HYMACS, a hybrid mass flux convection scheme for use in non-hydrostatic NWP models as COSMO

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Motivation:

convection $\longrightarrow$ heavy precipitation, lightning, gusts, hail, ...
usually on subgrid scale $\longrightarrow$ parameterize $\longrightarrow$ e.g. mass flux schemes

class. mass flux schemes: no net mass transport

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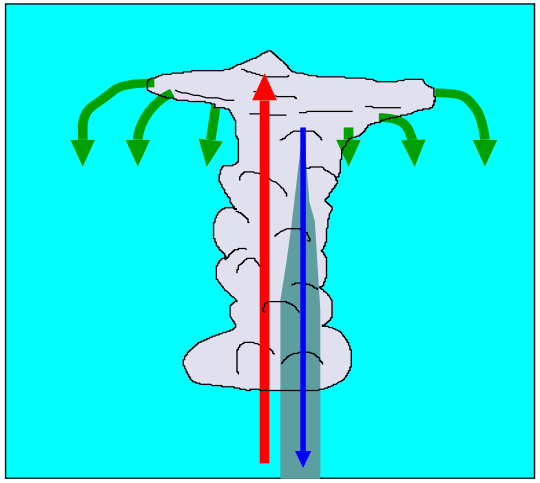

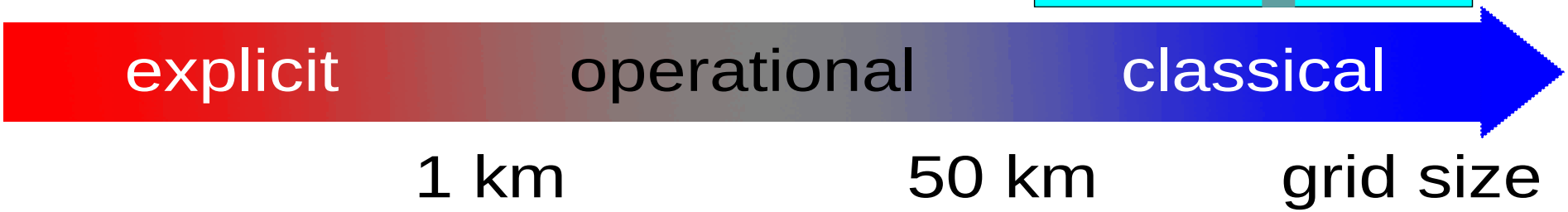

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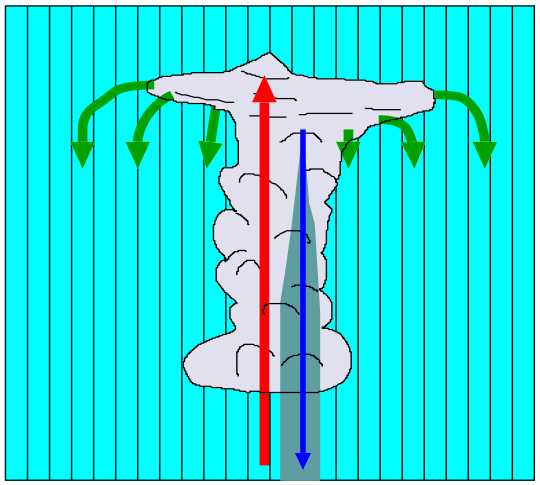

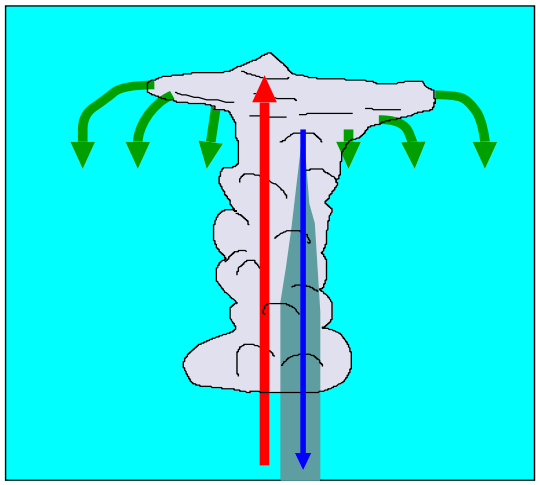

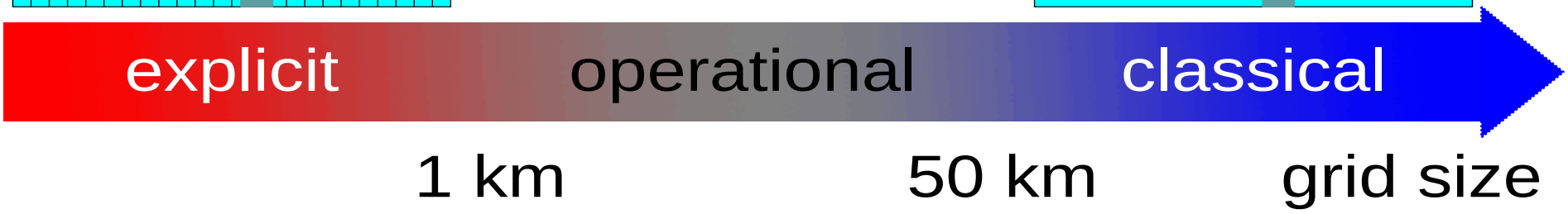

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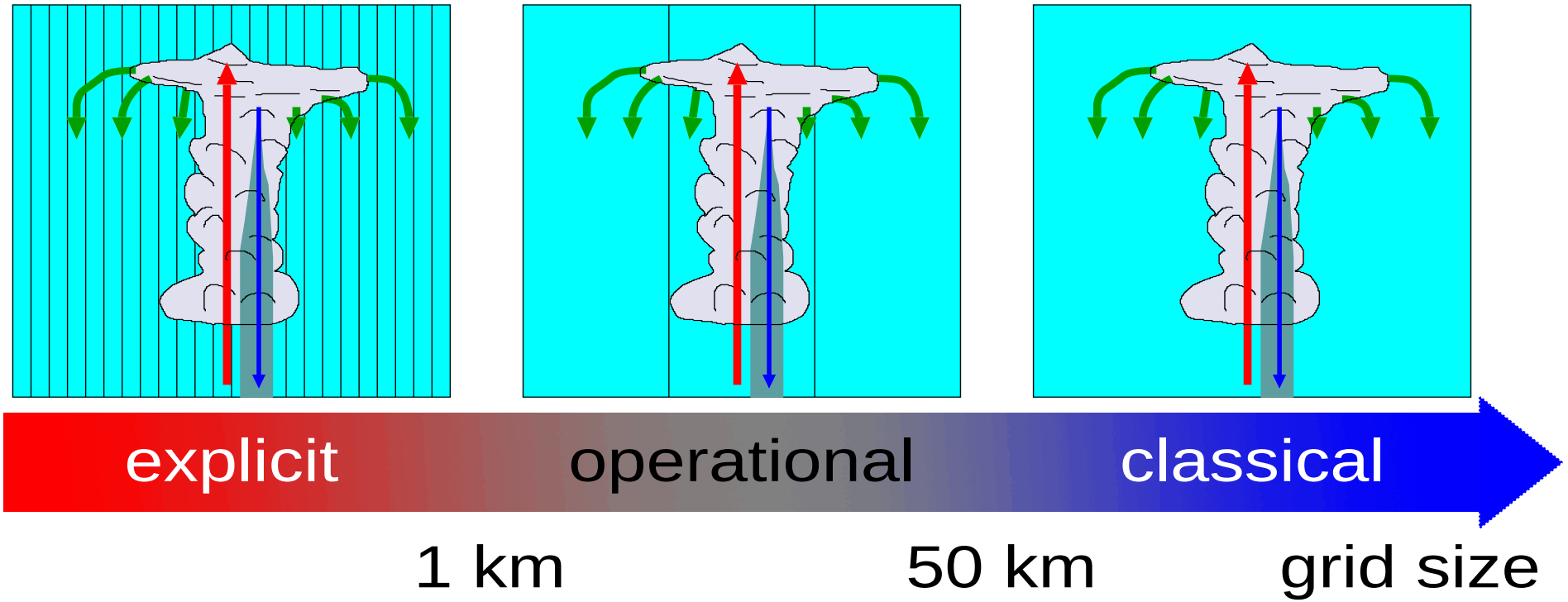


