中央氣象局全球模式系集颱風路徑預報系統（一）
CWB Global EPS for Typhoon-track (CWB GET): Part I

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Motivation

- Now, CWB has applied GSI-Hybrid (3D-Var+EnKF) data assimilation system and got improvements in forecast scores. The ensemble members partly come from lag average and another from NCEP's EnKF based on NMC method. The spread and accuracy of ensemble predictions are still needed to improve by modifying localiztion or adding new ensemble members based on Singular vectors.
- CWB global forecast system can afford 5-7 days typhoon track prediction for disaster reduction and control. Somehow, the ensemble can afford the probability forecast and the predictability explanation avoiding the single probably limited and bias forecast.

The Current Conditions of CWB GFS

- The CWB operation global forecast system is T319L40, and just implemented NCEP GSI-hybrid system. We can use the ensemble system of the GSI EnKF.
- The T42L40 tangent and adjoint model with simplified physics (PBL, diffusion, drag, etc.) are used for calculating singular vectors.

The Purpose

- Establish the ensemble system for typhoon track prediction based on singular vectors
- develop the diagnostic tools for statistical analysis, cluster analysis, and the probability forecast
- These SV ensemble members can be used in CWB GSI-hybrid and future 15-30 days forecasts

Singular Vectors (1)

$$\mathcal{J} = \frac{1}{D}\int_D \int_0^1 \frac{1}{2}(u'^2 + v'^2) + \frac{1}{2}\frac{C_p}{\bar{T}}T'^2 + \frac{1}{2}R_a\bar{T}\frac{p'^2}{\bar{p}^2}\,d\sigma\,dD$$

$$= \left\|\mathbf{x}'(t_f)\right\|^2 = \left\langle \mathbf{D}\mathbf{x}'(t_f)\,,\ \mathbf{E}\mathbf{D}\mathbf{x}'(t_f)\right\rangle$$

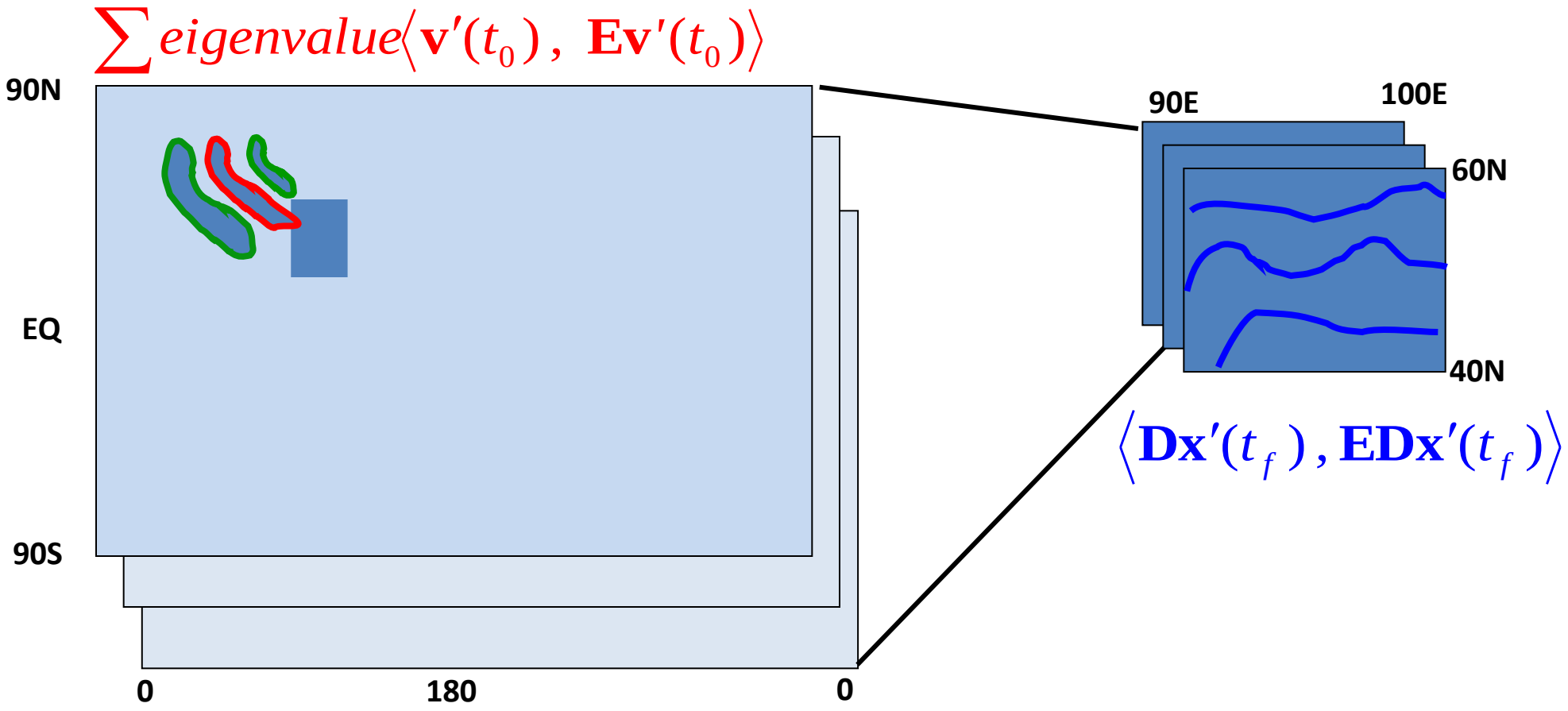
$$= \left\langle \mathbf{D}\mathbf{L}\mathbf{x}'(t_0), \mathbf{E}\mathbf{D}\mathbf{L}\mathbf{x}'(t_0)\right\rangle = \left\langle \mathbf{L}^{\mathbf{T}}\mathbf{D}\mathbf{E}\mathbf{D}\mathbf{L}\mathbf{x}'(t_0)\,,\ \mathbf{x}'(t_0)\right\rangle$$

