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Prognostic Graupel & New Cloud Overlap Scheme in Alaro

Joris Van den Bergh
Royal Meteorological Institute, Belgium

Collaboration with J.-F. Geleyn and R. Brozkova, CHMI

- Introduction.
- Overview of APLMPHYS.
- Reimplementing Diagnostic Graupel.
- Implementing Prognostic Graupel.
- New Cloud Scheme.
- Future Work.
- Summary.

Introduction

Introduction

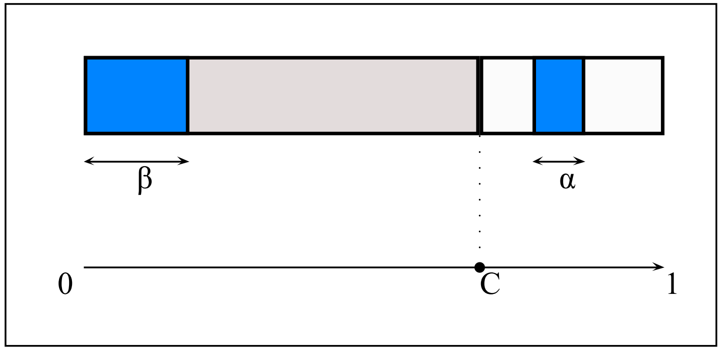
- We focus on the **APLMPHYS** subroutine.
  $\Rightarrow$ Computation of precipitation fluxes (rain and snow) at all model levels.
- We discuss implementation of new physics:
  - Change to the current diagnostic graupel.
  - Fully prognostic graupel.
  - New cloud overlap scheme.
- Implementation not restricted to only APLMPHYS (especially graupel)!

Overview of APLMPHYS

Principles and Assumptions

Overview of the principles and assumptions of APLMPHYS:

- Physical processes are mainly based on Lopez, 2001. Precipitation fluxes are calculated for each vertical level, starting from fluxes at previous level.
- 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. $0 < C < 1$, idem for α, β.



