NCEP GEFS Status and Plan

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EMC/NCEP
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Acknowledgements: Richard Wobus, Jiayi Peng, Jessie Ma
and all NCEP/EMC Ensemble Team Members

Outline

- Introduction: NCEP global ensemble forecast

- Recent GEFS Implementation in Feb. 2012
- Impact of the coming Hybrid data assimilation

- Model related uncertainty and the impact of STTP
- Ensemble Initialization and Roles of ETR and EnKF

- Comparison of ETR and EnKF initialization

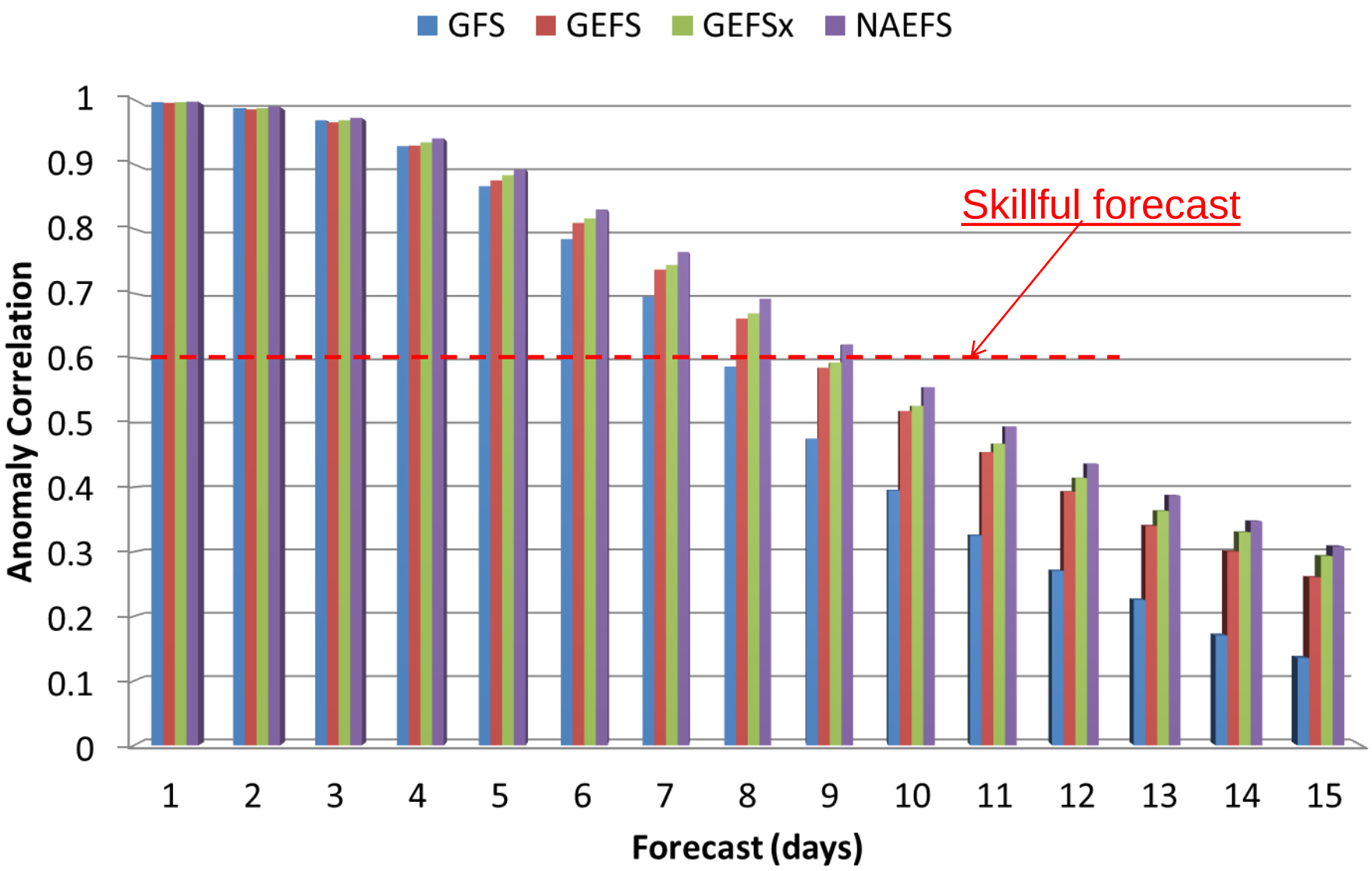
- Summary

Introduction:
NCEP's Global Ensemble Forecast

- **Multi-Center, Multi-Model Ensemble (NAEFS/NUOPC)**
  - NCEP, CMC, and FNMOC ensemble systems
- **Global Ensemble Forecast System (GEFS)**
  - Ensemble generation method
    - Initial perturbation (BV-ETR) and Model uncertainty (STTP)
  - Horizontal and vertical resolutions
  - NWP model, dynamics, physics and numeric (GFS model)
  - Data assimilation system (GSI, to be upgraded to GSI-EnKF Hybrid)
  - Post processing (Bias correction other techniques)
- **Operational GEFS products**
  - Provide forecast guidance as a single model ensemble
  - Have been steadily improved due to advances in data assimilation, NWP model and ensemble generation techniques
  - Contribute to, and benefit from NAEFS, NUOPC and other MMEs

NH Anomaly Correlation for 500hPa Height

Period: September 1st – November 30th 2011



Latest Upgrade (Feb.14, 2012)

- Model and Ensemble Techniques
  - Using GFS V9.01 (current operational GFS) instead of GFS V8.00
  - Improved Ensemble Transform with Rescaling (ETR) initialization
  - Improved Stochastic Total Tendency Perturbation (STTP)

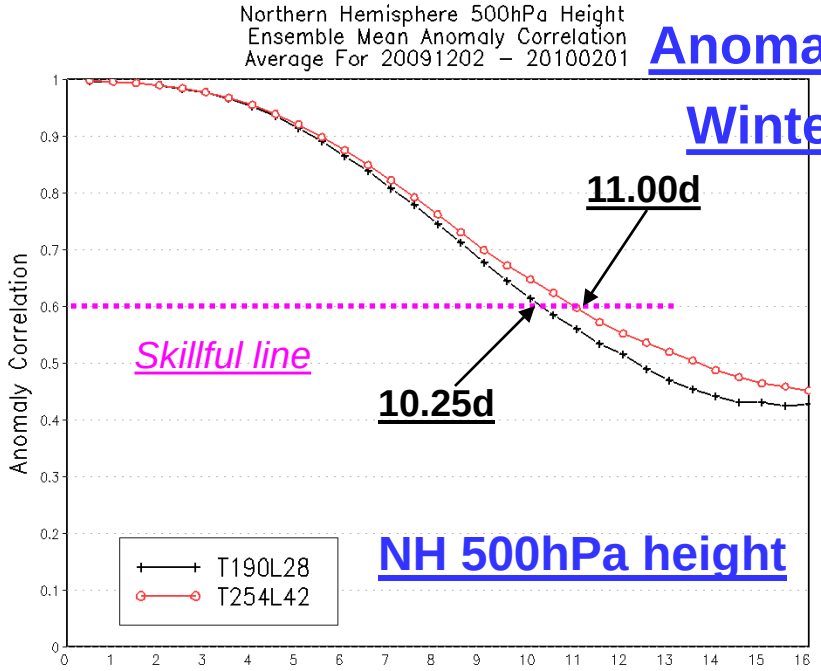
- Resolution
  - T254 (55km) horizontal resolution for 0-192 hours (from T190 – 70km)
  - T190 (70km horizontal resolution for 192-384 hours (remain unchanged)
  - L42 vertical levels for 0-384 hours (from L28)

- Unchanged:
  - 20+1 members per cycle, 4 cycles per day
  - pgrb file output at 1*1 degree every 6 hours
  - GEFS and NAEFS post processed output data format

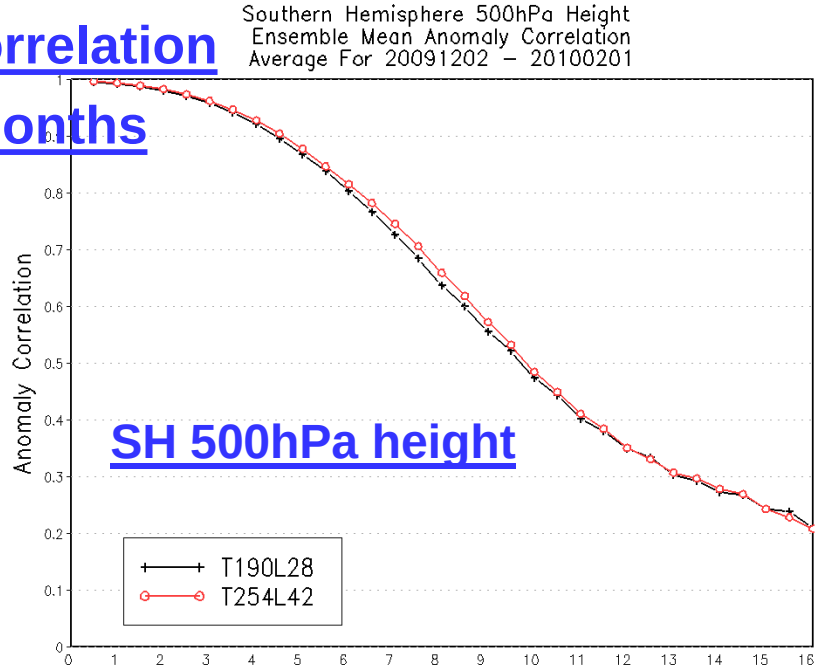
- What do we expect from this implementation?
  - Improve general probabilistic forecast skill overall
  - Significant improvement of tropical storm tracks (especially for Atlantic basin)

