An intermediate complexity microphysics scheme

And some informations about the next double suite …

15th ALADIN workshop
Bratislava 6-10 june 2005

Yves Bouteloup, François Bouyssel (GMAP)

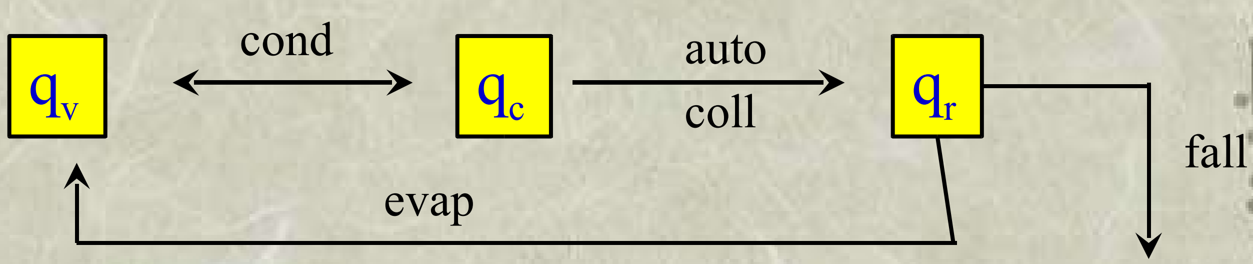
Pascal Marquet (GMGEC)

Adaptation of the scheme developed by Philippe Lopez (2002)

General

In its original scheme Philippe Lopez introduced two new prognostic variables qc and qr

$$
\begin{cases}
\dfrac{dq_c}{dt} = cond - auto - coll \\[2ex]
\dfrac{dq_r}{dt} = auto + coll - evap + fall
\end{cases}
$$



The partition between liquid and solid cloud water was diagnosed at each time step by :

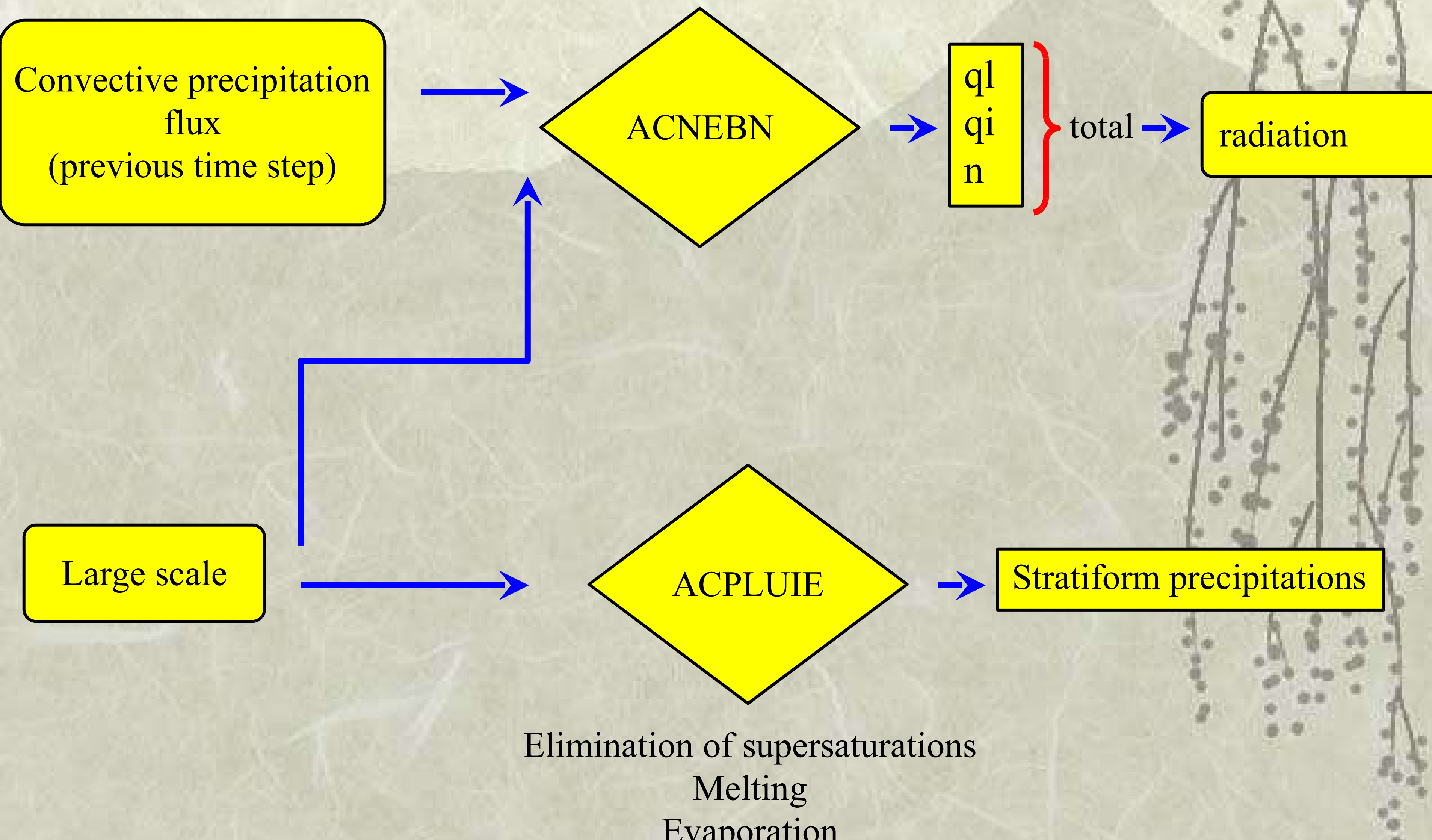
$$\alpha_i = \begin{cases} 1-\exp\left[-\left(\frac{T-T_f}{2\Delta T}\right)^2\right] & \text{for } T<T_f \\ 0 & \text{otherwise} \end{cases}$$

At each time step information about this partition was lost, this implied that the latent heat exchange was neglected

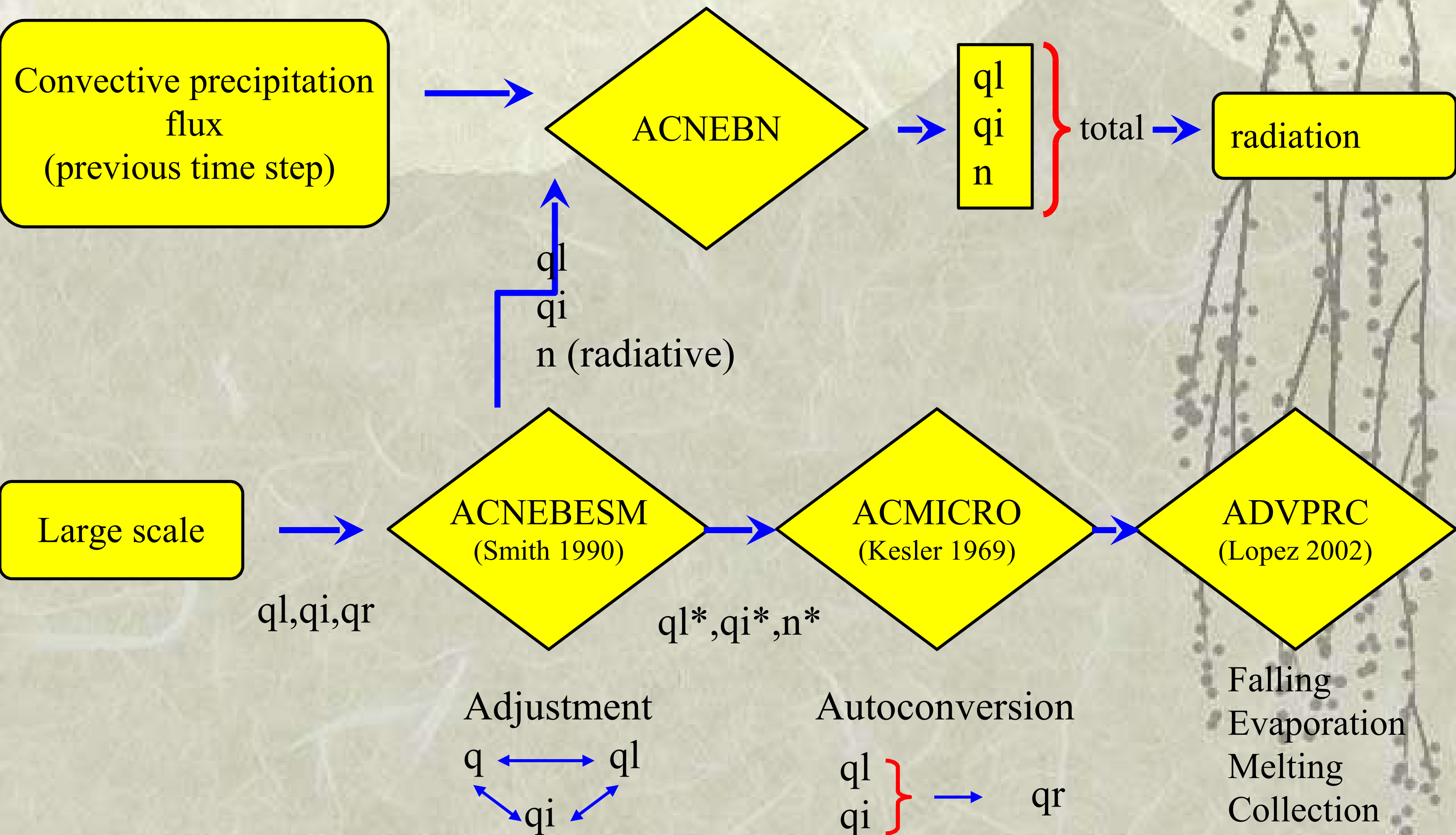
For this reason and problems of compatibility of code with the European Center (and AROME) we have separated qc ➔ ql and qi

