Preliminary evaluation for NAEFS inclusion of FNMOC ensemble

Part I: Raw forecast – winter
Part II: Bias corrected forecast – winter
Part III: Bias corrected forecast – spring
Part IV: Downscaled forecast – winter and spring

Bo Cui
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Present for NAEFS workshop
May 3rd 2012, Monterey, CA

Preliminary evaluation for NAEFS inclusion of FNMOC ensemble

Part I: raw forecast

Yan Luo, Bo Cui and Yuejian Zhu

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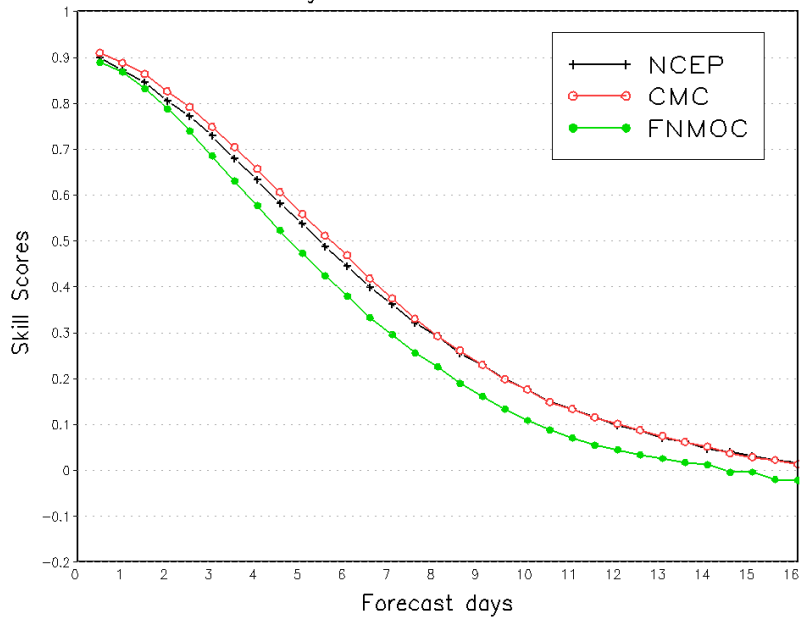March 8th 2012

NAEFS/NUOPC Configuration

Updated: February 14 2012

	NCEP	CMC	FNMOC
Model	GFS	GEM	Global Spectrum
Initial uncertainty	ETR	EnKF	(9) Banded ET
Model uncertainty Stochastic	Yes (STTP)	Yes (multi-physics)	None
Tropical storm	Relocation	None	None
Daily frequency	00,06,12 and 18UTC	00 and 12UTC	00 and 12UTC
Resolution	T254L42(0-8d) ~55km T190L42 (8-16d) ~70km	L40 ~ 66km	T159L42 ~ 80km
Control	Yes	Yes	No
Ensemble members	20 for each cycle	20 for each cycle	20 for each cycle
Forecast length	16 days (384 hours)	16 days (384 hours)	16 days (384 hours)
Post-process	Bias correction for ensemble mean	Bias correction for each member	Bias correction for member mean
Last implementation	February 14th 2012	August 17th 2011	September 14 2011

# Evaluation (1)

- Based on operational ensemble systems
- For all raw ensembles
- Period: Winter - Dec. 1st 2011 – Feb. 29th 2012
  - T190L28 GEFS configuration for Dec. 1st 2011 – Feb. 14th 2012
  - Full T254L42 GEFS comparison for spring will come out soon – expect even better
- Variables (10): 1000hPa, 500hPa height, 850hPa, 2-meter temperature, 250hPa, 850hPa and 10-meter U & V
- 2.5*2.5 degree resolution globally (verification only)
- Based on NUOPC verification matrix
- Verify against UKMet analysis
- Three ensembles
  - NCEP 20 ensembles (NCEP)
  - CMC 20 ensembles (CMC)
  - FNMOC 20 ensembles (FNMOC)
- More results:
  - http://www.emc.ncep.noaa.gov/gmb/yluo/NUOPC/NUOPC_win1112.html

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Northern Hemisphere 500hPa Height
Continous Ranked Probability Skill Scores
Average For 20111201 – 20120229

NCEP
CMC
FNMOC

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For 20111201 – 20120229

NCEP
CMC
FNMOC

Northern Hemisphere 500hPa Height
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20111201 – 20120229

NCEP
CMC
FNMOC
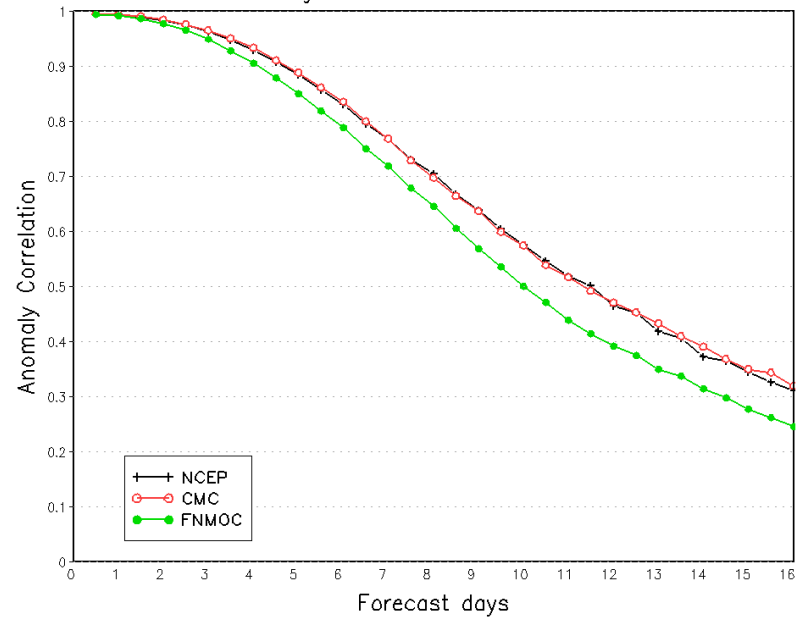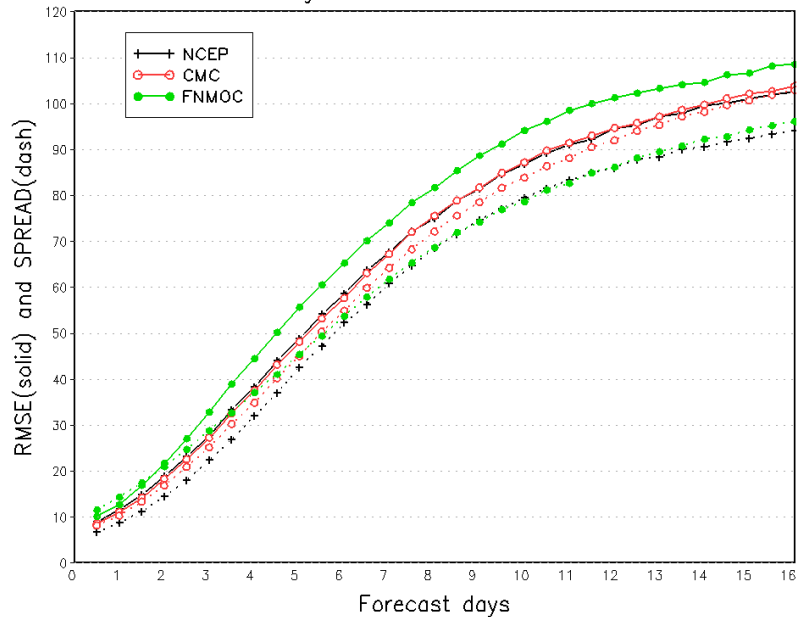
NH 500hPa geopotential height

Winter 2011-2012
December 1 2011 – February 29 2012

Top left – CRPS
Top right – AC for ensemble mean
Bottom left – RMSE and Spread

Summary (1)

- Three different forecasts are verified against independent analysis – UKMet analysis
- NCEP and CMC's performances are very closed to each other.
- NCEP has better performance than CMC for 1000hPa height on both probabilistic forecast and ensemble mean
- CMC has better performance than NCEP for 10-meter wind on probabilistic forecast
- CMC has better performance than NCEP for tropical winds on probabilistic forecast
- FNMOC has overall less skills than NCEP and CMC forecast for both probabilistic and deterministic evaluations.
- FNMOC has the closed forecast to NCEP and CMC for surface winds, but still has lowest skill
- 2-meter temperature is worst one for FNMOC, there are may be two possibilities as following:
  - FNOMC has large bias???
  - UKMet analysis is too warm (Tom Hamill's recently study)
 - Anyway, TIGGE study indicate that T2m has largest variables from centers

Evaluation (2)

- Based on operational ensemble systems
- For all raw ensembles
- Period: Dec. 1st 2011 – Feb. 29 2012
- Variables (10): 1000hPa, 500hPa height, 850hPa, 2-meter temperature, 250hPa, 850hPa and 10-meter U & V
- 2.5*2.5 degree resolution globally (verification only)
- Based on NUOPC verification matrix
- Verify against UKMet analysis
- Simply combination
- Three ensembles
  - NCEP 20 ensembles (NCEP)
  - NCEP and CMC 40 ensembles (NCEP+CMC)
  - NCEP and FNMOC 40 ensembles (NCEP+FNMOC)
  - NCEP, CMC and FNMOC 60 ensembles (NCEP+CMC+FNMOC)
- More results:
  - http://www.emc.ncep.noaa.gov/gmb/yluo/NUOPC/NUOPC_comb_win1112.html
  - http://www.emc.ncep.noaa.gov/gmb/yluo/NUOPC/NUOPC_COMB_win1112.html
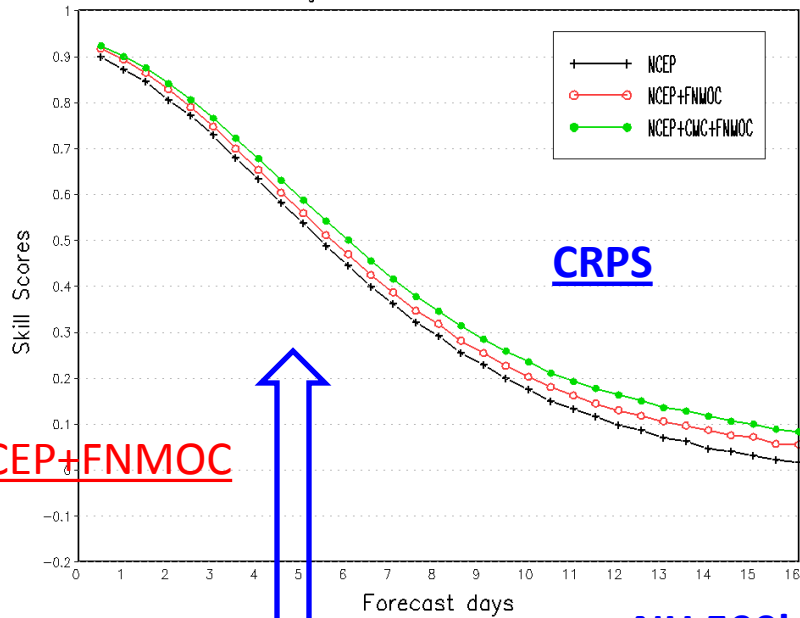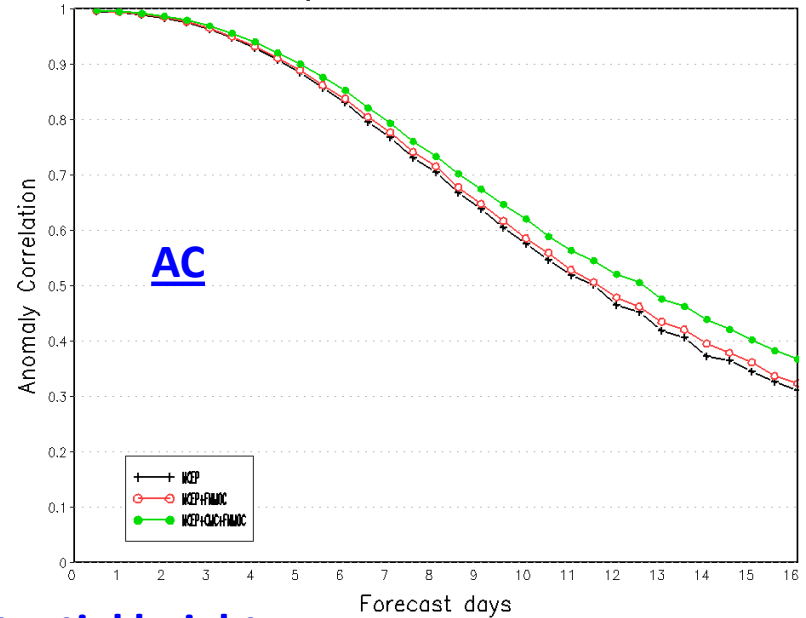
NH 500hPa geopotential height

Summary (2)

- All individual or combined forecasts are verified against independent analysis – UKMet analysis
- NCEP+FNMOC has better skills than either individual one for most variables except for surface temperature
- NCEP+CMC has better (best) scores for all demonstrated variables.
- NCEP+CMC+FNMOC has closed score as NCEP+CMC except for surface temperature (worse)
- Interesting discussion:
  - If we are starting NCEP+FNMOC first, values are added for most variables. Then, additional values added by third ensemble (CMC) – good multi-model ensemble
  - If we are starting NCEP+CMC first, significant values are added for all variables. Then, no need for third ensemble (FNMOC).
  - Looks there are different decisions from different orders.
  - Challenge - NAEFS (NCEP+CMC) was in operation at NOAA since 2006. How can we do for FNMOC ensemble???
  - What is the result If FNMOC has the similar skills as NCEP and CMC? Do we still see a big improvement from third ensemble?

