Experiment of Multi-physics Global Ensemble System

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Presenting for
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AMS NWP/WAF conference
Montreal, Canada, June 1st 2012

Motivation

- Background:
  - In 1992, NCEP implemented the first Global Ensemble Forecast System (GEFS). It was a single model ensemble and assimilated initial uncertainties by introducing Breeding Vector initial perturbations.
  - In general, ensemble forecasts are under dispersed (lack of spread) for medium- to extended range forecasts.
  - In 2010, NCEP implemented STTP (Stochastic Total Tendency Perturbation) in GEFS to add in part model related uncertainties.
- Current status of GEFS:
  - Ratio of Spread/RMS-error is smaller (<1) when model improved (Ideally, Spread/RMS-error = 1)
  - Ratio of spread/mean-track-error is about 0.5-0.7 for tropical storm 72-120 hour forecasts
  - Users complain ensemble forecasts are under dispersed, missing coverage of extreme (high impact) events
- Options to assimilate model uncertainties:
  - Stochastic physics (to be tested in NCEP GEFS)
  - Multi-physics (parameterizations)– under NEMS framework
  - Multi-model ensemble: (national and international): FIM, NUOPC and NAEFS

Under NEMS (NOAA Environmental Modeling System) infrastructure, we can test:

- Different models (GEFS, FIM, NMMB and etc…)
- Different dynamics (pressure, hybrid and other coordinates, …)
- Different physics and parameterizations

The Value of Ensemble Forecast

Ensemble forecasts provide valuable additions ("uncertainty") to deterministic forecasts.

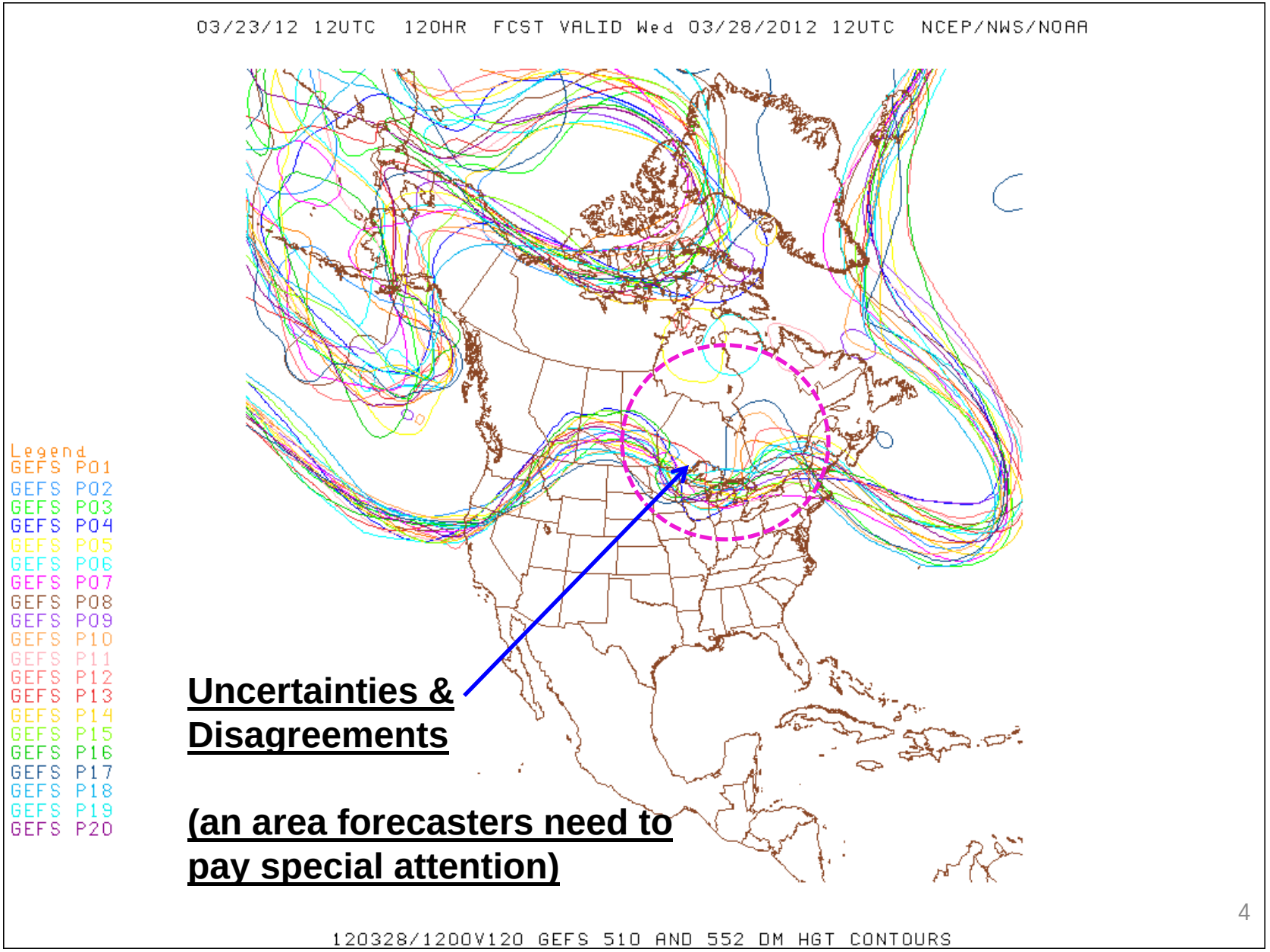
- Ensemble product is a combination of high resolution deterministic forecast (high quality and accuracy) and lower-resolution ensemble forecasts (uncertainty information).

