Next GEFS configuration

- Model
  - Current: GFS Euler model
  - Plan: GFS Semi-Lagrangian model
- Horizontal resolution
  - Current: T254 (55km for 0-192 hours), T190 (73km for 192-384 hours)
  - Plan
    - Option 1: T574 (T382 physics – 34km for 0-384 hours)
    - Option 2: T574 (T382 physics - 34km for 0-168 hours?), T382(T254 physics – 55km for 168-384 hours)
- Vertical resolution
  - Current: L42 hybrid levels
  - Plan:
    - Option 1: L42 hybrid levels to use less resources
    - Option 2: L64 hybrid levels to use match with GFS and DA
- Computation cost:
  - Current: 84 nodes (+ post process) for 55 minutes
  - Plan: 300 nodes (first 30 minutes), 250 nodes (2nd 30 minutes)
- Output:
  - Current: every 6-hr for 1*1 degree pgrb files
  - Plan: every 3-hr for 0.5*0.5 degree pgrb files
- Challenges:
  - T574L64 configuration will cost 250-300 nodes for one hour
  - Option: T574L42 configuration will use less resources, but the forecast quality will be degraded.

Next GEFS science

- Initial perturbations
  - Base: EnKF 6hr forecast
  - TS relocation – Yochrio's modification version (simplify the process)
    - Is testing the effect of perturbed TS intensity
  - Ensemble transform (ET) from 80 vectors
    - ET will apply to 80 EnKF f06 vectors
    - Centering for 20 selected perturbations for integration
    - Theoretically, this design will lost the advantage of lag ensemble
      - No continuation of perturbed vectors from cycle to cycle
  - Centralization
  - 3 dimensional rescaling (3DR)
    - Building analysis error variance (total energy norm)
    - Monthly average from past years EnKF analysis (less inflated one)
    - Rescaling 6hr forecast perturbations by applying 3DR
- Stochastic perturbations
  - Tune STTP for model change and initial perturbation changes
  - Turn off stochastic perturbations for surface pressure in STTP
- Expectations
  - Improve hurricane track forecast
  - Improve probabilistic forecast guidance
  - Improve predictability of HIW and extreme weather event

Initial Perturbations

Background: global ensemble will use EnKF 6-hr forecasts as initial perturbations, not EnKF analysis because the analysis is late.

Additional steps to improve initial perturbations:

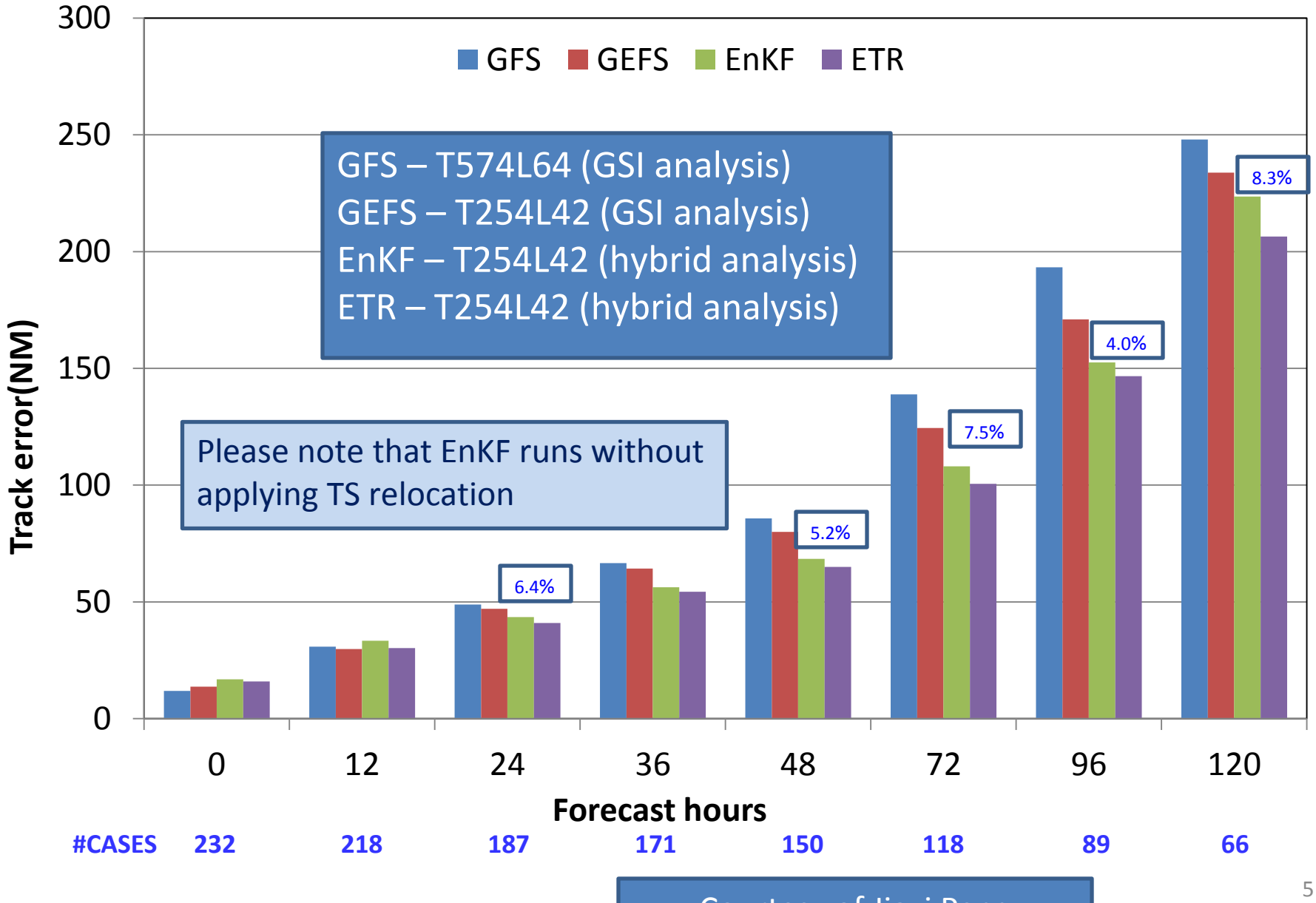
1. Tropical Storm Relocation
2. Ensemble transform
3. Centralization
4. Rescaling

Advantage/disadvantage – down stream applications

1. Tropical Storm Relocation

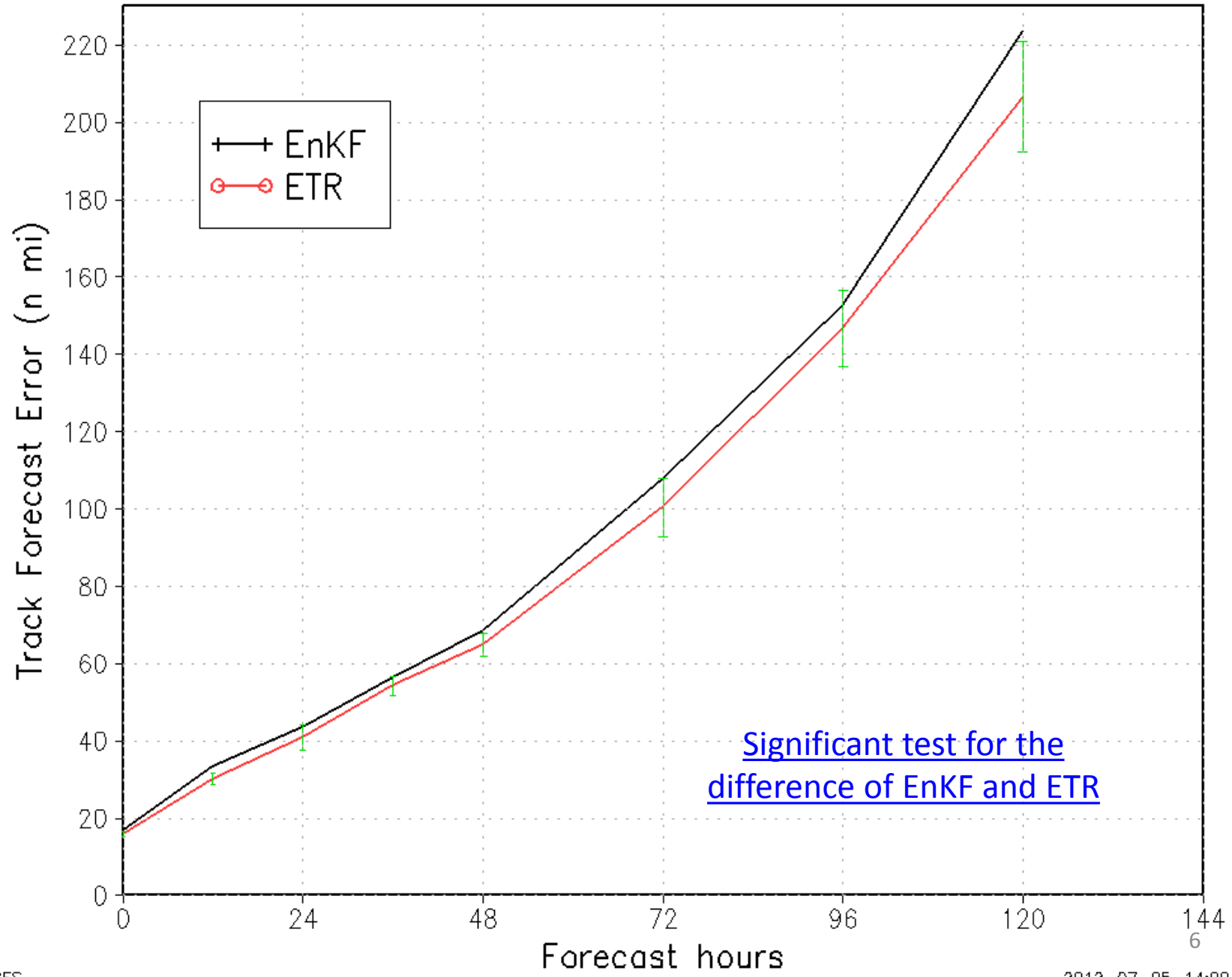
- We have tested EnKF based initial perturbations with/without applying Tropical Storm Relocation (2011 hurricane season). The results indicate there is significantly degraded track forecast skill if there is no TS relocation. (next two slides).
- We will use Mr. Ota's modified version to run ensemble TS relocation (no major difference)
- Will continue to improve TS relocation scheme.

