Use of a deep convection parameterization scheme at high resolution

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Topics

1. Prognostic Mixing
2. Compared Behaviours
3. Convergence towards explicit convection
4. The mesh fraction issue
5. Vertical equation
6. The mesh fraction issue from Bjerknes
7. Vertical equation and Buoyancy Reduction (BBR)
8. When resolved scheme does not take over
9. Prognostic closure
10. Model cloud evolution
11. Cloud top evolution
12. AEGNUM method
13. Resolution test
14. Behaviour comparison
15. Synthesis

RMI

Goal

This talk concerns the multi-scale aspect of 3MT :

Modular
Multiscale
Microphysics and
Transport scheme

Prognostic mixing

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- Downdraughts induce density currents and confine the updraught circulation
- Mixing air closer to updraught properties

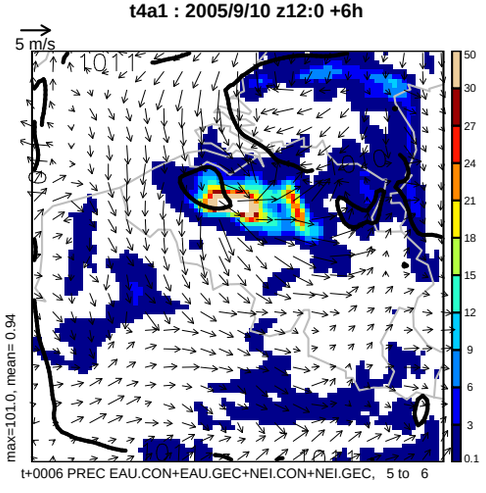
$$\lambda_u = \underbrace{\frac{\xi_{tx}(1-\zeta) + \xi_{tn}\zeta}{\phi - \phi_s}}_{turbulent} + \underbrace{\frac{\beta_E}{\triangle\phi}\max(0, \frac{\triangle\omega_u^*}{\omega_u^*})}_{organized}$$

$$\frac{\partial \zeta}{\partial t} = \frac{1}{\tau_E}\left(\kappa_E \hat{\sigma}_d (1-\zeta)^{N_1} - \zeta^{N_0}\right), \qquad 0 \le \zeta \le 1$$

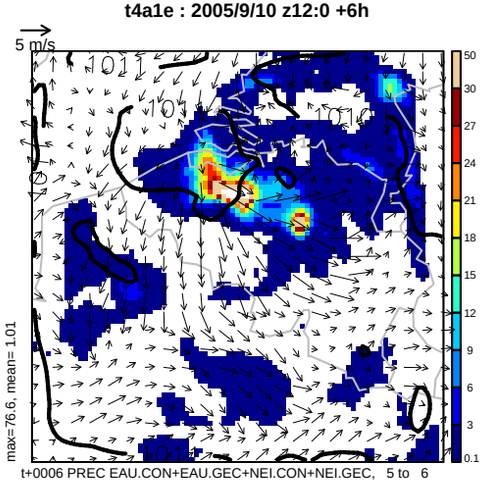
Parameters tuned wrt the diagnostic version.

RMI

Compared Behaviours 4km



3MT



+Prog Mixing

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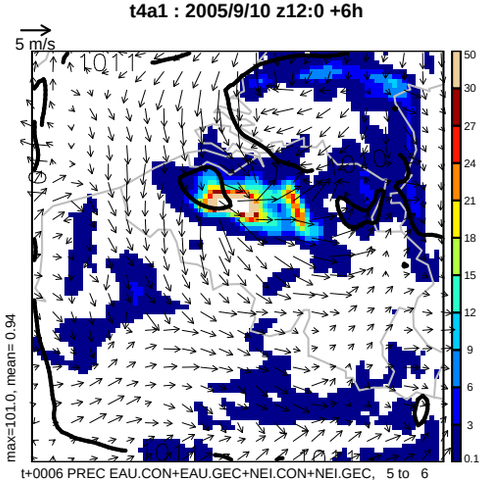

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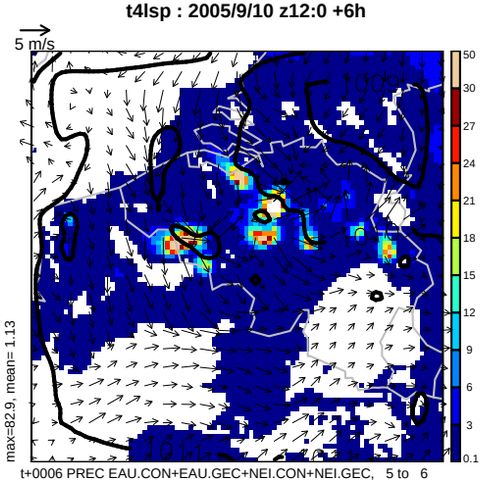
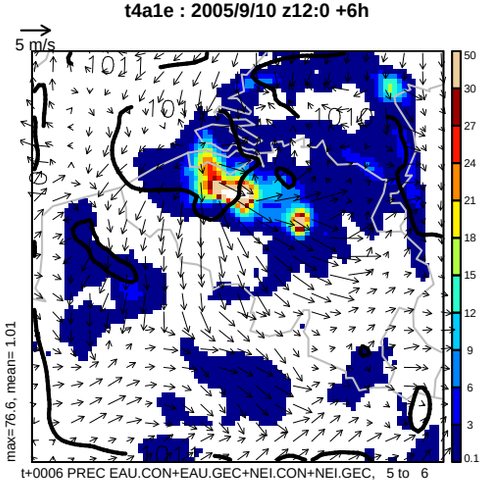


Diagnostic



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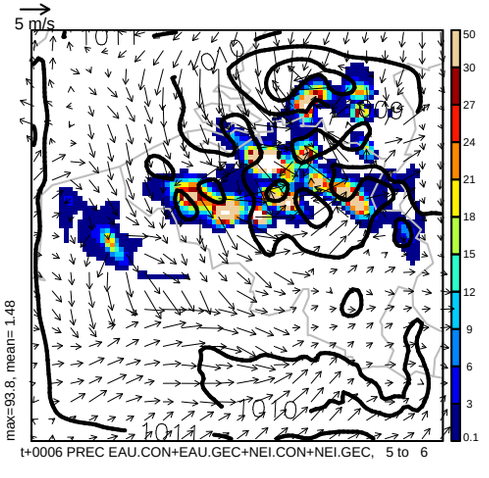

Explicit

RMI

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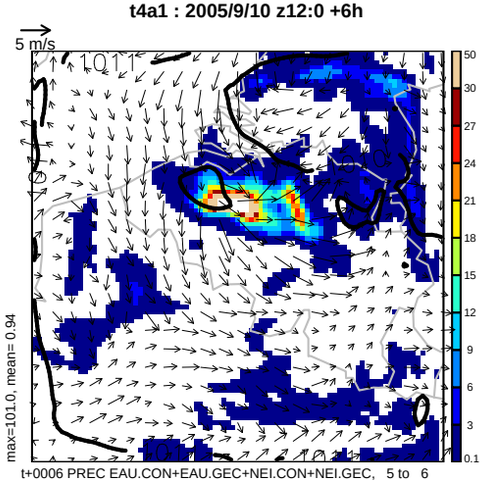

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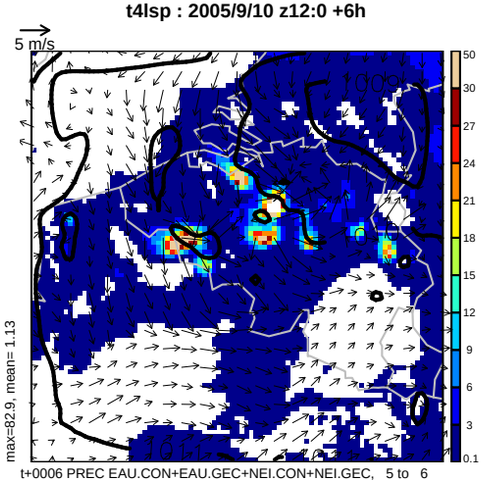

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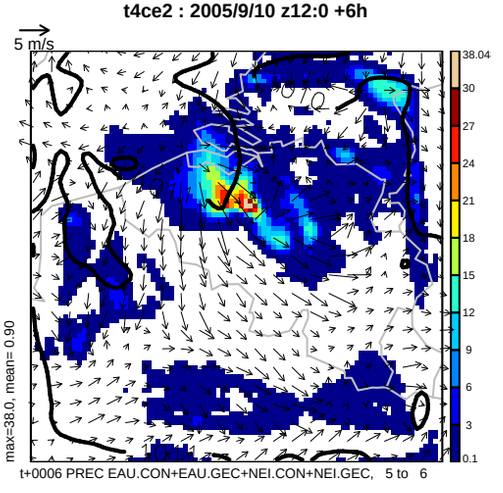
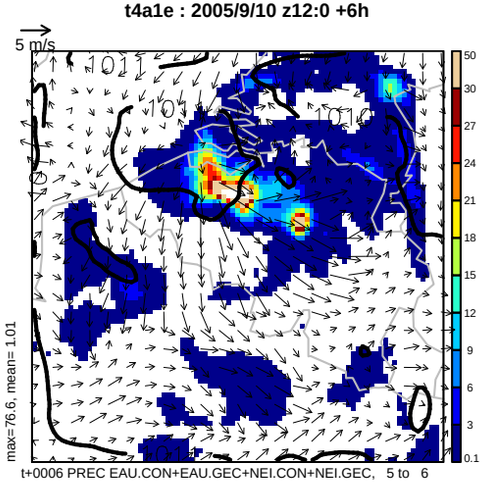


LIMTOP + BBR



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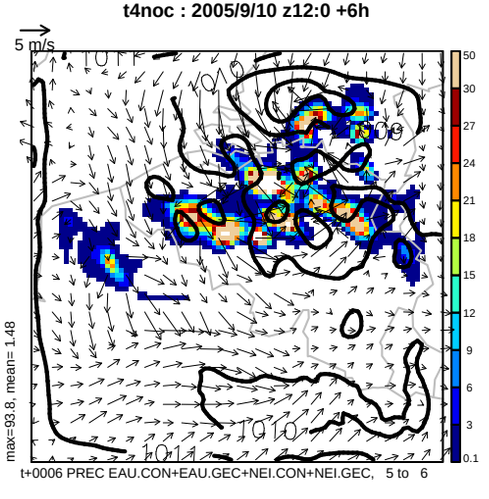

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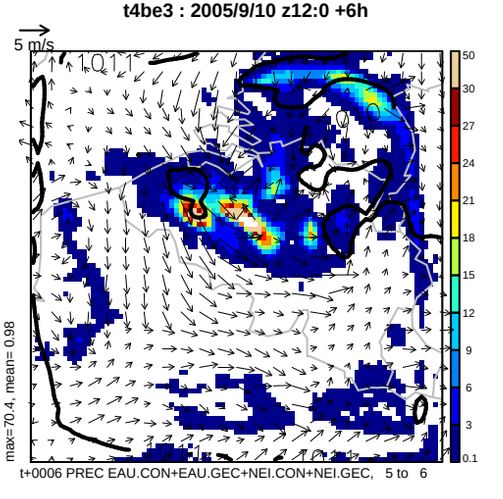
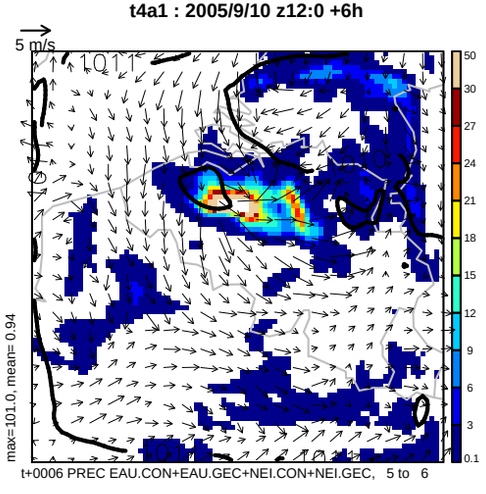
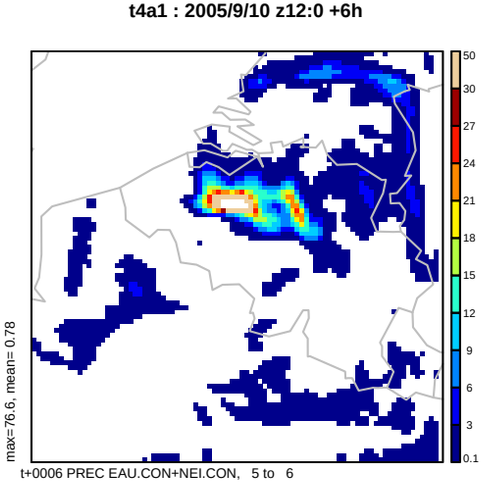


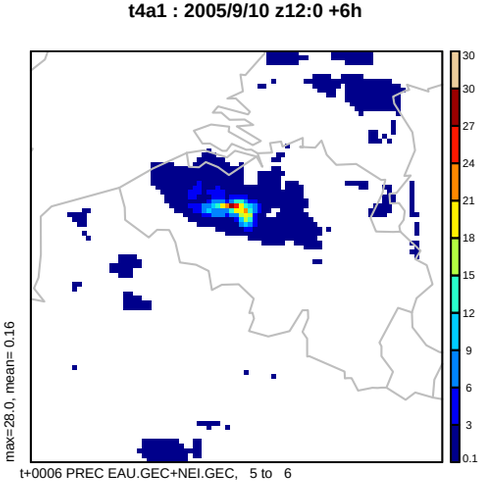
BBR + AEGNUM

RMI

Convergence towards resolved convection

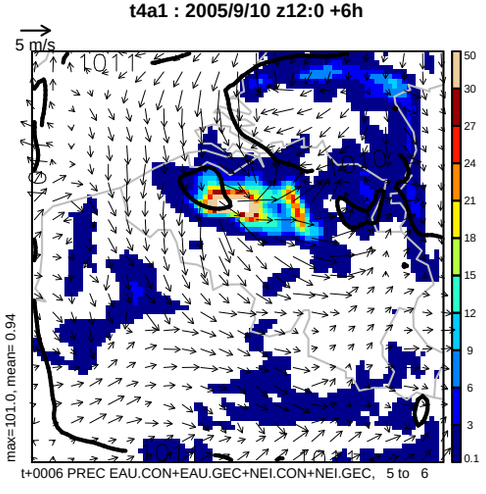


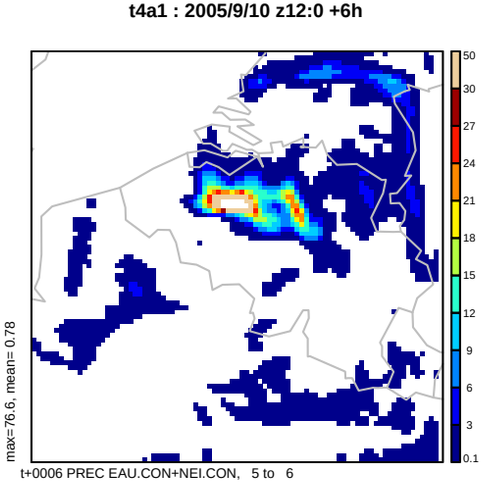


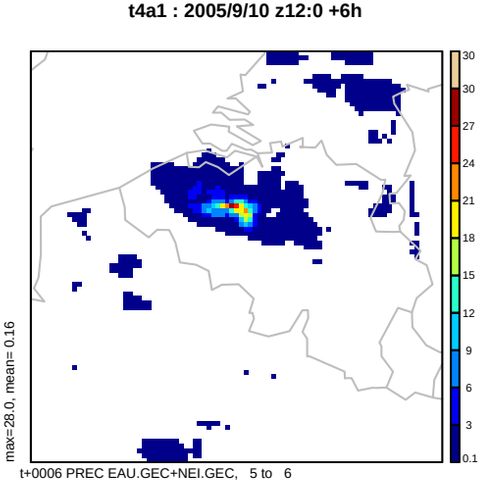


3MT : subgrid resolved

Convergence towards resolved convection







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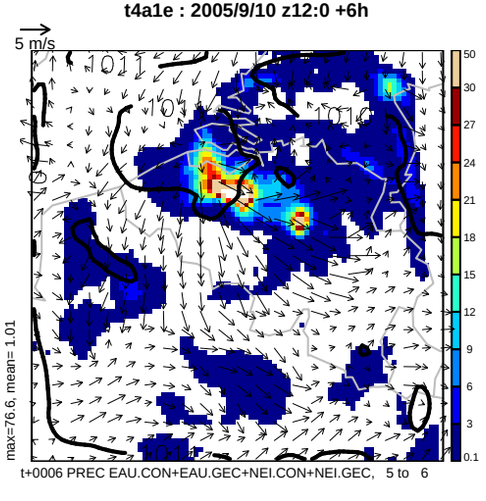

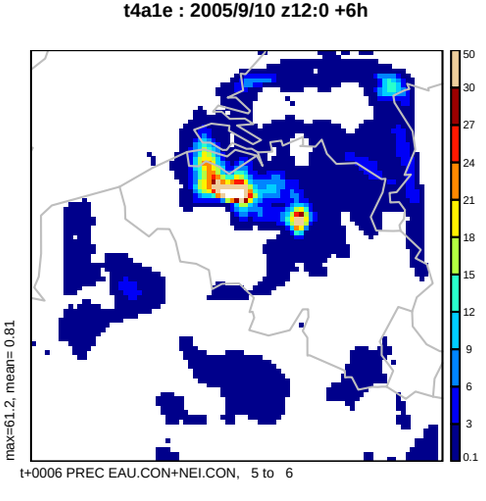

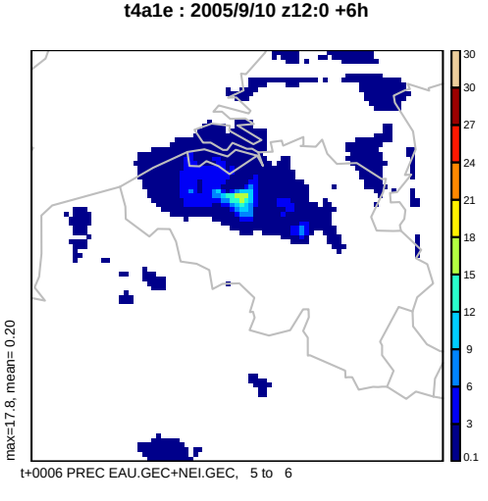

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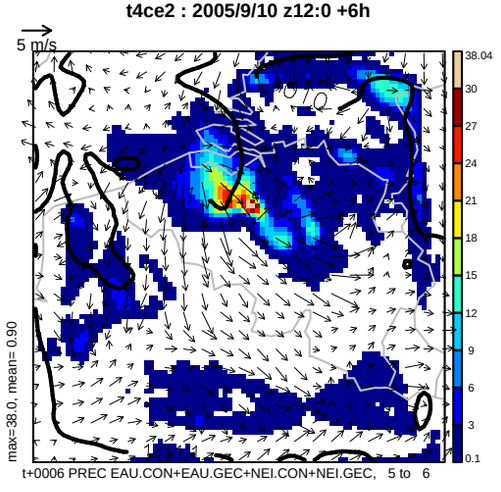

