Diagnosis of the meteorological situation of August 16^{th} 2003: an extreme hail event

ECSS 2004

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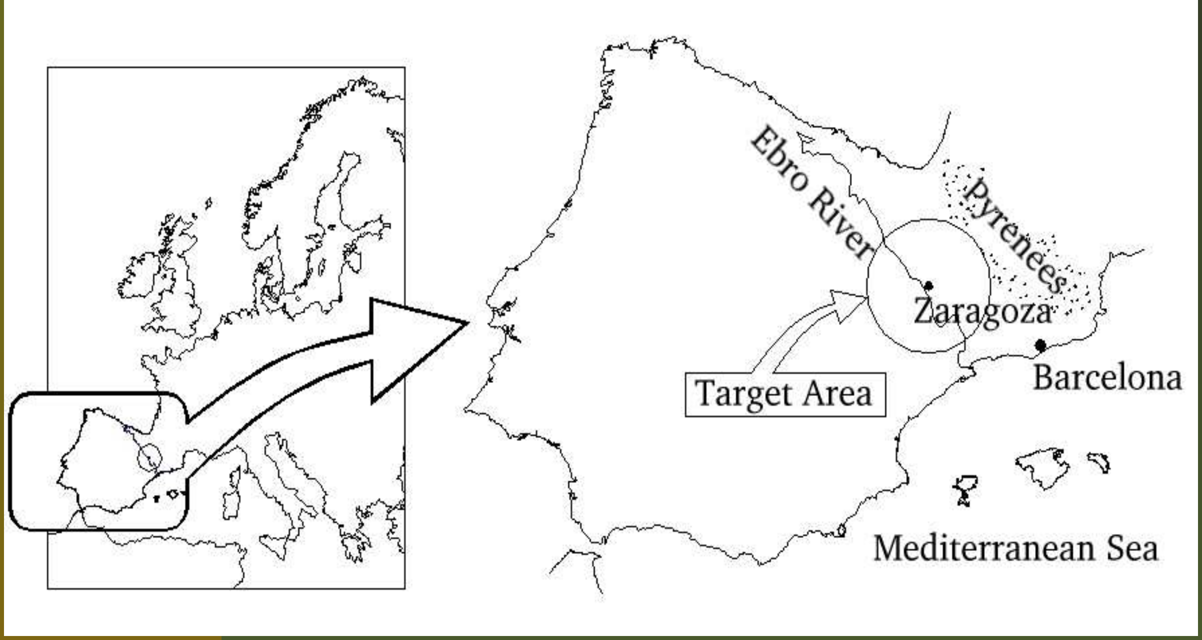
Introduction

Target Area: The Ebro Valley, northeast Spain



Severe storm in Alcañiz

- Time interval of the storm: 1530-1800 UTC
- Hail precipitation for 30 min aprox.
- Maximum precipitation rainfall rate of $92\ l\ m^{-2}$

Maximum hail size observed: 9-12 mm

Severe storm in Alcañiz

- Time interval of the storm: 1530-1800 UTC
- Hail precipitation for 30 min aprox.
- Maximum precipitation rainfall rate of $92\ l\ m^{-2}$

Street furniture ruined

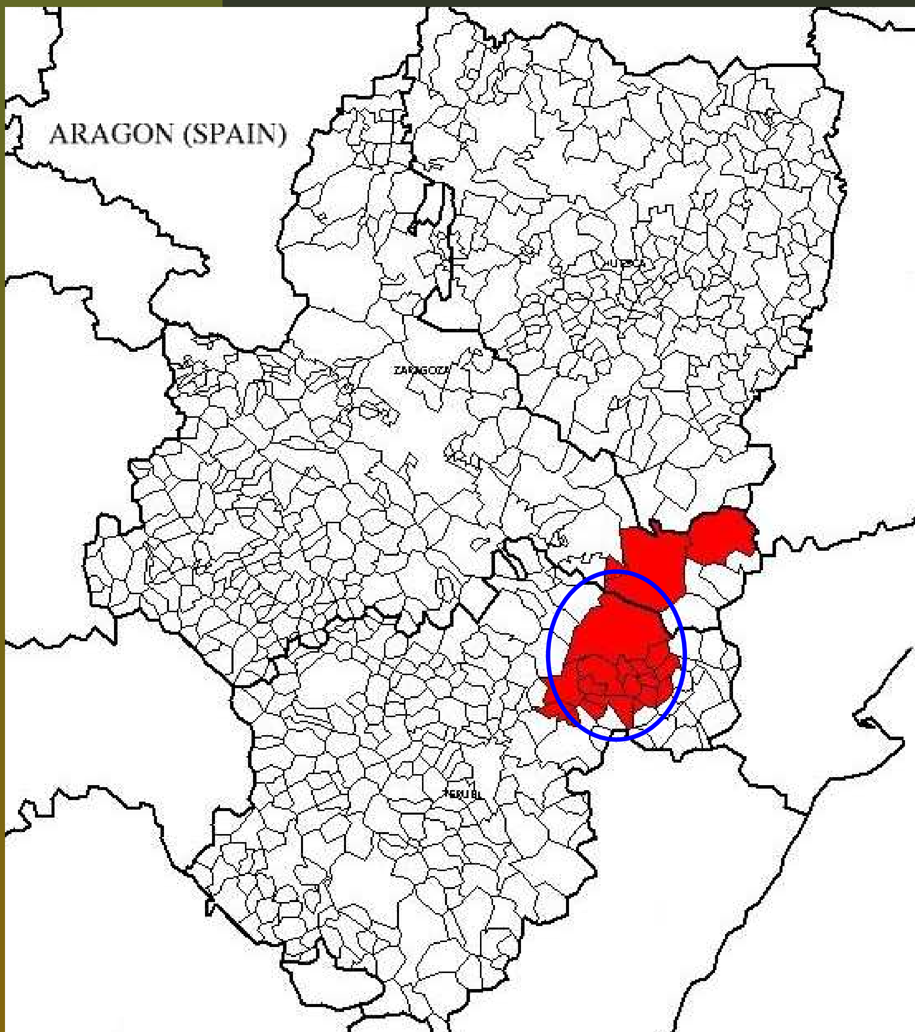
Severe storm in Alcañiz

- Time interval of the storm: 1530-1800 UTC
- Hail precipitation for 30 min aprox.
- Maximum precipitation rainfall rate of $92\ l\ m^{-2}$

