Gefördert durch: Bundesministerium für Wirtschaft und Energie aufgrund eines Beschlusses des Deutschen Bundestages

Gridcast

Deutscher Wetterdienst
Wetter und Klima aus einer Hand
DWD

# Representation of model error in ICON-EPS and COSMO-D2-EPS using a flow-dependent stochastic approach

**Martin Sprengel, Tobias Heppelmann, Christoph Gebhardt**

*The improvement of the inherent model error description is the main goal of ensemble development in the research project "gridcast" in which the German Meteorological Service (DWD) collaborates with the Fraunhofer IEE and the German transmission system operators. In order to achieve this goal, the DWD aims at characterizing and simulating the inherent model error in both the global ICON-EPS and the regional convection-permitting COSMO-D2-EPS.*

## Stochastic model for the model error

At each model integration time step, the model state tendency is updated with the simulated model error tendency; thus, the prognostic tendency equation satisfies:

$$\frac{\partial \phi}{\partial t} = \left[\frac{\partial \phi}{\partial t}\right]_{\text{Phys}} + \eta_\phi(x,t)$$

*$\phi$ = Prognostic variable (e.g. T, q, U, V)*
*$\eta$ = Model error tendency field*

The model error tendency is proposed to be simulated with a flow-dependent stochastic partial differential equation, i.e. *an Ornstein-Uhlenbeck process with an additive spatial diffusion term.*

$$\frac{\partial \eta_\phi(x,t)}{\partial t} = -\gamma_\phi \eta_\phi + \gamma_\phi \nabla \cdot \left(\lambda_\phi^2 \nabla \eta_\phi\right) + \sigma_\phi \xi(x,t)$$

*$\gamma$ = Relaxation parameter*
*$\lambda$ = Diffusion parameter*
*$\sigma$ = Standard deviation*
*$\xi$ = Gaussian noise term*

The parameters of the SPDE are estimated based on spatial and temporal correlations (García-Ojalvo et al. 1992).

## Results of parameter estimations and a first experiment

### COSMO-D2-EPS

**Grid spacing**: 2.2 km
**Vertical layers**: 65 (up to 22 km)
**Training data**: 1-hourly tendencies

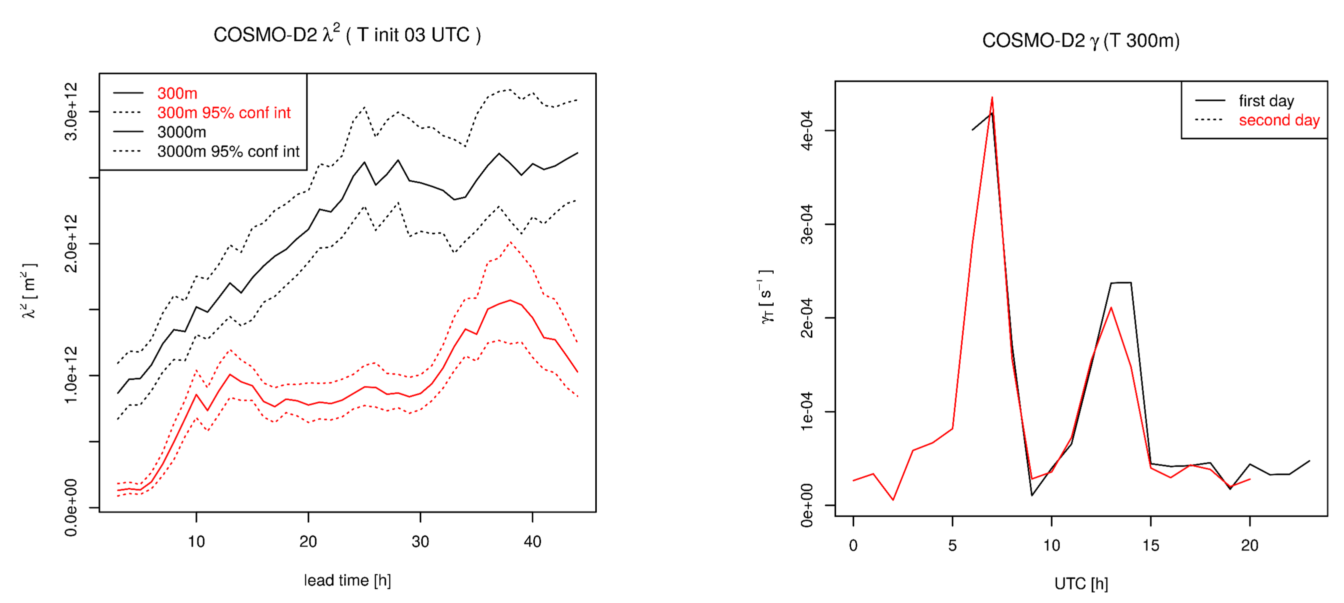


*Figure 1: Estimated diffusion parameter $\lambda$ as a function of the lead time for temperature T in 300m and 3000m height (left) and estimated relaxation parameter $\gamma$ as a function of time of the day for the first and the second forecast day (right).*

There is a general increase of $\lambda$ with the lead time. Closer to the ground the main growth happens during later morning hours, whereas above the boundary layer the growth is more constant.

