

Alaro-1 multiscale behaviour with cellular automata

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CA formulation in prognostic CSD closure

The prognostic closure

$$(\sigma_B^+ - \sigma_B^-) \underbrace{\left\{ \int_{p_b}^{p_t} \nu (h_u - h_e) dp + \alpha_k \int_{p_b}^{p_t} \nu \frac{(\omega_u^{\parallel})^2}{2\rho_0^2 g^2} dp \right\}}_E = (\sigma_B^{\parallel} - \sigma_B^+) \delta t \underbrace{\int_{p_b}^{p_t} \nu \omega_u^{\parallel} L_u \delta q_{ca}}_C$$

can be written:

$$\frac{\partial \sigma_B}{\partial t} = \frac{(\sigma_B^{\parallel} - \sigma_B^+)}{\tau_\phi}, \quad \tau_\phi = E/C$$

2 ways to introduce σ_{ca} and τ_{CA} :

$$\frac{\partial \sigma_B}{\partial t} = \frac{(\sigma_B^{\parallel} - \sigma_B^+)}{\tau_\phi} + \frac{(\sigma_{CA} - \sigma_B^+)}{\tau_{CA}} \quad \text{double relaxation}$$

$$\frac{\partial \sigma_B}{\partial t} = \frac{[\sigma_B^{\parallel} (1 - \frac{\tau_\phi}{\tau_{CA}}) + \sigma_{CA} \frac{\tau_\phi}{\tau_{CA}}] - \sigma_B^+}{\tau_\phi} \quad \text{modified target}$$

CA formulation in prognostic CSD closure

Use of a modified target:

$$\frac{\partial \sigma_B}{\partial t} = \frac{[\sigma_B^{\parallel} (1 - \frac{\tau_\phi}{\tau_{CA}}) + \sigma_{CA} \frac{\tau_\phi}{\tau_{CA}}] - \sigma_B^+}{\tau_\phi}$$

$\tau_{CA} = |\text{gcvcatau}|$, $\text{gcvcatau} < 0$ (bf version).

- $\tau_\phi \ll \tau_{CA}$: small E, large C, deterministic σ_B^{\parallel}
- $\tau_\phi = \tau_{CA}$: weak updraughts, target σ_{CA}
- $\tau_\phi > \tau_{CA}$: over-relaxation towards σ_{CA}

This method proves to saturate less than the other one.

Radiative condensates formulation (see previous talk)

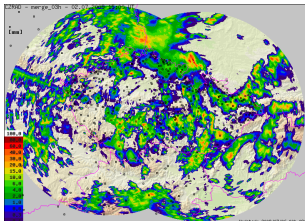
- prognostic: LNEB_FP=T, QXRAL=-1, QXRAL_ADJ=150
direct use of microphysical condensates and cloud fraction combining convective and stratiform (Xu-Randall) parts.
- diagnostic: LNEB_FP=F, QXRAL=150, QXRAL_ADJ=150, radiative condensates re-estimated from cloudiness, with Xu-Randall formulae.

CZ experiment and domains

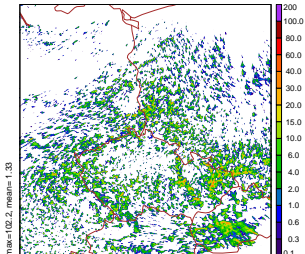
- tropical-like convection event in Central Europe, 2 July 2009
- Geometry: 87 hybrid levels, horizontal resolution between 16 and 1km
- Dynamics: non-hydrostatic $\Delta t = 30\text{s}$ for $\Delta x = 1\text{-km}$
- DFI initialization, coupling on LACE domain (down to 2km), 1-km coupled on 4-km reference run.
- Physics: full Alaro-1, CY43t1+bf: TOUCANS + Shallow convection, Radiation, non-saturated downdraught, CSD updraught
- Comparisons:
 - Stochastic physics: CA in DC closure.
 - recomputed XR-diagnostic vs prognostic microphysics condensates in radiation

Multi-scale results 15h $\Delta x = 1$ km

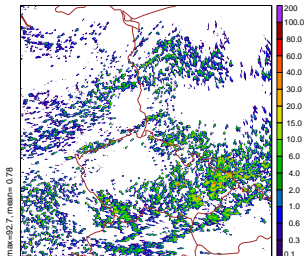
RADAR+Gauges



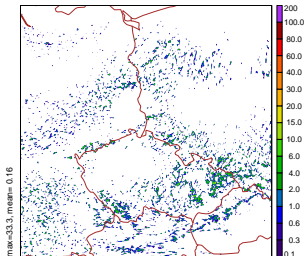
NODC



CSD

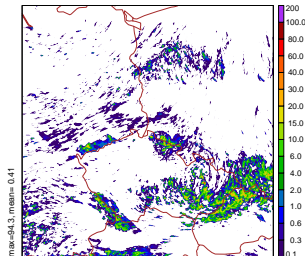


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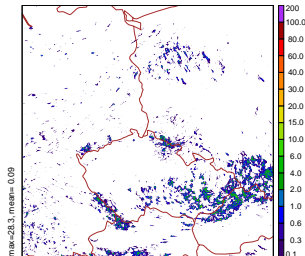


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3MT



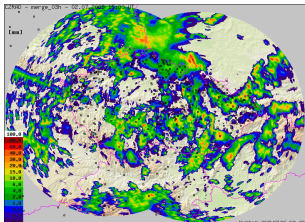
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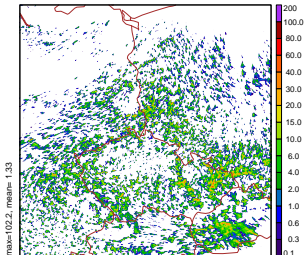
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Multi-scale results 15h $\Delta x = 1$ km

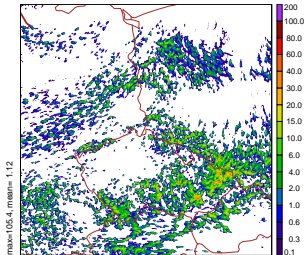
RADAR+Gauges



NODC

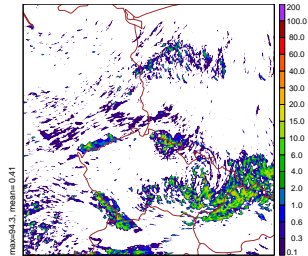


CSD+CA

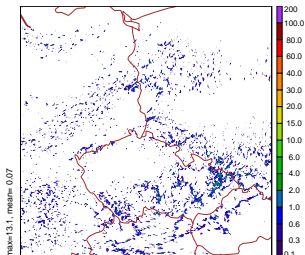


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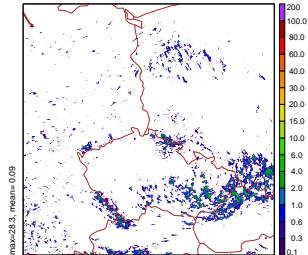
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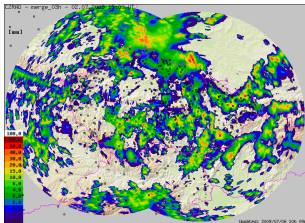
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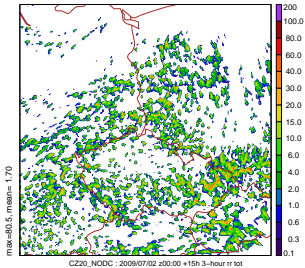
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Multi-scale results 15h $\Delta x = 2$ km

