Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

Universität
Karlsruhe (TH)

Idealized cloud resolving LM simulations of single convective systems applying a two-moment bulk microphysical scheme and comparison with radar data

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Offenbach a. M.

Seminar of the LM User Group, Langen, 6.3. – 8.3.2006

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Motivation and Goals

- Investigate the influence of ambient environmental conditions on convective cells (temperature, moisture, orography, aerosol regime, . . .)

- Goal: determine other parameters than RI_b, $CAPE$, . . . , to describe the influence on intensity, precipitation efficiency and accumulation

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- Test version of the LM, based on v3.16 1/2
- Cloud resolving simulations with $\Delta x \approx 1$ km
- Idealized studies: fixed lateral bc., idealized orography
- The smaller the scale, the more detailed physical descriptions are needed.

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2-Moment Bulk Microphysical Scheme

- 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

$$f(x) = N_0 x^{\nu} \exp(-\lambda x^{\mu})$$

- Added second graupel class (”hail”) to the two-moment scheme, separating graupel particles formed by riming and by raindrop freezing.

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1. 4 Simulations: 2 different 0°C-levels, maritime/continental, 3D bell-shaped mountain
2. Shifting of T-profile at constant $CAPE$, U and vertical buoyancy distribution
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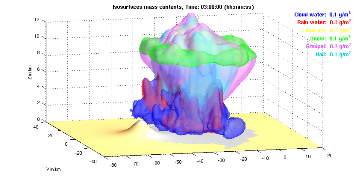
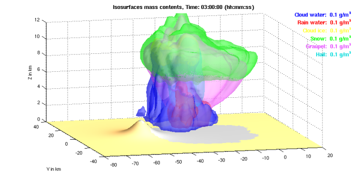
„Continentality"/ temperature regime

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

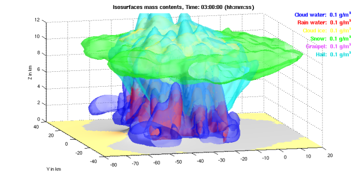
Maritime | Continental

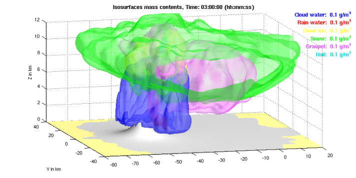
High 0°C-level





Low 0°C-level





„Continentality“/ temperature regime

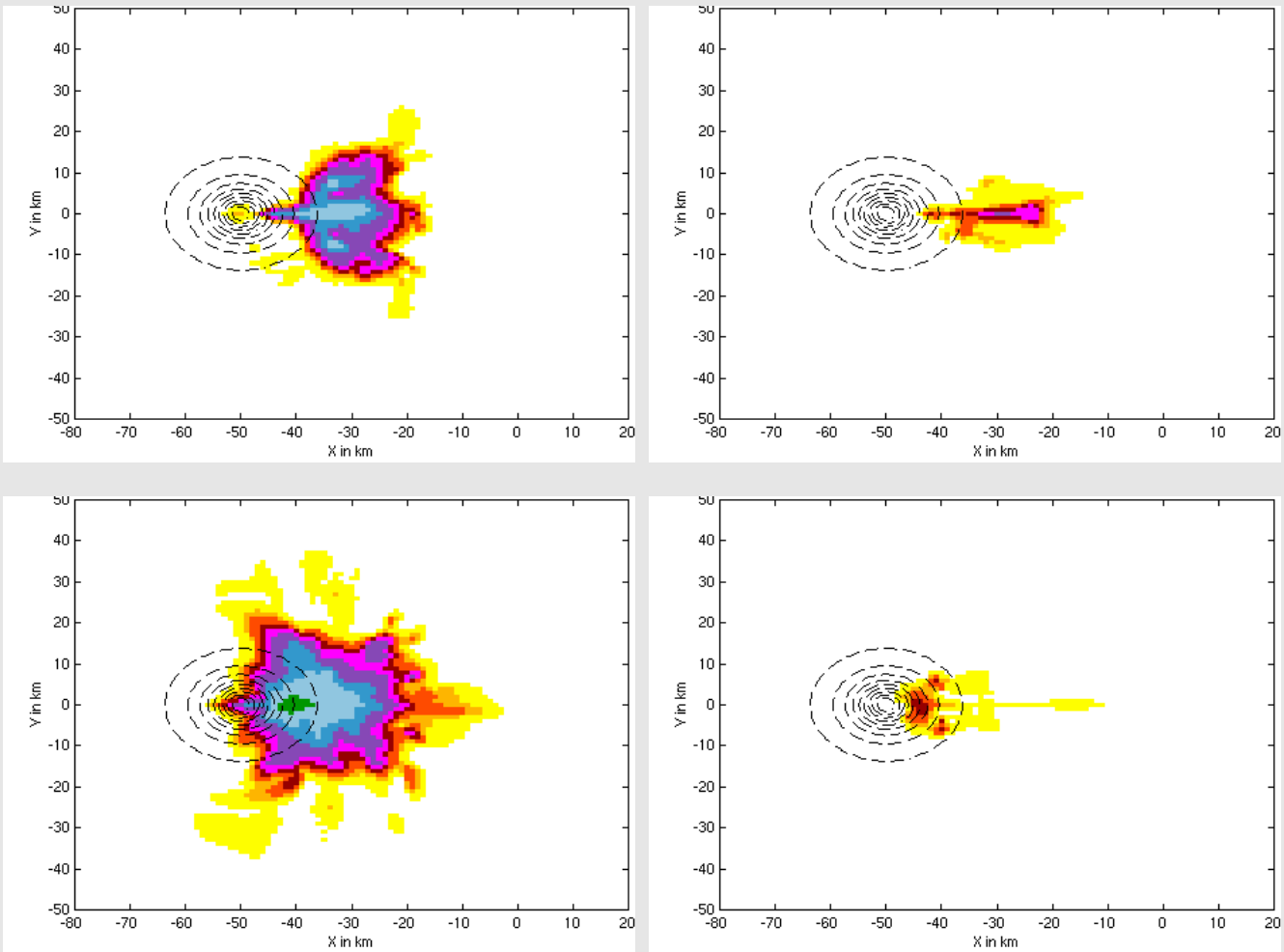
Accumulated precipitation in mm after 3 h.

Maritime

Continental

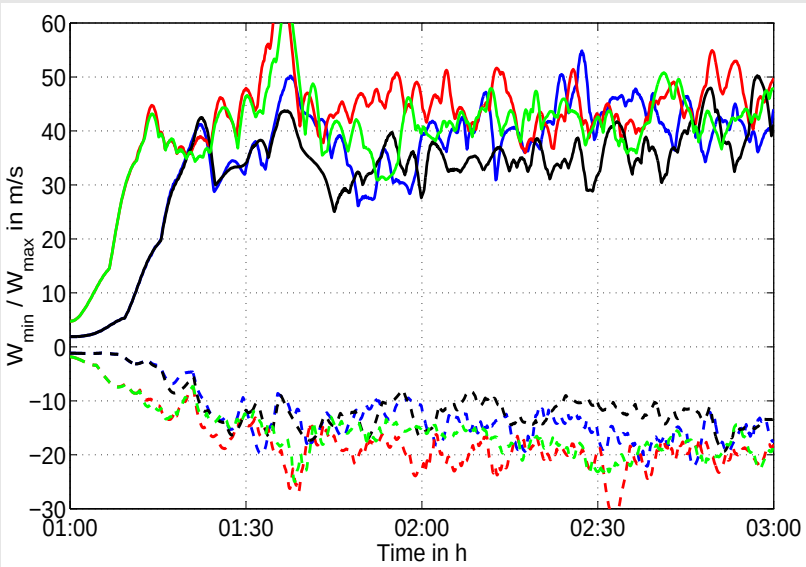
High 0°C-level

Low 0°C-level

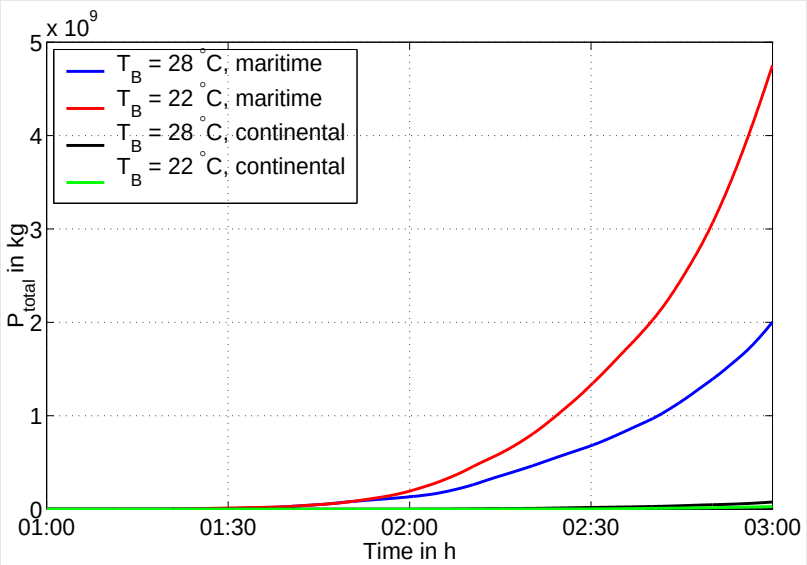


„Continentality“/ temperature regime

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



Total precipitation in 10^9kg



Moisture around the condensation level

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For illustration: 3D storm-relative streamlines of a fully developed supercell

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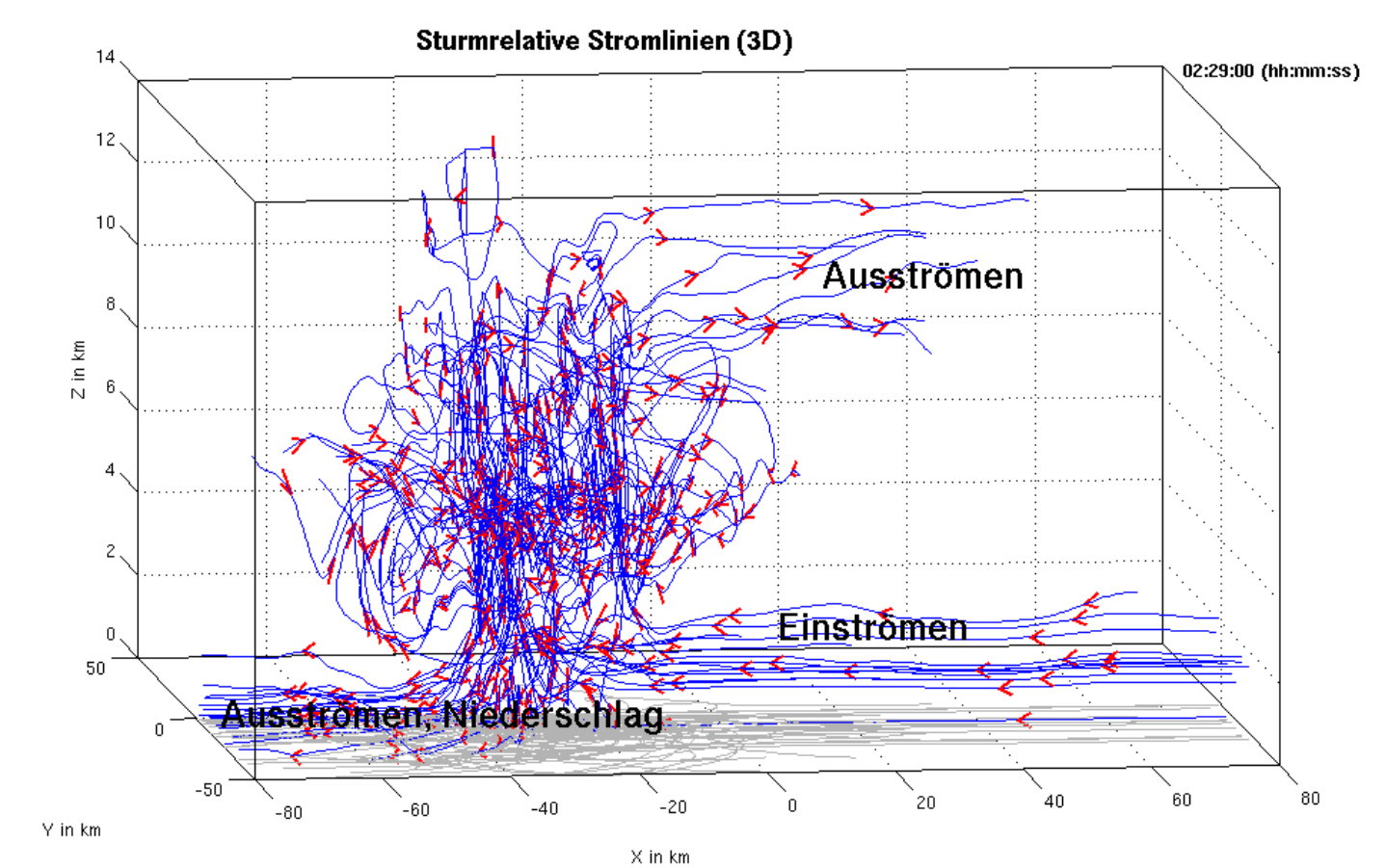

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2 simulations, $T_B = 34°C$, split-/supercell regime

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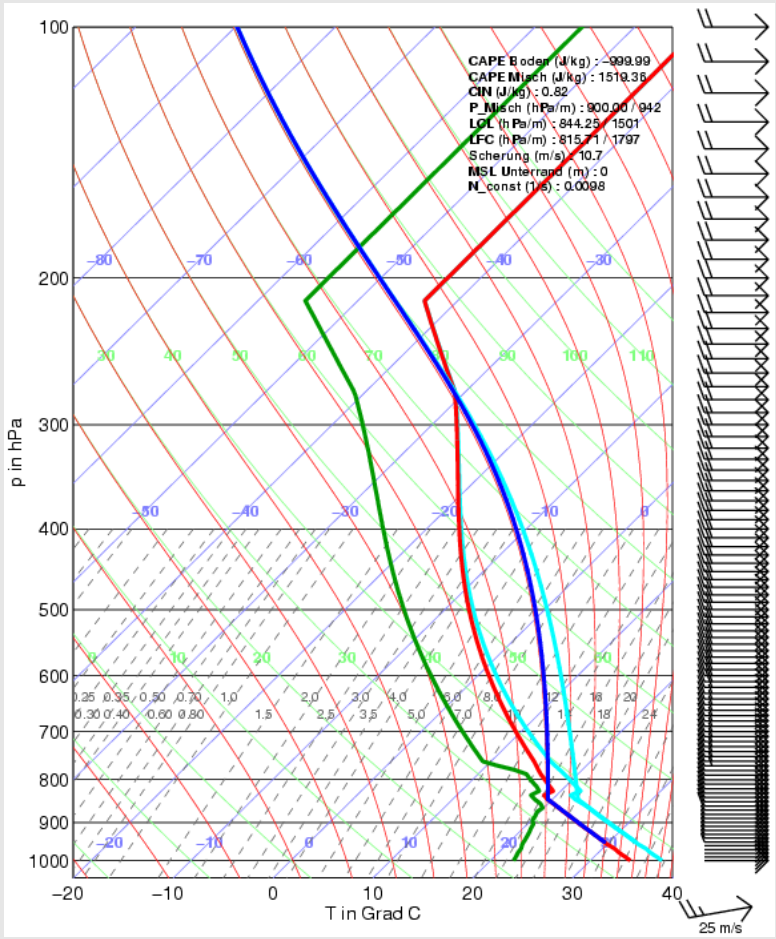
$RH_{HKN} = 92\ \%$



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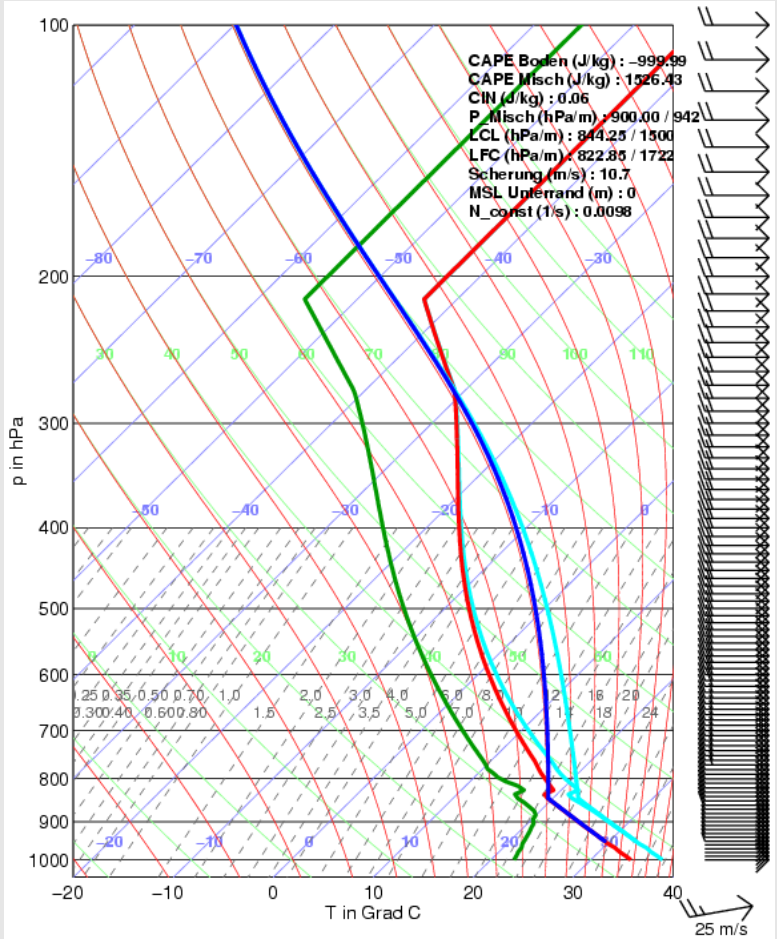

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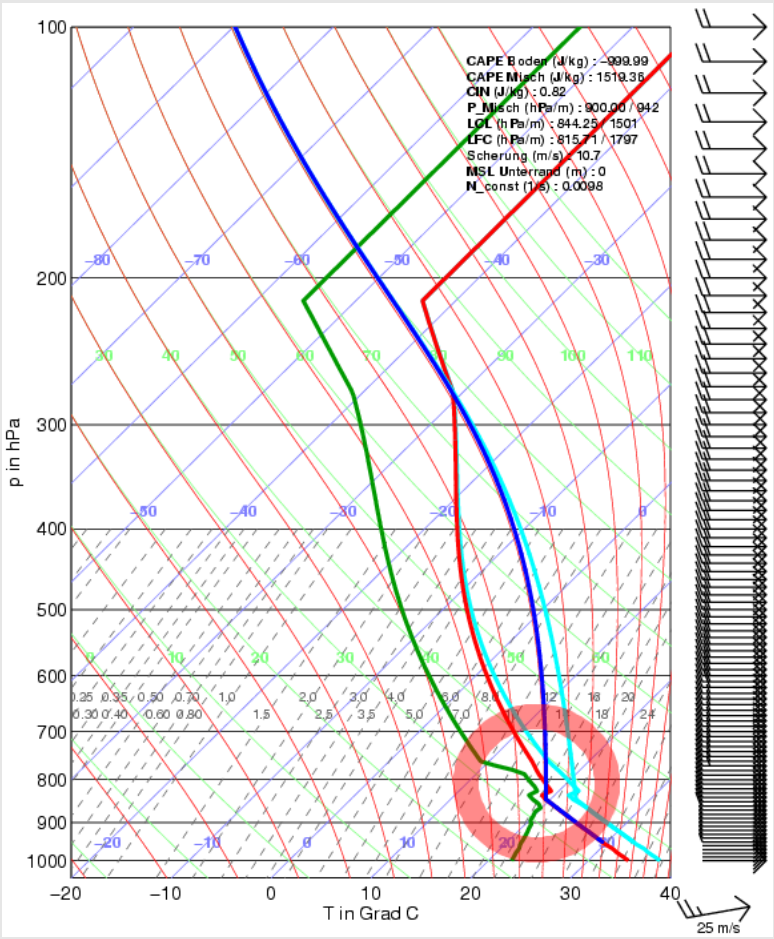

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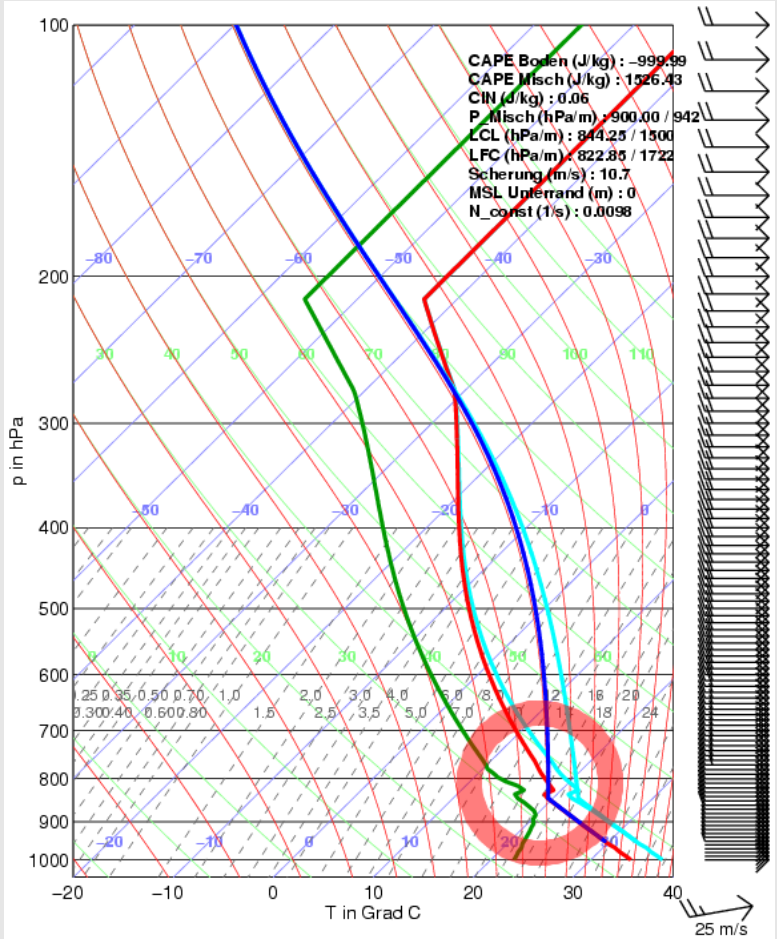

Moisture around the condensation level

Accumulated precipitation after 5 hours

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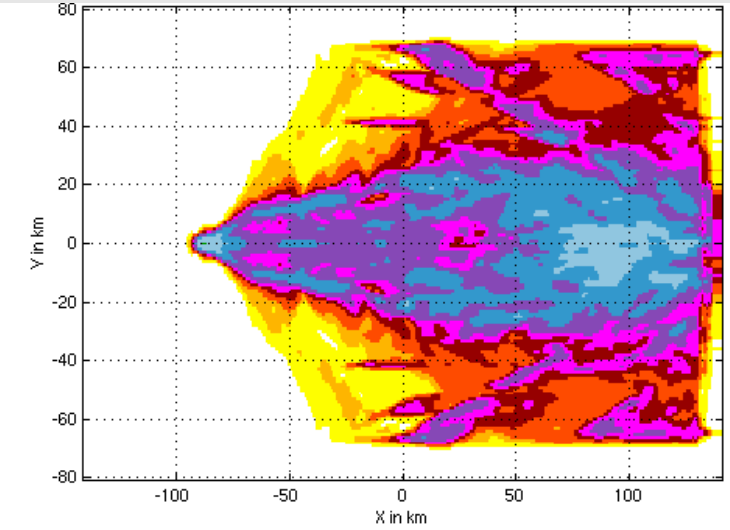

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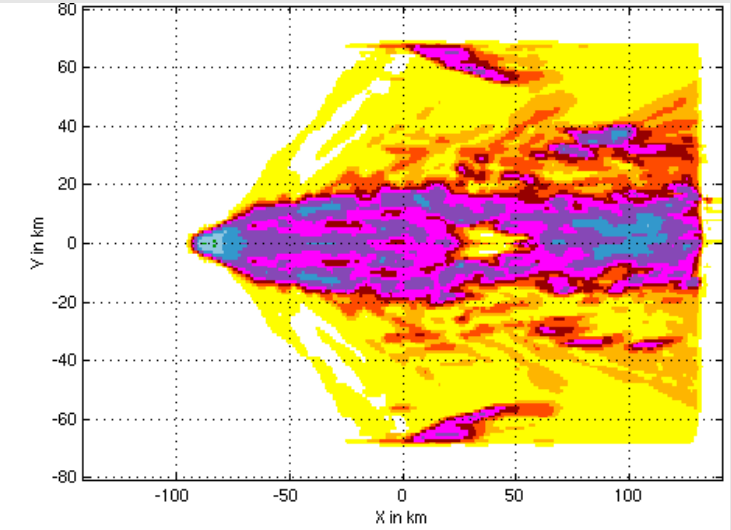

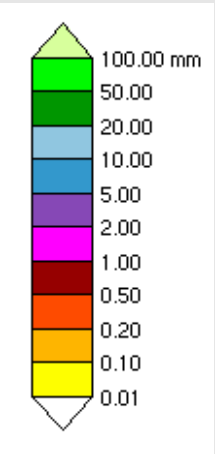

How realistic is this?

⇒ Comparison with measured radar reflectivity

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- To check the model setup qualitatively, e.g., subgrid scale turbulence parameterization (large vertical velocities are observed in simulations).
- Mainly to get a feeling for the accuracy of high resolution simulations.
- Last but not least: some parameters of the 2M-microphysics have to be adjusted.

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Calculation of radar reflectivity from model output

$$Z_e \sim \int_0^\infty \sigma_b(\text{shape}, D, \lambda, m) f(D) dD$$

- $f(D)$: gen. gamma distribution assumed, 2 free parameters deduced from hydrometeor number- and mass density.
- σ_b: Mie-scattering (one- and twolayered sphere) or Rayleigh-Approximation ($\sigma_b \sim D^6$)
- Hydrometeors = mixture of ice, air and water
  m = fct(T, λ, material, density, f_{melt})
  $\Rightarrow$ several state-of-the-art effective medium approximations implemented
  $\Rightarrow$ large variability/uncertainty in calculated Z_e
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A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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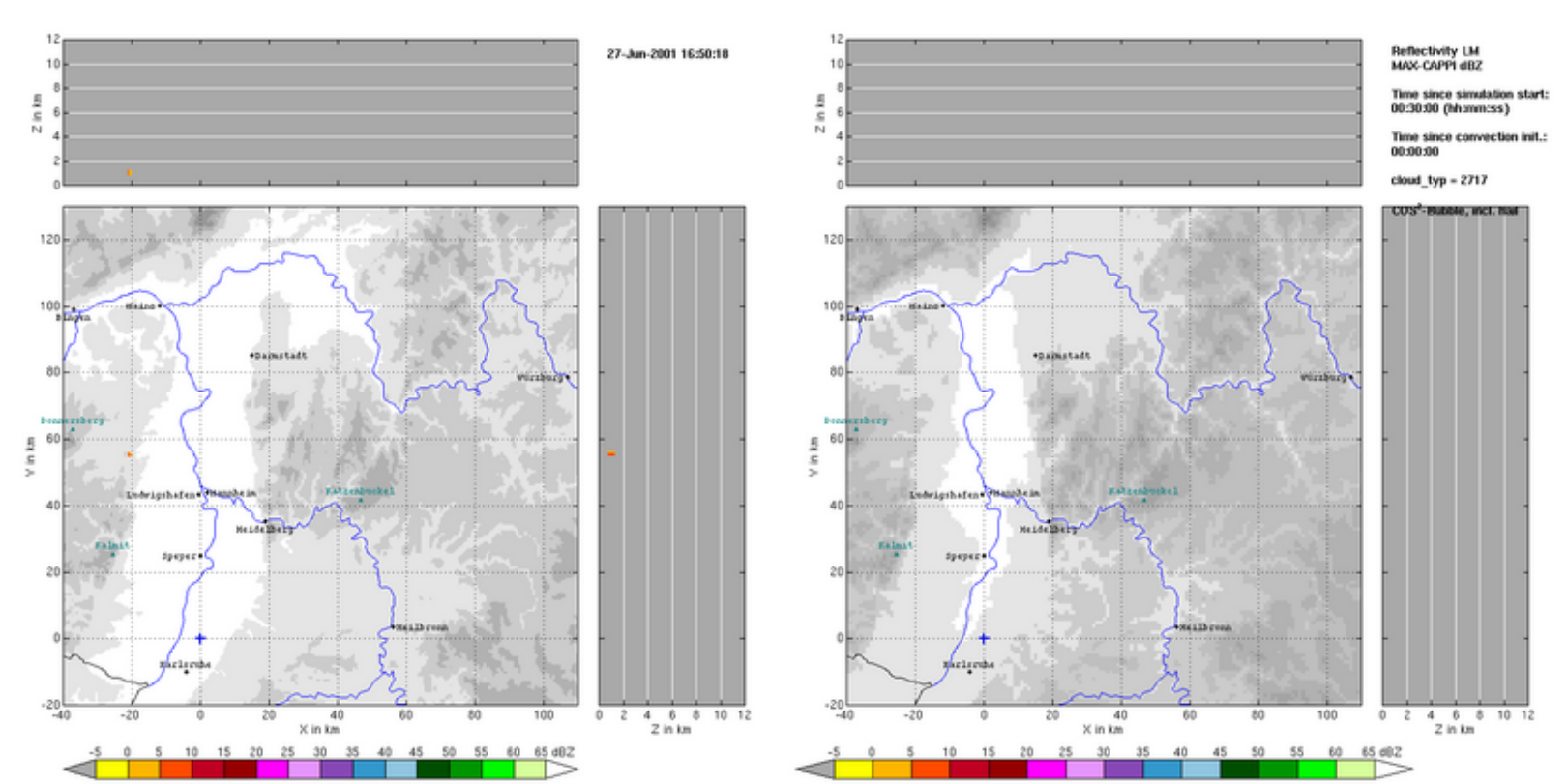

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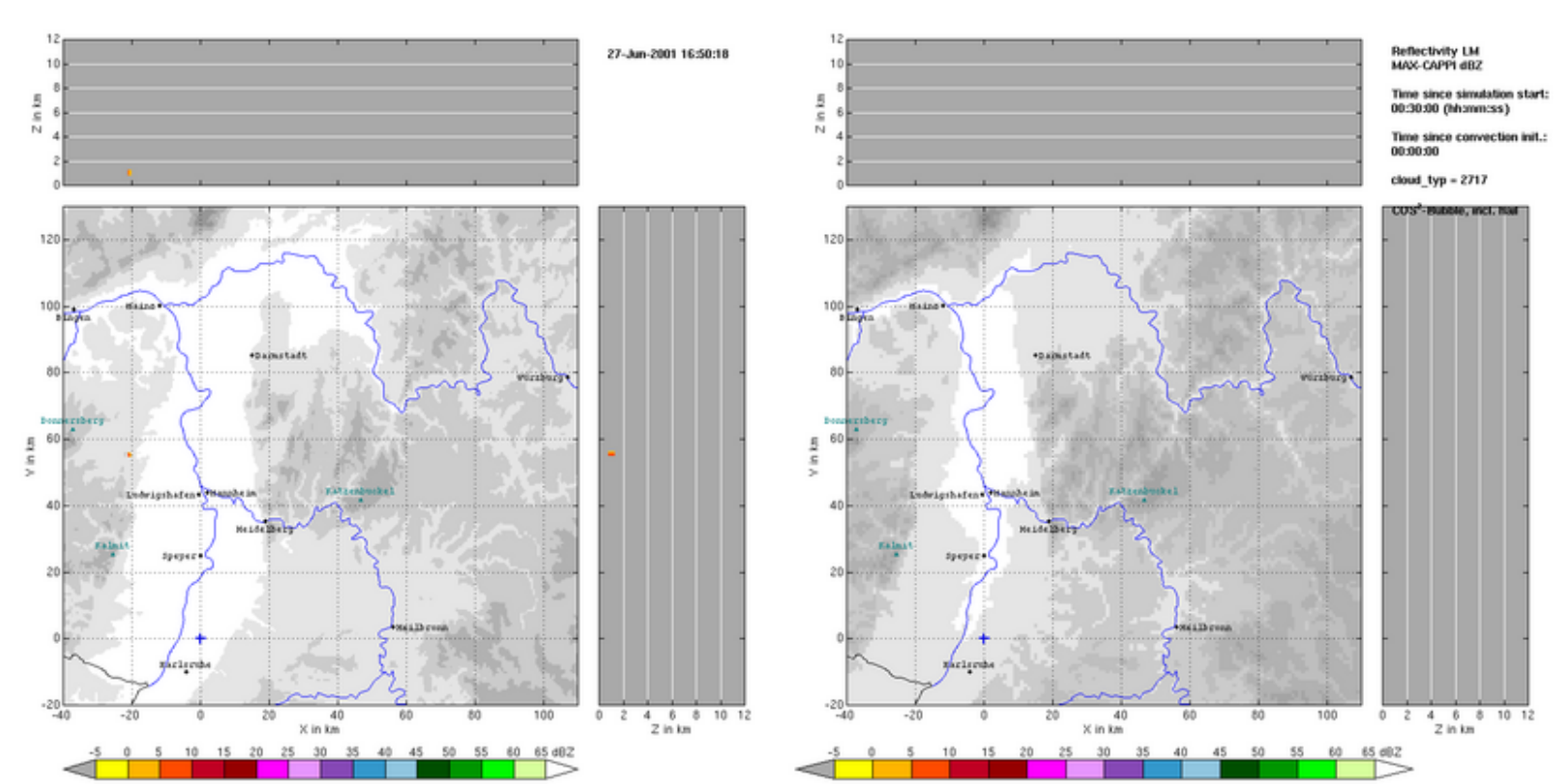

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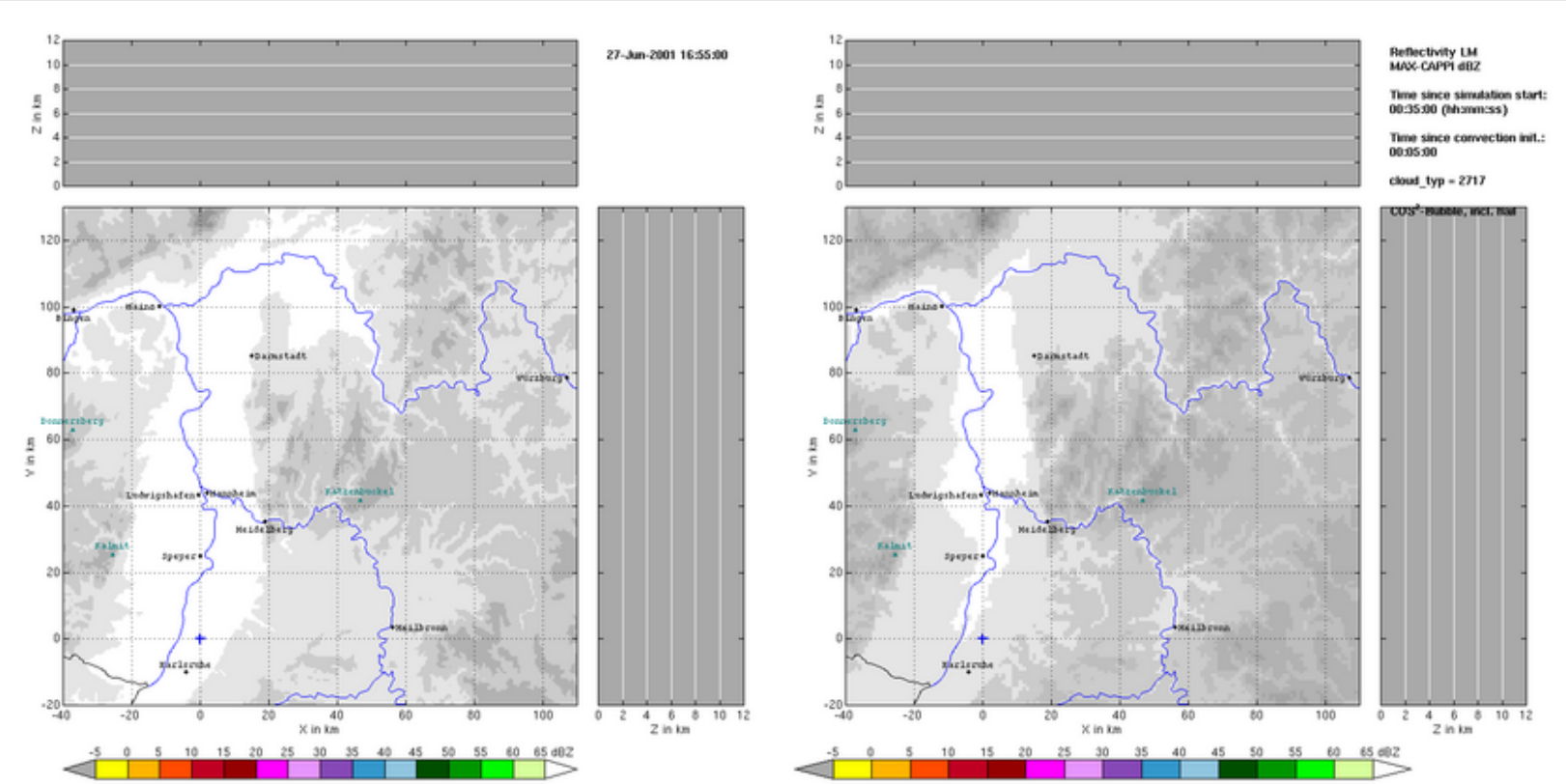

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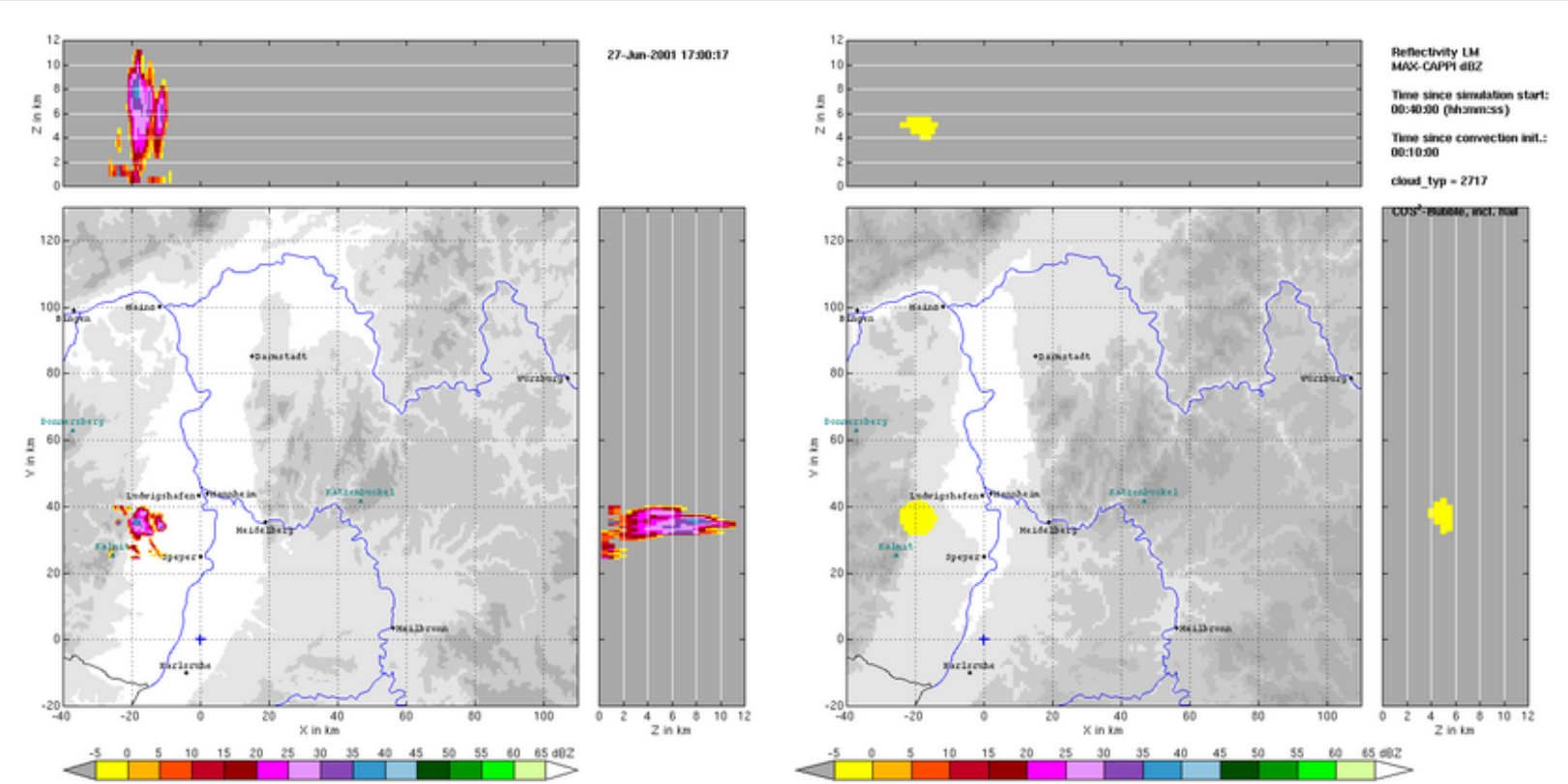