$$= \left\langle \mathbf{E}^{-\mathbf{1}}\mathbf{L}^{\mathbf{T}}\mathbf{D}\mathbf{E}\mathbf{D}\mathbf{L}\mathbf{x}'(t_0)\,,\ \mathbf{E}\mathbf{x}'(t_0)\right\rangle$$

Solving the $E^{-1}L^{T}DEDL$, get the eigen values and eigen vectors,

the eigen vectors are called singular vectors.

Singular Vectors (2)



The SV from Typhoon Domain

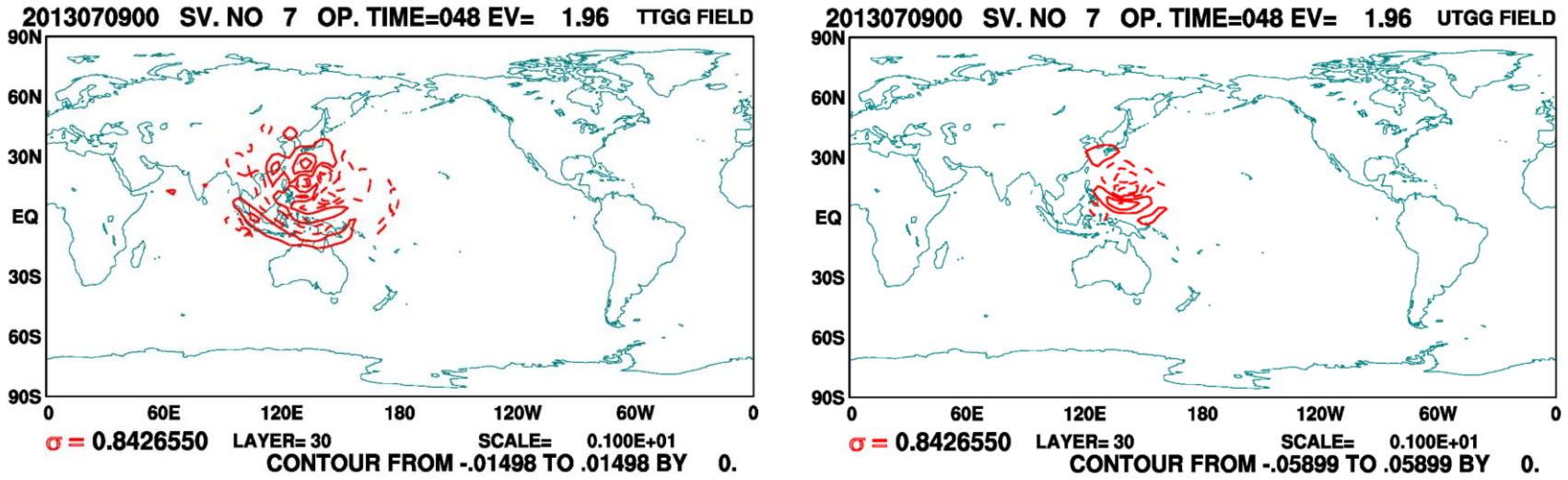
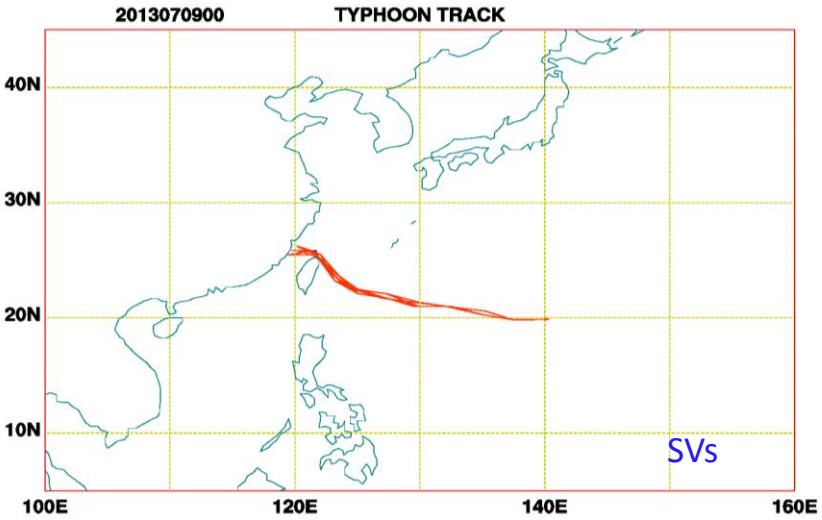
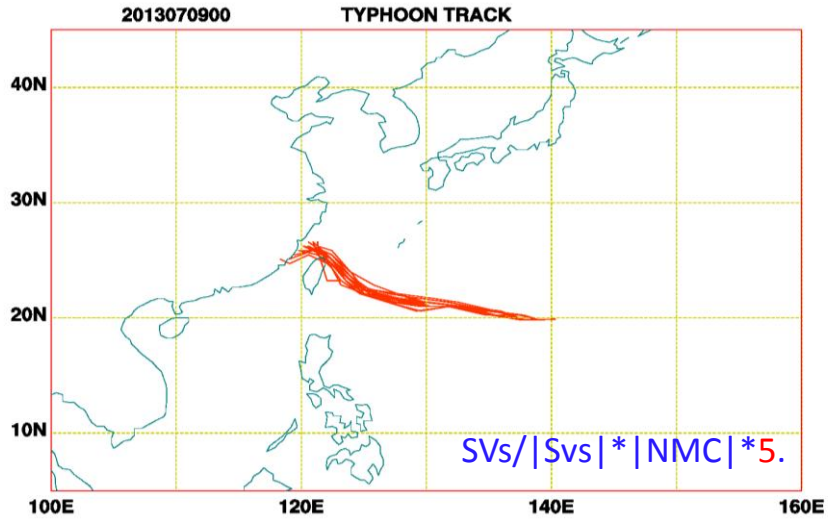
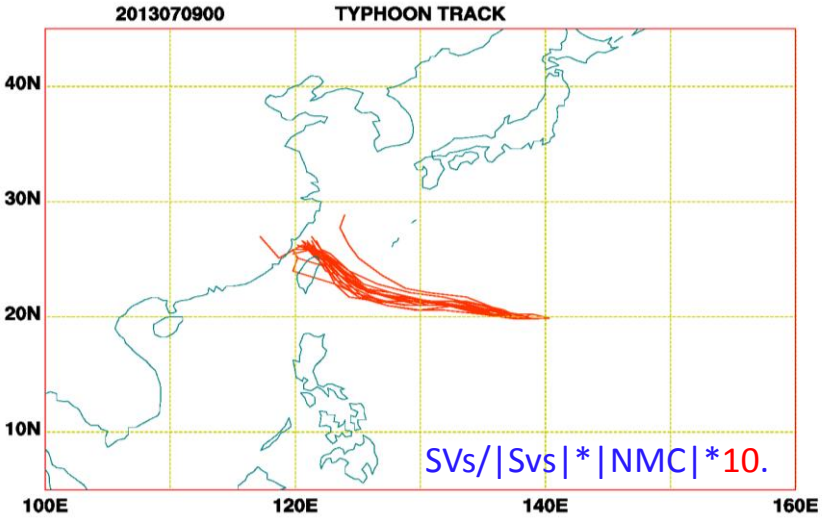


