THORPEX Proposal

Extensions and Improvements to the NAEFS Post-Processor at NCEP/EMC

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Outline

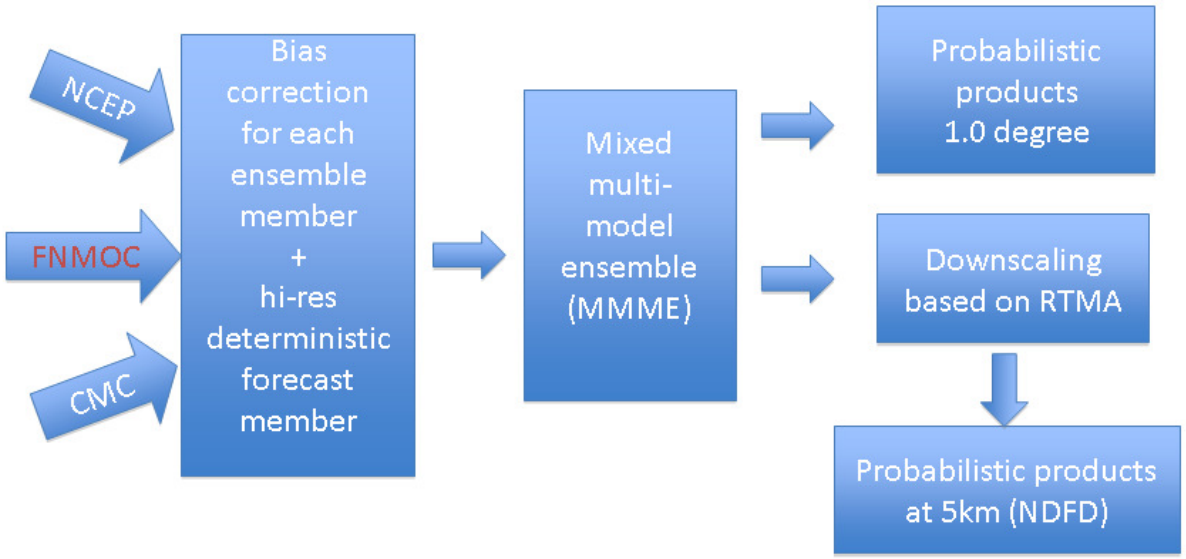
- Background
  - North American Ensemble Forecast System (NAEFS) and THORPEX
  - Current NCEP/EMC post-processing system
- Statistical Post-Processing Techniques in NAEFS
  - Effect of bias-correction
  - Impact of combined ensembles (NAEFS)
  - Challenge of reforecast for week-2 forecast improvement
  - Effect of statistical downscaling
- Further Development of Statistical Post-Processing for NAEFS
  - Future configuration of EMC ensemble post-processor

NCEP/EMC Statistical Post-Processing for NAEFS

- North American Ensemble Forecast System (NAEFS)
  - Operational multi-center ensemble forecast system, global ensemble forecasts from NWS and Meteorological Service of Canada (MSC), first established in 2004 at NCEP
  - NCEP operational counterpart to THORPEX/TIGGE
  - Positive impact for all participants

- Statistical Post-Processing Issues in NAEFS
  - GOAL
    - 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
  - APPROACH – 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

Current NCEP/EMC Statistical Post-Processing System



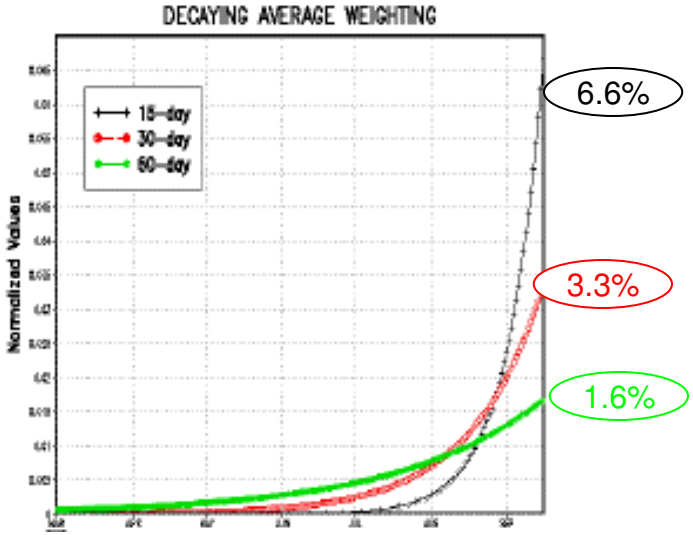
- Bias corrected NCEP/CMC GEFS and GFS forecast (up to 180 hrs), same bias correction algorithm
  - Combine bias corrected GFS and NCEP GEFS ensemble forecasts
  - Dual resolution ensemble approach for short lead time
  - GFS has higher weights at short lead time
- NAEFS products
  - Combine NCEP/GEFS (20m) and CMC/GEFS (20m), FNMOC ens. will be in soon
  - Produce Ensemble mean, spread, mode, 10% 50%(median) and 90% probability forecast at 1*1 degree resolution
  - Climate anomaly (percentile) forecasts also generated for ens. mean
- Statistical downscaling
  - Use RTMA as reference - NDGD resolution (5km), CONUS only
  - Generate mean, mode, 10%, 50%(median) and 90% probability forecasts

Bias Correction Method & Application

- **Bias Correction Techniques** – array of methods
  - Estimate/correct bias moment by moment
    - Simple approach, implemented partially
    - May be less applicable for extreme cases
- **Moment-based method at NCEP**: apply adaptive (Kalman Filter type) algorithm

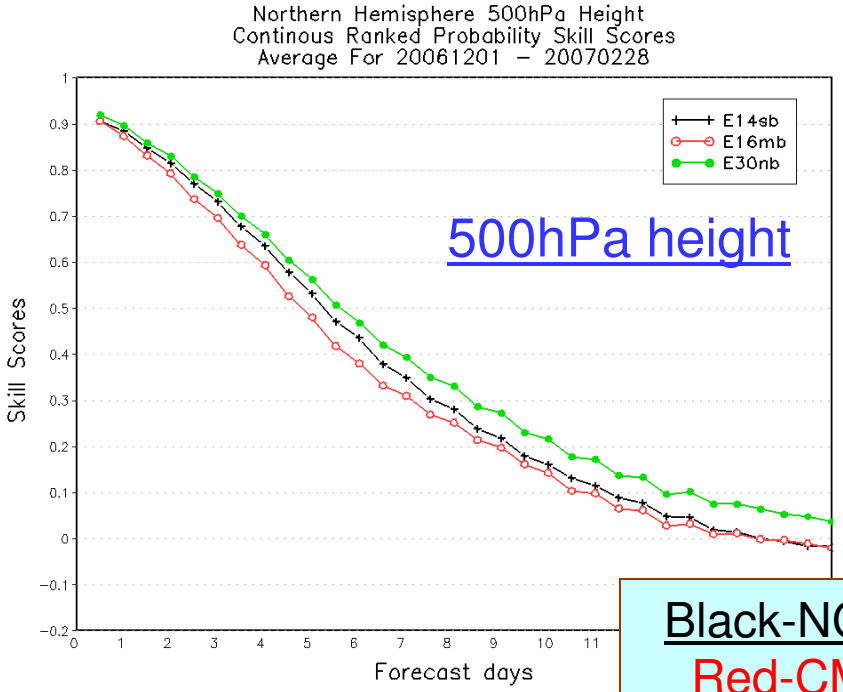
decaying averaging mean error = (1-*w*) * prior a.m.e + *w* * (f – a)

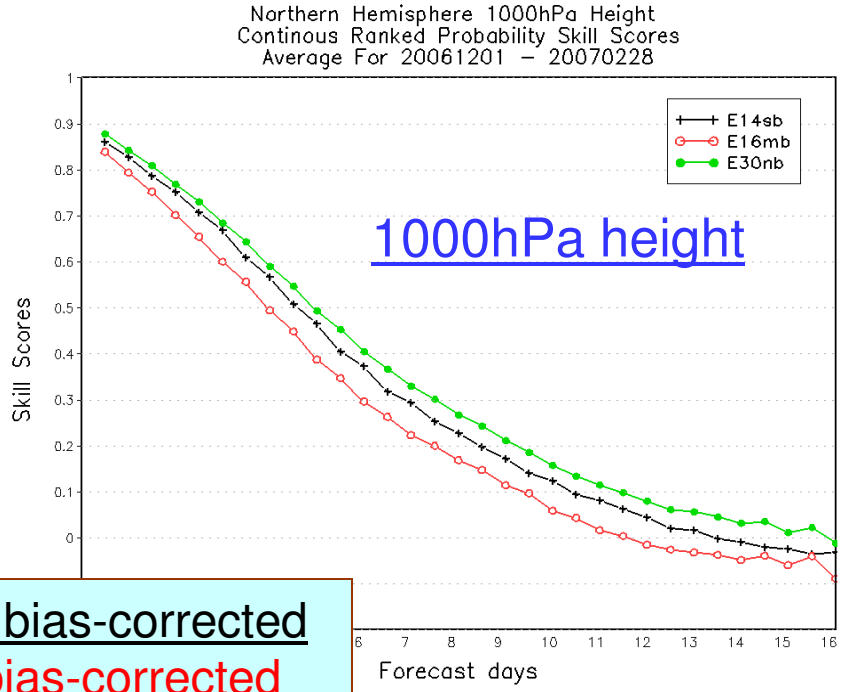
For separated cycles, each lead time and individual grid point, a.m.e = averaging mean error



