A Stochastic Perturbation Scheme (SPS) Representing Model Related Uncertainty in NCEP Global Ensemble Forecasting System

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Formulation (*Hou, Toth and Zhu 2006*)

General Expression: $\dot{X}_i = T_i + S_i$ **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

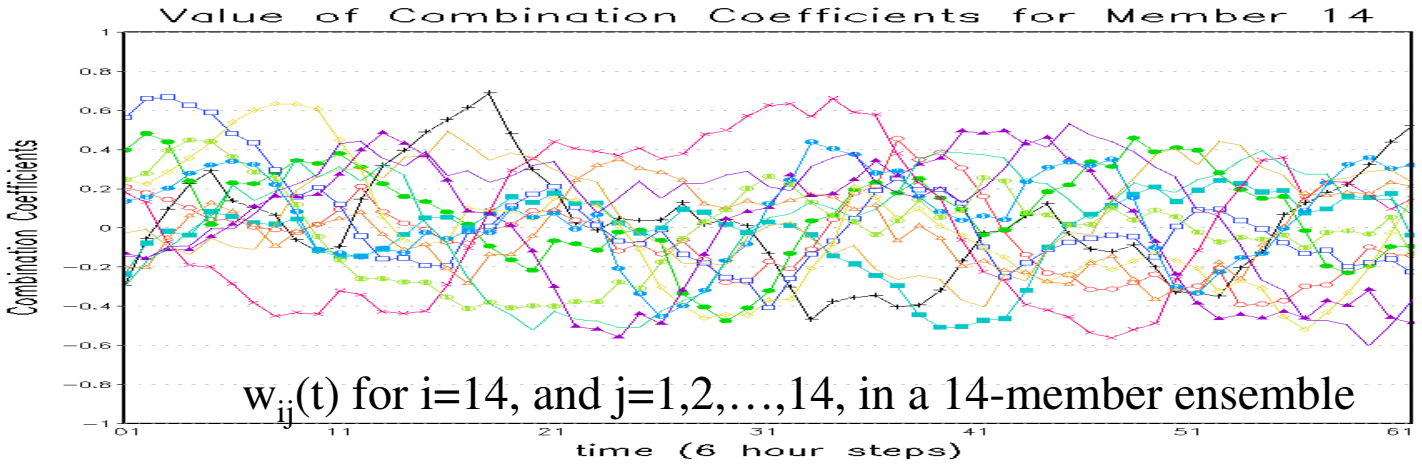
Formulation of S vectors:

$$S_i \sim \sum_j w_{i,j} P_j$$

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

Generation of combination coefficients:

An orthognormal matrix W, as a function of lead time t, is generated using the methodology and software provided by James Purser. Each coefficient $w_{i,j}$ is a random walk superimposed on a periodic function, and an example is shown.



$w_{ij}(t)$ for i=14, and j=1,2,…,14, in a 14-member ensemble

The Current Version (*Hou, Toth, Zhu and Yang, 2008*)

Use a finite difference form for the tendency, with 6 hour time interval

The Scheme is applied every 6 hours by modifying the model state using

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

For t=6h,12h,.....

Where γ is a rescaling factor $\gamma = \gamma_0 \gamma_1$

Global Rescaling γ_0, a logistic function of lead time t:

$$\gamma_0 = 0.03 + (0.105 - 0.03)\left\{1.0 - \frac{1.0}{1.0 + \exp[-0.02(t - 252h)]}\right\}$$

