Optimization of GEFS Stochastic Total Tendency Perturbation (STTP) Scheme with Upgraded GFS Model and Increased Resolution

*Dingchen Hou, Yuejian Zhu, Shrinivas Moorthi, Juhui Ma**, Weiyu Yang* and Richard Wobus**

Environmental Modeling Center/NCEP/NOAA
5200 Auth Road, Camp Springs, MD 20746, USA

* Also Affiliated with IMSG at EMC/NCEP/NOAA
** UCAR Visiting Scientist

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Outline

- Introduction to STTP
- Operational Implementation of STTP in 2010
- GEFS Upgrade Planned for 2011
- Results of STTP Parameter Tuning
- Summary

Introduction to
Stochastic Total Tendency Perturbation (STTP) Scheme

General Expression: $\frac{\partial X_i}{\partial t} = T(X_i;t) + S_i(t)$ **for each ensemble member i**

T=Conventional Tendency, S=Stochastic Tendency

Strategy: Use $P_i = T_i - T_0$ vectors as the basis for stochastic forcing S

Formulation of S vectors: $S_i \sim \sum_j w_{i,j} P_j$

Generate the S terms from (random) linear combinations of the conventional perturbation tendencies, similar to ET but applied to ensemble perturbation tendencies successively

Required Properties of S vectors:

Applied to all state variables (Yes)
Orthogonal (Ensured by the specification of $w_{i,j}$)
Flow dependent (Yes)
Spatial and cross-variable correlation (Automatically available)

Introduction to
Stochastic Total Tendency Perturbation (STTP) Scheme

Computational Implementation:

1. Integrate all ensemble members concurrently with ESMF
2. Use finite difference (6 hour interval) form for the stochastic term
3. Execute the original model executable but pause every 6 hours to modify the model state

$$X_i^{'} = X_i + \gamma \sum_{j=1}^{N} w_{i,j}(t)\left\{\left[\left(X_j\right)_t - \left(X_j\right)_{t-6h}\right] - \left[\left(X_0\right)_t - \left(X_0\right)_{t-6h}\right]\right\}$$

Where γ is a rescaling factor, controlling the size of stochastic perturbations added to the model

Impact on Ensemble Forecast

1. Increase ensemble spread and reduced outliers
2. Reduced systematic errors
3. Improved Probabilistic Forecasts

Operational Implementation of STTP with GEFS upgrading on Feb. 23 2010

GEFS Configuration

- Continue using the GFS version operational at that time
- Upgrade horizontal resolution from T126 to T190, with 28 vertical levels
  - 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 the implementation of STTP
- Add STTP to account for random model errors
  - Increased ensemble spread and improved forecast skill

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

STTP Specifications:

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

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

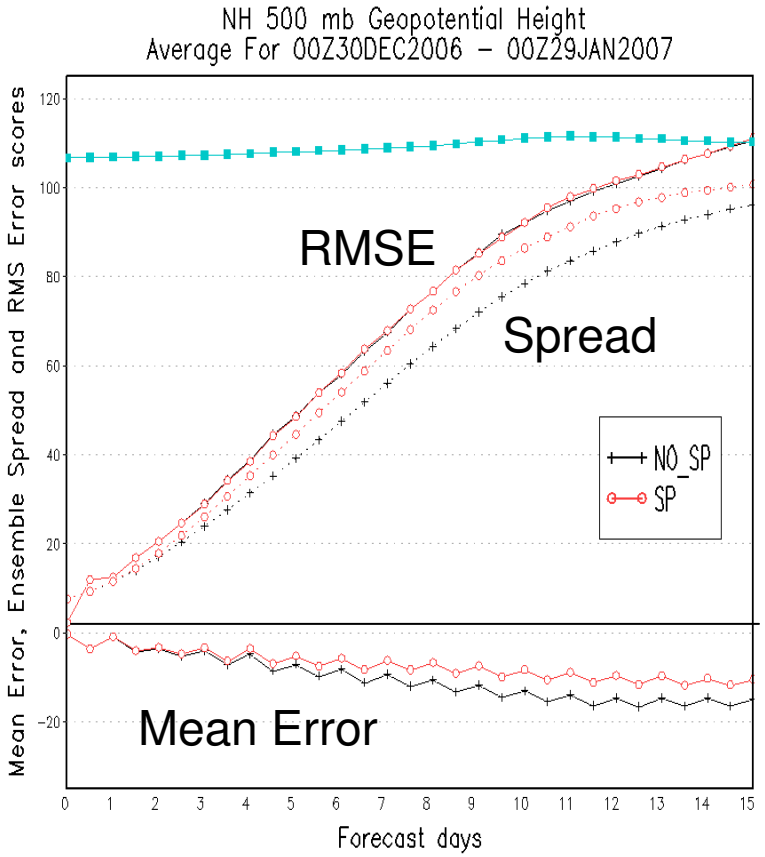
$$\gamma_0(t) = \pm[p_2 + (p_1 - p_2)\left\{1.0 - \frac{1.0}{1.0 + e^{-p_3(t-p_4)}}\right\}]$$

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
Parameters: p1=0.1, p2=0.01, p3=0.11, p4=252 hours
These are on the conservative side to ensure operational stability and minimize negative impacts
STTP functionalities are build in GFC code and STTP parameters hardwired