Principles and Assumptions

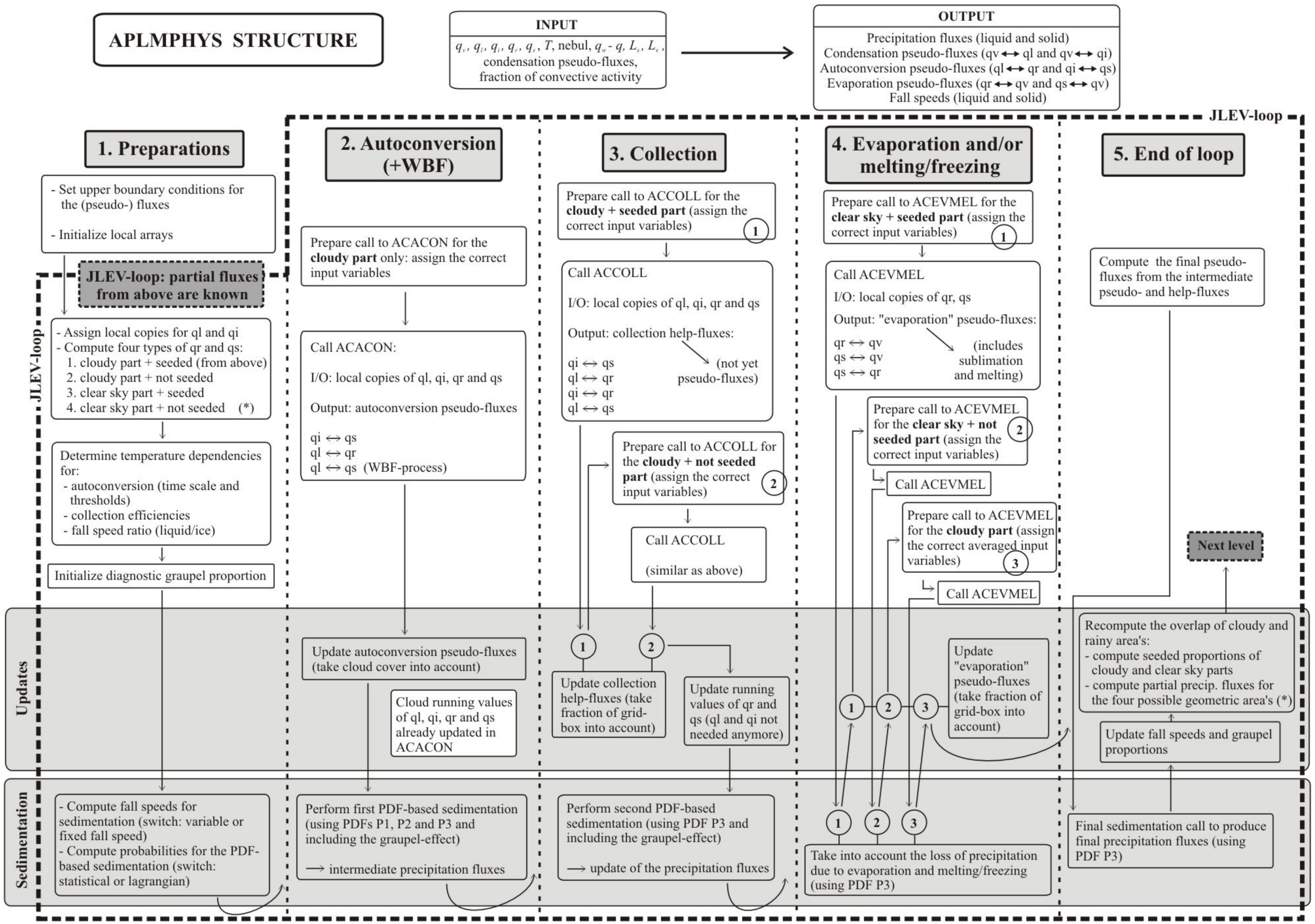
- Physical processes affecting the falling precipitation:
  - *Autoconversion (including WBF mechanism)*: ACACON. Called once, in the cloudy part.
  - *Collection*: ACCOLL. Called twice, in seeded & non-seeded cloudy parts separately.
  - *Evaporation/Sublimation & Freezing/Melting*: ACEVMEL. Called thrice, in seeded & non-seeded clear sky and averaged cloud. In the cloudy part, only freezing/melting takes place.
- Statistical sedimentation functions assumed identical in the four regions, saturation deficit $q_{\mathrm{sat}} - q$ 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.

Principles and Assumptions

- Statistical sedimentation:
  - Probabilistic treatment of fall speeds: unique advective fall speed replaced by PDF for speed $0 \rightarrow \infty$.
  - PDF is a decreasing exponential, so that origin of drops leaving a layer does not affect probabilities of reaching next layers.
  - Computation of sedimentation "transition" functions $P_{1/2/3}$ peformed for snow and rain (present in layer, coming from layer above, local production).
- The final computation in each layer is the *reorganisation step*, where fluxes are prepared for the next layer. 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.

Principles and Assumptions

Flowchart:



Options

Following options are available within APLMPHYS:

- Use of diagnostic graupel (LLPSGRP).
- Maximum or max-random cloud overlap (LLRNUMX).
- Statistical sedimentation (LLSTASED) or lagrangian advection (LLLAGSED).
- Variable hydrometeor fall speed proportional to precipitation flux (LLFSVAR) or constant fall speed (LLFSFIX).
  Variable fall speed $\Rightarrow \quad \bar{w} \sim (R/\rho^4)^{1/6}$.