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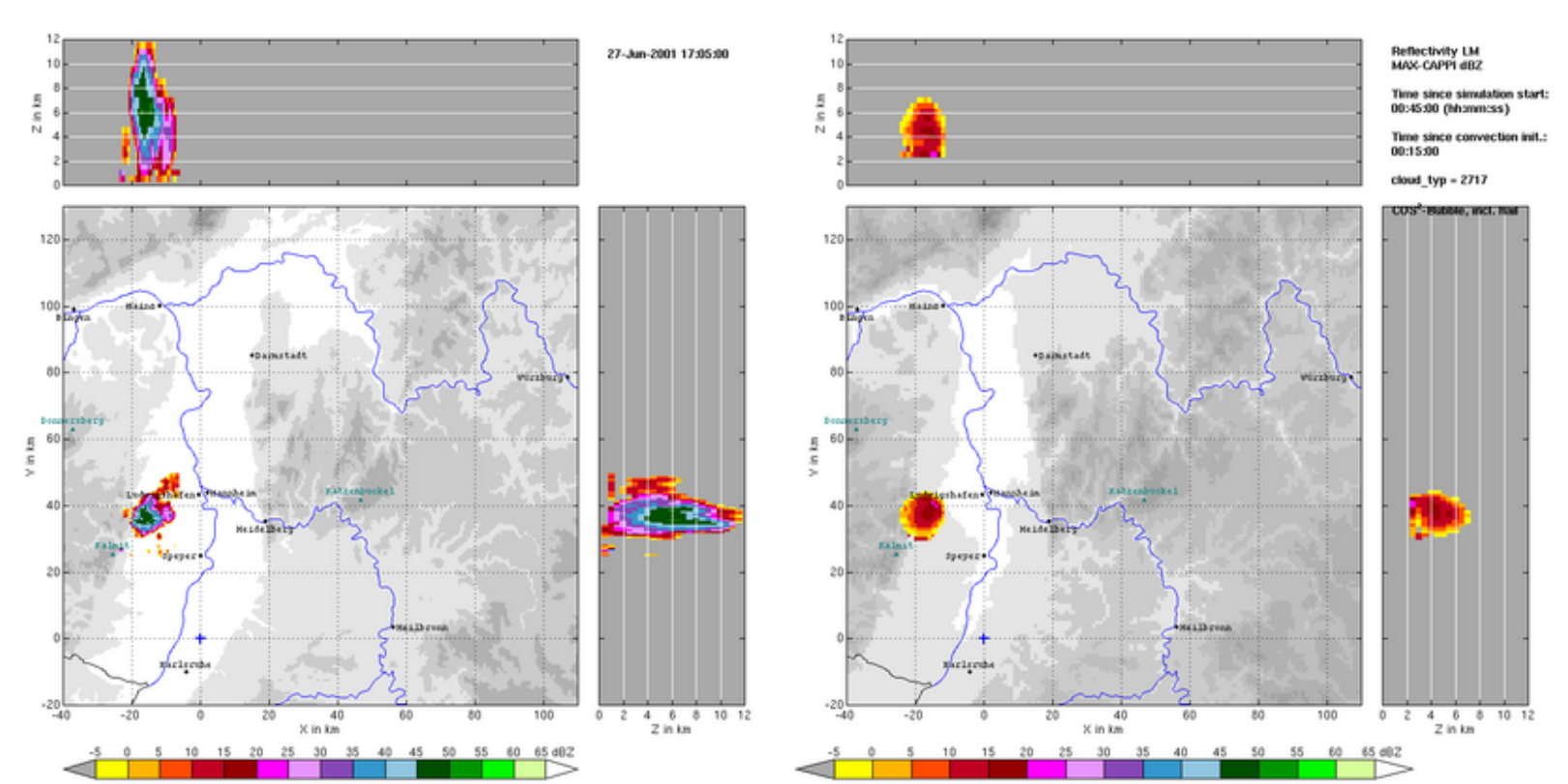

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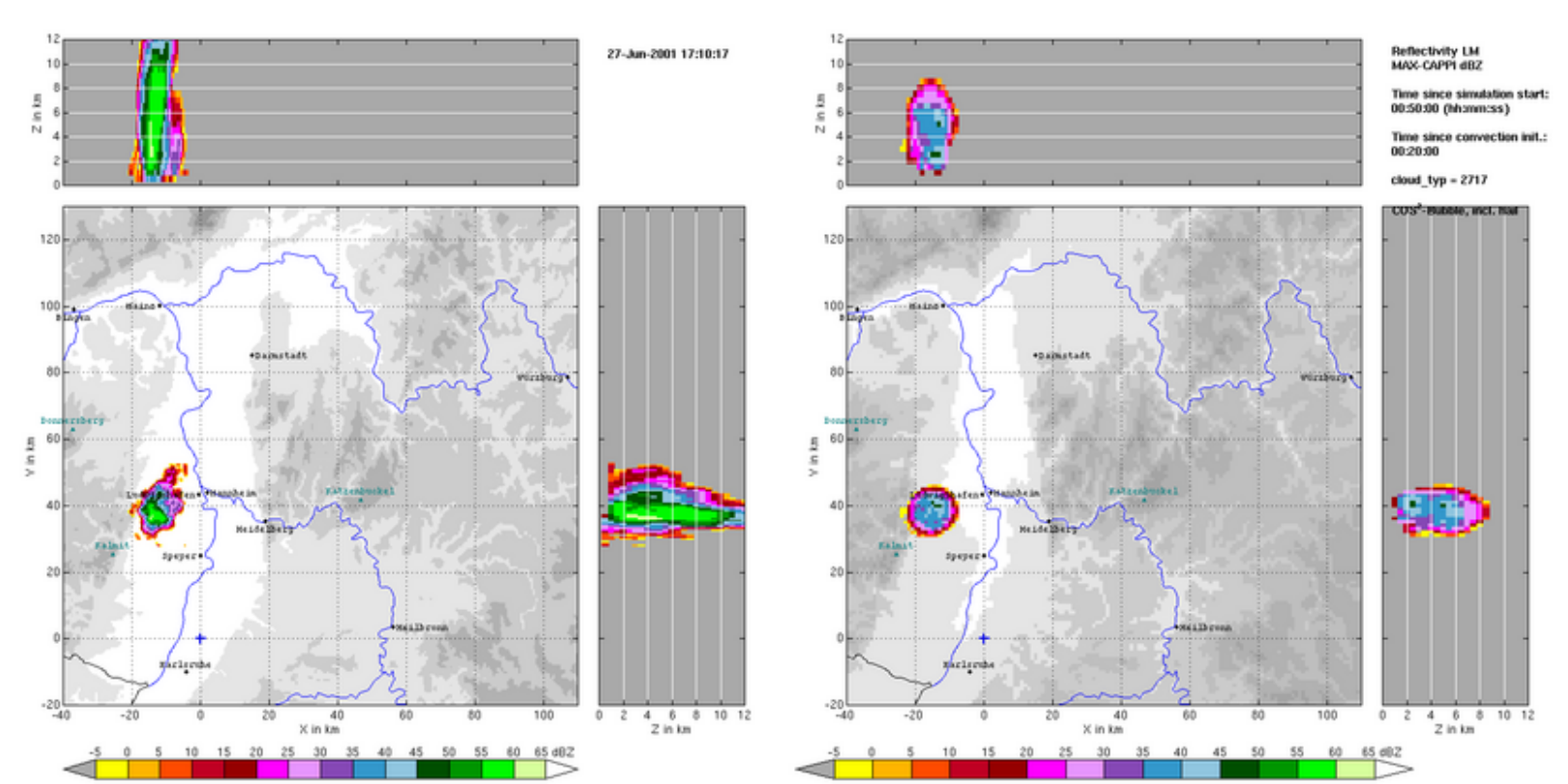

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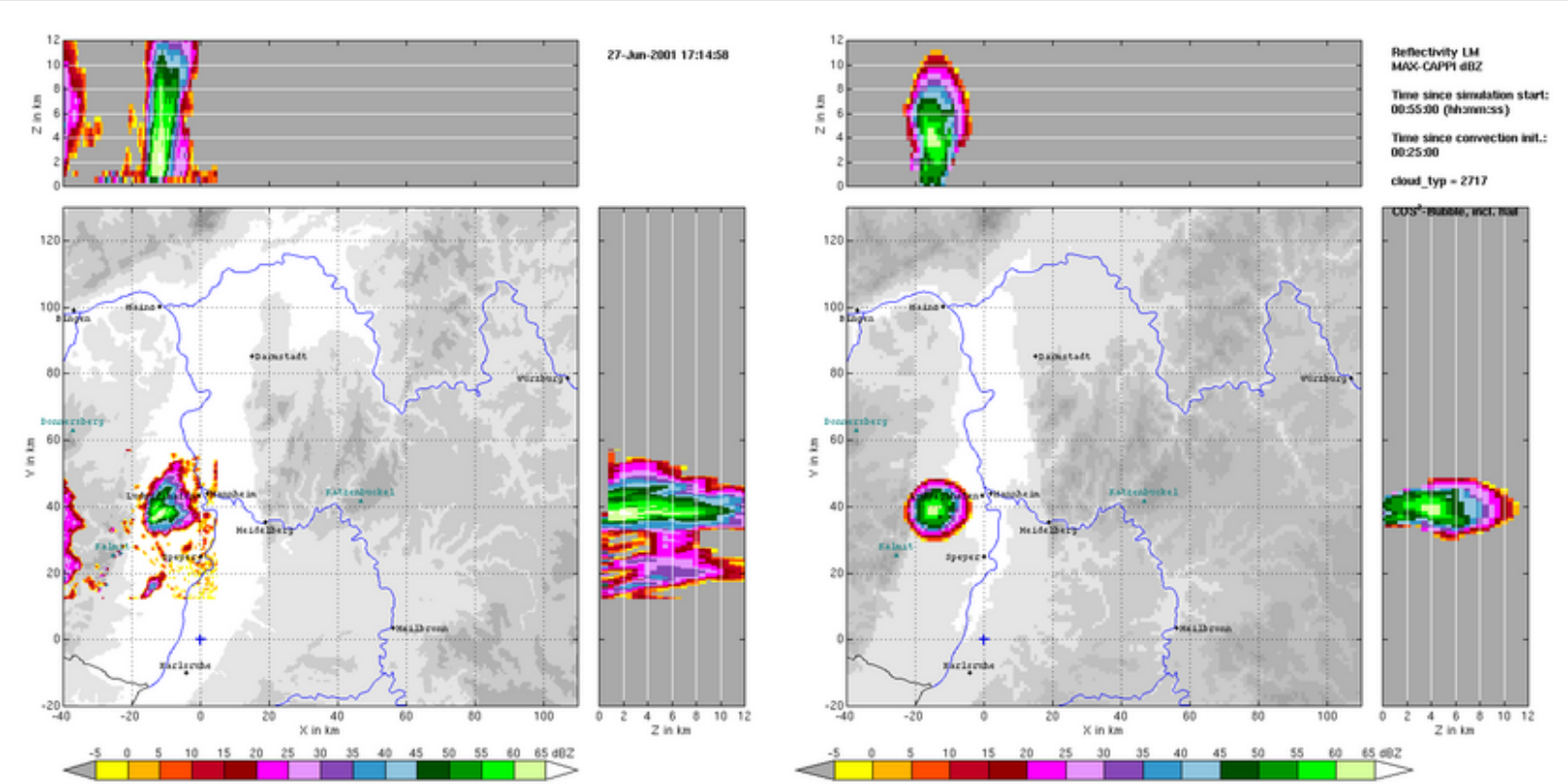

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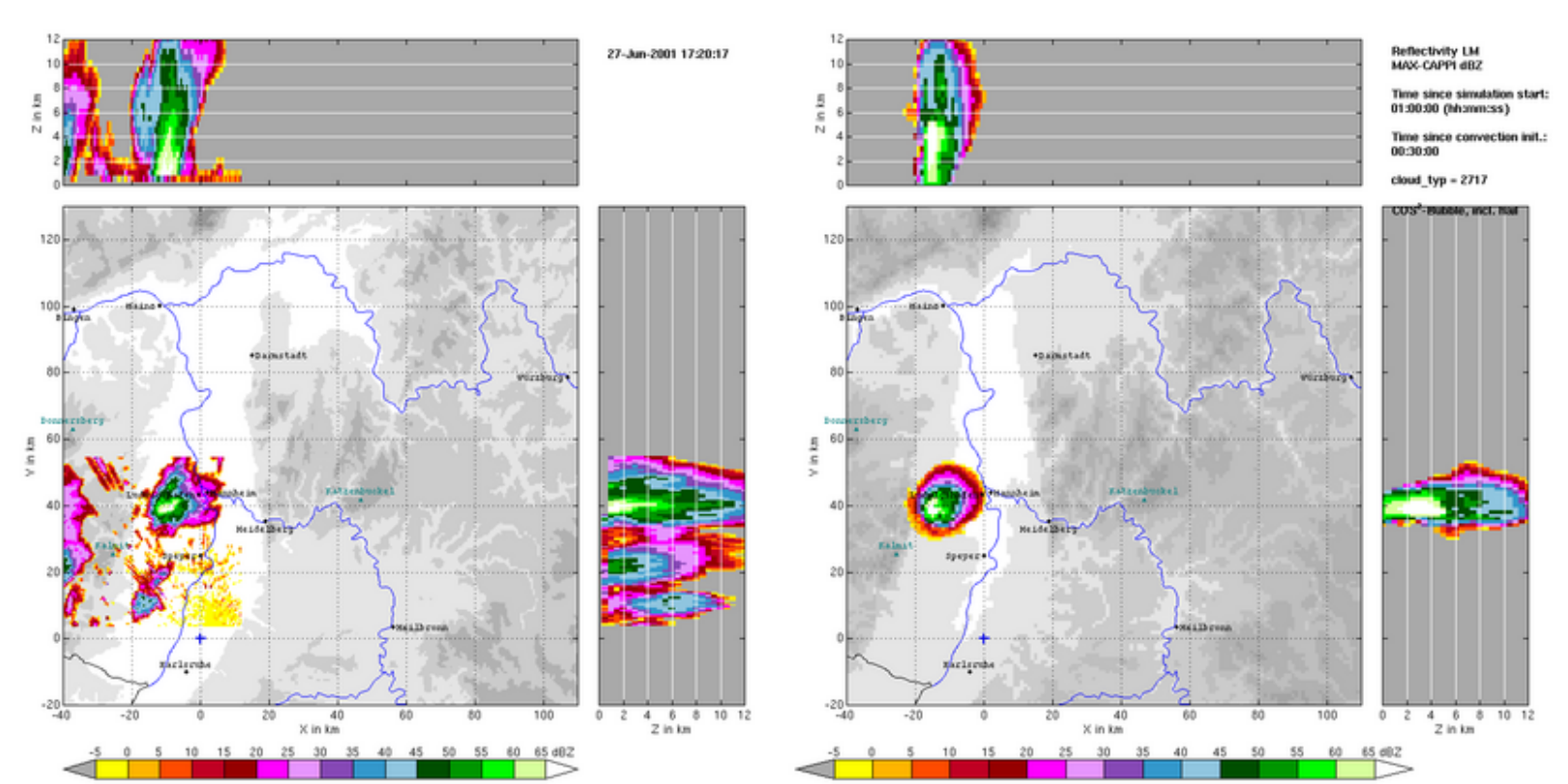

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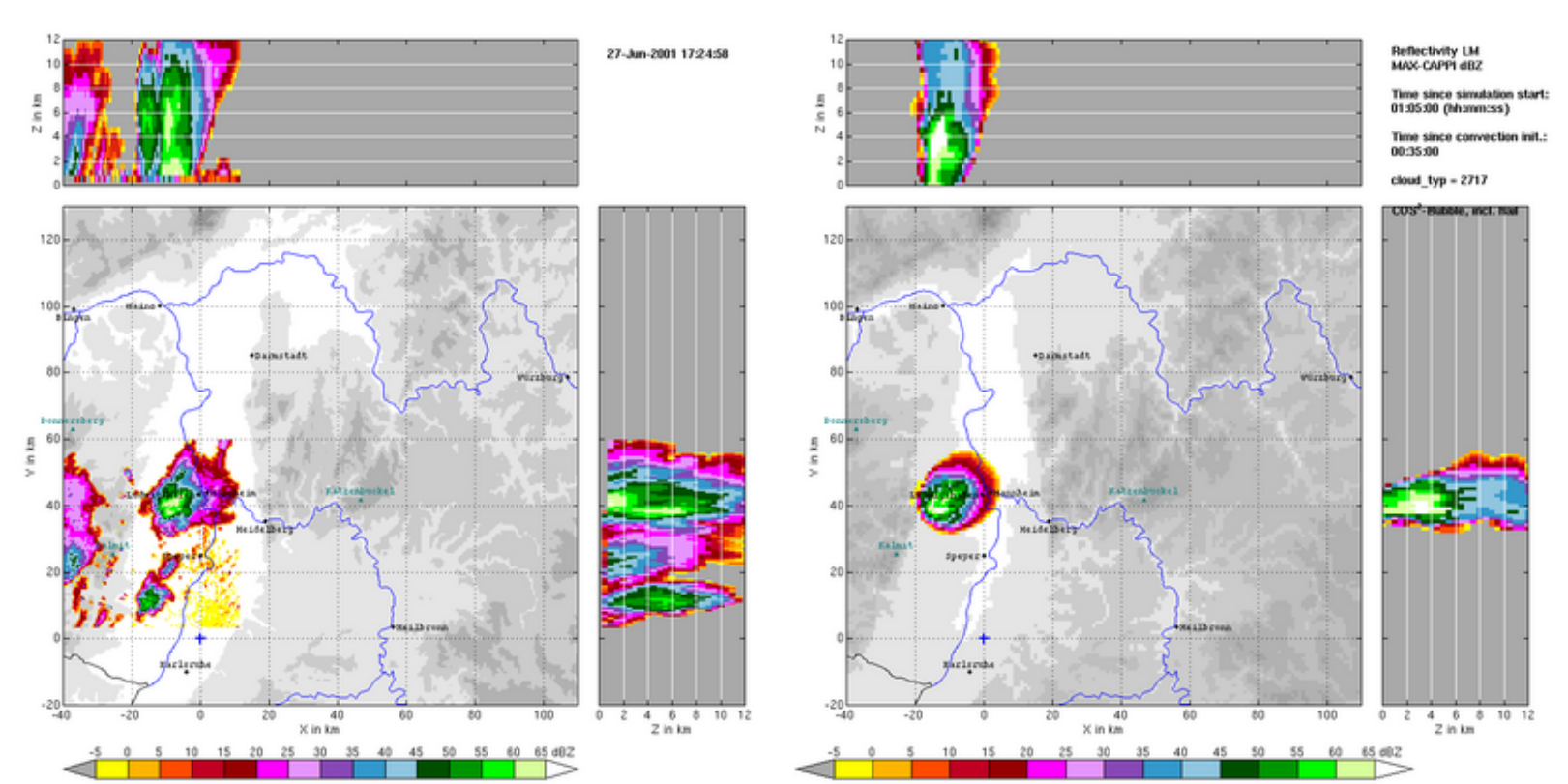

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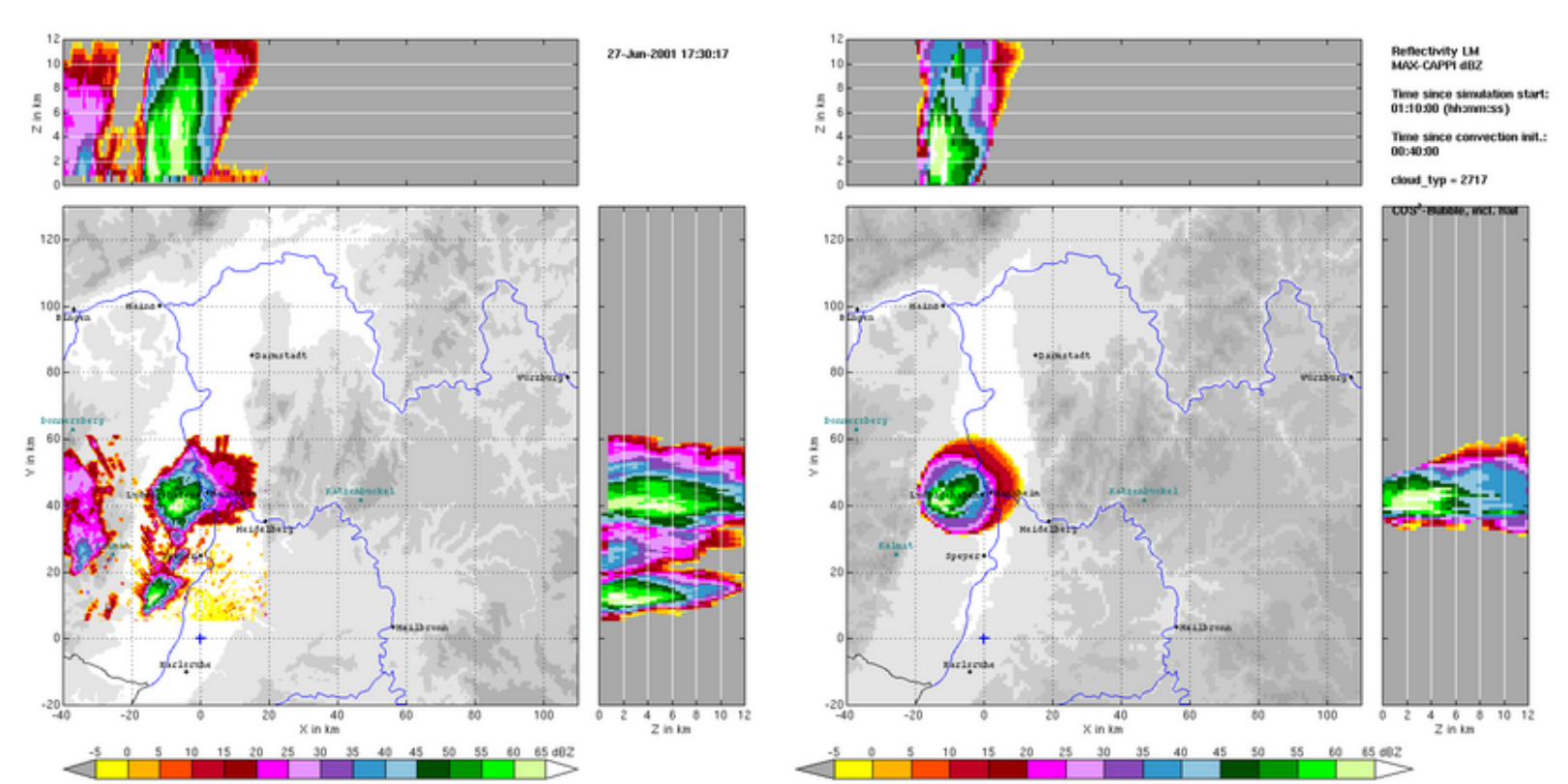

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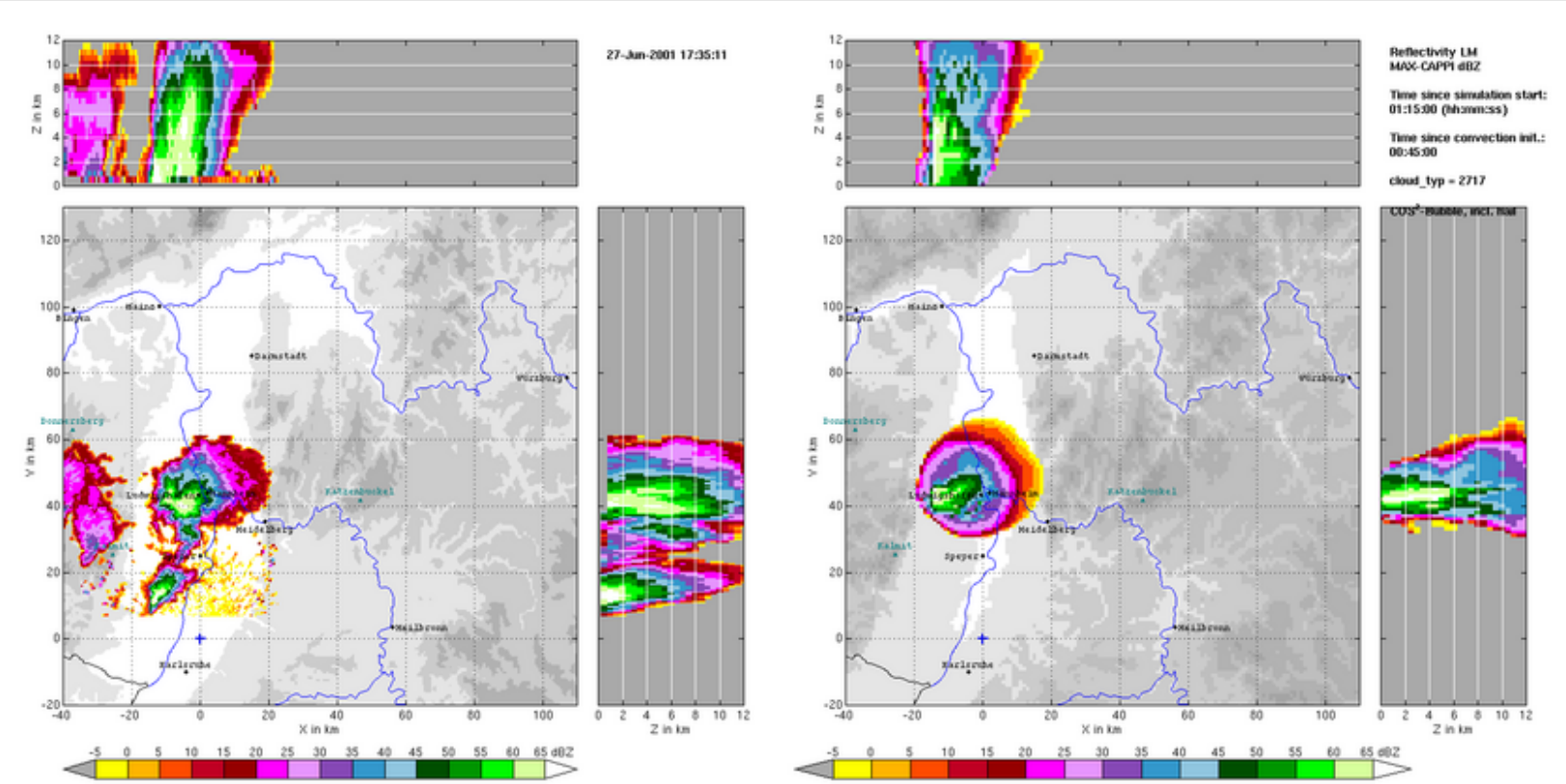

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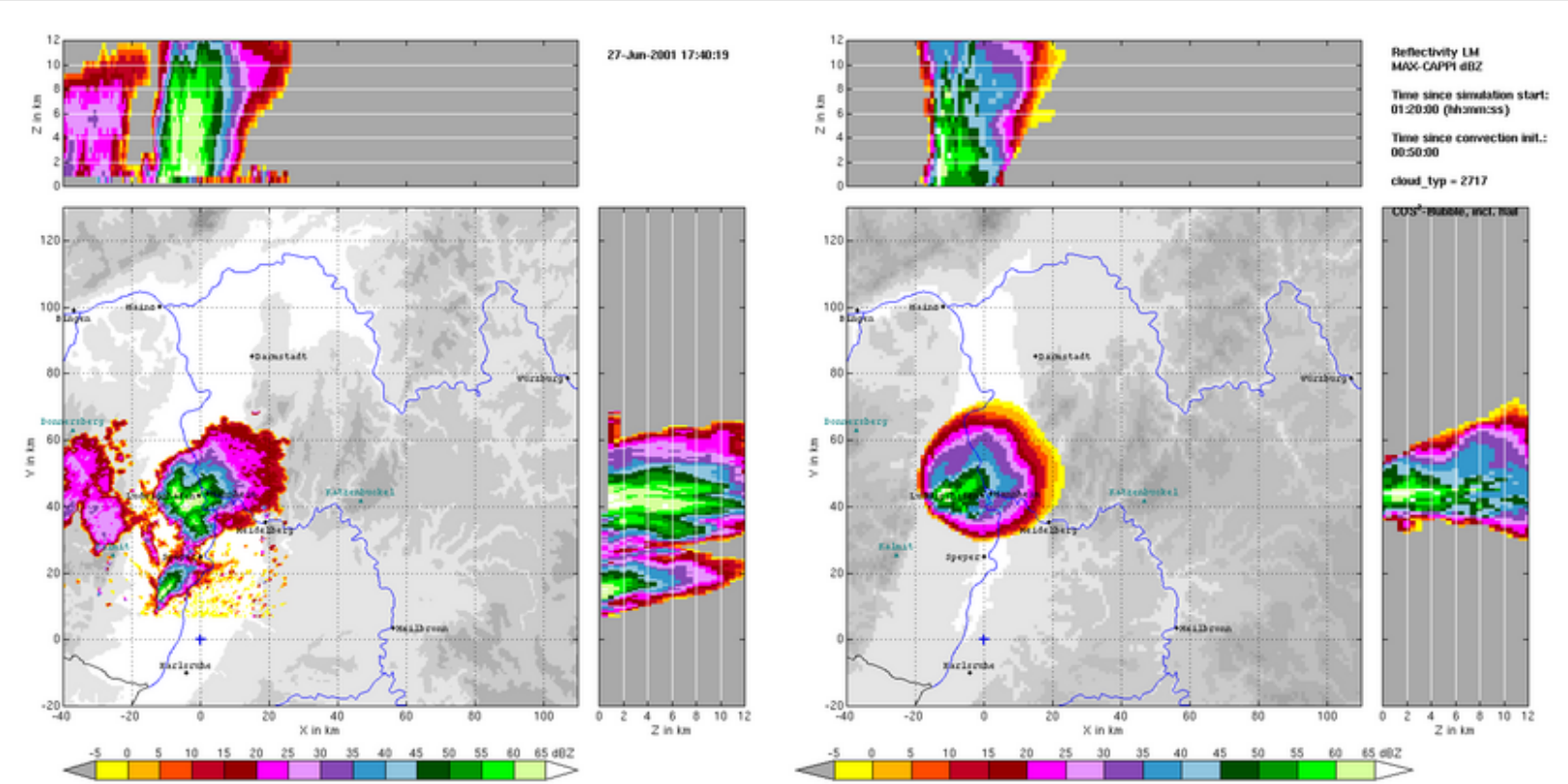


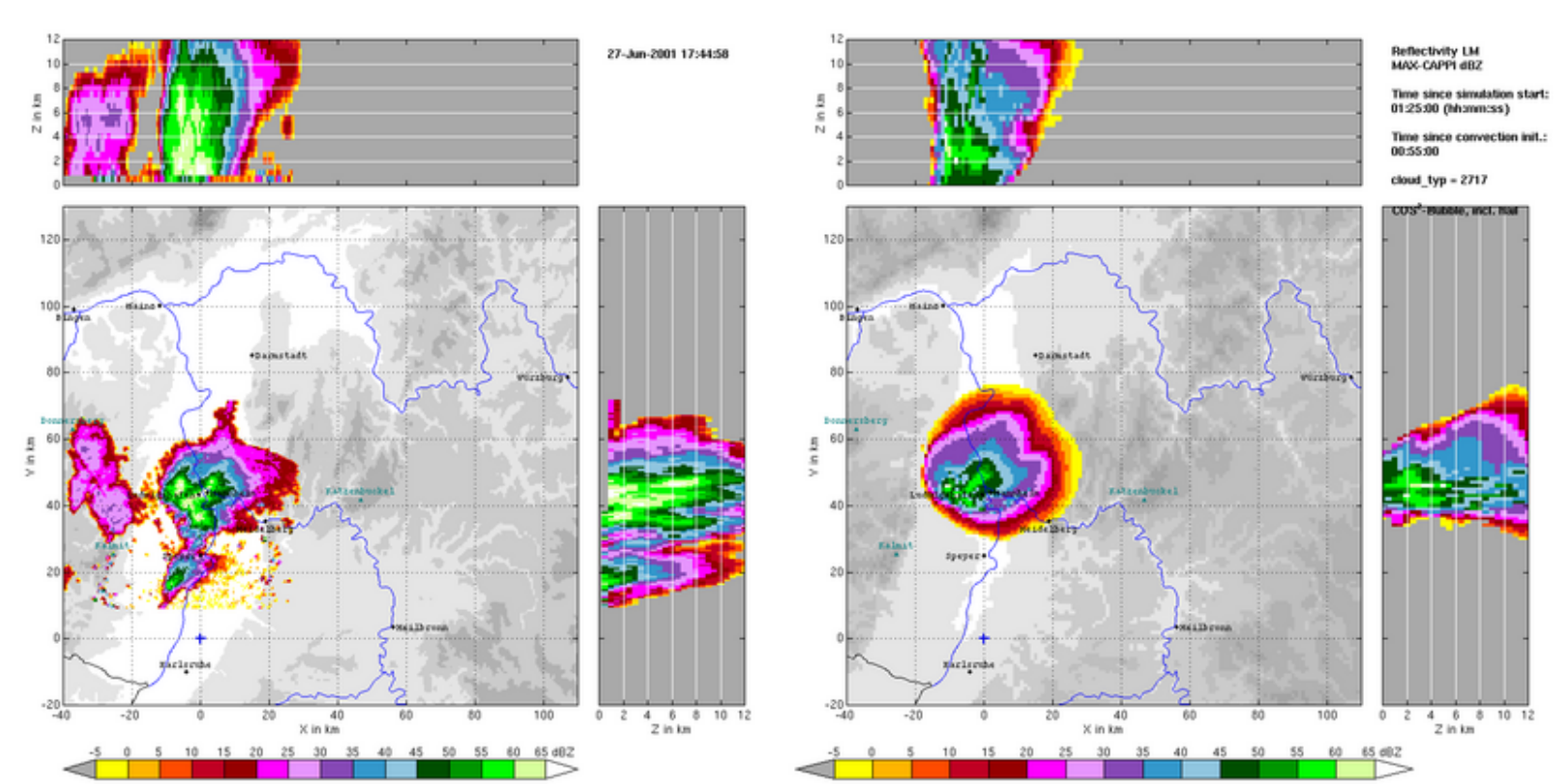
play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
`itype_turb` = 3



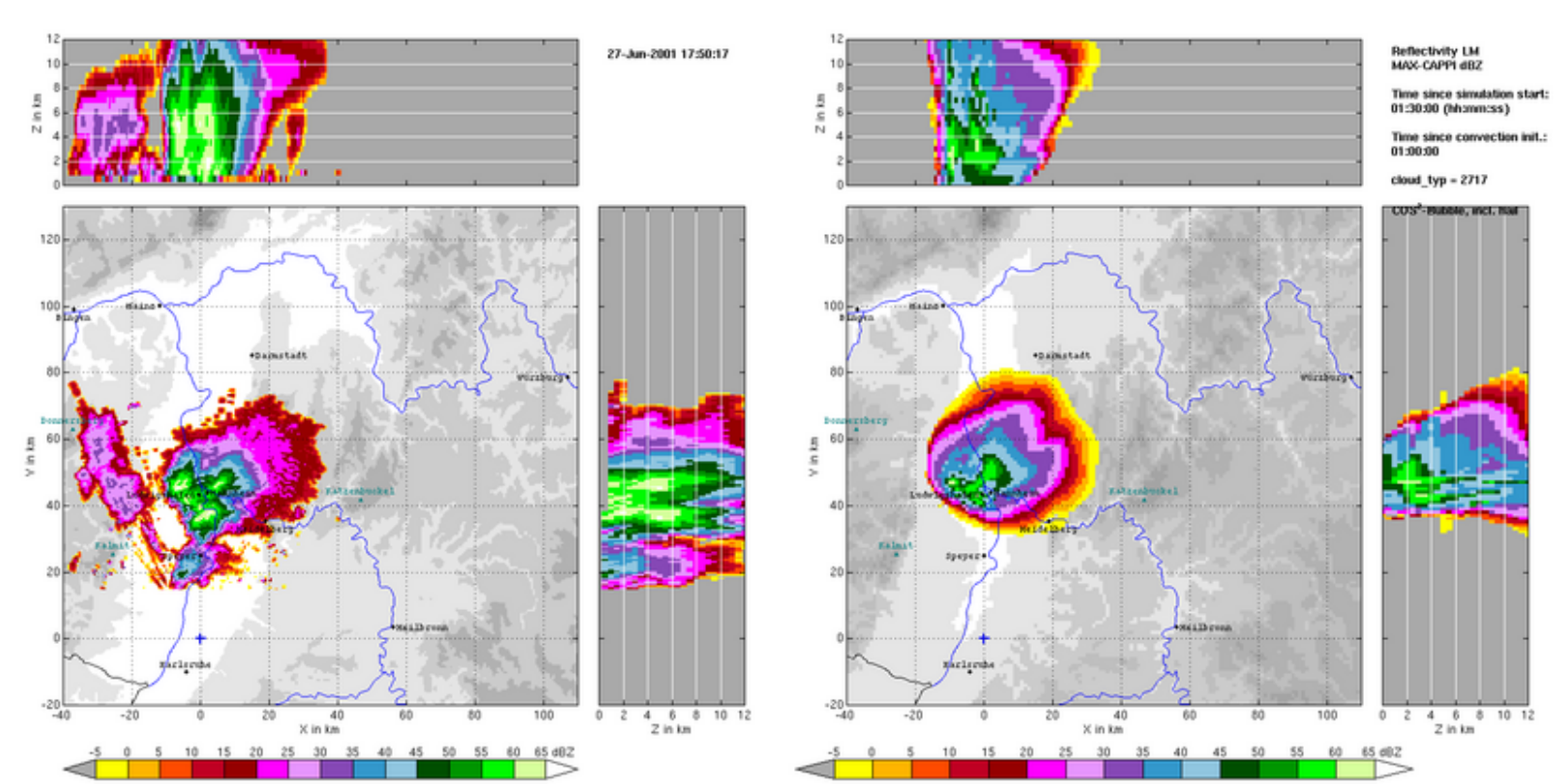
play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
`itype_turb` = 3



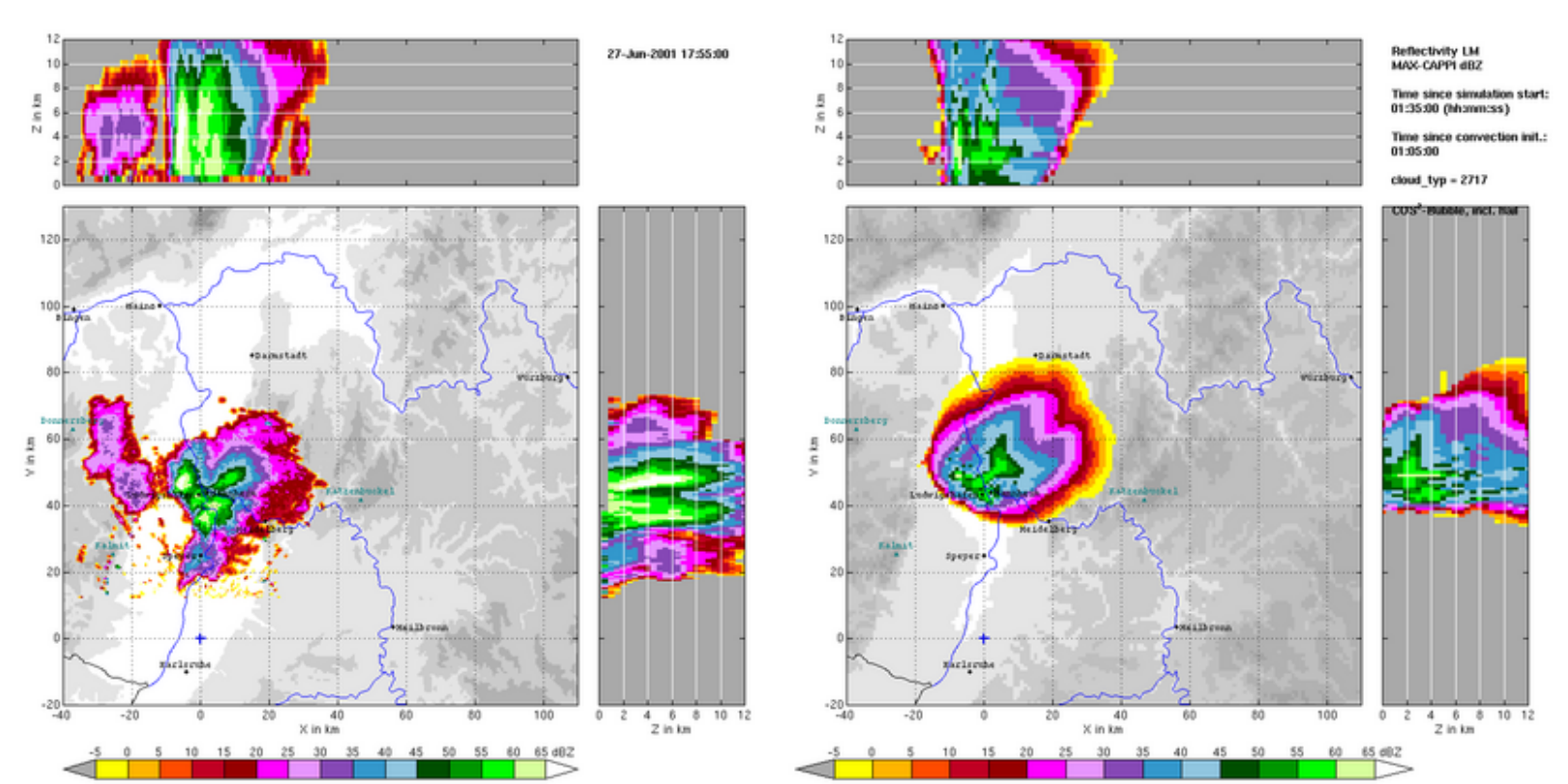
play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
`itype_turb` = 3



