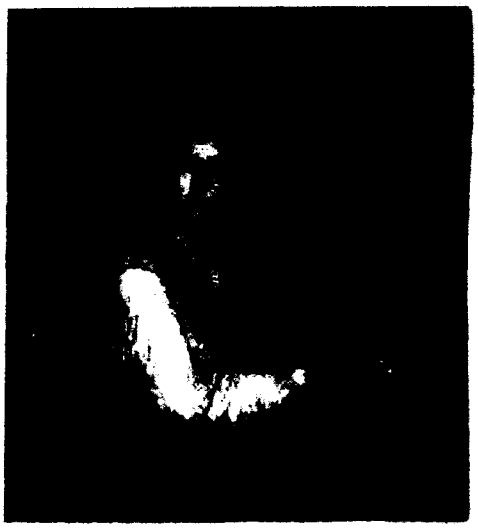
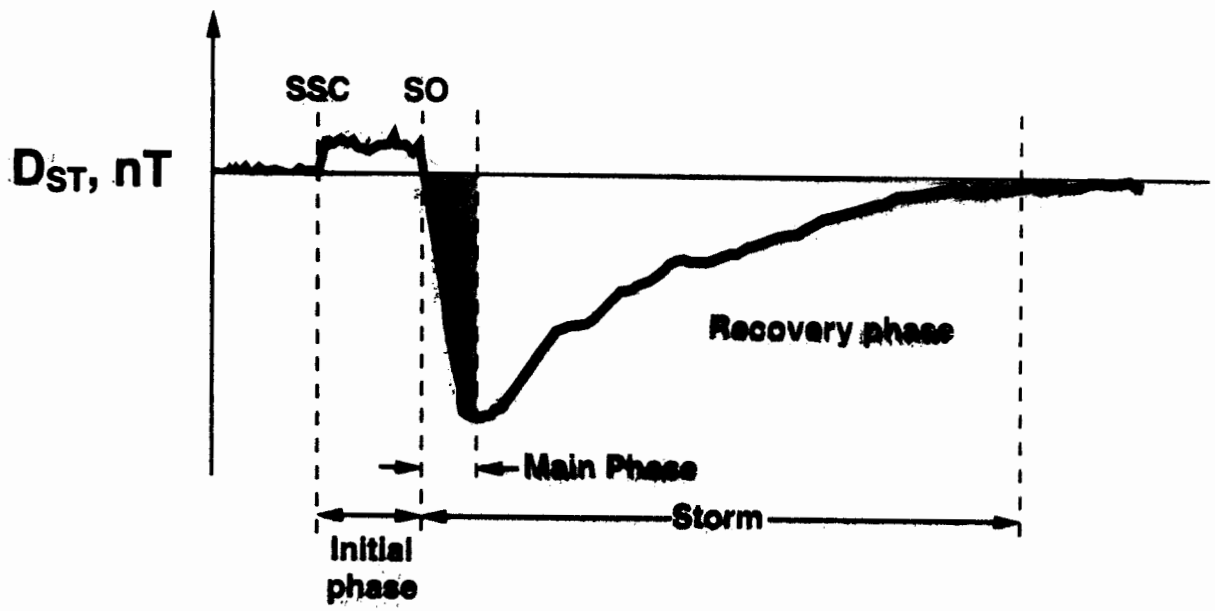
Magnetisches Ungewitter*



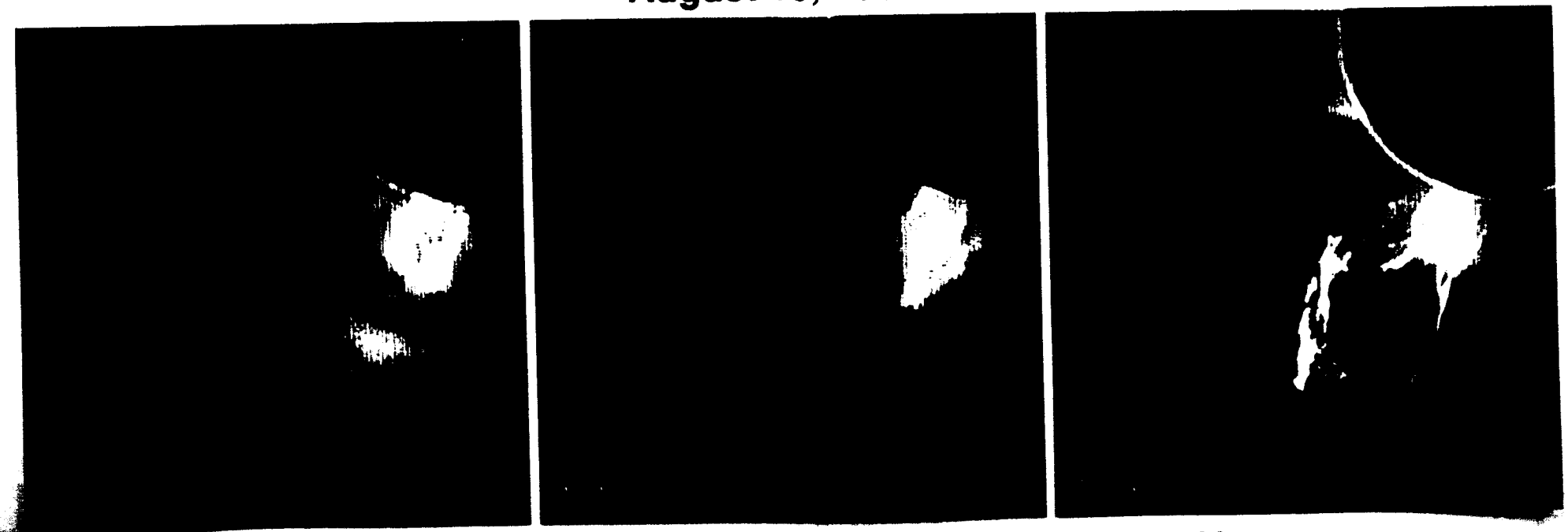
Baron Alexander von Humboldt discovered "Magnetisches Ungewitter," or magnetic storms. From May 1806 until June 1807 in Berlin, he and a colleague observed the local magnetic declination every half hour from midnight to morning. The observations were made using a microscope to identify the pointing direction of a magnetic needle. On December 21, 1806, for six consecutive hours he observed strong magnetic deflections, and also noted the presence of correlated northern lights (aurora) overhead. When the aurora disappeared at dawn, the magnetic perturbations did as well. This was reported in *Annales der Physik* (29, 425, 1808).

* From AGU's "Magnetic Storm" book (dedicated to Alexander von Humboldt), 1997.

