Core concepts of 3MT

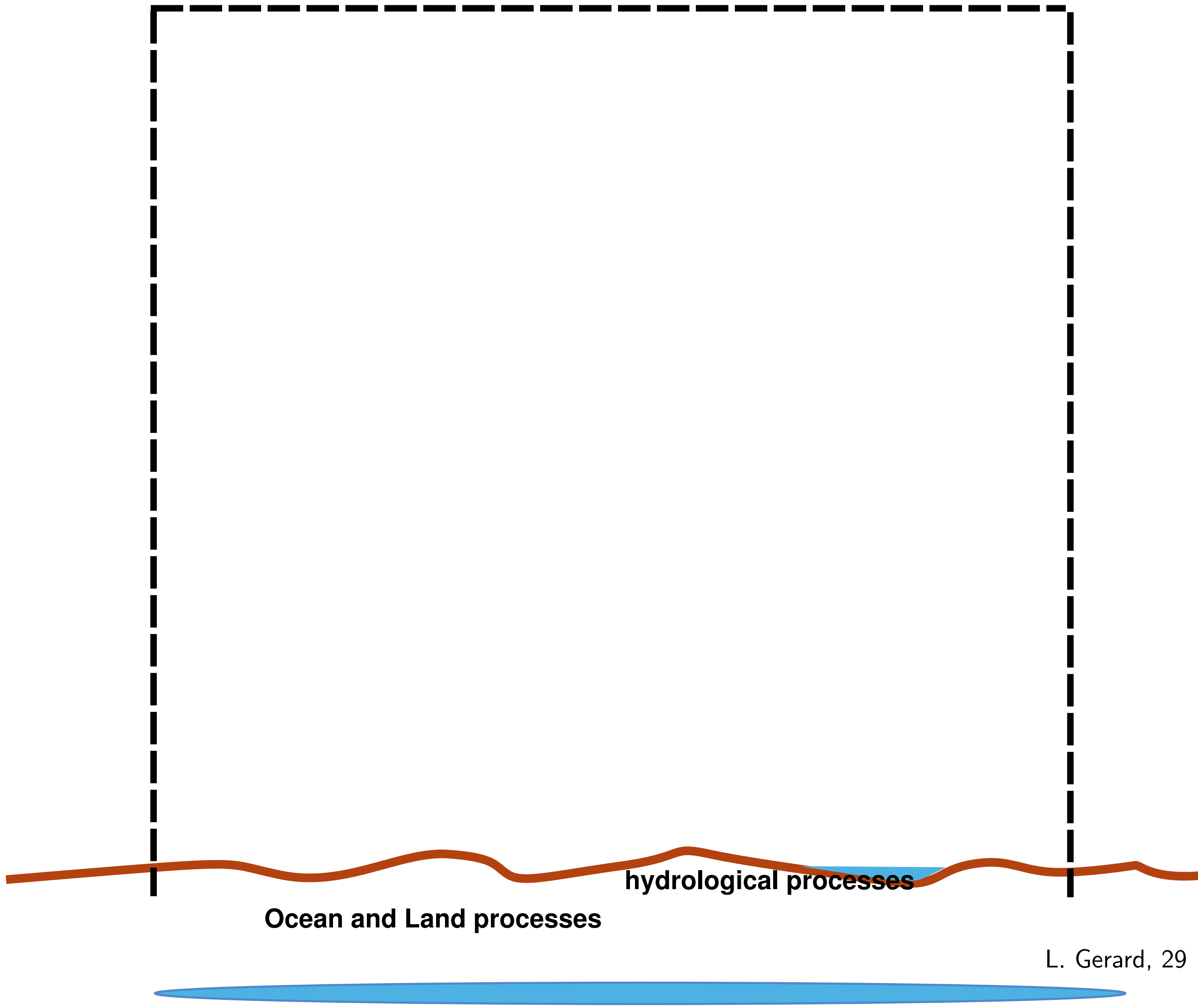
Luc Gerard

29 March 2007

Topics

1. Towards unified physics
2. Prognostic treatment
3. Cascading and processes interactions
   – Parallel vs sequential physics
   – Combining subgrid and resolved
4. Main choices for updraught
   seen from physics, seen from dynamics
5. General layout of the cascade
6. Equivalent Cloud Fraction
7. Significant mesh fraction
8. Example experiments

Physical context : towards unified physics



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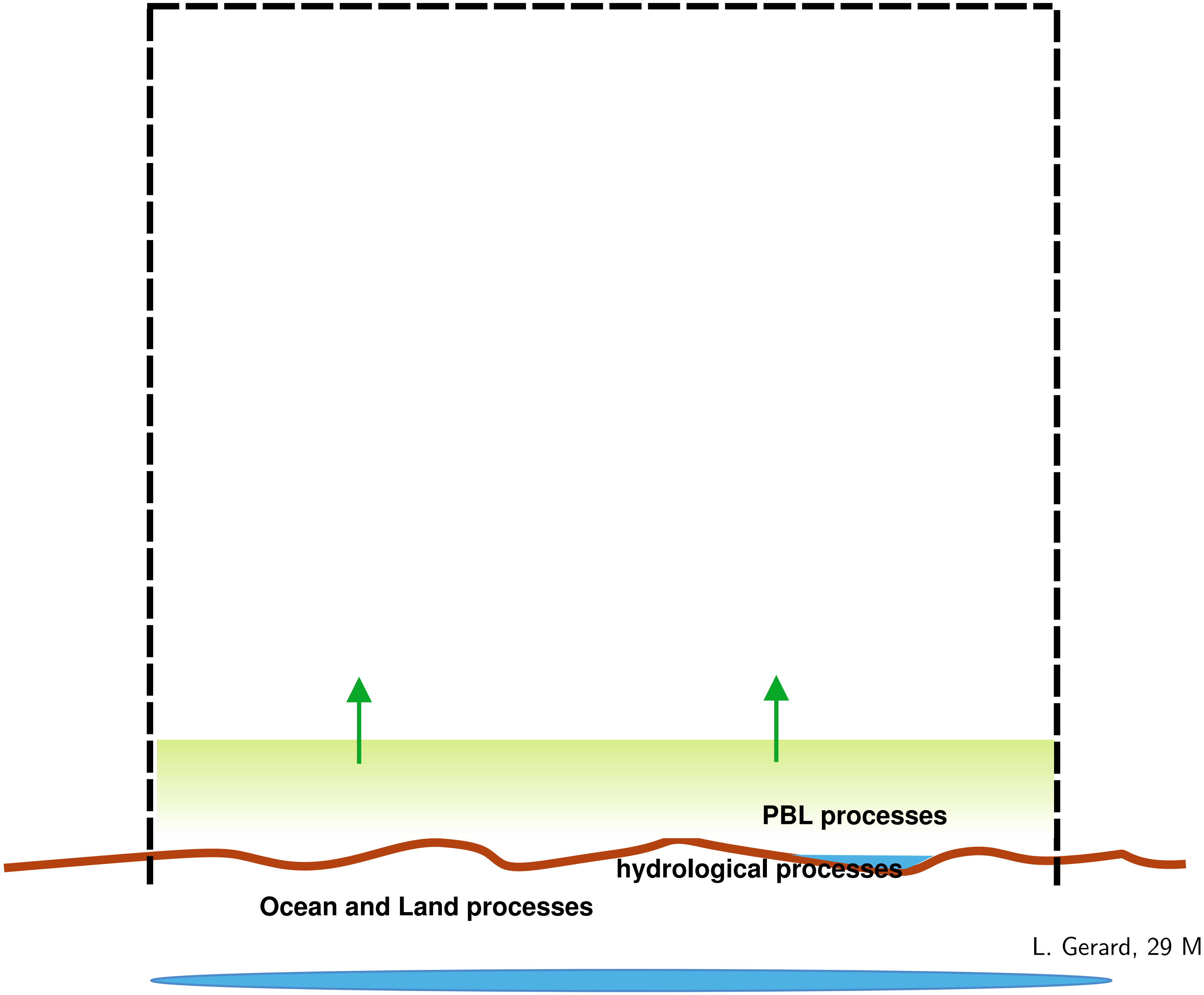

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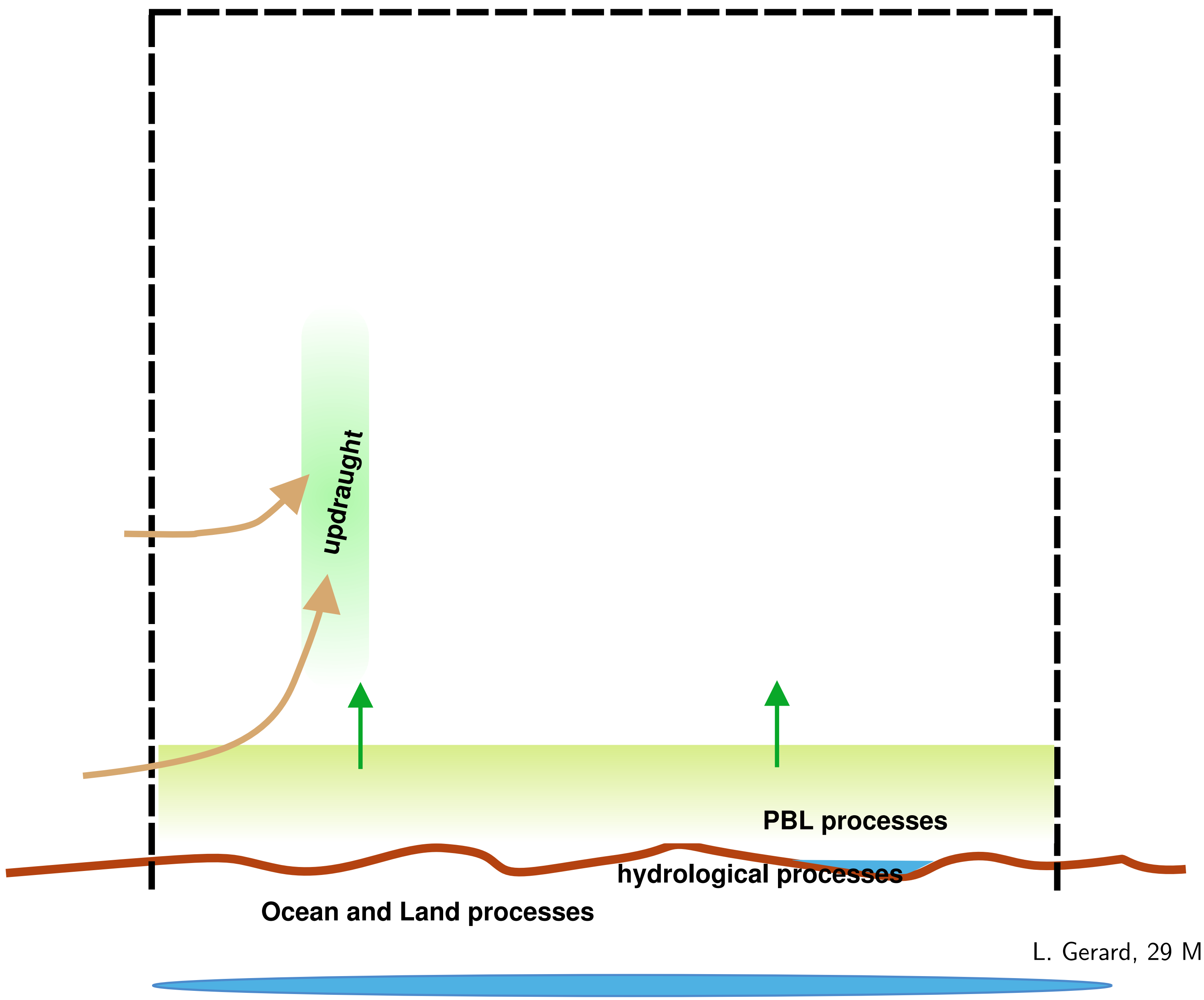

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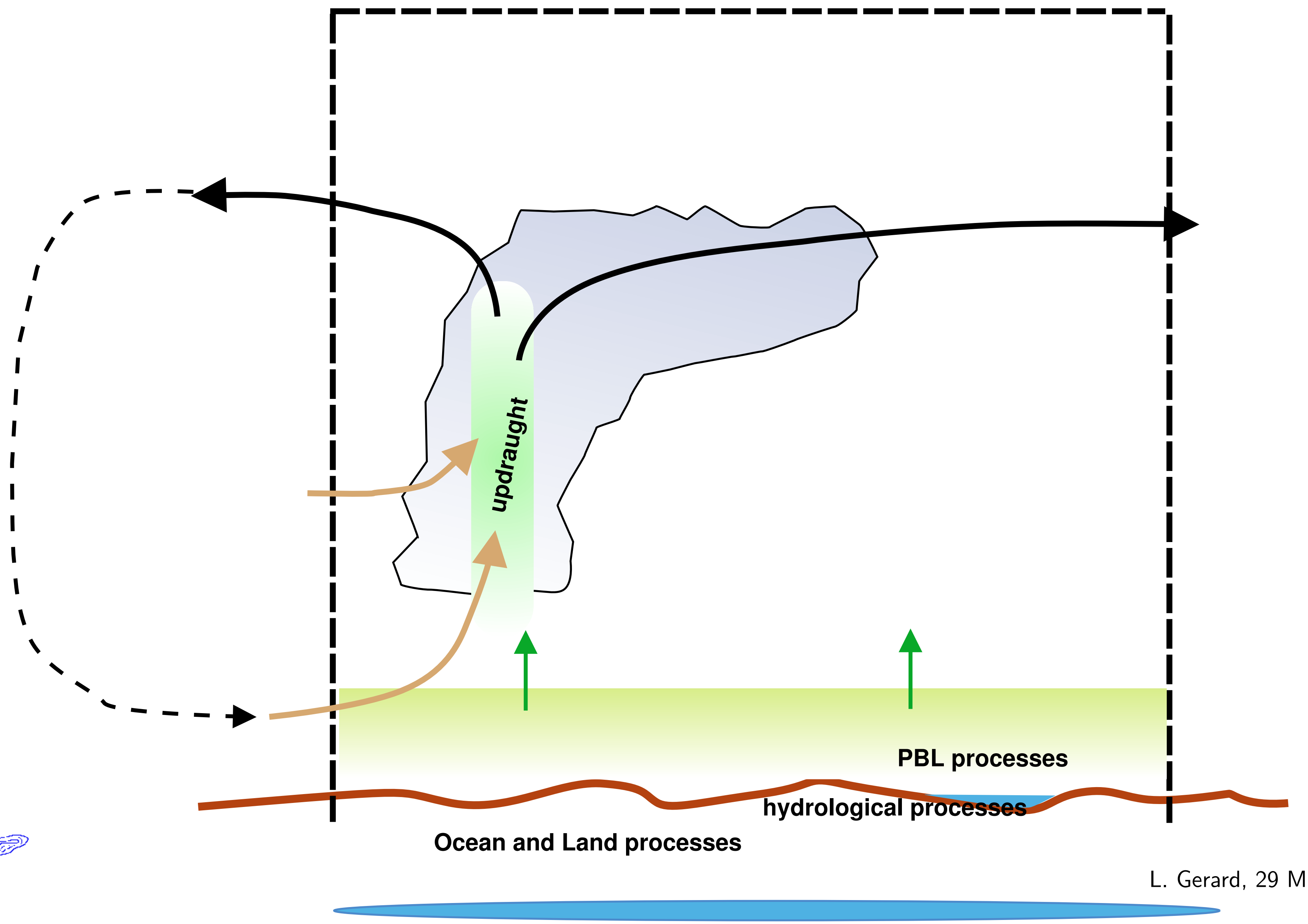

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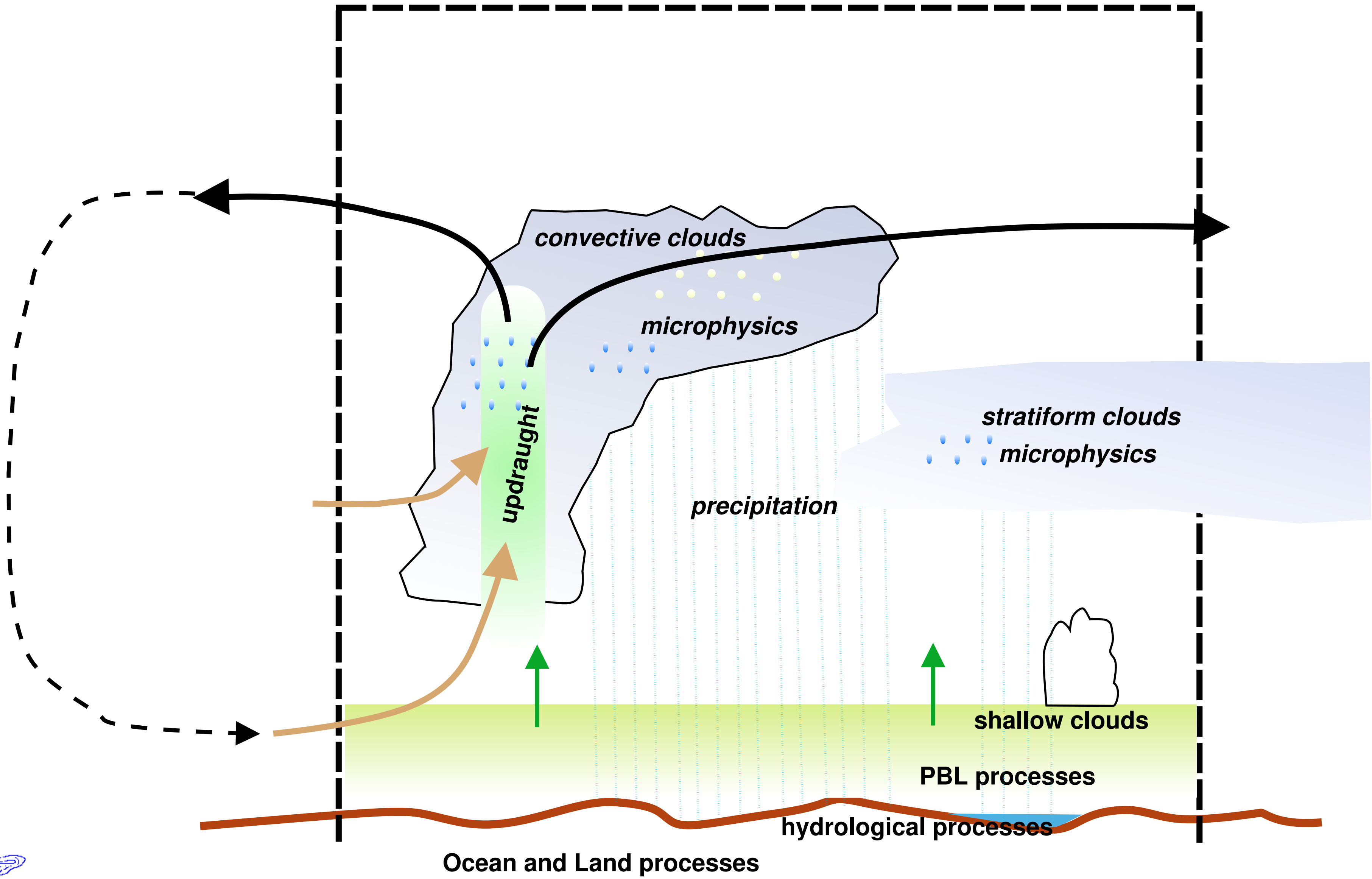

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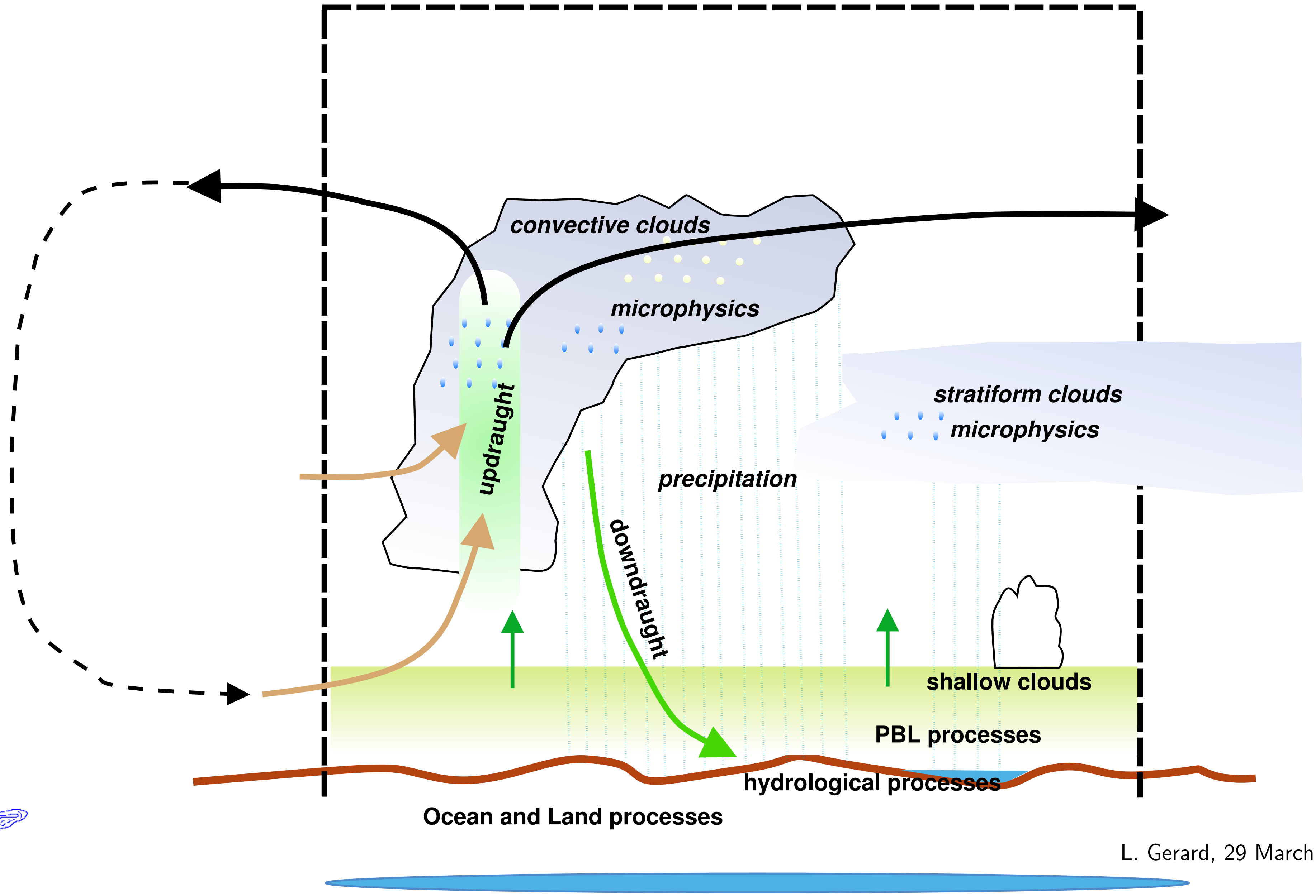

