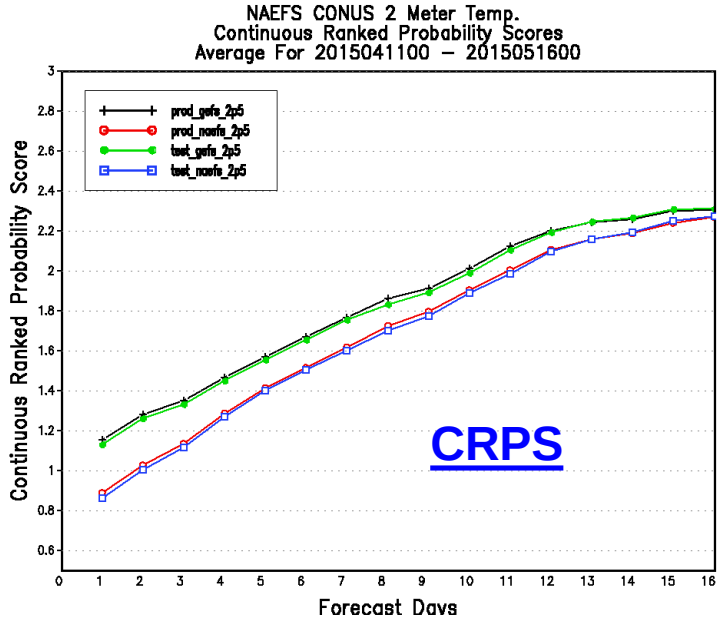
para_gefs_2p5: parallel GEFS downscaled product at 2.5km

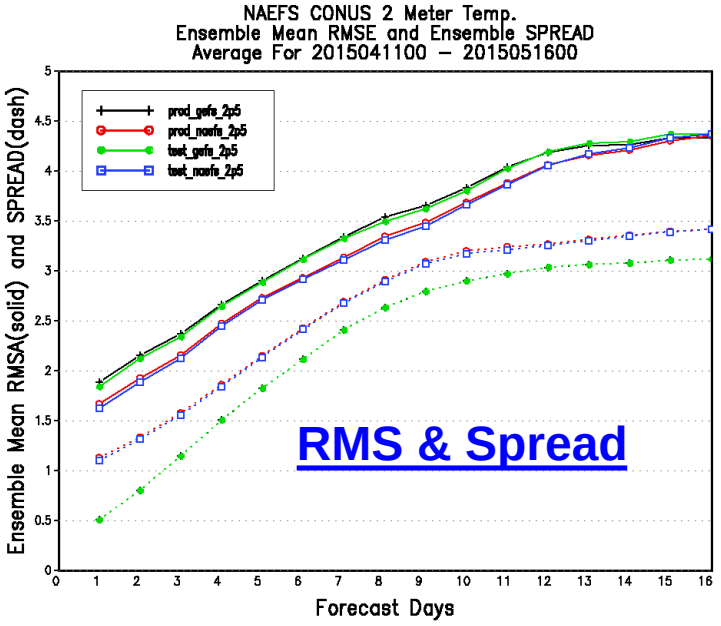
para_naefs_2p5: parallel NAEFS downscaled product at 2.5km

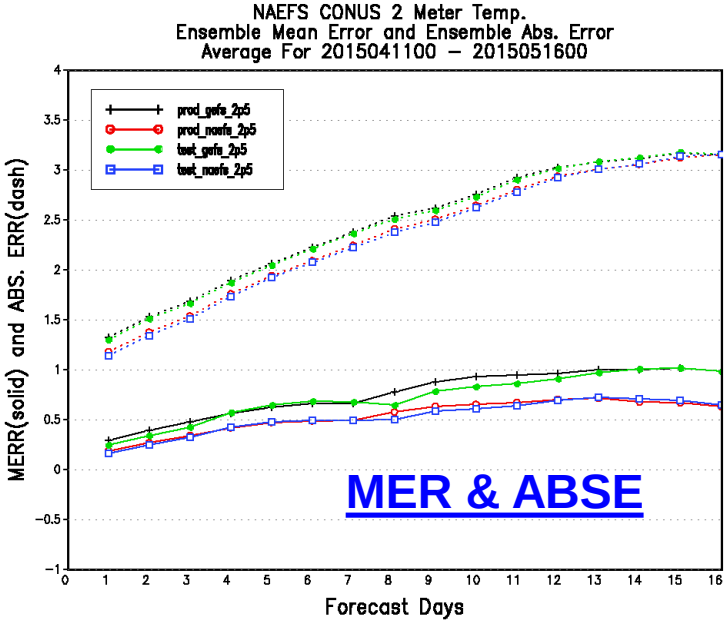
CONUS at 2.5km (prod_gefs_2p5 & prod_naefs_2p5 from interpolation of 5km forecasts)

