Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

Universität Karlsruhe (TH)
Forschungsuniversität · gegründet 1825

Explicit modeling of convective clouds in the WG Beheng (Karlsruhe)

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Our fields of work

- Detailed cloud microphysics parameterization, suitable for explicit simulation of convective clouds (2-moment bulk microphysical scheme)
- Numerical studies on sensitivities of convective clouds to ambient atmospheric parameters (profiles of T, $\vec{v}$, RH, aerosol regime) and orography – precipitation, microphys./dyn. feedback, hail formation
- Drop breakup: direct numerical simulations (ITLR Stuttgart), from that derivation of suitable parameterizations (Beheng et al., Phys. Rev. Lett., 2007)
- Measurement of raindrop size distributions at the ground (JWD, PARSIVEL)
- Radar meteorology: C-Band weather radar, K-band cloud radar, Micro Rain Radar (vertically pointing)

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2-moment bulk microphysical scheme

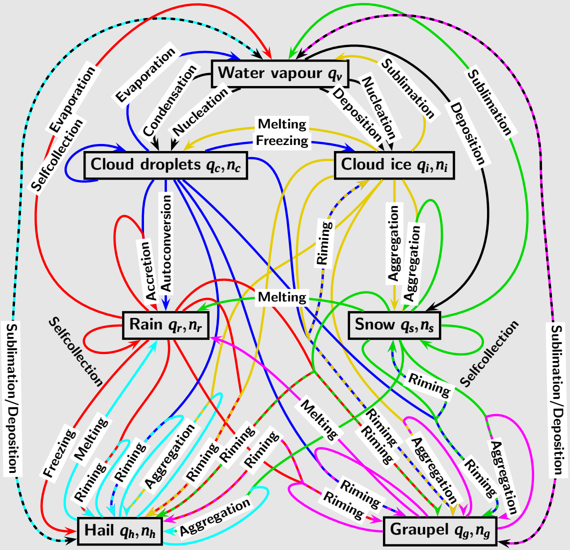
- Cloud droplets, rain, cloud ice, snow, graupel, hail
- For each hydrometeor category: rate equations for
  1. number density N (0. moment of PSD $f(x)$)
  2. mass density Q (1. moment of PSD $f(x)$)
- Parameterizations of microphysical processes based on the spectral balance eqn. for $f(x)$ and assumption

$$f(x) = N_0 \, x^\nu \exp\left(-\lambda \, x^\mu\right)$$

$$\nu, \mu = \text{const.}, \qquad \lambda = \left[\frac{\Gamma(\frac{\nu+1}{\mu})}{\Gamma(\frac{\nu+2}{\mu})} \frac{Q}{N}\right]^{-\mu}, \qquad N_0 = \frac{\mu \, N}{\Gamma(\frac{\nu+1}{\mu})} \lambda^{\frac{\nu+1}{\mu}}$$

Seifert and Beheng (2006a,b,c), Noppel et al. (2006), Seifert (2007), Blahak et al. (2008, in prep.)

2-moment bulk microphysical scheme



Parameterization of cloud droplet- and ice nucleation

At the moment: no explicit consideration of aerosol budget

$T < 0, S_i \geq 0, S_w < 0$	$T < 0, S_w \geq 0$
Depos. nucleation	Depos./condens. nucleation
Heterog./homog. freezing	Heterog./homog. freezing
	Droplet activation
	(Contact freezing not impl.)

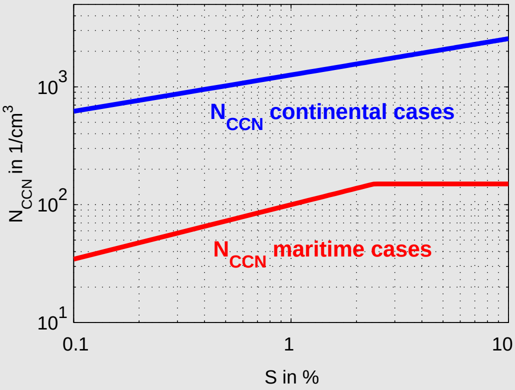
$T \geq 0, S_w \geq 0$

Droplet activation

Param. of cloud droplet nucleation

$$N_{CCN,diag} = a\,S_w^b$$

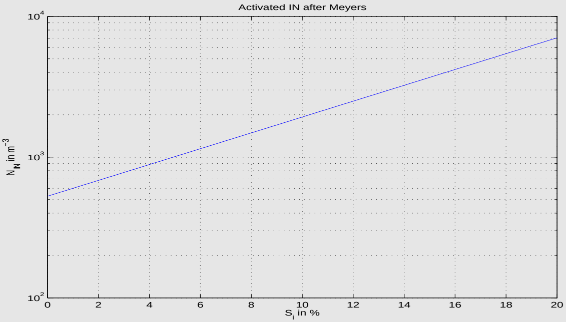
$$\frac{\partial N_c}{\partial t} = \begin{cases} \dfrac{N_{CCN,diag} - N_c}{\Delta t} & \text{for } N_{CCN,diag} > N_c \\ 0 & \text{otherwise} \end{cases}$$



Param. of depos./condens. ice nucleation 1

$$N_{ice,diag} = a \exp(b\,S_i)$$

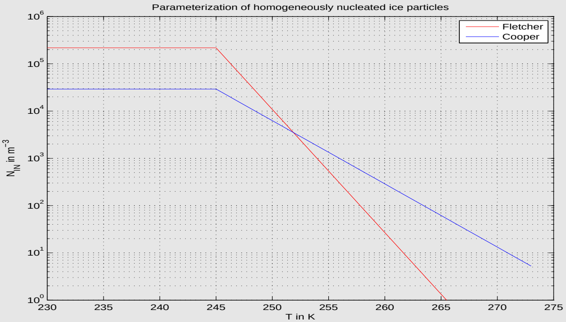
$$\frac{\partial N_i}{\partial t} = \begin{cases} \dfrac{N_{ice,diag} - N_i}{\Delta t} & \text{for } N_{ice,diag} > N_i \\ 0 & \text{otherwise} \end{cases}$$



Param. of depos./condens. ice nucleation 2

$$N_{ice,diag} = a \exp(b(T - T_0))$$

$$\frac{\partial N_i}{\partial t} = \begin{cases} \dfrac{N_{ice,diag} - N_i}{\Delta t} & \text{for } N_{ice,diag} > N_i \\ 0 & \text{otherwise} \end{cases}$$



Param. of heterogeneous/homogeneous freezing

$$\frac{1}{f_c(x)}\frac{\partial f_c(x)}{\partial t} = -x\,J(T)$$

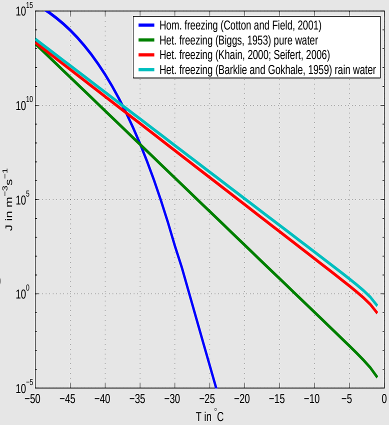
Heterog. freezing:

$$J(T) = a\exp(b(T-T_0)-1)$$

Homog. freezing:

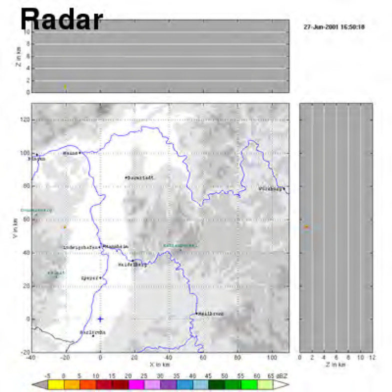
$J(T)$ after Cotton and Field, 2001)

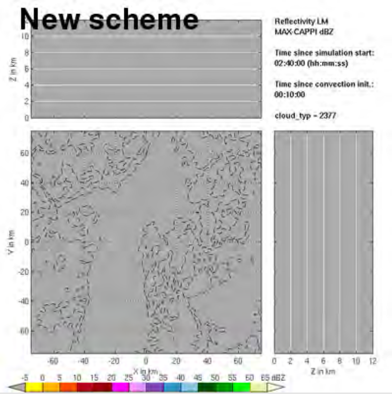
$\Rightarrow$ integration of $\partial_t f_c(x)$ and $x\partial_t f_c(x)$ over x leads to $\partial_t N_c$ and $\partial_t Q_c$ and corresp. source terms for ice particles



⟹ Cell splitting case, Mannheim, 27.6.2001

IMK-Radar (C-Band) | Semi-idealized COSMO run





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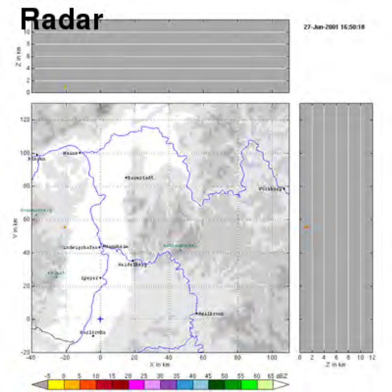

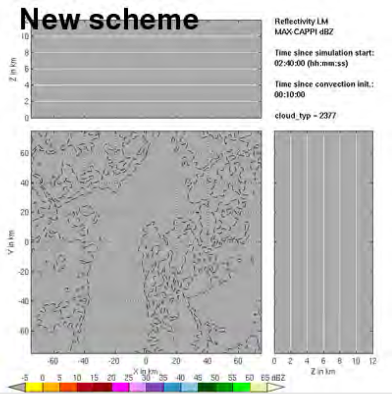

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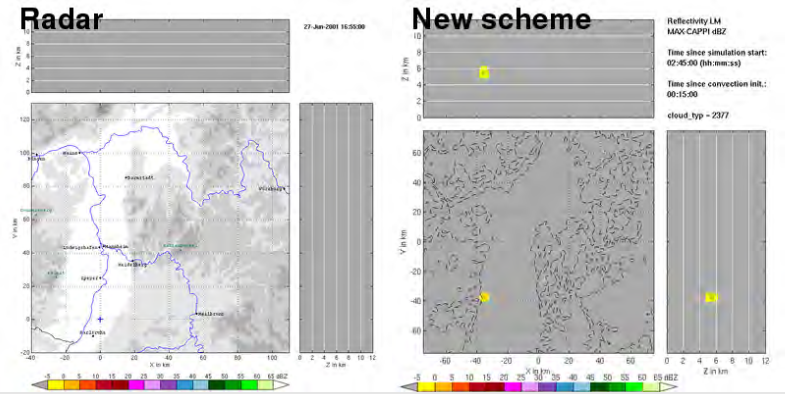

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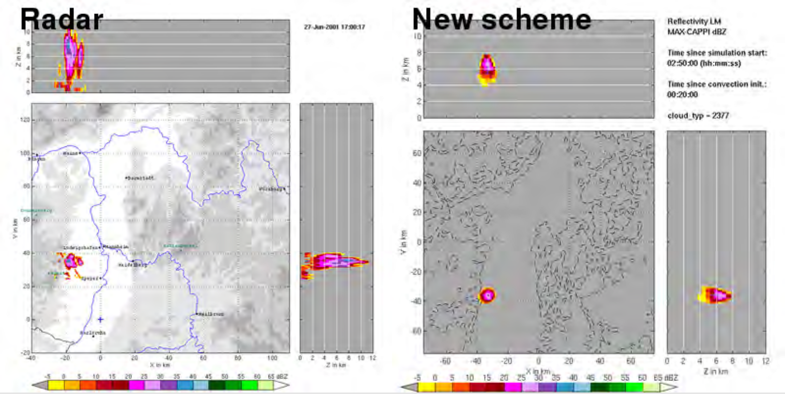