Regional Rescaling γ_1, a harmonic function of latitude and season:

$$\gamma_1 = 1.0 + A\sin(\theta)\sin\frac{2\pi(d-91)}{364}$$

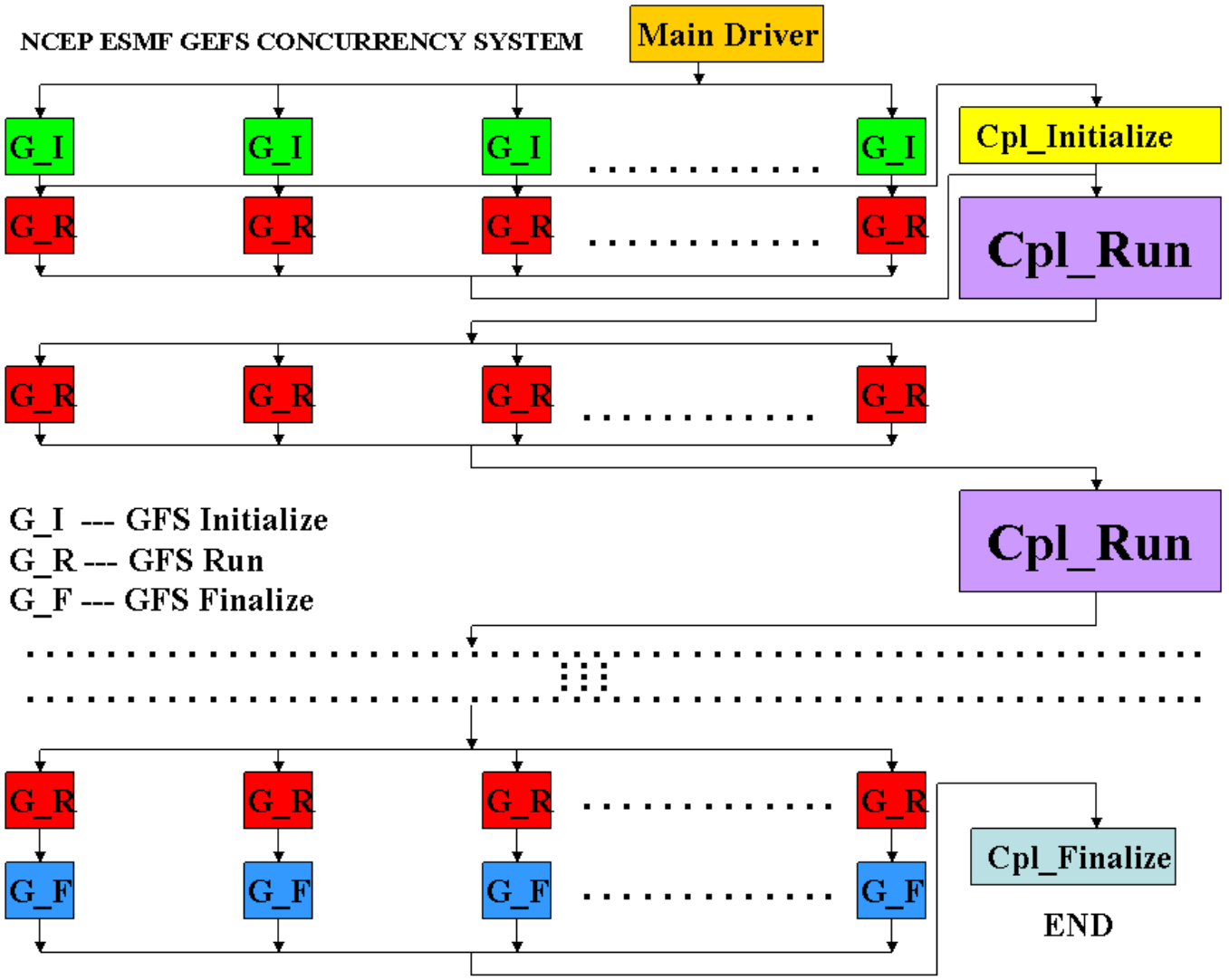
Θ=Latitude, A=0.2

d=Julian Day of the initial time

Implementation Under ESMF Environment

(ESMF=Earth System Modeling Framework)

Simultaneously integrating all members (Module G) and periodically applying SPS (Module Cpl)