- Ensemble uncertainty helps forecasters to assess high impact extreme weather events
  - Lower probability – tails of forecast distribution
  - Better decision
  - However, single model ensemble is usually under-dispersed

- Ensemble forecasts can be used to evaluate flip-flop high-resolution deterministic forecast

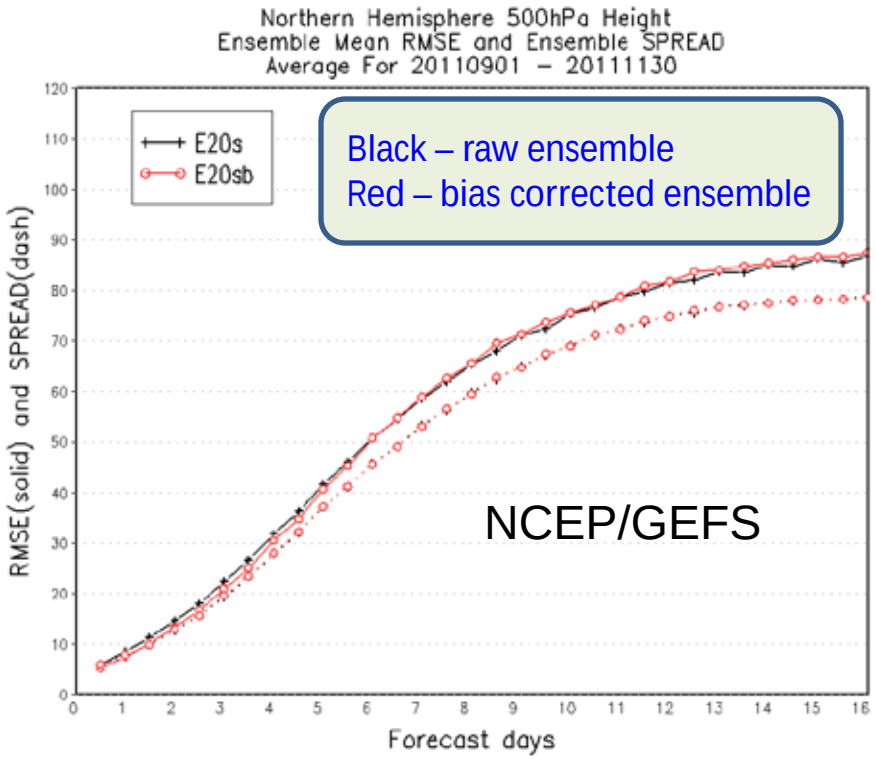
- Arguably, ensemble mean can at times provide more value for predicting large-scale flow at long lead time than single deterministic forecasts

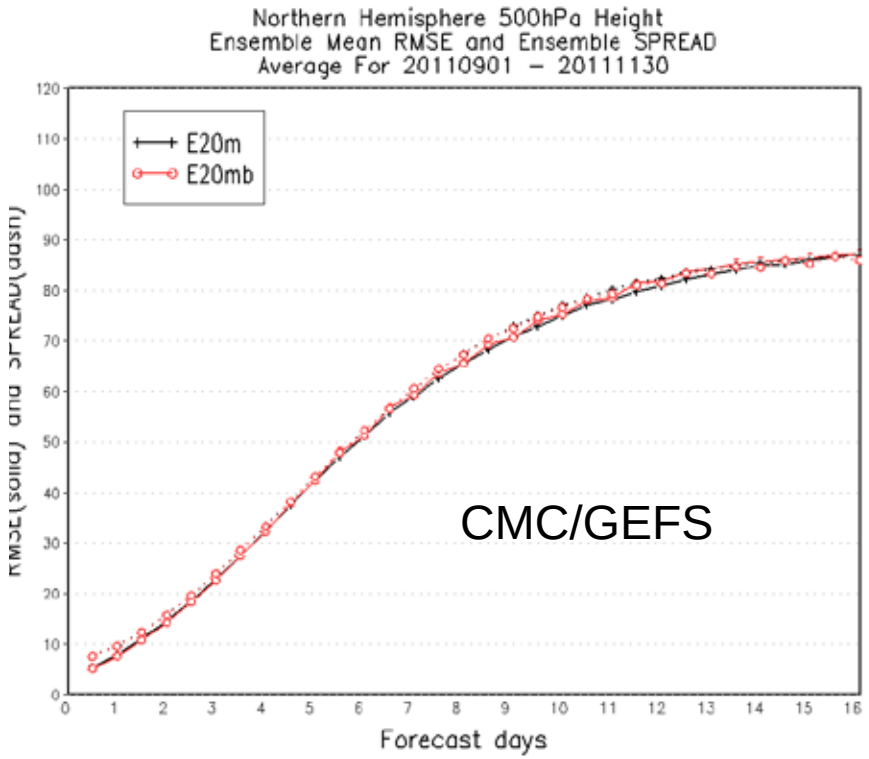
The Value of Ensemble Forecast



Which ensemble is better?

