

NAEFS / GEFS STATUS AND PLANS

NOAA/OAR/ESRL/GSD

Formerly with Ensemble & Probabilistic Guidance Team

Environmental Modeling Center

Acknowledgements: Andre Methot, Yuejian Zhu

OUTLINE / SUMMARY

- Overview of areas of ensemble work
- Review of NAEFS
 - Configuration
 - Products
 - Customers
 - Expansion
- Plans for GEFS component of NAEFS
- Relevance of NAEFS for regional ensembles
 - Boundary perturbations
 - Prototype for system design / collaboration / organization?

MAIN AREAS OF ENSEMBLE WORK

- Represent uncertainty in numerical forecasting
 - Tasks
 - Design, implement, maintain, and continuously improve **ensemble systems**
 - Topics
 - **Initial value** related uncertainty
 - **Model related** forecast uncertainty
 - Ensemble systems at NCEP
 - Global – NAEFS / GEFS
 - Regional – SREF
 - Climate – Contributions to future CFS configuration
- Statistical correction of ensemble forecasts
 - Tasks
 - Correct for systematic errors on model grid
 - Downscale information to fine resolution grid (NDFD)
 - Combine all forecast info into single ensemble/probabilistic guidance
- Probabilistic product generation / user applications
 - Contribute to design of probabilistic products
 - Support use of ensembles by
 - Internal users (NCEP Service Center, WFO, etc forecasters)
 - External users (research, development, and applications)

NORTH AMERICAN ENSEMBLE FORECAST SYSTEM (NAEFS)

CURRENT CONFIGURATION

- Definition
 - Multi-center ensemble system combining
 - 20 perturbed plus a control member out to 16 days twice a day on 1x1 lat/lon grid from
 - NCEP - Global Ensemble Forecast System (four times per day)
 - » T126L28, ET initial perturbation technique, no model perturbations
 - Canadian Meteorological Center (CMC)
- Operational steps
 - Generation NCEP global ensemble
 - Real time data exchange with CMC (50+ variables)
 - Bias correction of both ensembles (35 variables)
 - Incorporation of information from high resolution GFS
 - Downscaling of 1x1 bias corrected fields onto 5x5 km NDFD grid (4 variables)
 - Product generation – see next page

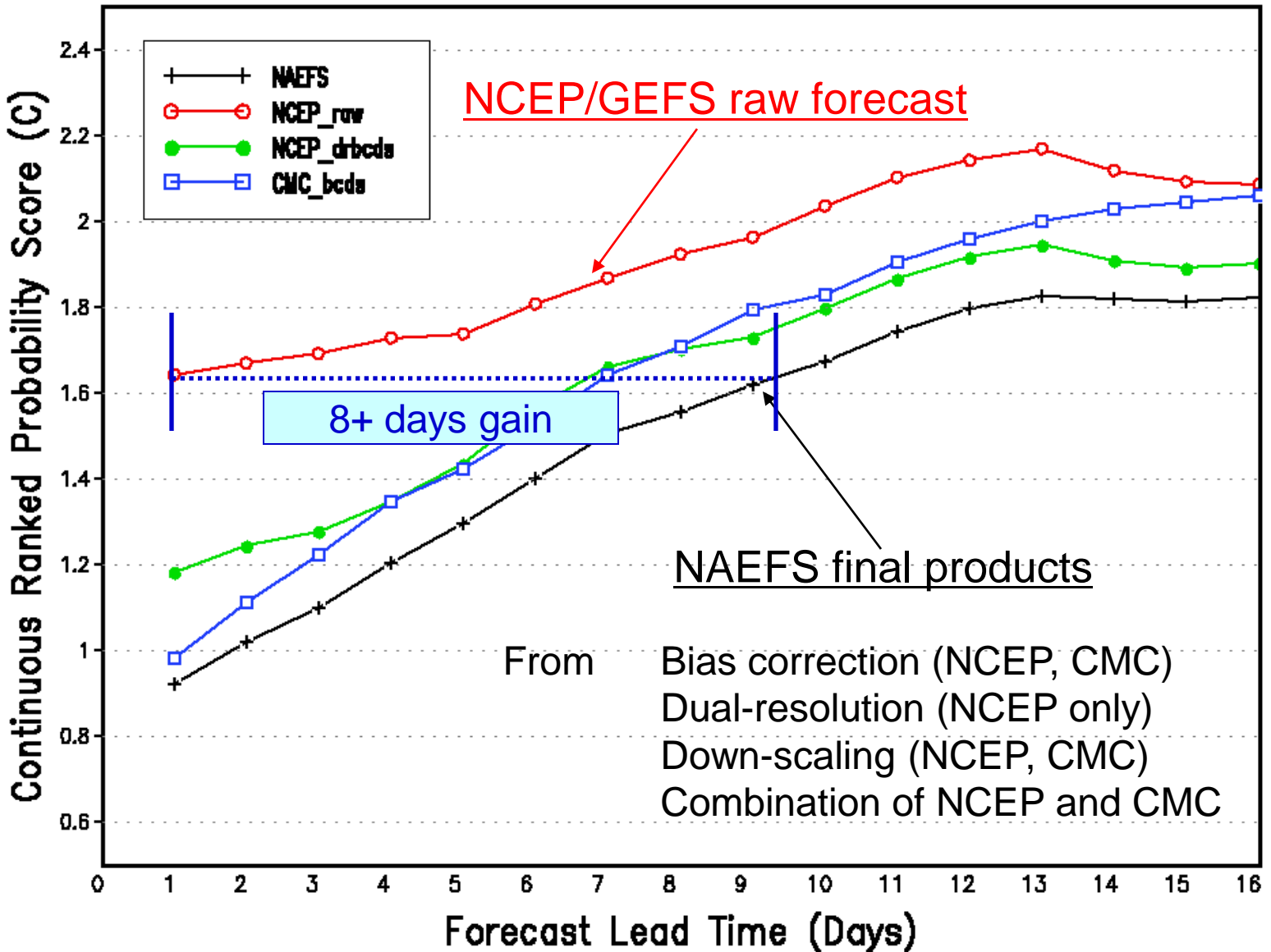
PRODUCTS

NORTH AMERICAN ENSEMBLE FORECAST SYSTEM (NAEFS)

- Basic products on 1x1 lat/lon grid
 - Bias corrected ensemble forecasts (42 members, 35 variables)
 - Climate anomaly forecasts for downscaling applications (42 members, 19 variables)
- Derived products
 - Mean, mode, 10, 50 (median), 90 percentile forecasts, spread on 1x1 lat/lon grid
 - Downscaled forecasts on 5x5 km grid (4 variables)
 - Week-2 temperature forecasts (jointly with CPC)
 - GEMPAK grids / images
 - Ensemble / probabilistic displays
- Distribution of products
 - Mainframe / NAWIPS for NCEP Service Centers
 - AWIPS for WFOs
 - WOC & NCEP ftp servers for grids for external users
 - Web sites for images
 - NCEP official web site
 - EMC experimental web site



NAEFS NDGD Probabilistic 2m Temperature Forecast Verification For 2007090100 – 2007093000



CUSTOMERS

NORTH AMERICAN ENSEMBLE FORECAST SYSTEM (NAEFS)

- NCEP Service Centers
 - Gridded fields, NAWIPS manipulation tools, images
- NCEP International Desks
 - South American Desk
 - African Desk
- WFOs
 - AWIPS grids, ftp'd grids, images
- RFCs
 - Grids (experimental)
- External users
 - Ensemble grids, images
- NAEFS partners
 - CMC
 - National Meteorological Service of Mexico (NMSM) – images
- International community
 - Severe Weather Forecast Demonstration Projects
 - Private companies



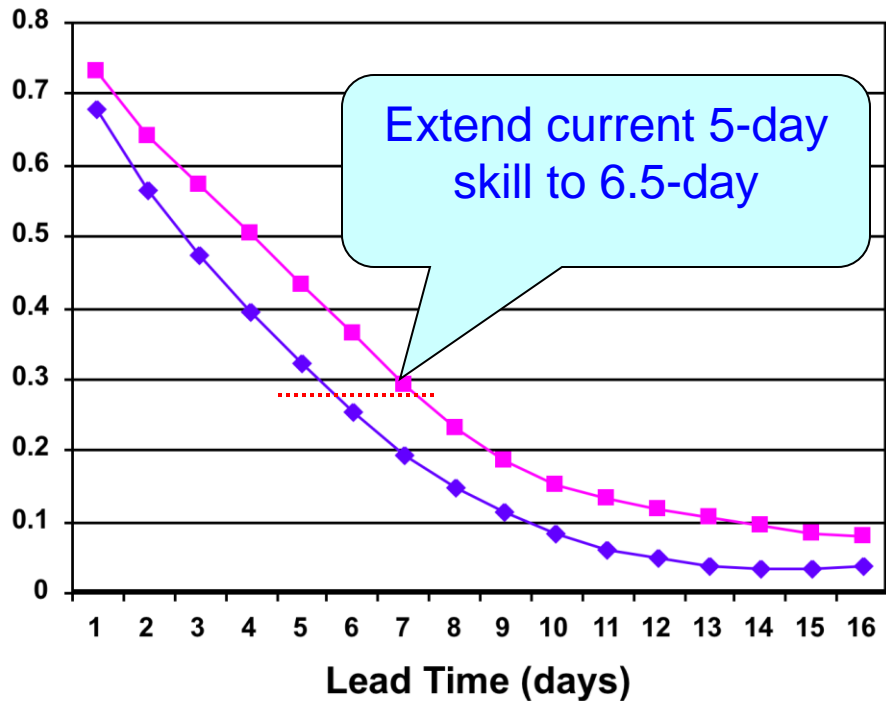
NEXT GEFS IMPLEMENTATION (~~Jan. 2009~~)

- Increase 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 skill and ensemble spread
- Introduce ESMF (Earth System Modeling Framework)
 - Version 3.1.0r
 - 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 (26 more) to pgrba files
 - Based on NAEFS user request
 - From current 52 to future 78 variables
 - For NAEFS ensemble data exchange

