



Interactive comment on “A subgrid parameterization scheme for precipitation” by S. Turner et al.

S. Turner et al.

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Received and published: 9 February 2012

Dear referee,

Thank you for these thoughtful comments, which provide an improved version of this paper. I apologize for the delay in sending the replies.

Note that three figures and one appendix are added to explain the new parameterization, following the referees comments.

AC: Author Comment | RC: Referee Comment

Major remarks

RC: It would be very useful to add a few sketches to describe the scheme.

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AC: Yes, 3 figures are added.

RC: 1. How do the four PDFs look like?

AC: One figure is added to show the four PDFs related to Tab. 2.

RC: 2. How do the PDFs look for $CF_H = 0$ and $CF_H > 0$?

AC: When $CF_H = 0$, all the CWC is uniformly distributed in the low CWC region, so there is no splitting of the CWC. When $CF_H > 0$, that means that there are a high and low CWC regions. See the new figures.

RC: 3. A sketch on how the overlap of rain fraction is handled.

AC: One figure is added to show the overlap of the cloud fraction and the rain fraction.

Specific remarks

RC: p1643: should the affiliation name be in upper cases?

AC: Yes, this affiliation name was obtained from CNRM officials.

RC: P1644 L5: PDF should be spelled out here

AC: Yes, correction done.

RC: P1645 L12: frequency of occurrence of clouds?

AC: Yes, it is the frequency of occurrence of clouds and precipitation. Text is changed.

RC: P1645 L15: does a problem with too much overcast skies matter here? It would indicate a problem with the grid-box mean relative humidity, rather than a problem with the subgrid-scale distribution.

AC: This is true on a single step perspective, but the grid-box mean relative humidity in the forecast model is sensitive to the precipitation parameterization scheme.

RC: P1645 L16: is there an upper bound as well?

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AC: This information is not available in the referenced reports.

RC: P1646 L3: It is understandable that the senior authors involved in this study may believe that they solved the problem of precipitation in large-scale models in their earlier research. However, also for general circulation model it remains a challenge, and the “drizzle problem” described for the mesoscale models on p1645 l16 also is a problem in GCMs.

AC: Yes, the text is changed as followed:

Before: At intermediate horizontal resolutions, however, i.e. when only a few clouds occupy the model grid, simulating the formation of precipitation remains a challenge.

After: At intermediate horizontal resolutions, however, i.e. when only a few clouds occupy the model grid, such a statistical approach is no longer valid.

RC: P1647 L24: it would be useful to discuss the works Jess, Spichtinger and Lohmann, A statistical subgrid-scale algorithm for precipitation formation in stratiform clouds in the ECHAM5 single column model, Atmos. Chem. Phys. Discuss., 11, 9335-9374 (2011) atmos-chem-phys-discuss.net/11/9335/2011/acpd-11-9335-2011.pdf and Zhang, Lohmann and Lin, A new statistically based autoconversion rate parameterization for use in large-scale models, J. Geophys. Res., 107, 4750 (2002) www.iac.ethz.ch/doc/publications/Zhang2002.pdf in this context.

AC: The present work is dealing with mesoscale modelling of cloud water variability, and despite the fact that the referenced papers are very interesting, they deal with global models. The problem of representing an ensemble of different cloud types in a grid box of 50-200 km is not the same as having cloud water inhomogeneities in a small grid box (1-5 km).

RC: P1647 L28: a superfluous space

AC: Yes, correction done.

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RC: P1648 L20: The cloud microphysical scheme employed in this study needs more details, and the reader should not be left with the reference (particularly since one of these is only a conference proceedings reference). Specifically, it is important to note that rain and snow are prognostic quantities, which are transported by advection, and to report the formulas for autoconversion (Kessler 1969 as stated on p1650 l20); and for accretion.

AC: Yes, an appendix is added to state all formulas for autoconversion, accretion, evaporation and sedimentation of rain.

RC: P1649 L18: how do the CCN translate to droplet number concentrations? are the latter then fixed, or do they depend on updraft velocities?

AC: The text is clarified as followed:

Before: DM simulations were performed with three CCN concentrations of 50, 70 and 100 cm⁻³, and will be identified as DM-50, DM-70 and DM-100 respectively.

