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Interactive Comment

Interactive comment on "Evaluation of the atmospheric transport in a GCM using radon measurements: sensitivity to cumulus convection parameterization" *by* K. Zhang et al.

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"The authors might want to consider discussing a little more about how the actual meteorological performance of the GCM depends on the convection scheme employed. Earlier studies (Ricciardulli and Garcia, 2000 JAS) suggest some very strange aspects of models run with ZM, at least in the tropics. Notably the simulated tropical precipitation in the NCAR model run with ZM is dominated by a very strong and regular diurnal cycle and is not realistically modulated from day-to-day. Could the high radon values in the upper troposphere in the GCM with the ZM scheme be due to very strong (perhaps unrealistcally strong?) diurnal pumping over tropical land areas?"

We would like to thank the reviewer for pointing out the issue of diurnal cycle in convection. This is a very interesting topic which motivated further investigations in our model results.

Before further discussion about our simulations, we want to mention two points:

First, many previous studies have found that the actual performance of a particular convection parameterization scheme in AGCMs can be model dependent (e.g. Liu et al., J. Climate, 2005, p3007-3020). The study mentioned by the reviewer (Ricciardulli and Garcia, 2000 JAS) was performed with an earlier version of the NCAR AGCM – CCM3. A number of changes had been made in the physics parameterizations when CCM3 evolved to CAM2, and the GAMIL model uses a completely different dynamical core. Thus it is possible that the behavior of the Zhang-McFarlane scheme appears different in the GAMIL model.

Second, regarding the study by Ricciardulli and Garcia (2000), we noticed that although the finding was that the standard CCM3 (using the "ZM95+Hack" scheme, denoted as CCM-Z) had much larger variance in the diurnal harmonics than the other configuration using only the Hack scheme, and that in the CCM-Z simulation the diurnal variances over tropical land areas are much stronger than over the oceans, the authors also stated that the high-frequency variance localized over continents was, anyway, considerably smaller than the observations. A study conducted by Tian et al. (2004 JGR D10101) reported that the AM2/LM2 model of the GFDL (using the relaxed Arakawa-Schubert formulation for convection) also underestimates the diurnal cycle of deep convection. Their conclusion was that the diurnal magnitudes over land were noticeably weaker in the model than in observations, and "the diurnal cycle simulation is much worse over ocean than over land" (paragraph 43). Having seen these results and facts, we feel that the behavior of the Zhang-McFarlane-Hack scheme in CCM3 was maybe not really weird.

Coming back to our results with the GAMIL model, we would like to draw the reader's attention to Figure 5 (page 2118) and Figure 13 (page 2126) of our discussion paper.

Note that the source of Radon resides at the Earth's surface over continents. The non-zero concentrations over the oceans are caused by horizontal transport. If the pumping over tropical land areas was significantly stronger in the ZMH simulation than in TN, we would expect to see larger differences over land than over ocean, especially near the surface (i.e., near the source). However this is not the case in panels a and b in Figure 5. In panels a,b,d and e of Figure 13 we do not see clear land-sea contrast, either. (Panels c and f do show an evident contrast, but this can be ignored since the Southern Hemisphere is dominated by ocean.) Having seen these plots, we tend to reject the hypothesis that the differences in the ZMH and TN simulations are mainly related to the pumping over tropical land, whatever time scale it may be associated with.

In the revised manuscript we have added some discussions on the differences in mass flux produced by the two convection schemes (also upon reviewer 1's request). The Zhang-McFarlane-Hack scheme suite has two components: the ZM95 scheme for deep penetrative convection, and the Hack (1994) scheme for middle and shallow convection. The Tiedtke-Nordeng scheme handles all three types, but only allows one type to take place each time the scheme is activated. We have added a figure in the manuscript showing the mass flux given by ZM95, Hack94 and TN in our simulations. The deep convection mass flux given by the ZM95 scheme is similar to the total flux in the TN simulation both in magnitude and in the characteristic pattern. A feature worth noting is that in the TN run the updraft is strongest in the tropics between 600 and 800 hPa, and decreases fast in the near-surface layers. In contrast, the regions associated with large mass flux (> 4 g m^{-2} s^{-1}) given by the ZM95 scheme almost reach the surface. The vertical motion resulted from the Hack scheme is characterized by strongest ascending in the near-surface levels over the storm tracks, and secondary strong drafts in the upper troposphere and in the tropical lower atmosphere. The comprehensive effect is that the total mass flux given by ZMH is significantly larger, especially at the lowest model levels. Given that the source of radon resides at the surface, this implies considerably more effective convective pumping towards the higher altitudes in

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the ZMH simulation than in TN.

To investigate the issue of dominant time scale, we performed two one-year simulations with the two convection schemes, from which 3-hourly output of precipitation and convective mass flux are obtained. Following Ricciardulli and Garcia (2000), the contribution to total variance from three frequency bands are computed: the low-frequency band with periods longer than 10 days, the medium frequency band with periods between 2 and 10 days and the high frequency band with periods between 6 hours and 2 days. Interestingly, the ZMH results (both precipitation and convective mass flux) have significantly weaker variance in the tropics compared to TN, and it is the TN scheme that shows strongest variation in the high frequency band. A closer check of the instantaneous output shows that, in the mid-latitude storm tracks, the two simulations are similar. However, in the tropics, the convective activity in the TN run is characterized by very strong, scattered and fast moving grid scale convective activities, while in the ZMH run the convection appears much less intense, covers considerably larger area, and changes evidently more slowly. A thorough investigation of the cause of these differences probably requires detailed comparison of the formulations of these two parameterizations (e.g., trigger condition, closure, and the related parameters), as well as the interaction with the other parts of the AGCM. We regard such an investigation beyond the scope of this study since we mainly focus on the *i*mpact of the convection scheme here. Further analysis and sensitivity studies have been planned for future study.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 2085, 2008.