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Hailstorms Characteristics And Initiation In Western Catalonia (Spain)

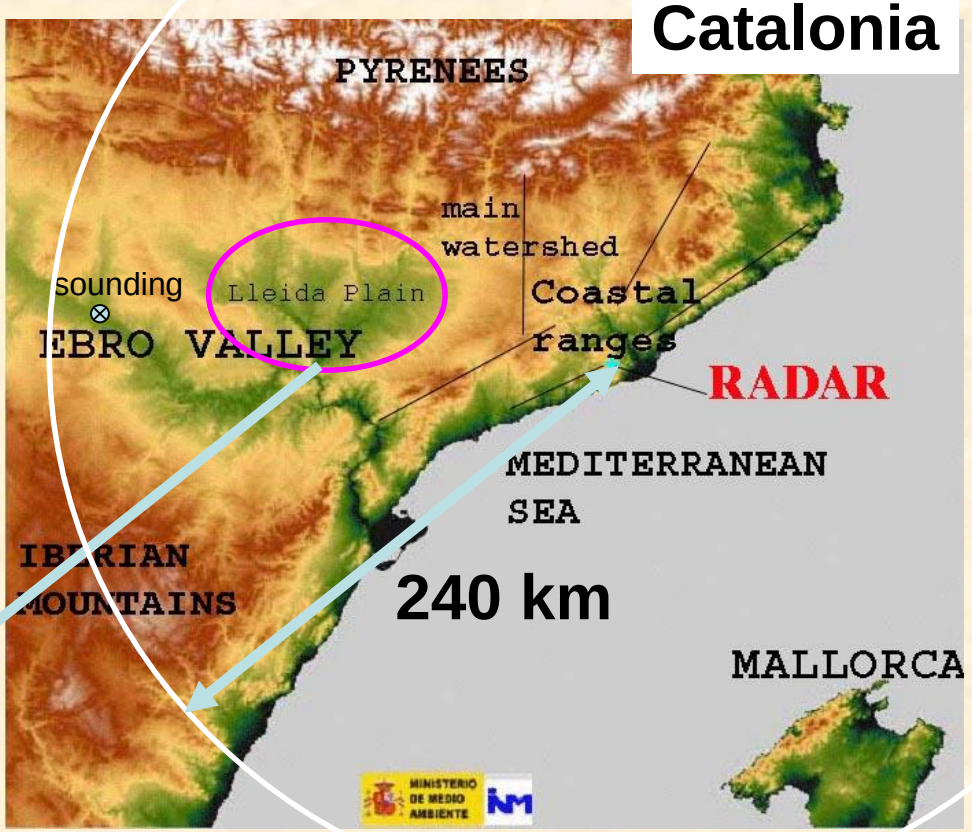
Ramón Pascual Berghaenel

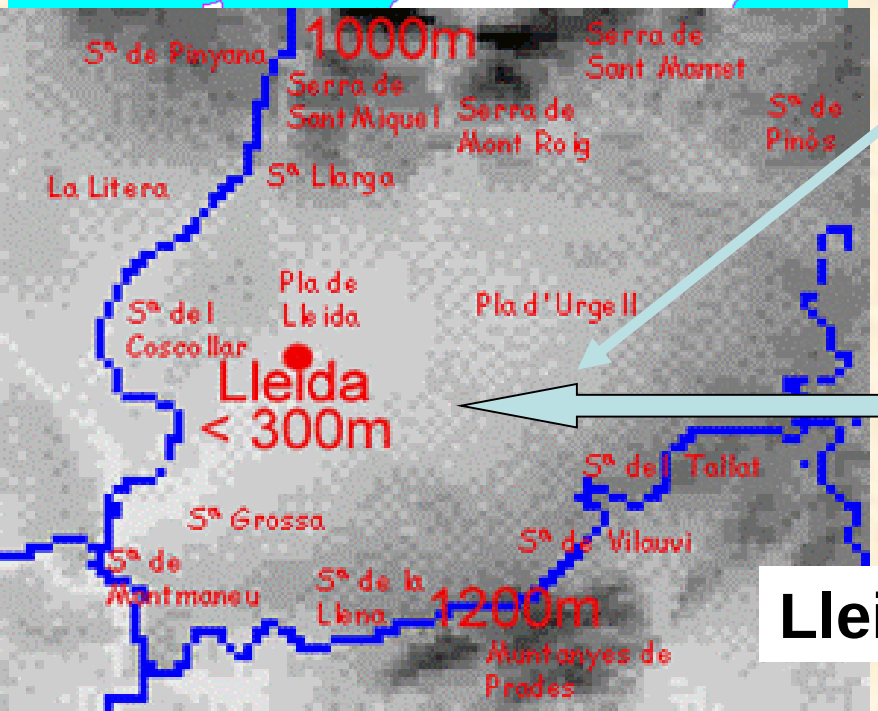
3rd European Conference on Severe Storms.
León, November, 2004.

Geographical Features

Western Mediterranean

Catalonia





Area studied: 36000 km^2

77 municipalities

Lleida Plain

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Data Collection (1)

- Surface observations from two automatic networks (INM, ADV): wind, precipitation, temperature, moisture.
- Hail data from a semiautomatic network (ADV).
- Zaragoza INM sounding data (130 km westward Lleida Plain).
- Numerical model outputs: INM-HIRLAM Model.
- Sea level pressure/frontal analysis charts (Met. Office).
- Satellite imagery: Meteosat (5,6,7) WV channel. NOAA-12,14, 15,16,17 channels 1,2,4,5 and 6.
- Lightning data (cloud to ground) (INM network).
- Radar data (Z) from Barcelona (INM) radar.

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Data Collection (2)

74 hail events (4.5 % of total) (8.2 hail events per season).

Two datasets:

- 47 hail events occurred between 15 April and 15 October, from 1995 to 1999 (lightning analysis). 920 days.

- 27 hail events occurred between 15 April and 15 October, from 2000 to 2003 (radar analysis). 736 days.

Time Series Analysis (1)

Total dataset

Hail events:

August: 22 %

May: 20 %

July: 18 %

October: 1 % (1 case)

First dataset

Hail Events/Thunder. day:

April: 44 % (low wet-bulb-zero height)

May: 33 %

August: 27 %

Severe hail events:

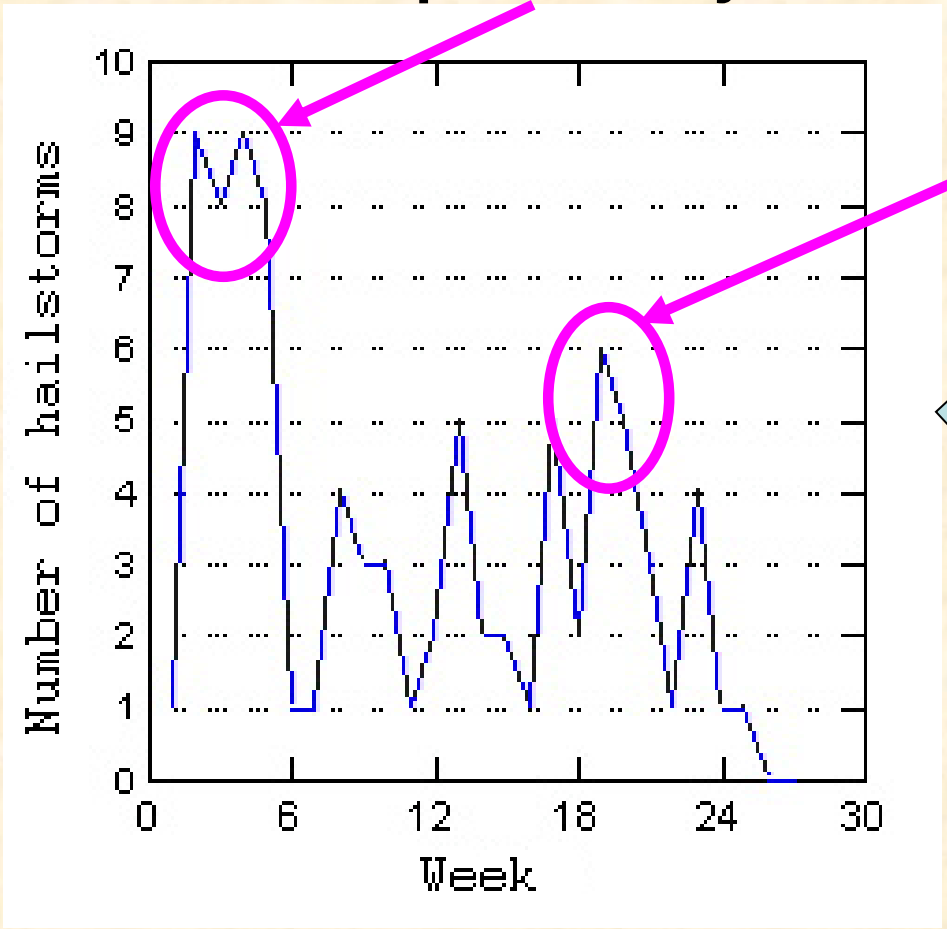
June: 31 %

May: 25 %

August: 25 %

Time Series Analysis (2)

