NOAA Environmental Satellite Measurements of Extreme Space Weather Events

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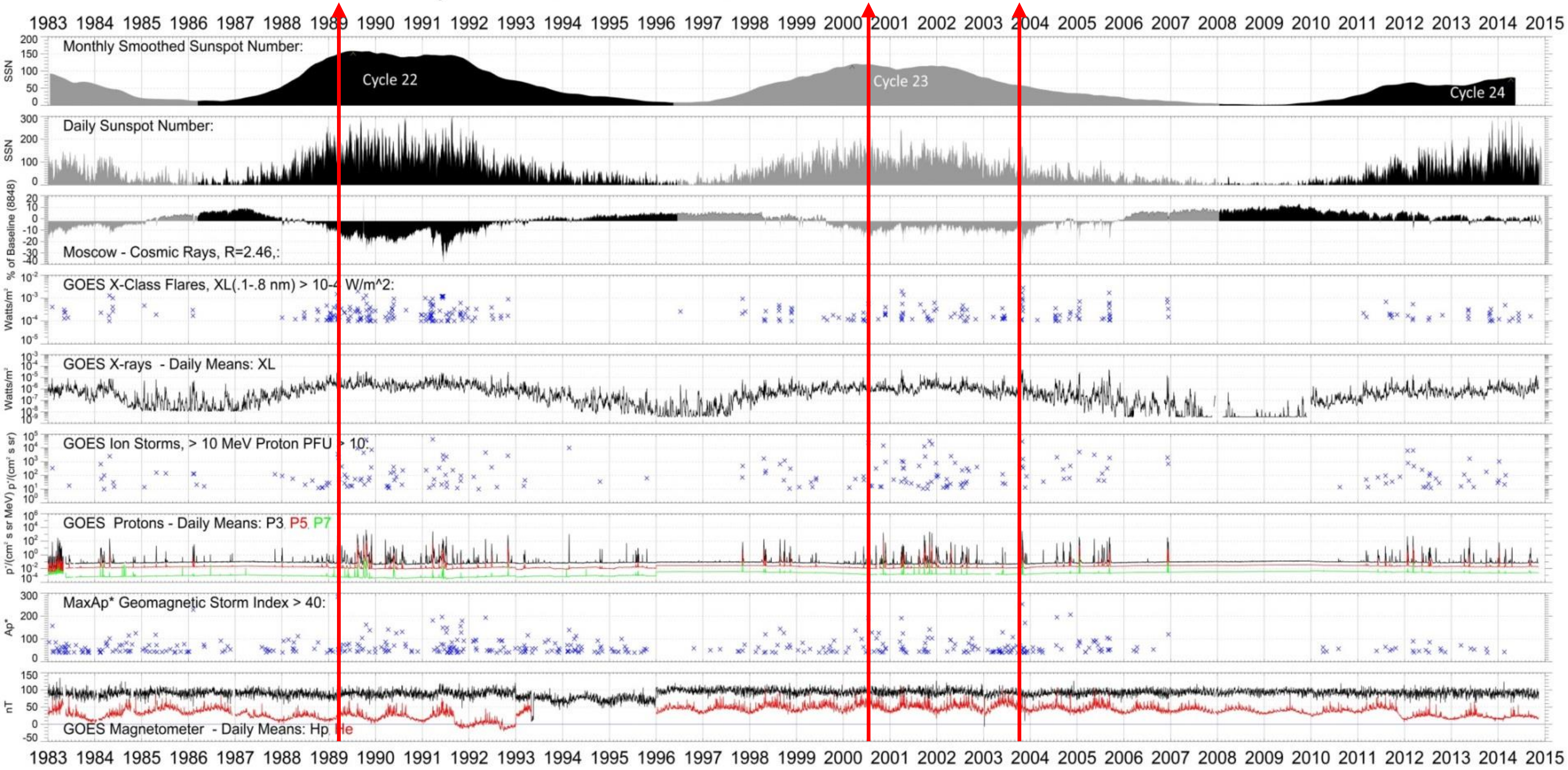
AGU Fall 2015

SM32A-01

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

GOES Overview (1983 – 2014)

Space Environment Overview: 1983-01-01 - 2014-12-31



Red Lines:
Mar 1989
Jul 2000
Oct 2003

	Start Date	Max Date	End Date	C-Class Flares	M-Class Flares	X-Class Flares	Ion Storms	Mag Storms Ap* > 40
Solar Cycle 22	1986-03	1989-07	1996-06	12,447	2,021	151	73	191
Solar Cycle 23	1996-06	2000-03	2008-01	13,102	1,437	126	92	158
Solar Cycle 24 *	2008-01	2014-04	TBD	5,288	488	35	32	25

NOAA Extreme Space Wx

NOAA Space Weather Scales

Category		Effect	Physical measure	Average Frequency (1 cycle = 11 years)
Scale	Descriptor	Duration of event will influence severity of effects		
Geomagnetic Storms			Kp values* determined every 3 hours	Number of storm events when Kp level was met; (number of storm days)
G 5	Extreme	Power systems: widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. Spacecraft operations: may experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. Other systems: pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.).**	Kp=9	4 per cycle (4 days per cycle)
Solar Radiation Storms			Flux level of ≥ 10 MeV particles (ions)*	Number of events when flux level was met**
S 5	Extreme	Biological: unavoidable high radiation hazard to astronauts on EVA (extra-vehicular activity); passengers and crew in high-flying aircraft at high latitudes may be exposed to radiation risk. *** Satellite operations: satellites may be rendered useless, memory impacts can cause loss of control, may cause serious noise in image data, star-trackers may be unable to locate sources; permanent damage to solar panels possible. Other systems: complete blackout of HF (high frequency) communications possible through the polar regions, and position errors make navigation operations extremely difficult.	10^5	Fewer than 1 per cycle
Radio Blackouts			GOES X-ray peak brightness by class and by flux*	Number of events when flux level was met; (number of storm days)
R 5	Extreme	HF Radio: Complete HF (high frequency**) radio blackout on the entire sunlit side of the Earth lasting for a number of hours. This results in no HF radio contact with mariners and en route aviators in this sector. Navigation: Low-frequency navigation signals used by maritime and general aviation systems experience outages on the sunlit side of the Earth for many hours, causing loss in positioning. Increased satellite navigation errors in positioning for several hours on the sunlit side of Earth, which may spread into the night side.	X20 ($2x10^{-3}$)	Fewer than 1 per cycle

