

# The effects of the strong thunderstorms seen in the ionosphere above Poland by DEMETER and Swarm satellites

Jan Błęcki, Jan Słomiński, Roman Wronowski, Ewa Słomińska, Andrzej Kułak,  
Janusz Młynarczyk, Karol Martyński, Rafał Iwański, Roger Haagmans, and Michel  
Parrot



## **The effects of the strong thunderstorms seen in the ionosphere above Poland by DEMETER and Swarm satellites.**

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### Abstract

Lightnings and particularly TLEs (sprites, jets, elves, halos) are associated with the electromagnetic connections and interactions between atmosphere, ionosphere and magnetosphere. DEMETER was a low-altitude microsatellite, it operated from June 2004 till December 2010 on a polar, circular orbit which altitude at the beginning was 710km but it was decreased to 660 km. DEMETER measured variations of the electric field in low frequency range from 0 to 20 kHz. The plasma analyzer instrument measured variations of the ion density 4 s time resolution. Langmuir probe gave the value of the electron temperature and density. A detector of energetic particle measured electrons and protons with energies from 70 keV to 2.34MeV every 4 s in survey mode and 1 s in burst mode. DEMETER has clearly shown, that thunderstorms and TLE can affected the ionosphere even at altitude of its orbit (680km). It registered many strong thunderstorms in Poland during its time of operation.

The Swarm constellation comprises 3 identical satellites launched on 22 November 2013 into a near-polar orbit. This set of satellites is still operating. Two of them are operating on the circular, polar orbits with initial altitude 460. Third one has also circular orbit, but with altitude 530. The orbits of the first 2 satellites are in almost the same plane, but third one is close to be perpendicular to the first two. The payload containing Vector Field Magnetometer, Absolute Scalar Magnetometer and Electric Field Instrument among other allows to study the effects in the ionosphere generated by thunderstorms. The measurements performed during flights over thunderstorms areas in Poland will be discussed in our presentation.

The discussion of the cross correlation between the ground based registrations (PERUN and VERA systems) and DEMETER and Swarm measurements of the ULF/ELF/VLF waves, electron density and temperature variations in the ionosphere related to the strong thunderstorms in Poland will be presented.

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# DEMETER

## Detection of Electro-Magnetic Emissions Transmitted from Earthquake Regions



Orbit: polar and circular

Altitude: 650km

ELF/VLF range for the electric field is from DC up to 20 kHz.

Ion density:  $5 \cdot 10^2 - 5 \cdot 10^6 / \text{cm}^3$

Ion temperature: 1000 K – 5000 K

Electron density:  $10^2 - 5 \cdot 10^6 \text{ cm}^{-3}$

Electron temperature: 500 K – 3000 K

Energetic electrons 30 keV– 10MeV

Ion composition  $\text{H}^+$ ,  $\text{He}^+$ ,  $\text{O}^+$ ,  $\text{NO}^+$

There are two modes: a survey mode where spectra of one electric and magnetic component are onboard computed up to 20 kHz and a burst mode where waveforms of electric and magnetic field are recorded up to 20 kHz.



# Strong thunderstorm seen by DEMETER over Central Poland

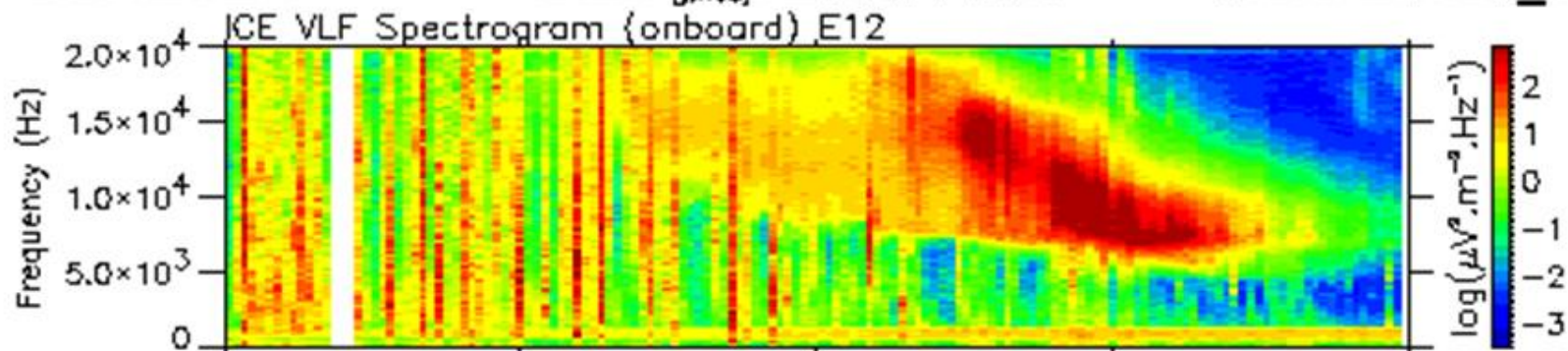
Date	Time	Latitude	Longitude	Location error in 10 m	Current max in A
30/06/2009	19:57:54	524105	150033	517	103380
30/06/2009	20:00:47	530546	234310	334	107170
30/06/2009	20:02:07	519554	210176	53	6370
30/06/2009	20:02:32	524673	153552	340	60980
30/06/2009	20:03:25	523102	143756	297	94850

# Strong thunderstorm seen by DEMETER over Central Poland

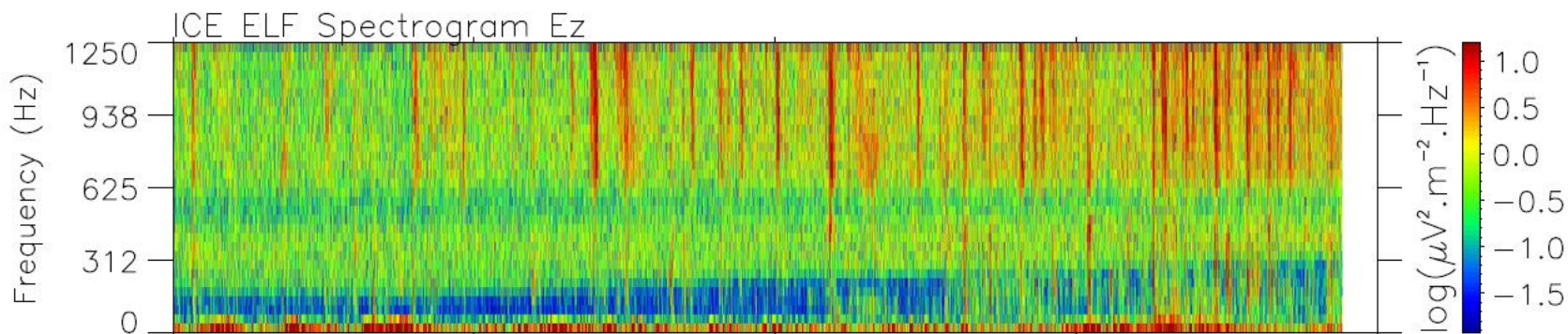
DEMETER

Date (y/m/d): 2009/06/30

Orbit: 26725\_1



UT	19:59:00	20:00:15	20:01:30	20:02:45	20:04:00
Lat.	46.00	50.50	54.97	59.42	63.82
Long.	19.98	18.20	18.14	13.64	10.49
MLT	22.18	22.21	22.24	22.27	22.32
L	2.02	2.38	2.89	3.66	4.83