More CONUS Verifications

CONUS Statistical Verification for T2m







prod_gefs: production GEFS

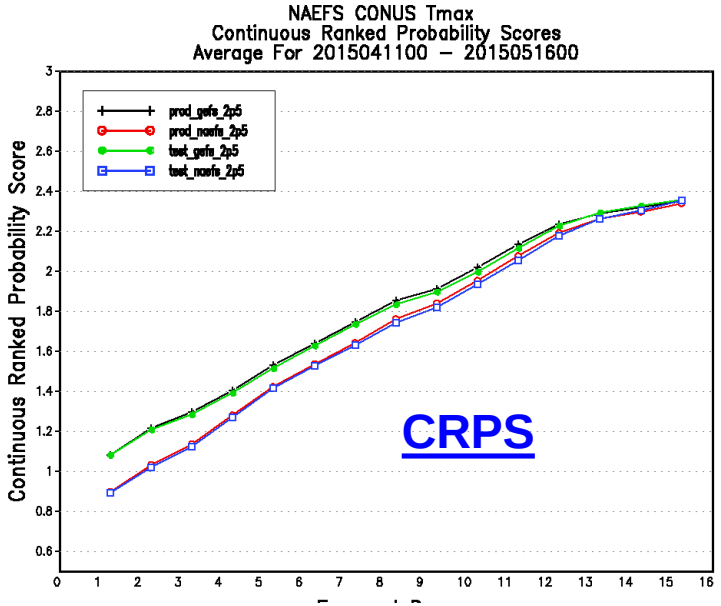
prod_naefs: production NAEFS

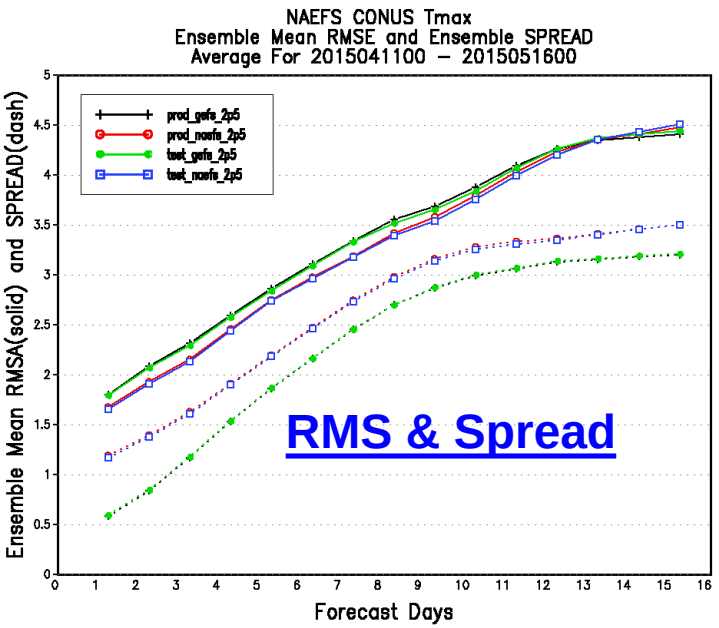
test_gefs_2p5: parallel GEFS

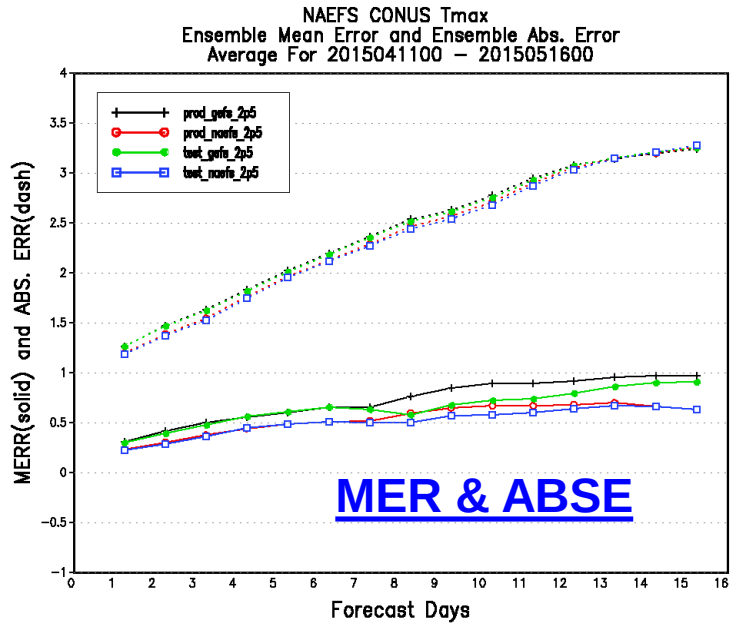
test_naefs_2p5: parallel NAEFS

Period: 20150411 - 20150516

CONUS Statistical Verification for Tmax







prod_gefs: production GEFS

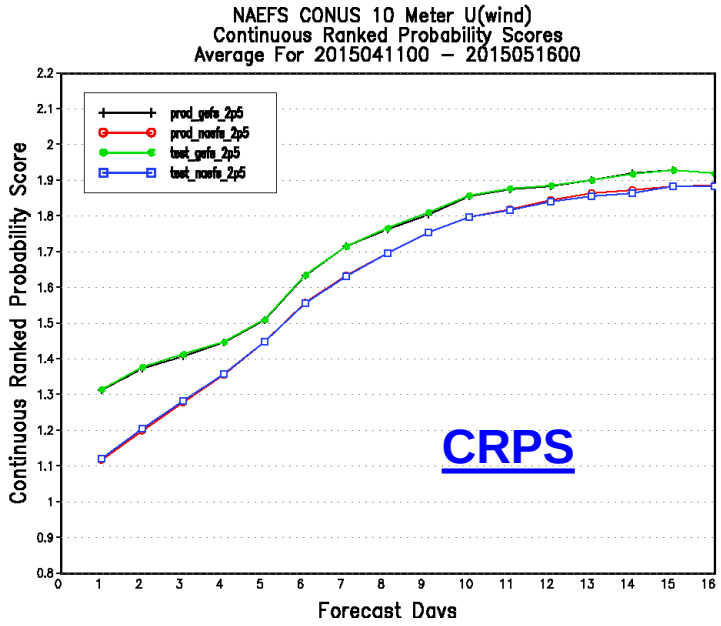
prod_naefs: production NAEFS

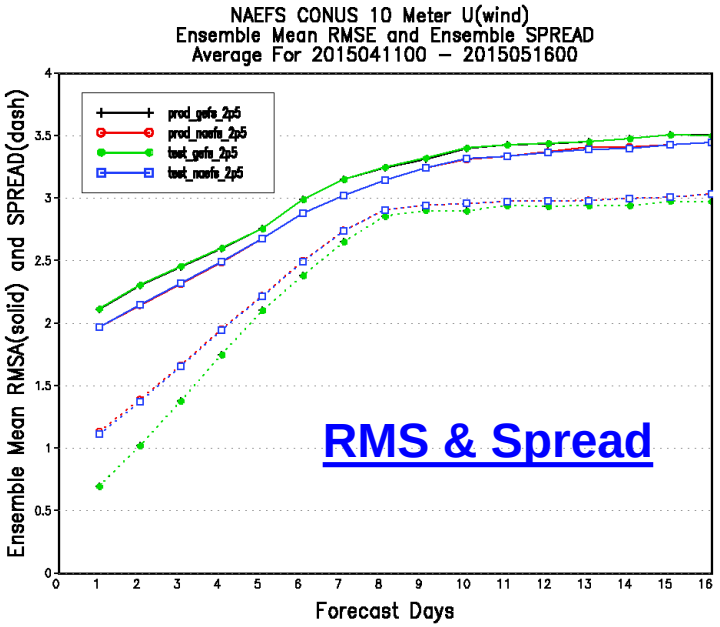
test_gefs_2p5: parallel GEFS

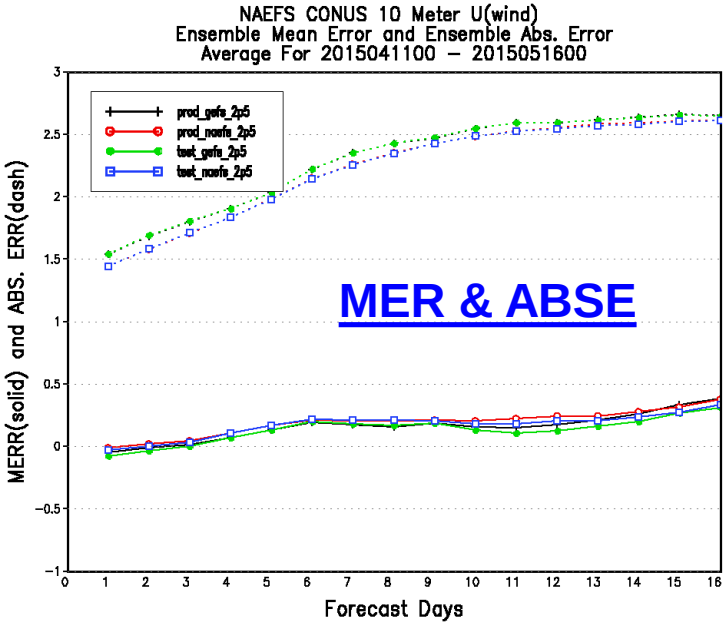
test_naefs_2p5: parallel NAEFS

Period: 20150411 - 20150516

CONUS Statistical Verification for 10m U







prod_gefs: production GEFS