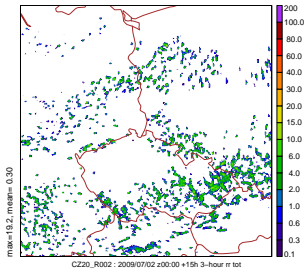
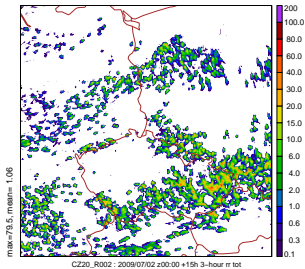
RADAR+Gauges



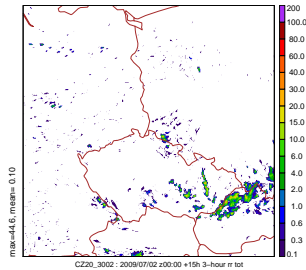
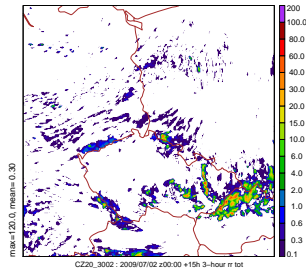
NODC



CSD

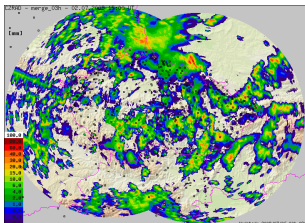


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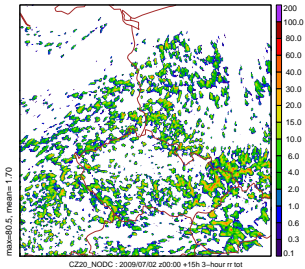


Multi-scale results 15h $\Delta x = 2$ km

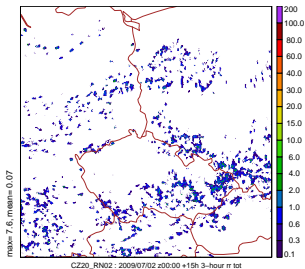
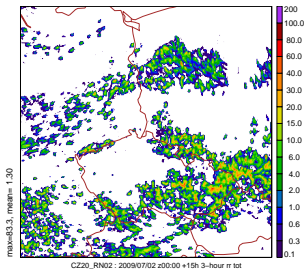
RADAR+Gauges



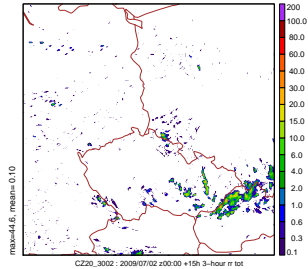
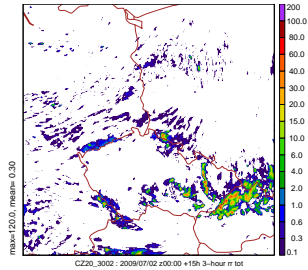
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CSD+CA

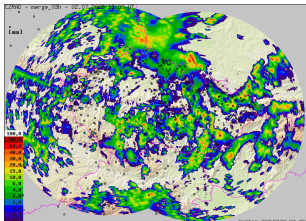


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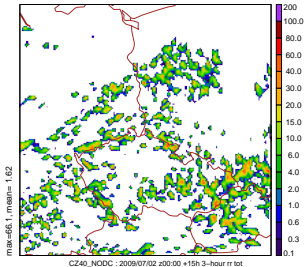


Multi-scale results 15h $\Delta x = 4$ km

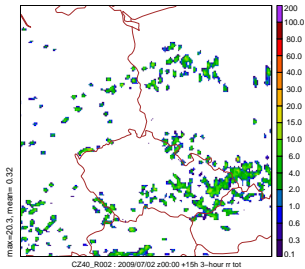
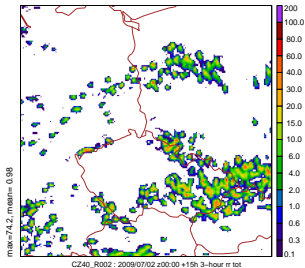
RADAR+Gauges



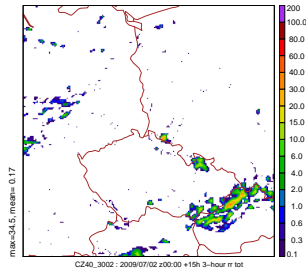
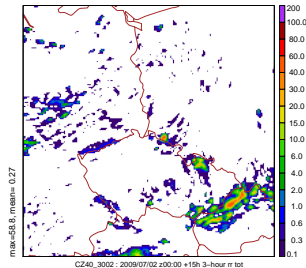
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CSD

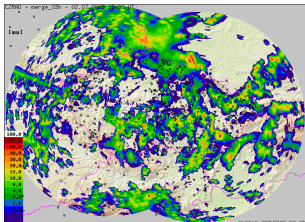


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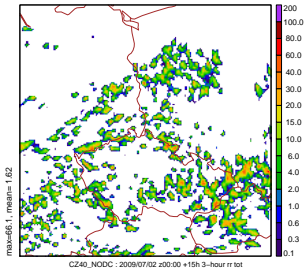


Multi-scale results 15h $\Delta x = 4$ km

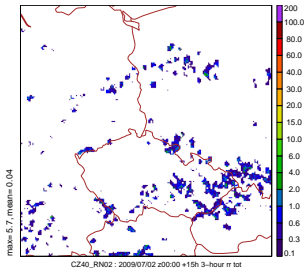
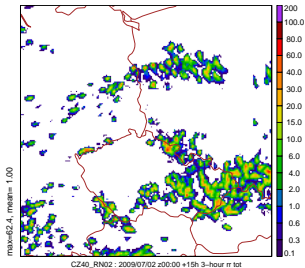
RADAR+Gauges



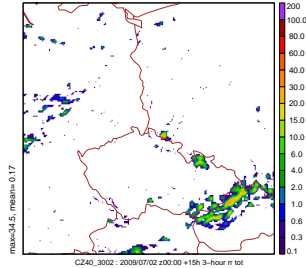
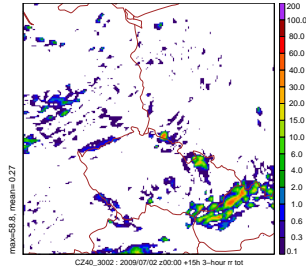
NODC



CSD+CA

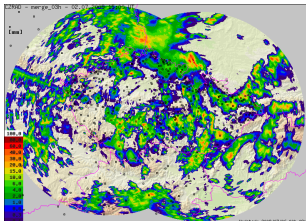


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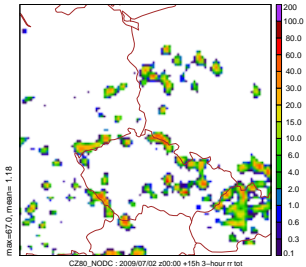


