Multi-phasic aspects at high resolution: numerical and physical open issues

(at least the know ones)

J.-F. Geleyn on behalf of many other people

Toulouse, 25/11/08

Or:

You liked the SLHD vs. microphysics story?

Then you'll surely be thrilled by the one of R vs. R_{gas}

Boundary conditions of the talk

- We are at the AROME typical scale (at larger scale the impacts are far less marked)
- Condensed phased are assumed to have a zero volume
- Boyle-Mariotte and Dalton laws are valid
- C_{pd}, C_{pv}, R_d, R_v, C_l, C_i are temperature independent

- All the content of the layer is assumed to be at its averaged temperature when it comes to thermodynamics
- We are searching barycentric equations' solutions

A physical constatation first (i.e. rather not an issue)

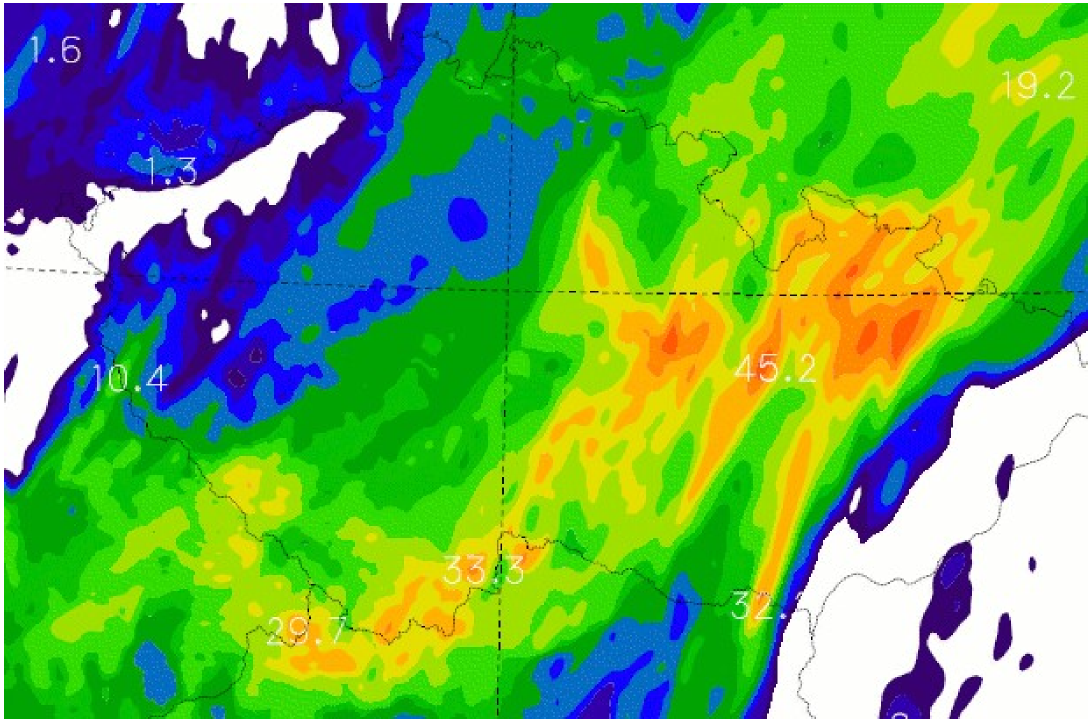
- This presentation will have a lot to do with the intra-time-step variations of C_p, C_v and hence R, following the phase changes of a truly multi-phasic system (here $q_{v/l/i/r/s}$, but it is sufficient to show problems)
- Remember indeed that $C_p=C_v+R$
- It is sometimes customary to say that neglecting the time variation of Cp (or Cv, or R) during the 'physical time-step' (under the influence of phase changes) has little impact.
- This is true for things like large scale budgets (DDH-like), but neither for scores (even at large scale) nor for 'events' at the AROME scale.

