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Evaluating the representation of clouds and precipitation in non-hydrostatic atmospheric models for the Belgian region

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Seventh international SRNWP-workshop on non-hydrostatic modelling
Bad Orb 5-7 November 2007

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Integrations with ARPS

Integrations with COSMO2.8

Comparison with MODIS

Nicole van Lipzig[1], *K. Van Weverberg*[1], *T. Steegmans*[1],
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Contents:

QUEST (Crewell et al.)

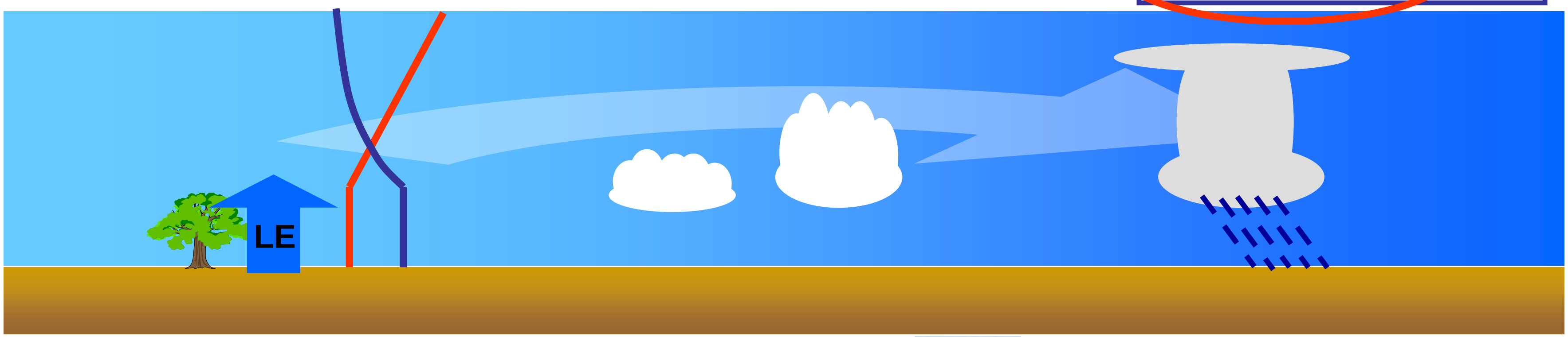
Quantitative evaluation of regional precipitation forecasts using multi-dimensional remote sensing observations

See also poster Thorsten Reinhardt et al

satellite

MSG ~ 5km; 15min
- Cloud Mask
- Cloud top pressure

MODIS ~ 1km; 1day
- Cloud Mask
- Optical thickness



IPT / Micro-wave

1D vertical; Lindenberg (and Cabauw)
- temperature profile
- humidity profile
- LWC

GPS

147 stations; Germany; 30min
- IWV

Ceilometer

17 stations; Germany; 1min; ranges up to 4km
- Cloud base height
- Cloud cover (<4km)

Radar

DX radar composite; 1km; 5min
- Rain rate

Polarimetric radar (DLR)

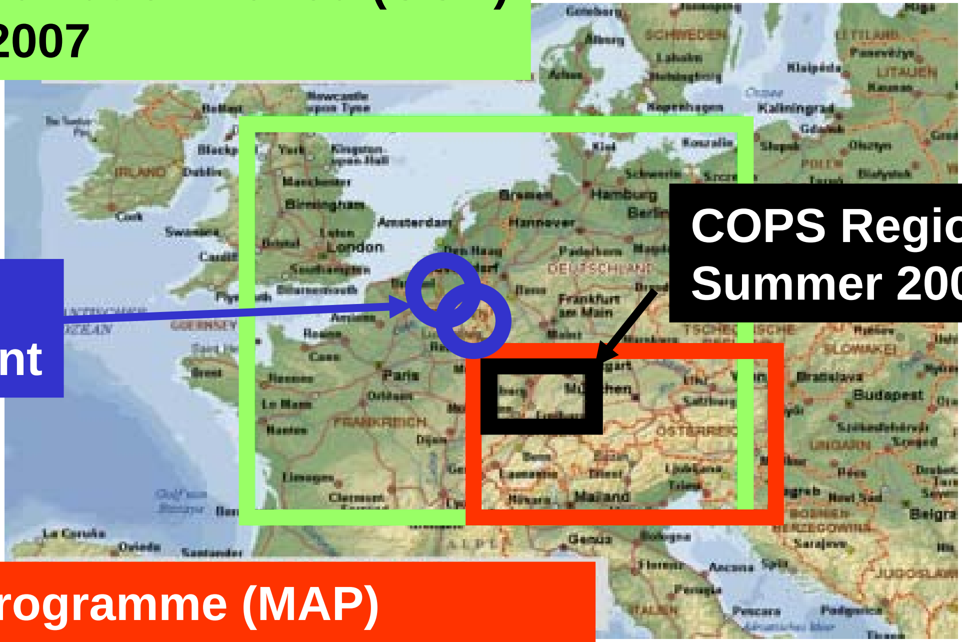
Weather radars Wideumont

Our region of interest

General Observation Period (GOP)
Entire year 2007

COPS Region
Summer 2007

Belgian Radars
Zaventem-Wideumont

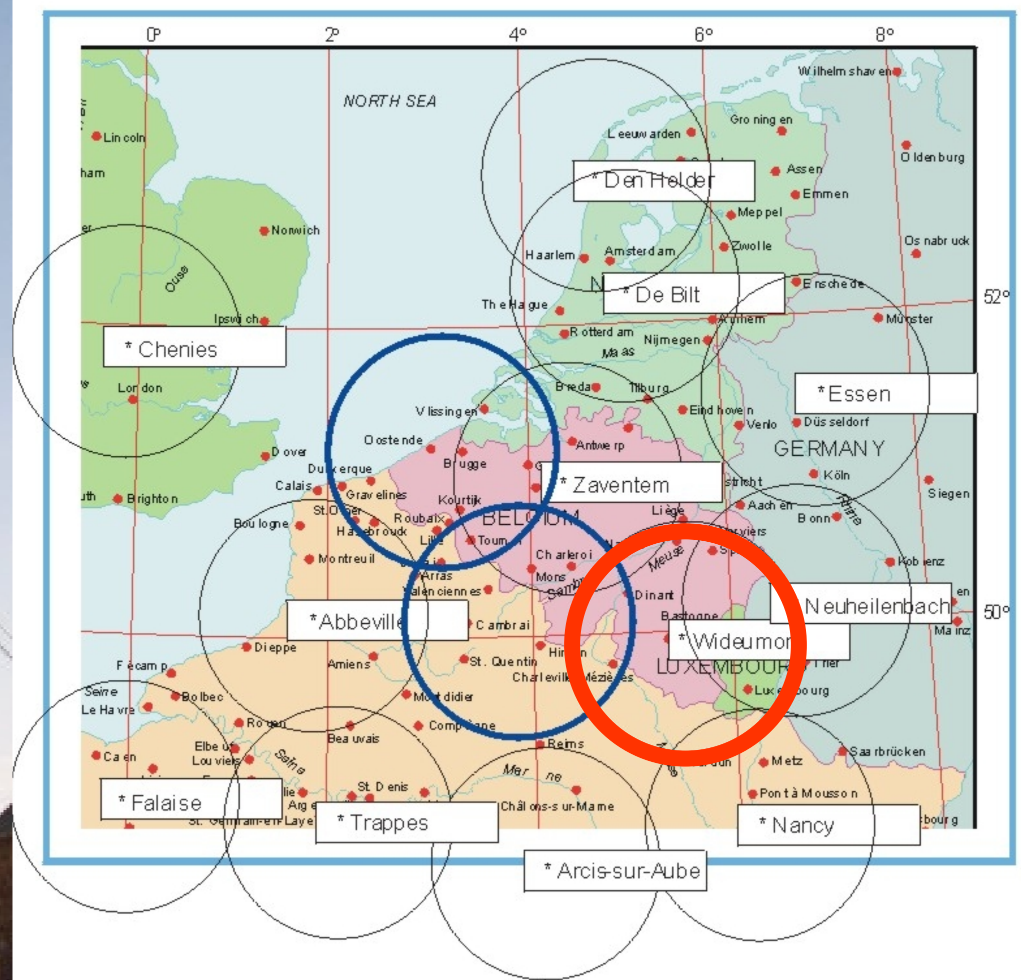


Mesoscale Alpine Programme (MAP)
Forecast Demonstration Project (FDP) region

Methods: Radar reflectivity

C-band weather Radar Wideumont (RMI)

- Scans at 10 elevation angles each 15 minutes (0.5 – 17.5 °)
- Horizontal resolution is 500 m in range and 1 degree in azimuth



Methods: Radar reflectivity

Based on Smith et al., 1975

Marshall-Palmer-type size distribution: $N_k(D) = N_{0k}\exp(-\lambda D)$ (1)

$$Z_k = \int_0^\infty N_k(D) D^6 dD \quad (2)$$

$$\text{Radar reflectivity factor for rain} = \mathrm{cnt}_1 \cdot \frac{(\rho q_r)^{7/4}}{N_r^{3/4}\rho_r^{7/4}} \quad (3)$$