Anomaly Correlation

Winter 2 months

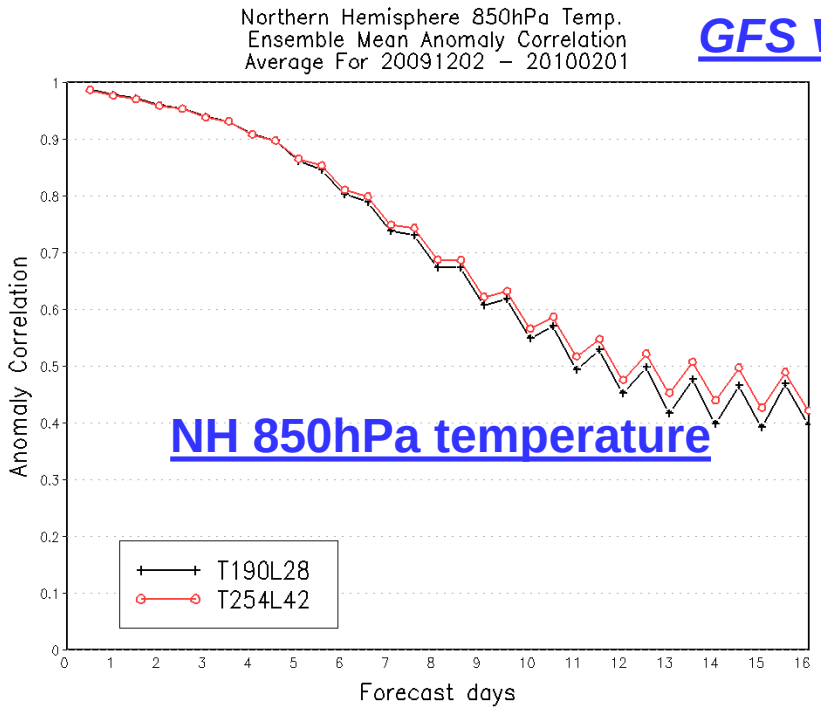


NH 500hPa height

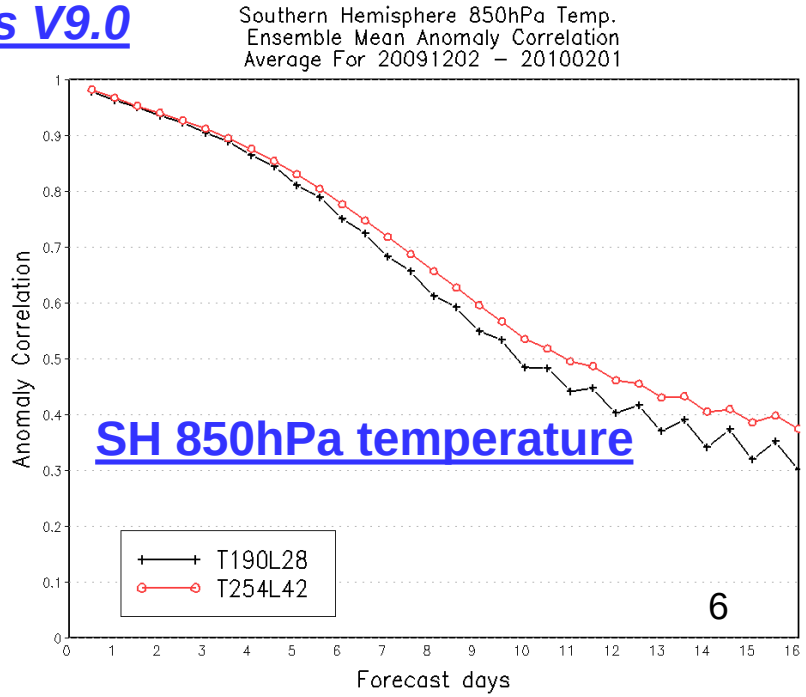


SH 500hPa height

GFS V8.0 .vs V9.0



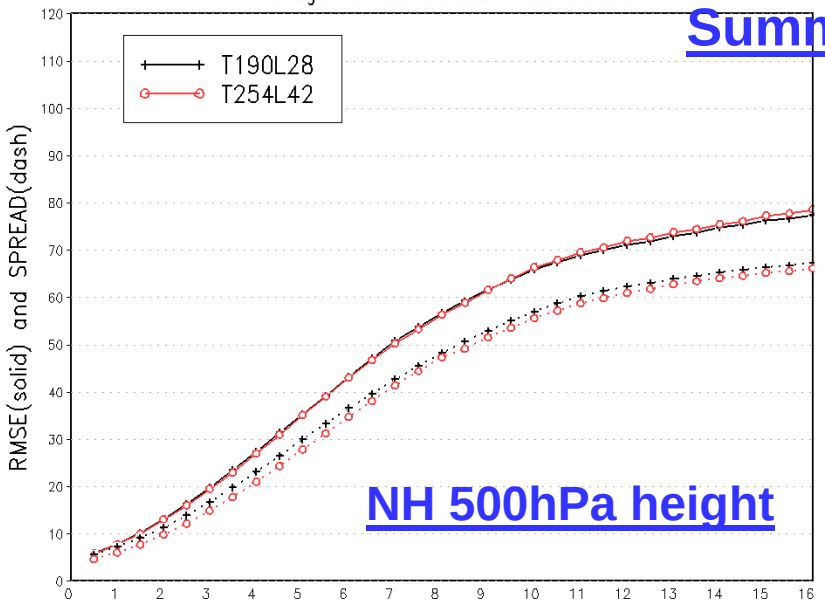
NH 850hPa temperature



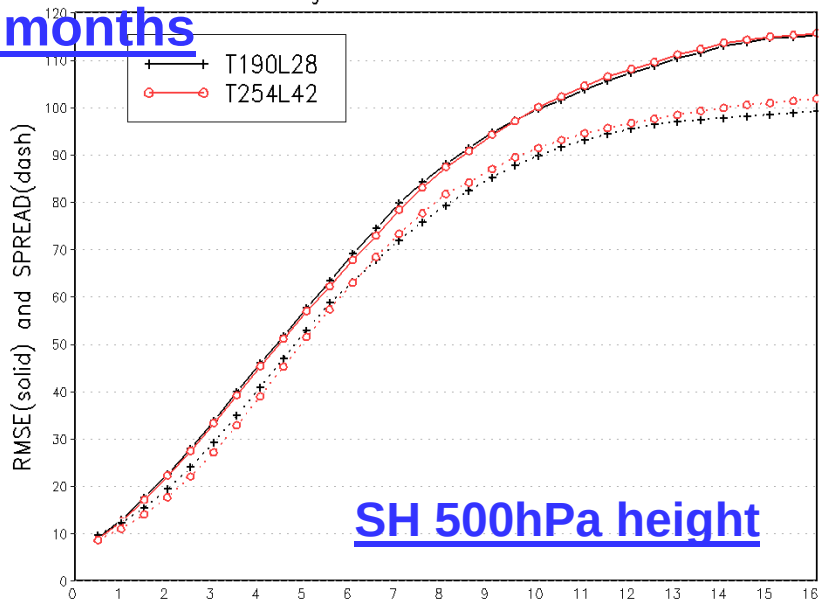
SH 850hPa temperature

RMS Error & Spread

Summer 2 months

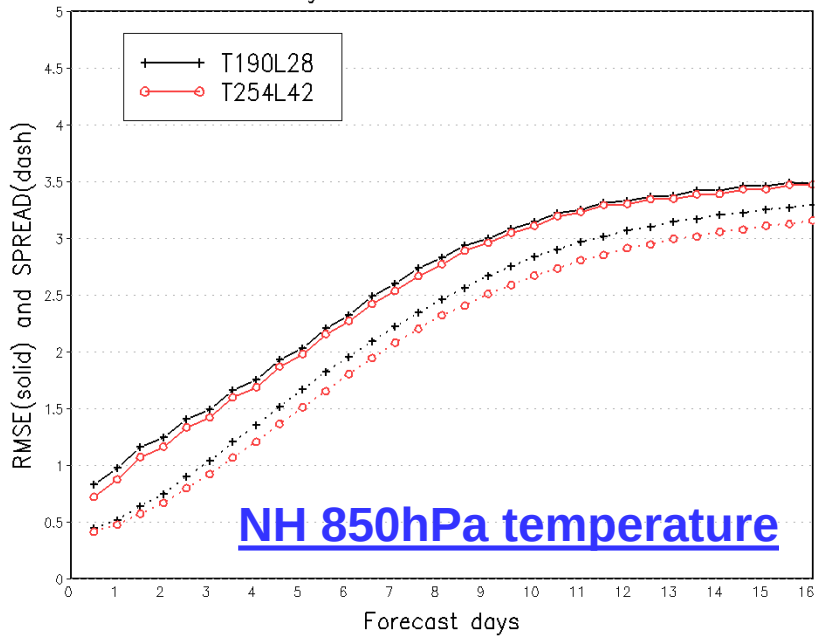


NH 500hPa height

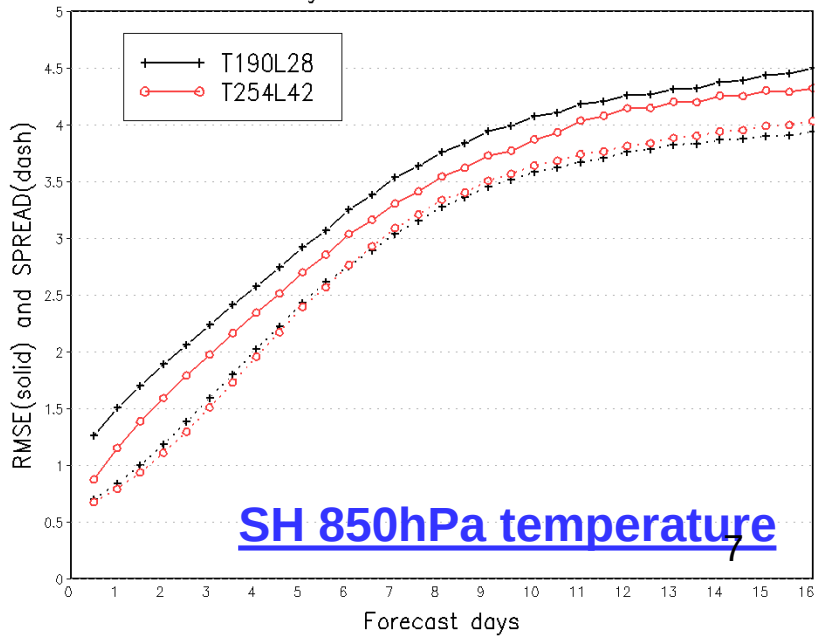


SH 500hPa height

GFS V8.0 .vs V9.0



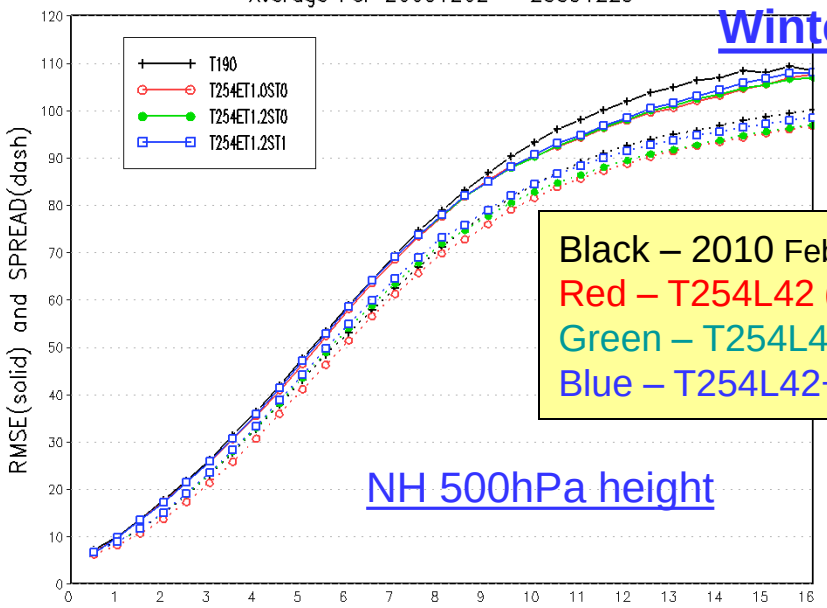
NH 850hPa temperature



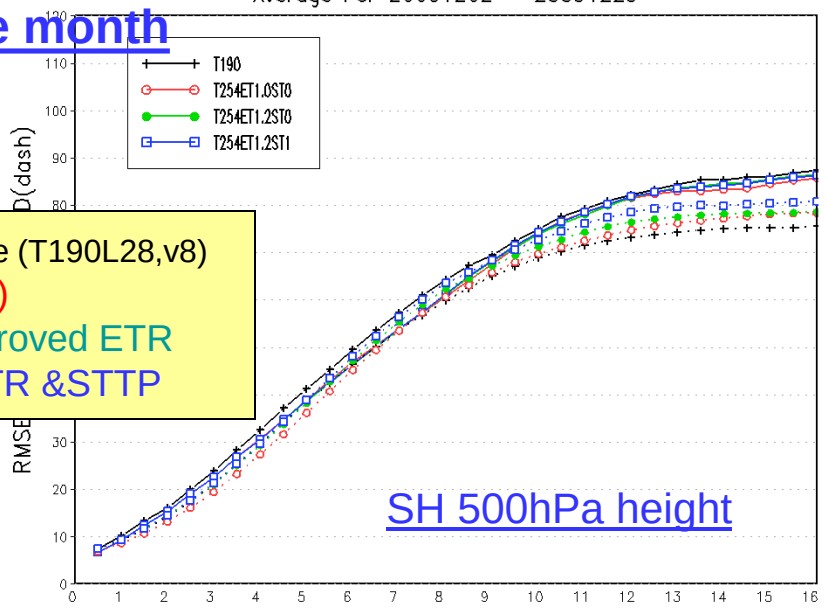
SH 850hPa temperature

RMS & Spread

Winter one month



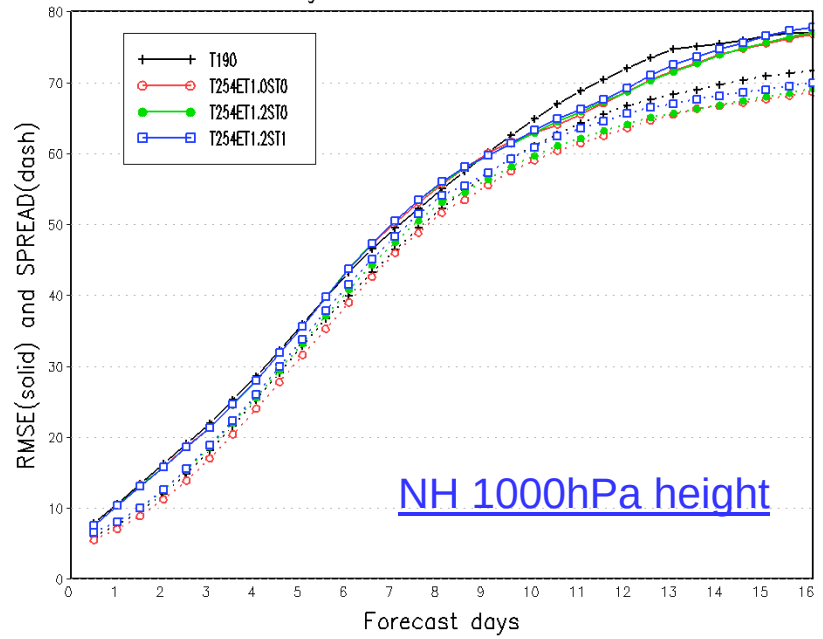
NH 500hPa height



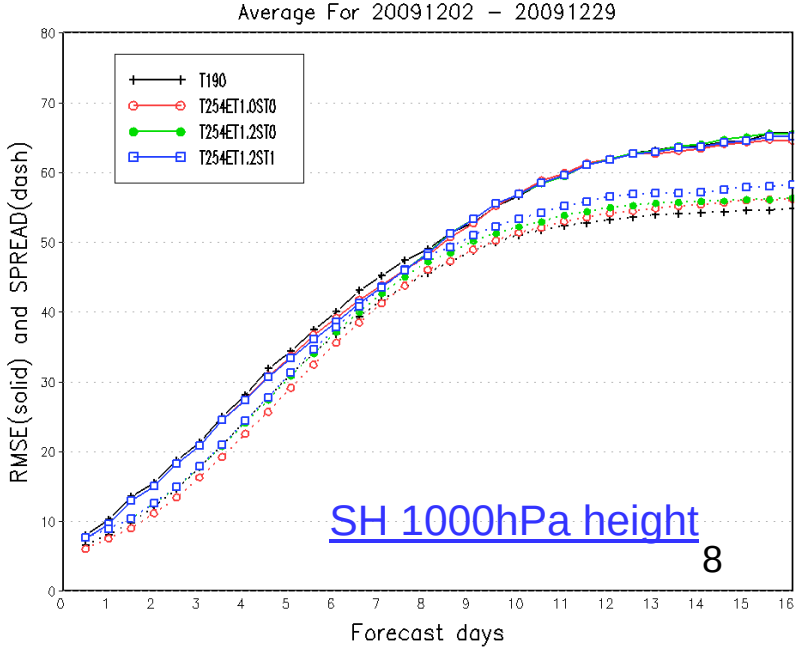
SH 500hPa height

Black – 2010 Feb upgrade (T190L28,v8)
Red – T254L42 (GFSv9)
Green – T254L42 + improved ETR
Blue – T254L42+imp ETR &STTP

GFS V8.0 .vs V9.0

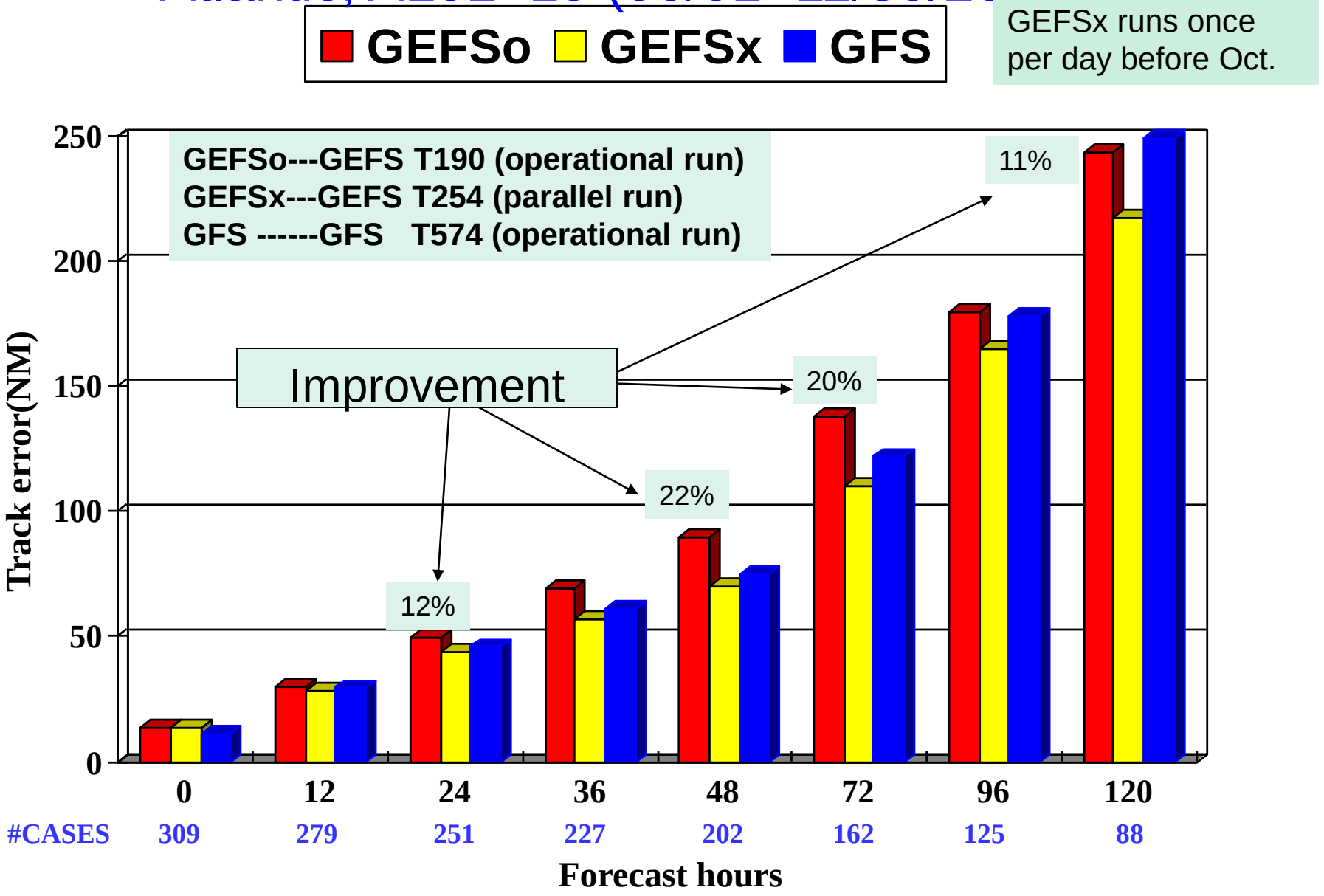


NH 1000hPa height



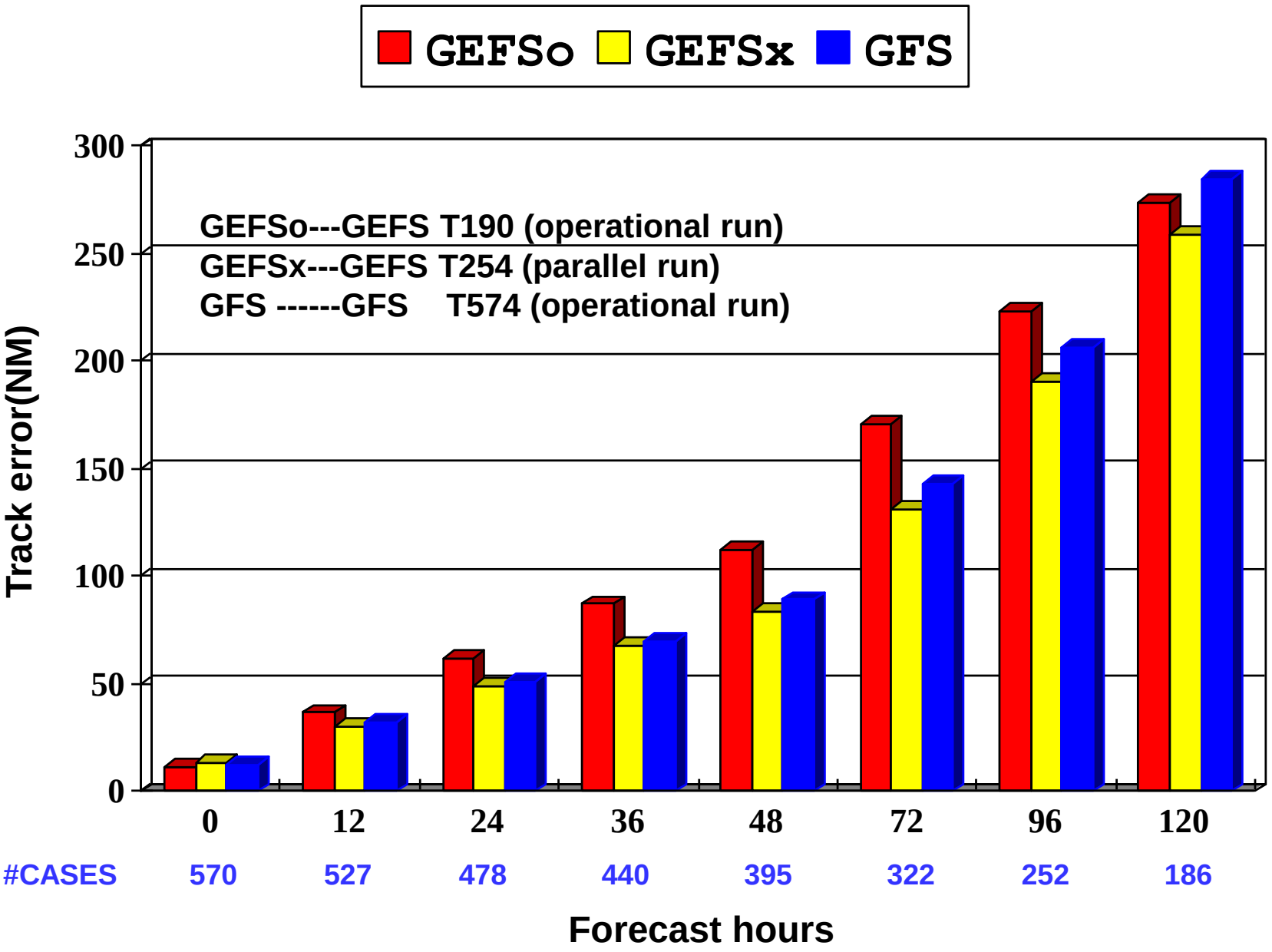
SH 1000hPa height

Tropical Storm Track Forecast
Atlantic, AL01~19 (06/01~11/30/2011)