2 April-19 May



5 August-25 August

Seasonal bias

Synoptic bias

Daily persistence is very low but ~ 40 % of hail events have another hail event in 7 days

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Synoptic Features (1)

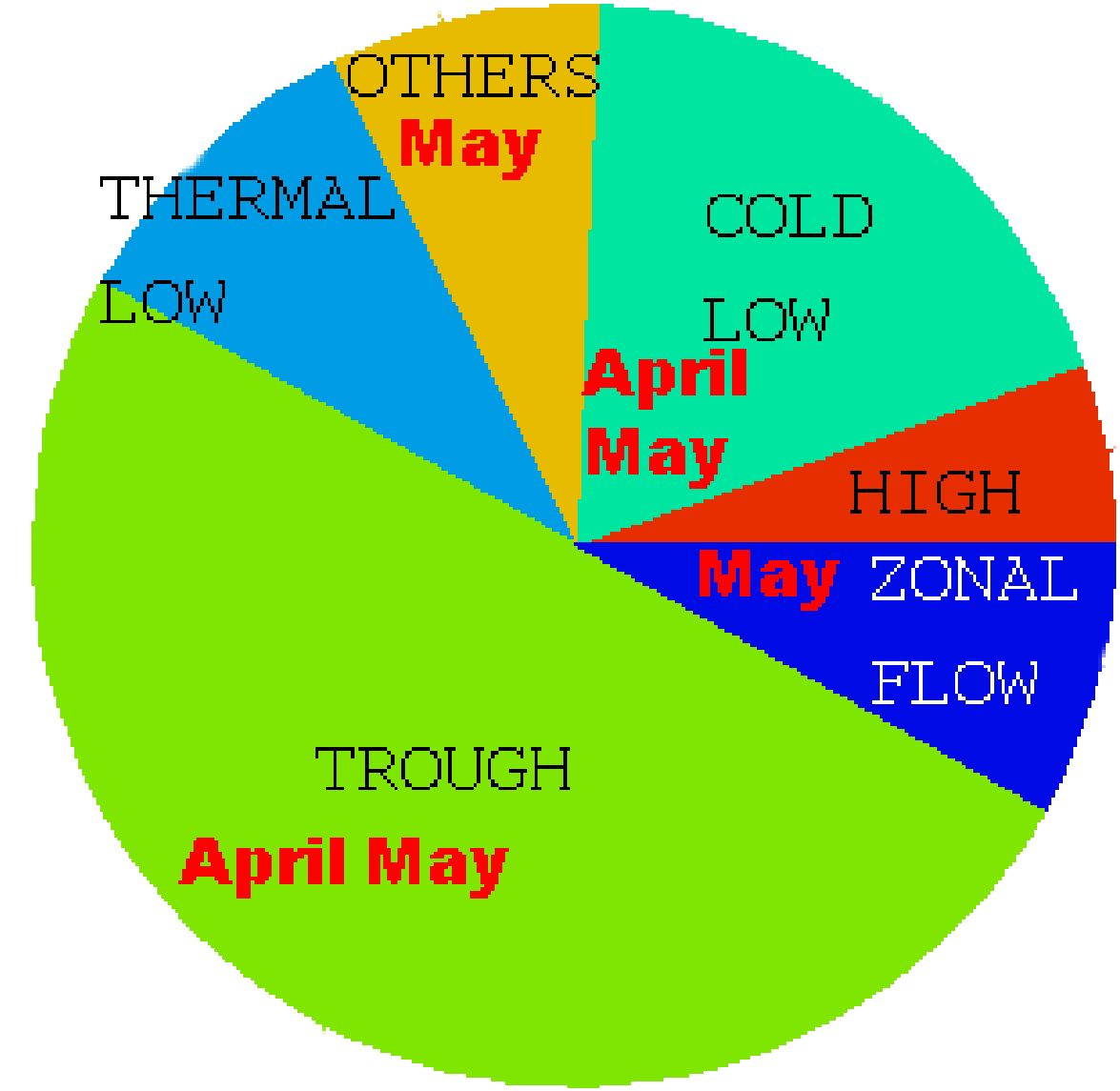
Synoptic patterns more common:

- Deep transient Atlantic trough (clearly identified >= 500 hPa) with or without cold front associated. Difluence.
- Westerly or southwesterly flow with embedded transient short wave (better identified in WV imagery). Difluence.
- Centred cold low.
- Thermal low over Iberian Peninsula.

Also:

- Westward moving synoptic troughs (retrograde).
- Subtropical interaction: Very important in spring.

Synoptic Features (2)



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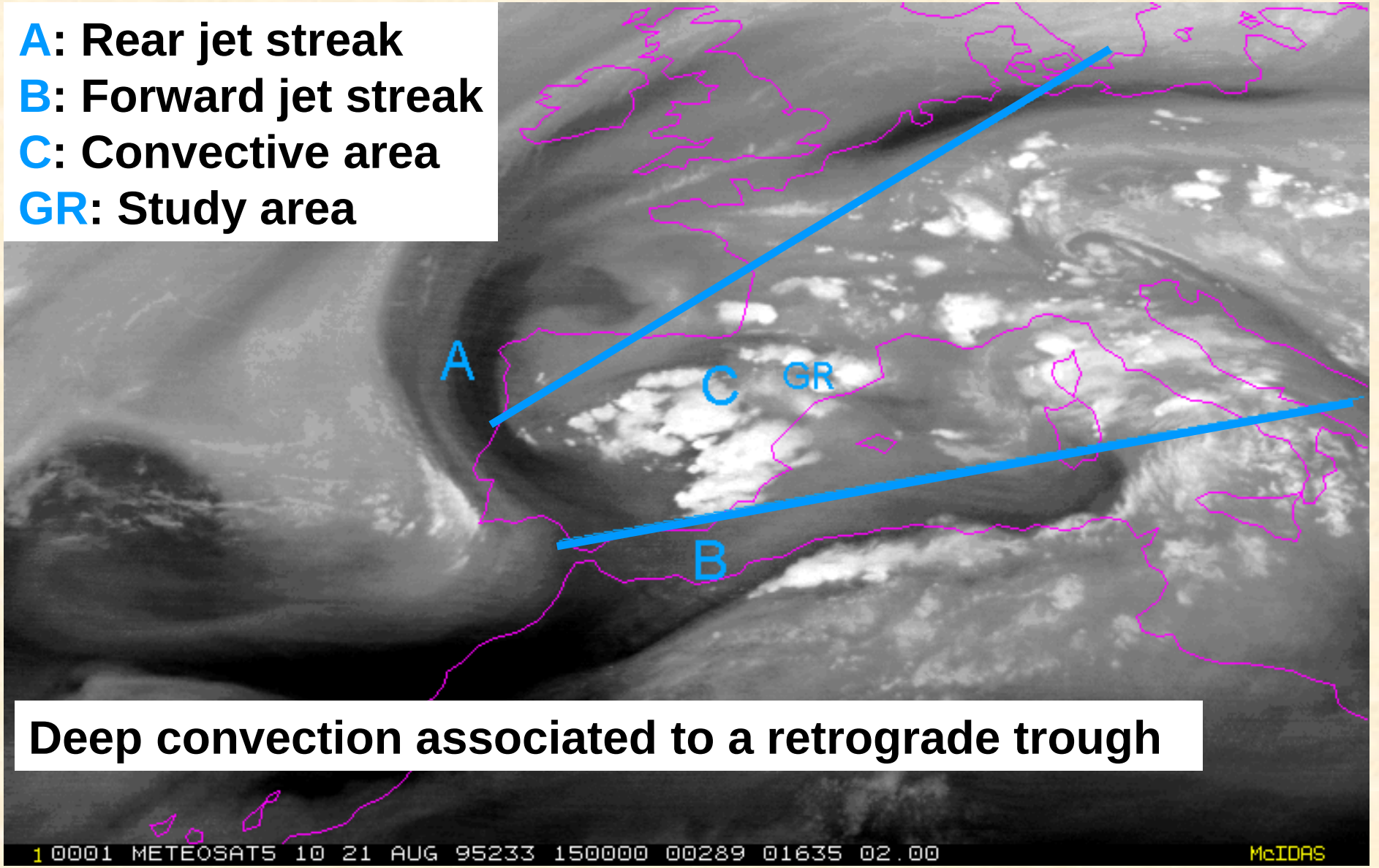
Synoptic Features (3)

