Documentation on

Cloudiness under its *n* shapes

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1. INTRODUCTION

Under the complex APLPAR sequence, which is imposed by the nature of the different processes, cloudiness in ALARO-0 is required for:

a) radiation, through subroutine ACRANEB, which uses total cloudiness as input, as well as the values of cloud liquid and ice contents;

b) turbulent vertical diffusion, in subroutine ACDIFUS, in case of prognostic cloud liquid and ice contents and uses the moist-conservative framework. In this case, a specific value for cloudiness is required.

c) evaporation/condensation, managed in routine ACCDEV;

d) microphysical processes, handled in subroutine APLMPHYS, in which cloudiness is required as a function of chosen options.

The computation of cloudiness is done in routines ACNEBCOND, ACNEBN for the case of stratiform and total values, respectively. Convective cloudiness is handled after the updraft parameterization, which is treated in ACCUVD.

Figure 1 shows the basic aspects of the flow scheme of information concerning the cloudiness issue under ALARO-0, both its computation and its use. An overview of the methods used for the computation of the cloud cover, as well the code structure and information flow will be given below.

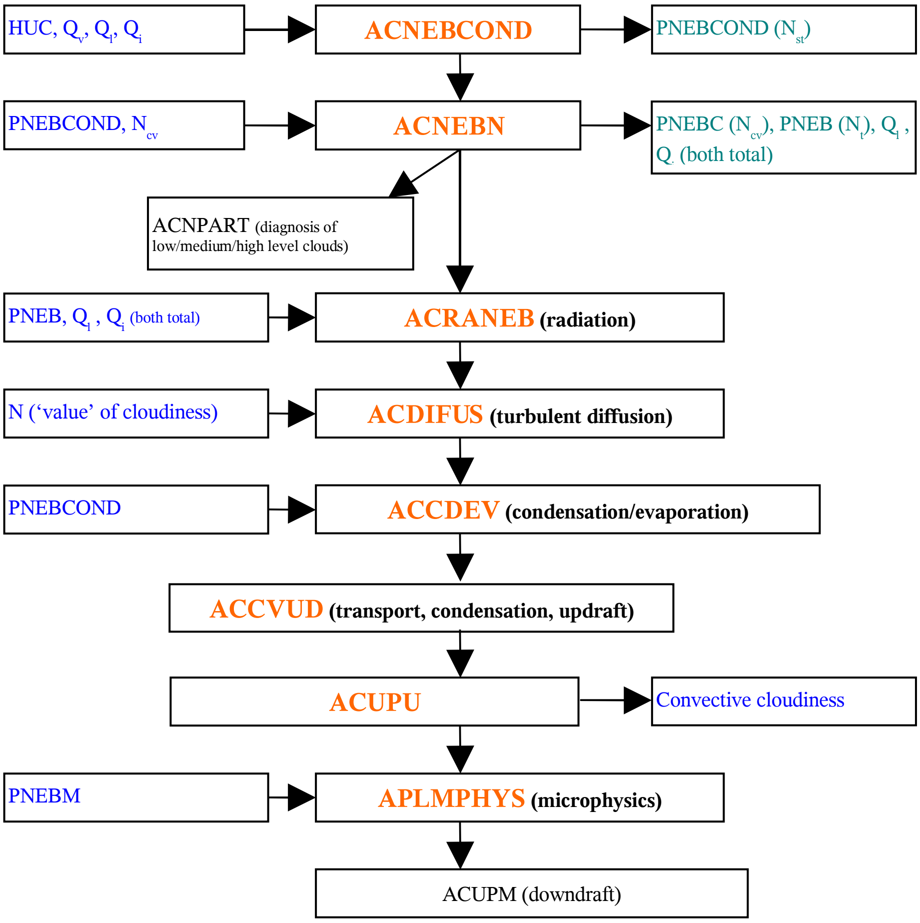

Figure 1 – Extract of the APLPAR sequence, showing where cloudiness is used or computed.

2. CLOUDINESS COMPUTATION ROUTINES

The cloudiness computation is done in routines ACNEBCOND and ACNEBN. The first routine computes the stratiform cloudiness, while the second combines it with the convective one, from the previous time-step. For each routine, its purpose and the main computations will be briefly enumerated. Finally, the main input/output variables are also provided, but notice that the ones considered are related to the issue of cloudiness, therefore disregarding any others.

2.1 Routine ACNEBCOND

Objective:

Computation of the stratiform cloudiness and the specific humidity for saturation.

Main input/output variables:

Table 1 - Main input variables of routine ACNEBCOND.

