February 2010 Upgrade of the NCEP Global Ensemble Forecast System (NAEFS)

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http://wwwt.emc.ncep.noaa.gov/gmb/yzhu/html/imp/201002_imp.html

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Rebecca Cosgrove and Daniel Starosta

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Planned Changes - Summary

- Continue using current operational GFS
- Upgrade horizontal resolution from T126 to T190
  - 4 cycles per day, 20+1 members per cycle
  - Up to 384 hours (16 days)
- Use 8th order horizontal diffusion for all resolutions
  - Improved forecast skills and ensemble spread
- Introduce ESMF (Earth System Modeling Framework) for GEFS
  - Version 3.1.0rp2
  - Allows concurrent generation of all ensemble members
  - Needed for efficiency of stochastic perturbation scheme
- Add stochastic perturbation scheme to account for random model errors
  - Increased ensemble spread and forecast skill (reliability)
- Add new variables (28 more) to pgrba files
  - Based on user request
  - Supports NAEFS ensemble data exchange
  - From current 52 (variables) to future 80 (variables)

NAEFS Configuration

Updated: September 2008, implemented Feb 2010

	NCEP	CMC
Model	GFS	GEM
Initial uncertainty	ETR	EnKF
Model uncertainty/Stochastic	Yes (Stochastic Pert)	Yes (multi-physics)
Tropical storm	Relocation	None
Daily frequency	00,06,12 and 18UTC	00 and 12UTC
Resolution	T190L28 (d0-d16)~70km	(d0-d16) ~1.0degree
Control	Yes	Yes
Ensemble members	20 for each cycle	20 for each cycle
Forecast length	16 days (384 hours)	16 days (384 hours)
Post-process	Bias correction for ensemble mean	Bias correction for each member
Last implementation	December 2008 (plan)	July 10th 2007

NEXT NAEFS exchange pgrba files

Variables	pgrba file	Total 80 (28)
GHT	Surface, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11 (3)
TMP	2m, 2mMax, 2mMin, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	13 (3)
RH	2m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11 (3)
UGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11 (3)
VGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11 (3)
VVEL	850hPa	1 (1)
PRES	Surface, PRMSL	2 (0)
PRCP (types)	APCP, CRAIN, CSNOW, CFRZR, CICEP	5 (0)
FLUX (surface)	LHTFL, SHTFL, DSWRF, DLWRF, USWRF, ULWRF	6 (6)
FLUX (top)	ULWRF (OLR)	1 (1)
PWAT	Total precipitable water at atmospheric column	1 (0)
TCDC	Total cloud cover at atmospheric column	1 (0)
CAPE and CIN	Convective available potential energy, Convective Inhibition	2 (1)
SOIL	SOILW(0-10cm), WEASD(water equiv. of accum. snow depth), SNOD(surface), TMP(0-10cm down)	4 (4)
Notes	Surface GHT is only in analysis file and first pgrb file when the resolution changed. 25 of 28 new variables are from pgrbb files, 10, 50hPa RH and SNOD are new variables	28 new vars

NEXT NAEFS pgrba_bc files
(bias correction)

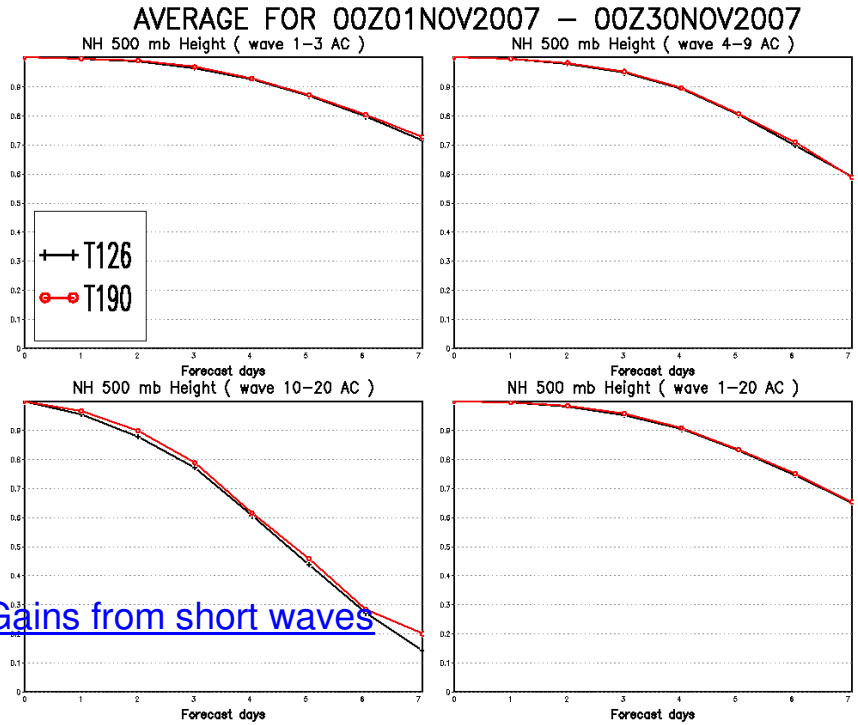
Variables	pgrba_bc file	Total 49 (14)
GHT	10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	10 (3)
TMP	2m, 2mMax, 2mMin, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	13 (3)
UGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11 (3)
VGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11 (3)
VVEL	850hPa	1(1)
PRES	Surface, PRMSL	2(0)
FLUX (top)	ULWRF (toa - OLR)	1 (1)
		14 new vars
Notes		

Horizontal resolution change

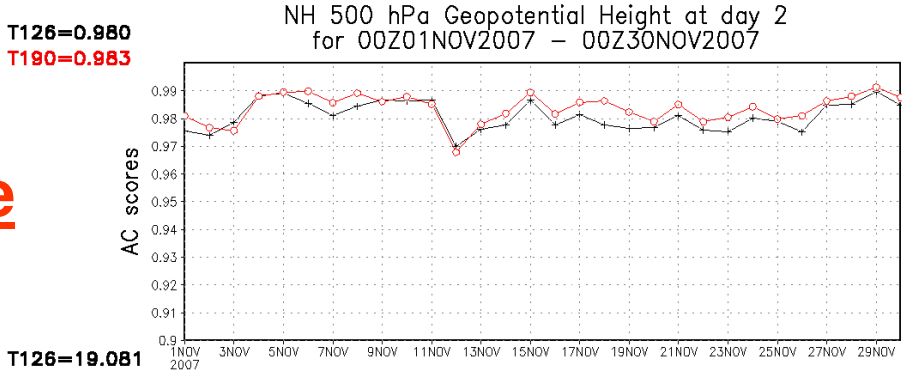
Ensemble control only (deterministic)