One interesting use of the 'as if' property of 3MT

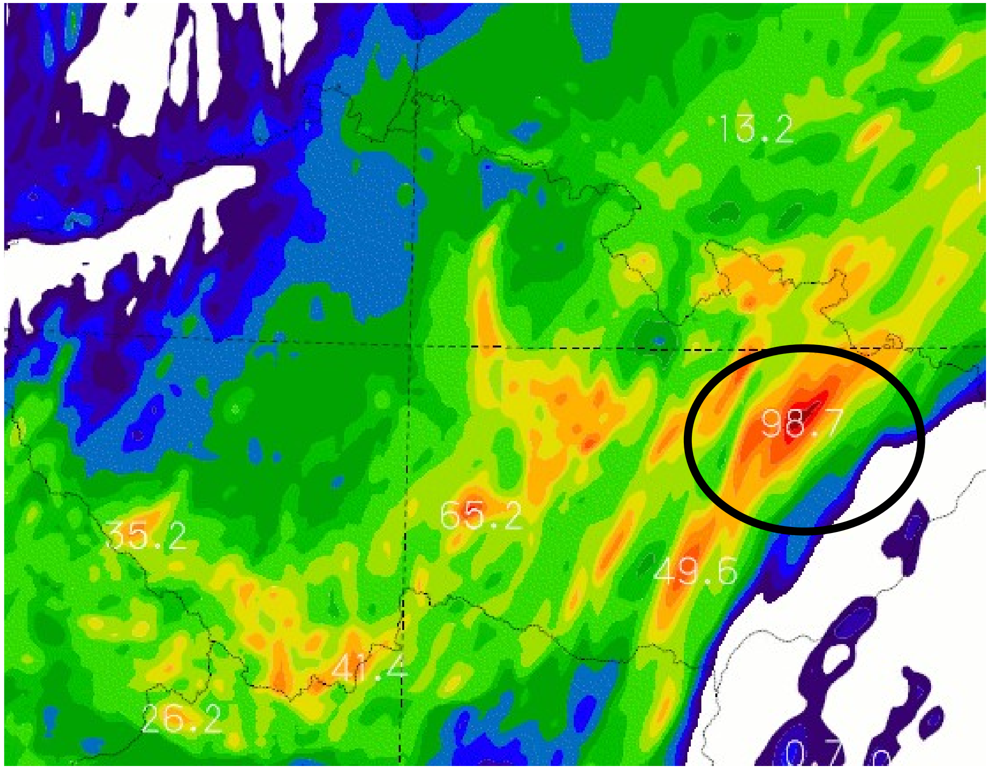
- Basically 3MT is a way to do '***as if***' deep convection was resolved but ***without*** needing to go to scales where this is true, thanks to:
  - Prognostic and diagnostic 'memory' of convection;
  - A single microphysical treatment beyond all sources of condensation.
- Because of the '*as if*', 3MT is an interesting way of testing things like they could be in AROME, but without modifying AROME when this is too demanding (see next bullet), which makes it then something between a parameterisation and a test-bed interface, for such purposes.
- Since ALARO-0 has a set-up for the exact conservation of enthalpy [d(CpT)/dt=Q'0] and since 3MT treats the whole water cycle with a prognostic microphysics package, it can be used for sensitivity tests. NB: AROME uses [Cp.dT/dt=Q'] which is not the same as the [Cp.dT/dt=Q'0] tested below.

Impact of (no) enthalpy conservation

ALARO test (with 3MT) on 2.3 km mesh and with 90s time step (set-up ~ AROME)
6h precipitation on 18/05/2008 (00H+18H)



with enthalpy conservation



without enthalpy conservation

Precipitation patterns are roughly the same, but the intensity is very different (even with this order of magnitude for the time step), nearly doubled at maximum

The LSPRT issue (1/3)