HYMACS (hybrid mass flux convection scheme)

- hybrid: parameterize up- / downdraft only (subgrid scale scheme)
  large scale subsidence grid scale NWP model

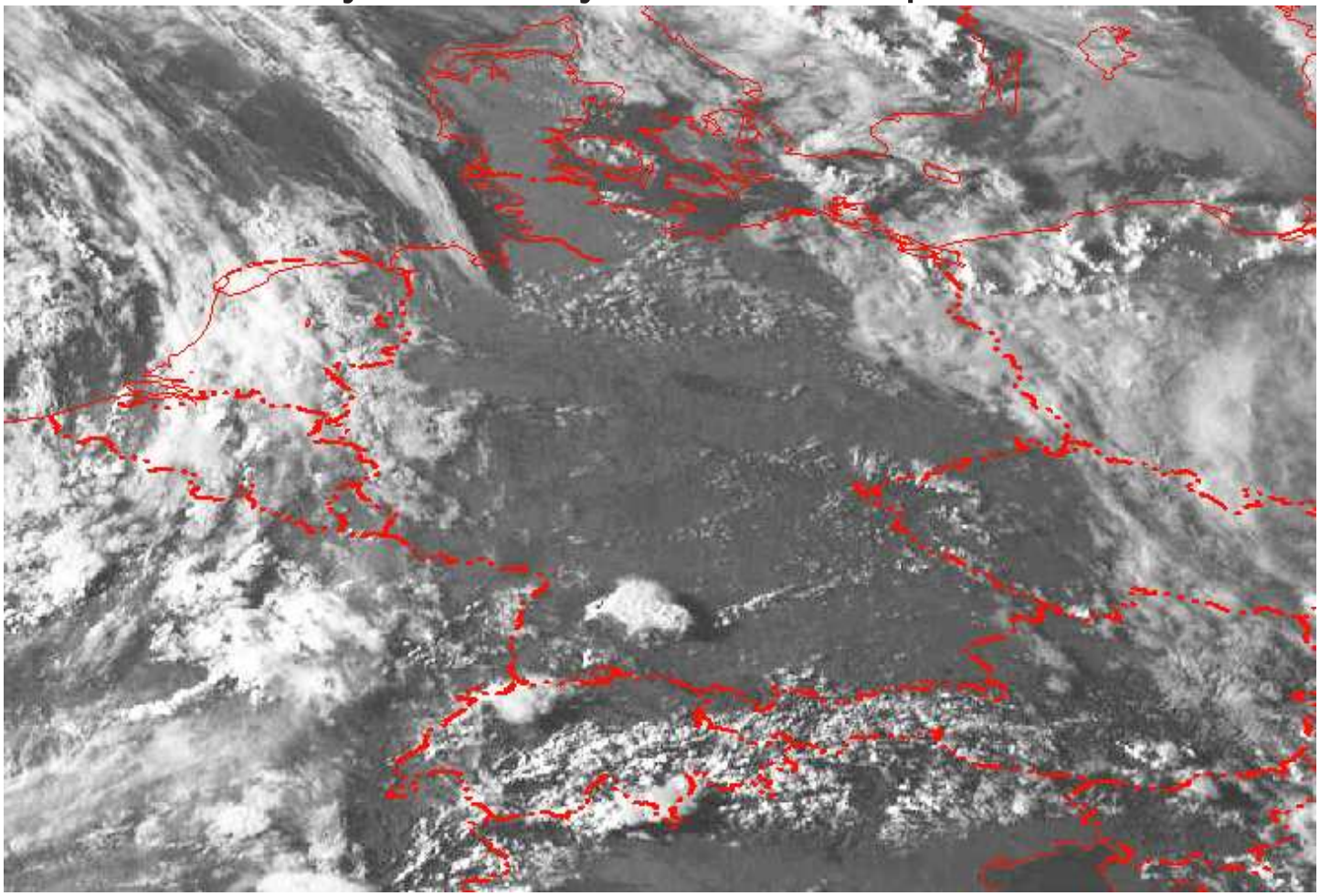
$\longrightarrow$ net mass transport by parameterization scheme

- applicable to wider range of grid sizes of hosting NWP model
- more realistic dynamics and distribution of precip.

- simple cloud model (up- / downdraft, precip., incl. ice phase)
- trigger: adopted from Fritsch and Chappell (1980), Kain (2004)
  and contribution from subcloud TKE
- closure: horiz. mass flux convergence

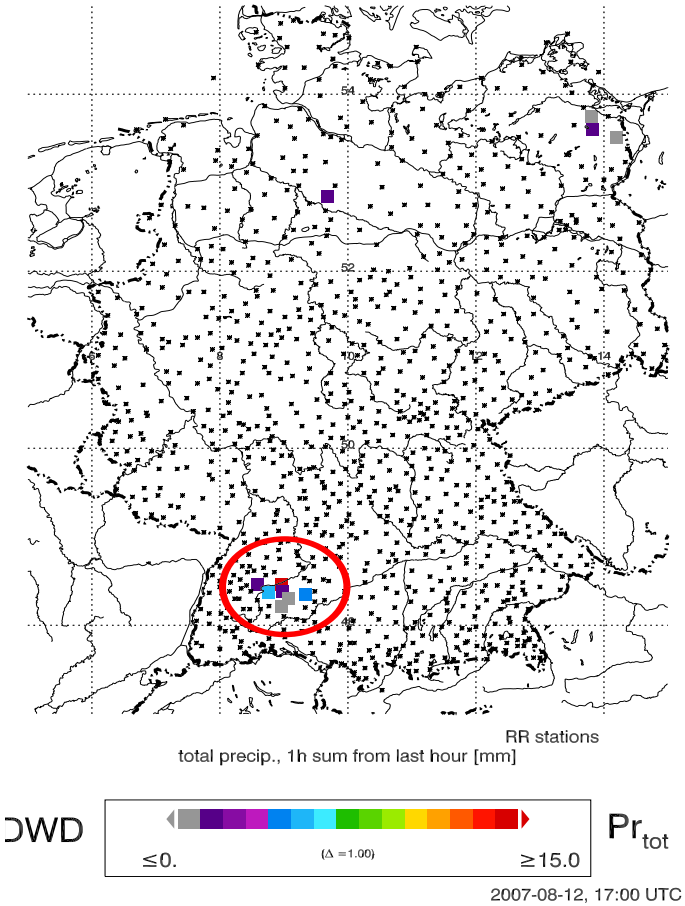
real case: 12.8.2007, air mass convection (day), cold front (night)

free forecasts, COSMO model, V4.6 (DWD)
Δx=7 km, Δt=40s, convection scheme called every 10min
init. at 6:00 UTC + hourly boundary data from op. COSMO–EU analyses

