Dancing red sprites and the lightning activity in their parent thunderstorm

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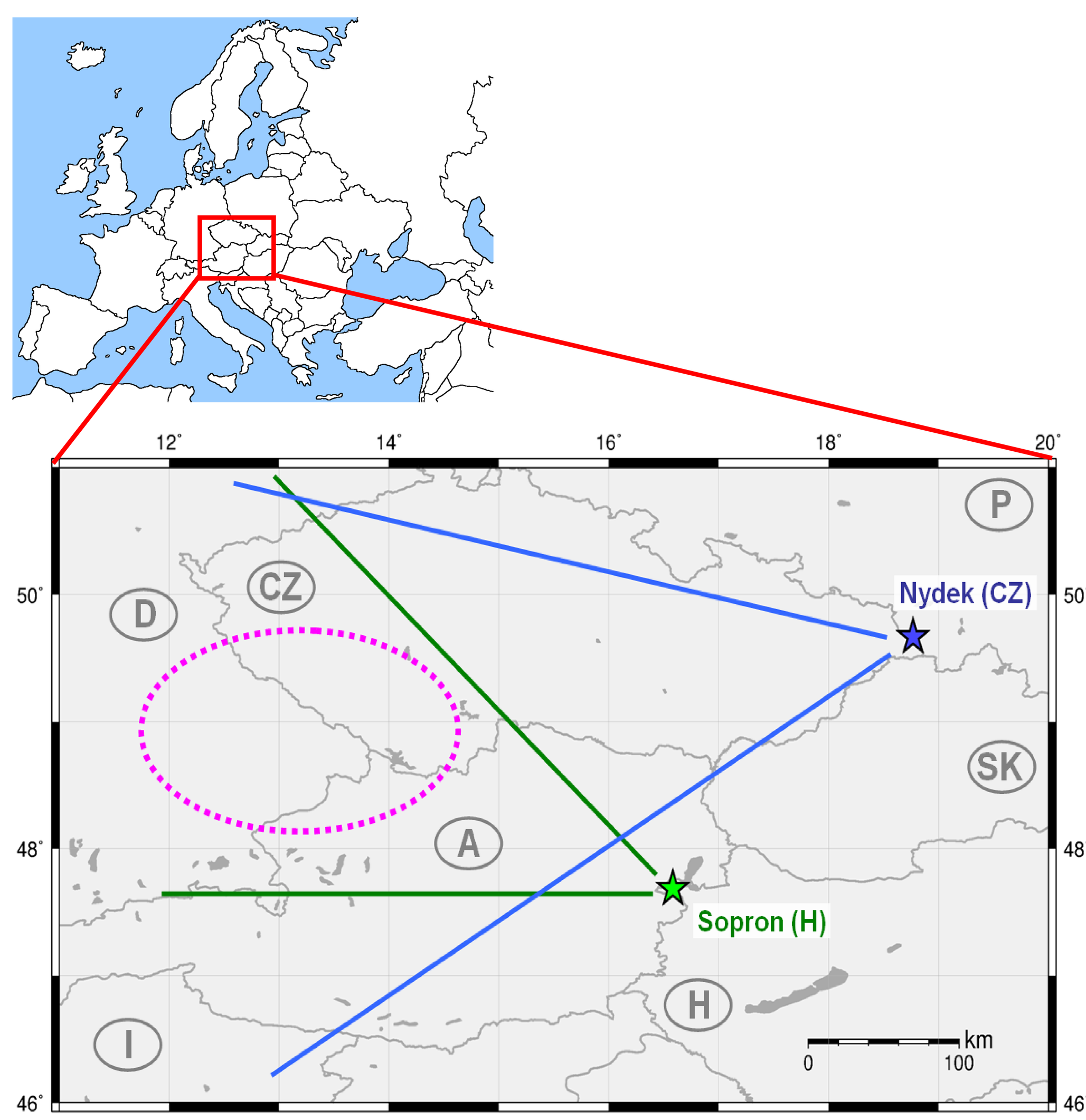
Introduction

Red sprites are brief optical emissions initiated in the mesosphere by intense tropospheric lightning discharges. A group of red sprites, in which the elements appear in rapid succession with some lateral offset from one another is referred to as a dancing sprite event [1,2,3,4]. The occurrence of such events implies that significant and sequential charge removal extending to large regions of the thunderstorm can take place in the underlying cloud system. In this work, we examine the relation of the locations and observation times of appearing sprite elements to the temporal and spatial distribution of the lightning activity in a specific sprite-active thunderstorm.

The selected mesoscale convective system (MCS) composed of several extremely active thundercloud cells crossed Central Europe from South-West to North-East through Germany, Austria, the Czech Republic, and Poland on the night of August 6, 2013. This MCS has triggered over one hundred sprites including several dancing sprite events. Video recordings of sprites captured from Sopron, Hungary (16.6°E, 47.7°N) and Nydek, Czech Republic (18.8°E, 49.7°N) were used to identify dancing sprite events and to determine the exact locations of the appearing sprite elements by a triangulation technique used originally to analyze meteor observations.



Equipment and data

The video recordings at Nydek were made using Watec 910HX camera equipped with Computar 3.5-10.5 mm (F/1.0) lens. The recordings at Sopron were made with Watec 902H2 Ultimate with Computar 8 mm (F/0.8) lens. At both sites, video frames were recorded in 720x576 pixel optical resolution and at 50 video fields per second (de-interlaced) so that the effective time resolution at each site was 20 ms. The effective horizontal FOV is 45° in Sopron and 37° in Nydek. At Sopron station, a GPS video time inserter provided information on the start and end time of exposition period of each video field with millisecond accuracy. Both sites utilized the UFO Capture event detection and analyzer software package to capture transient optical phenomena and to process the records. Lightning activity in the MCS has been reviewed using the database of LINET lightning detection network which fully covers the region of interest.