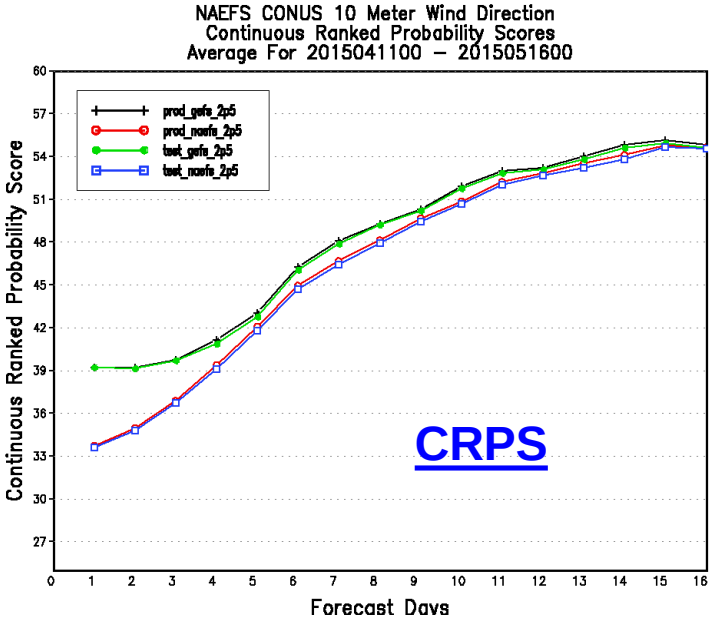
prod_naefs: production NAEFS

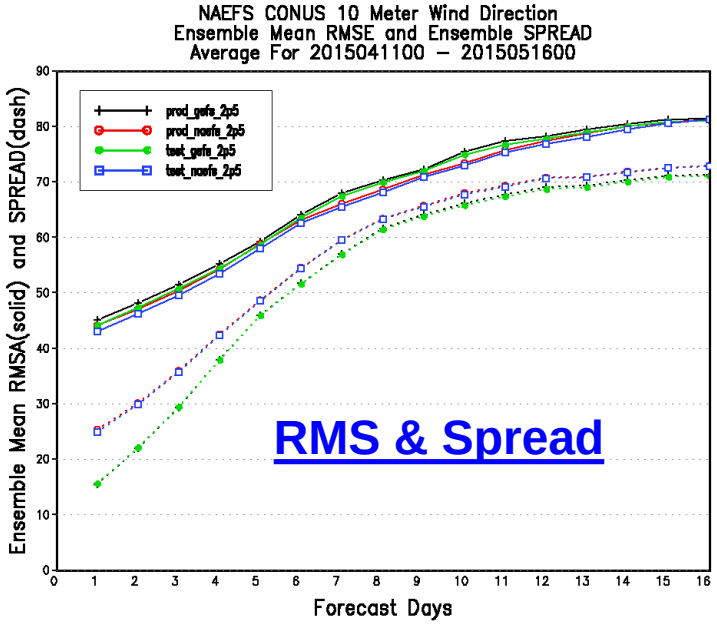
test_gefs_2p5: parallel GEFS

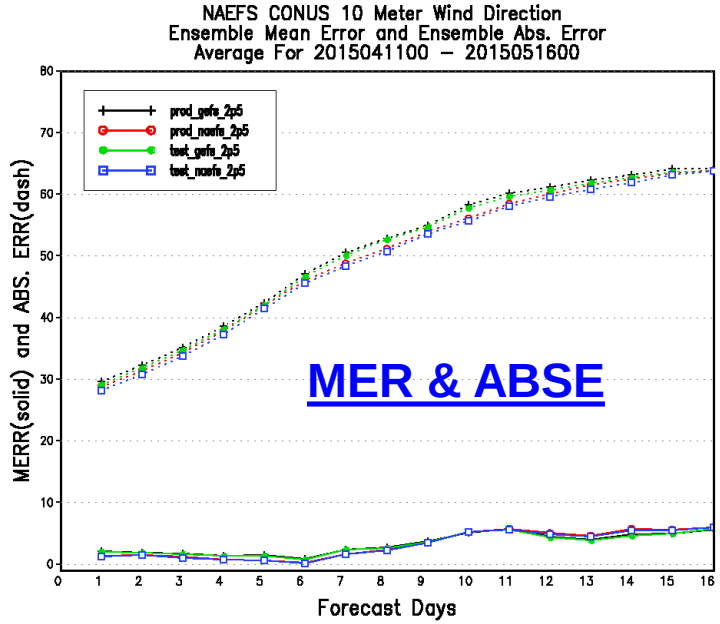
test_naefs_2p5: parallel NAEFS

Period: 20150411 - 20150516

CONUS Statistical Verification for Wind Direction







prod_gefs: production GEFS

prod_naefs: production NAEFS

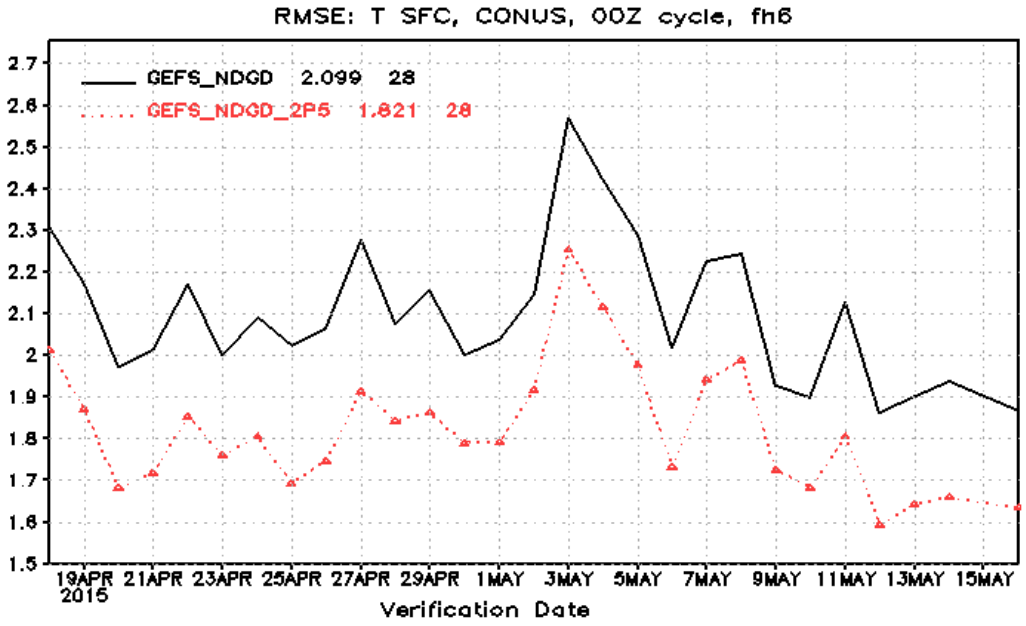
test_gefs_2p5: parallel GEFS

test_naefs_2p5: parallel NAEFS

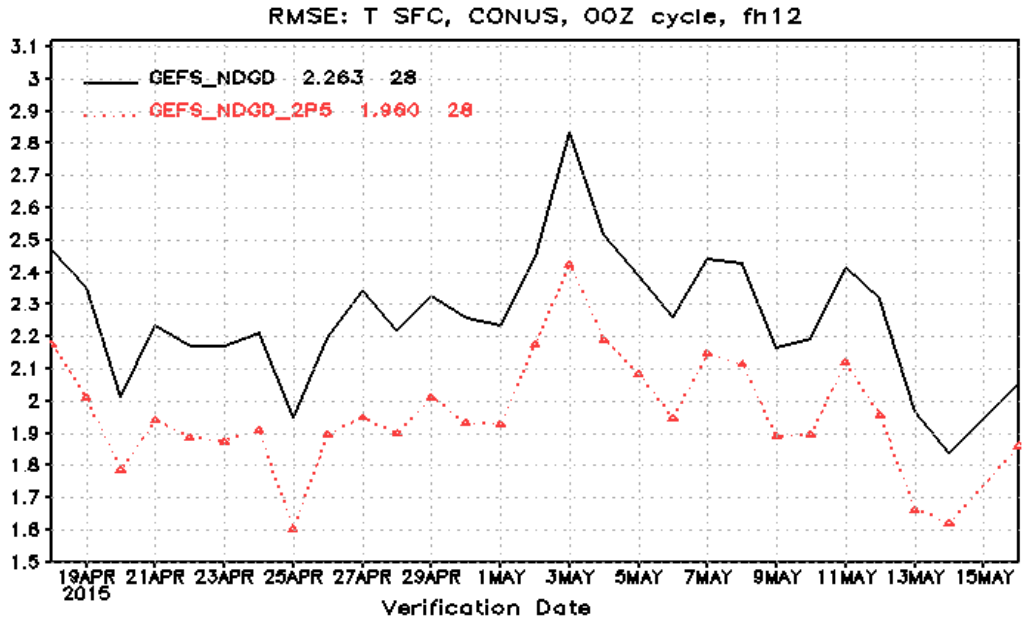
Period: 20150411 - 20150516

CONUS Statistical Verification again Observation (T2m)

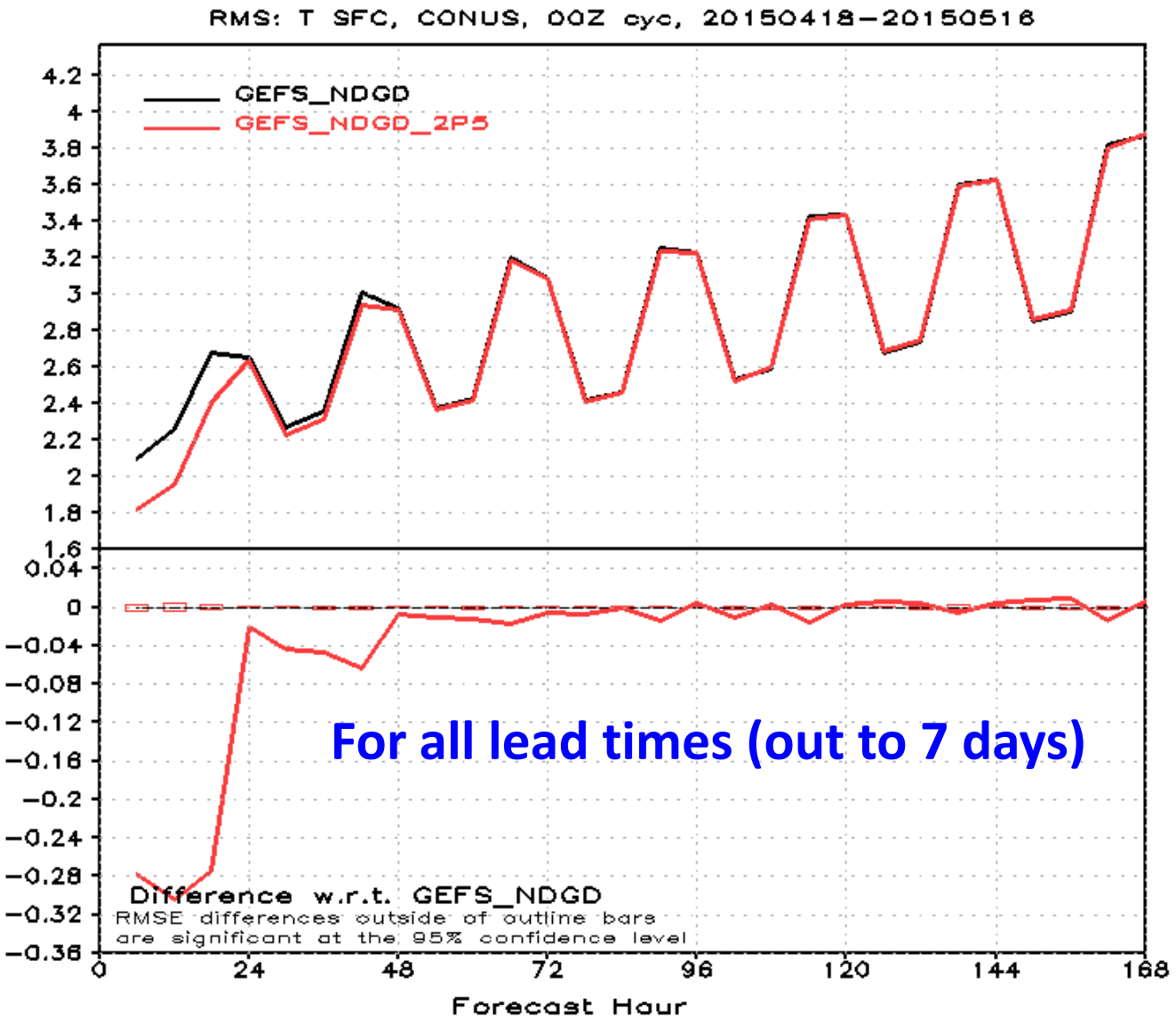
RMSE @ 6 fhr



RMSE @ 12 fhr



CONUS Statistical Verification again Observation (T2m RMS)



