# Introduction to JMA's new Global Ensemble Prediction System

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## 1. Introduction

The Japan Meteorological Agency (JMA) routinely operates several ensemble prediction systems (EPSs) to support forecasting work. Since February 2008, the Typhoon Ensemble Prediction System (TEPS) has been operated as part of JMA's suite of EPSs to support tropical cyclone (TC) track forecasting (JMA 2017). In January 2017, the Agency introduced the Global Ensemble Prediction System (GEPS) as a unification of the TEPS and the One-week EPS (WEPS) to achieve more efficient utilization of computer resources and intensify its EPS upgrade efforts. At the same time, JMA incorporated an upgraded forecast model, a Local Ensemble Transform Kalman Filter (LETKF) and perturbations on sea surface temperature (SST) into the GEPS. In March 2017, the One-month EPS was also merged with the GEPS.

This report gives an overview of the GEPS with particular focus on TC track forecasting. The system's specifications are outlined in Section 2, the impacts of the upgraded EPS on TC forecasting are covered in Section 3, and Section 4 gives a summary of the report.

## 2. Global Ensemble Prediction System Specifications

As well as covering a wide range of prediction periods from medium-range to extended-range forecasting, the GEPS also supports the issuance of five-day TC track forecasts. Its configuration is compared with that of the previous systems (TEPS and WEPS) in Table 1. Improvements include a revision of its parameterization schemes (those for land/sea surfaces, deep convection, cloud and radiation), a greater number of vertical layers (increased from 60 to 100), a change in top-level pressure from 0.1 to 0.01 hPa and the introduction of perturbations to SST, along with a revision of the initial perturbation production method via the introduction of an LETKF.

At present, 27 initial conditions are integrated twice a day from base times at 00 and 12 UTC using a low-resolution version of JMA's Global Spectral Model (GSM) to produce an ensemble of 11-day forecasts. The GEPS is also operated twice a day from base times at 06 and 18 UTC with a forecast range of 5.5 days when any of the following conditions is satisfied:

- A TC of tropical storm (TS*) intensity or higher is present in the RSMC Tokyo - Typhoon Center's area of responsibility (0 – 60°N, 100°E–180°).
- A TC is expected to reach TS intensity or higher in the area within the next 24 hours.
- A TC of TS intensity or higher is expected to move into the area within the next 24 hours.

* A TS is defined as a TC with maximum sustained wind speeds of 34 knots or more and less than 48 knots.

Unperturbed analysis is conducted by interpolating the analysis field in JMA's Global Analysis. The results of SST and sea ice analysis are referenced for the lower boundary condition, and the initialized condition is prescribed using the persisting anomaly. Accordingly, anomalies shown based on analysis for the initial time are fixed during the time integration. SST perturbations represent uncertainty in SST prescribed with a fixed anomaly.

Initial perturbations are generated using a combination of the LETKF (Hunt et al. 2007) and the singular vector (SV) method (Buizza and Palmer 1995). The ensemble spread with only perturbations from the LETKF, representing the uncertainty of initial conditions, shows underdispersiveness in medium-range forecasting. The LETKF combined with the SV for initial perturbations is adopted to mitigate this.

The Stochastically Perturbed Physics Tendencies (SPPT) scheme (Buizza et al. 1999) is used in consideration of model uncertainties associated with physical parameterizations. This scheme represents random errors associated with parameterized physical processes.

Table 1: Configurations of the current and previous systems. Bold red text represents major upgrades applied to the previous systems.

<table>
<tr><td></td><td colspan="2">Previous systems (before Jan. 2017)</td><td>Current system</td></tr>
<tr><td></td><td>Typhoon EPS (TEPS)</td><td>One-week EPS (WEPS)</td><td>Global EPS (GEPS)*</td></tr>
<tr><td>Main targets</td><td>Typhoon forecast</td><td>One-week forecast</td><td>Typhoon forecast, one-week forecast</td></tr>
<tr><td>Frequency</td><td>4 times a day (at maximum)</td><td>2 times a day</td><td>4 times a day when a TC is present, 2 times a day otherwise</td></tr>
<tr><td>Forecast range (initial time)</td><td>5.5 days (00, 06, 12, 18 UTC)</td><td>11 days (00, 12 UTC)</td><td>5.5 days (06, 18 UTC), 11 days (00, 12 UTC)</td></tr>
<tr><td>Ensemble size</td><td>25</td><td>27</td><td>27</td></tr>
<tr><td>Horizontal resolution</td><td colspan="3">TL479 reduced Gaussian grid system roughly equivalent to 0.375 × 0.375° (40 km) in latitude and longitude</td></tr>
<tr><td>Vertical resolution (model top)</td><td colspan="2">60 levels (0.1 hPa)</td><td>100 levels (0.01 hPa)</td></tr>
<tr><td>Initial perturbations (targeted area)</td><td>SV (western North Pacific, TC areas)</td><td>SV (Northern Hemisphere, Tropics, Southern Hemisphere)</td><td>SV (Northern Hemisphere, Tropics, Southern Hemisphere) + LETKF</td></tr>
<tr><td>Model ensemble</td><td colspan="3">Stochastically Perturbed Physics Tendency (SPPT)</td></tr>
<tr><td>Boundary perturbations</td><td colspan="2">None</td><td>Perturbations on SST</td></tr>
</table>

