Upward lightning emerging from cloud tops

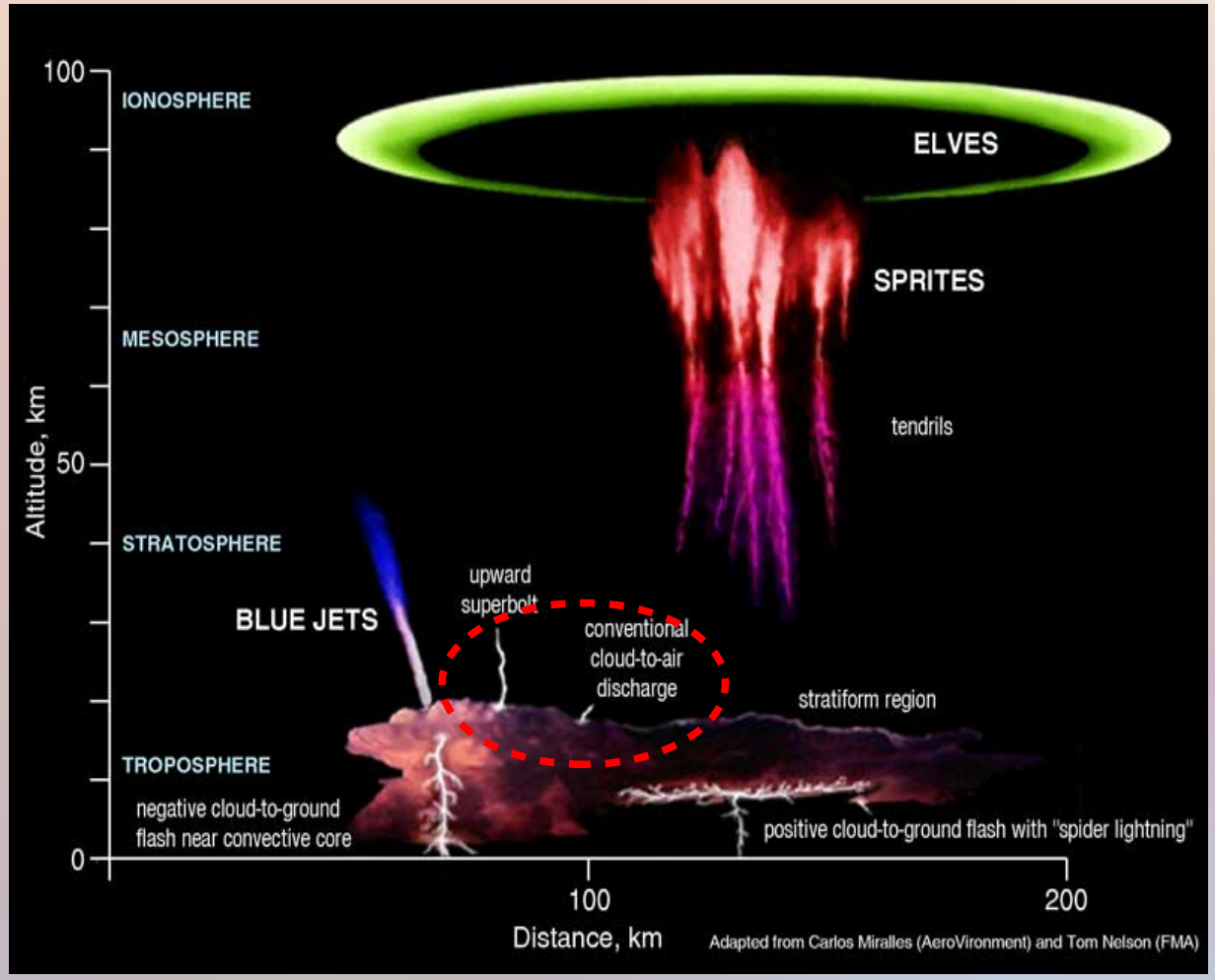
Oscar van der Velde[1]

Joan Montanyà[1], Nicolau Pineda[2], Serge Soula[3]

1. **Technical University of Catalonia**, Electrical Engineering Department, Lightning Research Group, Terrassa, Spain

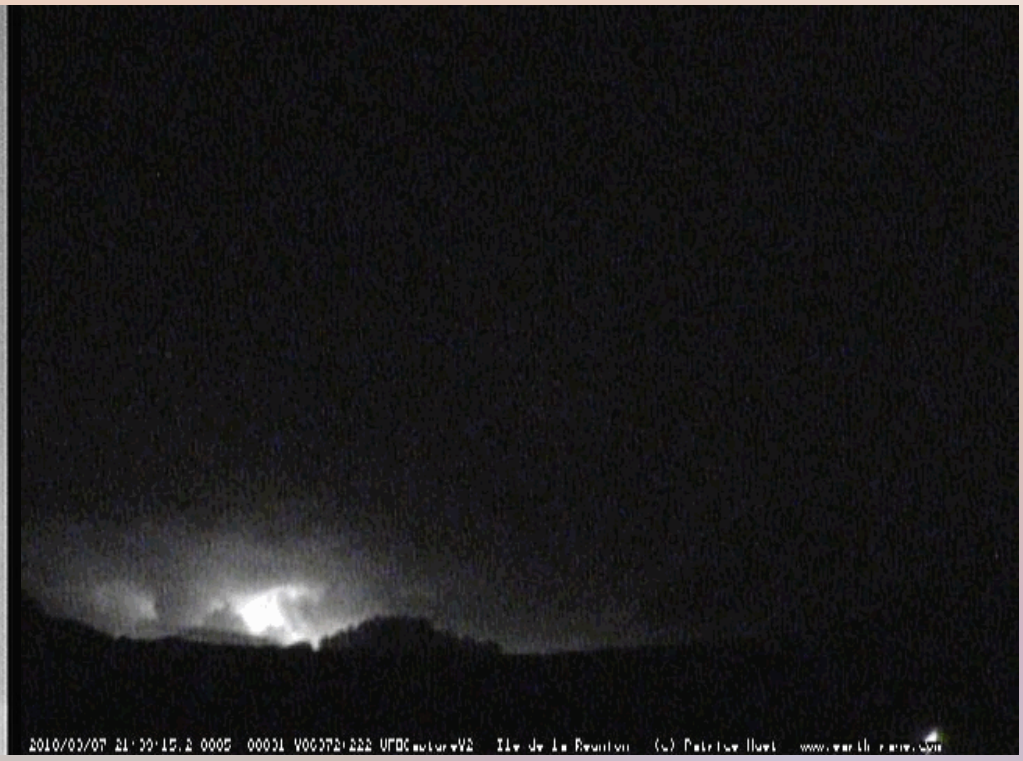
2. **Meteorological Service of Catalonia,** Barcelona, Spain

3. **Université de Toulouse**, Laboratoire d'Aérologie, Observatoire Midi-Pyrenées, Toulouse, France



7th European Conference on Severe Storms, Helsinki, Finland, 5 June 2013

Upward bolts: the first step to becoming a Gigantic Jet?