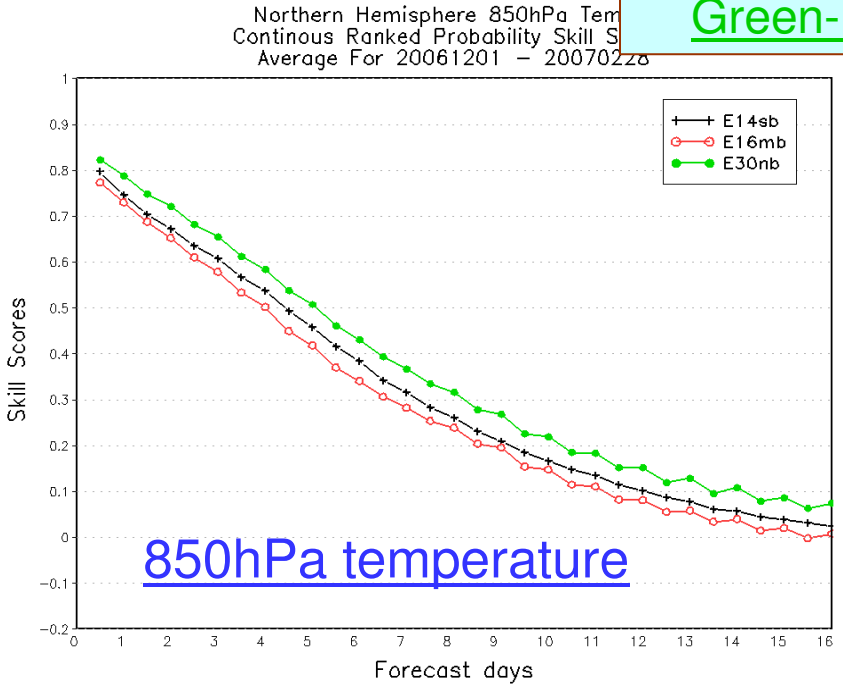
Toth, Z., and Y. Zhu, 2001

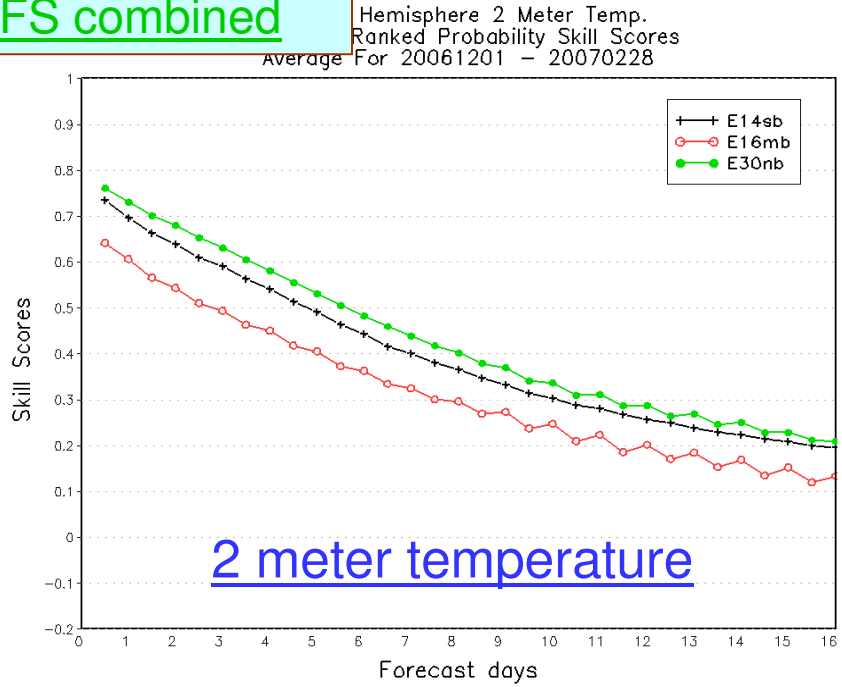
- Test different decaying weights. 0.25%, 0.5%, 1%, 2%, 5% and 10%, respectively
- Decide to use 2% (~ 50 days) decaying accumulation bias estimation

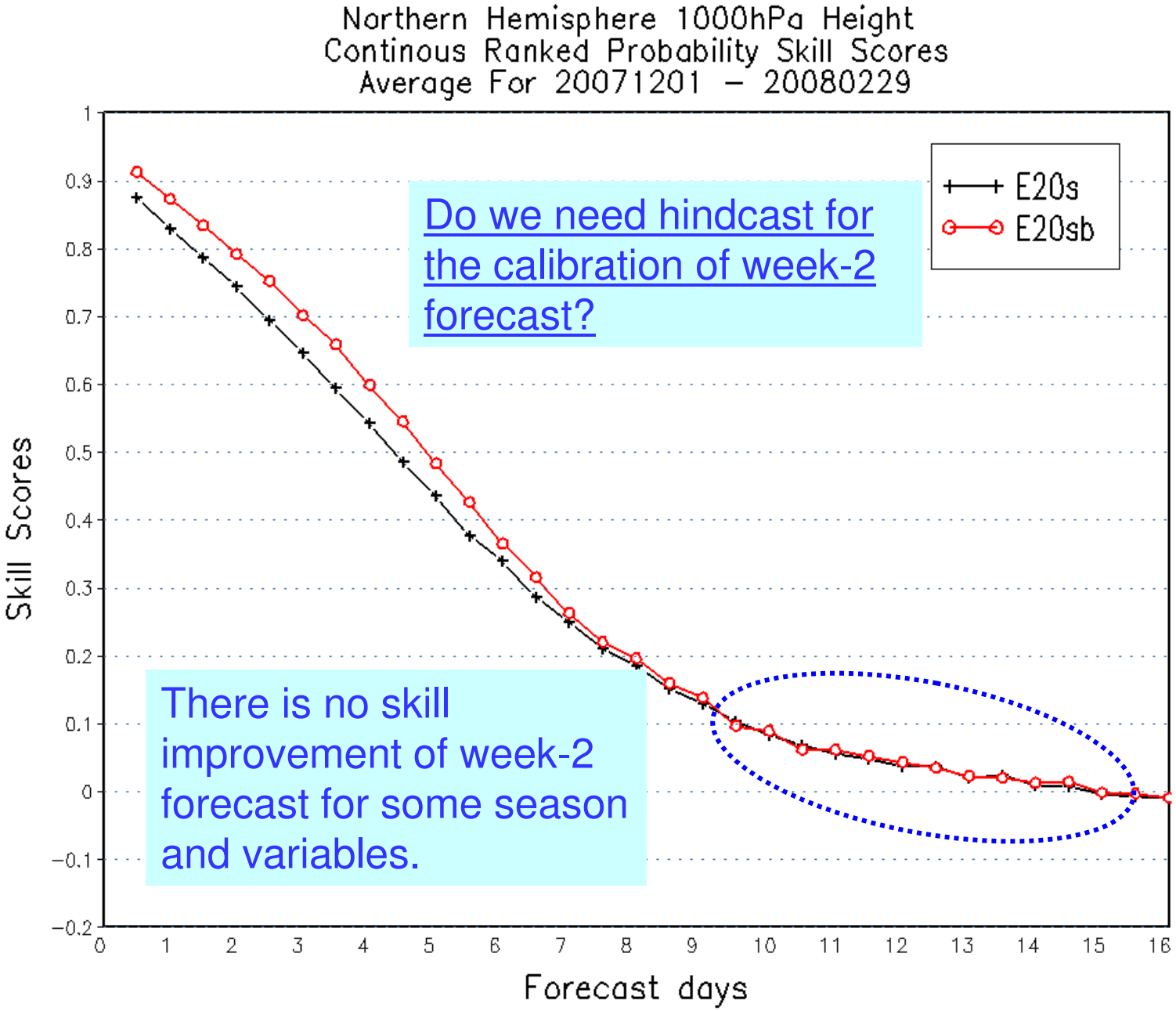




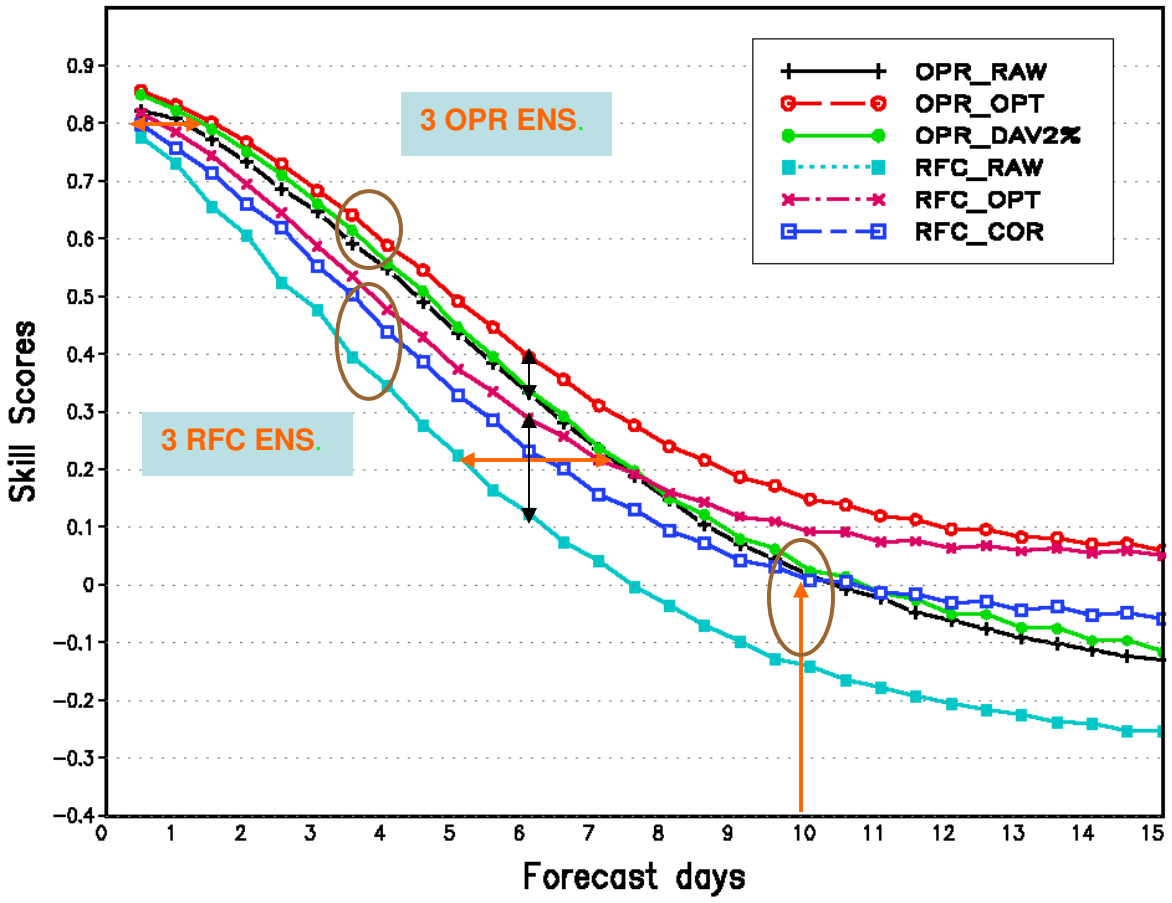
Black-NCEP bias-corrected
Red-CMC bias-corrected
Green-NAEFS combined






Northern Hemisphere 1000hPa Height
Continous Ranked Probability Skill Scores
Average For 20071201 – 20080229
Skill Scores
Forecast days
E20s
E20sb
Do we need hindcast for the calibration of week-2 forecast?
There is no skill improvement of week-2 forecast for some season and variables.

Comparison between Operational and Reforecast Ensembles



Annual Mean RPSS (20040301 – 20050228)

500 mb Height over Northern Hemisphere

Black-NCEP Raw

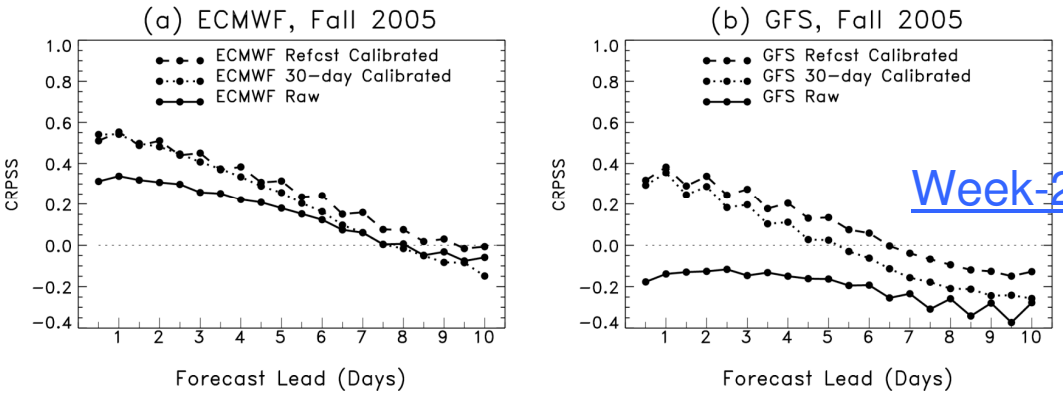
Green- NCEP Bias-Corrected

Blue-Calibrated Reforecast

(Remove 25-yr climatological mean forecast errors, 1998 modeling system, Hamill & Whitaker)

- Operational vs. reforecast ens.