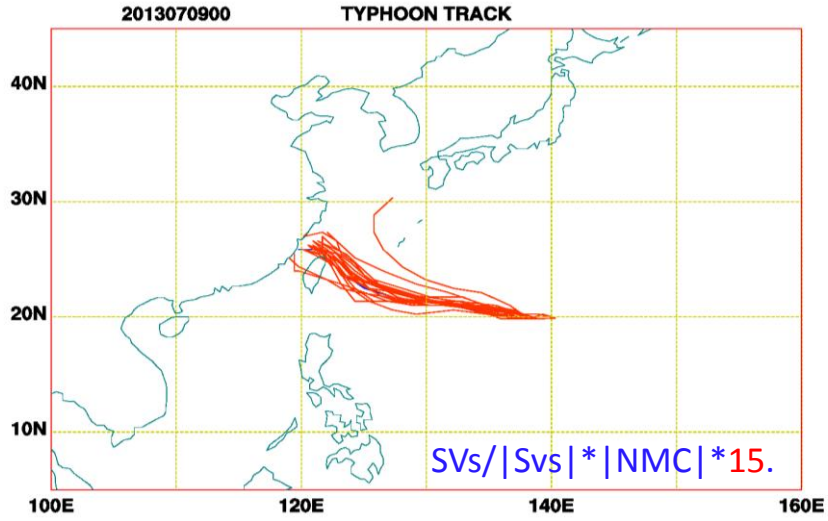
Fig. 2：The 48 hrs optimal modes, singular vector, based on typhoon domain inner product on the 2013070900 UTC are calculated. In here, we just show the seventh leading mode on the 30th layer around 850 hPa. The left panel shows the component on temperature, and the right panel shows the component on wind. The contour values point out the quantities can be regarded as the perturbation in contrast to the original variables.