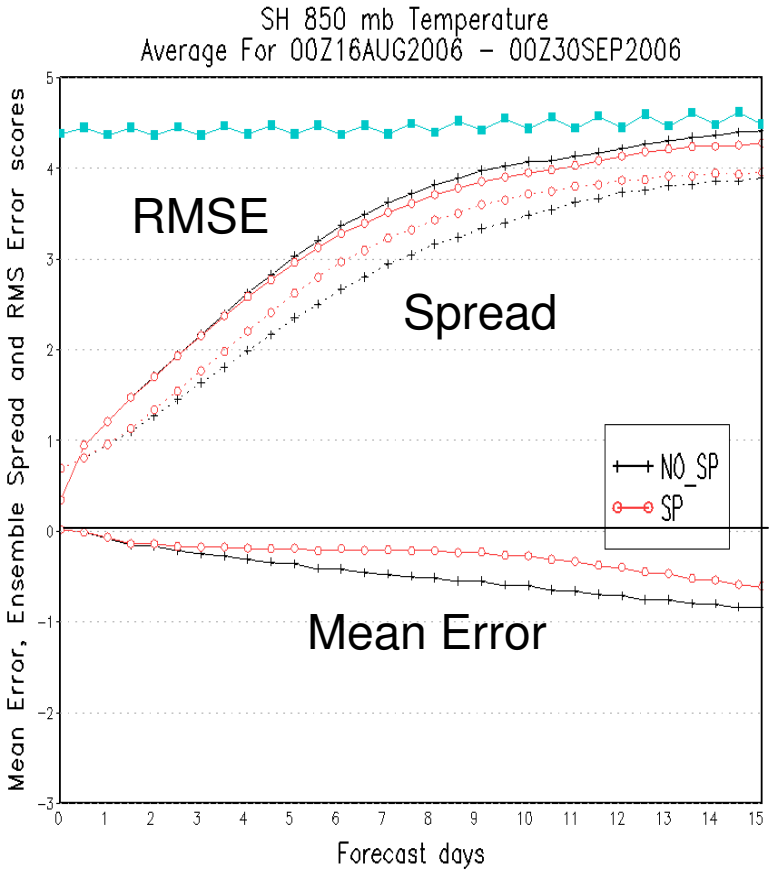
Operational Implementation of STTP with GEFS upgrading on Feb. 23, 2010

Test with T190L28 resolution, With STTP and Without STTP

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



NH H500 Winter



SH T850 Winter

NEXT Implementation of GEFS, Planed for 2011

- Using upgraded GFS model

  Improved physics packages

  Implemented in GFS high resolution run (T574L64) on July 28, 2010, but not in GEFS yet

  Improved performance in deterministic forecast

- Increasing Resolution:

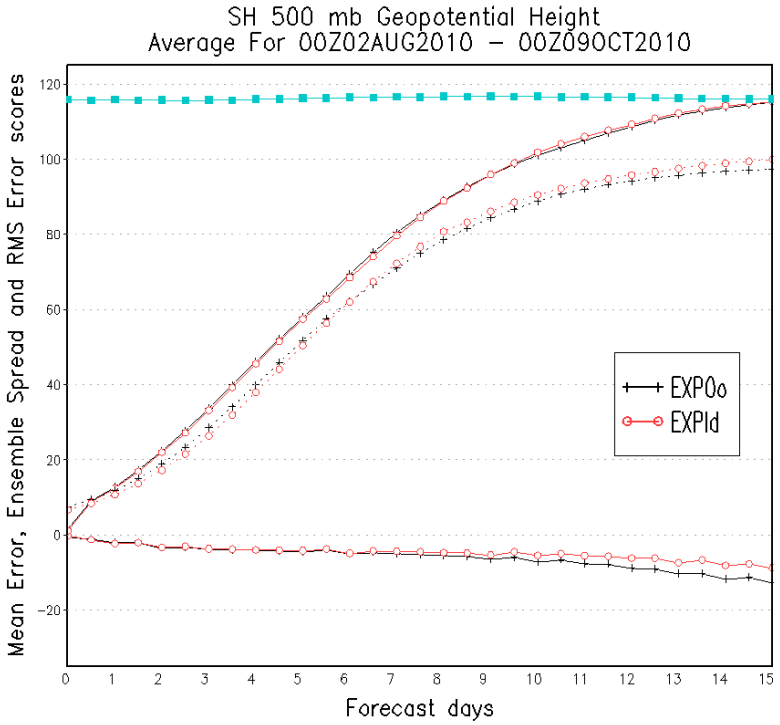
  T254L42 for 0-192hr, and then T190L42

- With necessary change and improvement in ETR (W. Wei):

  Changing the global rescaling parameter so that initial spread remains about the same (E0)

  Improving ETR by allowing vertical variation of scaling parameter to increase lower level spread (E1)

- Any Change in STTP? (To be studied in this poster)
  - Previous study suggests positive impacts of STTP will remain with upgraded model and increased resolution. This is the first opportunity to show this.
  - Is the current operational STTP parameter set still working with the planned configuration?
  - Can any change in STTP further improve forecast with the truncation at 192 hour?
  - Is the change sensitive to ETR modifications?
  - Further tuning to maximize the positive impact?



Operational (T190L28, Old GFS model)

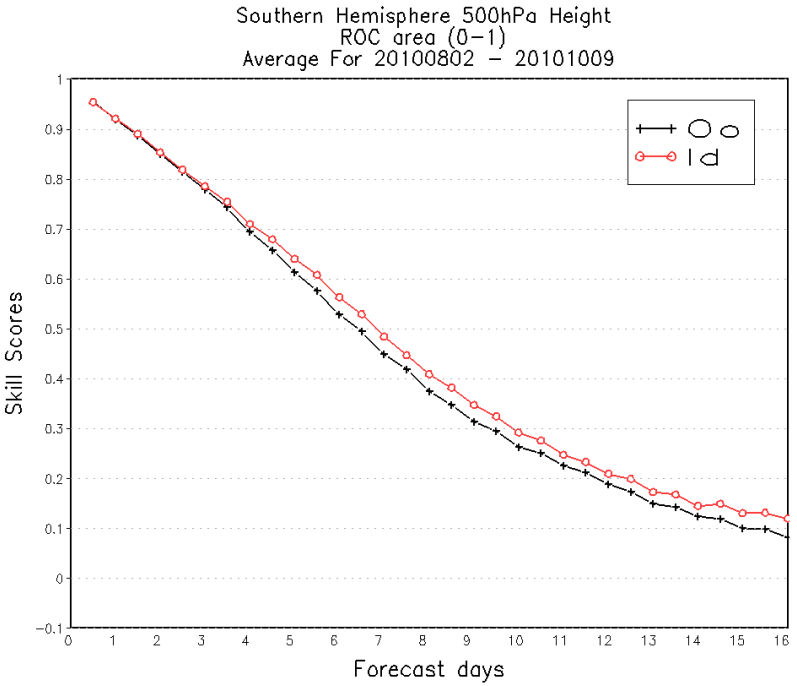
vs.