A: Rear jet streak
B: Forward jet streak
C: Convective area
GR: Study area



Deep convection associated to a retrograde trough

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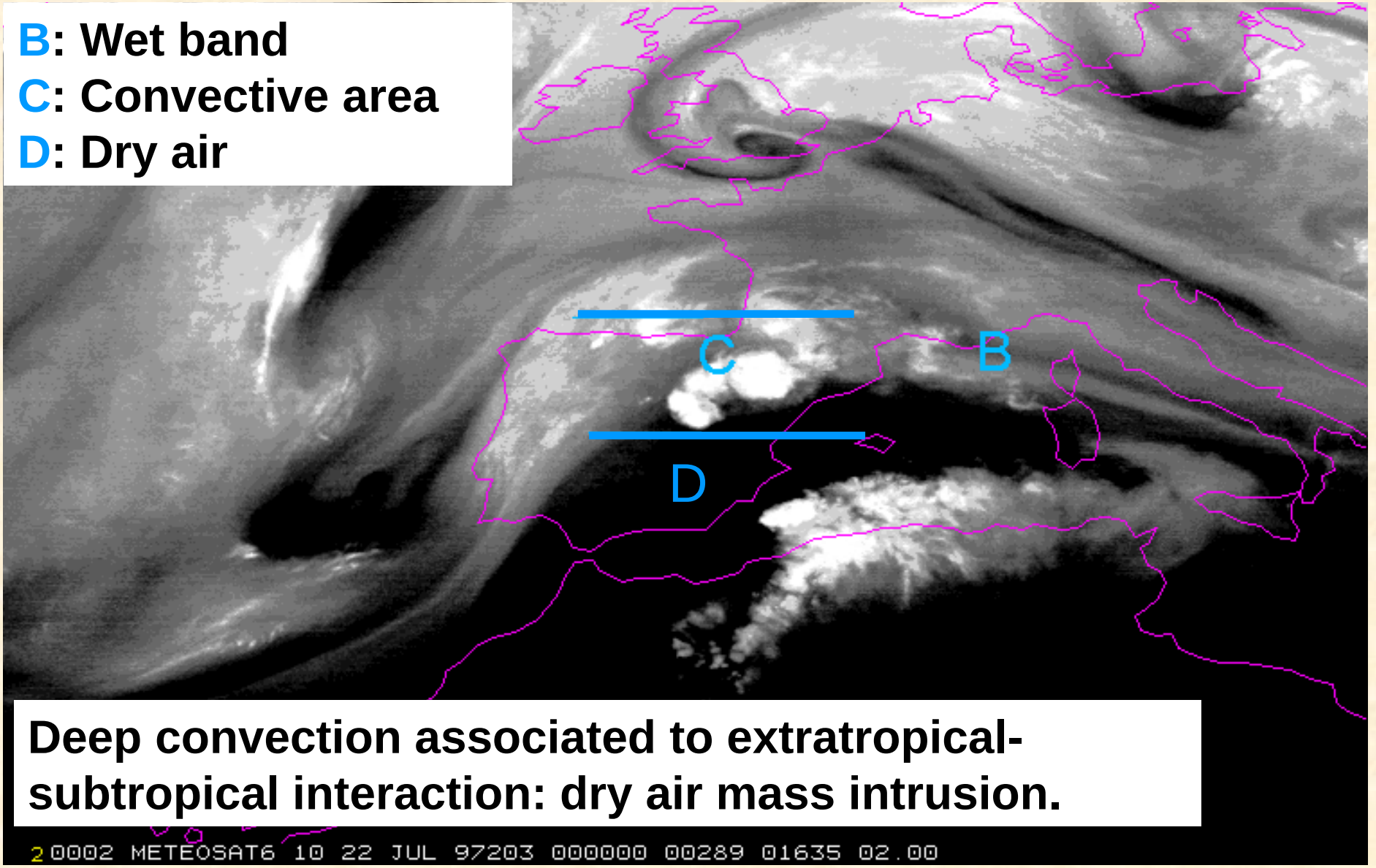
Synoptic Features (4)



Deep convection associated to extratropical-subtropical interaction: dry air mass intrusion.

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Synoptic Features (5)

	T850M	T700M	T500M
April	6	-4	-22,3
May	8,3	-1,6	-19,3
June	15,9	5,4	-13,5
July	16,2	5,6	-12,4
August	16,1	4,9	-12,6
September	13,6	2,8	-14,1
	T850MAX	**T700MAX**	**T500MAX**
April	10	0	-18
May	15	4	-14
June	18	8	-11
July	20	8	-10
August	22	8	-10
September	16	5	-13

Mean value

Seasonal bias of synoptic patterns and seasonal trend

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Mesoscale Features (1)

Dynamic mesoscale elements identified in WV imagery (upper levels):

- Short wave troughs
- Mesoscale vortices
- Jet streaks

- **Other mesoscale elements (low levels):**

- Boundaries
- Kinematic convergence zones

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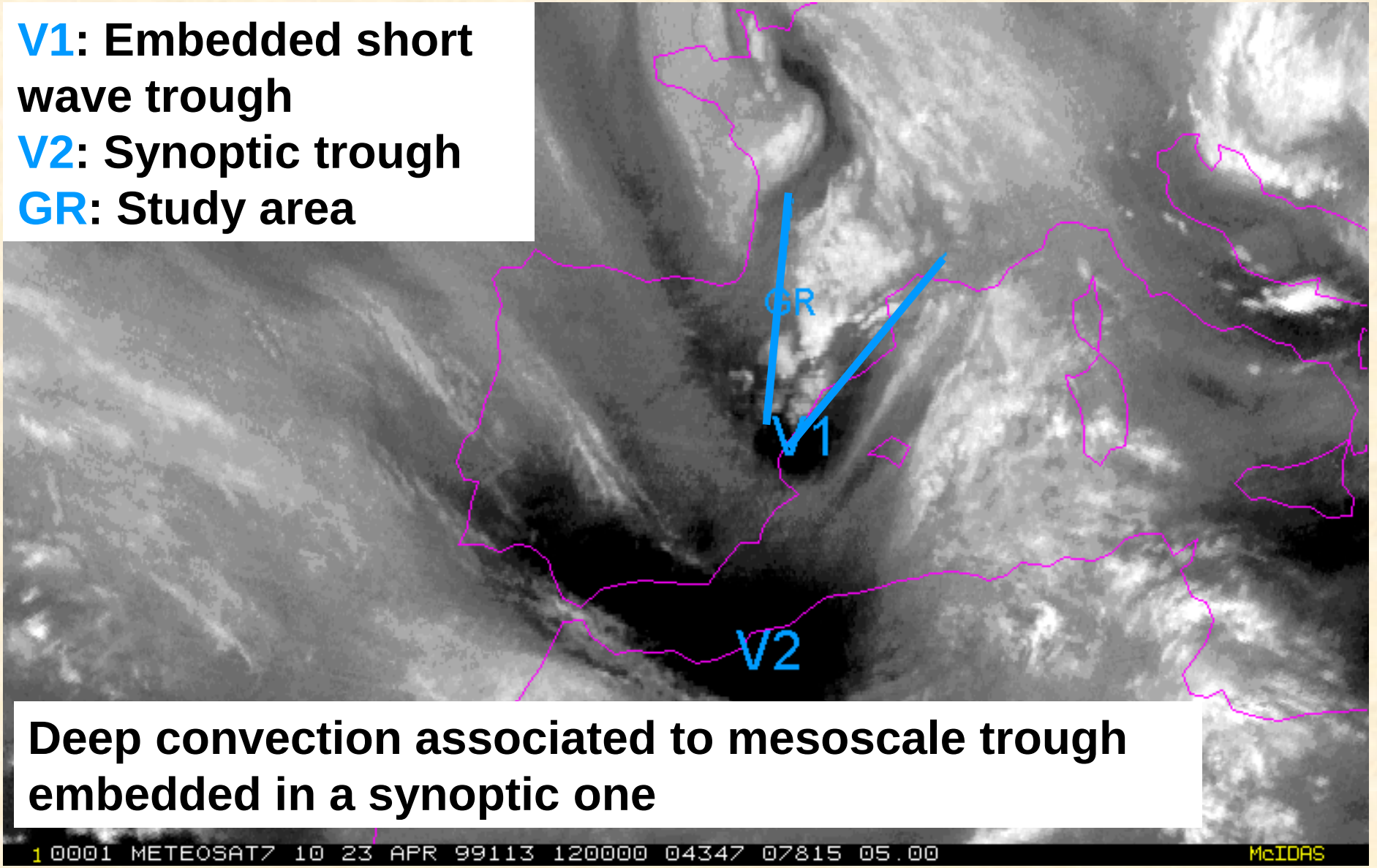
Mesoscale Features (2)

