Inclusion of New Probabilistic Forecasts to NAEFS

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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

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)**

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.

Brig. Gen. David L. Johnson, USAF (Ret.)
National Oceanic and Atmospheric Administration
Assistant Administrator for Weather Services

Dr. Marc Denis Everell
Assistant Deputy Minister
Meteorological Service of Canada

Dr. Michel Rosengaus
Head of Unit
National Meteorological Service of Mexico

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:

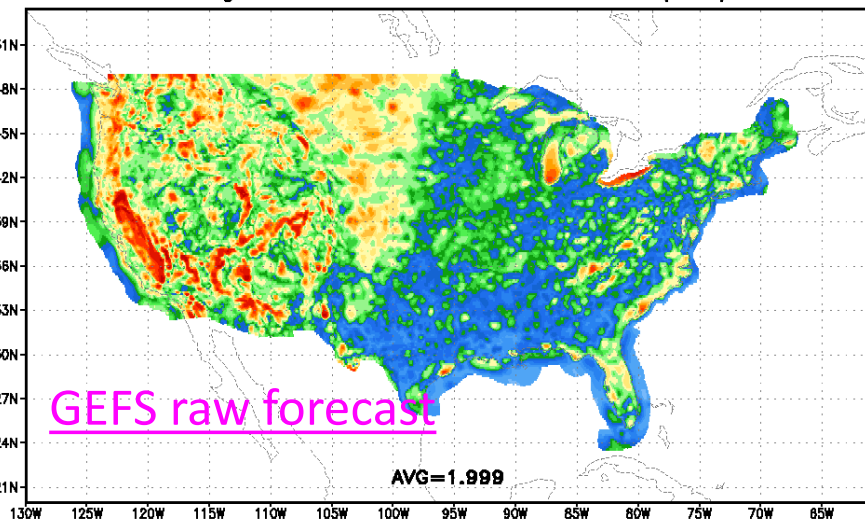$$F_{i,j}(t) = f_{i,j}(t) - B_{i,j}(t)$$


DECAYING AVERAGE WEIGHTING

- - - W=0.01
——— W=0.02
-·-·- W=0.05
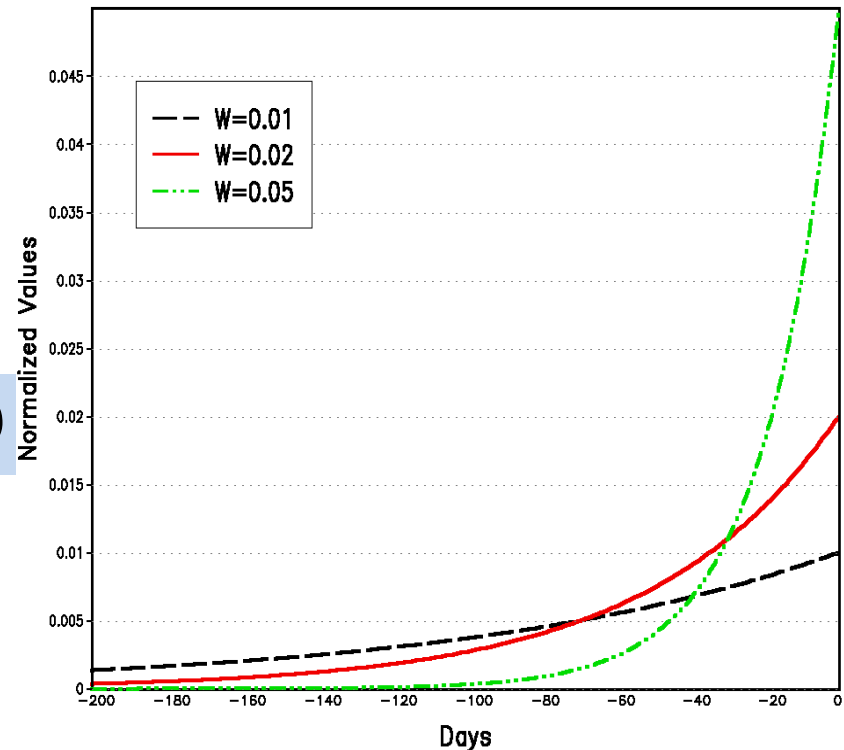
Simple Accumulated Bias

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

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CONUS GEFS Raw Ens. Mean Absolute Error w.r.t RTMA
2m Temperature (shaded, K)
Averaged From: 2007090100 to 2007093000 (12 h)

GEFS raw forecast

AVG=1.999

CONUS GEFS Bias Corrcted Ens. Mean Absolute Error w.r.t RTMA
2m Temperature (shaded, K)
Averaged From: 2007090100 to 2007093000 (12 h)

GEFS bias-corr. & down scaling fcst.

AVG=1.161

Averaged From: 2007090100 to 2007093000 (12 h)

NAEFS forecast

AVG=1.002
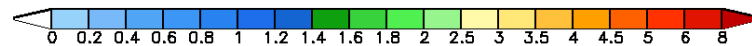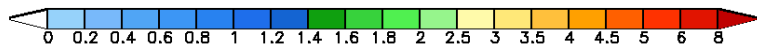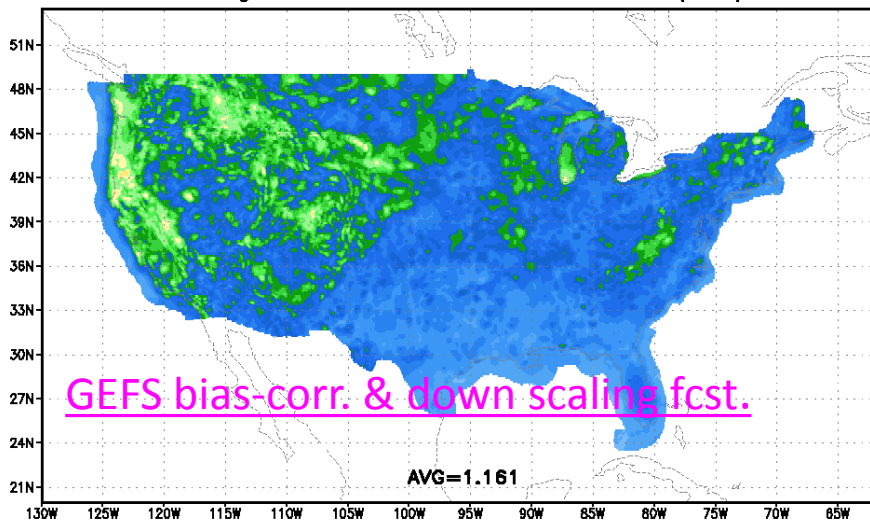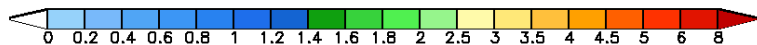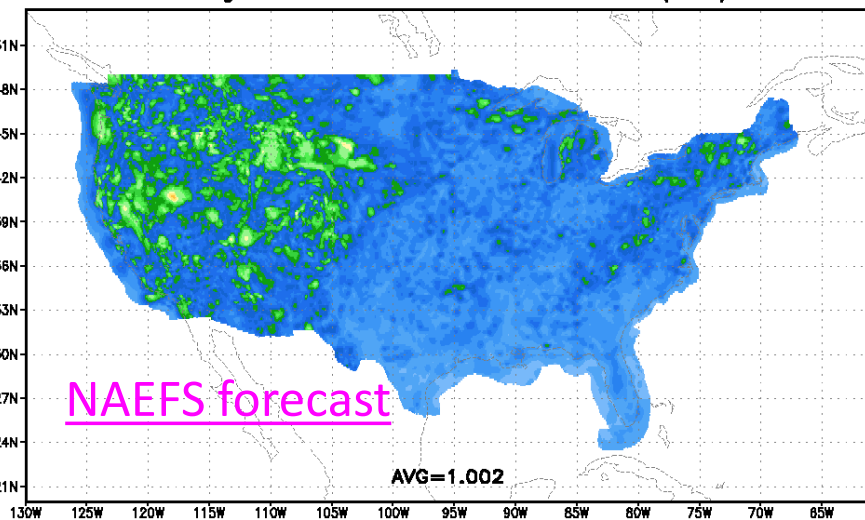
12hr 2m temperature forecast
Mean Absolute Error (MAE)
w.r.t RTMA for CONUS
average for September 2007