In contrast, the estimated $\gamma$ in Figure 1 shows the same behavior on the first and the second day of the forecast with a strong diurnal cycle. $\gamma$ is largest (= correlation times are shortest) during the morning and late afternoon.

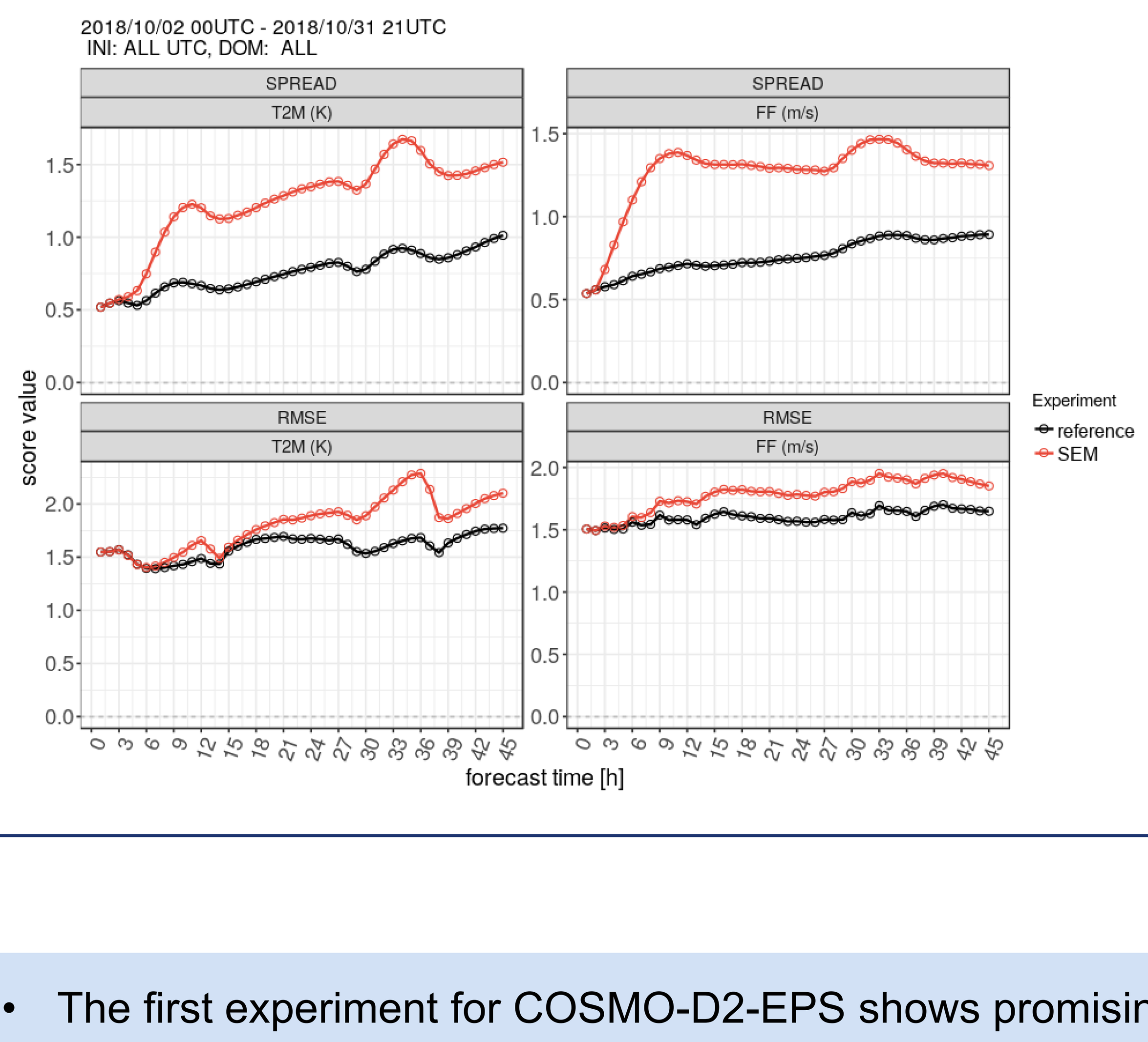


*Figure 2: Verification results of the first experiment of COSMO-D2-EPS with the stochastic model for the model error. Spread and RMSE are shown for 2m temperature and 10m wind speed. The spread is significantly increased (the stochastic perturbations were started at lead time +2.5h). The increase in RMSE especially at later hours requires further improvements of the parameter estimation.*

