Report on

Cloudiness under its *n* shapes

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1. INTRODUCTION

The APLPAR sequence is a parallel physics system, so that the updated fluxes and tendencies for enthalpy and kinetic energy, after the physical package, are the sum of the different values computed in each process. However, a cascading system was developed, in which an update of the moisture prognostic variables between parameterizations is made.

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 in itself is done in routines ACNEBCOND, ACNEBN for the case of stratiform and total values. 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. In each routine, the most important input and output variables are mentioned.

In the work developed at CHMI, a new routine was developed – named ACCDEVM. The objective of this new routine is to provide an alternative way of computing the total cloud cover, from the stratiform and convective cloudiness. Accordingly, the new code can, at a first stage, replace ACNEBN in the APLPAR sequence, in the computation of the total cloud cover.

The goal of the work was to address a feasible and physically sound way of combining the stratiform and convective cloudiness. The main inputs for the new routine are:

a) Temperature, vapour (q_v), liquid (q_l) and ice (q_i) contents, as well as the stratiform cloudiness, computed previously in ACNEBCOND;
b) in the case of 3MT, the convective cloudiness of the previous time step is available in the variable PUNEBH; otherwise the convective cloudiness must be computed.

The outputs that the new routine must provide to the code are the total cloudiness as well as the total quantities of the liquid and ice mass species to use as an input to radiation (ACRANEB).

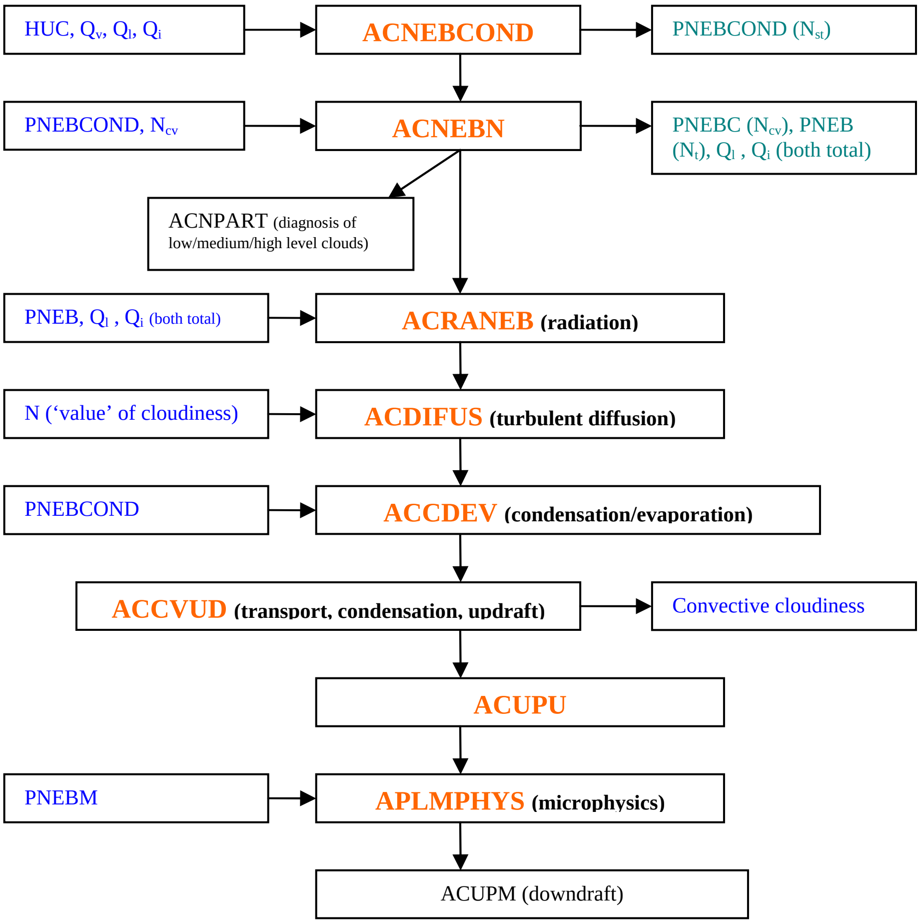

Fig. 1 – Extract of the APLPAR sequence, showing where cloudiness is used or computed.

