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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.

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Reply to Dr. Marco Giorgetta (for the authors of Cagnazzo et al., 2007)

http://www.cosis.net/copernicus/EGU/acpd/6/S7360/acpd-6-S7360.pdf

General comments:

We appreciate very much the discussions with Dr. Giorgetta at different meetings and his efforts to check the implementation of FUBRad into ECHAM5/MESSy by a detailed look into the computer code. This was motivated by the discrepancy between the general conclusions presented in Cagnazzo et al. (2007) and our study.

Cagnazzo et al. (2007) found an improvement in the shortwave (SW) heating in the stratosphere by splitting the single UV/VIS broadband of the standard ECHAM5 4-band radiation scheme (Fouquart and Bonnel, 1980; herafter FB) into two and by adding

an additional band between 185 and 250 nm. The additional UV band allows the calculation of ozone absorption in the Hartley band that leads in their simulation to an increase of the SW heating rate at the summer pole stratopause of about 1.8 K/day. The new SW heating rate profile appears to be in better agreement with a line-by-line reference calculation than the former standard 4-band scheme.

Our study does not support these findings. It is reasonable in Cagnazzo et al. (2007) that extending the Hartley band to shorter wavelengths leads to an increase of the SW heating rate. However: While we show that the spectral resolution of the 4-band FB scheme is not sufficient for reproducing heating rate variations due to the UV changes during the 11-year solar cycle, we find good agreement between the standard 4-band scheme and our FUBRad scheme, when integrating over the whole solar spectrum. SW heating rate profiles from both radiation codes, FUBRad and the standard 4-band FB scheme, are in very good agreement with libRadtran reference calculations for a variety of solar zenith angles as well as daily means at different latitudes.

Dr. Giorgetta formulated a list of questions which might help to solve the discrepancy. He addressed several problems particularly related to the vertical coupling of FUBRad to the FB scheme at 70 hPa. We are greatful that he detected two coding errors that indeed were related to the coupling and implementation procedure into the MESSy modular system. However, we emphasize that the removal of the bugs led to only very minor changes of the SW heating rates and these only at altitudes below 70 hPa (˜18 km) (not visible in the plotted heating rate profiles). While these changes might have some impact on the tropospheric radiation budget, they did not affect the above described SW heating rate discrepancy in the upper stratosphere.

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 use of total heating rates (ignoring chemical energy storage for consistency reasons). These changes were however of minor impact in the stratosphere and did

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not solve the heating rate discrepancy at the stratopause. For validation we use the 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 are convinced that our model does not give rise to erroneous conclusions in scientific applications.

It is 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).

Below we respond Dr. Giorgetta's comments where appropriate.

Dr Giorgetta criticised that Rayleigh scattering is not considered in FUBRad. It is correct that FUBRad neglects Rayleigh scattering. According to e.g., Strobel (1978), it is of sufficient accuracy for applications in MA GCMs to parameterize Rayleigh scattering in the Chappuis und Huggins bands by a reflecting layer in the lower atmosphere. We follow this approach in FUBRad. We further estimated the effect of multiple scattering in separate calculations with the reference model libRadtran. These confirmed the validity of the Strobel approximation for the vertical domain of FUBRad. Multiple scattering and scattering due to clouds at levels with pressures higher than 70 hPa (i.e. in the troposphere) is considered in the FB scheme.

Dr. Girogetta pointed at a possible coding error in the calculation of the optical path of the upward reflected solar radiation. He was right. We have corrected the coding error for the upward optical path. The effect was a slight improvement in the SW heating rates in the lower stratosphere.

Dr. Giorgetta pointed at inconsistencies in the vertical coupling between FUBRad and

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the FB scheme. We first would like to clarify that FUBRad computes downward fluxes between the top of the atmosphere (TOA) and 70 hPa and not between the surface and 70 hPa as is stated in the comment (2.B.1). The contribution of the Hartley bands at 244-278 nm to the transmissivity had been considered separately for technical reasons and erroneously omitted when coupling FUBRad to ECHAM5/MESSy. This has been corrected. We do not understand the further assumption of the author: Why should we exclude the 244-278 nm band if we intended to exclude the 206-244 nm band? The calculation of the transmissivity to be transferred from FUBRad to FB at 70 hPa has been corrected so that double absorption by ozone in FUBRad and FB is avoided. The same transmissivity is used now for the non-cloudy and for the cloudy atmosphere. (2.B.2-4) Altogether the removal of the coding errors did not affect the SW heating rates in the upper stratosphere, and hence were not responsible for the above described heating rate discrepancy between our study and Cagnazzo et al. (2007).

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