Summary and main findings

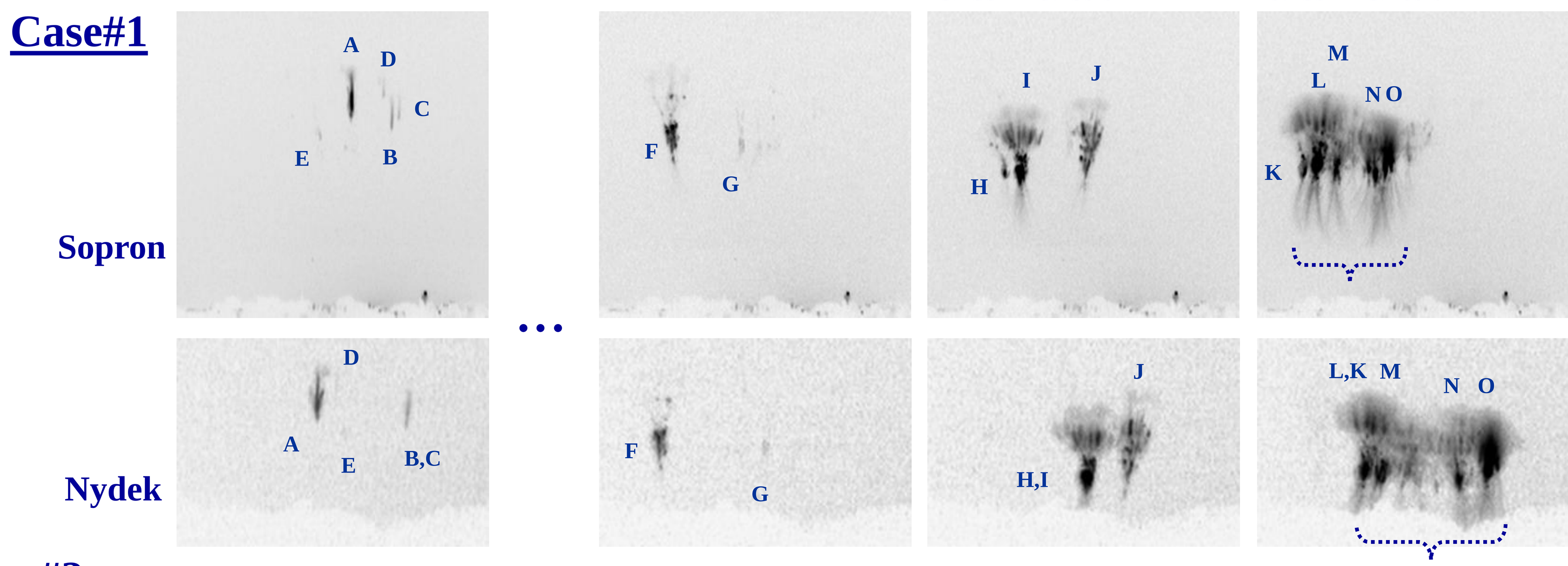
Three cases of dancing red sprites were considered in this study. The selected sprite events occurred within 90 minutes during which main convective cells of storm moved c.a. 50 km towards North-East. The multi-cell thunderstorm was producing several sprites and dancing sprite events in this period. The selected events featured sprite elements and groups which could be fairly easily identified at both observation sites.

