COSMO Simulations of a Strong Hailstorm with an Advanced 2-Moment Microphysical Scheme

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Motivation

ANTISTORM objectives:

- Study the impact of aerosols on severity of storms in Europe
- develop models that should help to improve forecast of such storms

Case study:

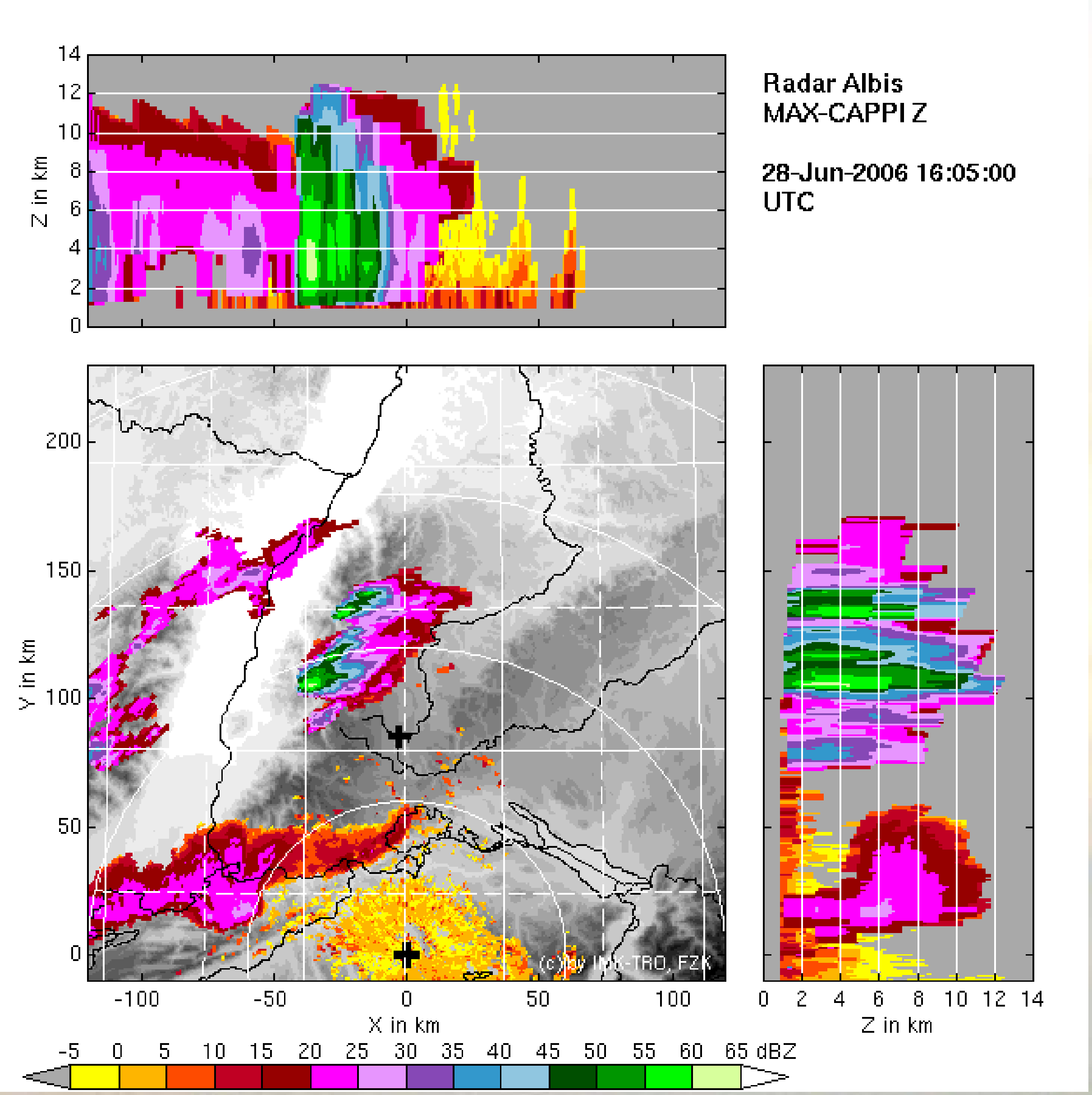
Severe hailstorm in Villingen-Schwenningen 28/06/2006

- large hail stones and extreme precipitation rates
- considerable damage, >100 people got hurt, one man drowned

Observations

Observations

Radar (Albis)



Observations

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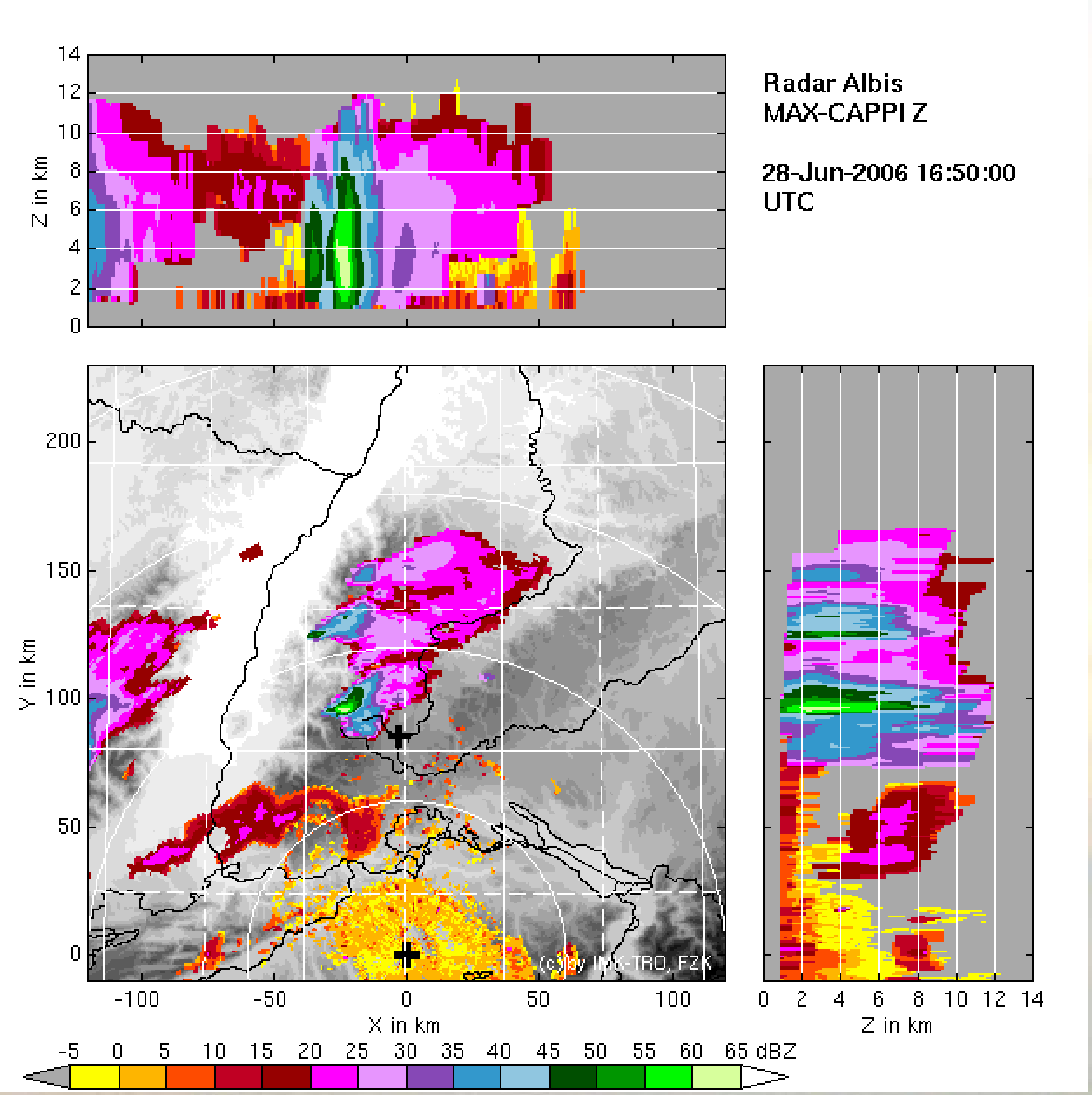

Observations

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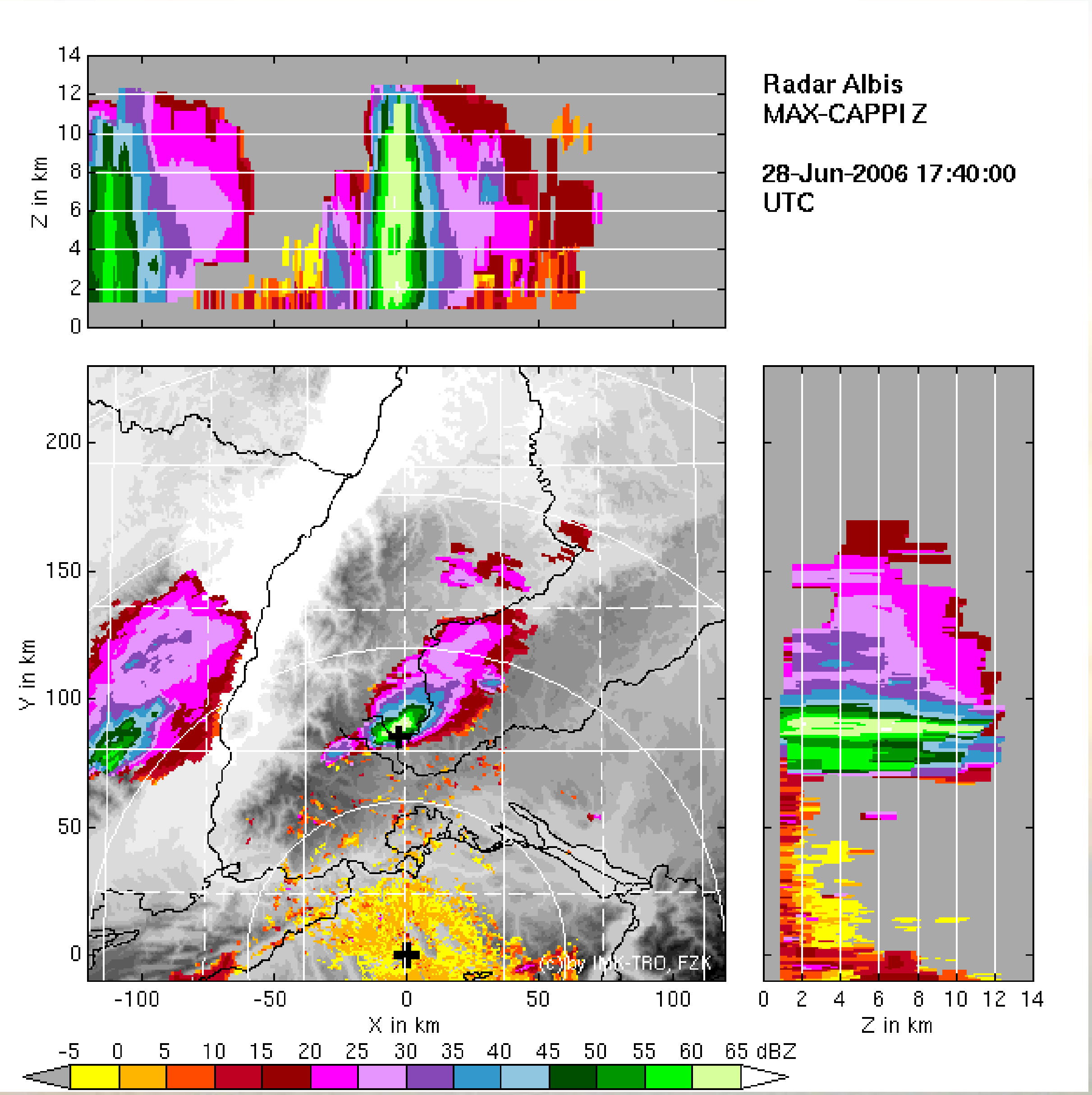
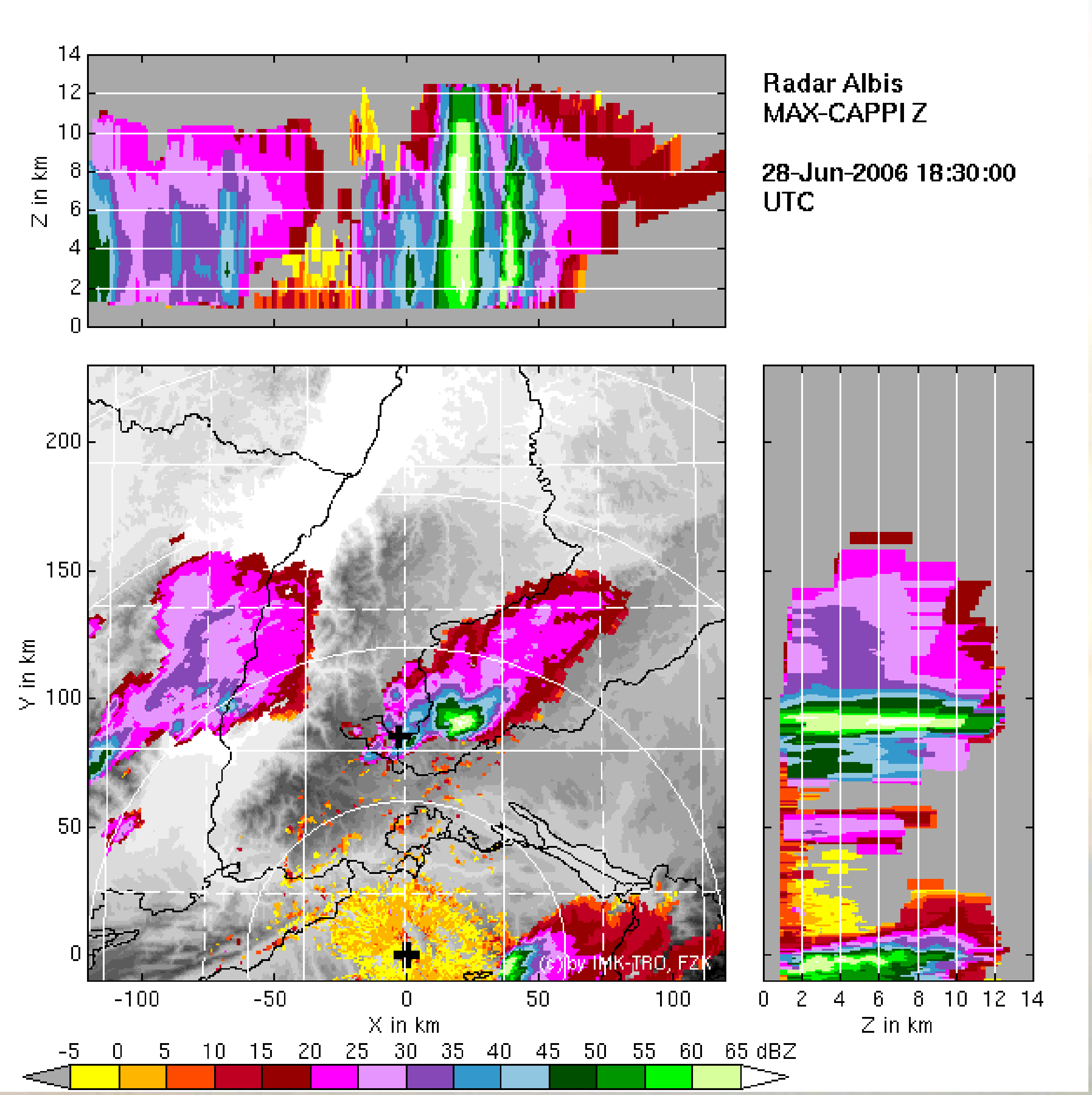


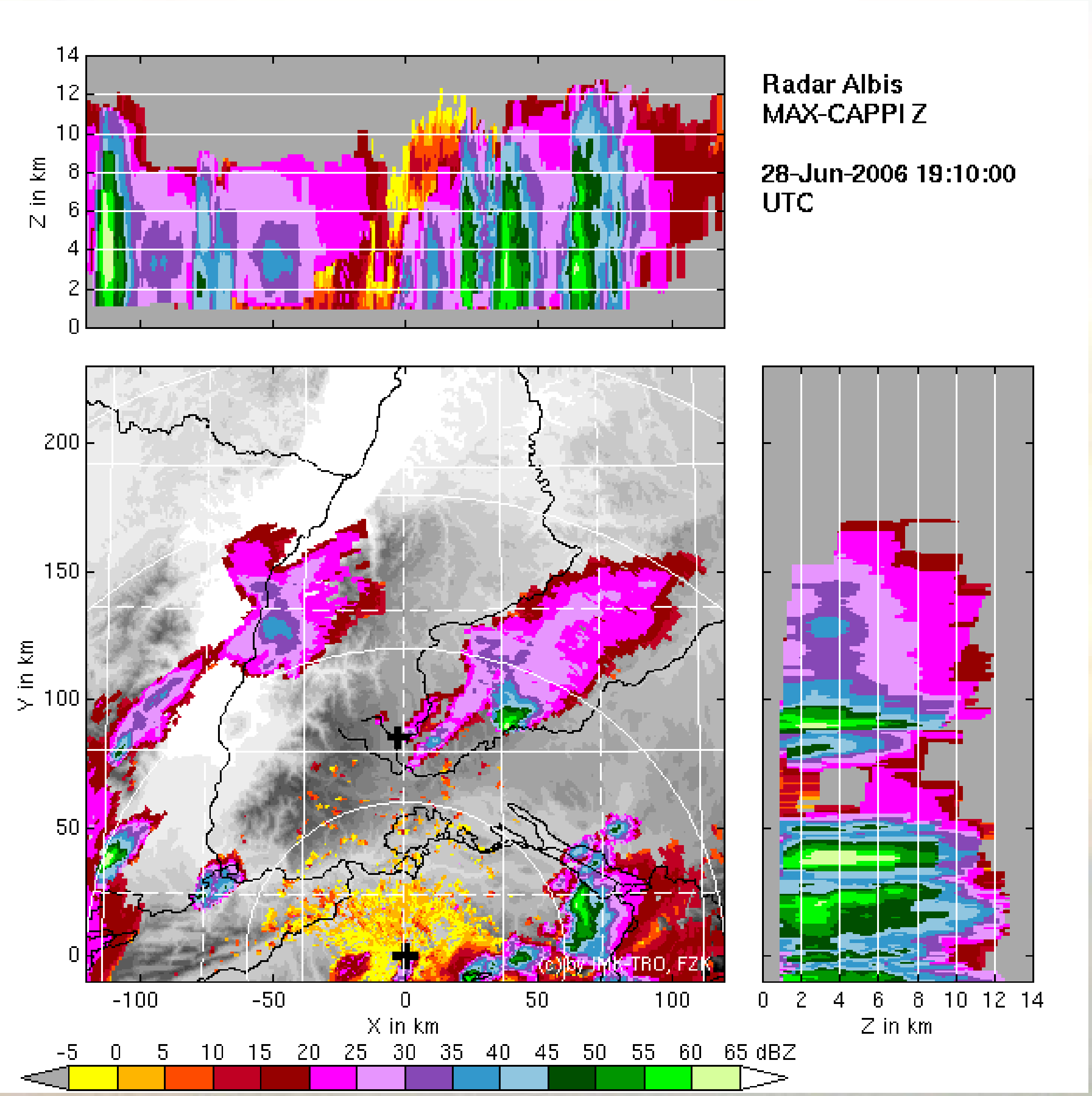
Observations

Radar (Albis)



