NAEFS Upgrade (v6)

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Presentation for EMC CCB/ODB
September 7/8 2017
Acknowledgements: Wen Meng, Dick Wobus and Jiayi Peng

Highlights

- **High resolution (0.5*0.5 degree) GEFS/NAEFS data exchange**
  - NAEFS/NUOPC agreement, users request
  - Every 3hrs for 0-8 days, then 6hrs out to 16 days.
  - NCEP GEFS bias correction at 0.5d resolution
    - Upgrade bias correction from 1.0d (and 2.5d) to 0.5d
    - Hybrid of decaying bias and reforecast bias
    - Add bias correction for 10m wind speed – users request
  - Downscaled products
    - General, no change for methodology, but input data from 0.5 degree bias corrected forecasts (surface variables only)
    - Precipitation downscaling

- Upgrade anomaly forecast products
  - Anomaly forecast (ANF)
    - 0.5d resolution for 19 variables (global) + precipitation (CONUS)
  - Extreme forecast index (EFI) – users request (ensemble users workshop)
    - New products – 4 variables (T2m, 10m wind speed, MSLP and precipitation)

- Implementation – December 2017

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 – March 29th 2016 — Version 5
  - CMC/GEFS/NAEFS high resolution upgrade – Q1 2018 — Version 6

- 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 Y. Luo, 2015: *"Precipitation Calibration Based on Frequency Matching Method (FMM)"* , Wea. 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, Y. Zhu, 2015: *"Improvement of Statistical Postprocessing Using GEFS Reforecast Information"* . Weather and Forecasting, Vol. 30, 841-854
  - Guan, H. and Y. Zhu, 2017: *"Development of verification methodology for extreme weather forecasts"* , Weather and Forecasting, Vol. 32, 470-491

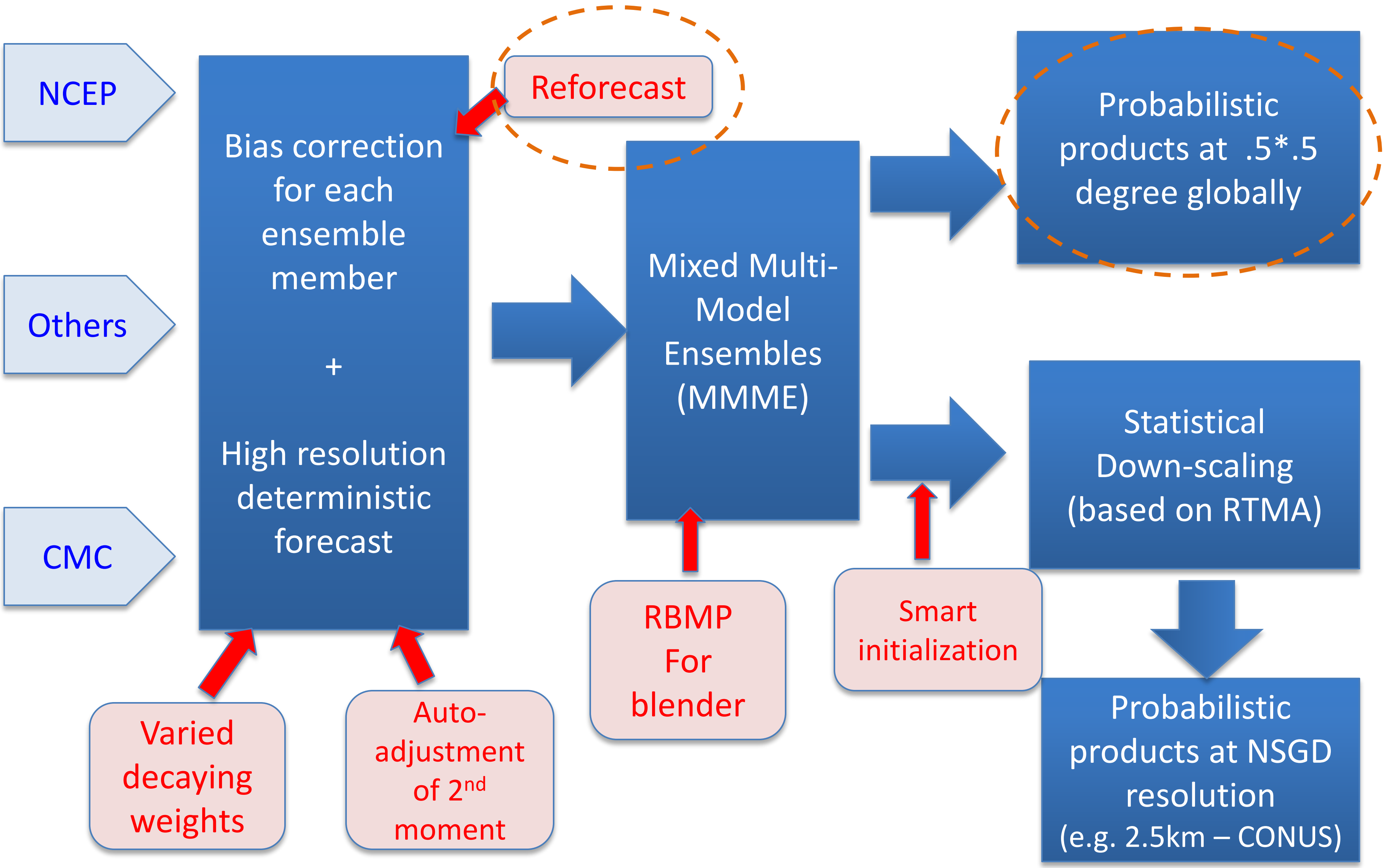
NAEFS Statistical Post-Process (SPP)

- 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

Improving NAEFS Statistical Post-Processing System



NAEFS Bias Correction
(Decaying average method)

1). Bias Estimation:

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

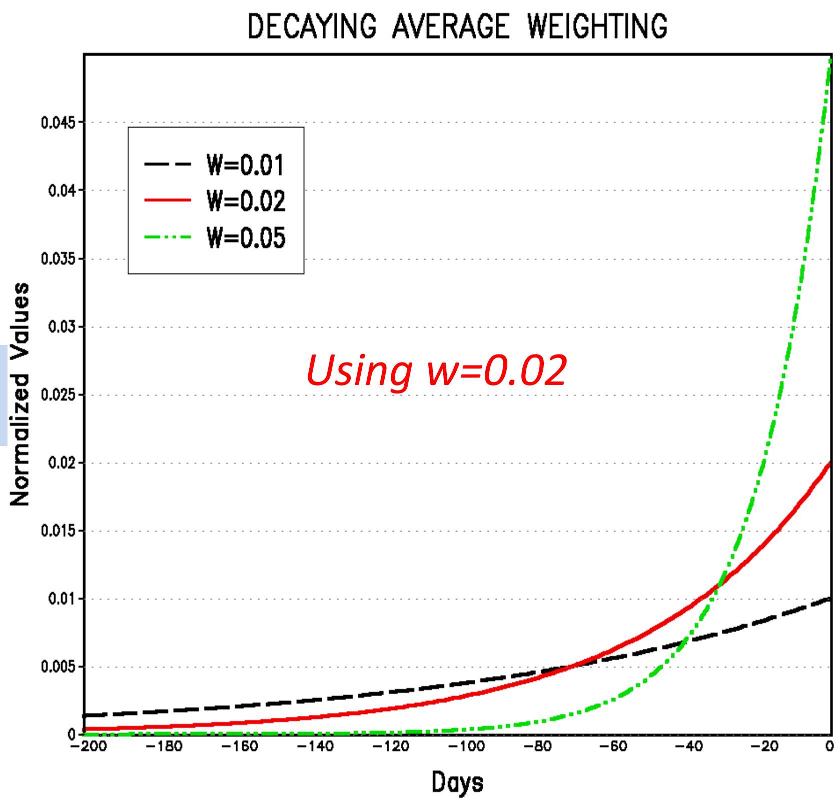
2). Decaying Average (Kalman Filter method)

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

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

4). Bias corrected forecast:

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

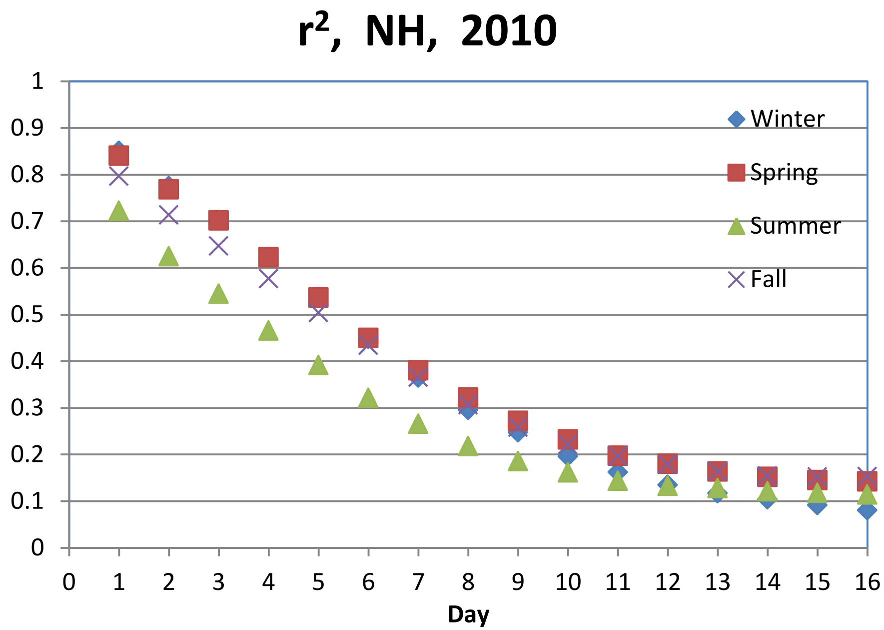


Simple Accumulated Bias

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

Ref: Cui, Toth, Zhu and Hou, 2012

Using reforecast to improve current bias corrected product



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.

Ref: Guan, Cui and Zhu: 2015

Bias corrected forecast: 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.

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

bias corrected forecast

raw forecast

reforecast bias

decaying average bias

NAEFS Global Grid Exchange Variables for 0.5d

Update: June 15 2017

Variables	Levels and Categories	Total 86/(2)
GHT	Surface, 10, 50, 100, 200, 250, 300, 500, 700, 850, 925, 1000 hPa	12/(1)
TMP	2m, 2mMax, 2mMin, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000 hPa	13/(0)
RH	2m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000 hPa	11/(0)
UGRD	10m, 10, 50, 100, 200, 250, 300, 400, 500, 700, 850, 925, 1000 hPa	13/(0)
VGRD	10m, 10, 50, 100, 200, 250, 300, 400, 500, 700, 850, 925, 1000 hPa	13/(0)
PRES	Surface, PRMSL	2/(0)
PRCP	APCP, CRAIN, CSNOW, CFRZR, CICEP	5/(0)
FLUX (surface)	LHTFL, SHTFL, DSWRF, DLWRF, USWRF, ULWRF	6/(0)
FLUX (top)	ULWRF (OLR)	1/(0)
PWAT	Total precipitable water at atmospheric column	1/(0)
TCDC	Total cloud cover at atmospheric column	1/(0)
CAPE	Convective available potential energy, Convective Inhibition	2/(0)
SOIL/SNOW	SOILW(0-10cm) , TMP(0-10cm down), WEASD(water equiv. of accum. Snow depth), SNOD(surface)	4/(0)
Other	850 hPa vertical velocity, Ice thickness (ICETK)	2/(1)
Notes	Current NAEFS grids at 1*1 degree New 0.5 degree added from users request	

NAEFS bias corrected variables for 0.5d

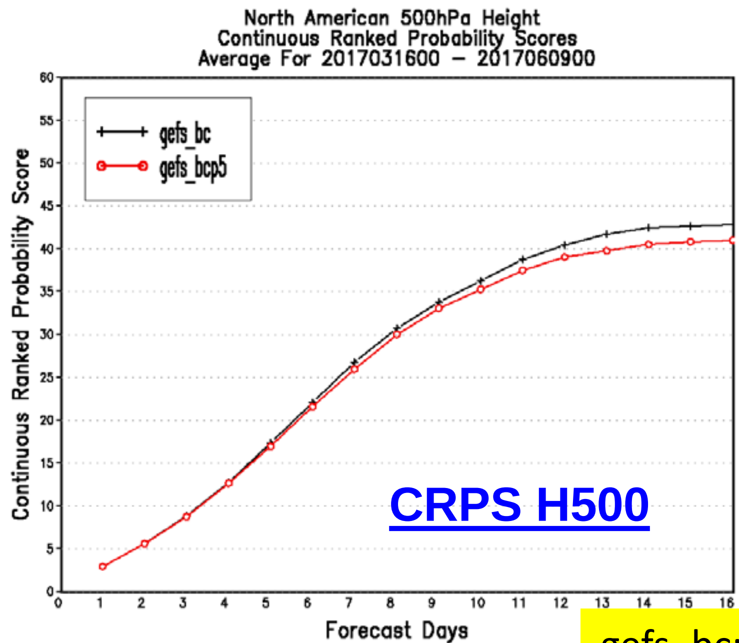
Update: June 15 2017

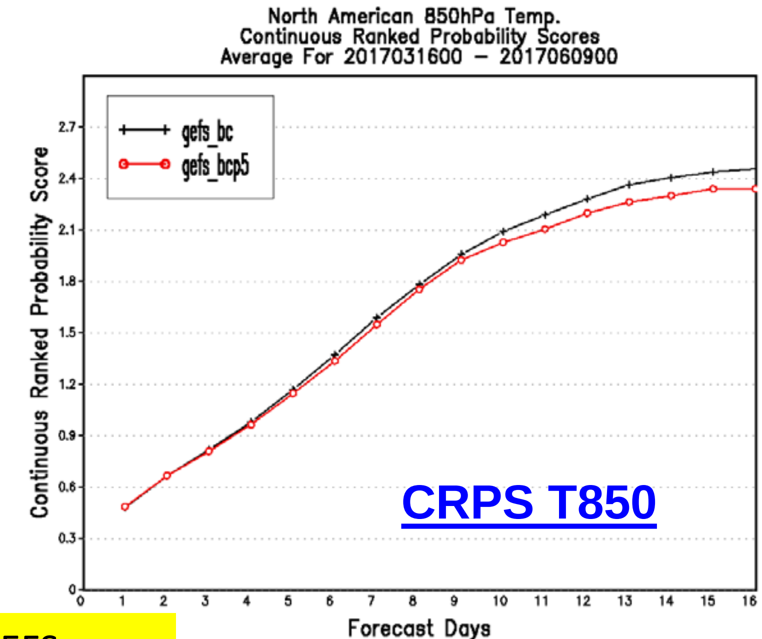
Variables	pgrba_bc file	Total 53 (1)
GHT	10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	10
TMP	2m, 2mMax, 2mMin, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	13
UGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11
VGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11
VVEL	850hPa	1
PRES	Surface, PRMSL	2
FLUX (top)	ULWRF (toa - OLR)	1
Td and RH	2m (April 8 2014)	2
TCDC	Total cloud cover (March 29 2016)	1
WIND	10 meter Wind speed (this upgrade)	0(1)
Notes	CMC do not apply for last 4 variables FNMOC data is in process now	

