The grey-zone challenge

Luc Gerard

28 March 2007

RMI

Topics

1. Large-scale equations
2. The Cloud-Resolving Model
   – Observations
3. The Coarse-Resolution Model
   – Discretisation and Averaging
   – Resolved fraction
   – The parametrization problem
4. High Resolution LAM
   – Physical processes interaction
   – Makeshift solutions
   – Benefits of our solution
5. Fair share of a single resource
6. General layout
7. Grey zone manifestations
8. Conclusions

The context of parametrization

$$\frac{\partial \overline{s}}{\partial t} + \overline{\mathbf{V}} \cdot \nabla \overline{s} + \overline{\omega} \frac{\partial \overline{s}}{\partial p} = L \cdot (\mathcal{C} - \mathcal{E}) + C_p \cdot Q_R - \frac{\partial \overline{\omega' s'}}{\partial p} - \left(\frac{\partial \overline{u' s'}}{\partial x} + \frac{\partial \overline{v' s'}}{\partial y} \right)$$

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    - becomes partly resolved by horizontal grid...

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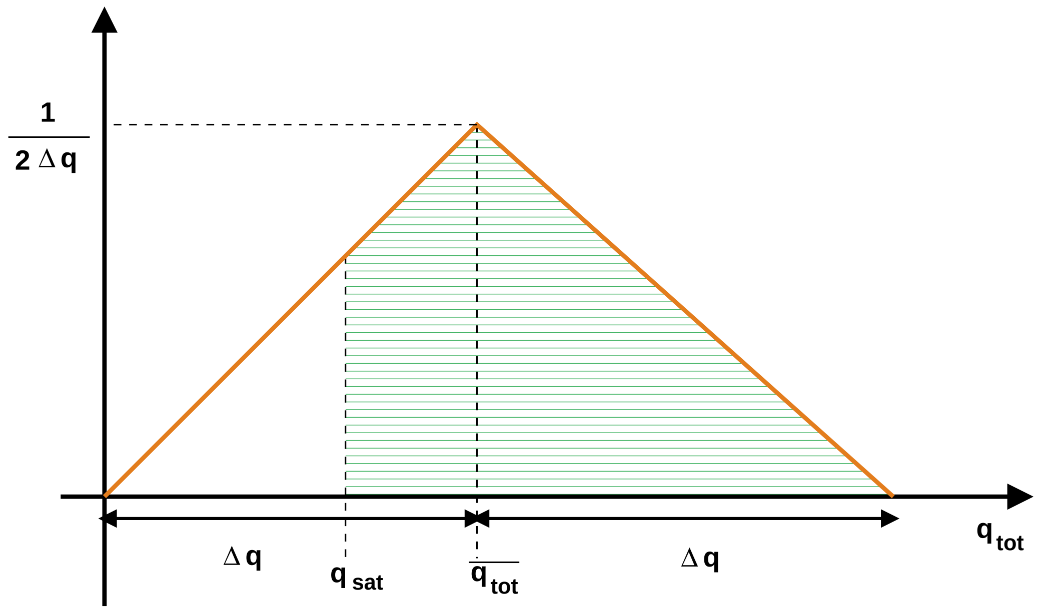

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⇒ no need of specific parametrization for deep convection,...
...for resolutions finer than... ?

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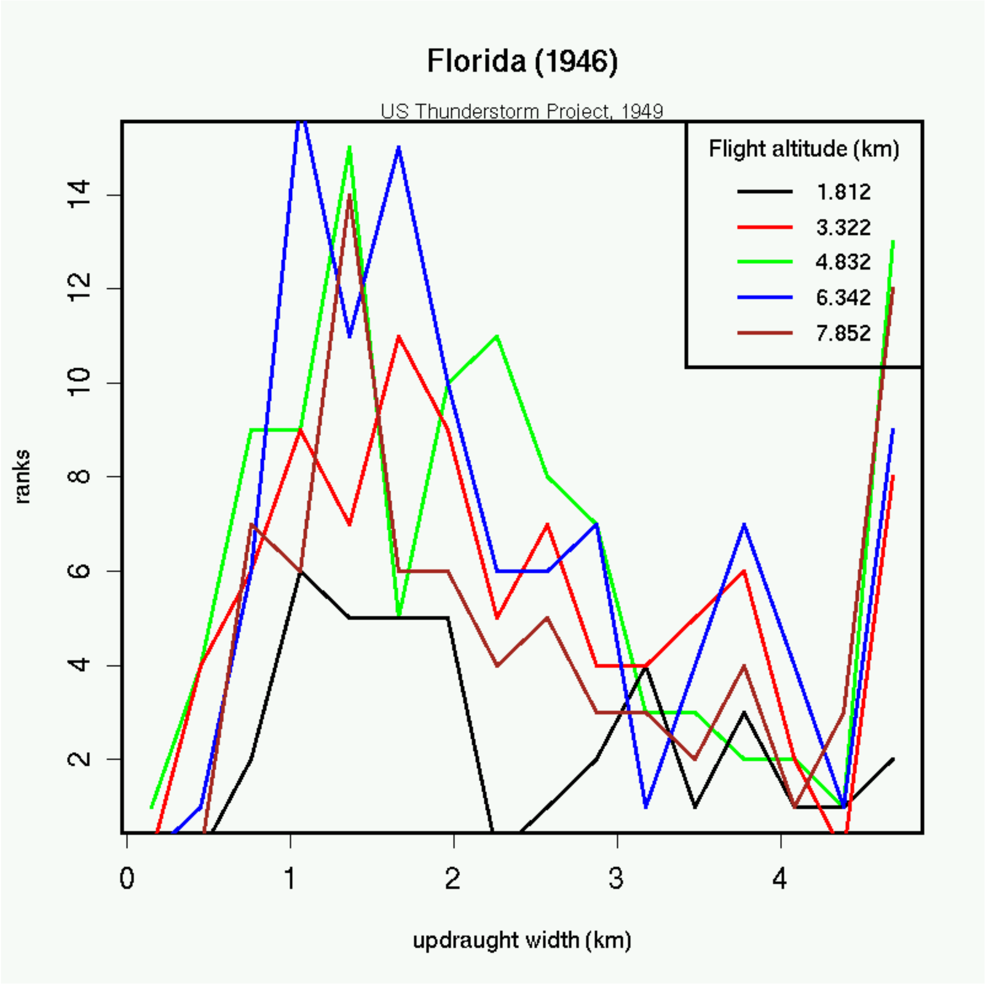
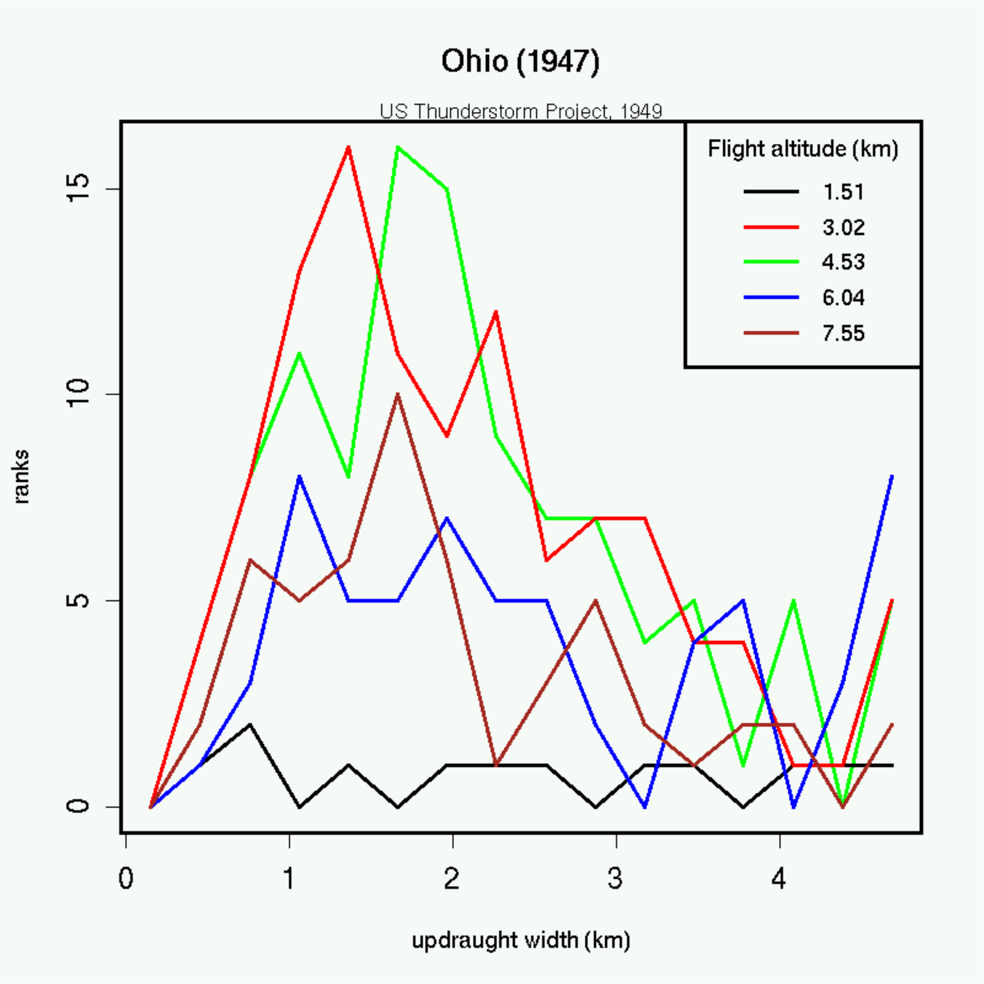
Observed individual cell widths





Single updraught width often between 500m and 4km – wider above

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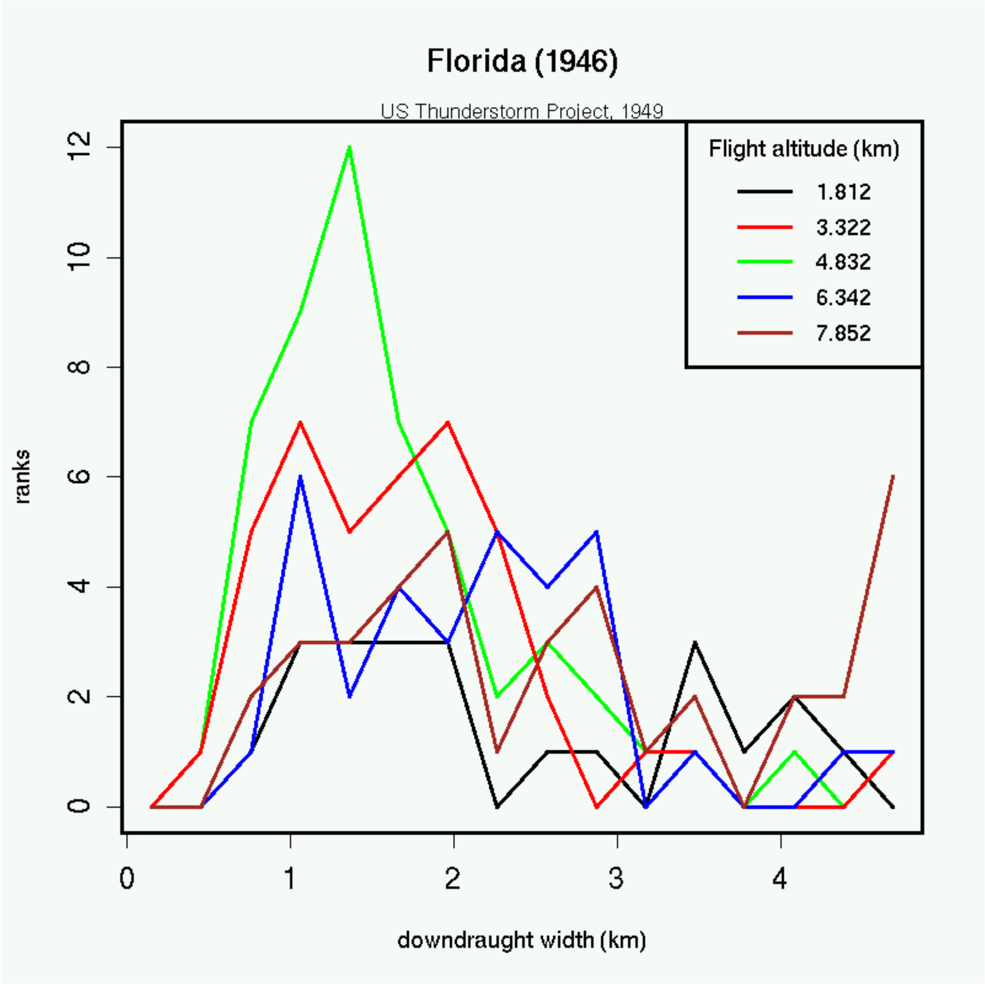

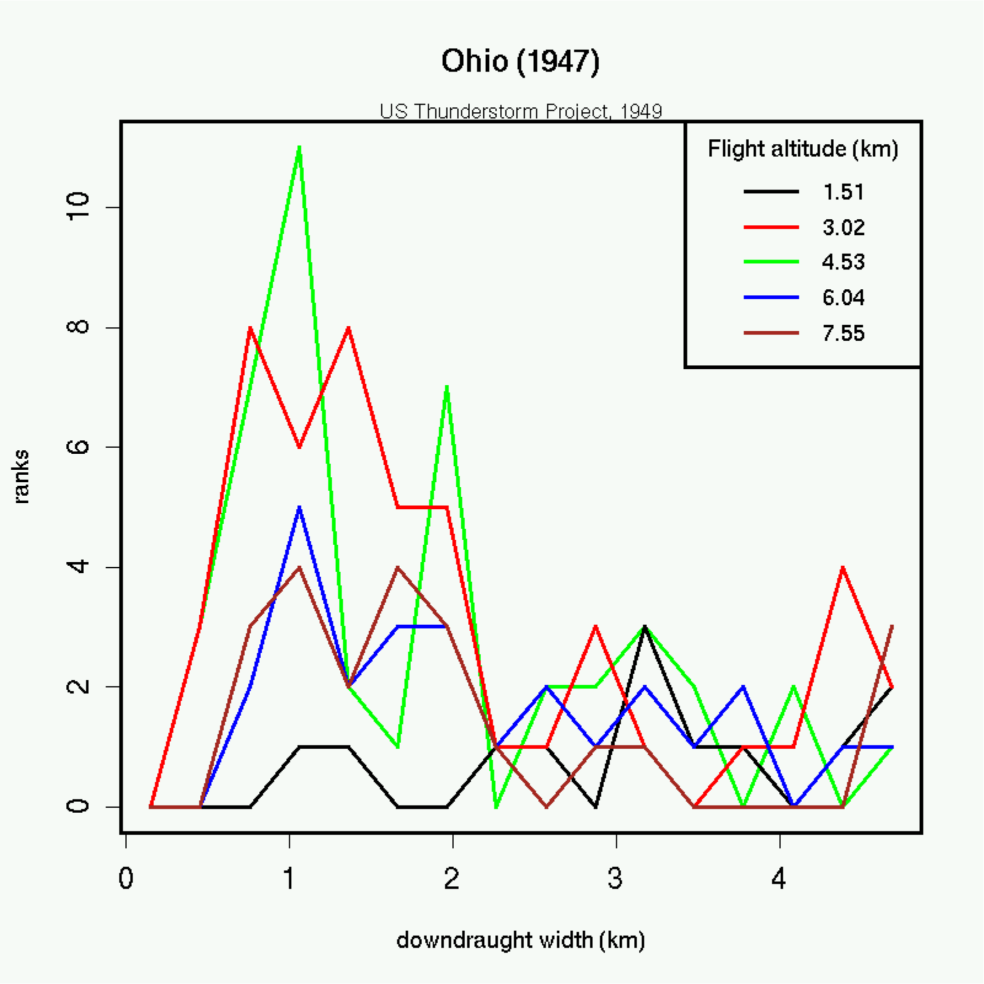

Single updraught width often between 500m and 4km – wider above

Single downdraught width often between 500m and 2km – wider below

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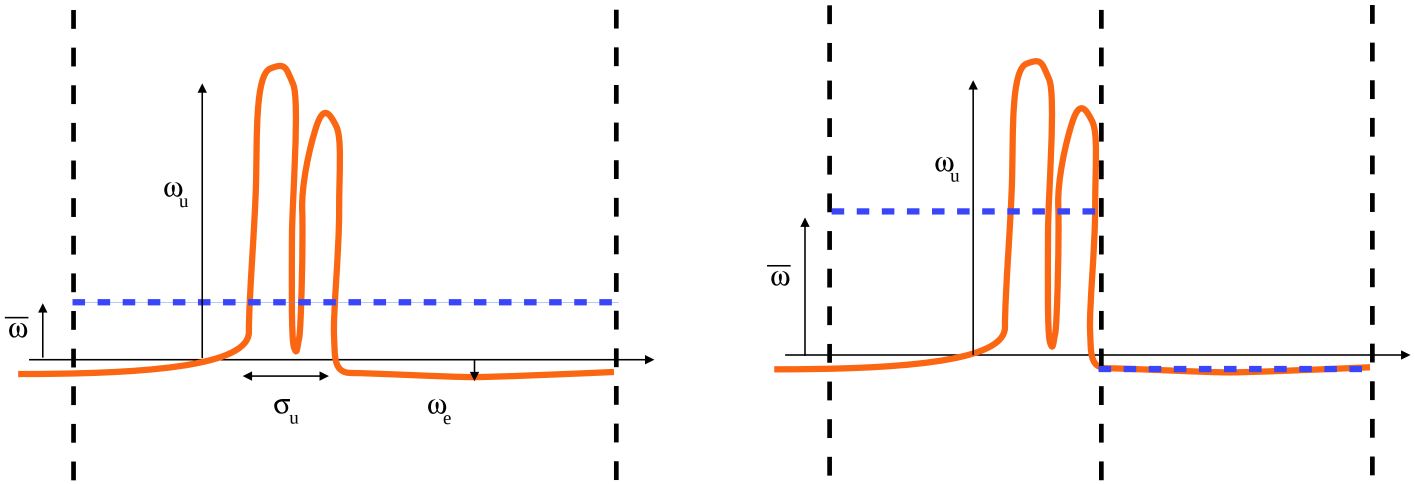
Horizontal resolution and averaging

Local saturation is correlated with the local vertical motion.