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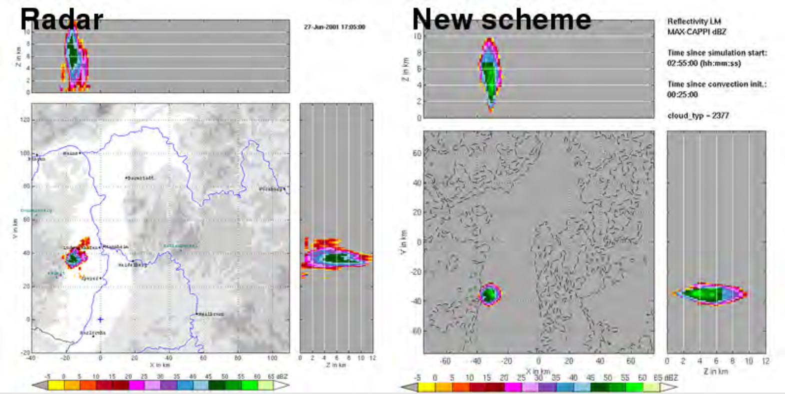

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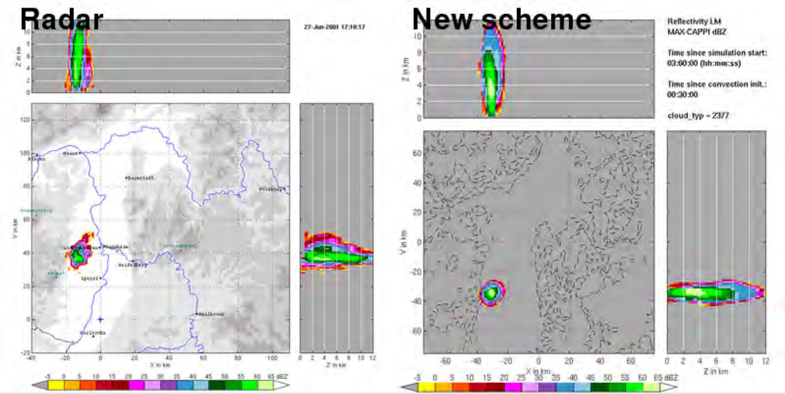

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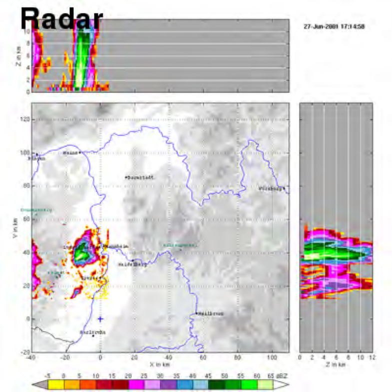

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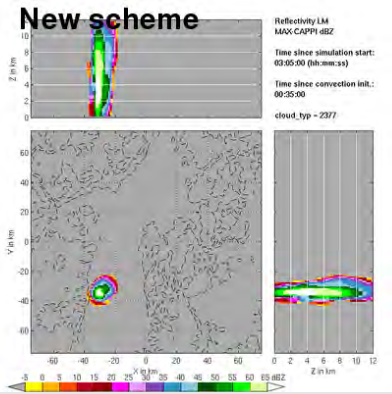

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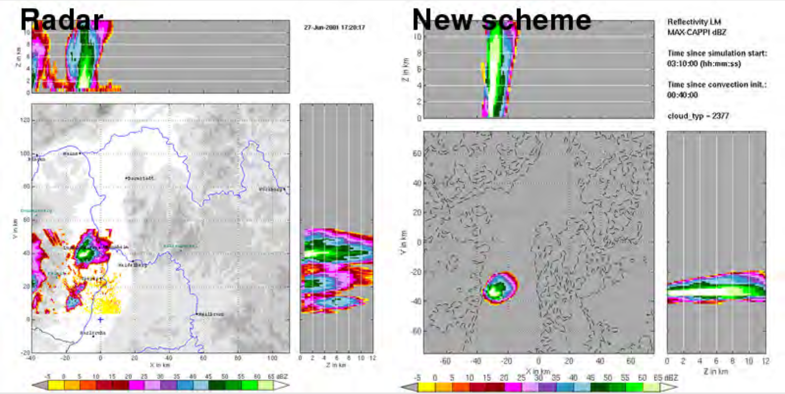

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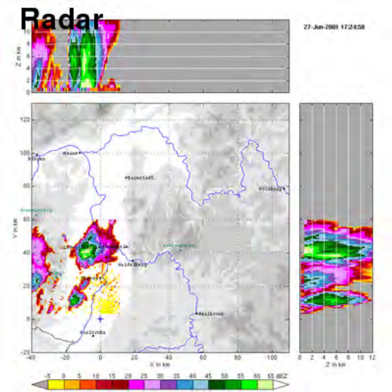

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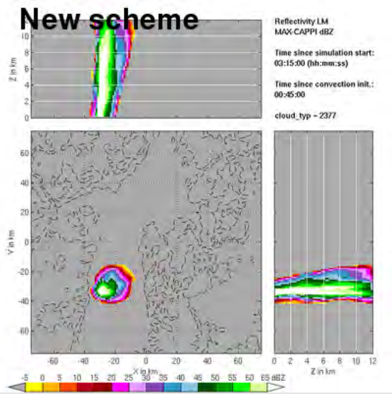

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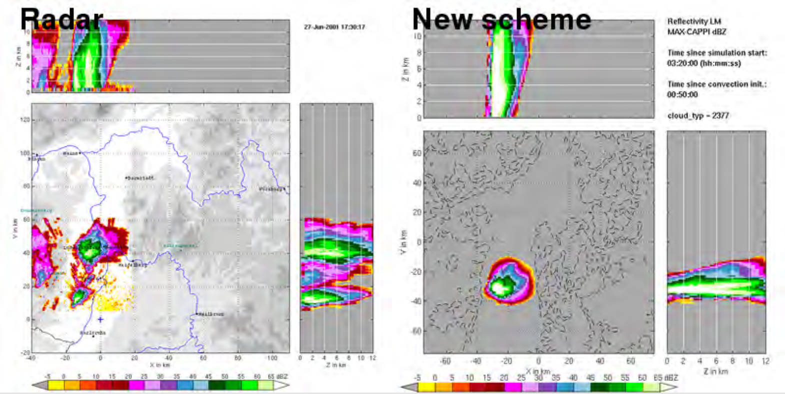

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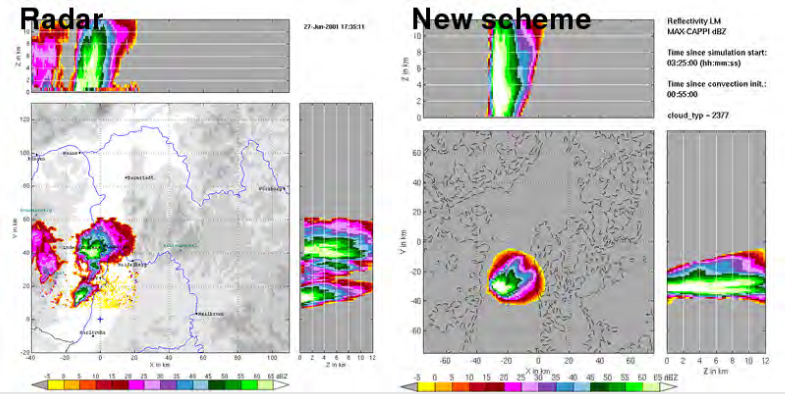

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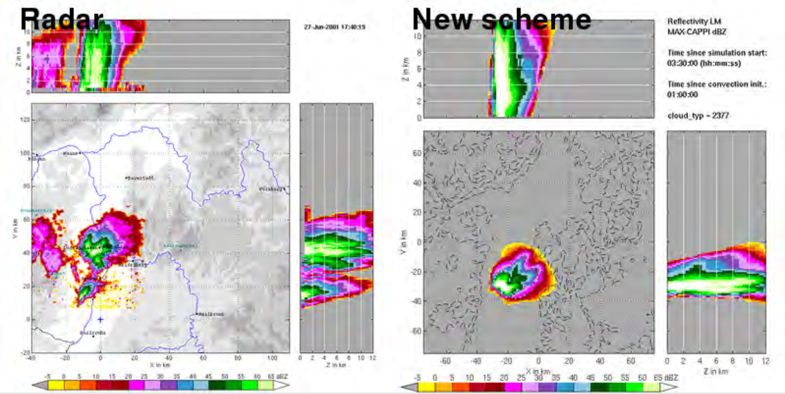

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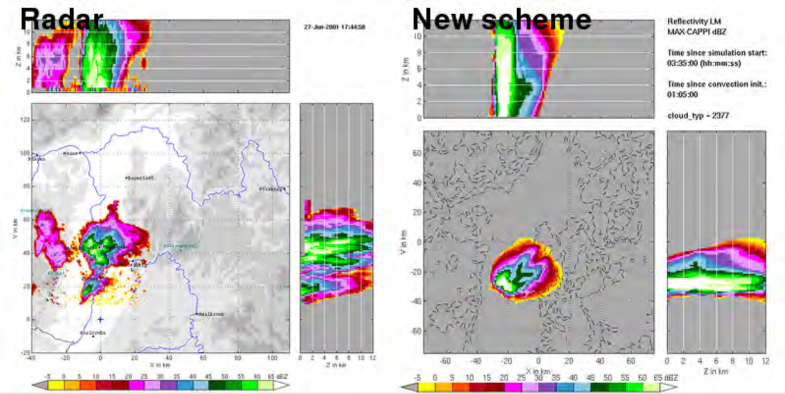

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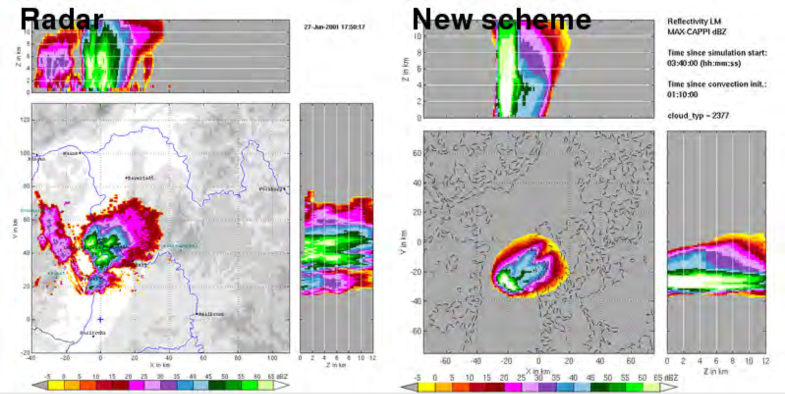

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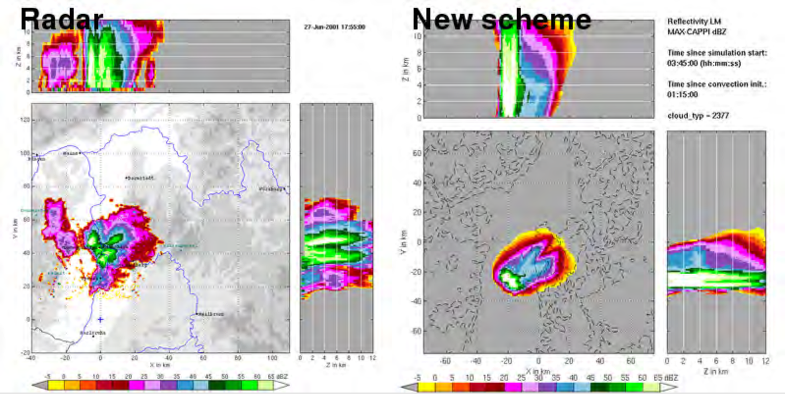