Upward lightning
September 2nd 2012, near Barcelona

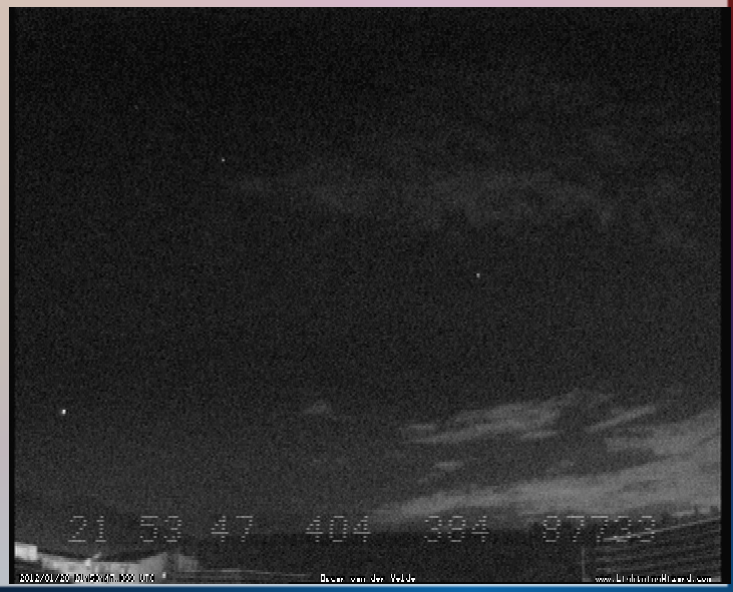
Cloud top 7 km

Gigantic Jet
Réunion island, Soula *et al.* 2011, JGR
Recorded by Patrice Huet

Cloud top 18 km

Upward lightning
September 2nd 2012, near Barcelona

January 28th 2012:

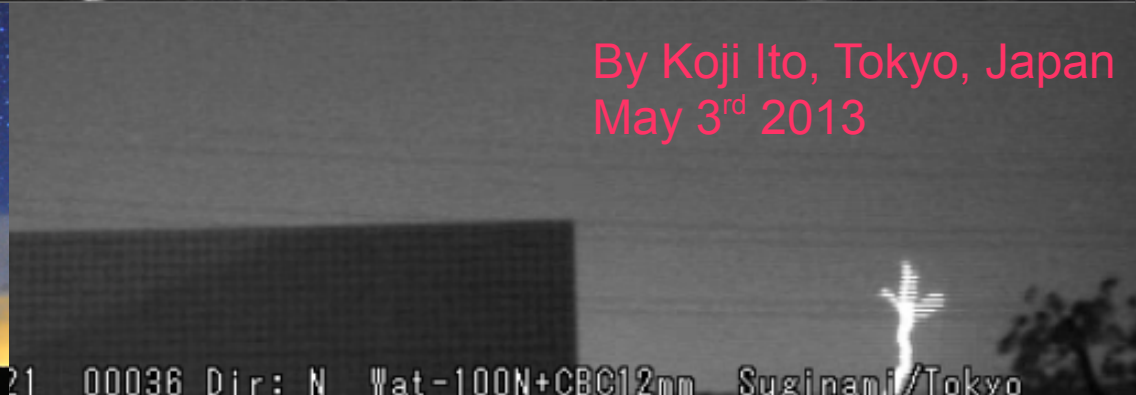


By Diego Valeri, Abruzzo, Italy, IMTN,
January 17th 2013

By Mr. Takeda, Kashiwa, Japan
October 23rd 2005

By Koji Ito, Tokyo, Japan
February 21st 2007

Wagga Wagga, Australia
August 23rd 2012



By Koji Ito, Tokyo, Japan
May 3rd 2013

Optically determined heights

Date	Events	Maximum altitude MSL	Cloud top MSL
10 November 2010	1	10.5 km	8.9 km
1 June 2011	1	11.8 km	9 km
28 January 2012	11	10.6 km	6.5-8.9 km
26 August 2012	12	10.7 km	7.8-9.8 km (12.9)
2 September 2012	3	9.2 km	6.7-7.6 km

Conclusion here:

- Despite reaching several kilometers higher than normal lightning, not reaching very high (still inside troposphere)
- In the high-topped summer case (26 Aug 2012), lightning emerged from small growing towers, not from those high tops

Events and meteorology

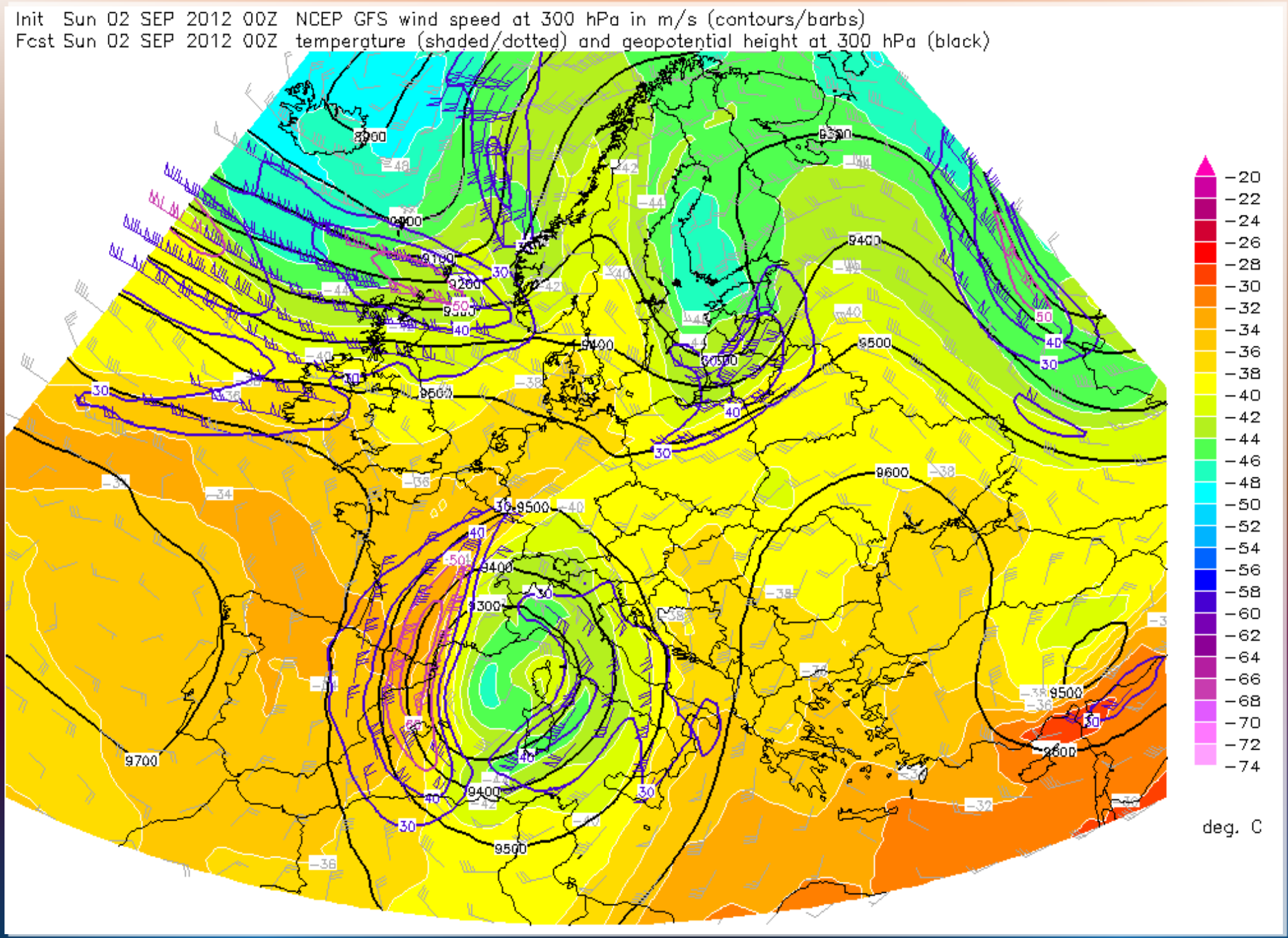
Date	Radar echo top 12 dBZ	Equilibrium Level °C	Wind Speed -20°C	Wind Speed -35°C
10 November 2010	8 km, growing	-33 / -50	15 kts	35 kts
1 June 2011	8-9 km	-35	40 kts	60 kts
28 January 2012	6-7 km	-28	10 kts	60 kts
26 August 2012	9-11 km, growing	-50	30 kts	55 kts
2 September 2012	7-8 km, growing briefly	-20	40 kts	65 kts

Sounding equilibrium levels are at lower altitudes than optically determined tops.
Soundings may not have sampled the airmass of the storm exactly.