More than 300 cars were damaged

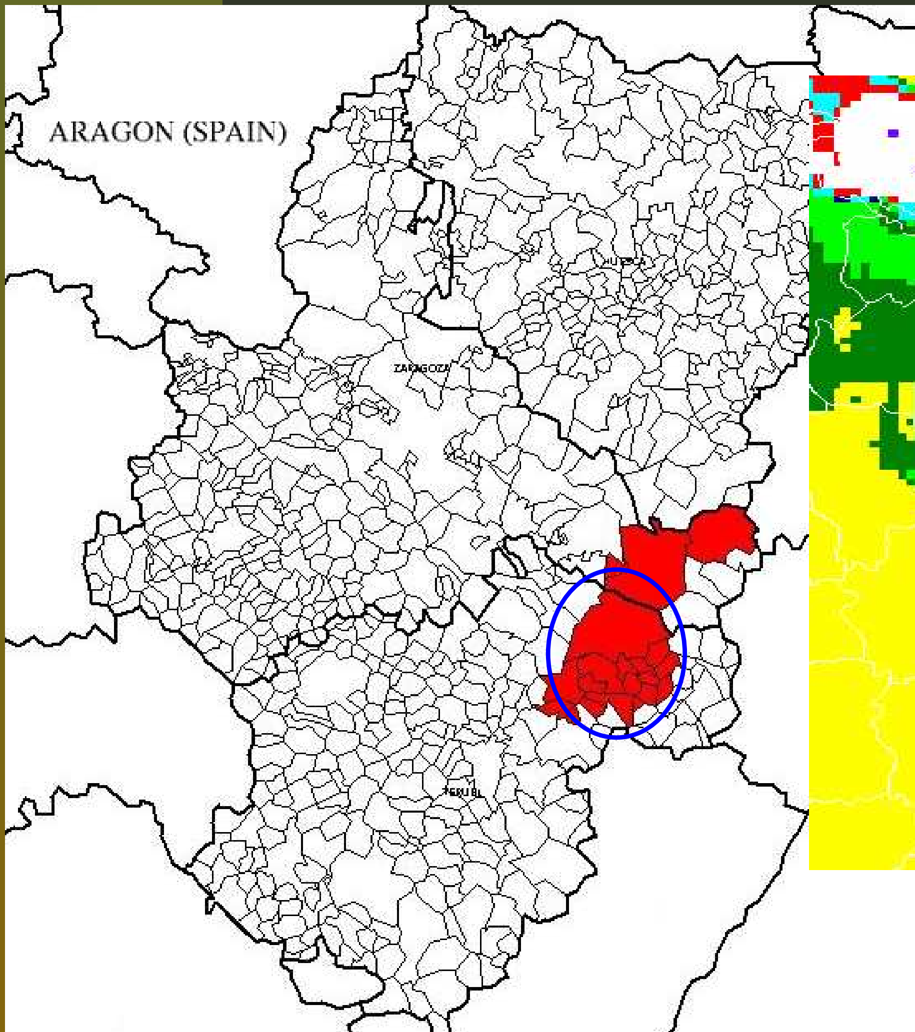
Storm of August 16^{th} 2003

Hail affected area

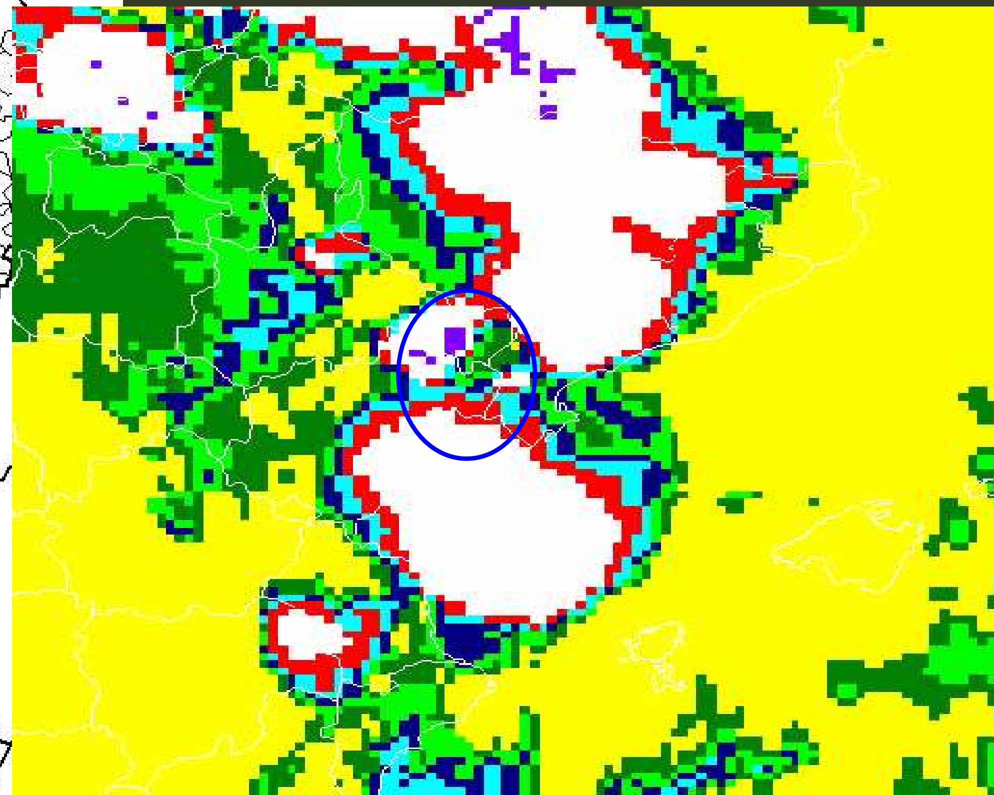


Storm of August 16^{th} 2003

Hail affected area



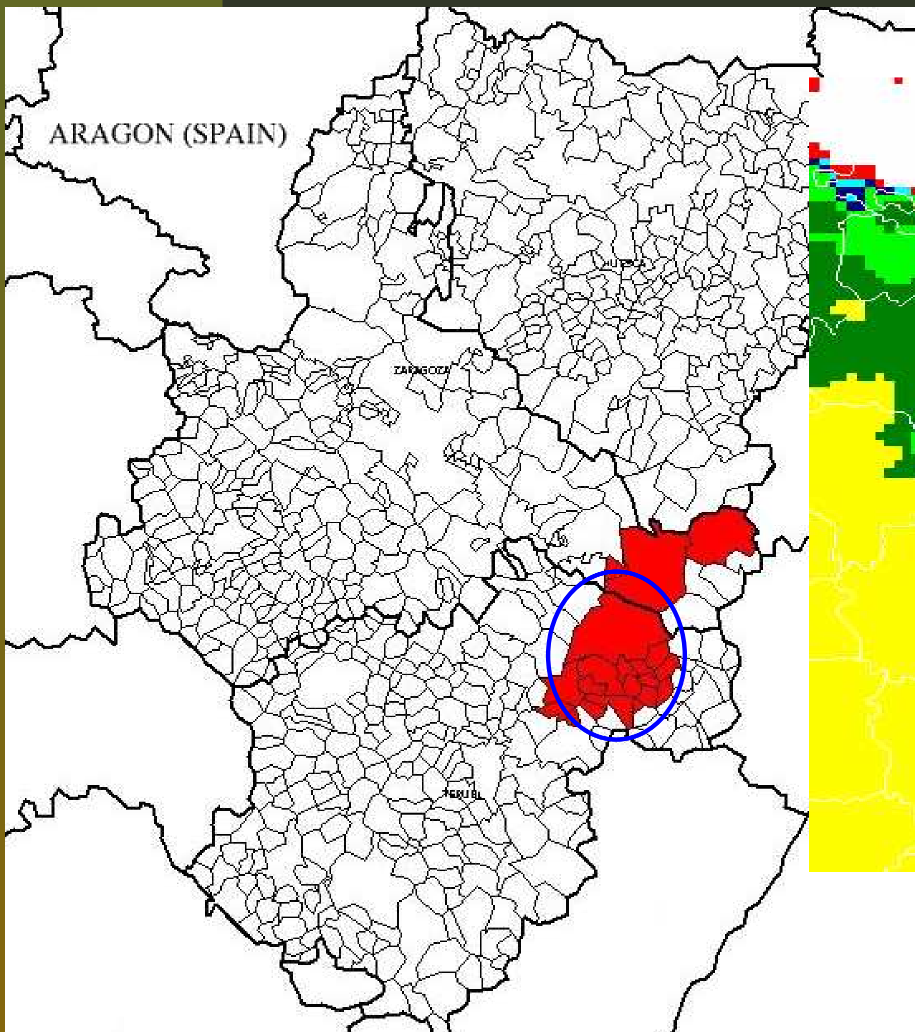
Meteosat images



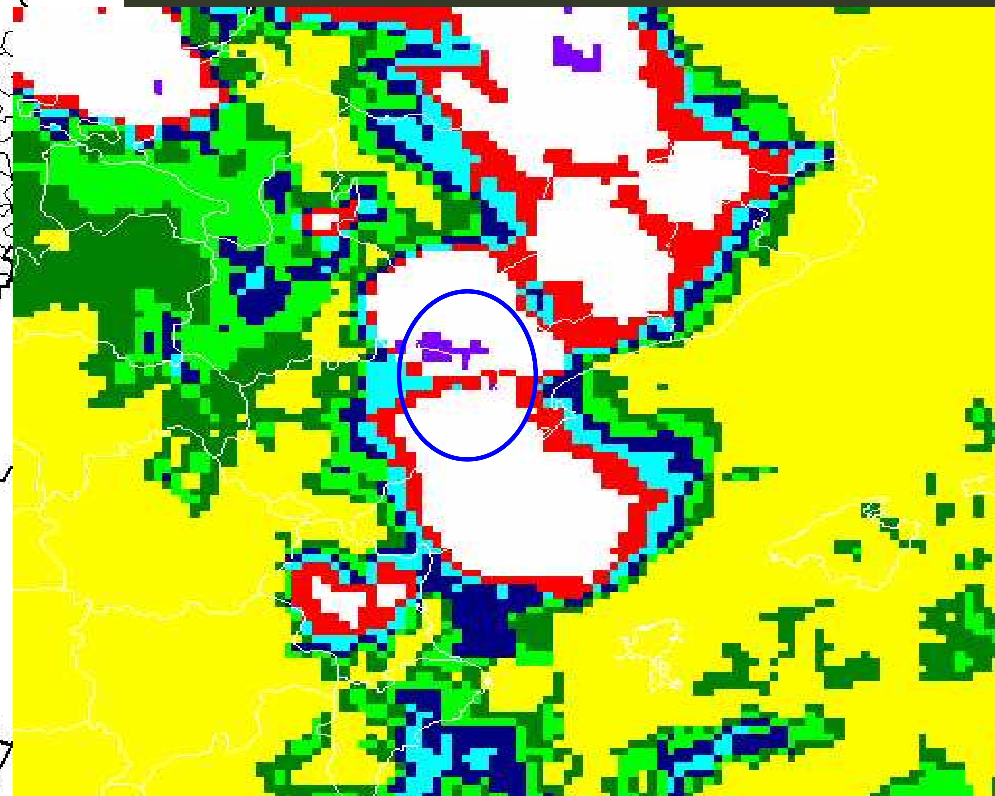
1600 UTC

Storm of August 16^{th} 2003

Hail affected area



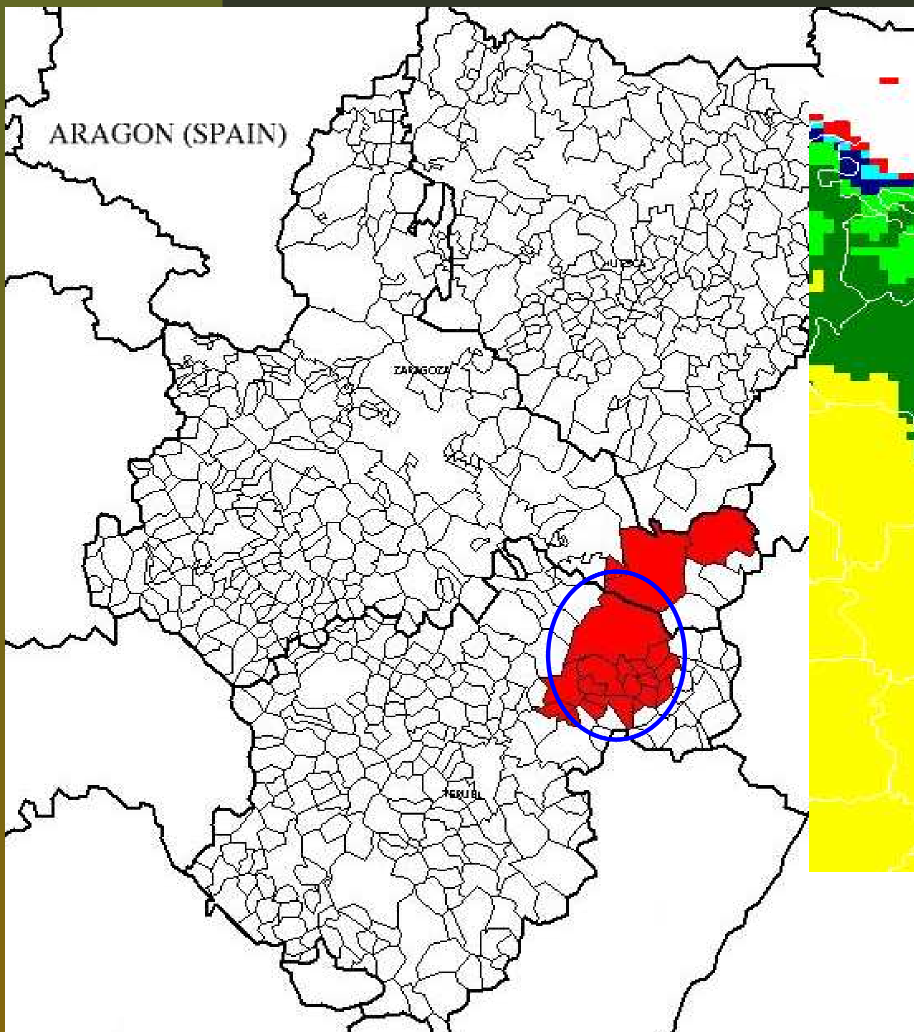
Meteosat images



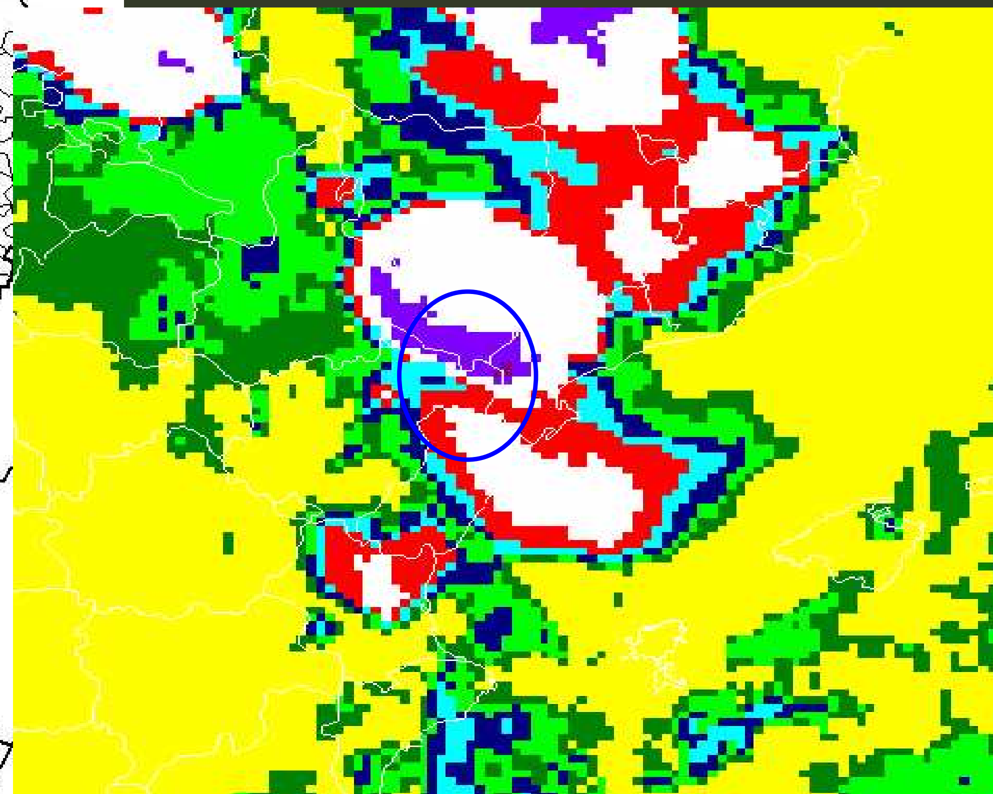
1630 UTC

Storm of August 16^{th} 2003

Hail affected area



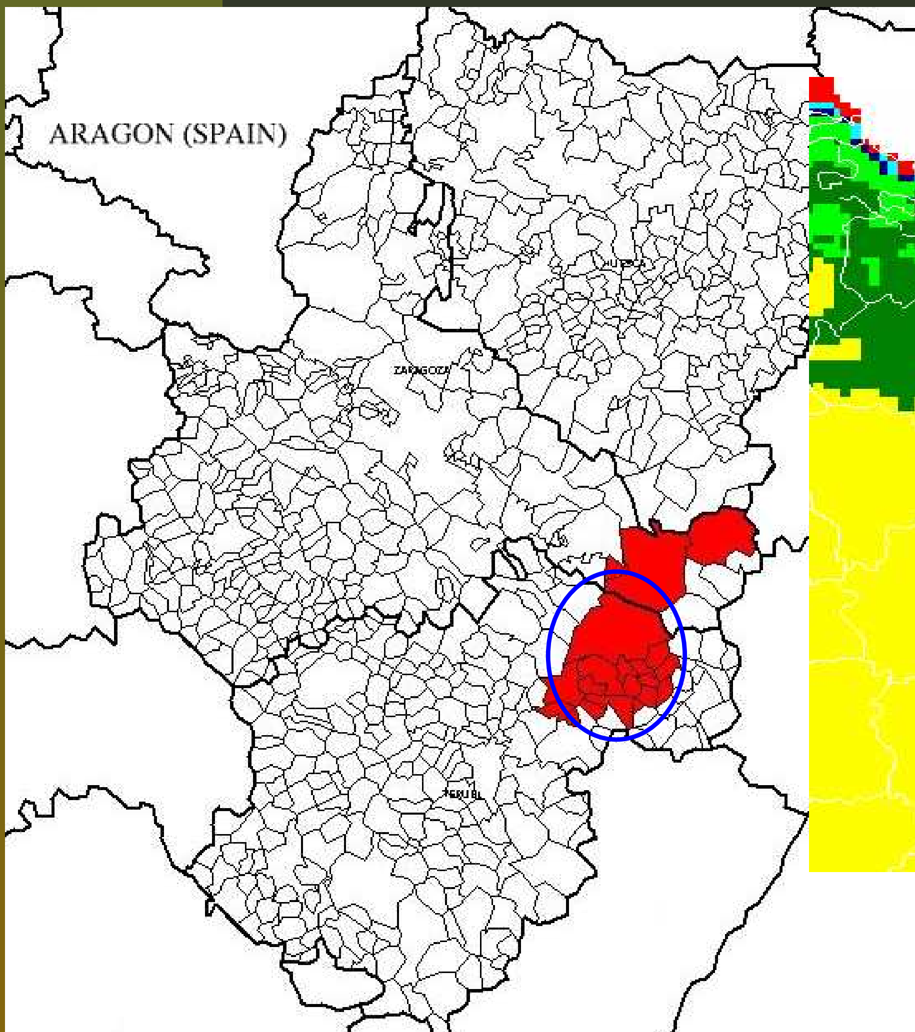
Meteosat images



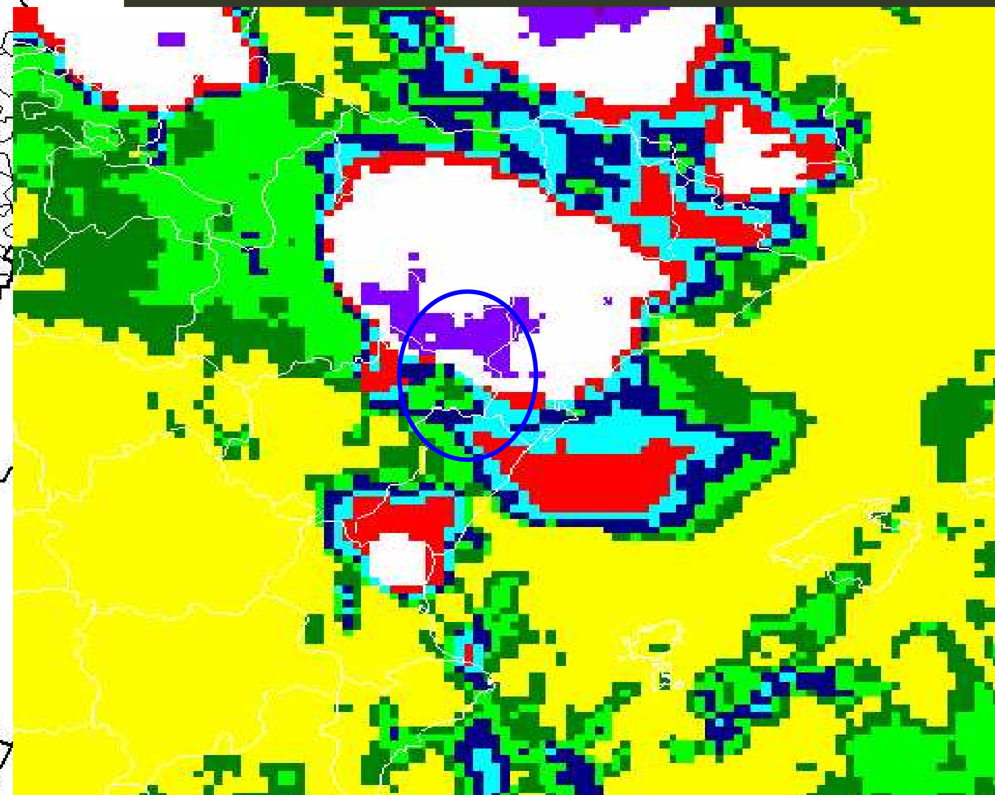
1700 UTC

Storm of August 16^{th} 2003

Hail affected area



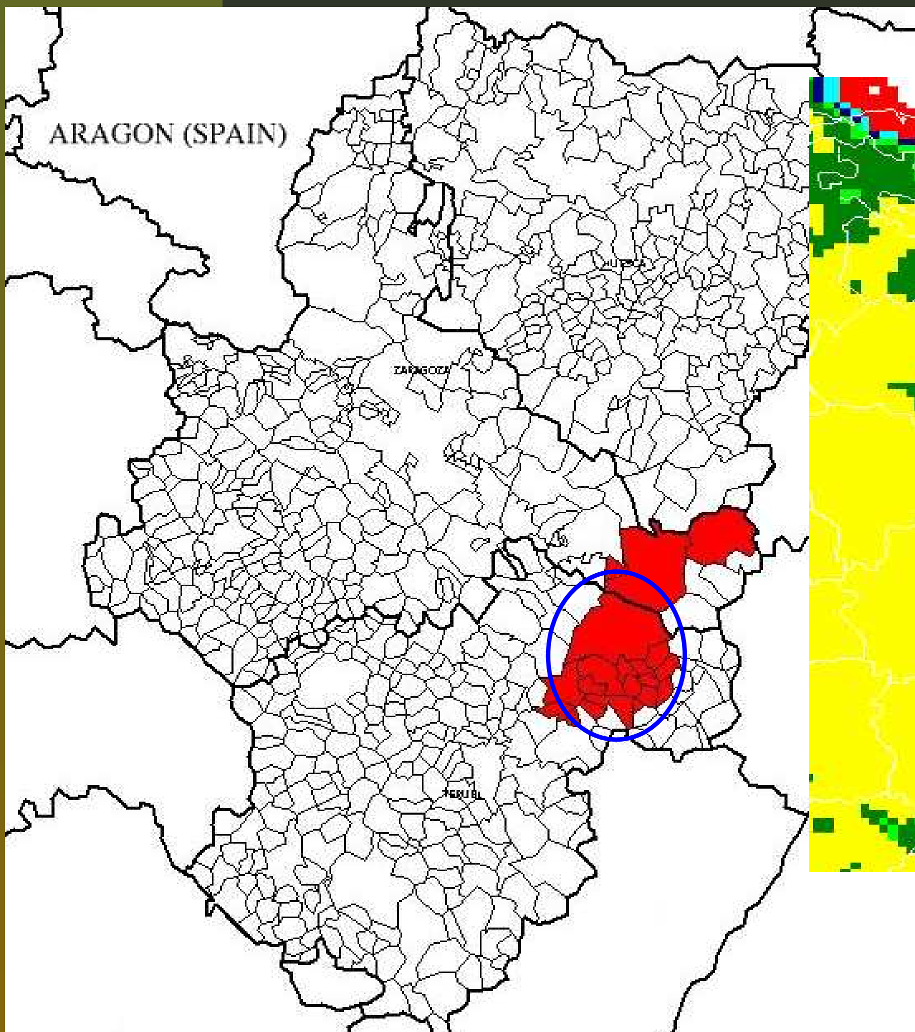
Meteosat images



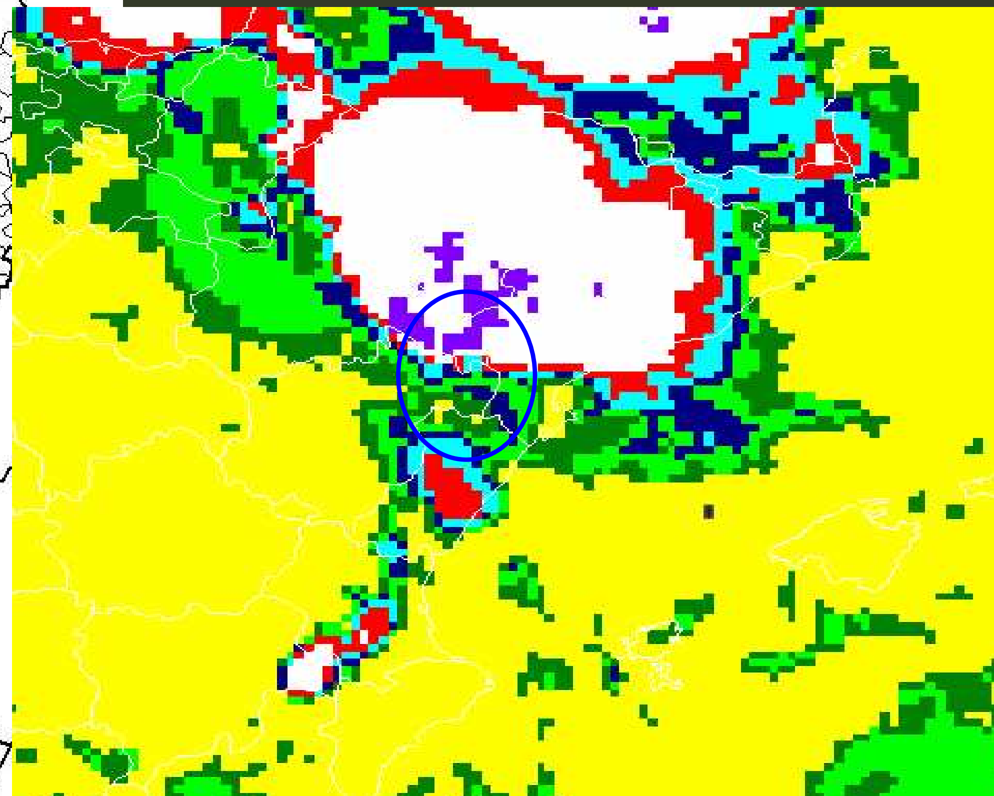
1730 UTC

Storm of August 16^{th} 2003

Hail affected area



Meteosat images

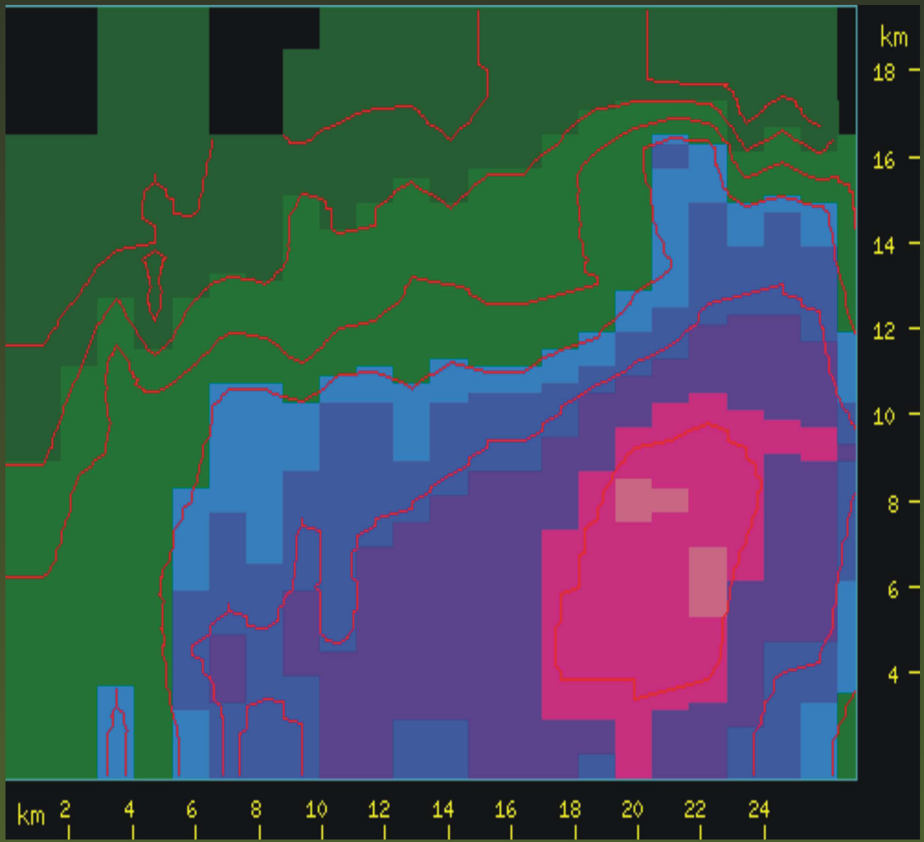


1800 UTC

Radar images (TITAN)

