

Ce qu'il faut connaître sur les éclairs et les moyens de s'en protéger

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Directeur de Recherches au CNRS

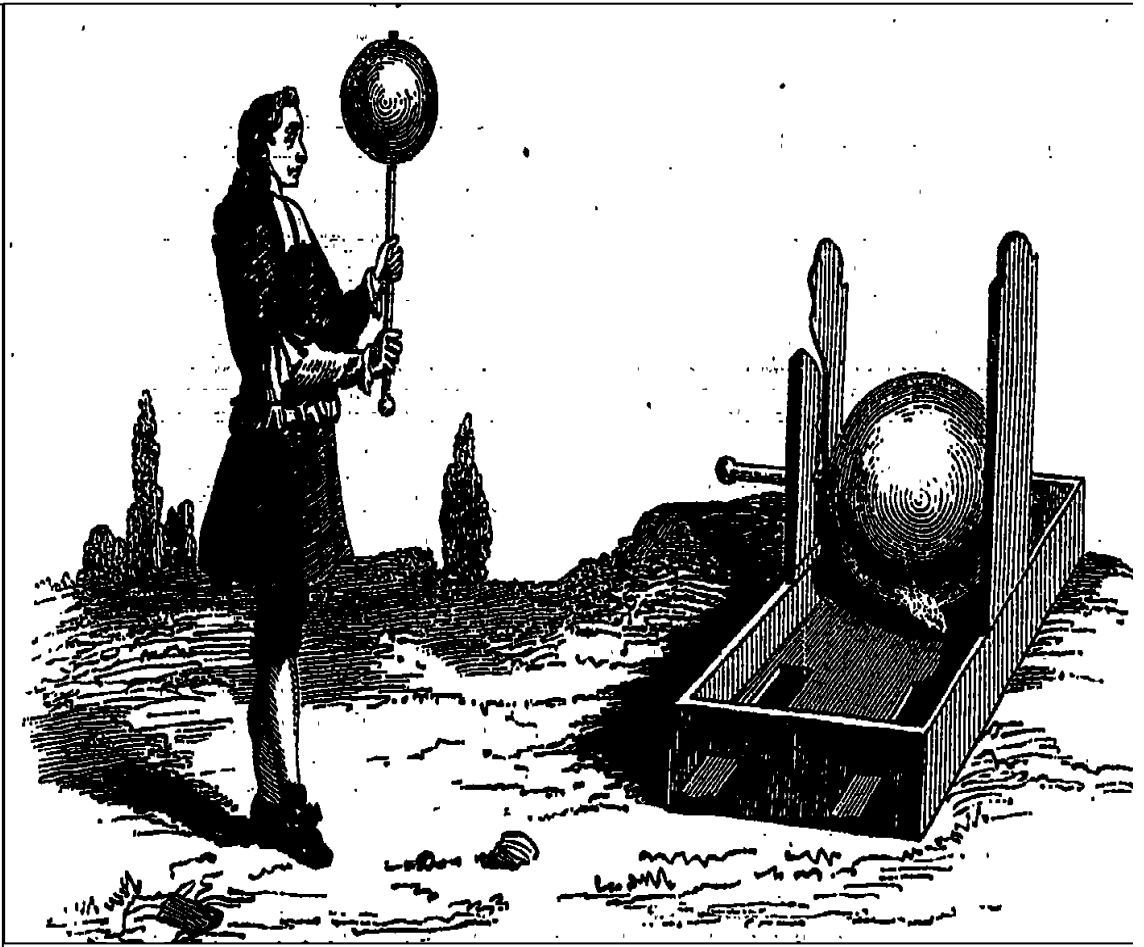
Laboratoire de Physique des Gaz et des Plasmas

Orsay, 23 octobre 2007

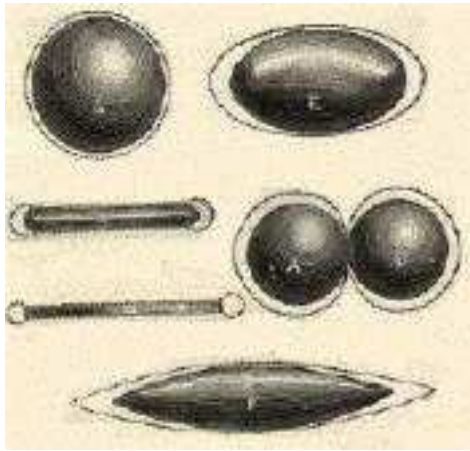
Mythologie de la foudre



FIGURE 1.1 — Sceau cylindrique de la première époque de Babylone datant d'environ 2000 ans av. J.-C.

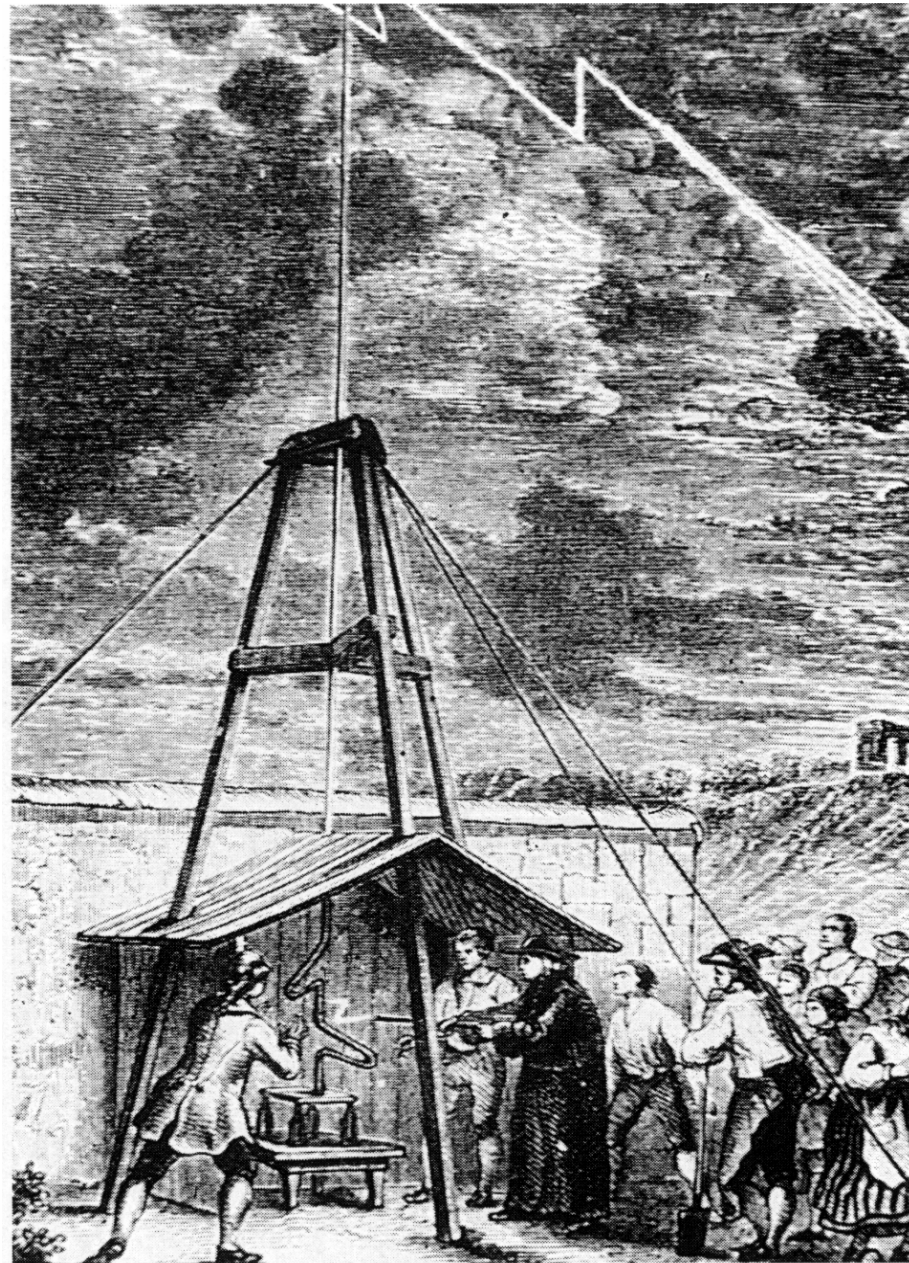


C'est Otto Von Guericke, inventeur de la machine électrostatique, qui fut le premier vers 1660, à produire une étincelle et proposer une explication électrique aux phénomènes orageux.

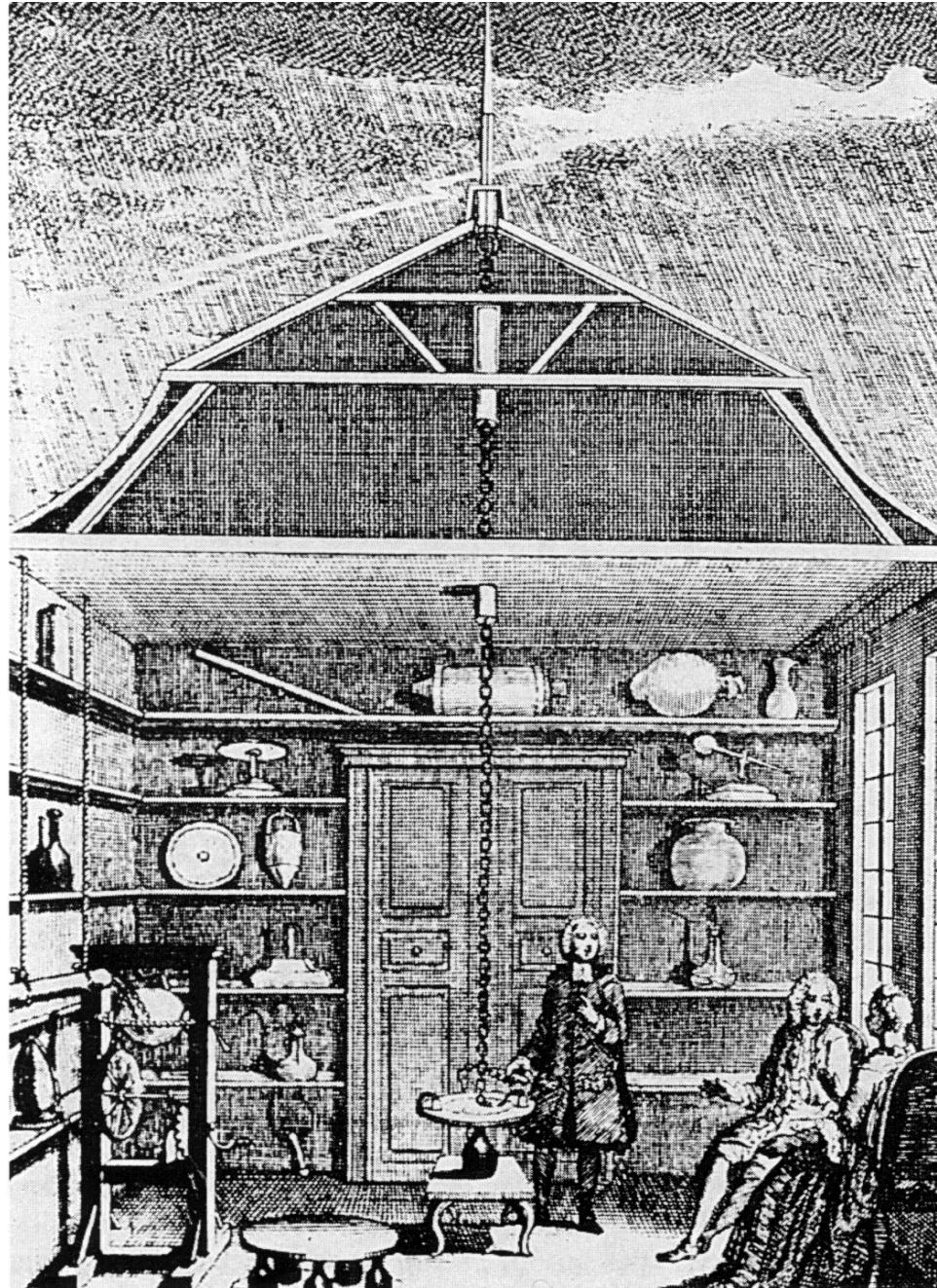


En 1748 Jallabert découvre le pouvoir des pointes

Premières expériences en 1752



Cabinet de Physique (18ième siècle)