Preliminary evaluation for NAEFS inclusion of FNMOC ensemble

Part II: bias corrected forecast
Winter - Prior NCEP GEFS implementation

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**Environmental Modeling Center**
NCEP/NWS/NOAA

March 30th 2012

Evaluation (3)

- Based on operational FNMOC ensemble system
- Apply NAEFS bias correction method for FNMOC ensembles
  - At 1*1 degree resolution
- Period: Dec. 1st 2011 – Feb. 29 2012
- Variables (10): 1000hPa, 500hPa height, 850hPa, 2-meter temperature, 10-meter U & V
- Based on NCEP/NAEFS verification matrix
- Verify against own analysis (FNMOC)
  - Verify at 2.5*2.5 degree resolution
- Comparing: raw ensemble and bias corrected ensemble
  - FNMOC 20 raw ensembles (E20f)
  - FNMOC 20 bias corrected ensemble (E20fb)
- More results:
  - http://www.emc.ncep.noaa.gov/gmb/yzhu/html/opr/naefs/FNMOC_FNMOCb_win1112.html

NAEFS products at 1*1 degree globally
(from bias corrected NCEP GFS/GEFS and CMC GEFS)

Variables	pgrb2a_bc and pgrb2a_an files	Total 49
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
	Anomaly forecast for 19 variables	
Notes	10%, 50%, 90% mean, mode and spread for 49 variables, 4 times per day, every 6 hours, out to 16 days	

Northern Hemisphere 850hPa Temp.
Continous Ranked Probability Skill Scores
Average For 20111201 − 20120229
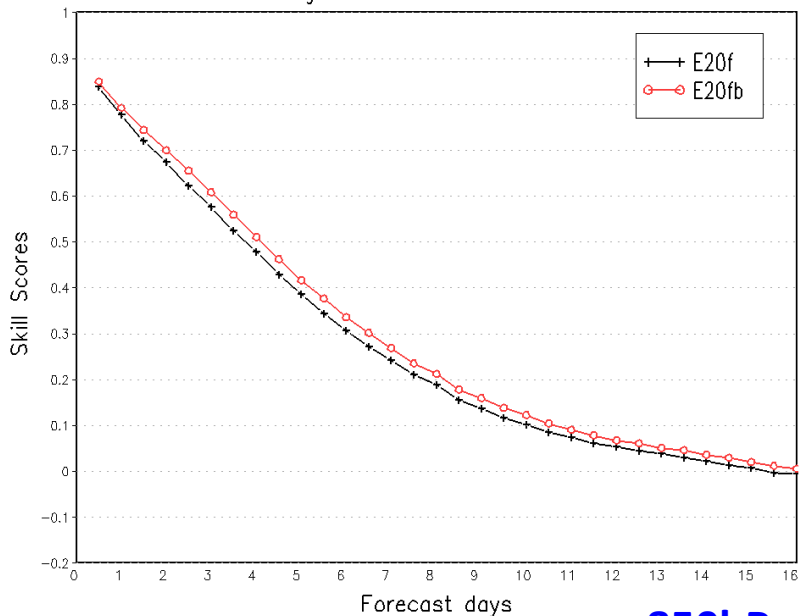
Northern Hemisphere 850hPa Temp.
Ensemble Mean Anomaly Correlation
Average For 20111201 − 20120229
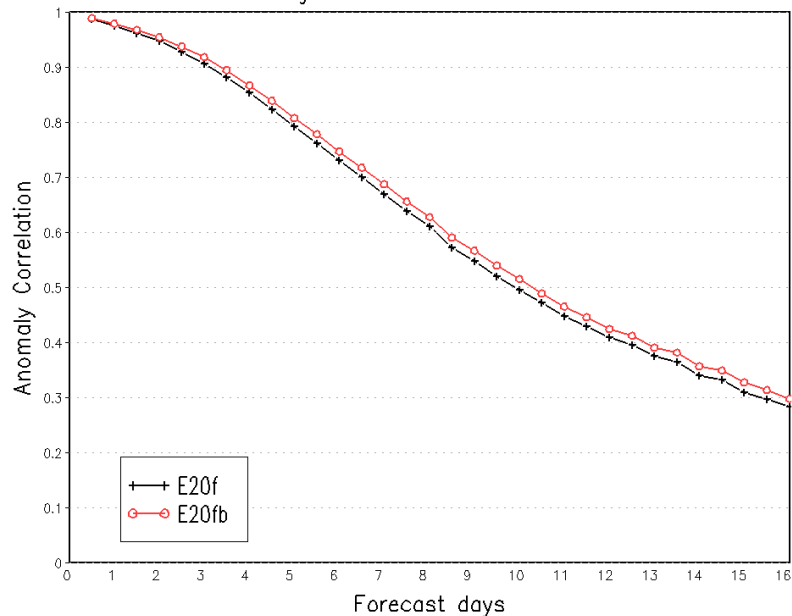
850hPa temperature

Northern Hemisphere 850hPa Temp.
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20111201 − 20120229
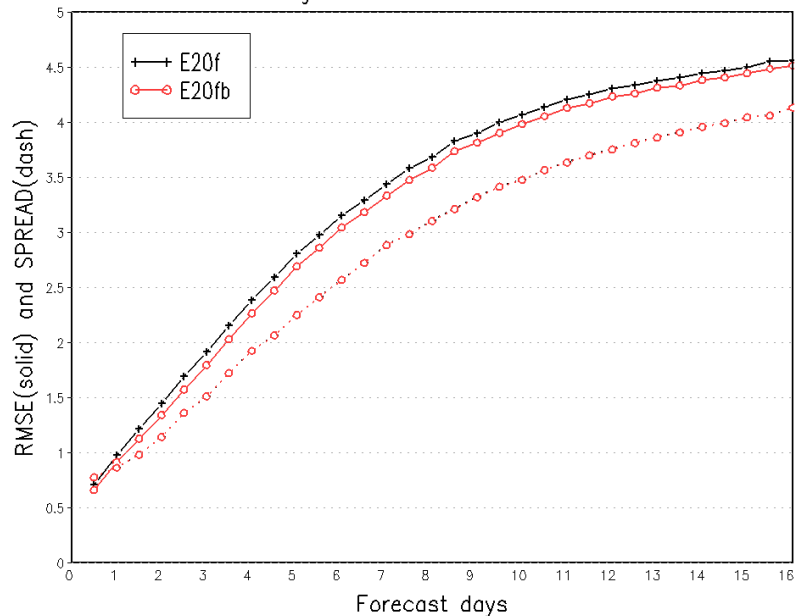
Northern Hemisphere 850hPa Temp. Histogram Distribution
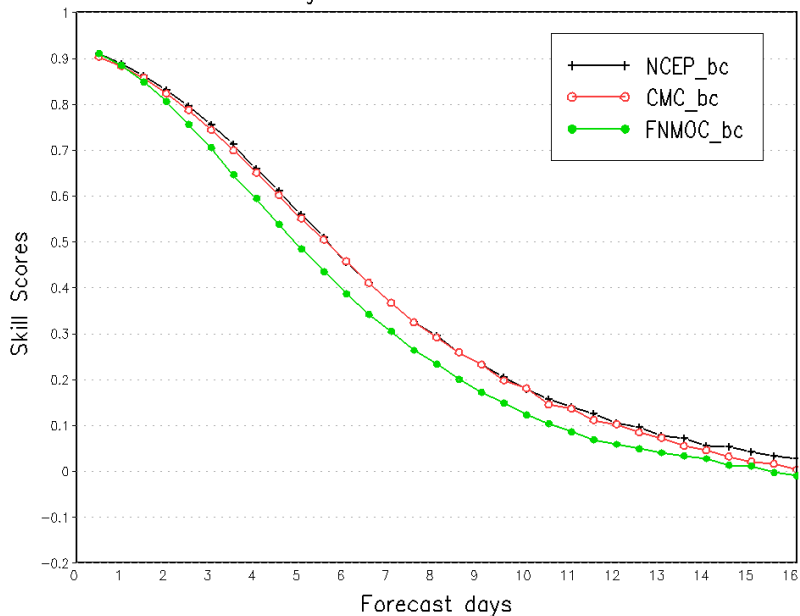Average For 20111201 − 20120229
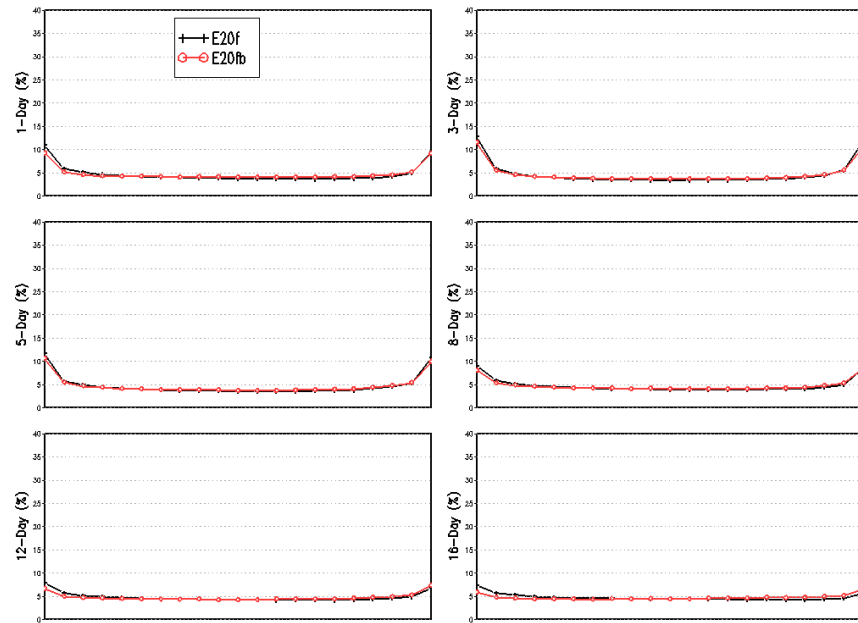
Summary (3)

- NCEP/NAEFS bias correction method could apply to any ensemble system calibration. At least it works very well for NCEP, CMC and FNMOC ensemble right now.
- The improvement will depend on model systematic error level.
  - 2-meter temperature has largest improvement through bias correction
- NCEP/NAEFS bias correction method is easiest way to carry on, and for operation application
  - It is not necessary to have training data – cold start
  - No additional disk space is needed (only one carry on bias accumulation files)
  - Less computation cost, one step for accumulation, one step for de-bias
  - Easy for forecast model upgrade – copy over one bias accumulation file or cold start.
- Suggestion: any new calibration method for future operational application needs to be compare to the results from NCEP/NAEFS bias correction method.

Evaluation (4)

- Based on operational ensemble systems
- For all bias corrected ensembles (all using their own analysis for bias correction)
- Period: Winter - Dec. 1st 2011 – Feb. 29th 2012
  - T190L28 GEFS configuration for Dec. 1st 2011 – Feb. 14th 2012
  - Full T254L42 GEFS comparison for spring will come out soon – expect even better
- Variables (10): 1000hPa, 500hPa height, 850hPa, 2-meter temperature, 250hPa, 850hPa and 10-meter U & V
- 2.5*2.5 degree resolution globally (verification only)
- Based on NUOPC verification matrix
- Verify against UKMet analysis
- Three ensembles
  - NCEP 20 ensembles (NCEP)
  - CMC 20 ensembles (CMC)
  - FNMOC 20 ensembles (FNMOC)
- More results:
  - http://www.emc.ncep.noaa.gov/gmb/yluo/NUOPC/NUOPC_bc_win1112.html

Northern Hemisphere 500hPa Height
Continous Ranked Probability Skill Scores
Average For 20111201 – 20120229

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For 20111201 – 20120229
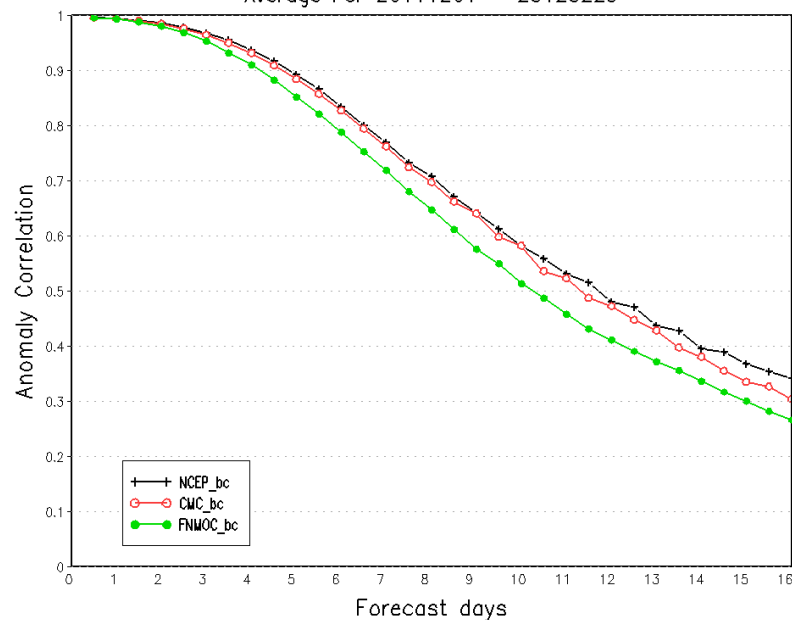
Northern Hemisphere 500hPa Height
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20111201 – 20120229

NH 500hPa geopotential height

Winter 2011-2012
December 1 2011 – February 29 2012

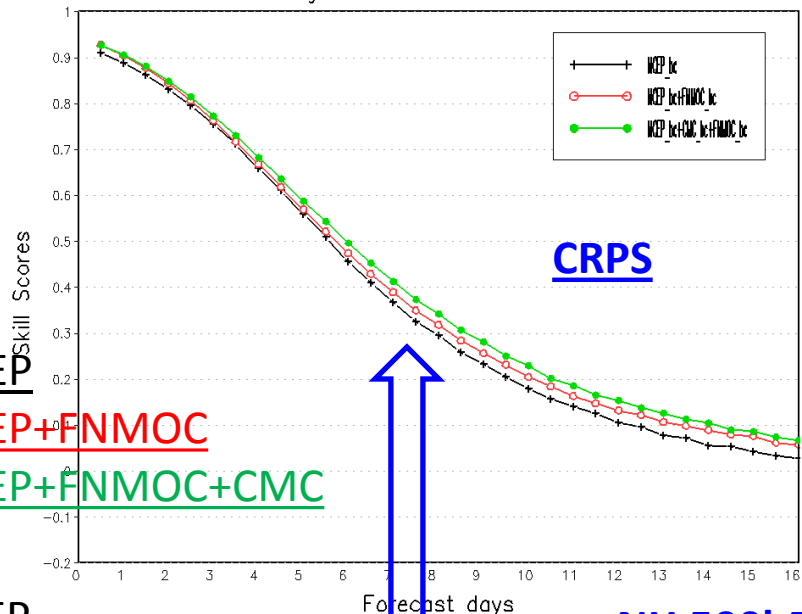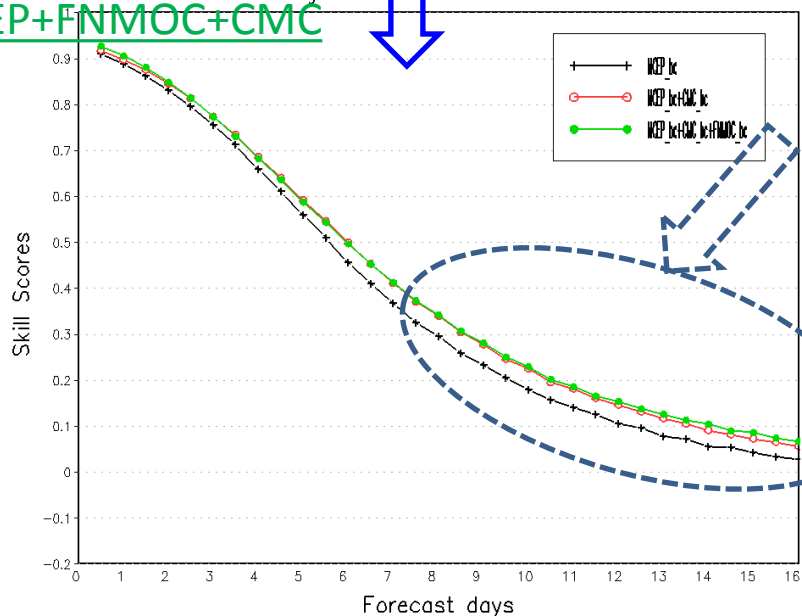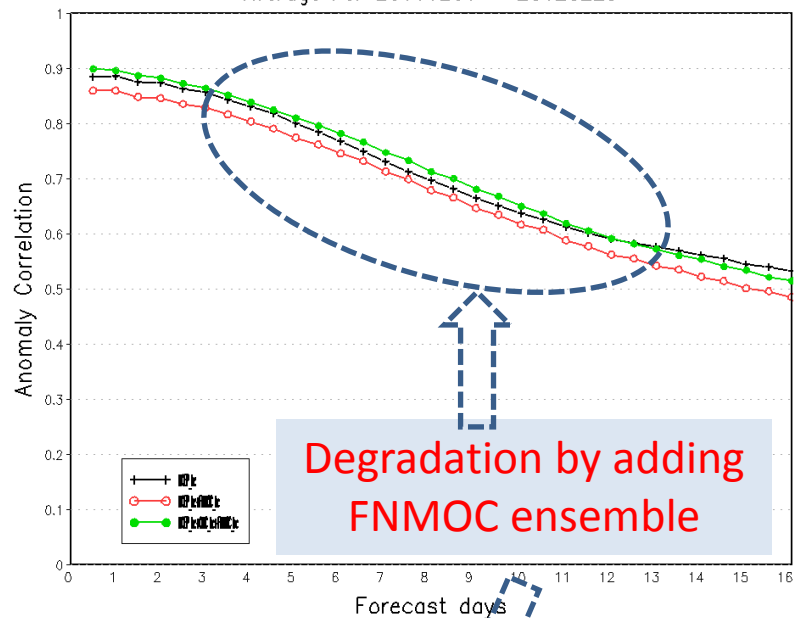Top left – CRPS
Top right – AC for ensemble mean
Bottom left – RMSE and Spread