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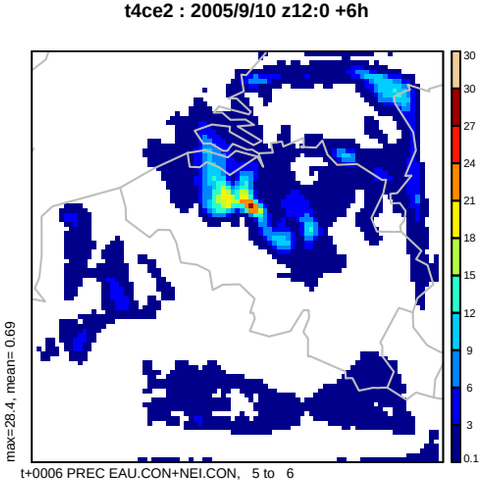
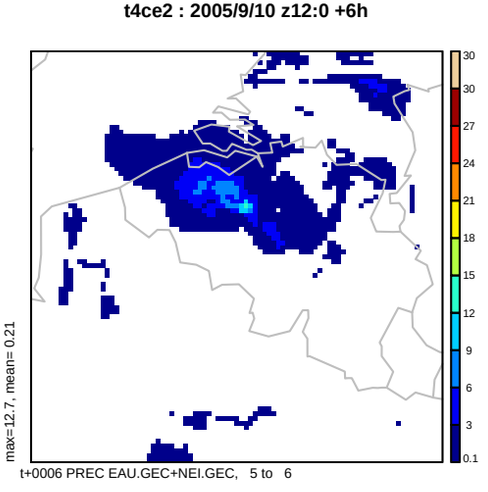
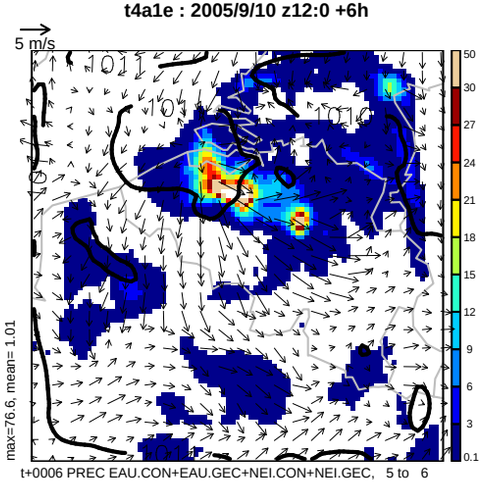


subgrid



resolved



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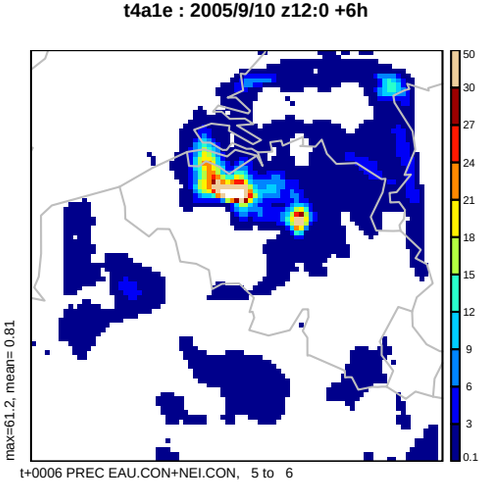

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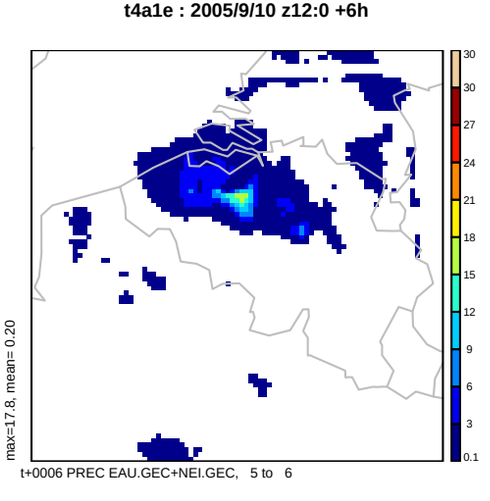

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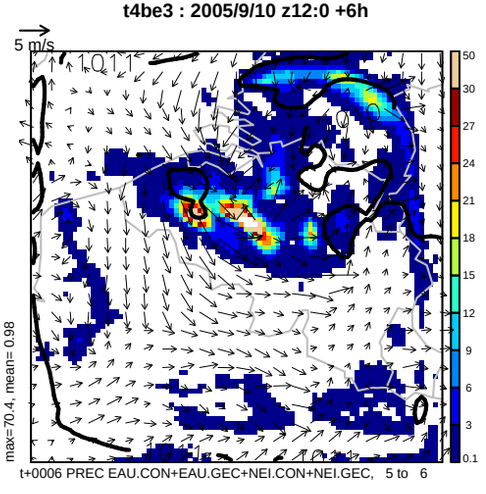
RMI

Convergence towards resolved convection



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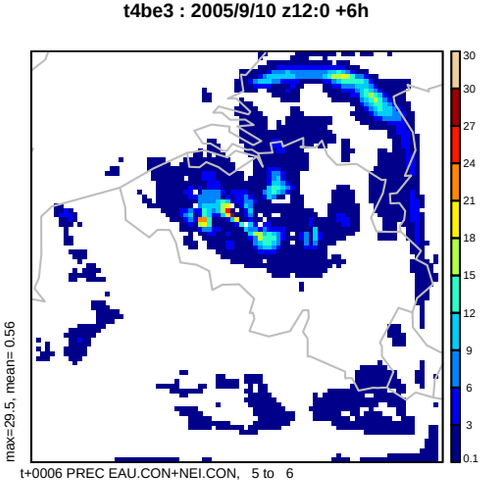

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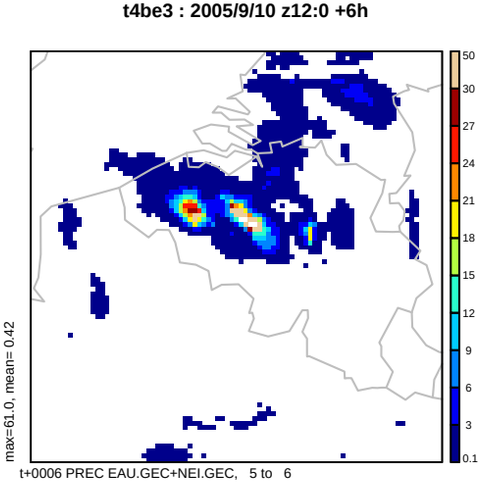

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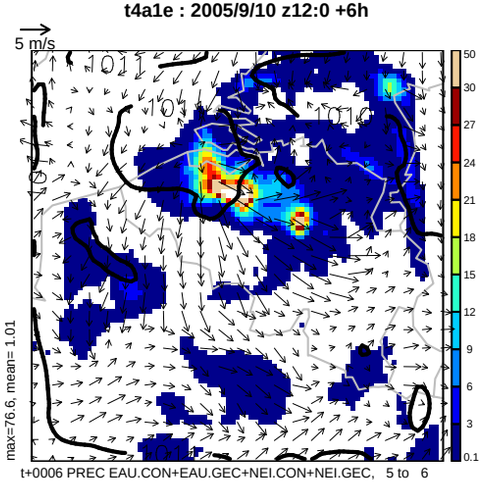

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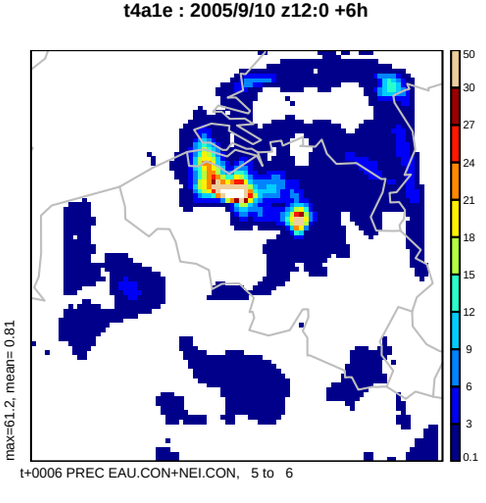

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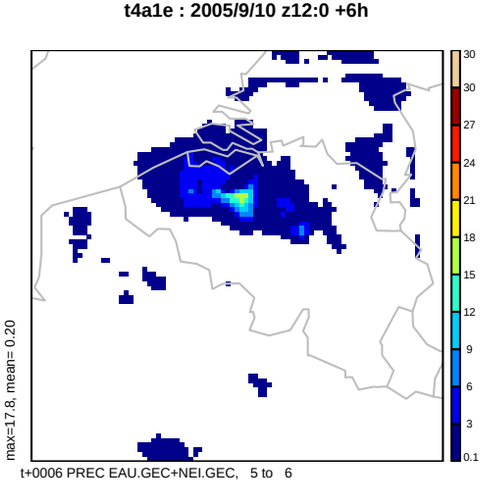

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RMI

Prognostic vertical motion Equation

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$$-\text{buoyancy} = -\frac{g^2}{1+\gamma R_a T_{vu}} \frac{p}{} \left\{ \frac{T_{vu} - \overline{T_v}}{\overline{T_v}} \right\}$$

conditions :

- $infinitely\ small$ ascending parcel in
- an environment $at\ rest$: $\omega_e = 0$.
- Apparent mass coefficient for spheric body : $\gamma = 0.5$

RMI

The mesh-fraction issue : physical approach

Bjerknes (1938) (+ Asai & Kasahara (1967)) :
Saturated adiabatic ascent in a *finite* environment.

Dry adiabatic subsidence makes that the system does not convert heat into kinetic energy unless the mesh fraction below a critical value.

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Dry adiabatic subsidence makes that the system does not convert heat into kinetic energy unless the mesh fraction below a critical value.
We express this as a *buoyancy loss* due to an increase of the environment temperature associated to $\omega_e^\diamond > 0$.
"Bjerknes Buoyancy Reduction"

How reduced subgrid condensation is (not) taken over by the resolved scheme ?

$$\left(\frac{\partial s}{\partial t}\right)_{\text{conv}} = L(\underbrace{C - E_c}_{\sigma_u \omega_u^{\diamond} \delta q_c} - E_P) + H_P - \underbrace{\frac{\partial \sigma_u \omega_u^* (s_u - \overline{s})}{\partial p}}_{\text{transport}}$$

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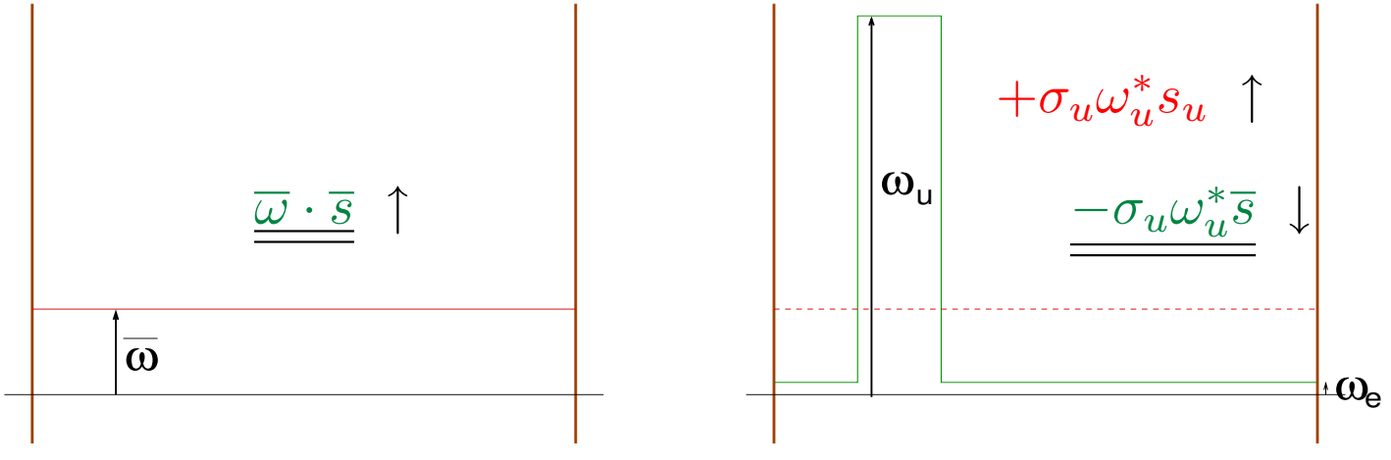
Subgrid transport replaces the upward transport by resolved $\overline{\omega}$



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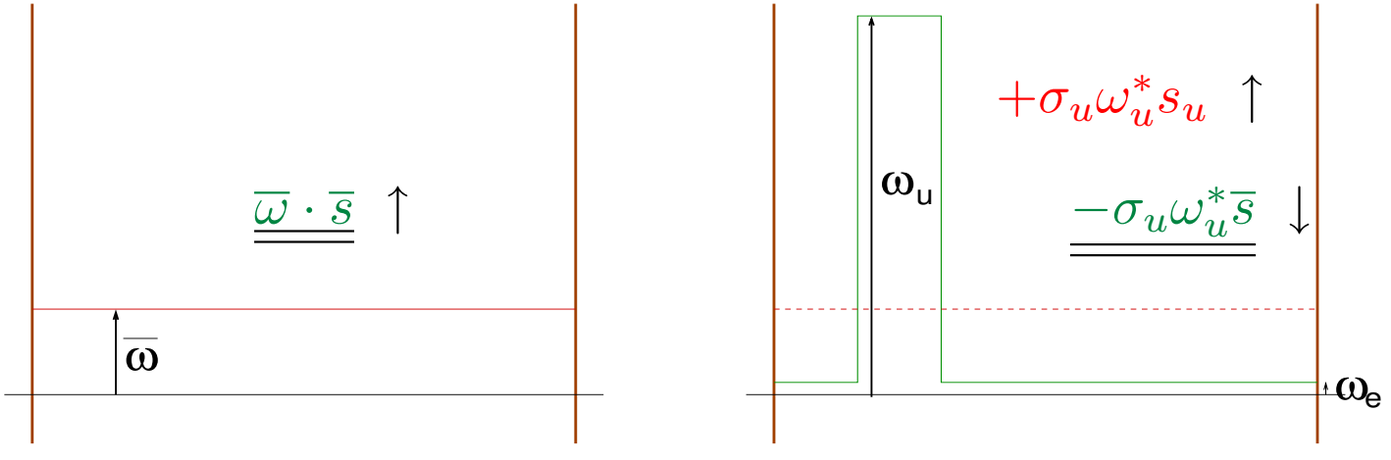


AND Subgrid condensation further heats and absorbs moistening

subsequently reducing the resolved condensation.

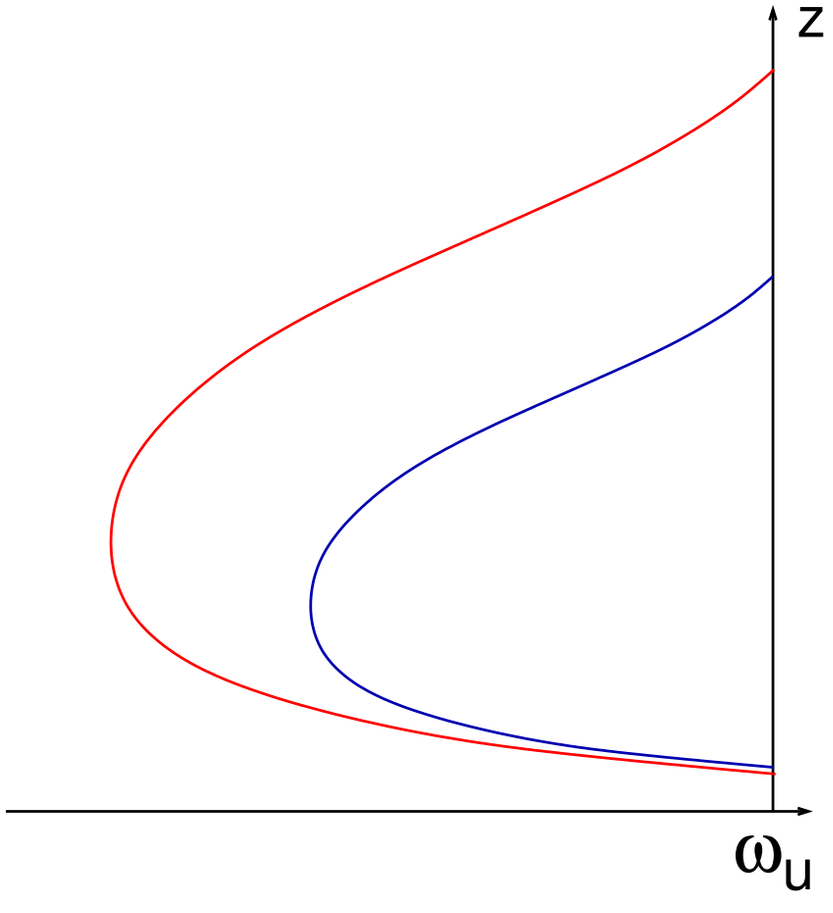
RMI

Prognostic closure by moisture convergence

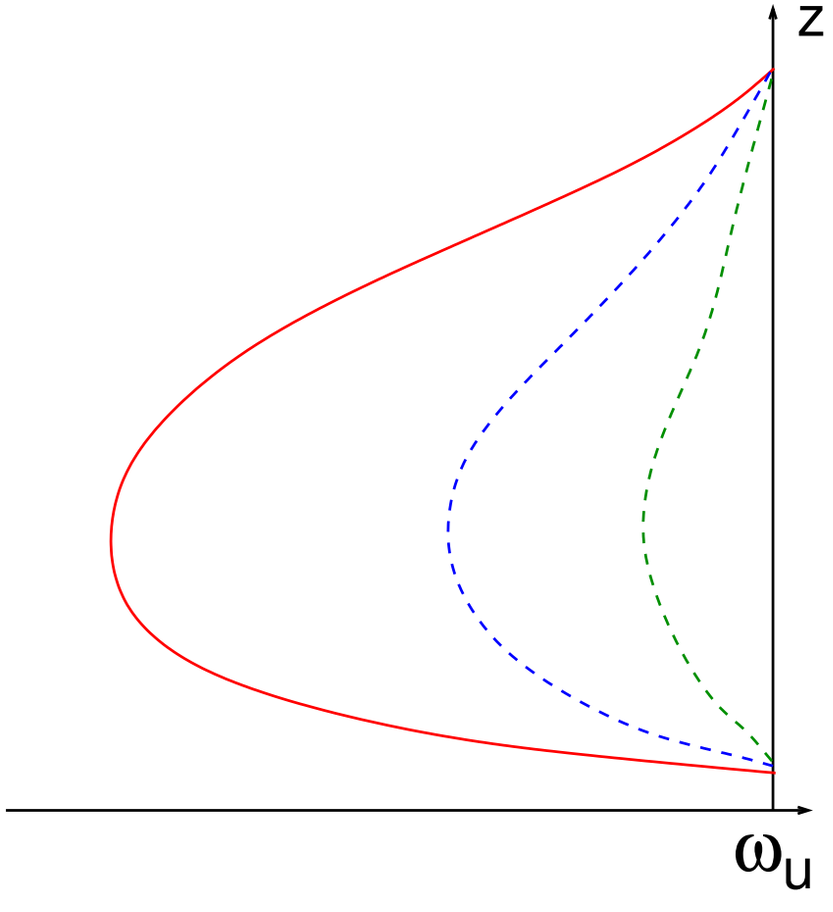
$$\sigma_u = \sigma_b \cdot f(p)$$

$$\frac{\partial \sigma_b}{\partial t} \int_{p_t}^{p_b} f \cdot (h_u - \overline{h}) \frac{dp}{g} = L \int_{p_t}^{p_b} \sigma_b f \omega_u^{\diamond} \; \underline{\underline{\frac{\delta q_{cu}}{g}}} + L \int_{p_t}^{p_b} \mathsf{CVGQ} \frac{dp}{g}$$