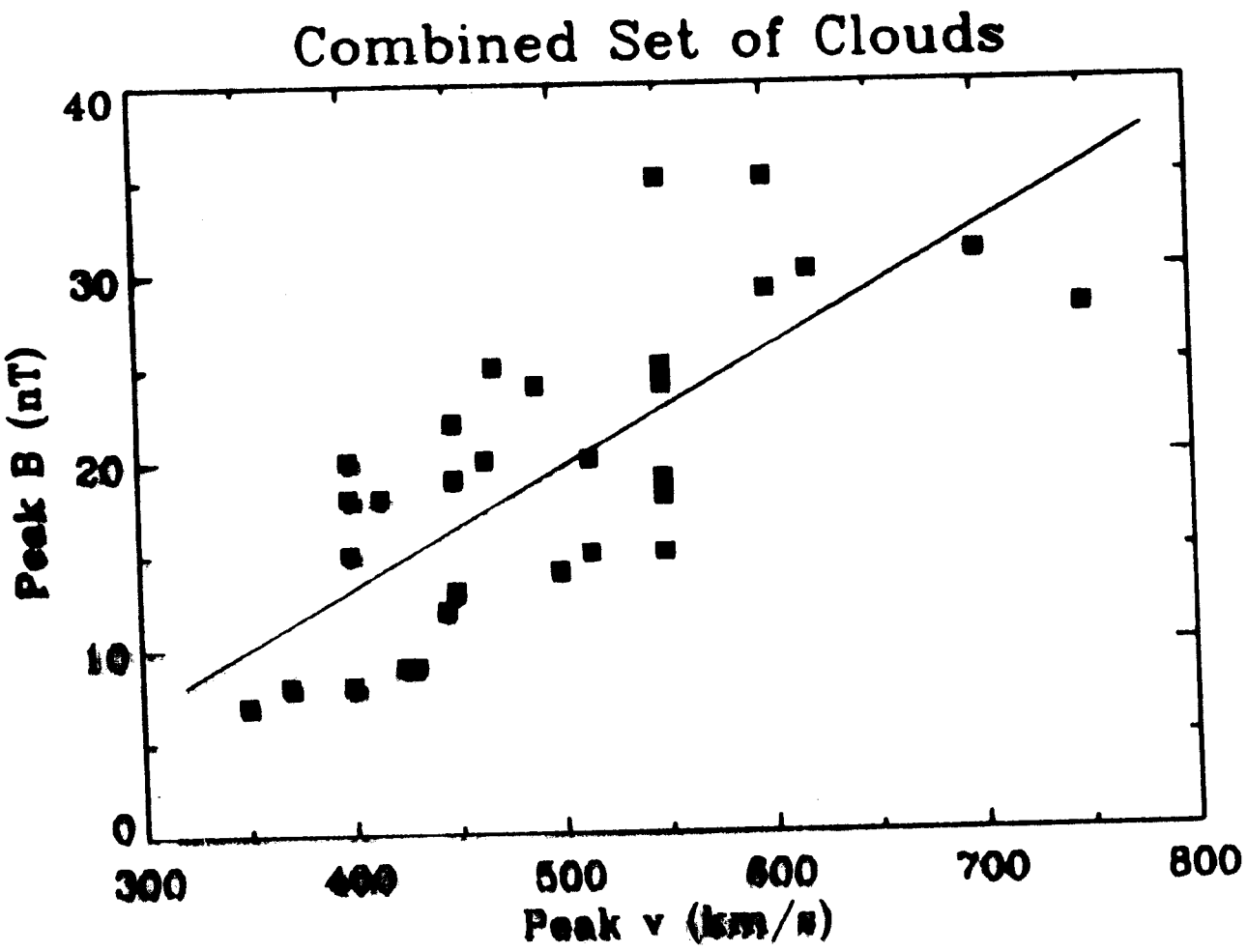
Solar Maximum (ICME) Storm

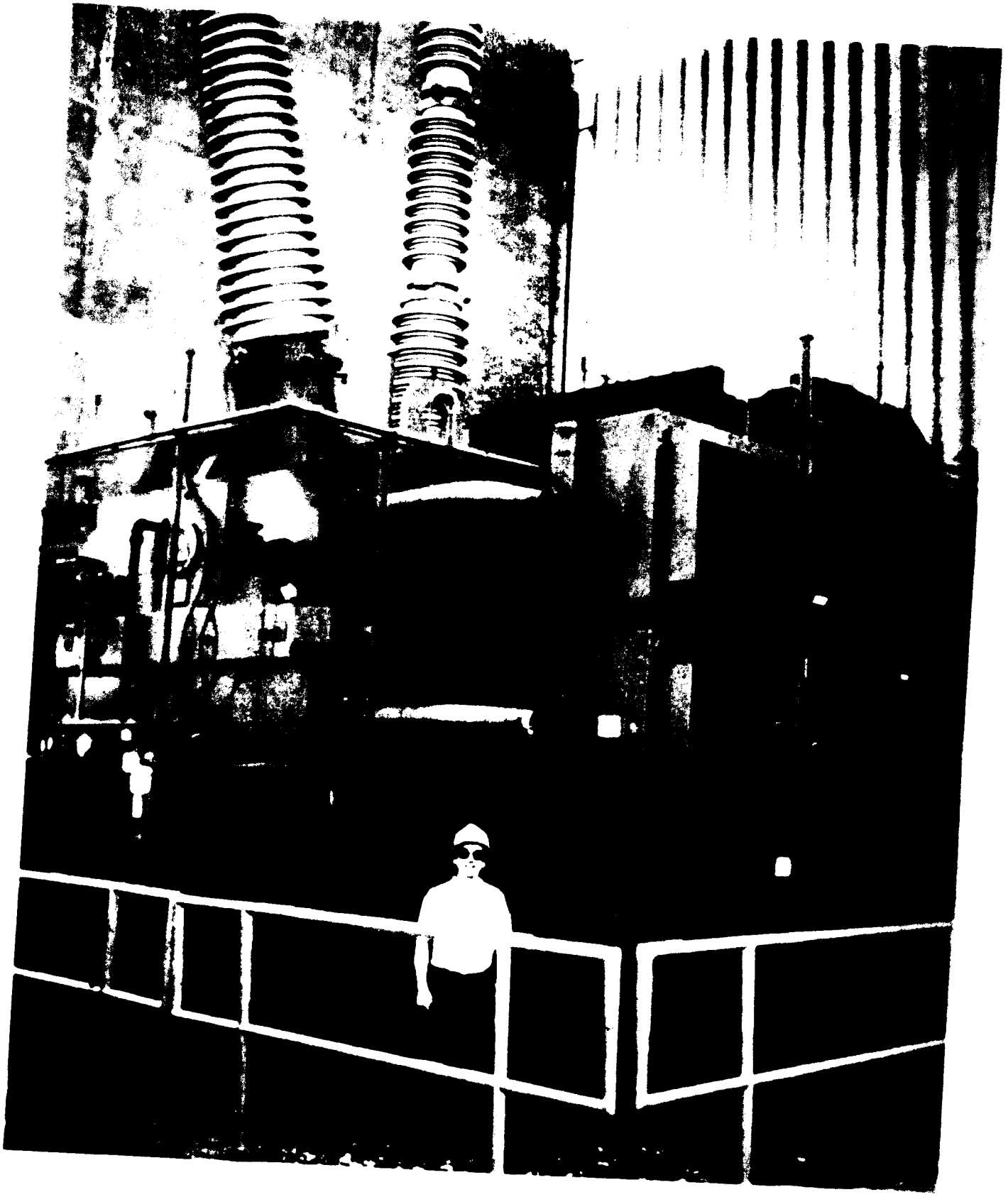


August 18, 1980

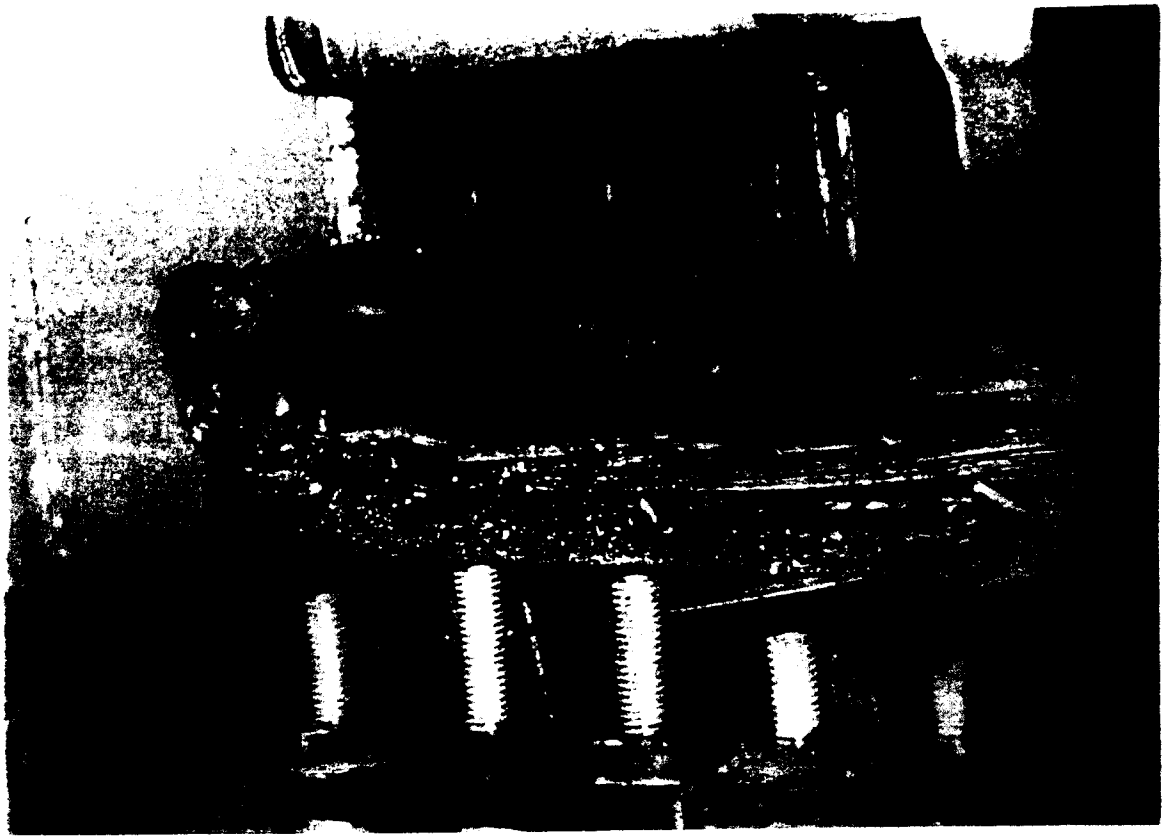


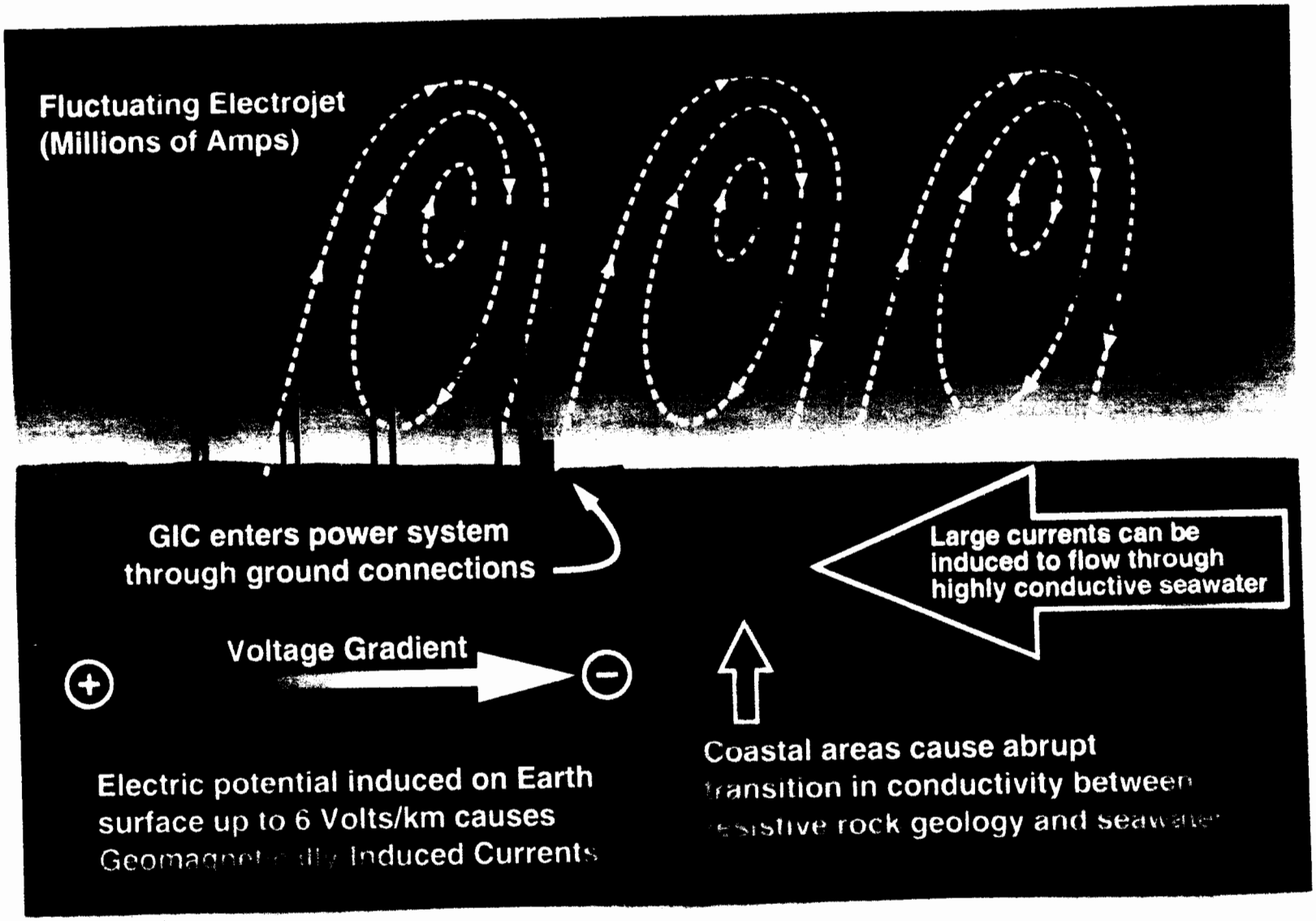
Source: High Altitude Observatory/Solar Maximum Mission Archives

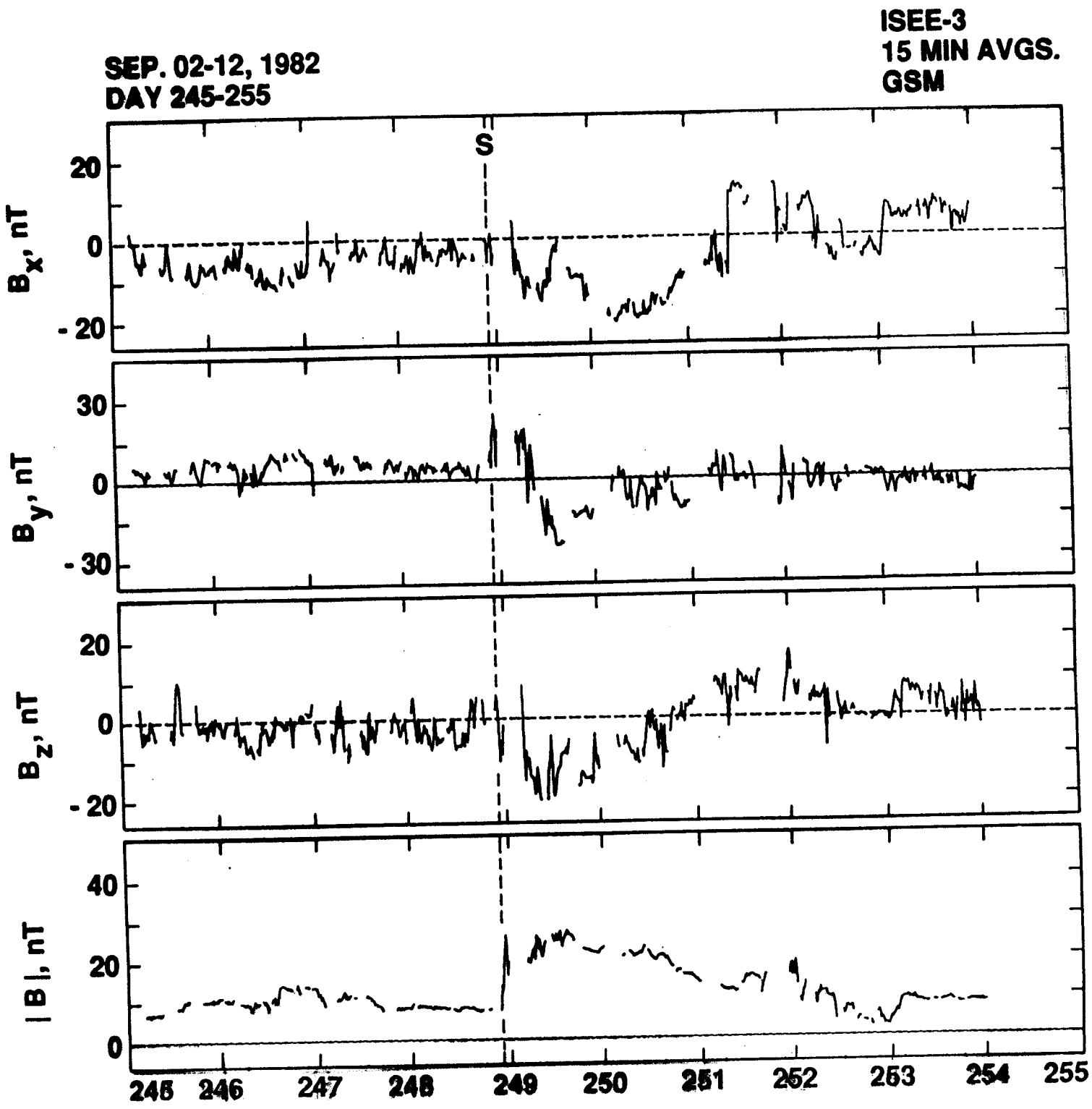

Combined Set of Clouds
Peak B (nT)
0
10
20
30
40
300
400
500
600
700
800
Peak v (km/s)