16
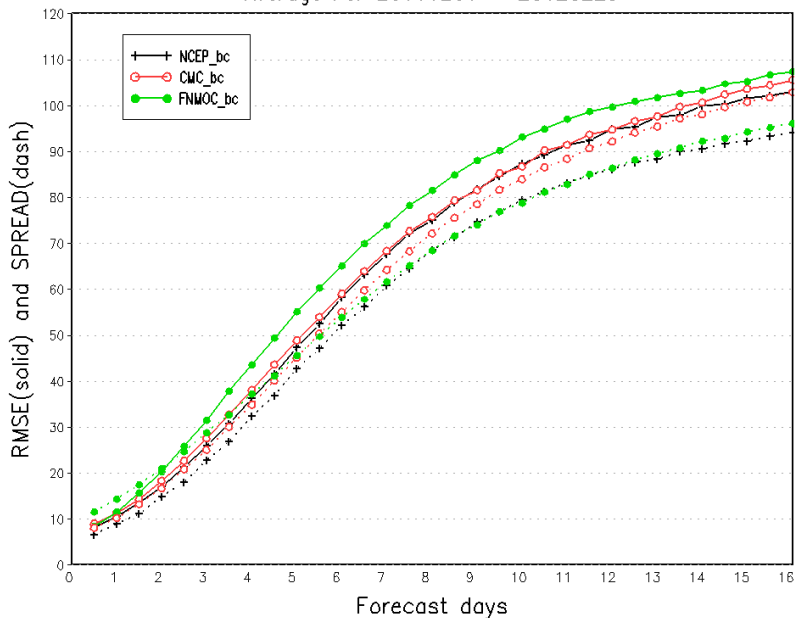
Summary (4)

- Three different bias corrected forecasts are verified against independent analysis – UKMet analysis
- NCEP and CMC's performances are very closed to each other.
- NCEP has better performance than CMC for 1000hPa height on both probabilistic forecast and ensemble mean
- CMC has better performance than NCEP for 850hPa temperature for day 1-2, but NCEP is better for week-2
- CMC has better performance than NCEP for tropical winds on probabilistic forecast and ensemble mean for both 850hPa and 250hPa
- FNMOC has overall less skills than NCEP and CMC forecast for both probabilistic and deterministic evaluations.
- FNMOC has the closed forecast to NCEP and CMC for 1000hPa and 500hPa heights, but still has lowest skill
- 2-meter temperature is still worst one for FNMOC when comparing to other variables:
  - UKMet analysis may be too warm (Tom Hamill's recently study)
  - Anyway, TIGGE study indicate that T2m has largest variables from centers

Evaluation (5)

- Based on operational ensemble systems
- For all bias corrected ensembles (all using their own analysis for bias correction)
- Period: Dec. 1st 2011 – Feb. 29 2012
- Variables (10): 1000hPa, 500hPa height, 850hPa, 2-meter temperature, 250hPa, 850hPa and 10-meter U & V
- 2.5*2.5 degree resolution globally (verification only)
- Based on NUOPC verification matrix
- Verify against UKMet analysis
- Simply combination
- Three ensembles
  - NCEP 20 ensembles (NCEPbc)
  - NCEP and CMC 40 ensembles (NCEPbc+CMCbc)
  - NCEP and FNMOC 40 ensembles (NCEPbc+FNMOCbc)
  - NCEP, CMC and FNMOC 60 ensembles (NCEPbc+CMCbc+FNMOCbc)
- More results:
  - http://www.emc.ncep.noaa.gov/gmb/yluo/NUOPC/NUOPC_bc_comb_win1112.html
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Northern Hemisphere 500hPa Height
Continous Ranked Probability Skill Scores
Average For 20111201 — 20120229

CRPS

NCEP
NCEP+FNMOC
NCEP+FNMOC+CMC

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For 20111201 — 20120229

AC

NH 500hPa geopotential height
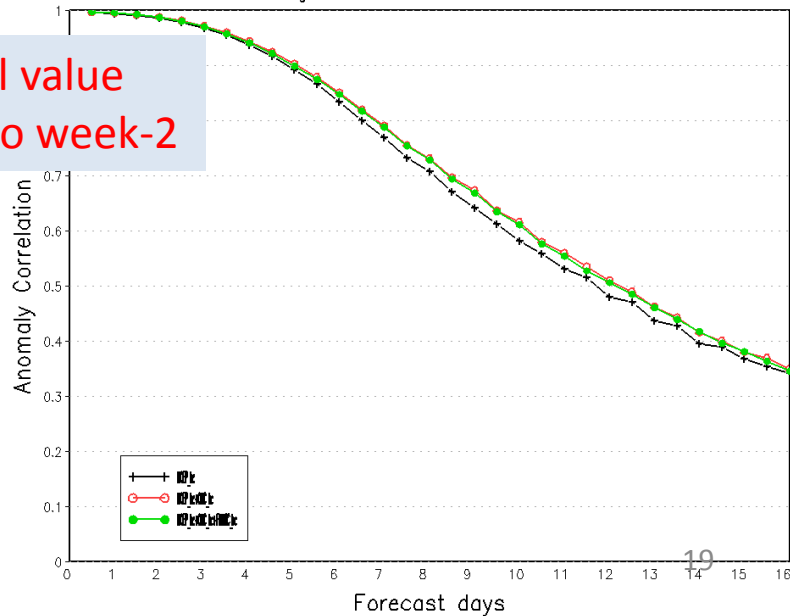
NCEP
NCEP+CMC
NCEP+FNMOC+CMC

Northern Hemisphere 500hPa Height
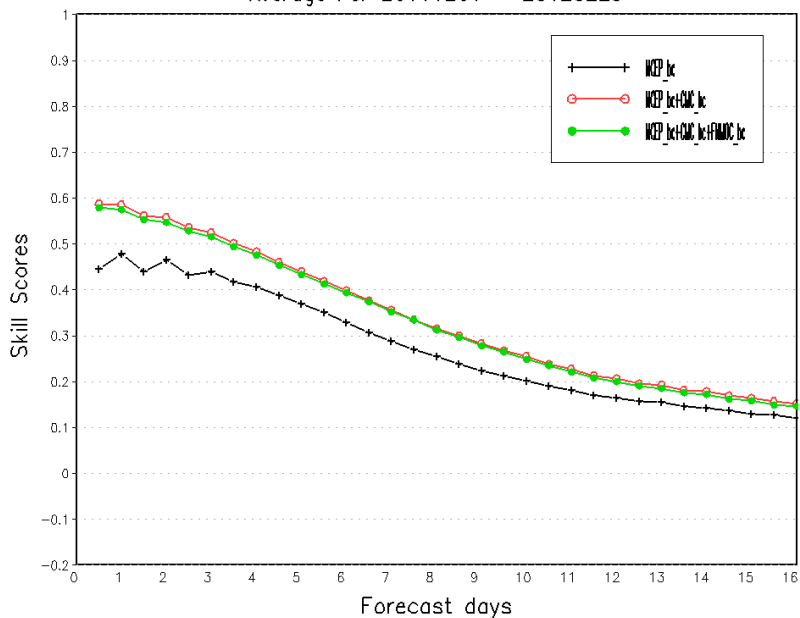Continous Ranked Probability Skill Scores
Average For 20111201 — 20120229

Small value
added to week-2

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For 20111201 — 20120229

19

Northern Hemisphere 2 Meter Temp.
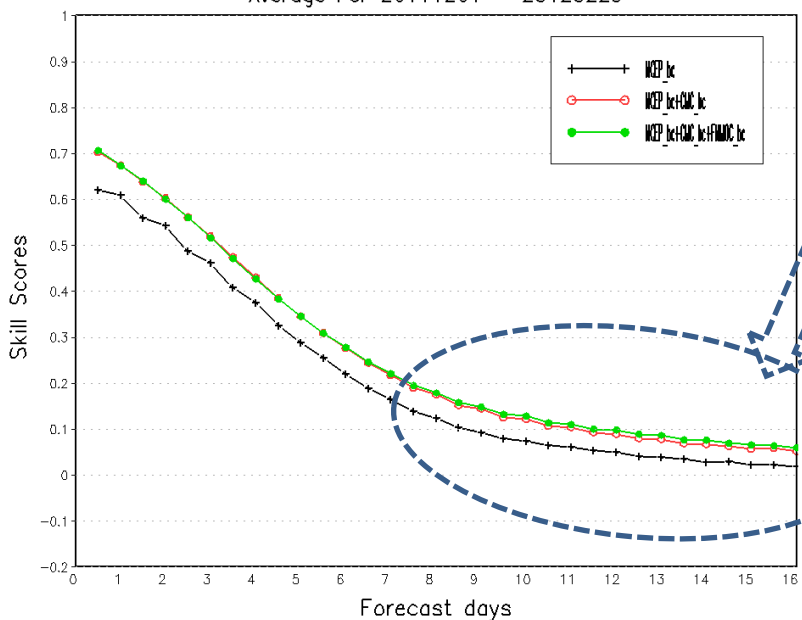Continous Ranked Probability Skill Scores
Average For 20111201 – 20120229

Northern Hemisphere 2 Meter Temp.
Ensemble Mean Anomaly Correlation
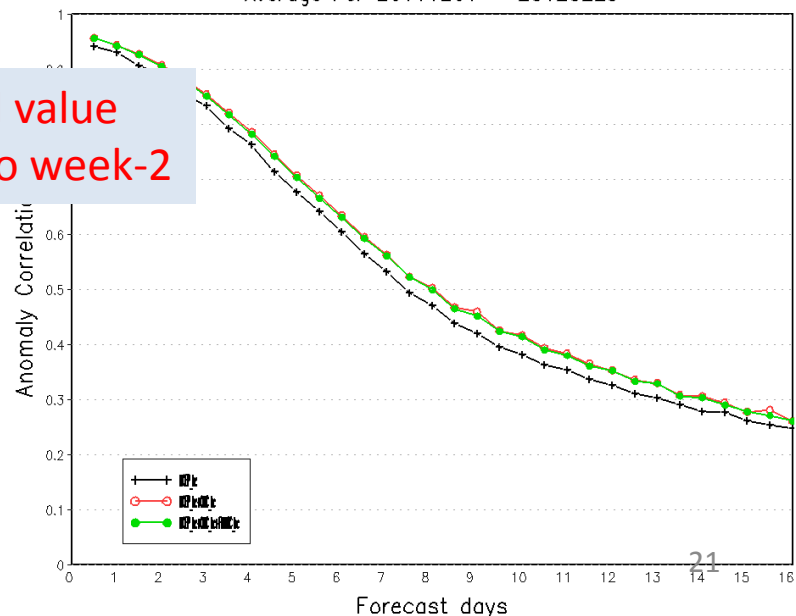Average For 20111201 – 20120229

Degradation by adding FNMOC ensemble

NH 2-meter temperature

Northern Hemisphere 2 Meter Temp.
Continous Ranked Probability Skill Scores
Average For 20111201 – 20120229

Northern Hemisphere 2 Meter Temp.
Ensemble Mean Anomaly Correlation
Average For 20111201 – 20120229

20

NH 10-meter U wind

Small value added to week-2

Summary (5)

- All individual or combined forecasts (bias corrected) are verified against independent analysis – UKMet analysis (except for slides indicated).
- NCEP+FNMOC has better skills than either individual one for most variables except for surface temperature (see discussion)
- NCEP+CMC has better (best) scores for all demonstrated variables.
- NCEP+CMC+FNMOC has closed score as NCEP+CMC except for
  - FNMOC add values
    - NA surface temperature – better than NCEP+CMC (bias corrected)
    - NH 500hPa height – a little gaining for week-2
    - Tropical 500hPa and 1000hPa height – significant gaining by adding FNMOC
    - NH surface wind – a little gaining for week-2
  - Degradation by add FNMOC
    - NH Surface temperature – a little degradation from ensemble mean (not probabilistic forecast)
- Interesting discussion:
  - If we are starting NCEP+FNMOC first, values are added for most variables. Then, additional values added by third ensemble (CMC) – good multi-model ensemble
  - If we are starting NCEP+CMC first, significant values are added for all variables. Then, no need for third ensemble (FNMOC).
  - Looks there are different decisions from different orders.
  - Surface evaluations – 2-meter temperature
    - There are large analysis variations from centers – based on Tom Hamill's latest study
    - We need to see more evaluations from CPC and CMC/MSC – against observations
    - To look at spring evaluation after GEFS upgrade

Preliminary evaluation for NAEFS inclusion of FNMOC ensemble

Part III: bias corrected forecast
Spring 2012 - after NCEP/GEFS implementation

Yan Luo, Bo Cui and Yuejian Zhu

Environmental Modeling Center
**NCEP/NWS/NOAA**

April 25th 2012

Evaluation (6)

- Based on operational ensemble systems
- For all bias corrected ensembles (all using their own analysis for bias correction)
- Period: Winter – Feb. 14th 2012 – Apr. 25th 2012
  - GEFS was implemented by Feb. 14th 2012
  - T254L42 (0-8 days), and T190L42 (8-16 days)
  - GFS V9.0
  - Tuned ETR and STTP of NCEP GEFS
- Variables (10): 1000hPa, 500hPa height, 850hPa, 2-meter temperature, 250hPa, 850hPa and 10-meter U & V
- 2.5*2.5 degree resolution globally (verification only)
- Based on NUOPC verification matrix
- Verify against UKMet analysis
- Three ensembles
  - NCEP 20 ensembles (NCEP)
  - CMC 20 ensembles (CMC)
  - FNMOC 20 ensembles (FNMOC)
- More results:
  - http://www.emc.ncep.noaa.gov/gmb/yluo/NUOPC/NUOPC_bc_spr2012.html

