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Ebro Lightning Mapping Array: sprite-producing lightning and ground-to-cloud-to-ground flashes

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In the summer of 2011 a three-dimensional lightning mapping array (LMA) has been deployed in the Ebro delta and surrounding area in eastern Spain. This area was chosen for its proximity to both summer storms over land and cold season thunderstorms over sea, which often produce transient luminous mesospheric events (mainly sprites and elves). In 2011, six of the twelve VHF band (60-66 MHz) sensors were operational, and more followed in early 2012. The area is also covered by LS8000 interferometer and LINET detection systems which provide complementary data.

The first flash analysed occurred at the end of the life of a thunderstorm cluster on July 12th and started as an upward negative leader launched by a windmill, growing into the lower positive charge region 3-4 km altitude above the windmills and at 5-7 km altitude eastward, into stratiform precipitation. Briefly, leaders expanded into the upper positive charge region (8-10 km). A downward negative leader reached the ground in the Ebro delta (visually confirmed and detected by LINET). It was followed by two more return strokes and further eastward expansion. The flash lasted 2 seconds and measured 38 km across. LINET and a SAFIR interferometer system did not detect the beginning of the upward flash. Several other complex flashes with horizontal extents larger than 60 km have been mapped since. Other interesting phenomena were observed as well: emissions detected every 3.15 seconds from some of the wind turbines (corona or short upward leaders), suggestive of the blade rotation, and aircraft flying around 8.5 km altitude through thunderstorm anvils showing up as sharp trails of pulses.

From July till December 2011 at least 33 sprites were recorded roughly within 150 km from the Ebro LMA. The initial data show the sprites to occur mainly over the sources emitted during the period between the triggering +CG and the onset of the sprite, from ∼6-8 km altitude (-15° to -30°C). This activity can be horizontally displaced 20 kilometers from the +CG stroke. In the cases of the short-delayed sprites (<30 ms), these sources tend to occur scattered along older channels which grew before the +CG occurred, indicating that the +CG most likely tapped charge directly from these channels. Column sprite elements tended to be grouped around the lightning branches developing before the +CG. In the cases of the longer-delayed sprites, usually carrots, leaders started to expand from pre-existing channels into new regions, discharging the cloud more gradually. We speculate that very large sprites may involve both processes simultaneously. As in our previous study, SAFIR interferometer source bursts tended to be collocated well with sprite azimuths and timing, although they also occur at other times and during common flashes. They might be associated with continuing currents. LMA source power increases to a maximum during sprites, but can also be elevated at other moments during the flash.

In addition, lightning flashes were recorded with a high-speed camera at 6688-15000 frames per second, allowing optical identification of processes which (fail to) emit mapped sources.