AL01-18,EP03-12, WP08-23 (07/01-10/25/2011)



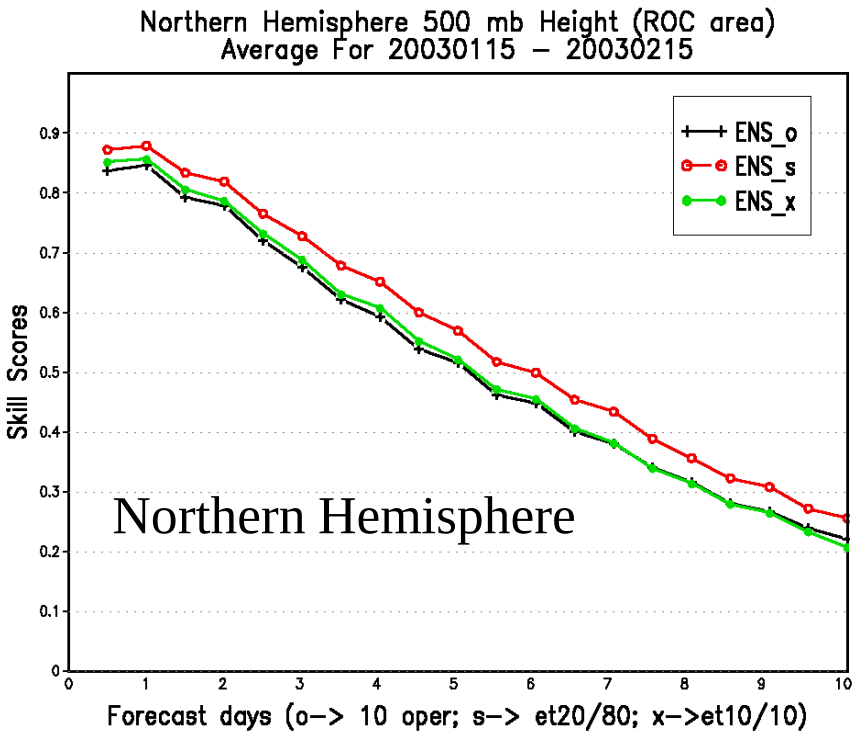
Courtesy of Jiayi Peng

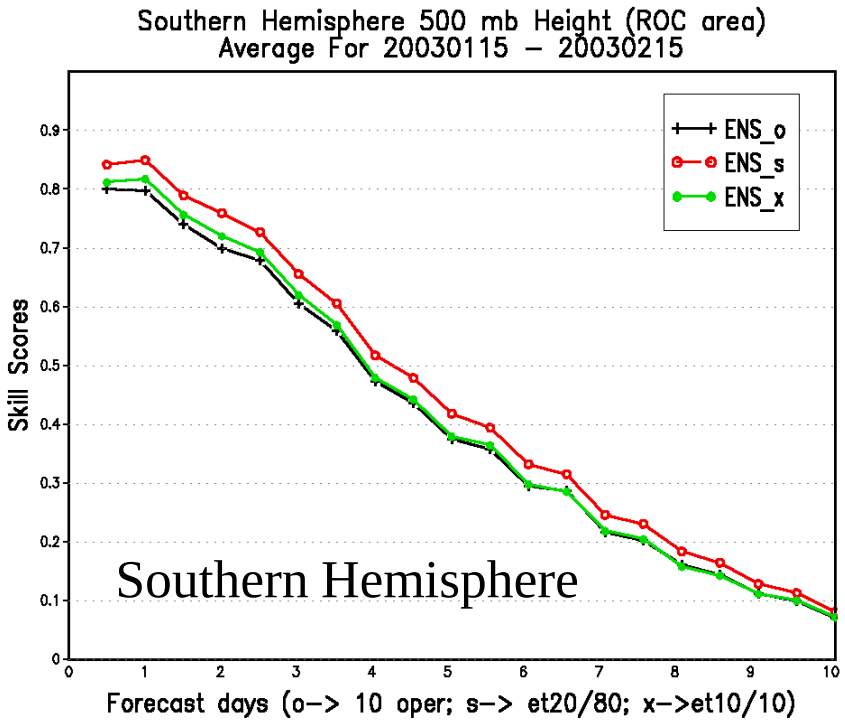
AL01-18,EP03-12, WP08-23 (07/01-10/25/2011)

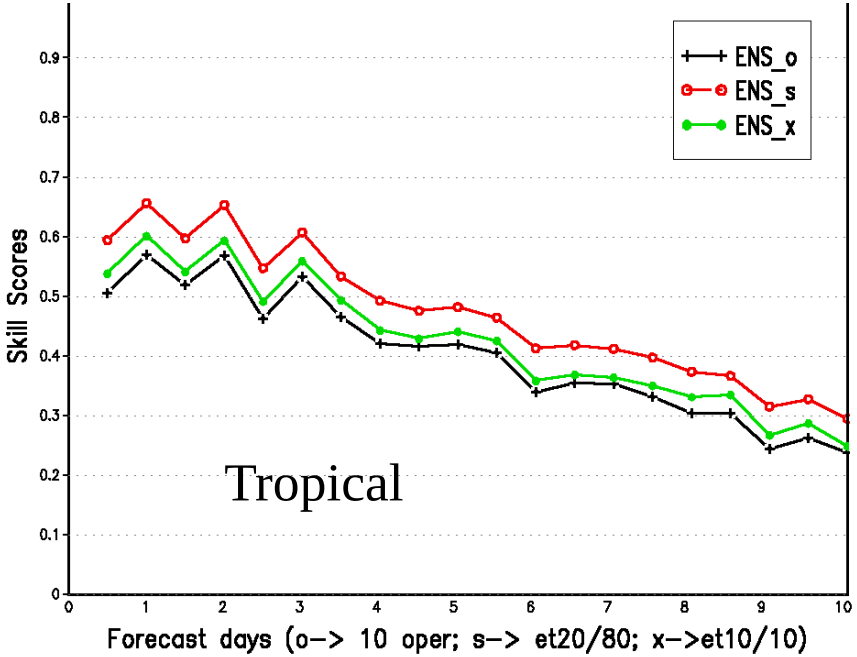


2. Ensemble Transform

- The concept of ensemble transform is to form orthogonal initial vectors (perturbations).
- Example from early study – first time to introduce ET to NCEP GEFS – 2005 (Wei, 2006 and 2008)
- Later example – 2012 for EnKF based initial perturbations (with/without ET)
- This is one step calculation.
- It is right process theoretically. We have an agreement with ESRL (Jeff Whitaker) earlier.