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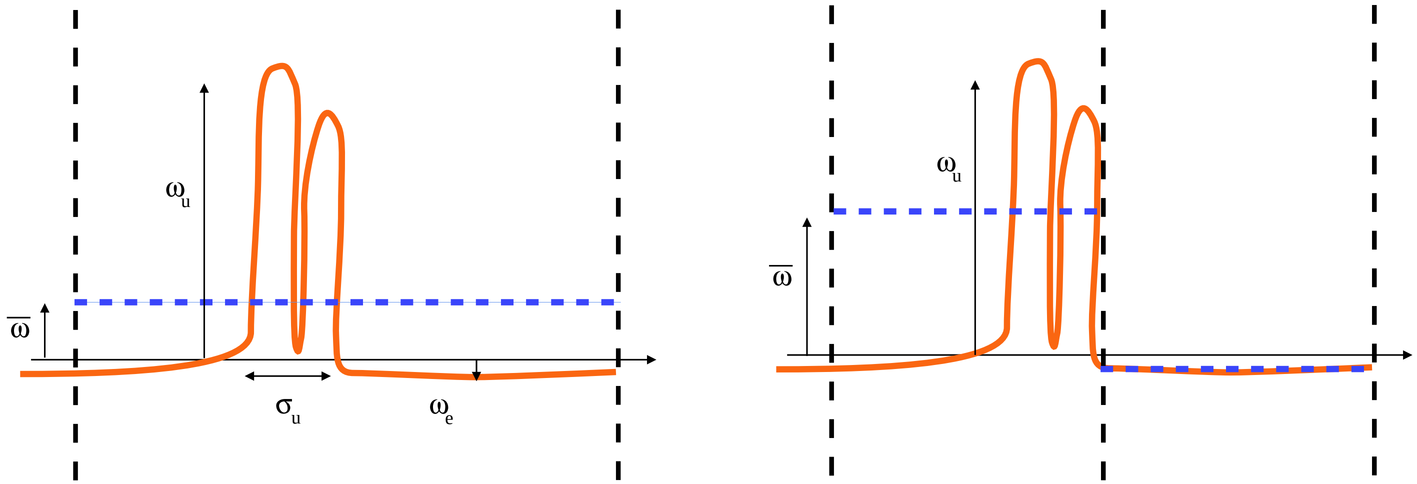

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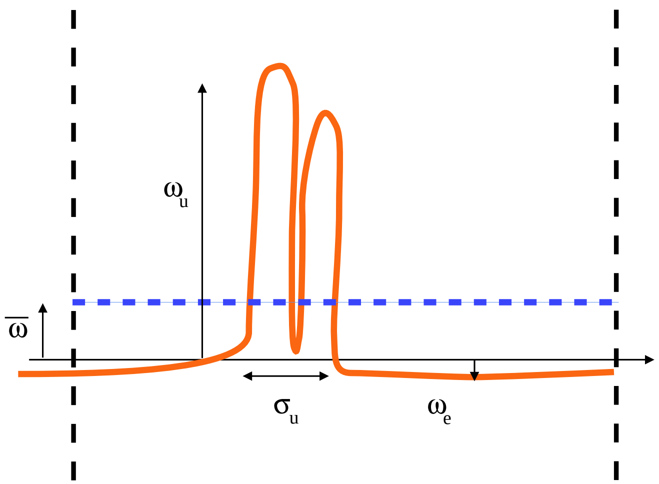

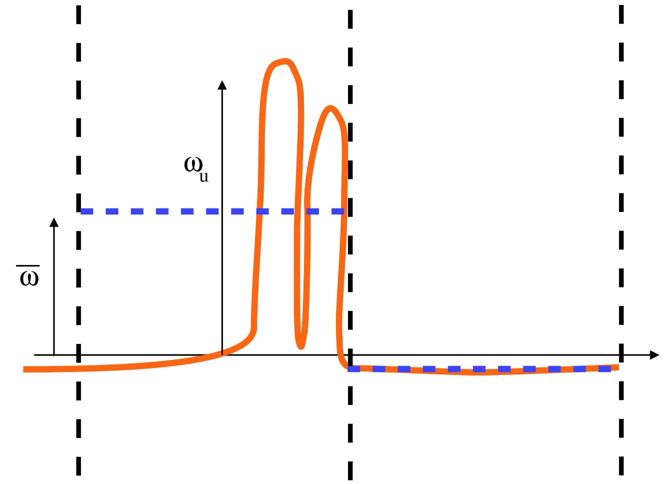

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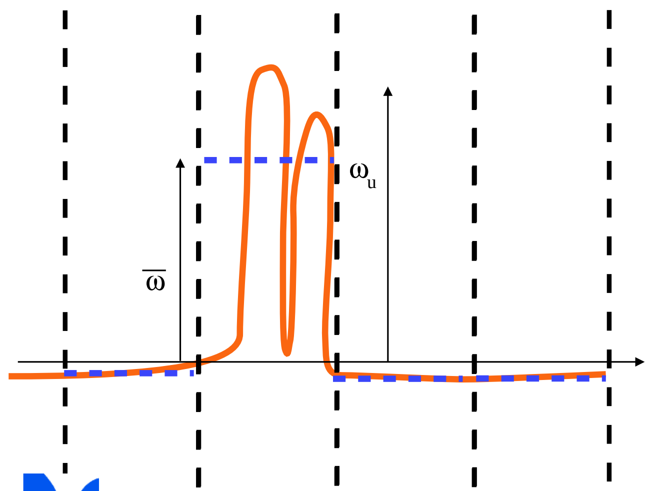

...and at 2km :
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RMI

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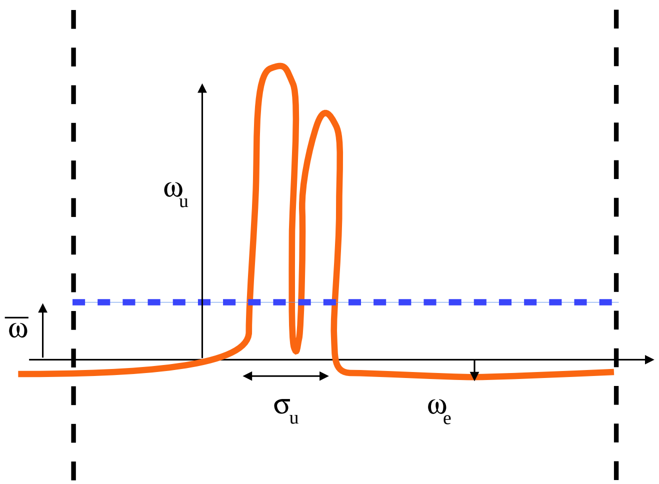

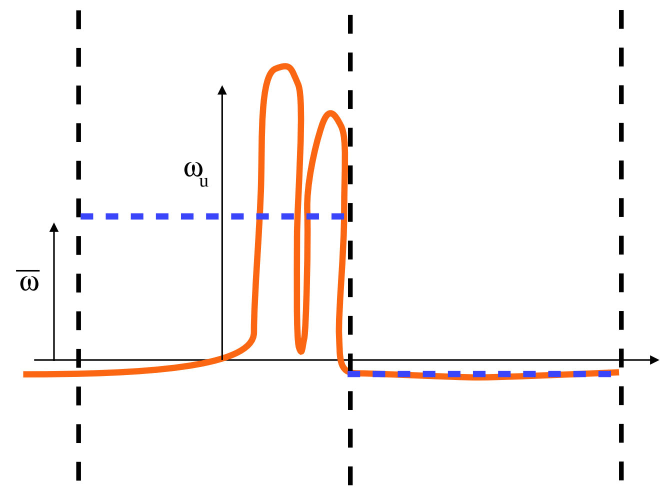

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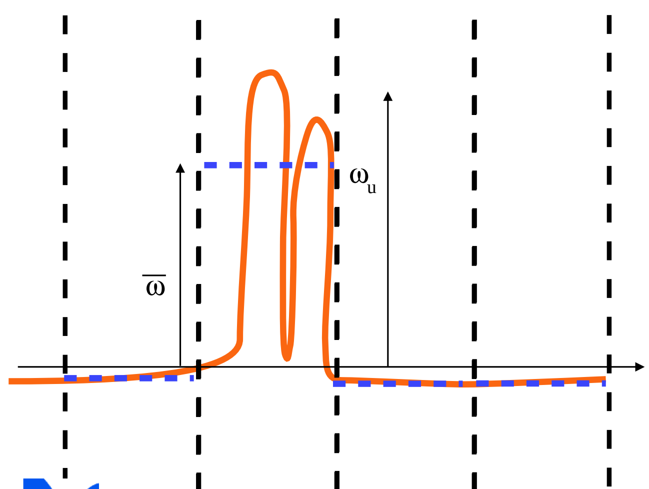

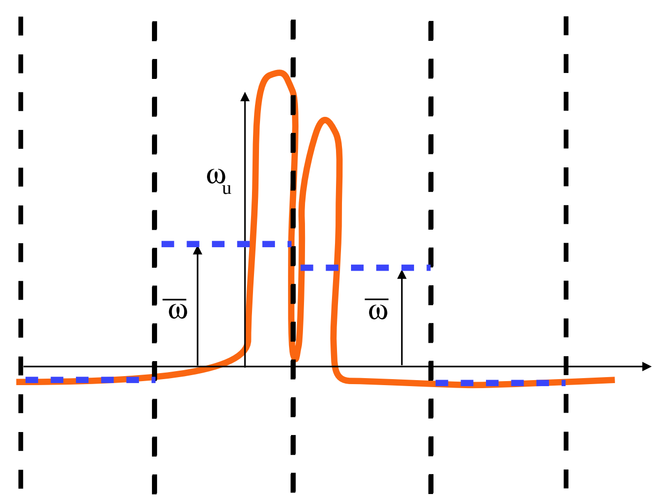

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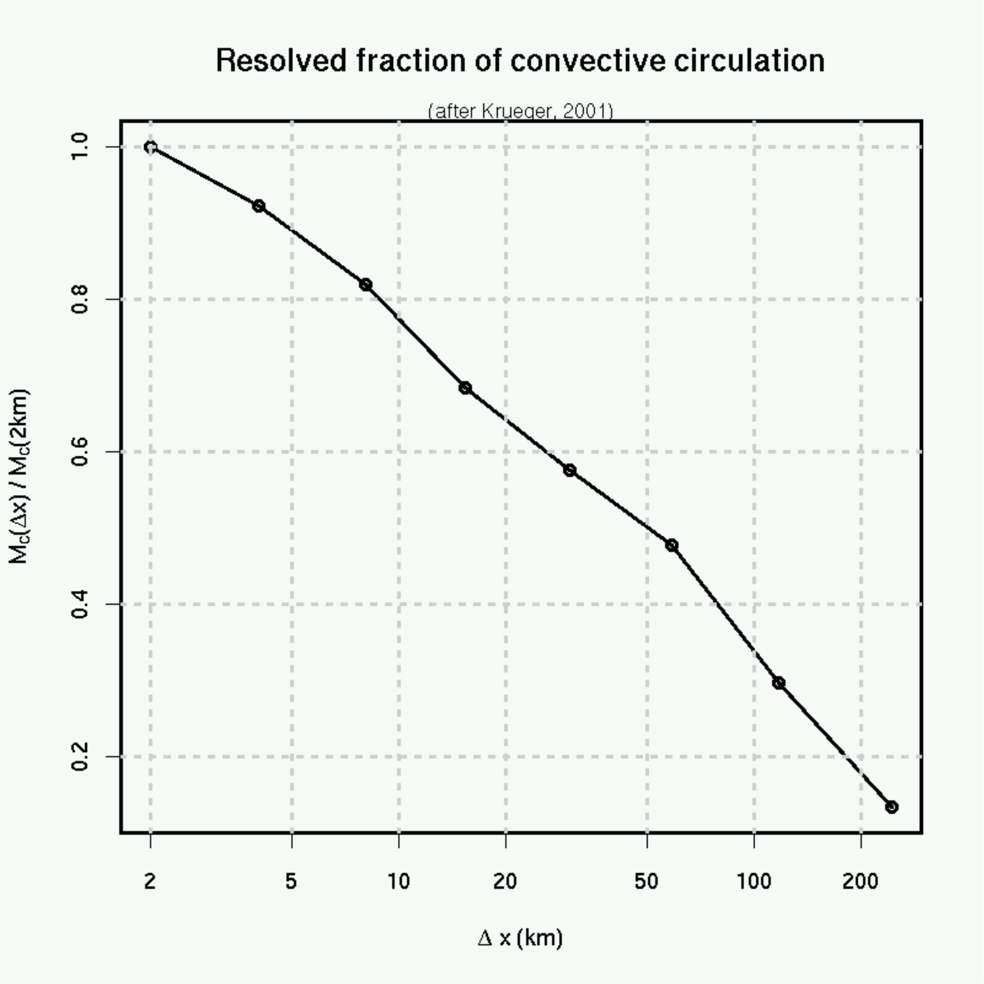
...or not ?

Which part is resolved ?

Krueger (2001) : 29-day 2-D CRM simulation, $\triangle x$=2km.