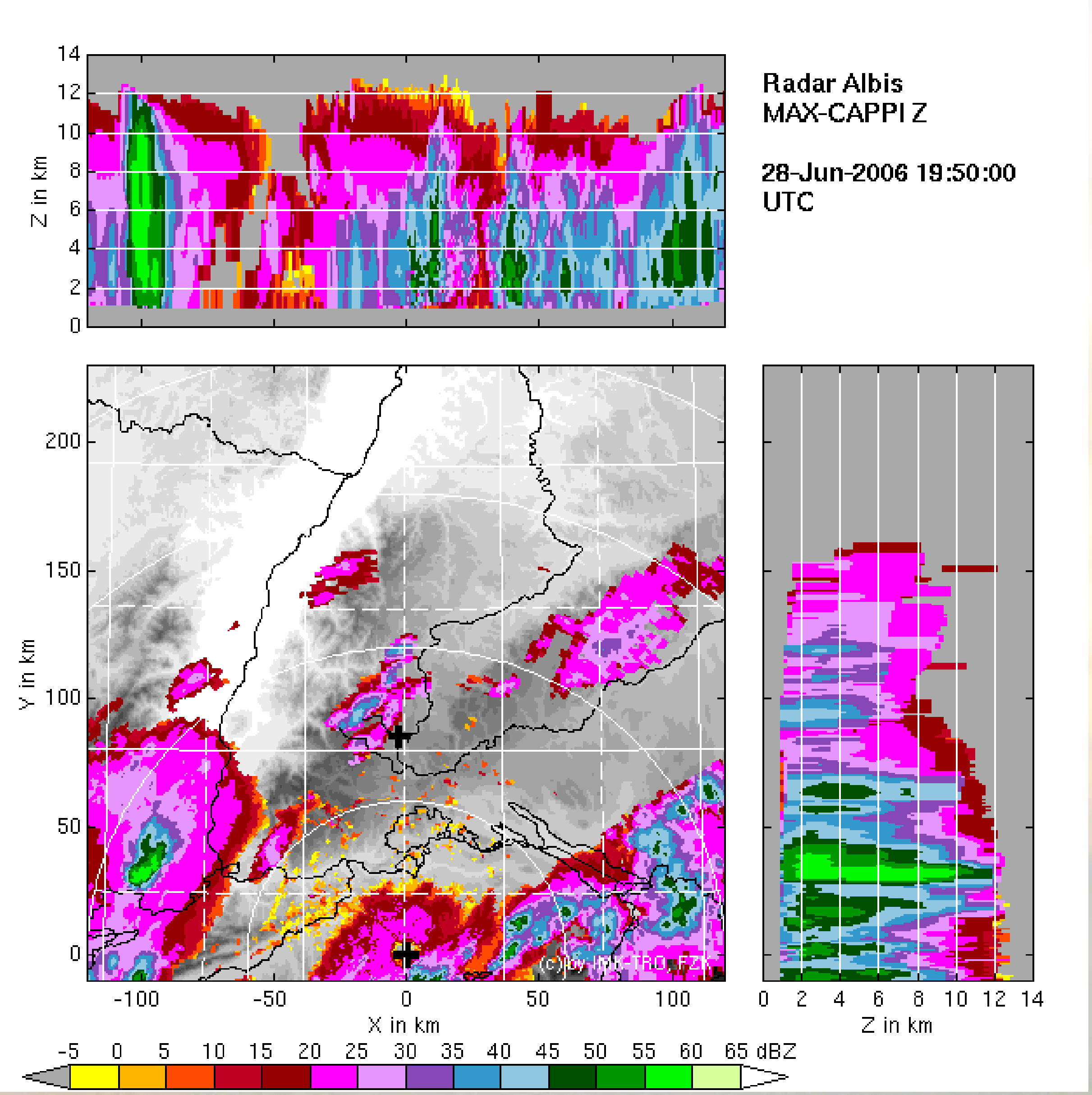
Observations

Radar (Albis)



Observations

Radar (Albis)



Model and Model Setup

Numerical Model:

- COSMO by the German Weather Service (version 3.19.x)
- extended 2-moment scheme by Seifert & Beheng (2006) for cloud microphysics
  - new scheme for nucleation of cloud droplets based on look-up tables by Segal & Khain (2006)
  - additional particle class “hail”, hail particles (embryos) are generated by
    - → the upper part of a freezing rain drop distribution
    - → graupel particles in “wet growth” mode

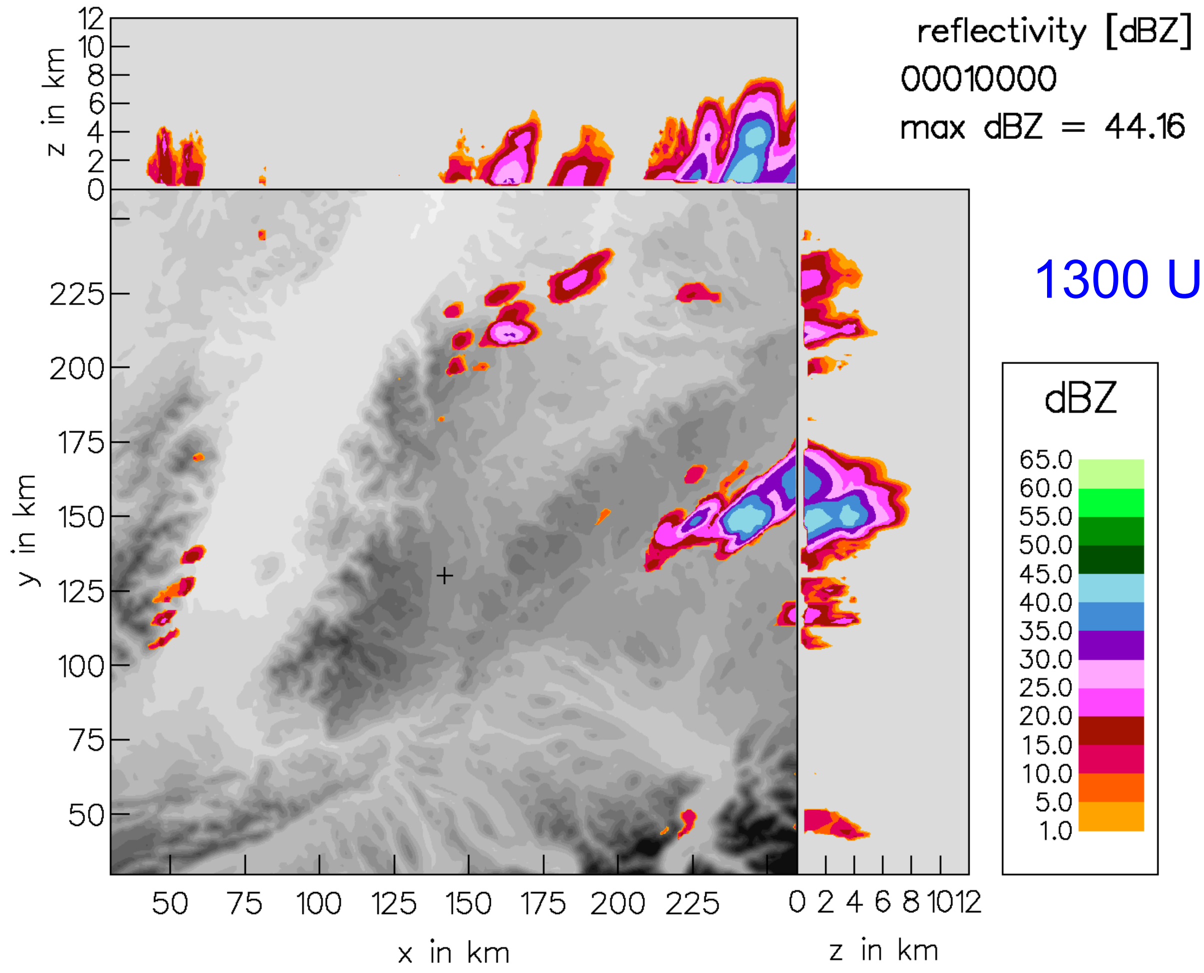
Model and Model Setup

Initialisation / Setup:

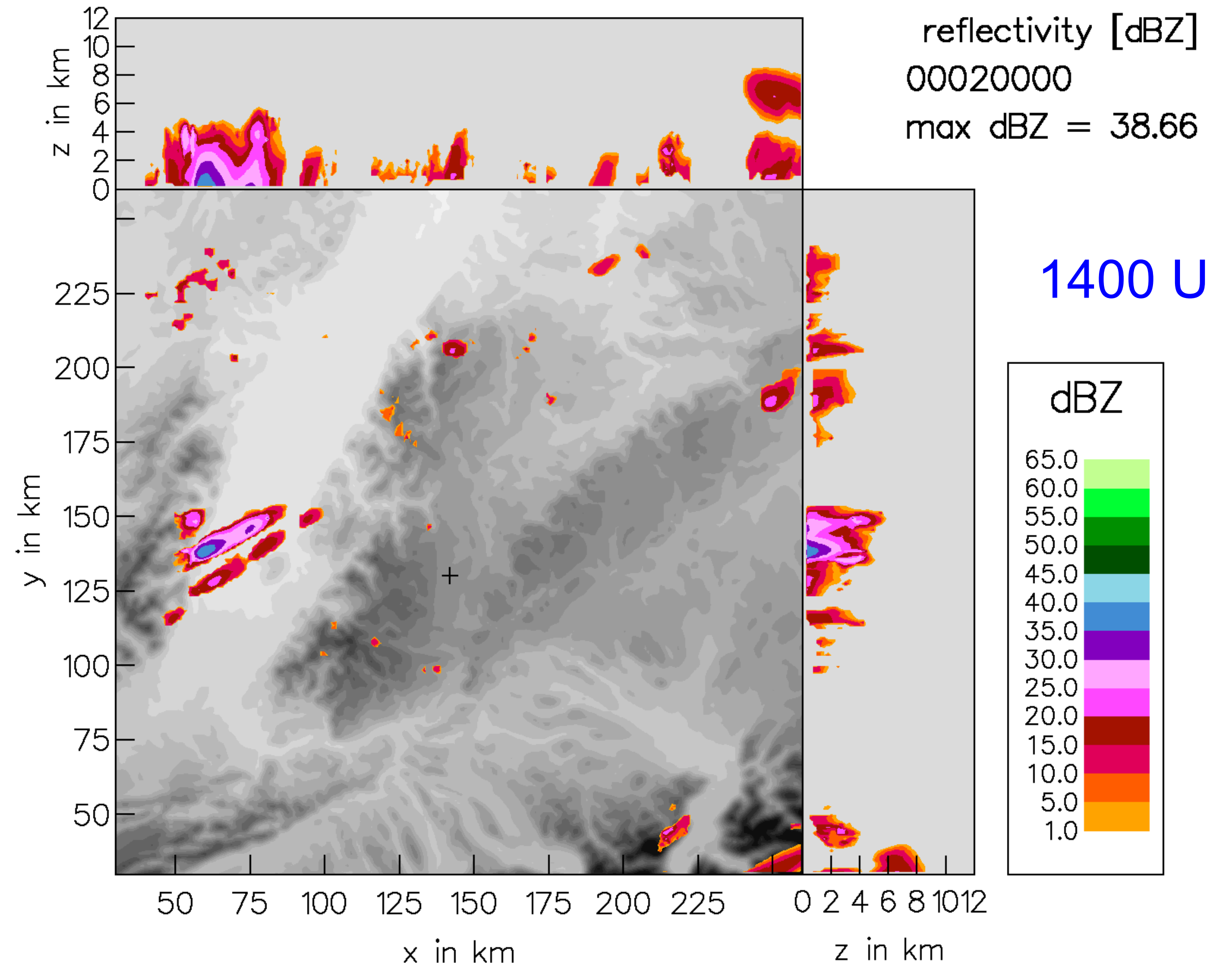
- horizontal resolution: 1 km
- initialization by COSMO-DE analysis (2.8 km, 12 UTC)
- boundary conditions: COSMO-DE forecasts (every hour)
- model domain: 291 x 291 grid points
- 4 different classes of CCN concentration:
  - ➔ low (→ N_{drop}= 100 cm^{-3})
  - ➔ intermediate (→ N_{drop}= 300 cm^{-3})
  - ➔ high (→ N_{drop}= 1000 cm^{-3})
  - ➔ very high (→ N_{drop}= 2000 cm^{-3})

The Simulated Hailstorm

intermediate CCN concentration



The Simulated Hailstorm



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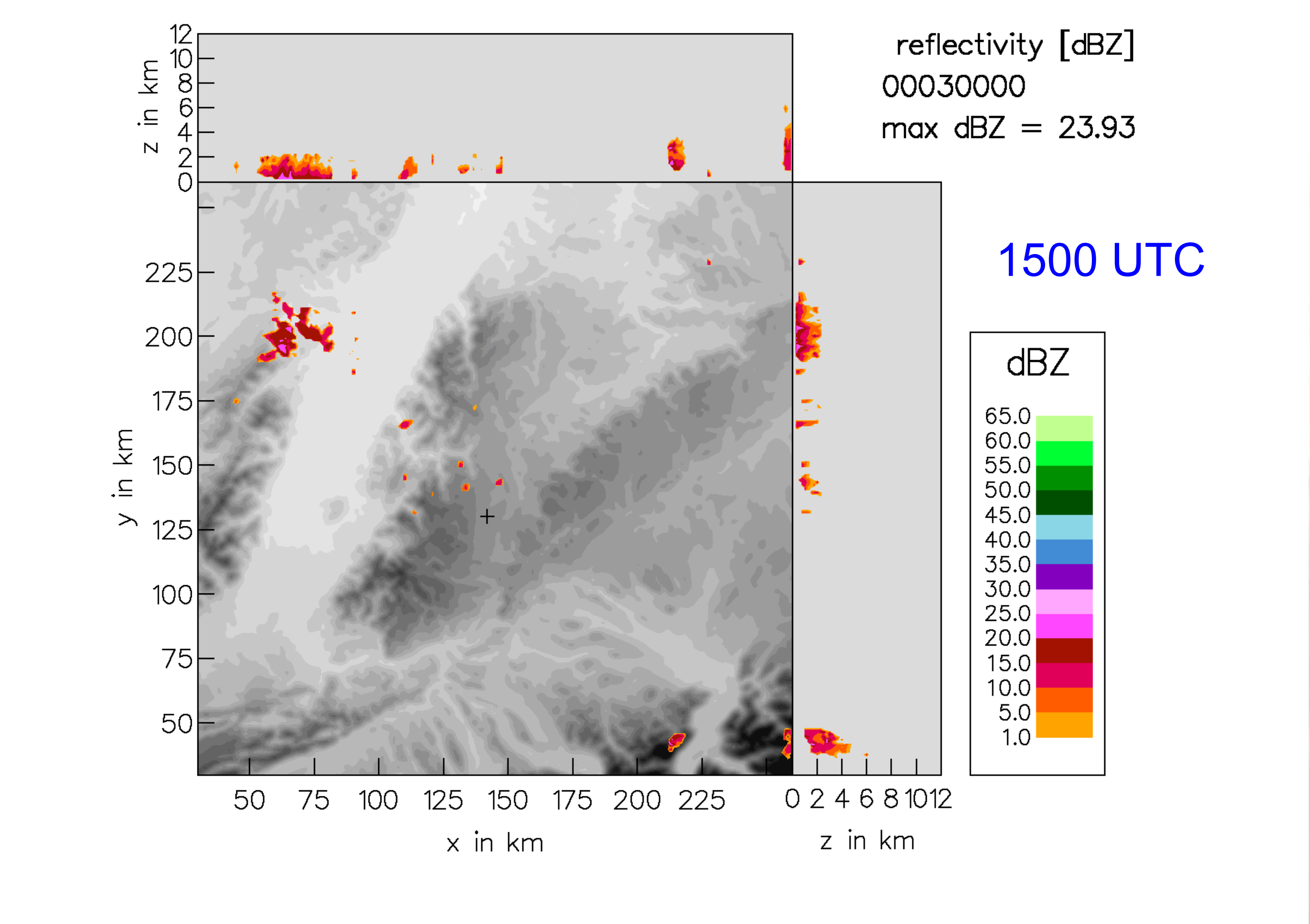

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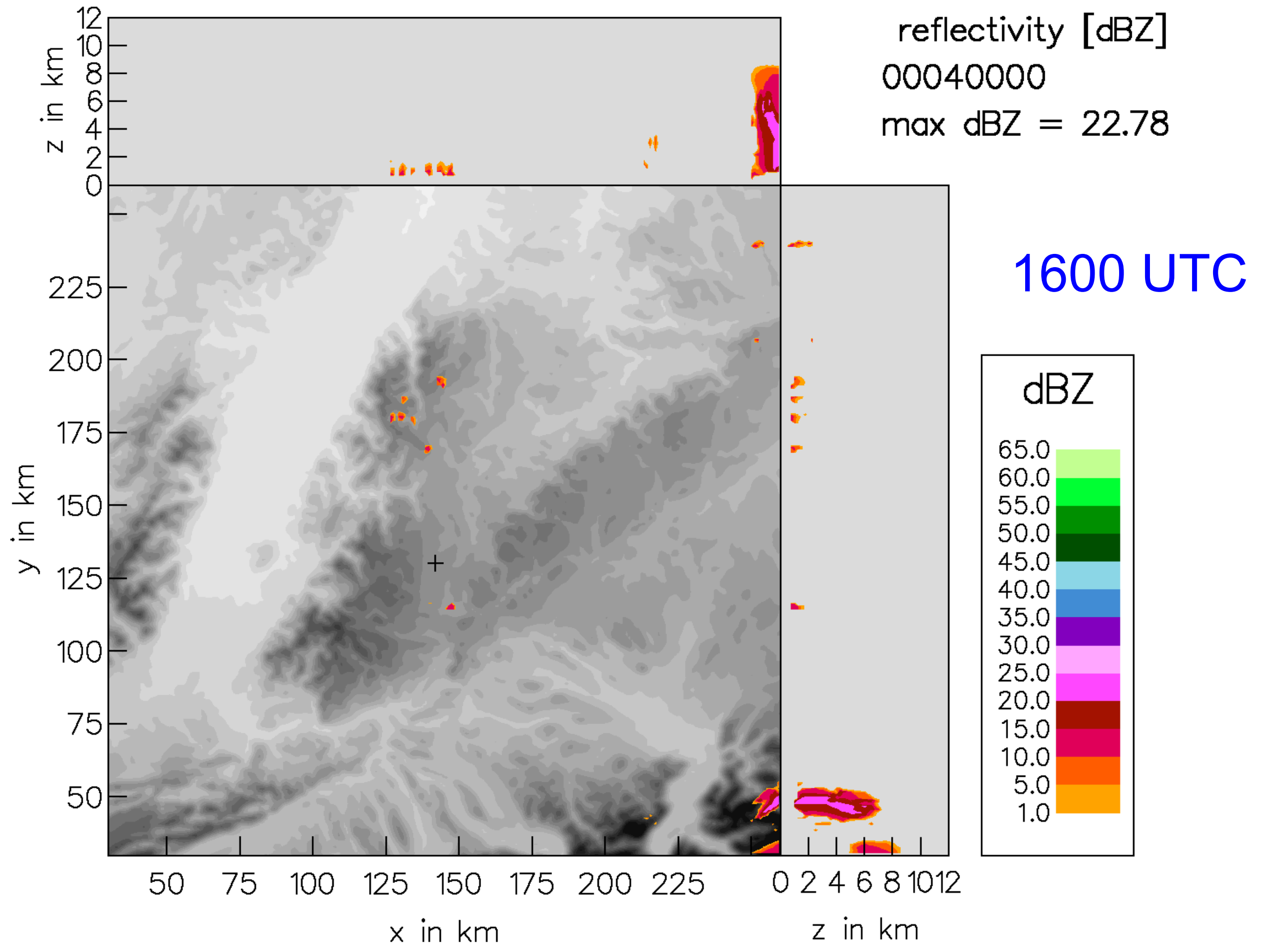