2. CLOUDINESS COMPUTATION

2.1 Xu-Randall Modified Scheme

Taking into account the approximation to the Xu-Randall modified formula (1), which finds an equilibrium point for stratiform condensation-evaporation of prognostic cloud cover:

$$N = \left(\frac{q_v}{q_w}\right)^r \frac{\alpha q_c}{\alpha q_c + (q_w - q_v)^\delta} \qquad (1)$$

where q_v stands for the vapour specie, q_c is the total condensate (sum of the liquid and ice species) and q_w is the saturation (different from the q_{sat} due to the release of latent heat when condensation occurs). The algorithm has one and one solution only and the problem is simplified if the constants r and δ are taken to be, respectively, 0.25 and 0.5. Finally, α is of the order of 100 and is the only tuneable parameter, once the vertical critical profile HUC is known.

Noticing that one has to fulfil conditions (2) and (3)

$$q_v = q_w\left(HU\left(1-N\right)+N\right) \quad (2)$$

$$q_c = q_t - q_v \quad (3)$$

where N is the cloudiness and q_t is the total moisture and by using the following change of variables, given by equations 4 to 7,

$$d_c = 1 - HU \quad (4)$$

$$x_{ref} = \frac{q_t}{q_w} - HU \quad (5)$$

$$A = \frac{\left(q_w d_c\right)^{\delta}}{\alpha q_w} \quad (6)$$

$$s = \frac{1}{1-N} \quad (7)$$

one gets equation 8,

$$x_{ref} = x(s) = d_c\left(1-\frac{1}{s}\right)\left(1+\frac{A}{d_c s^{\delta}}\left[\frac{1}{\left(1-\frac{d_c}{s}\right)^{r} - \left(1-\frac{1}{s}\right)}\right]\right) \quad (8)$$

The problem is then solved by a Newton loop in the variable *s* and the cloudiness is finally computed by inverting equation 7.

2.2 Combining stratiform and convective cloudiness

Two ways of combining the stratiform and convective cloudiness were studied in this work. The first one is based on an idea around the critical profile (HUC), which provides a saturation value, above which clouds appear. The critical profile is computed in ACNEBCOND and is a function of the grid mesh size. The computation of stratiform cloudiness is also done in the same routine by the modified Xu-Randall scheme described in a).

In the case of non existence of convective cloudiness, the total cloudiness is given by the value of the stratiform one. Identically, in case of non existence of stratiform cloudiness, the total cloudiness would be the convective one. The problem arises with non zero stratiform and convective cloudiness occurrence. In this case, the idea analysed was to compute a new critical profile.

From the convective cloudiness, s and x_{ref} could be computed by applying, respectively, equations 7 and 8. Assuming that the q_t and q_w at a given grid point remain valid for both stratiform and condensation cloudiness, a convective critical profile could then be computed. By mathematical manipulation (*e.g.* tanh) a new critical profile could be computed, hence allowing the calculation of the total cloudiness by the Newton Loop. Afterwards, the updated mass species could be computed easily by applying equations 2, 3 and the fonice function.

Although this procedure seemed feasible, unfortunately after some testing it was noticed that it would not work adequately in all the domain of cloudiness input. Indeed, if the values of both types of cloudiness were similar, one would compute adequate critical profiles; on the other hand, if the cloudiness were quite different (e.g. $N_{st} = 0.2$ and N_{cv} =0.6), the critical profile would be either negative or above one, hence unacceptable values.

The second way of combining is based on the variable x_{ref}, of equation 5 and two ideas were proposed:

1. For both the stratiform and convective cloudiness, one can compute the variable x_{ref} from equation 8 and obtain values representative of each one of the cloud types. Even though the stratiform cloudiness and cloud species have already information on convective processes, one can assume valid the hypothesis of simply adding the two x_{ref}. Applying the Xu-Randall modified scheme, the computation of the full cloudiness can be done, under the assumption that the critical vertical profile is valid. The computation of the full condensate can be done using equations 2 and 3. Finally, the fonice function allows the separation of the condensates between ice and liquid.

