ALARO-1: an overview

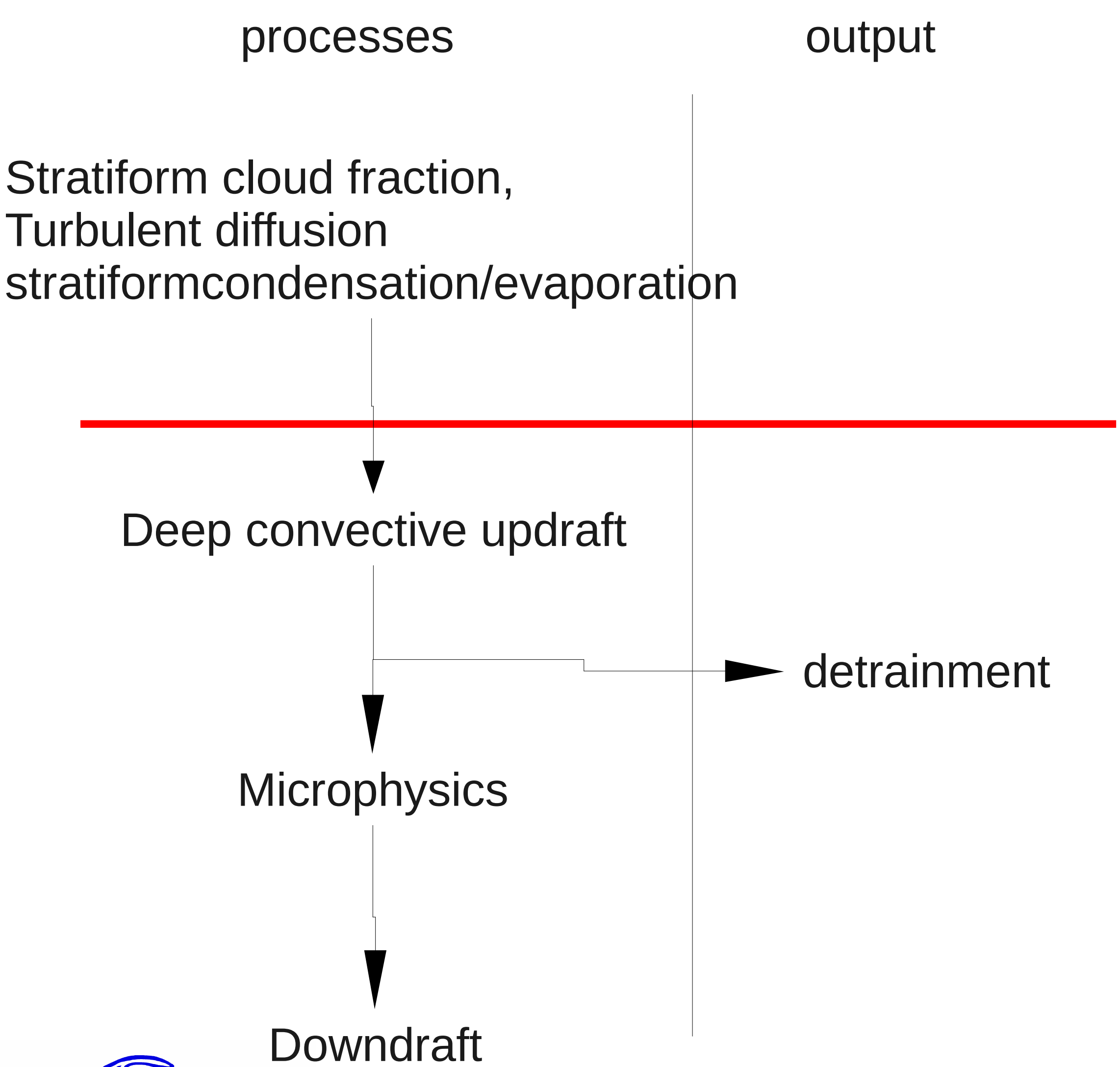
Piet Termonia

Reporting work of many others

Outline

- Rationale
- Scientific innovations:
  - TOUCANS
  - ACRANEB
  - Cellular Automata
- In the pipeline: CSU
- Assemblage of the latest development into ALARO-1: planning foreseen during the meeting 13-15 June, Ljubljana.

3MT: **M**icrophysics and **T**ransport

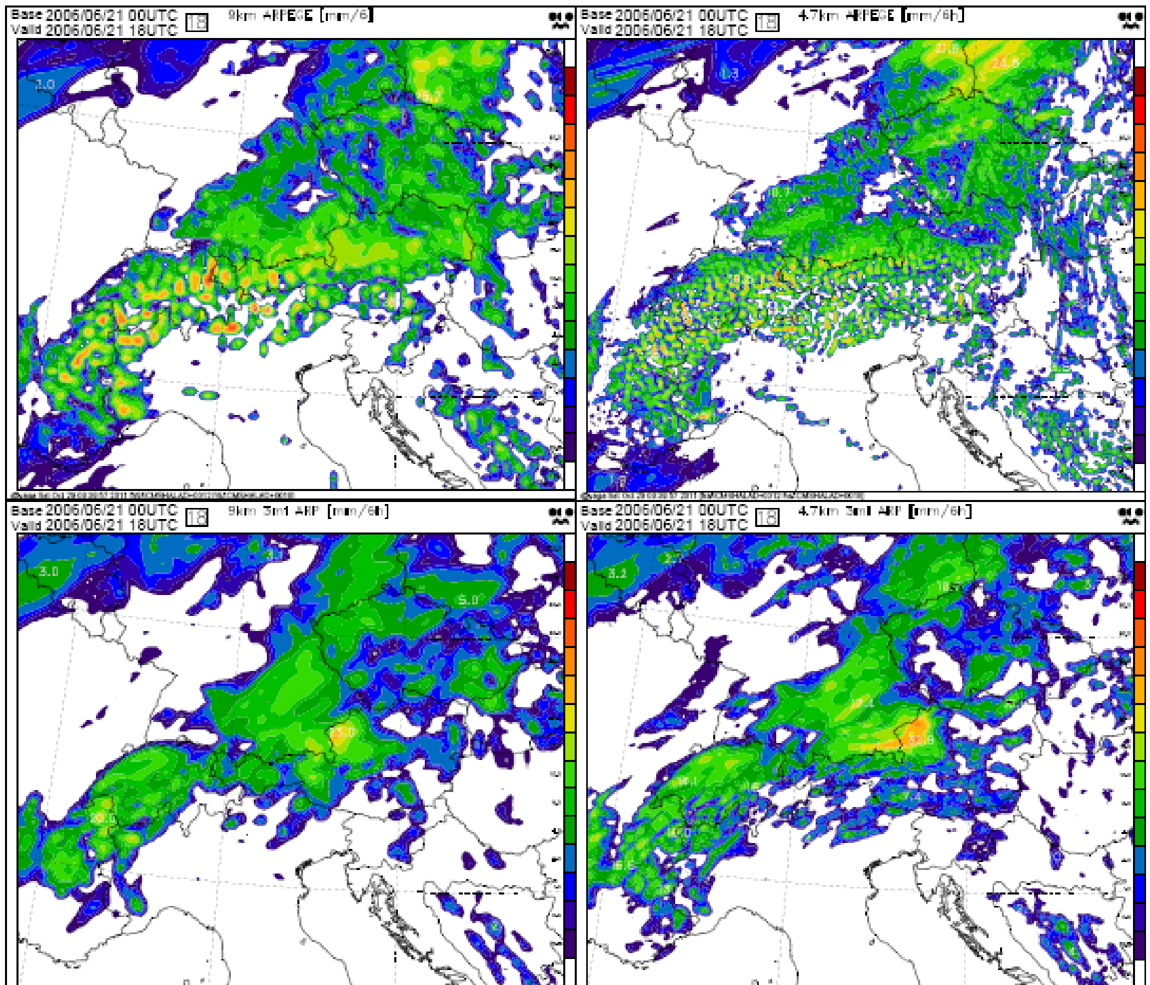


- Stands for Modular, Multi scale, Microphysics and Transport
- Key elements are:
  - It avoids **double counting** of (resolved and parametrized) precipitable water
  - There is no need to prescribe **detrainment, it is computed and it is "given back" to the dynamics** by relying on the MT concept of Piriou (2007).
  - It has a convective **memory** by prognostic mass fluxes.
  - Sequential coupling (while still producing the output in parallel) facilitates **conservation** properties

Running 3MT in the APREGE model.