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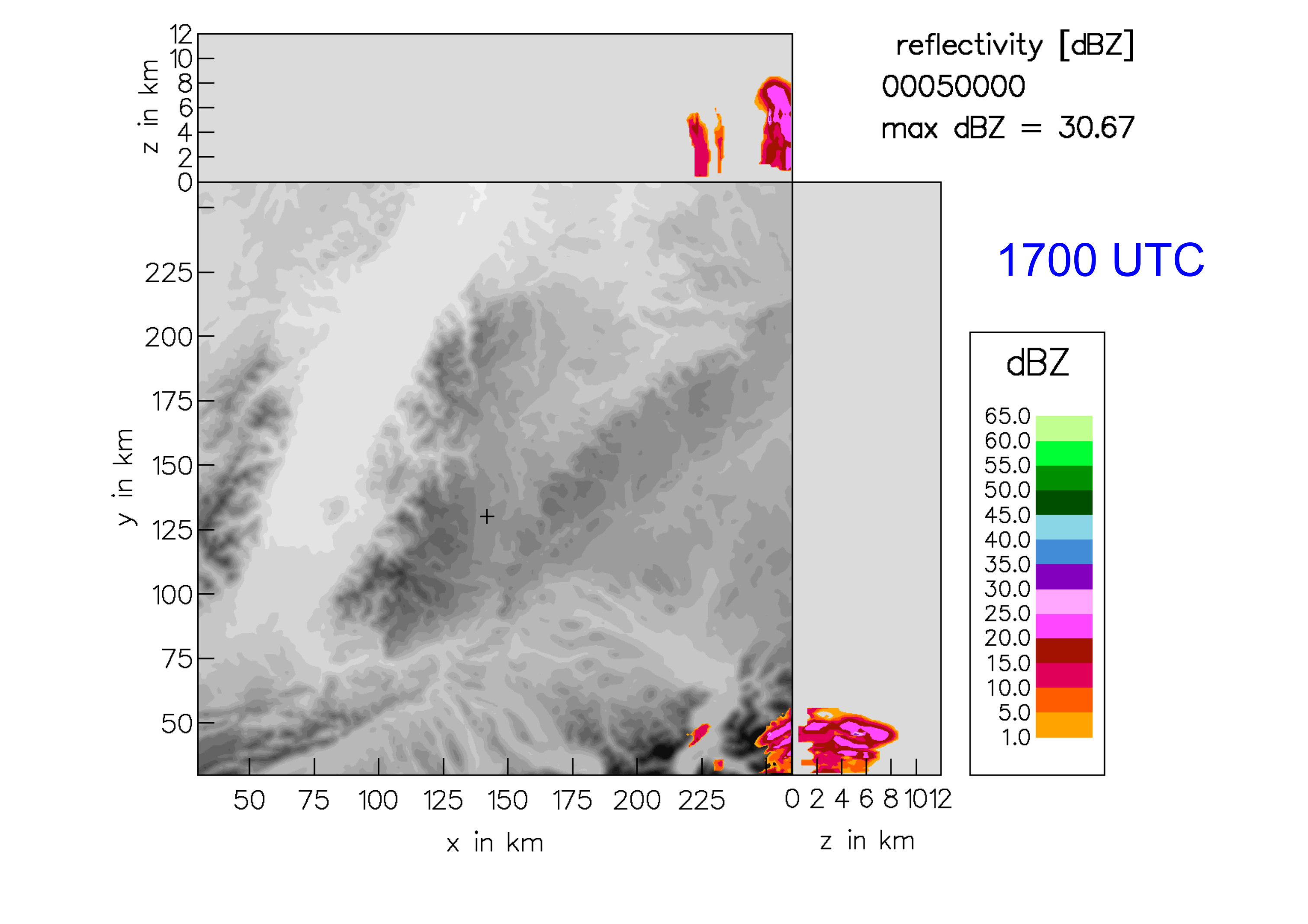

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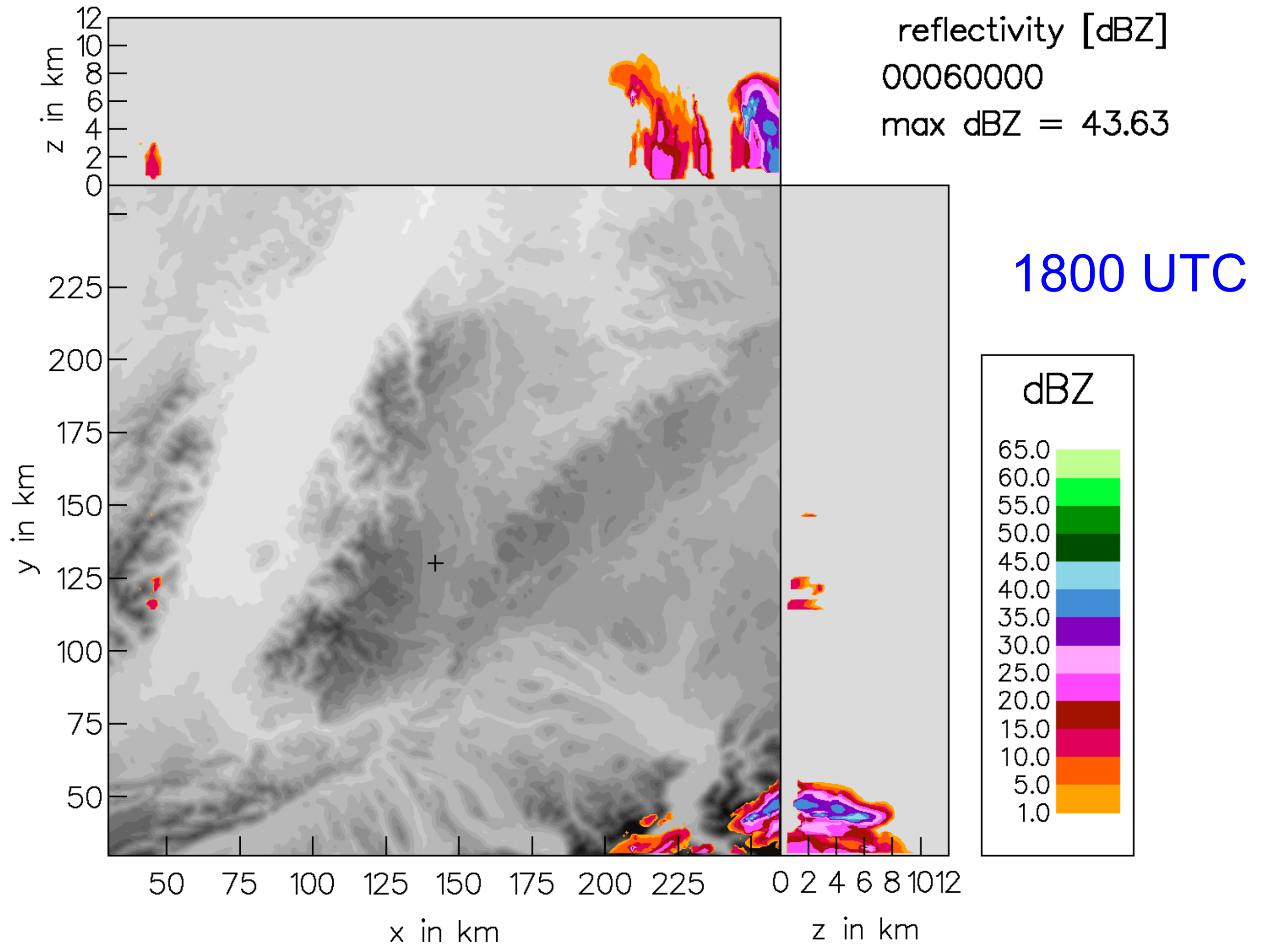

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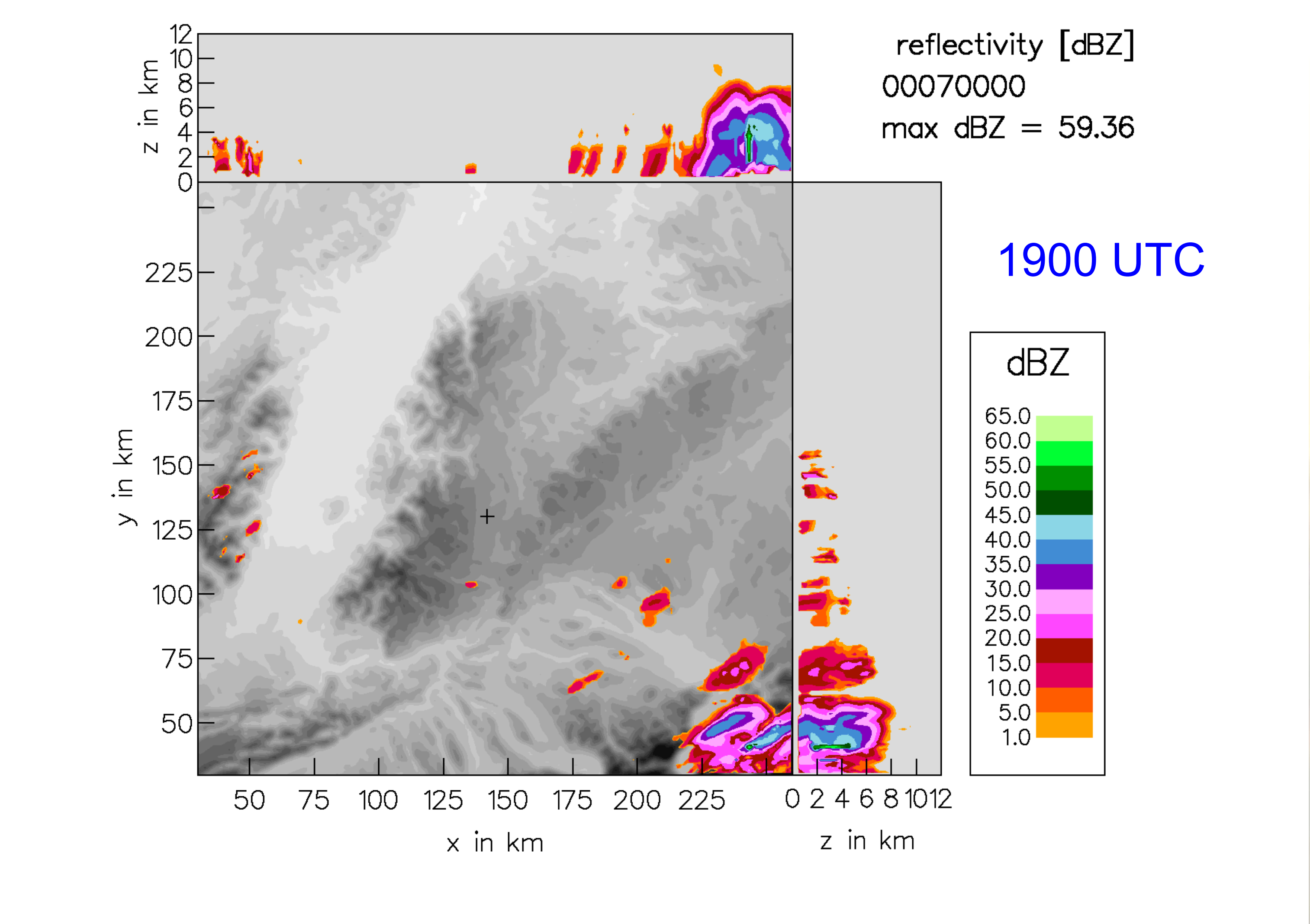

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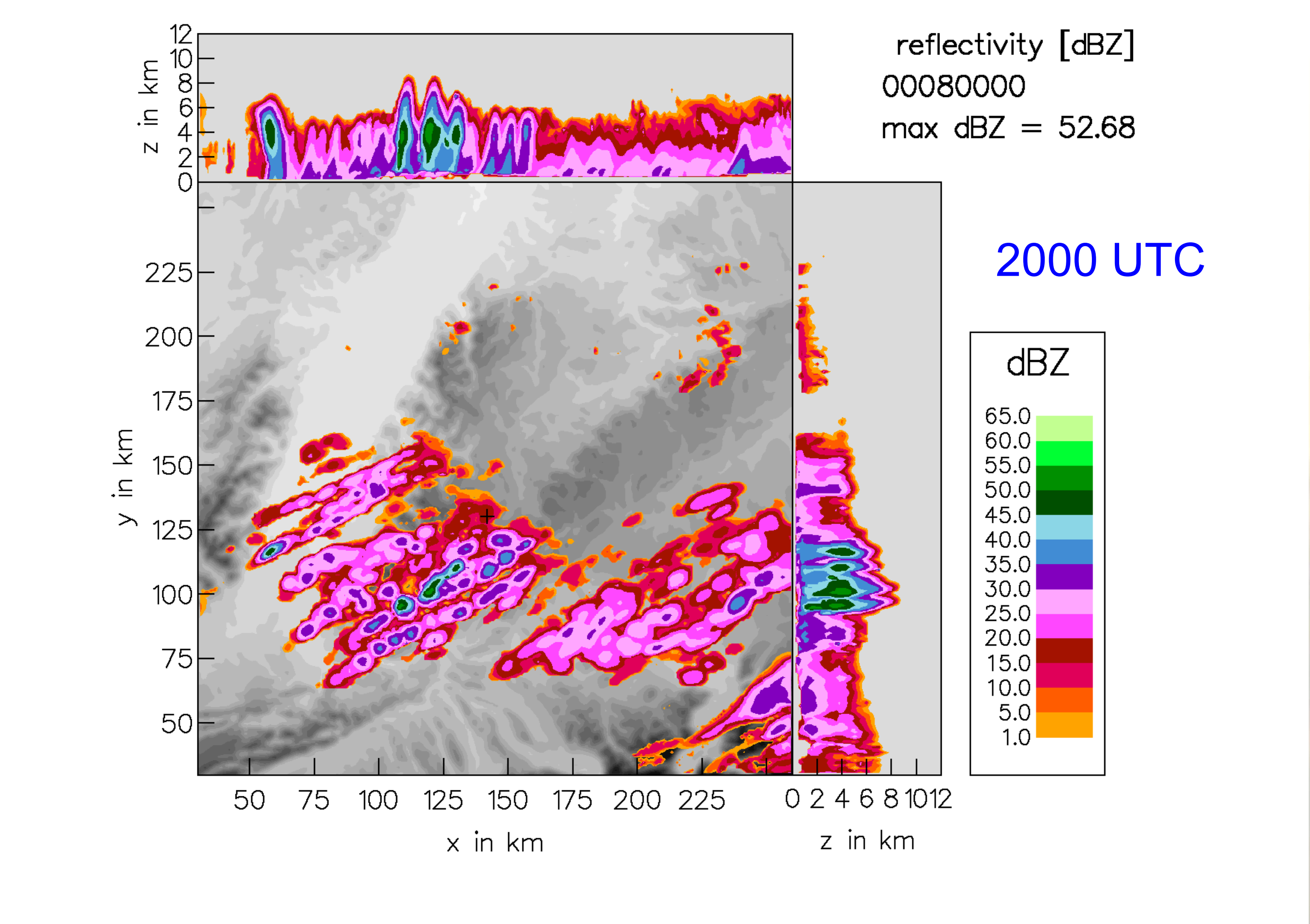

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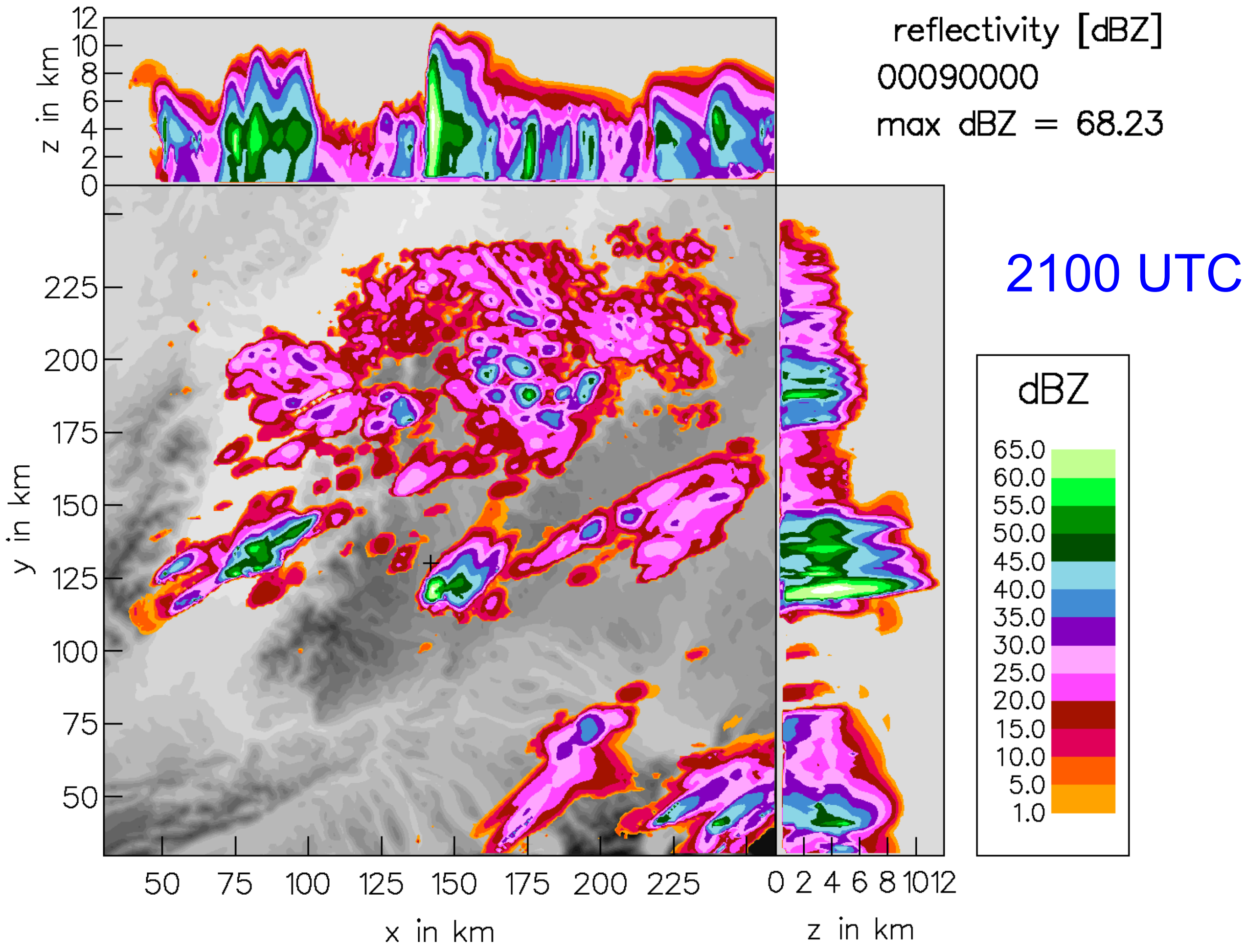

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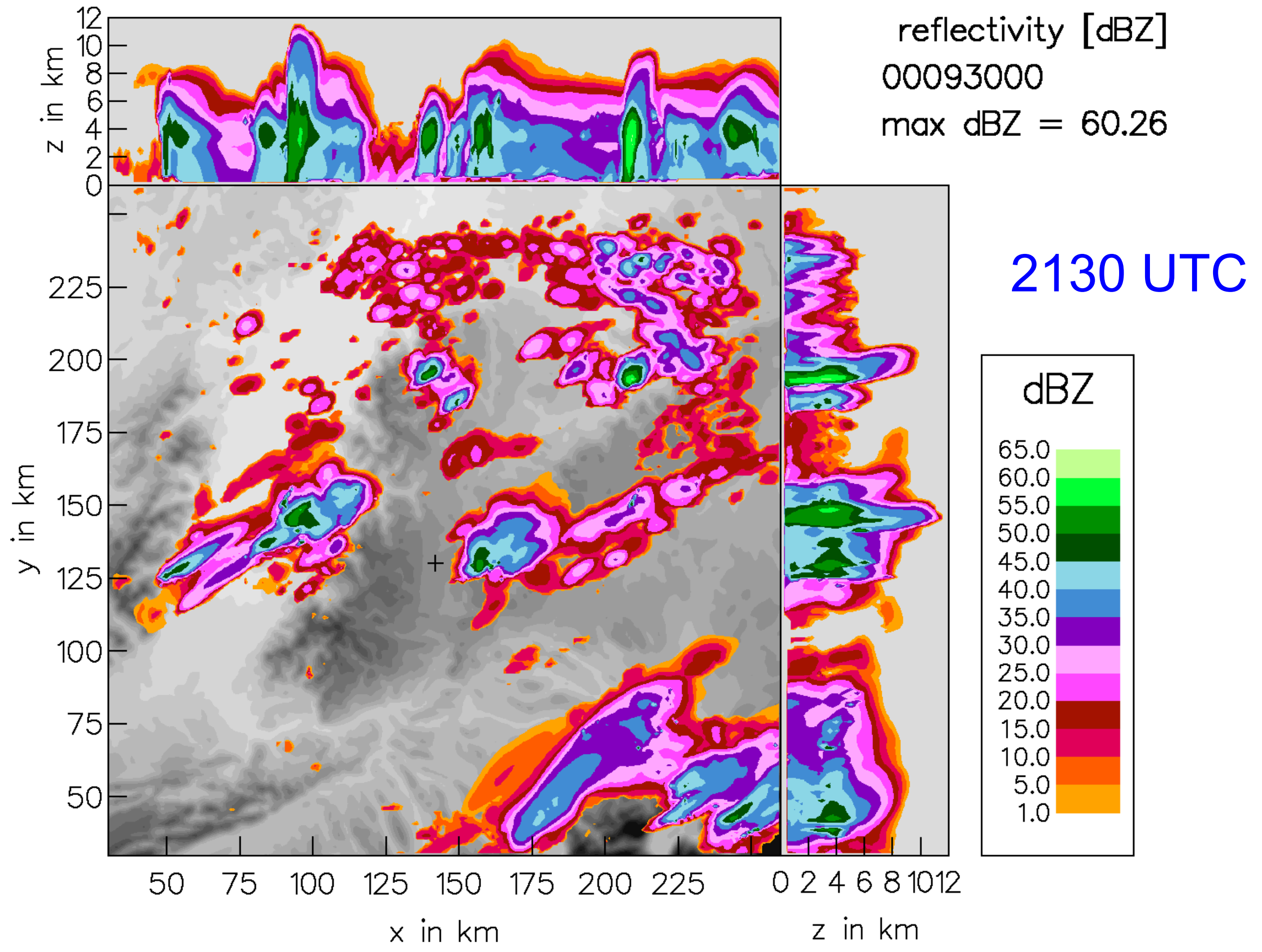