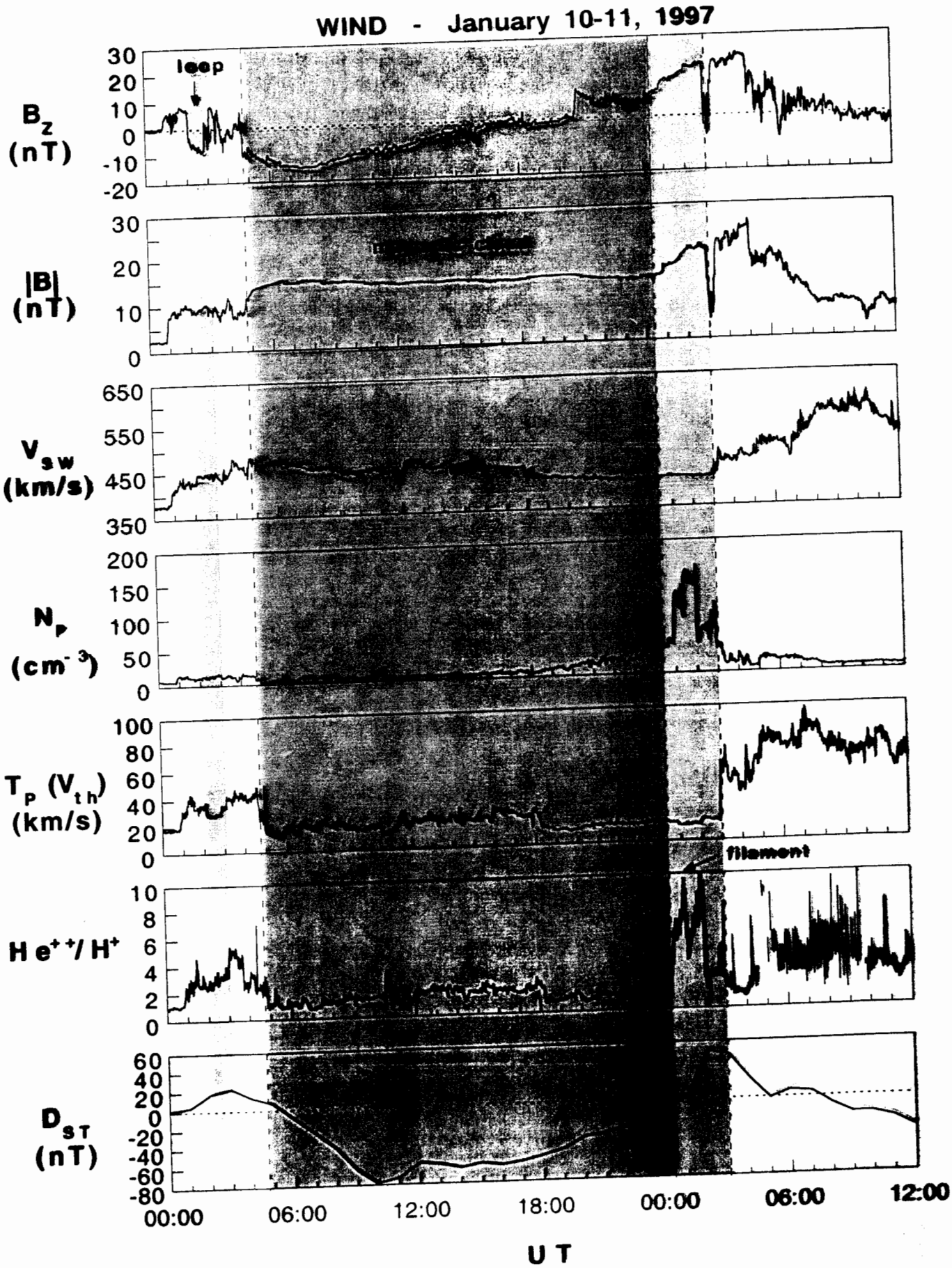


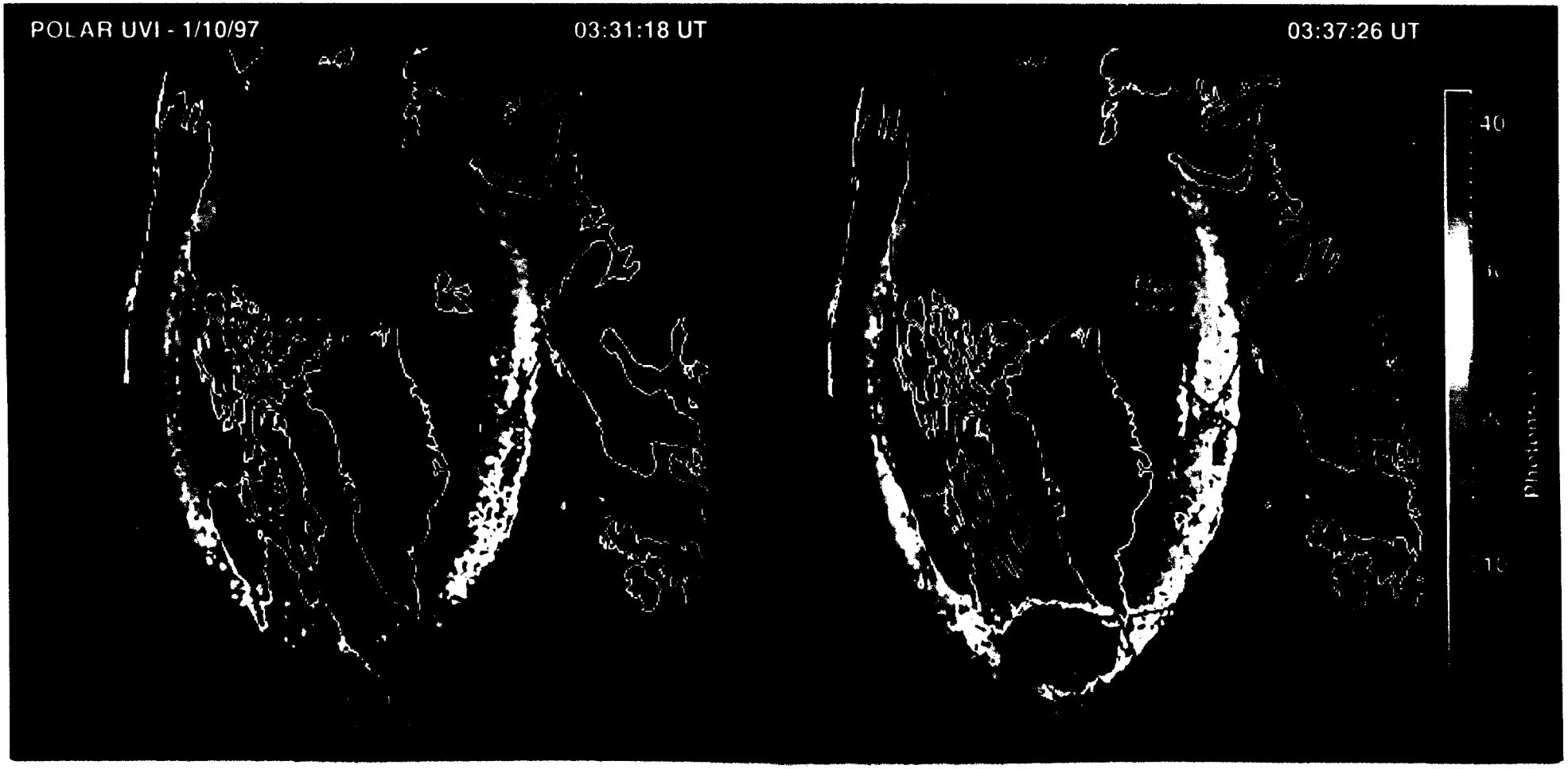
Magnetic Storm Transformer Damage

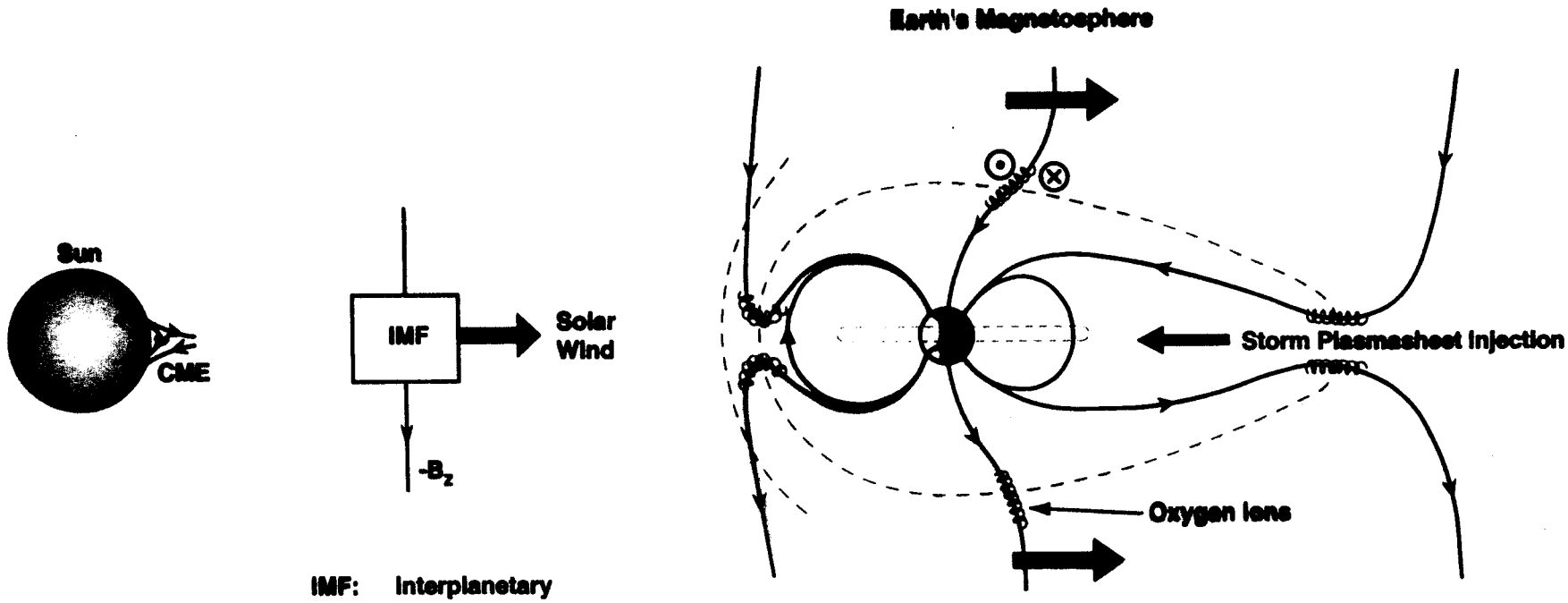



Fluctuating Electrojet
(Millions of Amps)
GIC enters power system
through ground connections
Large currents can be
induced to flow through
highly conductive seawater
Voltage Gradient
Electric potential induced on Earth
surface up to 6 Volts/km causes
Geomagnetically Induced Currents
Coastal areas cause abrupt
transition in conductivity between
resistive rock geology and seawater


ISEE-3
15 MIN AVGS.
GSM
SEP. 02-12, 1982
DAY 245-255
S
B_x, nT
20
0
- 20
B_y, nT
30
0
- 30
B_z, nT
20
0
- 20
| B |, nT
40
20
0
245
246
247
248
249
250
251
252
253
254
255

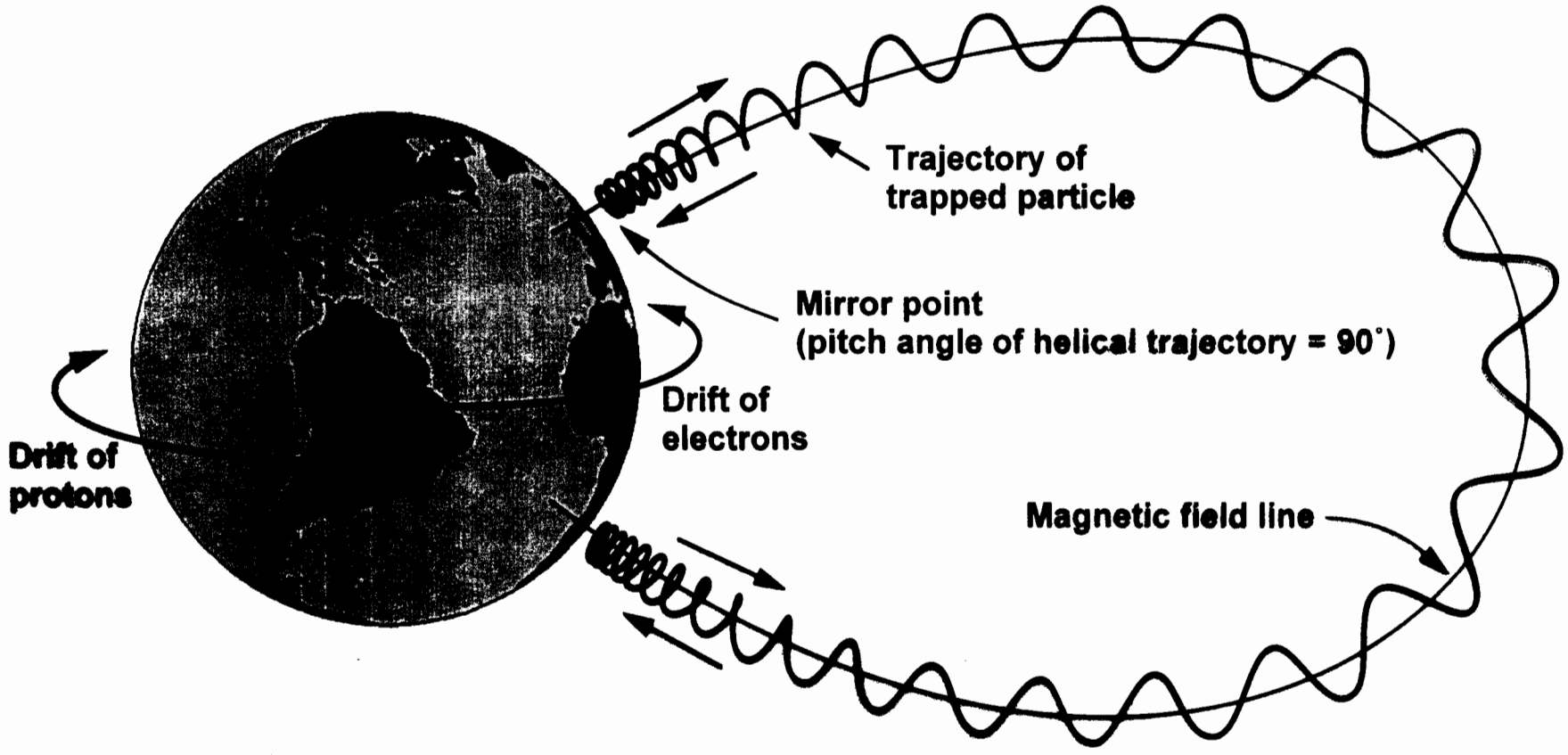

WIND - January 10-11, 1997
leep
filament
B_z (nT)
|B| (nT)
V_{sw} (km/s)
N_p (cm^{-3})
T_p (V_{th}) (km/s)
He^{++}/H^+
D_{ST} (nT)
00:00
06:00
12:00
18:00
00:00
06:00
12:00
UT


POLAR UVI - 1/10/97
03:31:18 UT
03:37:26 UT
40



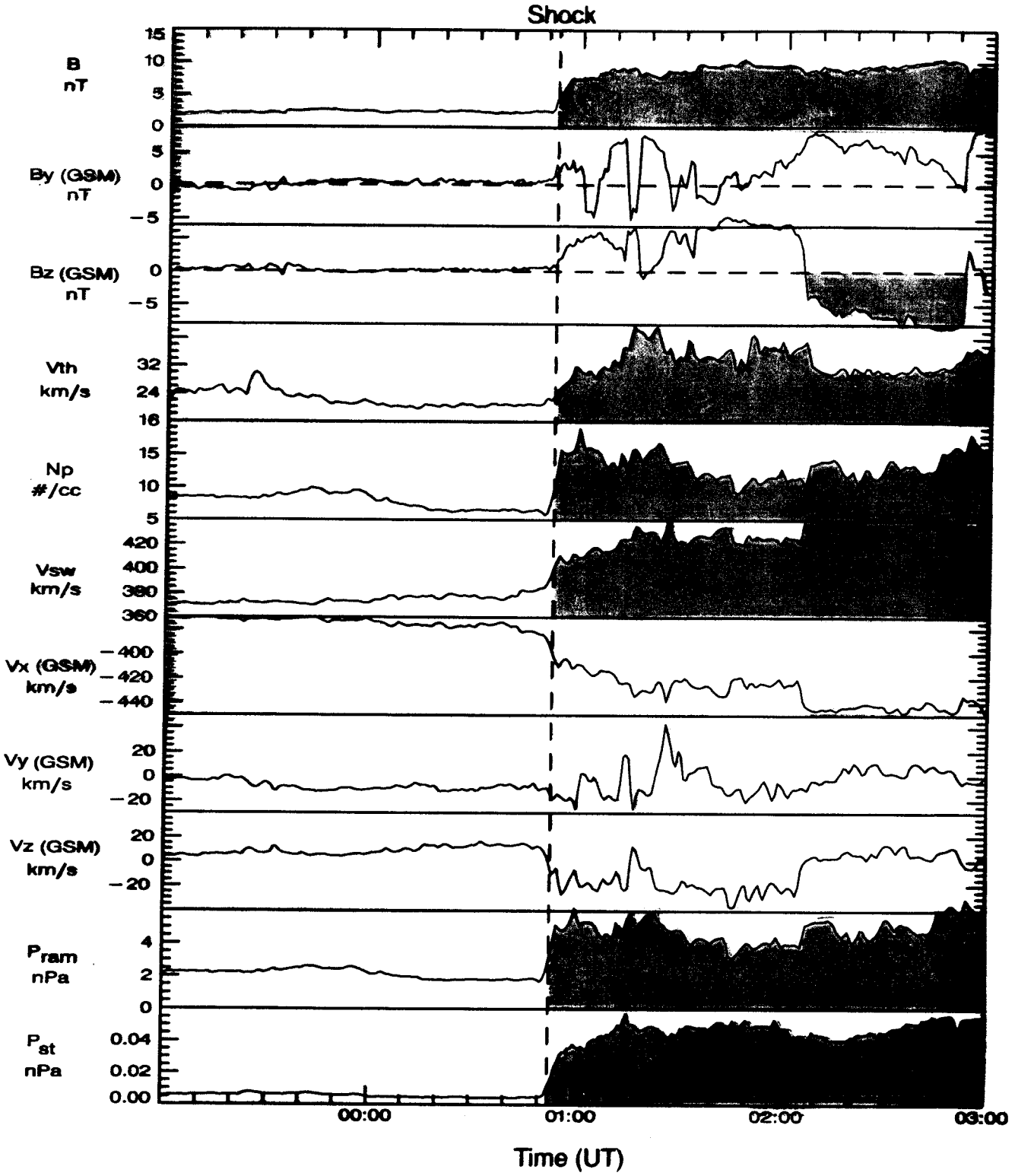
IMF: Interplanetary Magnetic Field

B_z: Southward component of IMF


Trajectory of
trapped particle
Mirror point
(pitch angle of helical trajectory = 90˚)
Drift of
electrons
Drift of
protons
Magnetic field line