NH 500-hPa Height Ensemble Mean RMSE and Ensemble Spread





NCEP - single model

CMC - multi-physics (parameterizations)

What do we have now?

- Current status for NCEP GEFS
  - Single model (initial perturbed) ensemble
- Ensemble forecasts available for NCEP in operation
  - NCEP global ensemble
  - Canadian multi-physics ensemble
  - NAEFS (NCEP GEFS + CMC GEFS)
  - NUOPC (NCEP GEFS + CMC GEFS + FNMOC GEFS)
  - ECMWF ensembles, UK ensembles, JMA ensembles
- Plan for discussion and future consideration
  - Testing GFS + FIM (multi-model – dynamic) ensemble
  - Possible other candidate (NMMB) in the future
  - Cost of maintaining models?
  - Value added to current NAEFS (already multi-model)?

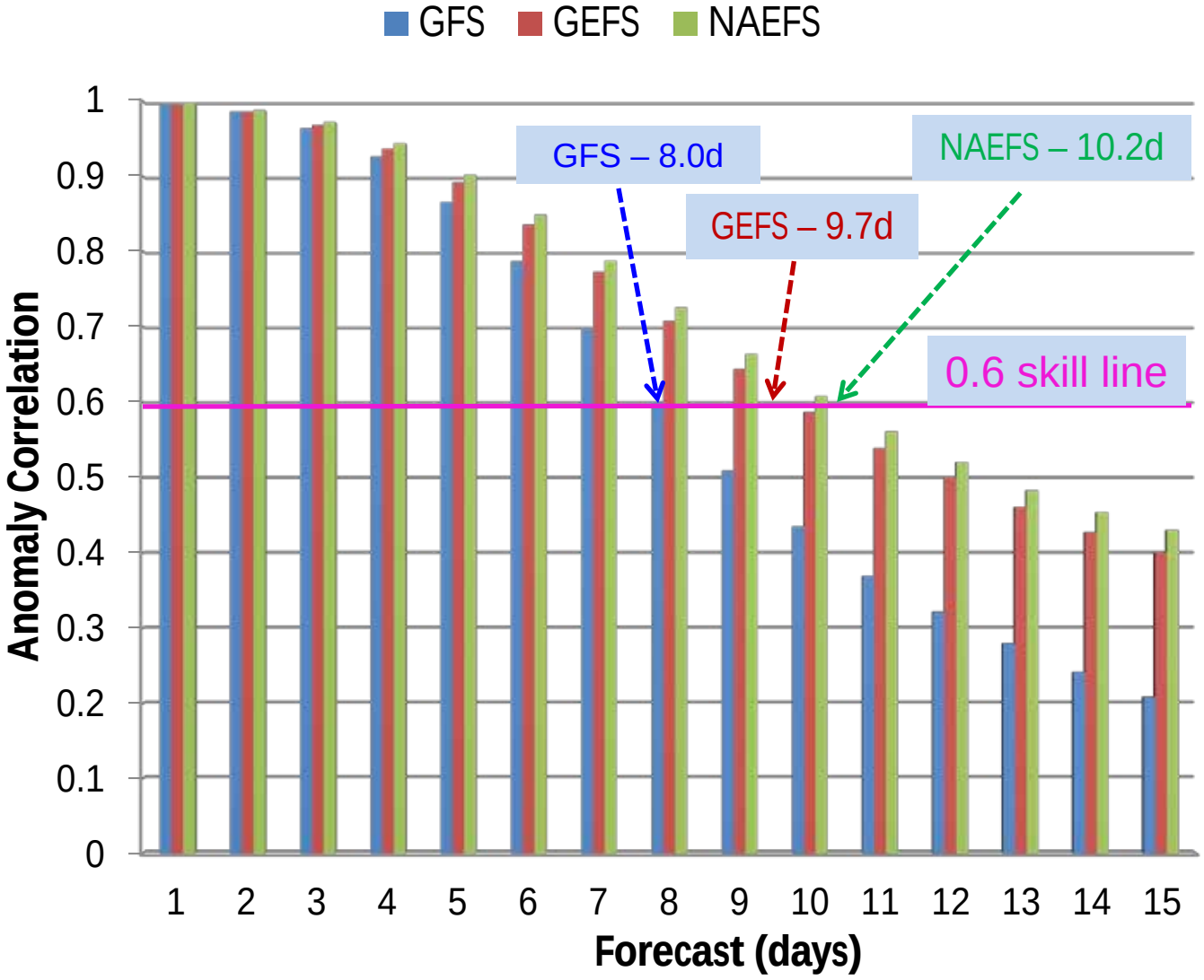
NAEFS/NUOPC Configuration

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 (d0-d8)~55km T190L42 (d8-16)~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