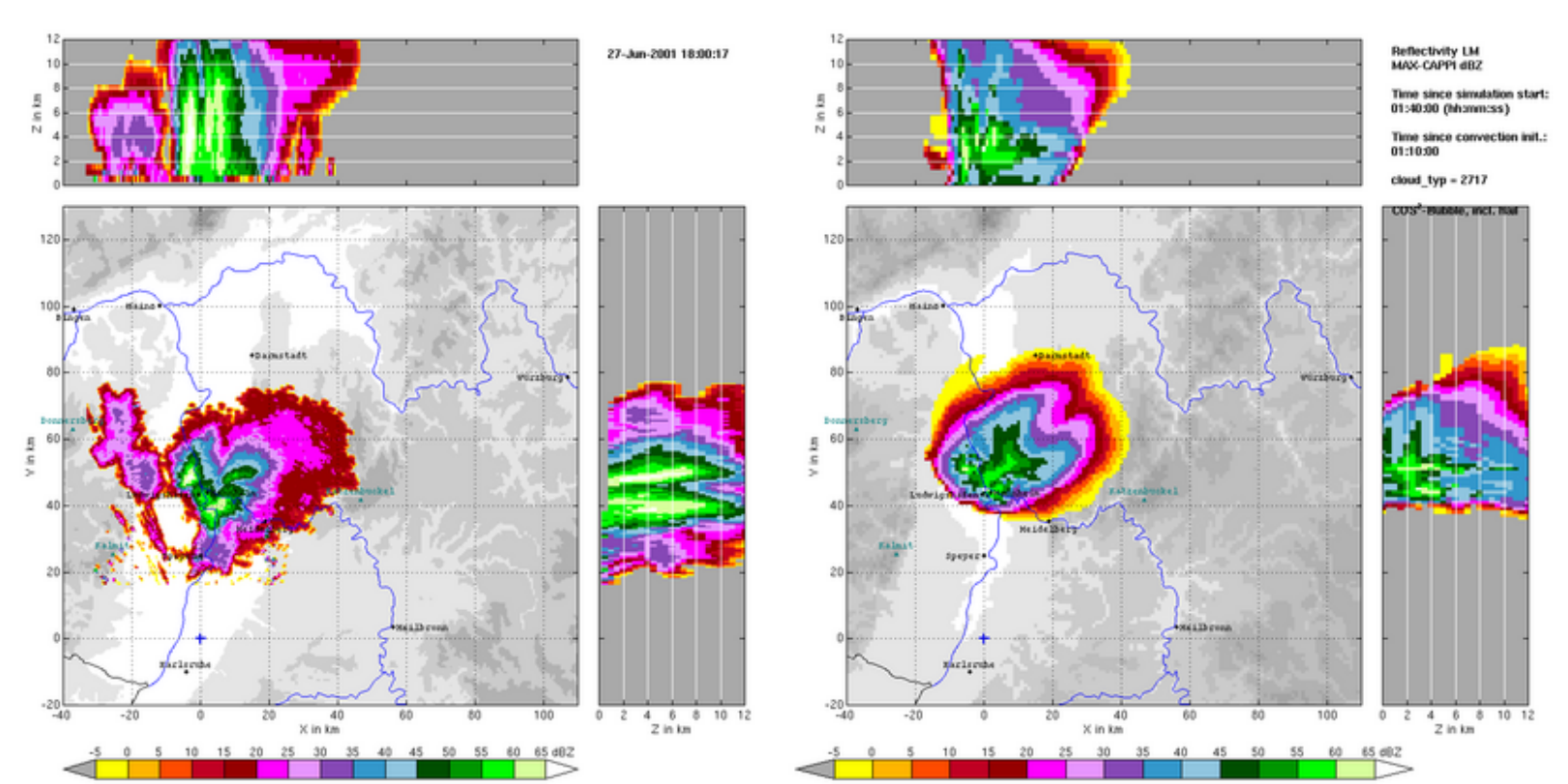
play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
`itype_turb` = 3



play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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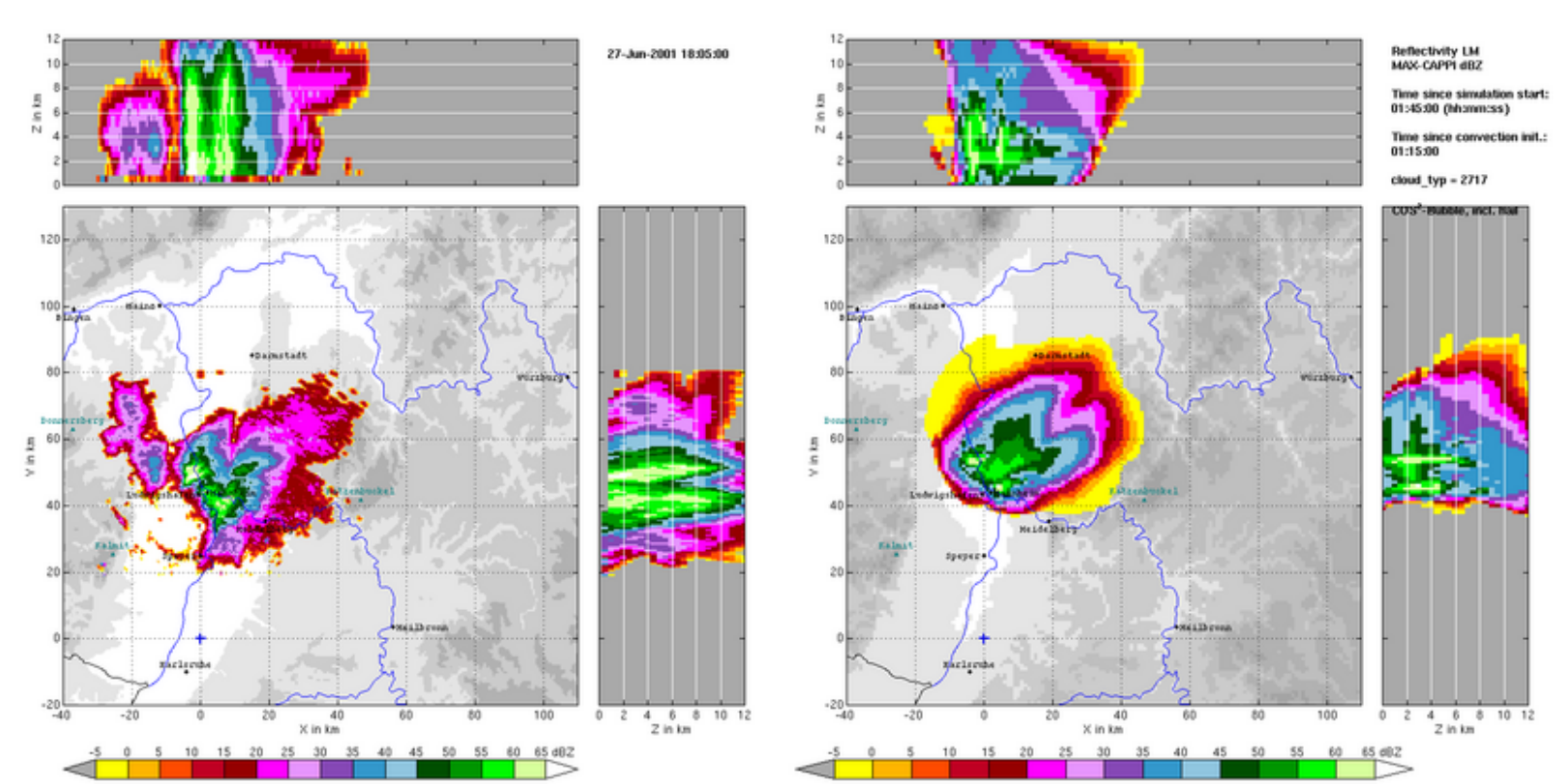

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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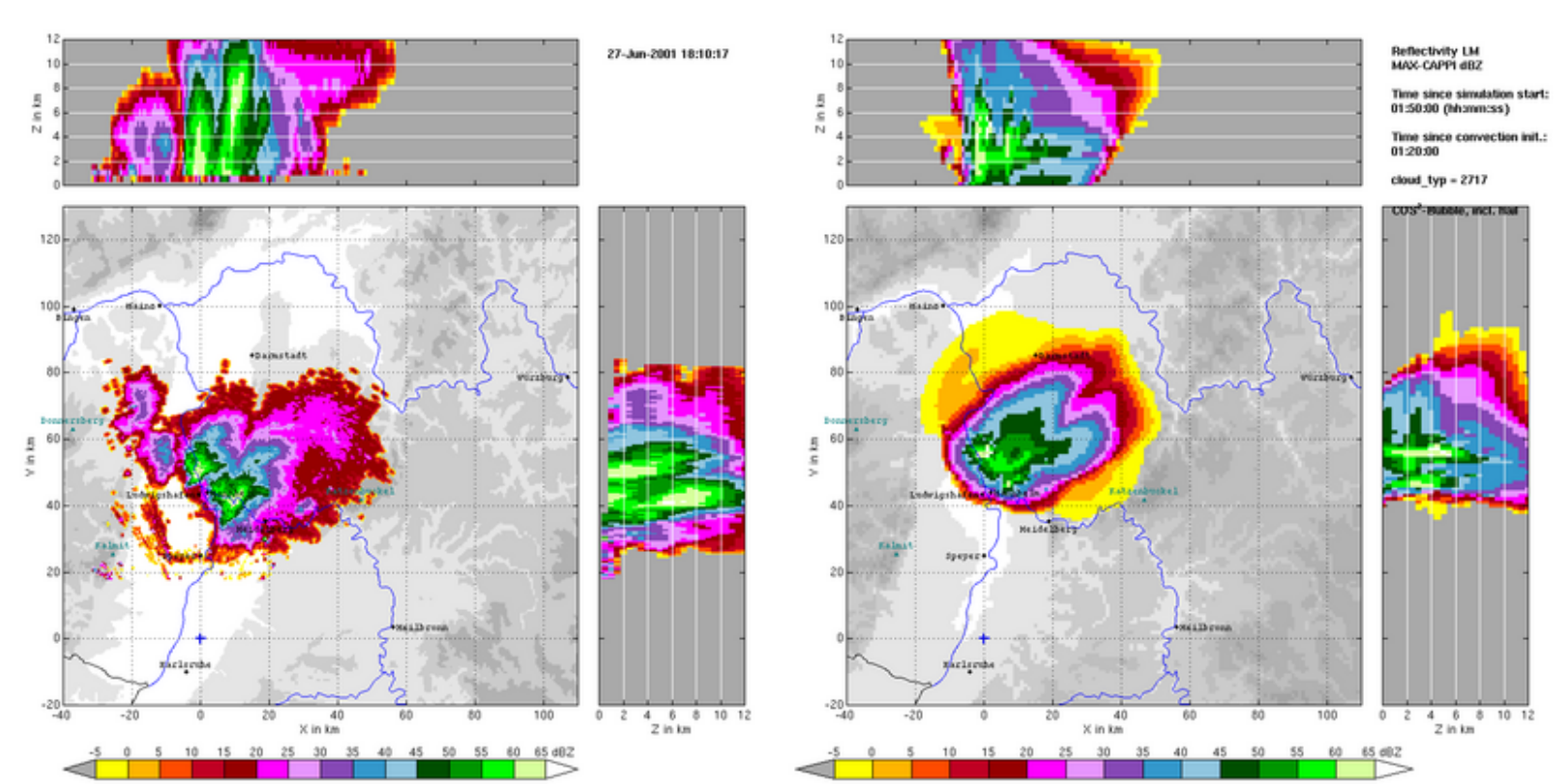

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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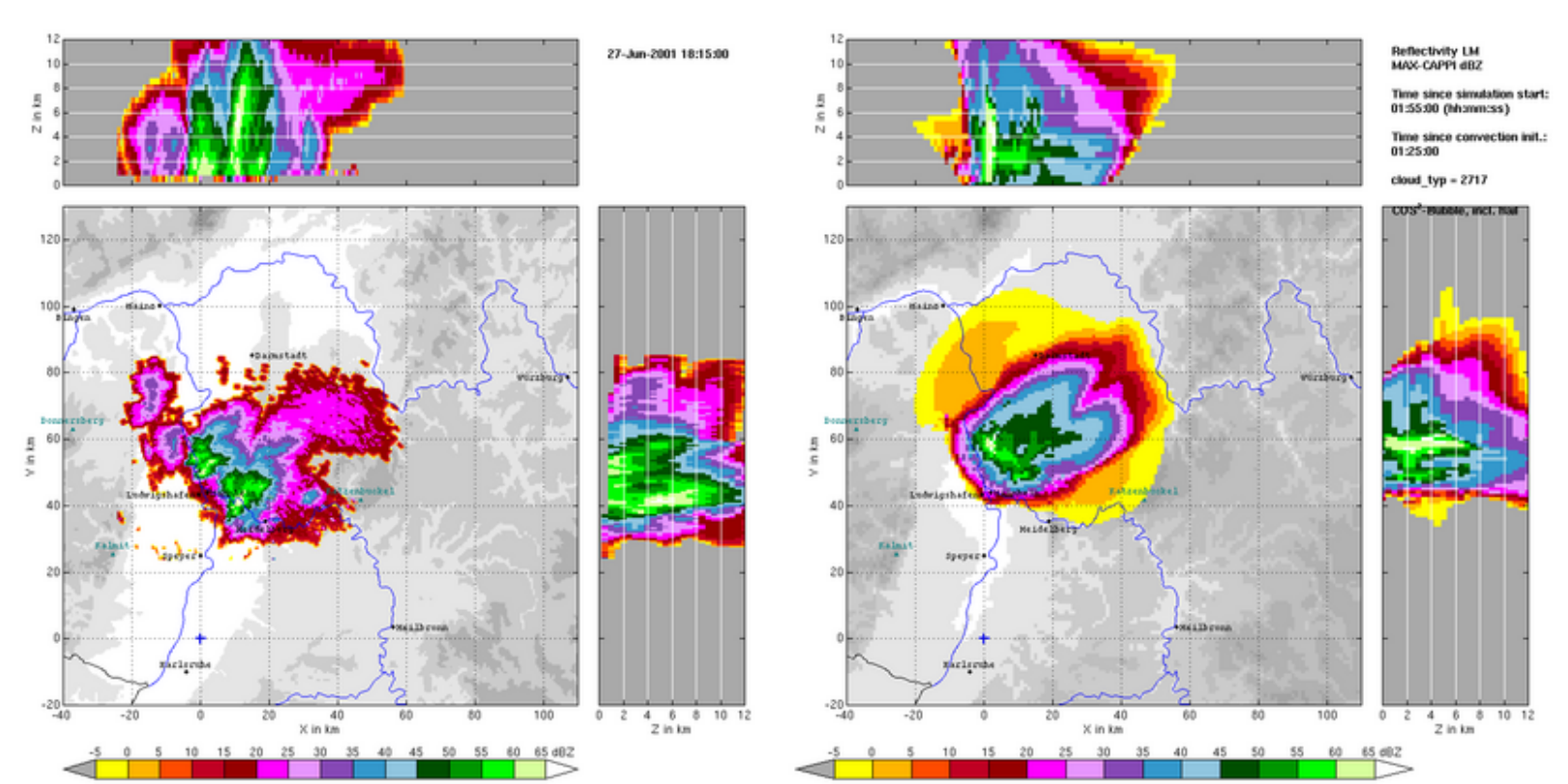

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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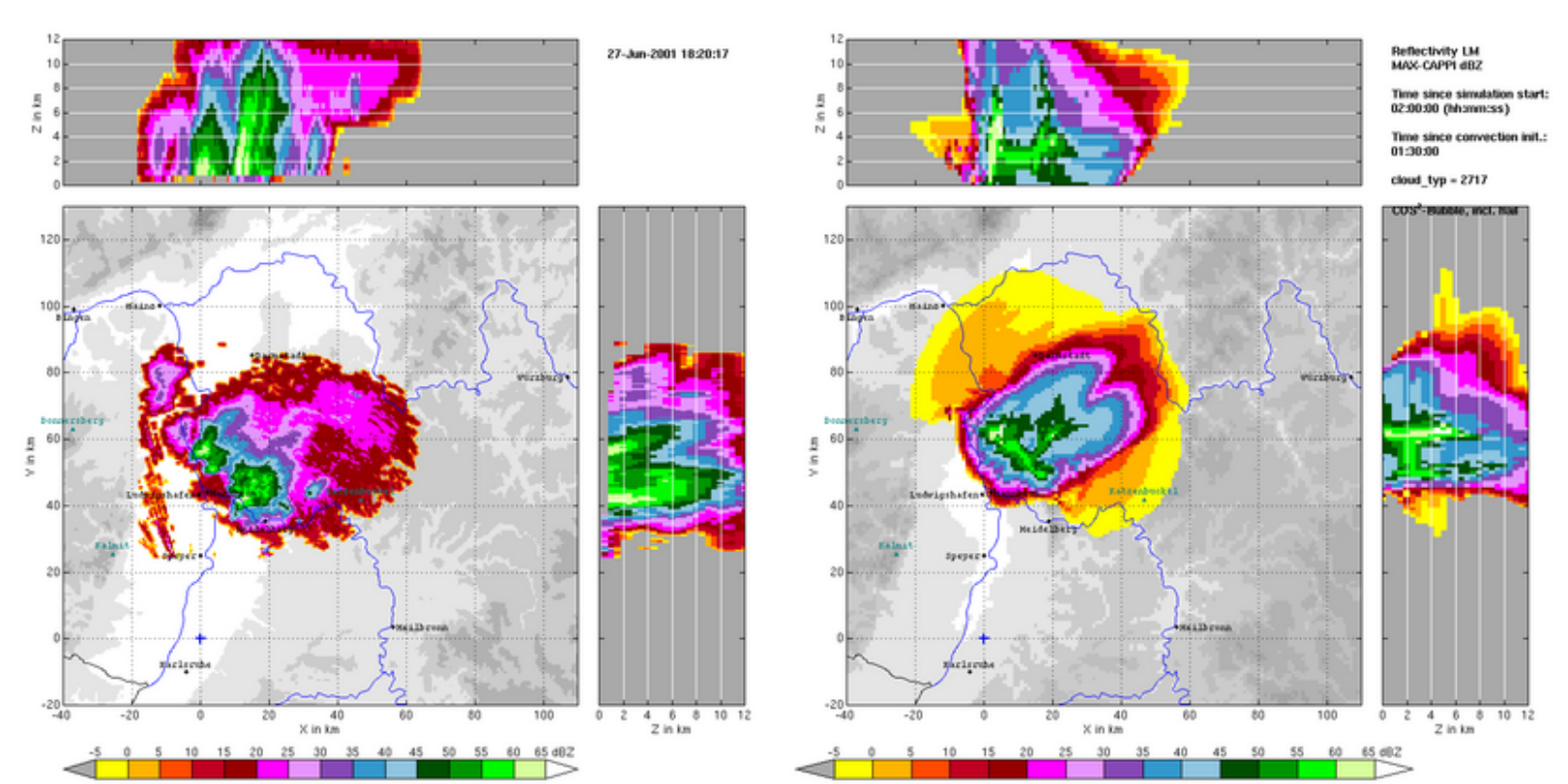

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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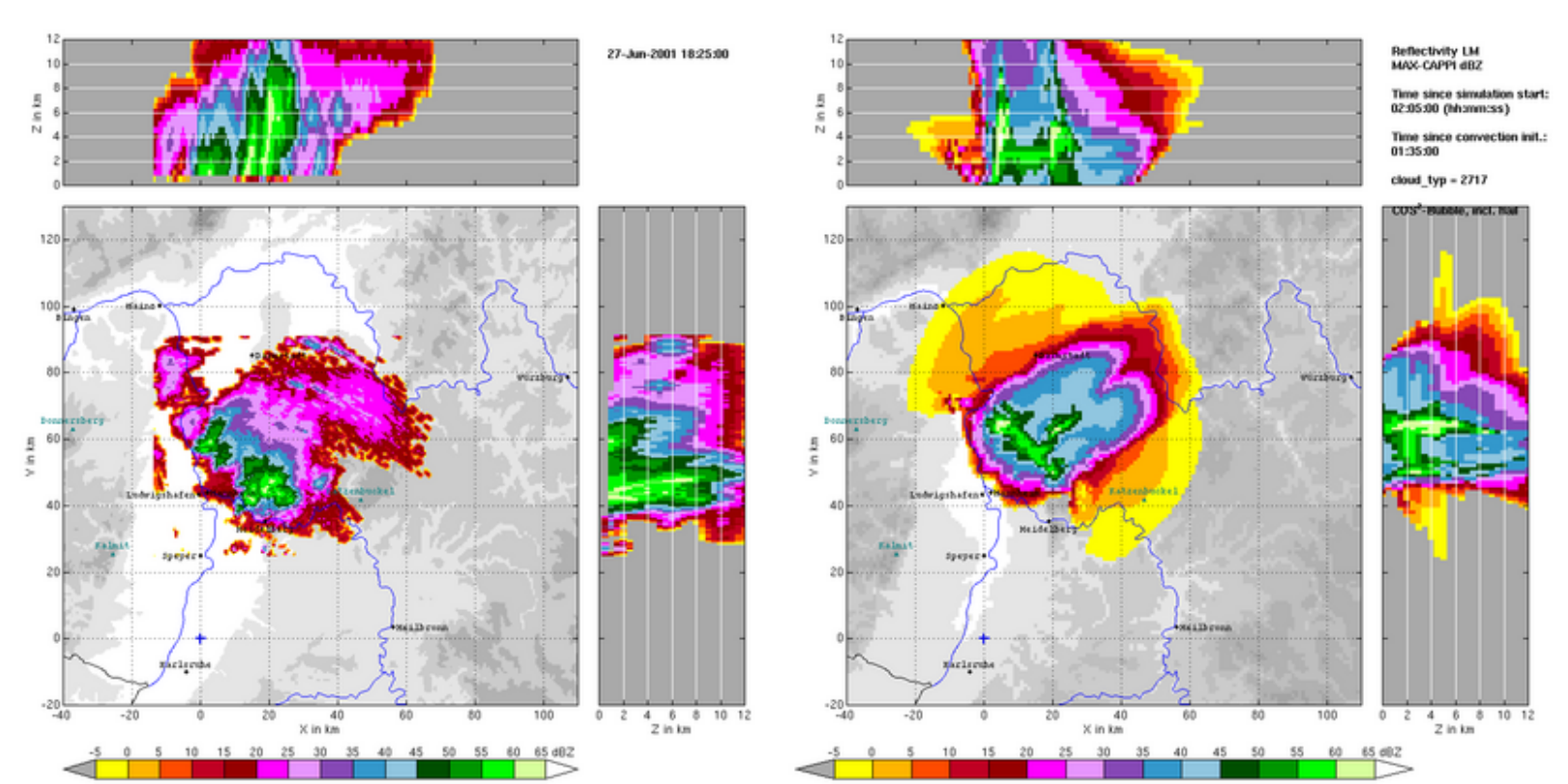

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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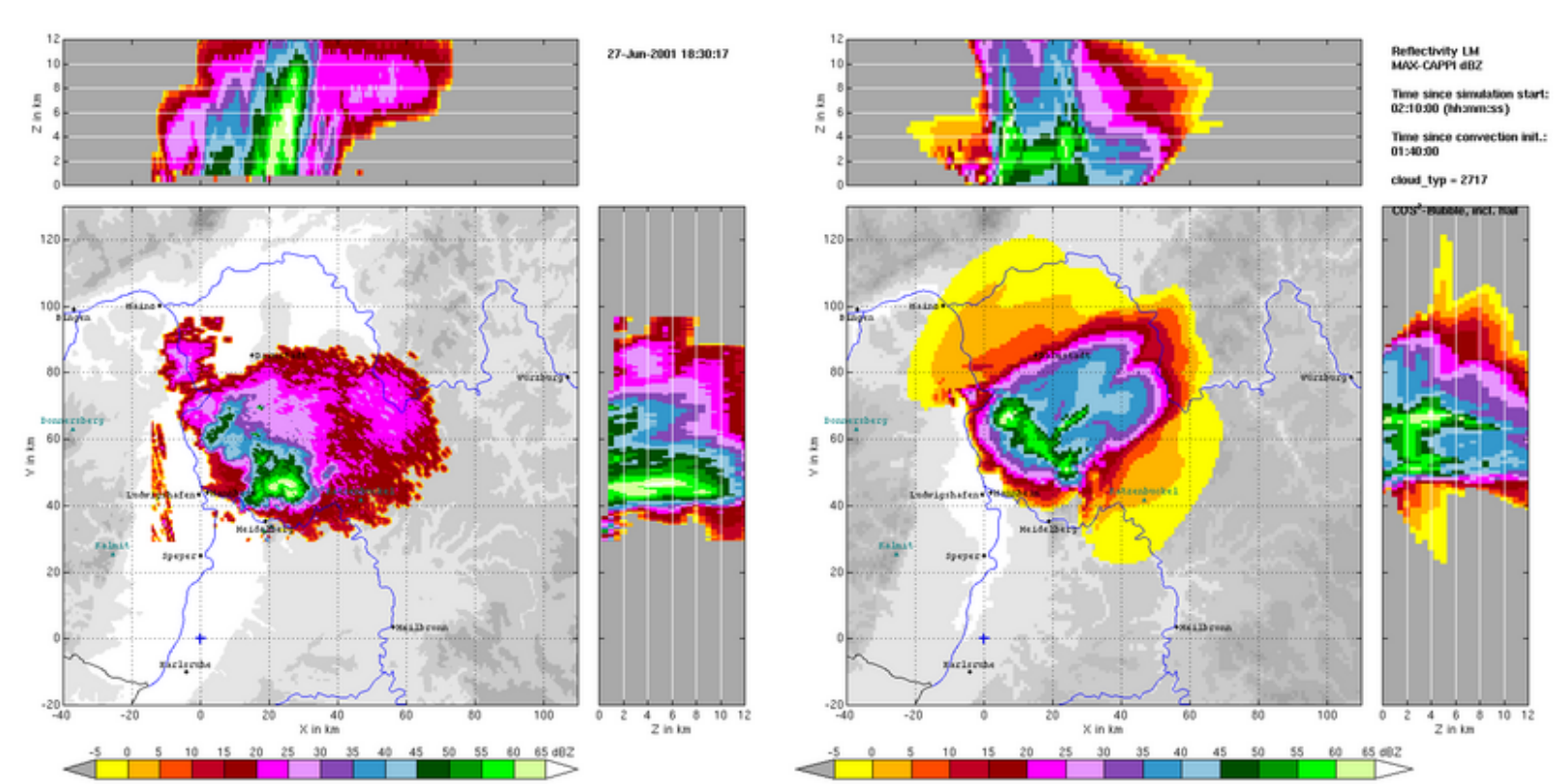

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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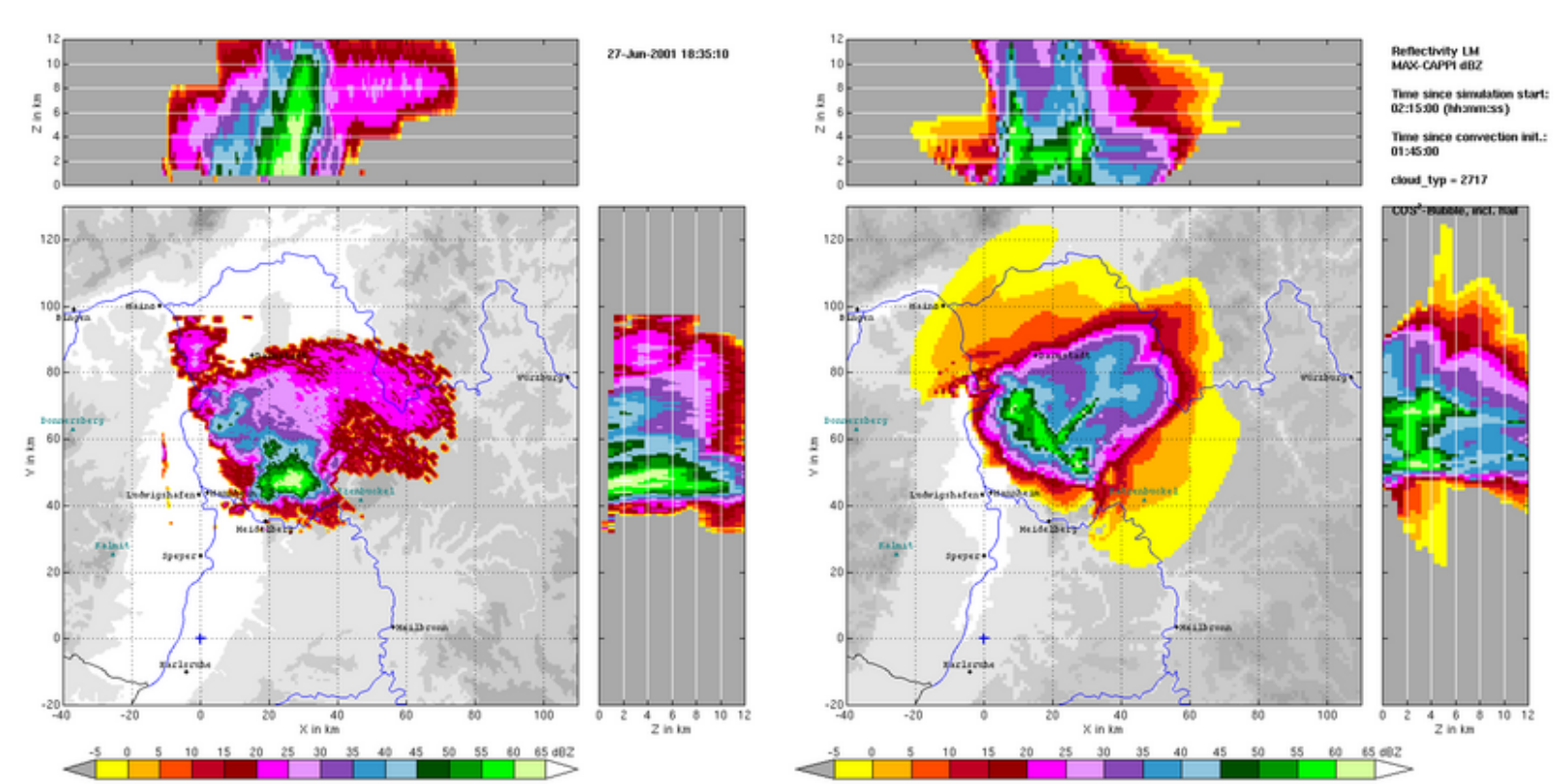

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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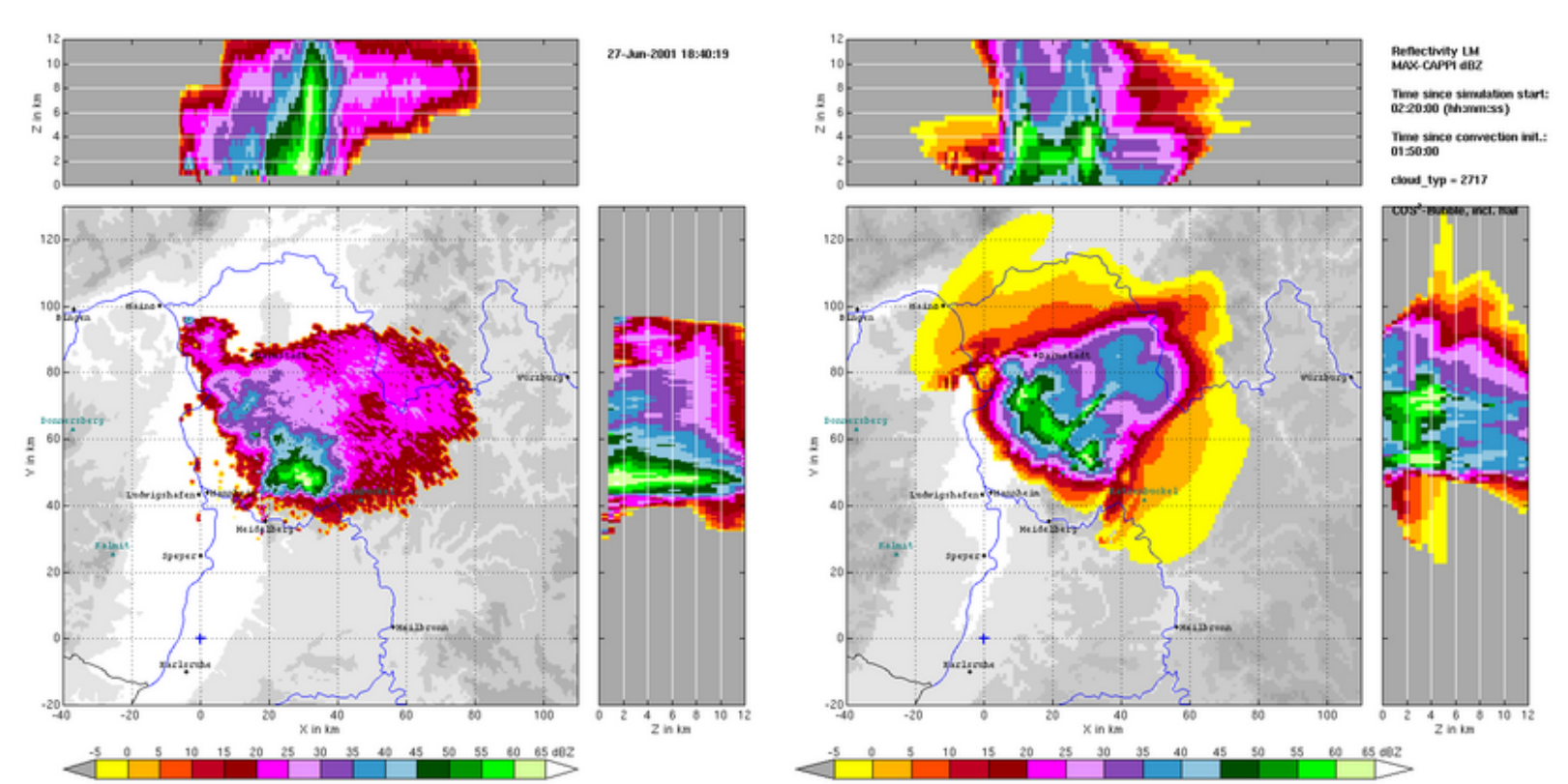

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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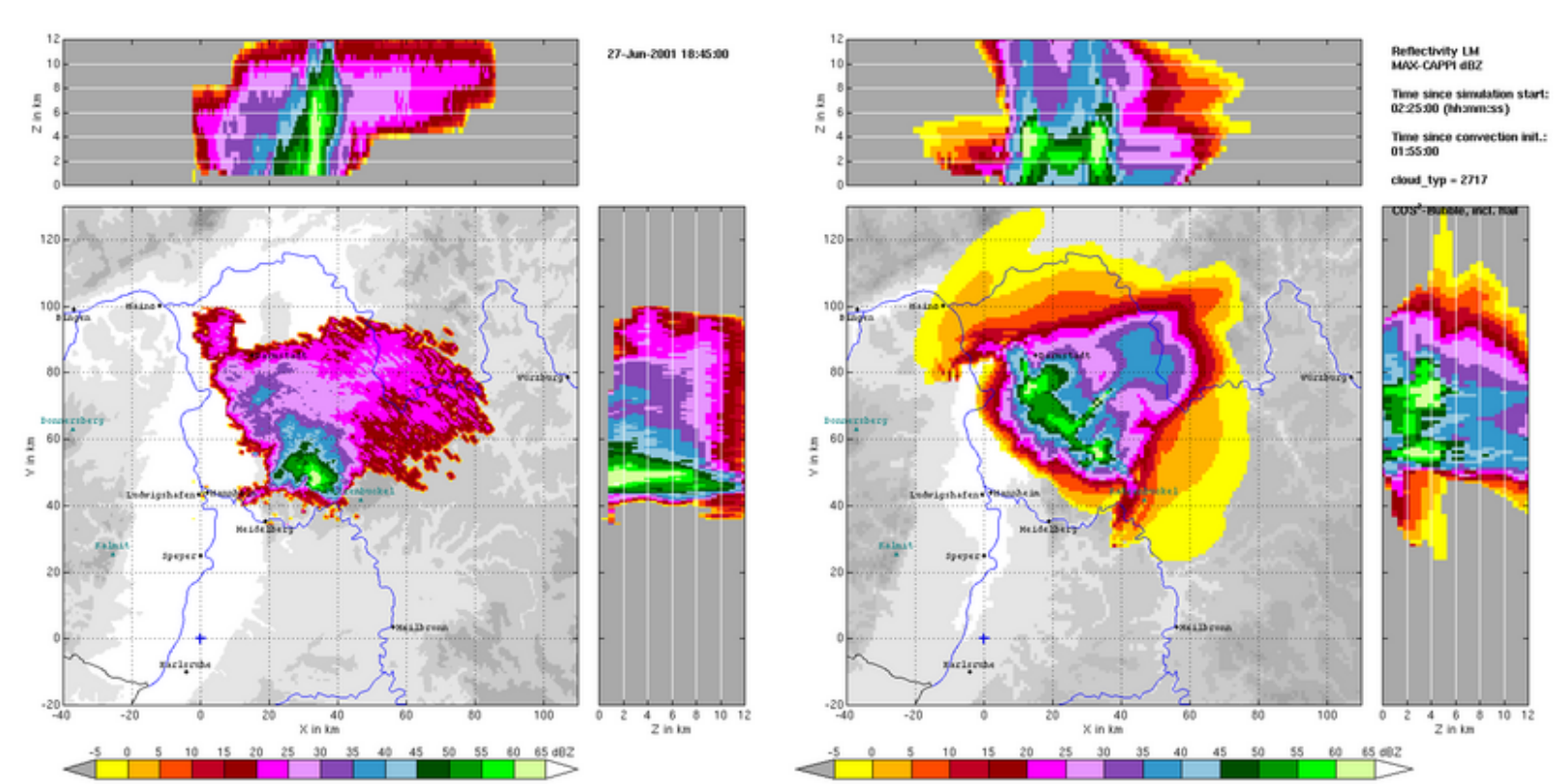

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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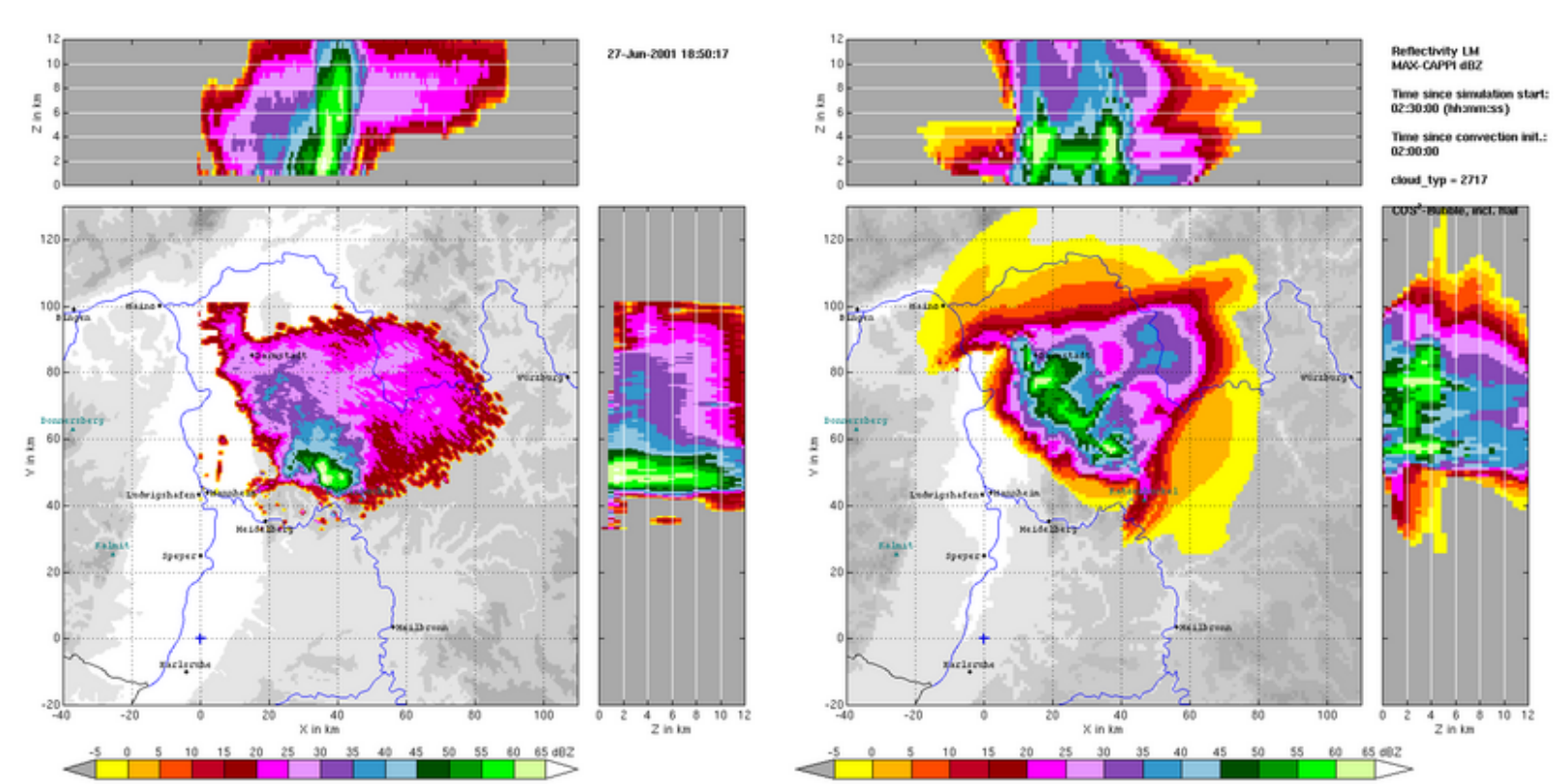

