Report of Inclusion of FNMOC Ensemble into NAEFS

Yuejian Zhu[1], Bo Cui[2]

[1]Environmental Modeling Center, NCEP/NWS
[2]SAIC at Environmental Modeling Center, NCEP/NWS

Acknowledgements

Michael Sestak, Fleet Numerical Meteorology & Oceanography Center

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Overview

- Background & Testing Procedure
- Results
- Conclusions
- Issues
- Recommendation and outlook

Background & Testing Procedure

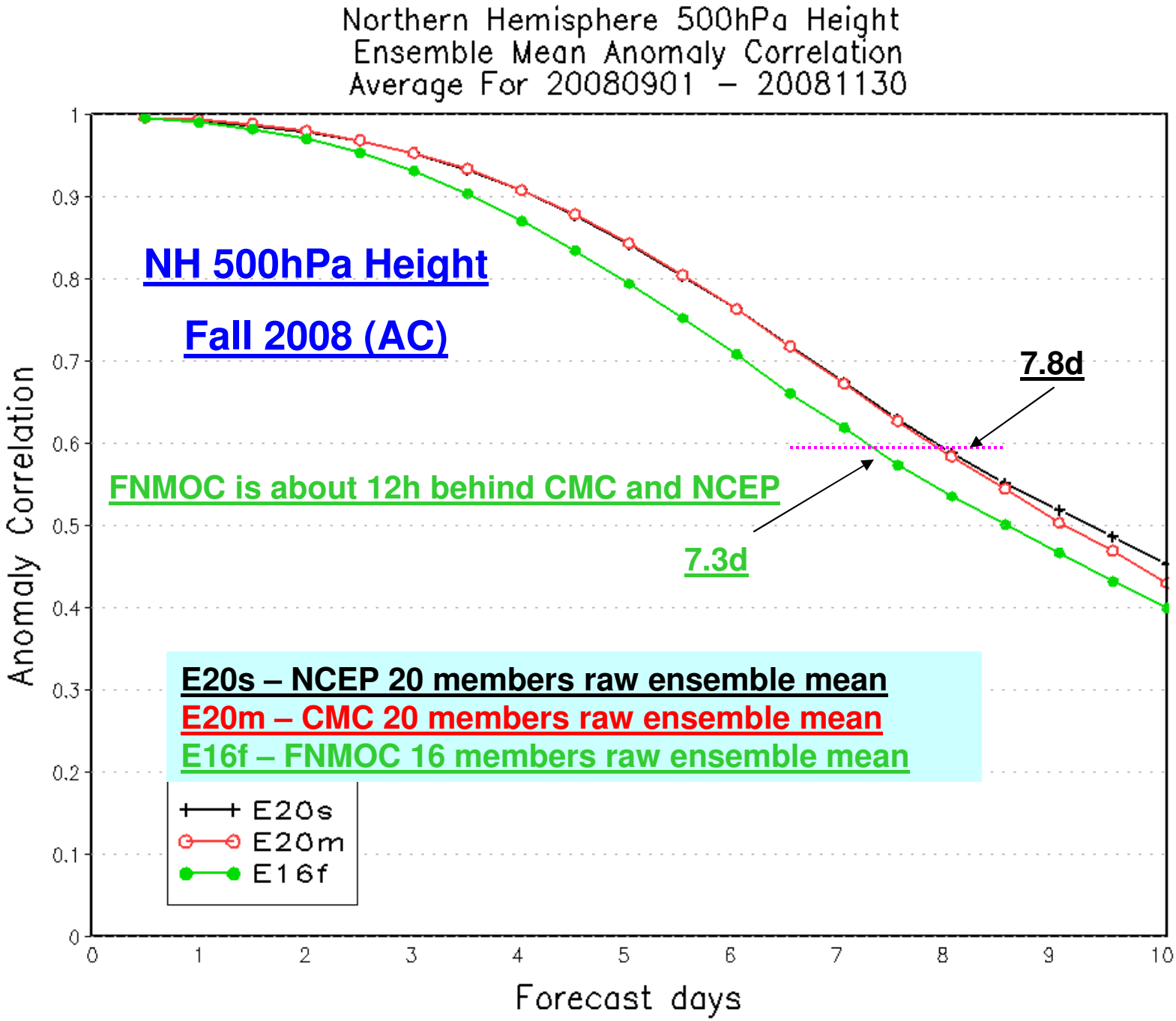
- **North American Ensemble Forecast System (NAEFS)**
  - Collaboration between NCEP, Meteorological Service of Canada (MSC), FNMOC and Mexico Weather Service
  - Elements:
    - Demonstrate value of Multi-Model Ensemble (MME)
    - Engage in collaborative software development, focused on postprocessing products from an arbitrary number of forecast systems
    - Establish operational data transfer
    - Application to operational products with shared software
    - Continue to monitor value-added with MME strategy