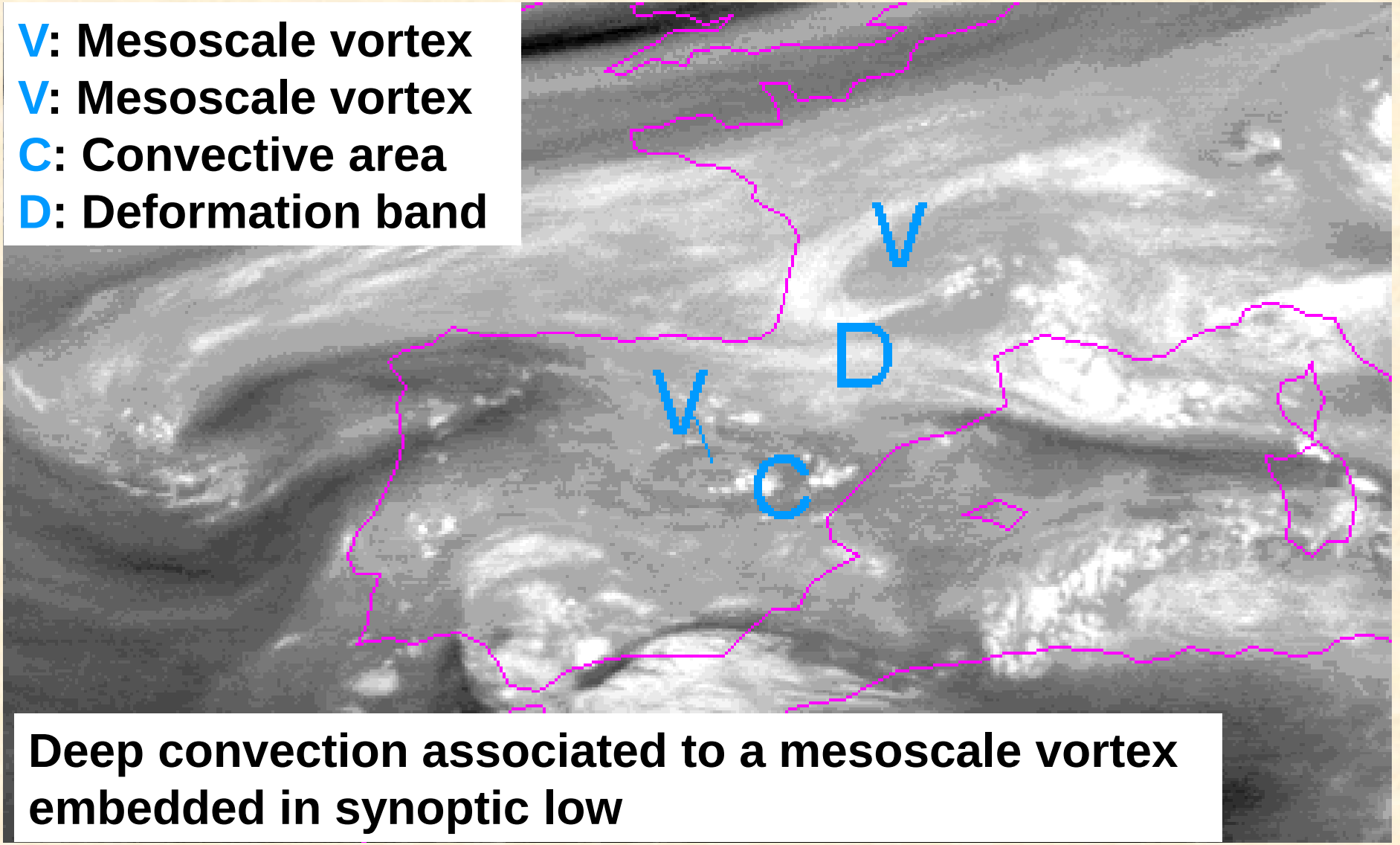
V1: Embedded short wave trough
V2: Synoptic trough
GR: Study area



Deep convection associated to mesoscale trough embedded in a synoptic one

Mesoscale Features (3)

V: Mesoscale vortex
V: Mesoscale vortex
C: Convective area
D: Deformation band



Deep convection associated to a mesoscale vortex embedded in synoptic low

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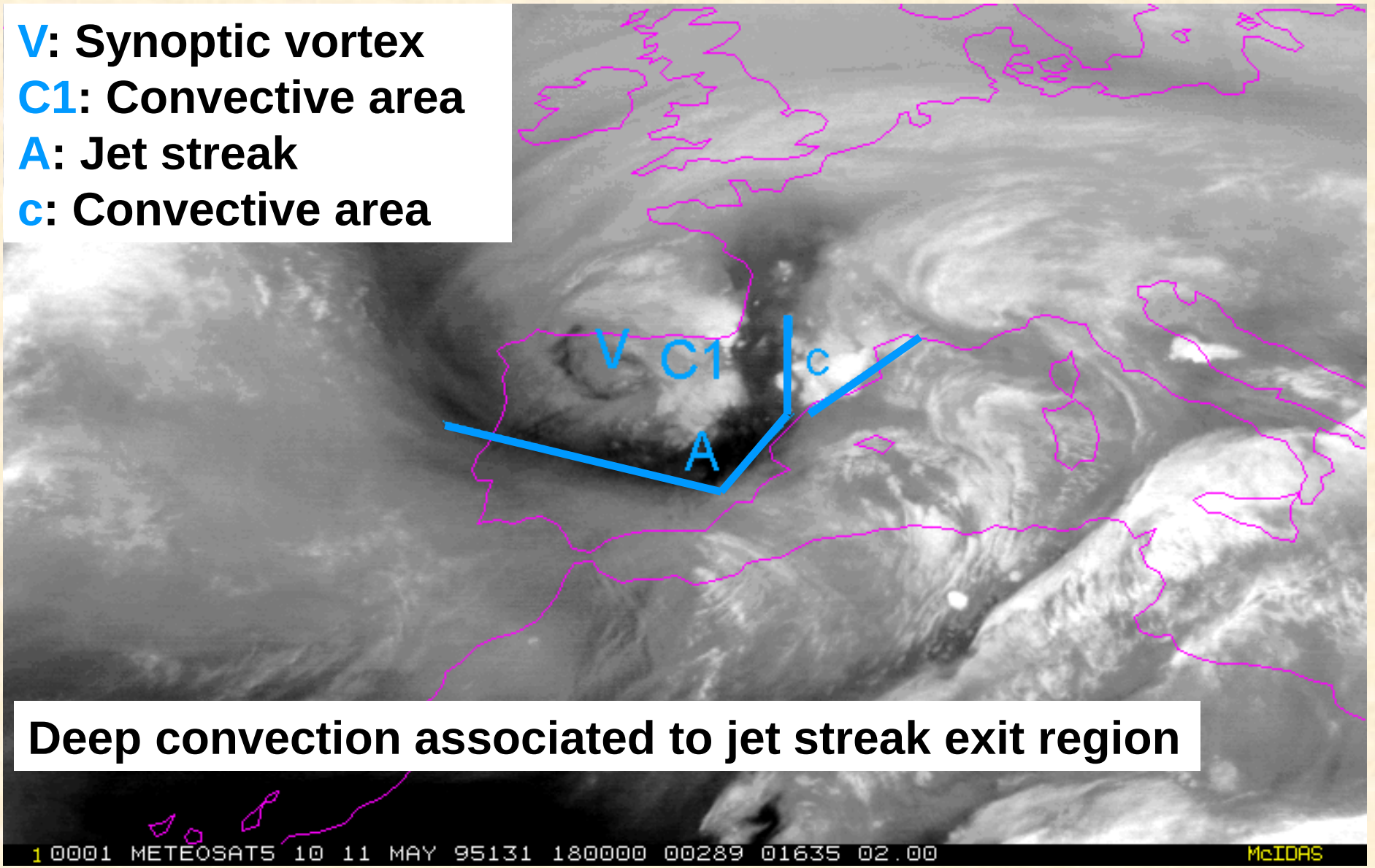
Mesoscale Features (4)

V: Synoptic vortex
C1: Convective area
A: Jet streak
c: Convective area



Deep convection associated to jet streak exit region

Mesoscale Features (5)

Planetary boundary layer convergence zones: lifting mechanisms

- Surface low over Ebro Valley.

origin 1) strong solar heating in the dry areas of the central Ebro Valley and 2) interaction between southerly and south-westerly synoptic flow and Iberian Mountains.

- Transient boundaries northwest-southeast oriented moving eastward.
- Frequent stationary boundary north-south oriented between Atlantic wet air masses over Iberian Peninsula and African dry air masses over western Mediterranean sea.