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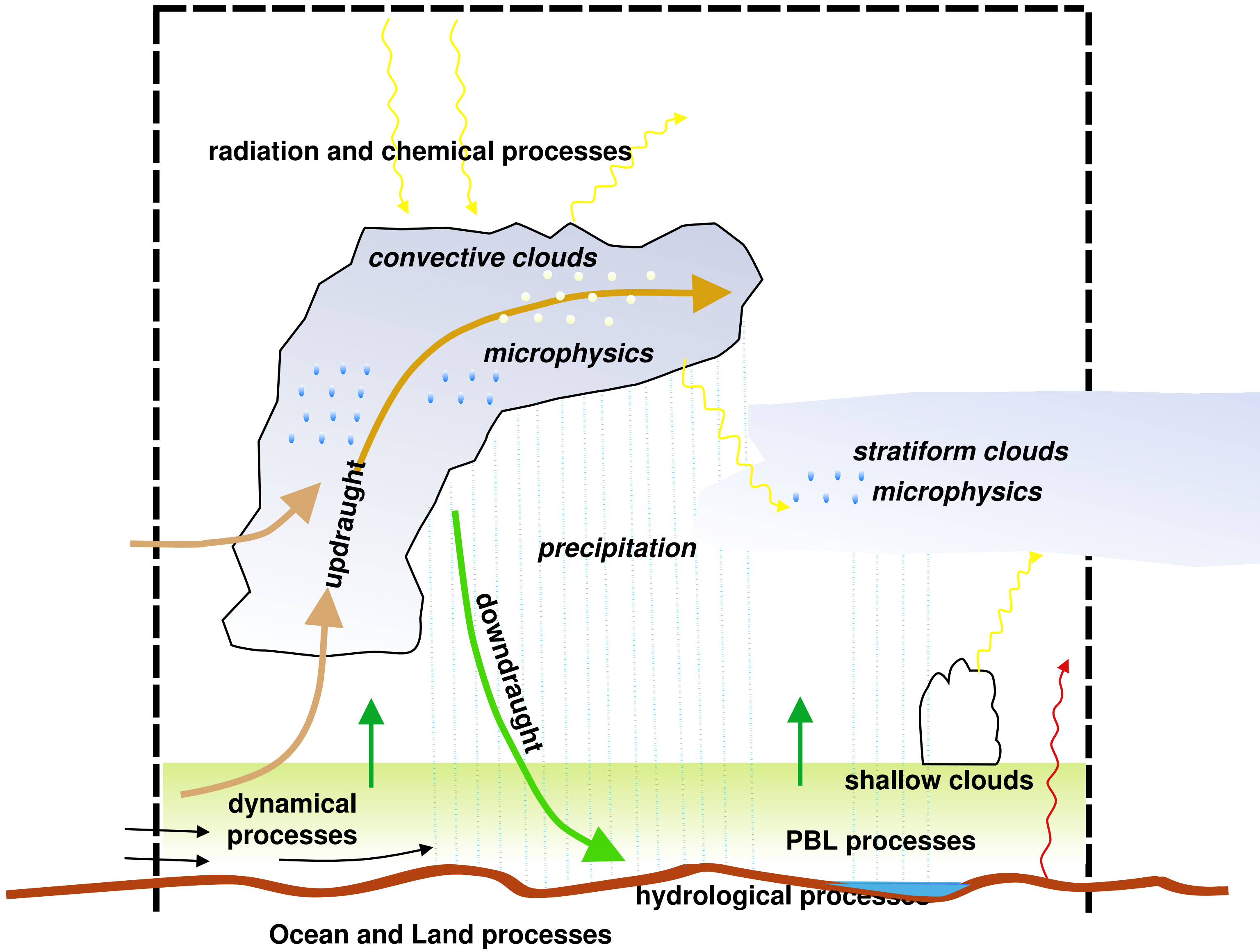

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  * Local effects : turbulent diffusion
  * Anvil clouds, radiative interactions
  * No physical separation, convective activity extends to Rossby radius of deformation (Mapes).
  * Small grid boxes and small time steps

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- Additional features
  - Explicit distinction of updraugt and environment mesh fractions
    * Separate treatment of condensation, $\omega_e \neq \omega_u$
    * Significant mesh fraction σ_u

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  - Geographical separation of trigger and effect.
  - Time separation : anvils and downdraught can now make their own life.

Cascading(1) : parallel vs sequential physics

Parallel physics

all processes acting from the same initial state

* Good modularity
* Implicit treatment induces steady-state error
* No single-way interactions, no cross interactions
* Parallel processes feeding on a single scarce resource results in
  - resource depletion (environmental blindness) or
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* Cross interactions by iteration of some parts / prognostic variables
* Avoids resource depletion / double counting

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Cascading of moist processes

(Retained solution)

* Modularity can be maintained
* No progress on steady state error (?)
* Single-way interactions chosen for physical realism
* Cross interactions possible through prognostic variables
* Resource depletion and double counting both avoided through carefull implementation.

Combining resolved and subgrid condensation

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$\Longrightarrow$ Idea :

separate input profile $\leftrightarrow$ convergence of vapour during time step

Fair share with two schemes

$$\overline{q_{t9}} = \overline{q_{v9}} + \overline{q_{\ell 9}} + \overline{q_{i9}}$$

$$\Downarrow \quad F^0_{\ell i},\ J^{\mathrm{td}}_i,\ J^{\mathrm{td}}_\ell$$

$$q_{\mathrm{sat}}(\overline{T_9}) \longrightarrow \boxed{\text{resolved condensation}} \longrightarrow F^0_{vi},\ F^0_{v\ell}$$

$$\overline{q_{v0}}\ ,\ \overline{q_{\ell 0}}\ ,\ \overline{q_{i0}}\ ,\ \overline{T_0} \qquad \text{and} \qquad f_{\mathrm{stra}}$$

$$\Downarrow$$

$$\mathit{MOCON} \longrightarrow \boxed{\text{Deep Convection}} \longrightarrow F^1_{vi},\ F^1_{v\ell},\ J^{\mathrm{cu}}_v,\ J^{\mathrm{cu}}_i,\ J^{\mathrm{cu}}_\ell$$

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

$$\Downarrow$$

$$\boxed{\text{Autoconversion}}$$

Main choices

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  - compute a single cloud profile by moving up (down) an air parcel with mean grid box properties along a pseudo-adiabatic trajectory with mixing.
  - limitations : assumes a draught area σ_u with $mean$ draught vertical velocity ω_u and $mean$ draught property ψ_u. Vertical transport $\sigma_u \omega_u \psi_u$ generally underestimated (Yano et al. 2004).

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– Draughts affect large scale through transport and condensation (MT-coupling).

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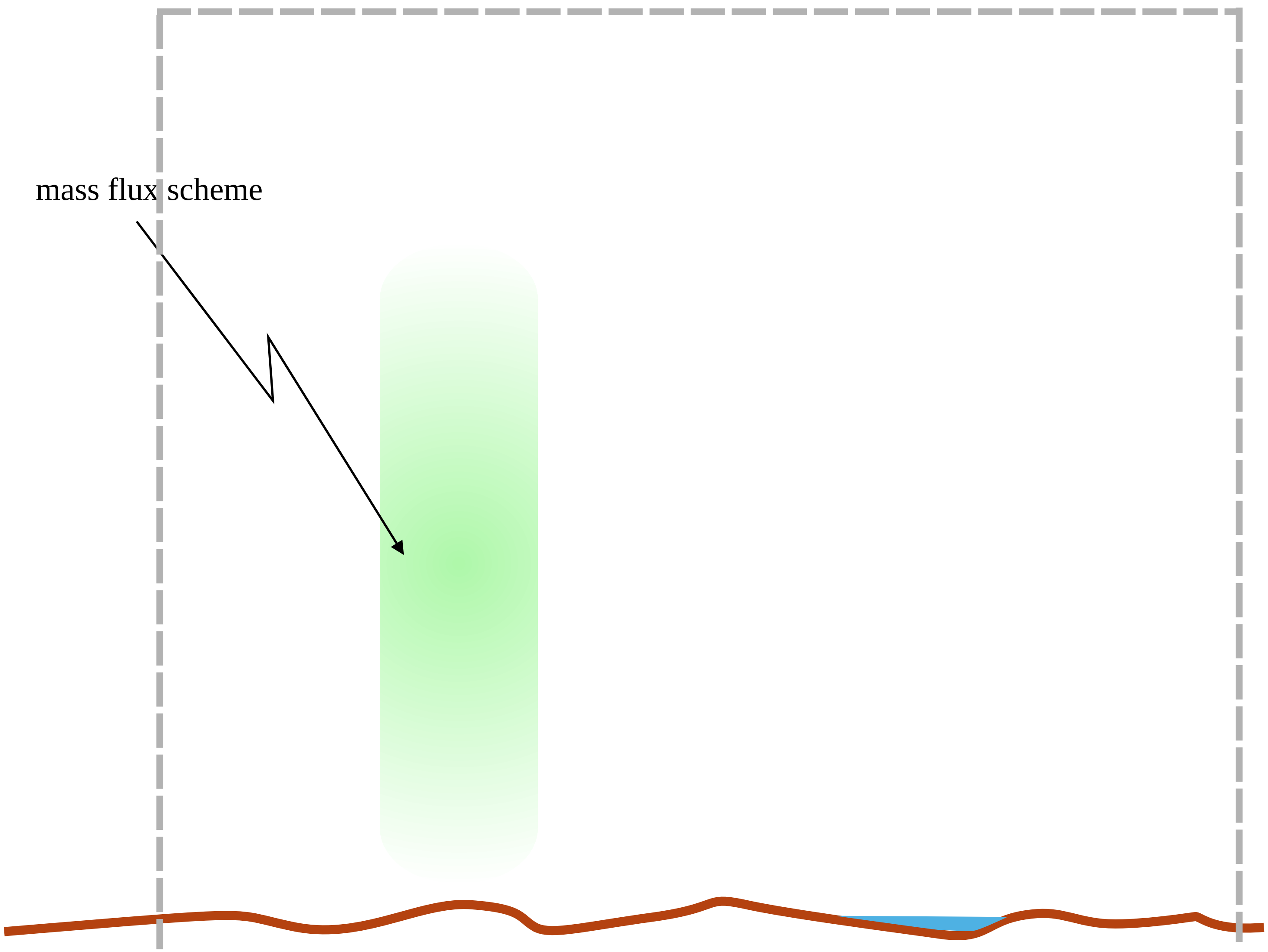

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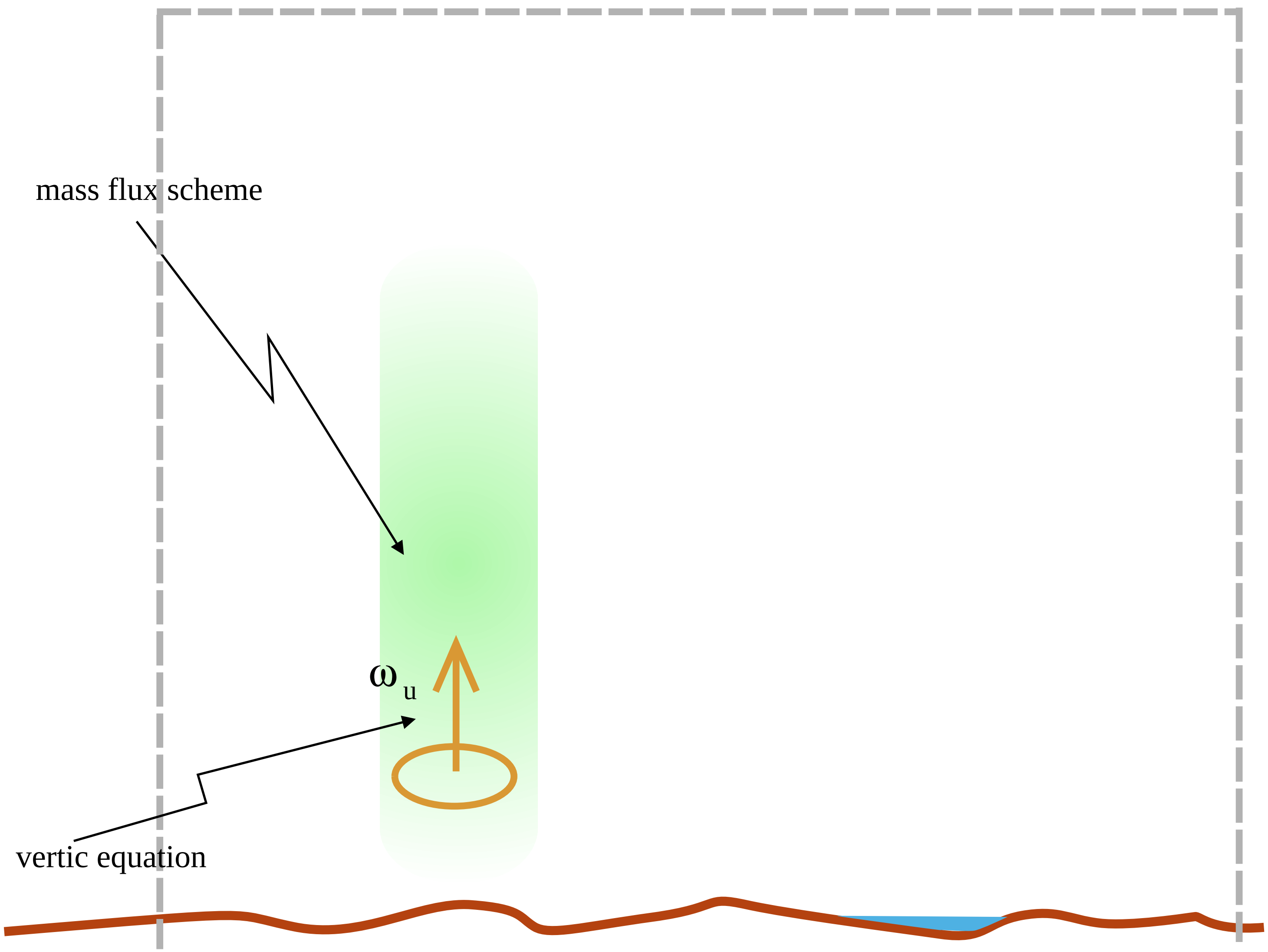

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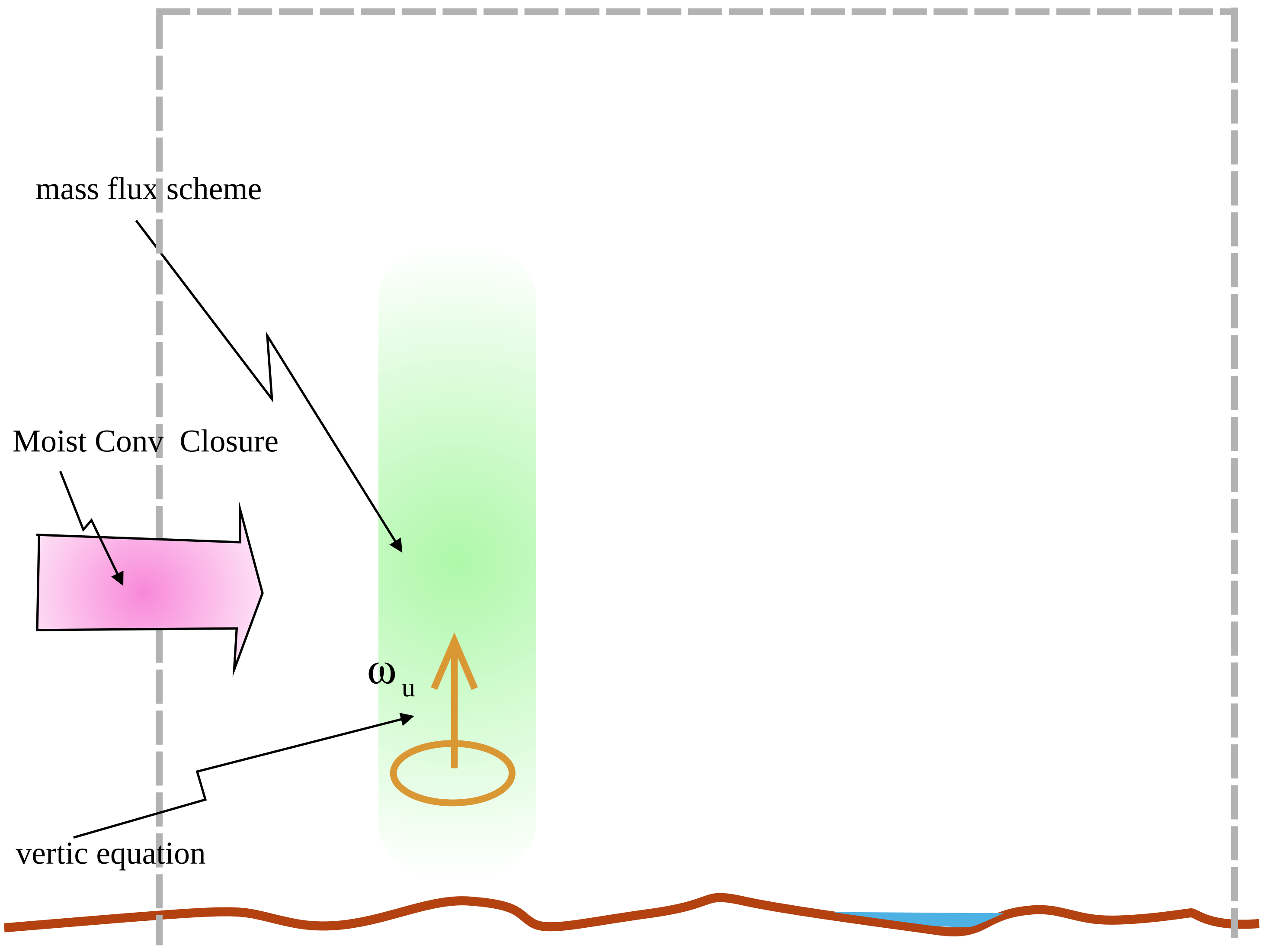

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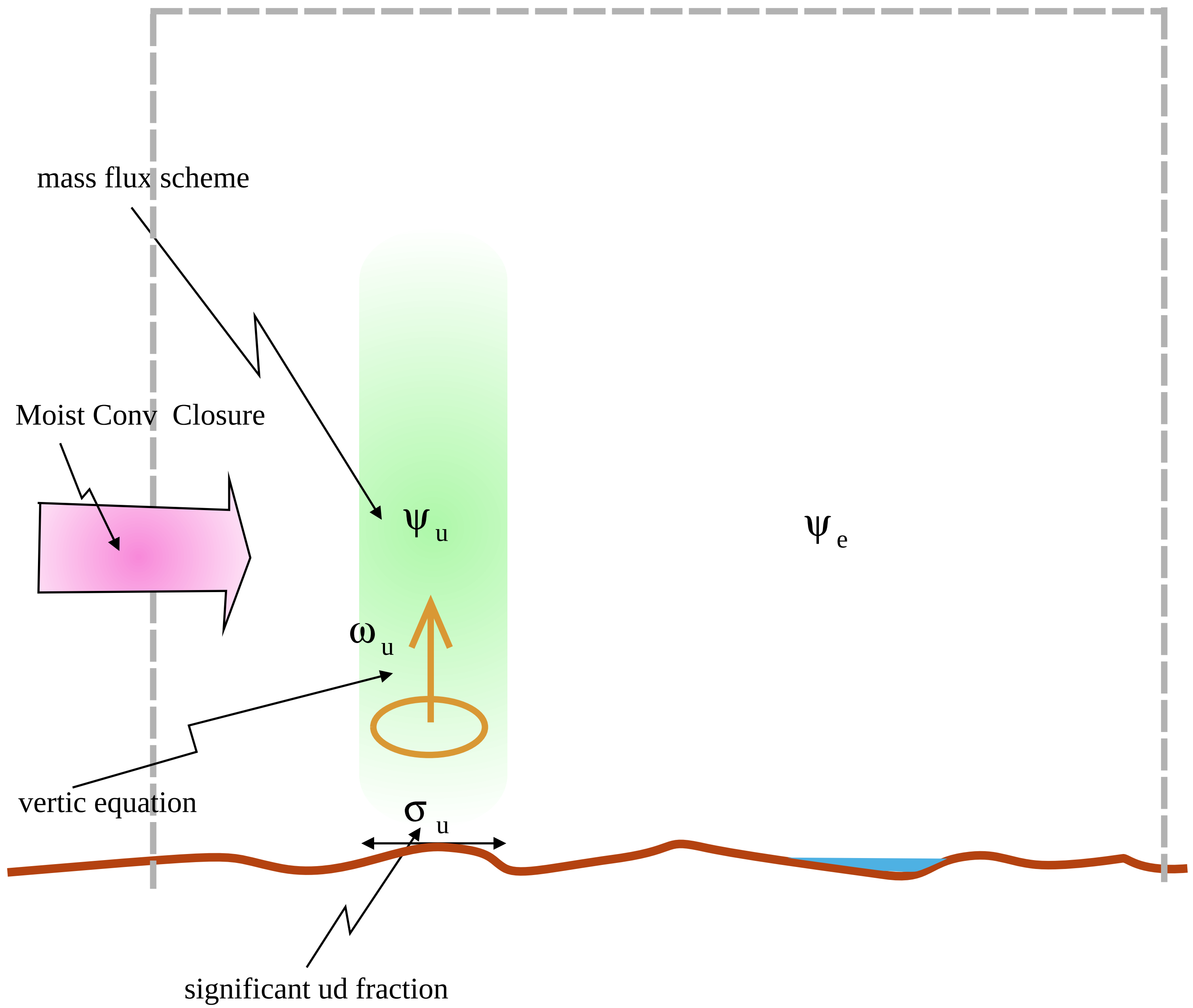