Part I: NCEP GEFS Bias Correction

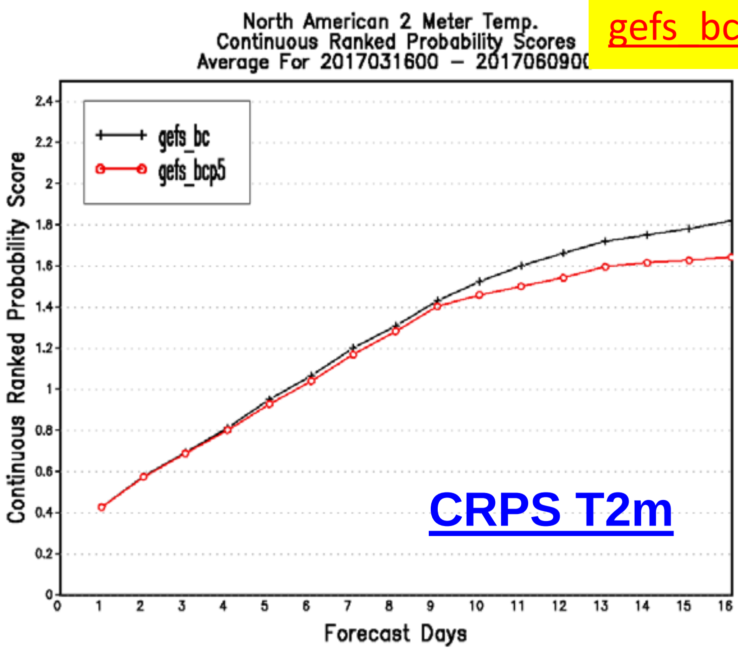
Upgrade, new added, downscaling

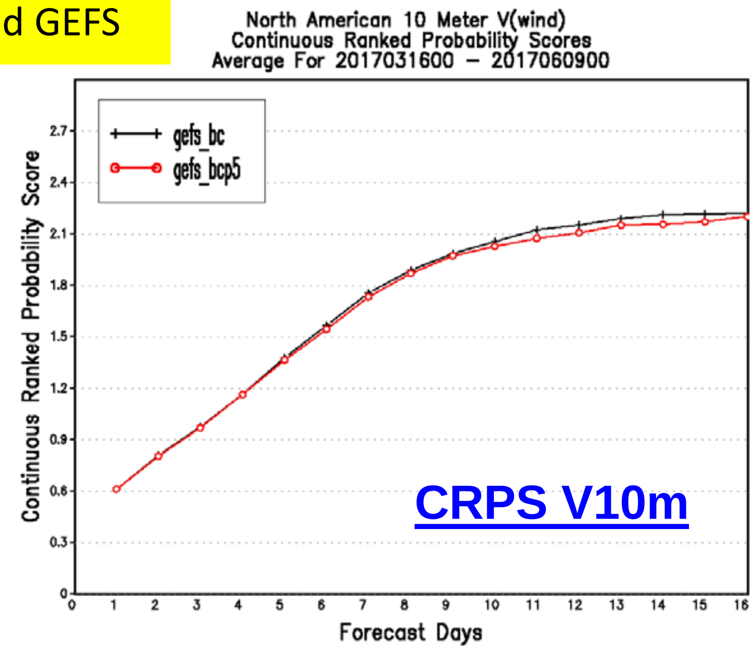
GEFS 1d and 0.5d Ensemble Comparison (2017 Spring)



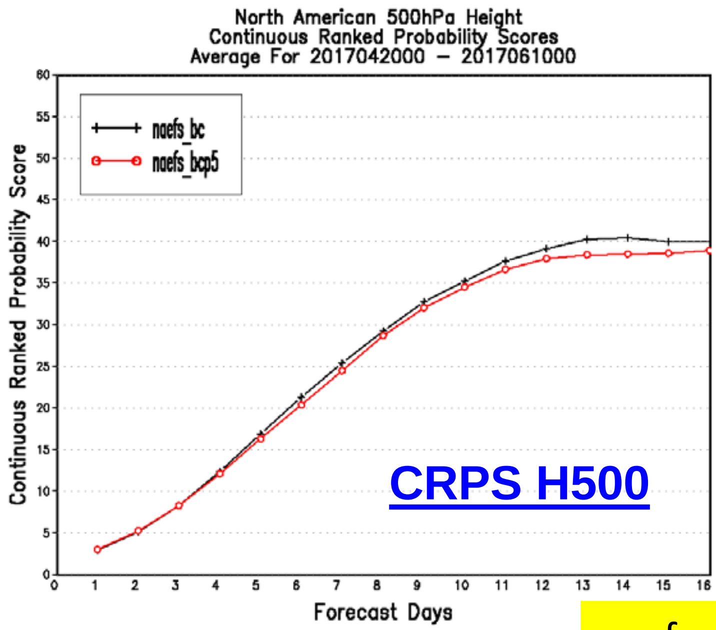


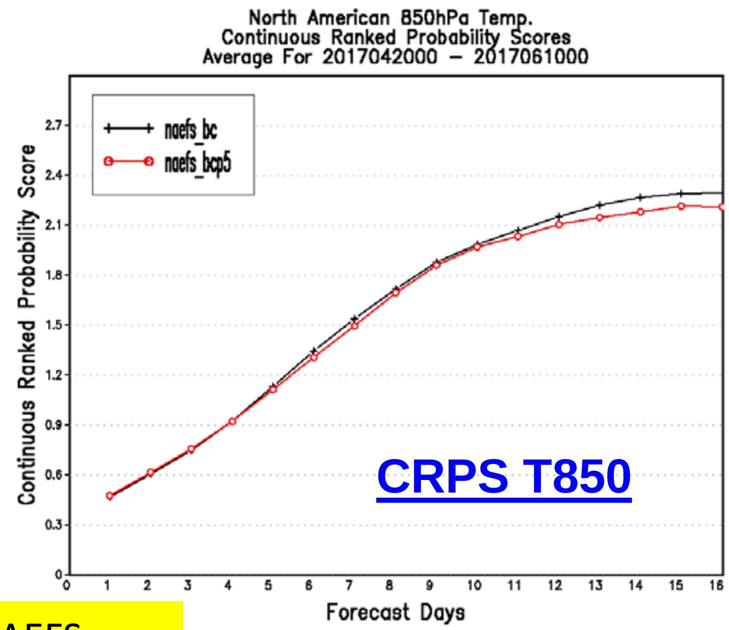
gefs_bc: 1d GEFS
gefs_bcp5: 0.5d GEFS



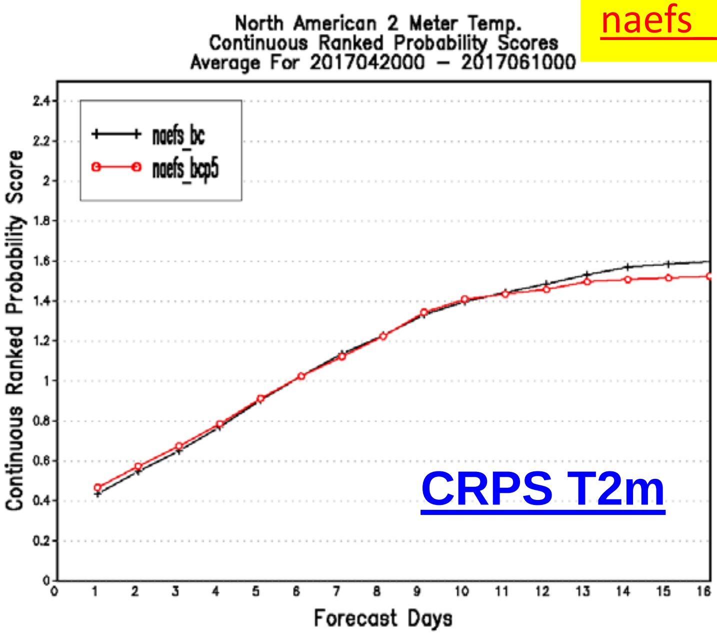


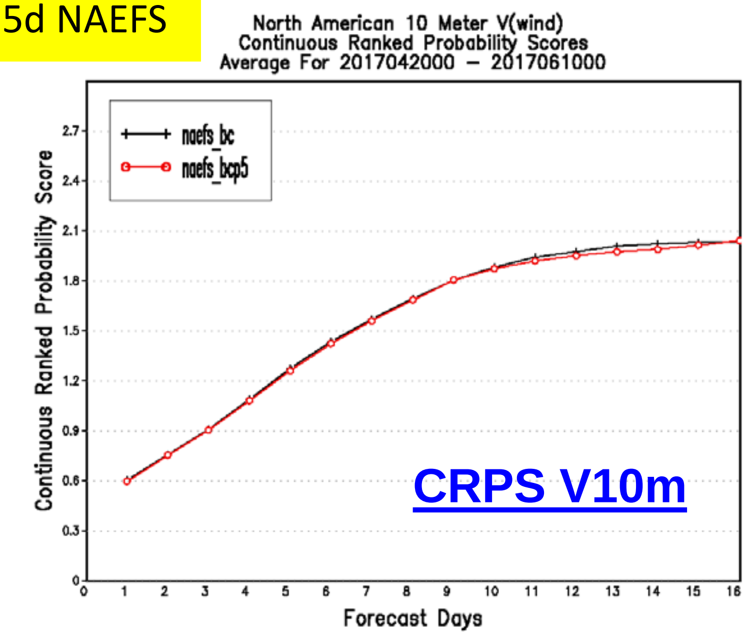
NAEFS 1d and 0.5d Ensemble Comparison (2017 Spring)



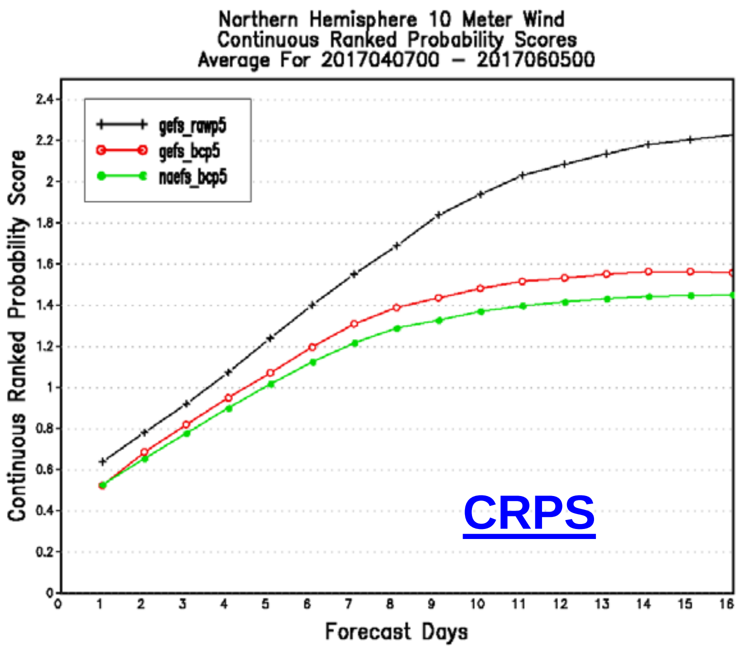


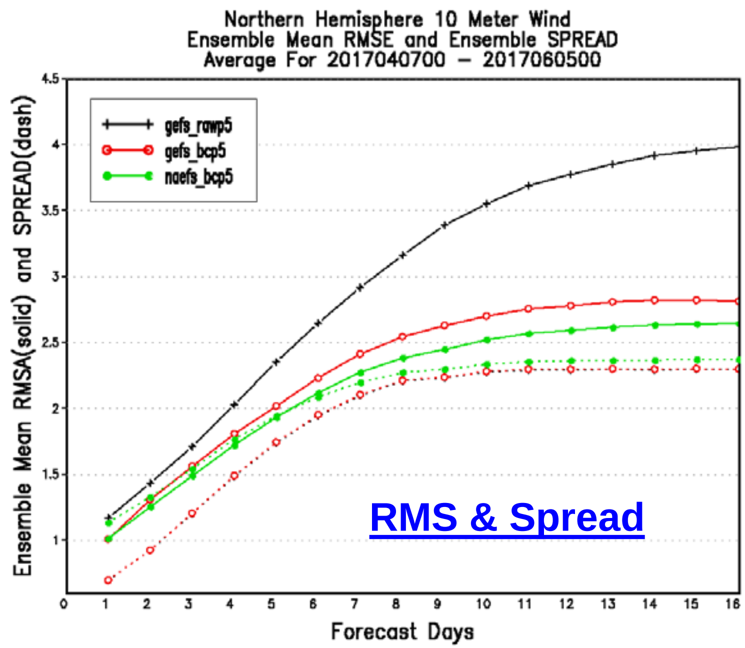
naefs_bc: 1d NAEFS
naefs_bcp5: 0.5d NAEFS