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
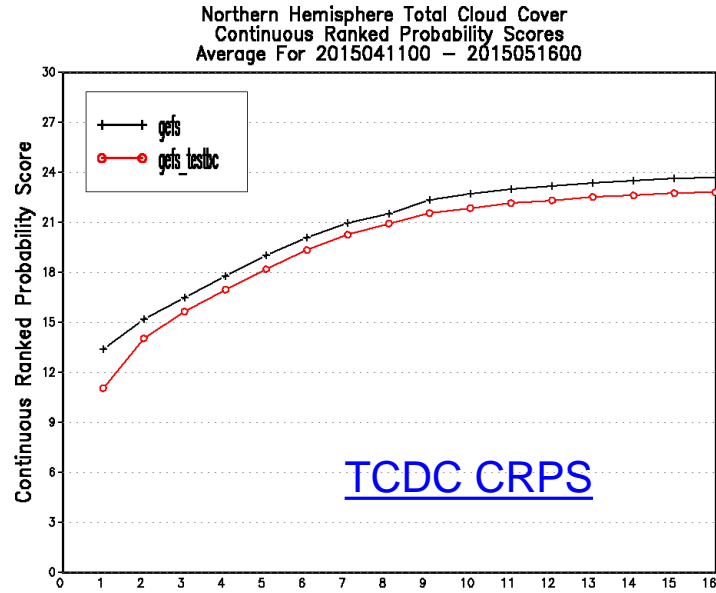
Plan: Q2FY2016 (NDGD resolutions)

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

Northern Hemisphere Total Cloud Cover
Continuous Ranked Probability Scores
Average For 2015041100 − 2015051600

TCDC CRPS

Northern Hemisphere Total Cloud Cover
Ensemble Mean RMSE and Ensemble SPREAD
Average For 2015041100 − 2015051600

TCDC RMS & Spread

Northern Hemisphere Total Cloud Cover
Ensemble Mean Error and Ensemble Abs. Error
Average For 2015041100 − 2015051600

TCDC Mean Err. & Abs Err

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

CONUS domain average

About 12% difference

Very difficulty to say:
GFS is over estimate or RTMA is under estimate?
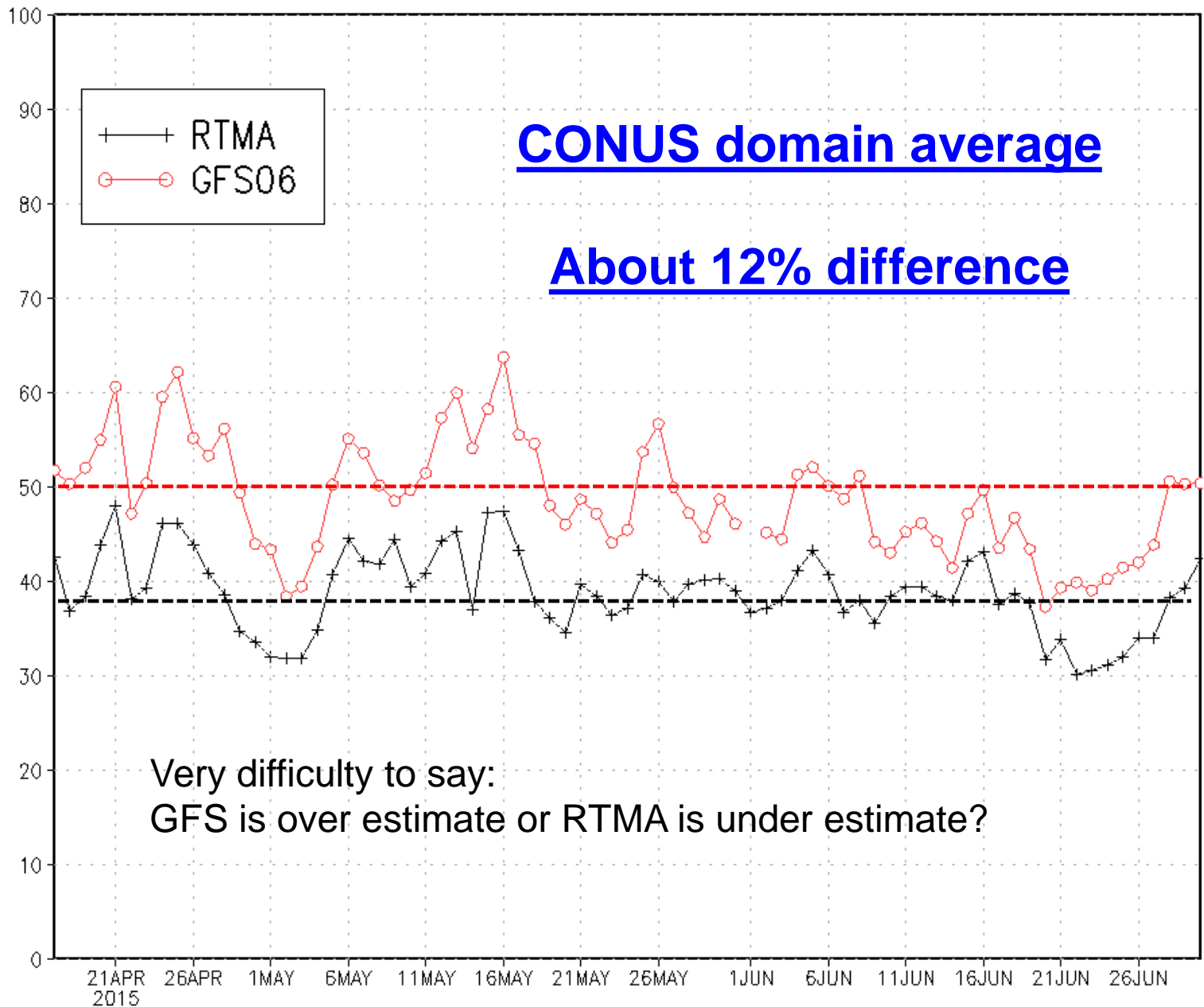
Sky Cover Comparison

Mon Dec 28 12:00:00 UTC 2015   GOES Imager Sky Cover Product (%)

Sky Cover Comparison

Mon Dec 28 12:00:00 UTC 2015   Satellite/Surface Blended Sky Cover (%)

1   25   50   75   99

Background satellite image valid 12:15:00 UTC
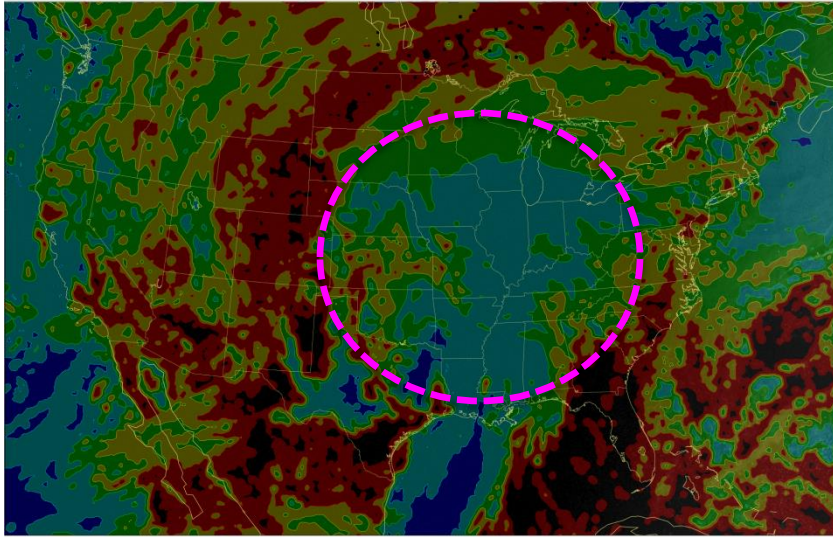
Sky Cover Comparison

Mon Dec 28 12:00:00 UTC 2015   RTMA Total Cloud Cover (%)
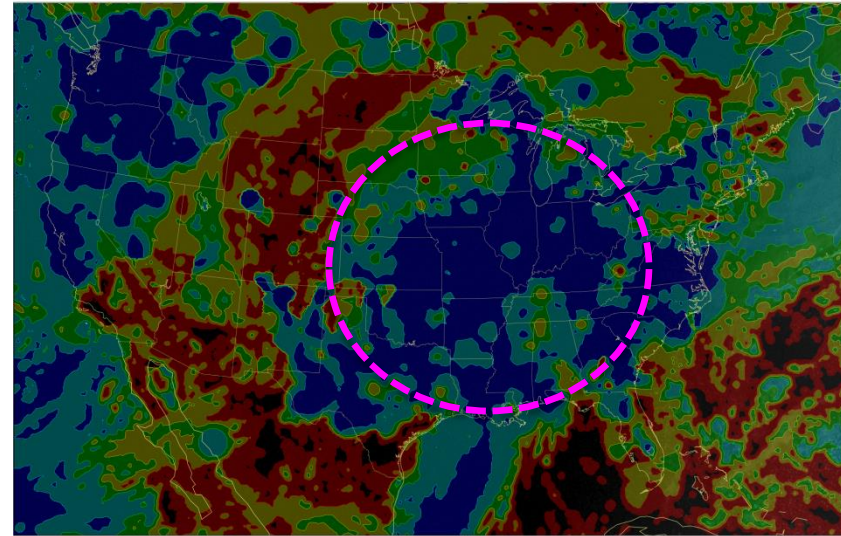
1   25   50   75   99

