Hailstorms Characteristics And Initiation In Western Catalonia (Spain)

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Geographical Features

Western Mediterranean

Area studied: 36000 km²
77 municipalities

Lleida Plain

Catalonia
**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.
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)

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

2 April-19 May

5 August-25 August

Seasonal bias

Synoptic bias
Synoptic Features (1)

Synoptic patterns more common:

- Deep transient Atlantic trough (clearly identified $\geq 500$ 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)
A: Rear jet streak
B: Forward jet streak
C: Convective area
GR: Study area

Deep convection associated to a retrograde trough
Deep convection associated to extratropical-subtropical interaction: dry air mass intrusion.
## Synoptic Features (5)

### Seasonal bias of synoptic patterns and seasonal trend

<table>
<thead>
<tr>
<th></th>
<th>T850M</th>
<th>T700M</th>
<th>T500M</th>
<th>T850MAX</th>
<th>T700MAX</th>
<th>T500MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>April</strong></td>
<td>6</td>
<td>-4</td>
<td>-22,3</td>
<td>10</td>
<td>0</td>
<td>-18</td>
</tr>
<tr>
<td><strong>May</strong></td>
<td>8,3</td>
<td>-1,6</td>
<td>-19,3</td>
<td>15</td>
<td>4</td>
<td>-14</td>
</tr>
<tr>
<td><strong>June</strong></td>
<td>15,9</td>
<td>5,4</td>
<td>-13,5</td>
<td>18</td>
<td>8</td>
<td>-11</td>
</tr>
<tr>
<td><strong>July</strong></td>
<td>16,2</td>
<td>5,6</td>
<td>-12,4</td>
<td>20</td>
<td>8</td>
<td><strong>-10</strong></td>
</tr>
<tr>
<td><strong>August</strong></td>
<td>16,1</td>
<td>4,9</td>
<td>-12,6</td>
<td>22</td>
<td>8</td>
<td><strong>-10</strong></td>
</tr>
<tr>
<td><strong>September</strong></td>
<td>13,6</td>
<td>2,8</td>
<td>-14,1</td>
<td>16</td>
<td>5</td>
<td>-13</td>
</tr>
</tbody>
</table>

Mean value
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
Deep convection associated to mesoscale trough embedded in a synoptic one
Mesoscale Features (3)

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

Deep convection associated to a mesoscale vortex embedded in synoptic low
Deep convection associated to jet streak exit region.
Mesoscale Features (5)

Planetary boundary layer convergence zones: lifting mechanisms

• Surface low over Ebro Valley.
  1) strong solar heating in the dry areas of the central Ebro Valley and origin
  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.
Mesoscale Features (6)

- Pyrenees
- 6 August 1999
- 12 UTC
- HIRLAM 0.5º

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

Convergence area

Iberian Mountains
Mesoscale Features (7)

6 August 1999 12 UTC
HIRLAM 0.5º

**Blue**: 850 hPa divergence

**Red**: Thermal Frontal Parameter (PFT)

**Pink**: Boundary axis

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

\[ \vec{u}_{\theta_w} = \frac{\nabla \theta_w}{|\nabla \theta_w|} \]
Mean Wind Vertical Profiles

35 soundings 00 UTC; 40 soundings 12 UTC

Notable vertical shear
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. 16,998 CG correctly detected (pink numbers).

<table>
<thead>
<tr>
<th>Red rectangle: Study area</th>
<th>150 km</th>
</tr>
</thead>
<tbody>
<tr>
<td>428</td>
<td>329</td>
</tr>
<tr>
<td>374</td>
<td>3040</td>
</tr>
<tr>
<td>348</td>
<td>2632</td>
</tr>
<tr>
<td>258</td>
<td>94</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Blue rectangle: Surrounding area</th>
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<tbody>
<tr>
<td>125 km</td>
</tr>
<tr>
<td>268</td>
</tr>
<tr>
<td>228</td>
</tr>
<tr>
<td>147</td>
</tr>
</tbody>
</table>

CG spatial distribution and thunderstorm entrance zones
Hailstorms Characteristics (2)

Entrance directions to the zone
Hailstorms Characteristics (3)

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

16 (25%) hailstorms almost stationary
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)

14:00 UTC - 16:00 UTC

16:00 UTC - 18:00 UTC

Dynamic + thermal forcing
### Hailstorms Characteristics (5)

#### Radar Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band (cm)</td>
<td>C; $\lambda = 5.4$</td>
</tr>
<tr>
<td>Resolution (km)</td>
<td>Normal: 2 x 2. Doppler: 1 x 1</td>
</tr>
<tr>
<td>Range (km)</td>
<td>Normal: 240. Doppler: 120</td>
</tr>
<tr>
<td>Exploration Interval (min.)</td>
<td>10 both modes</td>
</tr>
<tr>
<td>Peak Power (kW)</td>
<td>250</td>
</tr>
<tr>
<td>Beamwidth (deg.)</td>
<td>0.9°</td>
</tr>
<tr>
<td>Pulsed length (m)</td>
<td>Normal: 600. Doppler: 150</td>
</tr>
</tbody>
</table>
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.**
  1. Pixel convective: $Z \geq 45$ dBZ or $Z \geq 40$ 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.
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, ...
Hailstorms Characteristics (7)

Initiation location

Lleida Plain

Main hot spot
Thank you for your attention

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3rd European Conference on Severe Storms.