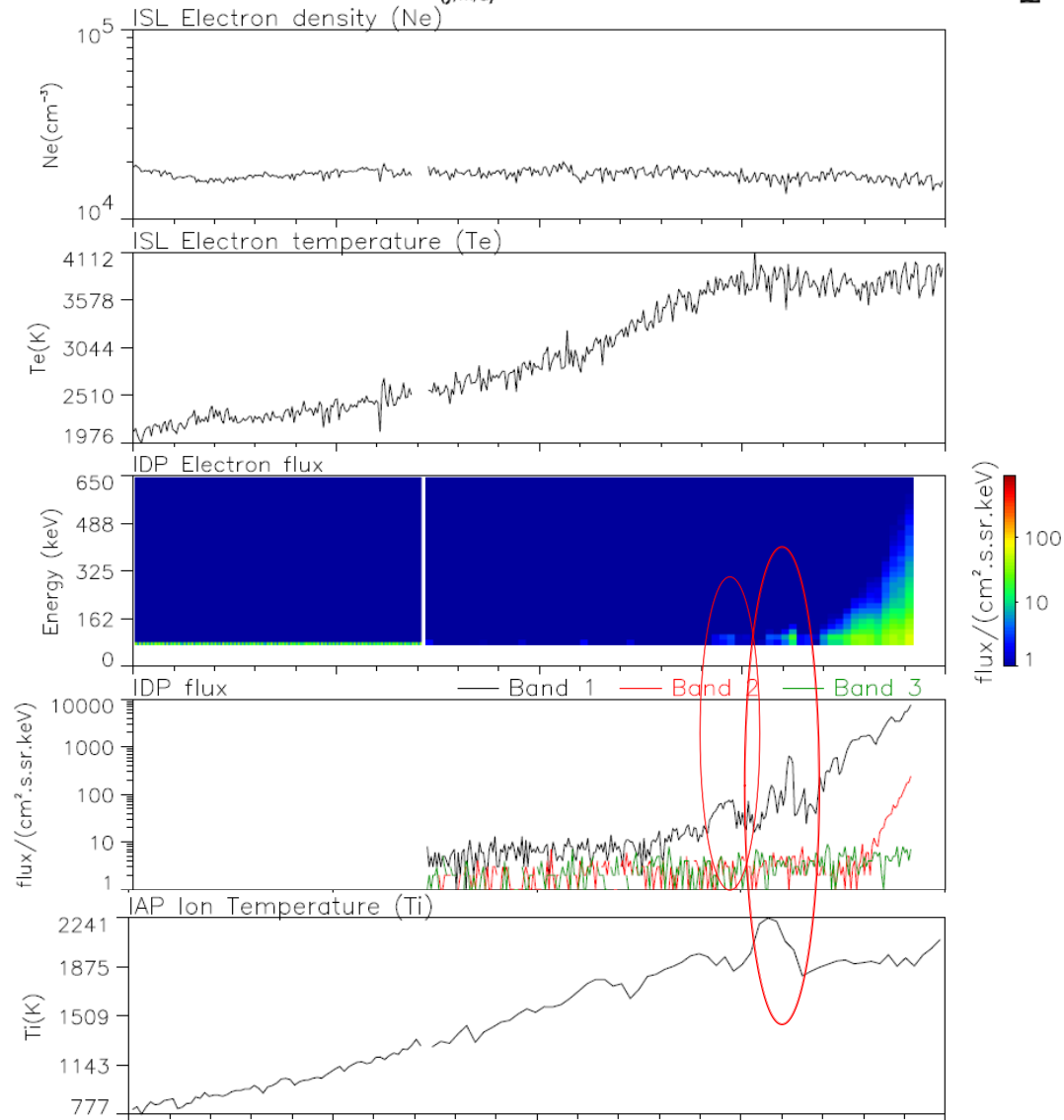


UT	19:57:00	19:57:38	19:58:17	19:58:56	19:59:35
MLT	22.15	22.16	22.17	22.18	22.19
L	1.59	1.74	1.88	2.01	2.17
Geom. Lat.	37.34	39.74	42.14	44.54	46.94

DEMETER

Date (y/m/d): 2009/06/30

Orbit: 26725\_1



UT	19:57:00	19:58:45	20:00:30	20:02:15	20:04:00
MLT	22.15	22.18	22.21	22.26	22.32
L	1.59	1.97	2.47	3.32	4.83
Geom. Lat.	37.34	43.84	50.35	56.85	63.35
Geom. Long.	102.05	102.02	102.08	102.31	102.81

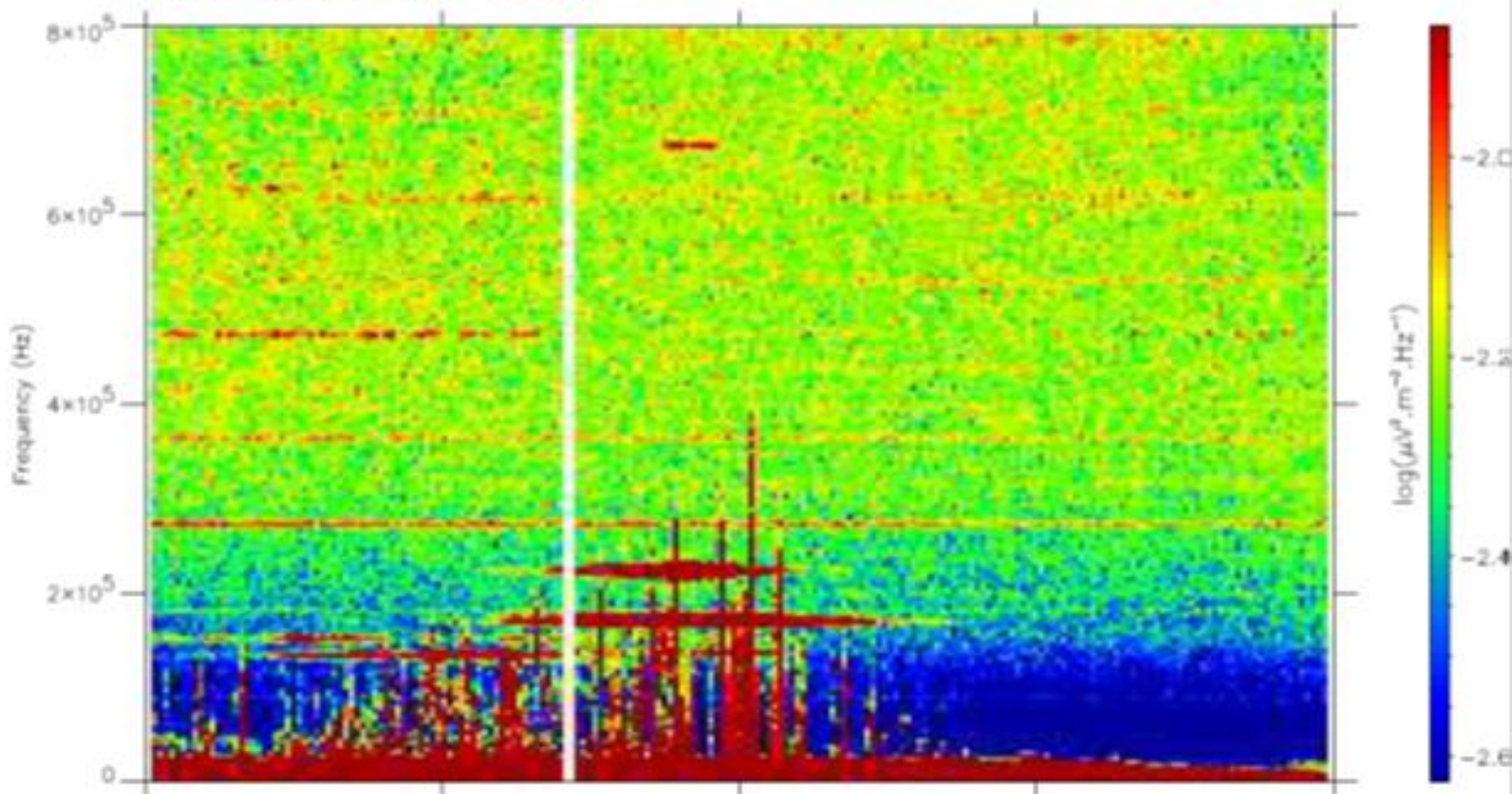


DEMETER

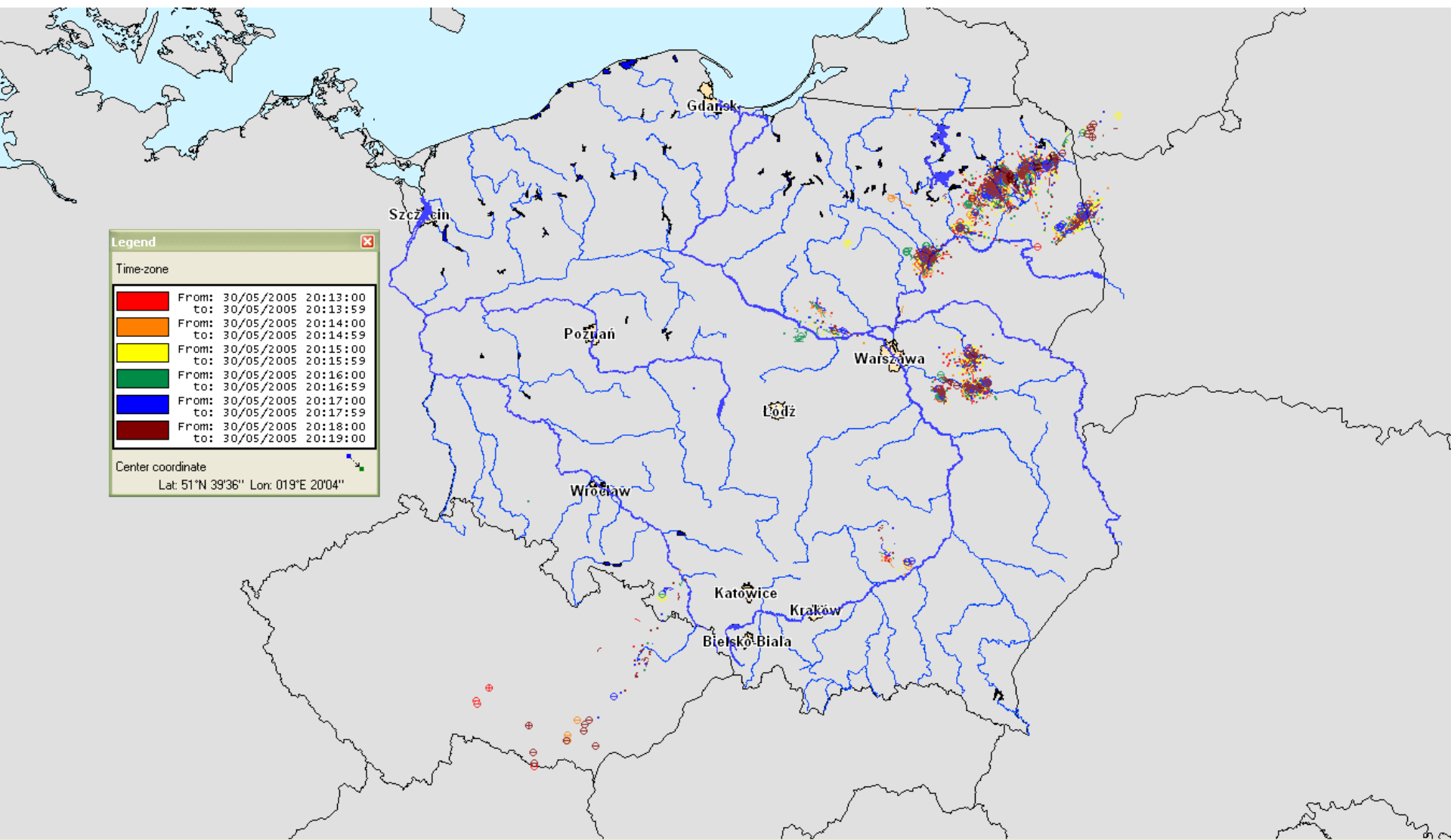
Date (y/m/d): 2009/06/30

Orbit: 26725\_1

ICE HF Spectrogram (onboard) E12



UT	19:57:00	19:58:45	20:00:30	20:02:15	20:04:00
Lat.	38.77	45.10	51.39	57.64	63.82
Long.	22.34	20.28	17.82	14.70	10.49
MLT	22.15	22.18	22.21	22.26	22.32
L	1.59	1.97	2.47	3.32	4.83







