

## ***Interactive comment on “A spectral nudging method for the ACCESS1.3 atmospheric model” by P. Uhe and M. Thatcher***

### **Anonymous Referee #1**

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#### General Comments:

This paper describes a new spectral nudging scheme that has been implemented in the ACCESS climate model in order to constrain the model toward ERA-Interim (ERA-I) reanalysis. The spectral nudging approach applies a low-pass spectral filter so that only large spatial scales are constrained. This filtering approach offers flexibility compared to Newtonian relaxation methods by allowing for the selection of the length scales as well as temporal scales to nudge. Since it is computationally expensive, the authors test implementations of 1-D filters compared to 2-D filters, as well as reducing the frequency that nudging is applied. Their analysis compares 500 hPa temperature between ERA-I and several simulations including control (not nudged), Newtonian relaxation nudging, and 1-D and 2-D spectral nudging with several length scales. Based on

C2292

their analysis, they conclude that using 1-D filters applied first in the meridional then zonal direction, and nudged once per hour, is the optimal, computationally efficient configuration.

The topic of the paper is a good fit for the scope of the journal. The description of the methods and results are clear. And the experiment design, testing several length scales and soft vs. hard nudging, is appealing. However, the analysis is very limited and only evaluates the impact of nudging on one model field (500 hPa temperature). Major revisions, providing much more detailed evaluation of the impact of this nudging approach on the simulated results, would be a greater benefit to the scientific community.

Observationally constraining a climate model, as is done here, implies a balance between (a) keeping the model state close to that of the host (ERA-I) and (b) allowing the model to behave as it would in a “free-running” mode. The balance between (a) and (b) depends on the application. For example, Zhang et al. [2014] evaluate the use of nudging for aerosol-climate studies and find an undesirable impact of nudging on cloud and precipitation processes when strong temperature nudging is included, therefore suggesting only nudging horizontal winds for these types of studies. Jeuken et al. [1996] discusses in detail the implications for what variables are nudged and what relaxation times are used, identifying important considerations including: (1) how well the nudged fields (e.g. T, U, and V) match the reanalysis, (2) the magnitude of nudging tendencies (model forcing) compared to model physics tendencies, and (3) the impact of nudging on unconstrained model fields (e.g. humidity, cloud water content, precipitation, etc.).

In this study only (1), how well the model is constrained, is evaluated, and only for 500 hPa temperature. For any application of this approach, it would be helpful to understand its impact on (2) model tendencies and (3) unconstrained model fields. The flexibility to nudge only large-scale features likely has benefits for reducing impacts on model behavior that can result from Newtonian relaxation methods, while still constraining circulation and meteorology. It is recommended that the analysis here be expanded

C2293

beyond just evaluating 500 hPa temperature.

Specific Comments:

1. Page 6686 - line 17: A more detailed description of how ERAI was interpolated and prepared for the ACCESS grid would be helpful. Vertical interpolation can create artifacts due to differences in model/reanalysis topography that can impact lower pressure levels high above the surface. It's possible the high temperature RMSE over mountain regions shown in Figure 1 is the result of topographic differences that were not properly accounted for in the interpolation scheme. How were ERAI and ACCESS topographic differences accounted for? What type of horizontal and vertical interpolation was used for temperature and winds? More description of the ERAI regridding procedure is needed.

2. Page 6687 - line 25: Figure 2 shows the "difference in variance of air temperature", but it is not discussed why this is a useful metric to evaluate or why the annual variance is too large in the control simulation and generally too small in the nudged simulations. A potentially more useful metric to quantify the degree to which ACCESS is constrained to ERAI would instead be the "variance of the difference in air temperature", which would show how nudging constrains the model to vary in the same way as ERAI, rather than just the amount of annual variability. Otherwise, more discussion is needed to clarify and explain the results shown in Figure 2.

3. Page 6689 - line 1: It could be useful to show the map of RMSE with 2D and 1D filters (as in Figure 1) to justify that not only global mean error is similar, but the spatial distribution as well.

4. Page 6689 - line 9: Figure 4 shows RMSE levels off after 4 days. Were these first few days included in the subsequent analysis (all other figures) or was there some spin up time before the analysis period? Spin up is usually needed, and these differences between the initial conditions and reanalysis should not be part of the nudging evaluation.

C2294

5. Page 6690 - line 7: A figure simply showing the difference between ACCESS simulations and ERAI could be helpful for illustrating that spectral nudging errors are random (positive and negative) and Newtonian relaxation is systemically warmer. What is the reason for this difference in the structure of errors with different approaches? Is this a result that is expected with the different implementations of nudging?

6. Page 6690: It would be helpful to add the control results to Table 1 and include RMSE and GAE for U and V as well.

7. Do RMSE and RMS (Figures 1 and 3) show a similar result for horizontal winds? What do the errors look like for other pressure levels higher and lower in the atmosphere?

8. What is the magnitude of the nudging tendencies compared to model physics and dynamics tendencies? How much influence do model physics have on the simulation when nudging is applied?

9. How does the implementation of nudging impact convection, clouds, precipitation, surface fluxes, TOA radiation, etc.?

10. Page 6690 - line 5: Should it be  $\lambda = 0.2$  instead of 0.1?

References:

Jeuken, A. B. M., P. C. Siegmund, L. C. Heijboer, J. Feichter, and L. Bengtsson (1996), On the potential of assimilating meteorological analyses in a global climate model for the purpose of model validation, *J. Geophys. Res.*, 101(D12), 16939–16950, doi:10.1029/96JD01218.

Zhang, K., Wan, H., Liu, X., Ghan, S. J., Kooperman, G. J., Ma, P.-L., Rasch, P. J., Neubauer, D., and Lohmann, U.: Technical Note: On the use of nudging for aerosol–climate model intercomparison studies, *Atmos. Chem. Phys.*, 14, 8631–8645, doi:10.5194/acp-14-8631-2014, 2014.

C2295

C2296