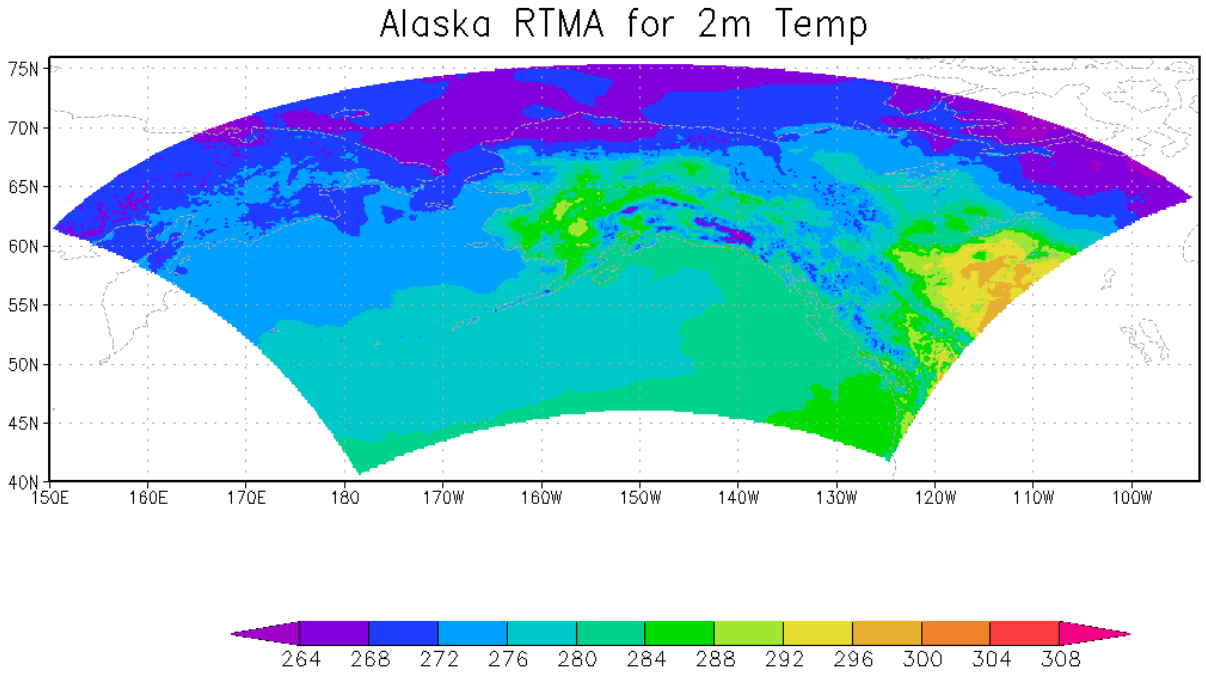
c. Alaska downscaling to 3km

Changes:

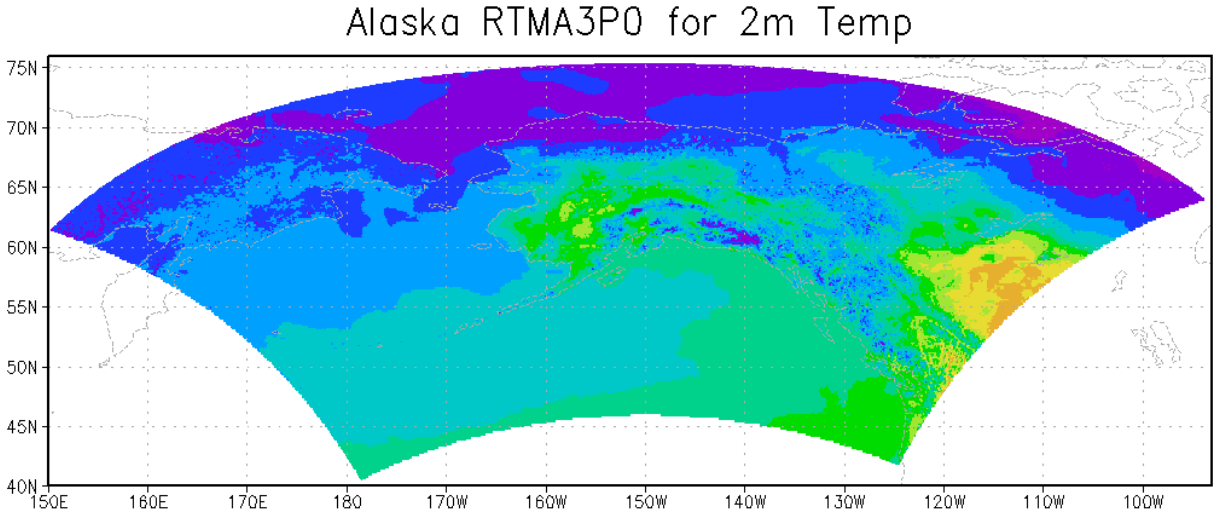
- ✓ Resolution from 6km to 3km
- ✓ Improve probabilistic skills

Alaska Downscaled Product Samples (NAEFS T2m 48hr Fcst)

