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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

Studies of Convection-Permitting Ensemble Forecasting for ICON-D2 with a 1km Nest over the Alps

Z. Parsakhoo*, C. Marsigli, C. Gebhardt*, A. Seifert*, J. Keller***

*Deutscher Wetterdienst (FE1), **Arpae-SIMC

Within the context of the "Global-to-Regional ICON digital twin" (GLORI) project, a convection-permitting ensemble forecasting is established in order to study the predictability of high-impact weather events with high-resolution modeling (up to 500 m) and the influence of the land-surface—atmosphere coupling mechanisms.

Introduction

Our first experiments use the ICON-D2-EPS operational setup for model perturbations (static parameter perturbation). Subsequently it analyzes the impact of different convection schemes on the predictability of the processes leading to convection development.
Specifically, we test the behavior of the convection scheme in two configurations: shallow-convection only, and deep-convection parameterization in the so-called gray-zone-tuning version. By selectively activating and deactivating these schemes, we aim to assess their individual contributions to the predictability.

Model Setup

In this work, we employ a nested domain with horizontal resolution of 1-km in the southern region of the ICON-D2, encompassing the Alps mountains (TEAMx domain, Figure 1). We run a 24-hour forecast simulation starting at 00UTC on the 21st of June 2022, with 20 ensemble members. The choice of the date is crucial as it corresponds to a day when the DWD recorded instances of heavy rain and hail in the Baden-Württemberg and Bavaria regions.

The experimental setup is summarized in Table 1, and the configuration of the convection parameterization for both domains is provided in Table 2.:

Table 1: Exp. Setup	
Two-way nesting	
Horizontal grid resolution	2km (ICON-D2), 1km (TEAMx*)
Upper boundary	22km
Vertical levels	65
LAT-BC	Forecasts (ICON-EU)
Perturbed initial conditions	KENDA (ICON-D2-EPS)
Forecast duration	24h starting on 2022062100
Forecast restart	6h
Ensemble members	20
Microphysics	1mom and 2mom
Turbulence	TURBDIFF
Land	TERRA
Standard operational model perturbations	

Table 2: Exp. conv. par. configuration

Exp. ID	1km	2km
A	shallow	shallow
B	shallow	shallow+deep (Gray-zone tuning)

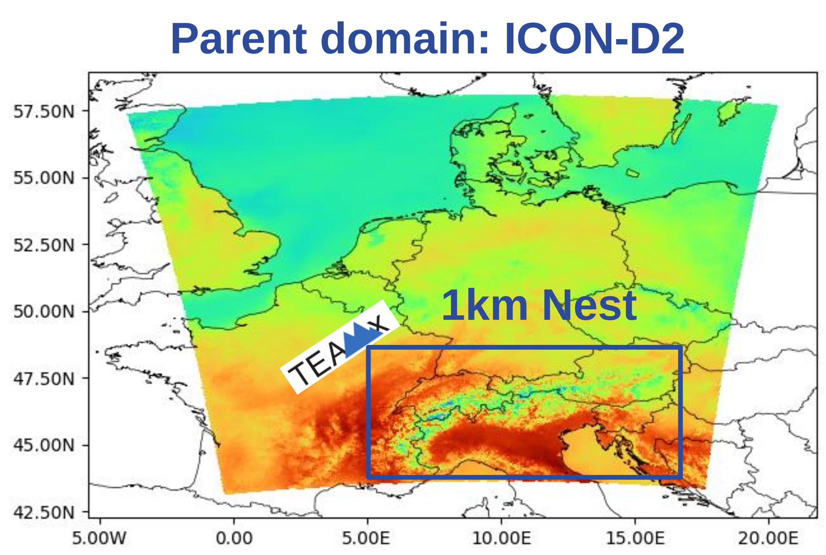

Figure 1: Model Domains: ICON-D2 at 2 km, nested Alps domain at 1 km.
*TEAMX: https://www.teamx-programme.org/

The deterministic runs from both experiments forecast less rain than observed. The Shallow-conv-only experiment (Exp. A2) forecasts relatively more rain than the GrayTuning experiment (Exp. B2). The precipitation is underestimated in the Alpine area between 9 and 11 deg and a maximum is forecasted more to the west, where we do not have a complete radar estimate (Figure 2). Some ensemble members forecast misplaced rain, while others forecast insufficient rain (Figure 3). Experiments with 2mom microphysics produce more realistic clouds than 1mom (not shown here).
In this case study, there is no significant difference in precipitation between 1 km and 2 km resolutions over southern Germany, and increasing horizontal resolution did not enhance forecast skills.
These findings motivate the introduction of additional model perturbations at higher resolutions. This is why we initiated the Stochastically perturbed parameterization (SPP) approach to enable more sophisticated perturbations for better capturing convection at finer resolutions.

