Recent Development to Improve NAEFS SPP

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Milestones

- Implementations
  - First NAEFS implementation – bias correction - May 30 2006
  - NAEFS follow up implementation – CONUS downscaling - December 4 2007
  - Alaska implementation – Alaska downscaling - December 7 2010
  - Implementation for CONUS/Alaska expansion – Q2FY14
- 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, 2013: *“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, 2013: “*Improvement of NAEFS SPP*”, (plan to submit to Weather and Forecasting)

Highlights

- Reforecast
  - Values
  - Possible future configuration
- 2nd moment adjustment
  - Completion of calibration
- Blender – Adjust BMA method
  - Un-equal weights
  - Tuning predicted variance

NAEFS Bias Correction

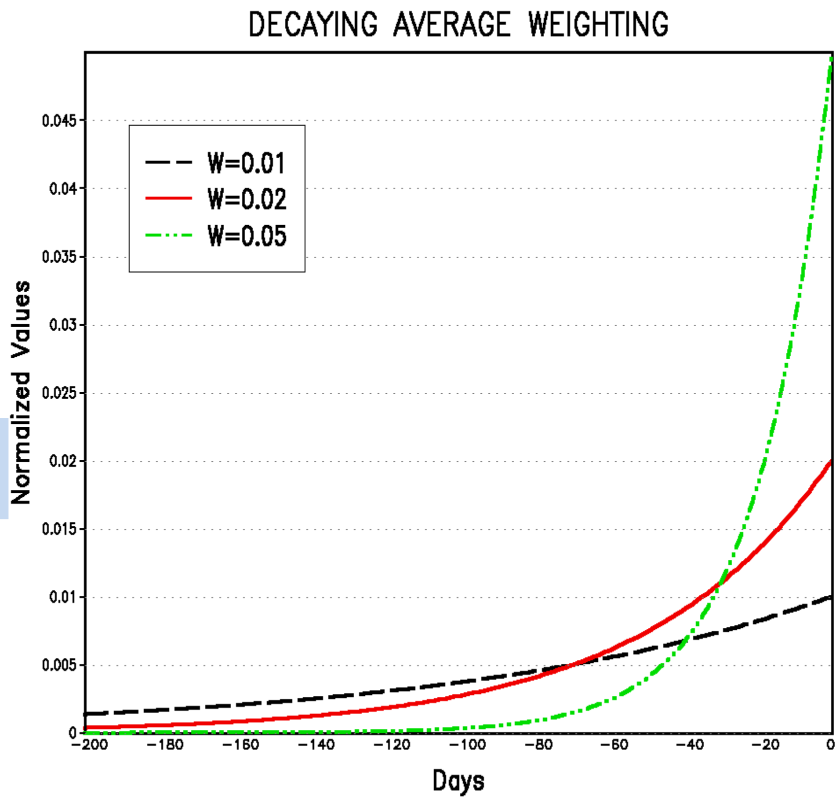
1). Bias Estimation:

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

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

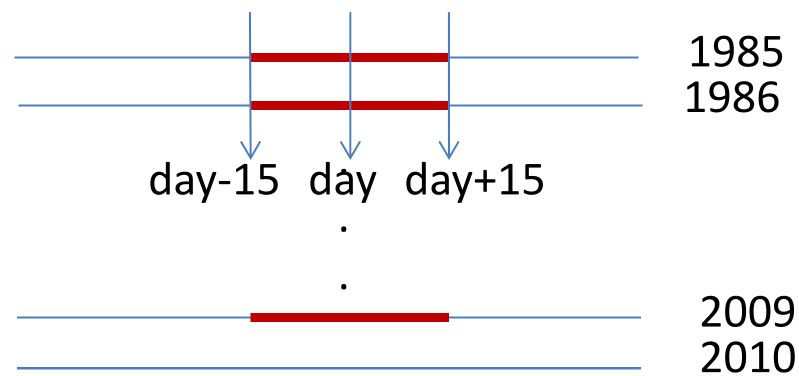
GEFS Reforecast

Configurations (Hamill et al, 2013)

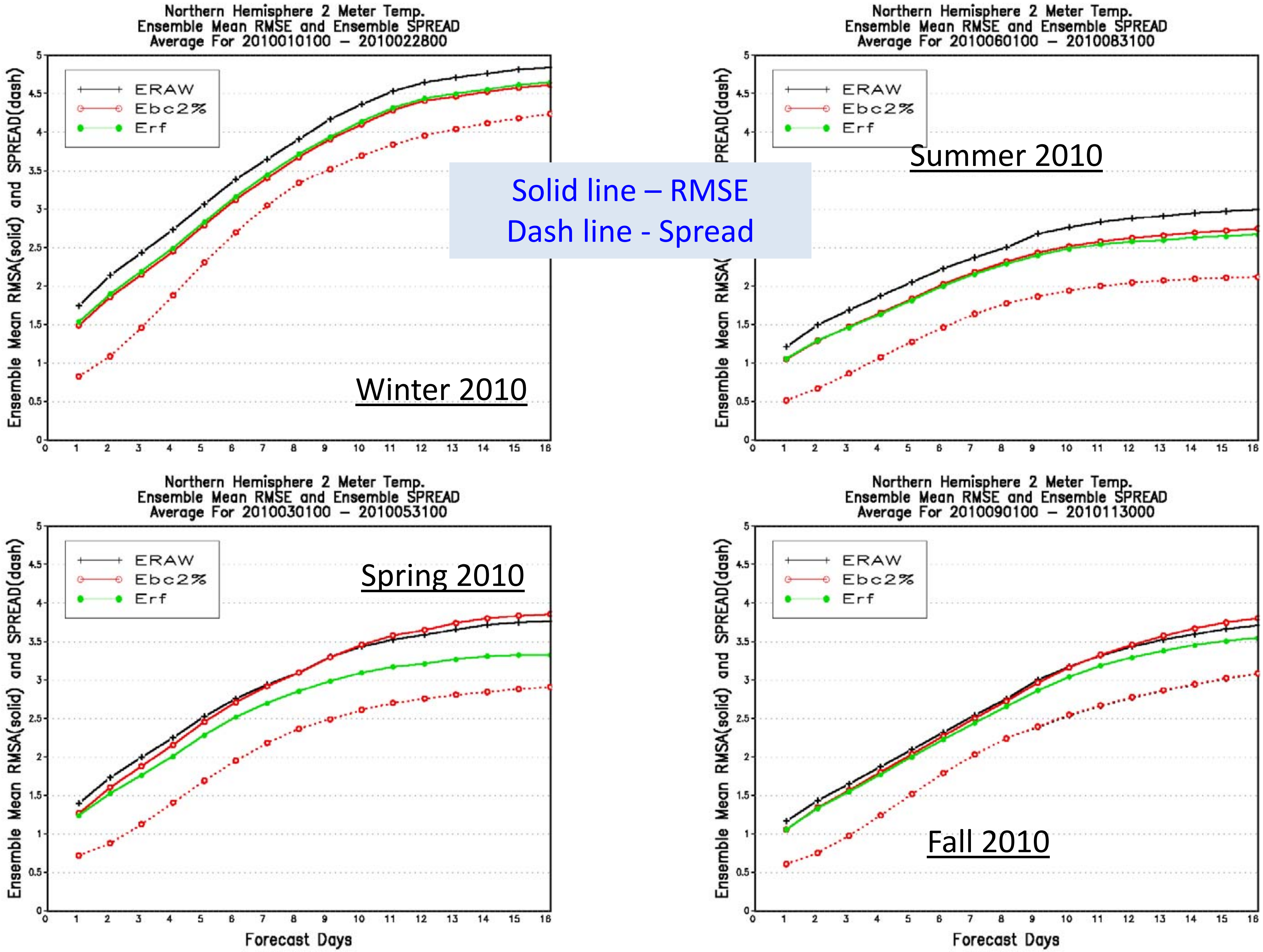
- Model version
  - GFS v9.01 – last implement – May 2011
  - GEFS v9.0 – last implement – Feb. 2012
- Resolutions
  - Horizontal – T254 (0-192hrs– 55km)
    T190 (192-384hrs – 70km)
  - Vertical – L42 hybrid levels
- Initial conditions
  - CFS reanalysis
  - ETR for initial perturbations
- Memberships
  - 00UTC - 10 perturbations and 1 control
- Output frequency and resolutions
  - Every 6-hrs, out to 16 days
  - Most variables with 1*1 degree
- Data is available
  - 1985 - current

