

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

### **Anonymous Referee #1**

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Overall the authors discuss a very important topic of numerically correct treatment of microphysical processes and make an excellent point or two regarding numerical stability unrelated to dynamics. However, their assertion of a "hidden climate forcing agent" due to using too long a timestep is entirely misleading alarmist speculation. Without more convincing evidence with actual simulations to show that precipitation changes in statistically meaningful ways due to this issue, I strongly object to these terms in the current manuscript. (pg.1405,ln.08 & pg.1406,ln.11)

Another weakness in the paper is the lack of considering various limitations that the bulk microphysics code authors may already include in their schemes to avoid phys-

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ically unrealistic things such as massively large water drops. For instance, most schemes would only reach relatively large value of cloud water content between approximately 1-10 g/kg for a single timestep, because, if the concentration of drops is so low as the authors assumed, then the median drop size would be far larger than 50 microns, which would immediately result in drops converting from the cloud water to rain categories and thereby reduce the cloud water content. This manuscript shows a range of conditions that rapidly becomes impractical in full model simulations as various assumptions in the schemes would typically prevent the occurrence of large water contents combined with low droplet concentrations. It is almost as though the authors are trying to exaggerate the severity of this problem by picking a number concentration of droplets of 10 per cc, a condition that no bulk microphysics author would consider wise for widespread usage. As the differences between figures 1&3 and Figs 2&4 show, the smaller the droplet concentration, the potentially more drastic need for short timesteps (e.g., Fig.2d)

Furthermore, this reviewer rarely sees cases where the model can sustain rain or cloud water contents above 1-3 g/kg for extended periods. Obviously, this is a condition associated with only the most massive updrafts in convective environments, which furthermore requires relatively short timesteps in the first place. So, while the authors make a solid argument of the existence of this issue, notice from Figs. 1-4 how almost no scheme has a serious problem for water contents below about 1 g/kg and using timesteps longer than 50 seconds. For that matter, the grid scales needed to produce such high water contents are of order 0.5 to 5.0km which would dictate a model timestep ranging approximately 3-30 seconds. Using Fig. 3 as a relevant example, note how the combination of cloud and rain water contents have to be at their most extreme values before the curves drop below approx 30 seconds. Given my own experience of how infrequently models produce 3-5 g/kg of water content and only do so with extremely high resolution and therefore extremely small timesteps, any assertion by the authors of a noticeable signal in output precipitation that is seriously flawed by approaching a S-M number larger than 1.0 is entirely mis-leading, since such condi-

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tions are rarely exceeded. Once again any concrete evidence of an actual problem in actual simulations is entirely lacking in this manuscript.

The criticism regarding "mass conservation" as a technique to prevent negative mixing ratios or number concentrations appears valid. The authors proposed solution related to autoconversion and accretion as sink terms for cloud water is logical and relatively simple to consider and implement. However, I believe a similar approach to treat the far more complex situation of combined 3-species interactions simultaneously with other processes is a far greater challenge. As an example, consider the case for sink terms for rain such as rain and snow colliding (to form graupel), rain freezing, and rain evaporating. While all of these processes reduce rain, the end result of various processes is different, such as graupel production (or perhaps snow or cloud ice) and source of vapor (in the case of rain evaporating). So how does one apply the proposed technique in the broader sense in order to capture all source/sink terms?

The reason the mass conservation step is found in nearly all bulk microphysics schemes is due to the calculation of a large number of source/sink transfer rates as if no other processes were occurring simultaneously. The creation of those transfer rates come from theoretical and/or laboratory results of a certain process in isolation. As such, one process does not "know" that another process is competing for the same resource (vapor for instance) and, therefore, a final check is done to "re-balance" the various terms in the event that many processes combined would "over-deplete" the total resources available. Basically, the number of source/sink terms operating in unison is large and interactions may be entirely non-linear. So the authors choosing of only 2 processes (autoconversion and accretion) is a great simplification of a far greater problem.

Artificial number concentration adjustments are a fact of life in codes dealing with incredibly small numbers or mass of hydrometeors as compiler optimization of codes is extremely dependent on many factors. Therefore, I see no potential solution that does not involve compiling without optimization which simply will not be an acceptable solu-

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tion. The re-adjustment of number to keep water drops within known physical sizes is absolutely necessary in this reviewer's opinion.

Minor issues:

In many locations in the manuscript, the authors are incorrectly using "tenths" and "hudredths" when they should be writing "tens" and "hundreds." Examples include lines 23 and 25 on page 1404 but there are other places as well.

There are numerous unnecessary acronyms.

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