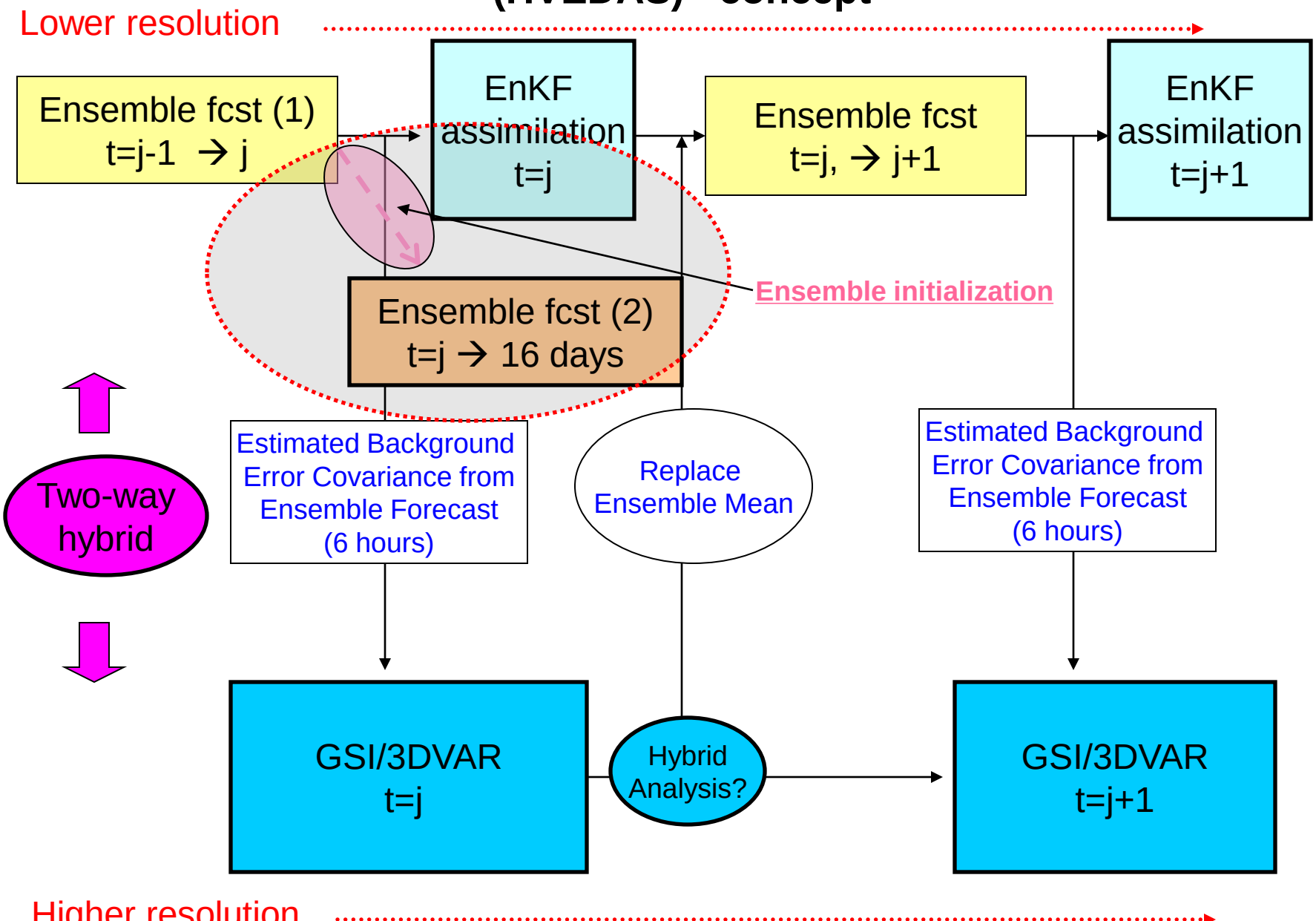
Tropical Storm Track Forecast

Atlantic, East and West Pacific, AL01~17, EP01~09,WP05~22 (06/01~09/30/2011)

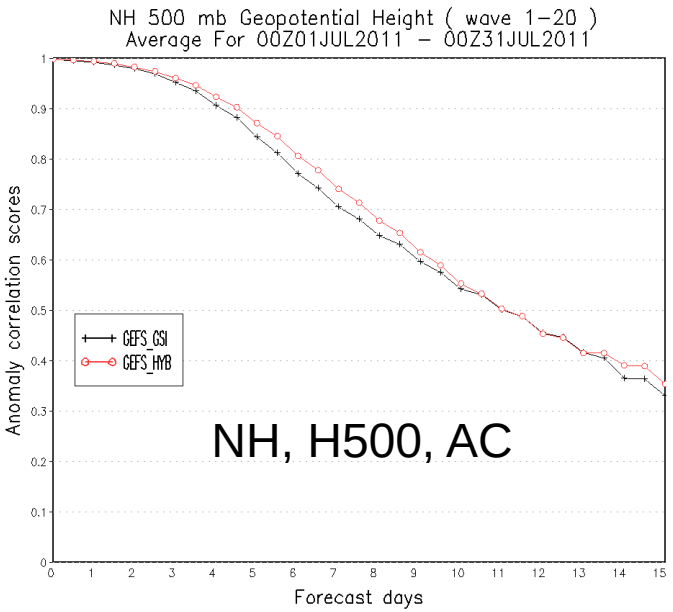


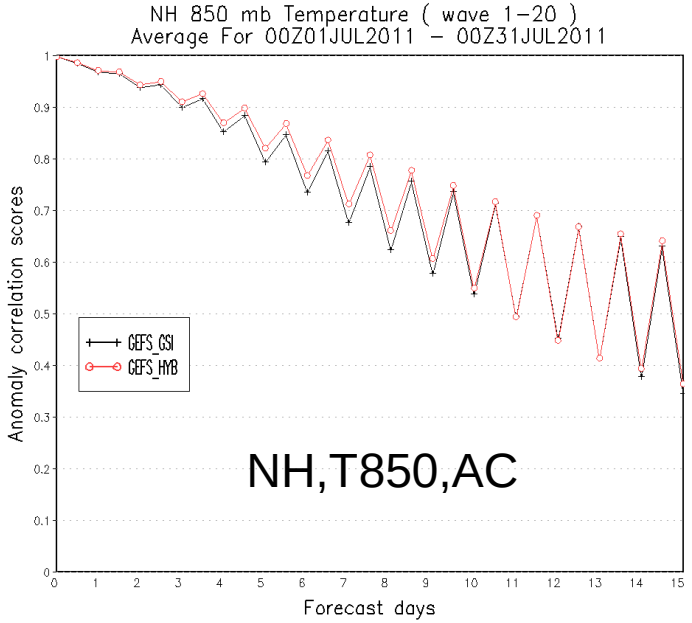
Impact of Coming Implementation of GSI-EnKF Hybrid Analysis

Flow Chart for Hybrid Variational and Ensemble Data Assimilation System (HVEDAS) - concept



Impact of the DA upgrade in May 2012:
Data assimilation upgrade: Hybrid GSI-EnKF

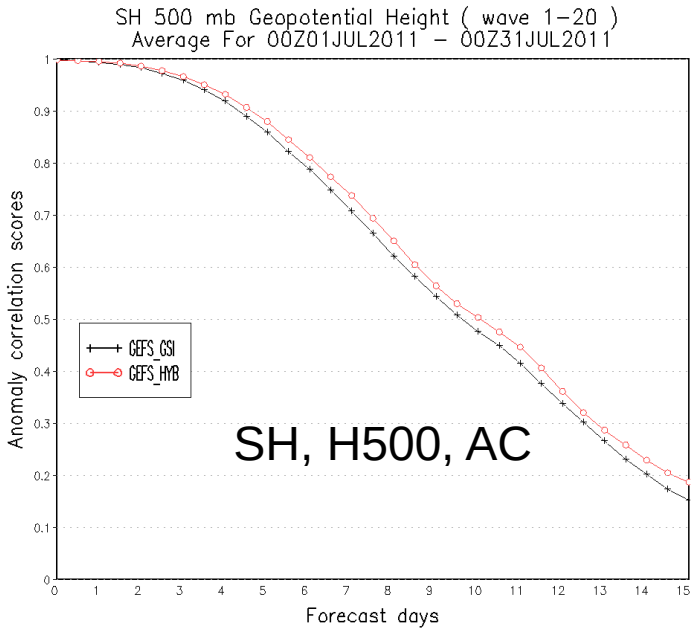


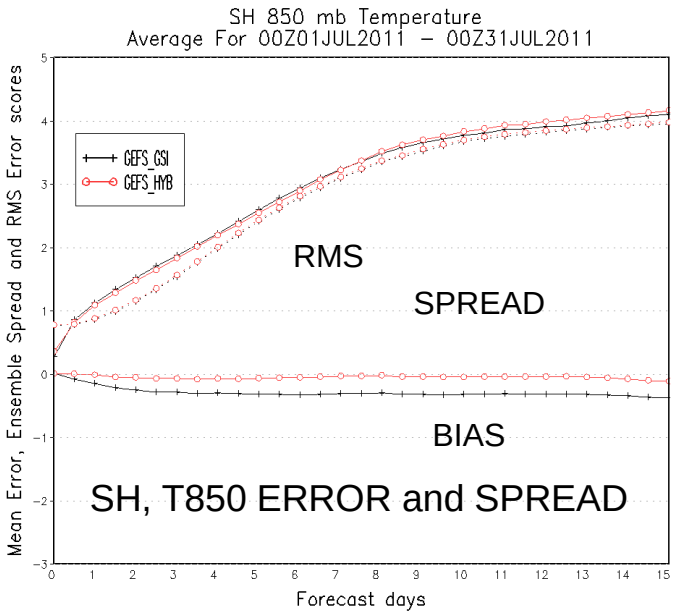


--- GSI
--- HYB

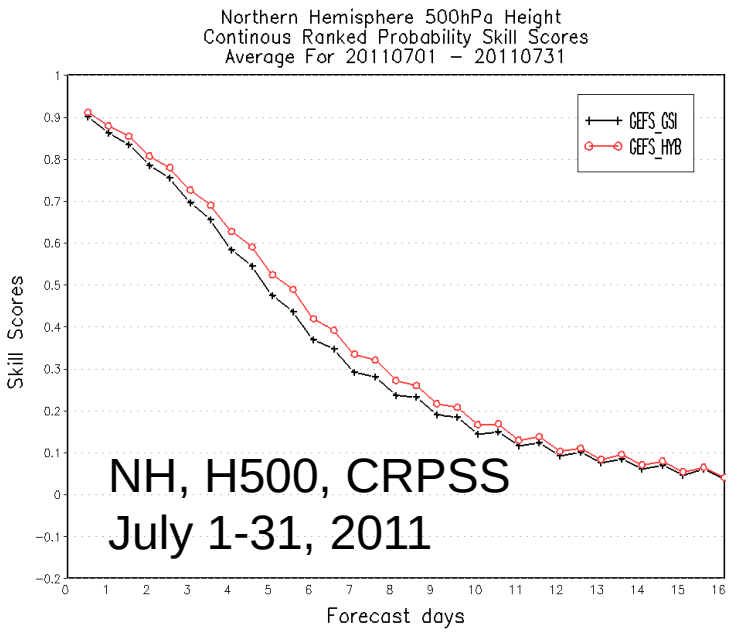
Ensemble Mean

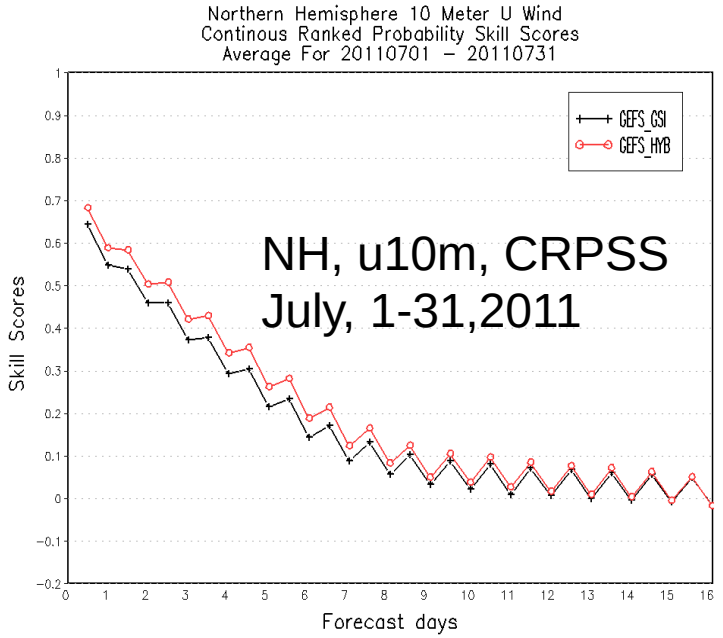
Improvement
Is expected,
Especially in
H500 AC and
SH T850 Bias





Impact of the DA upgrade in March/April 2012: Data assimilation upgrade: Hybrid GSI-EnKF





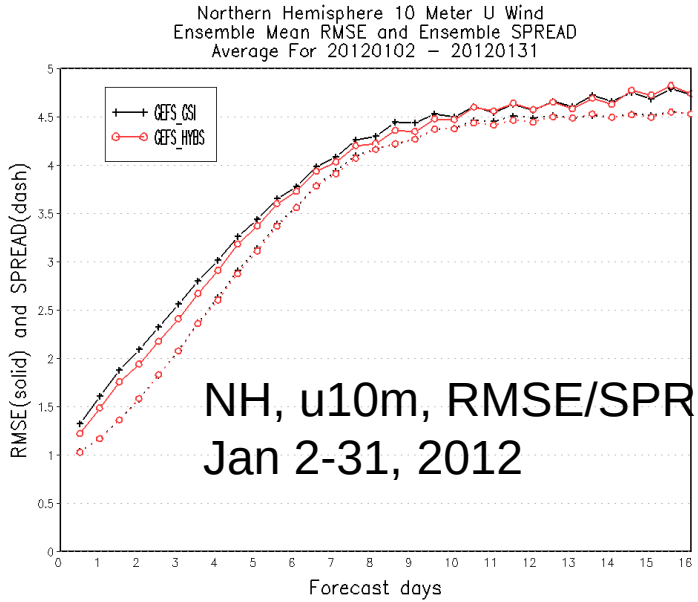
--- GSI
--- HYB

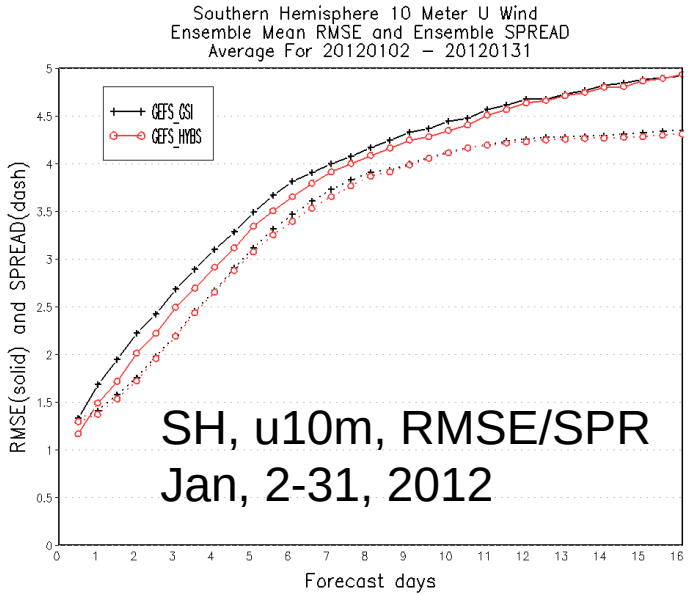
Probabilistic Forecast (CRPSS Is shown) will be improved.

