Improving the Cloud Overlap Scheme in APLMPHYS

Joris Van den Bergh, Royal Meteorological Institute Belgium
Work in collaboration with J.F. Geleyn and R. Brozkova

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Introduction and terminology

We discuss our work in progress on changes to APLMPHYS. For an overview of the APLMPHYS routine, see Geleyn et al, 2007. The physics is mainly based on Lopez, 2001. We focus here on changes that deal with the cloud geometry. In this part of the code, the precipitation fluxes are calculated for each vertical level starting from the fluxes at the previous level. We give here a reminder here of the basic principles involved.

- The *statistical sedimentation algorithm* (Geleyn et al, 2008) allows one to do all computations layer per layer. In a loop over the vertical layers, each computation uses only information from the layer directly above.
- Each vertical layer is divided in four parts. *Seeded* and *non-seeded* (by precipitation coming from above) parts of the *cloudy* fraction, and seeded and non-seeded parts of the *clear air* fraction. The non-seeded clear air fraction is relevant: it can contain residual q_r, e.g. from resolved advection. We denote with C the fraction of cloud cover, and α and β denote the seeded fractions of the clear and cloudy parts respectively. $0 < C < 1$, and idem for α, β. See figure 1 for a schematic.
- Physical processes affecting the falling precipitation:
  - *Autoconversion*: ACACON. Called once, in the cloudy part.
  - *Collection*: ACCOLL. Called twice, in seeded & non-seeded cloudy parts separately.
  - *Evaporation/Sublimation & Freezing/Melting*: ACEVMEL. Called thrice, in seeded & non-seeded clear sky and averaged cloud.
- Assumptions: statistical sedimentation functions are identical in the four regions, saturation deficit $q_{\text{sat}} - q$ is concentrated in the non-cloudy part ($q = q_s$ in the cloud), q_l and q_i are homogeneous within the cloud, and q_r and q_s are computed proportional to the local precipitation flux intensity.
- The cloud is assumed to create a *homogeneous output* at the bottom of a layer, mixing its own output with seeded precipitation from above.
- The final computation in each layer is the *reorganisation step*, where the fluxes are prepared for the next layer. This reorganisation depends on the *cloud overlap* scheme (see below). Currently, two schemes exist: according to the switch LRNUMX, either *random overlap* or *max-random overlap* is used. In these schemes α and β are updated, followed by the reorganisation of the fluxes.

Geometric fractions & precipitation fluxes

The fractions defined previously are sketched in figure 1.

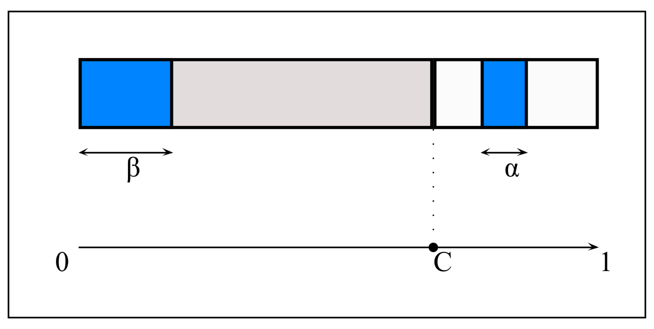

Figure 1: Fractions within one vertical layer. Cloudy fraction C (grey) and seeded fractions α, β (blue).

We write P_i for fluxes and F_i for partial fluxes. The residual (non-seeded) partial flux in the clear sky part (ZIPLRLE in the code) is denoted F_{RE}. We also have F_{RO}, F_{SE}, F_{SO} for the residual cloudy part, seeded clear sky part, and seeded cloudy part respectively. Fractions in the upper layer are denoted C^*, α^*, β^*, and outgoing partial fluxes (ZOPLRLE,...) are denoted as F^*_{RE}, ...
The total precipitation flux is given by:

$$P = (1-C)(1-\alpha)F_{RE} + (1-C)\alpha F_{SE} + C(1-\beta)F_{RO} + C\beta F_{SO} . \quad (1)$$

The updating $\alpha^*, \beta^* \to \alpha, \beta$ and reorganisation of the fluxes $F^*_i \to F_i$ between layers depends on C and C^*, and on the assumptions for how clouds overlap. In figure 2, two example configurations are illustrated for adjacent layers.

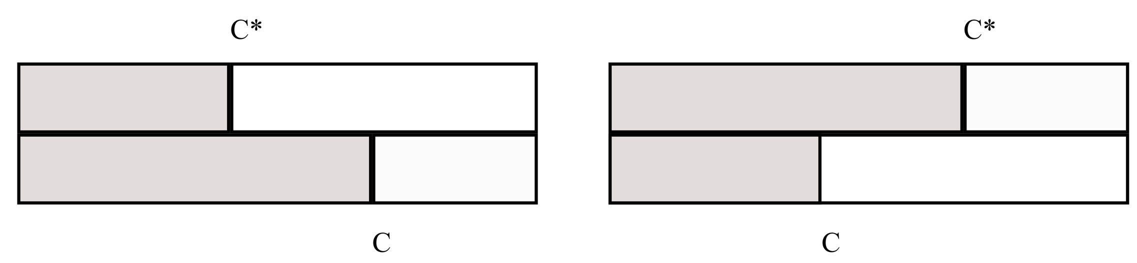

Figure 2: Cloud overlap with left $C > C^*$ (a), and right $C < C^*$ (b).