CRPSS for NH 850hPa temperature

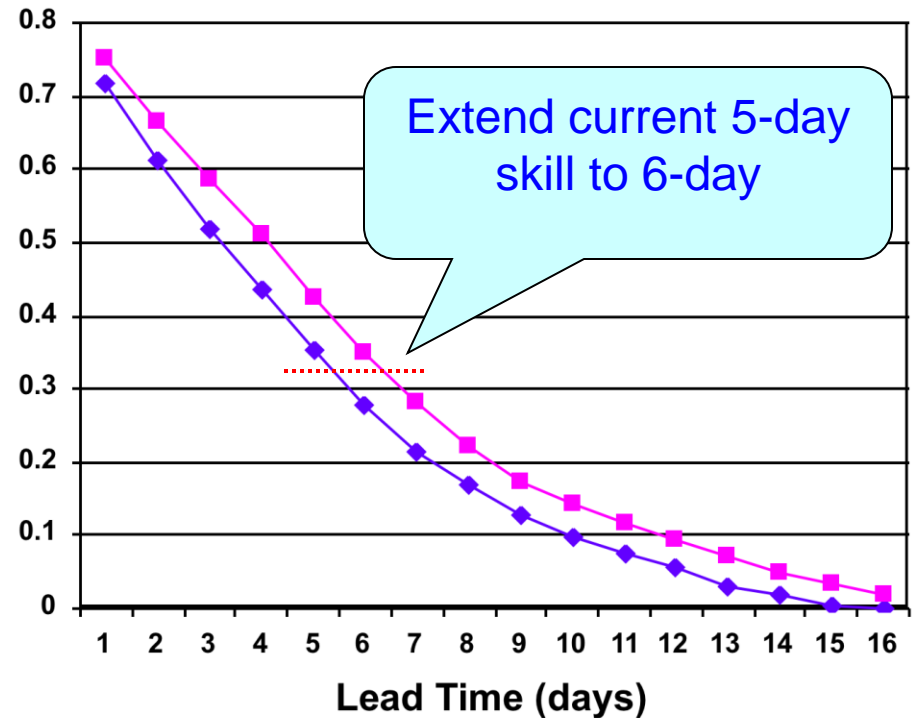
Summer (08/01-09/30/2007)

◆ ENSs ■ ENSg

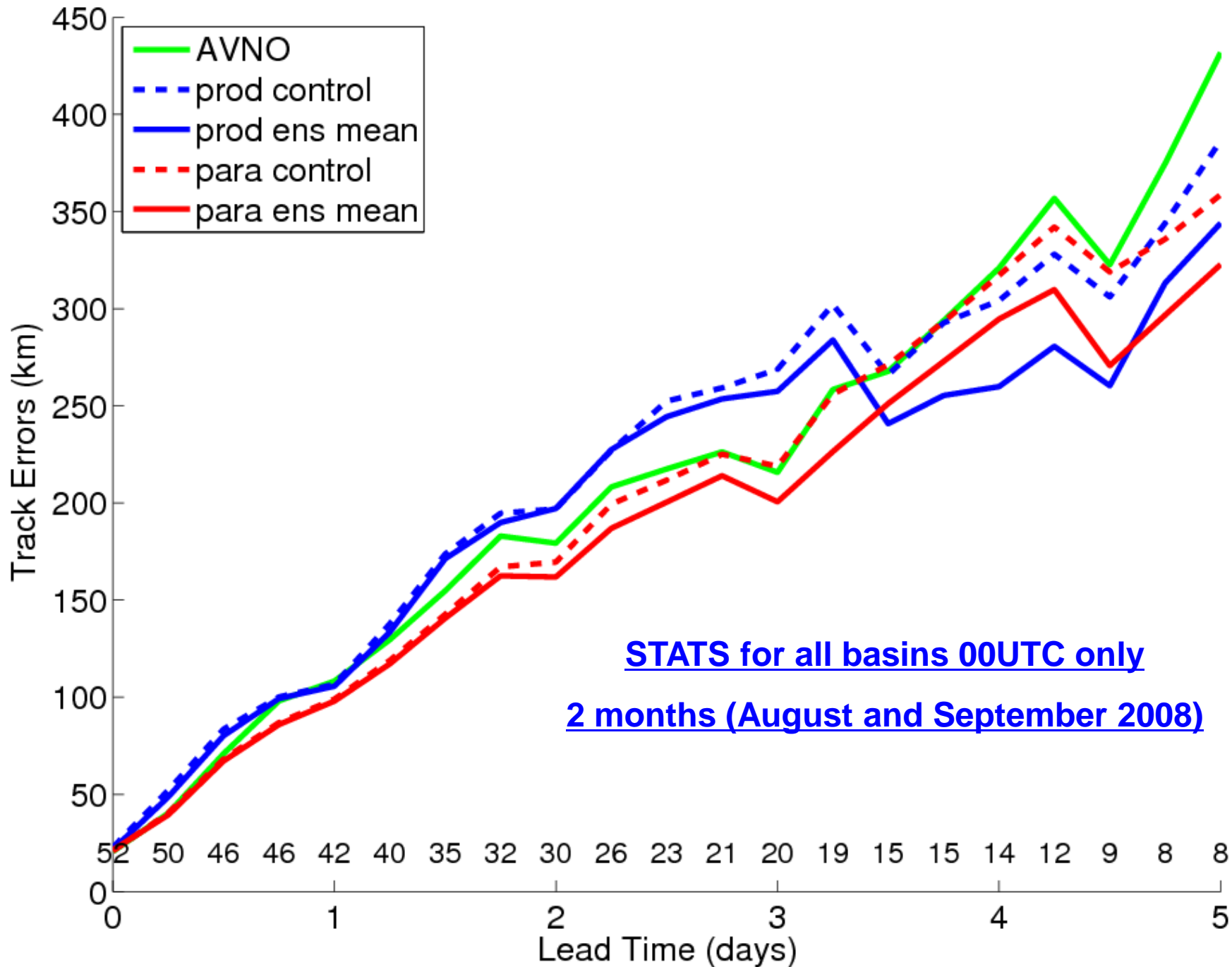


Winter (11/01-12/30/2007)

◆ ENSs ■ ENSx



Tropical Cyclone Track Error vs. Fhr – NCEP Ensemble



NAEFS future configuration

Updated: October 2008

	NCEP	CMC
Model	GFS	GEM
Initial uncertainty	ETR	EnKF
Model uncertainty	None	Yes
Stochastic physics	Yes	Yes
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 10 th 2007

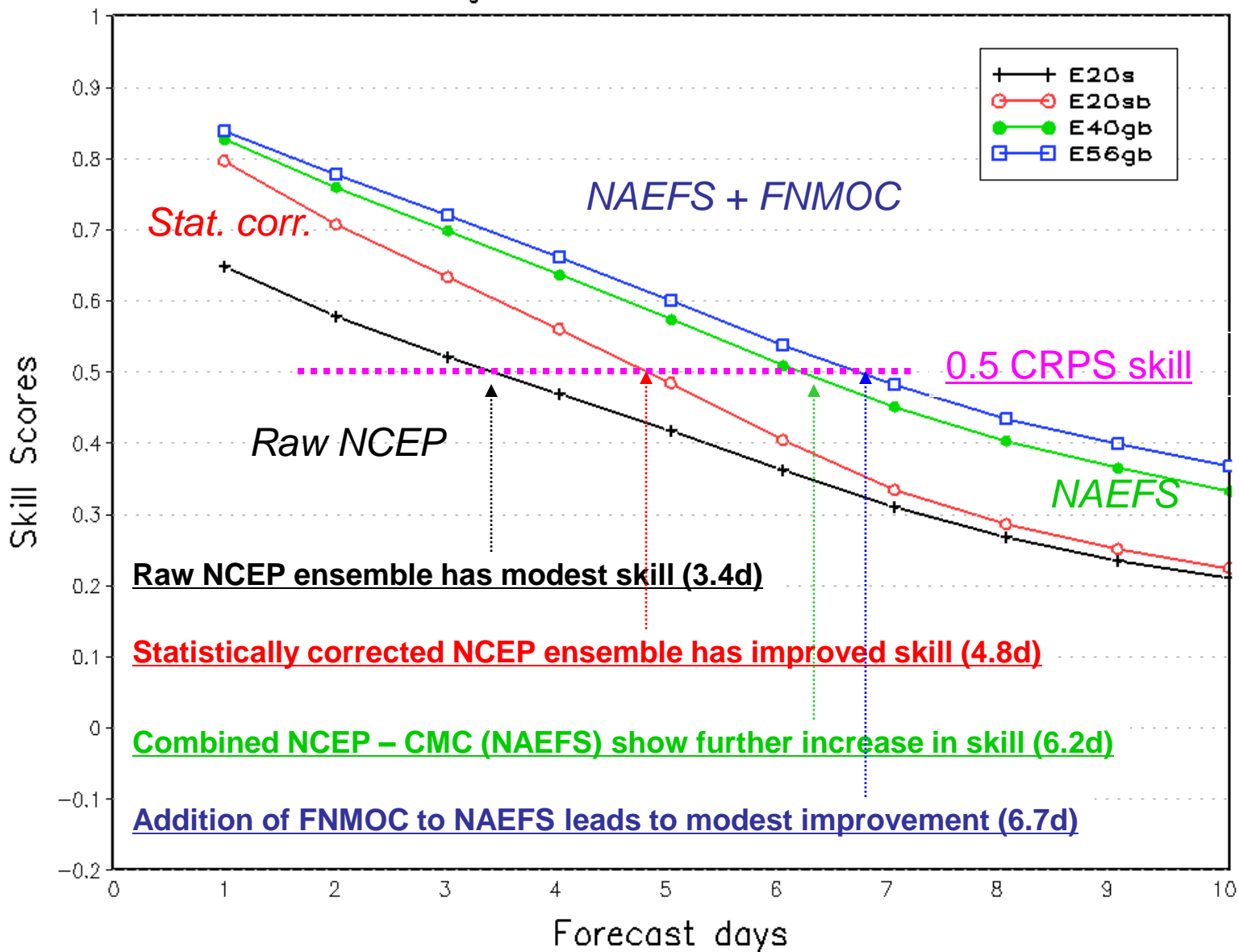
NAEFS EXPANSION PLANS FY2009/10

- Incorporate other ensemble data into NAEFS
 - One year evaluation period
 - Must coordinate with CMC
 - Use “mini-Bayesian” for testing
 - FNMOC global ensemble
 - Need to resolve the problem for data transform (still missing forecast data for FNMOC)
 - ECMWF global ensemble
 - Need to coordinate with NCO for 00UTC data and 6hr forecast intervals
- Probabilistic verification
 - Unified probabilistic verification (3Q, 2009)
 - Shared codes with SREF
 - Partnership with OHD, etc

The Value for inclusion of FNMOc ensemble into NAEFS

T2m: Against analysis (NCEP's evaluation)

Northern Hemisphere 2 Meter Temp.
Continuous Ranked Probability Skill Scores
Average For 20081201 – 20090228



GEFS IMPLEMENTATION PLANS FOR FY2010+

Real time generation of hind-casts

- Make control forecast once every ~5th day
 - T190L28, out to 16 days
 - Use new reanalysis (~30 yrs)
- Why
 - Increase sample of analysis – forecast pairs for statistical corrections
- Benefits
 - Improved bias correction beyond 5 days
 - Potential for regime / situation dependent bias correction