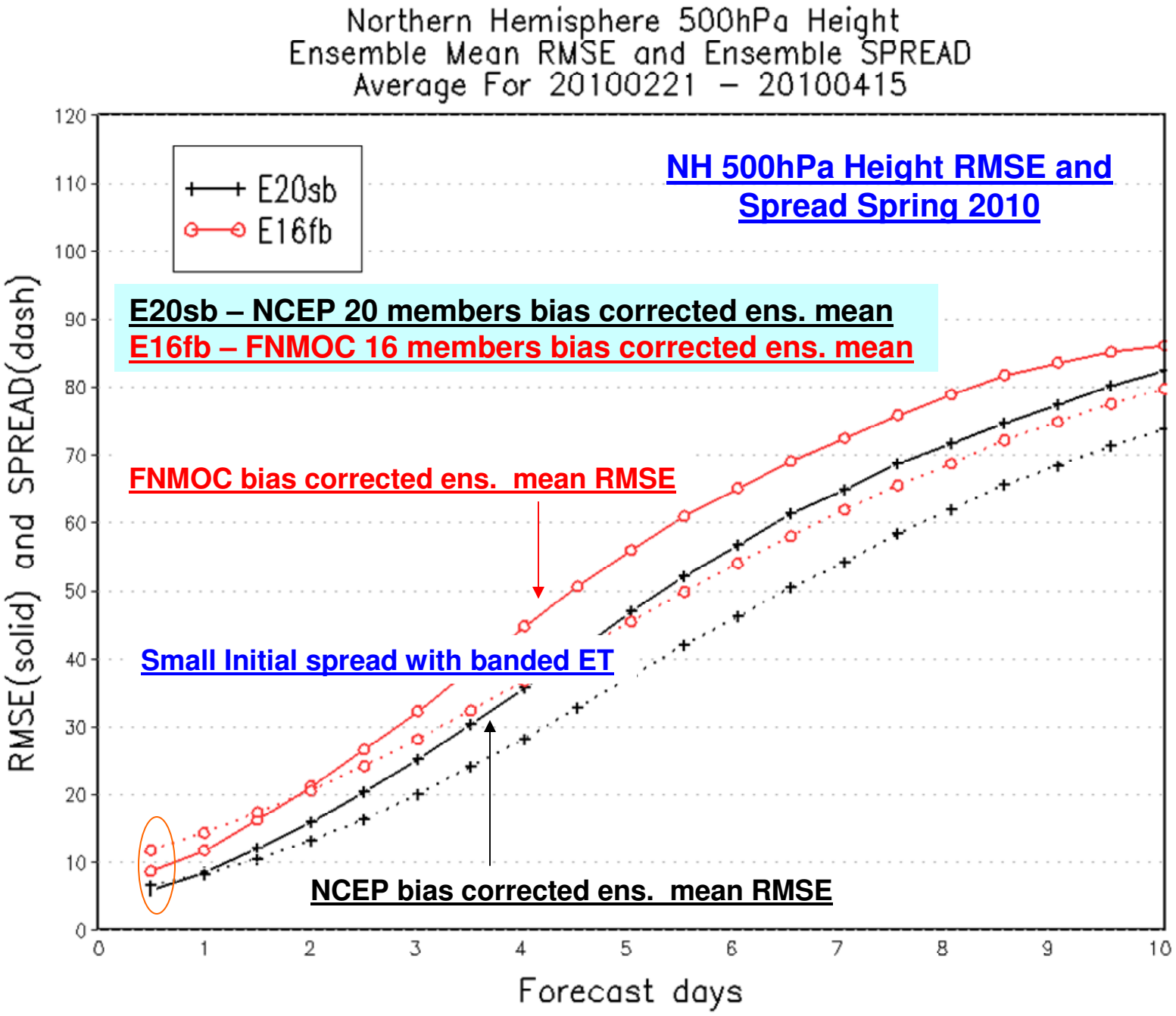
- **Global Ensemble Products**
  - NCEP – operational
    - 20 members -16 days
  - CMC – operational
    - 20 members - 16 days
  - FNMOC – experimental
    - 16 members – 10 days

Background & Testing Procedure (cont)