Current Diagnostic Graupel

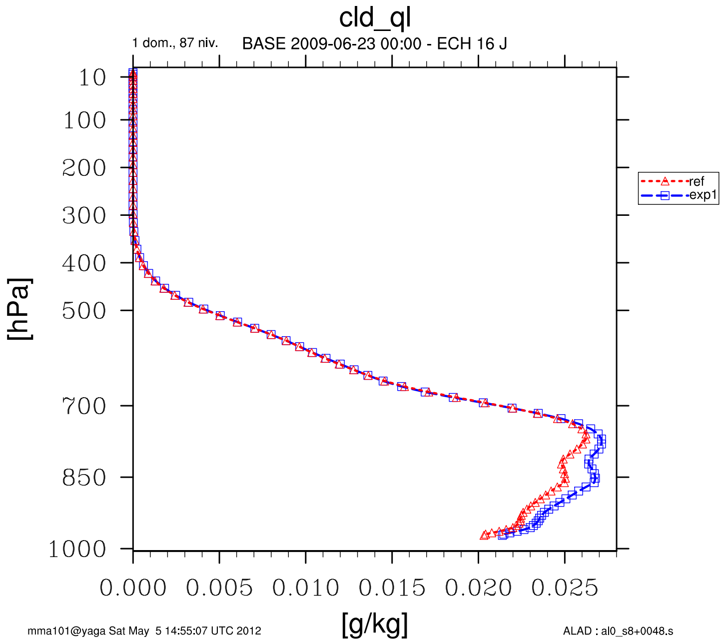
- Diagnostic graupel: synthesized as fraction r_g of total snow flux.
- Graupel fraction r_g exists within APLMPHYS only.
- Thermodynamic properties of snow, fall speed and collection efficiency of rain.
- Statistical sedimentation functions of rain.
- Graupel created by
  - Freezing rain.
  - WBF part of autoconversion.