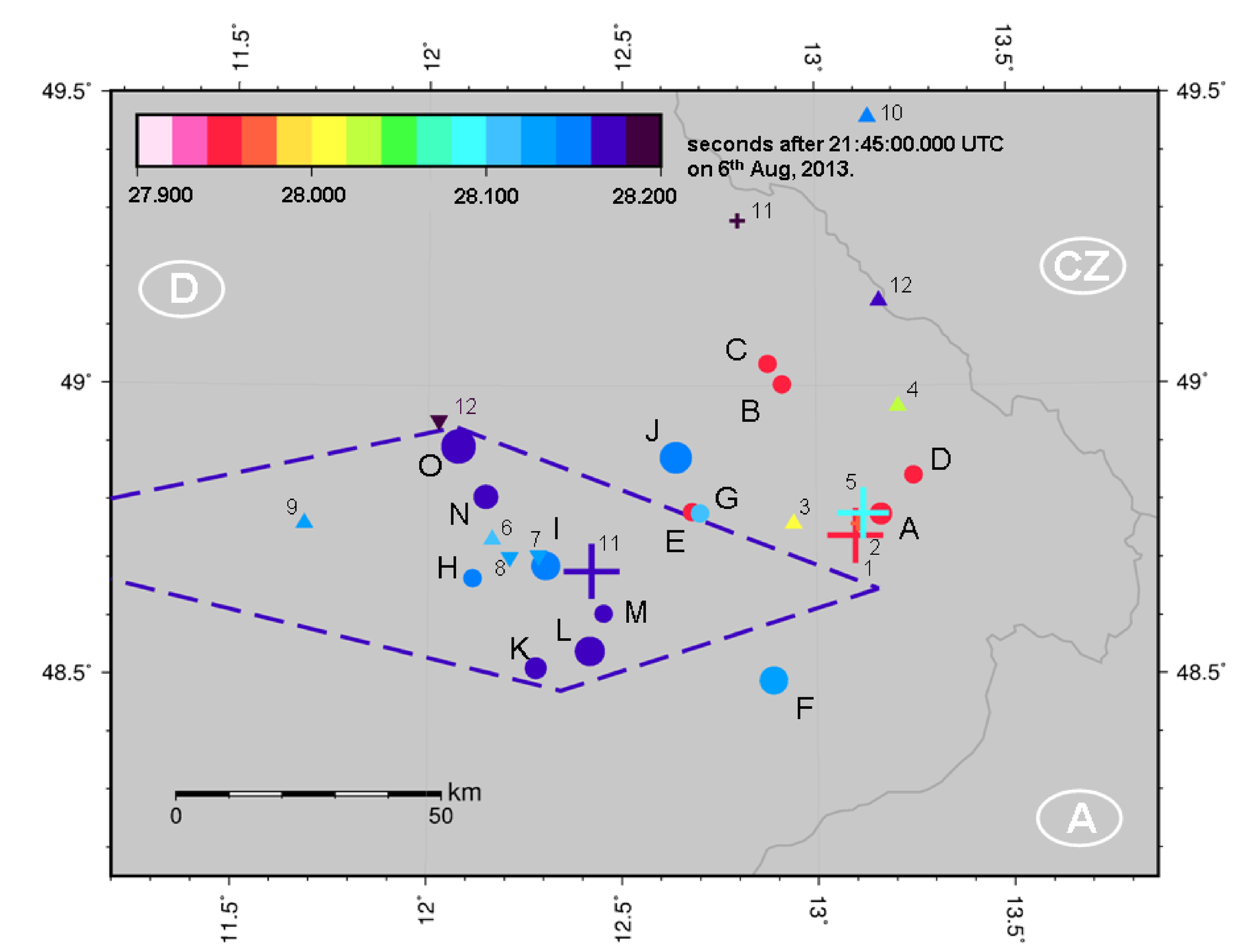
- Sprite-parent lightning (SPL) strokes occurred behind the convective cores of the thunderstorm, most probably in a trailing stratiform region. However, radar data is needed to confirm the latter speculation.
- Sprite triggering lightning strokes were mostly +CGs with peak currents close to or well above 20 kA. In case#3, the first sprites were triggered by a +IC stroke of 143.8 kA.
- In the examined cases, sprite elements occurred within a range of 50 km of the parent lightning stroke location. Sprite entities were scattered within this range so that the apparent geometric center of the sprite/group was displaced from the parent lightning stroke with a different offset, 10÷50 km.
- Both prompt and delayed sprites followed the triggering lightning stroke in some cases. The longest observed sprite delay time was 80-100 ms.
- SPL strokes occurring next in the sequence were displaced from the previous SPL stroke in most cases. The direction of displacement was different in the examined cases but usually it was similar within one dancing event-chain.
- Subsequent SPL strokes tend to occur within the area covered by sprites triggered by the previous SPL stroke. This suggests that sprites may pre-condition the underlying charge distribution for large +CG lightning, provided enough separated charge is available.