2. The second idea starts again from the computation of the stratiform x_{ref}, from N_{st}. In this case, if the convective cloudiness is zero than the full cloudiness is simply the stratiform one. Moreover, if the convective cloudiness is one, so is the total cloudiness. The idea that arises is that the full cloudiness can be regarded as vary from N_{st} to 1, as a function of the convective cloud cover. The application of this idea then requires the computation of x_{ref} in the case $N_{st} = 1$, keeping *HUC* and q_w constant. Then, the total x_{ref} ($x_{ref-total}$) is given by equation 9,

$$x_{ref-total} = x_{ref} + \left(x_{ref(1)} - x_{ref}\right)N_{cv} \qquad (9)$$

where x_{ref} and $x_{ref(1)}$ stand, respectively, for the x_{ref} computed for the actual and full stratiform cloudiness. The computation of the water species follow the procedure mentioned above.

3. CODING ROUTINE ACCDEVM

The new routine was made by using several pieces of code from routines ACNEBCOND and ACNEBN and by coding the combination of the stratiform and convective cloudiness as mentioned in 2. The routine performs the following computations:

a) Determines whether there is an inversion and in case there is, it changes the profile of temperature; this is a method used to minimize the fact that low clouds are poorly forecasted, as it acts as to enhance the depth of the temperature inversion by lowering the temperature at the bottom of the layer and increasing the vapour content; the outcome of this procedure is a new temperature (t^*) and vapour content (q_v^*);

b) Call to routine ACTQSAT to compute the updated q_w^*, as a function of the t^* and q_v^*;

c) In case of 3MT, the convective cloudiness from the previous step is available directly by the pseudo-historical variable PUNEBH; otherwise the convective condensate has to be computed from the precipitation flux. The computation of the convective cloudiness is done by the Xu-Randall Scheme, in routine ACNEBXRS;

d) The stratiform and convective cloudiness are combined by the procedures mentioned previously and the total cloudiness is computed. Finally, one gets the updated values of the condensates.

4. RESULTS AND REMARKS

During the stay at CHMI, the code was (apparently) successfully debugged, but unfortunately only the first proposed idea was tested due to the lack of time. Likewise, it was only possible to make forecasts plots for one day.

The initial/boundary files used were from the 12 UTC run from April 4th 2007 and the forecast length was 12 hours. Figures 2 and 3 show the 12 hours forecast plots for diagnosed high, medium and low level cloud cover, respectively from top to bottom.

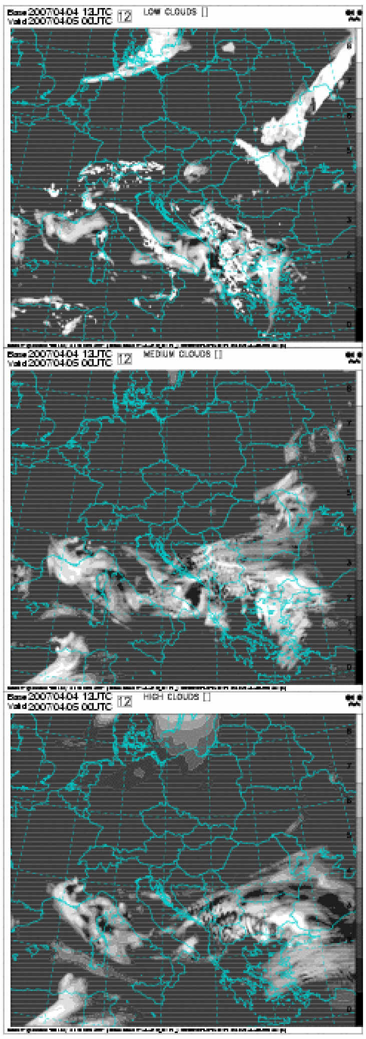

Fig. 2 – Cloud cover forecast (H+12), using ACCDEVM.