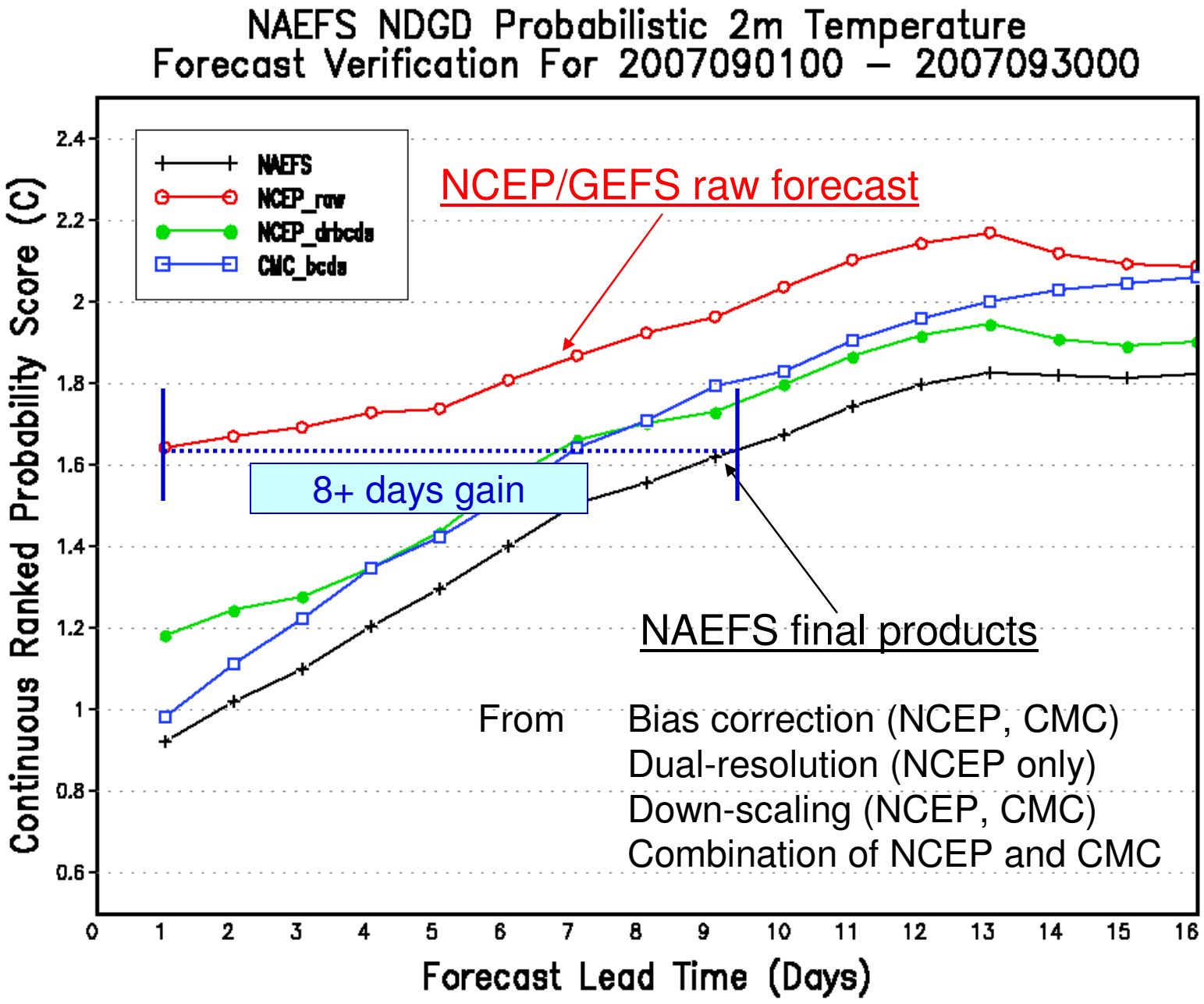
Operational forecasts (with or without bias correction) are better than the calibrated reforecast out to 9 - 10 days. Beyond 10 days, calibrated reforecast becomes competitive to or better than operational forecasts



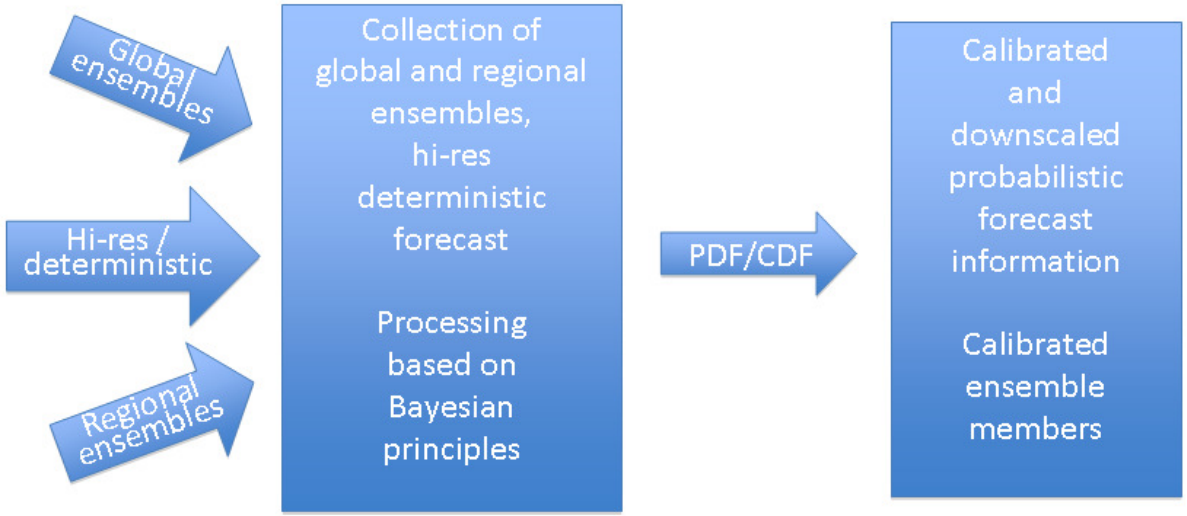
Week-2 improvement, Hamill et. al

Statistical downscaling for NAEFS forecast

- Proxy for truth
  - *RTMA* at 5km resolution
  - Variables (surface pressure, 2-m temperature, and 10-meter wind)
- Downscaling vector
  - Interpolate GDAS analysis to 5km resolution
  - Compare difference between interpolated GDAS and RTMA
  - Apply *decaying weight* to accumulate this difference – *downscaling vector*
- Downscaled forecast
  - Interpolate bias corrected 1*1 degree NAEFS to 5km resolution
  - Add the downscaling vector to interpolated NAEFS forecast
- Application
  - Ensemble mean, mode, 10%, 50%(median) and 90% forecasts


NAEFS NDGD Probabilistic 2m Temperature
Forecast Verification For 2007090100 – 2007093000
NAEFS
NCEP_raw
NCEP_drbcds
CMC_bcds
NCEP/GEFS raw forecast
8+ days gain
NAEFS final products
From
Bias correction (NCEP, CMC)
Dual-resolution (NCEP only)
Down-scaling (NCEP, CMC)
Combination of NCEP and CMC
Continuous Ranked Probability Score (C)
Forecast Lead Time (Days)
BO CUI, GCWMB/EMC/NCEP/NOAA

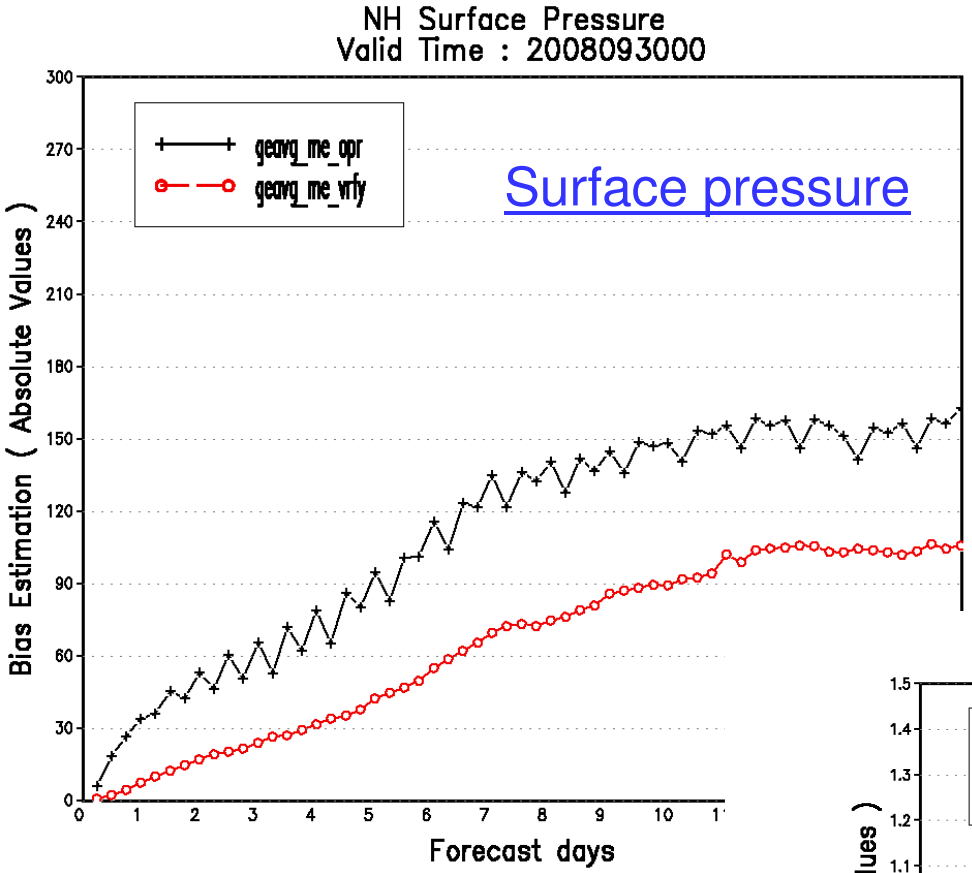
Development of Statistical Post-Processing for NAEFS



Future Configuration of EMC Ensemble Post-Processor

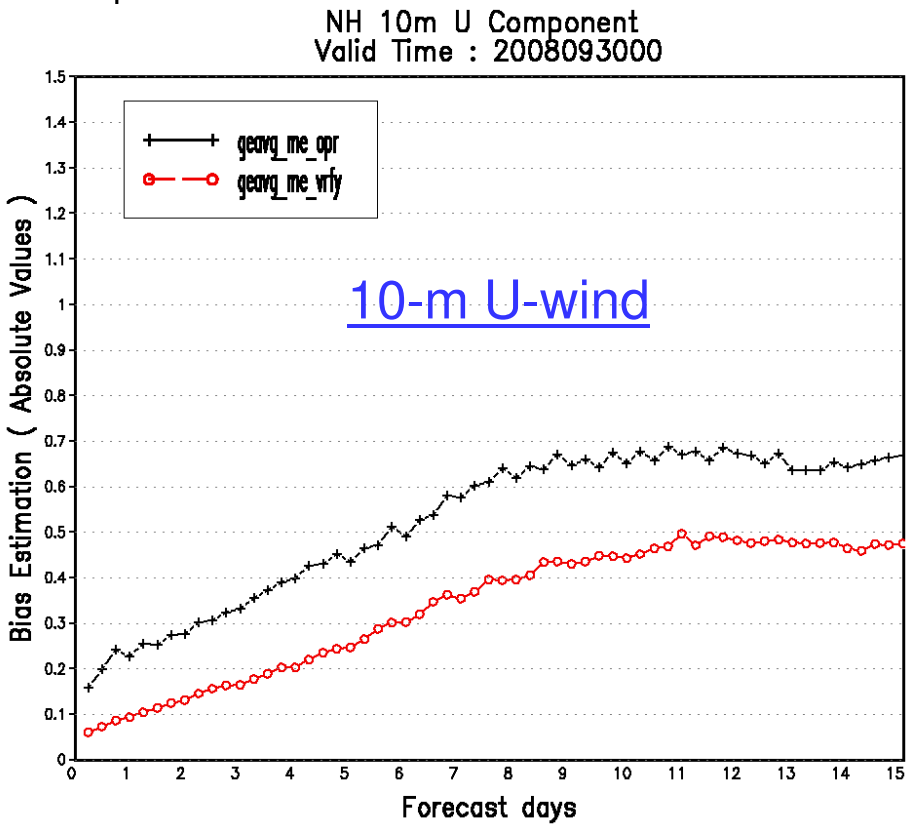
- Opportunities for improving the post-processor
  - Utilization of additional input information
    - More ensemble, high resolution control forecasts (hybrid?)
    - Using reforecast information to improve week-2 forecast and precipitation
    - Analysis field (such as RTMA and etc..)
  - Improving calibration technique
    - Calibration of higher moments (especially spread)
    - Use of objective weighting in input fields combination
    - Processing of additional variables with non-Gaussian distribution
  - Improve downscaling methods