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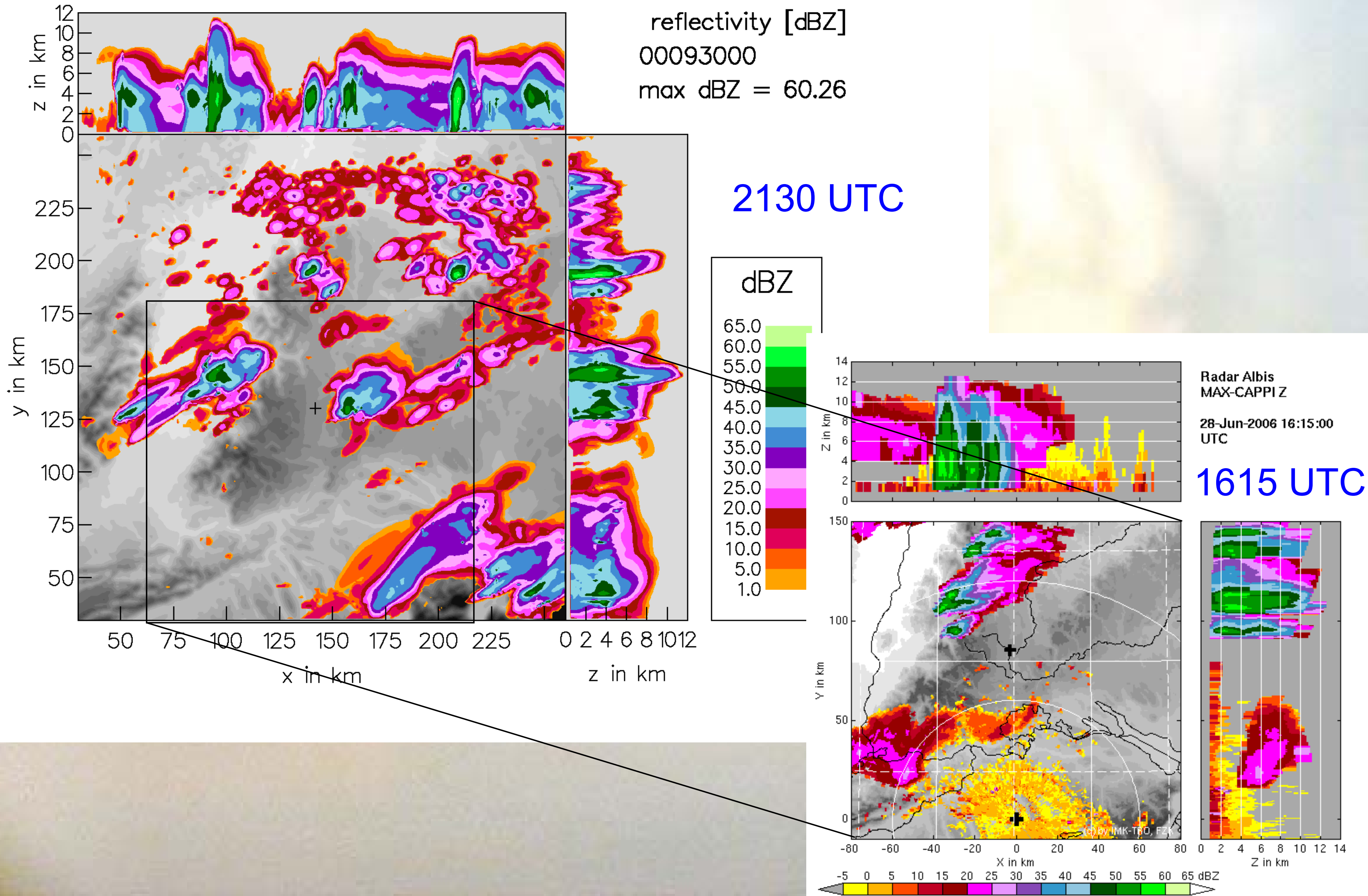

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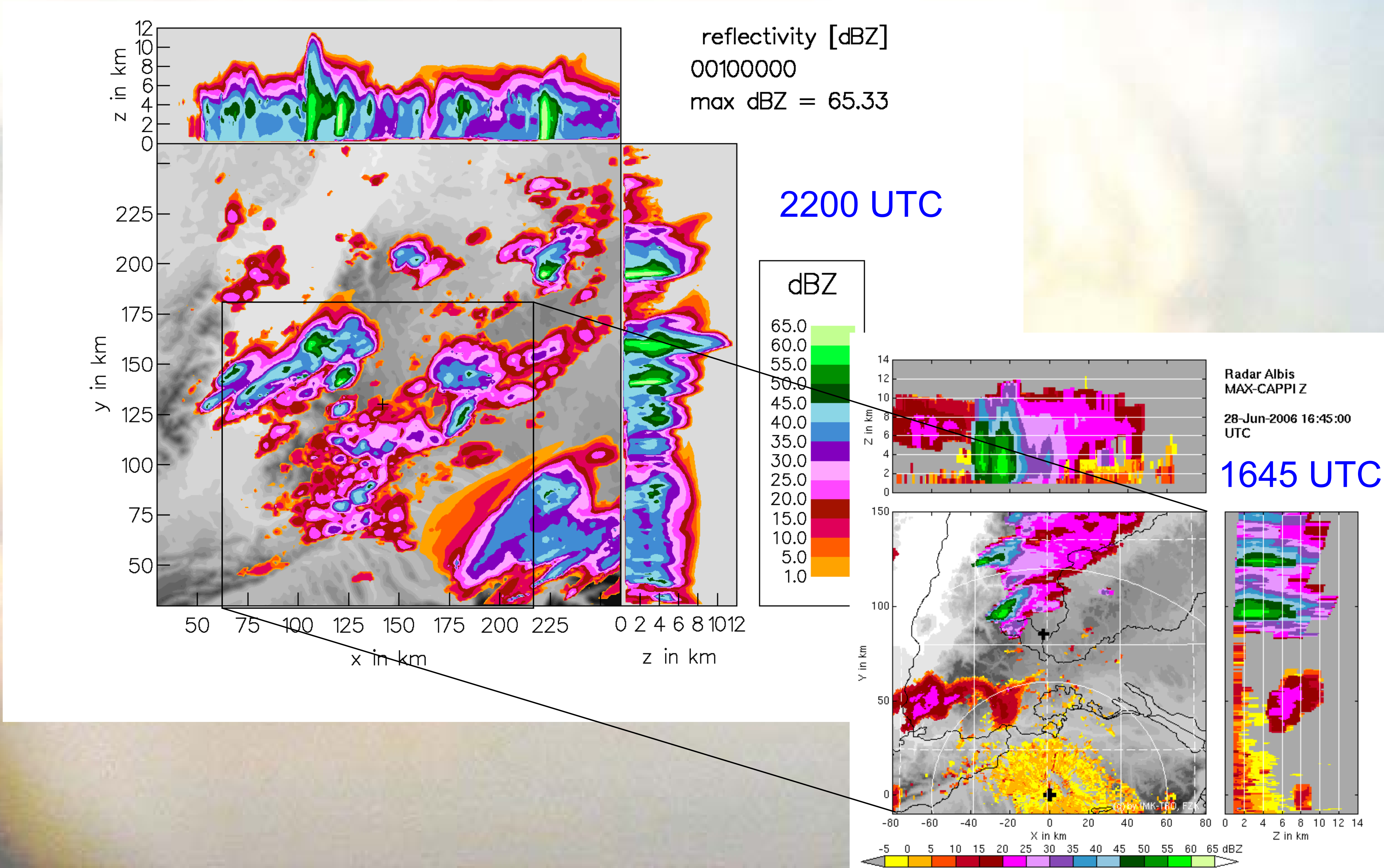

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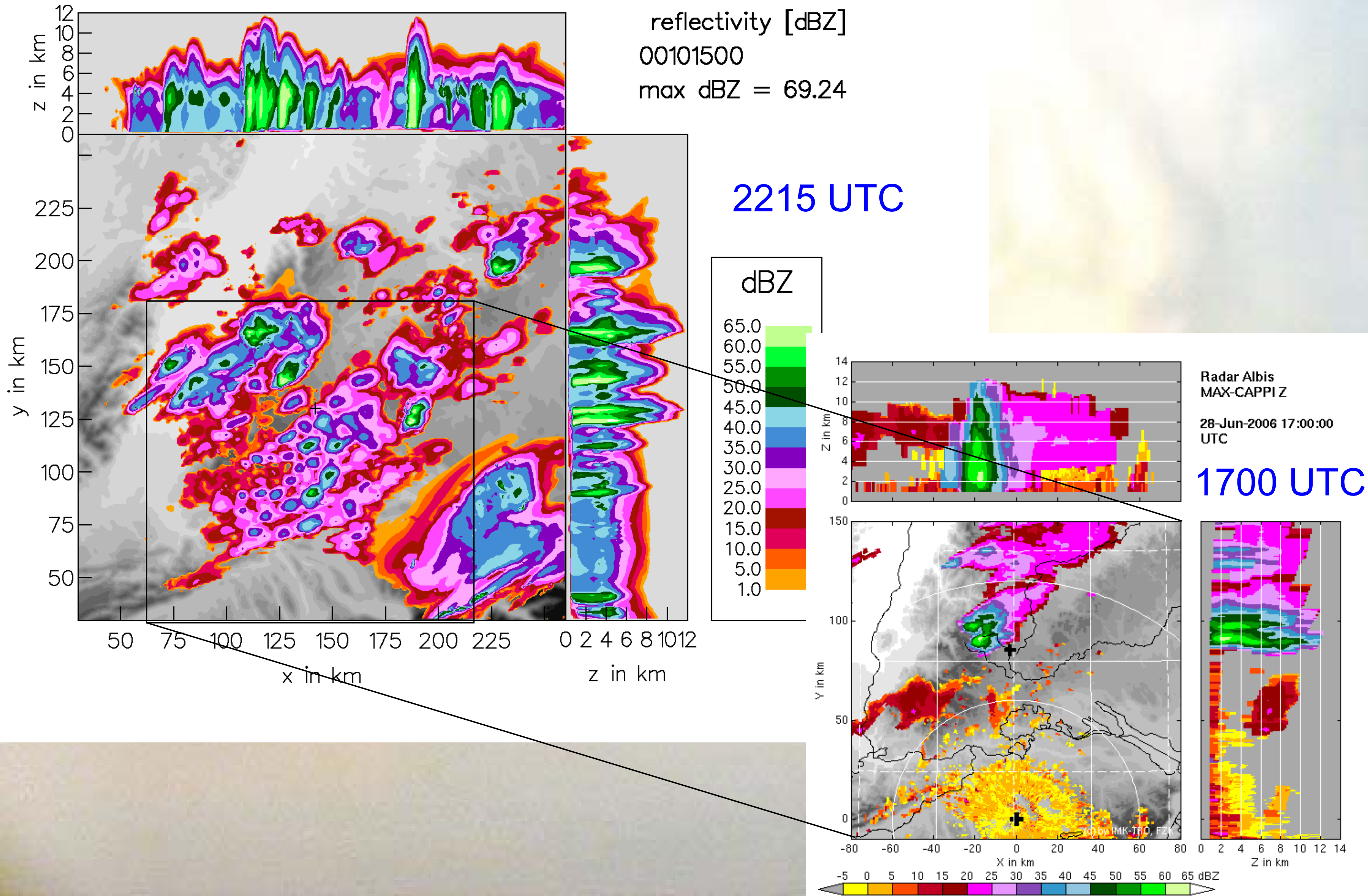

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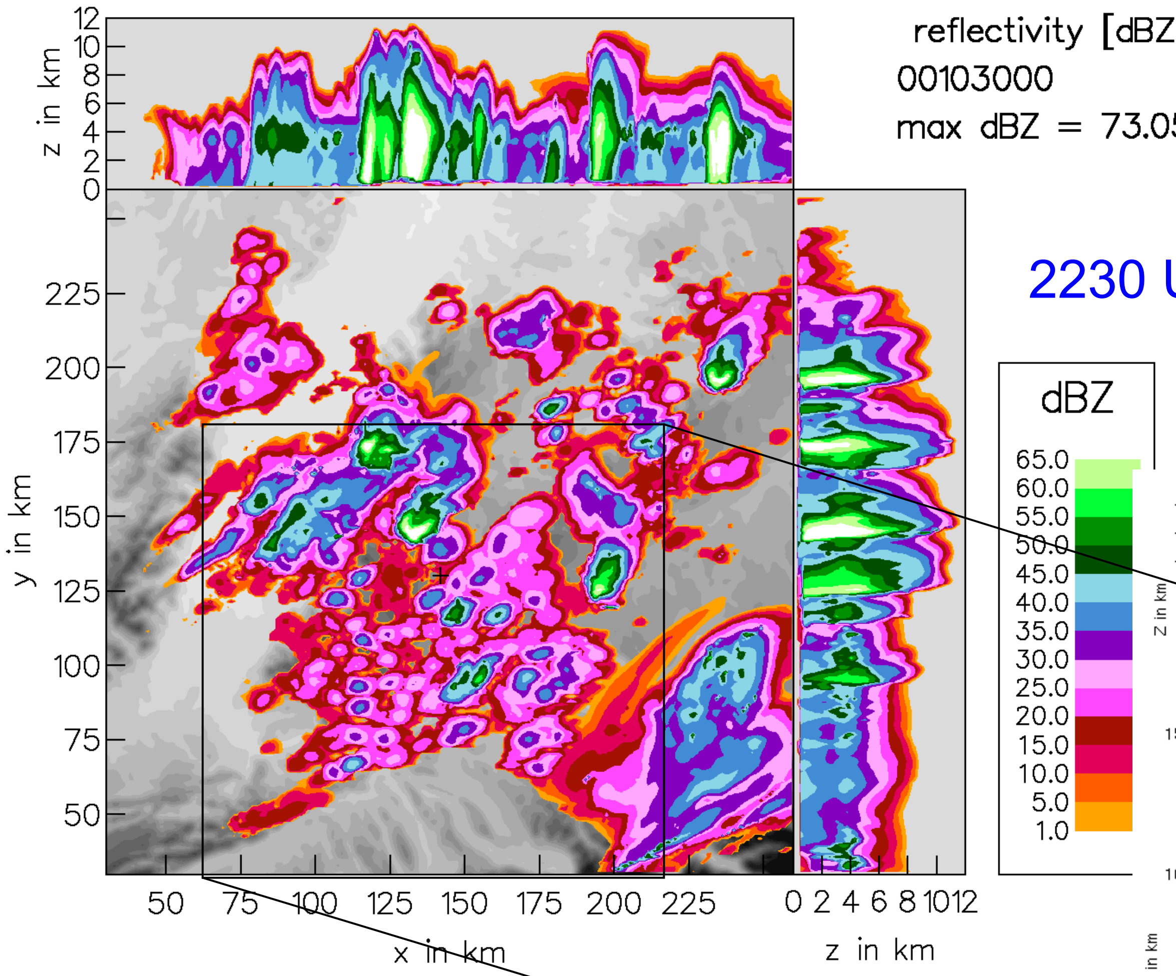

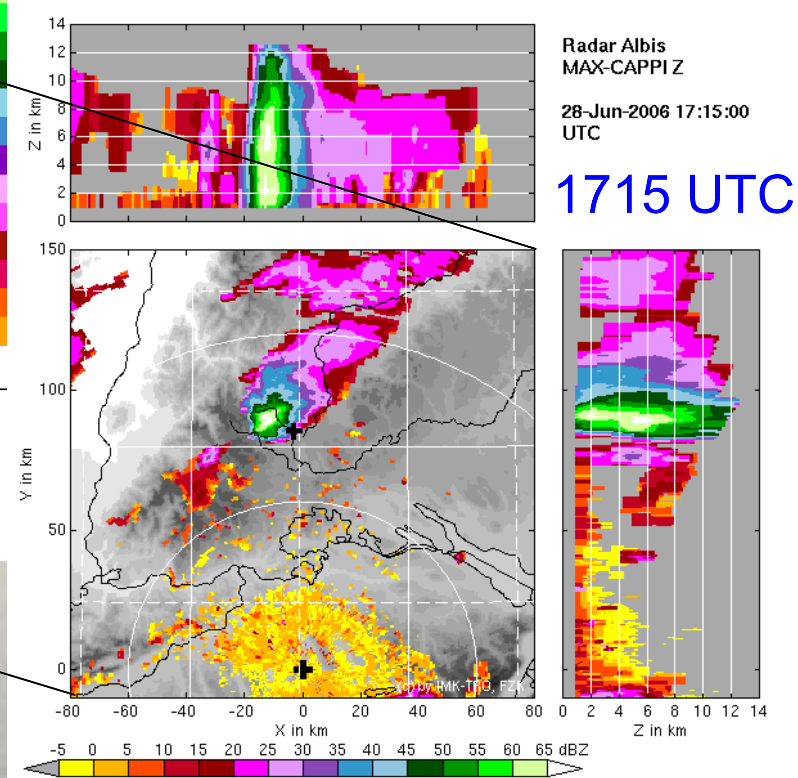

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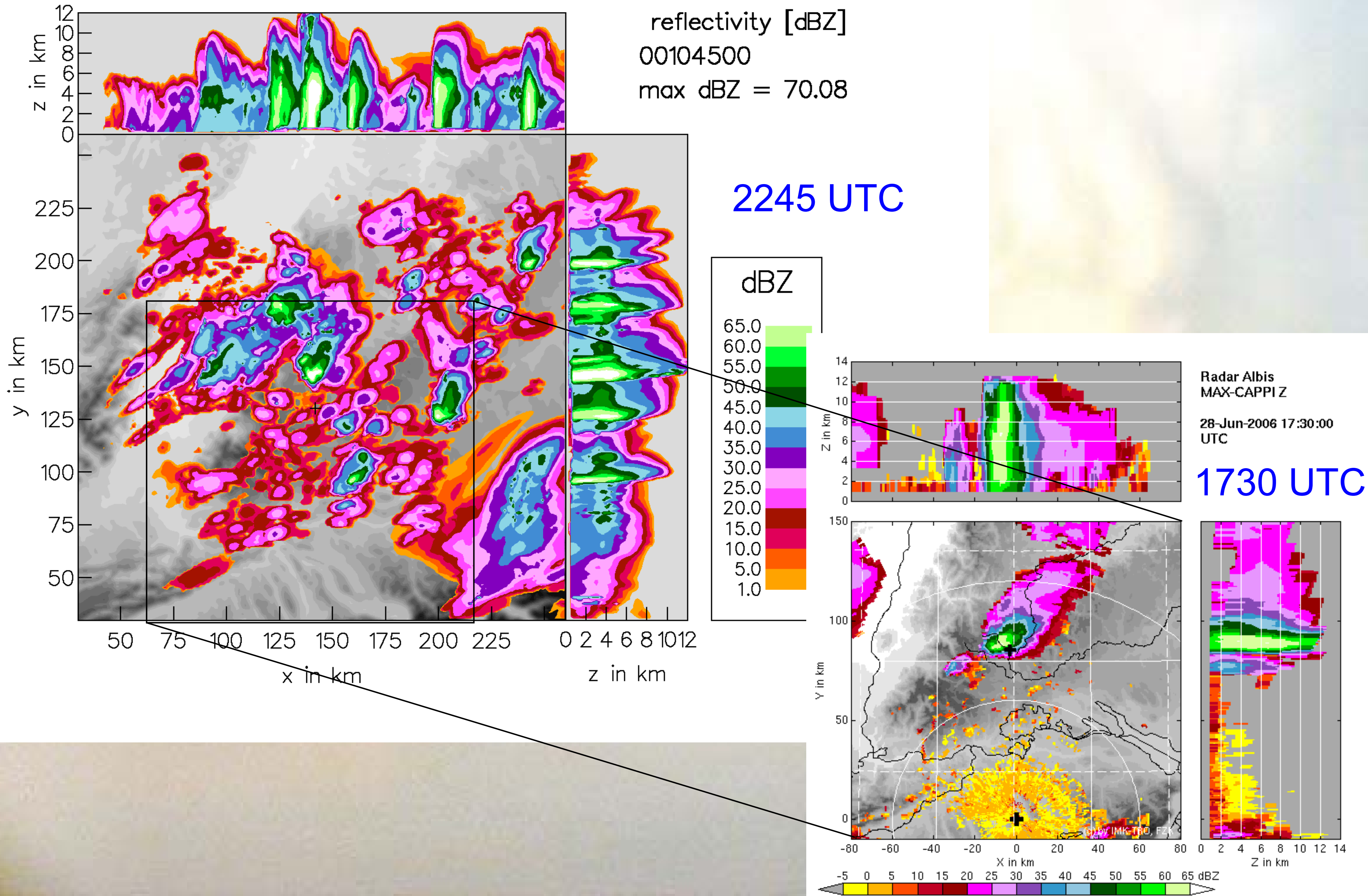