Early studies for ET

Winter of 2002-2003

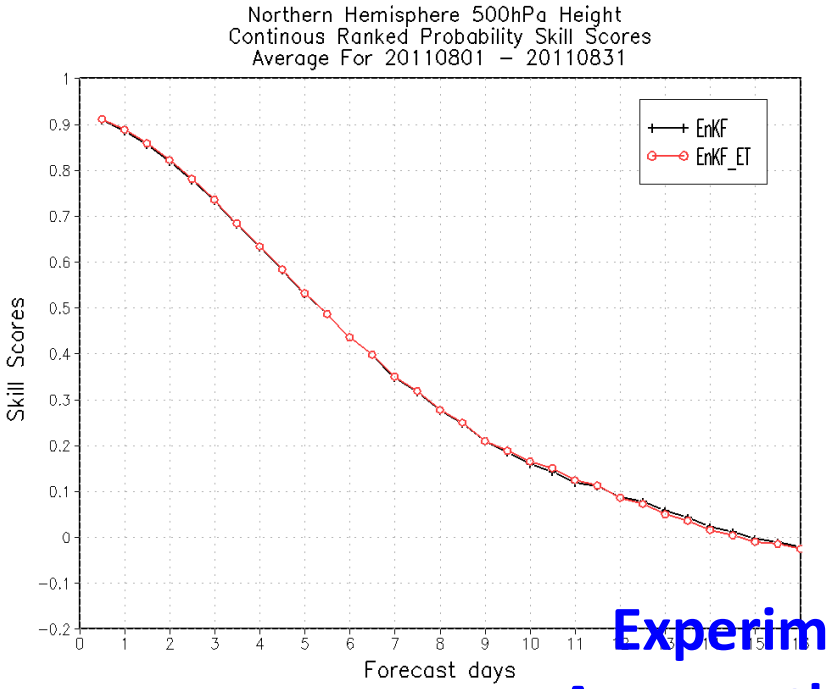
ROC scores for 32 cases

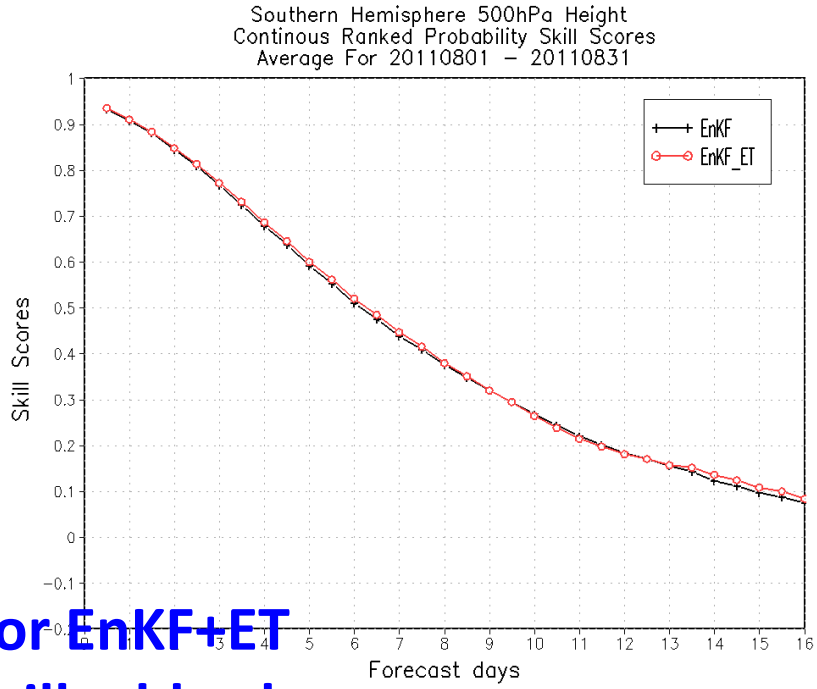
ENS-o → control runs

ENS-s → ET-20 members

ENS-x → ET-10 members

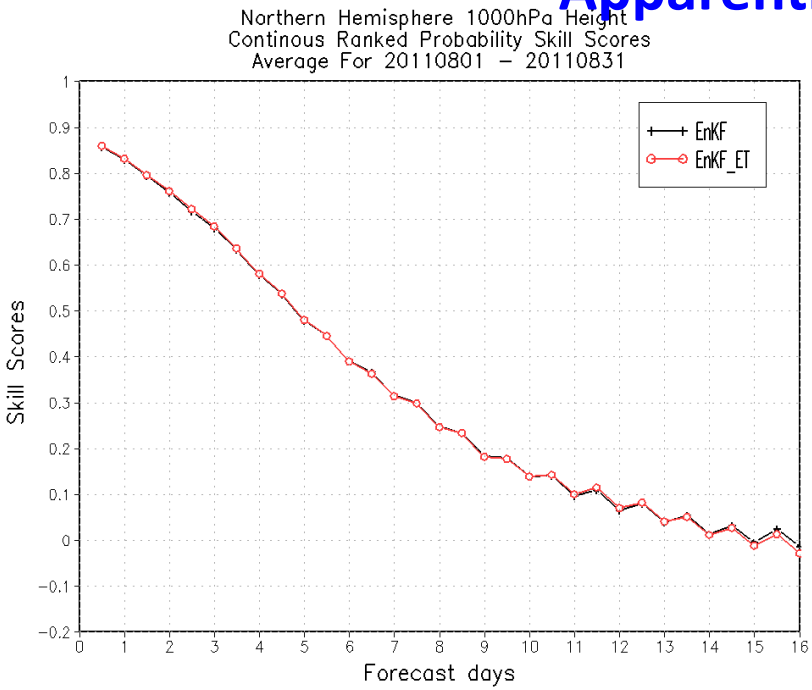
Courtesy of Dr. Mozheng Wei

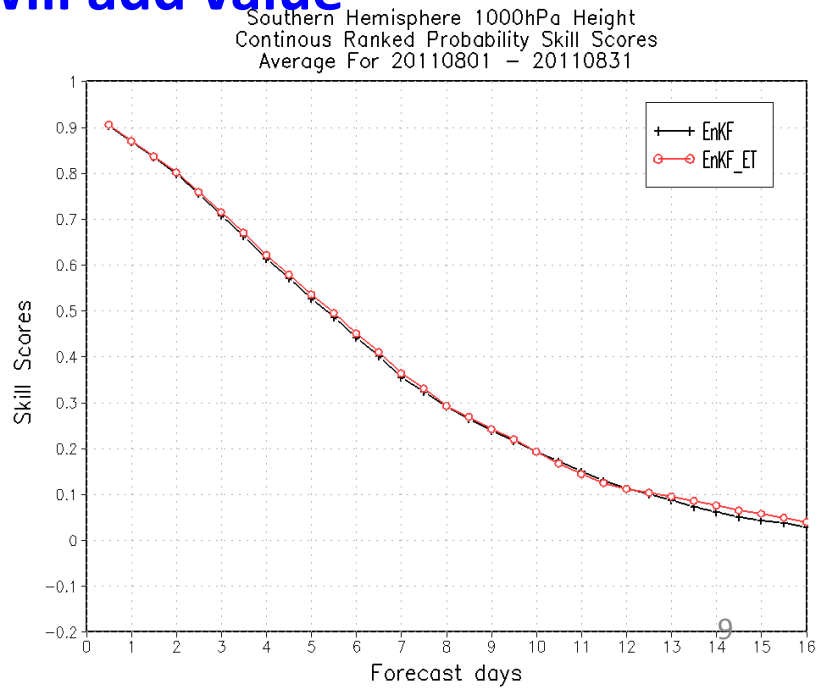




Experiments for EnKF+ET

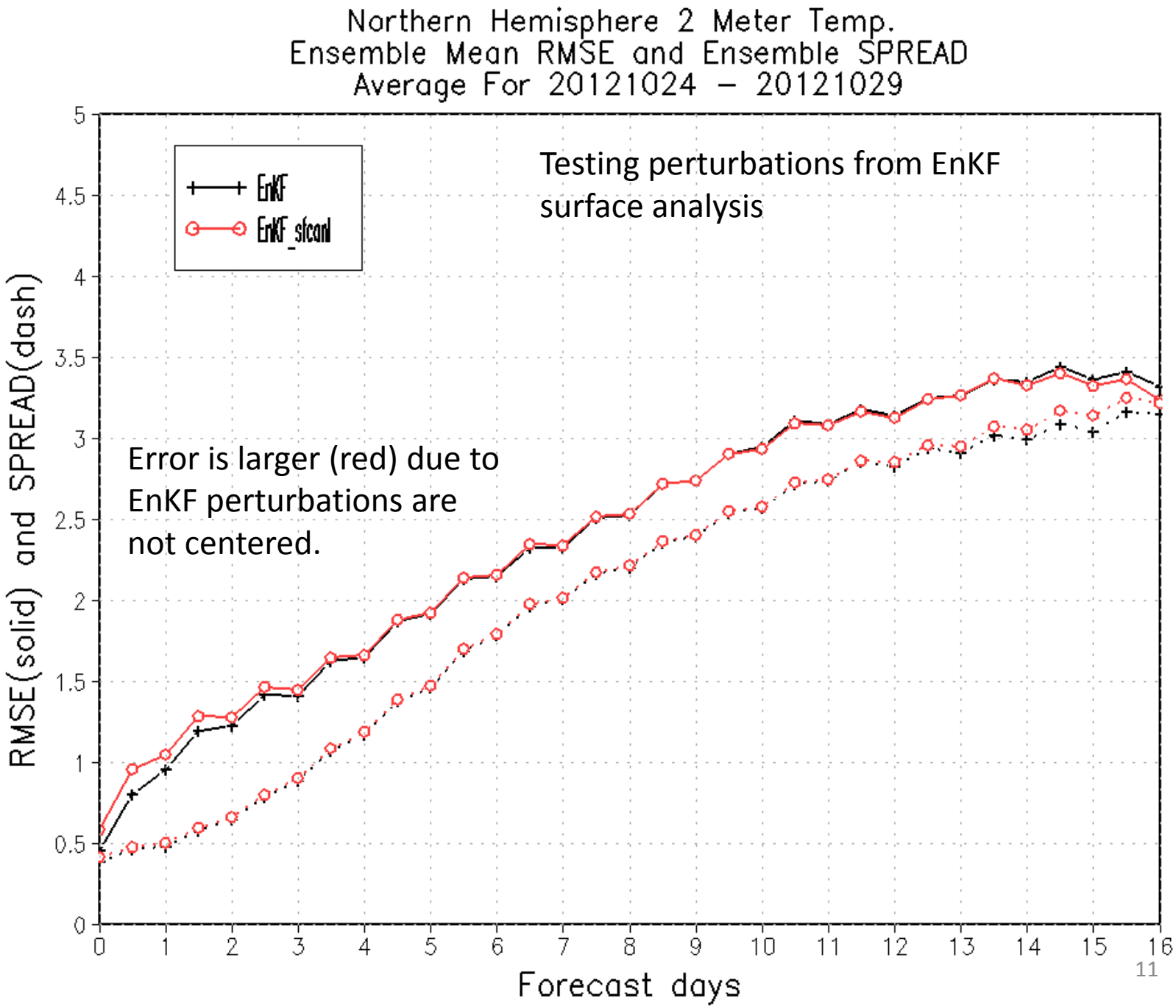
Apparently, ET will add value





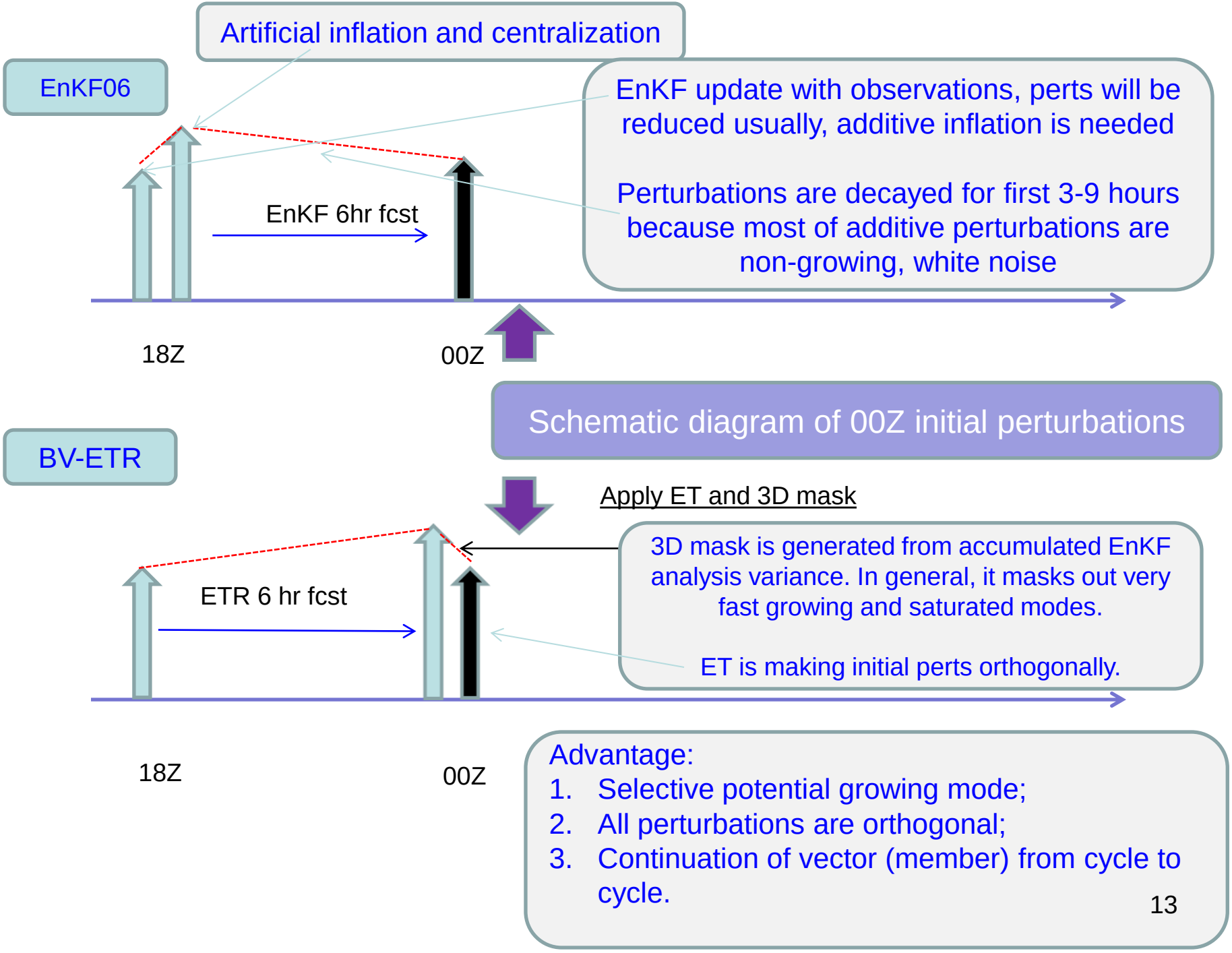
3. Centralization

- It is necessary to have additional step to centralize all perturbations if EnKF does not offer this future.
- Actually, EnKF f06 perturbations are not centralized for 20 members, even there are centralized from analysis (80 members)
- It is hard to understand if the perturbations are not centralized.
- Following example is testing from 20 EnKF surface perturbations without centralization. There is larger error for T2m for short lead time.
- This is one step calculation.
- It is right process theoretically. EnKF does the same thing when cycling EnKF and hybrid analysis.