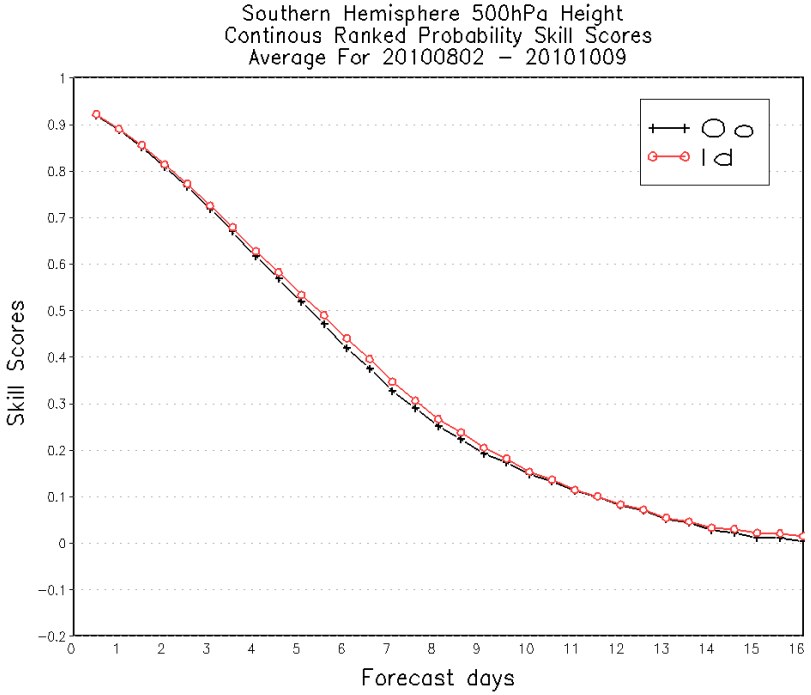
Planned (T254/190L42, New GFS model)

GEFS configurations

Without any change in STTP parameters

1. Significant improvement in probabilistic forecast due to model upgrade and increased resolution
2. Perturbation growth rate remains about the same
3. The current operational STTP parameter set works well with upgraded model and increased resolution