On the other hand we preserved only one variable for precipitations, which has two phases, snow and rain. Snow is assumed to melt instantaneously as soon as it enters a model layer with temperature above 0°C.
Respective falling speeds are 0.9m/s and 5m/s

Precipitation and cloudiness in operation



Precipitation and cloudiness
(Lopez/GMAP)



ACNEBSM :

Condensation/evaporation of cloud condensate is parameterized following the approach of Smith (1990), which specifies a triangular probability-density function for describing the subgrid fluctuations.
The width of the triangular distribution is adjusted via a critical relative humidity threshold.

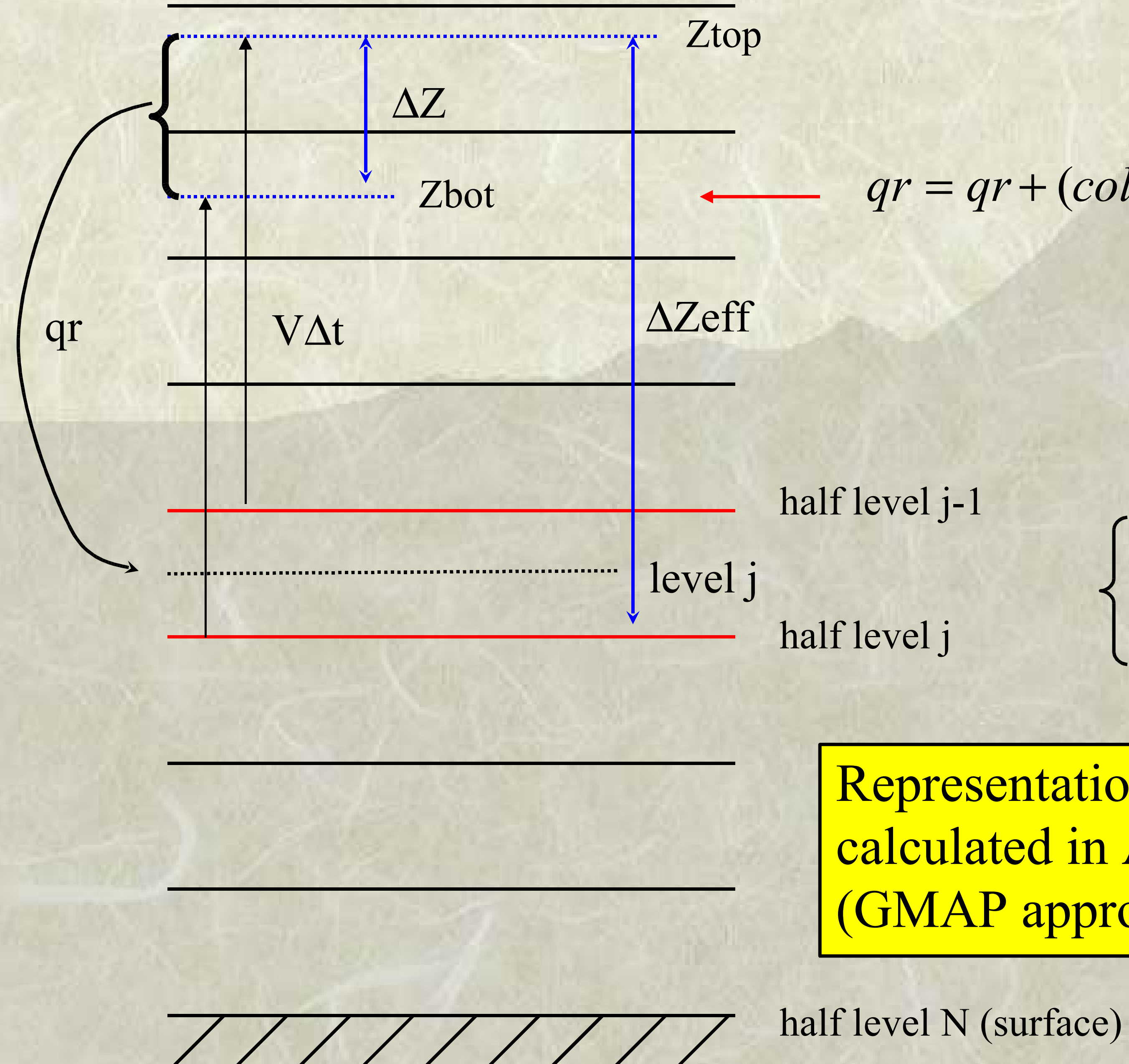
A specificity introduced at GMAP is to calculate a first cloudiness before the microphysics adjustment

ACMICRO :

Use a Kessler (1969) formulation

$$\begin{cases} AUTO_l = nk \max\left(0, \dfrac{q_l}{n} - q_{l0}\right) \\ AUTO_i = nke^{0.025\left(T-T_f\right)} \max\left(0, \dfrac{q_i}{n} - q_{i0}\left(T\right)\right) \end{cases}$$

The original Lopez scheme carried out the autoconversion at the beginning of the time step, which introduced a laminated field of precipitation. In GMAP version the autoconversion is continuous during the time step.



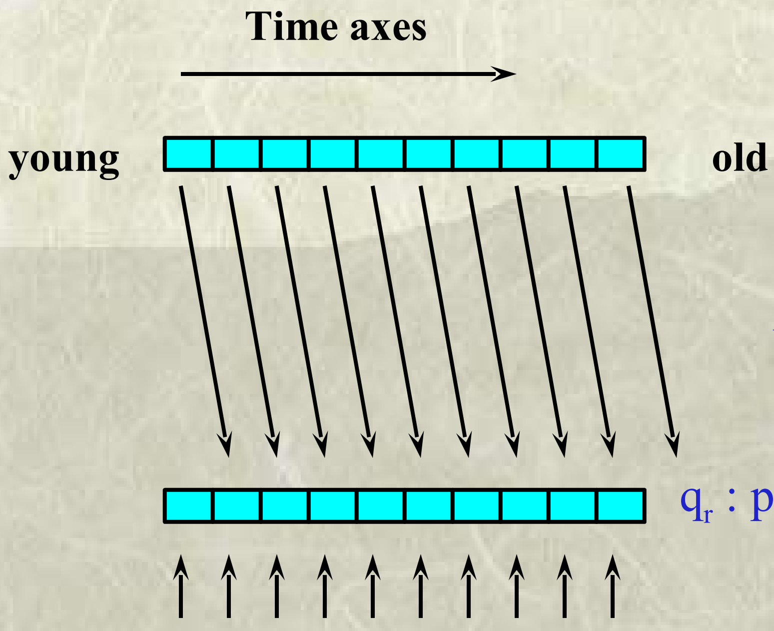
$$qr = qr + (coll - evap)\frac{qr}{qtot} + \frac{auto}{k}$$

- Autoconversion
- Evaporation
- Collection

Representation of the processes calculated in ADVPRC (GMAP approach)

The « age of rain » approach

Approach proposed by JFG independently of the modifications made at GMAP



Array representing the PDF of the age of the dropplets

Falling process

q_r : proportion of rain which stay at this level

$$(coll - evap)\frac{qr}{qtot} + \frac{auto}{k}$$

Where k is the size of the PDF array and : $qtot = \sum_k q_r$

Very similar to GMAP approach but with a larger numerical cost, because the PDF array must have a size larger than the number of vertical levels

The statistical approach (1)

Approach also proposed by JFG

The main idea is to simulate the falling process by a low cost statistical calculus

Consider the Marshall-Palmer's law : $N(D) = N_0 e^{-\lambda D}$ $\left(N = \frac{N_0}{\lambda} \right)$

With : $w(D) = aD$ We can write : $N(w) = \frac{N_0}{a} e^{-\frac{\lambda w}{a}}$

And then : $N(w > w_1) = \frac{N_0}{\lambda} e^{-\frac{\lambda w_1}{a}}$

The proportion od dropplets which cover the distance x during the time t is :

$$P(x,t) = e^{-\frac{\lambda}{a}\frac{x}{t}}$$

The statistical approach (2)

Now two hypothesis are made :

➔In a simple microphysics scheme where precipitation are supposed to have a constant falling speed this law is still verified

$$P(x,t) = e^{-\frac{x}{wt}}$$

➔The union of two sets of dropplets also verify the first hypothesis. This is similar to consider that in Marshall-Palmer's formula it's N_0 which is link to the rate of precipitation and not λ

Then, at each level of a model, whatever the origine of the dropplets, the first hypothesis is verified.