Northern Hemisphere 2 Meter Temp.
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20121024 - 20121029
EnKF
EnKF_stcanl
Testing perturbations from EnKF surface analysis
Error is larger (red) due to EnKF perturbations are not centered.
RMSE(solid) and SPREAD(dash)
Forecast days
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16

4. Rescaling

- Background of BV-ETR and EnKF (slides 13-14)
- Why do we need rescaling?
  - Because we use EnKF f06 for initial perturbations which is not EnKF analysis
  - Additive inflation to EnKF analysis is not good for ensemble initial perturbations either (because adding decay mode or non-growing mode – white noise); theoretically, stochastic perturbations will have the same characteristics (will test later).
  - In fact, we don't know the size of initial uncertainties. All of them are estimation.
  - For medium-range forecast, it is important to select potential growing mode, not larger initial perturbations (ECMWF ensemble is, and NCEP BV-ETR is, too). **Therefore, for the same growing rate, the smaller initial perturbation is better**.
- What do we expect after rescaling to EnKF f06? (slide #15)
  - Similar to EnKF anl (before additive inflation) in the vertical structure
- Comparison of EnKF anl and f06
  - The perturbations from EnKF f06 is larger and over-dispersive
  - Evaluate errors from own analysis is valid for longer lead-time forecast (slide #18 is from Dr. Buizza's recent presentation)
- The sizes of ECMWF ensemble initial perturbations is very small (slide #22)
- Rescaling is one step calculation.
- **We need to re-visit this conclusion since there is a change of EnKF analysis cycling which mainly introduces stochastic perturbations instead of additive inflation, new model and higher resolutions.**


Artificial inflation and centralization
EnKF06
EnKF update with observations, perts will be reduced usually, additive inflation is needed
Perturbations are decayed for first 3-9 hours because most of additive perturbations are non-growing, white noise
EnKF 6hr fcst
18Z
00Z
Schematic diagram of 00Z initial perturbations
BV-ETR
Apply ET and 3D mask
3D mask is generated from accumulated EnKF analysis variance. In general, it masks out very fast growing and saturated modes.
ET is making initial perts orthogonally.
ETR 6 hr fcst
18Z
00Z
Advantage:
1. Selective potential growing mode;
2. All perturbations are orthogonal;
3. Continuation of vector (member) from cycle to cycle.

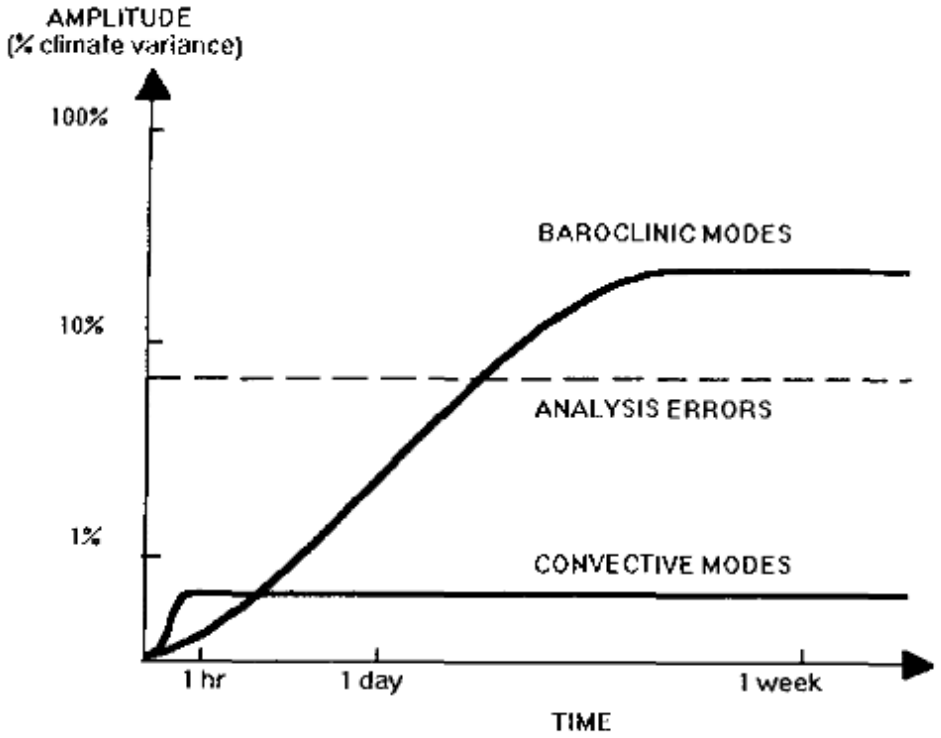
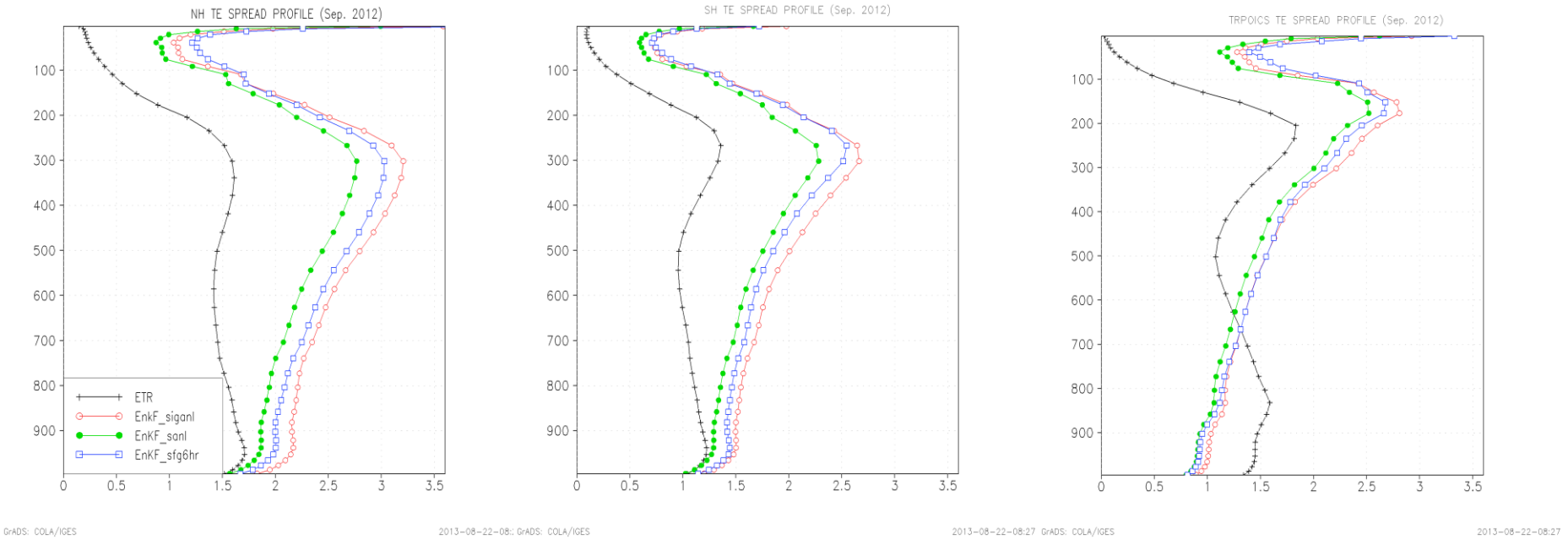


FIG. 6. Schematic of the time evolution of the rms amplitude of high-energy baroclinic modes and low-energy convective modes. Note that although initially growing much faster than the baroclinic modes, convective modes saturate at a substantially lower level.

In general, breeding method is more conception, and SV is more practical.

Since we don't know the size of initial uncertainties, we believe that smaller initial perturbations will be better (if it grows faster and catch up forecast errors)

Early study from Zoltan Toth: BAMS 1992



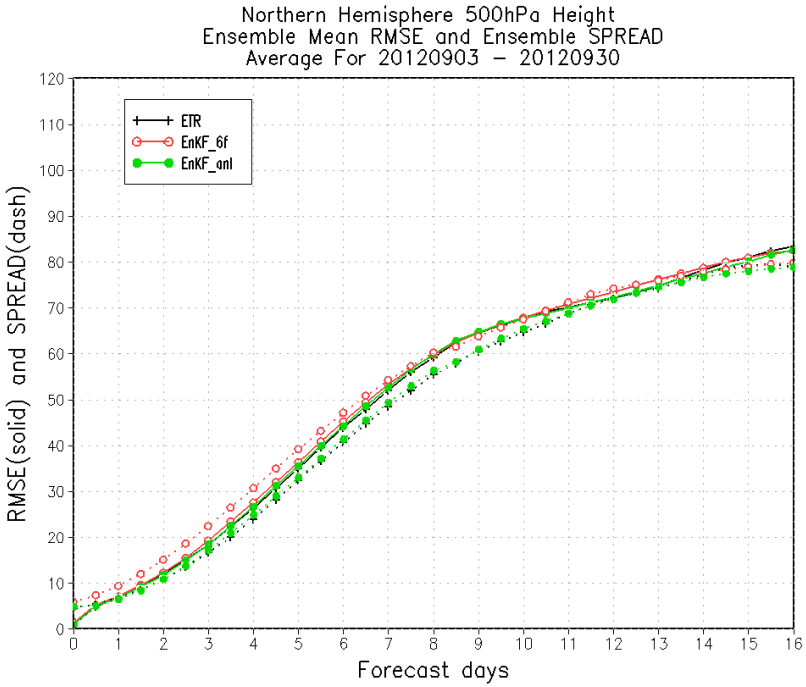
Black-ETR; Green-EnKF analysis without additive inflation; Red-EnKF analysis; Blue-EnKF f06

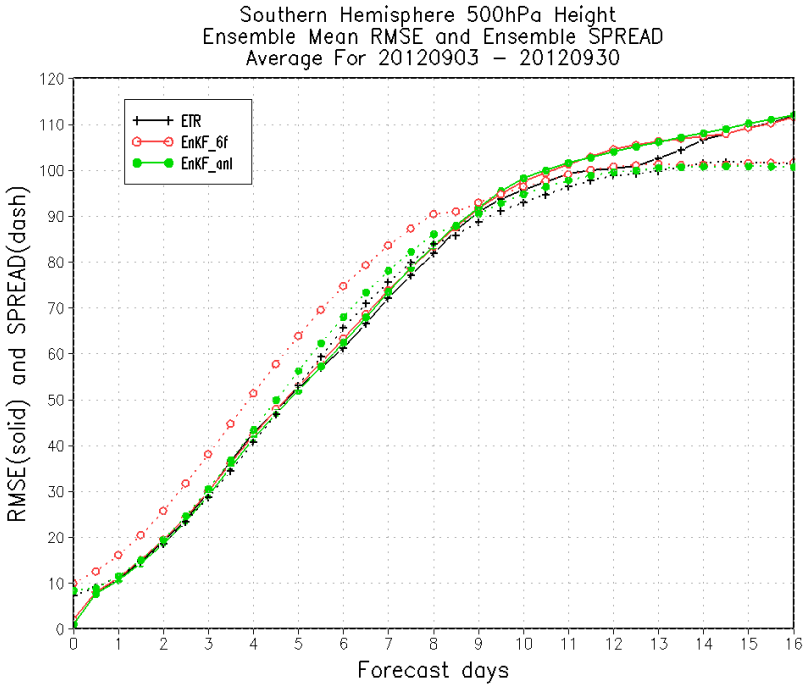
Vertical profiles of initial perturbation spread in terms of total dry energy in the ETR and EnKF experiments over a) NH, b) SH and c) Tropics. Three EnKF profiles represent the spread of EnKF perturbations after multiple inflations (green curves), additive inflation (red) and 6-hr forecast (blue). The profiles are averaged from 1 July – 17 Oct. 2011.

