

A hybrid and nonlocal convection parameterization scheme for the LM

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LM User Seminar, BTZ Langen, 5.-7.3.2007



Motivation:

convection crucial for **redistribution** of heat, moisture, and **mass**

→ precipitation forecast...

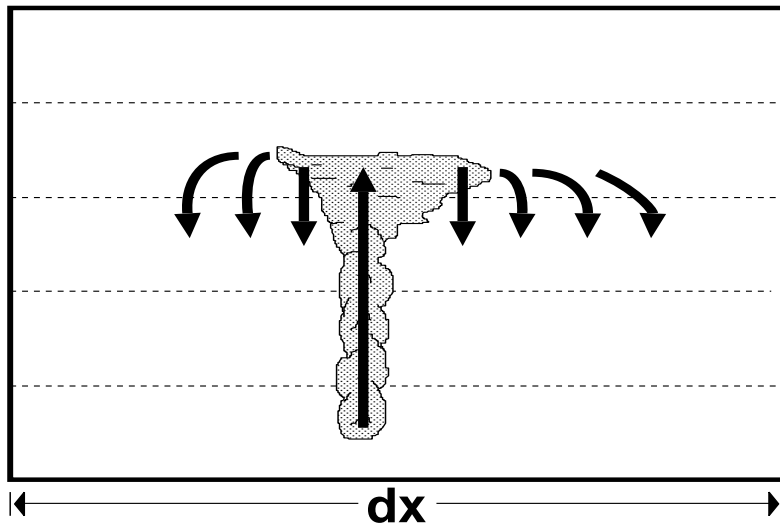
convection usually parameterized

→ mass flux schemes (**but no direct mass transport!**)

classical schemes

grid size $> 20\text{...}50$ km:

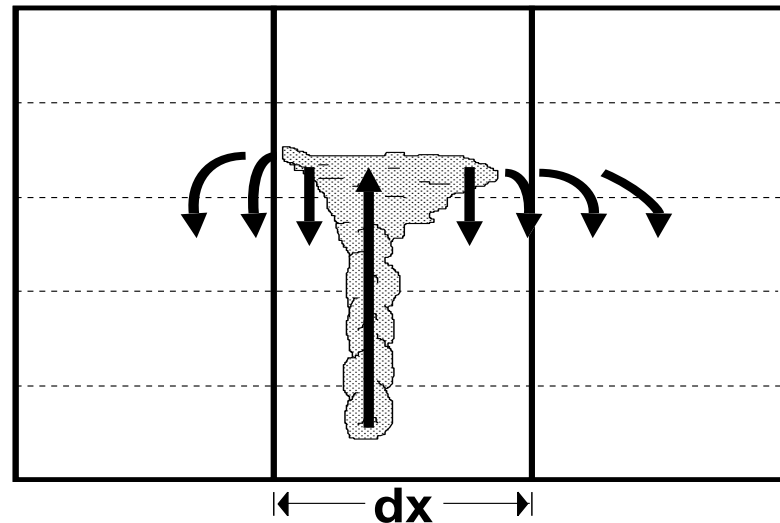
conv. **entirely subgrid scale**



new scheme

grid size $\approx 1\text{...}20$ km:

convection **partially resolvable**



Hybrid scheme:

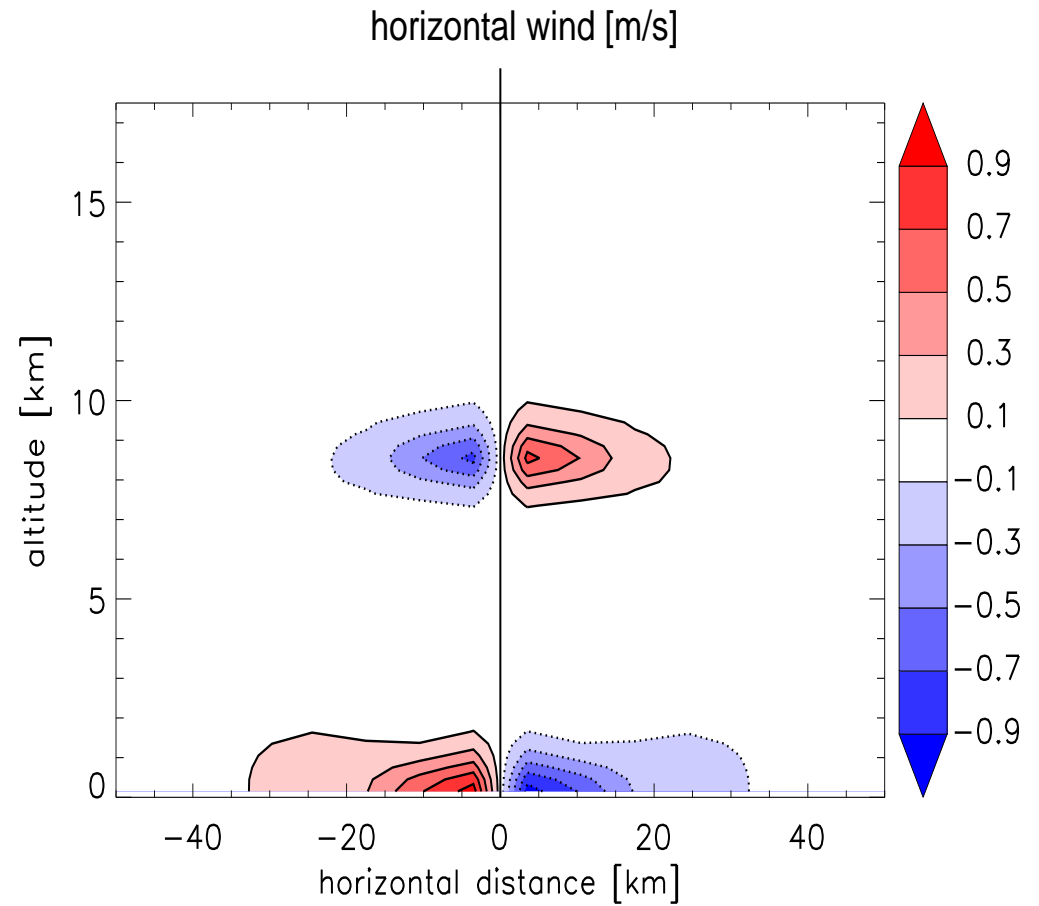
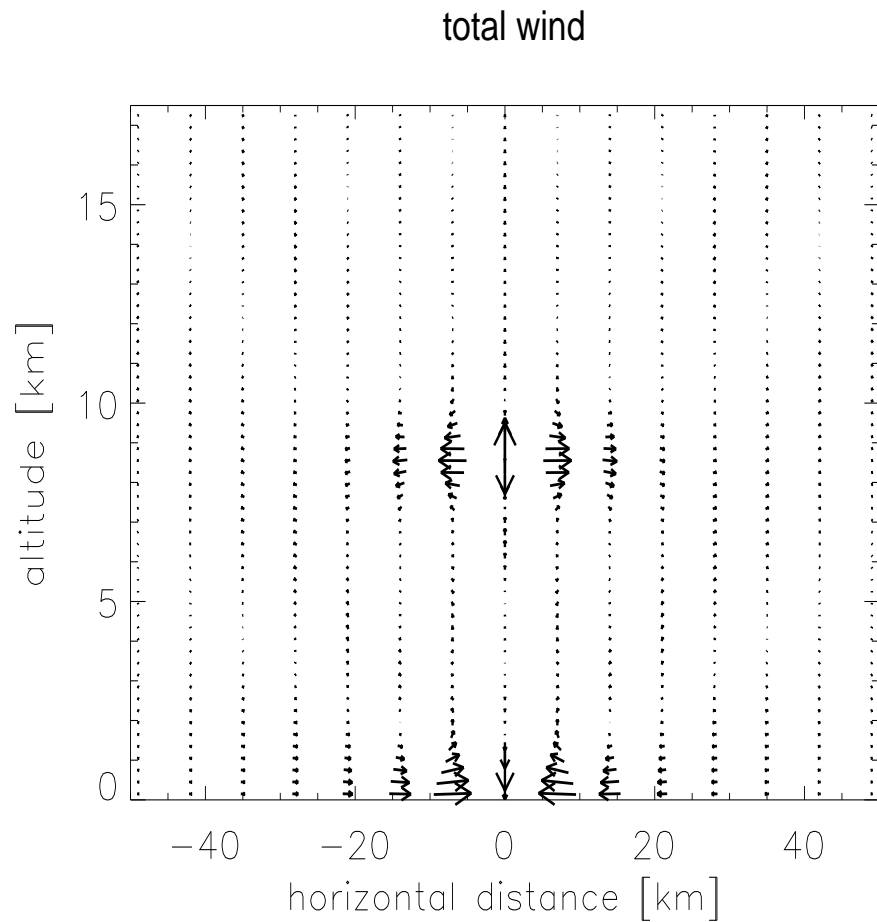
- parameterize up/downdraft (**subgrid scheme**)
environmental subsidence by **grid scale equations**
→ also influences neighboring grid boxes; non-local scheme
- *net* mass transport by parameterization scheme
- split mass flux into **grid scale** and **subgrid scale** contribution:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \mathbf{v}) + \nabla \cdot \mathbf{J}_m = 0$$

- treat convective moisture and heat fluxes analogously...
- more realistic dynamics, independence on grid size of hosting model

Subgrid scale mass transport:

LM, $\Delta x=7$ km, dry **subgrid scale mass transport** in single grid column
(detrainment at environmental temperature)



Overview of the work progress:

model:

subgrid scale mass transport scheme + ...