Using Reforecast Data

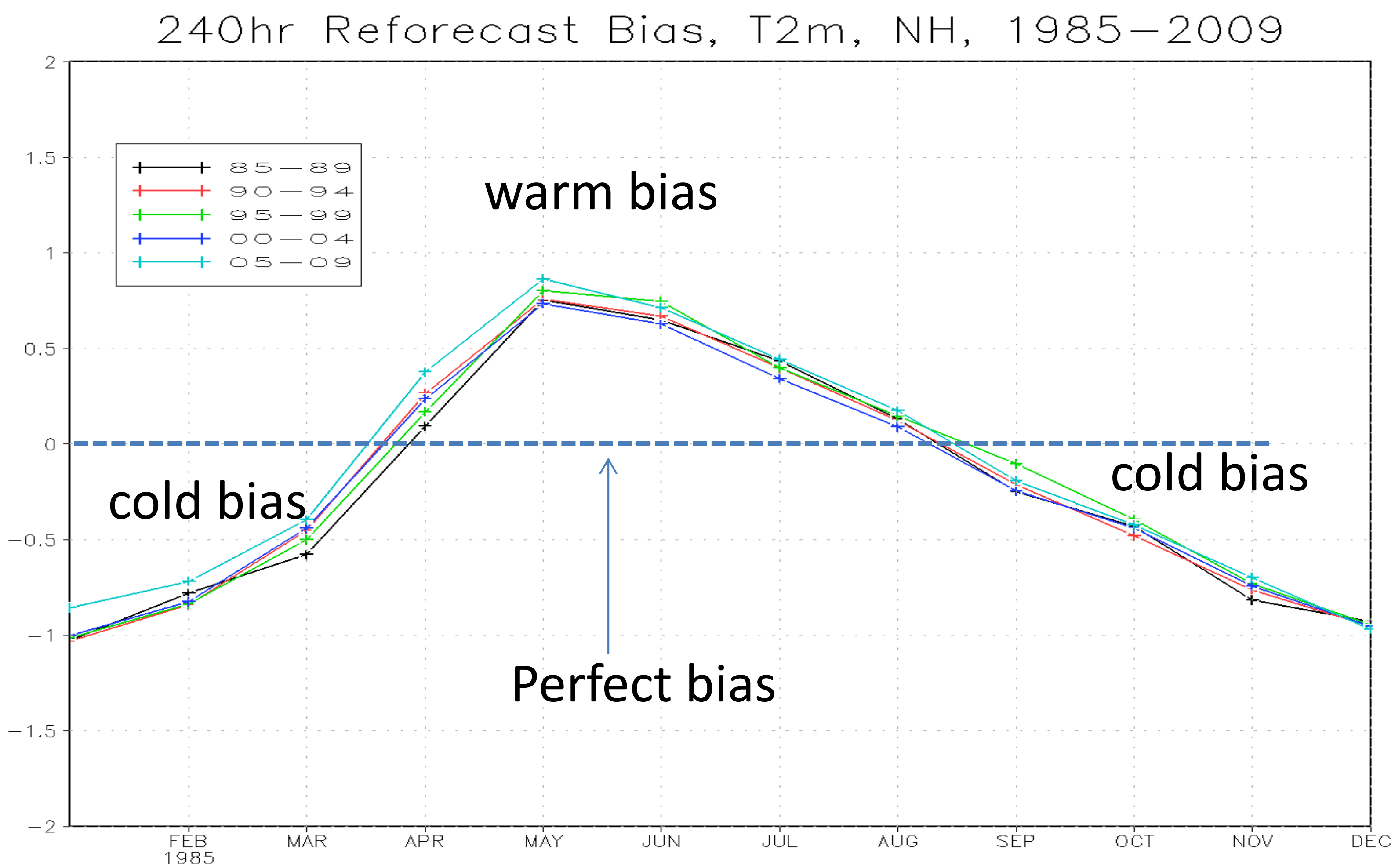
- Bias over 24 years (24X1=24)
  25 years (25x1=25)
- Bias over 25 years and 31day window
  (25x31)
- Bias over recent 2, 5, 10, and 25 years
  within a window of 31day
  (2x31, 5x31, 10x31, 25x31)
- Bias over 25 years with a sample interval
  of 7days within a window of 31days
  and 61days (~25x4 and ~25x8)



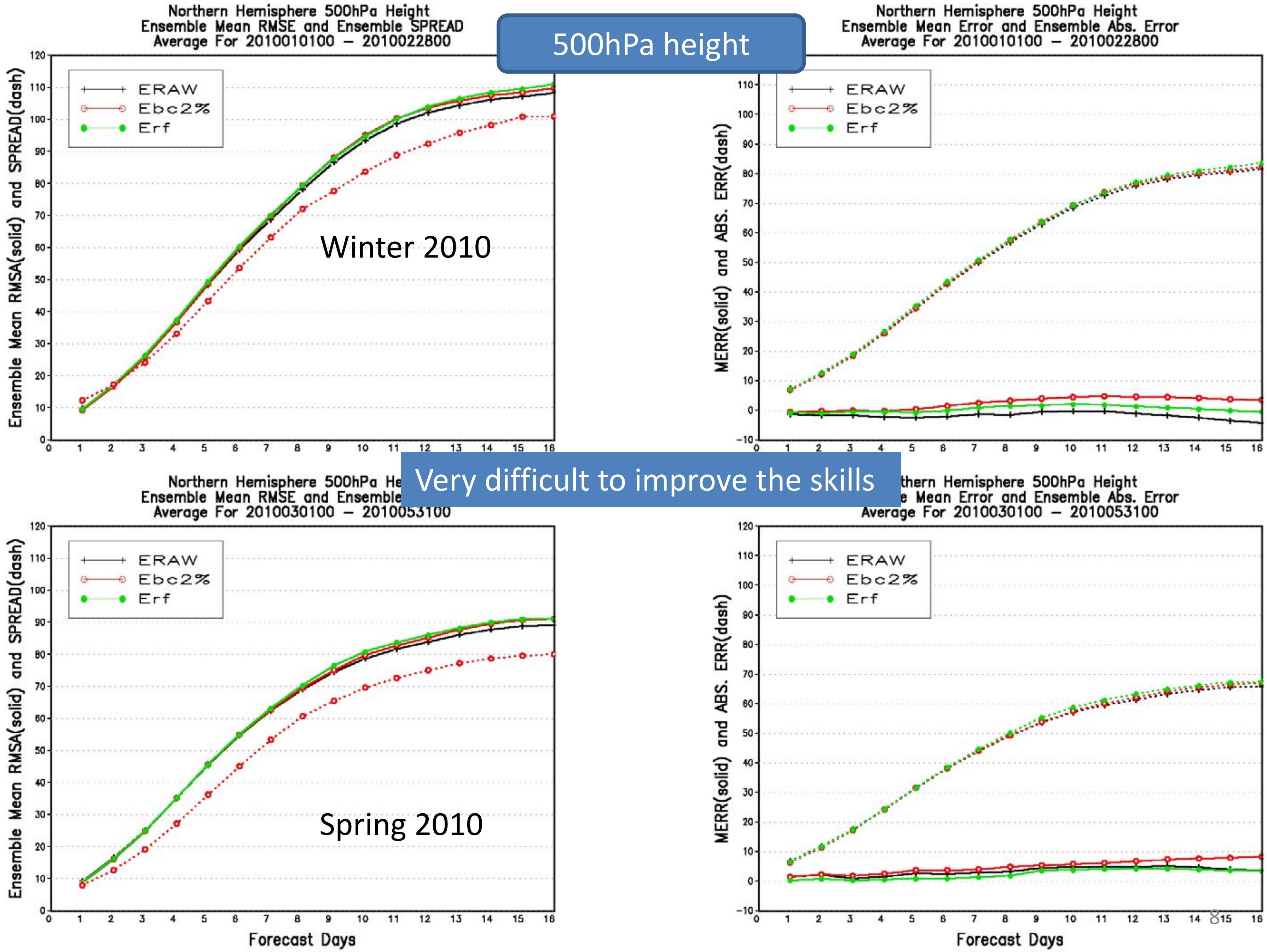
Using 25-year reforecast bias (1985-2009) to calibrate 2010 forecast



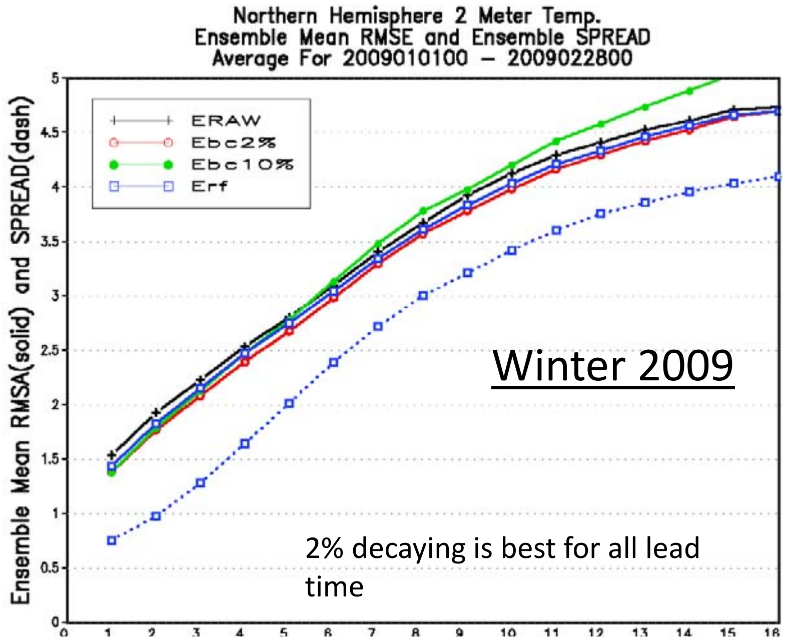
Reforecast bias (2-m temperature)

