Preliminary results with FB's

Eric Bazile[1]
Météo-France/CNRM

1. INTRODUCTION

In July 1997, J.F. Geleyn et al. (personal communication) have proposed a modular approach for the link between precipitation, prognostic liquid/ice water and cloud cover: the so-called "Functional Boxes". The aim of this proposal is to merge the ideas of [RK98], the relationship for the cloudiness proposed by [XR96] or [WF00] and the dynamics/physics interface of ARPEGE and HIRLAM. Two constraints are necessary for the success of this story: firstly the system should be able to run with a sequential approach for the physics (HIRLAM) or a parallel one (ARPEGE), secondly all the boxes could be shared or exchanged transparently with the HIRLAM code.

2. SHORT DESCRIPTION

Starting from the general equation of ARPEGE for the temperature, q_v, q_l, q_i described in [Baz95] and the microphysics processes we want to parametrize in the system, we can write the following set of equations:

$$\frac{\partial q_v}{\partial t} = A_{q_v} - g\frac{\partial(F_{q_v}^{turb} + F_{q_v}^{conv})}{\partial P} + E - CE$$

$$\frac{\partial q_l}{\partial t} = A_{q_l} - g\frac{\partial(F_{q_l}^{turb} + F_{q_l}^{conv})}{\partial P} + CE_l - AC_l + MF_c$$

$$\frac{\partial q_i}{\partial t} = A_{q_i} - g\frac{\partial(F_{q_i}^{turb} + F_{q_i}^{conv})}{\partial P} + CE_i - AC_i - MF_c$$

with $E = E_l + E_i$: evaporation of falling precipitation, $CE_{l/i}$: cloud condensation, $AC_{l/i}$: auto conversion, $MF = MF_c + MF_p$: melting-freezing in clouds + melting-freezing of falling precipitations.

After a bit of algebra, we obtain five equations for the five unknowns variables q_v^+, q_{sat}^+, q_c^+, f^+ (f=cloud cover) and W=CE-E:

$$\frac{\partial q_v}{\partial t} = M + fN - W$$

$$\frac{\partial q_c}{\partial t} = R + E - AC + W$$

$$\frac{\partial q_{sat}}{\partial t} = N - \alpha S + \alpha\beta W$$

[1] *Corresponding author address*: E. Bazile Météo-France, CNRM/GMAP 42 Av. Coriolis, 31057 Toulouse Cédex, France tel : (33) (0)5 61 07 84 68 - fax : (33) (0)5 61 07 84 53 email: eric.bazile@meteo.fr

$$W = CE_{conv} - E + \frac{1}{1+f\alpha\beta}(f(M + f\alpha S) + \frac{\partial f}{\partial t}\frac{q_c}{f})$$

f = cloud cover formulation from XR or WF.

M,N,R are the forcing terms provided by the dynamic and the rest of the physical parameterizations. $\alpha = \frac{\partial q_{sat}}{\partial T}$, $\beta = \frac{\rho(T)L_v + (1-\rho(T))L_s}{C_p}$ with $\rho(T)$ is the partition function for liquid and ice, and

$$S = \frac{g}{C_p}\frac{\partial T}{\partial P}(P_l(C_l - C_{pd}) + P_i(C_l - C_{pd})) + \frac{L_f}{C_p}(MF - E_l(1-\rho(T)) - E_i\rho(T))$$

The system have to be solved in W with an newton algorithm. The main problem is to be sure that the algorithm always provides a physical solution, but also not generates numerical instability.

3. TIME DISCRETISATION FOR W

The way to discretize in time F(W) is very important and can provide pessimistic conclusion for the XR cloud cover formulae (Fig: 1). The first version (described below) is very unstable for the XR cloud cover formulae but when we go to more "implicit" approach for F(W) the stability is clearly improved. So, we really need to be very attentive to the discretisation in the boxes !