Similar impact On surface variables

More improvements For short lead time

Similar results For opposite season





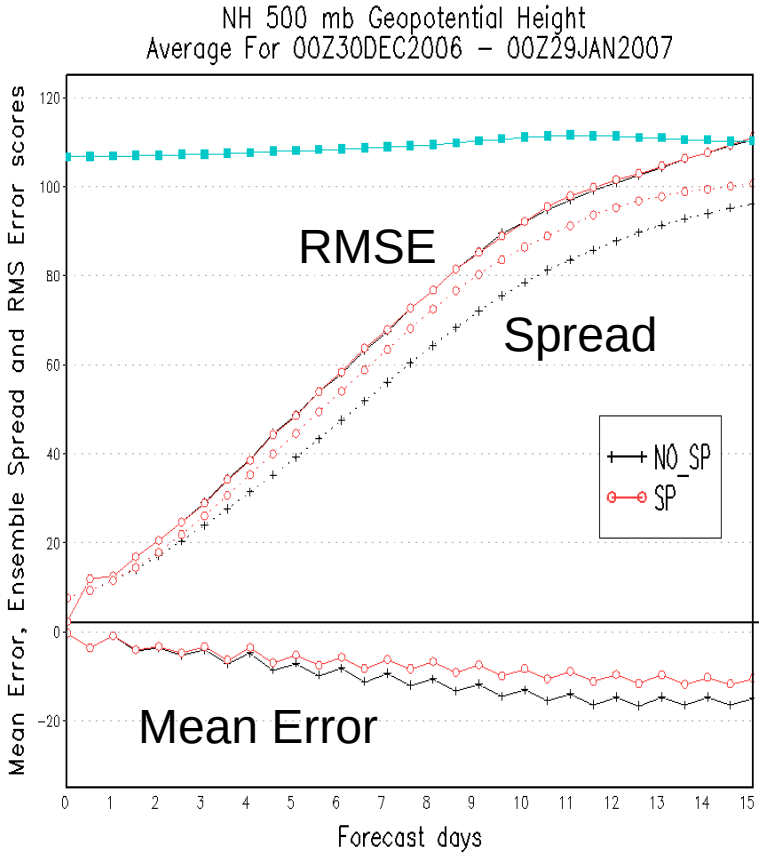
Model Related Uncertainty and Impact of STTP

Model Related Uncertainty and Impact of Stochastic Total Tendency Perturbation (STTP)

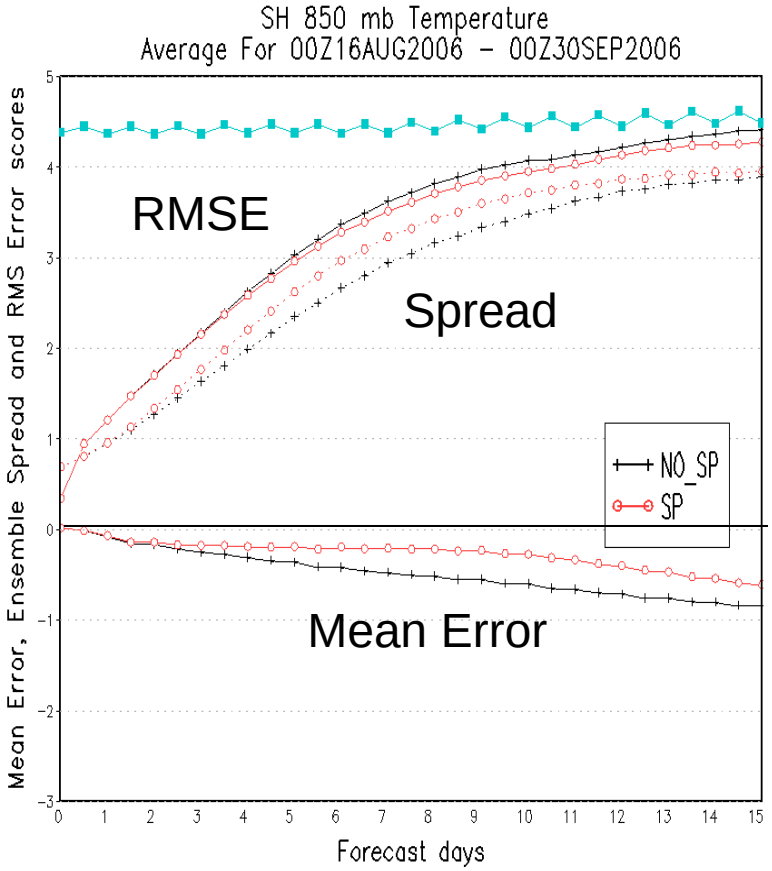
Operational Implementation of STTP with GEFS upgrade on Feb. 23, 2010

Two tests with T190L28 resolution, With STTP (SP) and Without STTP (NO_SP)

STTP Impacts: Reduced systematic error and increase in perturbation (spread) growth



NH H500 Winter



SH T850 Winter

Tuning of STTP Parameters for 2012 implementation

STTP amplitude Specifications:

$$\gamma = \gamma_1(\varphi, d)\gamma_0(t)$$

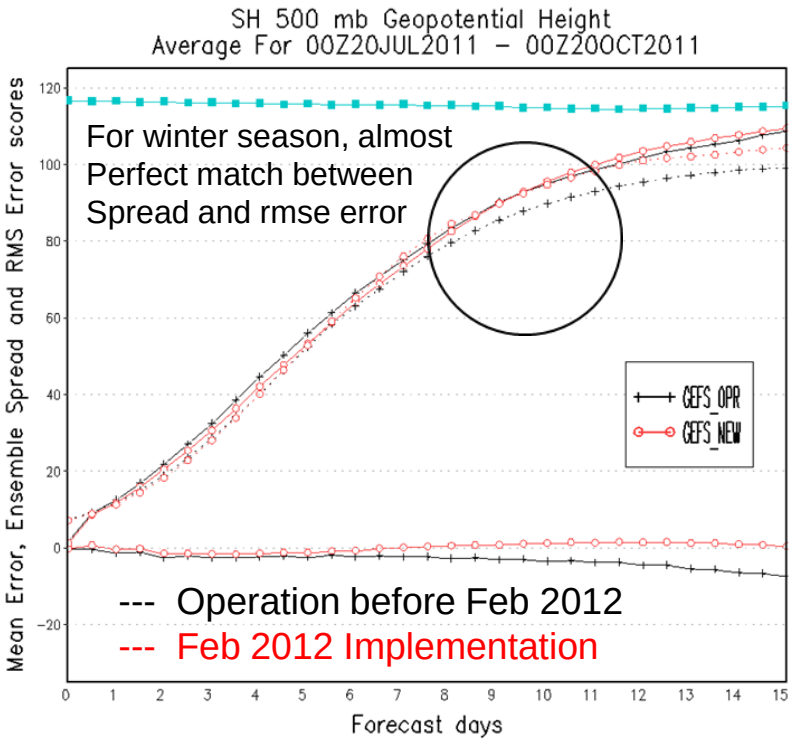
$$\gamma_1(\varphi, d) = 1.0 + 0.2\sin(\varphi)\cos\frac{2\pi d}{364}$$

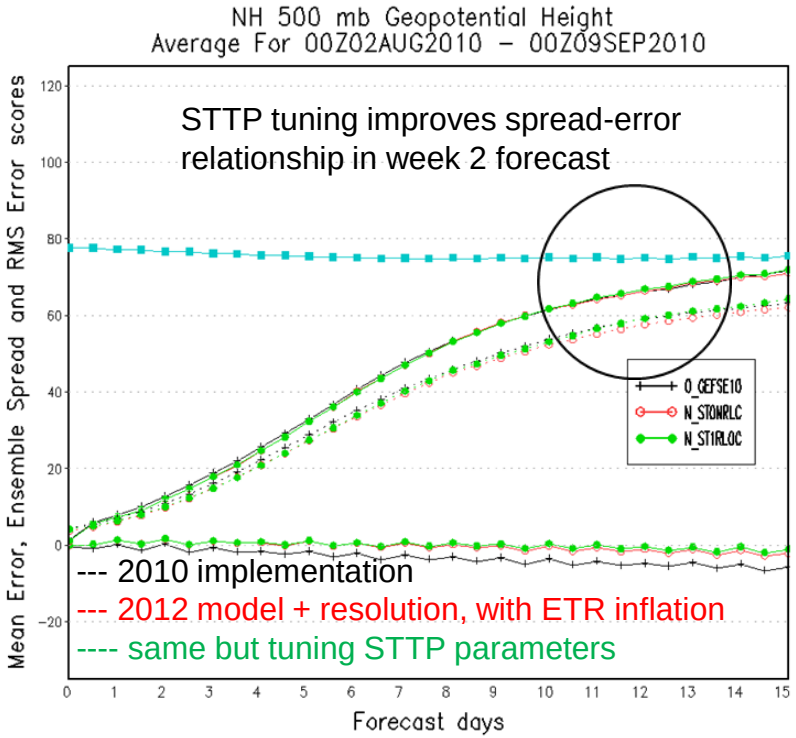
$$\gamma_0(t) = \pm[p_2 + (p_1 - p_2)\left\{1.0 - \frac{1.0}{1.0 + e^{-p_3(t-p_4)}}\right\}]$$

γ_1 : Seasonal and meridianal variation, fixed for each d, date of initialization
γ_0 : Rescaling factor as a function of lead time, negative sign is used

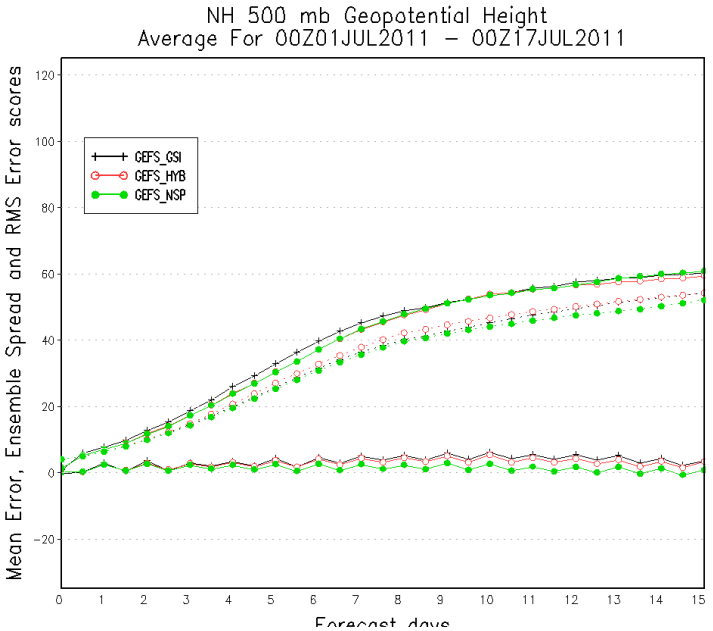
For the Feb 23, 2010 implementation:
p1=0.1, p2=0.01, p3=0.11, p4=252 hours (for uniform resolution)
These are on the conservative side to ensure operational stability and minimize negative impacts

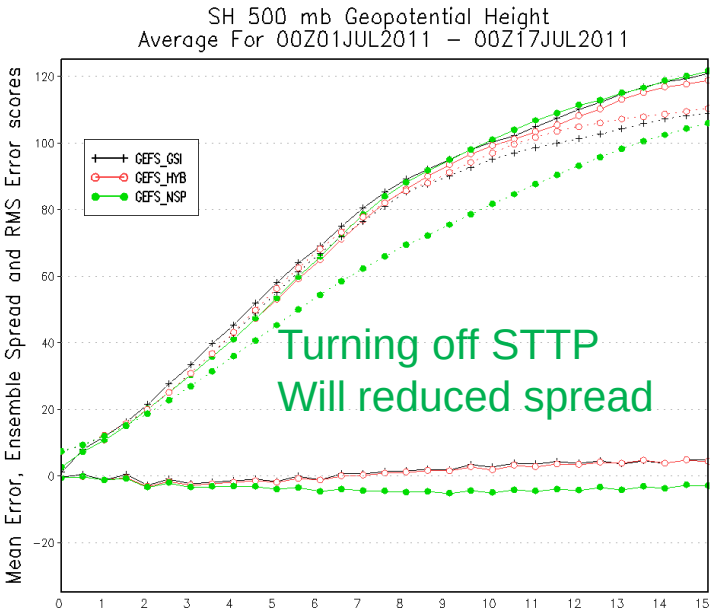
For the proposed 2012 implementation, slightly increase STTP amplitude, especially after 180h, to compensate for the model truncation.
p1=0.105, p2=0.03, p3=0.12, p4=252 hours (for variable resolution)