Buoyancy reduction vs cloud evolution



Buoyancy reduction vs cloud evolution



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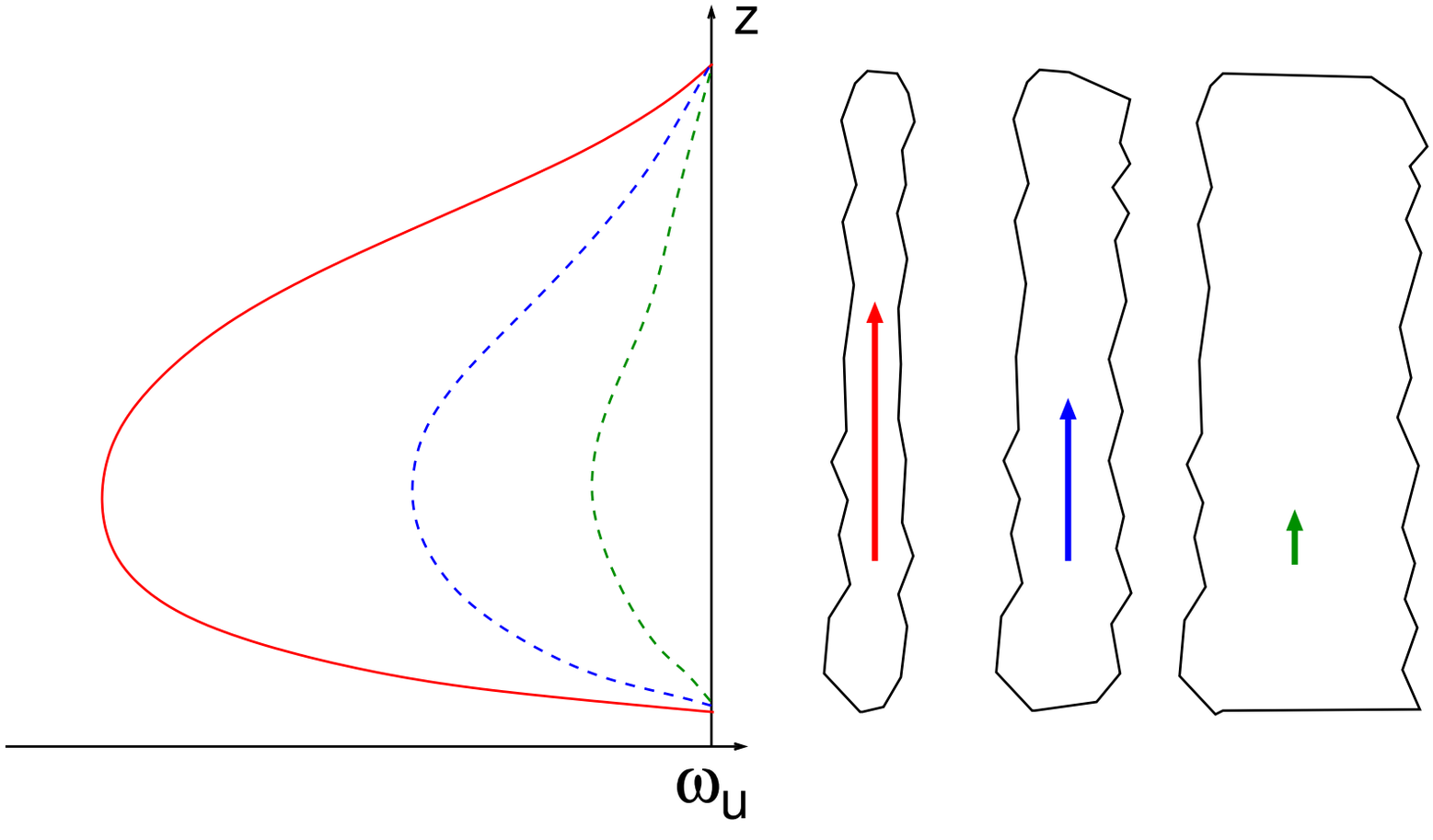

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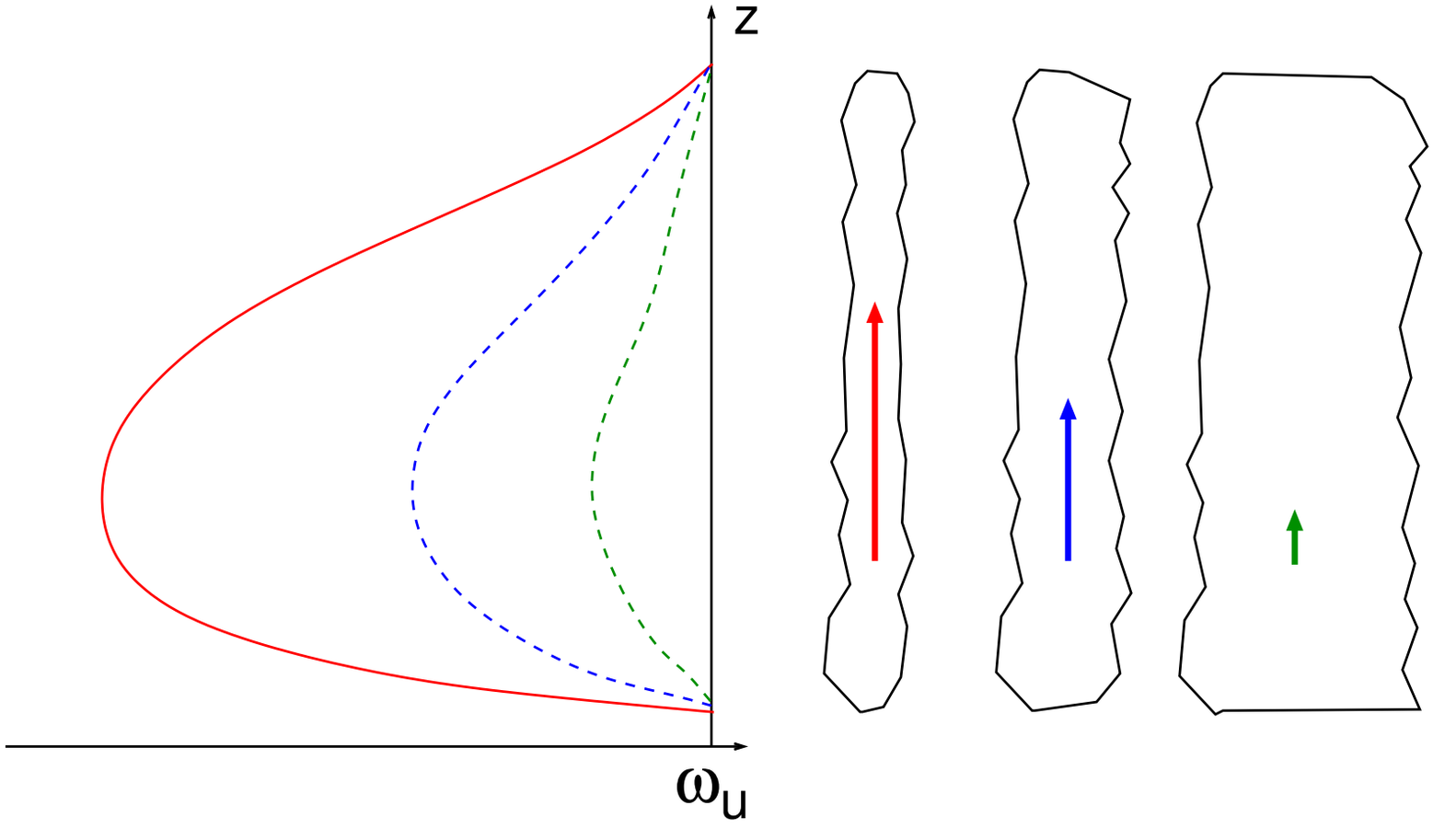
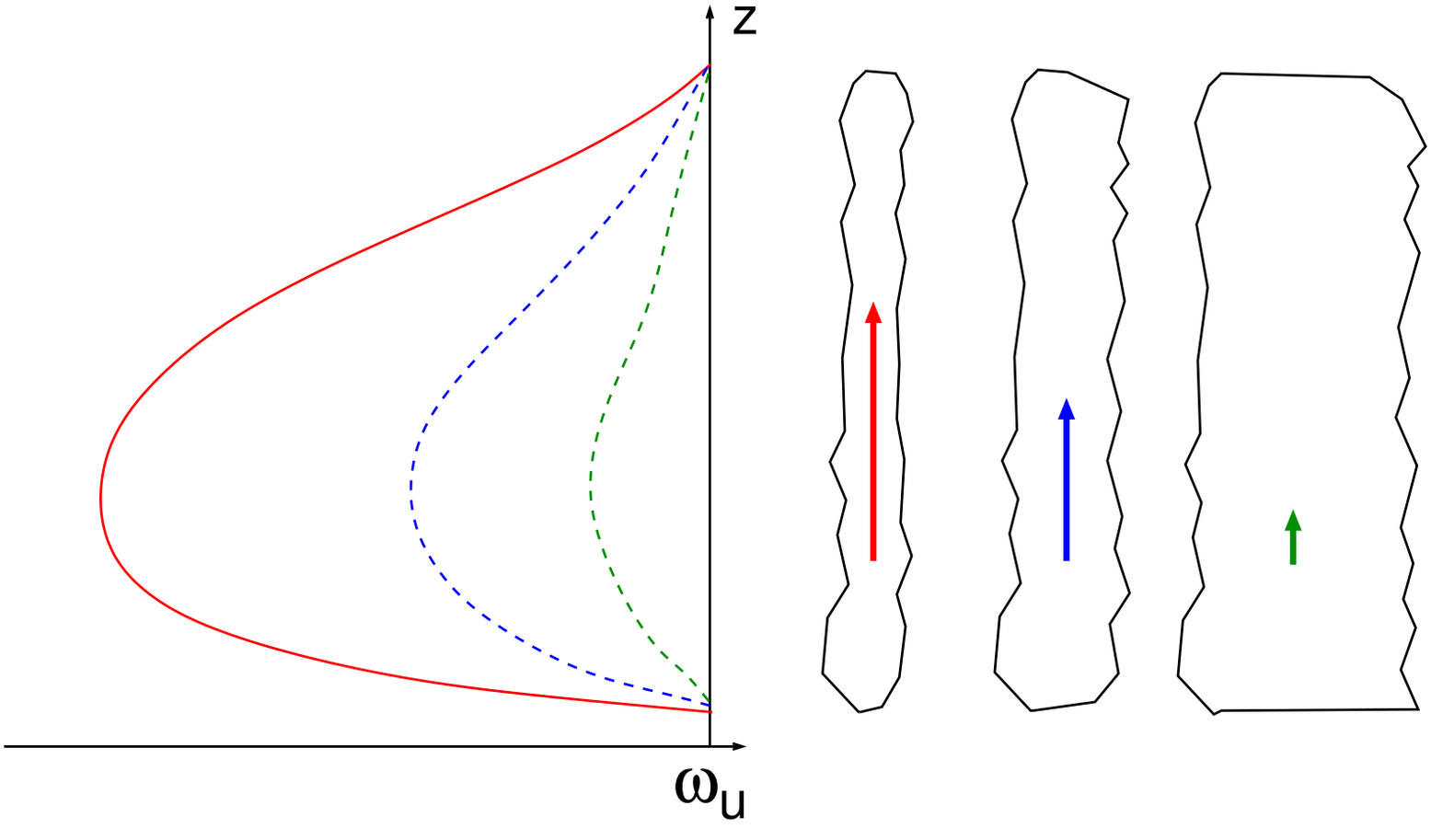


Small flux maintains significant transport
preventing the resolved scale to take the relay !

Cloud top evolution

Limit the cloud to the layers it can reach



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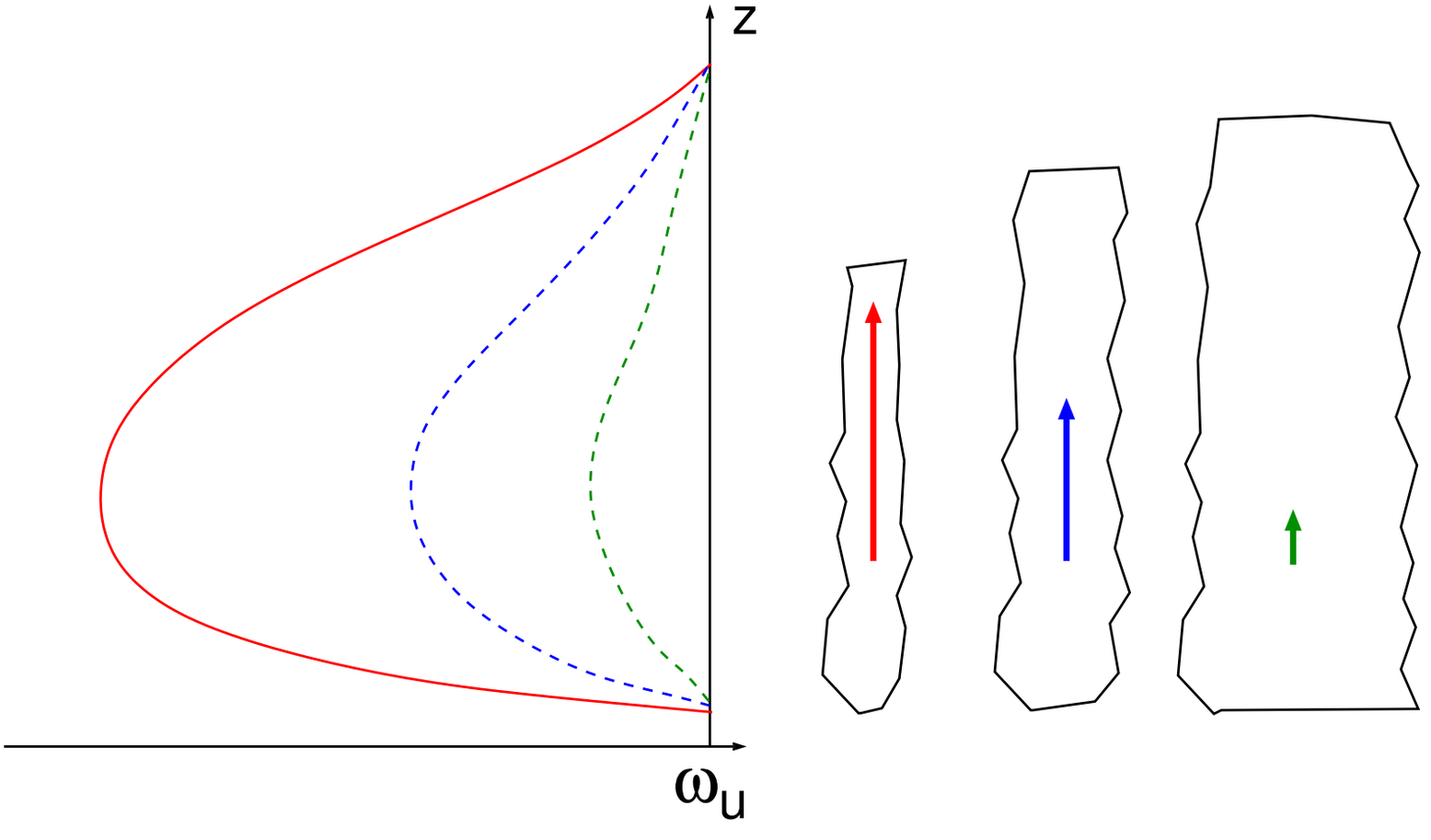