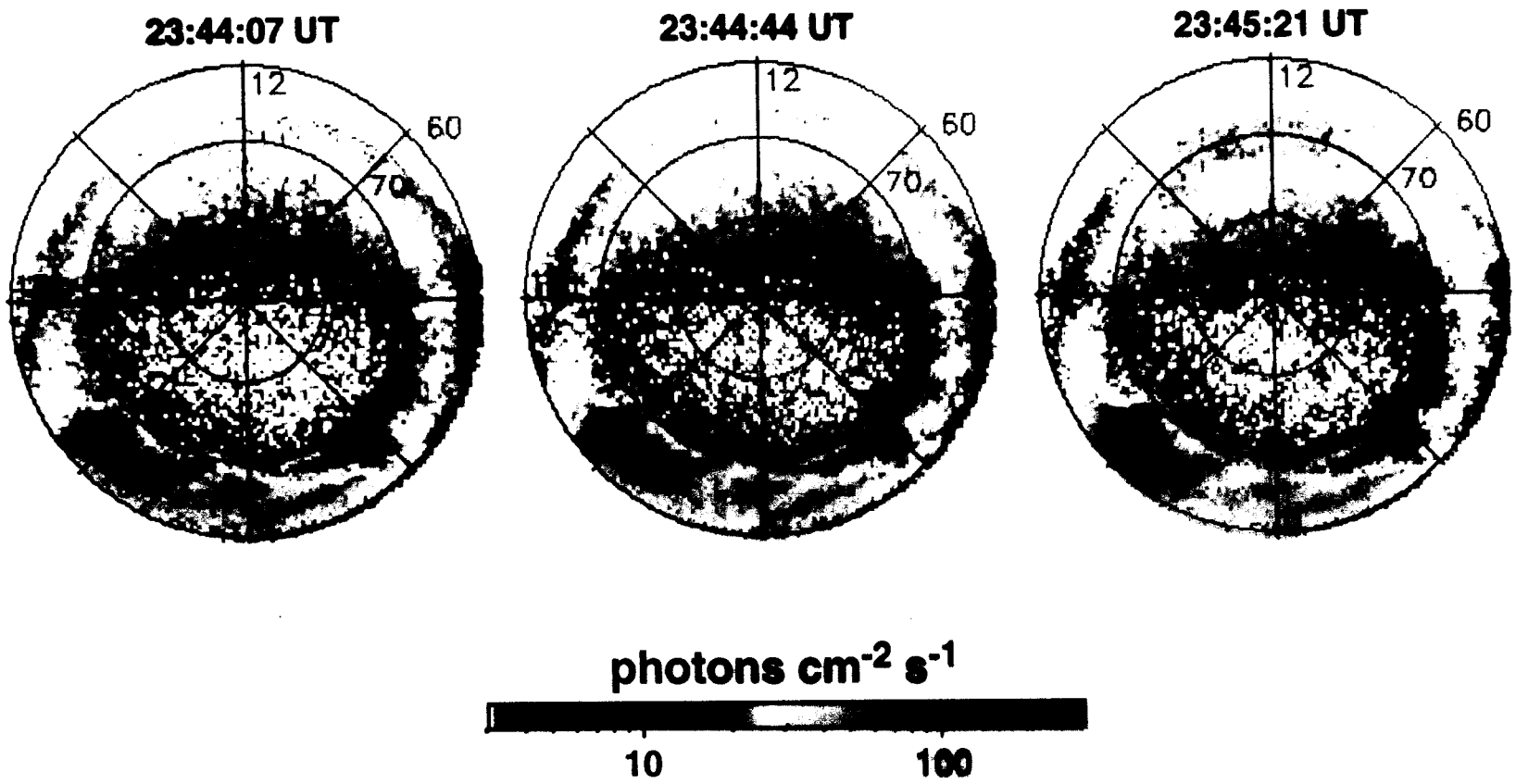
TMO JPL NASA
James W. Young 1981

WIND – January 10, 1997

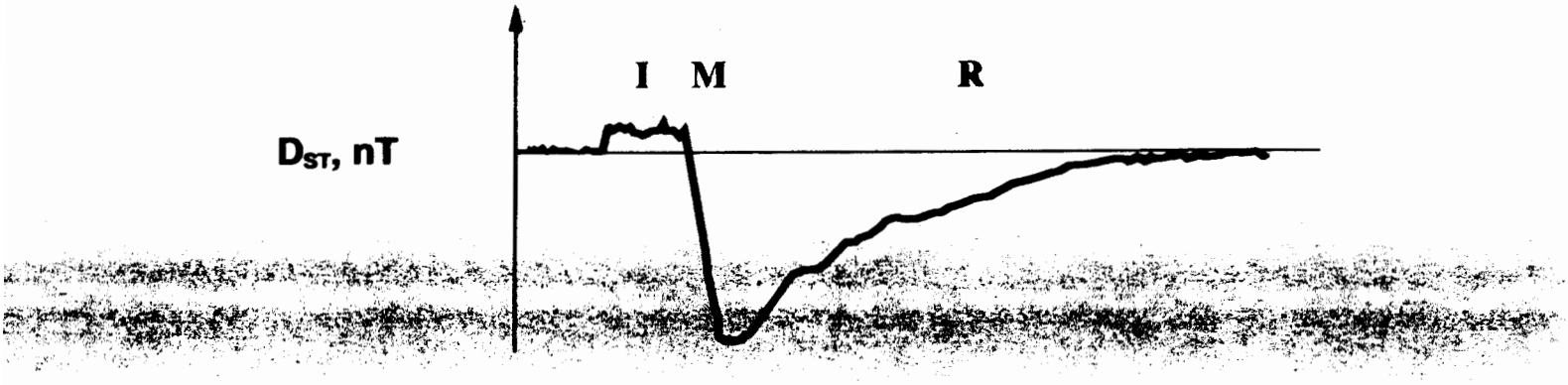


Xgsm (Re)	84.3	84.7	85.1	85.4	85.8
Ygsm (Re)	-54.9	-54.9	-55.2	-55.8	-56.6
Zgsm (Re)	-23.3	-23.1	-22.1	-20.4	-18.1