Event geographic position

E ..... DEMETER ..... E

lat (°) lon (°) dist (km) 2005-04-13 record < 185402 2005-06-20 Coordinates  
 51,78 19,45 500 19:31:00 << < 126840 > >> 04:16:30 geographic

Home

Orbit:

Demeter past

predicted

Double Star 1

Double Star 2

Jason

Conjugations:

Demeter-Jason

Info:

software

server

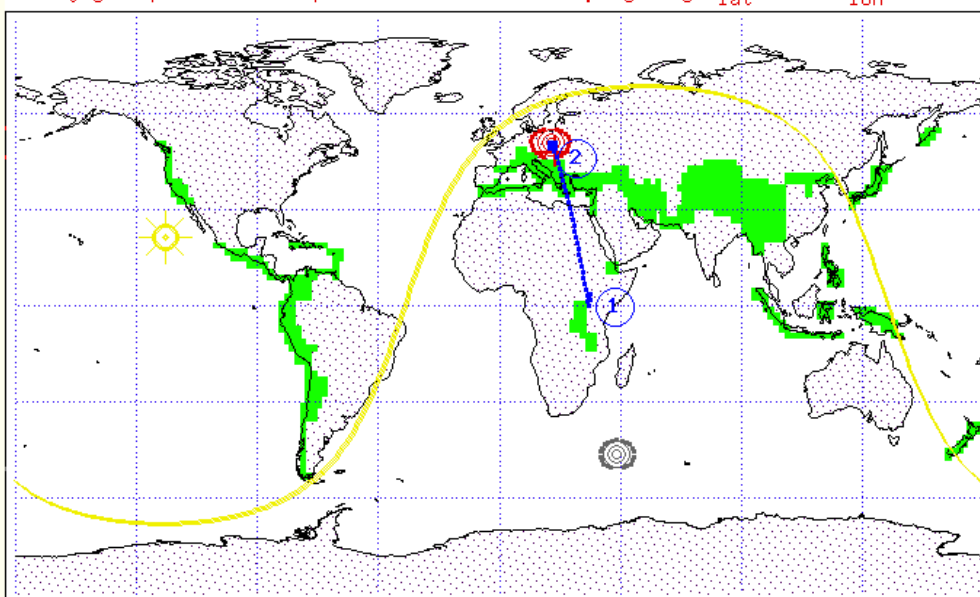


ESTEC

Contact:

J.Grygorczuk

Conjugate point of the epicenter at 710 km + geomag lat 47.05 lon 103.19



lat<sup>21.7</sup> lon<sup>235.4</sup>

- ① 2005-05-30 20.01.00.000
- ② 2005-05-30 20.16.00.000

UT	== geographic ==		dist	dist
	lat	lon	tloc	
20.01.00 9	34.11	22.3		5452 5628
20.01.30 8	33.72	22.3		5640 5436
20.02.00 8	33.33	22.3		5828 5246
20.02.30 2	32.95	22.2		5640 5433
20.03.00 2	32.56	22.2		5435 5638
20.03.30 2	32.17	22.2		5230 5842
20.04.00 3	31.79	22.2		5025 6048
20.04.30 3	31.39	22.2		4819 6253
20.05.00 3	31.00	22.1		4615 6458
20.05.30 3	30.60	22.1		4410 6663
20.06.00 3	30.20	22.1		4205 6868
20.06.30 4	29.80	22.1		3999 7074
20.07.00 4	29.39	22.1		3793 7279
20.07.30 4	28.97	22.1		3588 7484
20.08.00 4	28.55	22.0		3383 7689
20.08.30 4	28.12	22.0		3178 7894
20.09.00 4	27.68	22.0		2973 8100
20.09.30 4	27.23	22.0		2767 8305
20.10.00 4	26.77	21.9		2562 8510
20.10.30 3	26.30	21.9		2358 8715
20.11.00 3	25.82	21.9		2152 8920
20.11.30 3	25.32	21.9		1946 9126
20.12.00 2	24.81	21.9		1742 9330
20.12.30 1	24.28	21.8		1537 9535
20.13.00 1	23.72	21.8		1331 9741
20.13.30 0	23.15	21.8		1126 9946
20.14.00 9	22.55	21.7		921 10152
20.14.30 7	21.92	21.7		716 10356
20.15.00 6	21.26	21.7		511 10562
20.15.30 4	20.56	21.6		306 10767
20.16.00 2	19.82	21.6		104 10972



Event geographic position

E ..... DEMETER ..... E

lat (°) lon (°) dist (km) 2005-04-13 record < 185402 2005-06-20 Coordinates  
 51,78 19,45 500 19:31:00 << < 126870 > >> 04:16:30 geographic

Home

Orbit:

Demeter past

predicted

Double Star 1

Double Star 2

Jason

Conjugations:

Demeter-Jason

Info:

software

server

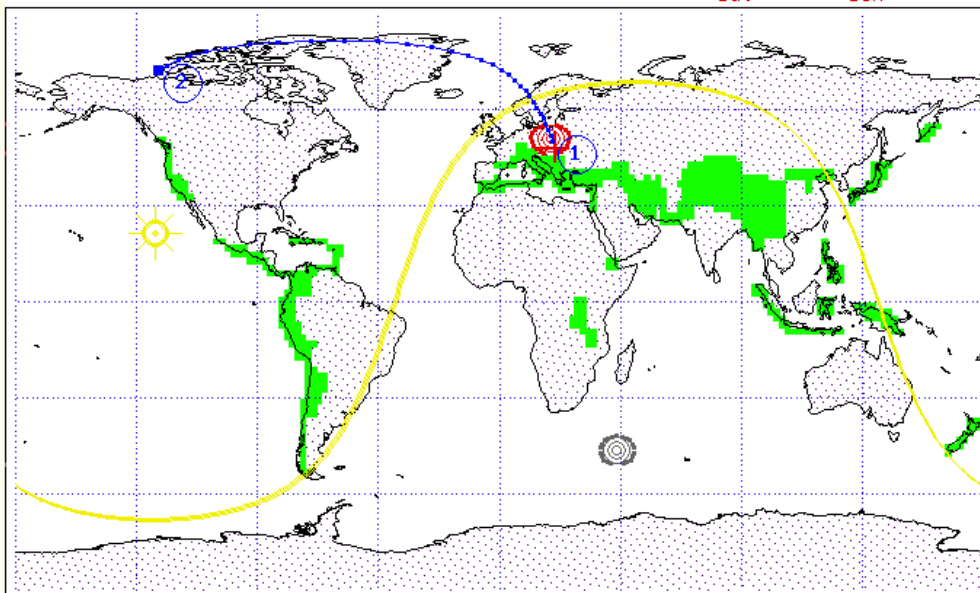


ESTEC

Contact:

J.Grygorczuk

Conjugate point of the epicenter at 710 km + geomag lat 47.05 lon 103.19



lat<sup>21.7</sup> lon<sup>231.6</sup>

- ① 2005-05-30 20.16.00.000
- ② 2005-05-30 20.31.00.000

UT	== geographic ==		dist	dist
	lat	lon	tloc	
20.16.00.2	19.82	21.6	21.6	104 10972
20.16.30.9	19.03	21.5	21.5	110 11177
20.17.00.7	18.19	21.5	21.5	313 11383
20.17.30.3	17.29	21.4	21.4	517 11587
20.18.00.9	16.31	21.4	21.4	722 11792
20.18.30.5	15.24	21.3	21.3	927 11997
20.19.00.0	14.08	21.3	21.3	1133 12202
20.19.30.4	12.79	21.2	21.2	1338 12408
20.20.00.6	11.37	21.1	21.1	1542 12611
20.20.30.8	9.76	21.0	21.0	1748 12817
20.21.00.8	7.95	20.9	20.9	1953 13022
20.21.30.6	5.88	20.8	20.8	2158 13226
20.22.00.1	3.47	20.6	20.6	2363 13431
20.22.30.3	0.66	20.4	20.4	2568 13635
20.23.00.1	357.32	20.2	20.2	2773 13840
20.23.30.3	353.30	19.9	19.9	2978 14044
20.24.00.7	348.40	19.6	19.6	3183 14248
20.24.30.1	342.37	19.2	19.2	3388 14452
20.25.00.9	334.90	18.7	18.7	3593 14656
20.25.30.7	325.74	18.1	18.1	3798 14859
20.26.00.8	314.80	17.4	17.4	4003 15063
20.26.30.4	302.46	16.6	16.6	4208 15266
20.27.00.0	289.65	15.8	15.8	4413 15469
20.27.30.8	277.50	15.0	15.0	4618 15672
20.28.00.2	266.86	14.3	14.3	4823 15875
20.28.30.0	258.00	13.7	13.7	5028 16076
20.29.00.9	250.80	13.2	13.2	5232 16277
20.29.30.3	244.97	12.8	12.8	5437 16479
20.30.00.7	240.24	12.5	12.5	5642 16680
20.30.30.4	236.35	12.3	12.3	5847 16879
20.31.00.6	233.11	12.1	12.1	6051 17077