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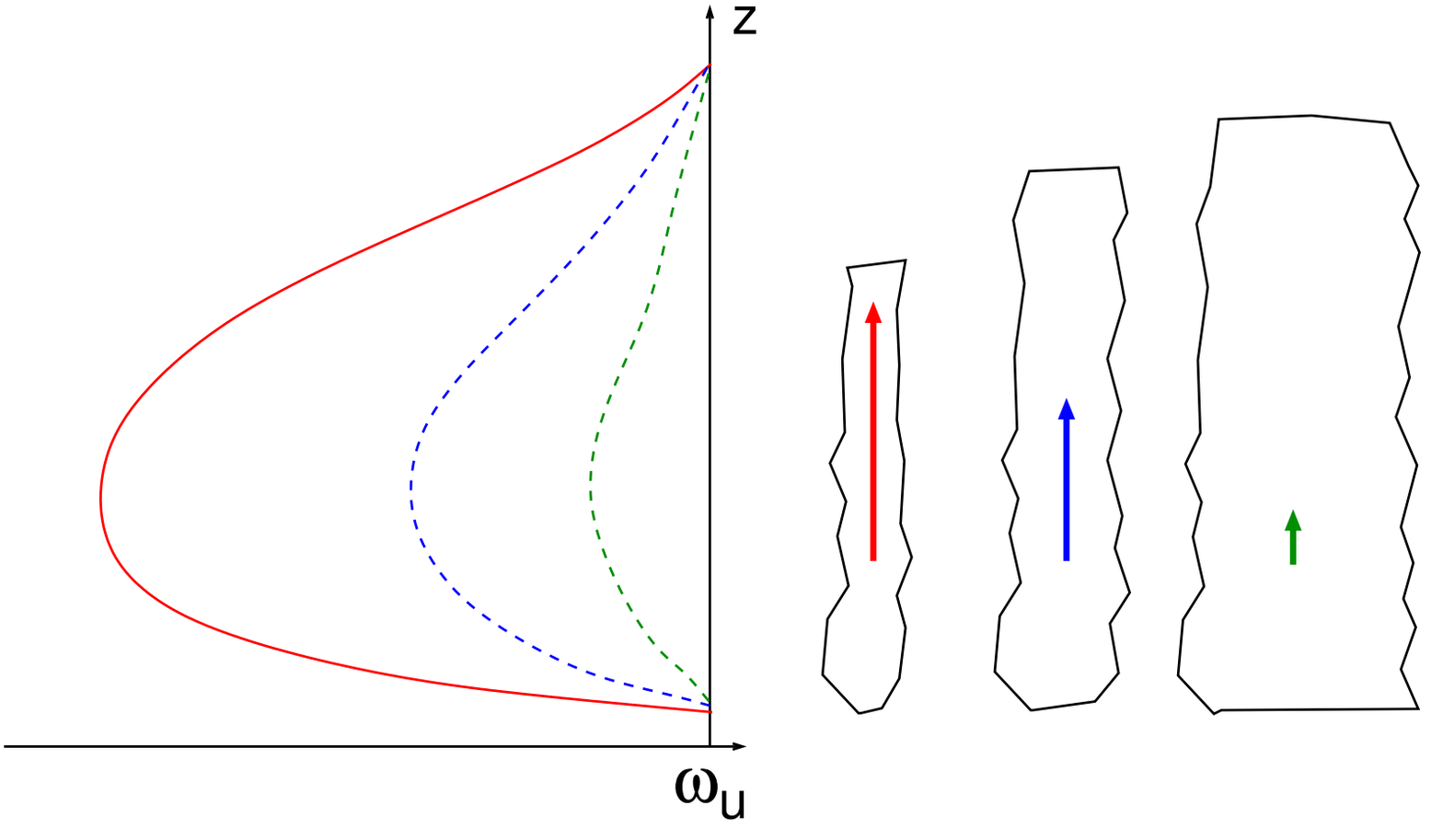

But this does not prevent reaching significant height while mesh fraction is small.

Cloud top evolution

– Start with a guessed minimum mesh fraction

Cloud top evolution

- Start with a guessed minimum mesh fraction $\longrightarrow$ how ?
- Provide a mechanism to $reduce$ cloud height $while$ mesh fraction increases

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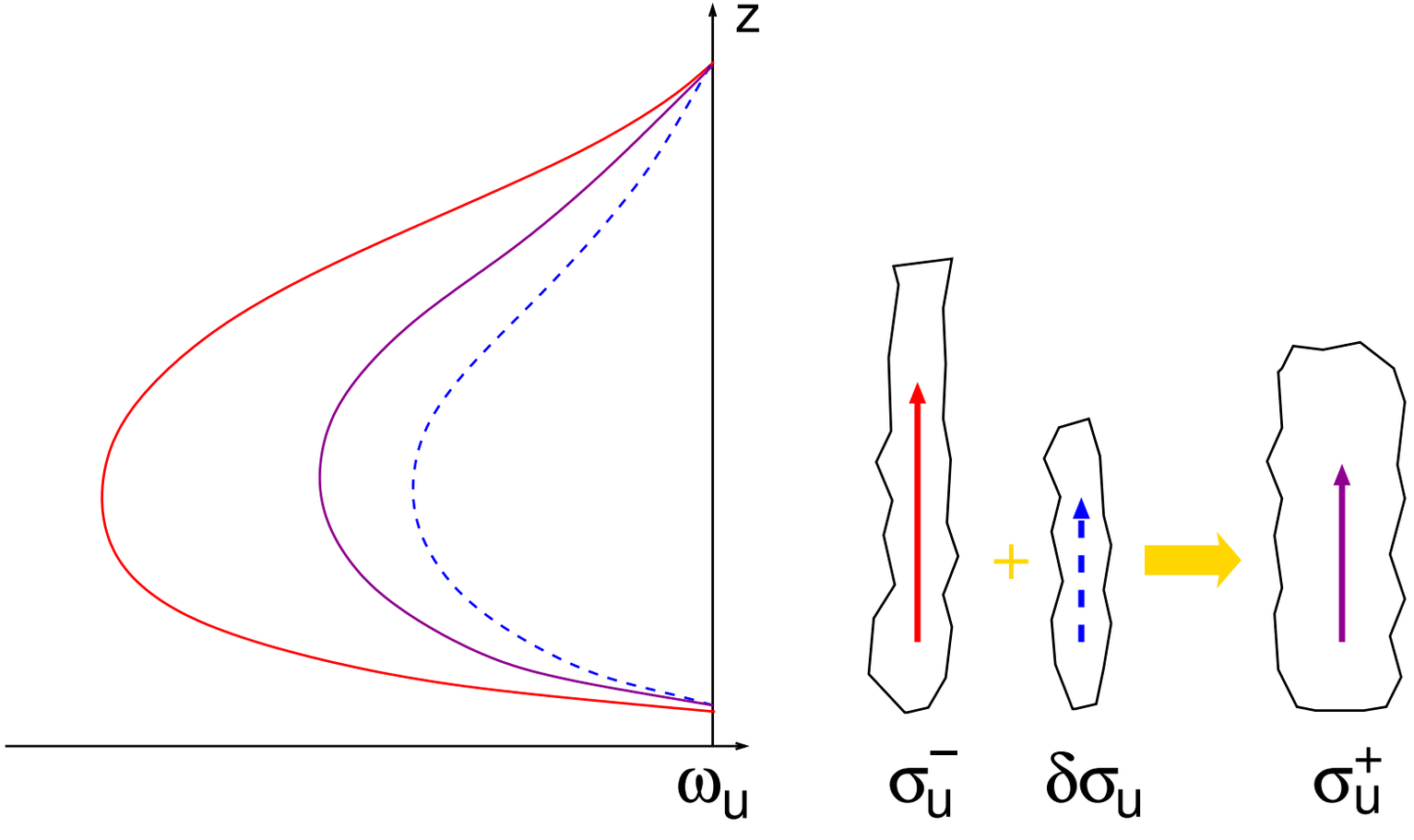
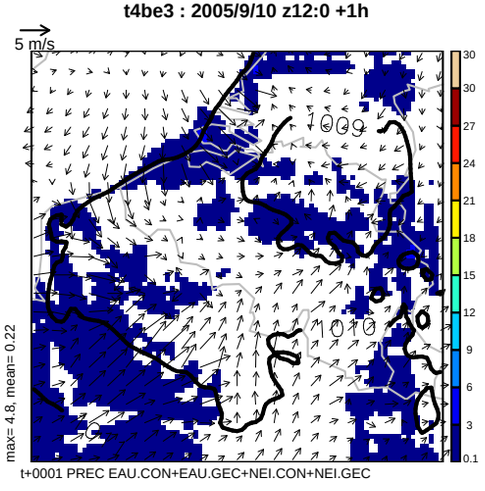
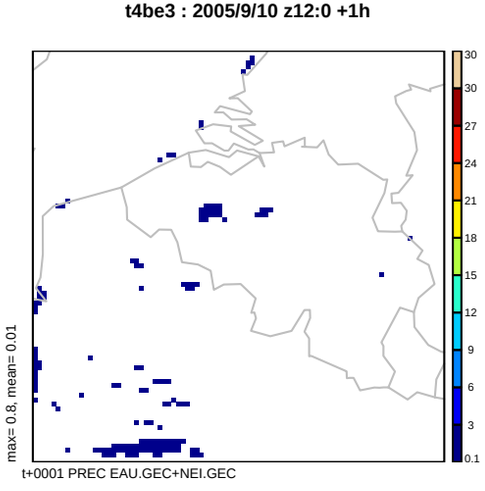
  Area Extension by Growing New Updraught and Merging

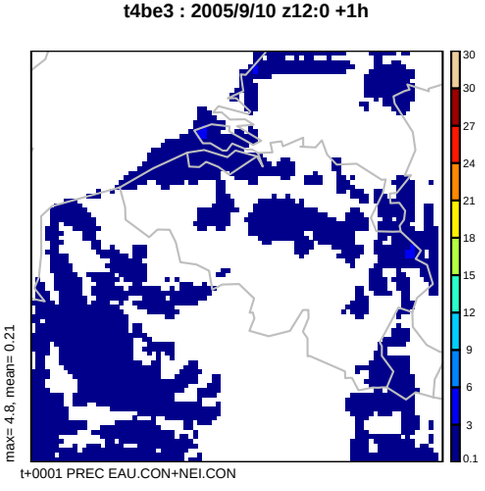


AEGNUM resolution test

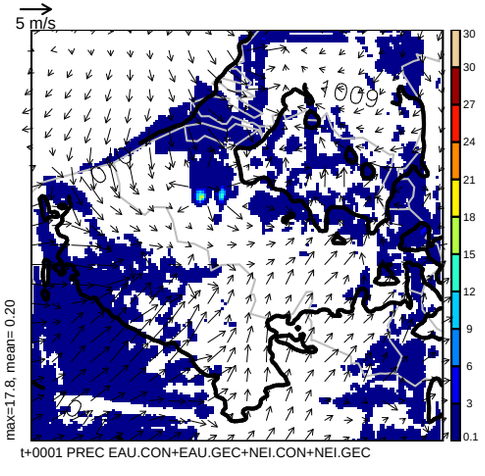
4.00km (HS)

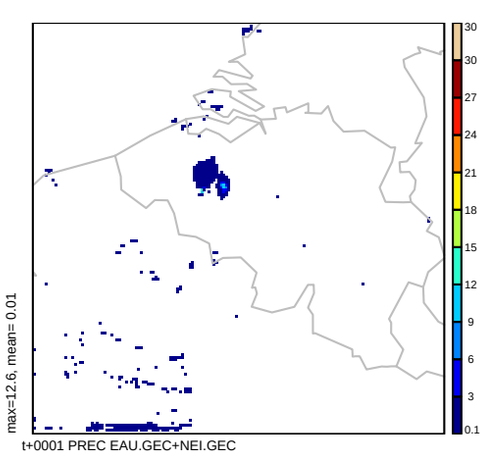


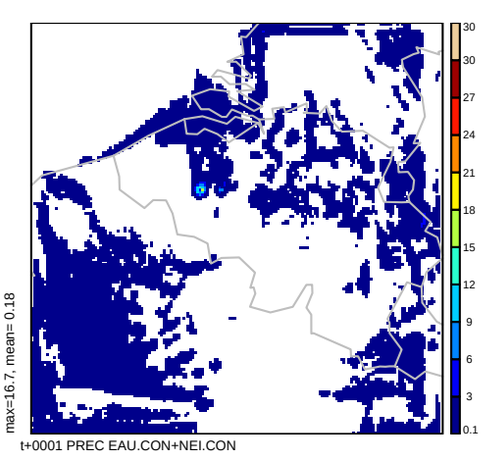




2.00km (NH)







+1h

Resolved

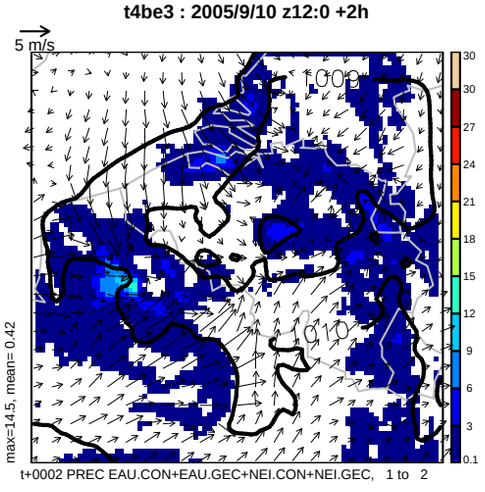
Subgrid

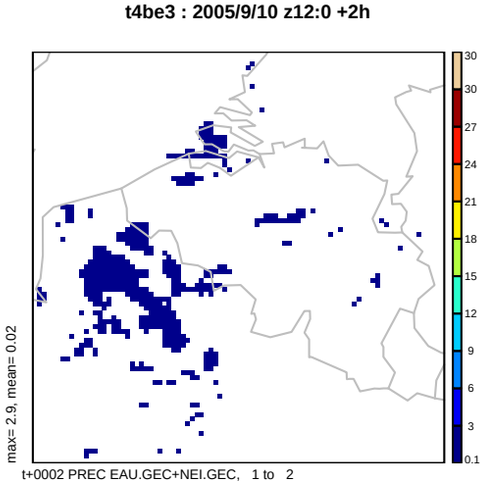
RMI

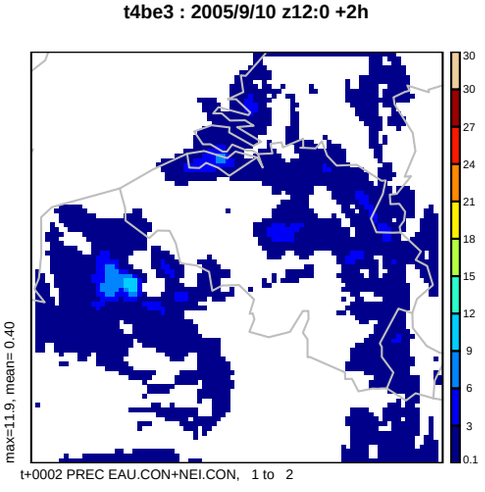
L. Gerard, 16 June 2009

AEGNUM resolution test

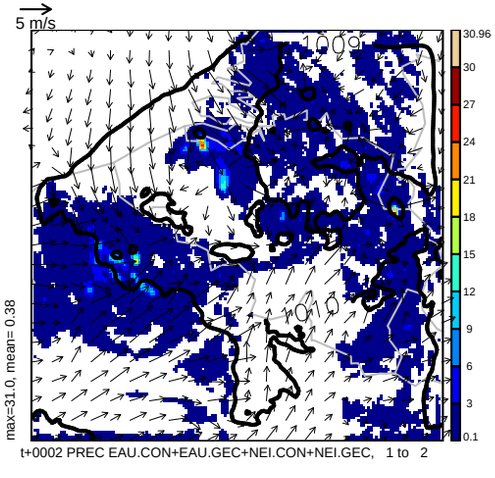
4.00km (HS)

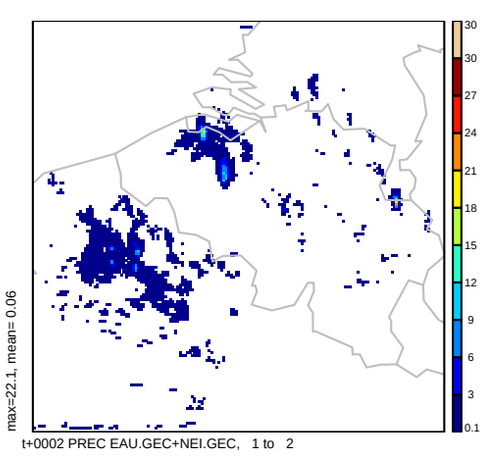


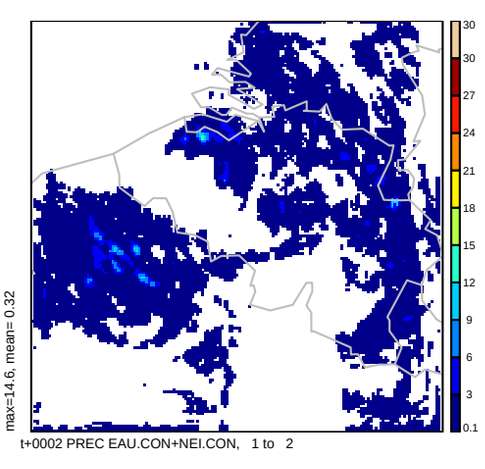




2.00km (NH)







+2h

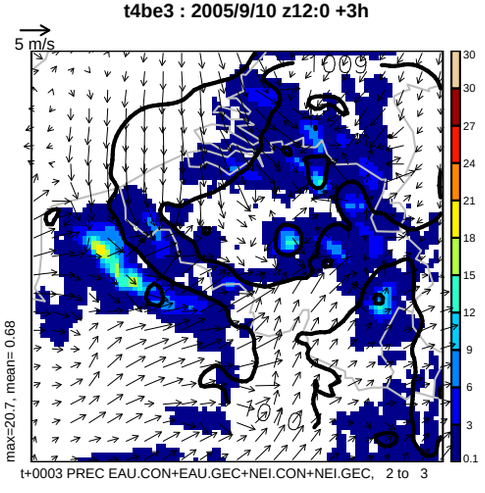
Resolved

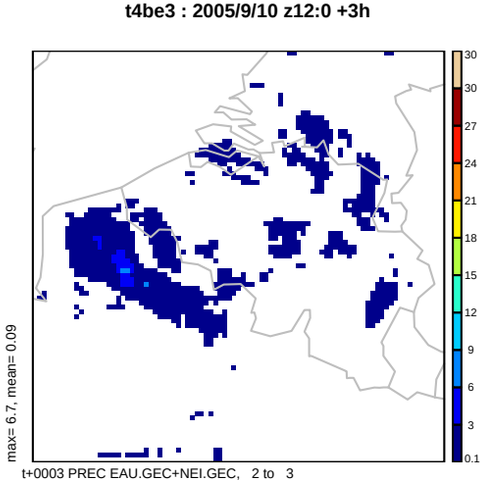
Subgrid

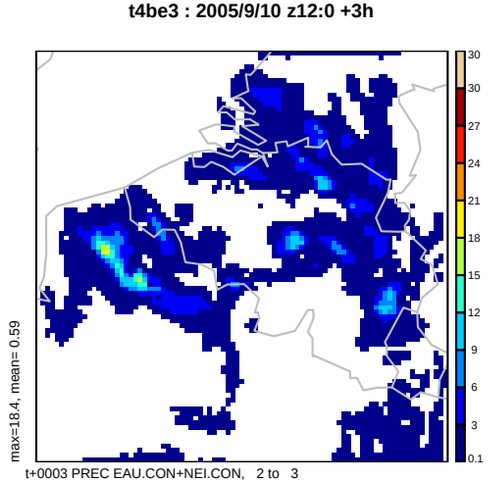
RMI

AEGNUM resolution test

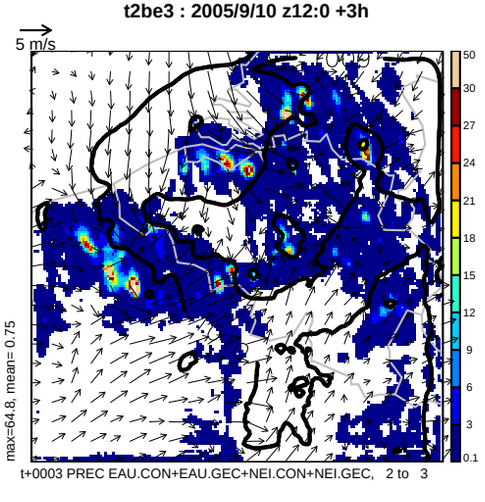
4.00km (HS)