Adaptive modification of initial and stochastic model perturbation variances

- Based on recursive average monitoring of
 - Forecast errors
 - Ensemble spread
- Why
 - Avoid having to tune perturbation size after each analysis/model/ensemble change
- Benefit
 - Improved performance
 - Easier maintenance

Hydro-meteorological (river flow) ensemble forecasting

- Pending on operational LDAS/GLDAS

Coupled ocean-land-atmosphere ensemble

- Couple MOM4 with land-atm component using ESMF
 - Depending on skill, extend integration to 35 days
 - Merge forecasts with CFS ensemble for seamless weather-climate interface
 - Land perturbations (later)
- Why
 - Explore predictability in intra-seasonal time scale
- Benefit
 - Potential skill beyond 16 days
 - Surface perturbations (4Q 2009)

- Bias correction
 - Develop, test, implement Bayesian bias correction technique
 - Apply on all prognostic model variables
 - Including “pseudo-precipitation”
- Downscaling
 - Improve methods
 - Apply to new variables

RELEVANCE OF NAEFS FOR REGIONAL ENSEMBLE PLANS

- Boundary conditions for regional ensemble
 - High quality operational forcing fields
- Prototype for conceptual plan
 - NOAA / National / Regional / International ensemble
 - NCEP GEFS / NUOPC / NAEFS / GIFS – TIGGE
 - NAEFS expansion into regional ensemble considered
 - Expand NUOPC to regional ensemble?
 - Engage with NOAA / National / Intl THORPEX activities
 - TIGGE-LAM subgroup of GIFS-TIGGE WG

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BACKGROUND

NAEFS STATISTICAL CORRECTION / PRODUCT PLANS FOR FY2009

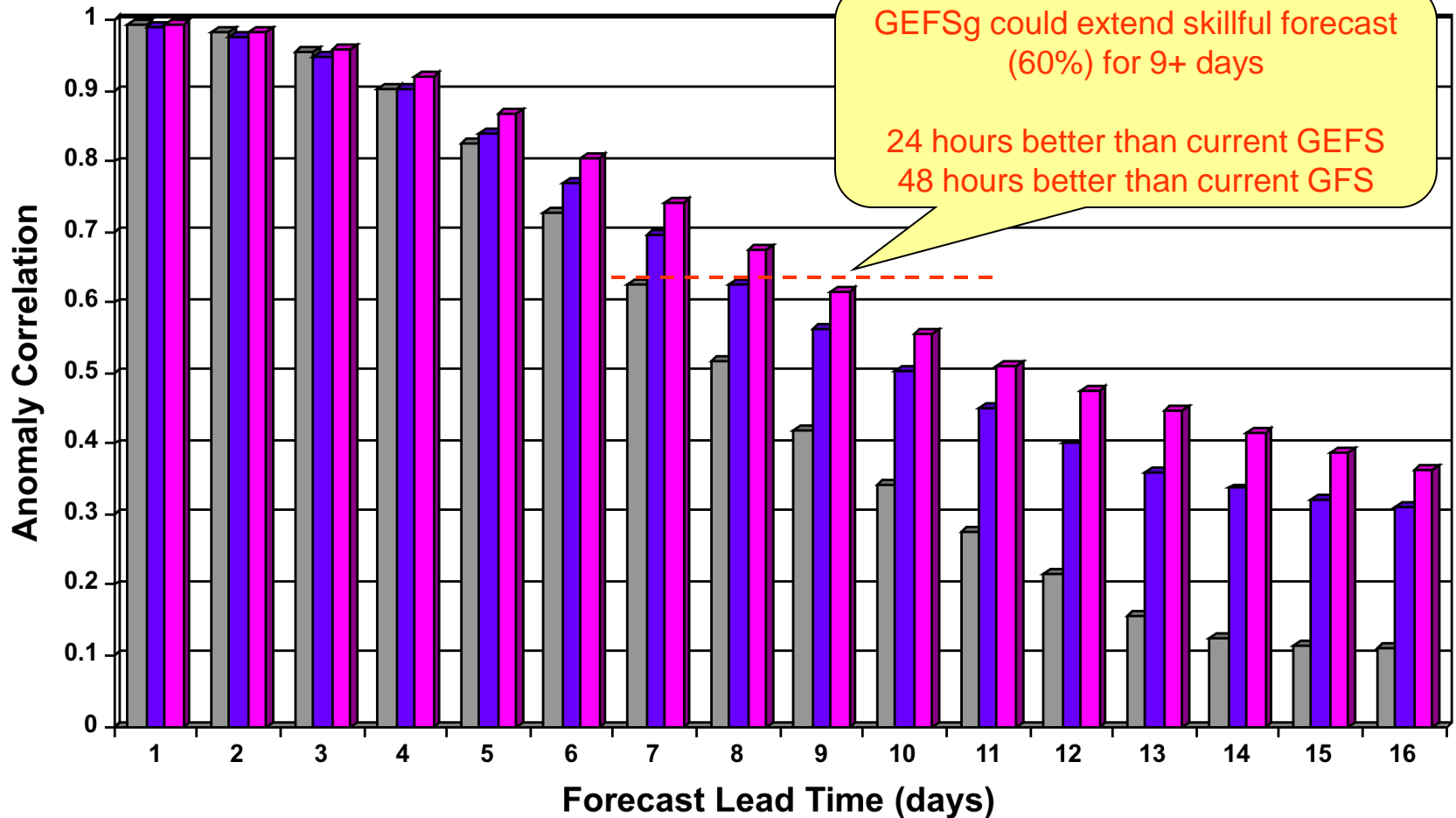
- Downscaling
 - CONUS
 - Additional variables (Tmax and Tmin, wind speed and direction)
 - Pending on RTMA availability
 - Alaska
 - 8 variables (T2m, Tmax, Tmin, Psfc, U10m, V10m, 10 meter Ws and Wd)
 - In testing
 - In collaboration with HPC Alaska Desk
 - Other regions
 - Hawaii, Puerto Rico and Guam
 - Pending on RTMA availability
- New NAEFS variables for data exchange
 - 25 additional variables
 - Use GRIB2 format – faster transfer (30 min saving)
 - Coordinated with CMC/MSC
 - Dedicated line for NCEP and CMC NAEFS data exchange
 - DS-3?
 - Earlier access to NAEFS ensemble & products