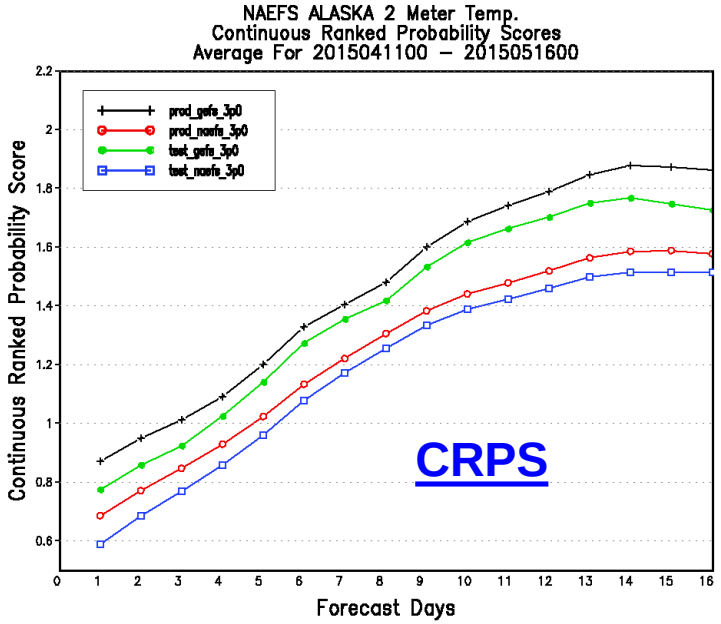
Production - 6km

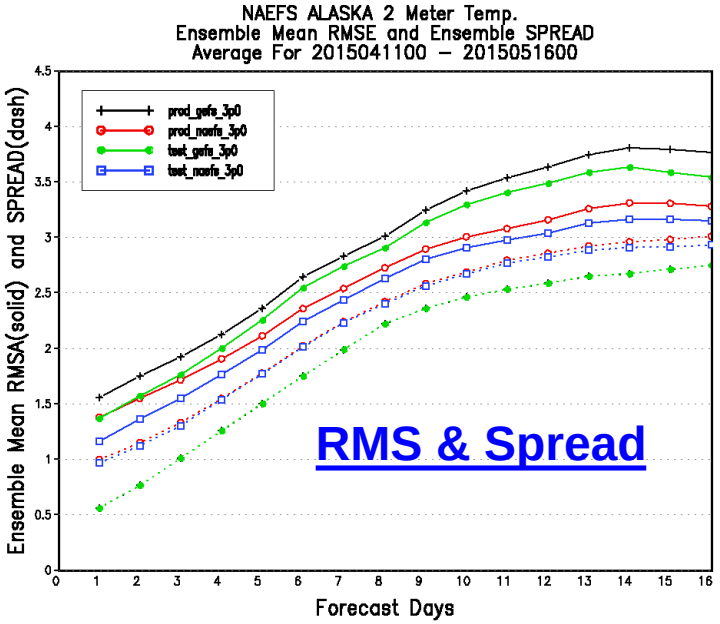


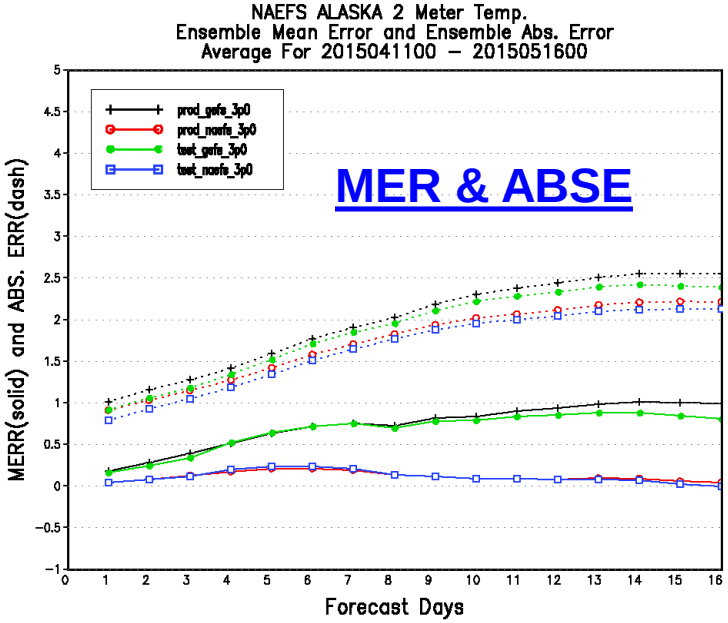
Parallel - 3km



Alaska Statistical Verification for T2m







prod_gefs: production GEFS

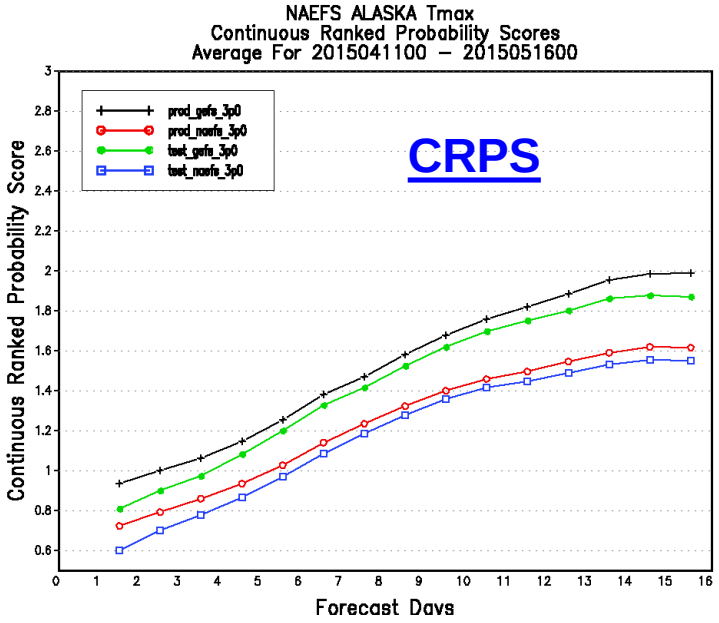
prod_naefs: production NAEFS

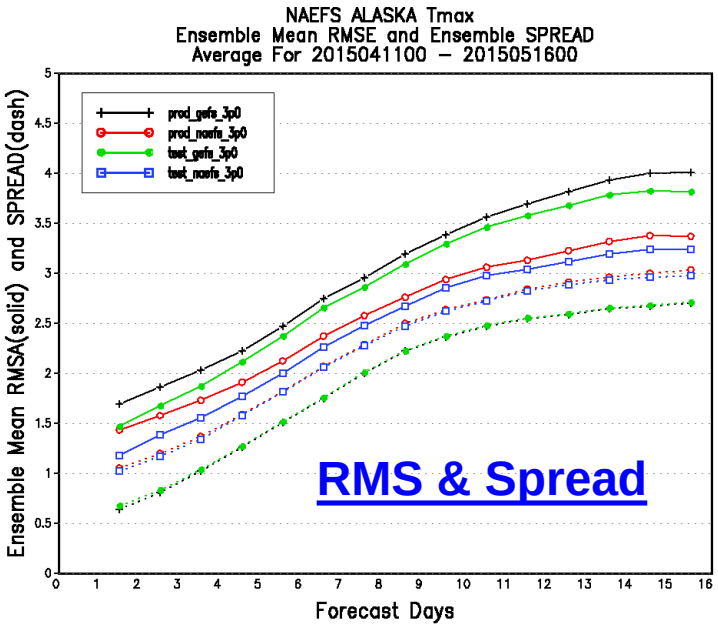
test_gefs_3p0: parallel GEFS

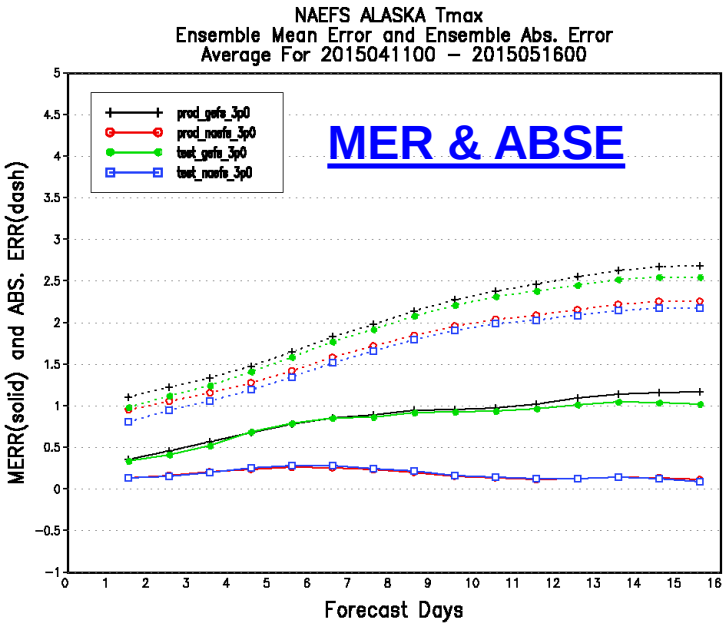
test_naefs_3p0: parallel NAEFS

Period: 20150411 to 20150516

Alaska Statistical Verification for Tmax