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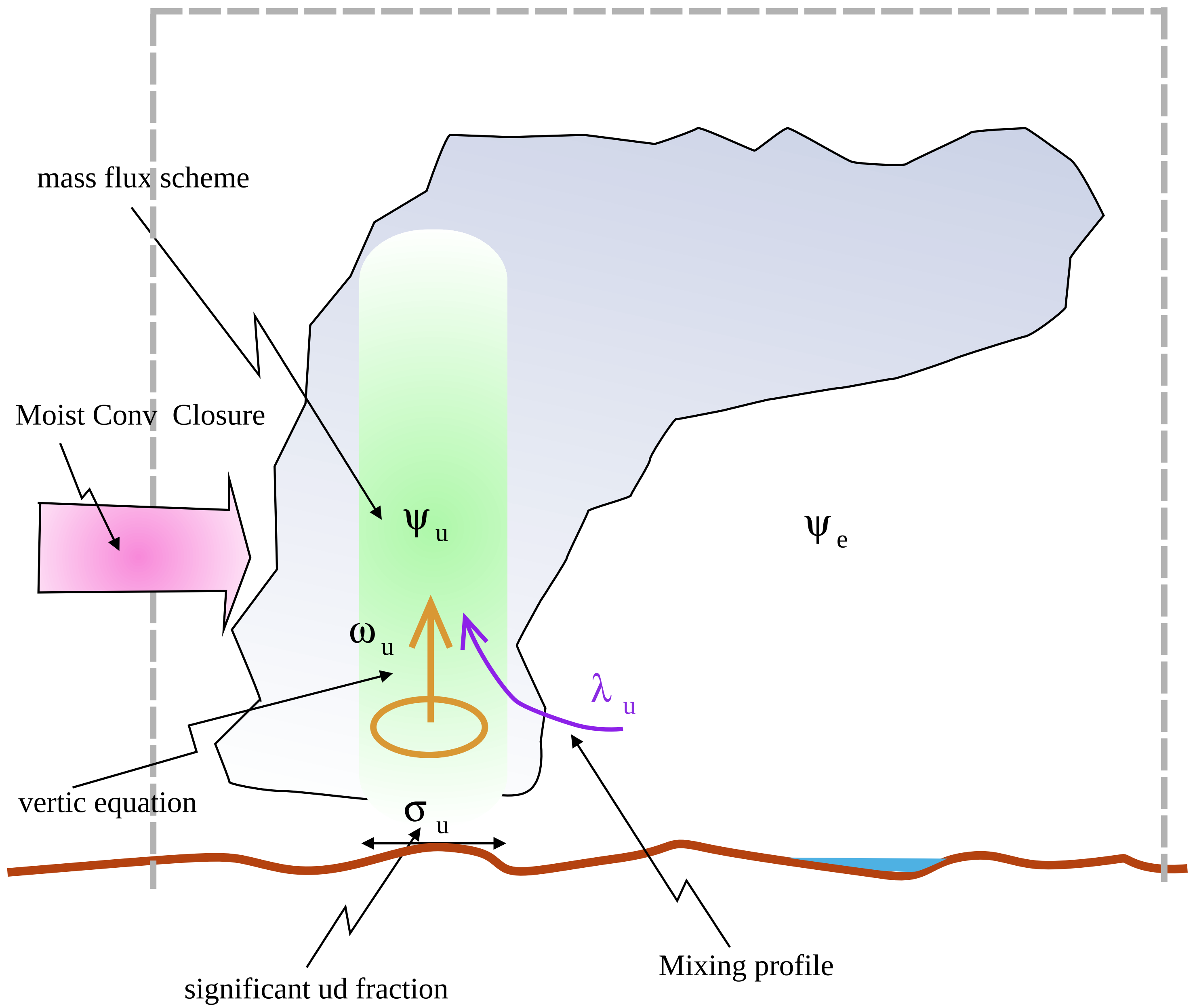

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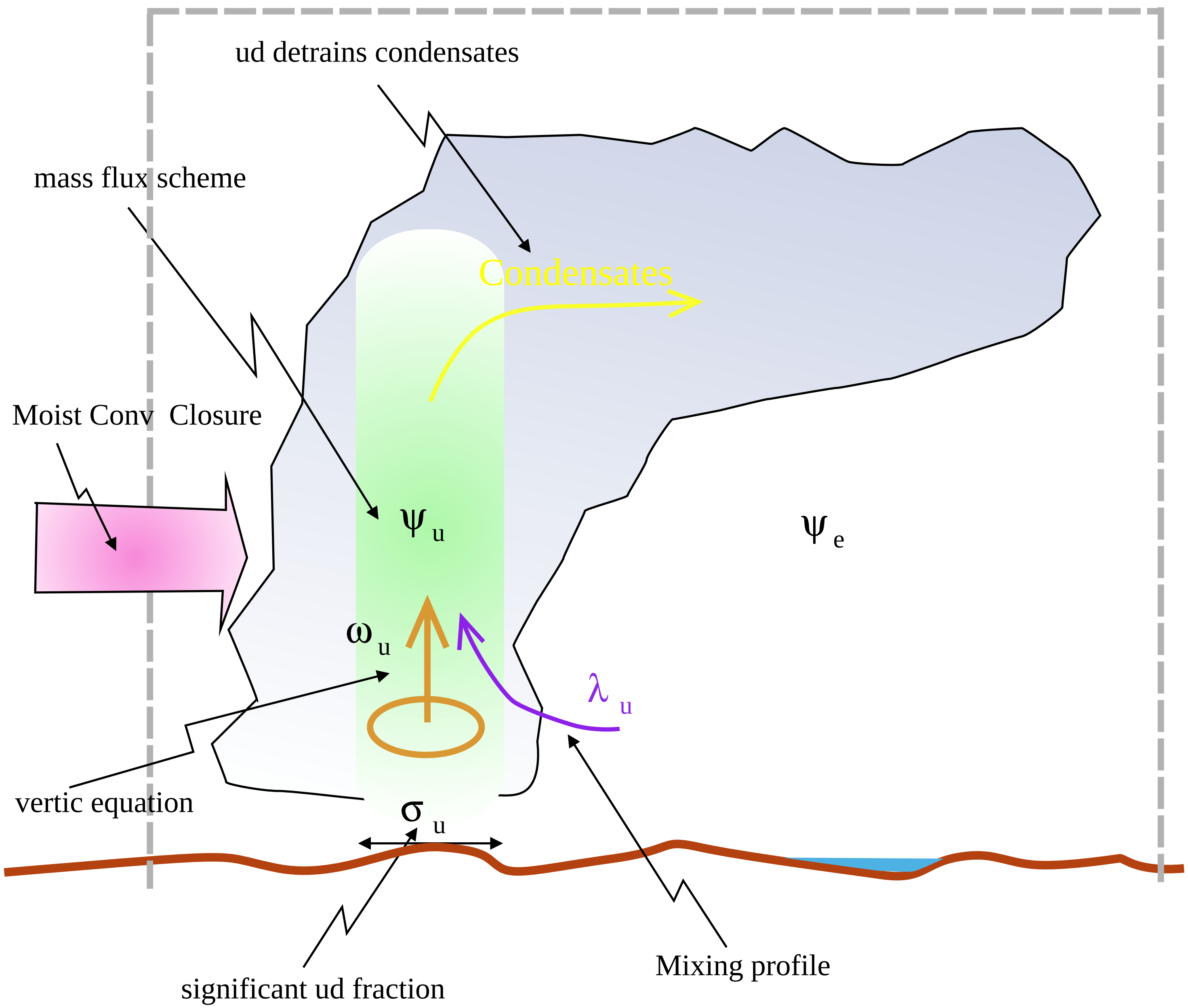

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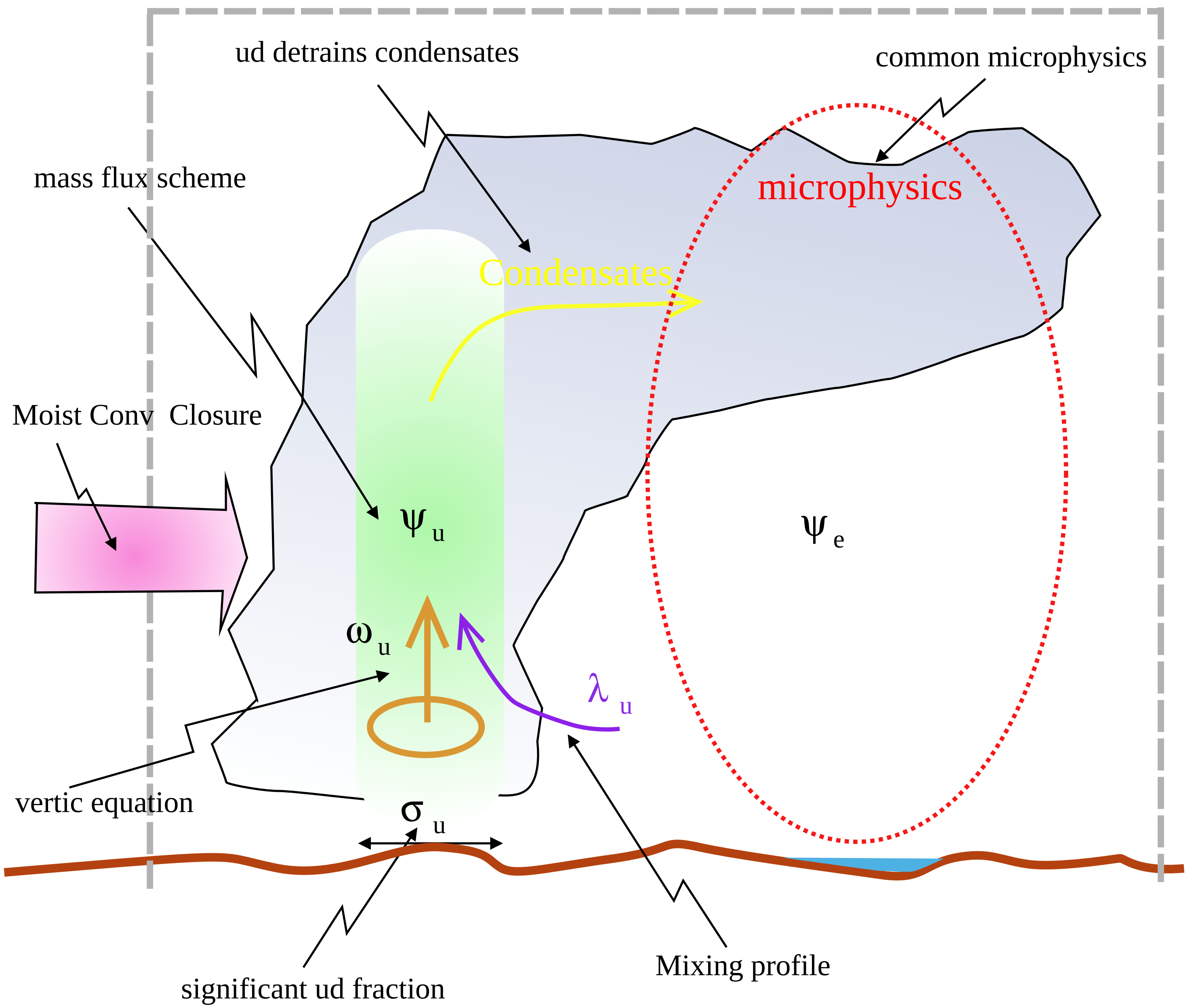

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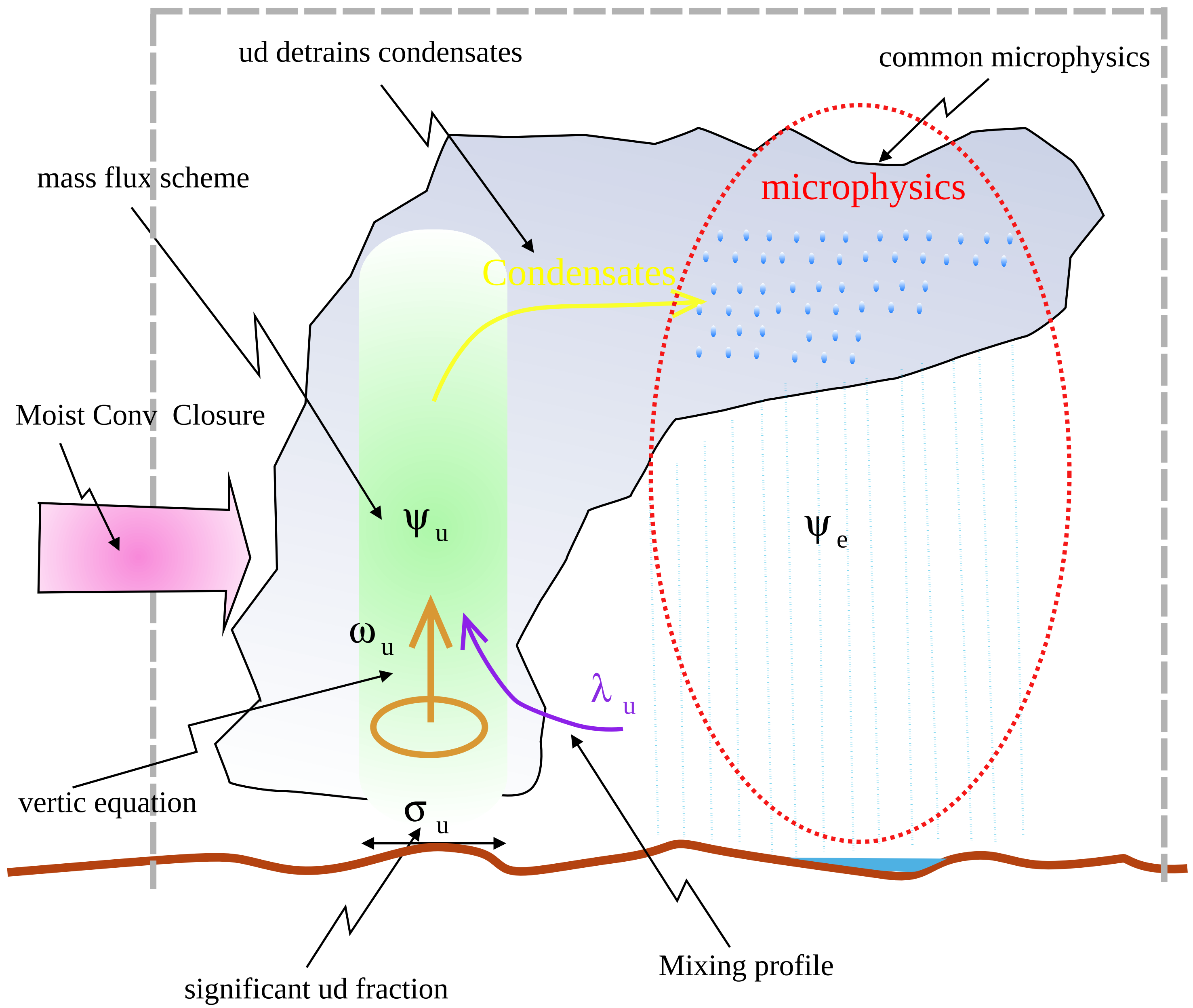

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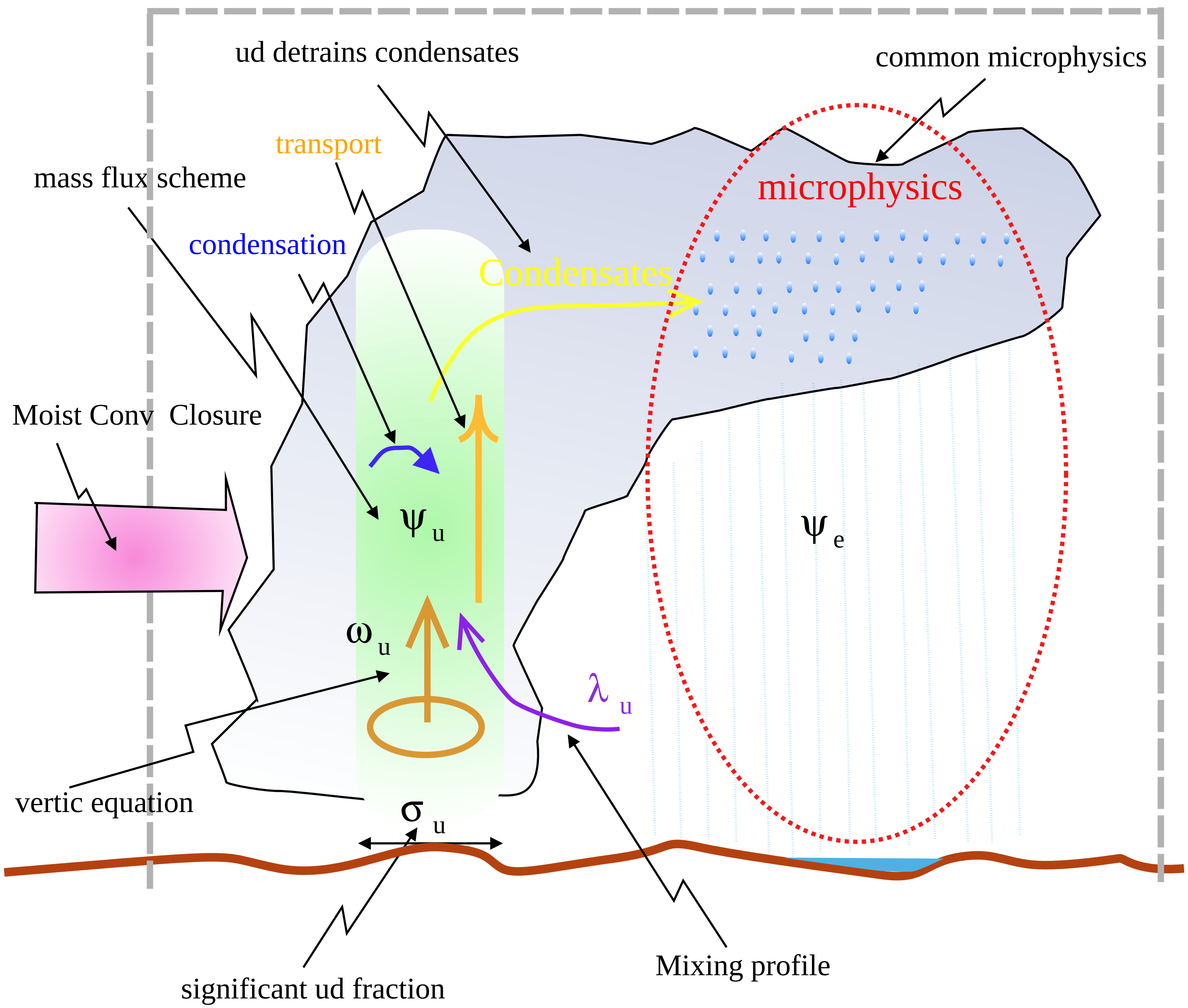
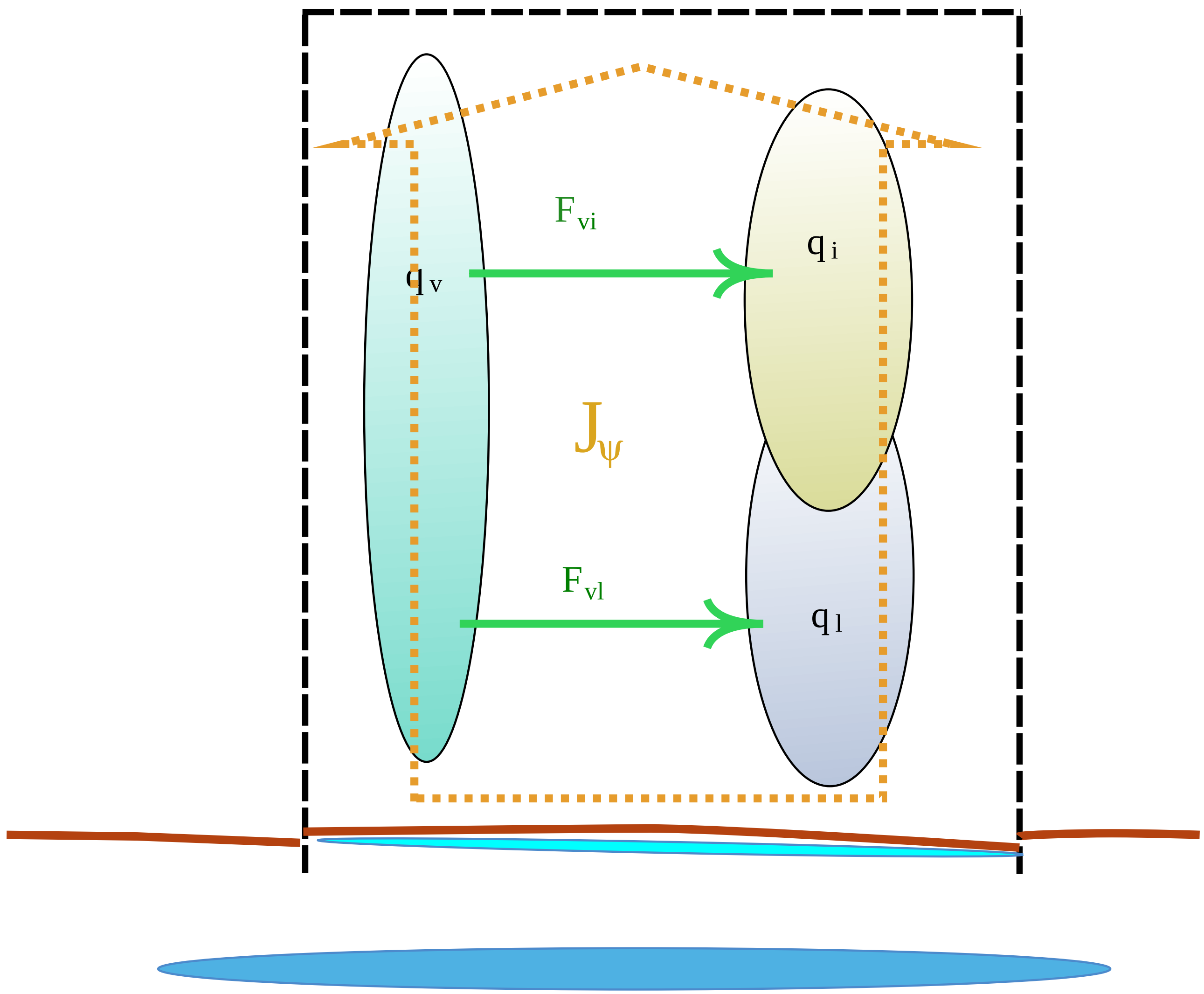