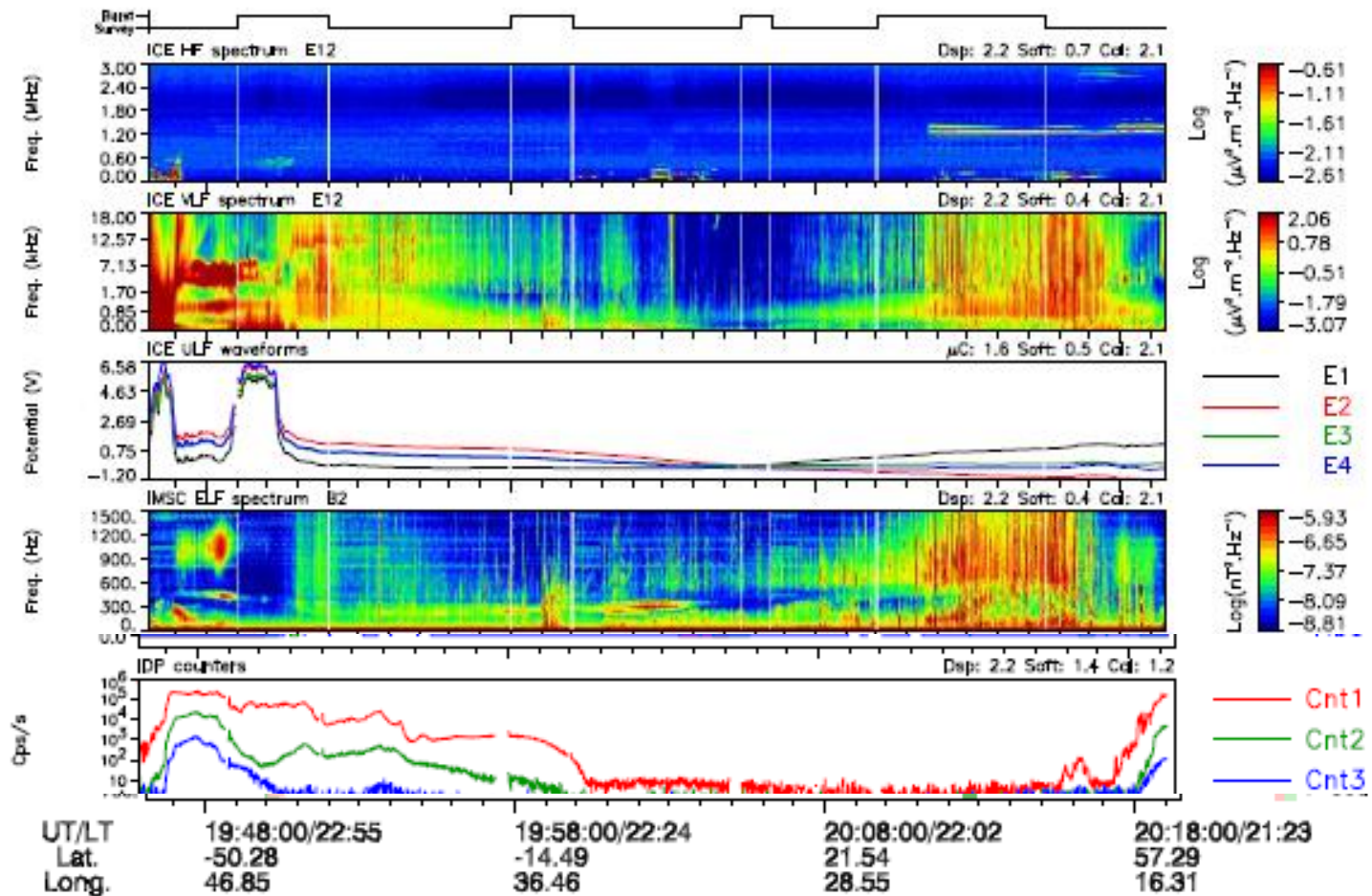
# DEMETER / QUICKLOOK

Date (GMT): 2005/05/30

Orbit: 04835\_1

Produced by LPCE 2005/05/31 05:22:23 v3.5

CBK CESR CETP CNES ICGP LPCE RSSD USN

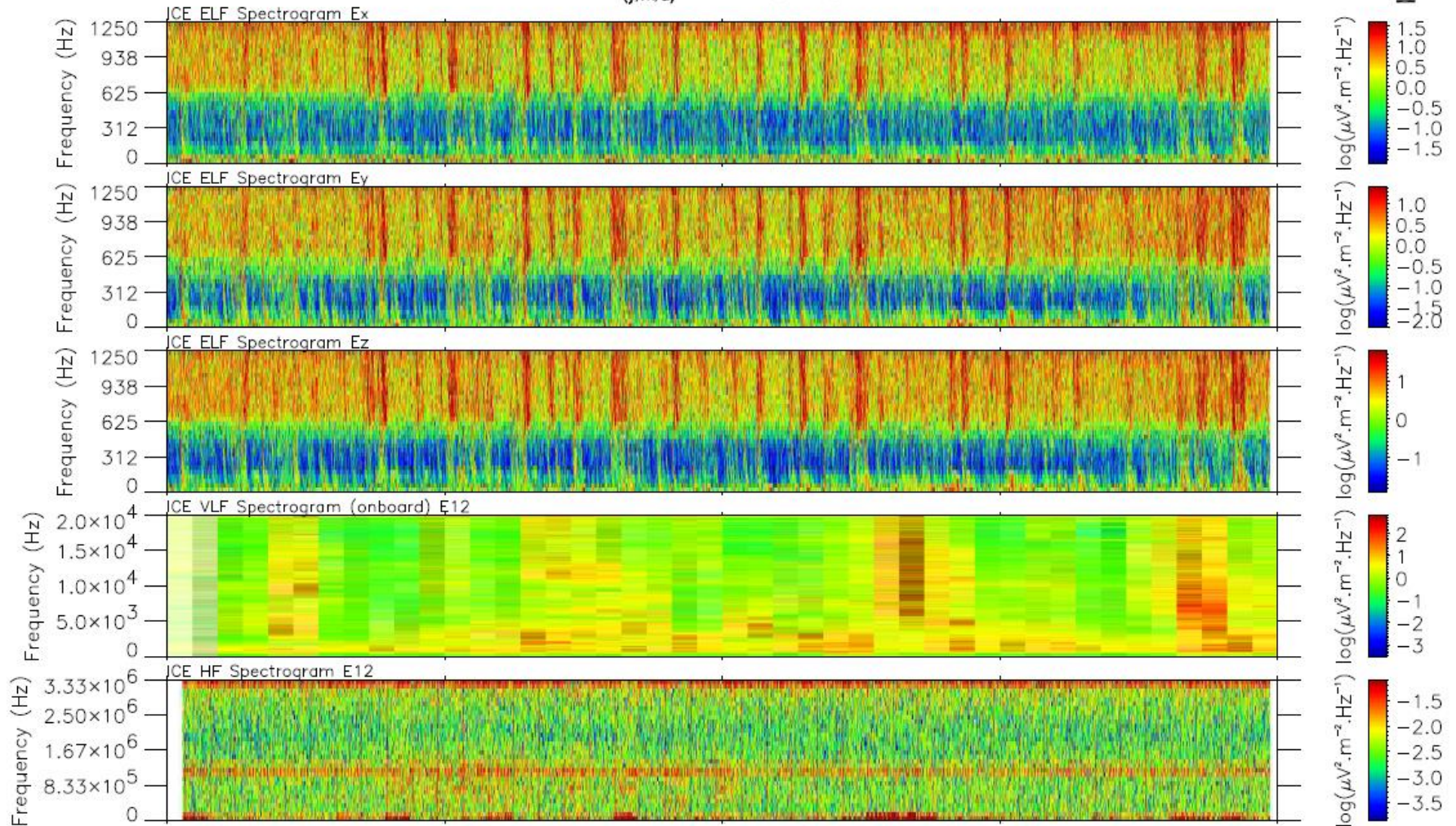




# DEMETER

Date (y/m/d): 2005/05/30

Orbit: 04835\_1

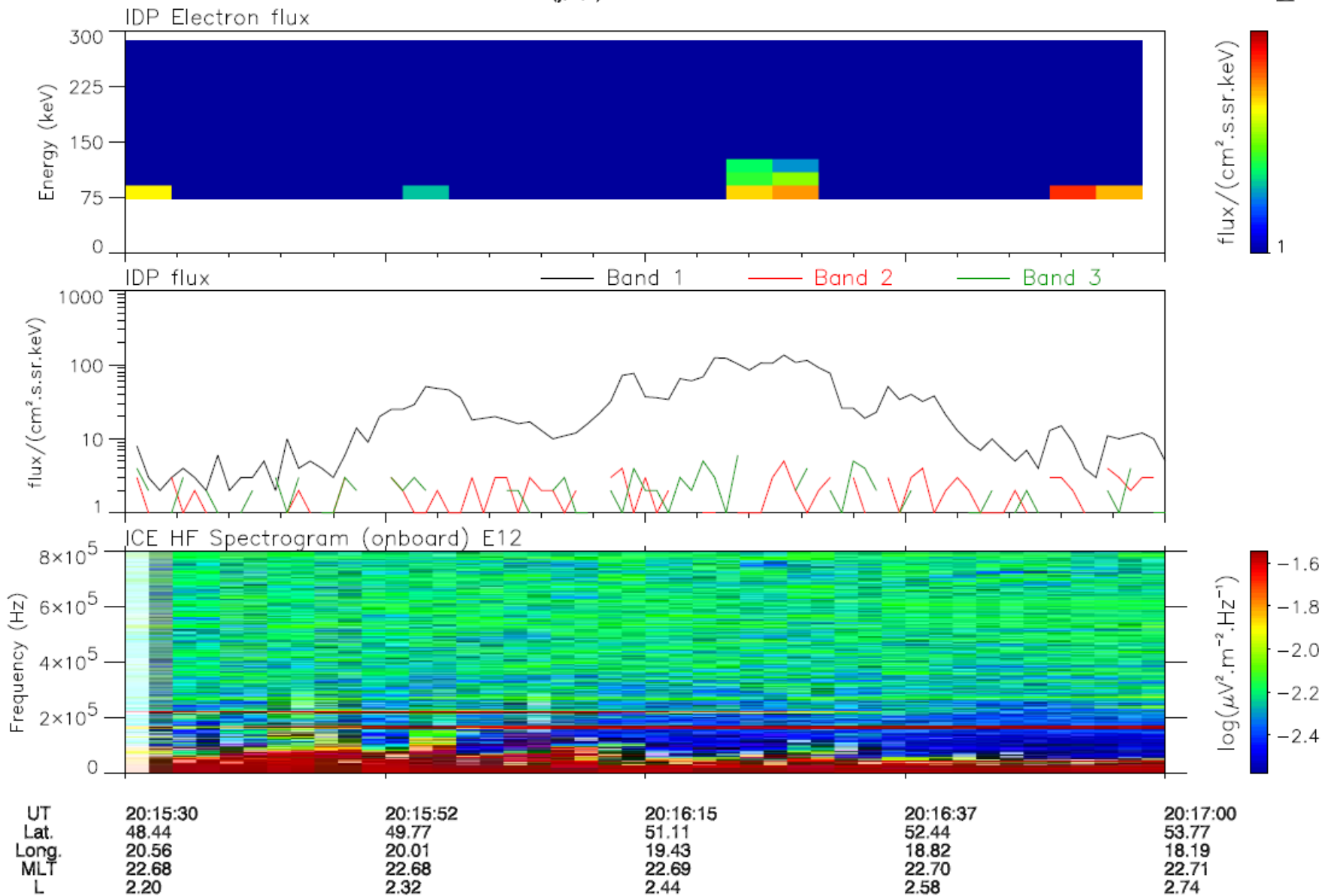


UT	20:14:00	20:14:22	20:14:45	20:15:07	20:15:30
Lat.	43.09	44.43	45.77	47.10	48.44
Long.	22.55	22.08	21.59	21.08	20.56
MLT	22.65	22.66	22.66	22.67	22.68
L	1.86	1.93	2.01	2.10	2.20

