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Nonlinear Processes in Geophysics
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Interactive comment on "Simulating model uncertainty of subgrid-scale processes by sampling model errors at convective scales" *by* Michiel Van Ginderachter et al.

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Short reply to Referee nr. 1 Referee nr. 1 correctly raises the issue: "the study lacks justification of its basic theoretical assumption". But, in fact, the study is based on the theoretical analysis of Nicolis (2003, 2014) and Nicolis et al. (2009) (which are cited). The referee is nevertheless right that a clear description of the justification is lacking in the manuscript. Below we give one that was included in a previous version of the manuscript, but that we, unfortunately, removed to keep the paper concise. We now realize that this may be crucial to make the paper readable, since one can, rightly so, not expect the reader to check the equations in the cited papers, even if they are

correctly cited.

In fact we compute ϵ in Eq. (6) below in a full NWP model and this theoretically defines what we mean by model error. It also defines what the "reference" is, namely X. We have also proven that removing the deep convection degrades the forecast, see Fig. 1 (we will add this to the revised manuscript), so we believe this ϵ can be called a model error. By carefully reducing the experiment to a difference in the contributions of a few controllable terms we ensure that the theory of Nicolis (2003) can be applied. The corresponding terms in the NWP model are shown in Eqs, (1)-(3) in the submitted manuscript. The convenient thing about the deep convection parameterization is that the terms can be nicely isolated (and in fact allows for generating perturbations that conserve energy). One could take different terms, but for a first study we limit it to deep convection, as it is an essential ingredient of the atmospheric dynamics at scales smaller than 10 km.

That said, this would not be possible if we have different set ups for the dynamics, e.g. in the resolution, or by changing the hydrostatic to a non-hydrostatic version, since than we cannot reduce the model error to a few terms and would prevent us to effectively separate the model error from initial condition errors.

We very much appreciate the comment of Referee nr.1 and will give a more detailed point by point reply in the final response. We plan to include the paragraph below in the manuscript, either in the full text or in the appendix.

Theoretical justification For low-order models a characterization of the model error has been done by Nicolis (2003), who investigates the dynamical and probabilistic aspect of the model error in the absence of initial condition errors, and Nicolis et al. (2009) who study the evolution of prediction error under the combined effect of initial condition and model errors. Essentially, the method used in Nicolis (2003) is described as follows: the respective correct evolution laws and model equations can be formally written as

$$\begin{aligned} \frac{d\mathbf{X}}{dt} &= \mathbf{f}(\mathbf{X}) && (1)\\ \frac{d\mathbf{Y}}{dt} &= \mathbf{g}(\mathbf{Y}). && (2) \end{aligned}$$

Starting from identical initial conditions $\mathbf{X}(t_0) = \mathbf{Y}(t_0)$ one can write for a sufficiently small time interval δt:

$$\begin{aligned} \mathbf{X}(t_0 + \delta t) &= \mathbf{X}(t_0) + \mathbf{f}(\mathbf{X}(t_0))\delta t && (3)\\ \mathbf{Y}(t_0 + \delta t) &= \mathbf{X}(t_0) + \mathbf{g}(\mathbf{X}(t_0))\delta t. && (4) \end{aligned}$$

The model error can be written as $\mathbf{U}(t) \equiv \mathbf{Y}(t) - \mathbf{X}(t)$ by extracting Eq. (3) from Eq. (4)

$$\mathbf{U}(t + \delta t) = (\mathbf{g}(\mathbf{X}(t_0)) - \mathbf{f}(\mathbf{X}(t_0))\,\delta t. \tag{5}$$

The model error source, determining the short time behaviour of $\mathbf{U}$ is then characterized by estimating

$$\epsilon = \mathbf{g}(\mathbf{X}) - \mathbf{f}(\mathbf{X}). \tag{6}$$

The aim of this paper is to study the feasibility of this method for estimating the model error source related to the absence of a parametrized convective forcing in a high order limited area model (LAM). This is done by running the ALADIN (Aire Limitée Adaptation Dynamique Développement International) numerical weather prediction (NWP) model in a configuration where deep convection is not parametrized and comparing it to a reference configuration with a scale-aware deep convection parametrization scheme.

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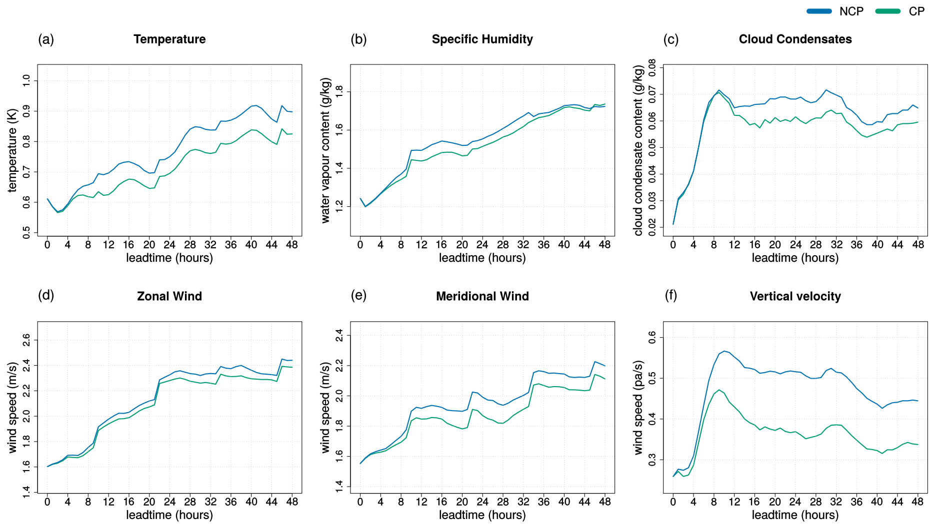

Fig. 1. RMSE (compared to the ERA 5 re-analysis) of the different model output variables at 850 hPa for the configuration with (green) and without (blue) convective parameterization.