prod_gefs: production GEFS

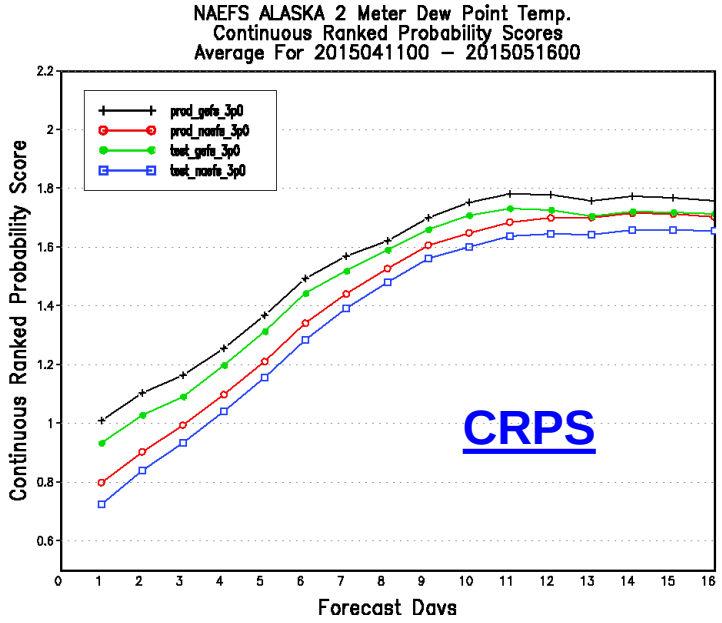
prod_naefs: production NAEFS

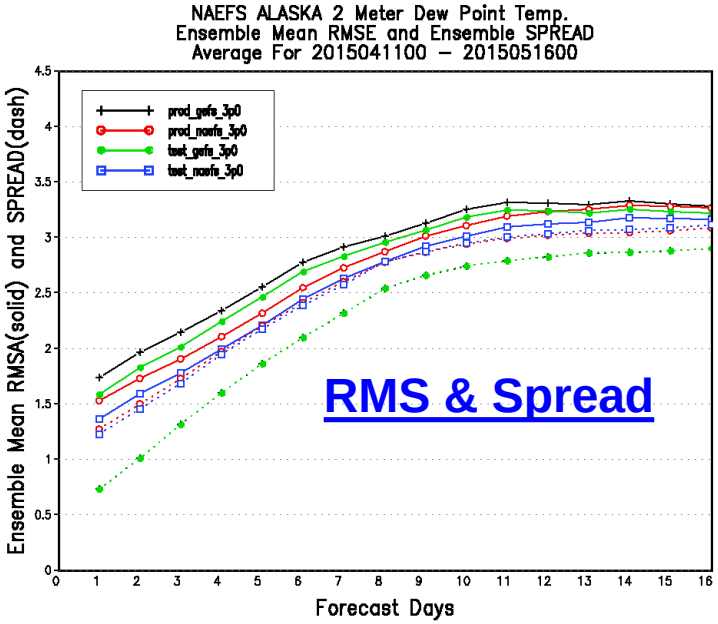
test_gefs_3p0: parallel GEFS

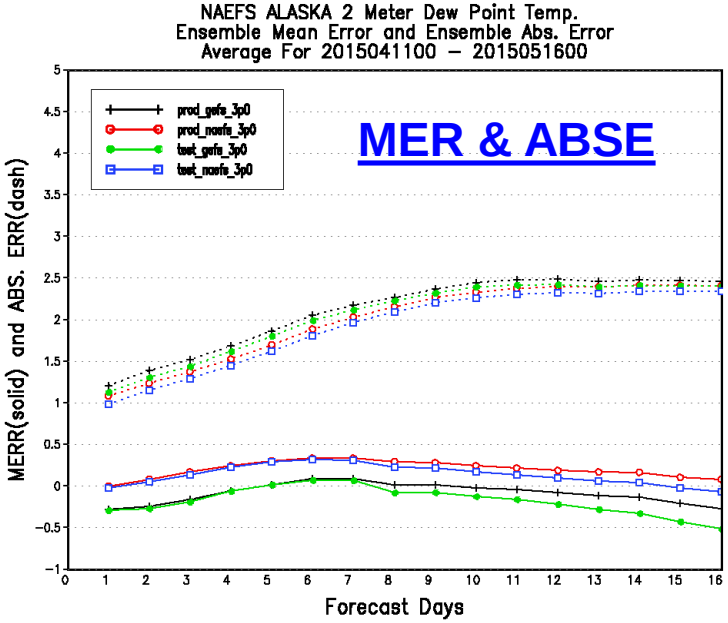
test_naefs_3p0: parallel NAEFS

Period: 20150411 to 20150516

Alaska Statistical Verification for Td2m







prod_gefs: production GEFS

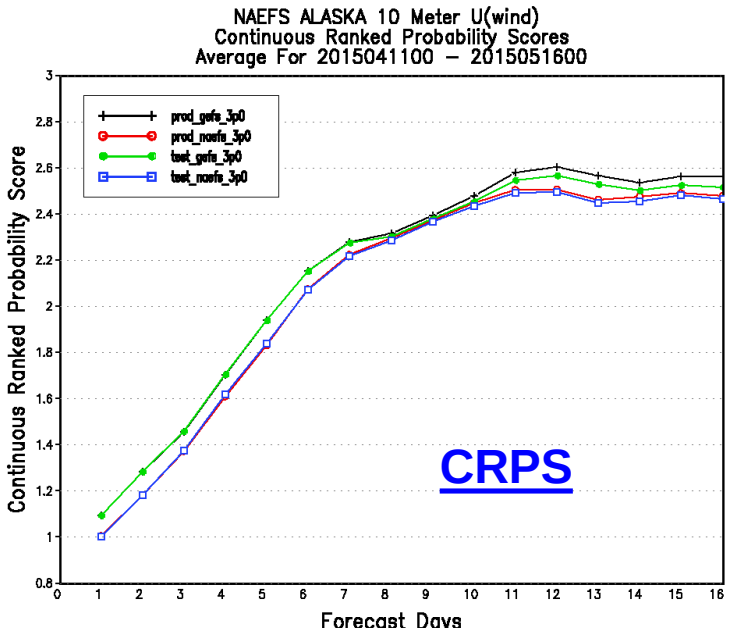
prod_naefs: production NAEFS

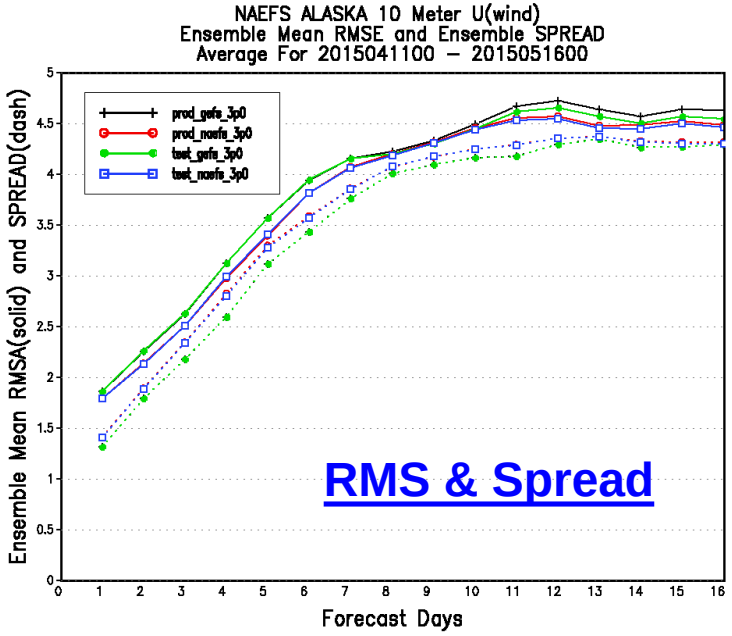
test_gefs_3p0: parallel GEFS

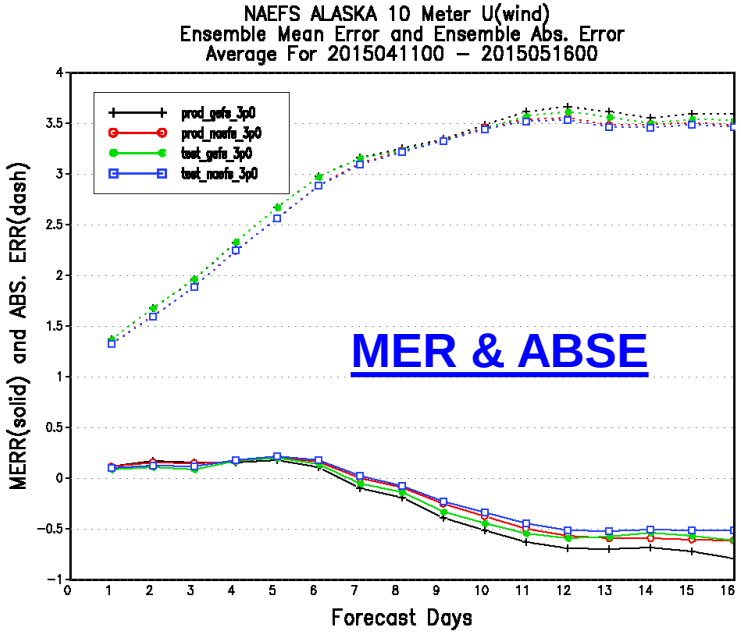