Background satellite image valid 12:15:00 UTC

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
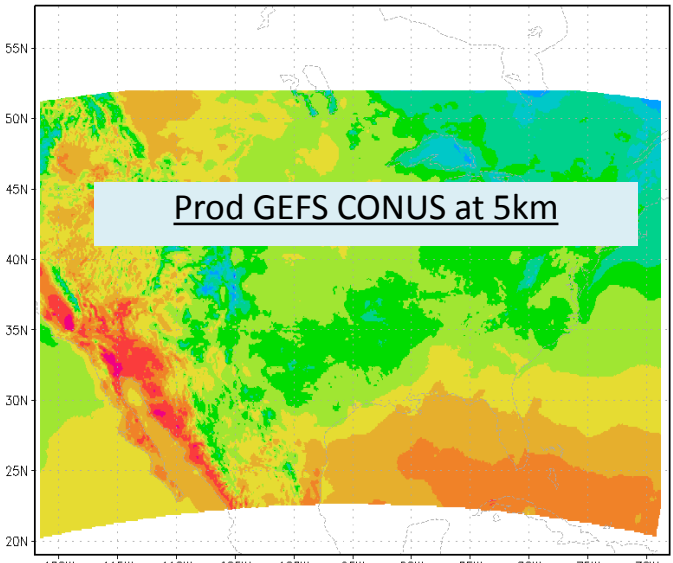
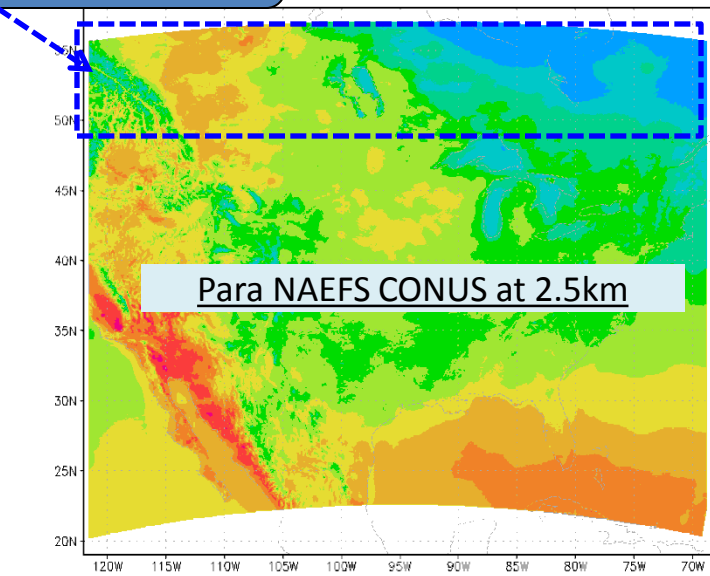Upgrade

Prod GEFS CONUS at 5km
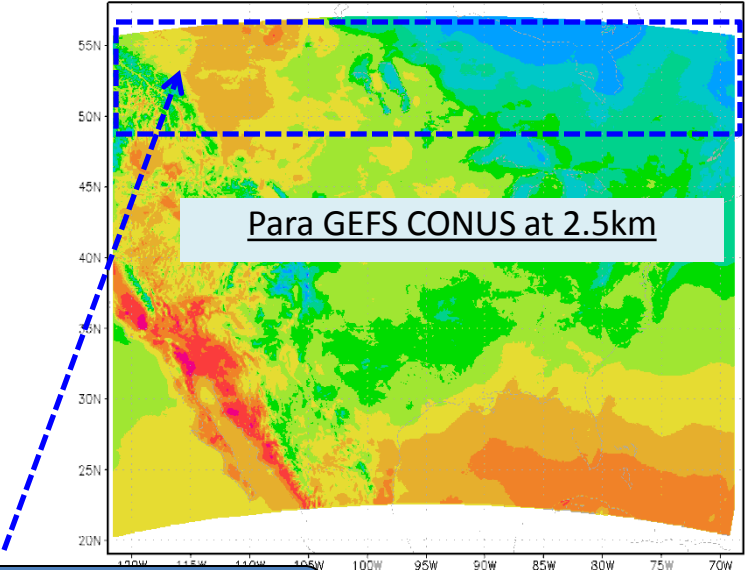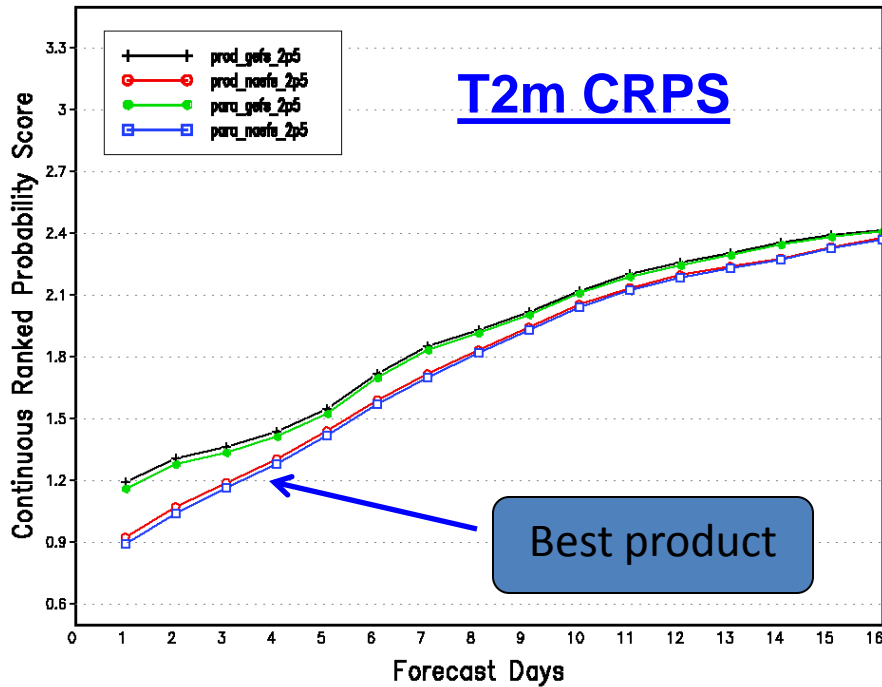
Para GEFS CONUS at 2.5km

Cover large area of Canadian
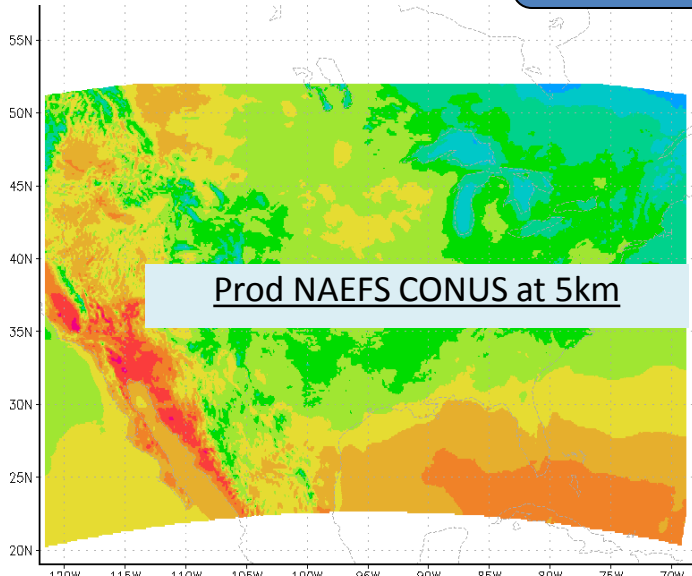
Prod NAEFS CONUS at 5km