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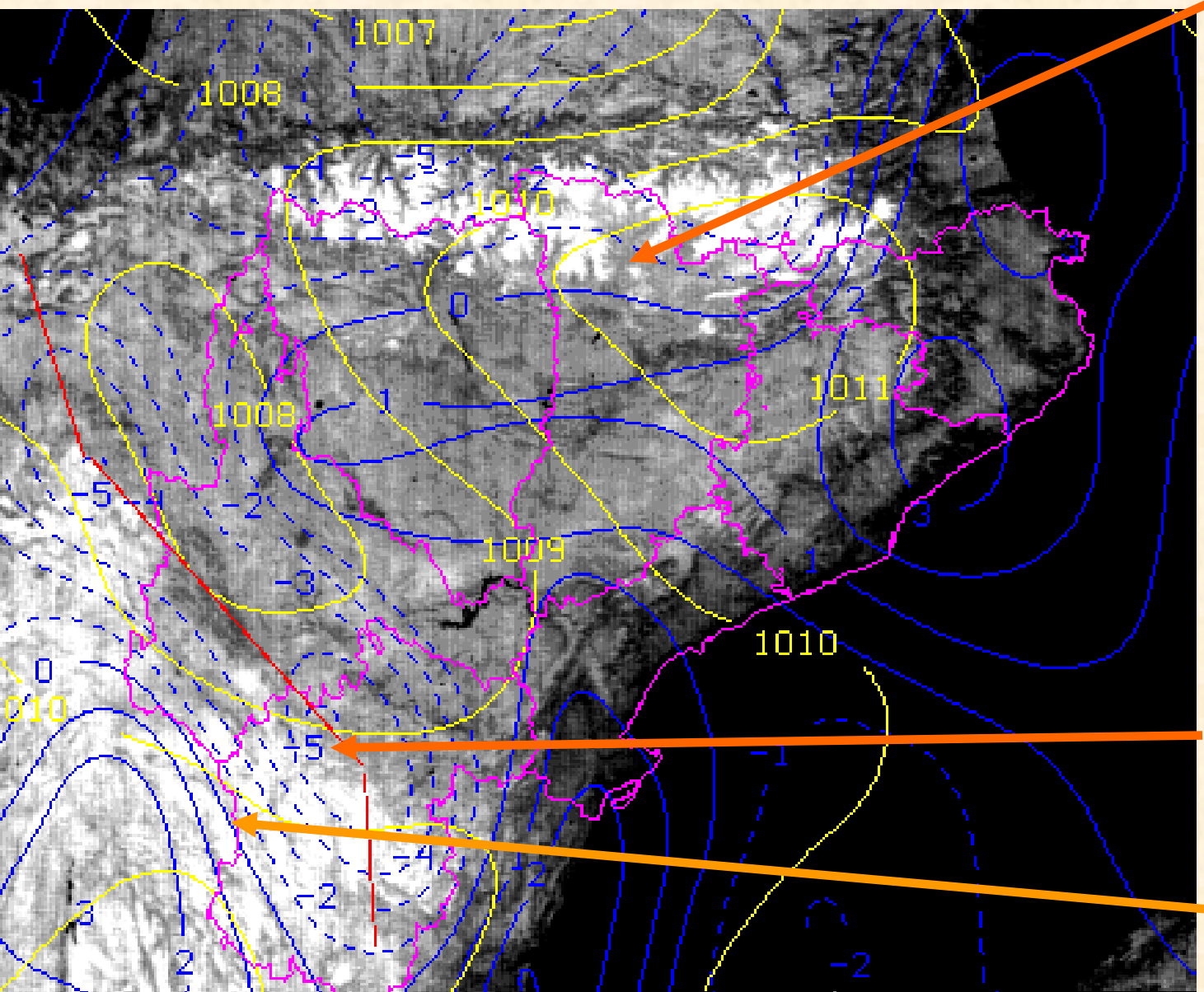
Mesoscale Features (6)



Pyrenees

6 August 1999
12 UTC
HIRLAM 0.5º

Yellow: PSL
Blue: 850 hPa divergence
Red: Convergence axis

Convergence area

Iberian Mountains

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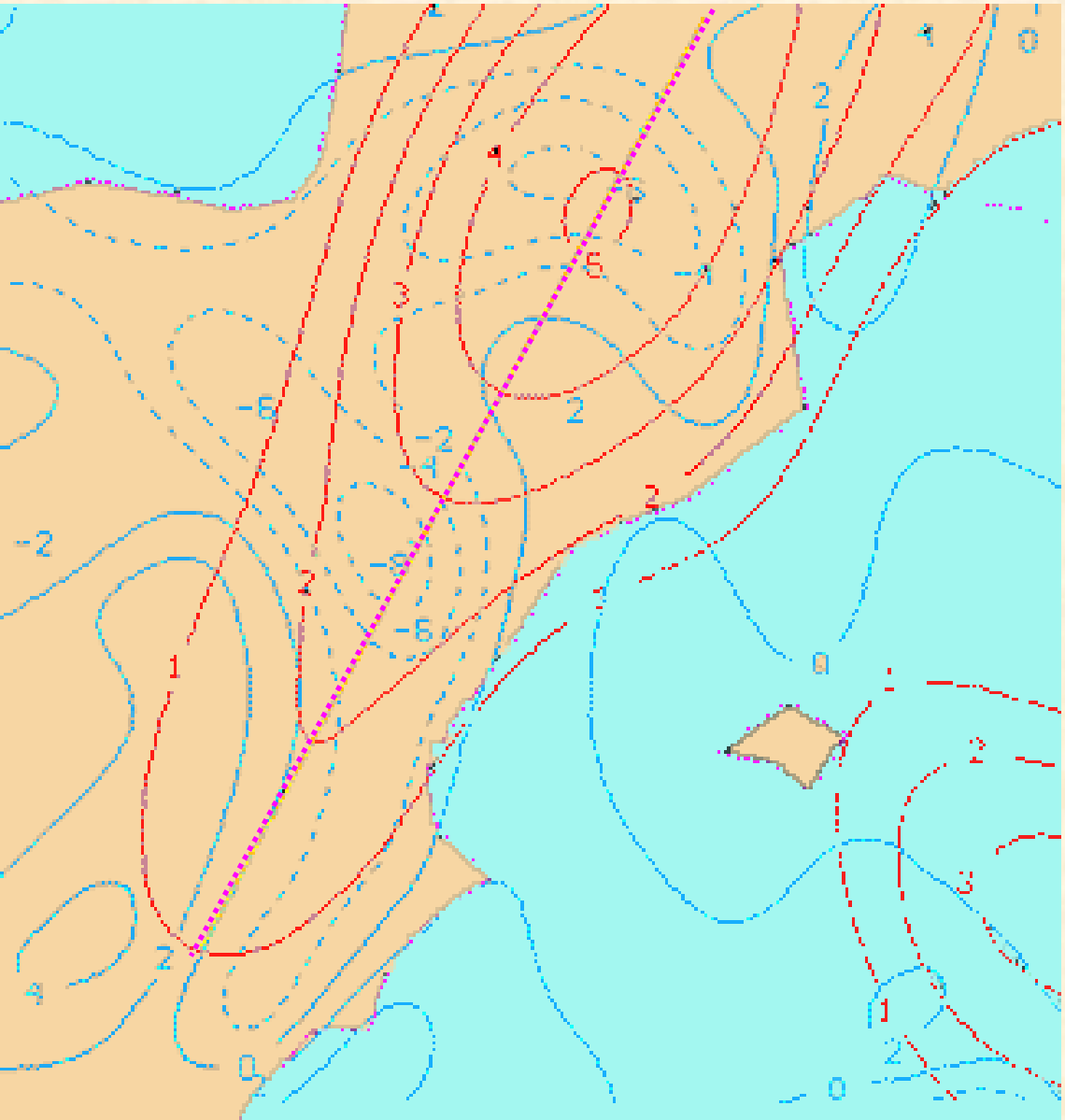
Mesoscale Features (7)



6 August 1999 12 UTC
HIRLAM 0.5º

Blue: 850 hPa divergence
Red: Thermal Frontal Parameter (PFT)
Pink: Boundary axis

$$PFT = -\vec{u}_{\nabla\theta_w} \nabla |\nabla\theta_w|$$

$$\vec{u}_{\theta_w} = \frac{\nabla\theta_w}{|\nabla\theta_w|}$$

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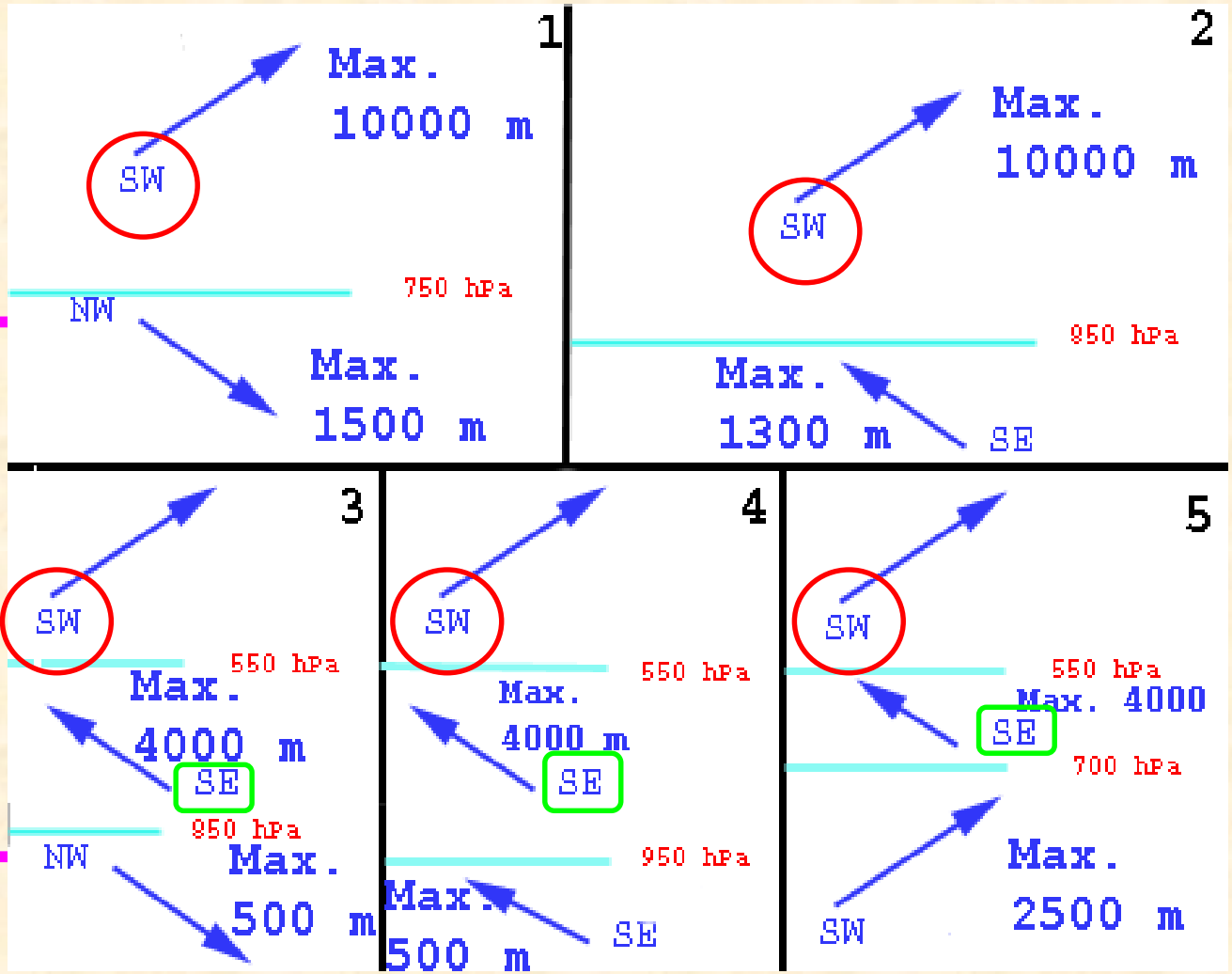
Mean Wind Vertical Profiles