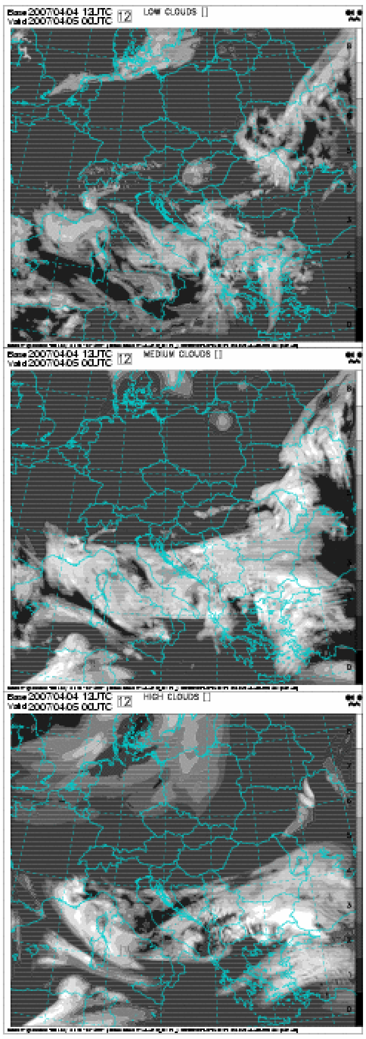

Fig. 3 – Cloud cover forecast (H+12), using the regular APLPAR sequence.

For comparison, figure 4 shows the infrared satellite image taken at 00:42 UTC April 5th, by NOAA 18. The cloud cover forecast from ALARO-0 has a very good resemblance with the observed field. On the other hand, when considering the forecast using the new routine one notices that it has a very strong contrast, particularly at the

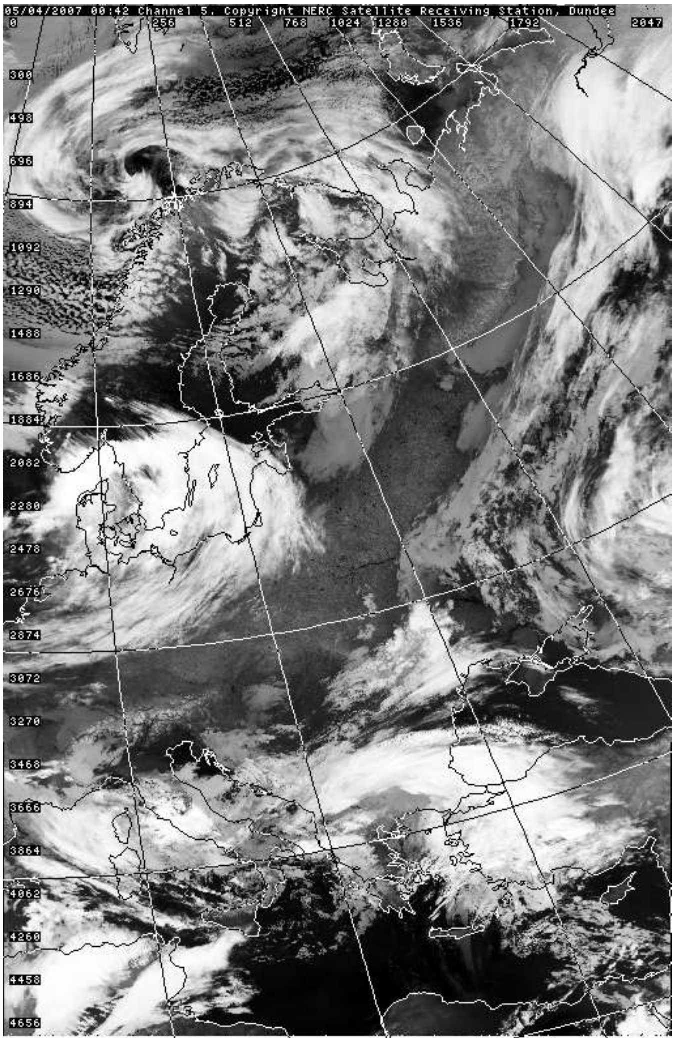

Fig. 4 – Infrared satellite image from 00:42 UTC, April 5th 2007
(Dundee Satellite Receiving Station).

lowest levels, which is clearly unrealistic. At any level, the new routine produces a smaller amount of clouds than it should, even though the pattern is correct. Even though the figure is not shown, in case one removes the convective clouds and considers only the stratiform x_{ref} , the remarks made previously remain valid as well. Therefore, it seems that the excessive contrast does not arise from the convective part but is a feature of the stratiform cloudiness computation.