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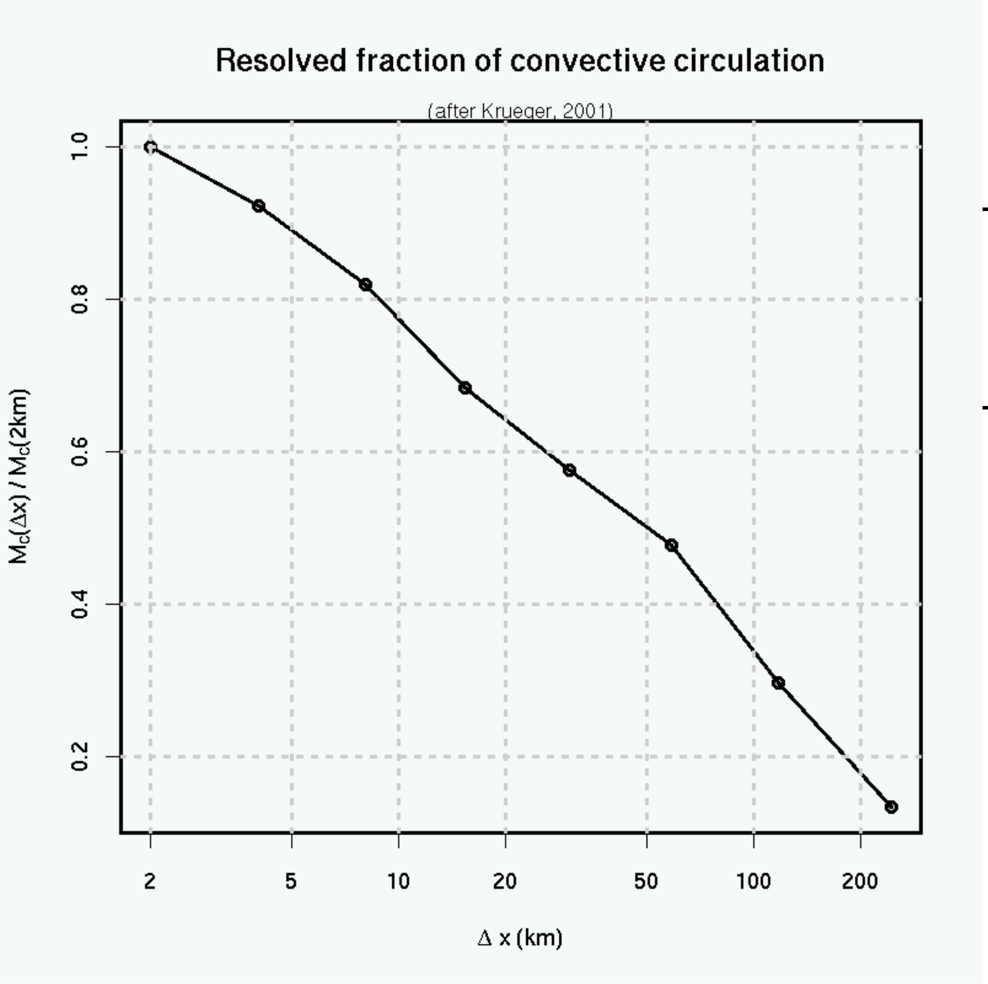

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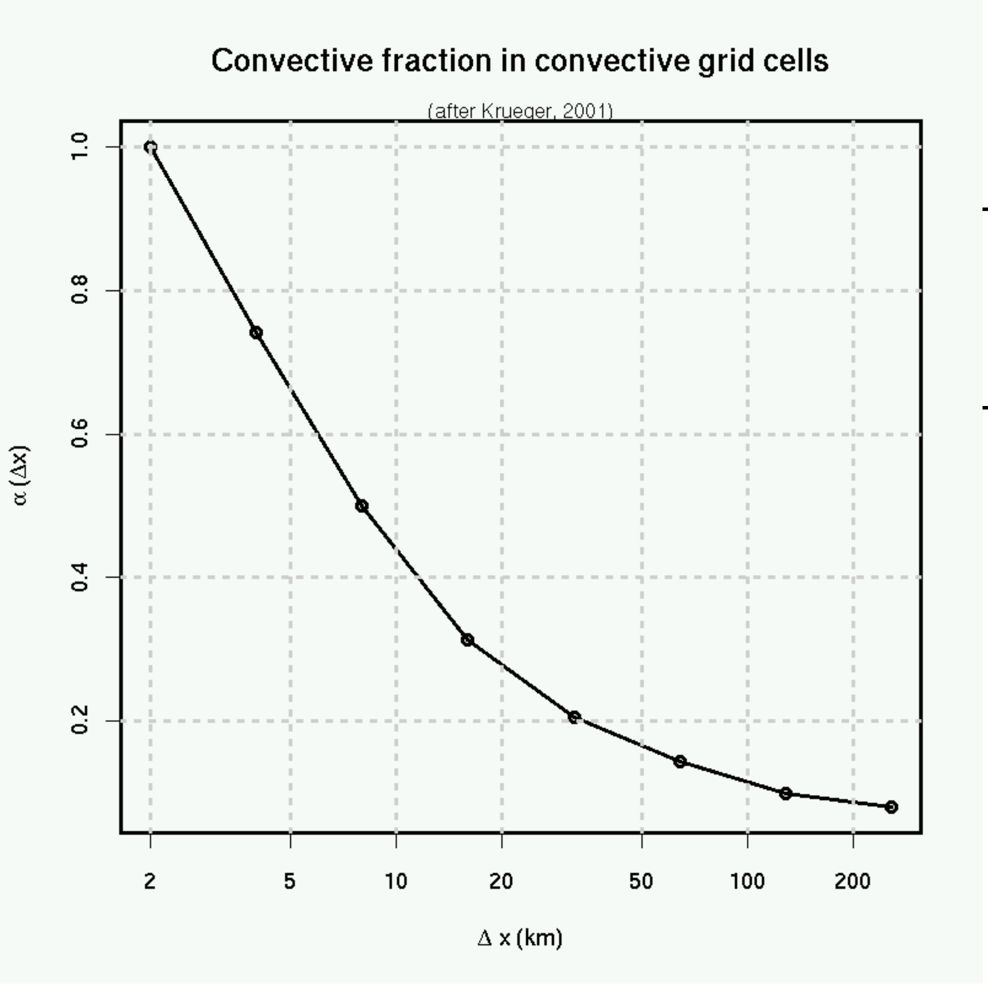

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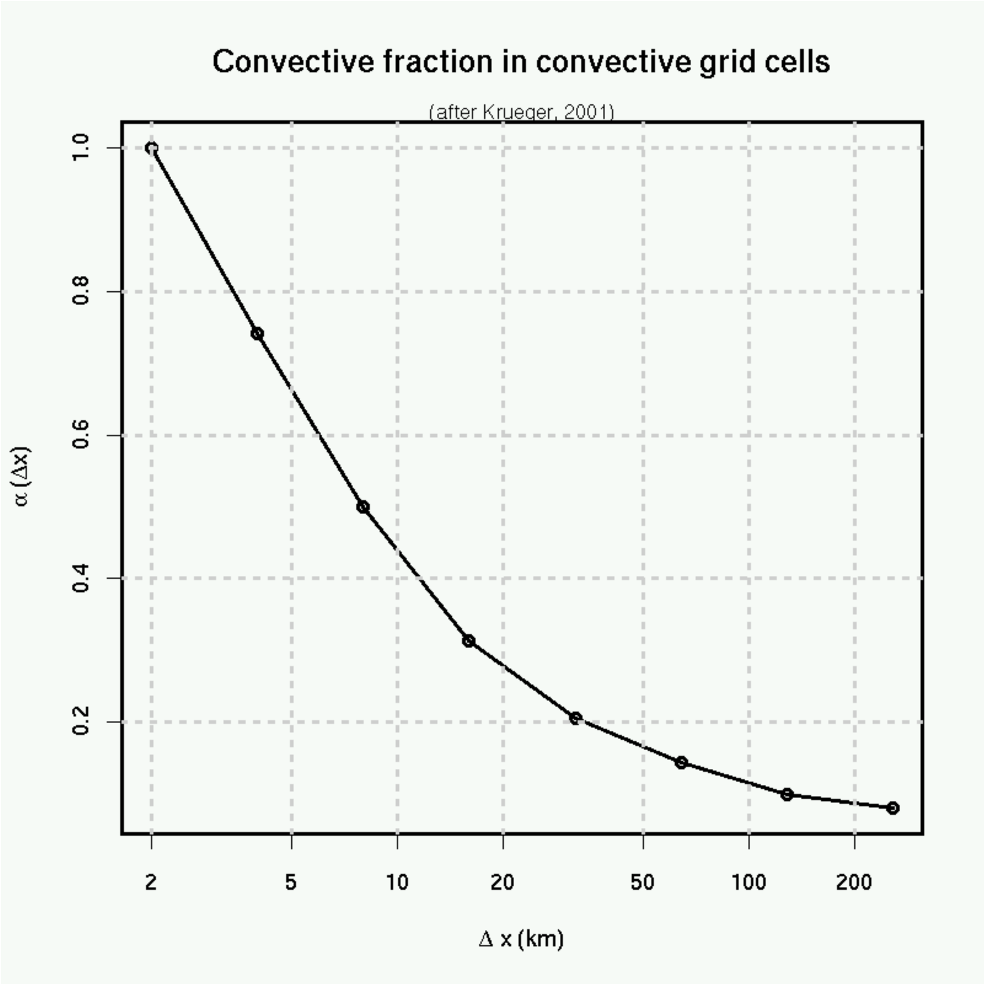

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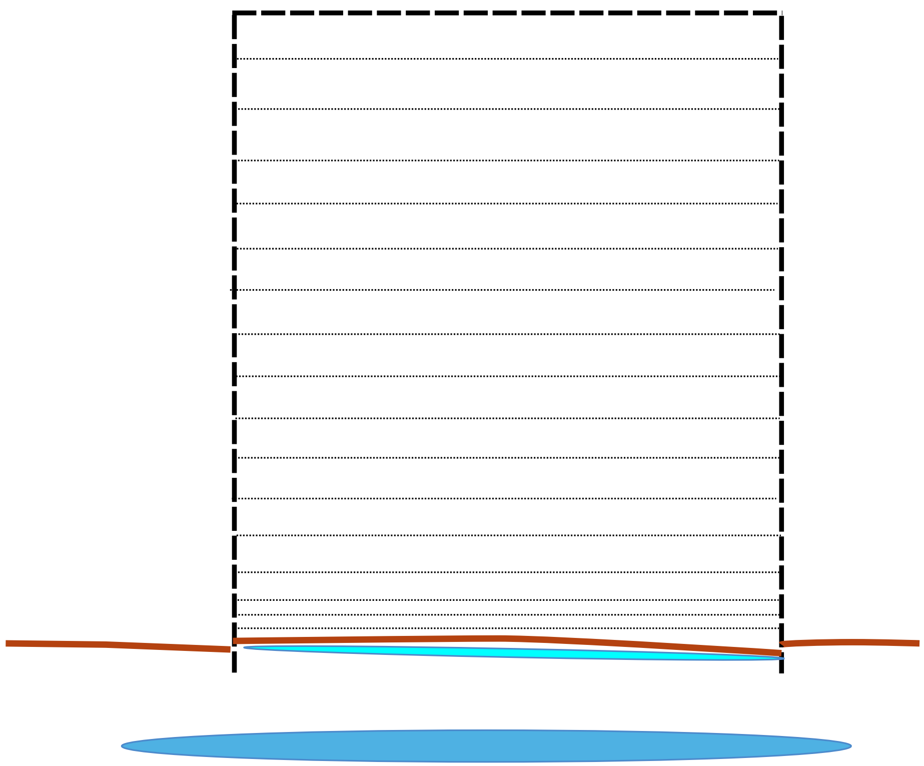
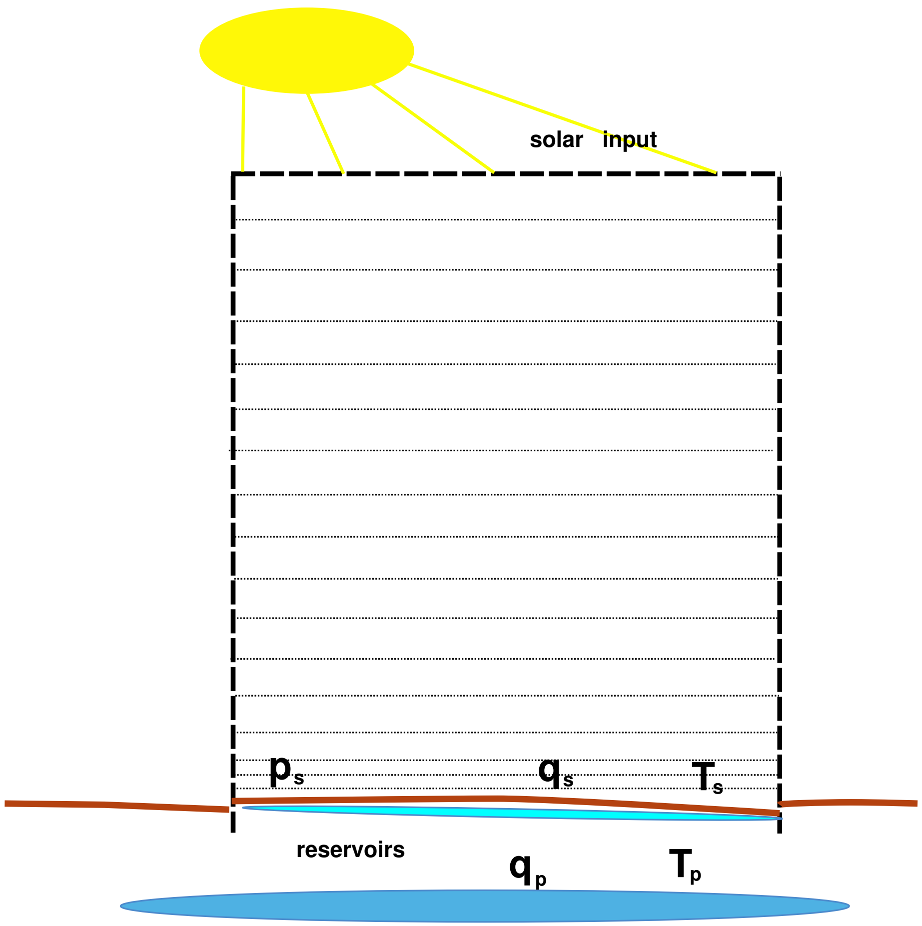
For instance : α=0.04 at $\triangle x$=32 km, 0.25 at 8km, 0.5 at 4km.