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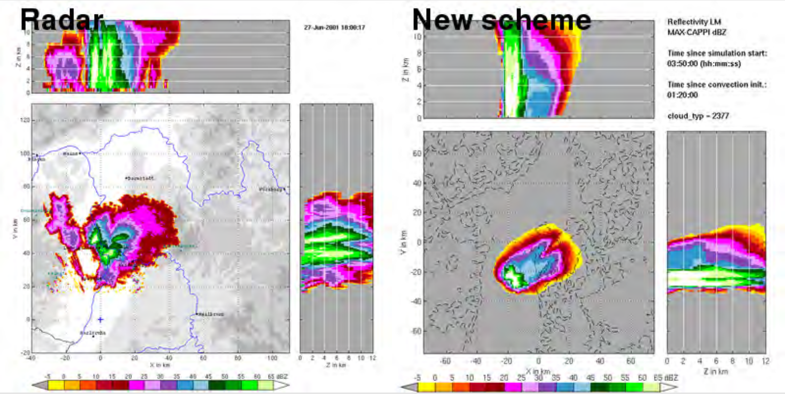

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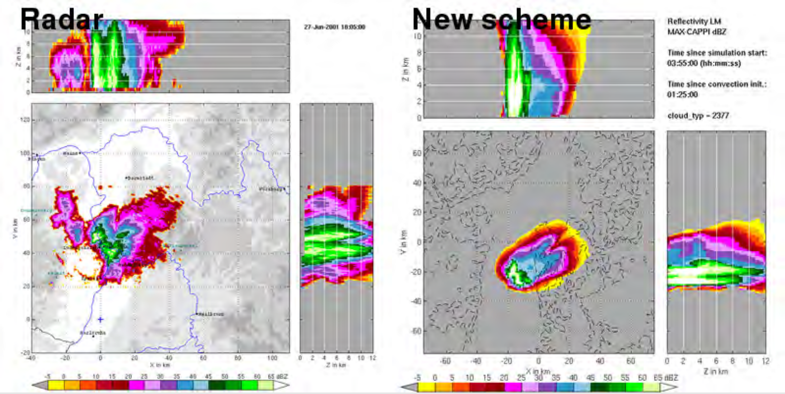

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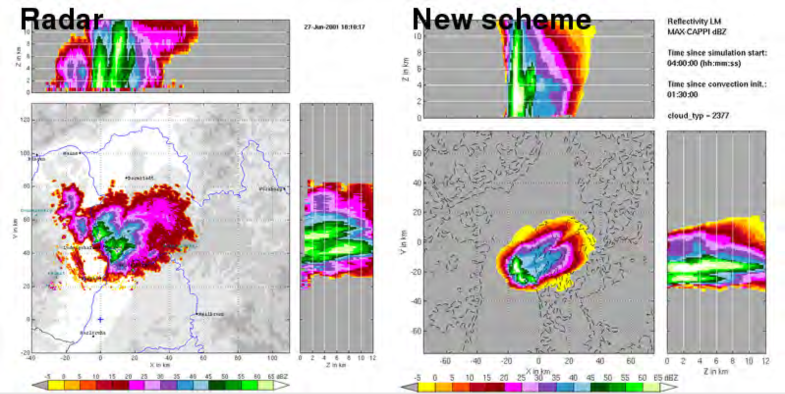

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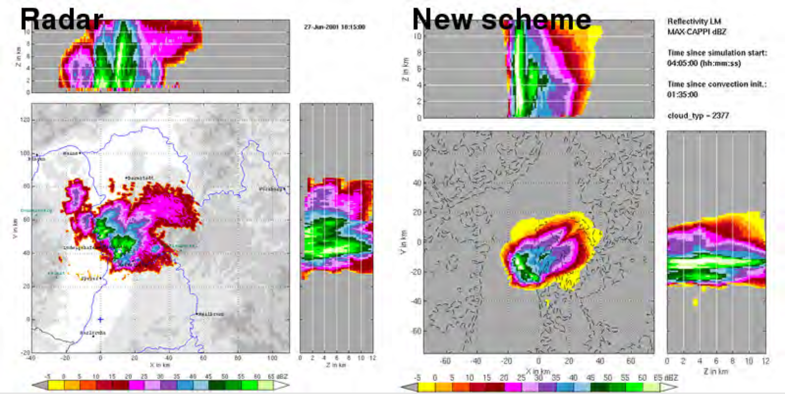

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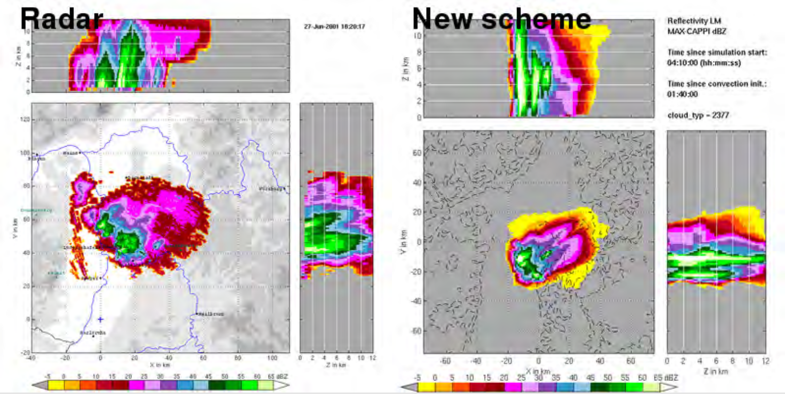

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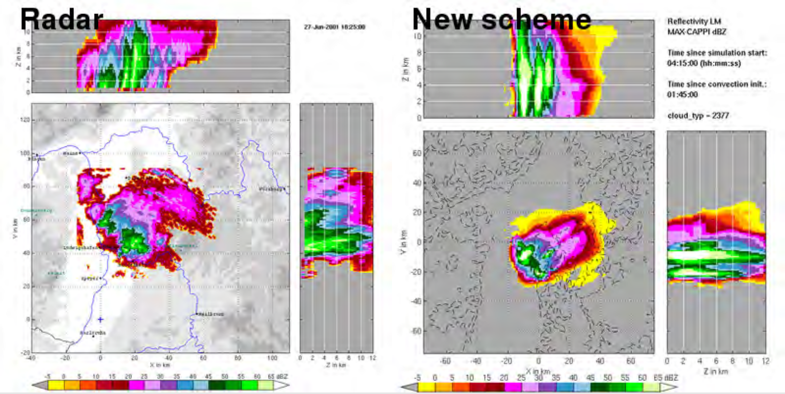

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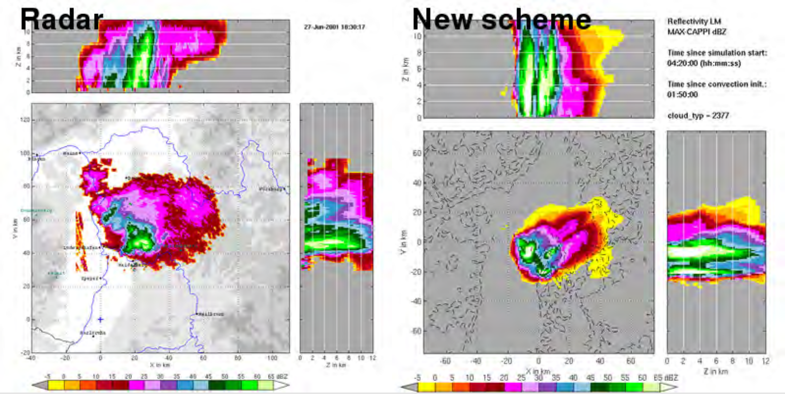

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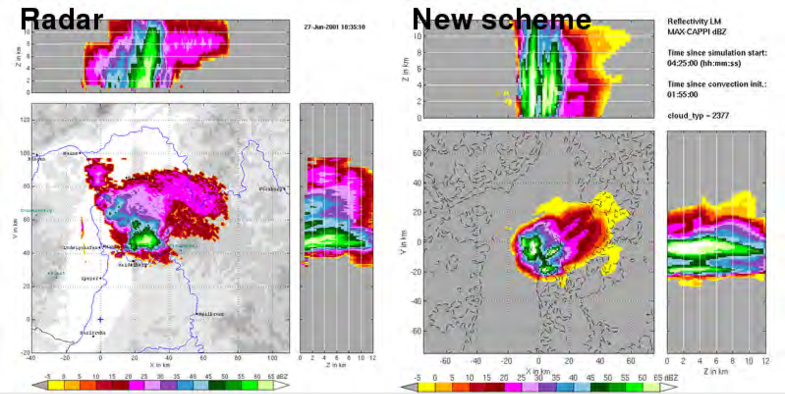

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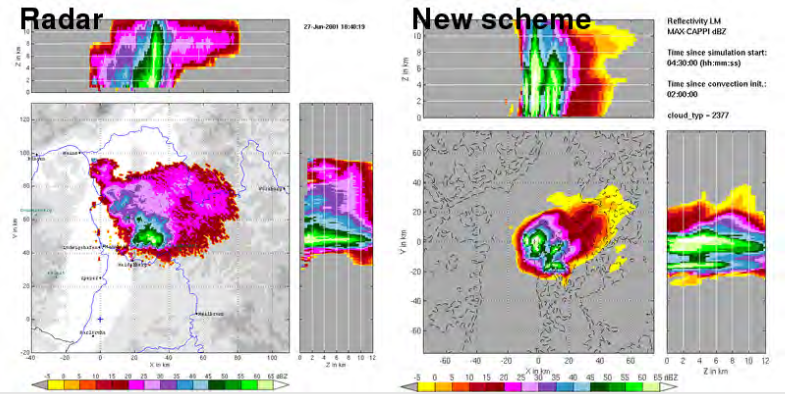

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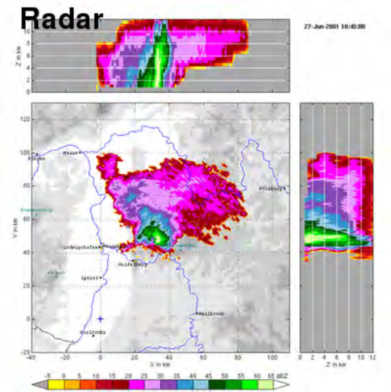

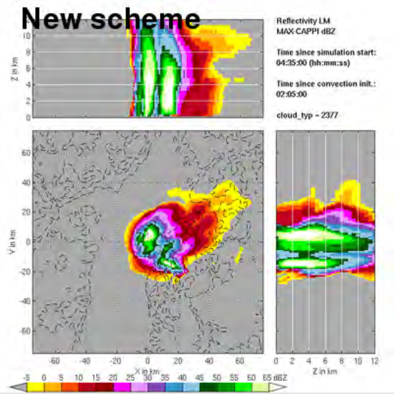

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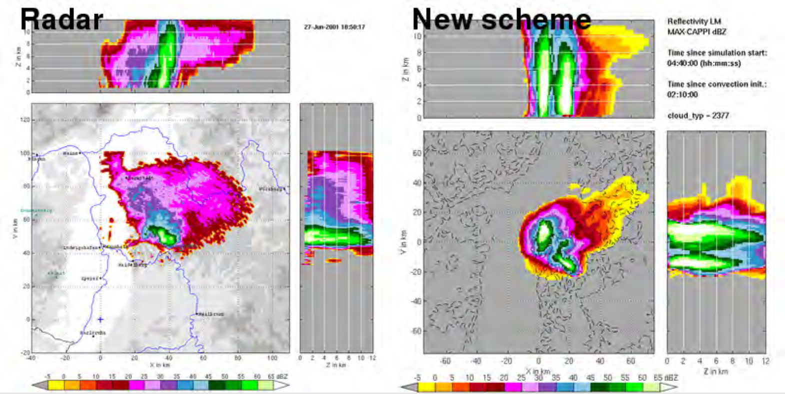