### ICON-EPS

**Grid spacing**: 40 km
**Vertical layers**: 90 (up to 75 km)
**Training data**: 6-hourly tendencies

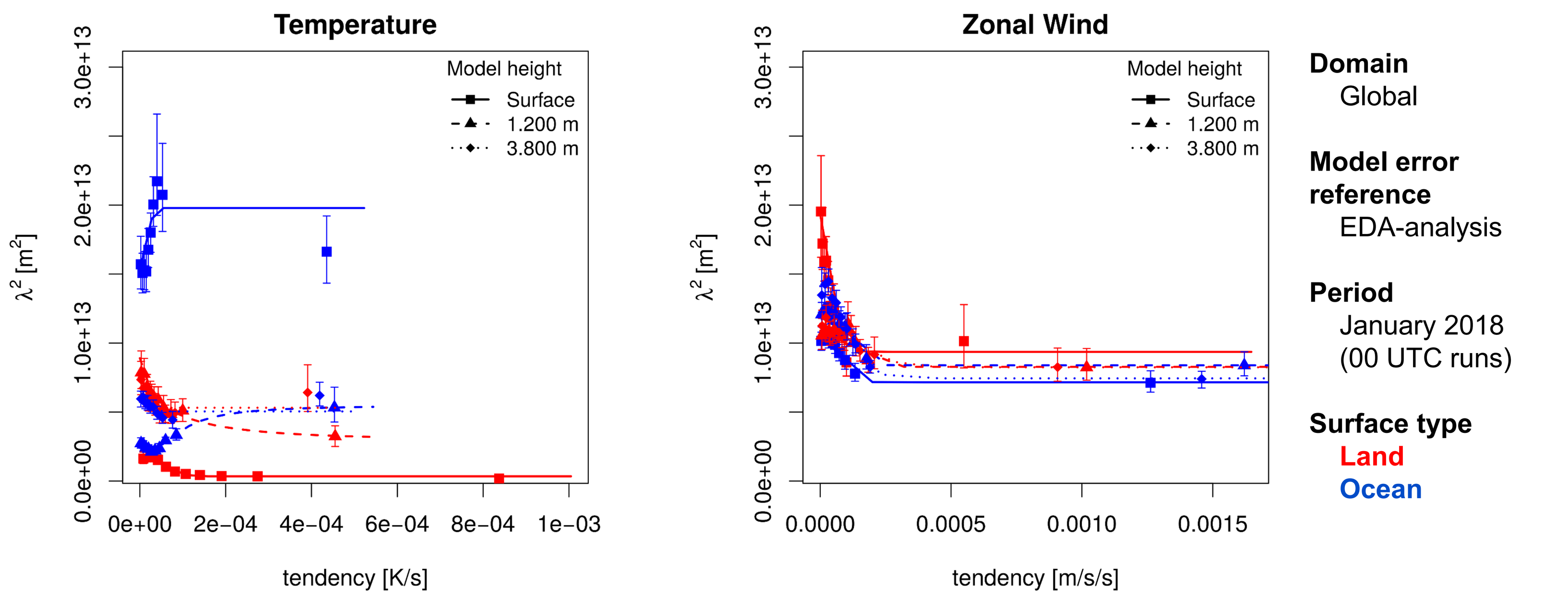


*Figure 3: Estimated diffusion parameter $\lambda$ as a function of the forecast tendency for three different heights at the model levels 90, 80, 70 of one ICON-EPS member for grid points over land (red) and over the ocean (blue). The error bars indicate the 95%-confidence interval of a bootstrap based on the forecast period.*