Background



Surface pressure

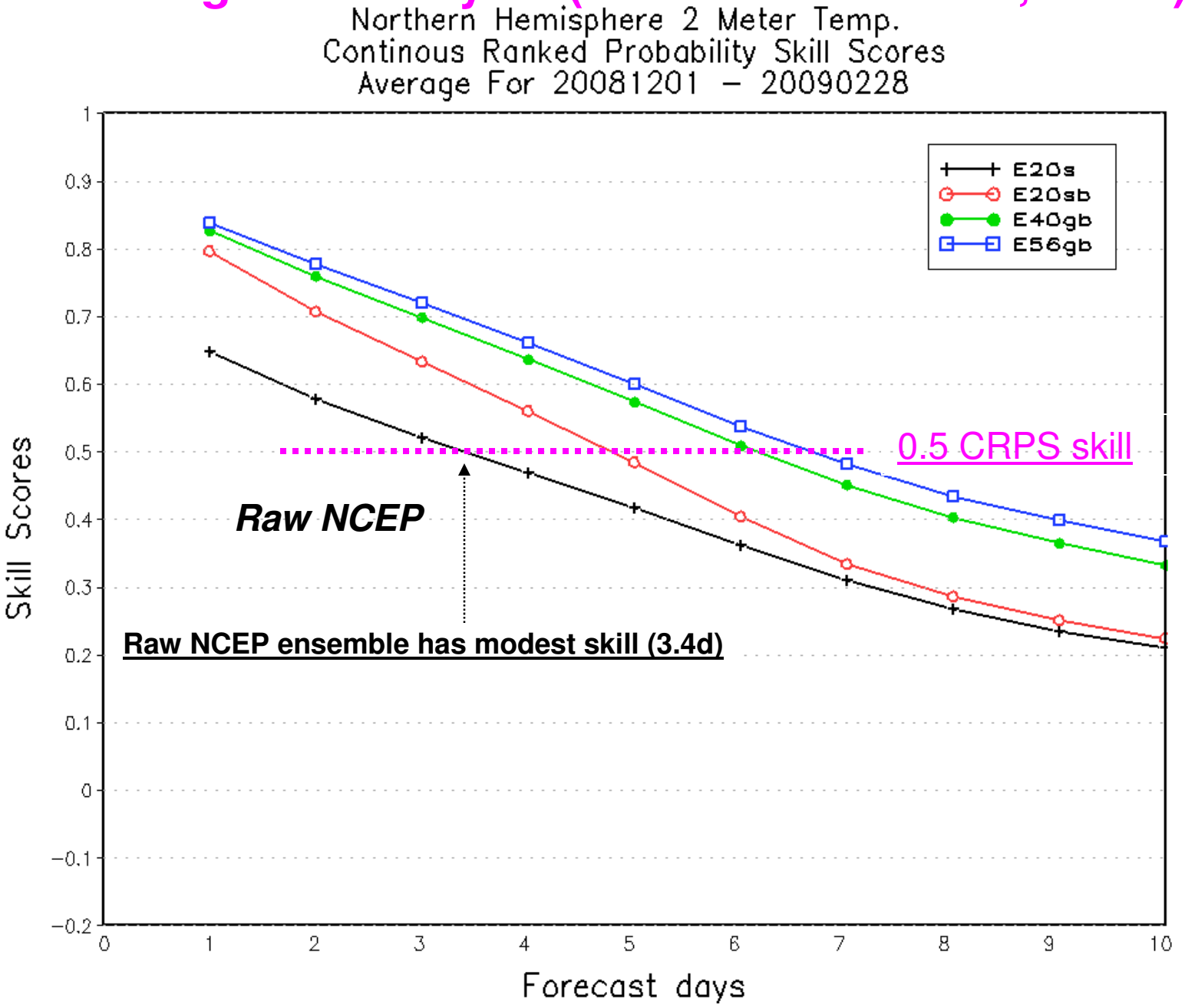
0.02 weight decaying average, updating every day



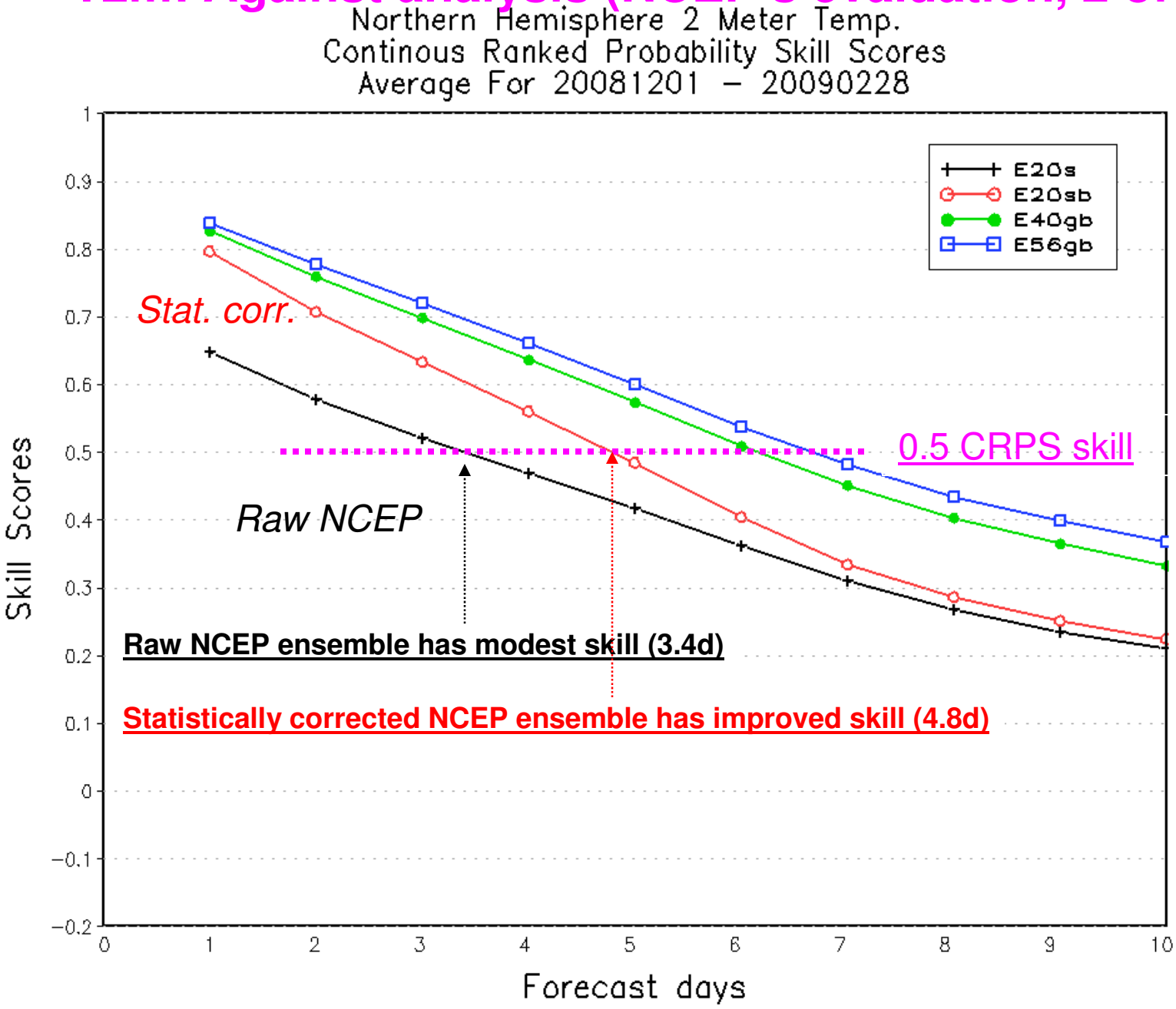
10-m U-wind

For all 35 bias corrected variables

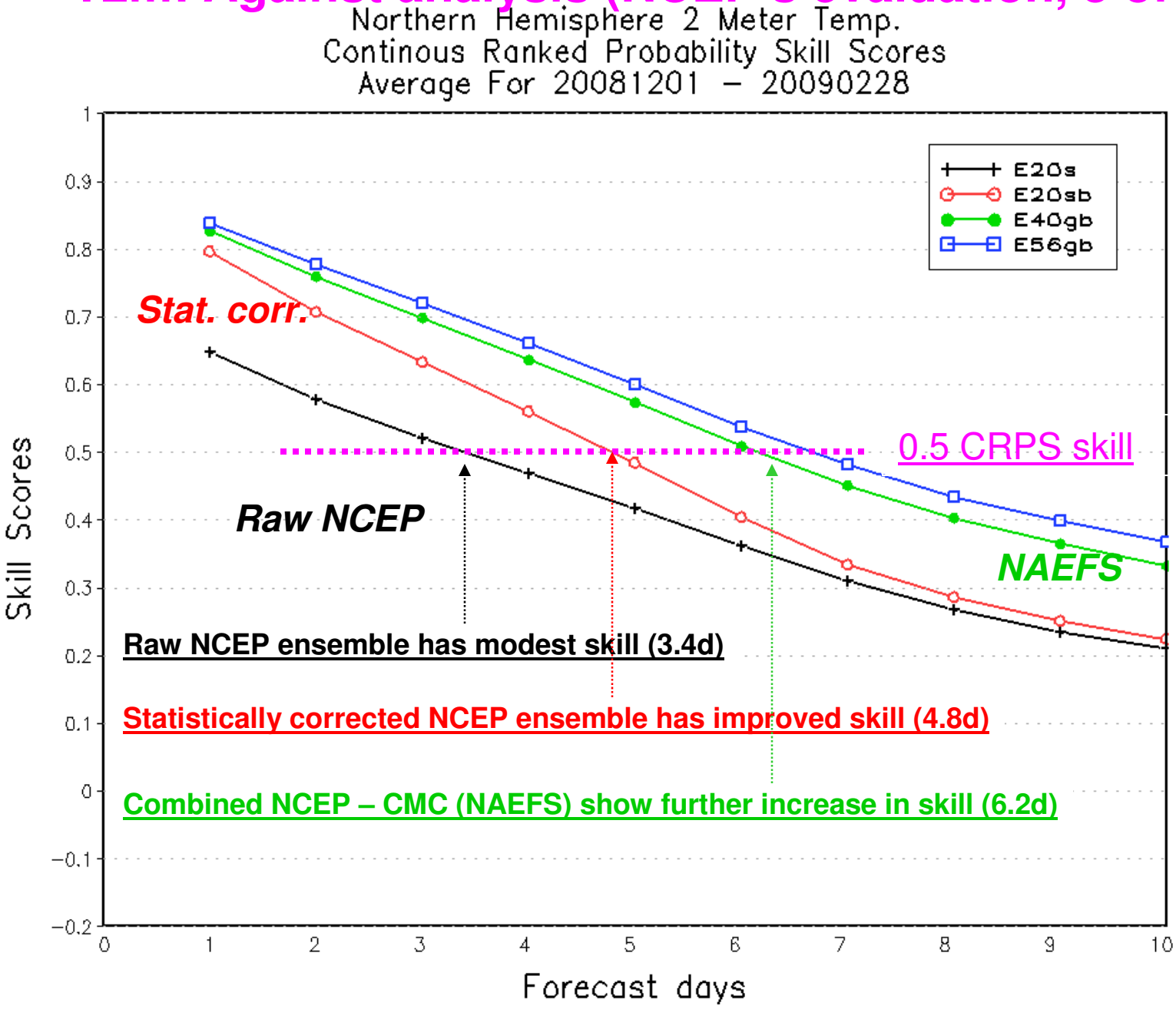
Value-added by including FNMOC ensemble into NAEFS
T2m: Against analysis (NCEP's evaluation, 1 of 4)



