EGU22-9076

Electromagnetic radiation following the first return strokes of negative and positive cloud-to-ground lightning flashes

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CG lightning [M. Popek, IAP CAS]

Motivation

What are the properties of electromagnetic radiation following the first RS?

What are the differences between -CG and +CG flashes?

→ deeper understanding of processes following the 1st RS

→ expanding general knowledge about +CG flashes

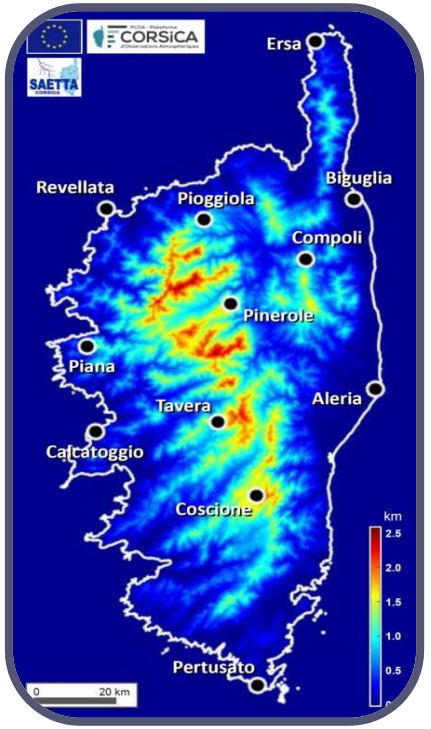
Measurement and data

SLAVIA sensor (BLESKA)
[web: bleska.ufa.cas.cz]

Northwestern Mediterranean:
September 2015 – December 2015

38 -CG and 16 +CG flashes

- Broadband receiver BLESKA
  (*Ersa, Corsica*)
- SAETTA (LMA)
  → VHF radiation sources and their location
- EUCLID (Météorage)
  → 2D location, polarity and peak currents

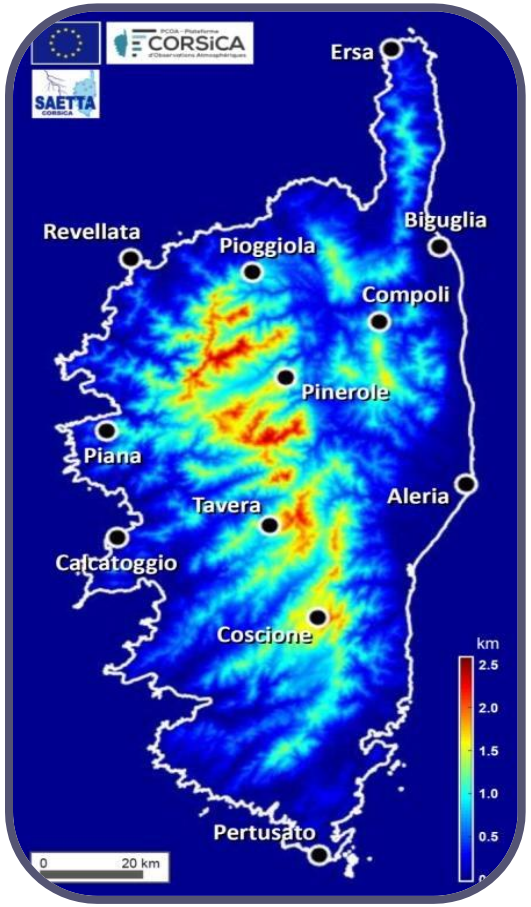


Map of SAETTA stations
[S. Coquillat, 2019]

Measurement and data

SAETTA (LMA): 12 stations

- Electric-field antennas, 60 – 66 MHz
- Every station in each 80-µs: total count (max 2000) of VHF sources, time and power of the strongest VHF source
- Different time of VHF source detection for each station
  → 3D location of VHF source