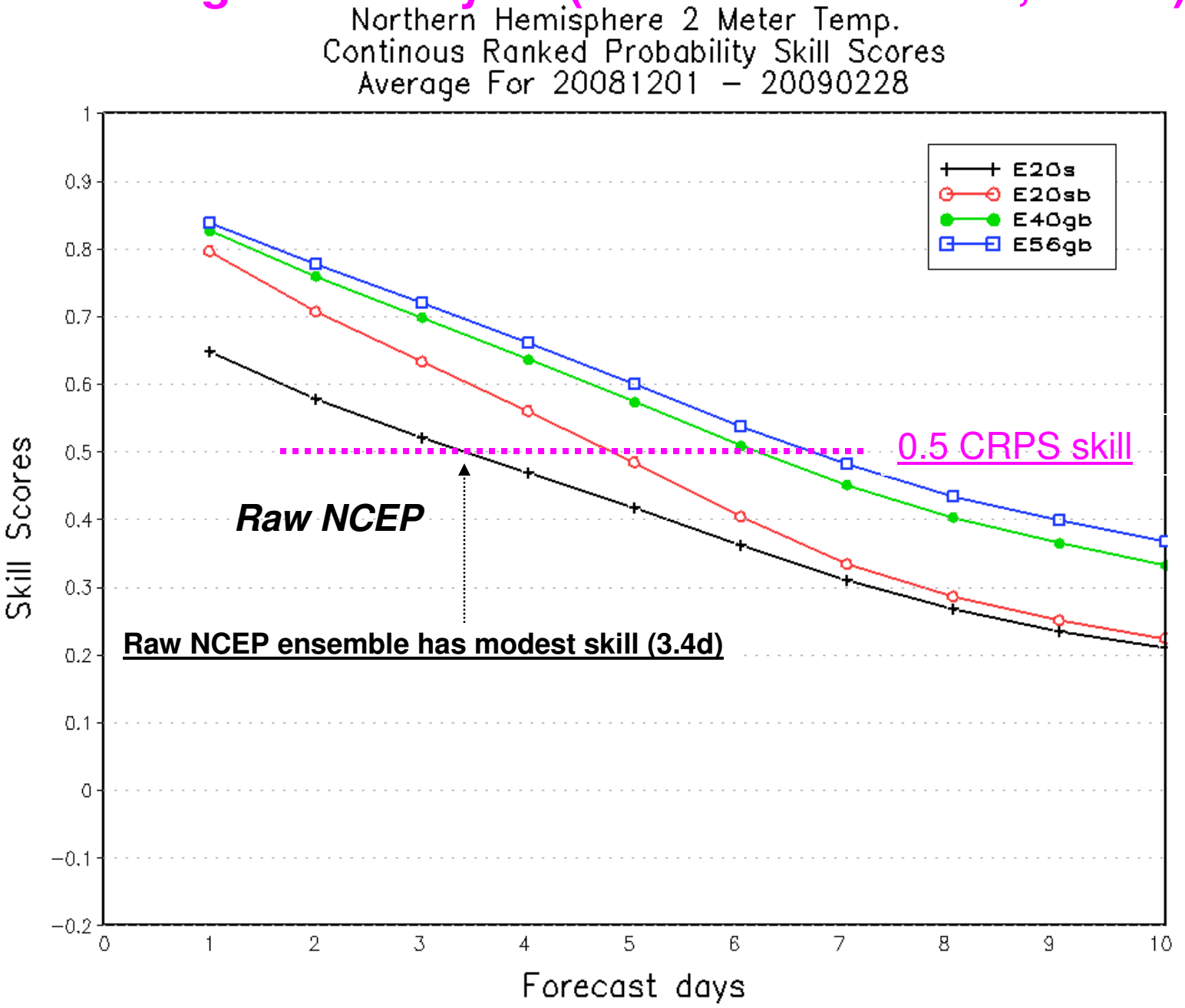
- **Forecast Data**
  - 11 months of data collected (off line)
  - Communications pathway established with FNMOC
  - Raw forecasts
    - Fall 2008 (September 1st – November 30th 2008)
    - Winter 2008/2009 (December 1st 2008 – February 28th 2009)
    - Spring 2009 (March 1st – May 31st 2009)
    - Spring 2010 (March 1st – April 15st 2010 after FNMOC banded ET implementation)
  - Bias corrected forecasts – All ensembles bias corrected against NCEP analysis
    - Winter 2008/2009 (December 1st 2008 – February 28th 2009)
    - Spring 2009 (March 1st – May 31st 2009)
    - Spring 2010 (March 1st – April 15st 2010)

- **Verification Methods**
  - Reference analysis
    - Individual ensembles – Each center's own
    - Combined ensembles – NCEP analysis
  - Scores
    - NCEP standard probabilistic verification package
      - AC and RMS for ensemble mean, spread, histogram
      - CRPS, RPSS, ROC, BSS (resolution and reliability)
  - Variables
    - 500 hPa and 1000 hPa height
    - 850 hPa and 2-meter temperature
    - 10-m U and V
    - Precipitation (limited scores, CONUS only)