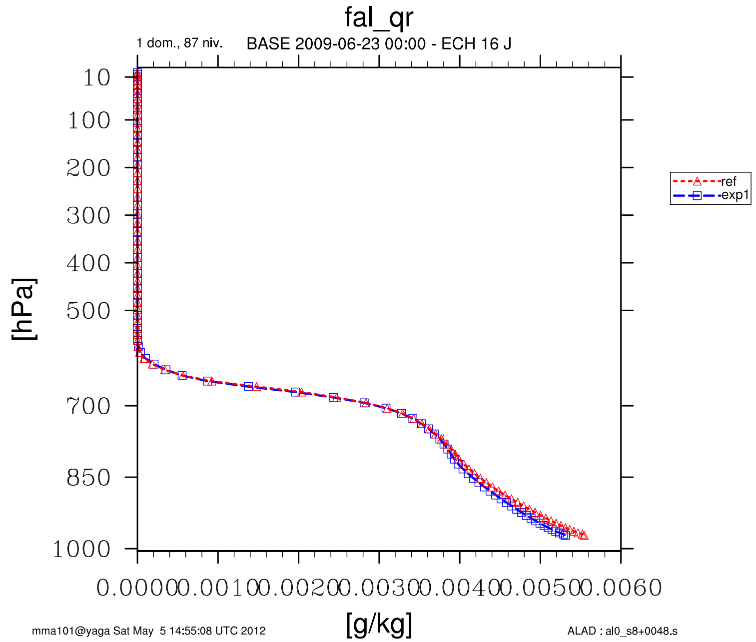
Reimplementing Diagnostic Graupel

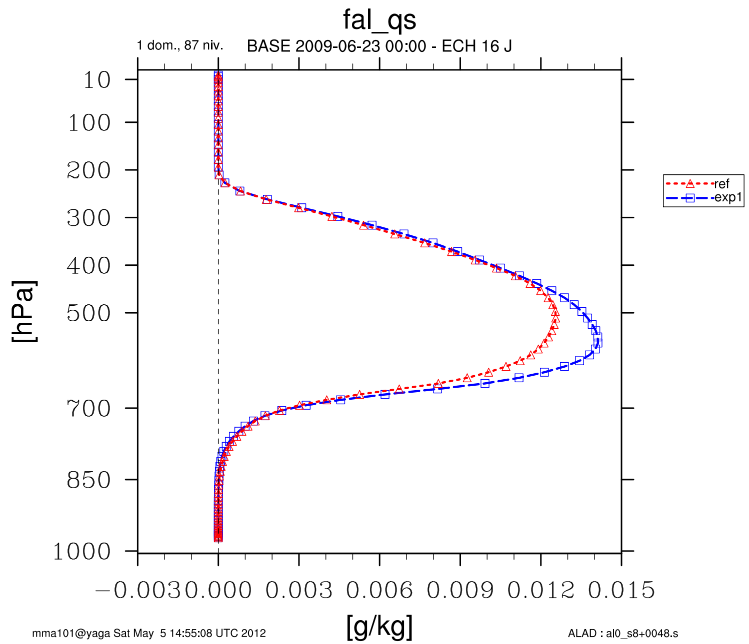
Reimplementing Diagnostic Graupel

- There is an error in the current version of APLMPHYS when diagnostic graupel is used with variable fall speed. This is because the statistical sedimentation functions used for graupel are those of rain. These are based on a fall speed taken proportional to the rain flux, which to zero when there is mainly snow and little rain.
  $\Rightarrow$ *Sedimentation of graupel too slow!*
- Solution: APLMPHYS was reimplemented with seperate statistical sedimentation functions for graupel. The proportionality factor relating fall speed to graupel flux is that of rain.
- Experimental results with the new version shown below: test over LACE domain (resolution 4.7km). Two parallel suites were run for 10 days during the very convective period of June 2009. Reference suite (AL0) has the pseudo-graupel switched on. Experiment (AL1) runs without pseudograupel. Averages of hydrometeors over the central European domain and over last 8 days are considered, at a forecast range of 48h.
- Results:
  - There is more suspended cloud water with graupel turned off. Without the graupel option, part of the precipitation falls slower, has more time to evaporate, and recreates more q_l by feedback.
  - There is more rain with graupel turned on and less snow. With graupel (higher fall speed than snow), there is depletion of snow, and more rain.

Experimental Results







Implementing Prognostic Graupel

Fully Prognostic Graupel

- We include graupel as third hydrometeor, on equal footing with snow and rain
  $\Rightarrow$ introduce q_g, P_g, . . .
- Physical processes: for now, the same as before. Graupel is created by WBF mechanism or as freezing rain. More processes between hydrometeors can/should be added in the future.
- Implented in APLMPHYS and its subroutines, APLPAR, also in CPTEND and CPTEND_NEW.
- Work to be done:
  - Changes to MF_PHYS.
  - Decisions to be made concerning code maintenance. "APLMPHYS with graupel" as new a version, or use of switches . . .

New Cloud Overlap Scheme

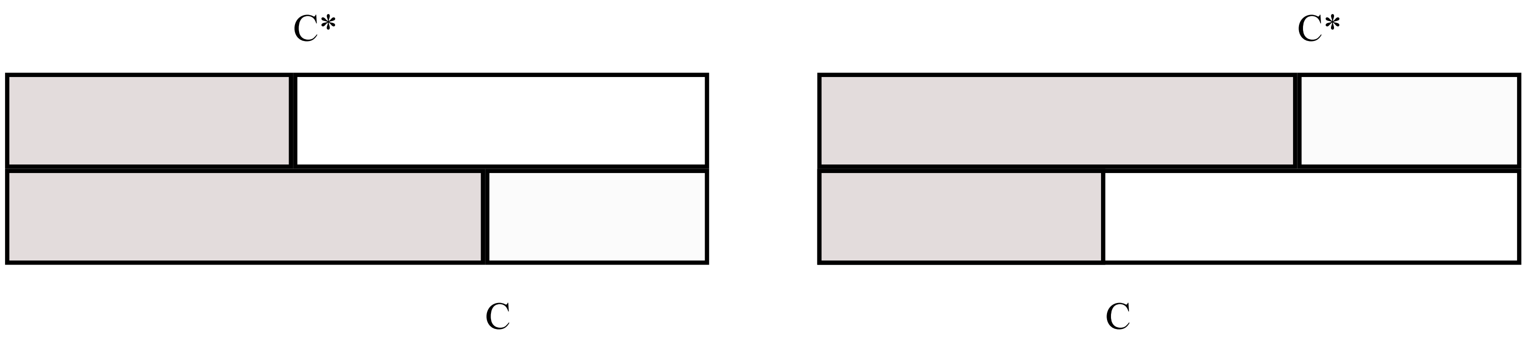
Cloud Overlap

We discuss the implementation of a new cloud overlap scheme.

- The total precipitation flux is given by a weighted sum of partial fluxes in the 4 geometric areas (cloudy/clear sky, seeded/non-seeded):

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

- Updating of $\alpha^*, \beta^* \to \alpha, \beta$ 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*.
- Example: maximum overlap $\Rightarrow$ two possible configurations:



- Current schemes in use (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 quite trivial (linear recombination).
- The case of max-random overlap is more complicated, with a dependence on the sign of $(C - C^*)$.