The Experiment of SVs ensemble, 20 members

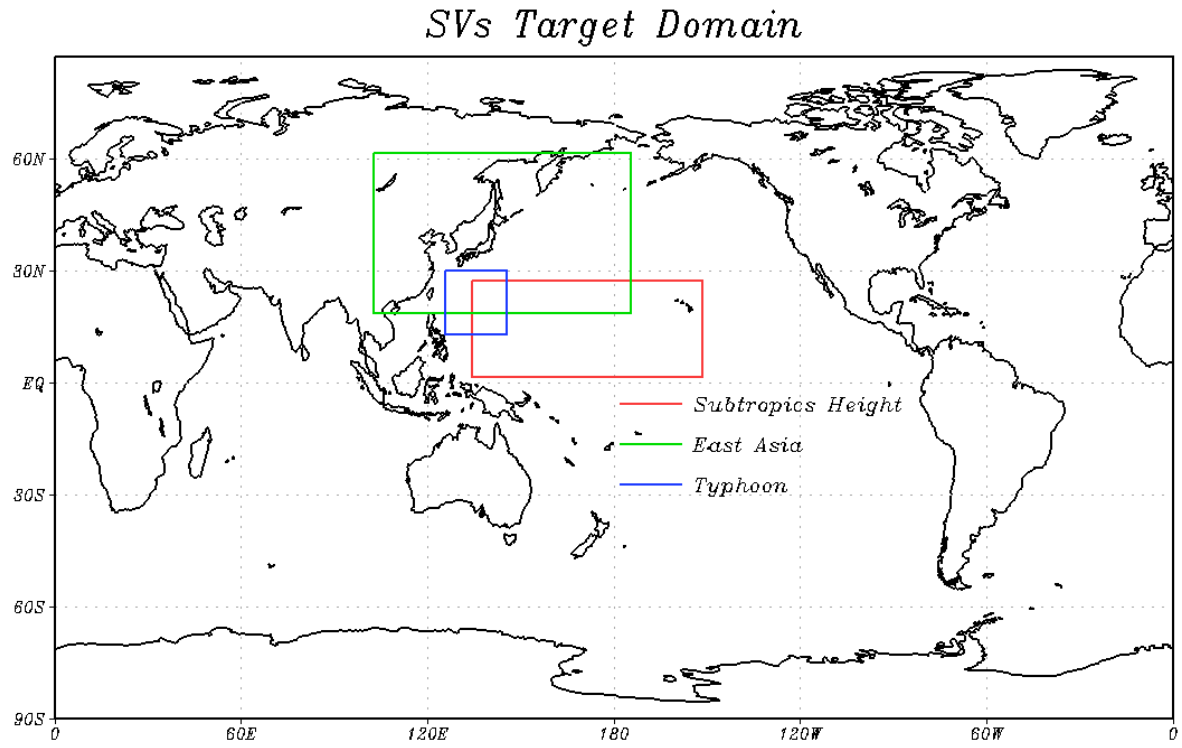








nested inner product domain



CWB Typhoon Track Ensemble System

CWB Global EPS for Typhoon-track (GET)			
resolution	deterministic model		T319L40
	ensemble		T319L40
initial perturbation, singular vector	global		T42L40
	nested typhoon domain	east Asia	20^0N-60^0N, 100^0E-180^0E
		typhoon	$15^0 \times 10^0$
optimization time	48 hrs		
ensemble size	20		
forecast length	5-day		

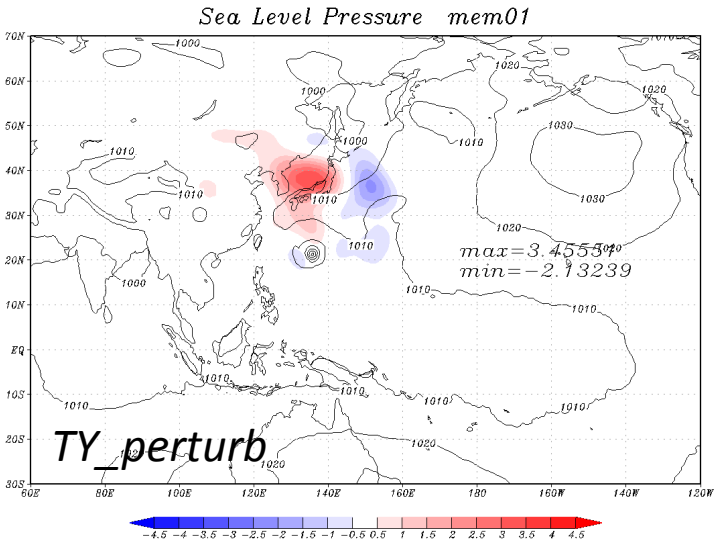
The Composition of Initial Perturbations