The statistical approach (3)

It is now possible to compute the three proportions which are needed by the falling process :
(Proportion of dropplets which leave the level during the time step)

1 : Dropplets which are in the level at the begining of the time step:

$$P_1 = \frac{1}{\Delta x}\int_0^{\Delta x} P_0(x,\Delta t)\,dx = \frac{w\Delta t}{\Delta x}\left(1 - e^{-\frac{\Delta x}{w\Delta t}}\right)$$

2 : Dropplets which come from the upper level:

$$P_2 = \frac{1}{\Delta t}\int_0^{\Delta t} P_0(\Delta x, t)\,dt = E_2\left(\frac{\Delta x}{w\Delta t}\right)$$

With :

$$E_n(z) = \int_1^{\infty} \frac{e^{-zt}}{t^n}\,dt$$

3 : Dropplets which are produced continously during the time step (autoconversion and collection)

$$P_3 = \frac{1}{\Delta x \Delta t}\int_0^{\Delta x}\int_0^{\Delta t} P_0(x,t)\,dx\,dt = \frac{1}{\Delta x}\int_0^{\Delta x} P_2(x)\,dx = \frac{w\Delta t}{\Delta x}\left(\frac{1}{2} - E_3\left(\frac{\Delta x}{w\Delta t}\right)\right)$$

The statistical approach (4)

Using the following relation (Abramovitch and Stegun p229 equation 5.1.19) :

$$\frac{1}{z+n} < e^{z} E_{n}(z) \leq \frac{1}{z+n-1}$$

It is possible to approximate E_2 and E_3

$$E_2(z) \approx \frac{e^{-z}}{1+z+\frac{z}{z+1}}$$

$$E_3(z) \approx \frac{e^{-z}}{2+z+\frac{z}{1+z}}$$

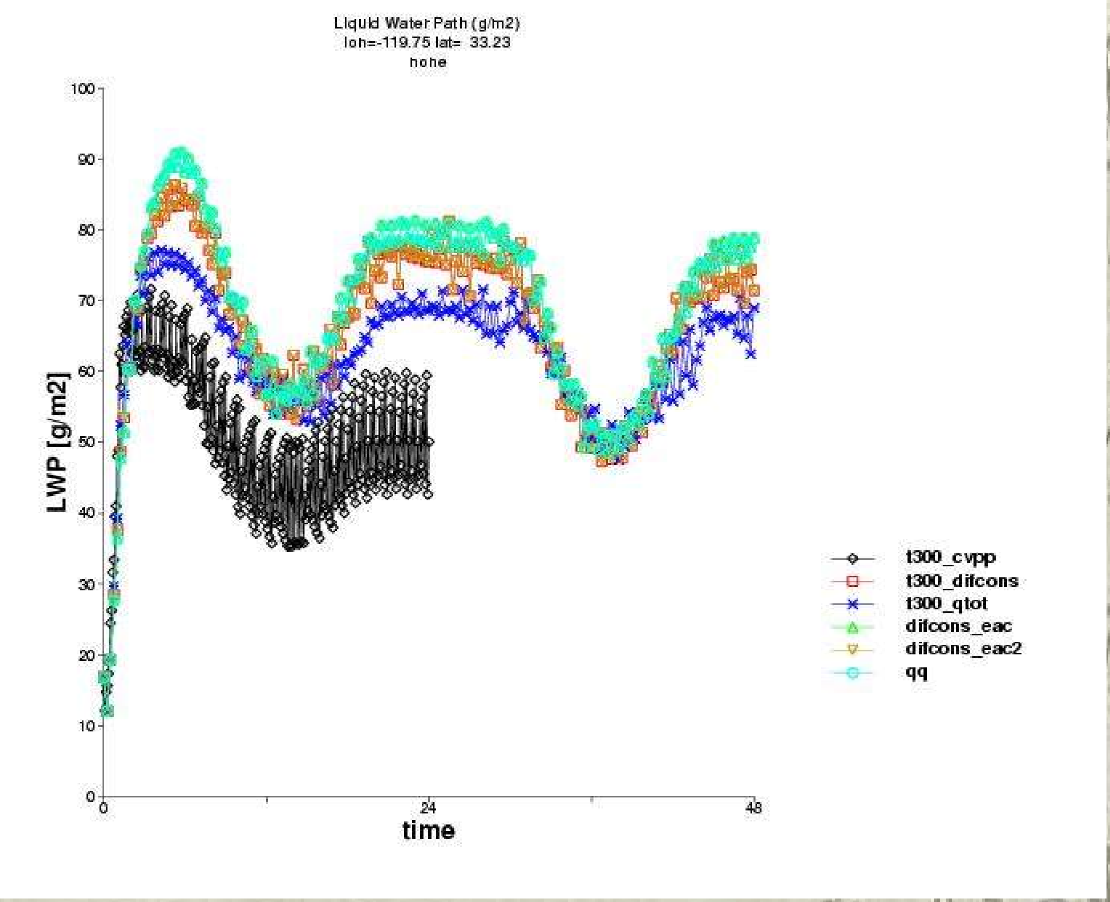
Instability problem

- ***Some instability in 1D (and mysterious blow up in 3D)***

- ***Necessary to diffuse cloud variables***

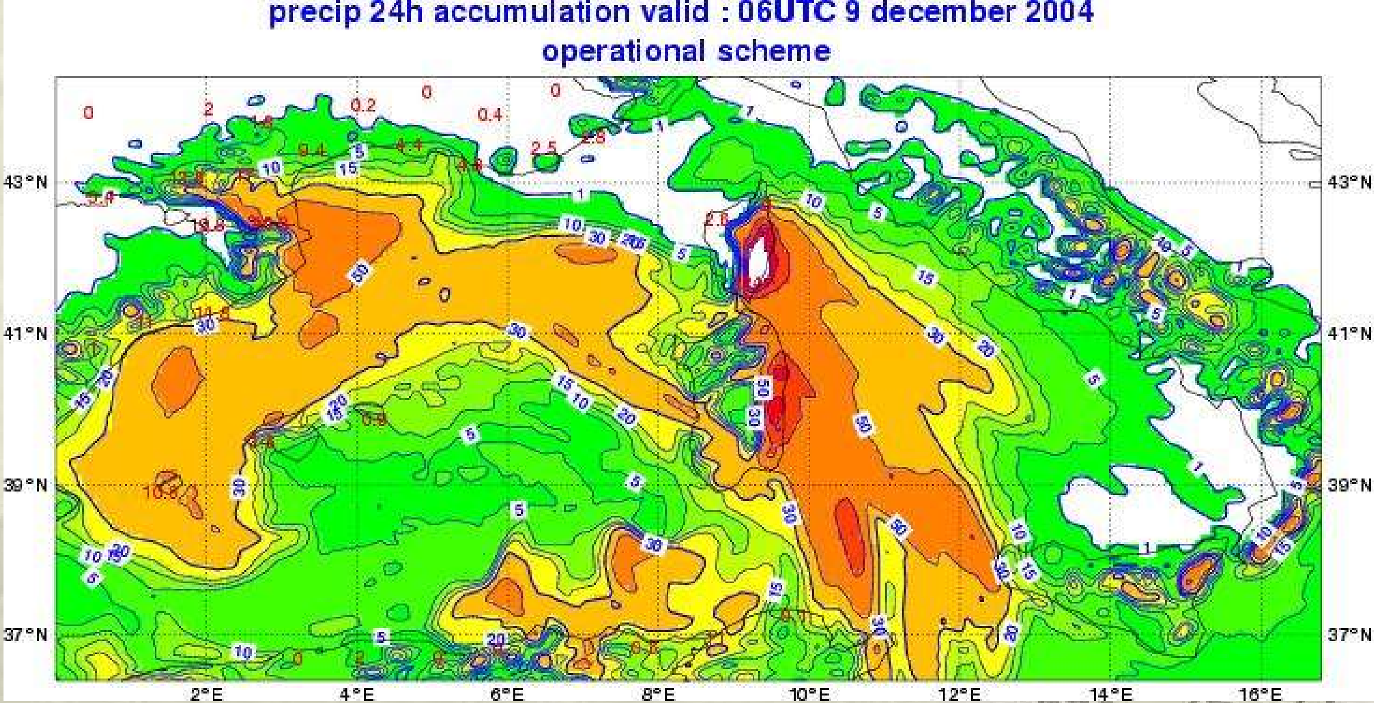
- ***The best way is to diffuse conservative variables***