NH Anomaly Correlation for 500hPa Height

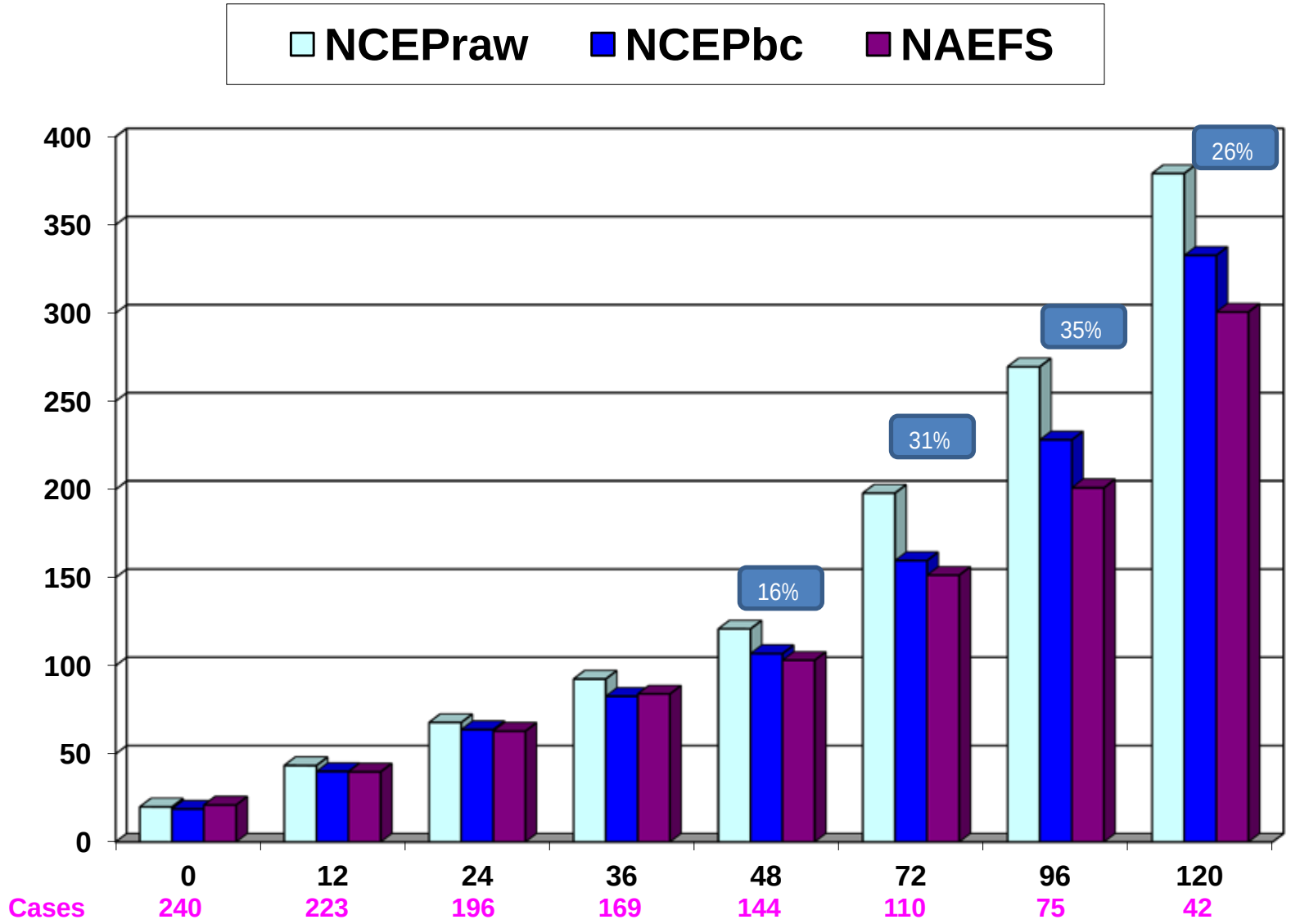
Period: January 1st – December 31st 2010



Benefit for forecast:

1. Ensemble mean will extend 1.7 days forecast ability to GFS – high resolution deterministic forecast
2. NAEFS will add additional 0.5 day forecast skill
3. Post process will add another additional (not shown here)