Case#1

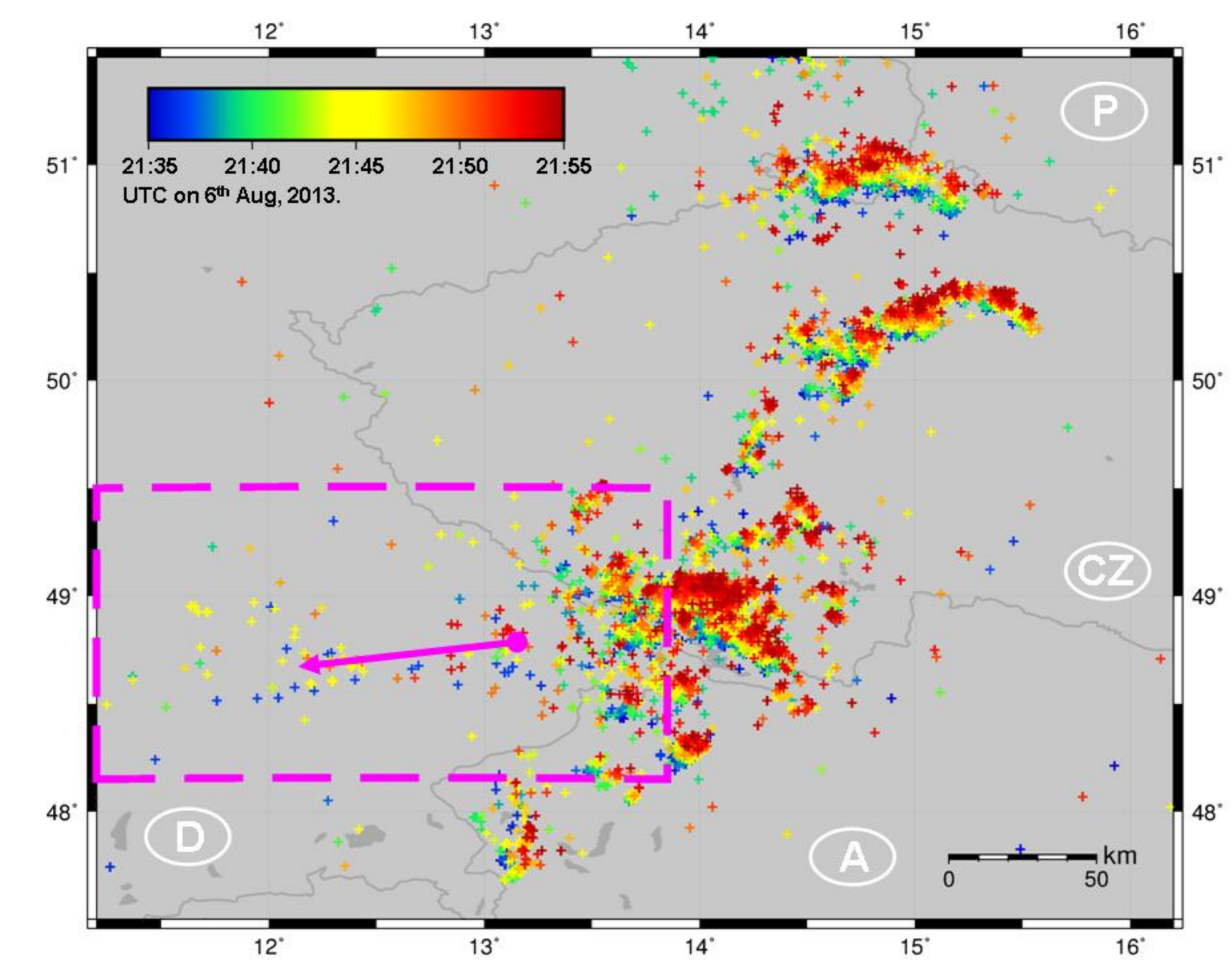
21:45:27.939 UTC

+ 000..060 ms	+ 160..200 ms	+ 200..220 ms	+ 220..240 ms
27.939 – 27.999 s	28.099 – 28.139 s	28.139 – 28.159 s	28.159 – 28.169 s





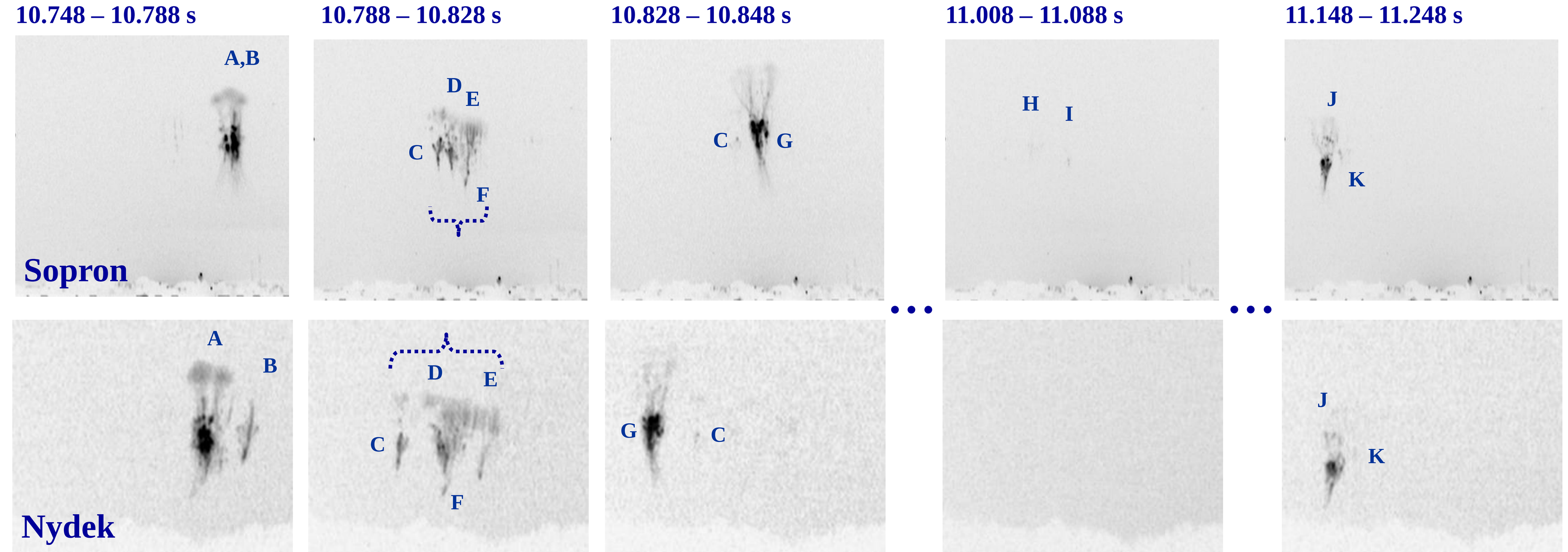
No.	Time (UTC)	Lon (deg)	Lat (deg)	1:CG,2:IC	Height (km)	Imax (kA)
1	21:45:27.941	13.1001	48.7422	1		53.2
2	21:45:27.966	13.1069	48.7626	1		7.4
3	21:45:28.012	12.9413	48.7628	2	0	3.5
4	21:45:28.028	13.2119	48.9643	2	9.4	4.9
5	21:45:28.080	13.1198	48.7804	1		18.9
6	21:45:28.118	12.1657	48.7356	2	19.5	4.8
7	21:45:28.132	12.2846	48.7082	2	6.8	-5.5
8	21:45:28.137	12.2106	48.7054	2	6.4	-5.5
9	21:45:28.138	11.6817	48.7619	2	0	4.8
10	21:45:28.141	13.1384	49.4619	2	0	6.7
11	21:45:28.171	12.4213	48.6812	1		74.9
12	21:45:28.173	13.1643	49.1457	2	0	5.7
13	21:45:28.188	12.0271	48.9400	2	8.2	-6
14	21:45:28.190	12.7988	49.2842	1		4.2