Average values:

Start	1520 UTC
End	1800 UTC
Z_{max}	$55.5\ dBZ$
Z_{med}	$43.3\ dBZ$
Echo top	$> 18.0\ km$

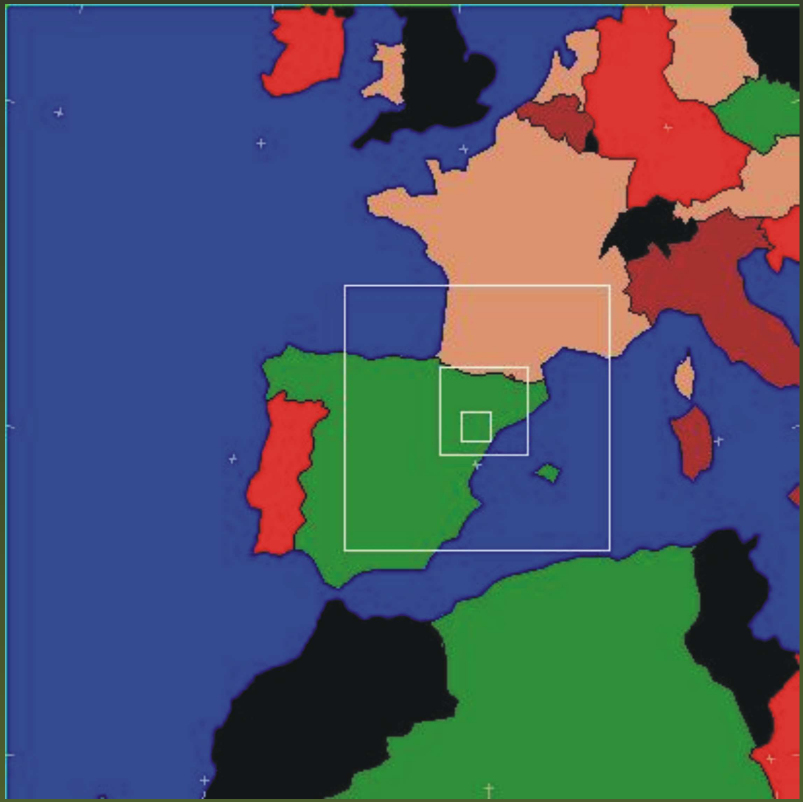


Vertical section of storm at $1623\ UTC$

Numerical simulation

MM5 Mesoscale Model

- Four nested domains.
- Horizontal mesh size of 18, 6, 2 and 0.67 km respectively.
- Each of domains defined by a grid of 151×151 dots.
- 23 vertical sigma levels.
- The simulation started at 00 UTC and finished at 12 UTC of the following day.
- Moisture scheme: Reisner graupel.
- Cumulus parameterization: Kain-Fristch scheme.



Numerical simulation

Two objectives:

I To study whether the model is able to reproduce the actual storm of Alcañiz.

II To carry out a sensitivity experiment, with the *Factor Separation* technique *(Stein and Alpert, 1993)**, to analyze the influence of physical relief and solar radiation on the development of the storm.

*Stein, U. and Alpert, P., 1993: Factor Separation in Numerical Simulations. *J. Atmos. Sci.*, 50, 2107-2115.

Control experiment: results

Domain 1:

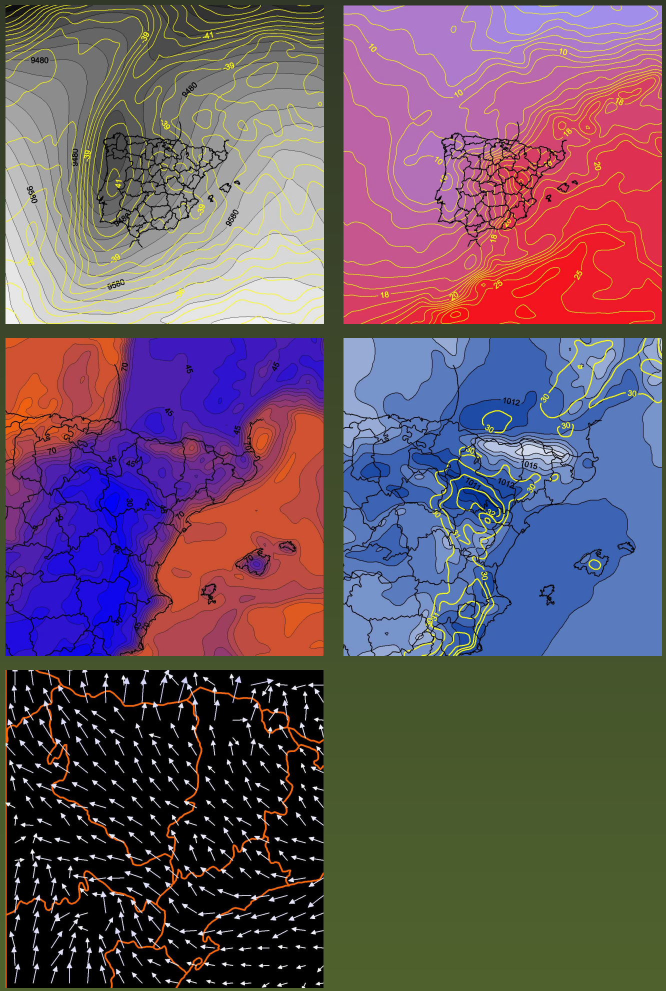
- Synoptic situation

Domain 2:

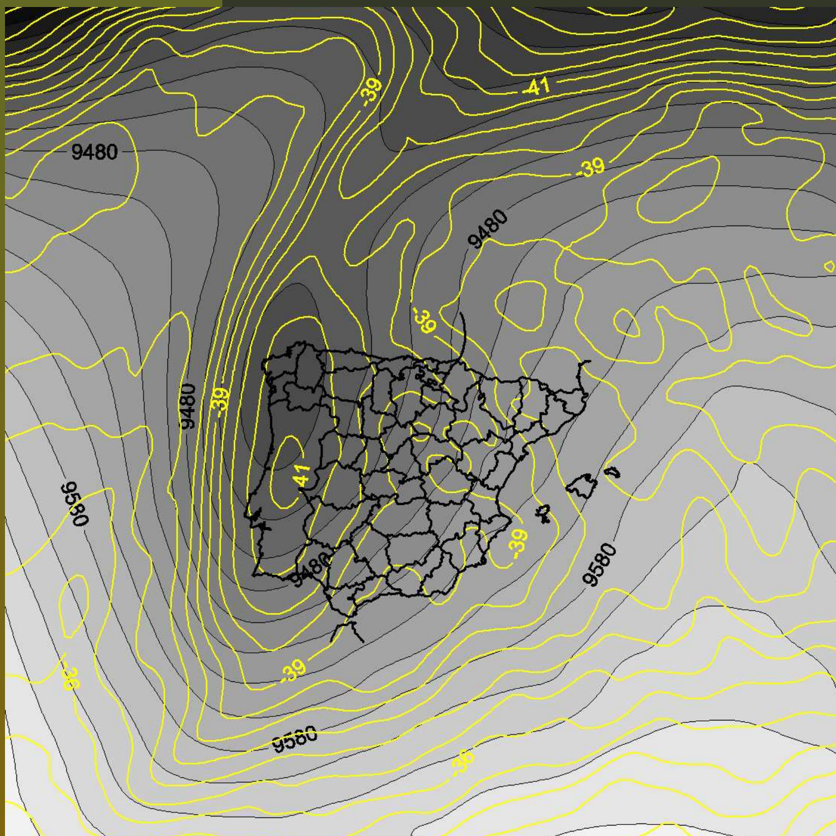
- Relative humidity
- Thermal mesolow

Domain 3:

- Surface wind field

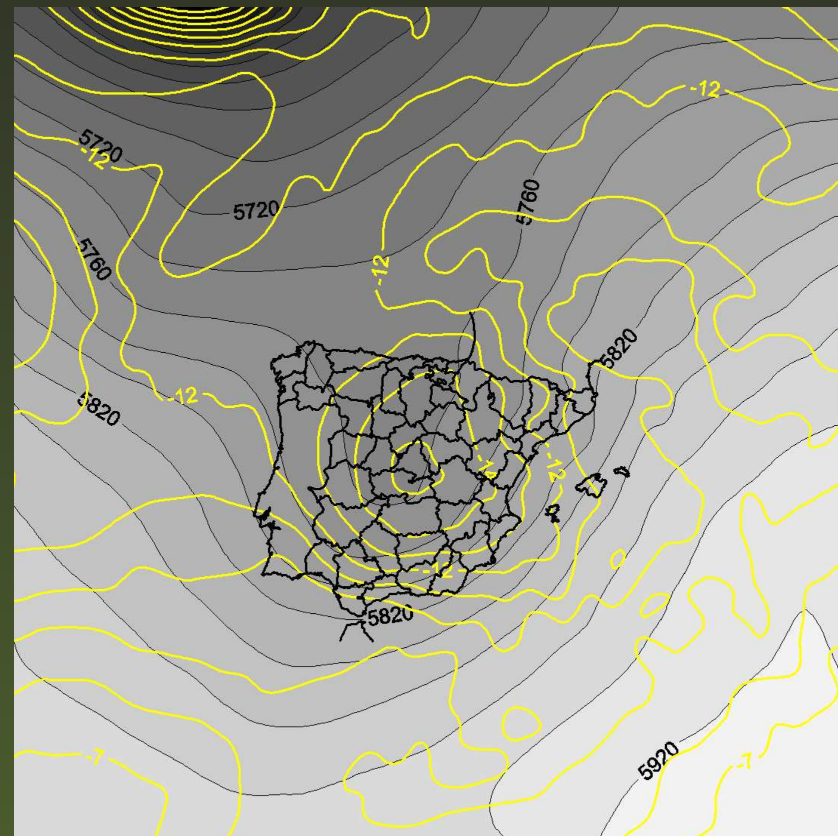


Control experiment: domain 1



Isohypses (gpm) and isotherms (^oC)

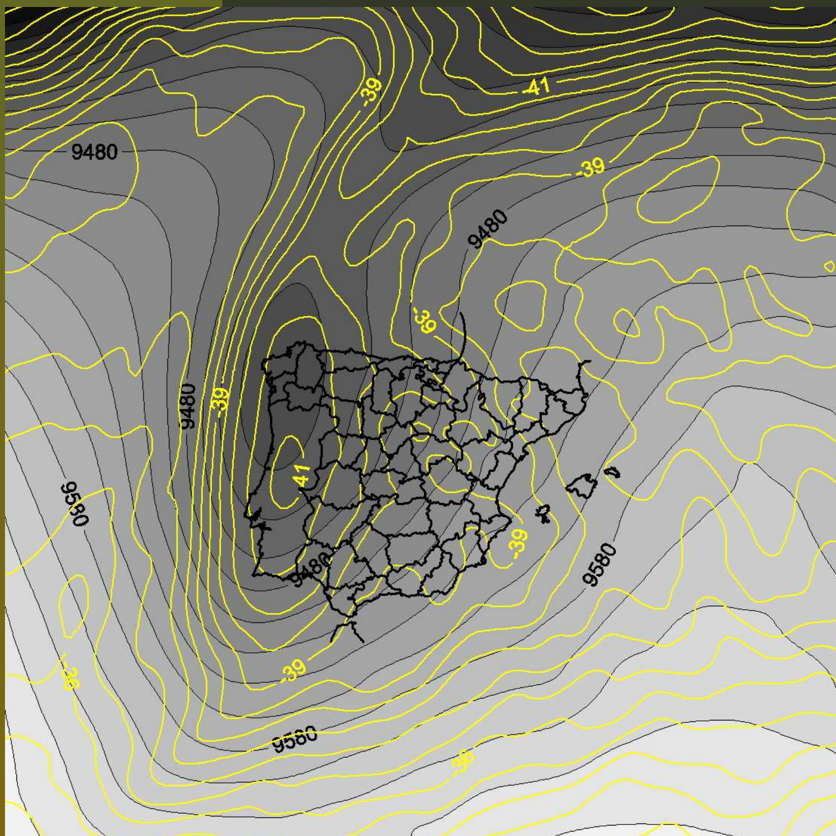
300 hPa at 1200 UTC



Isohypses (gpm) and isotherms (^oC)

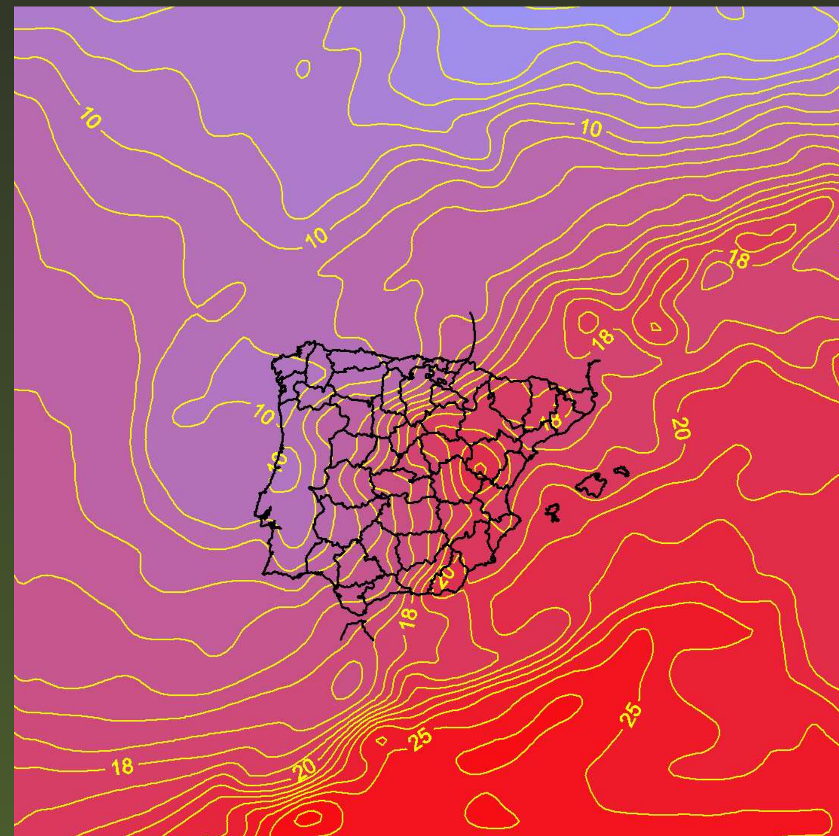
500 hPa at 1200 UTC

Control experiment: domain 1



Isohypses (gpm) *and isotherms* (^oC)