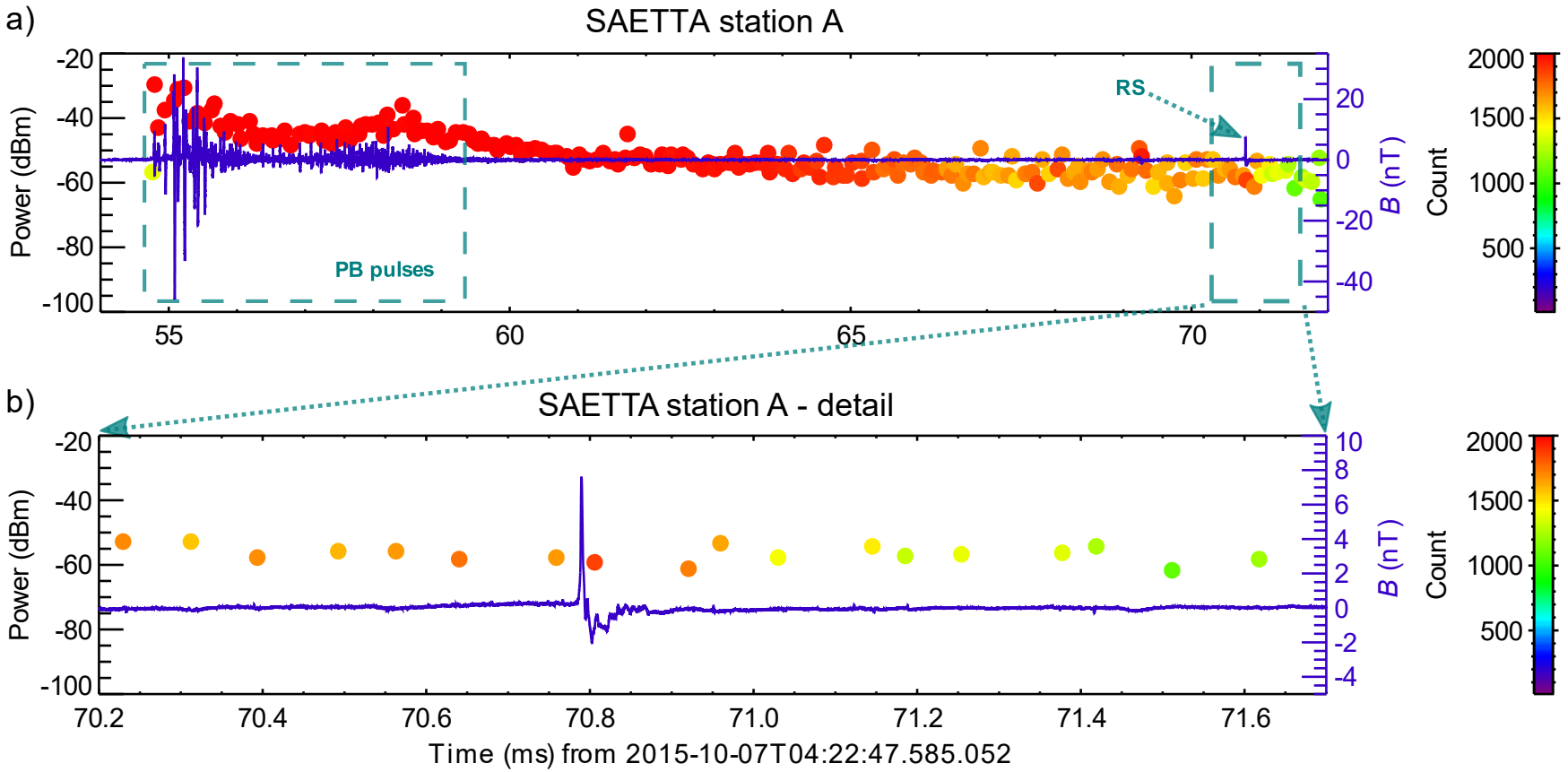
Map of SAETTA stations
[S. Coquillat, 2019]