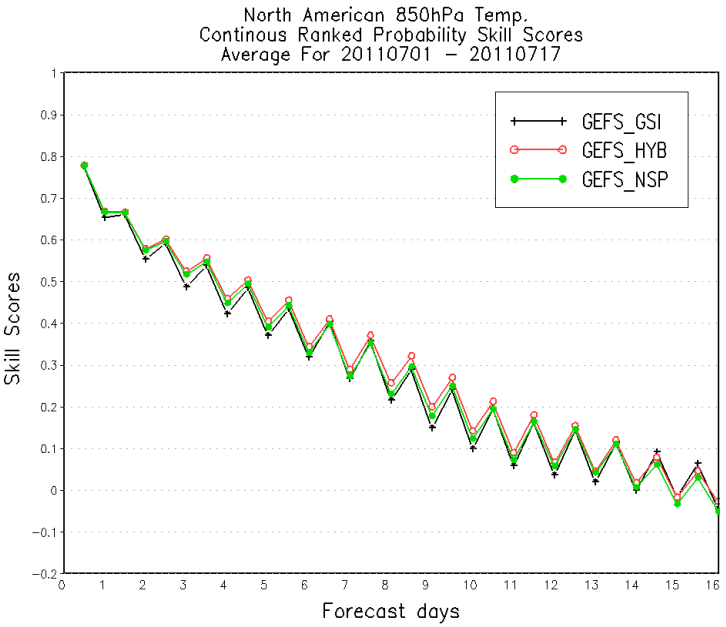


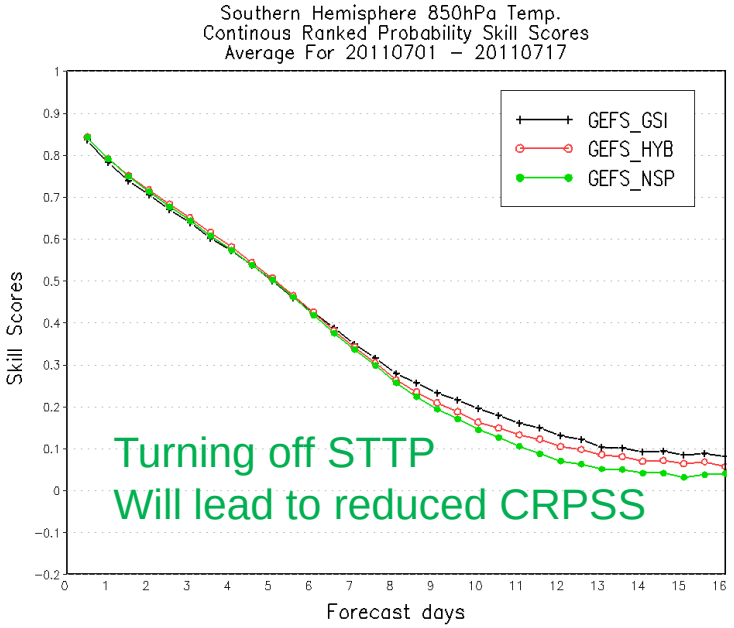


Impact of STTP, Parallel GEFS with Hybrid Analysis







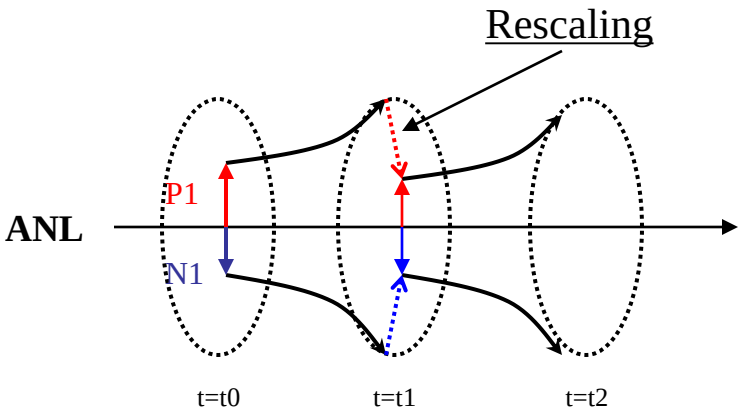


Model Related Uncertainty and Impact of STTP (Discussion)

- Model Related uncertainty is represented by STTP
  - Uncertainty for all dynamic, physical, and numerical sources
  - Not “physics” based
- Impact of STTP
  - Increase spread and improve probabilistic forecast skills
  - Reduce negative bias (but may increase positive bias)
  - improve probabilistic forecast skills
  - May increase positive bias and thus less effective in Summer
- Performance of the operational STTP scheme
  - Stable in operations
  - Robust with changes in model, analysis and resolutions
  - Minimum maintenance required
- Future of STTP
  - Complemented by physics based stochastic schemes
  - Work to tackle the “left over” model uncertainty by other schemes.

Ensemble Initialization and Future Role of ETR and EnKF

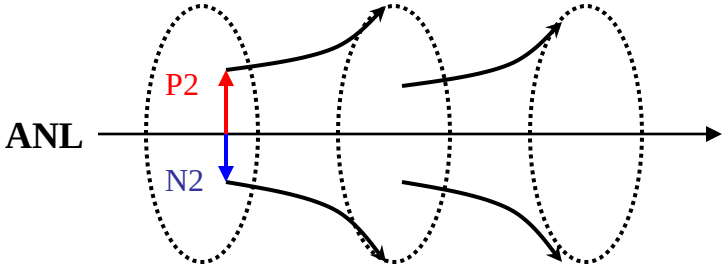
Bred Vector
(Introduced 1990's)



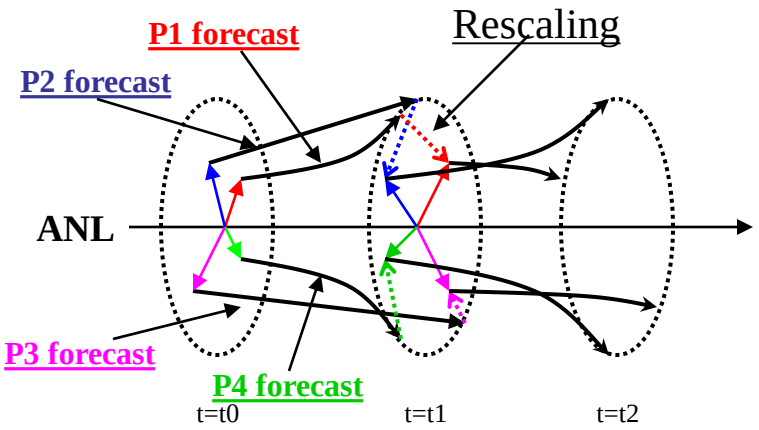
P#, N# are the pairs of positive and negative

P1 and P2 are independent vectors

Simple scaling down (no direction change)



Ensemble Transform with Rescaling
(Current Operation)



P1, P2, P3, P4 are orthogonal vectors

No pairs any more

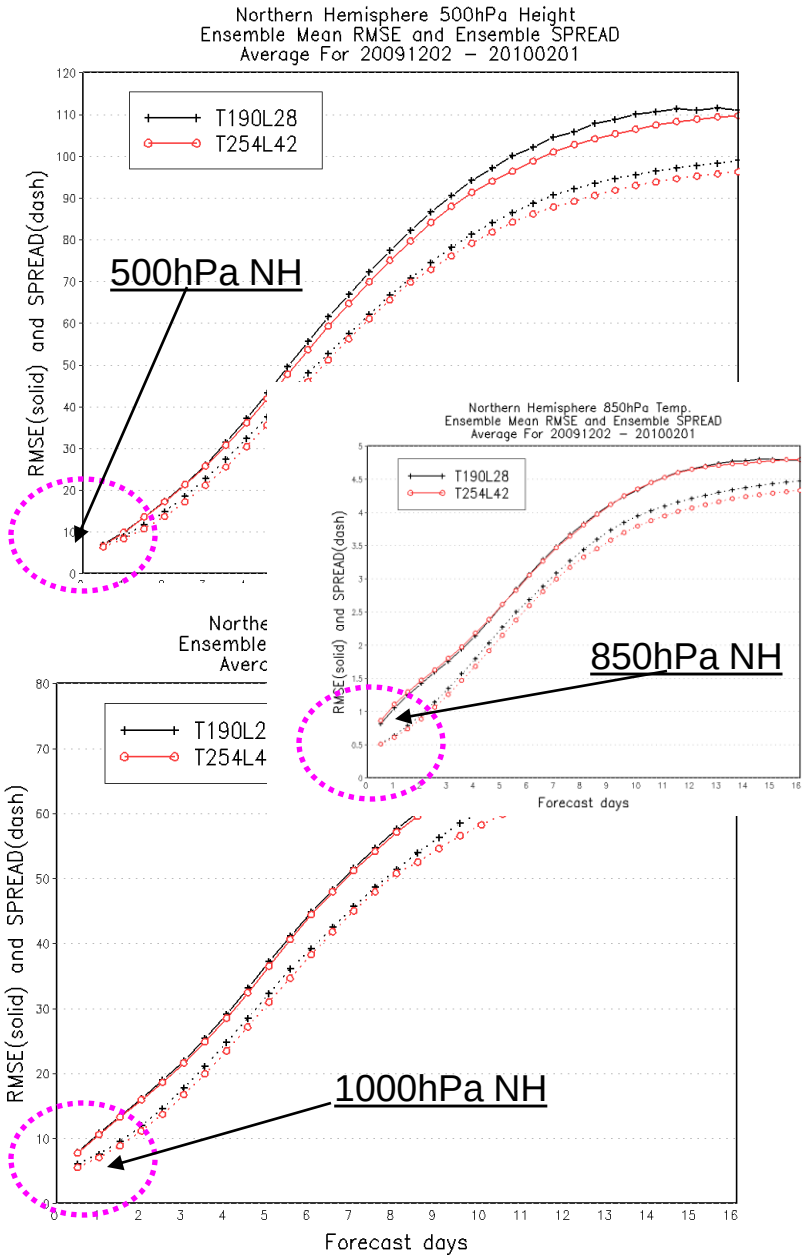
To centralize all perturbed vectors (sum of all vectors are equal to zero)

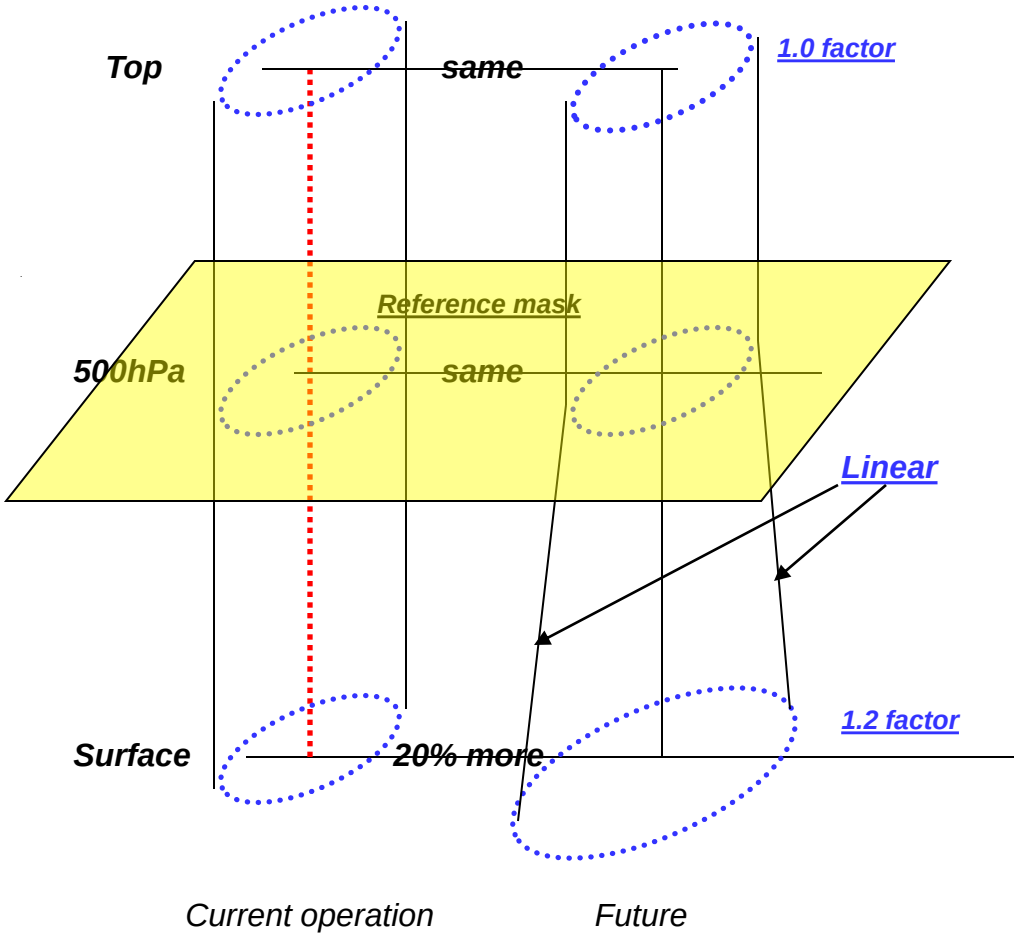
Scaling down by applying mask (2D mark is generated based on mid-of-troposphere near 500hPa as a reference)

The direction of vectors will be tuned by ETR.

Why and how do we tune ETR initial perturbations ?

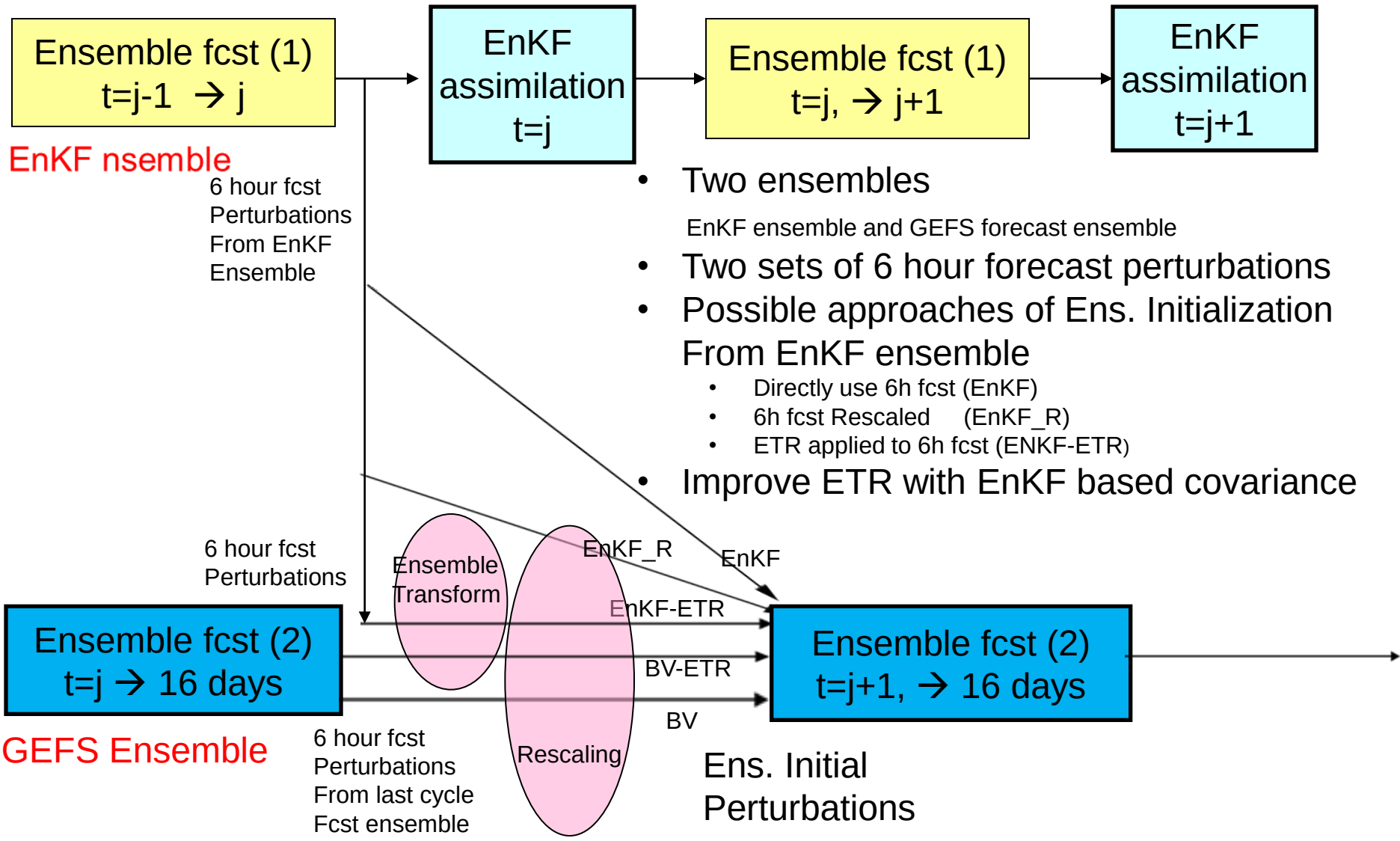
In Feb 2012 Upgrade





Schematic of tuning initial perturbations

Alternative Approaches of Ensemble Initialization Provided by the Hybrid GSI-EnKF Data Assimilation