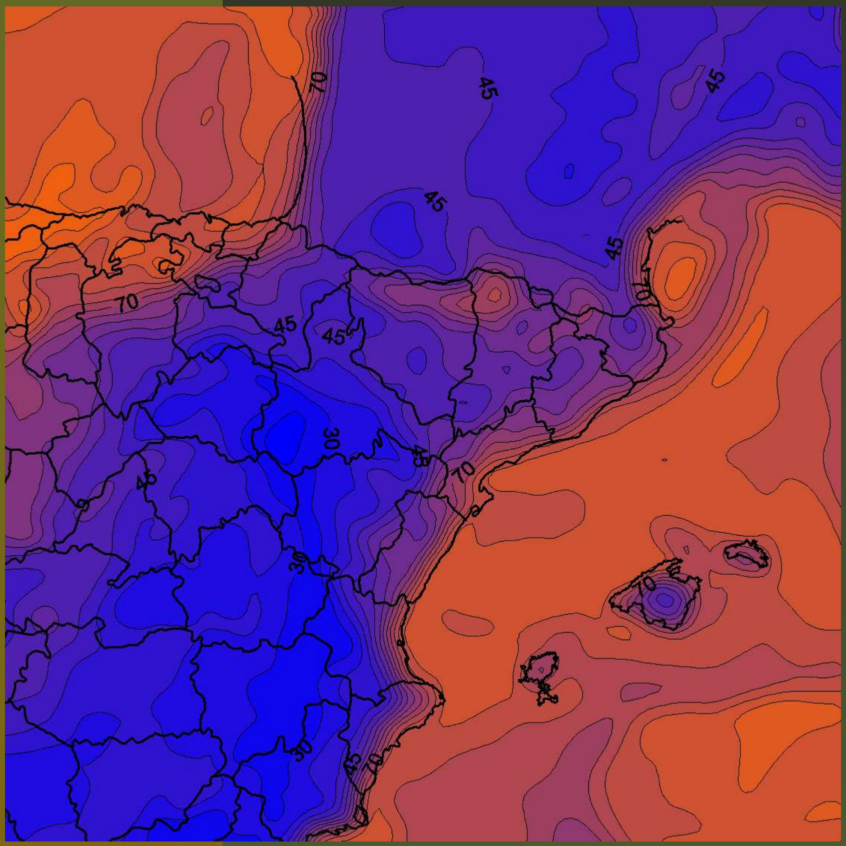
300 hPa *at 1200 UTC*



Isotherms (^oC)

850 hPa *at 1200 UTC*

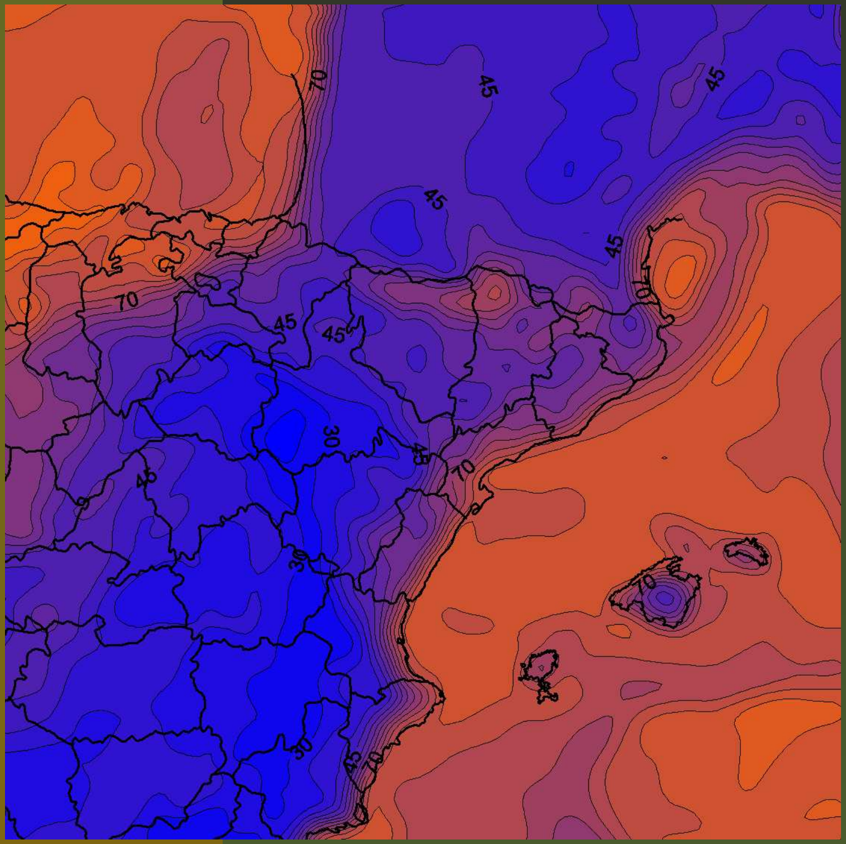
Control experiment: domain 2



Relative humidity (%)

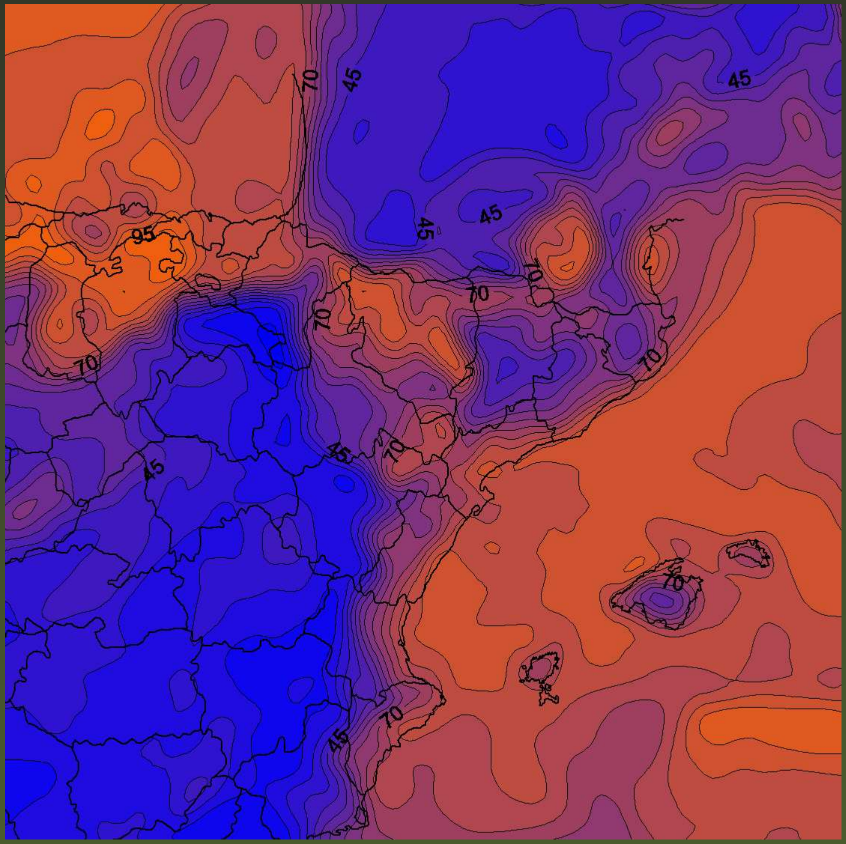
surface level at 1200 UTC

Control experiment: domain 2



Relative humidity (%)

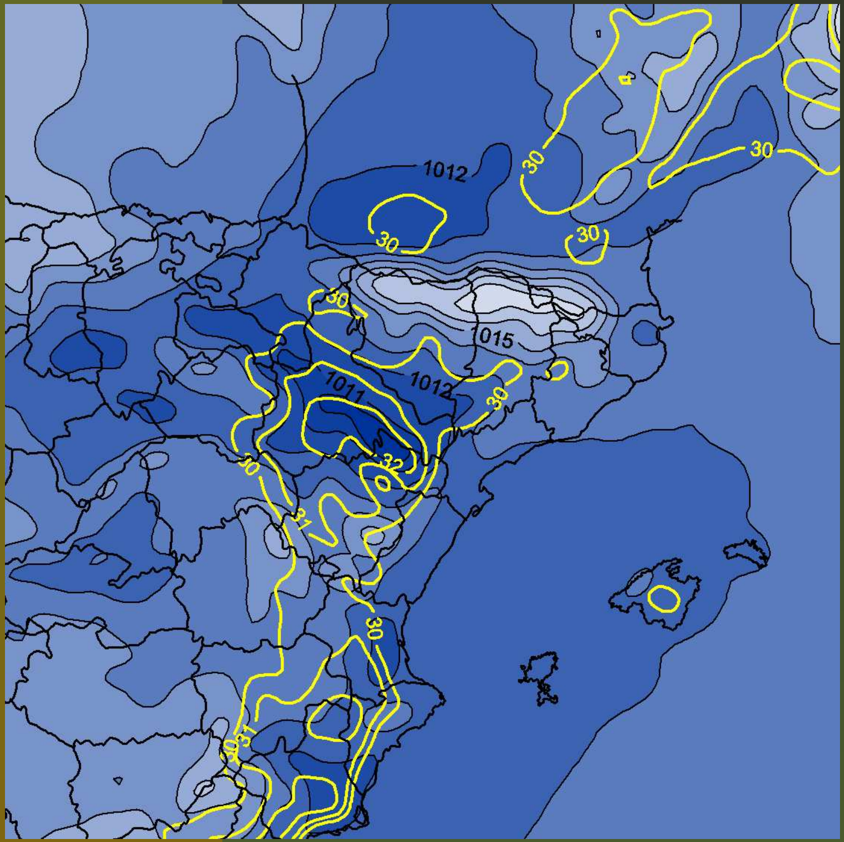
surface level at 1200 UTC



Relative humidity (%)

surface level at 1500 UTC

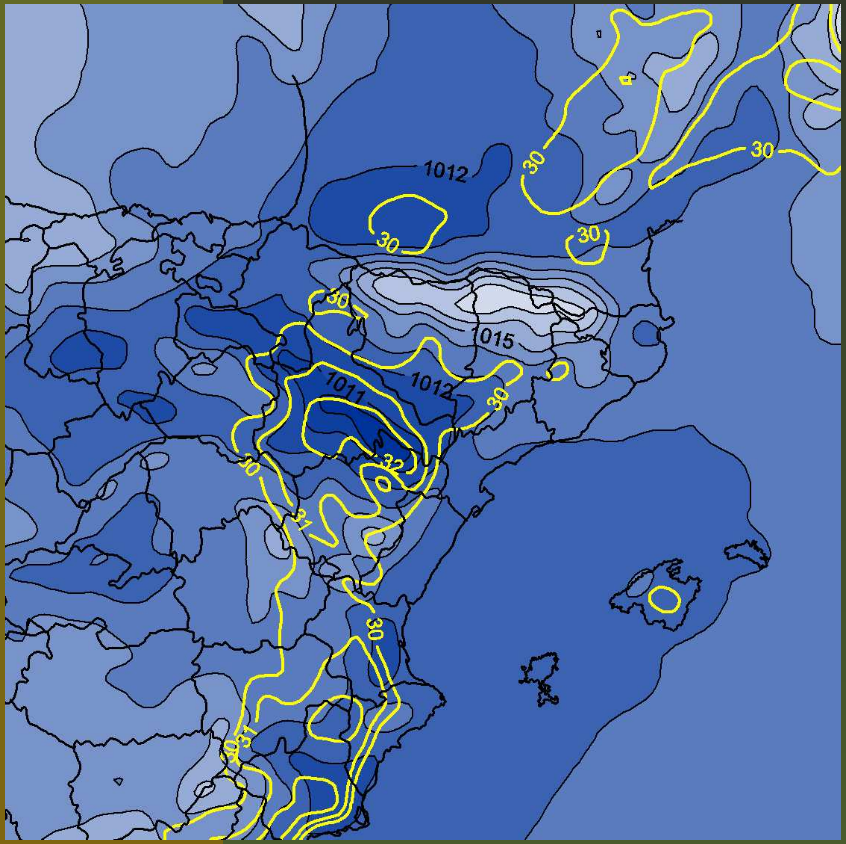
Control experiment: domain 2



Sea level pressure -blue color scale- (hPa)

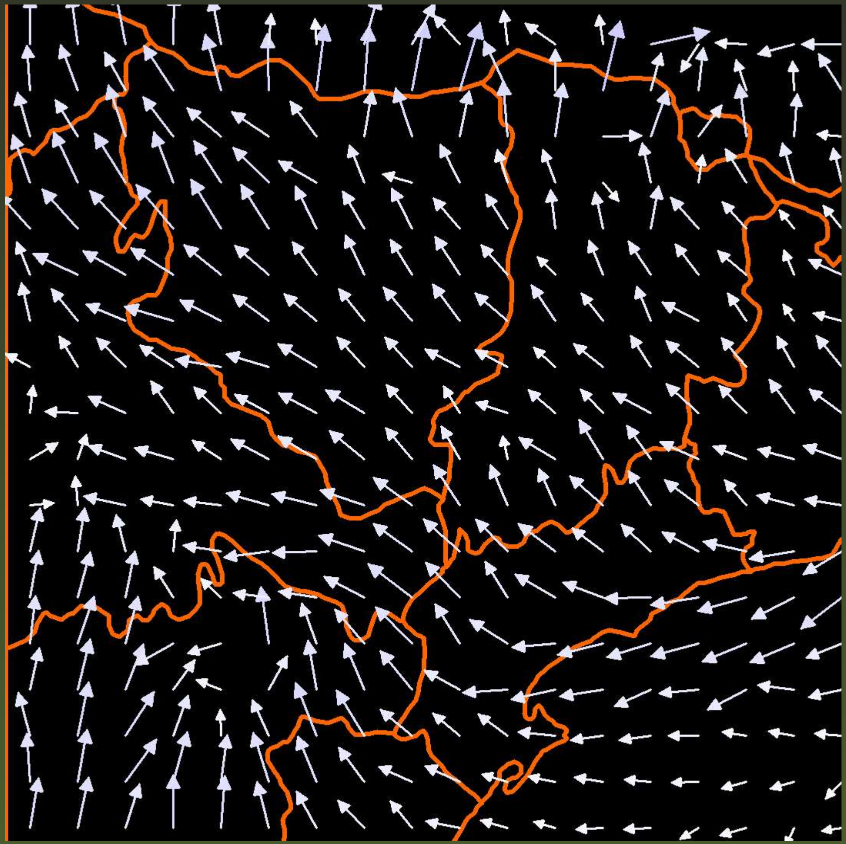
and isotherms with $T > 30^o C$ *at 1200 UTC*

Control experiment: domain 3



Sea level pressure -blue color scale- (hPa)

and isotherms with $T > 30^{o}C$ *at 1200 UTC*

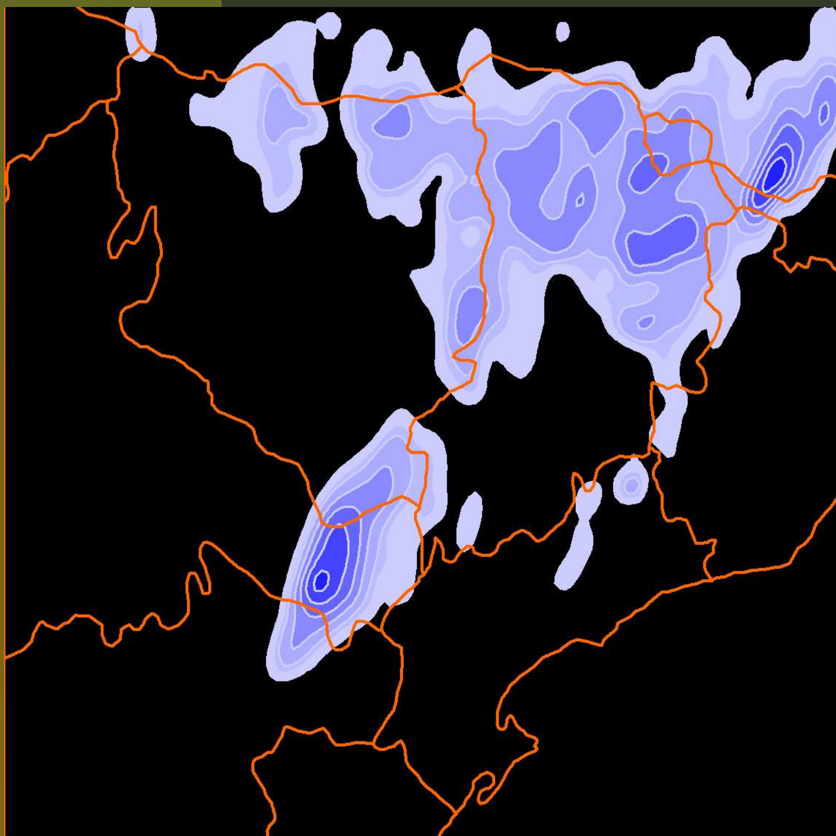


Wind field (longest vector is $12\ m\ s^{-1}$ *)*

900 hPa *at 1200 UTC*

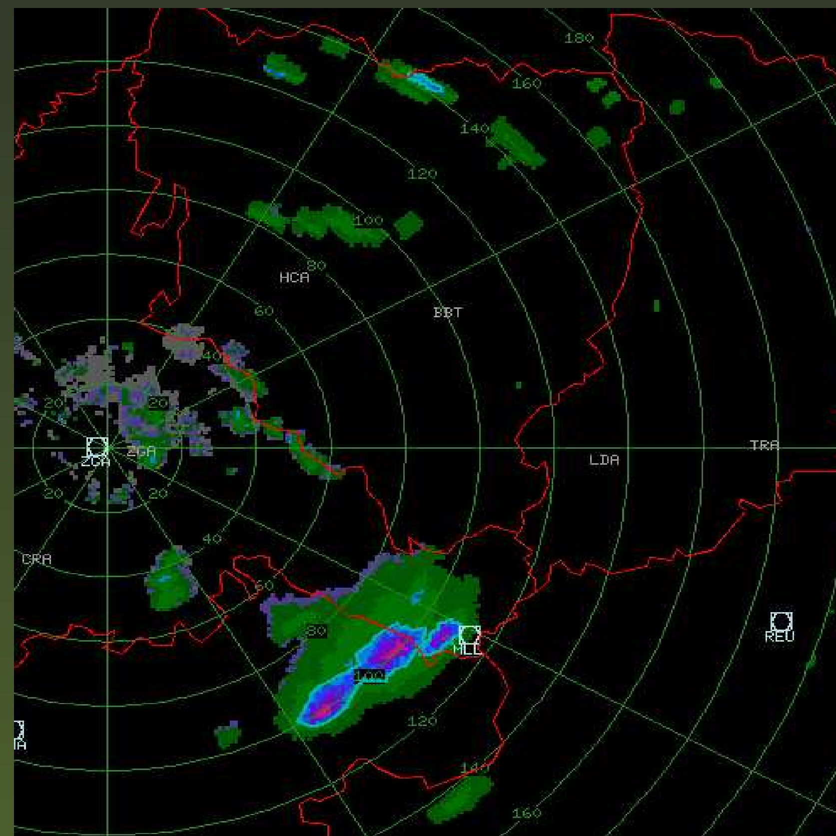
Radar images *vs.* MM5

Spatial comparison



Precipitation area between 1500 - 1830 UTC

(Domain 3)