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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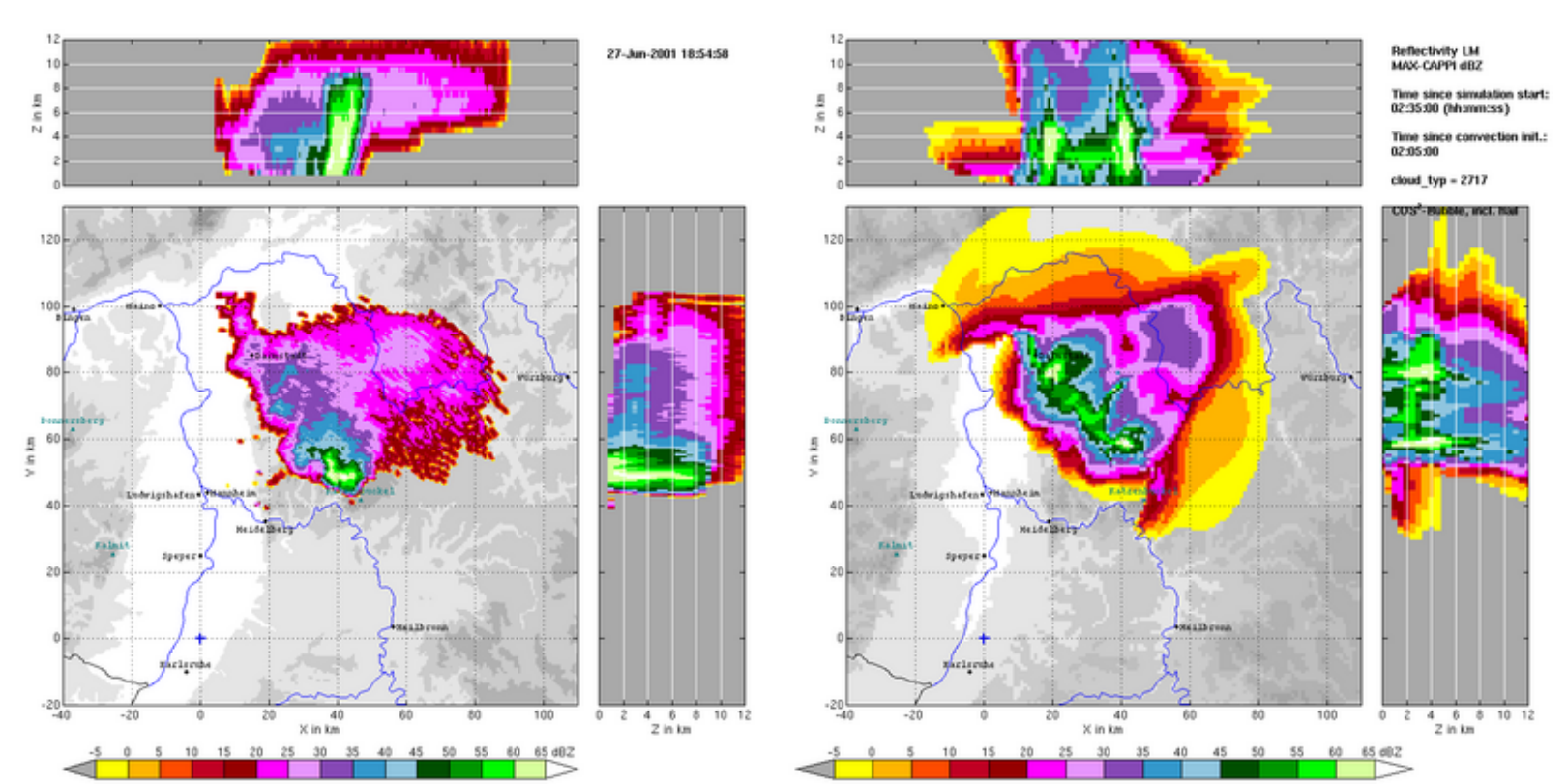

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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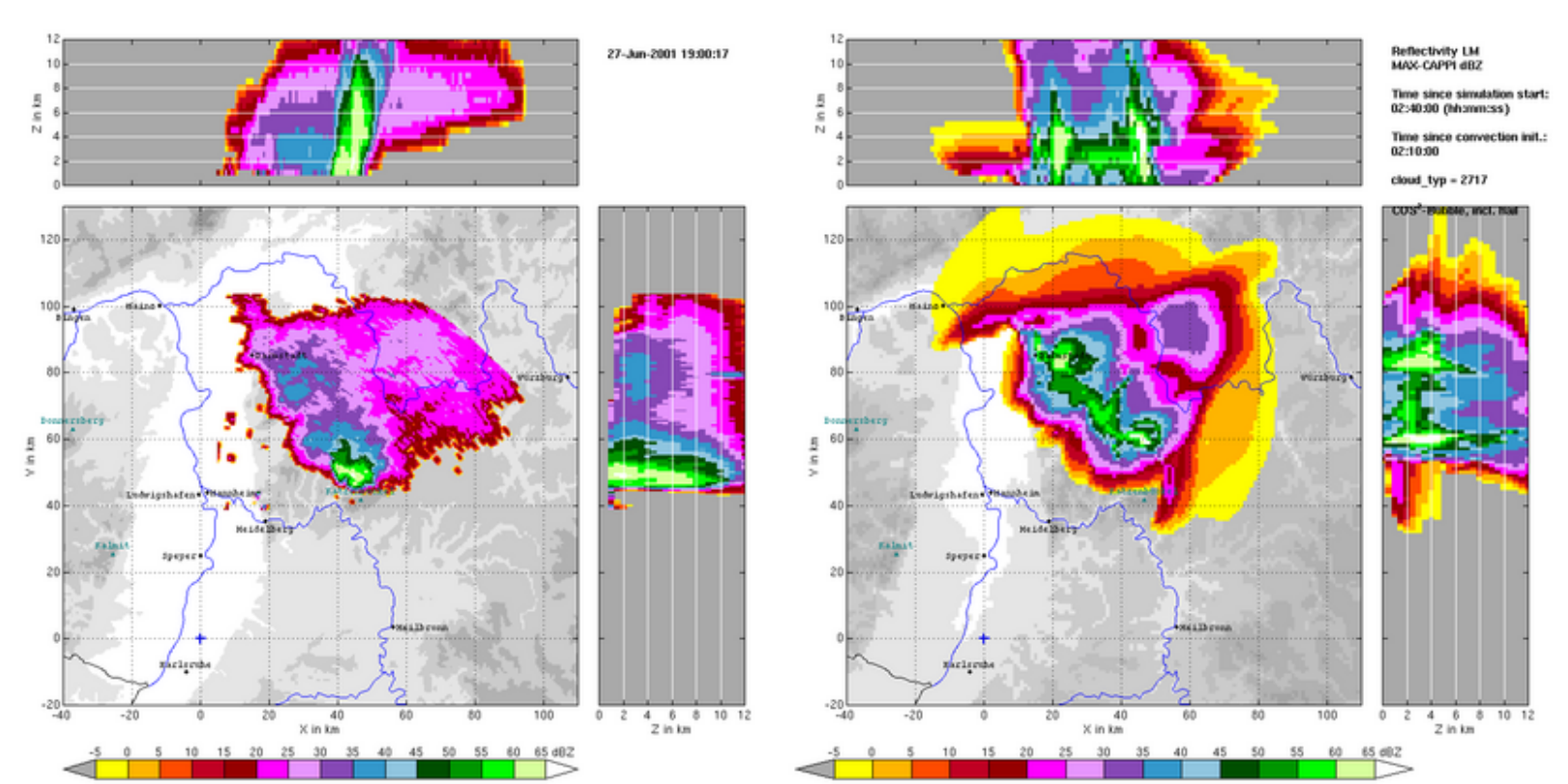

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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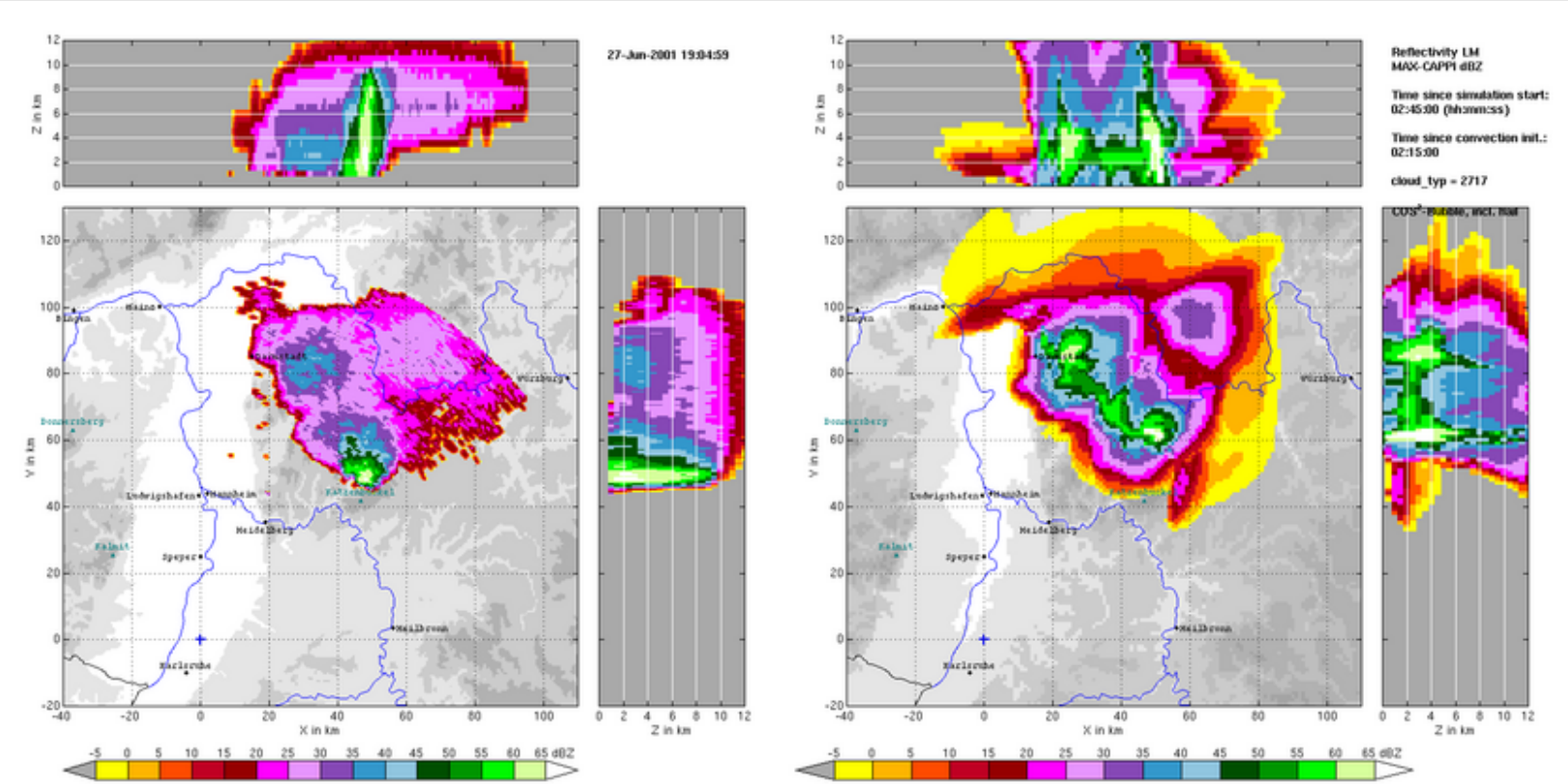

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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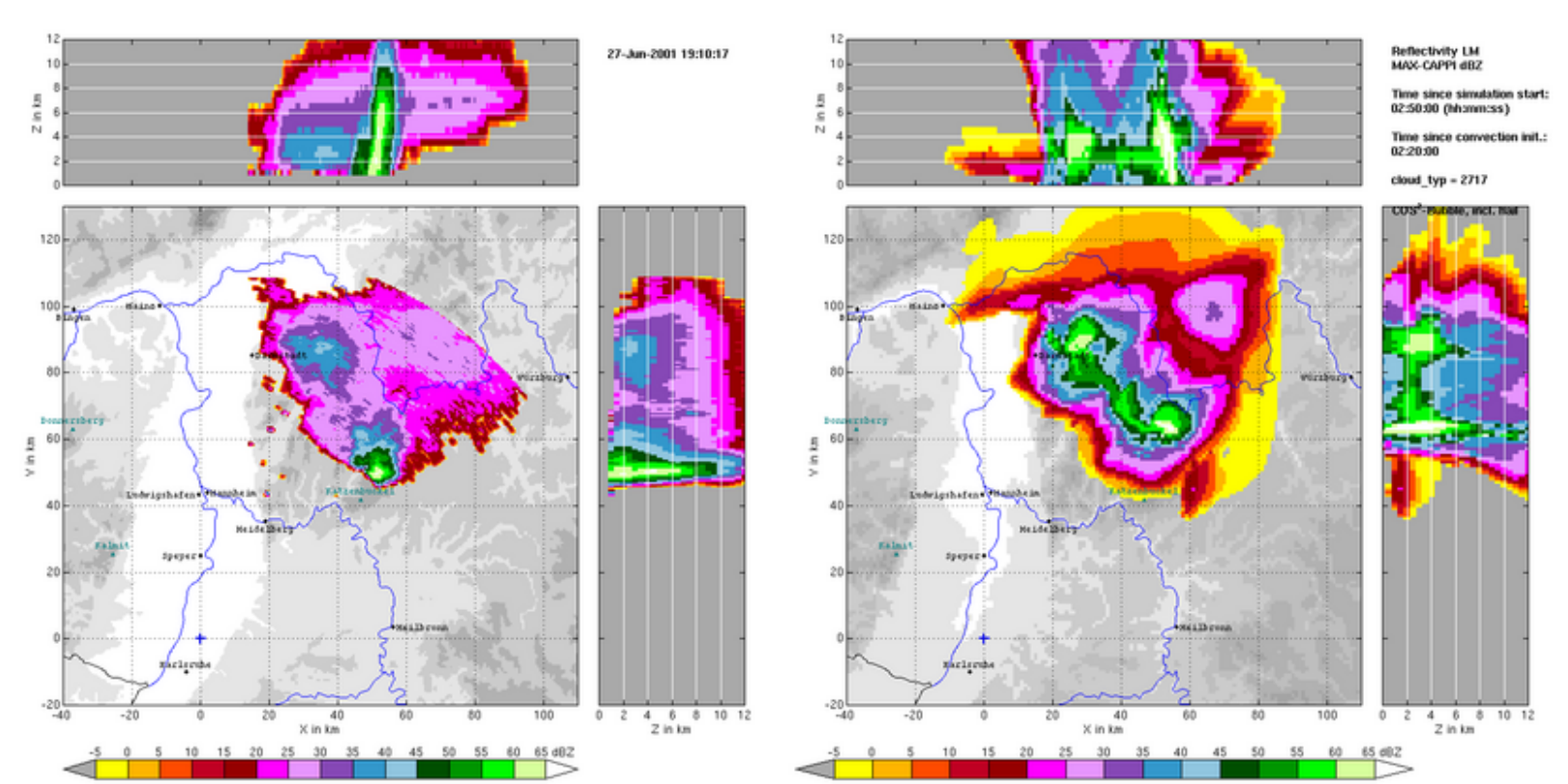

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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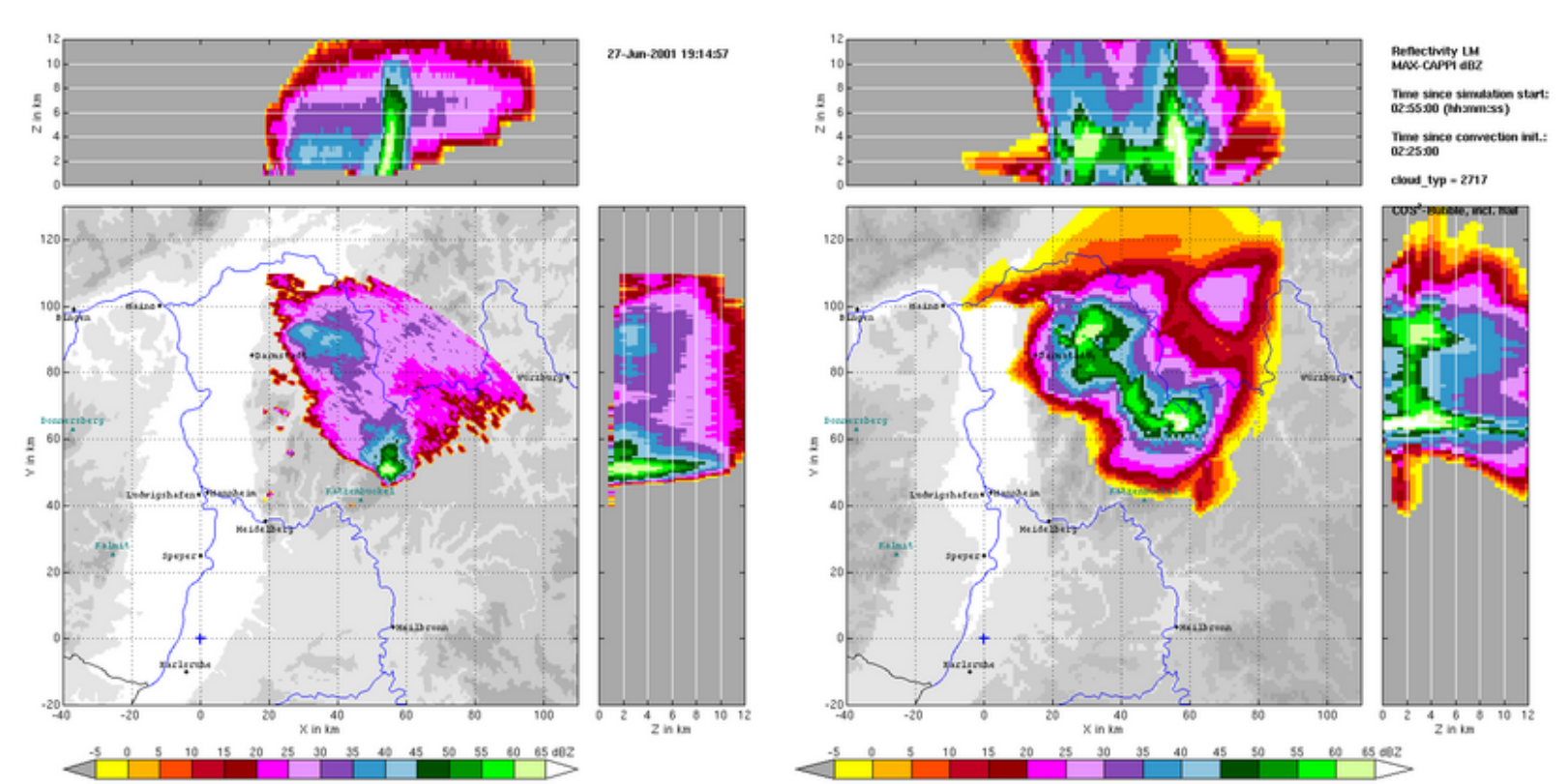

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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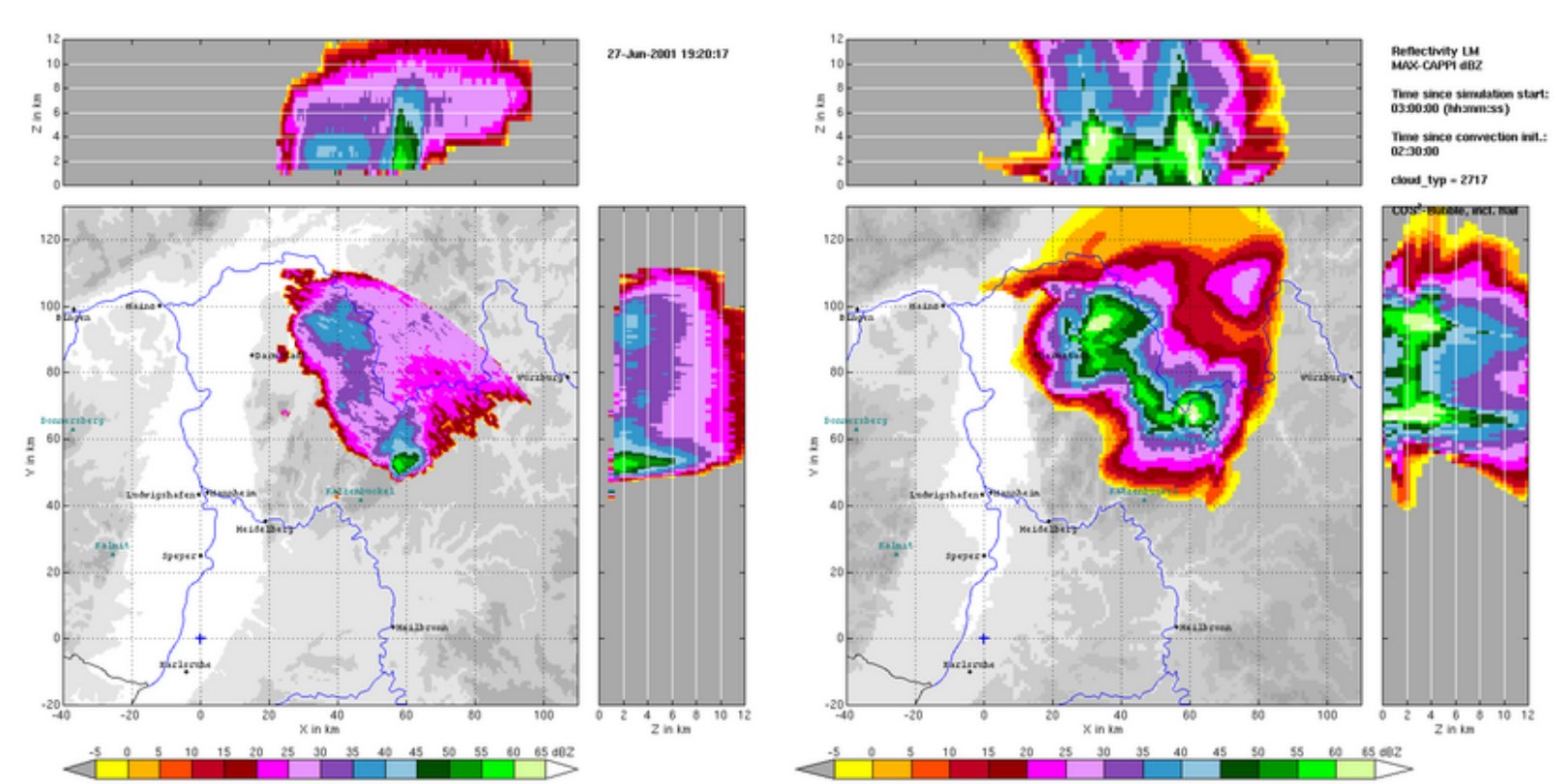


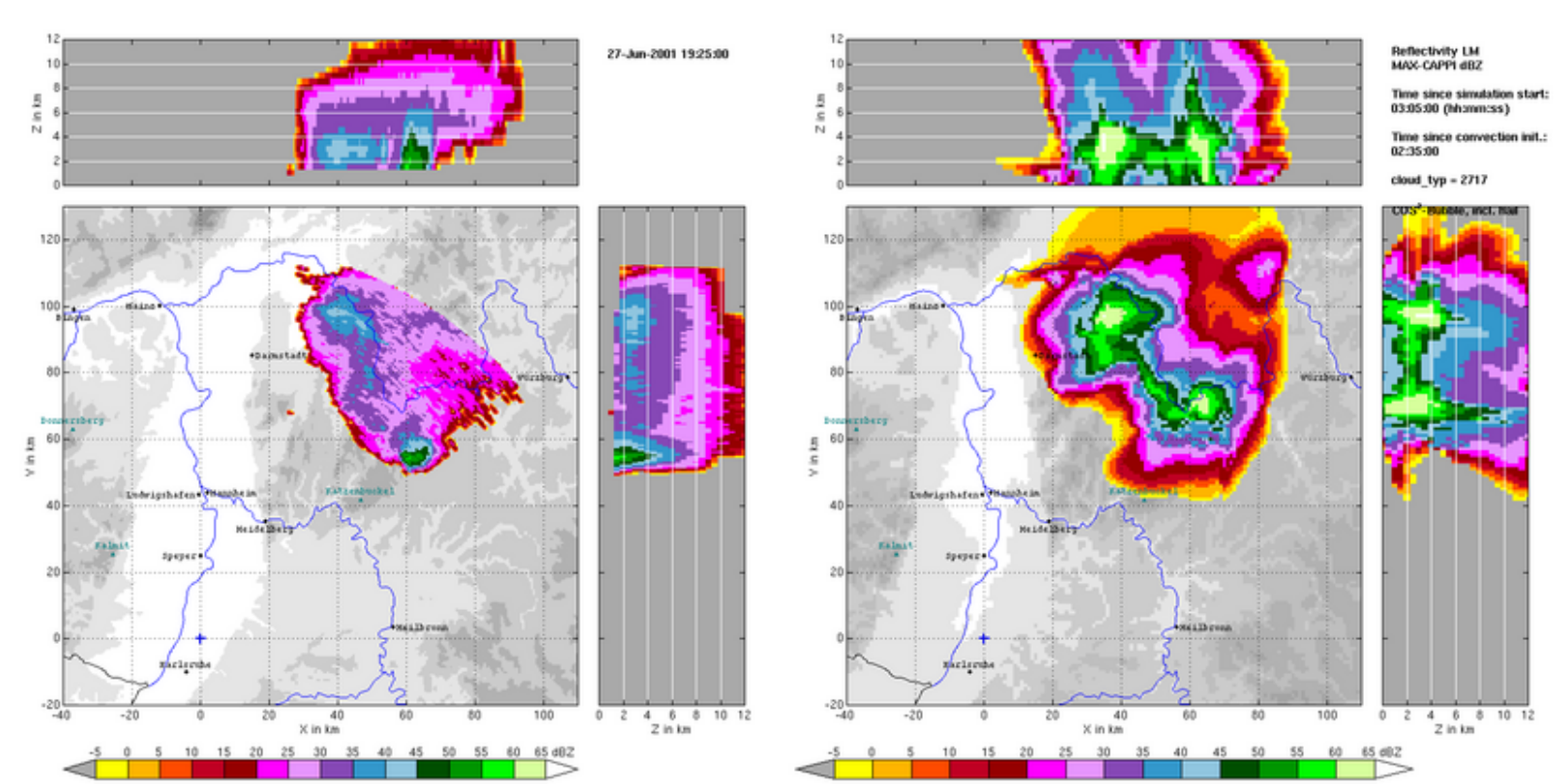
play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
`itype_turb` = 3



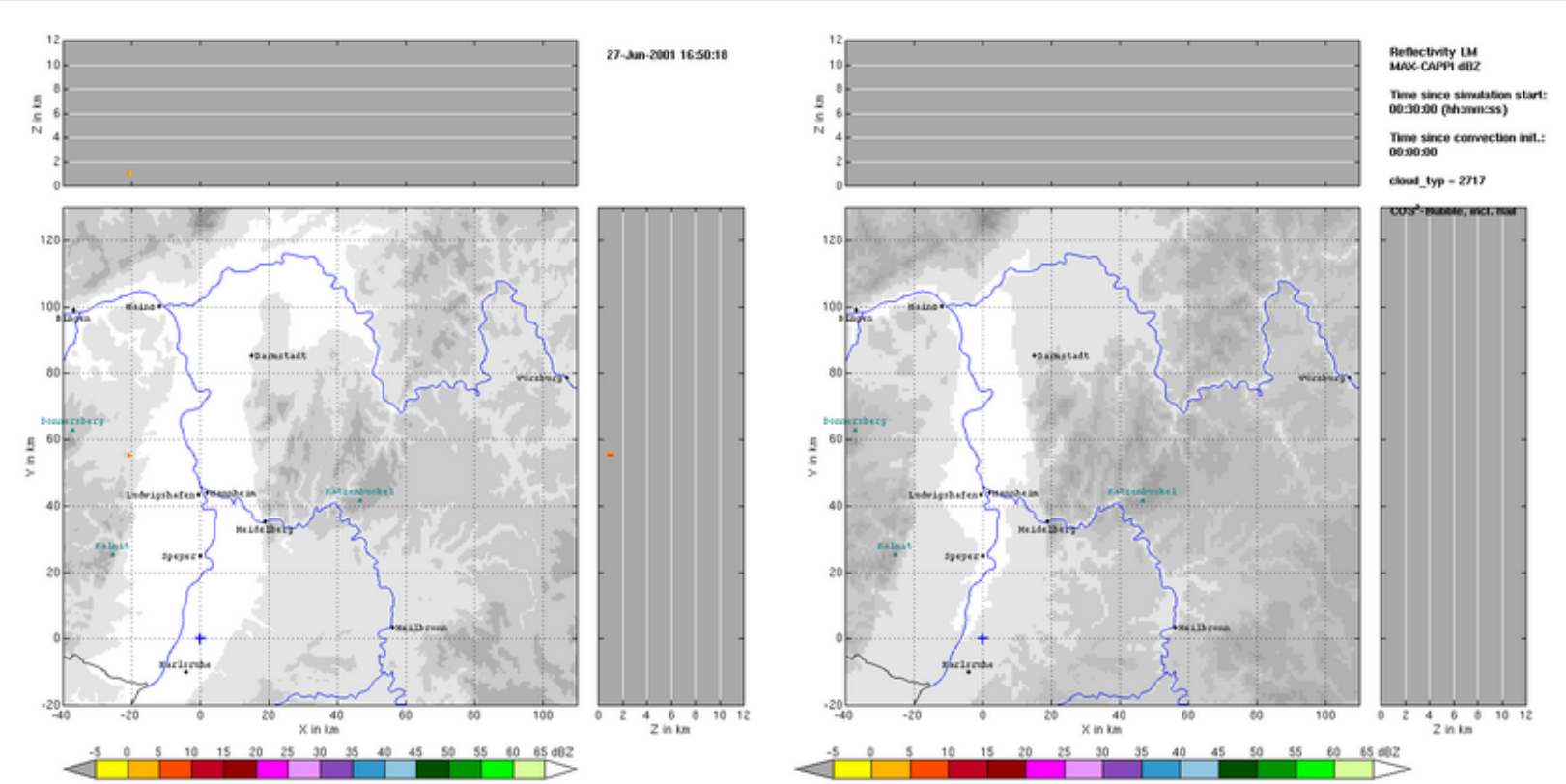
revert

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
`itype_turb` = 5



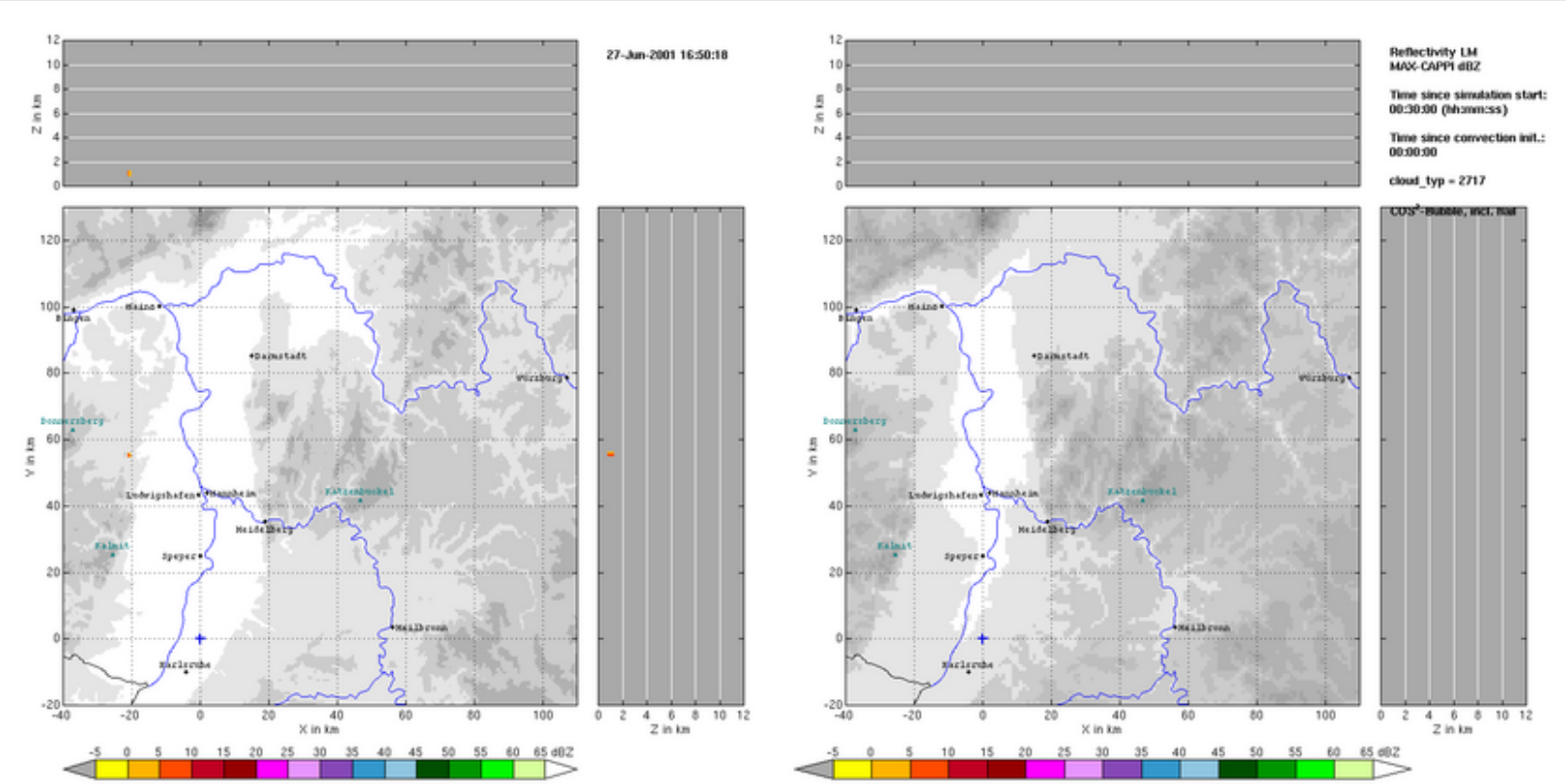
play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
`itype_turb` = 5



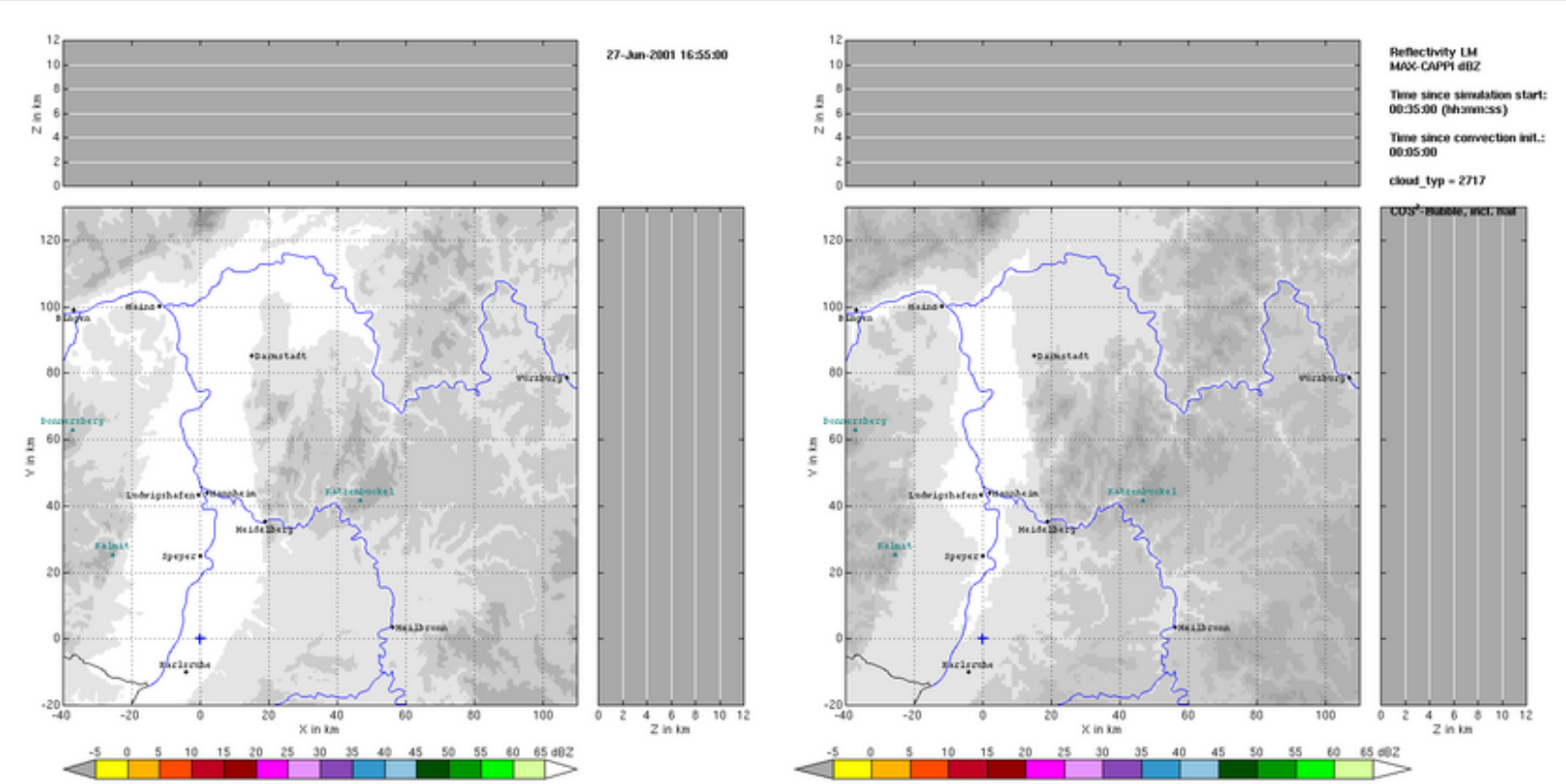
play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
`itype_turb` = 5



play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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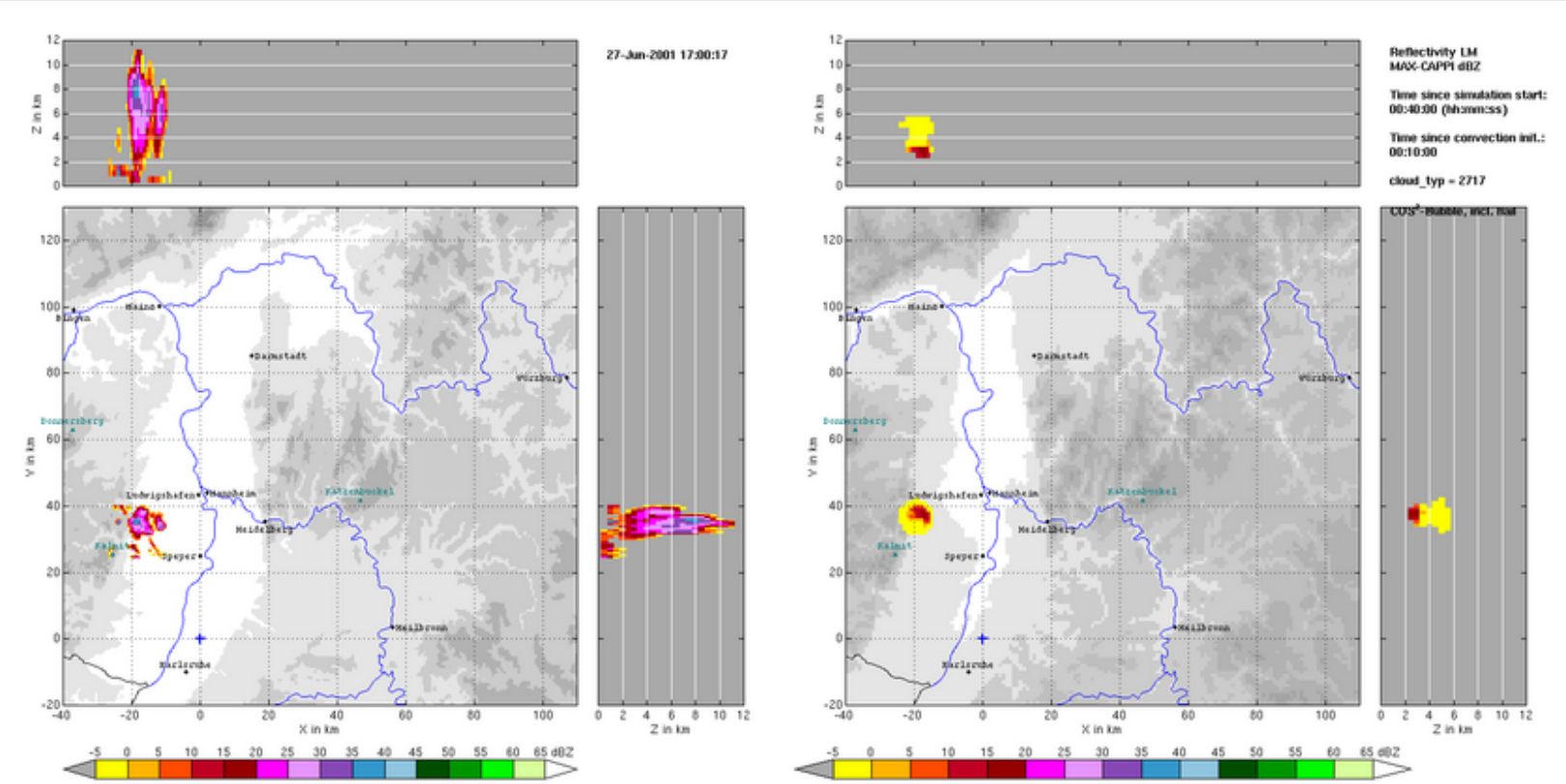