10m Wind Speed Before & After Bias Correction



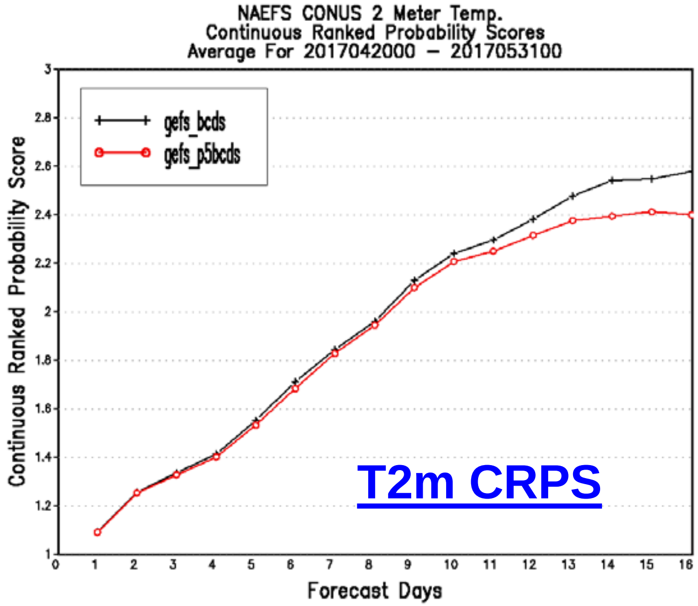


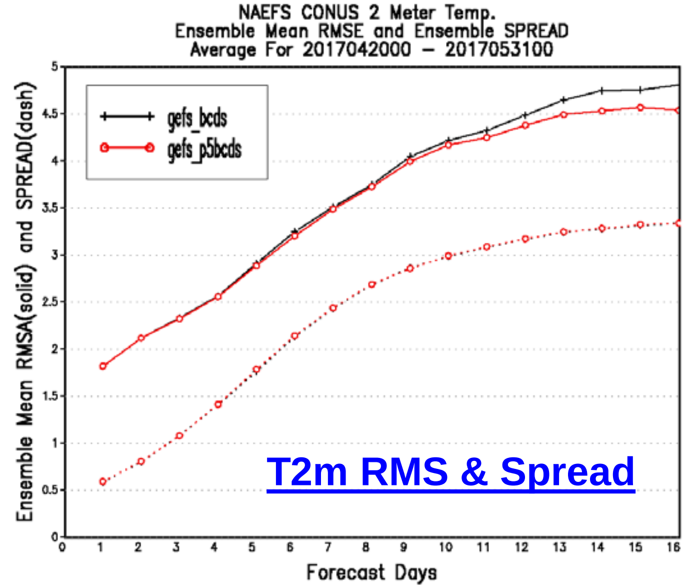
2017 Spring

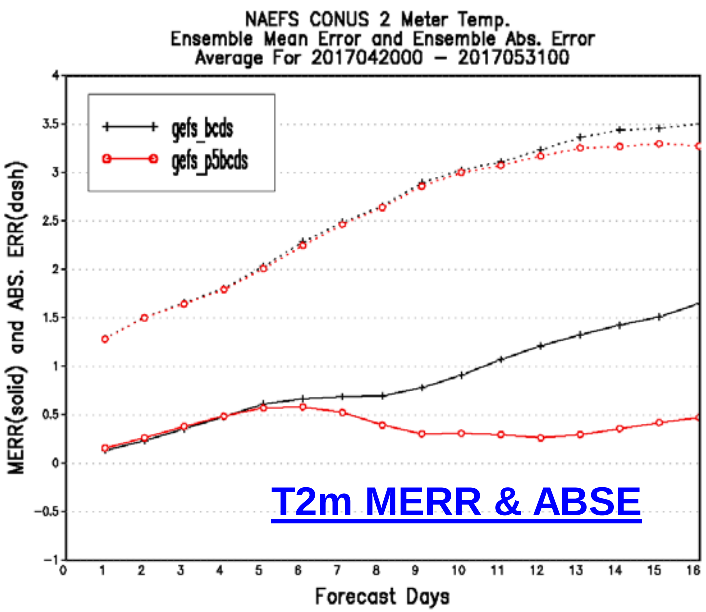
gefs_rawp5: 0.5d GEFS raw
gefs_bcp5: 0.5d GEFS bias corrected
naefs_bcp5: 0.5d NAEFS bias corrected

http://www.emc.ncep.noaa.gov/gmb/wx20cb/naefs.v6.0.0/crps_3line_gefsdev_2017040700.2017060500_24h/GEFS_Spr2017.html

CONUS Downscaled Product (2017 Spring)







2017 Spring

gefs_bcds: from 1d GEFS bias corrected fcst
gefs_p5bcds: from 0.5d GEFS bias corrected fcst

Verified CONUS RTMA Analysis

http://www.emc.ncep.noaa.gov/gmb/wx20cb/naefs.v6.0.0/conus_2lines_dev_2017042000.2017053100

Part I: NCEP GEFS Bias Correction

Upgrade for precipitation , and downscaling

Precipitation Calibrated Products

Upgrade NCEP/GEFS bias-corrected products

- From 2.5*2.5deg, 24hr accumulated QPFs/PQPFs, 00Z only (Implemented in May 2004)
- To 0.5*0.5 deg, 6 hr accumulated QPFs/PQPFs, 4 times daily
- Bias correction using frequency match and decaying average methods
  Ref: Zhu, Y, and Y. Luo, 2015: "Precipitation Calibration Based on Frequency Matching Method (FMM)". *Weather and Forecasting*, Vol. 30, 1109-1124
- Application: To generate anomaly forecast (ANF) and Extreme Forecast Index (EFI)

Add downscaled NCEP/GEFS forecasts (input from 0.5d)

- 6hr and 24hr QPFs/PQPFs, 4 times daily
- Downscaled from 0.5 degree bias-corrected forecast
- Statistical downscaling to 2.5km for CONUS
- Use CCPA climatology to derive downscaling ratio

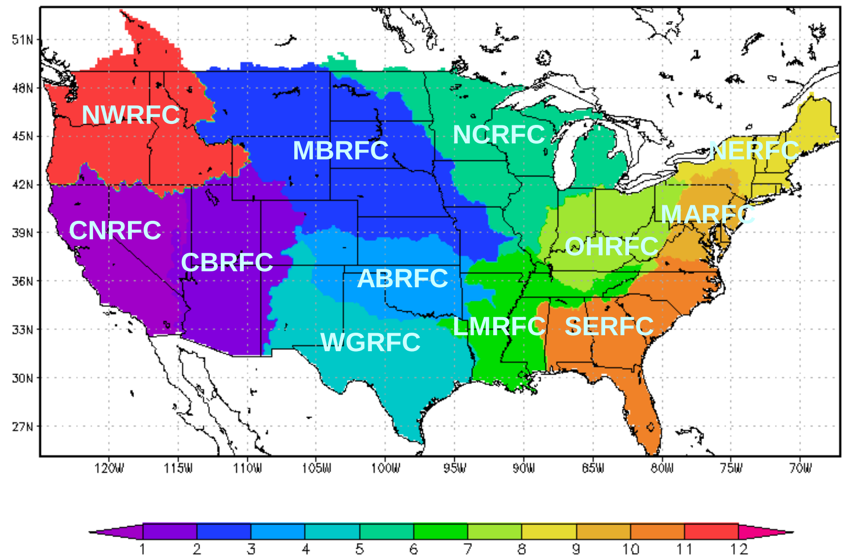
Precipitation Calibration Based on Frequency Matching Method (FMM)

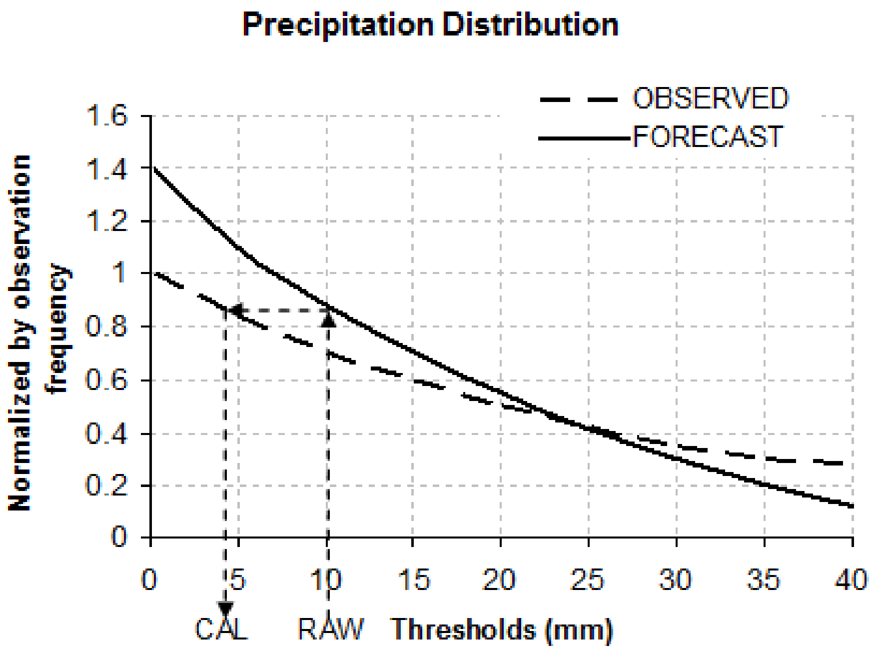
(Ref: Zhu and Luo, 2015: Weather and Forecasting)

