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Physical process based stochastic perturbation of model tendencies

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Numerical weather prediction (NWP) is, despite the high resolution (< 3km) of modern limited area models, still restricted to a plenty of parametrizations of physical processes not explicitly resolved in the numerical models. Such parametrisations always pose a source of model uncertainties that can in some situations significantly decrease the skill of the forecast. The use of stochastic physics in an ensemble prediction system (EPS) is a simple, computationally cheap and very effective way of representing such model errors. The most popular method of stochastic physics is called SPPT (Stochastically Perturbed Parametrisation Tendencies) and has been developed at the ECMWF. In SPPT a spectral pattern generator produces random noise which is used to perturb net model tendencies of temperature, water vapor content and winds. SPPT improves the reliability of forecasts by reducing biases in the ensemble forecasts and yielding a greater ensemble spread. However, SPPT is lacking physical consistency since only one single stochastic pattern is calculated and equally applied to the parametrized net tendencies of model variables. This would require a perfect correlation between the different schemes and a similar error characteristic, which is not always the case. Following this we have developed a physical process based stochastic scheme where partial tendencies of the radiation, shallow convection, turbulence and microphysics are perturbed separately including a consideration of the error representation in the subsequent schemes. Additionally, the perturbation patterns are especially tailored to the temporal and horizontal scale of uncertainty in the individual parametrizations. E.g. the pattern applied to the shallow convection parametrization has a much larger scale than for microphysics parametrization, etc. This method increased the stability of the model in the way that the tapering function, which is used in SPPT to reduce the perturbations to zero in parts of the atmosphere, could be switched off, except for turbulence. In a further development of this scheme the tendency perturbation of the turbulence parametrization has been replaced by parameter perturbations. In doing so temporally and spatially varying perturbations are directly applied to the key parameters in the turbulence parametrization (dissipation rate, mixing length, correlation factors).

The newly developed schemes have been tested over a 1-month summer and winter period, respectively, and verified against upper air analyses and surface observations. Beside an increase of model stability they led to statistically significant improvements of ensemble spread and to a generally better probabilistic performance compared to standard SPPT.