Para NAEFS CONUS at 2.5km

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

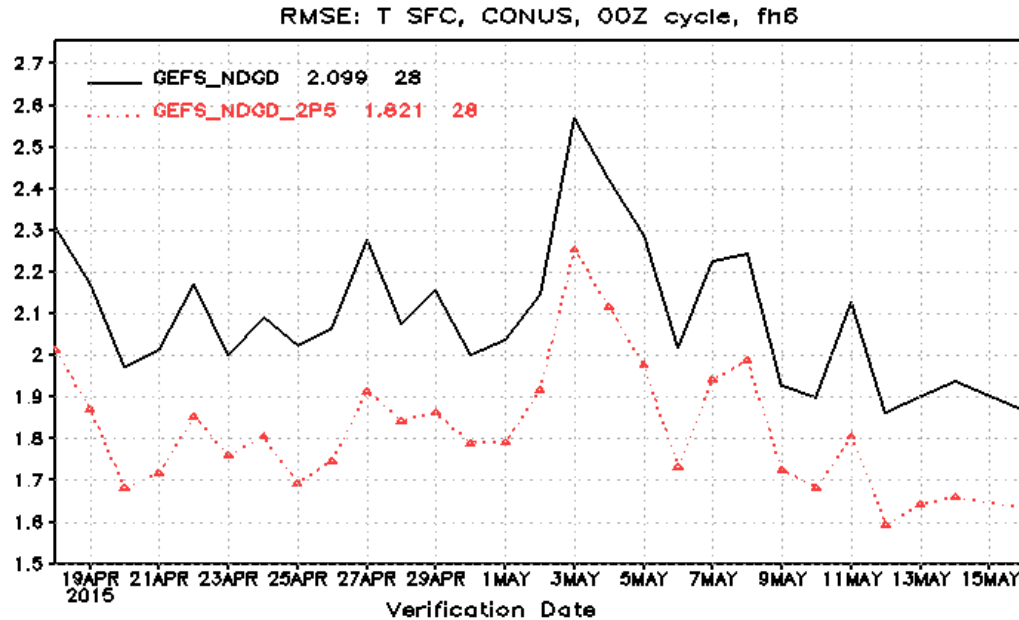**para_gefs_2p5**: parallel GEFS downscaled product at 2.5km

para_naefs_2p5: parallel NAEFS downscaled product at 2.5km

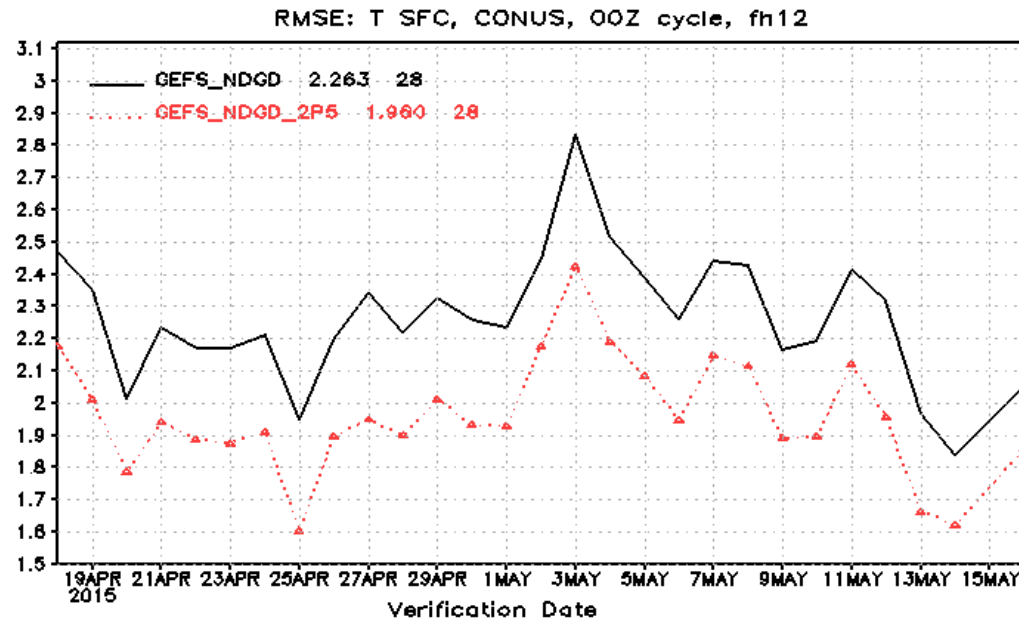CONUS at 2.5km (prod_gefs_2p5 & prod_naefs_2p5 from interpolation of 5km forecasts)

CONUS Statistical Verification again Observation (T2m)

RMSE @ 6 fhr

RMSE: T SFC, CONUS, OOZ cycle, fh6

GEFS_NDGD   2.099   28
GEFS_NDGD_2P5   1.821   28

RMSE @ 12 fhr

RMSE: T SFC, CONUS, OOZ cycle, fh12

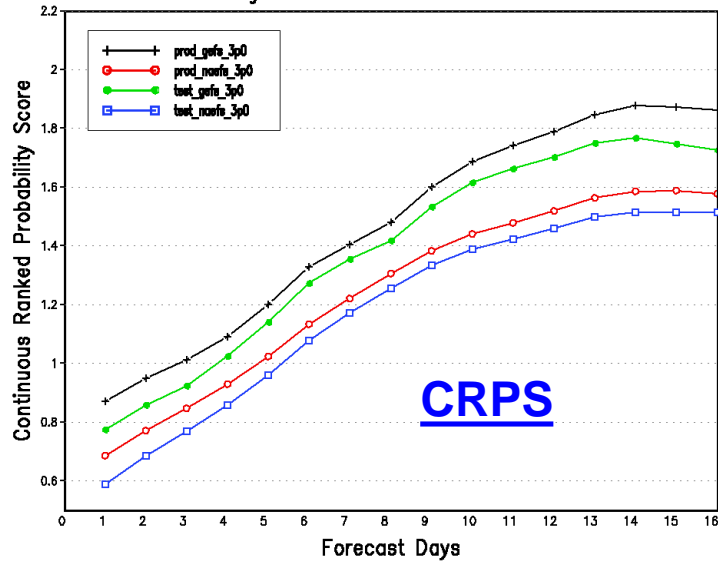GEFS_NDGD   2.263   28
GEFS_NDGD_2P5   1.960   28

Alaska downscaling to 3km
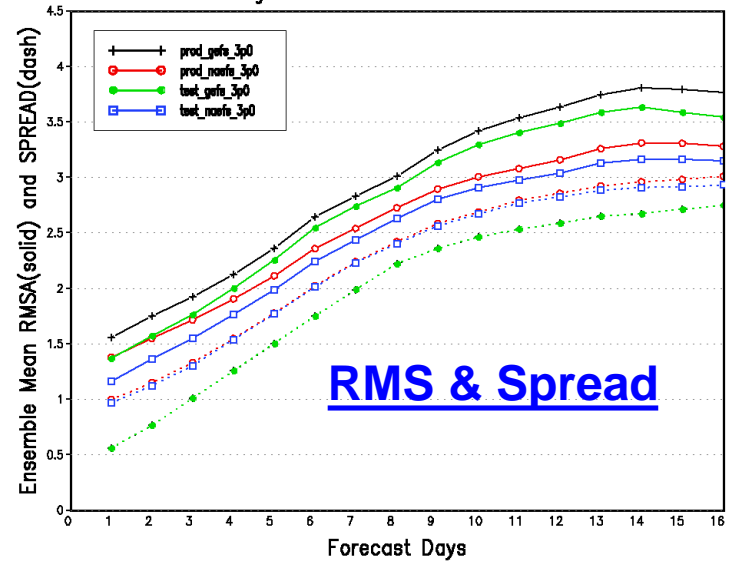
Changes:

- ✓ **Resolution from 6km to 3km**
- ✓ **Improve probabilistic skills**
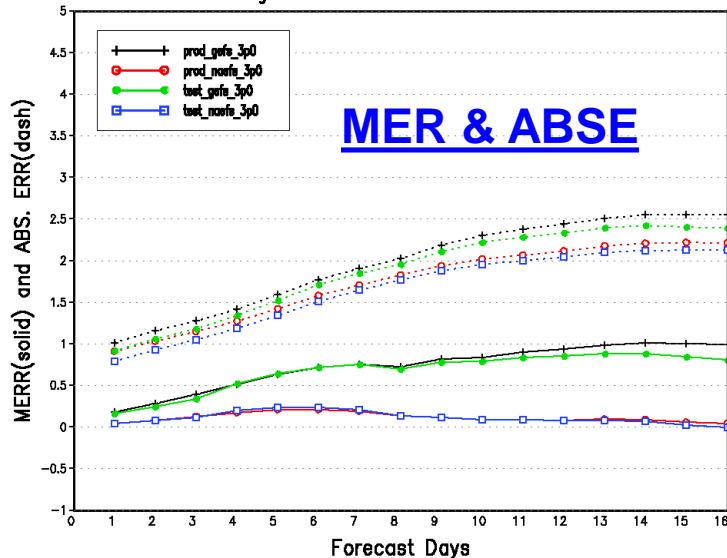
Alaska Statistical Verification for T2m