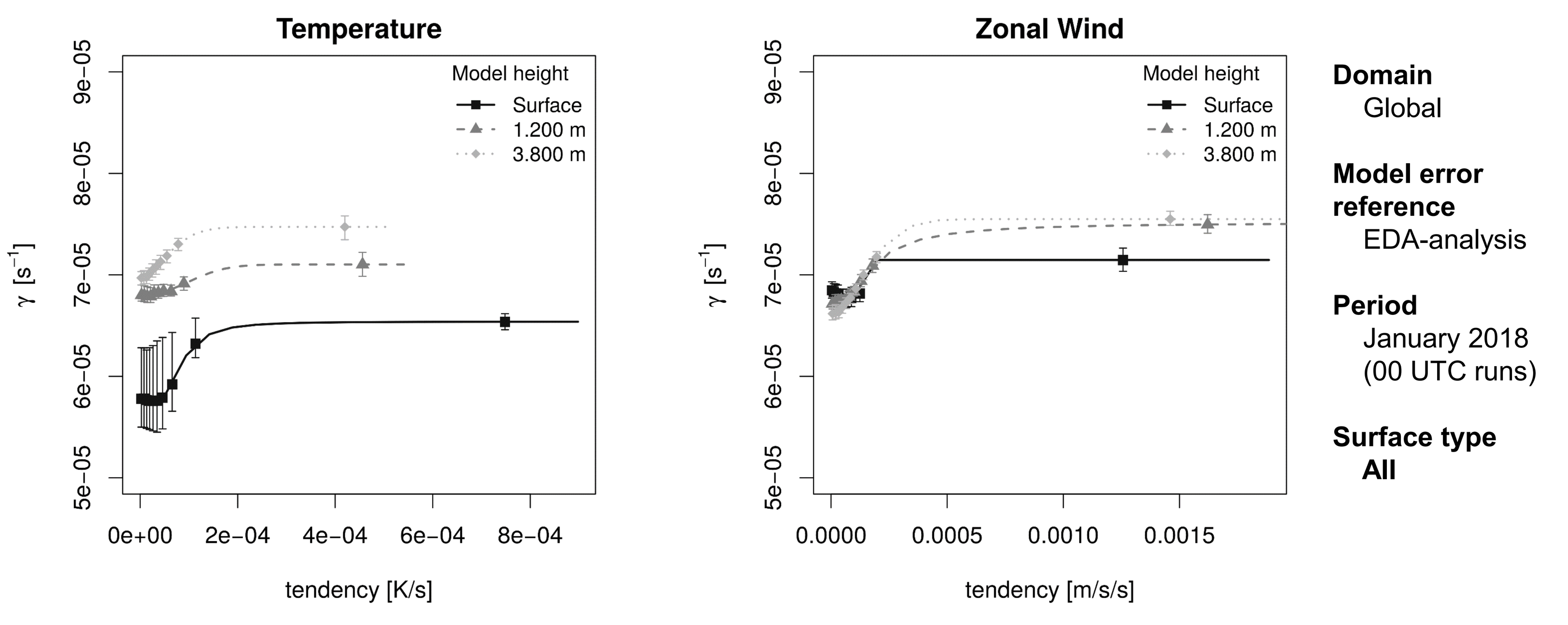


*Figure 4: As Fig.3, but here the estimated relaxation parameter $\gamma$ of the stochastic error model is shown for all grid points of the global model domain.*

For temperature, $\lambda$ depends on the surface type at model levels closer to the ground. With increasing model height, $\lambda$ indicates a convergence and faster correlation times $1/\gamma$ of the model error are found.

The parameters for zonal wind show a weak dependence on the surface type close to the ground. With increasing model height, a distinct convergence of the diffusion lengths and the relaxation times can be observed.

## Conclusion and Outlook

- The first experiment for COSMO-D2-EPS shows promising results.
- In order to reduce the growth in RMSE an improved estimation method for $\gamma$ has been developed; a new experiment is currently running.
- Fraunhofer IEE will use the experiments for a case study of one month (October 2018) to improve their electrical power injection prediction (PV + wind).
- For the global ICON-EPS, the parameters of the stochastic model for the model error are estimated for different model heights and variables, depending on the surface type (regions).
- As reference, we used the 6-hourly analyses from the ICON EDA.
- A num. experiment of ICON-EPS with the stochastic error model is in preparation.

**REFERENCES:** 1) ZÄNGL, G., REINERT, D., RÍPODAS, P., BALDAUF, M. (2015), The ICON (ICOsahedral Non-hydrostatic) modelling framework of DWD and MPI-M: Description of the non-hydrostatic dynamical core. Q.J.R. Meteorol. Soc., 141: 563–579; 2) ORRELL , D., L. SMITH, J. BARKMEIJER, T. N. PALMER, 2001: Model error inweather forecasting. – Nonlinear Processes in Geophysics, European Geosciences Union (EGU) 8, 357–371. <hal-00302046>; 3) TSYRULNIKOV, M.D., D. GAYFULIN, 2017: A limited-area spatio-temporal stochastic pattern generator. – Meteorol. Z. 26(5), 549–566. DOI: 10.1127/metz/2017/0815; 4) GARCÍA -OJALVO, J., J.M. SANCHO, L. RAMÍREZ-PISCINA, 1992: Generation of spatiotemporal colored noise.– Phys. Rev. A 46, 4670–4675; 5) PALMER, T. N., R. BUIZZA, F. DOBLAS-REYES, T. JUNG, M. LEUTBECHER, M., G.J. SHUTTS, M. STEINHEIMER, A. WEISHEIMER, 2009: Stochastic parametrization and model uncertainty. ECMWF Research Department Technical Memorandum. 598, pp. 42.

**Deutscher Wetterdienst**
**Offenbach am Main, Germany**
**Contact: Martin.Sprengel@dwd.de, Tobias.Heppelmann@dwd.de**