NH Anomaly Correlation for 500hPa Height

Period: August 1st – September 30th 2007

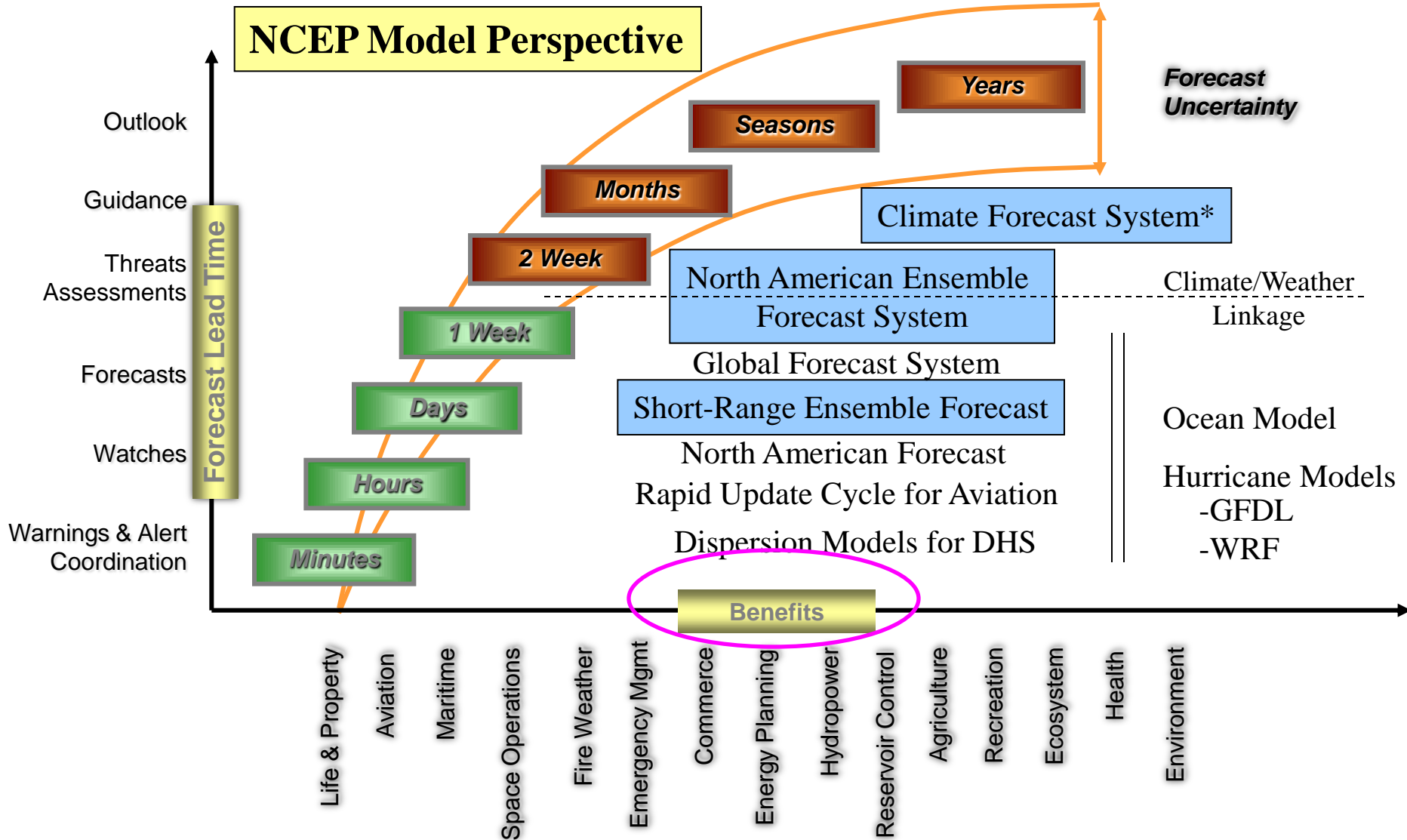
GEFSg is better than GFS at 48 hours

■ GFS ■ GEFS ■ GEFSg

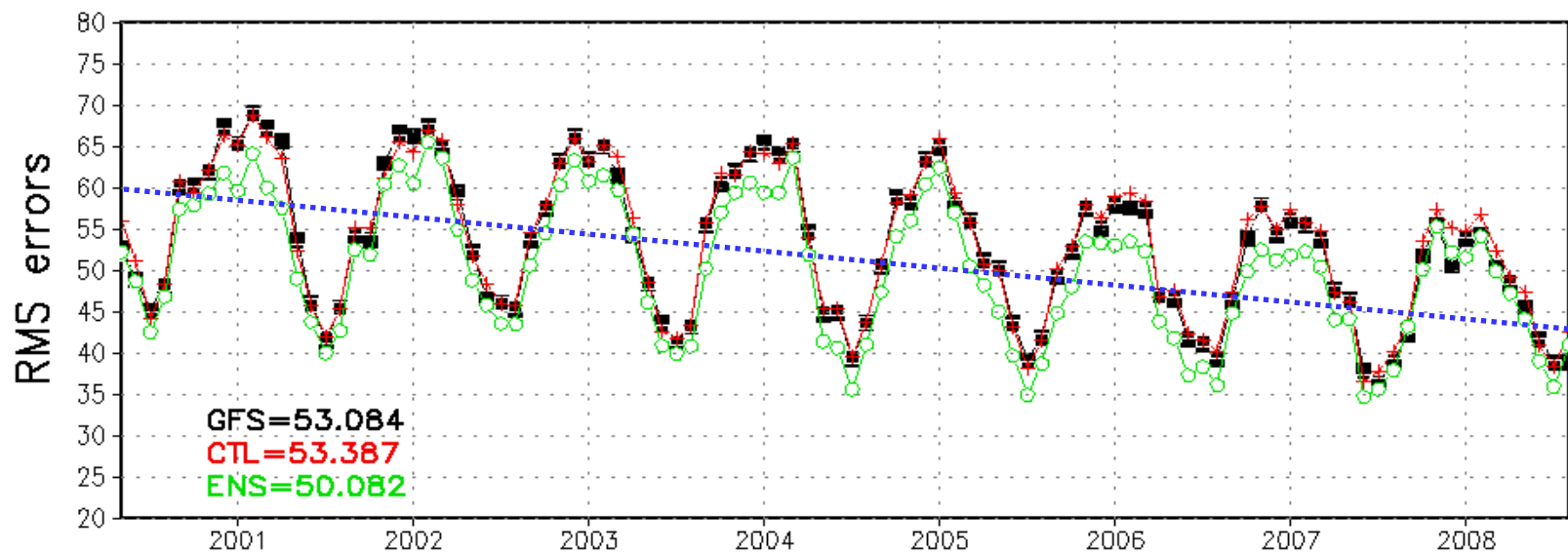
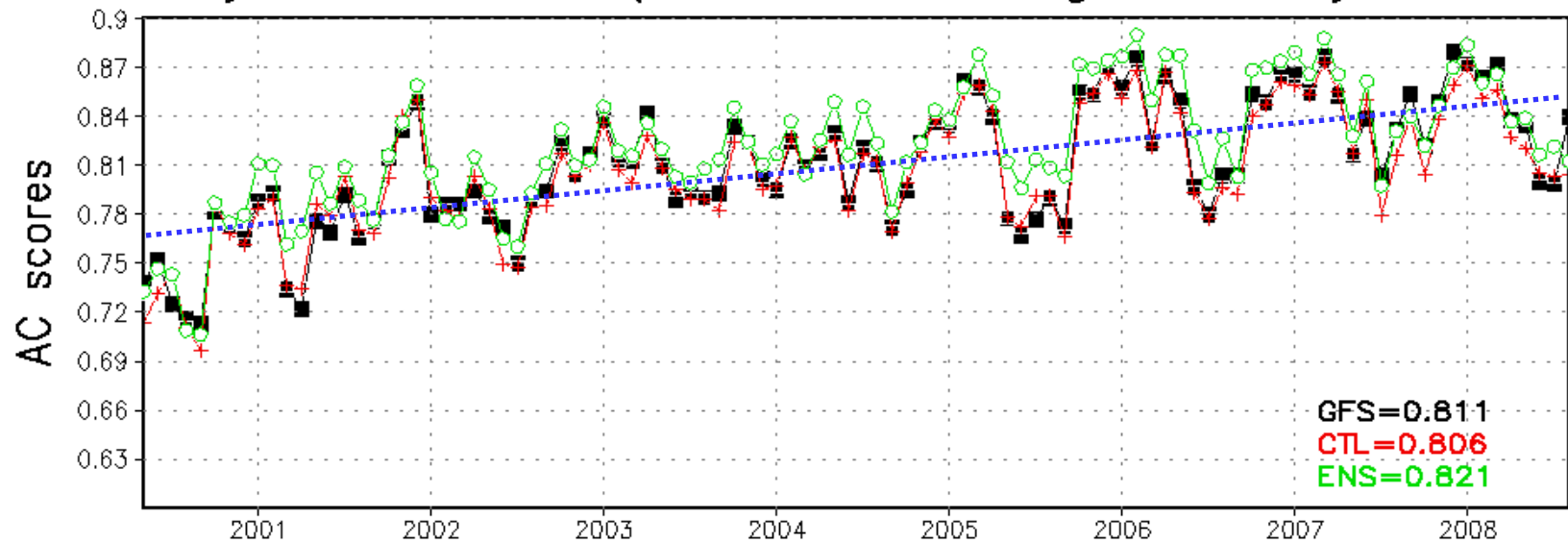




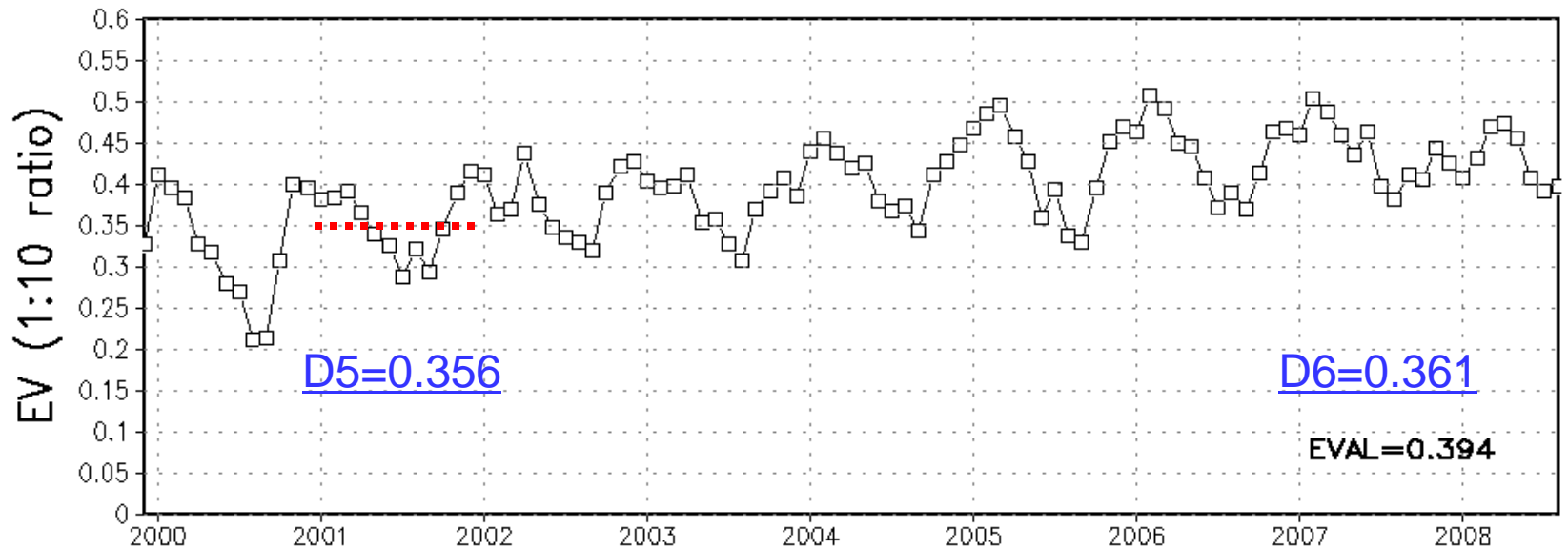
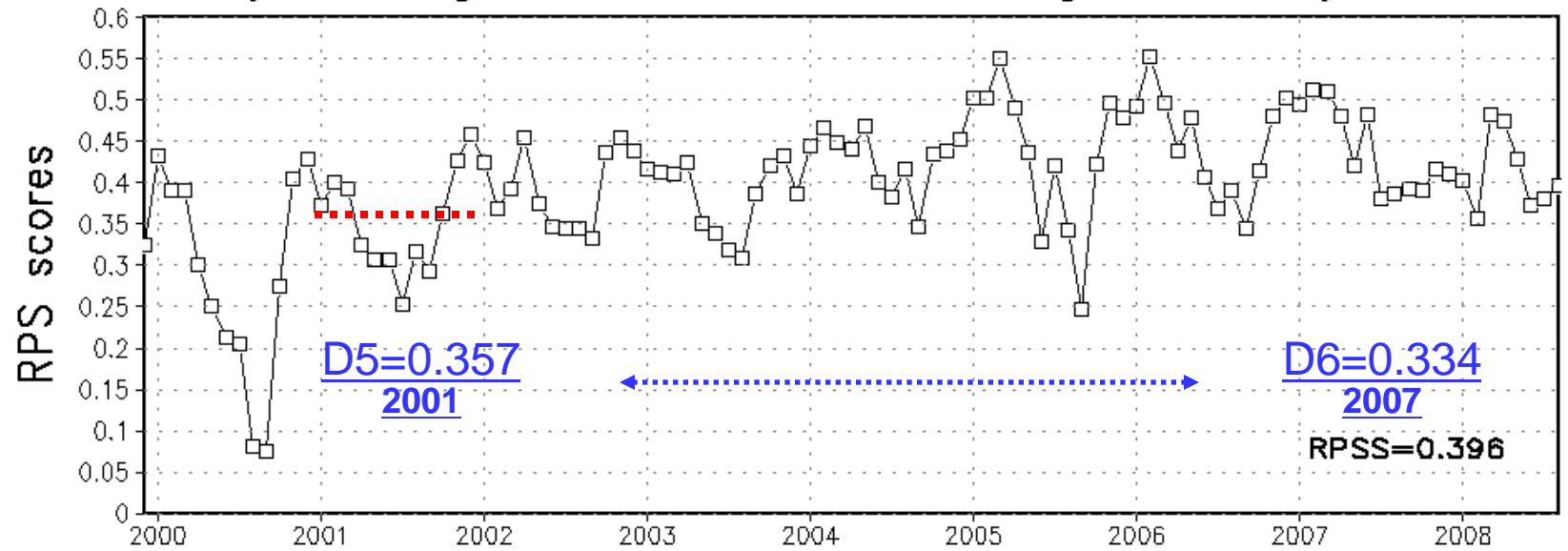
NWS Seamless Suite of Forecast Products Spanning Climate and Weather