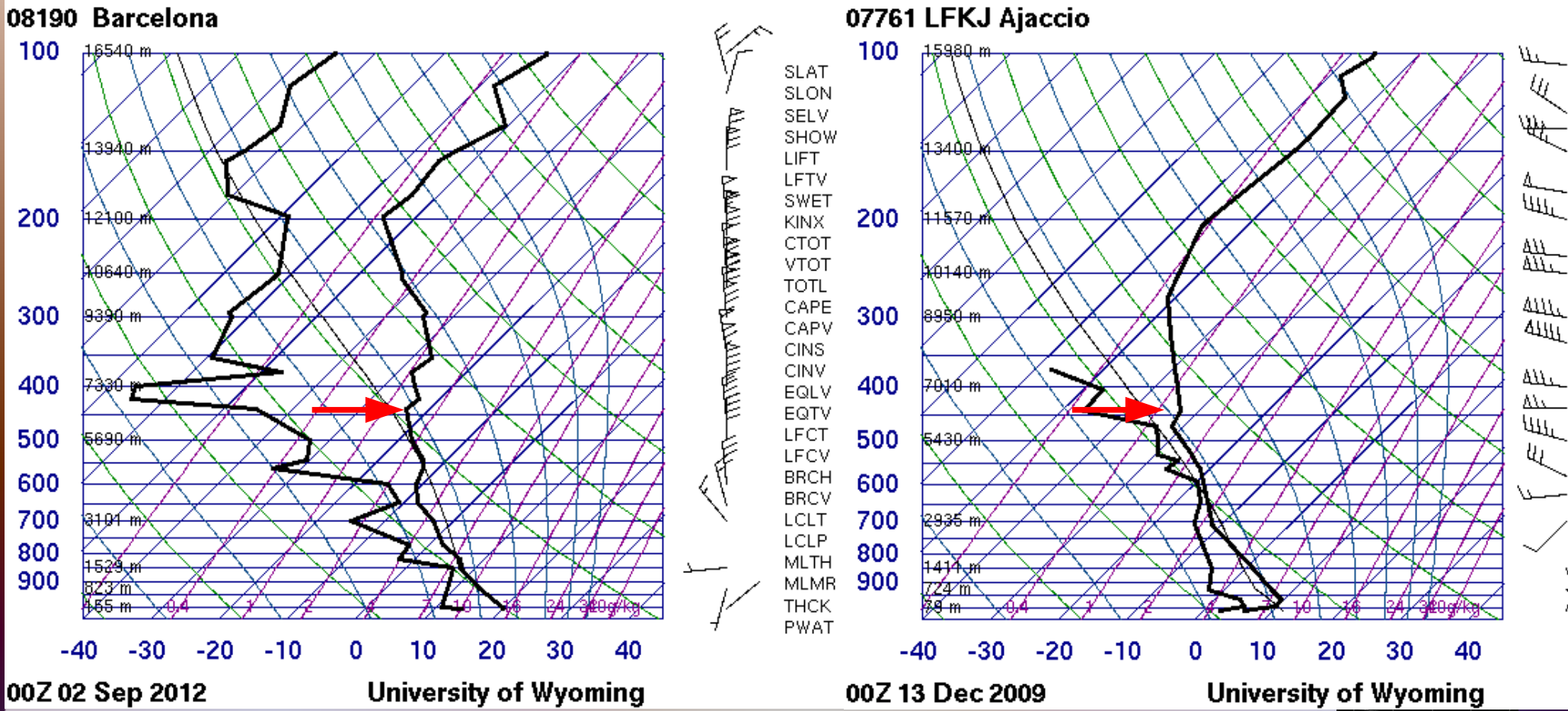
Meteorological setting:

1) At the edge of an Upper Level Low (cold pool) over northern Mediterranean
2) Lee convergence line of the Pyrenees near Barcelona after cold front pass.
3) Under 300 hPa jet stream

Convective Available Potential Energy only a few hundred J/kg, typically.

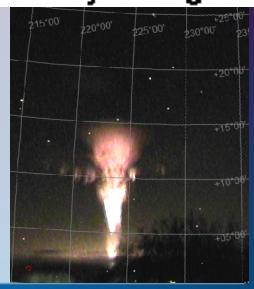

Init Sun 02 SEP 2012 00Z NCEP GFS wind speed at 300 hPa in m/s (contours/barbs)
Fcst Sun 02 SEP 2012 00Z temperature (shaded/dotted) and geopotential height at 300 hPa (black)
−20
−22
−24
−26
−28
−30
−32
−34
−36
−38
−40
−42
−44
−46
−48
−50
−52
−54
−56
−58
−60
−62
−64
−66
−68
−70
−72
−74
deg. C

Example soundings

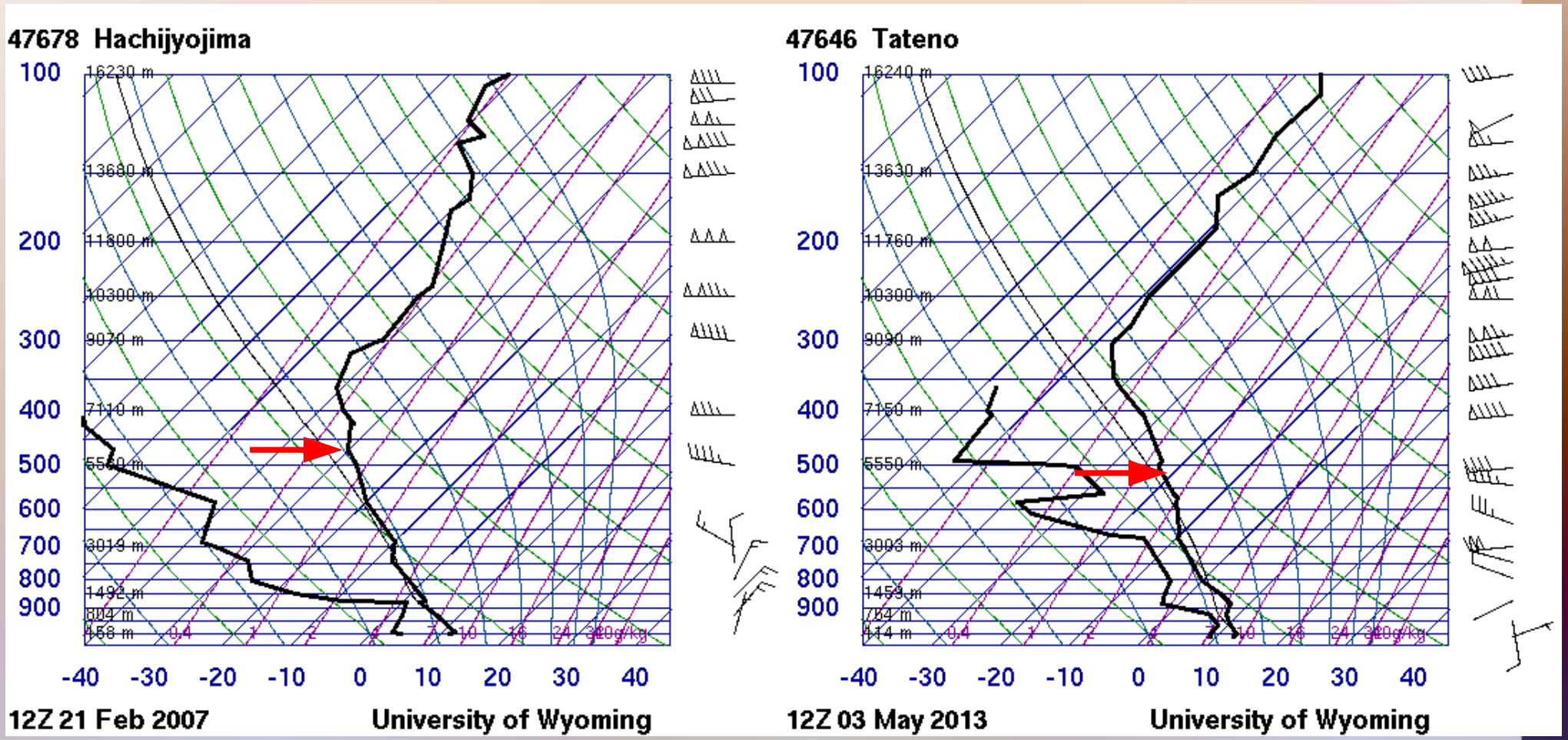


Upward lightning

Mediterranean winter **Gigantic Jet**
(van der Velde et al. 2010)