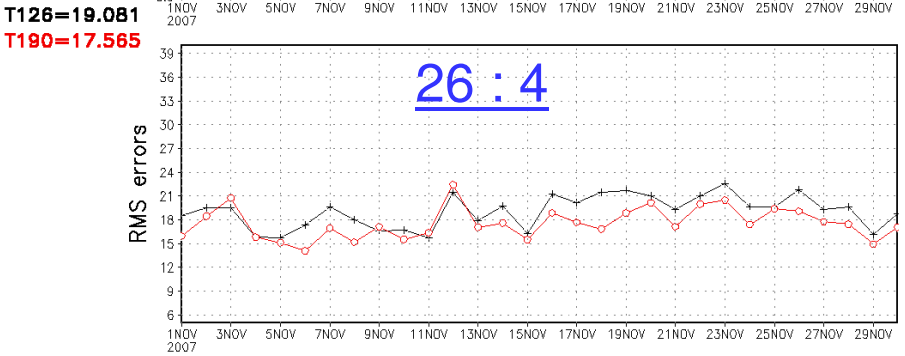
From T126 to T190

NH 500hPa geopotential height

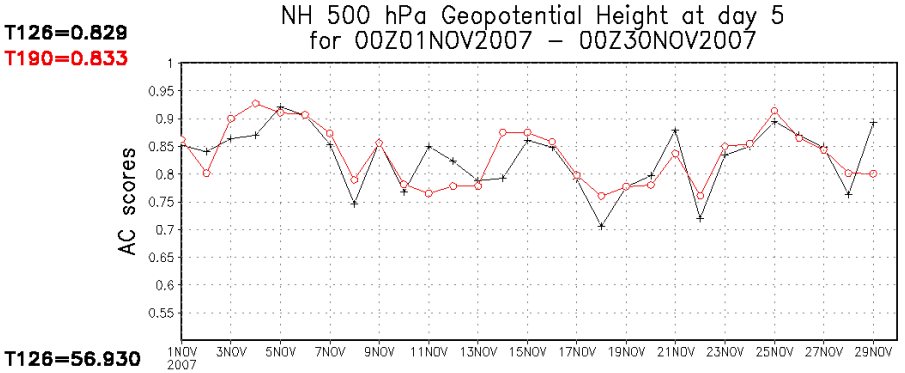


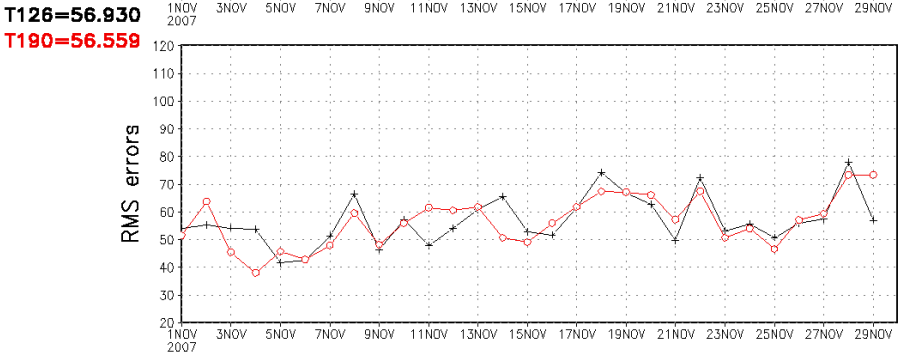
Gains from short waves





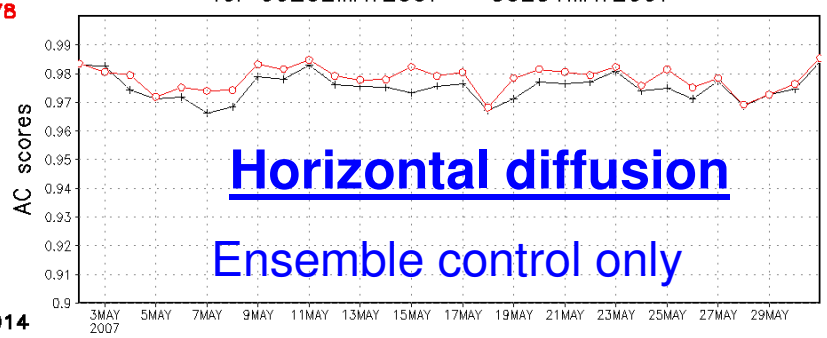
26 : 4





OPR=0.975
NHD=0.978

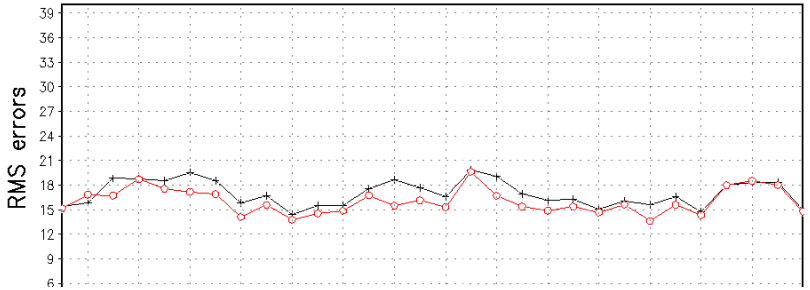
NH 500 hPa Geopotential Height at day 2
for 00Z02MAY2007 – 00Z31MAY2007



Horizontal diffusion

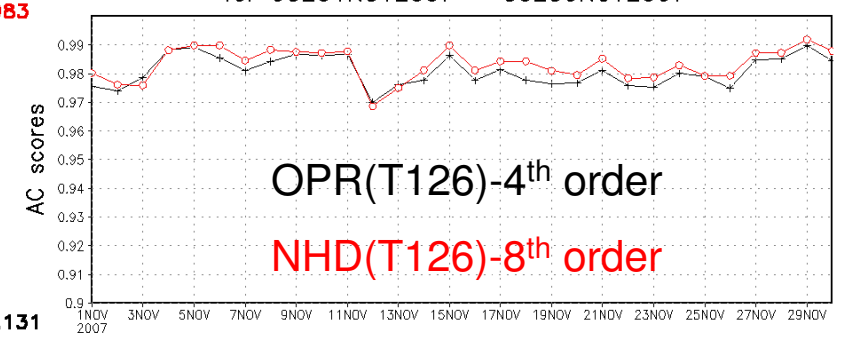
Ensemble control only

OPR=17.014
NHD=16.03



OPR=0.980
NHD=0.983

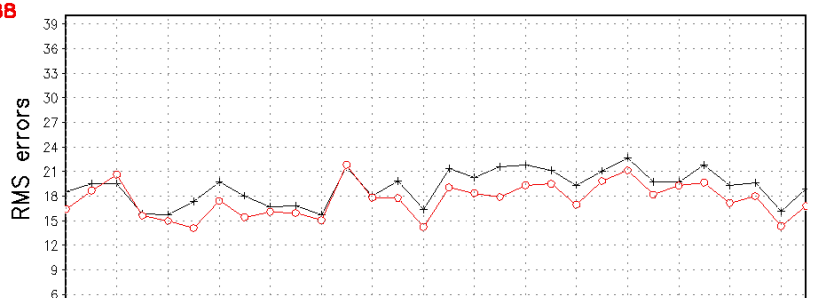
NH 500 hPa Geopotential Height at day 2
for 00Z01NOV2007 – 00Z30NOV2007



