Geosci. Model Dev. Discuss., 4, C1571–C1581, 2012
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Geoscientific Model Development Discussions

Interactive comment on "A subgrid parameterization scheme for precipitation" *by* S. Turner et al.

S. Turner et al.

turner.sandra15@gmail.com

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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

RC: P1651 L25: does it means that rain cannot decrease below (e.g., rain evaporation)? Is not it a serious inconsistency which leads to overestimation of rain at the surface? Detail also more what you mean by inconsistencies at line 26.

AC: No, rain decreases below by evaporation. 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 small grid box and precipitation associated with cumulus and stratocumulus clouds. Text is clarified as followed:

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 ÌČr/q ÌĎr. 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 L15-20: could you add a schematic?

AC: Yes, one figure is added.

RC: Could you schematically show the PDFs and their major parameters of Table 2 in some graphic form?

AC: Yes, one figure is added.

Specific comments:

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RC: P1644 L4: clouds and precipitation “formation”

AC: Yes, correction done.

RC: P1644 L7: model grid box

AC: Yes, correction done.

RC: P1644 L23: reaches a threshold of 10-12 um.

AC: Yes, correction done.

RC: P1644 L26: “ALL” cloud droplets?

AC: Not all, but most of them. Text is changed.

RC: P1645 L1: ...radius. This depends on the local...

AC: Yes, correction done.

RC: P1645 L7: . . .(NWP) and climate models...

AC: Yes, correction done.

RC: P1645 L15: “overcast grid boxes”: what does it imply? Is it relevant?

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 L19: add reference

AC: Unfortunately, we don’t have any reference. This information is coming from Meteo-France operationnal services.

RC: P1645 L23: ...model grid (>= 50 km), empirical . . .

AC: Yes, correction done.

RC: P1646 L1: At larger horizontal resolutions, however, only few clouds occupy the

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model grid, and simulating....

AC: Yes, correction done.

RC: P1646 L23: cloud formation depends jointly on temperature and humidity through relative humidity...

AC: Yes, correction done.

RC: P1646 L25-27: is the sentence necessary?

AC: No, it is eliminated.

RC: P1647 L7: . . . of the system with the purpose of increasing the cost....

AC: It is not an increase of the cost, but a decrease: sampling some of the states is cheaper than calculating all the possible states.

RC: P1648 L4-8: I would rewrite as: "The horizontal resolution of most of current state-of-the-art operational mesoscale forecast models now reaches 1-5 km, which allows to explicitly resolve...".

AC: Yes, correction done.

RC: P1648 L4-8: The following sentence "Meteo-France for instance..." is not needed.

AC: Yes, the sentence is eliminated.

RC: P1649 L18: describe how you go from CCN to droplets number.

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

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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 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 L4: not clear. Why?

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 L14-15: which are the values of qc_R and qc_M?

AC: For qc_R, the value is derived from the autoconversion parameterisation of the microphysics scheme; it can be of Kessler type or any other one. For qc_M, the value depends on the PDF shape. I suggest to keep only the qc_R in that sentence, with those modifications, and qc_M is explained in p1651 l5.

Correction for qc_R: Before: The CWC mean values in the CF_L and CF_H subcloud fractions, qc_L_tilde and qc_H_tilde, respectively, were then defined as the first moment of the PDF integrated from 0 to the collection threshold qc_R for qc_L_tilde and from the collection threshold to the maximum value qc_M for qc_H_tilde.

After: The CWC mean values in the CF_L and CF_H subcloud fractions are defined as for the first moment of the PDF, were qc_L_tilde is integrated from 0 to the collection threshold qc_R, which can be of Kessler type or any other one, and qc_H_tilde is the integration of all values higher than qc_R.

Correction for qc_M:

Before: After: To evaluate the sensitivity of the scheme to the PDF choice, tests were extended to rectangular and two triangular PDF. Table 2 shows ...

After: To evaluate the sensitivity of the scheme to the PDF choice, tests were extended to rectangular and two triangular PDF, as shown by Fig. 1 A variable named qc_M was added as the limit for the integration of the CWC and it is derived from the conservation of the CWC in the grid box. Table 2 shows ...

RC: P1650 L23: give references

AC: Yes, I didn't find any, if you can suggest one it would be nice. But I can say 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 L7-8: not clear

AC: Yes, the sentence is changed as followed:

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

After: As soon as the CWC is split into a high and a low part, qc_H_tilde > qc_tilde but there is little difference between the qc_H_tilde values derived using the four different PDF forms.

RC: P1652 L12: DM-100 and SM replace with p1653 l12: DM-100 and SM

AC: Yes, correction done.

RC: P1652 L15: “within”? Not clear

AC: Yes, it was not clear. The Fig. 4 may help to understand and the sentence is changed as followed:

Before: b. 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 L23: precipitation comparable to the observed amounts, but overall the precipitation...

AC: Yes, correction done.

RC: P1655 L7: why do you chose to show DM-50?

AC: We choose to show DM-50 because it was more consistent with observations for the stratocumulus case study. It was more difficult to produce rain with the DM-70 and DM-100 simulations.

RC: P1655 L10-12: could you comment more on this feature?

AC: Yes, clearly the microphysics scheme was not able to transform effectively CWC in RWC. Rain formation remains a difficult task, even for LES models.

RC: P1655 L18-20: this sentence should be moved up in the text

AC: Yes. Table 4 first appeared P1653 l 24. It is placed just next.

RC: Table 1: given how the discussion is organized in the text (DYCOMS first), I would switch the columns of RICO with those of DYCOMS

AC: Yes, correction done.