http://www.swpc.noaa.gov/noaa-scales-explanation

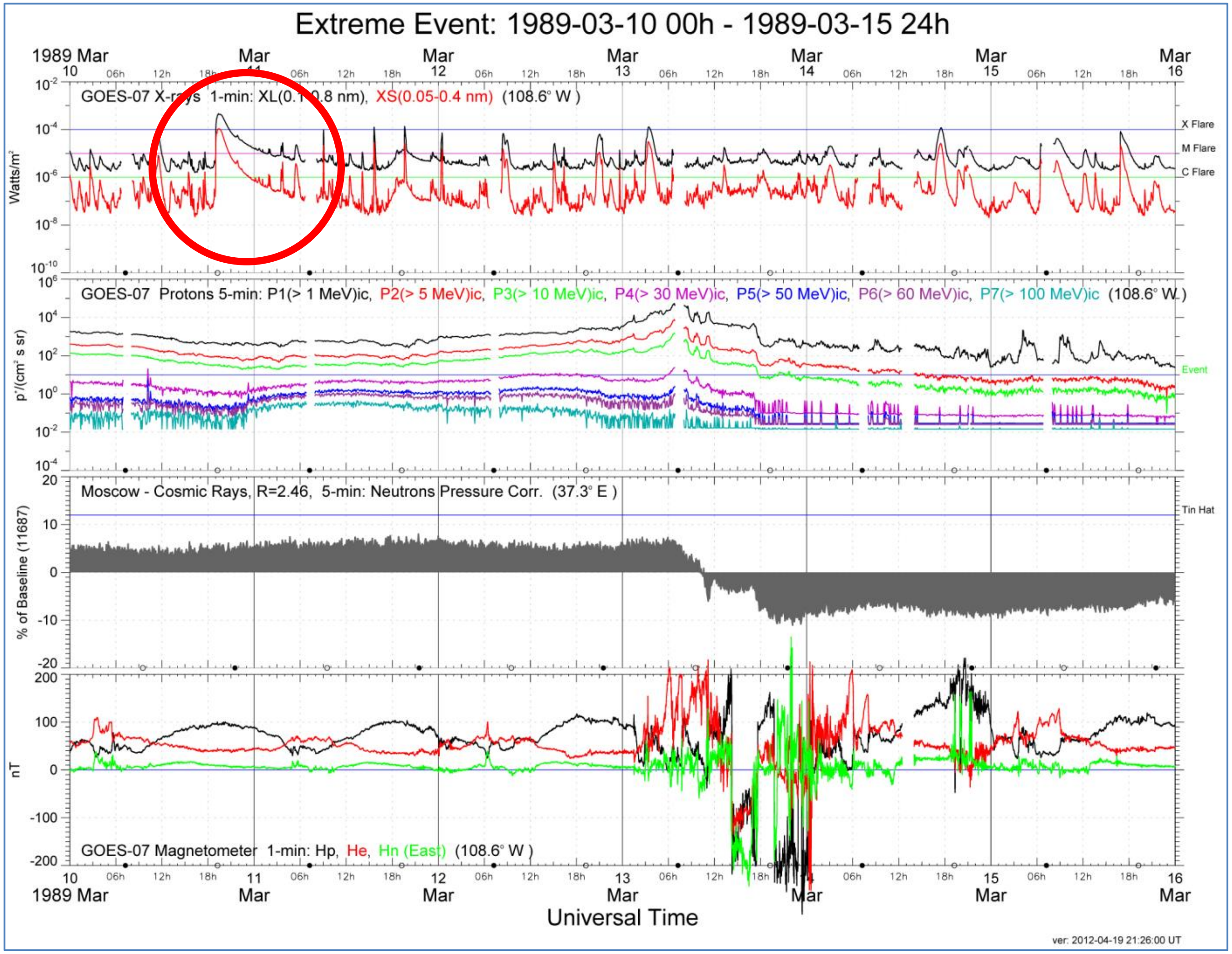
Extreme Events

Extreme Event	G-scale	R-scale	S-scale	Kp	Ap*	X-ray	SPE (pfu)
01-Aug – 14-Aug 1972	*G4*	*>R3*	*~S5*	*8o*	*223*	*>X5*[1]	*90000*[2]
10-Mar – 15-Mar 1989	**G5**	**R5**	**S3**	**9o**	**285**	**X15**	**3500**
26-Sep – 31-Sep 1989	G3	R3	S3	7o	104	X9	4500
18-Oct – 31-Oct 1989	G4	R4	S4	8+	162	X13	40000
22-Mar – 28-Mar 1991	G5	R3	S4	9o	181	X9	43000
01-Jun – 20-Jun 1991	G5	R4	S3	9o	196 / 149	X12 / X12	3000 / 1400
14-Jul – 16-Jul 2000	**G5**	**R3**	**S4**	**9o**	**192**	**X5**	**24000**
04-Nov – 08-Nov 2001	G4	R3	S4	9-	141	X1	31,700
10-Oct – 06-Nov 2003	**G5**	**R4/R5**	**S4**	**9o**	**252**	**X17 / X28**	**29500 / 353**
15-Jan – 24-Jan 2005	G4	R3	S3	8o	91	X2	5040
05-Dec – 17-Dec 2006	G4	R3	S3	8+	120	X9	1980
08-Mar – 17-Mar 2012	G4	R3	S3	8o	90	X5	6530

[1]SOLRAD9 (Dere et al. [1973]) // [2]IMP6 (Kohl et al. [1973]) // See UAG-28 – NGDC[1973]