Subgrid as seen from dynamics



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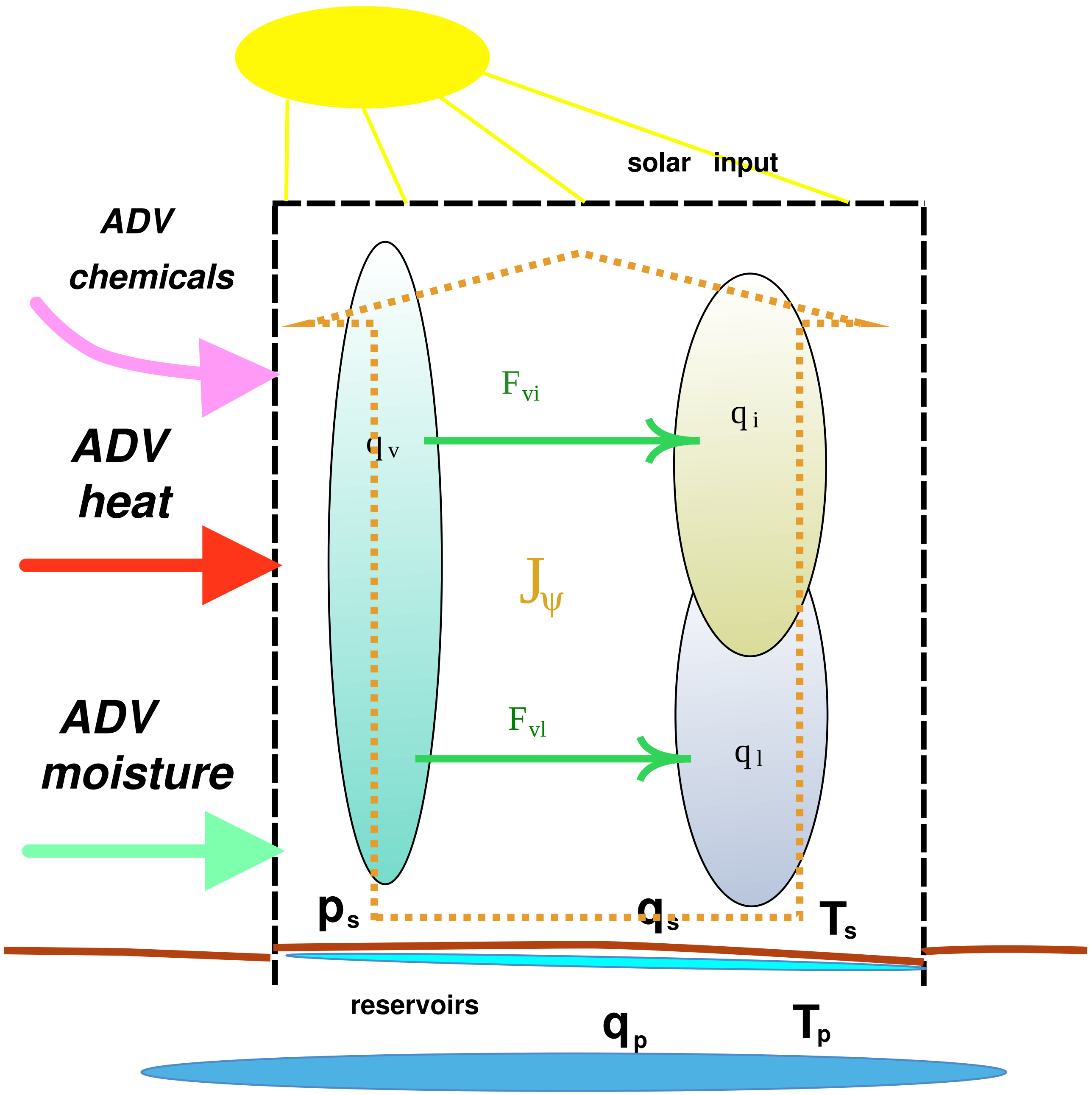

Cascade General layout

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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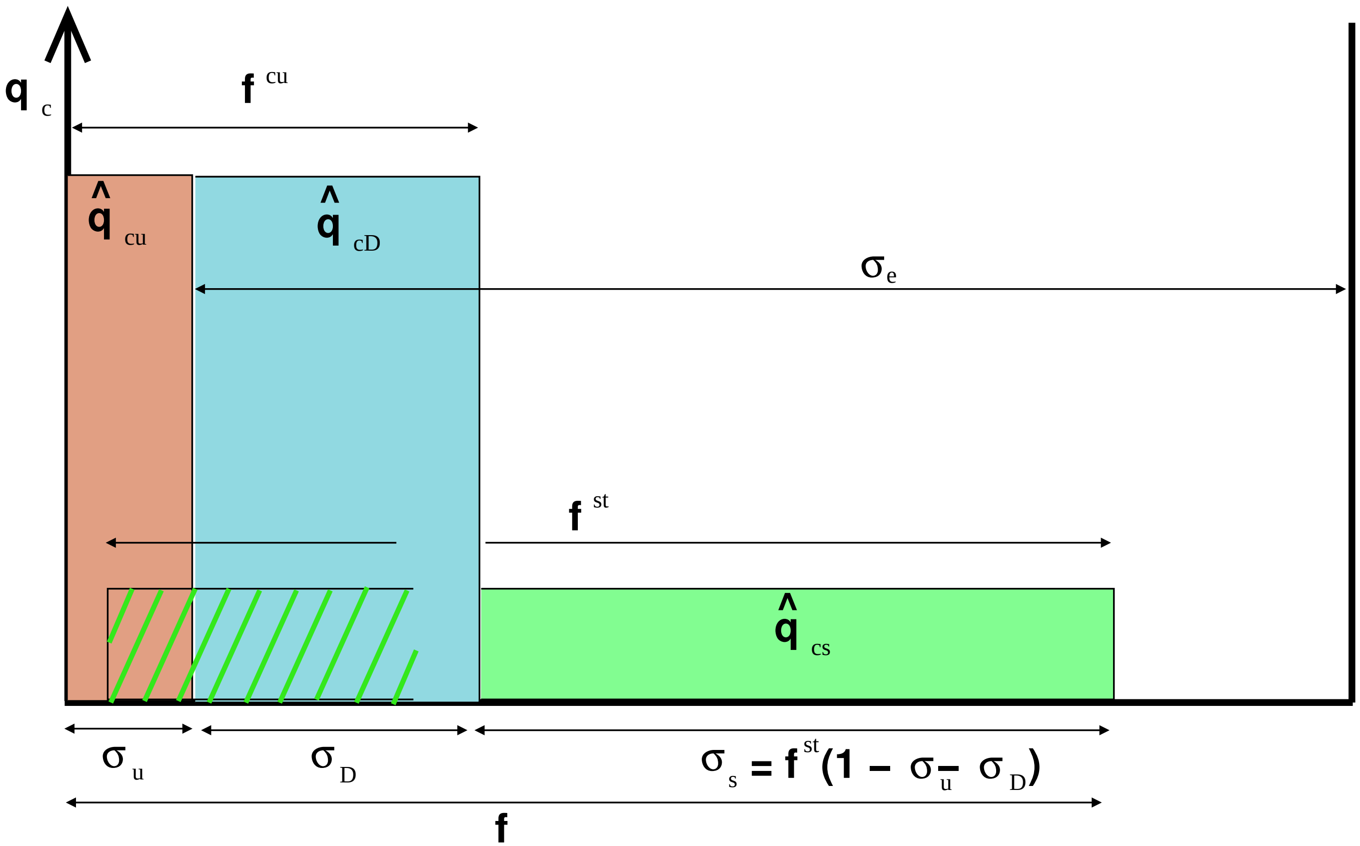
Equivalent cloud fraction



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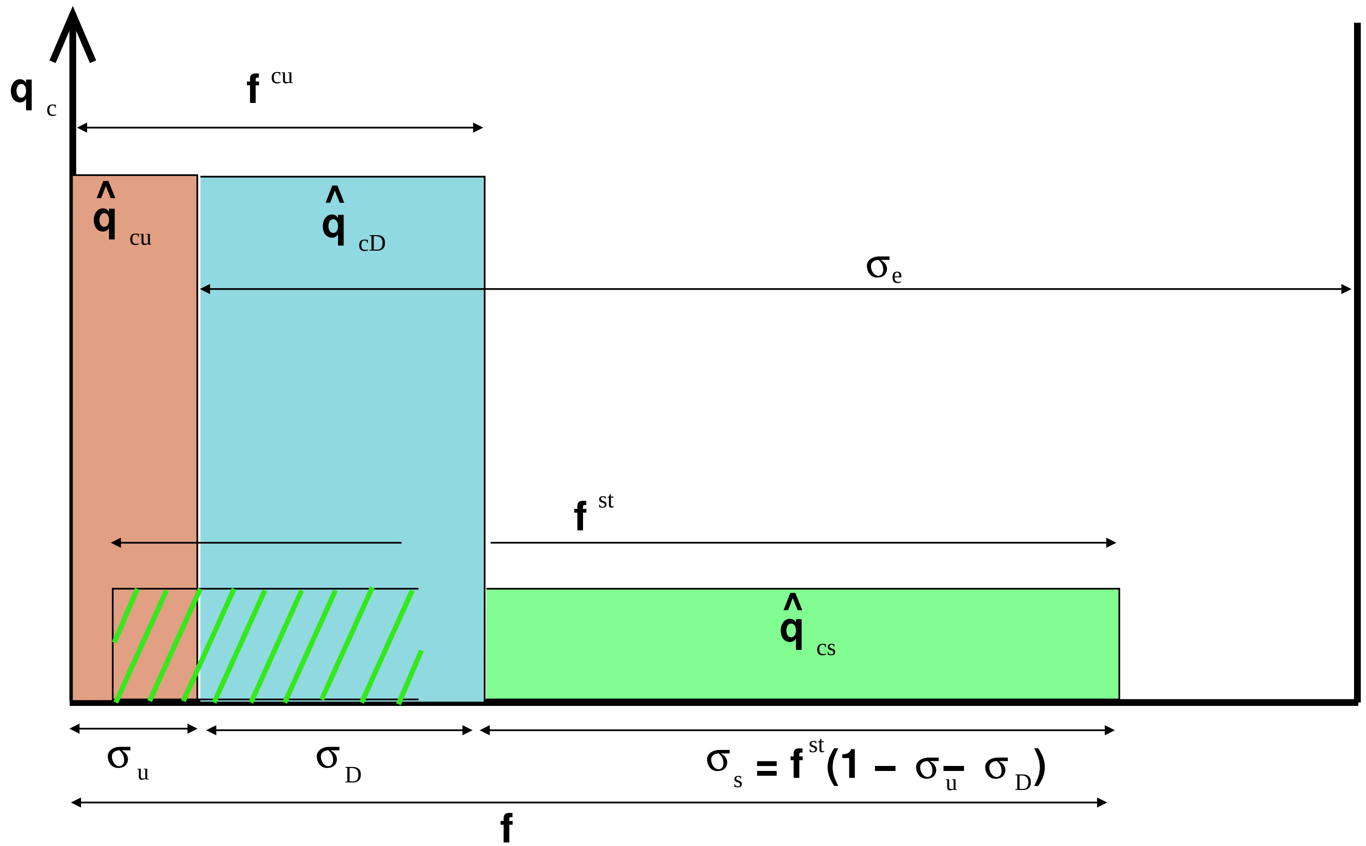

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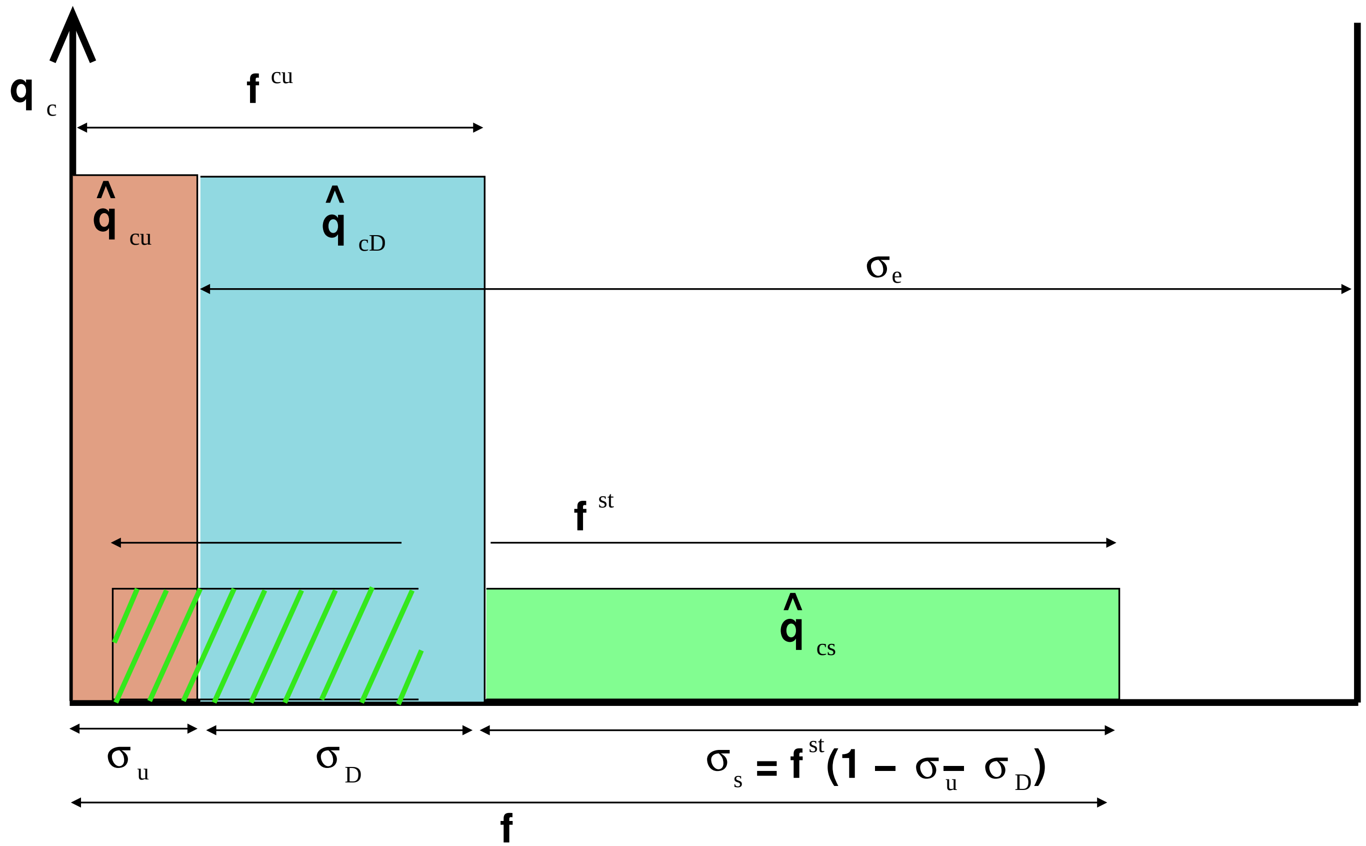

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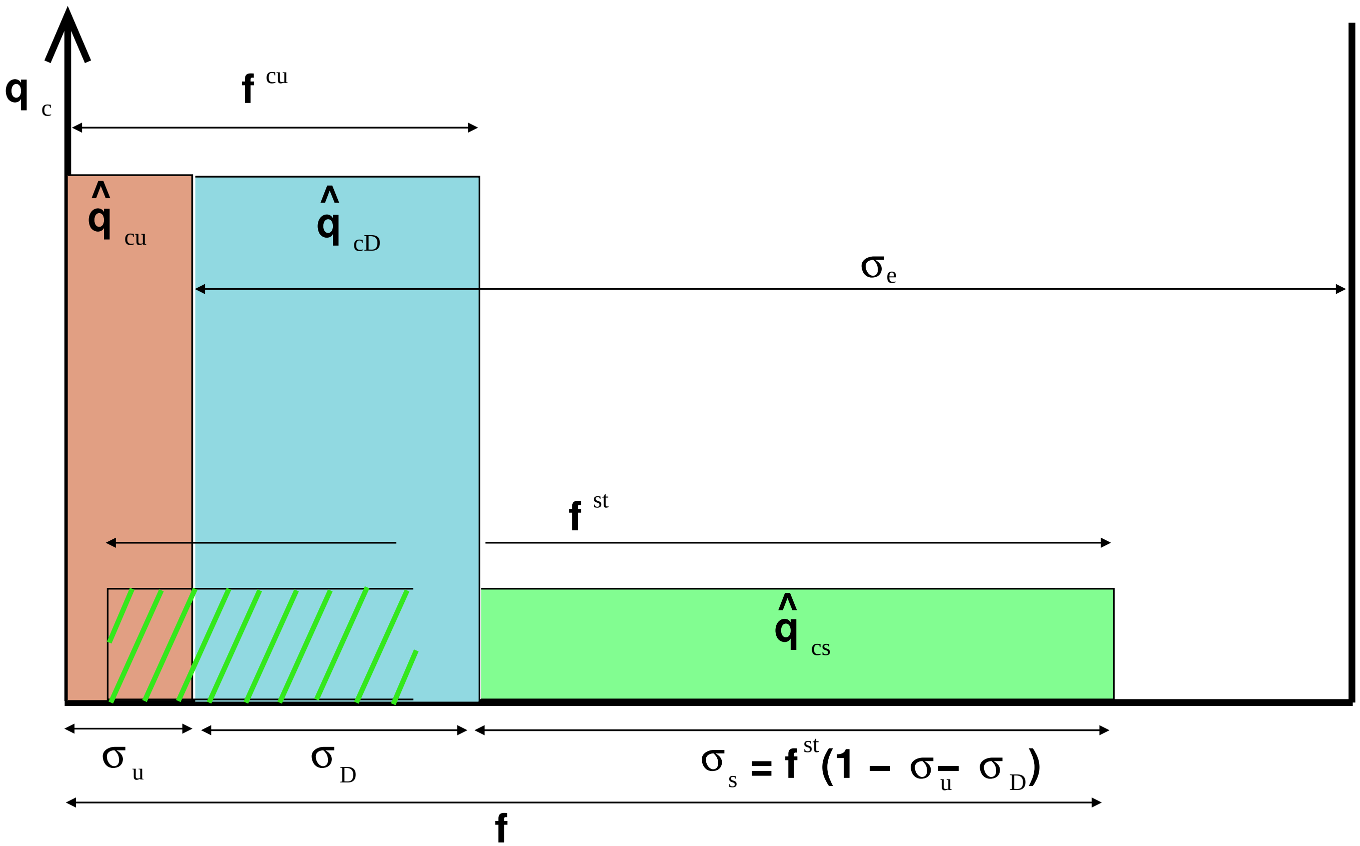

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idea : weighted interpolation of intensive condensates

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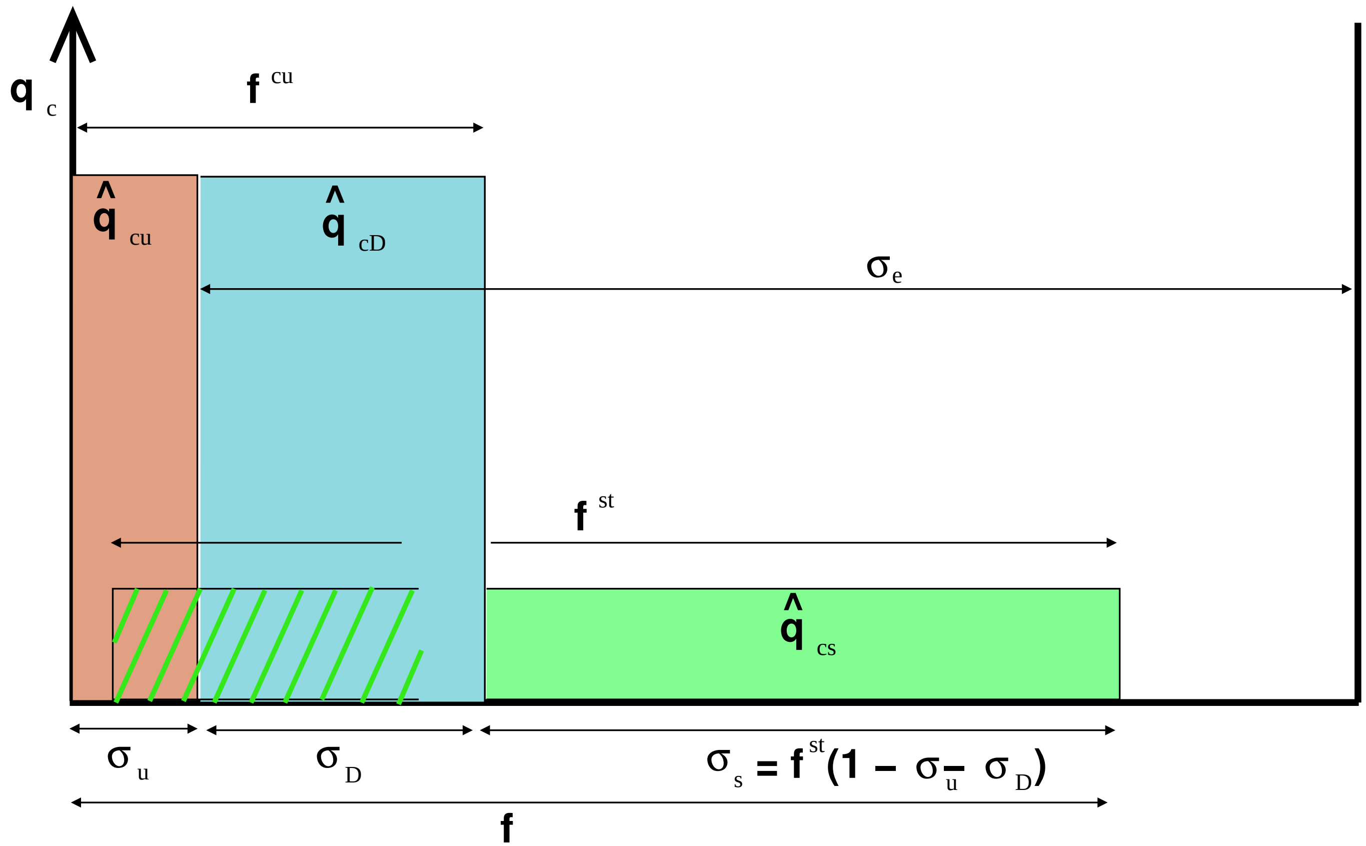

$$\widehat{q_{ce}} = \alpha_{\rm cu}\widehat{q_{cc}} + (1-\alpha_{\rm cu})\widehat{q_{cs}}$$

$$\equiv \frac{\overline{q_c}}{f^{eq}}$$

$$\alpha_{\rm cu} = \frac{F_{vc}^{cu}}{F_{vc}^{cu} + F_{vc}^{st}}$$

diluting $\overline{q_c}$ over $f \Rightarrow$ underestimation

concentrating $\overline{q_c}$ over $f^{cu} \Rightarrow$ overestimation

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1. Different properties in updraught, environment and average

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- Estimation of entrained properties
- $\omega_e \sim 0$

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   - Estimation of entrained properties
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   - Impact in cascade update ?

