Model Uncertainty Representation in COSMO-DE-EPS

Susanne Theis, Michael Buchhold, Christoph Gebhardt, Regina Kohlhepp, Andreas Röpnack

Deutscher Wetterdienst, Offenbach, Germany

The convection-permitting ensemble prediction system COSMO-DE-EPS has been running operationally at the German Weather Service (DWD) since 2012. It consists of 20 ensemble members with a grid spacing of 2.8 km. Ensemble forecasts are started 8 times per day with a lead time of 27 hours (03UTC run: 45 hours). The model domain comprises Germany and neighbouring areas. The ensemble represents forecast uncertainties by variations in initial conditions, lateral boundary conditions and model physics (Gebhardt et al., 2011; Peralta et al, 2012).

In the operational version of COSMO-DE-EPS, model uncertainties are represented by a multi-parameter approach. The method is closely connected to the advice of parametrization experts and it has the advantage of fast implementation. It is targeted to user-specific aspects of the forecast (e.g. precipitation, 2m-temperature). As a starting point, ensemble experts and parameterization experts come together, discuss forecast uncertainties and pre-select promising candidates for parameter perturbations (e.g. entrainment rate of shallow convection, critical value of normalized oversaturation in the microphysics scheme, asymptotic mixing length in the turbulence scheme). The discussion already refers to the evaluation criteria described below.

The current implementation is fairly simple. Some ensemble members run with the default value of the parameter and some run with an alternative value. These values are constant within the model domain and during forecast integration (0-27 hrs / 0-45 hrs). For some parameters, there is only one alternative value. For other parameters, there are two alternative values, but their differences to the default are not necessarily symmetric. Today, the operational COSMO-DE-EPS perturbs 5 parameters (5 default values and 7 alternative values).

Before operational implementation, the parameter perturbations have been evaluated with regard to the following criteria: (1) ensemble spread and (2) ensemble quality, including the criterion of similar quality and bias in each individual member (Gebhardt et al., 2011).

(1) In terms of ensemble spread, case studies indicate whether the multi-parameter approach is able to capture events that would have been missed otherwise. Further evidence is added by statistical analysis of many cases. In the statistical context, it can be crucial to diagnose spread in a regime-dependent way (Keil at al., 2013). It is also interesting to estimate “spread in location”, detecting to which extent the alternative scenarios cause precipitation to occur at locations different from the default scenario.

(2) In terms of ensemble quality, each member is evaluated individually and also the entire ensemble is evaluated (e.g. Brier Score, CRPS, spread-error relation). Verification of individual members explicitly looks at their forecast bias and at their forecast quality. If the members are similar in bias and quality, there is evidence that ensemble spread is not simply generated by differing biases and also that members may be treated as equally likely. The parameter perturbation is rated as suitable for operational use only if these criteria are fulfilled. In addition to the statistical evaluation, visual inspection of

individual fields is beneficial, because it can detect unrealistic behaviour in observation-sparse regions (e.g. over sea).

As the development involves a manual selection and testing procedure, the current approach requires some effort in maintenance. Adaptations become necessary whenever the model version or the user-specific aspects change. Recently, the renewable energy sector has become a potential user of the forecast, so there is an incentive to improve COSMO-DE-EPS with regard to additional aspects (e.g. low-level clouds and solar radiation, low-level jet and wind in 100m height). Similarly to other convective-scale ensembles, these variables suffer from a lack of ensemble spread in COSMO-DE-EPS. Current development has attained improvements by enlarging the set of perturbed parameters, so COSMO-DE-EPS will soon perturb 9 parameters (9 default values and 13 alternative values).

Further attempts at optimization require much effort with a relatively small gain. One issue is the optimal combination of different parameter values in each member. Current development aims at replacing the fixed setting by a randomized one, so the combination of different parameter values would be a random result and not subject to optimization. The random scheme would be active at each forecast start. It would assign the various parameter values to each member and they would still be constant during forecast integration. Verification indicates that forecast quality is not degraded by the randomly combined parameter perturbations.

The multi-parameter approach covers an incomplete portion of the entire model uncertainty. A fully stochastic approach is believed to have more potential if appropriately developed. As a medium-term goal, DWD's research team on "physical processes" is developing a stochastic perturbation of model tendencies (E. Machulskaya, DWD, see poster at this workshop). The approach consists in a prognostic equation of model error. The equation contains parameters which specify noise amplitude and its autocorrelation in space and time. By applying a proxy for model error, it can be shown that these parameters are statistically related to resolved model variables. This may be an opportunity to use resolved model variables as predictors for the evolution of model error, resulting in a flow-dependent model of the model error.

As a long-term goal, DWD also supports research via the Hans Ertel Centre for Weather Research. Within this framework, a stochastic parameterization of shallow cumulus convection is developed at the Max Planck Institute for Meteorology (Sakradžija, 2015). Also within this framework, a model error representation within ensemble based data assimilation is developed at the Ludwig-Maximilians University in Munich (M. Sommer, LMU, see poster at this workshop).

References:

Gebhardt, C., Theis, S.E., Paulat, M. and Z. Ben Bouallègue (2011): Uncertainties in COSMO-DE precipitation forecasts introduced by model perturbations and variation of lateral boundaries. Atmospheric Research 100, 168-177.

Keil, C., Heinlein, F. and G.C. Craig (2013): The convective adjustment time-scale as indicator of predictability of convective precipitation. Q. J. R. Meteorol. Soc. 140, 480-490.

Peralta, C., Ben Bouallègue, Z., Theis, S.E., Gebhardt, C. and M. Buchhold (2012): Accounting for initial condition uncertainties in COSMO-DE-EPS. J. Geophys. Res., 117 (D7), doi:10.1029/2011JD016581.

Sakradžija, Mirjana (2015): A stochastic parametrization of shallow cumulus convection for high-resolution numerical weather prediction and climate models. Reports on Earth System Science, Max-Planck-Institute for Meteorology, Hamburg, 144 pp.