**Geoscientific
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Comment

Interactive comment on "Analyzing numerics of bulk microphysics schemes in Community models: warm rain processes" *by* I. Sednev and S. Menon

Anonymous Referee #3

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Review of "Analyzing numerics of bulk microphysics schemes" by Sednev and Menon

This paper is a critique of the limiters in current microphysics schemes used in mesoscale and global climate models. The paper shows using simplified analysis how a maximum stability time step should be defined, and shows how microphysics schemes may violate it.

The paper is too dense and too long, and makes unjustified claims. Major sections are highly duplicative and need to be condensed and better related to each other as noted in the specific comments below. The paper takes a myopic focus on the stability of the schemes but does not show that the problems that occur significantly affect the

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desired solutions on the large scale: the impacts may be only for extreme events that rarely occur or that the codes are not designed to treat, because they represent cases where convective adjustment takes over.

The paper is not suitable for publication in GMD in its current form, and would need a major revision to be suitable. Finally, the paper is not written in grammatically correct English and needs some smoothing out of the language (particularly missing articles). This is not a fatal flaw, but needs to be corrected before the paper is accepted.

The basic tension is that the authors seek to make the differential equations dominate over mass and energy conservation. This might work for some scales, and it certainly might help in some cases in global models, but it is not clear that this is a major problem, or the solutions are appropriate.

To be publishable in GMD, this manuscript would have to be much shorter and less duplicative, and not make speculative statements, but provide more justification based on different case studies and even global analyses.

Major comments:

The authors do not justify their assertion that the problem of adjusting microphysical process rates to assure mass and energy conservation is an artificial forcing agent. If mass and energy were NOT conserved, this would be a forcing agent.

There is no general discussion of the magnitude of the effect. As such, the attacks on the suitability of the approach are mostly a red-herring. These claims (repeated several times) should be backed up with analysis or removed. It is not clear to this reviewer that the simplified alternatives proposed are any better. Yes, there may be cases where the process rates are wrong. But you have never shown that this will matter for the hydrologic cycle.

This paper zeros in on criticizing a particular set of assumptions in microphysics schemes without a discussion of the broader context. For example, the process rates

you are looking at are empirical, and what if they are simply wrong and inappropriate for the conditions of the state at a point? You are simply making the process rate dominant. It is not clear this is any better or worse than the mass conservation approach given simultaneous calculation of process rates.

As also noted below, just focusing on warm rain ignores other process rates in the microphysics that complicate (and may buffer) the equations.

Specific Comments:

Since the schemes here are used in many models the term 'community models' here is awkward. Why not just refer to 'bulk microphysics schemes commonly used in weather (mesoscale) and climate (GCM) models".

P1406, L4: "additional artificial concentration adjustment" is applied: Where? Is this specified?

P1406,L10: How is this an artificial forcing agent? Time integration limits solutions to be physically realistic (non-negative mixing ratios, consistency between mass and number). This is not a forcing agent.

P1406, L19: "Could lead to erroneous conclusions" regarding different processes and their relative magnitudes. This needs to be specified.

P1406, L23: What does SM refer to? Stability and What?

P1409: Eq 9 and 10: why neglect all the other microphysical processes here? The major difficulty of microphysics schemes and inconsistency is having to calculate all microphysical processes simultaneously. There are typically a lot more terms here. At least make a mention of that and how your solutions would approximate it or are illustrative.

P1409, eq 12: Again, what about other processes? Because of this, your equation is not a necessary condition in the schemes, it is only part of it. There are other source

and sink terms occurring simultaneously.

P1410, L0-8: There are multiple correct solutions for these differential equations based on a balance of processes. I do not think the characterization you have provided here is fair. Also, the wording here is very strange. Are all the schemes you list EEBMCs? Or are only some of them? It is not clear what you mean. The categories could be better described. 'Well-behaved' = checking for timestep limits.

P1410, L10: Why would a well behaved EEMBC not also need to have a mass conservation limiter due to other simultaneous processes?

P1412: Figs 1-4: The problem seems to be most acute for extreme conditions (Nc=10cm-3 is pretty low) and Large Qr and Qc. How often are these conditions found in the atmosphere? Certainly in the large scale models, bulk microphysics schemes are not applied to deep convective clouds where this problem is mostly seeming to occur (large updrafts would be needed to produce Qc and Qr in excess of 1-3g/kg). Thus this problem would not occur there.

Also: Why do you only show 4 schemes? Why not show the Rasch, Kessler and Lin schemes on the figures?

P1413, L17: Why should the schemes assume linearity? If they are non-linear, particularly for lots of processes, then would this analysis still hold? The non-linear nature and need for integration is the basis of how most of the explicit schemes work? I am not sure linearization is appropriate.

P1414,eq 19 and 20: Can you explain where the exponents come from for Qc and Qr (a reference to common formulations perhaps).

P1416: How is equation 40 different than equation 27? Sections 4.1 and 4.2 have a lot of duplicate algebra. Can you synthesize and explain it better?

P1417, L6: Where does lambda_1,2 come from? The reader (like me) may not be familiar with your matrix notation. Please explain.

P1418: Equation 51: how does this relate to equation 40 and 27? How is this valid if you add 8 other process rates?

P1418, L17-24: This is pretty much pure speculation. Do you show an example of where these schemes violate the condition in practice, and how it might affect solutions in a case? Note comments above that these schemes may not be treating the high LWP and Rain WP cases you are concerned with because they work in conjunction with moist convective adjustment.

P1419: Section 4.4 duplicates what you have gone over in 4.1 and 4.2 again. Perhaps they can be skipped in favor of this? What is worse, you don't refer back to the earlier sections and how the equations are related. You use the same language (e.g.: P1420,L11-13) but never acknowledge having used it before. Strange. How does this relate to the earlier sections? Perhaps combine them?

P1421, L7-13: again, is this a real issue or a red herring? When would it occur? What happens when you consider other process rates in your equations that are supposed to act simultaneously?

P1422, L5: I do not think your analogy holds. Ensuring mass an energy conservation in a microphysics scheme is not the same as the example you are proposing with advection, since reducing the velocity reduces the total energy (kinetic energy) and violates conservation laws.

P1424, L10: I am not convinced that your toy models with 2 processes would be sufficiently constrained to not need a mass conservation limiter if you applied this to a full model calculation.

P1425, L 25: You have not justified that this is a major concern, given the range of rates typical of the large scale stratiform clouds that the models are trying to reproduce.

P1426,L20-25: As noted, there is nothing in the manuscript to justify these statements. How does it impact the global water cycle? Can you show that changing the time step

to eliminate this problem changes the water cycle? This text has appeared 3 times verbatim in the manuscript (abstract, introduction and conclusions) without justification.

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