

Global MPAS-A Simulation with a Constant Pressure Upper Boundary

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Review for Geoscientific model development

In a previous article (Klemp, Skamarock (2022), cited by the authors and denoted as KS22) an upper boundary formulation was developed that follows a constant pressure surface. To demonstrate its ability, a 2D x-z-slice idealized test case (along the equator) describing the periodic response to a prescribed diurnal heating in the thermosphere was invented, too.

The current article mainly extends this 2D idealized test case to a full 3D test on the whole sphere. This idealized test then is applied to the MPAS-A model to demonstrate reasonable behaviour in particular of the upper boundary formulation. Furthermore, several tests with a more realistic setup taken from interpolated ERA5 analysis are performed, too.

I must say that I found the description of the idealized 3D test case hard to follow. Only when reading the description in KS22, I got some understanding, how this test case works and what is needed to perform it. This is surely not a lack of text here, but rather a matter of text organization. Whereas the description in KS22 is quite well understandable, here it is less well structured. At the end, my impression is that the 3D extension essentially is the addition of a latitudinally depending factor $\cos \gamma$. Why is it so much harder to understand than in KS22?

The current article aims to demonstrate the capability of MPAS-A to model the deep atmosphere in a correct manner and therefore is an important contribution to the related modeling community. This is supported by the more realistic tests in sec. 3, too. However, I think that the material should be presented in a way that is easier accessible to the reader, in particular readers from other modeling communities, too, who possibly wants to perform these test with their own model (see my major comments). Therefore, the description of the 3D test case should be revised in my opinion and I consequently assess the article as worth for publication after major revision.

Major comments

In my opinion, section 2 should be reorganized in a manner as it was done in KS22. There should be a subsection about the temperature distribution used (equations (6) and (2)), from this the diurnal heating rate (5) can be derived and finally the initial values T and the pressure field can be given.

In another subsection it should be described how to determine the constant pressure upper boundary surface. Some parts are mentioned e.g. in lines 98-103. This seems to be slightly different from KS22 (?).

In a third subsection one should describe what is necessary on the model side, to successfully perform this test (Rayleigh damping, ...)

Finally, in an own section the numerical experiments should be placed. This would e.g. contain l. 114-120 and l. 125-...

Minor comments

- author list: I think it is 'William' instead of 'Willam' Skamarock.
- l 37: 'although we no longer have a linear analytic solution for comparison ...'. Why is it not possible to do similar derivations as in KS22? As far as I can see, mainly the hydrostatic equation to derive the pressure field was used and a simplification to derive the velocity field was made. The additional $\cos \gamma$ -factor shouldn't be a too hard obstacle, isn't it? There seems to be a remark in l. 130 which I unfortunately don't understand. Or are there other obstacles that prohibit the derivation of a similar analytic solution? (no shallow atmosphere approximation?)
- l 65: '.. T_{t_0} at the constant pressure upper boundary ...'. If I insert eq. (1) into eq. (2) at $z = H$ then I don't get T_{t_0} . Isn't T_{t_0} rather the temperature for $z \rightarrow \infty$?
- eq. (1): this is just the specialized version of eq. (6) for $t=0$. I see the need for an initial condition, but again: the analogous presentation in KS22 starting from the full time dependent T-field is somehow much clearer to understand. By the way, the denotation with a *double* lower index 0 is misleading, t is obviously the denotation for 'top', t_0 gives the false impression of an initial time. I would rather write $T_{t,0}$ or even better $T_t(t=0)$.
- l. 74: 'Here, T_L is the temperature from the analytic solution ...'. What does this sentence mean? Do I have to insert the analytic solution from KS22 in T_L ? I guess not. Eq. (2) is just the eq. (14) from KS22 and I think this is what the authors wanted to express.
- l. 77-84: Also this paragraph is not wrong, but simply misleading. The reader expects the description of an idealized test case, therefore he/she wants to know which values e.g. for z_b , T_b , P_b , T_{bar} , ... must be specified. A sentence like 'For this purpose, we have chosen a WACCM-X simulation valid at ...' gives the impression that the modeler has to dig into this data set first. I think one could improve this text passage by just swapping lines 77-80 at the end of the paragraph with the note 'To motivate these values ...' (or one could even put it into a footnote)
- l. 125: what means 'initial simulations'?
- l. 205: I would add 'parameterization' after '(YSU) gravity wave drag'