Northern Hemisphere 850hPa Temp.
Continous Ranked Probability Skill Scores
Average For 20120214 – 20120425
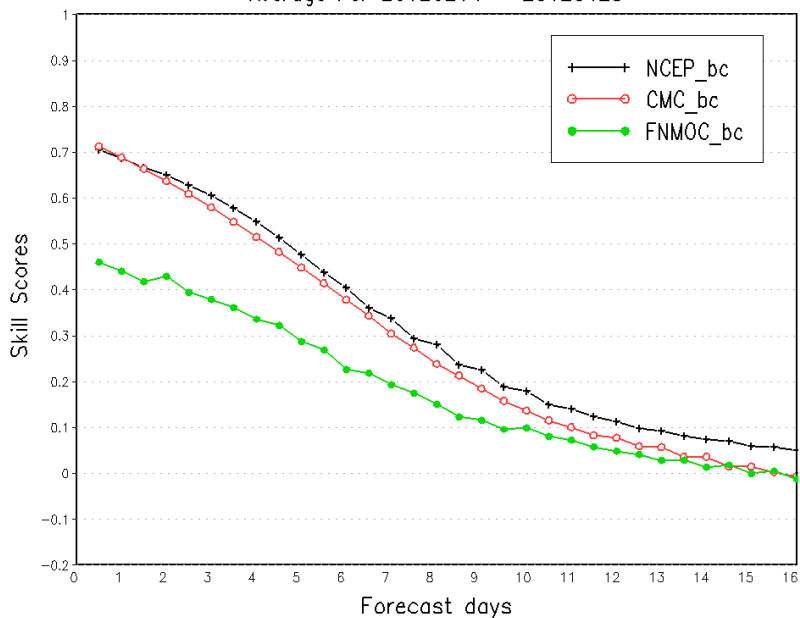
Northern Hemisphere 850hPa Temp.
Ensemble Mean Anomaly Correlation
Average For 20120214 – 20120425
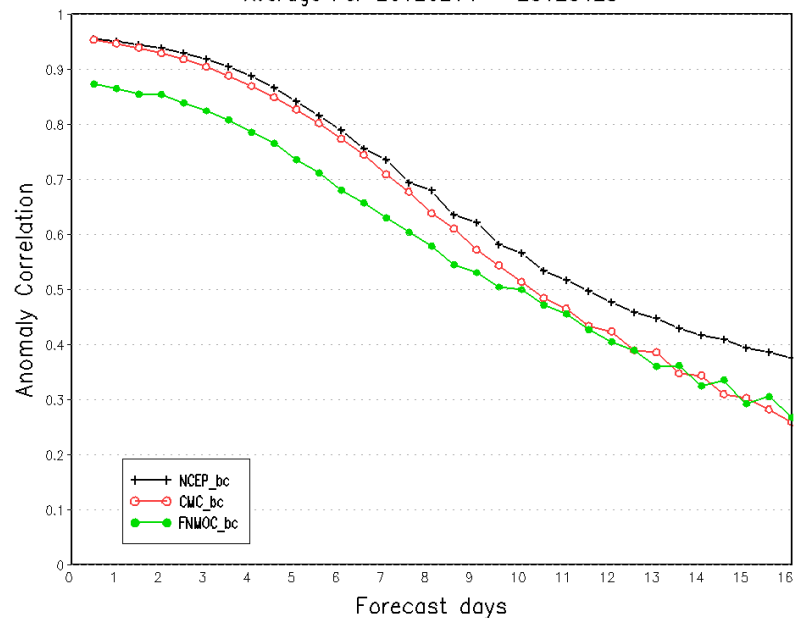
Northern Hemisphere 850hPa Temp.
Ensemble Mean RMSE and Ensemble SPREAD
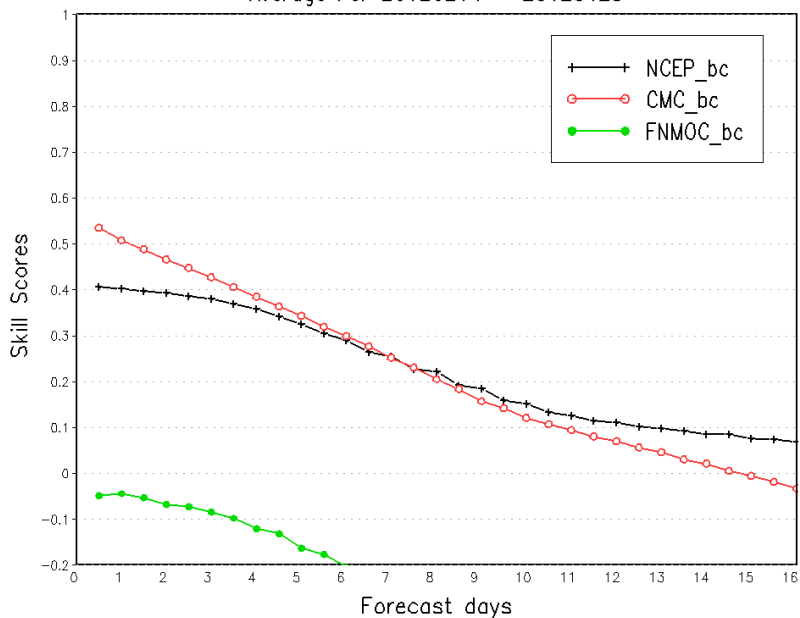Average For 20120214 – 20120425
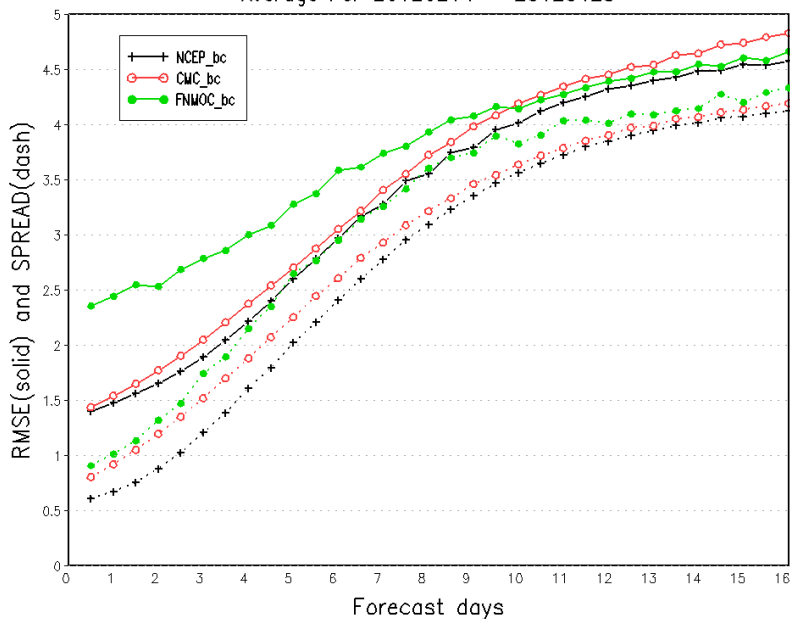
NH 850hPa temperature
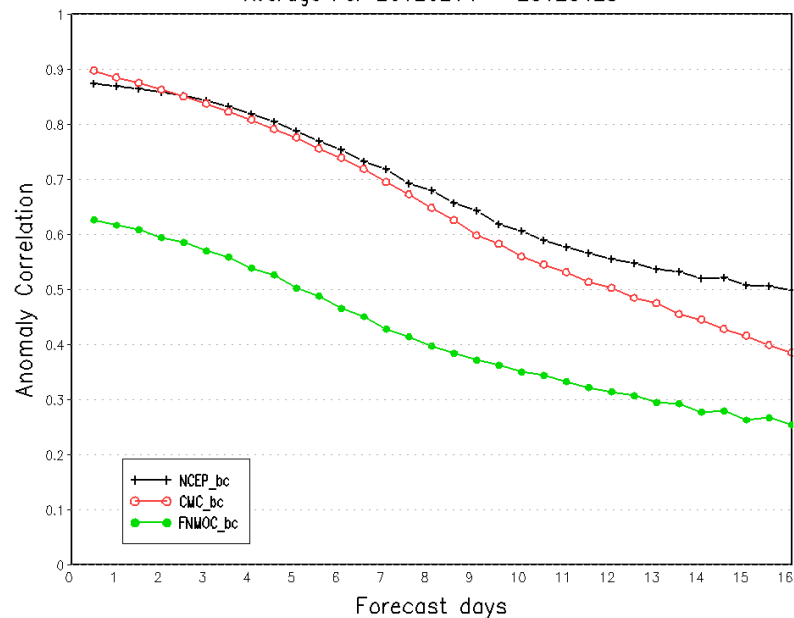
Spring 2012
February 14 – April 25 2012

Top left – CRPS
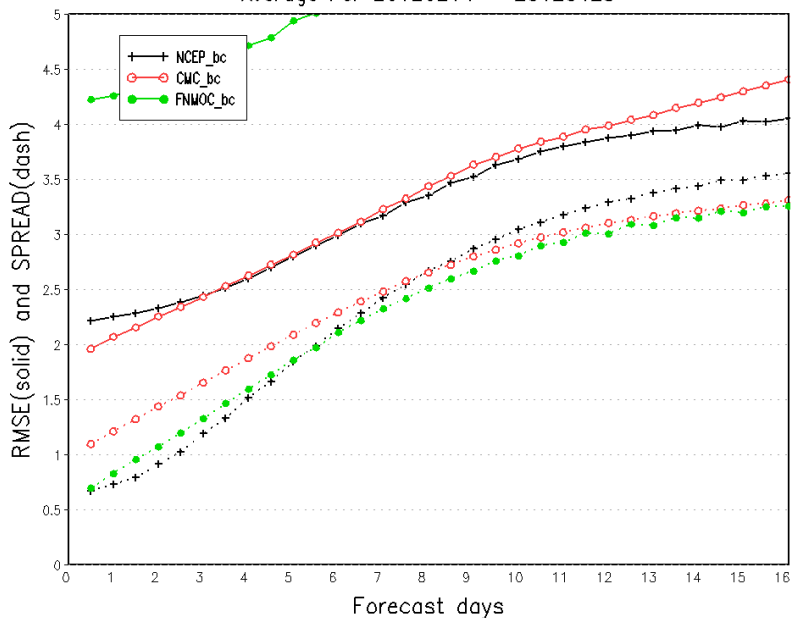Top right – AC for ensemble mean
Bottom left – RMSE and Spread

Northern Hemisphere 2 Meter Temp.
Continous Ranked Probability Skill Scores
Average For 20120214 – 20120425

Northern Hemisphere 2 Meter Temp.
Ensemble Mean Anomaly Correlation
Average For 20120214 – 20120425

Northern Hemisphere 2 Meter Temp.
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20120214 – 20120425

NH 2-meter temperature

Winter 2011-2012
December 1 2011 – February 29 2012

Top left – CRPS
Top right – AC for ensemble mean
Bottom left – RMSE and Spread

Summary (6)

- Three different bias corrected forecasts are verified against independent analysis – UKMet analysis
- NCEP and CMC's performances are very closed to each other.
- NCEP has better performance than CMC for 1000hPa height on ensemble mean
- NCEP has better performance than NCEP for 850hPa temperature for both probabilistic and ensemble mean beyond day-2
- CMC has better performance than NCEP for tropical winds on probabilistic forecast for 250hPa, but NCEP has better performance than CMC for 850hPa ensemble mean
- FNMOC has overall less skills than NCEP and CMC forecast for both probabilistic and deterministic evaluations.
- FNMOC has the closed forecast to NCEP and CMC for 1000hPa and 500hPa heights, and 850hPa/250hPa tropical winds, but still has lowest skill
- 850hPa and 2-meter temperature apparently has a problem since later winter. It is unreasonable worse than before (as Canadian detected earlier).

Evaluation (7)

- Based on operational ensemble systems
- For all bias corrected ensembles (all using their own analysis for bias correction)
- Period: Feb. 14 – April 25 2012
- Variables (10): 1000hPa, 500hPa height, 850hPa, 2-meter temperature, 250hPa, 850hPa and 10-meter U & V
- 2.5*2.5 degree resolution globally (verification only)
- Based on NUOPC verification matrix
- Verify against UKMet analysis
- Simply combination
- Three ensembles
  - NCEP 20 ensembles (NCEPbc)
  - NCEP and CMC 40 ensembles (NCEPbc+CMCbc)
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Northern Hemisphere 500hPa Height
Continous Ranked Probability Skill Scores
Average For 20120214 – 20120425

CRPS

Northern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For 20120214 – 20120425

AC
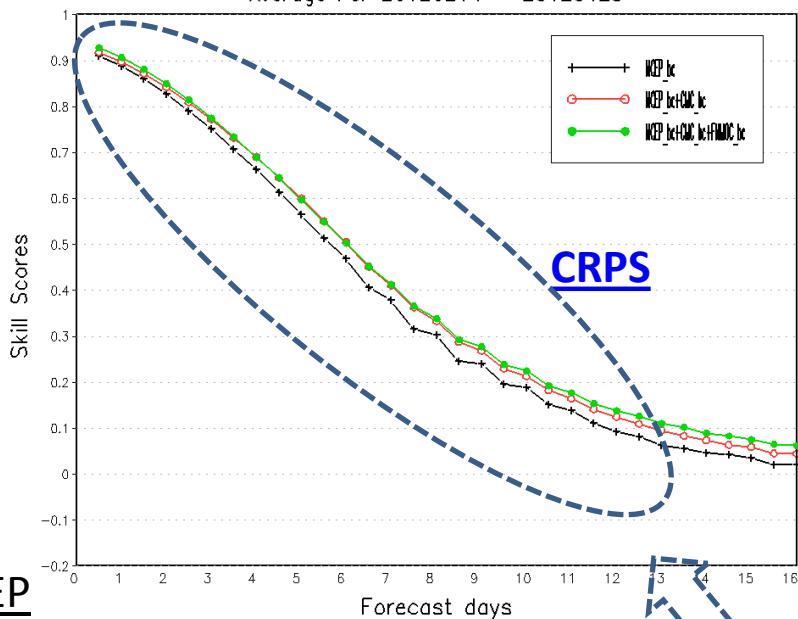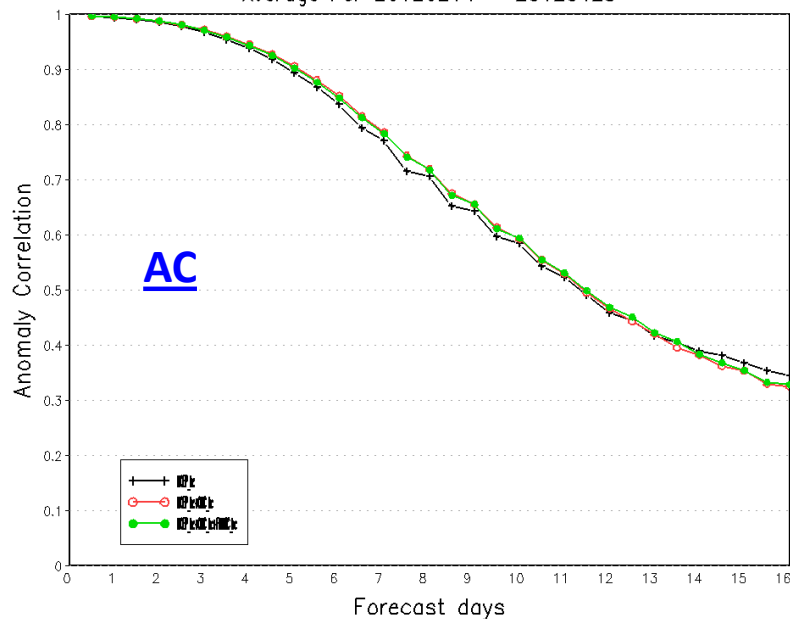
NCEP