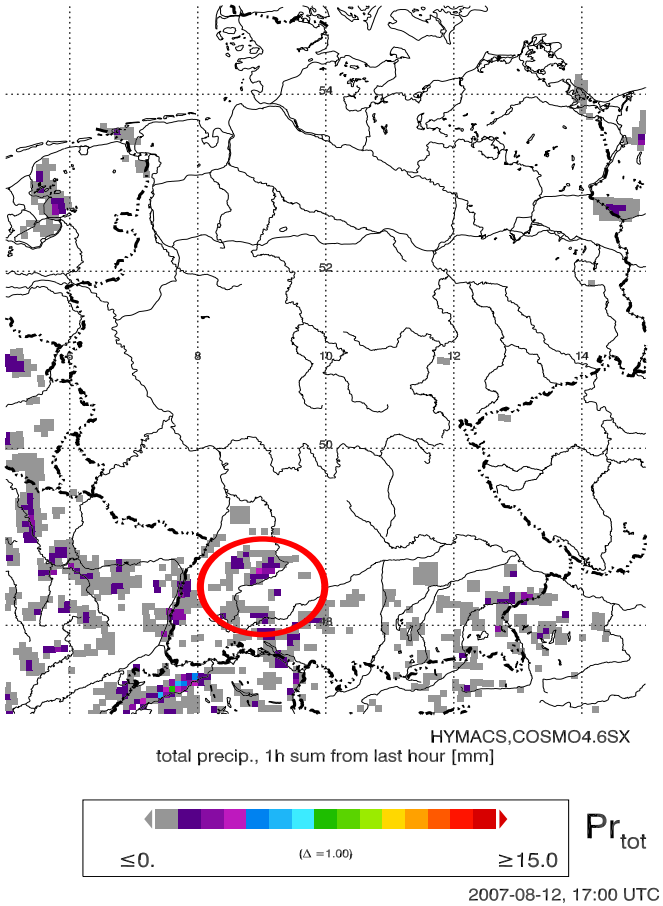


(MSG rapid scan, 12.8.2007, 17:00 UTC)

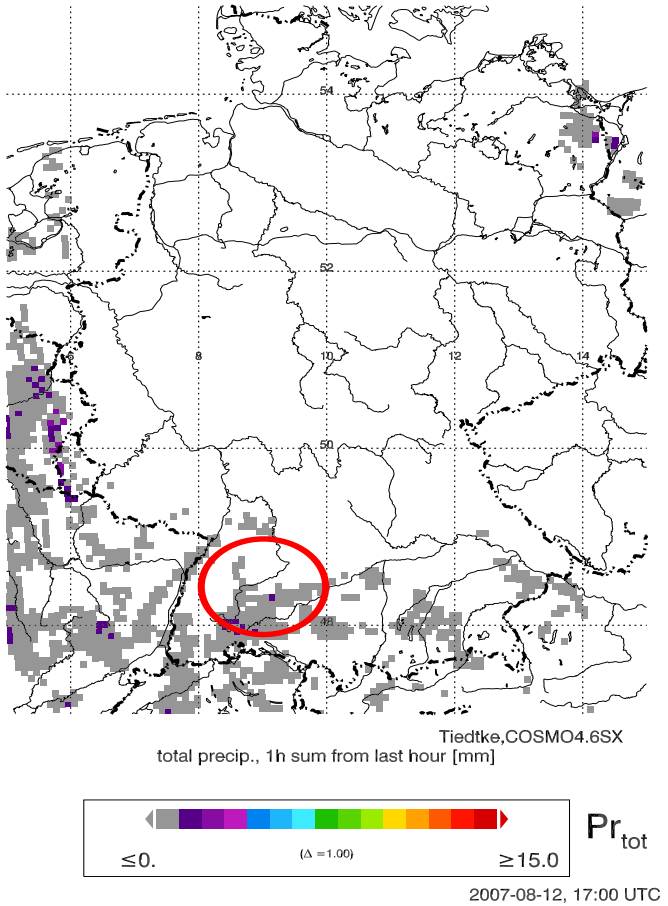
12.8.2007, 17:00 UTC: air mass convection



rain gauges
(DWD network)



COSMO 4.6
HYMACS



COSMO 4.6
Tiedtke

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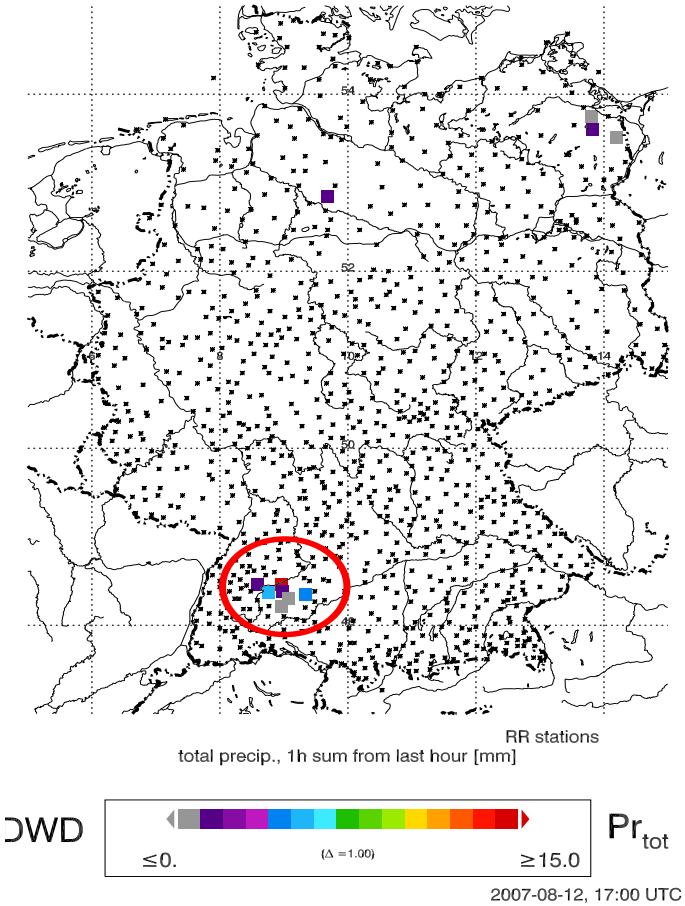

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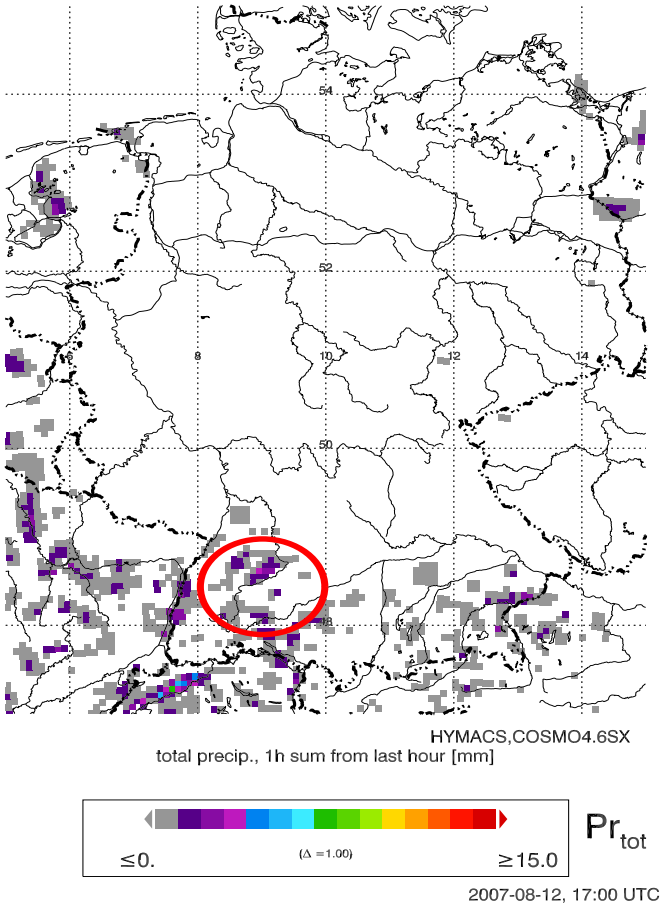