The parametrization problem



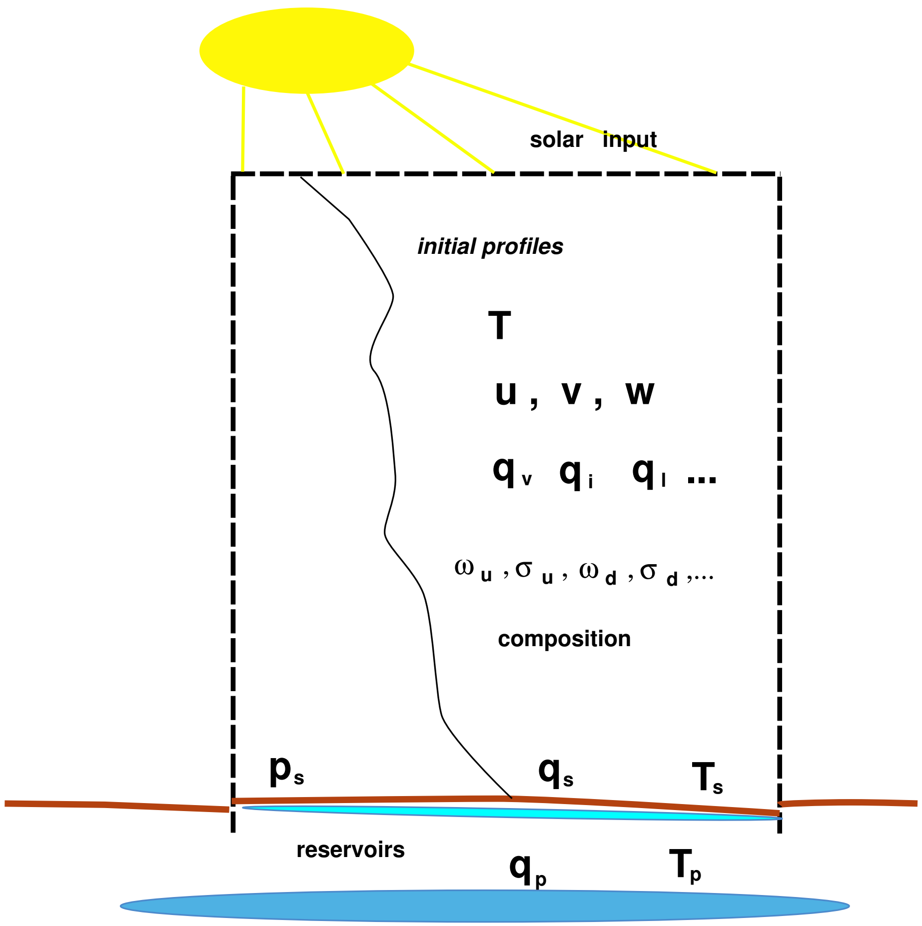
grid column

The parametrization problem



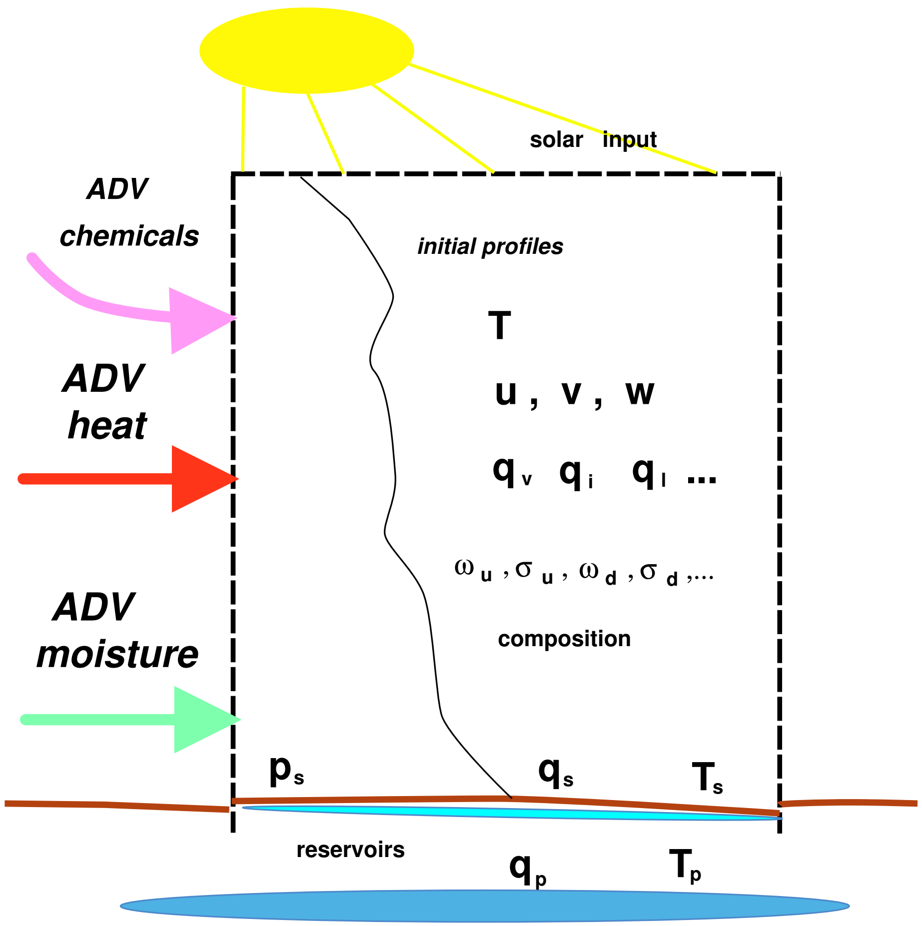
top and lower BC

The parametrization problem



model variables

The parametrization problem



Forcings

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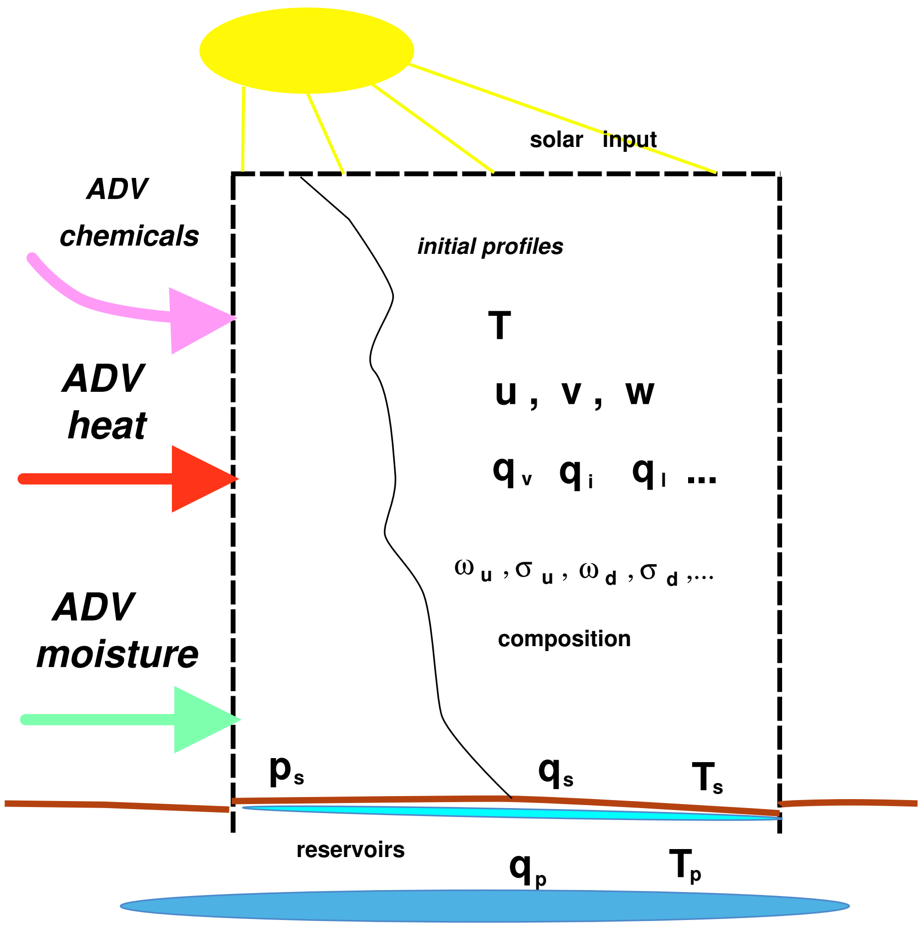
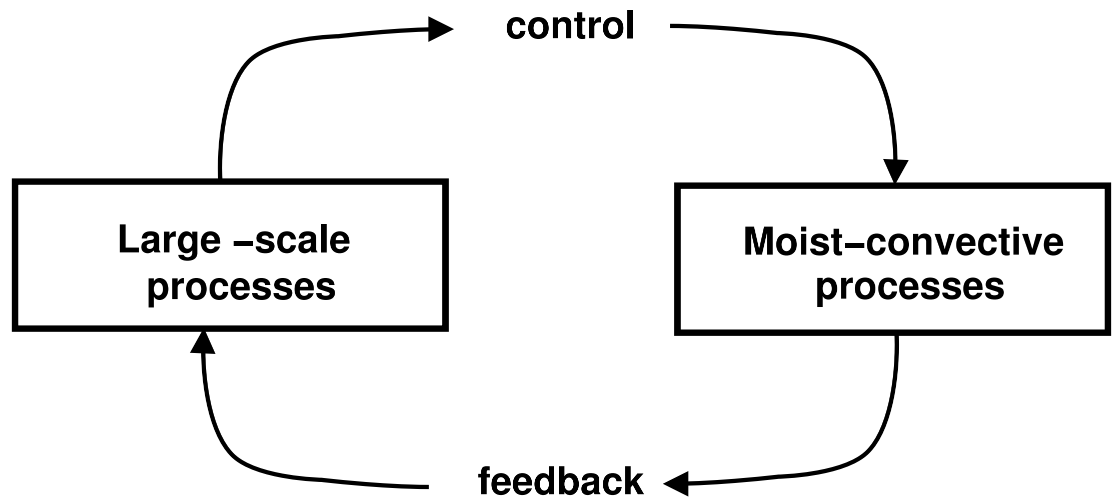
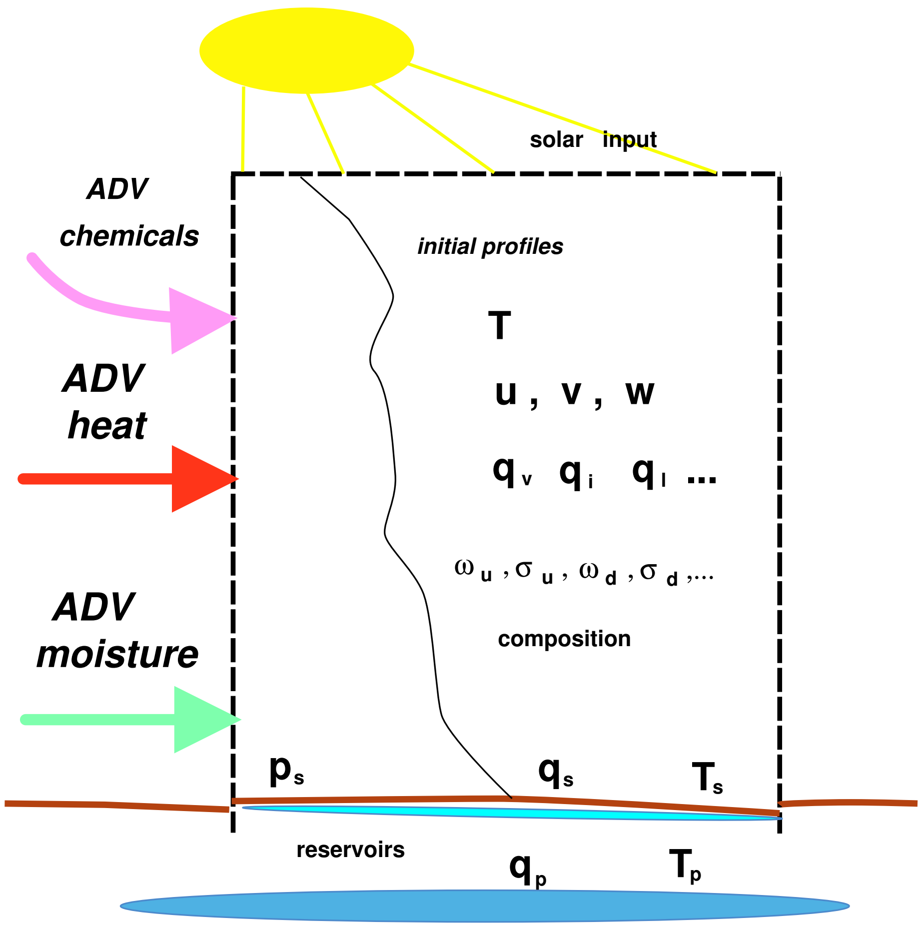


Dynamics



Moist processes :
traditional approach (Arakawa 1993)

The parametrization problem



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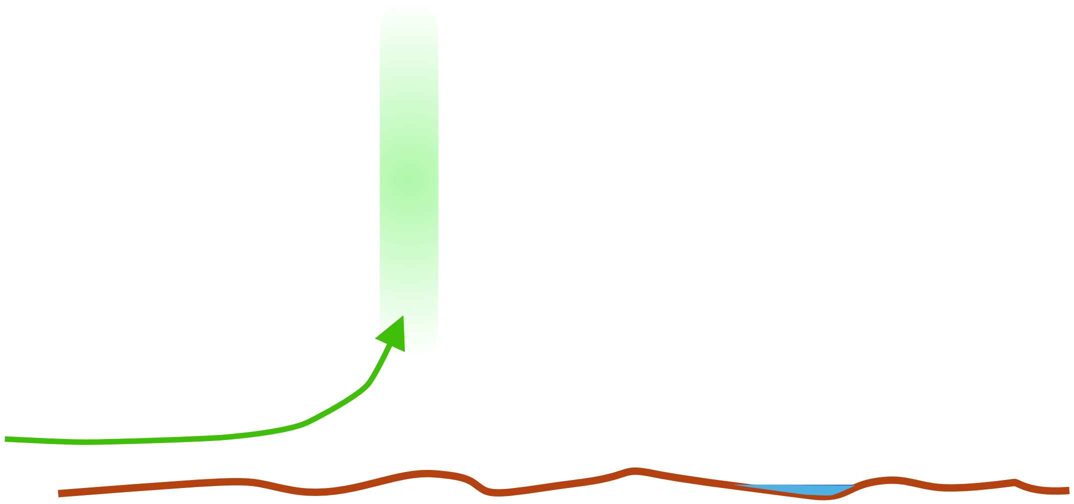
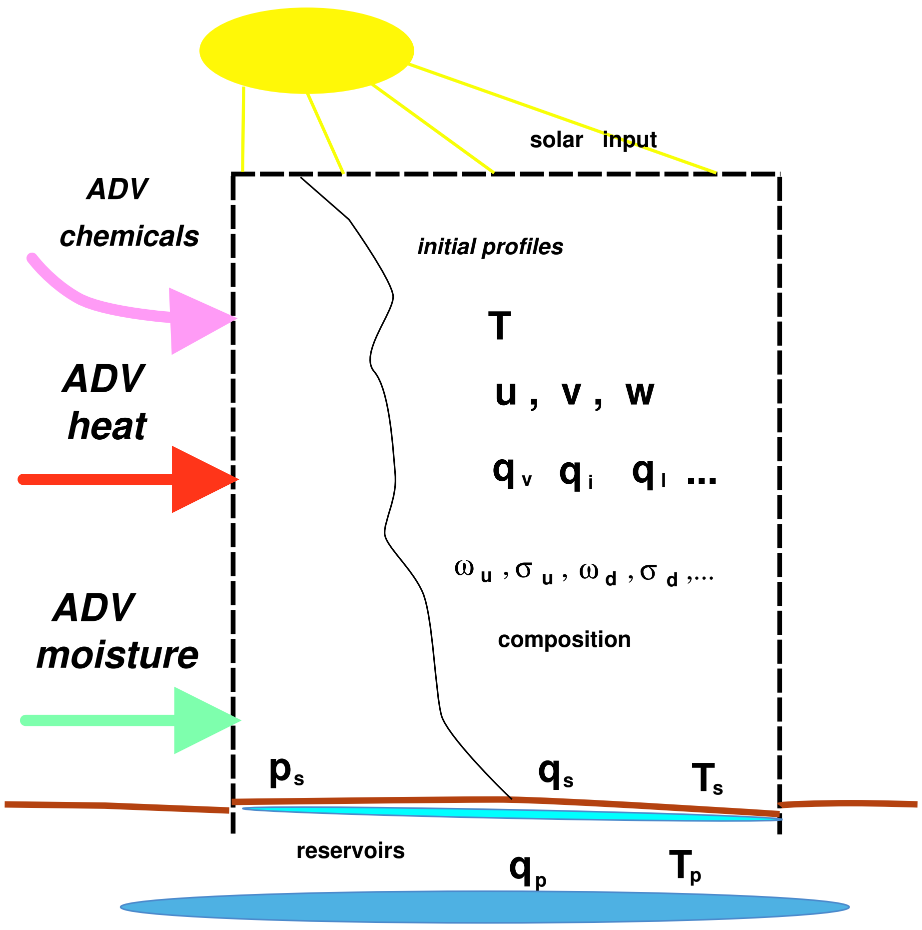