Multi-scale results 15h $\Delta x = 8$ km

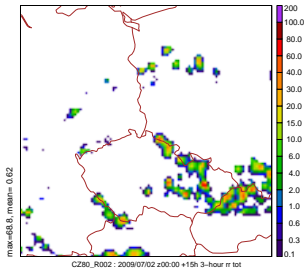
RADAR+Gauges



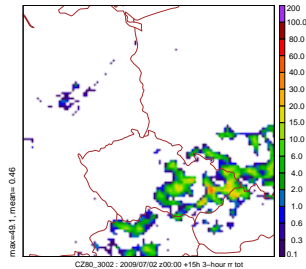
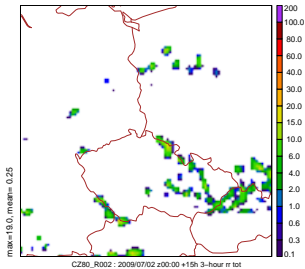
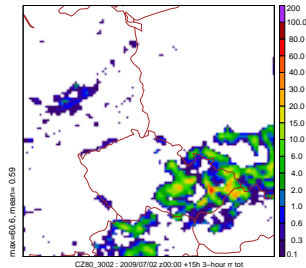
NODC



CSD



3MT



max=67.0, mean= 1.18

max=68.8, mean= 0.62

max=60.6, mean= 0.59

max=19.0, mean= 0.25

max=49.1, mean= 0.46

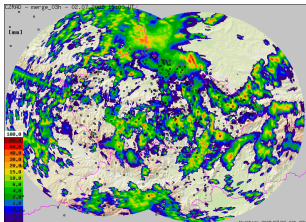
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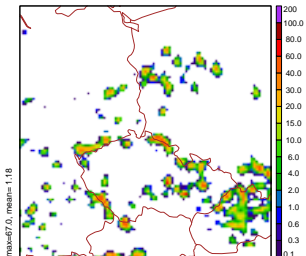
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Multi-scale results 15h $\Delta x = 8$ km

RADAR+Gauges

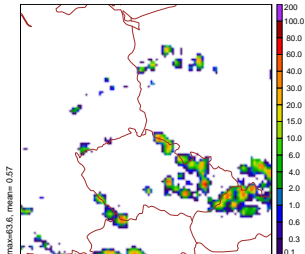


NODC



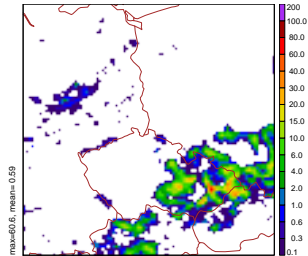
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CSD+CA

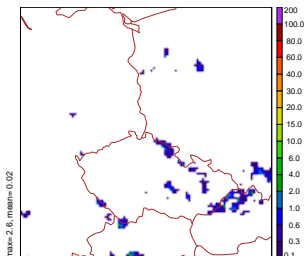


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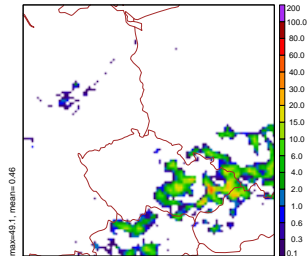
3MT



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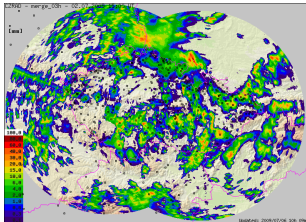
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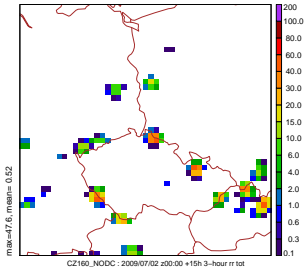
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Multi-scale results 15h $\Delta x = 16$ km

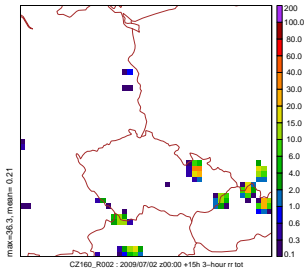
RADAR+Gauges



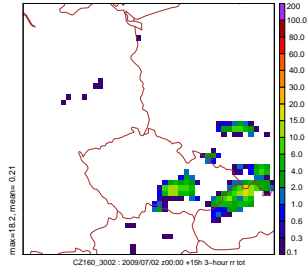
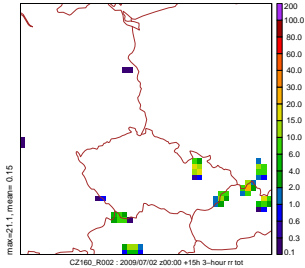
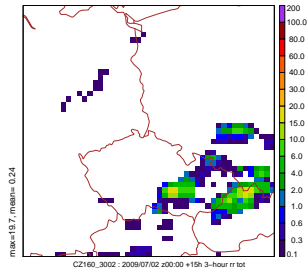
NODC



CSD

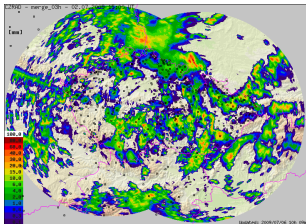


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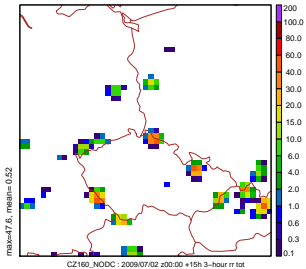


Multi-scale results 15h $\Delta x = 16$ km

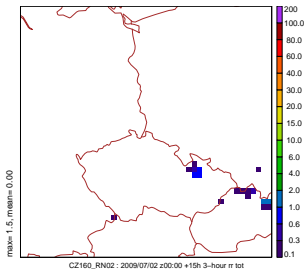
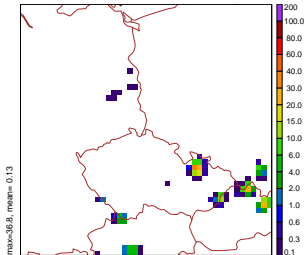
RADAR+Gauges



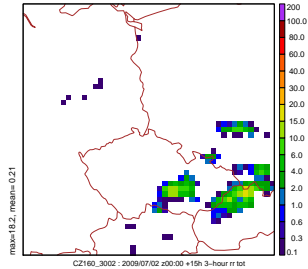
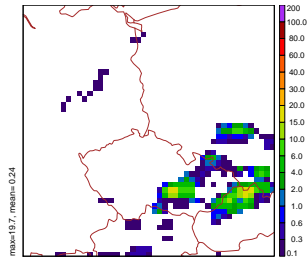
NODC



CSD+CA

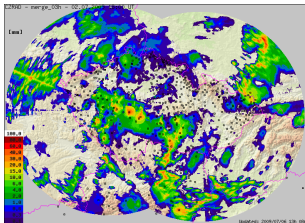


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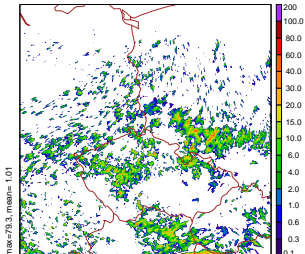