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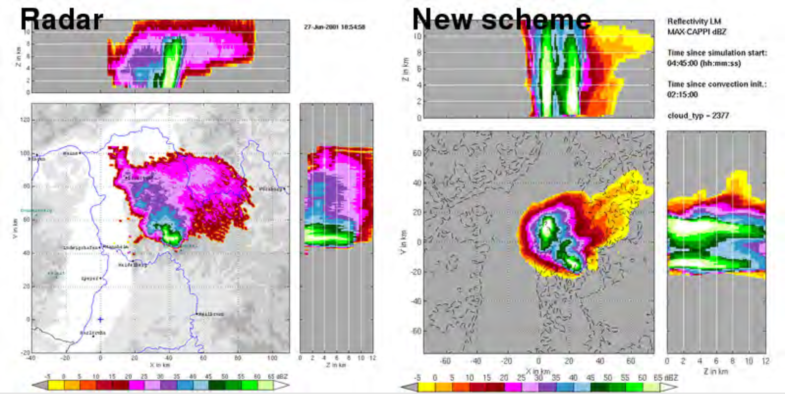

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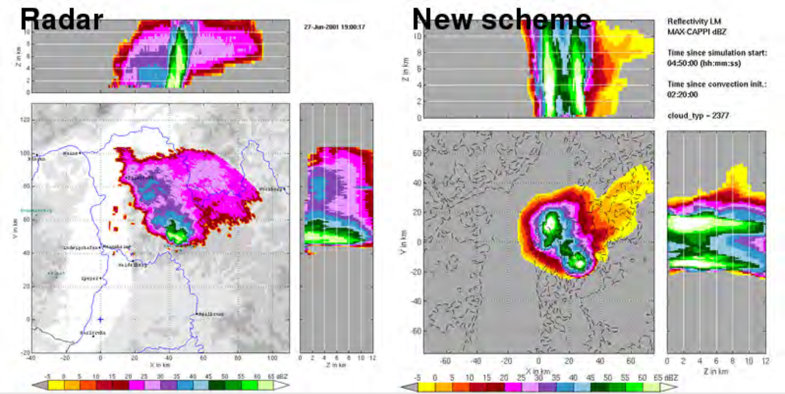

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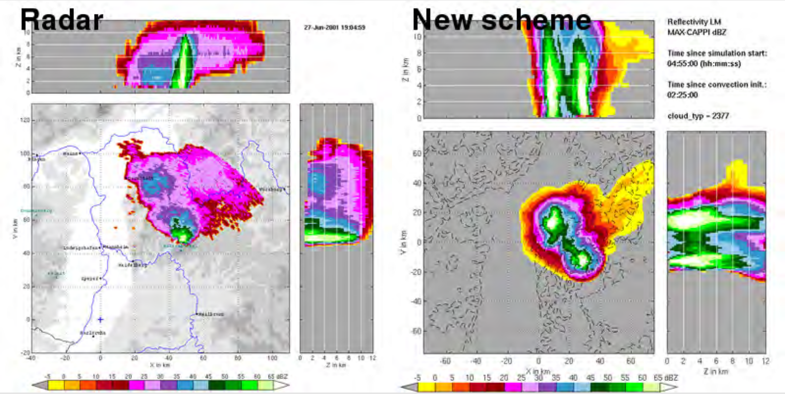

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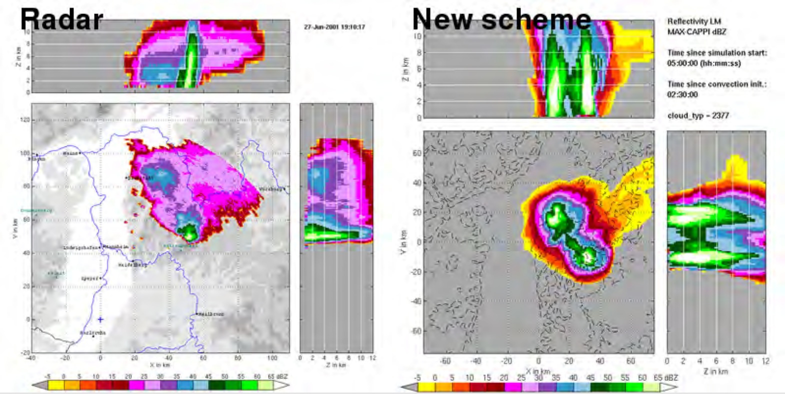

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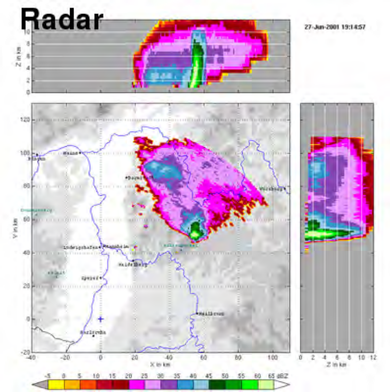
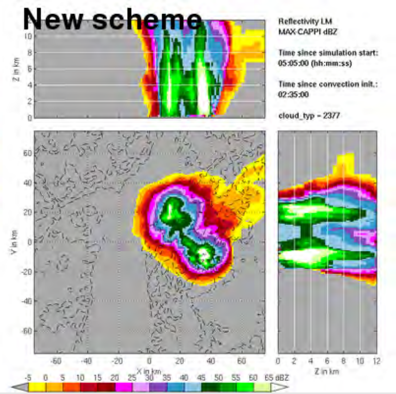


Semi-idealized COSMO run



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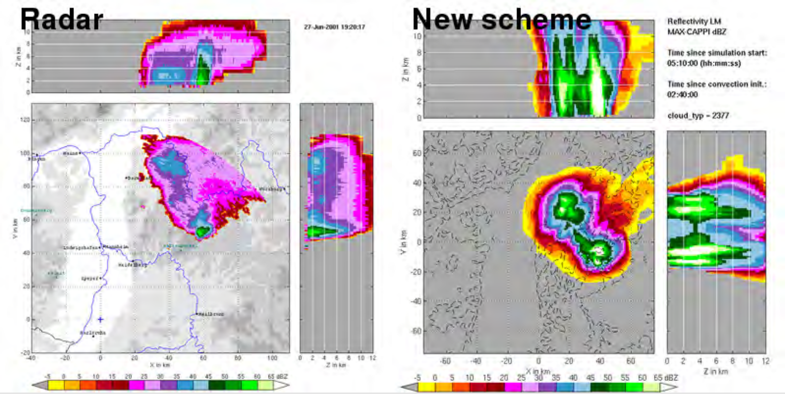

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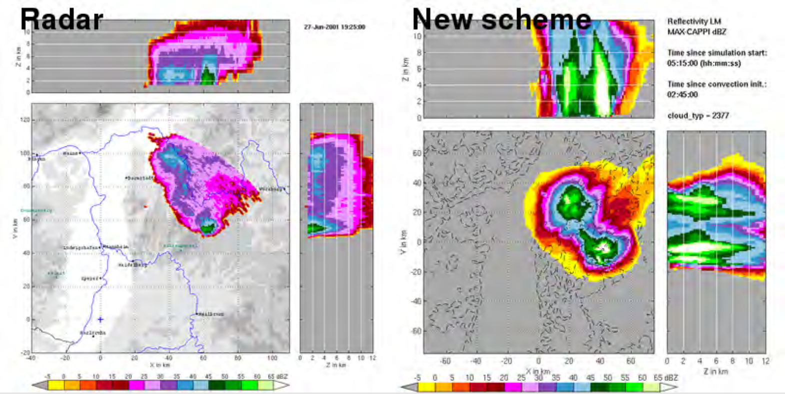

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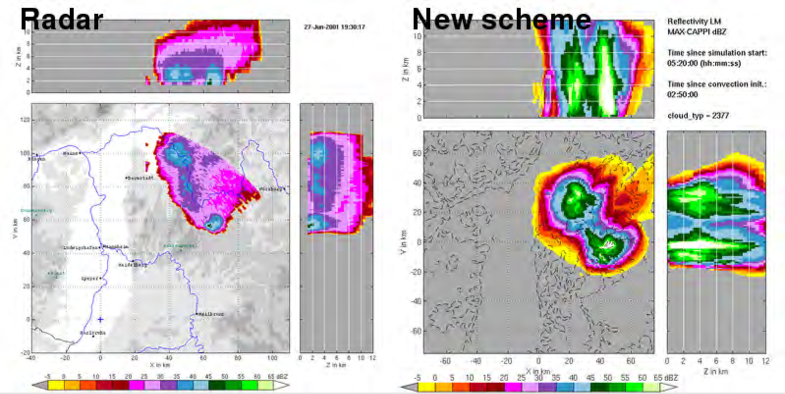
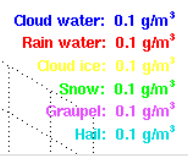
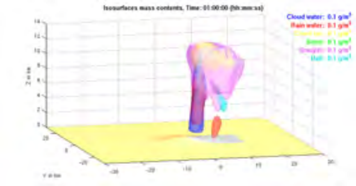
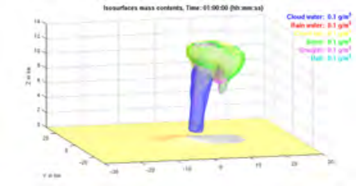
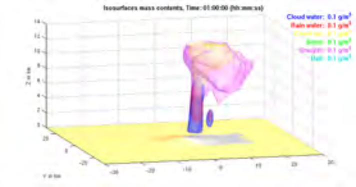
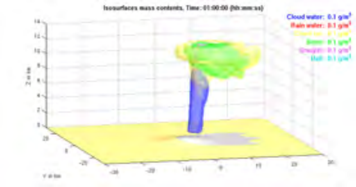


revert

Study on „Continentality“/ temperature regime



Isosurfaces of mass densitiy 0.1 $\mathrm{g\,m^{-3}}$ after 1:00 h

	Low CCN	High CCN
High 0°C-level		
Low 0°C-level		

Study on „Continentality“/ temperature regime

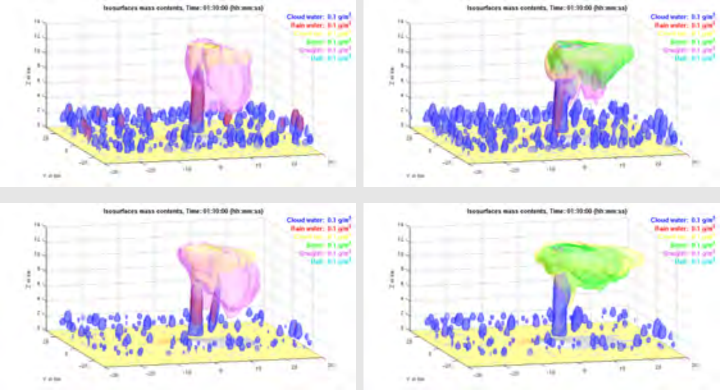
Isosurfaces of mass densitiy 0.1 $g\,m^{-3}$ after 1:10 h