35 soundings 00 UTC; 40 soundings 12 UTC

2 layers patterns

3 layers patterns



Notable vertical shear

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Convection Analysis. Methodology

Lightning data for 47 days (thunderstorms):

1. Objective CG discharges spatial and time distribution.
2. Subjective origin areas and main trajectories identification.
3. Subjective thunderstorms duration determination.

Radar data for 27 days (2D convective structures):

1. Subjective Z field interpretation (images movies).
2. Objective identification of cells origin.
3. Subjective identification of triggering mechanism.

Hailstorms Characteristics (1)
Lightning Data

- Thunderstorm analysis: 164 days. 16998 CG correctly detected (pink numbers).

150 km

125 km

428	**329**	239	80	258
374	***3040***	***2740***	***2278***	268
348	***2632***	***3217***	***3091***	228
258	94	132	**281**	147

Red rectangle: Study area

Blue rectangle: Surrounding area

CG spatial distribution and thunderstorm entrance zones

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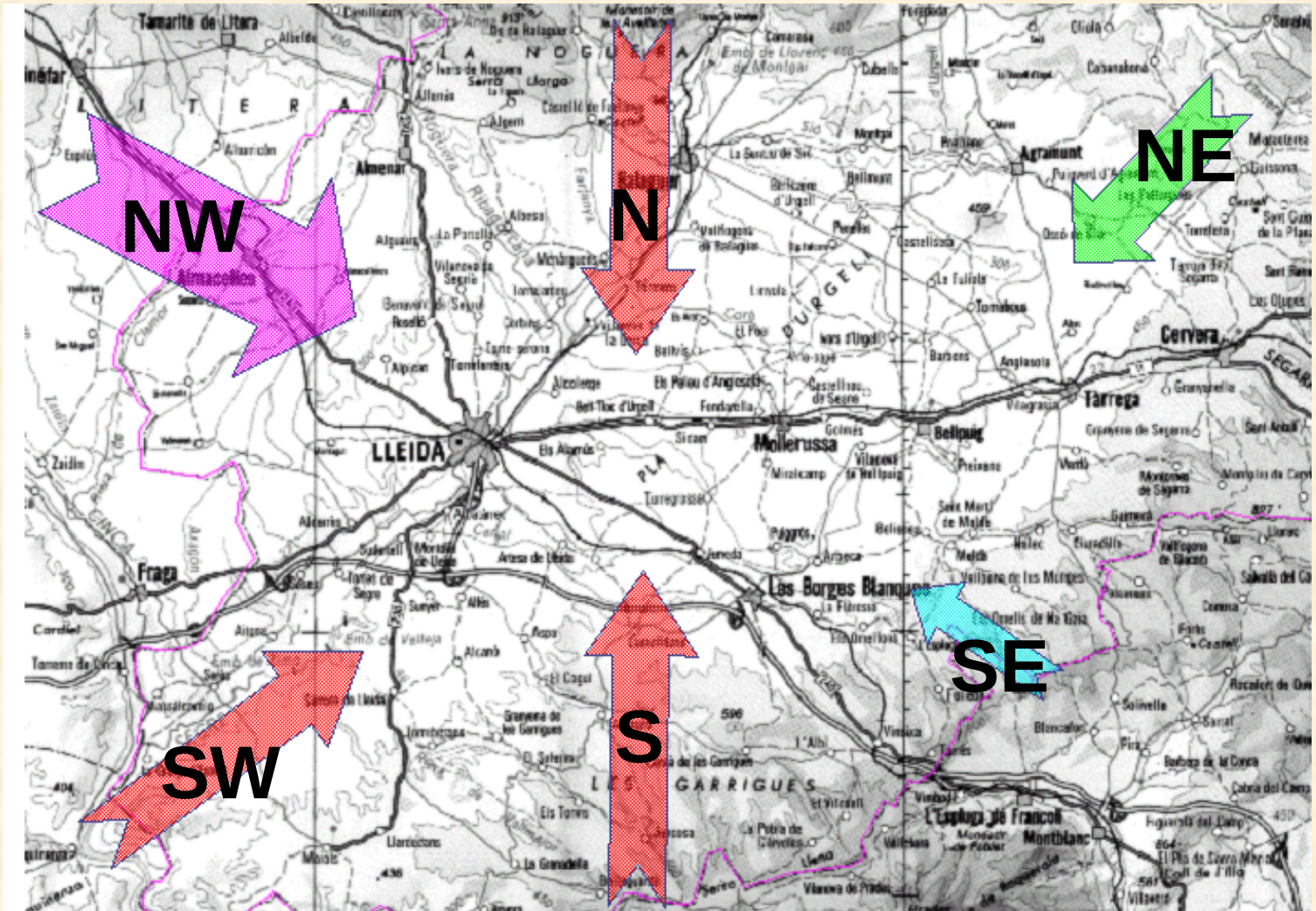
Hailstorms Characteristics (2)

Entrance directions to the zone



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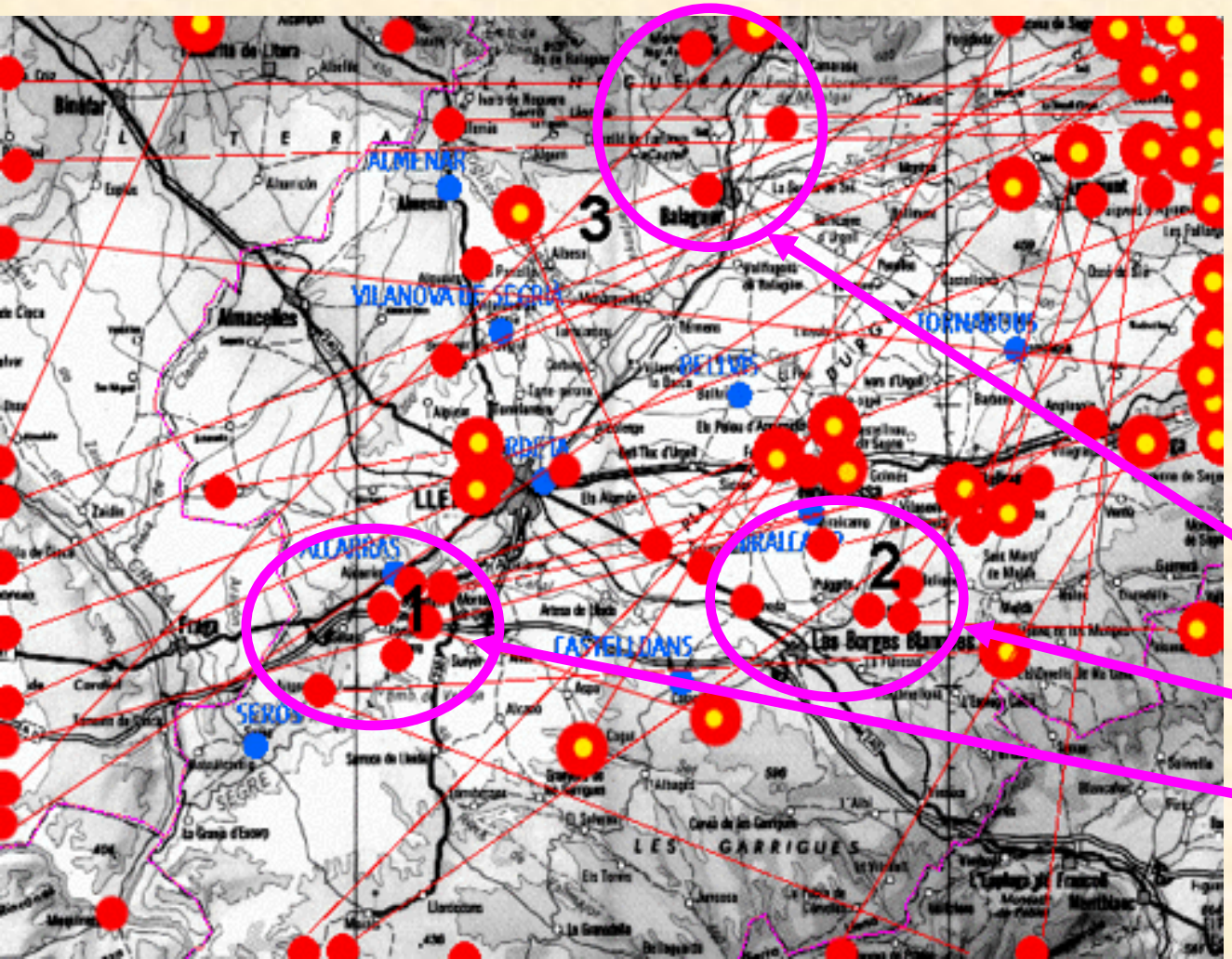
Hailstorms Characteristics (3)

Hailstorms analysis: 42 days (5 days without CG data).