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   – Estimation of entrained properties
   – $\omega_e \sim 0$
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2. No precipitation in the updraught ?

Significant mesh fraction

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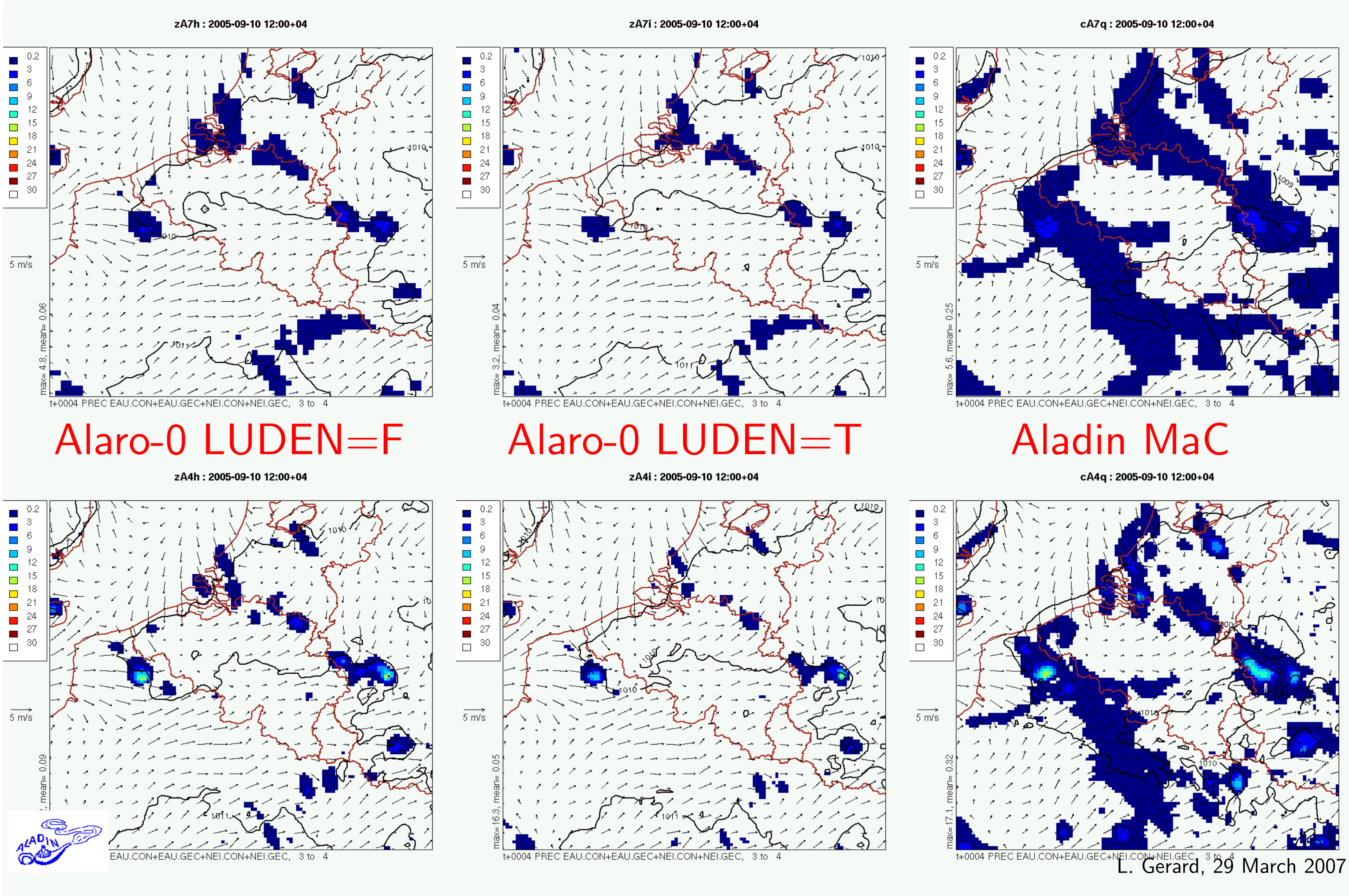
Thunderstorms on Saturday 10 September 2005

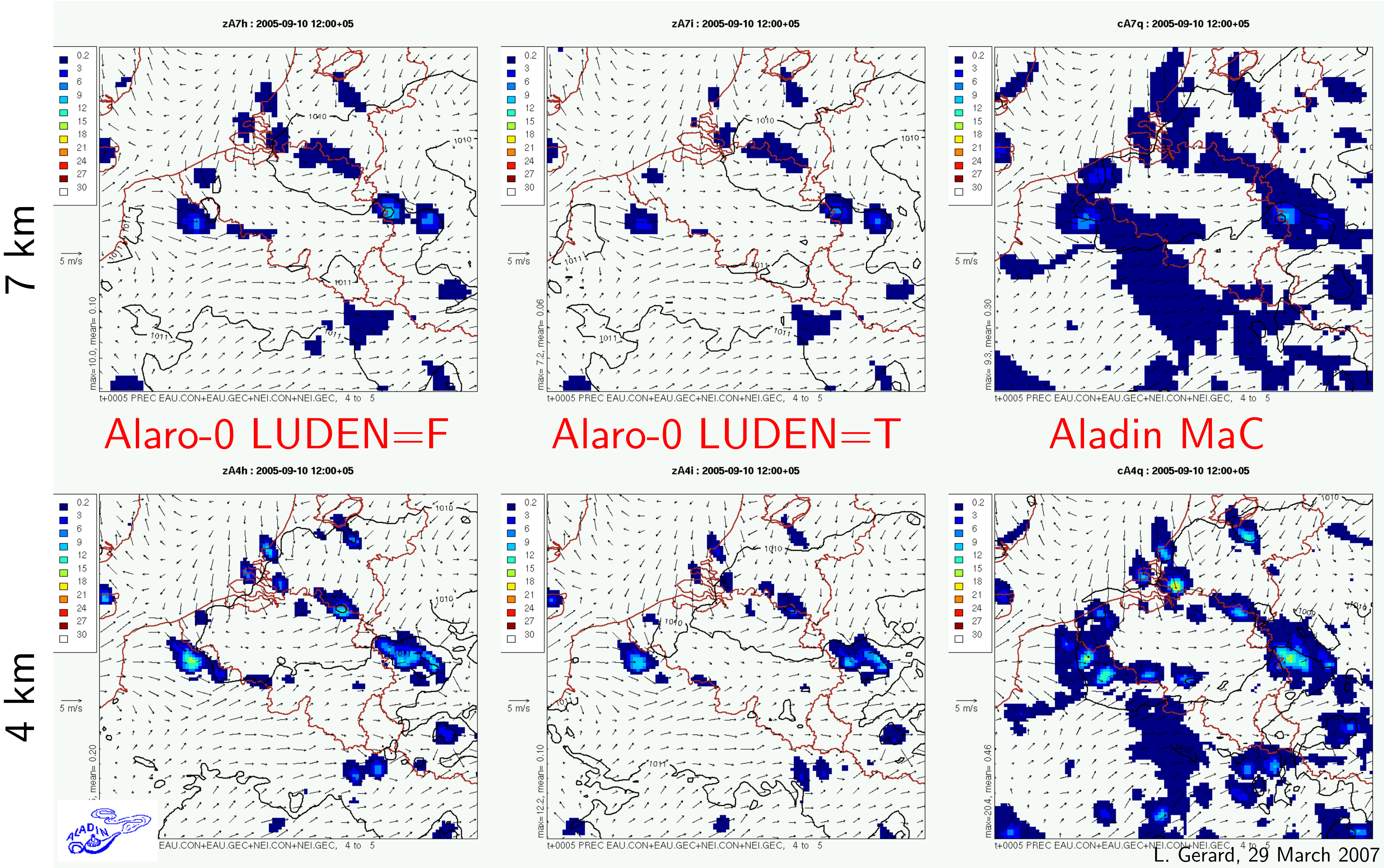
7 km

4 km



L. Gerard, 29 March 2007

Thunderstorms on Saturday 10 September 2005



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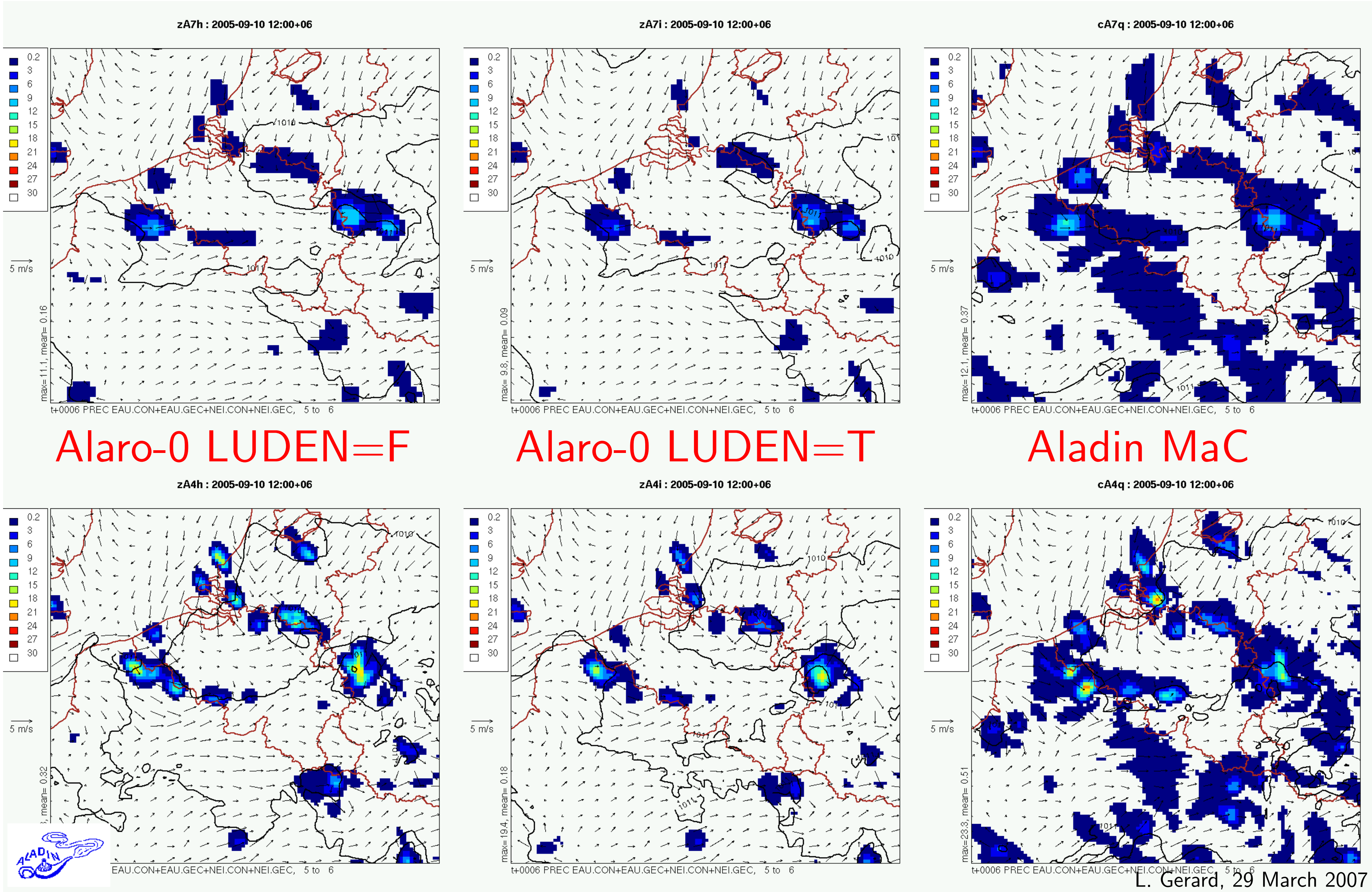

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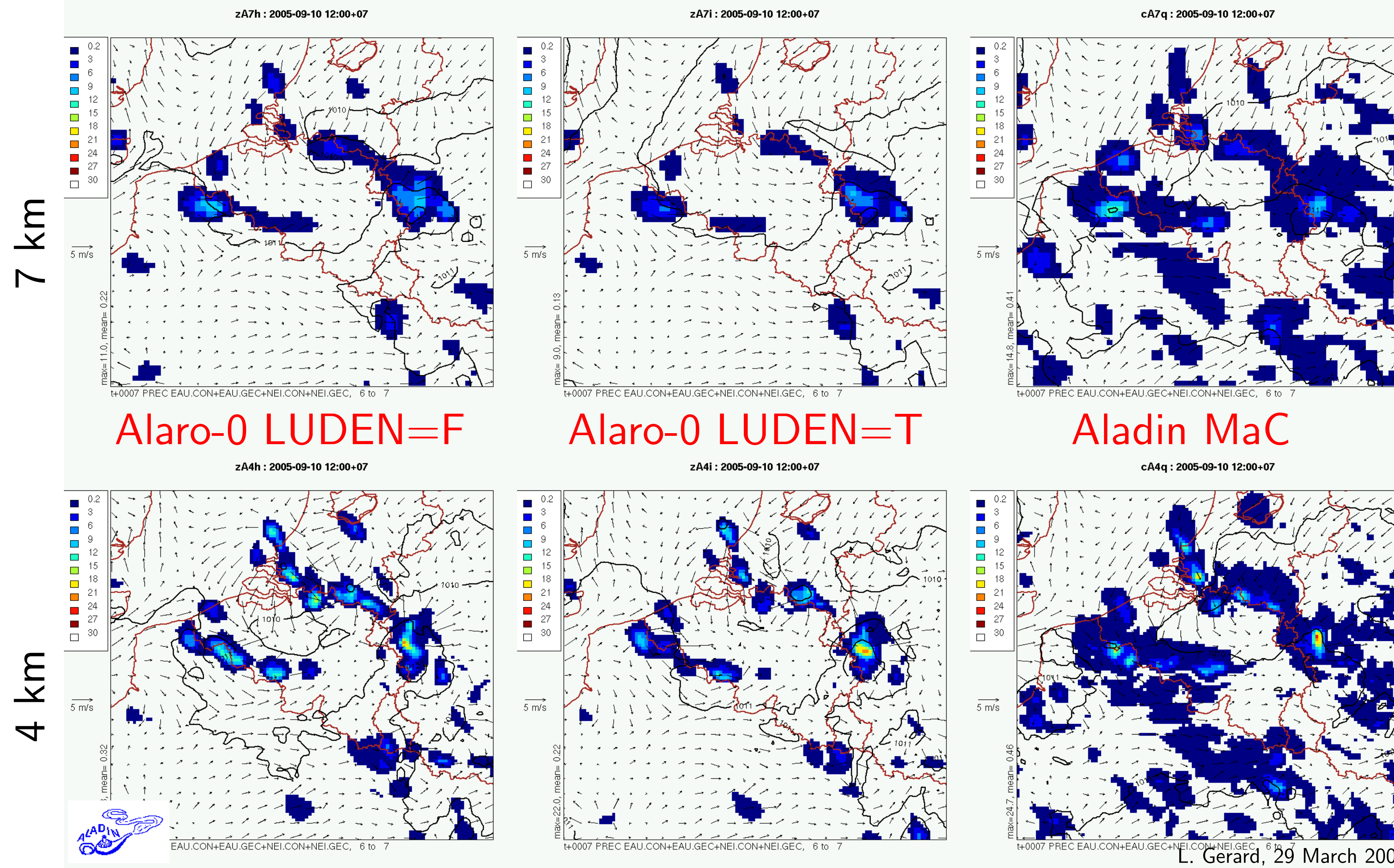

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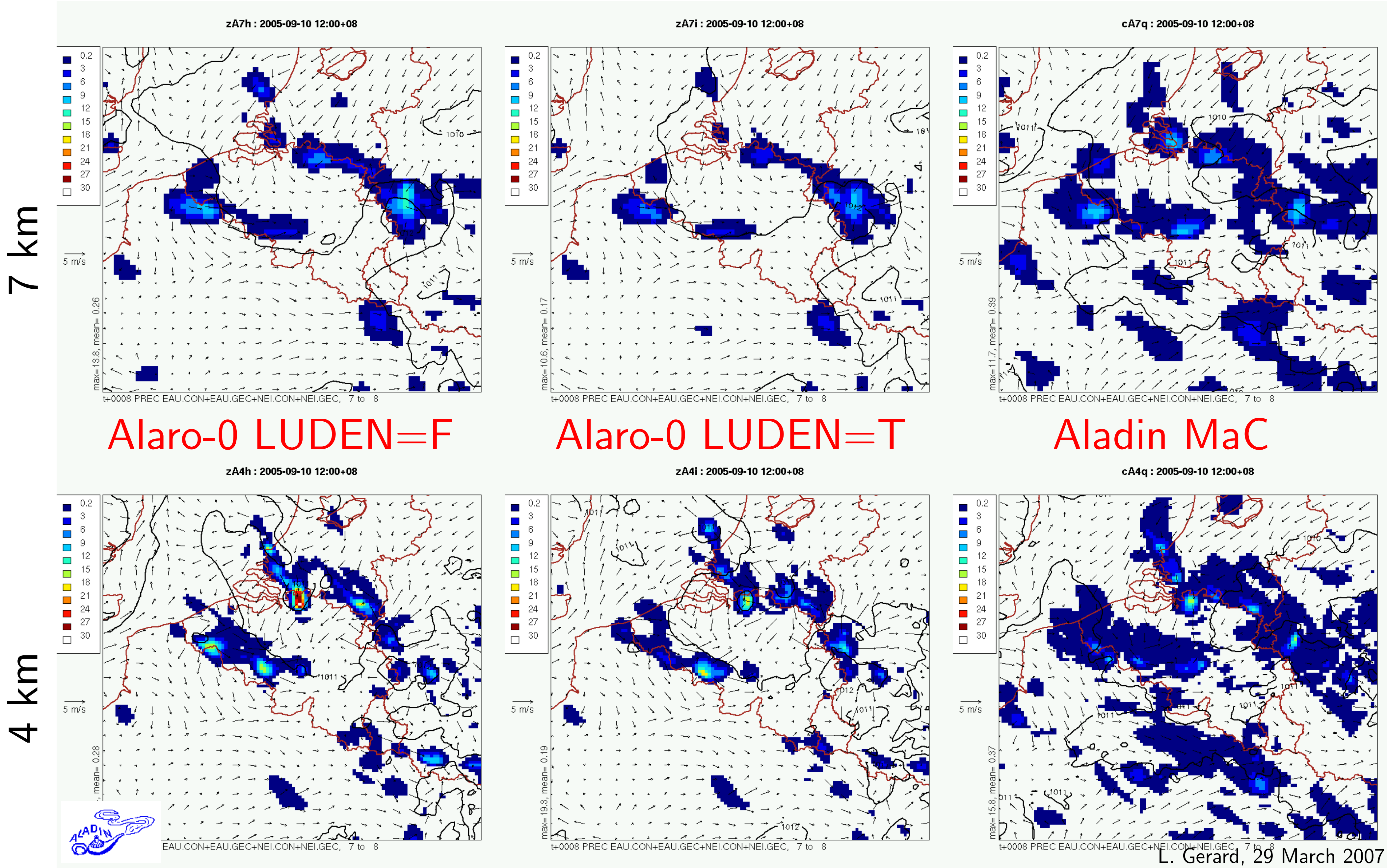

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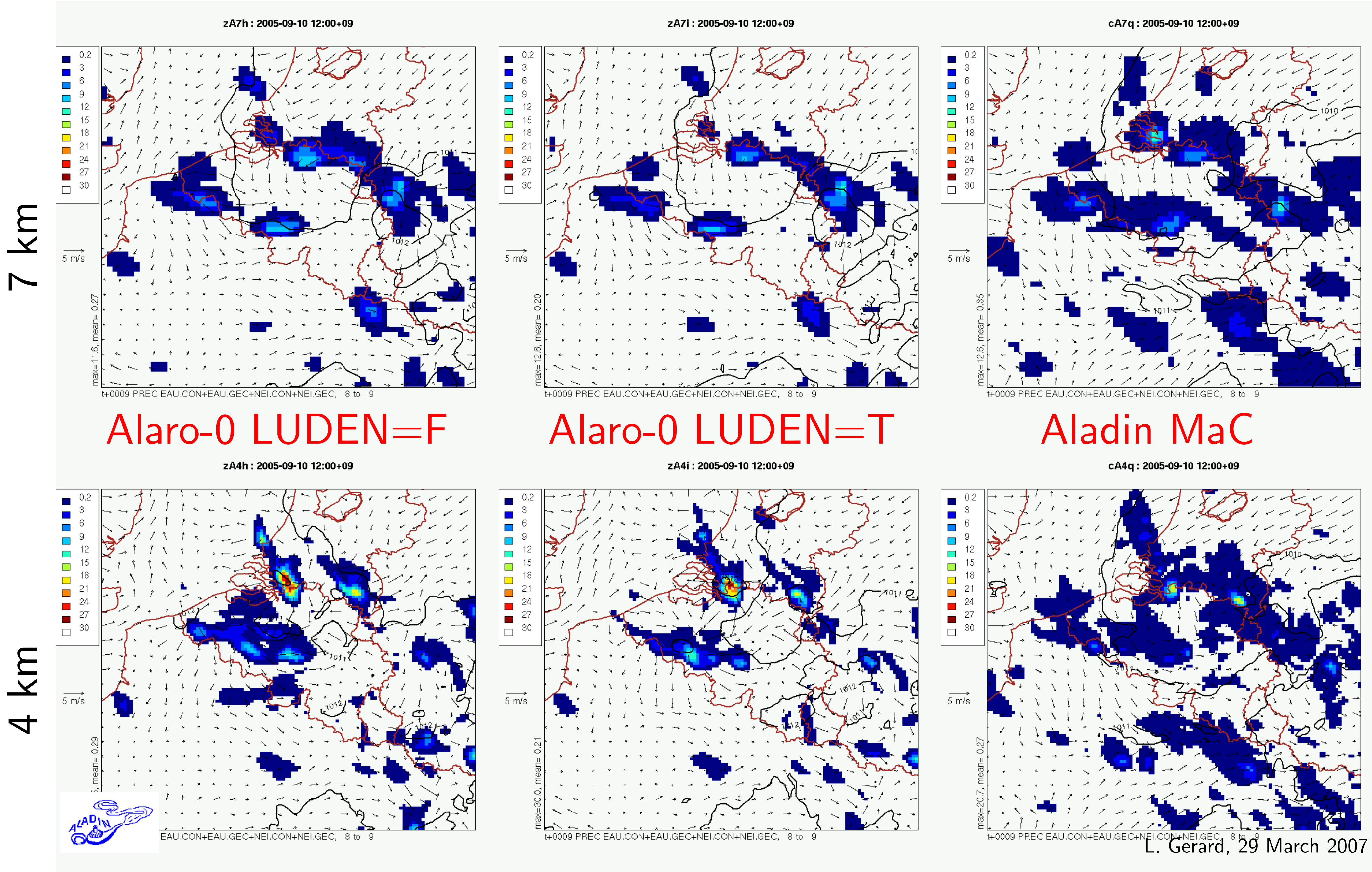