NCEP+CMC

NCEP+CMC+FNMOC

**500hPa geopotential height**

Southern Hemisphere 500hPa Height
Continous Ranked Probability Skill Scores
Average For 20120214 – 20120425
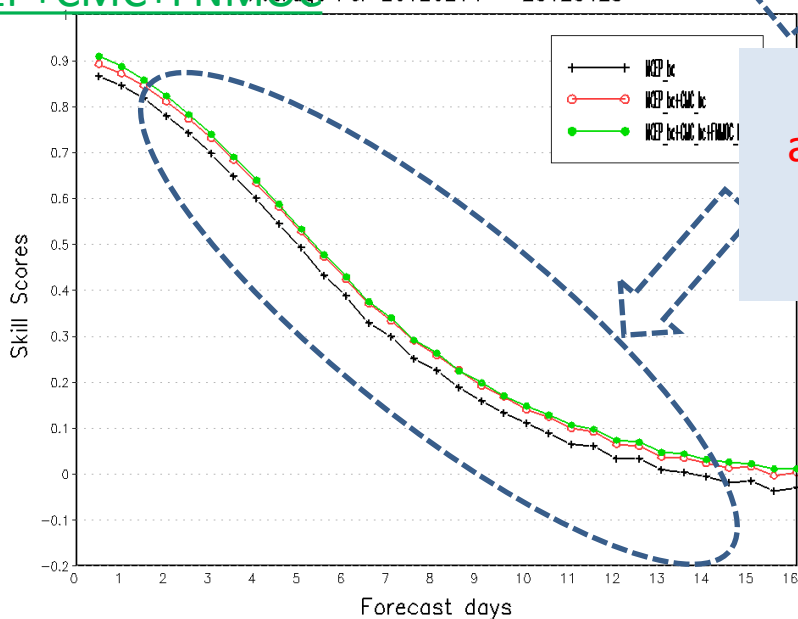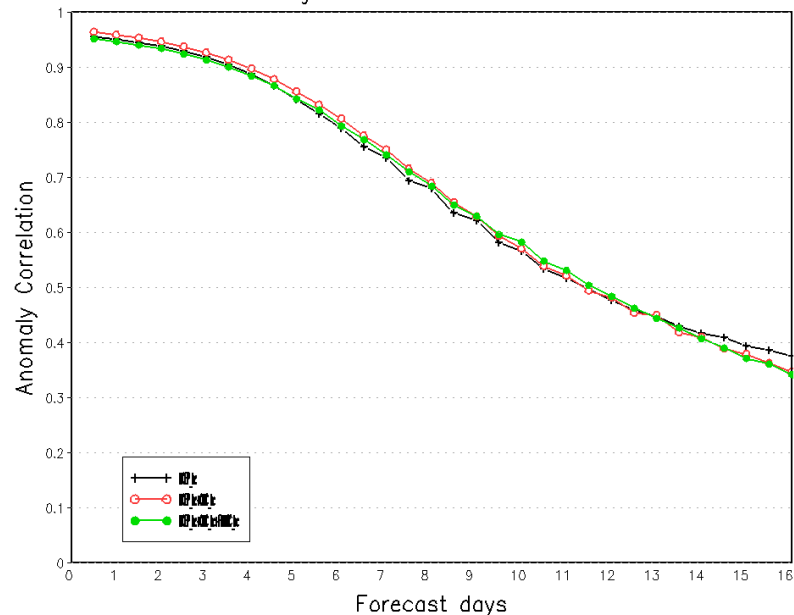
Small value added to short lead time and week-2

Southern Hemisphere 500hPa Height
Ensemble Mean Anomaly Correlation
Average For 20120214 – 20120425

29

Northern Hemisphere 850hPa Temp.
Continous Ranked Probability Skill Scores
Average For 20120214 – 20120425

Northern Hemisphere 850hPa Temp.
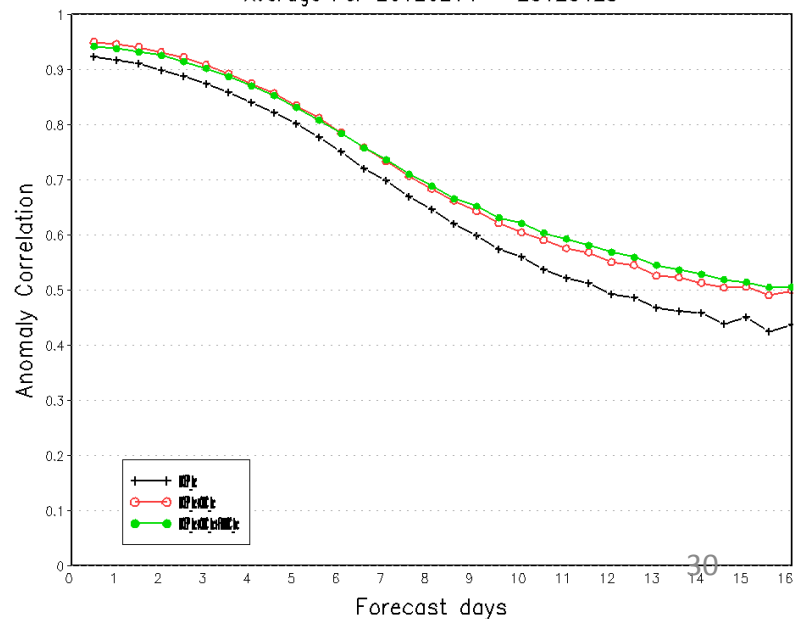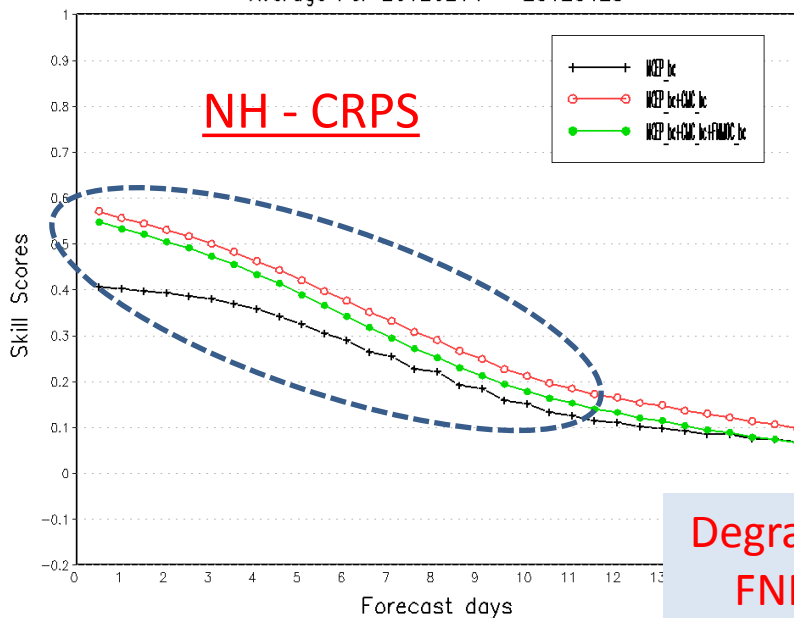Ensemble Mean Anomaly Correlation
Average For 20120214 – 20120425

degradation
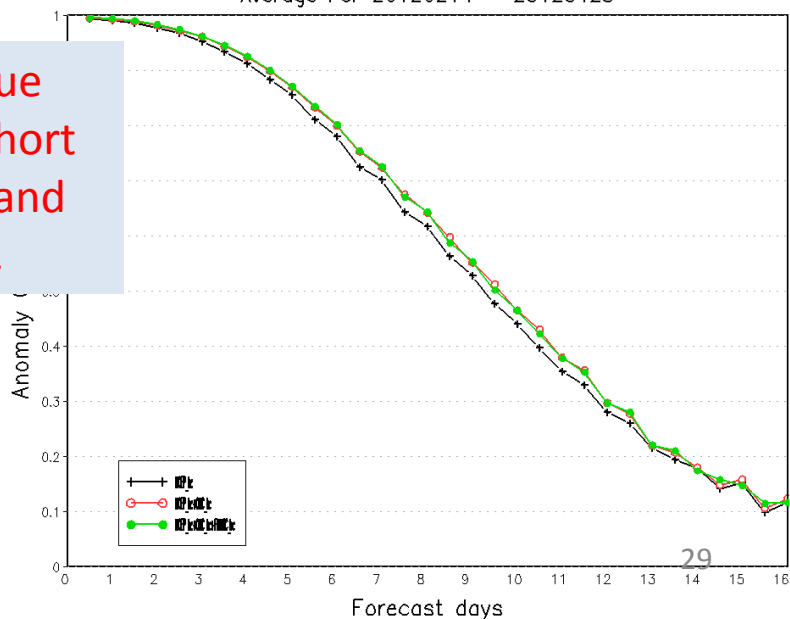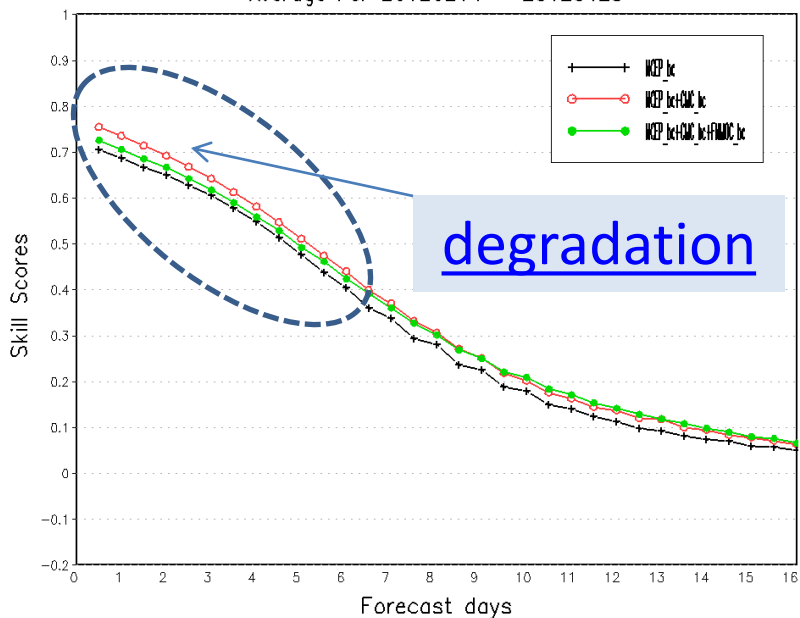
850hPa temperature

Southern Hemisphere 850hPa Temp.
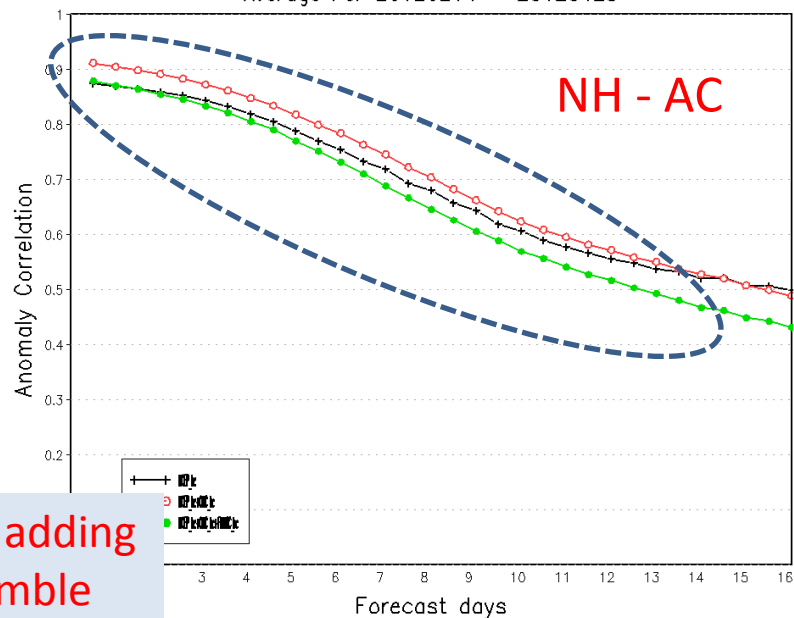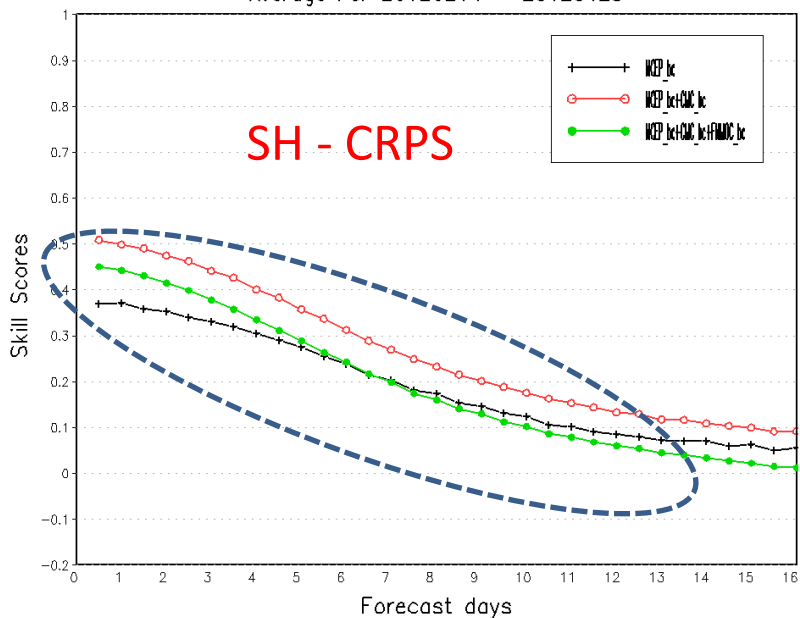Continous Ranked Probability Skill Scores
Average For 20120214 – 20120425

Southern Hemisphere 850hPa Temp.
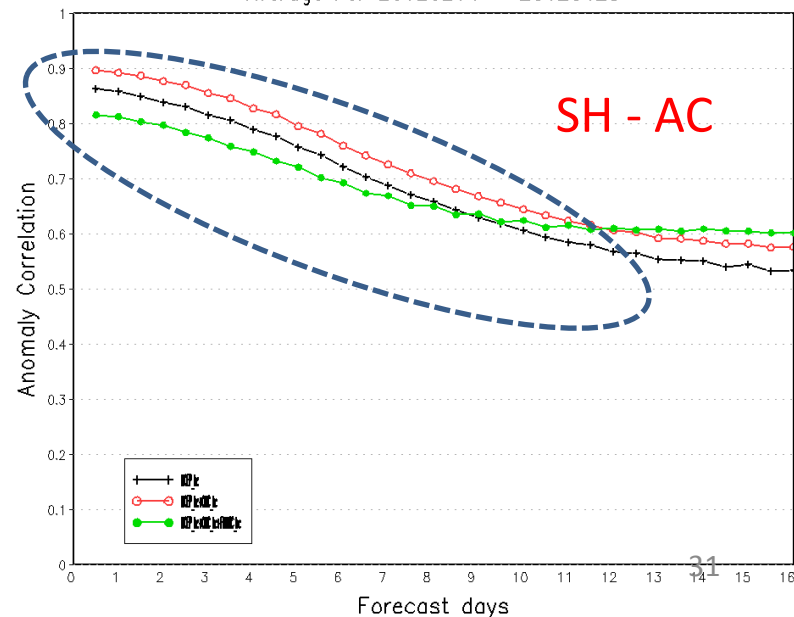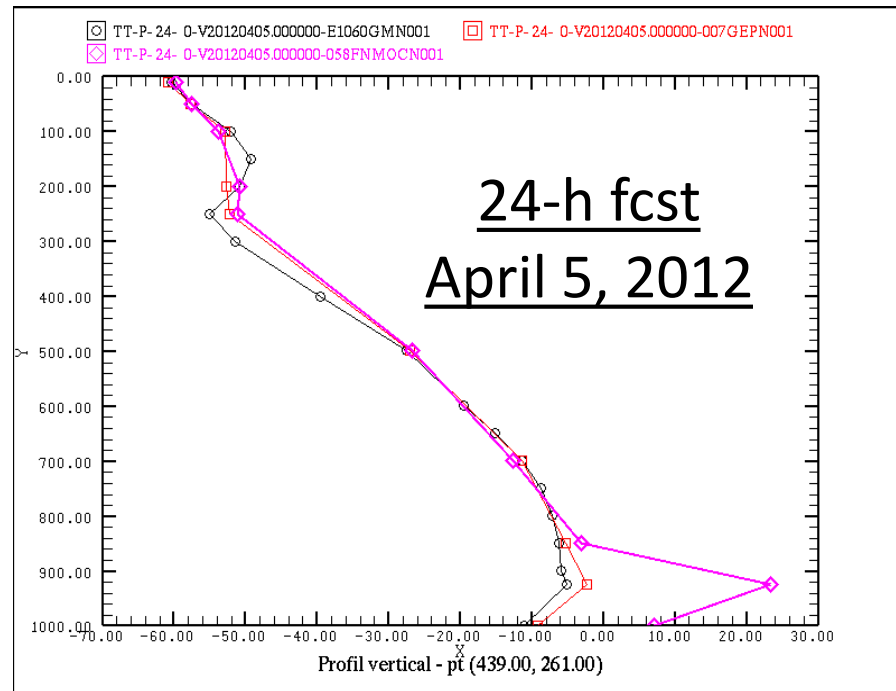Ensemble Mean Anomaly Correlation
Average For 20120214 – 20120425