Low CCN

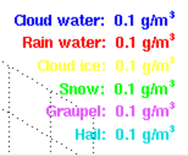
High CCN

High 0°C-level

Low 0°C-level



Study on „Continentality“/ temperature regime

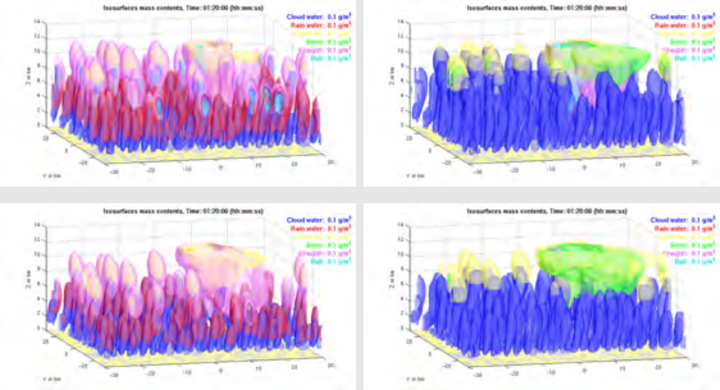


Isosurfaces of mass densitiy 0.1 g m^{-3} after 1:20 h

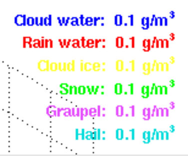
Low CCN | High CCN

High 0°C-level

Low 0°C-level



Study on „Continentality“/ temperature regime



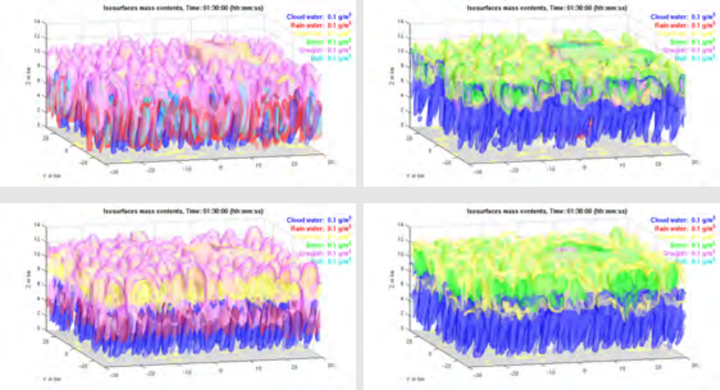
Isosurfaces of mass densitiy 0.1 g m^{-3} after 1:30 h

Low CCN

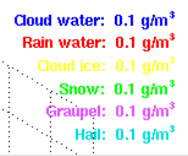
High CCN

High 0°C-level

Low 0°C-level



Study on „Continentality“/ temperature regime



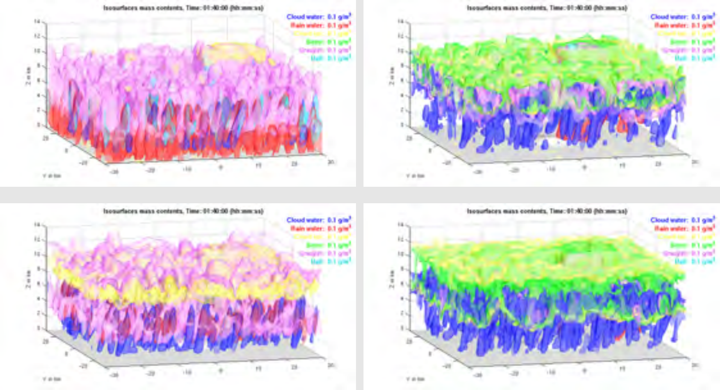
Isosurfaces of mass densitiy 0.1 g m^{-3} after 1:40 h

Low CCN

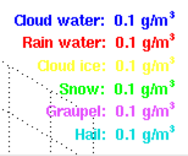
High CCN

High 0°C-level

Low 0°C-level



Study on „Continentality“/ temperature regime



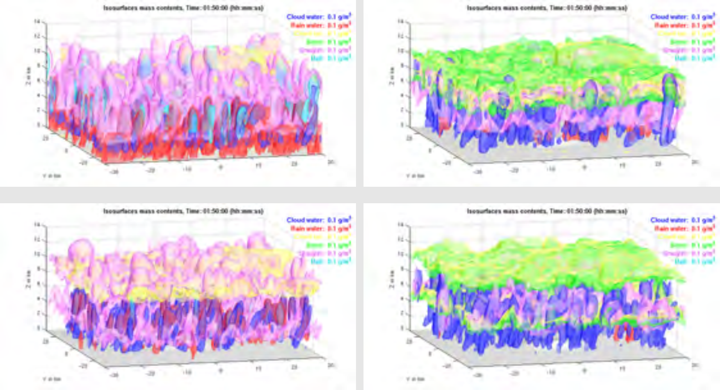
Isosurfaces of mass densitiy 0.1 $g\,m^{-3}$ after 1:50 h

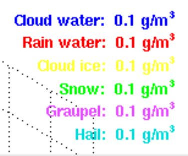
Low CCN

High CCN

High 0°C-level

Low 0°C-level



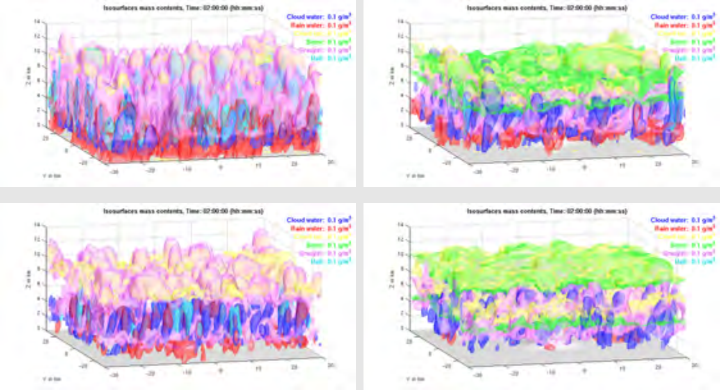


Isosurfaces of mass densitiy 0.1 $\mathrm{g\,m^{-3}}$ after 2:00 h

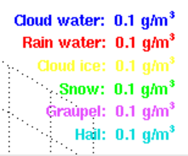
Low CCN | High CCN

High 0°C-level

Low 0°C-level



Study on „Continentality“/ temperature regime

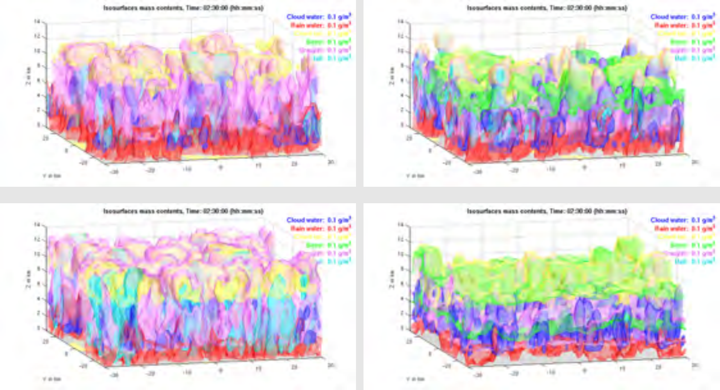


Isosurfaces of mass densitiy 0.1 g m^{-3} after 2:30 h

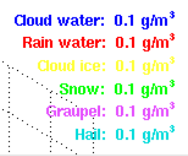
Low CCN | High CCN

High 0°C-level

Low 0°C-level



Study on „Continentality“/ temperature regime

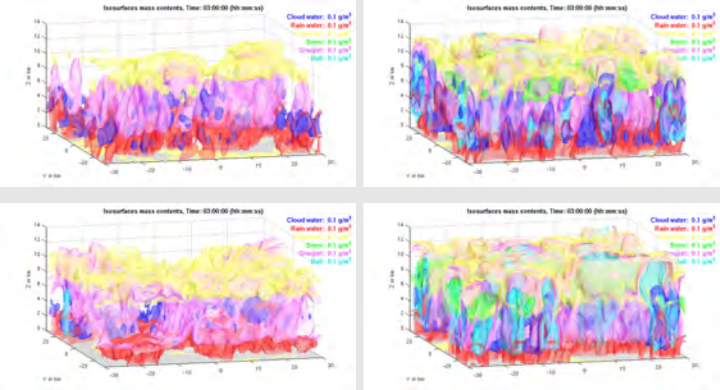


Isosurfaces of mass densitiy 0.1 g m^{-3} after 3:00 h

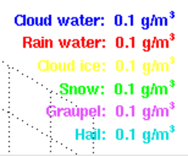
Low CCN | High CCN

High 0°C-level

Low 0°C-level



Study on „Continentality“/ temperature regime



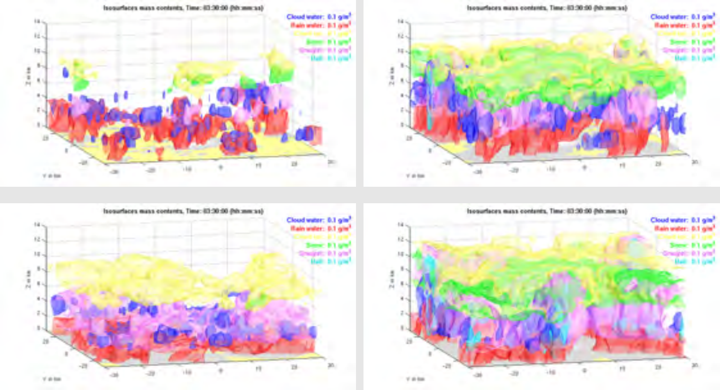
Isosurfaces of mass densitiy 0.1 $g\,m^{-3}$ after 3:30 h

Low CCN

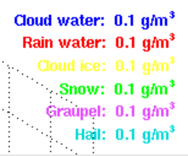
High CCN

High 0°C-level

Low 0°C-level



Study on „Continentality“/ temperature regime

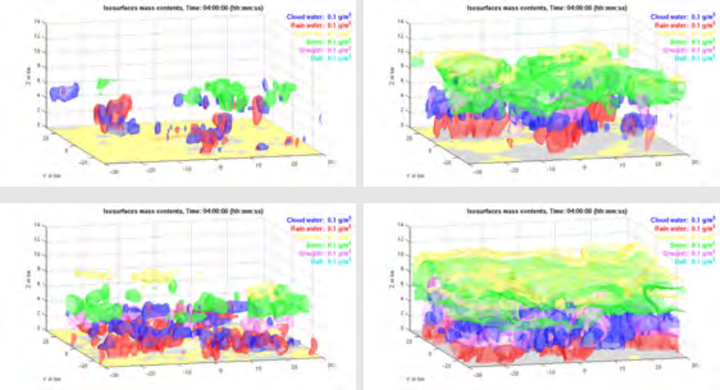


Isosurfaces of mass densitiy 0.1 g m^{-3} after 4:00 h

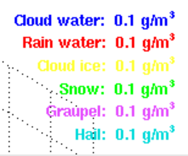
Low CCN | High CCN

High 0°C-level

Low 0°C-level



Study on „Continentality“/ temperature regime

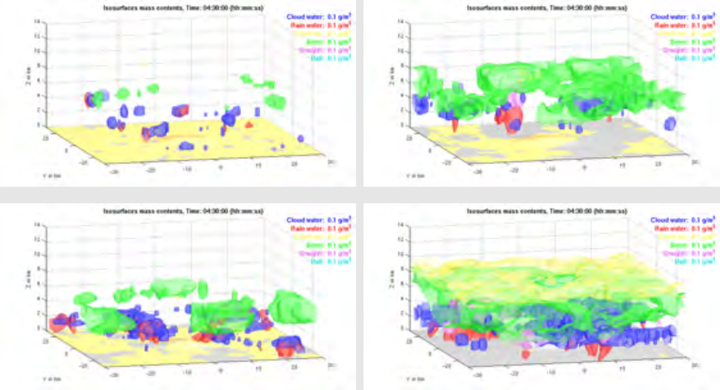


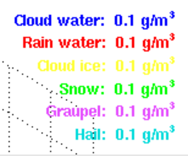
Isosurfaces of mass densitiy 0.1 $\mathrm{g\,m^{-3}}$ after 4:30 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level