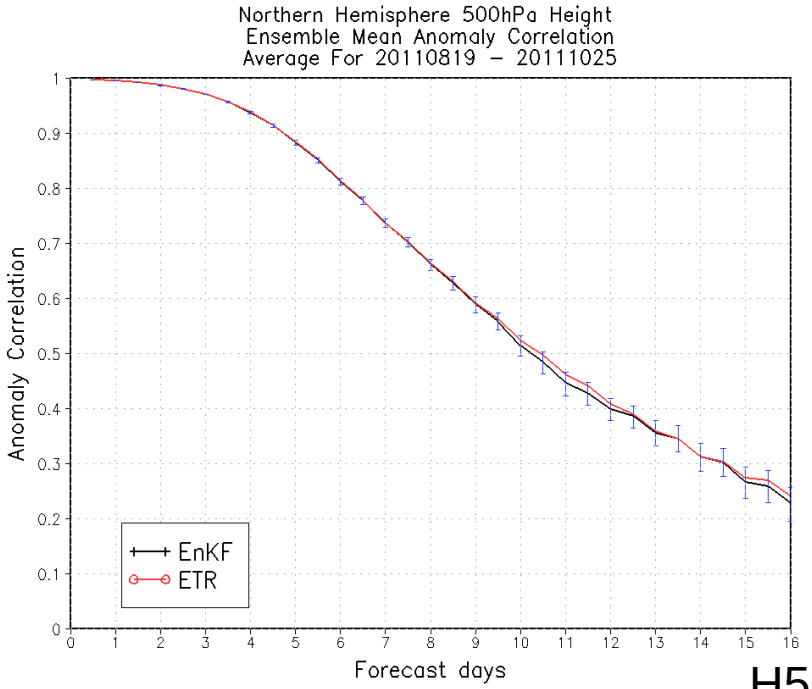
Ensemble initialization

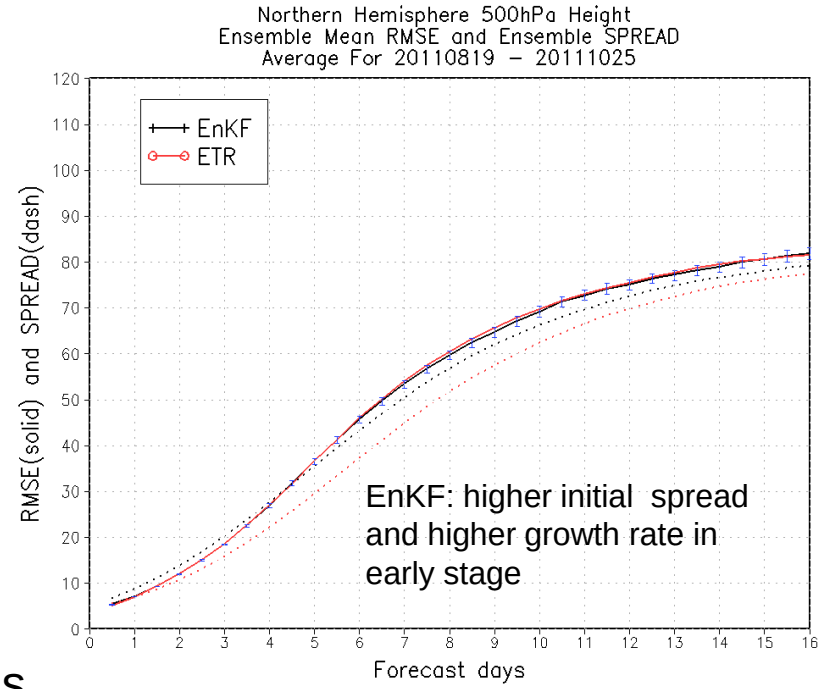
Comparison of ETR and EnKF initialization from hybrid analysis

Xiaqiong Zhou, Jeff Whitaker, Richard Wobus
Yuejian Zhu and Dingchen Hou
(NCEP and ESRL)

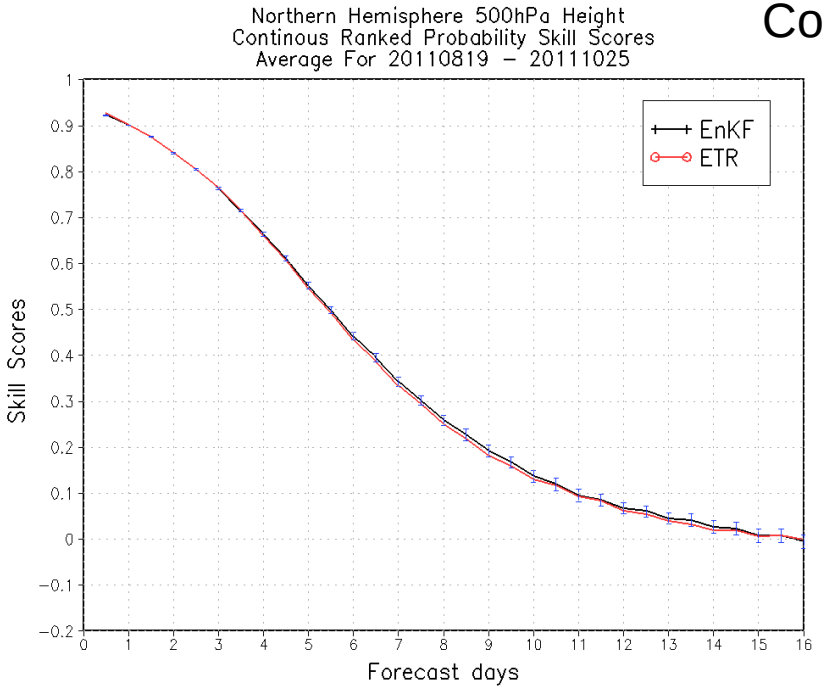
Expefriment Design

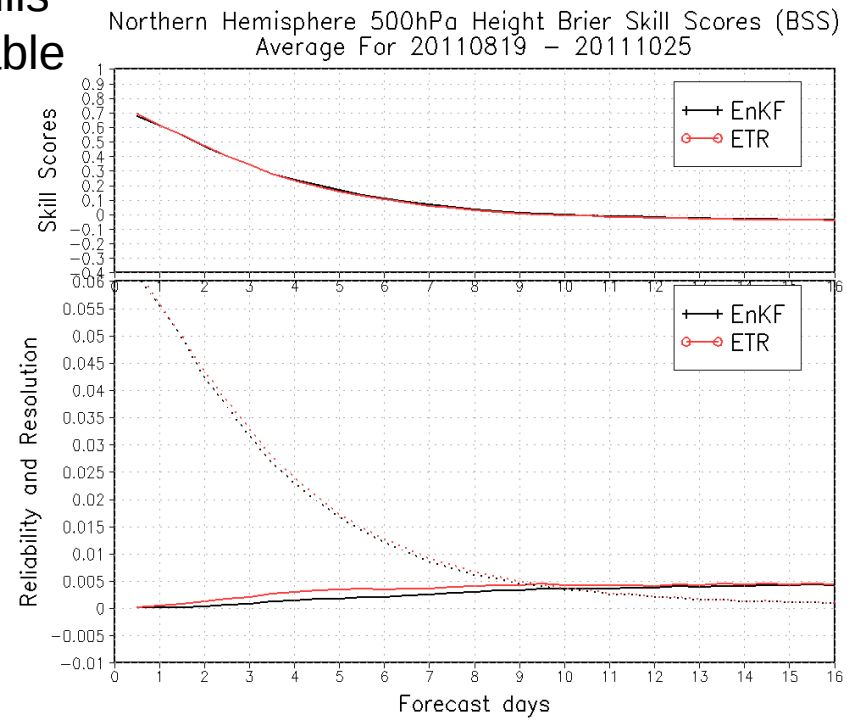
- Period: 08/19 – 10/25/2011
- Configuration: As current operational GEFS with Hybrid analysis, but without STTP
- Resolutions: T254L42/T190L42
- Forecast lead time: 16 days
- Initial condition: hybrid analysis (to be iplemented)
- Perturbed initial conditions: ETR and EnKF
- Verification against: hybrid analysis
- Statistics: http://www.emc.ncep.noaa.gov/gc_wmb/xzhou/EnKF_ETR_16d.HTML