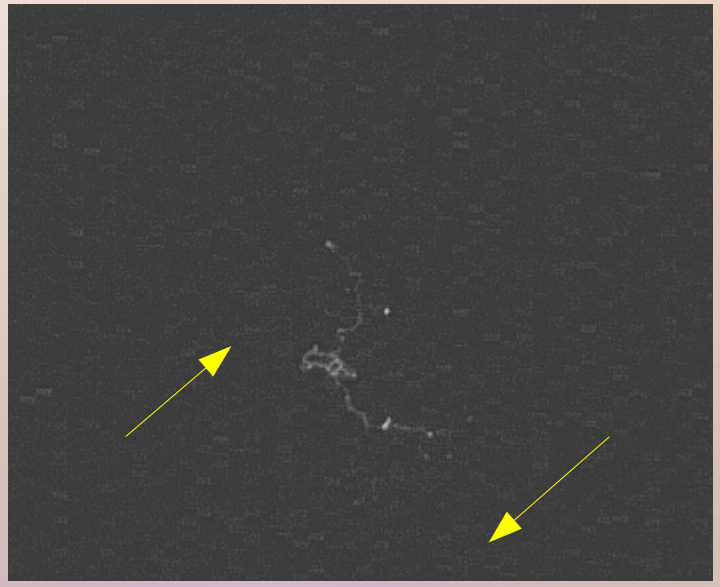
Japan soundings



Conclusions:

- very strong upper winds just above the cloud tops
- Low level directional shear

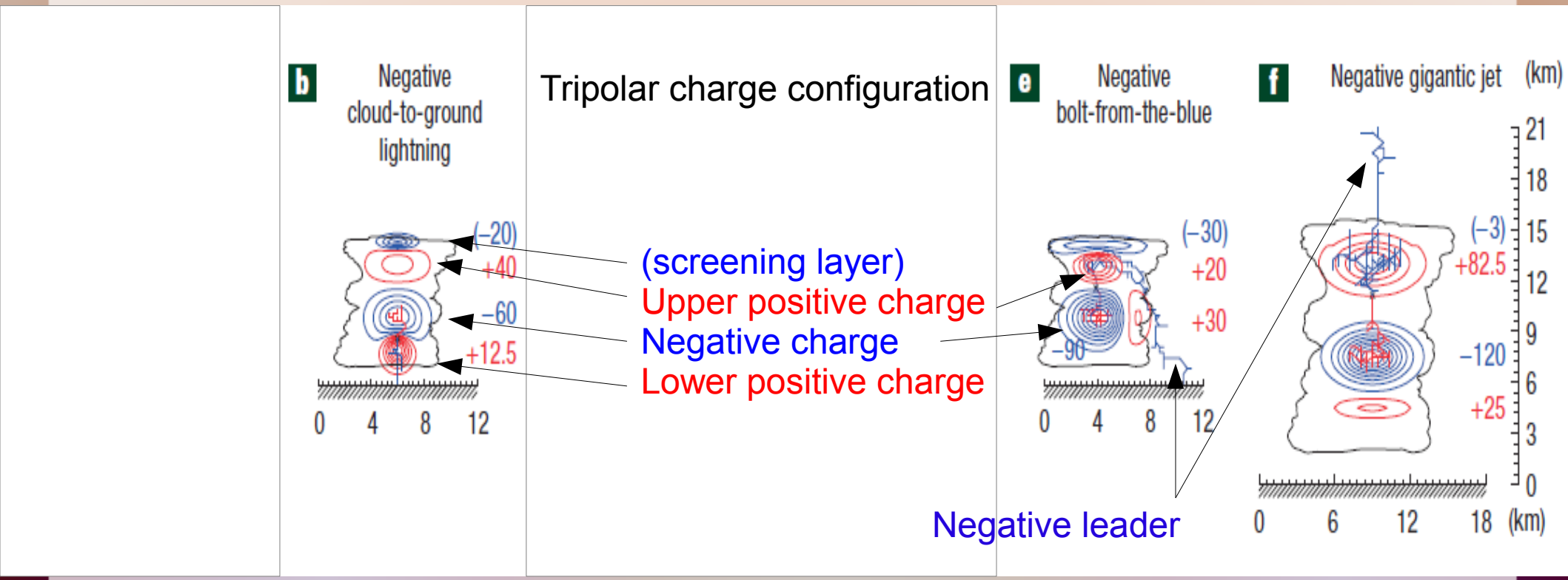
Is this different?
("bolt from the blue" with upward leaders)



Cloud top and ground indicated by arrows

- Inital negative leaders look weak here (high speed camera), but not for a Watec camera (previous images)
- Upward leaders are illuminated brightly after the return stroke (would be white-out in Watec images)
- In many upward cases a -CG stroke is detected immediately after the upward bolts.
- A bolt-from-the-blue stroke stops the upward propagation of leaders.

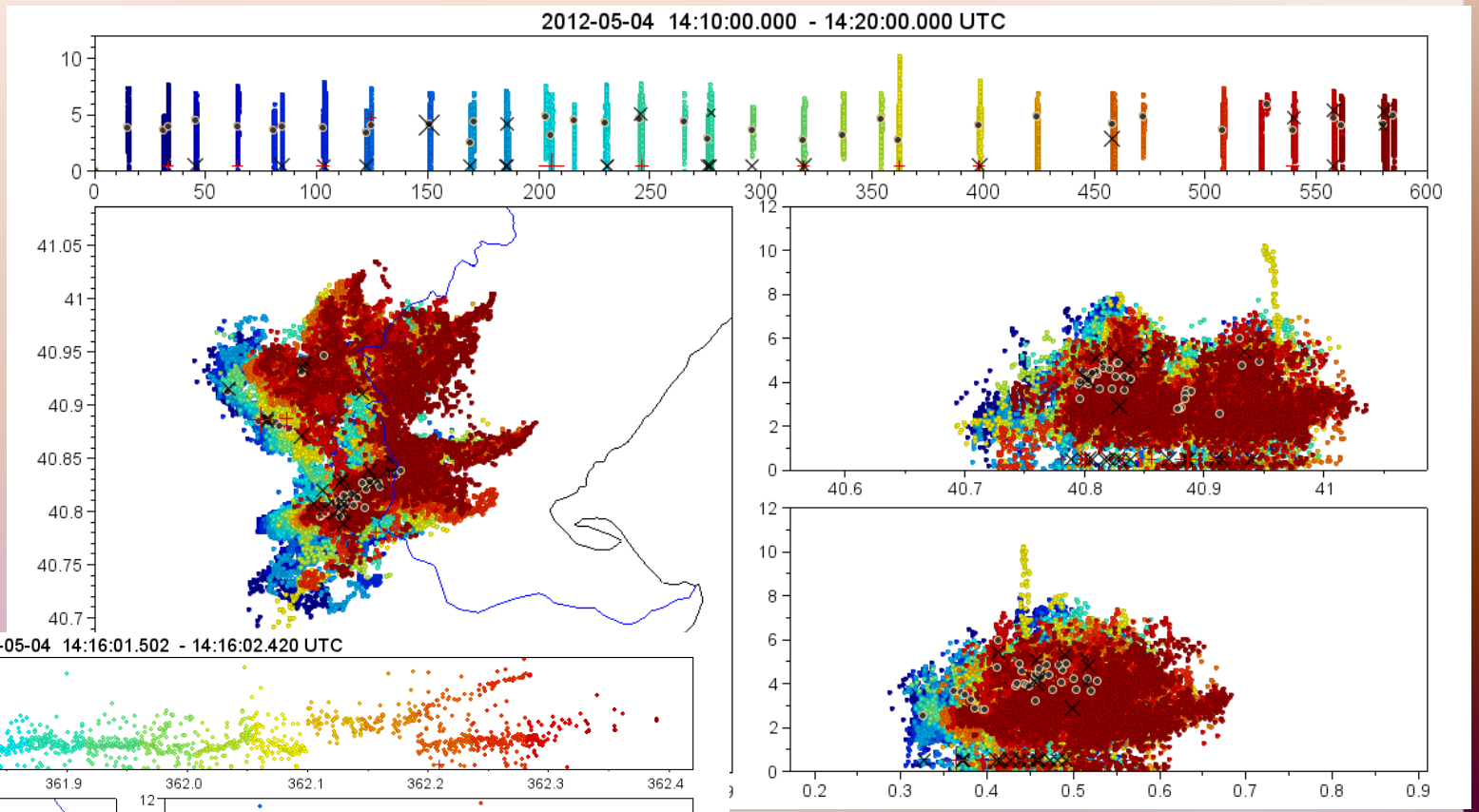
How does lightning escape from a cloud?