- ***Weak link with the time step***

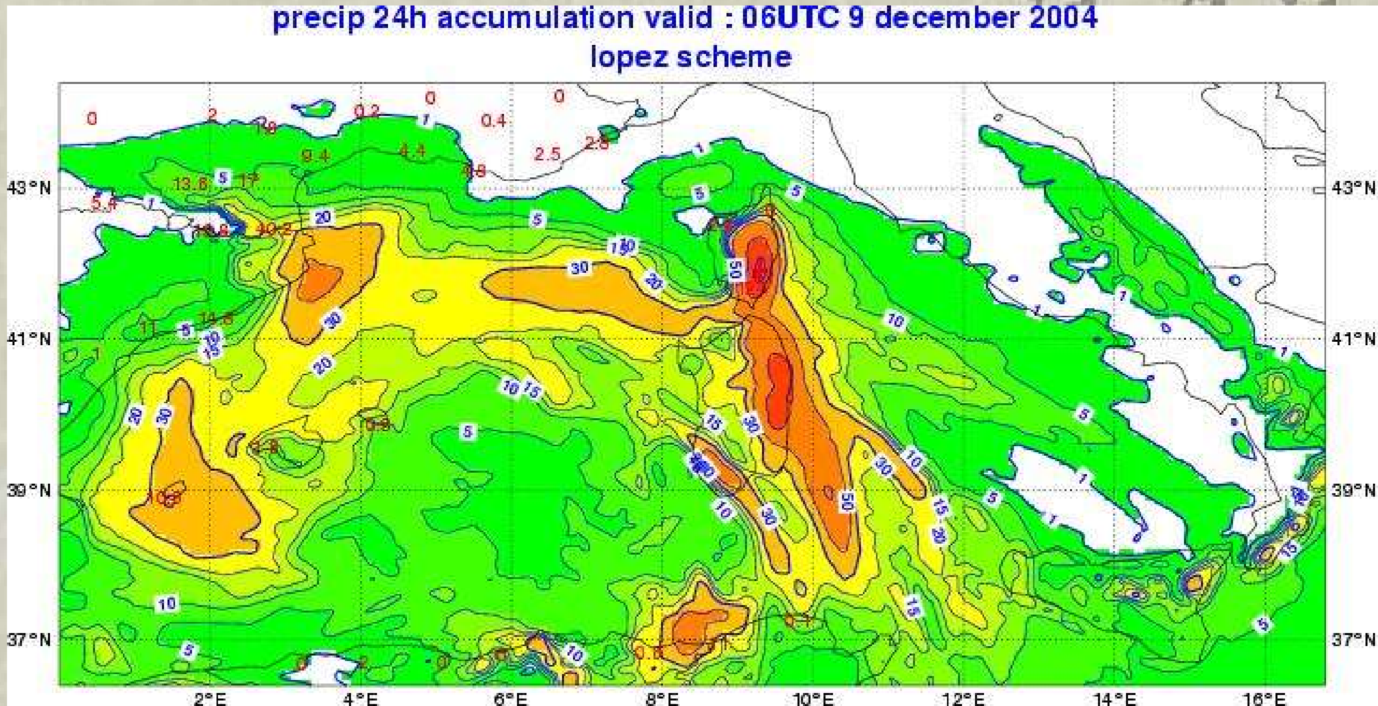


Corsica case
9 december 2004

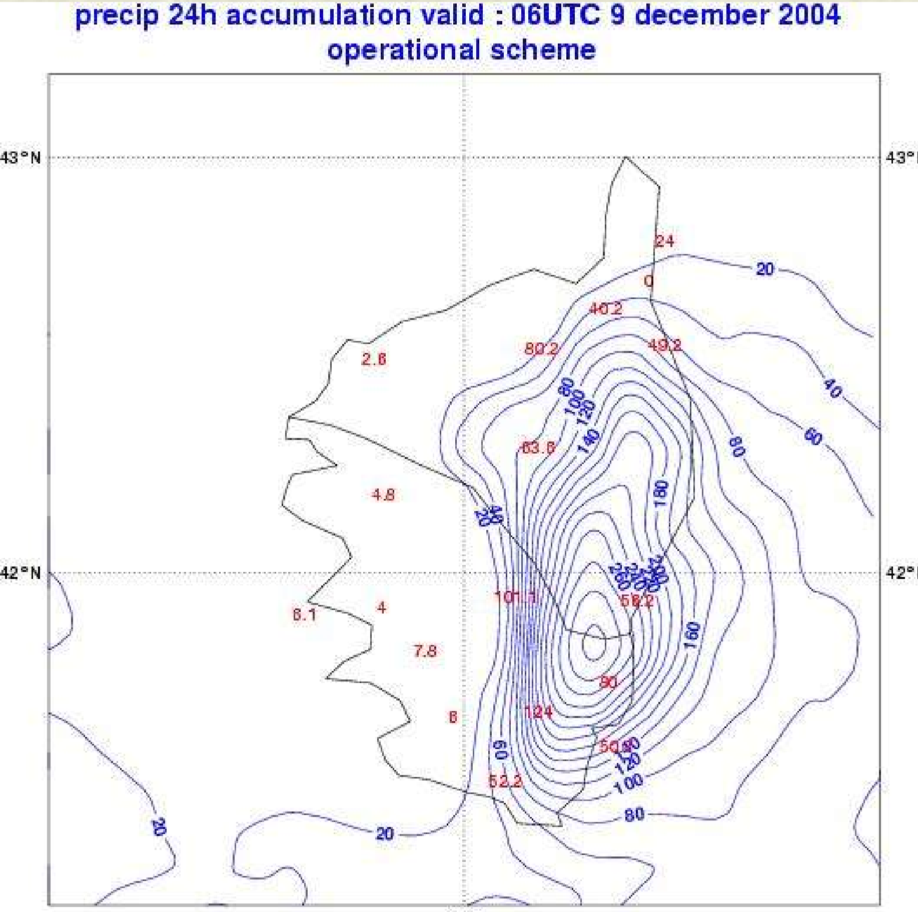
oper



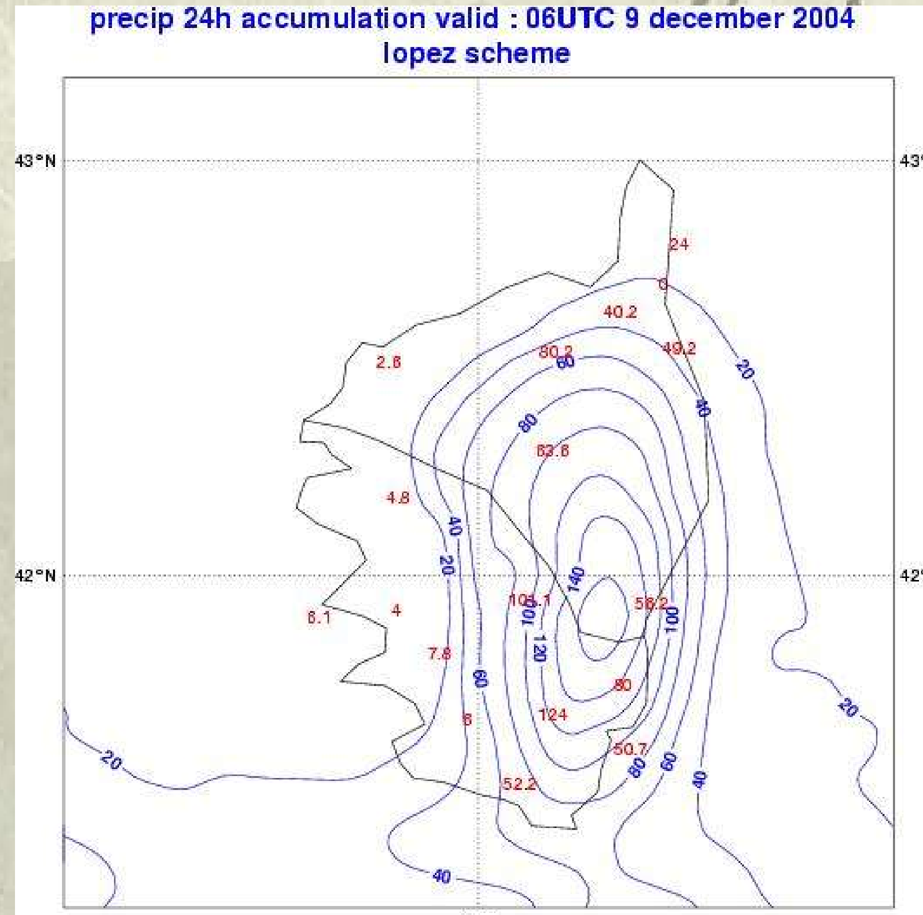
Lopez



Corsica case (9 december 2004)