L'accident de Richmann



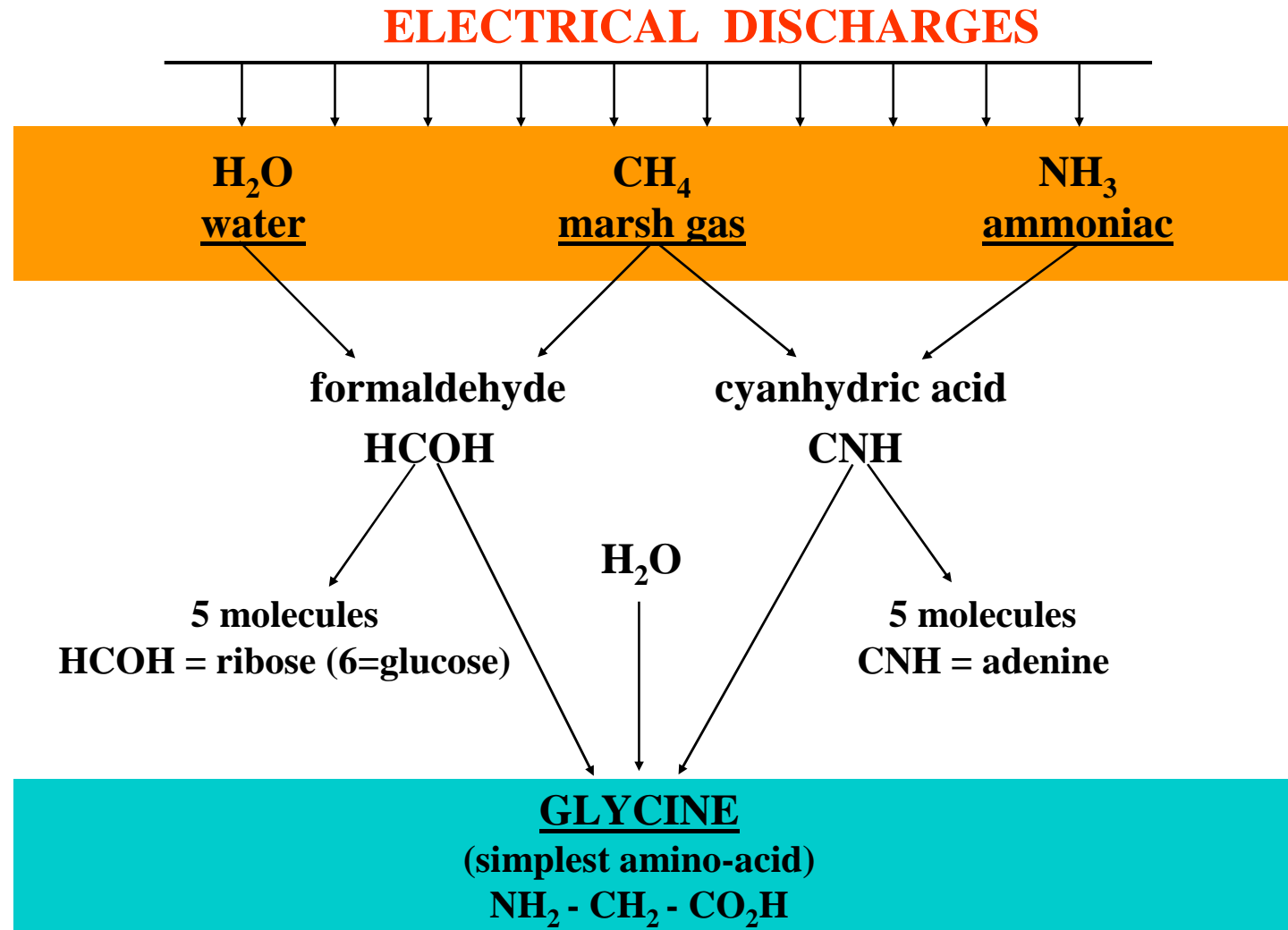
Chapeau-paratonnerre, Paris, 1778



Parapluie-paratonnerre, Barbeu-Dubourg

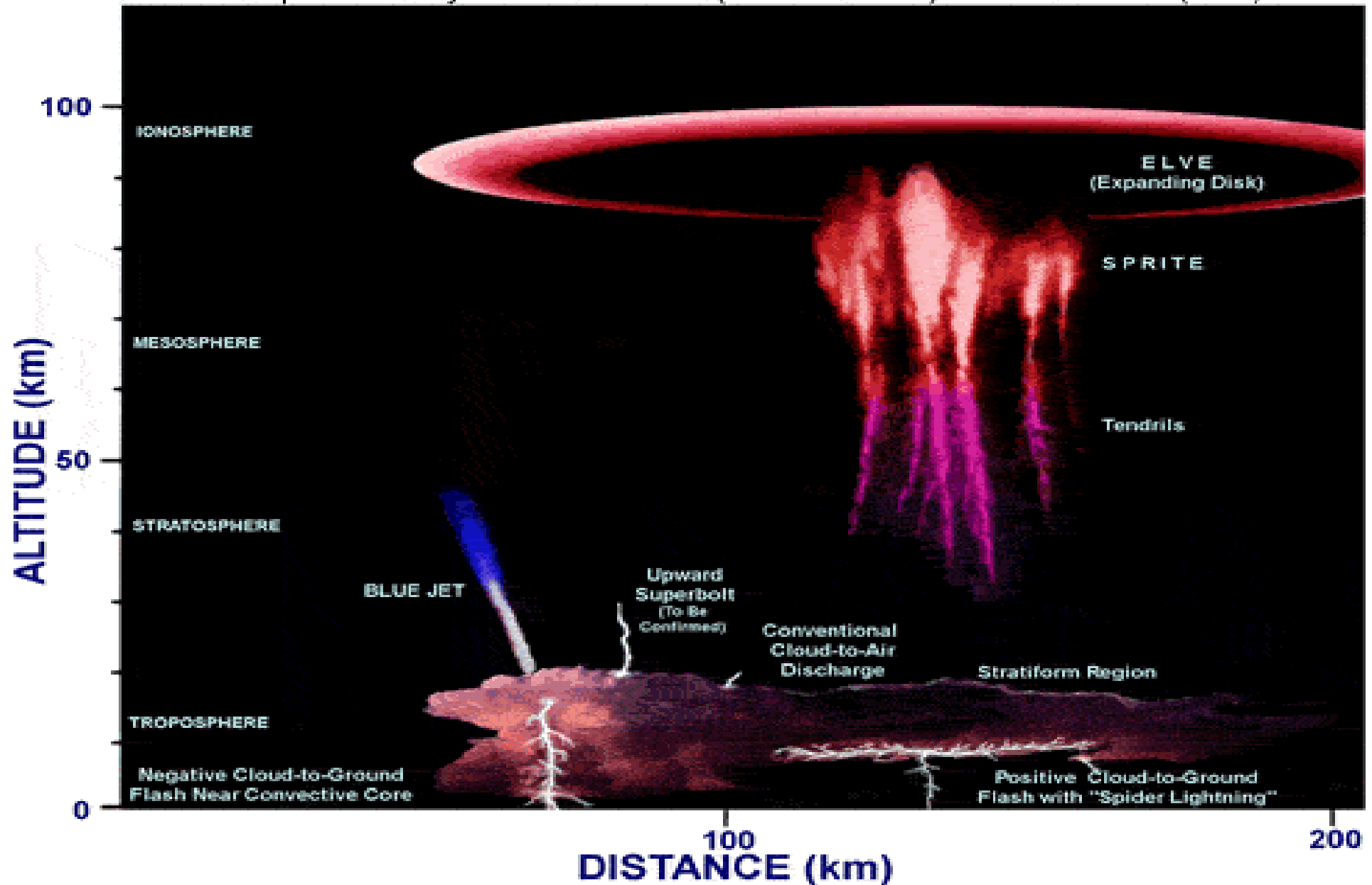


Expérience de Miller (1954)

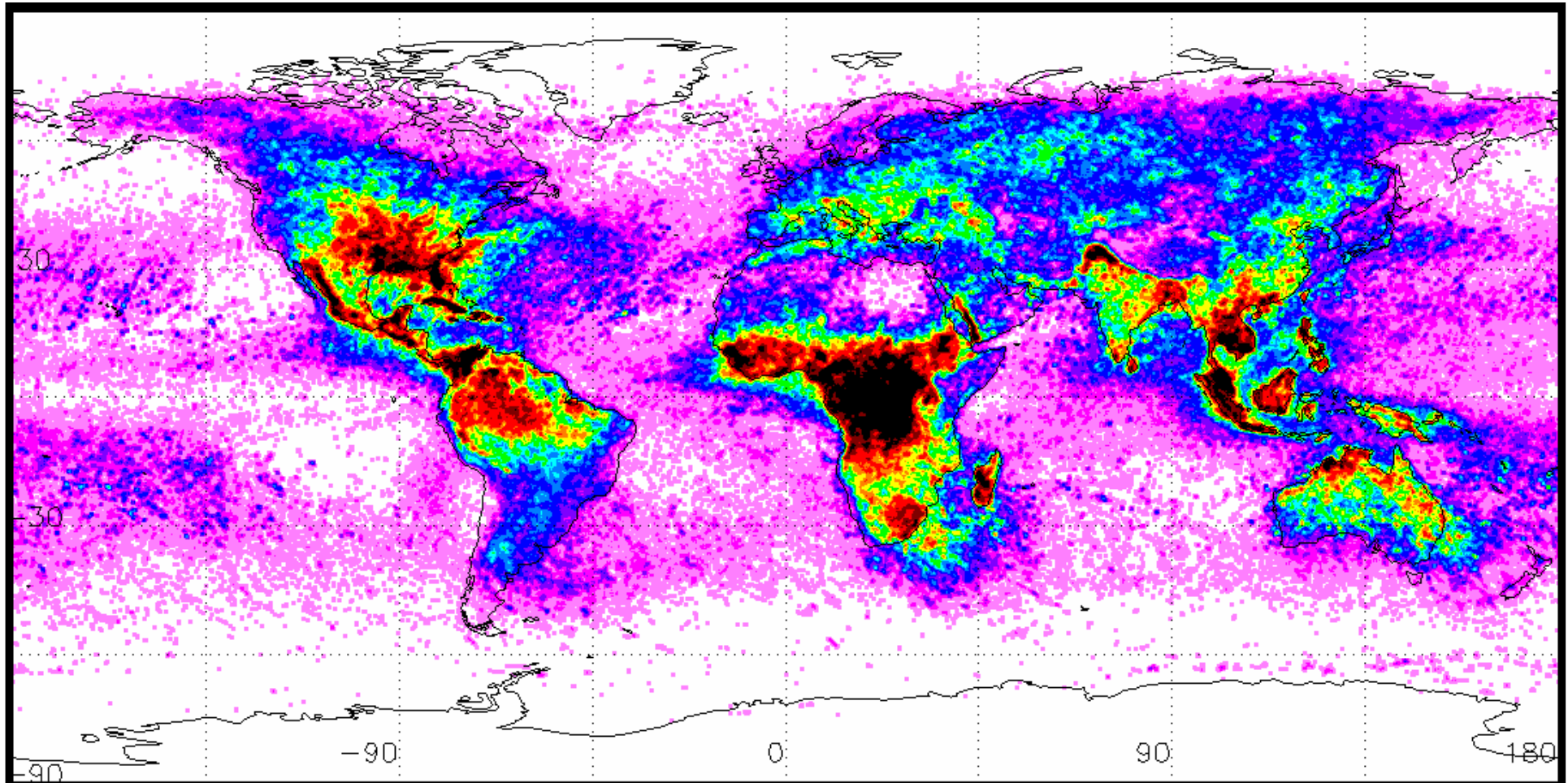


Différents types de phénomènes de foudre

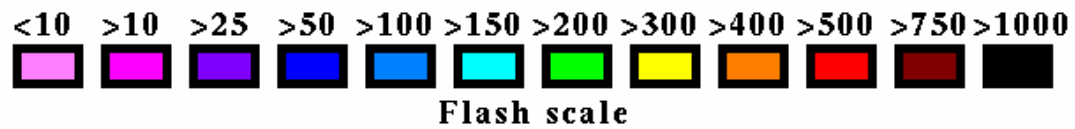
Graphic courtesy of Carlos Miralles (AeroVironment) and Tom Nelson (FMA)



Mission OTD



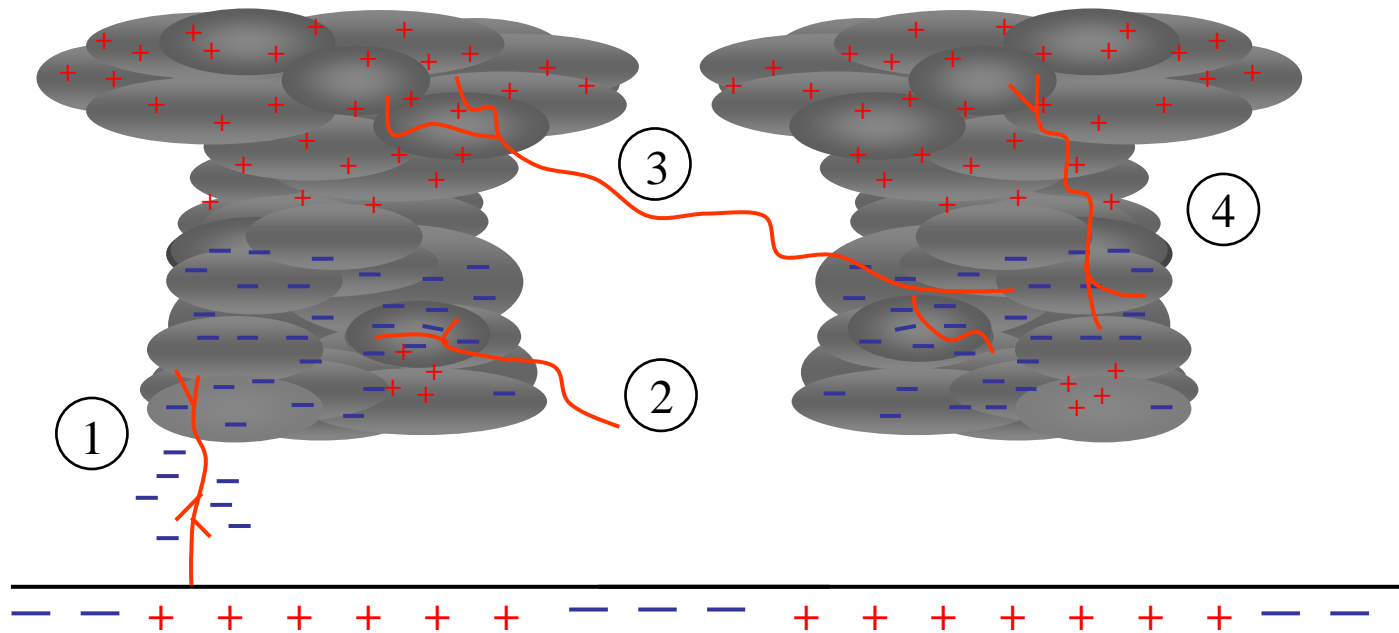
Orbits 17371
Areas 808854
Flashes 4345364
Groups 20727622
Events 42265608
(Created : 02/15/100)



April 12, 1995 - December 31, 1999

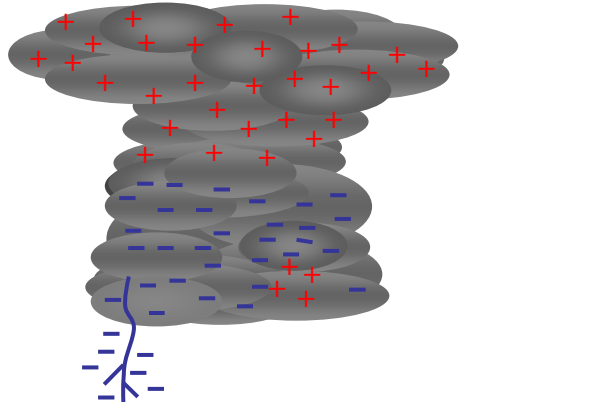


Quatre types d'éclair

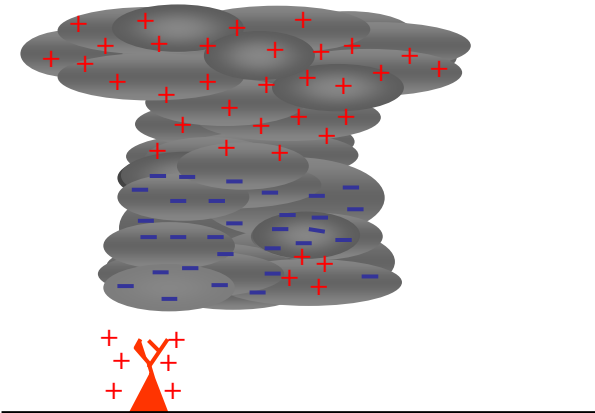


- ① Eclair nuage-sol
- ② Eclair nuage-air
- ③ Eclair inter-nuageux
- ④ Eclair intra-nuageux

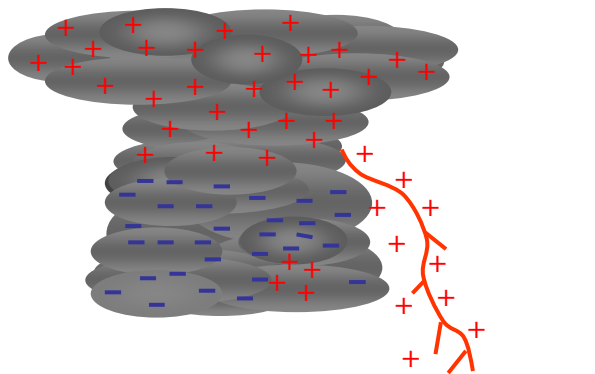
Quatre types d'éclairs nuage-sol selon K. Berger (1978)