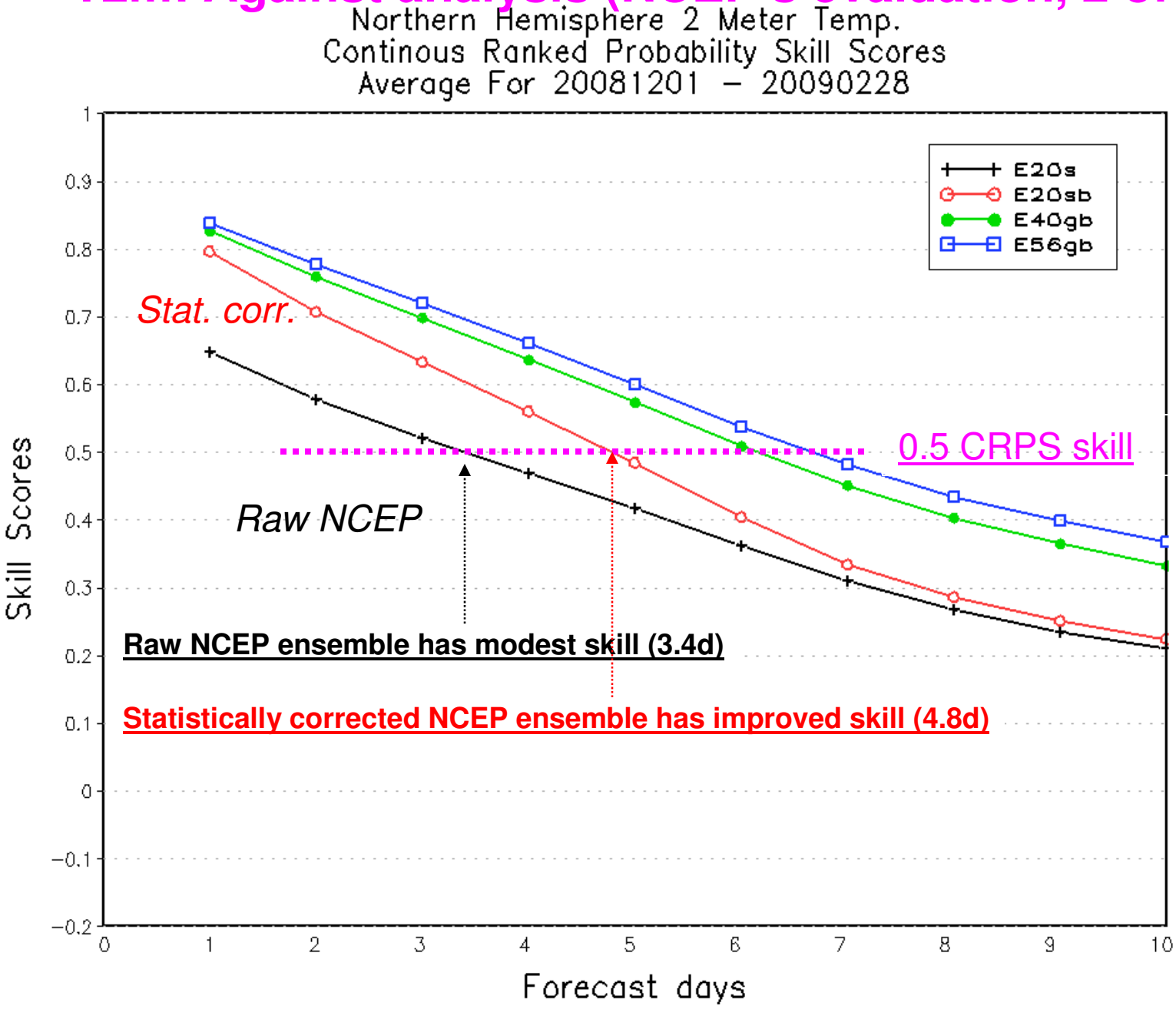

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For 20080901 – 20081130
NH 500hPa Height
Fall 2008 (AC)
7.8d
FNMOC is about 12h behind CMC and NCEP
7.3d
E20s – NCEP 20 members raw ensemble mean
E20m – CMC 20 members raw ensemble mean
E16f – FNMOC 16 members raw ensemble mean
E20s
E20m
E16f
Anomaly Correlation
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


Northern Hemisphere 500hPa Height
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20100221 - 20100415
E20sb
E16fb
NH 500hPa Height RMSE and Spread Spring 2010
E20sb – NCEP 20 members bias corrected ens. mean
E16fb – FNMOC 16 members bias corrected ens. mean
FNMOC bias corrected ens. mean RMSE
Small Initial spread with banded ET
NCEP bias corrected ens. mean RMSE
RMSE(solid) and SPREAD(dash)
Forecast days
0
10
20
30
40
50
60
70
80
90
100
110
120
0
1
2
3
4
5
6
7
8
9
10

