Representation of model error in COSMO and ICON

Part I: The SEM in COSMO-D2-EPS

Martin Sprengel, Tobias Heppelmann, Christoph Gebhardt

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Outline

1. The stochastic error model (SEM)
2. Results from experiments
3. Current development
4. Summary

Aim of the Project

- Aim: Improve reliabilty of COSMO-D2-EPS and ICON-EPS
- How to: Improving inherent description of model error due to imperfect physics parametrization
- Method: develop a model η for the model error tendency using a stochastic partial differential equation (SPDE)
- use this model η_X to correct the tendencies from the NWP online for a set of variables X:

$$\frac{\Delta X}{\Delta t}(x,t) = \left[\frac{\Delta X}{\Delta t}(x,t)\right]_{\text{phys}} - \eta_X(x,t)$$

The Stochastic Error Model

Use the equation for spatially correlated noise[a)], however with flow-dependent coefficients to account for weather dependence:

$$\begin{aligned}\frac{\partial \eta_X(x,t)}{\partial t} &= -\gamma(\tau_X)\eta_X(x,t) \\ &\quad + \gamma(\tau_X)\nabla\cdot\left(\lambda^2(\tau_X)\nabla\eta_X(x,t)\right) \\ &\quad + \sigma(\tau_X)\xi(x,t) \\ \tau_X = \tau_X(x,t) &\text{ is the tendency of the predictor variable } X\end{aligned} \tag{1}$$

- γ damping
- Diffusion λ guarantees spatial correlation
- ξ standard normal random field; σ standard deviation

Model error tendencies $\hat{\eta}$ are determined using historical forecasts and analyses

[a)] García-Ojalvo et al., Generation of spatiotemporal noise, *Phys. Rev. A* 1992

Evaluation of numerical experiments I

- I have conducted several numerical experiments
  - COSMO-D2-EPS in operational configuration w/o SEM
  - for a reference period of October 2018 (selected with Fraunhofer IEE)
- standard verification against SYNOP shows
  - Increase in spread as intended
  - However, also increased error
  - Ratio spread/skill improves especially for 10m wind (FF)
  - Further improvements needed to avoid increase in error
- analysis verification shows specific deficit in wind speeds at 100-600m height during nights with stable boundary layer
- reason seams to be linked to formation of nocturnal low-level jets

Evaluation of numerical experiments II

- detailed investigation of selected cases:
  1. nights of 12, 13, 14 Oct: clear days and nights
  2. nights of 23, 24, 25 Oct: passing of cold/warm front, storm
- analysis verification indicates forecast deficiencies especially in the first case
- how to discriminate between the cases automatically?

Bulk Richardson number

$$R_B = \frac{(g/T_v)\Delta\theta_v \Delta z}{(\Delta U)^2 + (\Delta V)^2} \tag{2}$$

- g gravitational constant
- absolute T_v virtual temperature
- Δz layer thickness
- $\Delta\theta_v$ change in virtual potential temperature across layer
- ΔU, ΔV change in wind speed across same layer

Bulk Richardson number

$$R_B = \frac{(g/T_v)\Delta\theta_v \Delta z}{(\Delta U)^2 + (\Delta V)^2} \tag{2}$$

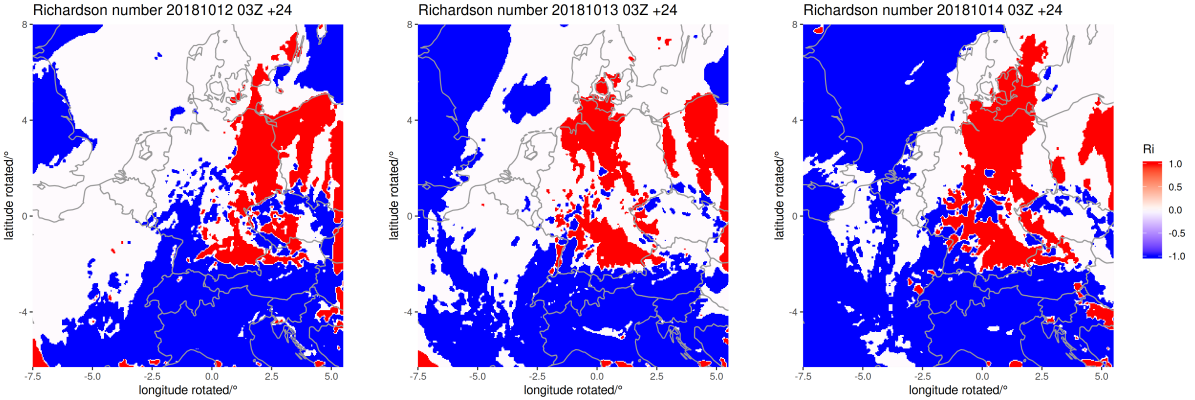
Our settings:

- Best discrimination was found for layer of level 65-55 (10m-300m)
- thresholding

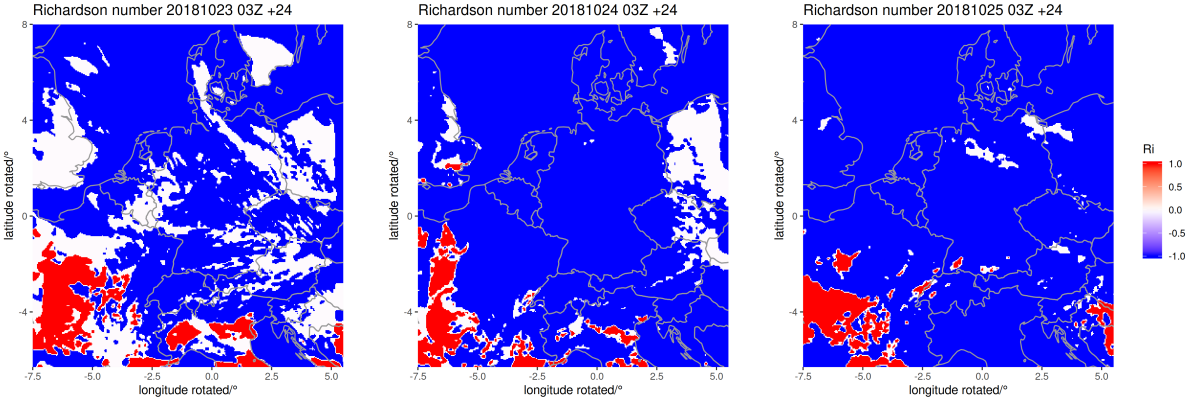
$$R = \begin{cases} 1 & R_B >= .25 \\ 0 & R_B \in (-.25, .25) \\ -1 & R_B <= -.25 \end{cases} \tag{3}$$

- Smoothing over box of 7x7 grid points

Richardson number: stable nights



Richardson number: unstable nights



Summary and next steps

Summary:

- first experiments look positive
- but need improvement for nights with stable boundary layer
- bulk Richardson number was found to effectively discriminate between (un)stable PBL

Next steps:

- add Richardson levels $R \in \{-1, 0, 1\}$ as predictors in addition to the tendency τ
- re-determine coefficients γ, λ, and σ as function of both τ and R
- implement the additional predictor R into COSMO
- perform new experiment