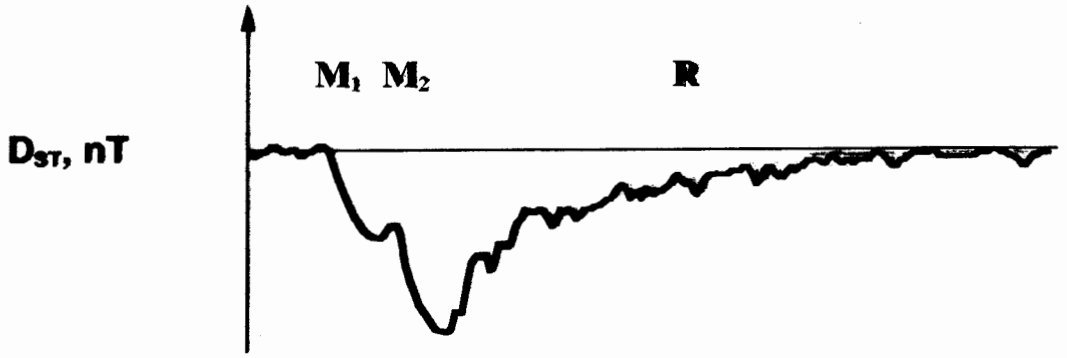
Polar Ultraviolet Imager (UVI) LBHL



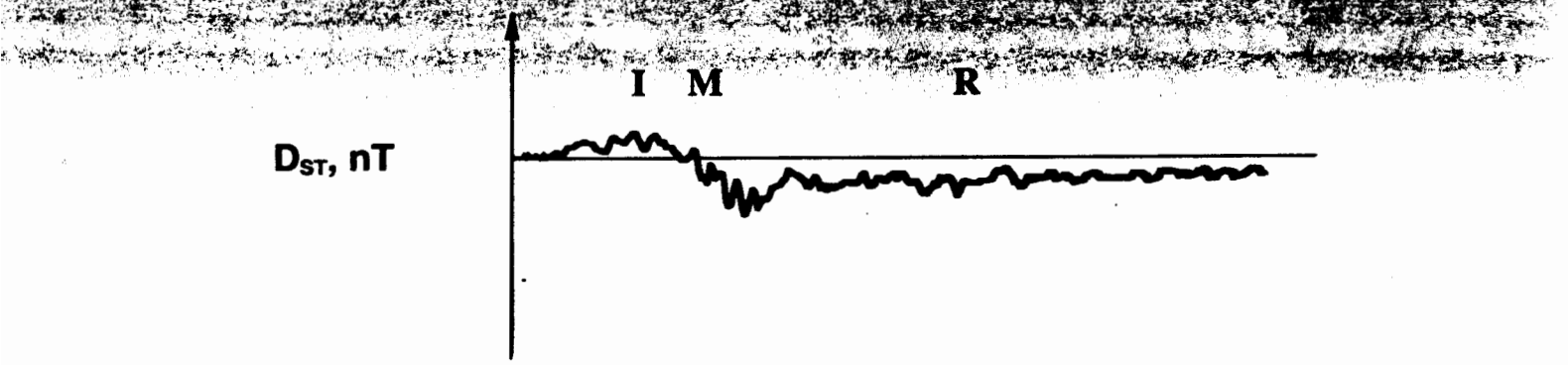
Solar Maximum (ICME) Storm

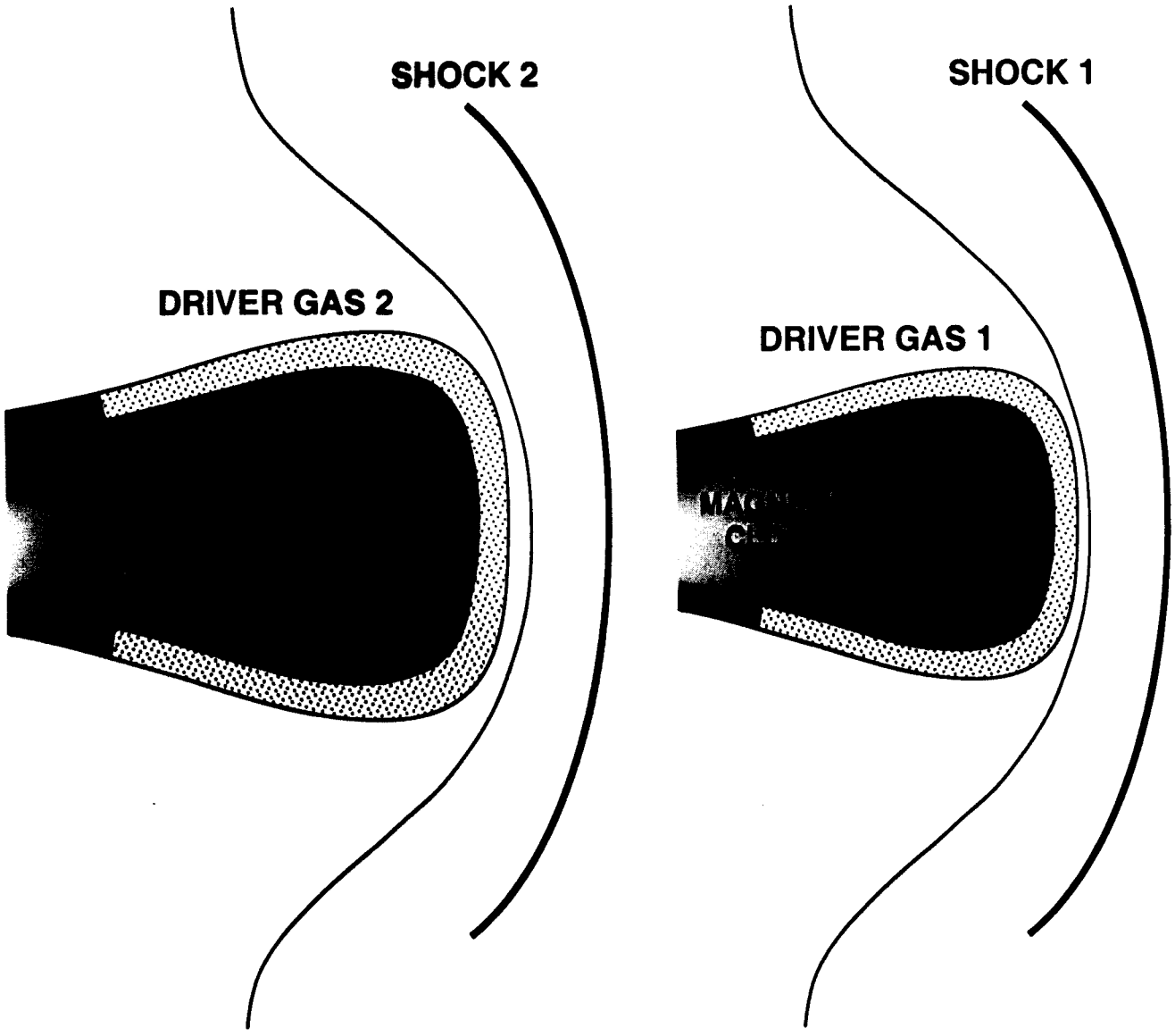


Solar Maximum Double Main Phase Storm



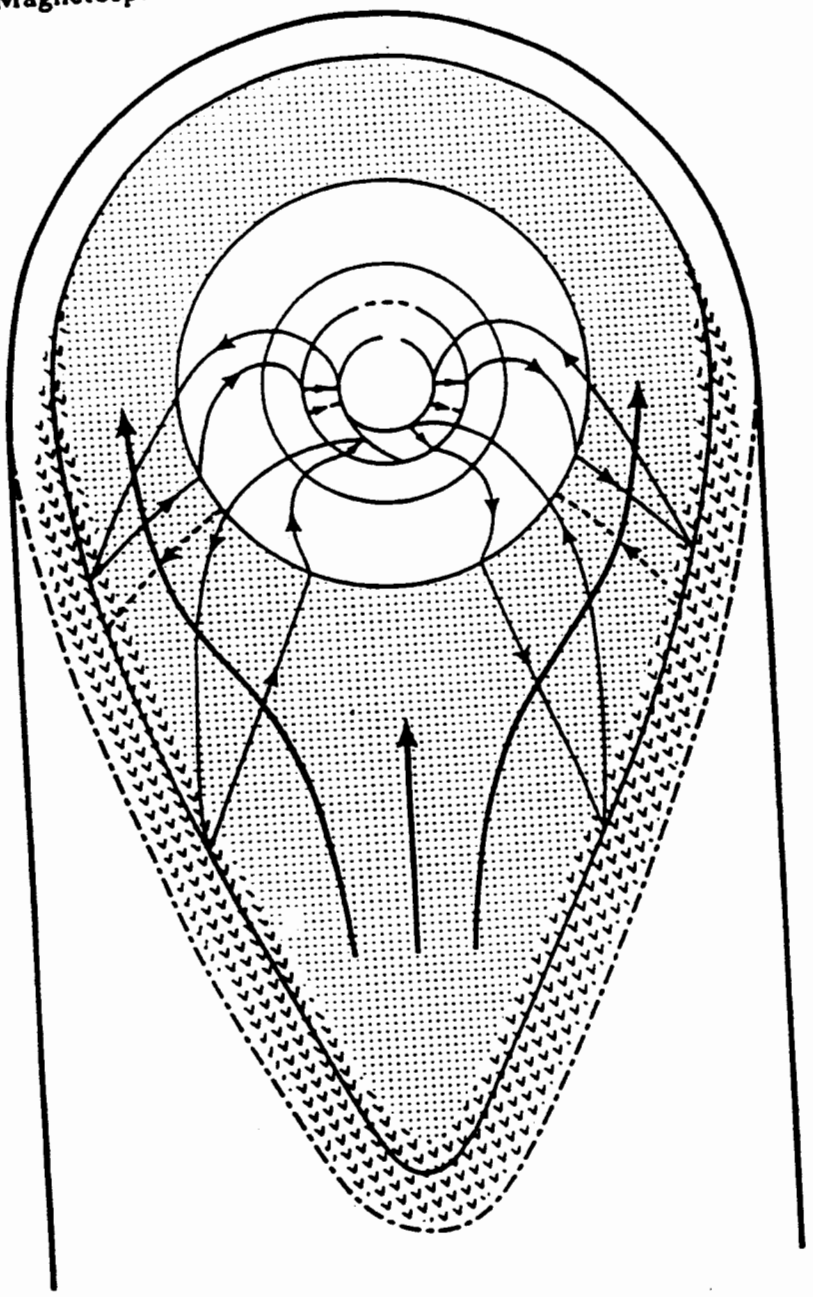
Solar Minimum (PCIR) Storm





BTT/JKA
July 1999

The Role of Magnetospheric Substorms in Magnetosphere-Ionosphere Coupling



Electric current flow

Electric field

Direction of plasma convective drift

Separatrix

Mapping of ionospheric bps to the magnetotail

Mapping of ionospheric cps to the magnetotail

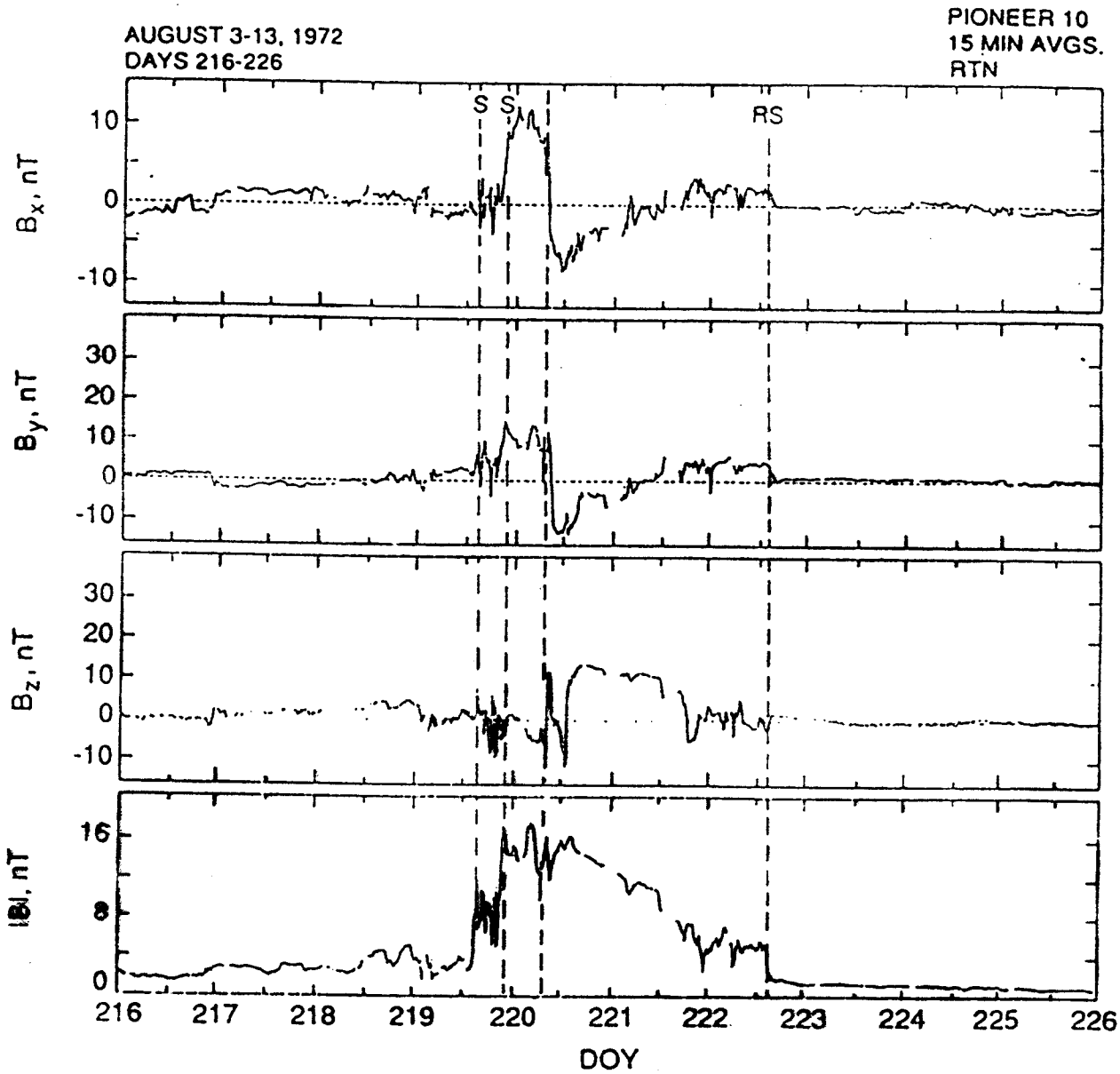


Fig. 2 The Pioneer 10 interplanetary magnetic field data at 2.2 AU from the Sun. Four regions of southward IMF are identified. Of parti[illegible] interest is an interval of northward directed fields from ~ 15 UT day 220 to ~ 11 UT day 221.

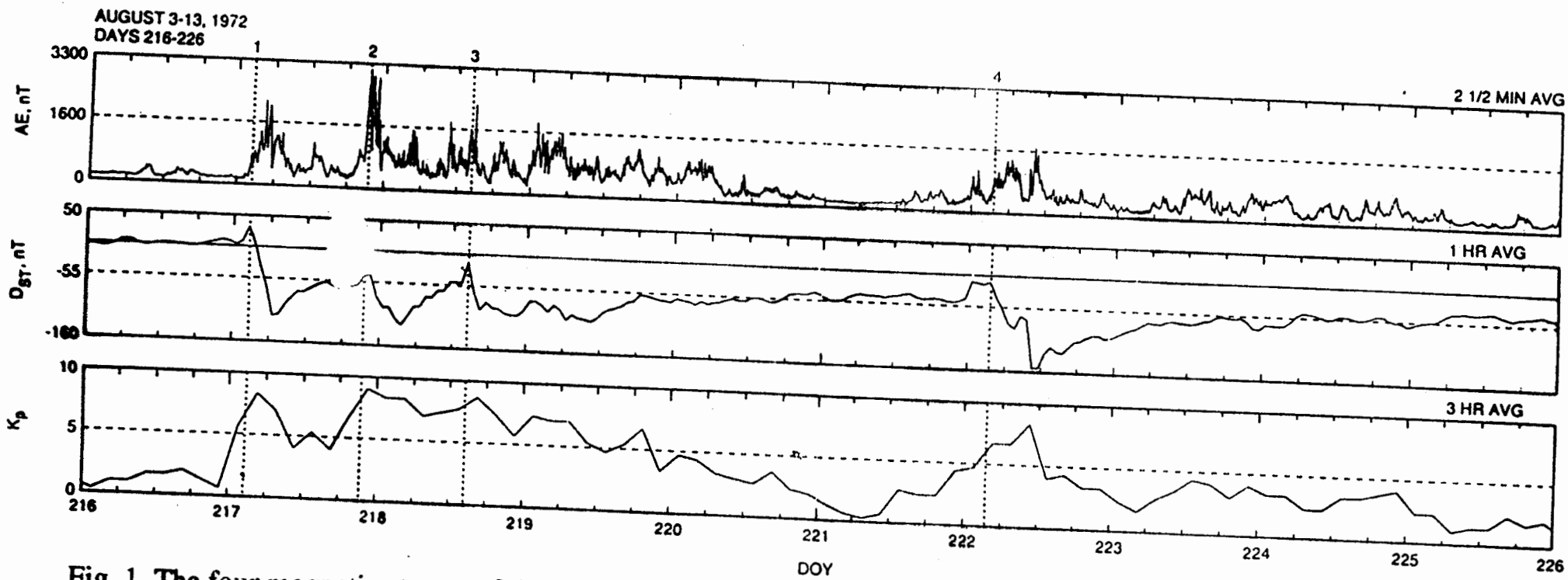


Fig. 1 The four magnetic storms of the August 1972 event. The dashed vertical line indicate the main phase onsets.

$$U_T \cong 1.2 \times 10^{17} \text{ erg s}^{-1}$$

EFFICIENCY OF SOLAR WIND ENERGY INJECTION INTO MAGNETOSPHERE DURING THE EVENT

$$\eta \cong 1.2 \times 10^{-3}$$

VISCOUS INTERACTION

SOLAR WIND ENERGY FLUX IMPINGING ON THE MAGNETOSPHERE

On 6 August 1972, $\rho = 3\ cm^{-3}$, $V_{SW} \sim 600\ km\ s^{-1}$ at Pioneer 9 (Mihalov et al. 1974)

Assume the diameter of the magnetosphere is ~ 20 Re. The cross-sectional area is ~ $10^{20}\ cm^2$

The solar wind energy flux impinging on the magnetosphere is ~ $10^{20}\ erg\ s^{-1}$

Magnetospheric Energy Output U_T (Akasofu, 1981)

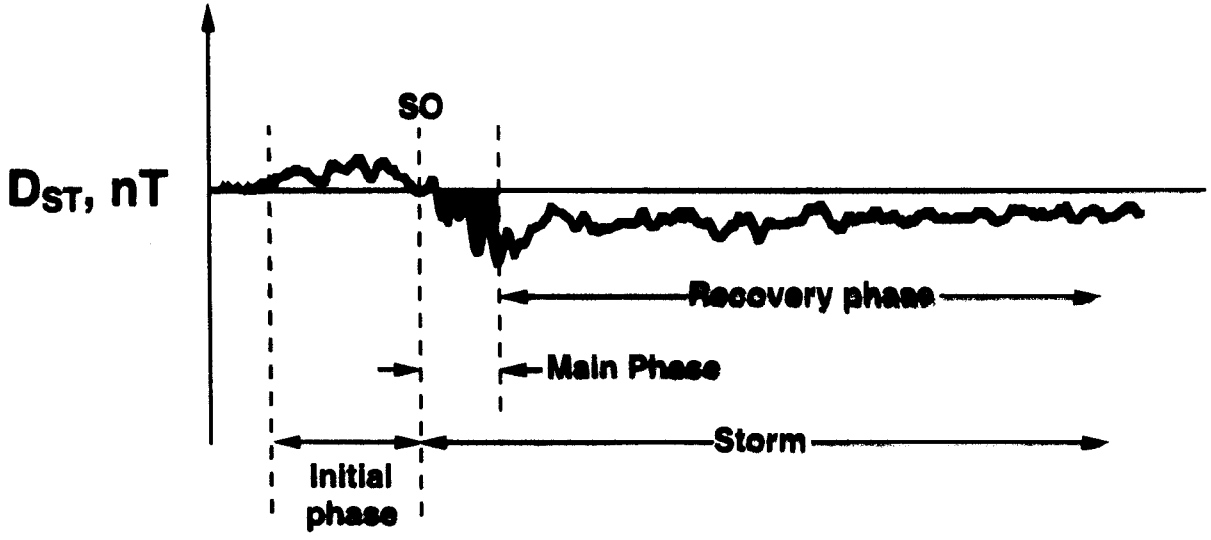
$$U_T = U_O + U_J + U_A$$

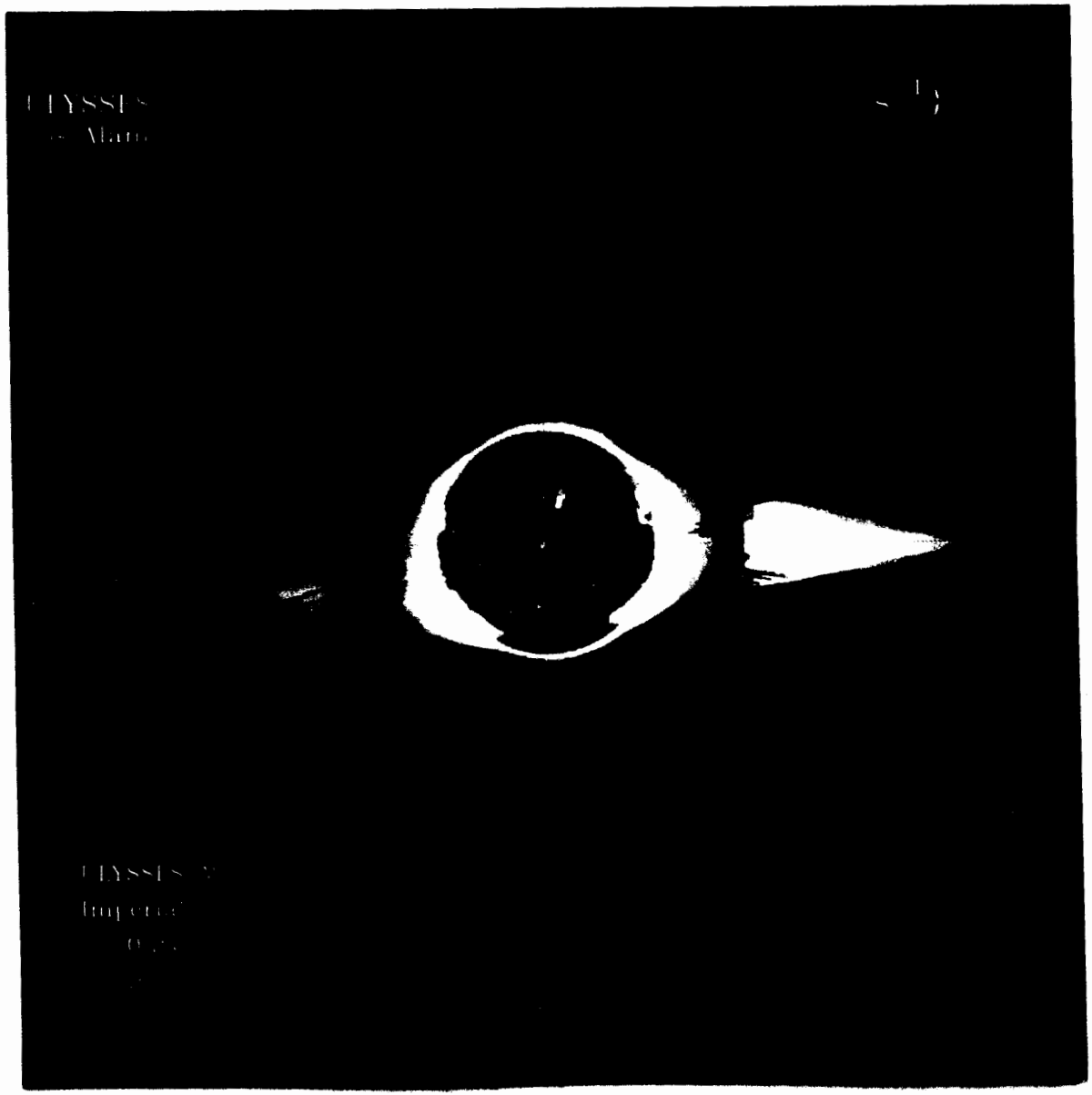
$$U_J + U_A \cong 3\ AE \times 10^{15}\ erg\ s^{-1}$$