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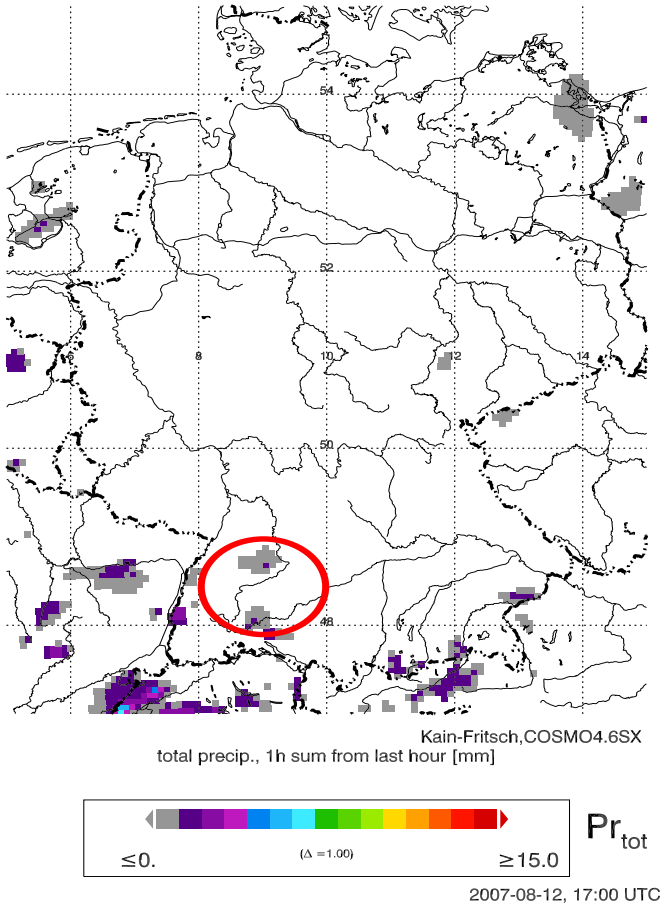
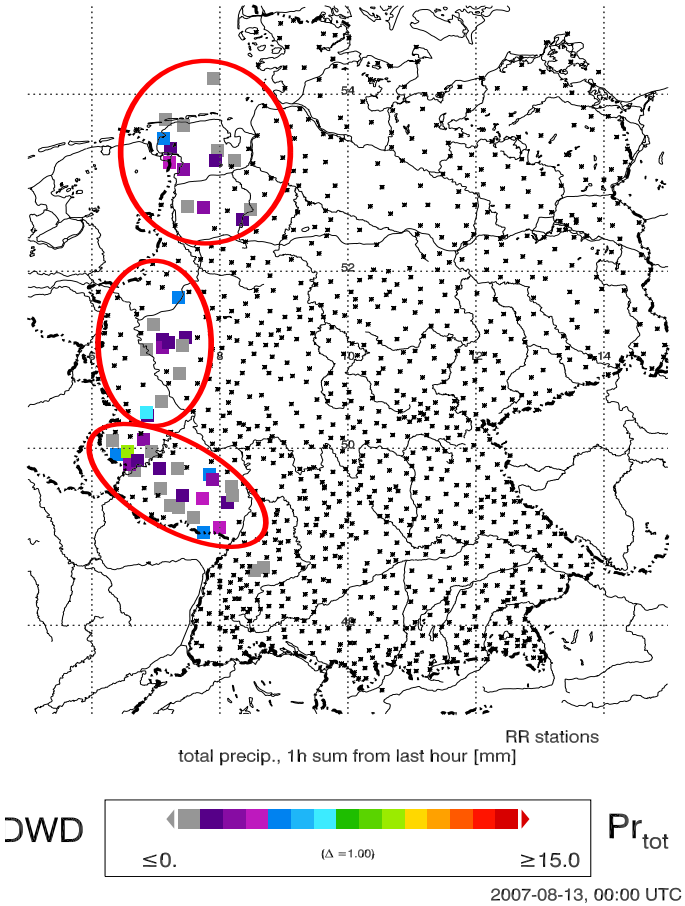


COSMO 4.6
Kain-Fritsch

13.8.2007, 0:00 UTC: cold front



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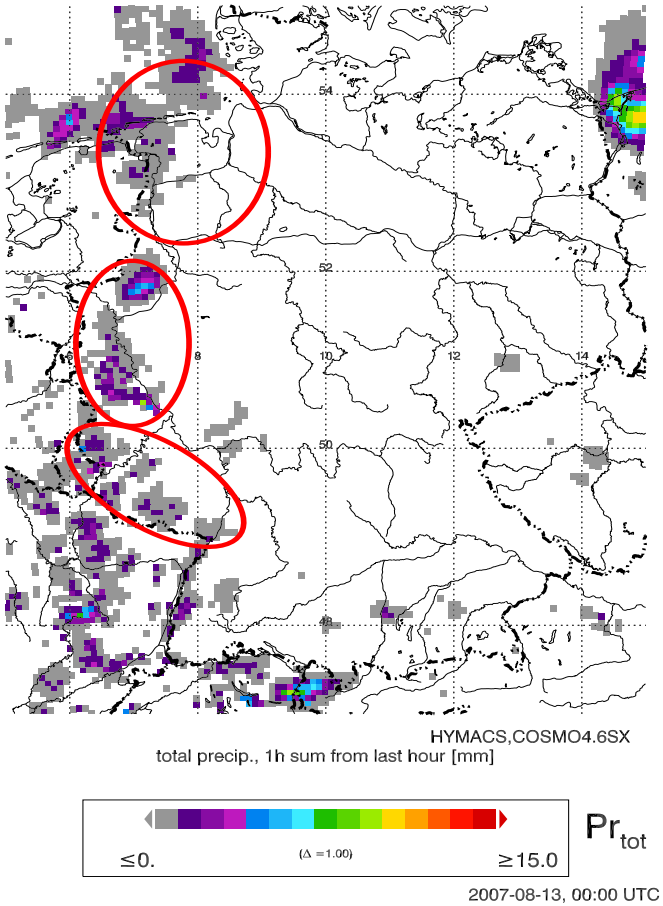

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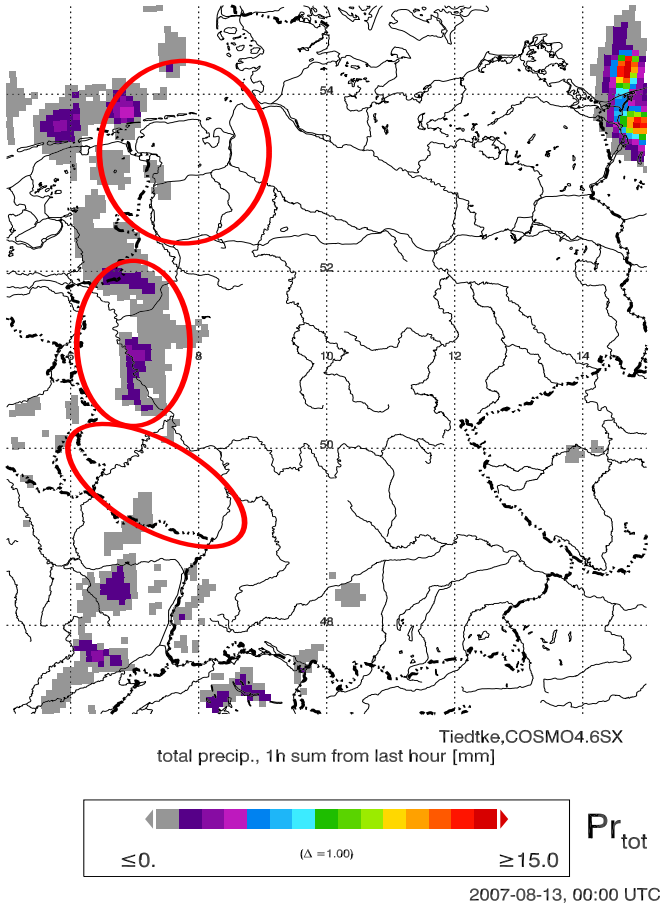