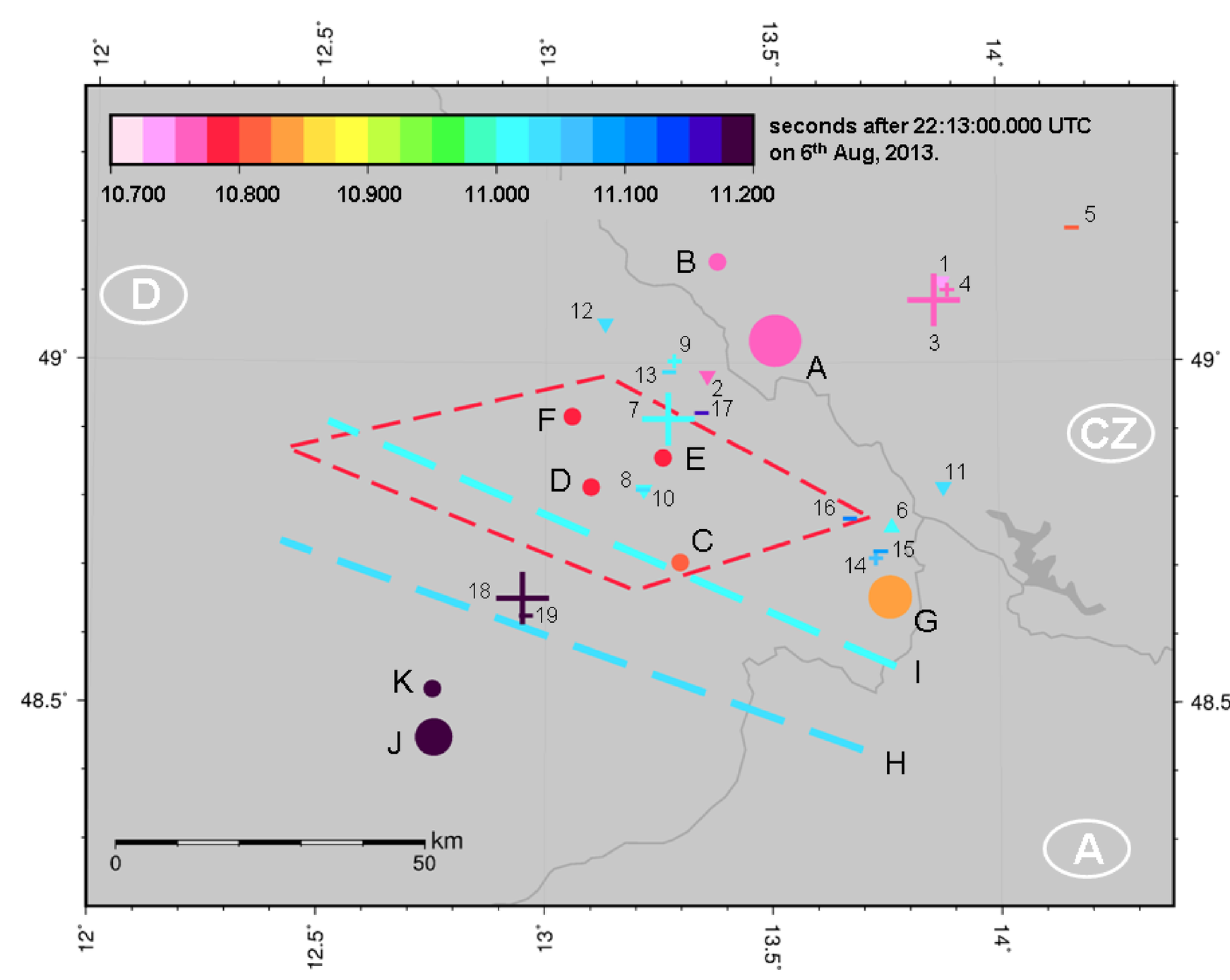


Case#2

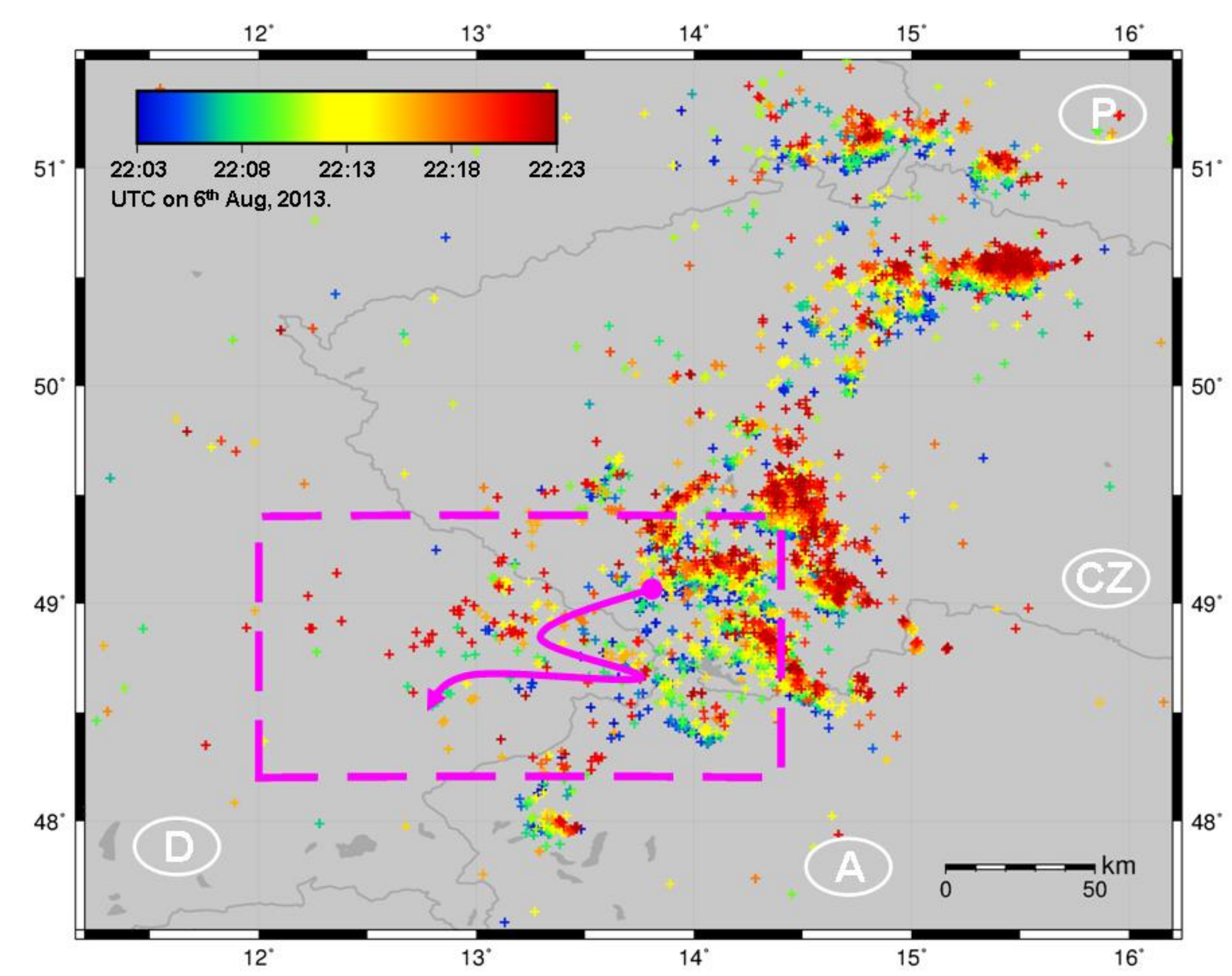
22:13:10.748 UTC

+ 000..040 ms	+ 040..080 ms	+ 080..100 ms	+ 260..340 ms	+ 400..480 ms
10.748 – 10.788 s	10.788 – 10.828 s	10.828 – 10.848 s	11.008 – 11.088 s	11.148 – 11.248 s





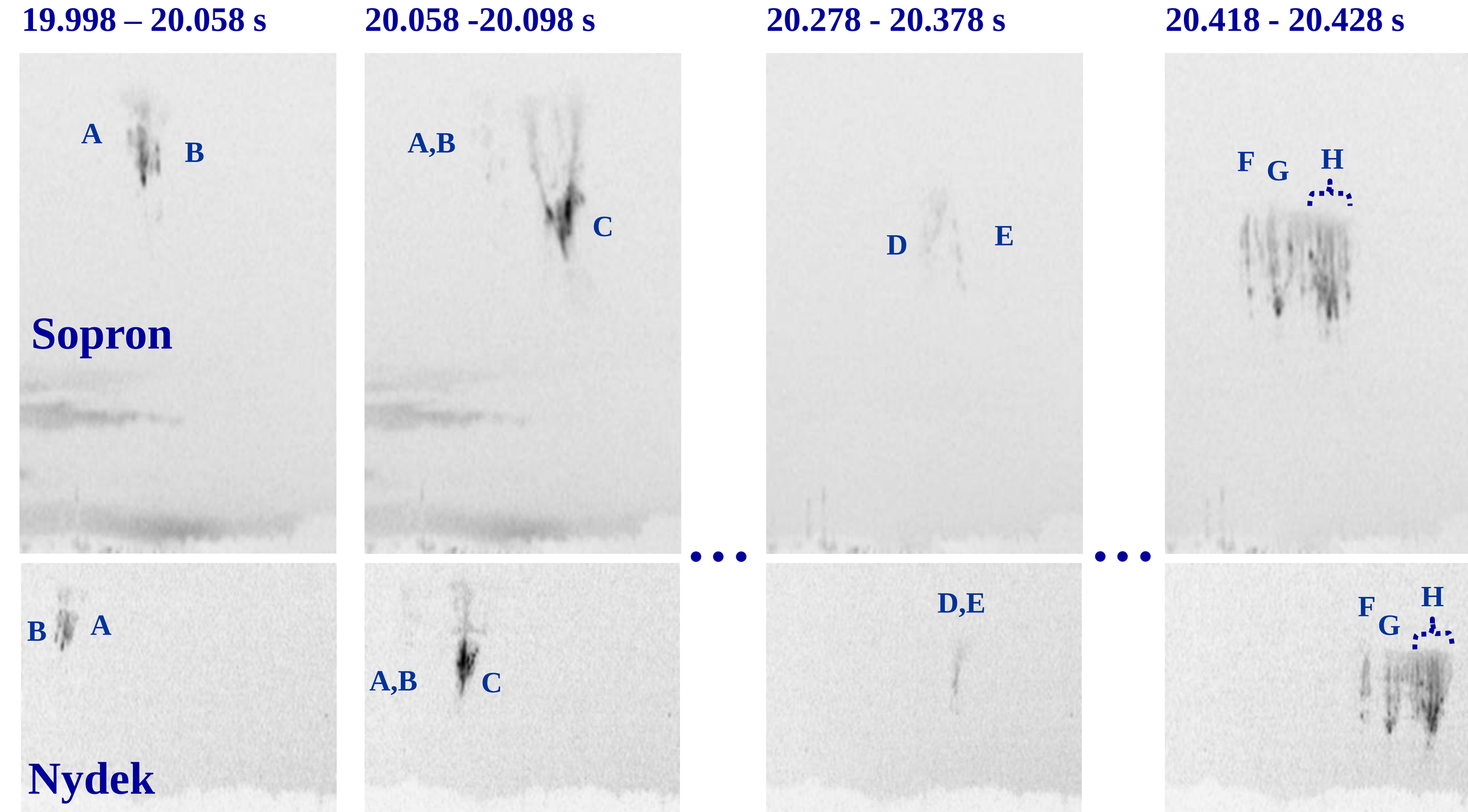
No.	Time (UTC)	Lon (deg)	Lat (deg)	1:CG,2:IC	Height (km)	Imax (kA)
1	22:13:10.744	13.8769	49.1176	2	0	-5.7
2	22:13:10.754	13.3573	48.9810	2	15.9	-3.8
3	22:13:10.759	13.8600	49.0905	1		45.4
4	22:13:10.766	13.8891	49.1053	1		6
5	22:13:10.808	14.1679	49.1945	1		-8.9
6	22:13:11.003	13.7636	48.7586	2	19.3	5
7	22:13:11.009	13.2704	48.9182	1		49.7
8	22:13:11.016	13.2168	48.8147	2	8.1	-5.1
9	22:13:11.023	13.2841	49.0022	1		7.1
10	22:13:11.039	13.2152	48.8148	1		-8.3
11	22:13:11.041	13.8779	48.8179	2	10.7	-7.7
12	22:13:11.043	13.1311	49.0574	2	11.2	-4.6
13	22:13:11.049	13.2723	48.9864	1		-6.7
14	22:13:11.072	13.7284	48.7143	1		8.5
15	22:13:11.081	13.7389	48.7242	1		-4.9
16	22:13:11.102	13.6716	48.772	1		-4.7
17	22:13:11.152	13.3444	48.9267	1		-6
18	22:13:11.191	12.9494	48.6559	1		42
19	22:13:11.196	12.9574	48.6305	1		-5.8