$AE \cong 40$ nT for two consecutive hours

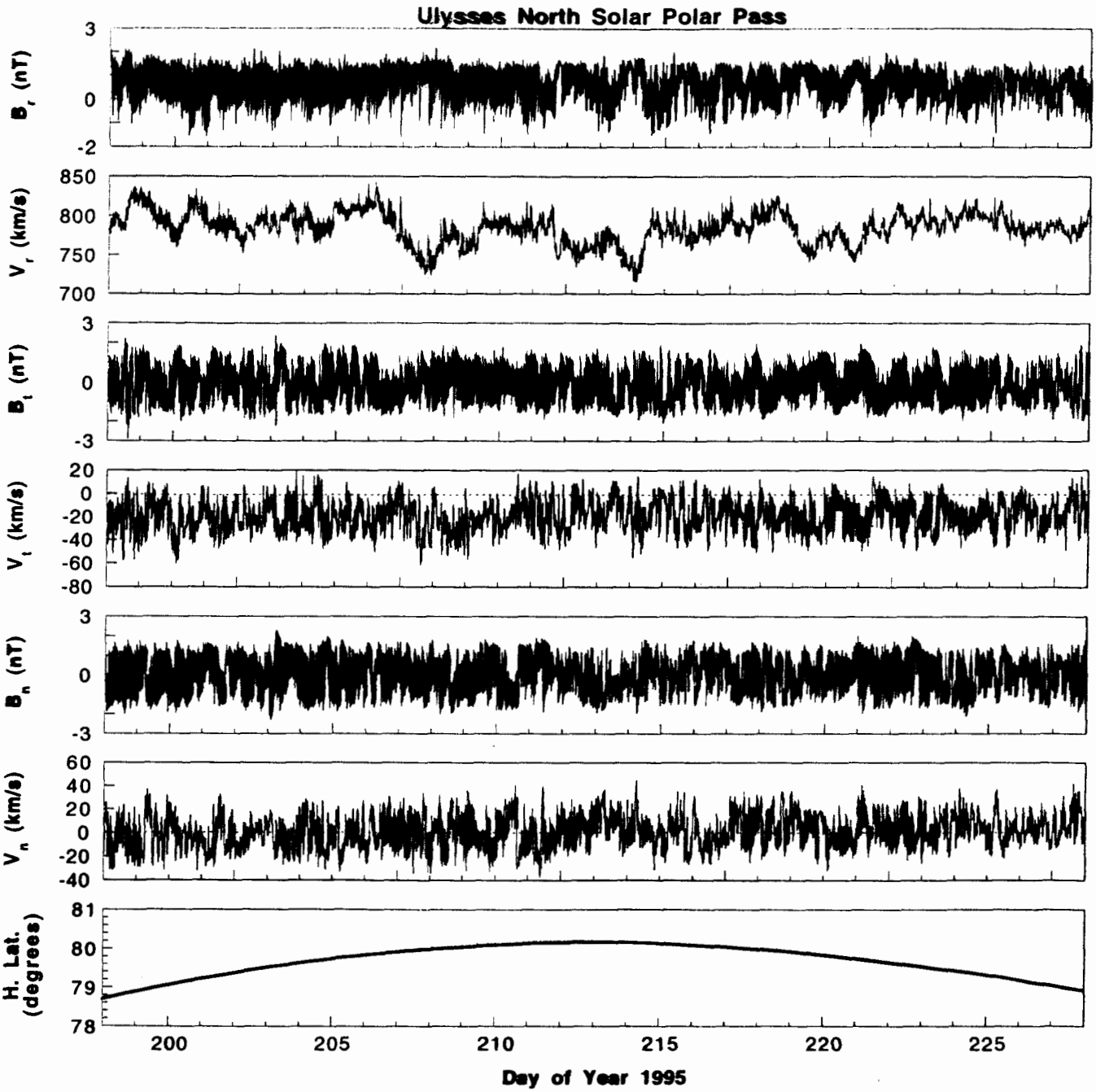
D_{ST} contribution negligible

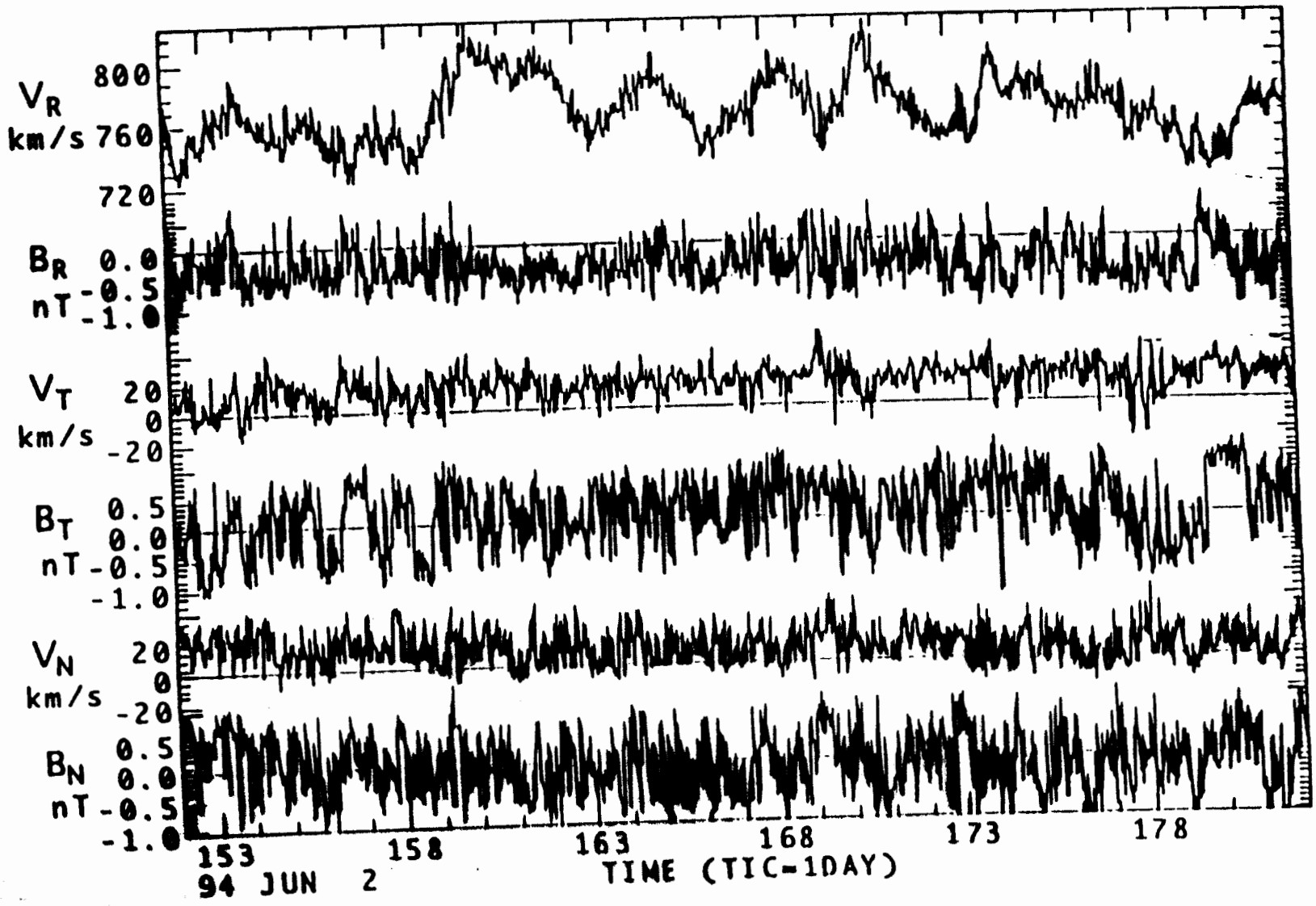
Solar Minimum (CIR) Storm



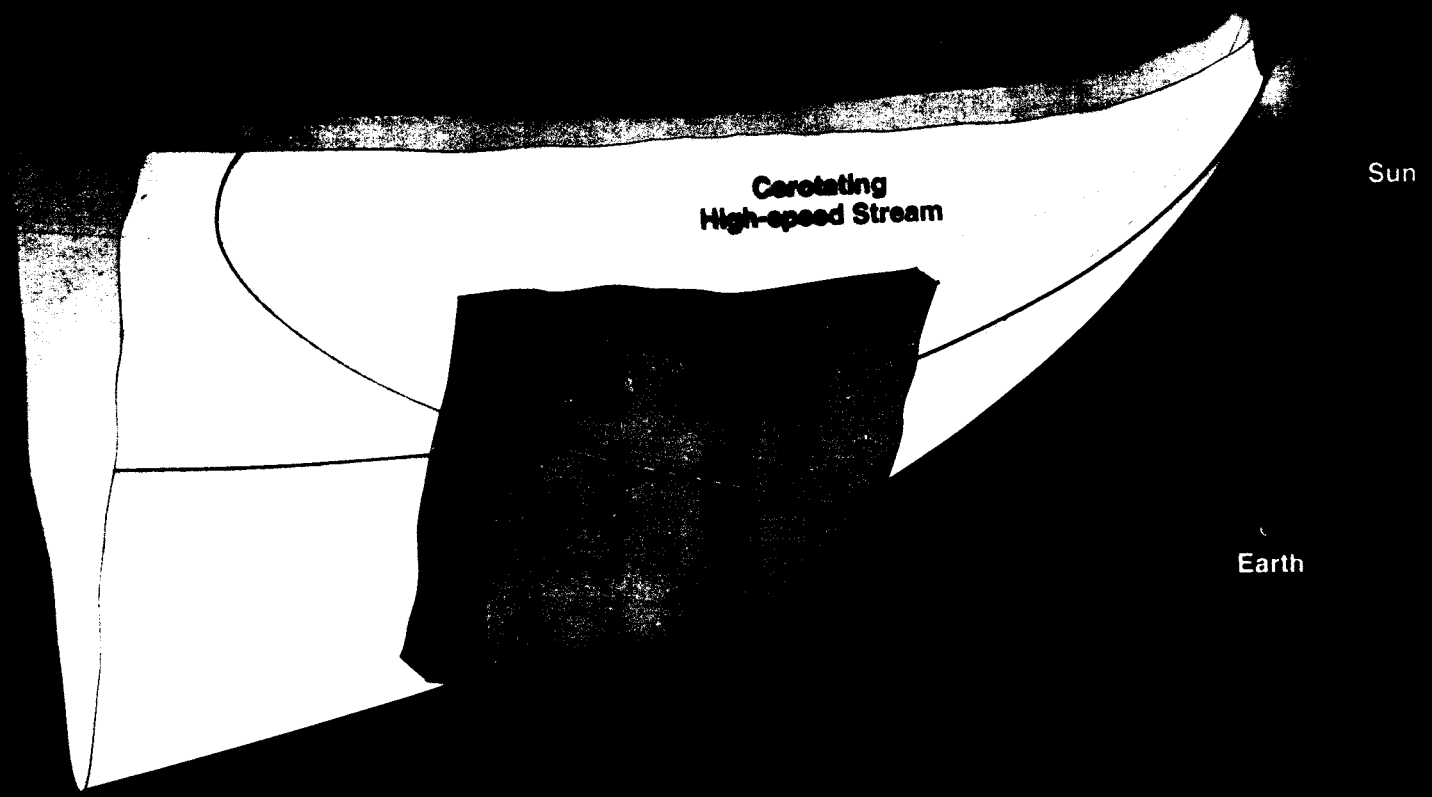

ULYSSES
Mars
ULYSSES

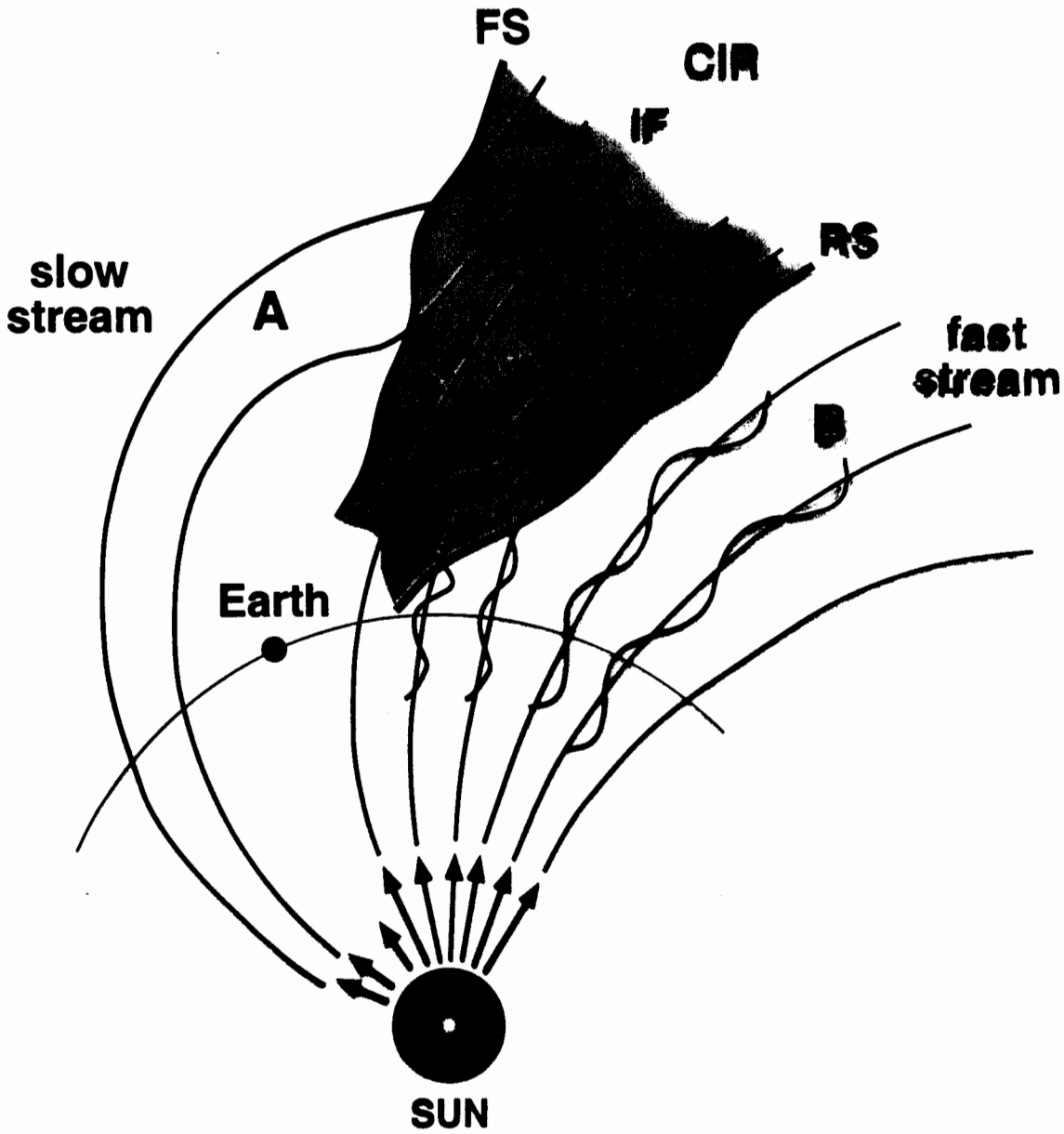
Yohkoh SXT 14 May 1992


Ulysses North Solar Polar Pass
B_r (nT)
3
0
-2
V_r (km/s)
850
800
750
700
B_t (nT)
3
0
-3
V_t (km/s)
20
0
-20
-40
-60
-80
B_n (nT)
3
0
-3
V_n (km/s)
60
40
20
0
-20
-40
H. Lat. (degrees)
81
80
79
78
200
205
210
215
220
225
Day of Year 1995


V_R
km/s
800
760
720
B_R
nT
0.0
-0.5
-1.0
V_T
km/s
20
0
-20
B_T
nT
0.5
0.0
-0.5
-1.0
V_N
km/s
20
0
-20
B_N
nT
0.5
0.0
-0.5
-1.0
153
158
163
168
173
178
94 JUN 2
TIME (TIC=1DAY)