SPP References: Ollinaho et. al. 2016, Frogner et. al. 2021, and Tsiringakis et. al. 2024

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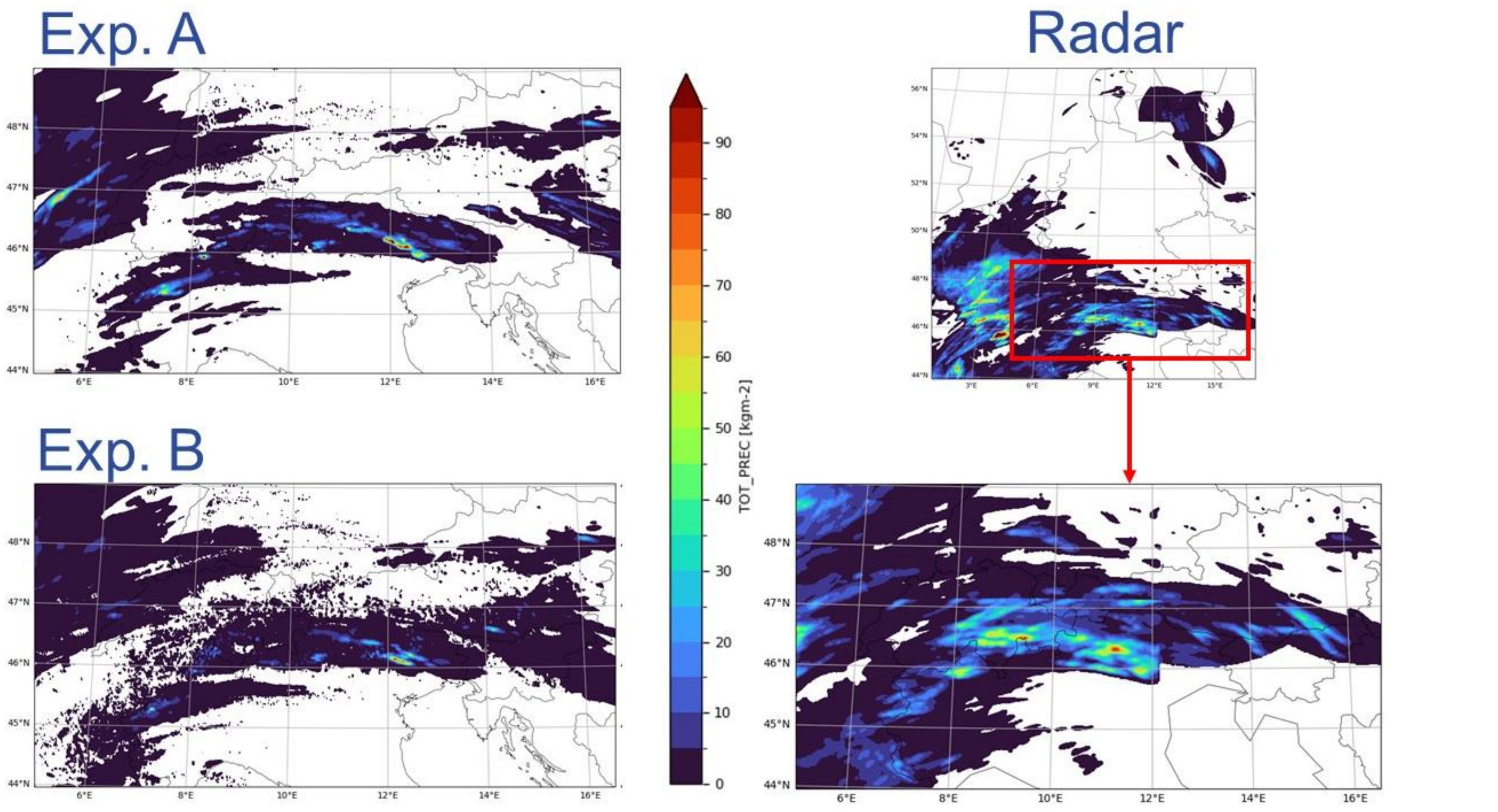

Figure 2: Total precipitation accumulated from 00 to 18 UTC from deterministic run for Exp. A (upper left), Exp. B (lower left. Right panel is the map of German radar composite.