9km ARPEGE

4km ARPEGE



9km 3MT

4km 3MT

Experiments and the rationale behind 3MT-in-ARPEGE

“When I was at Cornell, I often talked to the people in the psychology department. One of the students told me she wanted to do an experiment that went something like this--it had been found by others that under certain circumstances, X, rats did something, A. She was curious as to whether, if she changed the circumstances to Y, they would still do A. So her proposal was to do the experiment under circumstances Y and see if they still did A.

I explained to her that it was necessary first to repeat in her laboratory the experiment of the other person--to do it under condition X to see if she could also get result A, and then change to Y and see if A changed. Then she would know the real difference was the thing she thought she had under control.

She was very delighted with this new idea, and went to her professor. And his reply was, no, you cannot do that, because the experiment has already been done and you would be wasting time.”

R. Feynman, 1974, Caltech

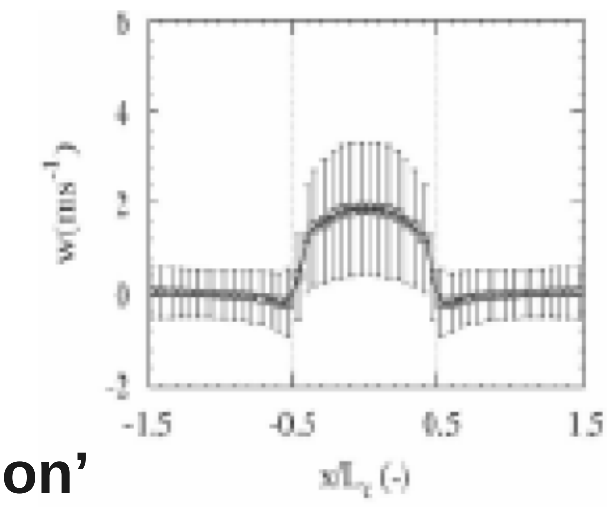
Think of the model code as your lab. You can fill in X as “mesoscale”, A as consolidated model performance, and Y Convection permitting scale ...

3MT: Modularity

- At the code side: the M/T split, the cascade and the specific approach to the protection of the convective cloud fraction, makes it quite modular.
- For instance it has been demonstrated by the work of R. Brožková, that the code organization of 3MT can be realized in a general enough manner to make several cross combinations (this was done by making to code ready to use 3MT in ARPEGE):
  - Two radiation schemes (RRTM/FMR compared to the ACRANEB of the ALARO scheme)
  - different types of vertical diffusion (the old ARPEGE type ACDIFUS, CBR, and KFB)
  - Lopez microphysics
  - Mountain drag of ARPEGE (compared to the one in ALARO)

3MT and shallow convection:

- The spirit of 3MT should in principle allow to treat any kind of convection (precipitating [like up to now], non-precipitating, dry).
- But the link with the ‘resolved’ condensation requires that the convective part connects the ‘thermal’ with the environment (Transport = return current outside).
- Convective clouds have a ‘shell’ of subsident motions, (Heus and Jonkers 2003)
- So shallow convection cannot enter the 3MT logic.
- **This lead to the decision to treat ‘shallow convection’ on the turbulent side .**



TOUCANS


Third
Order moments
Unified
Condensation
Accounting and
N-dependent
Solver (for turbulence
and diffusion)

TOUCANS

$$\frac{de}{dt} = -\frac{\partial}{\partial z}\left(\overline{e'w'} + \frac{\overline{p'w'}}{\rho}\right) + I + II + III$$

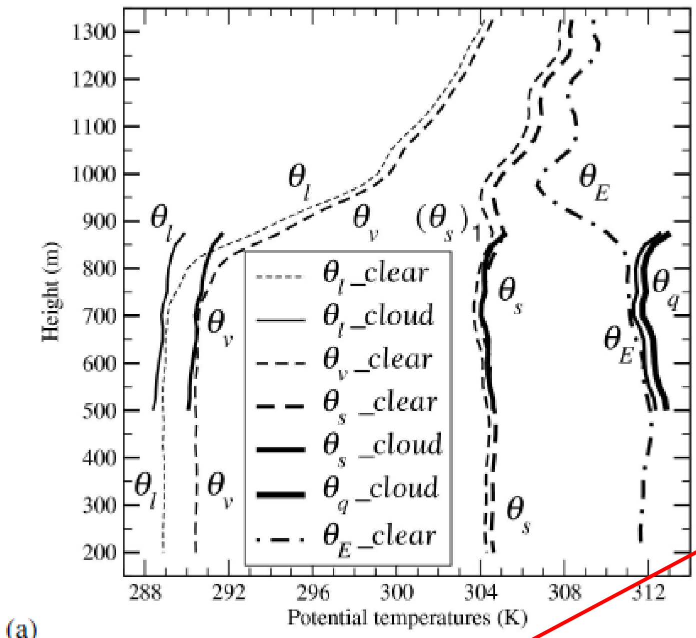
I (wind shear) and II (buoyancy) from
CBR (Cruxart, Bougeault, Redelsperger, 2000)

$$\frac{de}{dt} = -\frac{\partial}{\partial z}\left(\overline{-K_E\frac{\partial e}{\partial z}}\right) + \frac{1}{\tau_\epsilon}(\tilde{e} - e)$$

$$\tilde{e} = \frac{e}{\epsilon}(I + II)$$

- As an extension of the old Louis type formulation
- Allows to implement several ideas:
  - No critical Ri
    - Cheng et al. 2002, CCH02
    - Sukoriansky et al. 2006)
  - Anisotropy of turbulence
  - Prognostic TKE
  - Third-order moments
  - Shallow convection within turbulence

P. Marquet and J-F Geleyn: SC by a turbulence description, a step forward based on Marquet's moist entropy potential temperature



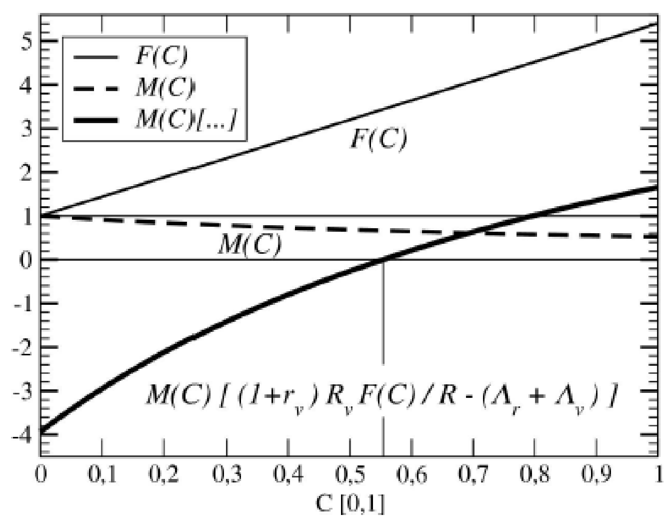
$$
\begin{aligned}
N^2(C) &= g\,M(C)\left(\frac{\partial \ln(\theta_s)}{\partial z}\right)_E + g\left(\frac{\partial \ln(q_d)}{\partial z}\right)_E \\
&+ g\,M(C)\,F(C)\left[(1+r_v)\,\frac{R_v}{R}\right]_E\left(\frac{\partial q_t}{\partial z}\right)_E \\
&- g\,M(C)\,[\,\Lambda_r+\Lambda_v\,]_E\left(\frac{\partial q_t}{\partial z}\right)_E . \qquad \text{(F.4)}
\end{aligned}
$$