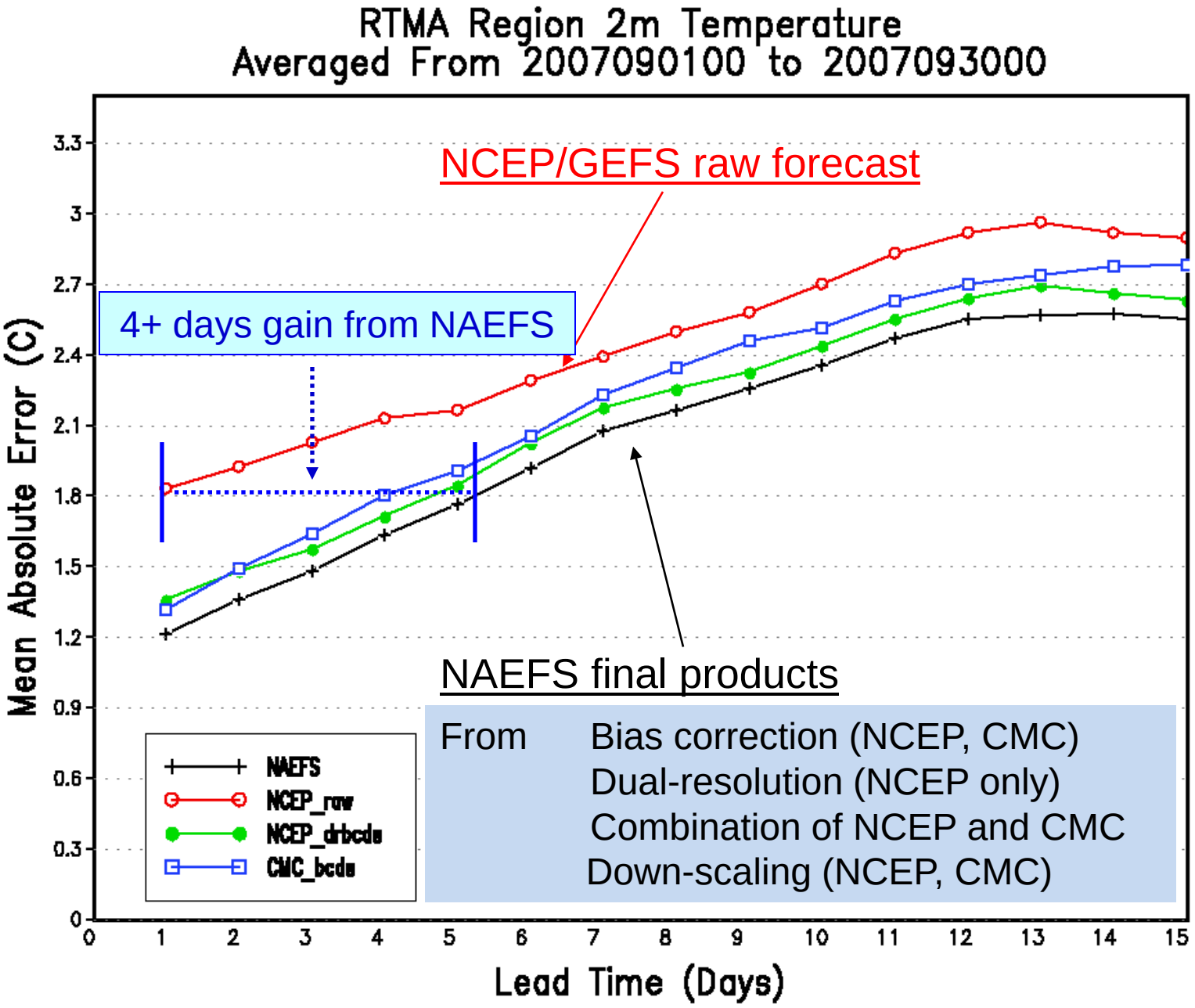
Track forecast error for 2009 season (AL+EP+WP)



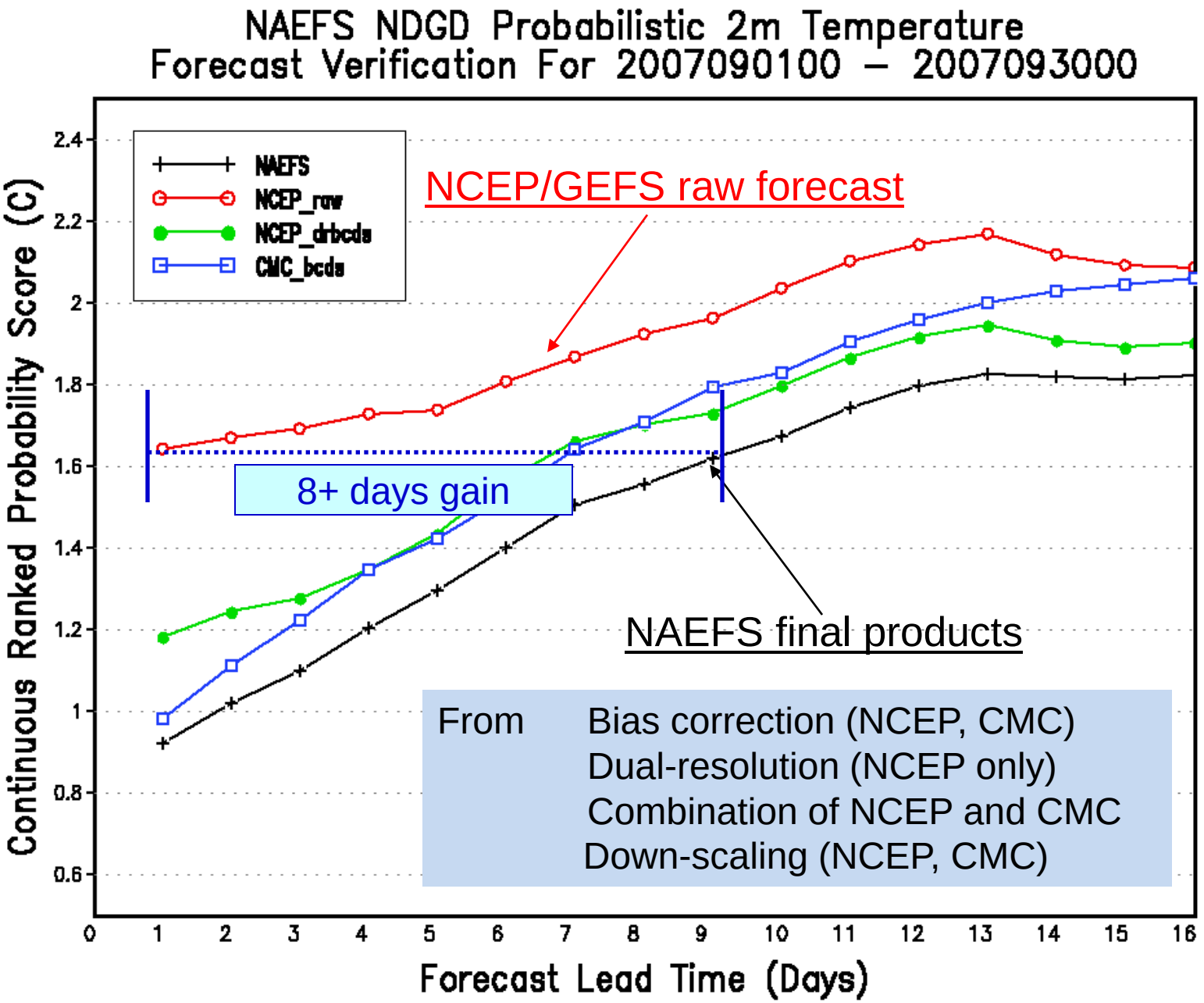
NAEFS is combined NCEP (NCEPbc) and CMC's (CMCbc) bias corrected ensemble and bias corrected GFS