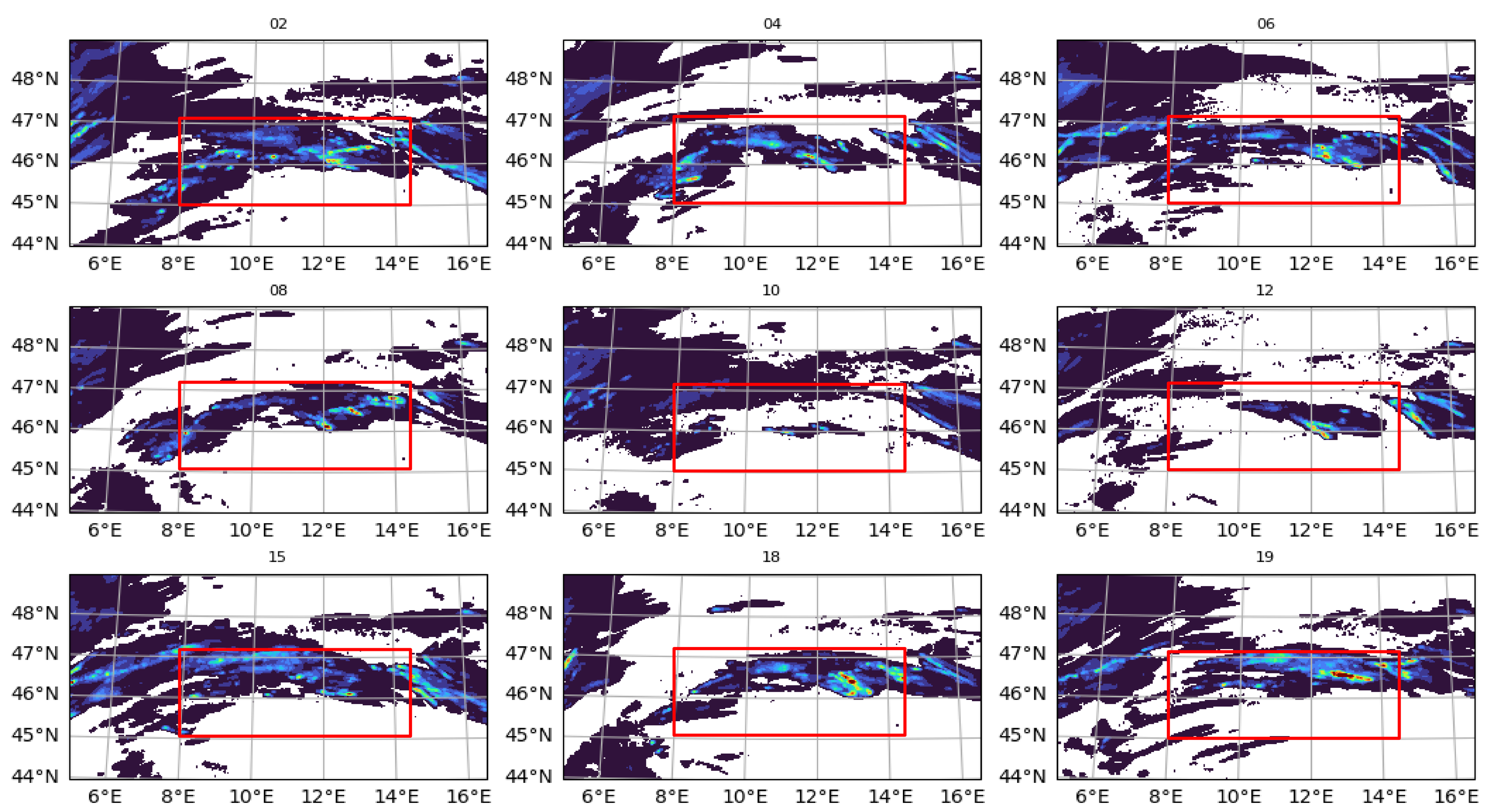

Figure 3: Total precipitation from randomely selected ensemble forecast runs at 18 forecast lead time from Exp. A. The colorbar is the same as Figure 2.