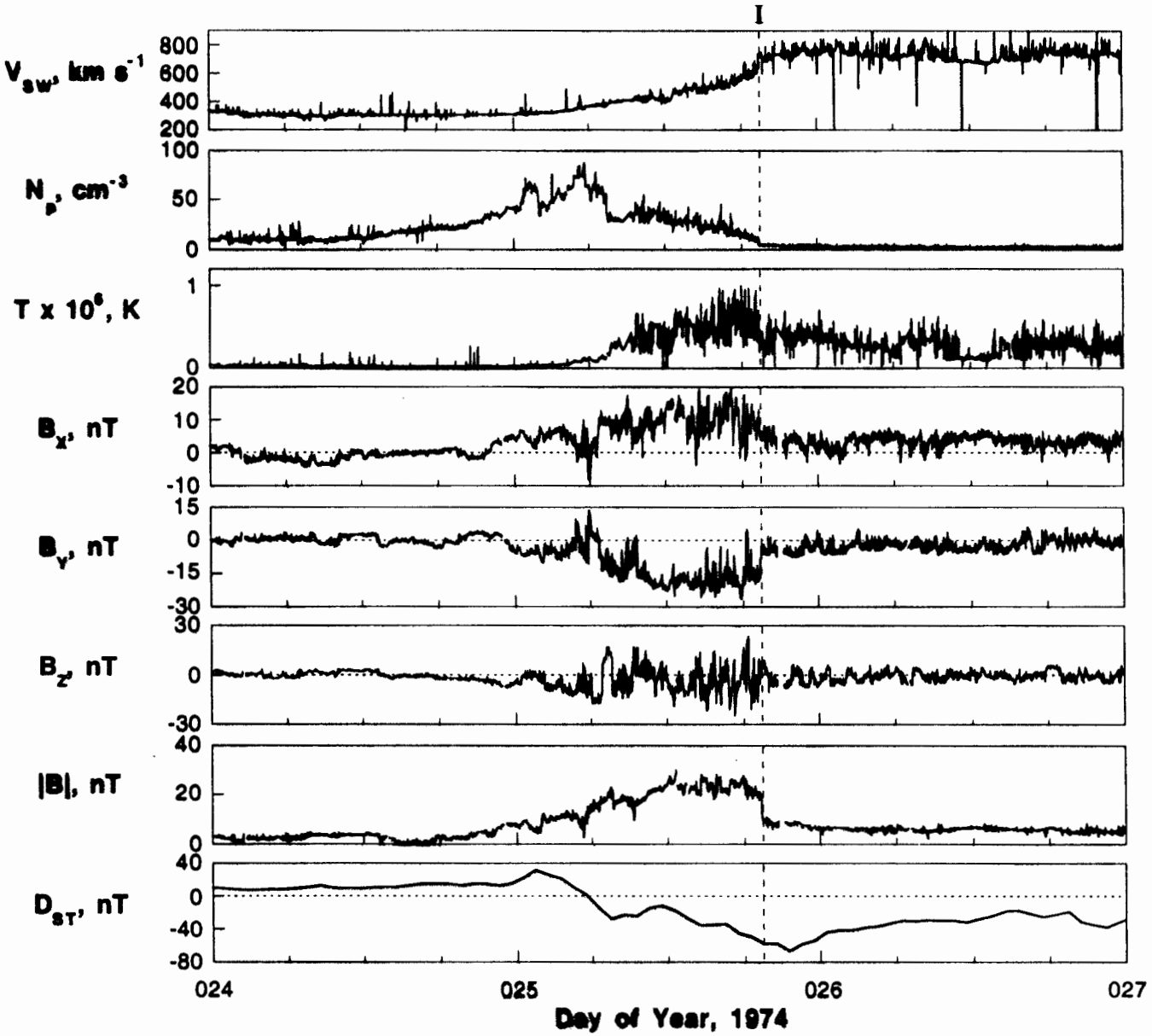
Corotating Interaction Region (CIR)

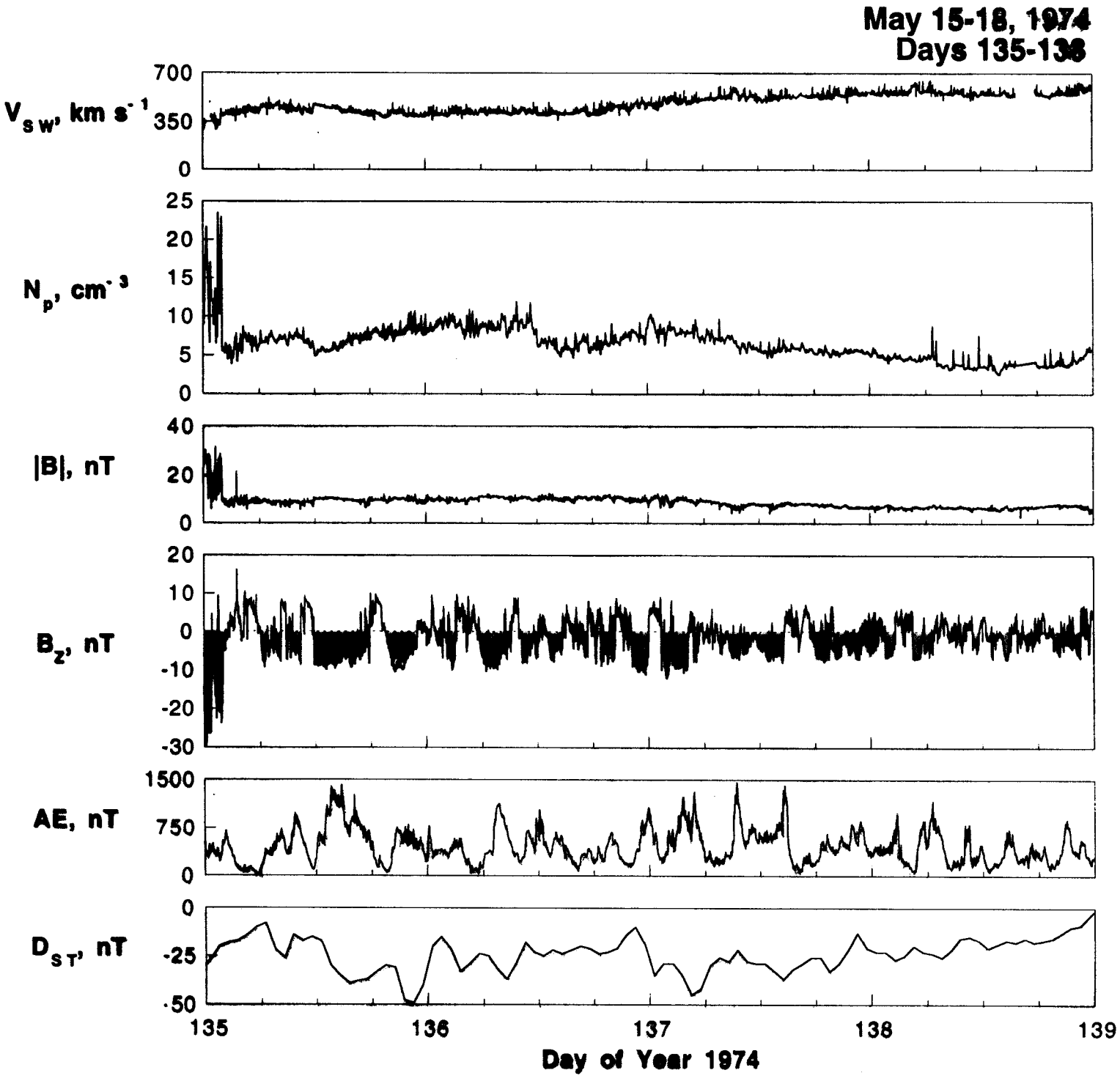




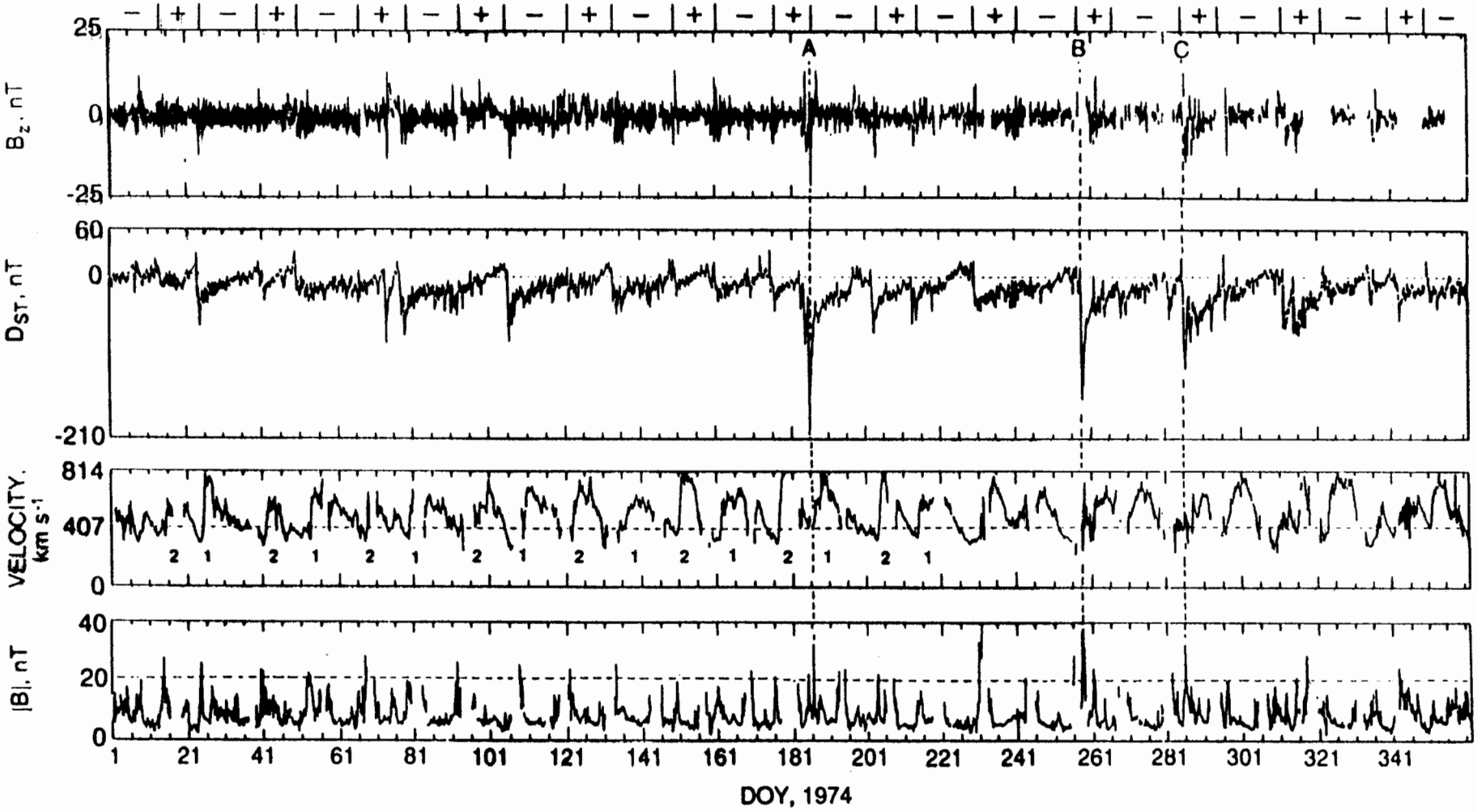
BTT/JKA
July 1999

IMP-8
January 24-27, 1974 (Day 024-027)



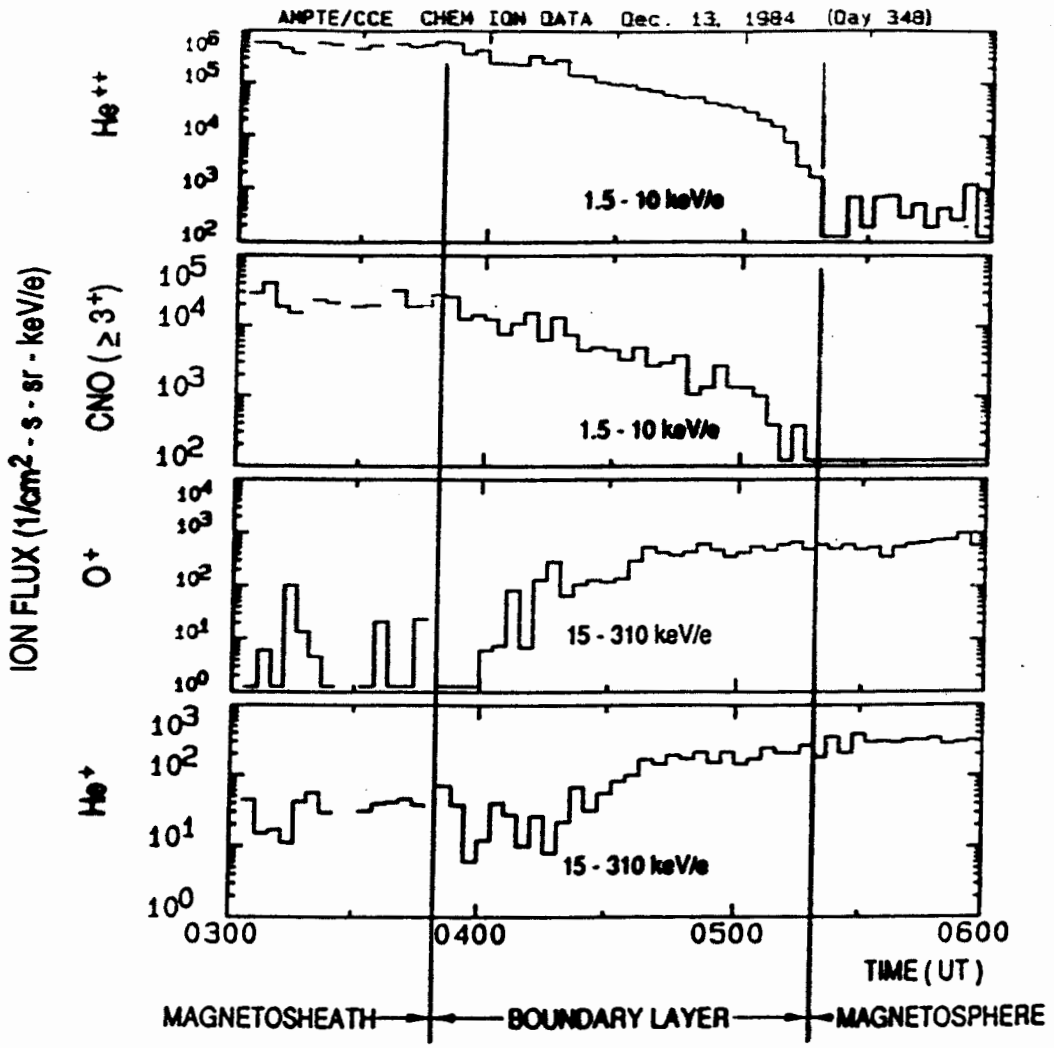

May 15-18, 1974
Days 135-138
V_{SW}, km s^{-1}
700
350
0
N_p, cm^{-3}
25
20
15
10
5
0
|B|, nT
40
20
0
B_z, nT
20
10
0
-10
-20
-30
AE, nT
1500
750
0
D_{ST}, nT
0
-25
-50
135
136
137
138
139
Day of Year 1974