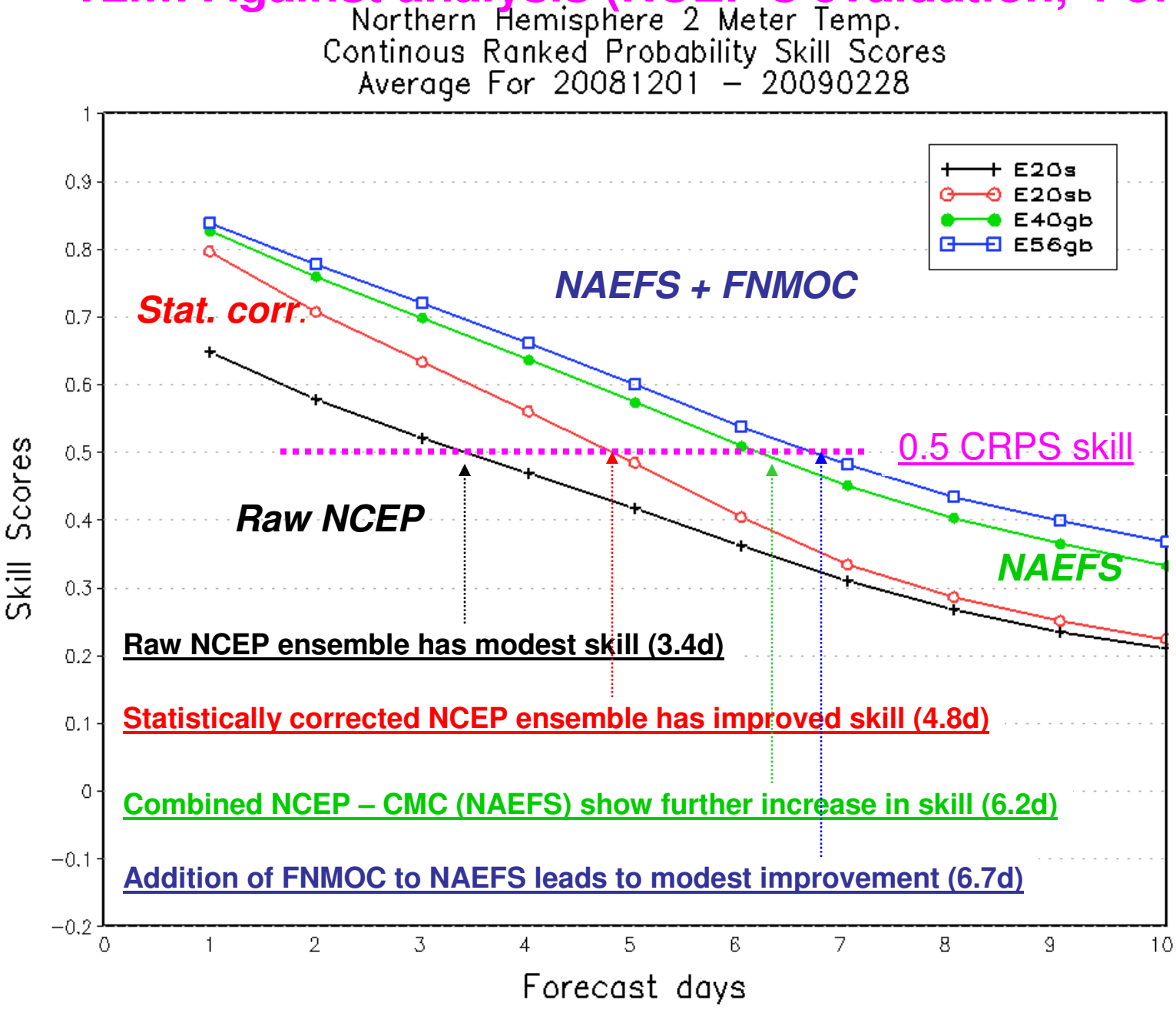
Value-added by including FNMOC ensemble into NAEFS
T2m: Against analysis (NCEP's evaluation, 2 of 4)



Value-added by including FNMOC ensemble into NAEFS
T2m: Against analysis (NCEP's evaluation, 3 of 4)



Value-added by including FNMOC ensemble into NAEFS
T2m: Against analysis (NCEP's evaluation, 4 of 4)



Proposed Research and Application at NCEP

- **Year 1**
  - Implement downscaled NAEFS forecasts for Alaska domain (6-hrly output to 16 days), including additional new near-surface variables (2m min/max & 10m wind speed and direction)
  - Implement new NAEFS by adding FNMOC global ensemble with bias correction (6-hrly output to 16 days)
  - Begin experiments using real-time reforecast data
- **Year 2**
  - Implement downscaled forecast for other regions (Hawaii, Guam, and Puerto Rico)
  - Implement new QPF bias correction at 1 by 1 degree resolution 6-hrly output to 16 days and generate PQPF for various threats (0.1mm, 1mm and etc.)
  - Implement statistical downscaling QPF to 5km for CONUS based on bias corrected QPF forecasts and generate PQPF for various threads
- **Year 3**
  - Upgrade downscaled NAEFS forecasts for resolution change and new variables
  - Implement calibrated precipitation forecast with 2nd moment adjustment

Schedule of Experiments at ESRL

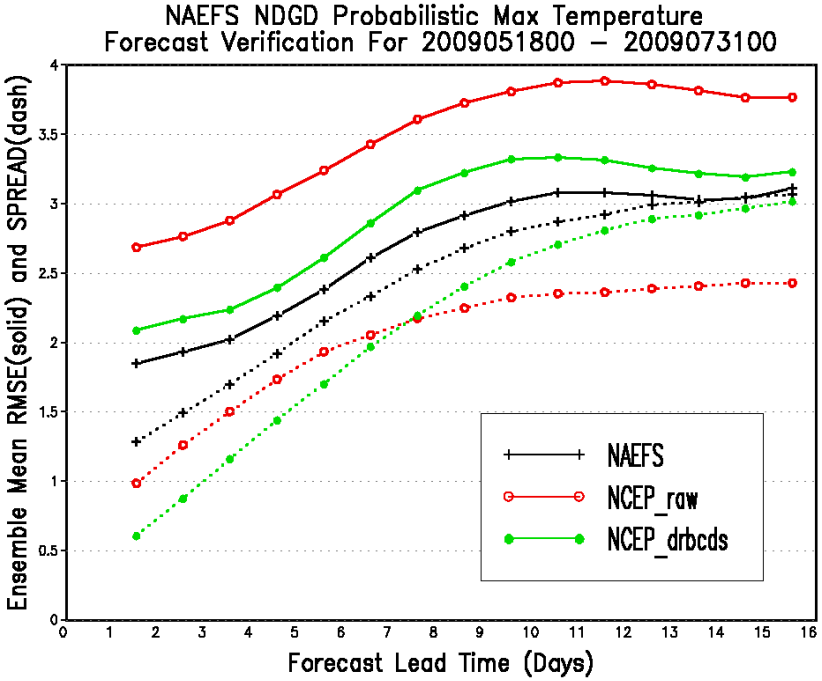
- **Year 1**
  - Begin tests on Bayesian processor. Demonstrate basic capabilities for bias correction and combination of disparate forecasts.
  - Test pseudo-precipitation as a method for conditioning the QPF variable to be continuous in space and amenable for use with a Bayesian processor.
- **Year 2**
  - Demonstrate agreement between adjustment of ensemble members and posterior PDF from Bayesian preprocessor.
  - Develop one or more "weather generators" to add subgrid-scale variance to coarse-grid forecasts.
  - Combine pseudo-precipitation and the new EMC/CDC precipitation climatology; evaluate effectiveness at forecasting extreme events with Bayesian processor.
  - Engage with MDL to define predictands and post-processing matrix for comparison (data, lead time, etc).
- **Year 3**
  - Demonstrate that the downscaled products exhibit the same calibration attributes as the coarse-grid ensemble.
  - Demonstrate any value added by real-time re-forecasting relative to the fixed-model approach now in operations.
  - Evaluate proposed methods for intercomparisons, jointly with ESRL/PSD, and pending MDL's participation.
  - Summarize the results and produce couple journal publications.

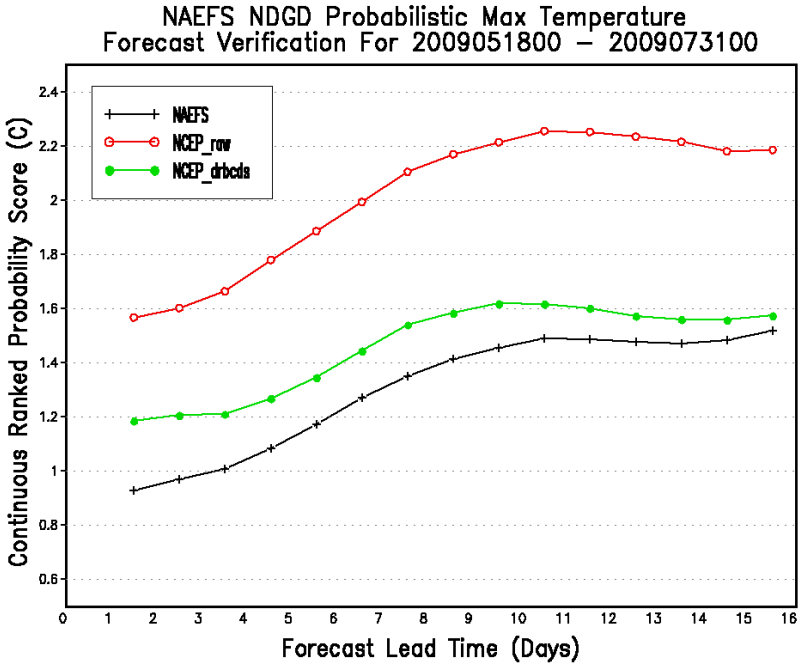
Proposed Research and Development

- Improve bias correction / forecast combination scheme
  - Developing and testing statistical post-processing techniques based on Bayesian principles to address some of the shortcomings of current NAEFS system
- Adjust ensemble forecasts: a simple “frequency matching”-type method
  - Point by point, the ordered series of ens. values are moved, represent the posterior distribution from last step
  - Preserve the ranks within the ens., providing useful forecast covariance information (i.e., joint probabilities, etc)
- Improve downscaling methods, generate more variables on NDFD scale
  - Real Time Mesoscale Analysis (RTMA) as proxy for truth
  - Develop methods to impart variance related to the scales not resolved by the NWP forecasts
- Special emphasis on precipitation, introduce pseudo-precipitation (PP)
  - PP equal to precipitation when larger than zero, and proportional to the moisture deficit with respect to saturation in a column of air
  - Explore alternative methods (e.g., Yuan et al. 2007 and Yuan et al. 2008) in case PP-based precipitation processing is not viable

