Lateral boundary relaxation and large scale nudging in RCM runs

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1. Introduction

Almost universally, in Regional Climate Modeling (RCM) integrations, Davies' relaxation lateral boundary conditions (LBCs) are applied. They force variables in a number of rows around the boundary to conform to the driver global model values, completely at the boundary, and less and less toward the inside of the integration domain. Very often, in addition, investigators apply so-called large scale or spectral nudging inside the domain, forcing the integration variables not to depart much from those of the driver model.

There is no scientific basis for these two practices.

2. So why then are these done by so many?

For the former of these two, relaxation LBCs, reasons must be either a belief that this is a practice RCM should follow, and/or a technique to address numerical issues of the limited area model used. This because the relaxation LBCs needlessly ignore the mathematics of the linearized linear initial/boundary condition system of the equations we deal with (e.g., McDonald 2003, among others). For the large-scale nudging, a belief only.

In the next three sections we show examples that in the absence of these two stratagems, the limited area model can improve on large scales inside its domain. This demonstrates that their use, aimed to force variables inside the domain not to depart much from those of the driver model, should be detrimental, unless there are numerical issues of the models used addressed by these techniques.

3. Fennessy-Altshuler upper Mississippi flood case

At the 2002 AGU Fall Meeting, Fennessy and Altshuler reported on a 9-member, 3-month simulation of the June-August 1993 minus 1988 precipitation over continental United States. Their results, Fig. 1, were published later by Veljovic et al. (2010). The observed flood maximum over central U.S. (middle) is totally missed by the driver GCM (top), while the nested Eta (bottom) shows a decent result in placing both the maximum over the U.S. Midwest and the drought over the U.S. southeastern states. For more detail see Veljovic et al. (2010) and Mesinger et al. (2012b).

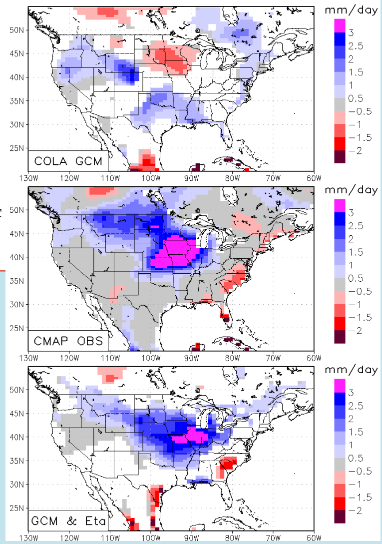


Fig. 1. June–August mean 1993 minus 1988 precipitation difference for (top) COLA AGCM 9-member ensemble, (middle) CMAP observations, (bottom) nested Eta 9-member ensemble. Differences significant at the 95% level are shaded (From Veljovic et al. 2010 © Gebrüder Borntraeger).

4. Downscaling South American present climate

In evaluation of the Eta RCM ability to downscale climate Chou et al. (2012) ran the Eta driven by 4-member HadCM3 1961-1990 runs. Resulting ensemble mean Eta streamlines at 200 hPa are shown in Fig. 2, right panels, December-February (DJF) above, and June-August (JJA) below. Mean streamlines of the GCM that gave LBCs to drive the Eta members are shown in middle panels, and the ERA40 reanalysis streamlines in the left panels. See Chou et al. (2012) for more detail.

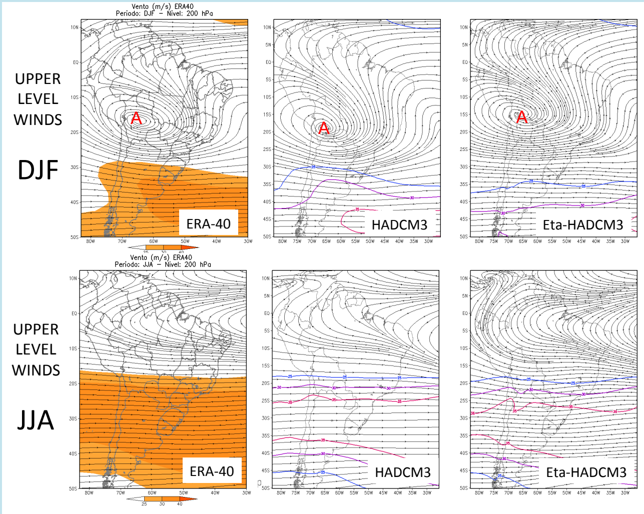


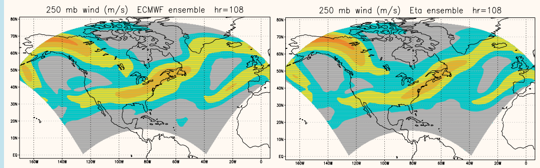
Fig. 2. Streamlines of the ensemble mean of 200 hPa wind, of four realizations of the Eta RCM, right panels, same but for the HadCM3 members that drove these Eta members, middle panels, both 1961-1990 runs. Same but for the ERA40, left panels. "Summer," DJF, above, "winter," JJA, below. Lines in color of the ensemble mean plots are contours of 25 (blue), 30 (purple) and 35 m s^{-1} (red), respectively.

The dominant large-scale feature of the South American summer circulation, top left, is clearly the so-called Bolivian high, centered just about at the middle of Bolivia, as denoted by A. HadCM3, top middle, places this center couple of hundred kilometers south-southwest of its ERA40 position. The Eta, top right, places it a bit to the north-northwest of the ERA40, more accurately than the driver HadCM3 model.

The difference between the two models in the general character of the tropical South American circulation of Fig. 2 is still more visible in winter months. The strictly zonal placement of the axis of the Atlantic vortex across all of the northern Brazil and further west is adequately depicted by the Eta while in the HadCM3 it includes a secondary axis directed northwest towards Guyana, not present in the ERA40 reanalysis.

5. Large scales skill of the Eta model

Operational use and several experiments additional to those of the past two sections indicated ability of the Eta to improve on large scales of its driver global models (Mesinger and Veljovic 2017). In Fig. 3 we expand on the results of the latest of these experiments. Its top left plot shows the mean 250 hPa wind speeds of the Eta ensemble, driven by the first 21 members of the ECMWF (EC further on) ensemble, top right. The two ensembles are initialized at 0000 UTC 4 October 2012, and their resolutions are about the same. EC analysis verifying at the time as the upper two plots is shown in the lower plot. Note the improvements of the Eta ensemble compared to that of the driver EC in further extending the jet streak entering Alaska towards the southeast, and in the position the jet streak across the U.S. New England states, eastern Labrador and off towards the tip of Greenland.



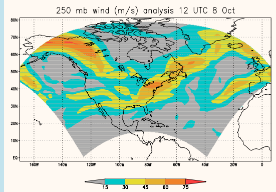


Fig. 3. 4.5 day 250 hPa wind speeds of the Eta ensemble, top right, and of its driver 21 member EC ensemble, top left, respectively. Verifying EC analysis, bottom.

6. Concluding remarks

The experiments with results pointed at in the preceding three sections have all been done using LBCs with driver model data prescribed along a single outermost line of grid points, with one less variable prescribed along the outflow than at the inflow parts of the boundary. In addition, no large scale nudging was used. Yet in all of them, the Eta RCM (Mesinger et al. 2012a, Mesinger and Veljovic 2017) for the most part improved on large scales of its driver GCM. Thus, had relaxation LBCs and/or large scale nudging been used, it would have had a detrimental, and not a beneficial effect. Is there a reason for this to be different for another RCM, and if so, why? We suggest that reconsideration of justifications for using these two practices is desirable.

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