C=0

C=1

Unsaturated moist air

$$
\begin{aligned}
N^2_{ns} &= \Gamma_{ns}\,\frac{\partial s}{\partial z} + g\,\frac{\partial \ln(q_d)}{\partial z} \\
&+ \Gamma_{ns}\left[(1+r_v)\,\frac{c_p\,R_v}{R} - c_{pd}\,(\Lambda_r+\Lambda_v)\right]\frac{\partial q_v}{\partial z} .
\end{aligned}
$$



Saturated moist air

$$
\begin{aligned}
N^2_{sw} &= \Gamma_{sw}\,\frac{\partial s}{\partial z} + g\,\frac{\partial \ln(q_d)}{\partial z} \\
&+ \Gamma_{sw}\left[(1+r_{sw})\,\frac{L_{vap}}{T} - c_{pd}\,(\Lambda_r+\Lambda_{sw})\right]\frac{\partial q_t}{\partial z}
\end{aligned}
$$

Shallow convective cloudiness

Compute the Richardson number corresponding to N2(C)

$$Ri_m = \left[gM(C)\left(\frac{\partial \ln(\theta_{s_1})}{\partial z}\right) - g\frac{\frac{\partial q_t}{\partial z}}{1-q_t} + gM(C)\left((1+r_v)\frac{R_v}{R_d.q_d + R_v.q_v}F(C) - \Lambda\right)\frac{\partial q_t}{\partial z}\right] \cdot \frac{1}{\left[\frac{\partial u}{\partial z}\right]^2 + \left[\frac{\partial v}{\partial z}\right]^2} \qquad (42)$$

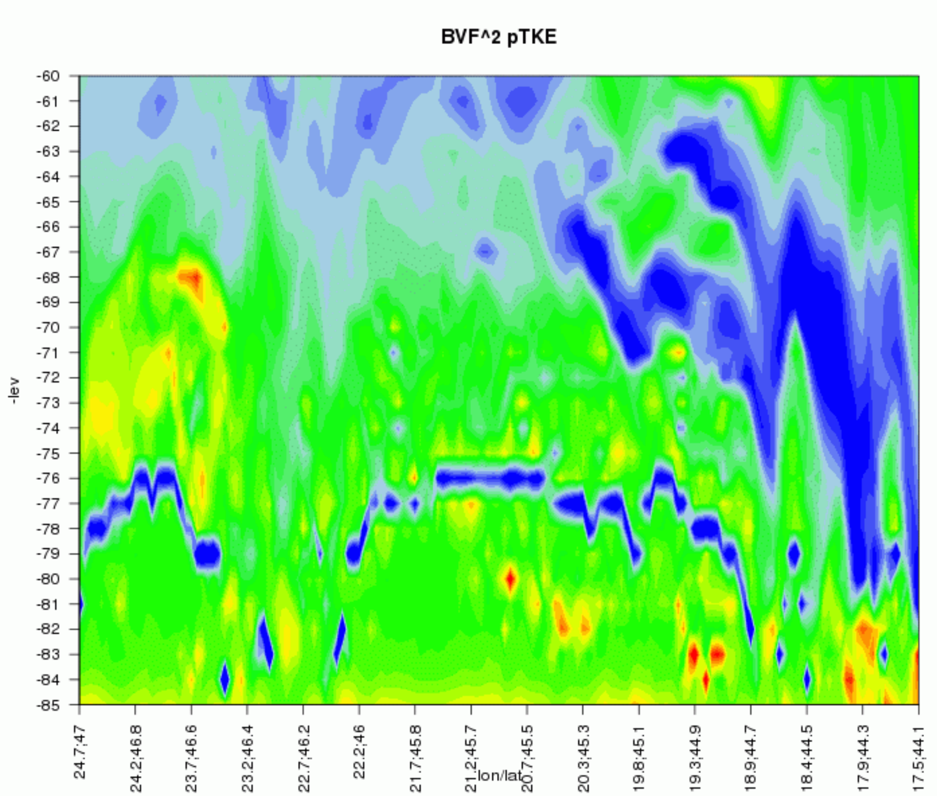
Shallow cloudiness is based the comparison of the TKE Ri: Ri' with Rim, e.g for CCH

$$\mathrm{SCC} = \frac{Ri'' - Ri_d}{Ri_m - Ri_d} \quad ,$$

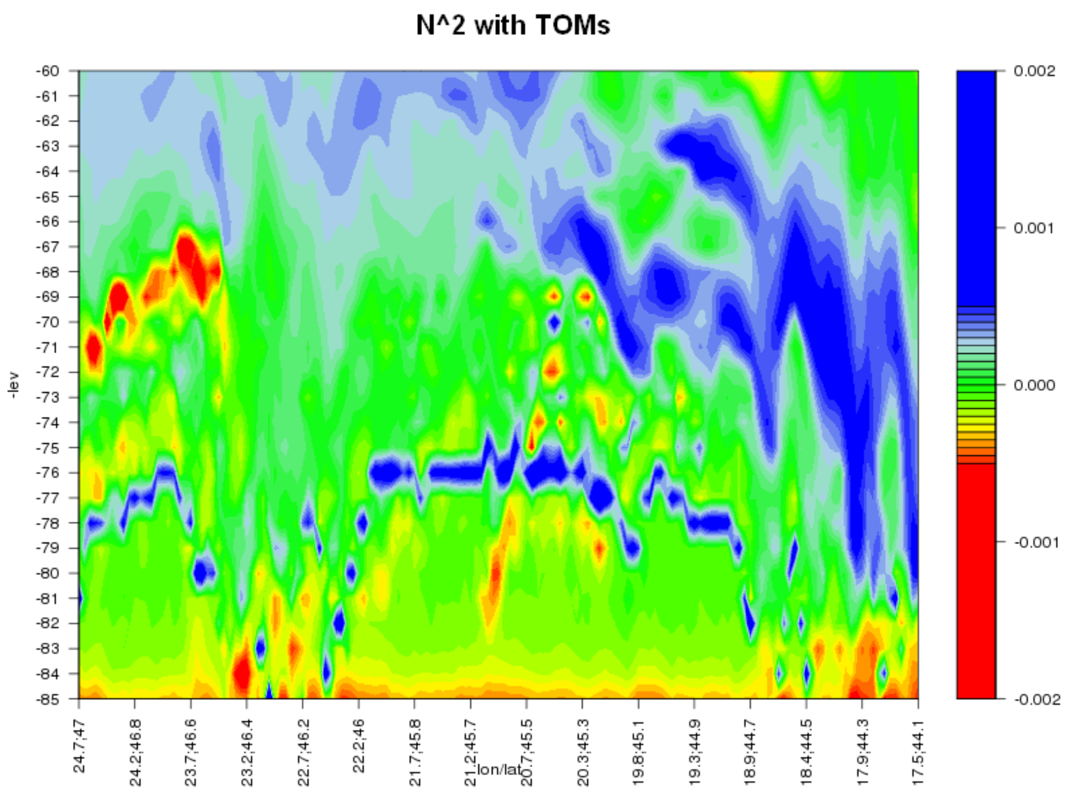
$$Ri'' = \min(\max(Ri_d, Ri'), Ri_m) \quad .$$