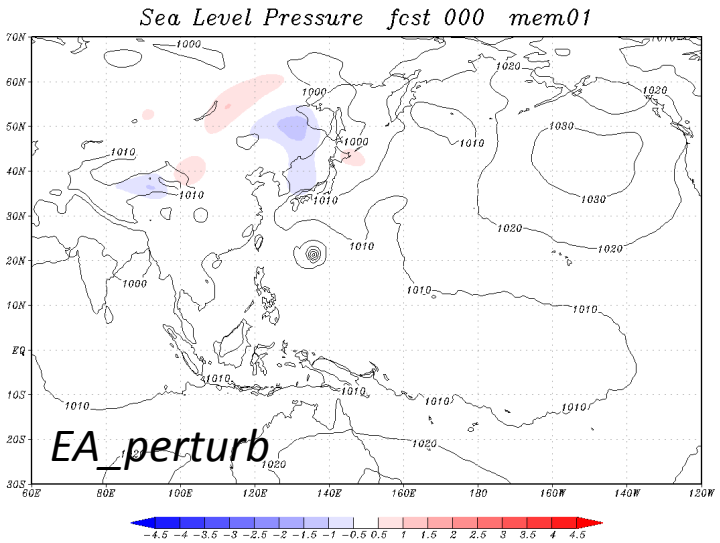
- Singular vectors calculated by nested domains, east asia and typhoon area, total energy norm.

$$perturb = TY\_perturb + EA\_perturb$$

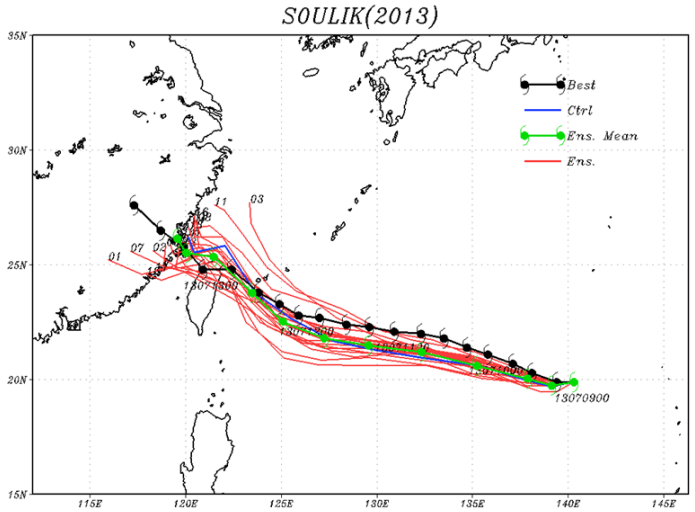
$$TY\_perturb = SV_{TY} / \left|SV_{TY}\right| \times \left|NMC\right| \times 10 \quad ,$$

$$EA\_perturb = SV_{EA} / \left|SV_{EA}\right| \times \left|NMC\right| \times 5 \quad .$$

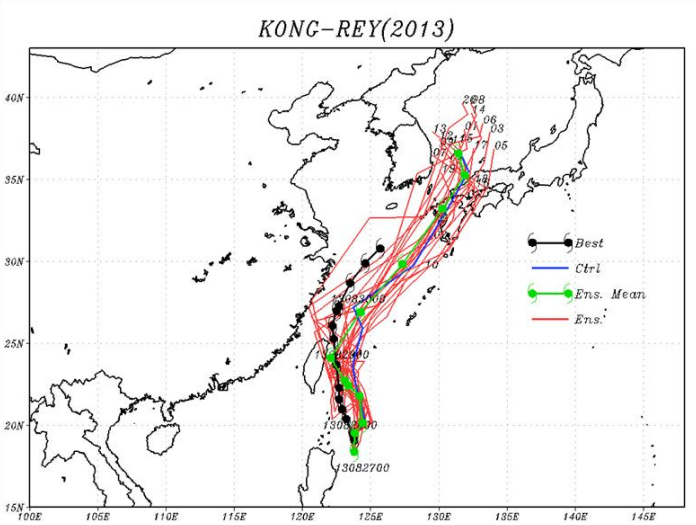




2013 Typhoon Cases



Initialized 00 UTC 09 July 2013



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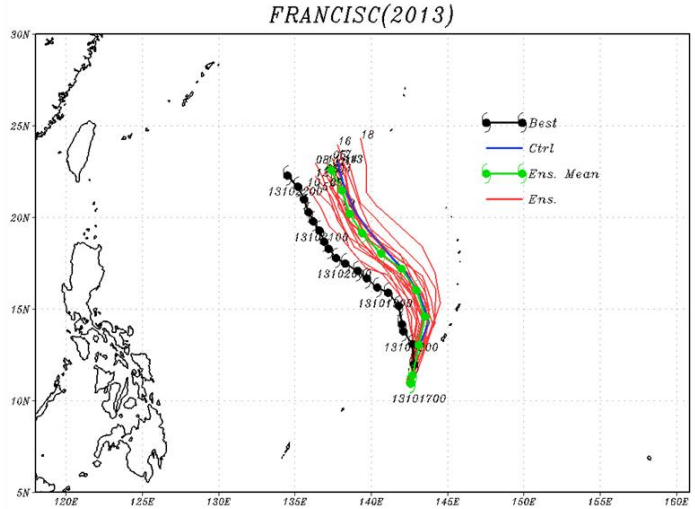