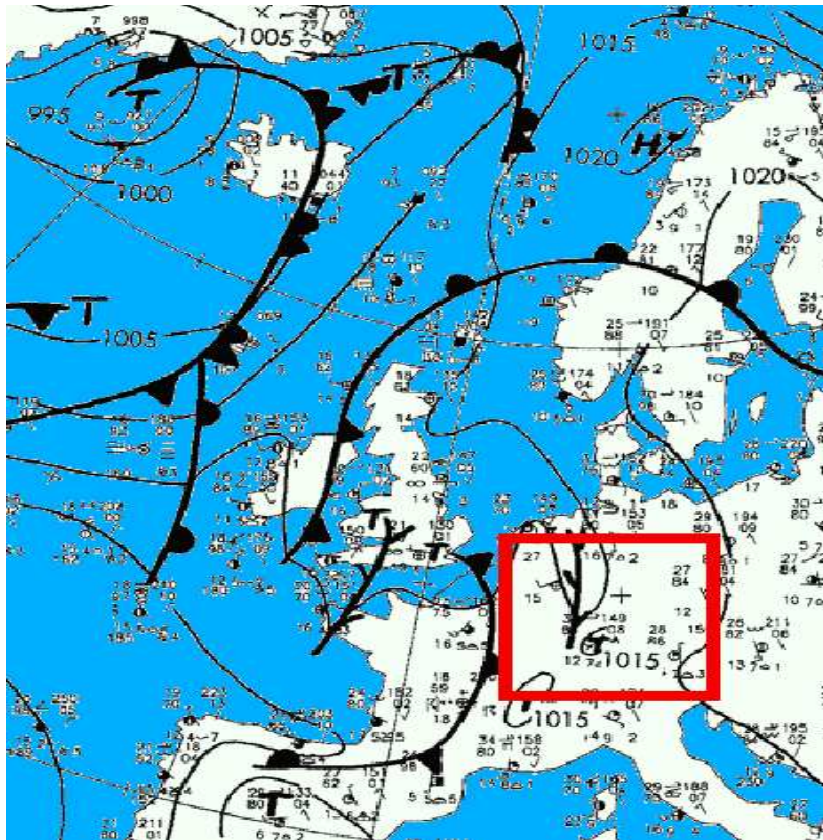
- cloud model and full moist thermodynamics
- trigger: Fritsch-Chappell type and **gustfront parameterization**
 - cell motion
- closure: moisture convergence closure (Tiedtke)
 - changed to **horiz. mass flux convergence closure**

simulations:

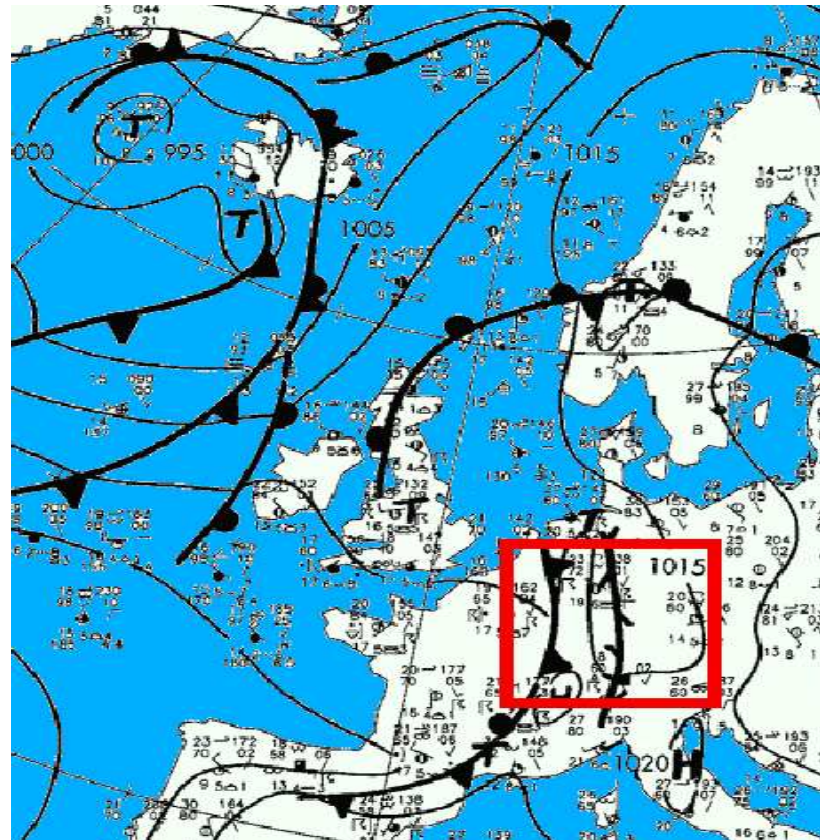
- idealized single column experiments
- idealized sea-breeze simulation
- simulation of **real cases**

Real case:

5.7.2006, convergence line and cold front → convective activity in the afternoon
LM (V3.19) 80×80 grid points, $\Delta x=7\text{km}$, 35 levels, $\Delta t=40\text{s}$, $\Delta t_{conv}=10\text{min}$