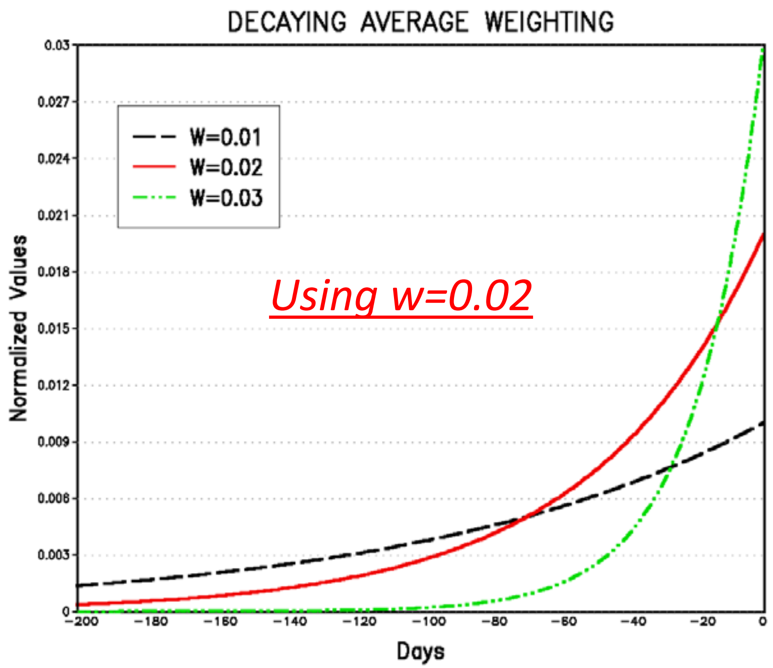
Calculate for Obs and Fcst respectively

$$\overline{CDF}_j = (1-W) * \overline{CDF}_{j-1} + W * CDF_j$$

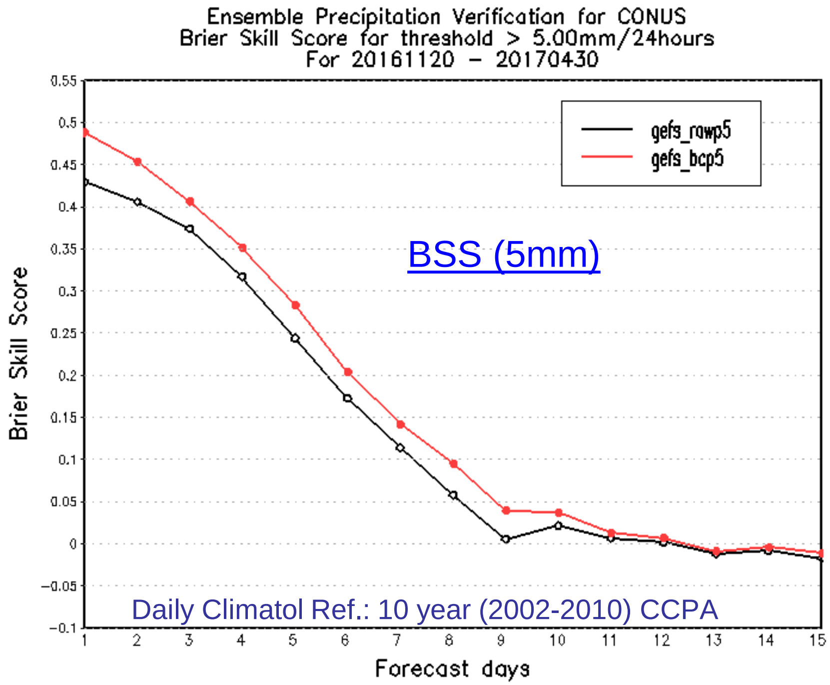
W is weight to accumulate CDF

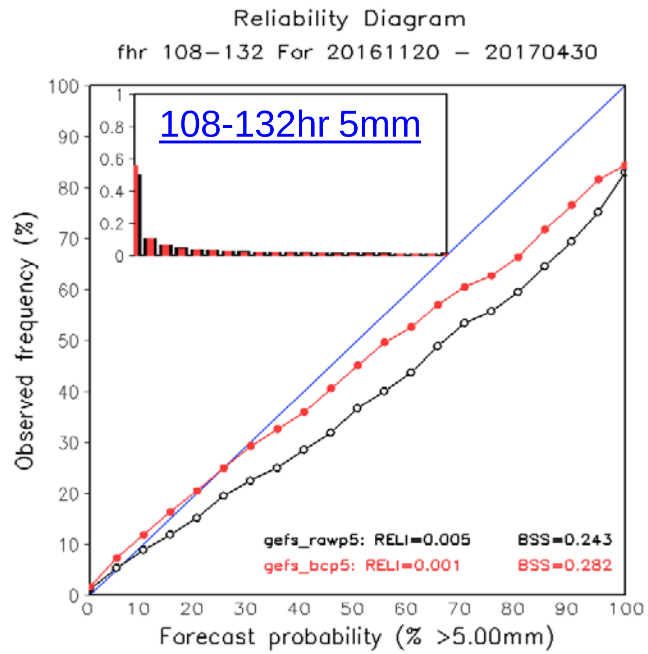


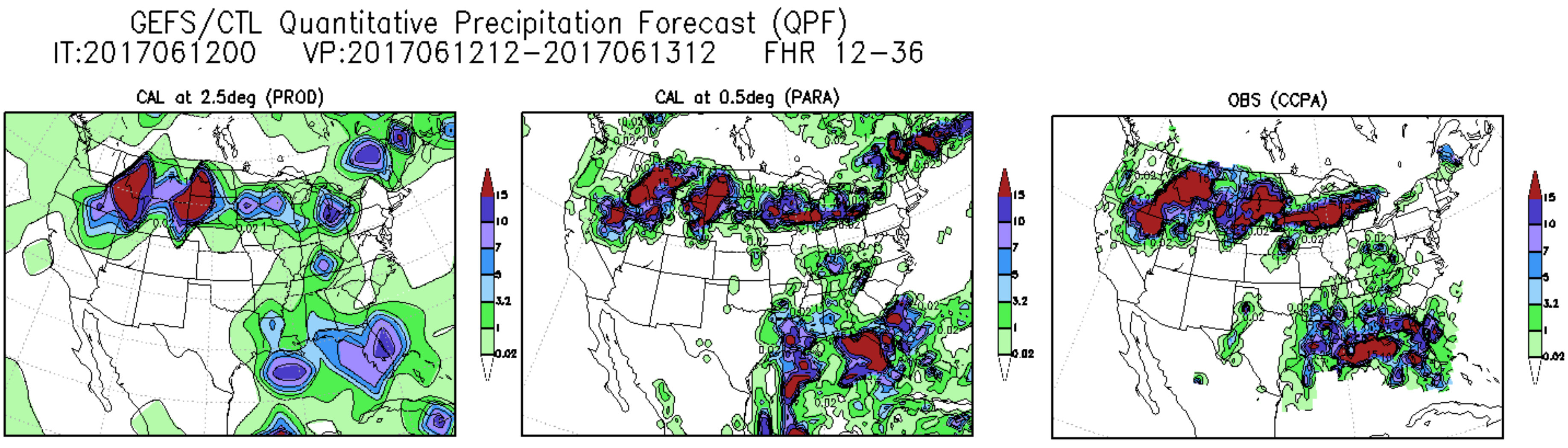




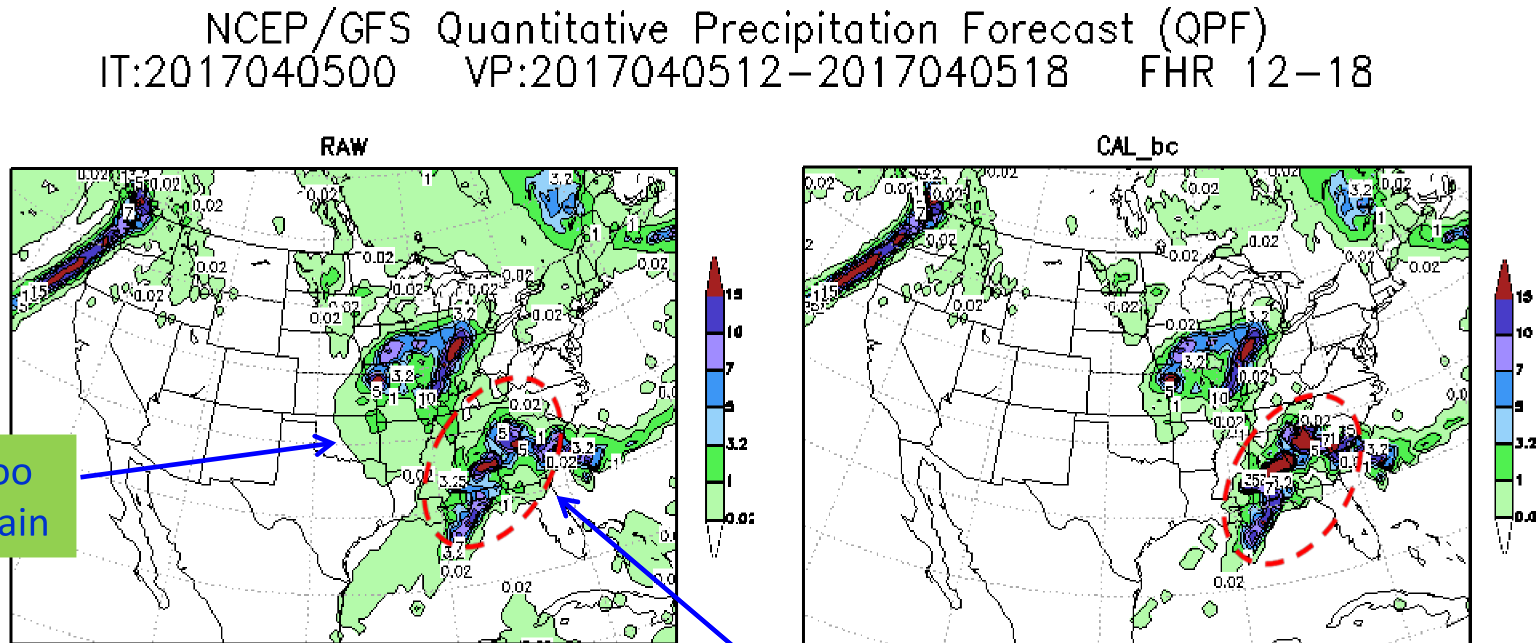
0.5deg Raw and Bias-corrected PQPF Verified against CCPA



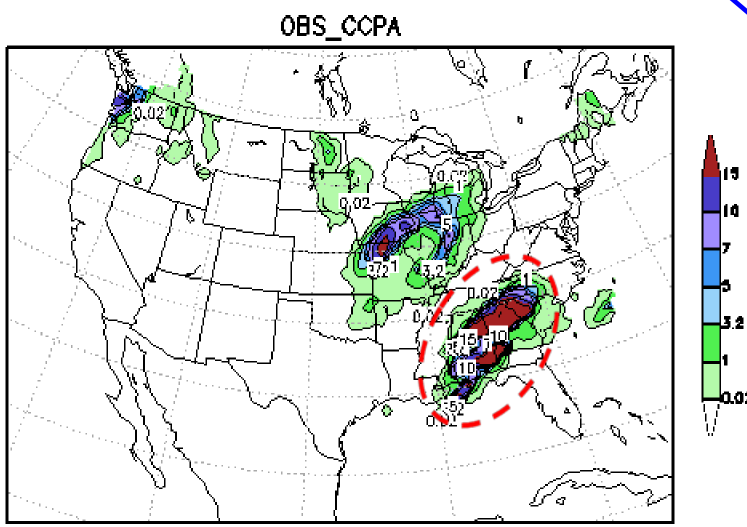




6-hr 0.5deg Raw and Bias-corrected QPFs Verified against CCPA



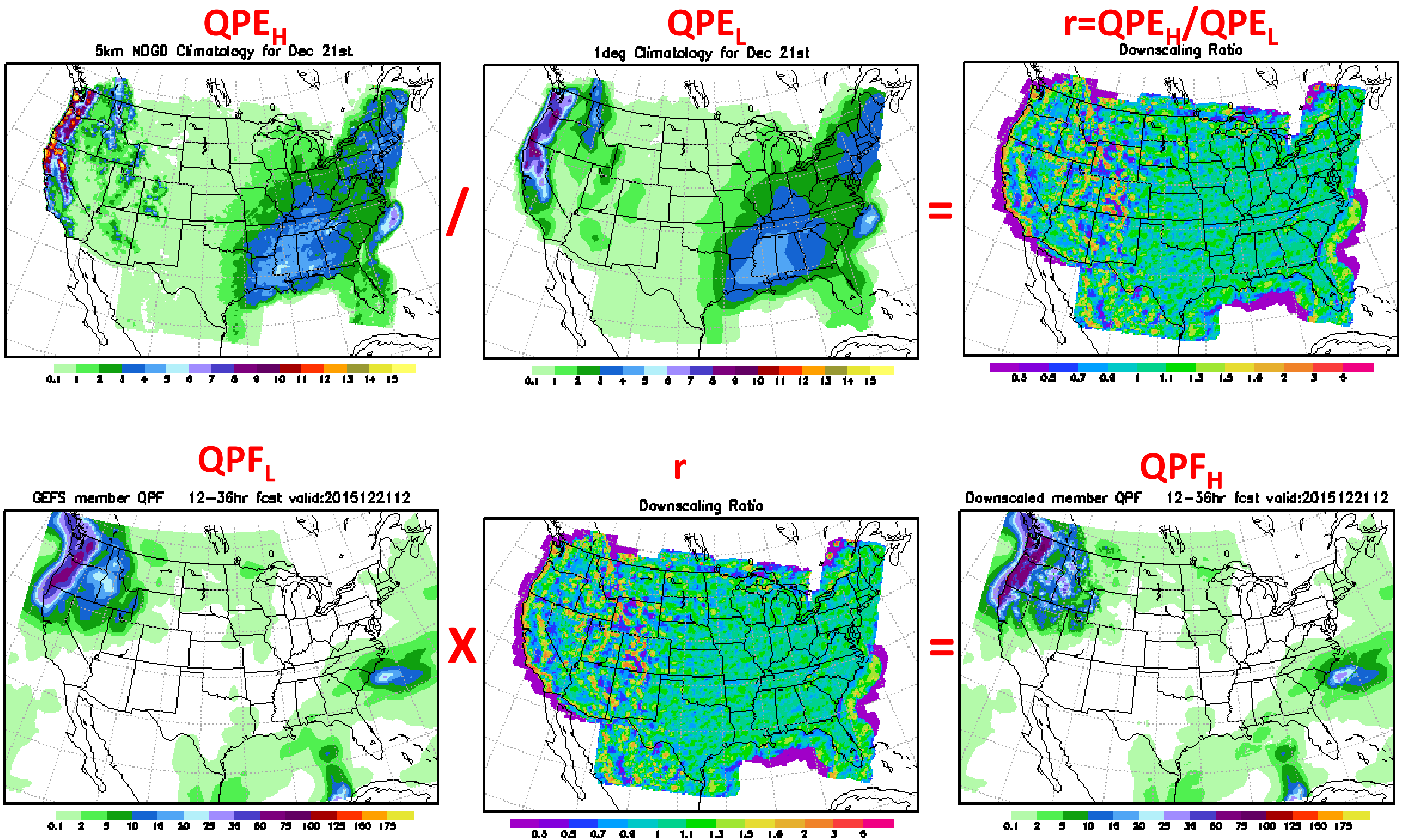
Generally, too much light rain



A dry bias for heavy rain across portions of the Gulf Coast and/or the Southeast

* GEFS_raw .vs GEFS_bc: 6hr accum, 0.5deg results from: http://www.emc.ncep.noaa.gov/gmb/yluo/GEFS_VRFY/CPQPF_6h.html

Downscaling Methodology

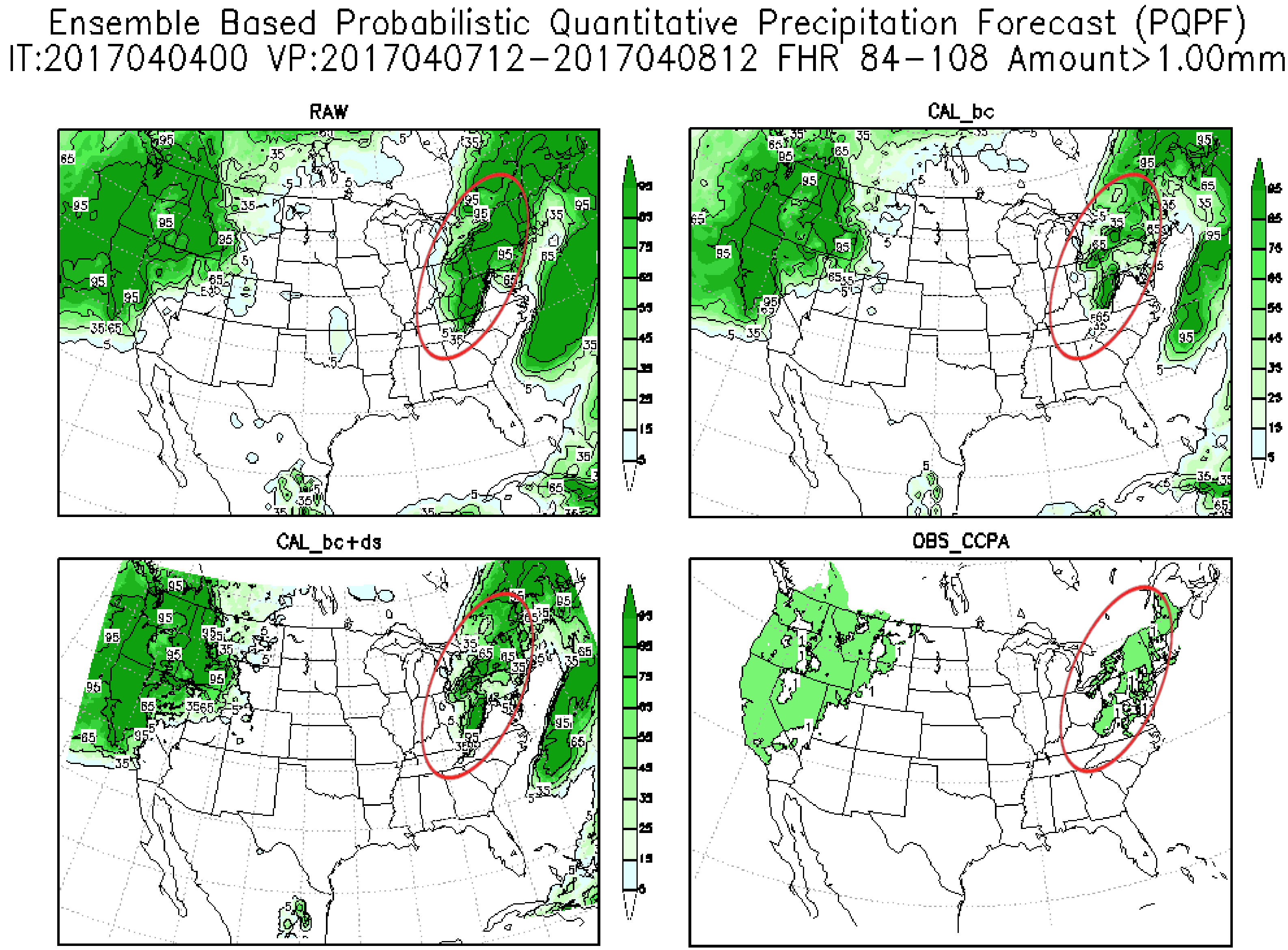


To avoid CONUS border issue (purple in r map), there is no downscaling outside of CONUS.