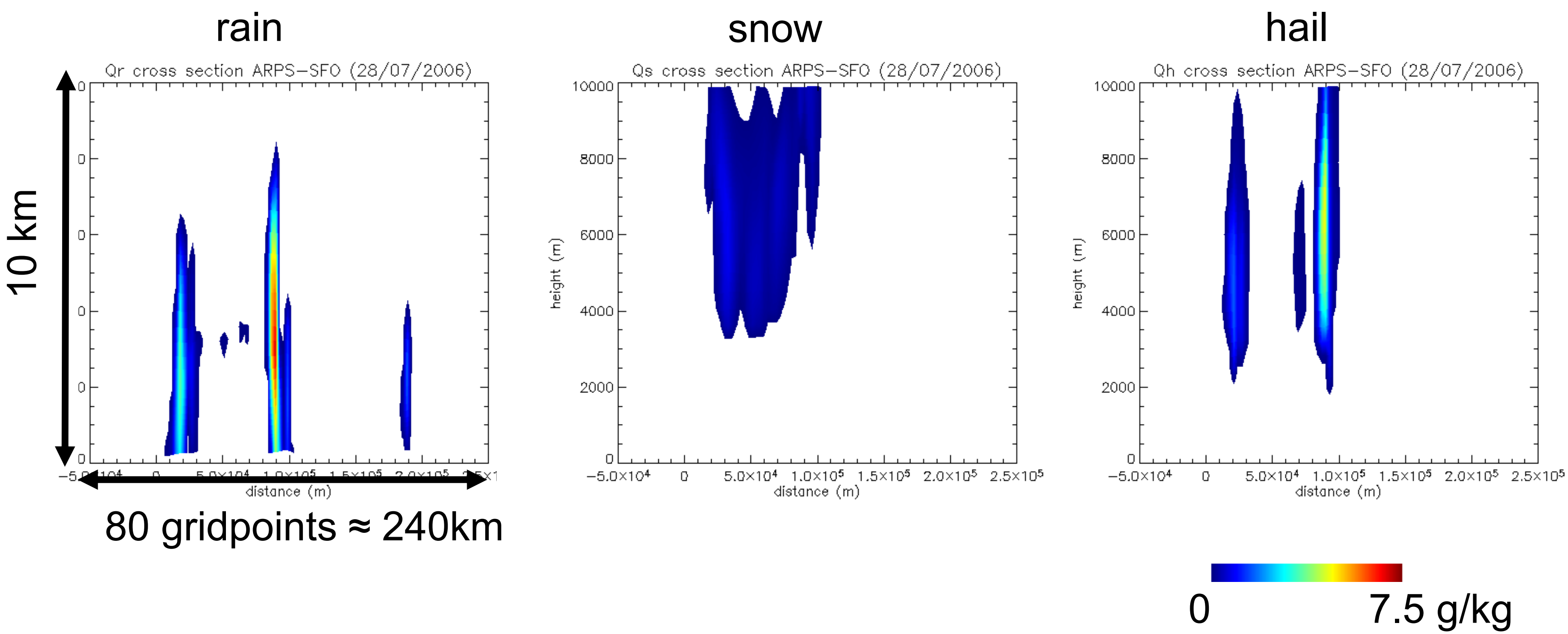
$$\text{Radar reflectivity factor for dry snow} = \mathrm{cnt}_2^* \cdot \frac{(\rho q_{s-})^{7/4}}{N_s^{3/4}\rho_i^{7/4}} \quad (4)$$

$$\text{Radar reflectivity factor for wet snow} = \mathrm{cnt}_1 \cdot \frac{(\rho q_{s+})^{7/4}}{N_s^{3/4}\rho_s^{7/4}} \quad (5)$$

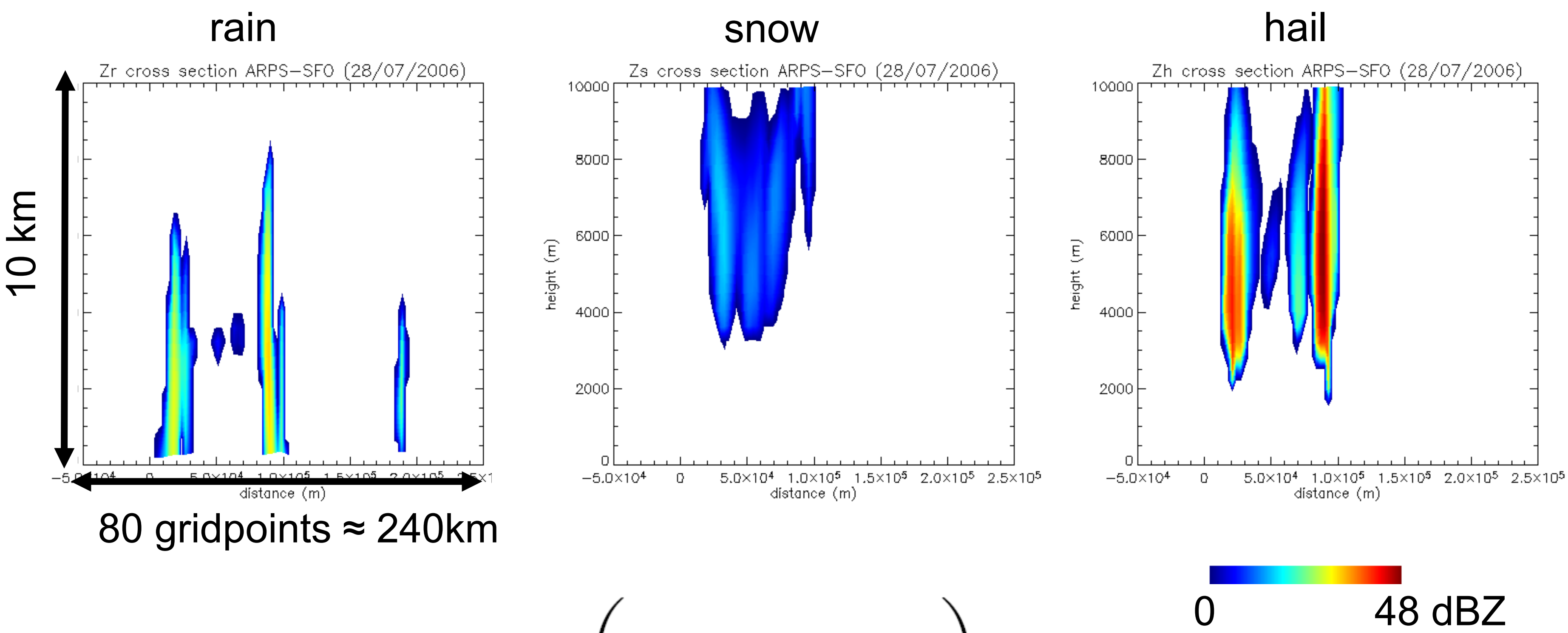
$$\text{Radar reflectivity factor for hail} = \mathrm{cnt}_3 \cdot \left(\frac{(\rho q_h)^{7/4}}{N_h^{3/4}\rho_h^{7/4}}\right)^{0.95} \quad (6)$$

* Taking into account the ratio of dielectric factors for water and ice

An illustration: Precipitating hydrometeors in ARPS



An illustration: Radar reflectivities in ARPS



$$Z = 10 \log_{10} \left(\frac{}{1 \text{ mm}^6 \text{ m}^{-3}} \right)$$

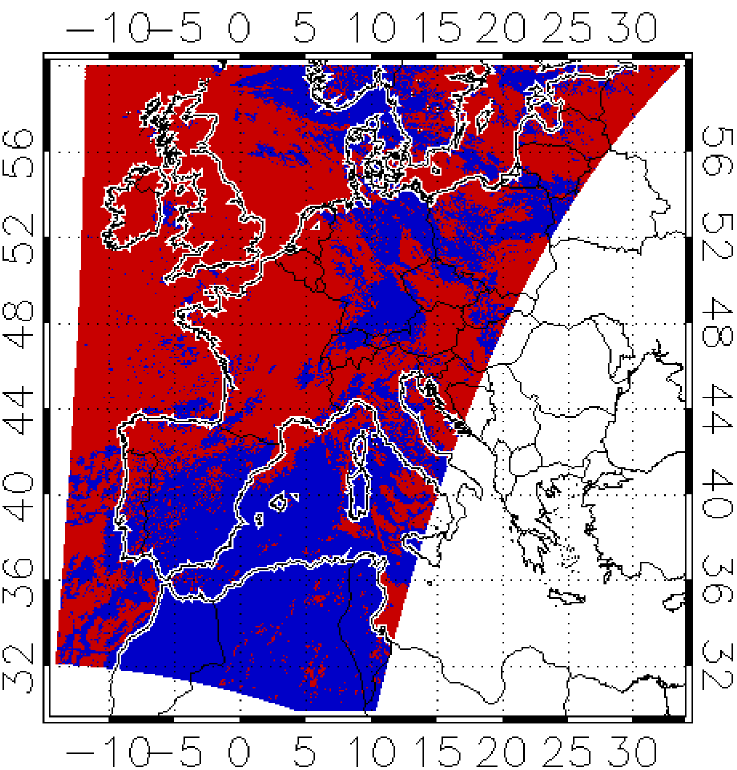
$$Z_e = Z_{er} + Z_{es} + Z_{eh}$$

Methods: cloud optical thickness

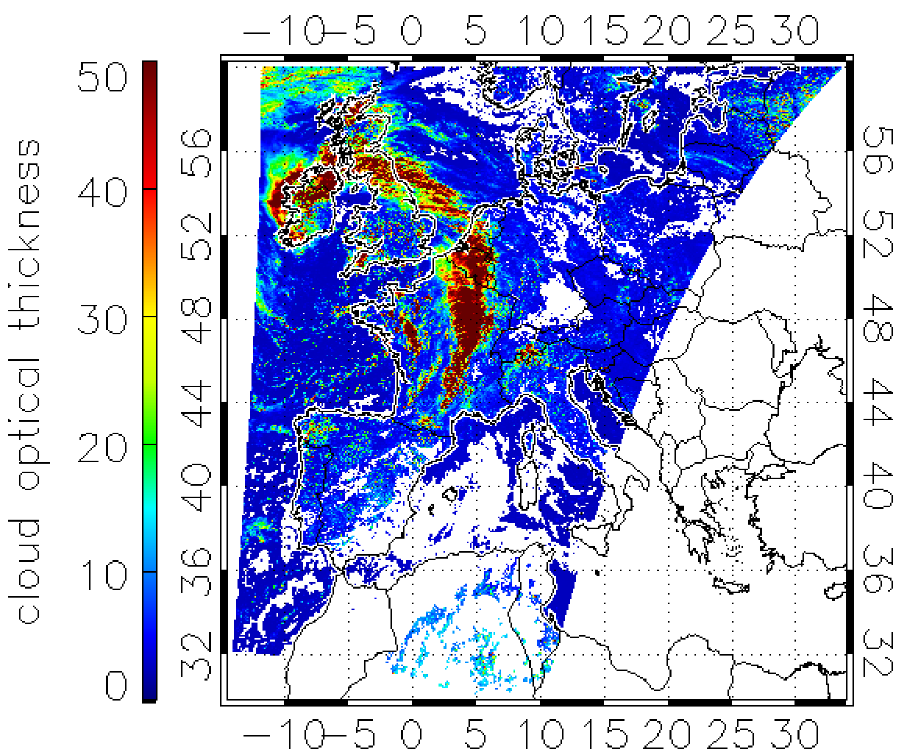
Developing a method to evaluate cloud optical thickness using satellite remote sensing (Van Lipzig et al., 2006; Schröder et al, 2006)