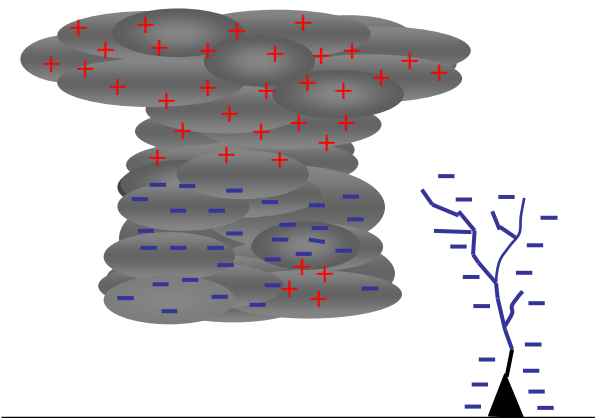
Traceur descendant négatif



Traceur ascendant positif



Traceur descendant positif



Traceur ascendant négatif

Trajectoires des éclairs



Eclair ascendant positif



Toronto CN Tower, Canada

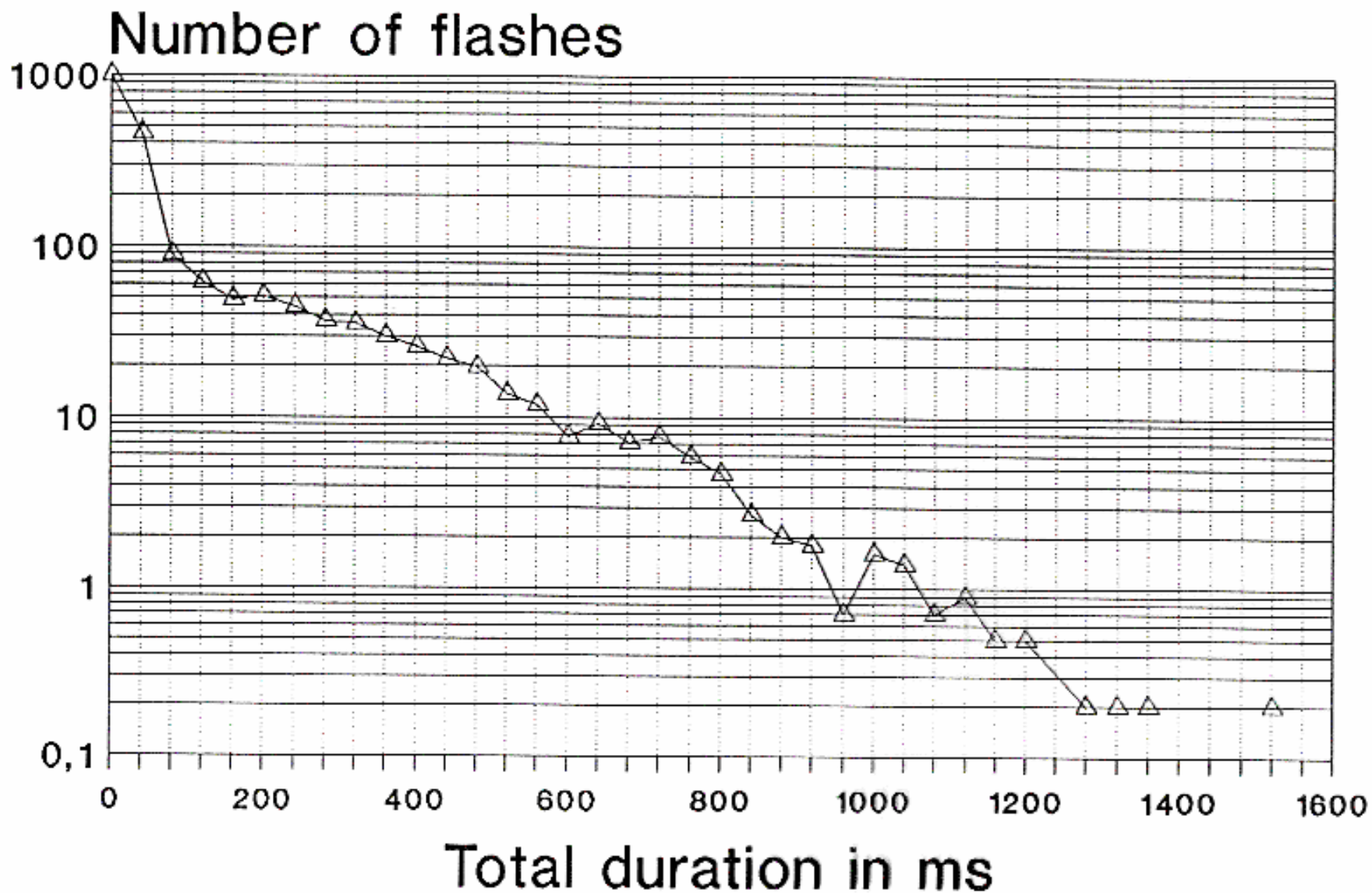
Impact sur un arbre

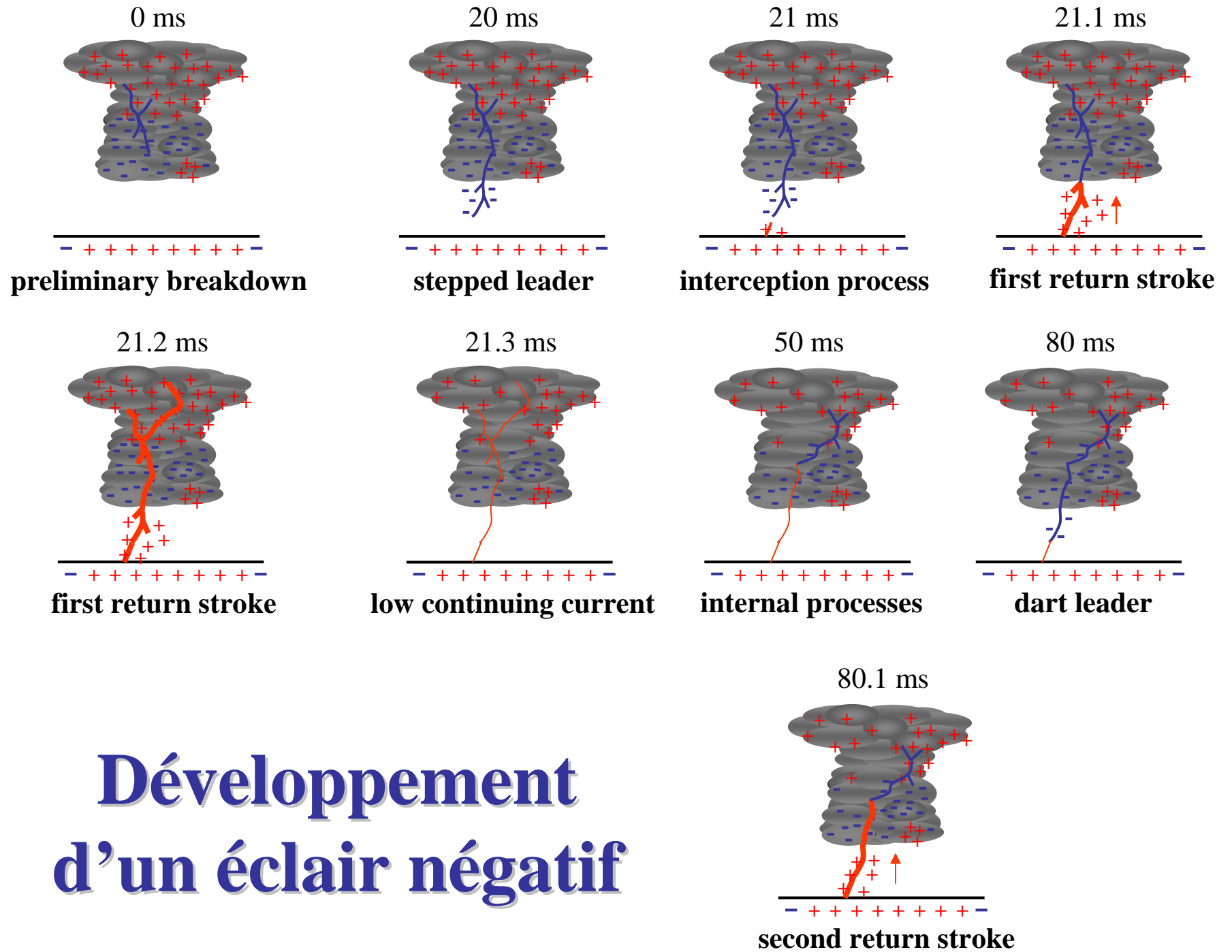


Eclair sur la Navette Spatiale



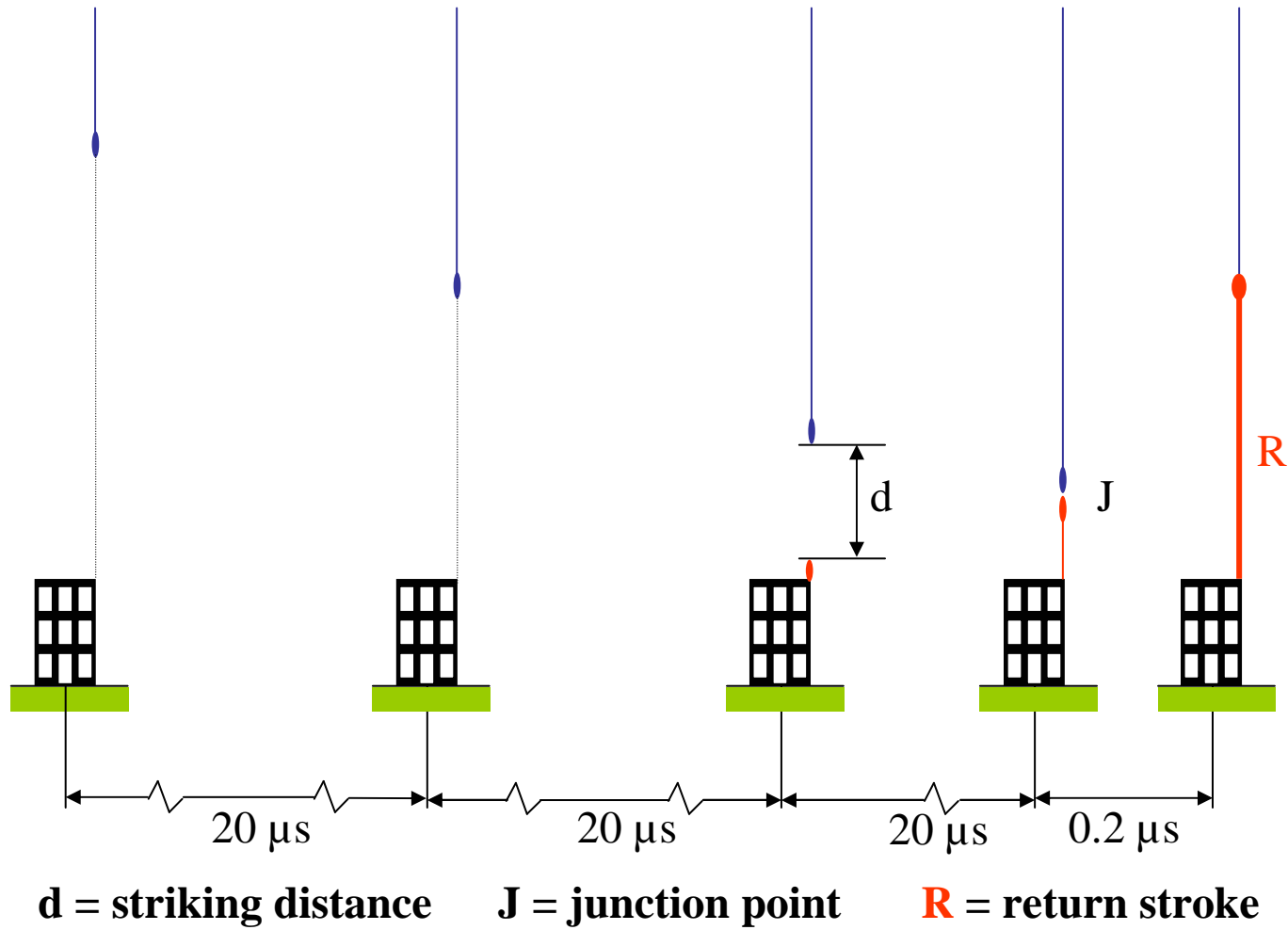
Durée totale des éclairs





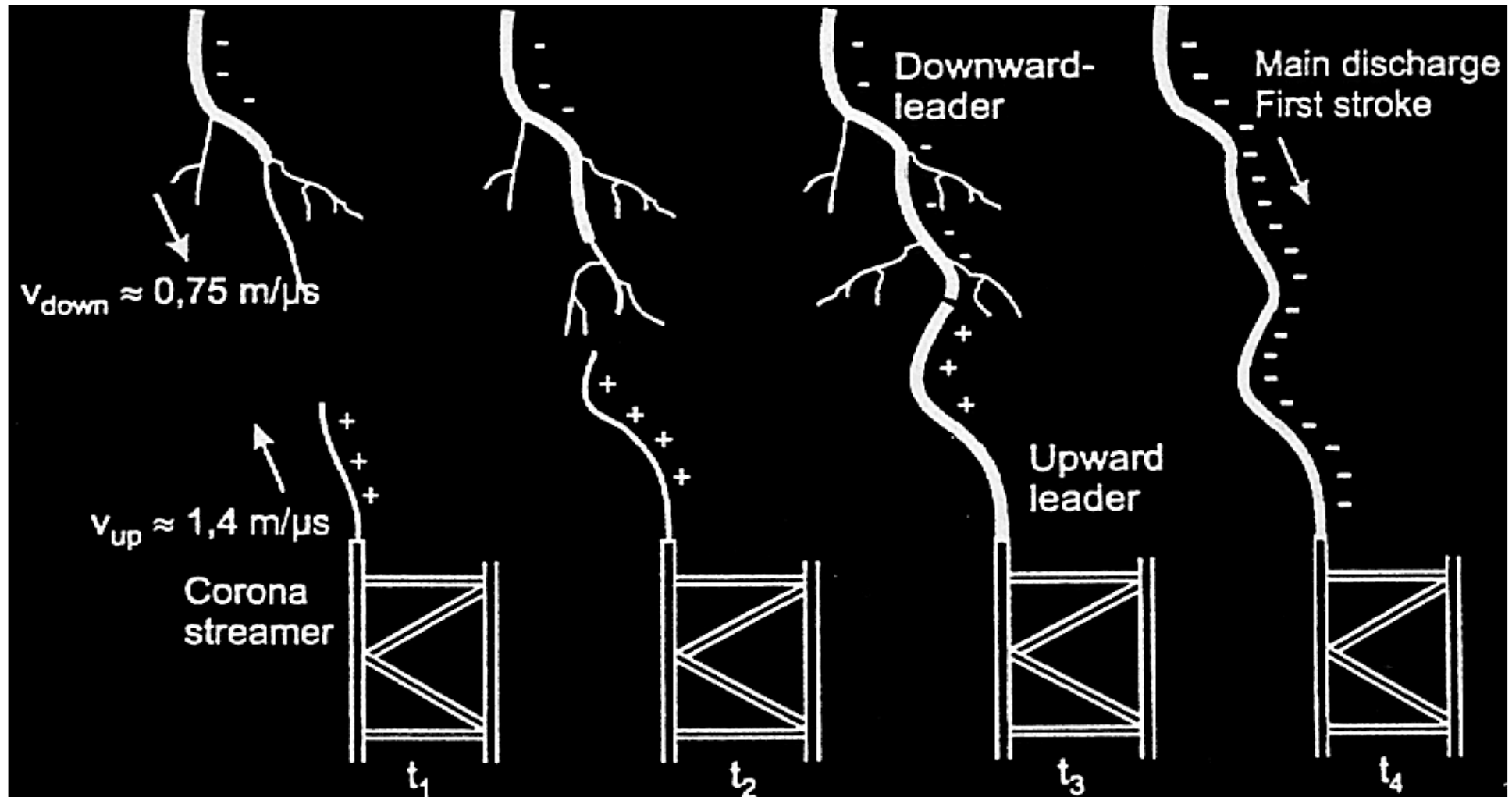
Développement d'un éclair négatif

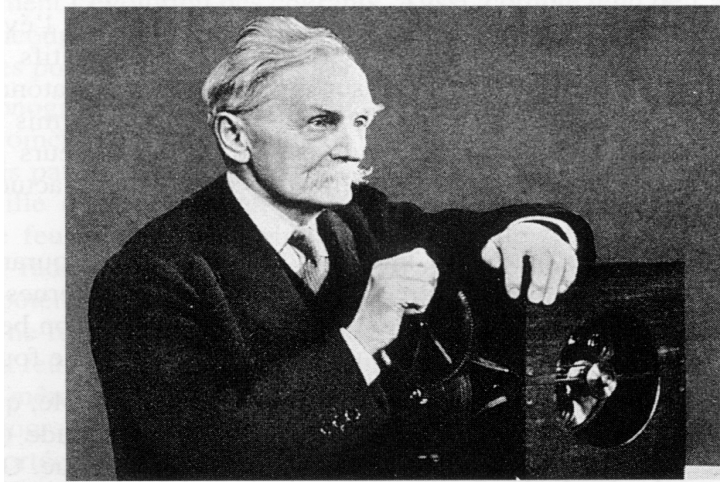
Attachement au sol



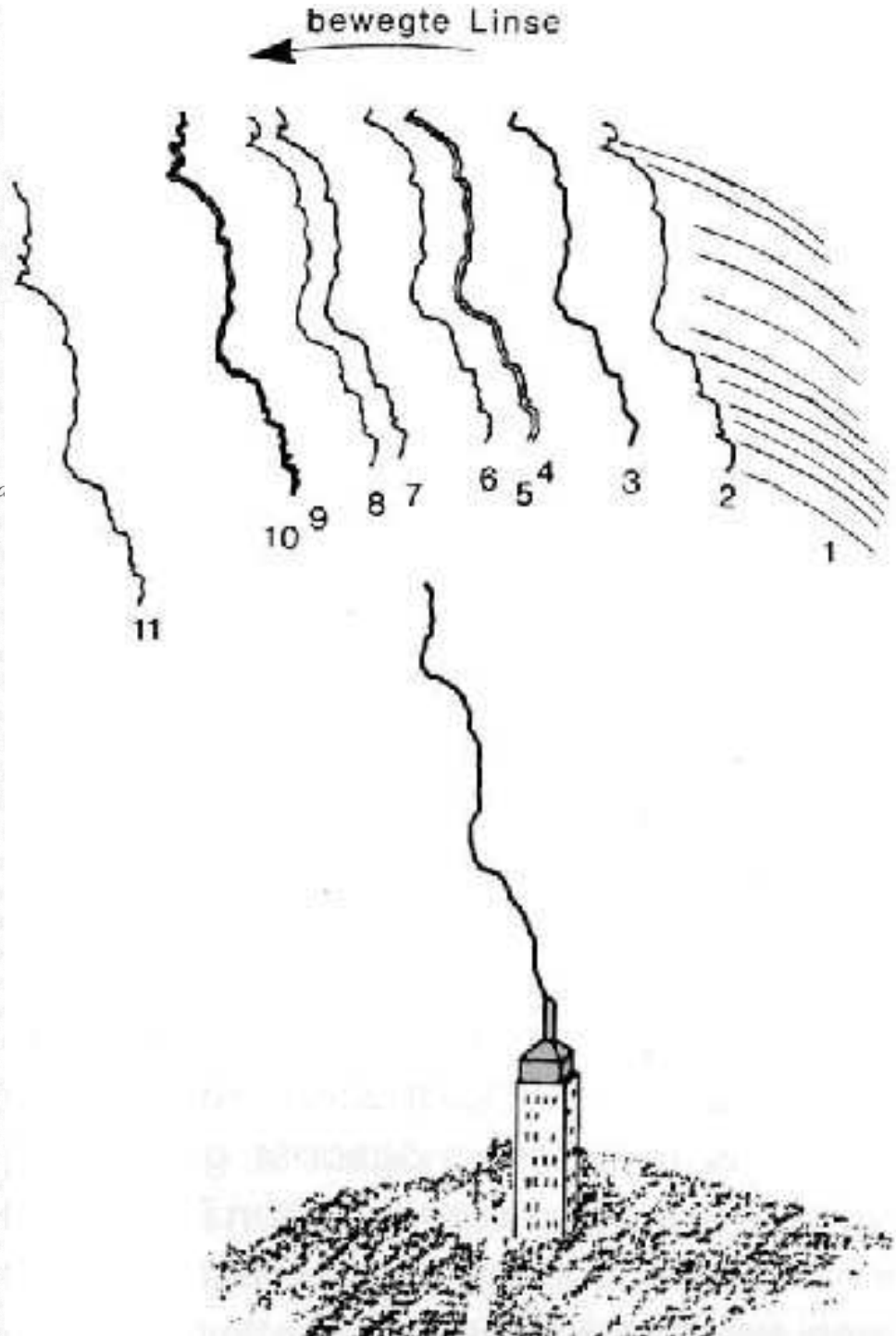
By courtesy of Pr Bouquegneau

Attachment sur une structure au sol

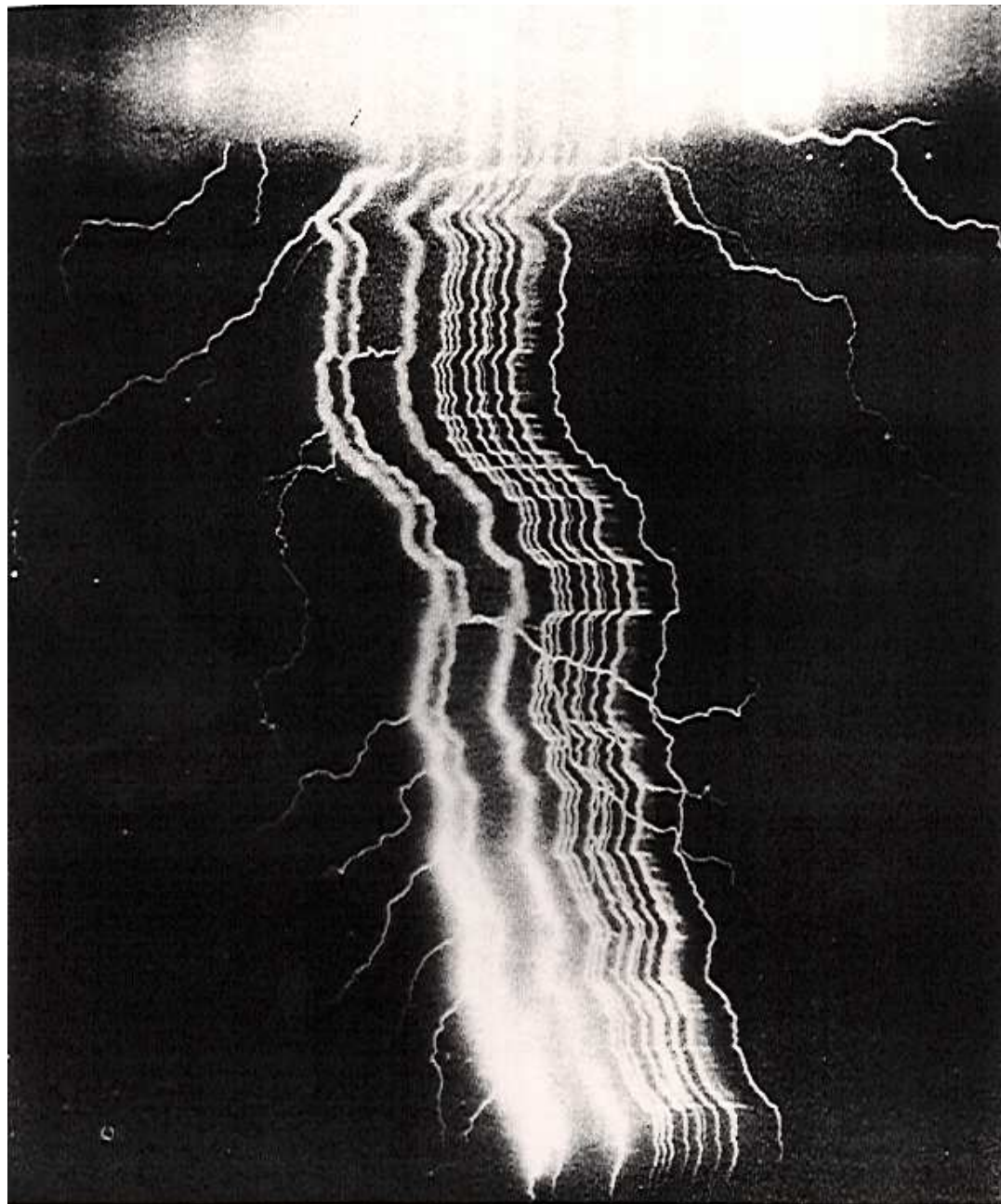




URE 3.2 — Sir Charles Vernon Boys et sa caméra à objectifs tournants



Eclair à réallumages multiples



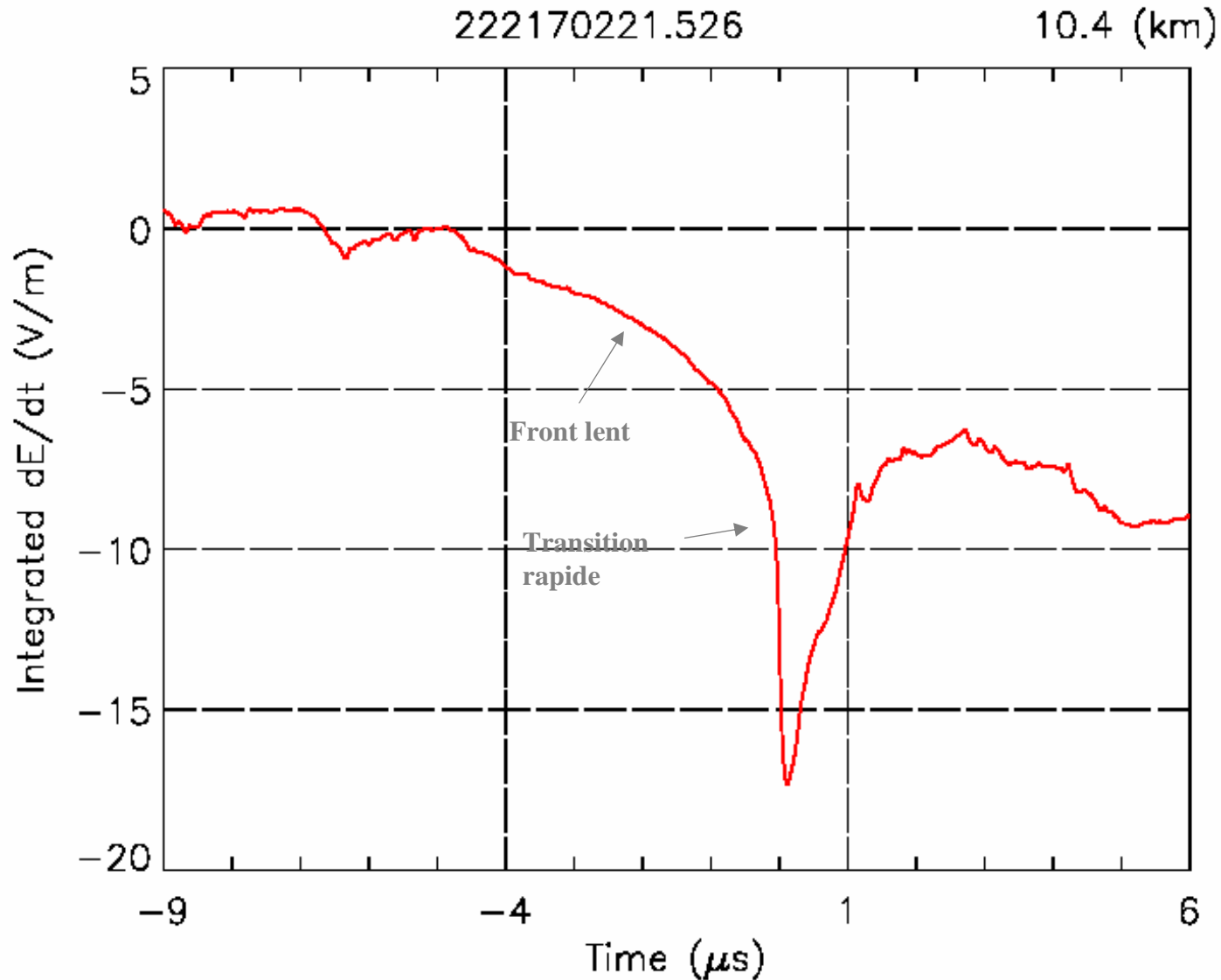
Return Stroke Characteristics

- **High peak current : 3-300 kA**
- **Typical velocity : light speed / 3**
- **Peak power : 100 MW / m**
- **Peak temperature : 30,000 K**
- **Front dl / dt : 1-2 10^{11} A / s**

Paramètres

Paramètre	Unit	Values (%) exceeding the indicated ones		