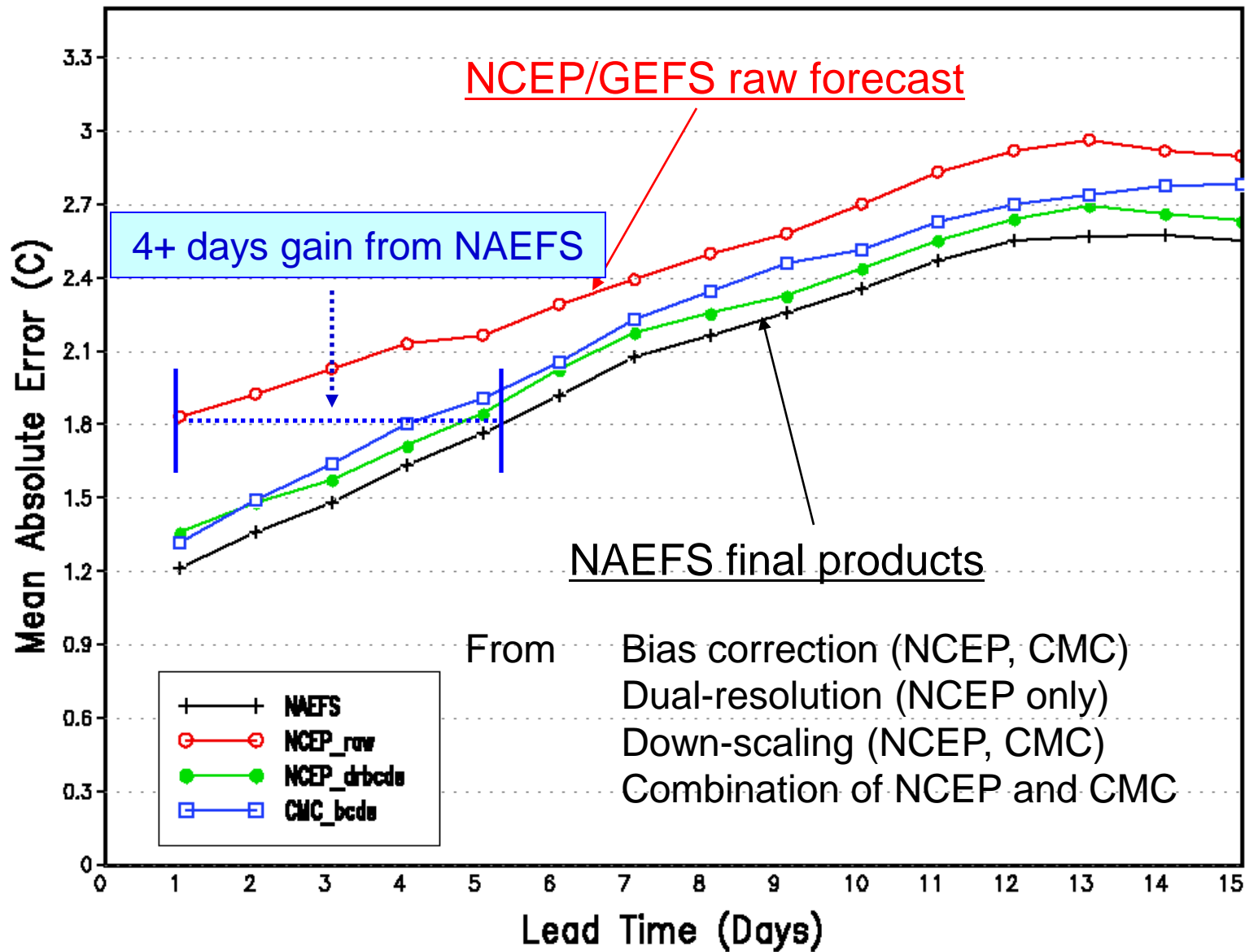
Monthly Ave. Scores (NH 500hPa Height, 5-day forecasts)



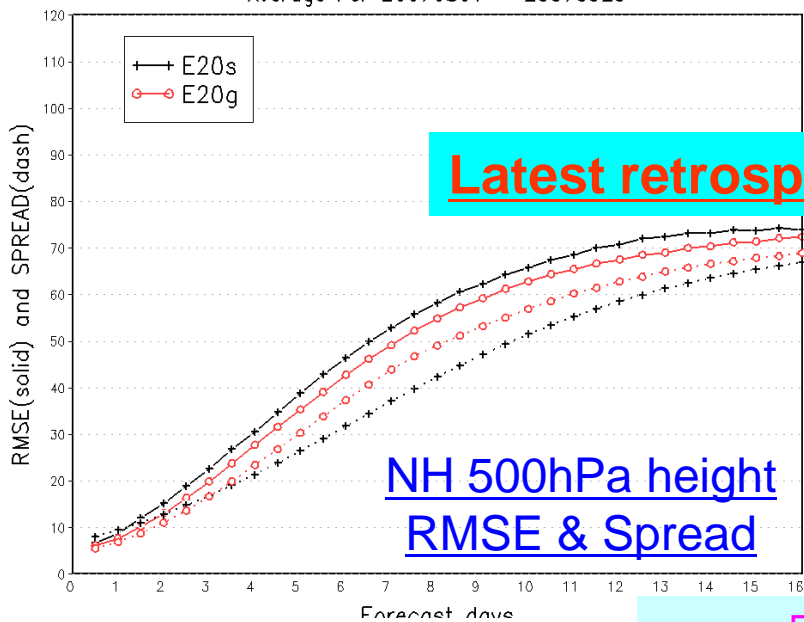
Monthly Average for NH 500hPa Height, 5-day forecasts



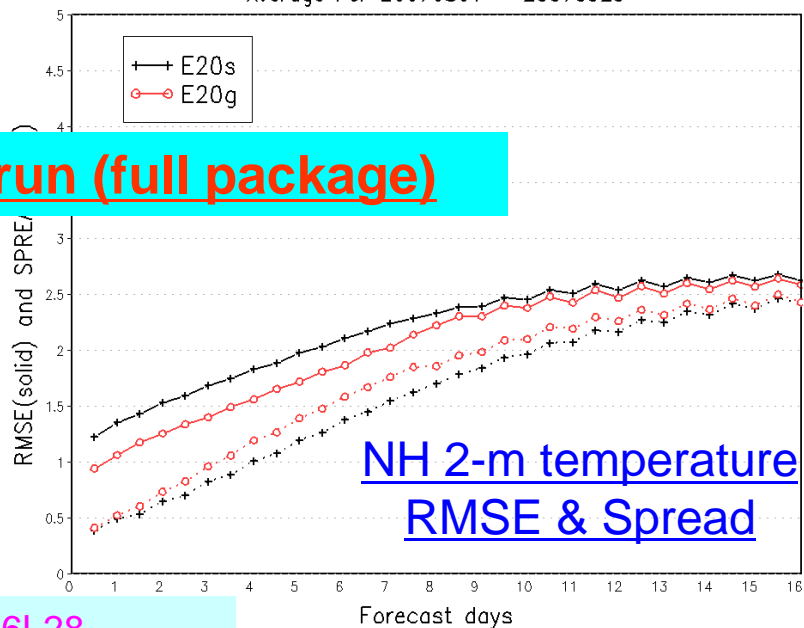
RTMA Region 2m Temperature Averaged From 2007090100 to 2007093000



Northern Hemisphere 500hPa Height
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20070801 - 20070929

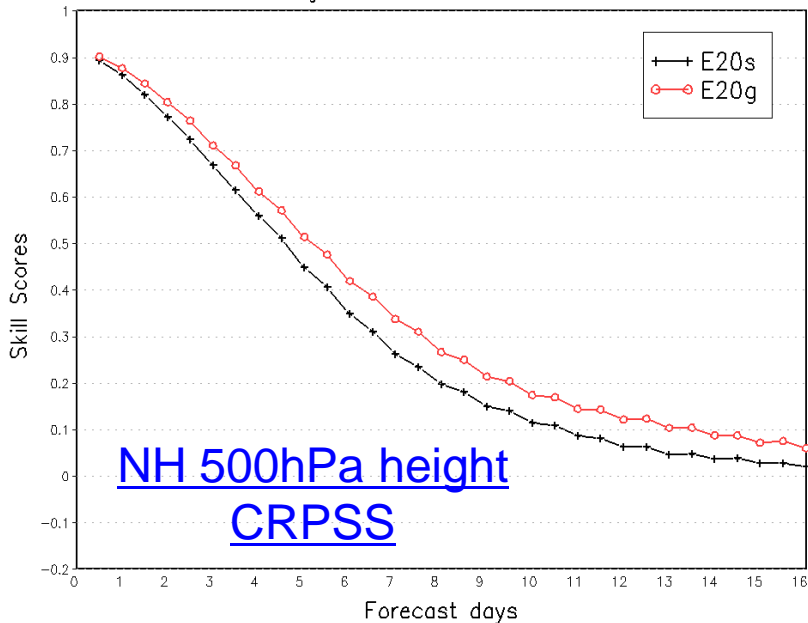


Northern Hemisphere 2 Meter Temp.
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20070801 - 20070929

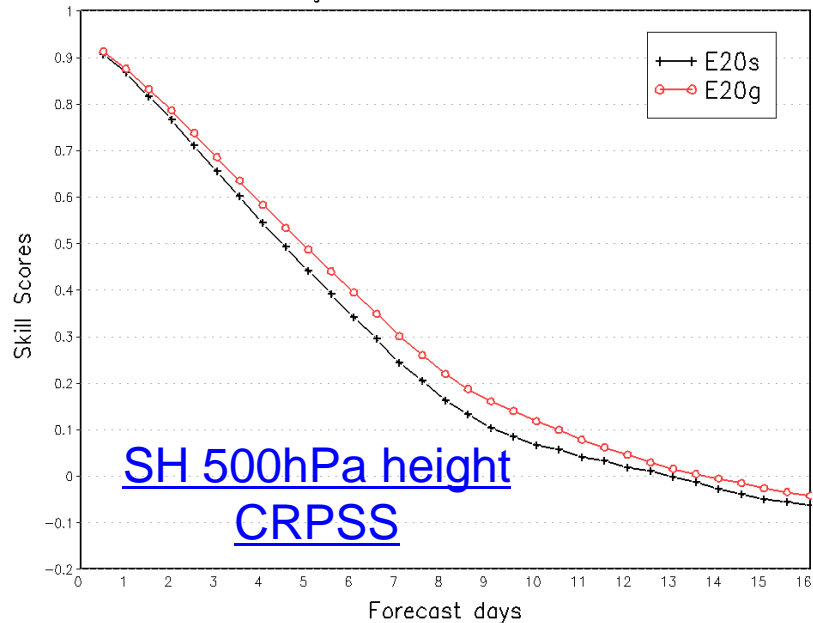


E20s - T126L28
E20g - T190L28 (0-180 only)