Multi-scale results 18h $\Delta x = 1$ km

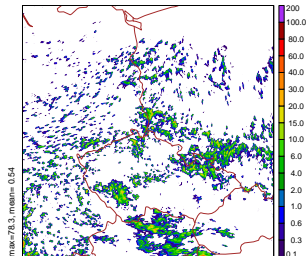
RADAR+Gauges



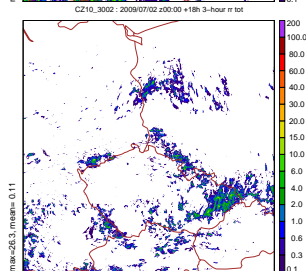
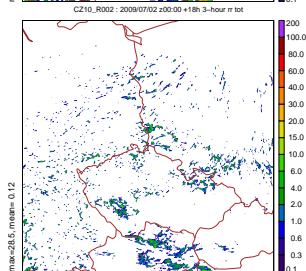
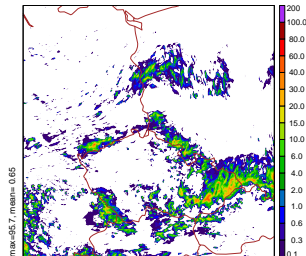
NODC



CSD



3MT



max=79.3, mean= 1.01

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max=26.3, mean= 0.11

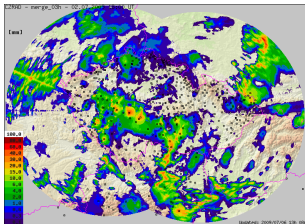
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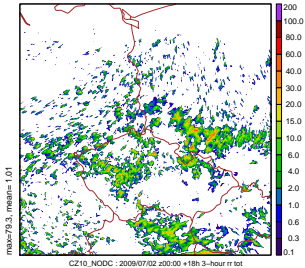
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Multi-scale results 18h $\Delta x = 1$ km

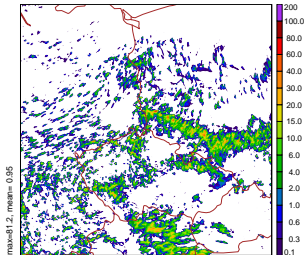
RADAR+Gauges



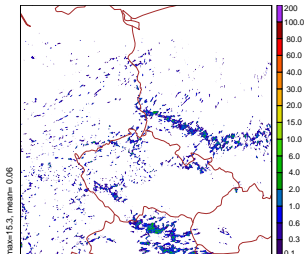
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CSD+CA

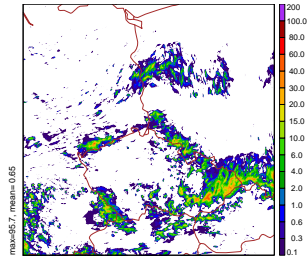


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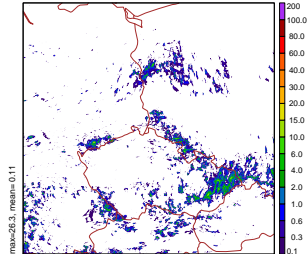


CZ10_RN02 : 2009/07/02 z00:00 +18h 3-hour rr tot

3MT



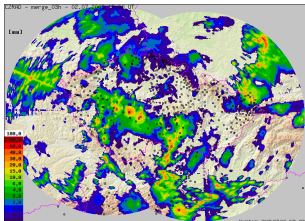
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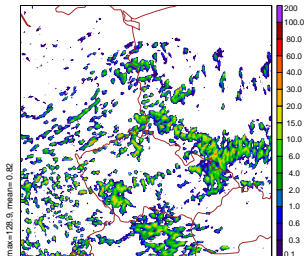
CZ10_3002 : 2009/07/02 z00:00 +18h 3-hour rr tot

Multi-scale results 18h $\Delta x = 2$ km

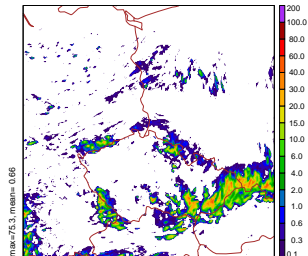
RADAR+Gauges



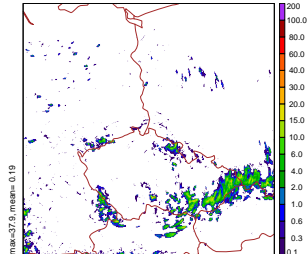
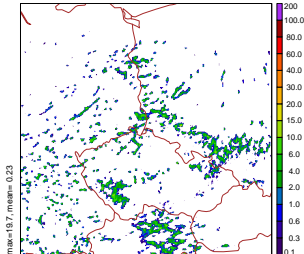
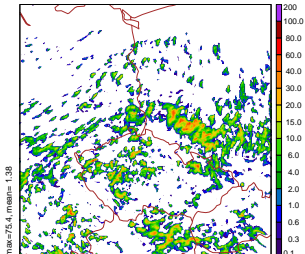
CSD



3MT



NODC



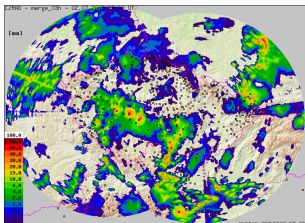
CZ20_NODC : 2009/07/02 z00:00 +18h 3-hour rr tot

CZ20_R002 : 2009/07/02 z00:00 +18h 3-hour rr tot

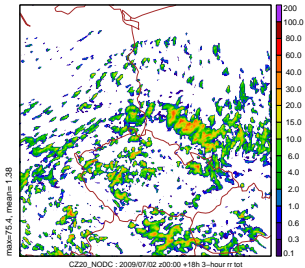
CZ20_3002 : 2009/07/02 z00:00 +18h 3-hour rr tot

Multi-scale results 18h $\Delta x = 2$ km

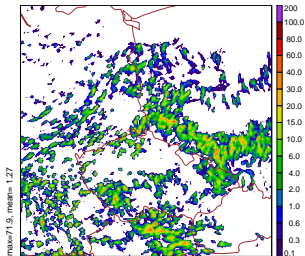
RADAR+Gauges



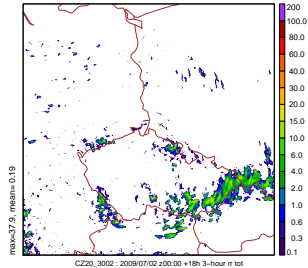
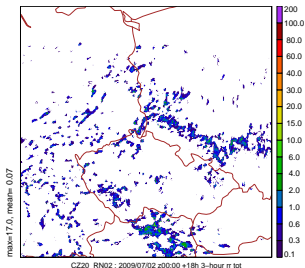
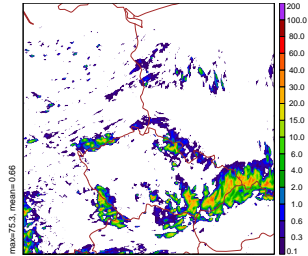
NODC