* The range of the prediction period in the table is limited to medium-range forecasting, but the GEPS produces ensemble forecasts up to 34 days ahead for extended-range forecasting.

## 3. Impact of Upgraded EPS on TC Track Forecasting

An experiment involving the use of the GEPS was conducted for the period covering 2015 and 2016 to evaluate the impact of the upgraded EPS on TC track forecasting. The results showed higher skill for TC track forecasting than the TEPS.

As shown In Figure 1, the average track forecast errors of both unperturbed forecasts and ensemble means for the western North Pacific were smaller than those for the TEPS. This positive impact mainly resulted from the introduction of the upgraded forecast model. However, the track errors of ensemble means were approximately equal to those of unperturbed forecasts in the GEPS and the TEPS.

As shown in Figure 2, the ensemble track spread from the GEPS was smaller than that from the TEPS up to 48 hours ahead. The ensemble spread with a forecast time of 120 hours from the

GEPS was larger than that from the TEPS. The ensemble spread deficiencies with a forecast time of 120 hours were mitigated in the GEPS, which was an expected effect from the revision of the initial perturbation production method.

From the cases verified, Figure 3 shows examples for T1618 tracks from the TEPS and GEPS initiated at 18 UTC on 1st October 2016. The TC tracks of individual ensemble members in the TEPS at time ranges of four to five days ahead veered southwestward from the best track. Meanwhile, the TC tracks in the GEPS varied along the best track during the period. Figure 4 shows examples for T1503 tracks from the TEPS and the GEPS initiated at 12 UTC on 11th March 2015. The results show the mitigation of spread deficiencies in the tropics. In addition, the speed of movement from the GEPS was closer to that of the best track.

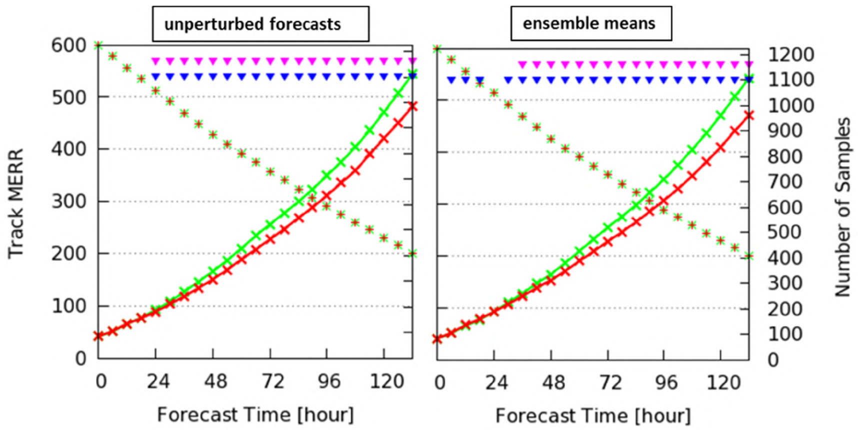


Figure 1: Average TC track errors of unperturbed forecasts (left) and ensemble mean forecasts (right) for the western North Pacific as a function of forecast time up to 132 hours. The red and green lines represent positional errors for the GEPS and the TEPS, respectively. Red plus marks and green x-marks indicate the number of cases included in the statistics. The pink/blue triangles at the top indicate a statistically significant difference of 0.05 with/without consideration of temporal correlation between the cases.