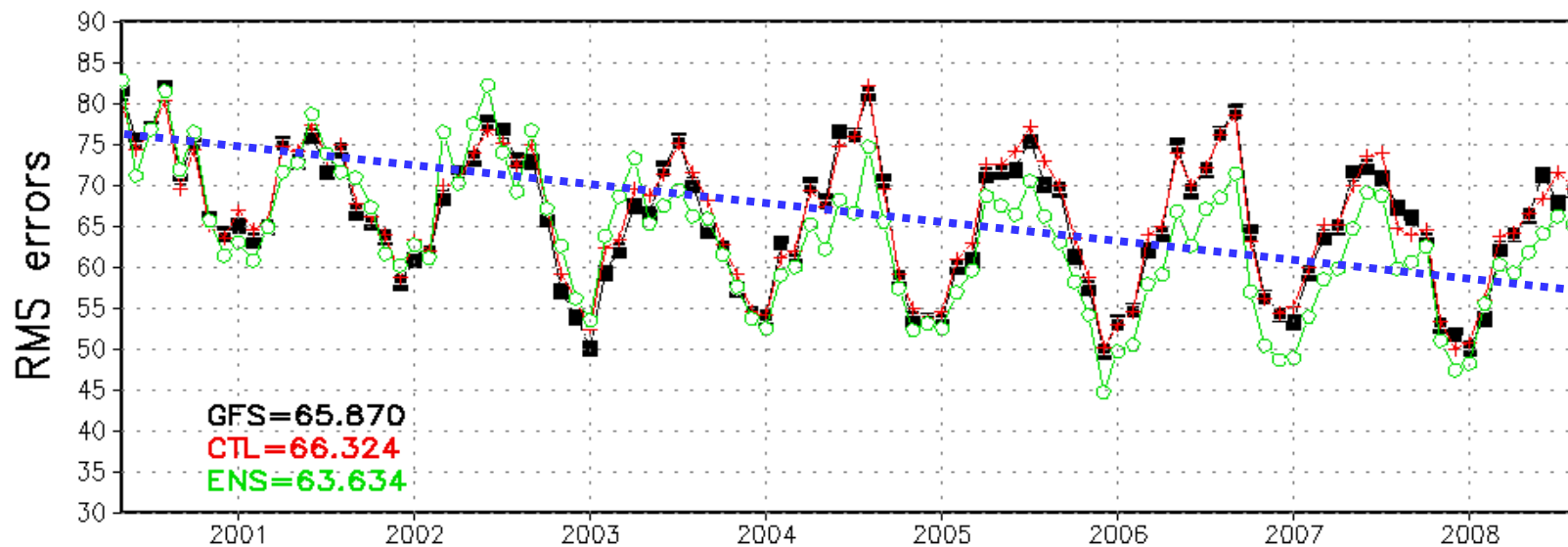
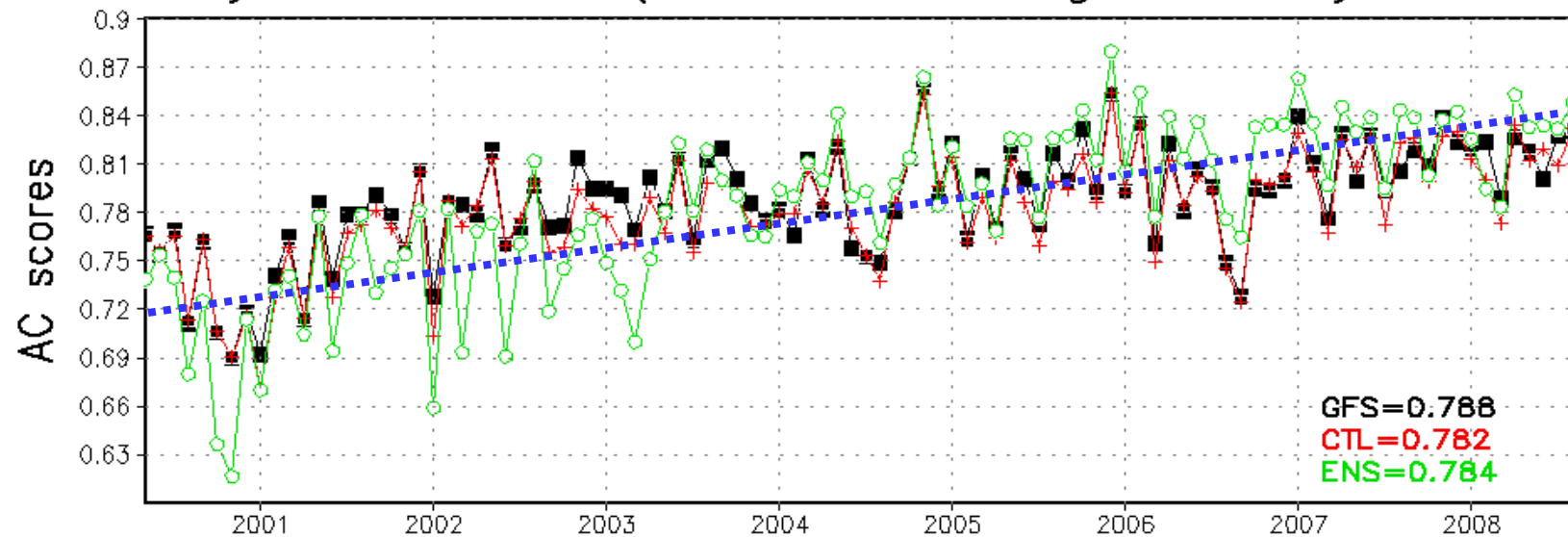
Northern Hemisphere 500hPa Height
Continuous Ranked Probability Skill Score
Average For 20070801 - 20070929



Southern Hemisphere 500hPa Height
Continuous Ranked Probability Skill Scores
Average For 20070801 - 20070929



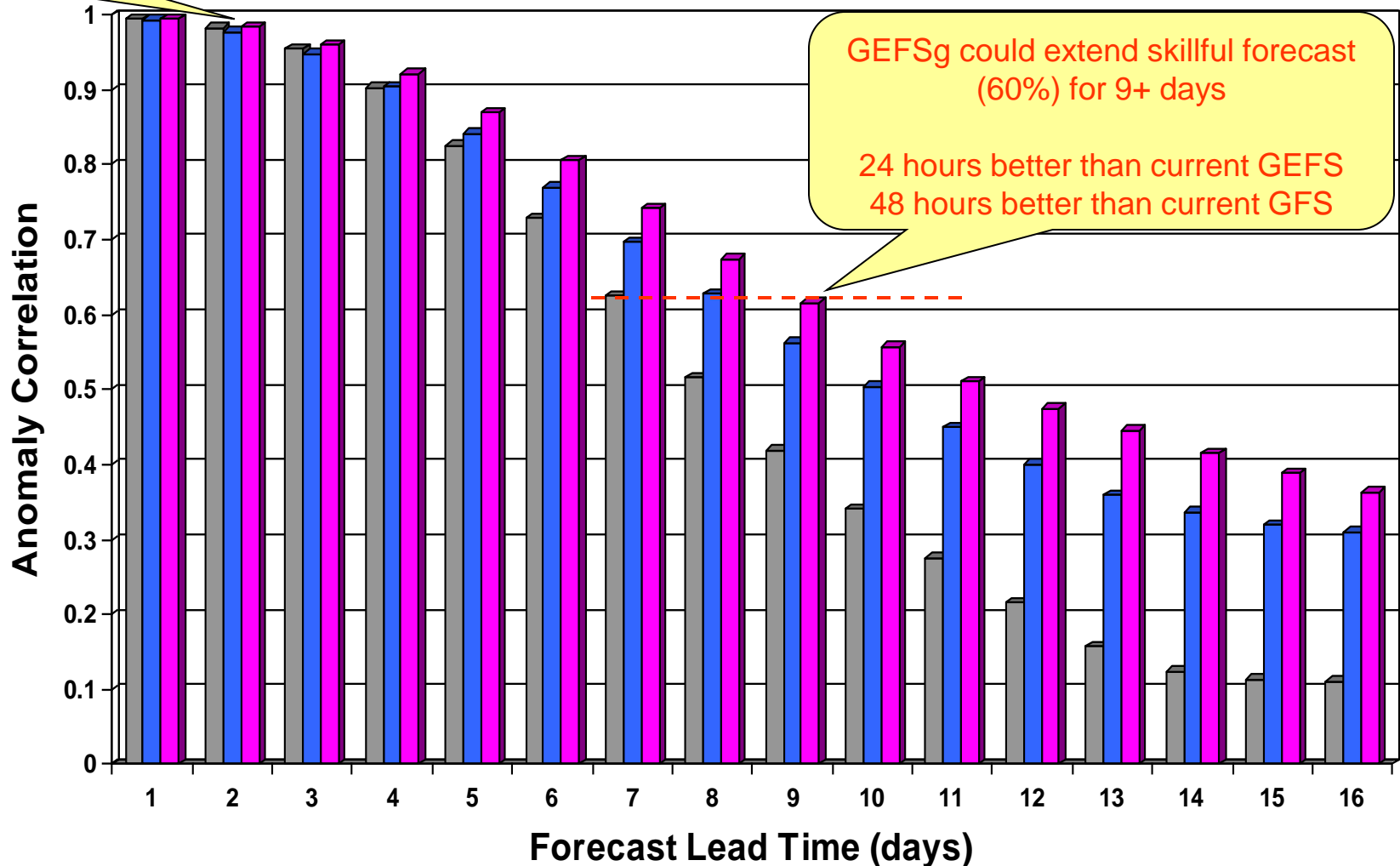
Monthly Ave. Scores (SH 500hPa Height, 5-day forecasts)



NH Anomaly Correlation for 500hPa Height

Period: August 1st – September 30th 2007

GEFSg is better than GFS at 48 hours



Plans for FY2010

- GEFS

- Configuration:

- Variable resolutions:

- T270L42 (0-180hr) (considering half-degree products)

- T190L28 (180-384hr)

- T126L28 (384-840hr)

- Full coupling with ocean model (assume in)

- Science:

- Improving TS relocation

- Adopt all new developed TS relocation schemes

- Improving stochastic scheme

- Adaptive 2/3-demisional parameters adjustment

Plans for FY2010 (Cont.)