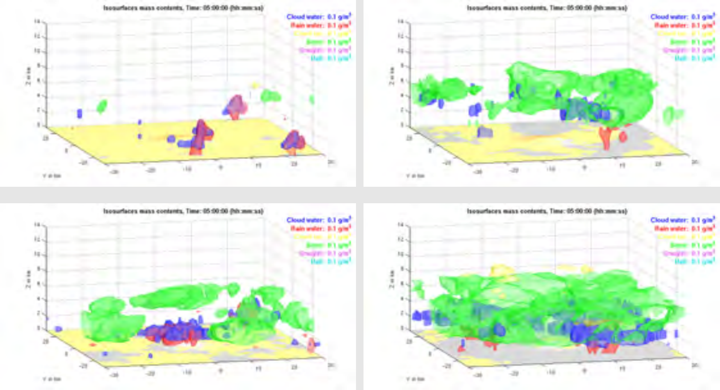


Isosurfaces of mass densitiy 0.1 $\mathrm{g\,m^{-3}}$ after 5:00 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level



Study on „Continentality“/ temperature regime

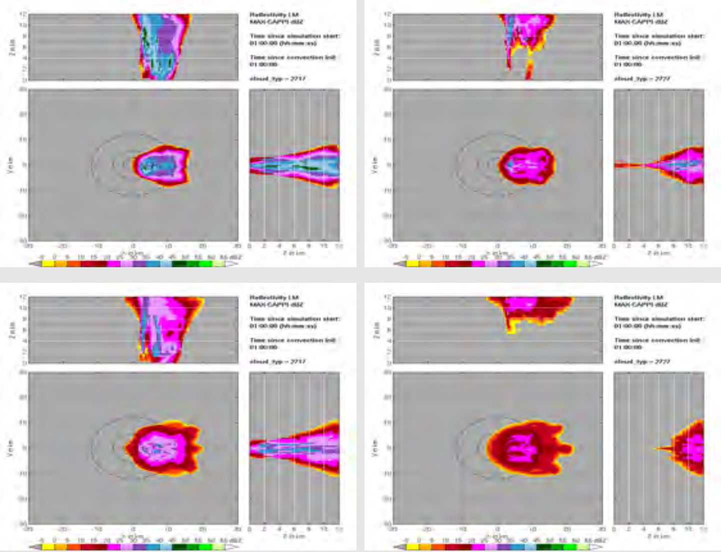
Simul. radar reflectivity in dBZ after 1:00 h

Low CCN

High CCN

High 0°C-level

Low 0°C-level



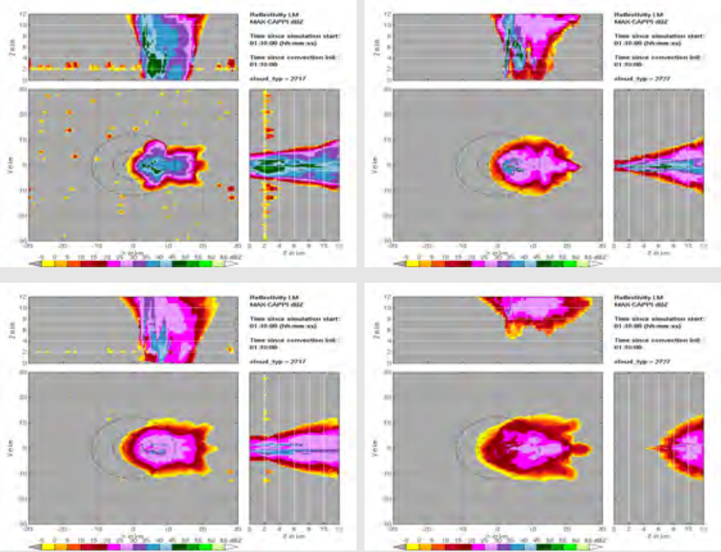
Study on „Continentality“/ temperature regime

Simul. radar reflectivity in dBZ after 1:10 h

Low CCN | High CCN

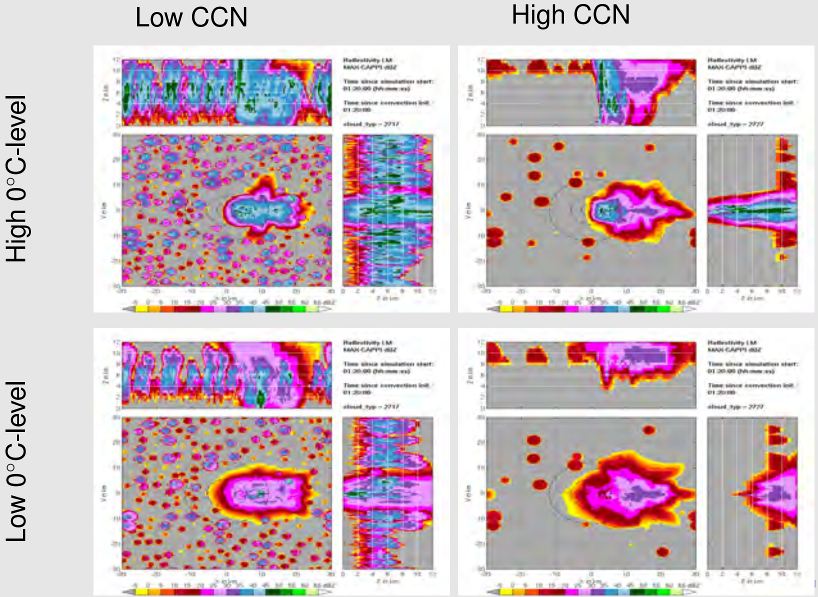
High 0°C-level

Low 0°C-level



Study on „Continentality“/ temperature regime

Simul. radar reflectivity in dBZ after 1:20 h



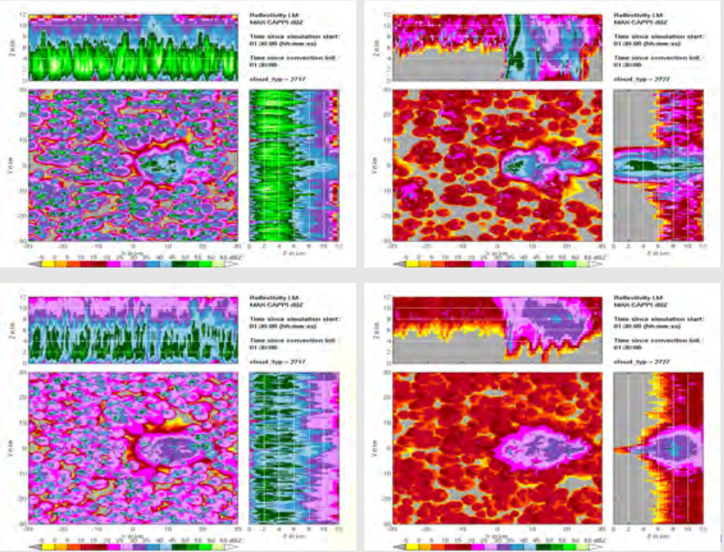
Study on „Continentality“/ temperature regime

Simul. radar reflectivity in dBZ after 1:30 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level



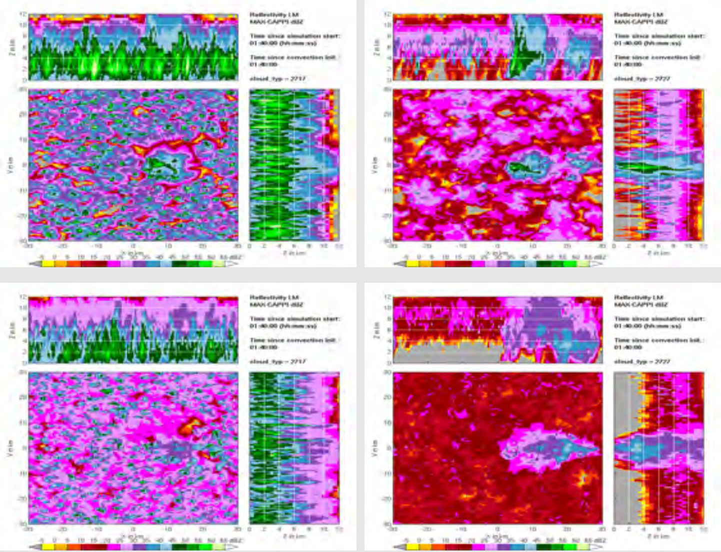
Study on „Continentality“/ temperature regime

Simul. radar reflectivity in dBZ after 1:40 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level



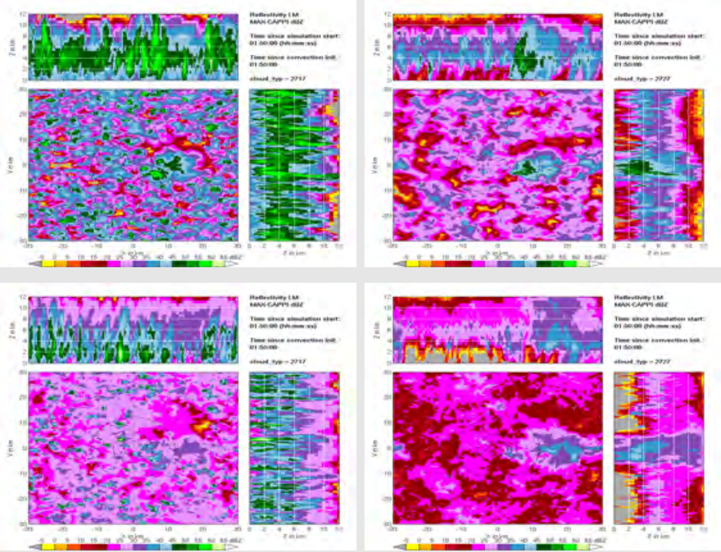
Study on „Continentality“/ temperature regime

Simul. radar reflectivity in dBZ after 1:50 h

Low CCN High CCN

High 0°C-level

Low 0°C-level



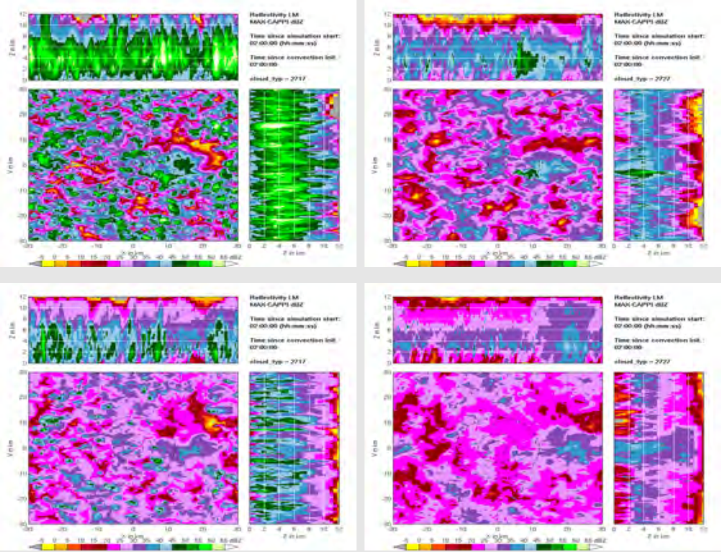
Study on „Continentality“/ temperature regime

