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Interactive comment on "3-D radiative transfer in large-eddy simulations – experiences coupling the TenStream solver to the UCLA–LES" *by* F. Jakub and B. Mayer

F. Jakub and B. Mayer

jakubfabian@gmail.com

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Response to Anonymous referee #1

1 General remarks

First of all we wanted to thank you for taking your time to go through the manuscript in detail. Your contribution is very much appreciated. Answers to the specific comments are given below.

- *This paper describes the work involved in coupling the TenStream solver to a large eddy model. Much of it is concerned with the efficiency of the scheme, which is fine. I do have a problem with the one "scientific" plot though (Fig. 1). The paper states that the evolution of the model is statistically indistinguishable, yet to me Fig. 1 clearly shows significantly more noise in the *domain mean* liquid water path when spectral sampling is turned on. Compare this to Fig. 1 of Pincus and Stevens (2009) which shows that liquid water mixing ratio exhibits about the *same* noise whether or not spectral sampling is used. This would seem to undermine a key result of the paper, and so needs much more investigation. For example: (1) If the LWP noise is detectable in the domain mean, surely the LWP of individual clouds has much greater noise? (2) Can this noise be mitigated, e.g. following my suggestion in item 4 below? In my view this issue needs to be addressed properly for this paper to be fully published.*

  You propose to change the methodology used to sample the spectral range less frequently in time while increasing the spectral sampling. We very much concur with your ideas that the ratio between spatial, temporal and spectral sampling could be improved. Recent works of Pincus(2013) and Bozzo(2014) in fact tackle these issues in detail sampling teams of spectral bands at a lower frequency in time. Although a lot could and should be done in that direction, we feel that this is beyond the scope of our manuscript because the only point we wanted to make was that the Monte-Carlo Spectral Integration still works if the same spectral band was sampled for all spatial columns. Concerning computational speed, there wouldn't be a difference in our application between sampling one band every time step or two bands every other time steps. We added a paragraph to the manuscript to further clarify why we feel that uniform MCSI is a viable option. Regarding this topic, please also note the more detailed explanations in the specific comments section.

2 Specific Comments:

- *Page 9022 Line 21: "energy-rich" to "energetic"*

  Changed

- *Page 9024 Lines 9-10: The references here are only to the LMU group, but other groups are working on the same problem, e.g. Tompkins and Di Giuseppe (JAS 2007) and Hogan and Shonk (JAS 2013) for the shortwave.*

  There is a fundamental difference between low-resolution models that need to be aware of sub-grid cloudiness and others where optical properties are supposed to be fully resolved. The TenStream relates to the latter. We added a sentence mentioning sub-grid-cloudiness aware parameterizations.

- *Page 9025, Equation on line 12: The important factor here is which dimension varies fastest in memory - this depends whether the equation is using the Fortran or C convention - please state.*

  The concern is not the memory layout but rather that for 1D radiative transfer solvers, heating rates are actually computed using only one dimensional vectors. We added two sentences to make that more clear.

- *The discussion in section 2.1 considers the case that radiation is run every timestep but just for one g-point. What if N g-points were computed every N timesteps, where N could be 2, 4, or a larger number? Presumably the cost of*

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reordering arrays would be less since it would not be incurred every timestep, and since the clouds only change by a small amount per timestep, very little additional error would be incurred? The heating rates could be applied evenly to a number of timesteps between calls to the radiation scheme, which might even be an improvement in terms of heating-rate noise, highlighted in my main comment at the start of this review.

You address two points here. The first one being the discussion in sec. 2.1 about the loop structures: there is no active reordering going on during runtime. The point we wanted to make is that 3D radiative transfer implies changes in function interfaces and data structures: moving from 1D to 3D. This is a direct result of the horizontal coupling and has to be done irrespective of the spectral sampling method.

Your second remark targets the question if Monte Carlo Spectral Integration may be improved with a different strategy. As we already stated in the general comments section above, this has been studied by Pincus(2013) and Bozzo(2014) and we feel that this is out of scope of this manuscript. However, we repeated the experiments on Mistral, additionally with the original MCSI, and the δ-four stream radiative transfer solver and, for better comparison to the work of Pincus(2009), plotted the conditionally sampled avg. liquid water content instead of the liquid water path. It is clear from the theoretical framework they proposed, that the uniform version should introduce more noise in the simulation. However, if that noise is unbiased and does not change the overall evolution of the simulation in the sense that e.g the boundary layer depth evolves unchanged, we argue that the principle ideas of LES as well as MCSI are satisfied. We hope the added discussion in in the MCSI section helps to clarify.

- *Page 9030 Line 10: please state the length of a timestep and the number of g points, to indicate how long it takes for all g points to be computed.*

The scaling experiments were not done using the MonteCarlo Spectral Integration. We added info about the spectral integration and the average time-step.

- *Figure 2: Explain the black/grey bars that form part of the color bar.*

  The black and gray bars show the alpha channel for the volume renderer. This is used to blend out certain value ranges or make objects semi-/transparent. We added the description to the figure.

- *Figure 4: Explain the legend of the panels with reference to Table 1.*

  Good point, done.

- *Listings 1 and 2: These are meaningless to anyone except a user of this specific model. Please write out what this means in English*

  Added the explanation and moved the listings into the appendix

Many thanks,

Fabian Jakub

References

Pincus, Robert and Stevens, Bjorn; Monte Carlo spectral integration: A consistent approximation for radiative transfer in large eddy simulations; Journal of Advances in Modeling Earth Systems; 2009; doi=10.3894/JAMES.2009.1.1

Pincus, Robert and Stevens, Bjorn; Paths to accuracy for radiation parameterizations in atmospheric models; Journal of Advances in Modeling Earth Systems; 2013; doi = 10.1002/jame.20027

Bozzo, Alessio and Pincus, Robert and Sandu, Irina and Morcrette, Jean-Jacques; Impact of a spectral sampling technique for radiation on ECMWF weather forecasts; Journal of Advances in Modeling Earth Systems; 2014; doi = 10.1002/2014MS000386

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