# DEMETER

Date (y/m/d): 2005/05/30

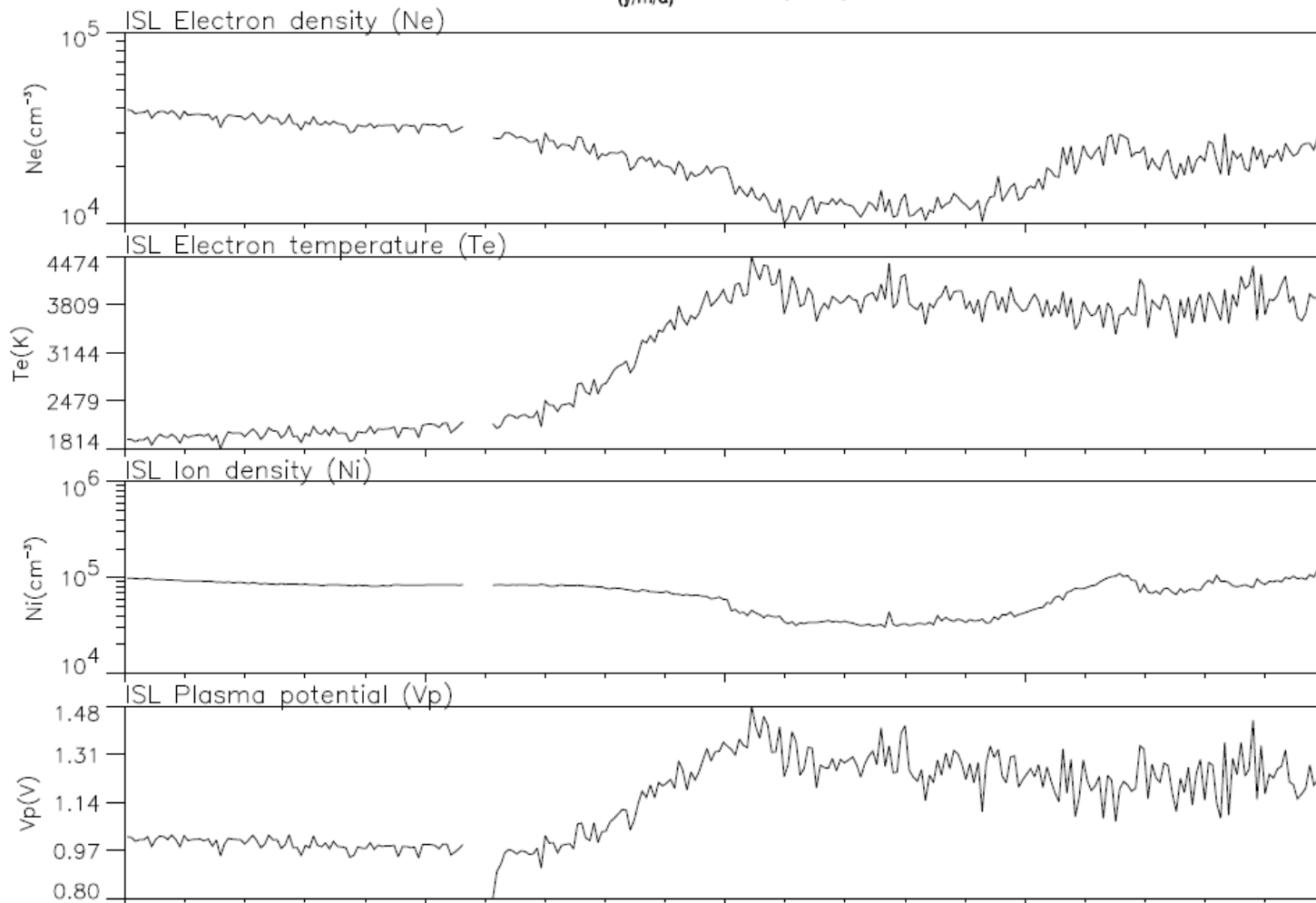
Orbit: 04835\_1



# DEMETER

Date (y/m/d): 2005/05/30

Orbit: 04835\_1



UT	20:14:00	20:15:15	20:16:30	20:17:45	20:19:00
Lat.	43.09	47.55	51.99	56.41	60.80
Long.	22.55	20.91	19.03	16.80	14.08
MLT	22.65	22.67	22.70	22.72	22.76
L	1.86	2.13	2.53	3.11	3.96







Event geographic position

E ..... DEMETER ..... E

lat (°) lon (°) dist (km) 2009-07-18 record < 185427 2009-09-20 Coordinates  
 51,78 19,45 500 04:42:00 << < 16270 > >> 13:55:00 geographic ▾