Simul. radar reflectivity in dBZ after 2:00 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level



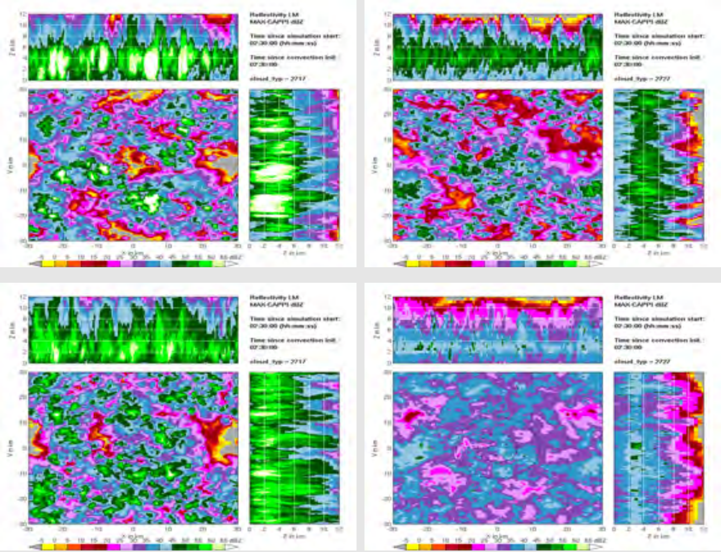
Study on „Continentality“/ temperature regime

Simul. radar reflectivity in dBZ after 2:30 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level



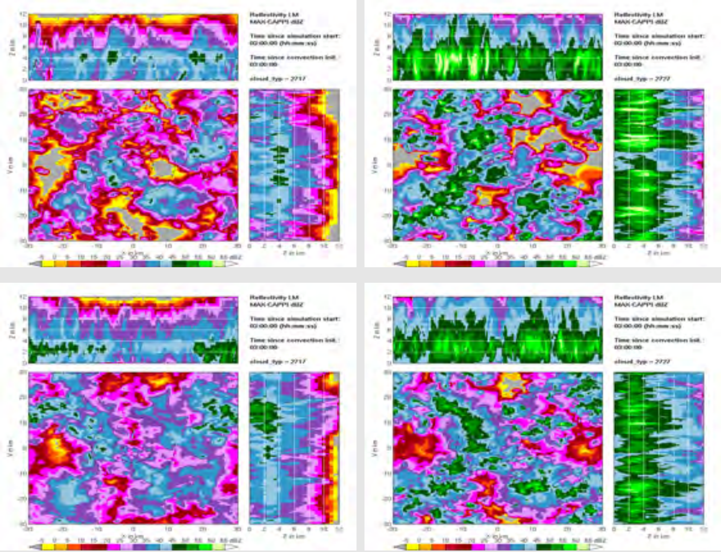
Study on „Continentality“/ temperature regime

Simul. radar reflectivity in dBZ after 3:00 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level



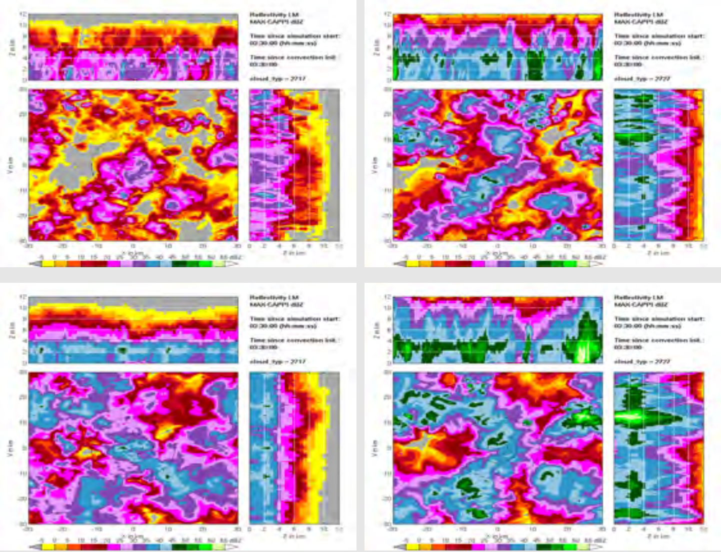
Study on „Continentality“/ temperature regime

Simul. radar reflectivity in dBZ after 3:30 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level



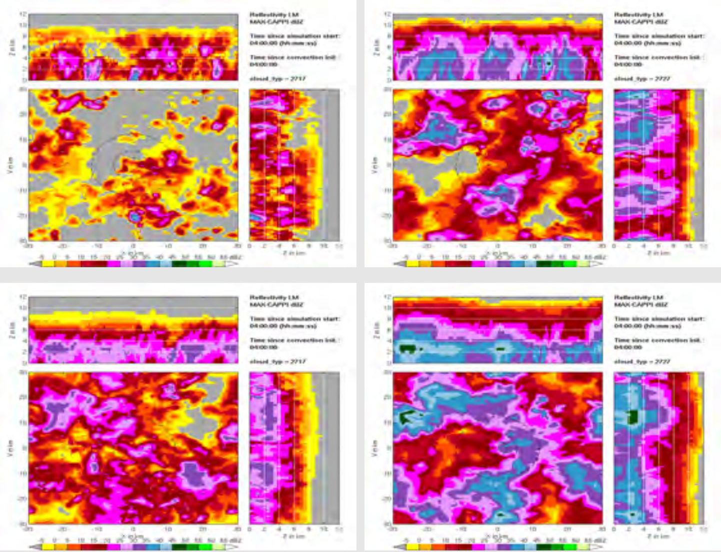
Study on „Continentality“/ temperature regime

Simul. radar reflectivity in dBZ after 4:00 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level



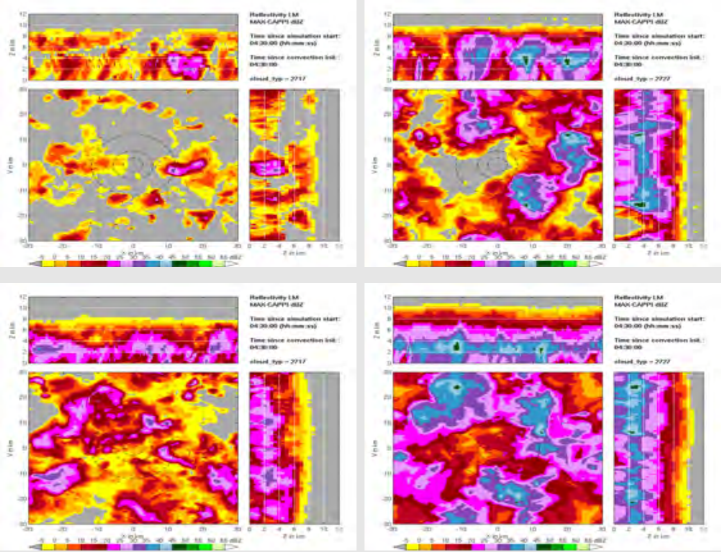
Study on „Continentality“/ temperature regime

Simul. radar reflectivity in dBZ after 4:30 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level



Study on „Continentality“/ temperature regime

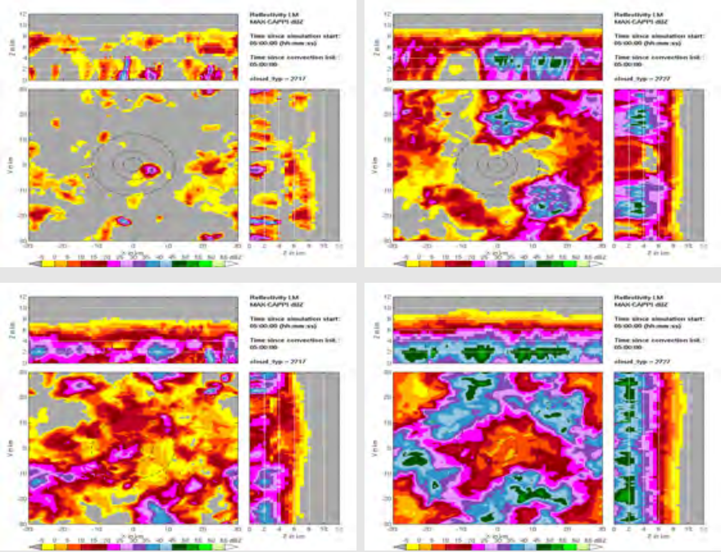
Simul. radar reflectivity in dBZ after 5:00 h

Low CCN

High CCN

High 0°C-level

Low 0°C-level



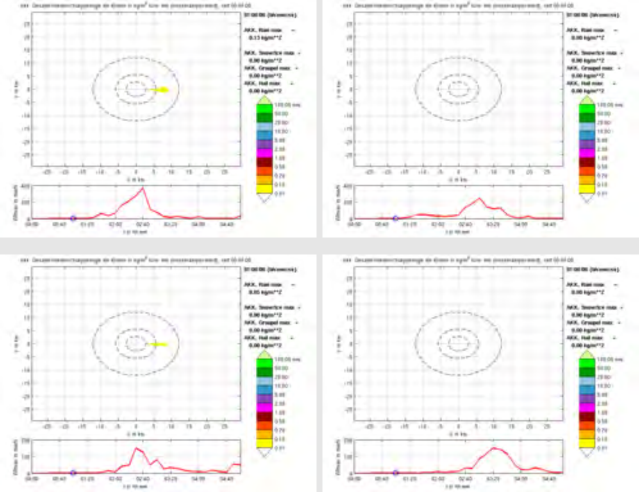
Study on „Continentality“/ temperature regime

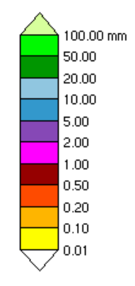
Accumulated precipitation in mm after after 1:00 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level

