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A frontal thunderstorm with several multi-cell lines found to produce energetic preliminary breakdown

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A convective activity developed along the Mediterranean Coast of southern France in the early hours of 19 June 2013, in a southerly flow created by a low of pressure centered on the Bay of Biscay. The storm system had a multi-cell character forming several parallel convective lines in the NW-SE direction and produced numerous lightning as reported by the lightning detection network EUCLID.

During this thunderstorm ten sequences of unusually strong preliminary breakdown (PB) pulses were recorded by two different receivers. For measurements of the time derivative of the horizontal component of the magnetic field at distances 69-176 km from the source lightning discharges, we used a Shielded Loop Antenna with a Versatile Integrated Amplifier (SLAVIA) connected to a ground-based version of the broadband TARANIS receiver sampling at 80 MHz. Electric-field snapshots of a vertical electric field were recorded at distances 258-377 km from the source discharges by a dipole whip antenna mounted on a mast, with a receiver sampling at 12 MHz.

The inspection of electromagnetic waveforms revealed that the observed PB pulses were followed by an intracloud (IC) activity in 7 cases or by very weak return stroke (RS) pulses in the remaining 3 cases. The peak currents which generated these strong PB pulses reached -36 kA as reported by EUCLID. The peak amplitudes of the largest pulses within individual PB sequences exceeded the peak amplitudes of the following RS pulses. The electric field amplitudes of the largest PB pulses normalized to the 100 km range reached on average 6 V/m. Their initial polarity confirmed the movement of the negative charge downward, as in case of negative cloud-to-ground (CG) discharges. The duration of the trains of strong PB pulses, the interpulse intervals, and bipolar shapes of individual pulses did not differ from properties of PB pulses preceding usual negative CG flashes.

To explain our electromagnetic observations, we examined vertical profiles of the radar reflectivity measured by the French radar network ARAMIS, and its horizontal distribution at an altitude of 3 km, where we expected the lightning initiation processes of negative CGs or inverted ICs to occur. We also checked the maps of the cloud top temperature obtained by the radiometer onboard the METEOSAT satellite close to the time of occurrence of the observed strong PB pulses. We combined these maps with the location of strong PB pulses detected by EUCLID together with locations of the CG and other IC discharges detected by EUCLID in a 10 min window around the radar or cloud top temperature records. We have found that all strong PB pulses occurred relatively isolated in smaller spots with a reflectivity of about 30-40 dBz. The cloud top temperature related to these spots varied from -39 to -50 °C. Both the radar reflectivity and the cloud top temperature of these spots were less extreme than in regions with intense CG lightning activity. As the energetic pulses were also isolated in time, we hypothesize that the observed thunderstorm might have been unusually electrified with temporal strong negatively charged pockets leading to production of energetic PB pulses and a strong lower positive charge region responsible for the weak or missing CG return strokes.