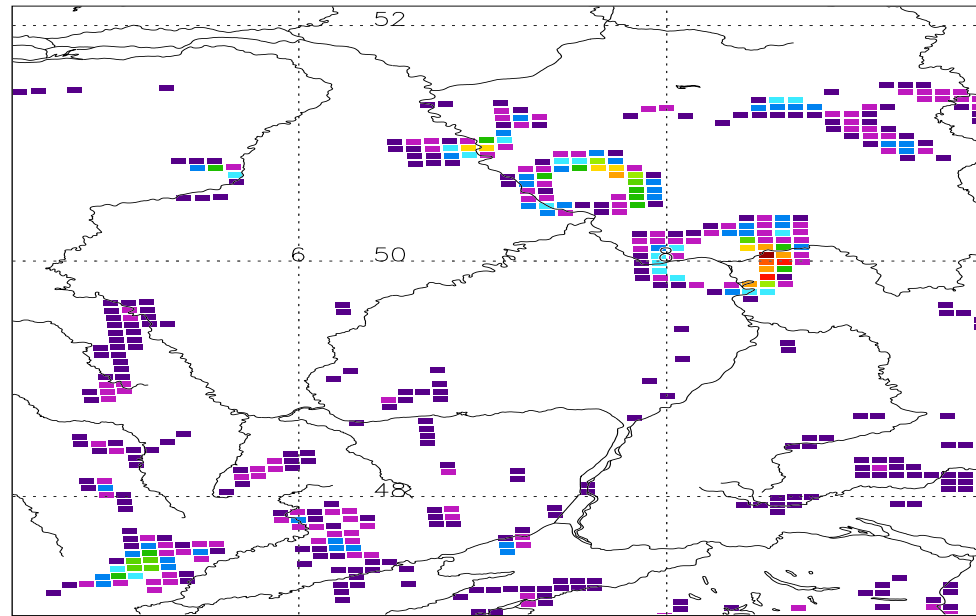


DWD analyses: 5.7.06, 12:00 GMT

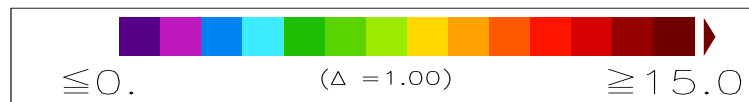


5.7.06, 18:00 GMT

Hybrid scheme, but moisture convergence closure:



conv. precip. rate [mm/h]



Pr_{conv}

5.7.06, 14:20:00 GMT

- subgrid convection too weak for sufficient stabilization
- strong grid scale convection in cluster core
- strong surface cooling stops subgrid conv. from inside outwards
- bubble pattern in convective precip.

Horizontal mass flux convergence closure and Fritsch-Chappel trigger:

MC closure: $M_{LCL}^u = (\Delta x)^2 \int_{surf}^{LCL} \nabla_{\mathbf{h}} \cdot (\rho \mathbf{v}_{\mathbf{h}}) d\mathbf{z}$

FC trigger: $\Delta T = \sqrt[3]{\gamma \bar{w}}$

→ start convection, where parcel with $\bar{T} + \Delta T$ can reach LFC,
i.e. where \bar{w} becomes critical

→ avoid grid scale updrafts by fast subgrid scale mass transp.

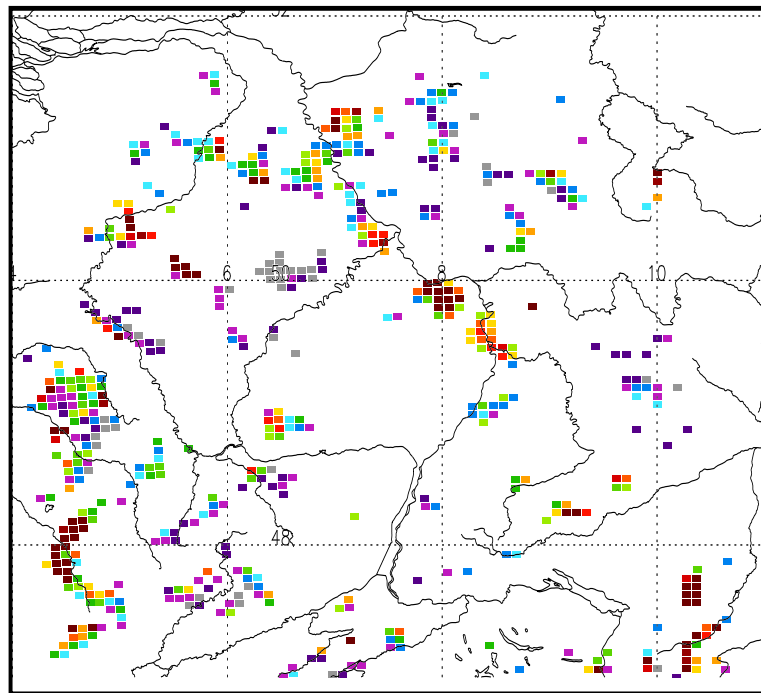
→ **suppression of grid scale convection by anticipating stabilization**

...actual purpose of a convection scheme !