Northern Hemisphere 2 Meter Temp. Continous Ranked Probability Skill Scores — Average For 20120214 − 20120425 (NH - CRPS)

Northern Hemisphere 2 Meter Temp. Ensemble Mean Anomaly Correlation — Average For 20120214 − 20120425 (NH - AC)

Southern Hemisphere 2 Meter Temp. Continous Ranked Probability Skill Scores — Average For 20120214 − 20120425 (SH - CRPS)

Southern Hemisphere 2 Meter Temp. Ensemble Mean Anomaly Correlation — Average For 20120214 − 20120425 (SH - AC)

Degradation by adding FNMOC ensemble

2-meter temperature

January 2012

Observations and FNMOC 24hr forecasts of T 925 at station 70308 in Alaska in January 2012
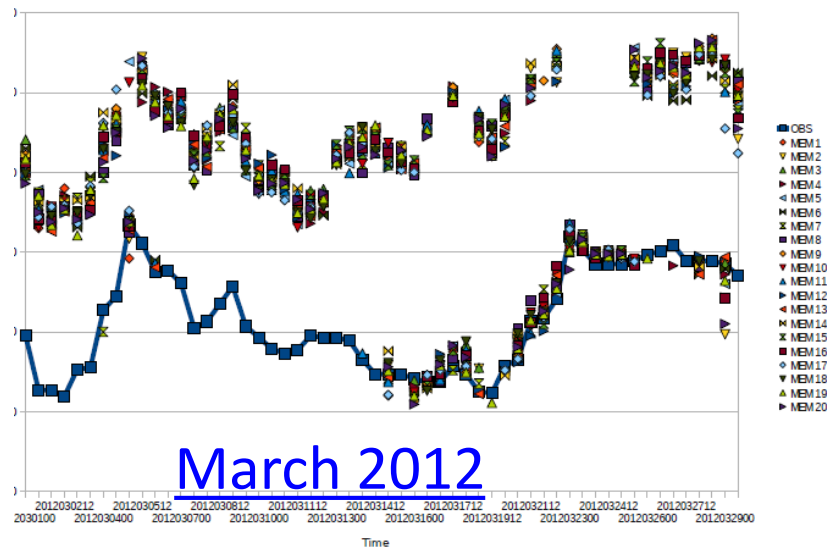
24-h fcst
April 5, 2012

February 2012

Observations and FNMOC EPS 24hr forecasts of T 925 at station 70308 in Alaska in February 2012

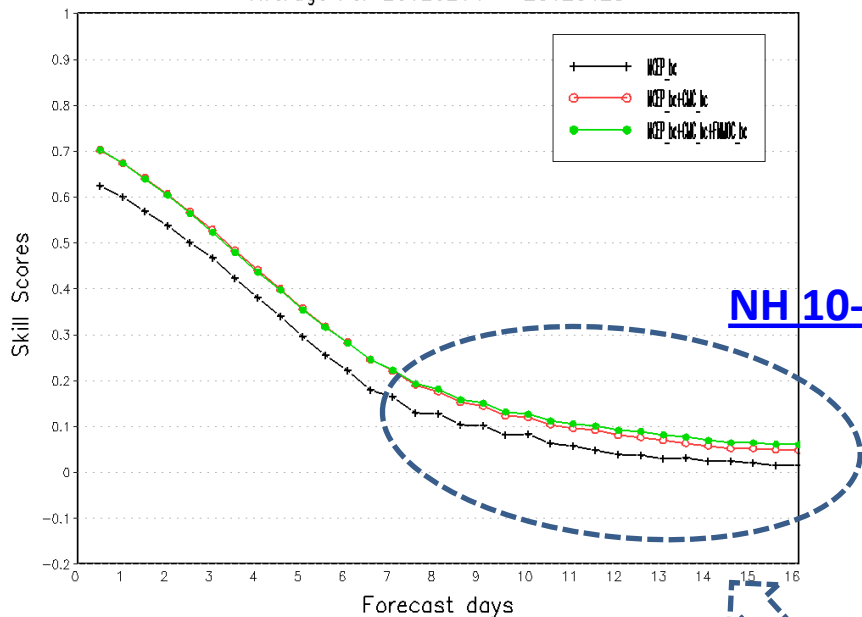Observations and FNMOC EPS 24hr forecasts of T 925 at station 70308 in Alaska in March 2012
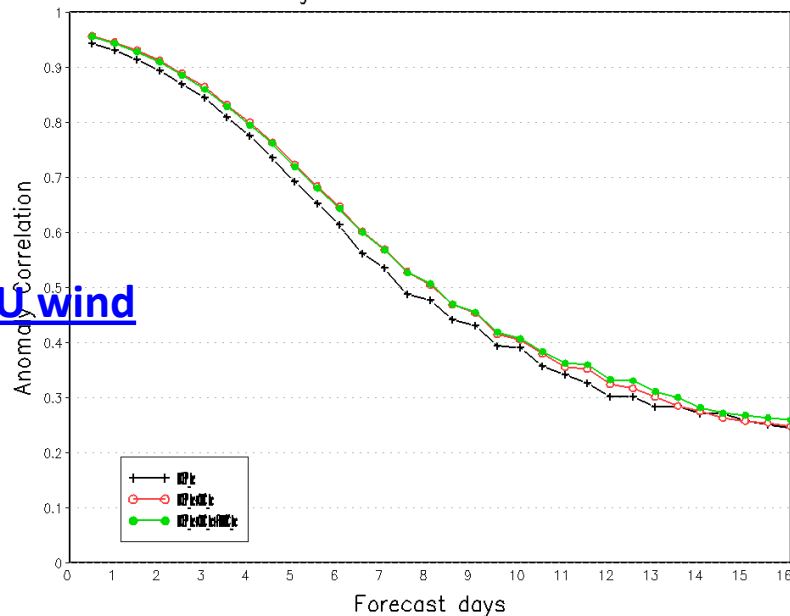
March 2012

Courtesy of Normand Gagnon

Page 1

NH 10-meter U wind

NH 10-meter V wind

Small value
added to week-2

33
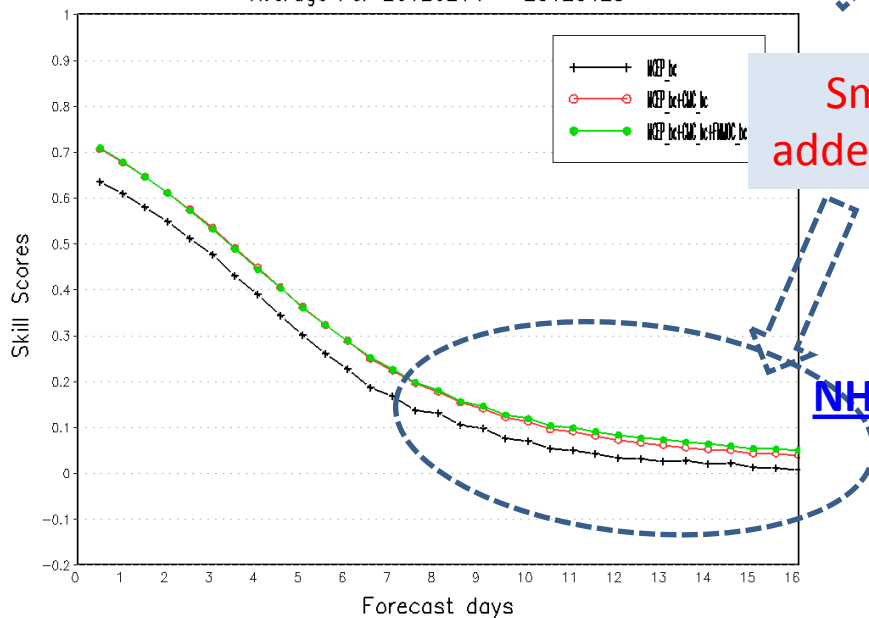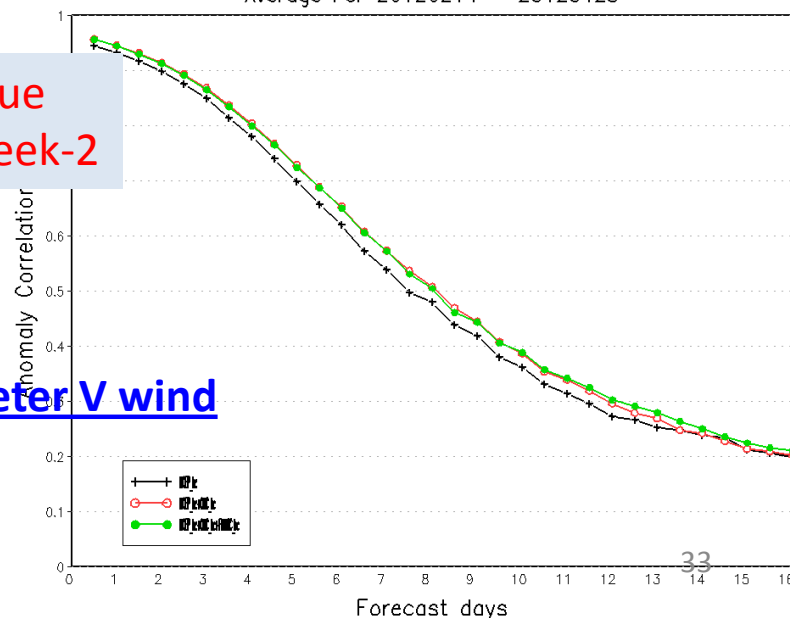
Summary (7)

- All individual or combined forecasts (bias corrected) are verified against independent analysis – UKMet analysis (except for slides indicated).
- NCEP+FNMOC has better skills than either individual one for most variables except for surface temperature (see discussion)
- NCEP+CMC has better (best) scores for all demonstrated variables.
- NCEP+CMC+FNMOC has closed score as NCEP+CMC except for
    - FNMOC add small values (and no degradation)
        - NH 500hPa height – a little gaining for week-2 for probabilistic forecast
        - SH and Tropical 500hPa and 1000hPa height – significant gaining by adding FNMOC
        - NH surface wind – a little gaining for week-2 for both probabilistic and ensemble mean
        - 850hpa and 250hPa winds – a little gaining (at least no degradation)
        - Apparently, add values from heights, a little gain (week-2) for winds
    - Degradation by add FNMOC
        - NH Surface temperature and 850hPa temperature – need to investigate (why???)
- Interesting discussion:
    - Based on spring evaluations, the results are similar (with some difference) from winter
    - There is a problem for model lower lever (and surface) temperatures (don't know where and why) – need to get answer
    - Challenges and concerns:
        - Operational stabilization (consistence)
        - Daily monitoring (with quick responds and solving problem)