TOUCANS scheme: the effect of TOMS

PseudoTKE (current)



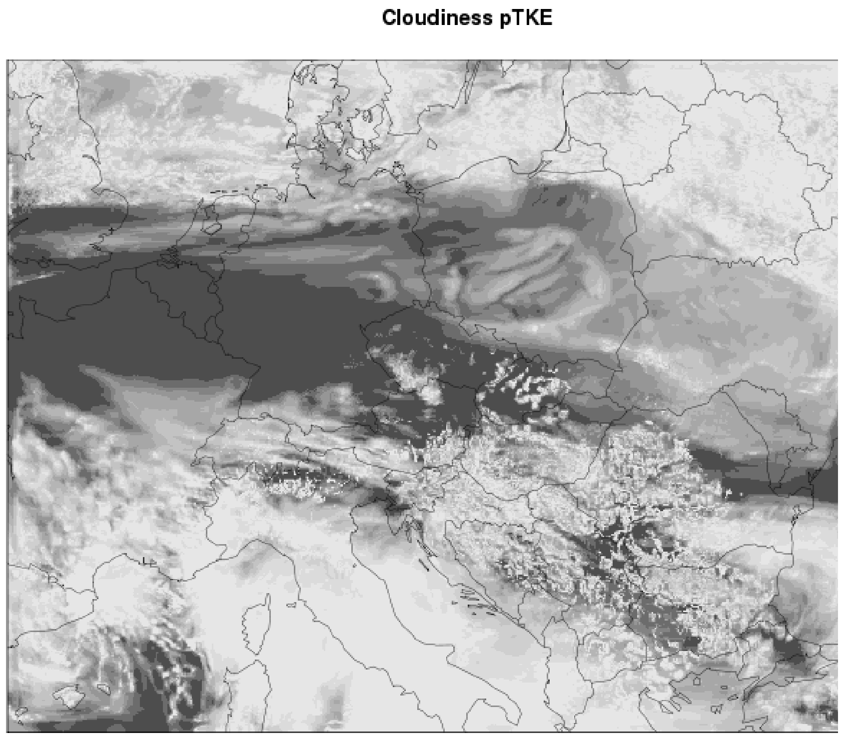
TOUCANS with Third Order Moments



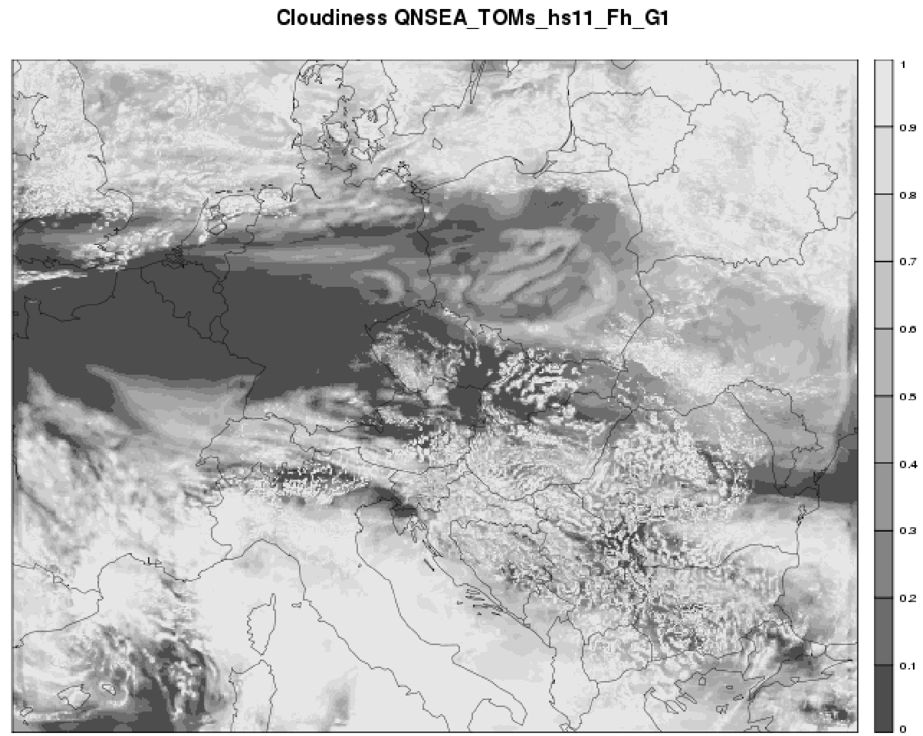
Vertical cross section for Brunt Vaisalla frequency (BVF)
(30h of integration, start at 3.3.2011 6:00 am, operational CHMI horizontal and vertical resolution)

TOUCANS scheme

PseudoTKE (current)



TOUCANS with Third Order Moments

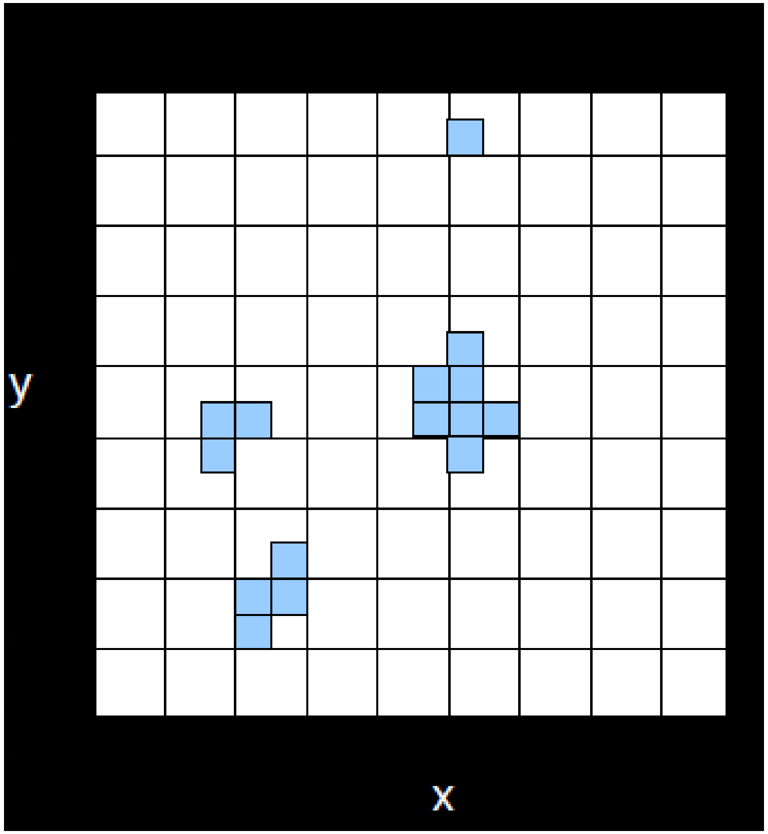


more shallow convection (inversion) clouds, but disappearing to during the daytime.