To avoid extreme outliers, r is bounded: 0.3 < r < 5 (cold seasons); 0.9 < r < 5 (warm seasons).

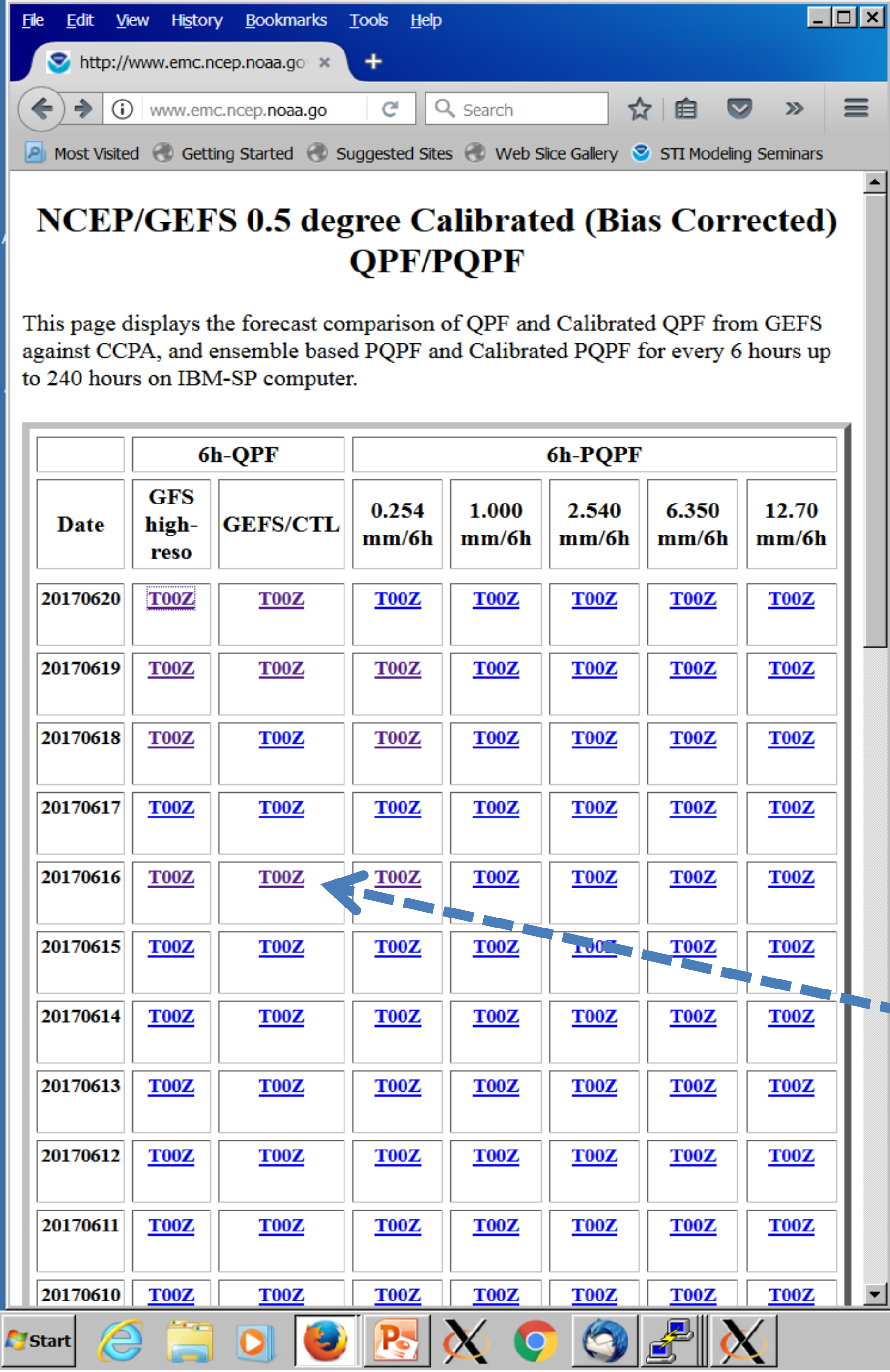
24-hr PQPFs Verified against CCPA

PQPF(>1.00mm)



GEFS_raw .vs GEFS_bc .vs GEFS_bc+ds 24hr accum results from:

http://www.emc.ncep.noaa.gov/gmb/yluo/GEFS_VRFY/CPQPF_24h.html



NCEP/GEFS 0.5 degree Calibrated (Bias Corrected) QPF/PQPF

This page displays the forecast comparison of QPF and Calibrated QPF from GEFS against CCPA, and ensemble based PQPF and Calibrated PQPF for every 6 hours up to 240 hours on IBM-SP computer.

	6h-QPF		6h-PQPF				
Date	GFS high-reso	GEFS/CTL	0.254 mm/6h	1.000 mm/6h	2.540 mm/6h	6.350 mm/6h	12.70 mm/6h
20170620	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z
20170619	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z
20170618	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z
20170617	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z
20170616	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z
20170615	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z
20170614	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z
20170613	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z
20170612	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z
20170611	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z
20170610	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z	T00Z

EMC real-time parallel experiments

Started from April 1st

Running four times per day

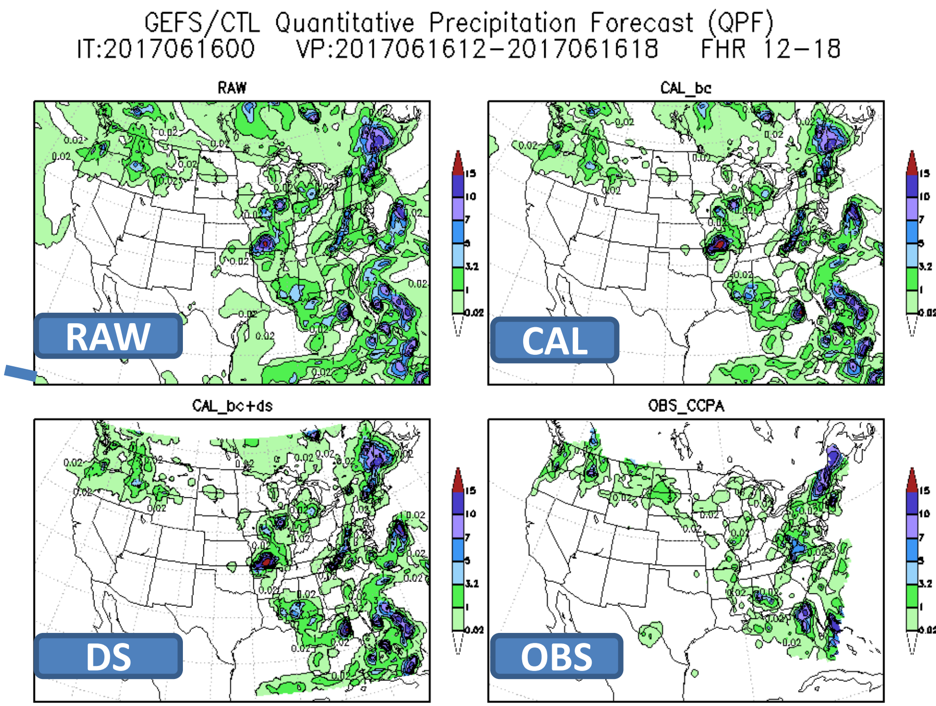
(Demonstrated only by 00Z cycle)

6hr products

http://www.emc.ncep.noaa.gov/gmb/yluo/GEFS_VRFY/CPQPF_6h.html

24hr products

http://www.emc.ncep.noaa.gov/gmb/yluo/GEFS_VRFY/CPQPF_24h.html



Part II: Anomaly Forecast Products

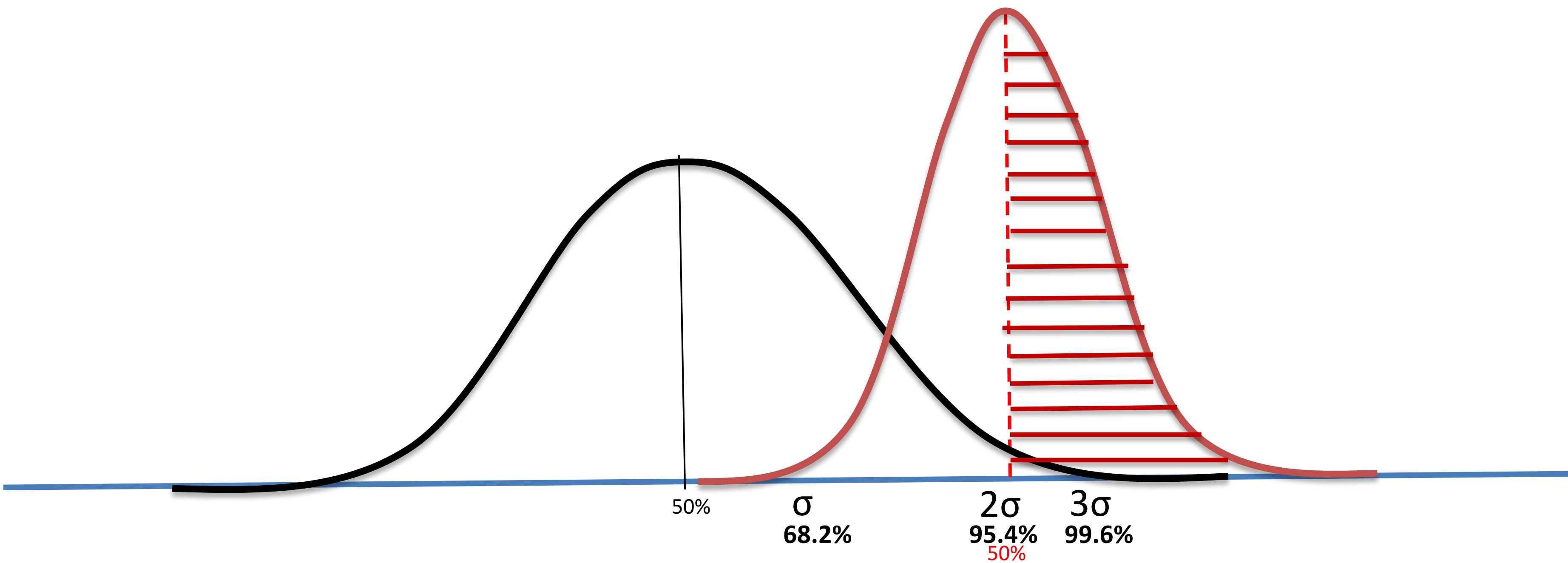
Extreme Weather Forecast Products

- Current status
  - Anomaly Forecast (ANF)
    - NCEP operation since 2006 (19 variables)
    - 1.0 degree resolution
    - No precipitation
    - NWS/WR experiment: http://ssd.wrh.noaa.gov/satable/
  - No Extreme Forecast Index (EFI) product
    - ECMWF and CMC have applied in their operation
    - But, user request through “Ensemble Users Workshop”

- NAEFSv6 upgrade
  - For all bias corrected forecast
  - ANF for 0.5d, include precipitation
  - EFI for 0.5d, T2m, 10mw, Prcip, MSLP

- Reference:
  - Guan, H. and Y. Zhu, 2017: "*Development of verification methodology for extreme weather forecasts*“ Weather and Forecasting, Vol. 32, 470-491

Anomaly Forecast (ANF)