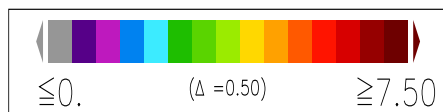
Comparison of convective precipitation:

model init.: 11:00 GMT, free run with hourly boundary data from DWD analyses

hybrid scheme

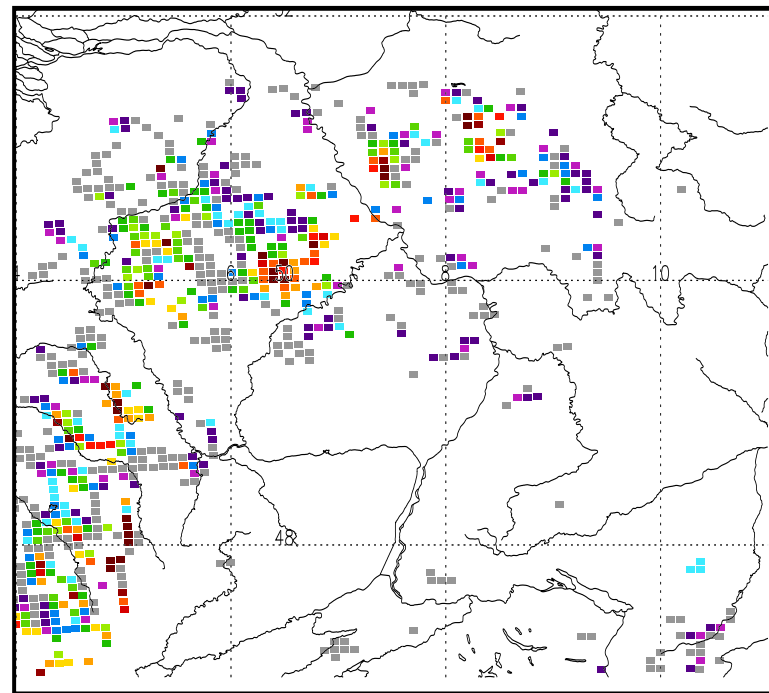


conv. precip. rate [mm/h]

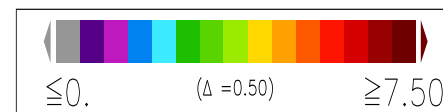


Pr_{conv}
5.7.06, 13:00:00 GMT

Tiedtke

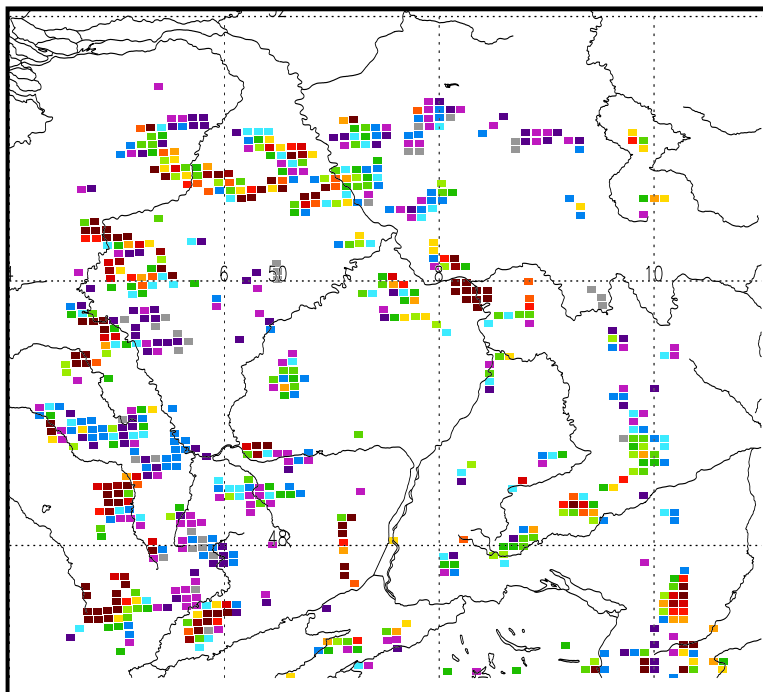


conv. precip. rate [mm/h]