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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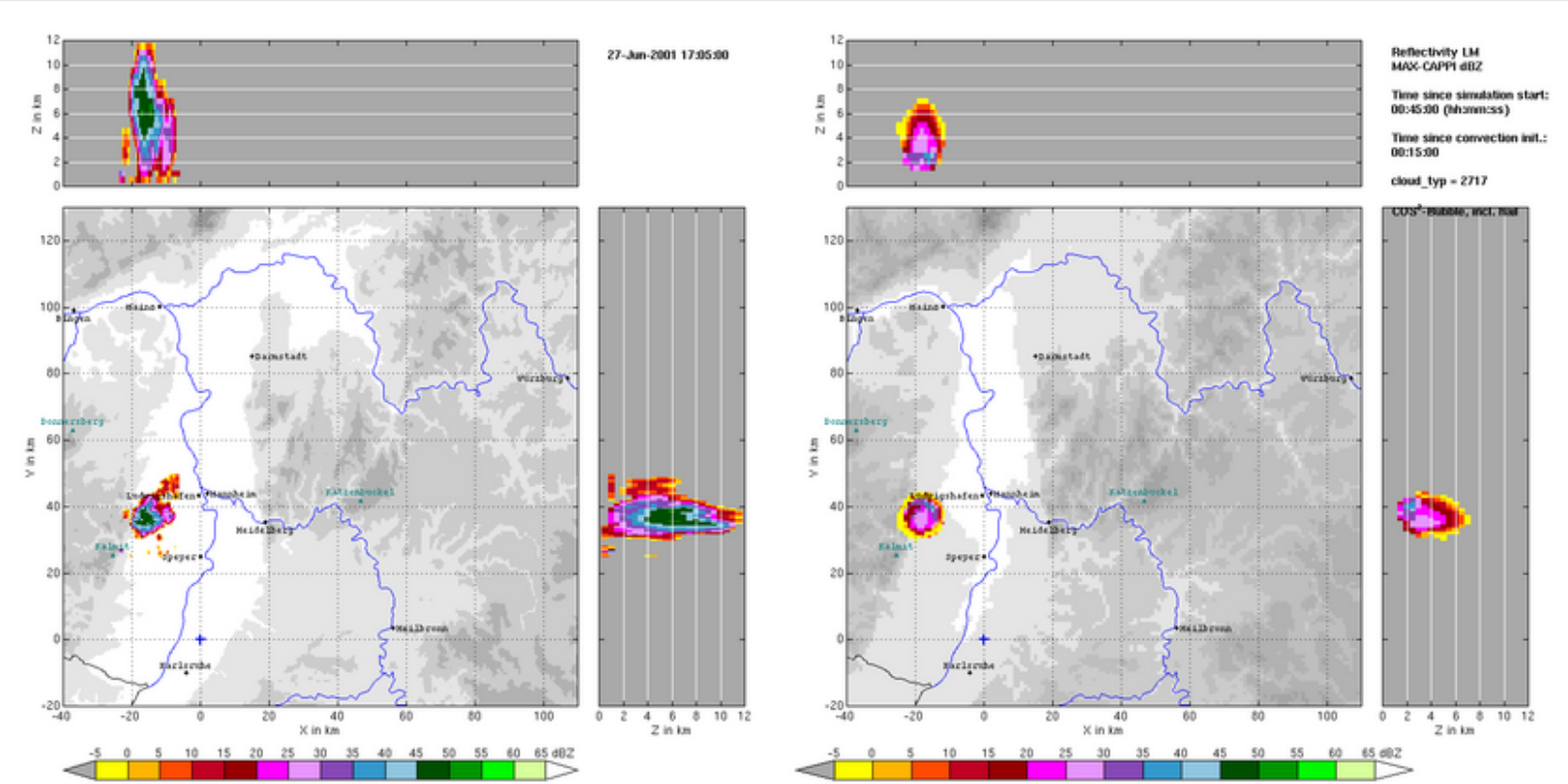

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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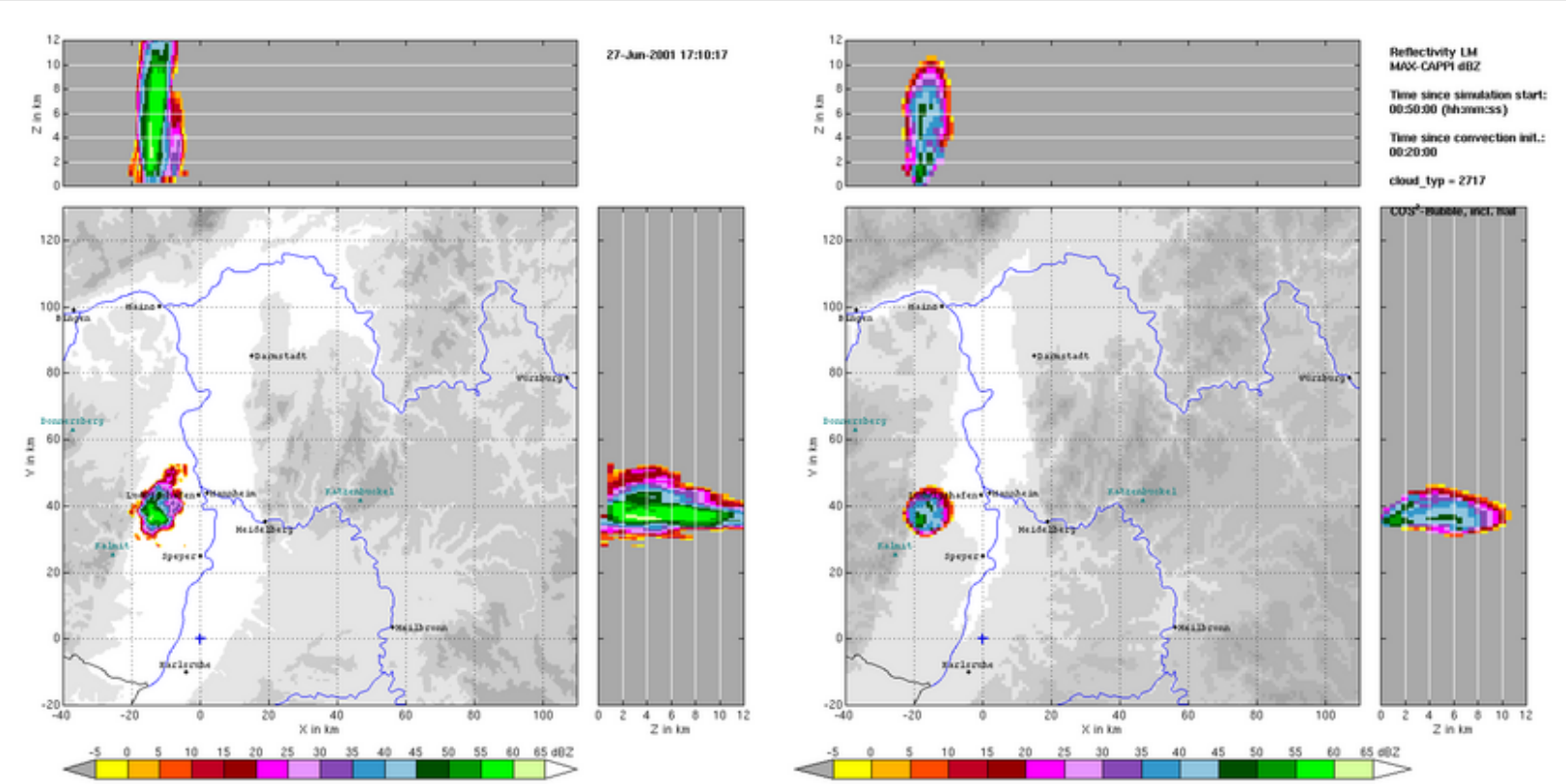

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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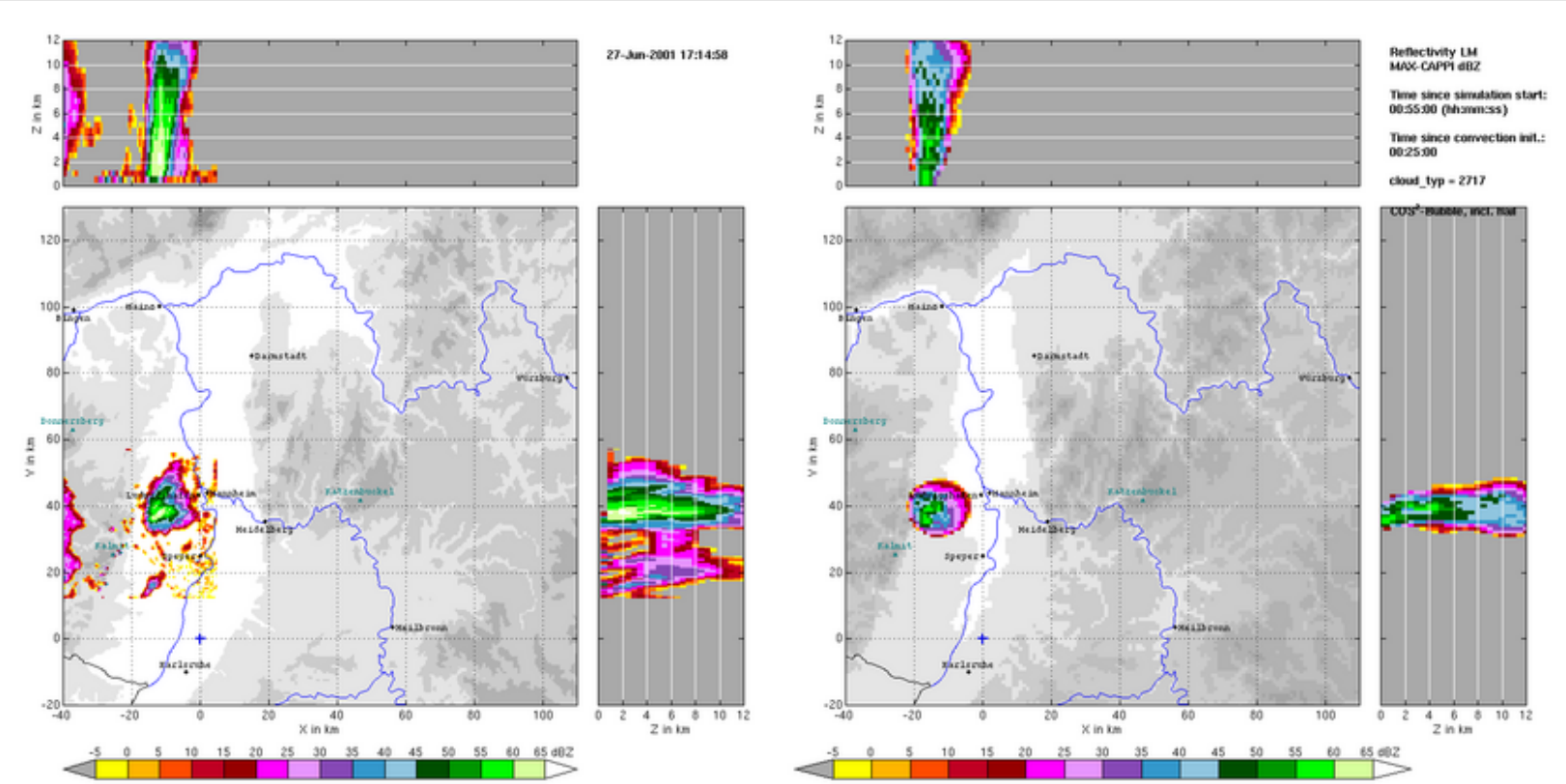

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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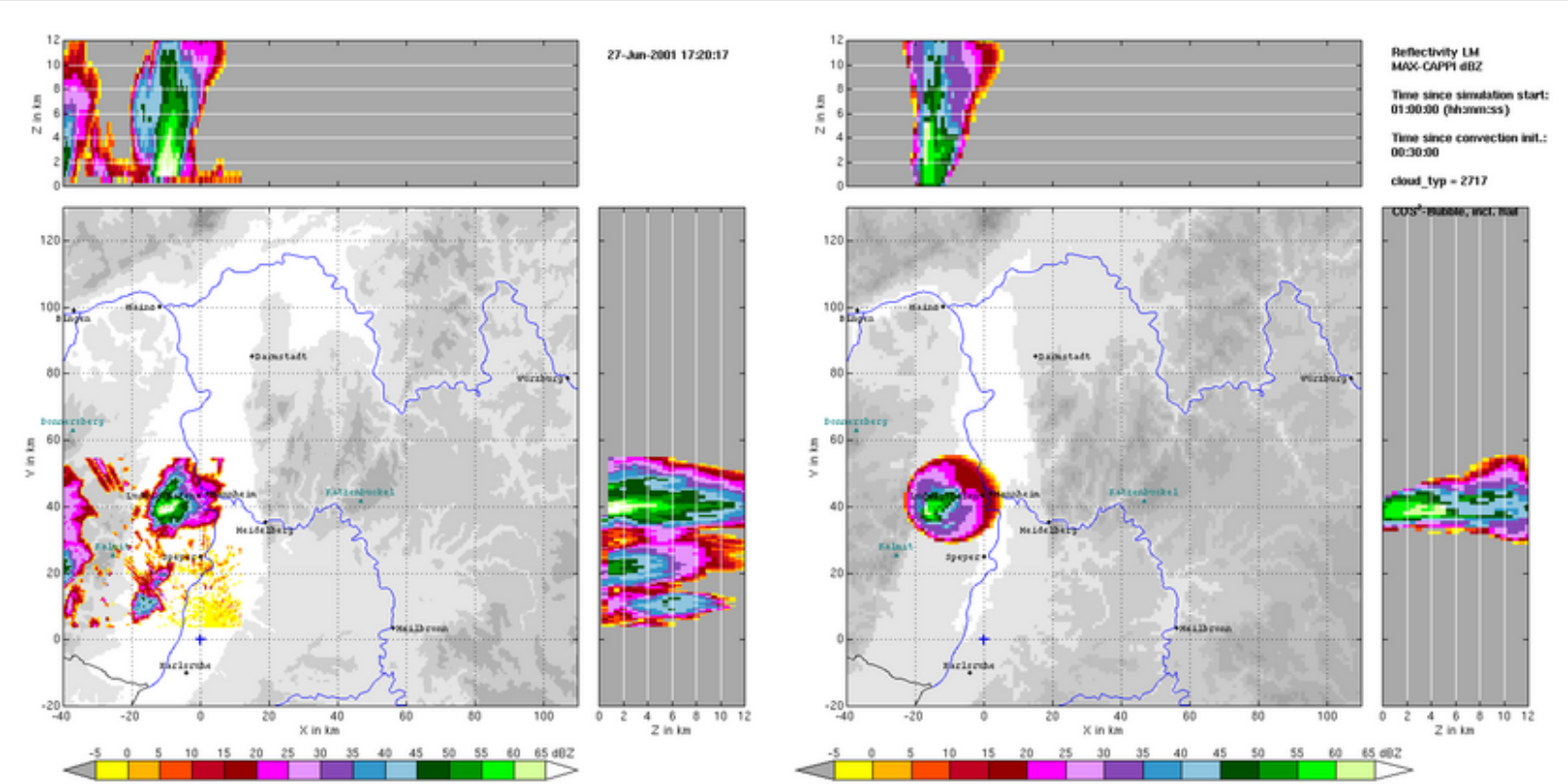

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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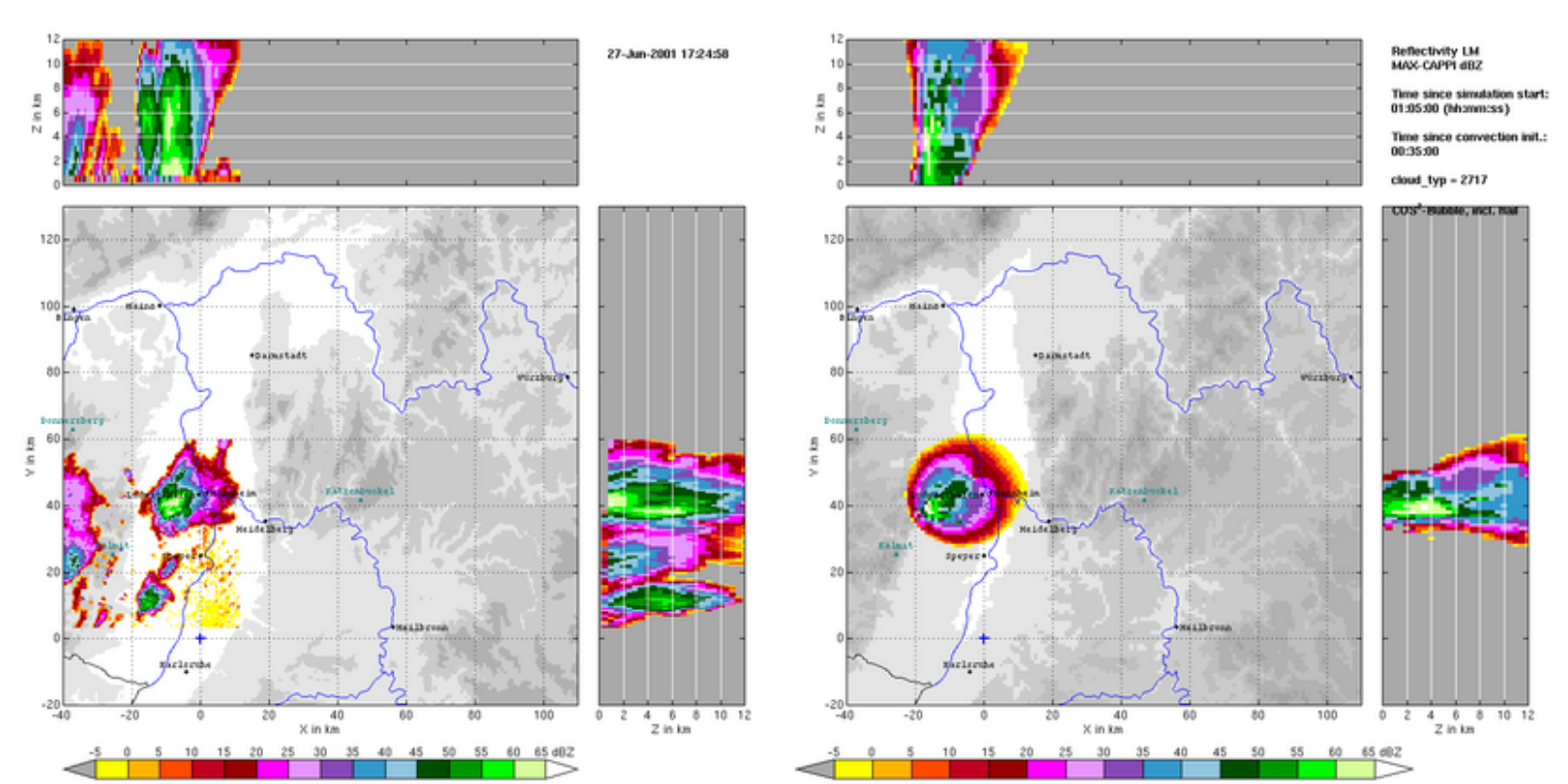

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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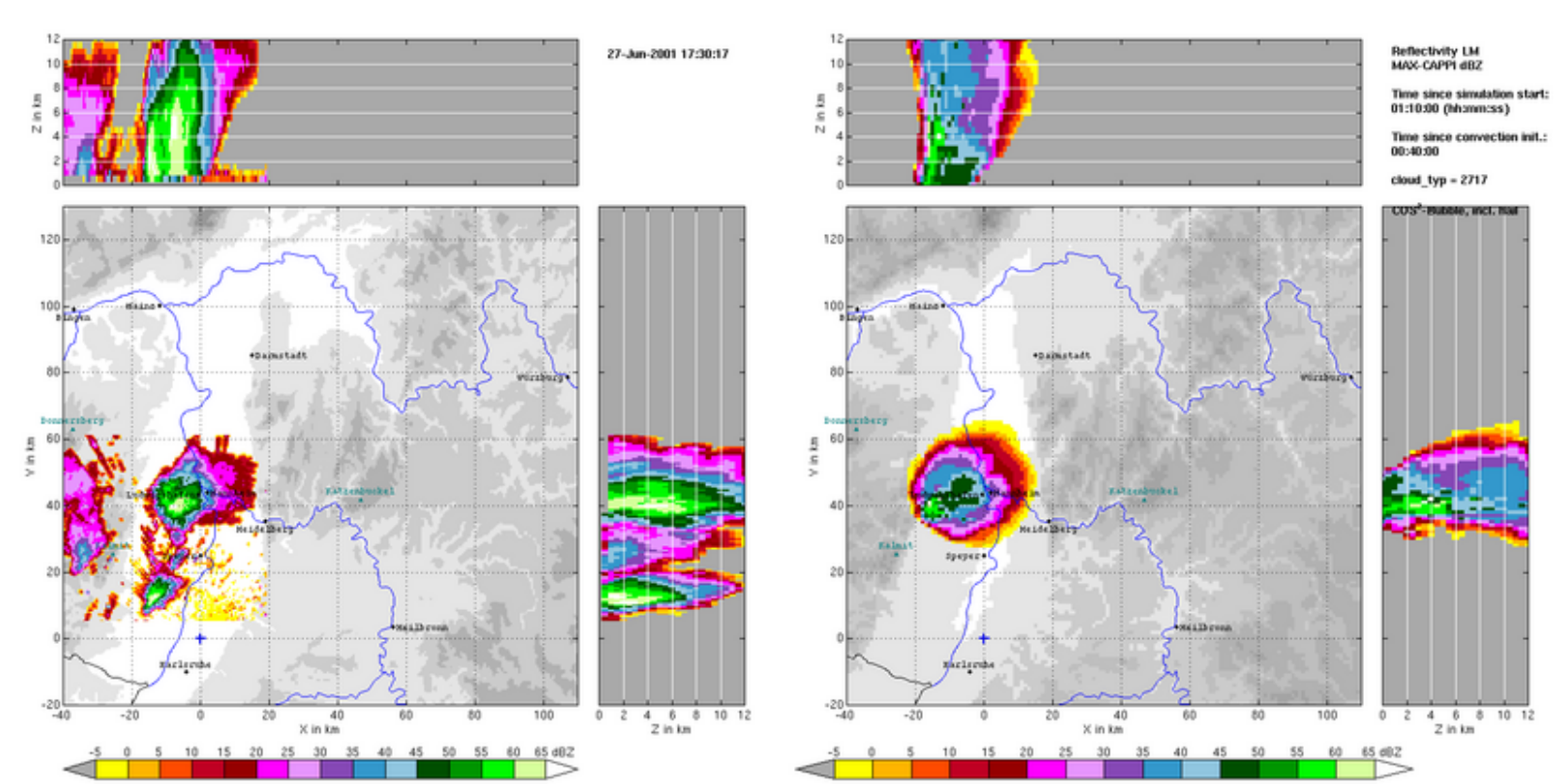

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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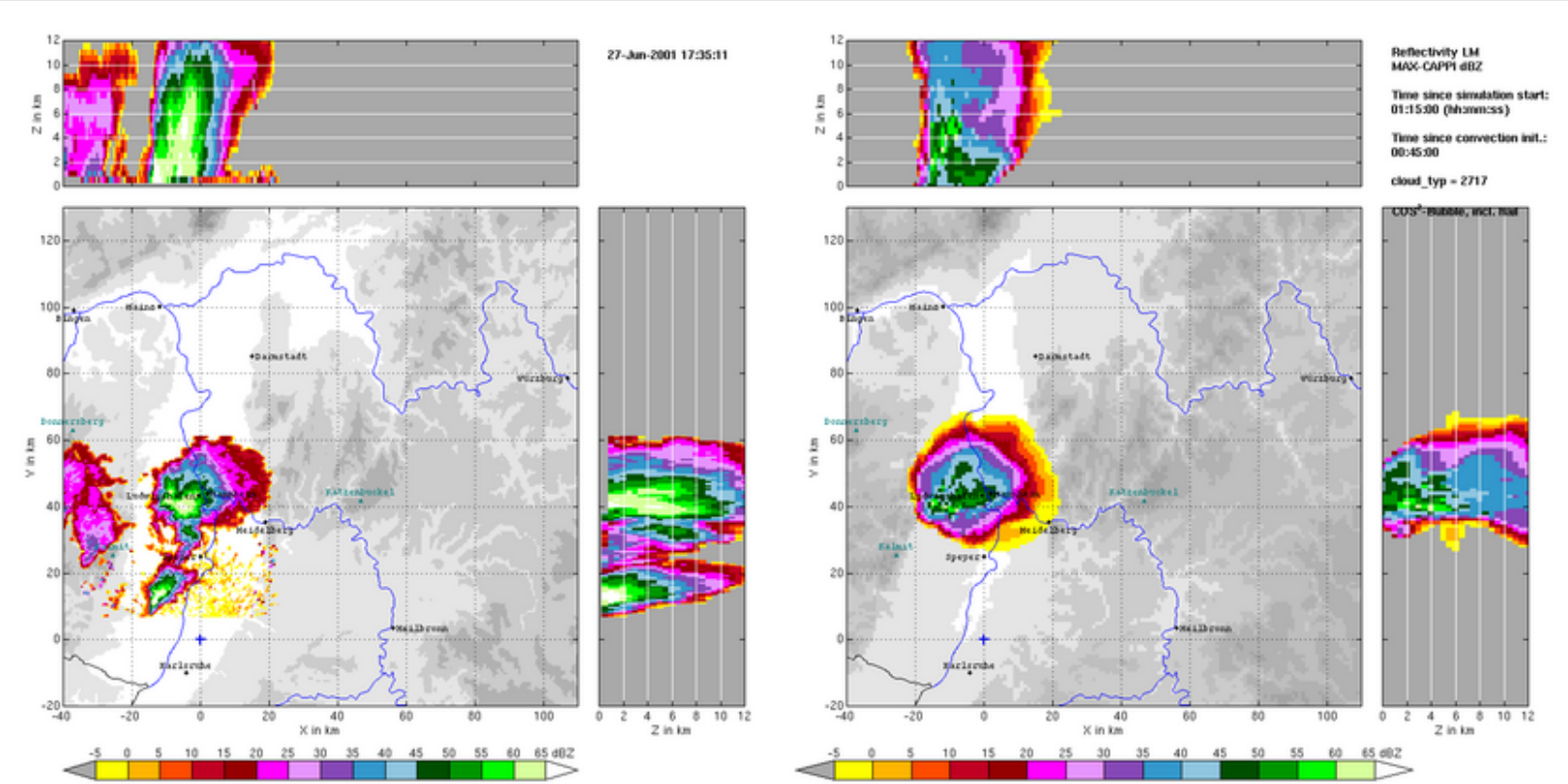

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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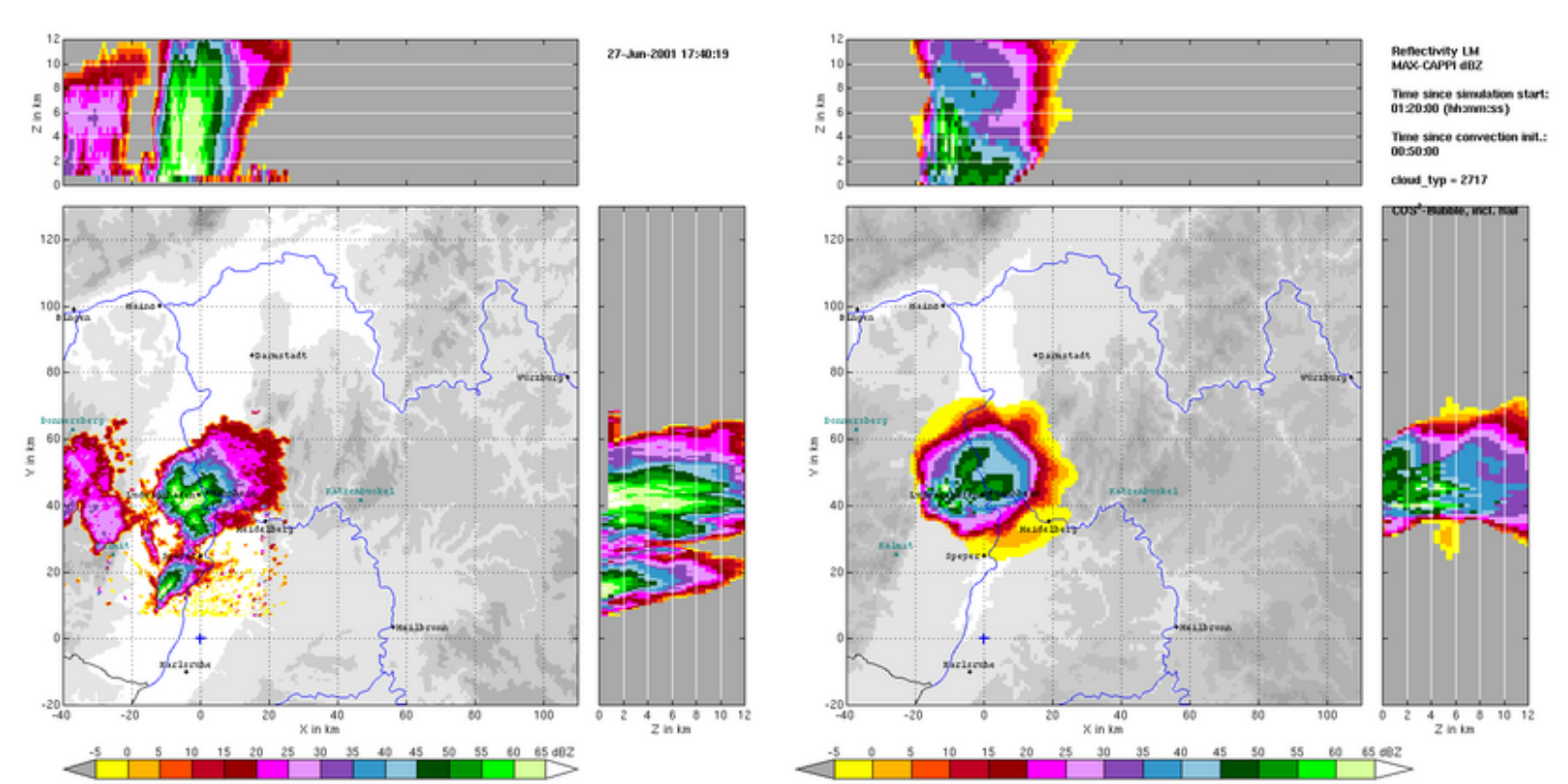

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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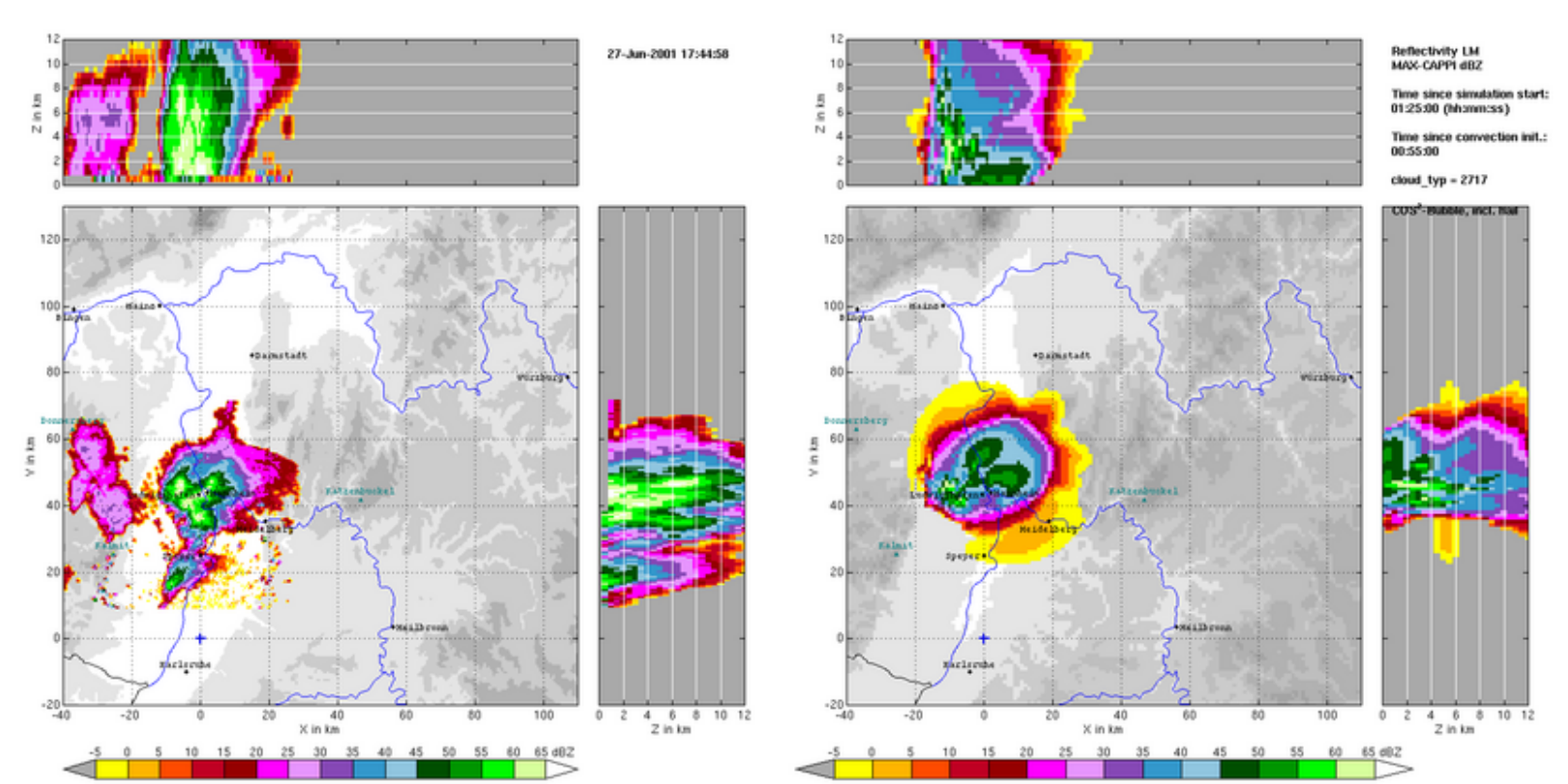

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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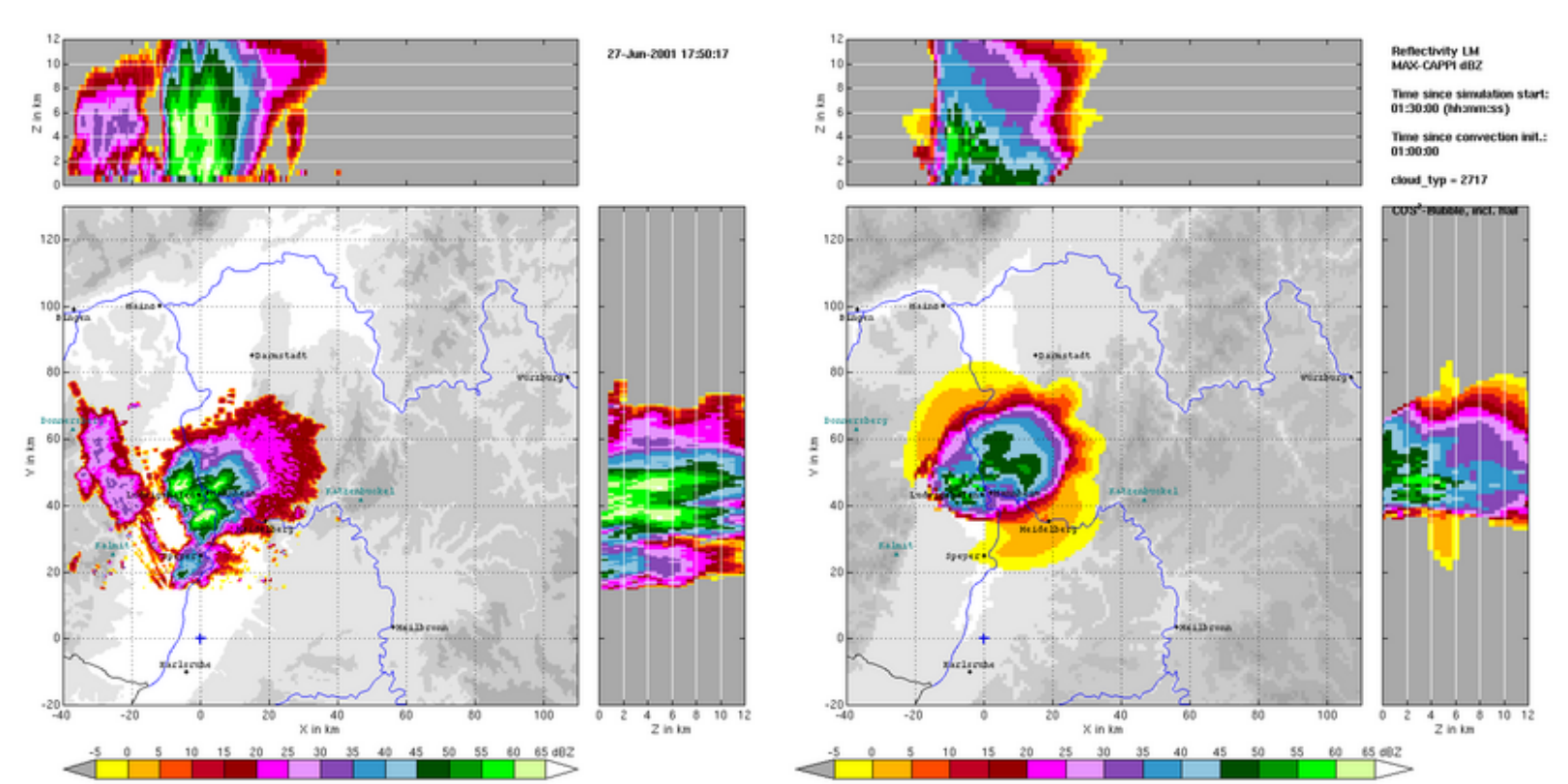

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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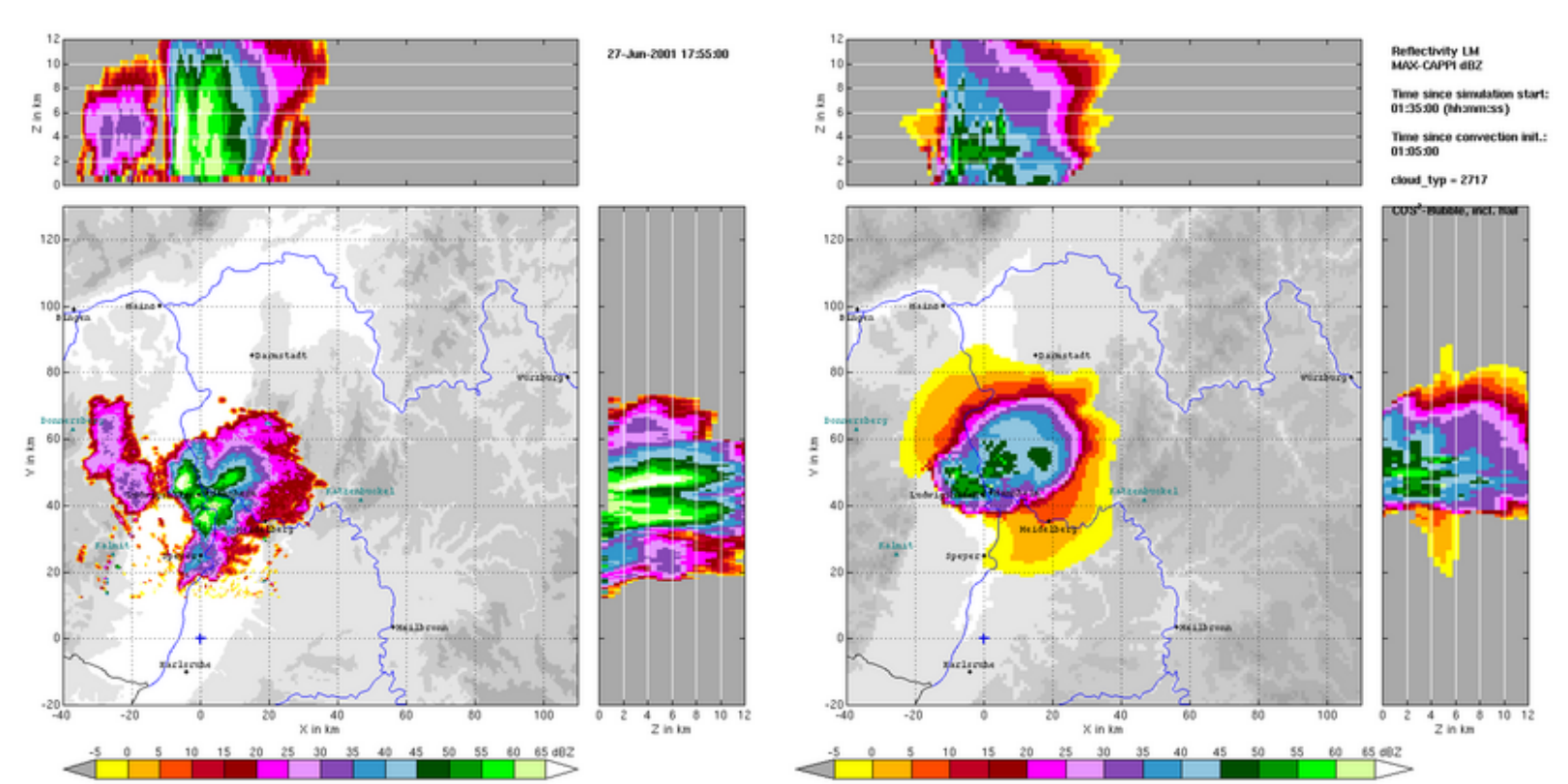