		95%	50%	5%
Peak currents				
first negative strokes and negative flashes	kA	14	30	80
subsequent negative strokes	kA	4.6	12	30
positive flashes	kA	4.6	35	250
Charge				
first negative strokes and	C	1.1	5,2	24
negative flashes	C	0.2	1.4	11
subsequent negative strokes	C	1.3	7.5	40
positive flashes	C	20	80	350
Front duration				
first negative strokes	µs	1.8	5,5	18
subsequent negative strokes	µs	0.22	1.1	4.5
positive flashes	µs	3.5	22	200
Maximum rate of rise (di/dt)				
first negative strokes	kA/µs	5.5	12	32
subsequent negative strokes	kA/µs	12	40	120
positive flashes	kA/µs	0.2	2.4	32
Pulse duration				
first negative strokes	µs	30	75	200
subsequent negative strokes	µs	6.5	32	140
positive flashes	µs	25	230	2000
Time intervals between				
negative strokes	ms	7	33	150
Flash duration				
negative (simple or multiple)	ms	0.15	13	1100
negative (multiple only)	ms	31	180	900
positive	ms	14	85	500
i²dt integral				
first negative strokes and negative flashes	A².s	6.0 10³	5.5 10⁴	5.5 10⁵
subsequent negative strokes	A².s	5.5 10²	6.0 10³	5.2 10⁴
positive flashes	A².s	2.5 10⁵	6.5 10⁵	1.5 10⁷

Champ électrique E, à 100 km de distance (Krider, Willett)





