Impact of a stochastic deep convection scheme using cellular automata in the meso-scale ensemble prediction system; Harmon-EPS.

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There is a long standing discussion in the Numerical Weather Prediction (NWP) community whether model error (arising from model physics) should be represented in form of stochastic physics applied a posteriori after the tendencies from the physical parameterizations have been computed, or whether it should be included at the source of uncertainty, at the sub-grid, in form parameter perturbations or a stochastic parameterization (see for instance various methods discussed in Berner et al. 2016). Although the latter sounds appealing, since one could really address the model error in a more physically motivated manner, the former has proven more successful in many ensemble prediction systems, using the stochastically perturbed parameterization tendency (SPPT) scheme (e.g Buizza et al., 1999, Palmer et al., 2009), and the stochastic kinetic energy backscatter scheme (SKEBS) (Shutts, 2005). One reason for the success of these schemes is the fact that the scheme are correlated in space and time over scales far beyond the sub-grid scale, whereas sub-grid representation of model error, such as parameter perturbations or white noise stochastic parameterizations, are limited to the “column physics”, and thus there are no spatial and temporal correlations of the perturbations.

One way to include both spatial correlations, and temporal memory to a stochastic parameterization included on the sub-grid, was to couple a cellular automaton to the deep convection parameterization of the NWP model, ALARO (Bengtsson et al. 2013). The cellular automaton is in this scheme acting on the sub-grid of the NWP model and can form clusters which can organize themselves across the NWP model's grid-boxes to enhance deep convective organization. This way the cellular automata can form a “fraction of the NWP grid-box” that are later coupled back to the model via the updraft mesh-fraction in the closure assumptions of the deep convection parameterization. The cellular automata is only coupled back to the deep convective evolution of the updraft mesh-fraction if the value of CAPE exceeds a certain threshold.

The aim of the study presented at this workshop was to understand whether such a stochastic parametrization on the sub-grid scale could be used in order to represent the uncertainty associated with deep convection, and provide more reliable probabilistic forecasts in an ensemble prediction system for the mesoscale. Describing the statistical effect that deep convection has on the large-scale flow in a stochastic manner means that the resolved scale variables, such as the vertical and horizontal wind or temperature, would respond differently to the convection scheme each time the model was run. Thus, the stochasticity of the implemented parametrization can be studied by examining the ensemble spread in resolved model variables generated from the sub-grid scheme. The expectation is to capture better the range of possible convective responses given by the ensemble members in the resolved fields of the model.

The study has been published in Bengtsson and Körnich, 2016. The ensemble prediction system used is called Harmon-EPS, it is an ensemble prediction system aimed at the mesoscale and is based on the Hirlam Aladin Regional/Mesoscale Operational NWP In Europe (HARMONIE) forecast system, which is developed within the two HIgh Resolution Limited Area Model (HIRLAM)–Aire Limit´ee Adaptation dynamique D´eveloppement InterNational (ALADIN) consortia, a collaboration on NWP development between 26 countries in Europe.

It was found that the stochastic cumulus parametrization does in general give an increased amount of convective precipitation in regions where CAPE is large. This resulted in a larger ensemble spread of convective precipitation. However, as a consequence of the parametrization, resolved precipitation was reduced due to an increase in sub-grid precipitation, giving a decreased ensemble spread over the domain average for total precipitation. Such reduction in resolved precipitation also led to an improvement in precipitation bias for the test-period, which in general improved the skill. Thus, from the classical view of introducing stochastic physics in order to increase the ensemble spread, doing so within the physical sub-grid parametrization is not straightforward. Various feedbacks within the physical parameterization even lead to a reduced spread in some instances where the skill was improved.

Overall, for 6 h accumulated precipitation, the BSS, CRPS and mean bias were for the most part improved (with the exception of small thresholds for precipitation in the BSS), which suggests that the ensemble forecast was improved, however, not by reason of increasing the spread but instead by improving the skill, due to the inclusion of the dependence of CAPE in the closure and the memory and lateral communication of the cellular automata.

In the future the scheme's impact will be tested on equatorially coupled waves over the Tropics in order to understand further the potential for "upstream" representation of model error when the coupling between the deep convective organization and the atmospheric flow is large.

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