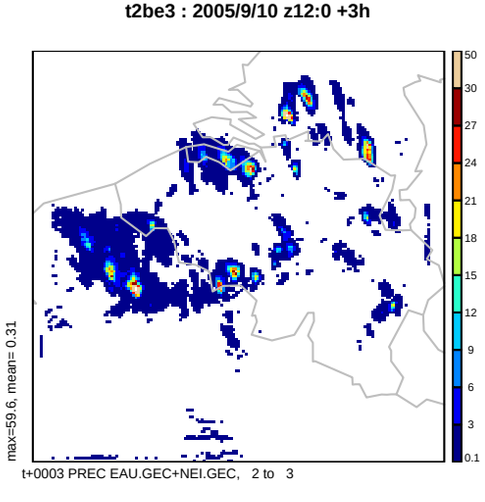


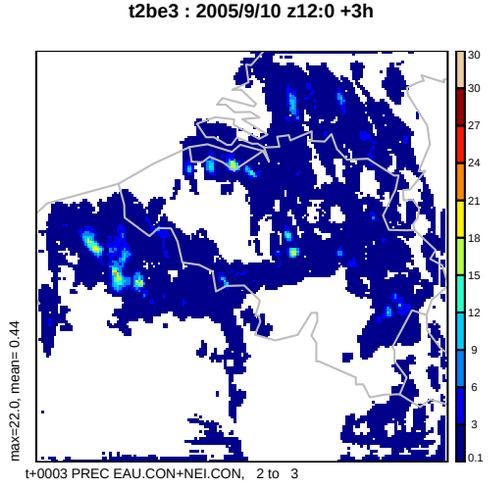




2.00km (NH)







+3h

Resolved

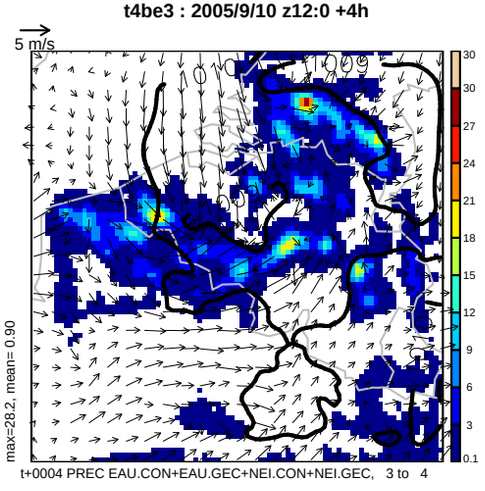
Subgrid

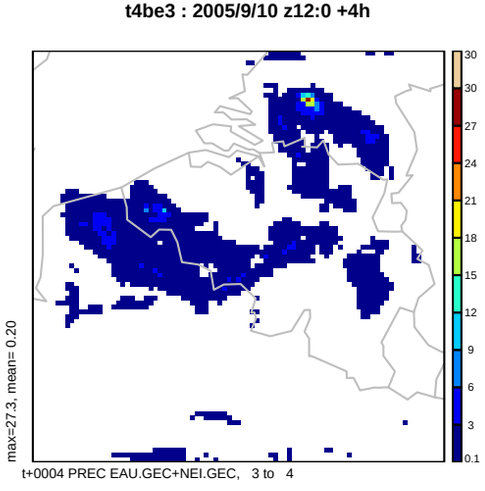
RMI

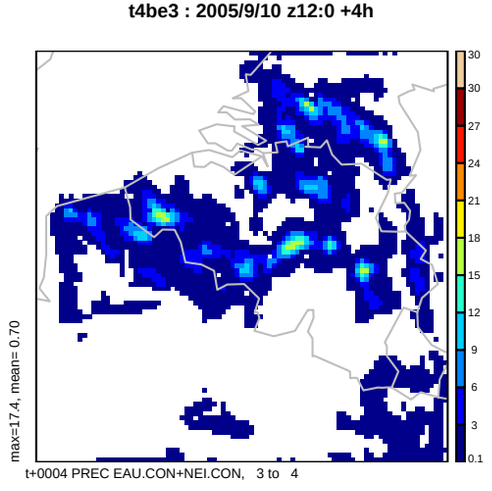
L. Gerard, 16 June 2009

AEGNUM resolution test

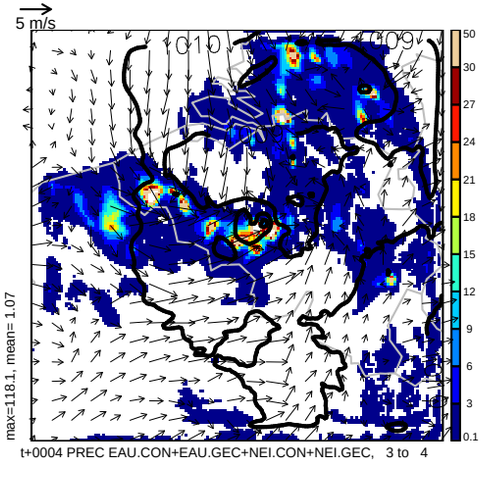
4.00km (HS)

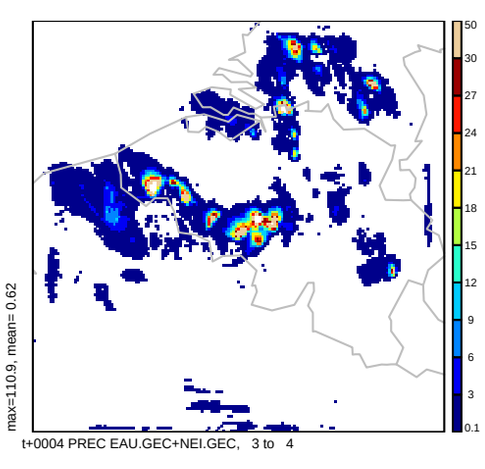


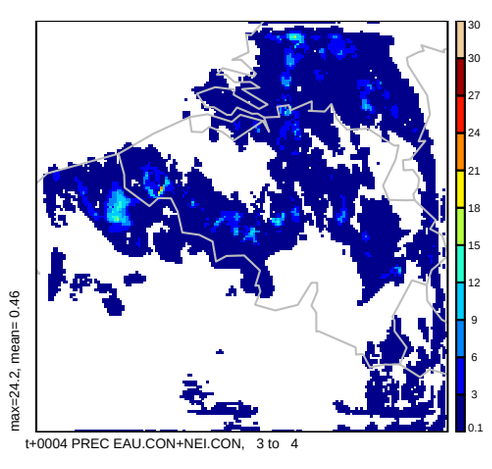




2.00km (NH)







+4h

Resolved

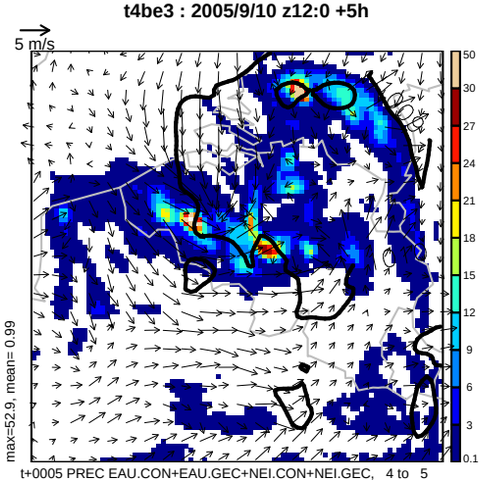
Subgrid

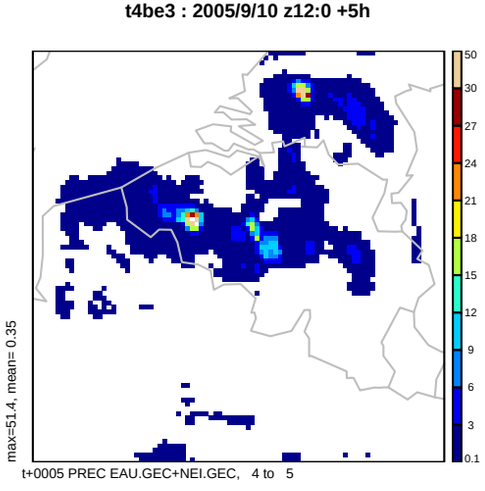
RMI

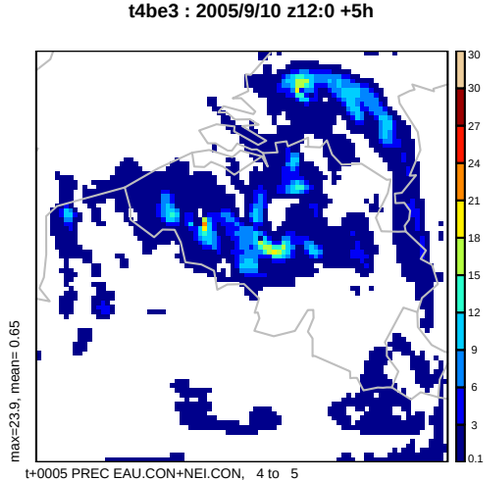
L. Gerard, 16 June 2009

AEGNUM resolution test

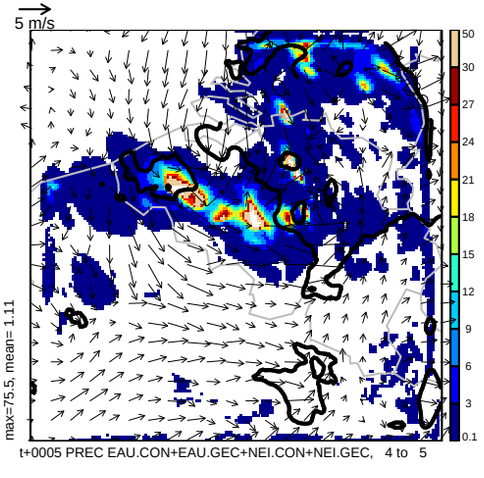
4.00km (HS)

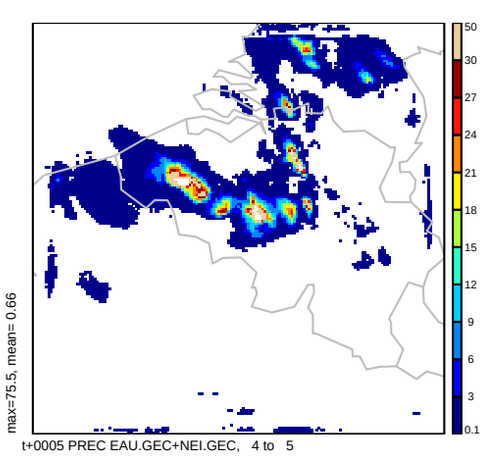


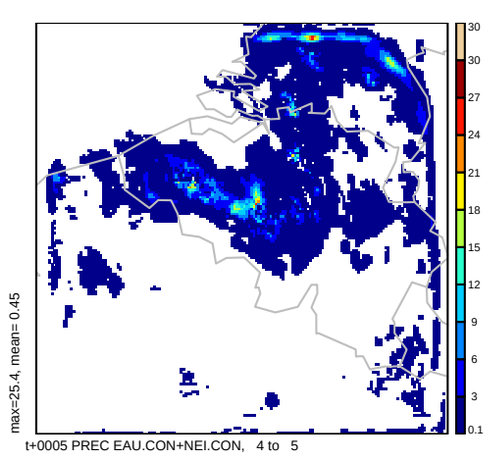




2.00km (NH)







+5h

Resolved

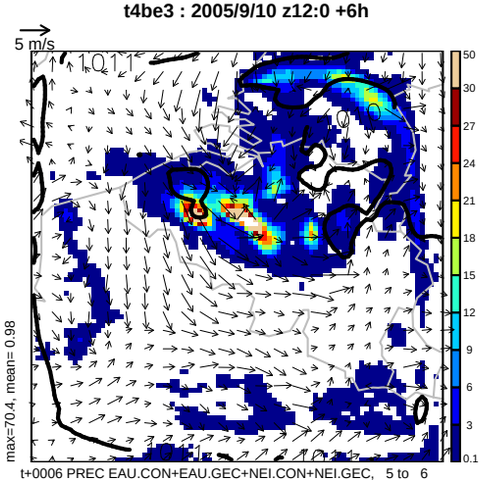
Subgrid

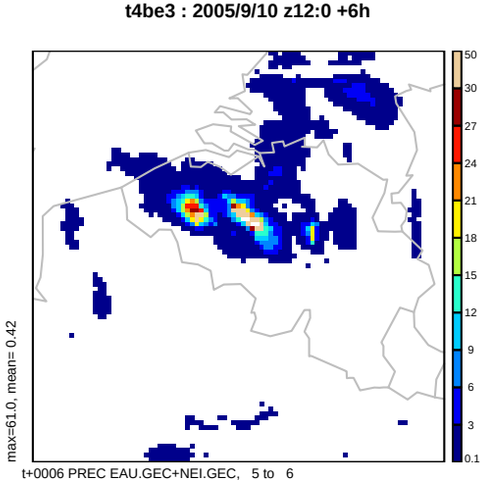
RMI

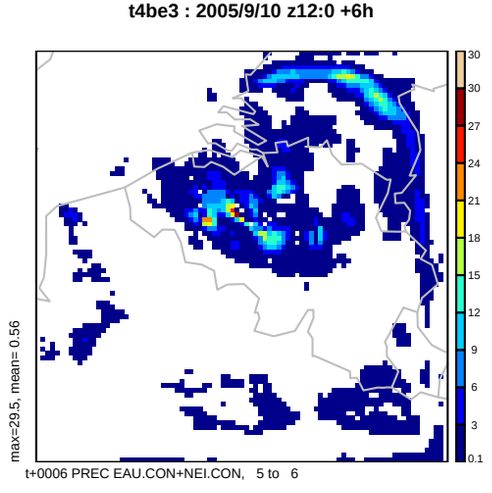
L. Gerard, 16 June 2009

AEGNUM resolution test

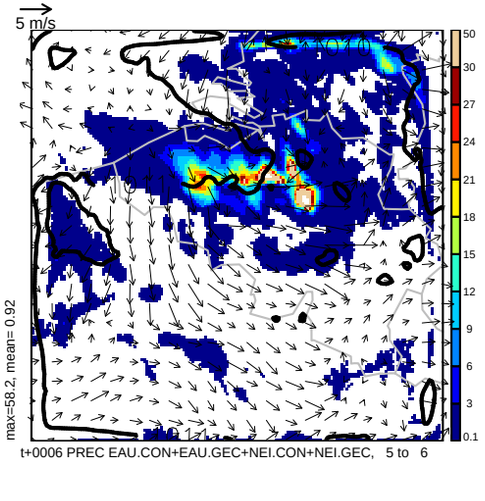
4.00km (HS)

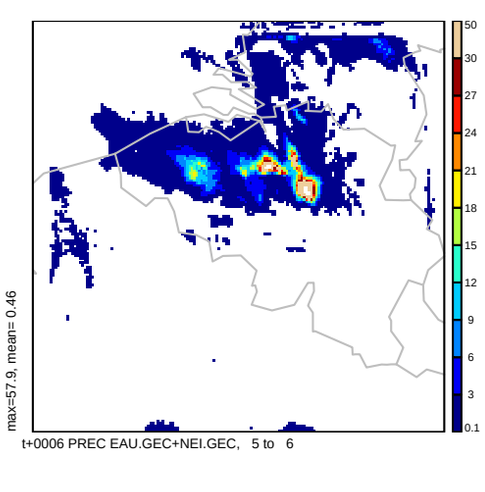


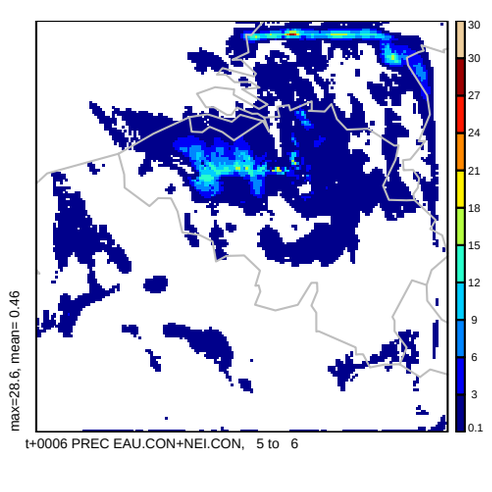




2.00km (NH)