Proposed Research and Development

- Use of reforecast, real time reforecast experiment
  - ECMWF: good results using a strategy of running reforecasts (or hindcasts) in real time
    - Same model used for operational forecasting
  - EMC: comparison of regime-dependent and climate mean bias correction techniques
    - Regime-dependent (with small sample) bias correction works better at short lead times
    - Climate-mean method (with much larger sample) works better at long lead times
  - Benefit from new high-resolution reforecast dataset developed by NCEP/EMC
    - Test post-processing methodology, compare with calibration method at ESRL/PSD
- Intercomparisons and collaborations
  - NWS: Unified Ensemble Post-processing System (NUEPS)
    - Produce guidance for Weather Information Database (WIDB)
  - NCAR/Developmental Testbed Center (DTC) and NOAA/ESRL: DTC Ensemble Testbed (DET)
    - NUEPS and DET program facilitate comparisons/ testing of multiple post-processing methods
    - An alternative dataset to the NAEFS for developing bias correction techniques
  - NOAA/ Meteorological Development Lab (MDL)
    - Model Output Statistics (MOS) produce site-specific guidance
    - Gridded MOS (GMOS) and Ensemble Kernel Density MOS (EKDMOS)
      - EKDMOS produce a forecast PDF / cumulative distribution function (CDF)
  - NAEFS post-processing focuses on gridded data
    - Compare bias correction procedure
      - Using the NAEFS system and DET data
      - Compare with available algorithms developed at MDL


NAEFS NDGD Probabilistic Max Temperature
Forecast Verification For 2009051800 – 2009073100
Ensemble Mean RMSE(solid) and SPREAD(dash)
Forecast Lead Time (Days)
NAEFS
NCEP_raw
NCEP_drbcds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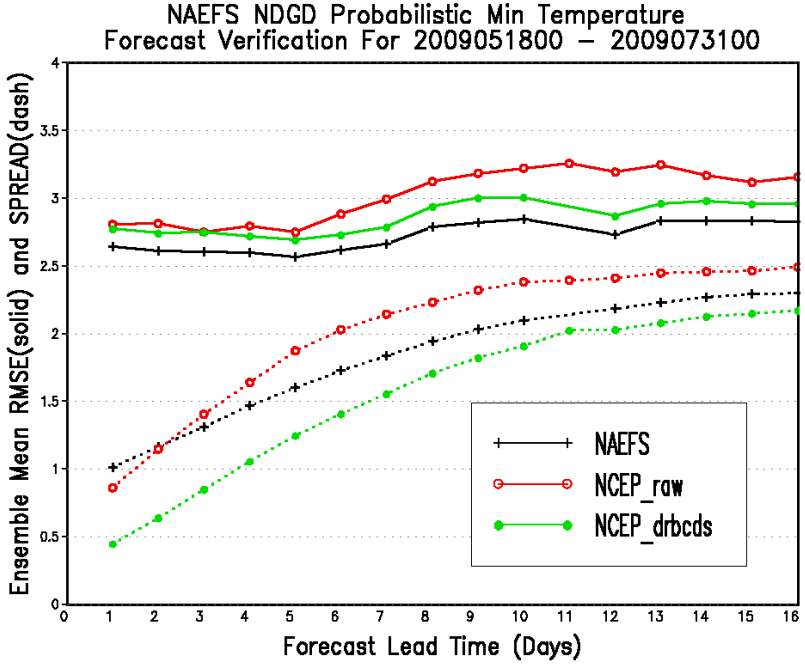
NAEFS NDGD Probabilistic Min Temperature
Forecast Verification For 2009051800 – 2009073100
Ensemble Mean RMSE(solid) and SPREAD(dash)
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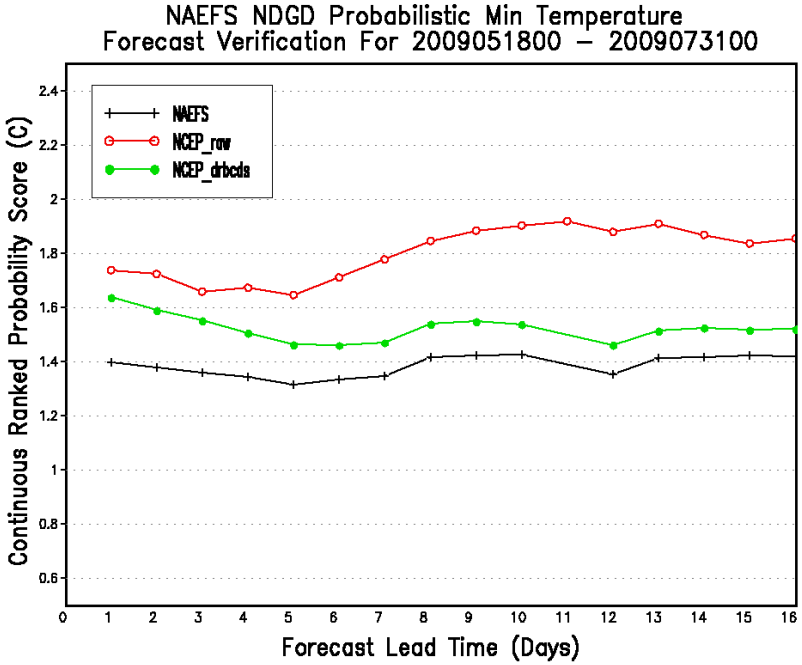
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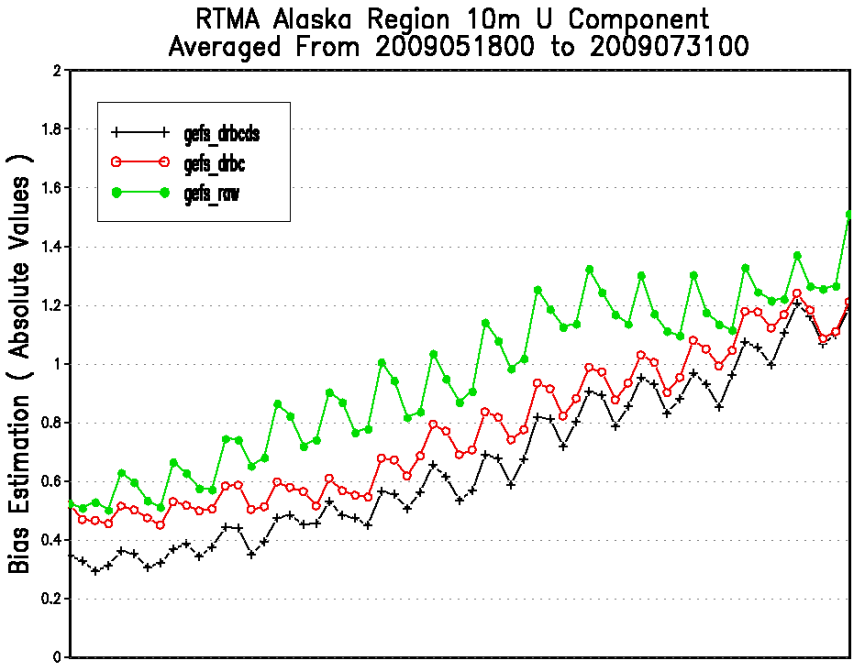