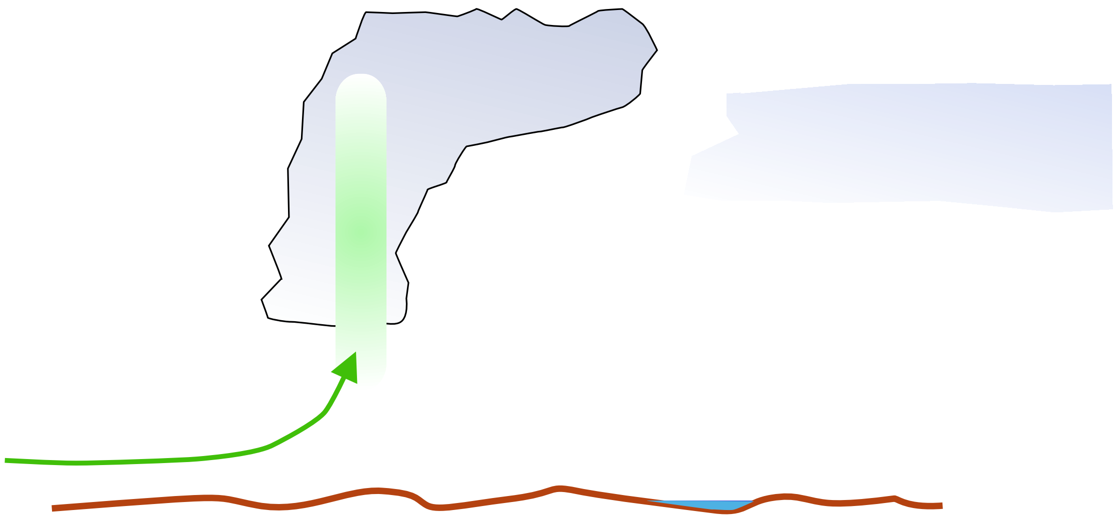
Slow large scale forcing

quick updraught response

$\Rightarrow$ Quasi Equilibrium Arakawa-Schubert, 1974

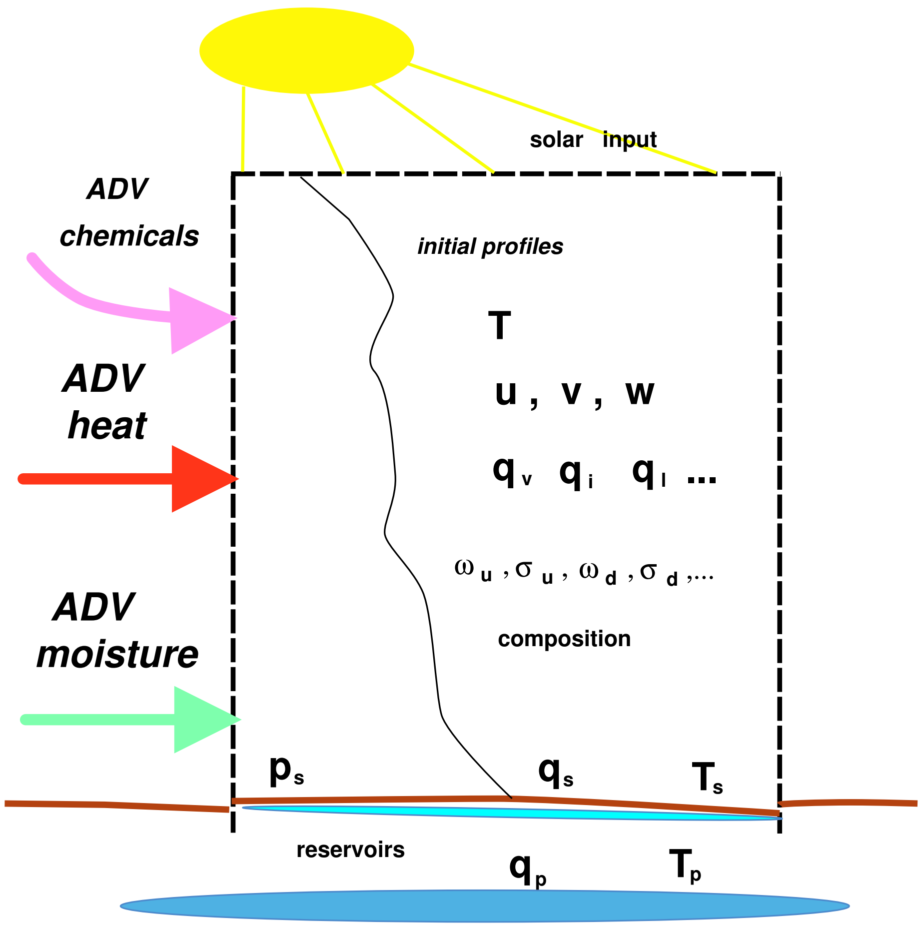
The parametrization problem

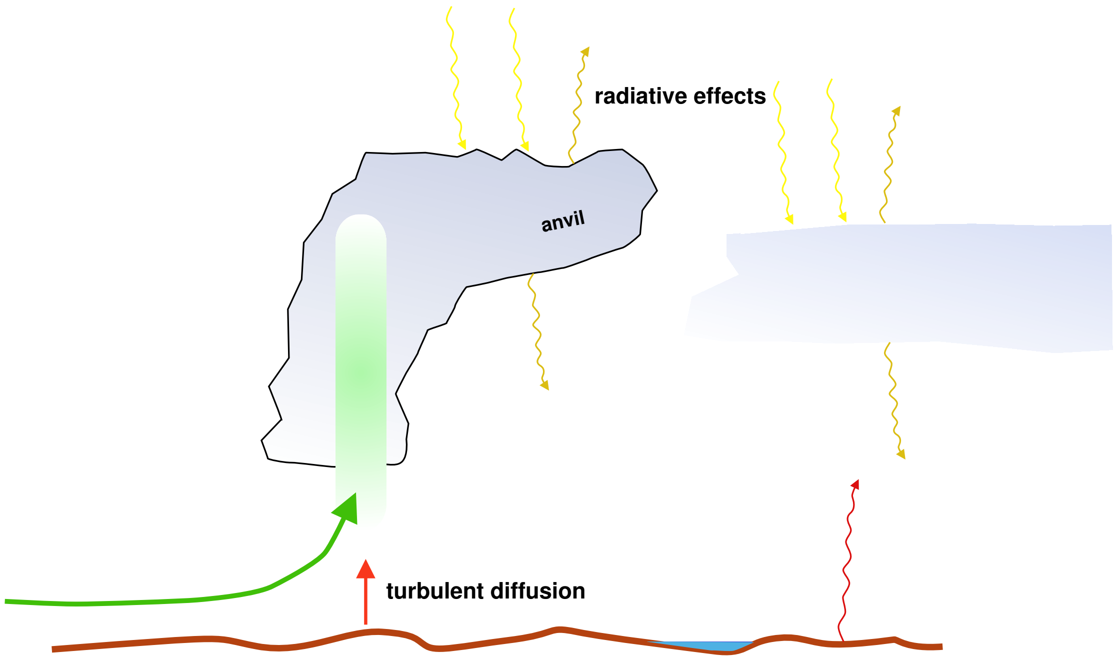




Dynamics

The parametrization problem

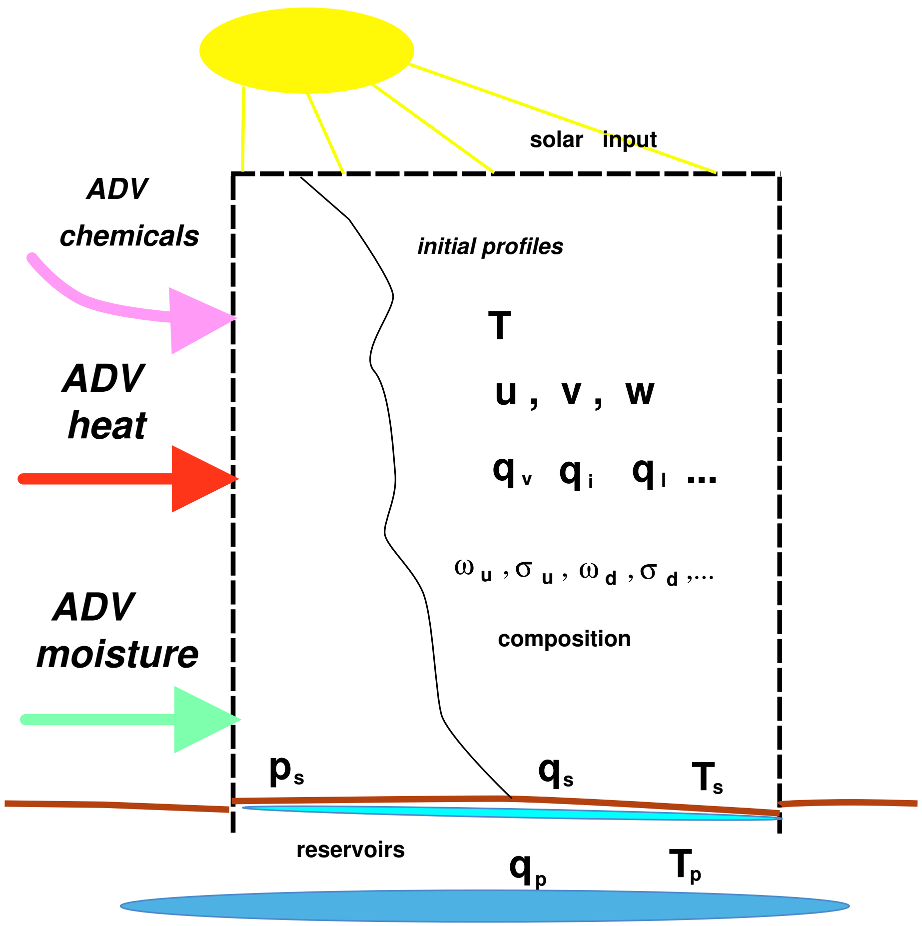




Faster interactions
$\Longrightarrow$ evolution equation required

Dynamics

The parametrization problem



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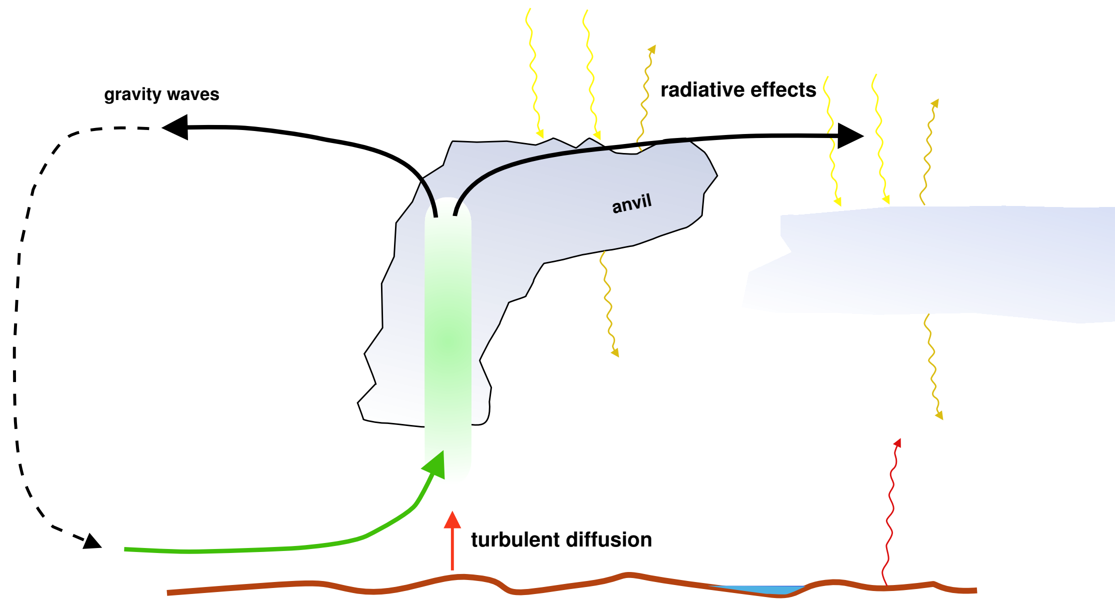
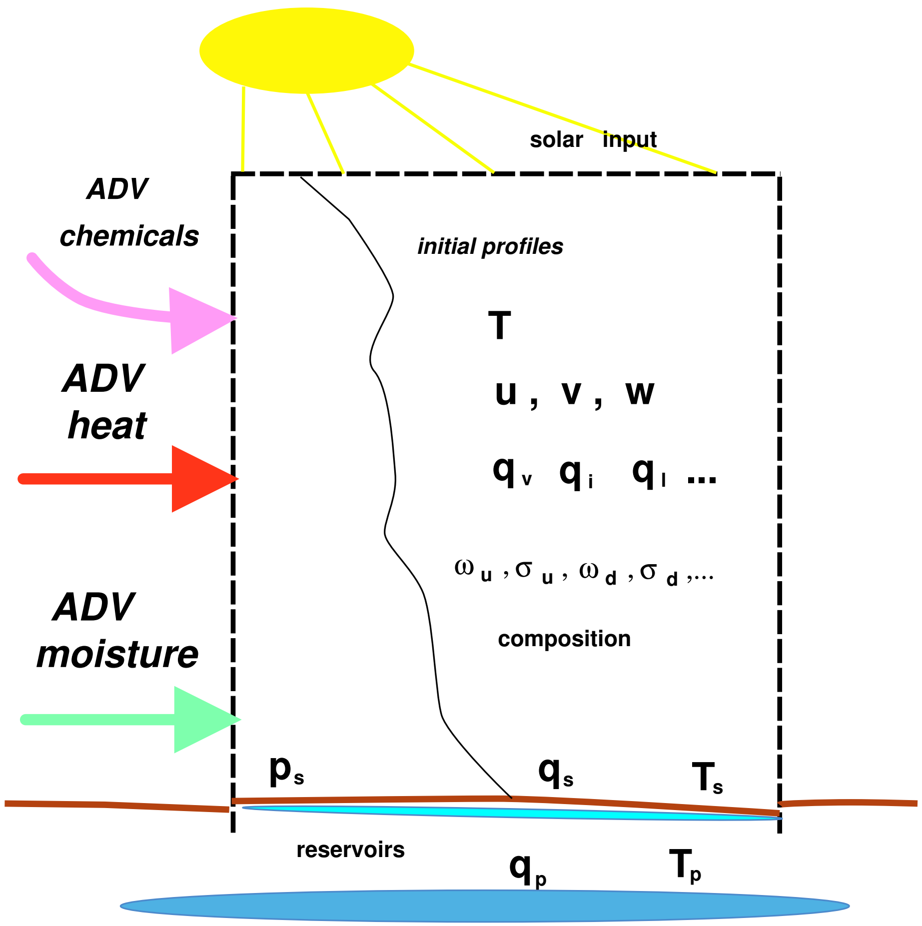


Convective circulation extends gradually to the Rossby radius of deformation

"Large-scale" $\neq$ "Non convective"

causality discussion

The parametrization problem



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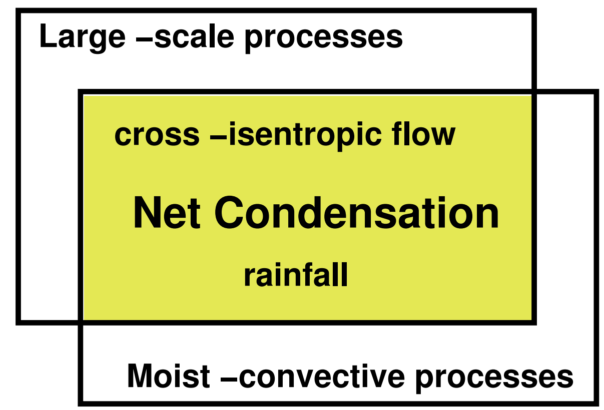
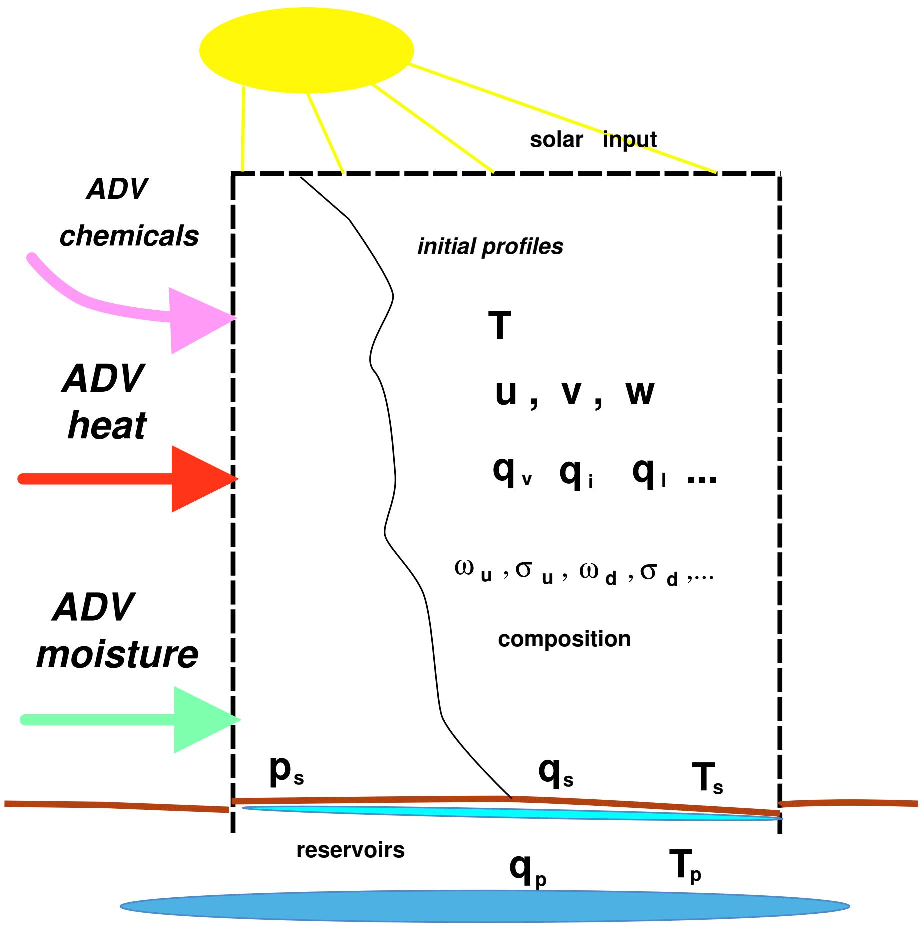


