

Representation of model error in COSMO and ICON

Part II: Ensemble Perturbations in ICON-EPS

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Concept of Model Error Simulation

A-priori correction of forecast tendencies

$$\frac{\Delta X}{\Delta t}(x, t) = \frac{\Delta X}{\Delta t}(x, t)_{ph} + \eta_X(x, t)$$

X : Prognostic Variable

Simulation of the **model error** η_X using

- a stochastic partial differential equation (SDE)
- spatially correlated noise (García-Ojalvo et al., 1992)

$$\frac{\partial \eta_X}{\partial t} = -\gamma \eta_X + \gamma \nabla \cdot (\lambda^2 \nabla \eta_X) + \sigma \xi$$

$\eta_X = \eta_X(x, t), \xi = \xi(x, t)$
 $\lambda = \lambda(\tau_X), \gamma = \gamma(\tau_X), \sigma = \sigma(\tau_X), \tau_X = \frac{dX}{dt}(x, t)$

γ : Relaxation coefficient

λ : Diffusion coefficient to guarantee spatial correlation

σ : Standard deviation of the stochastic noise term ξ (“Gaussian noise”)

Stochastic Ensemble Perturbations in ICON

- Parameters of the stochastic differential equation are estimated offline dependent on the **predictor variable**, **model run**, **model height**, and **member ID**, but also **region** and **surface type**.
- 2-dimensional perturbation fields** applied at 3 discrete model levels (90,80,70) and vertically interpolated to levels 90-65.
- Perturbations are induced at each **complete slow physics** time step
=> tested setting: every 6 model time steps (36 minutes).

	ICON-EPS	COSMO-D2-EPS
Training tendencies Δt	6-hourly	1-hourly
Reference analysis	analysis ensemble	deterministic
Surface type distinction	land/ocean	no distinction

Experimental Setup

Ensemble System:	ICON-EPS (experimental branch with SEM)
Model resolution:	40 km, 90 levels
Ensemble size:	40 members
Time period:	October 2018, 00/12 UTC main runs (no ass.)
Full verification:	<u>not yet</u> finished, but test case studies available

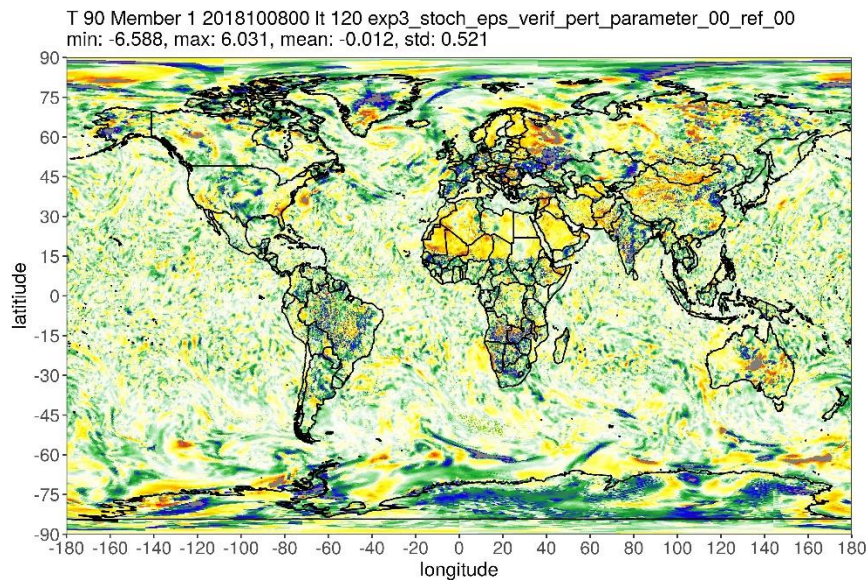
2 Setups:

1. ICON-EPS + fixed parameter perturbations (operational setup)
2. ICON-EPS + stochastic error model

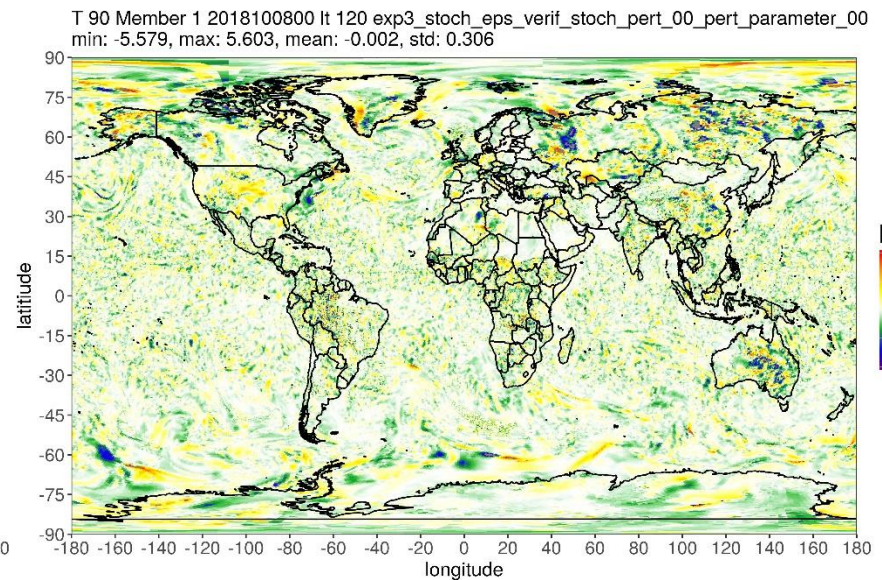
Test Cases with Ensemble Perturbations

10 m Temperature (surface layer)
Simulated Member #1: +120 h

Parameter Perturbations only

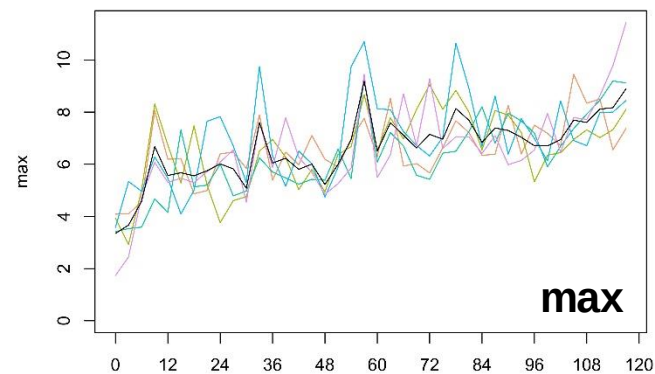
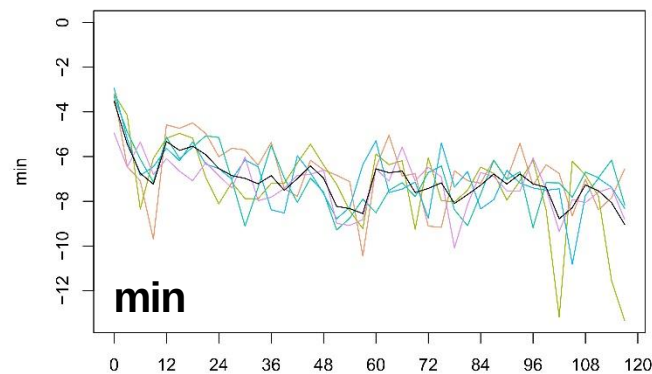