CSD+CA

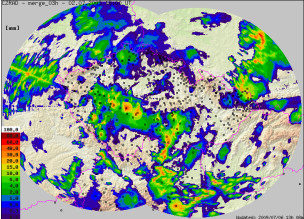


3MT

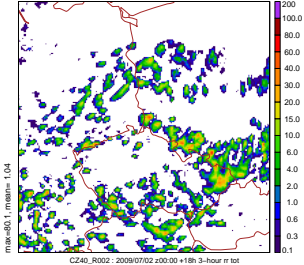


Multi-scale results 18h $\Delta x = 4$ km

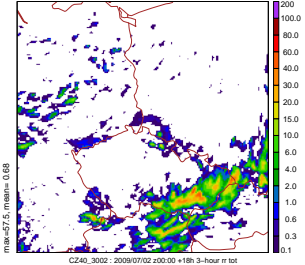
RADAR+Gauges



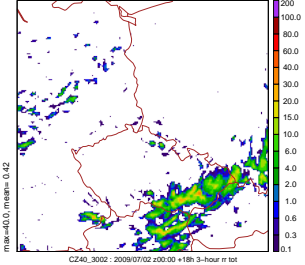
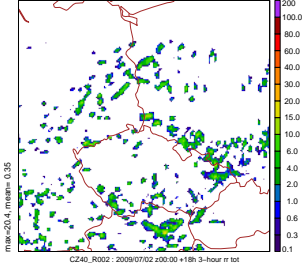
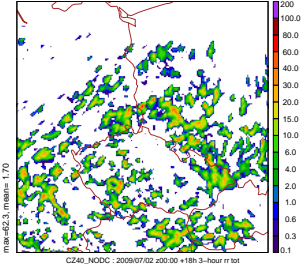
CSD



3MT

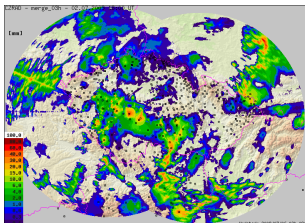


NODC

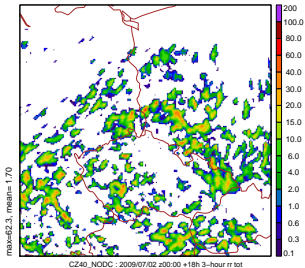


Multi-scale results 18h $\Delta x = 4$ km

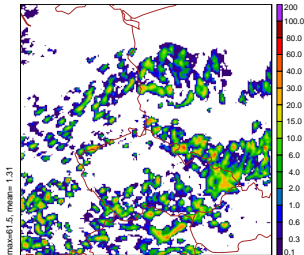
RADAR+Gauges



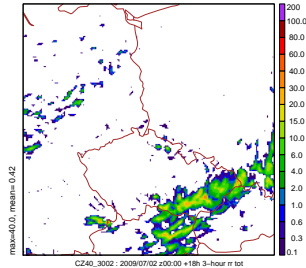
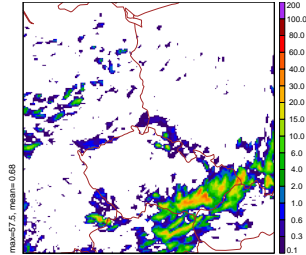
NODC



CSD+CA

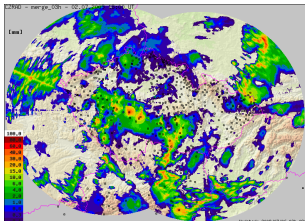


3MT

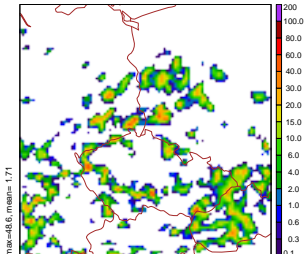


Multi-scale results 18h $\Delta x = 8$ km

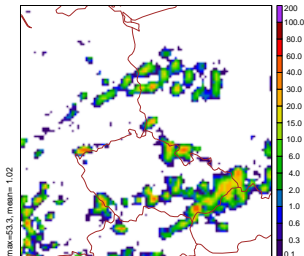
RADAR+Gauges



NODC

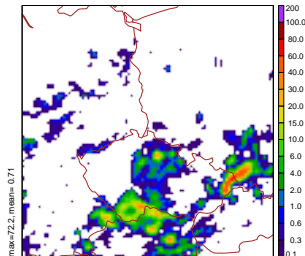


CSD

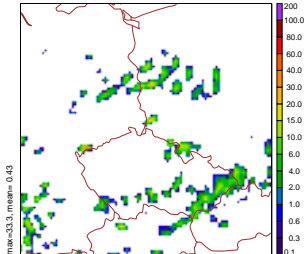


CZ80_R002 : 2009/07/02 z00:00 +18h 3-hour rr tot

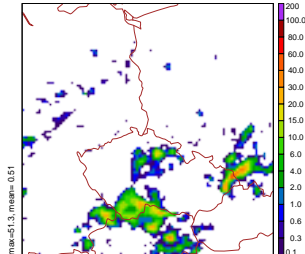
3MT



CZ80_3002 : 2009/07/02 z00:00 +18h 3-hour rr tot



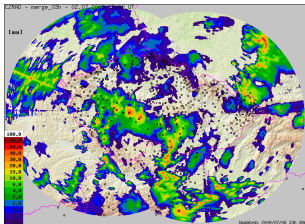
CZ80_R002 : 2009/07/02 z00:00 +18h 3-hour rr tot



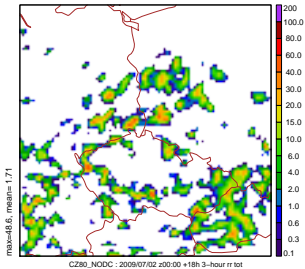
CZ80_3002 : 2009/07/02 z00:00 +18h 3-hour rr tot

Multi-scale results 18h $\Delta x = 8$ km

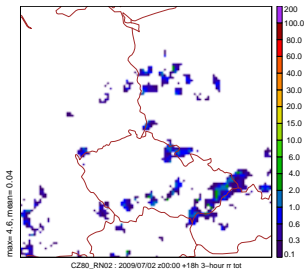
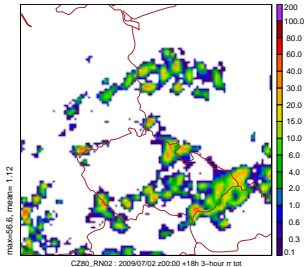
RADAR+Gauges



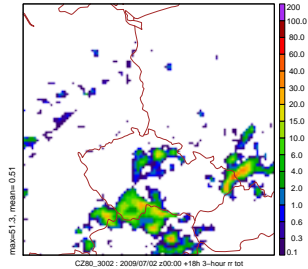
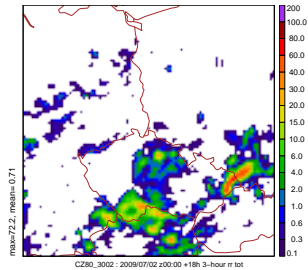
NODC