Contributed by Dr. Jiayi Peng (EMC/NCEP)

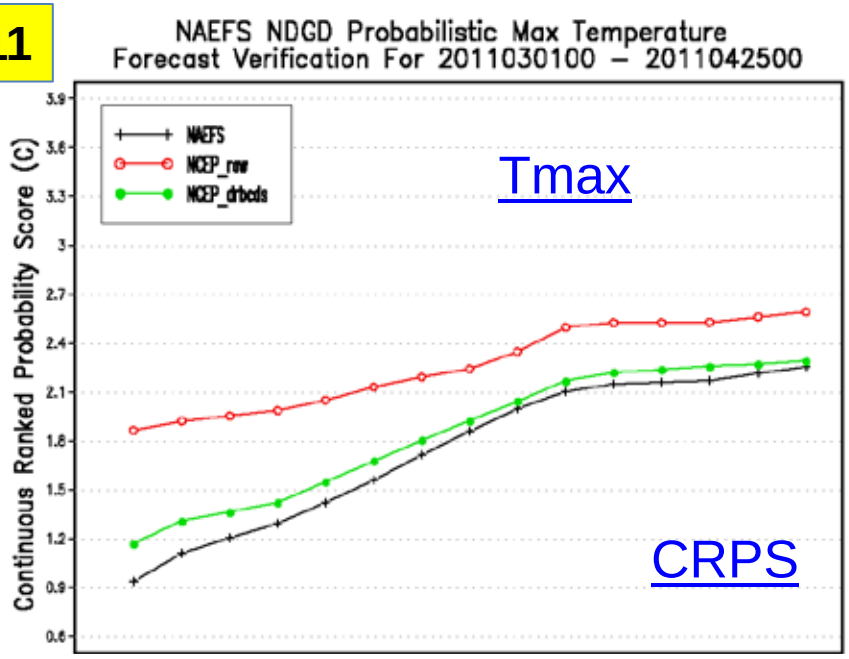
2007

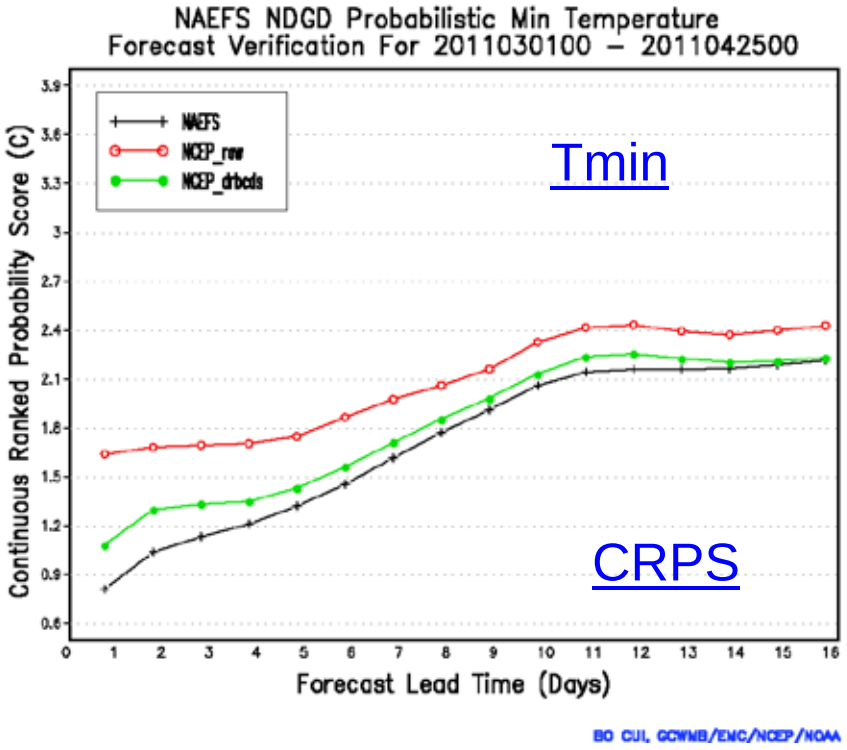

RTMA Region 2m Temperature
Averaged From 2007090100 to 2007093000
NCEP/GEFS raw forecast
4+ days gain from NAEFS
NAEFS final products
From Bias correction (NCEP, CMC)
Dual-resolution (NCEP only)
Combination of NCEP and CMC
Down-scaling (NCEP, CMC)
NAEFS
NCEP_raw
NCEP_drbcda
CMC_bcda
Mean Absolute Error (C)
Lead Time (Days)
0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
3
3.3
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

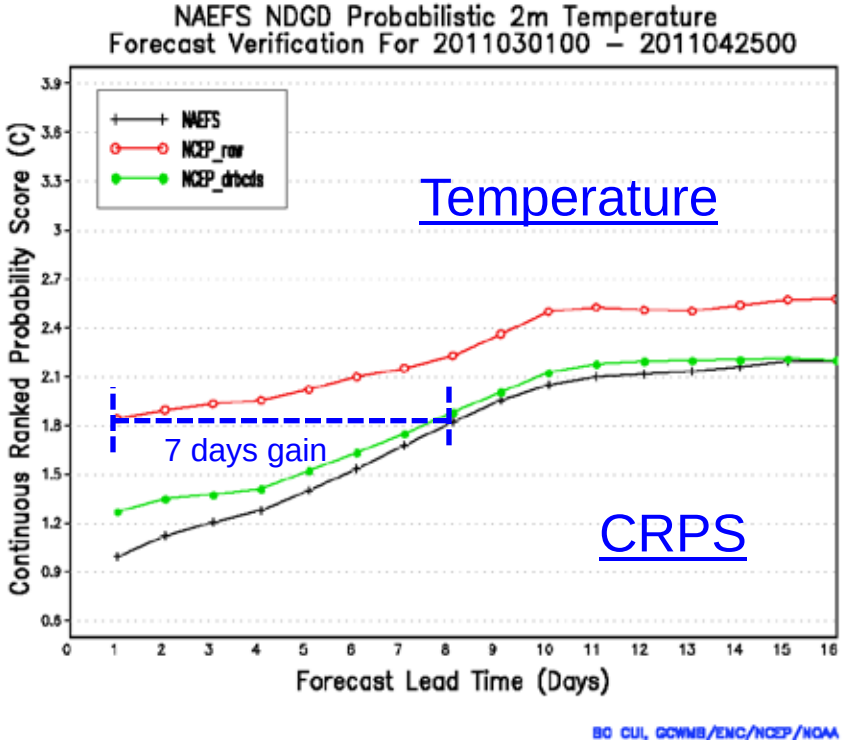
2007


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)
Combination of NCEP and CMC
Down-scaling (NCEP, CMC)
Continuous Ranked Probability Score (C)
Forecast Lead Time (Days)