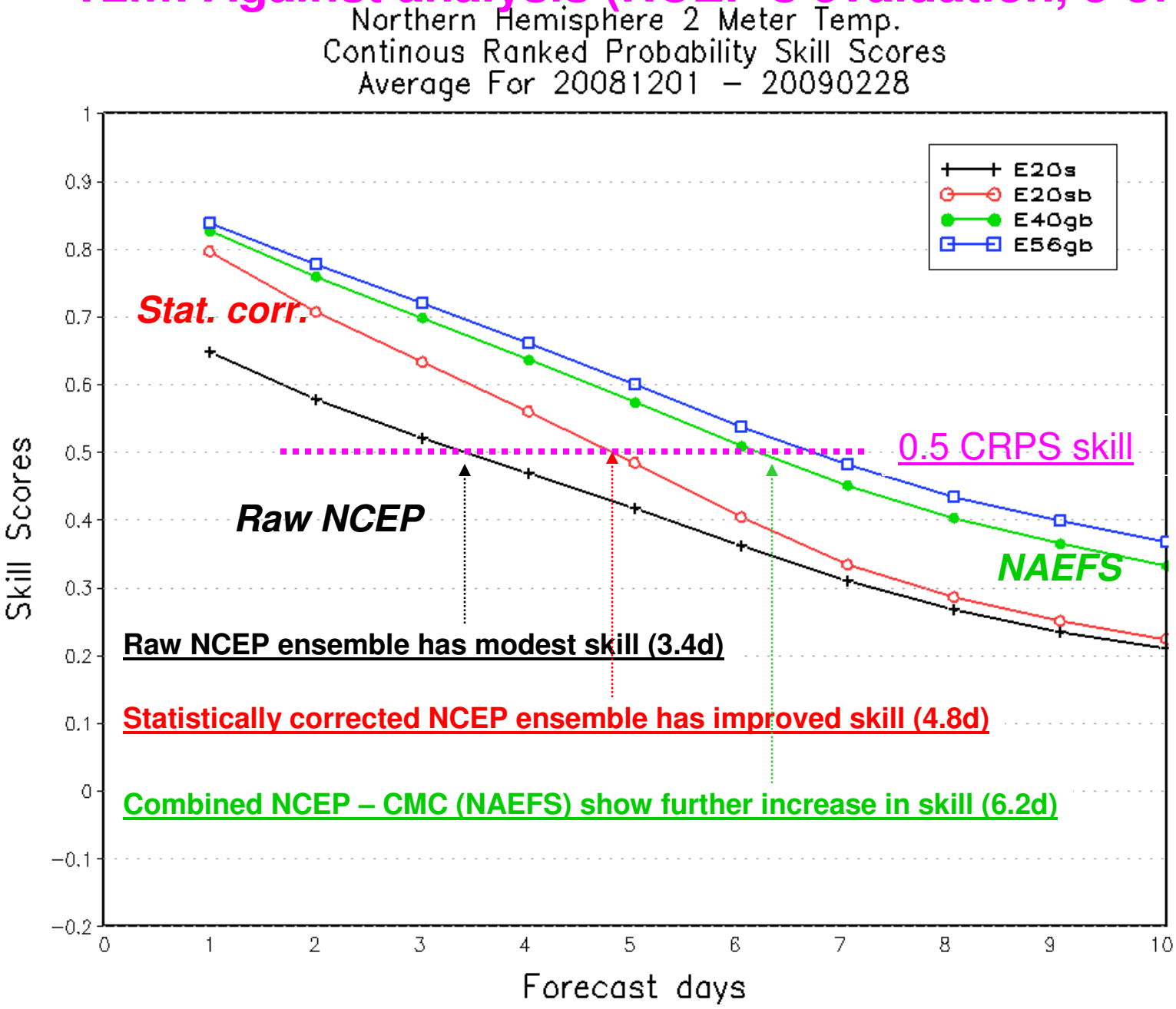
Value-added by including FNMOC ensemble into NAEFS
T2m: Against analysis (NCEP's evaluation, 1 of 4)