Stochastic Error Model



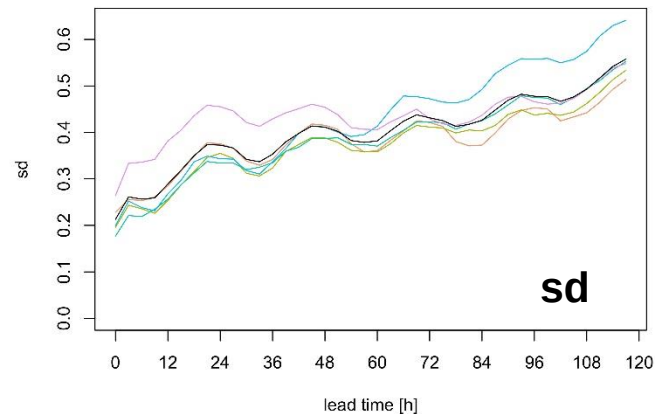
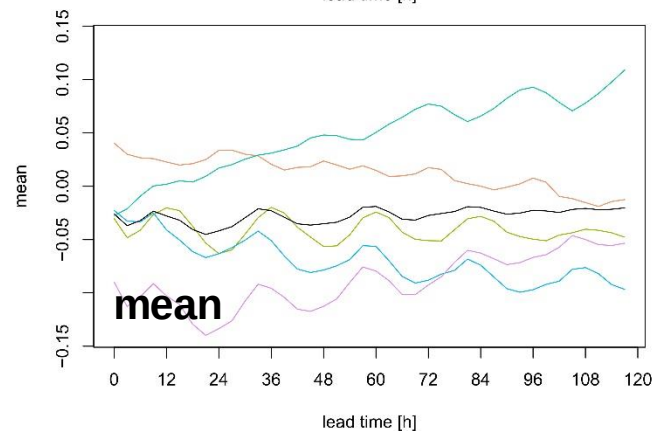
10 m Temperature: Spatial mem-statistics of param. pert.

Difference: pert_parameter-ref T 90 20181008 00UTC DOM01



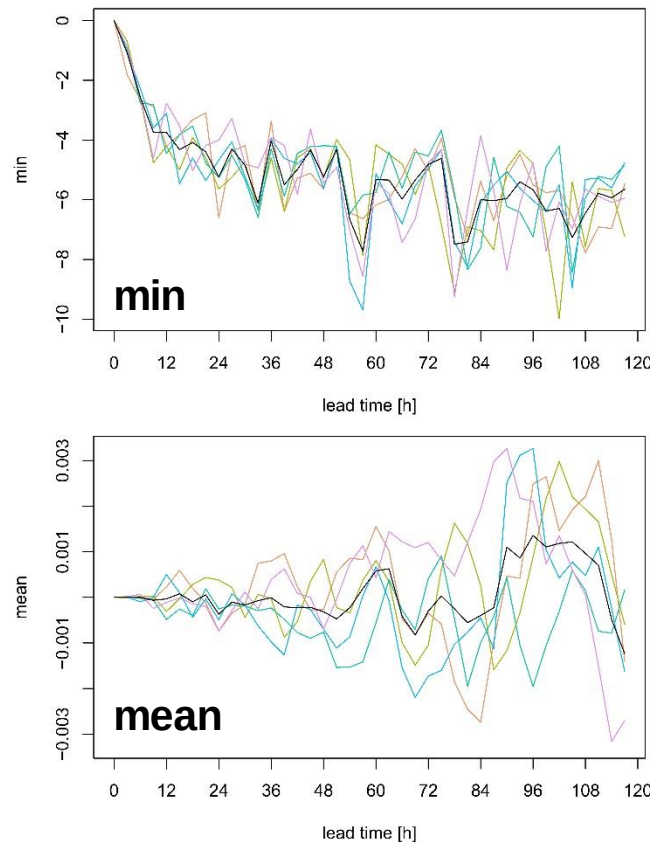
Colored:
5 members

Black:
Mean value



10 m Temperature: Spatial mem-statistics of SEM pert.