Results

Corsica, Autumn 2015 – analyzed flashes : 38 –CG, 16 +CG

- PB pulses preceding RS pulse: All -CG flashes; only 8 +CG flashes
  - -CG: $\langle T_{(PB\text{-}RS)} \rangle$ = 8 ms; +CG: $\langle T_{(PB\text{-}RS)} \rangle$ = 22 ms
- **Météorage**:
  - All flashes: CG discharge corresponding in time to RS pulse
  - All -CG and 6 +CG (out of 8 +CG): IC discharge corresponding in time to the strongest PB pulse
  - -CG: $\langle |I_{RS}| \rangle$ = 75 kA, $\langle |I_{PB}| \rangle$ = 18 kA, $\langle (I_{PB}/I_{RS}) \rangle$ = 0.6
  - +CG: $\langle I_{RS} \rangle$ = 85 kA, $\langle I_{PB} \rangle$ = 17 kA, $\langle (I_{PB}/I_{RS}) \rangle$ = 0.2
- **SAETTA**:
  - Relation between magnetic-field waveforms and VHF sources detected by individual SAETTA stations

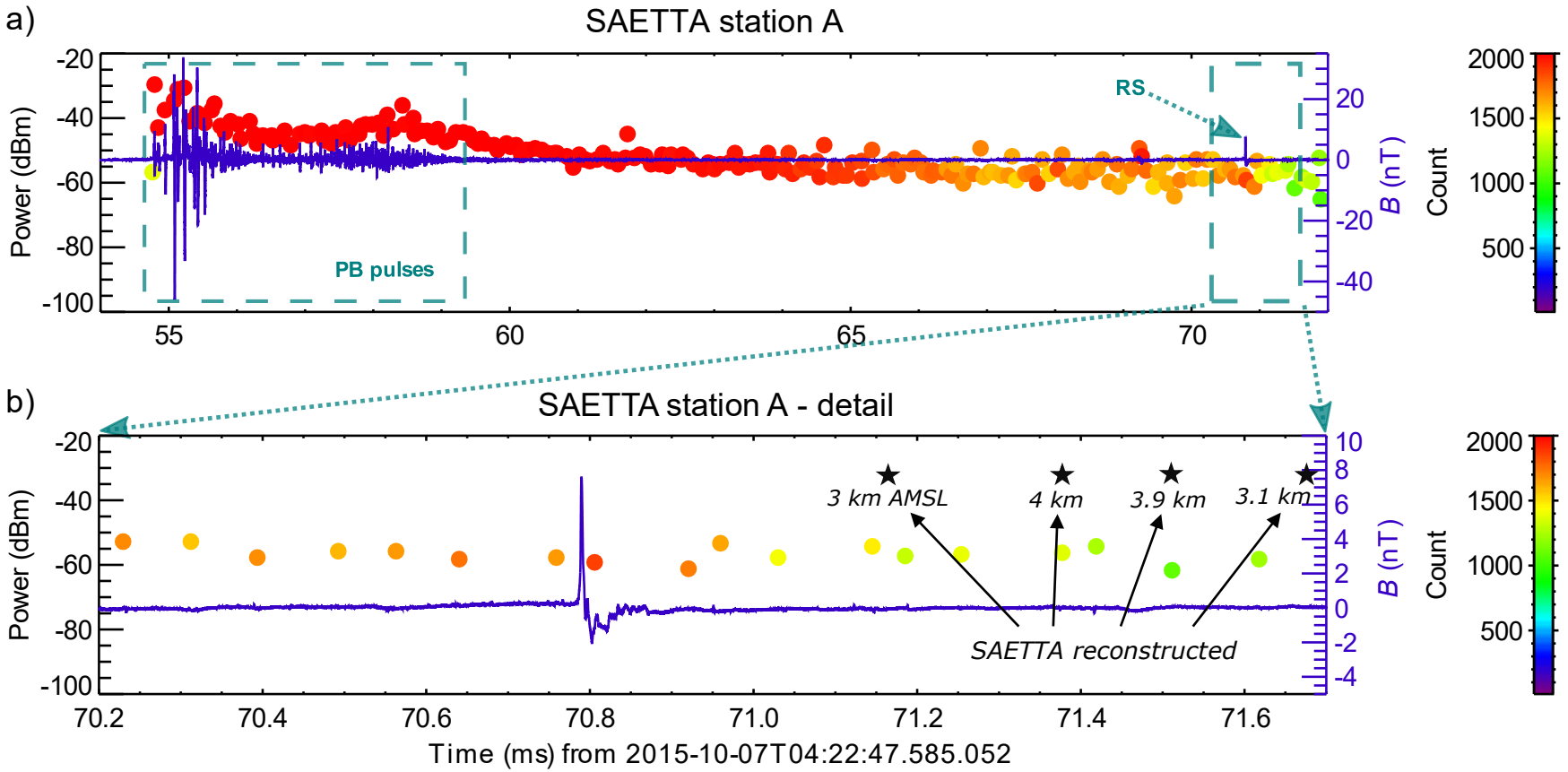
SAETTA: Negative CG flashes



During PB stage
– high radiation rates of VHF sources
→ confirming results of Kolmašová et al., 2018