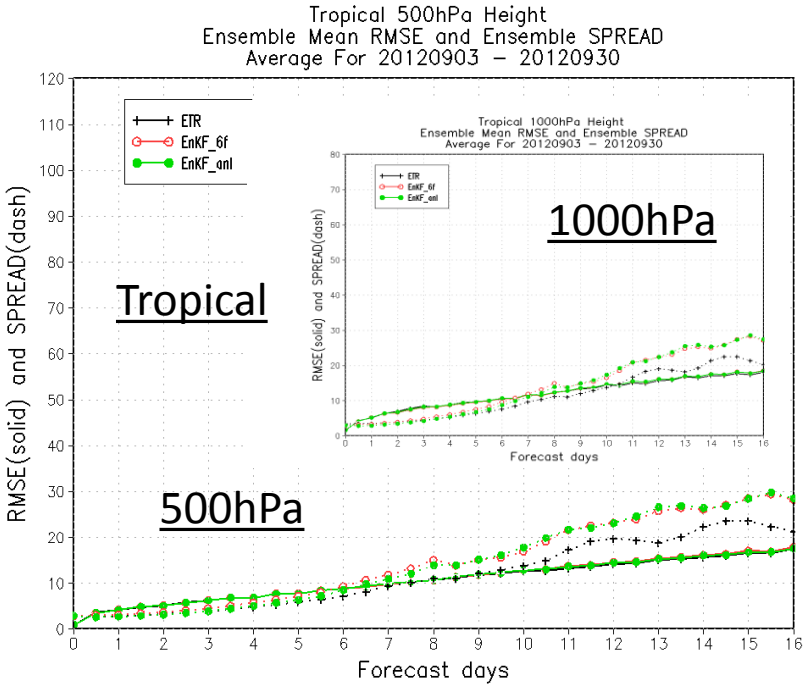
Experiment (1)

- Comparison of EnKF anl and EnKF f06 perturbations

- Period: 2012/09/03 – 2012/09/30 (27 days)
- Current operational model configuration
  - T254L42 (0-192 hours)
  - T190L42 (192-384 hours)
- STTP is on
- No ETR process for EnKF
- Three different initial perturbations
  - BV-ETR operation
  - EnKF Anl (final analysis)
  - EnKF F06 (from previous cycle)
- Machine – WCOSS







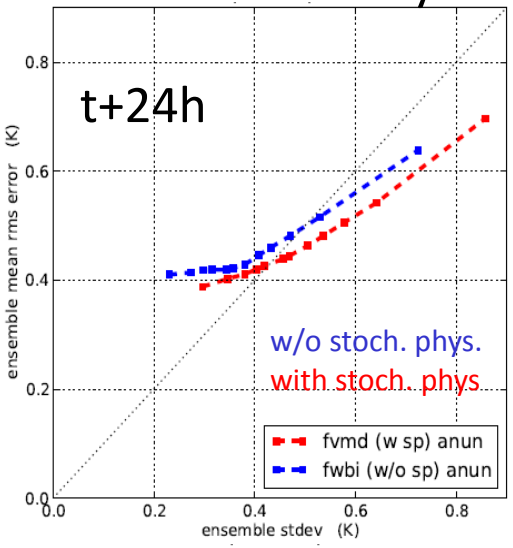
Apparently, the initial perturbations from EnKF f06 has much larger initial uncertainties for both hemispheres. It is larger than EnKF anl and ETR cycling. The skills are all similar (or a little degraded) from this short statistics.

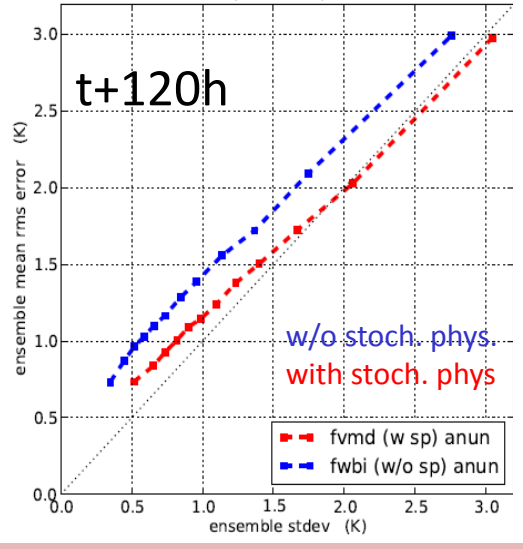
Tropical is over-dispersion for all three, and longer lead times, but both of EnKF anl and f06 are very similar which means this is not related initial perturbations, we need to inspect STTP as well.

How do they perform? Ensembles must be reliable

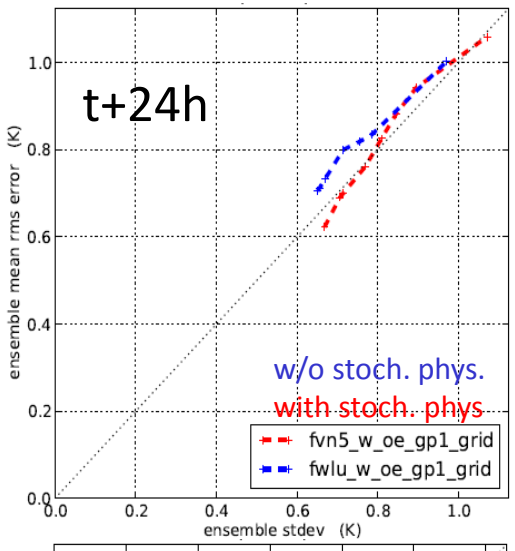
ENS reliability is sensitive to verification field (analysis or obs).

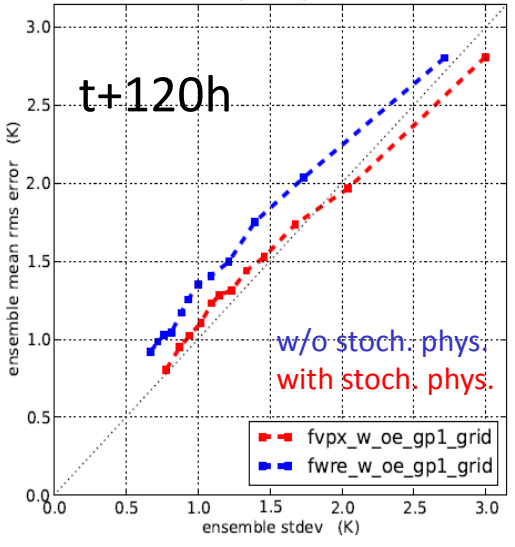
NH T500 – fc v analysis



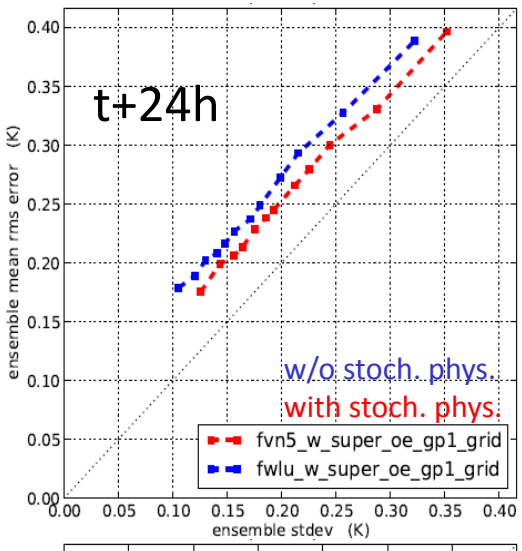


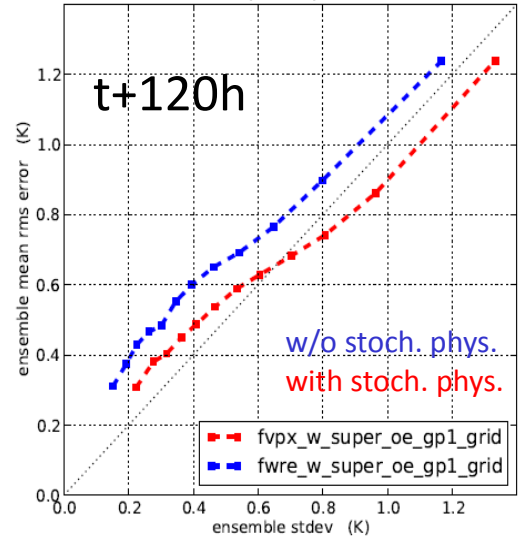
NH T500 – fc v radiosondes





NH T500 – fc v AMSUA





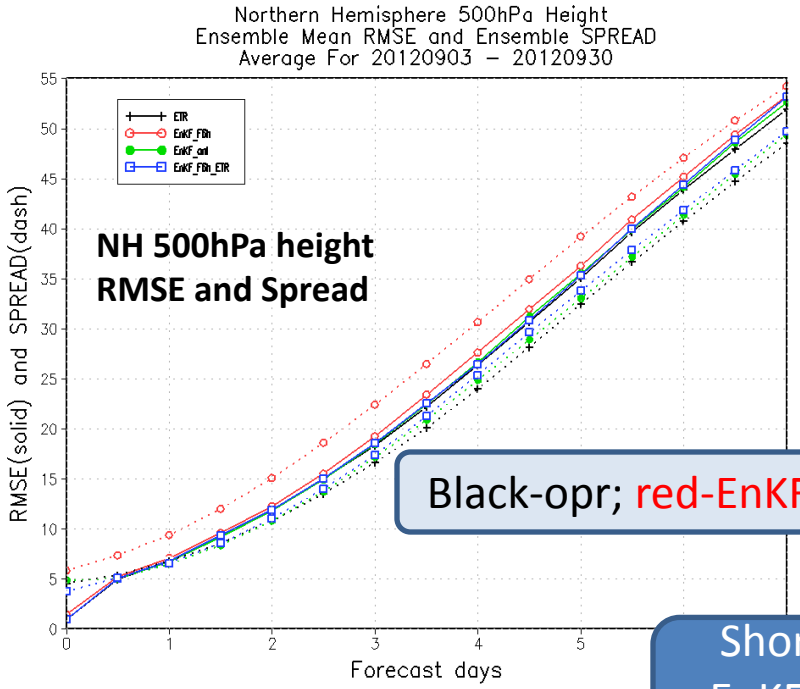
This verification indicates that the statistics are sensitive to verify analysis/observation for short lead-time, but not for 120 hours