- NAEFS
 - New NAEFS component – FNMOC global ensemble
 - 4Q 2009 – 2Q 2010
 - Pending on one year evaluation (May 2008 – April 2009)
 - Using mini-Bayesian method for first moment correction
 - Need to coordinate with CMC/MSC
 - Improving NAEFS products
 - Introduce full Bayesian model to calibrate high moments
 - For precipitation forecast
 - All variables
 - Statistical down-scaling
 - Precipitation
 - Improving current method
 - Adding new variables (pending on RTMA availability)
 - TC related products
 - Including bias correction
 - Seamless weather-climate interface
 - Merge GEFS and CFS

Background!!!

Acknowledgements

EMC: Richard Wobus, Dingchen Hou, Bo Cui

Malaquias Pena, Weiyu Yang, Julia Zhu,

Mozheng Wei, Mike Charles,

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John Ward and Steve Lord

CPC: Qing Zhang, Jon Gottschalck, Jae Schemm

NCO: Christine Caruso Magee, Joey Carr, Brent Gorden,

Daniel Starosta

MDL: Kathryn Gilbert

MSC/Canada: Lewis Poulin and Andre Methot

CCS resources (estimated)

- Computation (Current)
 - T126L28 out to 384 hours
 - Assigned window (75min)
 - Actually using 45 minutes
 - Average 38 nodes
- Computation (future)
 - T190L28 out to 384 hours
 - Use 50 min
 - Average 60 nodes
 - 75% additional computer resources
- Space (current)
 - T126L28 out to 384 hours
 - Pgrba files
 - 17 days on CCS for bias correction
 - 55G (x4 per a day)
- Space (future)
 - T190L28 out to 384 hours
 - Pgrba files
 - 17 days on CCS for bias correction
 - 83G needed (x4 for a day)

NEXT NAEFS exchange pgrba files

Variables	Pgrba file	Total 78 (26)
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)
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	Convective available potential energy	1 (0)
SOIL	SOILW(0-10cm), WEASD(water equiv. of accum. snow depth), SNOD(surface), TMP(0-10cm down)	4 (4)
		26 new vars
Notes	Surface GHT is only in analysis file and first pgrb file when the resolution changed. 23 of 26 new variables are from pgrbb files, 10, 50hPa RH and SNOD are new variables	

NEXT NAEFS pgrba_bc files

(bias correction)

Variables	pgrba_bc file	Total 48 (13)
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)
PRES	Surface, PRMSL	2 (0)
VGRD	10m, 10, 50, 100, 200, 250, 500, 700, 850, 925, 1000hPa	11 (3)
FLUX (top)	ULWRF (toa - OLR)	1 (1)
		13 new vars
Notes		

Horizontal resolution change

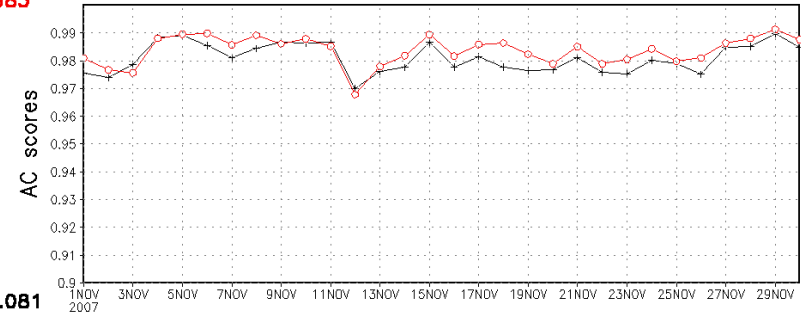
Ensemble control only (deterministic)

From T126 to T190

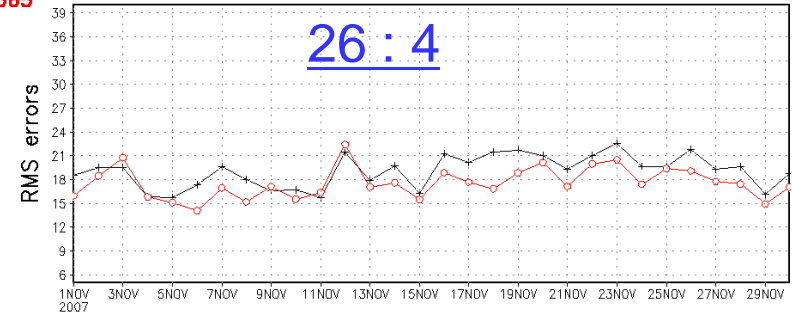
NH 500hPa geopotential height

T126=0.980
T190=0.983

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



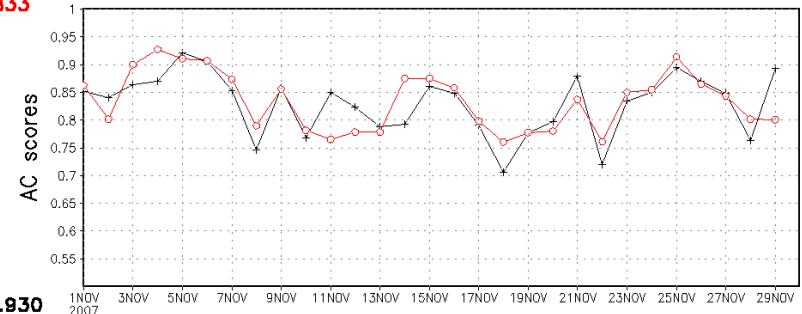
T126=19.081
T190=17.565



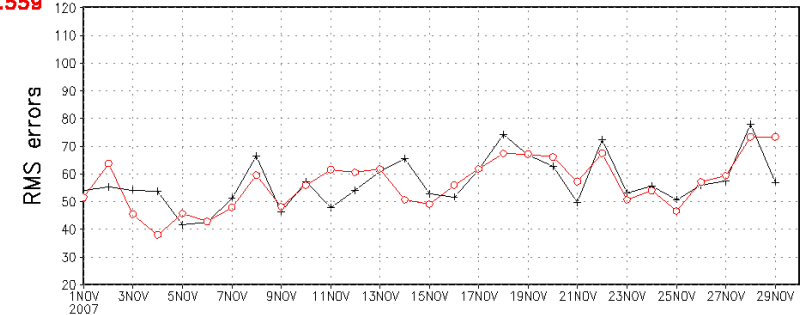
26 : 4

T126=0.829
T190=0.833

NH 500 hPa Geopotential Height at day 5
for 00Z01NOV2007 – 00Z30NOV2007



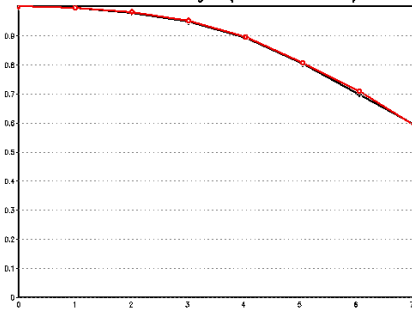
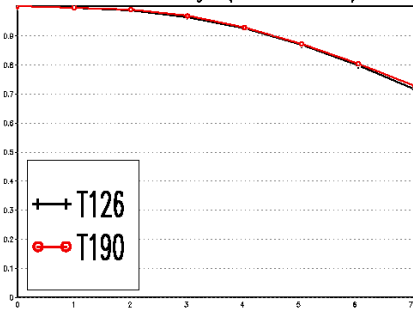
T126=56.930
T190=56.559



AVERAGE FOR 00Z01NOV2007 – 00Z30NOV2007

NH 500 mb Height (wave 1-3 AC)

NH 500 mb Height (wave 4-9 AC)



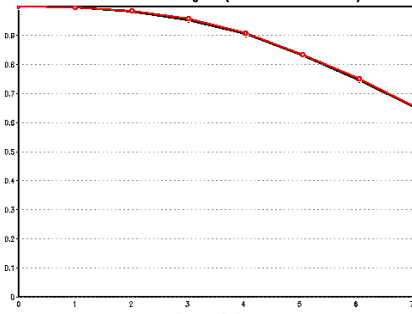
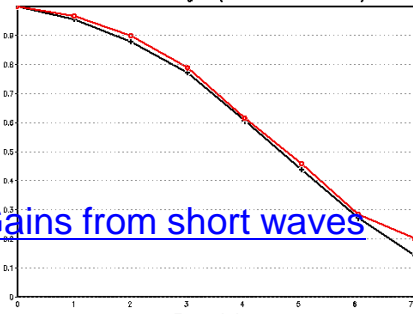
+ T126
o T190

Forecast days

Forecast days

NH 500 mb Height (wave 10-20 AC)

NH 500 mb Height (wave 1-20 AC)