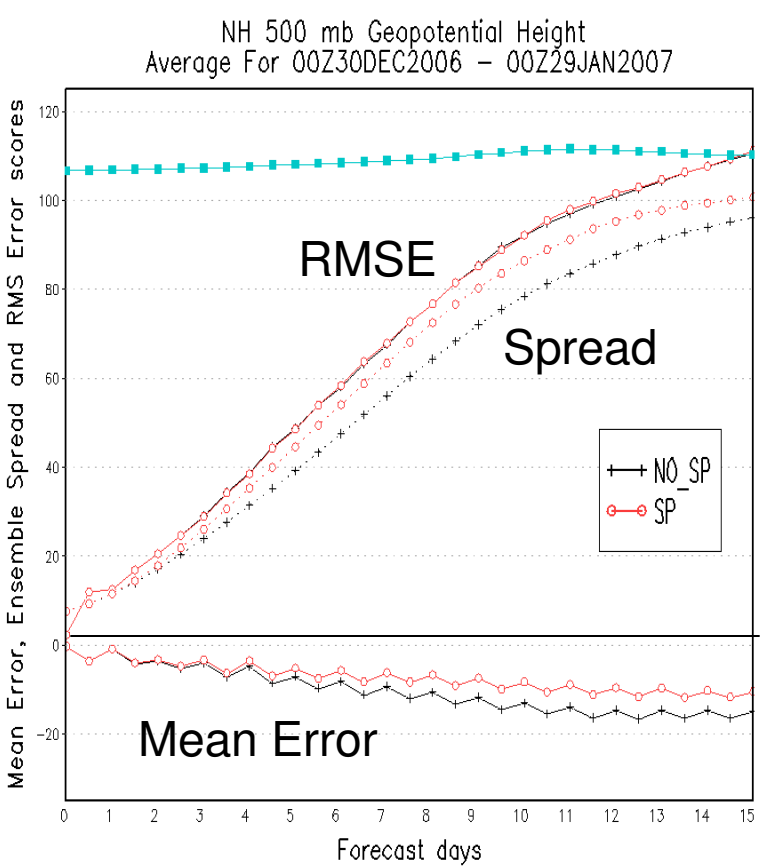


Impact on Ensemble Forecast

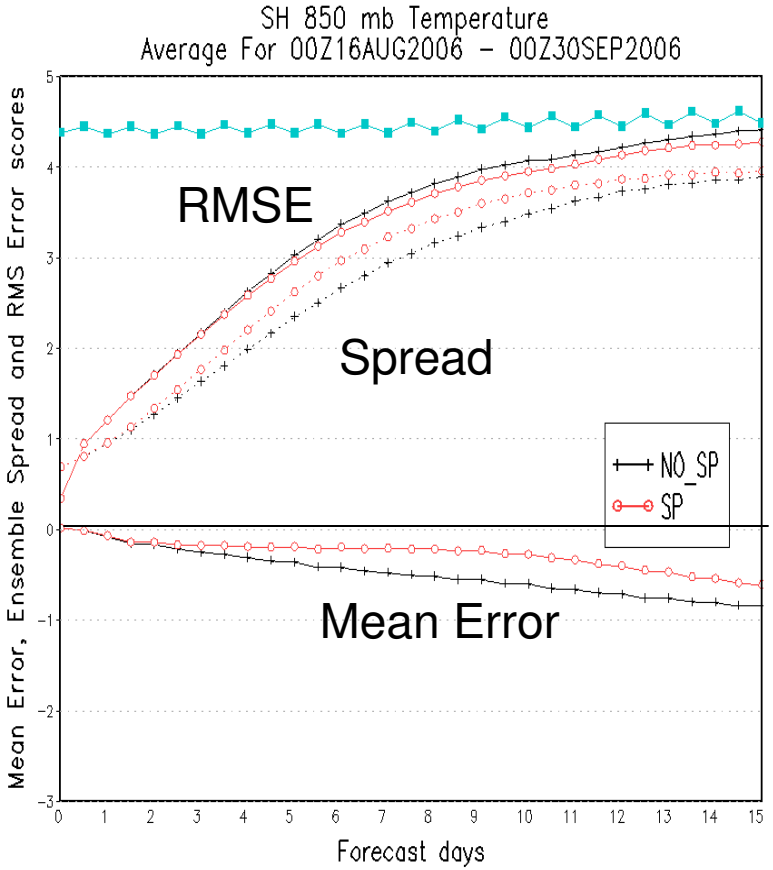
- Increase in ensemble spread toward RMSE of ensemble mean;
- Reduction in systematic (domain mean) error
- Improvement in ensemble based probabilistic forecast, especially the reliability related scores;
- Improvement in ensemble pdf, measured by the CRPSS score;
- Additive impact to increase in model resolution;
- Additive impact to (off line) statistical bias correction.

