Responses to the reviewers

Large impact of tiny model domain shifts for the Pentecost 2014 MCS over Germany

by Christian Barthlott and Andrew I. Barrett November 26, 2019

Dear Editor,

This letter accompanies our revised manuscript. We are grateful for the reviewer's helpful comments, and hope our revision addresses them all. Below we detail the changes made in our revision. We include the text of the reviews in black, our responses are in blue.

Reviewer 2

This study presents the results of a simple experiment to test the sensitivity in simulating a high impact precipitation event over Germany by shifting the model domain by seemingly inconsequential amounts. While the study focuses on the impact of the domain shifts, essentially the ensemble model setup is an exercise in perturbing the initial conditions/lateral boundaries and thus the intrinsic predictability of convective storms. The main result of the ensemble was that members that initialized convection in France and then subsequently moved over cooler, ocean air resulted in weaker convection that dissipated before being able to intensify into the observed MCS in Germany. On the other hand, members that kept the convection over land where it was able to tap into a more favorable environment produced convective systems that were reasonably well forecasted over Germany.

In general, this paper needs provide a clearer link to previous studies that have investigated the impact of perturbing the initial conditions/lateral boundaries. I am still unconvinced that shifting the domain would be a more promising avenue to "account for uncertainties in the initial and boundary conditions" than other techniques (see the work from Ryan Torn and colleagues since the mid-2000s). Additionally, I believe more analysis is needed than a cursory comparison of precipitation and environmental parameters. What preempted the deviations in convection evolution over land/sea? Plots and discussions of differences in upper-level vorticity, MSLP, and even SSTs would improve the analysis. Once these two chief concerns have been addressed, I will provide a more thorough review, including specific comments and suggestions, prior to publication.

- The first point we want to address is similar to the reply to the first and second comment of Reviewer #1. We do not believe that our technique is a new method to generate ensembles with perturbed initial/boundary conditions in operational convective-scale ensemble forecasting. However, we were surprised to see such a large influence of these tiny changes on the simulation results and strongly believe that this method should be tested for more cases (also with different extents of domain shifting) and other models. It may also be that the high sensitivity is a feature of days with low predictability only, which would be a useful information to have. Therefore, a more systematic evaluation is left for future work. The goal of this paper was not to assess the impact of other perturbation techniques, as we already mentioned the poor forecast quality of the operational COSMO-DE-EPS of the German Weather Service in the introduction. It is of special interest to see, if other cases with low predictability (i.e. forecast busts) show the same sensitivity. However, we think that such an analysis would not fit into the present paper and is therefore left for future work. For these reasons, we did not refer much to other techniques to perturb initial and boundary conditions in our manuscript.

  Changes to paper

Abstract:
This study demonstrates the potentially huge impact of tiny model domain shifts on forecasting convective processes in this case, which suggests that ~~the inclusion of this simple method in convective-scale ensemble forecasting systems~~ *the sensitivity to similarly small initial condition perturbations* should be evaluated ~~for different cases, models~~ *across other cases, model* and weather regimes.

Summary:
The results of this work suggests that ~~the method of~~ model domain shifting could be used to ~~account for~~ *quantify how* uncertainties in the initial and boundary conditions ~~by introducing a small disturbance at model initialization~~ *contribute to the predictability of an event*. However, this single case study needs to be expanded to cover more cases ~~. Thus, it is of interest to further evaluate this simple approach of domain shifting,~~ ,for example in weather regimes with strong synoptic forcing and more stratiform precipitation and in other models such as ICON...

- The upper-level dynamics are similar in all model runs in the early stage of the convection over France. Hoskins et al. (1978) demonstrated that the traditional form of the quasi-geostrophic omega equation can be rewritten using the Q-vector and that regions of upward (downward) vertical motion are associated with Q-vector convergence (divergence). In Fig. R.1, there are no noticable differences in the Q-vector divergence, nor does the model simulate any variations in geopotential height. This indicates that the large scale forcing is similar for these model runs. We included a statement on that at the end of section 4.6.

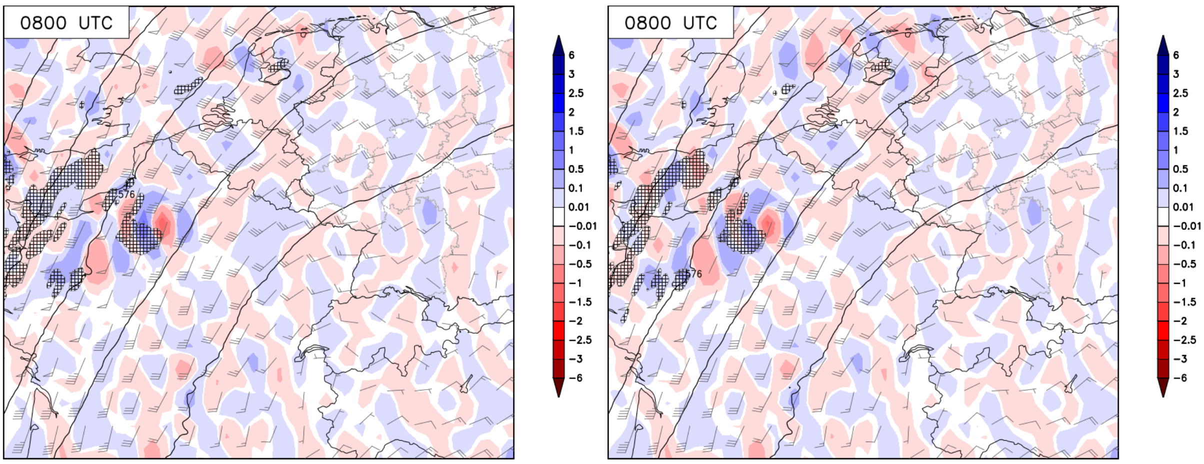

Figure R.1: Q-vector divergence (colours), 500 hPa geopotential height (contour lines), and precipitation rate (hatched) for the W run (left) and the REF run (right) at 0800 UTC.