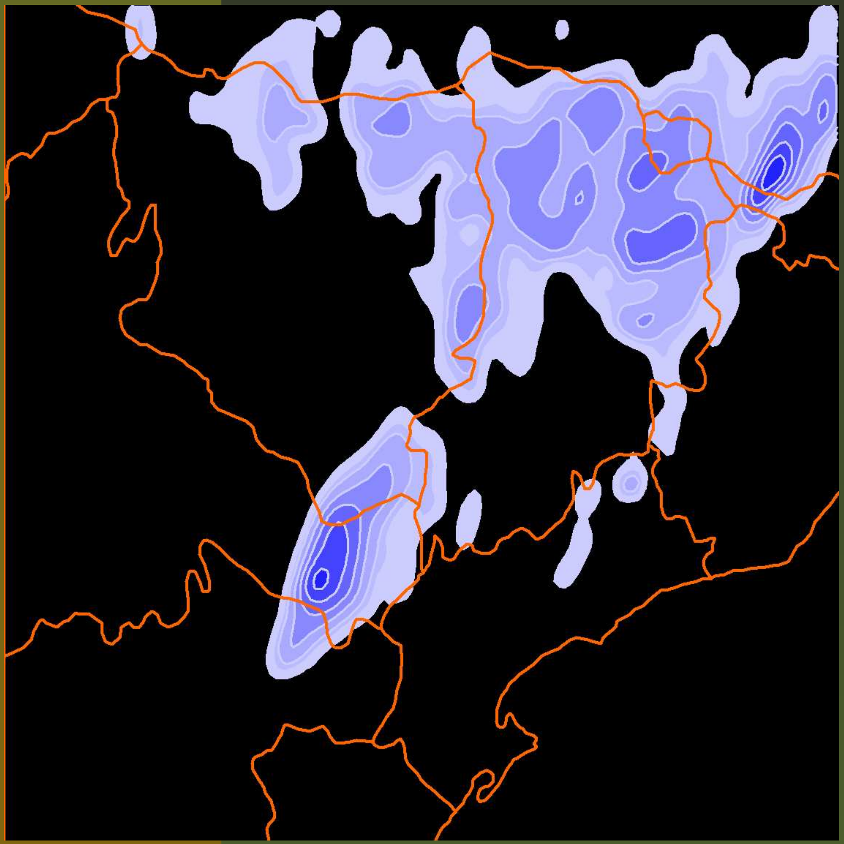


Radar: composite image of reflectivity factor

at 1623 UTC

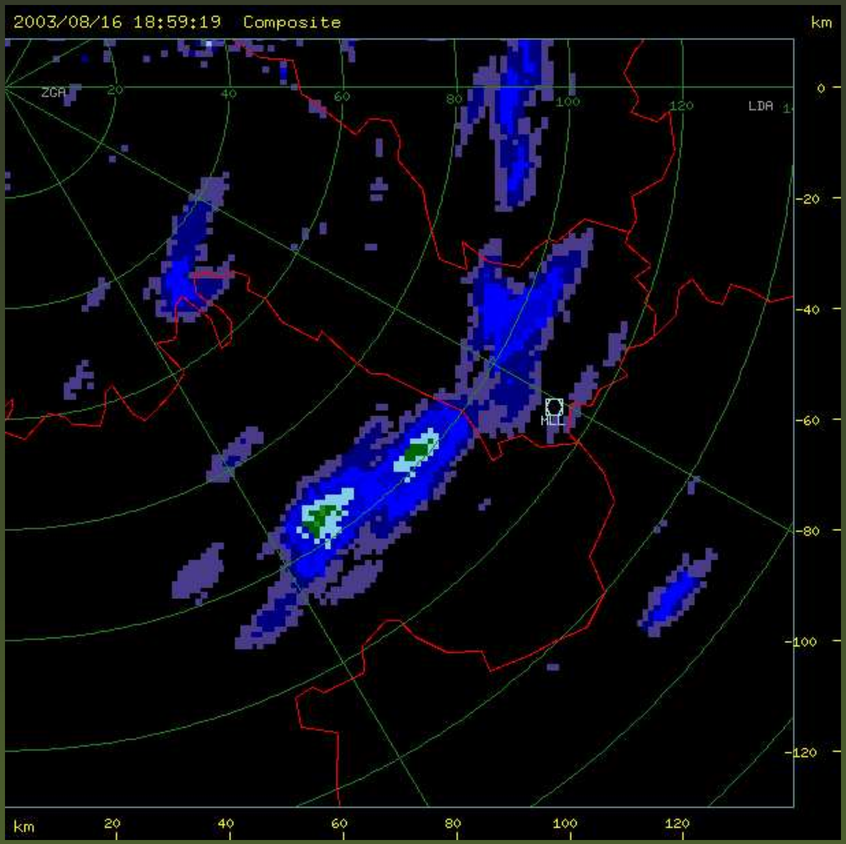
Radar images *vs.* MM5

Spatial comparison



Precipitation area between 1500 - 1830 UTC

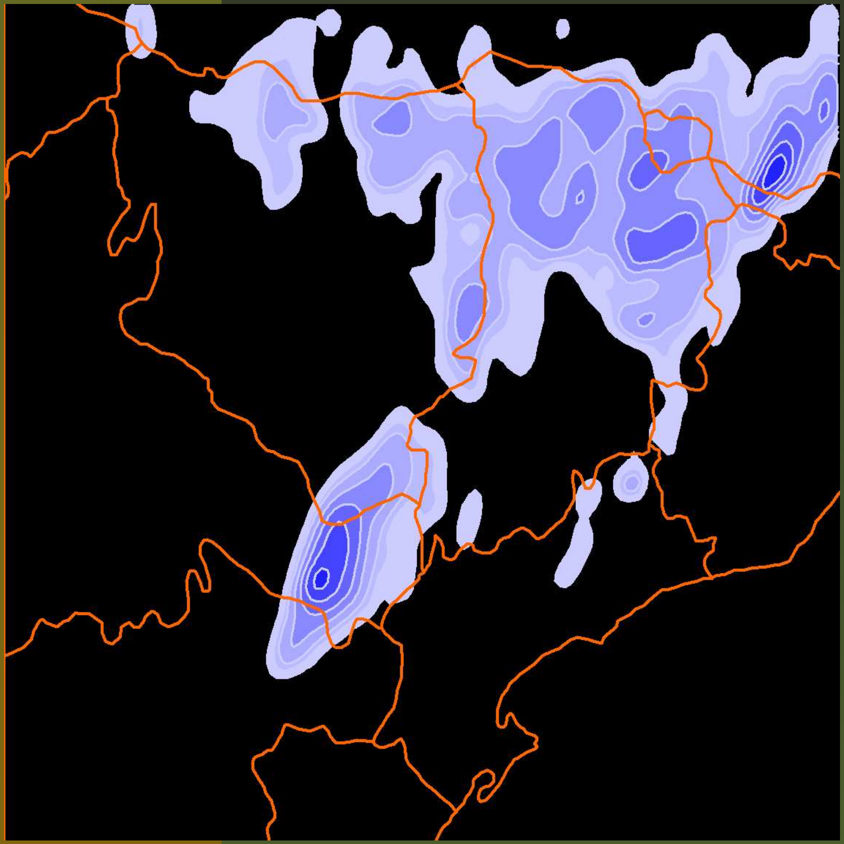
(Domain 3)



Radar: total precipitation in the study area

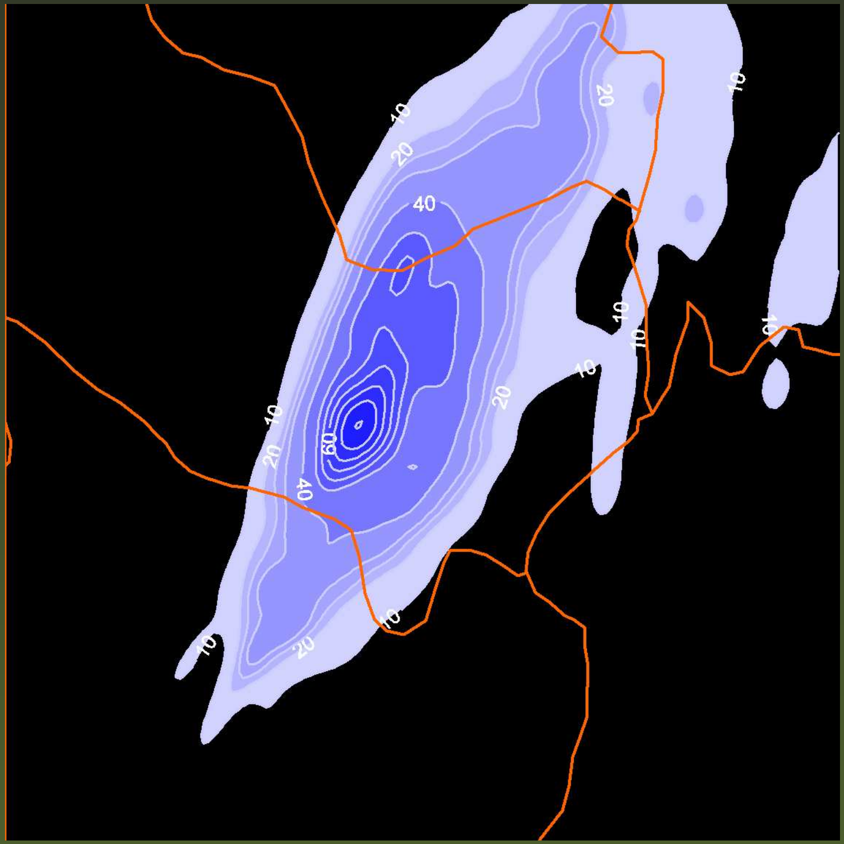
Radar images *vs.* MM5

Simulated precipitation (1500-1830 UTC)



Precipitation area between 1500 - 1830 UTC

(Domain 3)

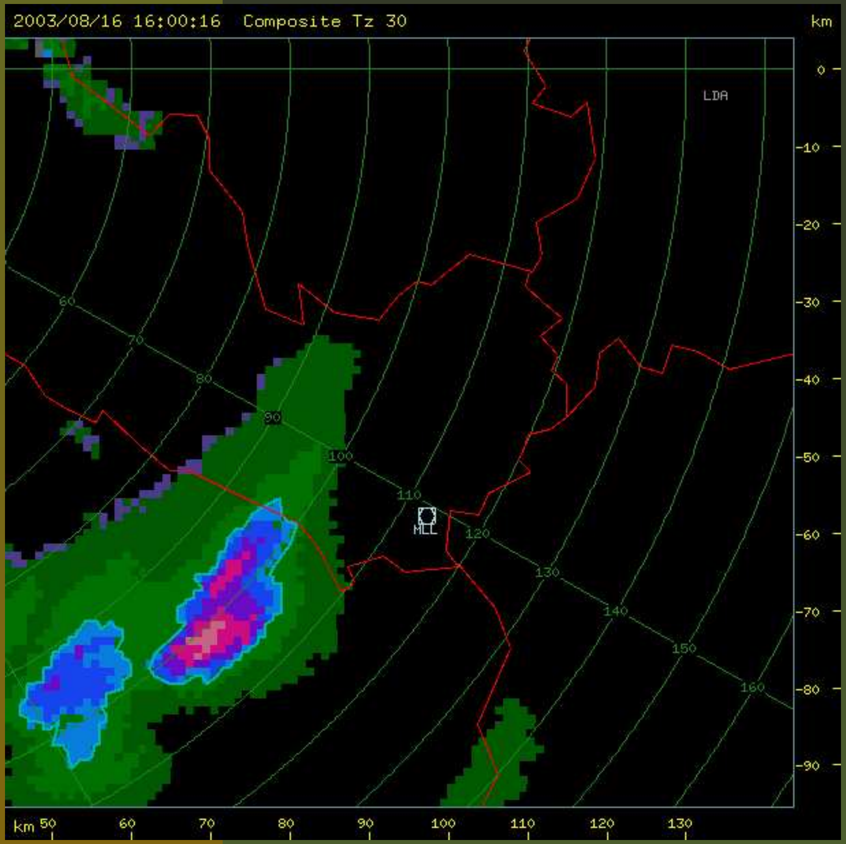


Accumulated precipitation field

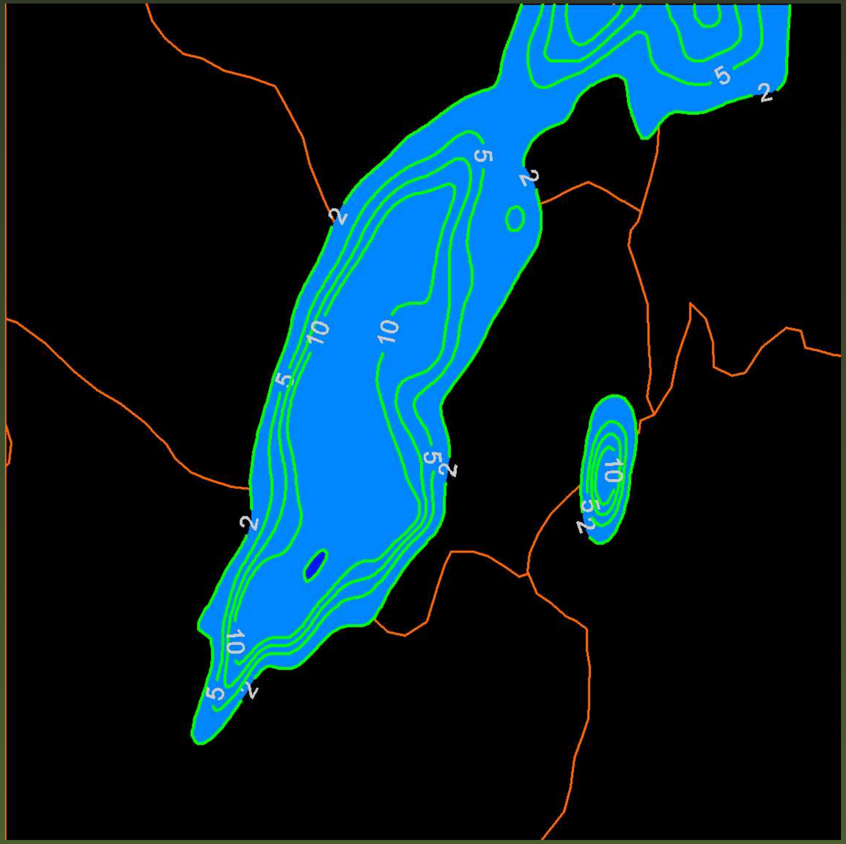
(Domain 4) (max. $75\ mm$)