OPR(T126)-4th order

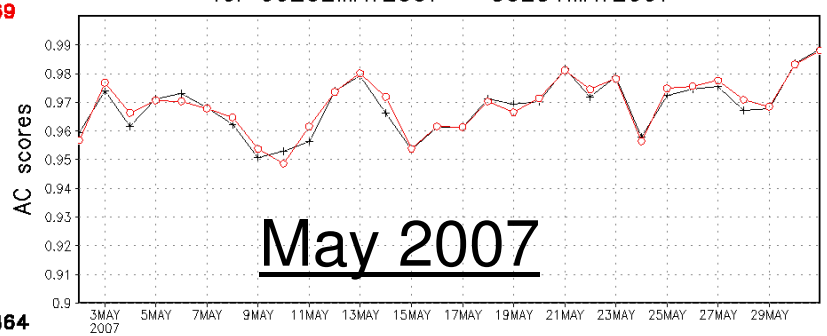
NHD(T126)-8th order

OPR=19.131
NHD=17.588



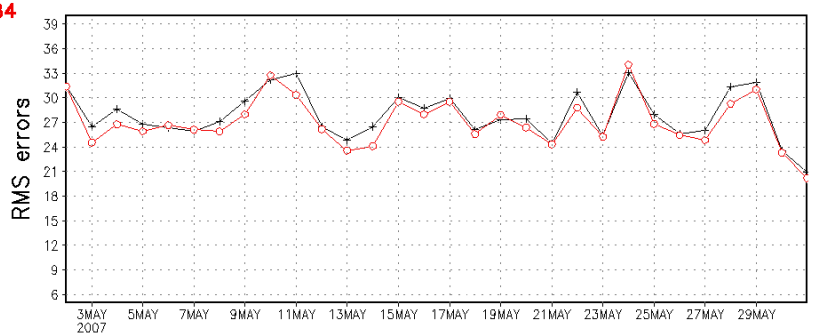
OPR=0.968
NHD=0.969

SH 500 hPa Geopotential Height at day 2
for 00Z02MAY2007 – 00Z31MAY2007



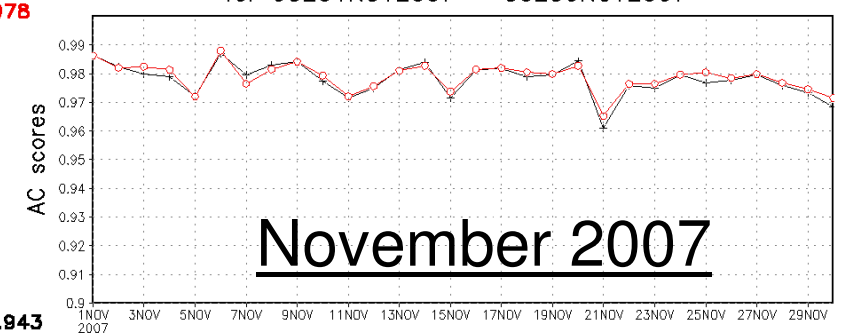
May 2007

OPR=27.864
NHD=27.084



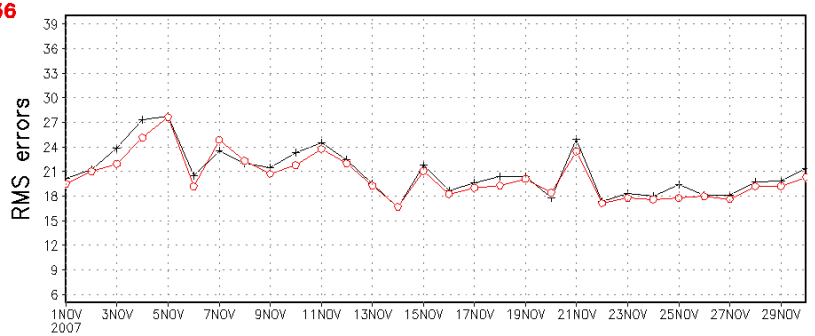
OPR=0.978
NHD=0.978

SH 500 hPa Geopotential Height at day 2
for 00Z01NOV2007 – 00Z30NOV2007

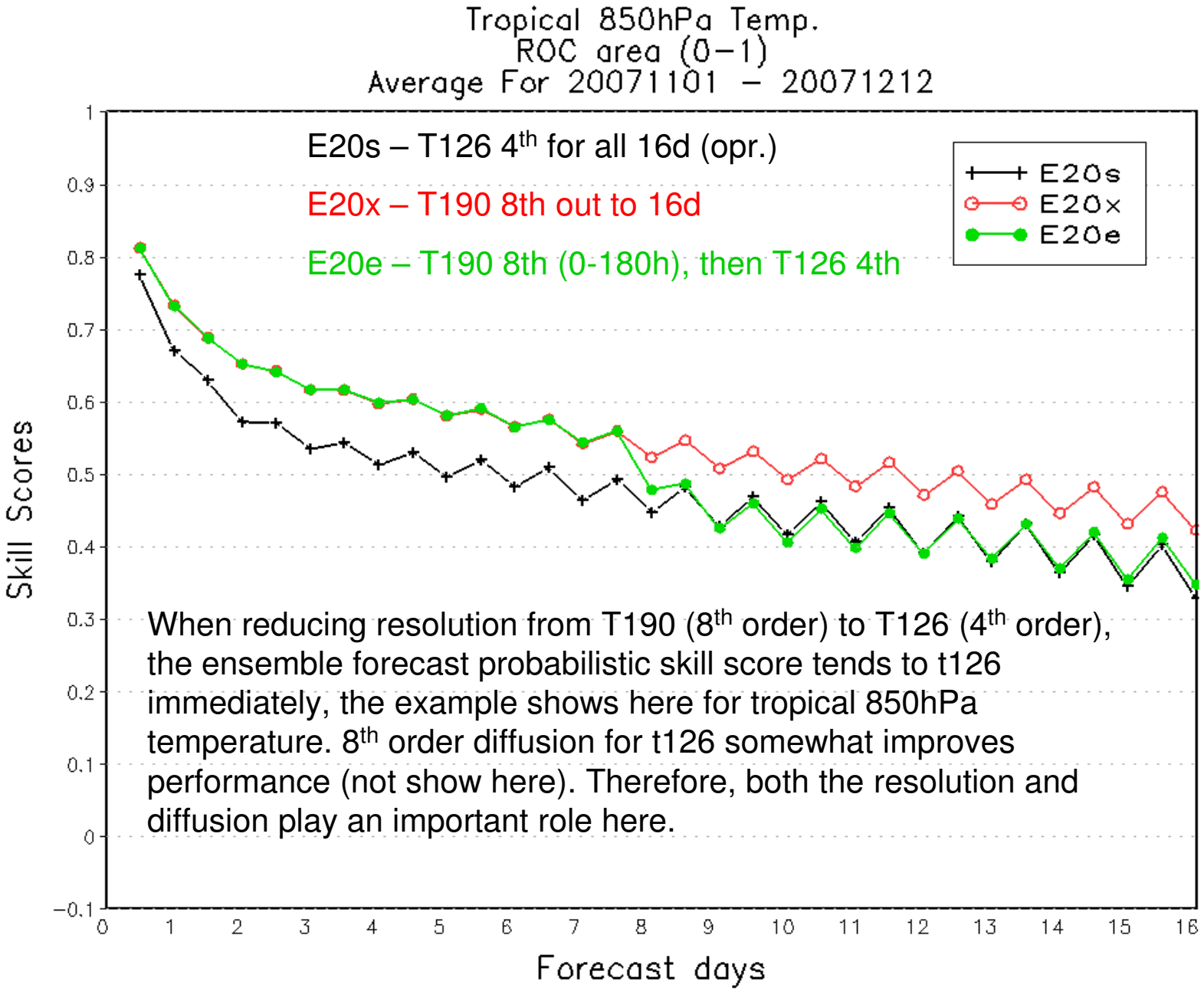


November 2007

OPR=20.943
NHD=20.336

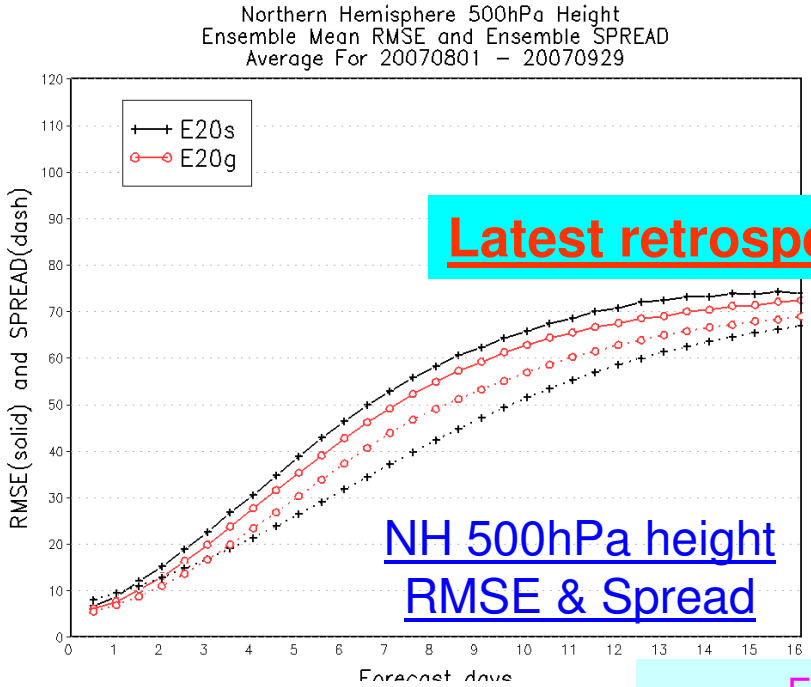


Resolution and Diffusion for Global Ensemble Without Stochastic