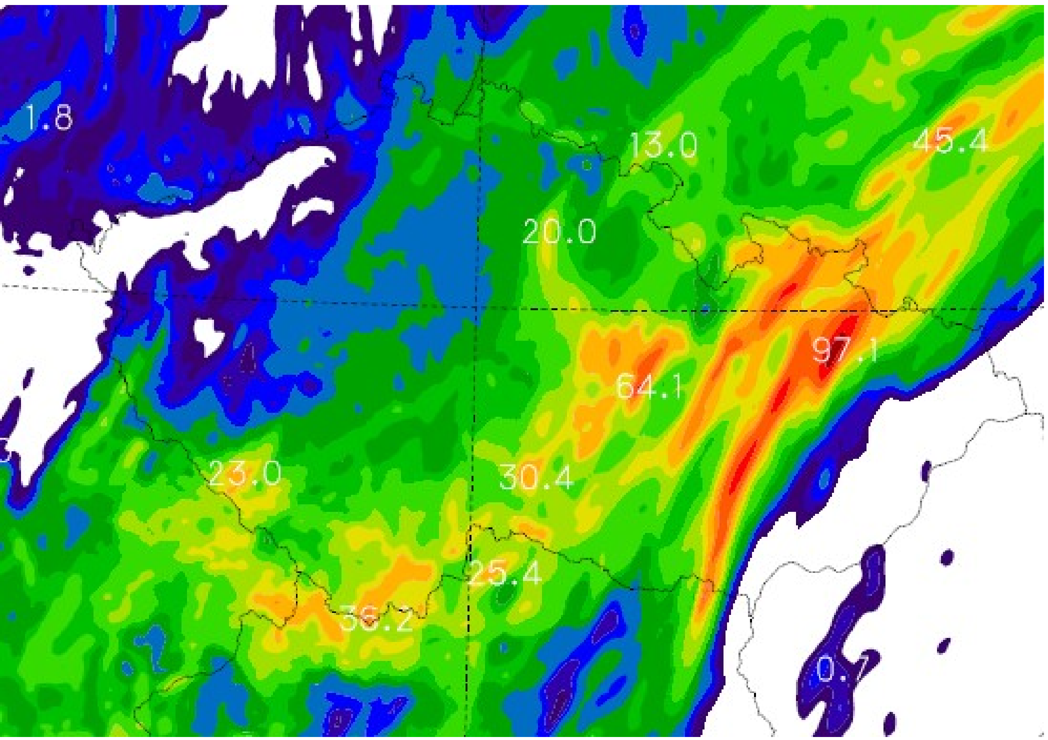
- The topic addressed here is specific to spectral modelling.
- The computation of the horizontal Grad(Phi) contribution to the pressure gradient term requires to use only derivatives of the prognostic variables.
- So-called grid-point variables (hydrometeors typically) cannot enter this computation if T is the thermodynamic prognostic spectral variable.
- In such a case (and provided q_v is treated spectrally) the computation is approximated by using $R=R_d+q_v(R_v-R_d)$
- But, with barycentric equations, in the vertical we use $d(Phi)=-[R_d(1-q_v-q_l-q_i-q_r-q_s)+R_v.q_v].T.d(ln(p))$

The LSPRT issue (2/3)

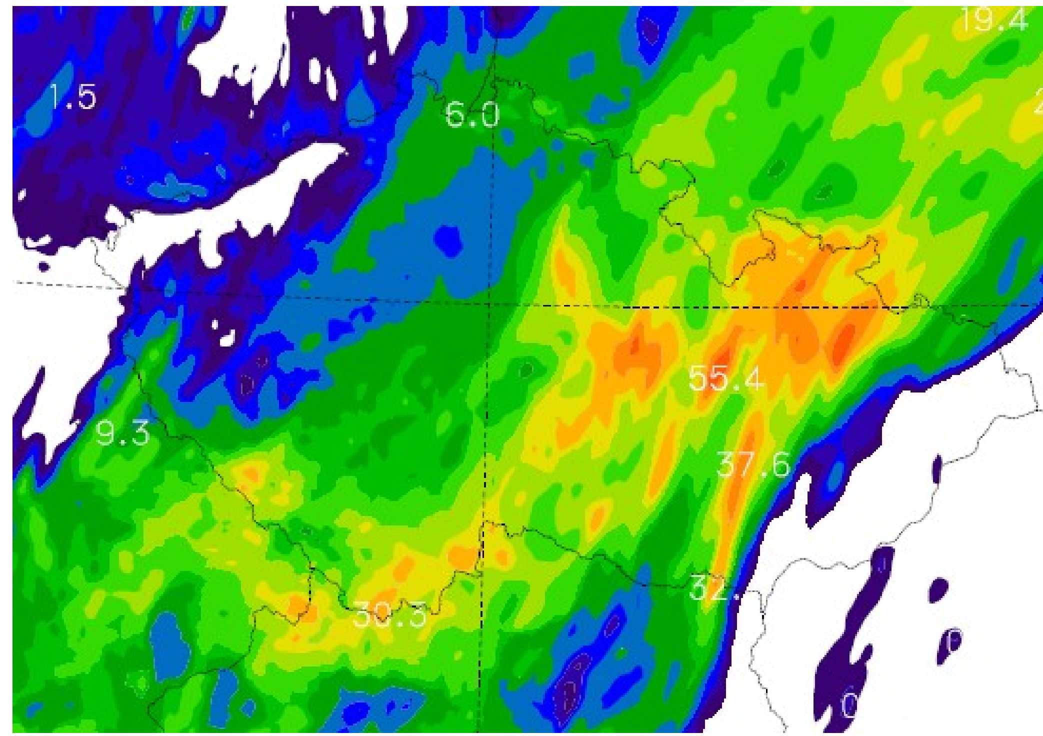
- Even if the order of magnitude appears smaller than in the neglection of C_p variations, the impact of the inconsistency at the AROME scale can be devastating (see next viewgraph).
- Wer know this because there exist the LSPRT=.T. option in the IAAAAH code, which makes RT the thermodynamic spectral prognostic variable.
- And LSPRT can work either with q_v in grid-point or q_v spectral. The latter case allows a clean comparison with the LSPRT=.F. case, for evaluating the impact of the discrepancy between the respective vertical and horizontal gradients of geopotential.