12 Aug 2004 MODIS overpass 10:55UTC

Cloud cover



Cloud optical thickness



Clouds in atmospheric models affect:

1: precipitation: q^{c}, q^{i}

2: source/sink of heat related to phase changes: q^{c}, q^{i}

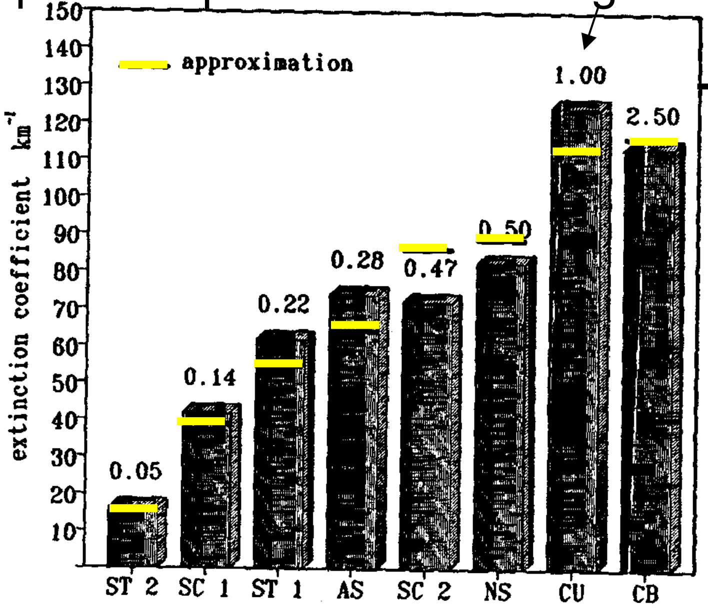
3: radiation: optical properties

Radiation code LM (Ritter and Geleyn, 1992)

Radiative fluxes and heating rates ← Cloud optical properties ← Bulk model quantities

Coefficients for 8 different cloud types → (Cloud optical properties)

Specific liquid water content g m^{-3}



$$r_e = c_7 + c_8 \rho_{LW}$$

$$\delta = \{c_1 + \frac{c_2}{r_e}\} \rho_{LW} \Delta z$$

Methods: cloud optical thickness

Clouds in atmospheric models affect:

1: precipitation: $q^{c,}$ q^{i}

2: source/sink of heat related to phase changes: $q^{c,}$ q^{i}

3: radiation: optical properties

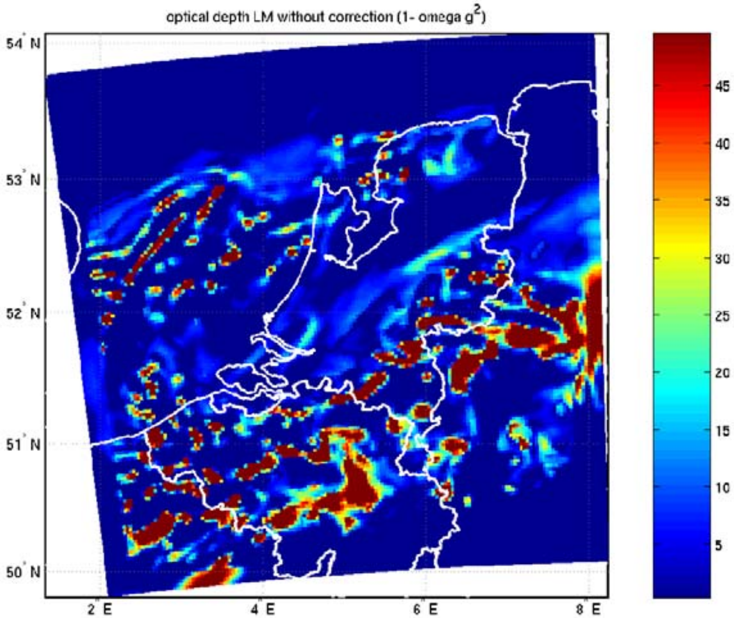
Radiation code other models (e.g. ECMWF)

$$\delta = \frac{3\rho_{LW}\Delta z}{2r_e}$$

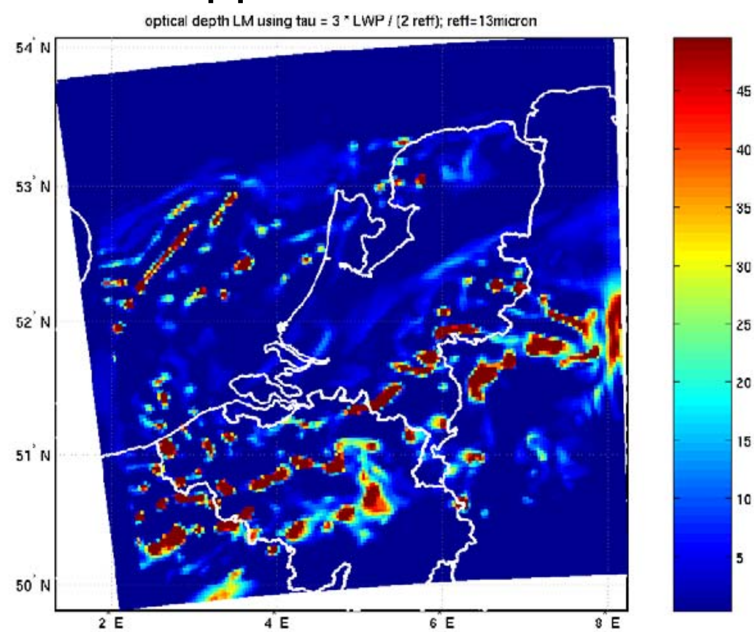
With r_e constant

COSMO2.8 Cloud optical thickness 12 Aug 2004 MODIS overpass 10:55UTC

Formulation from COSMO-code



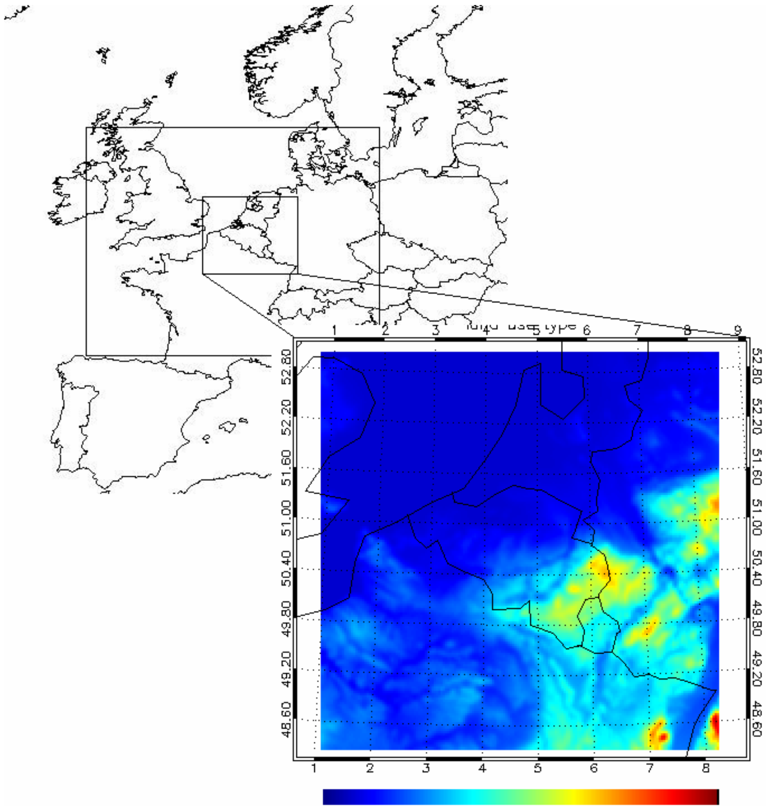
Approximation



Model description

Advanced Regional Prediction System (ARPS): Non-hydrostatic mesoscale model (Xue et al. 2000, 2001), developed at CAPS

COSMO2.8: Non-hydrostatic mesoscale model (Doms et al., 1999)



ARPS (integrations by Kwinten Van Weverberg): Double one-way nested grid with successive Δx of 9 km and 3 km. Smallest model domain centered over Belgium. Boundary and initial conditions derived from ECMWF operational analysis. 50 vertical levels

No convection parameterization in smallest domain, Kain-Fritsch convection parameterization larger domain

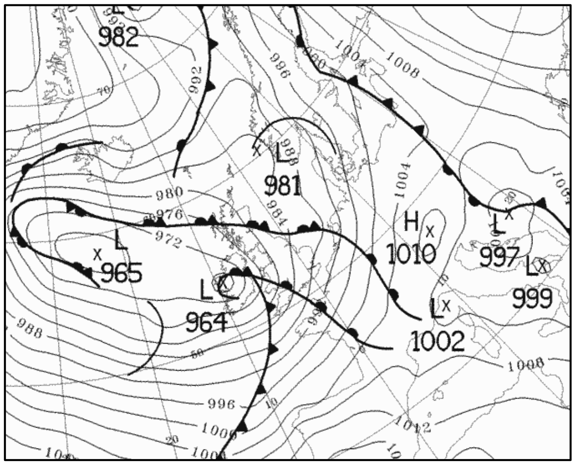
Lin-Tao microphysics (including rain, snow, hail, cloud ice, cloud water)