Cloud overlap schemes

Current schemes in use are (switch LRNUMX):

- Random scheme: cloud overlap is random.
- Max-random scheme: clouds overlap maximally with the cloud in the layer above. If there is a clear layer above, the overlap is random with clouds further up.

In the case of random overlap, updating the geometric fractions and partial fluxes is trivial (linear recombination). The case of max-random overlap is more complicated, depending on the sign of $(C - C^*)$. As an example, we give here the updating equations for α and β for the case $C < C^*$ (figure 2b).

$$\alpha = [(1-C^*)\alpha^* + (C^* - C)](1-C)^{-1}, \quad \beta = 1 . \quad (2)$$

For the flux updating equations, see Geleyn et al, 2007. The random scheme typically underestimates cloud cover, while the max-random scheme can overestimate it. We will investigate the potential improvement based on "interpolating" these two schemes, as described for example in Hogan and Illingworth, 2000. We introduce an interpolation parameter ϵ going from zero (random scheme) to one (max-random scheme). We call it the epsilon-max-random scheme. Such a scheme can be summarized schematically as: *a fraction ϵC overlaps maximally with C^*, while $(1-\epsilon)C$ is distributed randomly.* See figure 3 for a diagram. Such a method was already tested by C. Wittmann in the diagnostics of cloud cover (subroutine ACNPART). A value $\epsilon = 0.8$ was suggested there.

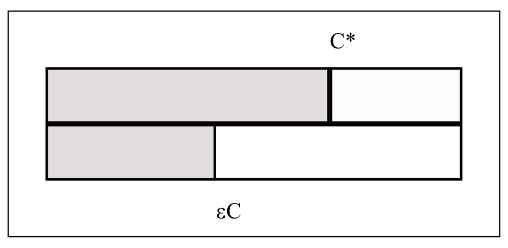

Figure 3: Cloud overlap in the "epsilon-max-random scheme". A fraction ϵC is overlapped maximally.

To implement the epsilon-max-random scheme in APLPHYS, we need new updating equations for α and β, and for the partial fluxes. These are presented in the next section.

Reorganising the precipitation fluxes with the new scheme

New updating of the geometric fractions:

$$\alpha = \frac{(\max(\epsilon C, C_*) - \epsilon C) + \alpha_* (1 - \max(\epsilon C, C_*))}{1 - \epsilon C},$$
$$\beta = \frac{C(1-\epsilon C)\left[C_* + \alpha_*(C - C_*)\right] + (1-C)\left[\min(\epsilon C, C_*)(1-\alpha_*) + \alpha_* C\right]}{C(1-\epsilon C)} .$$

For the updating of the partial fluxes, a test on the sign of $\epsilon C - C^*$ is now necessary:

1. $\epsilon C > C_*$. In this case, one has $\alpha = \alpha_*$.

$$F_{SE} = F^*_{SE} , \quad (3)$$
$$F_{SO} = \frac{C_*}{C\beta} F^*_{SO} + \frac{\alpha(C - C_*)}{\beta C} F^*_{SE} . \quad (4)$$

2. $\epsilon C < C_*$.

$$F_{SE} = \frac{\alpha_*(1-C_*)}{\alpha(1-\epsilon C)} F^*_{SE} + \frac{C_* - \epsilon C}{\alpha(1-\epsilon C)} F^*_{SO} , \quad (5)$$
$$F_{SO} = \frac{C_*}{\beta C} \frac{\epsilon C(1-C) + (1-\epsilon)CC_*}{(1-\epsilon C)C_*} F^*_{SO} + \frac{\alpha_*(1-\epsilon)(1-C_*)}{\beta(1-\epsilon C)} F^*_{SE} . \quad (6)$$

Also, in both cases one has $F_{RE} = F^*_{RE}$. The correct behaviour for $\epsilon = 0$ (random) and $\epsilon = 1$ (max-random) can be established, taking into account that one has $\beta = 1$ when $\epsilon = 1$ and $C < C_*$, and that $\alpha = \beta$ when $\epsilon = 0$. Also, one can check that the formulas above give the same results for the "crossing" case: imposing $C_* = \epsilon C$ and taking into account $\alpha = \alpha_*$ gives the required result. These equations have been implemented numerically in a new version of APLMPHYS, which we intend to test with the aim of optimizing ϵ.

Conclusions & References

Conclusions

We described a new cloud overlap scheme that interpolates between the random and max-random schemes, by means of a continuous parameter ϵ. We presented the necessary equations to implement this scheme in APLMPHYS.

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Contact:
joris.vandenbergh@meteo.be

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