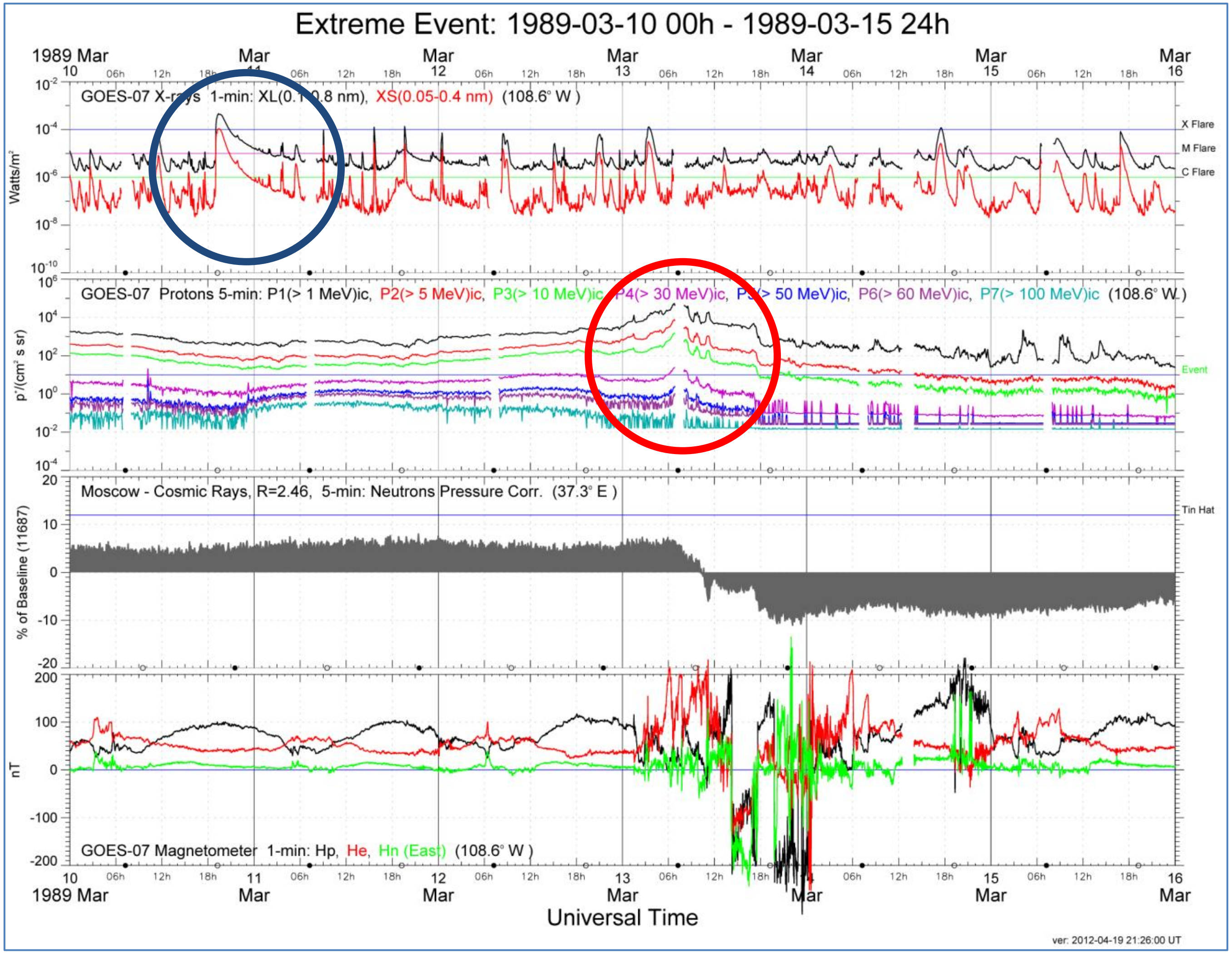
10-15 Mar 1989

R5



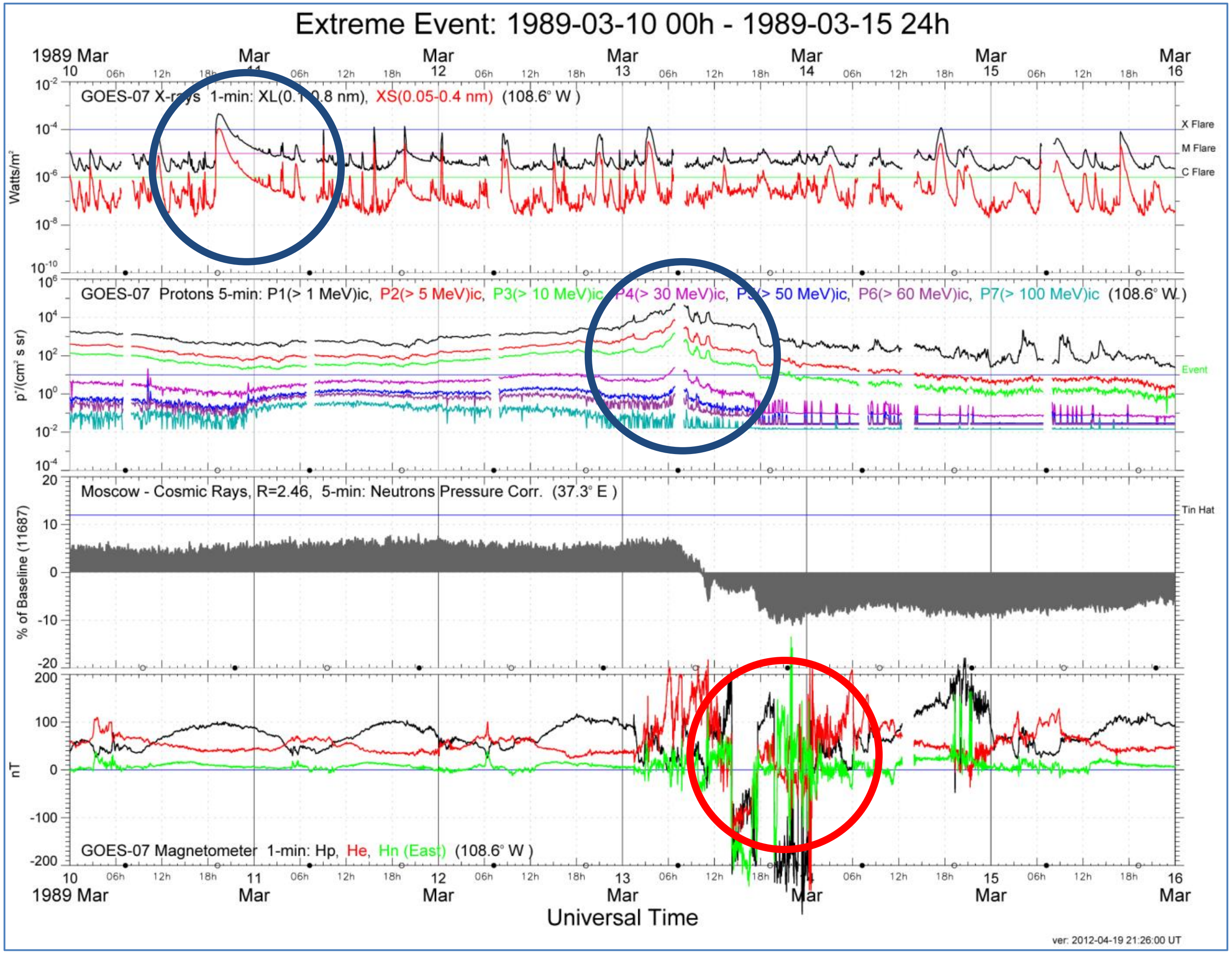
10-15 Mar 1989

R5
S3



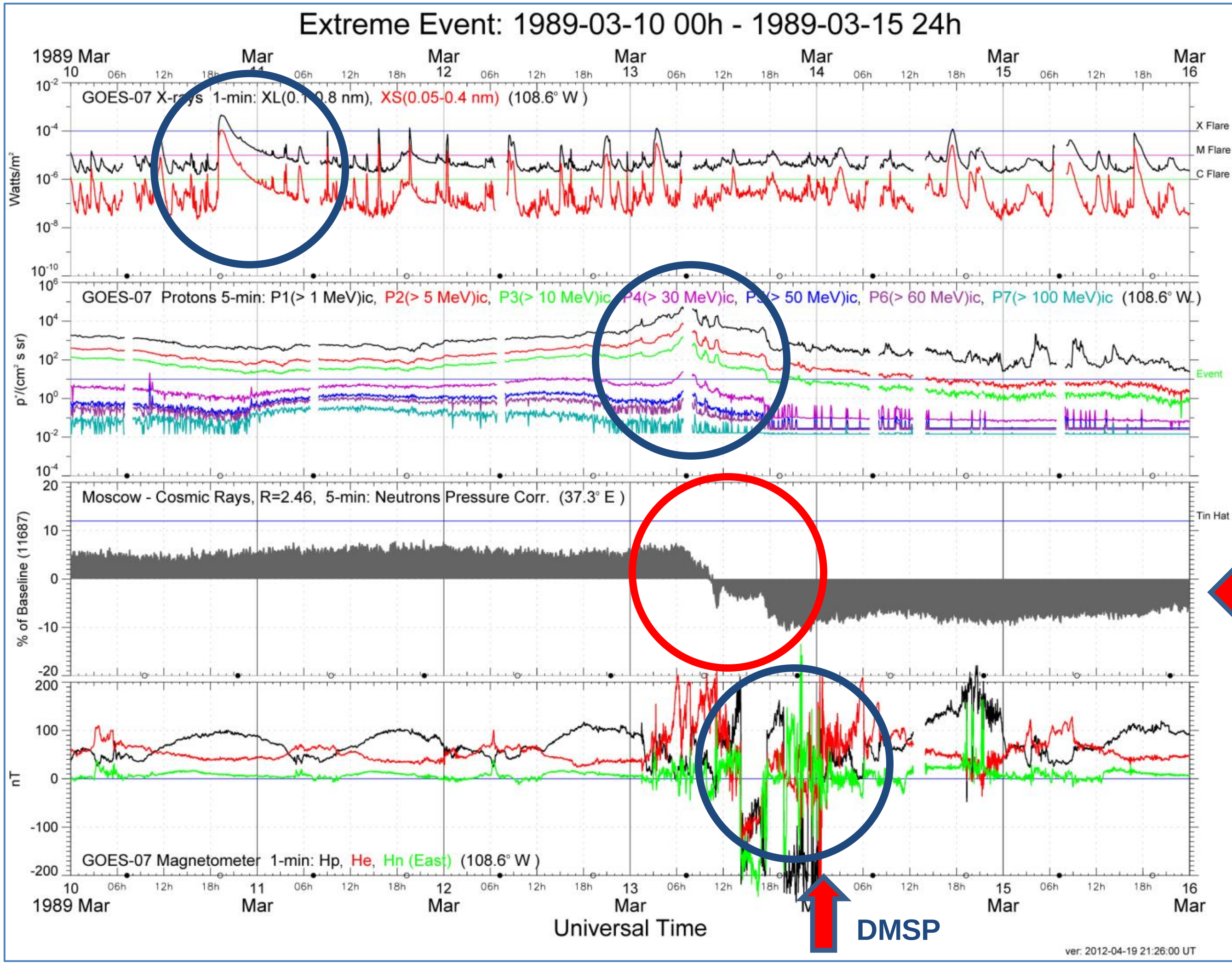