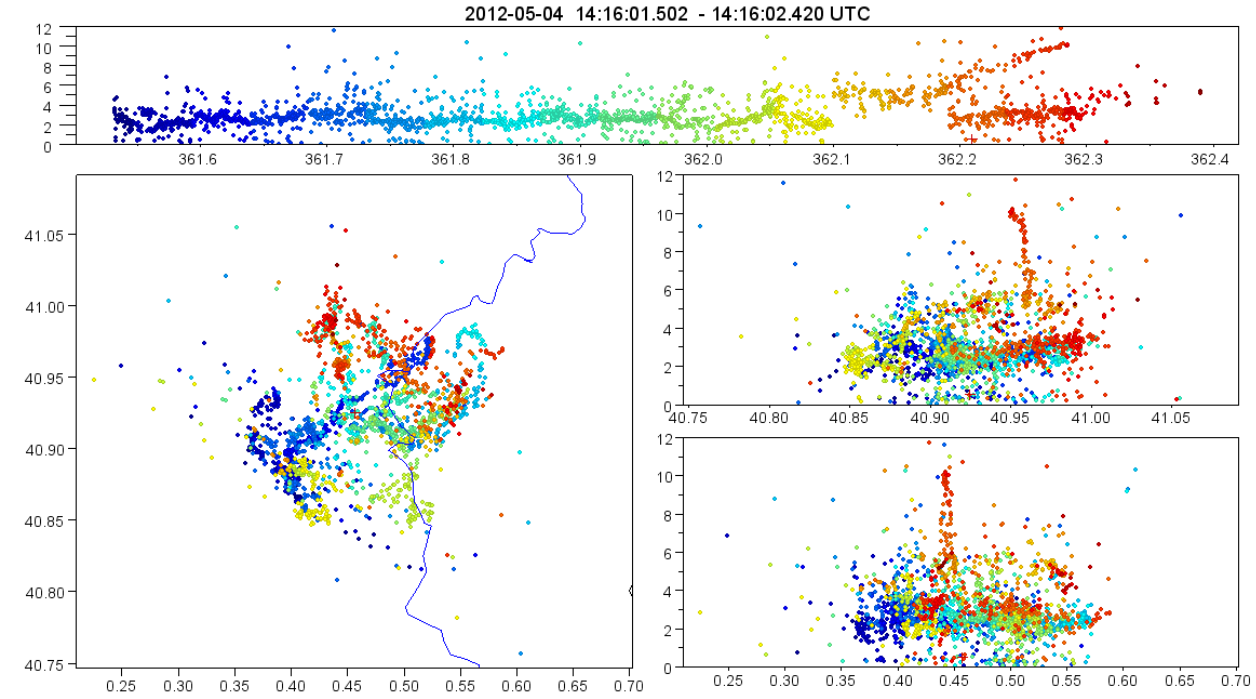


from Krehbiel *et al.* 2008, Nature Geoscience

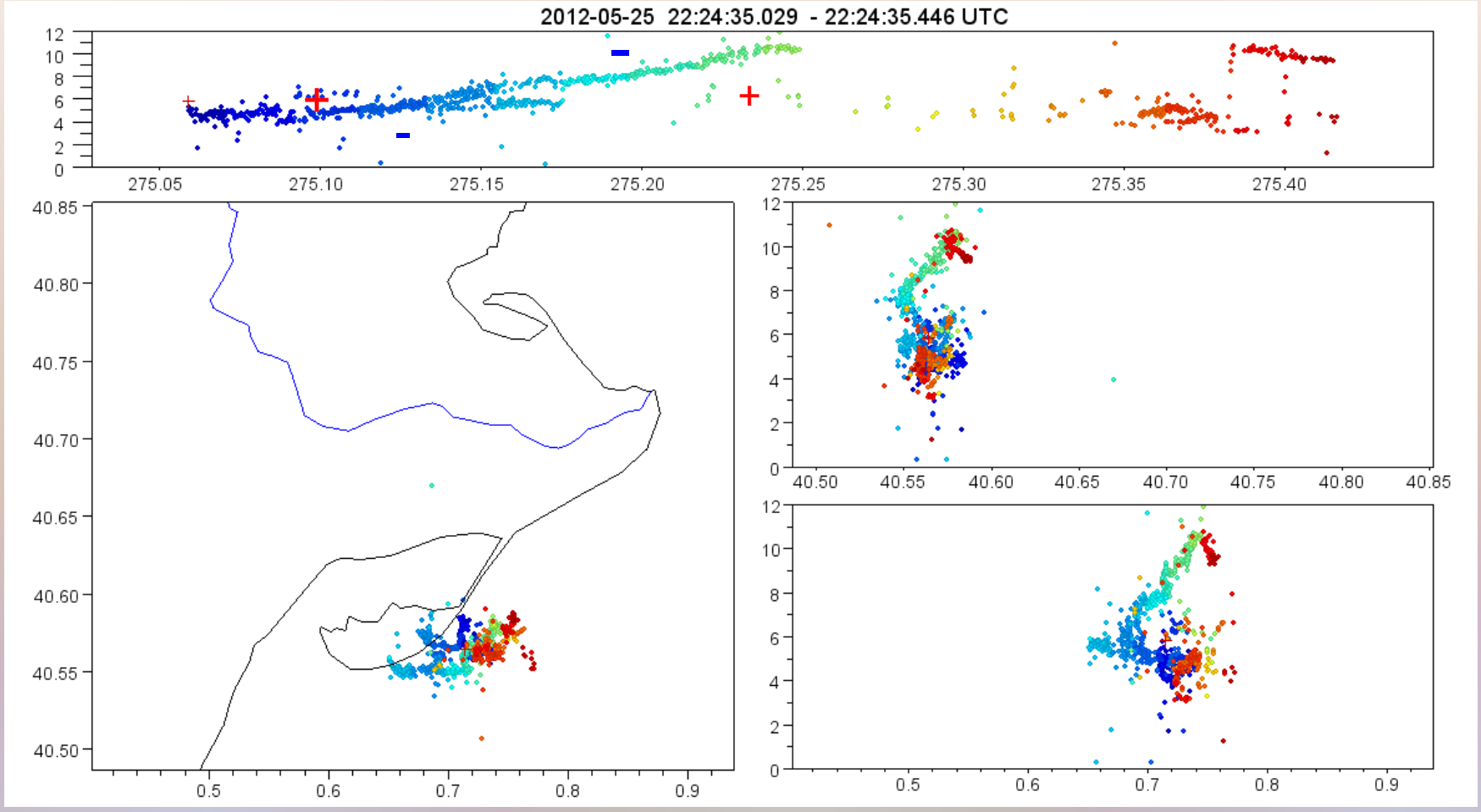
- If lightning is initiated between two *imbalanced* opposite charge regions,
- One leader end can propagate through the weaker charge region → out of the cloud
- Mixing of screening layer with the upper charge region → favorable situation for upward escaping lightning

Ebro LMA examples of upward bolts





Upward lightning: inverted “bolt from the blue”



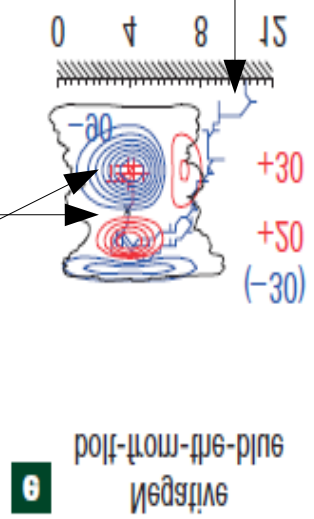
Structure: lower negative leader moving up passing the central negative charge - “inverted bolt from the blue”

Radar echo tops showed the lightning escaped from side of cloud and probably reconnected to the the cloud top (10 km).

inverted “bolt from the blue”