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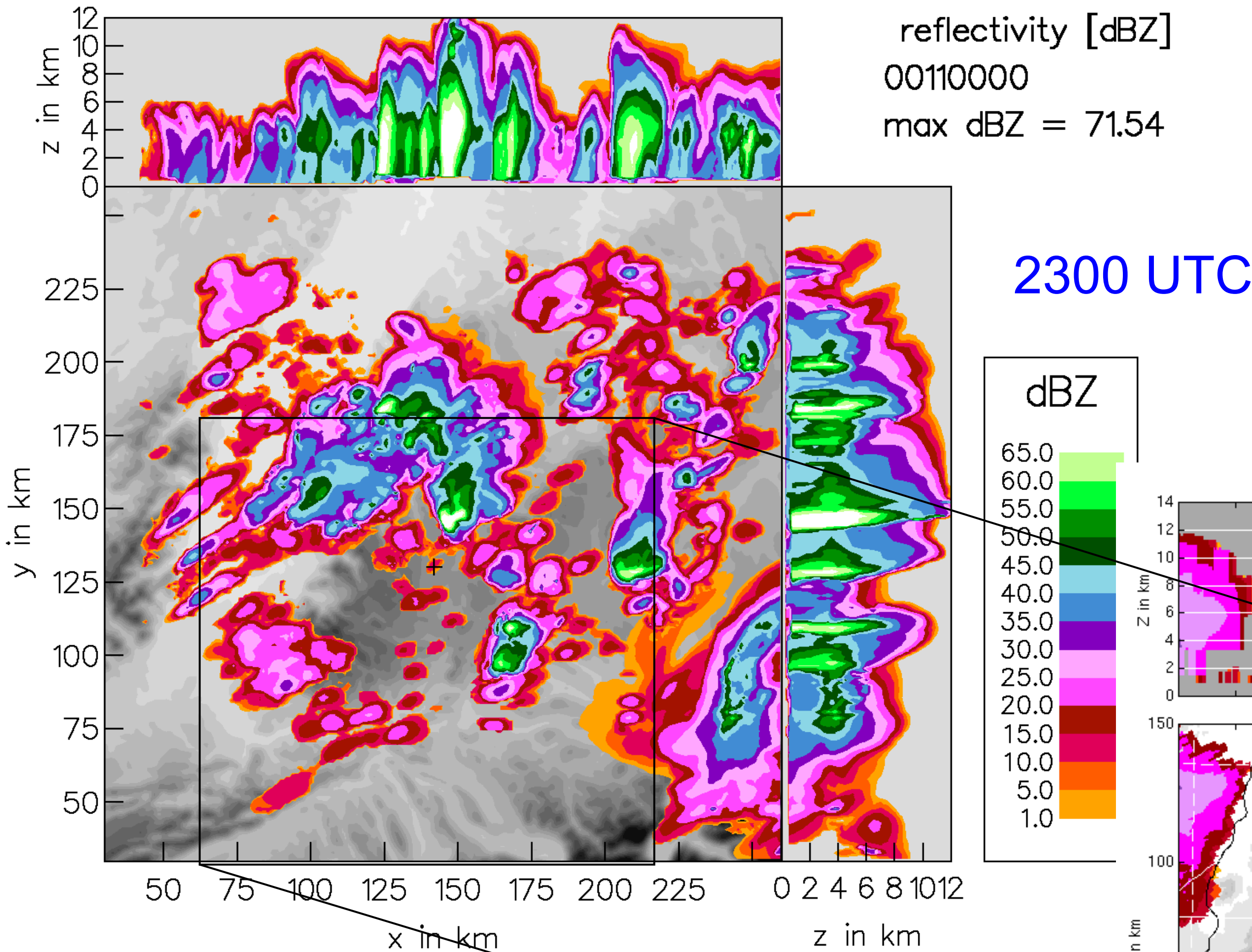

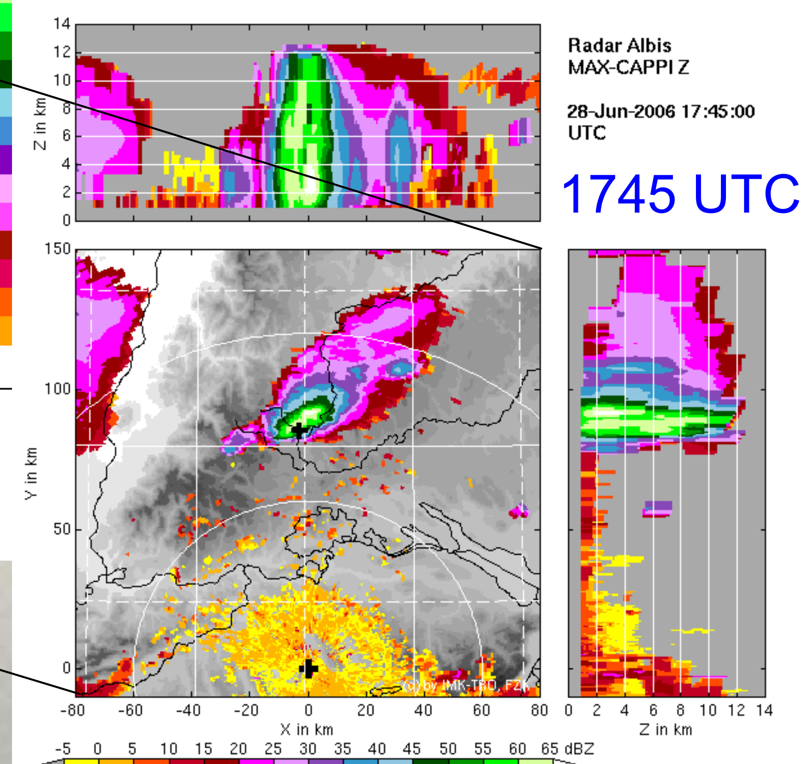

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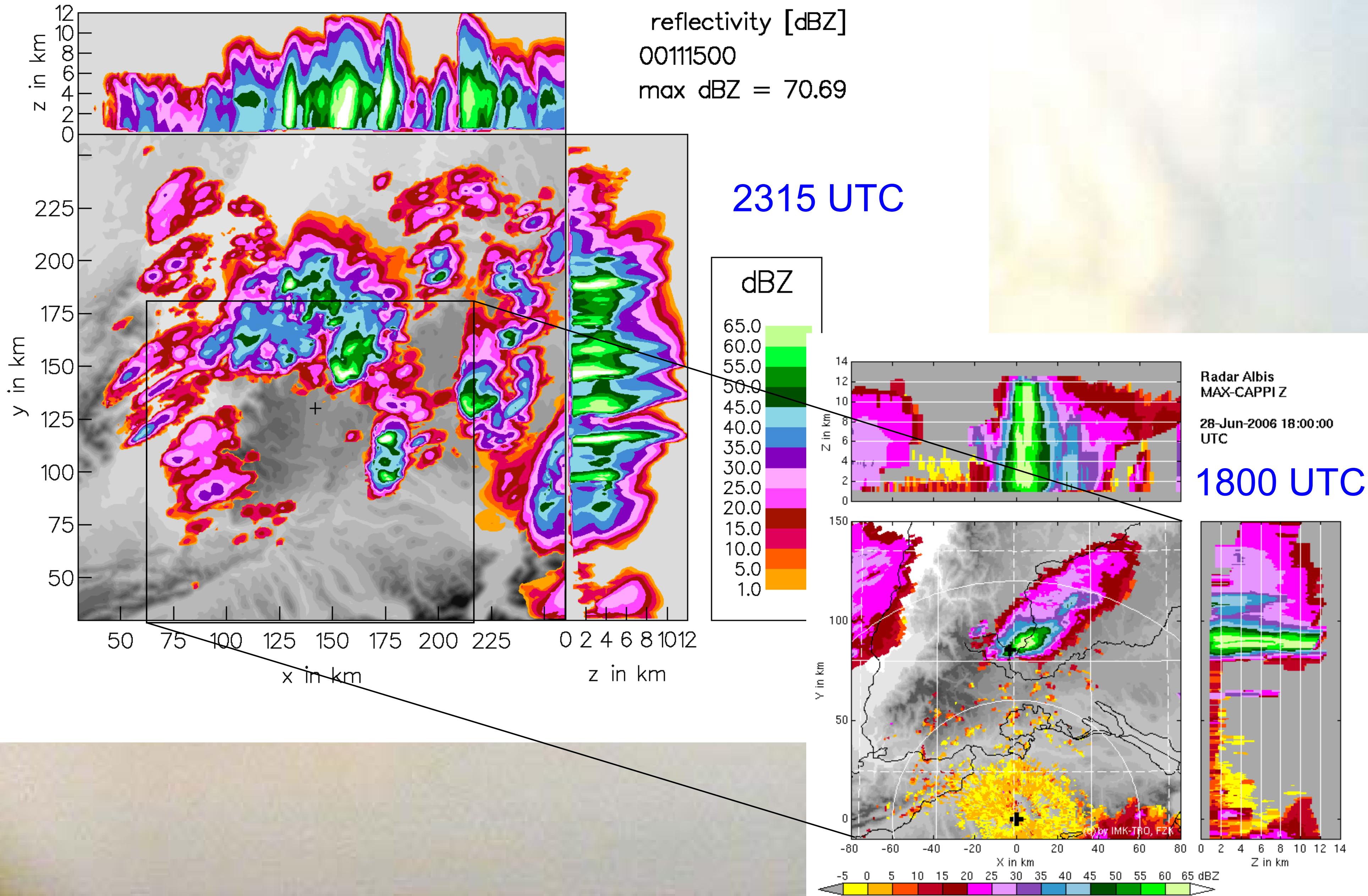

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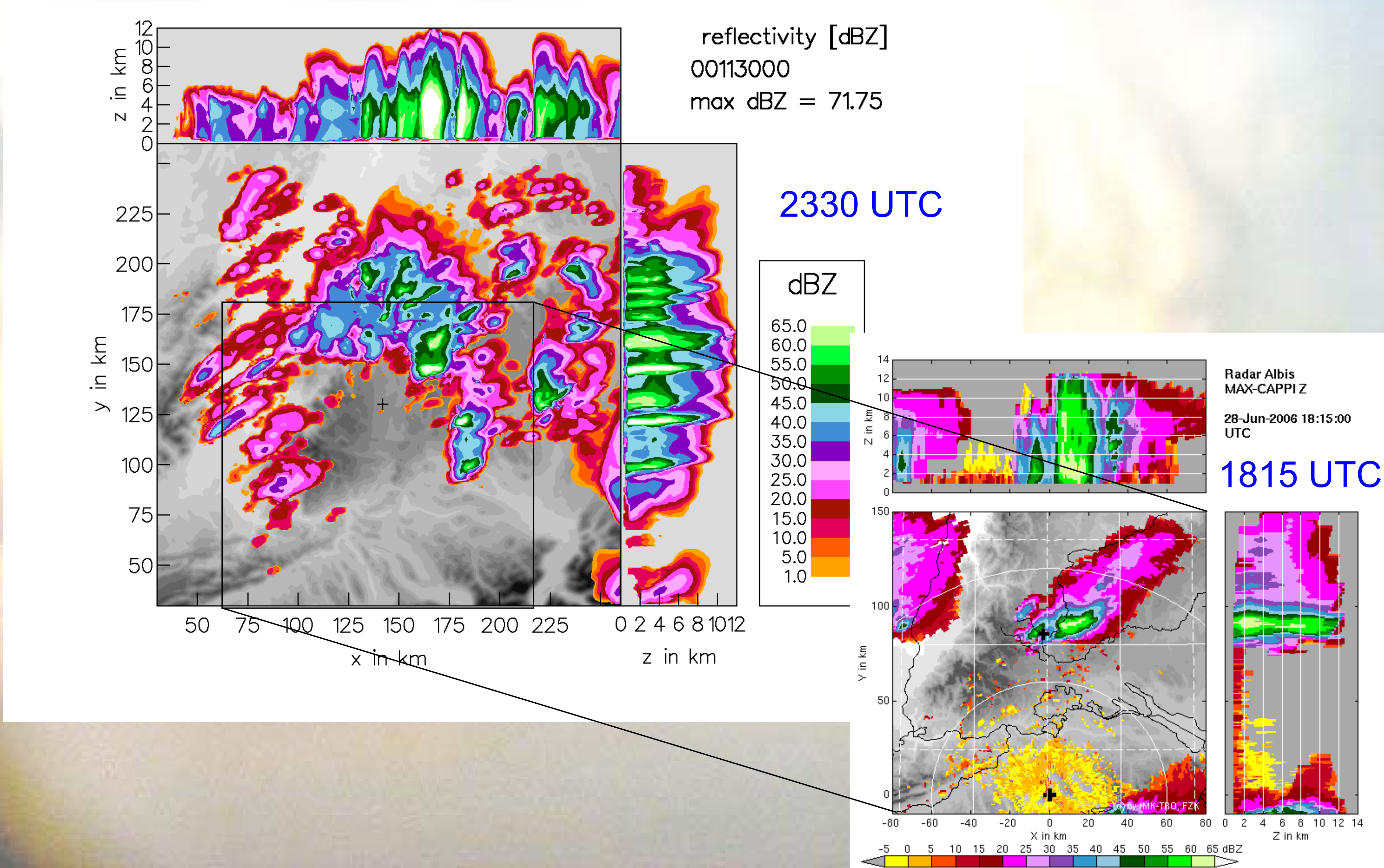

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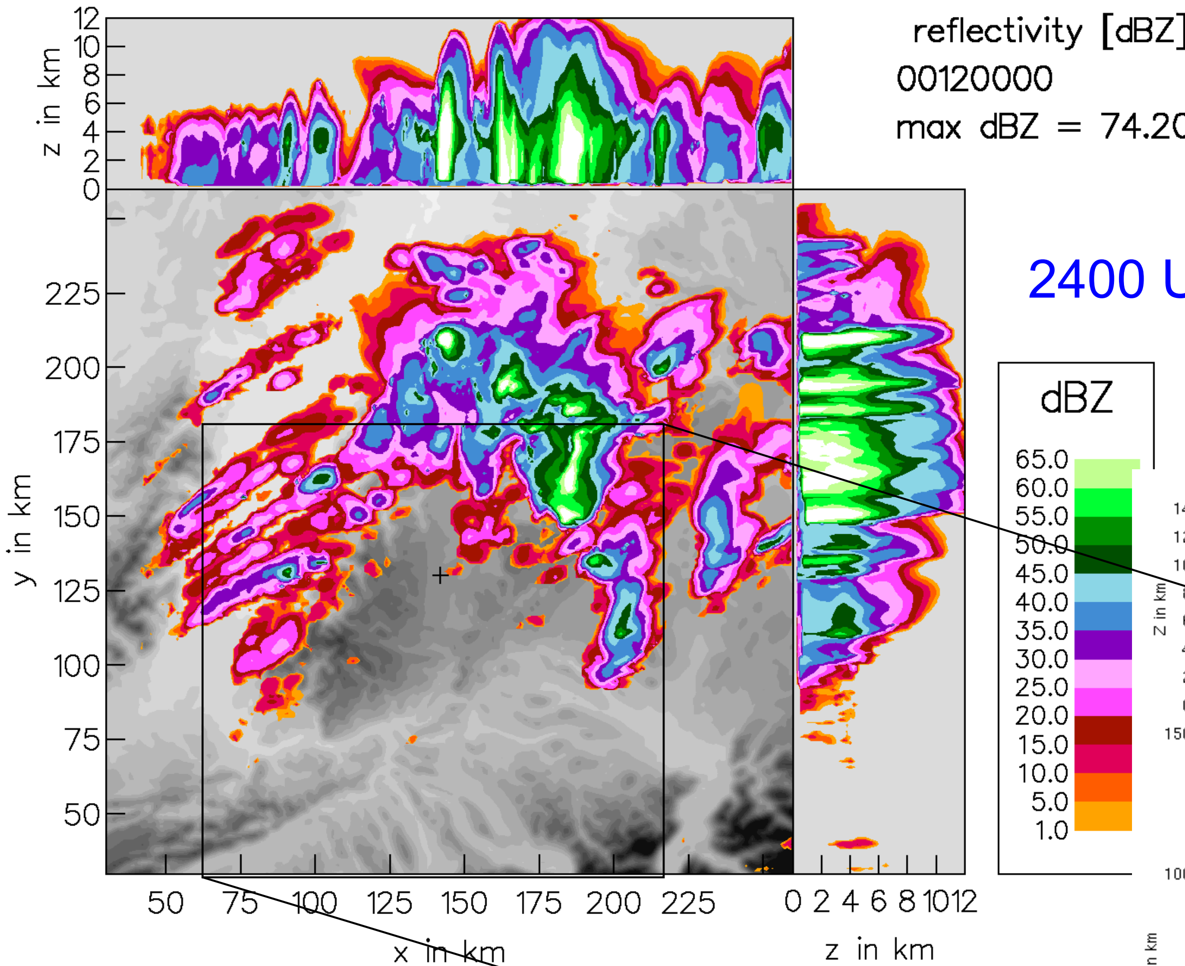