The LSPRT issue (3/3)

Grad (RT) with qv only; dx = 2.3km



Grad (RT) with all species



Associated questions:

- Any other similar omission will likely cause similar feed-backs;
- Initialization: filtering RT is detrimental. **Work on a solution for DFI dearly needed**.

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The issue of projectibility on T & p in the compressible case (1/2)

- When dealing with fully compressible equations, one is in principle able to reproduce what happens in nature under the influence of heat sources/sinks. Both temperature and pressure evolve and gravity+acoustic waves re-establish the equilibrium.
- In the ‘dry’ case, the impact of using this refinement is rather small.
- But going to the simulation of the whole moisture cycle (with enthalpy conservation) the equations take an interesting shape

The issue of projectibility on T & p in the compressible case (2/2)

$d(\mathbf{C_p}T)/dt - RT.d\,ln(p)/dt = Q'_0$ **&** $d\,ln(p)/dt + (C_p/C_v).D_3 = \mathbf{0}$

become

$d(\mathbf{C_v}T)/dt + RT.D_3 = Q'_0$ **&** $d\,ln(C_v p/\mathbf{R})/dt + (C_p/C_v).D_3 = \mathbf{Q'_0}/(CvT)$

i.e. we have to take into account the variation of **R** (of 'physical' origin)

Here R (for the multiphasic state) is defined by

$\boldsymbol{\rho.R = \rho_{gas}.R_{gas}}$

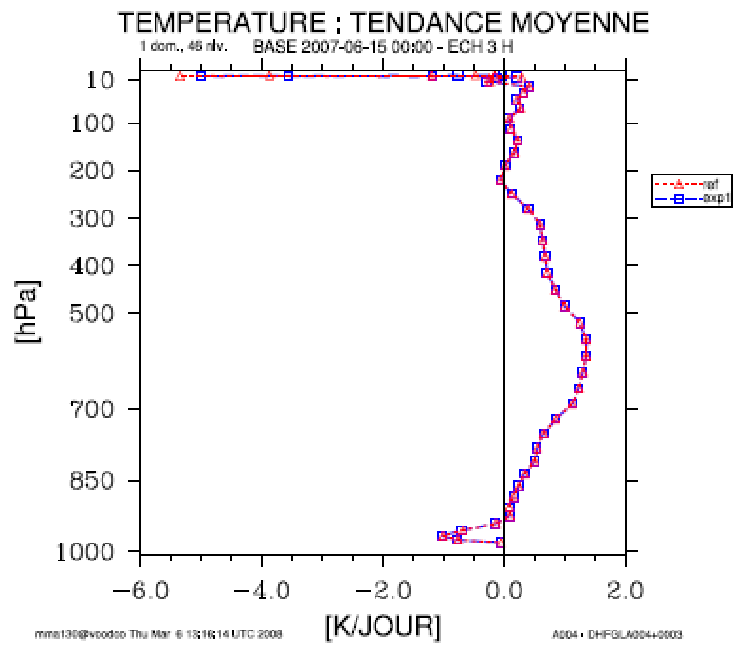
in order of course to avoid a problem similar to the LSPRT one