Controlling the stochastic aspects:

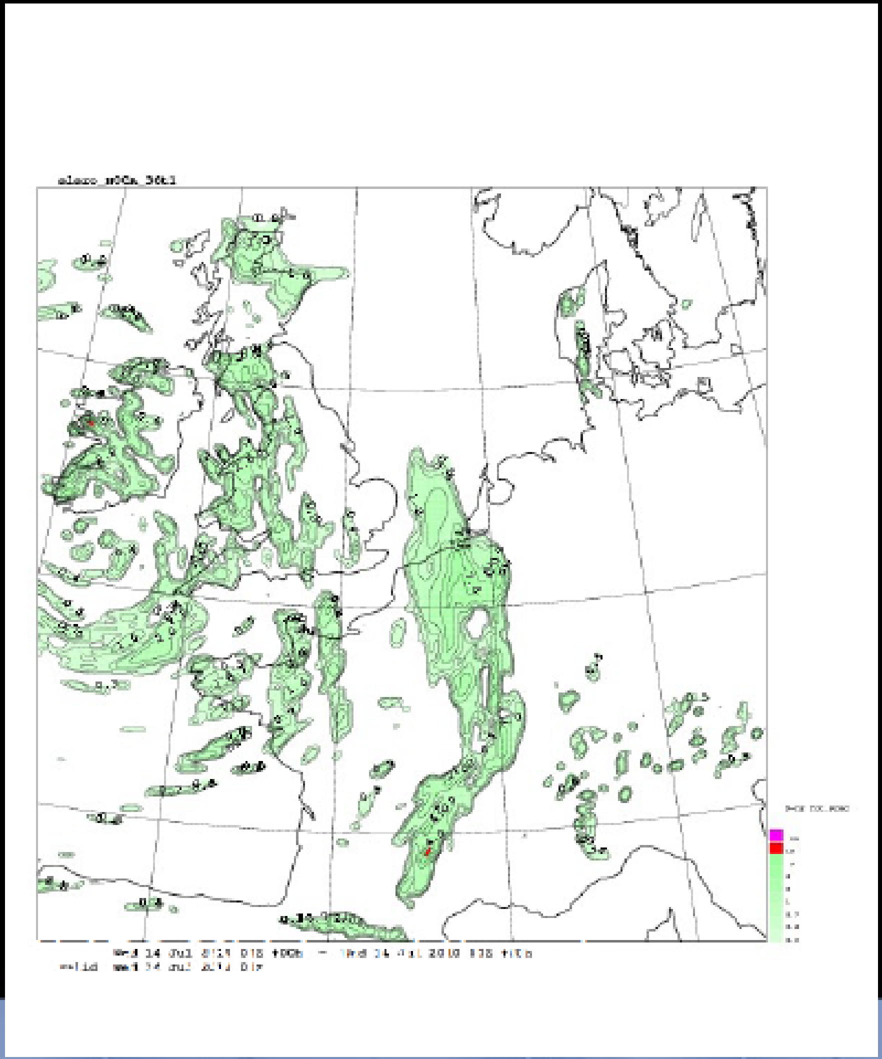
Cellular automata (CA)

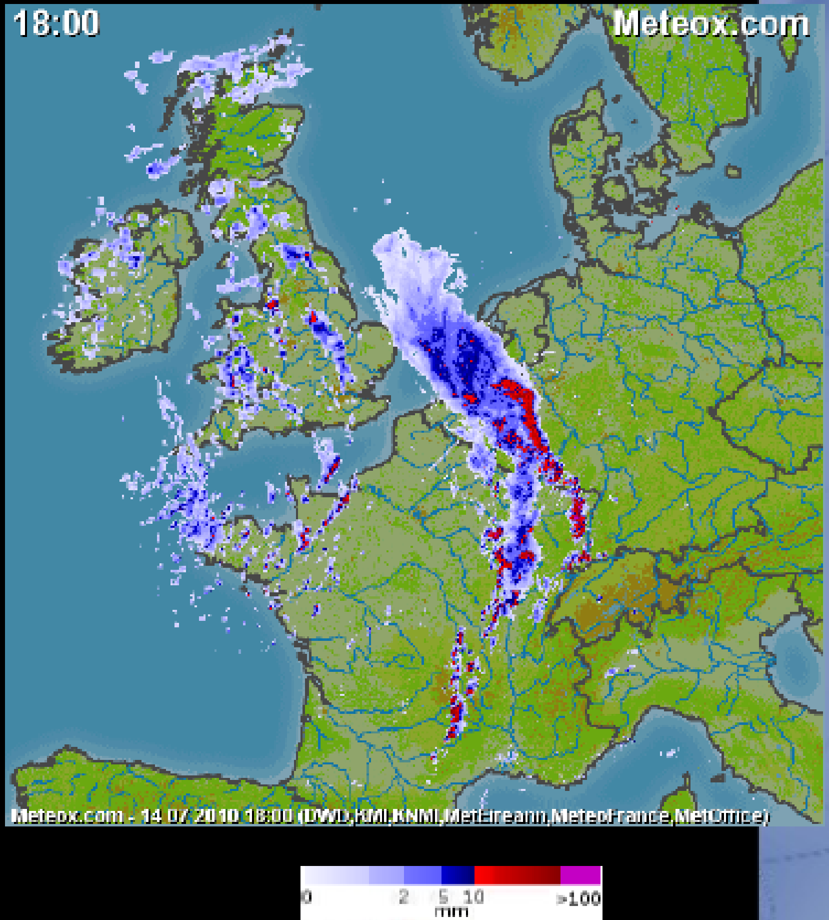
Stochasticity: Cellular automata
Lisa Bengtsson



- Palmer (2001), Shutts (2005) and Berner (2008): use cellular automata to generate stochasticity.
- The aim is to add some stochasticity with sufficient back scattering
- In this work it is implemented in the deterministic model.
- It has *stochasticity*, *laterality* and *memory*

Radar image, squalline 14/7-10
16 UTC (or 18 CET)

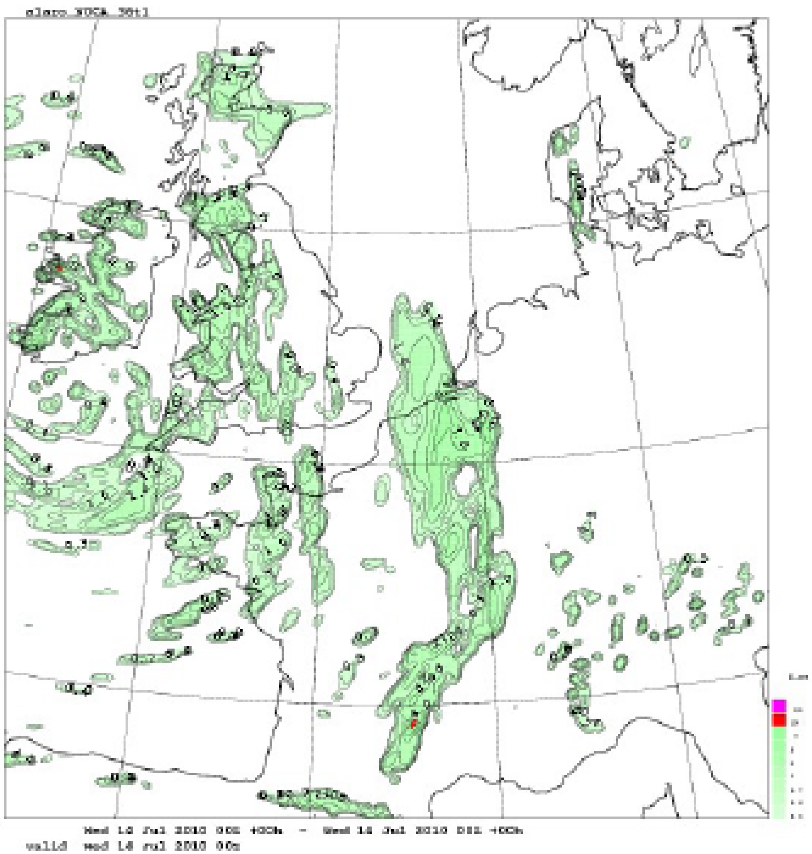




1 hour precip from radar image.