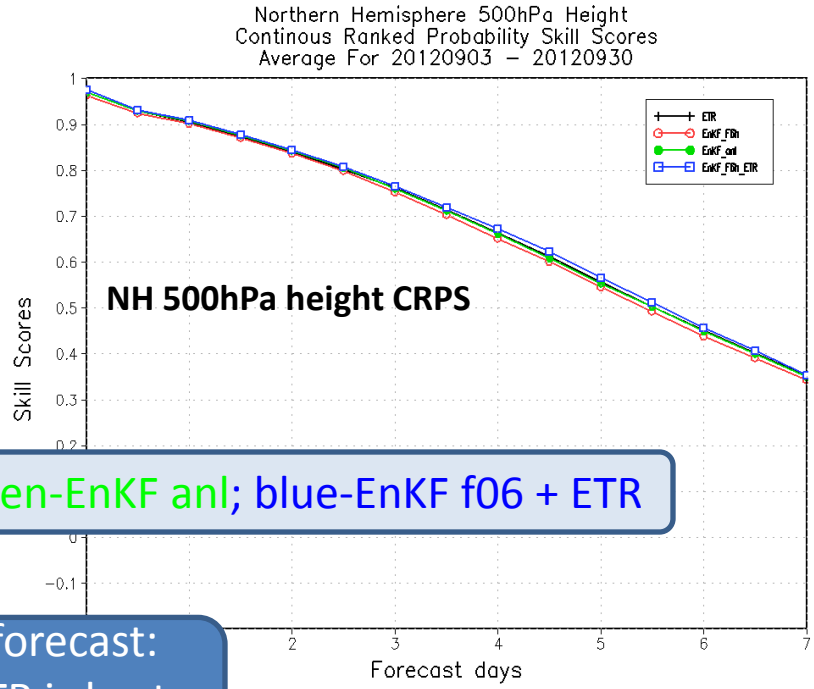
(From M Yamaguchi)

Experiment (2)

- Comparison of EnKF anl, EnKF f06 and recaling perturbations

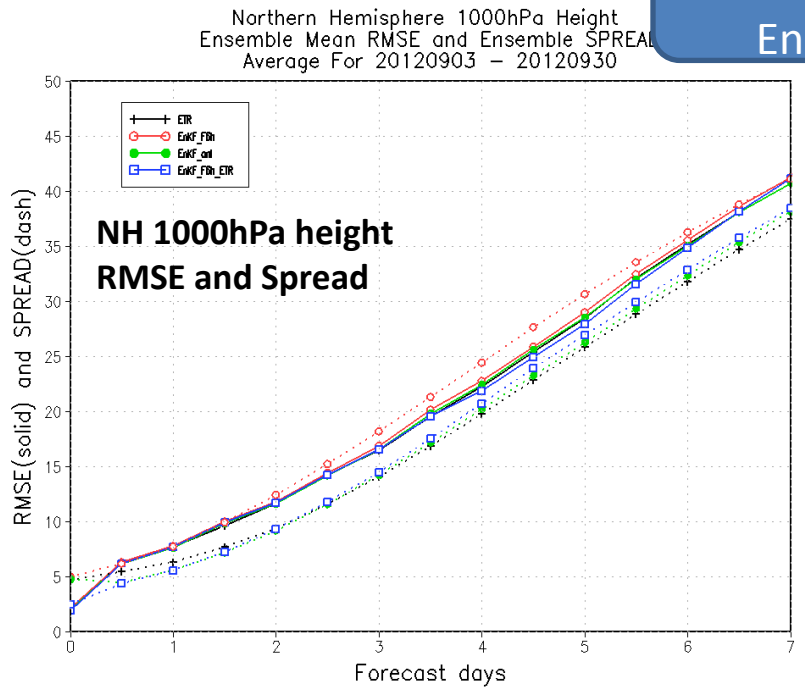
- Period: 2012/09/03 – 2012/09/30 (27 days)
- Current operational model configuration
  - T254L42 (0-192 hours)
  - T190L42 (192-384 hours)
- STTP is on
- Four different initial perturbations
  - BV-ETR operation
  - EnKF Anl (final analysis)
  - EnKF F06 (from previous cycle)
  - EnKF F06 (from previous cycle) + Rescaling
- Machine – WCOSS

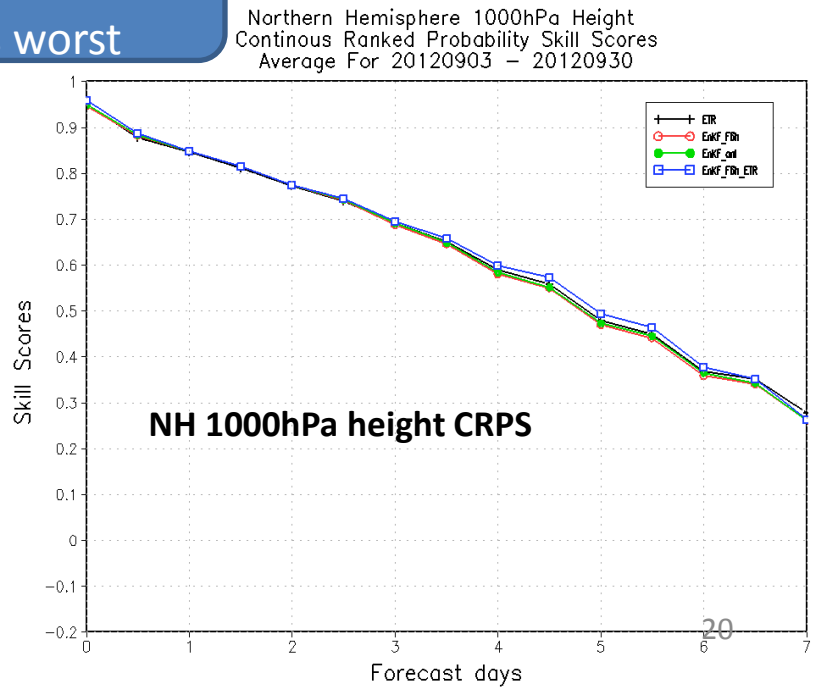




Black-opr; red-EnKF f06; green-EnKF anl; blue-EnKF f06 + ETR

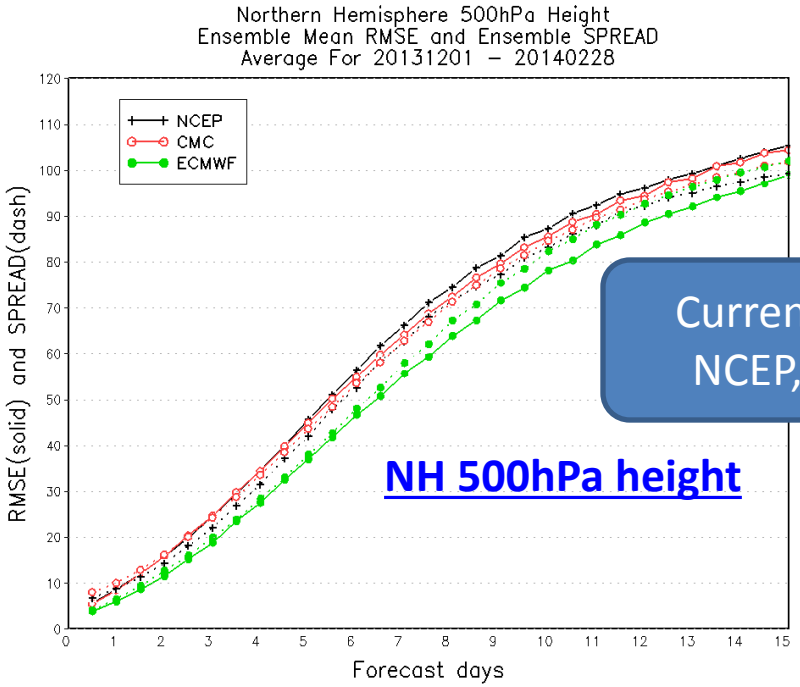
Short-range forecast:
EnKF F06 + ETR is best
EnKF F06 is worst