After RS
– decrease of number and power of detected VHF sources
→ expected

SAETTA: Negative CG flashes

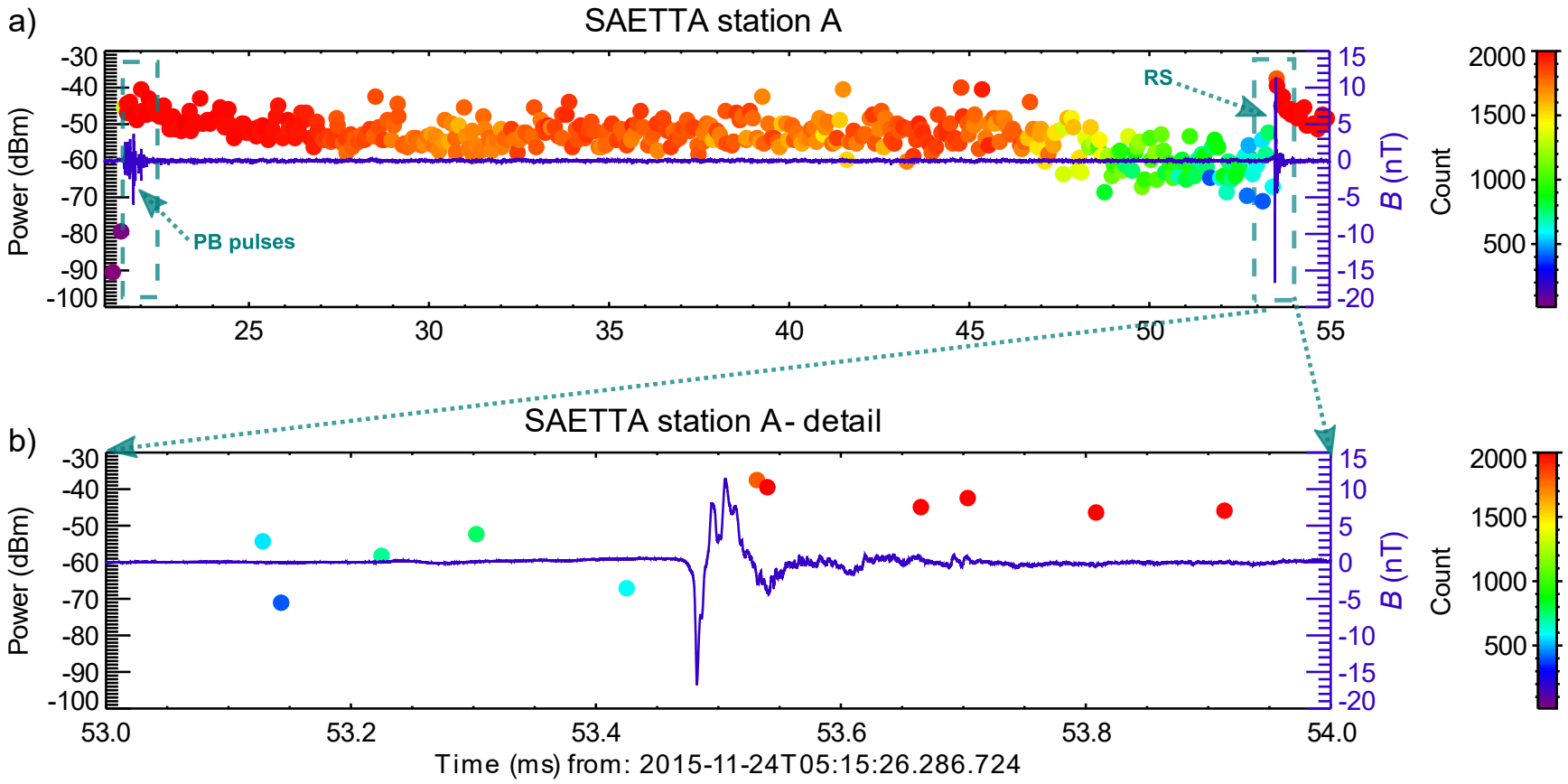


After return stroke

– start of decreasing of VHF radiation rates: 66 µs after RS pulse peak (average)