Impact of SPS on Ensemble Mean Forecast

----- Reduced (Negative) Bias and Increased Spread



NH H500 Winter



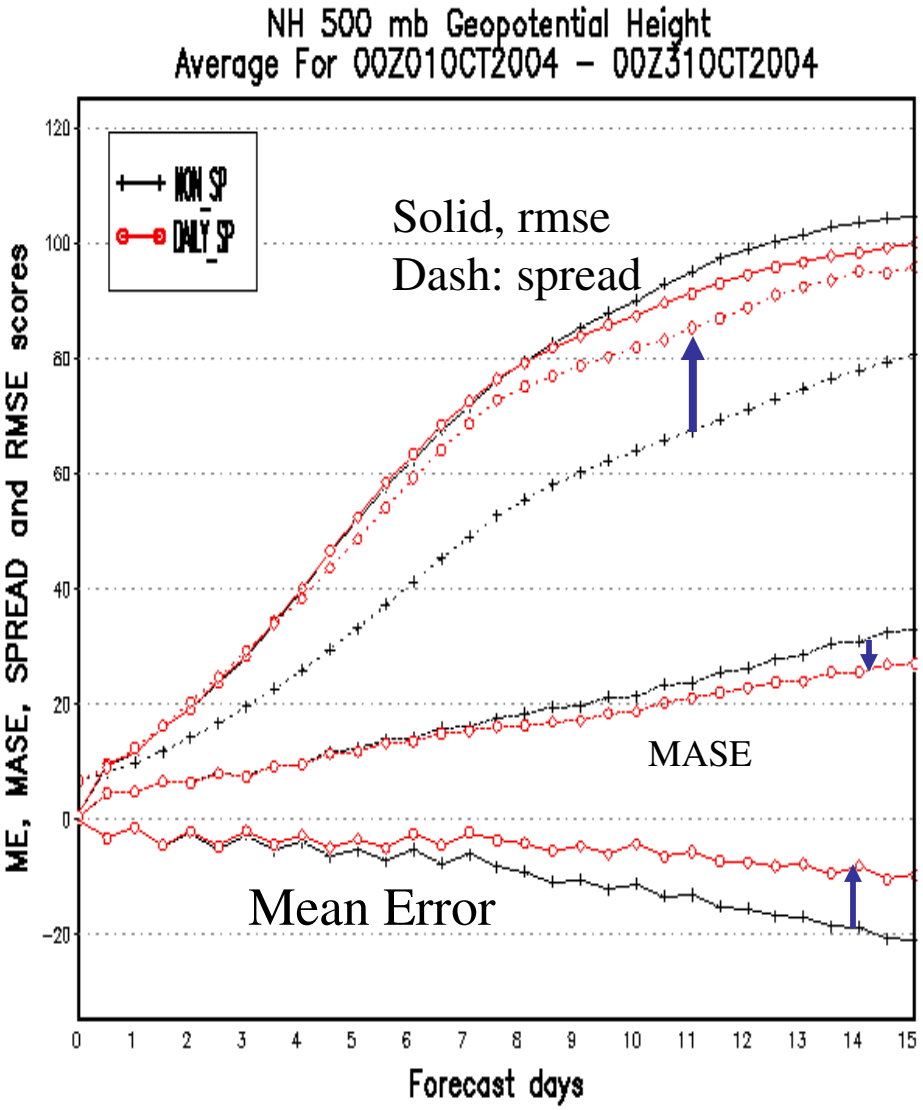
SH T850 Winter