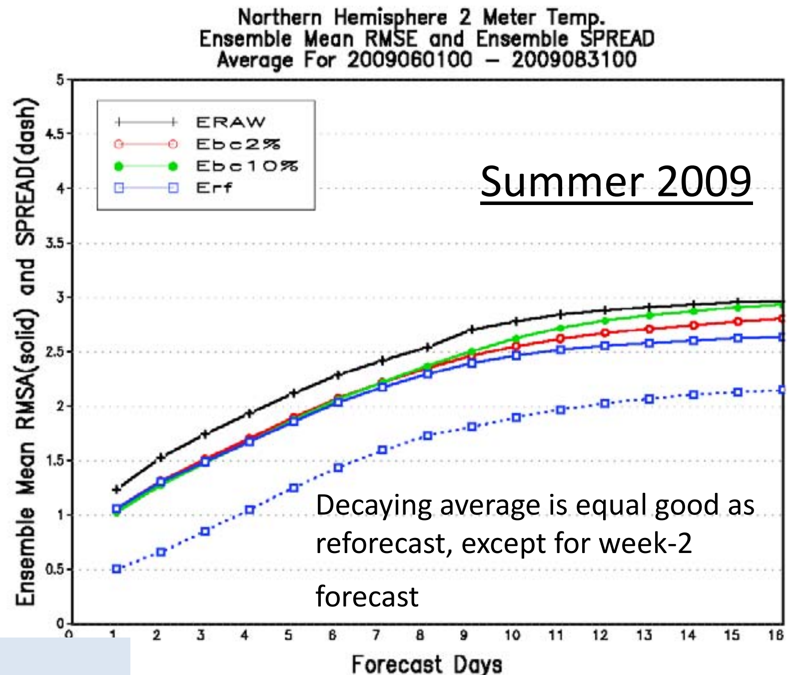


Using 25-year reforecast bias (1985-2009) to calibrate 2010 forecast

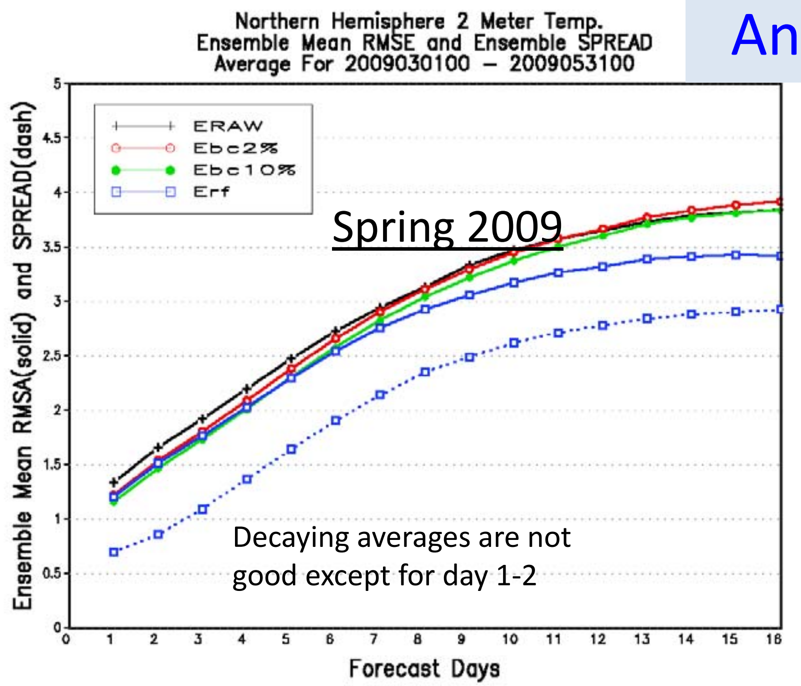


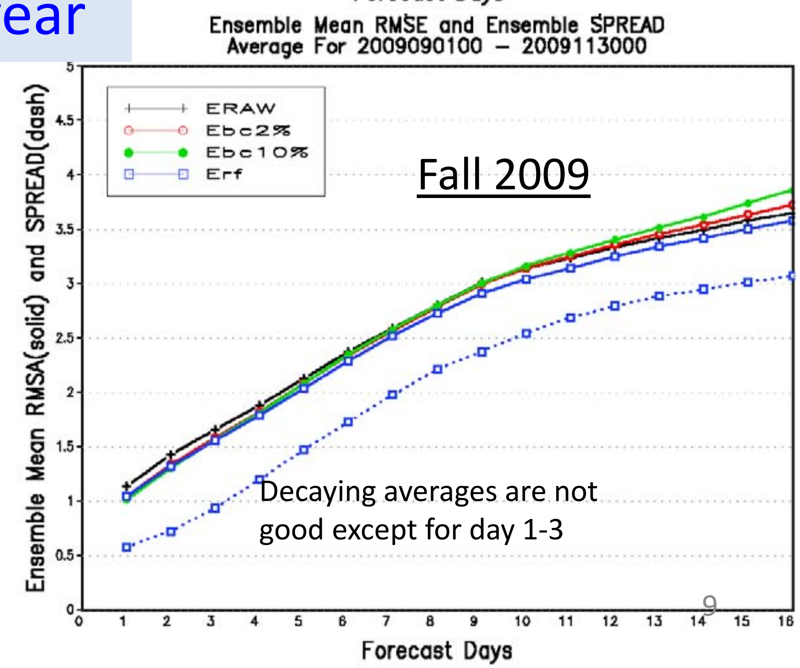
Using 24-year reforecast bias (1985-2008) to calibrate 2009 forecast



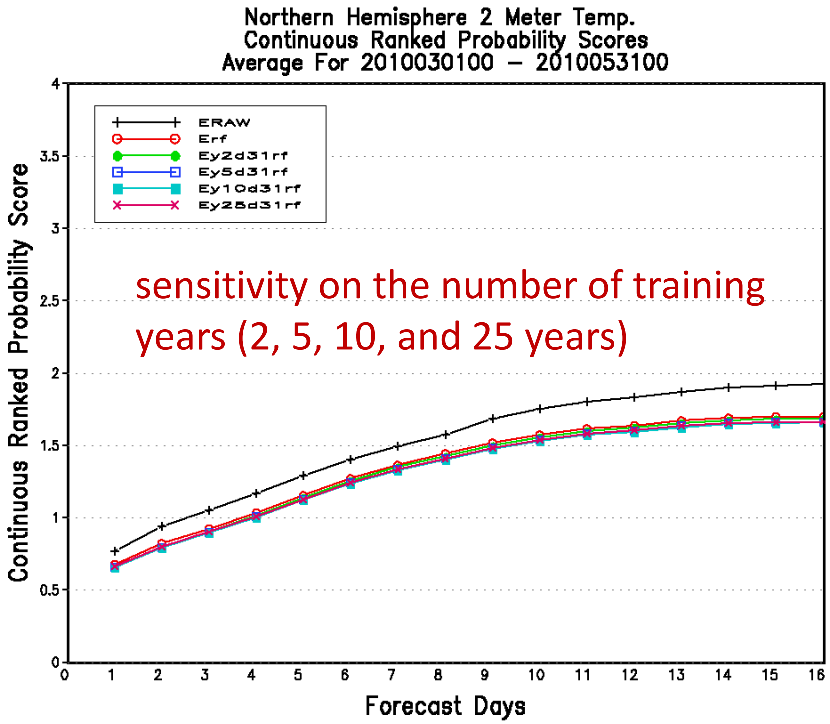


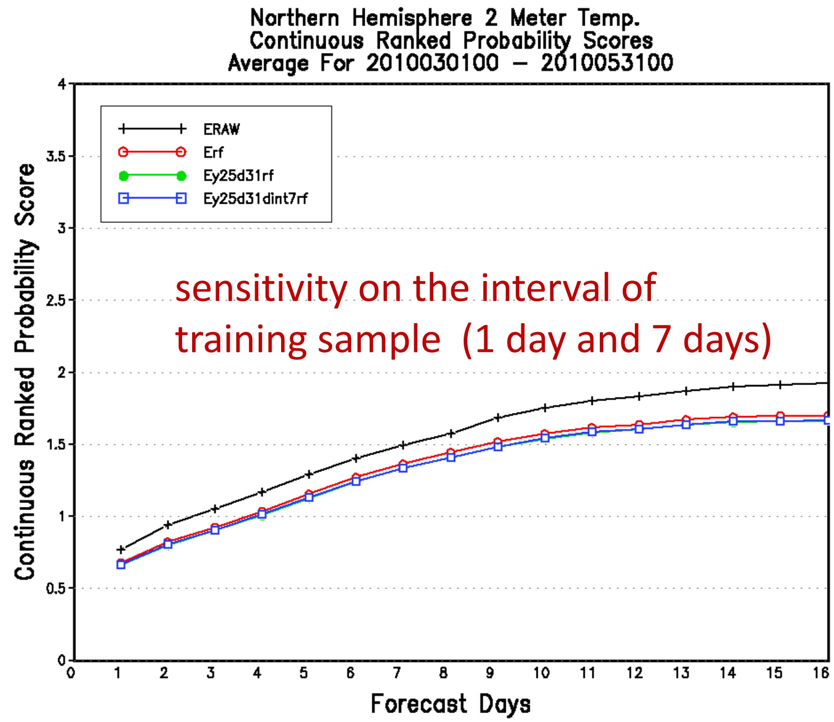
Another year





T2m calibration for different reforecast sample sizes

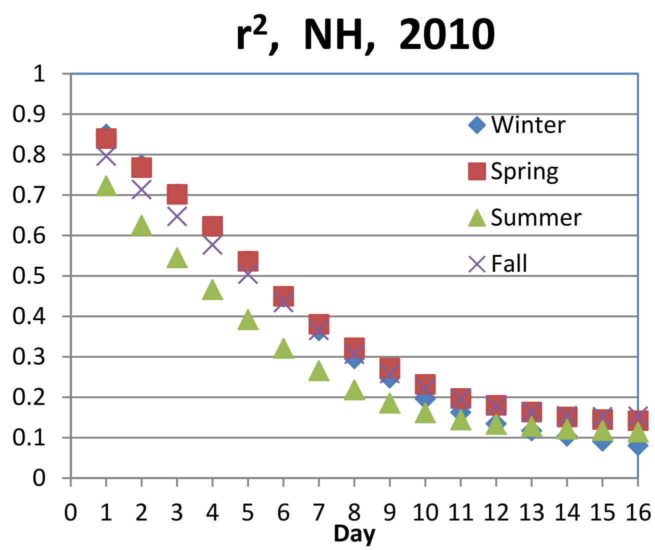




Long training period (10 or 25 years) is necessary to help avoid a large impact to bias correction from a extreme year case and keep a broader diversity of weather scenario!!

Skill for 25y31d's running mean is the best. 25y31d's thinning mean (every 7 days) is very similar to 25y31d's running mean. → 25y31d's thinning mean can be a candidate to reduce computational expense and keep a desiring accuracy!!!