– decrease to 1500 VHF sources: max 1.85 ms after RS pulse peak

SAETTA: Positive CG flashes

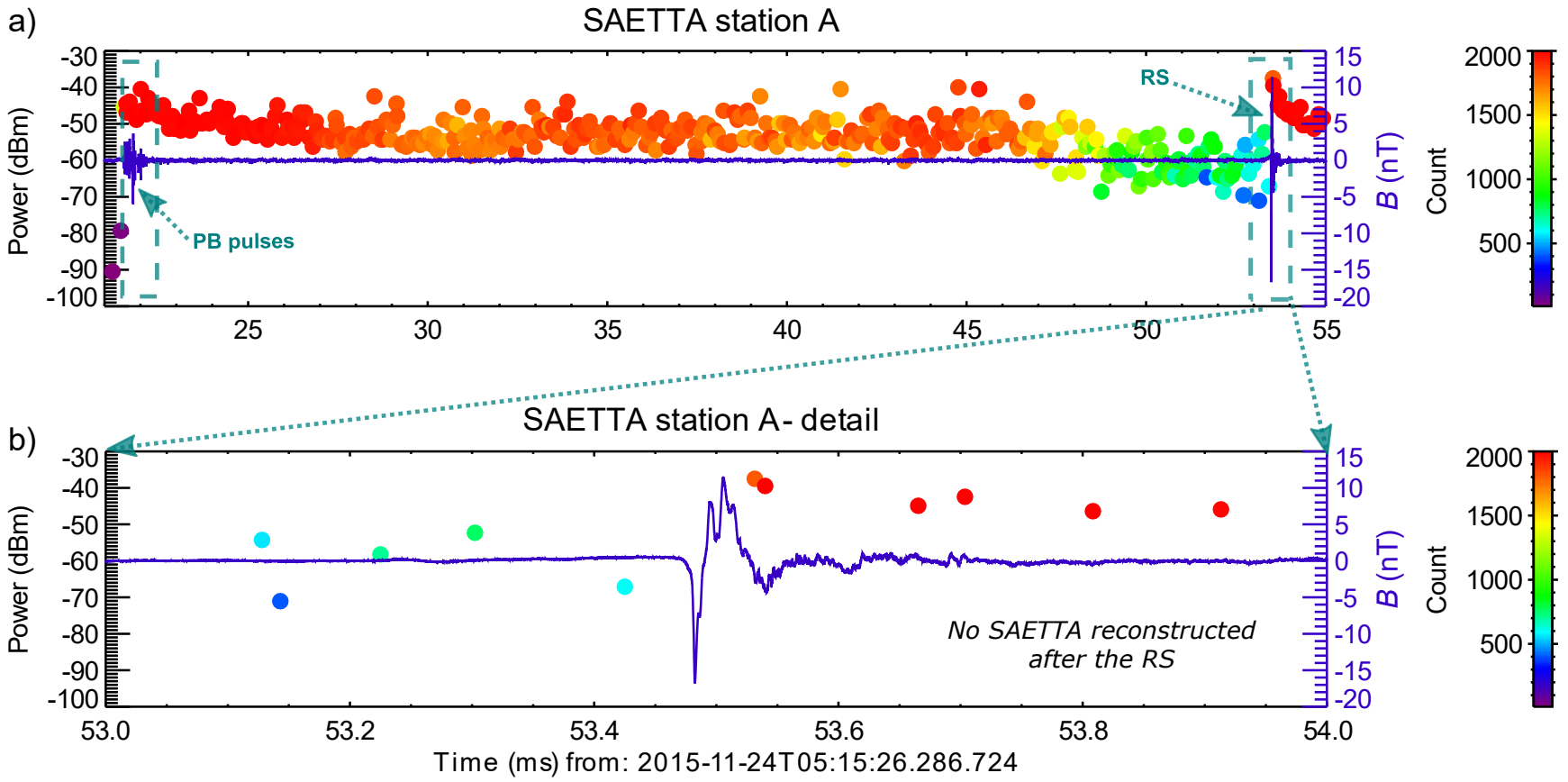


After return stroke

– <u>increase</u> of number and power of <u>VHF sources</u>

– <u>irregular bipolar pulses</u> in magnetic-field waveforms (lasting up to 50 ms)

SAETTA: Positive CG flashes



After return stroke

– duration <u>of strong VHF</u> radiation: <u>34.53-161.95 ms</u>

– irregular pulses: amplitude of the biggest pulse 2-10nT

– No reconstructed VHF sources

→ fast <u>step-like extensions</u> of <u>in-cloud</u> lightning <u>channels</u>

SAETTA: Summary

Difference between -CG and +CG flashes in terms of electromagnetic radiation following the 1st RS → strong VHF radiation in +CG

-CG flashes: decrease of number and power of VHF sources

- maximum count of 2000 VHF sources: 66 µs after RS pulse peak (average)
- decrease to 1500 VHF sources: 1.85 ms after RS pulse peak or sooner
- Reconstructed VHF sources reported by SAETTA after RS pulse peak

+CG flashes: fast increase of number and power of VHF sources

- decrease to 1500 VHF sources: 161.95 ms after RS pulse peak or sooner; the median value 34.53 ms

  → much longer than in -CG flashes
- Visible sequence of irregular bipolar pulses lasting up to 50 ms
  - amplitude of the biggest pulse: 2-10 nT

SAETTA: Summary

Difference between -CG and +CG flashes in terms of electromagnetic radiation following the 1st RS → strong VHF radiation in +CG

+CG flashes: no reconstructed VHF sources immediately after the RS

The lack of 3D located VHF radiation sources, compared to high number of sources detected by individual stations is probably caused by a decreased performance of LMA locating algorithm when too many VHF pulses are detected.

The more VHF pulses are detected at the 80 μs time intervals, the harder is to connect corresponding VHF sources from each individual station. That is because each station saves only information about the most powerful VHF source detected during each time window, information about other sources is not available and thus they cannot be 3D reconstructed.

SAETTA: Summary

Difference between -CG and +CG flashes in terms of electromagnetic radiation following the 1st RS → strong VHF radiation in +CG

+CG flashes: fast increase of number and power of VHF sources

We speculate that the rapid increase of VHF radiation in positive flashes is due to a large potential difference between the end of the freshly neutralized return stroke channel and the positive charge layer in the thundercloud.

As a result, a new electric breakdown might occur and a negative leader could propagate inside the thundercloud in a stepped manner, emitting electromagnetic radiation in a wide range of frequencies.