Difference: stoch_pert-ref T 90 20181008 00UTC DOM01

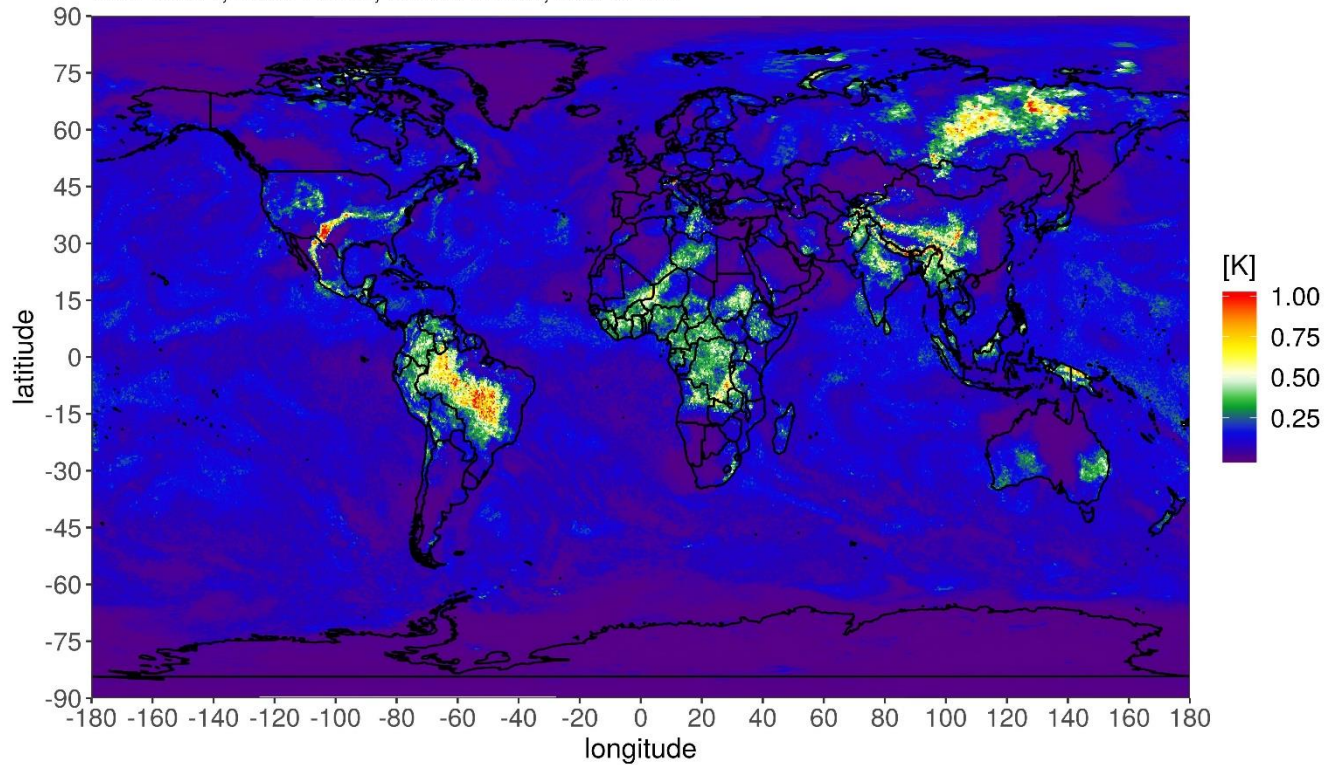


Colored:
5 members

Black:
Mean value

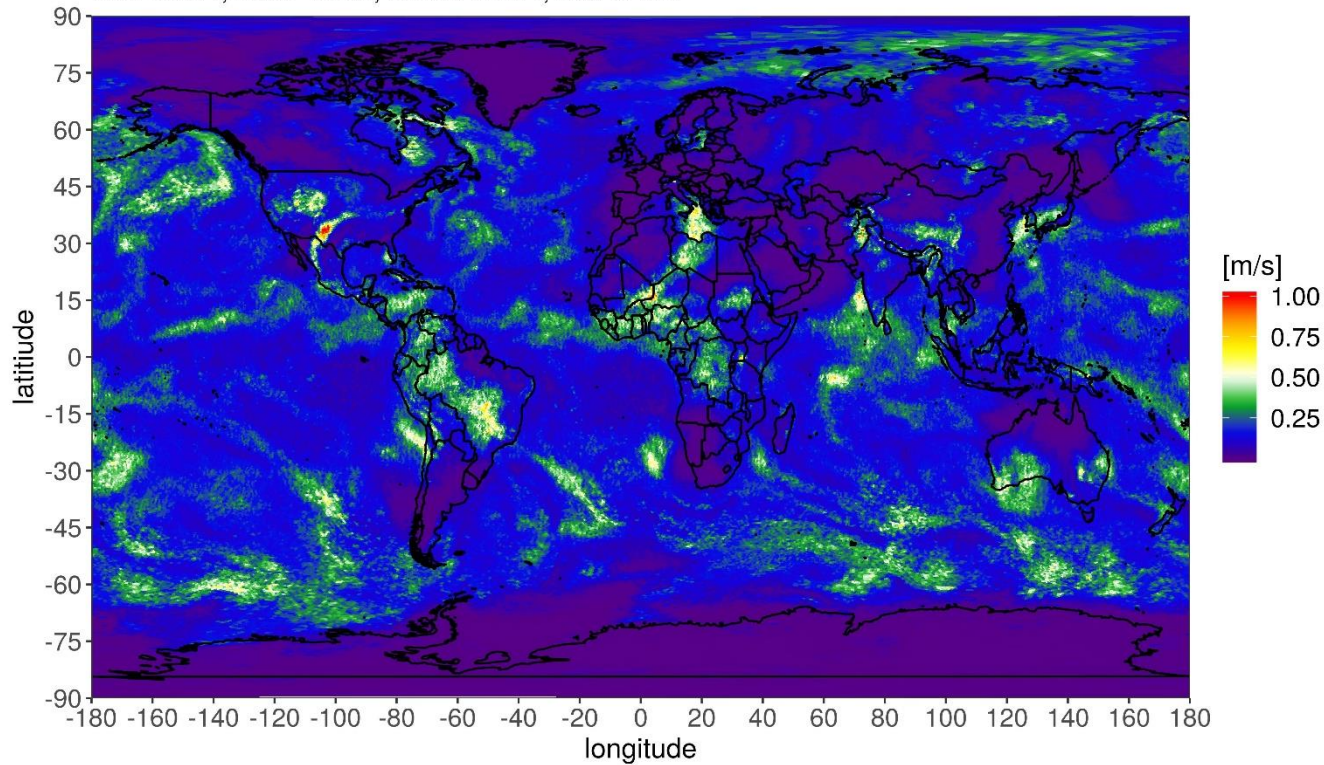
10 m Temperature: EPS Spread by SEM after 24h

T 90 Derived Stdv 2018100400 lt 24 exp4_stoch_eps_verif_stoch_pert_00_pert_parameter_00
min: 0.001, max: 2.213, mean: 0.106, std: 0.102



10 m Zonal Wind: EPS Spread by SEM after 24h

U 90 Derived Stdv 2018100400 lt 24 exp4_stoch_eps_verif_stoch_pert_00_pert_parameter_00
min: 0.001, max: 1.421, mean: 0.151, std: 0.102



Summary and next steps

Summary:

- The stochastic EM is implemented into the ICON model code.
- First ensemble test experiments show an additional increase of ensemble spread which has to be investigated in full experiments.

Next steps:

- Run ICON-EPS experiments w/o stochastic EM.
- Run ICON-EPS experiments with stochastic EM w/o parameter perturbations in order to **evaluate** the **impact of both types** of ensemble perturbations.

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 in weather 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;
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- 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.