Fulgurite record

Rakov, Uman

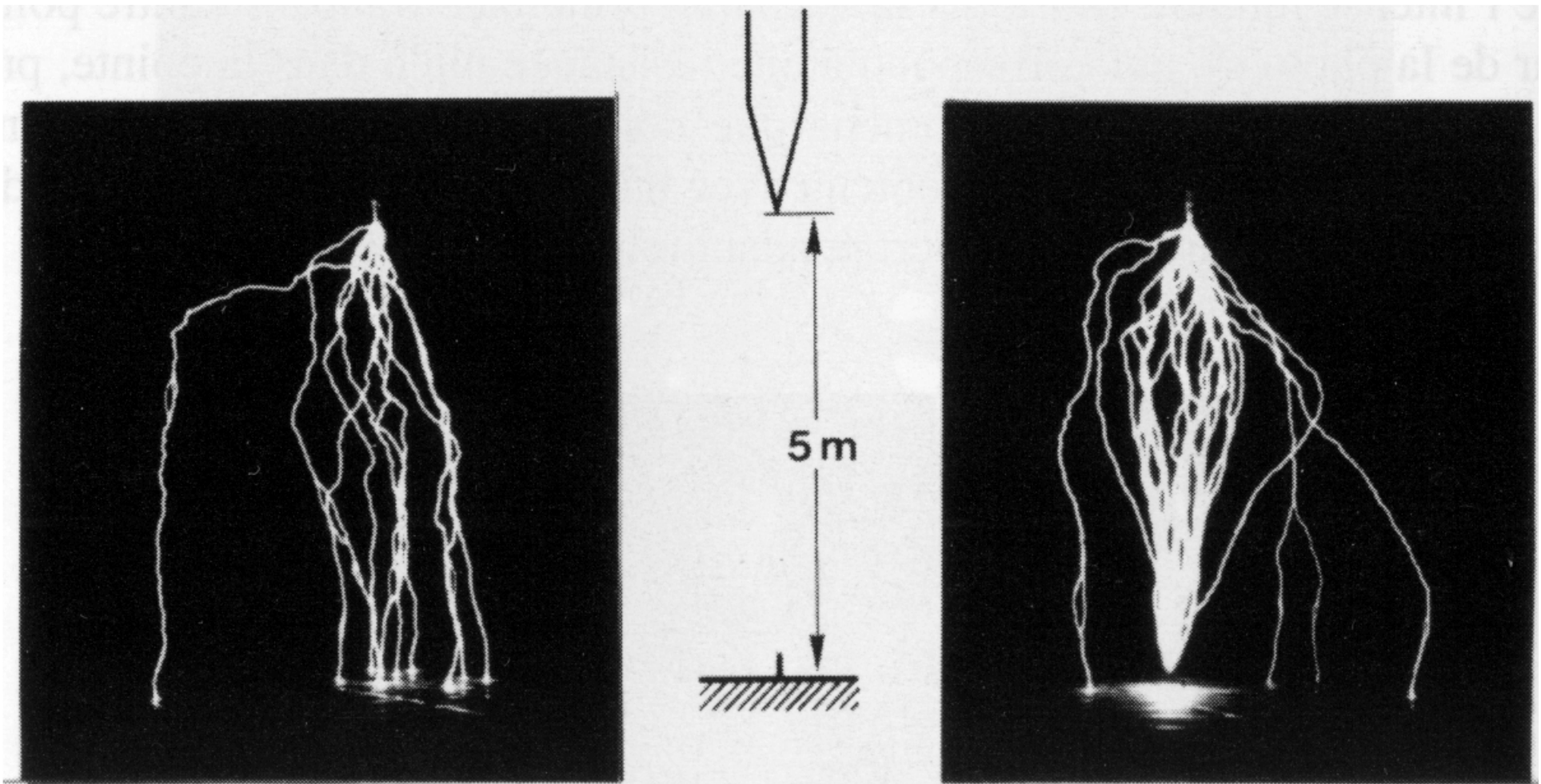
Diverses échelles des études expérimentales sur la foudre

Laboratoire

Foudre déclenchée artificiellement

Observations in situ

Modélisation numérique de l'interception



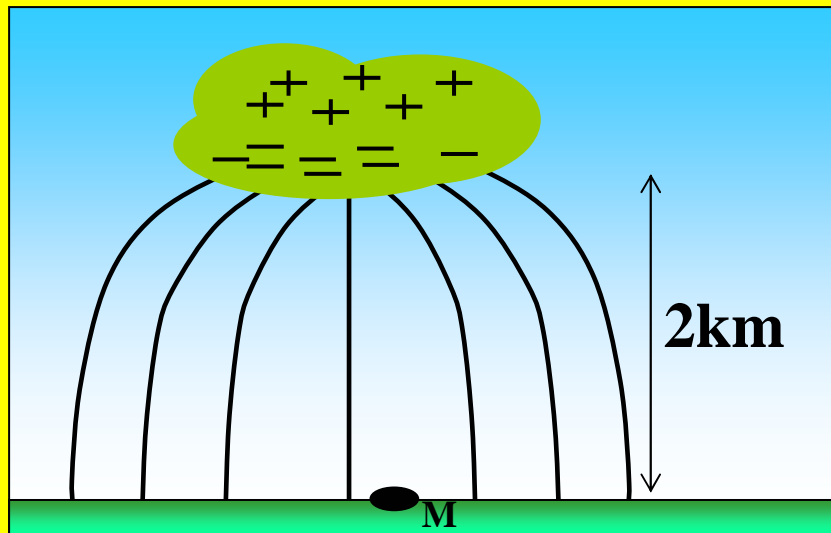
(a)

(b)

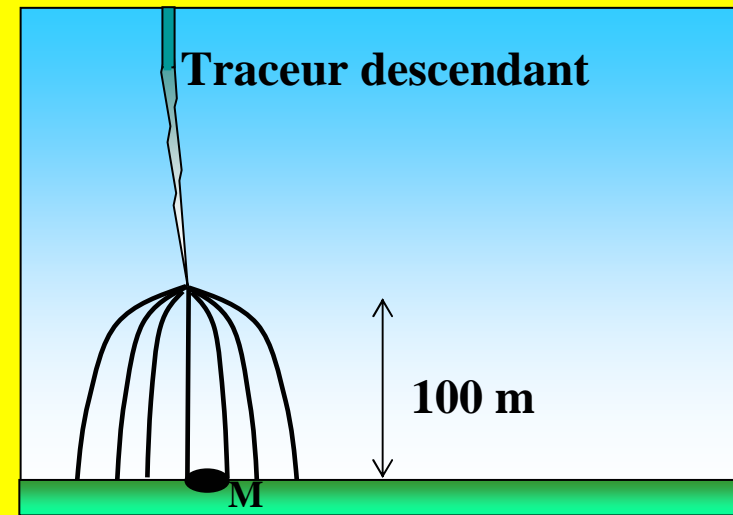
FIGURE 9.10 — Démonstration du pouvoir de capture d'une tige au sol.
a) Décharges sans tige ; b) Décharges avec tige.

Simulation du traceur ascendant en laboratoire

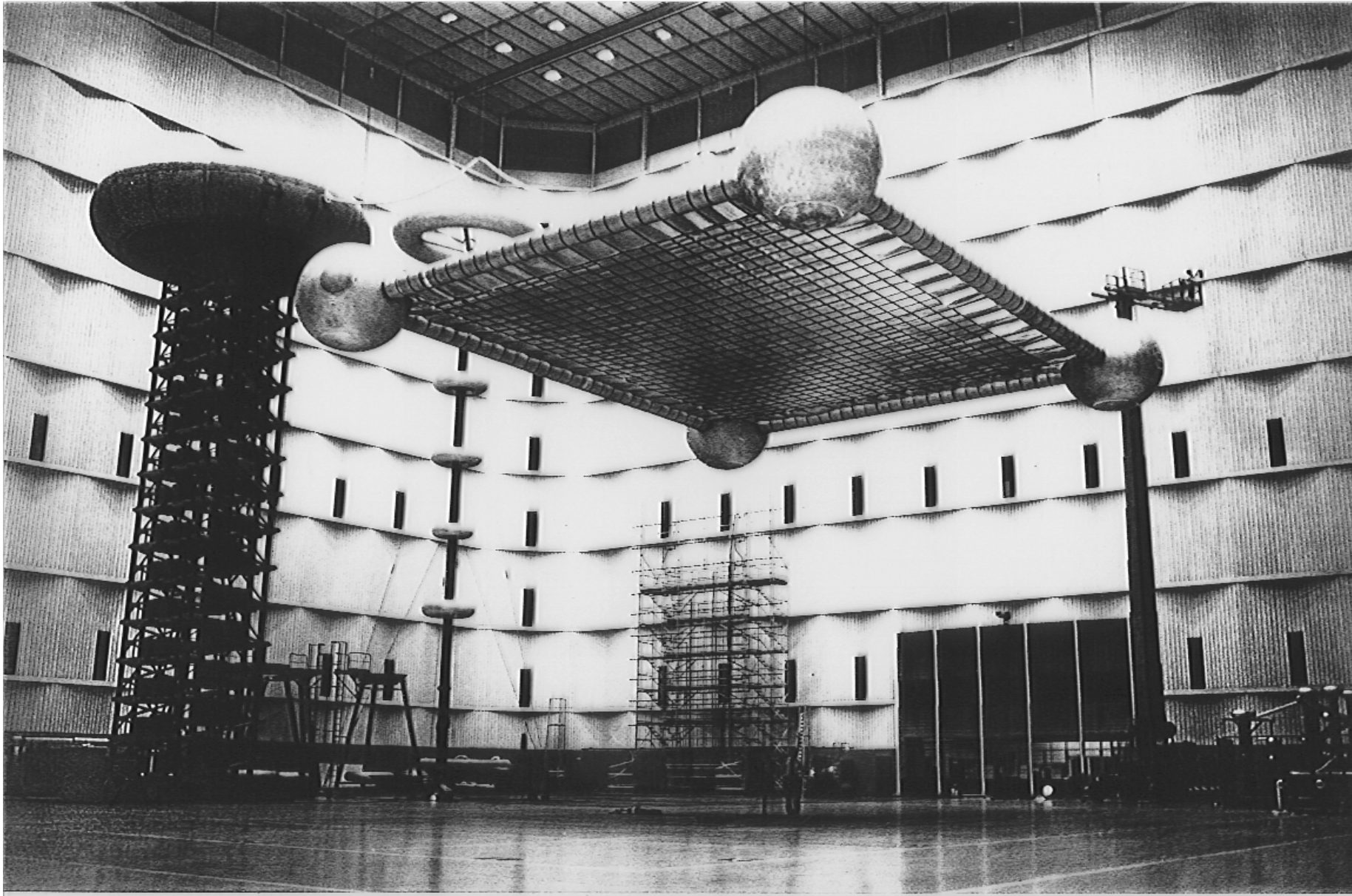
Champ permanent



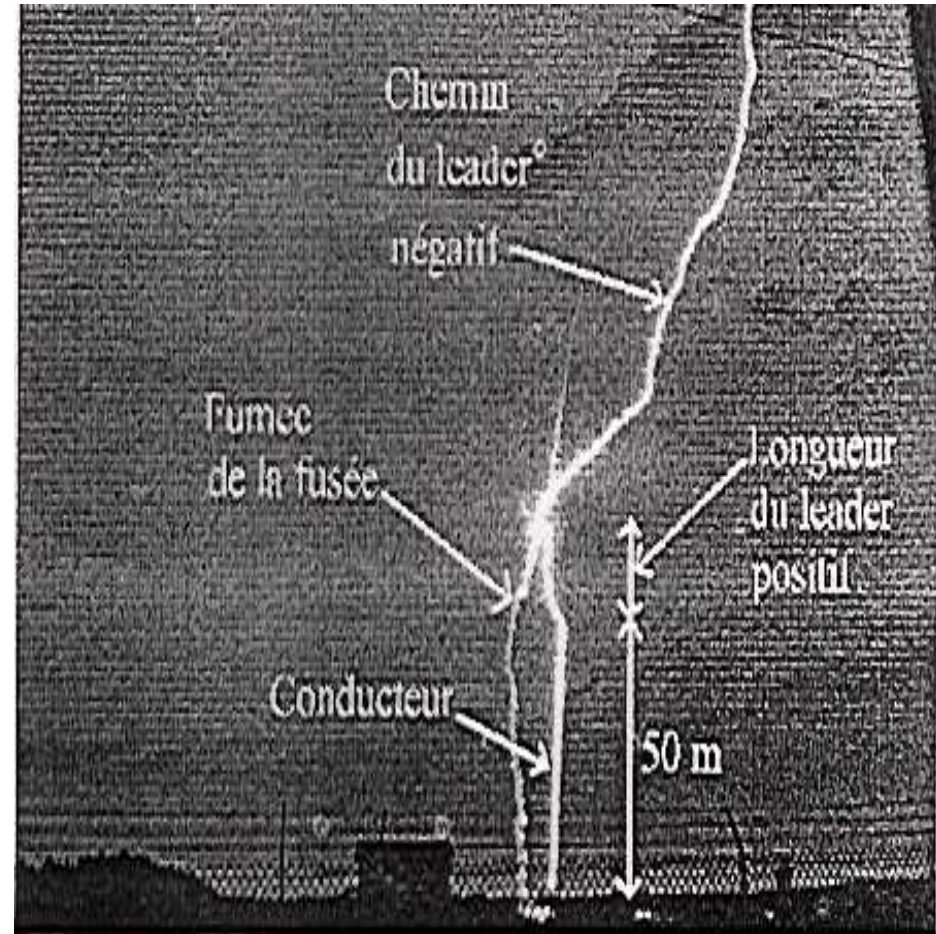
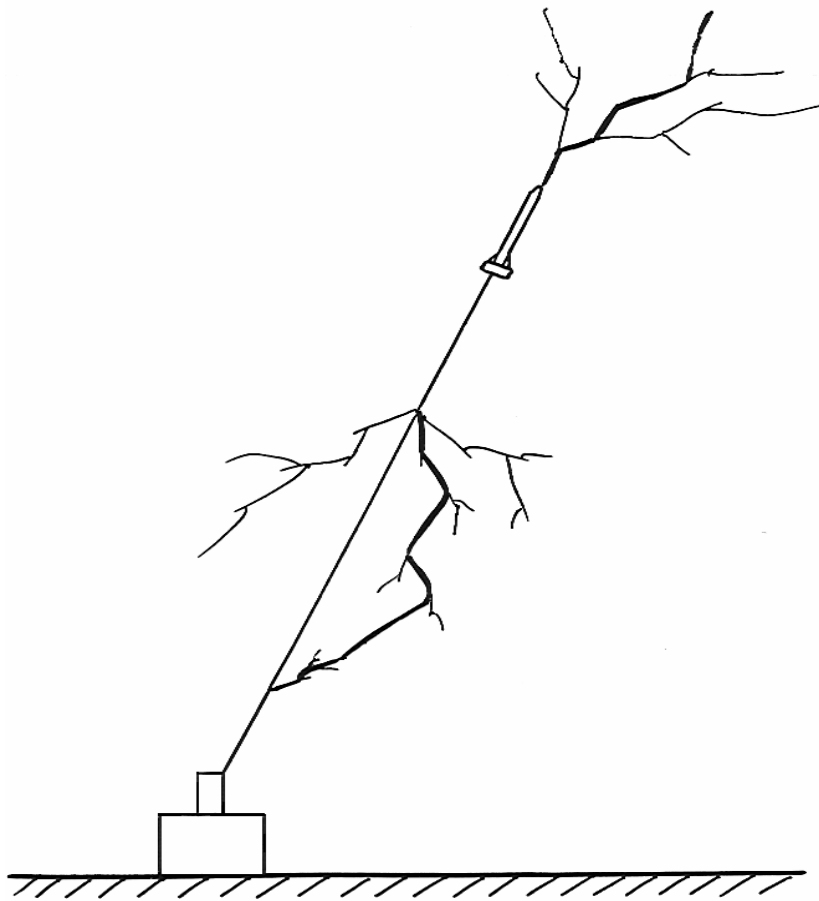
Champ du traceur