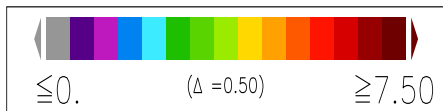


Pr_{conv}
5.7.06, 13:00:00 GMT

hybrid scheme

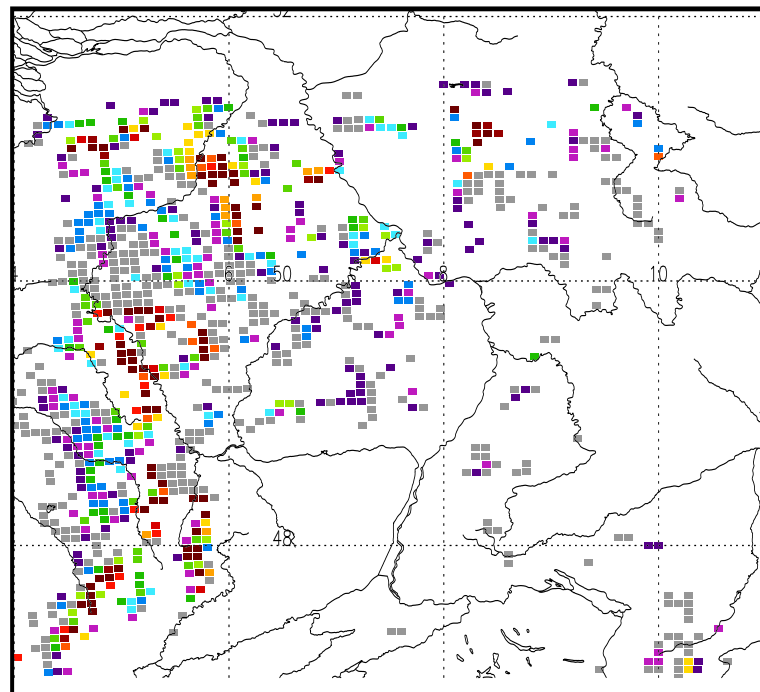


conv. precip. rate [mm/h]

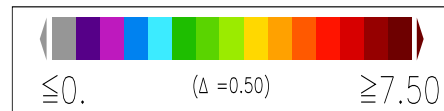


Pr_{conv}
5.7.06, 14:00:00 GMT

Tiedtke

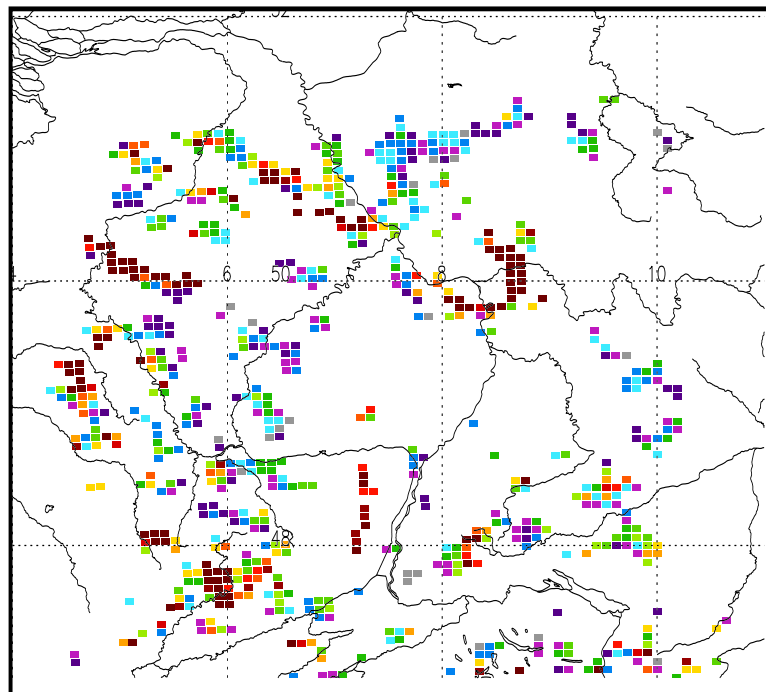


conv. precip. rate [mm/h]

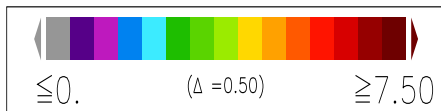


Pr_{conv}
5.7.06, 14:00:00 GMT

hybrid scheme

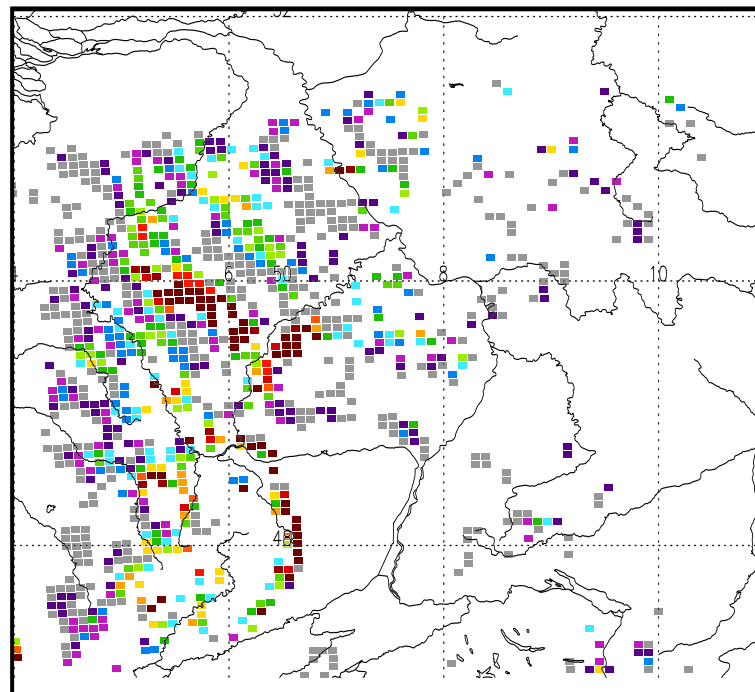


conv. precip. rate [mm/h]