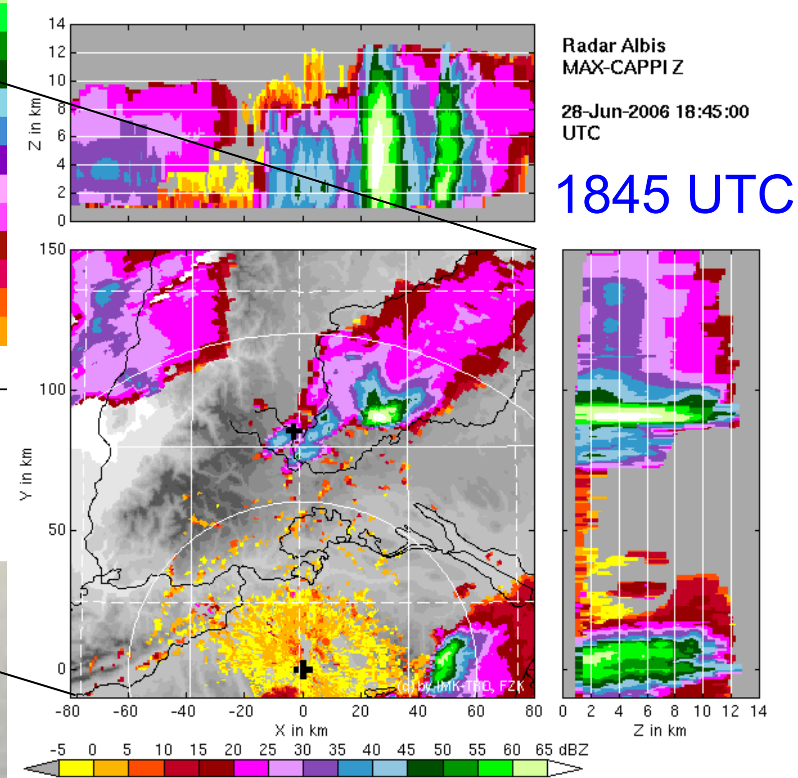

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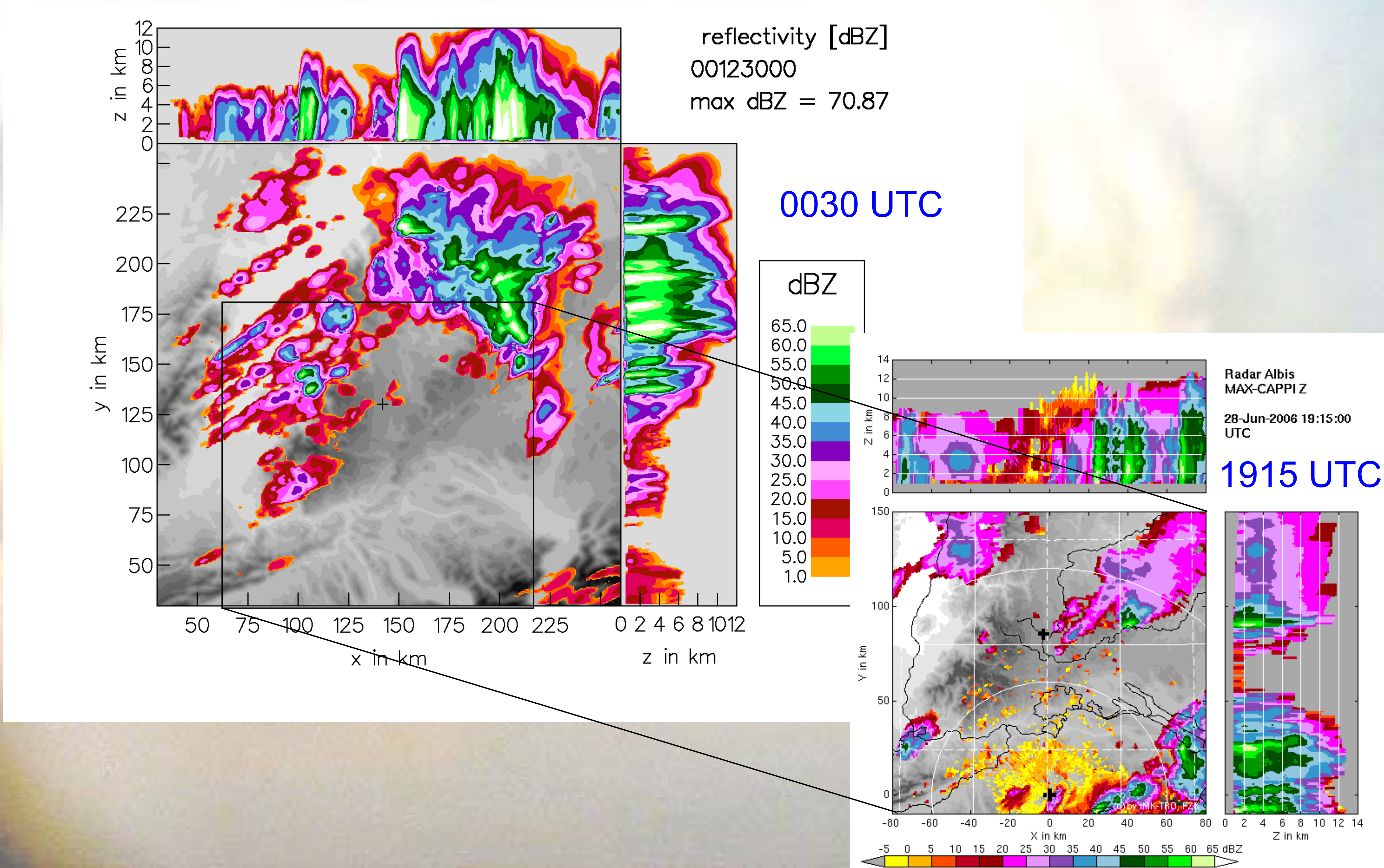
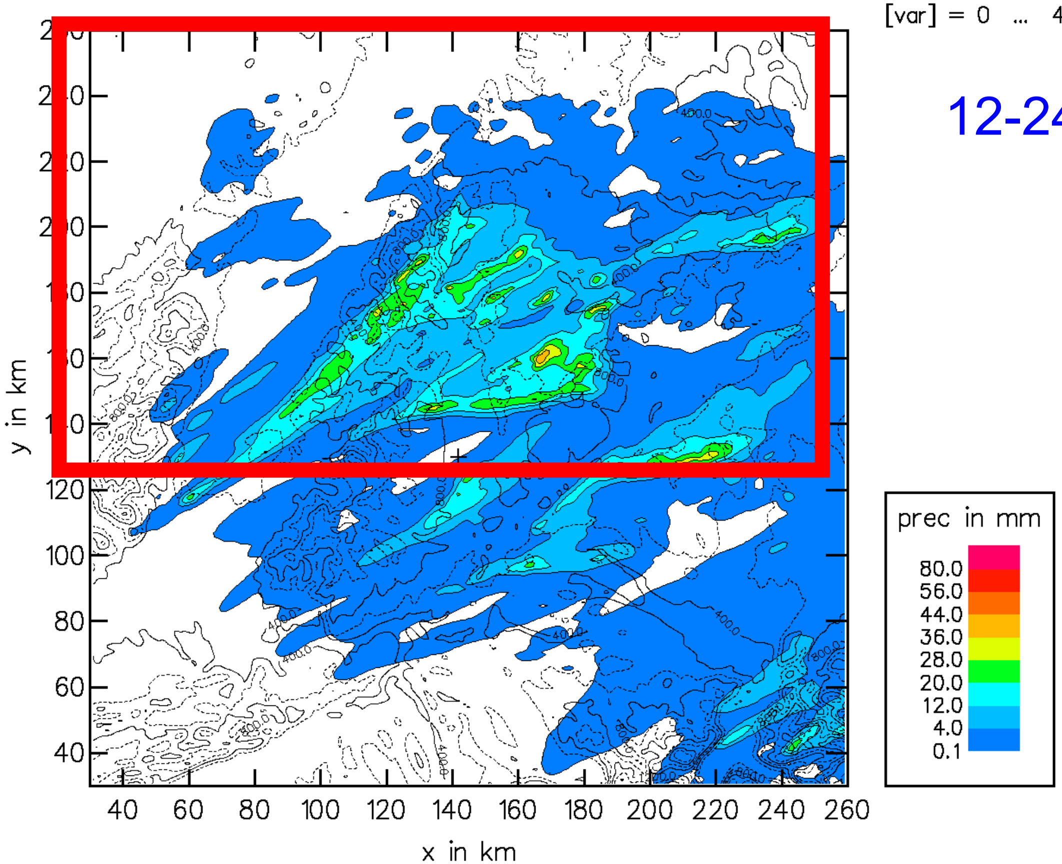