Inverted charge configuration

Negative leader



Positive charge

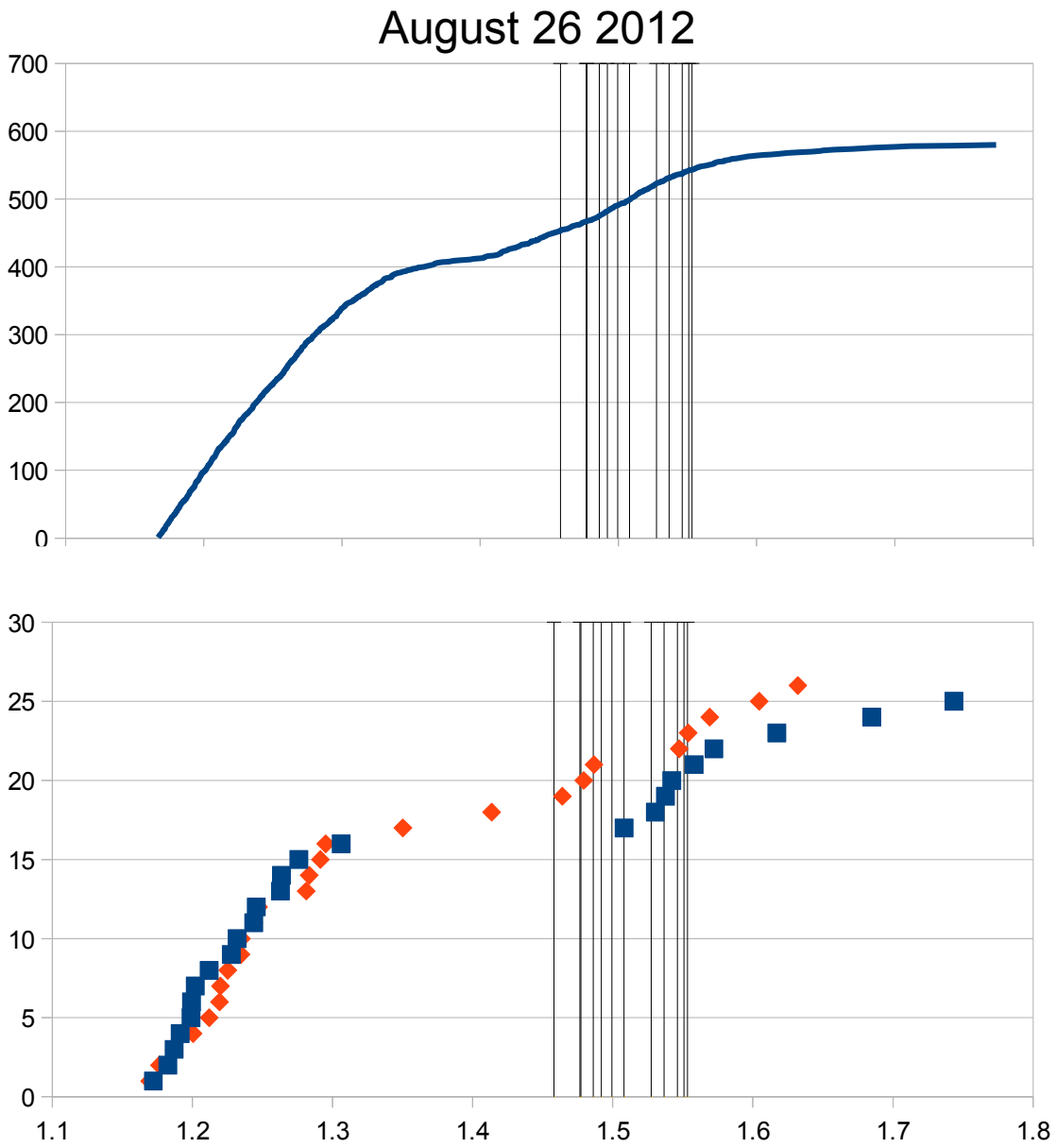
Negative charge

Not mentioned by Krehbiel *et al.* 2008, Nature Geoscience

Conclusions

- >50 kts (25 m/s) cloud top wind (or its shear) seems to prevent a screening layer from forming.
- Cloud tops in the -30° to -50°C range – 6-9 km – lower than typical summer storms – exposed tower (not a wide anvil)
- Inverted "bolt from the blue" observed by LMA – a type not listed by *Krehbiel et al.* (2008)
- Low -CG rates around the event times (lower +charge absent or – charge at larger height).
- Strong convective growth observed in most cases. (similar to Réunion island gigantic jets case)
- In some events, a bright -CG stroke followed immediately. Likely prevented the upward leaders to reach higher.