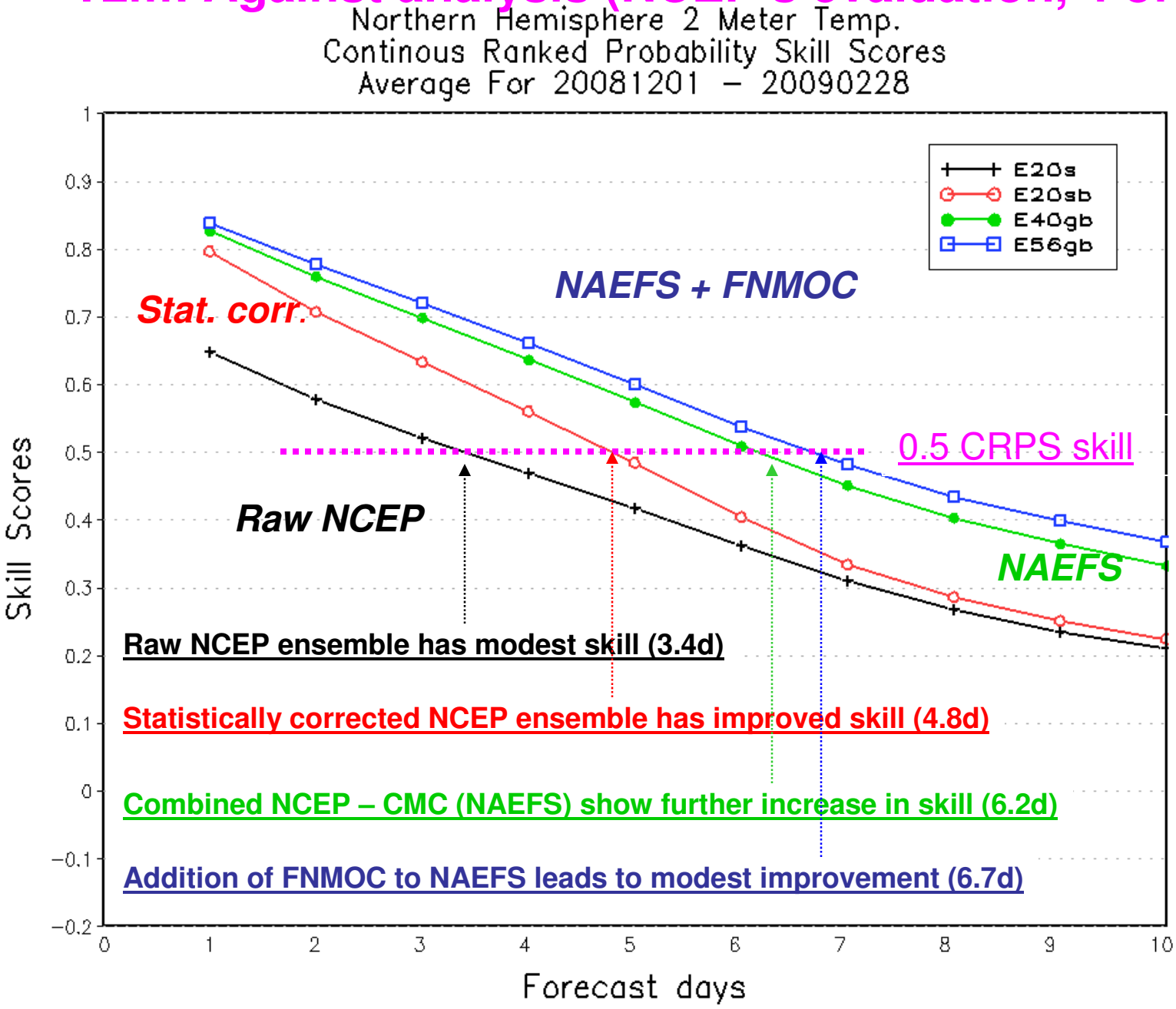
Value-added by including FNMOC ensemble into NAEFS
T2m: Against analysis (NCEP's evaluation, 2 of 4)



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

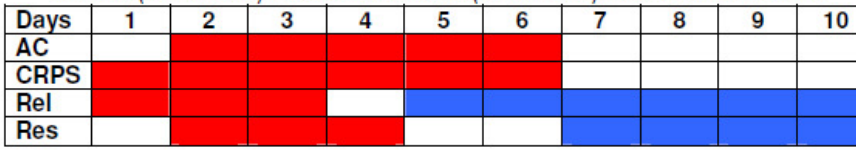


Value-added by including FNMOC ensemble into NAEFS
T2m: Against analysis (NCEP's evaluation, 4 of 4)

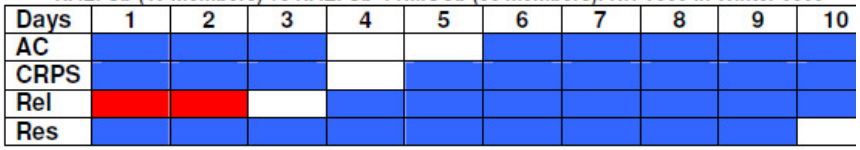


Value-added by including FNMOC ensemble into NAEFS

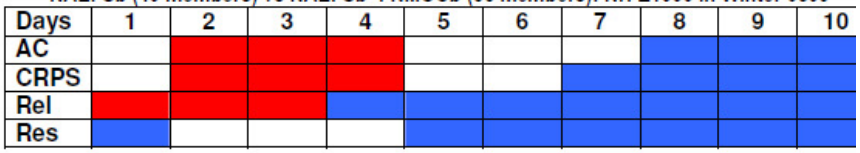
NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-Z500 in Winter 0809