CSD+CA

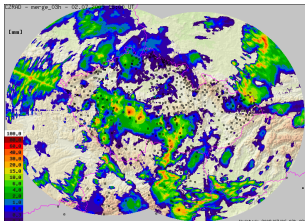


3MT

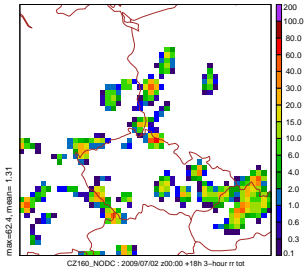


Multi-scale results 18h $\Delta x = 16$ km

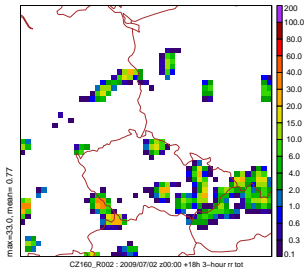
RADAR+Gauges



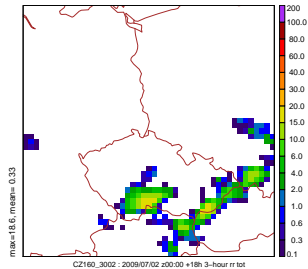
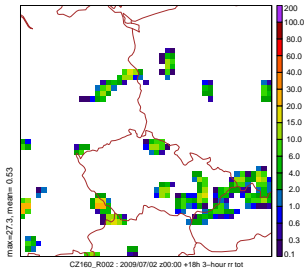
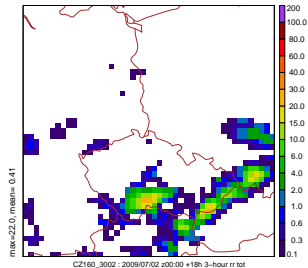
NODC



CSD

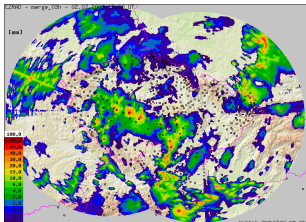


3MT

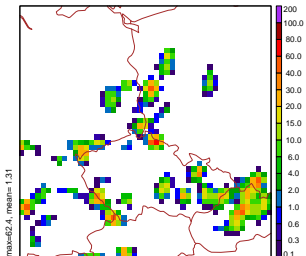


Multi-scale results 18h $\Delta x = 16$ km

RADAR+Gauges

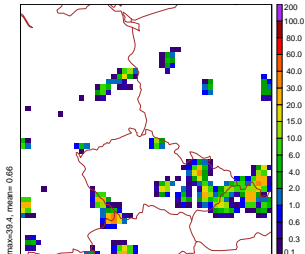


NODC



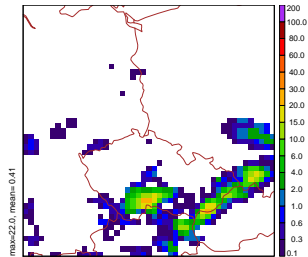
CZ160_NODC : 2009/07/02 200:00 +18h 3-hour rr tot

CSD+CA

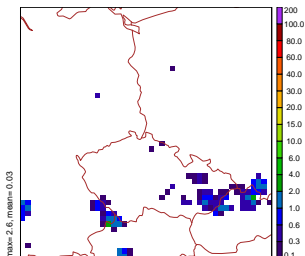


CZ160_RN02 : 2009/07/02 200:00 +18h 3-hour rr tot

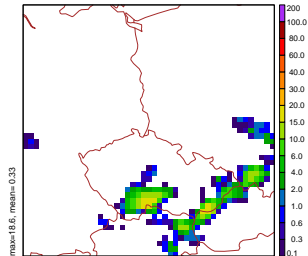
3MT



CZ160_3002 : 2009/07/02 200:00 +18h 3-hour rr tot



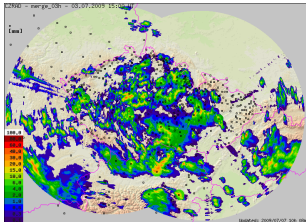
CZ160_RN02 : 2009/07/02 200:00 +18h 3-hour rr tot



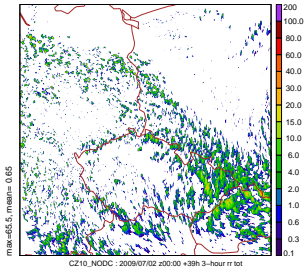
CZ160_3002 : 2009/07/02 200:00 +18h 3-hour rr tot

Multi-scale results 39h $\Delta x = 1$ km

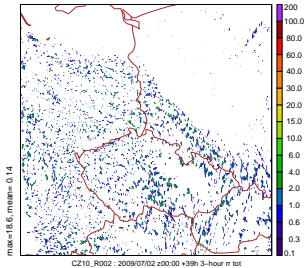
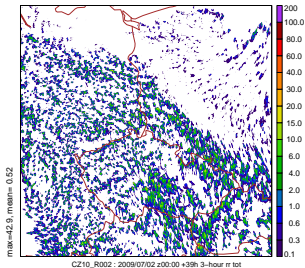
RADAR+Gauges



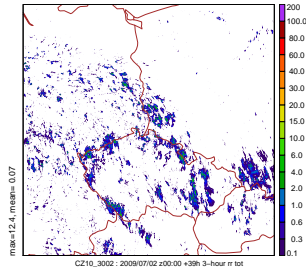
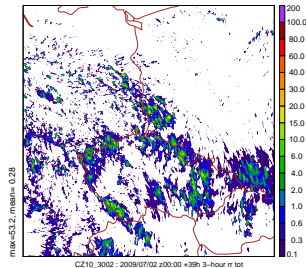
NODC



CSD

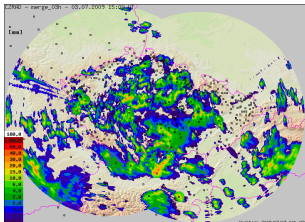


3MT

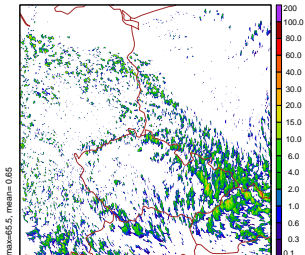


Multi-scale results 39h $\Delta x = 1$ km

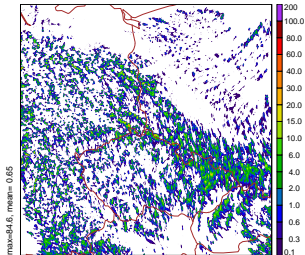
RADAR+Gauges



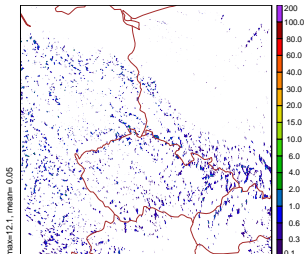
NODC



CSD+CA

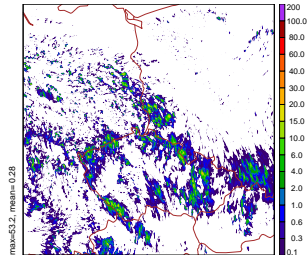


CZ10_RN02 : 2009/07/02 00:00 +39h 3-hour rr tot

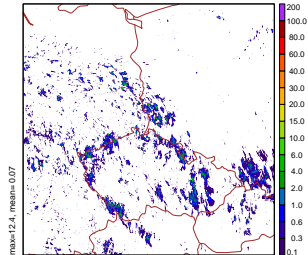


CZ10_RN02 : 2009/07/02 00:00 +39h 3-hour rr tot

3MT



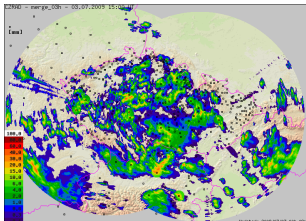
CZ10_3002 : 2009/07/02 00:00 +39h 3-hour rr tot