2011







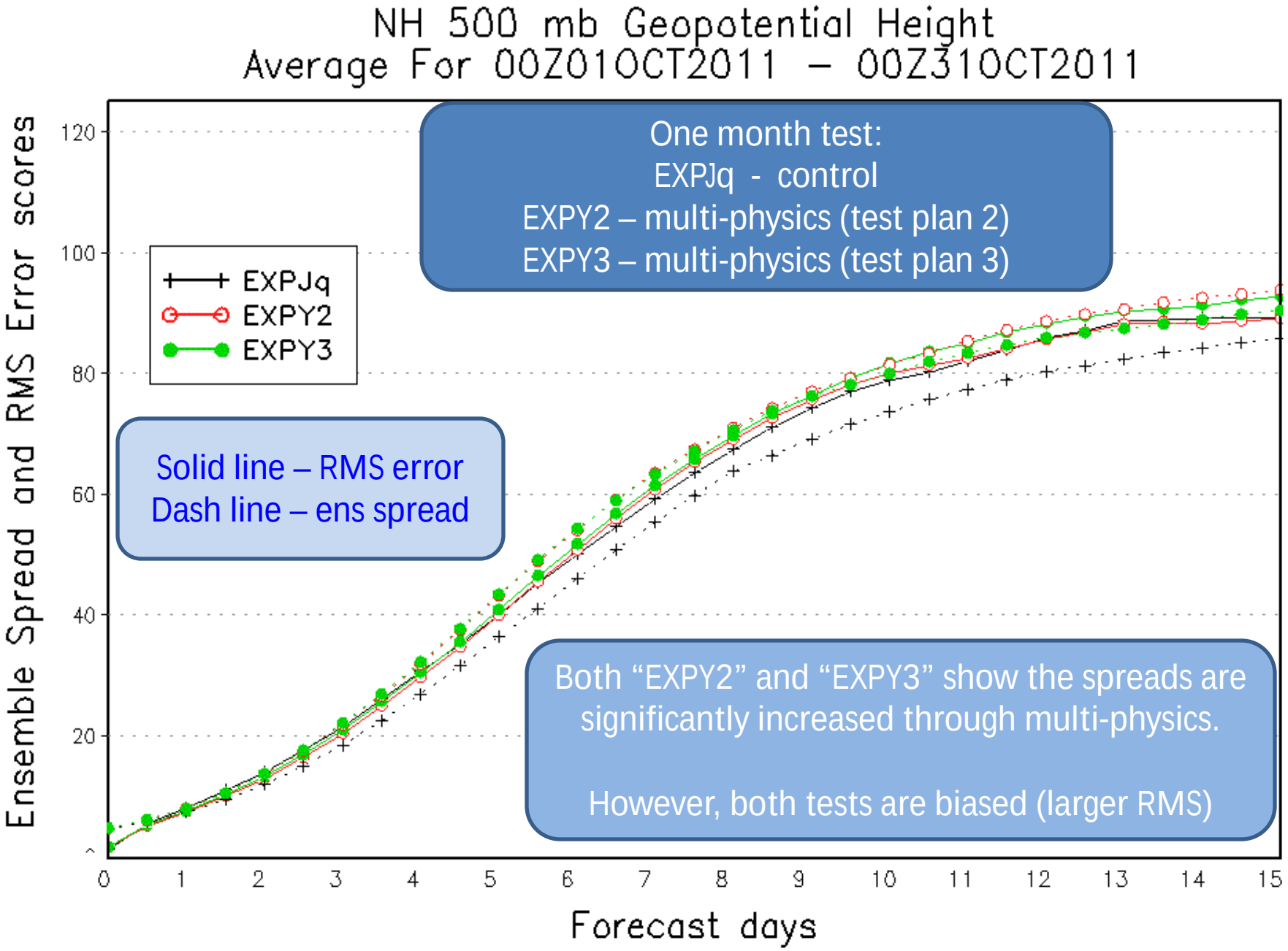
Latest evaluation for CONUS temperature forecast by apply :

1. Bias correction at 1*1 degree for NCEP GFS/GEFS, CMC/GEFS
2. Hybrid bias corrected NCEP GFS and GEFS
3. Apply statistical downscaling for all bias corrected forecast
4. Combined all forecasts at 5*5 km (NDGD) grid with adjustment - NAEFS

Multi-physics and parameterizations

#	Deep Convection	Shallow Convection	PBL	Micro Physics
1	Simplify Arakawa Schubert	Shallow Convection (1)	PBL (1)	Zhao
2	Relaxed Arakawa Schubert	Shallow Convection (1)	PBL (1)	Zhao
3	Simplify Arakawa Schubert	Shallow Convection (2)	PBL (1)	Zhao
4	Relaxed Arakawa Schubert	Shallow Convection (2)	PBL (1)	Zhao
5	Simplify Arakawa Schubert	Shallow Convection (1)	PBL (2)	Zhao
6	Relaxed Arakawa Schubert	Shallow Convection (1)	PBL (2)	Zhao
7	Simplify Arakawa Schubert	Shallow Convection (2)	PBL (2)	Zhao
8	Relaxed Arakawa Schubert	Shallow Convection (2)	PBL (2)	Zhao
9	Simplify Arakawa Schubert	Shallow Convection (1)	PBL (1)	Ferrier
10	Relaxed Arakawa Schubert	Shallow Convection (1)	PBL (1)	Ferrier
11	Simplify Arakawa Schubert	Shallow Convection (2)	PBL (1)	Ferrier
12	Relaxed Arakawa Schubert	Shallow Convection (2)	PBL (1)	Ferrier
13	Simplify Arakawa Schubert	Shallow Convection (1)	PBL (2)	Ferrier
14	Relaxed Arakawa Schubert	Shallow Convection (1)	PBL (2)	Ferrier
15	Simplify Arakawa Schubert	Shallow Convection (2)	PBL (2)	Ferrier
16	Relaxed Arakawa Schubert	Shallow Convection (2)	PBL (2)	Ferrier
17	Simplify Arakawa Schubert	No SC	PBL (1)	Zhao
18	Relaxed Arakawa Schubert	No SC	PBL (1)	Ferrier
19	Opr	Opr	Opr	Opr
20	Opr	Opr	Opr	Opr

Initial test of multi-physics ensemble



Conclusion and future plan

- NAEFS multi-model ensemble gives higher skill scores than GEFS single model ensemble.
- Multi-model ensemble improves uncertainty forecast.
- Preliminary tests of multi-physics ensemble showed positive impact; however, physics parameters need to be adjusted to reduce RMS.
- Future Plans
  1. continue to test multi-physics parameterizations under the NEMS framework.
  2. test multi-model ensemble, including GFS, FIM, and NMMB etc.
  3. test stochastic physics tendency (SPT) scheme in current GEFS
- Compare current NAEFS with future NUOPC