NAEFS ALASKA 2 Meter Temp.
Continuous Ranked Probability Scores
Average For 2015041100 – 2015051600

CRPS

NAEFS ALASKA 2 Meter Temp.
Ensemble Mean RMSE and Ensemble SPREAD
Average For 2015041100 – 2015051600

RMS & Spread

NAEFS ALASKA 2 Meter Temp.
Ensemble Mean Error and Ensemble Abs. Error
Average For 2015041100 – 2015051600

MER & ABSE

prod_gefs: production GEFS

prod_naefs: production NAEFS
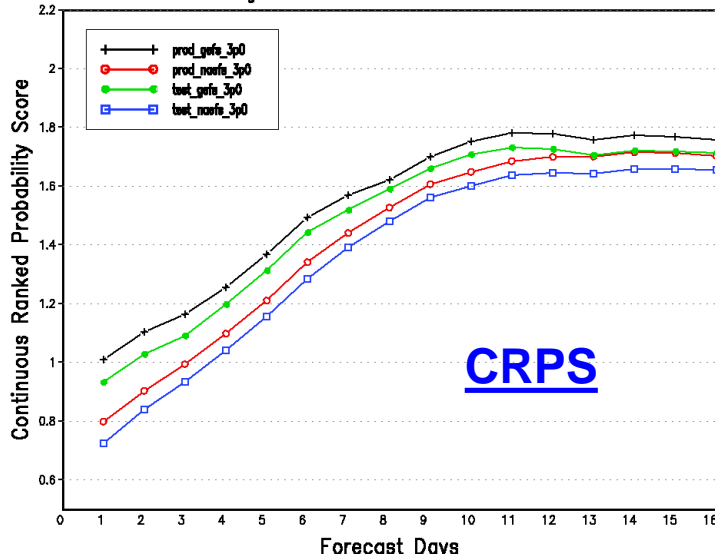
test_gefs_3p0:   parallel GEFS

test_naefs_3p0: parallel NAEFS

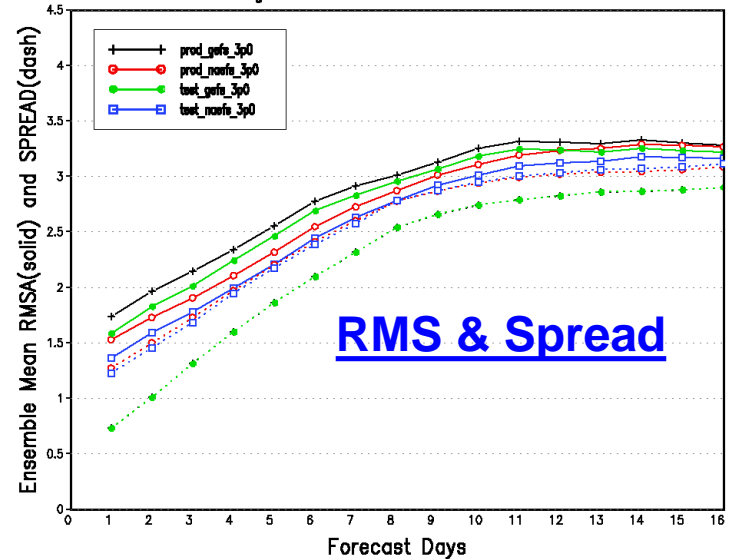**Period: 20150411 to 20150516**
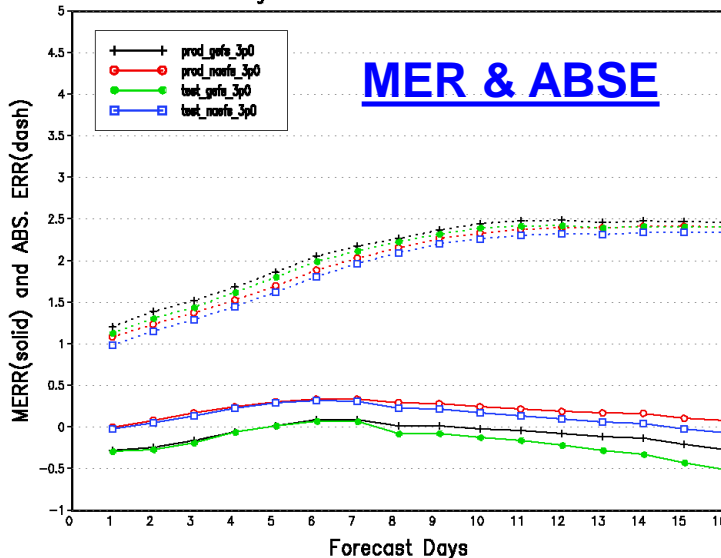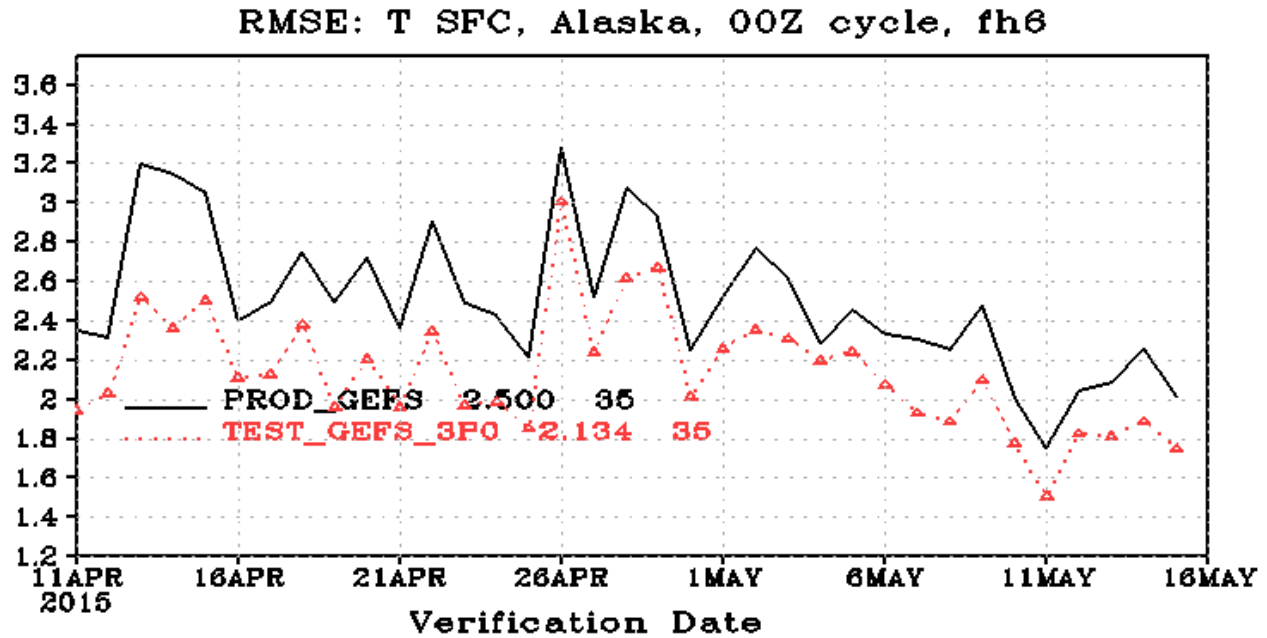
Alaska Statistical Verification for Td2m