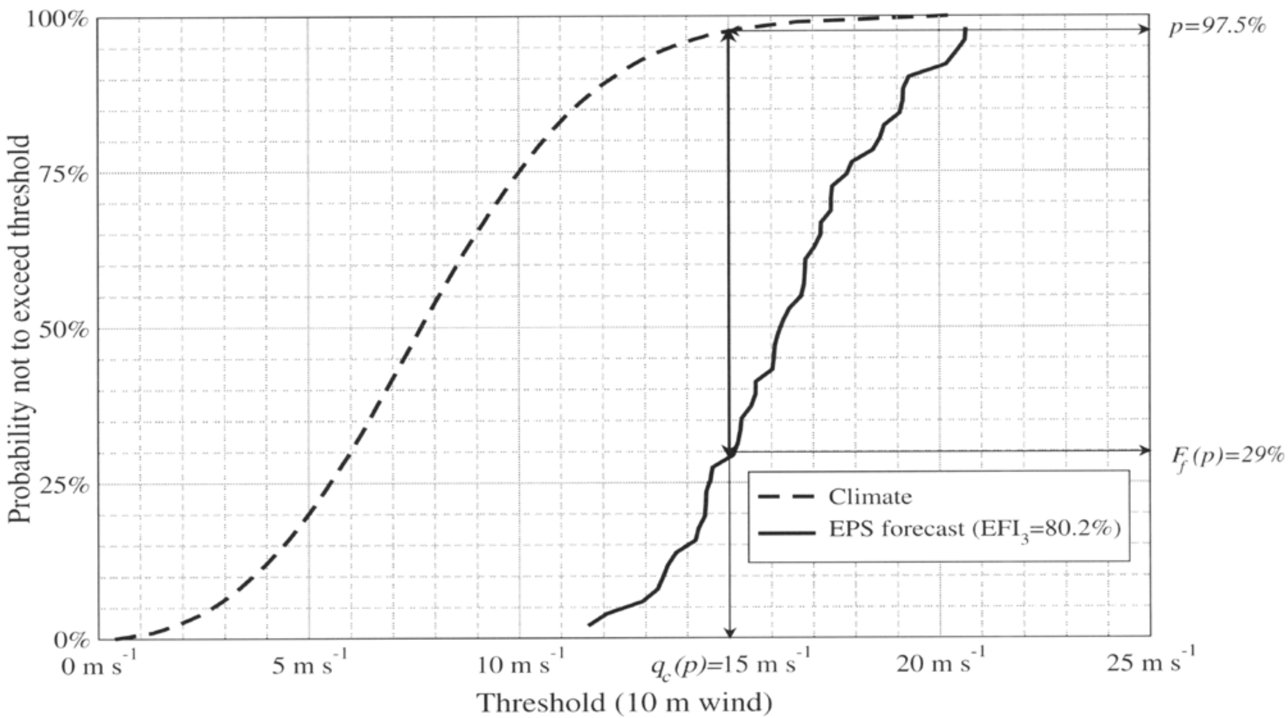
Schematics diagram for anomaly forecast (PDF)

Definitions for Anomaly Forecast

Percentage of ensemble forecast (shaded area) which exceeds climate threshold (for example: 2σ) (NCEP/ NAFES product)

Extreme Forecast Index (EFI)

(Lalaurette, 2003)



The EFI is a measure of the difference between the model climatological forecast distribution and the current ensemble forecast distribution.

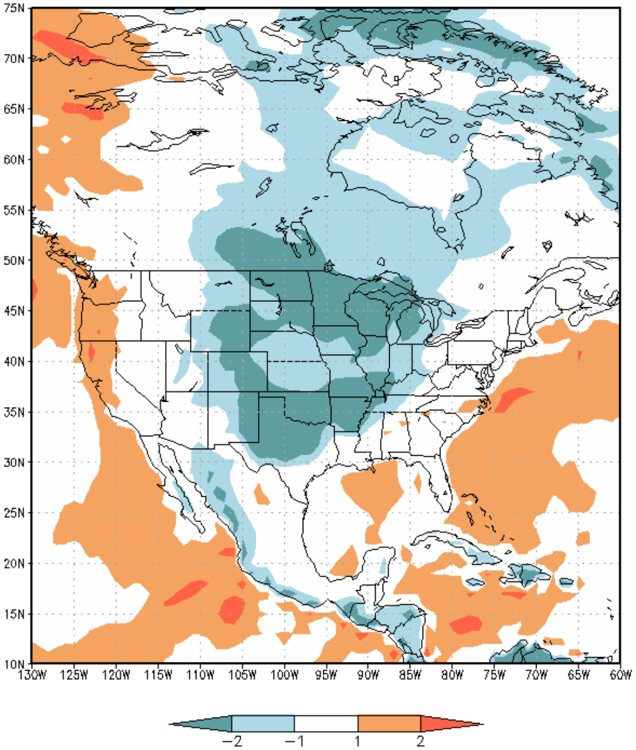
CDF: cumulative distribution function

Modified Equation
(Zsooter 2006)

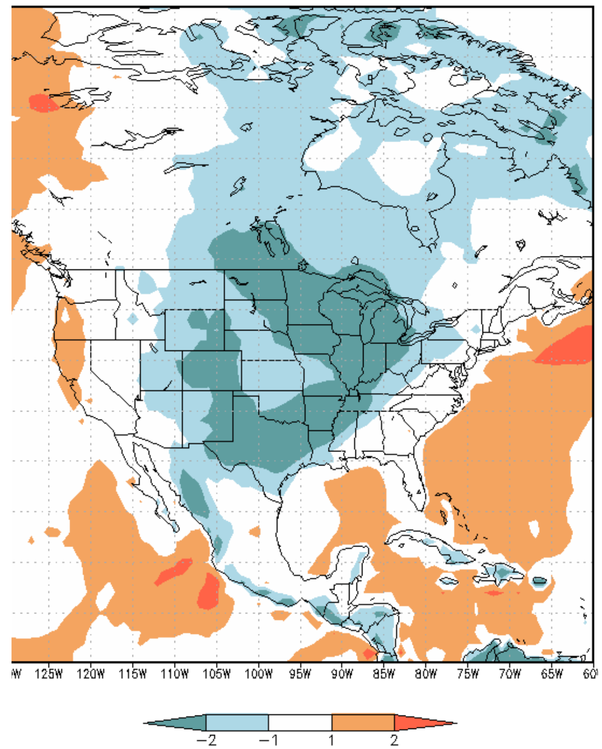
$$EFI = \frac{2}{\pi}\int_0^1 \frac{p - F_f(p)}{\sqrt{p(1-p)}}\,dp$$

Example of extreme cold weather event (Valid: 2015030500)

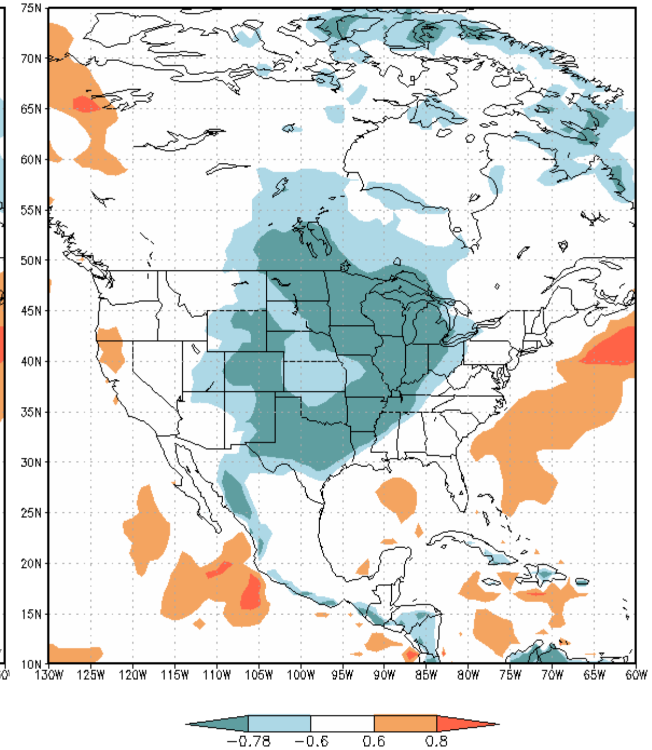
Observed anomaly (analysis)

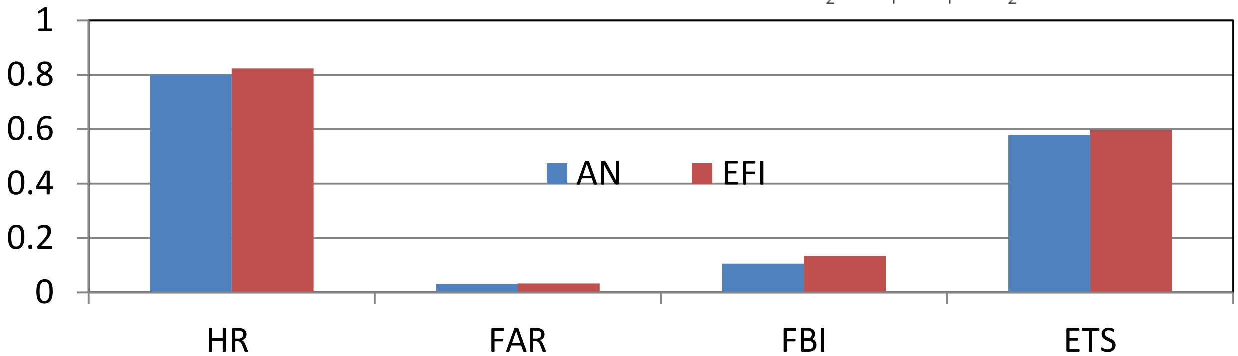


Anomaly Forecast (ANF)



Extreme Forecast Index (EFI)

