Eta vs sigma: Precipitation scores, monotonic and unconditionally stable horizontal diffusion scheme and Gallus-Klemp test

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Prior to the 2006 NCEP parallel comparing the NMM-WRF/GSI against the Eta/EDAS system, then operational at the US NWS, five times documented tests were done comparing the Eta model against the same code switched to use sigma. The eta version did better in all of them, with precipitation scores and more accurate placement of storms standing out. For a more detailed summary of the results of these tests see Mesinger and Veljovic (2014).

A possibility cannot be excluded that the better precipitation scores of the Eta were a result of its schemes having been adjusted to perform best with the use of the eta. To this end perhaps convincing information came once the NMM-WRF was considered ready for a pre-implementation "parallel" test against the operational Eta, on the same large domain and resolution, in January 2006. Prior to that, a new and more advanced data assimilation system, GSI, was developed for the NMM-WRF. As this test of the two models with their data assimilation systems followed several years of full attention at NCEP given exclusively to the NMM, with the operational Eta "frozen," presumably there was enough time to address the issue of precipitation schemes having been tuned to the eta, if so. Yet, in about a five+ month parallel, as shown in Fig. 1, the Eta system still showed better precipitation scores than the NMM-WRF system, and increasingly so as one moved further away from the initial time when the different data assimilation systems should have had the most impact.

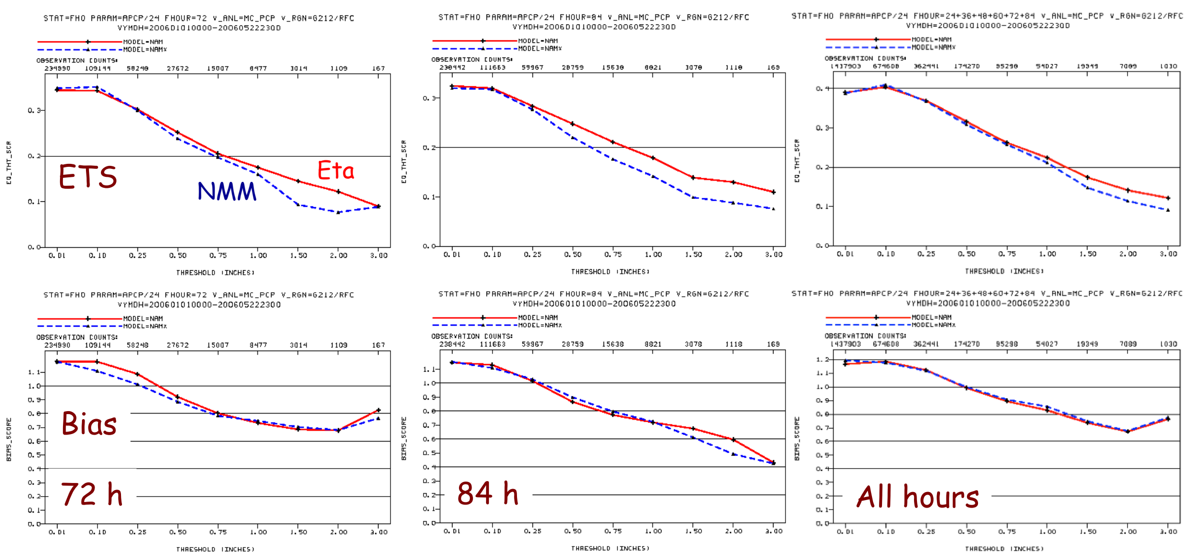

Fig. 1. 24-h precipitation Equitable Threat Scores (above) and Bias Scores (below) of the Eta/EDAS (red) and NMM-WRF/GSI (blue), of the 1 January-22 May 2006 parallel, run at 12-km resolutions. 24-h precipitation thresholds are increasing from 0.01 to 3 in/24 hours along the abscissas. Verifications at 72 h (left), 84 h (middle), and combined 24, 36, 48, 60, 72 and 84 h (right). After DiMego (2006).