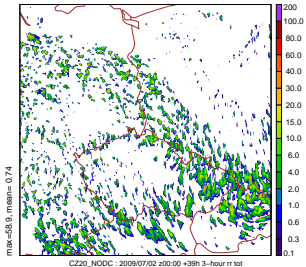
CZ10_3002 : 2009/07/02 00:00 +39h 3-hour rr tot

Multi-scale results 39h $\Delta x = 2$ km

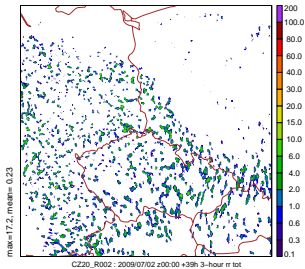
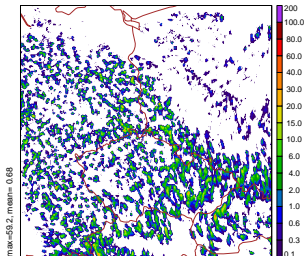
RADAR+Gauges



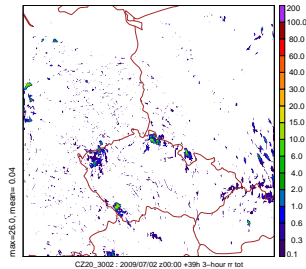
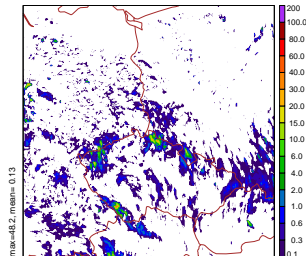
NODC



CSD

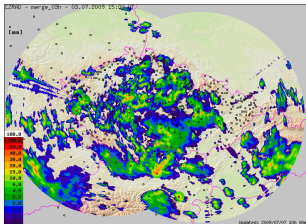


3MT

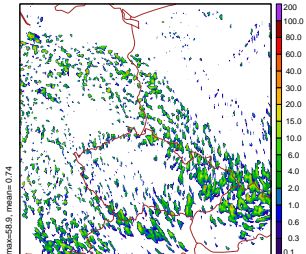


Multi-scale results 39h $\Delta x = 2$ km

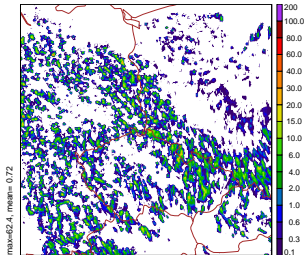
RADAR+Gauges



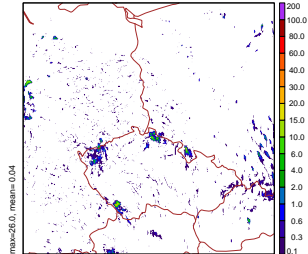
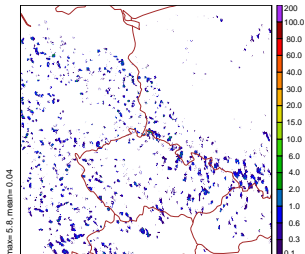
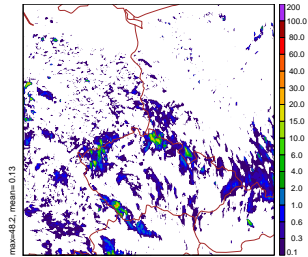
NODC



CSD+CA

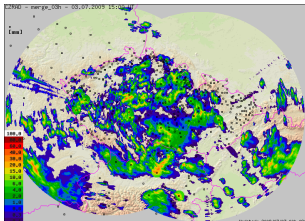


3MT

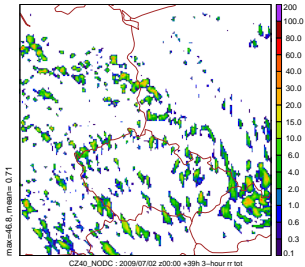


Multi-scale results 39h $\Delta x = 4$ km

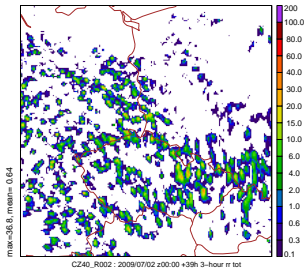
RADAR+Gauges



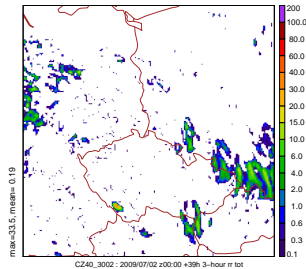
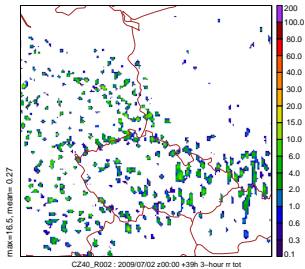
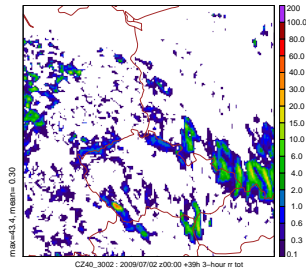
NODC



CSD

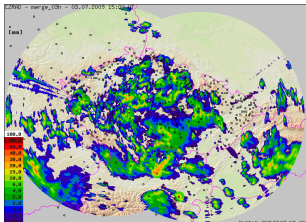


3MT

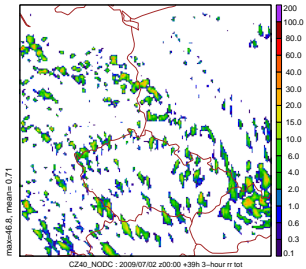


Multi-scale results 39h $\Delta x = 4$ km

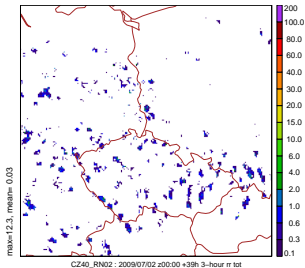
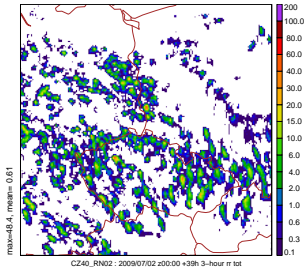
RADAR+Gauges



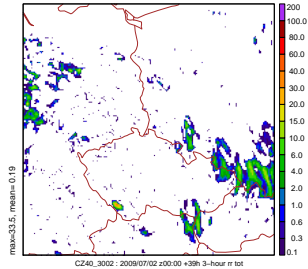
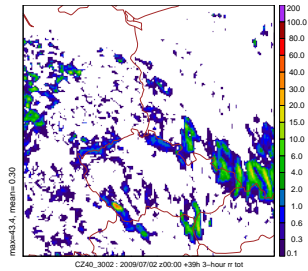
NODC