prod_gefs: production GEFS

prod_naefs: production NAEFS

test_gefs_3p0: parallel GEFS

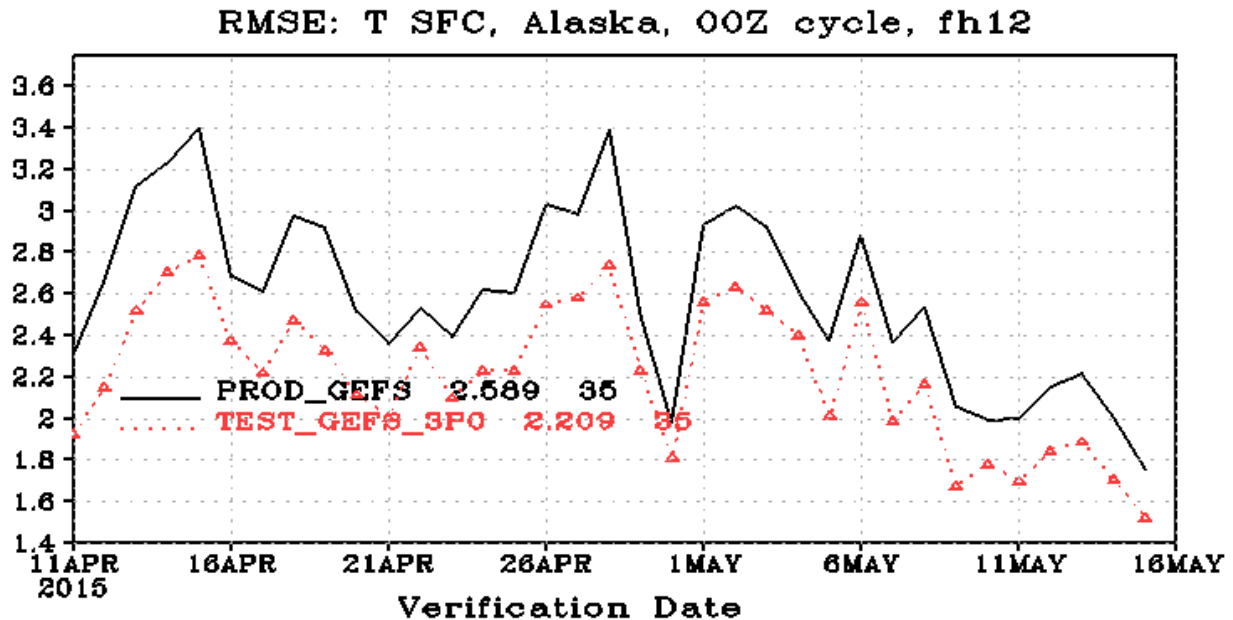**test_naefs_3p0**: parallel NAEFS

Period: 20150411 to 20150516

Alaska Statistical Verification again Observation (T2m)

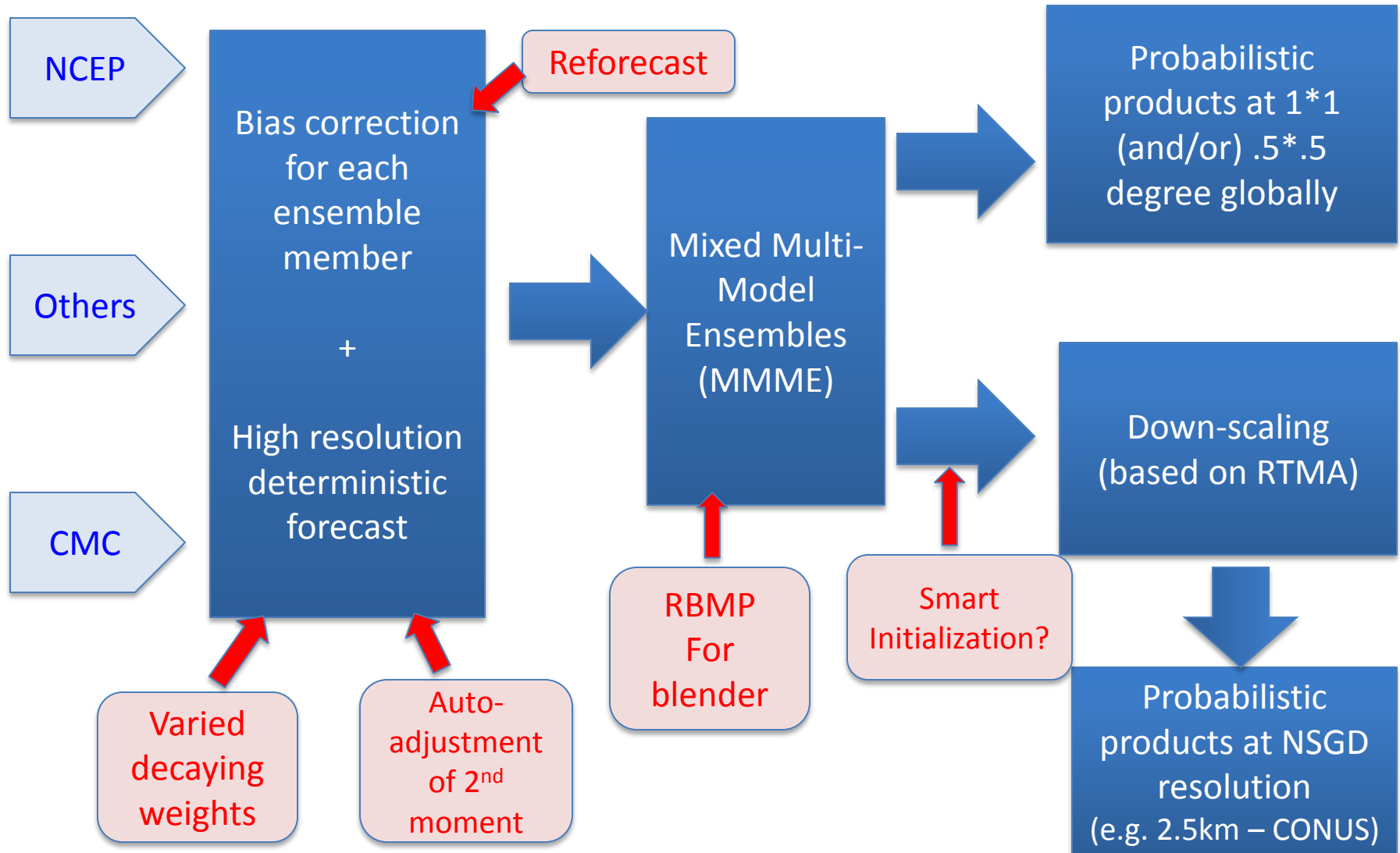**RMSE @ 6 fhr**

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

NCEP

Others

CMC

Bias correction for each ensemble member

+

High resolution deterministic forecast

Reforecast

Mixed Multi-Model Ensembles (MMME)

Probabilistic products at 1*1 (and/or) .5*.5 degree globally

Down-scaling (based on RTMA)

Probabilistic products at NSGD resolution (e.g. 2.5km – CONUS)

Varied decaying weights

Auto-adjustment of 2nd moment

RBMP For blender

Smart Initialization?

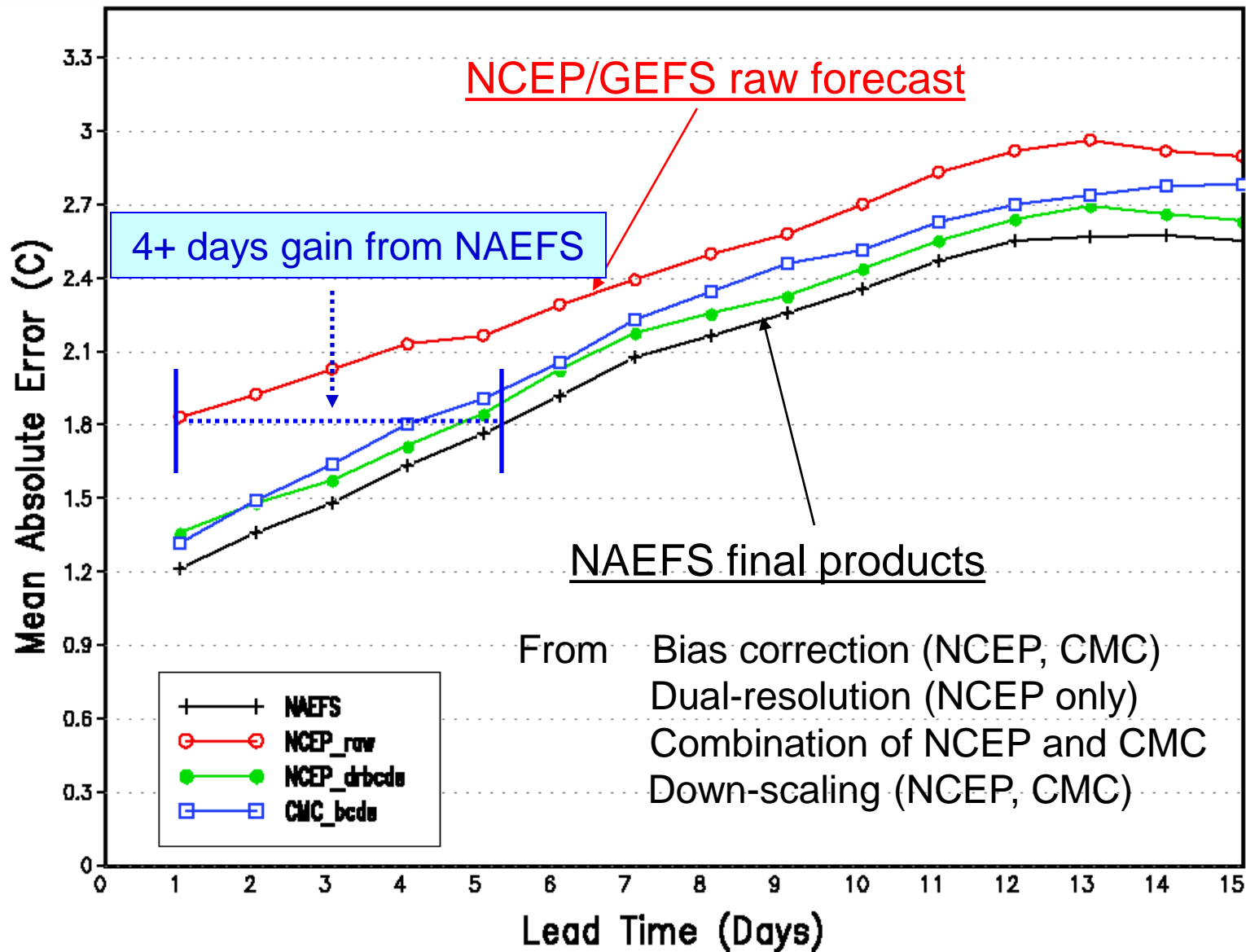# Thanks and questions?

