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Atmospheric Chemistry and Physics Discussions



# *Interactive comment on* "Towards a better representation of the solar cycle in general circulation models" *by* K. M. Nissen et al.

**K. M. Nissen et al.**

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Reply to specific comments of Referee #1

1.The title of our manuscript does not imply that our work enhances the scientific understanding of solar variability influence on climate. It clearly states that our intention is to demonstrate that short-wave radiation schemes are an essential prerequisite in general circulation models to properly simulate solar variability effects on stratospheric heating rates. We agree that Egorova et al. (2004) already pointed at this problem for the ECHAM model (and we apologize not to have given proper reference) but nevertheless, it is still practice to use SW radiation codes with inappropriate spectral resolution in GCM simulations with variable solar input. Therefore we think that our work is an important contribution to further attract the attention of the GCM and CCM community to this problem. The Cagnazzo et al. (2006) paper had not been published in time to

be considered in this work. It is of course discussed in the revised version.

2.Compared to the conveniently used SW GCM radiation codes, the FUBRad code can be regarded as a high-resolution code, as is explained in the revised version. Differences to ECHAM were not only found due to the missing spectral region in ECHAM but also to the calculation of solar heating rates in narrower intervals of the ECHAM code. We have added an estimate on the number of spectral intervals needed for solar cycle studies.

3.We include a table of the FUBRad spectral intervals in the revised version. We agree that for consistency total heating rates should be used in the online simulations. These are displayed now in the figures of the revised version.

4.We did perform a detailed validation of the FUBRad scheme with the line-by-line model libRadtran including heating rates for different solar zenith angles and different atmospheric models. However for space reasons, only one figure had been included in the original manuscript. We extended this figure in the revision, and added difference plots.

5.Given the results of Cagnazzo et al. (2007), we carefully checked again the parameterizations used in the FUBRad scheme, the parameter settings, the input data, as well as the coding. This led to an update of the ozone absorption cross sections in FUBRad as well as the removal of two minor coding errors in the coupling of FUBRad to the Fouquart and Bonnel scheme. We further use total heating rates now (ignoring chemical energy storage for consistency reasons). These changes were however of minor impact in the stratosphere and did not solve the heating rate discrepancy at the stratopause. For validation of the FUBRad results we use an independent line-by-line reference model, libRadtran, which is a well established reference scheme used in a number of radiation scheme intercomparisons (for details see manuscript).

The intensive revisiting of our work and the excellent agreement of FUBRAD SW heating rate profiles with libRadtran give us confidence in the accuracy of our results. We



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are convinced that our model does not give rise to erroneous conclusions in scientific applications. This is confirmed by a comparison of absolute SW heating rates at the summer pole stratopause , calculated in different GCM simulations that were performed under solar minimum conditions (see new Table 2 in the manuscript). Also included are the results from Cagnazzo et al. (2007) and a reference calculation using WMO (1986) spectral fluxes and absorption cross sections (Shine and Rickaby, 1989). The latter two simulations were performed under climatological mean conditions but the difference between solar min and climatological mean SW heating rates should not exceed 0.1 K/day (see Figure 2 in the manuscript). It is evident that the FUBRad heating rates agree well with the WMO reference calculations and do not reveal any systematic bias.

We thus cannot support the results of Cagnazzo et al. (2007). Of course, it appears to be reasonable that the additional calculation of ozone absorption in the Hartley band in their new 6-band FB scheme leads to an increase of the SW heating rate compared to the standard 4-band FB scheme used in this study. It is however beyond our possibilities to find explanations for the discrepancies between the two studies, without having more details of the radiation code implementation in Cagnazzo et al. (2007).

6.We agree that the mean stratospheric temperature in a perpetual January simulation should be expected to be different from an annual cycle simulation. However, the solar induced temperature difference in the radiatively determined summer hemisphere and equatorial regions should not be largely affected by the perpetual season mode.

Technical corrections:

1. The paper is submitted.

2. All references to the observed solar signal had been included.

3. We have included deviations in our plots.

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Interactive comment on Atmos. Chem. Phys. Discuss., 7, 45, 2007.