Improving the Stochastically Perturbed Parametrisation Tendencies Scheme using High-Resolution Model Simulations

Hannah Christensen[1], Sarah-Jane Lock[2], Andrew Dawson[1] and Tim Palmer[1]
1. Atmospheric, Oceanic and Planetary Physics, University of Oxford
2. European Centre for Medium-Range Weather Forecasts

Stochastic parametrisations are used in weather forecasts as a physically motivated way of representing model uncertainty due to unresolved processes. In particular, the "Stochastically Perturbed Parametrisation Tendencies" (SPPT) scheme has become widely implemented in operational centres. SPPT is a holistic approach that represents uncertainty in all the sub-grid physics parametrisation schemes. It is easy to implement, and has beneficial impacts on medium range, seasonal and climate timescales. In the SPPT approach, the tendencies from the different parametrisation schemes are added together, and a spatially and temporally correlated random number is used to multiply this total tendency:

$$T = D + (1+e)\sum_{i=1} P_i$$

where T is the final total tendency, D the tendency from the dynamics scheme P_i, the tendency from the ith parametrisation scheme, and e, the spatially and temporally correlated zero-mean random number (Palmer et al, 2009).

However, despite the widespread use of the SPPT approach, little work has focused on providing a firm physical basis for the SPPT scheme. The scheme involves several assumptions. Firstly, the errors from different parametrisation schemes are assumed perfectly correlated. Secondly, the imposed spatial and temporal correlations are not based on observations, though the optimal magnitude of the noise has been justified.

The sensitivity of the scheme to the first of these assumptions can be tested. A generalised version of SPPT is developed whereby the individual parameterisation schemes are perturbed with an independent stochastic perturbation field. This 'independent SPPT' (iSPPT) approach assumes the errors from the different schemes are uncorrelated, and allows the user to set the noise magnitude and spatial and temporal characteristics separately for each parametrisation scheme. A 'partially independent' approach can also be used, whereby some schemes are perturbed with the same stochastic pattern, while others are perturbed independently.

A series of 21 member ensemble forecasts were performed in CY41R1 at T_L255 and in CY42R1 at $T_{CO}255$. Standard SPPT was compared to iSPPT and to a partially independent SPPT in which two patterns were used, one for the moist and one for the dry processes. iSPPT led to a significant improvement in ensemble forecast reliability in the tropics, increasing the spread, reducing the ensemble mean error, and improving the continuous ranked probability skill score across a range of variables. However, in the southern extratropics the iSPPT scheme leads to a slight increase of error. The two-pattern approach seems to be a good compromise, performing well in all regions across many variables. Both iSPPT and partially independent SPPT have the largest impact in regions with significant convective activity, correcting the underdispersive nature of the ensemble in those regions.

However it is likely that the true parametrisation errors are neither perfectly correlated, as in SPPT, nor uncorrelated, as in iSPPT. We propose the use of high-resolution model simulations to explicitly measure the difference between the parametrised and 'true' sub-grid tendencies: in this way, we characterise the error in the tendency that stochastic schemes such as SPPT seek to represent. This allows for a more systematic approach towards improving SPPT.

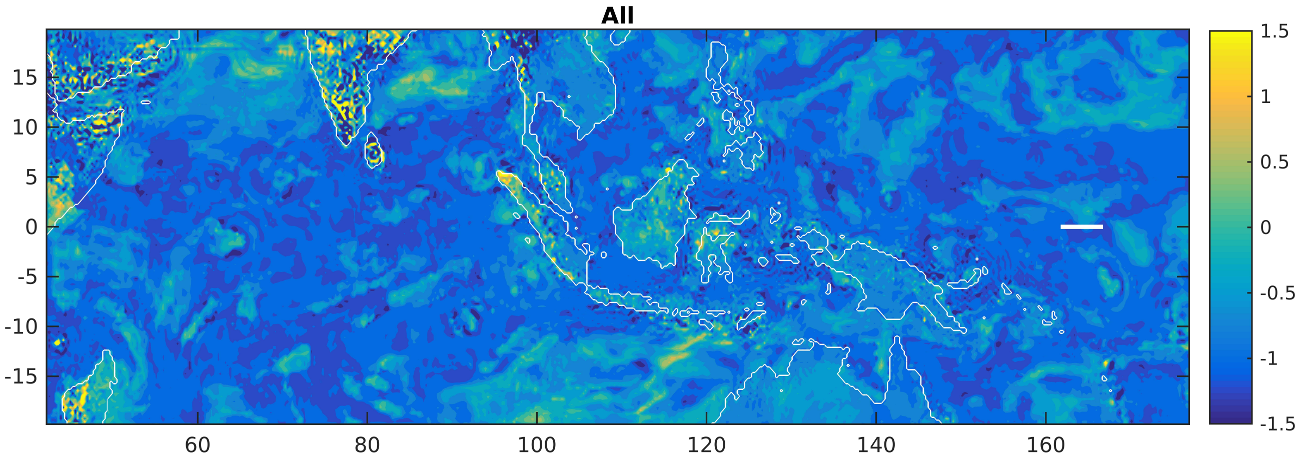
We use data from a high-resolution convection permitting integration with the UK Met Office limited area model as 'truth'. The model is run at 4km horizontal resolution with 70 levels in the vertical up to the model top at 40 km, and covers a large tropical domain (15,500 km x 4,500 km), focusing on regions of tropical convection in the Indian Ocean and West Pacific. This integration was performed as part of the CASCADE project (Holloway and Woolnough, 2013).

The high-resolution data is coarse-grained to the resolution of the ECMWF ensemble prediction system. This is used to provide initial conditions and forcing data for the IFS single column model (SCM). Short-range predictions with the SCM (15 minutes to one hour) are compared to the coarse-grained CASCADE data to derive the error statistics.

The SPPT equation can be rearranged to give:

$$T - D - \sum_{i=1} P_i = e \sum_{i=1} P_i$$

T is the 'true' total tendency from the CASCADE dataset, while D and P_i are the dynamics and physics tendencies from the SCM. All tendencies are a function of height at each location, while e, the optimal multiplicative perturbation, is a scalar. We can therefore solve this equation as a function of position and time to calculate a snap-shot of the optimal perturbation field, such as that shown below:



By repeating this calculation for all time steps within the CASCADE dataset, we can build up statistics of the optimal perturbation to be used in SPPT. We can also repeat the calculation allowing each parametrisation scheme to be perturbed independently, as in iSPPT. This allows us to investigate the error characteristics of each parametrisation scheme separately. It is hoped these measurements will improve both holistic and process based approaches to stochastic parametrisation.

<u>References</u>

Palmer, T. N., R. Buizza, F. Doblas-Reyes, et al, (2009) Stochastic parametrization and model uncertainty. Technical Report 598, ECMWF Shinfield park, Reading.

Holloway, C. E. and S. J. Woolnough, (2013). The effects of explicit versus parameterized convection on the MJO in a large-domain high-resolution tropical case study. Part I: Characterization of large-scale organization and propagation. J. Atmos. Sci., 70 (5), 1342–1369.