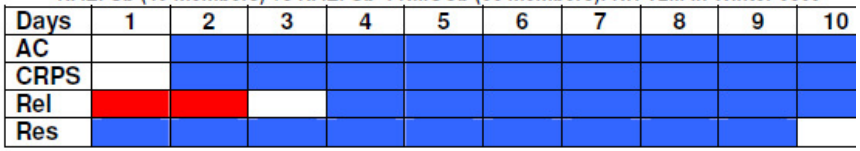
NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-T850 in Winter 0809



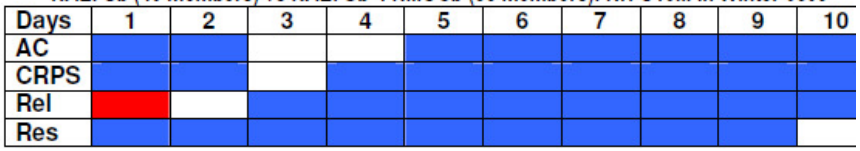
NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-Z1000 in Winter 0809



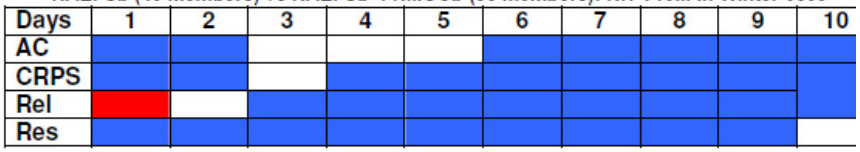
NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-T2M in Winter 0809



NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-U10M in Winter 0809

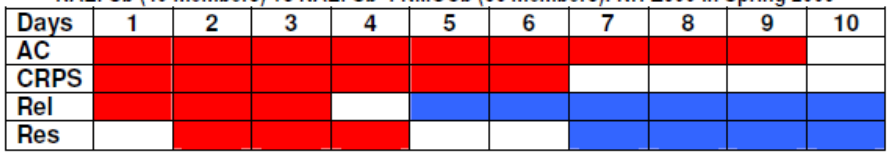


NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-V10M in Winter 0809

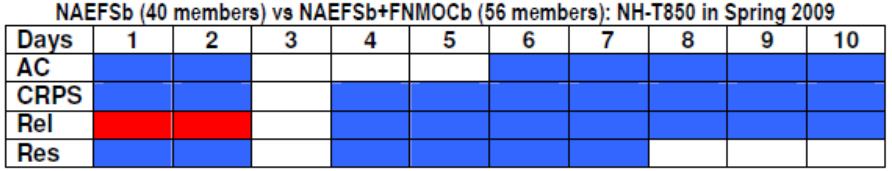


- Using 95% confidence interval (2.5%-97.5%), BLUE means NAEFSb+FNMOCb is significantly better than NAEFSb, RED means otherwise.
- The reliability (Rel) and resolution (Res) are from Brier Score decomposition.

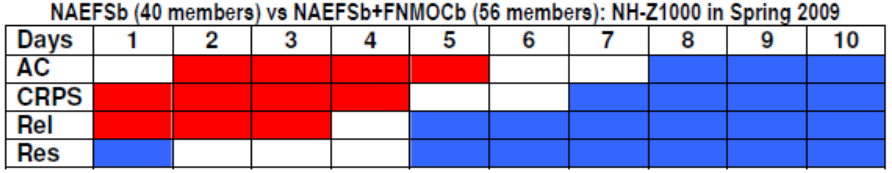
NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-Z500 in Spring 2009



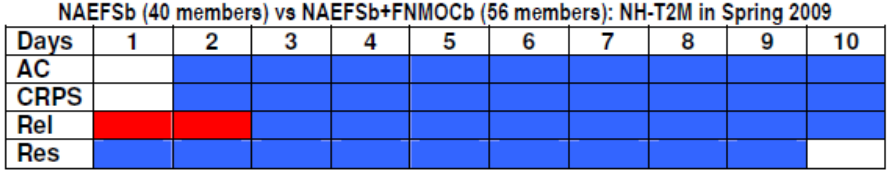
NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-T850 in Spring 2009



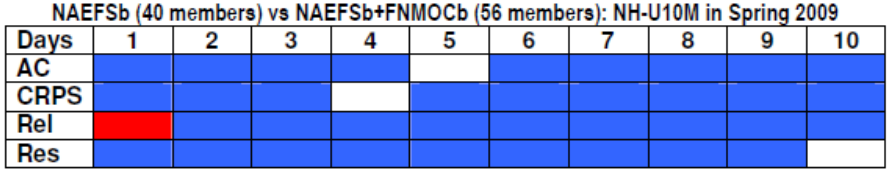
NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-Z1000 in Spring 2009



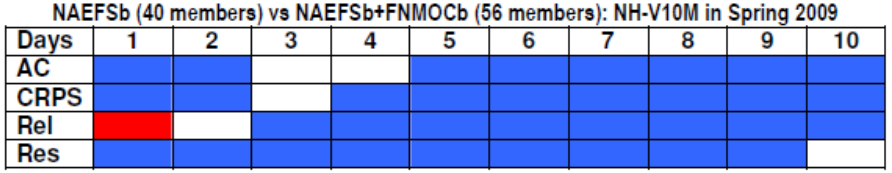
NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-T2M in Spring 2009



NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-U10M in Spring 2009



NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-V10M in Spring 2009



- Using 95% confidence interval (2.5%-97.5%), BLUE means NAEFSb+FNMOCb is significantly better than NAEFSb, RED means otherwise.
- The reliability (Rel) and resolution (Res) are from Brier Score decomposition.