10-15 Mar 1989

R5
S3
G5



10-15 Mar 1989

R5
S3
G5



Forbush Decrease

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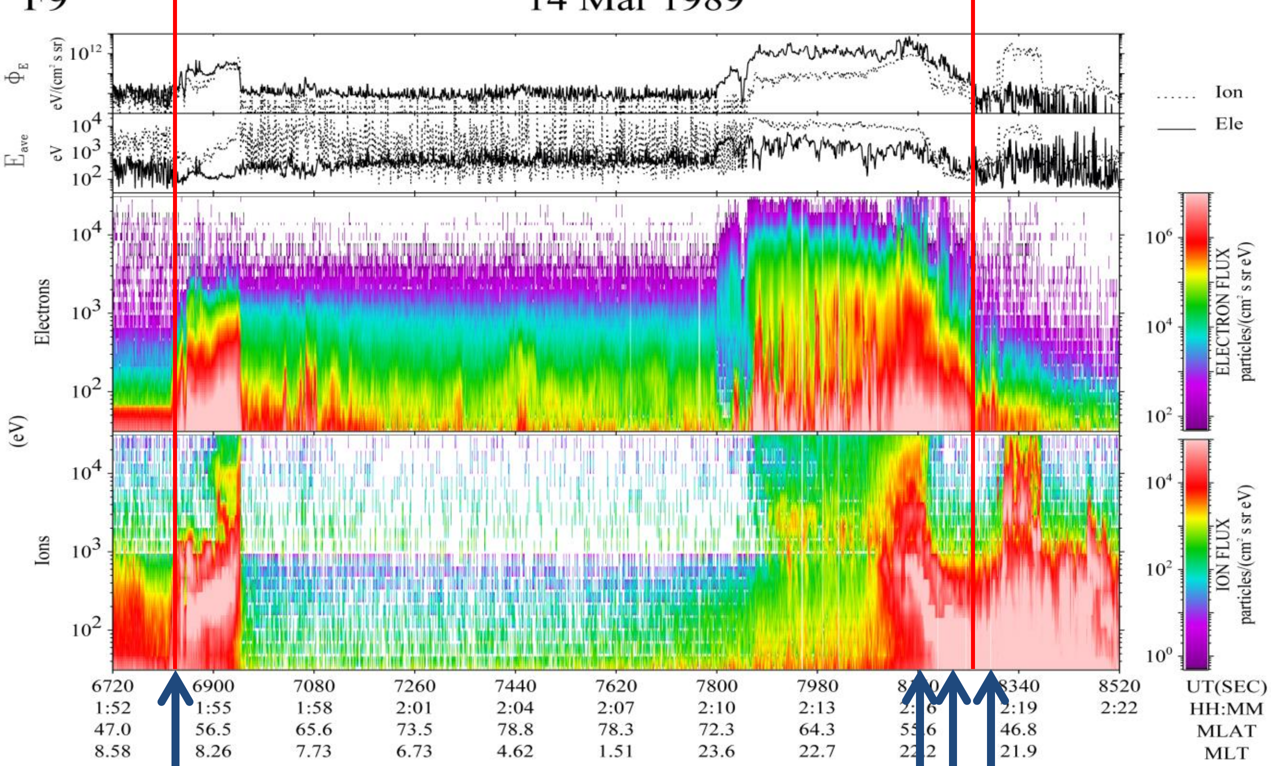
10-15 Mar 1989