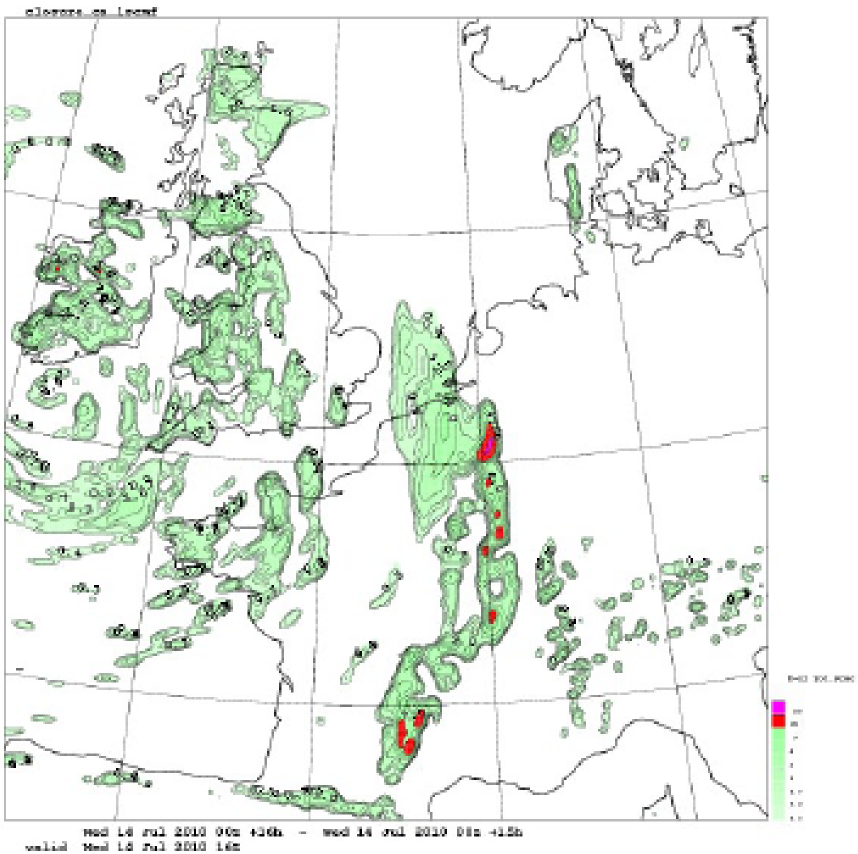
Total precipitation, 2010-07-14, 16 UTC

ALARO reference, 36h1.1



16 UTC

ALARO CA-CAPECONV, 36h1.1

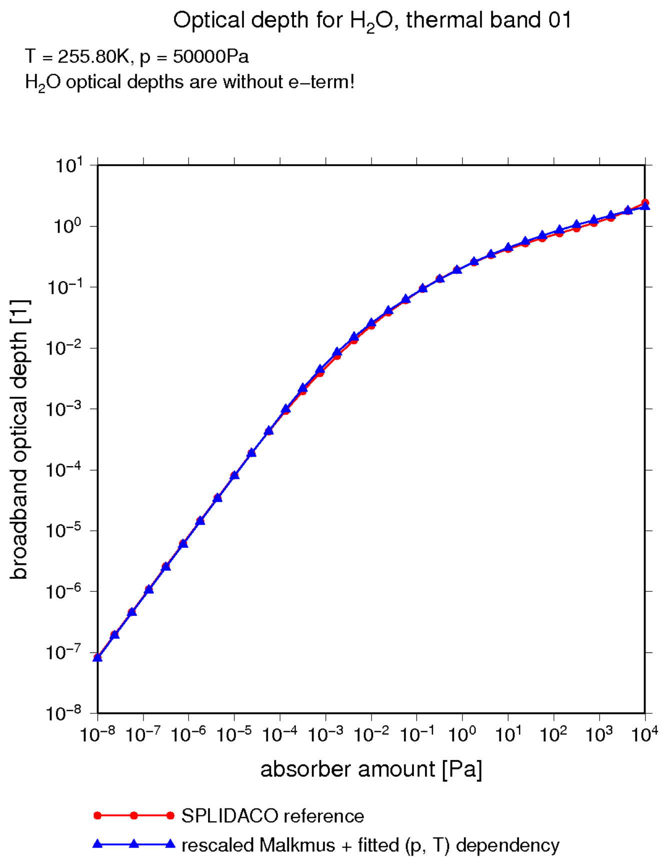


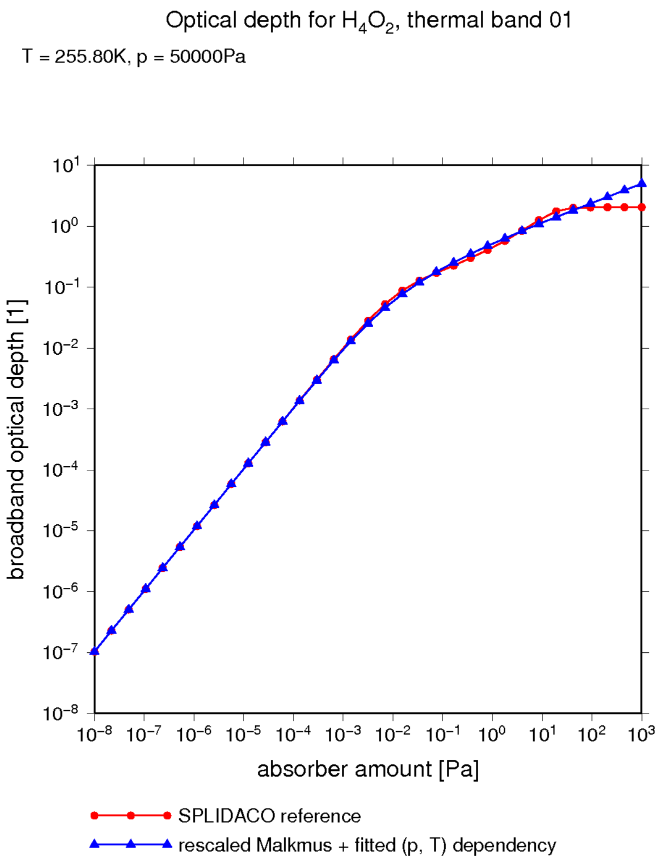
16 UTC

ACRANEB

- The Pade fit is now replaced by a rescaling method within the Malkmus formula adding only two fitting parameters.
- The e-type continuum is now computed with by a modified overlap between H_2O and H_4O_2