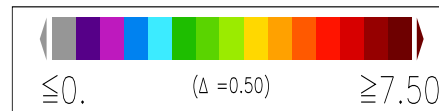


Pr_{conv}
5.7.06, 15:00:00 GMT

Tiedtke



conv. precip. rate [mm/h]



Pr_{conv}
5.7.06, 15:00:00 GMT

Self-organisation:

interaction between cells by ...

- thermodynamical feedback to grid (conv. T tendency, class. schemes)
- **dynamical feedback** to grid (conv. ρ or p tendency, hybrid scheme)
→ gravity waves → hydrostatic adjustment

... handling of gust fronts ?

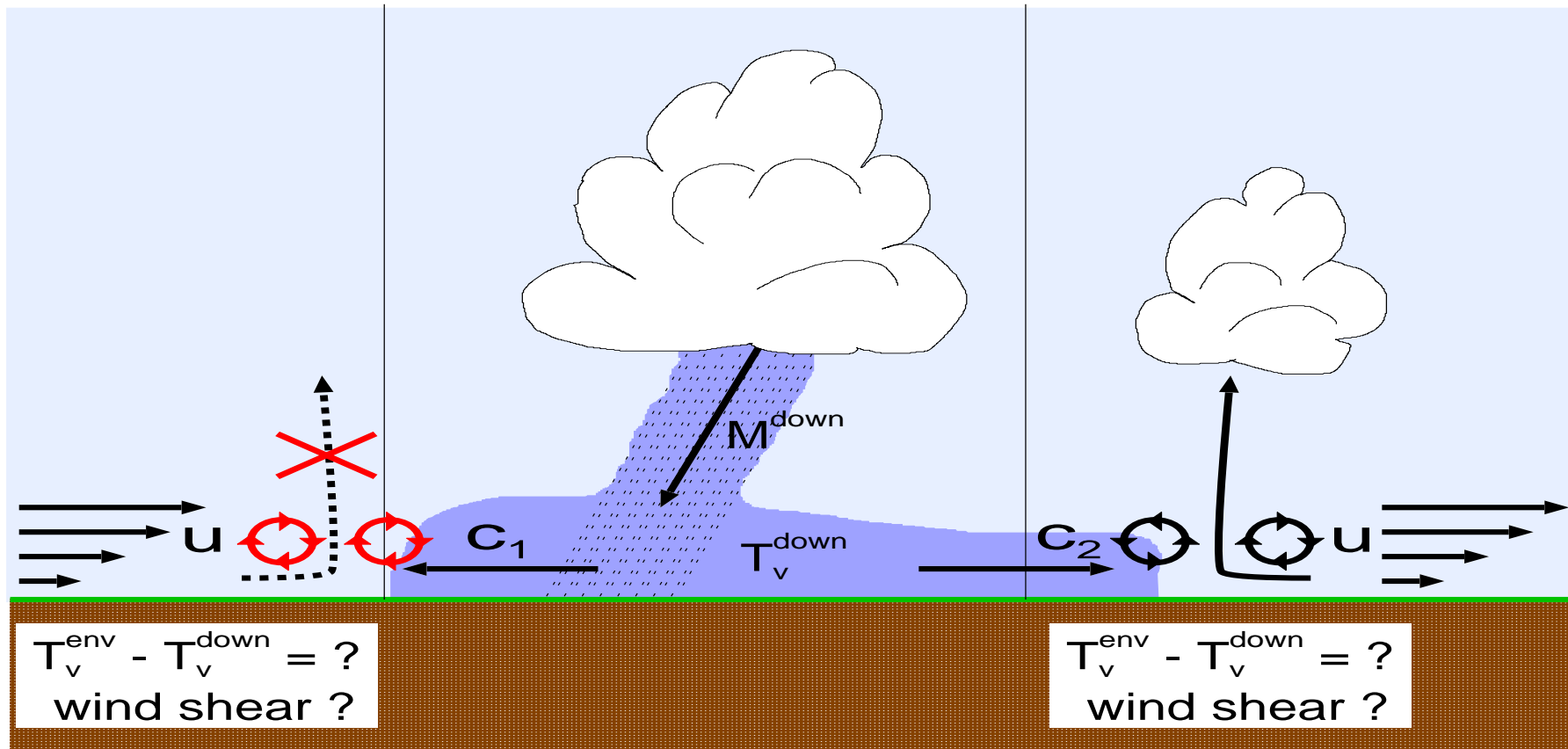
classically:

cold downdraft → detrainment → $\bar{T}(t + \Delta t) = \bar{T}(t) + \dots + \Delta t \left. \frac{\partial T}{\partial t} \right|_{conv} + \dots$

mixing with warm environment → **no strong cold pool!**

gust front parameterization:

- determine “subgrid cold pool” from $M^{\text{down}}, T_v^{\text{down}}$ without mixing
- max. $\bar{T}_v - T_v^{\text{down}}$ and opt. windshear criterion
 $\Delta u \approx c$ (Weisman+Rotunno, 2004) \rightarrow direction of cold pool outflow
- “trigger bonus” for corresp. neighbor grid cells to favor **init. of new cells**

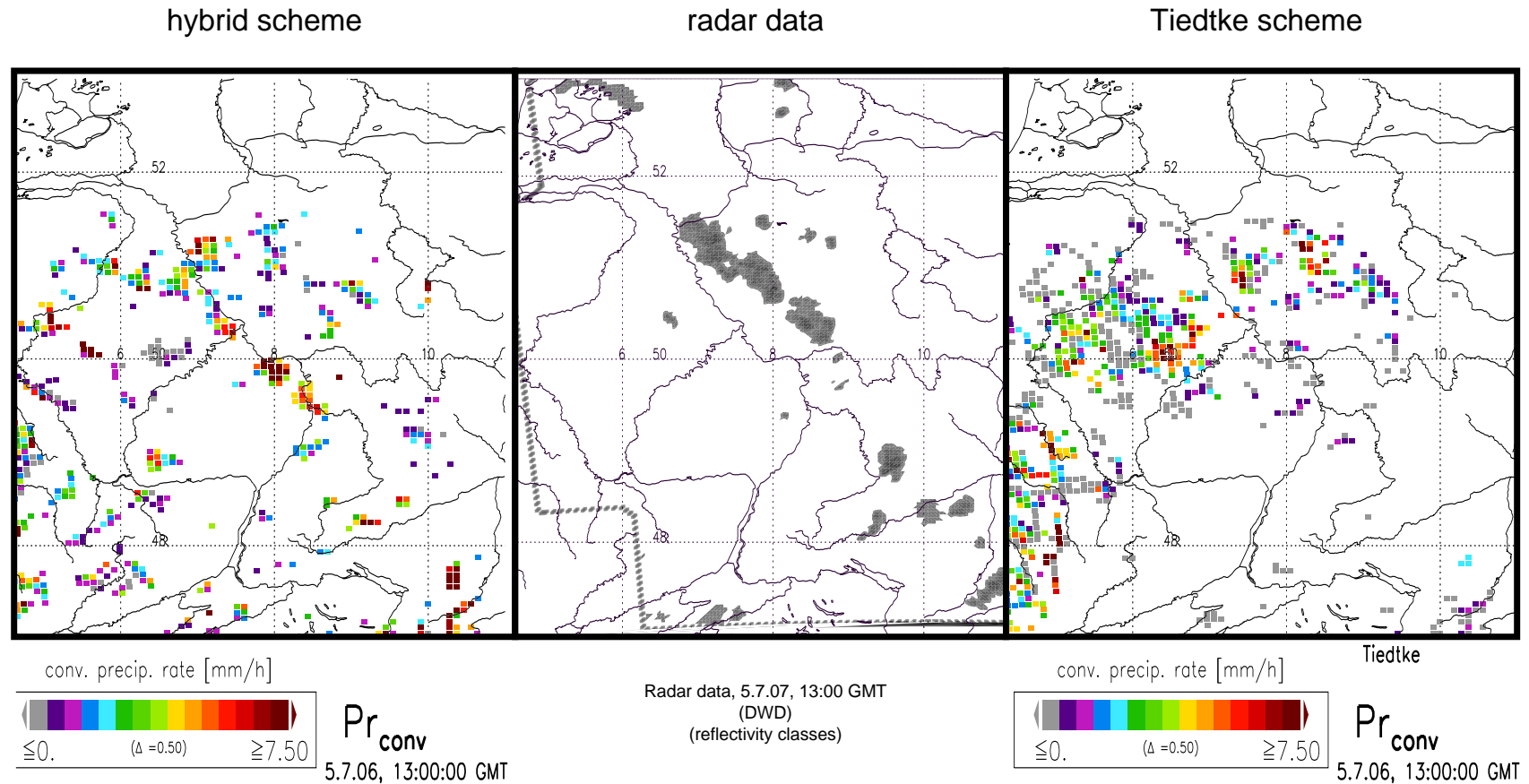


Outlook:

- gust fronts (as shown above) ...
- parameterization of life cycle of conv. cells
- tuning with observational data (DWD, QUEST, GOP, COPS/IOP)
 - especially cloud model
- validation
 - different meteorol. situations
(cold front, orographically induced cells, upper level cold air, ...)

Comparison with radar data:

model init.: 11:00 GMT, free run with hourly boundary data from DWD analyses



mean Pr_{tot} (grid boxes with meas.):

hybrid scheme: 7.3 mm, Tiedtke: 6.4 mm, DWD stations: 7.2 mm