+6h

Resolved

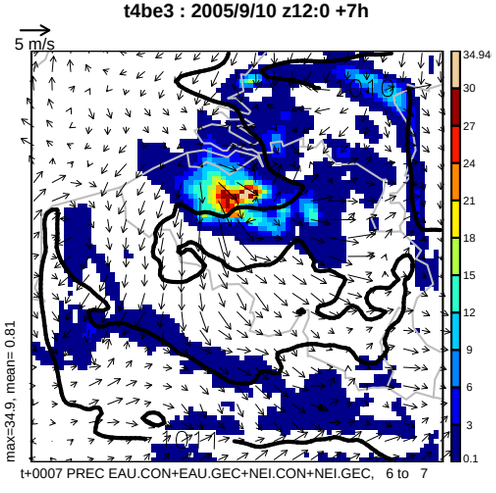
Subgrid

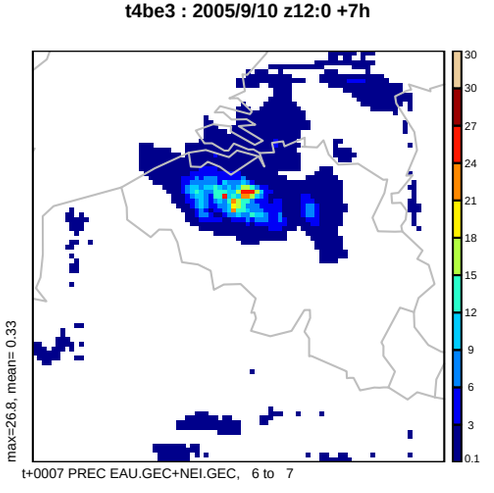
RMI

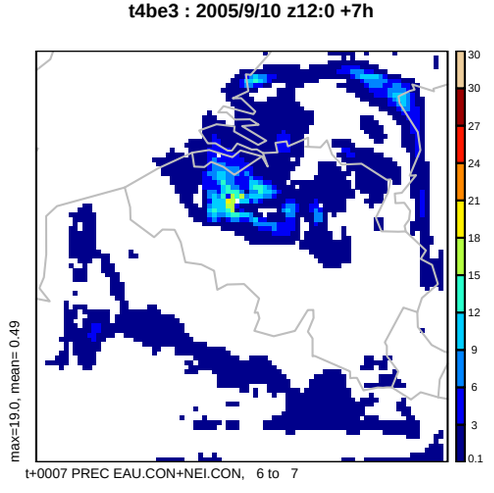
L. Gerard, 16 June 2009

AEGNUM resolution test

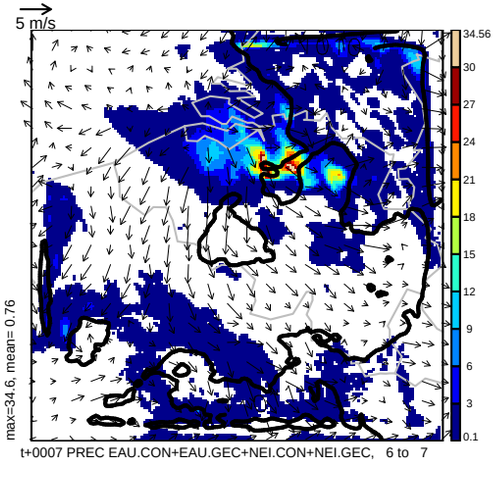
4.00km (HS)

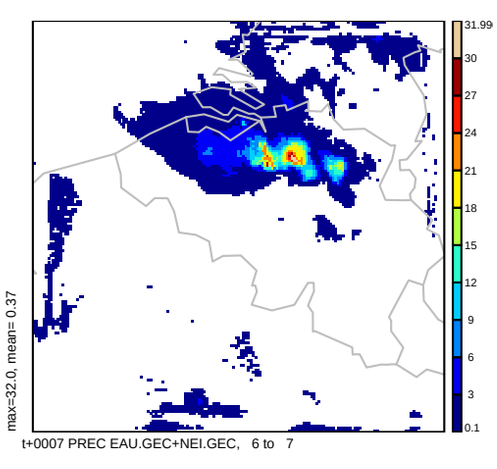


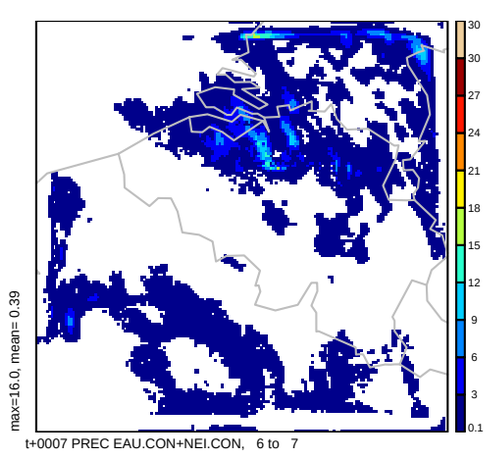




2.00km (NH)







+7h

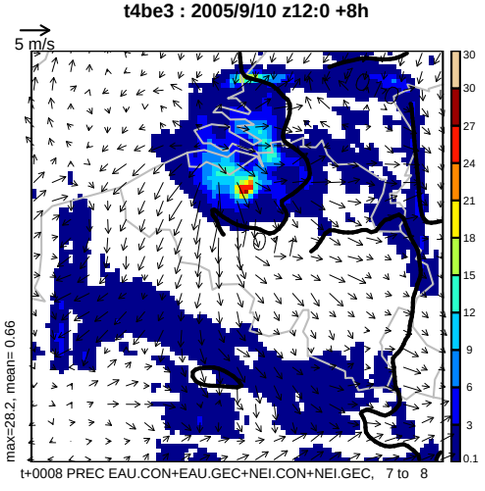
Resolved

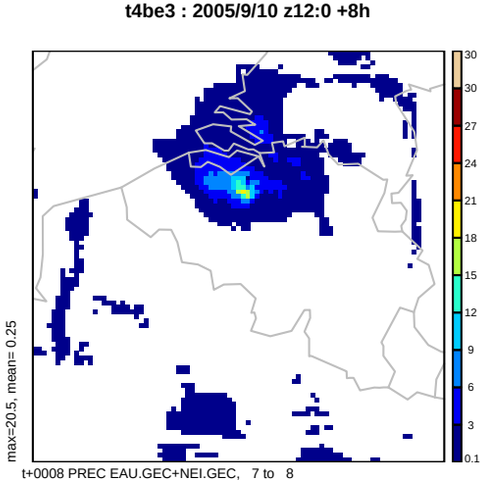
Subgrid

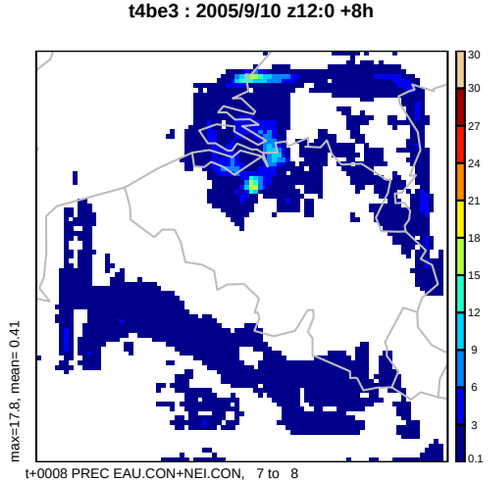
RMI

AEGNUM resolution test

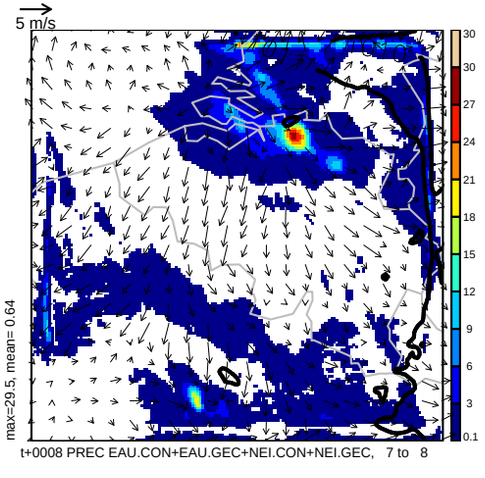
4.00km (HS)

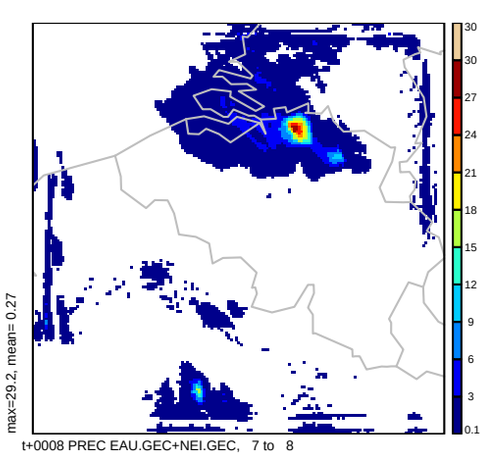


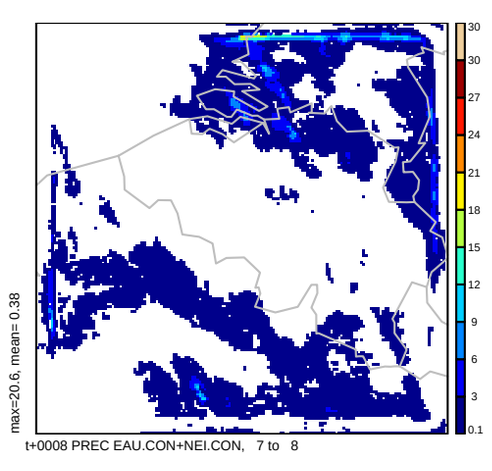




2.00km (NH)







+8h

Resolved

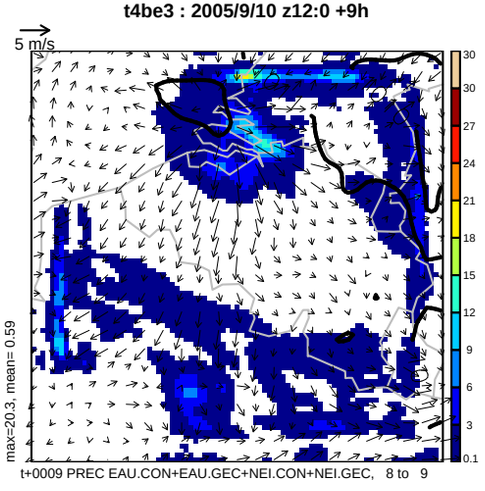
Subgrid

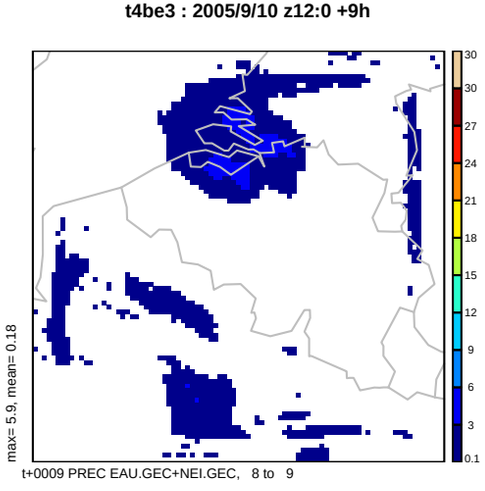
RMI

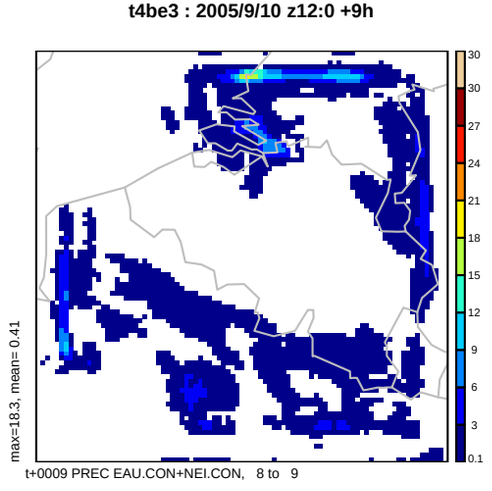
L. Gerard, 16 June 2009

AEGNUM resolution test

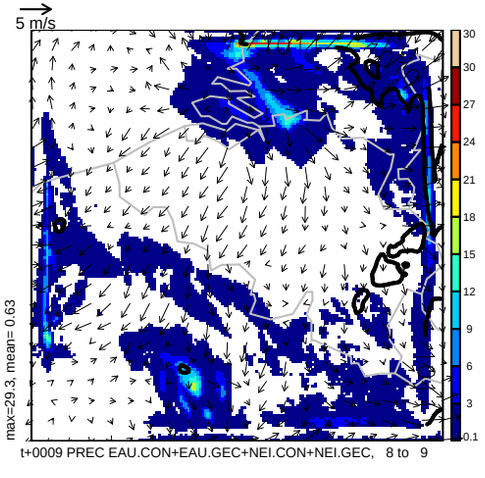
4.00km (HS)

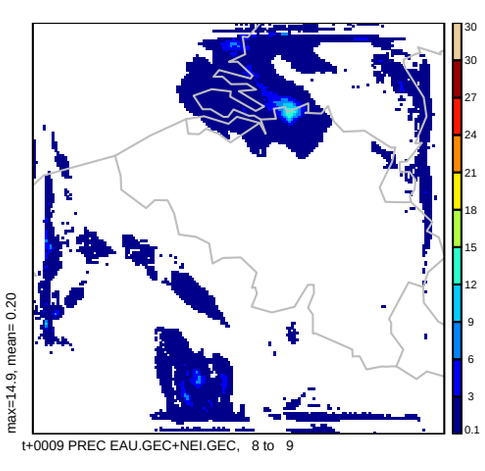


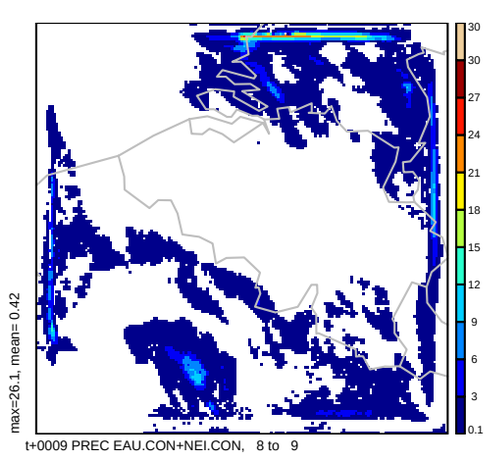




2.00km (NH)







+9h

Resolved

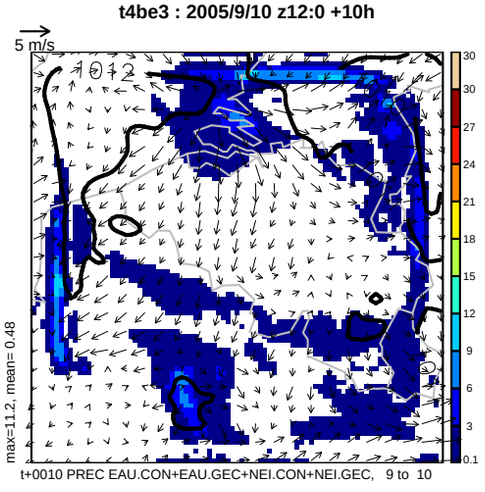
Subgrid

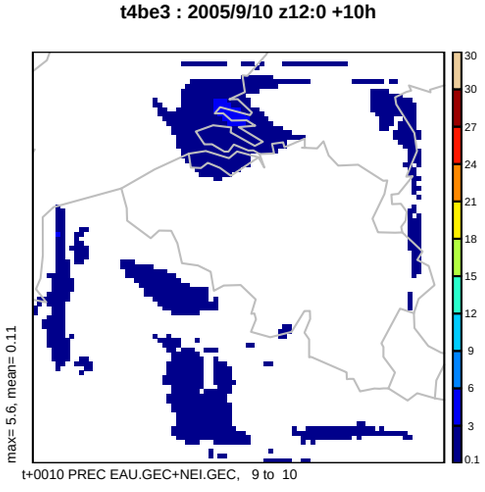
RMI

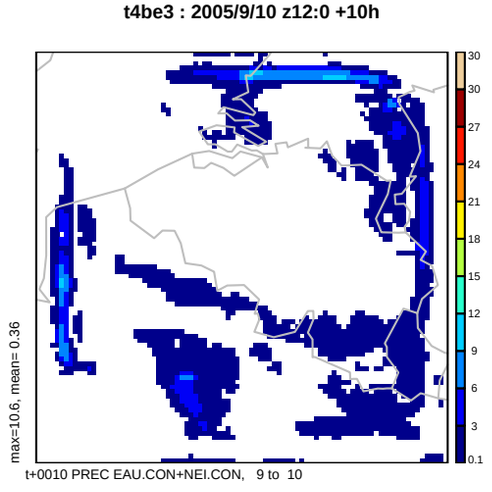
L. Gerard, 16 June 2009

AEGNUM resolution test

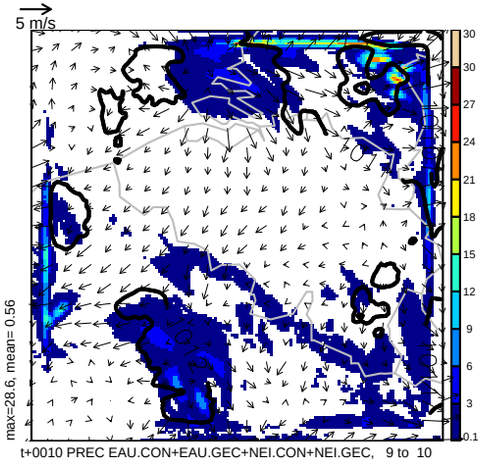
4.00km (HS)

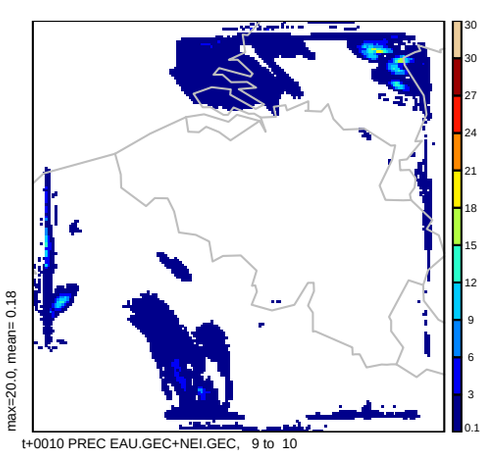


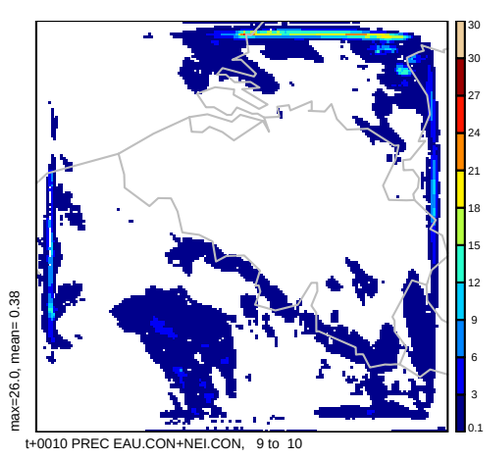




2.00km (NH)