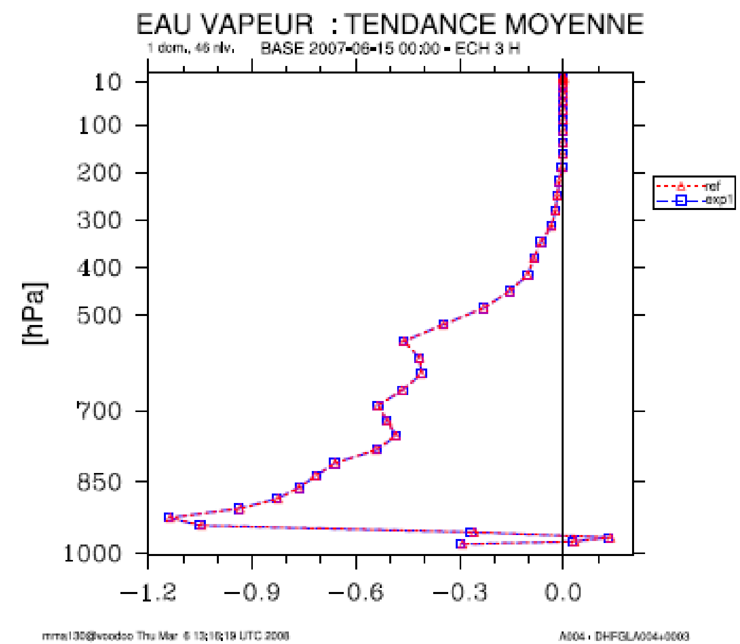
Test with the same case as twice previously ….

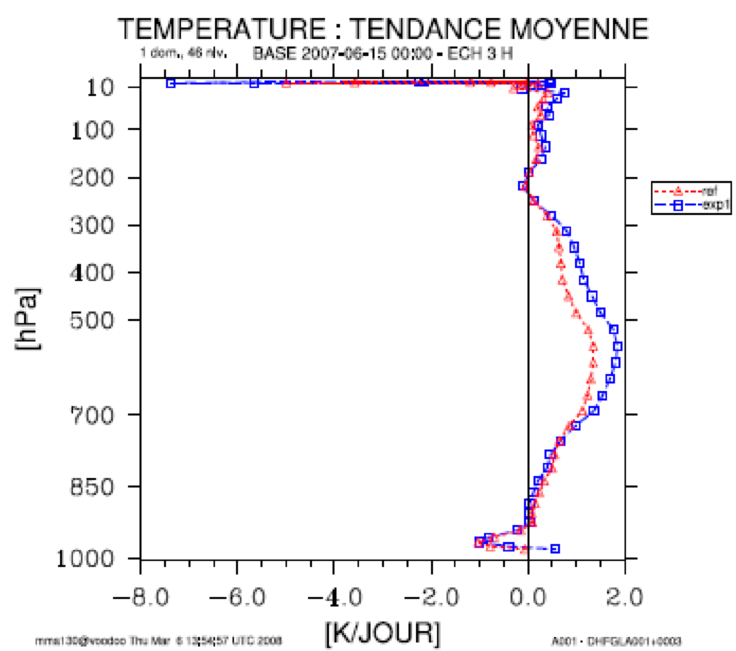
Some DDH study

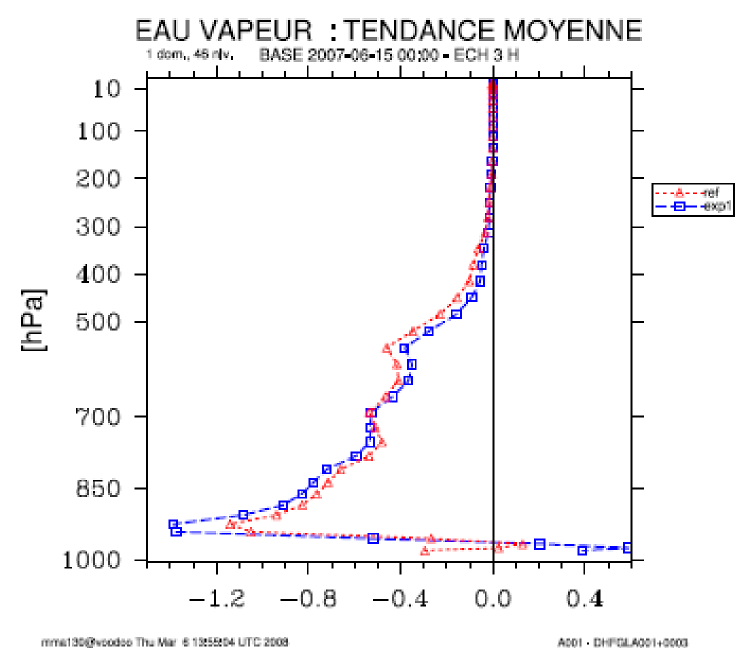
- When avoiding the extreme situation of the previously mentioned test, we look at the results from the very simple angle of the DDH tendency of T and q_v.
- This may appear too simplistic but it is already instructive!!