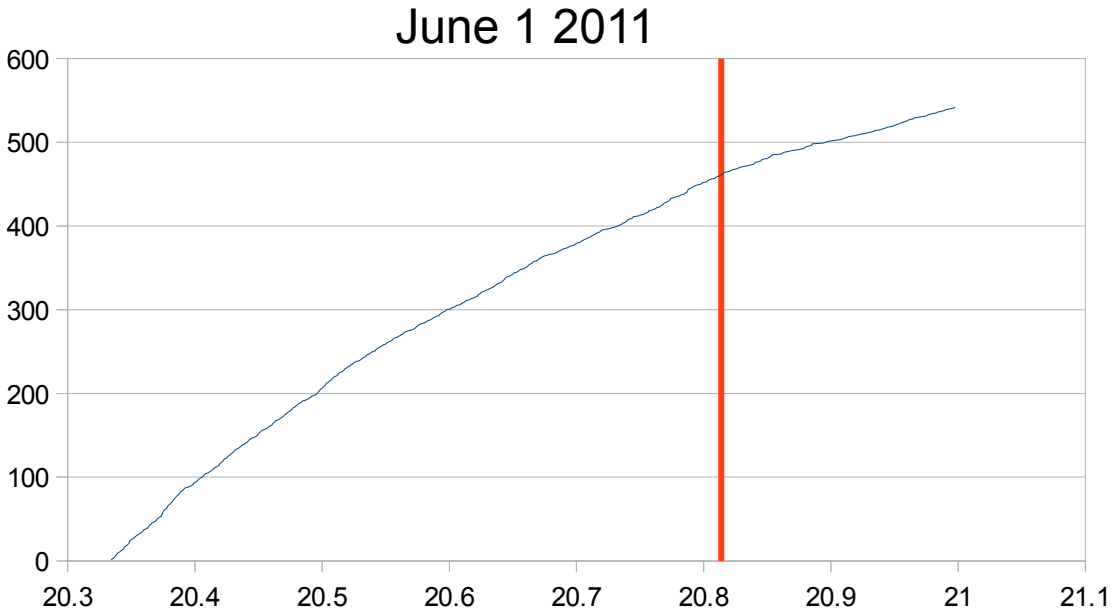
Flash rates

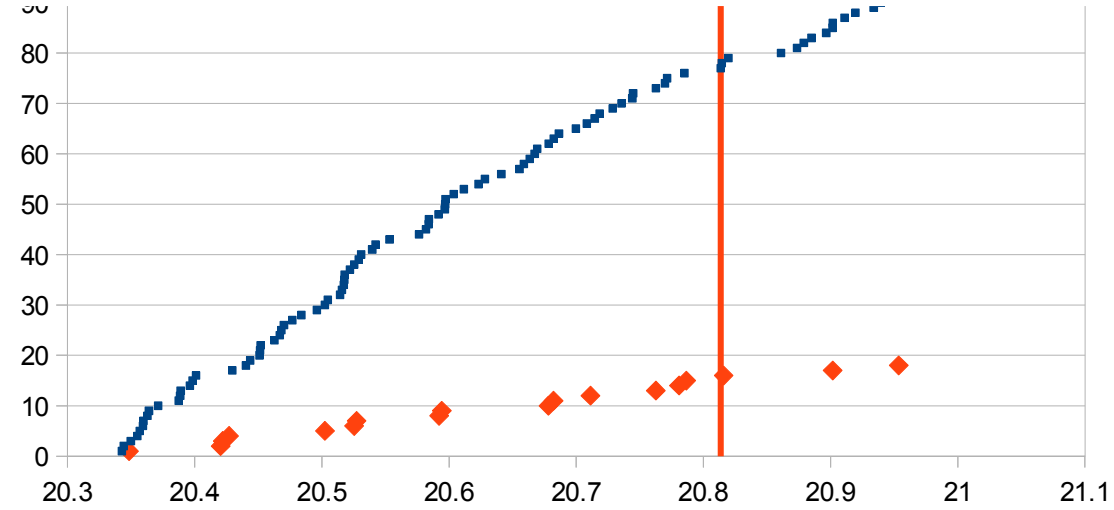


Lightning Mapping Array
Total flash rates

LINET LF-TOA network
-CG (blue) flashes
+CG (red) flashes

Flash rates

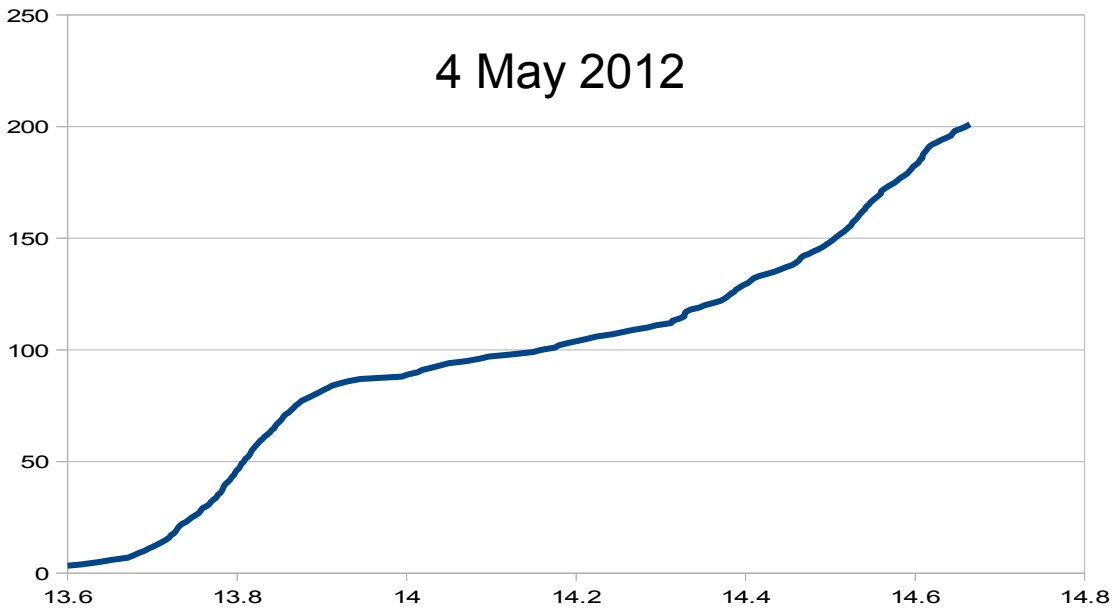




LS8000 VHF
interferometer network
Total flash rates

LINET LF-TOA network
-CG (blue) flashes
+CG (red) flashes

Flash rates



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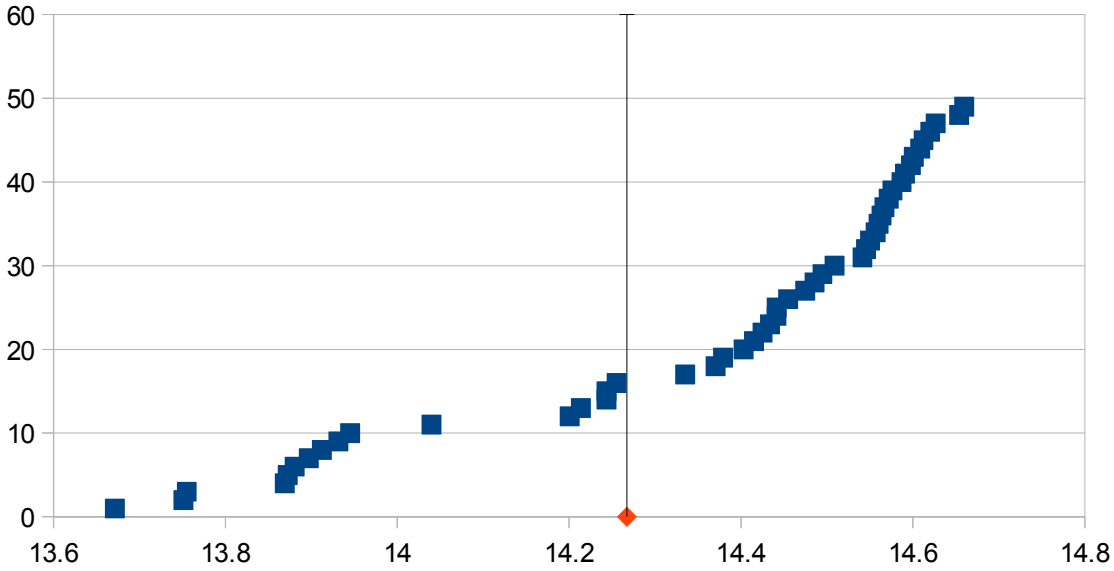
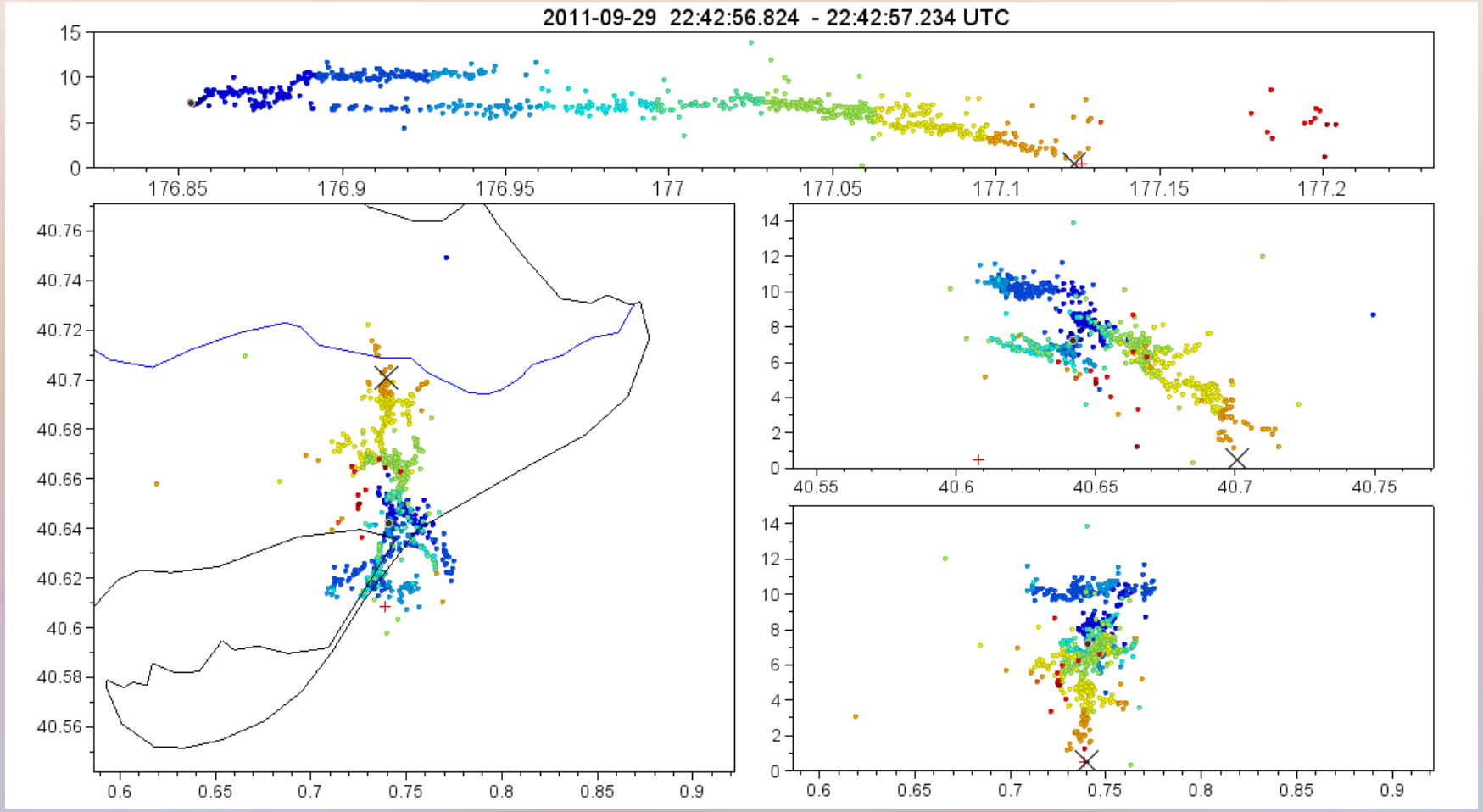
Total flash rates