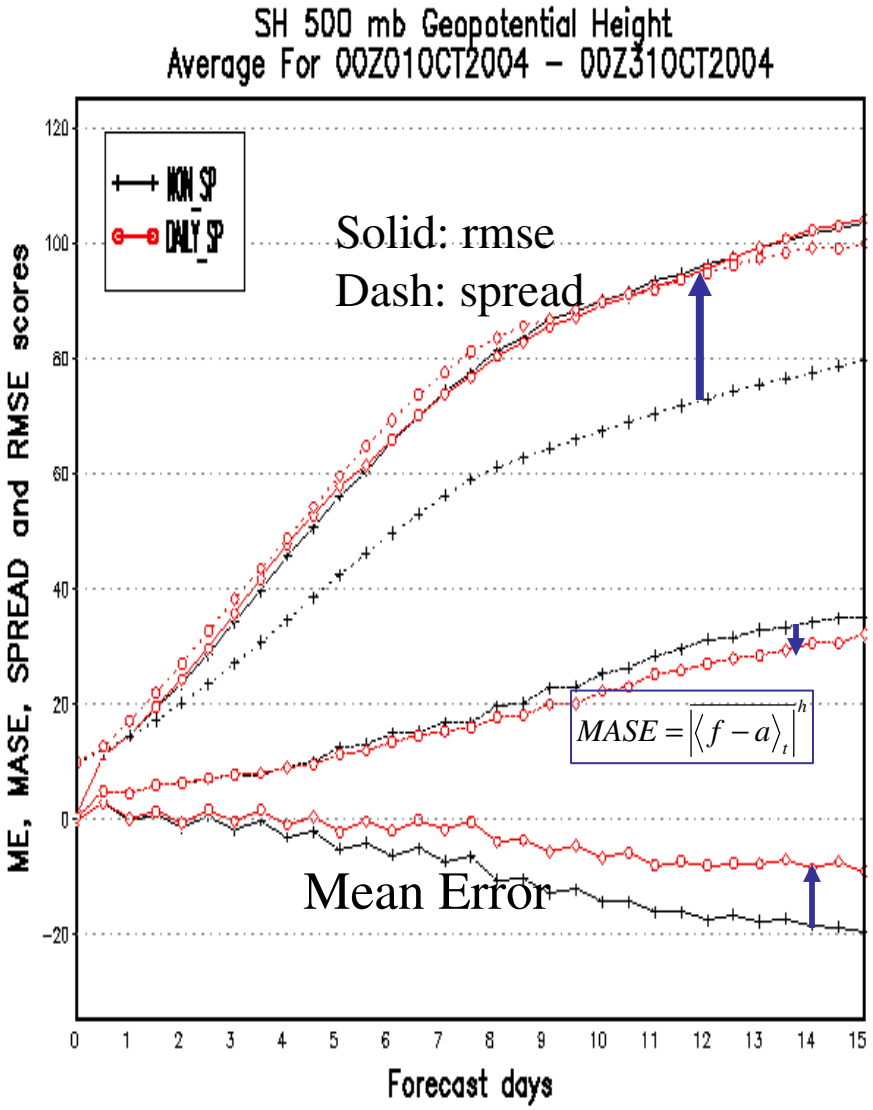
Impact of SPS on Ensemble Mean Forecast

Increased Spread, Reduced Mean Error (ME)

Reduced Mean Absolute Systematic Error (MASE)