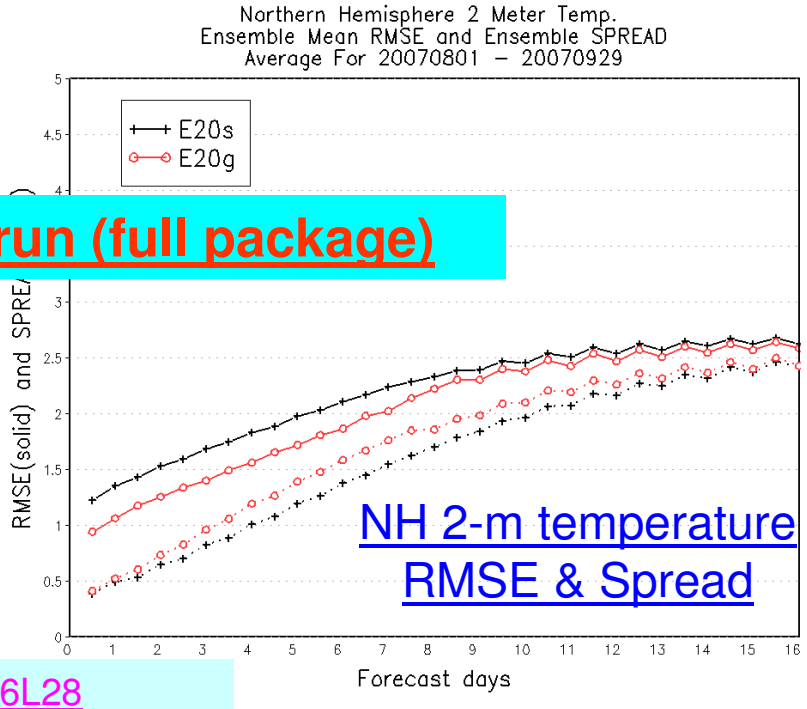


When reducing resolution from T190 (8th order) to T126 (4th order), the ensemble forecast probabilistic skill score tends to t126 immediately, the example shows here for tropical 850hPa temperature. 8th order diffusion for t126 somewhat improves performance (not show here). Therefore, both the resolution and diffusion play an important role here.

Latest retrospective run (full package)

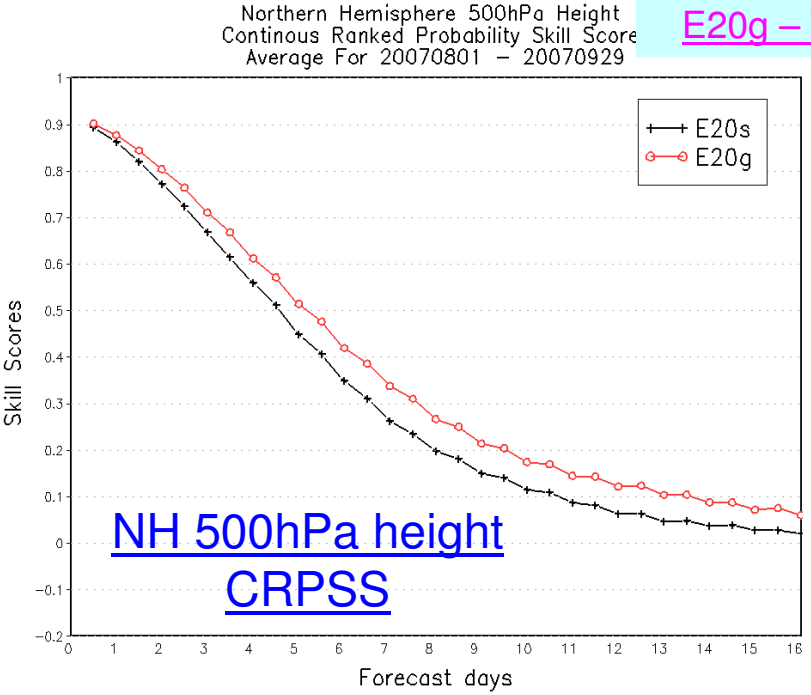


NH 500hPa height
RMSE & Spread

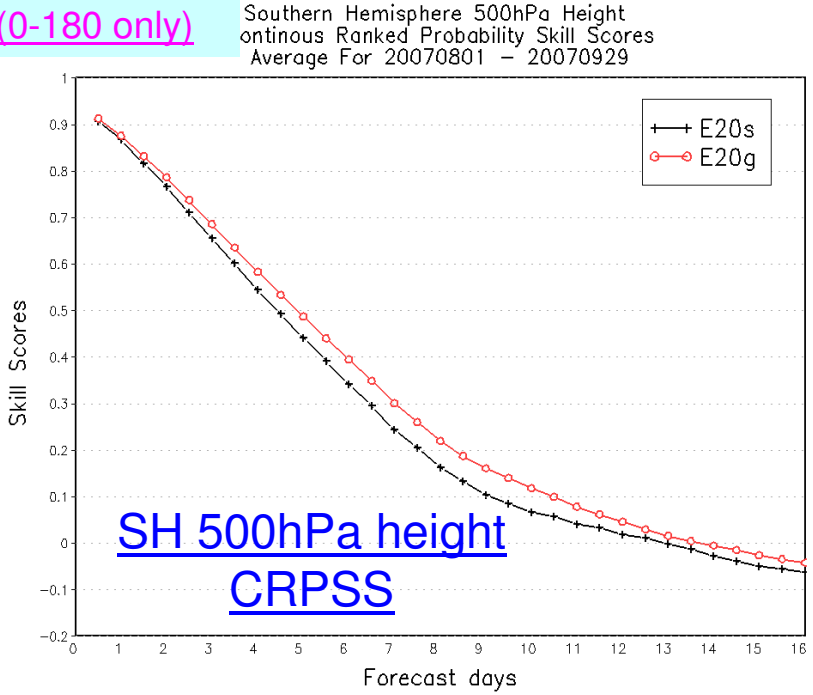


NH 2-m temperature
RMSE & Spread

E20s – T126L28
E20g – T190L28 (0-180 only)