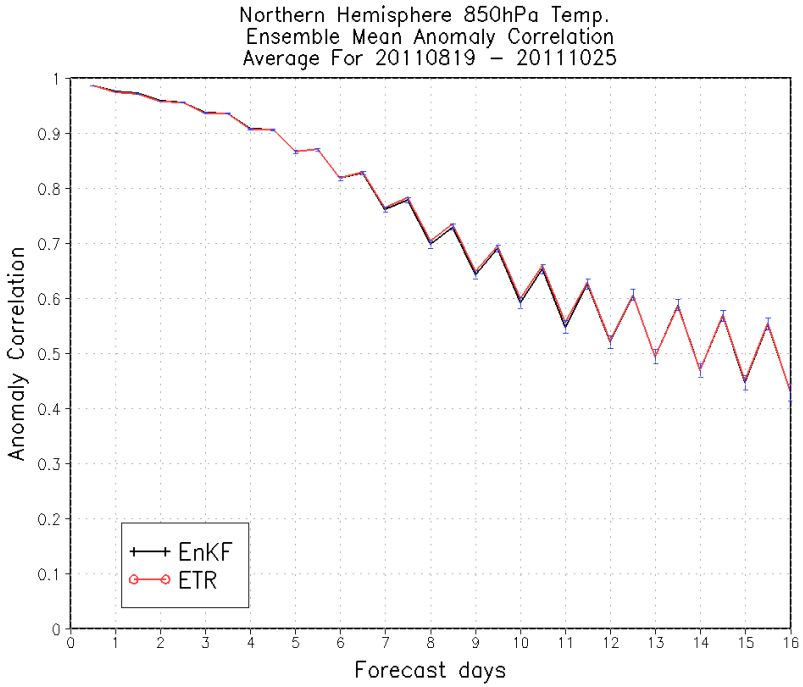


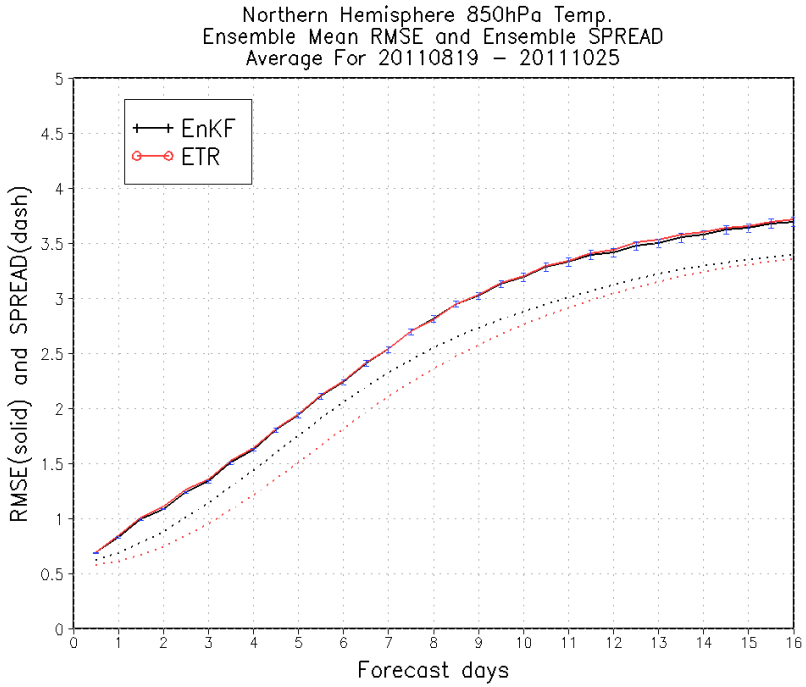


H500, skills Comparable

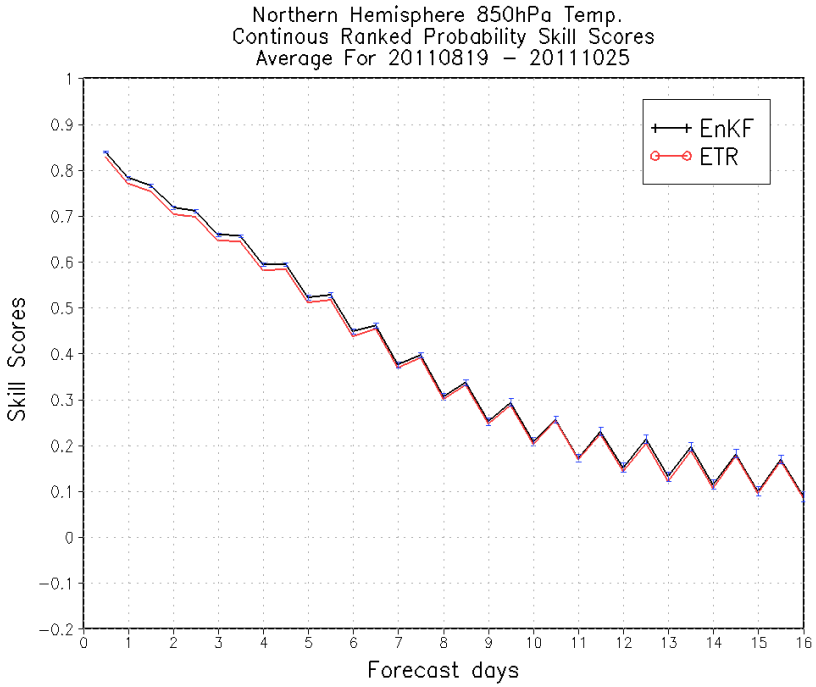


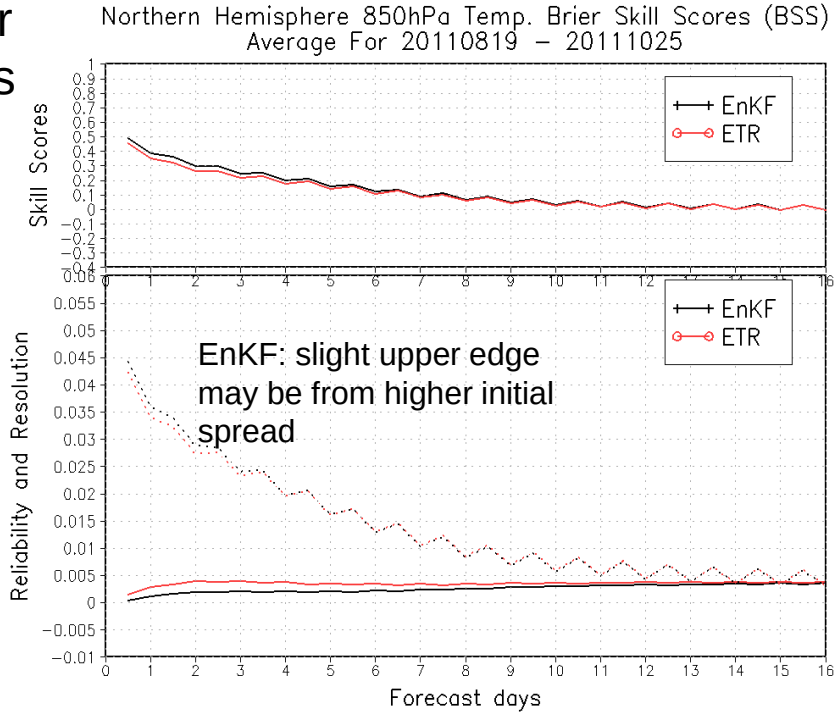


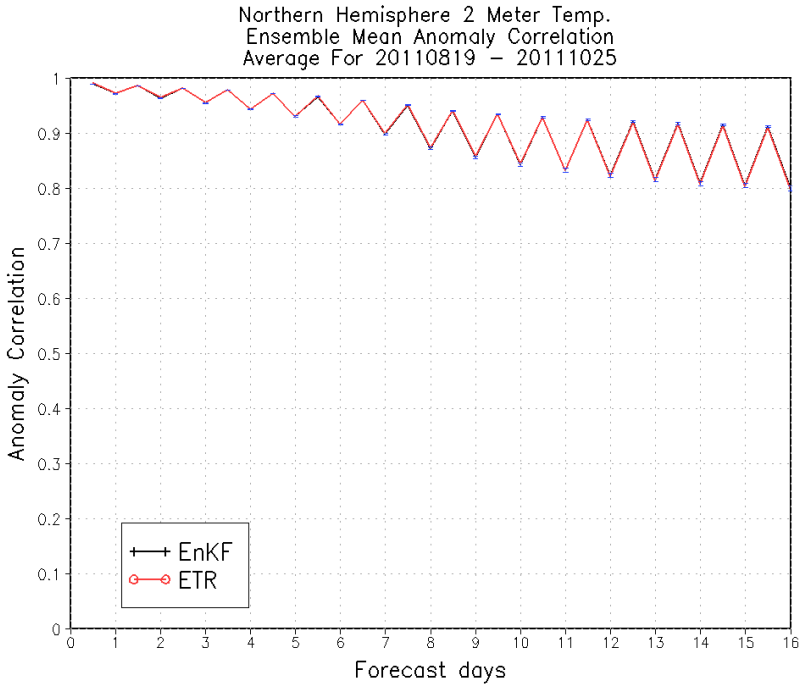


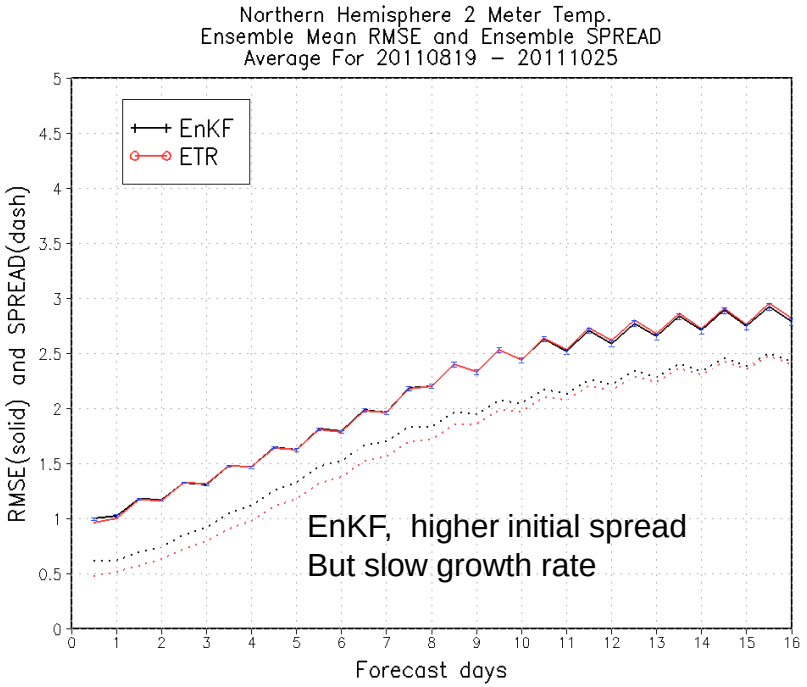


T850 similar results

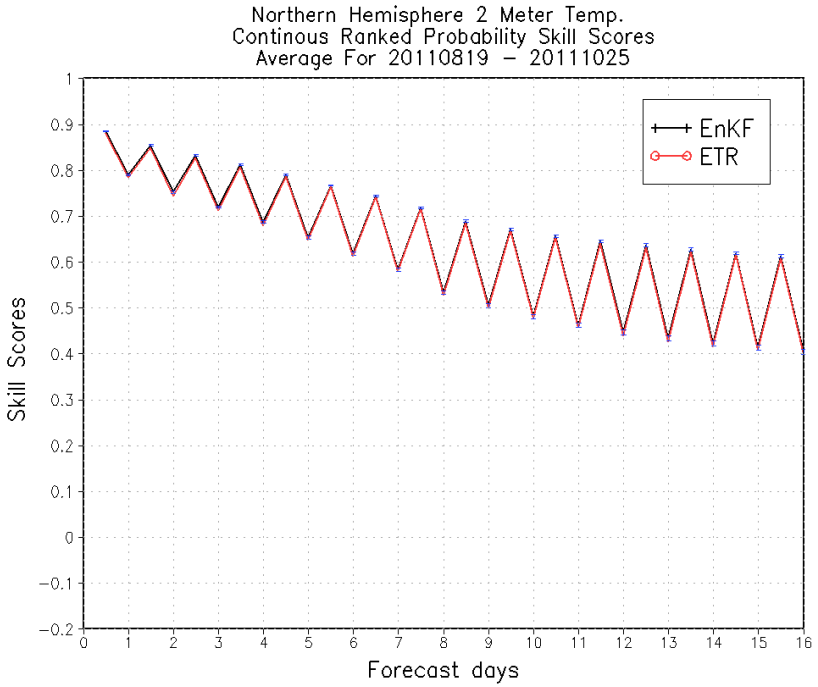


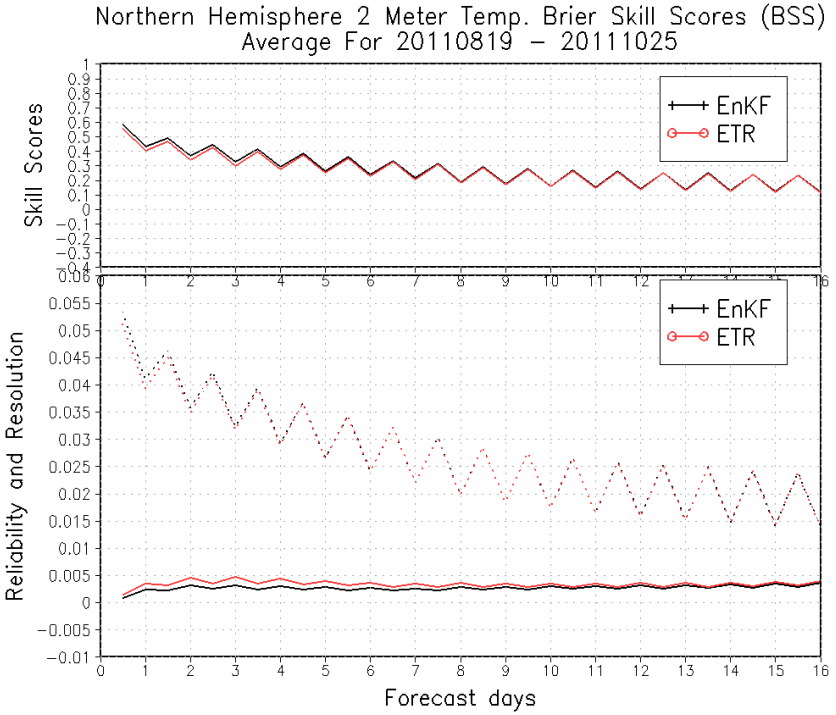



Northern Hemisphere 2 Meter Temp.
Ensemble Mean Anomaly Correlation
Average For 20110819 – 20111025
Anomaly Correlation
Forecast days
EnKF
ETR

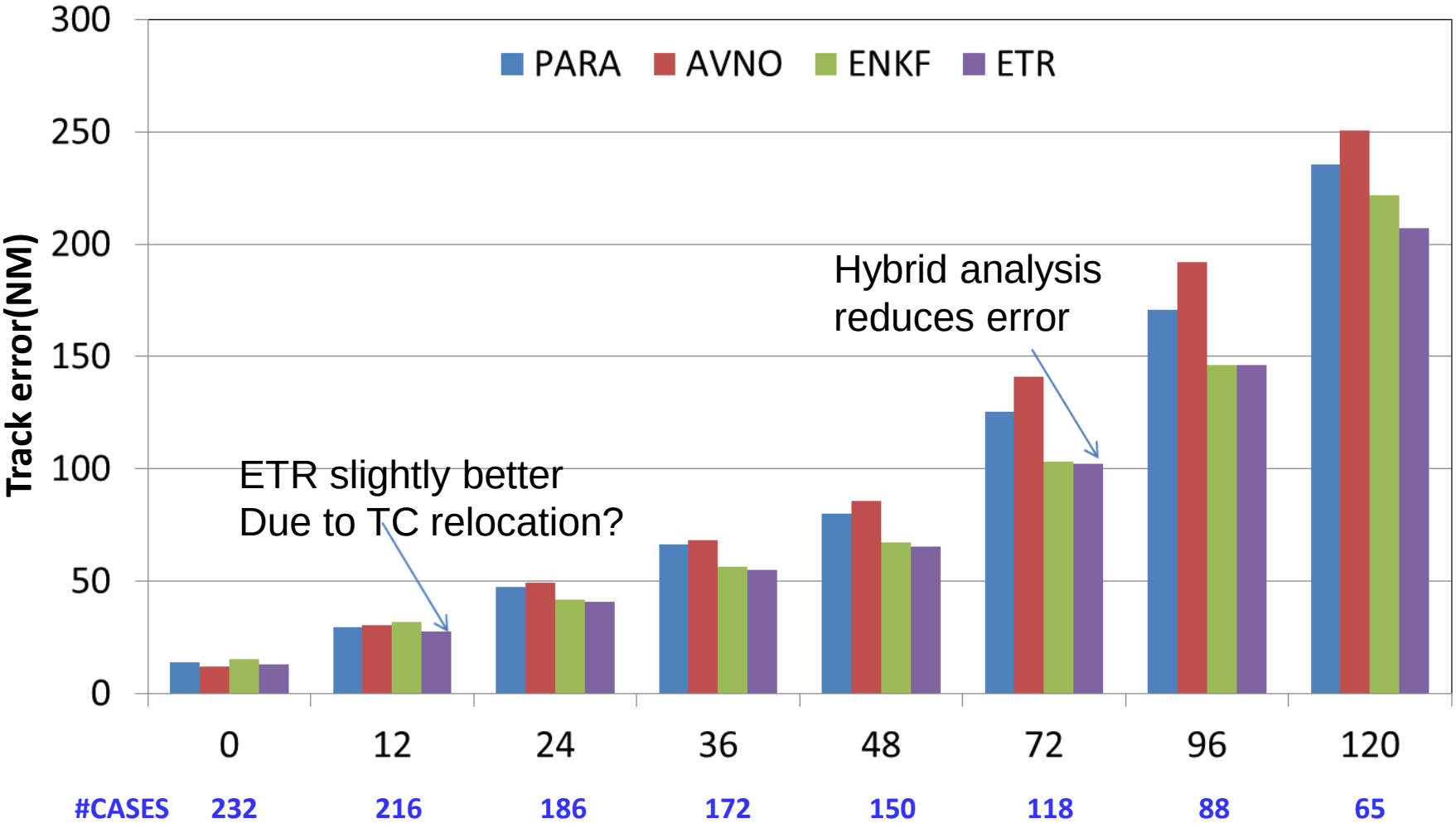

Northern Hemisphere 2 Meter Temp.
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20110819 – 20111025
RMSE(solid) and SPREAD(dash)
Forecast days
EnKF
ETR
EnKF, higher initial spread
But slow growth rate

T2m


Northern Hemisphere 2 Meter Temp.
Continous Ranked Probability Skill Scores
Average For 20110819 – 20111025
Skill Scores
Forecast days
EnKF
ETR


Northern Hemisphere 2 Meter Temp. Brier Skill Scores (BSS)
Average For 20110819 – 20111025
Skill Scores
Reliability and Resolution
Forecast days
EnKF
ETR

Tropical Storm Track Forecast Errors
AL01-18,EP03-12, WP08-23 (07/01-10/25/2011)



Forecast hours

PARA----GEFS T254 parallel (GSI)

AVNO----GFS T574 (GSI)

ENKF---GEFS T254 ENKF (hybrid analysis)

ETR----GEFS T254 ETR (hybrid analysis)

Summary

- Recent GEFS implementation, with major model upgrade and resolution increases, significantly increased the forecast performance, especially in hurricane track forecast.

- With the anticipated upgrade in Data Assimilation (GSI-EnKF Hybrid), the new GEFS product will be further improved, especially in warm season.

- The STTP scheme, implemented in Feb 2010, works well and requires minimum adjustment in system upgrade. It led to striking increase in probabilistic forecast skills, especially in week 2. It is expected to be complementary to physics based stochastic schemes.

- Improvement in ensemble initialization has always been our focus and the implementation of Hybrid GSI/EnKF Data Assimilation provide various possibilities. The application of error covariance from EnKf 6h forecast will be explored.

- Experiment is performed to initialize ensemble perturbation from EnKF 6h forecast. Preliminary comparison with the current ETR method suggests that the two methods have comparable forecast skills and more comprehensive study is necessary.

Background

Multi-model
Global Ensemble Forecast System

Yuejian Zhu

Ensemble Team Leader
EMC/NCEP

The Value of Ensemble Forecast

- Offer additional information to deterministic forecast – “uncertainty”
- Ensemble uncertainty forecast could help for high impact or extreme weather event – lower probability – tails of forecast distribution – single model ensemble is usually under-dispersed
- Help for flip-flop (or in-consistent) forecast through ensemble mean
- Ensemble mean could have more value for large scale system forecast, longer lead time forecast
- However - Ensemble can not help to answer all questions

Cost of Ensemble Prediction System

- Current status
  - Single model (initial perturbed) ensemble - GEFS
- Ensemble forecast 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
  - Testing GFS + FIM (multi-model – dynamic) ensemble
  - Possible other candidate in the future (NMMB)??
  - Cost of maintaining models??
  - Value added to current NAEFS – multi-model??