"Large-scale" and "Moist-convective" overlap
(Mapes 1997)

The parametrization problem



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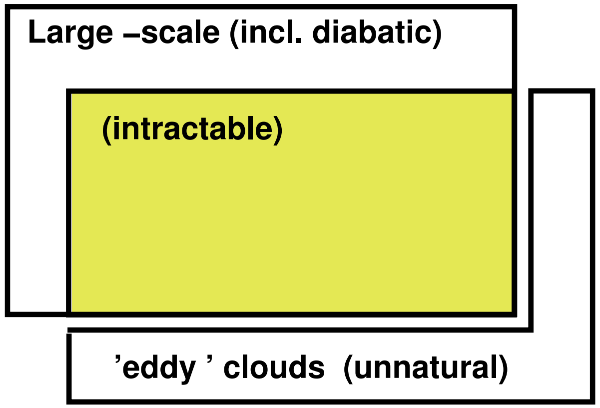
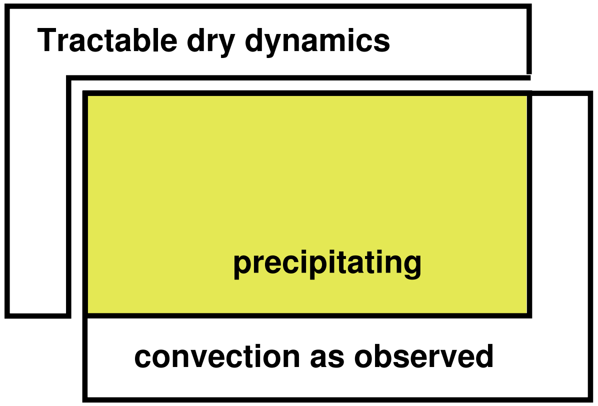


True scale separation
(Mapes 1997)

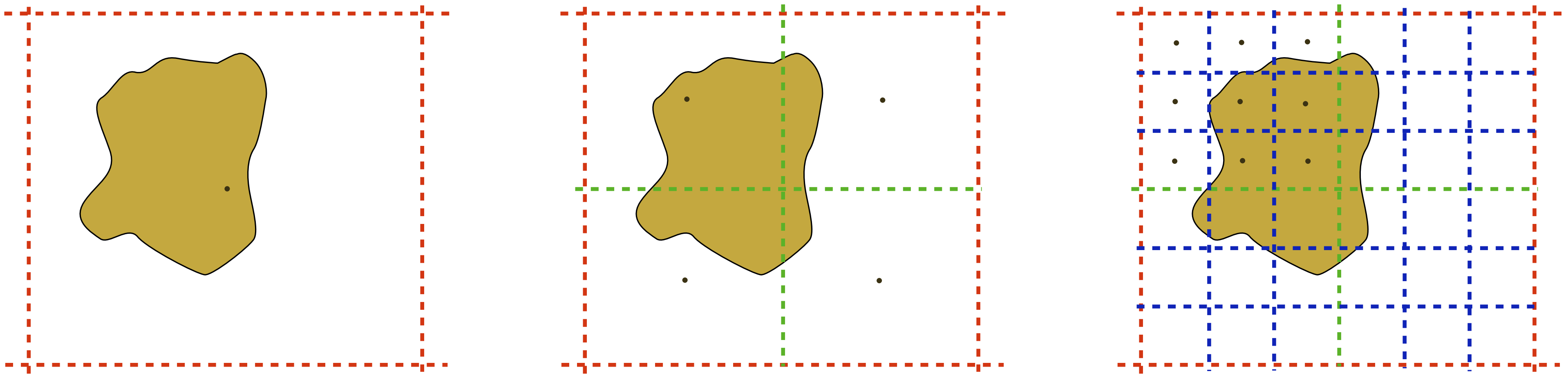


Moist-dry separation
(Mapes 1997)

RMI

High resolution LAM

– Deep convection is more and more resolved : the resolved vertical velocity increases when decreasing the grid-box length.



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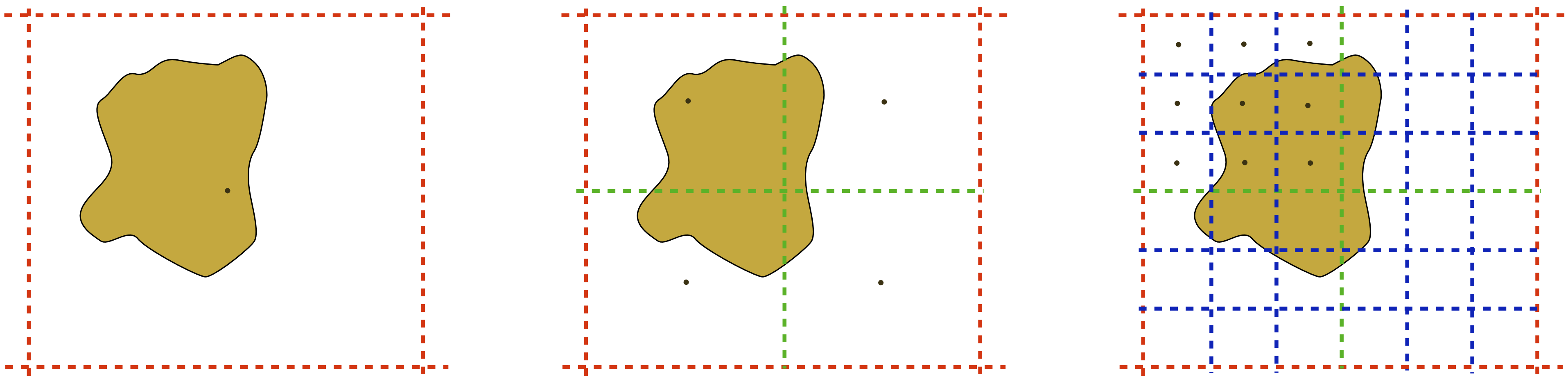

⇒ so does the resolved saturation and condensation !

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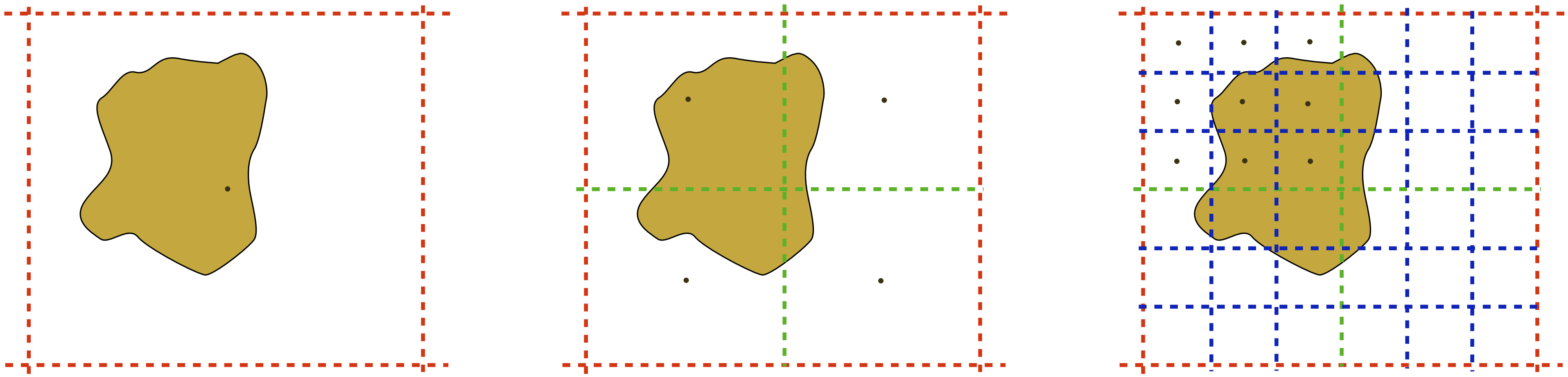

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– Time step becomes shorter – prognostic approach required.

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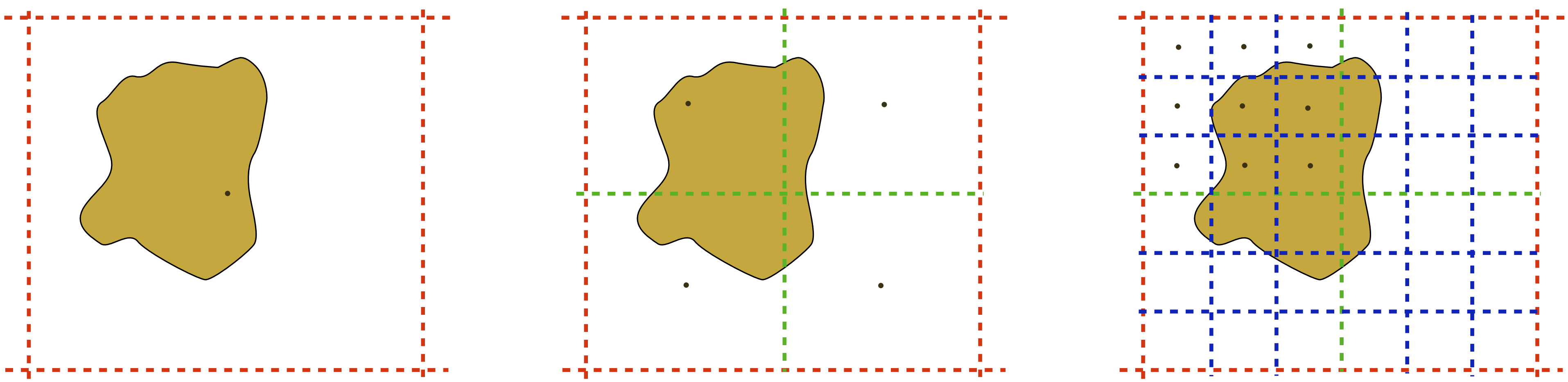

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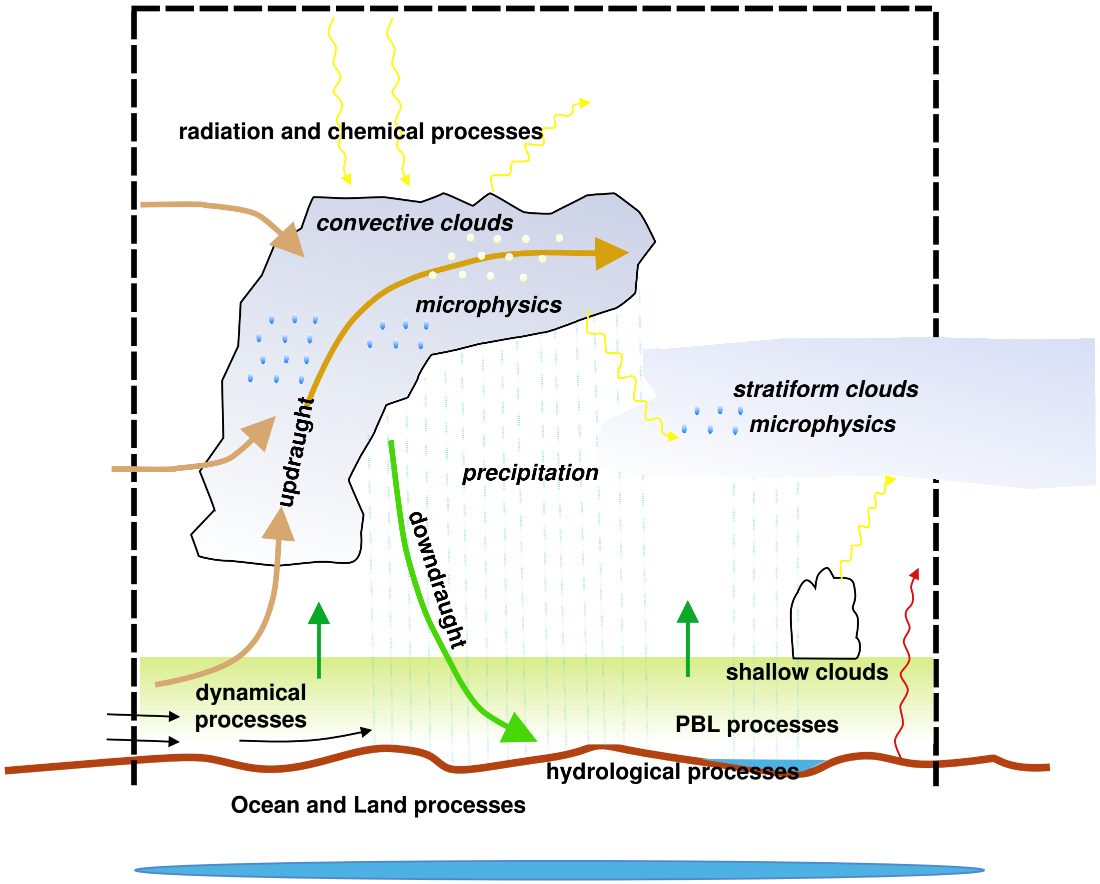
– Interactions between concurrent parametrizations must be handled properly.

Interacting processes

– Cloud interacts with all other processes $\Longrightarrow$ towards integrated physics

(Arakawa 2004)



Physical Processes

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– At least at the same time step :
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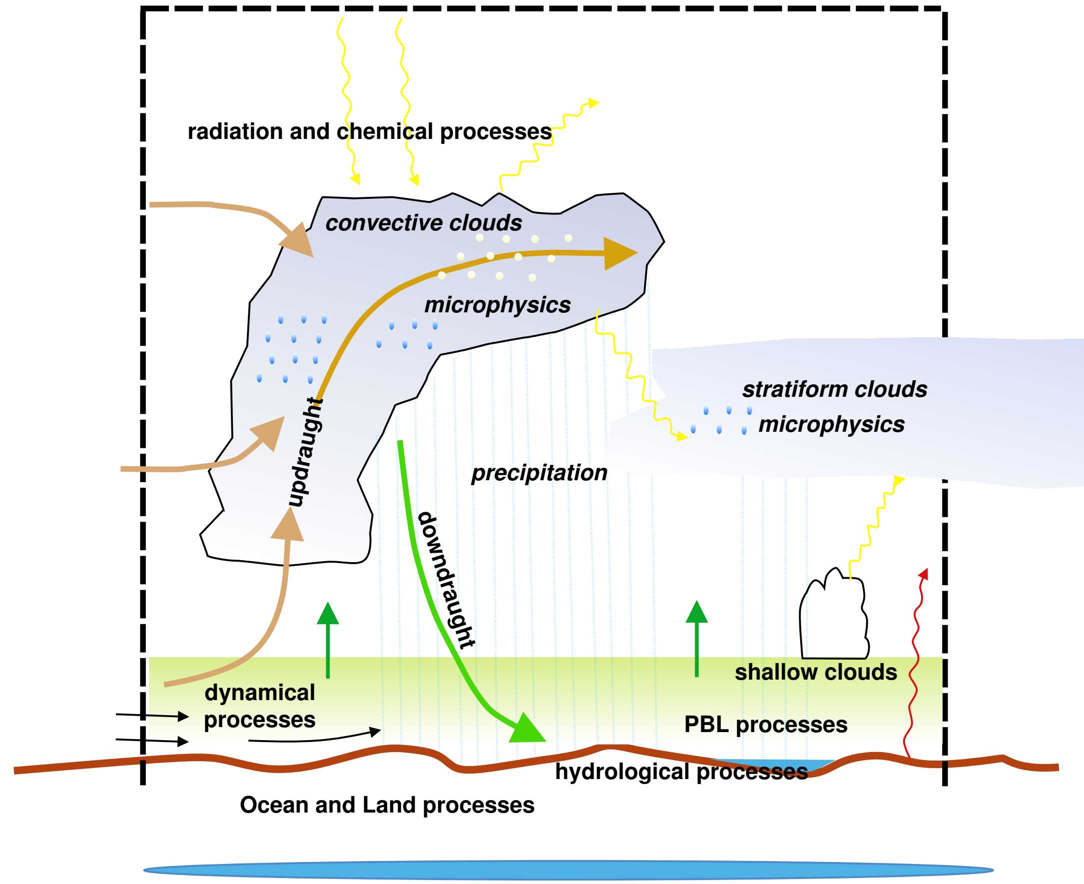