After: The DM scheme rely on four prognostic variables : the cloud droplet and drizzle/rain drop concentration, and the cloud droplet and drizzle/rain drop mixing ratios. A fifth prognostic variable is used to account for already activated CCN, following the activation scheme of Cohard et al. (1998), which is an extension of the Twomey (1959) parameterization for more realistic activation spectra. The number of CCN, activated at any time step, is equal to the difference between the number of CCN which would activate at the diagnosed pseudo-equilibrium peak supersaturation in the grid (depending on updraft velocity and temperature) and the concentration of already activated aerosols. DM simulations were performed here with activation spectra producing concentrations of activated nuclei at 1% supersaturation of 50, 70, and 100 cm⁻³, called DM-50, DM-70 and DM-100, respectively.

and the two added references:

Cohard, J.-M., J.-P. Pinty, and C. Bedos, 1998: Extending Twomey's analytical estimate

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of nucleated cloud droplet concentrations from CCN spectra. J. Atmos. Sci., 55, 3348-3357.

Twomey, S., 1959: The nuclei of natural cloud formation. Part II: The supersaturation in natural clouds and the variation of cloud droplet concentration. Geophys. Pure Appl., 43, 243-249.

RC: P1650 L3: For the models in use here, no assumption is necessary. A subgrid scheme for cloud fraction is used.

AC: Yes, text is changed as followed:

Before: We assumed that the model was already equipped with a parameterization of the cloud fraction (CF).

After: The Meso-NH model already uses a subgrid scheme for cloud fraction (CF).

RC: P1650 L5: This is unclear. Why would the subgrid-scale variability of cloud water be generally more homogeneous if a cloud fills the entire grid-box? Is that not also a contradiction to the statement by the authors that they think such a scheme is most useful for models with a resolution of order 1 - 5 km?

AC: With no subgrid scheme the mean CWC is distributed over the whole grid box, hence the local value $qc_{\tilde{}}$ = $qc_{\bar{}}$ is lower than when using a subgrid scheme $qc_{\tilde{}}$ = $qc_{\bar{}}/CF$ with $CF < 1$. It is not obvious in this case that the splitting of CWC between high and low values will be sufficient for the onset of precipitation.

RC: P1650 L7: it would be good not to mix abbreviations and symbols with identical meanings. In general, symbols are preferable.

AC: The CWC (cloud water content) abbreviation is used to make the text easier to read, and it is a general expression; it should not be mixed with $qc_{\bar{}}$, $qcL_{\bar{}}$, $qcH_{\bar{}}$, $qc_{\tilde{}}$, $qcL_{\tilde{}}$, $qcH_{\tilde{}}$.

RC: P1650 L12: The very crucial parameter of the autoconversion threshold needs

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to be defined clearly. It seems to be chosen at 10 - 12 μm in mean volume radius (p1644 l23), which would translate to about 0.4 g m⁻³ in liquid water content for a droplet number concentration of 100 cm⁻³ (smaller ones for the other droplet number concentrations) according to p1645 l2.

AC: In this study, the autoconversion threshold is of a Kessler type, i.e. 0.5 g/kg. But this new parameterisation does not explicitly define this threshold because it takes any value that is already in the microphysical scheme. That is why it was not explicitly stated. A reference to the appendix is made in order to give the values used in the simulations presented in this study.

RC: P1650 L24: a reference is missing here.

AC: Yes, I didn't find any, if you can suggest one it would be nice. But I can add that we observed it in our RICO data, as followed:

Before: Statistics of CWC derived from past observations and LES cases suggest that linear or quadratic decreasing functions could be suitable for describing its PDF.

After: Statistics of cumulus CWC derived from past observations and LES cases suggest that linear or quadratic decreasing functions could be suitable for describing its PDF, as it is shown in Fig. 9 (old version, Fig. 12 in the new version).

RC: P1651 L7: until $q_{c_tilde} = q_{c_R}$? Does this not imply the PDF is always symmetric?

AC: The sentence was not clear. It is changed as:

Before: When CWC was low, CF_L was higher than CF_H until it reached the q_{c_R} limit, and then the inverse prevailed.

After: As soon as the CWC is split into a high and a low part, $q_{c_H_tilde} > q_{c_tilde}$, but there is little difference between the $q_{c_H_tilde}$ values derived using the four different PDF forms.

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RC: P1651 L25: which level?

AC: The levels where the rain is formed. Text is changed.