Radar images *vs.* MM5

Temporal-spatial comparison



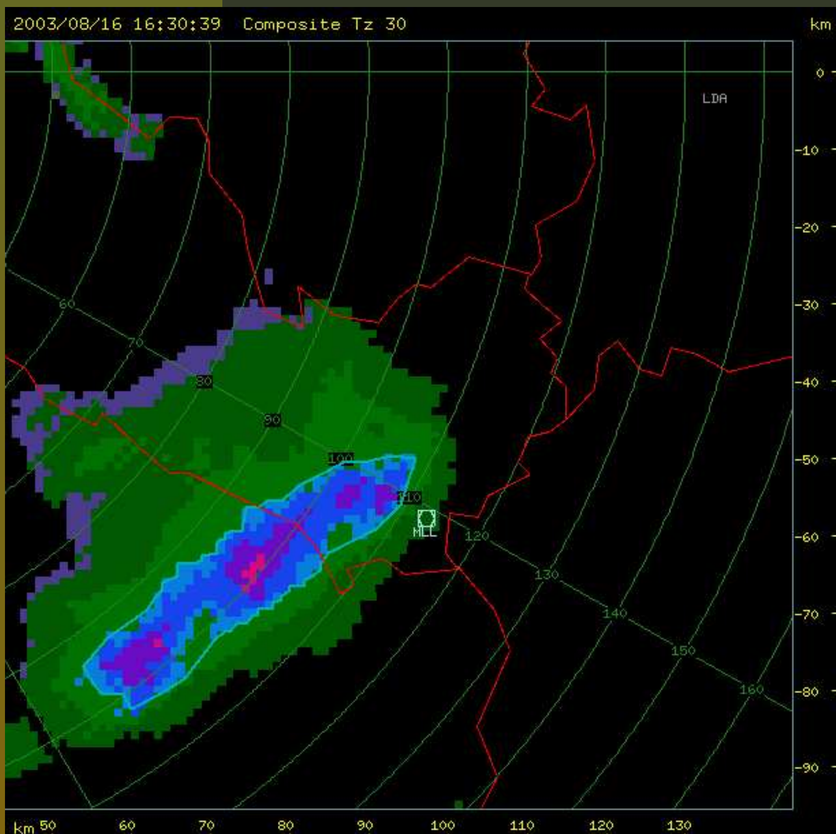
Composite image of Z at 1600 UTC



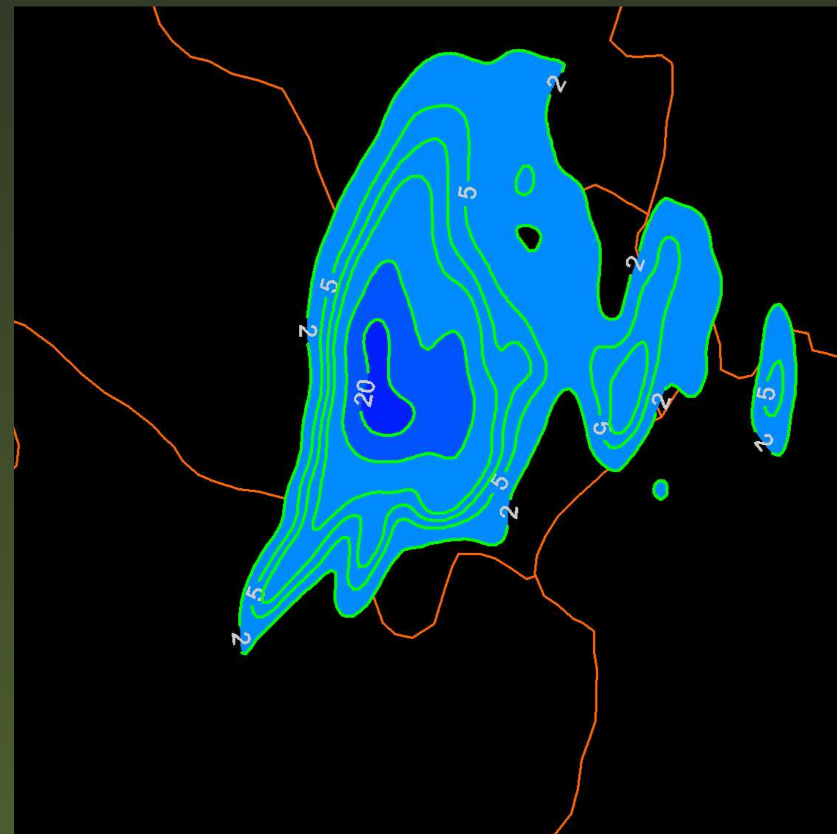
Accumulated precipitation field (1530-1600 UTC)

Radar images *vs.* MM5

Temporal-spatial comparison



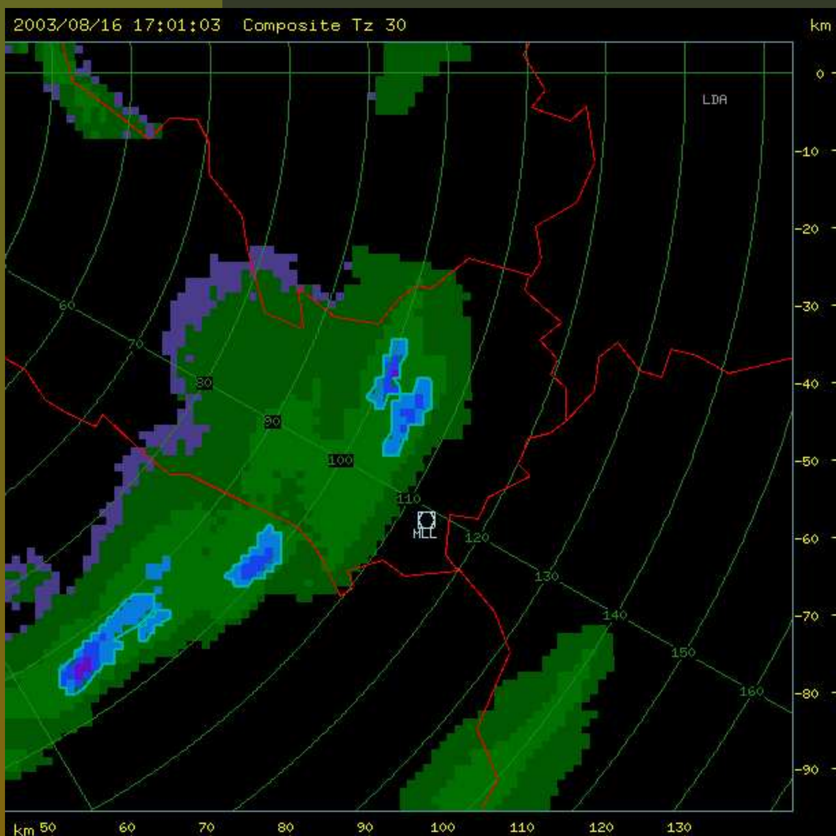
Composite image of Z at 1630 UTC



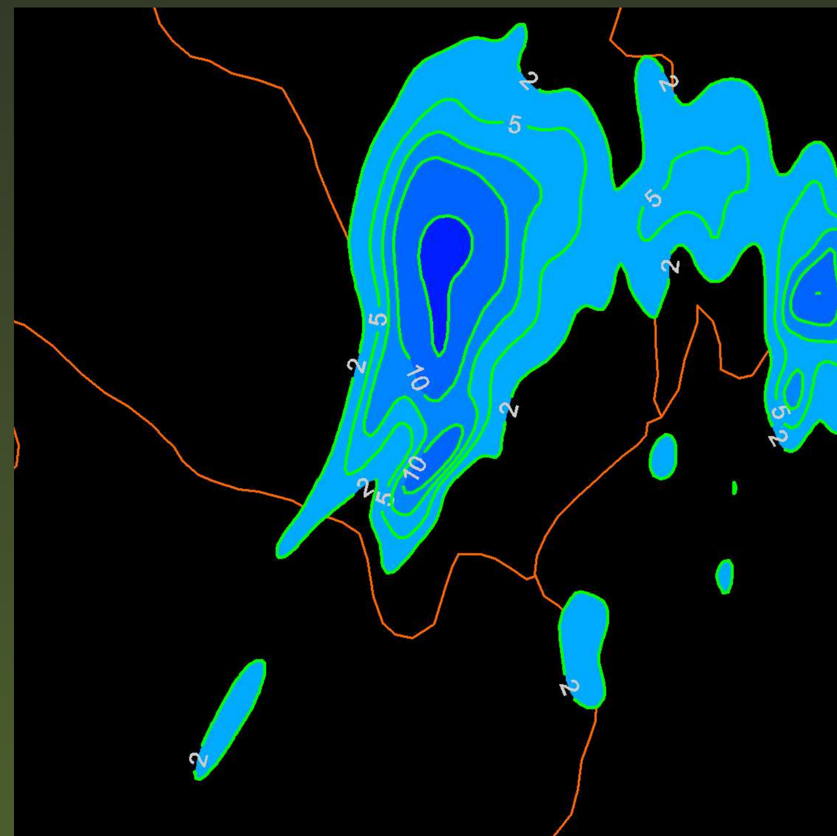
Accumulated precipitation field (1600-1630 UTC)

Radar images *vs.* MM5

Temporal-spatial comparison



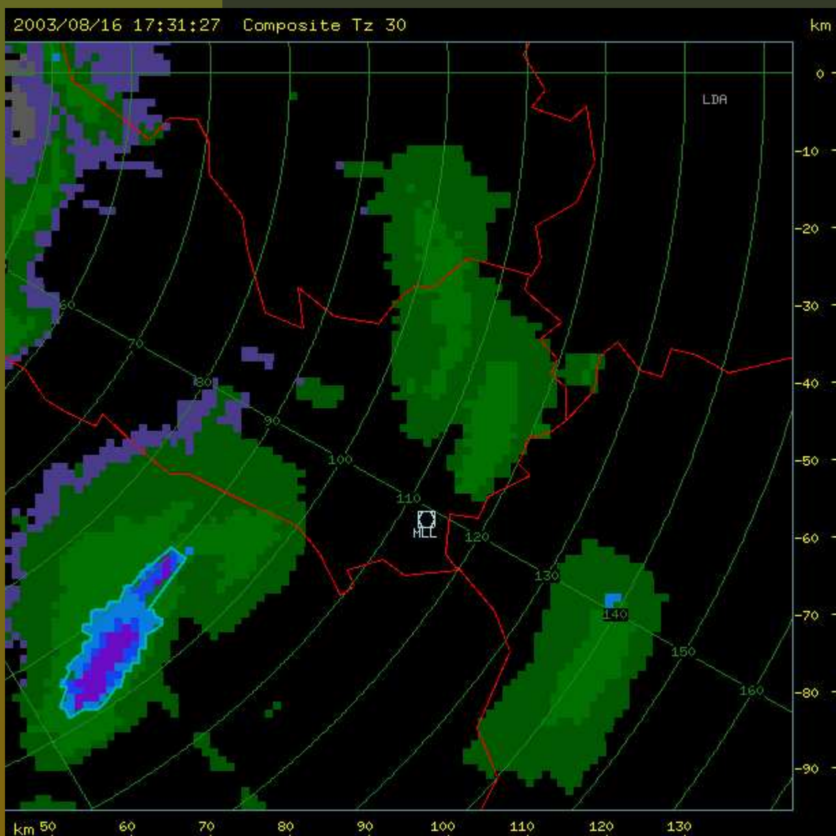
Composite image of Z at 1700 UTC



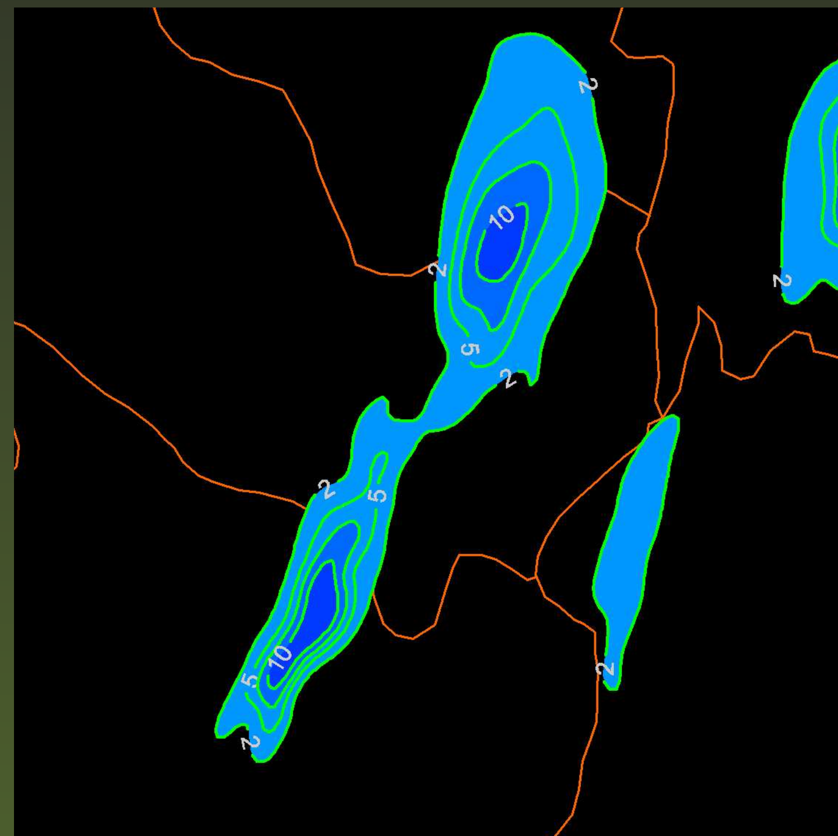
Accumulated precipitation field (1630-1700 UTC)

Radar images *vs.* MM5

Temporal-spatial comparison



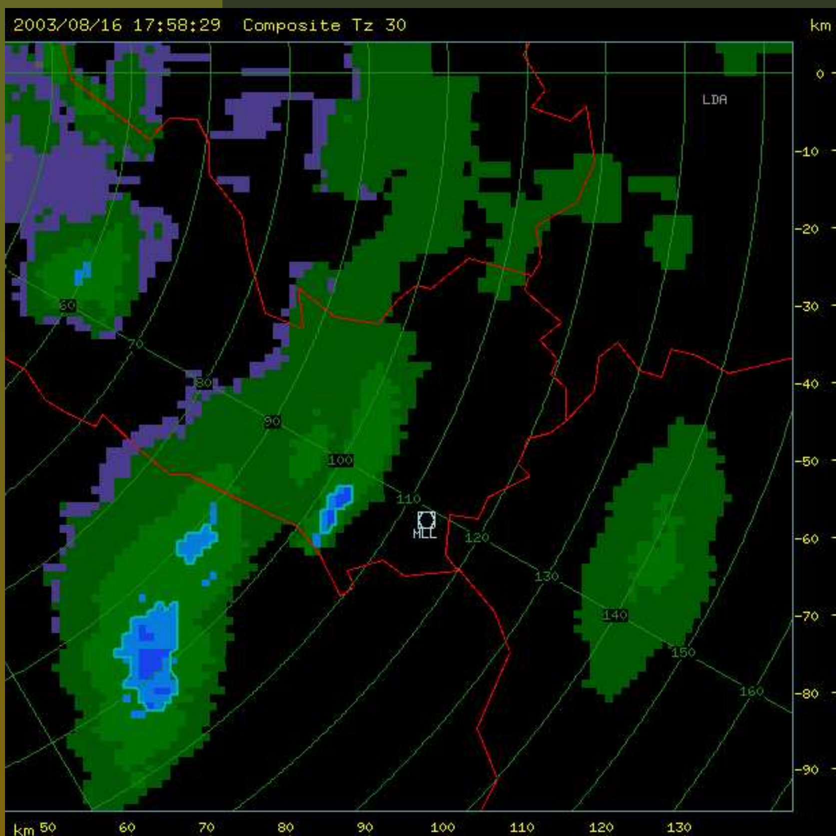
Composite image of Z at 1730 UTC



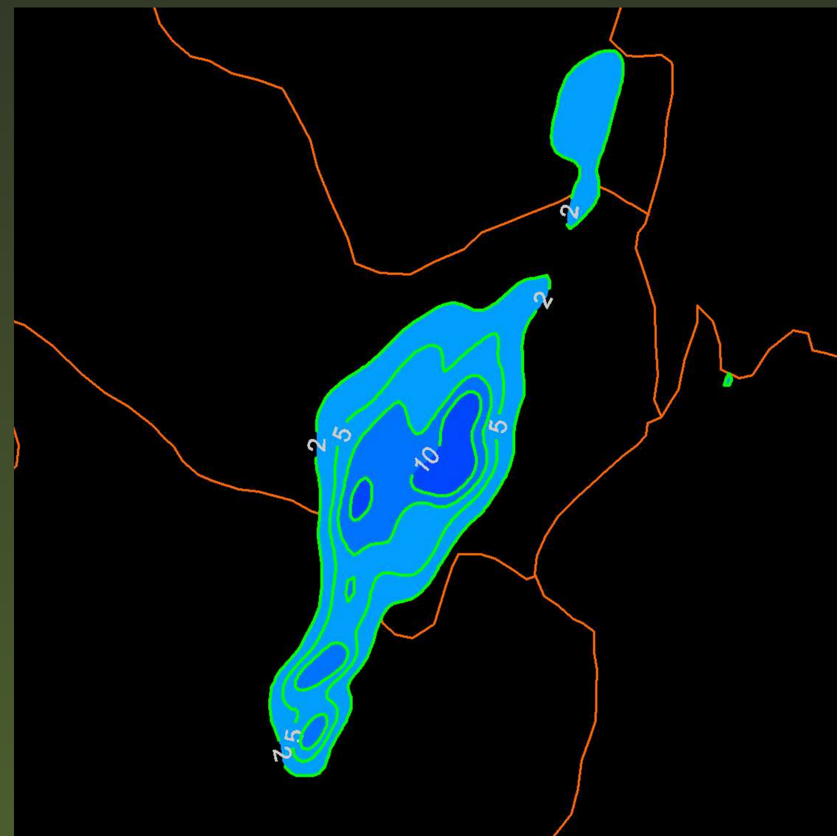
Accumulated precipitation field (1700-1730 UTC)

Radar images *vs.* MM5

Temporal-spatial comparison



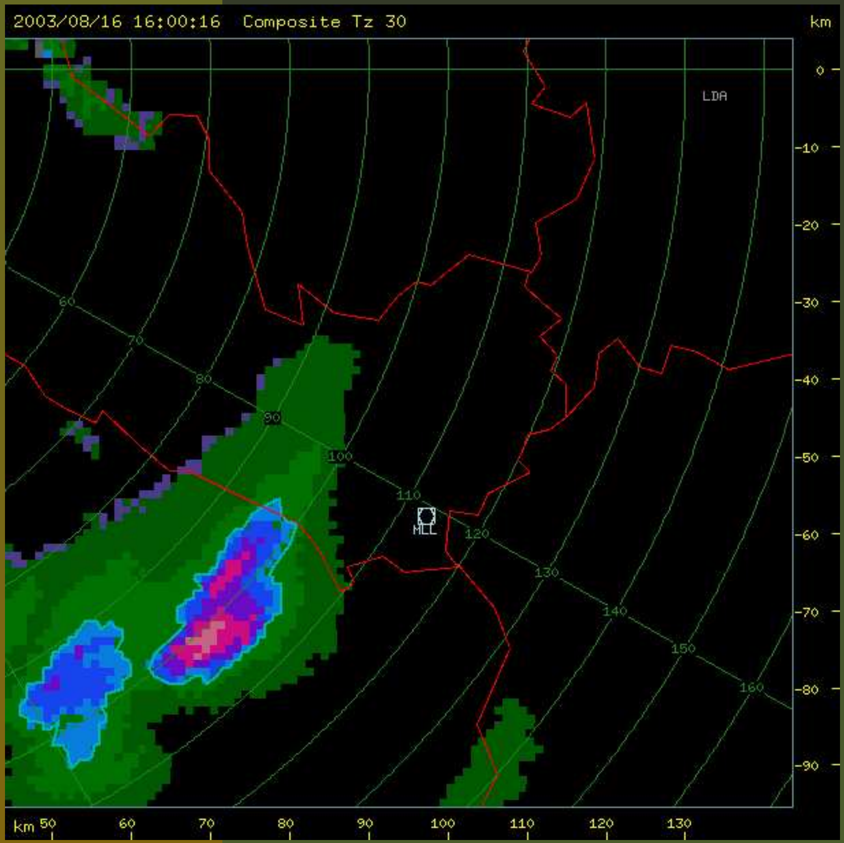
Composite image of Z at 1800 UTC



Accumulated precipitation field (1730-1800 UTC)