Oper

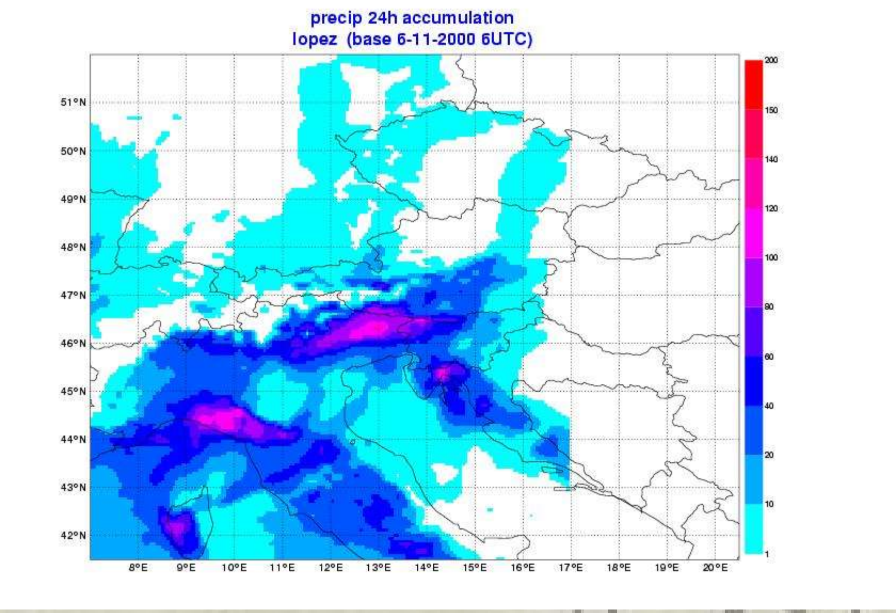


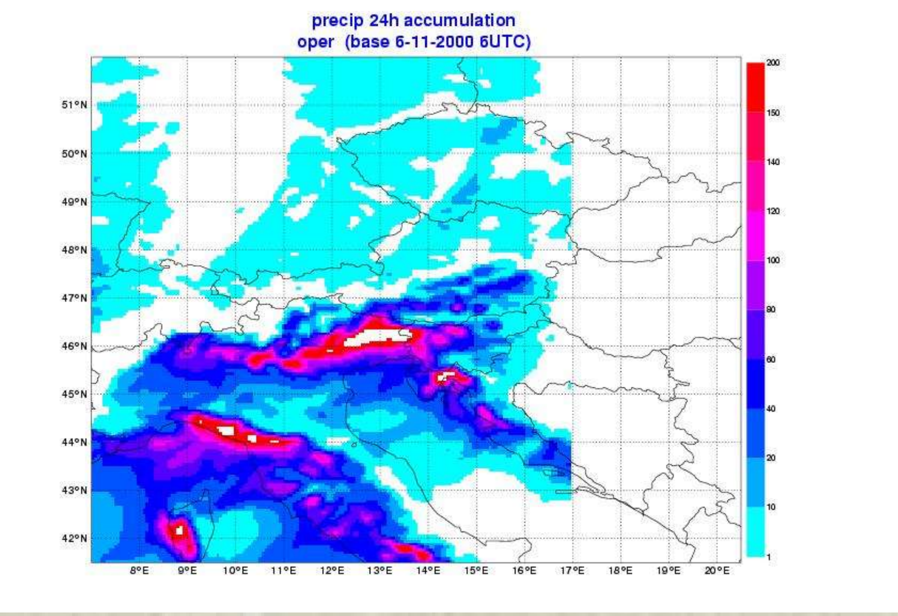
Lopez

Austrian alpin case (6 november 2000)

Thank you very much to Thomas Haiden and Christoph Wittmann (ZAMG)

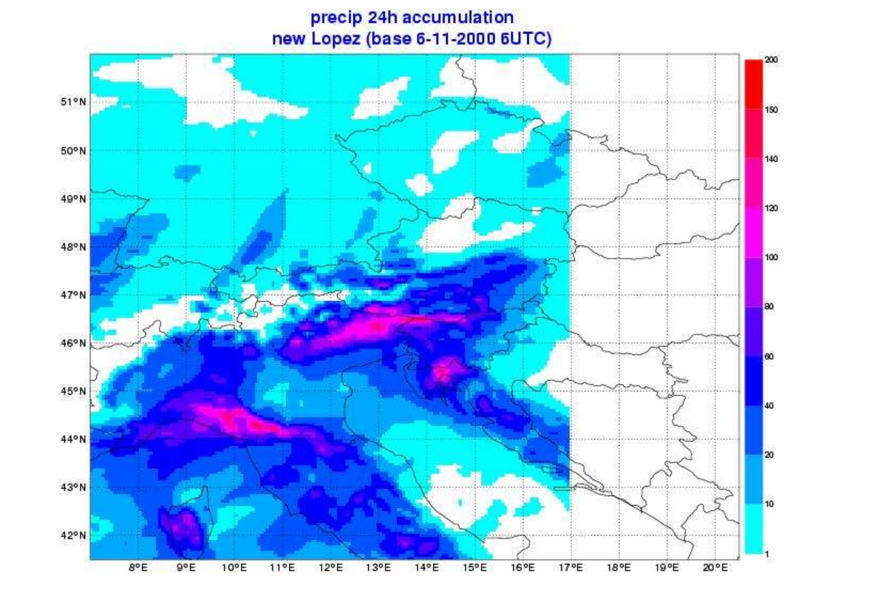
Lopez first version





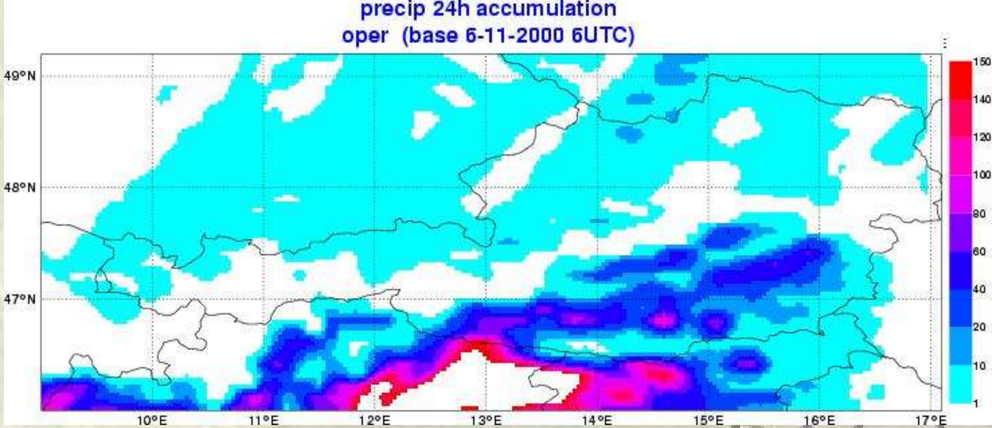
Oper

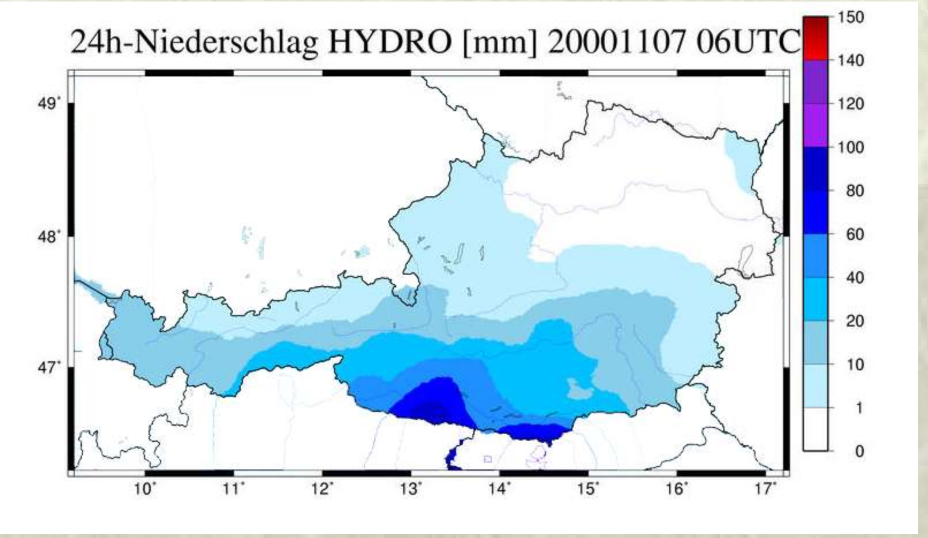
Lopez last version



Austrian alpin case (6 november 2000)

