Response to Review Comment 3 (RC3)

Manuscript: egusphere-2023-2129
Title: A dynamic approach to three-dimensional radiative transfer in numerical weather prediction models: the dynamic TenStream solver v1.0
Authors: Richard Maier, Fabian Jakub, Claudia Emde, Mihail Manev, Aiko Voigt, and Bernhard Mayer

We thank Anonymous Referee #2 for his or her comments on our manuscript, which we will respond to below. To structure our response, the referee's comments are printed on a gray background color, while our answers are displayed on ordinary white background.

This is a very interesting paper on speeding up three-dimensional (3D) radiative transfer calculations toward potential use in numerical weather prediction (NWP).

I am very impressed by the paper. It is an important topic, as 3D radiative transfer will require attention as NWP models move to higher resolution.

The methodological advances are carefully designed and effective. I like that the basic ideas are simple and clever and intuitive (e.g., using time-stepping to update the radiative field, and using incomplete solves), while careful attention to details is also crucial to the success of the method (e.g., in the details of the Gauss-Seidel iterations).

The comparisons in the paper are also thorough and include comparisons to a 1D delta-Eddington solver, a 3D Monte Carlo solver, and the original TenStream solver. It is very valuable to have each one of these comparisons, since they span a range of options for speed and accuracy.

The limitations of different methods are also discussed. For instance, the new method is slightly slower than 1D delta-Eddington, and not as accurate 3D Monte Carlo when operated at lower calling frequencies. I appreciate the attention given to these limitations.

It is a very good paper in all aspects: comprehensive, careful, well-written. I appreciated the schematic illustrations, which are helpful for clarifying technical details and main ideas.

I think the paper could be accepted in its current form, but I will mention one specific comment that the authors may wish to address.

Specific comment:

The title mentions NWP as the aim. Then the paper presents results for hectometer-scale grid spacings of large-eddy simulations. On the other hand, I would imagine that NWP will be operating at kilometer-scale horizontal grid spacings for quite some time into the future. If that is the case, then will a major modification of your methods be required in order to work effectively with kilometer-scale horizontal grid spacings, where propagation of radiation in horizontal directions is not well-resolved? I would think so.

While the main conceptual ideas of using a time-stepping scheme and incomplete solves will stay the same on kilometer-scale horizontal resolutions, we will certainly have to make some adjustments to the dynamic TenStream solver. Currently, we think that two main modifications will be needed, which we both addressed in the "Summary and Outlook" section of the paper: First, we will have to consider sub-grid scale inhomogeneities such as cloud fraction inside a certain grid box. Secondly, we will also have to parallelize the model in order to run efficiently on the large domain sizes that come with global or regional-scale NWP models.

If you agree that major modification of your methods will be required in order to work effectively with kilometer-scale horizontal grid spacings, then I would suggest a change to the title (and also possibly some changes in the Introduction section and Summary and outlook section). For instance, in the title, possibly change 'A dynamic approach to' to 'A dynamic approach toward', or change 'in NWP' to 'in LES' or 'in hectometer-scale NWP'. Then you could save the NWP emphasis for a later paper when you can address the difficulties that will arise in using dynamic TenStream on actual NWP models with kilometer-scale grid spacing.

Thank you for this suggestion. To clarify that the solver is currently only designed for the use on subkilometer-scale horizontal resolutions, we have changed the title to “A dynamic approach to three-dimensional radiative transfer in subkilometer-scale numerical weather prediction models: the dynamic TenStream solver v1.0”.

The revised version will also include minor adjustments in the “Introduction” and “Summary and Outlook” sections of the paper to stress that this first version of the dynamic TenStream solver is only designed for the use on subkilometer-scale horizontal resolutions:

In the introduction, we added the following bold parts: “[…] To address this high computational cost of current 3D solvers, we present **a first step towards** a new, "dynamic" 3D radiative transfer model that is based on the TenStream solver. **Currently designed for the use at subkilometer-scale horizontal resolutions,** this new, fully three-dimensional solver accelerates 3D radiative transfer towards the speed of currently employed 1D solvers by utilizing two main concepts. […]”.

A similar modification was applied in the “Summary and Outlook” section of the paper: “Based upon the TenStream solver, we presented a new radiative transfer model **currently designed for the use at subkilometer-scale horizontal resolutions** that allows us to calculate 3D radiative fluxes and heating rates at a significantly increased speed by utilizing two main concepts that both rely on the idea that the radiative field is not likely to totally change in between two calls of the scheme: [...]”

This was the only issue I want to mention, and I otherwise was pleased and impressed by the careful comparisons and discussions of limitations.

Technical correction:

Line 505: "In here" should be just "Here"

We changed that as suggested.