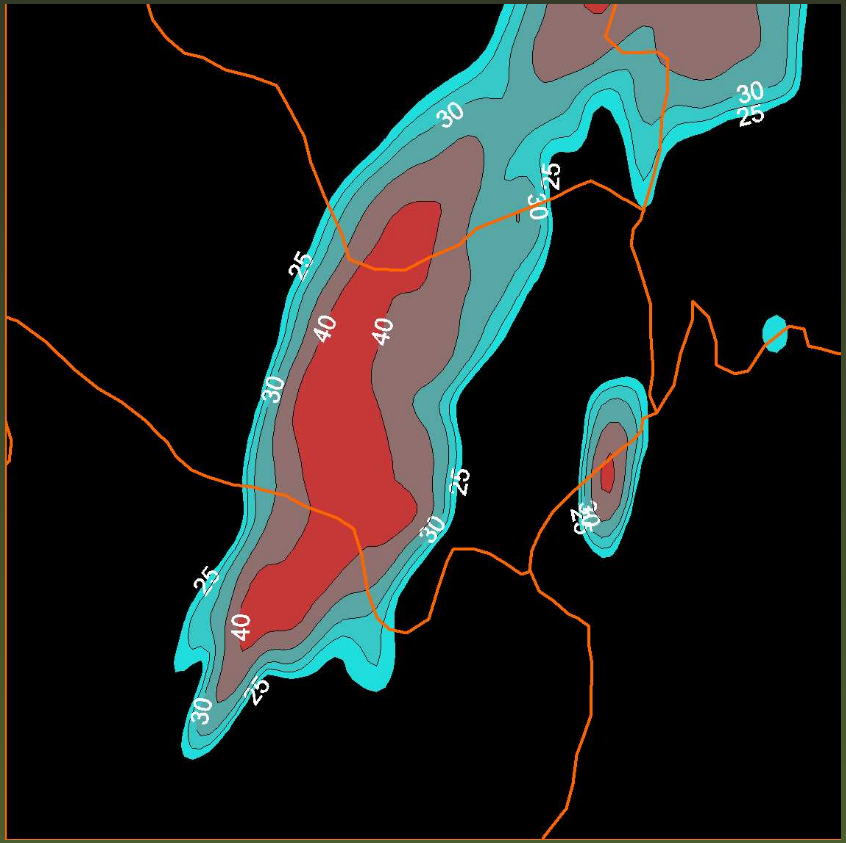
Radar images *vs.* MM5

Reflectivity factor simulation



Composite image of Z at 1600 UTC

$\bar{Z}_{max} = 45.7\, dBZ$

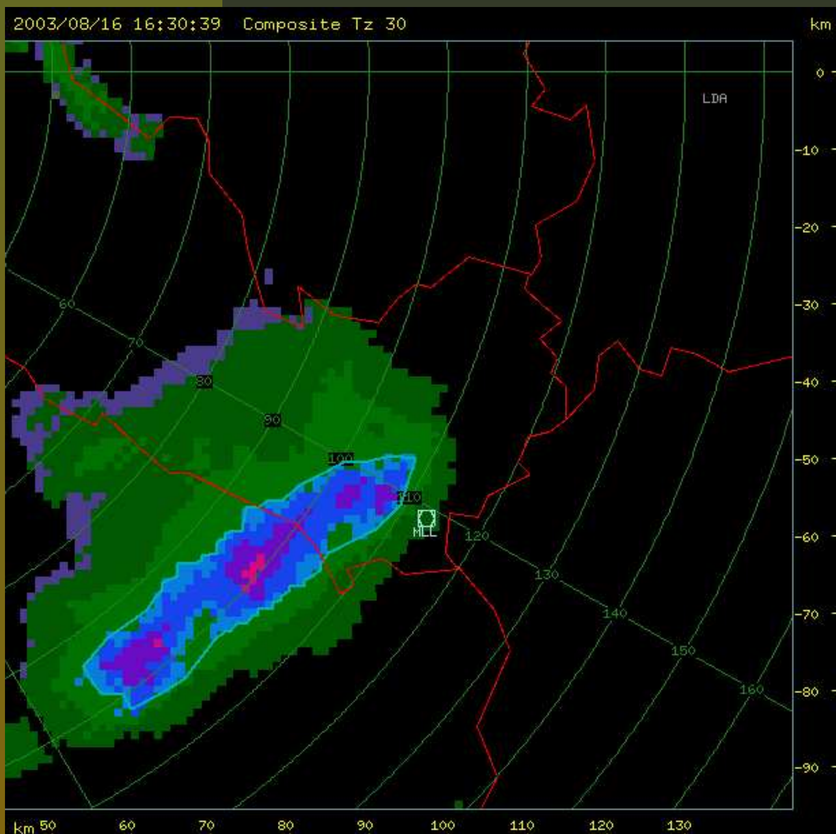


Reflectivity factor average field (1530-1600 UTC)

$\bar{Z}_{max} = 43\, dBZ$ $\mathbf{Z = 200R^{1.6}}$

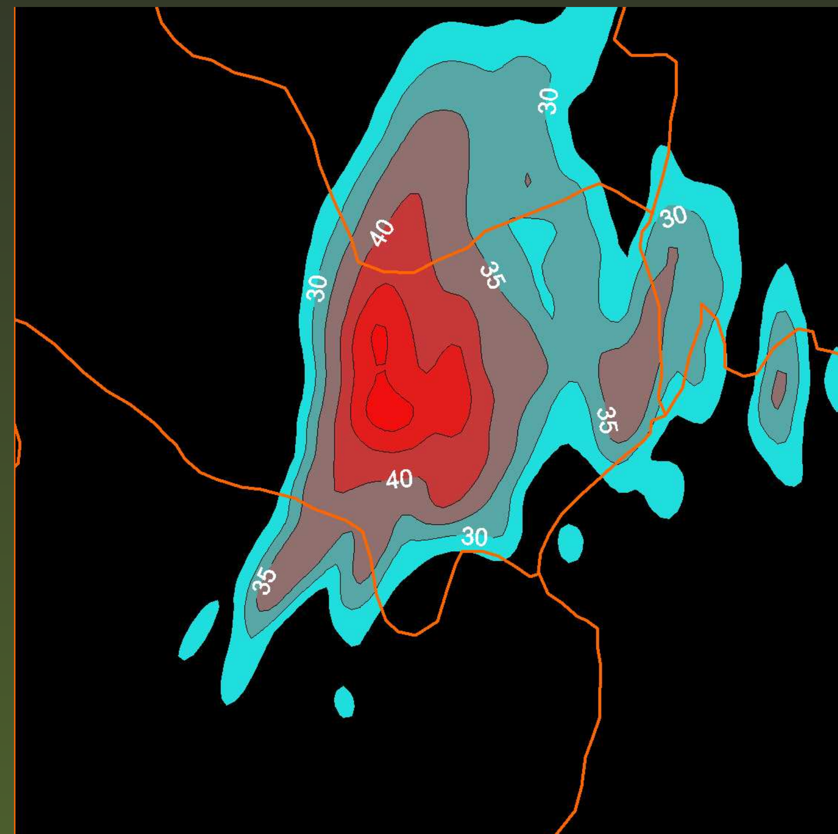
Radar images *vs.* MM5

Reflectivity factor simulation



Composite image of Z at 1630 UTC

$\bar{Z}_{max} = 46.4\, dBZ$

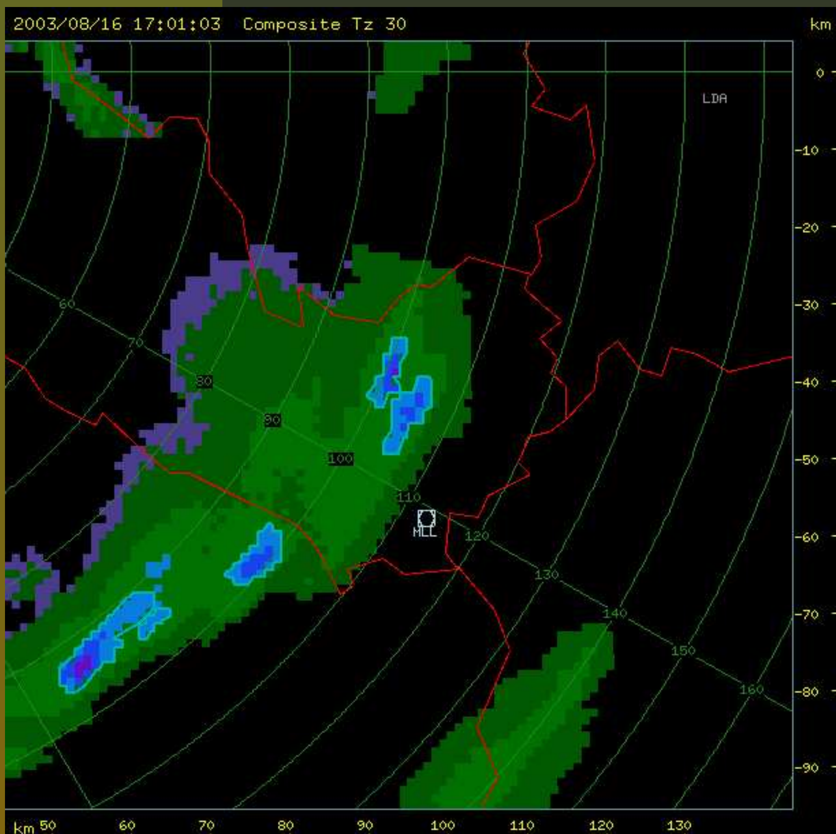


Reflectivity factor average field (1600-1630 UTC)

$\bar{Z}_{max} = 45\, dBZ$

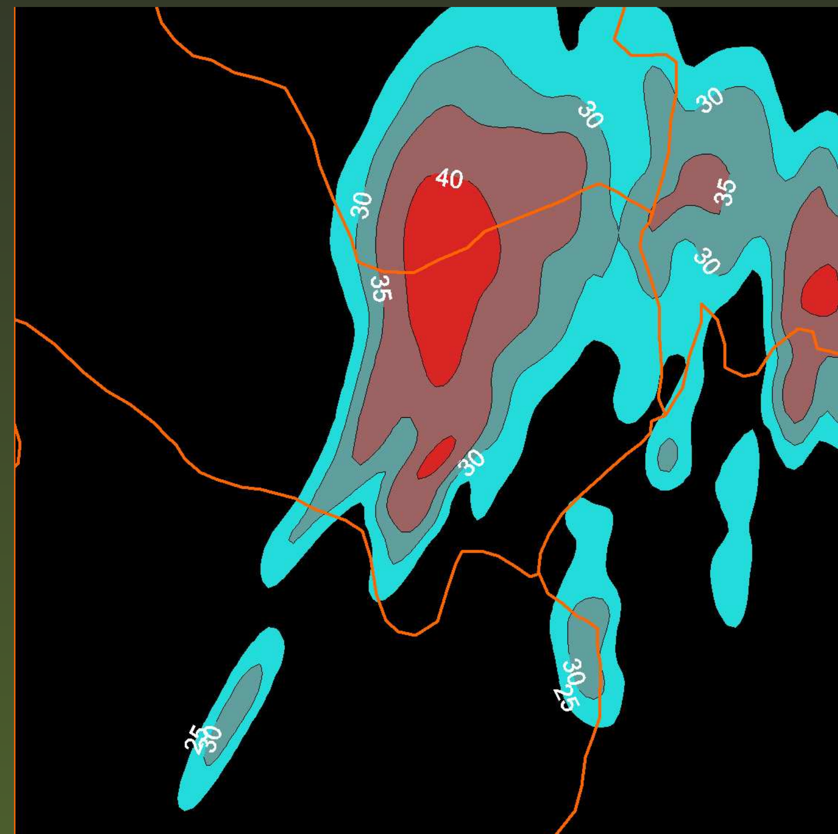
Radar images *vs.* MM5

Reflectivity factor simulation



Composite image of Z at 1700 UTC

$\bar{Z}_{max} = 43.5\, dBZ$

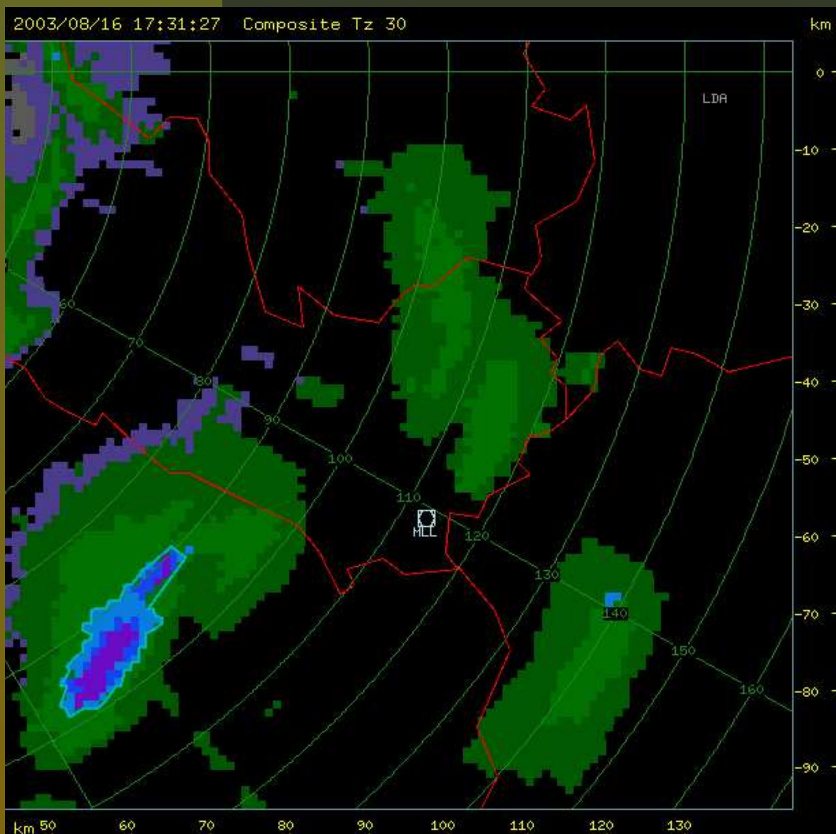


Reflectivity factor average field (1630-1700 UTC)