Changes to paper
"In addition to this analysis, we further want to point out that the upper-level dynamics are similar in all model runs in the early stage of the convection over France. Hoskins (1978) showed that the traditional form of the quasi-geostrophic omega equation can be rewritten using the Q-vector and that regions of upward (downward) vertical motion are associated with Q-vector convergence (divergence). We calculated the divergence of the Q-vector at 500 hPa and found no noticable differences between successful and unsuccessful runs, nor does the model simulate any variations in geopotential height (not shown). This indicates that the large scale forcing is similar for these model runs and not responsible for the simulation result differences. "

- We also analysed SST as suggested. Our reply is the same as for Reviewer #1 (minor comment 6): The surface temperature and CAPE are depicted in Fig. R.2. The sea surface temperature is much lower than the land surface temperature, at least in the northwestern coast of France where no significant amounts of rain was simulated in the last hours. As a result of these lower temperatures, CAPE is significantly reduced over sea. Along the coastline, there is a strong gradient in temperature (23 → 15 deg C) and CAPE. These statements also hold true for the remaining model runs. We added some remarks on that in the text, but decided not to provide an extra figure.

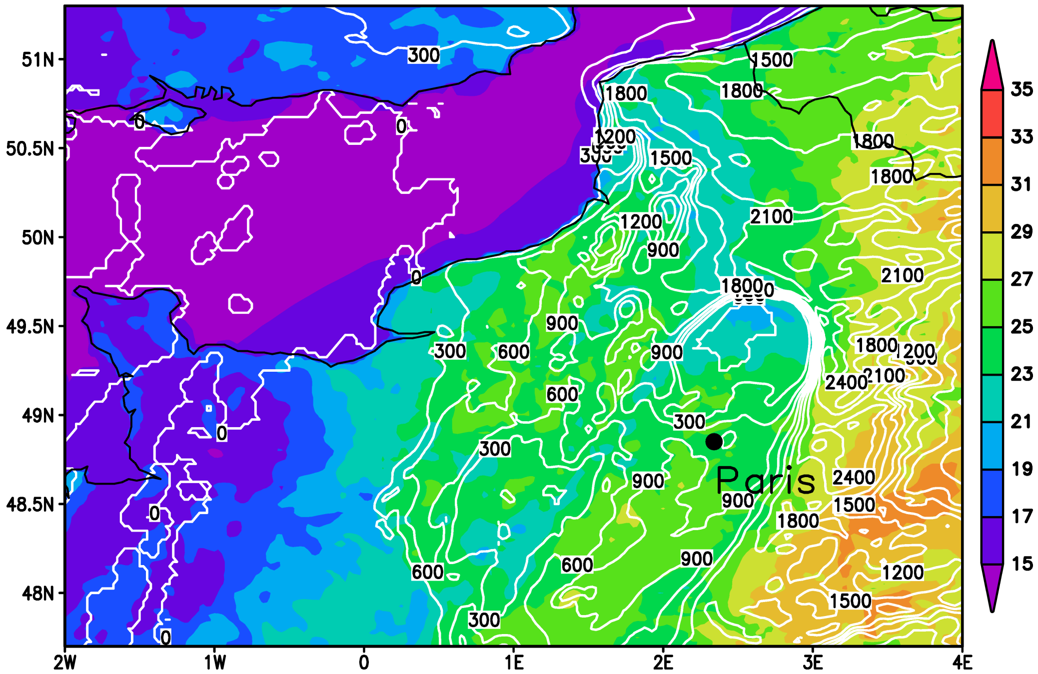

Figure R.2: Surface temperature of the REF run at 1000 UTC (colours, in deg C) and CAPE (white contours, in $\mathrm{J\,kg^{-1}}$).

Changes to paper:
"The sea surface temperatures along the French coast lie around 15°C and are much lower than the land surface temperatures (around 23°C, not shown). This temperature distribution is similar in all model runs for the preconvective environment."

- Furthermore, we conducted an ensemble sensitivity analysis and included those results in a new section.

  Changes to paper:
  We include the sensitivity analysis in a new section 4.5, this includes explanation of the ensemble sensitivity analysis method and interpretation of the results and includes discussion of the newly added Figure 9.

Additional changes to the paper:

1. We included a new sentence in the introduction about two recent papers:

   "Recent studies of Schneider et al. (2019) and Keil et al. (2019) have also shown that different assumptions for the amount of cloud condensation nuclei could be included in convective-scale ensemble forecasting, but only if the model employs a double-moment microphysics scheme."

2. Old Figure 9 was enhanced by increasing the size, length, and density of the wind arrows.
3. Information about the financial support was added.