Introduction of Global Ensemble Typhoon Forecast System of CWB

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The Structure of Numerical Weather Prediction

CWB GFS design chart

Data Assimilation
-- 4D-EnVar,
-- scale dependent analysis

Physical processes
-- parameterization
-- micro physics

dynamic core
-- equal area mapping
-- semi-Lagrangian
-- non-hydrostatic

ensemble prediction
-- stochastic physics

probability forecasts, downscaling forecasts
Why Ensemble

• extract the nonlinear instability of the inner dynamic process of atmosphere by singular vectors

• Present the model uncertainty by SPPT and SHUM
# CWB Typhoon Track Ensemble System

## CWB Global EPS for Typhoon-track (GET)

<table>
<thead>
<tr>
<th>Description</th>
<th>Deterministic Model</th>
<th>Ensemble Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>T319L40; T511L60</td>
<td>T319L40; T511L60</td>
</tr>
<tr>
<td>Initial Perturbation, Singular Vector</td>
<td>Global</td>
<td></td>
</tr>
<tr>
<td>Nested Typhoon Domain</td>
<td>East Asia</td>
<td>20°N-60°N, 100°E-180°E</td>
</tr>
<tr>
<td></td>
<td>Typhoon</td>
<td>15° × 10°</td>
</tr>
<tr>
<td>Optimization Time</td>
<td>48 hrs</td>
<td></td>
</tr>
<tr>
<td>Ensemble Size</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Forecast Length</td>
<td>5-day</td>
<td></td>
</tr>
</tbody>
</table>
In Past ...

• achieved **GET (Global Ensemble Prediction System for Typhoon-track)** based on T511L60
  -- prepare all the scripts for parallel run
• developed stochastic physical processes
• helped to establish 45 days EPS based on SVs
• prepared clustering and probabilistic diagnosis tools for EPS
In 2016...

• prepare **GET** parallel run (quasi-operation) based on T511L60

• improve the efficiency of **Stochastically Perturbed Parameterization Tendencies Scheme (SPPT)** and different **horizontal structure** on 45 days forecast

• Develop the probabilistic, clustering studies for downscaling (with statistic team)
SPPT Pattern (the first 100 time steps)

- The SPPT is the foundation stone of other stochastic physics processes like SHUM, SKEB, VC, etc.

Thanks Dr. Daryl Kleist and Prof. Yuejien Zhu

Horizontal scale ~ 500 km
Stochastic Physics Experiments

- Singular Vector (control run)
- SPPT + SV (SPPT)
- SHUM+SPPT+SV (SHUM)
The Typhoon Noul, 18 UTC 3 May – 18 UTC 11 May
The Typhoon Noul, 18 UTC 3 May – 00 UTC 12 May

Track Error and STD of Ensemble Members

No significant track error differences between experiments
No obvious differences in ensemble TY track spread

Ensemble Spread

Track error from deterministic run, control ensemble mean, SPPT ensemble mean, and SHUM ensemble mean
SPPT, ctrl, and Difference (1)
SHUM, ctrl, and Difference (2)
SHUM, SPPT, and Difference (3)
Hurricane Joaquin

Courtesy of Wen-Hsin Teng
Probabilistic Estimation (1)

CWB GEps for Typhoon-track (GET)
Initial time = 15080300

Best Track
PCA(24hr)
PCA(48hr)
PCA(72hr)
PCA(96hr)
PCA(120hr)

Courtesy of Young-Sin Lai
Probabilistic Estimation (2)

CWB GEps for Typhoon-track (GET)
Initial time = 15100100

Best Track
Ensemble
PCA(24hr)
PCA(48hr)
PCA(72hr)
PCA(96hr)
PCA(120hr)

Courtesy of Young-Sin Lai
Summary

- For typhoon tracks, there are not so obvious differences.
- For checking the spread of U on lat-z cross section, SPPT/SHUM increase the spread. That will be useful in future DA and 45 days forecast.
- More cases will be analyzed.
Future Work

• Test different SPPT horizontal scales, e.g. 1000/2000 km perturbations
• Diagnose the tropical cyclone by potential vorticity budget
• Improve the efficiency of SPPT schemes
• Implement the SPPT in DA and 45 days forecast
Thanks!
Animation (1) ... around typhoon
Animation (2) ... around mid-latitude
The Singular Vector Horizontal Structure (1)
The Singular Vector Horizontal Structure (2)
The Typhoon Track

CWB GEps for Typhoon-track (GET T511L60)
Initial time = 15080200

- Best Track
- Ens. Mean
- Ensemble
- Ctrl

w/o SPPT

SPPT
The Difference between SPPT and w/o SPPT in horizontal (1)
The Difference between SPPT and w/o SPPT in horizontal (2)
Animation (1) ... around typhoon
Animation (2) ... around mid-latitude
Algorithm of SPPT

1. Set \( r = \sum \hat{r}_{mn} Y_{mn} \), where \( \hat{r}_{mn} \) is spectral coefficient \((m, \text{zonal wave number index}; \ n, \text{total wave number index})\) and \( Y_{mn} \) is spherical harmonic function. Given white noise \( \eta_{mn} \) on spectral coefficient domain and set the initial
\[
\hat{r}_{mn}(0) = (1 - \phi^2)^{-1/2} \sigma_n \eta_{mn}(0),
\]
where \( \phi = \exp(-\Delta t/\tau) \),
\[
\sigma_n = F_0 \exp(-\kappa T n(n+1)/2),
\]
\[
F_0 = \left( \frac{\text{var}(r)(1 - \phi^2)}{2 \sum_{n=1}^N (2n+1) \exp(-\kappa T n(n+1))} \right)^{1/2}
\]

2. with red noise evolution over the time,
\[
\text{for } t = 0, T \quad /* \text{time evolution} */
\]
\[
\hat{r}_{mn}(t+1) = \phi \hat{r}_{mn}(t) + \sigma_n \eta_{mn}(t)
\]
\end

3. Define horizontal and vertical weighting function, \( \gamma \) and \( \mu \). Let model physical tendency term \( X \), and
\[
\text{for } t = 0, T \quad /* \text{time evolution} */
\]
\[
X_{\text{new}}(t) = (1 + \gamma \cdot \mu \cdot r(t)) X_{\text{old}}(t)
\]
\end
The Z-cross Difference between SPPT and w/o SPPT (1)
The Z-cross Difference between SPPT and w/o SPPT (2)
The Z-cross Difference between SPPT and w/o SPPT (3)
The Z-cross Difference between SPPT and w/o SPPT (4)
Use SPPT only ...
SPPT+SHUM

SOUDELOR, 2015080200, SPPT+SHUM, U spread

SPPT

SOUDELOR, 2015080200, SPPT, U spread
The Diff. between SPPT+SHUM and Ctrl

Noul, 20150318-2015051200, SHUM/SPPT-SPPT, U spread
w/o sppt; control run

Spread of U at 120 h, initial time 2015080200

SV without setting beyond 60N
Spread of U at 120 h, initial time 2015080200
The difference between SPPT and w/o SPPT

Spread of U at 120 h, initial time 2015080200
For Comparison...use SPPT only
The Z-Cross of Dry Total Energy (1)
The Z-Cross of Dry Total Energy (2)
The Z-Cross of Dry Total Energy (3)
The Z-Cross of Dry Total Energy (4)
The Z-Cross of Dry Total Energy (5)