RC: P1651 L28: so a 2D field is stored? is this one advected? or how could it be consistent with the advected 3D rain? how is the evaporation of rain handled? - all this needs explanation.

AC: There is evaporation of rain below cloud cells, but only the rain water content is affected, and the rain fraction in a column is set to be constant until rain is reaching the ground. It is not exactly true in real clouds, but it is a good approximation for a small grid box and precipitation associated with cumulus and stratocumulus clouds. Text is clarified as followed:

After: A realistic approach would be to advect the rain fraction like any conservative variable, considering that the fraction is uniformly distributed over each model grid. This is feasible if one more prognostic variable is added, namely the subgrid value of the RWC. After advection, the rain fraction can thus be calculated as $q_{\text{sub}} \cdot \bar{RWC} / q_{\text{grid}}$. At this stage, however, a simpler, economical solution was tested that did not require an additional variable. The RWC is advected like all other model variables and the rain fraction is following the rain in the column: once precipitation had formed in a model column, the rain fraction was translated to the whole column below, down to the ground. In other words, the rain fraction in a model column was equal to the maximum of the rain fractions at the levels where rain is formed. Note that there is no horizontal advection of the rain fraction. Because RWC can be advected but its fractional part cannot, possible inconsistencies between this simple probabilistic approach and the 3-D advection of RWC were further accounted for by setting the rain fraction to zero in grids where the RWC was less than a small threshold value.

RC: P1652 L9: also multi-layered clouds are an issue.

AC: Yes, text is changed as followed:

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Before: Such an assumption mimics the LES when clouds are growing vertically, but it obviously fails when clouds are tilted because of wind shear.

After: Such an assumption mimics the LES when clouds are growing vertically, but it obviously fails for multi-layered clouds or when clouds are tilted because of wind shear.

RC: P1652 L15: probably not within CF_L , but within $RF - CF_H$, which in this case is less than CF_L .

AC: Yes, this can happen. The text is changed as followed:

Before: $CF_H < RF < CF$: accretion is calculated using qc_H_tilde within CF_H and qc_L_tilde within CF_L and there is no evaporation.

After: b. $CF_H < RF < CF$: accretion is calculated using qc_H_tilde in the CF_H region and qc_L_tilde in the $RF - CF_H$ region, and there is no evaporation.

RC: P1653 L12: the second “DM-50” probably should read “DM-100”

AC: Yes, correction done.

RC: P1657 L26: this is an astonishing result from the observations, and one is tempted to believe more in the model. Or is there an explanation?

AC: We believe in the observational data set, and clearly the model was not able to convert enough cloud water into rain water. This is a clear limitation of the microphysics parameterization.

RC: P1658 L4: “produce surface rain at all”

AC: Yes, correction done.

RC: P1659 L9: “BL” should be spelled out here, where it occurs the first time

AC: It appears first p.1647 l27, and was spelled there. But, there was a double spelling that is eliminated.

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RC: P1669 Table 4: “simulated surface precipitation”

AC: Yes, correction done, as well for for table 6.

RC: P1672 Fig. 1: it would be useful to show the autoconversion threshold in the plots

AC: Yes, it has been added.

RC: P1683 Fig. 12: “South-West”

AC: Yes, correction done.

Please also note the supplement to this comment:

<http://www.geosci-model-dev-discuss.net/4/C1553/2012/gmdd-4-C1553-2012-supplement.pdf>

Interactive comment on Geosci. Model Dev. Discuss., 4, 1643, 2011.

GMDD

4, C1553–C1564, 2012

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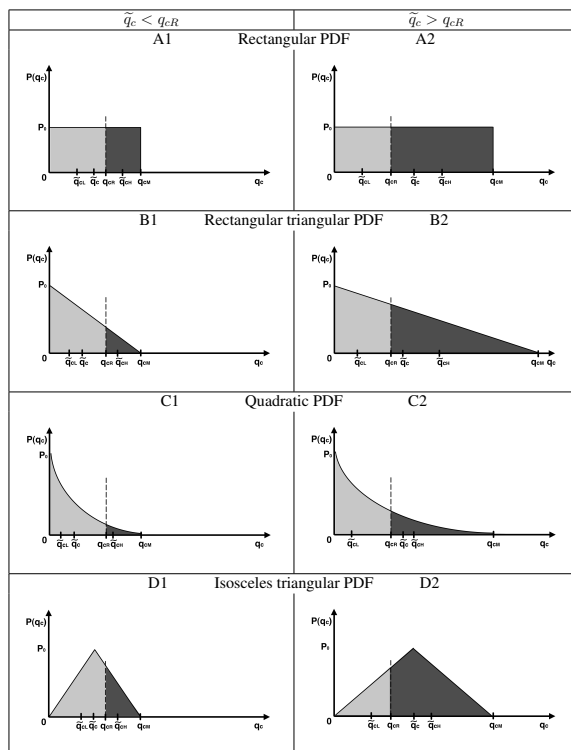