Using reforecast to improve current bias corrected product (240-hr forecast, 2010)



raw forecast

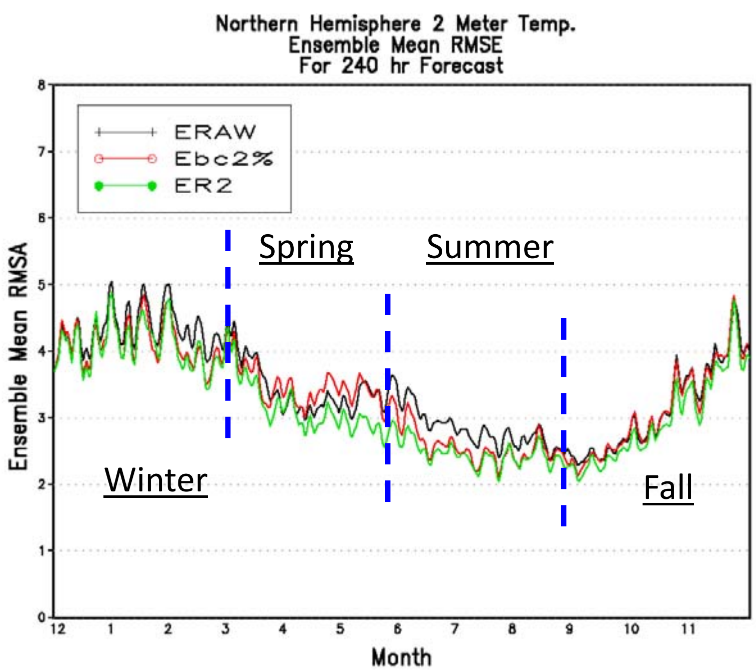
Estimated by linear regression from joint samples

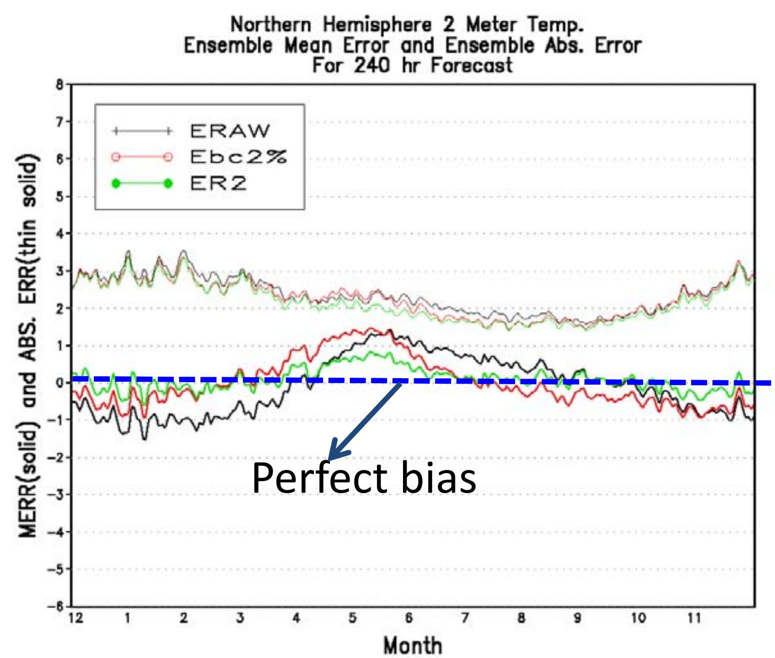
$$F^{*m}_{i,j} = f^{m}_{i,j} - (1 - r^{2}_{i,j}) \cdot b_{i,j} - r^{2}_{i,j} B_{i,j}$$

bias corrected forecast

reforecast bias

decaying average bias





Highlights

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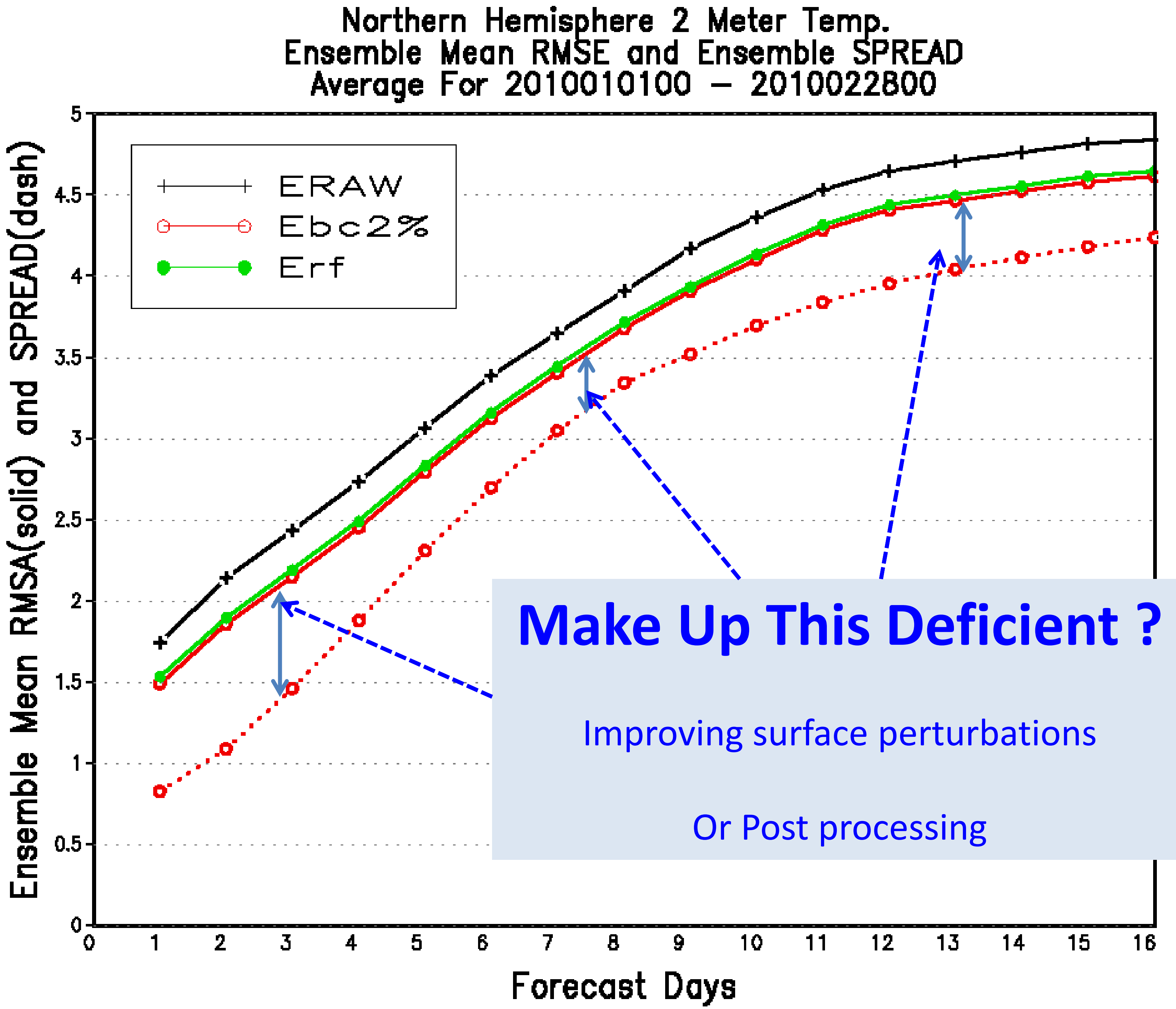
  - Values
  - Possible future configuration
- 2nd moment adjustment
  - Completion of calibration
- Blender – Adjust BMA method
  - Un-equal weights
  - Tuning predicted variance



Northern Hemisphere 2 Meter Temp.
Ensemble Mean RMSE and Ensemble SPREAD
Average For 2010010100 – 2010022800
Ensemble Mean RMSA(solid) and SPREAD(dash)
Forecast Days
ERAW
Ebc2%
Erf
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Make Up This Deficient ?
Improving surface perturbations
Or Post processing

2nd moment adjustment

1st moment adjusted forecast

2nd moment adj.