Extra slides

Equal weight for NAEFS

RTMA Region 2m Temperature
Averaged From 2007090100 to 2007093000

NCEP/GEFS raw forecast

4+ days gain from NAEFS

NAEFS final products

From   Bias correction (NCEP, CMC)
        Dual-resolution (NCEP only)
        Combination of NCEP and CMC
        Down-scaling (NCEP, CMC)

Mean Absolute Error (C)

Lead Time (Days)

Legend:
+ NAEFS
○ NCEP_raw
● NCEP_drbcds
□ CMC_bcds

NAEFS NDGD Probabilistic 2m Temperature Forecast Verification For 2007090100 – 2007093000
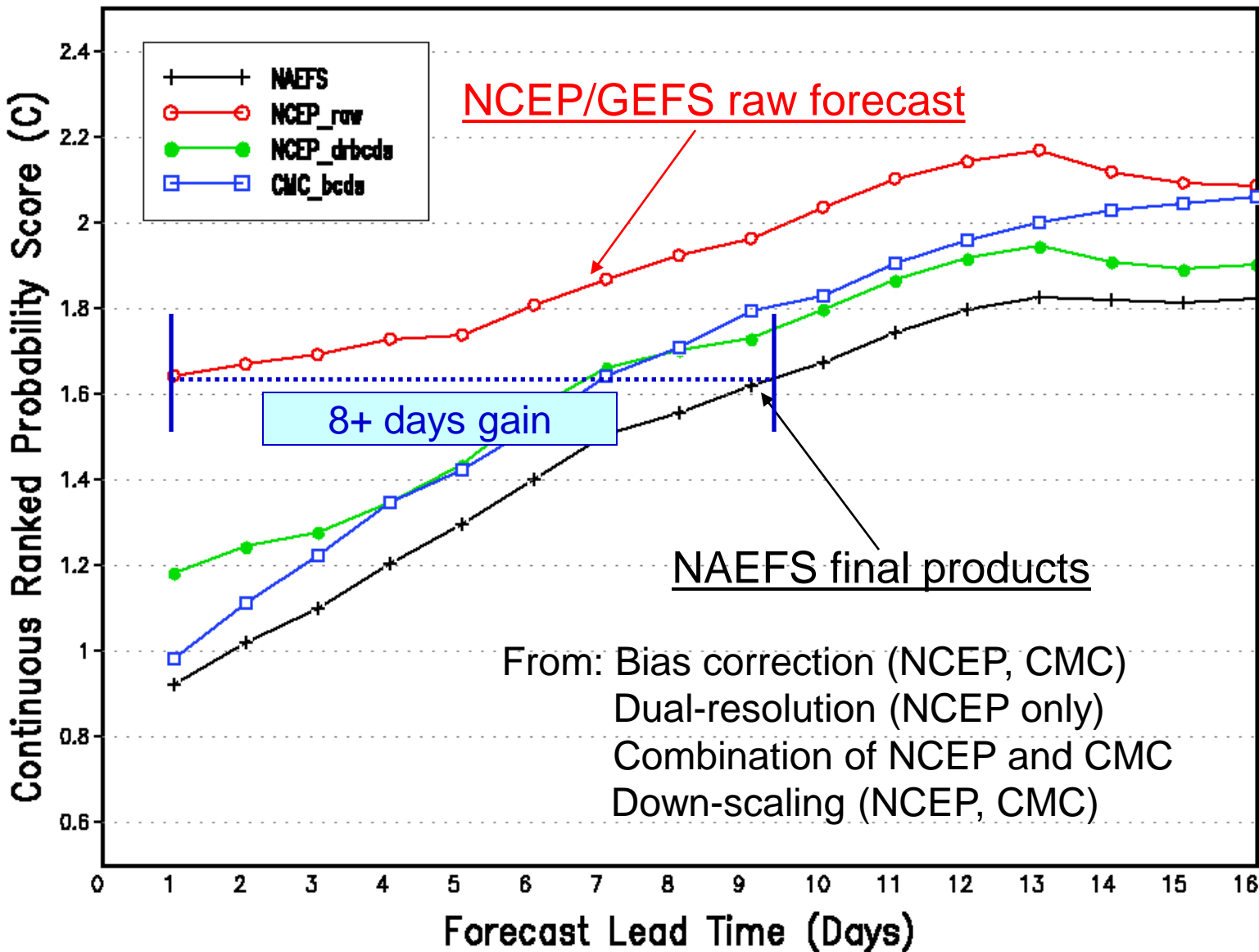
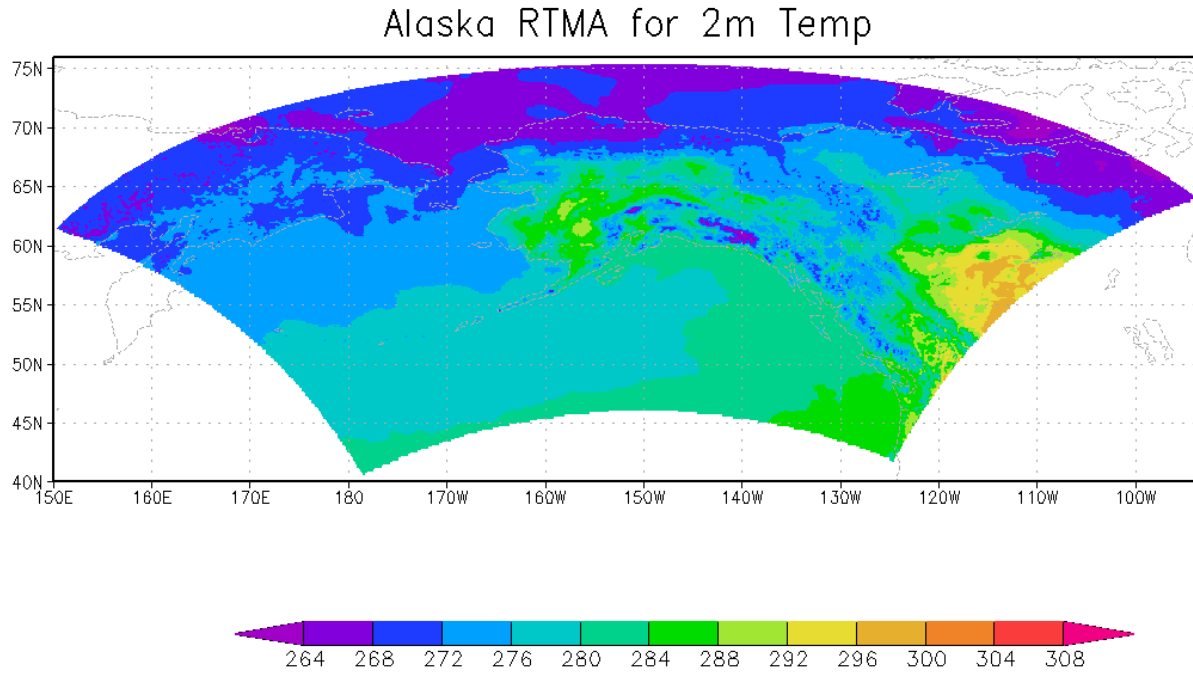Equal weight for NAEFS

NCEP/GEFS raw forecast

8+ days gain

NAEFS final products

From: Bias correction (NCEP, CMC)
Dual-resolution (NCEP only)
Combination of NCEP and CMC
Down-scaling (NCEP, CMC)