A strange result







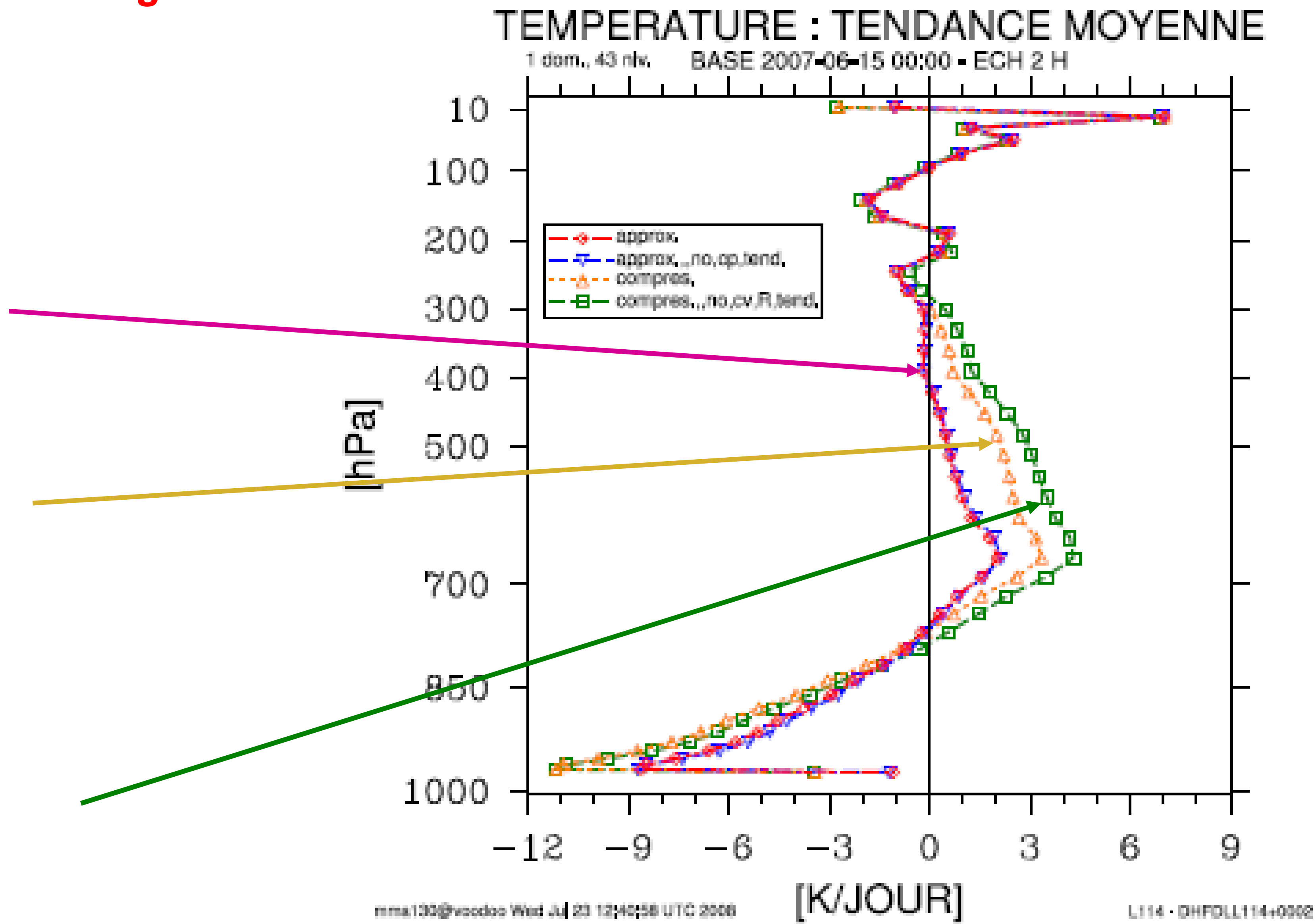


The problem is that the result was obtained in …

ARPEGE !!!

Even stranger (returning to ALADIN 9km)

Impact of the last test goes in the 'wrong' direction against 'intuition'



The problem of interpreting the ‘strange results’

- A coding bug is not excluded (despite many verifications)
- Sylvie recently proposed to look back at a rather strong ‘underlying’ hypothesis.
- This is the one consisting in computing ‘fluxes’ of C_pT+Phi and applying their divergence only to C_pT.
- As long as we are not having a pivoting role for dR/dt this is an ‘homogeneous’ assumption from one set-up to the next.
- But otherwise, it amounts to say that Phi is influenced by the RT variation only in terms of R.dt/dt, which is certainly inconsistant!
- **A track to study** …