Expériences en laboratoire HT



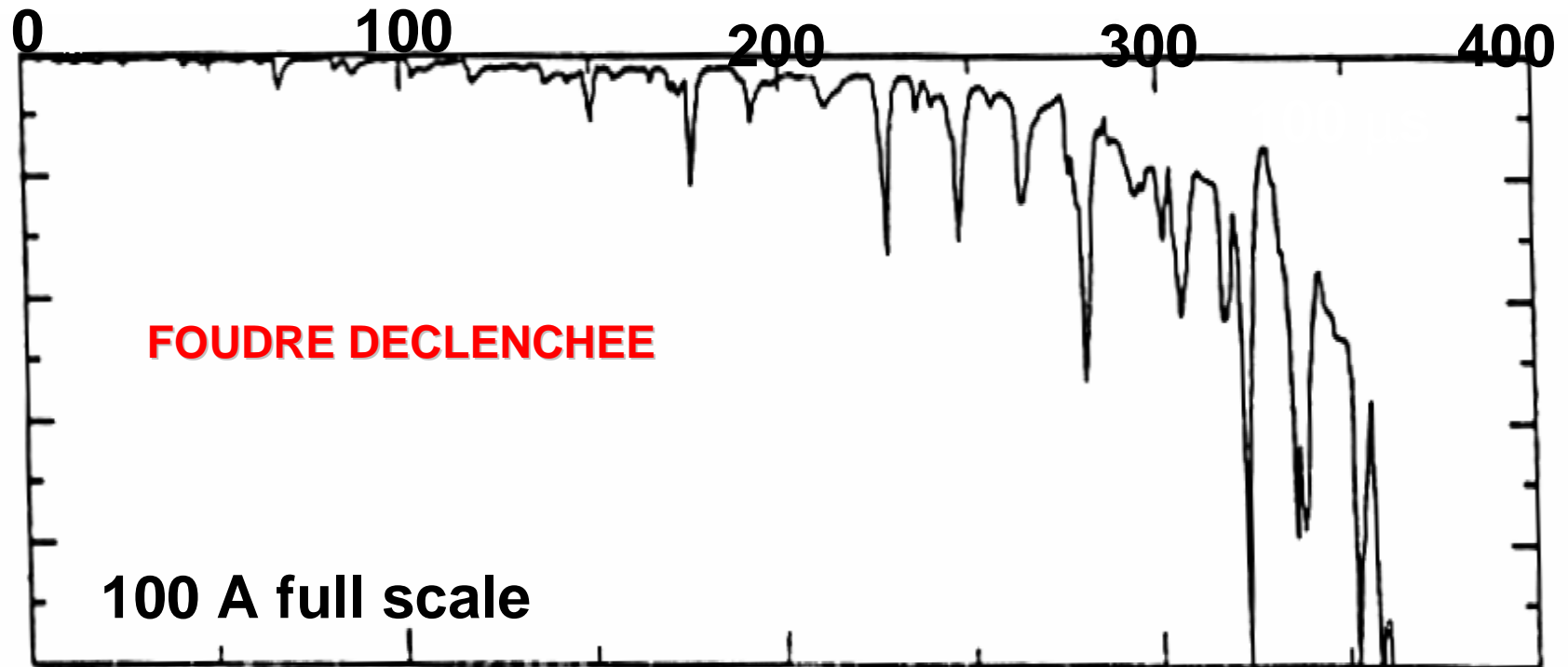
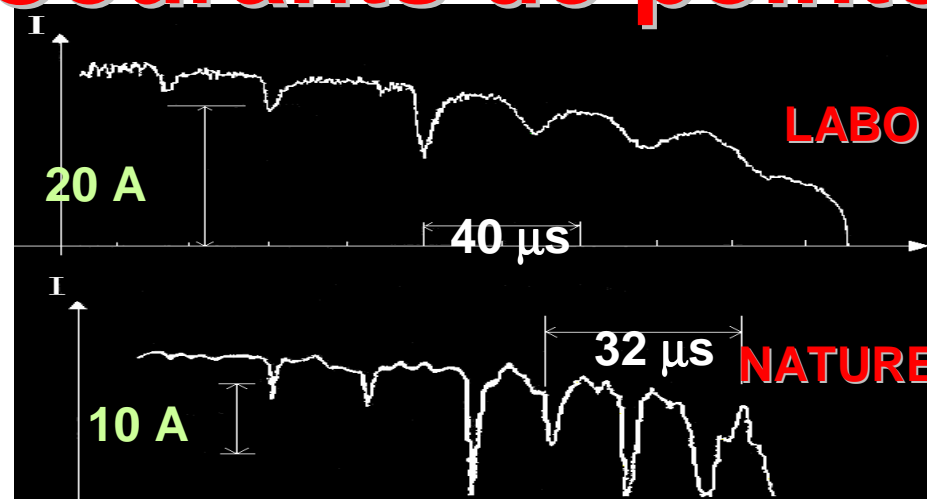
Déclenchement en haute altitude



Expériences de Socorro (NM)



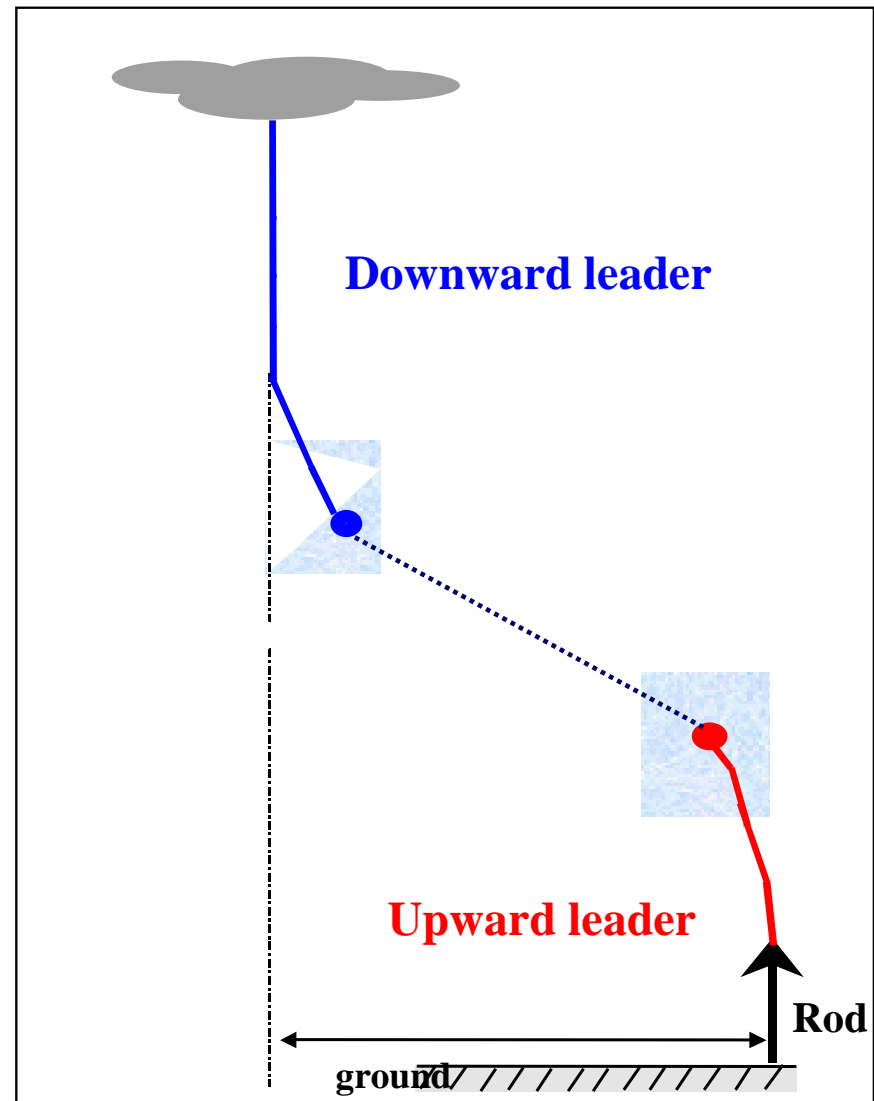
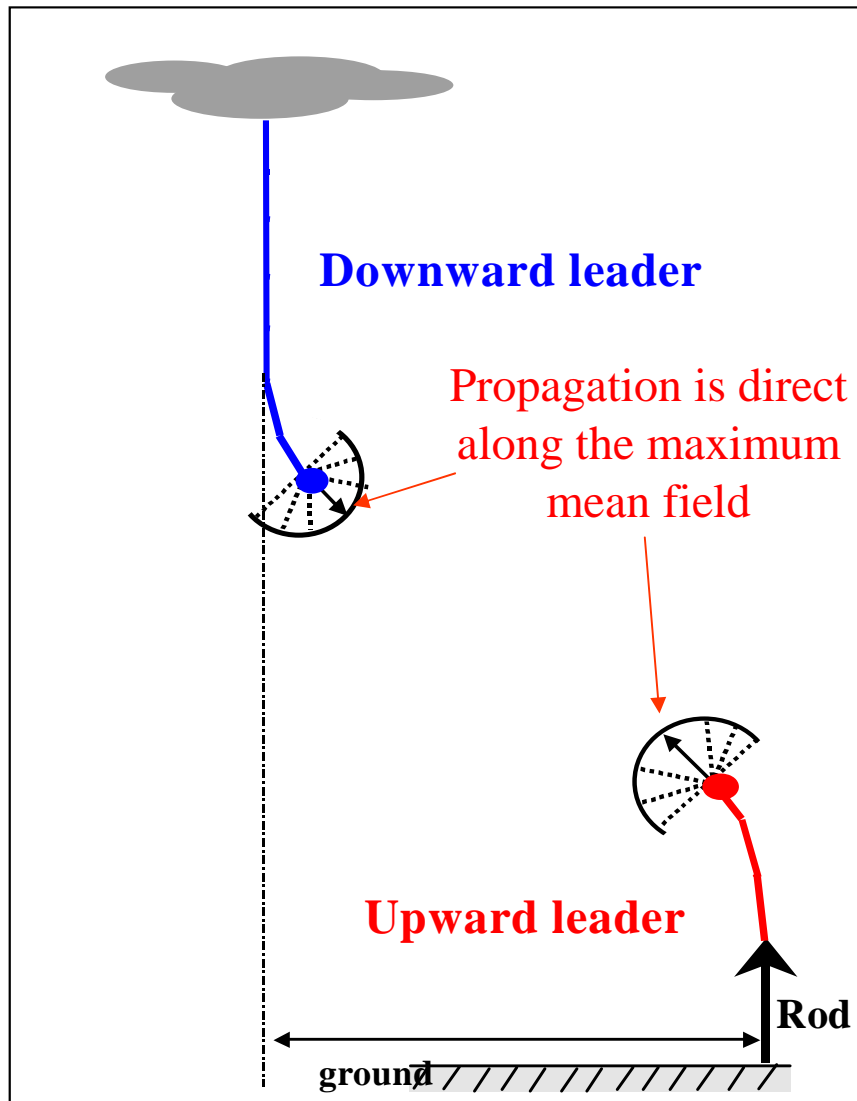
Courants de pointes



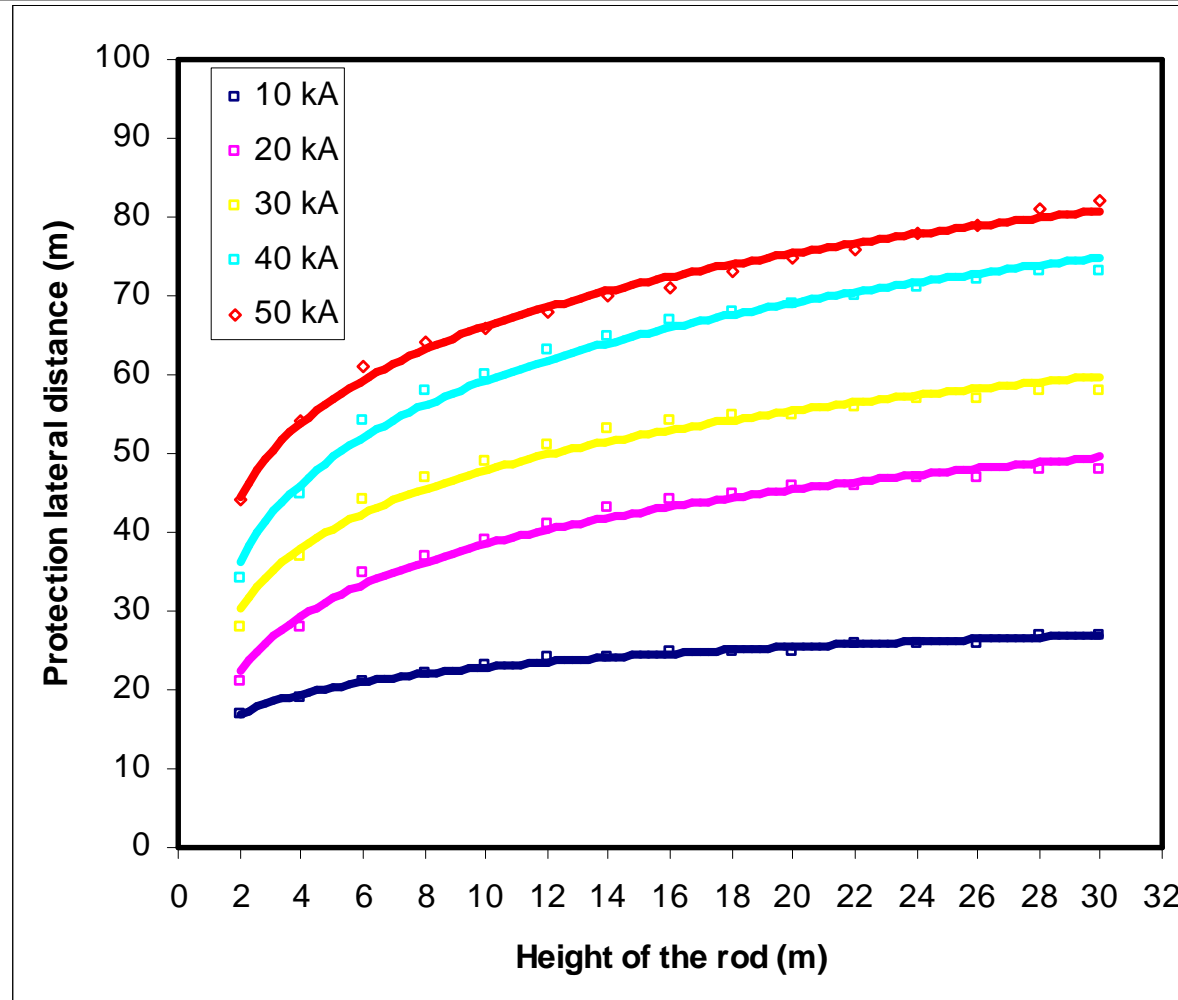
Modélisation de l'interception de la foudre