Home

Orbit  
 Demeter past  
 predicted

Double Star 1  
 Double Star 2  
 Jason

Conjugations:  
 Demeter-Jason

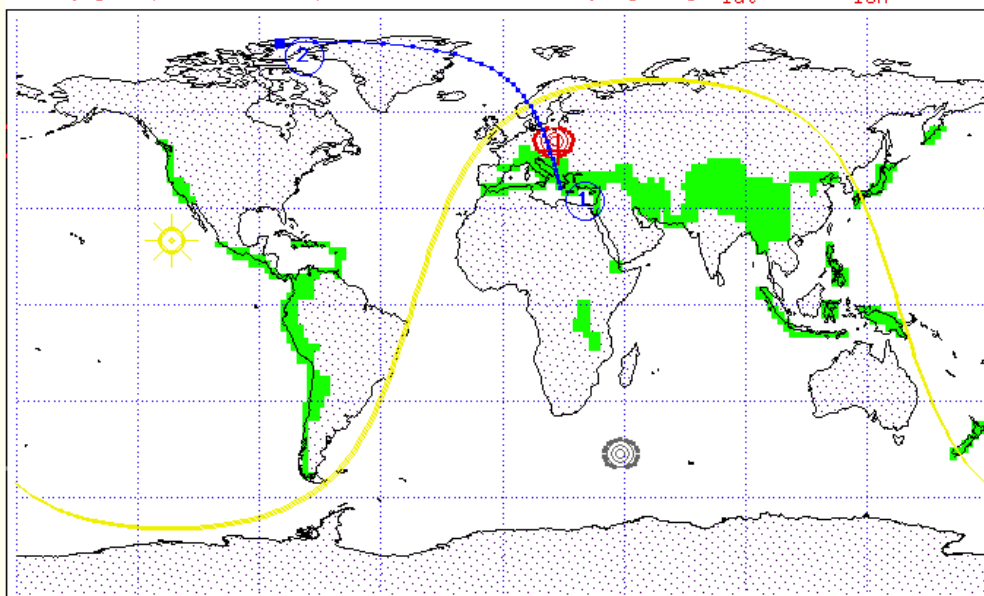
Info:  
 software  
 server



ESTEC

Contact:  
 J.Grygorczuk

Conjugate point of the epicenter at 710 km + geomag lat 47.05 lon 103.19



lat<sup>20.1</sup> lon<sup>237.4</sup>

- ① 2009-07-23 20.02.00.000
- ② 2009-07-23 20.17.00.000

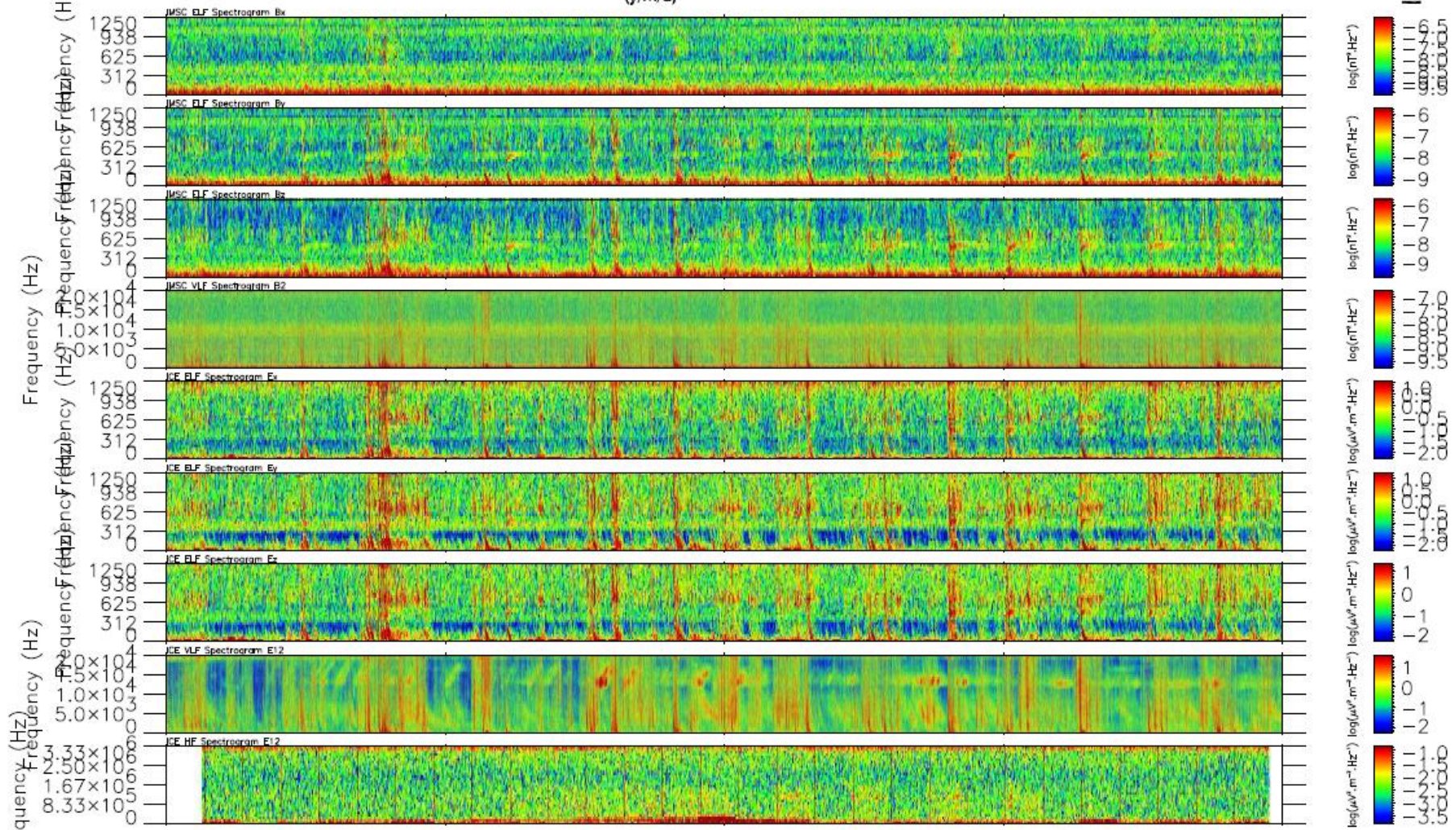
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	lat	lon	tloc		
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20.03.00 3	20.28	21.4		1192	9906
20.03.30 4	19.70	21.4		988	10113
20.04.00 5	19.10	21.3		785	10320
20.04.30 5	18.46	21.3		586	10526
20.05.00 5	17.80	21.3		394	10732
20.05.30 5	17.09	21.2		229	10939
20.06.00 5	16.34	21.2		187	11146
20.06.30 4	15.54	21.1		321	11352
20.07.00 3	14.68	21.1		506	11558
20.07.30 1	13.76	21.0		703	11764
20.08.00 9	12.75	21.0		905	11971
20.08.30 6	11.65	20.9		1108	12177
20.09.00 3	10.45	20.9		1313	12383
20.09.30 8	9.11	20.8		1517	12589
20.10.00 2	7.61	20.7		1722	12794
20.10.30 5	5.91	20.6		1928	13000
20.11.00 6	3.98	20.4		2134	13206
20.11.30 5	1.75	20.3		2340	13411
20.12.00 1	359.14	20.1		2546	13617
20.12.30 3	356.05	19.9		2752	13822
20.13.00 0	352.33	19.7		2957	14026
20.13.30 0	347.79	19.4		3163	14231
20.14.00 1	342.18	19.1		3369	14435
20.14.30 9	335.19	18.6		3575	14639
20.15.00 8	326.48	18.0		3781	14843
20.15.30 2	315.84	17.3		3988	15047
20.16.00 1	303.46	16.5		4194	15250
20.16.30 1	290.16	15.6		4400	15452
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# DEMETER

Date (y/m/d): 2009/07/23

Orbit: 27063\_1



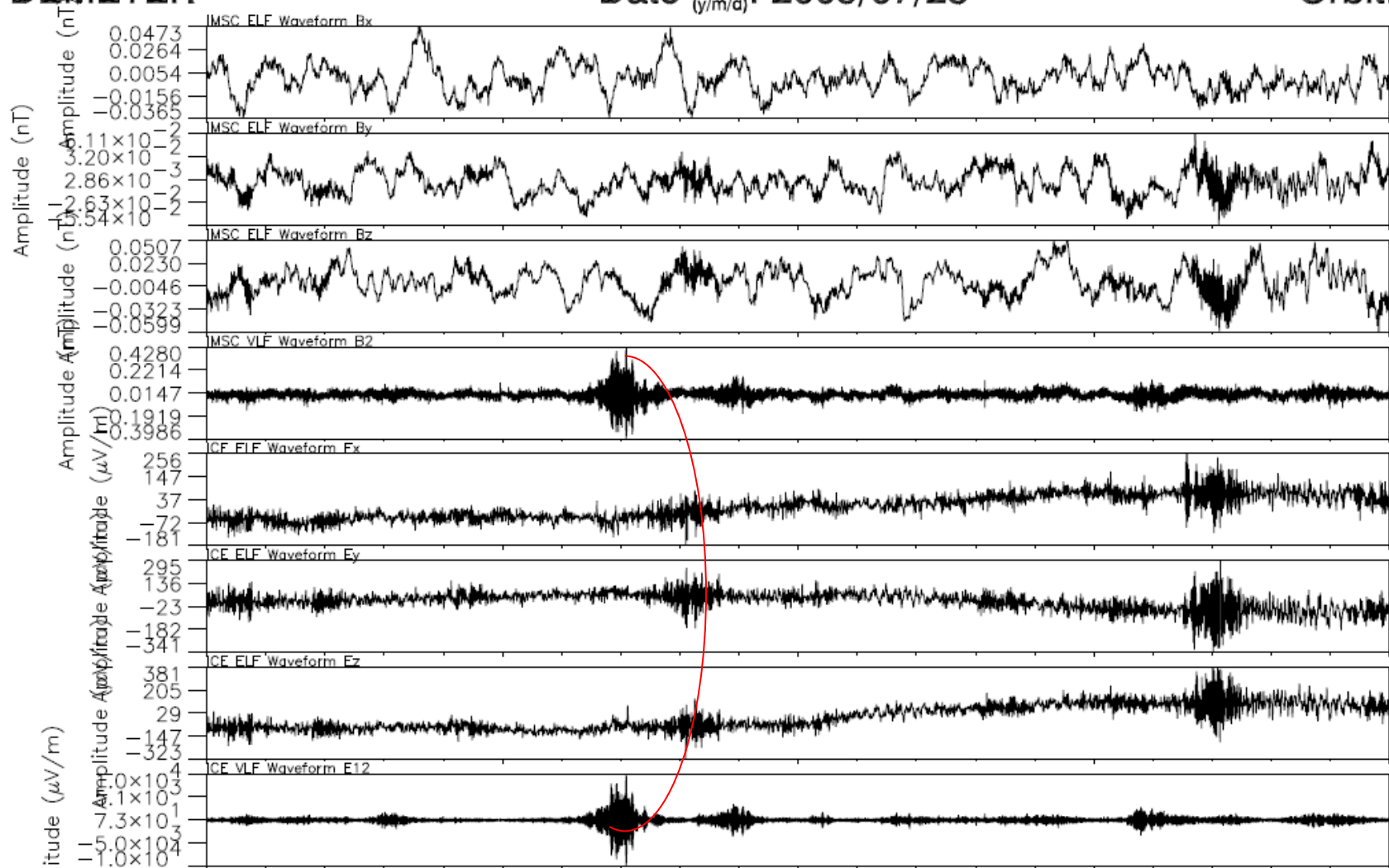
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Lat.	47.55	48.45	49.35	50.25	51.15
Long.	17.80	17.44	17.09	16.72	16.34
MLT	22.10	22.11	22.11	22.12	22.12
L	2.14	2.21	2.28	2.37	2.45