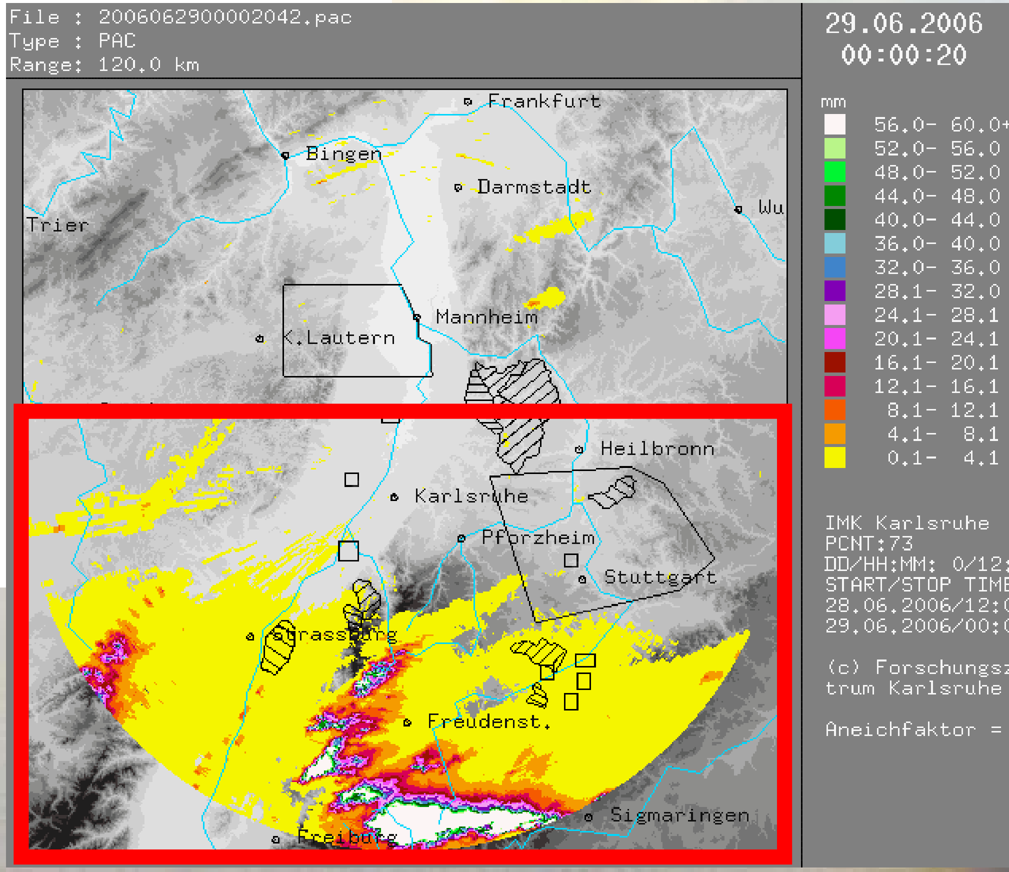
The Simulated Hailstorm

accumulated precipitation



12-24 UTC

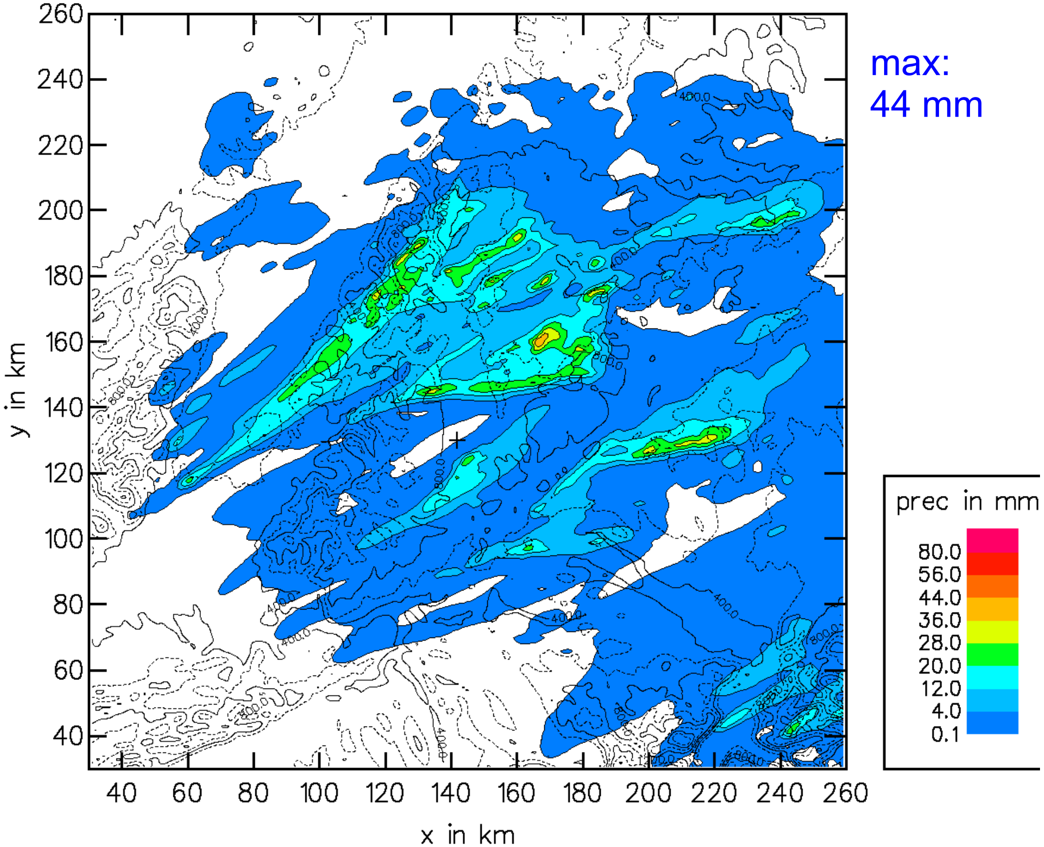
10-22 UTC



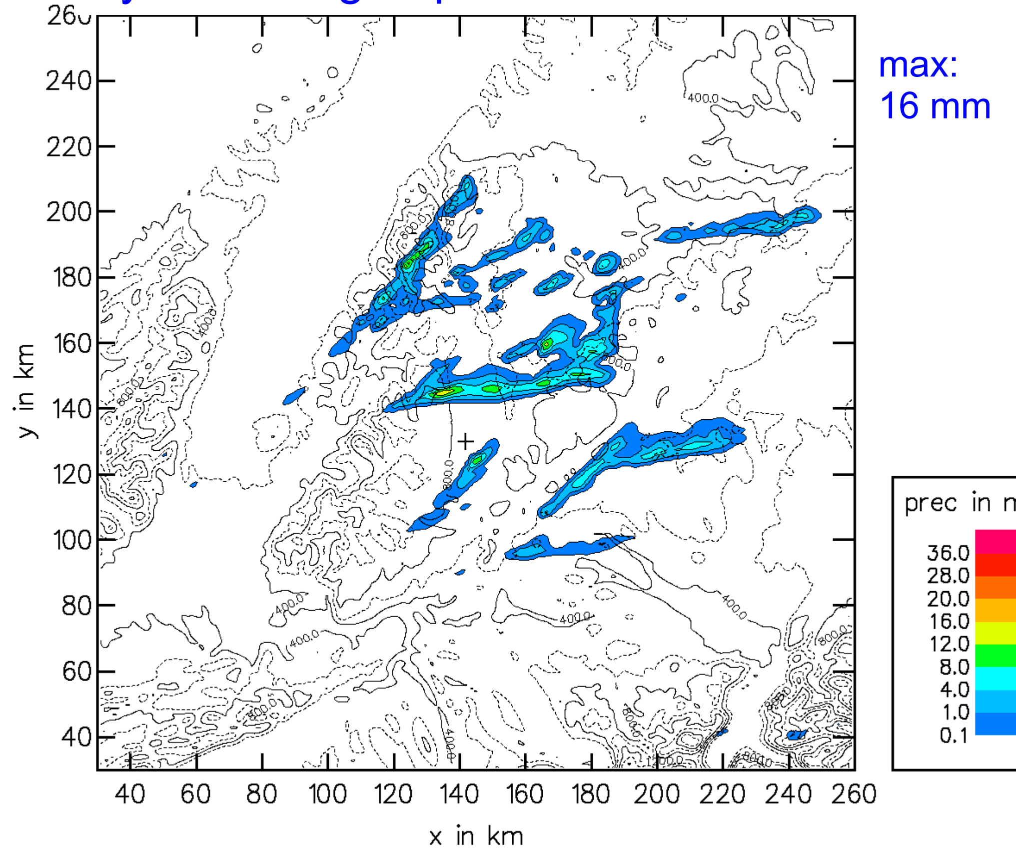
The Simulated Hailstorm

accumulated precipitation 12-24 UTC

total



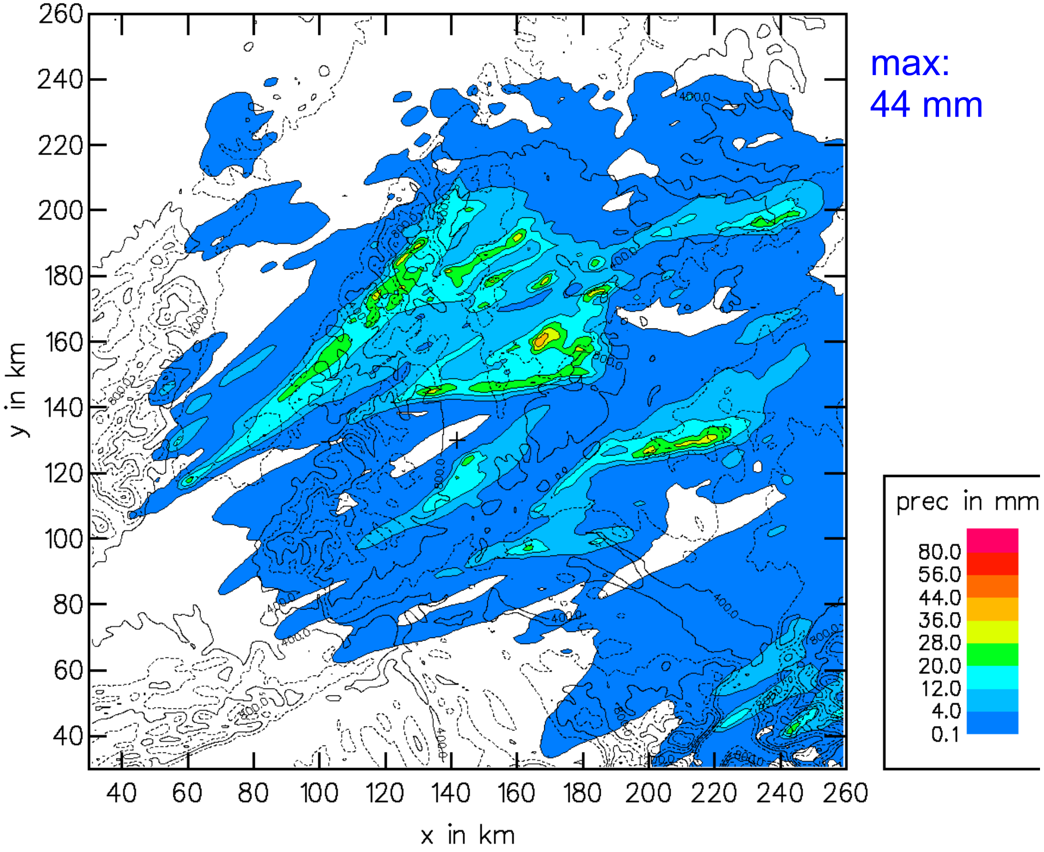
by hail and graupel



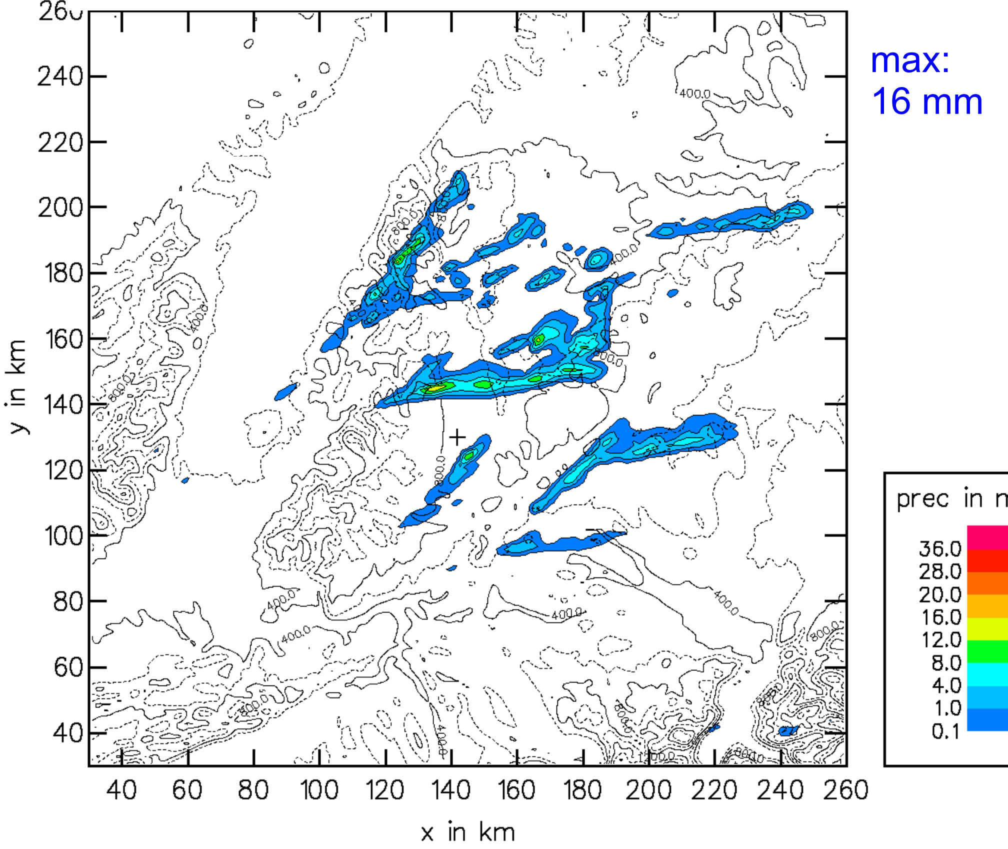
The Simulated Hailstorm

accumulated precipitation 12-24 UTC

total



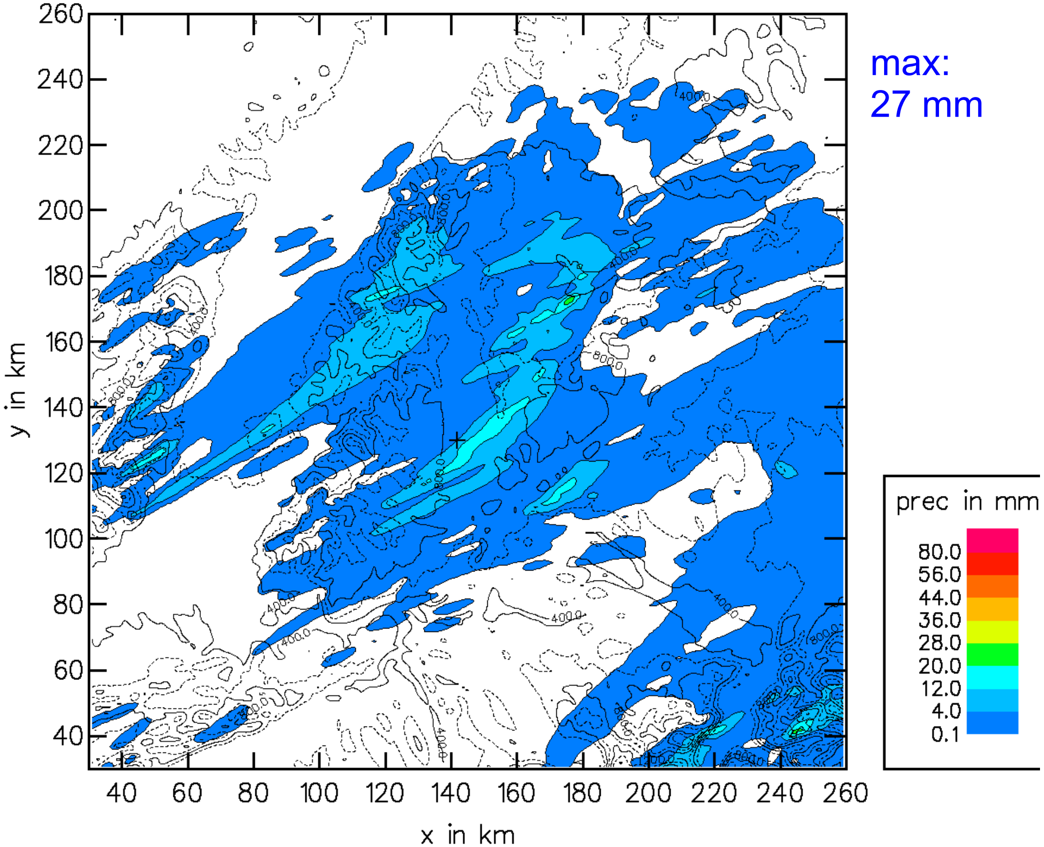
by hail and graupel



The Simulated Hailstorm

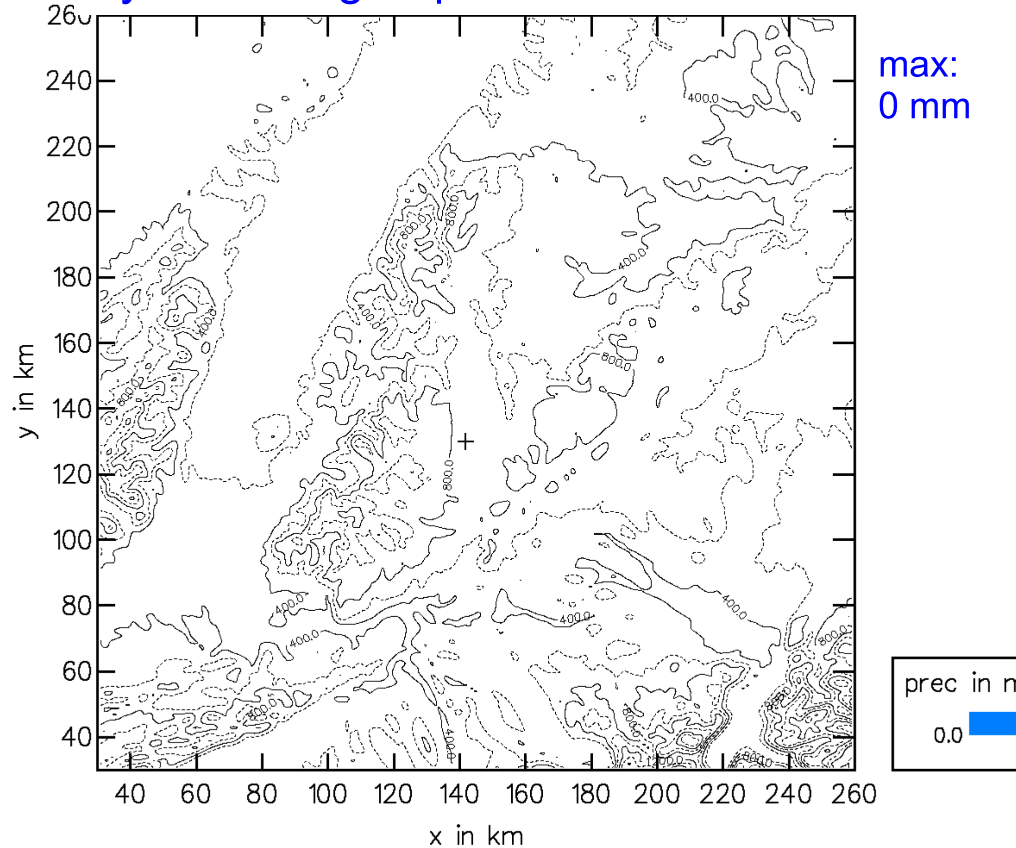
accumulated precipitation 12-24 UTC

total



max:
27 mm

by hail and graupel

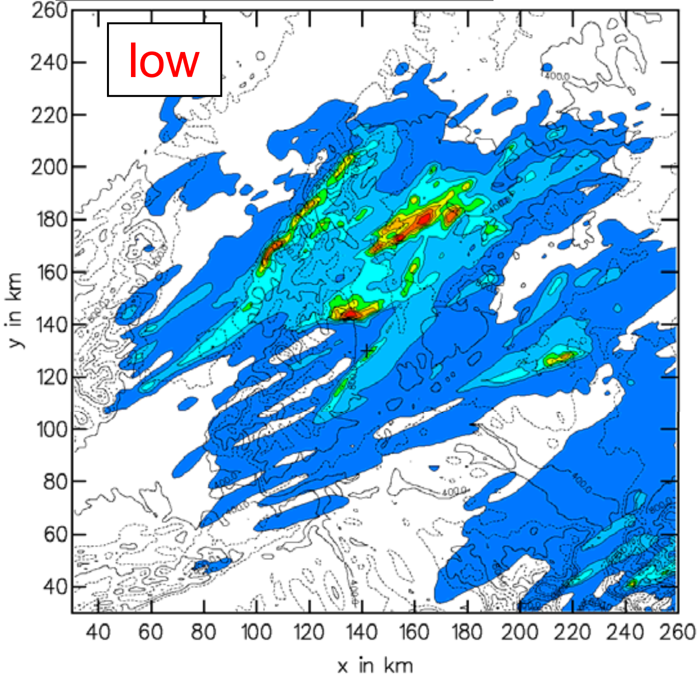


max:
0 mm

the same, but with the standard 1-moment scheme

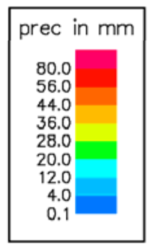
CCN Impact

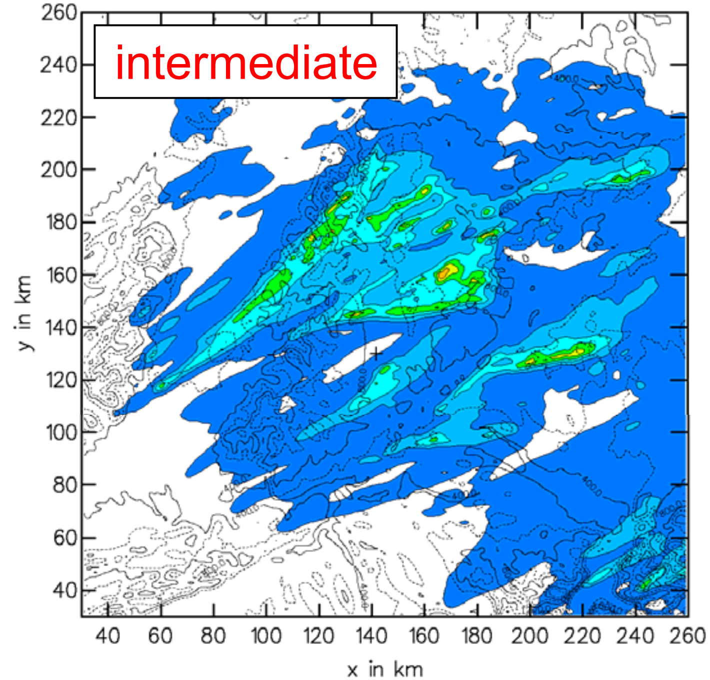
accumulated precipitation 12-24 UTC



max:
77 mm

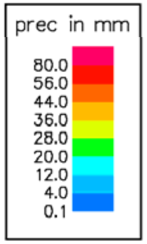
tot. vol.:
110 10^6 m^3

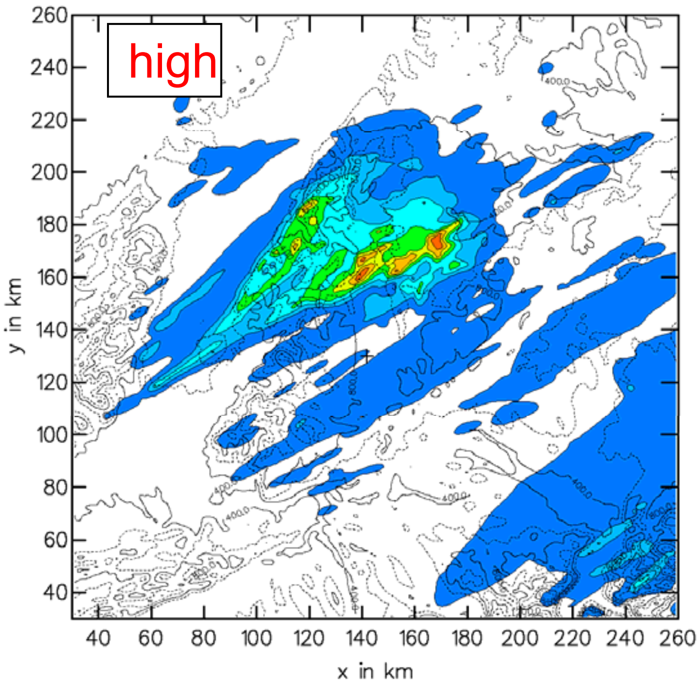




max:
44 mm

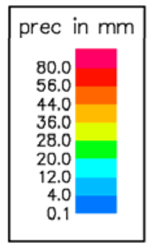
tot. vol.:
115 10^6 m^3

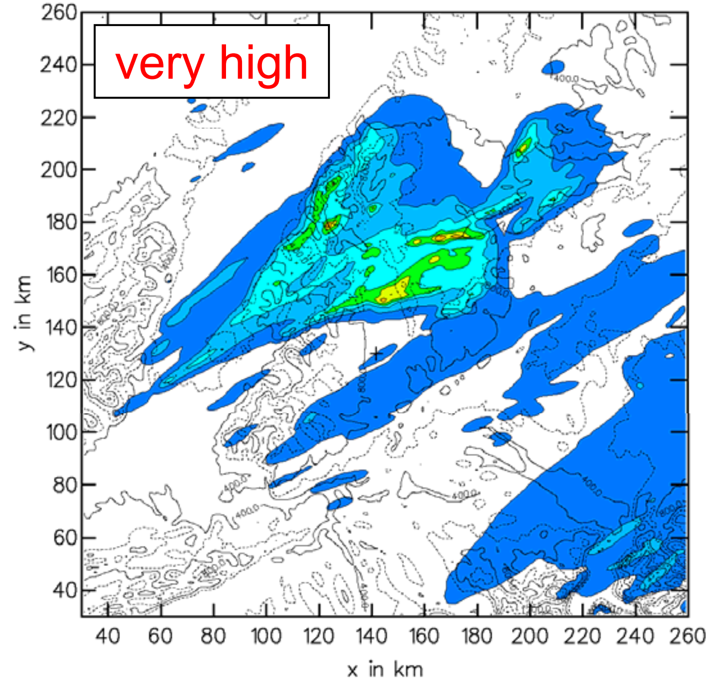




max:
49 mm

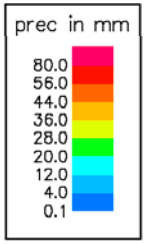
tot. vol.:
80 10^6 m^3





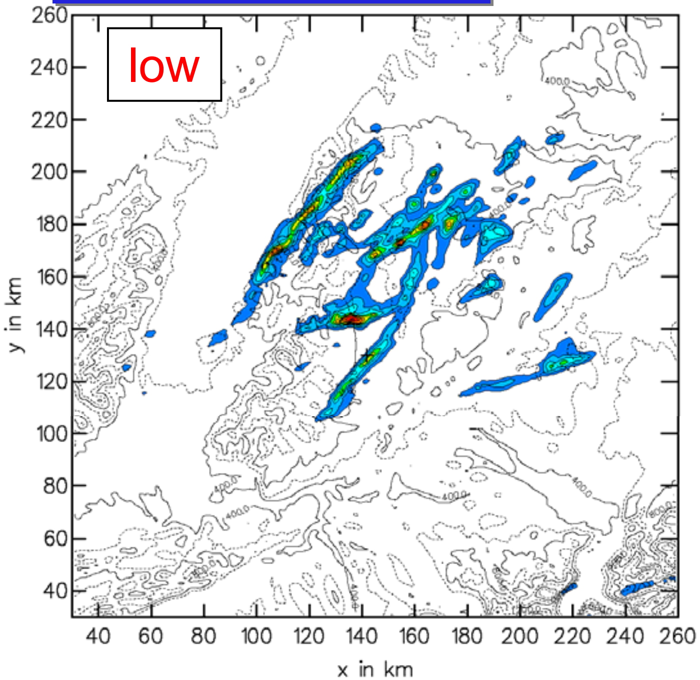
max:
45 mm

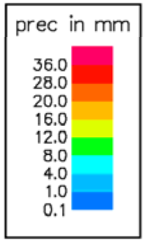
tot. vol.:
85 10^6 m^3



CCN Impact

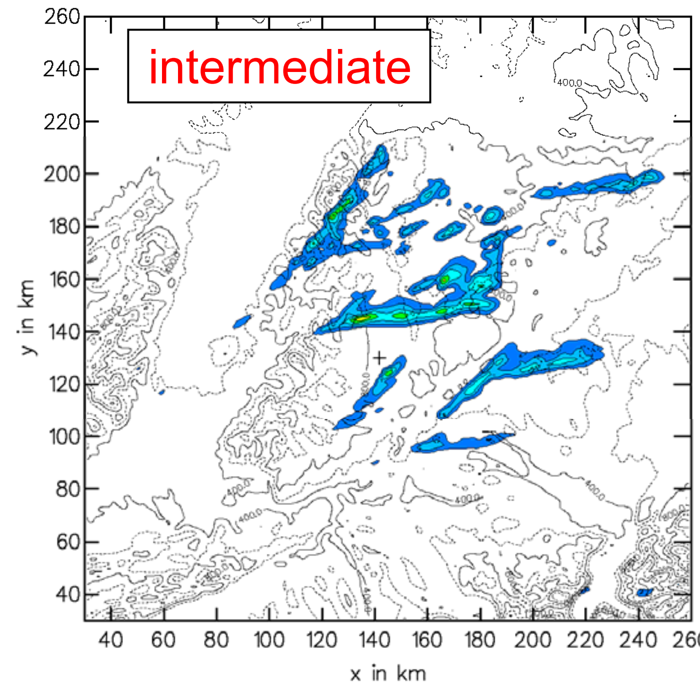
acc. precipitation 12-24 UTC by *graupel and hail*