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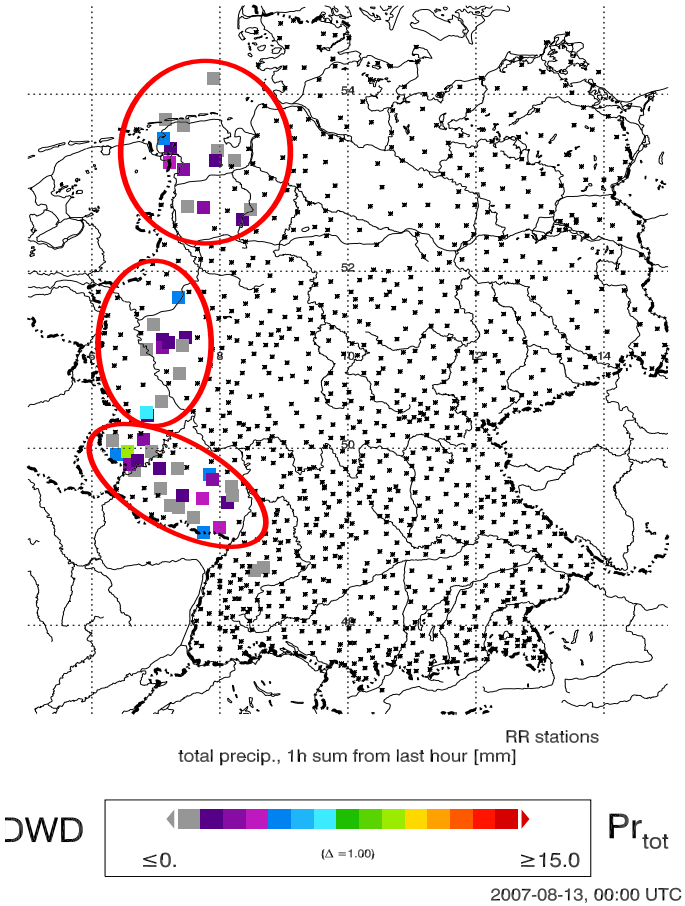

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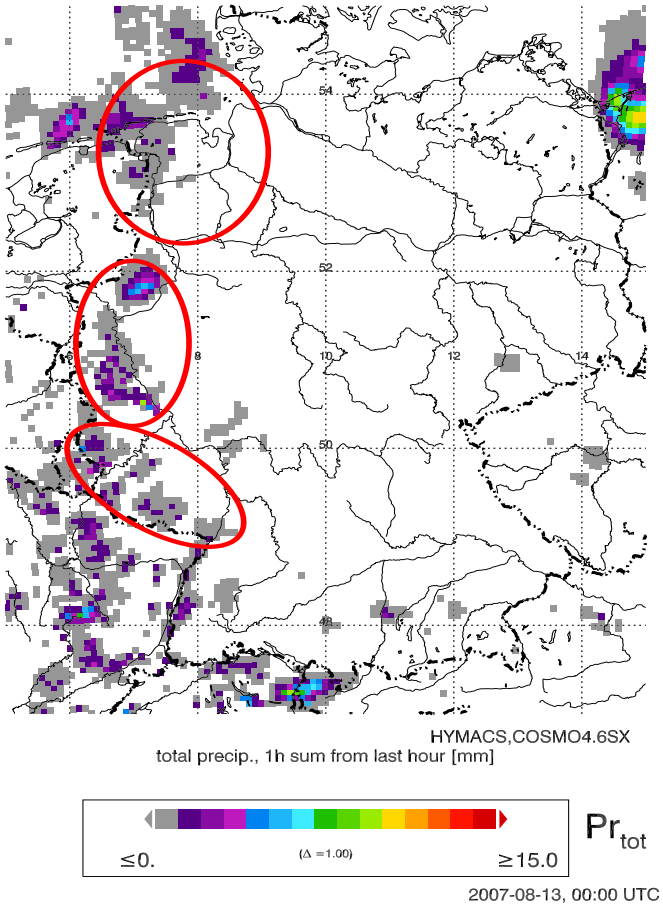

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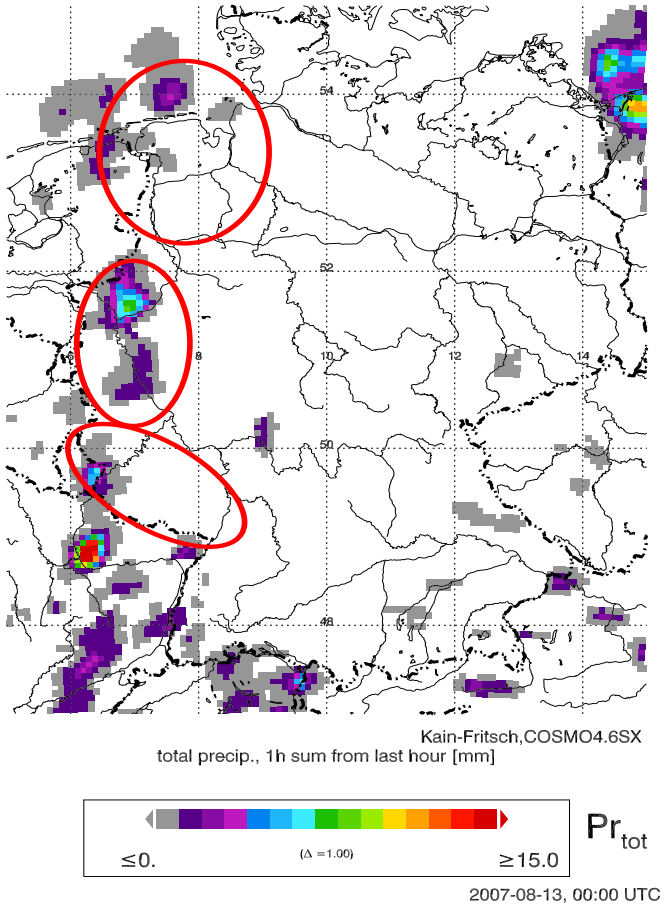
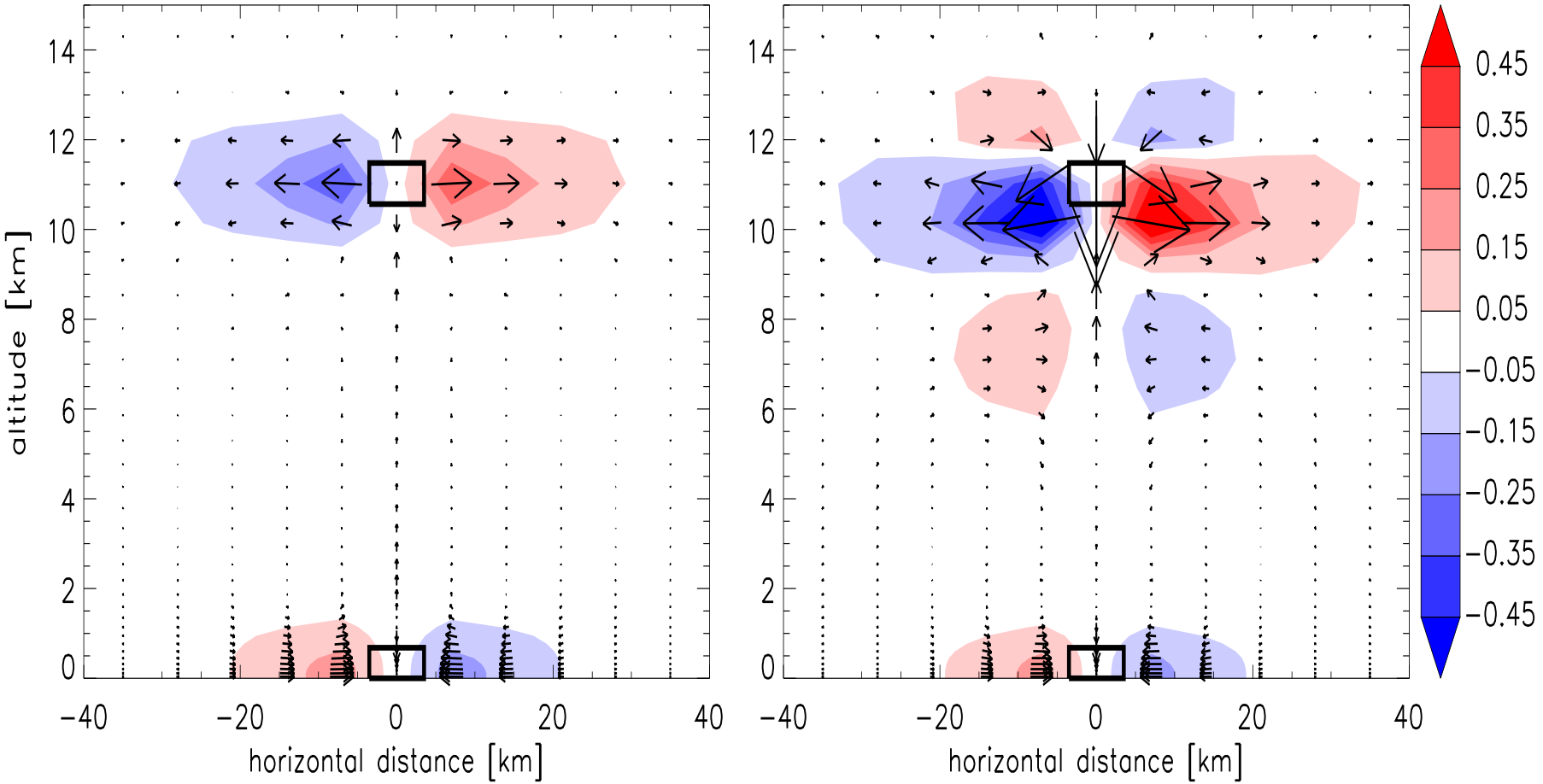