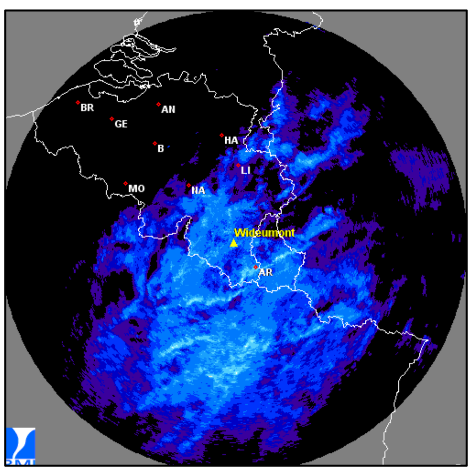
COSMO2.8 (integrations by Ingo Meirold-Mautner): Version 3.21 integrations centered above Belgium, Δx = 2.8km, 160x160 grid points, 50 levels, prognostic variables for cloud, ice, rain, snow, graupel, driven by COSMO-LME analyses

Description of the cases

Stratiform precipitation case

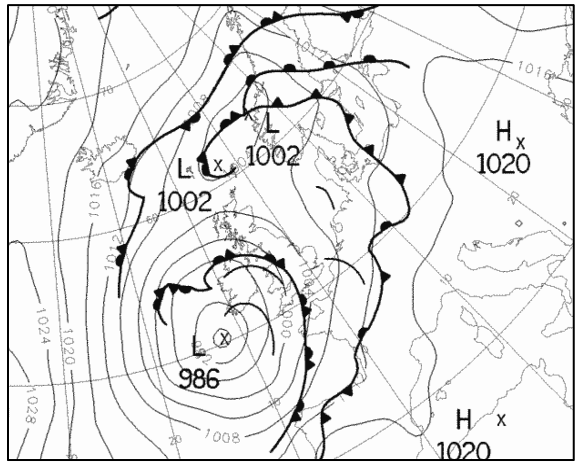
23/11/2006

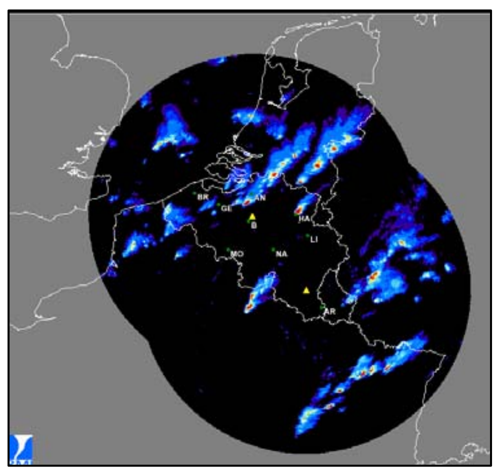




Dynamically driven convective case

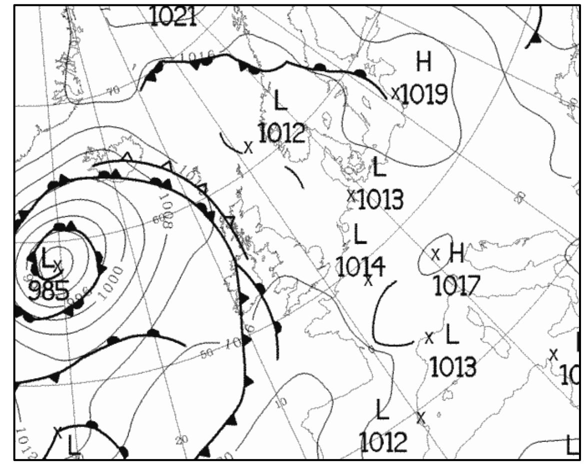
01/10/2006

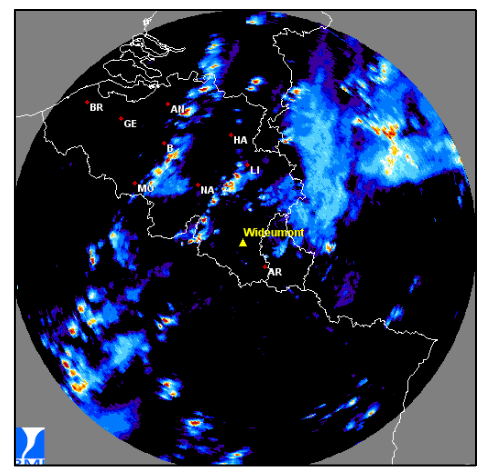




Thermodynamically driven convective case

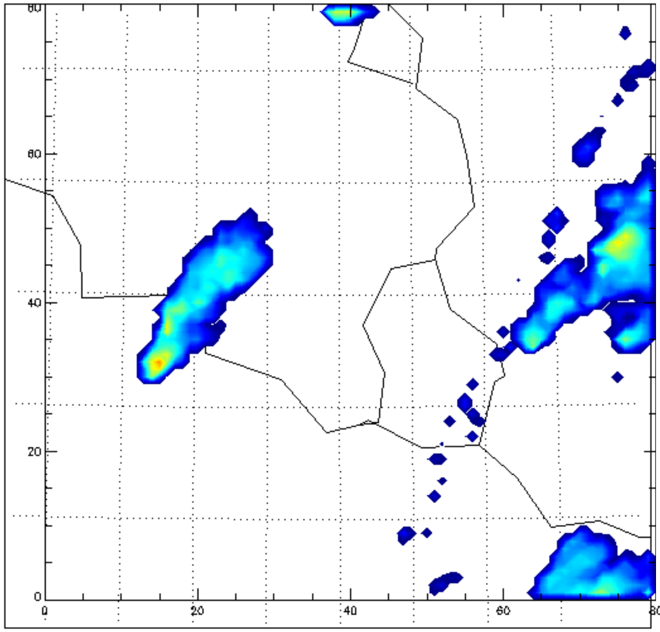
28/07/2006



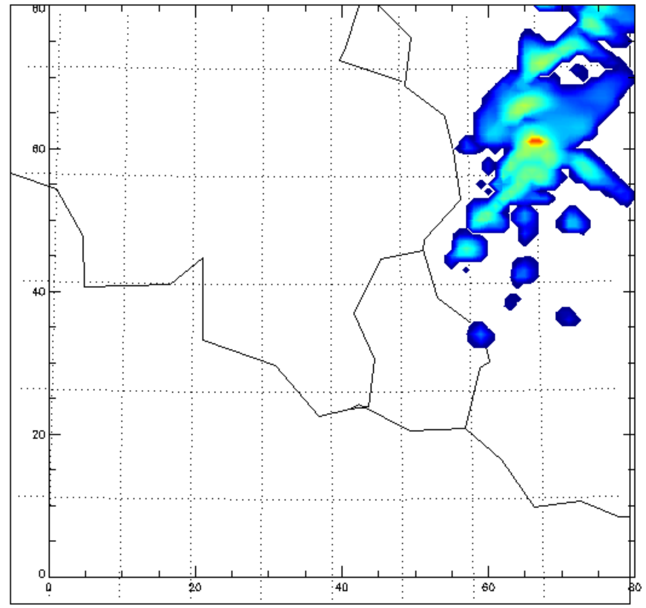