Modèle de Gérard Berger et Sonia Aït-Amar

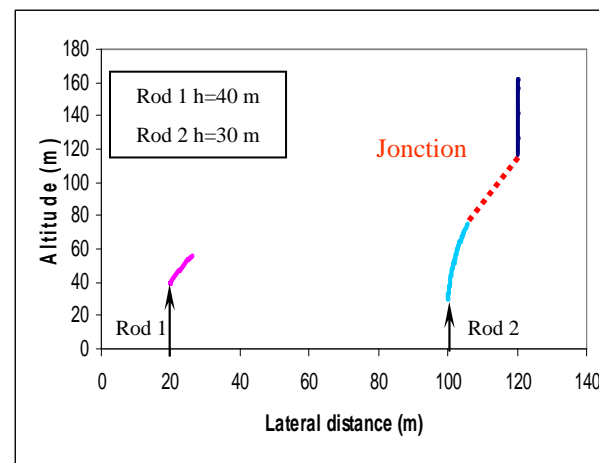
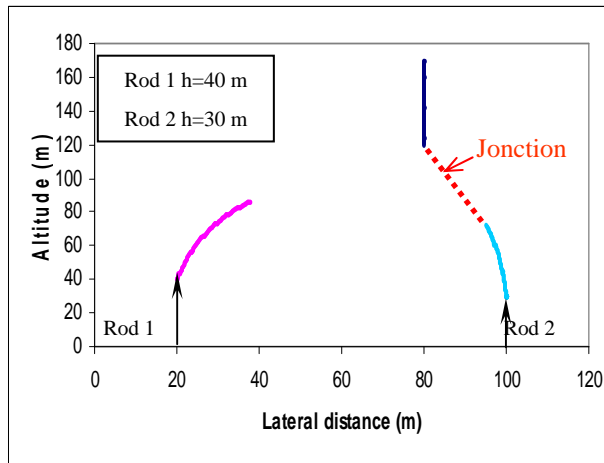
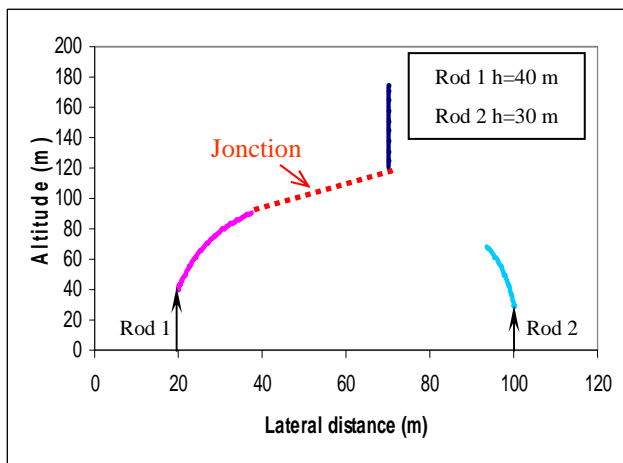
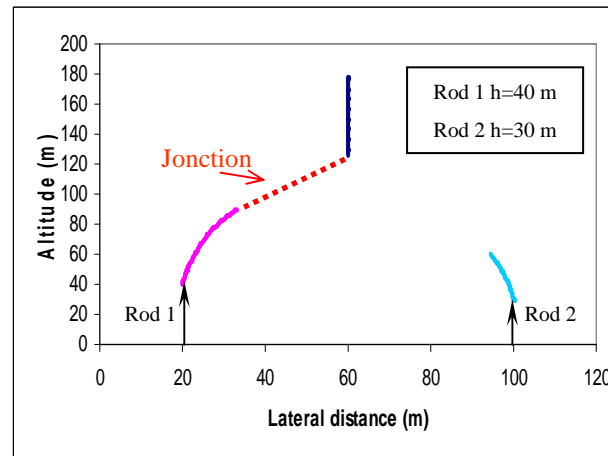
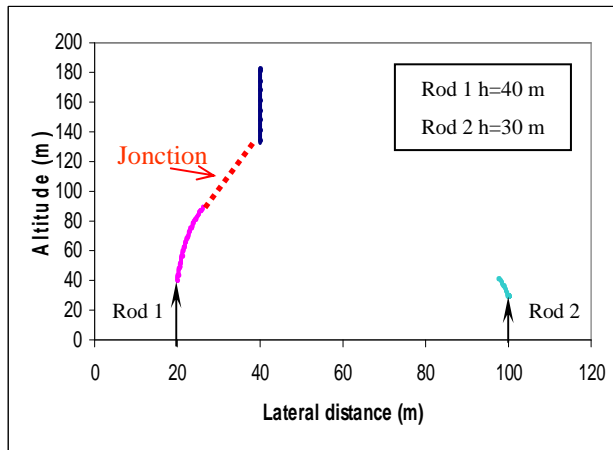
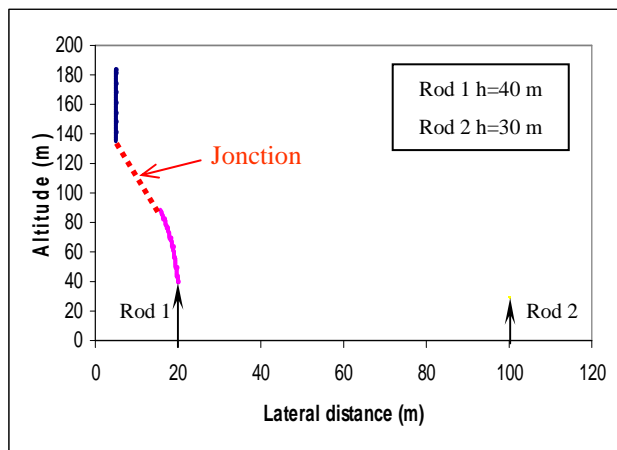
Principes du modèle



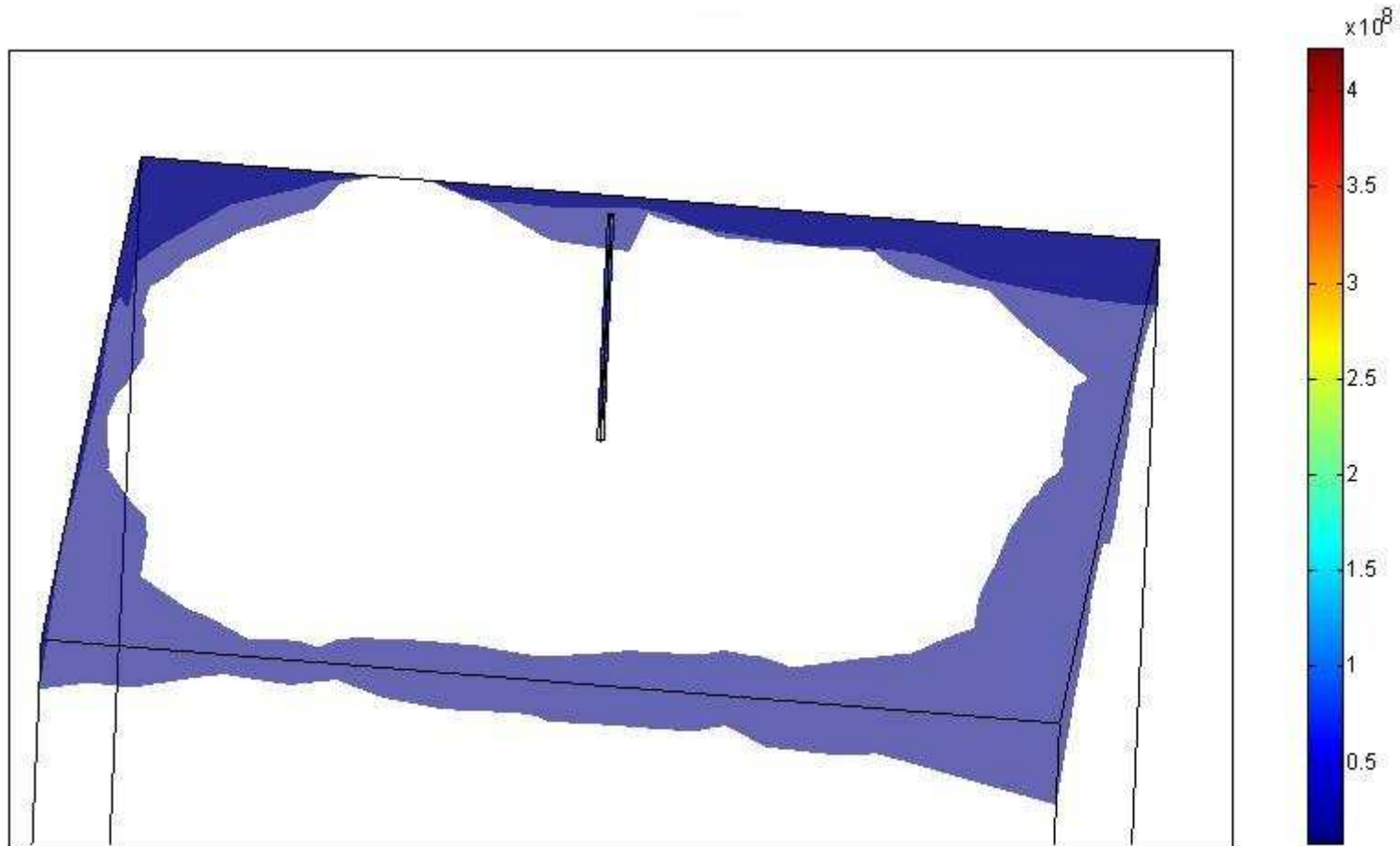
The case of an unique Franklin rod on a flat ground



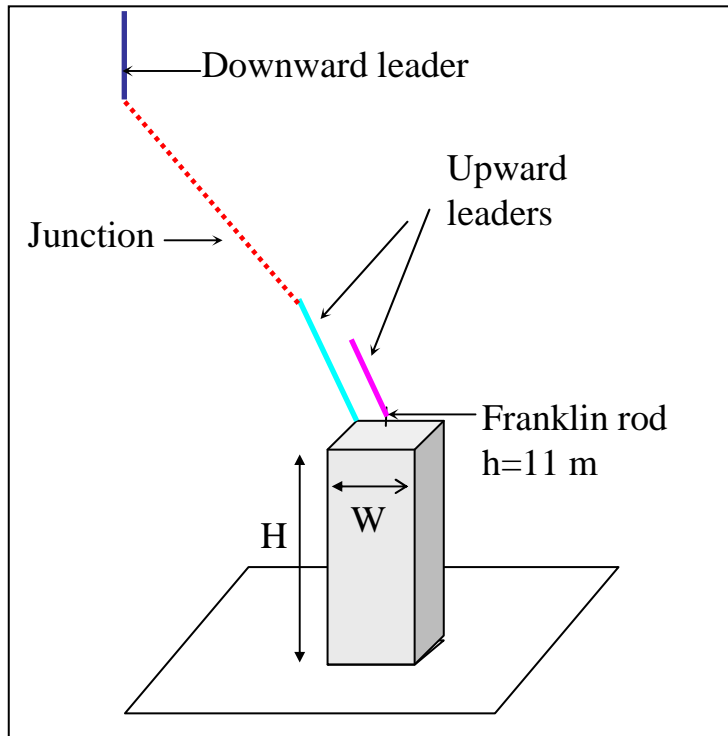
The effect of the lightning rod height on the protection lateral distance for different lightning current. $R_v=1$



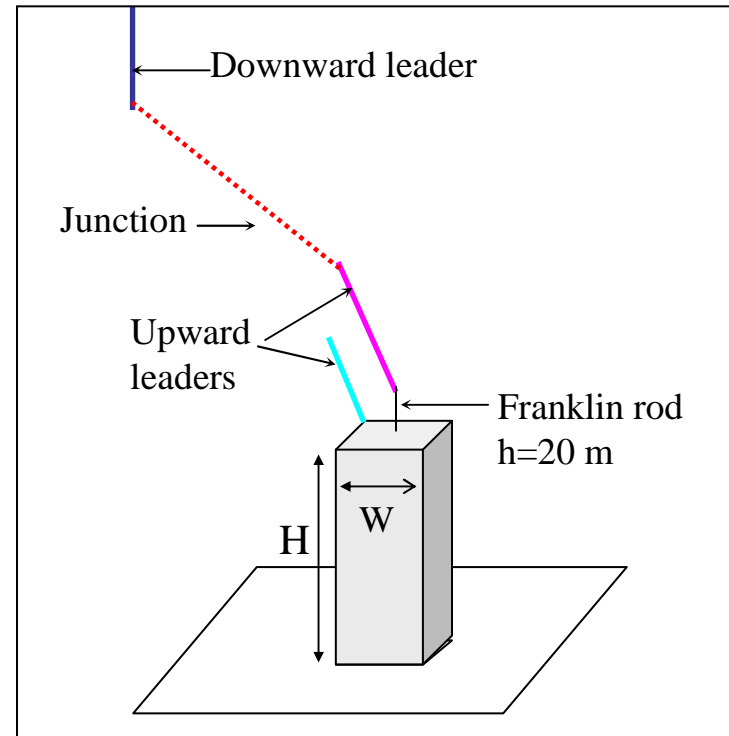
Deux paratonnerres en compétition. I= 50 kA



Distribution du champ sur le sommet d'une structure



A 3D illustration of the failure of the electrogeometrical model. Junction with the structure. $I=10\text{ kA}$, $R_v=2$, $W=40\text{ m}$, $H=100\text{ m}$



A 3D illustration of a protected structure. Junction with the Franklin rod. $I=10\text{ kA}$, $R_v=2$ $W=40\text{ m}$, $H=100\text{ m}$.