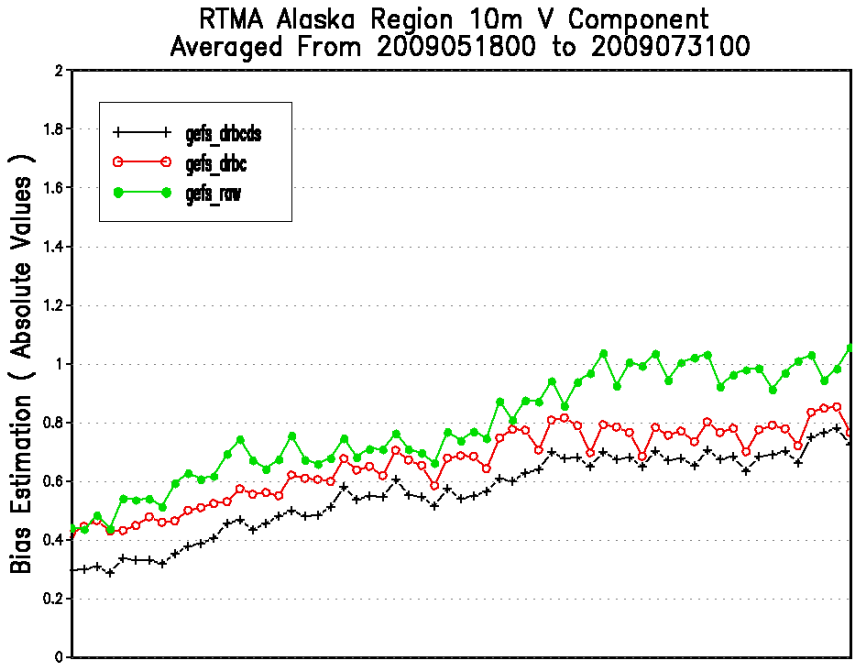

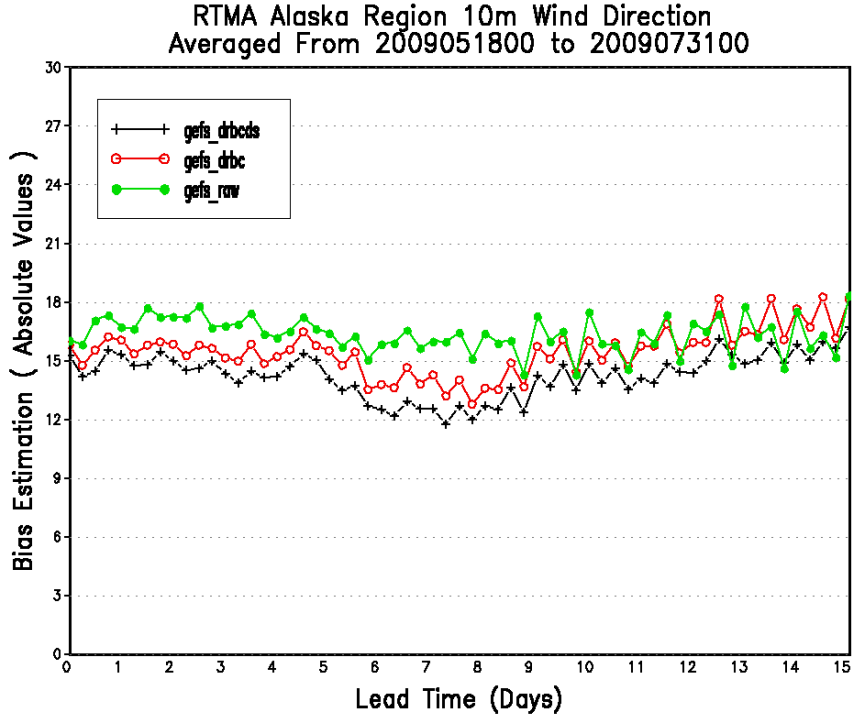

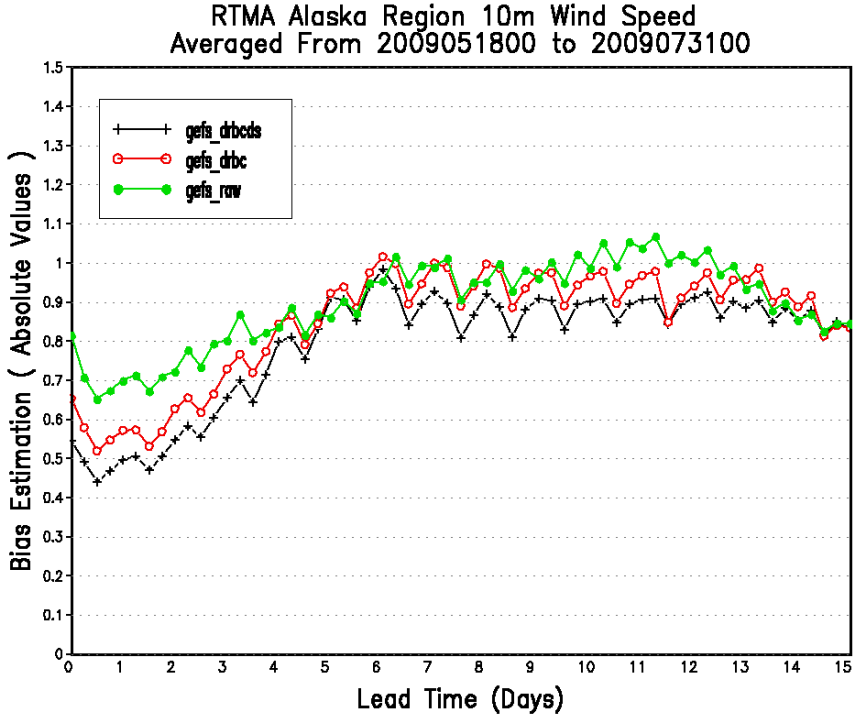

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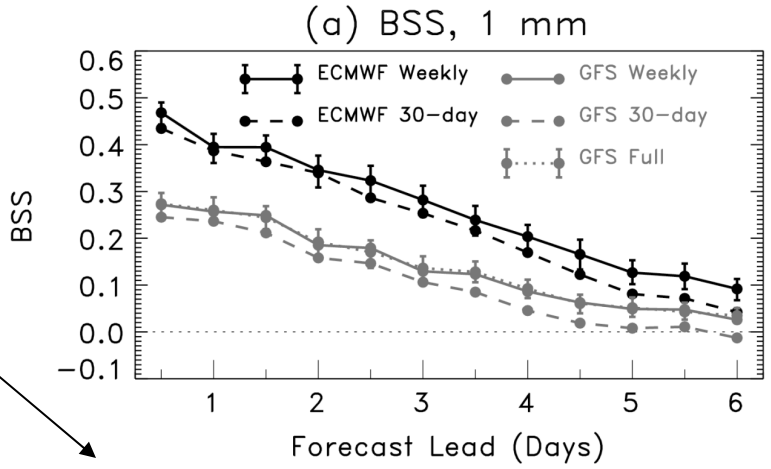
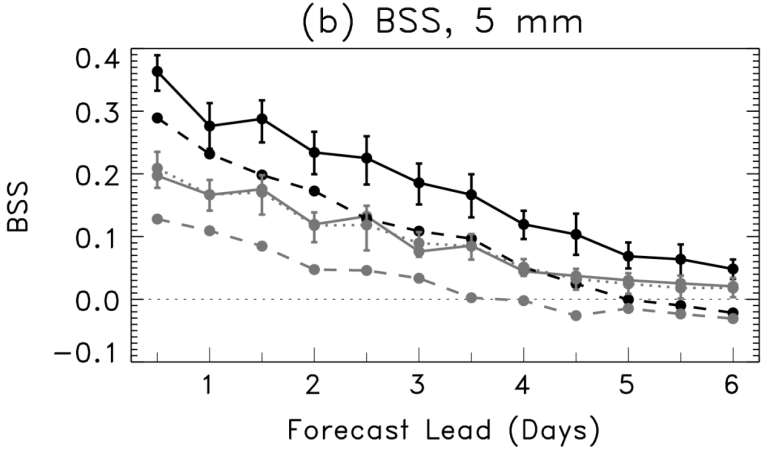
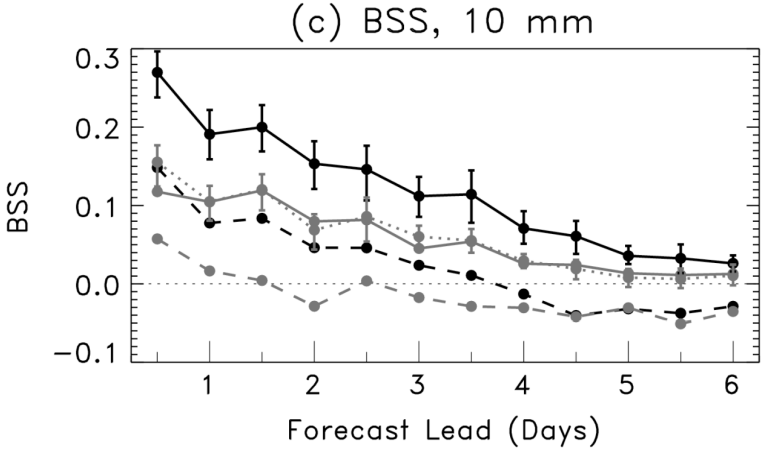
Precipitation

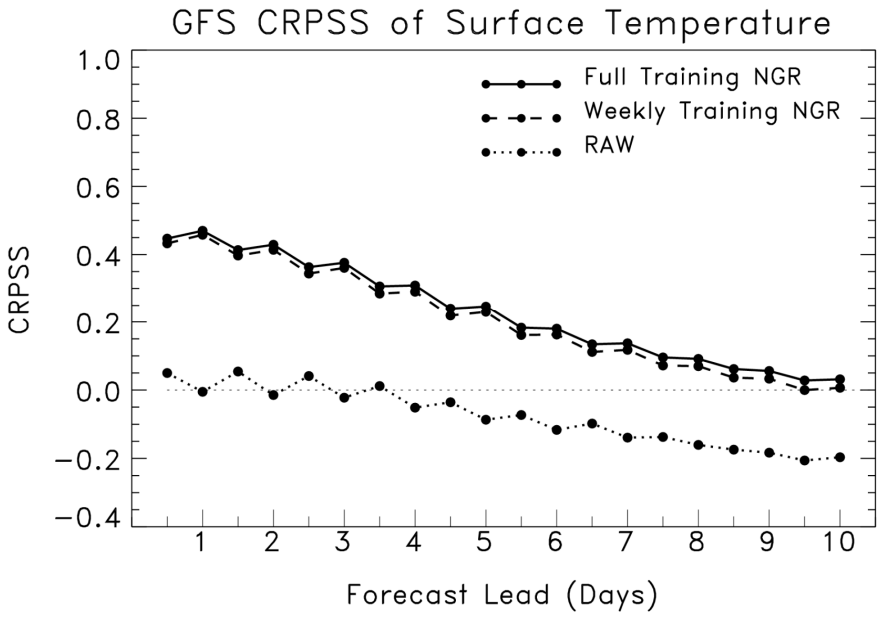
Early study (Hamill Et al..): Comparison of large samples to small samples

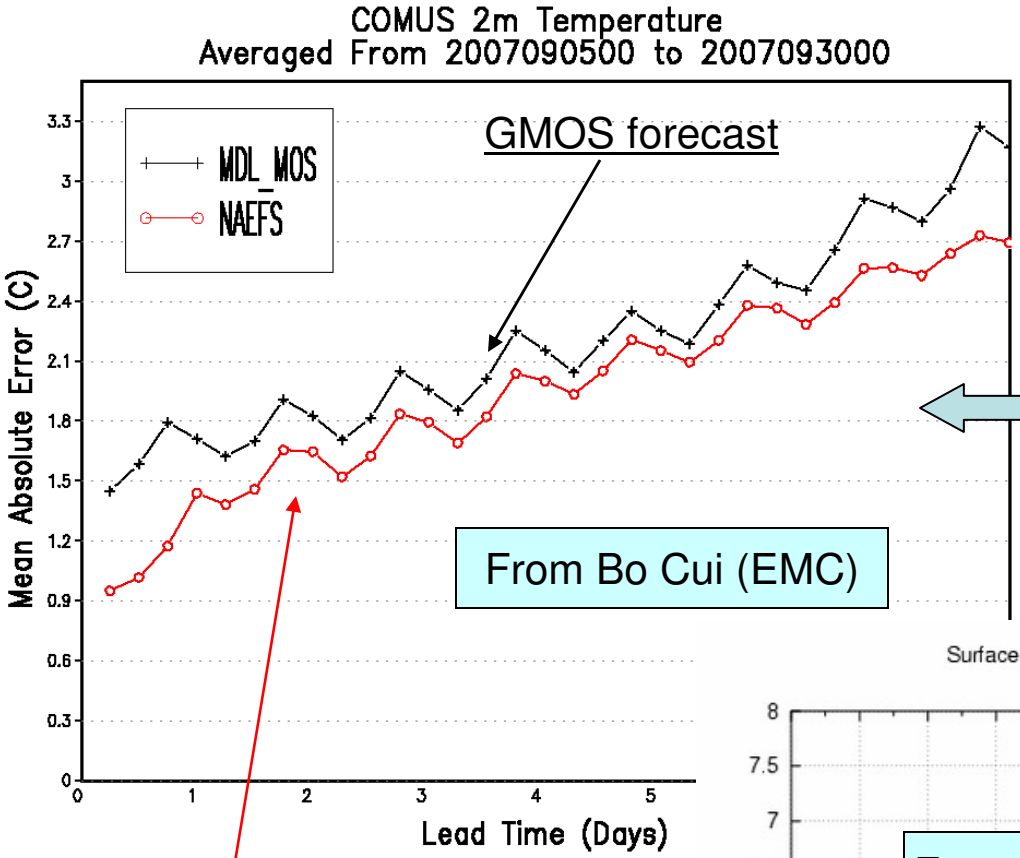






Surface temperature





GMOS forecast

From Bo Cui (EMC)