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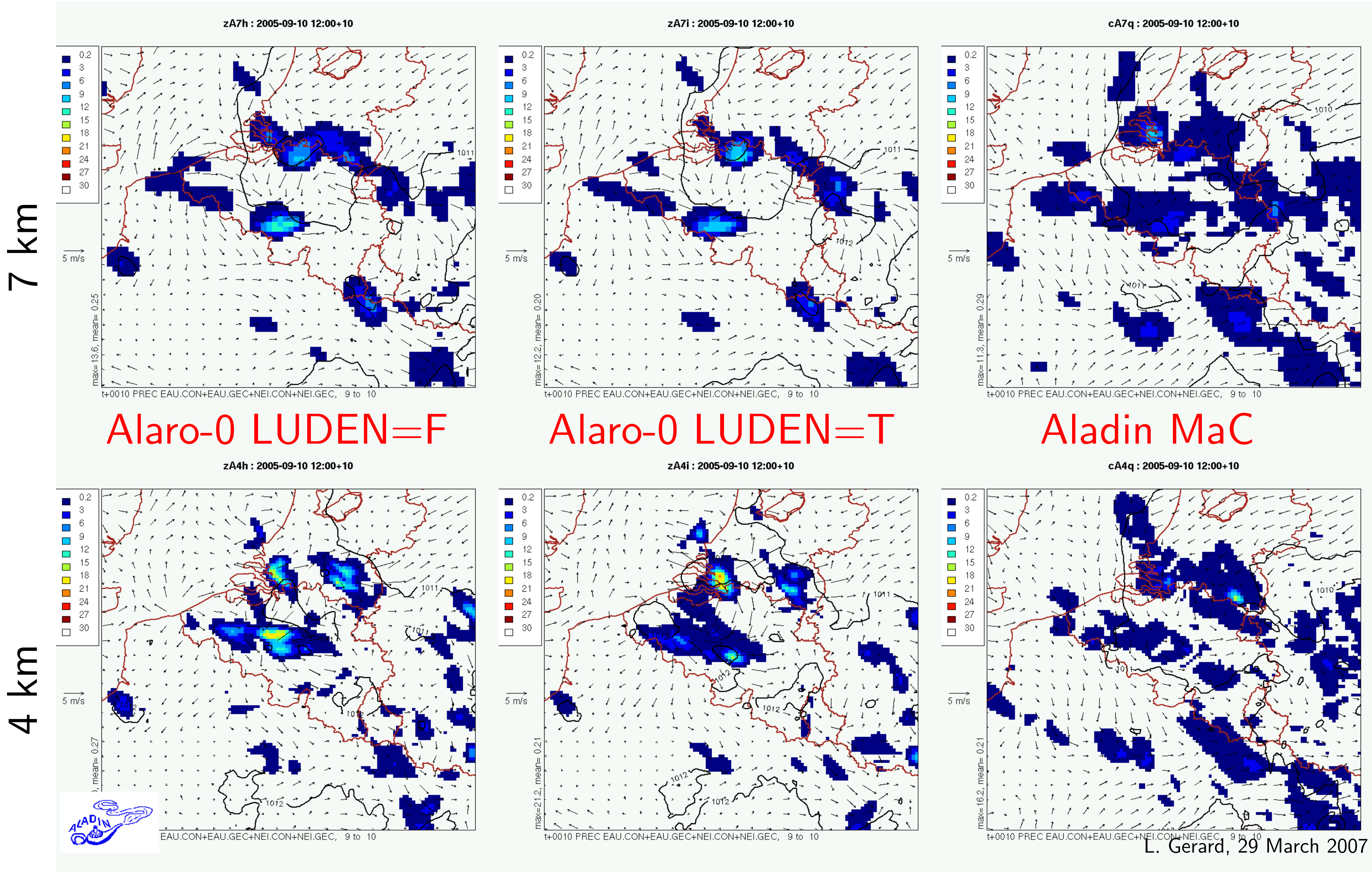

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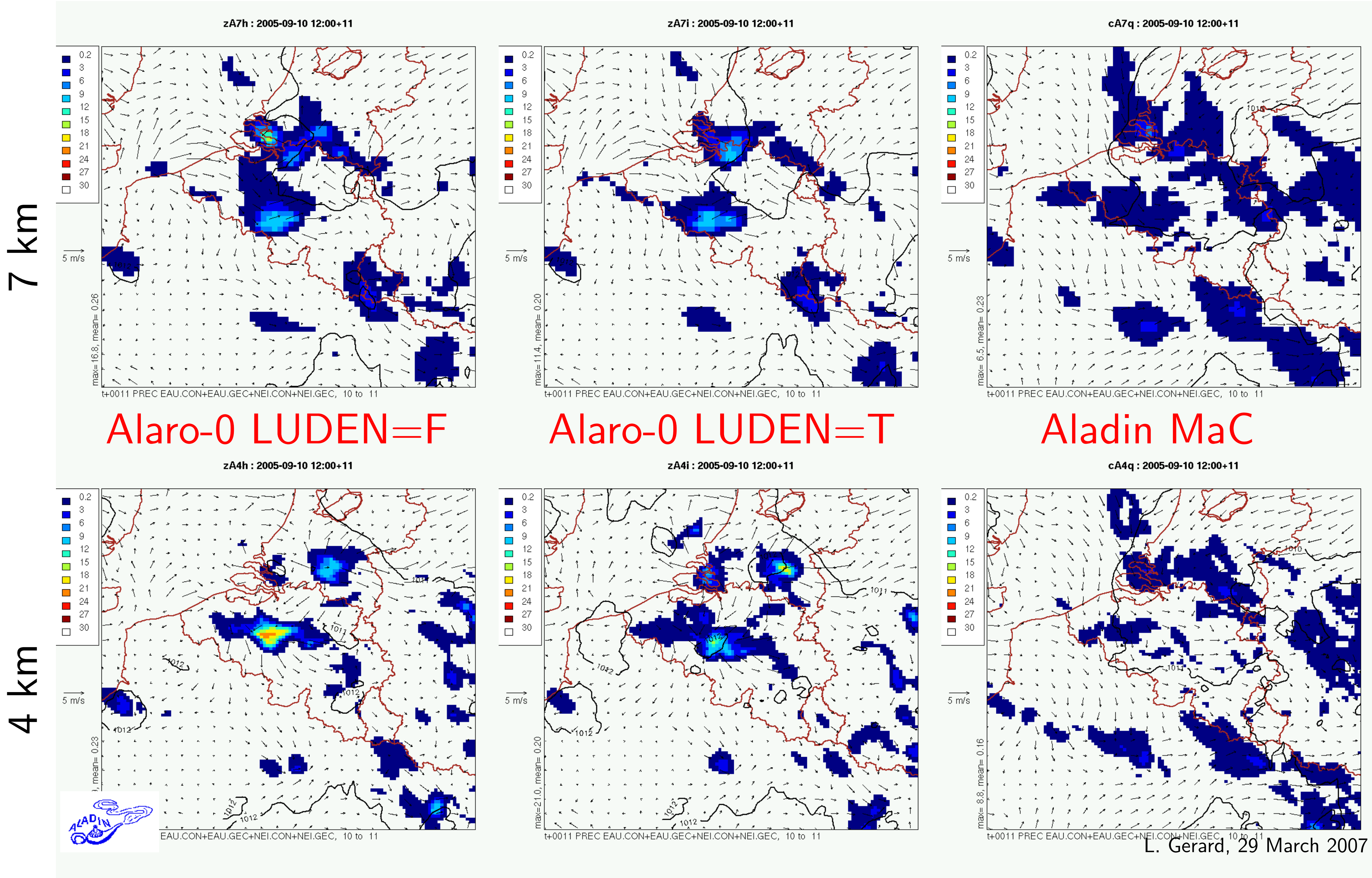

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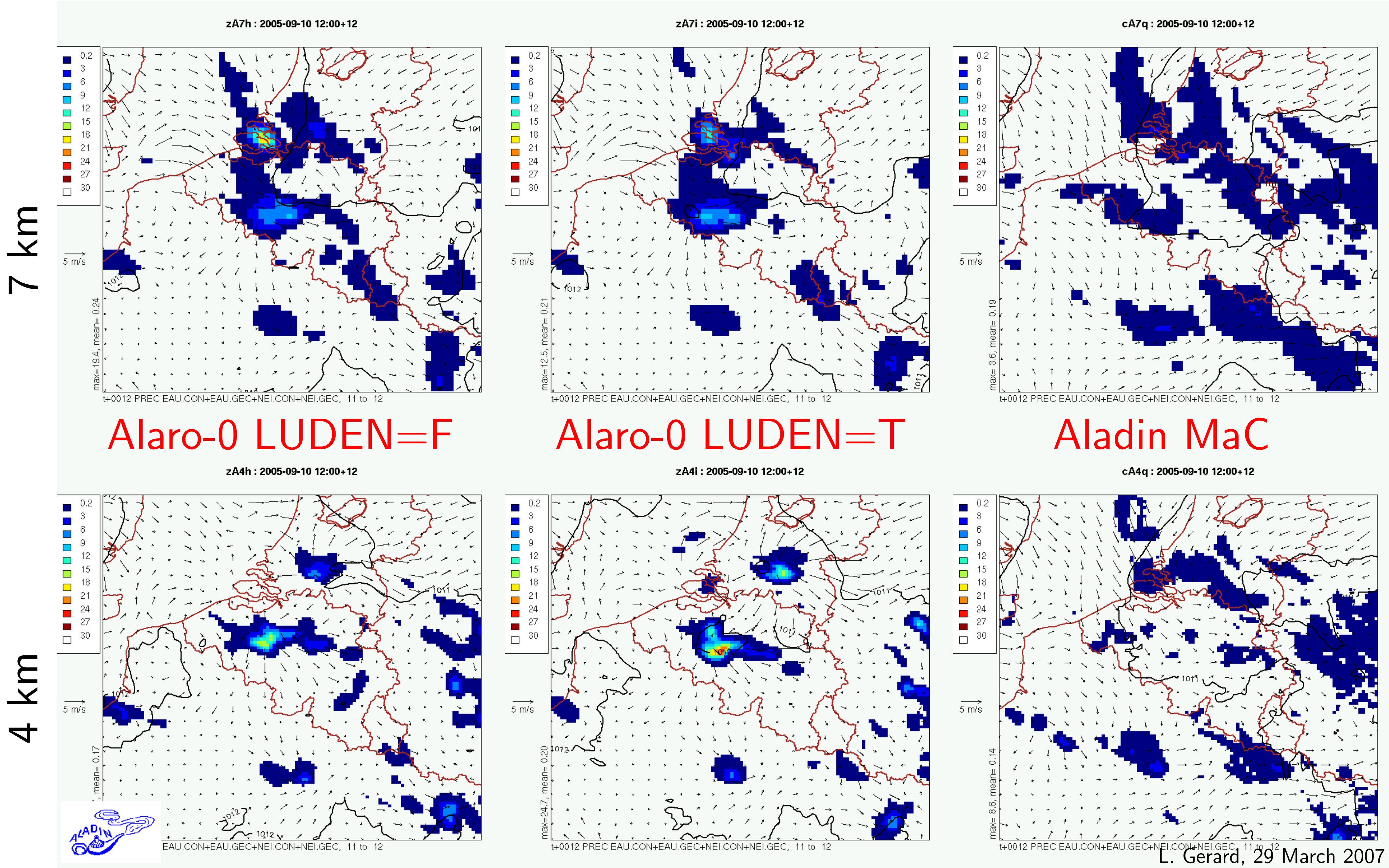

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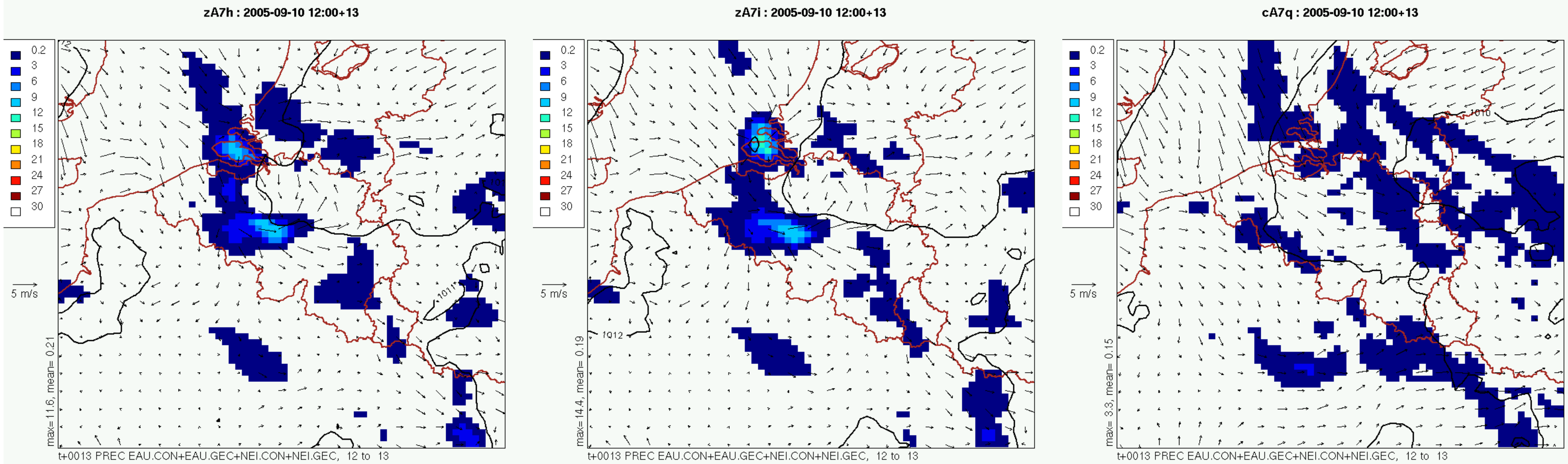
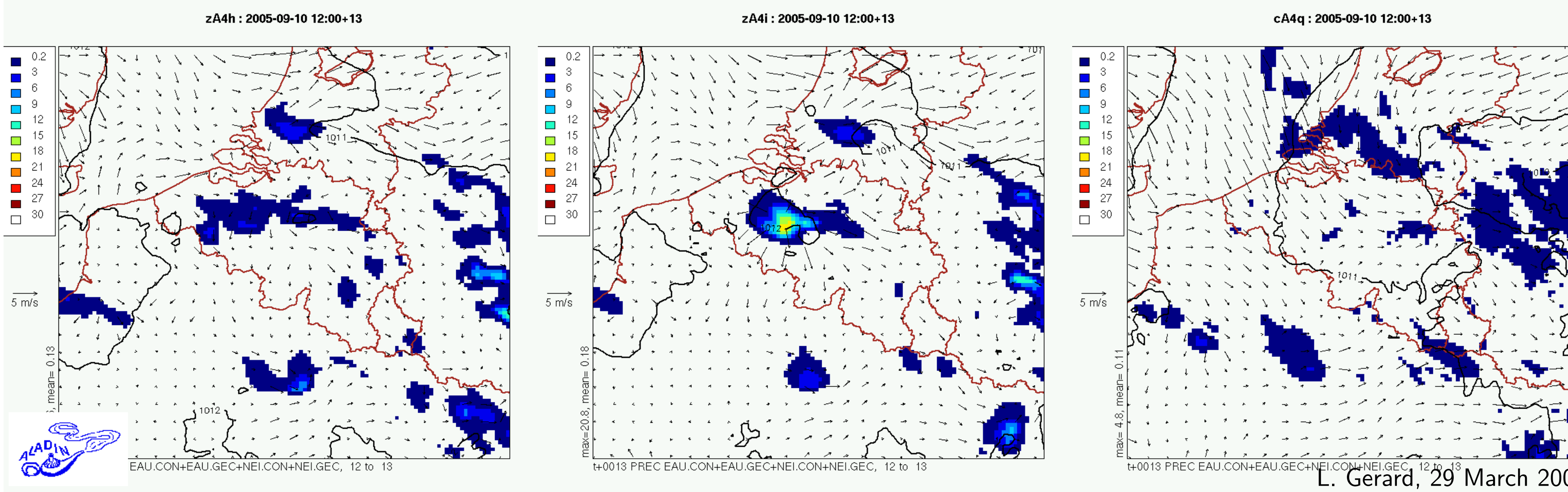


Alaro-0 LUDEN=F

Alaro-0 LUDEN=T

Aladin MaC

4 km



L. Gerard, 29 March 2007

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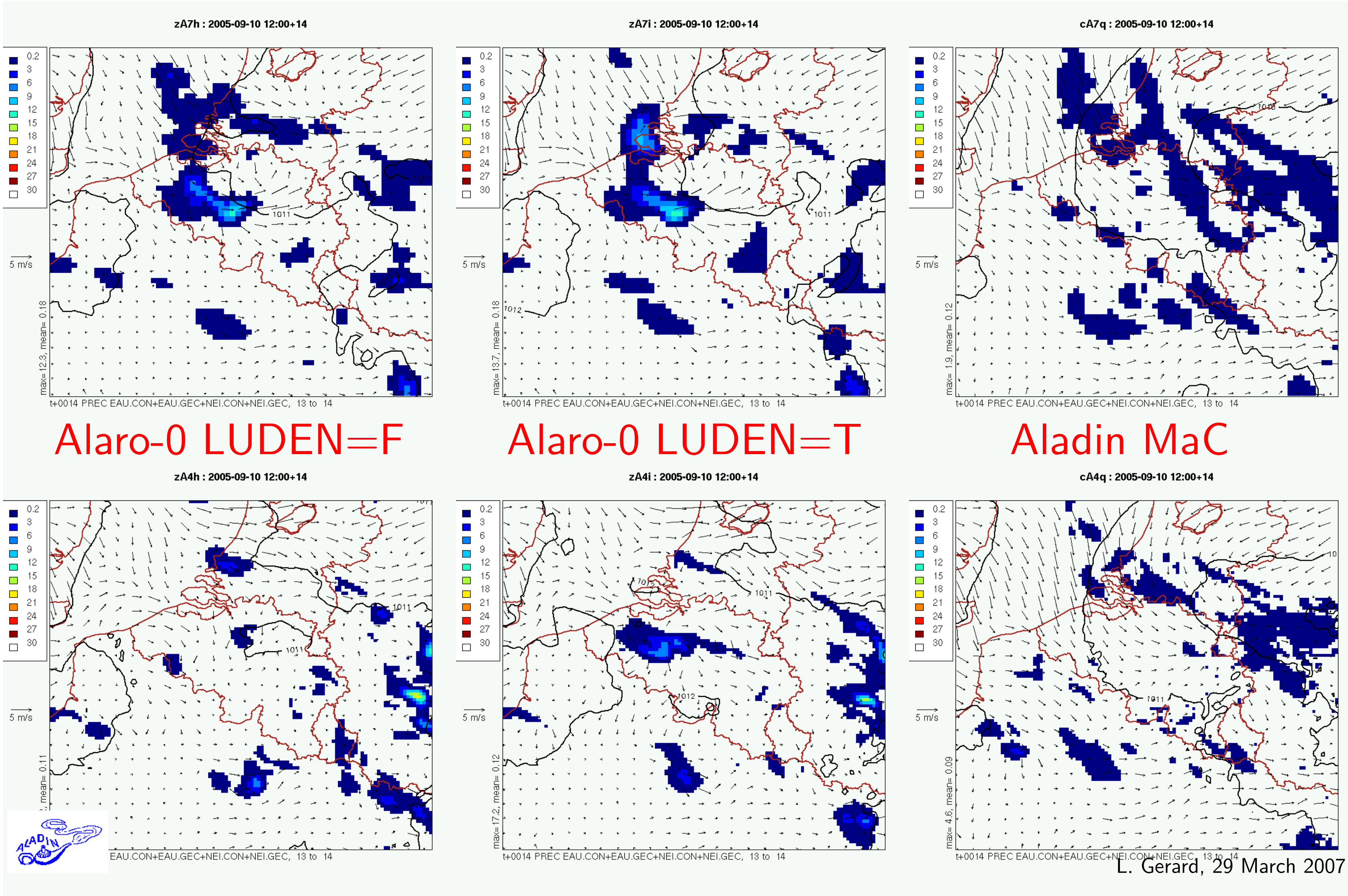
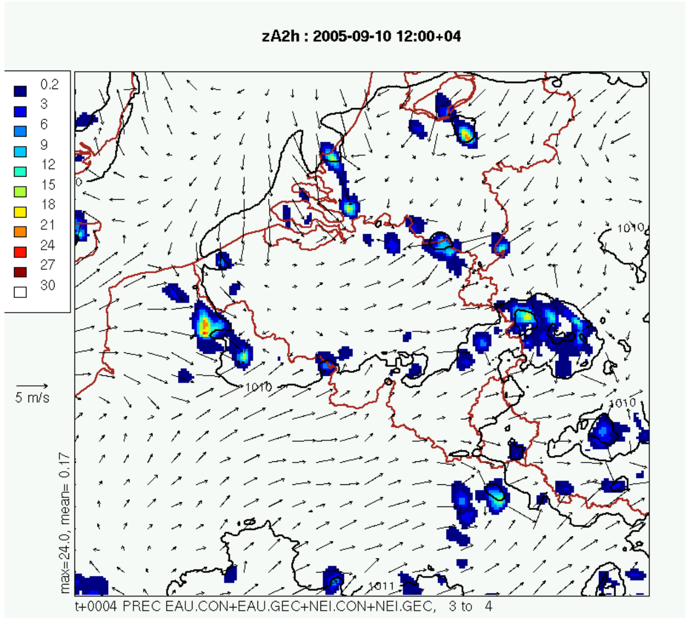
4 km