Value-added by including FNMOC ensemble into NAEFS

NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-Z500 in Spring 2010

Days	1	2	3	4	5	6	7	8	9	10
AC										
CRPS										
Rel										
Res										

NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-T850 in Spring 2010

Days	1	2	3	4	5	6	7	8	9	10
AC										
CRPS										
Rel										
Res										

NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-Z1000 in Spring 2010

Days	1	2	3	4	5	6	7	8	9	10
AC										
CRPS										
Rel										
Res										

NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-T2M in Spring 2010

Days	1	2	3	4	5	6	7	8	9	10
AC										
CRPS										
Rel										
Res										

NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-U10M in Spring 2010

Days	1	2	3	4	5	6	7	8	9	10
AC										
CRPS										
Rel										
Res										

NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): NH-V10M in Spring 2010

Days	1	2	3	4	5	6	7	8	9	10
AC										
CRPS										
Rel										
Res										

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NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): SH-Z500 in Spring 2010

Days	1	2	3	4	5	6	7	8	9	10
AC										
CRPS										
Rel										
Res										

NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): SH-T850 in Spring 2010

Days	1	2	3	4	5	6	7	8	9	10
AC										
CRPS										
Rel										
Res										

NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): SH-Z1000 in Spring 2010

Days	1	2	3	4	5	6	7	8	9	10
AC										
CRPS										
Rel										
Res										

NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): SH-T2M in Spring 2010

Days	1	2	3	4	5	6	7	8	9	10
AC										
CRPS										
Rel										
Res										

NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): SH-U10M in Spring 2010

Days	1	2	3	4	5	6	7	8	9	10
AC										
CRPS										
Rel										
Res										

NAEFSb (40 members) vs NAEFSb+FNMOCb (56 members): SH-V10M in Spring 2010

Days	1	2	3	4	5	6	7	8	9	10
AC										
CRPS										
Rel										
Res										

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- The reliability (Rel) and resolution (Res) are from Brier Score decomposition.

Preliminary Conclusions

- **Individual ensemble systems (individual Centers' forecasts)**
  - NCEP and CMC have similar performance
  - FNMOC performance similar to NCEP & FNMOC for near surface variables, including precipitation
  - FNMOC is less skillful than NCEP and CMC for upper atmosphere variable (500hPa)

- **Combined ensemble system (without bias correction)**
  - Multi-model ensembles have higher skill than single system
  - Adding FNMOC ensemble to current NAEFS (NCEP+CMC) adds value for most forecast variables
    - Noticeable improvement for surface variables
    - Minimal improvement for upper atmosphere

- **Combined ensemble system (with operational NAEFS bias correction)**
  - Improved near surface variables with FNMOC ensemble
    - NCEPbc + CMCbc + FNMOCbc
  - Less improvement for upper atmosphere (e.g. 500hPa height))
    - Some degradation for short lead times (related to large spread in FNMOC ensemble)

- **CMC evaluation against observations**
  - Preliminary results combining raw ensembles are mixed
  - Results with bias corrected data still mixed

Recommendation and Outlook

- **NCEP plans to include FNMOC ensemble in NAEFS based on**
  - Preliminary evaluations (shown here)
  - Future improvements
    - NOGAPS 4-D Var (recently implemented)
    - Ensemble system upgrade (banded ET implemented Feb. 2010)
      - Reduced initial ensemble spread for variables related to 500hPa height
    - Extended forecast from current 10d to 16d
    - 4 additional members (16 → 20)
    - Increase variables from 52 to 73(80)
    - Upgrade exchange data format to GRIB2 for reduced data flow
  - Earlier data delivery from FNMOC
  - Final Real Time parallel evaluation (Q4FY10) with all partners (NCEP, FNMOC, MSC) for 3-months including above improvements
    - MSC reserves right to not include FNMOC data but no decision yet
- **Proposed data flow**
  - NCEP data: NCEP to FNMOC and CMC directly
  - FNMOC data: FNMOC to NCEP, then NCEP to CMC
  - CMC data: CMC to NCEP, then NCEP to FNMOC (?)
- **Anticipated implementation: Q1FY11**
  - Address new issues as they arise

Backup