AB = 51.8º MLAT

AB = 51.6º MLAT



Kezhma, Russia (λ = 58.7º)
(Krasnsyarsk Krai)

Washington D.C. (λ = 38.9º)

Boston (λ = 42.4º)

Montreal (λ = 45.5º)

Take Aways:

Flare Class: X15

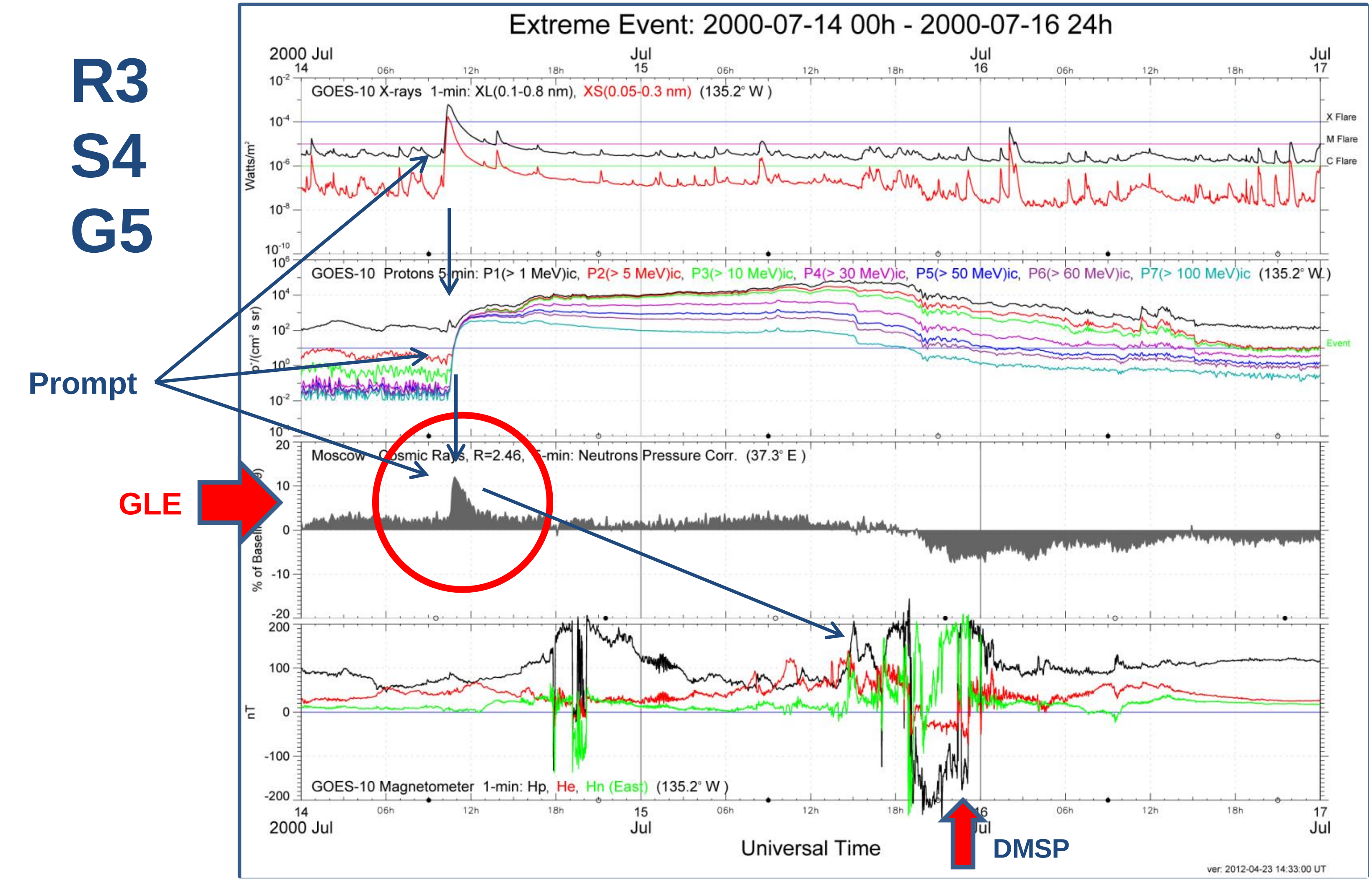
SPE: Slow rise

Forbush decrease

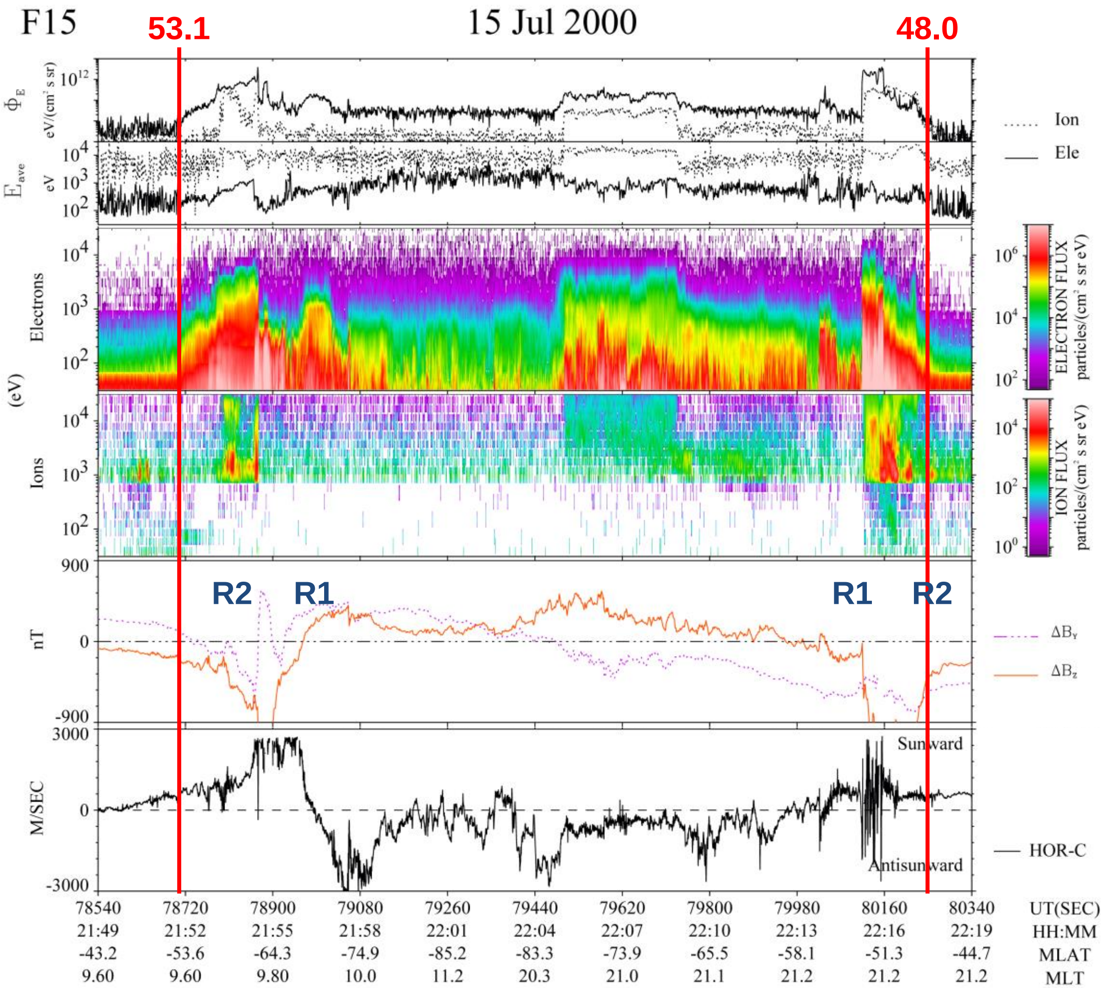
Expanded auroral zone

14-16 Jul 2000

R3
S4
G5



14-16 Jul 2000



Field-Aligned Currents (FACs)

Region 1/2 FACs
>> 1 μA/m²

Convective Drifts

Morningside drifts
> 3 km/s (~150 mV/m)

Take Aways:

SPE: 24,000 pfus

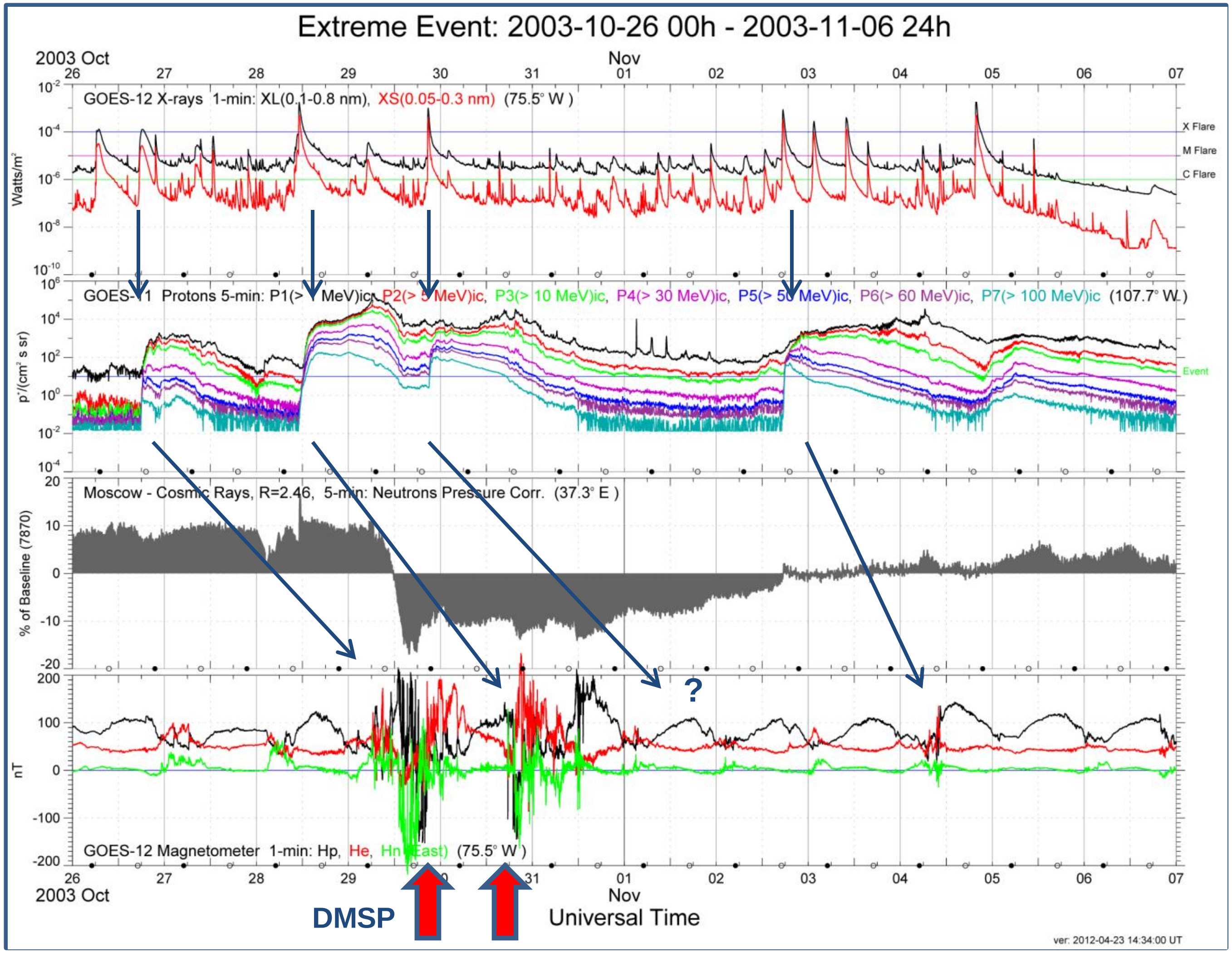
Prompt rise

Ground Level Event

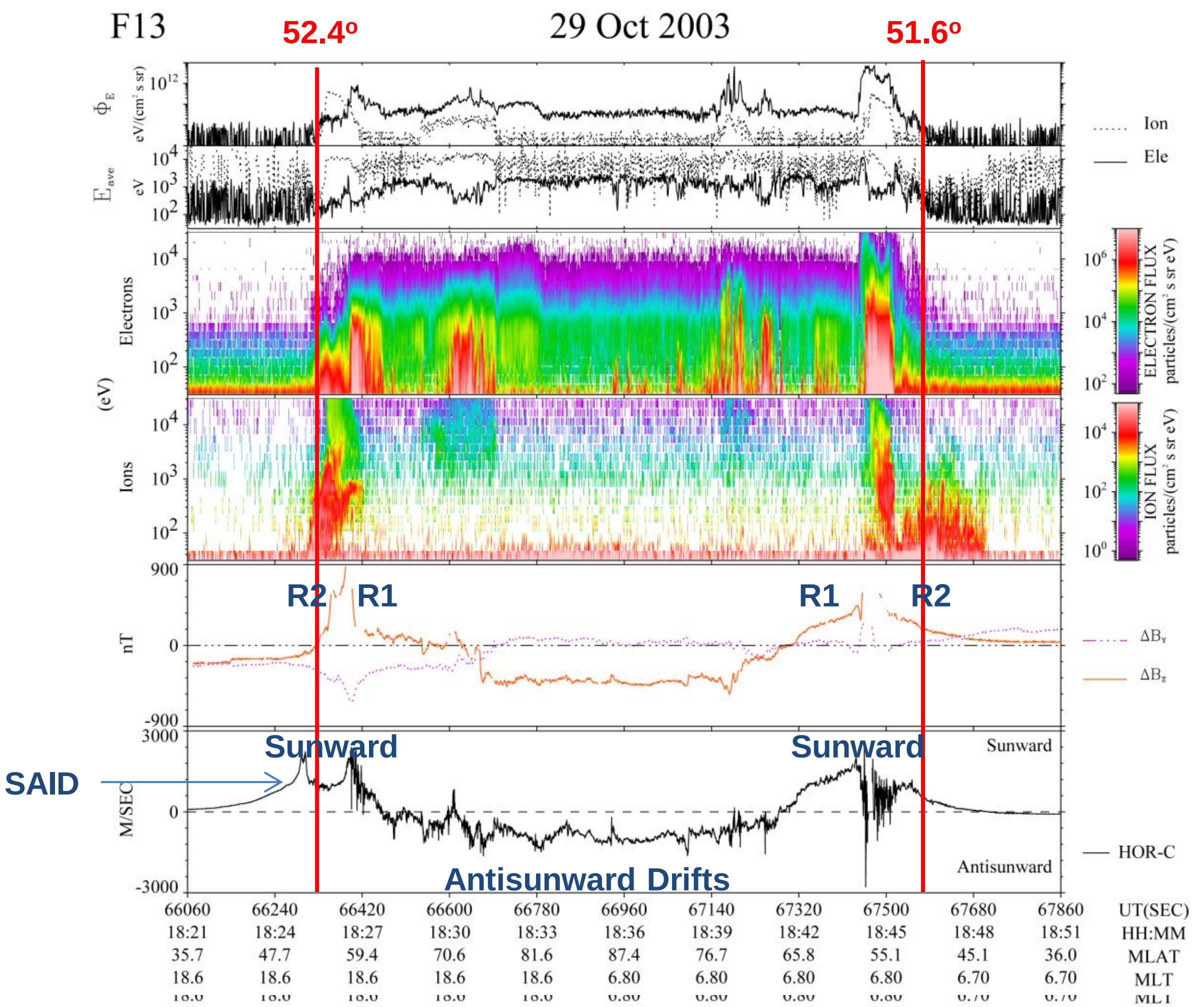
Ionospheric response

10-Oct – 06 Nov 2003

R4/5
S4
G5



10-Oct – 06 Nov 2003

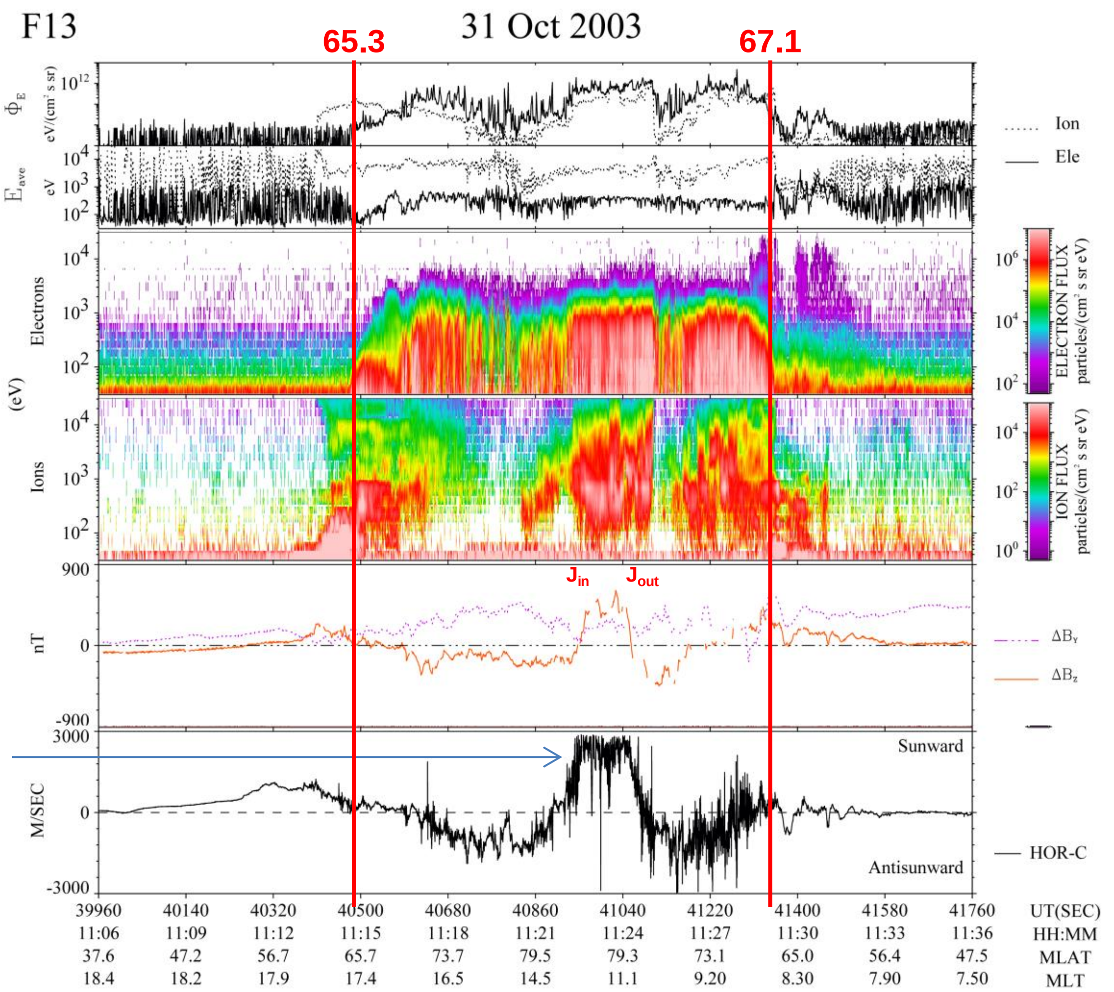


Take Aways::

Expanded Auroral Zone

Typical -IMF Bz

10-Oct – 06 Nov 2003



Reversed Convection ($E_{Dusk-to-Dawn}$)

Take Aways::

- Compressed polar cap