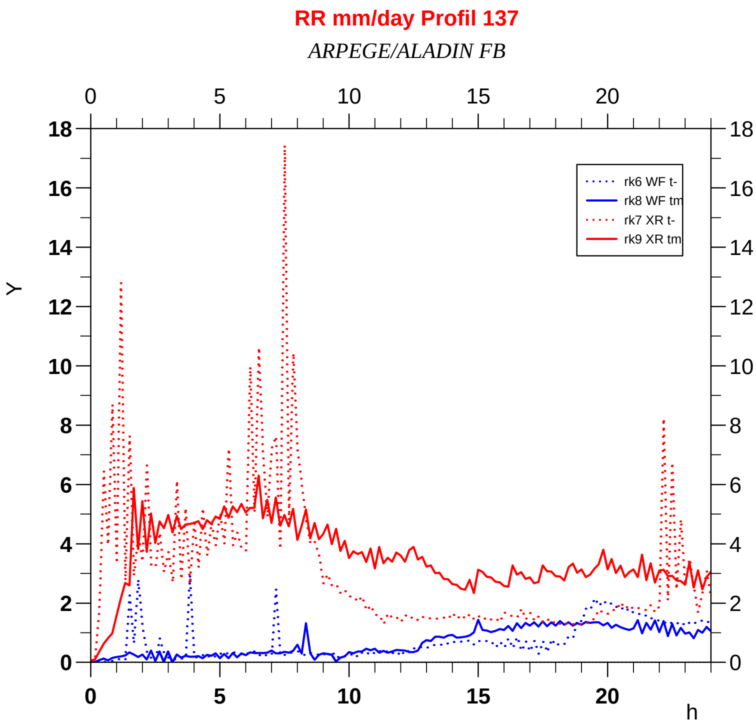

Figure 1: Time evolution of the precipitation in 1D model with the two cloud cover formulae XR (gray) and WF (black), dotted line the first version of the discretisation, full line: middle point for the time discretisation

<u>Time discretisation v1:</u>

$$F(W) = (1 + f^m\alpha\beta)(CE_{conv} - E - W) + f^m(M + f^-\alpha S) + (f^+ - f^-)/\delta t \cdot \frac{q_c^-}{f^-}$$

with $f^m = (f^+ + f^-) \cdot 0.5$

$$\frac{\partial F(W)}{\partial W} = -(1 + f^m\alpha\beta) + \frac{\partial f^+}{\partial W}\left(0.5 \cdot \alpha\beta(CE_{conv} - E - W) + 0.5(M + f^-\alpha S) + \frac{q_c^-}{f^-\delta t}\right)$$

Time discretisation v2:

$$F(W) = (1 + f^m\alpha\beta)(CE_{conv} - E - W) + f^m(M + f^m\alpha S) + (f^+ - f^-)/\delta t \cdot \frac{q_c^m}{f^m}$$

$$\frac{\partial F(W)}{\partial W} = -(1 + f^m\alpha\beta) + 0.5\frac{\partial f^+}{\partial W}\left(\alpha\beta(CE_{conv} - E - W)\right)$$
$$+0.5\frac{\partial f^+}{\partial W}\left((M + f^m\alpha S) + f^m\alpha S + \frac{q_c^m}{f^m}(\frac{2}{\delta t} - \frac{f'}{f^m})\right) + 0.5\frac{f'}{f^m}$$

with $f' = (f^+ - f^-)/\delta t$

4. Results

Two type of test have been made in the 1D Model: firstly 24h forecast without forcing on an unstable vertical sounding just to see if the results are physical, secondly with the GATE experiment (always in 1D) with a dynamical forcing and we compare the temperature bias along the 20 days forecast. For all the test I have tried to validate the method with the two cloud cover formulae but also for the sequential approach (M, N, R computed) and the parallel one (M=N=R=0.).

The Fig: 2 show the total cloud water content in the reference and in the experiment with the "boxes" it seems that the main features of a convective clouds are more physical with the experiment than the reference. But the same tuning in the GATE experiment underline a problem with the ice phase after 6 days of integration (Fig: 3).

To conclude: more work is needed but we can be optimistic on the pertinency of the approach if we are able to solve the problem of the ice phase on the GATE experiment. In any way, in Météo-France the deadline for the boxes is the 01/01/2001 !!!

References

[Baz95] E. Bazile, *Study of a prognostic cloud scheme in arpege*, Tech. Report 20, HIRLAM, Swedish Meteorological and Hydrological Institute, S-60176 Norrkopping, Sweden, 1995.

[RK98] P. J. Rasch and J. E. Kristjansson, *A comparison of the CCM3 model climate using diagnosed and predicted condensate parameterizations*, J. Climate **7** (1998), 1587–1614.

[WF00] R. Wood and P. R. Field, *Relationships between total water, condensed water, and cloud fraction in stratiform clouds examined using aircraft data*, J. Atmos. Sci. **57** (2000), 1888–1905.

[XR96] K.M. Xu and D.A. Randall, *A semi-empirical cloudiness parameterization for use in climate models*, J. Atmos. Sci. **53** (1996), 3084–3102.

