**Atmospheric
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Interactive comment on "The CCCma third generation AGCM and its extension into the middle atmosphere" by J. F. Scinocca et al.

J. F. Scinocca et al.

Received and published: 19 June 2008

We thank the reviewer for his or her comments.

1) With respect to the suggestion that the paper might be better categorized as a Technical Paper, our preference would be that it remain in the research category. The material in Sections 3.3-3.5 generalizes beyond the CCCma middle-atmosphere model. It is very relevant to current middle-atmosphere modelling efforts and it is our hope that it will be found useful to other modelling centres.

2) The discussion of Courant numbers was not very clear and we thank the reviewer for pointing this out. AGCM3 does use a semi-implicit time-stepping treatment for the gravity-wave components of the primitive equations but uses a explicit centred leapfrog time stepping algorithm for advection by the large-scale wind. Our definition of the

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Interactive Discussion

Discussion Paper

Courant number is in the context of the large-scale advection.

The reviewer is correct that the use of a the semi-Lagrangian algorithm for the dynamical core as well as for the tracers would permit longer time steps eliminating the excessive diffusion obtained when the SL scheme was used just for tracer advection.

We agree with the reviewer that the presentation of the hybrid approach requires a more rigorous nomenclature. Expression (1) is an identity so we have left this unaltered. We have modified expression (2) by removing the the assignment to s (P7889 L12) . We have also modified the discussion along the lines suggested by the reviewer in the revised manuscript. The term "hybrid transform" has been replaced by "hybrid procedure" and "hybridization" and we will attempt to make its meaning clearer in the revised manuscript along the lines suggested by the reviewer.

The hybridization procedure has been included in the model description because it is a feature of the model. While it has been used for moisture for quite some time in the CCCma AGCMs it has not yet been employed for the tracers used in middle-atmosphere chemistry. As discussed in Section 3.1 the model uses the "physics filter" of Lander and Hoskins (1997) to mitigate potential artifacts associated with the spectral advection of chemical species. In the future, the hybrid procedure may be employed for chemical species in our tropospheric chemistry modelling efforts but this has not yet been decided.

3) The warm bias in Figure 4 (panels a and b) is due primarily to the orographic GWD parameterization. As discussed in Section 3.3, it arose from development efforts of our tropospheric version of AGCM3 (i.e. Scinocca and McFarlane 2000) in which non-orographic gravity waves were not parameterized. The addition of non-orographic GWD to the CMAM does not really impact on this bias (e.g. Fig 4a and b look similar to the temperature bias associated with Fig. 2e and f - not shown in the manuscript). The reason non-orographic GWD has little impact on the warm bias near 50hPa is most likely our choice of launching non-orographic gravity waves from 100hPa. From

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Discussion Paper

recent discussions with researchers at other modelling centres, who launch their non-orographic gravity waves from the surface or mid troposphere, it would seem that a lower launching height would mean more of an impact of non-orographic GWD on the temperature bias at 50hPa. The revised manuscript includes the following discussion of this point at the end of Section 3.3:

"In alleviating the lower stratospheric temperature biases near 50hPa we have focused on adjustments to the orographic rather than non-orographic GWD. This is because the winds and temperatures in this region are more sensitive to the orographic drag in AGCM3. This may in part be due to the decision to launch the non-orographic waves from 100hPa (S03) in DYN-MAM. Model's that launch their non-orographic gravity waves from the surface, or in the troposphere, may find that these waves have more influence on the winds and temperatures near 50hPa."

4) Minor Comments Typos.

P7885 L4. Modified as suggested.

P7885 L14. The sentence has been reworded for clarity.

P7886 footnote 2. Corrected.

P7887 L7. Modified as suggested.