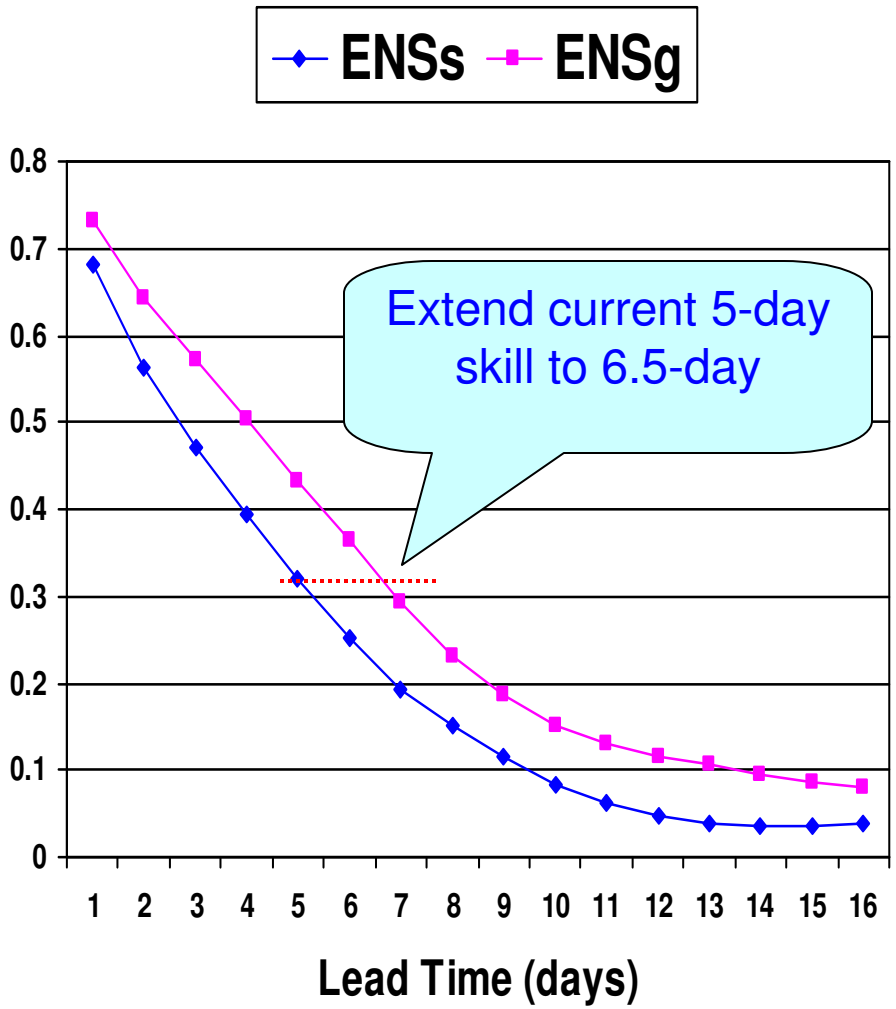
NH 500hPa height
CRPSS



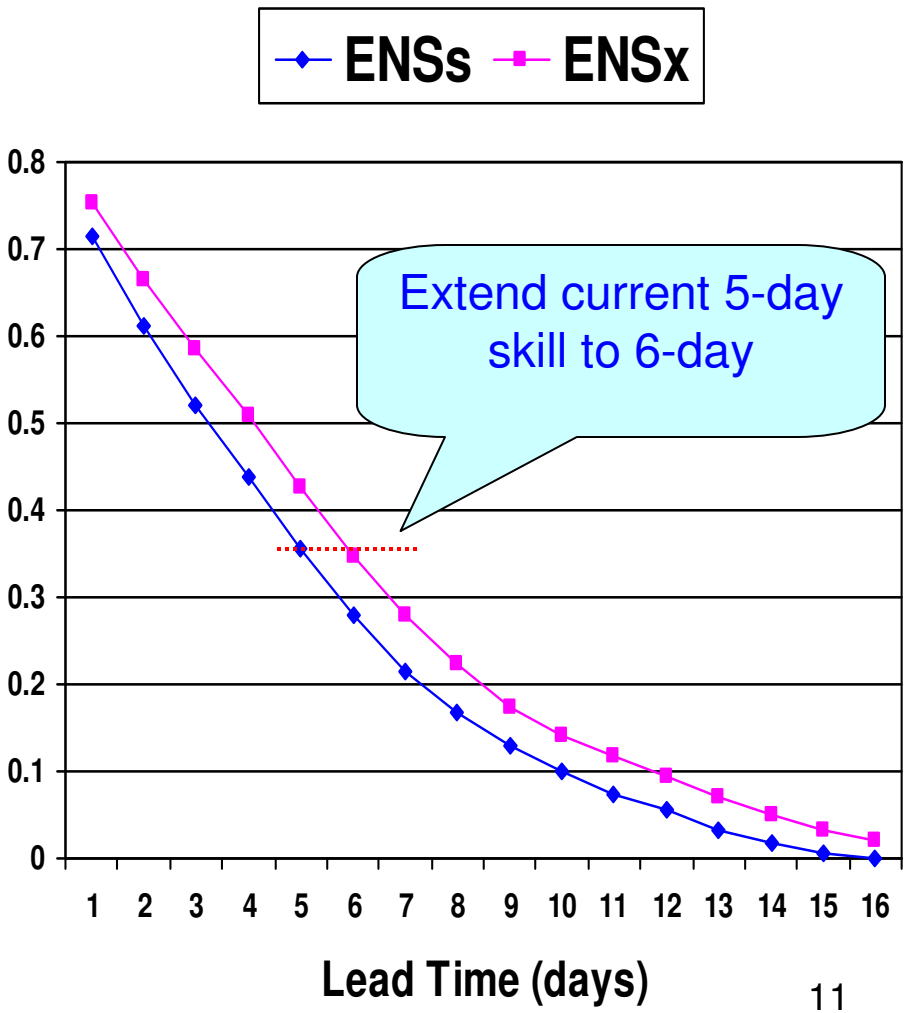
SH 500hPa height
CRPSS

CRPSS for NH 850hPa temperature

Summer (08/01-09/30/2007)