Results: October case

Radar 18:00

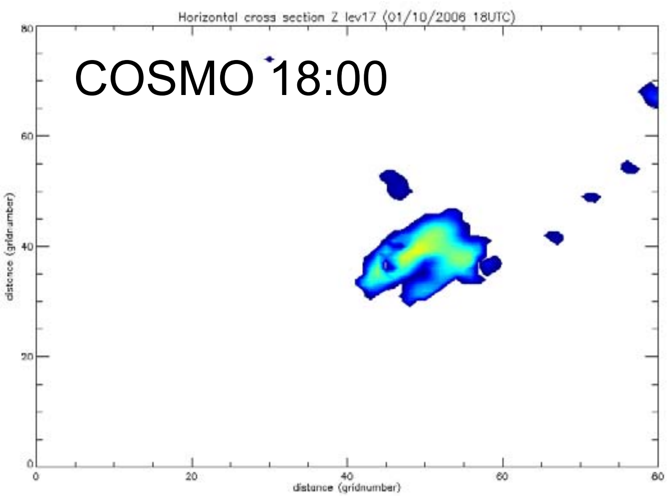


ARPS 18:00

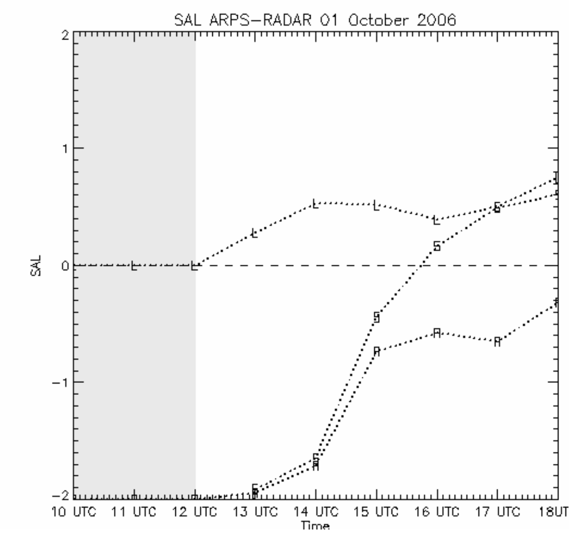


80 gridpoints ≈ 240km

80 gridpoints ≈ 240km

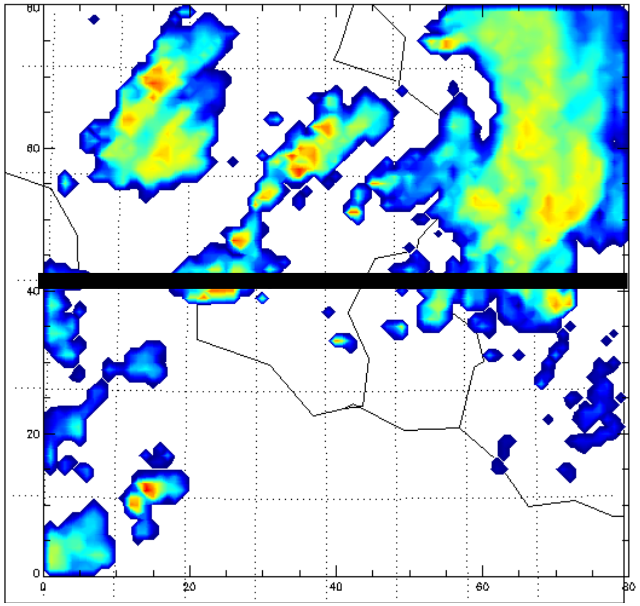


Reflectivities

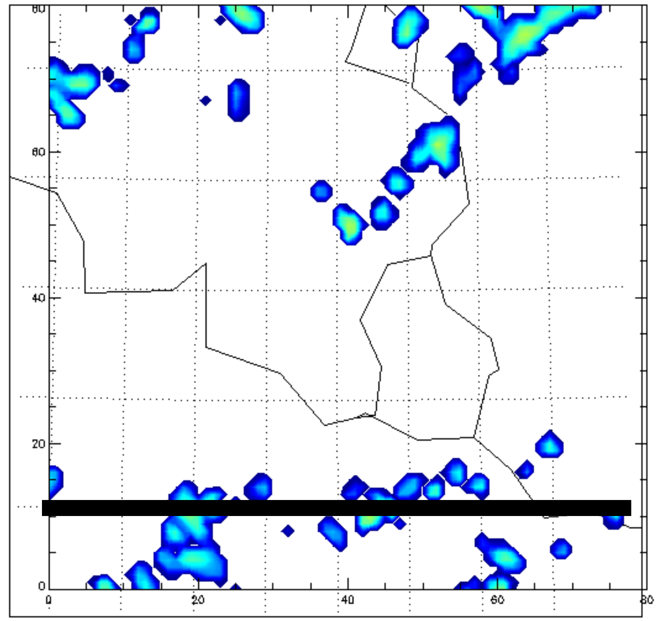


Results: July case

Radar 15:00

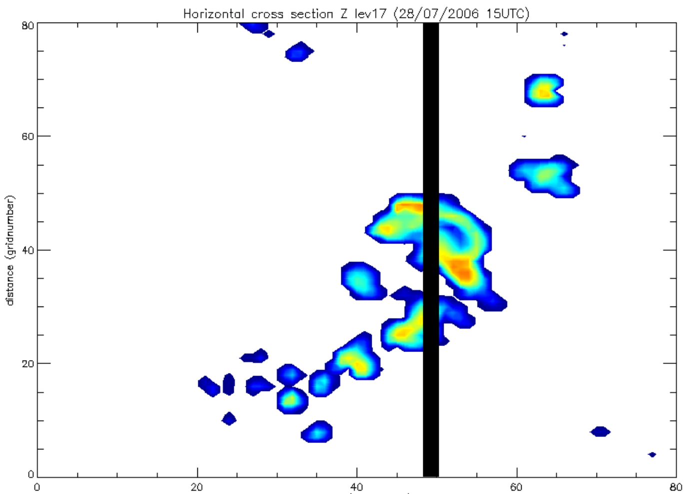


ARPS 15:00



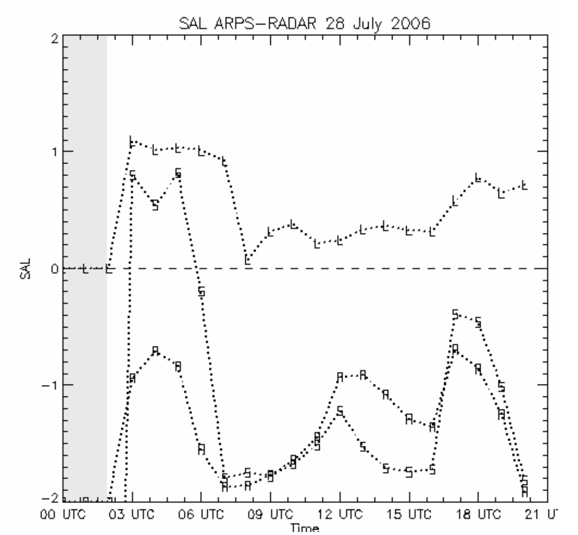
80 gridpoints ≈ 240km

80 gridpoints ≈ 240km



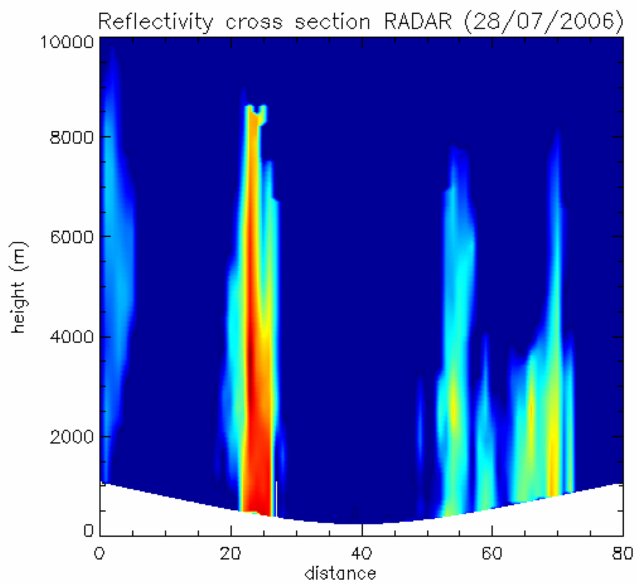
COSMO 15:00

Reflectivities

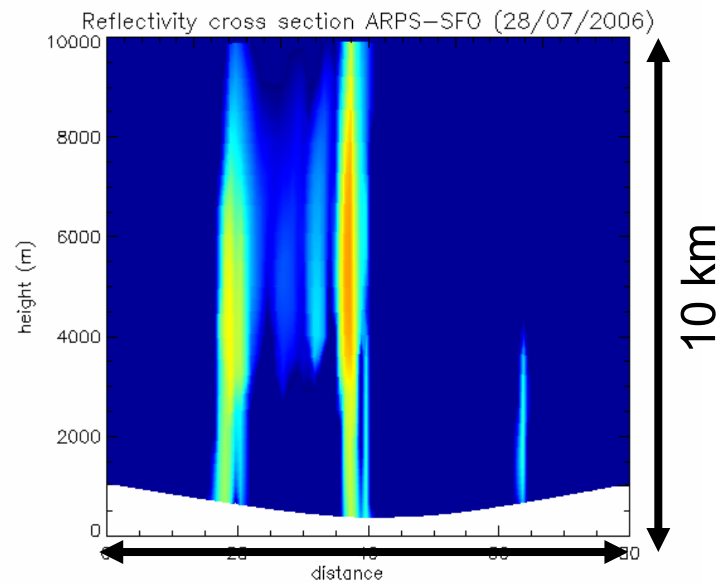


Results: July case

Radar 15:00

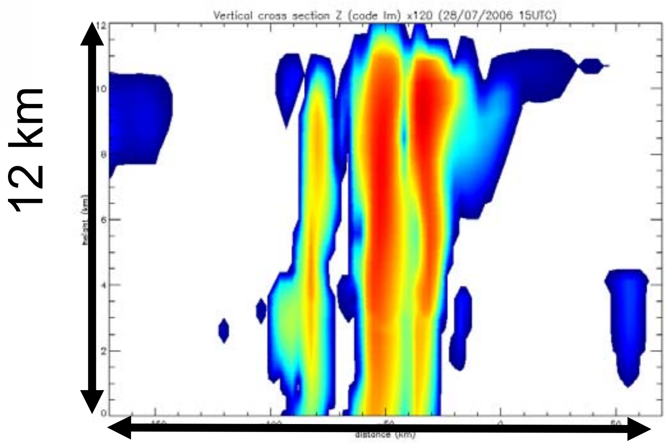


ARPS 15:00