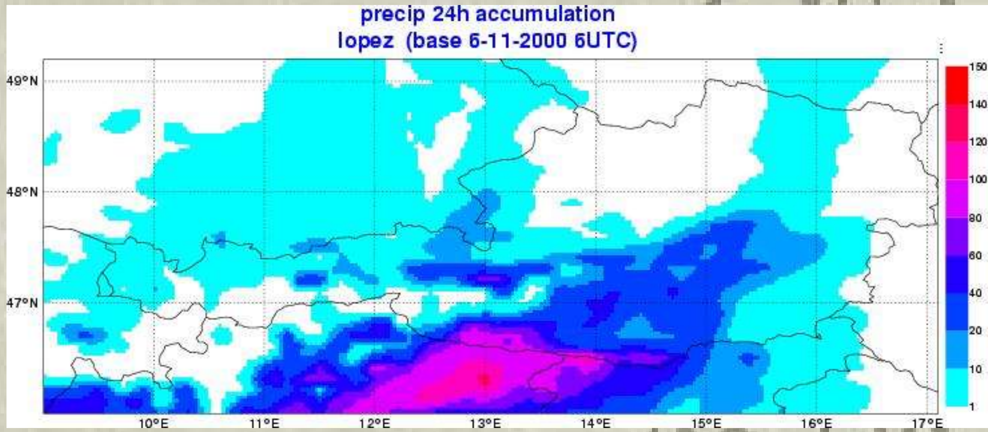
Oper



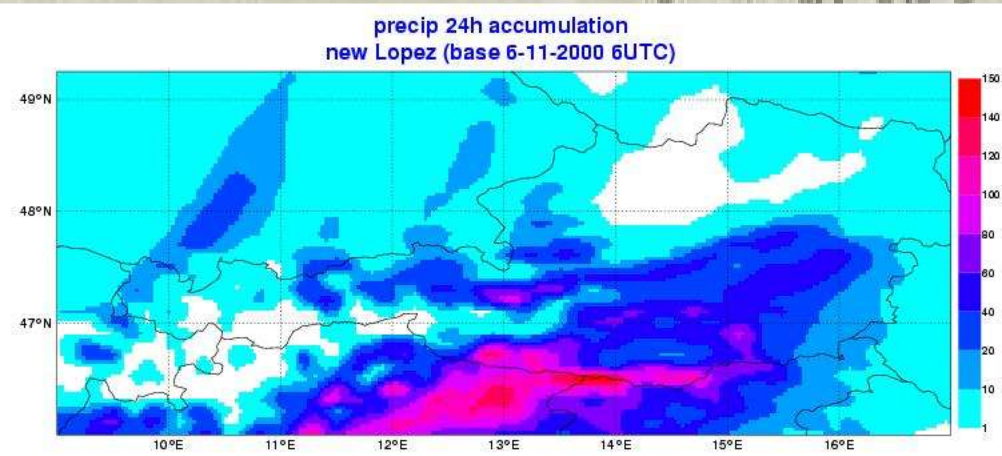


Observations (from ZAMG)

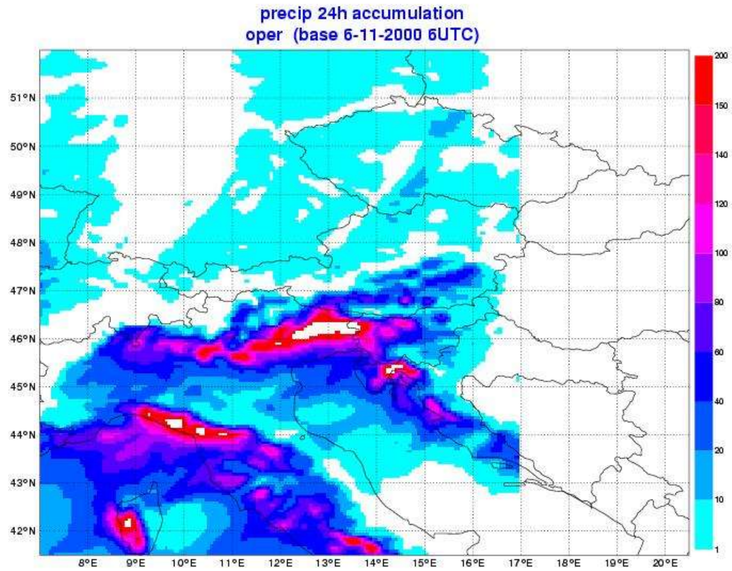
Lopez



Lopez new



Impact of advection



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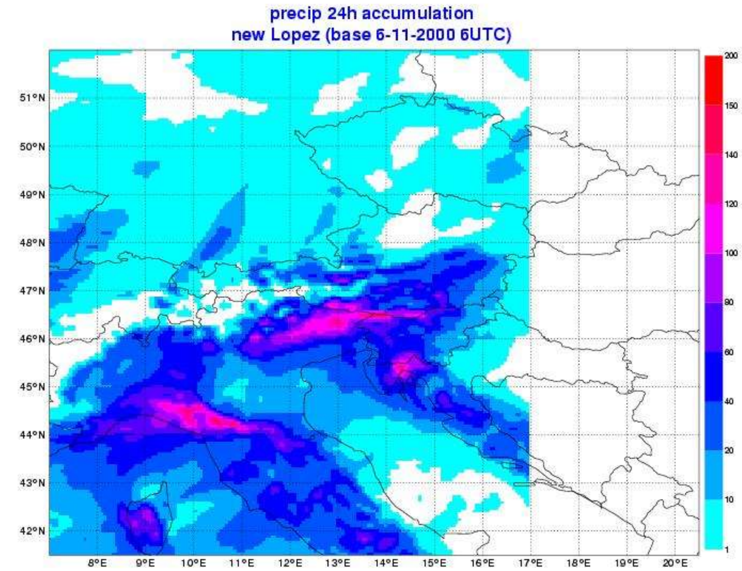
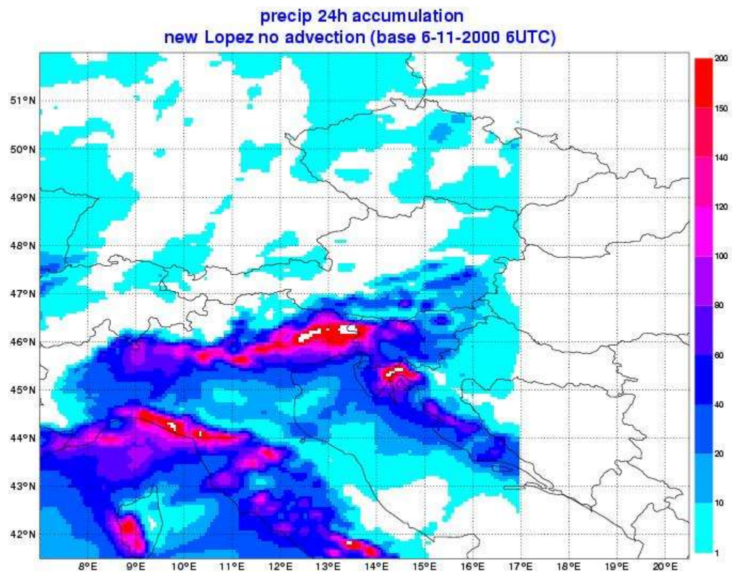
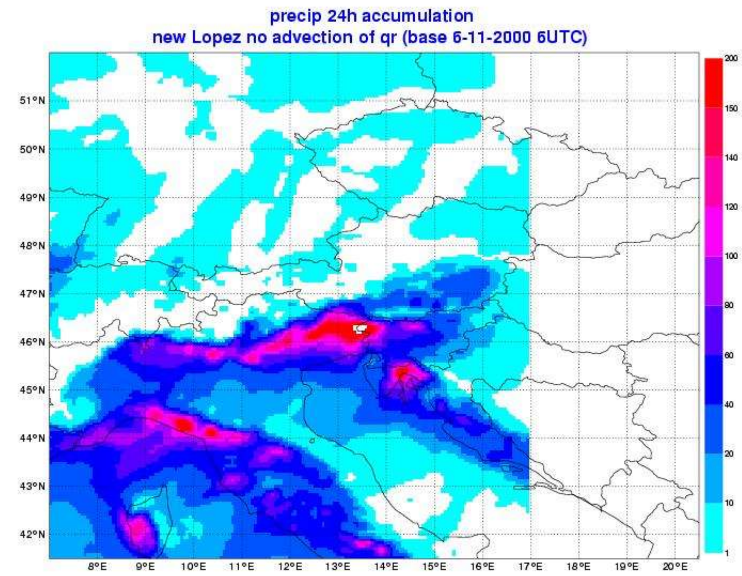


Lopez

Lopez no advection of ql, qi and qr



Lopez no advection of qr



Test in a global 4DVAR

Contains :

New radiation scheme (ECMWF sw with 6 spectral intervals and RRTM with tuning of ice cloud optical properties)