$$F_{i,j}^{m} = F*_{i,j}^{m} + (1 - R_{i,j}) \cdot D^{m}$$

$$D^{m} = (f^{m}(t+1) - \overline{f}(t+1))$$

$$\overline{R} = \frac{\overline{S}}{\overline{E}}$$

R=1 if E=0

Estimated by decaying averaging

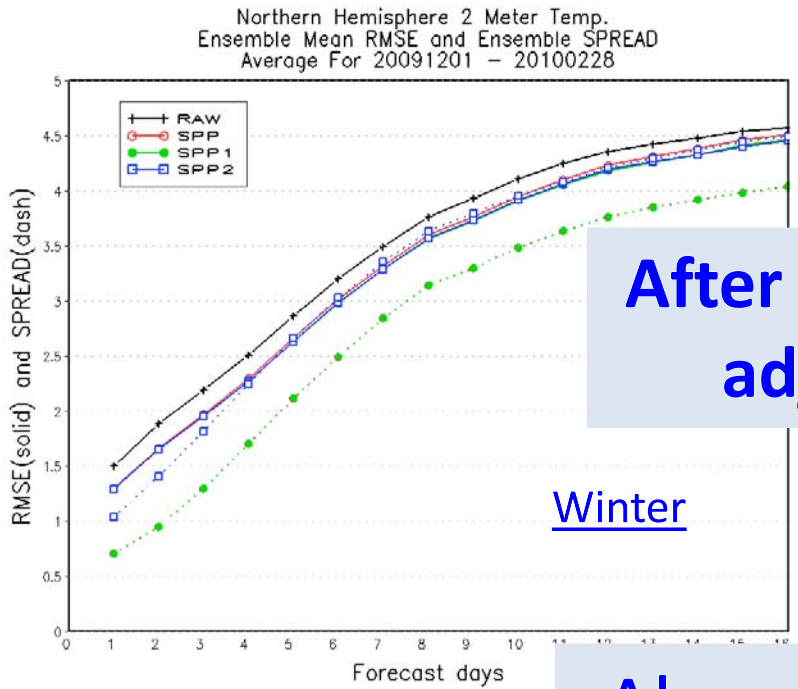
Ensemble skill

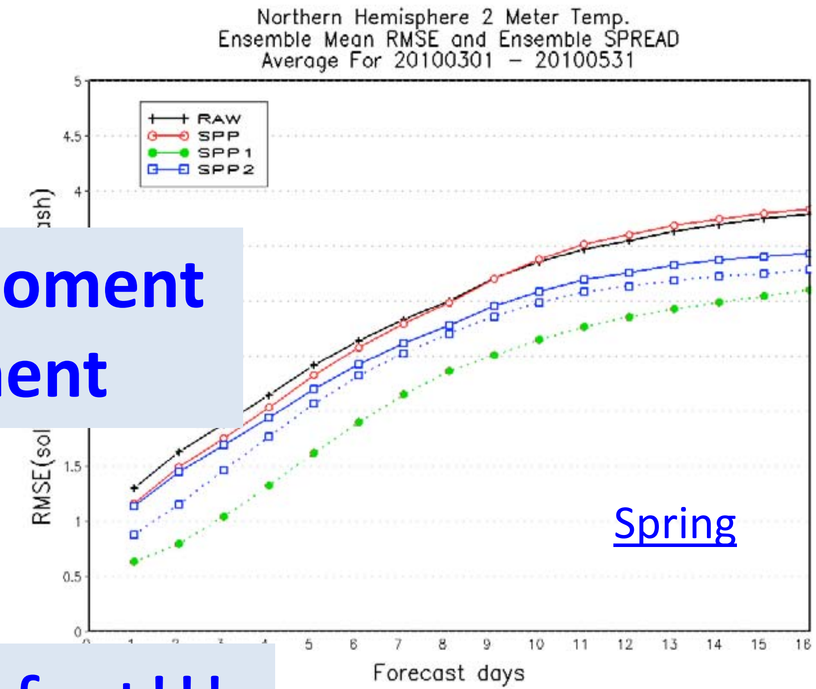
$$\overline{E} = \sqrt{\frac{1}{N}\sum_{t=1}^{N}(\overline{f}(t) - a(t))^{2}}$$

Ensemble spread

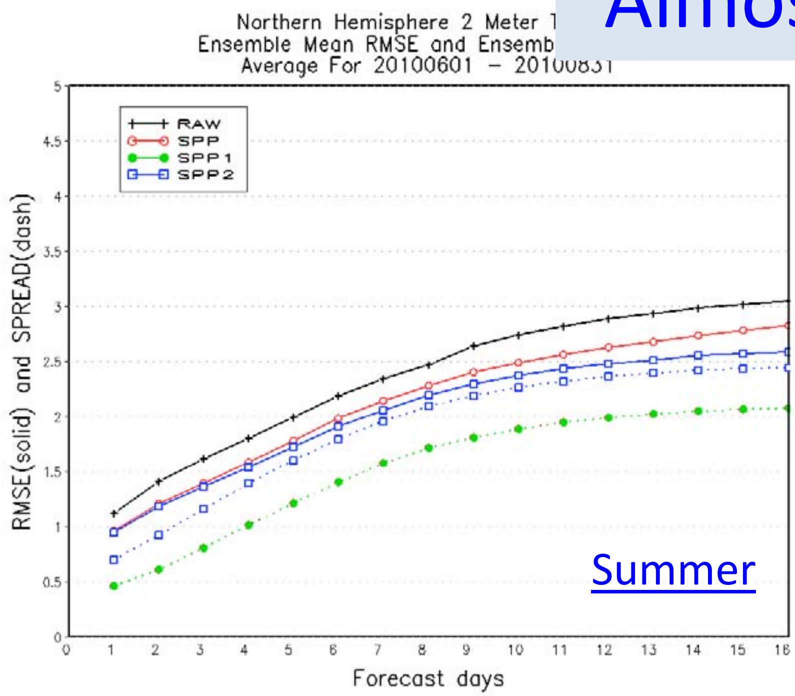
$$\overline{S} = \frac{1}{N}\sum_{t=1}^{N}\sqrt{\frac{1}{M-1}\sum_{m=1}^{M}(f^{m}(t) - \overline{f}(t))^{2}}$$

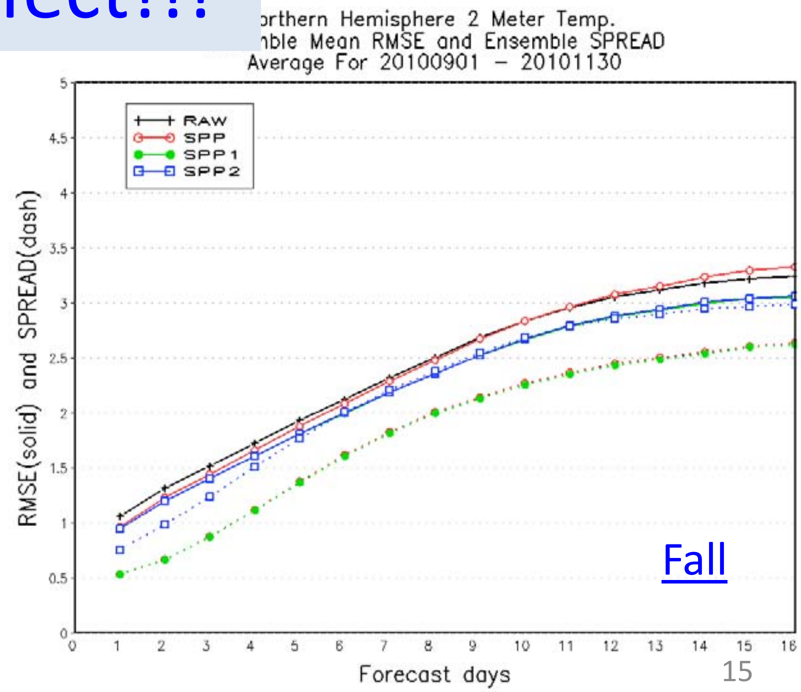
After 2nd moment adjustment





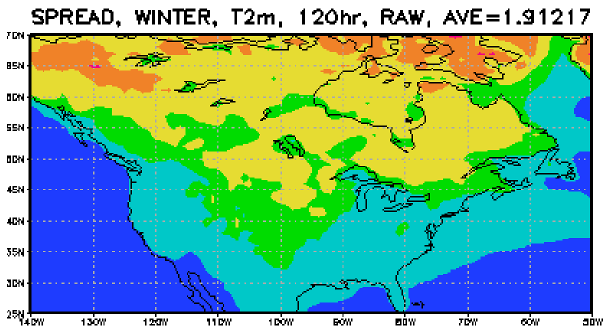
Almost Perfect!!!