NAEFS final products

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

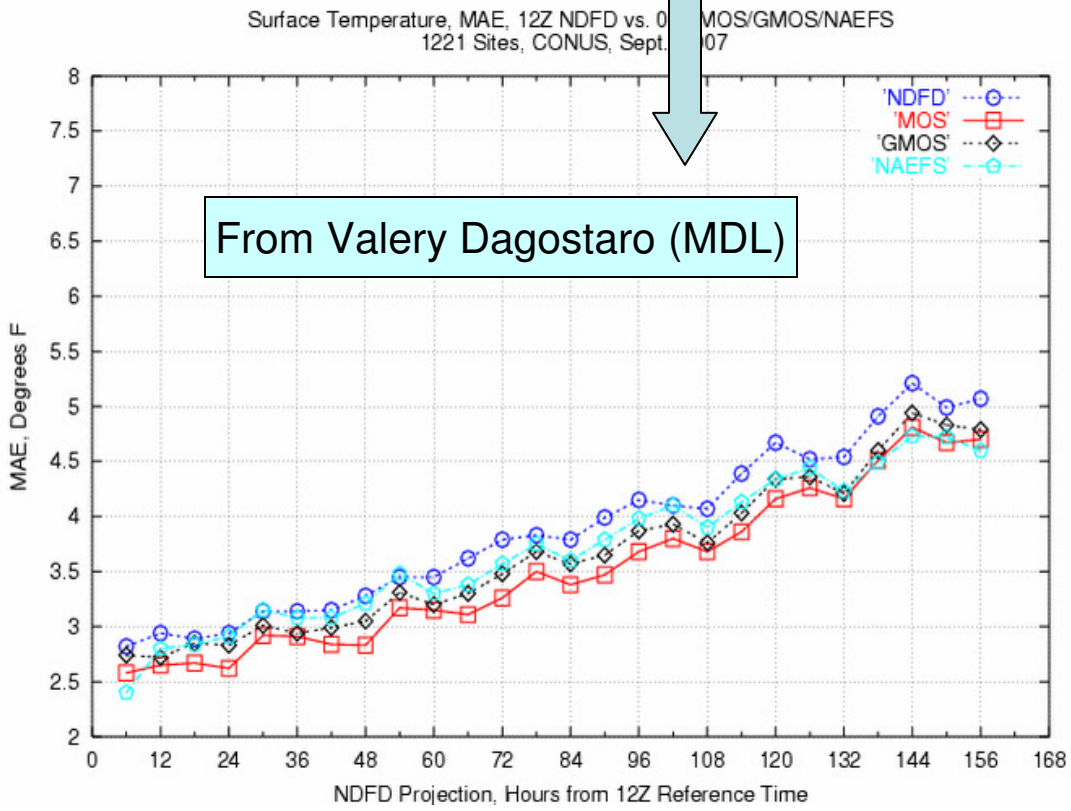
CONUS 2m Temperature

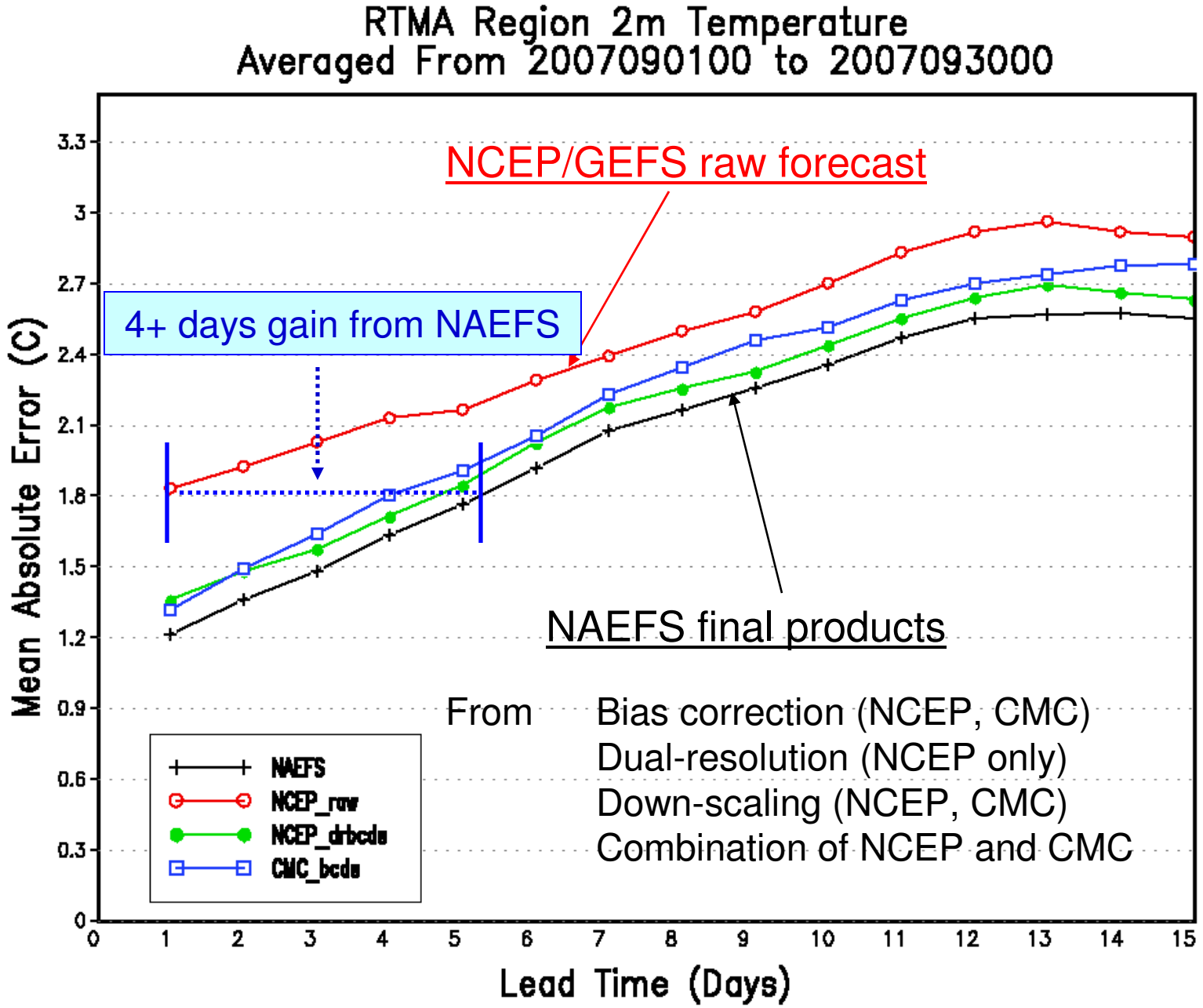
For September 2007

Verify against RTMA

Verify against observation

From Valery Dagostaro (MDL)





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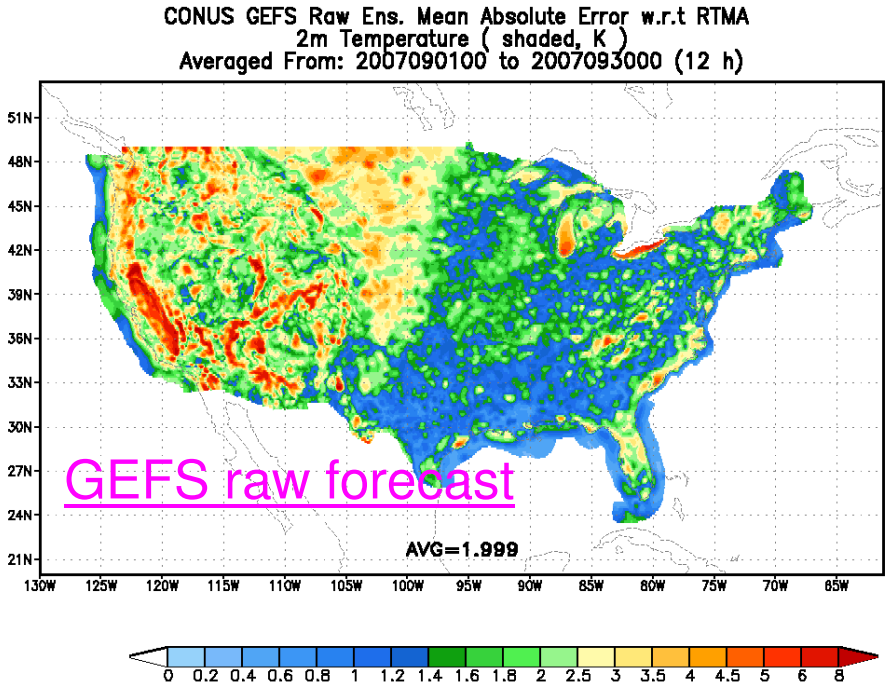

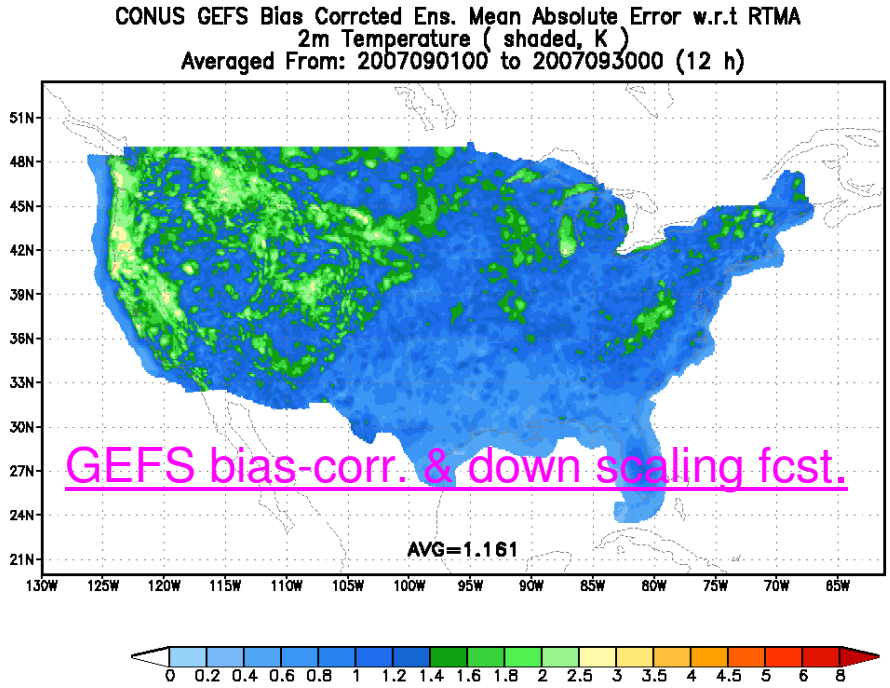

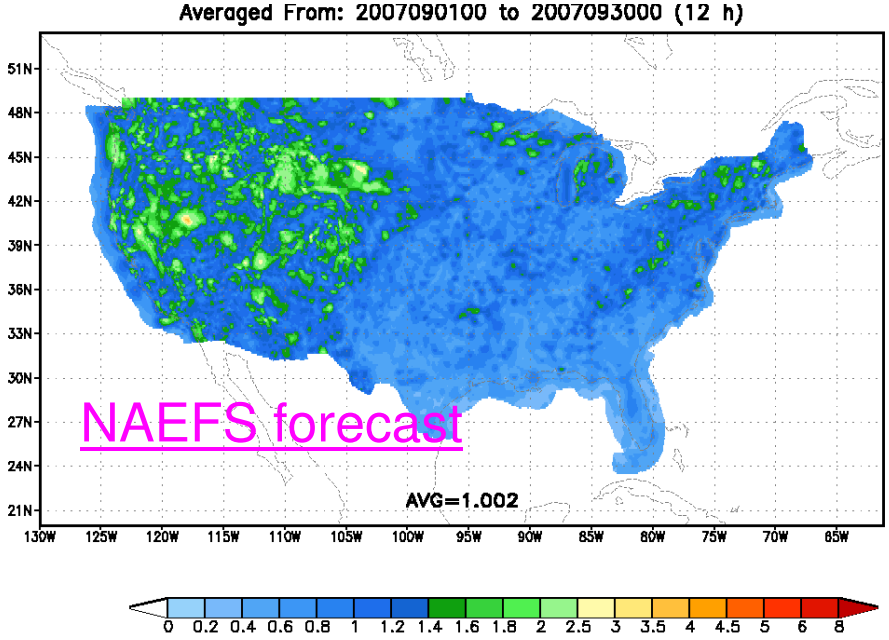

12hr 2m T forecast
Mean Absolute Error
w.r.t RTMA for CONUS
Average for September