CSD+CA

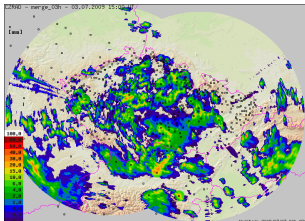


3MT

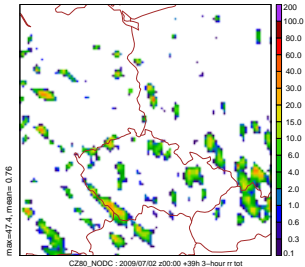


Multi-scale results 39h $\Delta x = 8$ km

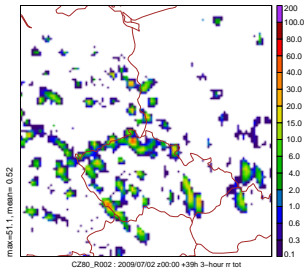
RADAR+Gauges



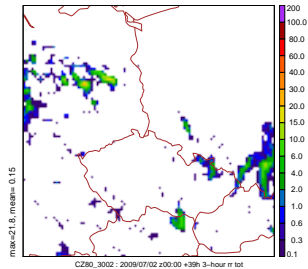
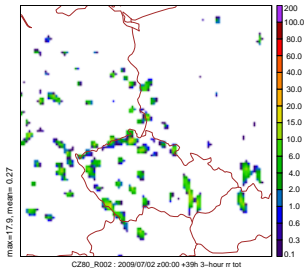
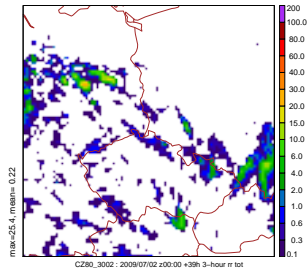
NODC



CSD

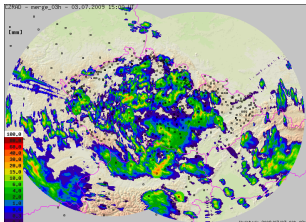


3MT

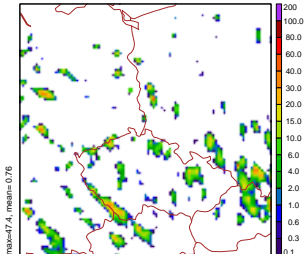


Multi-scale results 39h $\Delta x = 8$ km

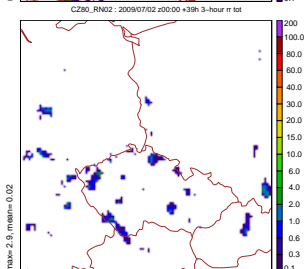
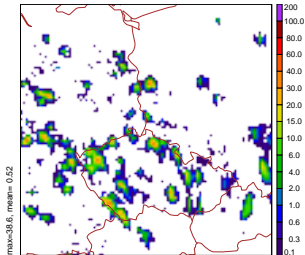
RADAR+Gauges



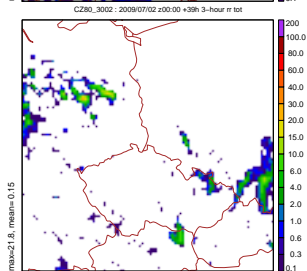
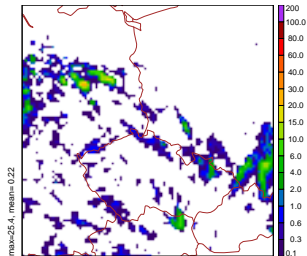
NODC



CSD+CA



3MT



max=47.4, mean=0.76

max=38.6, mean=0.52

max=25.4, mean=0.22

max=2.9, mean=0.02

max=21.8, mean=0.15

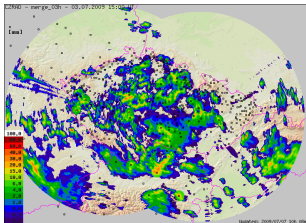
CZ80_NODC : 2009/07/02 z00:00 +39h 3-hour rr tot

CZ80_RN02 : 2009/07/02 z00:00 +39h 3-hour rr tot

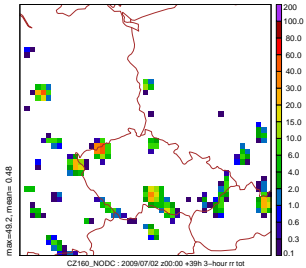
CZ80_3002 : 2009/07/02 z00:00 +39h 3-hour rr tot

Multi-scale results 39h $\Delta x = 16$ km

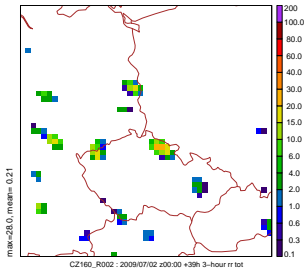
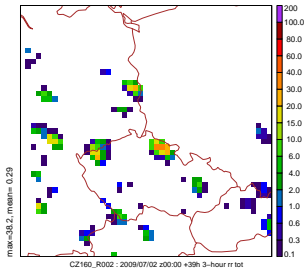
RADAR+Gauges



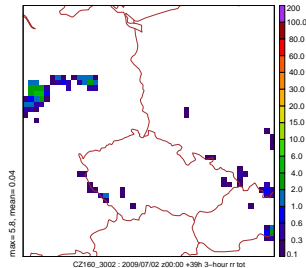
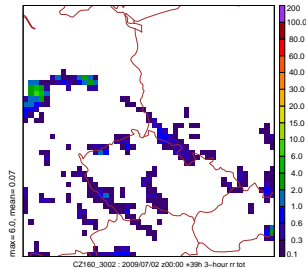
NODC



CSD

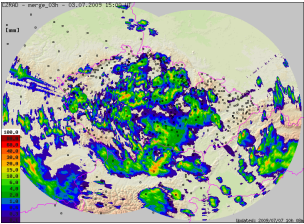


3MT

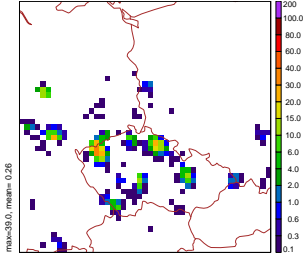


Multi-scale results 39h $\Delta x = 16$ km

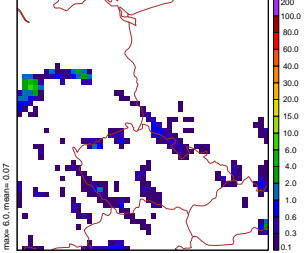
RADAR+Gauges



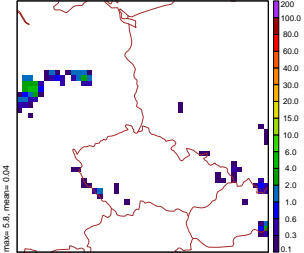
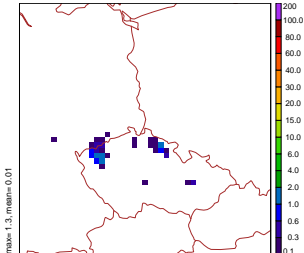
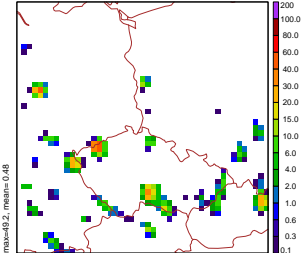
CSD+CA



3MT



NODC



CZ160_NODC : 2009/07/02 20:00 +39h 3-hour rr tot

CZ160_RN02 : 2009/07/02 20:00 +39h 3-hour rr tot

CZ160_3002 : 2009/07/02 20:00 +39h 3-hour rr tot

Summary

- CSD formulation often closer to reality than 3MT for this case.
- Maintaining a parameterization allows to use CA, while explicit deep convection misses small precipitation.
- CA helps organization at fine resolution
- CA reduces subgrid part at all resolutions