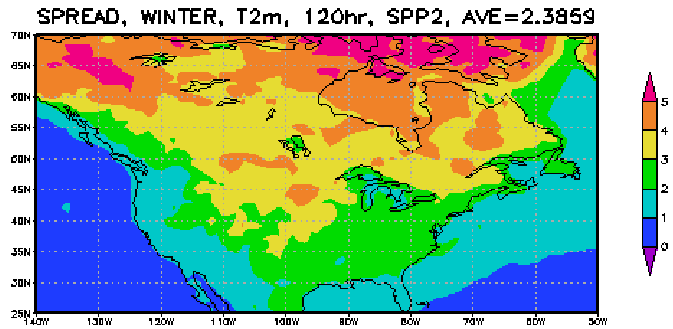




Surface Temperature (T2m) for Winter (Dec. 2009 – Feb. 2010), 120-hr Forecast

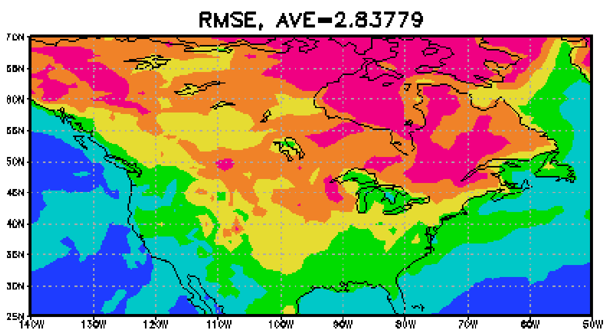
SPREAD

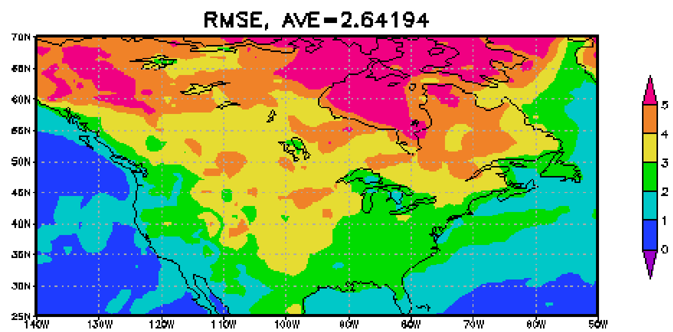




25% spread increased

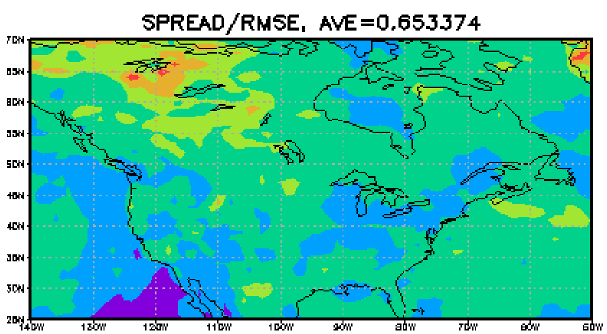
RMSE

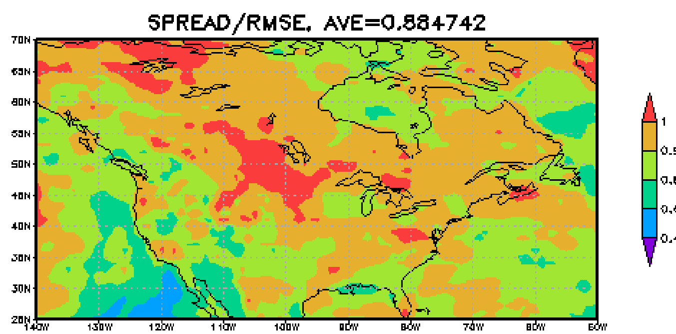




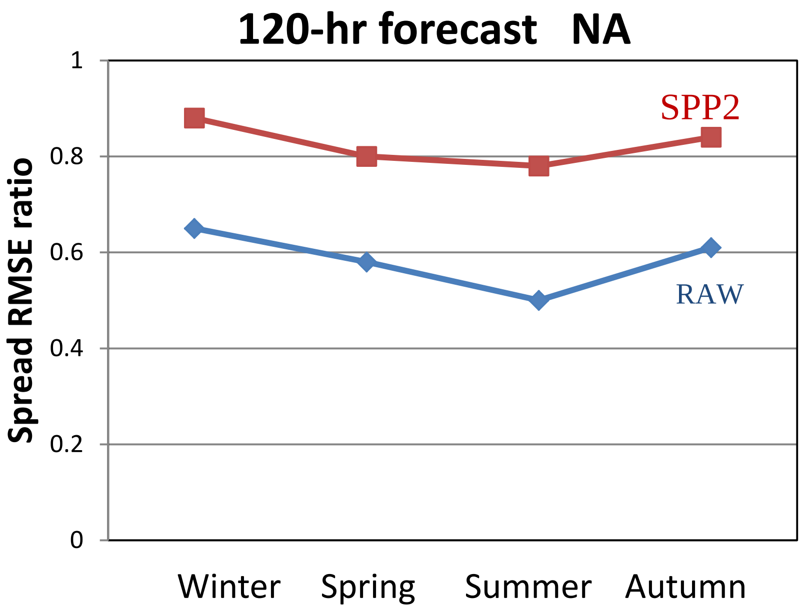
7% RMSE reduced

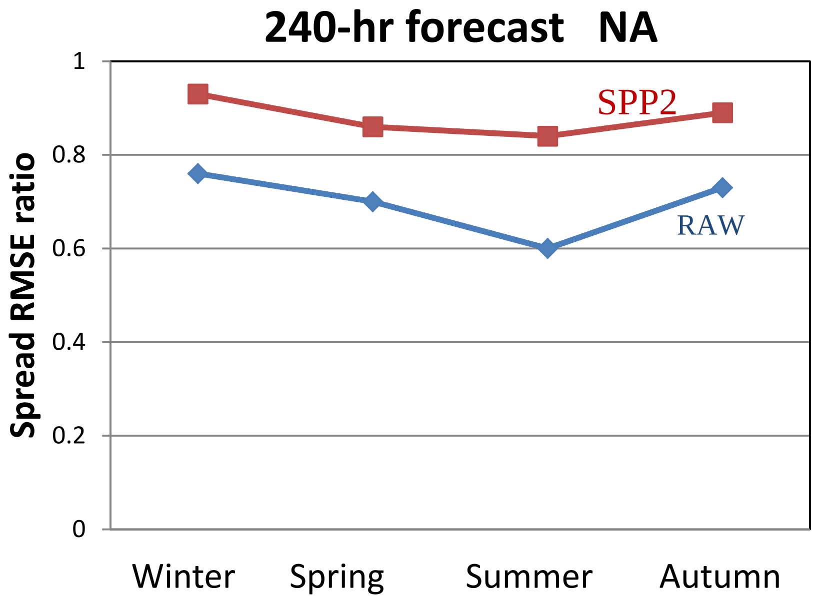
SPREAD /RMSE





Improving Under-dispersion for North America (Dec. 2009 – Nov. 2010)





Improving under-dispersion for all seasons with a maximum benefit in summer.

Highlights

- Reforecast
  - Values
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- Blender – Recursive Bayesian Model Process (RBMP)
  - Un-equal weights
  - Tuning predicted variance

We thank to Dr. Bruce to allow us adapting his BMA codes.

Bayesian Model Average

Weights and standard deviations for each model (k - ensemble member) at step *j*

$$w_k^j = \frac{1}{n}\sum_{s,t}\hat{z}_{k,s,t}^j \qquad \sigma_k^{2\,j} = \frac{\sum_{s,t}\hat{z}_{k,s,t}^j \cdot (y_{s,t} - \tilde{f}_{k,s,t})^2}{\sum_{s,t}\hat{z}_{k,s,t}^j}$$

Sum of (s,t) represents the numbers of obs.

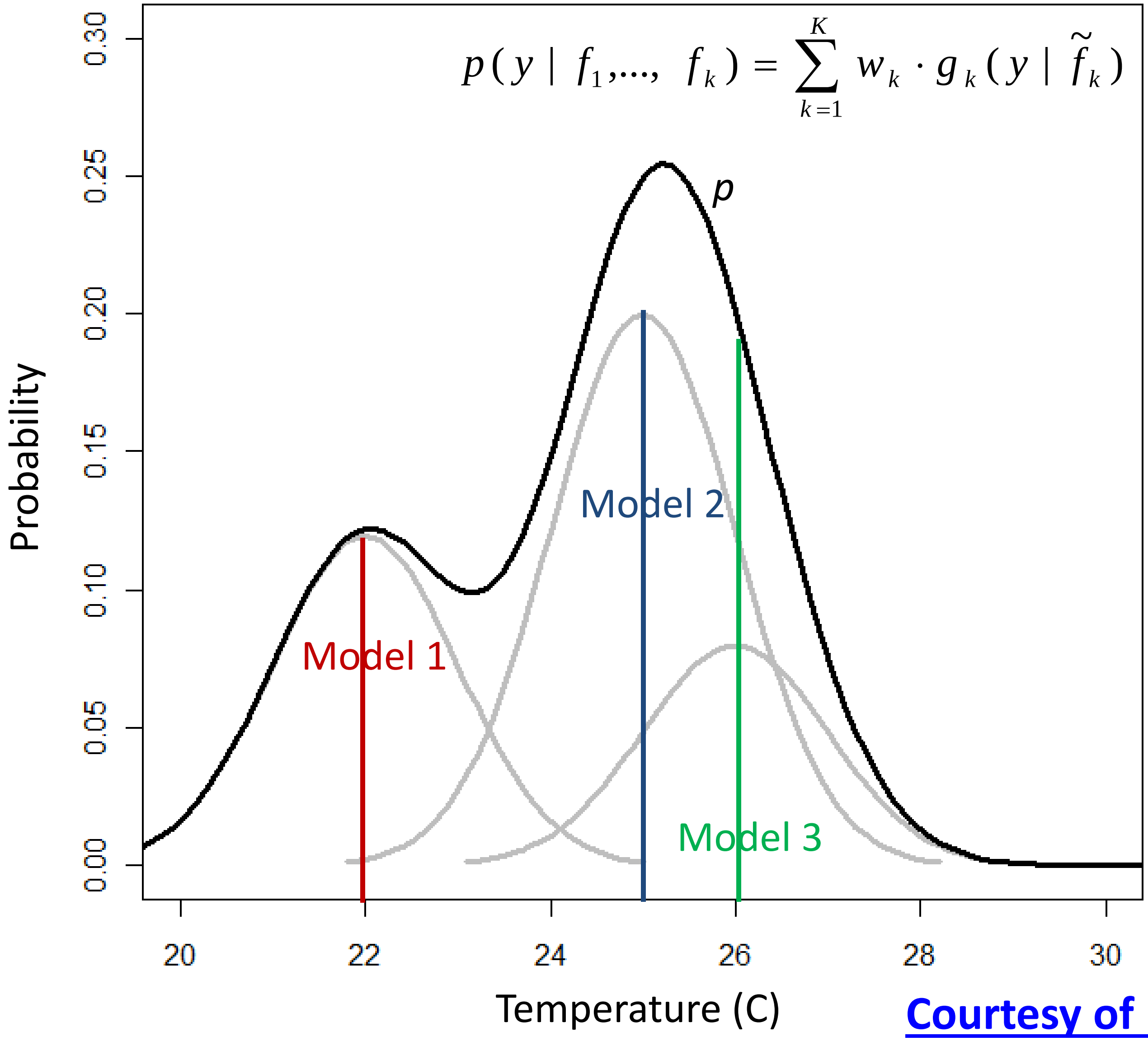
Finally, the BMA predictive variance is

Between-forecast variance — Within-forecast variance

$$Var(y_{s,t} \mid \tilde{f}_{1,s,t},\ldots,\tilde{f}_{K,s,t}) = \sum_{k=1}^{K} w_k\Big(\tilde{f}_{k,s,t} - \sum_{i=1}^{K} w_i \cdot \tilde{f}_{i,s,t}\Big)^2 + \sum_{k=1}^{K} w_k \cdot \sigma_k^2$$

It is good for perfect bias corrected forecast,
Or bias-free ensemble forecast, but we do not