COSMO 4.6
Kain-Fritsch

subgrid scale mass transport:

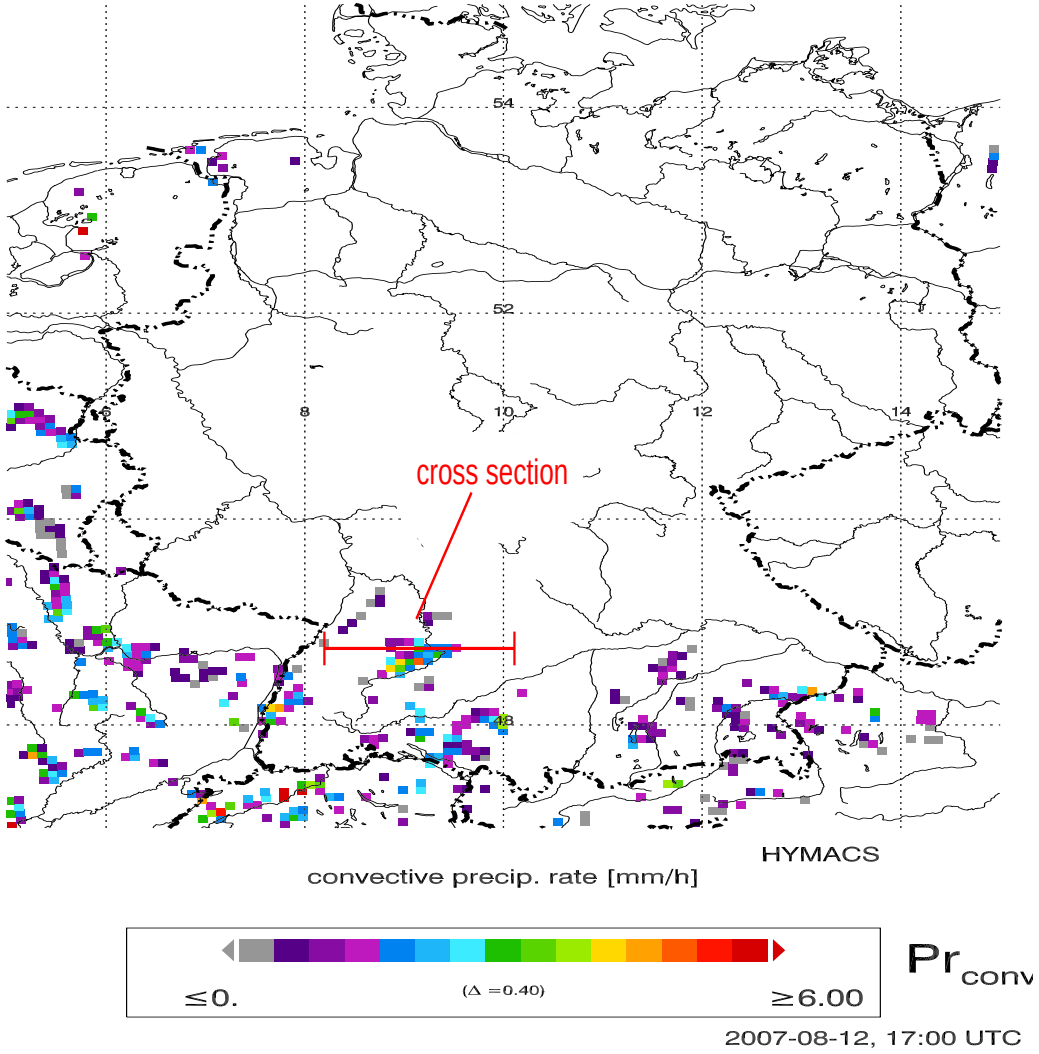
idealized conv. transp. in single grid column



transport of mass only

transp. of mass, heat, moisture

12.8.2007, 17:00 UTC (air mass convection)