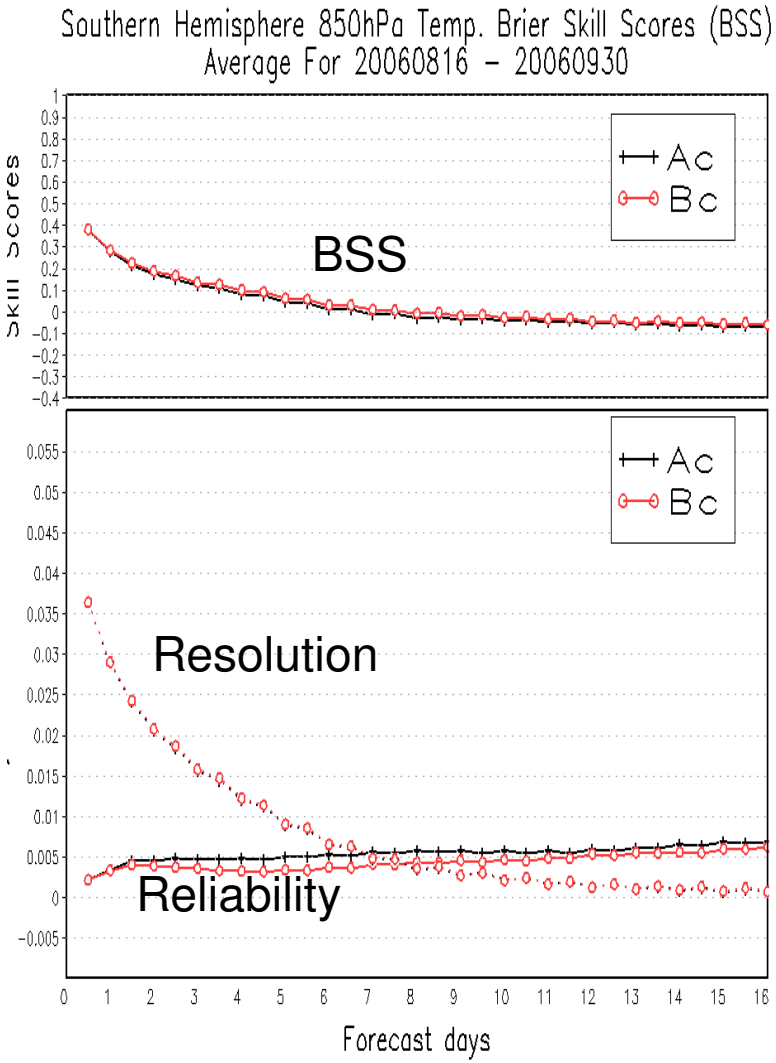
----- Without SPS ------- With SPS

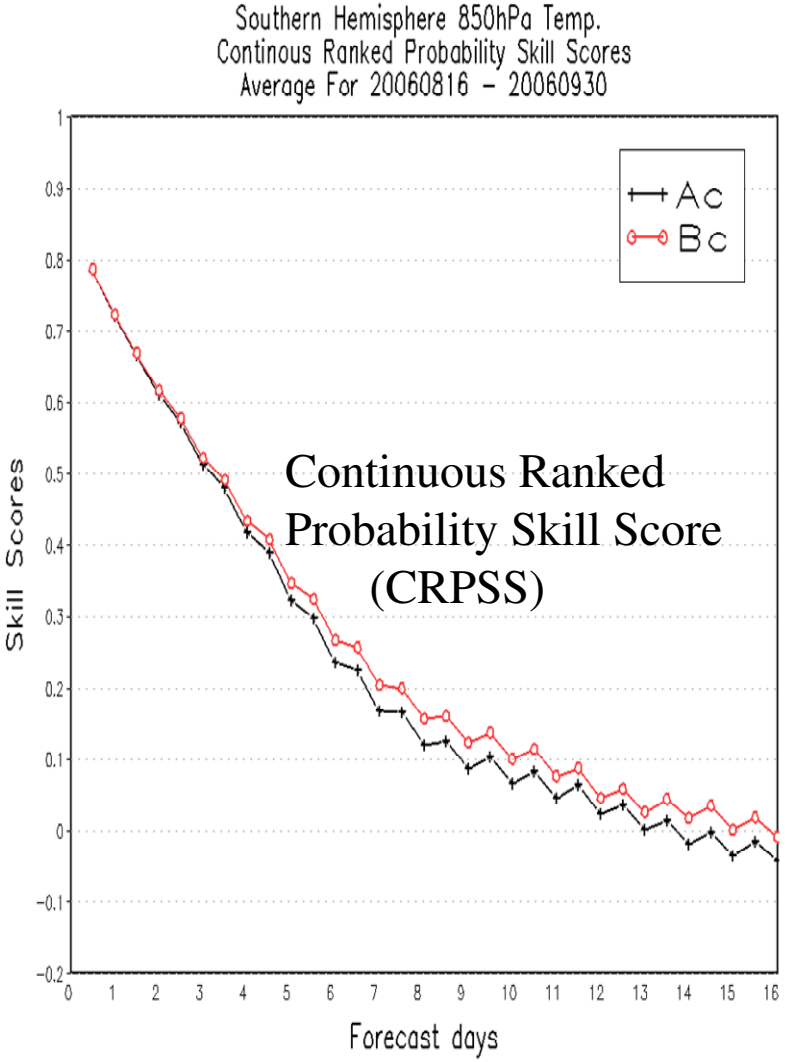




Impact of SPS on
Ensemble Based Probabilistic Forecastand Ensemble pdf