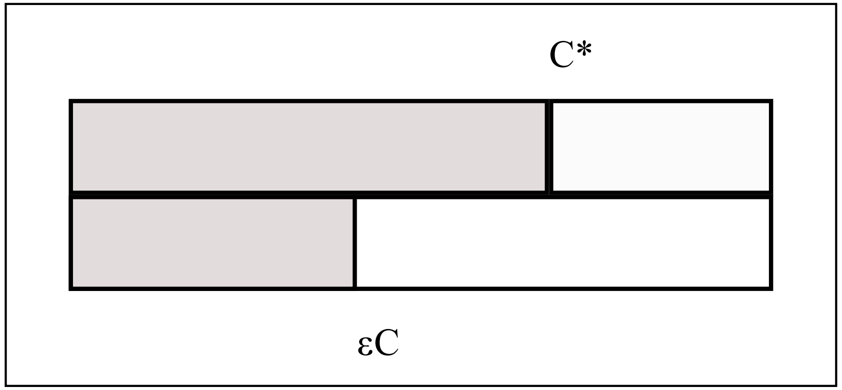
$$\alpha = \frac{[\max(C, C^*) - C + \alpha_*(1 - \max(C, C^*))]}{1 - C},$$

$$\beta = \frac{[\min(C, C^*)(1 - \alpha_*) + \alpha_* C]}{C}.$$

- Flux updating equations not shown here, see Geleyn et al, 2007.

New Cloud Scheme

- The random scheme typically overestimates cloud cover, while the max-random scheme can underestimate it.
- We hope to gain model improvement based on “interpolating" these two schemes, in analogy to the work of Hogan and Illingworth, 2000. We introduce an interpolation parameter ϵ going from zero (random scheme) to one (max-random scheme).
  $\Rightarrow$ New "**epsilon-max-random scheme**".
- Interpretation of the mathematics:
  A fraction ϵC overlaps maximally with C^*, while $(1-\epsilon)C$ is distributed randomly.
- Cfr. implementation by C. Wittmann in the diagnostics of cloud cover (subroutine ACNPART) $\Rightarrow$ $\epsilon \sim 0.8$.



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

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

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

New Cloud Scheme

- To implement the epsilon-max-random scheme in APLPHYS, we need new updating equations for α and β, and for the partial fluxes.
-
$$\alpha = \frac{(\max(\epsilon C, C_*) - \epsilon C) + \alpha_* (1 - \max(\epsilon C, C_*))}{1 - \epsilon C},$$
$$\beta = \frac{(1-\epsilon)C) [C_* + \alpha_*(C - C_*)] + (1 - C) [\min(\epsilon C, C_*)(1 - \alpha_*) + \alpha_* C]}{C(1 - \epsilon C)}.$$
- Equations for updating the partial fluxes were also obtained (not shown). These are also different! A test on the sign of $(\epsilon C - C^*)$ is now necessary.
- The equations have been implemented numerically in a new version of APLMPHYS.

- Optimal value of ϵ for model performance: validation tests in progress.

Future Work

Work in progress and plans for the future:

- Graupel
  - Validation, test impact of introduction prognostic graupel.
  - Introduction of new processes between hydrometeors (cfr. ICE-3, MESO-NH).
- Clouds
  - Optimisation of interpolation parameter ϵ.
  - Investigate correspondence of ϵ to decorrelation length (Shonk et al), related to vertical layer separation distance.
  - Triple Clouds, . . .

Summary

- We described a new cloud overlap scheme that interpolates between the random and max-random schemes, by means of a continuous parameter ϵ. We have implemented the equations to update the geometric fractions and reorganise the partial fluxes when going from one layer to the next. Validation tests are in progress.
- We reimplemented the current diagnostic graupel scheme in APLMPHYS, to correct an error that shows up when the variable fall speed option is used.
- We have also implemented fully prognostic graupel versions of APLMPHYS and its subroutines, and CPTEND. This should replace the diagnostic graupel option in the near future. Some questions remain concerning code management.