BMA predicted probability

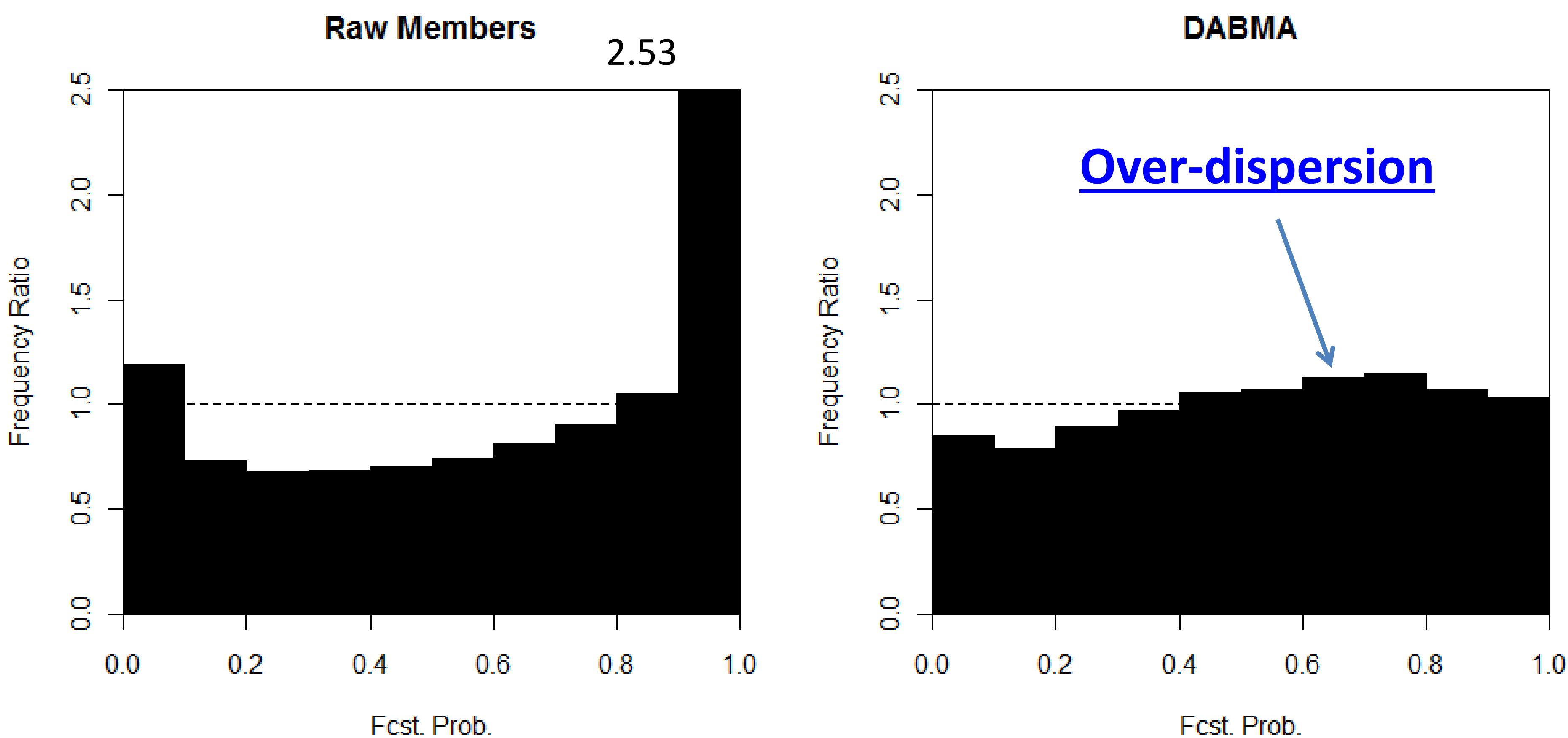


[Courtesy of Dr. Veenhuis]()