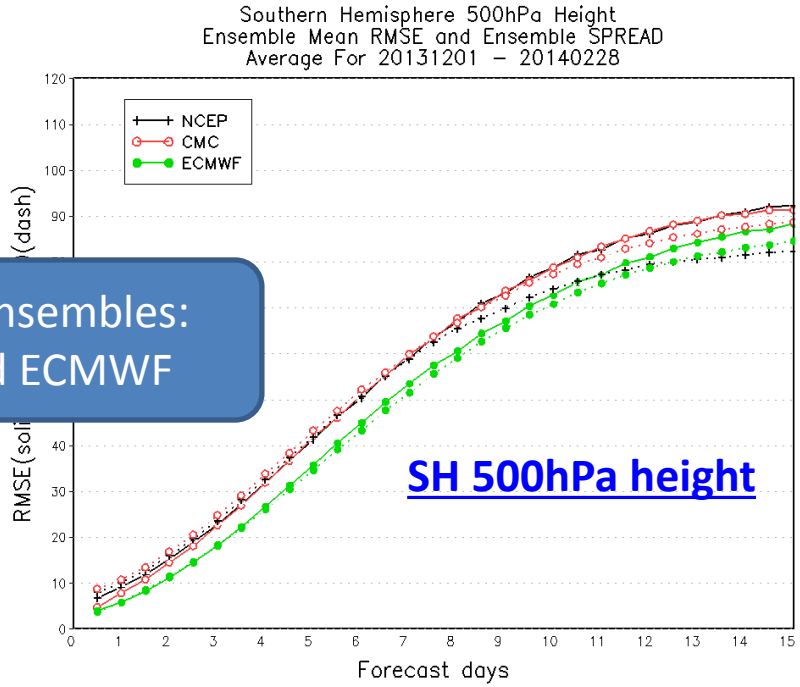




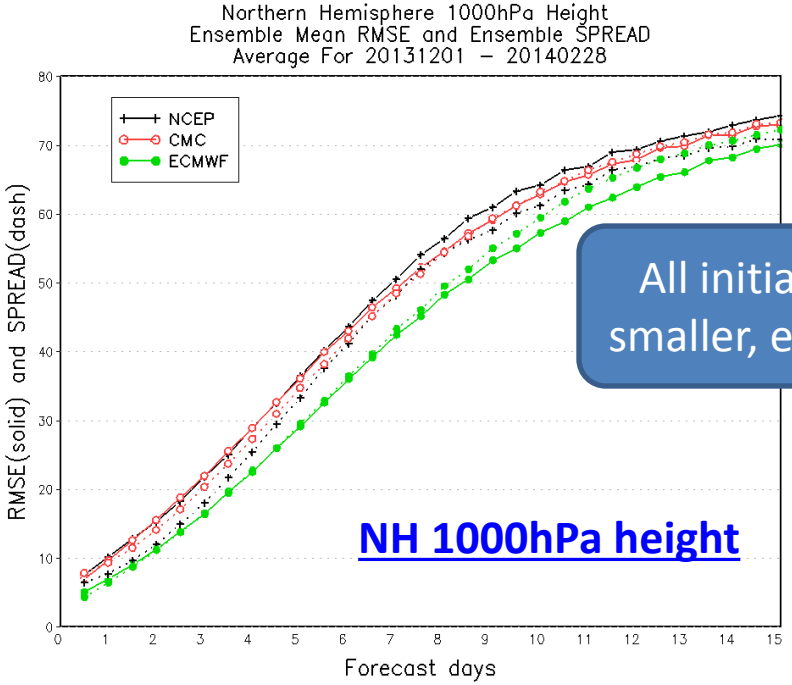
Compare to other global ensembles

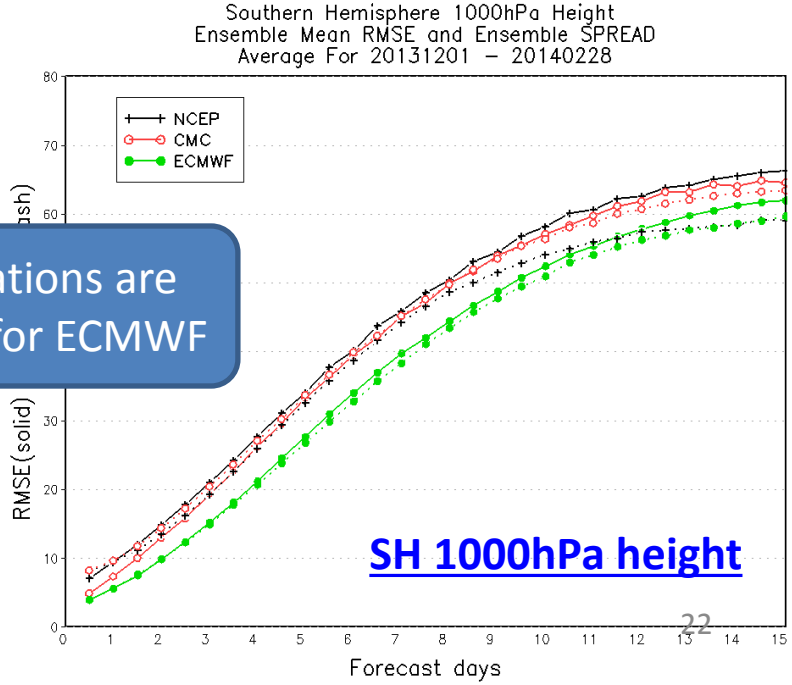
ECMWF has relatively smaller initial perturbations





Current three ensembles:
NCEP, CMC and ECMWF





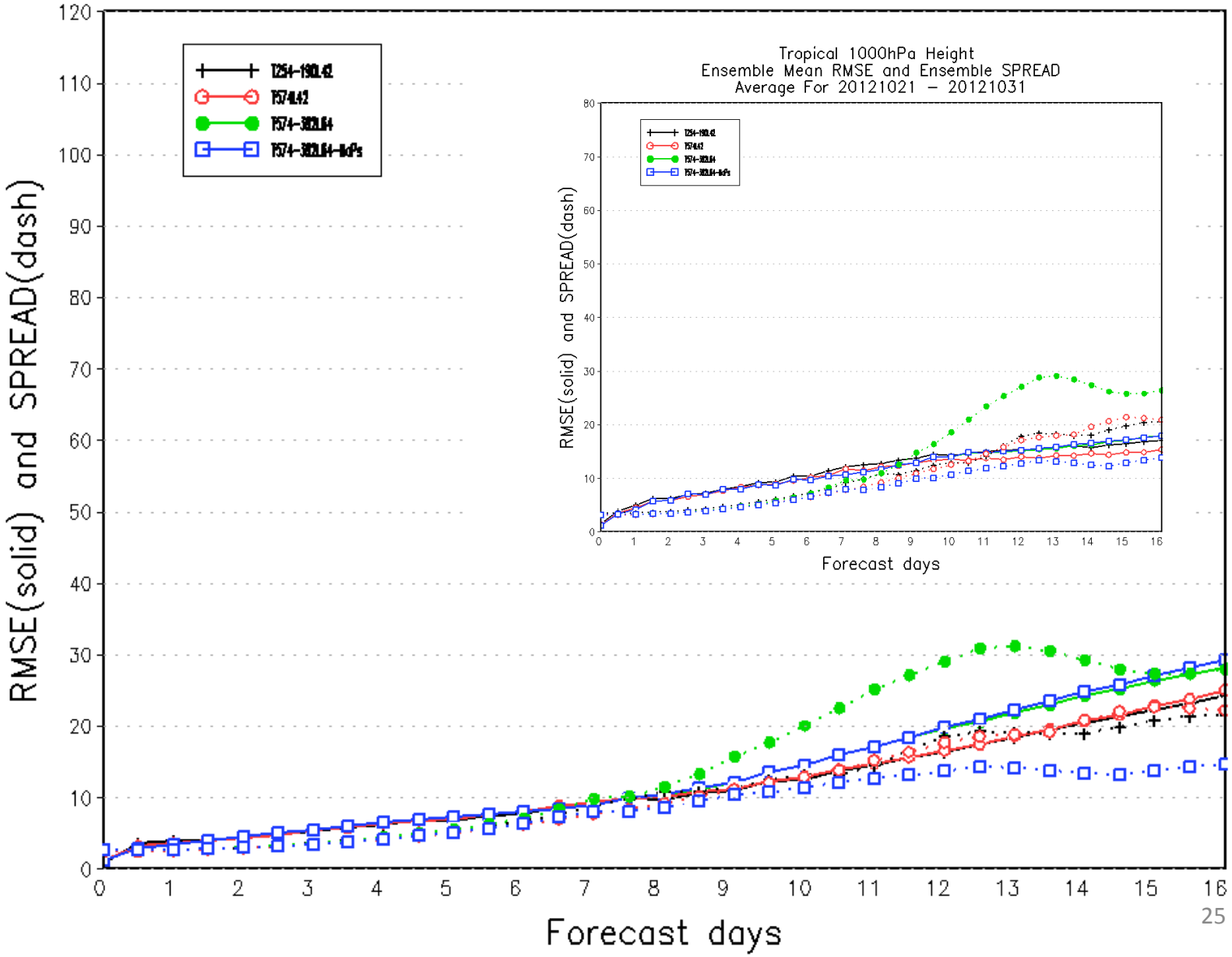
All initial perturbations are
smaller, especially for ECMWF

Down stream application – Wave Ensemble

- Traditionally, NCEP global ensemble is using Breeding Vector on 6-hr cycling, each ensemble vector (member) is continually growing with time integration. This is important for one of GEFS down stream application – swell (ocean) of wave ensemble prediction.
- After introduce EnKF perturbations, this future will be dis-continued, the evaluations will be investigated (later).

Stochastic perturbations

- STTP – stochastic total tendency perturbations
  - Tune parameters for higher resolution model
  - Tune parameters for new semi-Lagrangian model
  - Turn off stochastic perturbations for surface pressure (log Ps).
  - to suppress the overgrowth of spread in geopotential height over the Tropics
- Other stochastic schemes – in testing
  - SPPT, SHUM, SKEB and VC have already installed in GFS system for EnKF analysis, will test these schemes for extended forecasts.

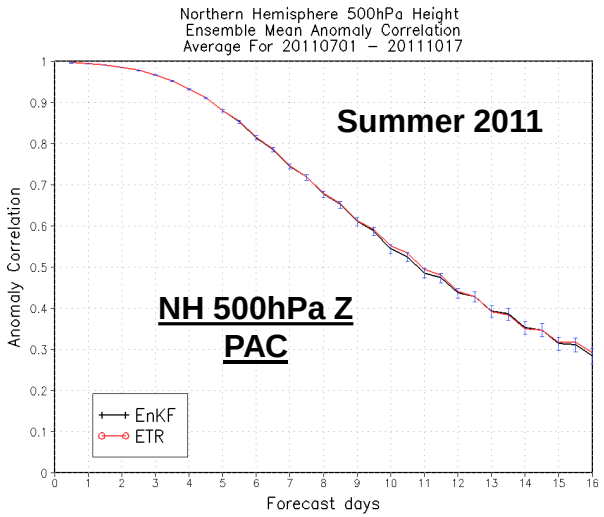

Tropical 500hPa Height
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20121021 - 20121031
RMSE(solid) and SPREAD(dash)
Forecast days
Tropical 1000hPa Height
Ensemble Mean RMSE and Ensemble SPREAD
Average For 20121021 - 20121031
RMSE(solid) and SPREAD(dash)
Forecast days

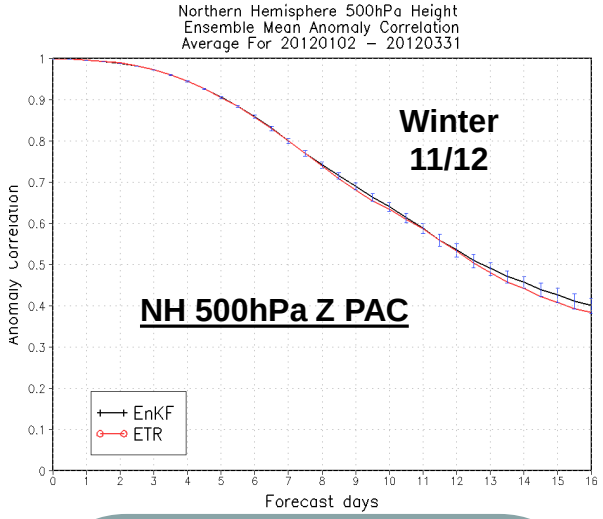
Background!!!