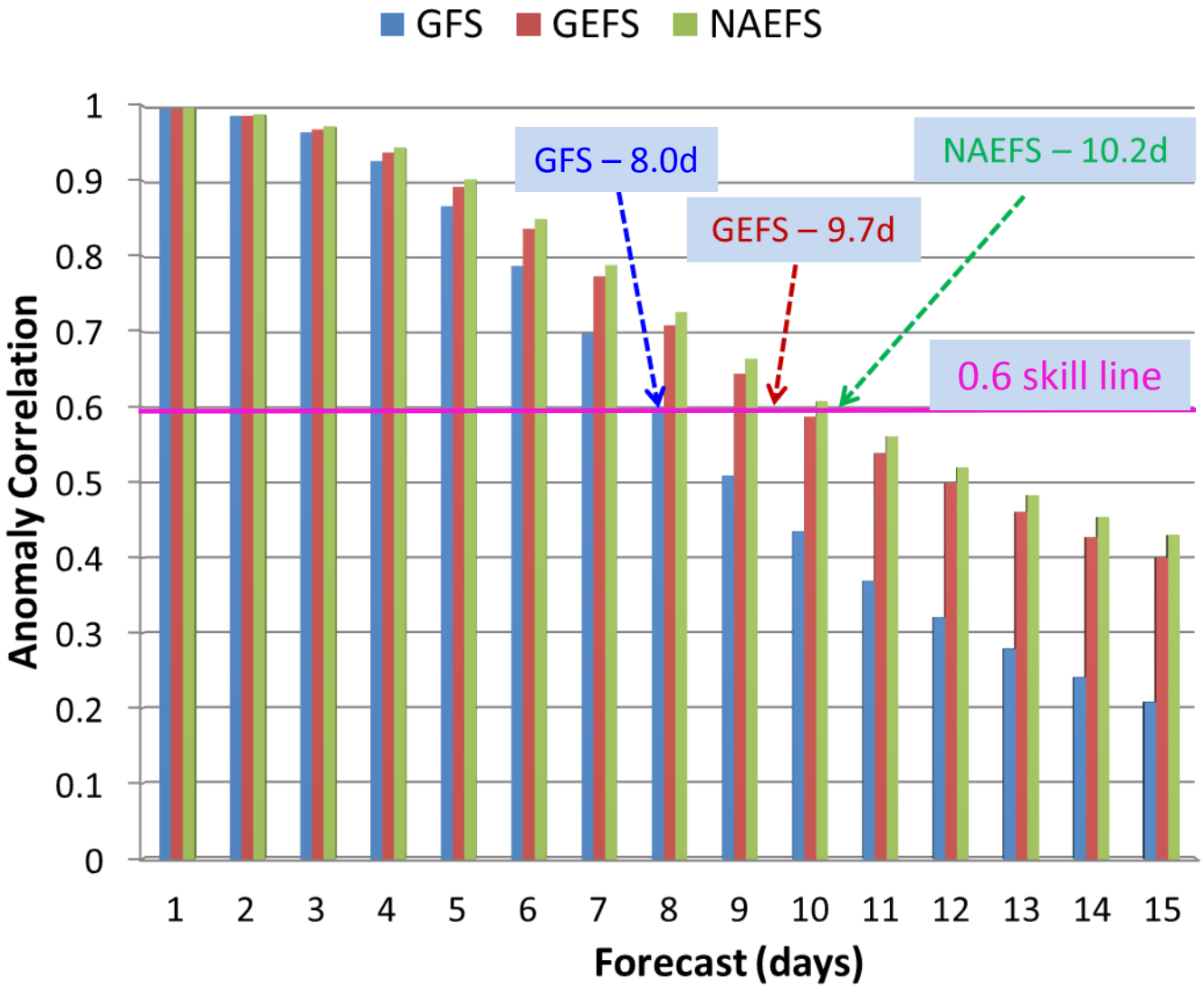
NAEFS/NUOPC Configuration

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

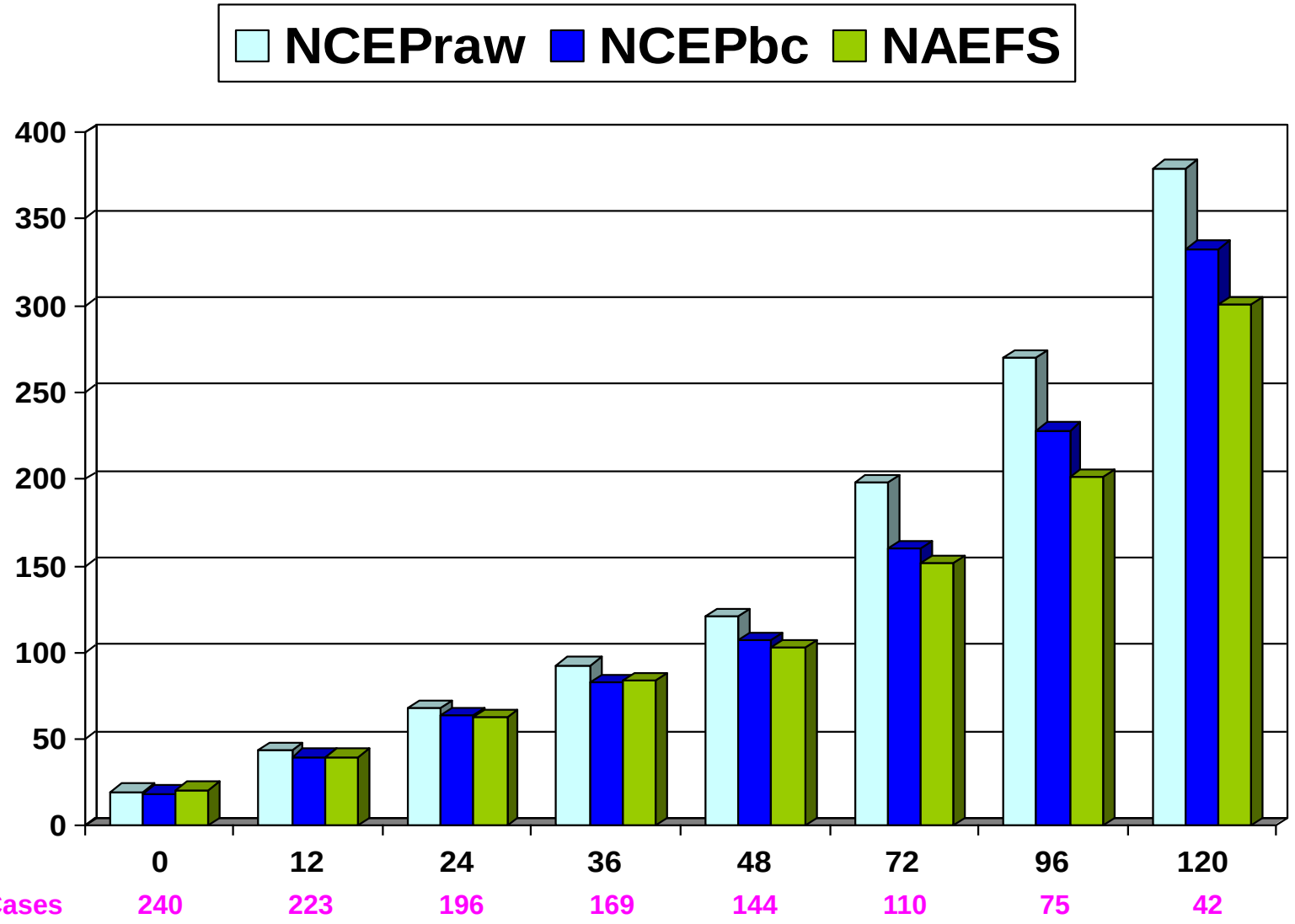
Period: January 1st – December 31st 2010



Benefit for forecast:

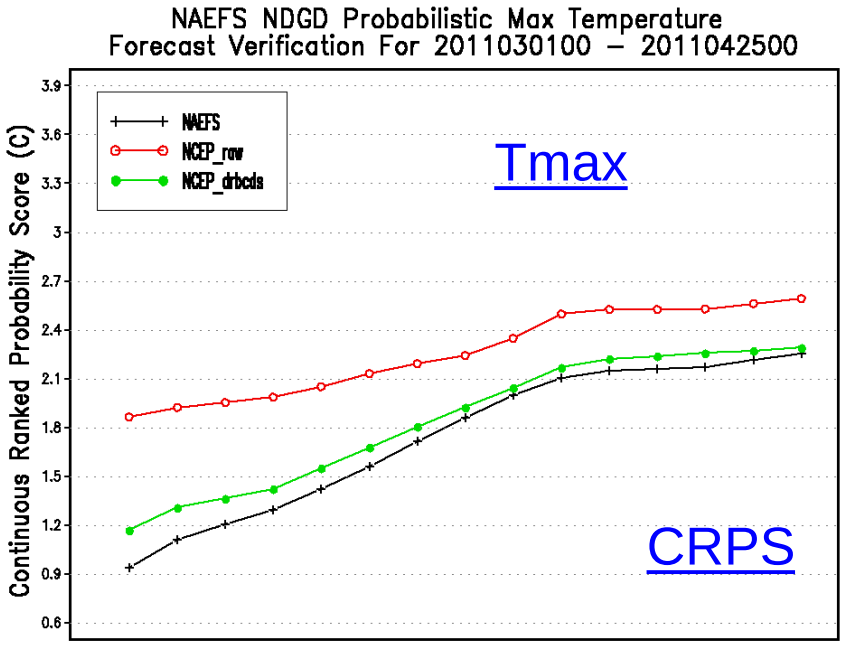
1. Ensemble (GEFS) mean extends 1.7 days forecast ability
2. NAEFS adds additional 0.5 day forecast skill
3. Post process will add another additional

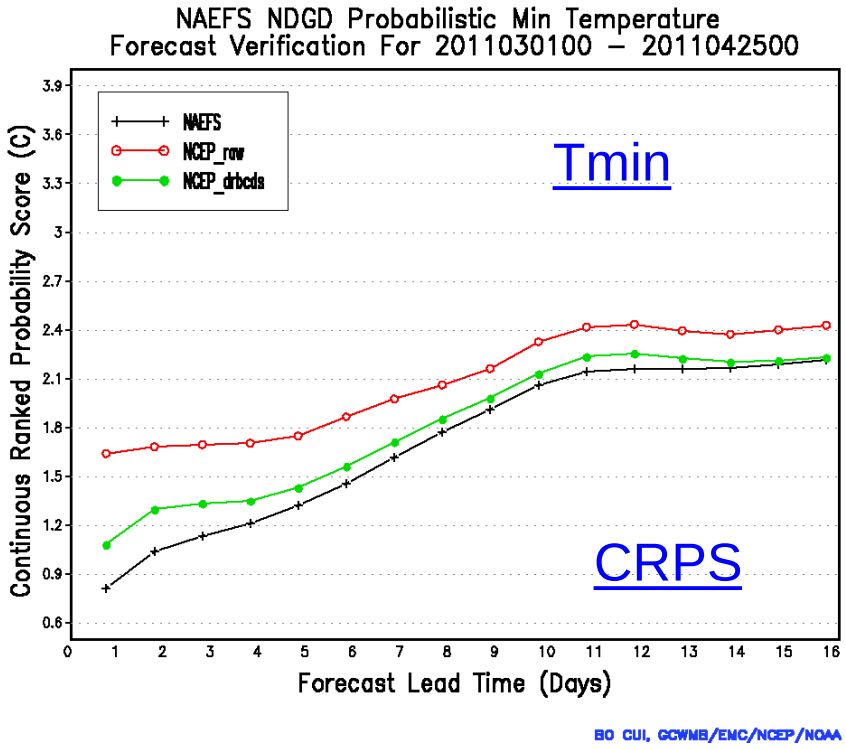
Track forecast error for 2009 season (AL+EP+WP)

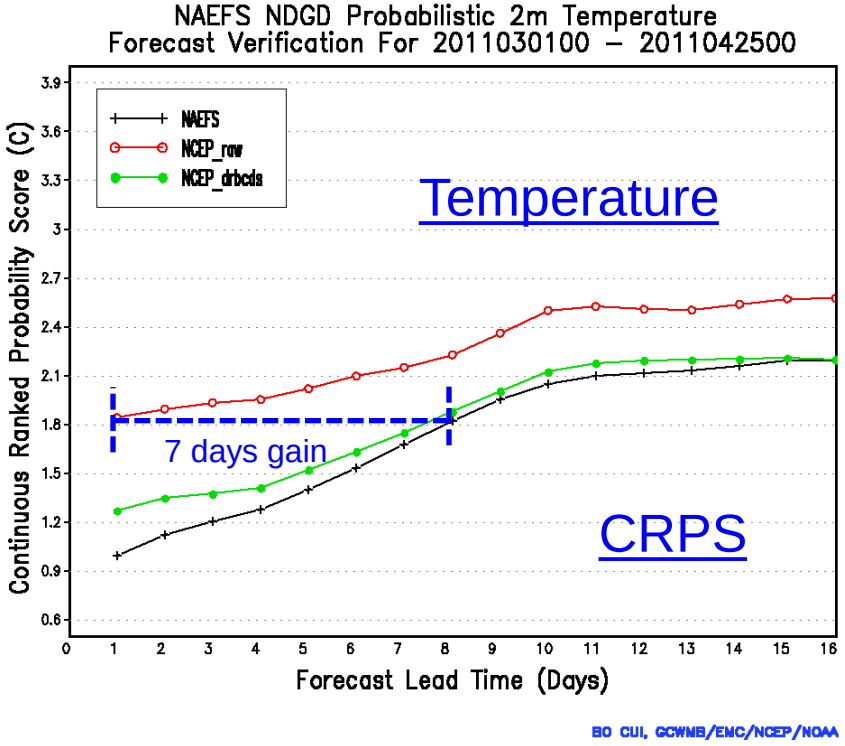


NAEFS is combined NCEP (NCEPbc) and CMC's (CMCbc) bias corrected ensemble and bias corrected GFS

Contributed by Dr. Jiayi Peng (EMC/NCEP)



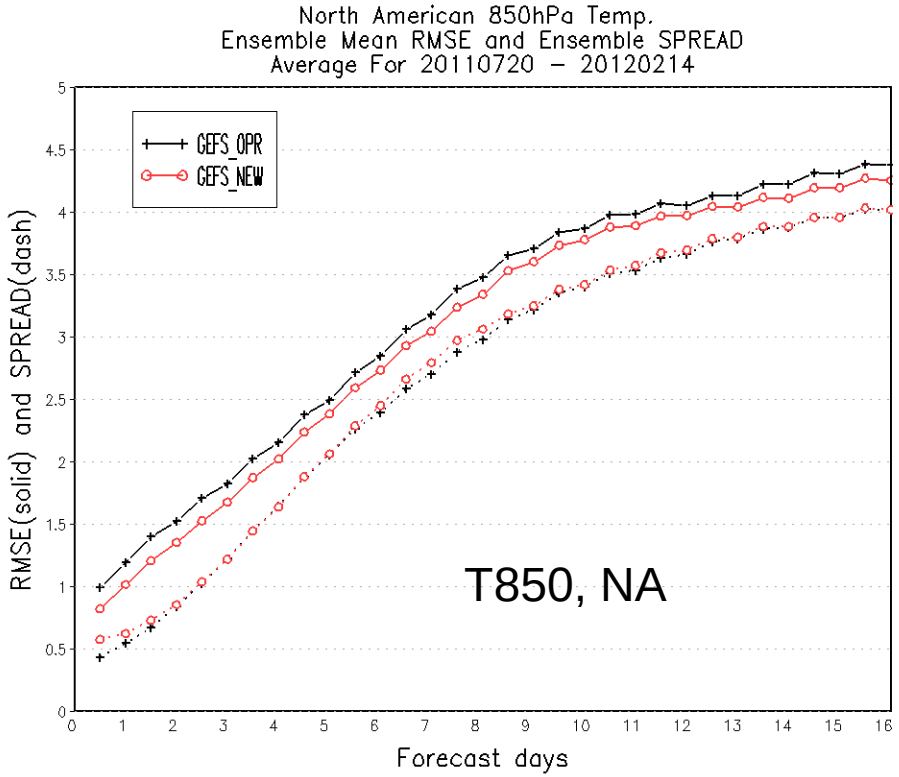


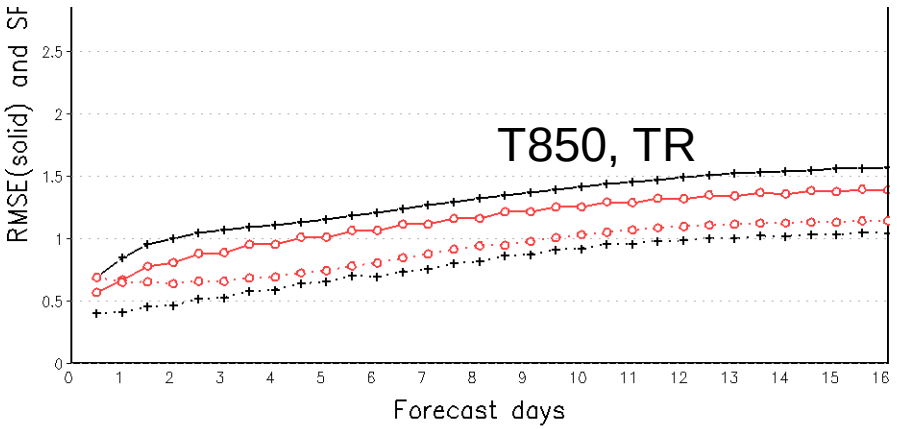


Latest evaluation for CONUS temperature forecast by apply :

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

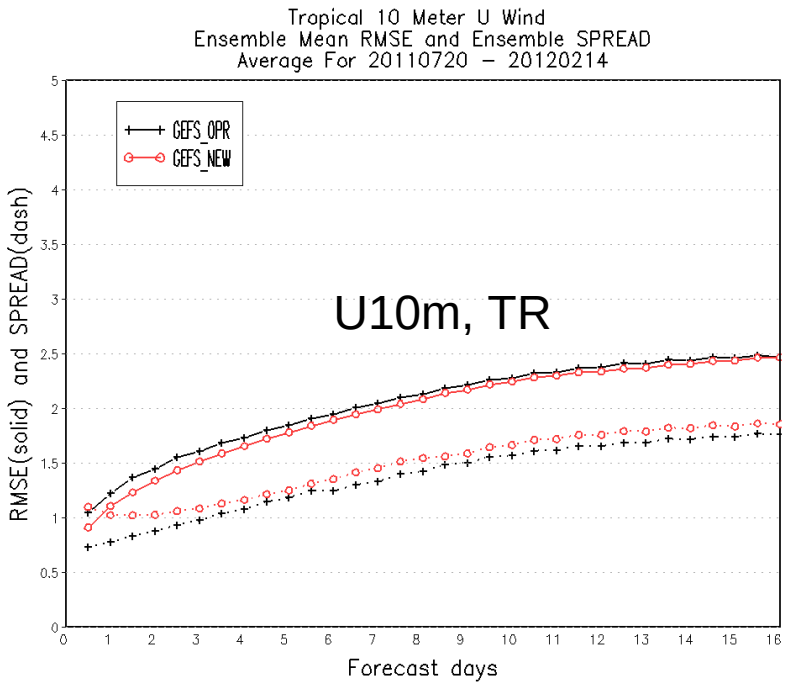
Impact of initial perturbation inflation





- Larger initial perturbations in lower levels
- But grow row slower for the first 48 hours
- Even decrease in tropics

- Modest impact in extratropics
- Moderate impact in the Tropics



NAEFS Current Configuration

Updated: February 14th 2012

	NCEP	CMC	NAEFS
Model	GFS	GEM	NCEP+CMC
Initial uncertainty	ETR	EnKF	ETR + EnKF
Model uncertainty/Stochastic	Yes (Stochastic Pert)	Yes (multi-physics)	Yes
Tropical storm	Relocation	None	
Daily frequency	00,06,12 and 18UTC	00 and 12UTC	00 and 12UTC
Resolution	T254L42 (d0-d8)~55km T190L42 (d8-16)~70km	(d0-d16) ~ 66km	1*1 degree
Control	Yes	Yes	Yes (2)
Ensemble members	20 for each cycle	20 for each cycle	40 for each cycle
Forecast length	16 days (384 hours)	16 days (384 hours)	16 days
Post-process	Bias correction (same bias for all members)	Bias correction for each member	Yes
Last implementation	February 14th 2012	August 17th 2011	

Impact of the DA upgrade in May 2012: Data assimilation upgrade: Hybrid GSI-EnKF