+10h

Resolved

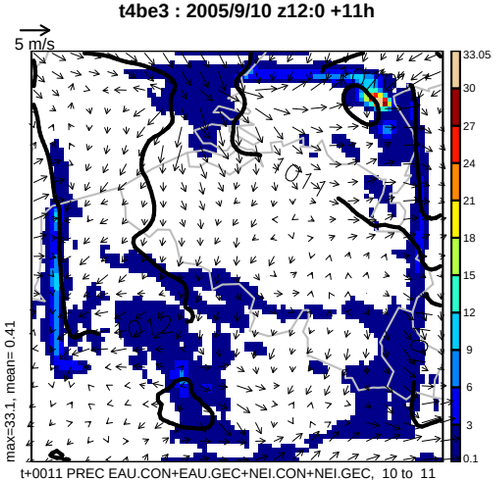
Subgrid

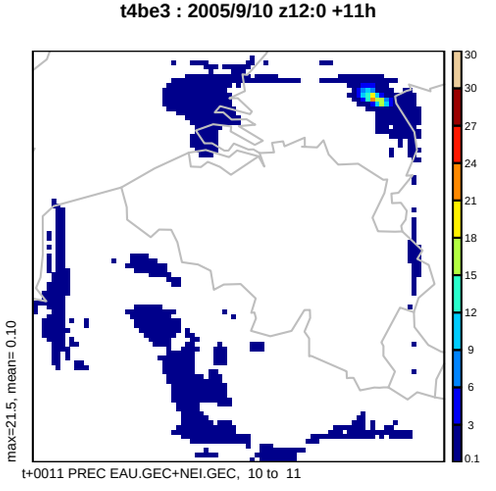
RMI

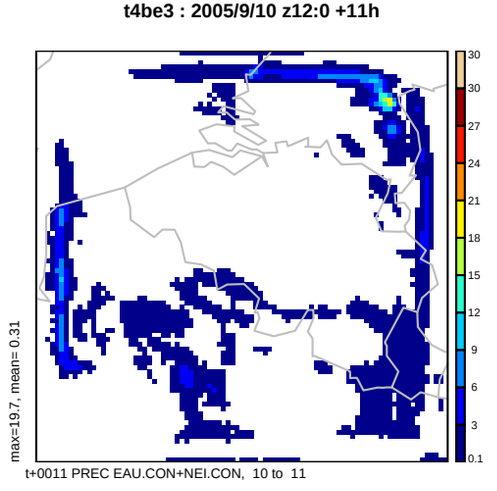
L. Gerard, 16 June 2009

AEGNUM resolution test

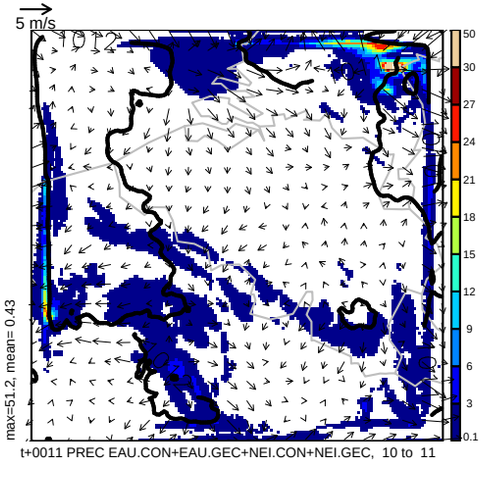
4.00km (HS)

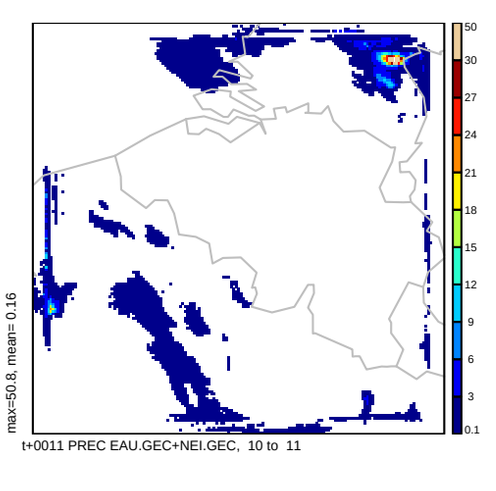


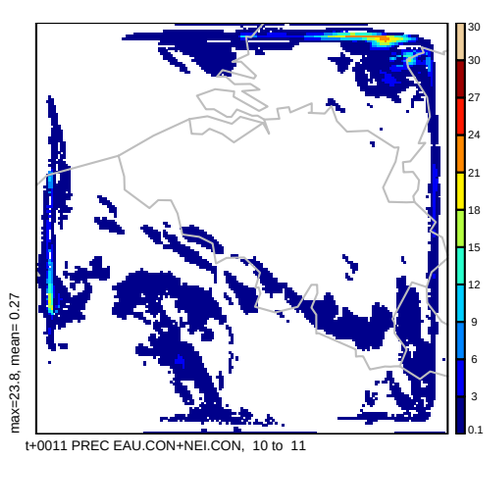




2.00km (NH)







+11h

Resolved

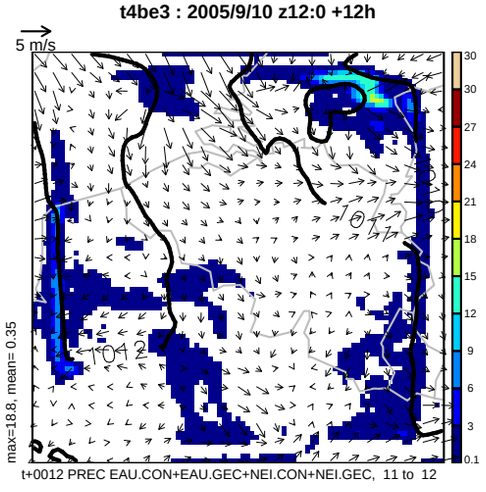
Subgrid

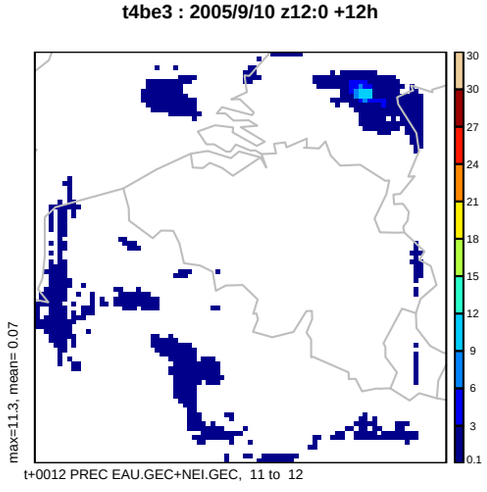
RMI

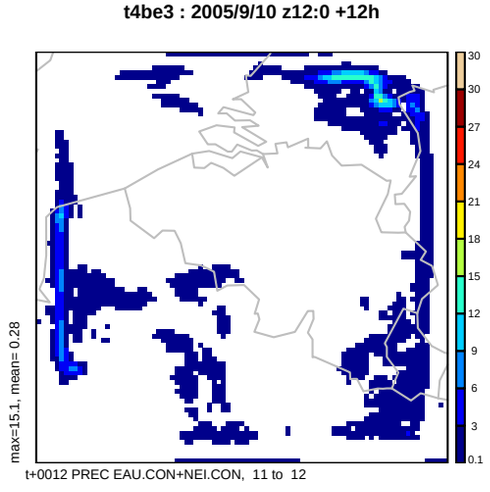
L. Gerard, 16 June 2009

AEGNUM resolution test

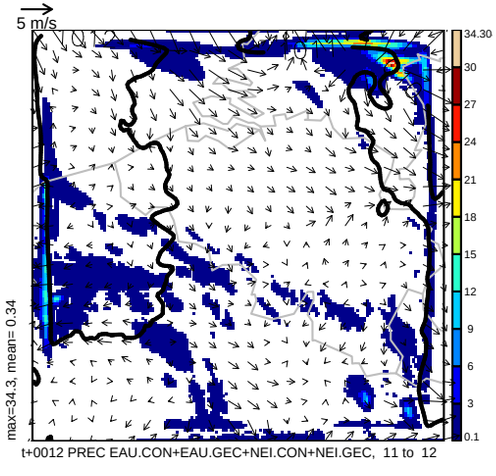
4.00km (HS)

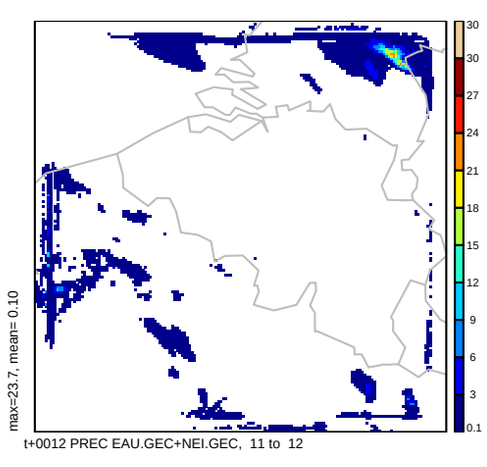


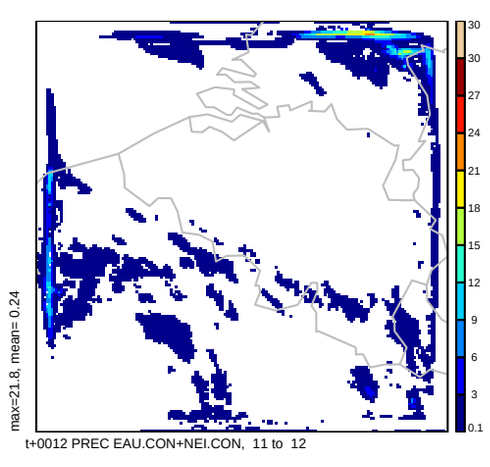




2.00km (NH)







+12h

Resolved

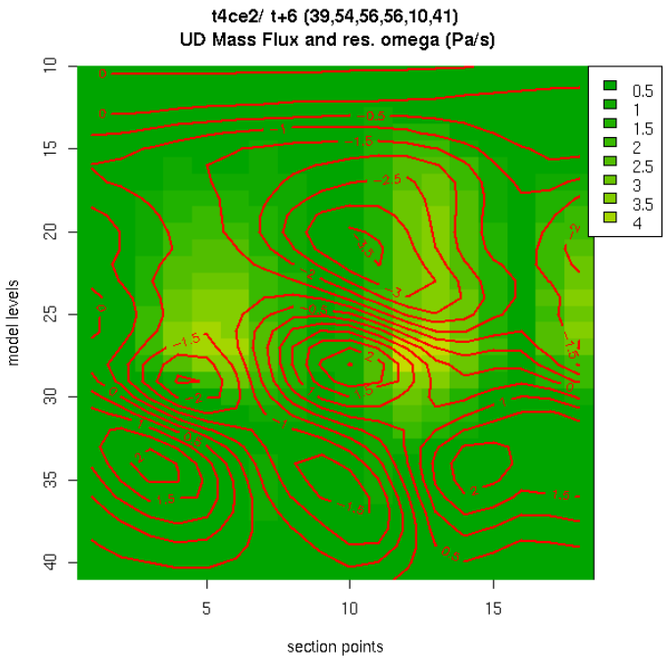
Subgrid

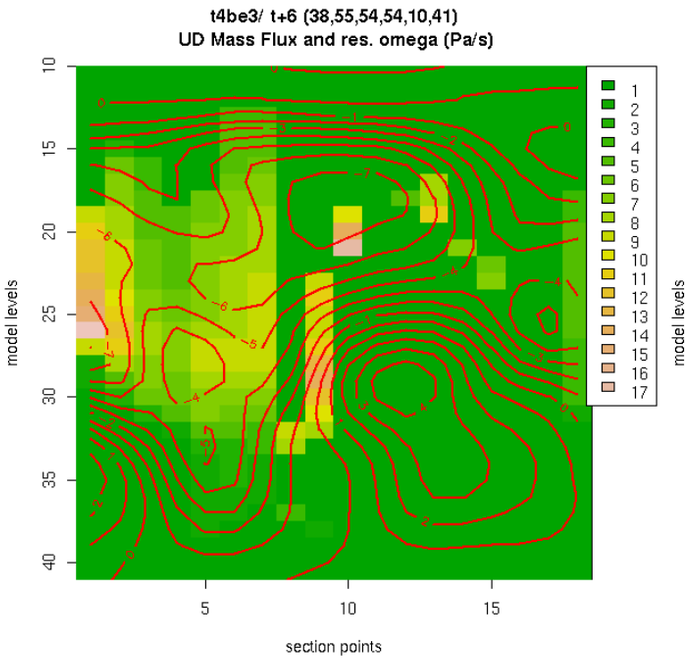
RMI

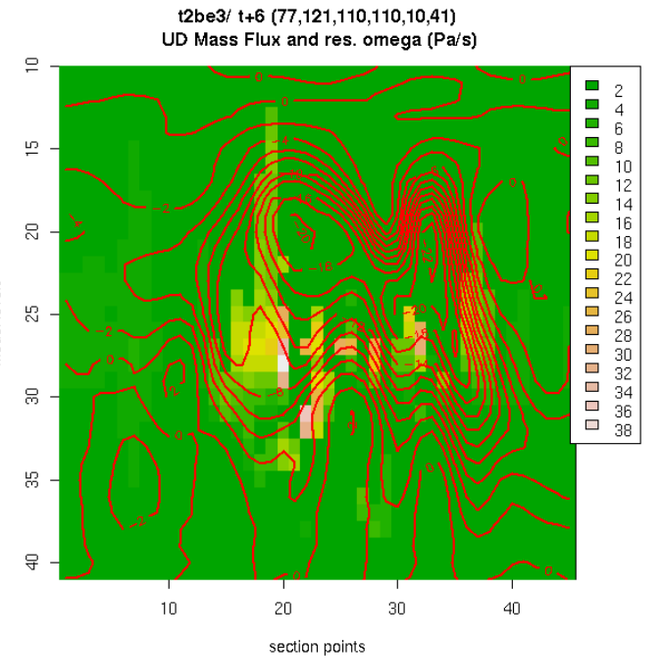
L. Gerard, 16 June 2009

Behaviour comparison

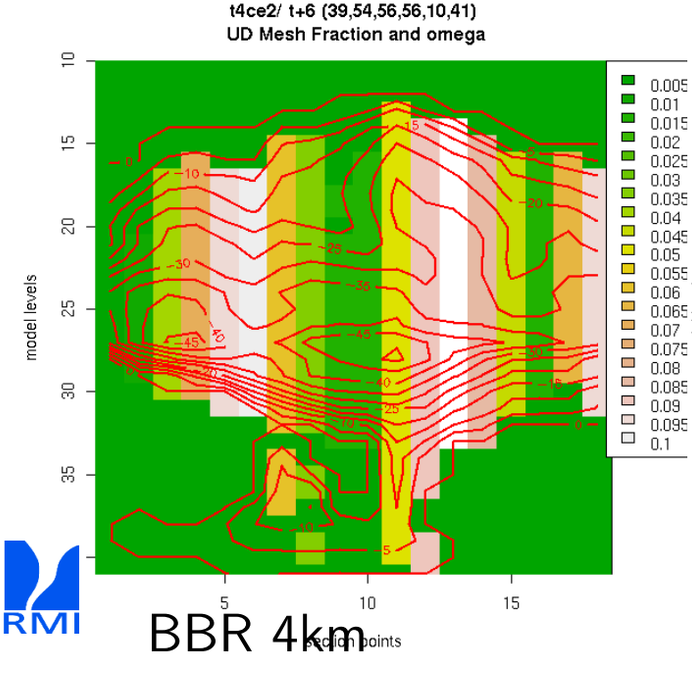
$-\sigma_u \omega_u$, $\overline{\omega}$