RC: Fig. 2: "..., rain water content (), and surface . . .."

AC: Yes, correction done.

RC: Fig. 12: when was the simulation initialized (how many hours ahead)? Ouest–> West

AC: The simulation was initialized at 00 UTC. Correction done for Ouest to West.

Please also note the supplement to this comment:
http://www.geosci-model-dev-discuss.net/4/C1571/2012/gmdd-4-C1571-2012-supplement.pdf

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

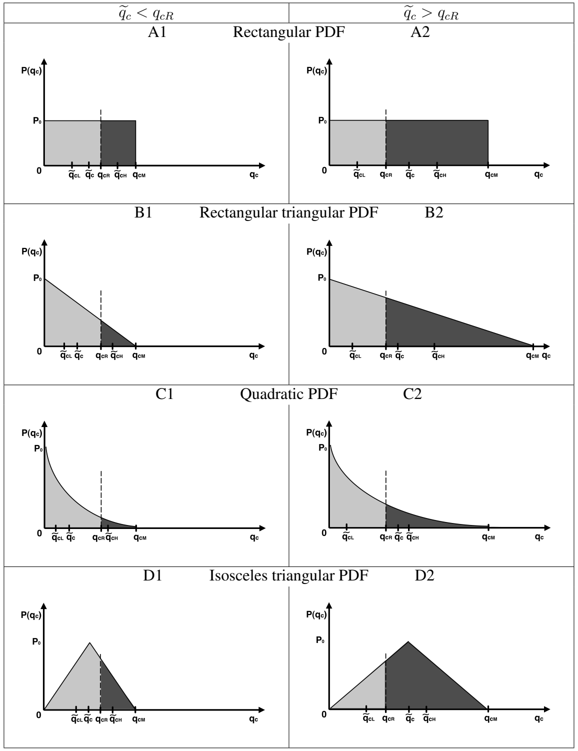

Figure 1: Graphs of the four PDF forms used to represent the CWC. Light grey represents regions of low CWC and dark grey represents high CWC. The local mean CWC, the local low CWC and local high CWC are, respectively, $\widetilde{q}_c$, $\widetilde{q}_{cL}$ and $\widetilde{q}_{cH}$. The autoconversion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

Fig. 1.

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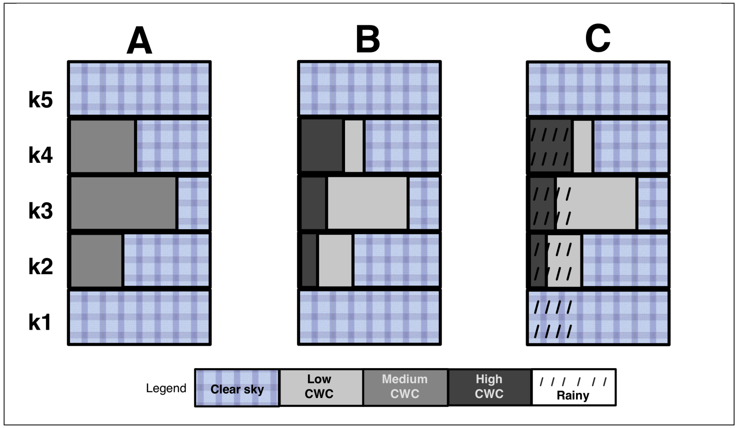

Figure 3: A, B and C are the successive steps of the numerical treatment of the cloud and rain vertical overlap in a model column. (A) The maximum cloud overlap is applied for adjacent or non-adjacent layers. (B) The same maximum cloud overlap of (A) is applied for the new parameterization using the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

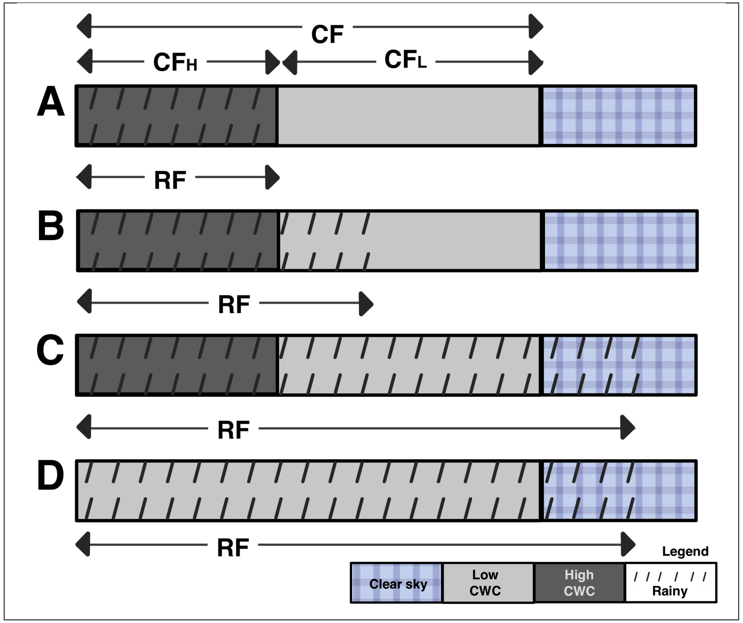

Figure 4: Four horizontal views of a grid box, with the splitting of the CWC in two regions of low and high CWC. RF and CF are the rain and the cloud fractions, with CF_L representing the cloud fraction in the low CWC region and CF_H the cloud fraction in the high CWC region (see text for details about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

Fig. 3.