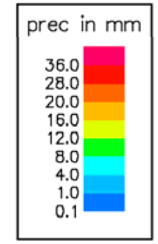




max:
38 mm

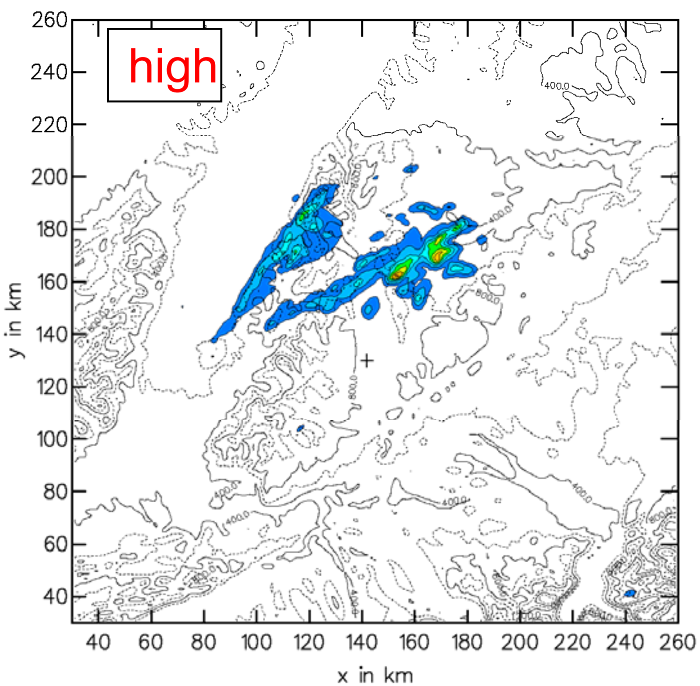
tot. vol.:
9.4 10^6 m^3

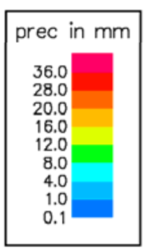




max:
16 mm

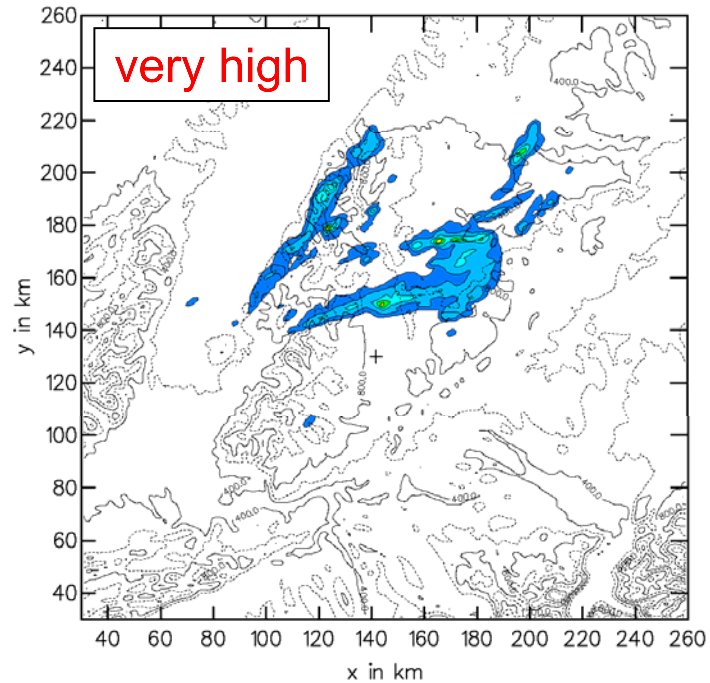
tot. vol.:
5.0 10^6 m^3

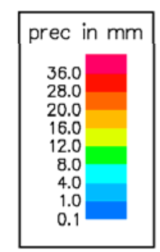




max:
22 mm

tot. vol.:
3.8 10^6 m^3



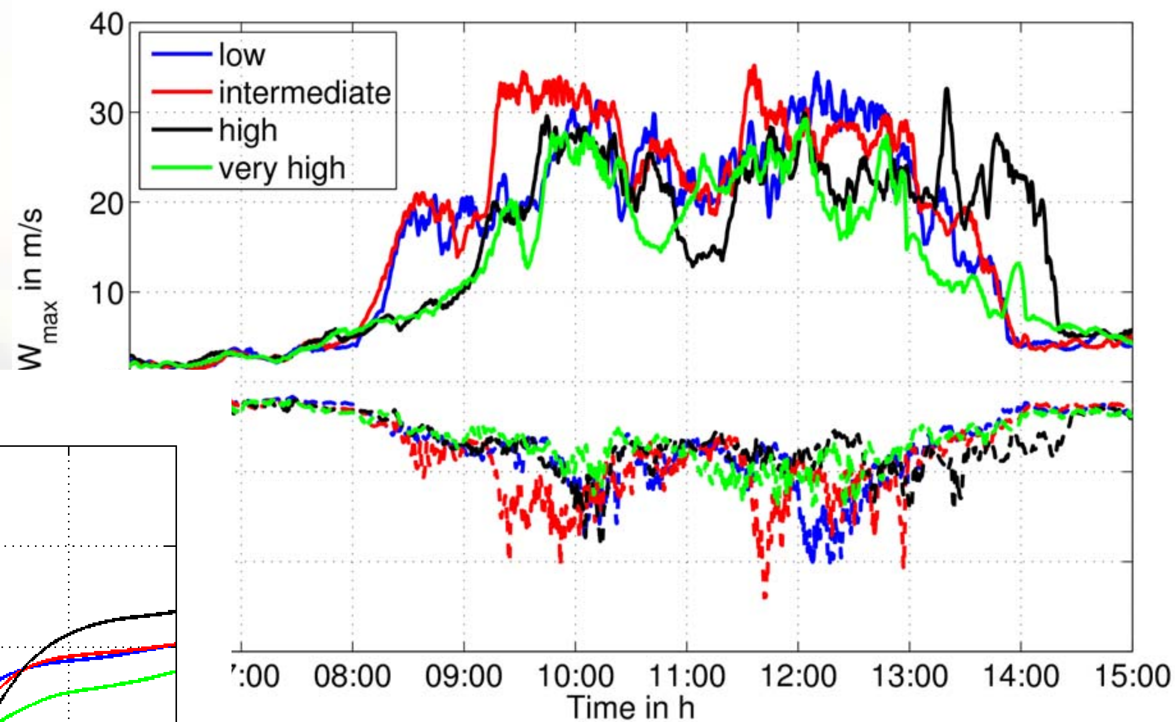


max:
16 mm

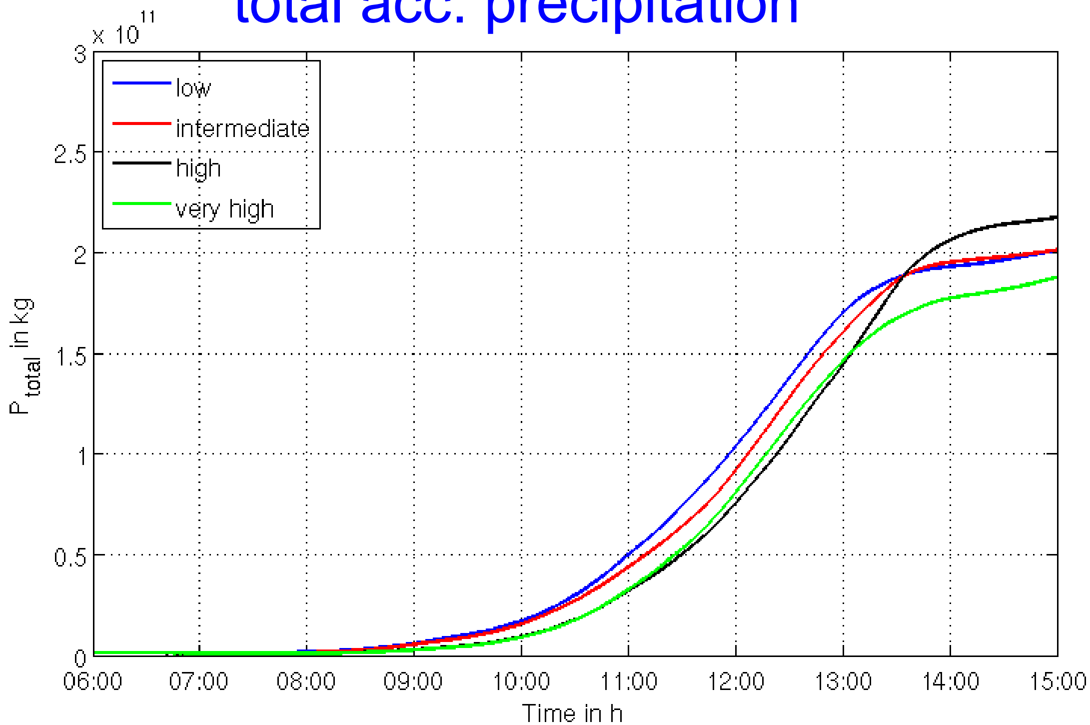
tot. vol.:
4.0 10^6 m^3

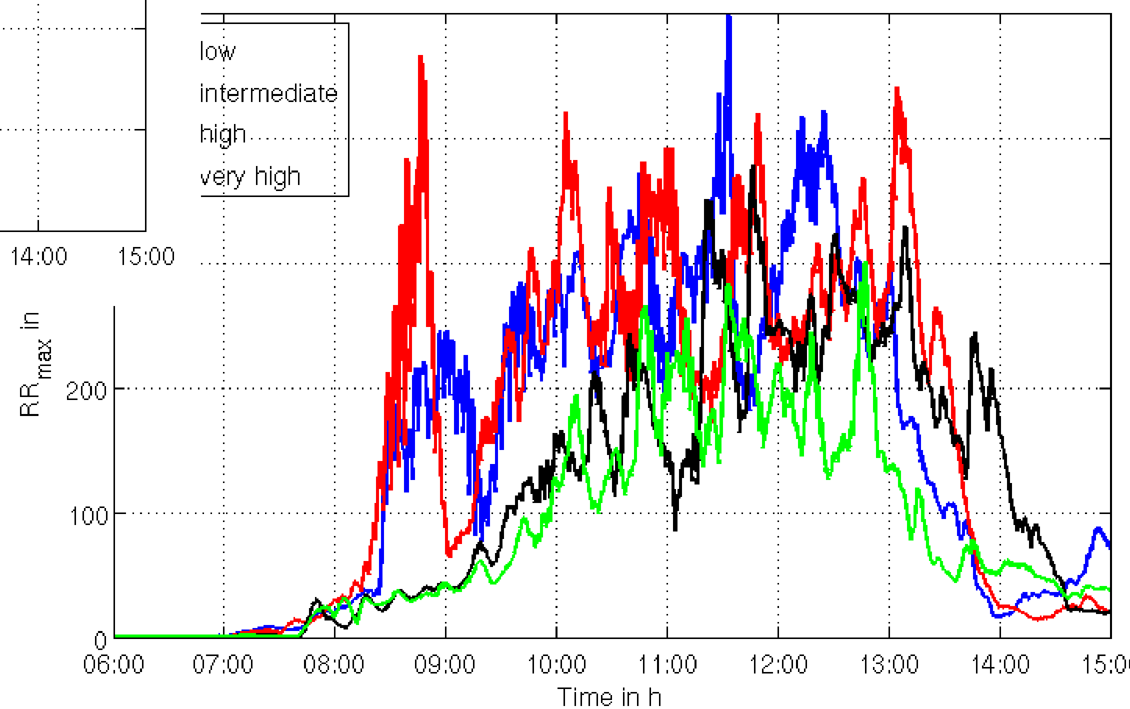
CCN Impact

max. up- and downdrafts



total acc. precipitation

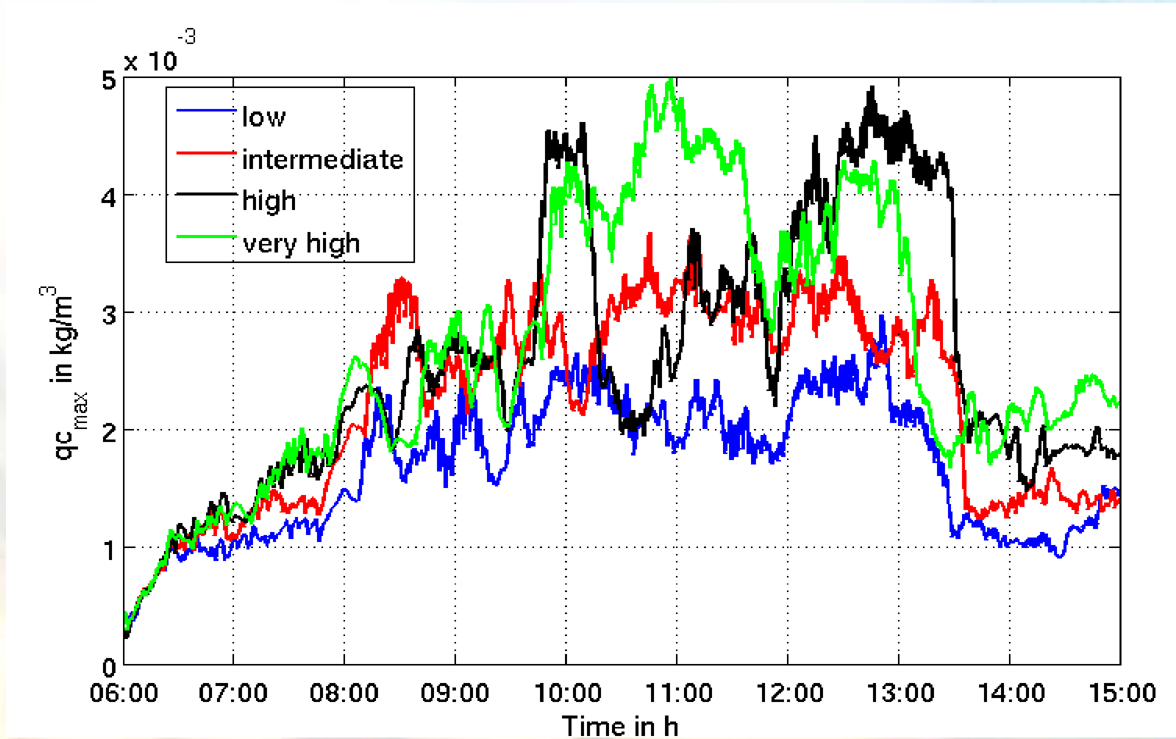




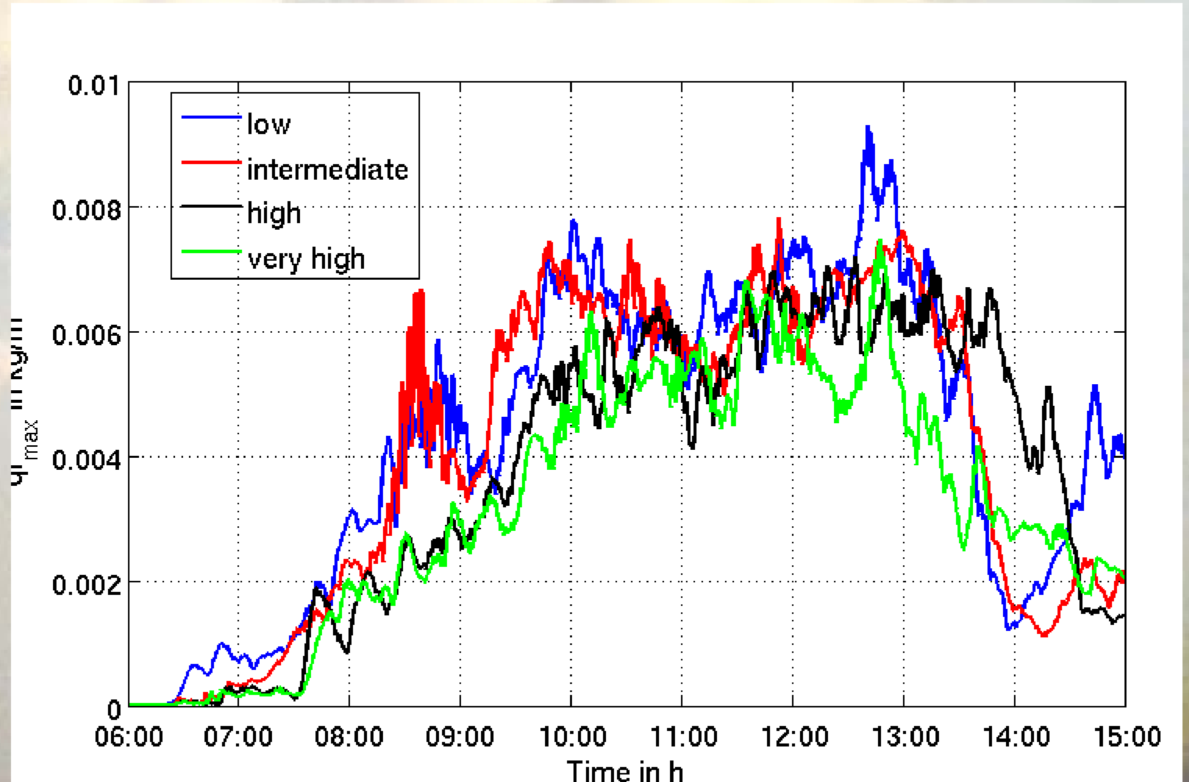
CCN Impact

max. mass density

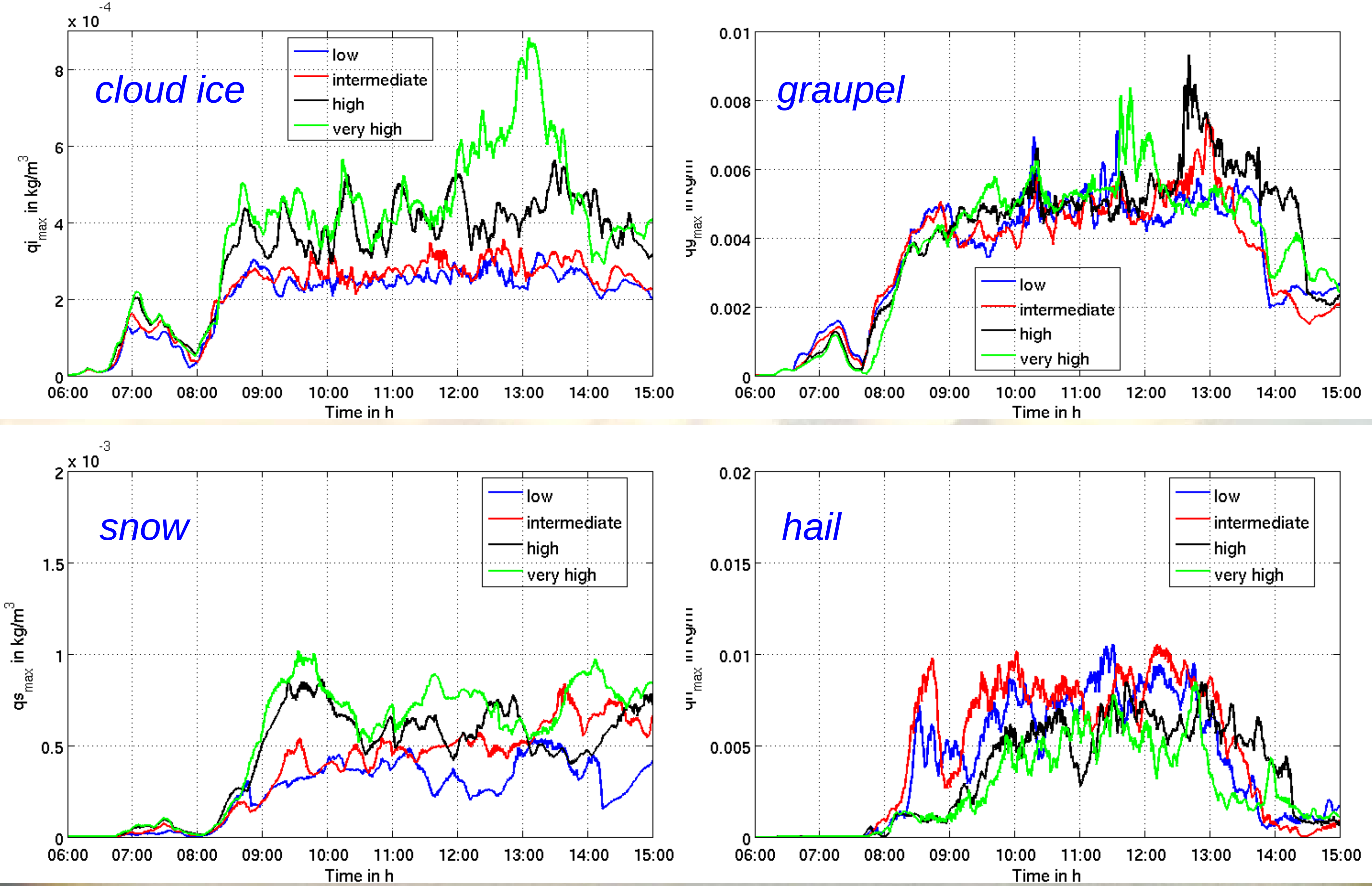
cloud droplets



rain drops



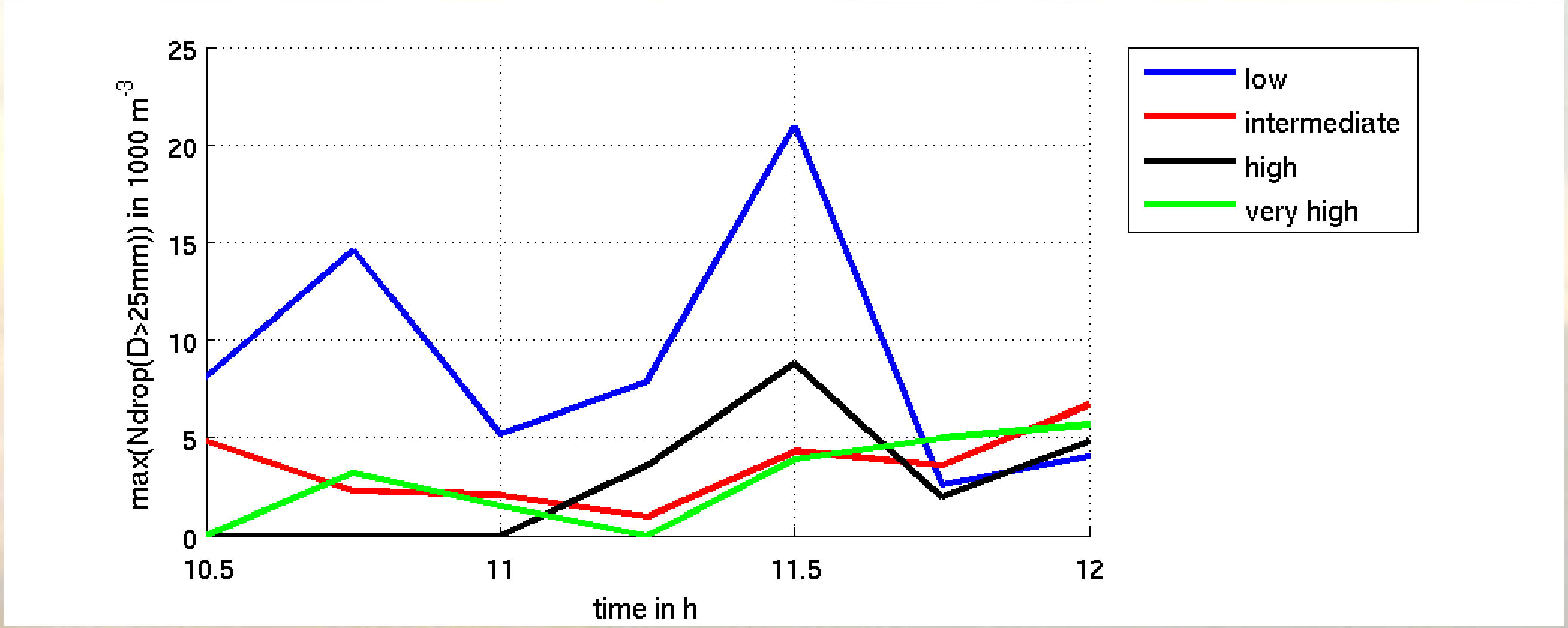
CCN Impact


cloud ice
graupel
snow
hail
low
intermediate
high
very high
x 10^-4
qi_max in kg/m^3
x 10^-3
qs_max in kg/m^3
Time in h
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
0
2
4
6
8
0.002
0.004
0.006
0.008
0.01
0.5
1
1.5
0.005
0.015
0.02

CCN Impact

Maximum number density of large hail particles (D>25mm)

(Calculated from the predicted moments and the assumed generalized gamma-distribution for z ≤ 2 km amsl)



Summary and Conclusions

✓ COSMO with the 2-moment microphysics scheme generates a convective storm that resembles the observed one quite well (even though some hours late)

✓ the model produces large hailstones (D > 25 mm) and a realistic amount of precipitation by hail

✓ CCN concentration has a strong impact on precipitation rates

✓ impact especially strong on precipitation by frozen hydrometeors

✓ general conclusion whether increased CCN concentration increases or decreases the severity of storm is not possible

The End