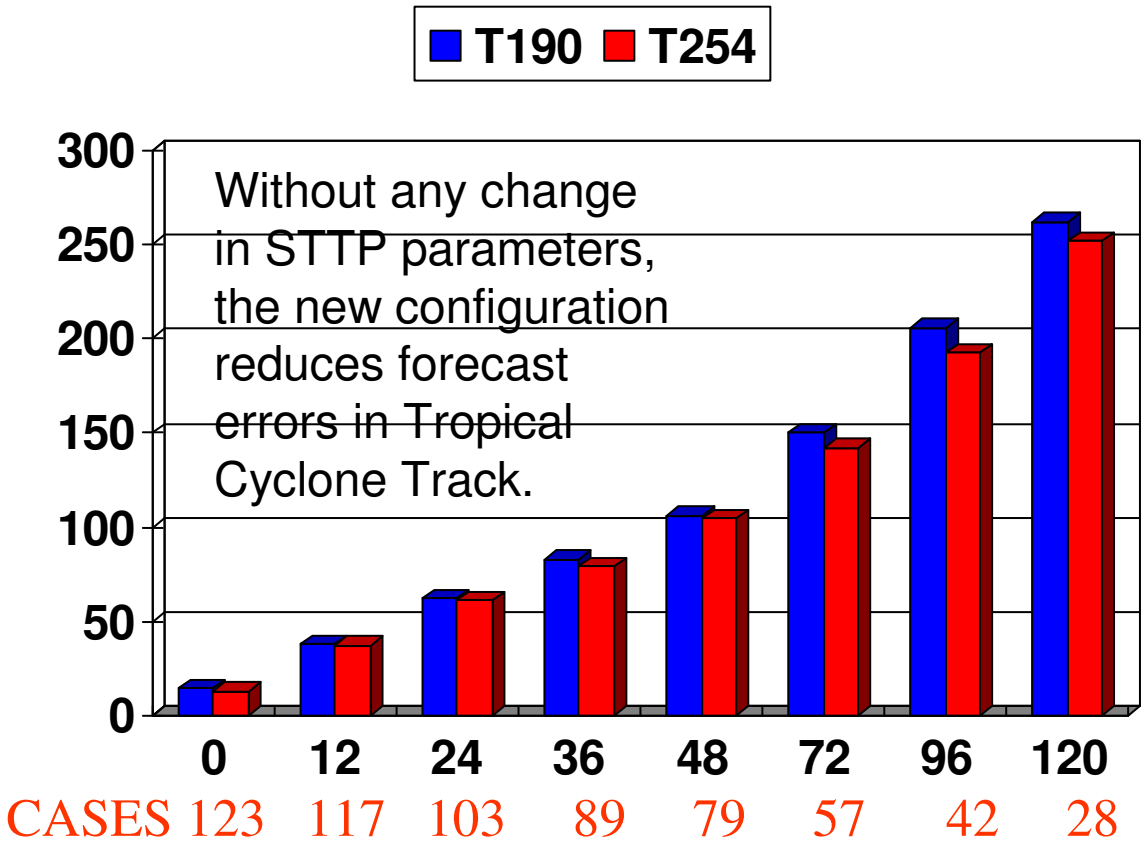




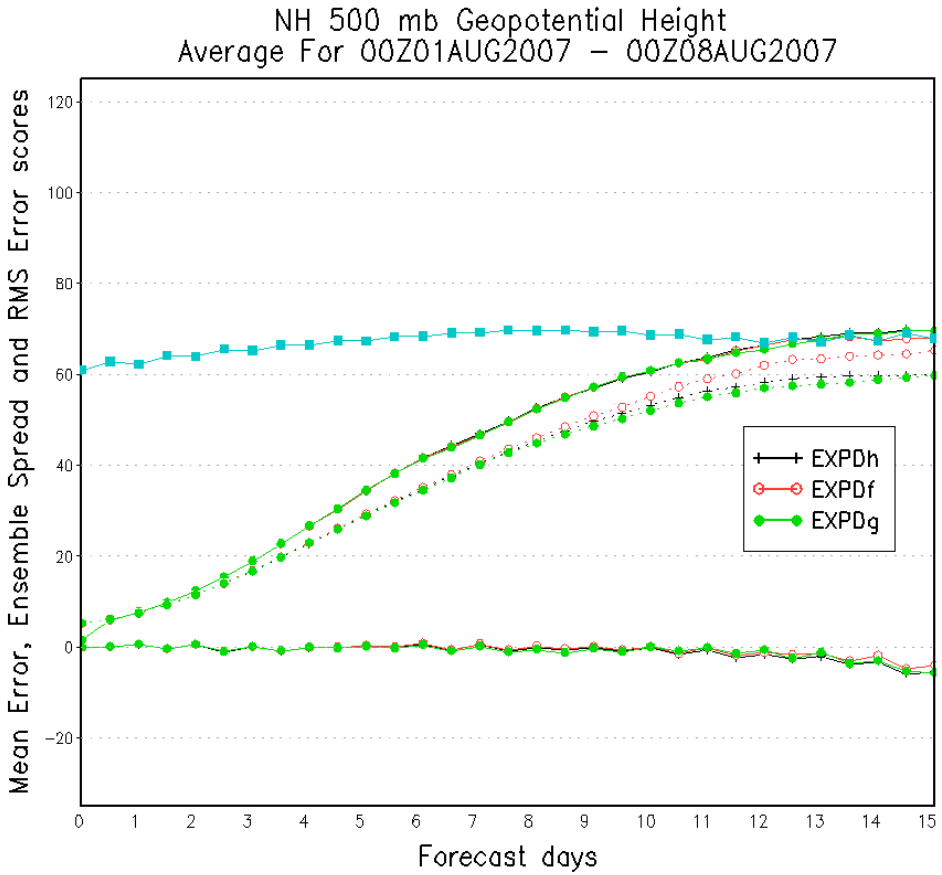
GEFS TC Track Error

----T190L28 (Operational) vs. T254/190L42 (New GFS)

Verification and Plot by Jiayi Peng



AL04-17; EP07-12; WP05-14



STTP Change for Truncation

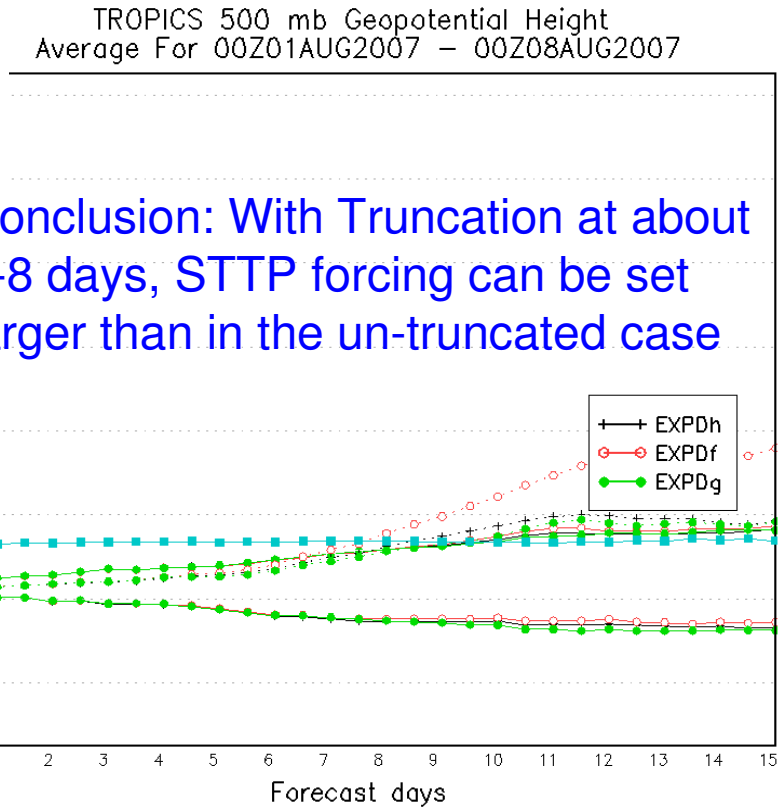
Test with T190/126L28 and old GFS
(Truncation at 180h)

Three Experiments:

T190L28P0: Works well

T190L28P1: Increasing STTP size improves spread for NH + SH, but too large spread over Tropics

T190/126L28P1:Truncation brings it down



Conclusion: With Truncation at about 7-8 days, STTP forcing can be set larger than in the un-truncated case

Two sets of STTP Parameters:

P0: Operational setting
p1=0.1, p2=0.01, p3=0.11, p4=252 hours

P1: Increase STTP size, especially after 180h
p1=0.105, p2=0.03, p3=0.12, p4=252 hours