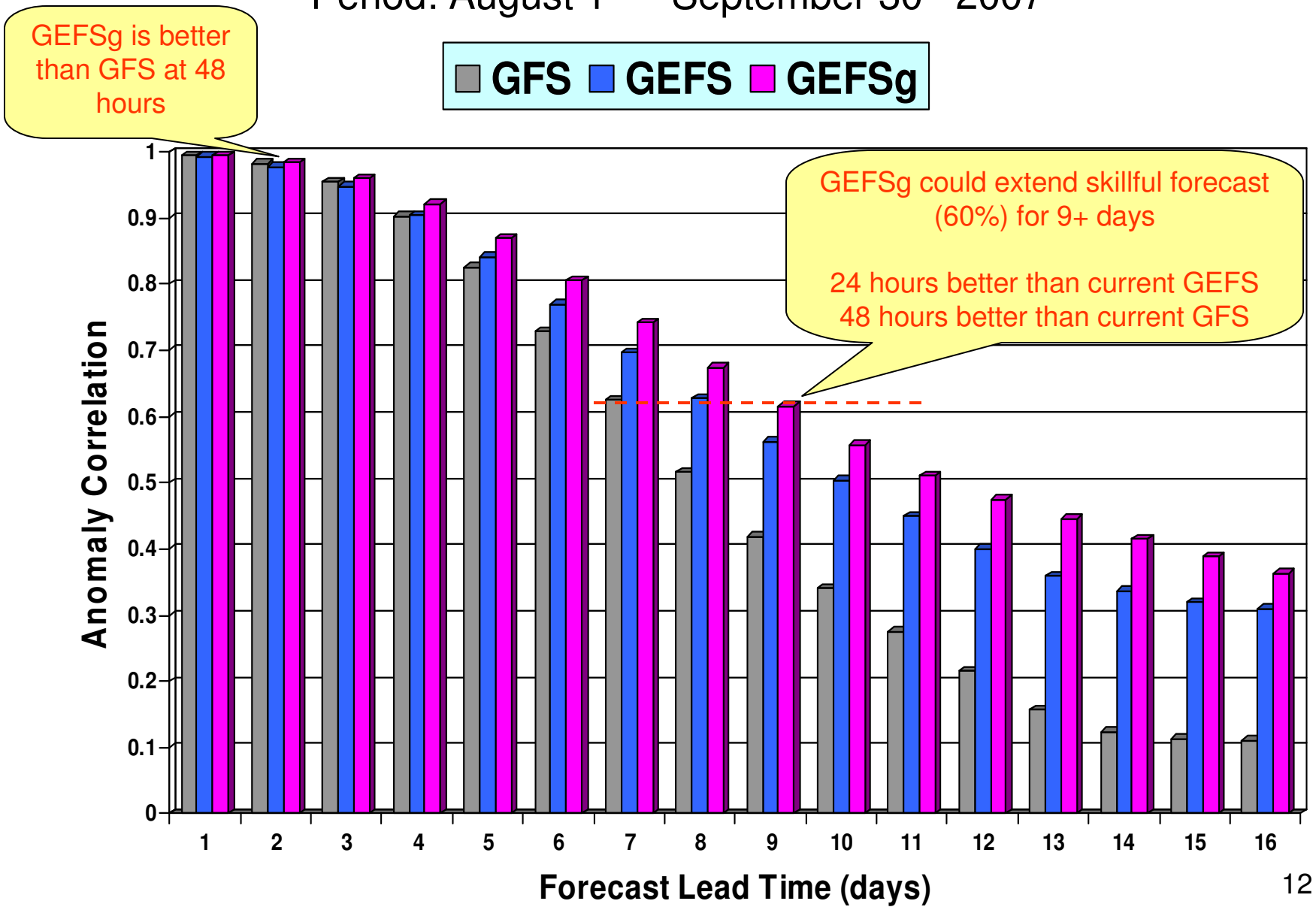


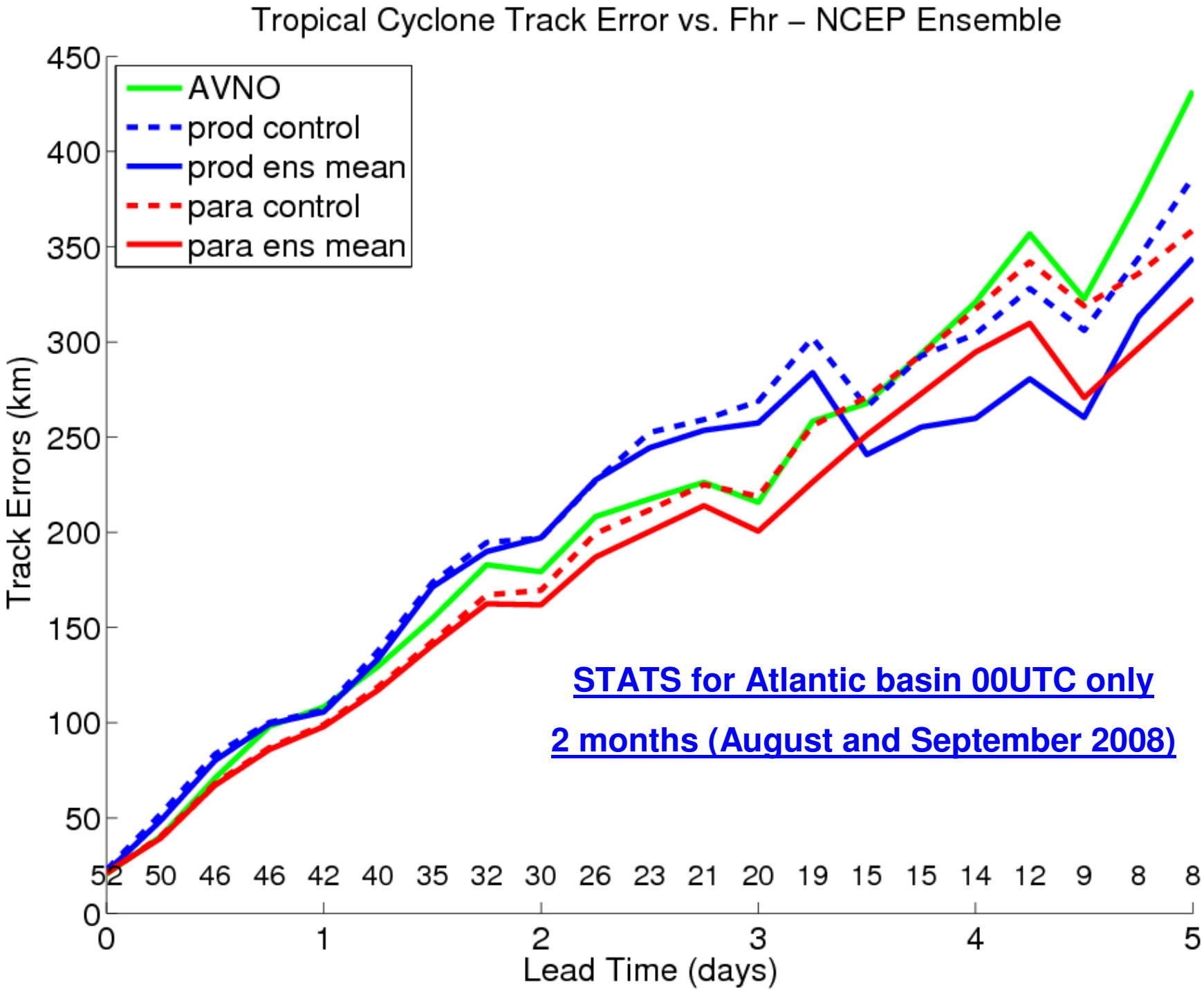
Winter (11/01-12/30/2007)



NH Anomaly Correlation for 500hPa Height

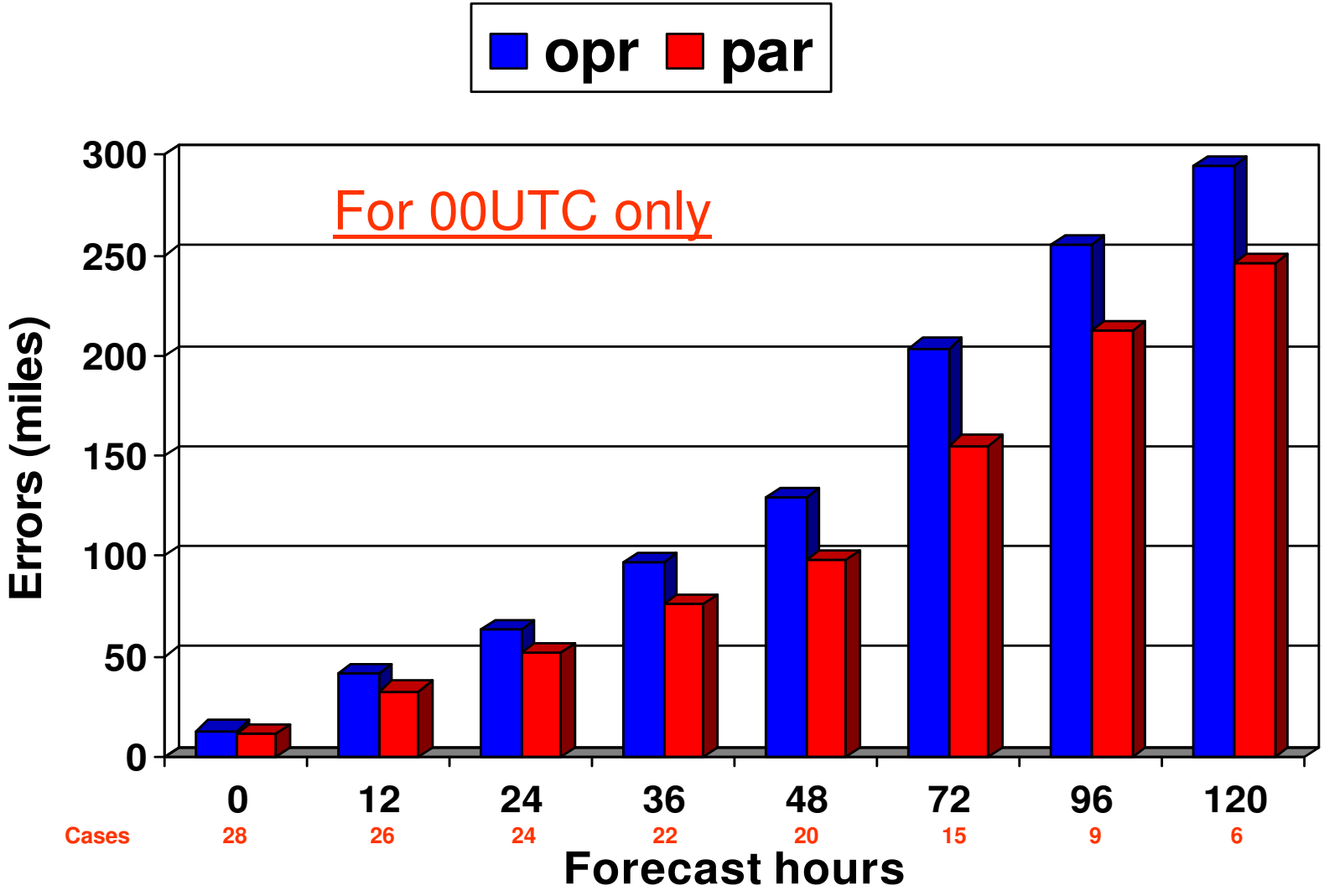
Period: August 1st – September 30th 2007