These results seem however not to have had much impact on a widespread belief that the eta coordinate is "ill suited for high resolution prediction models," that followed an experiment done by Gallus and Klemp (2000) on flow over a bell-shaped topography. Our emulation of the Gallus-Klemp experiment using the "sloping steps" refinement of the eta discretization (Mesinger et al. 2012) led to a result much better than that using the original eta discretization, but still not one to be completely satisfied with.

Recently it was noted that the Eta horizontal diffusion scheme was not made aware of the sloping steps upgrade. This was addressed and in addition the horizontal diffusion scheme was refined so as to be unconditionally stable and monotonic. Namely, blow-ups of the code's Smagorinsky-like scheme run at 1-km resolution over a rough coastal topography of the state of Rio de Janeiro occurred, and were found to have been caused by the linear instability of the diffusion scheme. This was presumably due to a local too high value of the diffusion coefficient that resulted from a high value of the velocity deformation. This is governed by the flow as it develops and so cannot be necessarily prevented by a choice of the numerical value of the coefficient used. A remedy was put in place by preventing the diffusion increment to change the sign of the five point Laplacian of the field being diffused, thus putting in place an unconditionally stable and monotonic horizontal diffusion scheme.

With these refinements the Gallus-Klemp experiment was rerun, obtaining the result shown in the right hand plot of Fig. 2. For comparison, the result obtained by Gallus and Klemp using a nonhydrostatic Eta code of Gallus and Rancic in which they have modified advection schemes at points adjacent to the step corners using an assumed condition of the y-component vorticity being zero at the corners, is shown in its left hand plot.

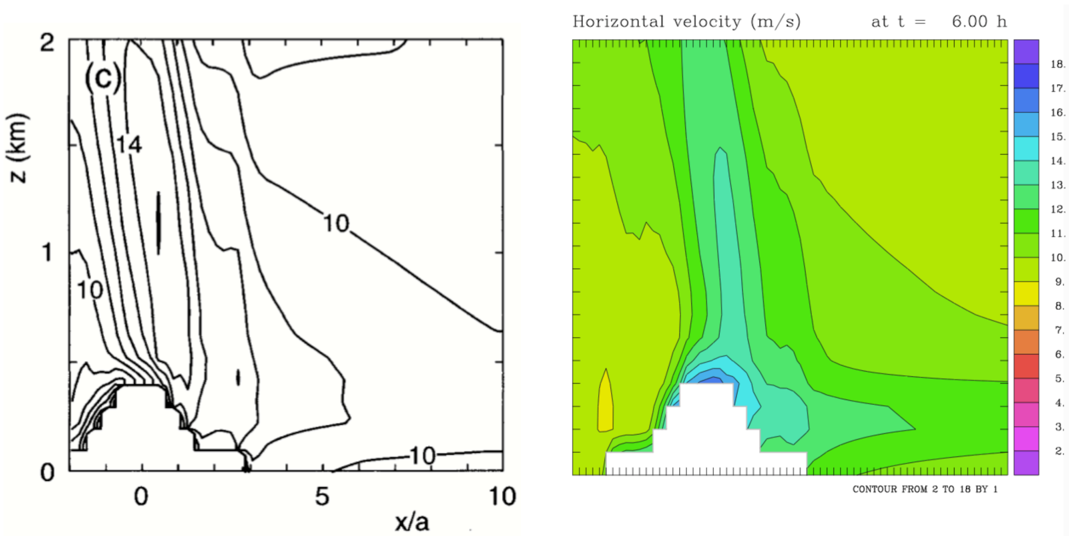

Fig. 2. Gallus-Klemp experiment run with the Eta code allowing for velocities at slopes in the horizontal diffusion scheme, right. The plot (c) of Fig. 6 of Gallus and Klemp (2000), left.

Along with the results of Veljovic reported on in another contribution to this issue demonstrating that the skill the Eta achieved against its ECMWF driver ensemble members was largely due to the use of the eta coordinate, this result is considered a strong evidence of the opportunity wasted by models using terrain following coordinates.

References

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