Stochastically perturbed parameterization (SPP)

Alternatively to static parameter perturbation (as operational at DWD), an uncertain parameter is perturbed using a temporally evolving stochastic pattern:

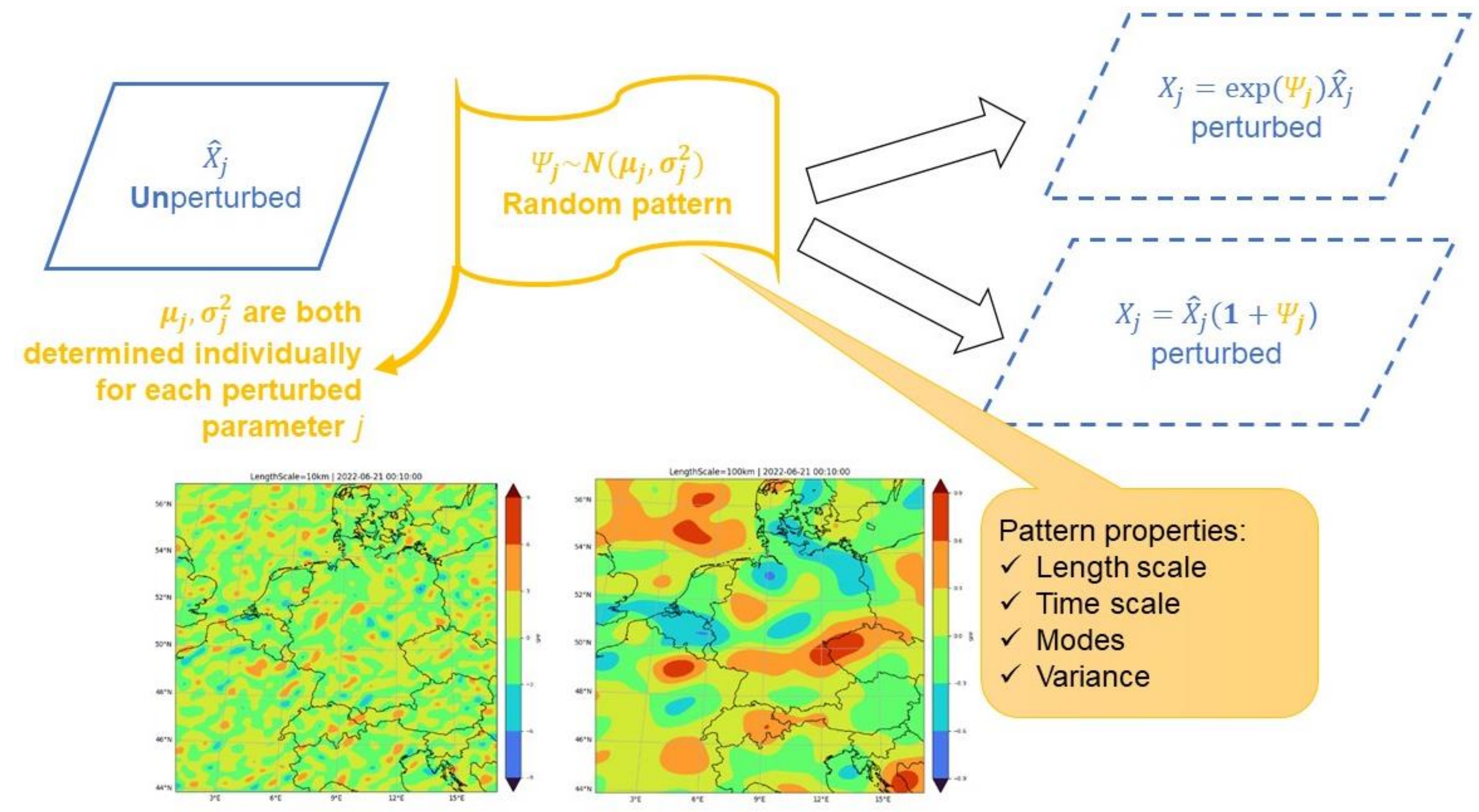

Figure 4: Schematic of SPP mechanism illustrating parameter perturbations.

In ICON, SPP for deterministic forecasts was implemented by Axel Seifert specifically for perturbing graupel sedimentation velocity in the microphysics scheme. We extended this implementation for ensemble mode and tested the SPP scheme in limited-area runs, examining model stability across different SPP properties such as variance.

Future Plans

- Expanding SPP implementation to perturb additional uncertain parameters in various schemes.
- Testing SPP in the convection scheme, focusing on *rdepths* (maximum allowed shallow convection depth), with technical support from Daniel Reinert (DWD).
- Evaluating SPP performance in ICON-LAM across different horizontal resolutions
- Extending SPP implementation and testing for a nested domain.

GLORI – Global-to-Regional ICON digital twin
FE 11 – Data Assimilation and Predictability Division
(E-Mail: zahra.parsakhoo@dwd.de)