- Very strong sunward convection in polar cap
- +IMF Bz

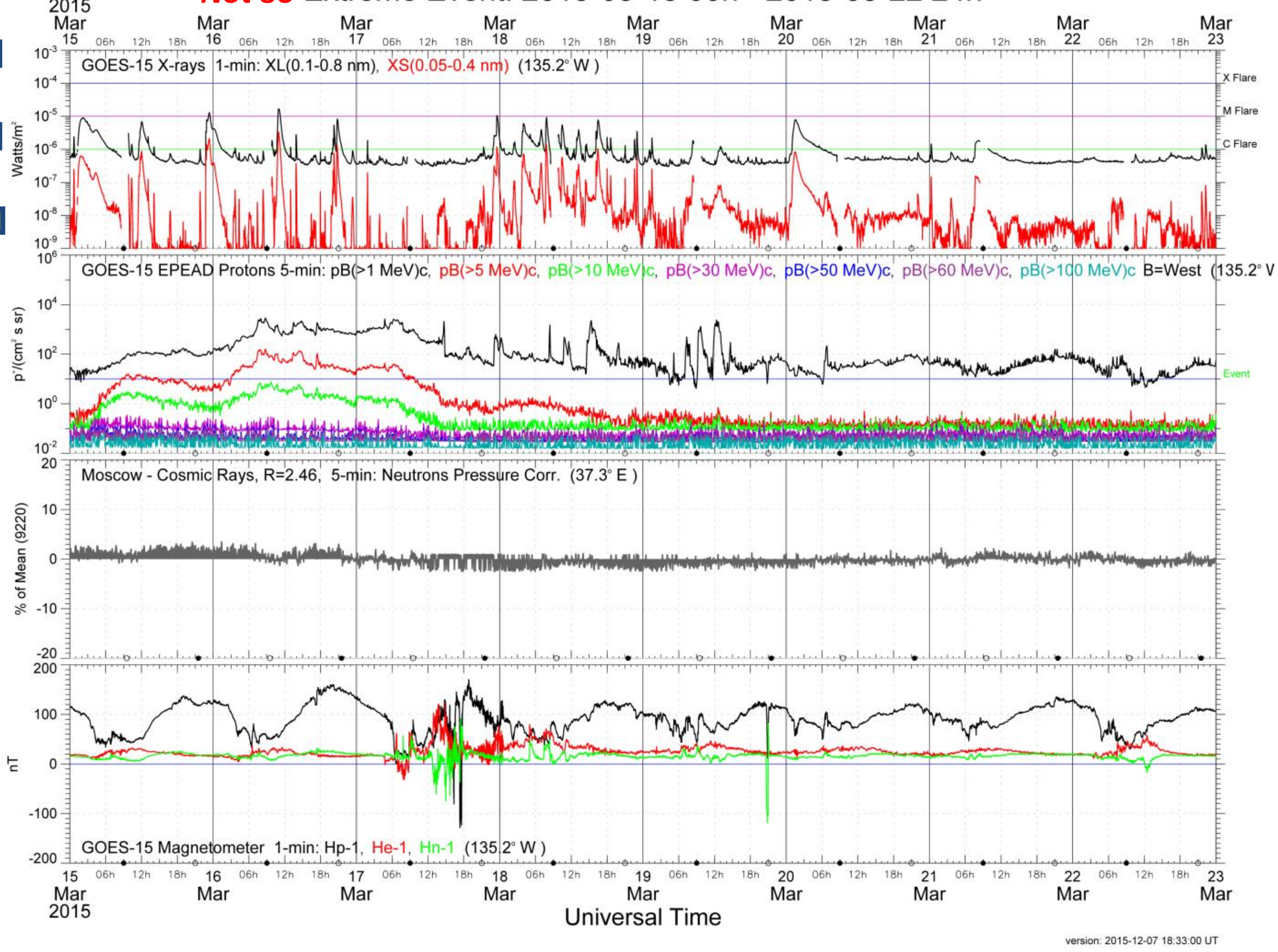
March 15-22, 2015

R1

S0

G4

Not so Extreme Event: 2015-03-15 00h - 2015-03-22 24h



See Rob Redmon SM41C-2499

Summary

- Long-term measurements of the space environment provide opportunities to compare / contrast extreme SWx events
- Since the mid 1970s the NOAA GOES satellites have monitored the GEO environment in much the same way
- The NOAA Space Weather Scales provide an easy way to characterize the impact of extreme events
- When combined with data from polar-orbiting satellites these data can provide a synoptic view of the space environment
- GOES satellites will provide continuity of measurements through 2036 (at least)
- Well characterized auroral measurements will sunset when DMSP reaches its End-Of-Life (EOL) – possibly sooner