Atmos. Chem. Phys. Discuss., 6, S1744–S1747, 2006
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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A modified band approach for the accurate calculation of on-line photolysis rates in stratospheric-tropospheric Chemical Transport Models" *by* J. E. Williams et al.

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Received and published: 12 July 2006

The referee objects to our use of a two-stream method for the online calculation of actinic fluxes due to the shortcomings related to the calculation of the multiple-scattering contribution to the actinic flux. Of course we agree that the more streams a radiative transfer code has the more accurate the solution for the radiative transfer equation with respect to the scattering component will be. We acknowledge that both the FTUV and FAST-J2 methods, which have been mentioned by the referee, both use an 8-stream method for the solution of this problem and have included the relevant discussion in the introduction of our manuscript. However, considering the application, a global chemistry transport model with high spatial resolution and extensive chemistry, the use of an 8-stream solver would severely degrade the computational performance of our CTM

by increasing the runtime. The performance of the band approach is dependent on the spectral grid used in the model (i.e.) it cannot be too coarse. Therefore we are somewhat limited as to the resolution of the wavelength grid we can use. The extension of the two-stream approximation to account for sphericity, which is discussed in the paper, should be viewed as a pragmatic way of dealing with this issue. Appendix A clearly shows that this makes a substantial improvement to the resulting actinic fluxes for sza$>$85 degrees as compared to a full spherical reference model. Moreover, given that processor speed is continually increasing there is no reason why we cannot upgrade to a more expensive RT solver in the future. Furthermore, if adopted in a regional chemical model we would advise such a step. In light of this discussion we will add comments on this issue to the section dealing with use in other models.

We would also like to remark that FAST-J2, which is the only code capable of calculating photolysis frequencies for the stratospheric species such as N2O and the CFC's, has it's own caveats as highlighted by the following quote from Bian and Prather (2002): "Fast-J2 is not designed for conditions with very large aerosol loading in the stratosphere (e.g.) the first months of Pinatubo cloud. In such circumstances, the code would have to be adjusted to calculate the 11 short-wavelength bins with full multiple scattering as in the fast-J code. Also, the wavelength optimization has been designed for conditions of high sun, active photochemistry; and hence caution and further tests would be needed before fast-J2 is applied to studies of the winter polar stratosphere with twilight photochemistry". Therefore, in spite of the claims of the referee, it seems that the errors and performance of Fast-J2 is dependent on the aerosol loading even though it uses an expensive 8-stream solver, and the wavelength grid would need redefinition for high zenith angles. A prime motivation for our work was to produce a scheme which could capture the ozone depletion at the end of a polar winter meaning that J values for high zenith angles is a main focus.

The referee complains that we "proceed down a path of antiquated radiative transfer" however FAST-J2 also employs the methods of Feutrier (1964) and Chandrasekhar

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(1960) for the calculation of anisotropic scattering and for the parameterizations of the temperature dependent absorption properties, respectively. Moreover, we update the description of the direct beam in the two-stream approximation with the pseudo-spherical approximation based on more recent literature (e.g. Rozanov, et al, 2000; Walter et al, 2004). Therefore, we cannot agree with this remark.

We also feel that the referee's statement that "errors of 20% are not acceptable" at the surface in the presence of cloud to be overstated as this error pertains to 100% cloud cover, a scenario almost never encountered in a CTM. Moreover, considering the other errors introduced into the model by the meteorological parameterisations, unresolved micro-physics, grid resolution, emissions estimates, uncertainties in reaction rates, etc. we feel that the errors introduced by the shortcomings of the two-stream approach are not dominating. The referee states that the band approach "is also a bit out of date" although it has been adopted, and is still used, in a host of CTM and GCM models in Europe (e.g. TM4, TM5, MATCH-MPIC and ECHAM). Therefore we feel that this extension of the method is valid as it is currently being employed for scientific studies whose results are incorporated into international policy assessments (e.g. IPCC, Stevenson et al, 2006).

Another consideration is the ethos we have adopted of making a code as transparent and flexible as possible. The original method used a parameterisation with respect to the slant optical depth, which made it difficult for people to implement. This is why we have moved away from the use of large pre-calculated look-up tables, which need to be subsequently indexed when performing calculations online. Moreover, as a result of the averaging that is needed for large spectral bins the inclusion of new laboratory data for temperature and pressure dependent absorption properties can be rather complicated (Cameron-Smith, 2000) and often requires a fit of the experimental data to be provided in a formulated way. For any potential user this requires knowledge and expertise of how to perform such steps. We cover our concerns on this in the text given in the introduction by "[the use of look-up tables] Ĕ. can be rather inflexible if regular

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updates are needed to input parameters such as absorption co-efficients, where the re-calculation of large look-up tables is often undesirable."

Finally, the referee suggests that an intercomparison should be made between all the alternative methods which have been developed to calculate online photolysis rates in large global models in order to examine the differences in their performance. While we agree that such an intercomparison would be useful, the aim of this paper is to provide a literature source documenting this particular method. An intercomparison could be the focus of a separate study.

Additional References:

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Interactive comment on Atmos. Chem. Phys. Discuss., 6, 3513, 2006.