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Summary

Representation of model uncertainties for ensemble forecasts- Sarah-Jane Lock

With ensemble forecasts, we seek to present some measure of the uncertainty around a forecast. Collectively, the ensemble members should provide a cluster of possible outcomes that spans the parameter space that will include the true outcome. Averaged over many ensemble forecasts, a *reliable* ensemble will exhibit a *spread* (as measured by the square root of the mean of the ensemble variances) that approximates the ensemble *error* (the RMSE of the ensemble means). From a reliable ensemble, the ensemble spread from a new forecast can be used as a predictor of the likely error of the forecast ensemble mean. Predicting the likely error from an ensemble with too little spread yields over-confident forecasts.

At ECMWF, the IFS ensemble members are generated by perturbations to the initial conditions (designed to represent uncertainty in the initial state of the model) and by perturbations during model integrations (representing uncertainty associated with the model formulation itself). A representation of model uncertainty in ensemble forecasts has been implemented in the IFS since 1998, since recognising that representing initial conditions uncertainty alone yields ensembles with too little spread for medium-range forecasts (Buizza et al., 1999).

Currently in the IFS ensembles, two stochastic parameterisation schemes are used to represent model uncertainty: the Stochastically Perturbed Physics Tendencies scheme (SPPT; Palmer et al., 2009) and the Stochastic Kinetic Energy Backscatter scheme (SKEB; Shutts, 2005; Berner et al., 2009).

SPPT is used to represent model uncertainty due to the physics parameterisation schemes, which use simplified models to simulate processes that are complex, sub-grid-scale and/or poorly constrained by observations. SPPT applies perturbations to the winds, temperature and humidity fields by stochastically perturbing the net tendencies due to the physics parameterisation schemes. The unperturbed tendencies give rise to the perturbed tendencies through multiplicative noise taken from a 2D field of random numbers, which are correlated in space and time.

SKEB uses a stochastic method to simulate the upscale transfer of kinetic energy that is observed in the real atmosphere, but which is missing from the model due to there being no mechanism to make energy at the sub-grid-scale available for use at larger scales. In SKEB, kinetic energy is injected by perturbing the wind fields via a forcing term to the streamfunction. The forcing term is constructed from a 3D field of random numbers, that include space and time correlations, which are modulated by an estimate of the assumed local dissipation due to model inaccuracies. The estimated dissipation includes contributions from dissipative numerical methods (the explicit diffusion operator and the semi-Lagrangian transport scheme) and from unresolved kinetic energy sources in sub-grid deep convection.

Characterising the model errors that are due to model uncertainty is difficult since the uncertain processes are generally small in scale and often with large variations (in time and space), making suitable observation datasets hard to come by. Instead, coarse-graining studies have used model simulations to investigate the differences between a coarser-resolution parameterised forecast and the "truth" as approximated by a higher-resolution forecast (Shutts and Palmer, 2007). This coarse-graining work has informed the choice of parameters determining the correlation patterns and scales in the SPPT and SKEB random number fields.

The impact of SPPT and SKEB on the skill of the IFS medium-range ensemble (ENS) forecasts is routinely assessed. The schemes contribute increased ensemble spread leading to improved skill scores being observed across forecast variables, regions and lead times. In the extra-tropics, SPPT and SKEB contribute a similar impact in terms of increased spread. In the tropics, SPPT has a much greater impact than SKEB.

Recent analyses of seasonal forecasts from System 4 (S4) have shown that including the stochastic schemes gives rise to reduced systematic errors associated with overly active tropical convection; improved statistics of the Madden Julian Oscillation; and Pacific-North American circulation regimes that better agree with reanalyses (Weisheimer et al., 2014). For these longer timescales, the bulk of the impact can be attributed to SPPT.

Current research into the representation of model uncertainty in the IFS ensembles seeks to focus perturbations more closely on individual parameters than is currently done via SPPT. Ongoing work suggests some improved medium-range forecast skill is possible from randomly perturbing parameters related to boundary layer processes.

References

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