STTP Change for Truncation

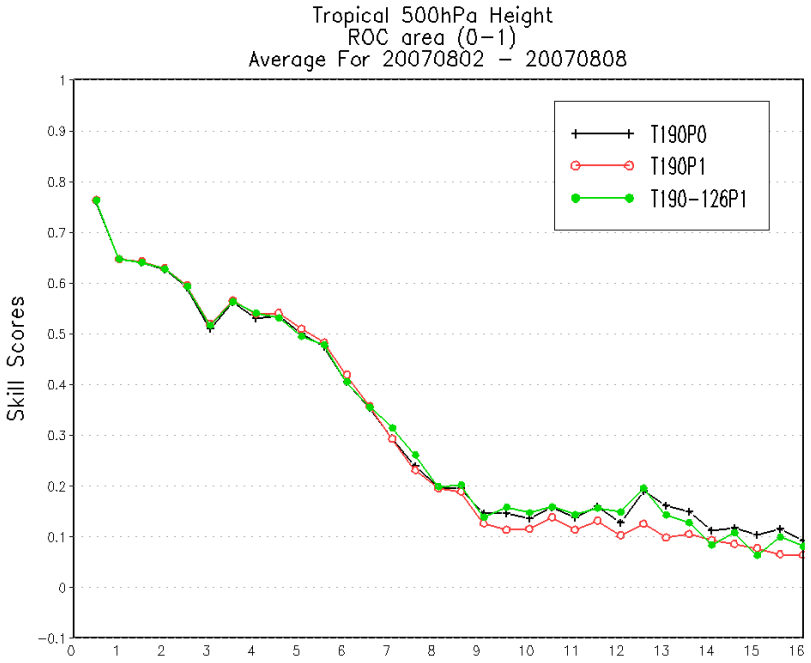
Test with T190/126L28 and old GFS

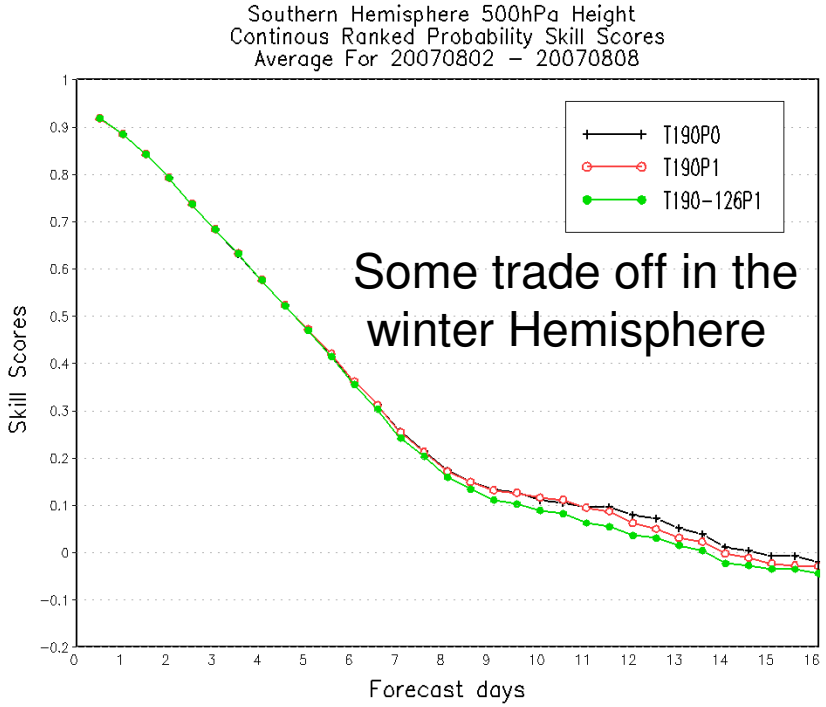
(Truncation at 180h)

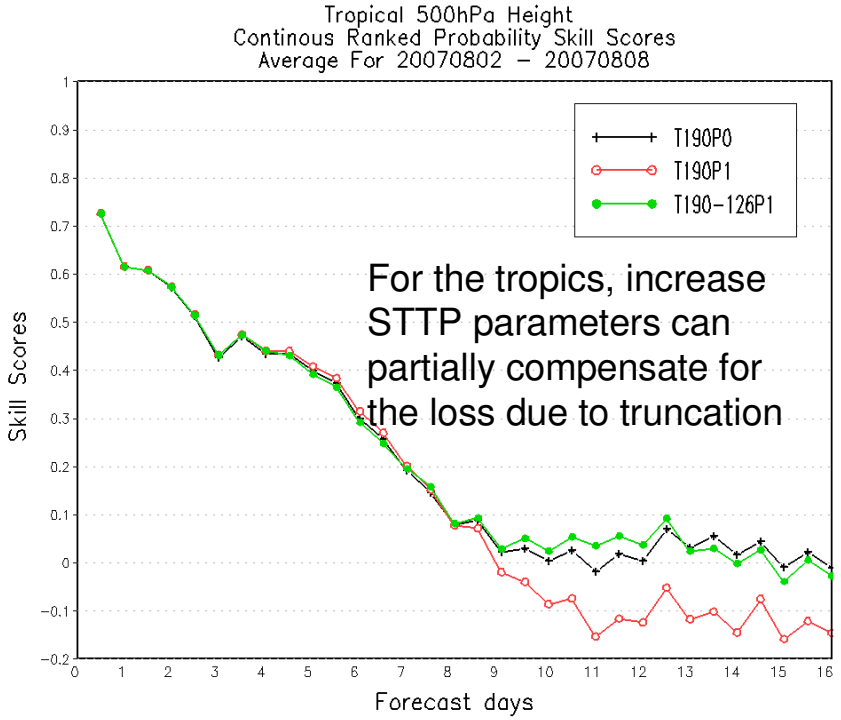
Discussion:

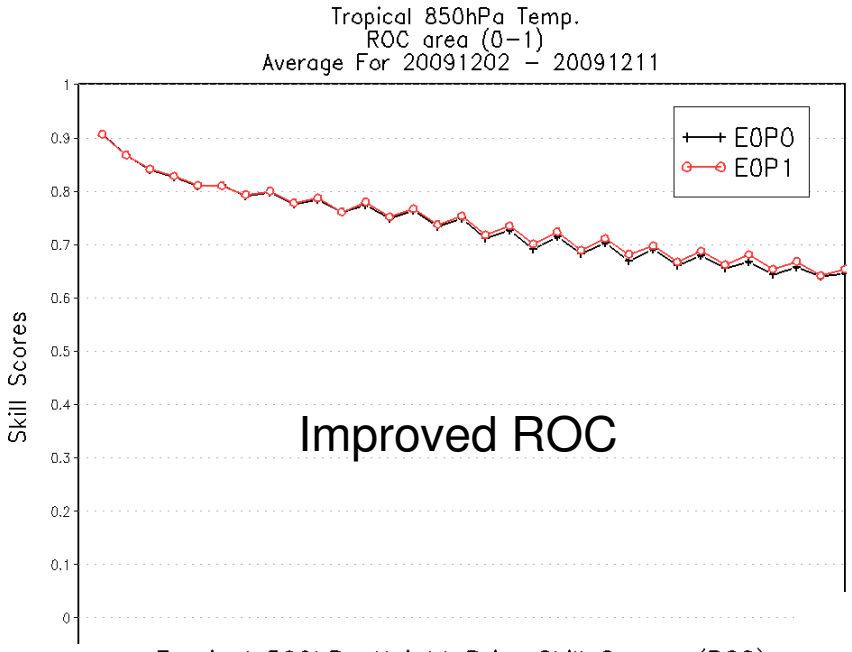
With Truncation at about
7-8 days, STTP forcing can be set to be larger than ir the un-truncated case

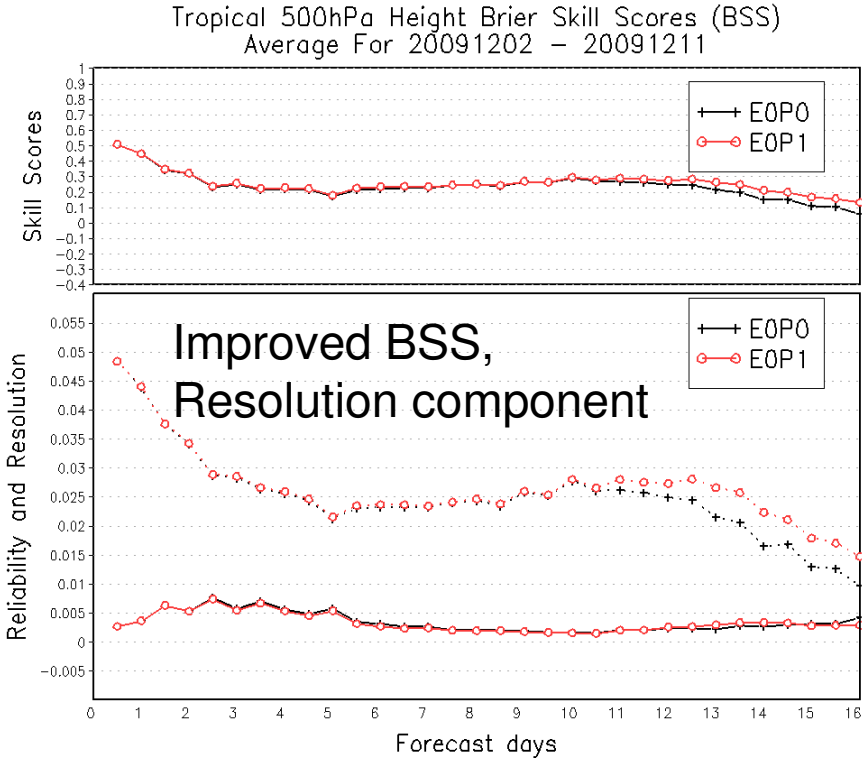
This is shown here for T190/126L28 resolution.
How about T254/190L42 resolution?











STTP Change for Truncation

Test with T254/190L42 and new GFS

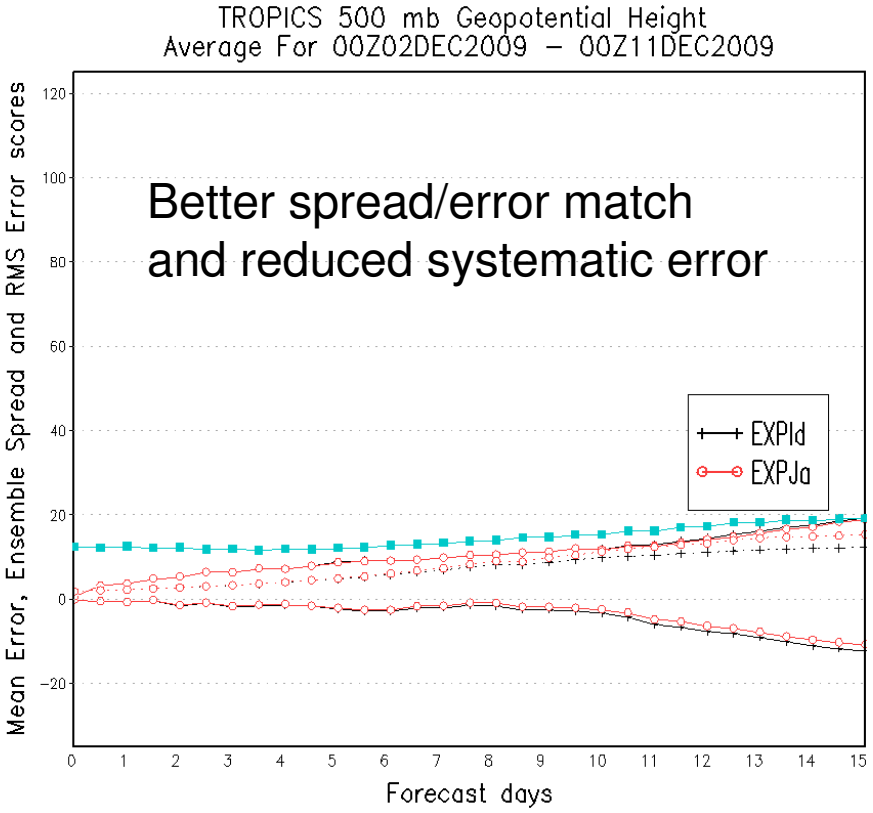
With 3 experiments, all with truncation at 192h

STTP P0: Bench mark

STTP P1:

Increasing STTP size improves forecast over Tropics: Better Error/spread match improves probabilistic forecast skills;