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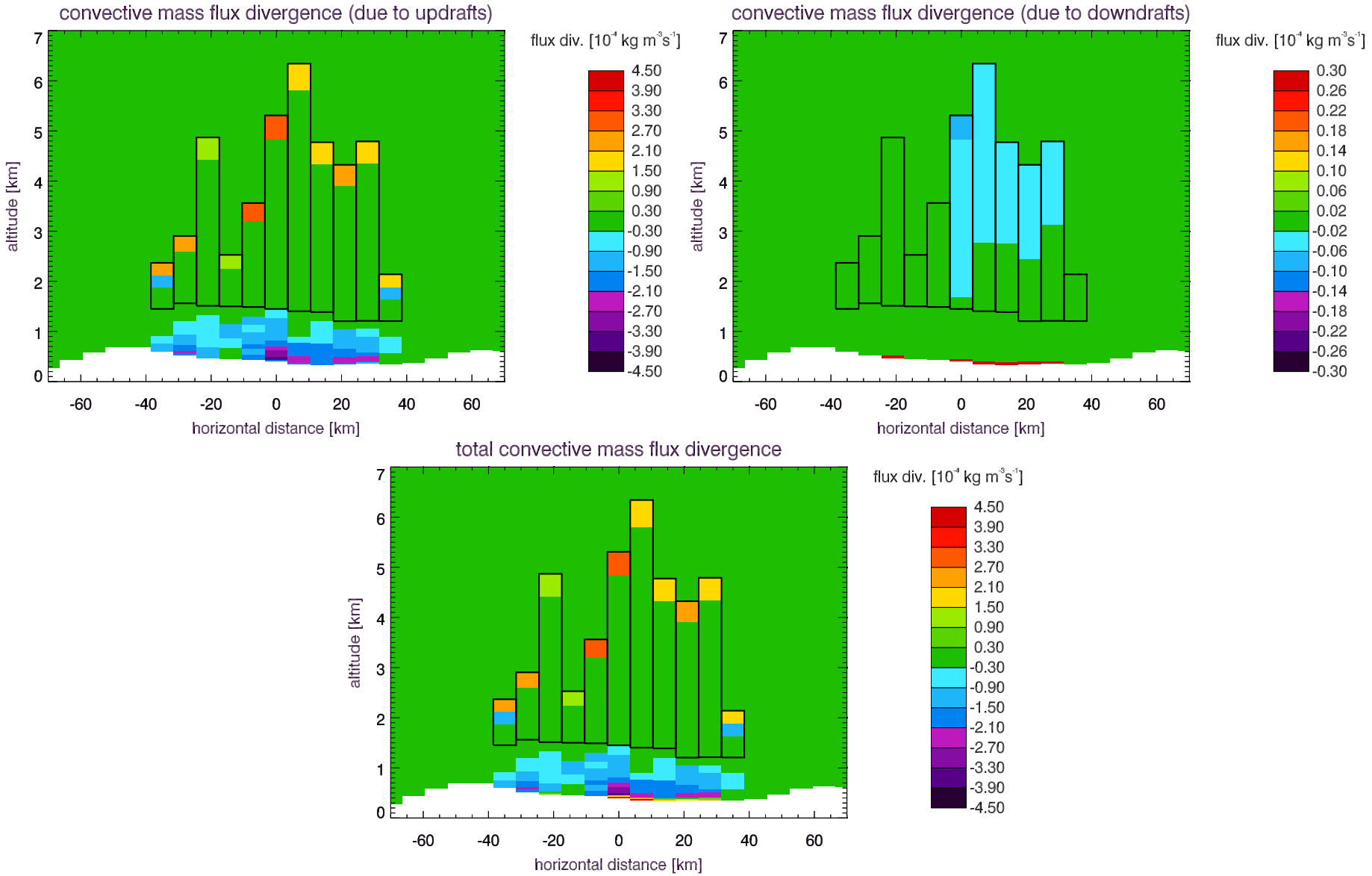
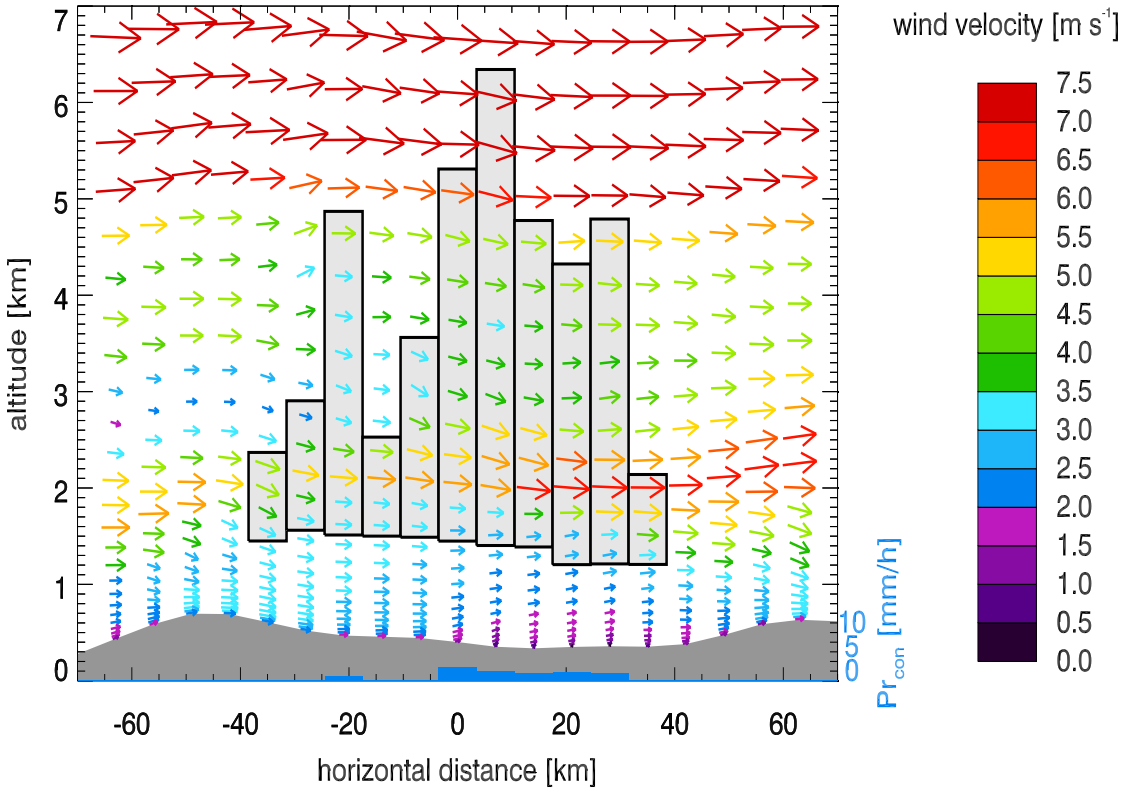
mass exchange between HYMACS and COSMO:



12.8.2007, 17:00 UTC (air mass convection)

wind field across convective cluster ...



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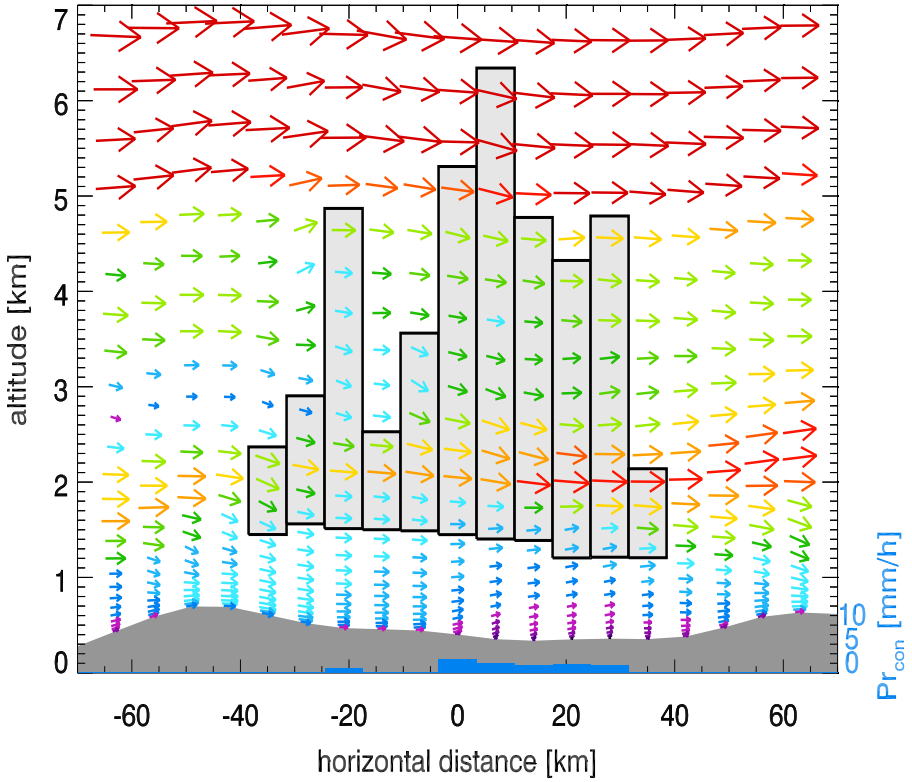
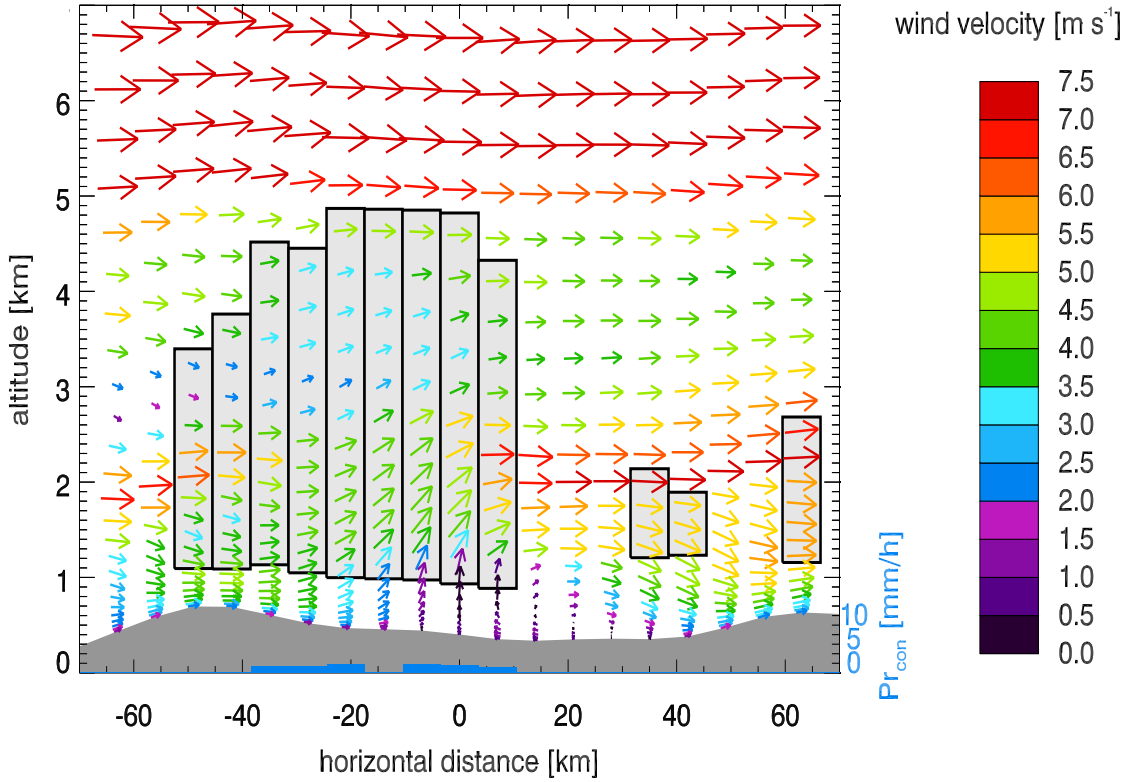