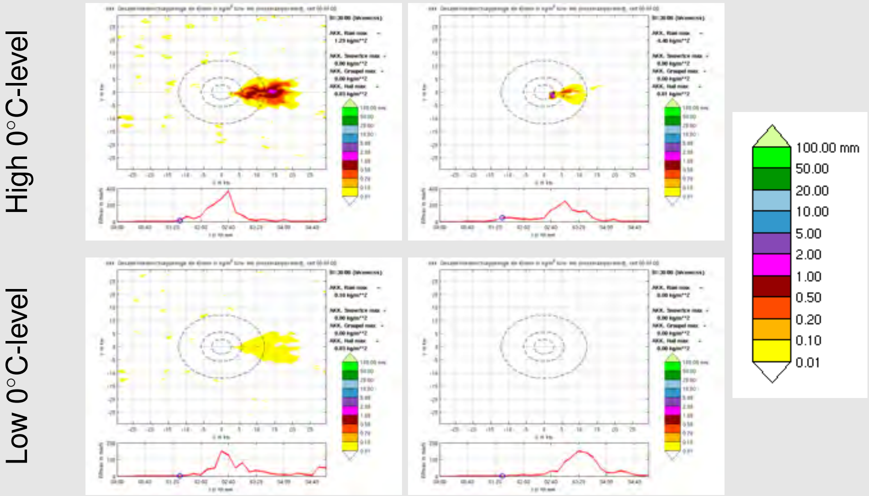




Study on „Continentality“/ temperature regime

Accumulated precipitation in mm after after 1:30 h

Low CCN High CCN



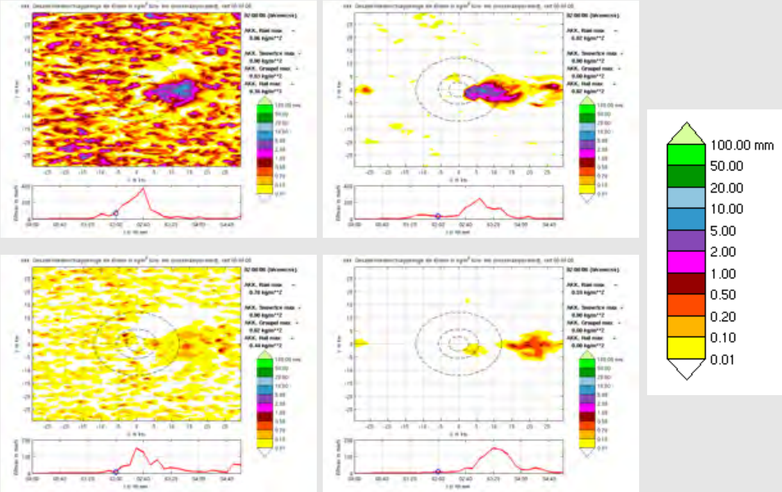
Study on „Continentality“/ temperature regime

Accumulated precipitation in mm after after 2:00 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level



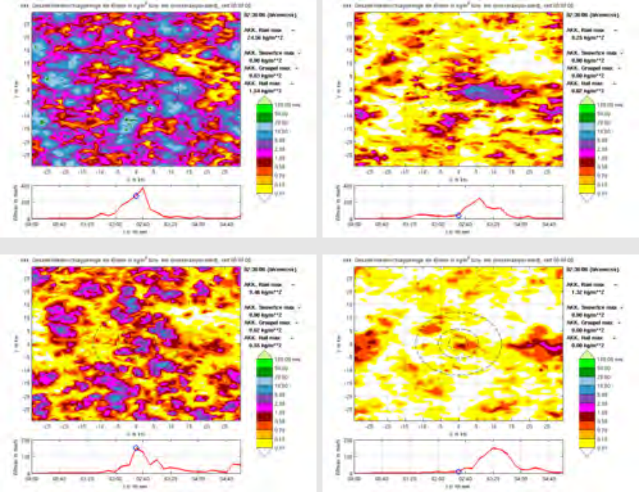
Study on „Continentality“/ temperature regime

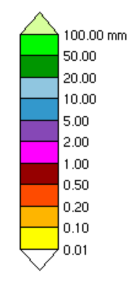
Accumulated precipitation in mm after after 2:30 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level





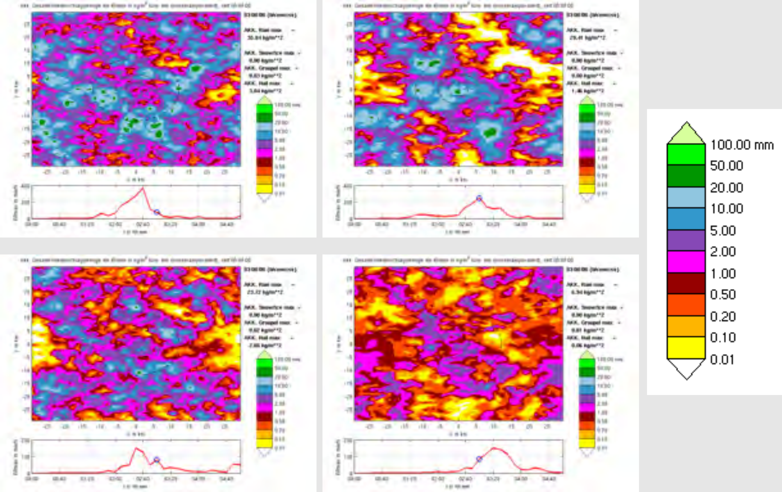
Study on „Continentality“/ temperature regime

Accumulated precipitation in mm after after 3:00 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level



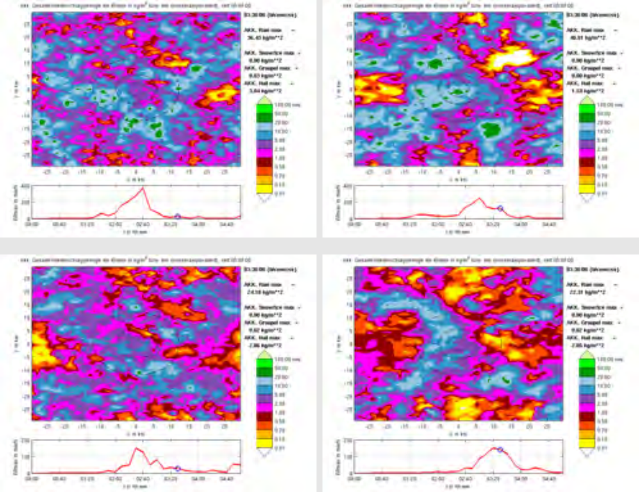
Study on „Continentality“/ temperature regime

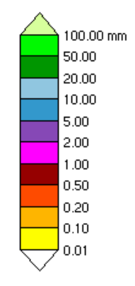
Accumulated precipitation in mm after after 3:30 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level





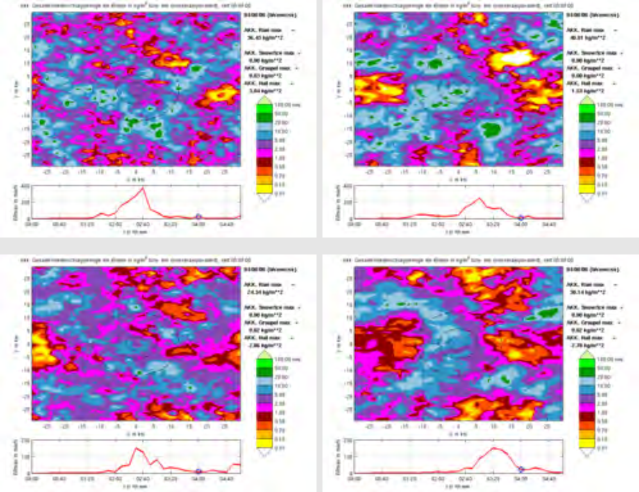
Study on „Continentality“/ temperature regime

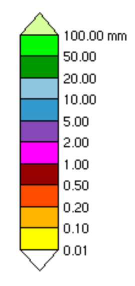
Accumulated precipitation in mm after after 4:00 h

Low CCN | High CCN

High 0°C-level

Low 0°C-level





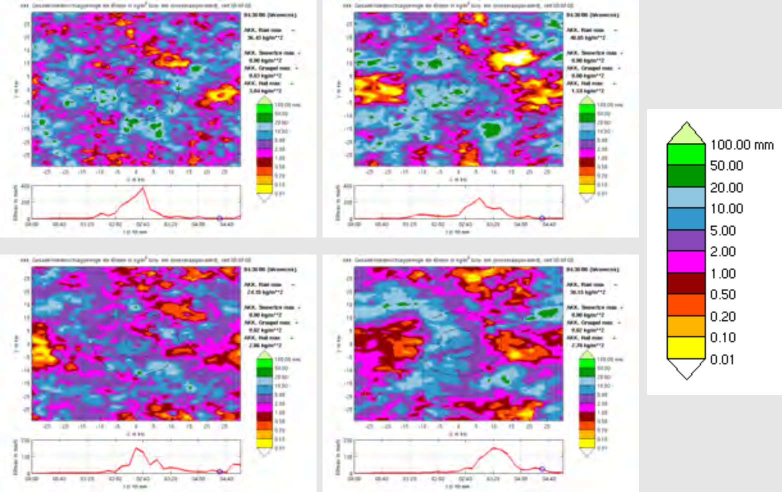
Study on „Continentality“/ temperature regime

Accumulated precipitation in mm after after 4:30 h

Low CCN High CCN

High 0°C-level

Low 0°C-level



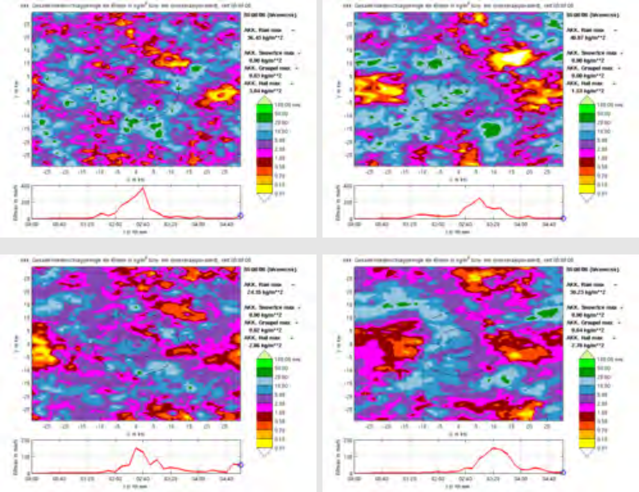
Study on „Continentality“/ temperature regime

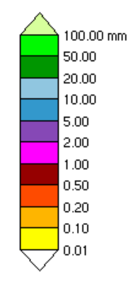
Accumulated precipitation in mm after after 5:00 h

Low CCN | High CCN

High 0°C-level

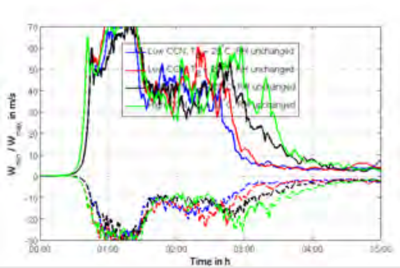
Low 0°C-level



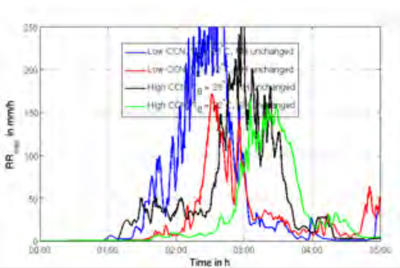


Study on „Continentality“/ temperature regime

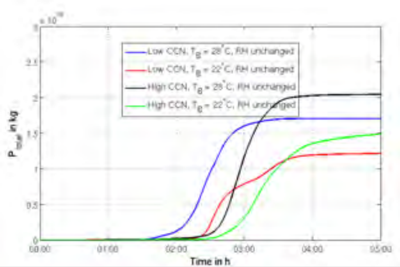
Max./min. W in $\mathrm{m\,s^{-1}}$



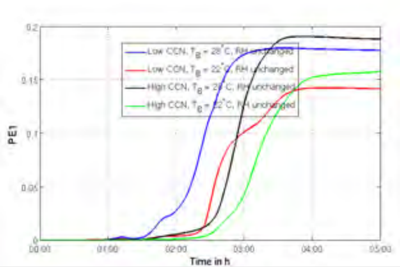
Max. R in $\mathrm{mm\,h^{-1}}$



Total precipitation in kg



Precipitation efficiency



Enough for the moment!

Hail initiation in the 2-moment scheme

New scheme