Impact mainly in week 2



STTP Parameter Tuning
Combined with ETR modification

E0: ETR as in operation

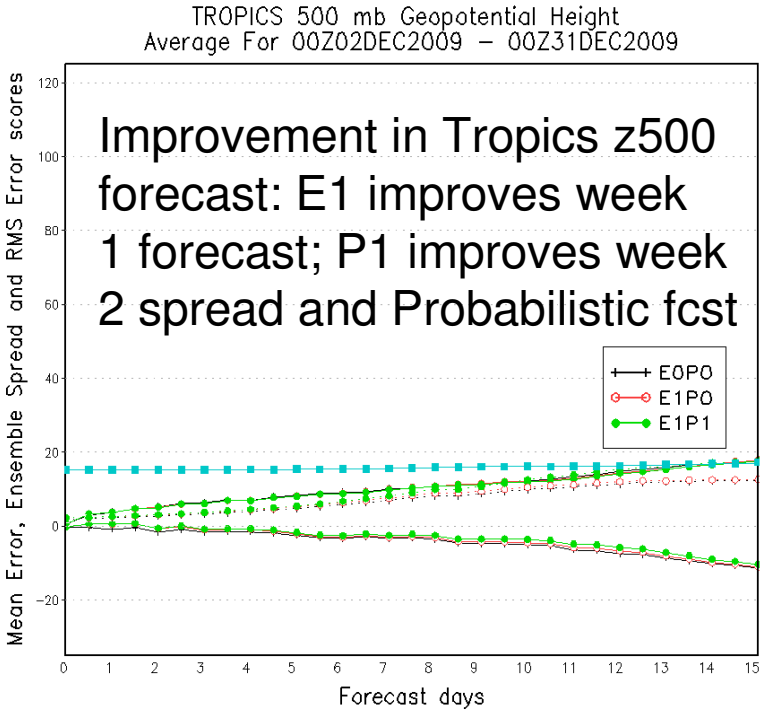
E1: ETR modification by M. Wei

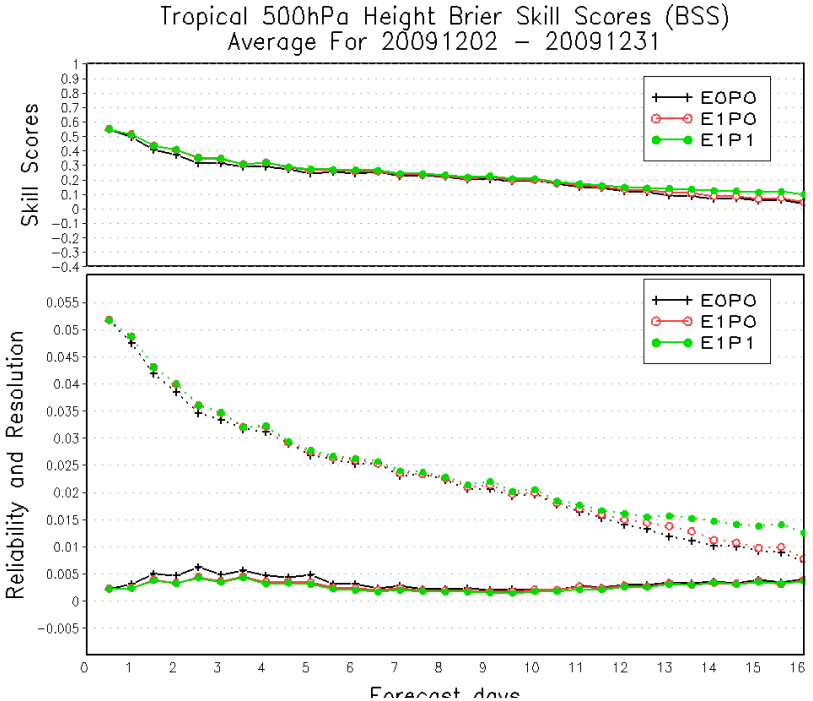
Three Experiments (T254/190L42):

