1. Introduction
On January 19, 2017, Japan Meteorological Agency started the operation of Global Ensemble Prediction System (GEPS) which unify the three existing operational EPSs (Typhoon, One-week and One-month EPS). GEPS uses the perturbations from the Local Ensemble Transform Kalman Filter (GETKF) combined with Singular Vectors (SVs) as the initial perturbations. To mitigate the issue of underdispersiveness in the LETKF, the operational LETKF applies adaptive multiplicative covariance inflation based on the statistics of innovations and observational increments. Current inflation scheme has several issues such as excessive inflation with abruptly reduced observational coverage. To address these issues, the adaptive inflation methods using the relaxation to prior spreads (RTPS) and the relaxation to prior perturbations (RTPP) have been tested in the LETKF in JMA GEPS.

2. Specifications of GEPS and LETKF

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<th>Global EPS (GEPS)</th>
<th>Specifications of the JMA Global EPS.</th>
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<td>Main targets</td>
<td>Typhoon forecast, One-week to One-month forecasts</td>
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<tr>
<td>Frequency</td>
<td>4 times a day when TC exists, 2 times a day otherwise</td>
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<td>Forecast range</td>
<td>5.5 days (06,18UTC), 11 days (00,12UTC) 18 days (00,12UTC on Sat. and Sun.), 34 days (00,12UTC on Tue. and Wed.)</td>
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<td>Ensemble size</td>
<td>27 upto 11 days, 13 Afterwards</td>
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<td>Resolution</td>
<td>TL479L100 (approx. 40 km, model top: 0.01 hPa) up to 18 days, TL391L100 (approx. 55 km) afterwards</td>
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<td>Initial perturbations</td>
<td>SV (NL, TR and SH) + LETKF</td>
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<td>Model ensemble</td>
<td>Stochastically Perturbed Physics Tendency (SPPT)</td>
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<td>Boundary perturbations</td>
<td>Perturbations on SST</td>
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<td>LETKF in GEPS</td>
<td>Specifications of the JMA Global EPS.</td>
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3. Covariance inflation methods

Current method based on $d_{0}^{a} \cdot d_{0}^{aT} = HHH^{T}$ where $d_{0}^{a}$ is approximately derived from $d_{0}^{a}$ HSE and transformation matrix on grid i.

Adaptive RTPS/RTPP based on $d_{w}^{a} \cdot d_{w}^{aT} = HHH^{T}$ Kotsuki et al. (2017)

Relaxation to Prior Spreads (RTPS): $X_{w} = \frac{\alpha \sigma + (1 - \alpha) \sigma^{2}}{\sigma^{2}}$ where $X_{w}$ is the analysis spread, $\alpha$ is the forecast spread, $\sigma^{2}$ is the analysis spread, $\lambda$ is the mean inflation, $\sigma$ is the observation space.

Adaptive RTPS and RTPP are also possible with similar way.

4. Experimental settings

**Period:**
- Summer: From June 10, 2015 to September 11, 2015 (w/o satellite radiance and GNSSRO after August 1, 2015)
- Winter: From November 10, 2015 to March 11, 2016 (not shown)

**Experiments:**
- CNTL: Adaptive multiplicative inflation (current scheme)
- RTPS: Adaptive RTPS
- RTPP: Adaptive RTPP

For RTPS and RTPP, inflation coefficients are estimated only with in-situ observations. Ensemble mean analysis is replaced with the deterministic analysis (4D-Var).

5. Results

**Estimated coefficients are stable after short spin-up periods (~5 days)**
- Coefficient of RTPS is larger than that of RTPP.
- Raw estimated coefficients are larger on 00,12UTC compared to 06,18UTC.
- Coefficients get slightly smaller w/o satellite observations.

**Comparisons on analysis spreads and robustness to the changes on observing systems**

**RTPS and RTPP have larger analysis spread over the storm tracks and smaller spread over the tropics compared to CNTL.**
- Difference of spread from CNTL is more pronounced for RTPP than RTPS.
- Analysis spread on lower stratosphere is much smaller for RTPS and RTPP compared to CNTL. Spread of the first guess ensemble is smaller than that of the analysis ensemble, suggesting that the inflation keeps the spread on the stratosphere.
- Perturbations of RTPS grow faster than RTPP which indicates more balanced perturbations for RTPP (not shown).

**Results of the abrupt denial of satellite observations indicate the excessive inflation for CNTL in upper troposphere to stratosphere while RTPS and RTPP handle it better and they are more robust to the sudden changes on observing systems.**

6. Summaries and plans

- Current adaptive multiplicative inflation scheme used in the LETKF of the operational JMA GEPS has problems. For example, the excessive inflation can be applied especially when the incoming observations are suddenly reduced.
- Adaptive RTPS and RTPP based on Kotsuki et al. (2017) have been developed and tested on LETKF in JMA GEPS.
- Both adaptive RTPS and RTPP run stably and are found to be more robust on the abrupt changes on the observing systems compared to the current scheme.
- Plan to test GEPS using the perturbations from adaptive RTPS or RTPP experiments.
- Plan to apply the adaptive RTPS or RTPP to the hybrid 4D-Var using LETKF which is currently under the development as the next generation data assimilation system.

**References**