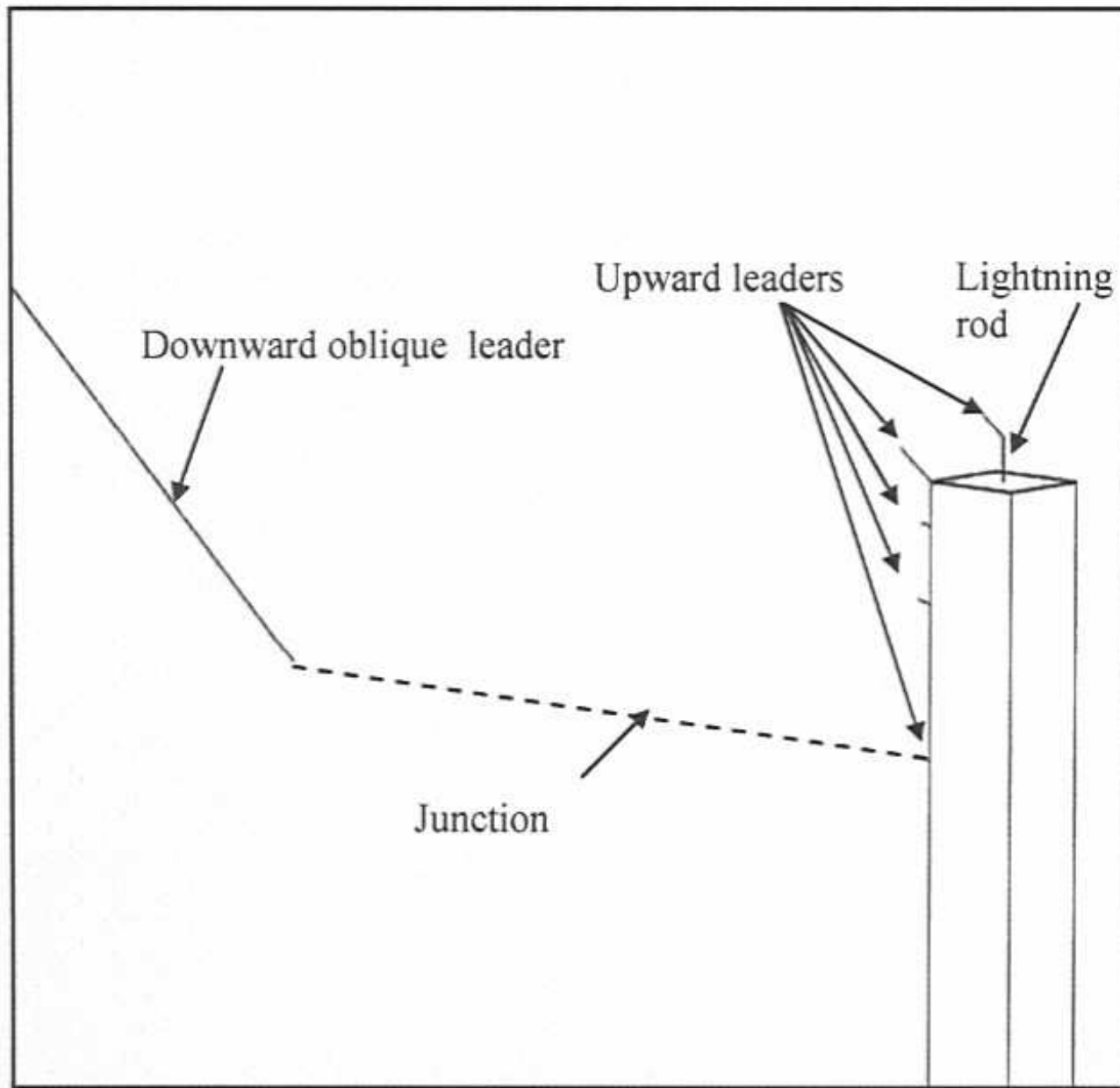
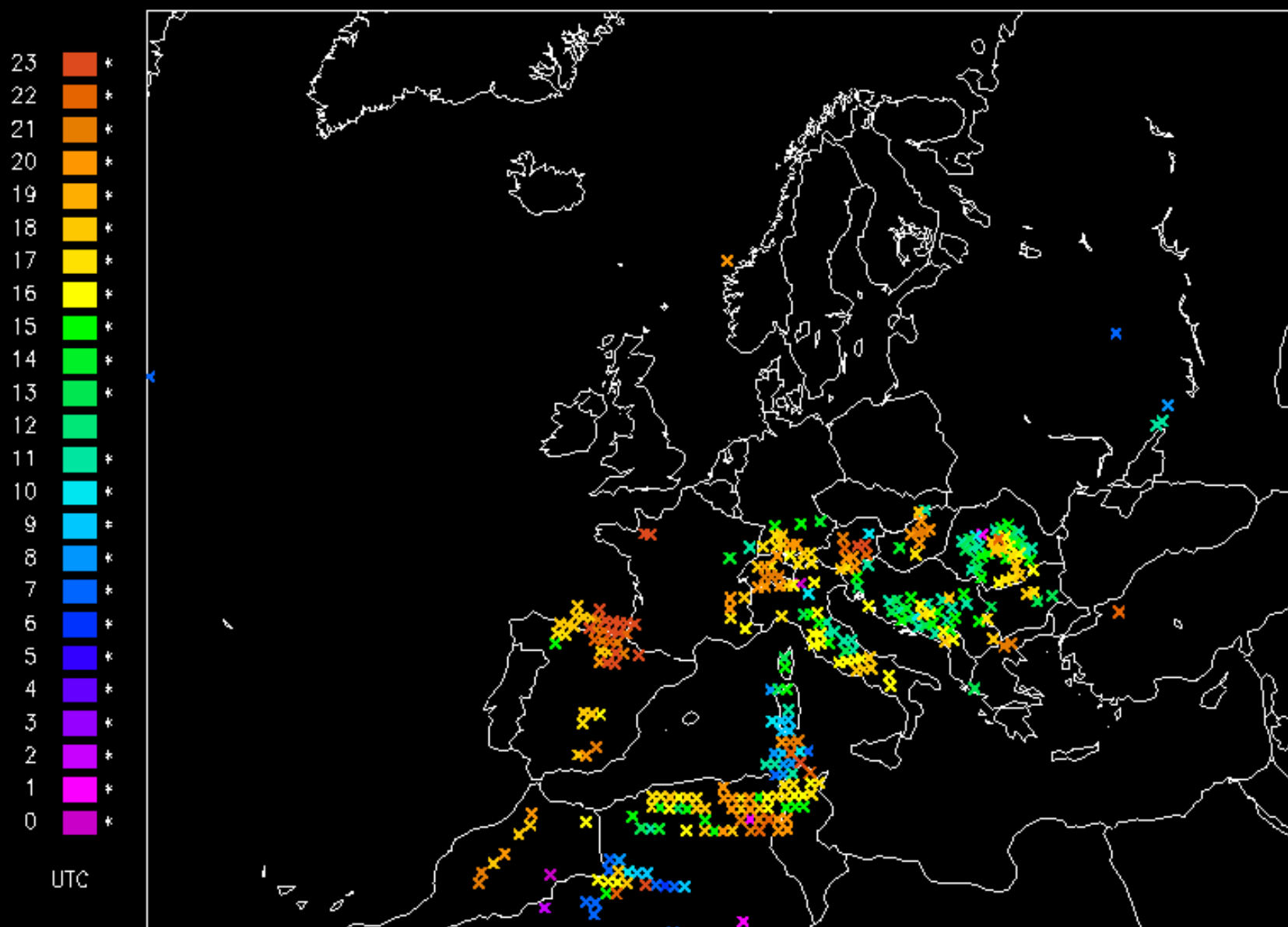
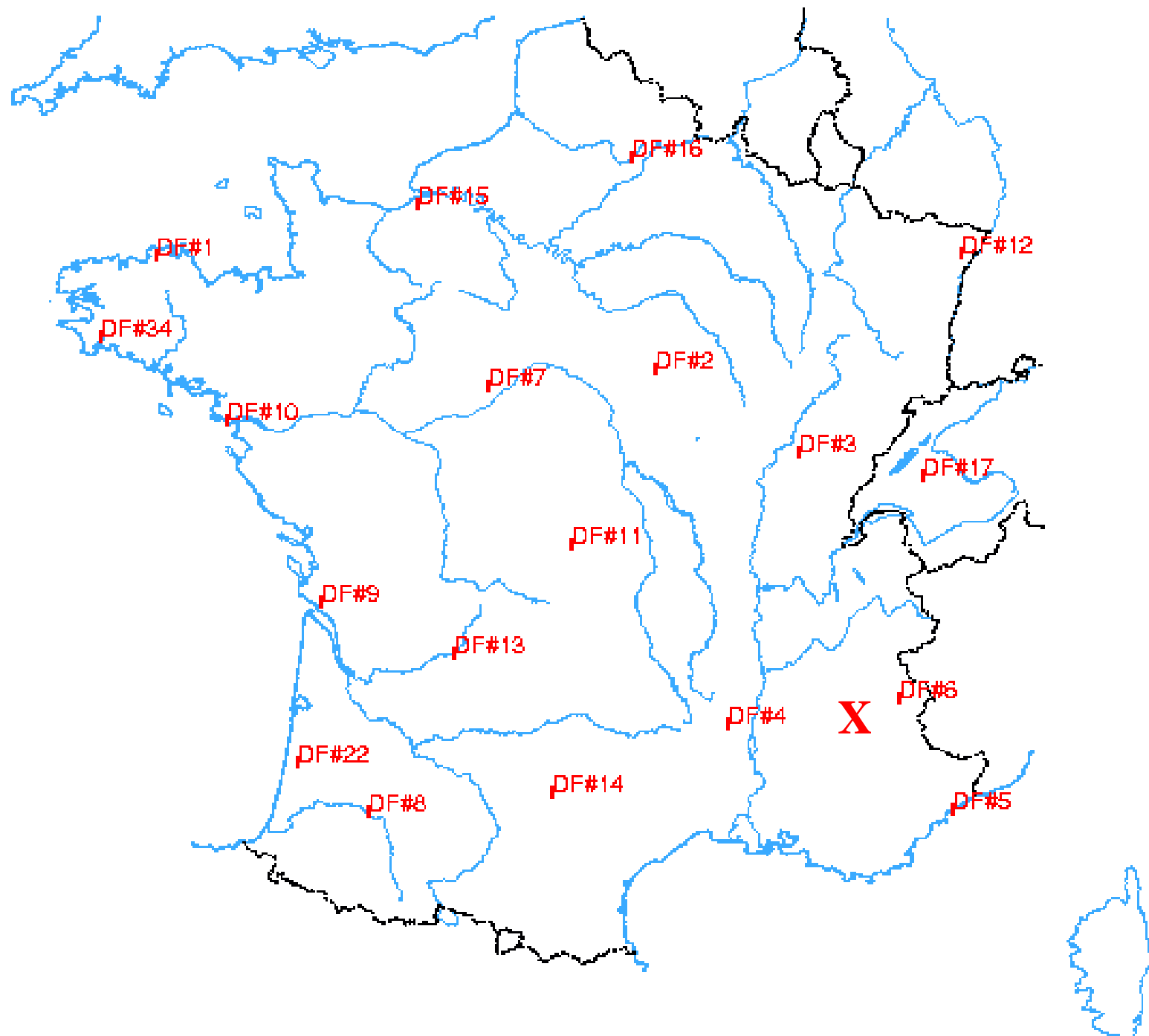


Fig. 10. A 3D illustration of a protected structure strike by oblique downward leadered structure. $I=50$ kA, $R_v=1$, $h=11$ m.

Sferics (Blitze) 07Jun2003 00 – 23 UTC



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LIGHTNING SURVEY France

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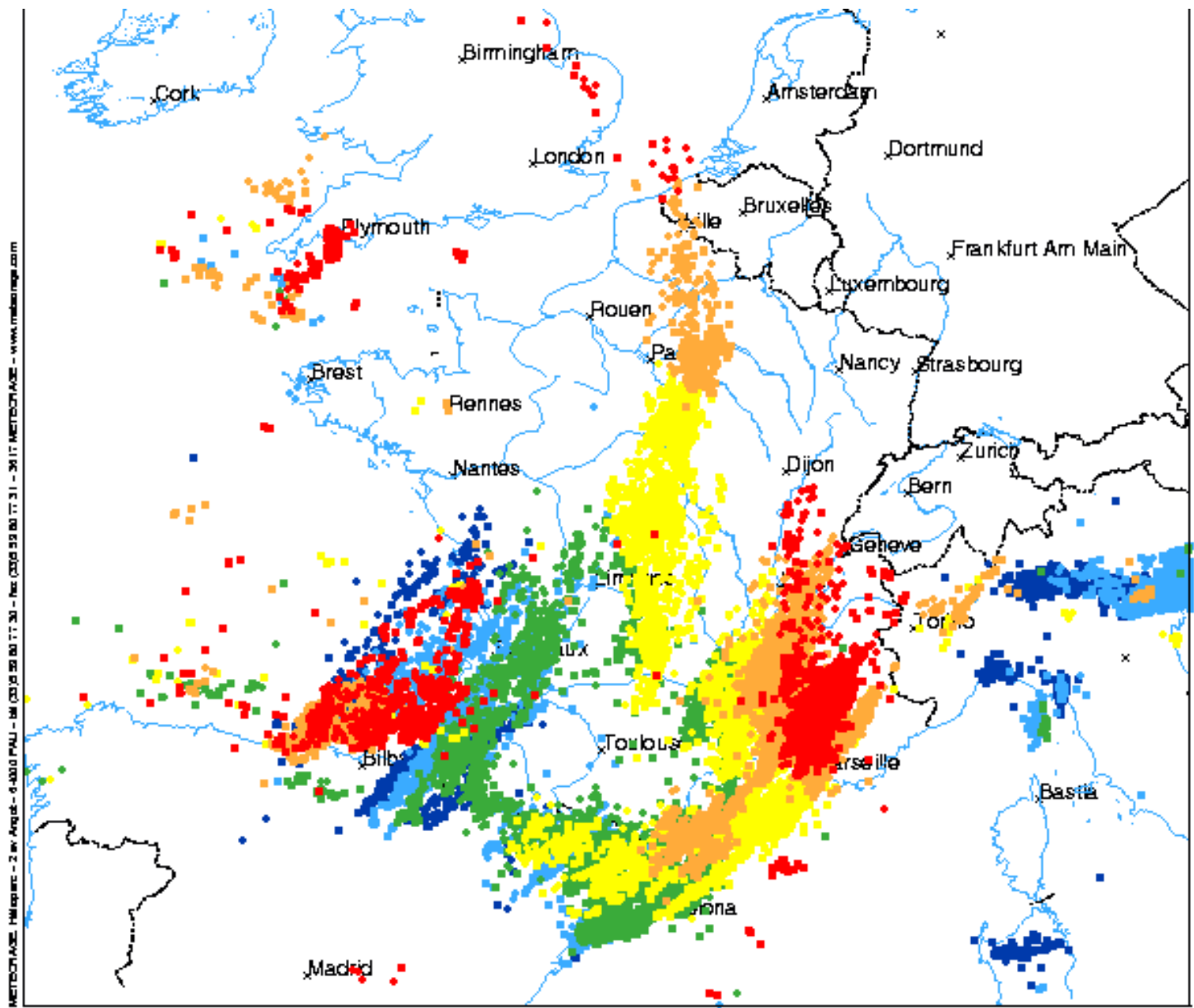
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19/09/2000 16:00:00	Nb= 4810
19/09/2000 20:00:00	Nb= 2887
19/09/2000 23:59:59	

Reference : 5-1209

NUMBER OF IMPACTS	
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Negative:	25543 ■
in.cloud:	0 ■
Total :	28062

METEORAGE

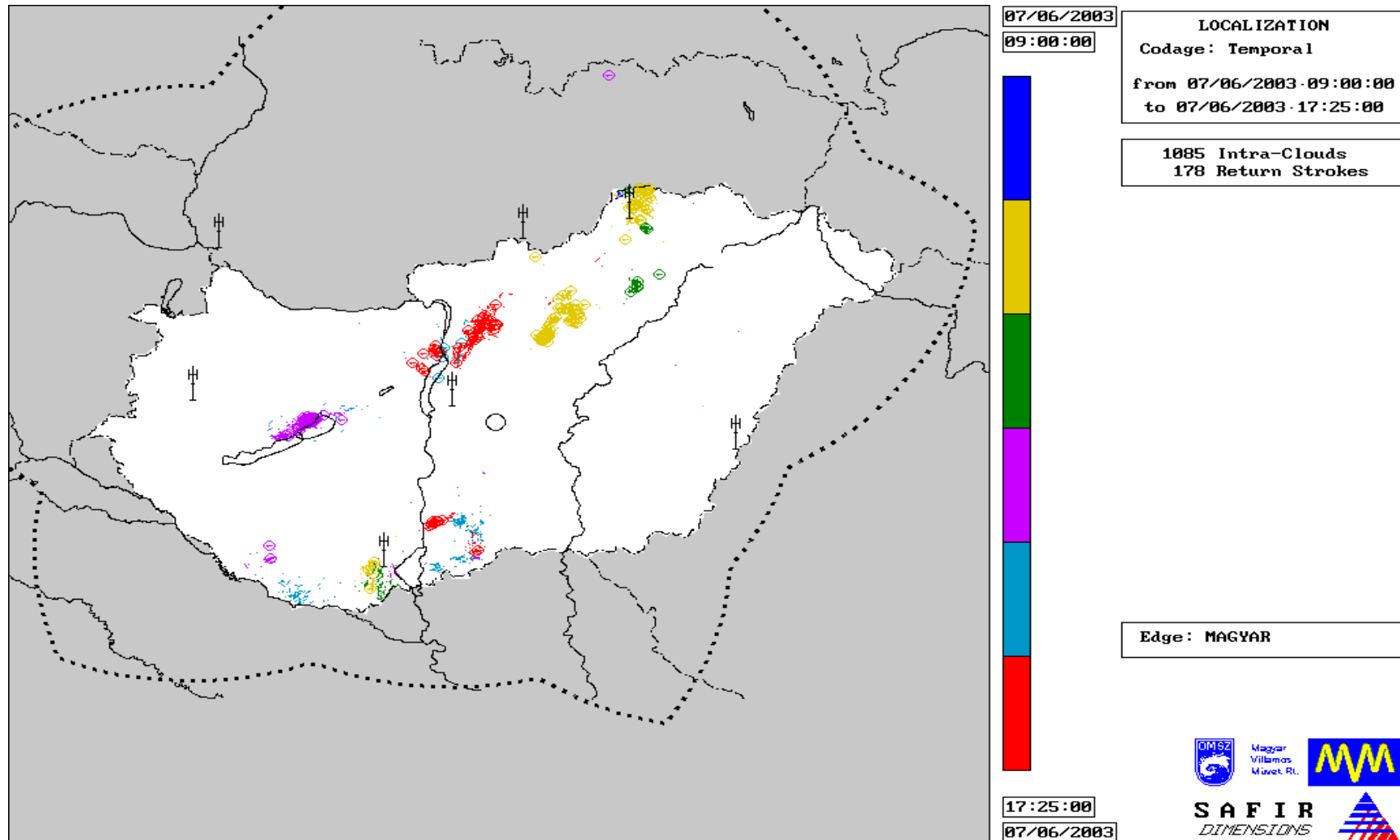


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Scale 1/8333333

SAFIR Hongrie : Foudre globale



SAFIR Hongrie : foudre au sol