Preliminary evaluation for NAEFS inclusion of FNMOC ensemble

Part IV: Downscaled forecast

Bo Cui and Yuejian Zhu

Environmental Modeling Center
NCEP/NWS/NOAA

April 25th 2012

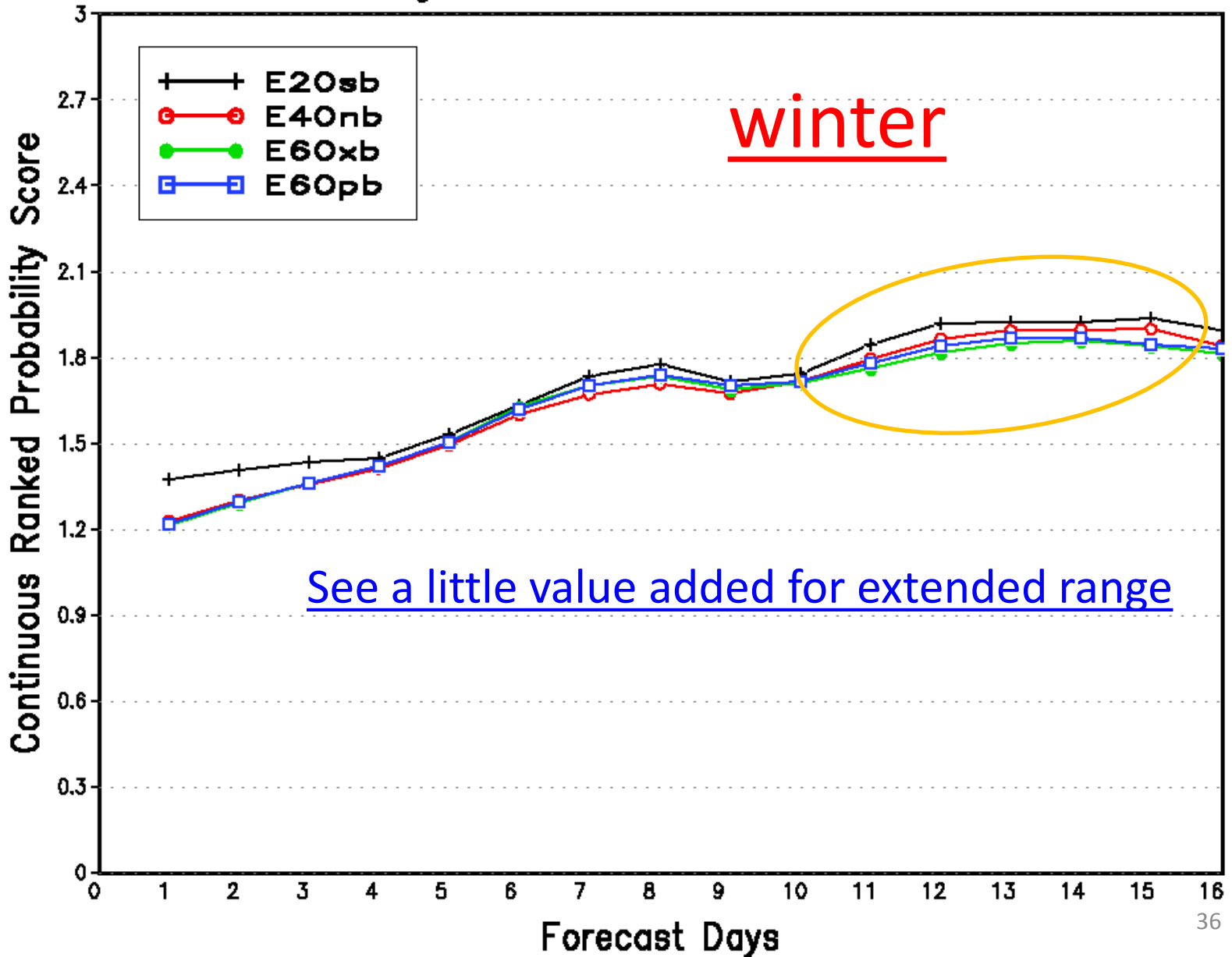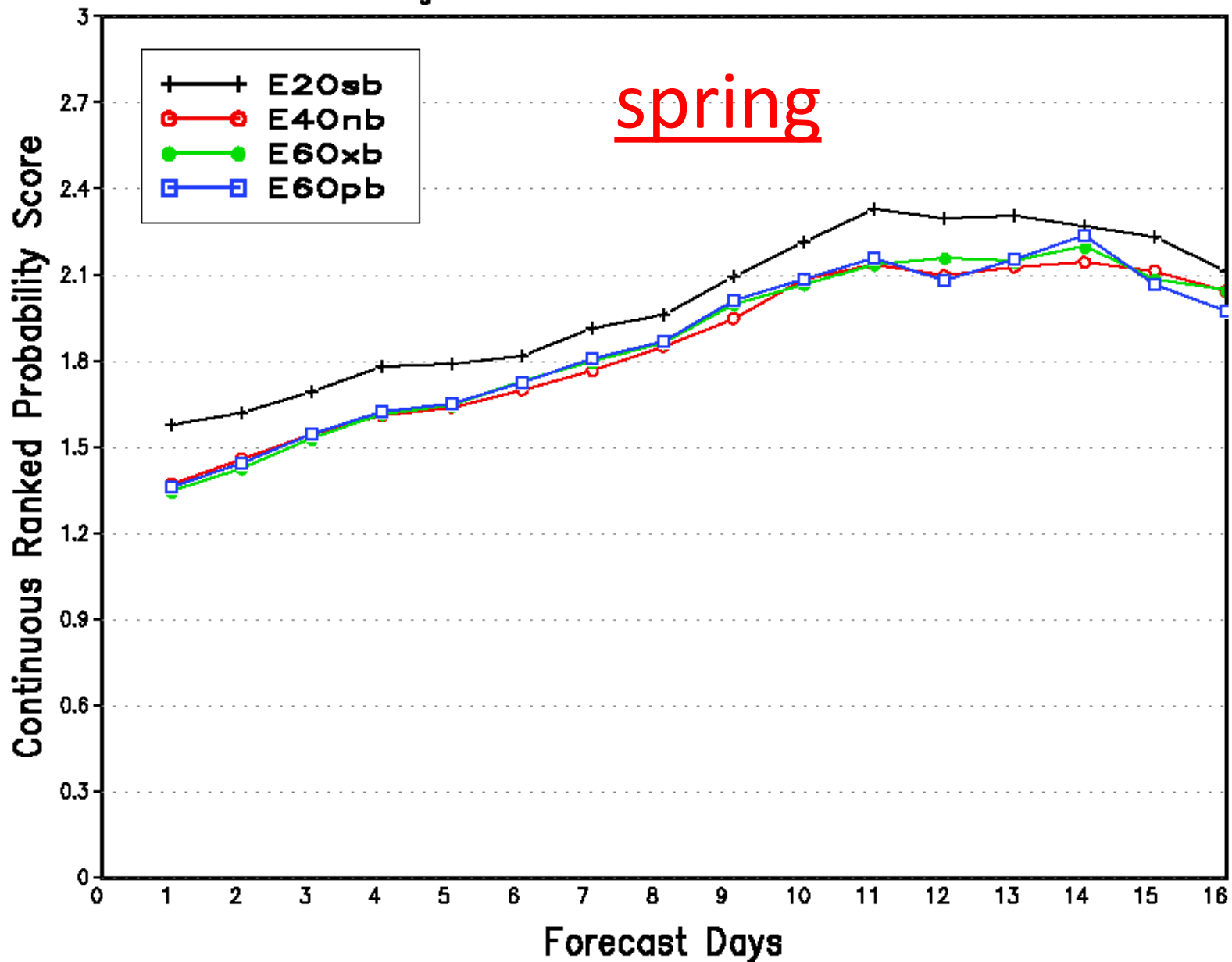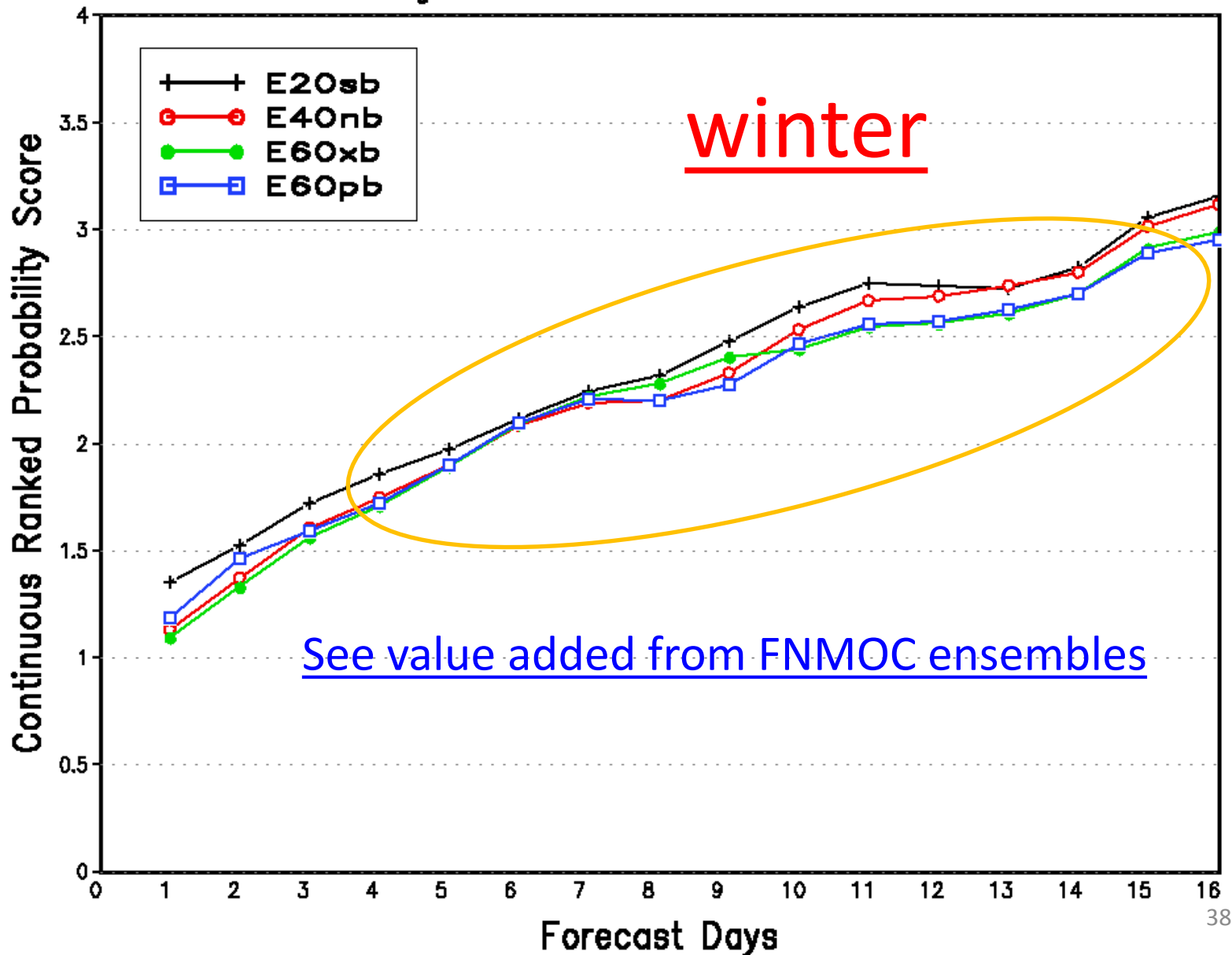NAEFS CONUS 10 Meter U(wind)
Continuous Ranked Probability Scores
Average For 2011120100 − 2012012000

winter

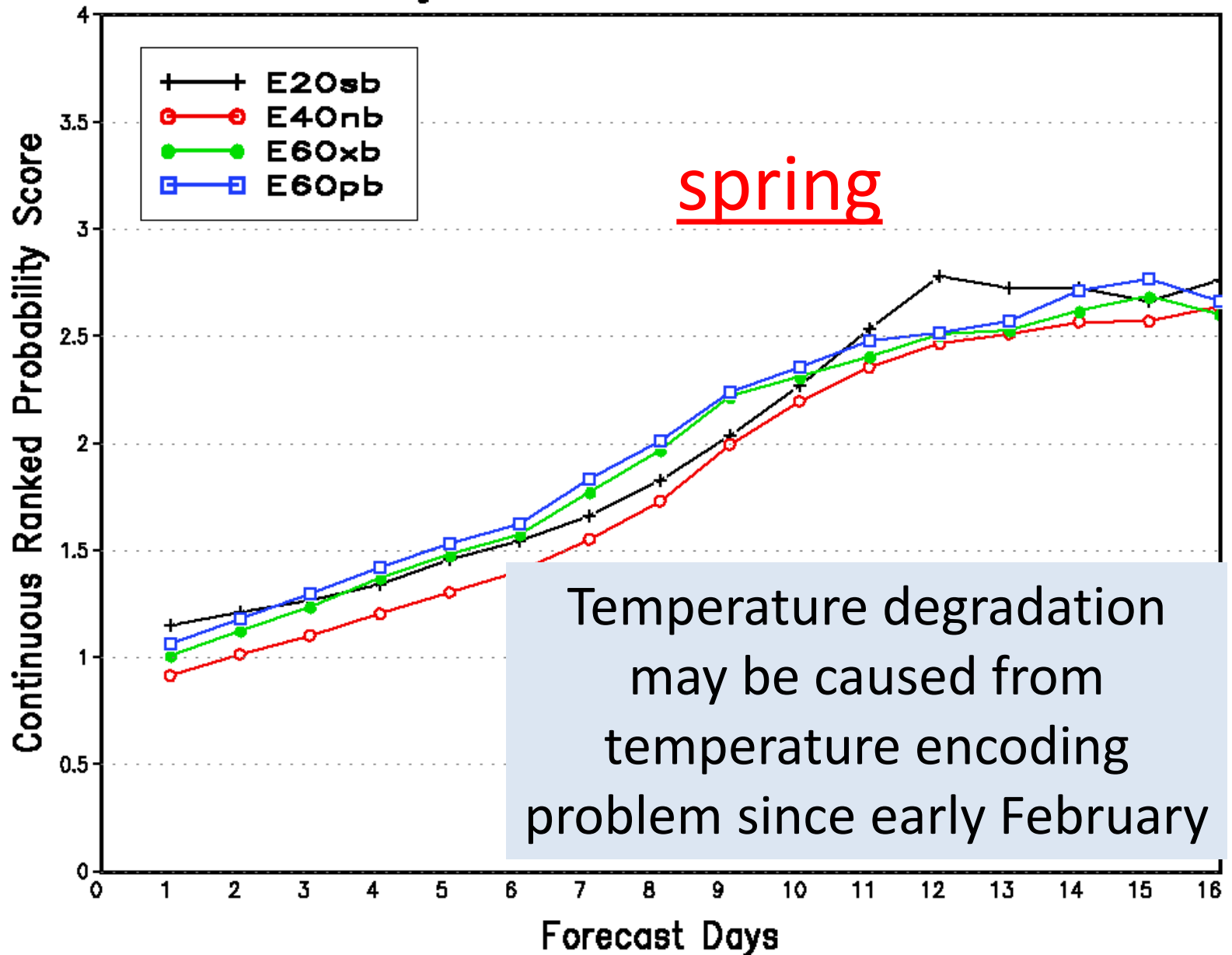See a little value added for extended range

NAEFS CONUS 10 Meter U(wind)
Continuous Ranked Probability Scores
Average For 2012021500 − 2012042000

spring

NAEFS CONUS 2 Meter Temp.
Continuous Ranked Probability Scores
Average For 2011120100 − 2012012000

winter

See value added from FNMOC ensembles

NAEFS CONUS 2 Meter Temp.
Continuous Ranked Probability Scores
Average For 2012021500 − 2012042000

spring

Temperature degradation may be caused from temperature encoding problem since early February

Suggestions

- Need to identify the problem for lower levels and surface temperatures.

- Suggest to start evaluation again after problem is completely solved.

- It is big challenge for NCEP/CMC/FNMOC to exchange and collect all three ensembles for real time operation in unified format.

- Three centers need to coordinate/collaborate closely in the future, especially for model major upgrade.
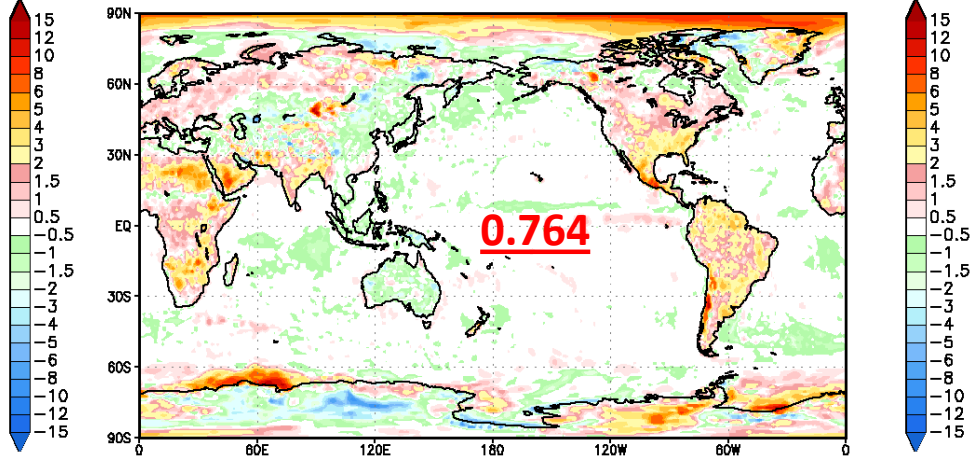
Background!!!