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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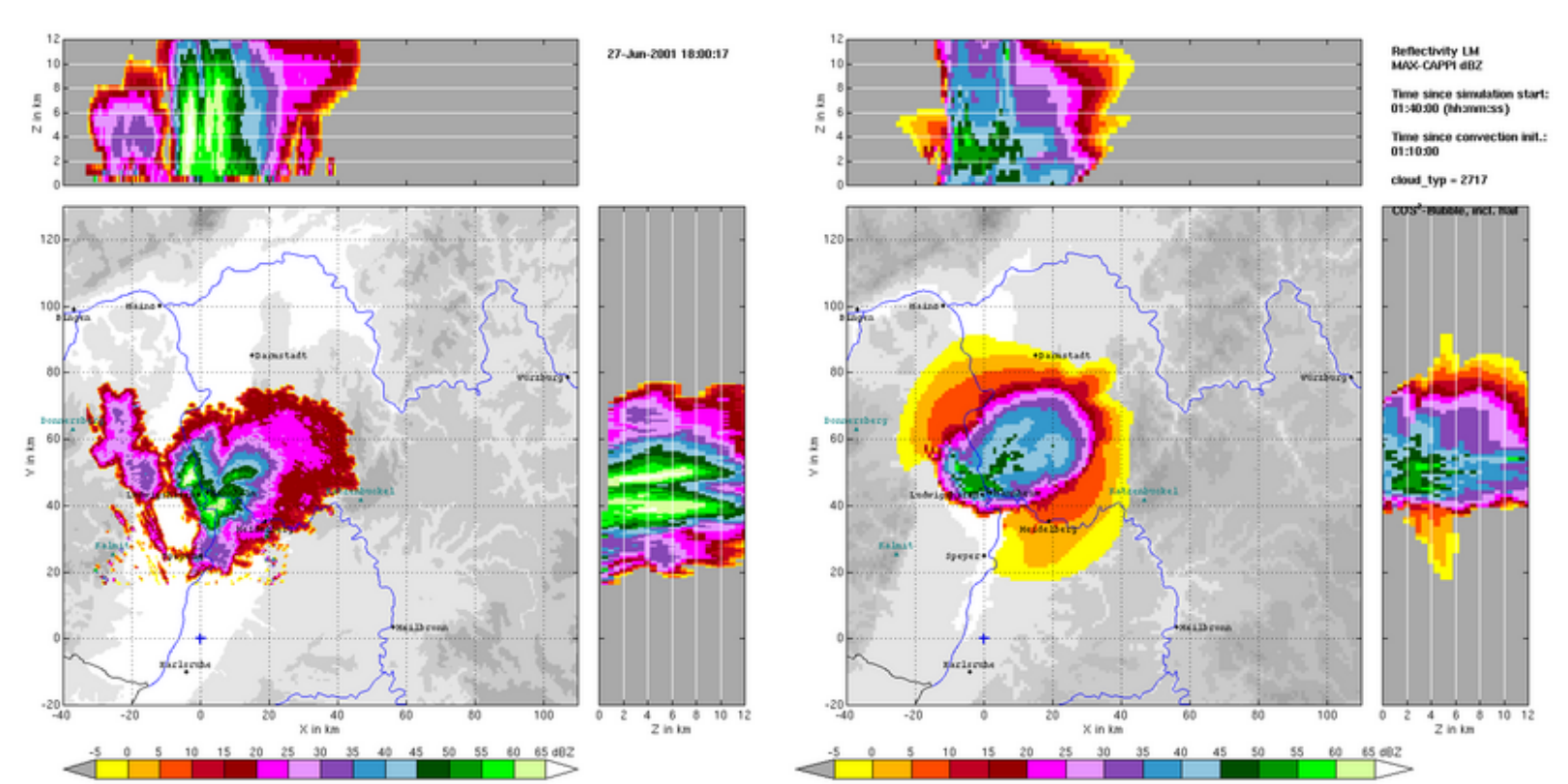

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
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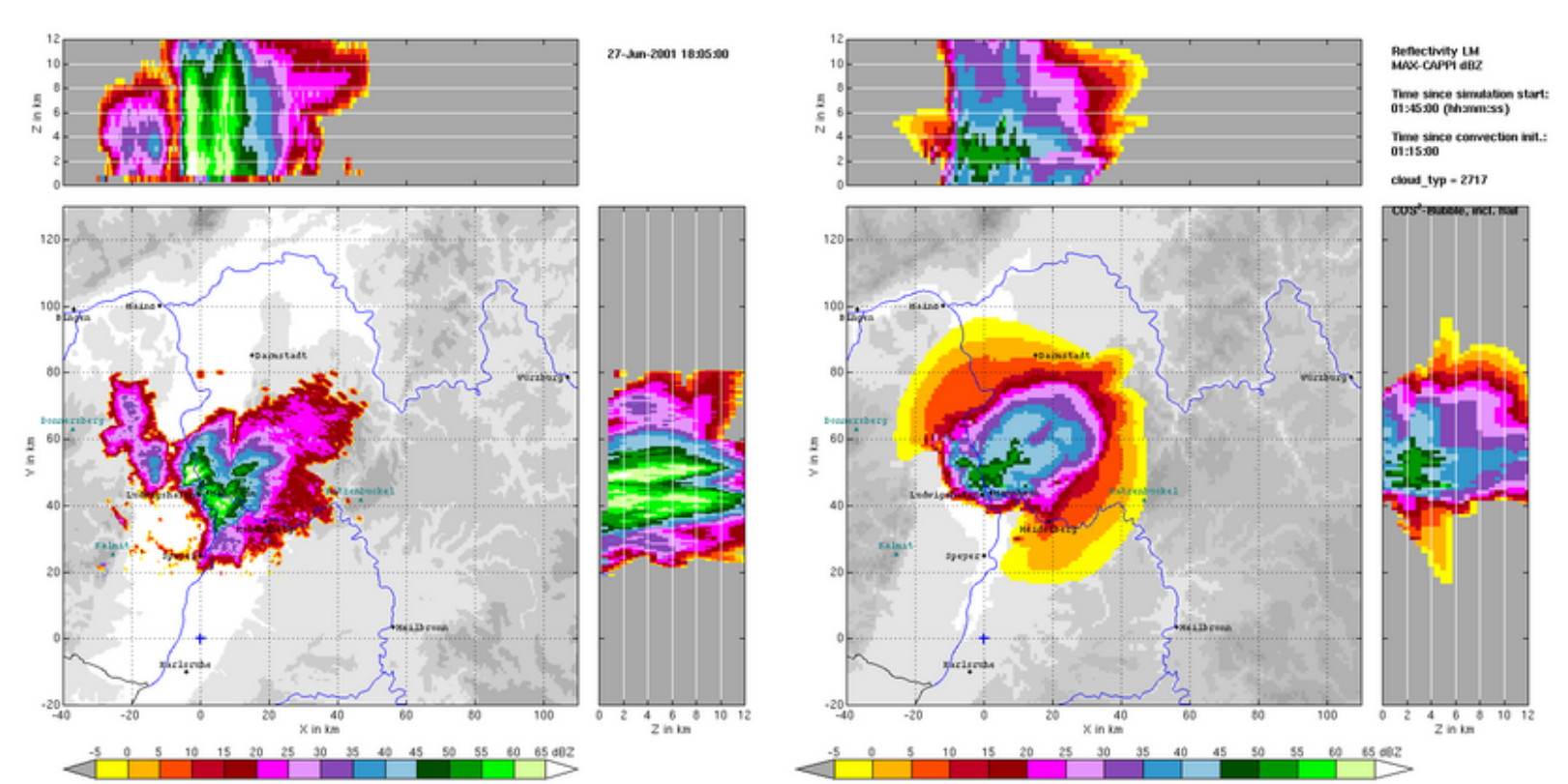

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

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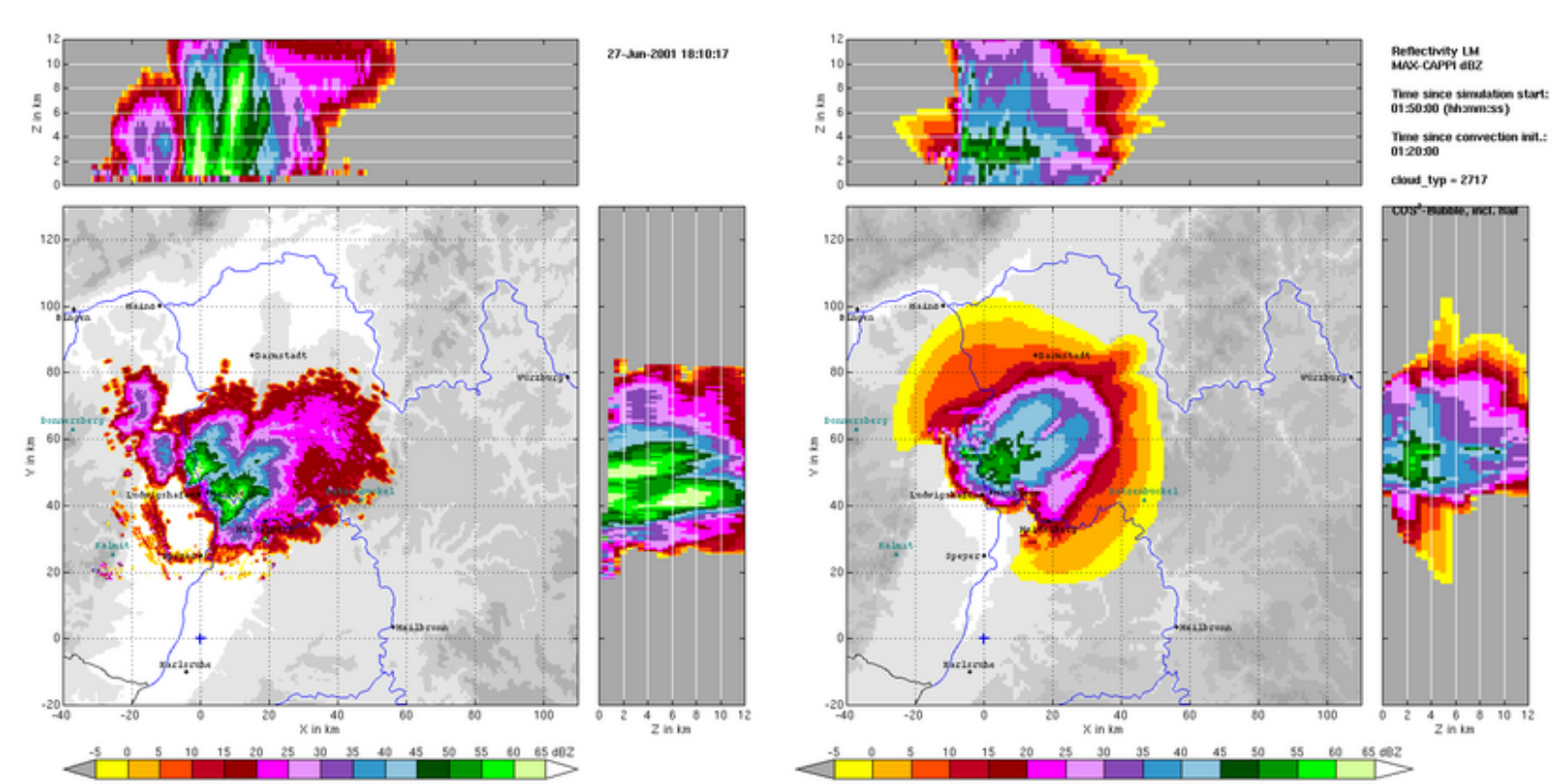

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

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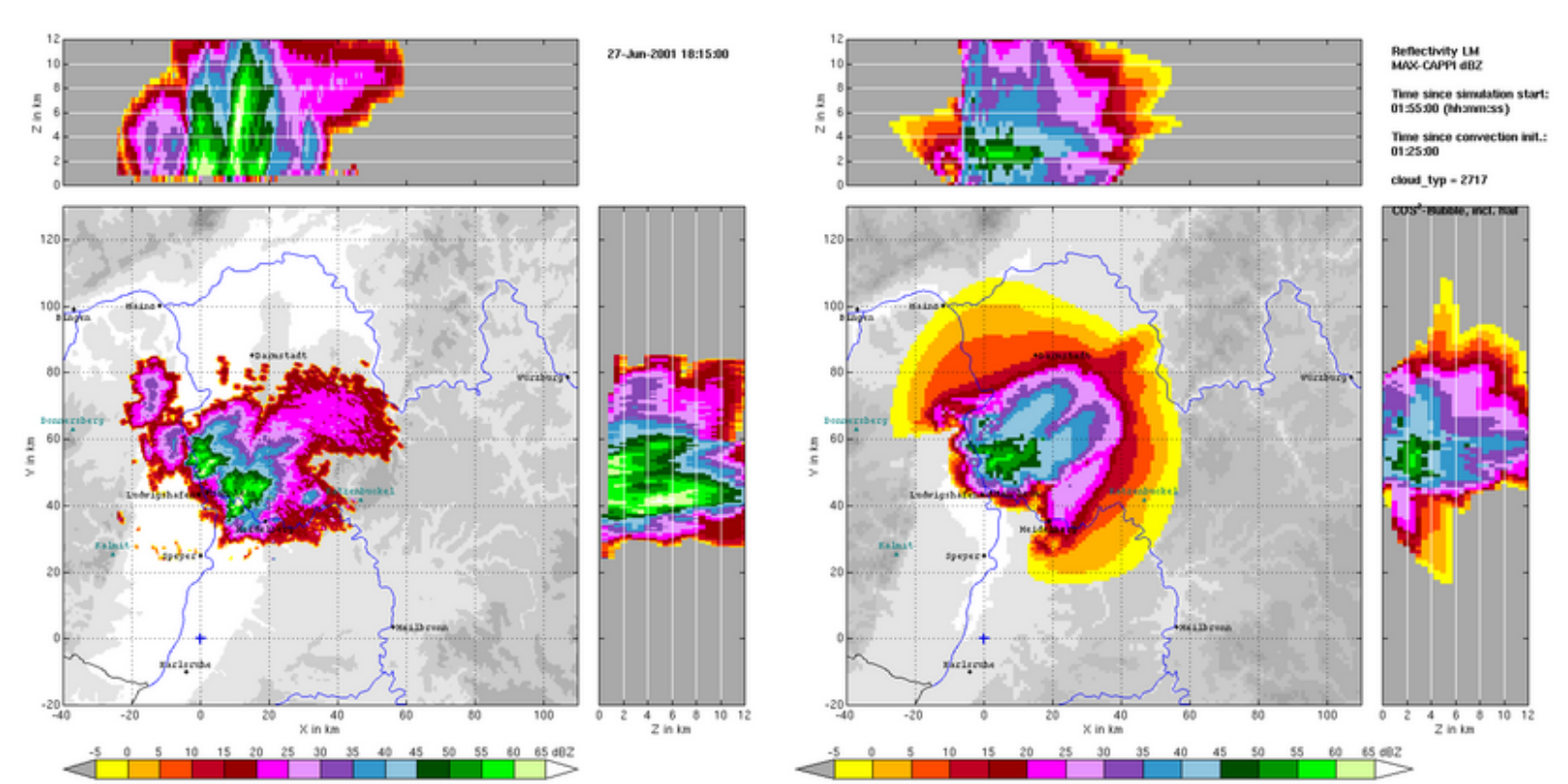

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

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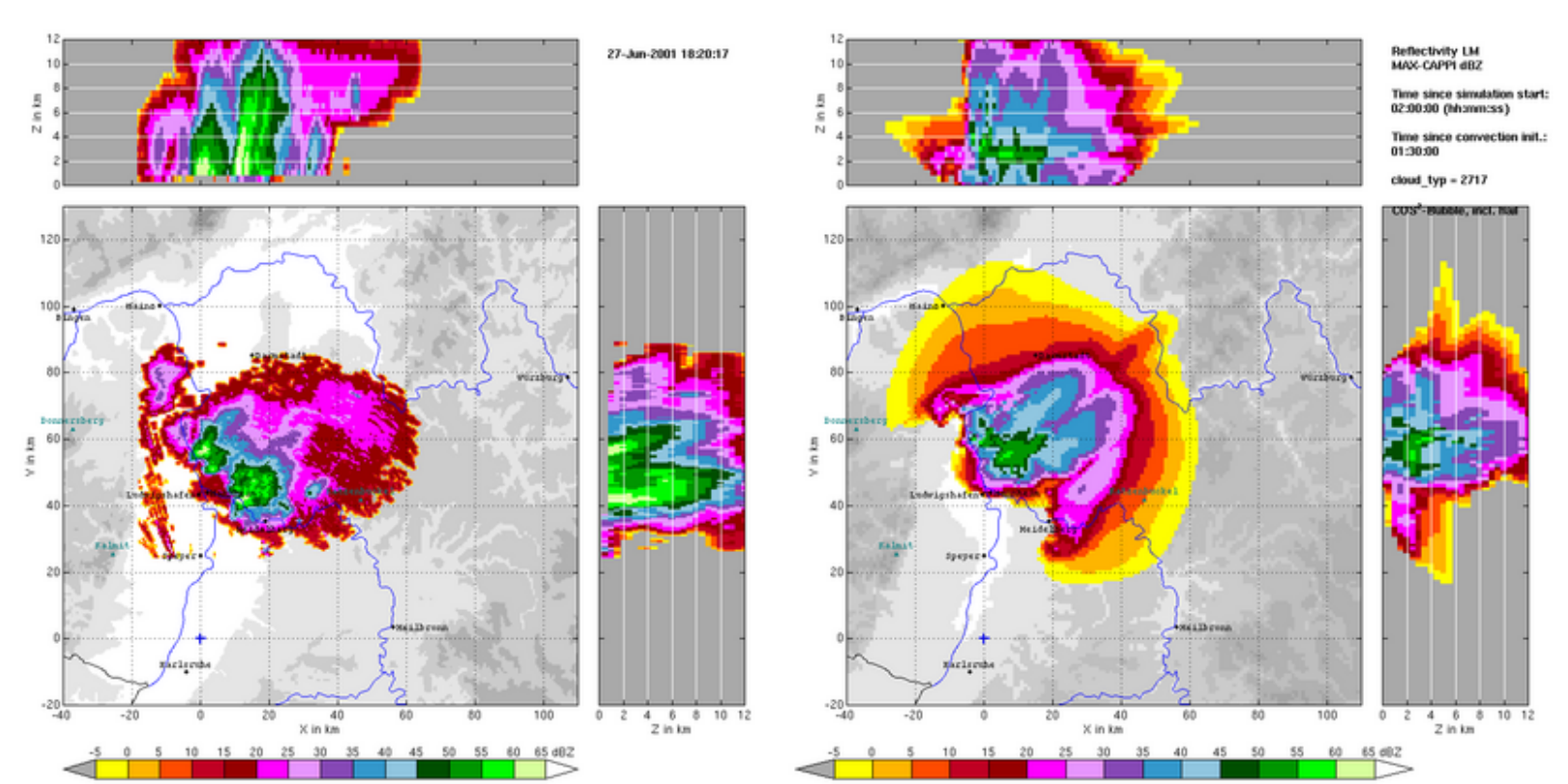

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

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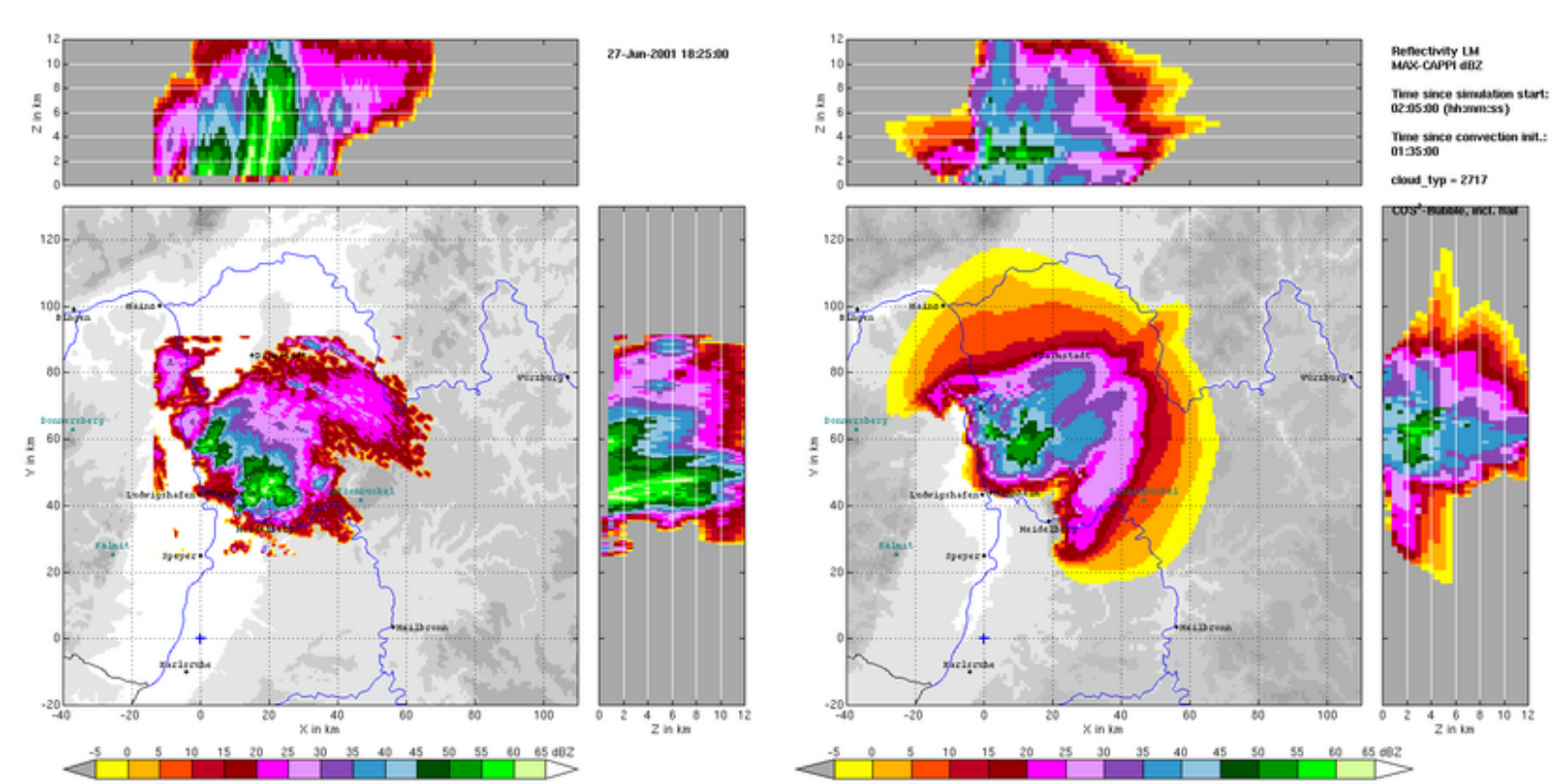

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

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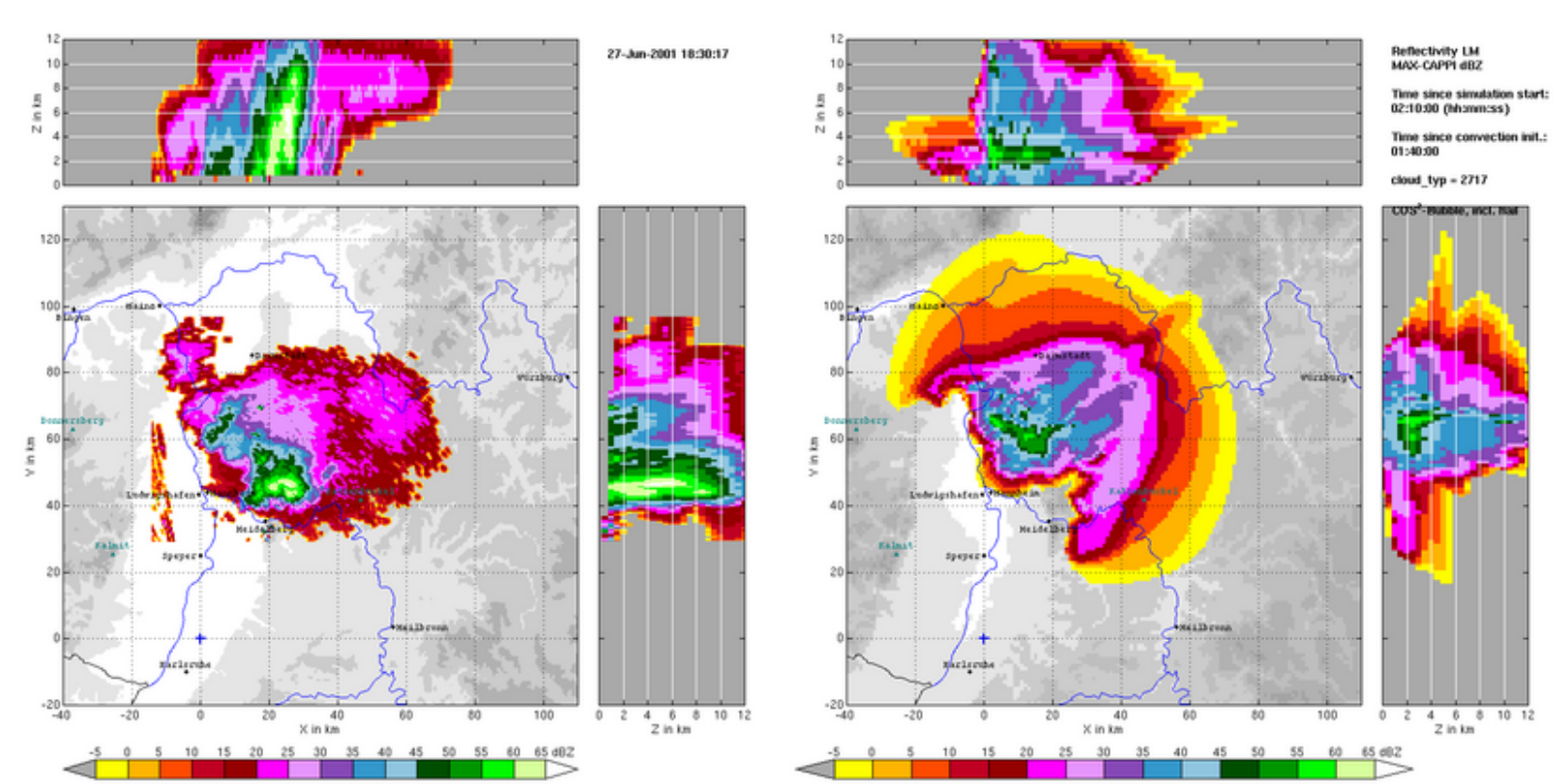

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A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

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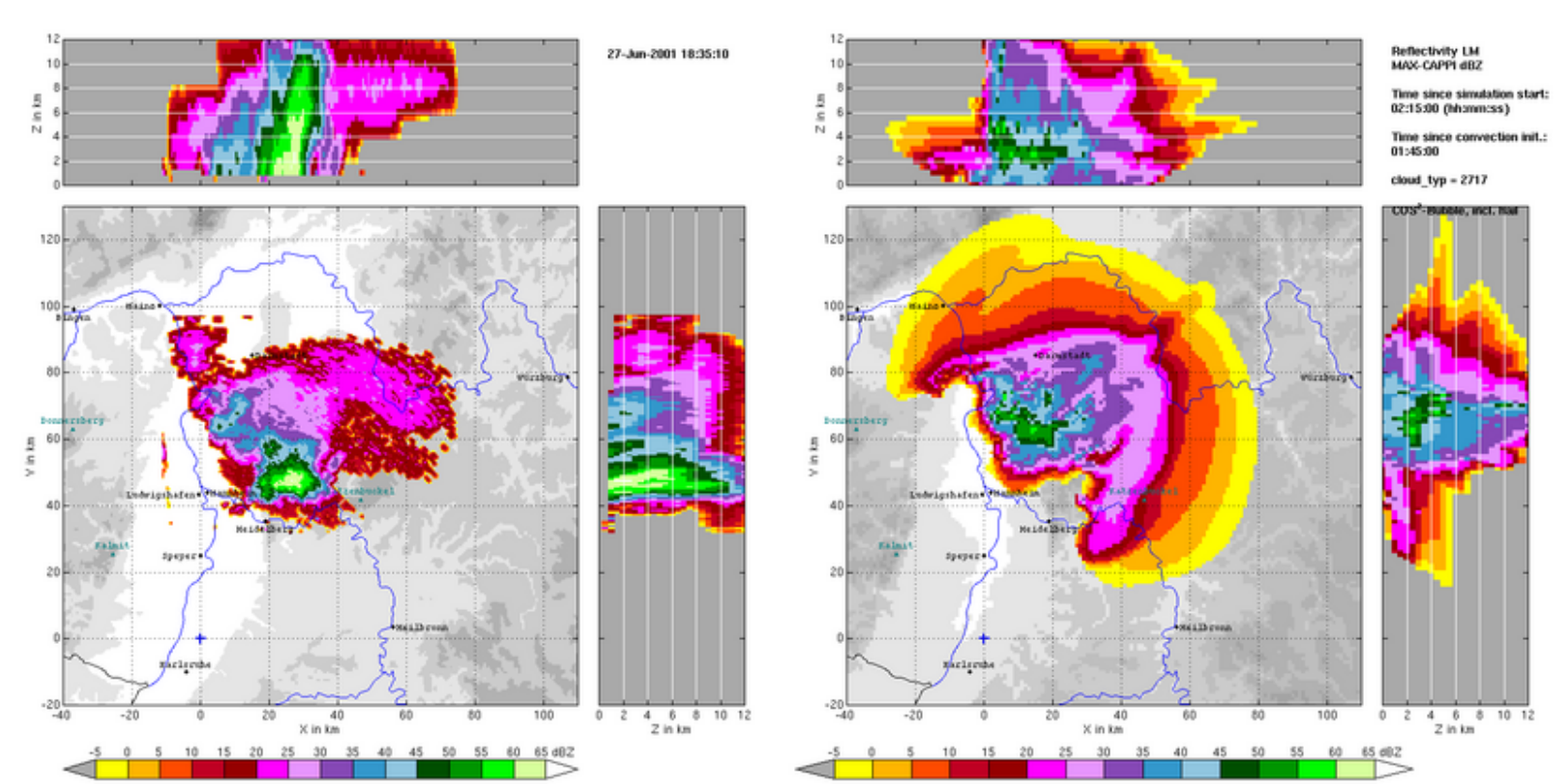

play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

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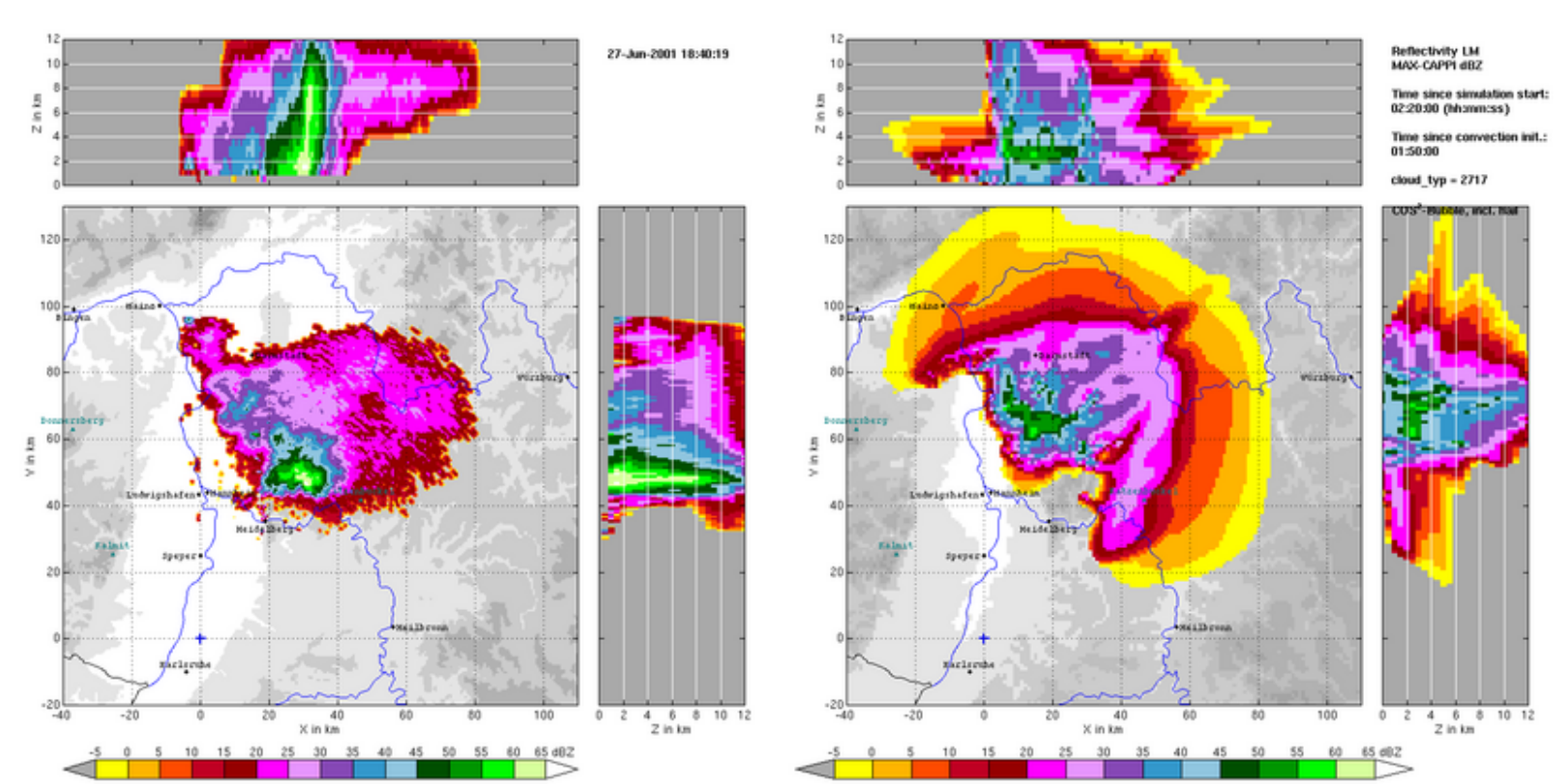


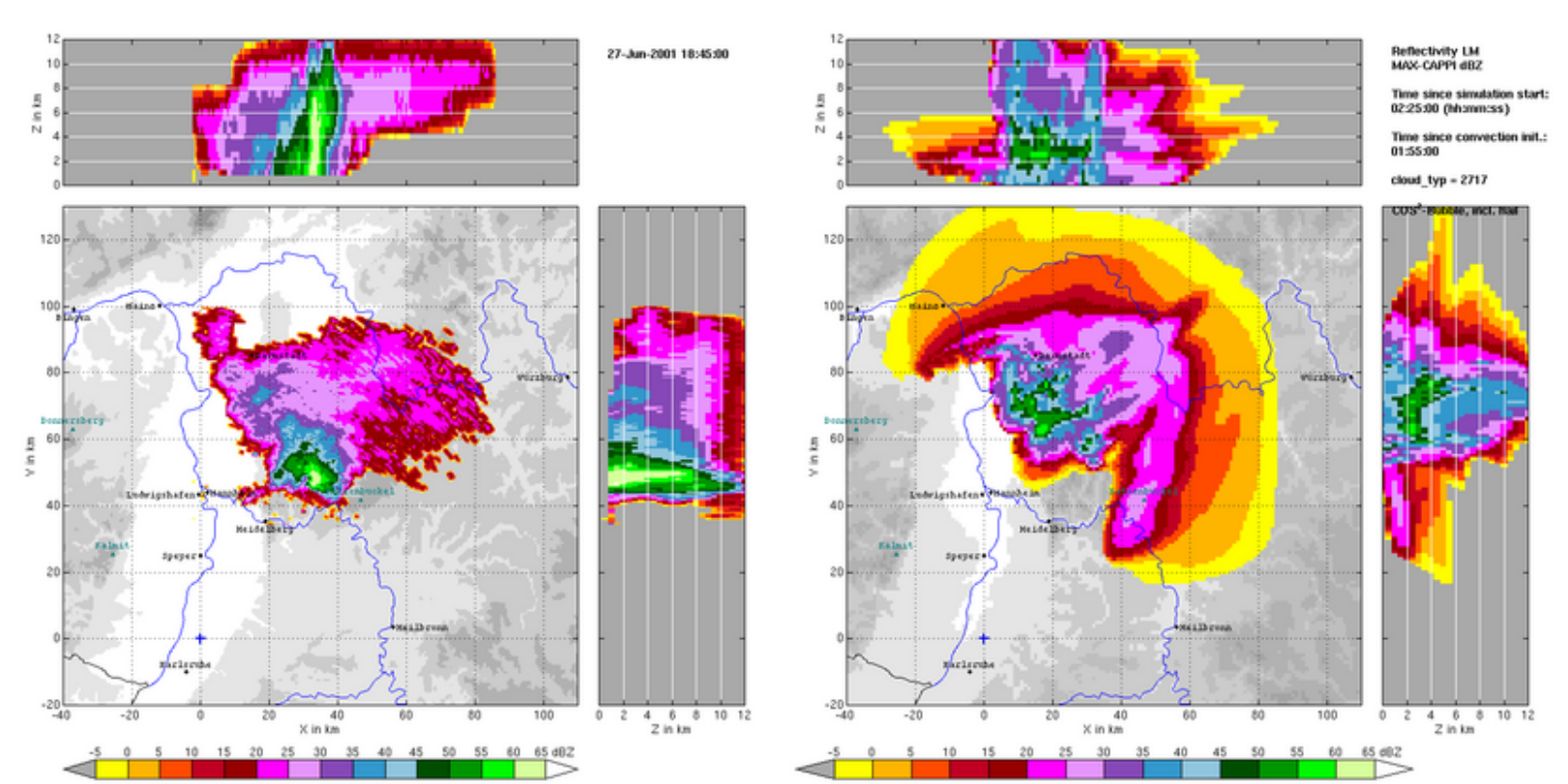
play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

Idealized LM run
`itype_turb` = 5



play

A case study

27.6.2001, cell splitting near Mannheim

IMK-Radar

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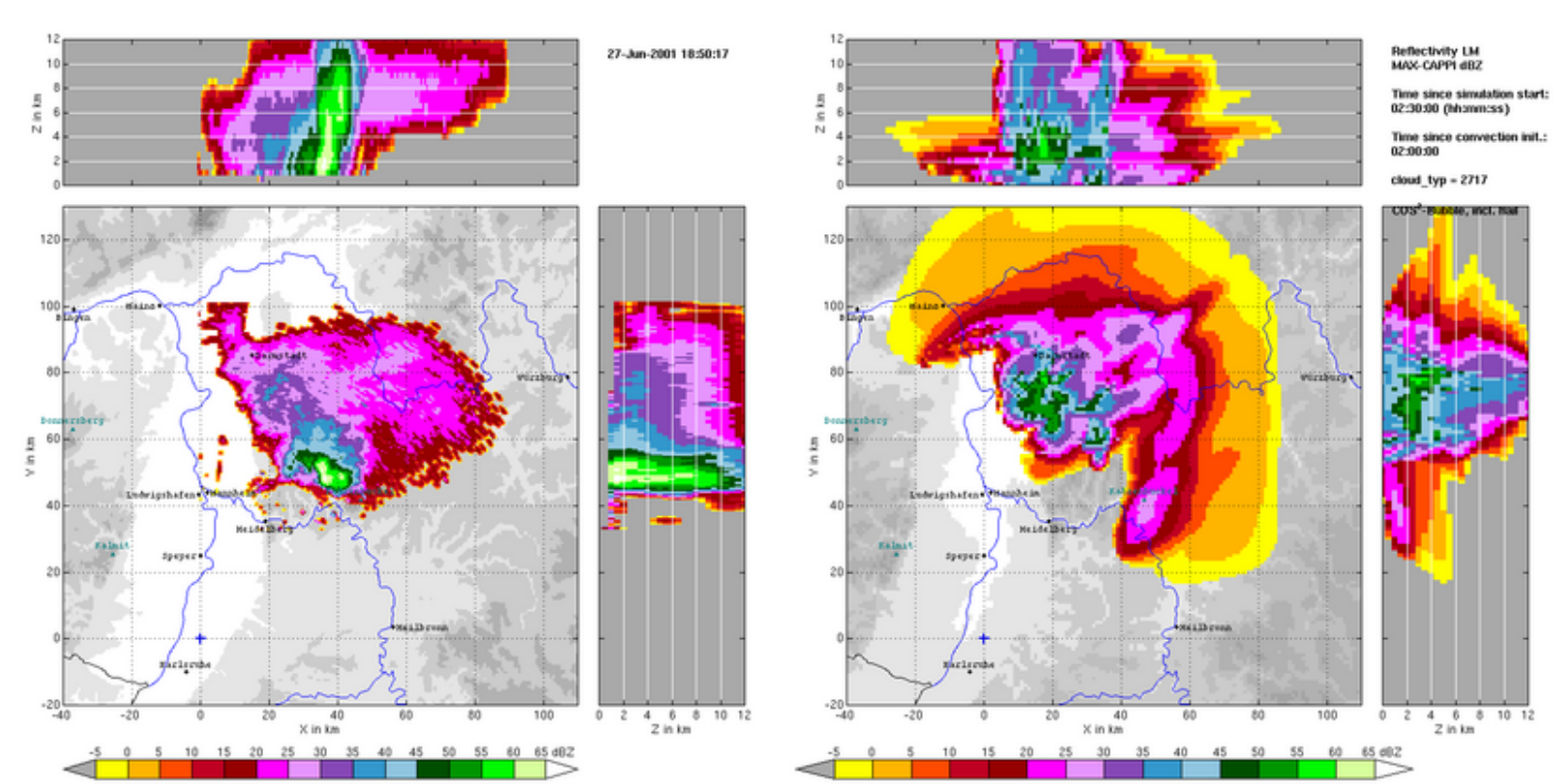