80 gridpoints ≈ 240km

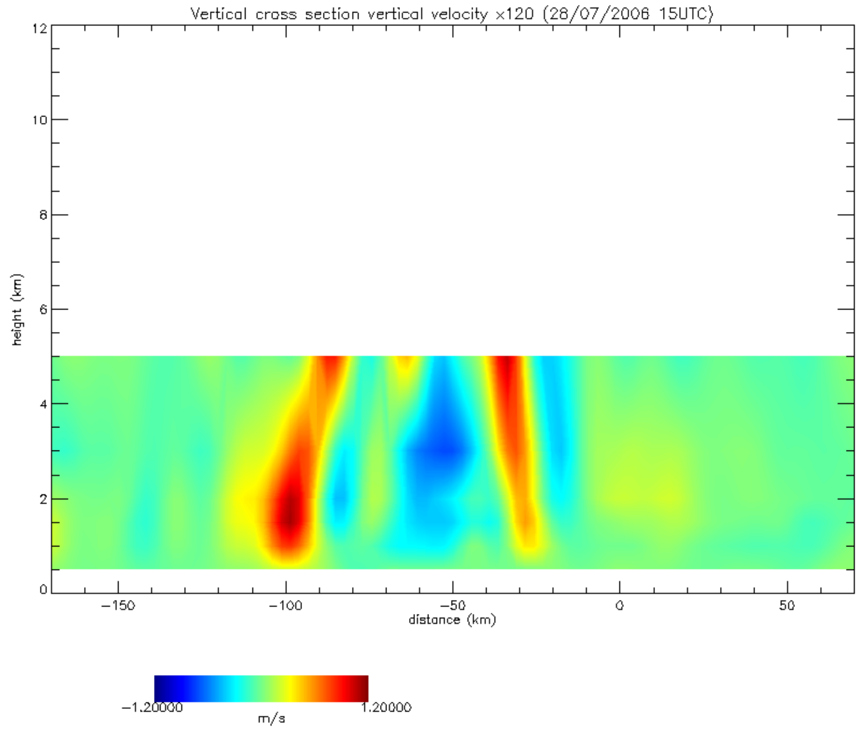
0 56 dBZ



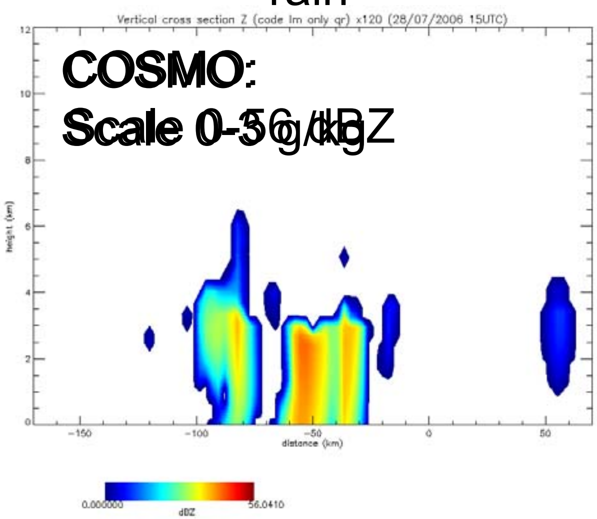
80 gridpoints ≈ 240km

COSMO 15:00

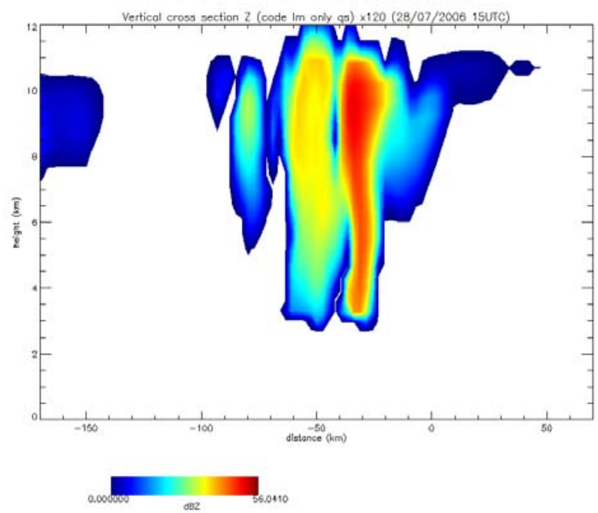
Results: July case



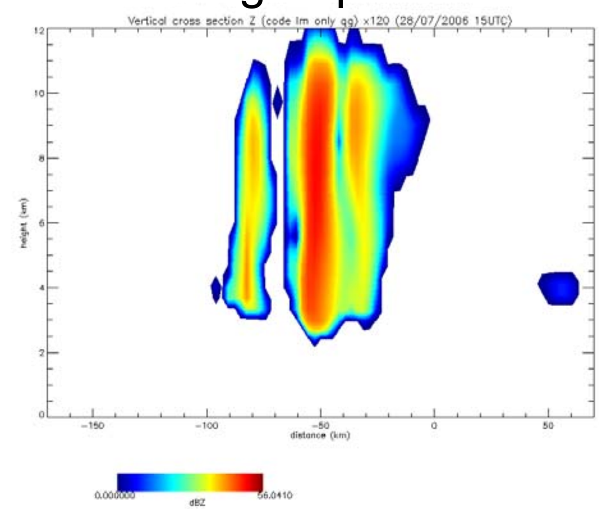
rain



snow

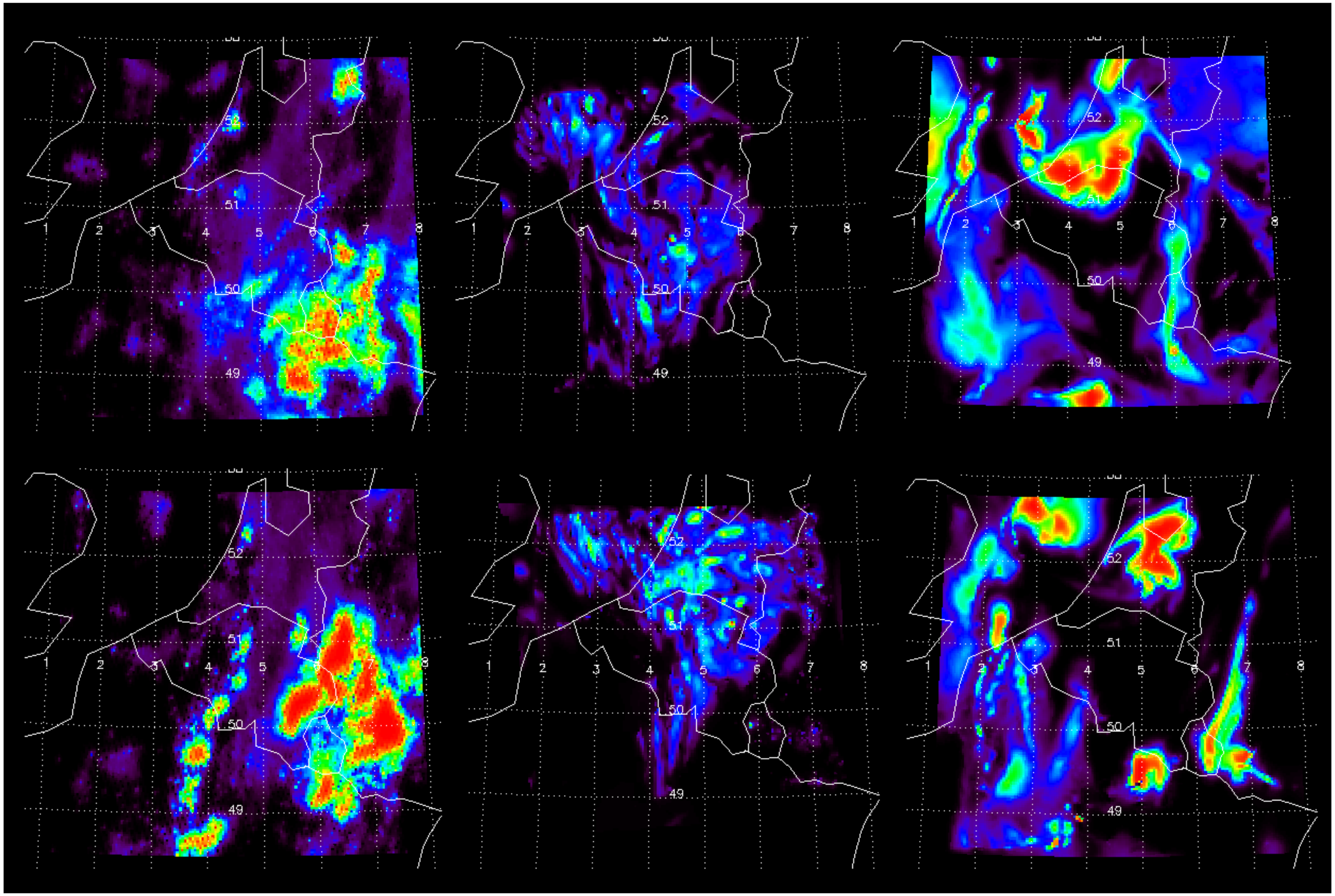


graupel

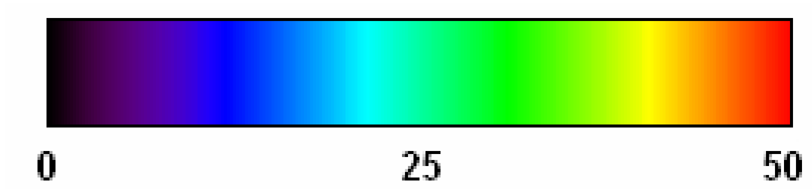


Results: July case

MODIS 10:30 COSMO 9:00 ARPS 9:00



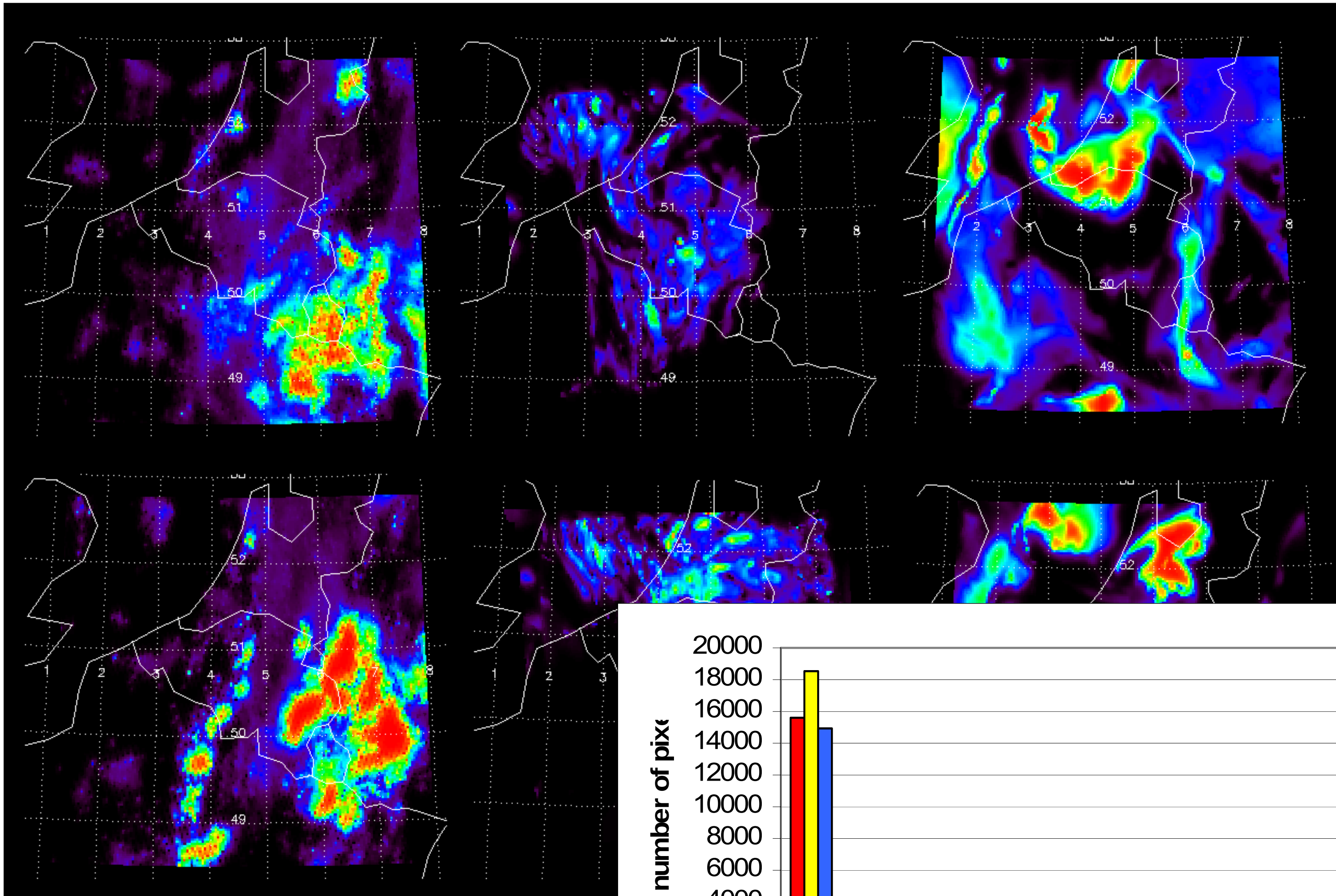
MODIS 12:15 COSMO 12:00 ARPS 12:00



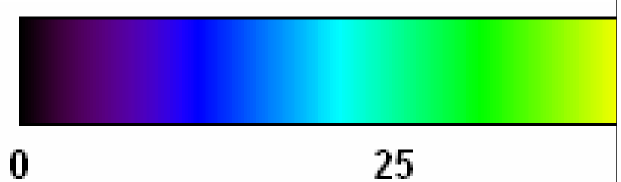
Cloud optical thickness July case

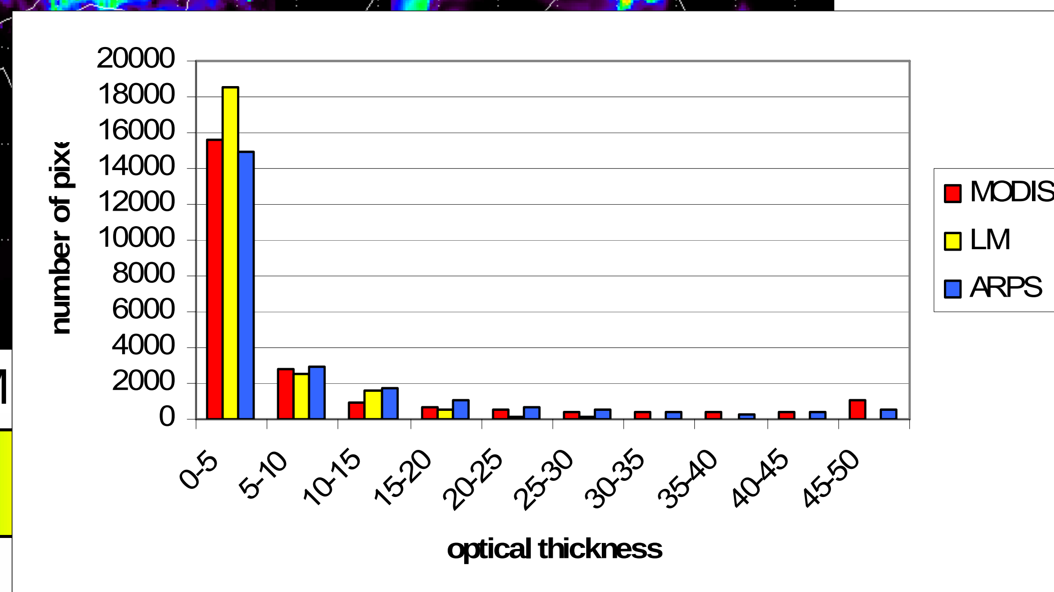
Results: July case

MODIS 10:30 COSMO 9:00 ARPS 9:00