BO CUI, GCWMB/EMC/NCEP/NOAA

CONUS Statistical Verification again Observation
(T2m RMS error)

RMS: T SFC, CONUS, 00Z cyc, 20150418-20150516

For all lead times (out to 7 days)

Difference w.r.t. GEFS_NDGD
RMSE differences outside of outline bars
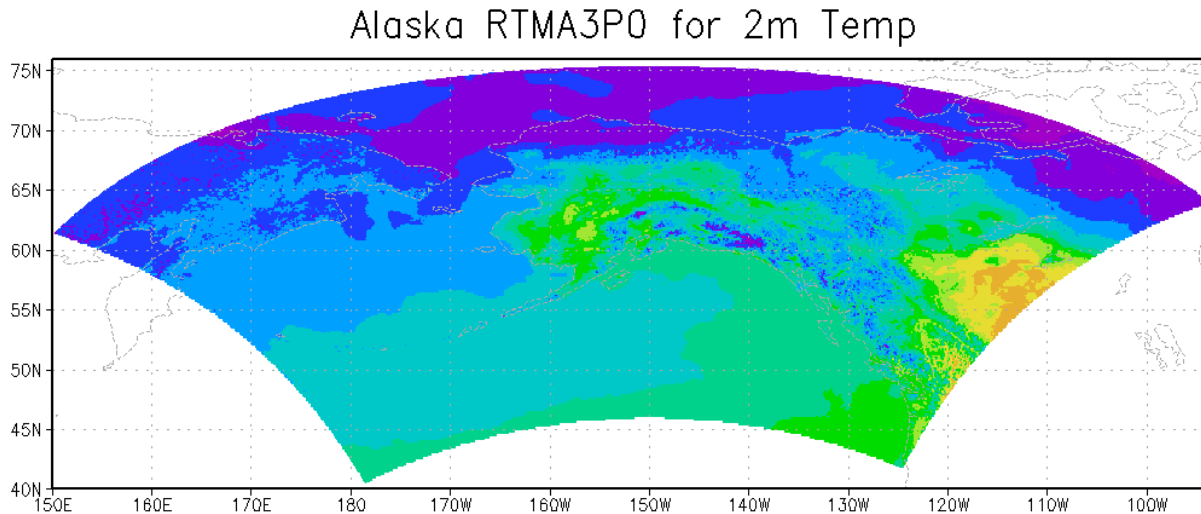are significant at the 95% confidence level

Forecast Hour
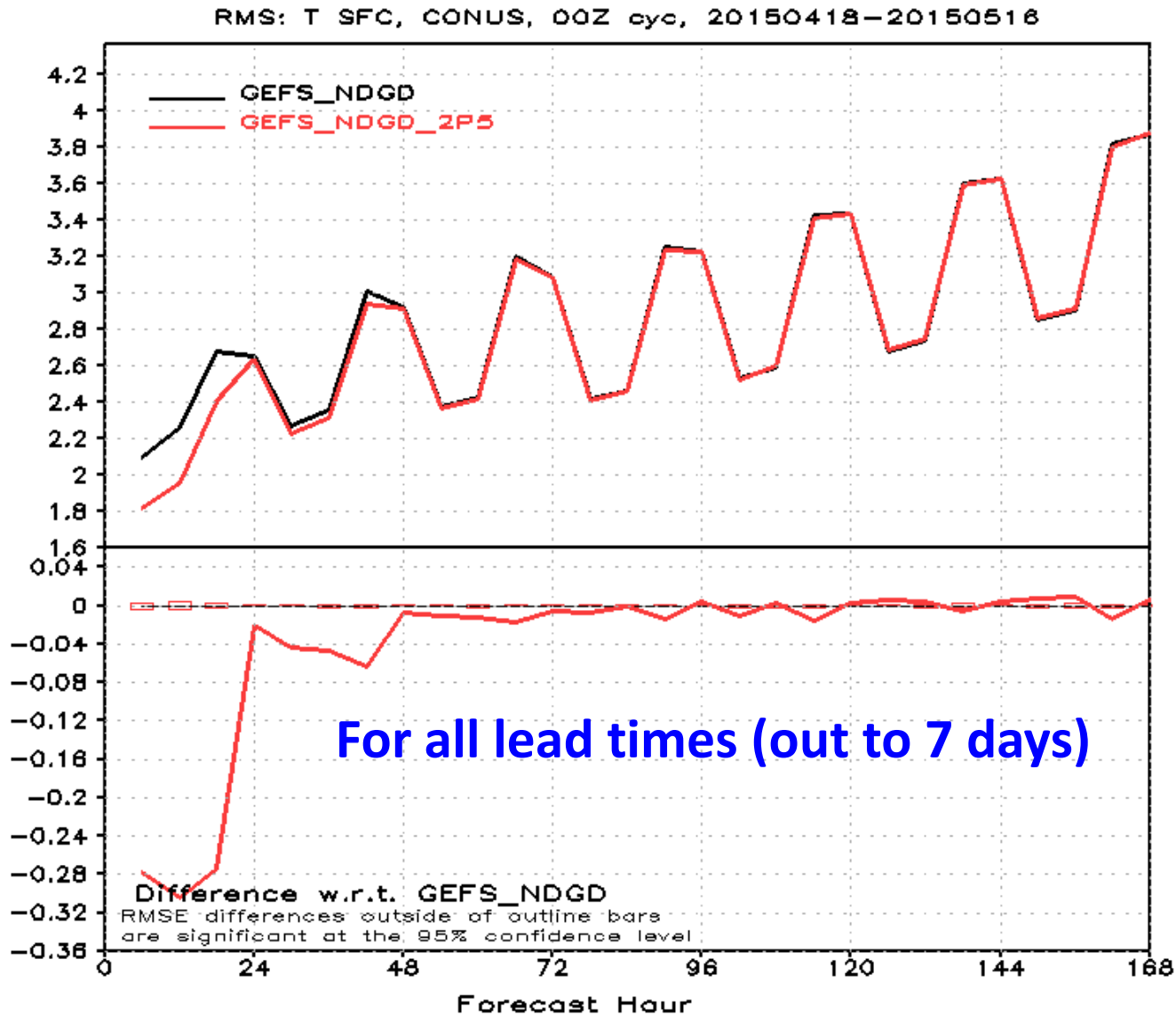
Alaska Downscaled Product Samples (NAEFS T2m 48hr Fcst)

Production - 6km

Alaska RTMA for 2m Temp

264 268 272 276 280 284 288 292 296 300 304 308

Parallel - 3km

Alaska RTMA3P0 for 2m Temp

Alaska Statistical Verification for Tmax

NAEFS ALASKA Tmax
Continuous Ranked Probability Scores
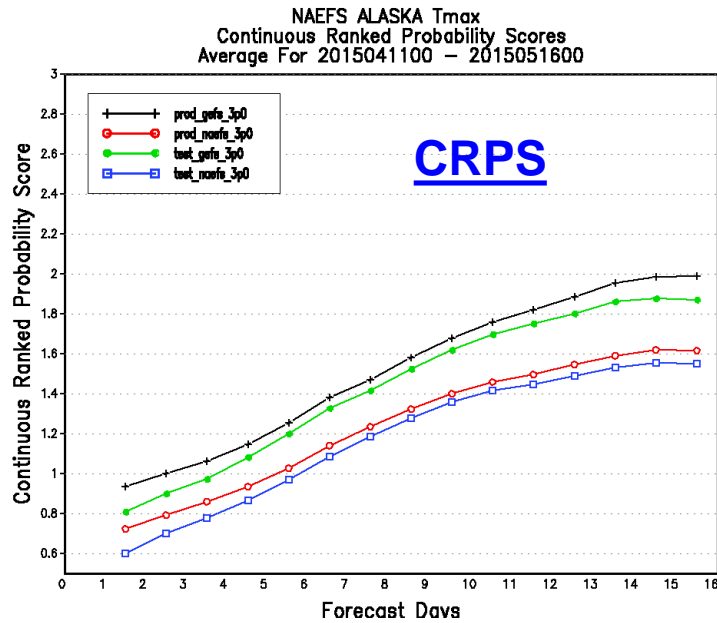Average For 2015041100 − 2015051600

CRPS

NAEFS ALASKA Tmax
Ensemble Mean RMSE and Ensemble SPREAD
Average For 2015041100 − 2015051600

RMS & Spread

NAEFS ALASKA Tmax
Ensemble Mean Error and Ensemble Abs. Error
Average For 2015041100 − 2015051600

MER & ABSE

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)