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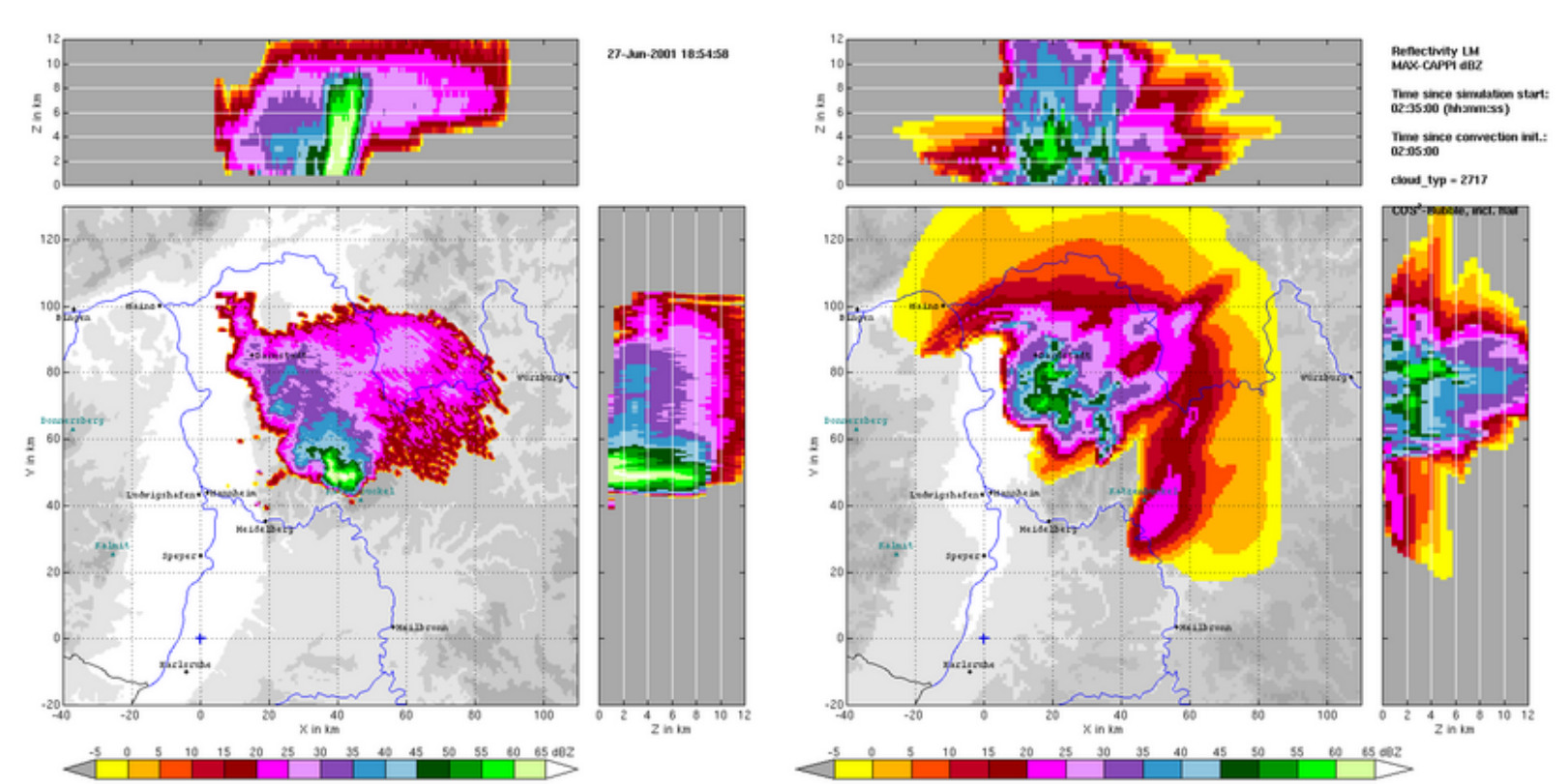

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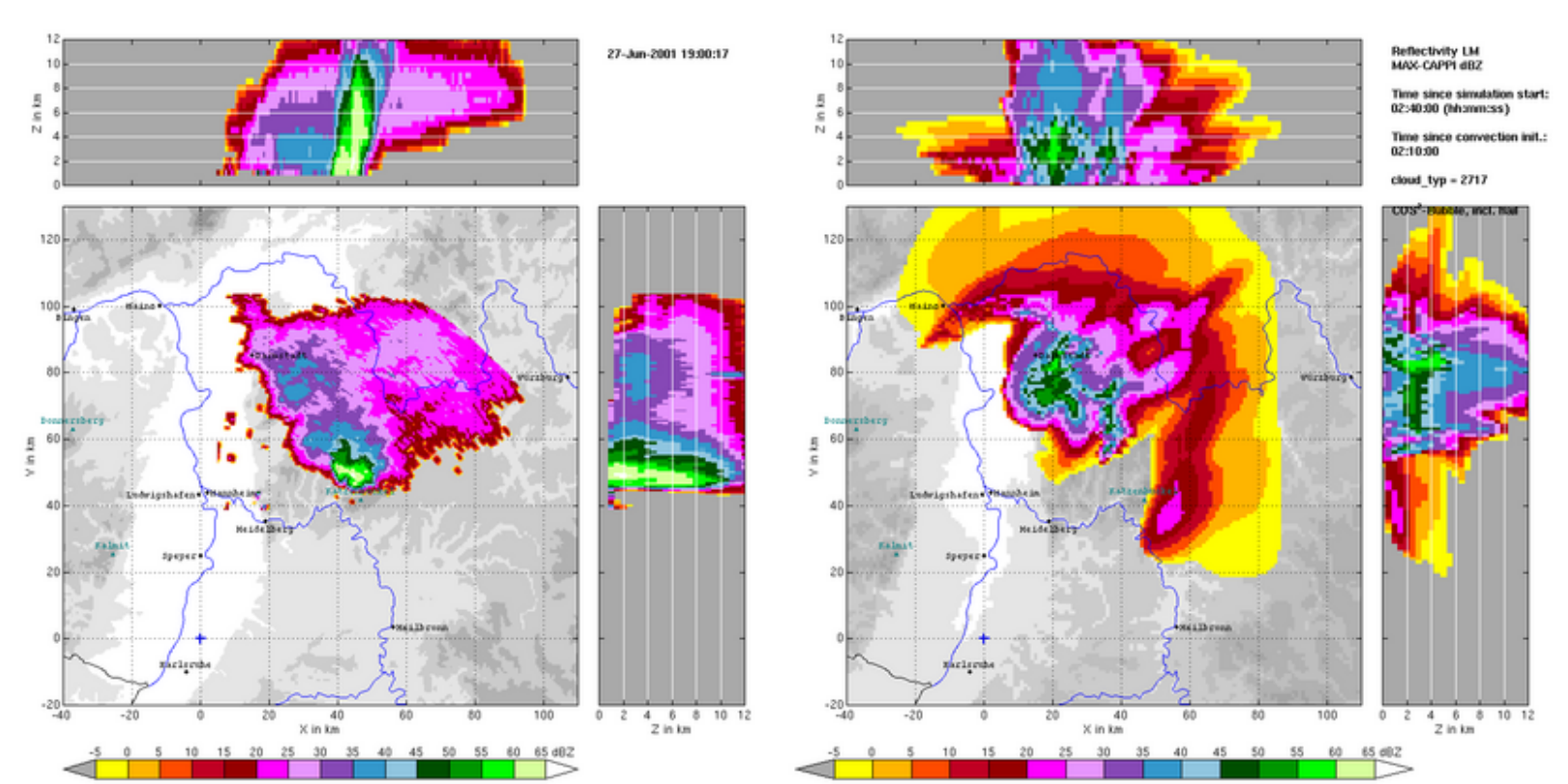

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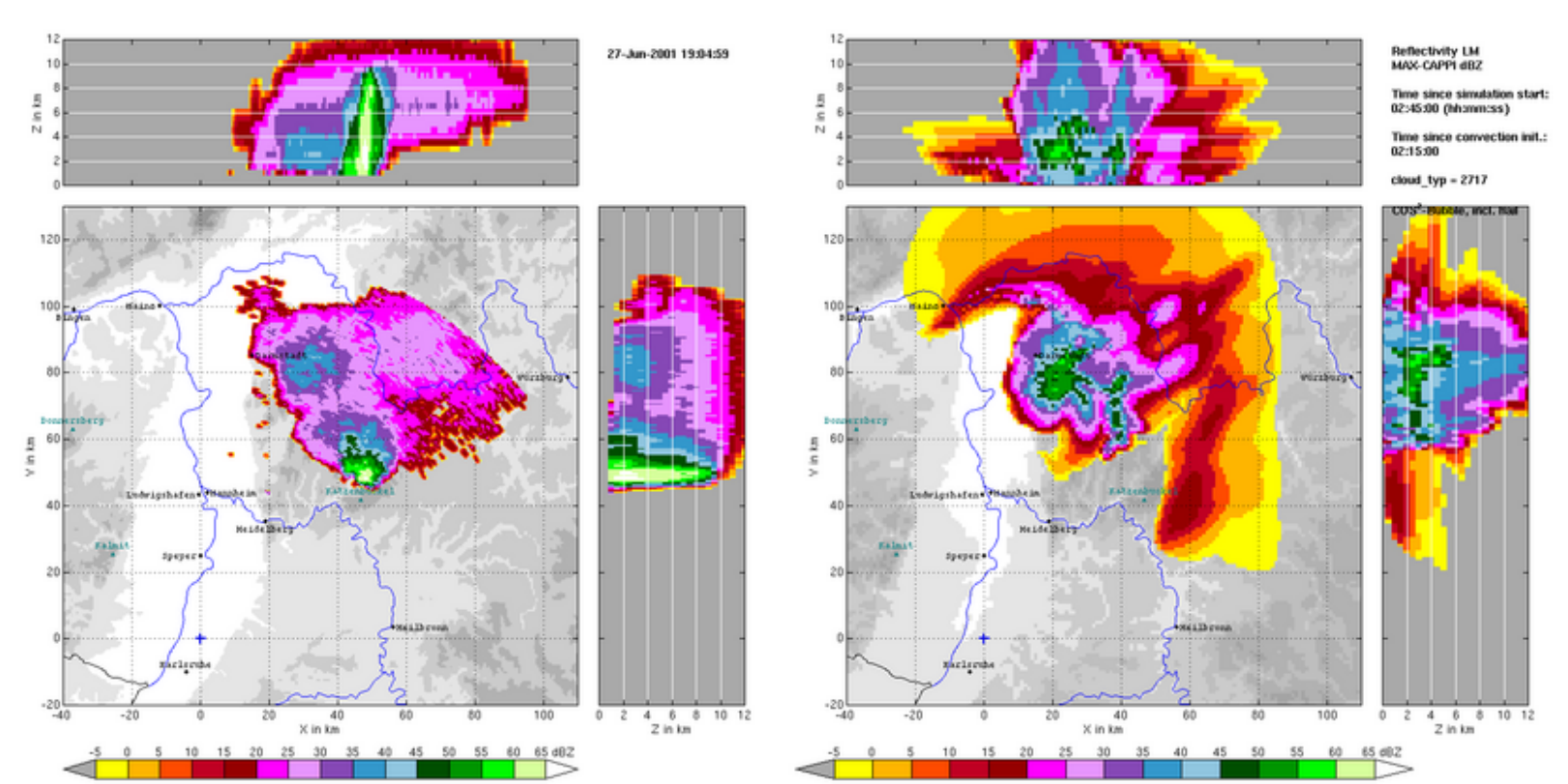

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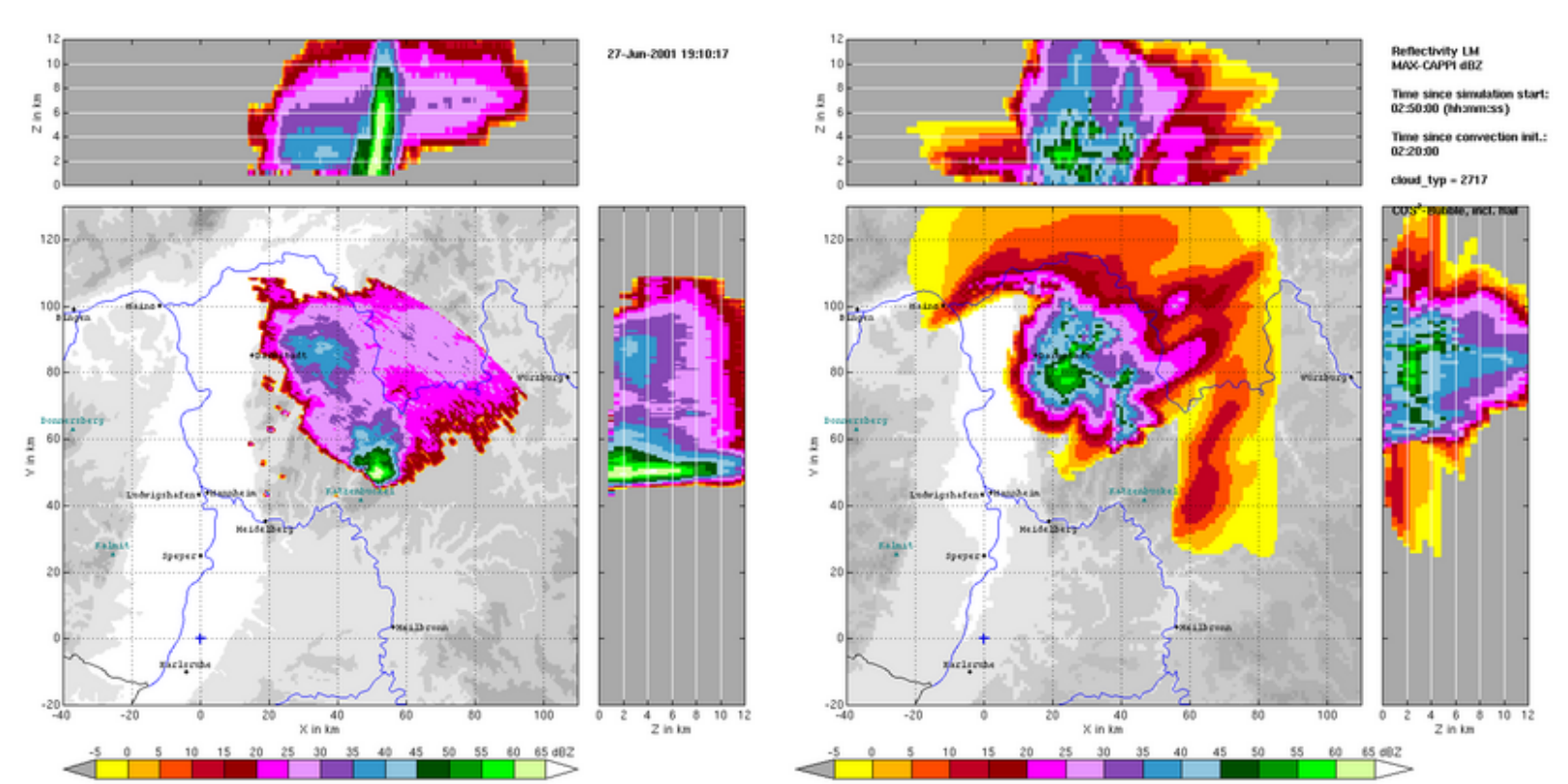

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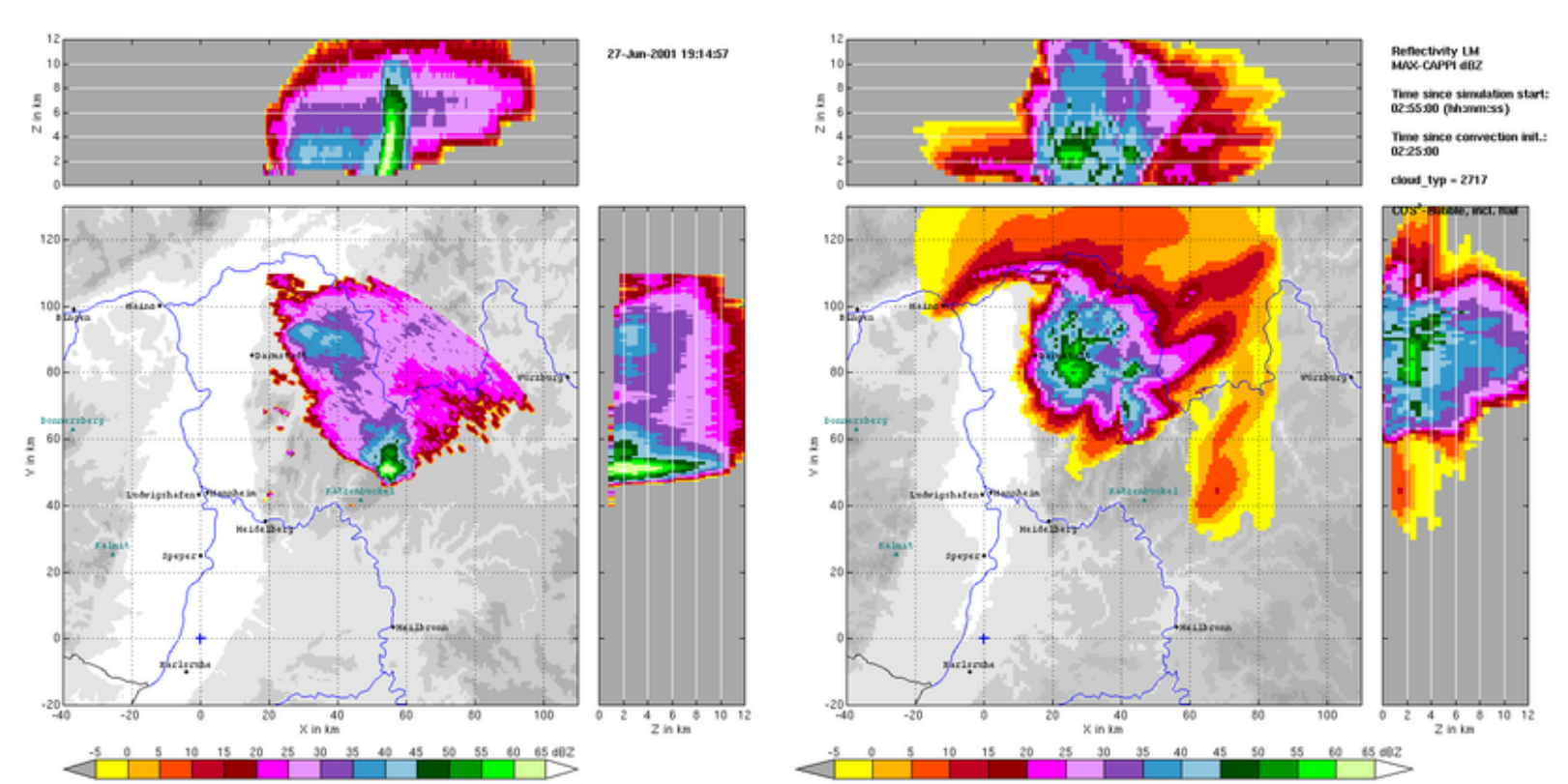

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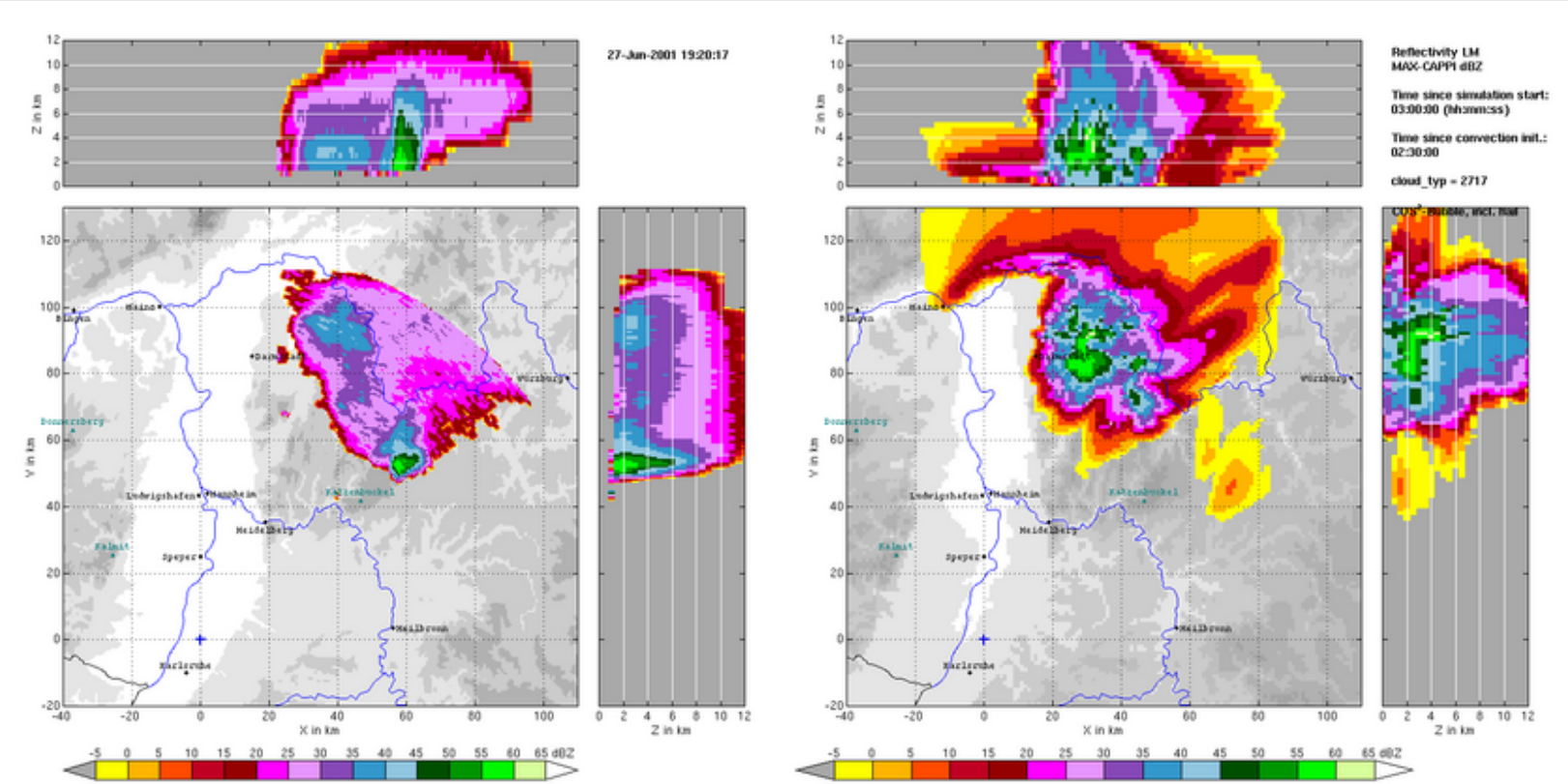

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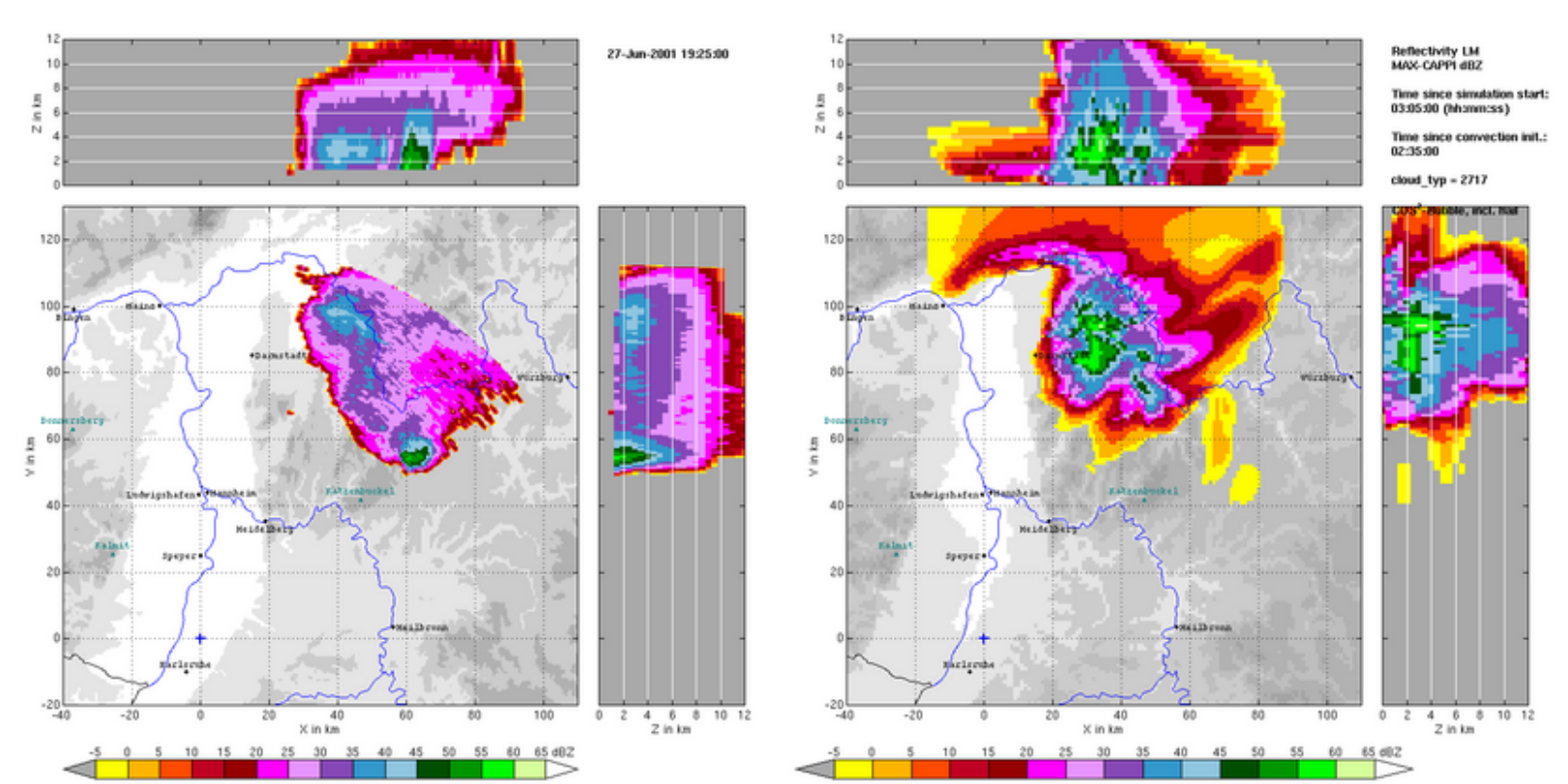
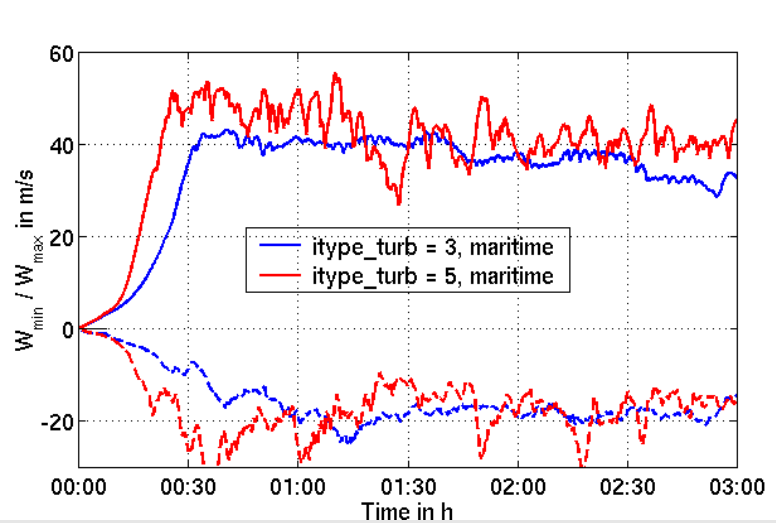


revert

A case study

Max./min. vertical vel. in m/s



A case study

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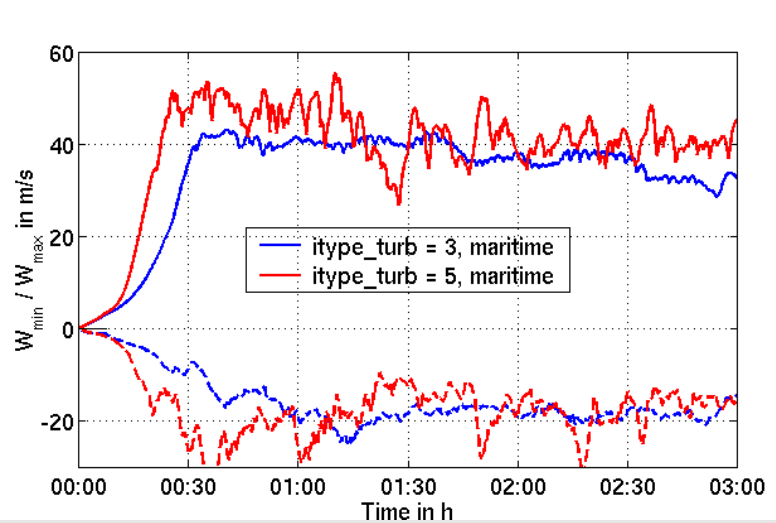
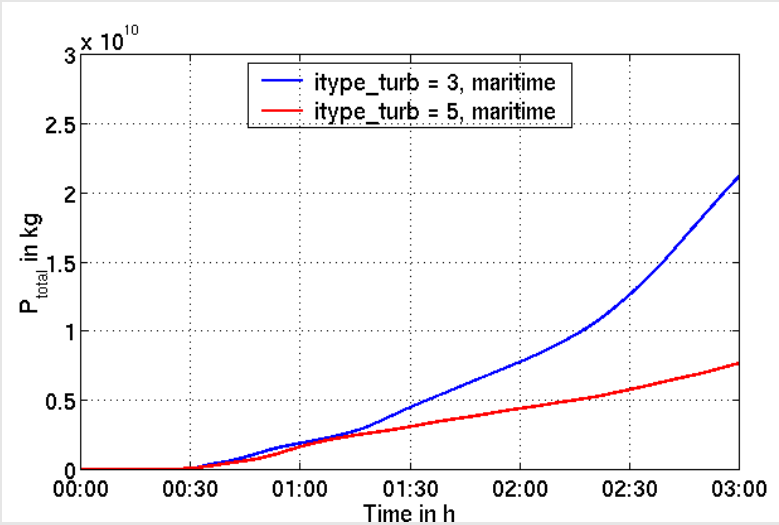


Total precipitation in kg



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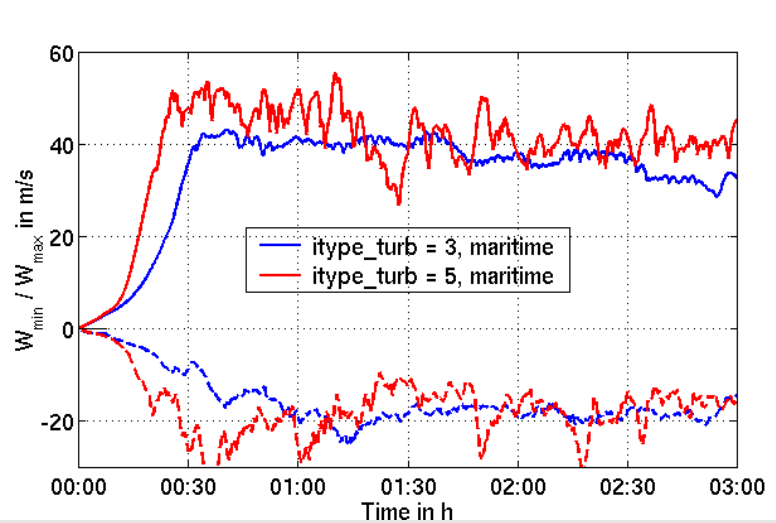

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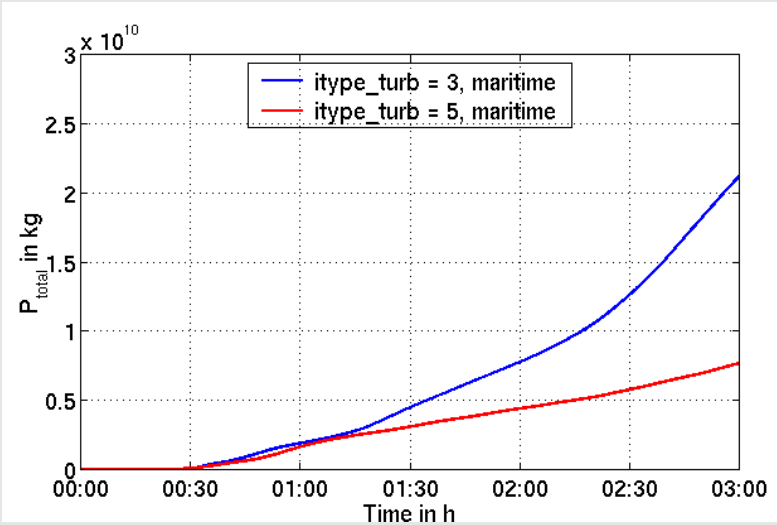
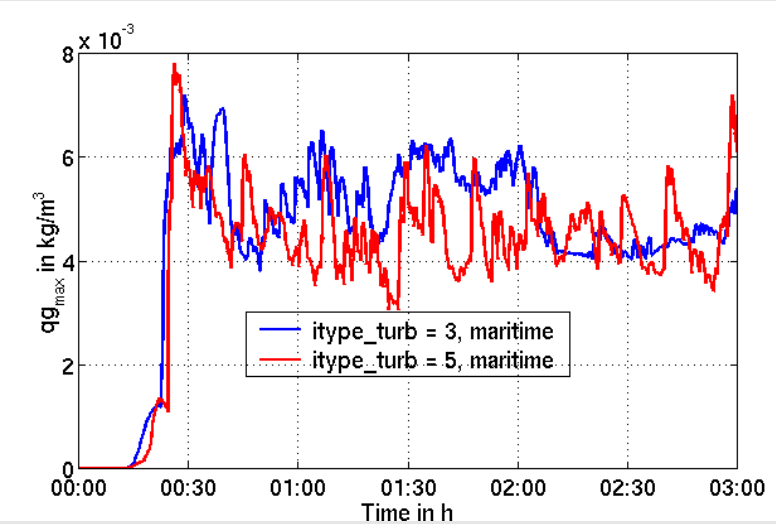


Max. graupel content in kg/m^3



A case study

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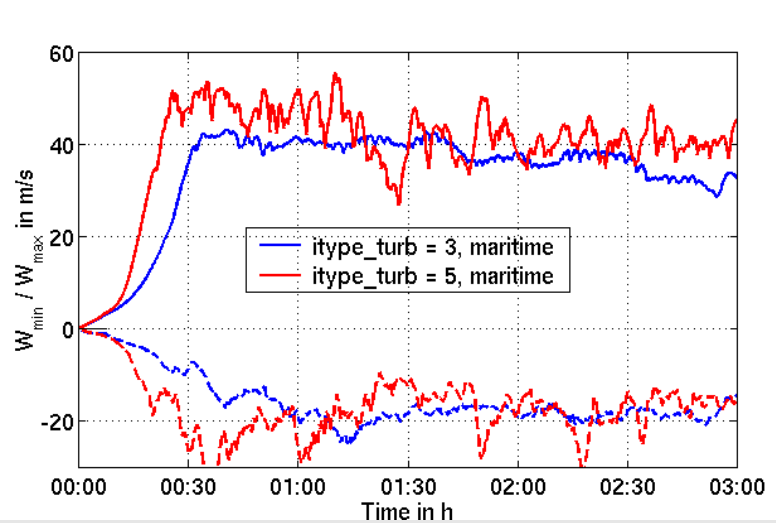

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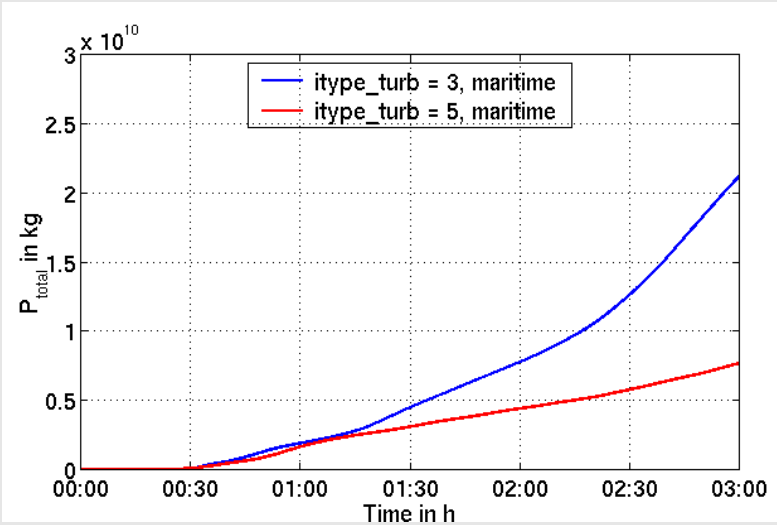

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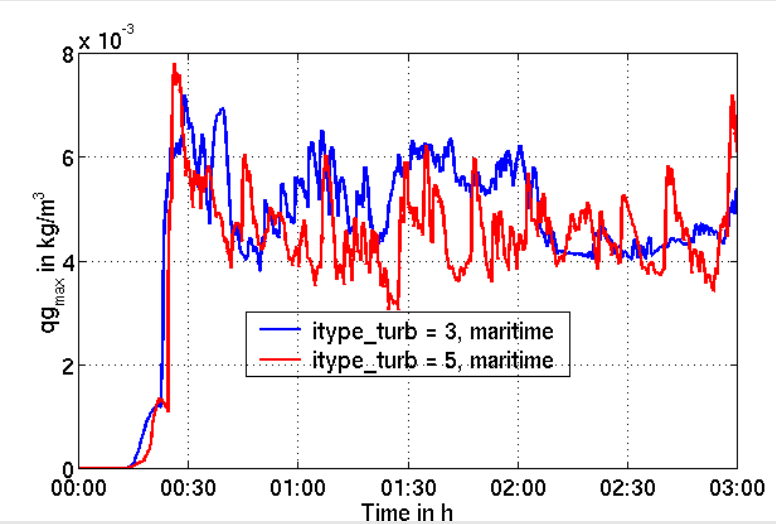
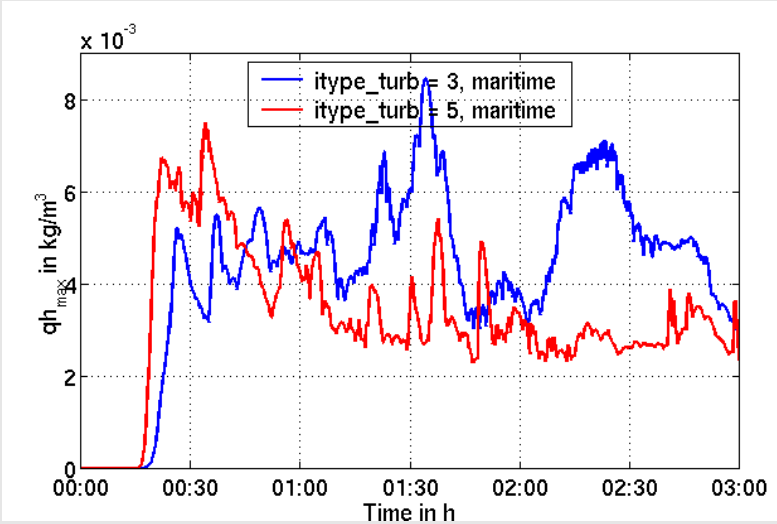


Max. hail content in kg/m^3



Mie or Rayleigh?

Reflectivity in dBZ after 2 h

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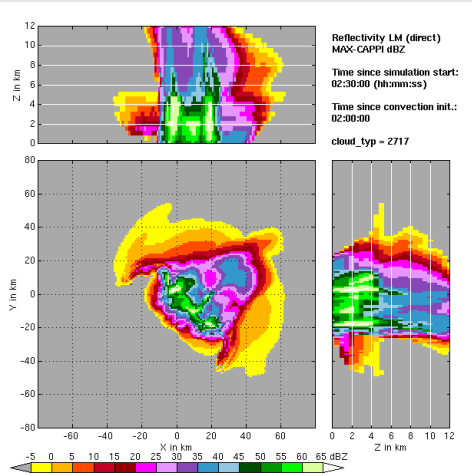
Reflectivity in dBZ after 2 h

Mie-Scattering



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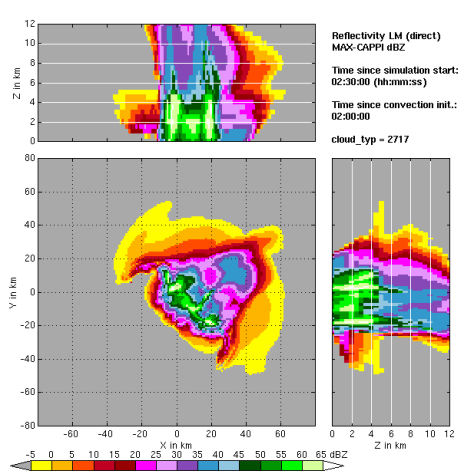
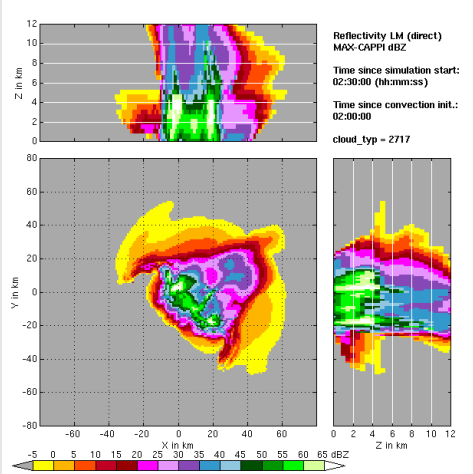


Rayleigh-Approx.