L. Gerard, 29 March 2007

Thunderstorms on Saturday 10 September 2005

2 km



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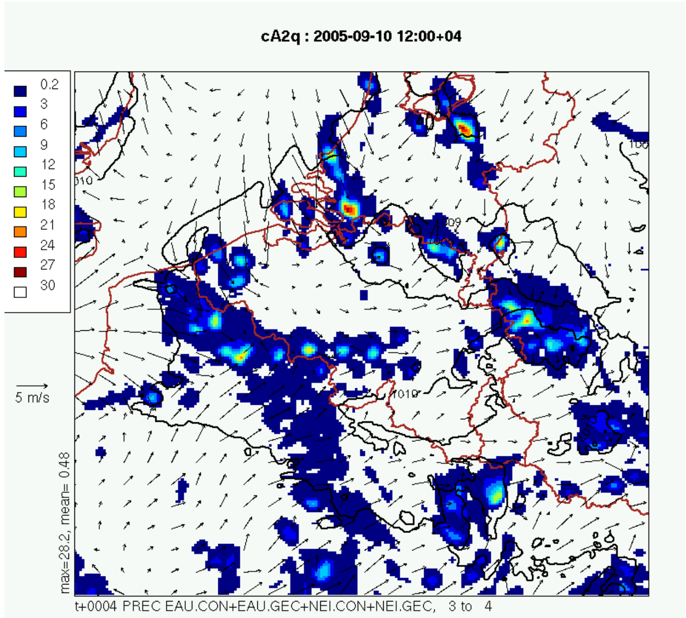
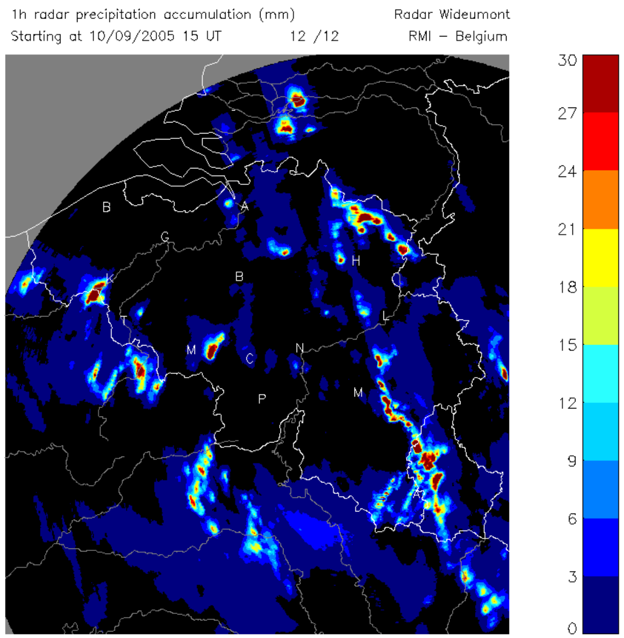


Aladin MaC

Radar



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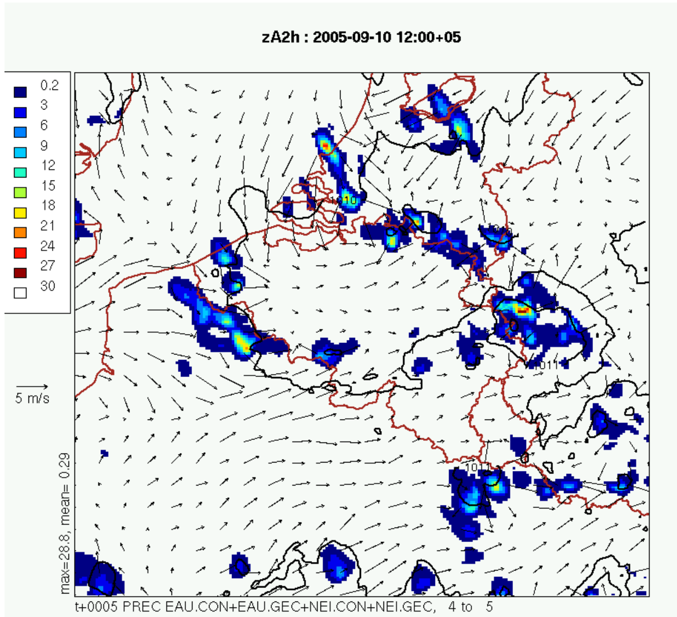

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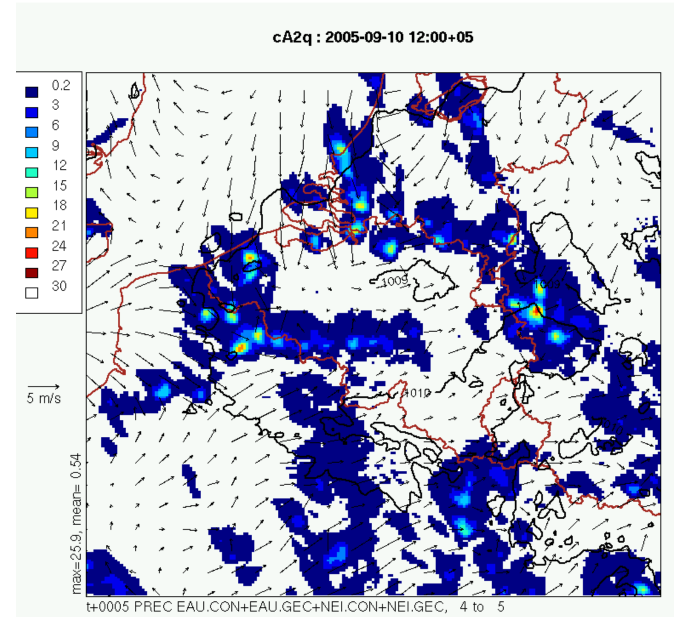

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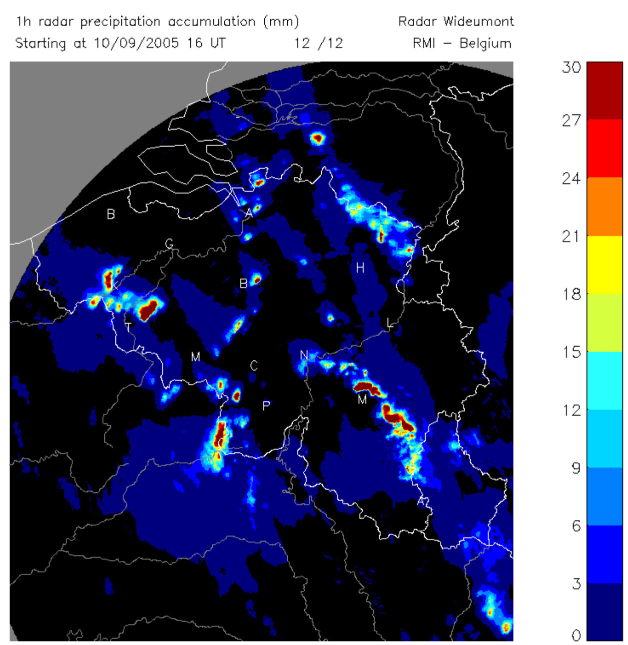

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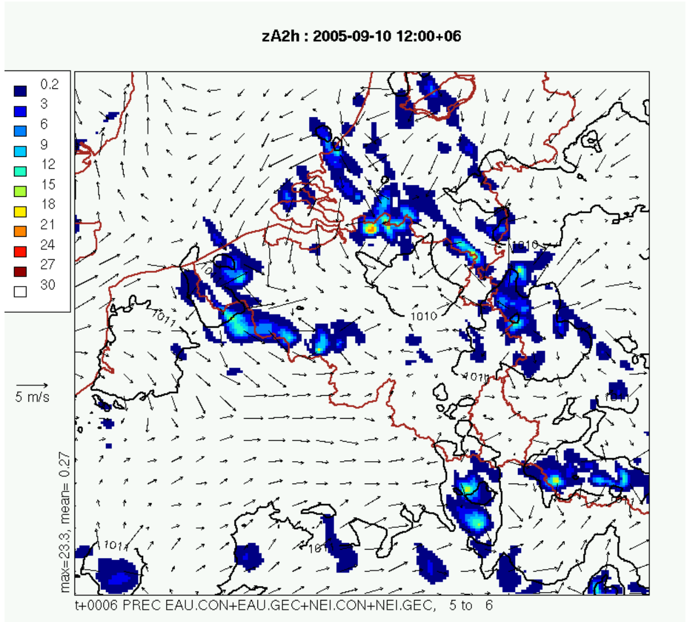

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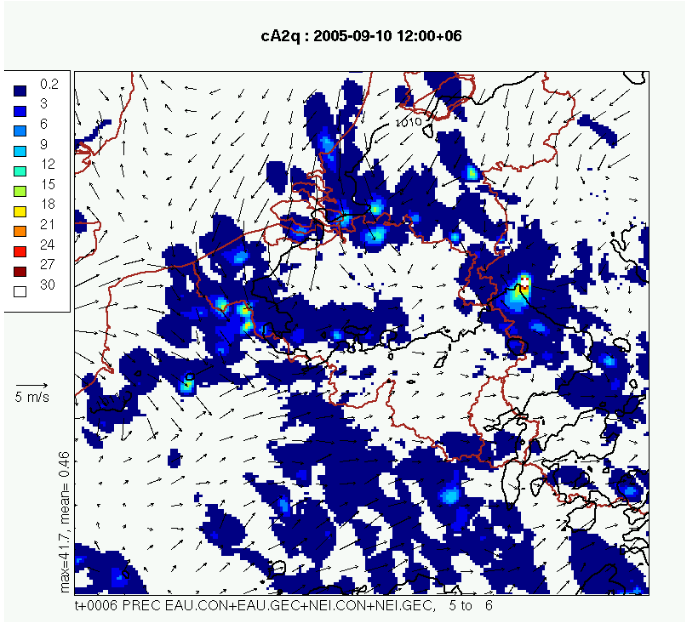

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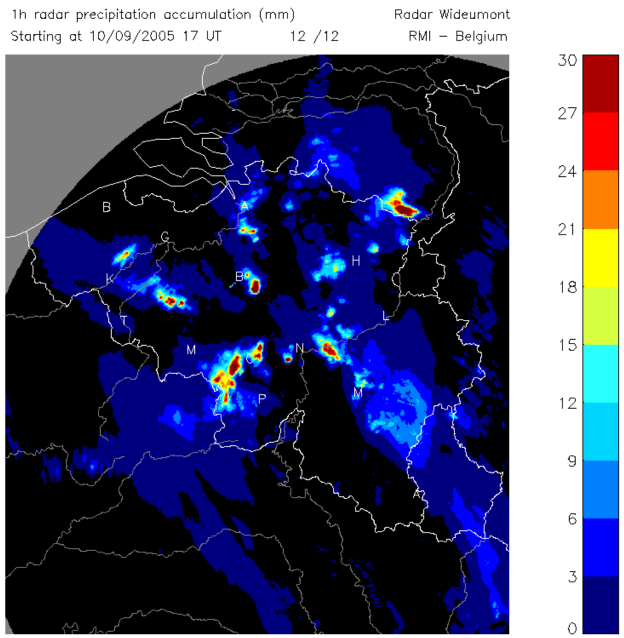

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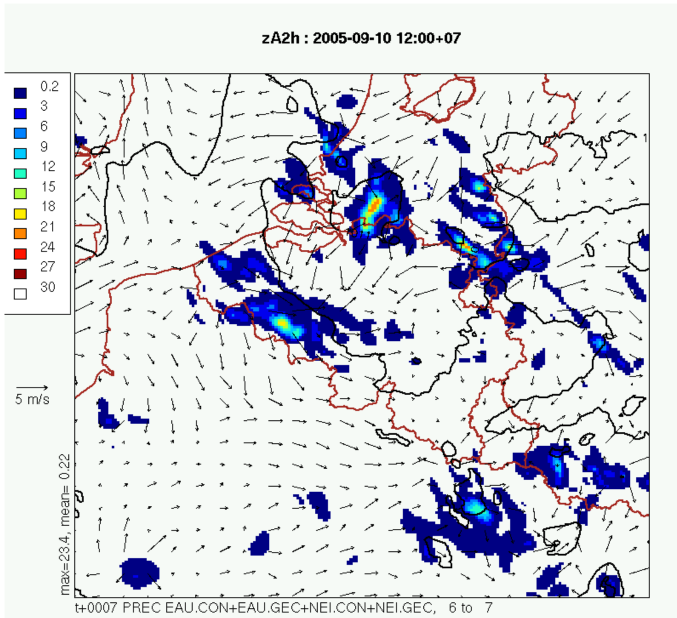

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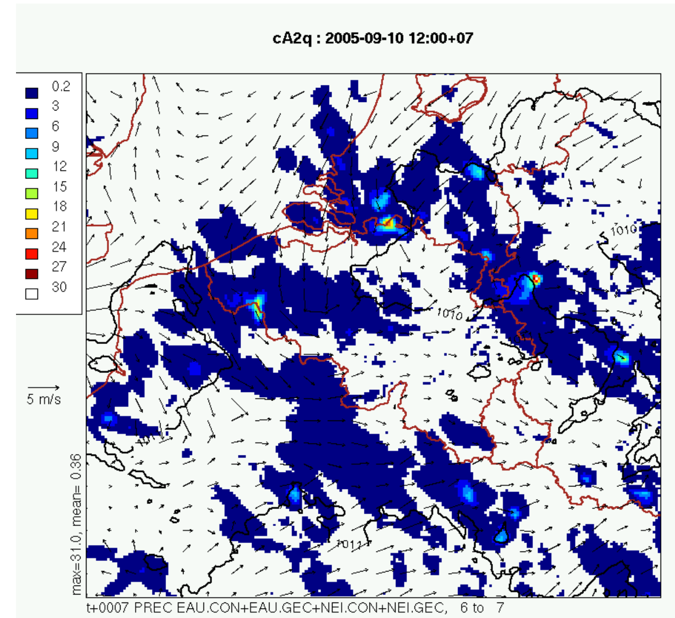

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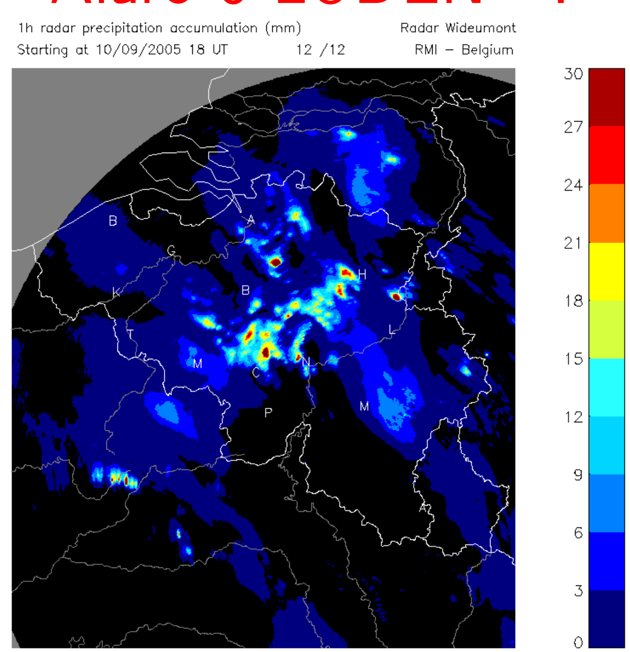

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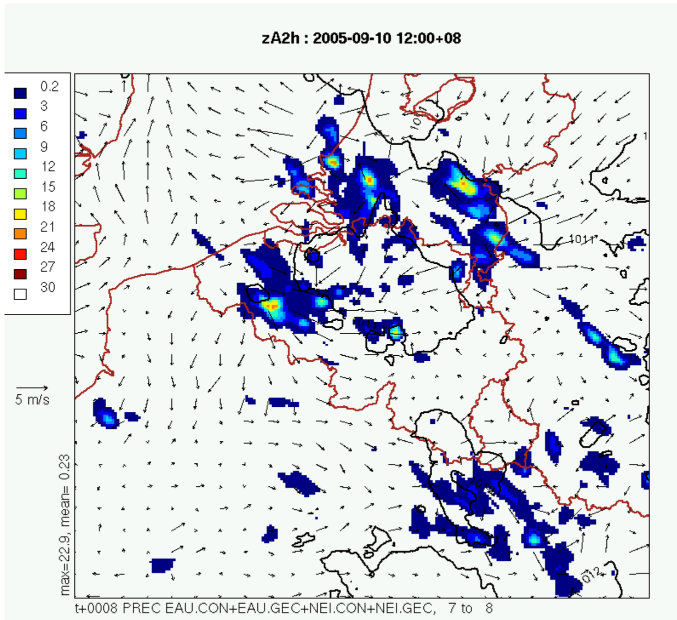

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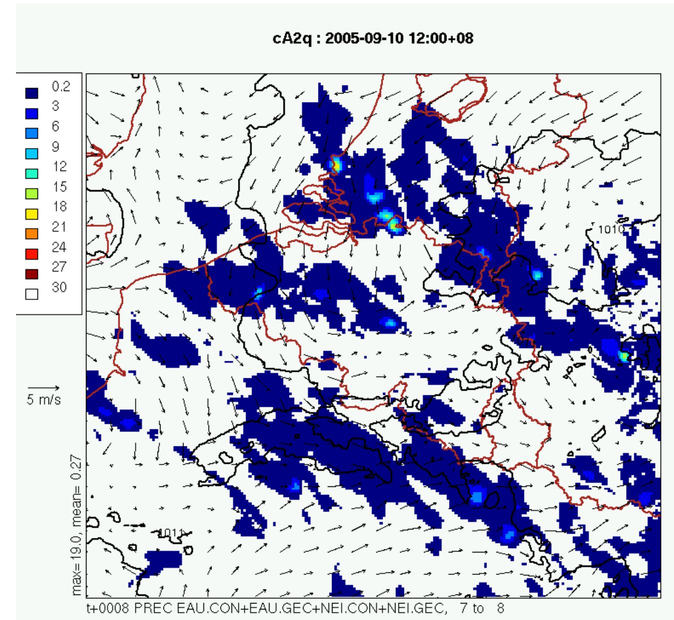

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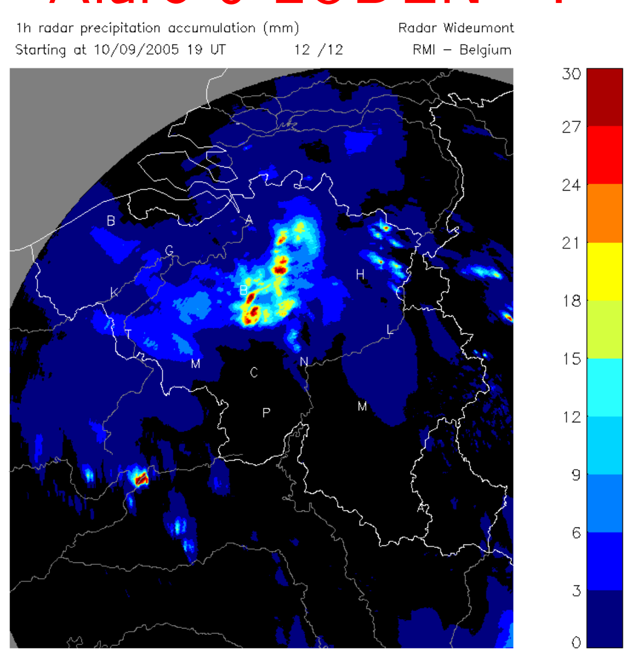

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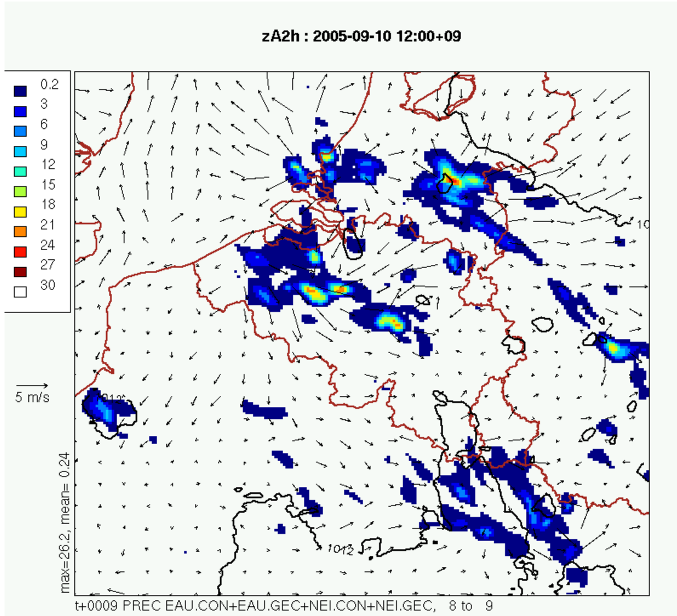

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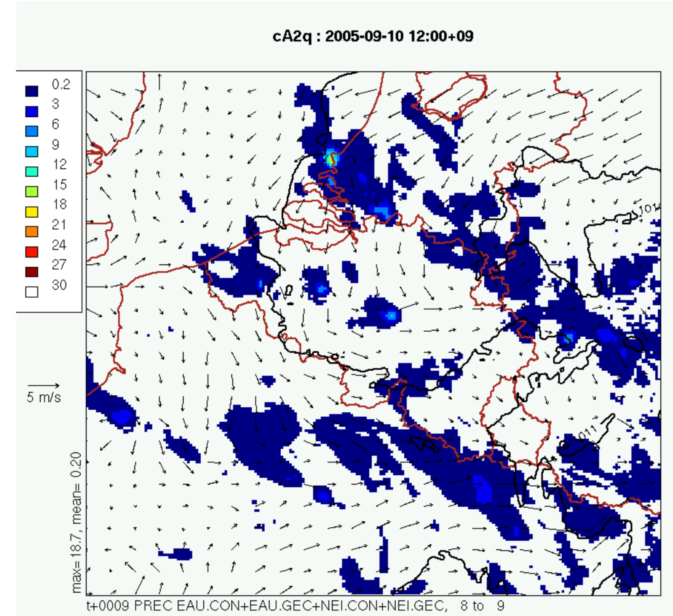