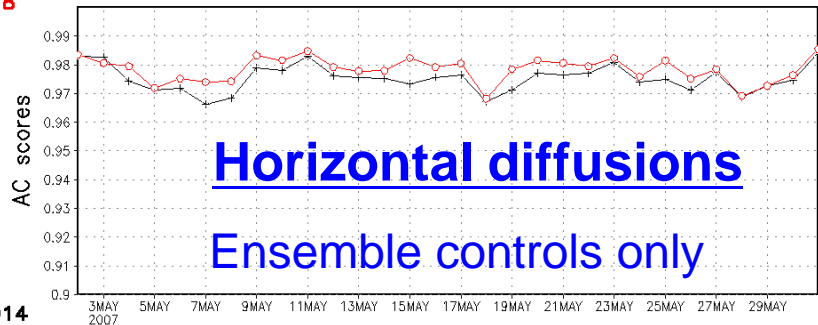
Forecast days

Forecast days

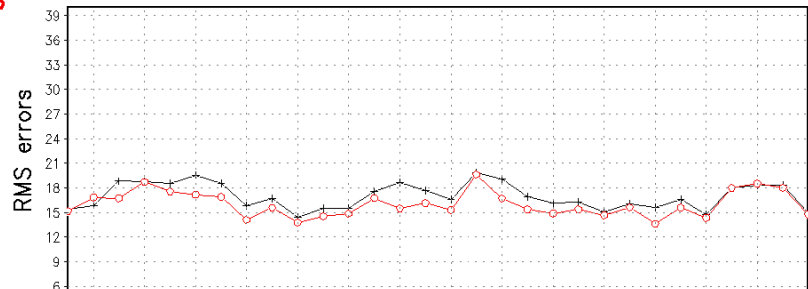
Gains from short waves

OPR=0.975
NHD=0.978

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

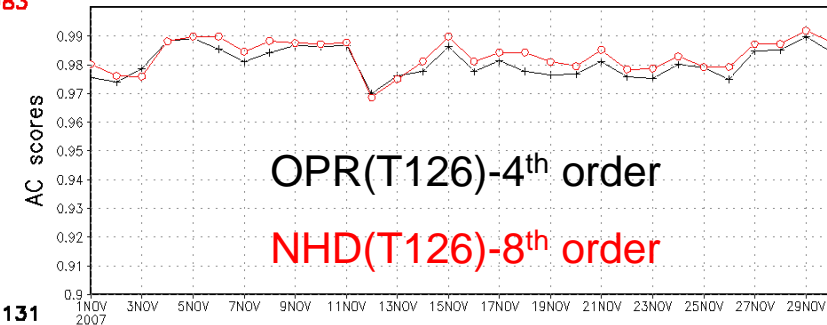


OPR=17.014
NHD=16.03

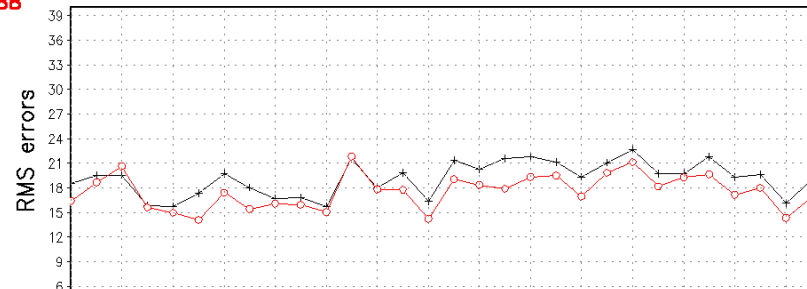


OPR=0.980
NHD=0.983

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

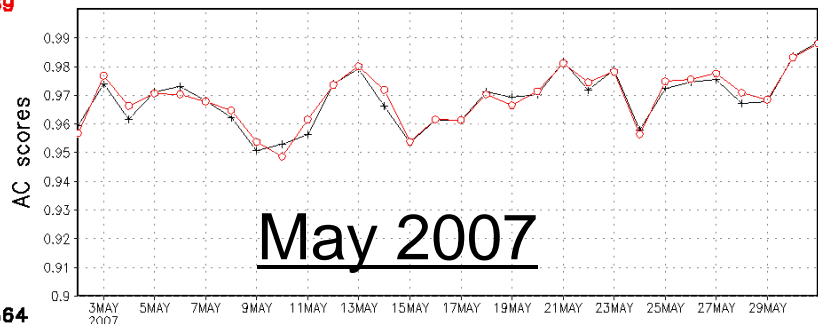


OPR=19.131
NHD=17.588

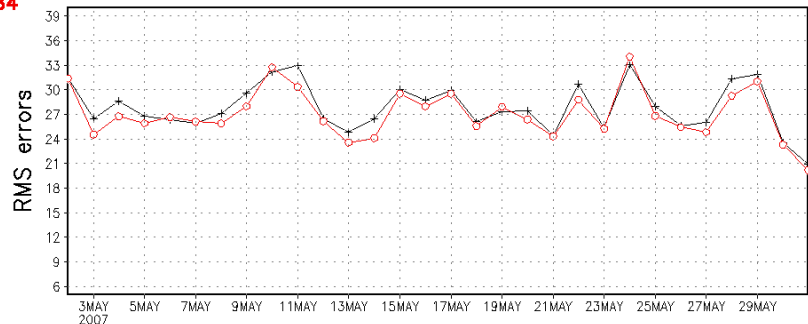


OPR=0.968
NHD=0.969

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

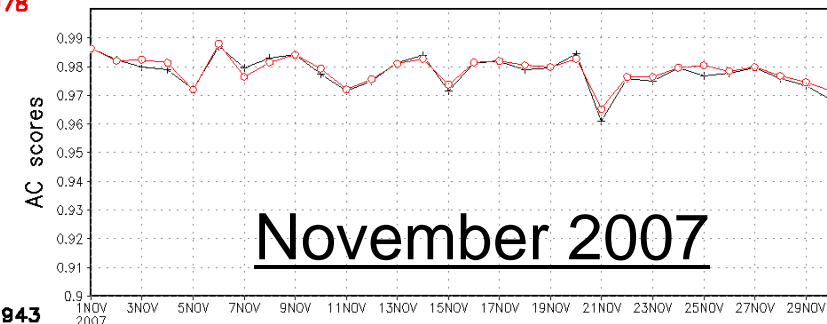


OPR=27.864
NHD=27.084

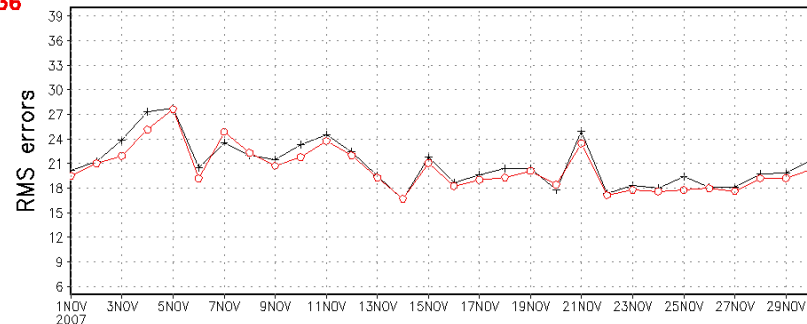


OPR=0.978
NHD=0.978

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

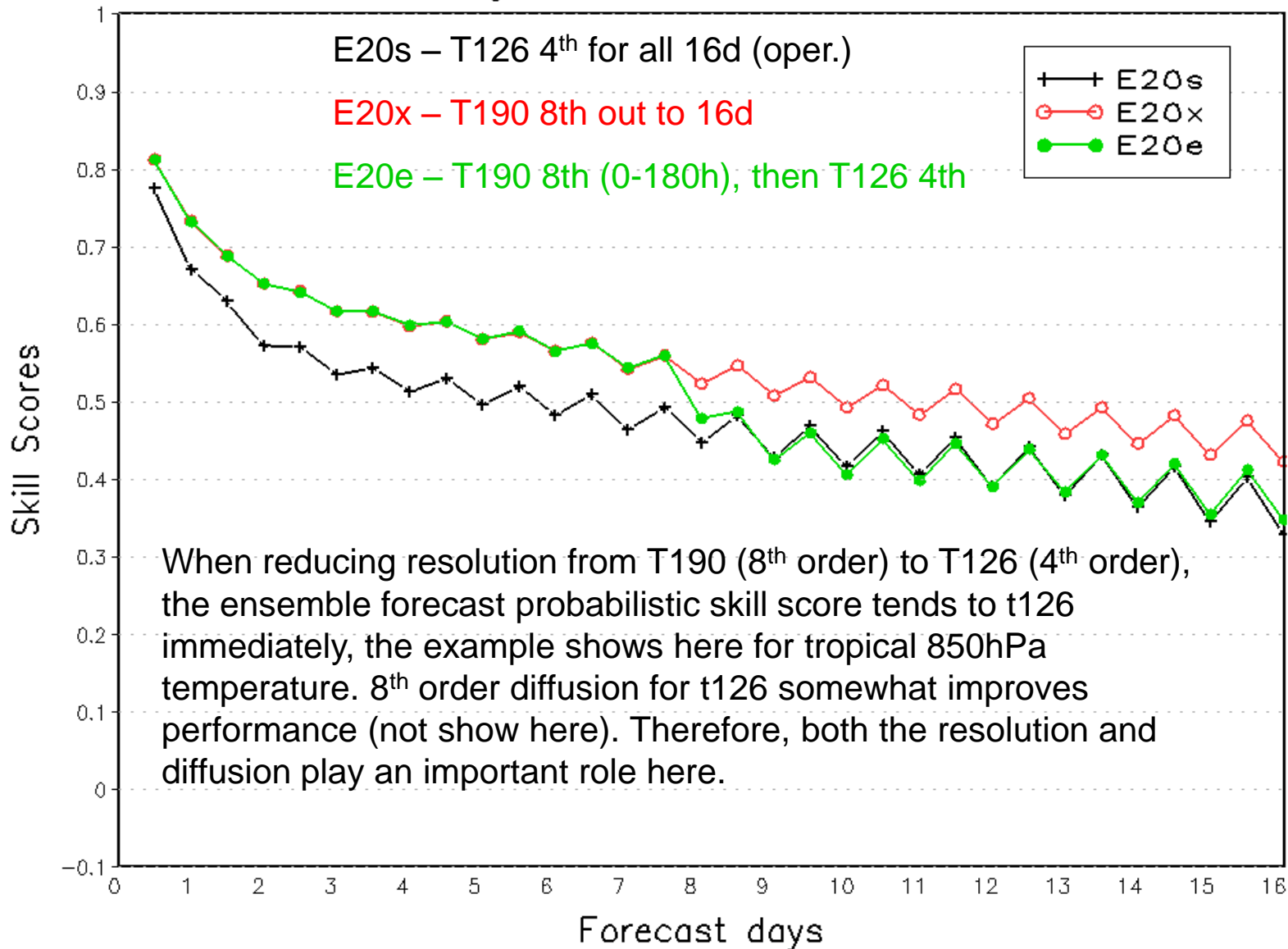


OPR=20.943
NHD=20.336



Resolution and Diffusion for Global Ensemble Without Stochastic

Tropical 850hPa Temp.
ROC area (0-1)
Average For 20071101 - 20071212



Conclusion

- Based on two sets of retrospective runs (summer and winter 2007)
 - New package improved the forecast skill (score) significantly
 - For deterministic (ensemble mean)
 - For probabilistic (ensemble distribution)
- The better results is benefited from:
 - Increase horizontal resolution (include diffusion)
 - Stochastic perturbation scheme
 - Better initial condition (analysis)
 - Better forecast model (GFS)

Remain Issues

- Tune initial perturbation (may leave this to next implementation)
 - Need to adjust the size of initial perturbation, due to:
 - Model resolution changed
 - Model diffusion scheme changed
 - Improved analysis
 - Experiments are running, but very slow
 - Due to limit computation resource
- Examine bias corrected forecast and down scaling forecast
 - No enough CCS disk storage for 17d pgrb files on line
- Verify tropical storm tracks
 - Working on 2007 summer season
 - Planned for 2008 summer season
- Resource problem
 - Personnel
 - Computation and storage

Downstream Dependencies

- Sigma files
 - SREF
 - Yes
 - It uses sigma forecast
 - Wave ensemble
 - No
 - It uses bias corrected 10m winds
 - Tracking
 - No
 - It uses pgrba file
 - MDL GMOS
 - No
 - It uses pgrba and pgrbb files
 - Public access
 - No
 - We don't post sigma files to public
- pgrb files (pgrba + pgrbb)
 - SREF
 - No
 - It produces pgrb file by itself
 - Wave ensemble
 - Yes
 - But file has the same format for 10m wind
 - Tracking
 - Yes
 - But it uses pgrba file only, the file has the same format
 - MDL GMOS
 - Yes
 - It uses both pgrba and pgrbb
 - Public access
 - Yes
 - pgrba and pgrbb