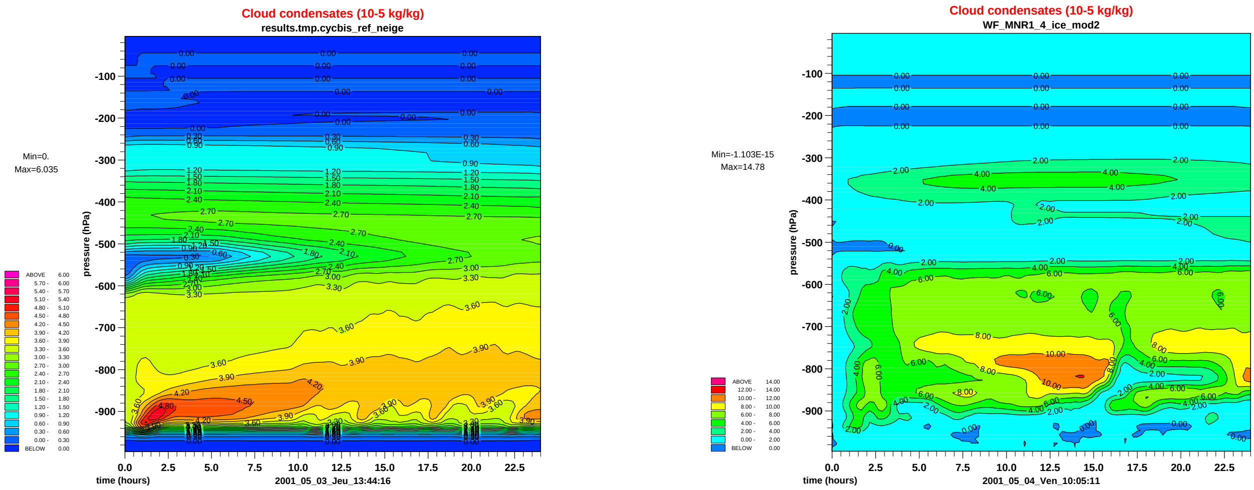

Figure 2: Left: Cloud condensate for ARPEGE. Right: Cloud condensate for ARPEGE with boxes + WF + sequential approach

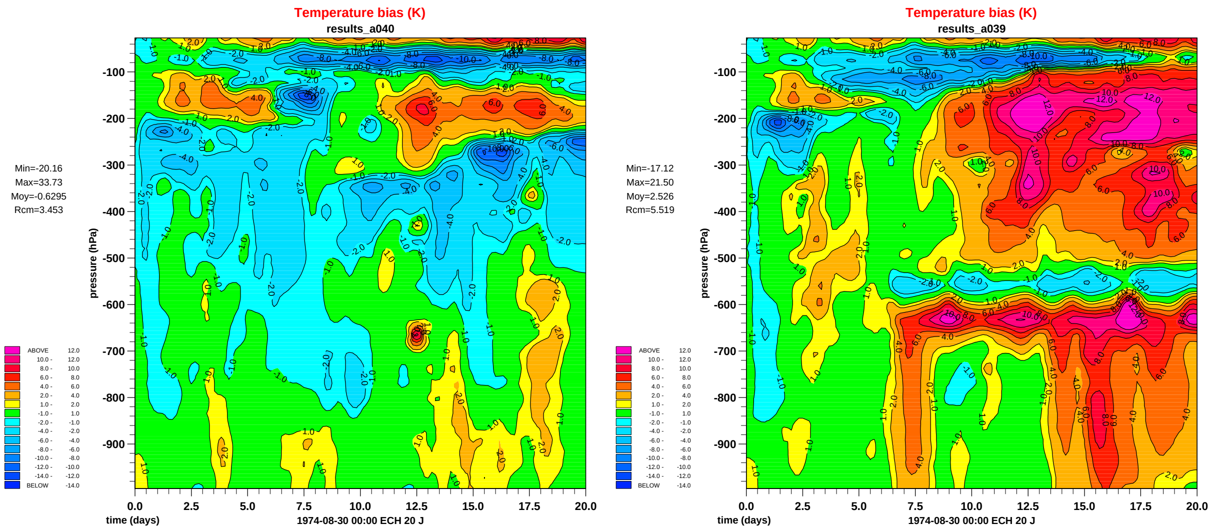

Figure 3: GATE experiment: temperature bias along the 20 days forecast. Left: boxes + WF + sequential approach + without ice phase. Right : the same but with the ice phase