Review of
A deep-atmosphere extension in a nonhydrostatic dynamical core: formulation and idealized tests
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The manuscript describes the deep-atmosphere extension of the previously published shallow-atmosphere GMCORE atmospheric dynamical core. Specifically, the extension avoids making the shallow-atmosphere geometrical approximation and 'traditional approximation' and instead uses full Euclidean geometry. It also allows the gravitational acceleration to depend on radial distance from earth's centre. The deep-atmosphere extension largely follows previously published work (the theory of Wood and Staniforth (2003), and the deep-atmosphere formulations of the ICON and MPAS models). Nevertheless, I think it would be useful and appropriate to have the GMCORE formulation documented in the open literature.

Reasonable test cases, a baroclinic wave case on a small planet and a tropical cyclone case, are presented to confirm that the deep-atmosphere formulation is working correctly. It was good to see the tropical cyclone case carried out for multiple initial conditions to confirm that the signal is systematic and robust.

It would have been good to see at least one test case extending into the mesosphere and thermosphere, since the opening paragraphs discuss high-top modelling as a motivation. However, that might require a formulation that can handle variable composition.

Below I make some suggestions, generally minor, for improving the manuscript, mostly related to the clarity of the presentation.

Specific points

1. Line 36. This is not strictly incorrect, but a more natural viewpoint is that the deep atmosphere equations are the more fundamental equation set and the shallow-atmosphere equations are an approximation.

2. Line 55. while most *nonhydrostatic* models use a height-based vertical coordinate. (Hydrostatic models commonly use a pressure- or mass-based coordinate.)

3. Lines 72-74. The sentence is a bit awkward because Wood and Staniforth (2003) did not use the vector-invariant form. Can it be rephrased?

4. Some things are not clear about equations (1)-(7) and the subsequent discussion. Is the constant G related to $g(r)$ in some way, or is it an arbitrary constant? Is G the same as g_0 introduced later in the definition of π (equation (14))? What is s (line 124), and how does it relate to η? Is the $(r/a)^2$ factor in (2) a geometrical factor (as in (14)) rather than describing the vertical variation of $g(r)$?

5. Line 143. dictates the *dry* atmospheric mass?

6. Lines 144-145. I don't understand this remark. Height-based coordinate models typically predict density, or density can easily be computed from the predicted variables. Computing the mass in an atmospheric layer is then simply a case of doing a (discrete) vertical integral, no more complicated than (17).

7. Near line 156, perhaps mention that GMCORE uses a Lorenz vertical grid.

8. Lines 158-160. Do you really use a third-order polynomial reconstruction? Bendall and Kent used the quadratic PPM reconstruction. Also, Bendall and Kent were targeting cubed-sphere grids; are there any issues in applying the scheme near the poles of a longitude-latitude grid?

9. Line 178. Here I think you mean the temporal pressure increment (see equation (20)), but in equation (18) δp appears to be a vertical pressure increment. Please be explicit, or you will quickly lose readers. Also, what is gamma in equation (20)?

10. Equations (22) and (23). How is W_j related to H_j?

11. Lines 217-219. How large does N_j become near the pole? The communication cost must become significant at some point as resolution is refined.

12. Lines 250-256. The word 'configuration' is sometimes used to distinguish the full radius and small radius cases, and sometimes to distinguish the shallow-atmosphere and deep atmosphere cases, with the potential to confuse the reader. Can you rephrase? Check also for other occurrences.

13. What resolution, horizontal and vertical, was used for the baroclinic wave test? What vertical resolution was used for the tropical cyclone test?

14. Figure 4 caption and line 325. The figure does not show rainfall, so the reader cannot see any spiral rainband structures.

Typos etc

Equations should be punctuated just like the rest of the text.

Line 85. rate of planetary?

Line 148. matches $\rightarrow$ match

Line 314. the present supplementary?