S/SW/W ➡ E/NE

16 (25%) hailstorms almost stationary

Origin

Final

Hot spots

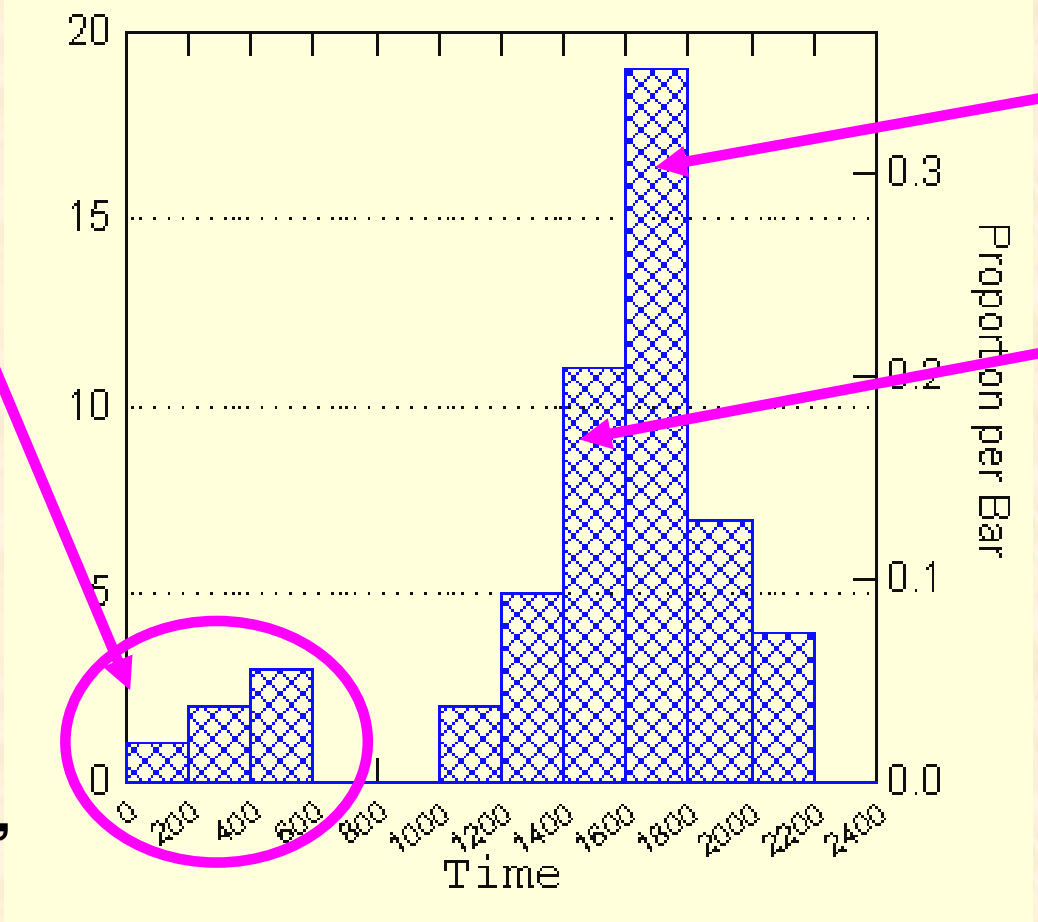
Hailstorms Characteristics (4)

Frequency of hailstorms start-time (CG data)

Nocturnal convection (external origin).

Dynamic forcing

Duration:
Internal 1 h (life cycle)
External 1 h:30' (propagation)



16:00 UTC - 18:00 UTC

14:00 UTC - 16:00 UTC

Dynamic + thermal forcing

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Hailstorms Characteristics (5)
Radar Data

Band (cm)	C; λ = 5.4
Resolution (km)	Normal: 2 x 2. Doppler: 1 x 1
Range (km)	Normal: 240. Doppler: 120
Exploration Interval (min.)	10 both modes
Peak Power (kW)	250
Beamwidth (deg.)	0.9°
Pulselength (m)	Normal: 600. Doppler: 150

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Hailstorms Characteristics (5)

- **Complete set:** 27 days (751 ZNP selected).
- **Raw polar volumes correction:** Ground clutter identification and substitution, orography screening correction, rain over radome effect recovering (Sempere-Torres *et al*, 2003).
- **PPI0s generation.**
- **Identification and tracking of convective cells** (Steiner et *al*, 1995): Operational objective identification software (YRADAR) (Martin, 2001).
  1. Pixel convective: Z ≥ 45 dBZ or Z ≥ 40 dBZ and it is a local maximum or it is close enough to a convective pixel. Convective 2D structures (cells) identified.
  2. A cell as new when it is not linked to any previous structure.

Hailstorms Characteristics (8)

Convective structures:

- Isolated single cells (11 events)
- Squall lines (9 events) with and without trailing stratiform area associated.
- Others: Cell groups, stratiform bands with embedded cells.

Structures displacement (Propagation + Movement):

Main trajectories: SW to NE and W to E.

Anomalous trajectory: SE to NW (from hot spot 2) with outflow triggering mechanism.

Hailstorms Characteristics (6)

Convection initiation:

2D new structures identified: 270

Daily max. 26, min. 0, mean 10

Mesoscale effects:

Orography, Boundaries **+**

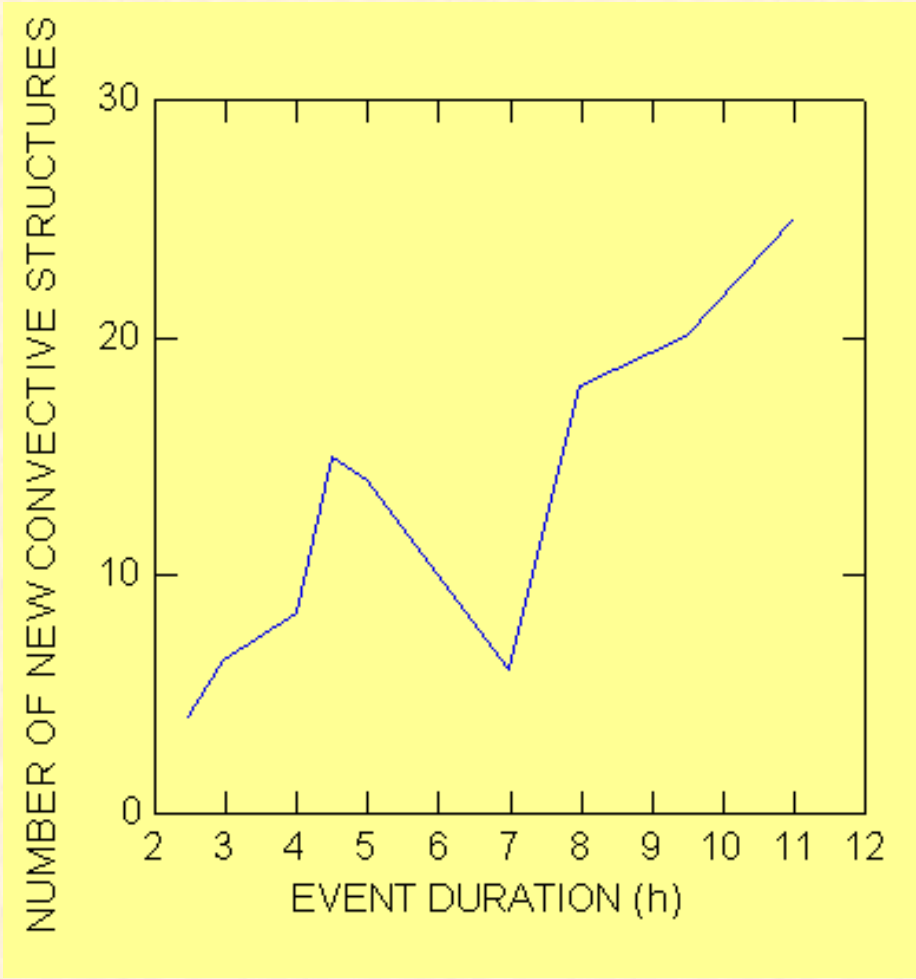
Convective scale effects:

Outflows (secondary convection), splits, merging, **+**

Identification algorithm effects : thresholds, ...