Code Name	Variable
PT	Temperature
PQW	Equilibrium water in case of exact saturation
PQ	Specific humidity of vapour
PQL	Specific humidity of suspended liquid
PQI	specific humidity of suspended ice

Table 2 - Main output variables of routine ACNEBCOND.

Code Name	Variable
PNEBCOND	Stratiform cloudiness
PHCRICS	Critical relative humidity profile for the resolution
PRMF	Fraction of ice
PQSATS	Specific humidity of saturation

Main computations within routine:

1. Computation of the fraction of ice;
2. Computation of the PHCRICS, as a function of the mesh-size;
3. The computation of the cloudiness can be done using two methods:
   a) Xu-Randall modified scheme, if LXRCDEV=.TRUE.;
   b) Smith-Gerard scheme, if LSMGCDEF=.TRUE.

For further details on the methods for computing cloudiness, see specific documentation [1].

2.2 **Routine ACNEBN**

Objective:

Combining the stratiform and convective cloud covers.

Main input/output variables:

Table 3 - Main input variables of routine ACNEBN.

Code Name	Variable
PFPLC	Convective precipitation flux
PQSAT	Specific humidity of saturation
PHUC	Critical relative humidity profile
PQ	Specific humidity of vapour
PQL	Specific humidity of suspended liquid
PQI	Specific humidity of suspended ice
PNEBS	Stratiform cloudiness
PQLIS	Stratiform condensate

Table 4 - Main output variables of routine ACNEBN.

Code Name	Variable
PNEB	Total cloudiness for radiation
PNEBC	Convective cloudiness for radiation
PQICE	Total specific humidity of suspended ice, for radiation
PQLI	Total specific humidity of suspended liquid, for radiation

Main computations within routine:

1. Checks whether there is an inversion. In case there is, the temperature at the end of the layer is decreased, reinforcing it. Consequently, an updated profile of temperature and water vapour is derived. This computation allows better forecasts of low level clouds during inversion events;
2. Computation of the stratiform condensate, as a function of the total water content (using the updated profile for vapour to account for step 1), the specific humidity of saturation and an empirical function tuned from observations;
3. Computation of the convective condensate, using the convective cloudiness of the previous time-step.
    - Under the 3MT option, the Xu-Randall formula is inverted to allow the computation of the total convective condensate from the convective cloudiness.
    - If not 3MT, then the convective condensate is computed from convective precipitation flux.
4. Computation of the full condensate as a sum of the individual ones;
5. Computation of the full cloudiness, by the Xu-Randall formula, via routine ACNEBXRS;
6. The convective cloud cover for radiation is diagnosed as being proportional to convective condensate when compared to the total one, times the full cloud cover.

The ouputs from ACNEBN are the inputs for the routine ACRANEB. Similarly, they are also the input for routine ACNPART, which diagnoses the low, medium and high cloud covers, as well as the convective one.

3. ROUTINES REQUIRING CLOUDINESS INPUT

3.1 **Routine ACRANEB**

This routine handles the radiation computations, so the main inputs for this routine are the total cloudiness (PNEB) and ice (PQICE) and liquid total (PQLI) specific humidity, computed in ACNEBN.

3.2 Routine ACDIFUS

Routine ACDIFUS handles the vertical turbulent diffusion. In case one has prognostic liquid and ice contents and uses the moist-conservative variables (LDIFCONS=.TRUE.), the vertical transport is done using the dry static energy and the moist equivalent dry static energy. A value for cloudiness is then necessary to go back to values of the individual water species. An unclear issue is whether the cloudiness used here should be the stratiform or the full cloud cover.

Estimating the vertical turbulent diffusion of the condensates in routine ACDIFUS requires a cloud fraction variable called *fdiff*, which can take the values described in table 5.

Table 5 - Cloudiness values for input in ACDIFUS.

fdiff Value	Comment
0	No input for cloudiness is used
1	Cloudiness is taken as being the stratiform one
2	Cloudiness is taken as the total one

Due to problems arising when cloudiness is provided, for now, the value is set to 0.

3.3 **Routine ACCDEV**

Routine ACCDEV computes the resolved condensation/evaporation fluxes and the cloudiness is actually needed in the computation if done under the ‘ACPLUIE_PROG’ scheme (LXRCDEV=.TRUE.). In case one considers the Smith-Gerard scheme (LSMGCDEV=.TRUE.) one uses the cloudiness indirectly, via the water species. For further details concerning this routine, please refer to [2].

Table 6 - Cloudiness values for input in ACDDEV.