test_naefs_3p0: parallel NAEFS

Period: 20150411 to 20150516

Alaska Statistical Verification for 10m U







prod_gefs: production GEFS

prod_naefs: production NAEFS

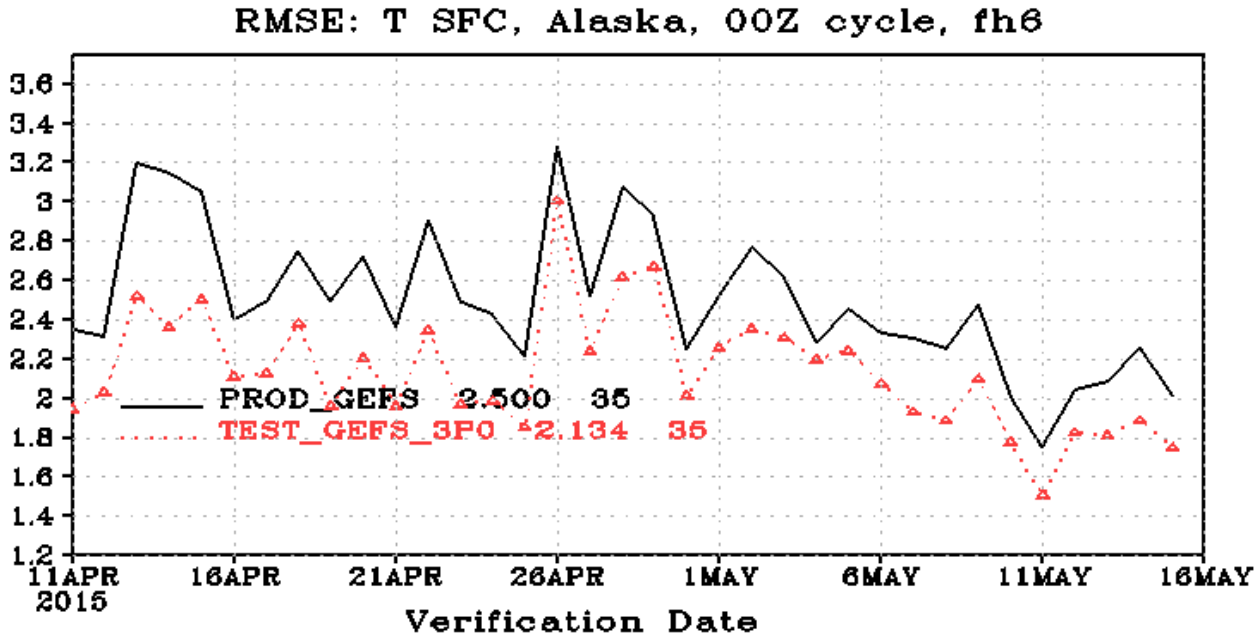
test_gefs_3p0: parallel GEFS

test_naefs_3p0: parallel NAEFS

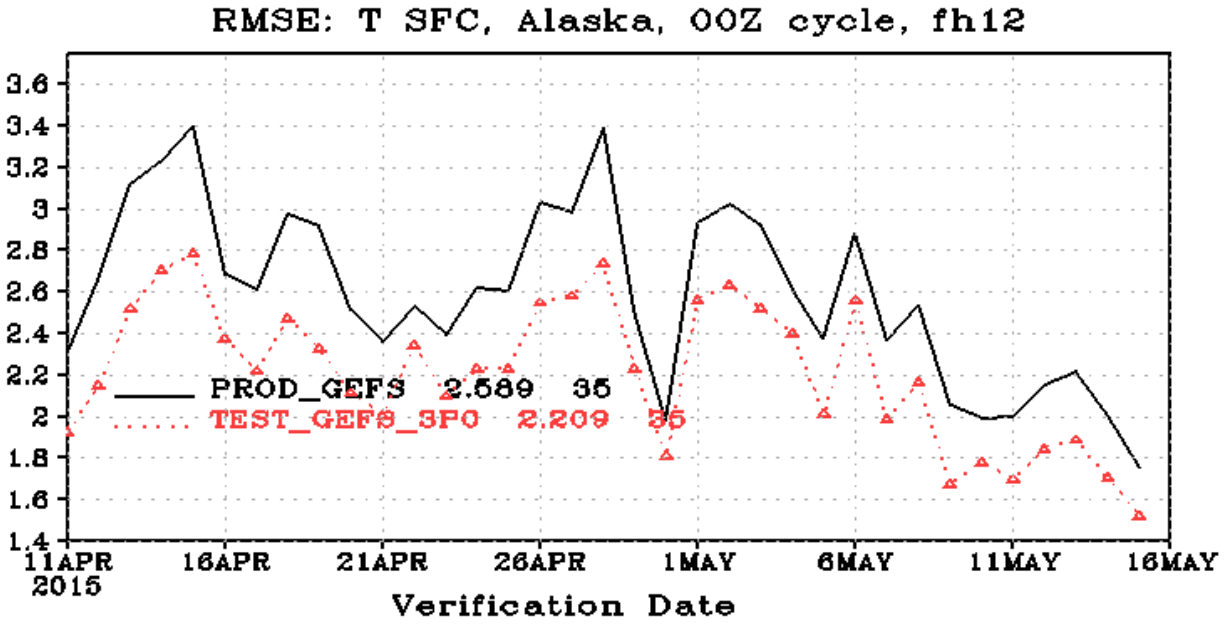
Period: 20150411 to 20150516

Alaska Statistical Verification again Observation (T2m)

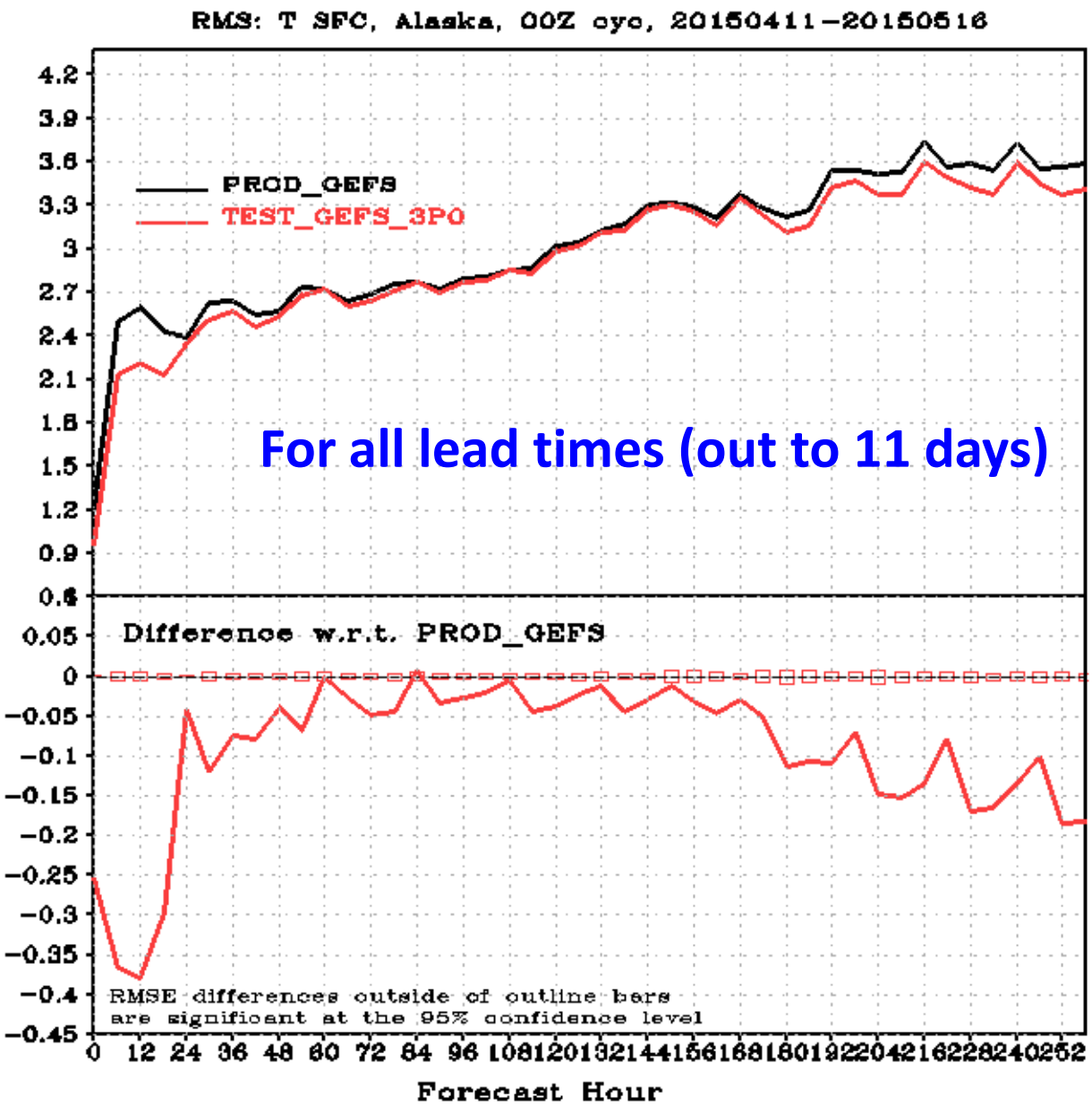
RMSE @ 6 fhr



RMSE @ 12 fhr



Alaska Statistical Verification again Observation (T2m RMS)