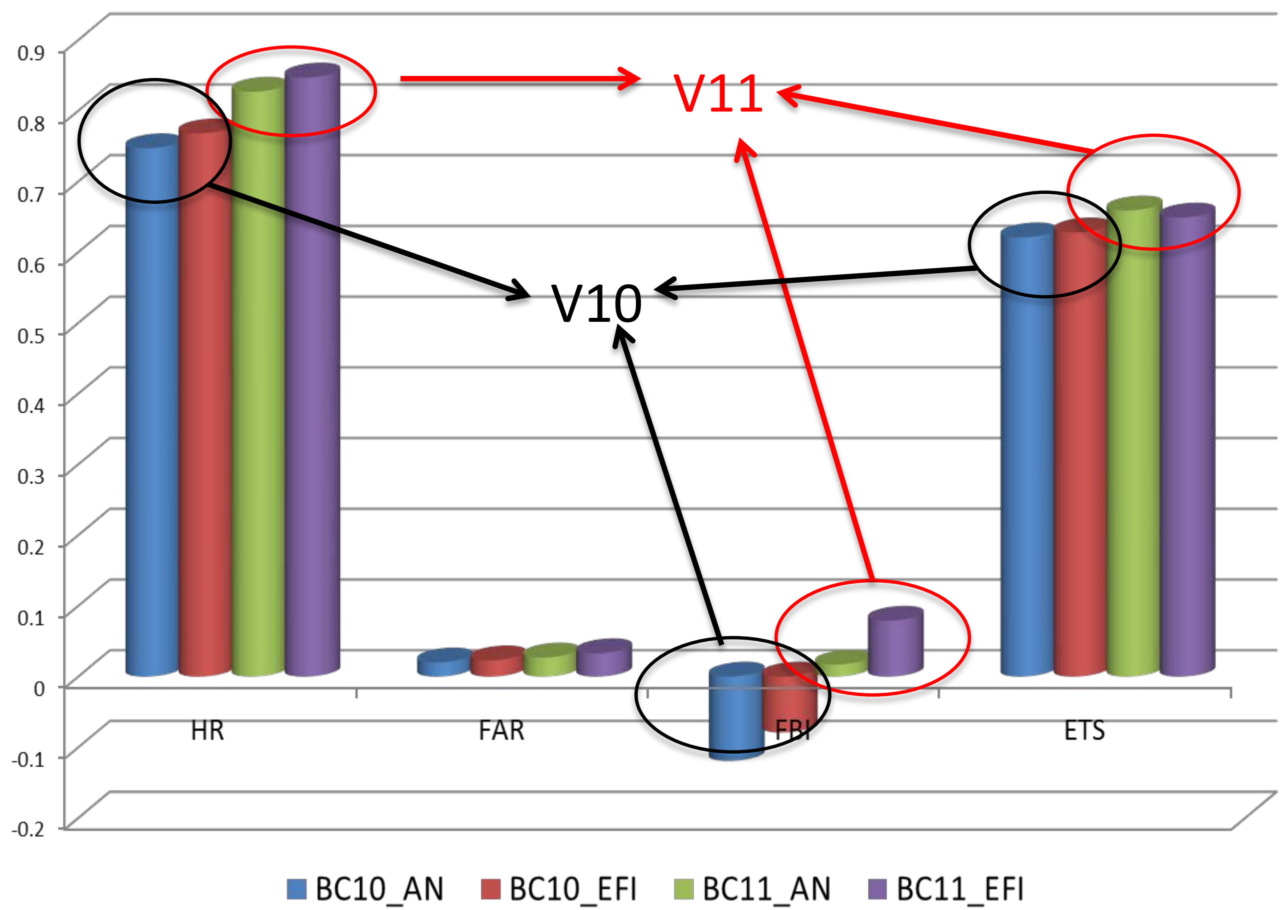




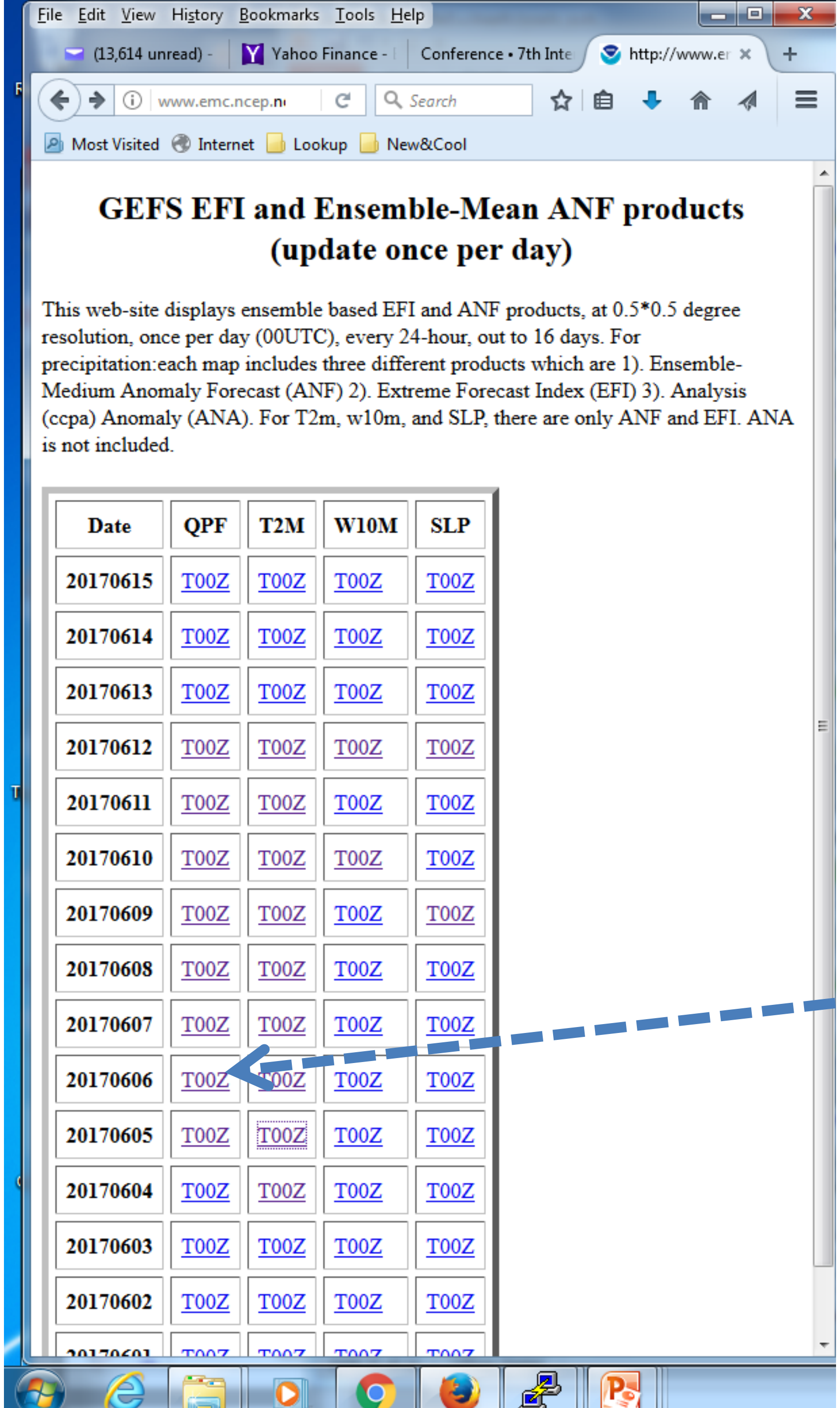
Example of bias corrected T2m against observed climatology

Ref: Guan, H. and Y. Zhu, 2017

Statistics for extreme cold weather event (11 cases) for 13-14 winter (V10 and V11 bias-corrected forecast)



Ref: Guan, H. and Y. Zhu, 2017



GEFS EFI and Ensemble-Mean ANF products (update once per day)

This web-site displays ensemble based EFI and ANF products, at 0.5*0.5 degree resolution, once per day (00UTC), every 24-hour, out to 16 days. For precipitation:each map includes three different products which are 1). Ensemble-Medium Anomaly Forecast (ANF) 2). Extreme Forecast Index (EFI) 3). Analysis (ccpa) Anomaly (ANA). For T2m, w10m, and SLP, there are only ANF and EFI. ANA is not included.

Date	QPF	T2M	W10M	SLP
20170615	T00Z	T00Z	T00Z	T00Z
20170614	T00Z	T00Z	T00Z	T00Z
20170613	T00Z	T00Z	T00Z	T00Z
20170612	T00Z	T00Z	T00Z	T00Z
20170611	T00Z	T00Z	T00Z	T00Z
20170610	T00Z	T00Z	T00Z	T00Z
20170609	T00Z	T00Z	T00Z	T00Z
20170608	T00Z	T00Z	T00Z	T00Z
20170607	T00Z	T00Z	T00Z	T00Z
20170606	T00Z	T00Z	T00Z	T00Z
20170605	T00Z	T00Z	T00Z	T00Z
20170604	T00Z	T00Z	T00Z	T00Z
20170603	T00Z	T00Z	T00Z	T00Z
20170602	T00Z	T00Z	T00Z	T00Z
20170601	T00Z	T00Z	T00Z	T00Z

EMC real-time parallel experiments

http://www.emc.ncep.noaa.gov/gmb/wd20hg/html/EFIANF.html

Running once per day

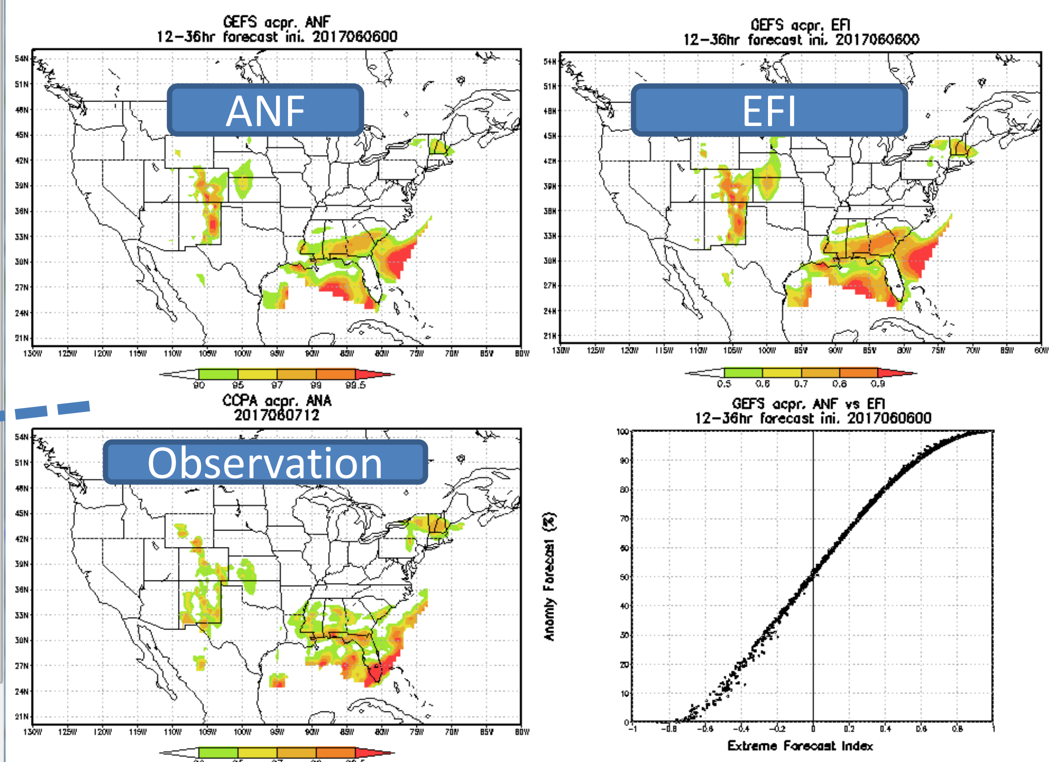
4 variables:

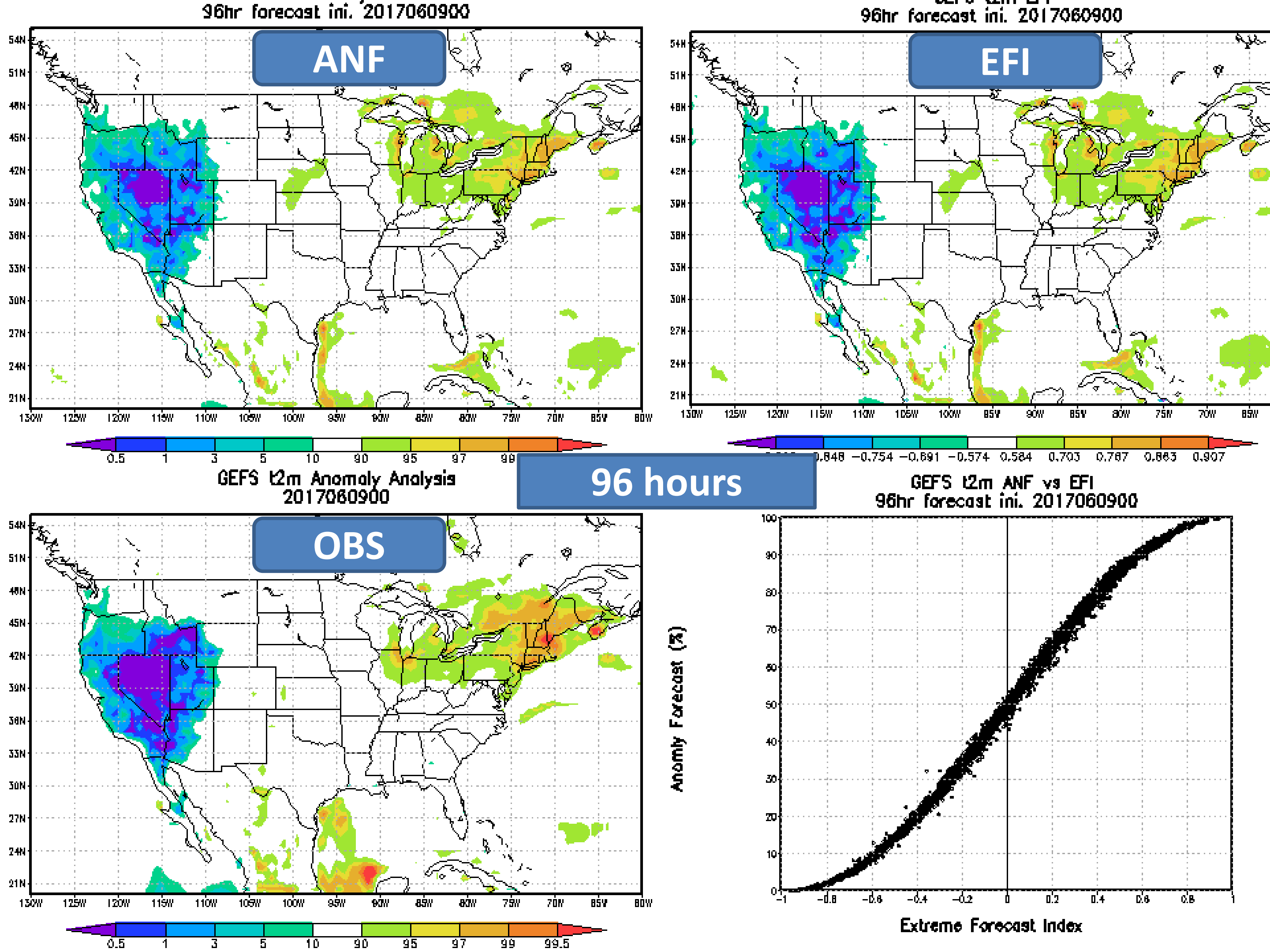
Surface pressure

Precipitation

Surface temperature

Surface wind speed




96hr forecast ini. 2017060900
ANF
96hr forecast ini. 2017060900
EFI
0.5 1 3 5 10 90 95 97 99
-0.848 -0.754 -0.691 -0.574 0.584 0.703 0.787 0.863 0.907
96 hours
GEFS t2m Anomaly Analysis
2017060900
OBS
0.5 1 3 5 10 90 95 97 99 99.5
GEFS t2m ANF vs EFI
96hr forecast ini. 2017060900
Anomaly Forecast (%)
Extreme Forecast Index

Issues, downstream and evaluation

- SCN (TIN) is ready to NCO dataflow team.
- Impact of downstream:
  - Wave ensemble? (no impact - confirmed)
  - NBM – contact to Jeff Craven (MDL)
  - CPC – contact to Jon Gottschalck, Matt Rosencrans
- Evaluations:
  - WPC – contact to Mike Bodner's team
  - CPC – Jon Gottschalck sends us comments for upgrade.
  - NWS/ER – contact Richard Grumm (SOO)
  - EKDMOS – contact to John Wagner (MDL)
  - 1st energy

User feedback

- WPC day 8-10 experiment (Mike Bodner et al)
  - Meeting/discussion-every other Thursday
  - August 24 (example)
    - Temperature blending: **GEFS_bc(45%)**; EC_ens(45%); GEFSv10(10%)
    - Precipitation blending: **GEFS_bc(45%)**; EC_ens(40); GFS(15)
  - **Implementation – Yes**
- CPC (Jon Gottschalck et al.)
  - CPC **supports the upgrade** as the only change is with respect to the resolution and format of the data which we have confirmed we can properly adjust to when and where required and will re-affirm during the NCO data flow review period with this upgrade.
  - Since we do not have any science related feedback to provide (data length was not sufficient to adequately draw any reliable conclusions)
- NWS/ER (Richard Grumm)
  - Quote for "ANL" and "EFI": "General concise and useful conclusions. We need more **operationally available data and products of this type in real-time**."
- MDL EKDMOD (John Wagner)
  - Testing 0.5d GEFS and 0.5d NAEFS
  - No significant difference from current operational 1.0 data
  - **Implementation - Yes**

Response from public (private sector) users

Yuejian,

Thanks for the updated slides. I apologize for not getting this back to you sooner. I did go through this upon your original email, but was sidetracked before I had a chance to respond.

FirstEnergy looks forward to seeing the changes in the upgrade. The bias correction of precipitation looks very promising, and we have seen value in the frequency matching method elsewhere. The downscaling of the precipitation will also looks promising.

We look forward to seeing the bias correction of 10m winds as well. We have historically not used this parameter from the NAEFS, but will make a point to look at it once it is available.