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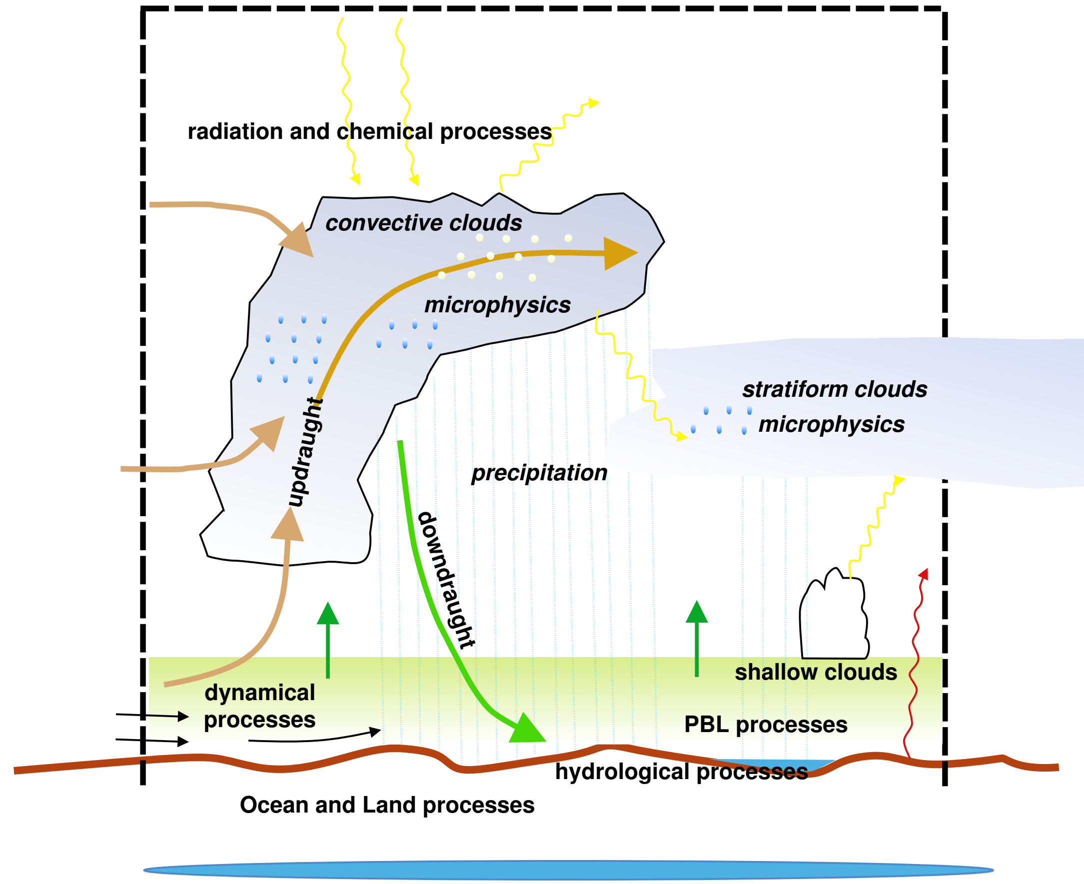

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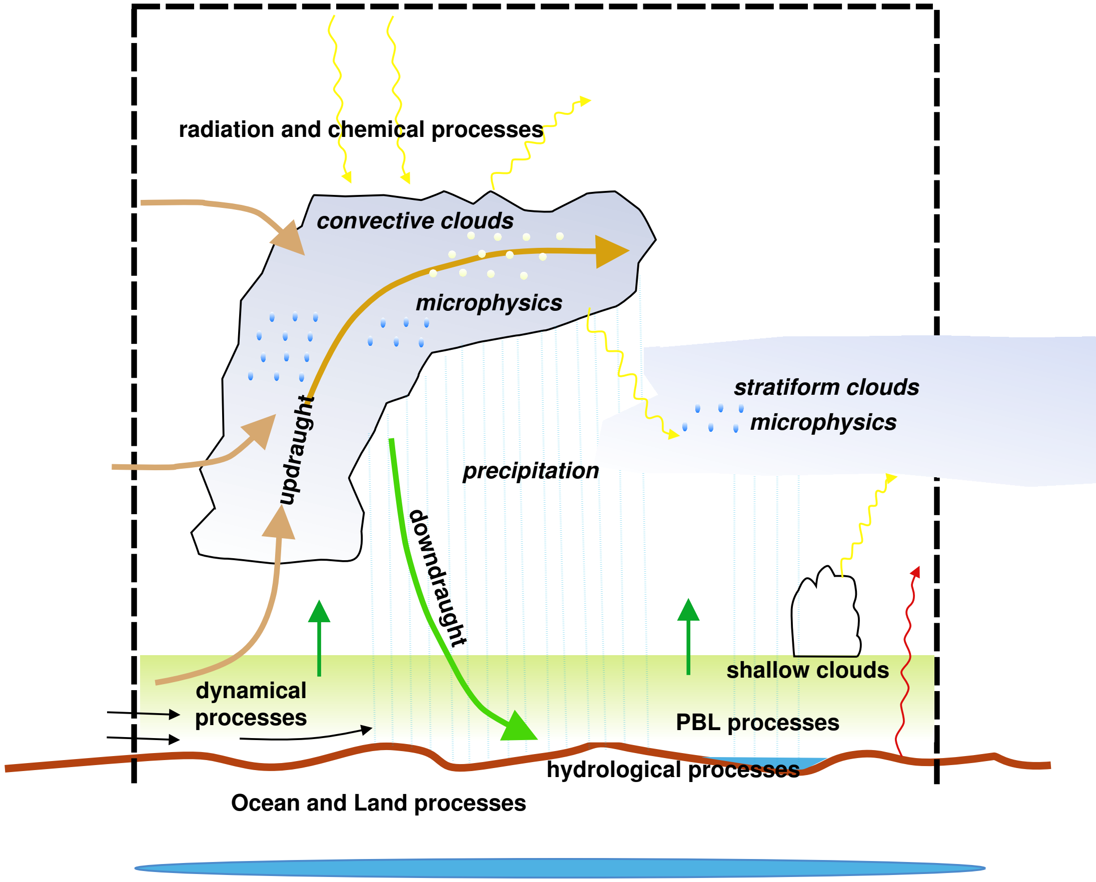

Physical Processes

Makeshift solutions for the grey zone

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– Grabowski(2001) : embedded 2-D Cloud-Scale Resolving Model : useful for climate, less for operational forecast.

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- Possibility of a variable mesh size keeping a single compatible physics.

Finding the fair share out of the waterhole

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modulate ?

$$\Downarrow$$

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$$\overline{q_{v1}}\ ,\ \overline{q_{\ell 1}}\ ,\ \overline{q_{i1}}\ ,\ \overline{T_1} \qquad \text{and} \qquad f = \max(f_{\text{stra}}, \sigma_D)$$

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Cascade General layout

(Fix negative contents from advection) $\Big\} \longrightarrow$ J_ℓ^{cor}, J_i^{cor}, J_v^{cor}

$[q_v^*, q_i^*, q_\ell^*] \swarrow$

$\boxed{\text{Resolved cloud fraction}}$

$f^{st} \swarrow$ (f^*, Radiation)

$\searrow$($T_{\rm surf}$, Turbulent diffusion) $\longrightarrow$ J_ℓ^{td}, J_i^{td}, J_v^{td}, J_S^{td}

$[\cancel{q_v^*}, q_i^*, q_\ell^*, T^*] \swarrow$

$\boxed{\text{Resolved condensation}} \longrightarrow F_{vi}^{st}, \ F_{v\ell}^{st}$

$[q_v^*, q_i^*, q_\ell^*, T^*] \swarrow$

moistureconver- gence $\longrightarrow$ $\boxed{\text{Deep convection}} \longrightarrow$ F_{vi}^{cu}, $F_{v\ell}^{cu}$, J_v^{cu}, J_i^{cu}, J_ℓ^{cu}, J_S^{cu}, J_V^{cu}

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$[q_v^*, q_i^*, q_\ell^*, T^*]\swarrow$

$$f^{cu} = \sigma_D + \sigma_u,$$

$$\alpha_{\text{cu}} = \frac{F_{vc}^{cu}}{F_{vc}^{cu} + F_{vc}^{st}} \longrightarrow f^{eq}$$

$\boxed{\text{Microphysics}} \longrightarrow F_{is},\ F_{\ell r},\ [F_{\ell i}],\ \mathcal{P}_r,\ \mathcal{P}_s,\ F_{rv},\ F_{sv}$

$F_{hP} \swarrow$ $\qquad [q_v^*, q_i^*, q_\ell^*, T^*]\swarrow$

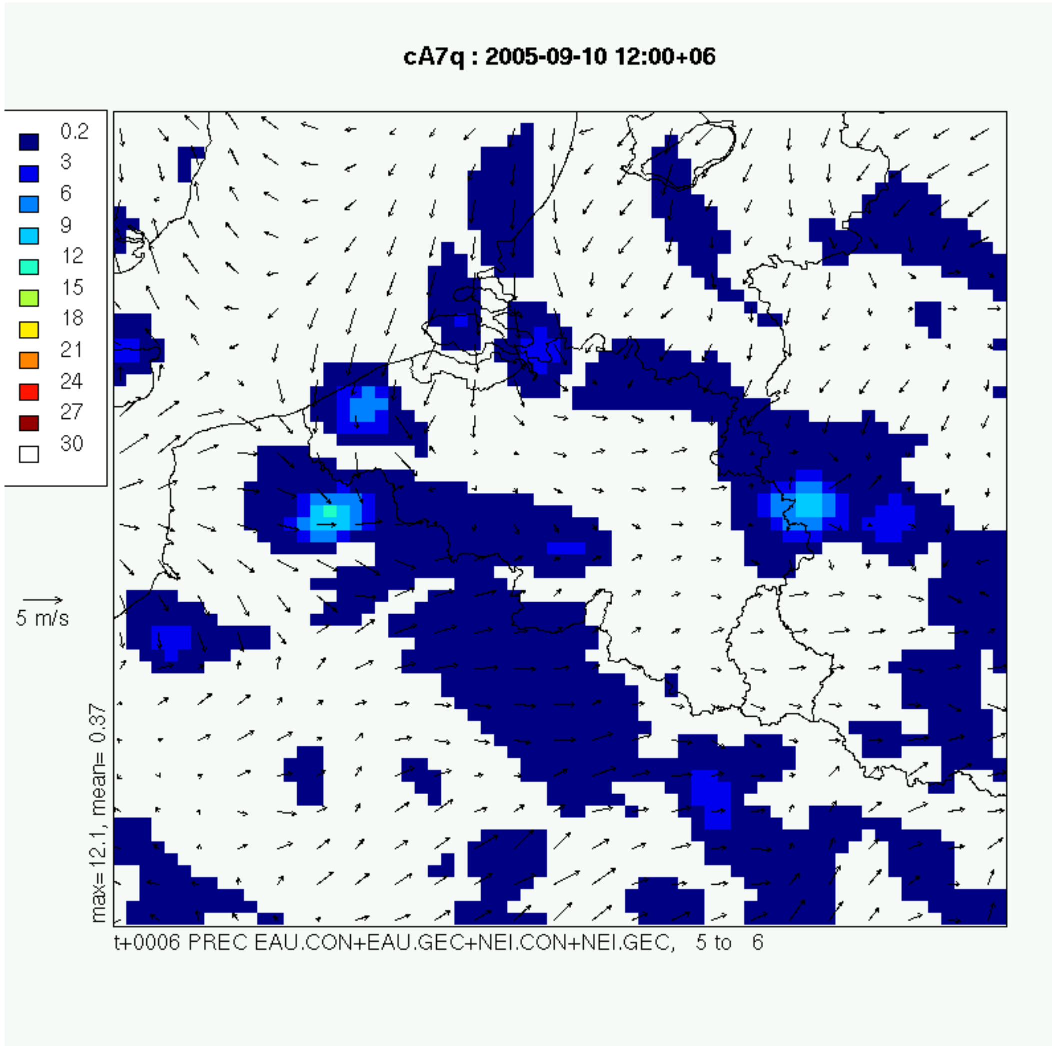
$\searrow$ $\boxed{\text{Downdraught}} \longrightarrow F_{rv}^{dd},\ F_{sv}^{dd},\ J_v^{cu},\ J_i^{cu},\ J_\ell^{cu},\ J_S^{cu},\ J_V^{cu}$

$[q_v^*, q_i^*, q_\ell^*]\swarrow$ $\qquad \mathcal{P}_r,\ \mathcal{P}_s\swarrow$

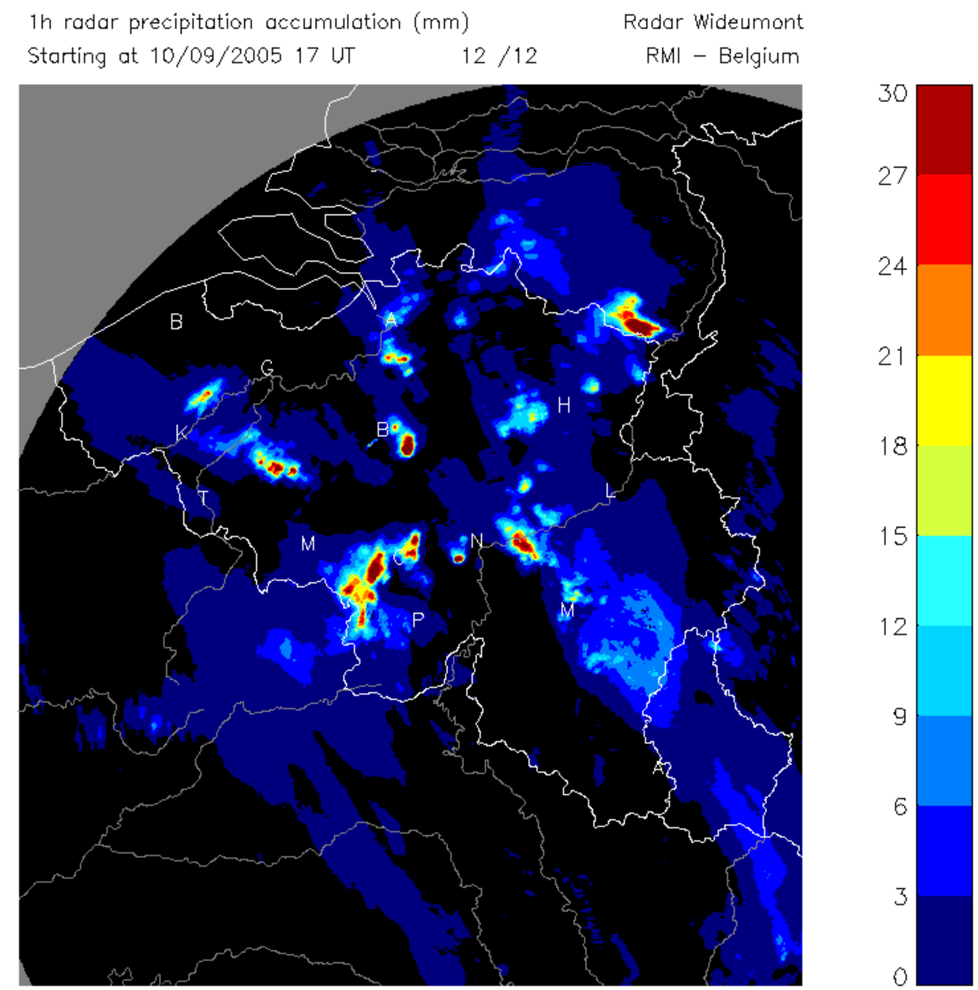
$\alpha_{\text{cu}} \longrightarrow$ (Convective/ Resolved) $\longrightarrow \mathcal{P}_r^{cu},\ \mathcal{P}_s^{cu},\ \mathcal{P}_r^{st},\ \mathcal{P}_s^{st}$