The analysis of the output of the model also provides very useful statistics, which are presented in tables 1 to 4, respectively for the regular APLPAR sequence and for the one using the new routine ACCDEVM. Tables 1 and 2 show the average grid point norms for the cloud water species q_l (liquid), q_i (ice), q_r (rain) and q_s (snow). Tables 3 and 4 show the grid point norms for the cloudiness fields and radiation.

Table 1 – Grid point norms for mass species,
with the regular APLPAR sequence (H+12).

Field	Average	Minimum	Maximum
q_l ($kgkg^{-1}$)	0.100e-4	-0.216e-4	0.966e-2
q_i ($kgkg^{-1}$)	0.437e-5	-0.776e-5	0.336e-2
q_s ($kgkg^{-1}$)	0.141e-4	-0.132e-4	0.834e-2
q_r ($kgkg^{-1}$)	0.206e-5	-0.123e-4	0.256e-2

Table 2 – Grid point norms for mass species in the APLPAR sequence,
with the new ACCDEVM routine (H+12).

Field	Average	Minimum	Maximum
q_l ($kgkg^{-1}$)	0.102e-4	-0.168e-4	0.969e-2
q_i ($kgkg^{-1}$)	0.436e-5	-0.507e-5	0.333e-2
q_s ($kgkg^{-1}$)	0.138e-4	-0.164e-4	0.816e-2
q_r ($kgkg^{-1}$)	0.207e-5	-0.136e-4	0.255e-2

Table 3 – Grid point norms for cloudiness and radiation fields,
for the regular APLPAR sequence (H+12).

Field	Average	Maximum
Total cloudiness	0.405	0.998
Convective cloudiness	0.786e-2	0.406
High cloud cover	0.222	0.998
Medium cloud cover	0.241	0.992
Low cloud cover	0.163	0.911
Top solar radiation (Wm^{-2})	0.709	---
Surface solar radiation (Wm^{-2})	0.486	---
Top thermal radiation (Wm^{-2})	-0.908	---
Surface thermal radiation (Wm^{-2})	-0.303	---

Table 4 – Grid point norms for cloudiness and radiation fields,
for the APLPAR sequence with the new ACCDEVM routine (H+12).

Field	Average	Maximum
Total cloudiness	0.248	0.999
Convective cloudiness	0.107e-1	0.906
High cloud cover	0.113	0.969
Medium cloud cover	0.118	0.994
Low cloud cover	0.122	0.999
Top solar radiation (Wm^{-2})	0.791	---
Surface solar radiation (Wm^{-2})	0.588	---
Top thermal radiation (Wm^{-2})	-0.957	---
Surface thermal radiation (Wm^{-2})	-0.360	---

The analysis of tables 1 to 4, suggest the following:

a) The average amount of total cloudiness computed with the new routine decreases by 40%; in the medium and upper levels the decrease is around 50% and only 25% at the lowest levels;

b) However, although the decrease is smaller in the lowest levels, in fact this is where the forecast is actually worse. The reason for this number is due to the extremely high values of cloudiness where the model forecasts it. However there are extensive areas where it should produce clouds and it does not;

c) The maximum value of cloud cover is always higher when using the new routine;

d) the computation of the convective cloudiness is producing extremely high values, when convection exits. Indeed, the maximum value when using the regular cycle is 0.406, but with the ACCDEVM this figure is doubled;

e) As the new cloud output goes directly into ACRANEB, radiation values also differ. In the case of the solar radiation at the surface, the values are 21% higher than using the new routine, when compared with the regular cycle.

5. FUTURE WORK

Even though the routine was successfully debugged, so that the model runs, something must be incorrect in the computation of the convective cloud cover. Even with this eventual bug corrected, it seems clear that it is not the cause for the excessive contrast between areas with and without clouds. As the values of the water species are not much different in both, one may think that the problem may arise from the critical vertical profile being used.

After this issue has been addressed, work can proceed to the coding/debugging of the second idea for the computation of the total cloudiness. Once the fields seem correct, validation must be made to study the impact of this new computation.

Further Reading

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

[2] Geleyn, J.F., *Algorithmic sequences in APLPAR, associated variables' evolutions for the two basic versions of ALARO-0*, February 2007;

[3] Geleyn, J.F. and R. Brozkova, *Basic ideas about the use of a Xu-Randall modified formula to find an equilibrium point for stratiform condensation-evaporation of prognostic cloud water*, March, 2007;