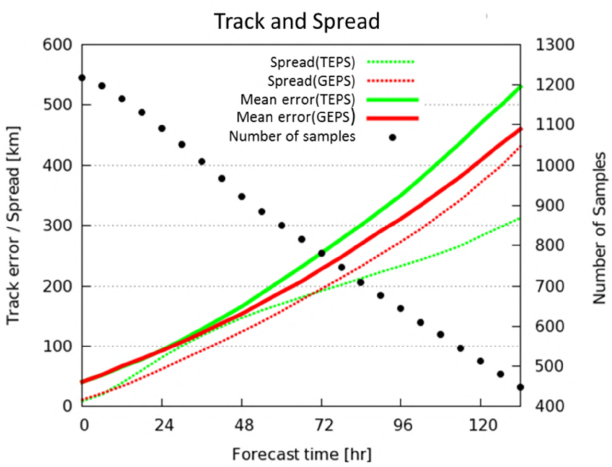


Figure 2: Average TC track errors (solid lines) and spreads (dotted lines) of ensemble mean forecasts for the western North Pacific as a function of forecast time up to 132 hours. The red

and green lines represent verification results for the GEPS and the TEPS, respectively. The black circles indicate the number of samples verified based on the vertical scale on the right.

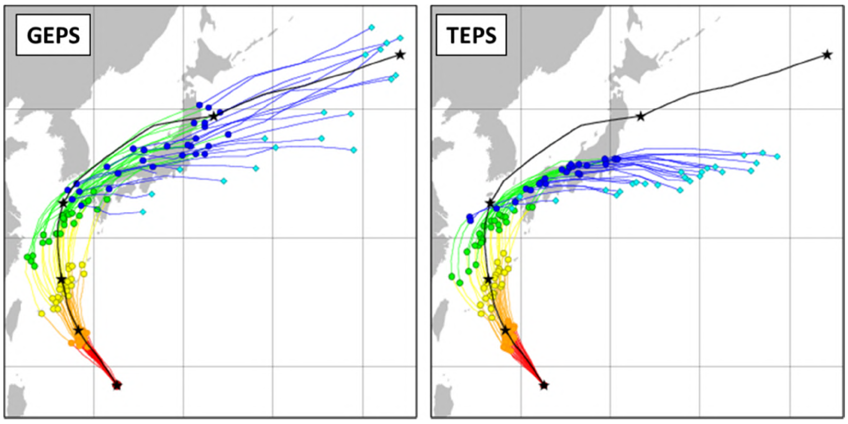


Figure 3: Comparison of TC forecast tracks up to five days ahead derived from the GEPS (left) and the TEPS (right). All tracks are for T1618 initiated at 18 UTC on 1st October 2016. Black lines represent the best track, and stars indicate TC positions on each day. The red, orange, yellow, green and blue lines represent the TC forecast tracks of individual ensemble members at time ranges of less than one day ahead, one to two days ahead, two to three days ahead, three to four days ahead and four to five days ahead, respectively. The circles on each line indicate TC forecast positions up to five days ahead.

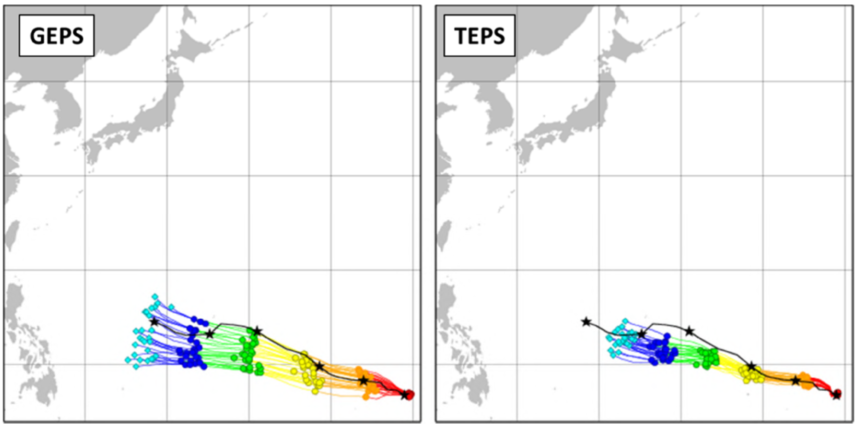


Figure 4: As per Figure 3, except with all tracks for T1503 initiated at 12 UTC on 11th March 2015

**4. Summary**

In January 2017, JMA implemented the GEPS, in which the TEPS and the WEPS were unified with the introduction of the upgraded forecast model, a revision of the initial perturbation production method and other adjustments. Verification results for the period covering 2015 and 2016 showed that these upgrades had made a positive impact on TC track forecasting for the western North Pacific, including the mitigation of spread deficiencies at time ranges of four to five days ahead and the reduction of track forecast errors.

**References**


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Buizza, R. and Palmer, T. N., 1995: The singular-vector structure of the atmospheric global circulation. J. Atmos. Sci., 52, 1434 – 1456.

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