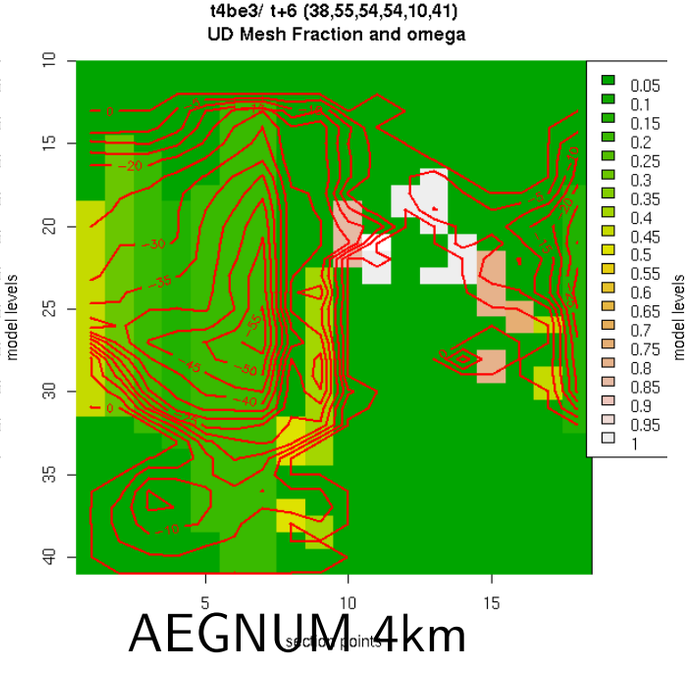


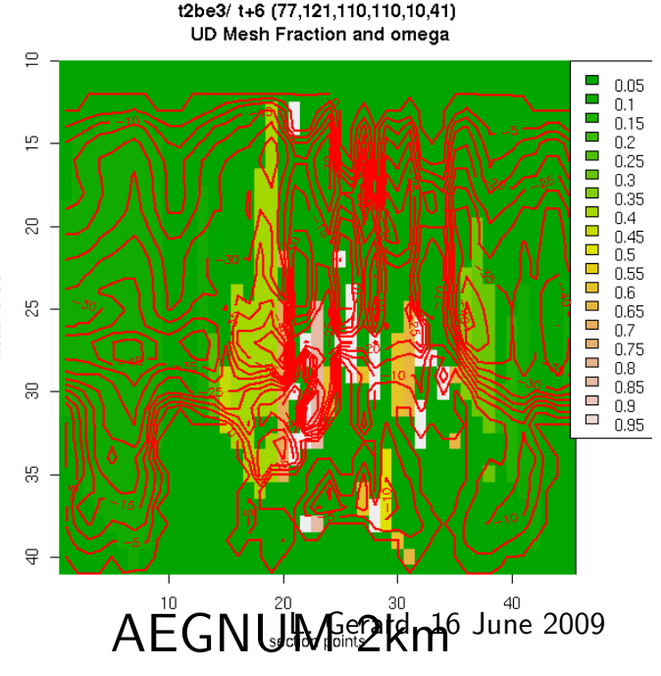




σ_u, ω_u







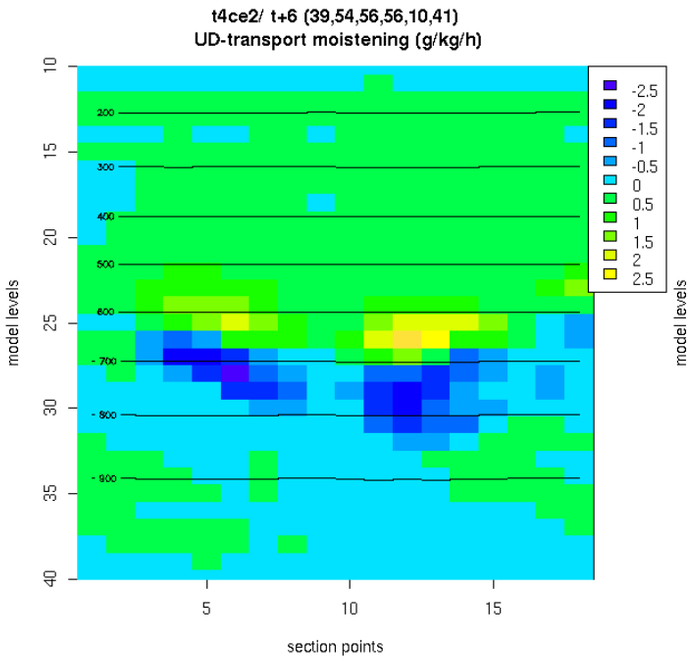
BBR 4km

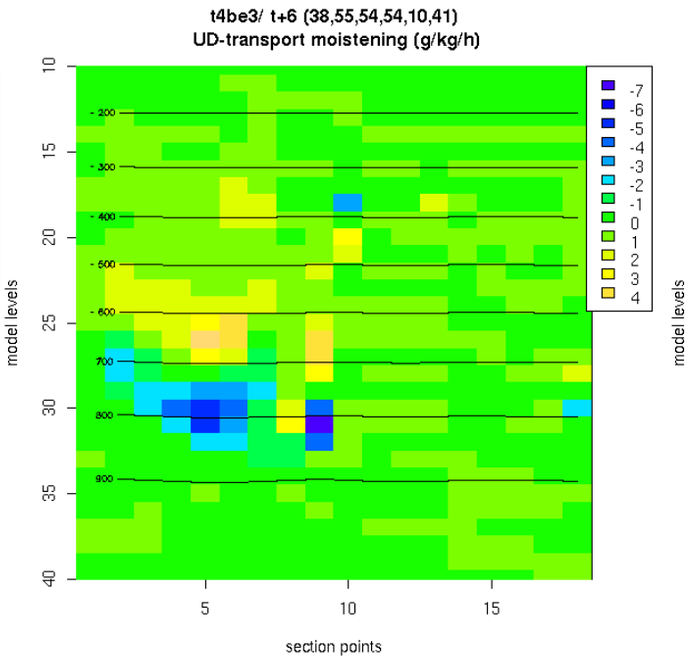
AEGNUM 4km

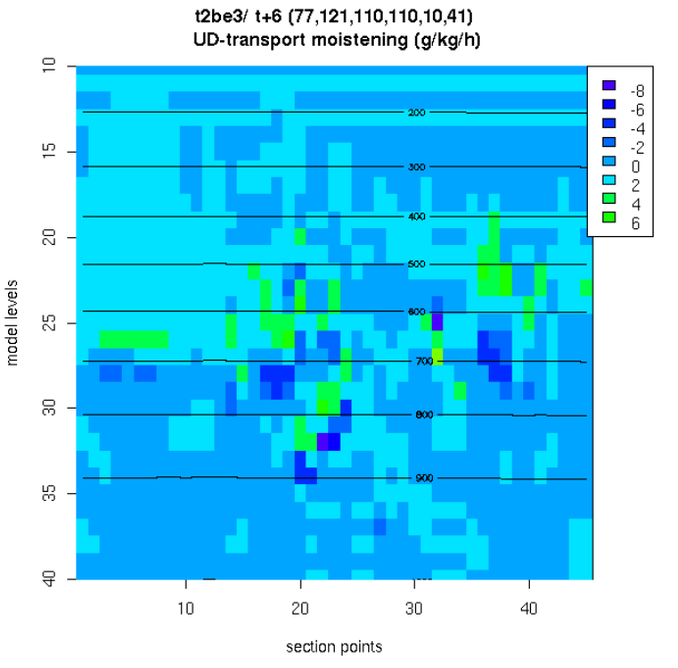
AEGNUM 2km

Behaviour comparison

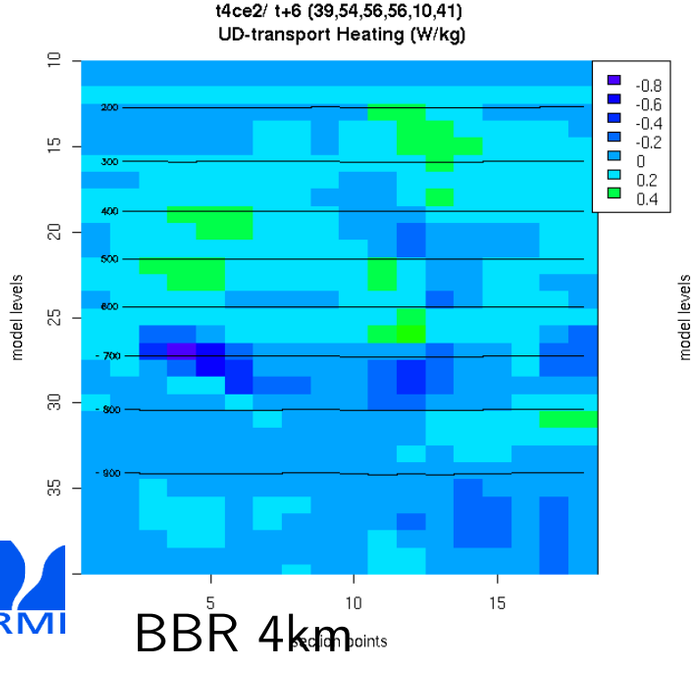
transp. Moistening

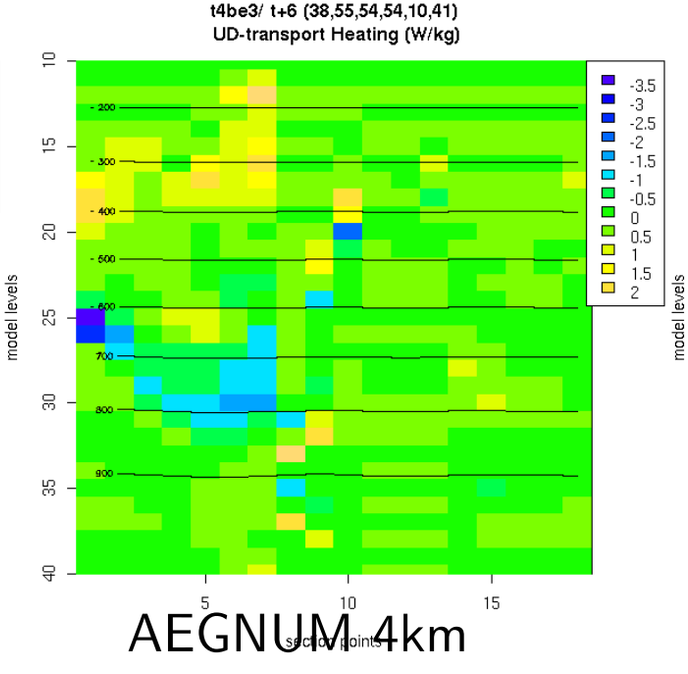


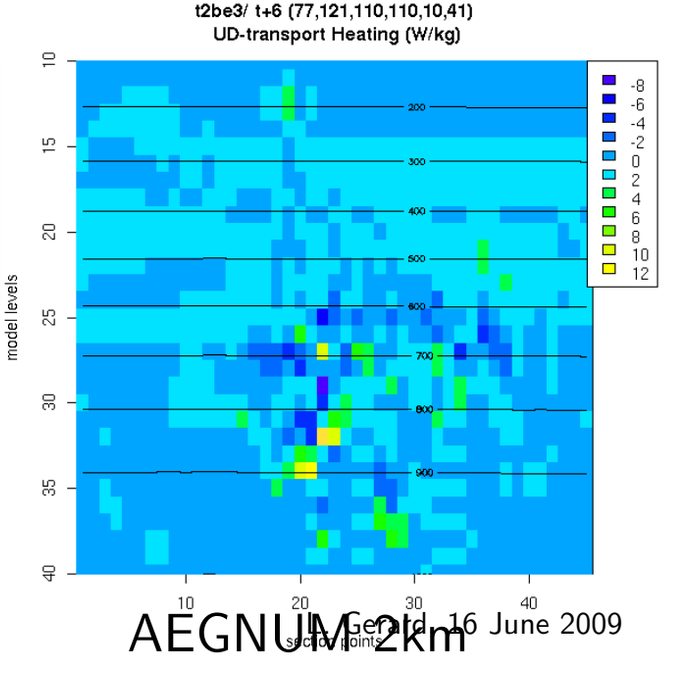




transp. Heating







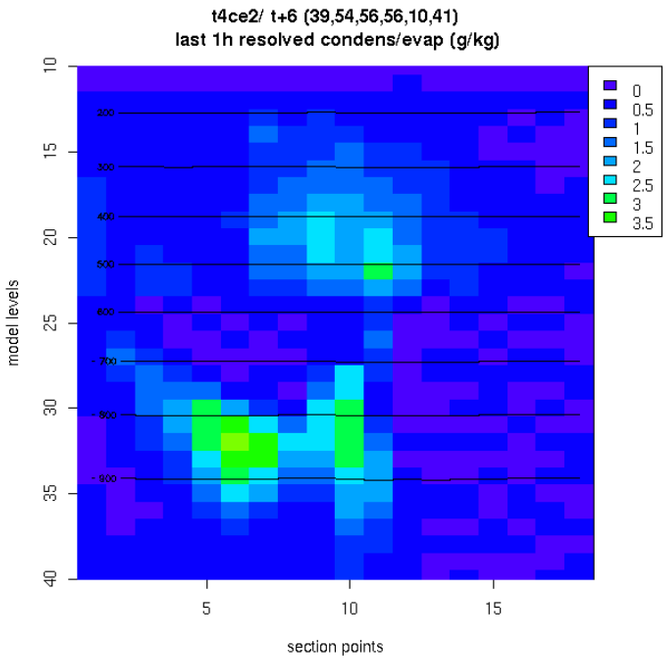
BBR 4km

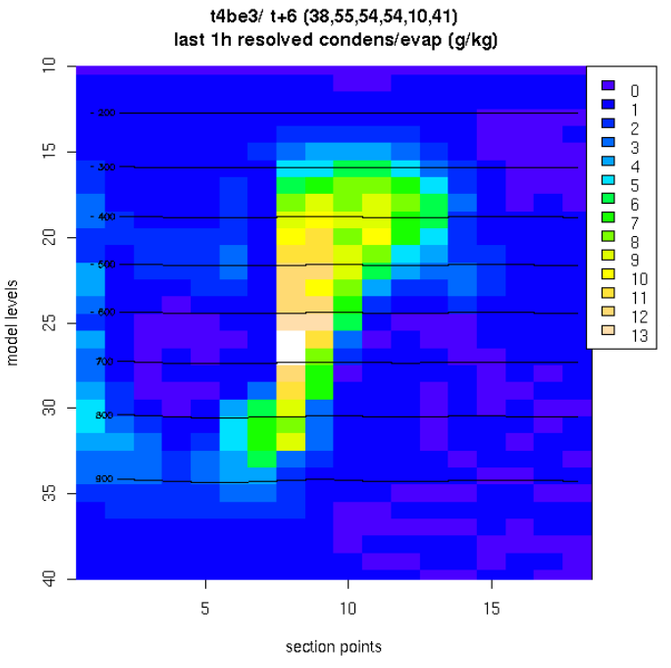
AEGNUM 4km

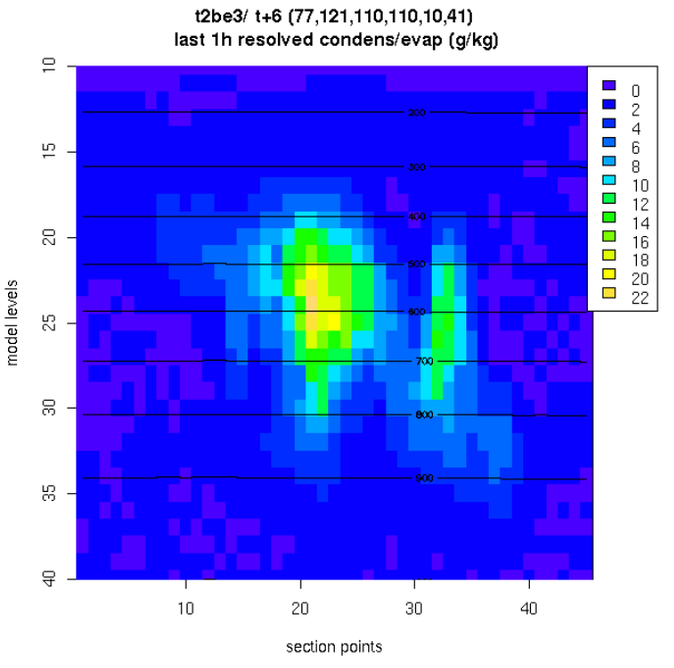
AEGNUM 2km

Behaviour comparison

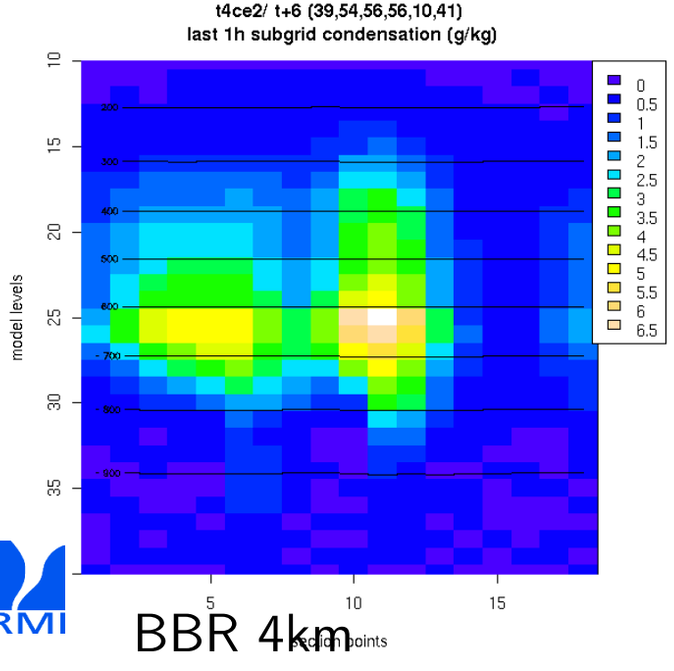
Resolved cond

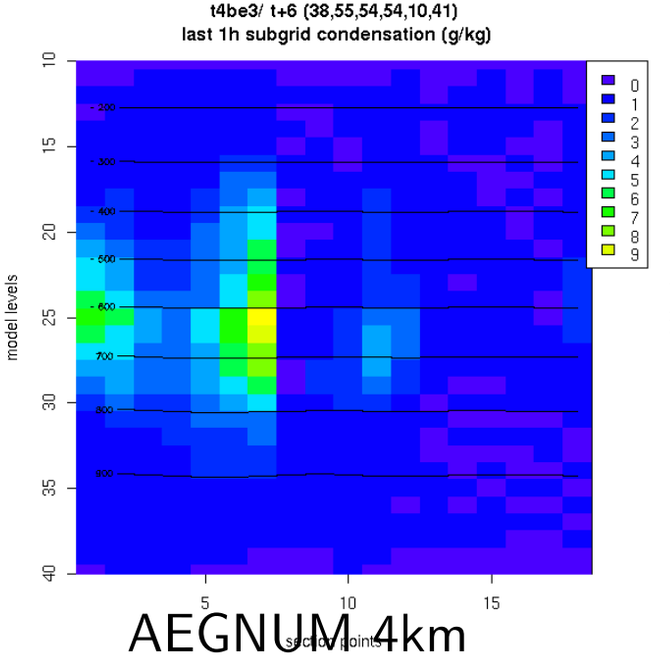


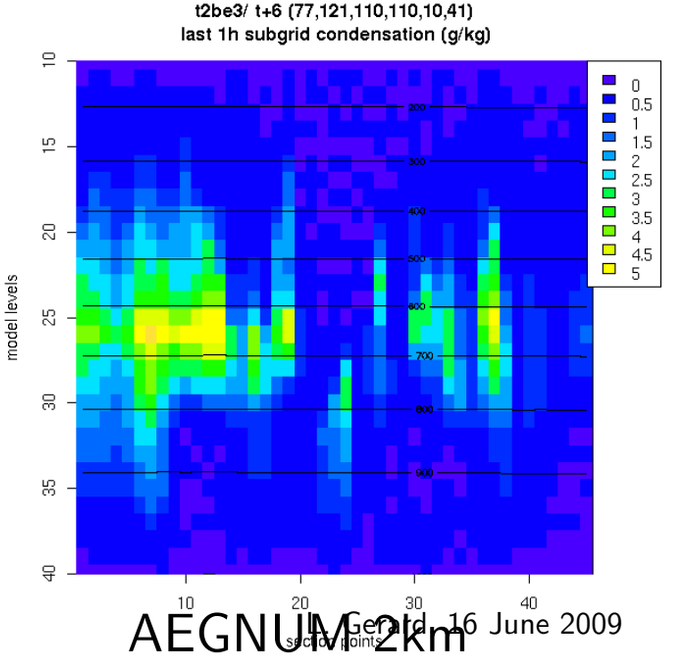




Subgrid cond.







BBR 4km

AEGNUM 4km

AEGNUM 2km

Synthesis

- Prognostic mixing produces consistent behaviour
- 3MT's simple representation still performant and yields consistent precipitation fields at 4km.
- AEGNUM method appears to make possible convergence towards resolved convection
  - Consistent forecasts at 8, 4 and 2km(NH) resolutions
  - The subgrid part gives a hand to the resolved scheme in transient phases, and both schemes appear to take over.
  - Also at 2km resolution and below, the subgrid scheme might be useful in the transient phases, eventhough the mature phases are completely resolved.
- The consistency of the forecasts with completely different ratio of subgrid to resolved precipitation supports the earlier results of 3MT.