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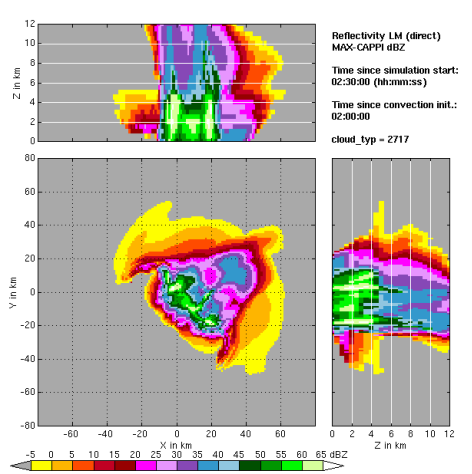

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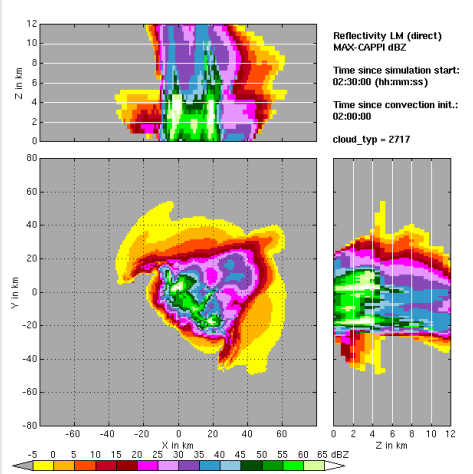
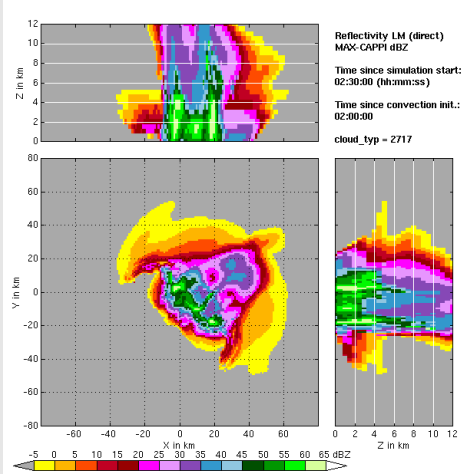


Rayleigh, different formula for *m*



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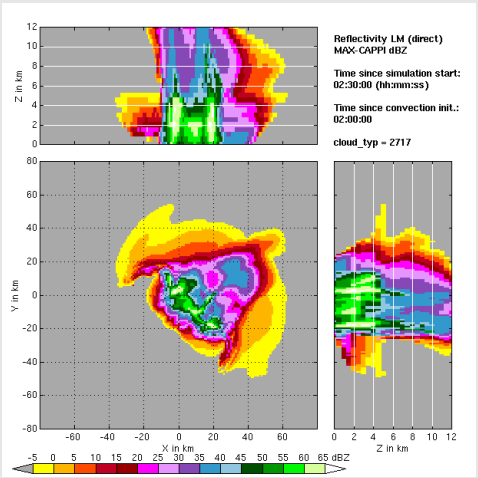

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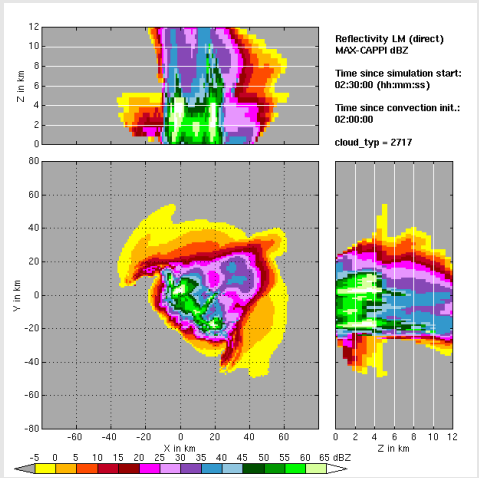

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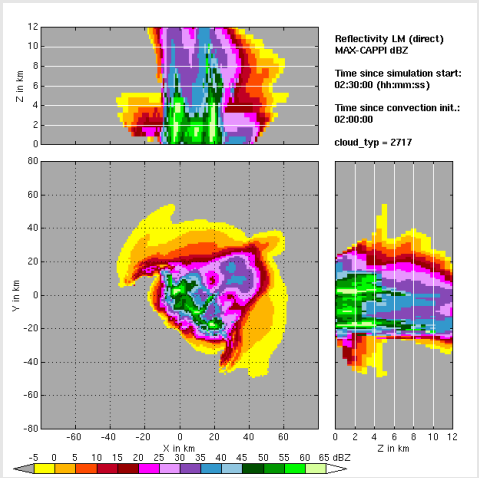

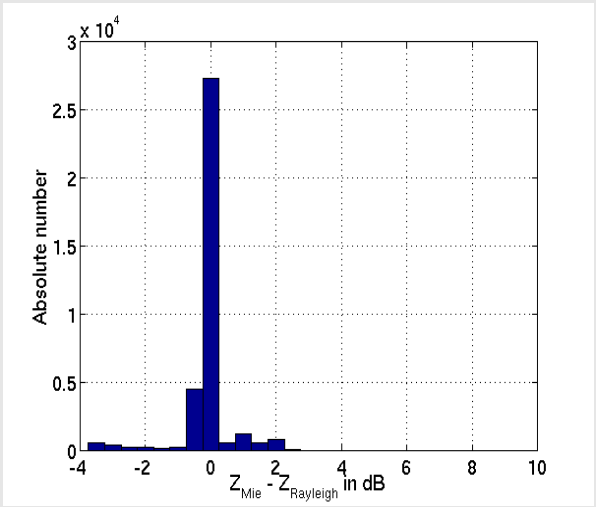

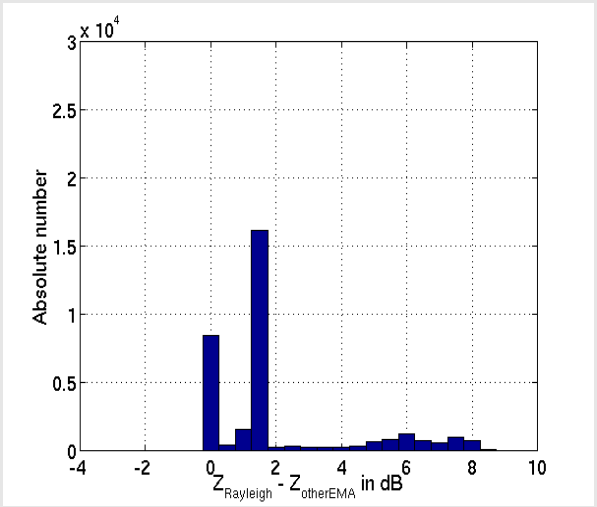

Summary

- Second graupel class (”hail”) added to the two-moment scheme, separating graupel particles formed by riming and by raindrop freezing.

  More details in the following talk by Heike Noppel.

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- $\Longrightarrow$ New radar reflectivity module for our LM test version (grid point values): Mie- or Rayleigh-option, careful treatment of melting hydrometeors.
- Usable online or offline.
- For C-Band calculations, Rayleigh approximation sufficient for our purpose, but large reflectivity uncertainty due to variability of the particle's refractive index. Problems especially for melting hydrometeors.
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- Standard turbulence scheme (`itype_turb=3`) promising for high resolution cloud resolving simulations of convective cells.

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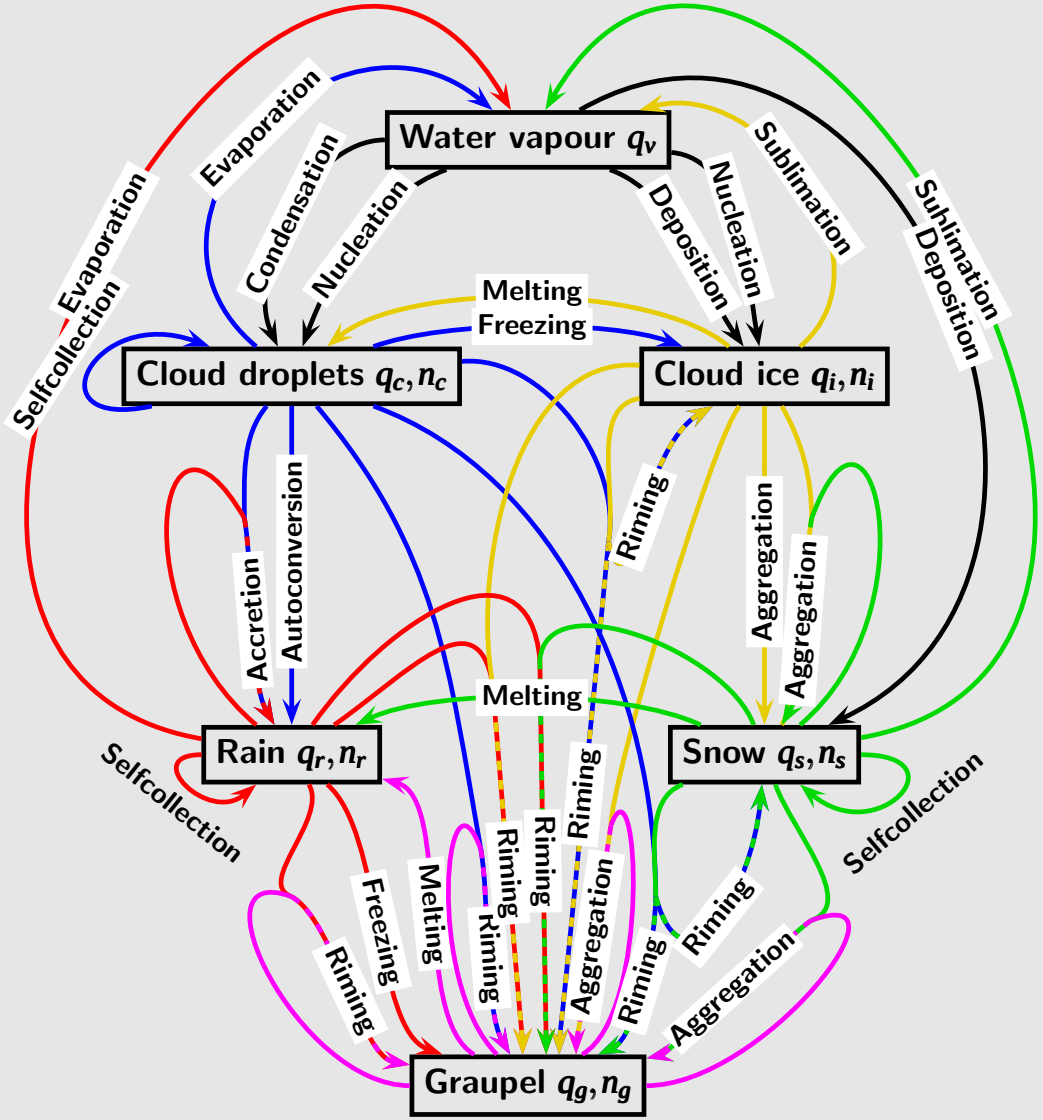
Summary

Thank you for your attention!

2-Moment Bulk Microphysical Scheme



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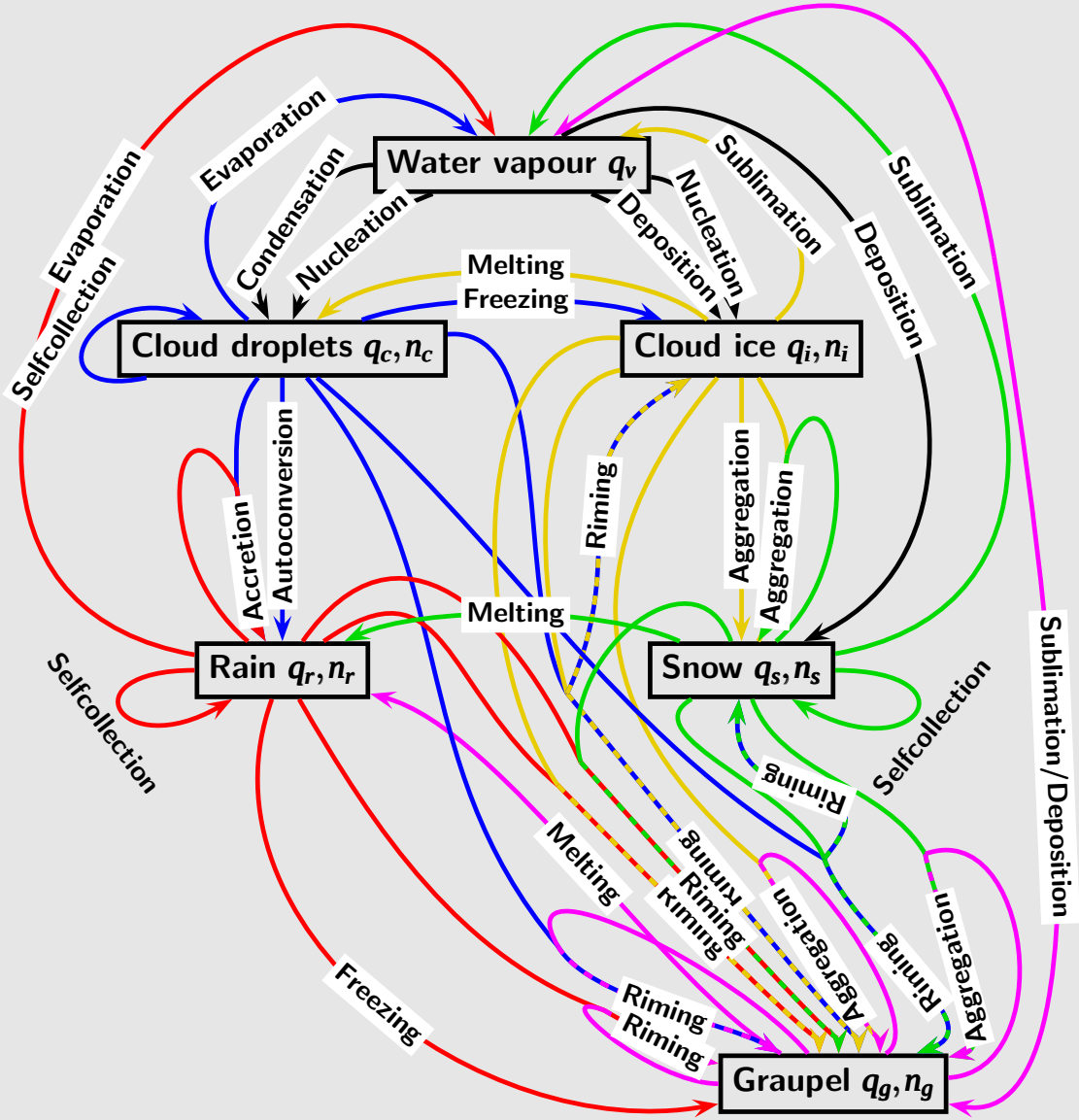

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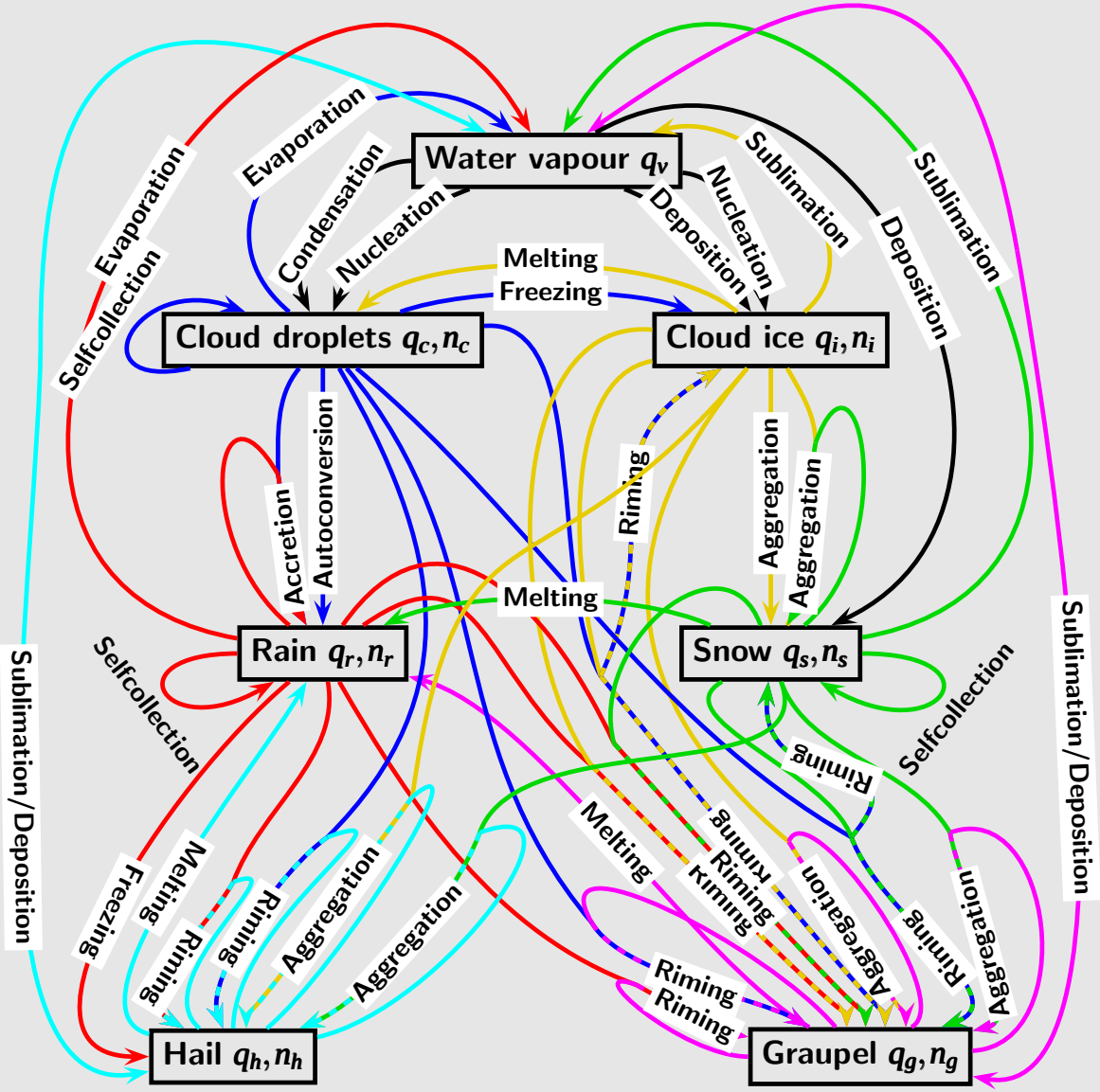

High 0°C-level

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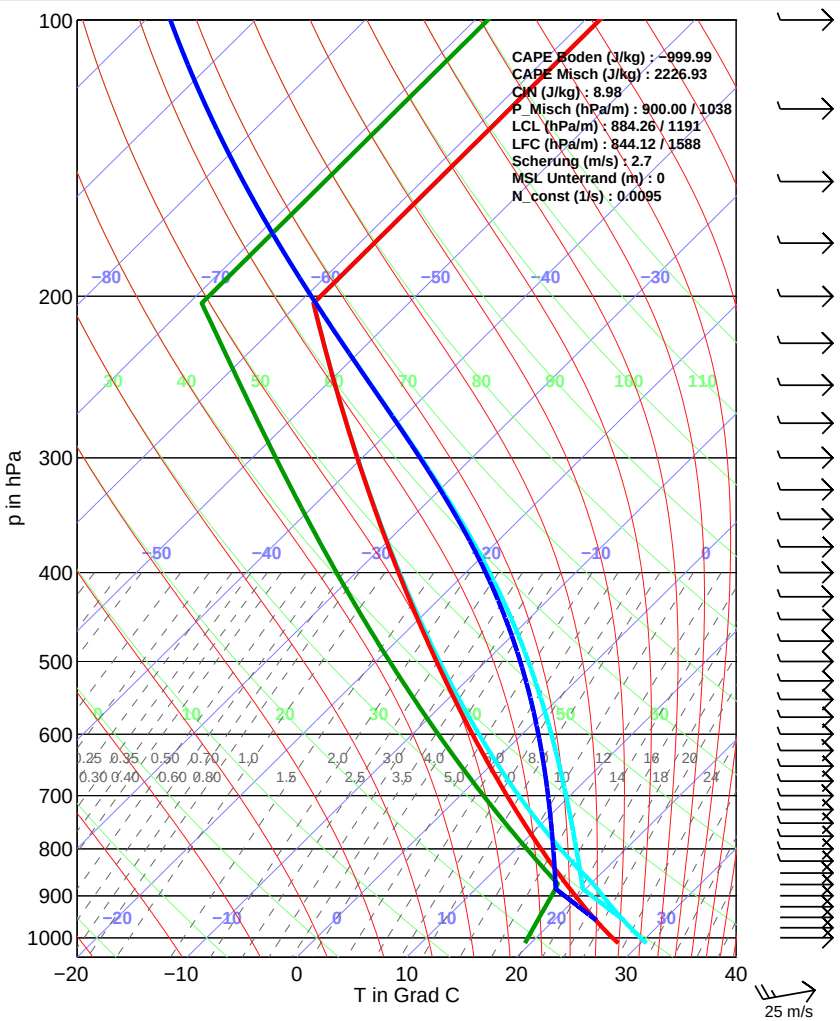

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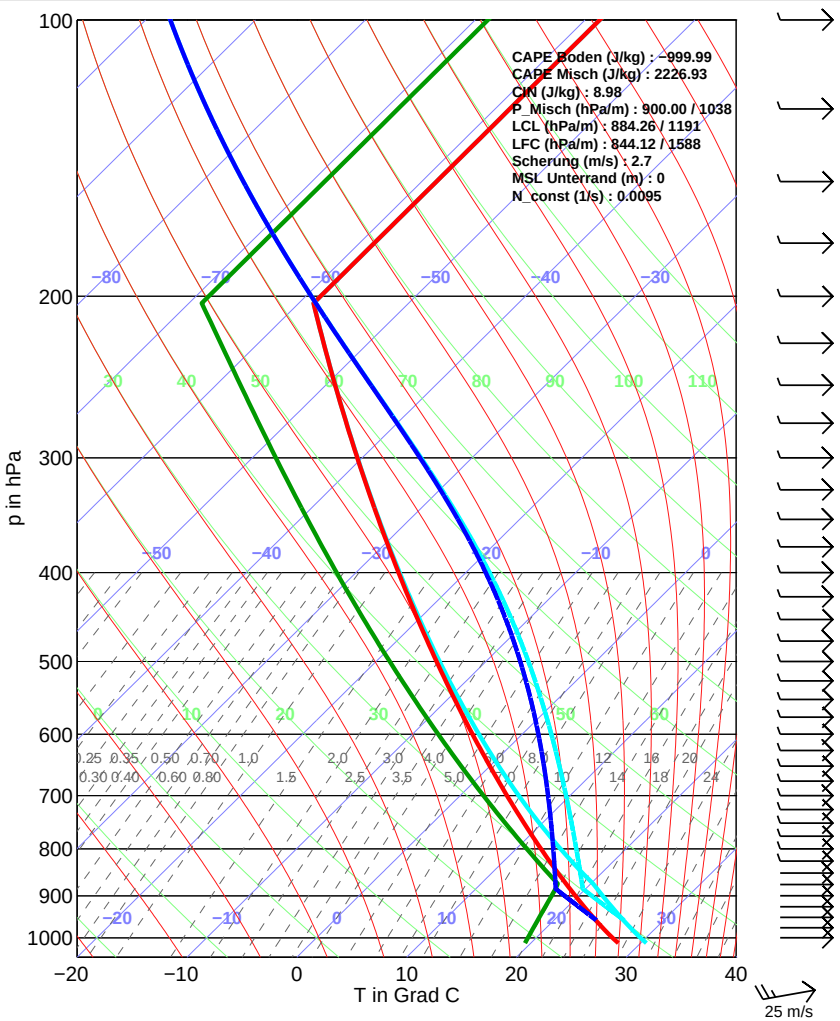
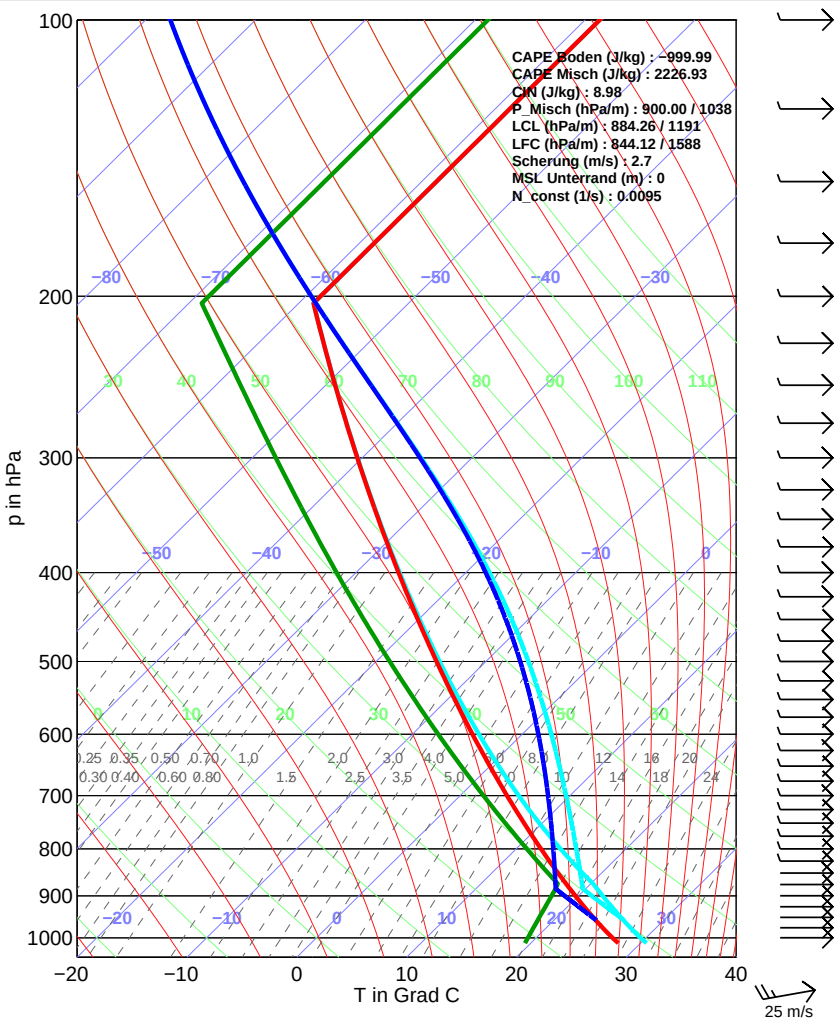


- $T_B = 28°C$
- LCL in 1200 m AGL
- 0°C-level in 3700 m AGL
- $CAPE = 2200\ \mathrm{J\,kg^{-1}}$
- $U_\infty = 5\ \mathrm{m\,s^{-1}}$
- Single-/multicell regime

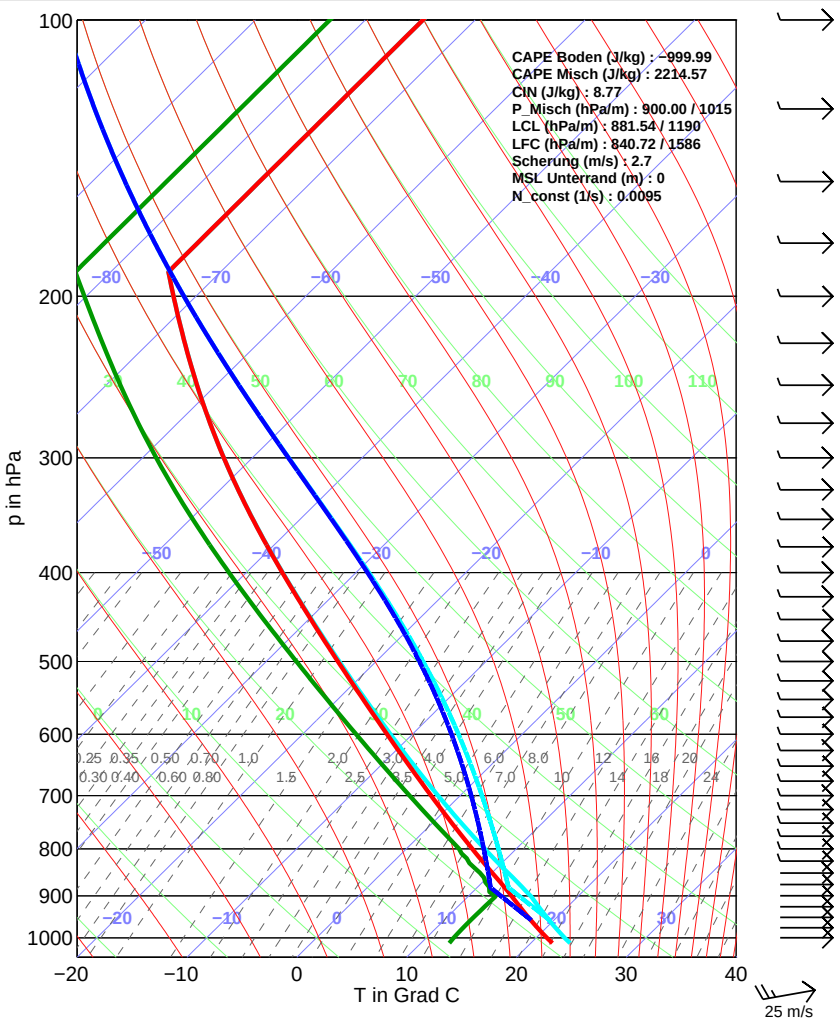
High 0°C-level

Shifting temperature at constant *CAPE* . . .

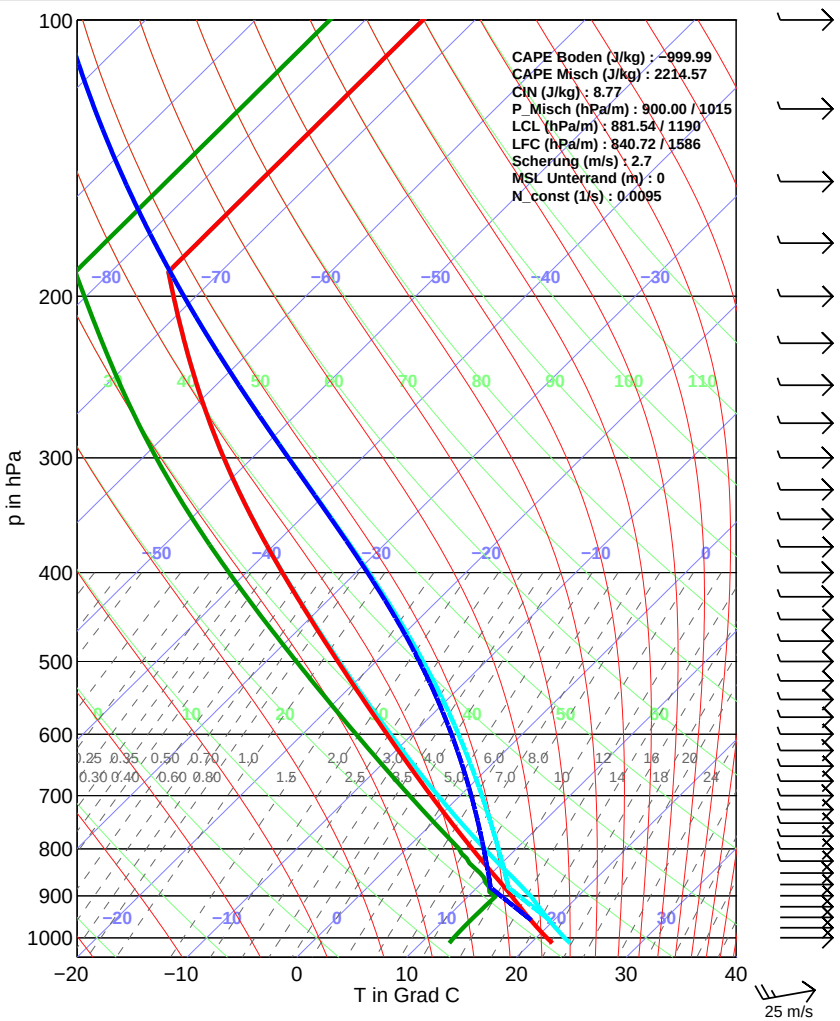
High 0°C-level



Low 0°C-level


CAPE Boden (J/kg) : -999.99
CAPE Misch (J/kg) : 2214.57
CIN (J/kg) : 8.77
P_Misch (hPa/m) : 900.00 / 1015
LCL (hPa/m) : 881.54 / 1190
LFC (hPa/m) : 840.72 / 1586
Scherung (m/s) : 2.7
MSL Unterrand (m) : 0
N_const (1/s) : 0.0095
p in hPa
T in Grad C
25 m/s

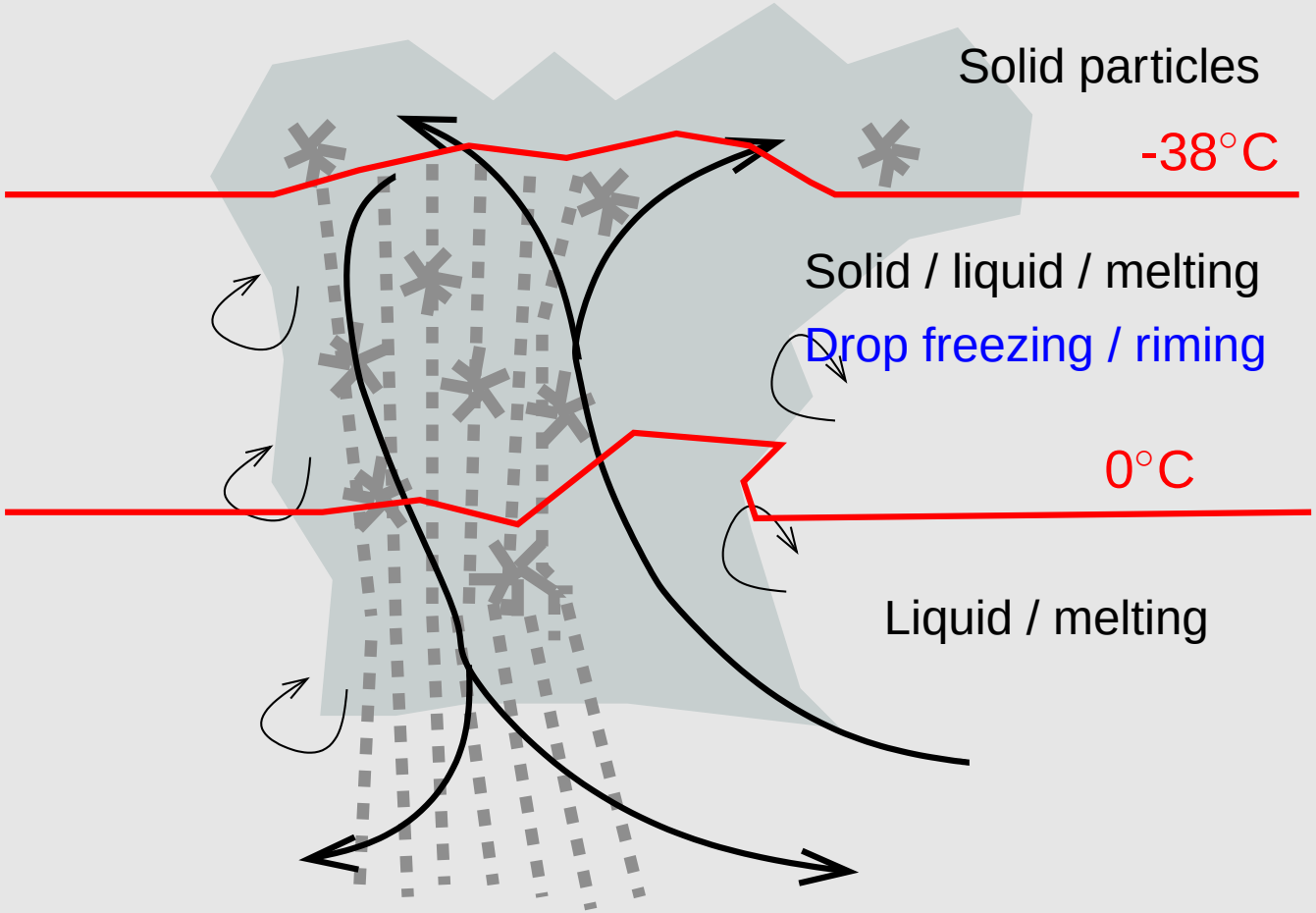
Low 0°C-level



- $T_B = 22°C$
- *LCL* in 1200 m AGL
- 0°C-level in 3700 m AGL
- $CAPE = 2200\ \mathrm{J\,kg^{-1}}$
- $U_\infty = 5\ \mathrm{m\,s^{-1}}$
- Single-/multicell regime
- Same vertical buoancy distribution!

„Continentality“/ temperature regime

Hypothesis:



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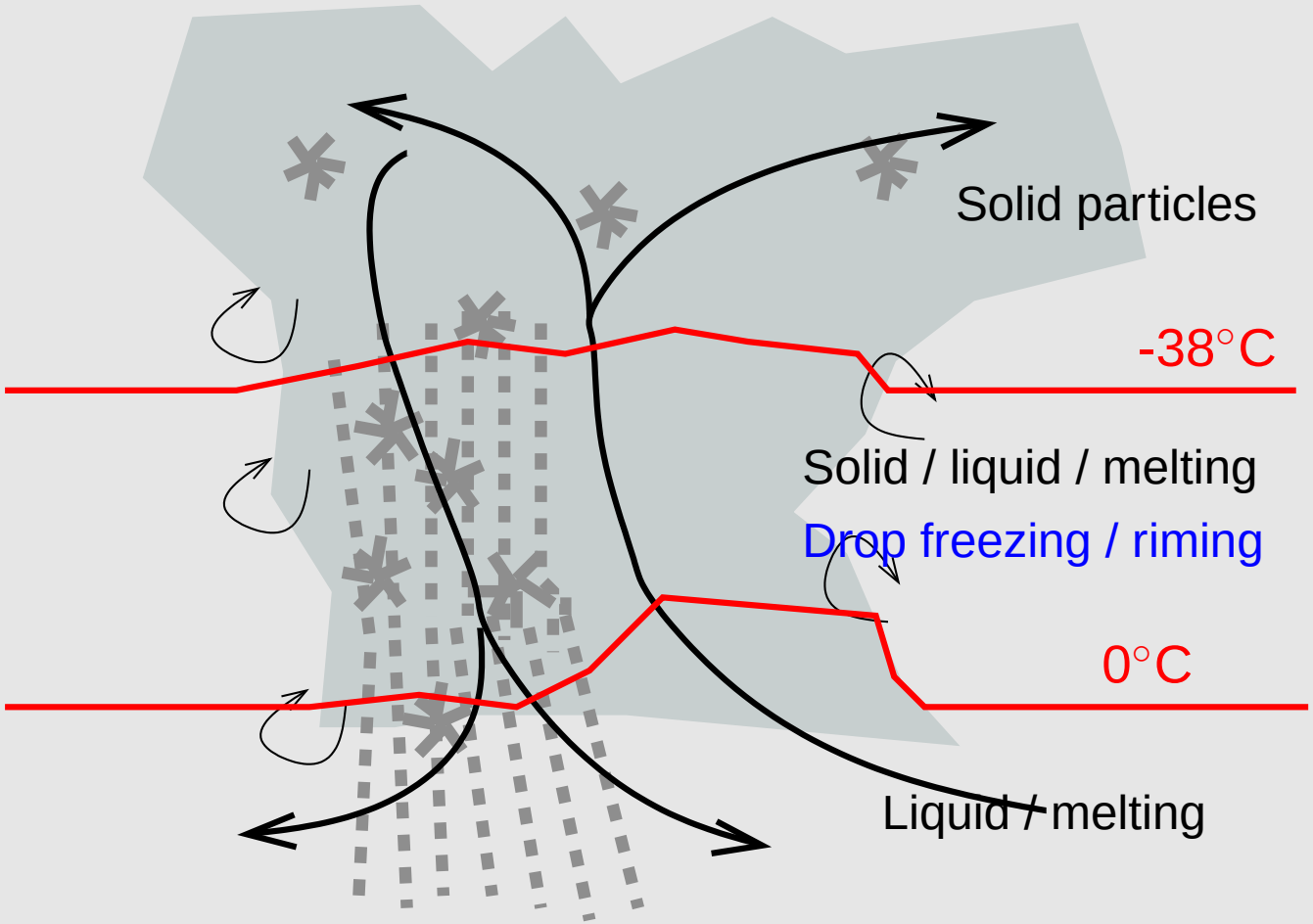

Calculation of radar reflectivity from model output

Conceptual problem: melting particles, especially graupel and hail

$\Rightarrow$ assumption: $f_{melt} = \mathrm{fct}(T, D)$