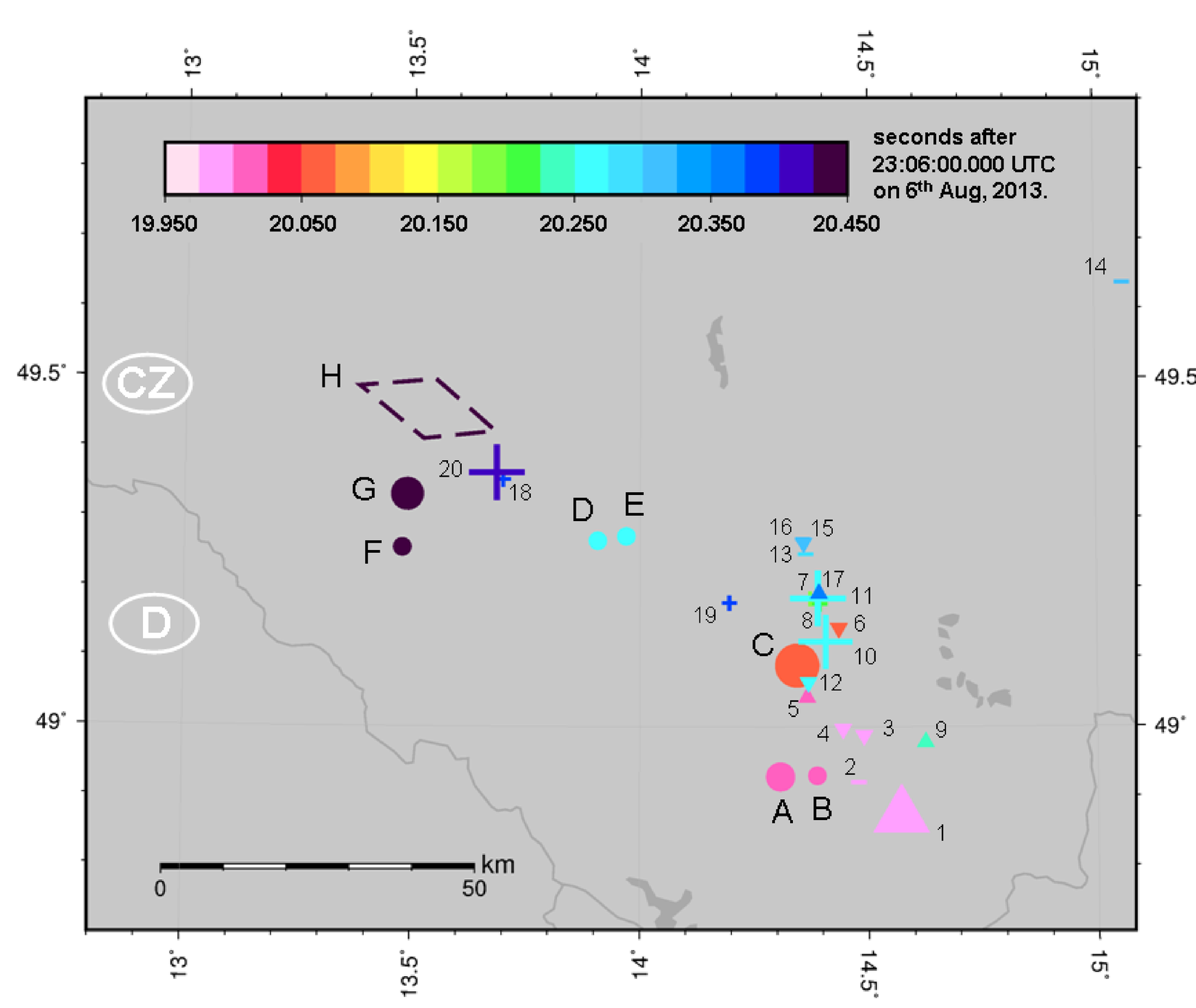


Case#3

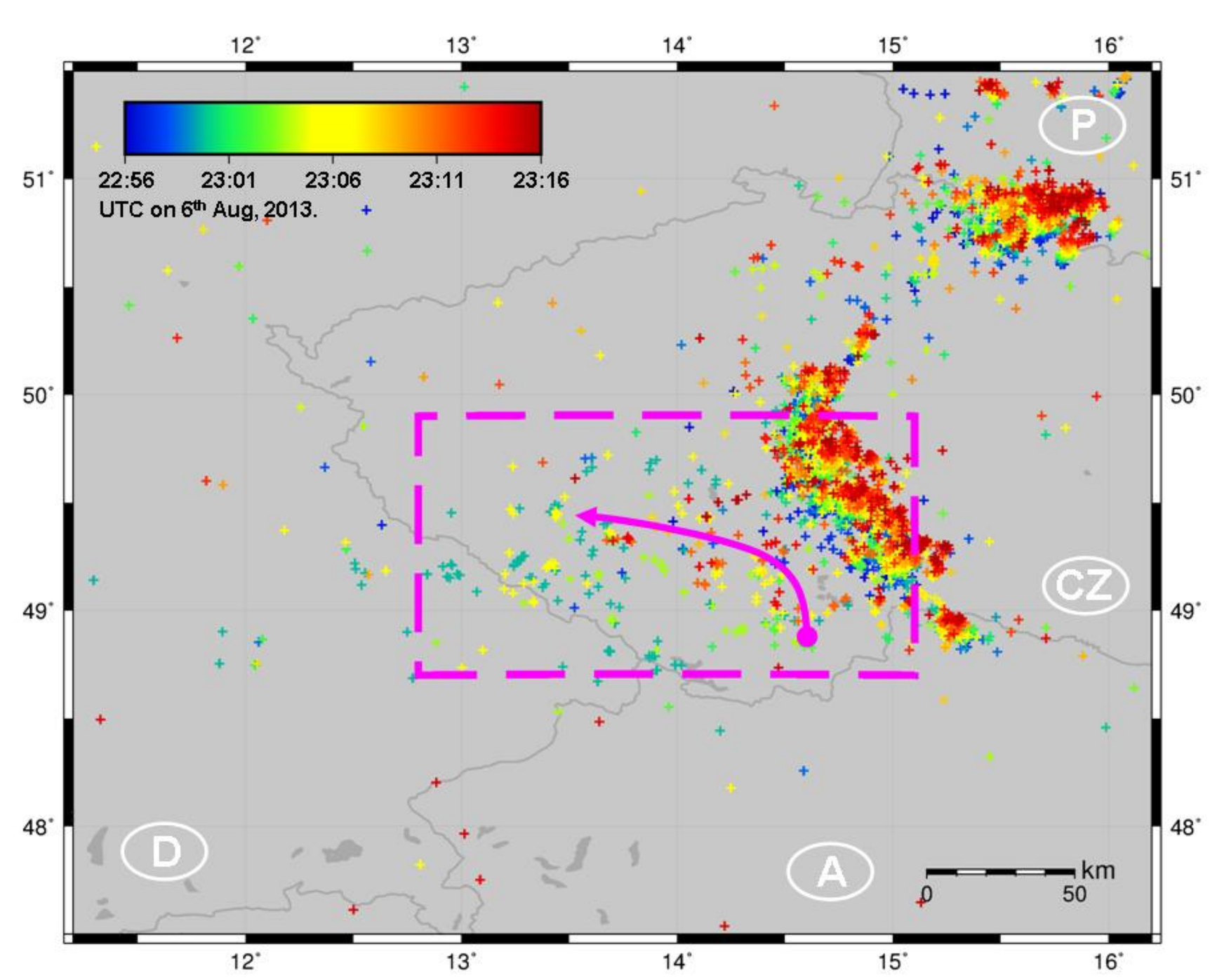
23:06:19.998 UTC

+ 000..060 ms	+ 060..100 ms	+ 280..380 ms	+ 420..440 ms
19.998 – 20.058 s	20.058 -20.098 s	20.278 - 20.378 s	20.418 - 20.428 s





No.	Time (UTC)	Lon (deg)	Lat (deg)	1:CG,2:IC	Height (km)	Imax (kA)
1	23:06:19.977	14.5708	48.8710	2	9.2	143.8
2	23:06:19.985	14.4781	48.9205	1		-9.5
3	23:06:19.996	14.4900	48.9873	2	12.6	-3.6
4	23:06:19.999	14.4442	48.9965	2	10.4	-4.7
5	23:06:20.015	14.3660	49.0421	2	10.8	4.1
6	23:06:20.052	14.4353	49.1414	2	0	-4.2
7	23:06:20.180	14.3721	49.1838	1		3.9
8	23:06:20.207	14.3936	49.1761	1		5.5
9	23:06:20.228	14.6245	48.9774	2	11.1	7.2
10	23:06:20.254	14.4060	49.1220	1		19.7
11	23:06:20.256	14.3893	49.1844	1		22.1
12	23:06:20.266	14.3686	49.0636	2	7	-7.1
13	23:06:20.299	14.3629	49.2478	1		-4.4
14	23:06:20.306	15.0618	49.6364	1		-7.2
15	23:06:20.315	14.3583	49.2639	2	13.5	-4.9
16	23:06:20.325	14.3566	49.2696	1		-3.7
17	23:06:20.375	14.3919	49.1912	2	10.8	5.2
18	23:06:20.377	13.6985	49.355	1		4.2
19	23:06:20.387	14.1956	49.1777	1		7.8
20	23:06:20.423	13.6845	49.3647	1		70.2



Acknowledgements

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Some related papers

[1] Lyons, 1994, GRL, doi: 10.1029/94GL00560 (luminous tructures in the stratosphere)
[2] Lyons, 1996, JGR, doi: 10.1029/96JD01866 (sprites above U.S. High Plains)
[3] Hardman et. al. 2000, JGR, doi:10.1029/1999JD900325 (sprite observations in Australia)
[4] Lu et al., 2013, JGR, doi:10.1002/jgrd.50459 (sprites and LMA flash structure)