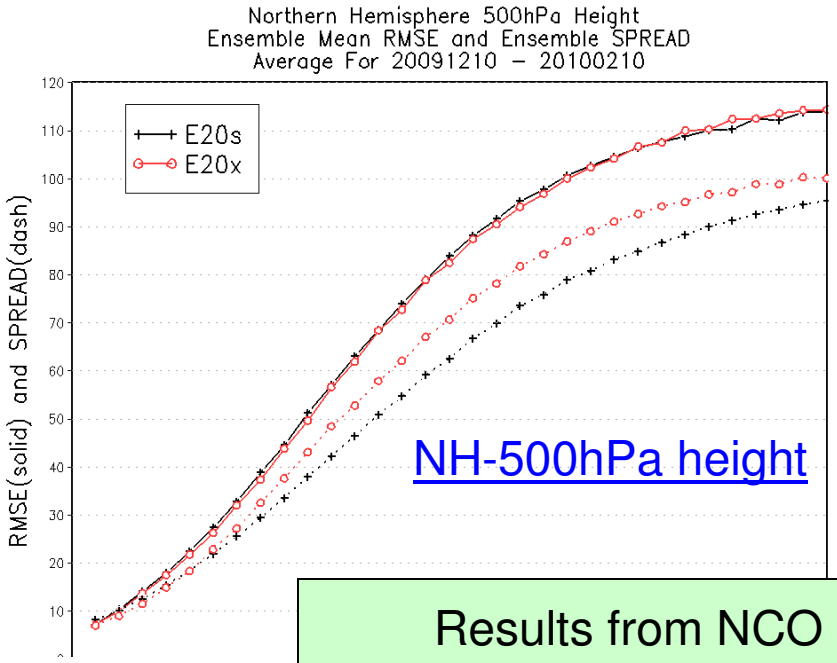


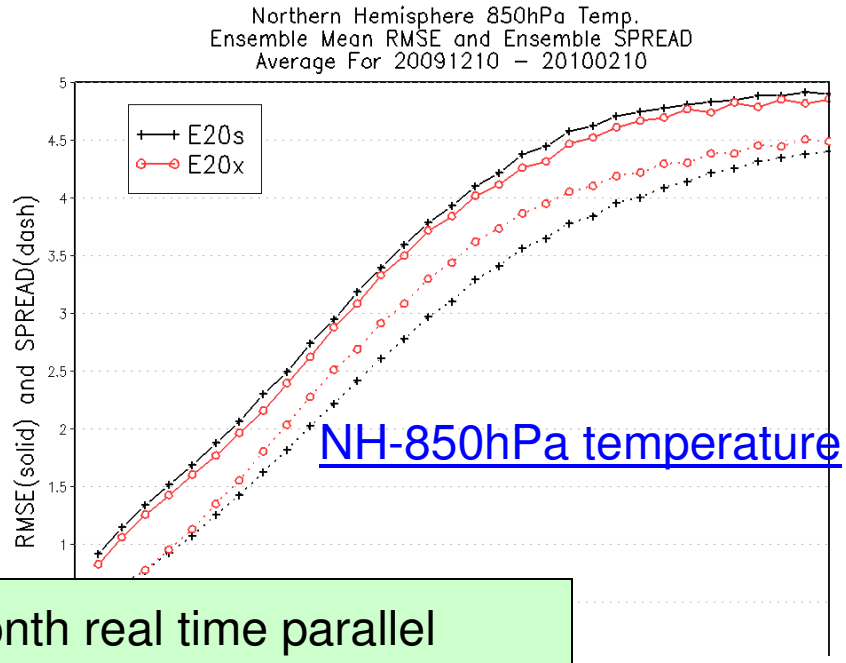

Tropical Cyclone Track Error vs. Fhr – NCEP Ensemble
AVNO
prod control
prod ens mean
para control
para ens mean
Track Errors (km)
450
400
350
300
250
200
150
100
50
0
52 50 46 46 42 40 35 32 30 26 23 21 20 19 15 15 14 12 9 8 8
0
1
2
3
4
5
Lead Time (days)
STATS for Atlantic basin 00UTC only
2 months (August and September 2008)

Summary of the important cases of Bill Jimena, Rick and Ida

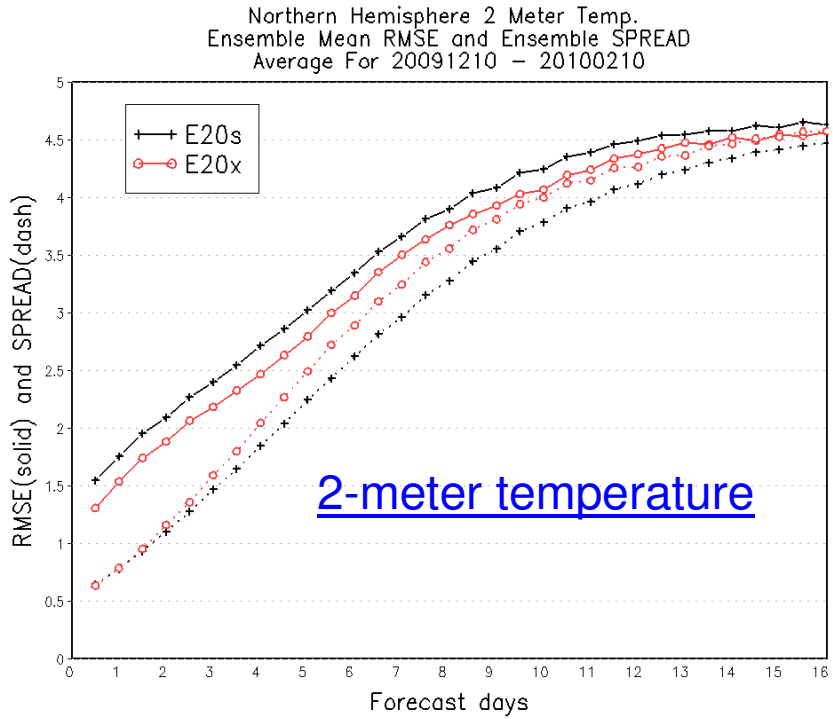
TS track errors (2009)

