Contribution ID: **44** Type: **Invited Talk**

What features, beyond the vertical coordinate, are responsible for the Eta model skill?

Tuesday 8 October 2024 17:15 (30 minutes)

At the preceding MoW conference, an experiment reported in Mesinger and Veljovic (JMSJ 2020) was presented showing an advantage of the Eta ensemble over its driver ECMWF members in placing 250 hPa jet stream winds east of the Rockies. However, that Eta ensemble switched to use sigma, also achieved 250 hPa wind speed scores better than its driver members, although to a lesser extent. Thus, the Eta must include feature(s) additional to the eta coordinate responsible for this advantage.

An experiment we have done suggests that the van Leer type finite-volume vertical advection of the Eta, may be a significant contributor. Having replaced a centered finite-difference Lorenz-Arakawa scheme, this finite-volume scheme visibly improved the simulation of a downslope windstorm in the lee of the Andes.

Another likely feature contributing to that advantage is the sophisticated representation of topography, designed to arrive at the most realistic grid-cell values with no smoothing (Mesinger and Veljovic, MAAP 2017).

While apparently a widespread opinion is that it is a disadvantage of terrain intersecting coordinates that "vertical resolution in the boundary layer becomes reduced at mountain tops as model grids are typically vertically stretched at higher altitudes (Thuburn, 10.1007/978-3-642-11640-7 2011),"a comprehensive 2006 NCEP parallel test gave the opposite result (Mesinger, BLM 2023).

Many thousands of the Eta forecasts demonstrate that the relaxation lateral boundary condition, almost universally used in regional climate models, is unnecessary. Similarly, so-called large scale or spectral nudging, also based on an ill-founded belief, should be detrimental if numerical issues of the limited area model used are addressed. Note that this is confirmed by the Eta vs ECMWF results referred to above.

Even so, to have large scales of a nested model ensemble members mostly more accurate than those of their driver members, surely requires a lateral boundary condition scheme that is not inducing major errors. The scheme of the Eta at the outflow points of the boundary prescribes one less condition than at the inflow points (e.g., Mesinger and Veljovic, MAAP 2013), and has for that reason been referred to by McDonald (MWR 2003) as one of "fairly well-posed"schemes.
Some or all these might have made the Eta do so well in a recent performance comparison of REMO, WRF, RegCM4, RCA, and Eta, over the topography challenged Andes-western Amazon region (Gutierrez et al., JGR Atmos 2024). With various global driver model combinations, three using the Eta ranked the best.

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Session Classification: Numerical Mathematics B