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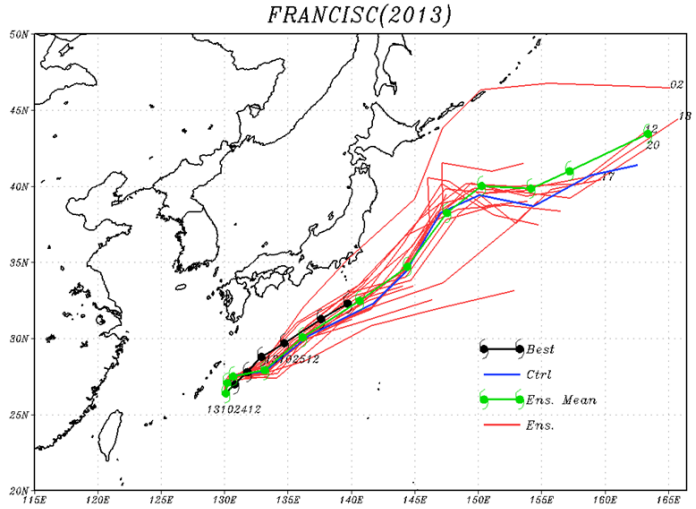

Initialized 12 UTC 24 Oct. 2013

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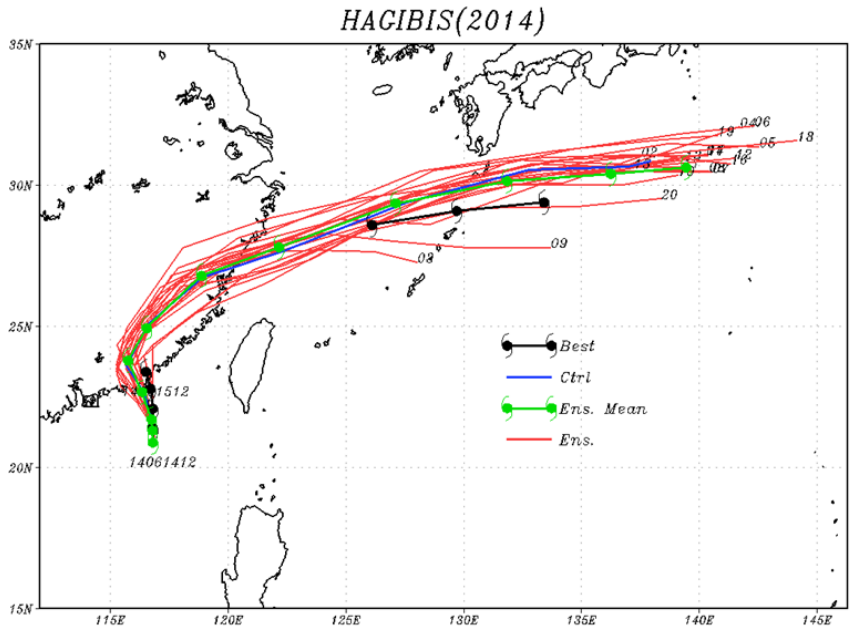