The EFI will be very valuable and we look forward to use it.

Thank you for including FirstEnergy in the evaluation! Please let us know if you have any questions.

Regards,

Brian Kolts (and Thomas Workoff) Staff Scientist (July 6 2017)
FirstEnergy 330 436 1404

NAEFS (NUOPC) Version 6.0
Status as of 9/7/17

G

Project Information & Highlights

Leads: Yuejian Zhu/ Bo Cui (EMC), Steven Earle (NCO)

Scope: Introduce higher resolution raw (CMC) and bias corrected (NCEP and CMC) global ensemble forecast. Improve methodology (hybrid of decaying and reforecast) for bias correction. Introduce extreme forecast products.

Expected benefits: Higher quality NAEFS products

Dependencies: Data exchange with CMC (and FNMOC)

G Schedule

Milestones & Deliverables	Date	Status
Freeze system code; deliver to NCO if applicable	4/10/17	Completed
Complete full retrospective/real time runs and evaluation	9/06/17	On track
Conduct CCB and deliver final system code to NCO	9/07/17	On track
Issue Technical Information Notice	9/15/17	On track
Complete 30-day evaluation and IT testing	11/30/17	On track
Operational Implementation	12/05/17	On track

EMC	NCO	Red text indicates change from previous quarter

G Issues/Risks

Issues: Users evaluation for combined (NCEP + CMC) products;
Mitigation: delay implementation

G Resources

Staff: 0.5 Fed FTEs (Yuejian Zhu 0.3; Dingchen Hou 0.2) + 2.0 contractor FTEs (Bo Cui 0.8; Richard Wobus 0.5; Yan Luo 0.2; Hong Guan 0.2; Jiayi Peng 0.2; Wei Li 0.1) including dev of NAEFS and NUOPC.

Funding Source: STI

Compute: parallels: 50 nodes for 2 months (Delta: 40 nodes); **EMC Dev**: 50 nodes for 1-year (Delta: 40 nodes); **Ops**: 60 nodes (Delta: 30 nodes - higher water mark)

Archive: 10TB (no changes); **Ops**: 12 GB per cycle (no major changes)

R Management Attention Required	Y Potential Management Attention Needed	G On Target

Resource of changes

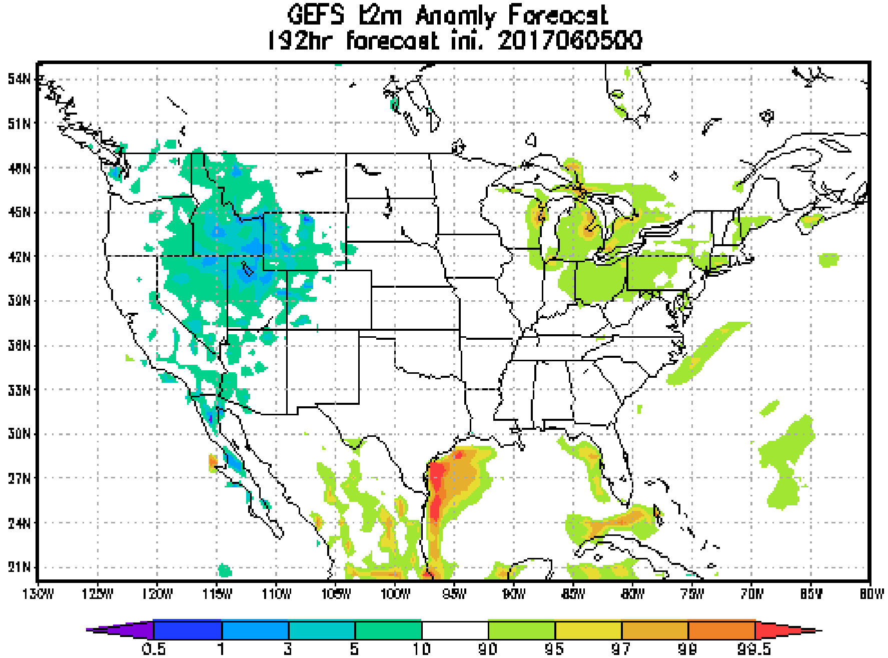
- Current:
  - Length of process – last 2+ hours
  - How many nodes? - 30 nodes (peak)
  - Start time / end time – +6:00 - +8:00
  - Disk storage per cycle (28GB per cycle)
    - 17GB (pgrb2ap5)
    - 6.4GB (pgrb2a)
    - 10GB (pgrb2a_bc for GEFS and CMC)
    - 4GB (pgrb2a_an for GEFS and CMC)
- Future:
  - Length of process – last 2+ hours
  - How many nodes? – 60 nodes (peak)
  - Start time / end time – +6:00 - +8:00 (? Need more tests on CRAY)
  - Disk storage per cycle (99GB more per cycle)
    - 6.4GB (pgrb2a), 10GB (pgrb2a_bc), 4GB (pgrb2a_an)
    - 28GB (pgrb2ap5, redistributed variables)
    - 44GB (pgrb2ap5_bc, new for GEFS and CMC)
    - 24GB (pgrb2ap5_an, new for GEFS and CMC)
    - 2GB (pecp_gb2, ndgd_prcp_gb2, new for precipitation)

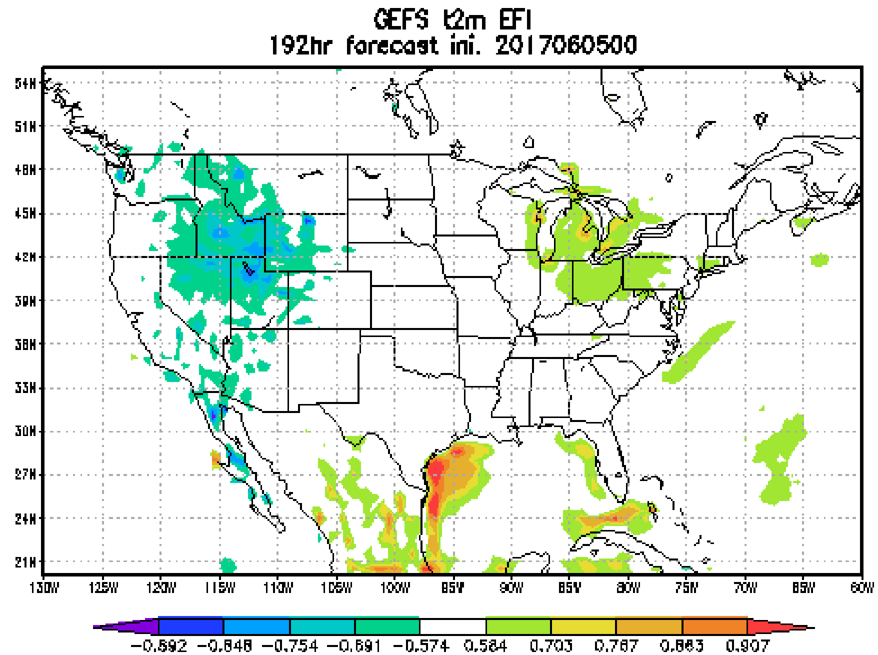
Output Size Comparison NAEFS prod vs. NAEFS v6

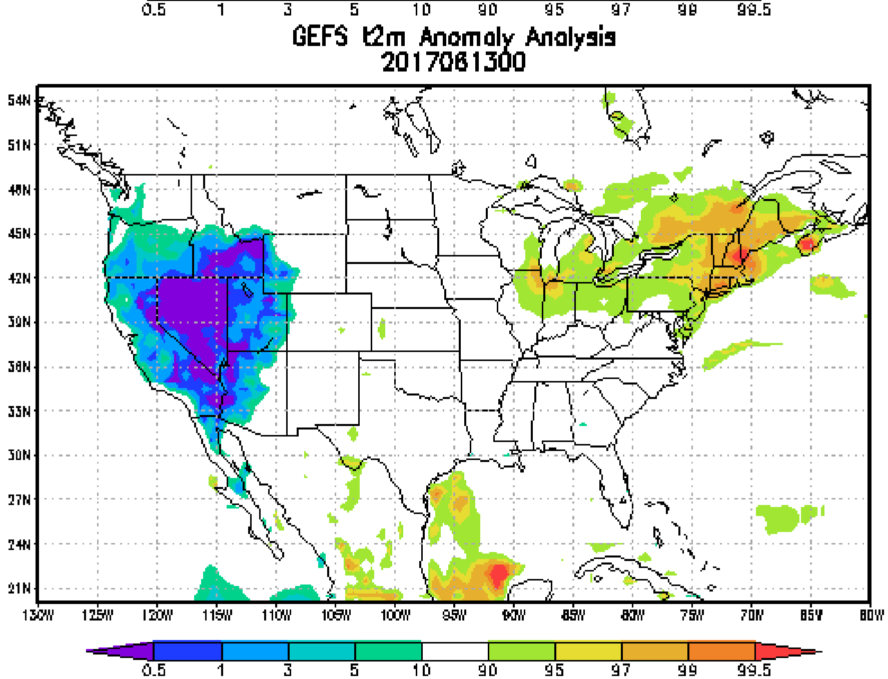
- NAEFS Prod
  - NCEP/GEFS
    - 1.0d bias corrected forecasts (6 hourly, pgrb2a_bc, 4.8GB)
    - 1.0d anomaly forecast (pgrb2a_an, 2GB)
  - CMC
    - 1.0d raw GEFS forecast (pgrb2a, 4.2GB)
    - 1.0d bias corrected forecast (/dcom, 3GB)
  - NAEFS
    - 1.0d probabilistic forecasts (pgrb2a_bc, 944MB)
    - 1.0d anomaly forecast (pgrb2a_an, 69M)
- NAEFS v6
  - NCEP/GEFS
    - 0.5d bias corrected forecasts (3 hourly for day 8, new pgrb2ap5_bc, 22GB)
    - 0.5d anomaly forecast (new pgrb2ap5_an, 10GB)
    - 0.5d bias corrected prcp (prcp_gb2, 1GB)
    - 2.5km bias corrected and downscaled prcp for CONUS (new ndgd_prcp_gb2, 1GB)
  - CMC
    - 0.5d raw GEFS forecast (new pgrb2ap5, 28GB)
    - 0.5d bias corrected forecast (/dcom, 21GB)
  - NAEFS
    - 0.5d probabilistic forecasts (new pgrb2ap5_bc, 4GB)
    - 0.5d anomaly forecast (new pgrb2ap5_an, 1GB)

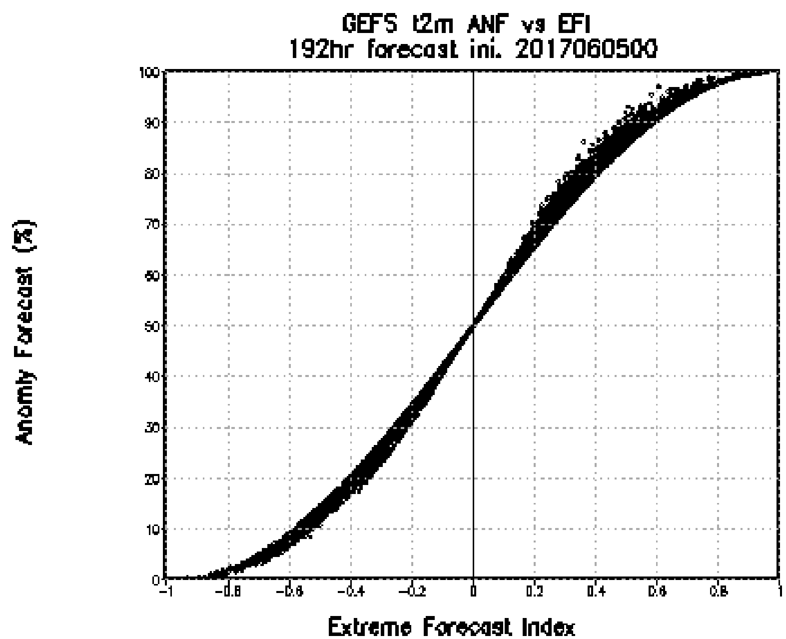
Extra slides!!!

Demonstration of Animation (valid for 2017060500)









Input/Output Changes

- Current:
  - Input & Output : 1x1 degree global fields

- Future:
  - Input - 0.5d global ensemble data
    - NCEP (re-organized pgrb2ap5) and CMC
    - Raw and bias corrected forecast
  - Output – 0.5d global ensemble data
    - NCEP
      - reorganized pgrb2ap5 (raw) and pgrb2bp5 (raw) for public (TIN)
      - new pgrb2ap5_bc for public replace pgrb2a_bc (TIN)
      - prcp_gb2 for 0.5d bias corrected prcp (TIN)
      - new ndgd_prcp_gb2 for 0.5d bias corrected and downscaled prcp
      - ensstat (???)
    - CMC
      - 0.5d raw GEFS forecast for public replace pgrb2a (TIN)
      - 0.5d bias corrected forecast for public (new)
    - NAEFS
      - new pgrb2ap5_bc & pgrb2ap5_an to replace pgrb2a_bc & pgrb2a_an (TIN)

Ensemble Output Size Estimation for NAEFS v6

- NCEP/GEFS
  - 0.5d bias corrected forecasts (3 hourly for day 8, new pgrb2ap5_bc, 22GB)
  - 0.5d anomaly forecast (new pgrb2ap5_an, 10GB)
  - 0.5d bias corrected prcp (prcp_gb2, 1GB)
  - 2.5km bias corrected and downscaled prcp for CONUS (new ndgd_prcp_gb2, 1GB)
- CMC
  - 0.5d raw GEFS forecast (/dcom, 28GB)
  - 0.5d bias corrected forecast (/dcom, 21GB)
- NAEFS
  - 0.5d probabilistic forecasts (new pgrb2ap5_bc, 4GB)
  - 0.5d anomaly forecast (new pgrb2ap5_an, 1GB)