HYMACS



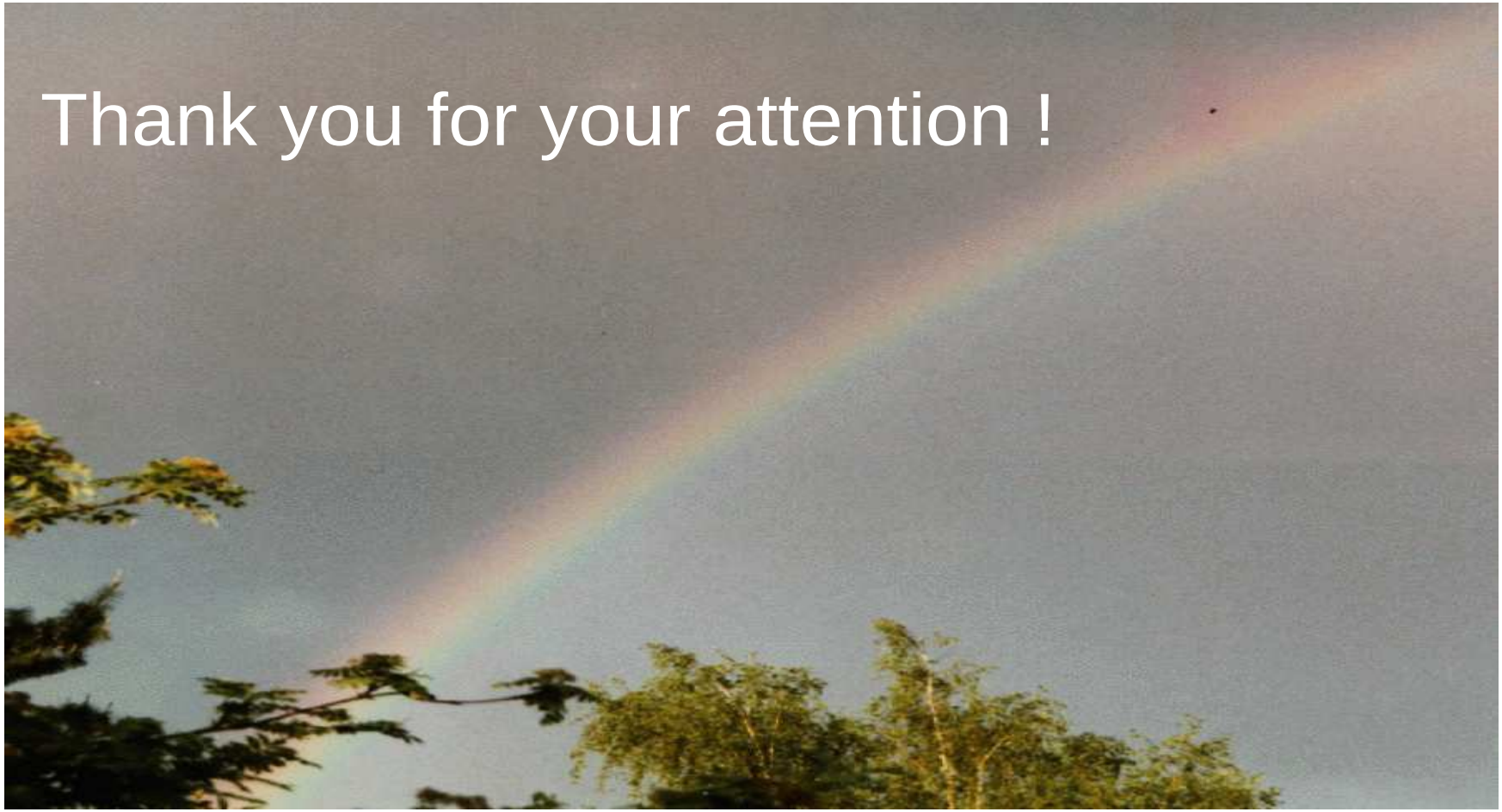
Kain-Fritsch

Summary:

HYMACS - rain gauges / classical conv. schemes
$\longrightarrow$ realistic spatial distribution of precipitation

$\longrightarrow$ realistic dynamics in environment of conv. cells
$\longrightarrow$ suppression of grid scale convection

tuning of cloud model / trigger
$\longrightarrow$ absolute precipitation amounts



Publications:

- Kuell, V., and A. Bott, 2008:
  A hybrid convection scheme for use in non-hydrostatic numerical weather prediction models,
  Meteorol. Z., 17, 775-783.
- Kuell, V., A. Gassmann and A. Bott, 2007:
  Towards a new hybrid cumulus parameterization scheme for use in non-hydrostatic weather prediction models,
  Q. J. R. Meteorol. Soc., 133, 479-490.

convection scheme:

subgrid scale transport of mass, heat, moisture + ...

- cloud model (up–/downdraft, precip., incl. ice phase)
- trigger: analoguously to Fritsch and Chappell (1980), Kain (2004):
  at LCL: $\Delta T^u_{v,FC} = \sqrt[3]{\gamma(\bar{w} - w^*)}$ with w^* as threshold
  and: $\Delta T^u_{v,TKE} = T^* \sqrt[3]{v_{TKE}} - T_0$ with $v_{TKE} = \sqrt{2\,\overline{TKE}}$
  LFC reached / CIN overcome ?

- closure: at first moisture convergence closure (Tiedtke, 1989)
  $\longrightarrow$ several cases with too weak stabilization $\longrightarrow$ grid scale convection
  $\longrightarrow$ better: horiz. mass flux convergence closure
  $M^u_{LCL} = (\Delta x)^2 \int\limits_{USL} \nabla_h \cdot (\rho \mathbf{v}_h) dz$

$\longrightarrow$ effective suppression of grid scale convection