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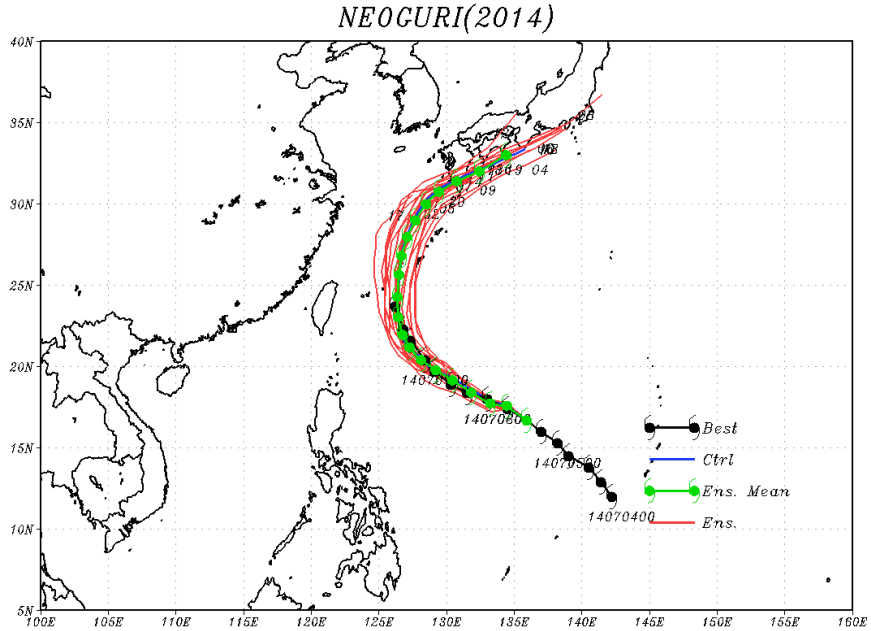
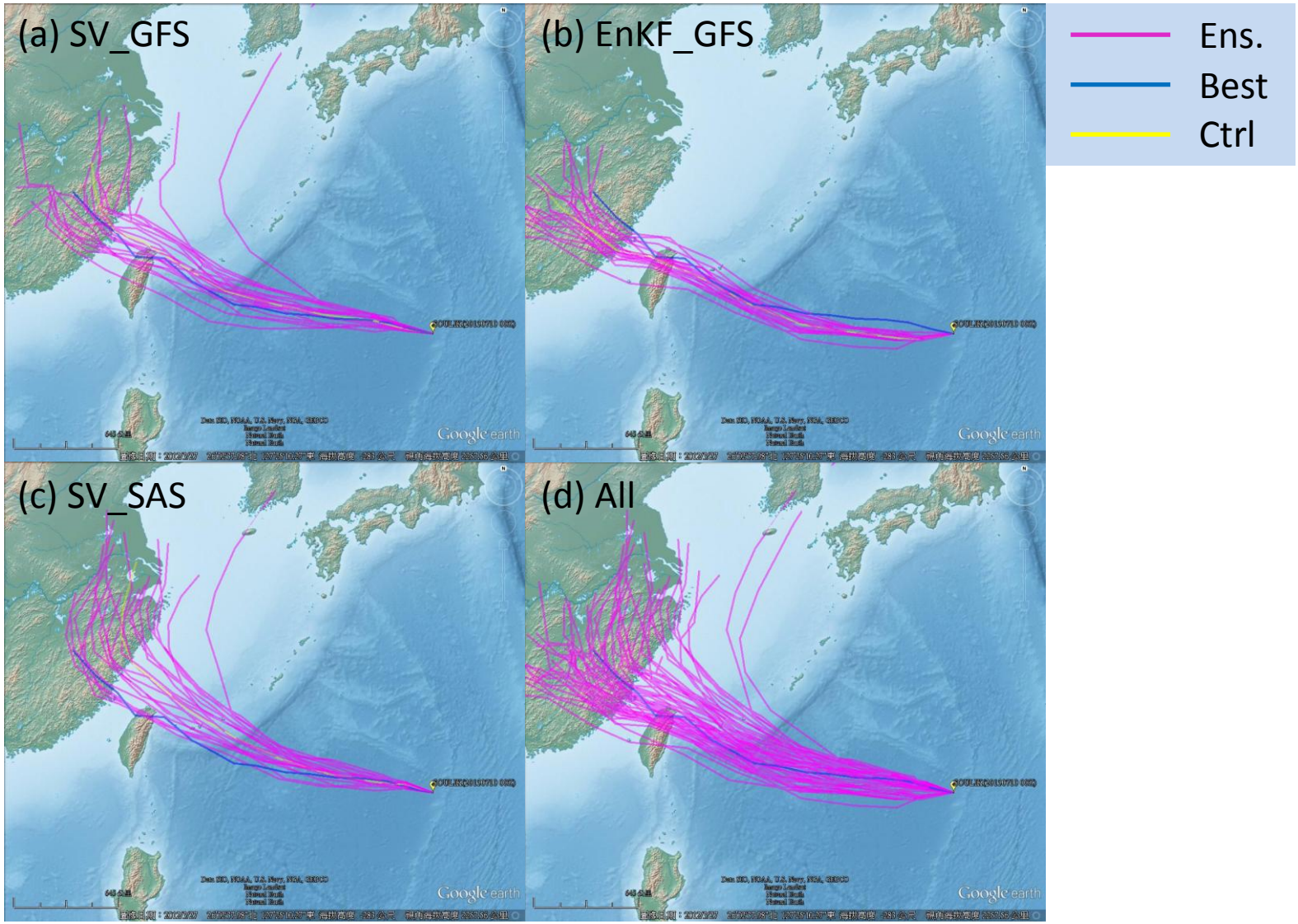