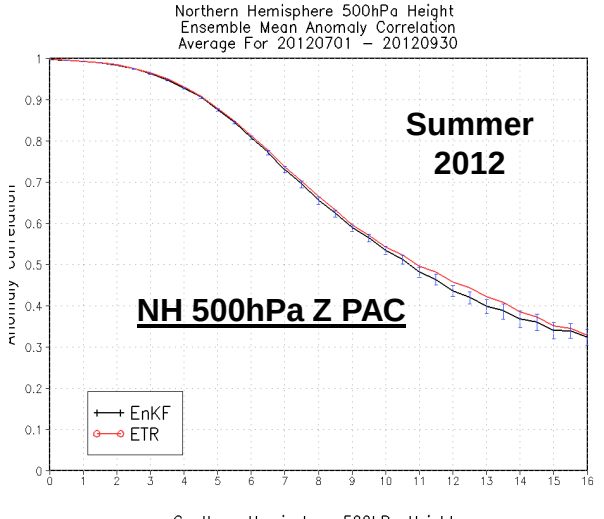
EMC's Plan to Reframe GEFS Initializations

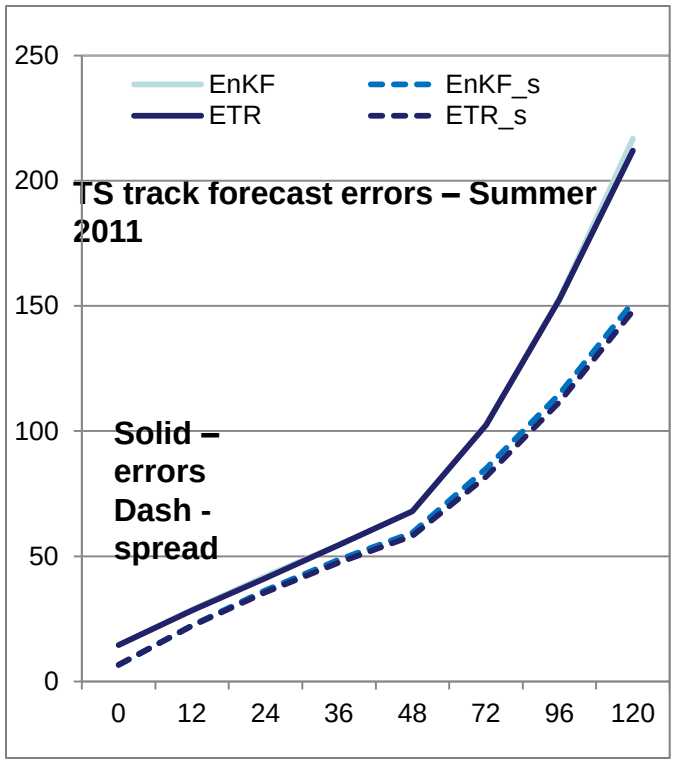
- Background:
  - *BV-ETR:* It is NCEP Global Ensemble Forecast System (GEFS) initialization since 1992 – which is dynamically breading orthogonal, fast growing perturbations in region of high baroclinicity.
  - *HVEDAS:* Hybrid Variational Ensemble Data Assimilation System has been implemented on May 22nd, to deliver better quality of analysis (or initial condition of forecast) through improved background error covariance from EnKF 6hr forecasts.
  - *EnKF:* Ensemble Kalman Filter data assimilation has been implemented on May 22nd for HVEDAS, which evolves an ensemble over data assimilation, updated at successive observation times.
  - *Evaluations:* To assess the difference by comparing BV-ETR and EnKF (F06) initialized ensemble forecast (show statistics – next slide).
- Motivations:
  - To reduce computational cost of double cycling of 80 members ensemble short forecasts.
  - To enhance our Global Ensemble Forecast System (GEFS).
  - To take the best of BV-ETR and EnKF, improving ensemble initial perturbations and forecast (in studying).
- In reality:
  - In daily operation, EnKF and HVEDAS run later (final - +6hrs) than GEFS (+4.5hrs). Therefore, EnKF (F06) from previous cycle could be only one for possible GEFS initial perturbations. In fact, EnKF (F06) perturbations are not ideally (optimum) representing analysis uncertainties. Additional processes, such as rescaling, adjustment and et al. are necessary.

Comparison of ETR .vs EnKF (f06) initialized ensemble forecasts



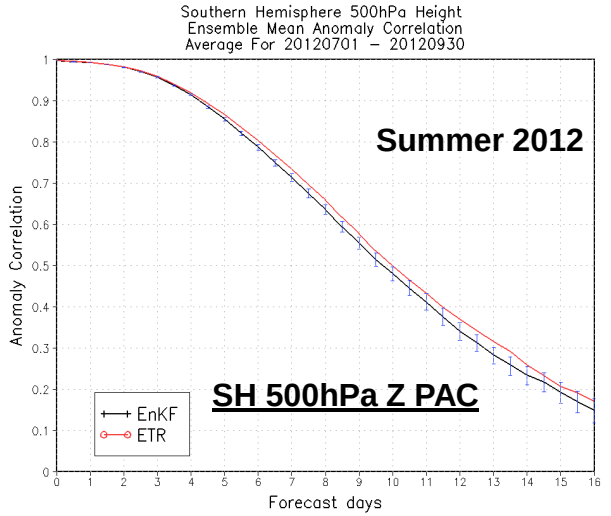


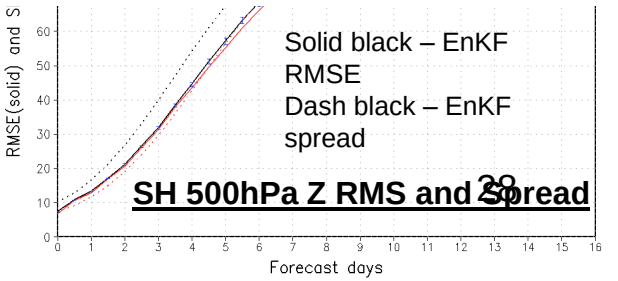




Summary of comparison:
(Three seasons – Summer 2011, Winter 2011/2012 and Summer 2012)

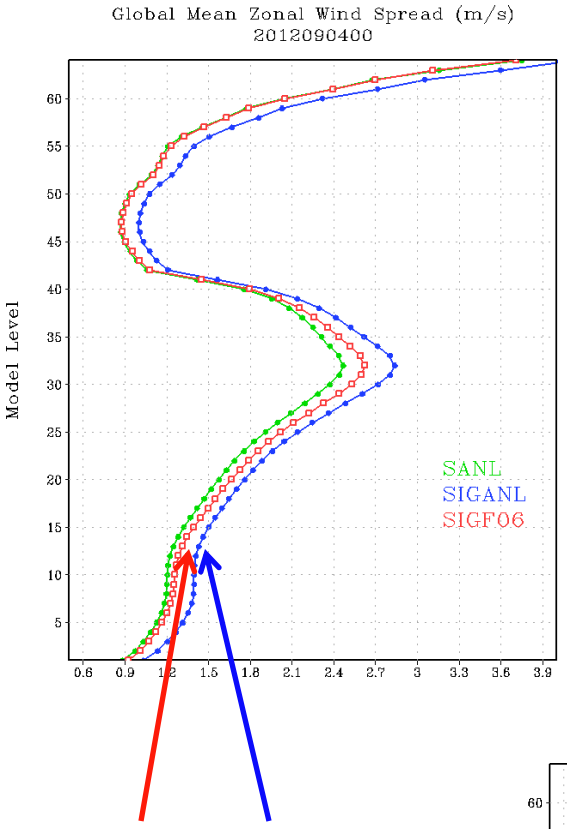
1. For Northern Hemisphere ensemble mean and probabilistic forecasts – they are very similar to each other; the differences are insignificant mostly. EnKF has a little better probabilistic forecast for very short lead time due to larger spread.
2. For Southern Hemisphere mean and probabilistic forecast – ETR is better than EnKF, especially for the two summer seasons. EnkF is over dispersion for SH in generally.
3. Tropical Storm track forecast, ETR and EnKF have similar forecast errors and ensemble spread for two summer seasons. The differences are insignificant.
4. For summer 2012, ETR is better than EnKF's performance over all.

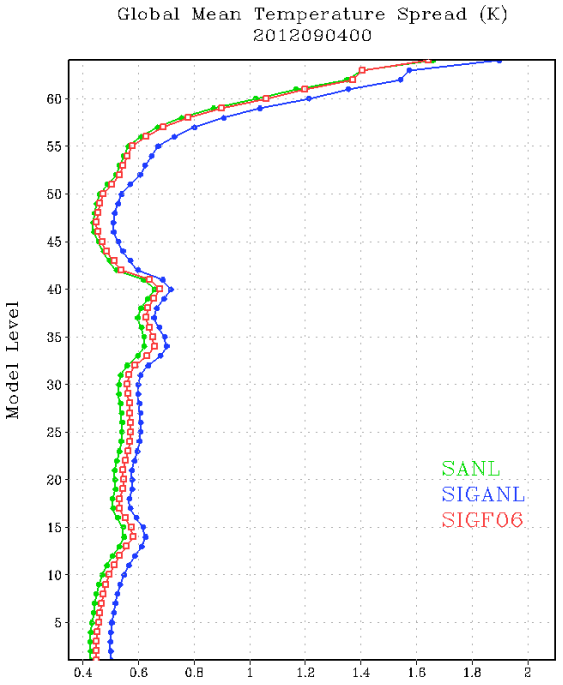




Plans

- Short-term: mainly focus on next implementation.
  - Build up updated (accumulated) EnKF based analyses error variance (potential 3D rescaling mask) to replace current operational analysis error variance (2D mask).
  - Investigate EnKF (f06) forecast perturbations as potential candidate of GEFS initial perturbations.
    - Continue comparing EnKF (f06) ensemble forecast to current operation to confirm there are no major degradations.
    - Test ET applied to EnKF (f06) perturbations by using analysis variance as statistical reference – emphasize smaller scale analysis error.
    - Test ET for EnKF (F06) perturbations with 3D/2D (mask) rescaling.
    - Test different rescaling factors for latitude band to reduce initial spread of EnKF (f06), especial for southern hemisphere.
  - Other possibilities and options (depends on the resources)
    - Investigate BV-ETR perturbations.
      - At lower resolution (T62L64) with cycling (much cheaper).
      - Emphasize large scale initial errors, baroclinic scale (breeding) and maximum growing vectors (ET).
    - Combine EnKF (f06) perturbations and ET (lower resolution) perturbations (with rescaling?) – similar concept to ECMWF's configuration (EDA+SV)
    - Test Analysis Error Covariance(AEC)-Singular Vector (SV) for EnKF forecast perturbation (refer to Wang and Hamill)
- Long-term:
  - Continue our investigation for optimum global ensemble initialization.
  - Study the perturbations for surface variables which include soil moisture, soil temperature, SST and etc.





Spread is decaying from siganl levels to a level close to the original sanl (pre-inflation) value