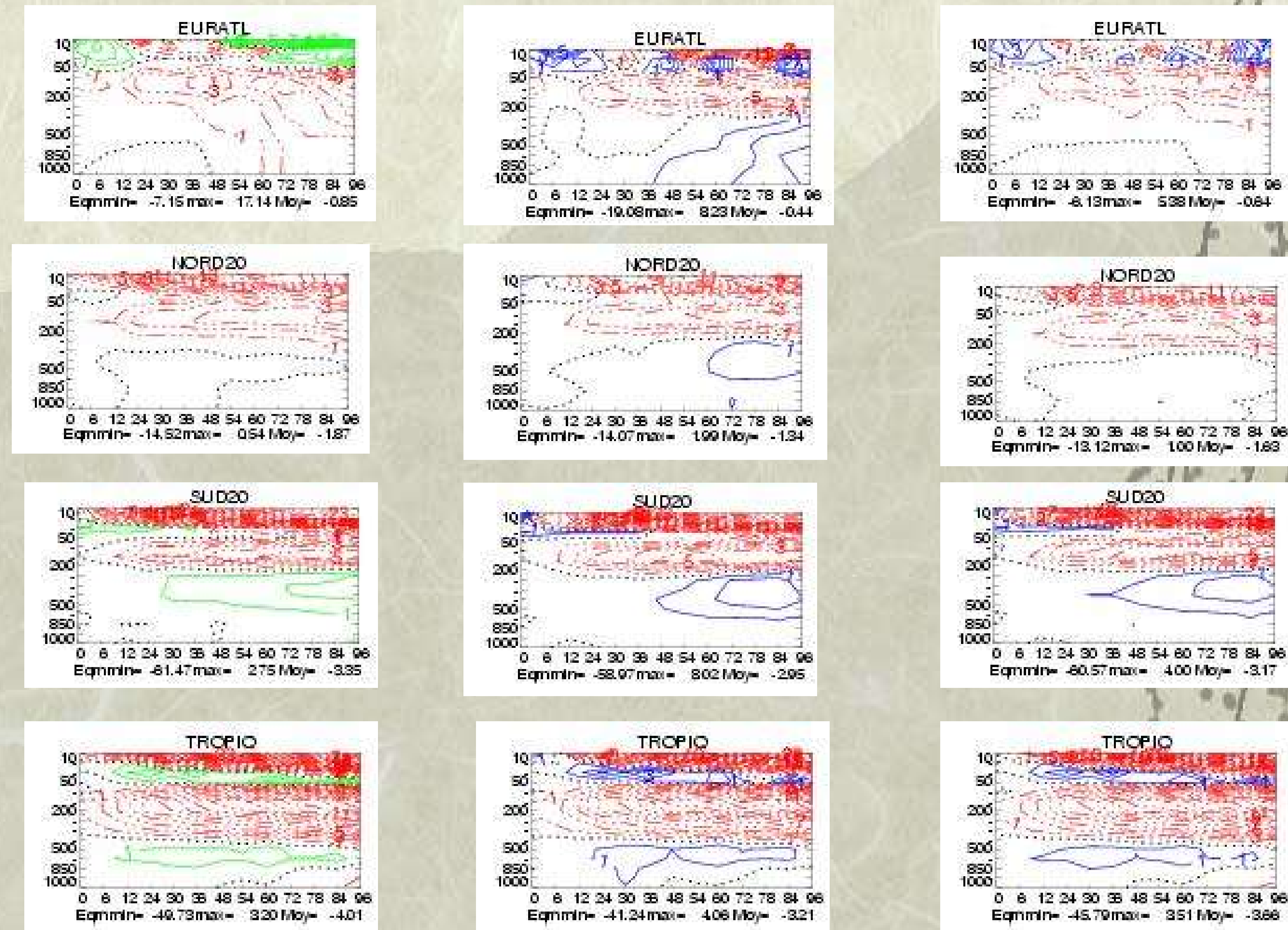
New microphysics scheme

46 levels ➔ tuning of the mesopheric drag

- 31 days during january 2005
- Large difference in score between the first part and the second part of the experiment
- Part 2 better than part 1 in eurat/nord20/sud20 ➔ stabilisation of the model ?
- Good results on 1998 christmas storm