# DEMETER

Date (y/m/d): 2009/07/23

Orbit: 27063\_1

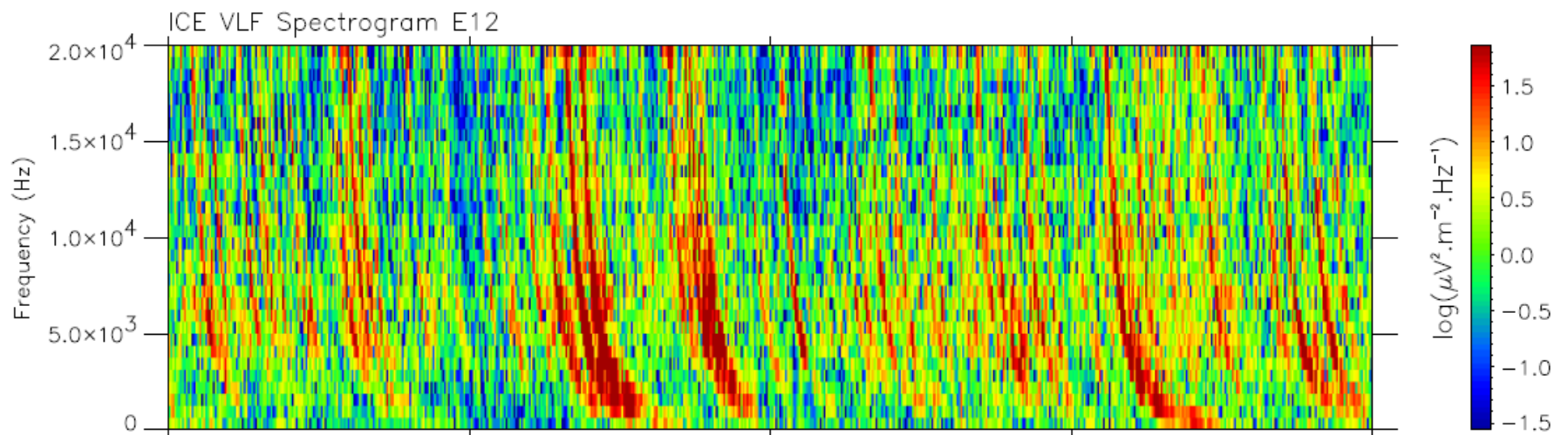
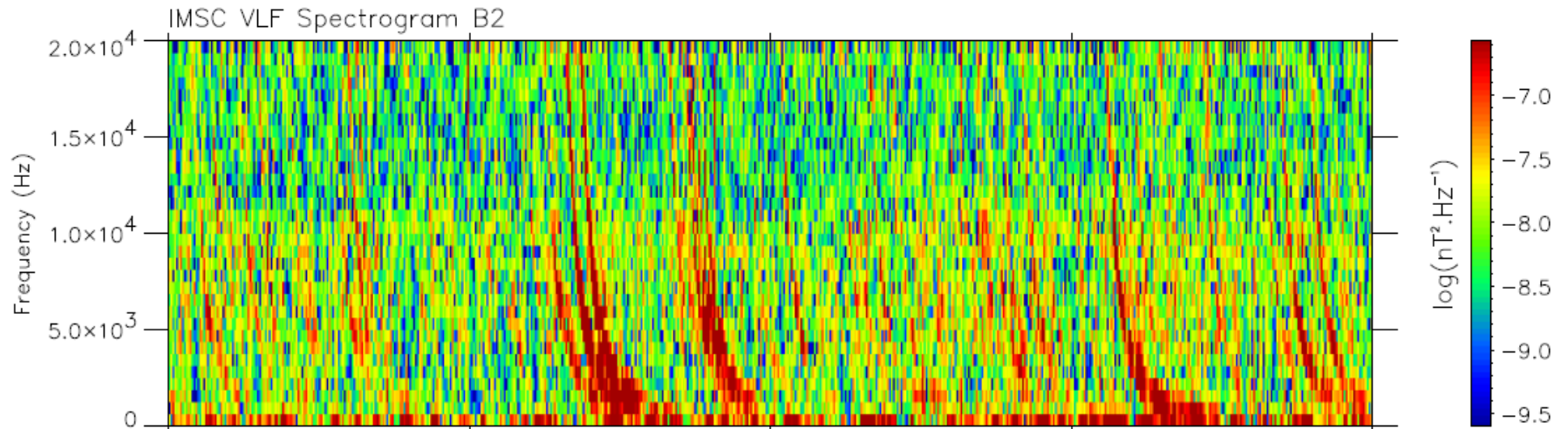


UT	20:05:33	20:05:33	20:05:33	20:05:33	20:05:34
Lat.	49.53	49.55	49.56	49.58	49.59
Long.	17.02	17.01	17.00	17.00	16.99
MLT	22.12	22.12	22.12	22.12	22.12
L	2.30	2.30	2.30	2.30	2.31

DEMETER

Date (y/m/d): 2009/07/23

Orbit: 27063\_1

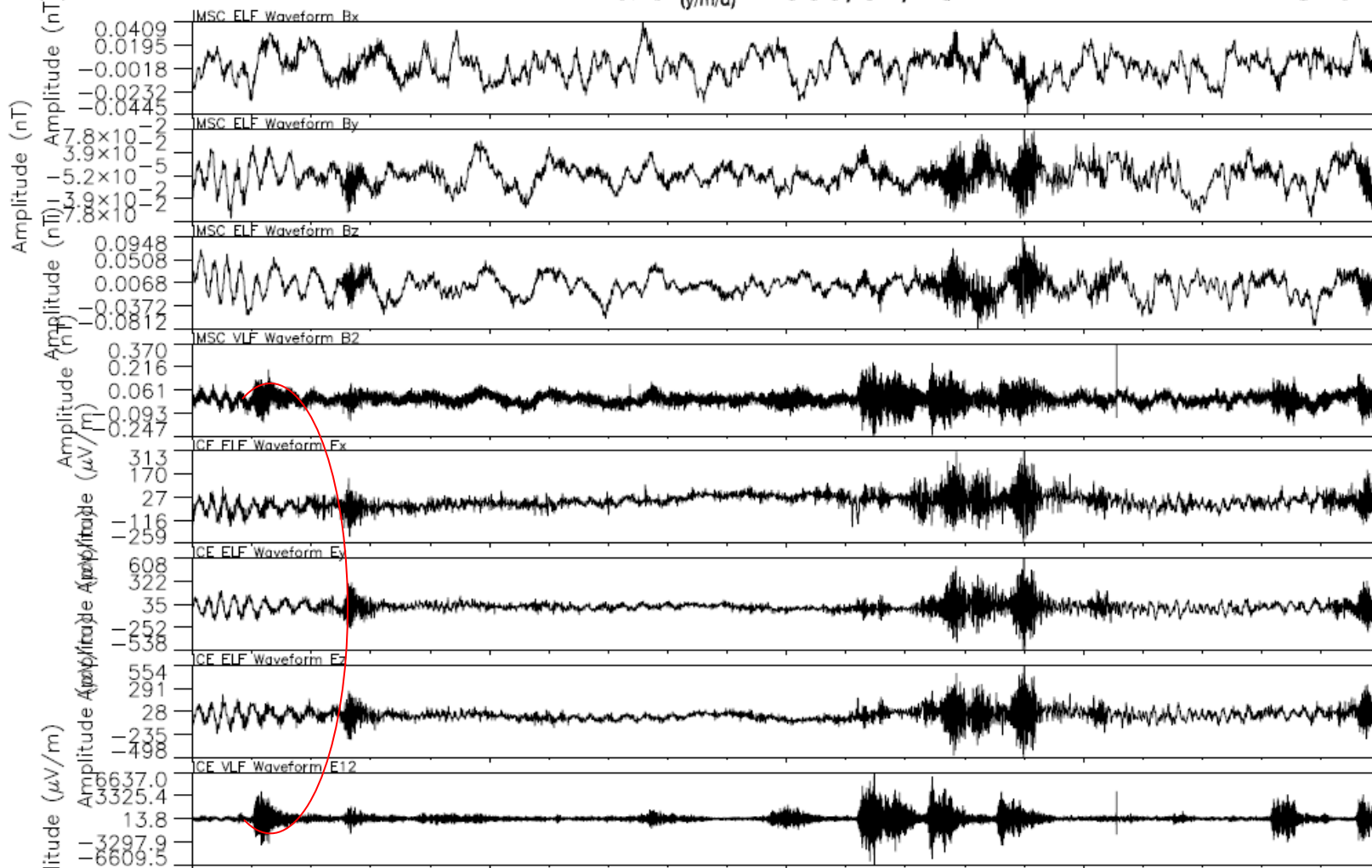


UT	20:05:33	20:05:33	20:05:33	20:05:33	20:05:34
Lat.	49.53	49.55	49.56	49.58	49.59
Long.	17.02	17.01	17.00	17.00	16.99
MLT	22.12	22.12	22.12	22.12	22.12
L	2.30	2.30	2.30	2.30	2.31