Radiation



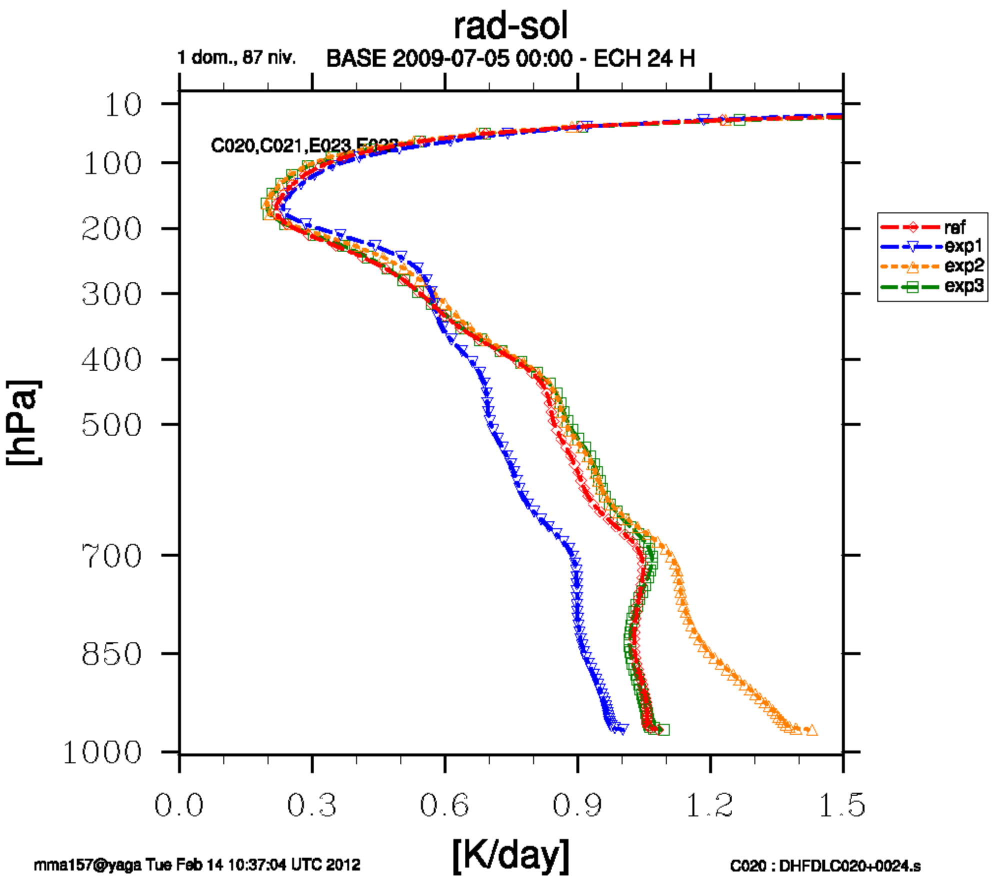


Optical depth for H2O and H4O2, homogeneous case

saturation of SPLIDACO reference red curve at right edge is not realistic

Radiation

solar heating rates



red - FMR reference

blue - current ACRANEB
(no overlaps or e-type in solar)

yellow - new ACRANEB with solar e-type but ignoring overlaps

green - new ACRANEB with solar e-type and all 6 pair overlaps (H_2O-H_4O_2 being the most important one, the others could be neglected in solar).

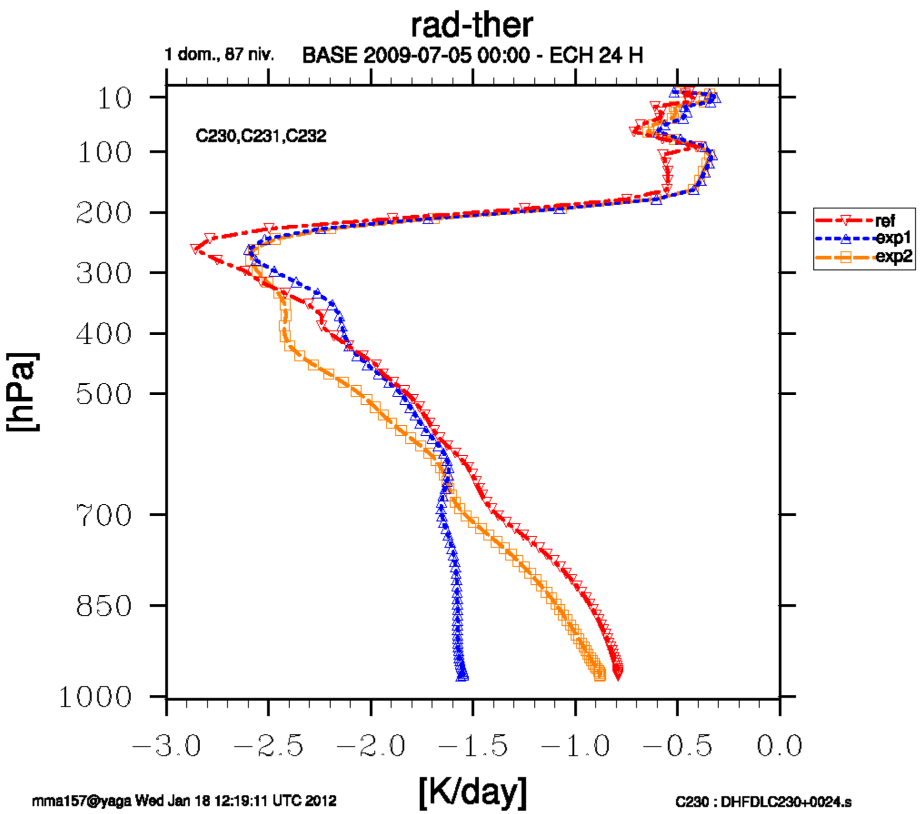
isothermal simulation with full model

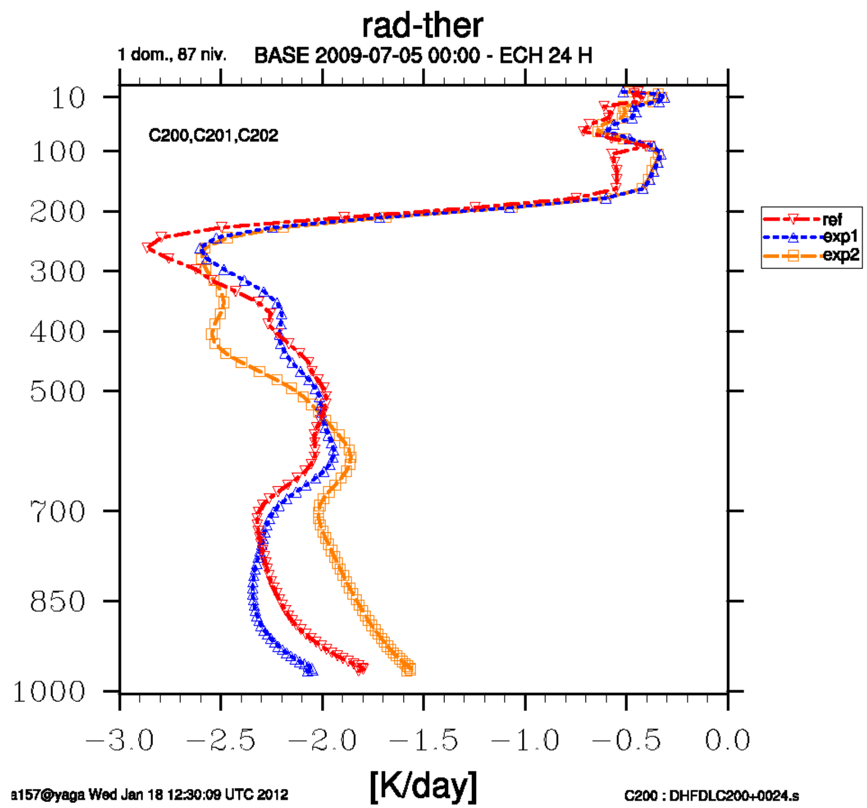
red - RRTM

blue - current ACRANEB

yellow - new ACRANEB

radiative cooling rates





isothermal simulation with full model

only H2O without e-type being radiatively active.

including e-type continuum (considering overlaps with H2O)

In the pipeline, as an extra

To illustrate the potential in the potential in the

Multiscale

CSU scheme triggering

- 3D academic experiment (WK), single profile with CAPE,
  3-km radius θ perturbation ($<$2K) at the center of domain, zonal wind shear,
  no orography, 85 p-levels.