Thunderstorms on Saturday 10 September 2005

Accumulated rain 17 to 18h utc

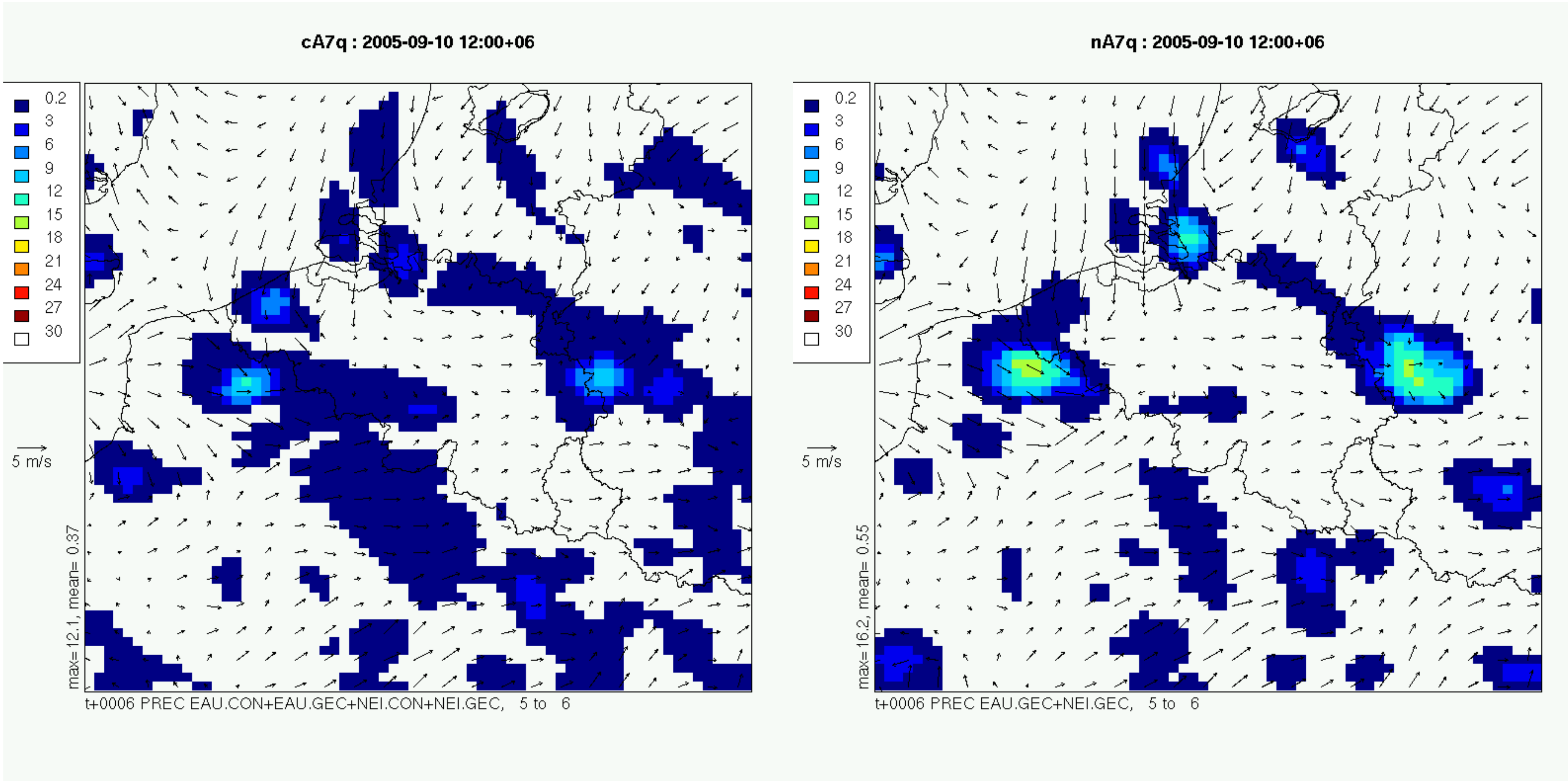


7.00km MaC full package



Wideumont Radar

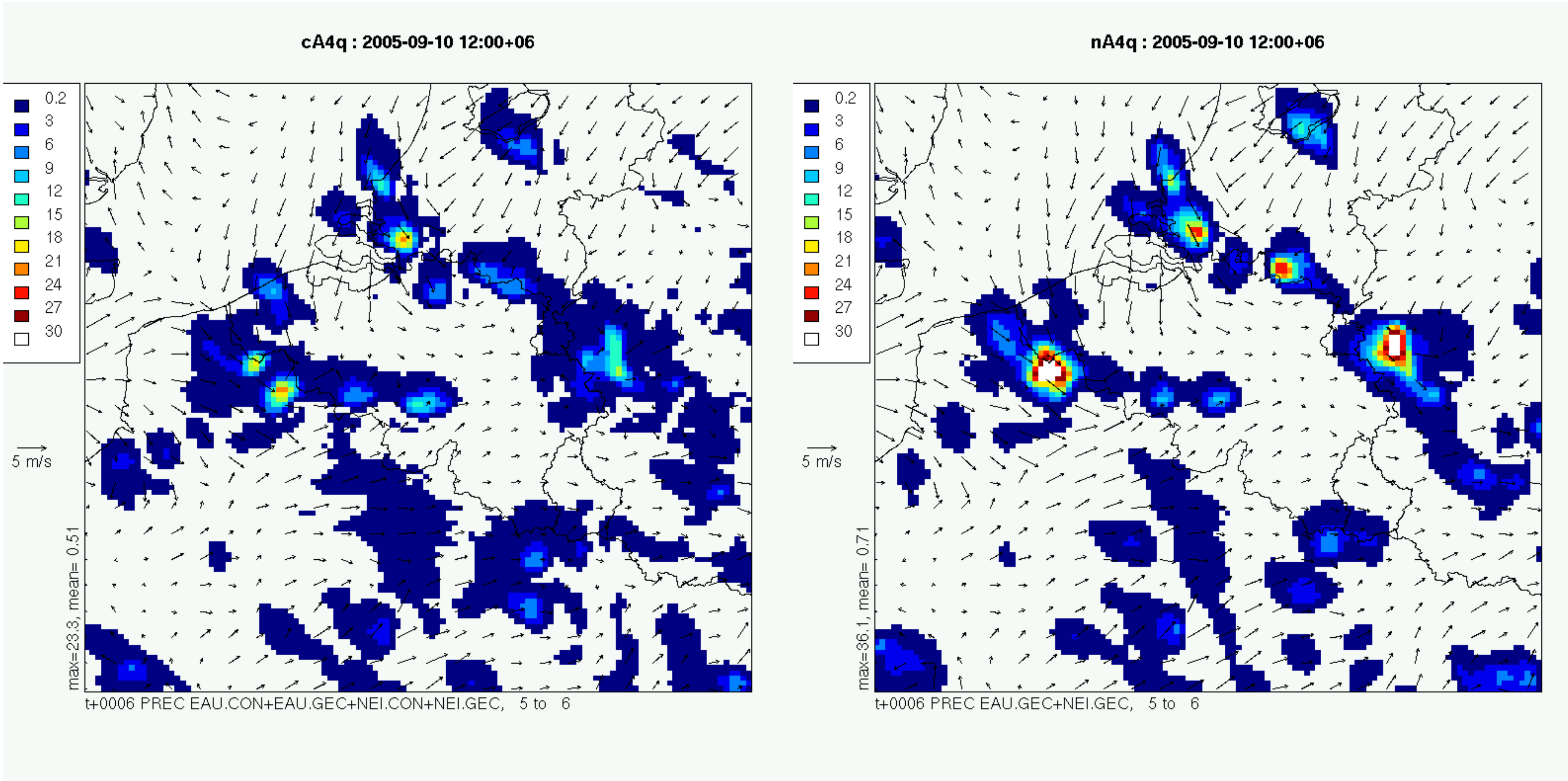
Intense small cells produce limited amounts when averaged over a 50 km^2 grid-box area



7.00km MaC full package

7.00km Resolved scheme alone

updraughts forced to wider than realistic scale (Deng and Stauffer 2006)



4.00km MaC full package

4.00km Resolved scheme alone

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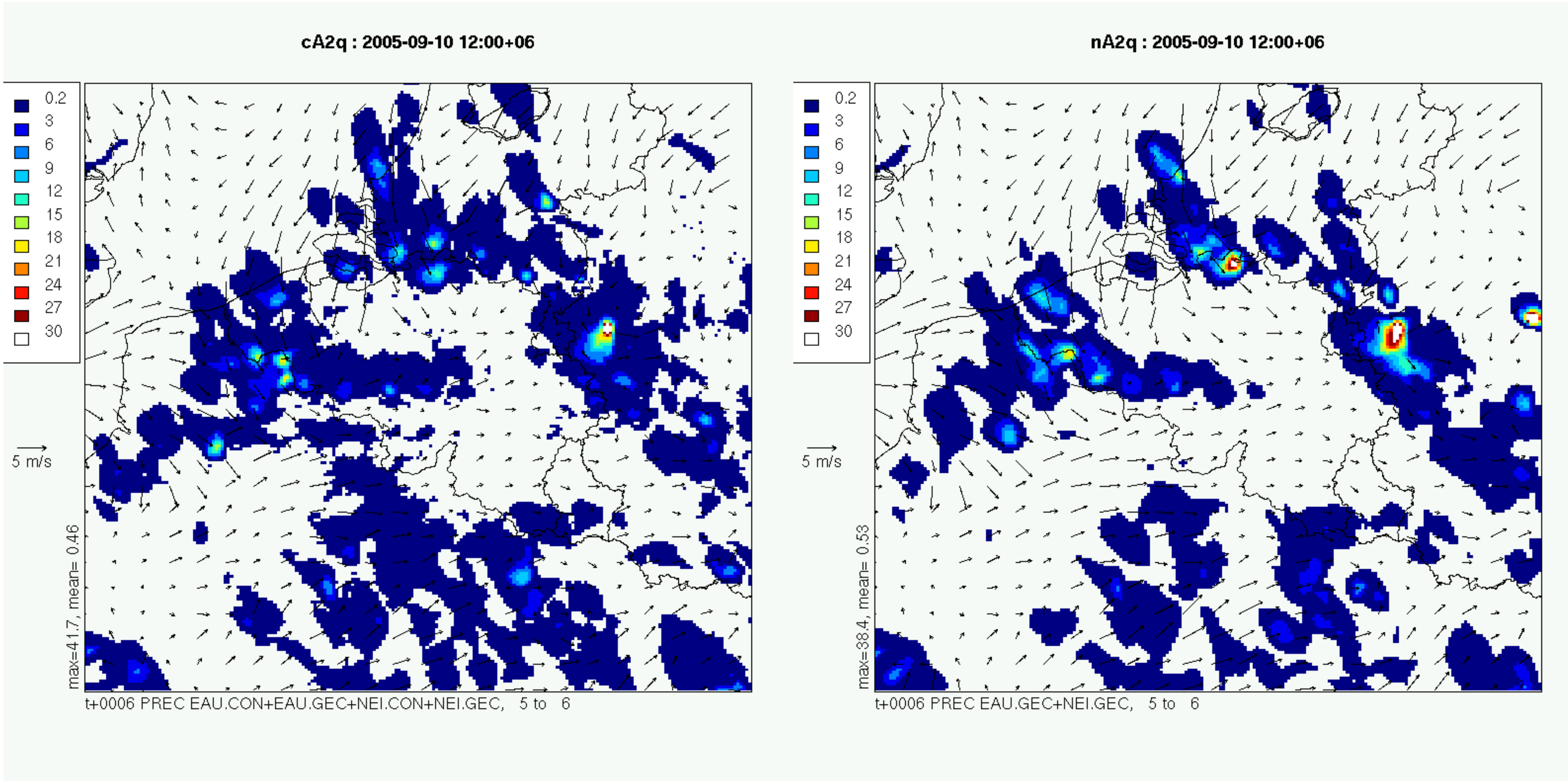
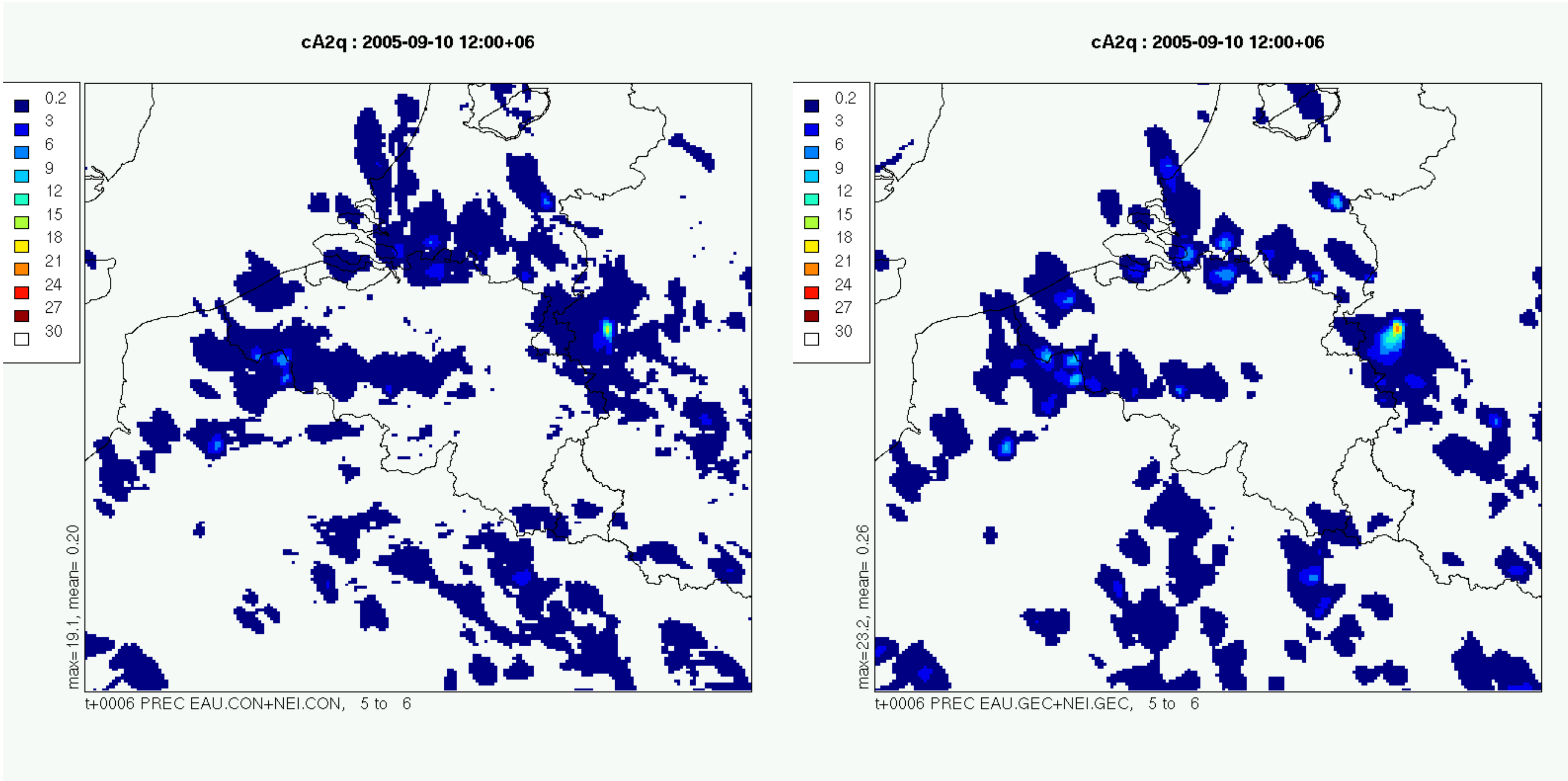


2.18km MaC full package

2.18km Resolved scheme alone

visible convergence, not yet complete...



2.18km Subgrid part

2.18km Resolved part

...subgrid scheme cares for non hydrostatic effects in the frame of the hydrostatic dynamics