DOPPLER RADAR OBSERVATIONS OF THE 7 SEPTEMBER 2005 TORNADIC THUNDERSTORM NEAR BARCELONA, SPAIN

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## Background

### Tornadoes and Tornadic Thunderstorms

Davies-Jones et al. 2003, AMS MM 28

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<th>Type I tornadoes (form within a ME)</th>
<th>Type II tornadoes (no ME, but CL)</th>
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<td>- SC in a line of thunderstorms</td>
<td>- Gustnado (along gust front, no condensation-funnel)</td>
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<td>- mini SC (small ME) Suzuki et al. 2000, MWR</td>
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### Doppler Signatures

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<th>ME</th>
<th>TVS</th>
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Introduction

■ A series of waterspouts & tornadoes (largest local outbreak) were observed in the afternoon of 7 September 2005. Most of them started as waterspouts and moved inland (to NW) a few km.

■ They affected the SW Barcelona metropolitan area (including the airport), a densely populated zone (many pictures & videos).
The site survey identified four different tracks. Some visual reports indicate up to 11 funnel-clouds.

Despite extensive damage (8.5 M€), intensity generally weak (F0 – F1) but one F2 (affected 2 commercial airplanes, hangar, VOR, etc.). Fortunately no fatal victims.
Cloud structures with rotational aspect (1820 UTC). Photograph courtesy of M. Messegue.
• Deep cold (upper level) low over Iberian Peninsula (-18°C 500 hPa).

• Jet streak (SE-NW oriented) over Catalonia.

• Weak warm advection < 850 hPa over Catalonia.

• Low-level E/NE flow over Catalonia.

• Easterly LLJ (40 kt) at 850 hPa. Max. vel. 110 km/h < 1500 m. At 500 m ASL, 100 km/h (Fabra obs.).

• Moderate instability (554 J/kg) but high vertical wind shear and helicity (217 m²/s²) (Conditions associated to severe storms according to local studies, cg Tudurí & Ramis 1997, WF)
- N of the CL, the flow E/NE while & S side ranged from SE to SW, i.e.
  there was horizontal directional shear (HDS) across the CL.
- No evident mesoscale temperature gradient was present.
- Convective line developed along the CL.
- 1610 to 2020 UTC:
  504 IC and 101 CG flashes
- Tornadic period (1700 to 1800 UTC):
  92 IC and 17 CG flashes.
- From the 101 CG flashes, only 4 had positive polarity, and no positive CG flashes were registered from 1700 TU to 1800 TU.
- IC/CG ratio was 5.0 (in terms of severity a normal thunderstorm for this region, Montanyà et al ILDC 2006).

- Relatively low cloud tops

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• CMT Catalunya
• CMT Balears
• Convective cells (CC) associated to tornados developed/moved along CL (Train effect Doswell et al., 1996 WF)
• CL persisted for 4 hours. Maximum length: 200 km.
• Small MCS: Back building squall line. Bluestein and Jain, 1985 JAS
• Possible mini-bow echoes along CL.
• Small intense (40-50 dBZ) CC over the sea. Low echotops (< 6 km).
• No clear classical supercell features (No mesocyclone identified,..).
PBE Radar observations: RV

- Warm advection & vertical wind shear ("S" shaped W field)
- Wind maximum (LLJ) just before the waterspouts & tornadoes

4.0° PPI radial velocity field (m/s) observed by the PBE radar.
…Moreover, though there are important blockages to the N (Bech et al. 2003 J AOT), coverage is good to the S.

A velocity couplet was identified in 4 different PPIs of the 1700 UTC PBE volume scan.

The couplet was embedded in a high vertical shear environment and was located very near the radar (8 km). It extended from 1.5 to 3.0 km and was approximately 2.5 km wide. If associated to a rotating structure, it would be a misoanticyclone.

It was observed in the limit of a precipitating structure coming from the SE, the same direction...

PBE radar 6º PPI (17:03 UTC) velocity couplet in the radial wind field (bottom) and the corresponding cross section (top) between the segment AB. Rings are at 5 km intervals and maximum height is 5 km.

- Possible MISOANTICYCLONE.
PBE Radar observations: RV & Z

PBE radar 8⁰ PPI (18:34 UTC) reflectivity factor (left) and radial wind (right). Rings are at 10 km intervals. Colour scales as in previous images.

Characterisitc shape, similar to small “hook echo”?  
Velocity couplet, possible mi(e)socyclone
Concluding remarks (1/2)

Some characteristics identified about the environment:

- **Mesoscale convergence line** over the sea resulting possibly from flow interaction with Balearic Islands. Recurrent convergence lines with similar synoptic situations (Balearic Island outbreak, Homar et al 2001 At.Res.).

- **LLJ** north side of convergence line, prior to waterspouts & tornados.

- Formation of a **Convective Line** formed along the convergence line (small squall lines with slow northward movement).

- **Horizontal Directional Shear** across the CL and strong updrafts could have favoured waterspouts and tornadoes development and movement along convective line.
Concluding remarks (2/2)

Regarding the **convective structures** associated to the waterspouts & tornadoes:

- **No classical supercell tornadoes** (No mesocyclone, Z, sat) but possible miso(anti)cyclones identified (mini SC?).

- Identification of developing **CL over the sea** (HRVIS MSG and Z field) could alert forecasters. Also, **LLJ** and **shear** near **CL**.

- **Subjective** identification of small couplets (associated with misoscale circulations) is difficult in operational surveillance tasks. Possible use of **automatic** procedures, Conejo & Elizaga, 2004 INM TN43.

- Despite their potential destructive effects the **tornadic cells presented a modest appearance** in remote sensing operational products (input from spotters could help!).