P7887 L17. We agree and have used "smaller" in place of "reduced" here. To clarify the interaction of nonlinear and linear grids we have removed the final sentence (L.18-20) and replaced this with:

"Employing the double transform procedure, the time-stepping algorithm is as follows: First advection is performed on all prognostic variables (i.e. vorticity, divergence, temperature, specific humidity, surface pressure, and any tracers), which results in intermediate values for each field. These intermediate fields are then transformed to the linear Gaussian grid where physical tendencies are evaluated. Finally, the time step is completed by the application of these physical tendencies in spectral space as a

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Interactive Discussion

Discussion Paper

correction to each intermediate prognostic field."

P7887 L21. The term 1:1 spectral transform was meant to imply that an initial spectral field and a copy that under went a transform to and from physical space are equivalent to machine precision. This has been changed in the revised manuscript to, "The linear grid is the smallest Gaussian grid that allows an exact (to machine precision) spectral transform to and from physical space."

P7894 L9. This is a good point. We have changed, "unresolved orography" to "unresolved mesoscale orography".

P7894 L24. We have changed "the momentum directed into each of the half spaces which lie to the left and right of the current wind direction." to "the net momentum directed to the left and right of the current wind direction."

P7894 L26. Modified as suggested.

P7895 L2. Modified as suggested.

P7895 L9. Modified as suggested.

P7897 L13. We treat H_2O and O_3 iteratively, and CO_2, CH_4, N_2O, CFC11 and CFC12 with constant mixing ratios by assuming they are well mixed.

P7897 L18. This has been changed to "which is based on version 2.2 of Clough et al.~(1989), often referred to as CDK2.2."

P7897 L28. We have added the reference: Baker, G. A.: Essentials of Pad\'e Approximants. New York, Academic Press, 1975, pp 306.

P7899 L13. While the model employs a hybrid sigma/pressure vertical coordinate (eta), the physics package operates on sigma levels (the conversion from eta to sigma is straightforward and performed upon entry into the physics package). We have removed the word "(sigma)" from the revised manuscript to avoid confusion.

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Interactive Discussion

Discussion Paper

P7901 L18. The requirement of sufficiently cold lower stratospheric polar temperatures for the formation of PSCs is essential to the simulation of polar ozone loss. Warm biases near 50hpa are not uncommon (even though cold biases often exist above and below this level - eg see panels a and b of Fig. 4).

P7904 L9-16. The point here is that the problematic power at the truncation scale of the model is being directly forced by the physics rather than from resolved dynamical motions. The downscale cascade is provided here as an example.

P7905 L6. The physics filter is applied in spectral space on "the copies" of the prognostic fields used as input to the physics package." (P7904 L27)

P7906 L6. Modified as suggested.

P7906 L10. As described in section 3.1, the AGCM3 radiation scheme is merged with the non-LTE scheme of Fomichev and Blanchet (1995) over height ranges of 40-7hPa. In AGCM3 we do not simulate above 1hPa.

P7907 L1. By "seasonal mean DJF and JJA zonal winds" we do in fact mean the three month averages of zonal wind over the seasons DJF and JJA.

P7907 L2. SPARC stands for "Stratospheric Processes and their Role in Climate." Expanding this acronym out would add little to the discussion at this point and the reference is provided if there is need for additional information.

P7909 L8. We have modified the wording here to "Further, there is an increase in the mean sea-level pressure bias in the SM00_WMO configuration which is consistent with the trade-off between wind and mean sea-level pressure biases discussed in SM00."

P7911 L8. "everywhere above 100\,hPa" has been changed to "at elevations above"

P7911 L18. The enhanced vertical resolution is required in the tropics for the participation of resolved waves in the driving of the QBO. (By construction, this is also

accompanied by higher resolution in the extra-tropics.)

P7911 L28. Flux, yes. But also once can adjust the launch height and spectral content of the parameterized waves.

P7912 L20. "a continual" changed to "perpetual"

P7912 L26. "2x" changed to "twice the flux".

P7913 L27. "limited discussion to" changed to "focused the discussion primarily on"

P7916 The xo and Xlow values for the radon-222 will be included in the revised text.

p7925-7927,7929. The plots will be modified for increased readability along the lines suggested by the reviewer.

p7930. The units are mass mixing ratio kg/kg of dry air.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 7883, 2008.

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