----- Improved verification Scores

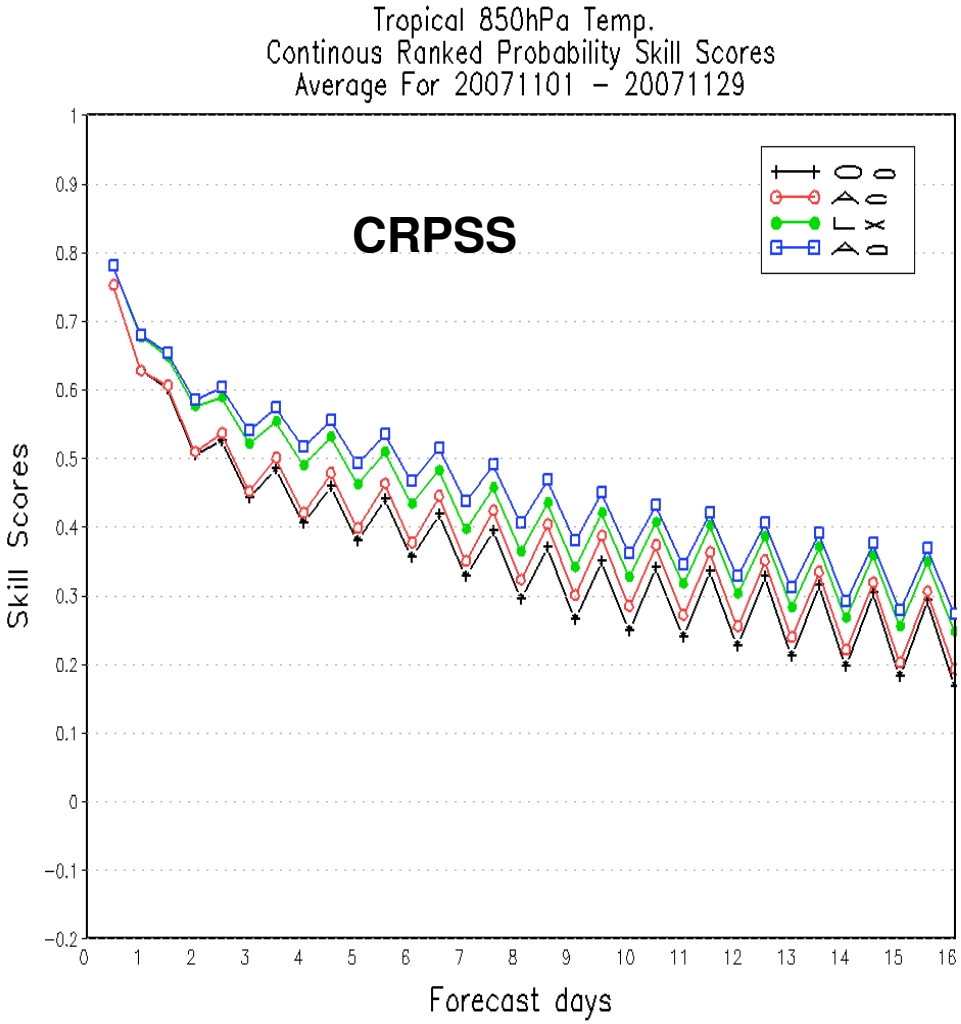


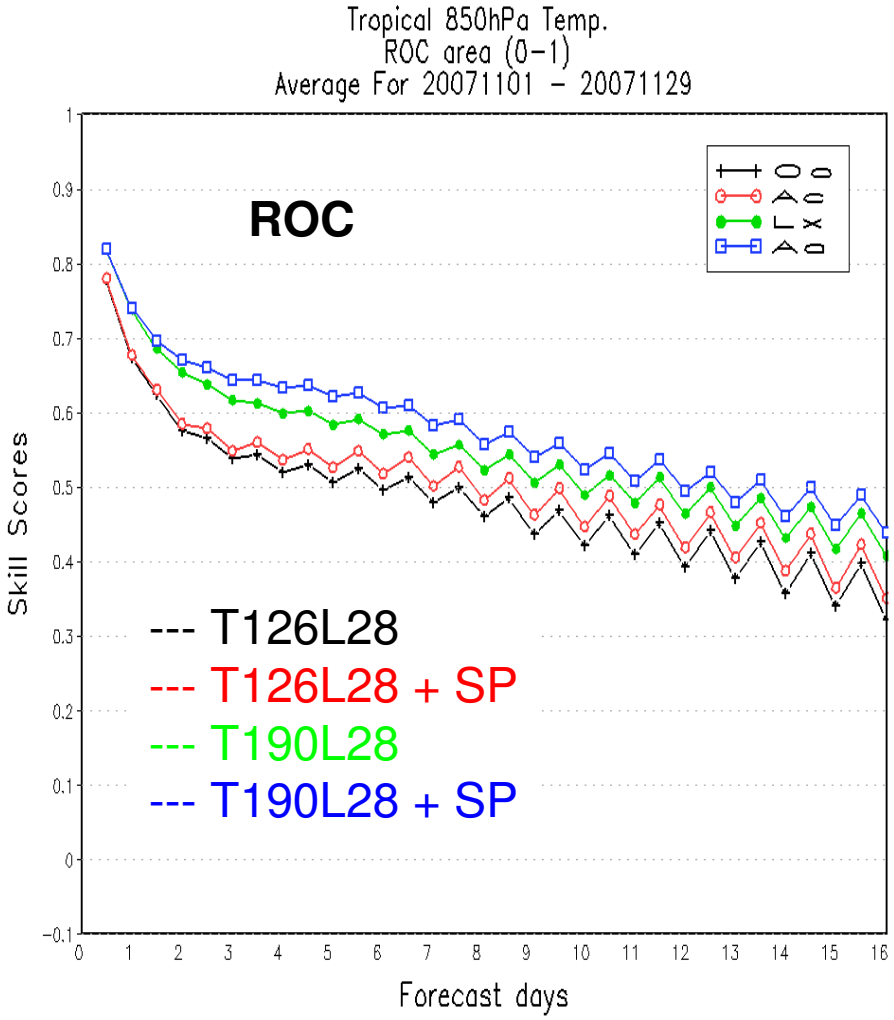


Impact of SPS

T126L28 vs. T190L28 resolution

Additive impacts with increase in resolution





Impact of SPS

Additive Impact with Statistic Bias Correction (PP)

For RPSS Score, the positive impact of SPS and PP adds up