Radar effects:

Attenuation, screening, …



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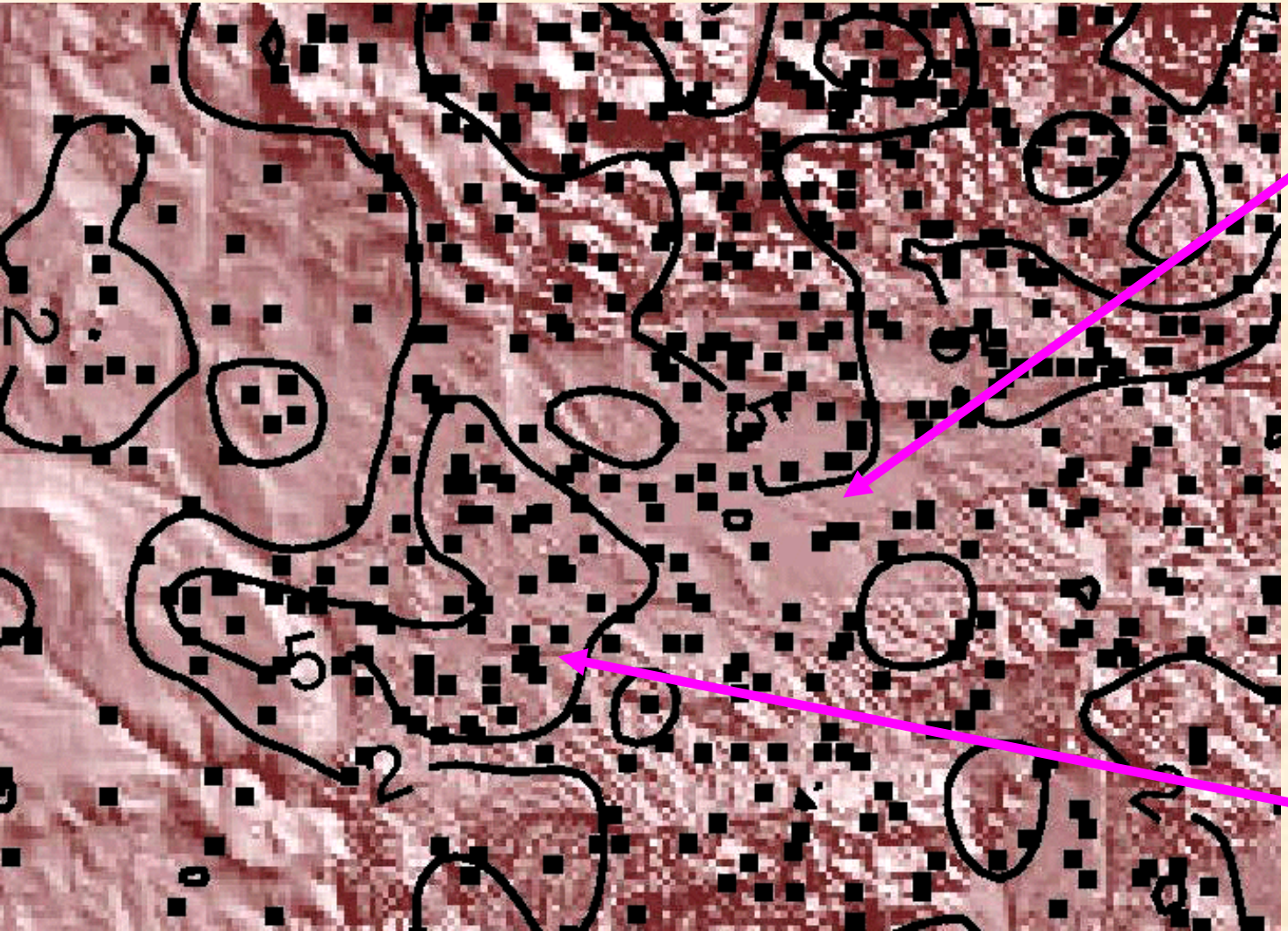
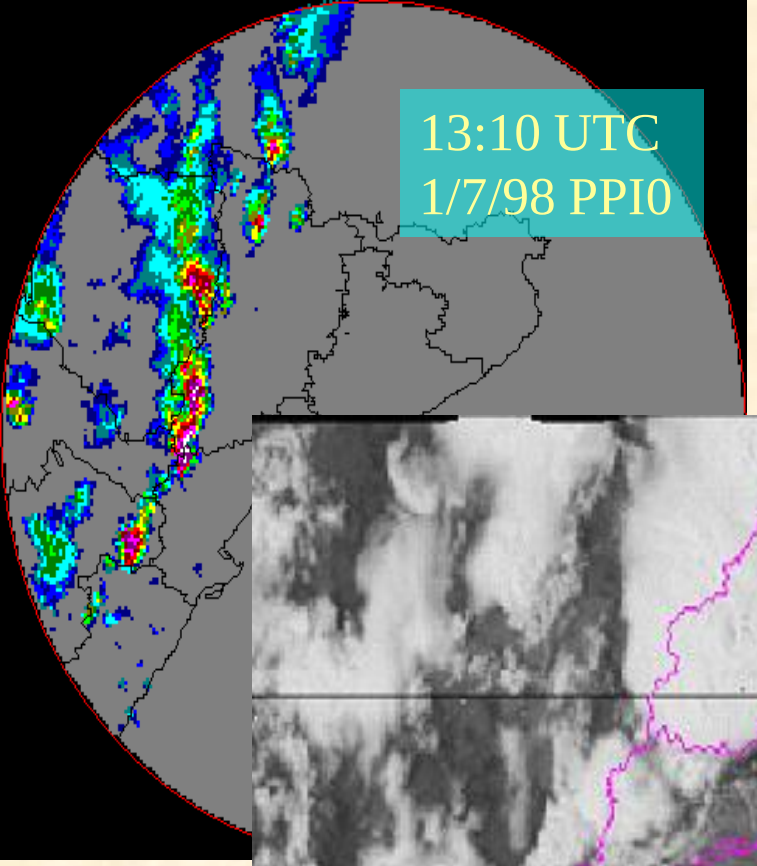
Hailstorms Characteristics (7)

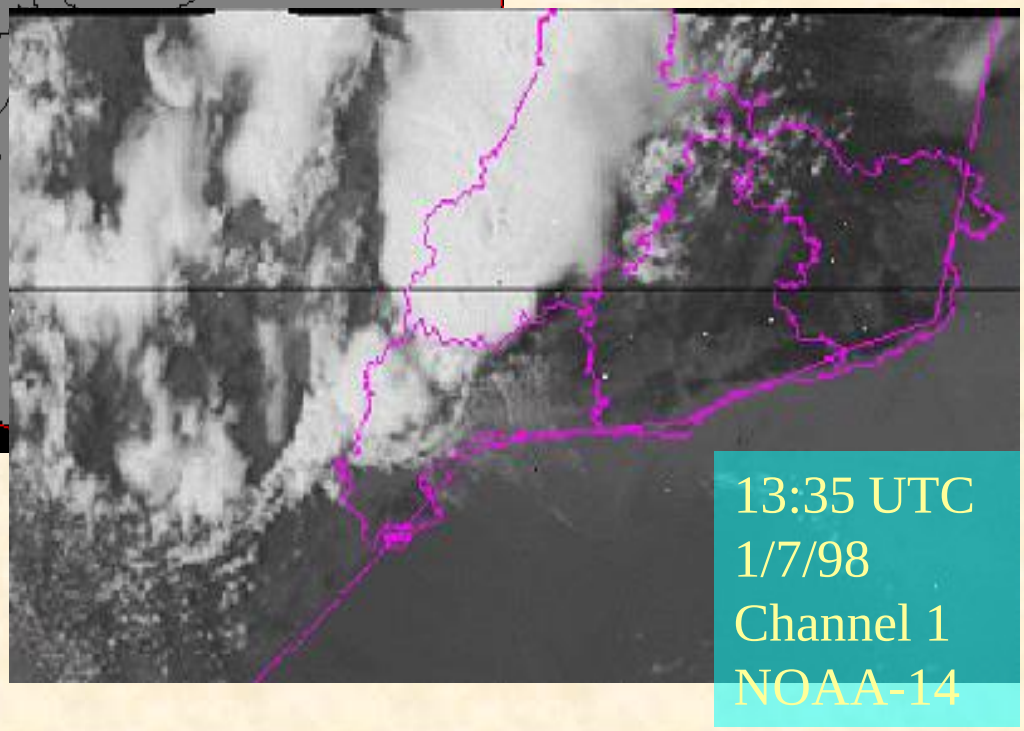
Initiation location



Lleida Plain

Main hot spot





Thank you for your attention

Ramón Pascual Berghaenel
ramonp.bar@inm.es
CMT en Catalunya
INM: www.inm.es

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