T2m analysis difference accumulation (decaying average (0.3) since 20100901)

2m Temp. Diff. between NCEP and FNMOC Analysis (K)
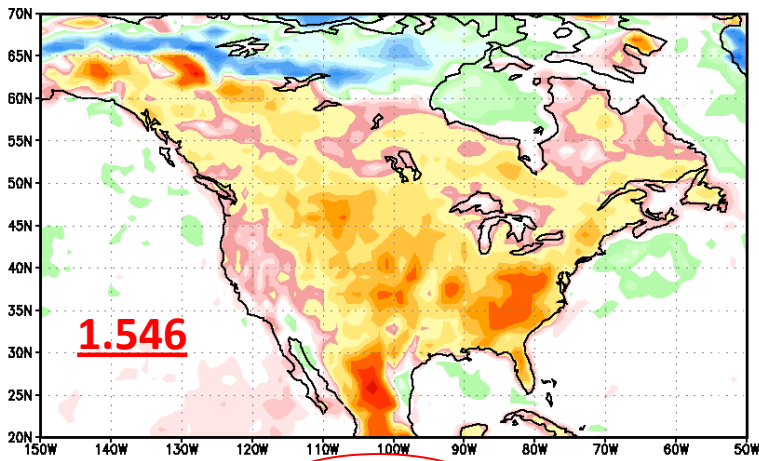at 2010102600
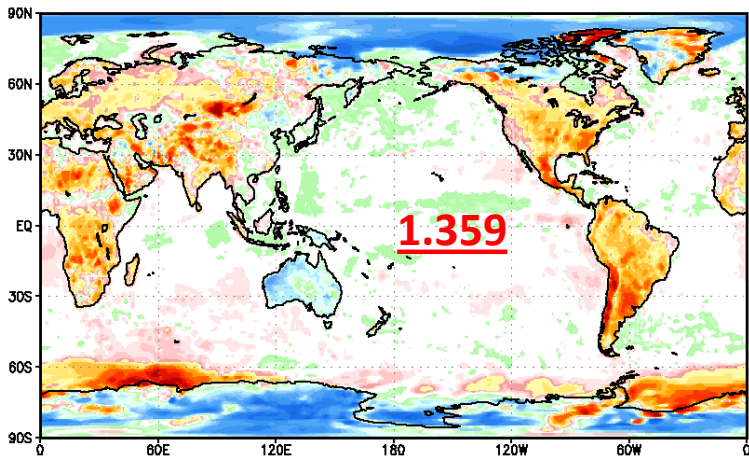
1.359

ABSAVG=1.359

2m Temp. Diff. between NCEP and CMC Analysis
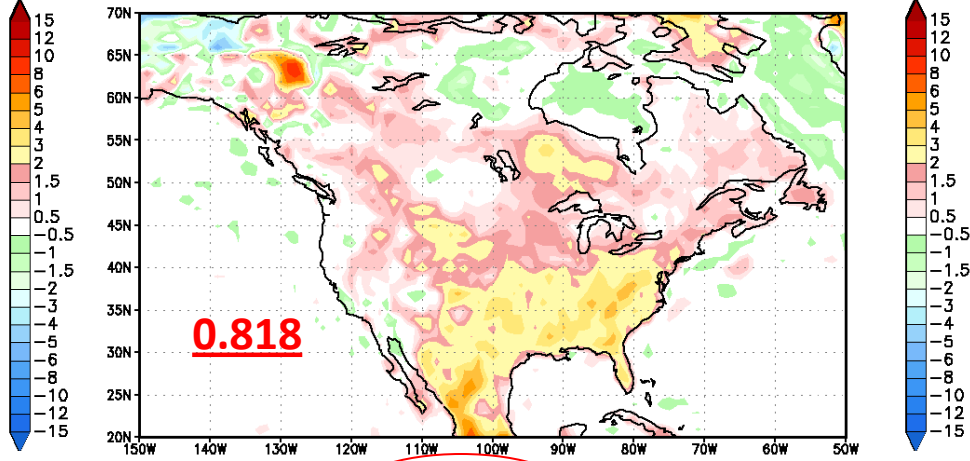at 2010102600

0.764

ABSAVG=0.764

2m Temp. Diff. between NCEP and FNMOC Analysis (K)
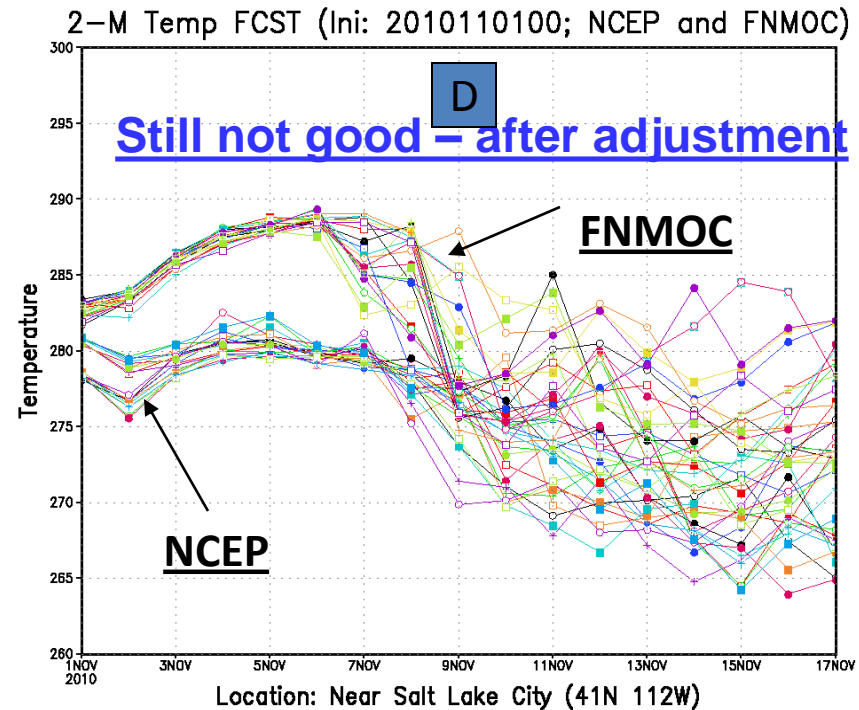at 2010102600

1.546

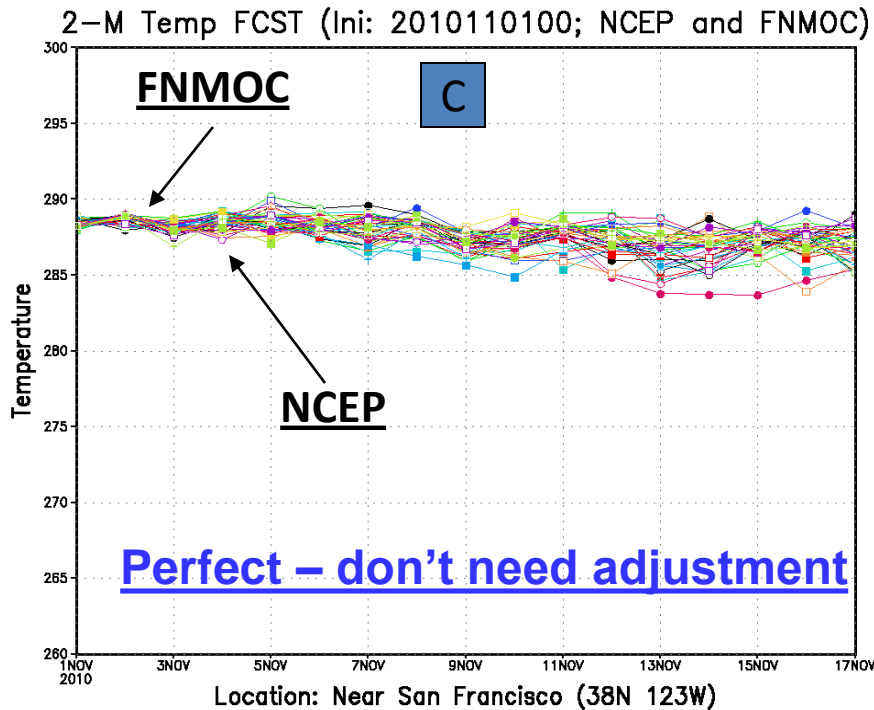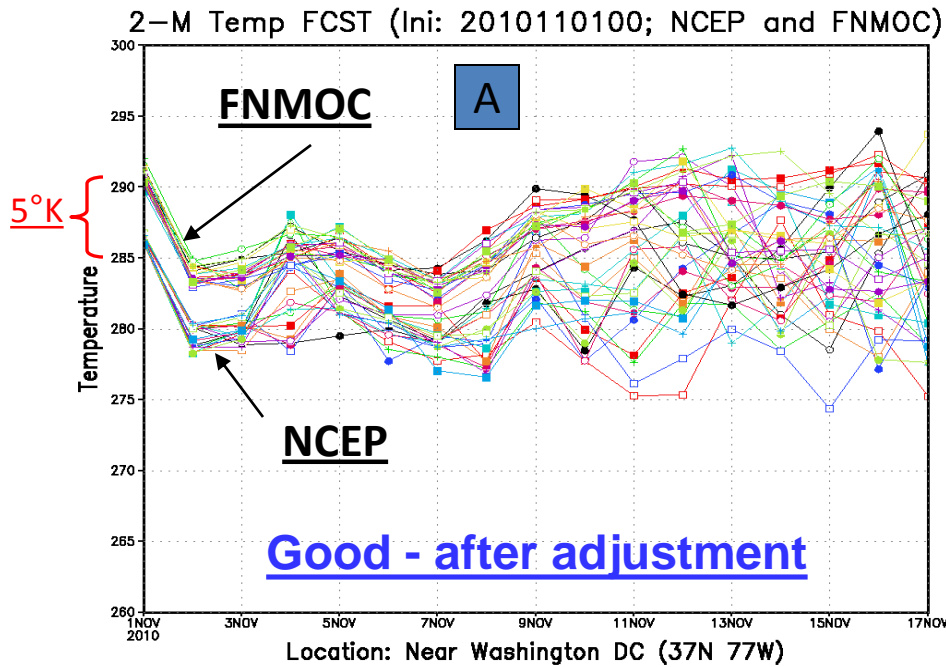ABSAVG=1.546

2m Temp. Diff. between NCEP and CMC Analysis
at 2010102600
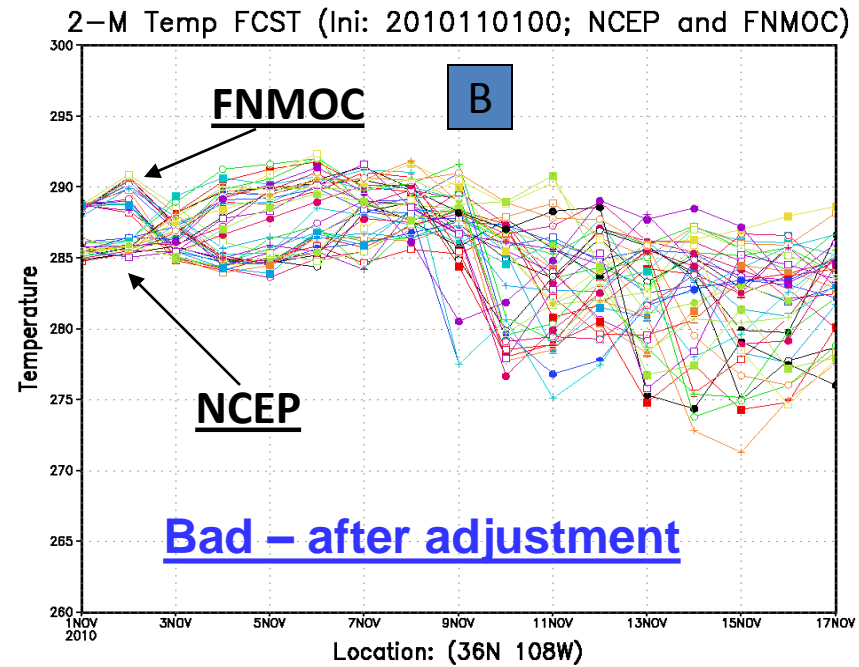
0.818

ABSAVG=0.818

A — 2-M Temp FCST (Ini: 2010110100; NCEP and FNMOC)
FNMOC, NCEP, 5°K
Good - after adjustment
Location: Near Washington DC (37N 77W)

B — 2-M Temp FCST (Ini: 2010110100; NCEP and FNMOC)
FNMOC, NCEP
Bad – after adjustment
Location: (36N 108W)

C — 2-M Temp FCST (Ini: 2010110100; NCEP and FNMOC)
FNMOC, NCEP
Perfect – don't need adjustment
Location: Near San Francisco (38N 123W)

D — 2-M Temp FCST (Ini: 2010110100; NCEP and FNMOC)
Still not good – after adjustment
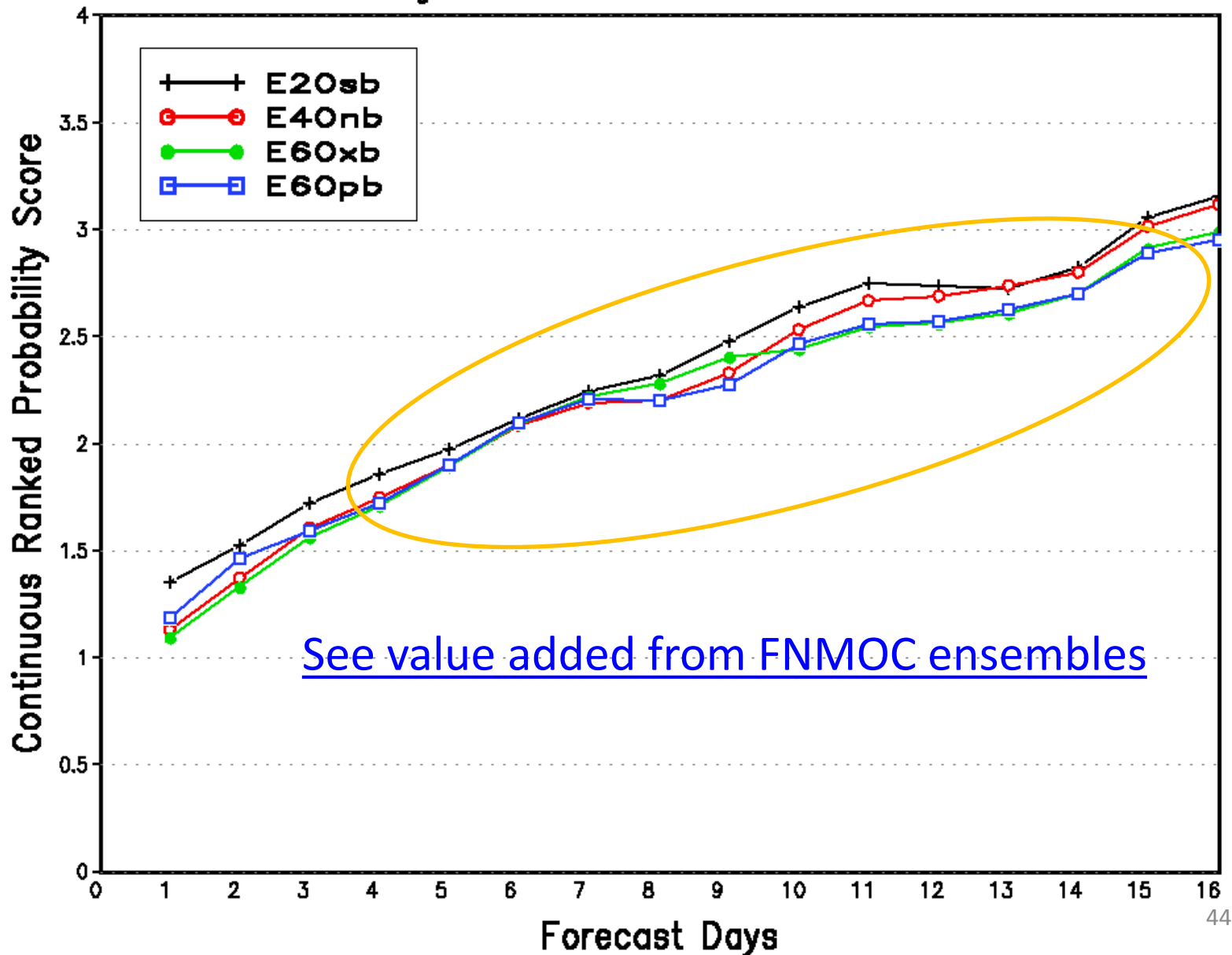FNMOC, NCEP
Location: Near Salt Lake City (41N 112W)

NAEFS CONUS 2 Meter Temp.
Continuous Ranked Probability Scores
Average For 2011120100 - 2012012000

See value added from FNMOC ensembles