# DEMETER

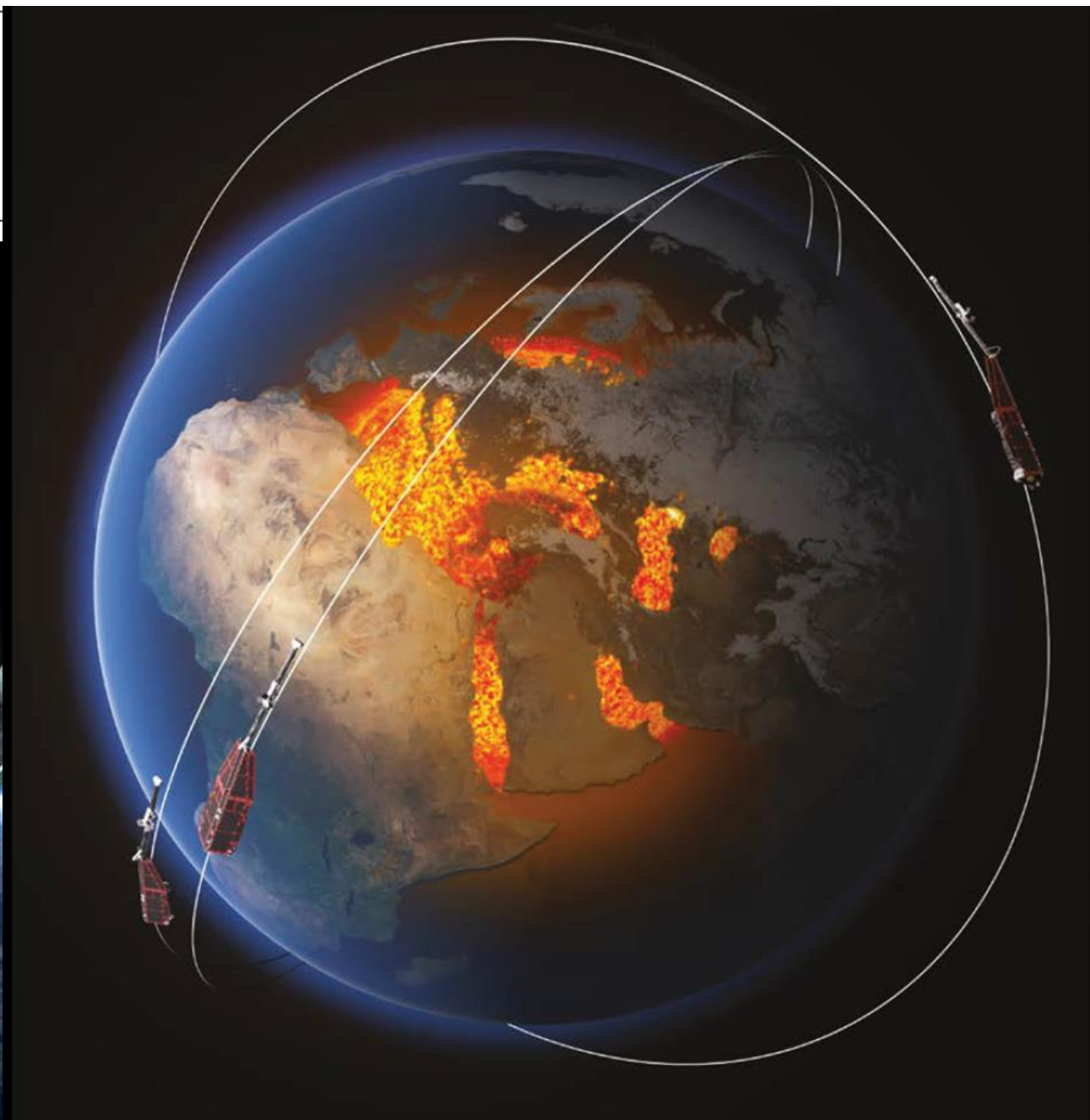
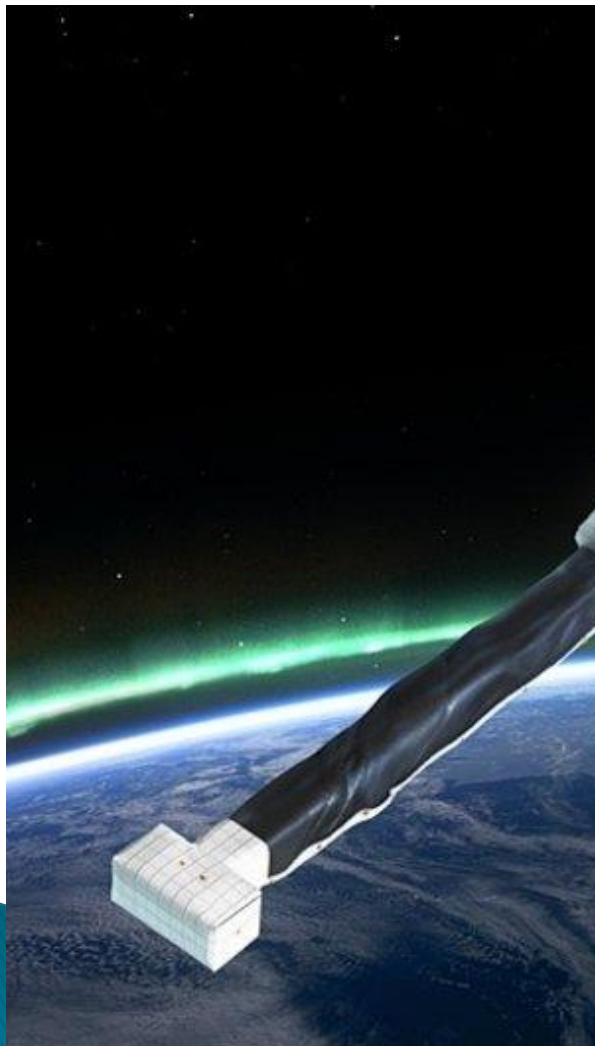
Date (y/m/d): 2009/07/23

Orbit: 27063\_1



UT	20:05:38	20:05:38	20:05:38	20:05:38	20:05:39
Lat.	49.83	49.85	49.86	49.88	49.89
Long.	16.89	16.88	16.88	16.87	16.87
MLT	22.12	22.12	22.12	22.12	22.12
L	2.33	2.33	2.33	2.33	2.33

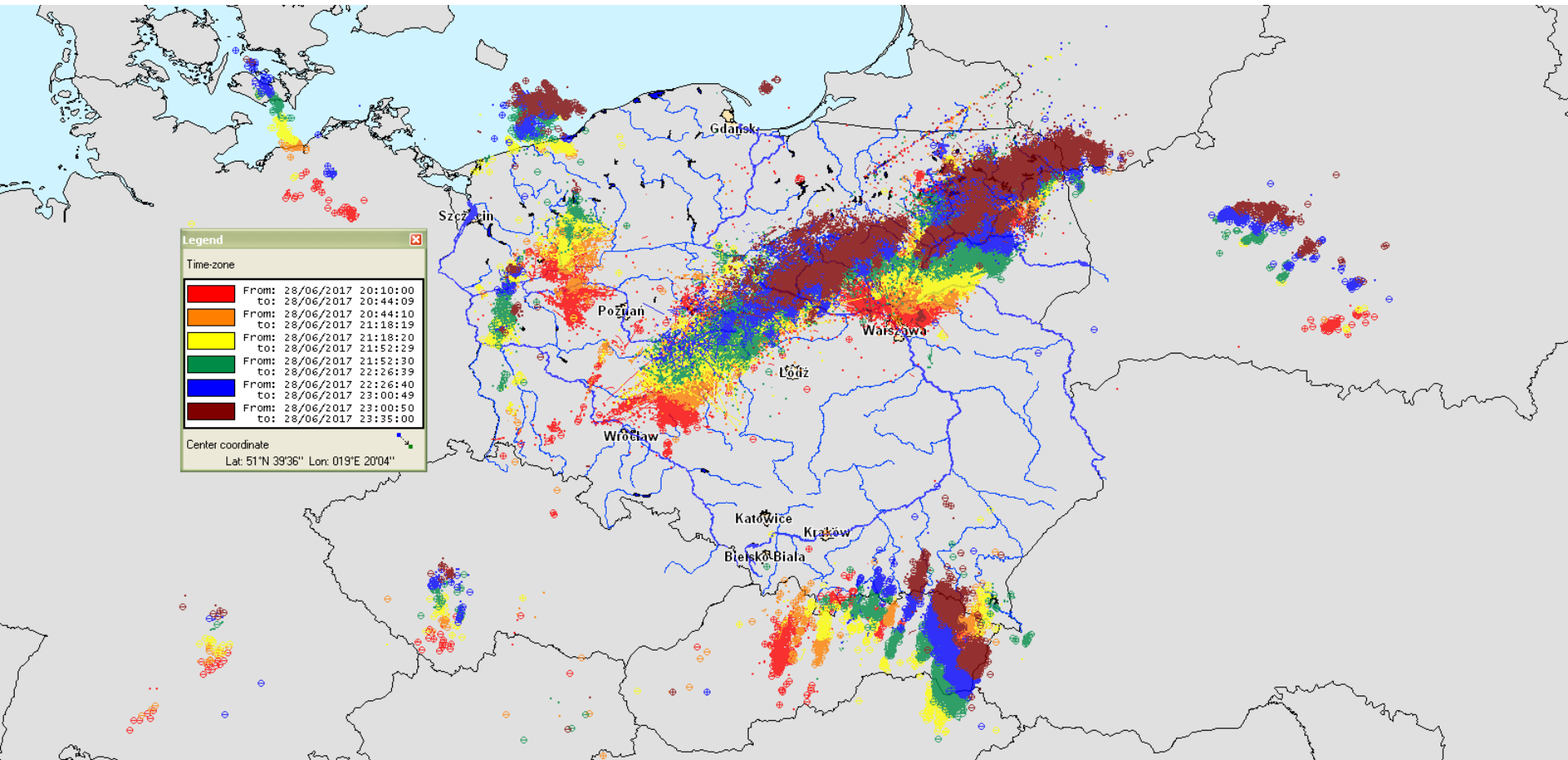




## Payload Configuration

- Absolute Scalar Magnetometer (ASM)
- Vector Field Magnetometer (VFM)
- Electrical Field Instrument (EFI)
- Startracker System (STR)
- GPS Receiver (GPSR)
- Accelerometer (ACC)
- Laser Retro Reflector (LRR)

# Thunderstorm on 28.06.2017





$T_0 = 2017-06-28\ 20:20:00.763000$ ,  $T_n = 2017-06-28\ 21:15:08.057000$   
Sw. B, Eq. cr. LT, Asc: 21:48:20.262000, Desc: 09:48:29.737000