LINET LF-TOA network
-CG (blue) flashes
+CG (red) flashes

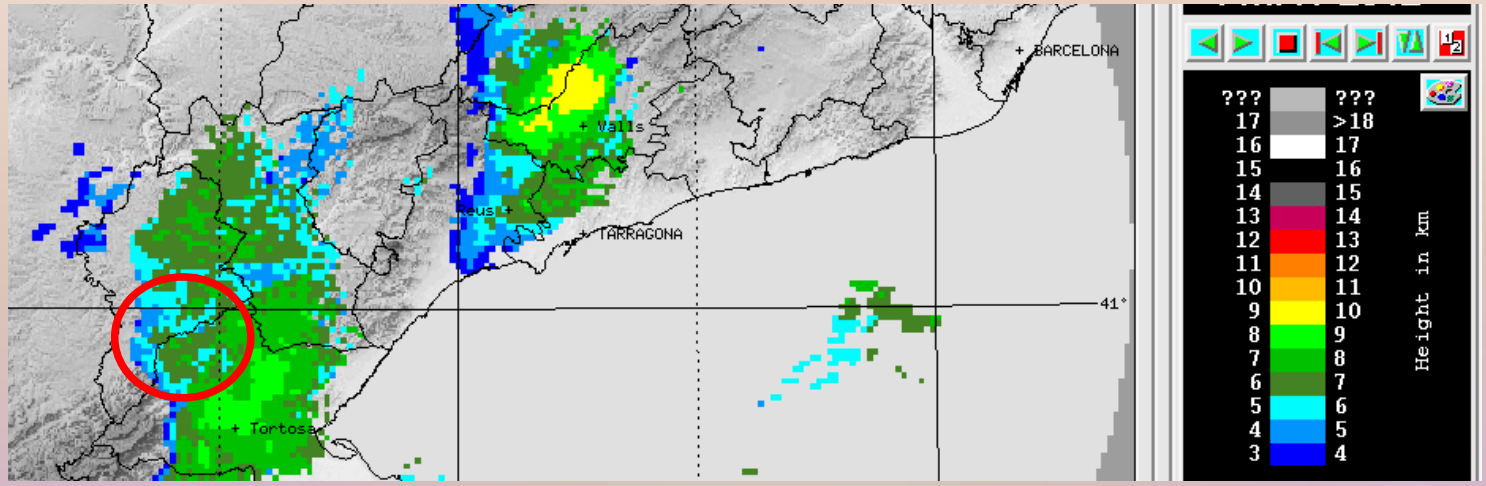
Bolt from the blue -CG



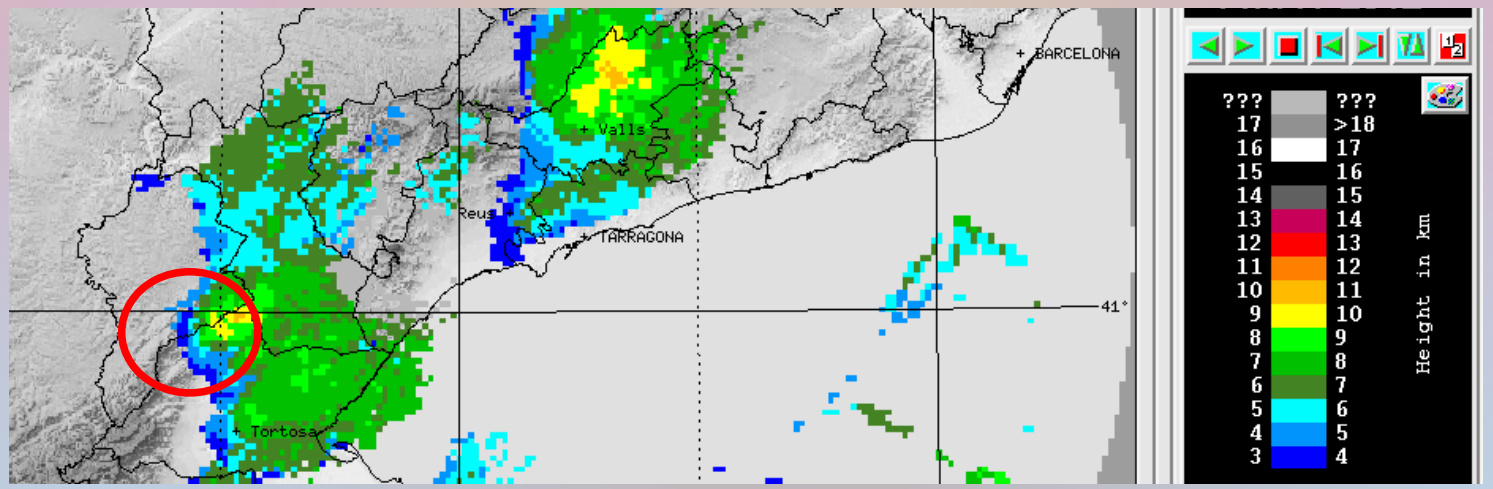
Radar echo tops

Strong vertical growth to 10 km

14:12

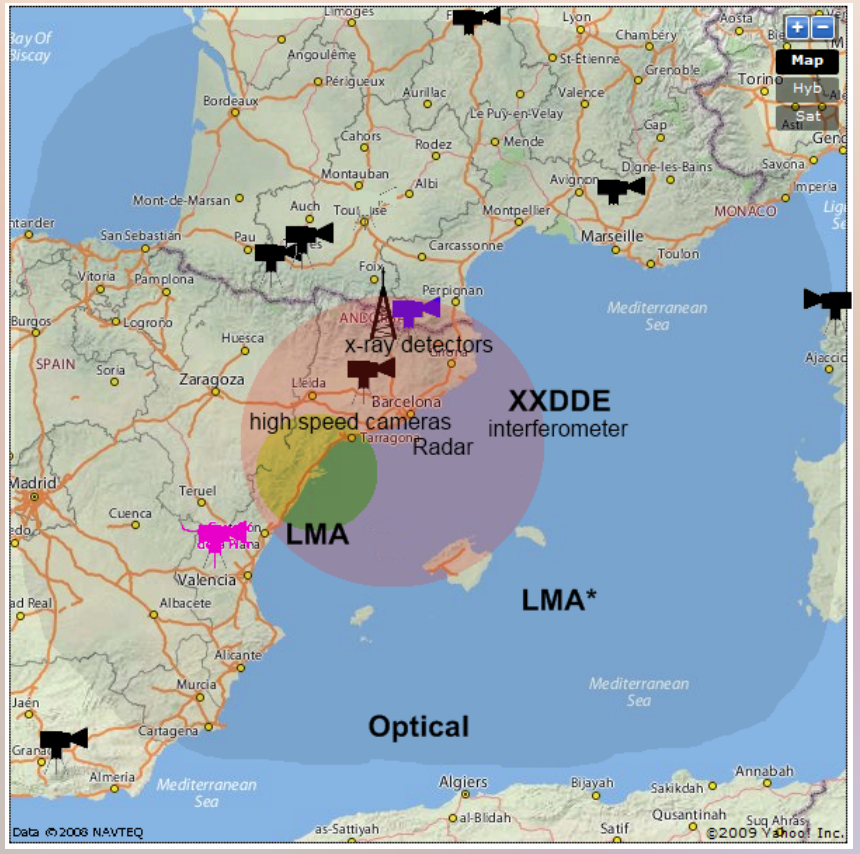


14:24



Ebro Lightning Mapping Array

- developed by New Mexico Tech
- 3D time-of-arrival
- 11 sensors currently installed
- Baselines 6-25 km
- 40 by 70 km area
- 60-66 MHz (VHF)
- 12500 peak amplitude samples per second (80 μs)



Well located for warm and cold season storms + sprite observations