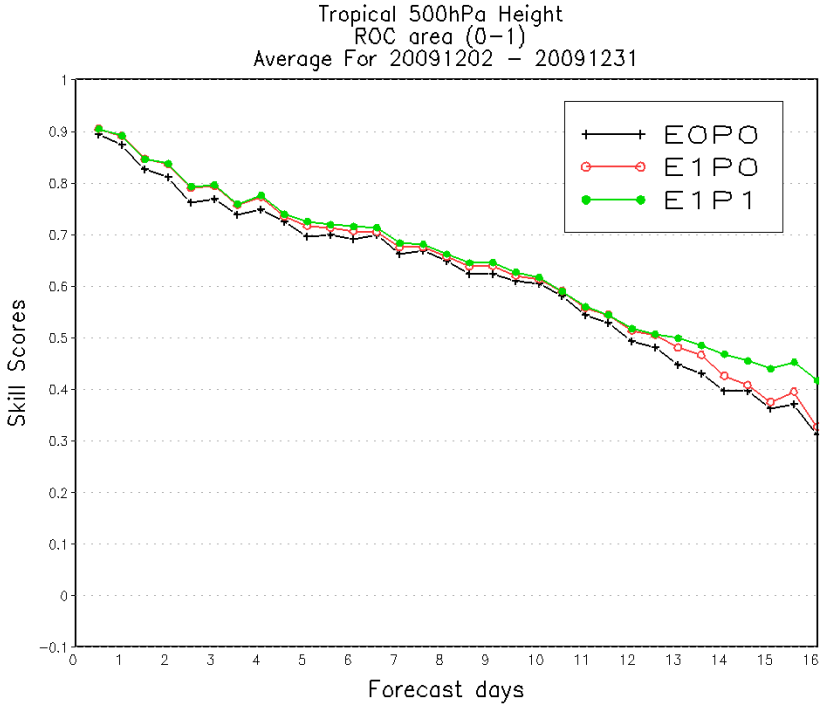
E0P0

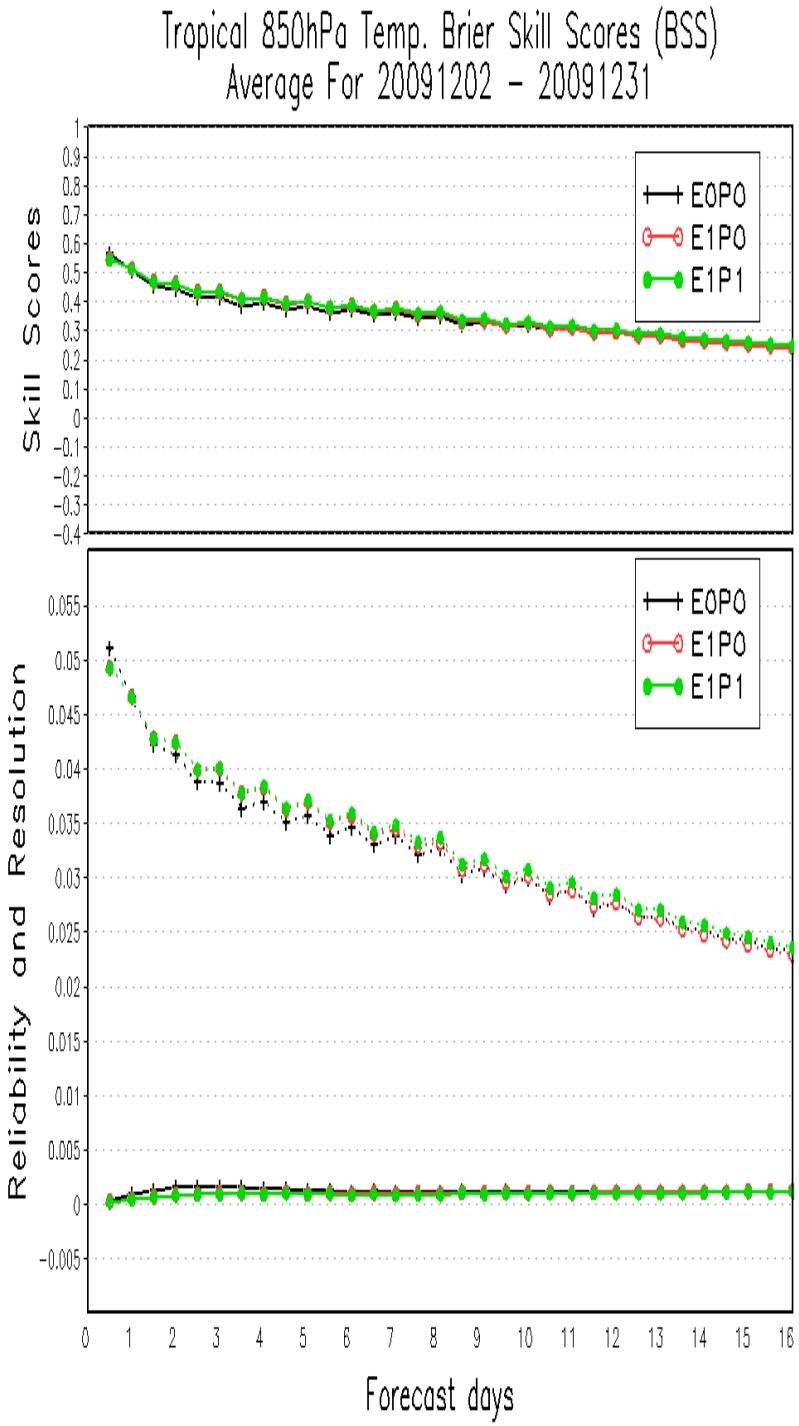
E1P0

E1P1

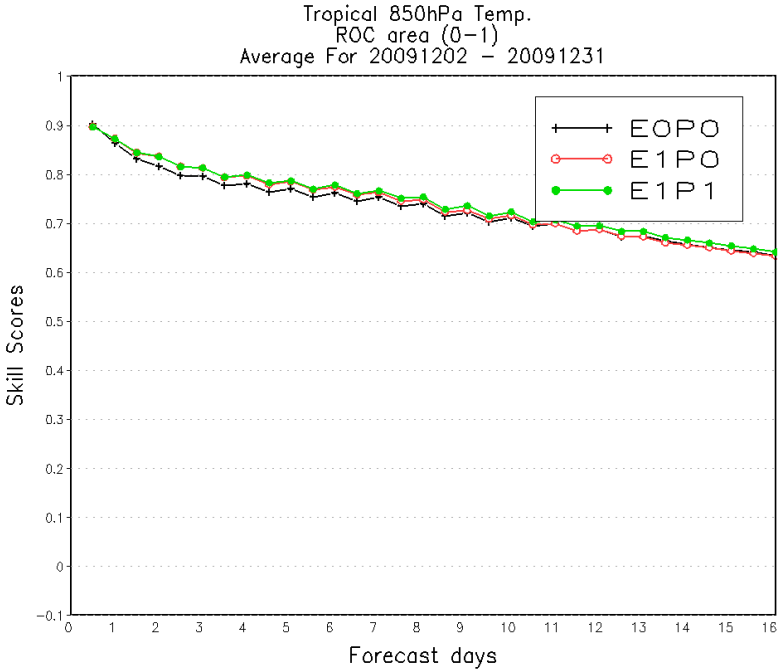








Improvement in Tropics t850 forecast:
E1 improves week 1 forecast;
P1 improves week 2 spread and probabilistic fcst



Summary

- The positive impacts of STTP in GEFS remains true with upgraded GFS model and increased resolution.
- The current operational setting of STTP parameter set still works well with the planned configuration, T254L42 upto 192 hours and then truncated to T254L42.
- With the planned truncation at 192 hour, the STTP forcing can be set larger to maximize the benefit, especially over the Tropics.
- The STTP parameter change is not sensitive to ETR modifications.
- Further tuning to maximize the positive impact is still possible.
- A new set of STTP parameters is proposed.
- GFS model code is modified to facilitate parameter tuning of STTP.