Figure 1: Graphs of the four PDF forms used to represent the CWC. Light grey represents regions of low CWC and dark grey represents high CWC. The local mean CWC, the local low CWC and local high CWC are, respectively, \tilde{q}_c , \tilde{q}_{cL} and \tilde{q}_{cH} . The autoconversion threshold is q_{cR} , and the maximum value of the CWC is q_{cM} .

Fig. 1.

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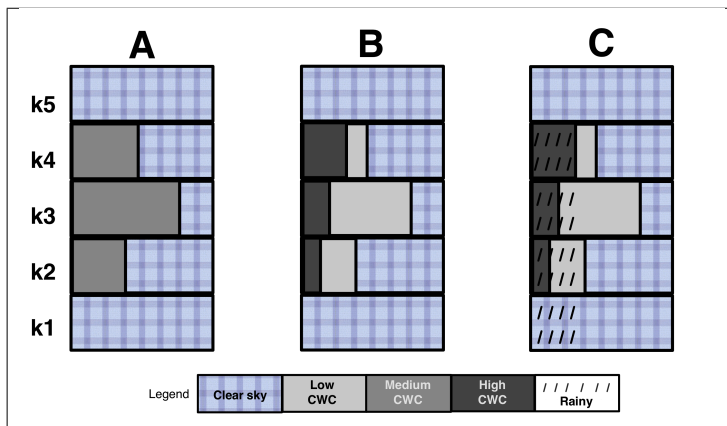


Figure 3: A, B and C are the successive steps of the numerical treatment of the cloud and rain vertical overlap in a model column. (A) The maximum cloud overlap is applied for adjacent or non-adjacent layers. (B) The same maximum cloud overlap of (A) is applied for the new parameterization using the splitting of the CWC in two regions, and maximally overlapping the high CWC regions. (C) The rain is falling vertically with a maximum vertical overlap.

Fig. 2.

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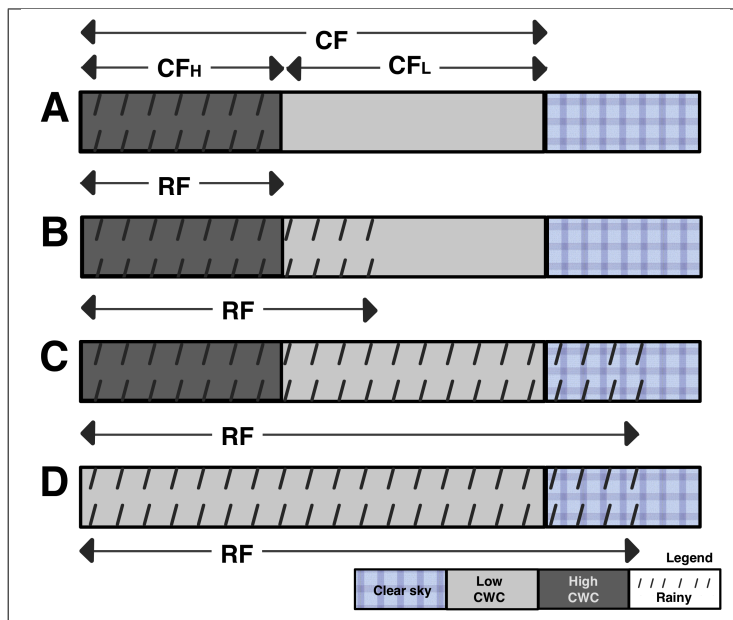


Figure 4: Four horizontal views of a grid box, with the splitting of the CWC in two regions of low and high CWC. RF and CF are the rain and the cloud fractions, with CF_L representing the cloud fraction in the low CWC region and CF_H the cloud fraction in the high CWC region (see text for details about differences in accretion and rain evaporation in A, B, C and D).

Fig. 3.

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