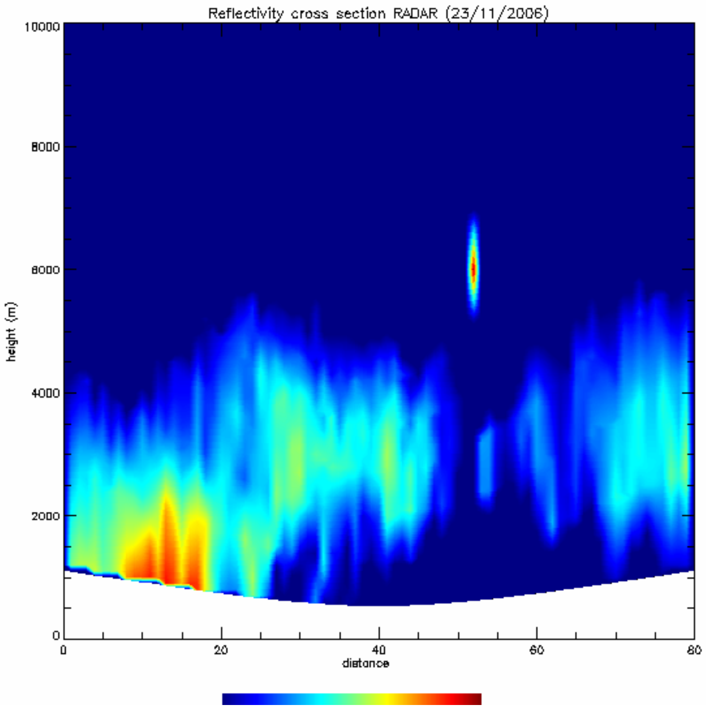
MODIS 12:15 COSM



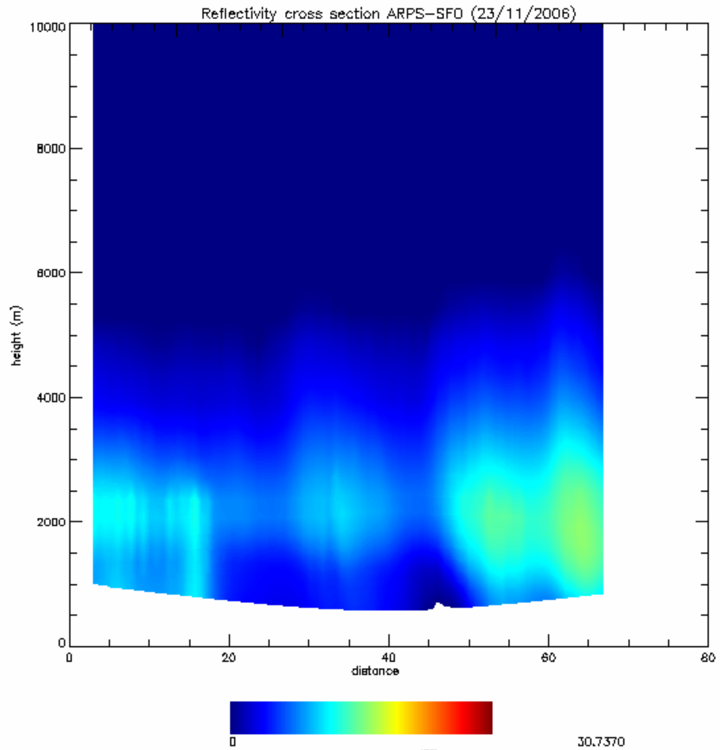


Results: November case

Radar 6:00



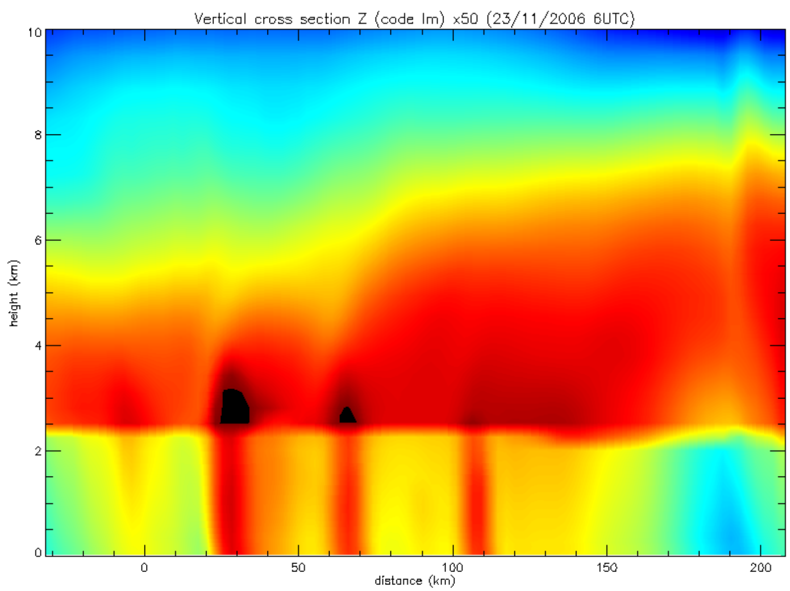
ARPS 6:00



10 km

0 31 dBZ

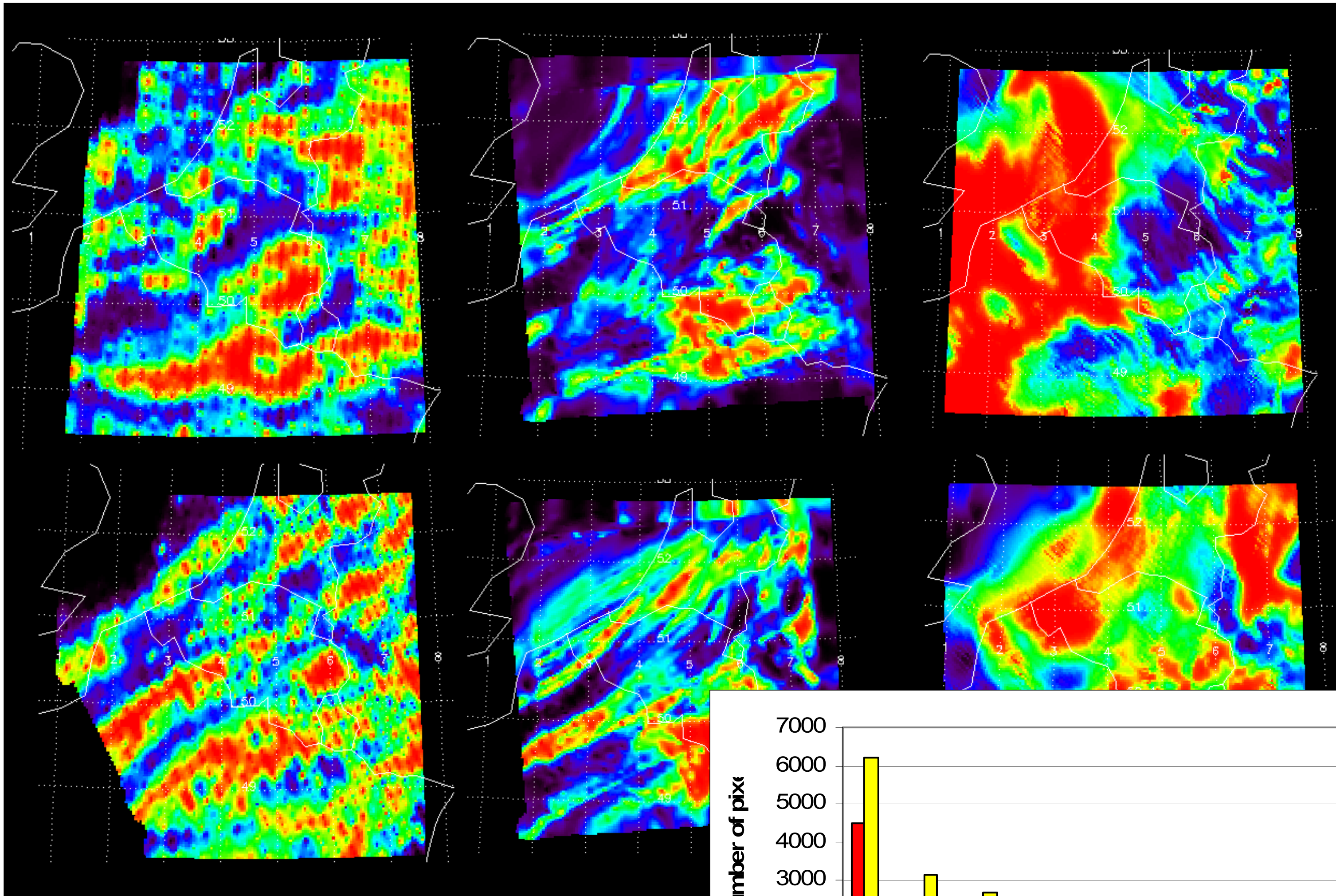
80 gridpoints ≈ 240km



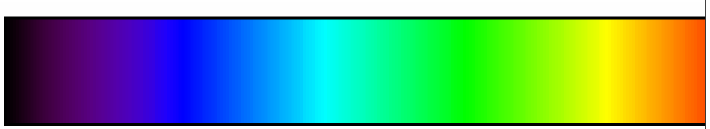
COSMO 6:00

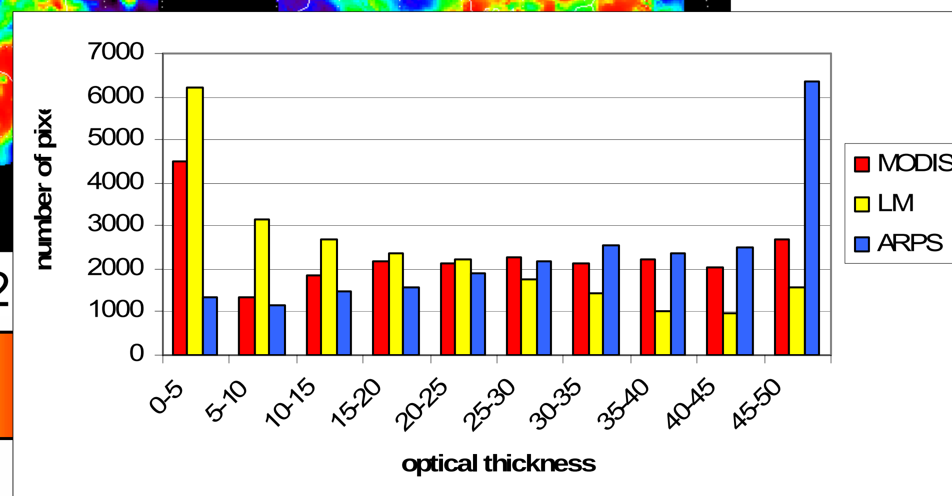
Results: November case

MODIS 9:55 COSMO 9:00 ARPS 9:00

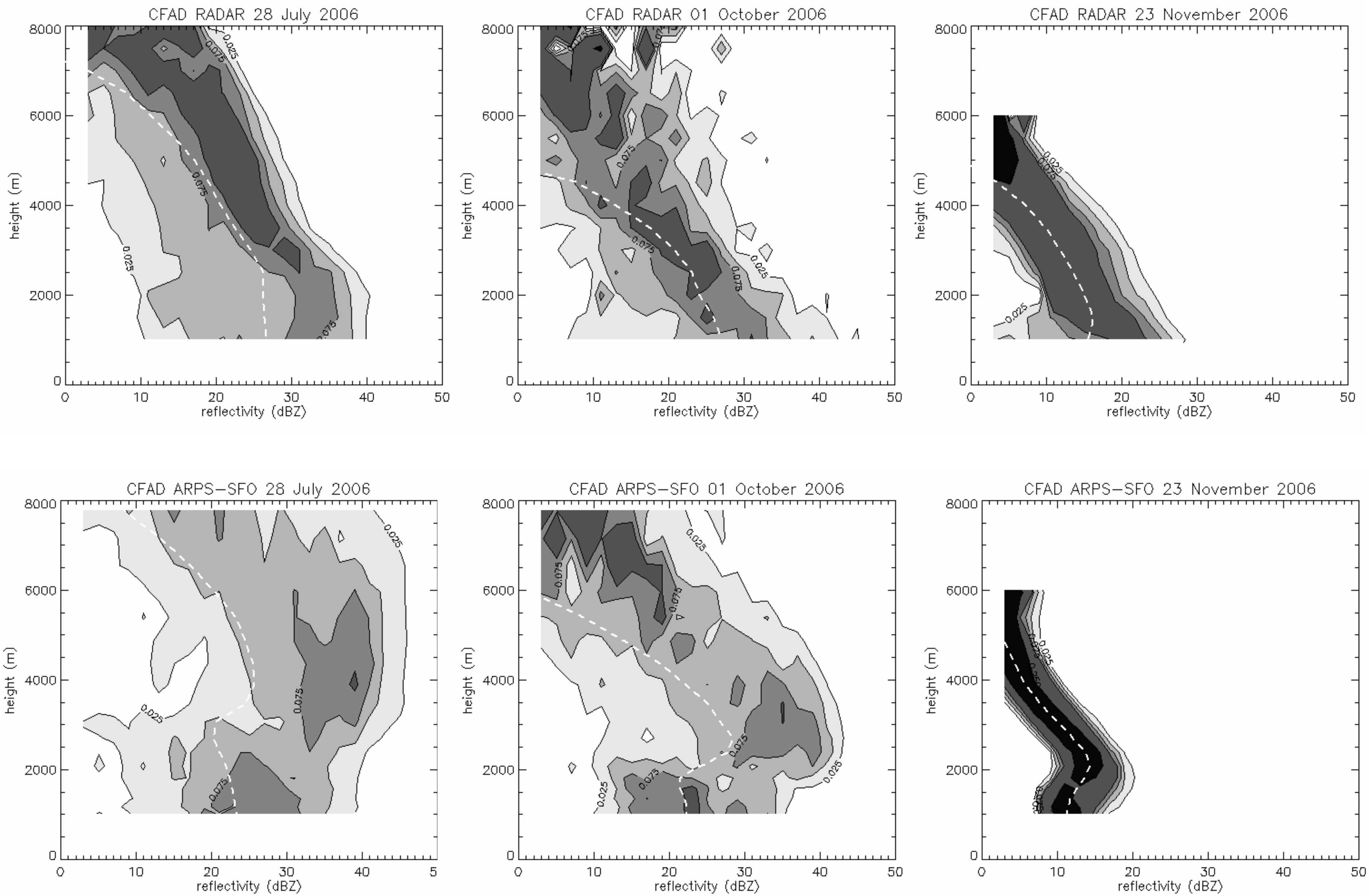


MODIS 11:40 COSMO 12





Results


CFAD RADAR 28 July 2006
CFAD RADAR 01 October 2006
CFAD RADAR 23 November 2006
CFAD ARPS−SFO 28 July 2006
CFAD ARPS−SFO 01 October 2006
CFAD ARPS−SFO 23 November 2006
height (m)
reflectivity (dBZ)
0
2000
4000
6000
8000
0
10
20
30
40
50
0.025
0.075

Summary

Guidelines for model evaluation

• 3D radar volume data in combination with satellite data give useful complementary information for model evaluation

• By looking at volume data, additional information is available on:

- the size of the convective cells
- changes in the variability with height

• **ARPS** reflectivity very sensitive to amount of hail; this explains most discrepancies between radar and ARPS; too high hail amount just above the freezing level

• **COSMO2.8** version 3.21:

- precipitating hydrometeors are separated
- cloud optical thickness is too small for all these cases