DABMA Applied SREF 850hPa temperature

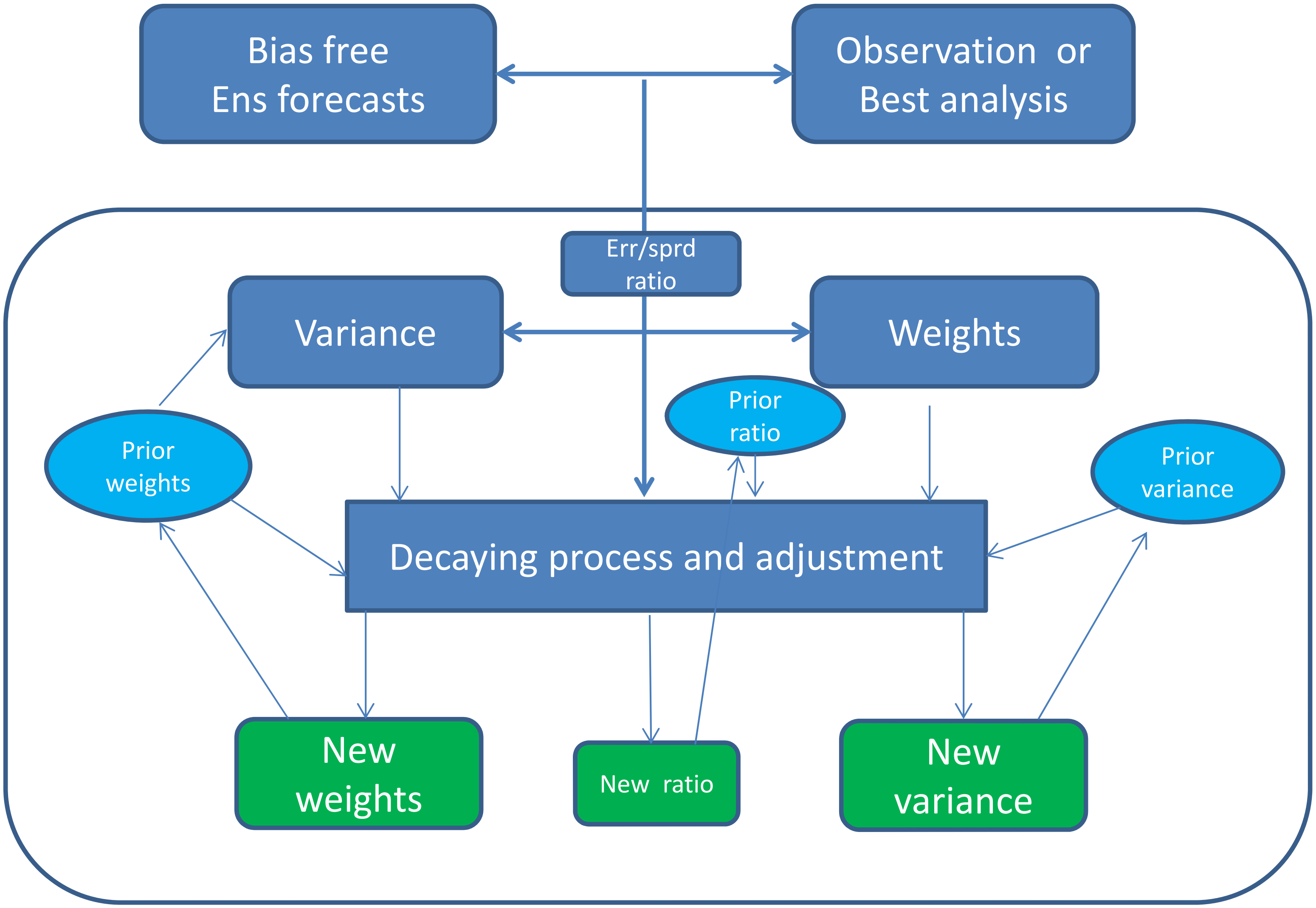
15 Dec. 2012 – 10 Feb. 2013

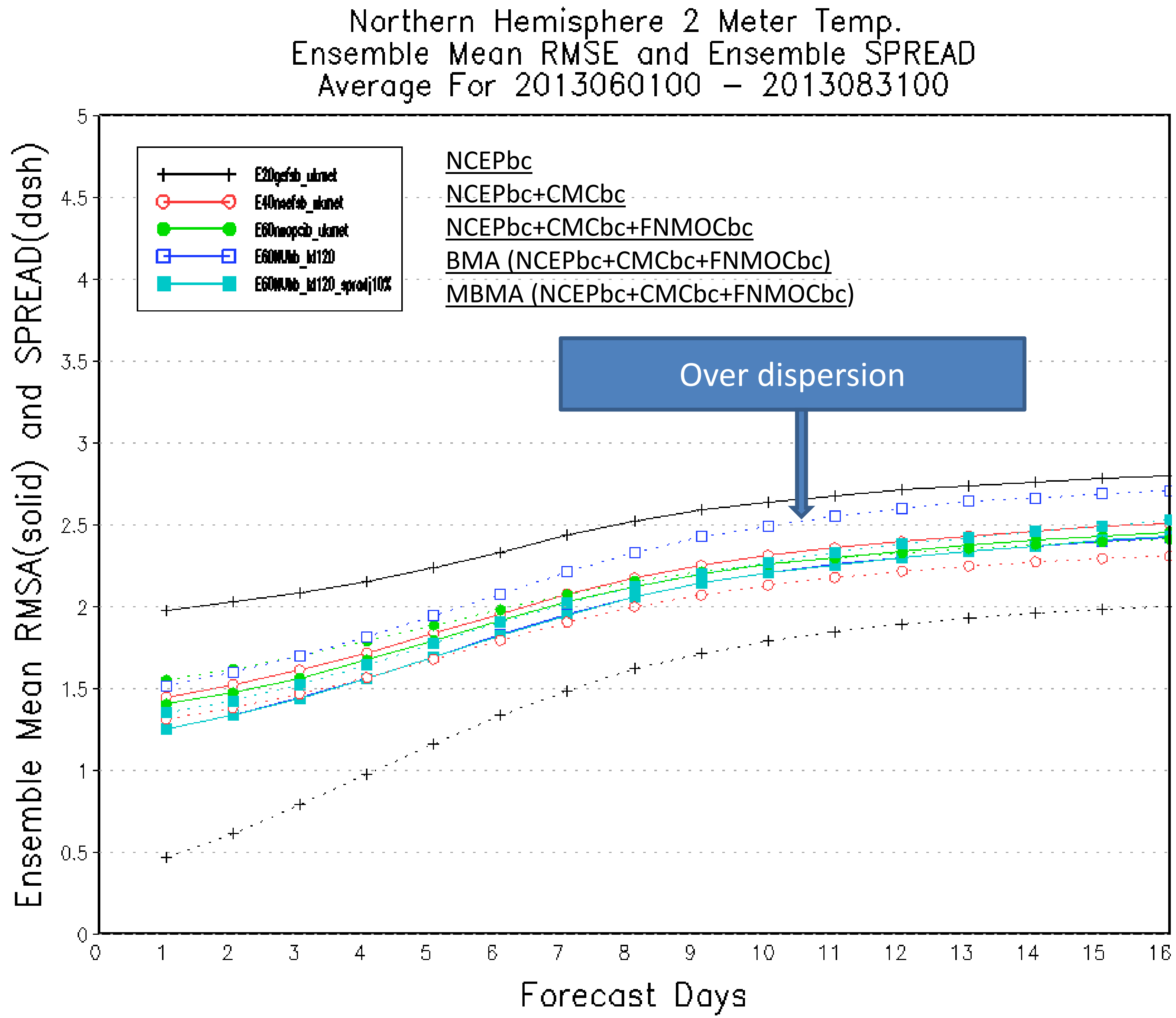
48-hr Projection



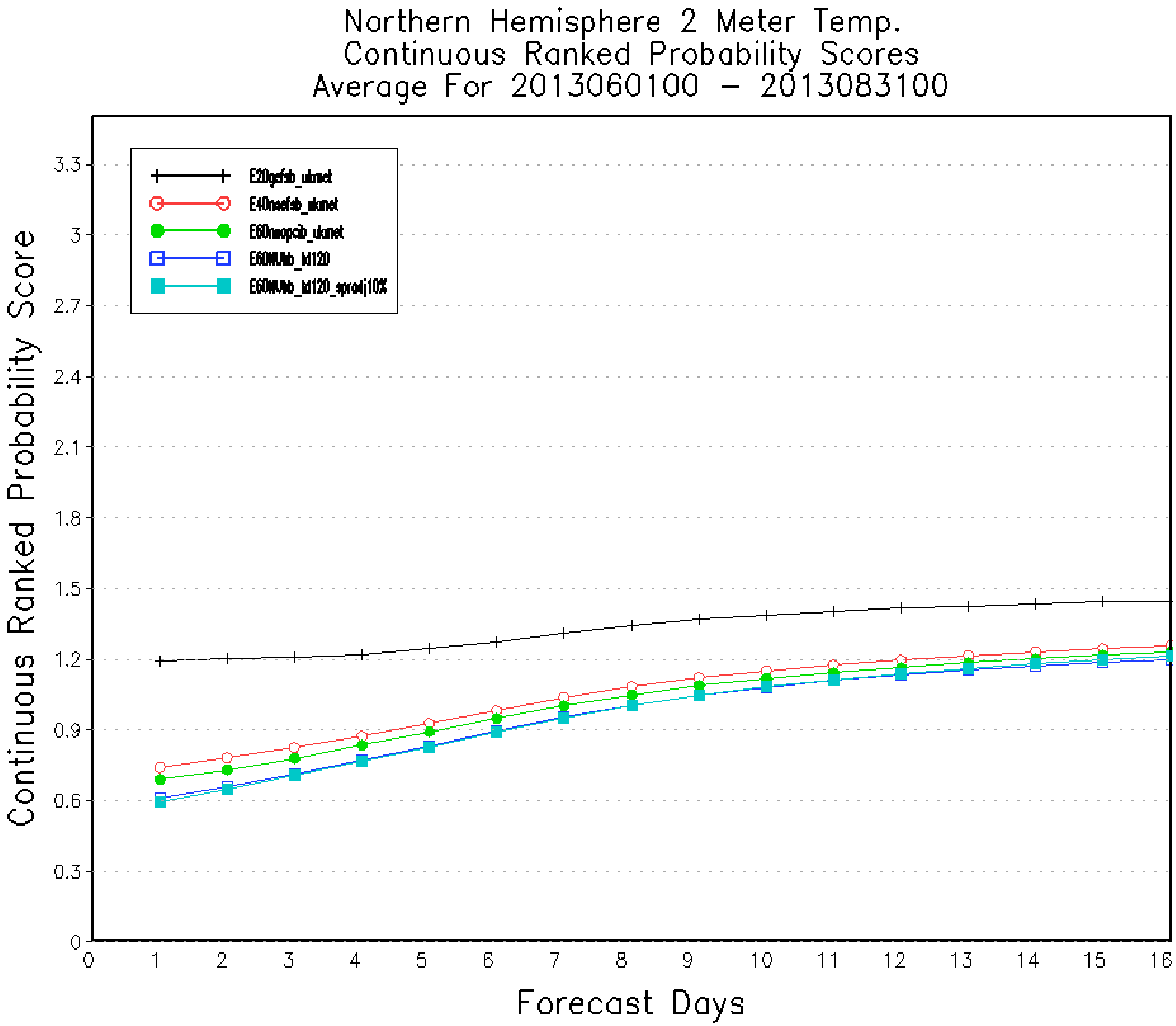
Courtesy of Dr. Veenhuis

Flow Chart of Recursive Bayesian Model Process (RBMP)





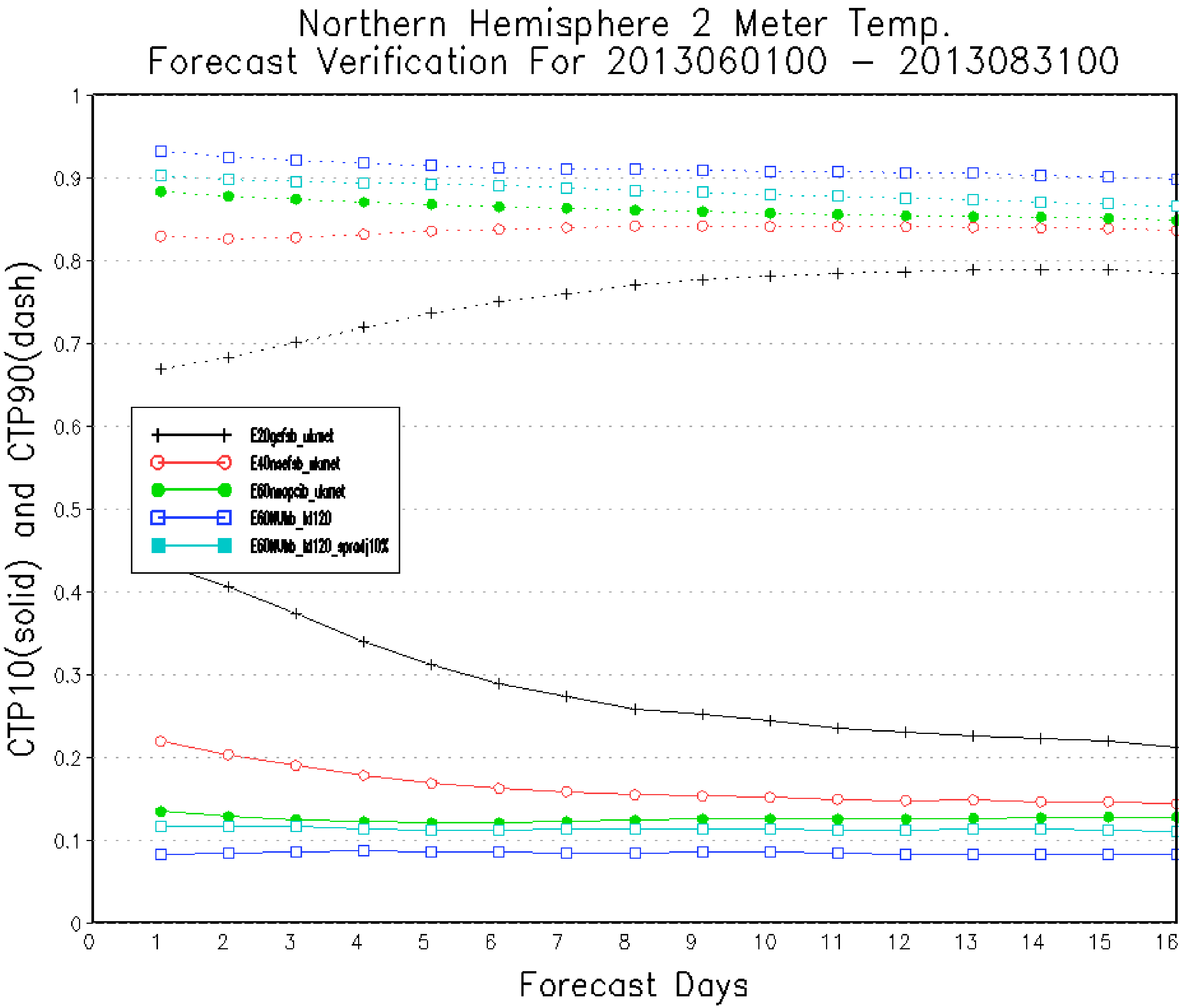
Northern Hemisphere 2 Meter Temp.
Ensemble Mean RMSE and Ensemble SPREAD
Average For 2013060100 – 2013083100
E20gefsb_ukmet
E40naefsb_ukmet
E60naepcib_ukmet
E60MUhb_ld120
E60MUhb_ld120_spradj10%
NCEPbc
NCEPbc+CMCbc
NCEPbc+CMCbc+FNMOCbc
BMA (NCEPbc+CMCbc+FNMOCbc)
MBMA (NCEPbc+CMCbc+FNMOCbc)
Over dispersion
Ensemble Mean RMSA(solid) and SPREAD(dash)
Forecast Days
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16


Northern Hemisphere 2 Meter Temp.
Continuous Ranked Probability Scores
Average For 2013060100 – 2013083100
E20gefsb_uknet
E40naefsb_uknet
E60nmopcib_uknet
E60NUAb_bl120
E60NUAb_bl120_spradj10%
Continuous Ranked Probability Score
Forecast Days
3.3
3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

Summary

- Surface temperature is strongly biased for NH
  cold bias for winter, warm bias for summer
- Reforecast has overall best value of calibration, decaying averages are
  good for winter/summer, but not good for transition season
- Very difficult to improve the skills for 500hPa height
  possibly due to less bias or insensitivity to bias correction
- 25y31d's thinning mean can be a candidate to reduce computational
  expense and keep a broader diversity of weather scenario.
- Adding reforecast information improve current bias-corrected product for
  all seasons with a maximum benefit between March and May.
- Bias and its seasonal variation are model-dependent. Whether the
  improvement found here will occur for the new GEFS version need to
  be confirmed!!
- 2^{nd} moment adjustment helps increase spread and improve under-
  dispersion for all seasons with a maximum improvement in summer.
- Adding 2^{nd} moment adjustment makes the BMA method more robust.

Background



Northern Hemisphere 2 Meter Temp.
Forecast Verification For 2013060100 – 2013083100
CTP10(solid) and CTP90(dash)
Forecast Days
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16