Cut-cell Eta: Design and skill in jet stream position accuracy compared to its driver ECMWF ensemble, and illustrations

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1. Introduction

Various sets of tests have been performed comparing the results of the Eta against its version switched to sigma. In all of them the eta version did better. However, a poor result of an Eta in case of a Wasatch windstorm, and an experiment of Gallus and Klemp, led many to consider the eta to be "ill suited for high-resolution models." Still, in a 5+ month parallel done in 2006 the Eta/EDAS system resulted in better precipitation scores than the WRF-NMM/GSI put together to replace it (Mesinger and Veljovic 2017, Fig. 4). Following a refinement of the eta discretization making it a simple cut-cell scheme, the Gallus-Klemp separation of the flow behind a bell-shaped topography was shown not to occur (ibid., Fig. 7).

2. Eta vs. ECMWF skill in ensemble experiments

Tests of the impact of the use of the eta resumed via experiments with the Eta driven by ECMWF (EC) 32-day ensemble members. Using a score verifying *placement* of the variable selected (Mesinger 2008), chosen to be 250 hPa winds of speeds > 45 m s^{-1}, as well as the RMS wind difference, generally advantage of the Eta was seen in spite of about the same resolution of two models during the first 10 days of the experiment. This advantage was particularly visible when a deep upper tropospheric trough was crossing the Rockies the first 2-6 days of the experiment. To test how much this advantage was due to the use of the eta, the experiment was redone with the Eta members switched to use sigma. Results are shown in Fig. 1.

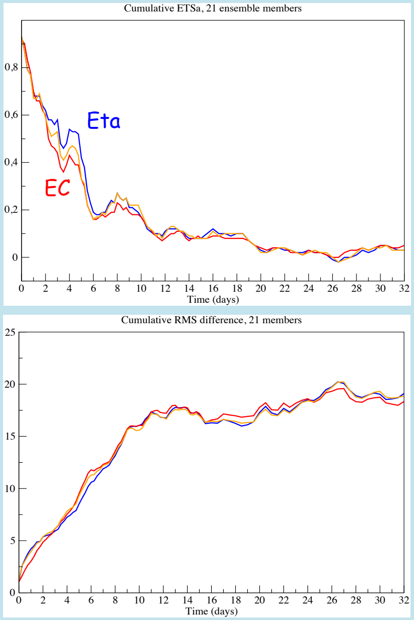

Fig. 1. Bias adjusted ETS (or, Gilbert) scores of wind speeds greater than 45 m s^{-1}, upper panel, and RMS wind difference, lower panel, of the driver EC ensemble members (red), Eta members (blue), and Eta members run using sigma coordinate (orange), all at 250 hPa and with respect to EC analyses. Initial time is 0000 UTC 4 October 2012.

3. Average wind speed maps and numbers of "wins"

For illustration of what flow features are responsible for the advantage of the Eta at about the 2-6 day time, in Fig. 2 we show 250 hPa wind averages for all three sets of 21 members, at day 4.5.

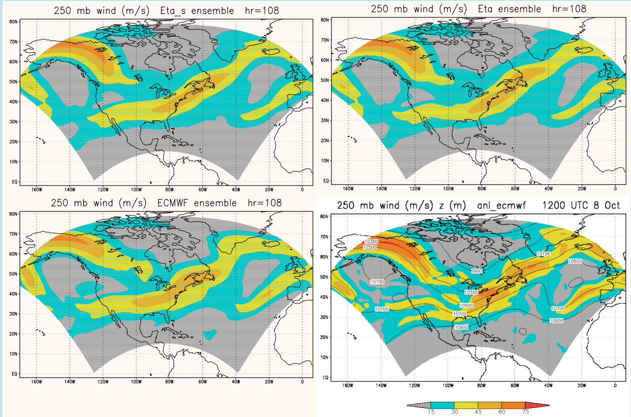

Fig. 2. Ensemble average, 21 members, at 4.5 day time: EC verification analysis bottom right, EC driver members bottom left, Eta members top right, Eta/sigma members top left.

Another verification method we use is the number of "wins" of one model vs. another. In Fig. 3, left panel, number of wins of the Eta 250 hPa winds of speeds > 45 m s^{-1} and its EC driver members vs. each other is shown as a function of time, according to our score verifying the placement of the variable selected, ETSa. Same, but according to the RMS difference of forecast and analyzed winds, right panel.

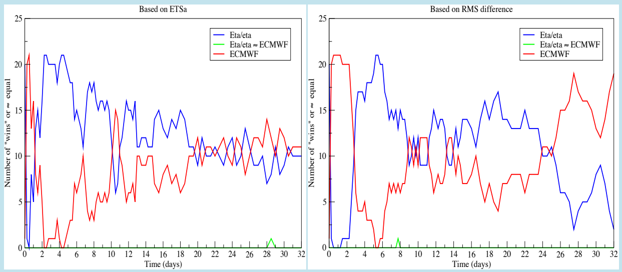

Fig. 3. Number of "wins" of one model members vs. another: blue, Eta, red, their EC driver members.

We are somewhat puzzled by the rather good Eta/sigma performance shown in Figs. 1-2. For more information in Fig. 4 we show "wins" of the Eta/sigma vs. the EC. While the Eta/sigma is still clearly "winning," it does not win with such a total superiority of winning repeatedly all the 21 members. Reasons possibly helping the Eta/sigma display this much advantage over the EC are discussed in Mesinger and Veljovic (2017).

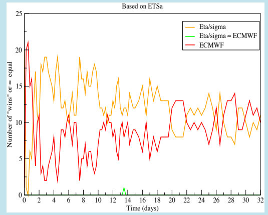

Fig. 4. Number of "wins" of one model members vs. another: orange, Eta using sigma, red, its EC driver members.

4. More verification results

A confirmation of the advantage of the Eta model over the EC is obtained also using the extreme dependency score (EDS), designed for forecasts of rare binary-events (Stephenson et al. 2008). In Fig. 5 we show the number of "wins" of the Eta model in two versions vs. EC, according to the EDS.

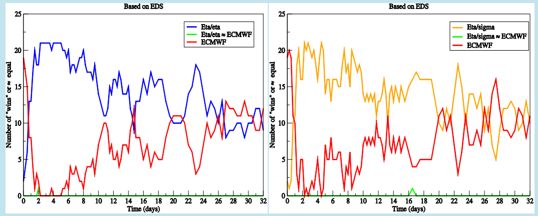

Fig. 5. Left: as in the left panel of Fig. 3, but according to the EDS; right: as in Fig. 4, but according to the EDS.

5. Concluding remarks

With almost all atmospheric weather and climate models using terrain-following (sigma) coordinates we feel the possibility of systematic errors resulting from the use of the sigma coordinate deserves attention. Note that no sigma system pressure gradient force discretization removes the sigma system problem of failing to take account of physically needed information if topography is steeper than a critical value (e.g., Mesinger et al. 2012). Results shown, similar to those of Steppeler et al. (2013), we feel strongly suggest the use of quasi-horizontal coordinates should help increase the skill of atmospheric weather and climate models, via removal of systematic sigma system pressure gradient force and/or other errors.

References

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