$\bar{Z}_{max} = 42\, dBZ$

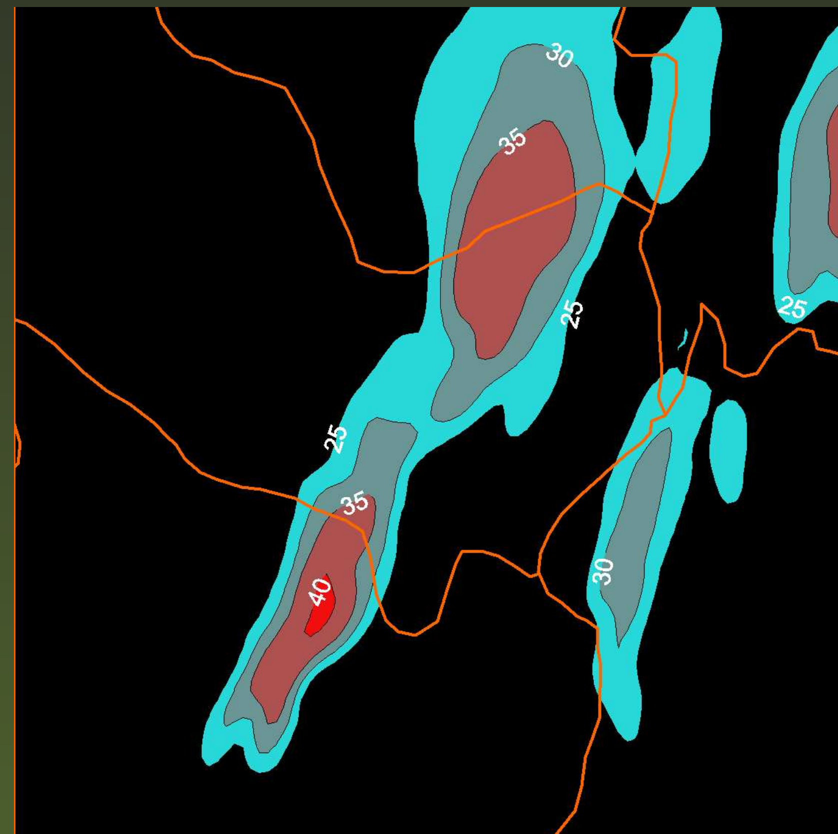
Radar images *vs.* MM5

Reflectivity factor simulation



Composite image of Z at 1730 UTC

$\bar{Z}_{max} = 45.4\, dBZ$

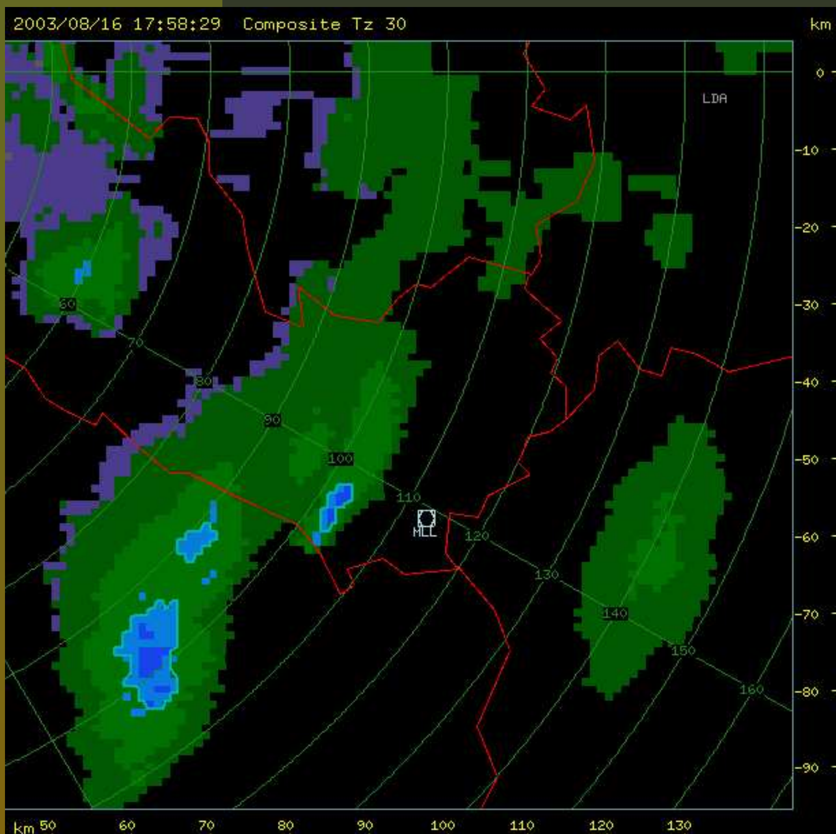


Reflectivity factor average field (1700-1730 UTC)

$\bar{Z}_{max} = 40\, dBZ$

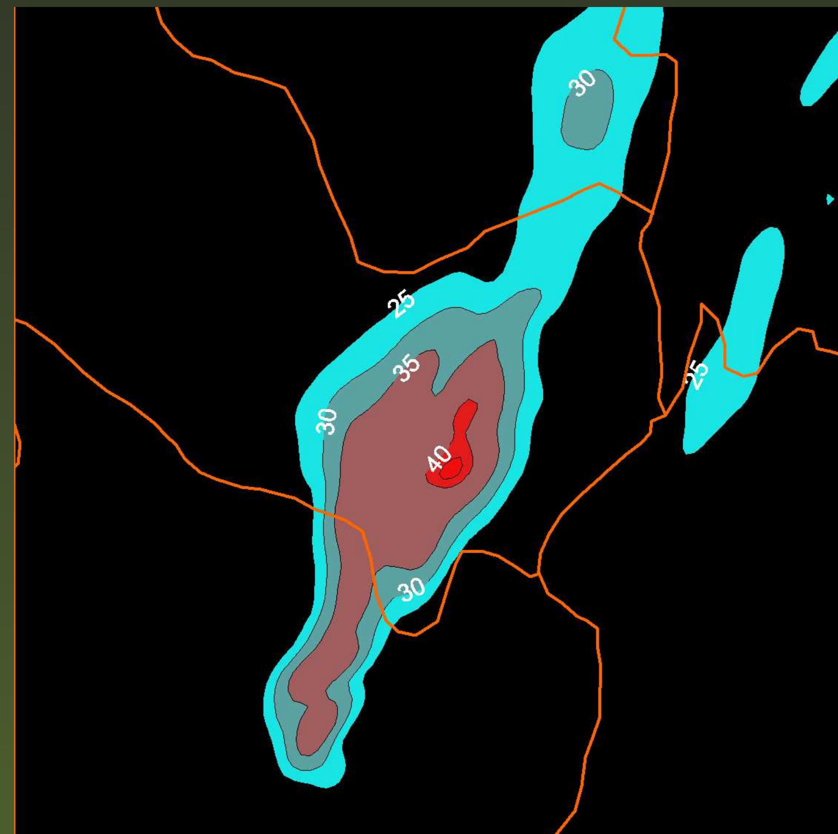
Radar images *vs.* MM5

Reflectivity factor simulation



Composite image of Z at 1800 UTC

$\bar{Z}_{max} = 43.8\, dBZ$



Reflectivity factor average field (1730-1800 UTC)

$\bar{Z}_{max} = 40\, dBZ$

Sensitivity experiment

Four simulations were performed:

- Control simulation: f_{12}
- A simulation without solar radiation: f_1
- A simulation without orography: f_2
- A simulation without both: f_0

Sensitivity experiment

Four simulations were performed:

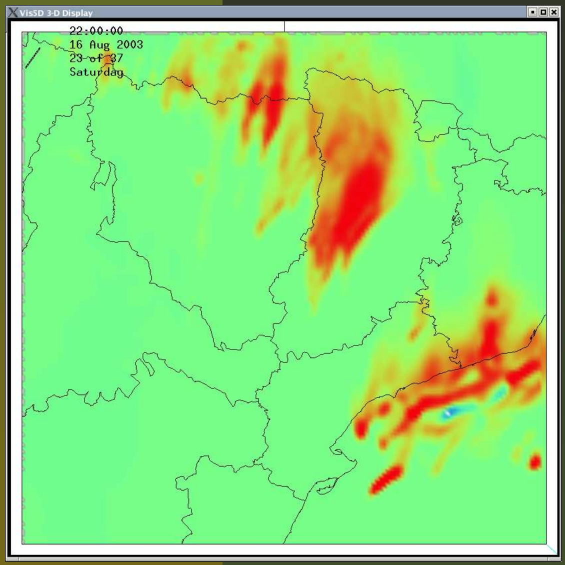
- Control simulation: f_{12}
- A simulation without solar radiation: f_1
- A simulation without orography: f_2
- A simulation without both: f_0

Rainfall induced by ...

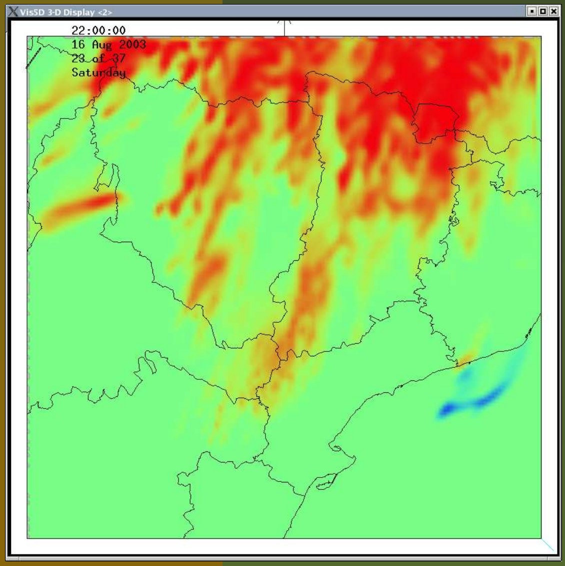
$$\text{terrain: } \hat{f}_1 = f_1 - f_0$$
$$\text{solar radiation: } \hat{f}_2 = f_2 - f_0$$
$$\text{synergic effect: } \hat{f}_{12} = f_{12} - (f_1 + f_2) + f_0$$

Precipitation area

Induced by terrain $\hat{f}_1$

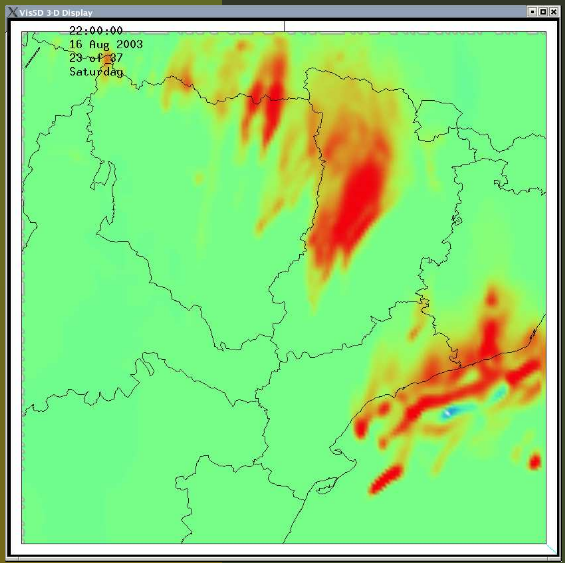


Induced by radiation $\hat{f}_2$

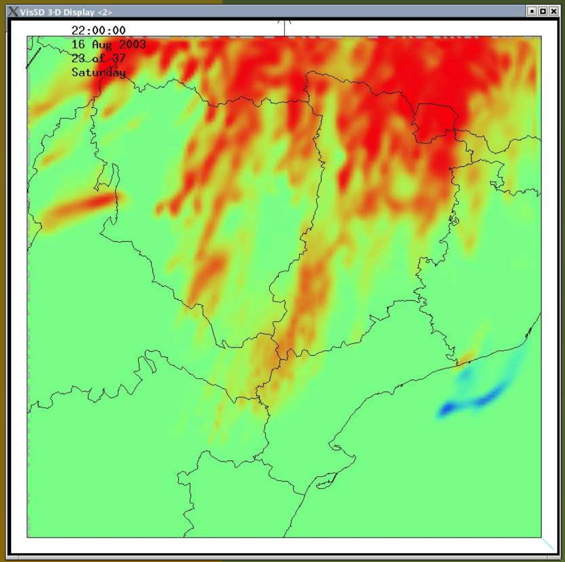


Precipitation area

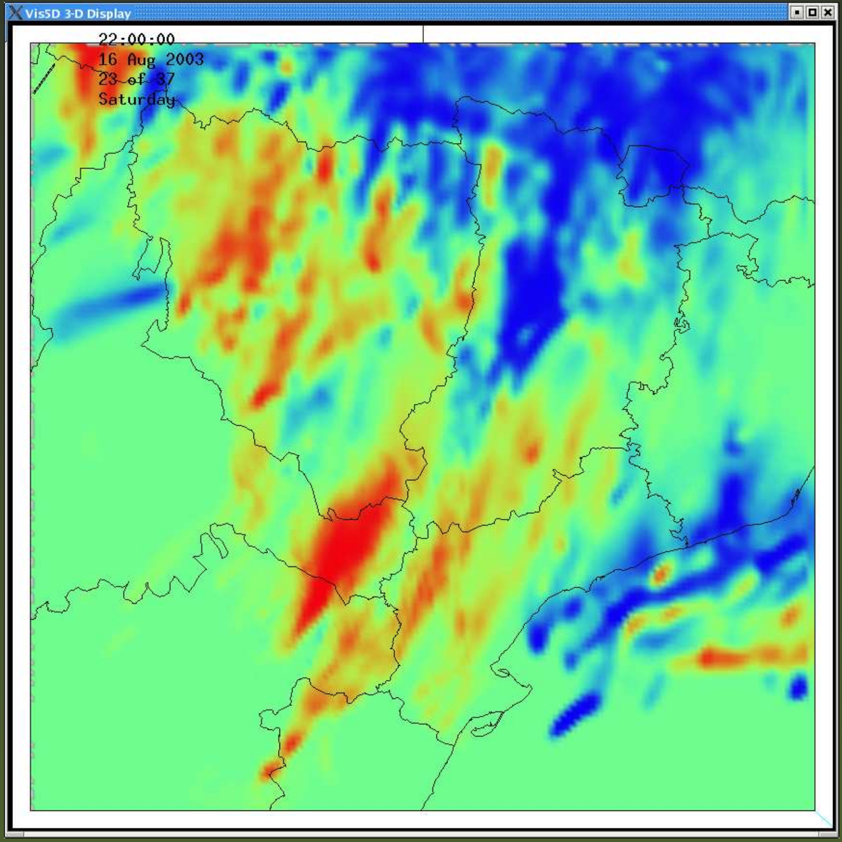
Induced by terrain $\hat{f}_1$



Induced by radiation $\hat{f}_2$

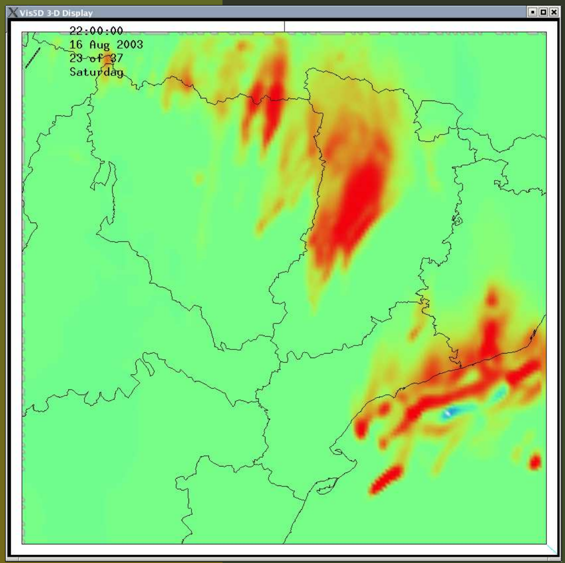


Induced by synergic effect $\hat{f}_{12}$

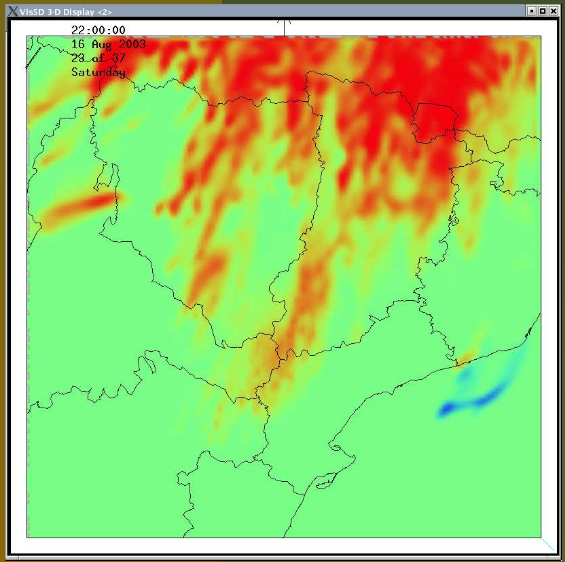


Precipitation area

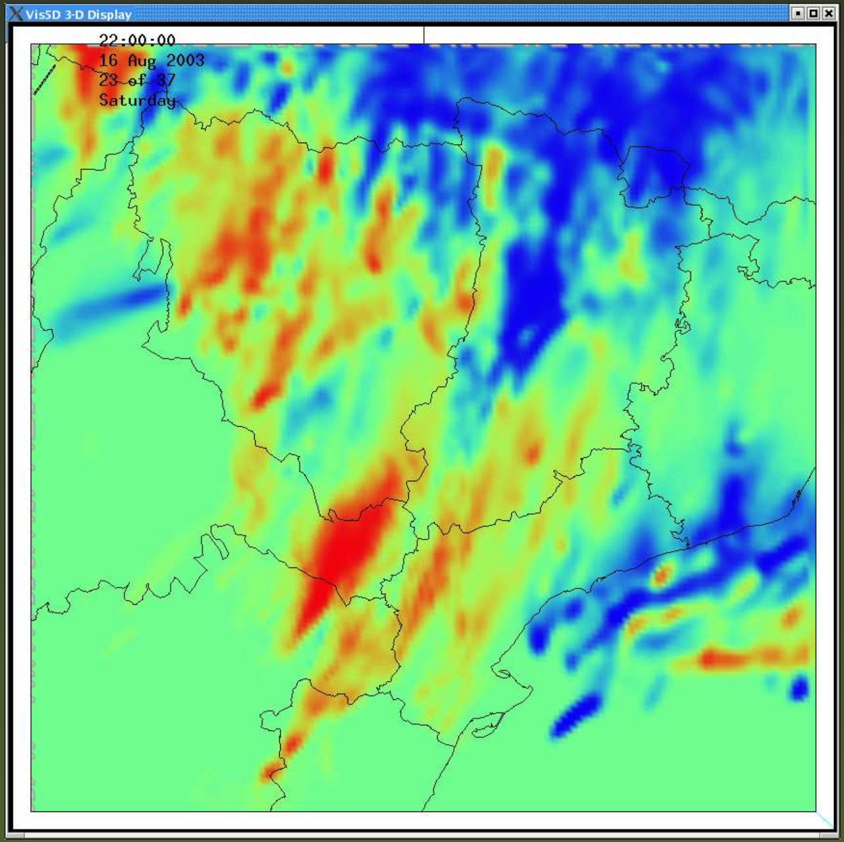
Induced by terrain $\hat{f}_1$



Induced by radiation $\hat{f}_2$



Induced by synergic effect $\hat{f}_{12}$



This interaction is fundamental for rain localization and has a suppressing effect in other areas.

Diagnosis of the meteorological situation of August 16^{th} 2003: an extreme hail event

ECSS 2004

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