Summary of downscaling

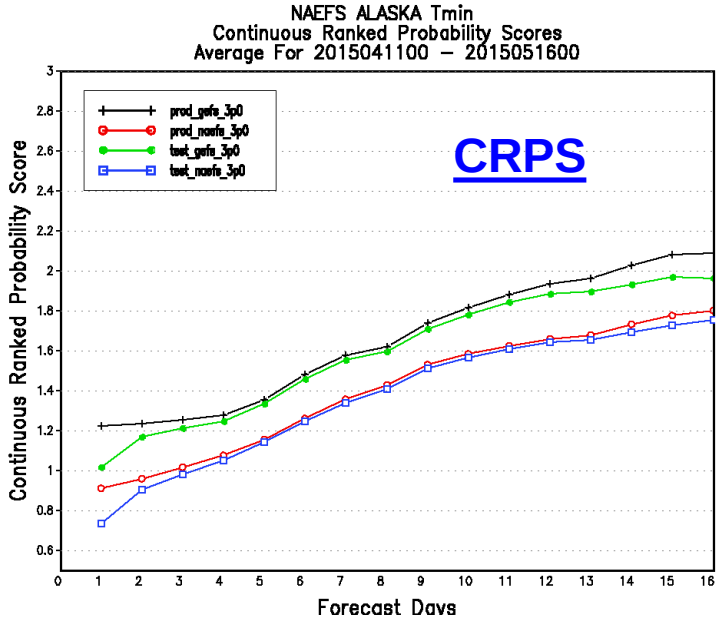
- CONUS
  - 2.5km (finer) resolution to match up NDGD resolution
  - Extend coverage of large Canadian portion for NAEFS project
  - Slightly better skills for all downscaled variables
  - No degradation
- Alaska
  - 3.0km (finer) resolution to match up NDGD resolution
  - Much better skills (or improvement) for T2m, Tmax, Td2m
  - Less improvement for U10m
  - No degradation

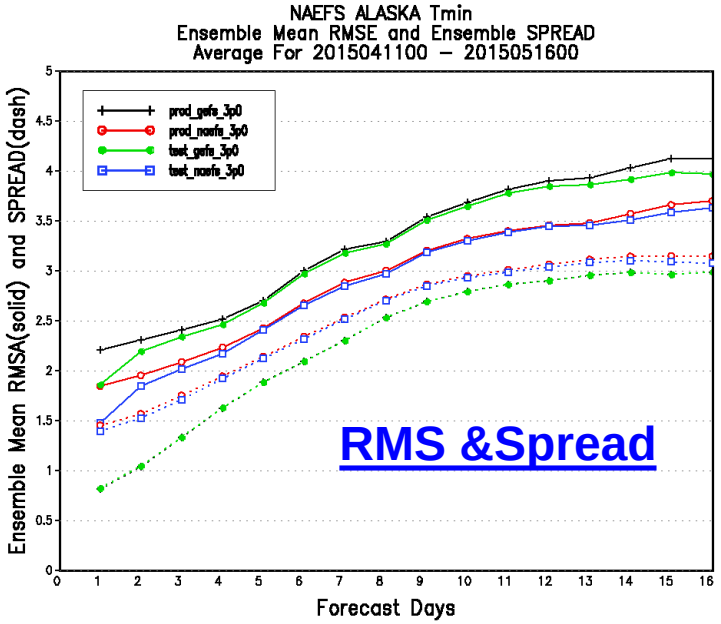
Conclusions

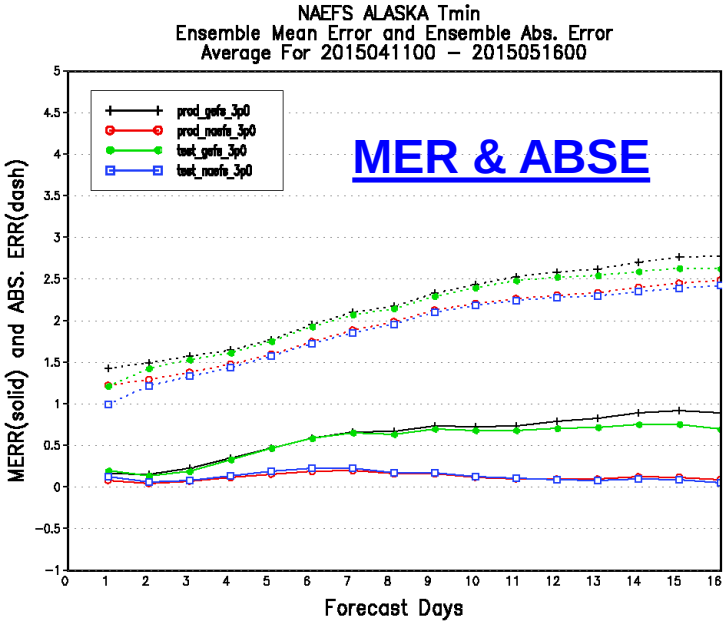
- Will deliver best products after NAEFS SPP
  - All positive from our evaluation
- Cost of computation and disk storage
  - Computer: Current – 20 nodes; future – 40 nodes for 1hr
  - Disk: Current – 10GB/day for ndgd_gb2; future – 44GB/day
- Has presented all results to
  - NAEFS monthly tele-conference
  - WPC DTB and forecasters
- Implementation timeline:
  - January 2016 (Q2FY16)

Thanks and questions?

Alaska Statistical Verification for Tmin







prod_gefs: production GEFS

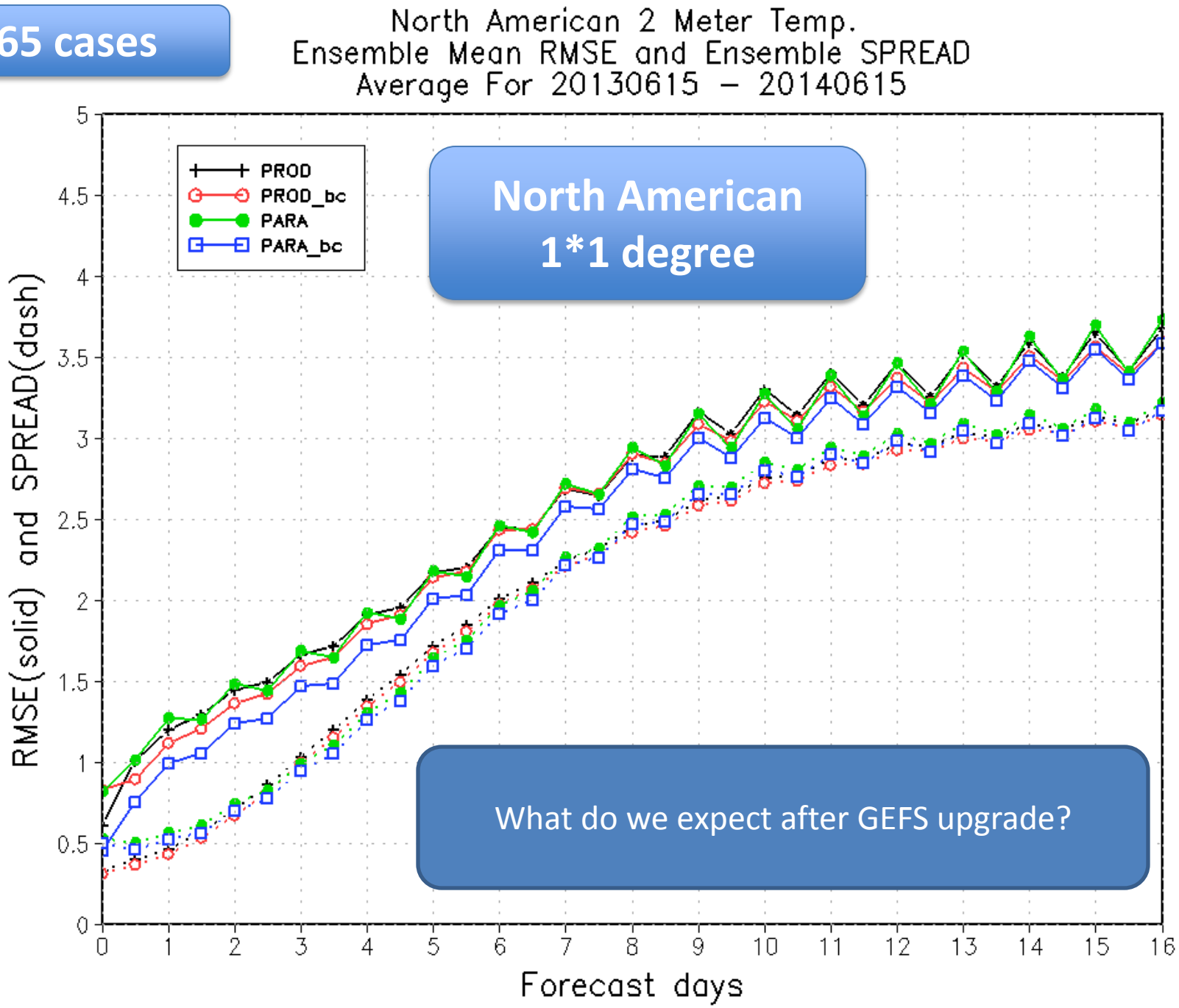
prod_naefs: production NAEFS

test_gefs_3p0: parallel GEFS

test_naefs_3p0: parallel NAEFS

Period: 20150411 to 20150516

365 cases



North American 1*1 degree

What do we expect after GEFS upgrade?