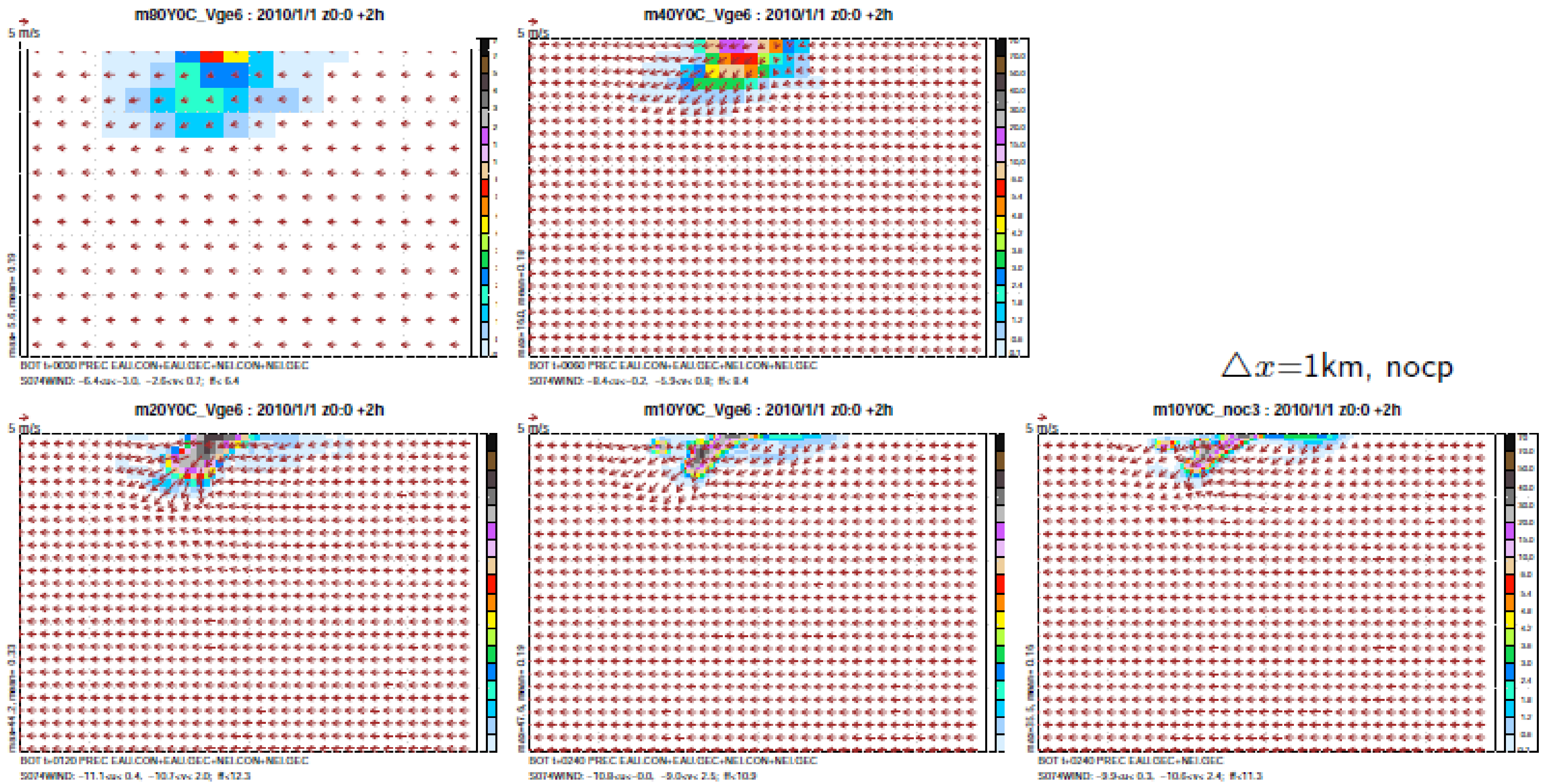
- CSU scheme, CAPE (PEC) closure, τ=3h, NH dynamics, no radiation.

- Triggering is crucial (very weak forcing): the new method follows the CSU concept, depending on resolved condensation.

- Half of domain shown, 2h-accumulated precipitation, total and subgrid
  $\triangle x$= 8, 4, 2, 1km.

CSU scheme triggering

$\triangle x$=8km $\triangle x$=4km

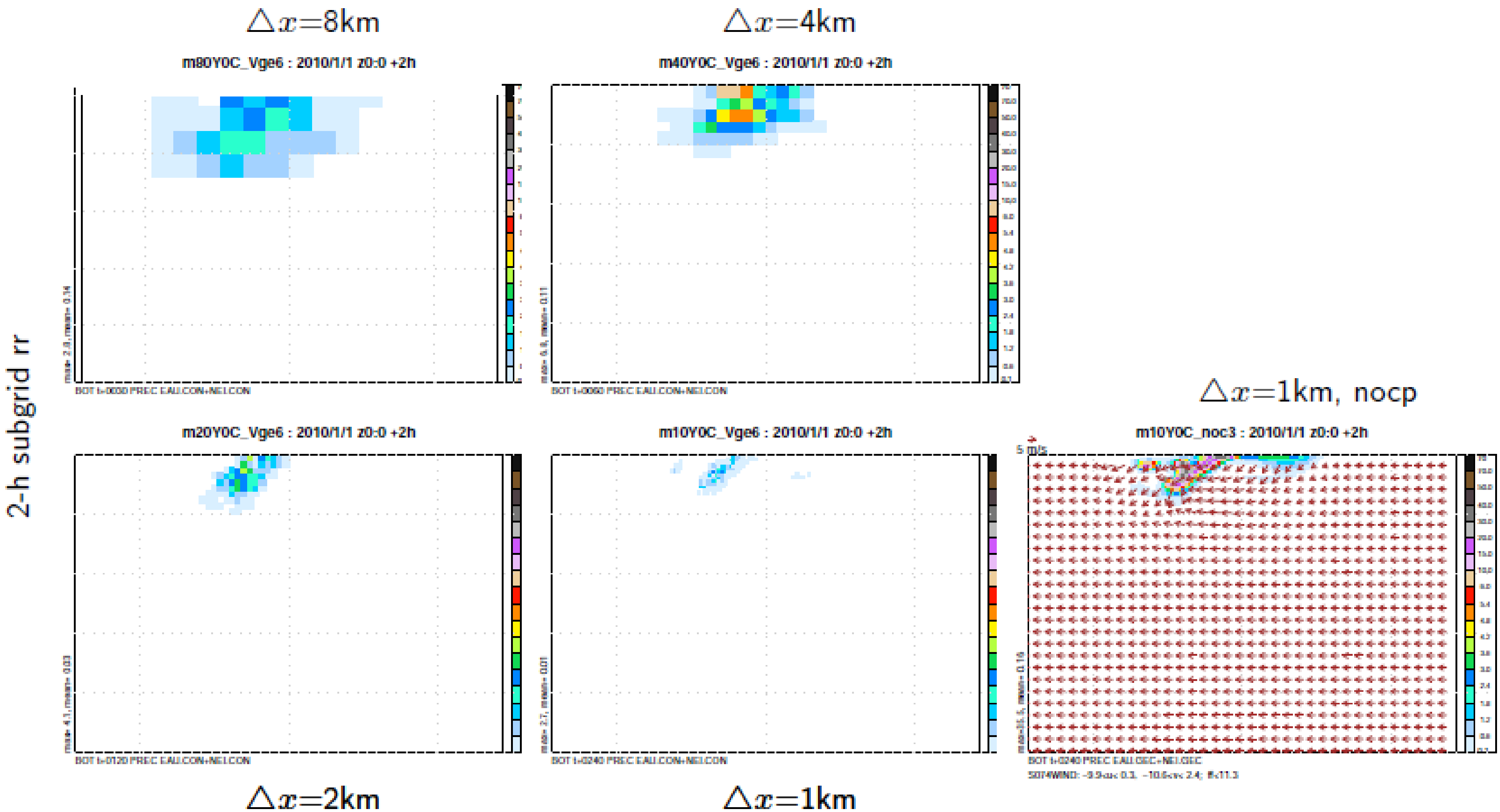


2-h surf rr

$\triangle x$=1km, nocp

$\triangle x$=2km $\triangle x$=1km

CSU scheme triggering



Next step

- ALARO-1 meeting, 13-15 June 2012, Ljubljana: Assemblage into ALARO-1