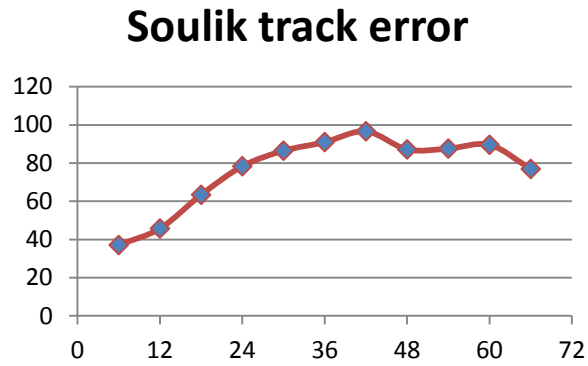
Initialized 12 UTC 05 July 2014

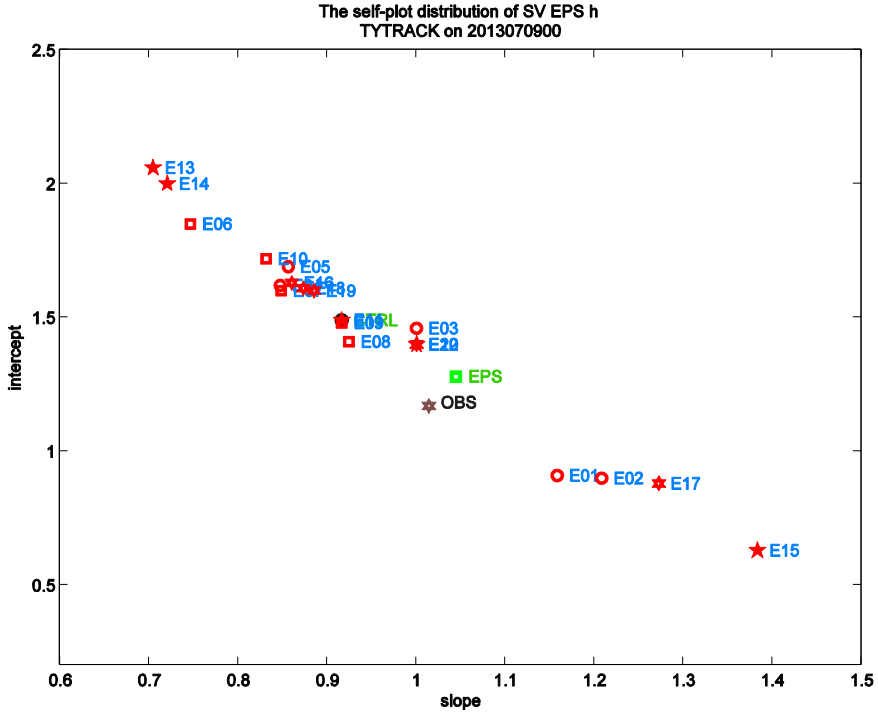
The Future …

SV+EnKF+New Physics: 60 members



The Spread of Ensemble





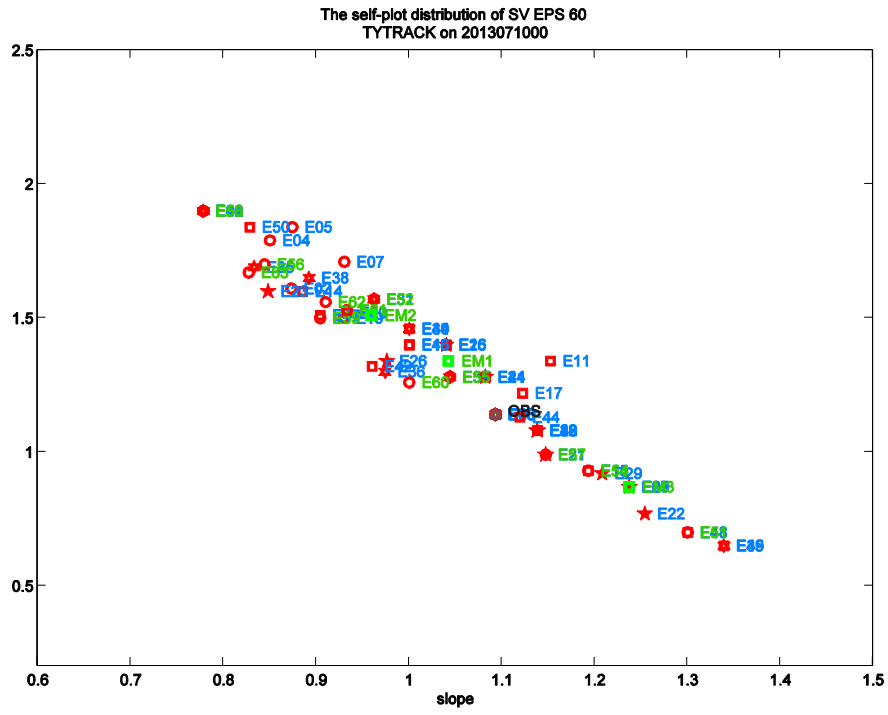


Fig. 3: The ensemble spread of typhoon Soulik track based on fractal dimension are shown. The each point stands for on typhoon track. The closer the two points are, the more similar tracks the two tracks are. (a) the spread from 20 SVs; (b) the spread from SVs, EnKF, and new physics total 60 members.

Conclusions

- The spread of ensemble typhoon track is not so obvious by directly adding SV into GFS model. We need to enlarge the quantity of SV by NMC method for getting better ensemble spread.
- Currently, we adopt two nested domains (east Asia and typhoon area) total energy norm to calculate SVs. In the future, we will consider the subtropical area in SV calculation.
- The track ensemble spread of the 6 hrs update cycle EnKF is not so dispersive and we think there are more modification and tuning works should be tested.
- Some statistical diagnoses should be done. Develop the Probability forecast tools and products.