Reply to reviewer #2

We thanks the reviewer for the careful and positive review and the comments that helped us to improve the manuscript.

Specific comments:

Reviewer: *L1 in P5082: Correct the unit of omega$_r$. It should be [1/m] or [1/mm], not [m].*

Reply: This should read [1/m]. We have corrected this. Thanks.

Reviewer: *L10 in P5083: Im a little worried about the negative fall velocity for very small equivalent diameter. Below I did some calculations: (i)A ccording to the parameter values in L8 in P5083, $v_r(D_r) < 0$ for $D_r < 32$ um. (ii)According to the parameter values in SB2006, $v_r(D_r) < 0$ for $D_r < 110$ um. In this sense, the present formulation is safer than SB2006. Is this the reason why you modified the values? It may be required to implement some limiter to avoid the side effect of the negative fall velocity. It would be informative to readers if you can show some know-how regarding the limiter.*

Reply: For a bulk microphysics scheme it is most important that the bulk sedimentation velocities remain positive. This is garantueed for the chosen approximations. The size of the raindrops is limited, by definition, to 80 μm diameter which makes especially the current choice perfectly valid. Of course, often the integrations are done from zero to infinity and then the result has to be check for its validity in the relevant parameter range.

Reviewer: *The paragraph starting at L11 in P5087: The bulk velocity formulations are not straightforward to me. In L16 in P.5087, you mention D^2-weighted fall speeds for both species, but Eq (17) shows a $D^2 x$ weighting.*

Reply: The relevant sentences read:

> A more detailed analysis of the asymptotic behavior, which should recover the continuous growth equations, shows that the bulk terminal fall velocity of the collecting particles should be weighted with D^2 while the bulk fall speed of the collected particles has to be weighted with $D^2 x$ (Seifert, 2002). When using a two-moment scheme the equation for the number densities should apply D^2-weighted fall speeds for both species.

We think that this exactly describes the weighting applied in Eq. (17), i.e., D^2-weighted fall speeds for both species in case of number concentrations ($n = 0$) and a $D^2 x$ of the collectee in case of the mass equation ($n = 1$) while the collector always has a D^2 weighting.

Reviewer: *I cannot really follow Eqs. (19) and (20). Why integration over $dD_i * dx_j$ in Eq. (19) and $dD_i * dx_j$ in Eq. (20)? Shouldnt they be $dx_i * dx_j$ or $dD_i * dD_j$? Similarly, why $f(x)$ and $f(D)$ are mixed in the two equations?*

Reply: In Eqs. (19) and (20) it is unnecessary to mix $f(D)$ and $f(x)$ and we will formulate this differently in the revised version. Nevertheless, we are sometimes mixing $f(x)$ and $f(D)$ in our equations. The reason for that, on one hand, the SB two-moment scheme is written with particle mass as the primary size variable and internal coordinate, i.e., it uses $f(x)$. With the Atlas-type fall speed for rain it is, on the other hand, more convenient to use $f(D)$. For example, we wanted to keep the same formulation as in SB2006 for graupel and only change the formulation for rain. The resulting equation is then most easy to implement in our code, because the coefficient in the graupel-terms are identical to SB2006. From a mathematical point of view it is no problem to mix $f_r(D)$ and $f_g(x_g)$, because

$$f_i(x_i)f_j(x_j)dx_idx_j = f_i(D_i)f_j(x_j)dD_idx_j = f_i(x_i)f_j(D_j)dx_idD_j = f_i(D_i)f_j(D_j)dD_idD_j. \quad (1)$$

Note that we are here following the convention that $f(x)$ and $f(D)$ are different functions.

Reviewer: *Overbars of xr, vg, Dr, Ds, Dg, Di, Dj in Eqs. (29), (33), (34), (35), (36), (45), (46), (51), (54) and (55) are not defined.*

We have fixed this and the overbar notation is now properly defined with $\bar{x}_j = L_j/N_j$, $\bar{D}_j = D_j(\bar{x}_j)$ and $\bar{v}_j = v_j(\bar{x}_j)$ for any species $j \in \{r, g, i, s, h\}$

Technical corrections:

Reviewer: *L15 in P5080: "As most earlier parameterizations DID, SB2006 limited. . ."*
Fixed.

Reviewer: *L18 and below in P5080: consistency on Sect or Section.*
The abbreviation Sect. was introduced during the technical editing by the GMD staff and we simply accepted their modifications of the manuscript. We have now changed everything back to section.

Reviewer: *L27 in P5080: remove in before discussed.*
Fixed.

Reviewer: *L10 in P5086: $M_{j,0}$ not $M_{0,j}$.*
Fixed, and thanks for the very careful reading.