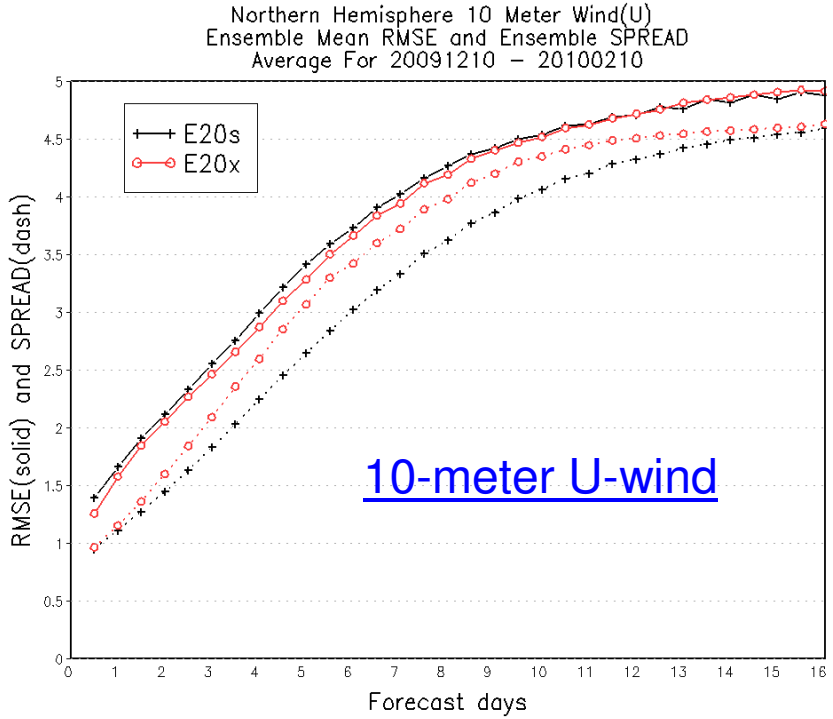






Results from NCO 2-month real time parallel





Subjective Evaluation

- TPC, HPC, and CPC were requested to participate
- HPC's recommendation for implementation
  - Yes
- TPC's recommendation for implementation
  - Yes
- AWC's recommendation for implementation
  - Yes
- CPC's recommendation for implementation
  - Yes
- WFO's Evaluation (State College, PA -Richard Grumm)
  - Good
- Other evaluation
  - None

HPC's evaluation

- General evaluation
  - Is the overall probabilistic forecast skill of the GEFS improved?
    - Yes, noticeably larger spread.
  - Is the overall ensemble mean forecast skill improved?
    - Similar to slightly improved over operational GEFS
- QPF evaluation
  - Improved depiction of orographic precipitation
  - Can have larger maximas
- Overall impression:
  - Improvement relative to operational

TPC's evaluation

- Tropical Cyclones
  - TC Track errors for the new ensemble mean are smaller compared to the operational ensemble mean at most lead times
    - Results varied from case to case
    - Evaluation based on a relatively small sample of cases (1 August-30 September 2008, and selected runs from Bill, Ida, Jimena and Rick in 2009)
  - In some cases, the observed TC track now lies within the parallel ensemble envelope where it was outside the operational ensemble envelope
  - With the increase in resolution, the vortex tracker is able to follow the TC in more ensemble members at longer time ranges.
  - This will help to improve the availability of the ensemble mean, particularly at longer lead times
  - **The overall ensemble mean forecast skill and probabilistic forecast skill of the GEFS are improved**
- Marine
  - The parallel ensemble mean generally has better defined features
    - This is especially beneficial for small-scale, terrain driven events (i.e., gap wind events in the Pacific) where there is more structure in the parallel wind field compared to the operational mean
  - For synoptic scale features, the pattern in the parallel mean is often similar to that seen in the operational ensemble mean
  - In cases where the operational ensemble mean did not perform well (15-17 January 2010 Gulf of Mexico cyclone), the parallel mean did not show dramatic improvement
  - **The overall ensemble mean forecast skill is improved**

AWC's evaluation

- **Evaluation of Retrospective Runs**
  - **General Comments:**
    - The improvement in scores at 500 hPa are notable and remarkably consistent in the 1.5 to 5.0 day range of interest to AWC's future forecast interests.
  - **Direct comparison of Operational and Proposed Change:**
    - I focused on the 500 hPa retrospectives from day 1.5 to 5.0 as this forecast range is most applicable to AWC's current and immediate future missions.
    - saw only one score set that appeared significant worse for the new implementation compared to the current one (ROC over tropical domain for Winter 2007/2008)—**pretty remarkable!**
  - For future evaluations I would like to see statistics for 250 hPa geopotential heights and wind speeds.
- **Real-Time Parallel Runs:**
  - **General comments:**
    - In the 500 hPa day 1.5 to 5.0 range the improvements in the skills scores over the evaluation period appear less than those in the retrospectives. The amount of spread in members is greater, suggesting potential for fewer observations outside the ensemble envelope.
  - **Direct comparison of operational and proposed change:**
    - I was unable bring in daily runs due to lack of advance notice and high support staff workload during the evaluation period. I am relying on the verification statistics for this evaluation.

CPC's evaluation

- Real-Time Parallel Runs:
  - General comments: As is typically the case, the evaluation period is far too short to draw any significant conclusions from the limited results obtained. I am attaching a few slides which depict these results
  - Direct comparison of operational and proposed change:
    - The D+8 500-hPa average anomaly correlation scores for both the Northern Hemisphere and PNA sector are virtually identical over the one month period. The average D+11 scores were slightly worse, but not enough to be statistically significant.

WFO's evaluation (State College)

- Several interesting events presented opportunities to compare the operational to the higher resolution GEFS to include:
  - The Christmas Eve southern plains snow storm. The higher GEFS showed wind anomalies, a deeper cyclone and higher QPF values compare to the operational GEFS. The two systems looked relatively similar.
  - The later December and early January block were well predicted by both GEFS systems. During this period of time several unusual snow storms and episodes were particularly well predicted to include the East Asian snow and the United Kingdom snow events.
  - **The new GEFS seemed to have higher QPF amounts during many events relative to the GEFS.** This was evident during the massive cyclone that crossed the United States on 21-25 January 2010 and the eastern US heavy rainfall event of 24 January 2010. It clearly out performed the GEFS with regards to snowfall in KY for the 29-30 January storm.
- We shared our site with other offices to include WFO-Sterling, the three AK Region offices, and Pittsburgh. The site was well received. Overall impressions were favorable as the new version of the GEFS generally was similar to the older version. It appeared show more details and in several big precipitation events showed higher probabilities and higher mean QPF values. Having these data was and continues to be an advantage to us. It appears to be showing good details with the unfolding East Winter Storm predicted for the Friday-Saturday time period. We really think these data were ready for prime time several weeks

Conclusion

- Based on three sets of retrospective runs (summer, winter 2007, and summer 2008) and NCO real time parallel (since December 10 2009)
  - New package improved the forecast skill (score) significantly
    - For deterministic (ensemble mean)
    - For probabilistic (ensemble distribution)
- The better results are mainly from:
  - Increase horizontal resolution (include diffusion)
  - Stochastic perturbation scheme
- The better results are benefited from
  - The improvement of analysis (initial conditions)
  - The forecast model (GFS) improvements