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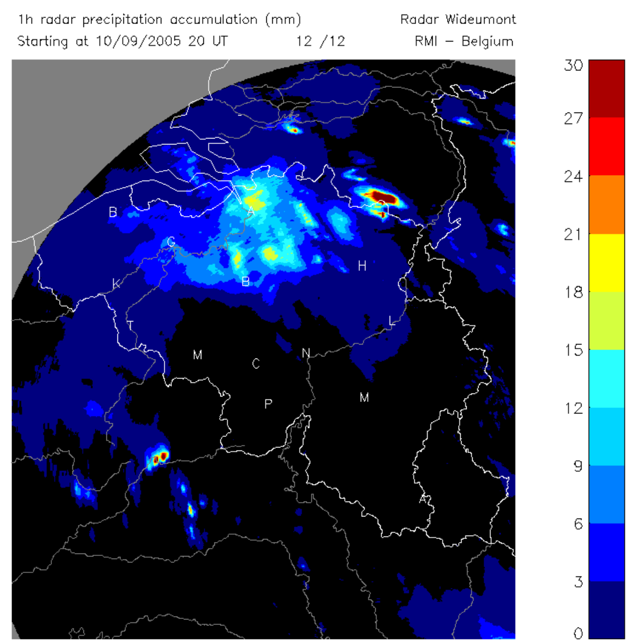

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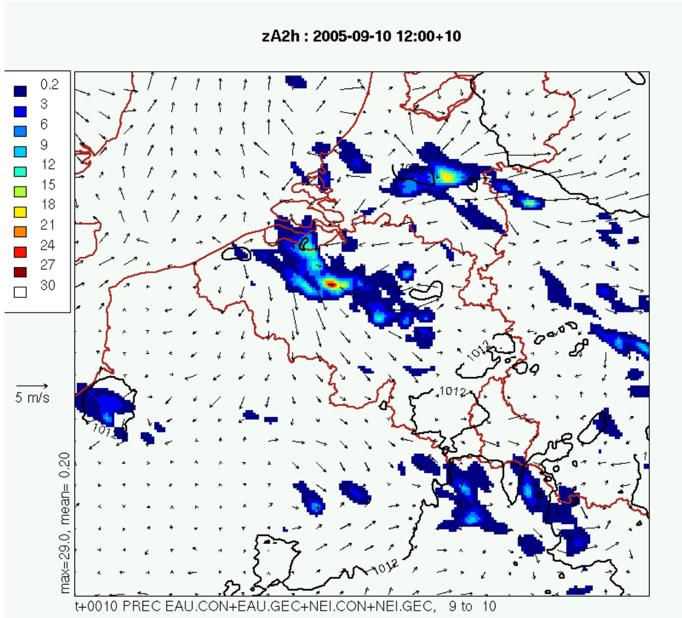

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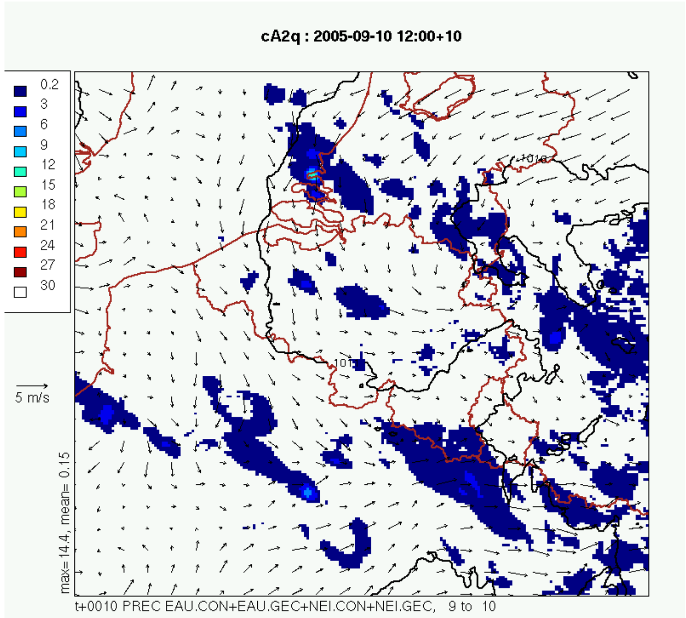

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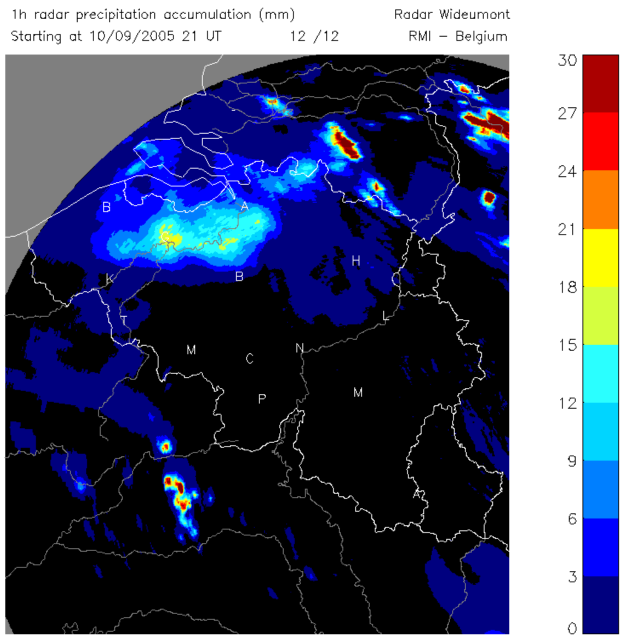

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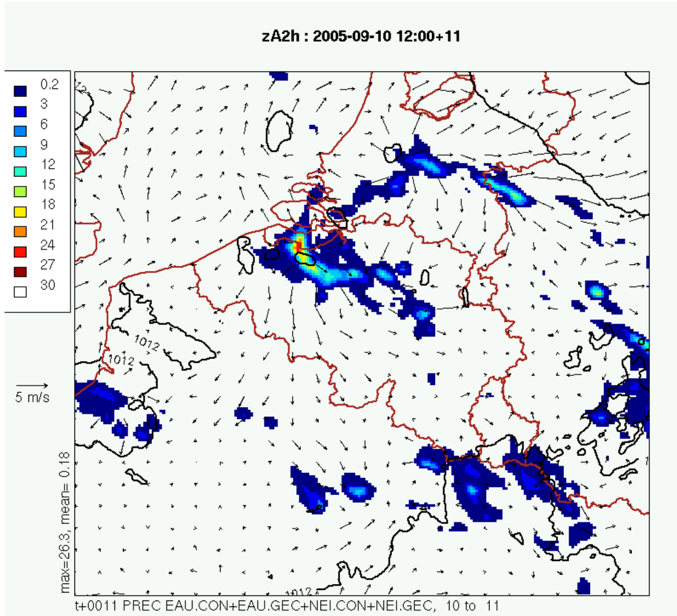

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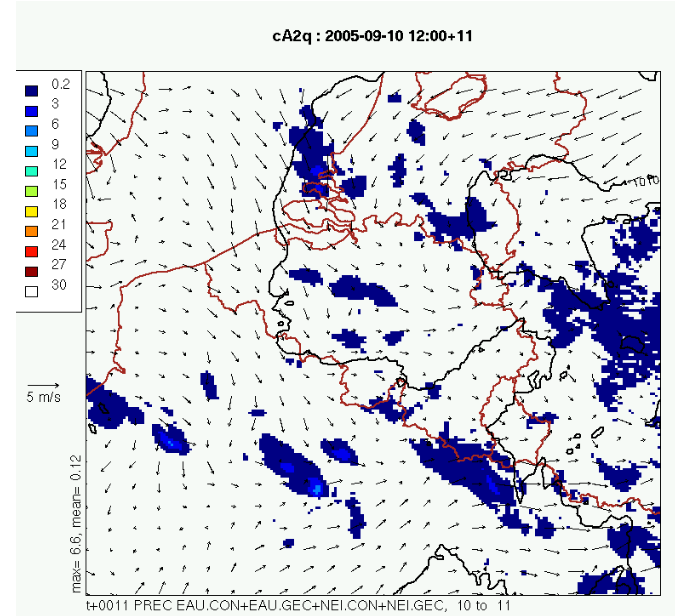

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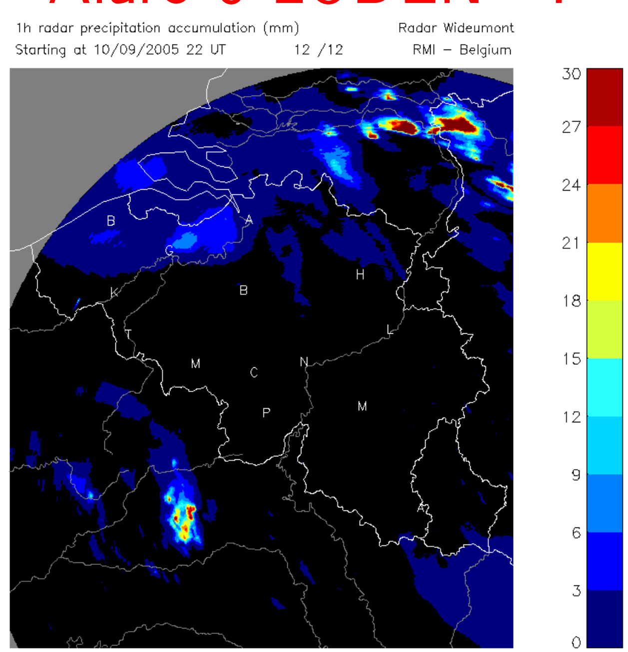

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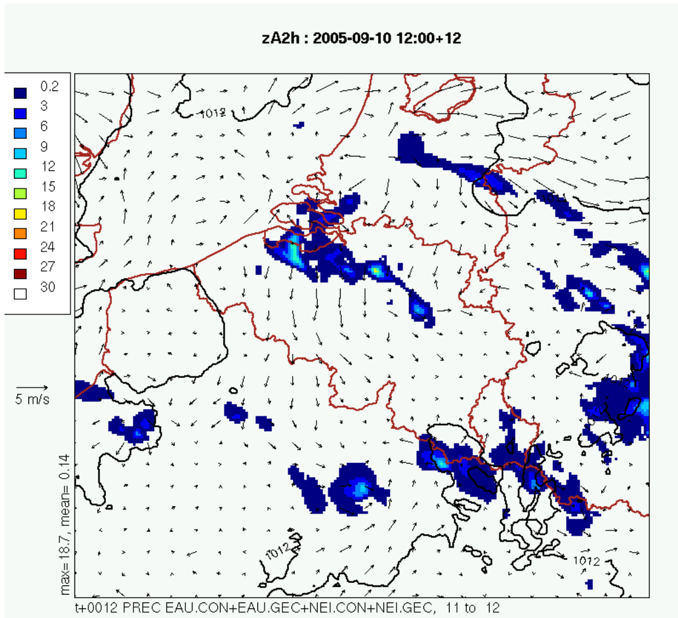

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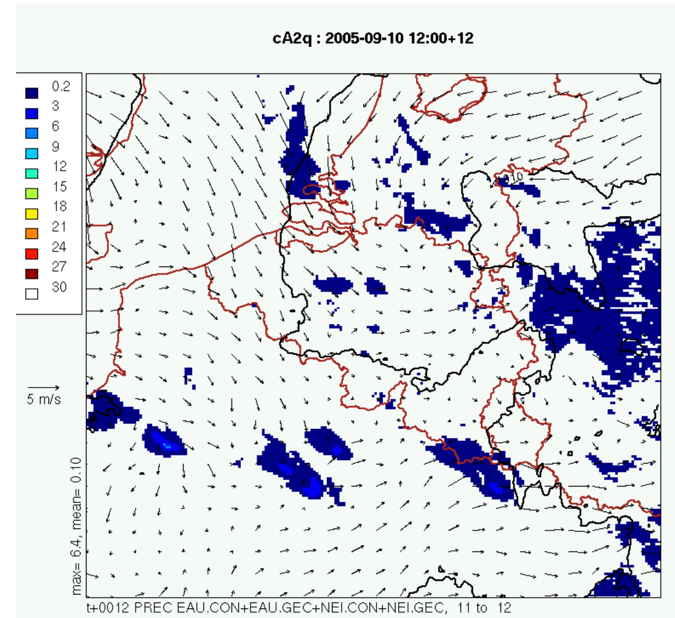

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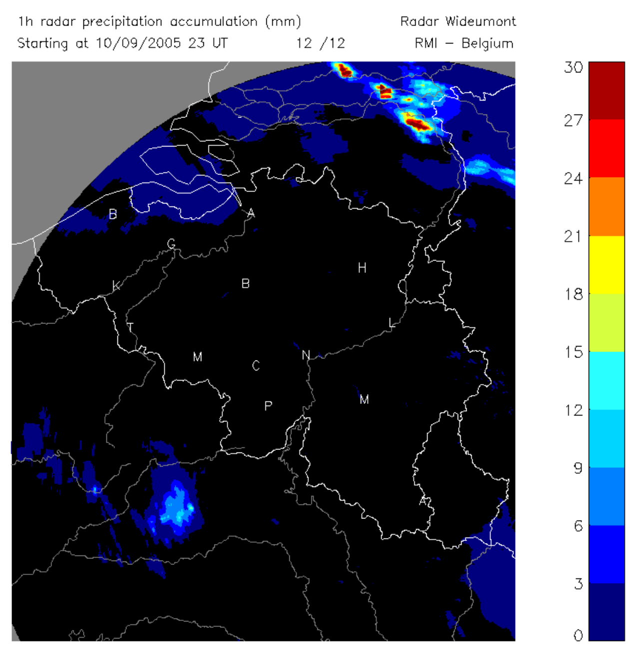

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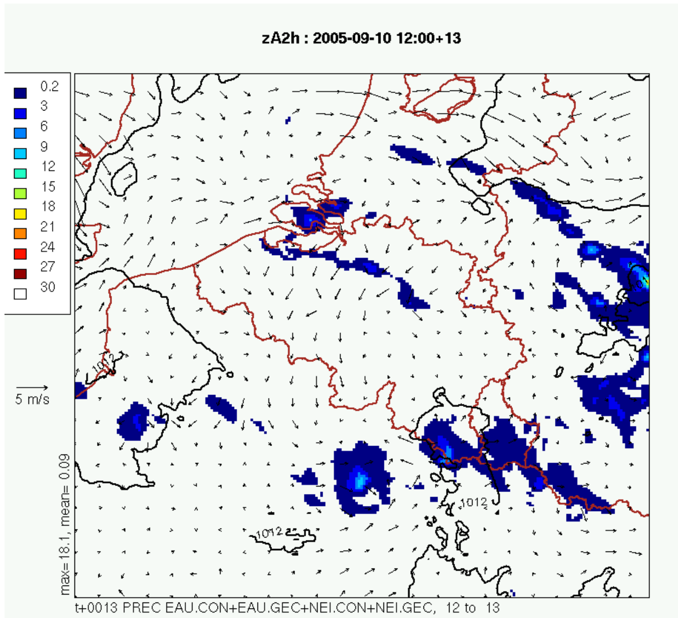

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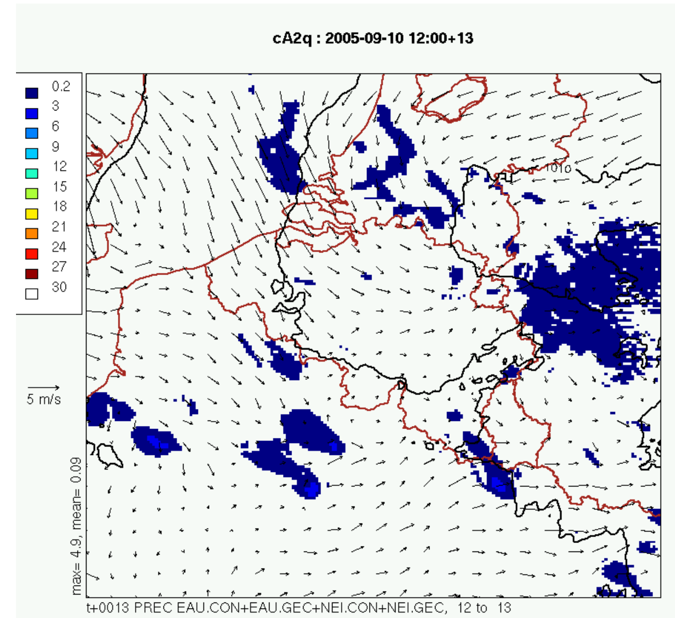

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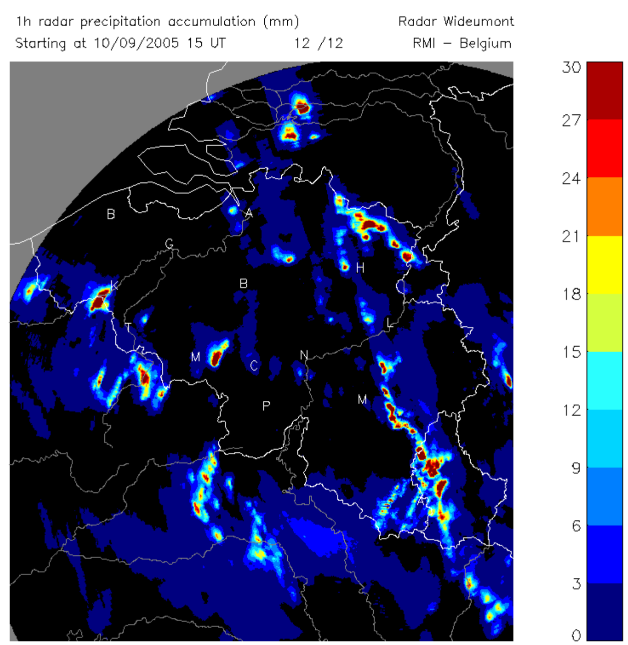

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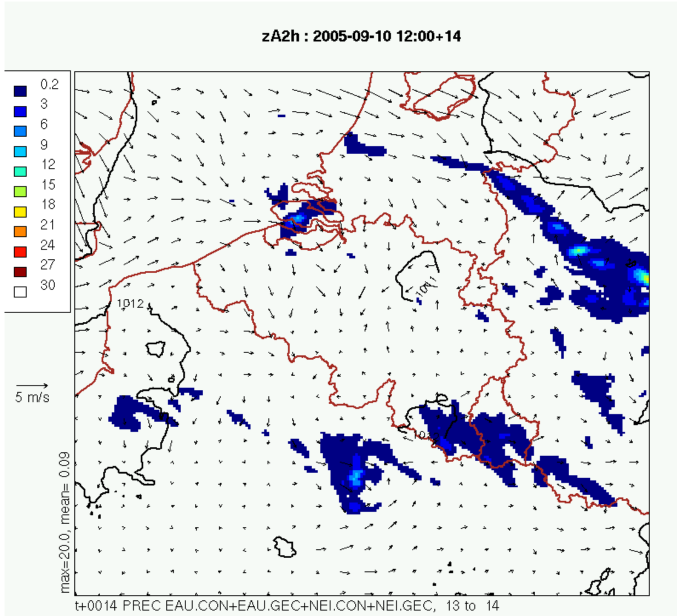

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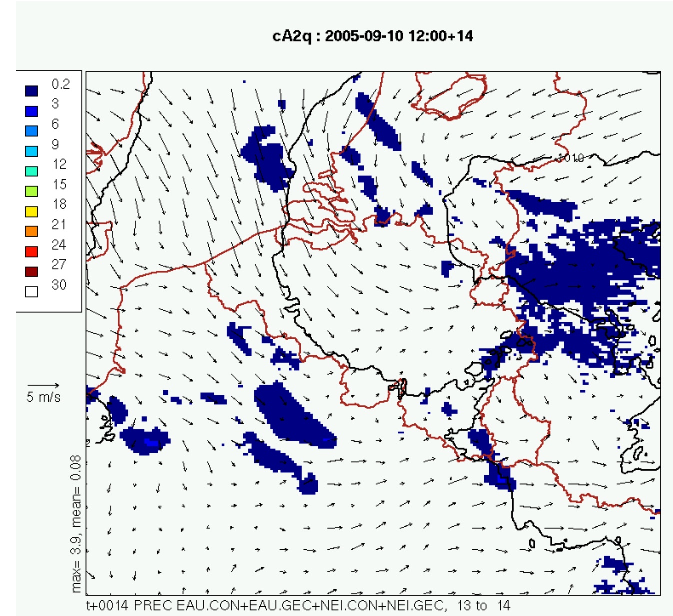

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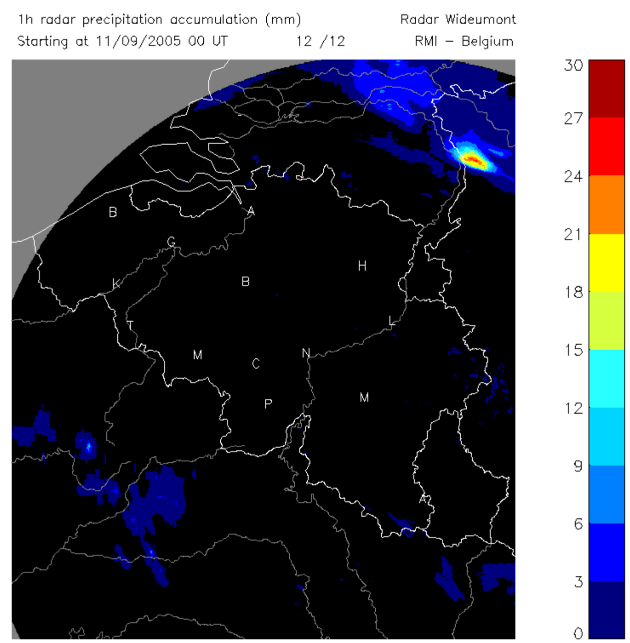

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