Code Name	Variable
PQSATS	Specific humidity of saturation
PRMF	Fonice Function
PQ	Specific humidity of vapour
PQL	Specific humidity of suspended liquid
PQI	Specific humidity of suspended ice
PNEBCOND	Stratiform cloudiness

3.4 **Routine APLMPHYS**

Routine APLMPHYS computes the precipitation fluxes for water and snow and the linked pseudo-fluxes (condensation, auto-conversion, evaporation).
In microphysics cloudiness is required to describe the effects of its geometry in precipitation fluxes and non-linearities of microphysical processes. Two options to describe cloud geometry are allowed: random cloud overlap (LRNUMX=.FALSE.) or maximum overlap of adjacent clouds and random overlap of clear air separated parts (LRNUMX=.TRUE.).
If one considers LSTRAPRO=.TRUE., the APLMPHYS routine is called from ACCDEV and uses the stratiform cloudiness as input. If running under 3MT, it is called from APLPAR and the cloudiness must be a combination of the stratiform one plus some information from the convective part. Further details can be obtained in [3].

4. PSEUDO-HISTORIC CONVECTIVE CLOUDINESS

Unlike the stratiform cloudiness, the convective one is computed later in the APLPAR sequence and is kept for use in the computation of the total cloudiness in the following time step. The routines that allow the computation of the convective cloudiness are the ACCVUD (handling the updraft) and the ACUPU (updating internal state after updraft).
Figure 2 presents a scheme of the grid box sub-areas assumed in the convection parameterization (adapted from Gerard [4]).

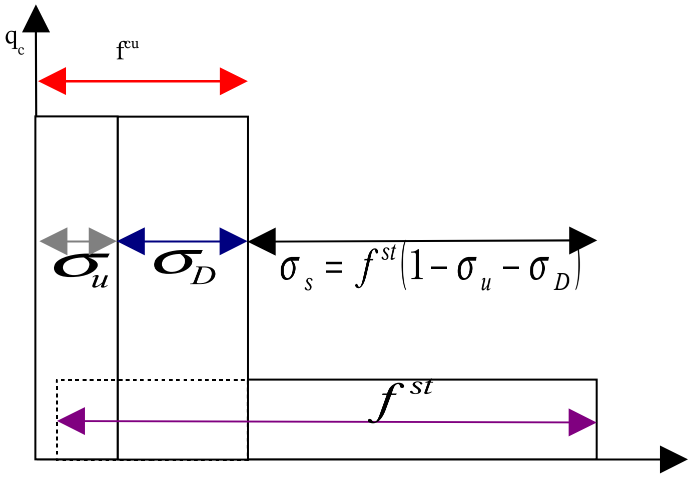

Figure 2 – Grid box sub-areas (adapted from Gerard [4]).

In 3MT, after routine ACUPU, the pseudo-historic convective cloud fraction is stored in variable PUNEBH, as given in (1).

$$\text{PUNEBH}=\sigma_u+\sigma_D \qquad (1)$$

σ_u and σ_D stand for the fraction of the grid box occupied by the updraft area (computed in ACCVUD) and the detrainment material (from ACUPU), respectively.
The convective (f^{cu}) and the stratiform (f^{st}) cloud cover can overlap and the total cloud cover assumed in further computations is given by $f=f^{cu}+f^{st}-f^{cu}f^{st}$. The resolved condensate, that is, the stratiform one, is assumed to be homogeneously distributed over the whole fraction f^{st} , so that a part of it contributes to the condensates in the convective area.
The distribution of the condensate over the grid box is a problem. If one considers it to be evenly distributed than the total precipitation will be smoothed, as the convective maximum will not be

taken into account. On the other hand, if the condensate is considered to be mainly in the convective area, spots may arise in the forecast field.

The presented discussion is very effective in recalling a problem that arises when combining the stratiform with the convective cloudiness. Indeed, when computing the stratiform cloud cover, the values of the water species are assumed to be representative of the ‘resolved’ part only, but in fact they already have some information on the convective processes.

REFERENCES

[1] Wittmann, C., *ACNEBCOND documentation*, March 2007, www.rclace.eu;

[2] Wittmann, C., *ACCDEV documentation*, March 2007, www.rclace.eu;

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ADDITIONAL LITERATURE

[5] Geleyn, J.F., *Some basic ideas about cloudiness in ALARO-0*, February 2007, personal documentation;

[6] Geleyn, J.F., *Algorithmic sequences in APLPAR, associated variables’ evolutions for the two basic versions of ALARO-0*, February 2007, www.rclace.eu;

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