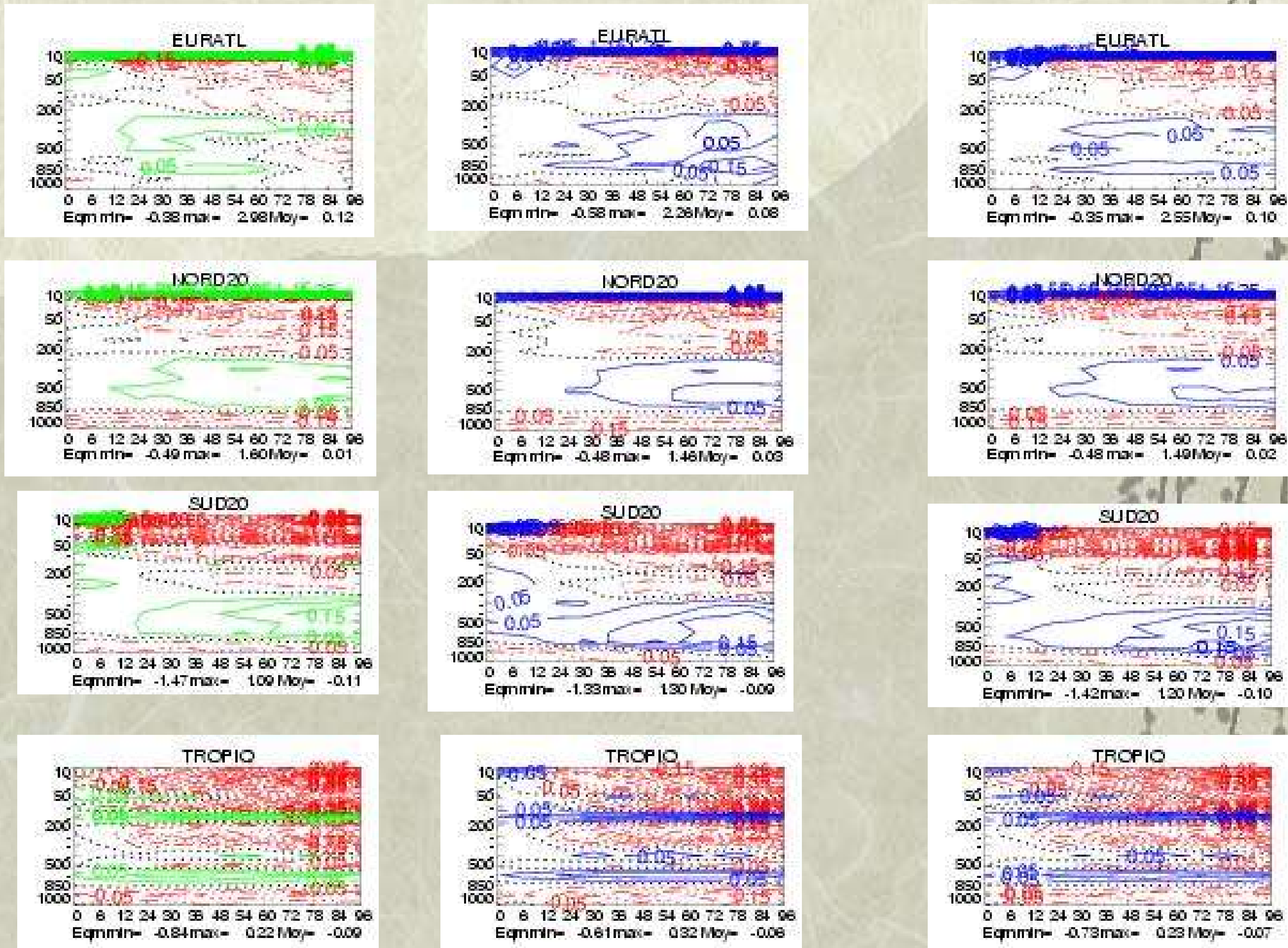
Geopotential

2/01 to 16/01 | 16/01 to 2/02 | 2/01 to 2/02



Temperature

2/01 to 16/01 | 16/01 to 2/02 | 2/01 to 2/02

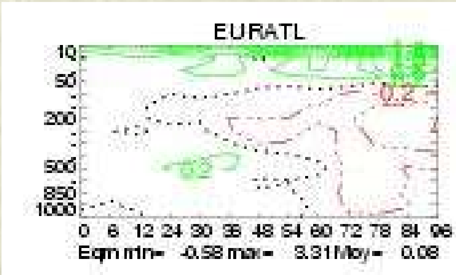


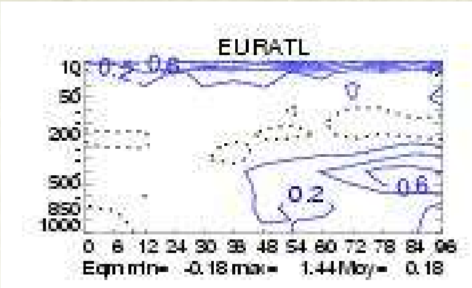
Wind

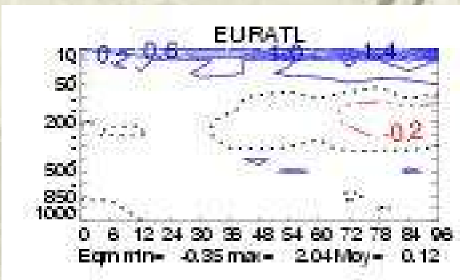
2/01 to 16/01

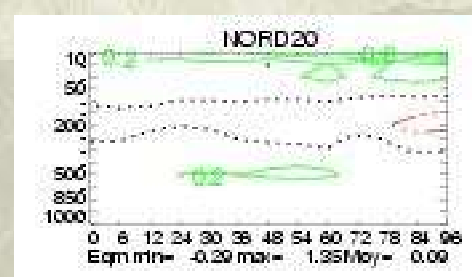
2/01 to 16/01

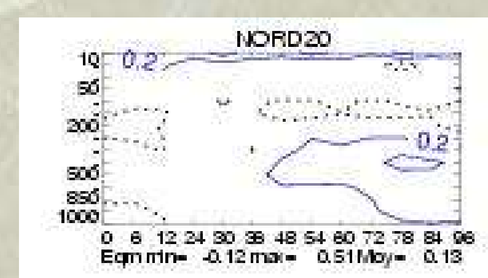
2/01 to 16/01

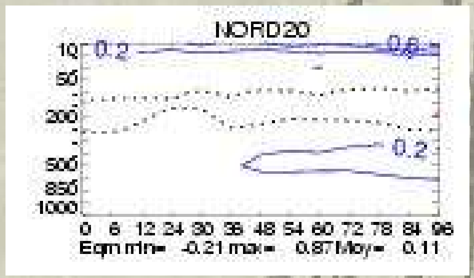


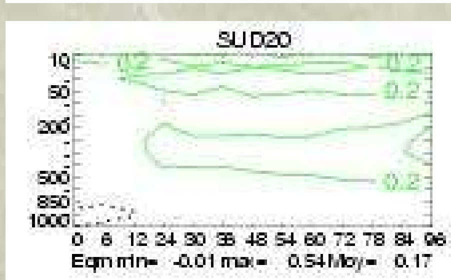


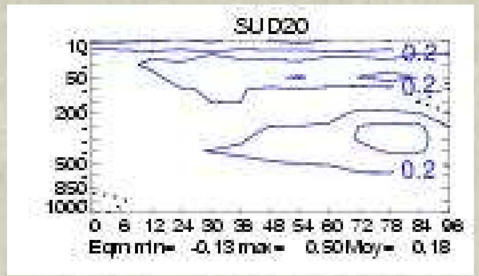


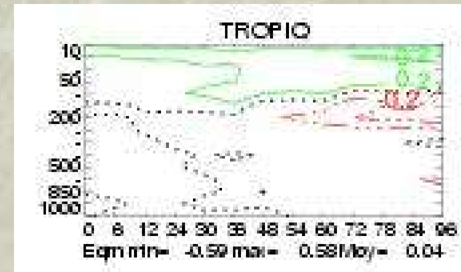


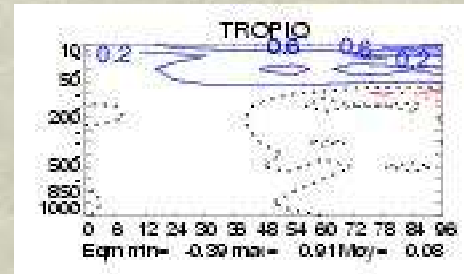


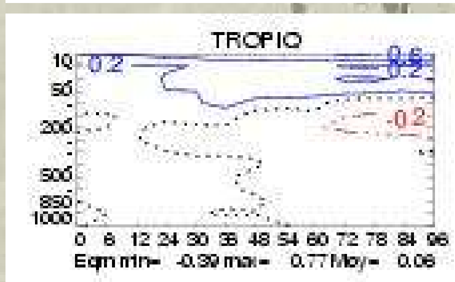












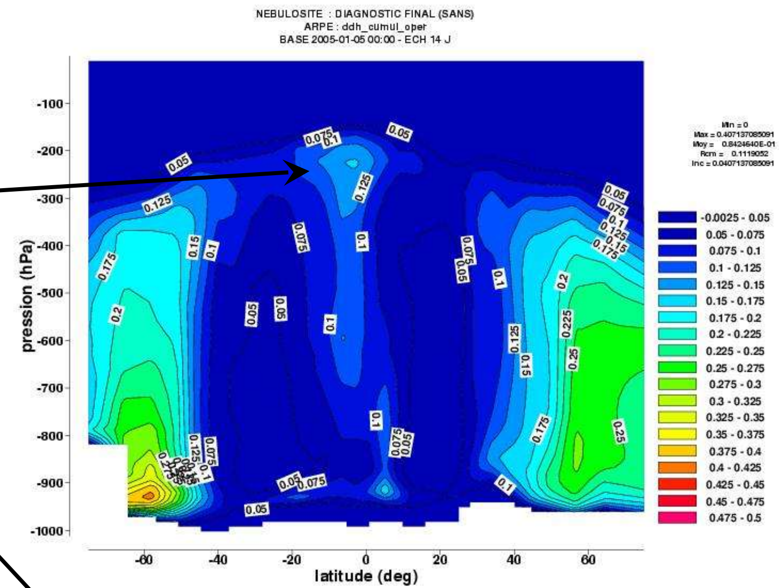
Some problems …

More high level tropical clouds

But not enough for RRTM !

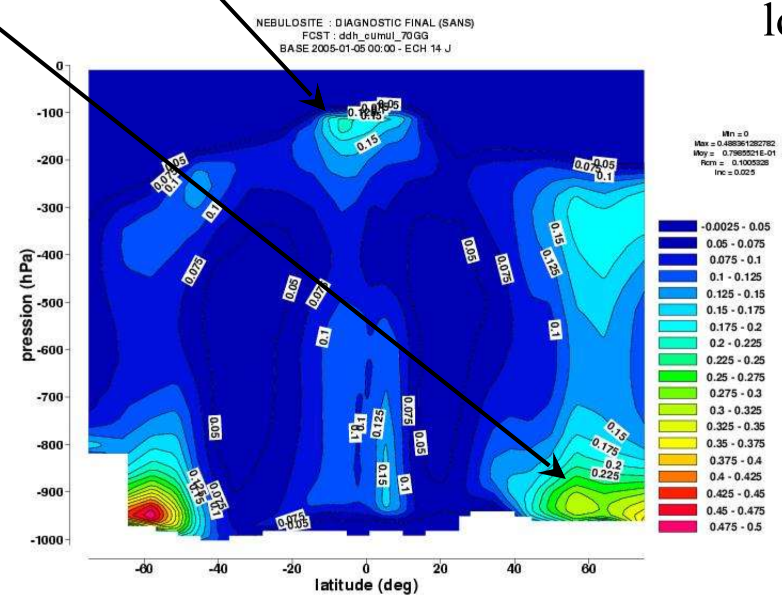
And too much low level clouds

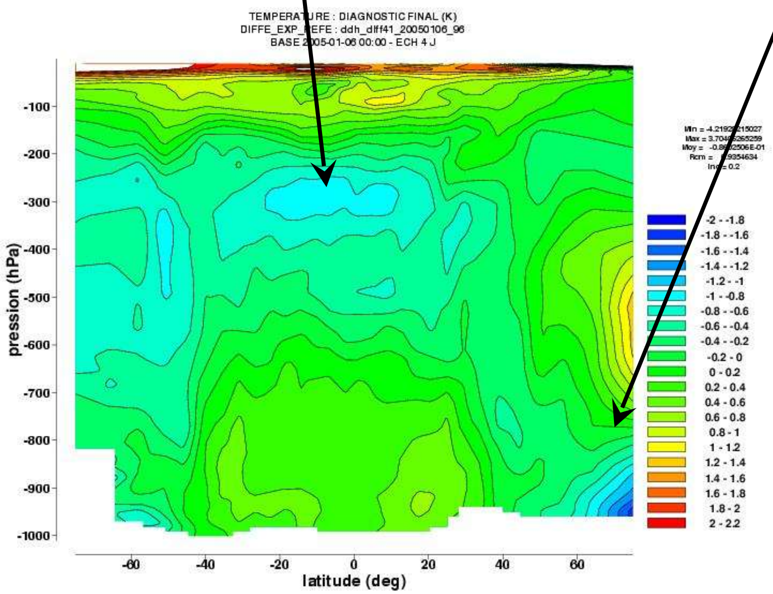
oper



Cloudiness

lopez





New 4DVAR experiment (runing presently)

• Tuning of the microphysics scheme in order to minimize tropical biais and too much low level cloud in polar region in winter. (tuning of ice autoconversion)

• Modification of the computation of convective cloudiness

• Tuning of deep convection : GCVNU=3.5E-5

• Tuning of vertical diffusion (BEDIFV=0.1 and XDAMP=2)

In the futur double suite (end of june):

• New gravity wave drag (but still enveloppe ?)
• New Jo (from the works of Bernard Chapnik)
• Convective precipitation flux read and write in historical files (no impact)