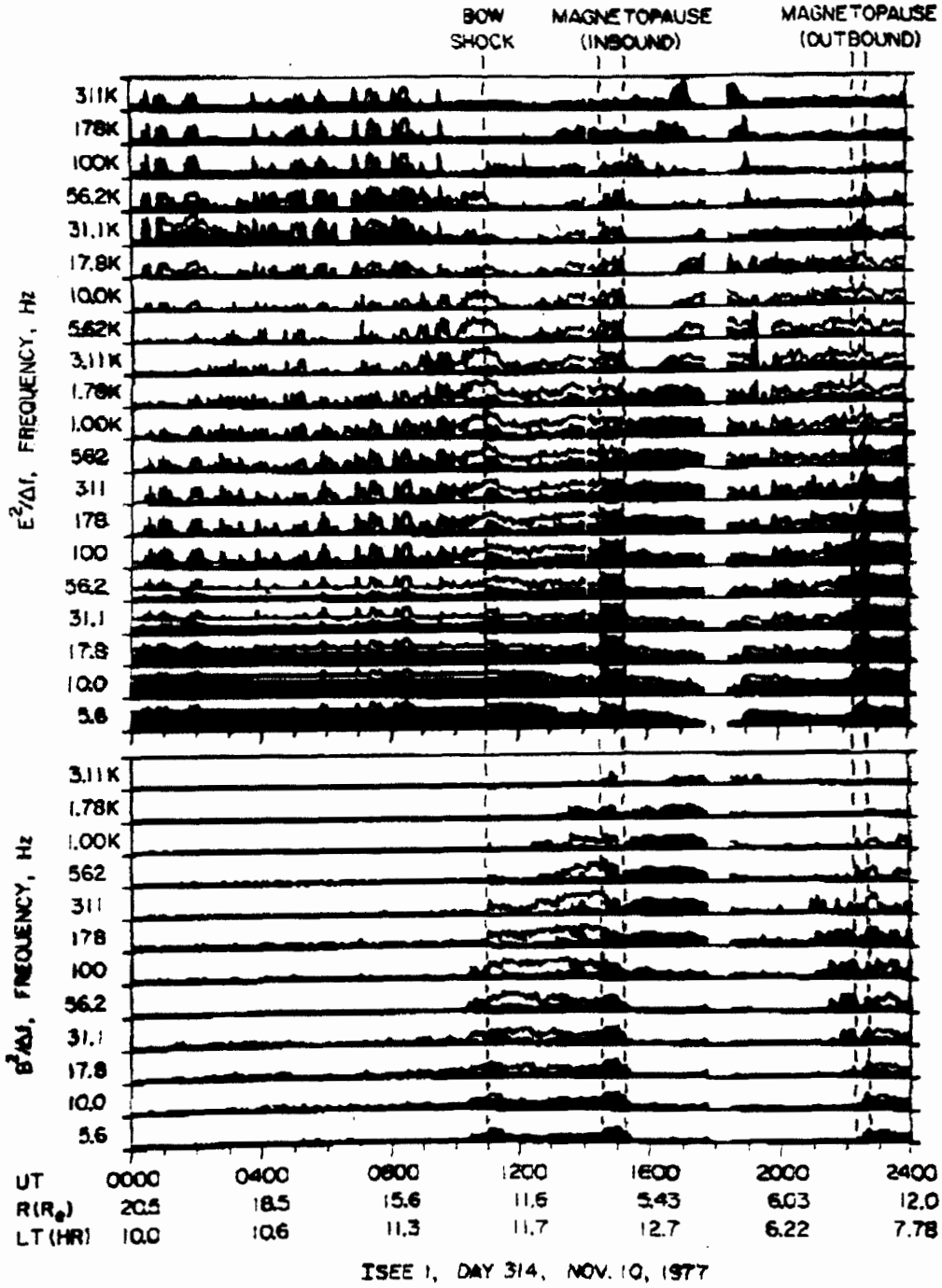
SOLAR WIND – MAGNETIC STORM CORRELATIONS



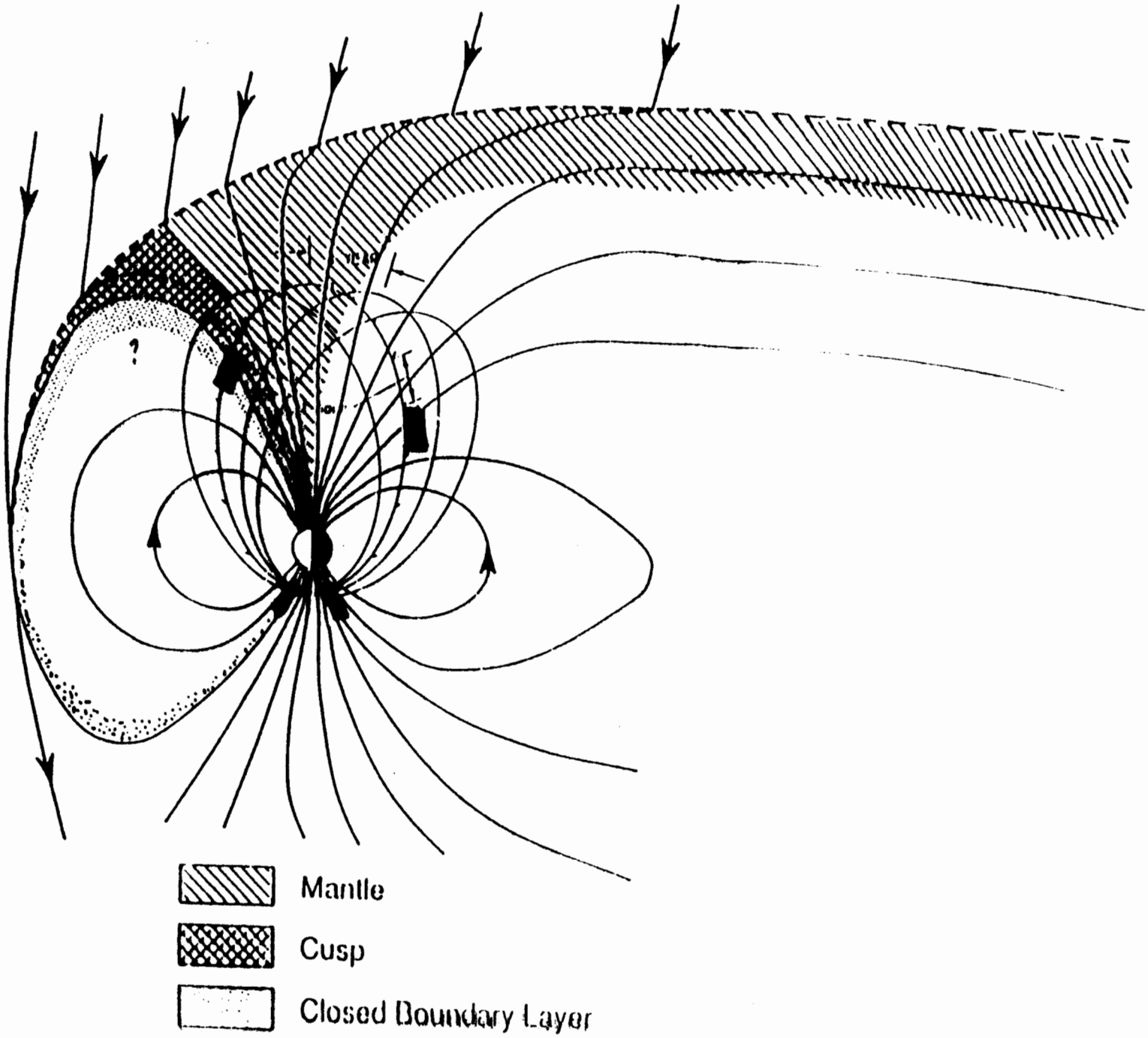
Geomagnetic Activity Can be Higher During Solar Minimum Than During Solar Maximum

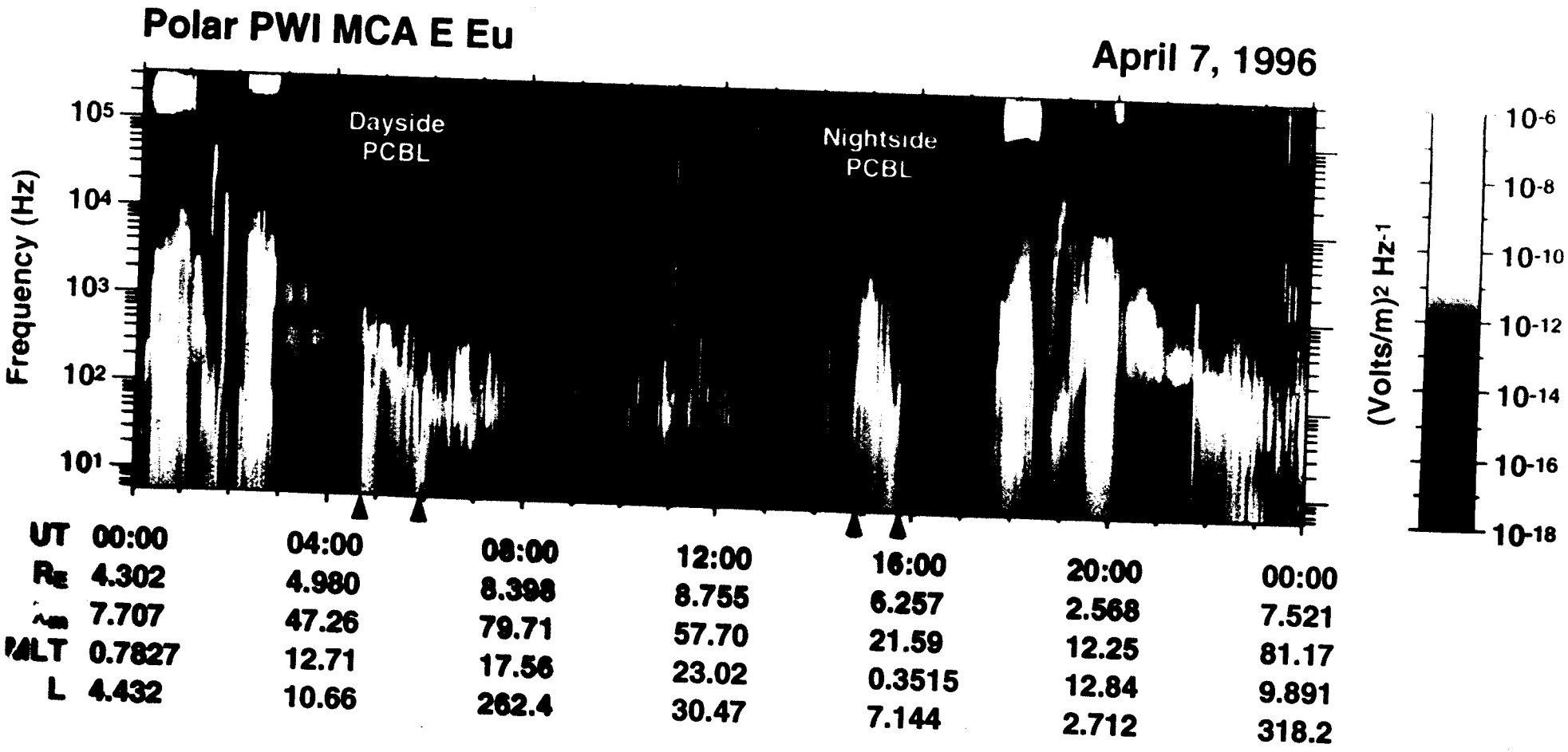
Solar Minimum		Solar Maximum	
$\overline{AE}_{1973}$ = 247 nT	$\overline{Dst}_{1973}$ = -14 nT	$\overline{AE}_{1979}$ = 221 nT	$\overline{Dst}_{1979}$ = -16 nT
$\overline{AE}_{1974}$ = 283 nT	$\overline{Dst}_{1974}$ = -14 nT	$\overline{AE}_{1980}$ = 180 nT	$\overline{Dst}_{1980}$ = -11 nT
$\overline{AE}_{1975}$ = 224 nT	$\overline{Dst}_{1975}$ = -10 nT	$\overline{AE}_{1981}$ = 237 nT	$\overline{Dst}_{1981}$ = -24 nT

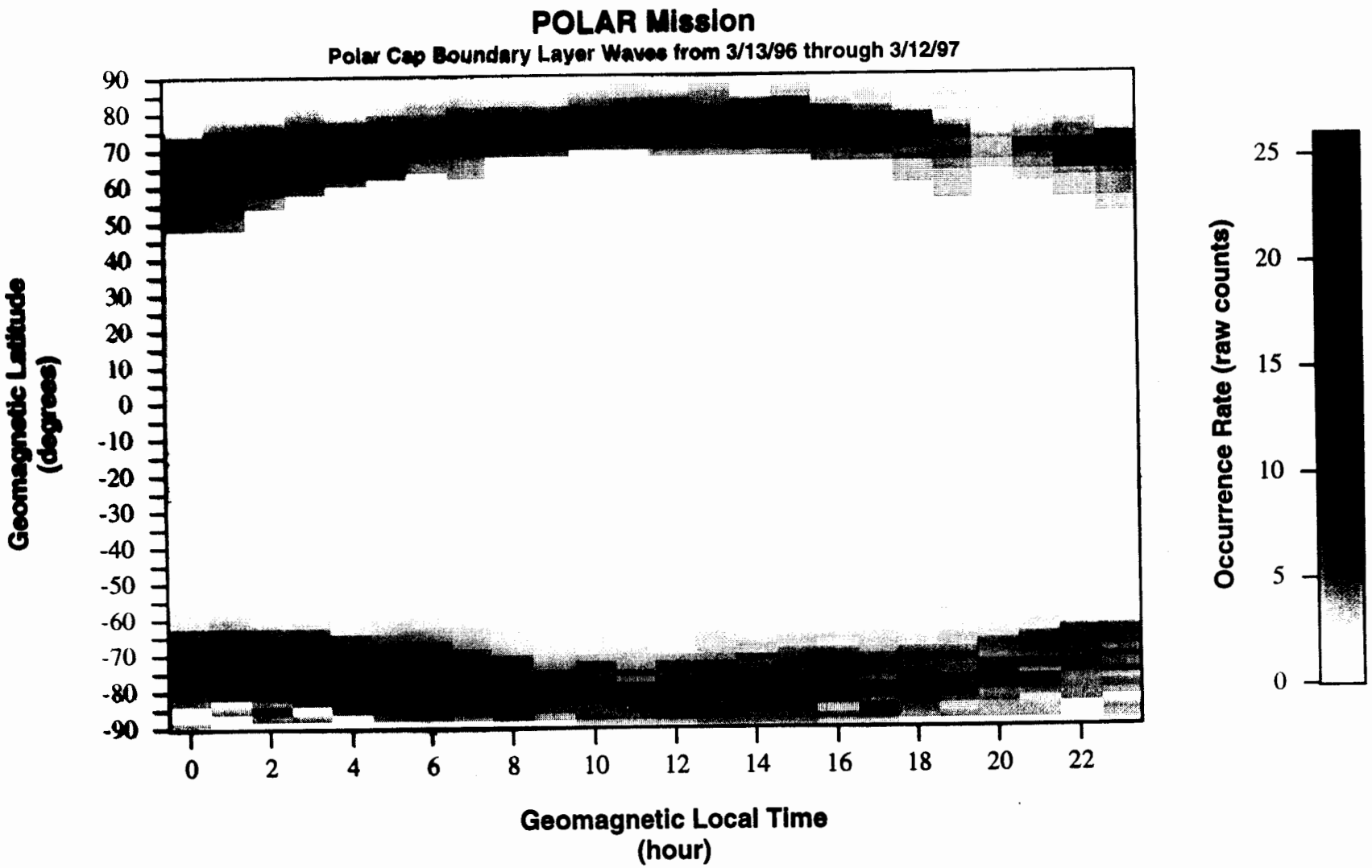

AMPTE/CCE CHEM ION DATA Dec. 13, 1984 (Day 348)
ION FLUX (1/cm² - s - sr - keV/e)
He++
1.5 - 10 keV/e
CNO (≥ 3+)
1.5 - 10 keV/e
O+
15 - 310 keV/e
He+
15 - 310 keV/e
0300
0400
0500
0600
TIME (UT)
MAGNETOSHEATH
BOUNDARY LAYER
MAGNETOSPHERE



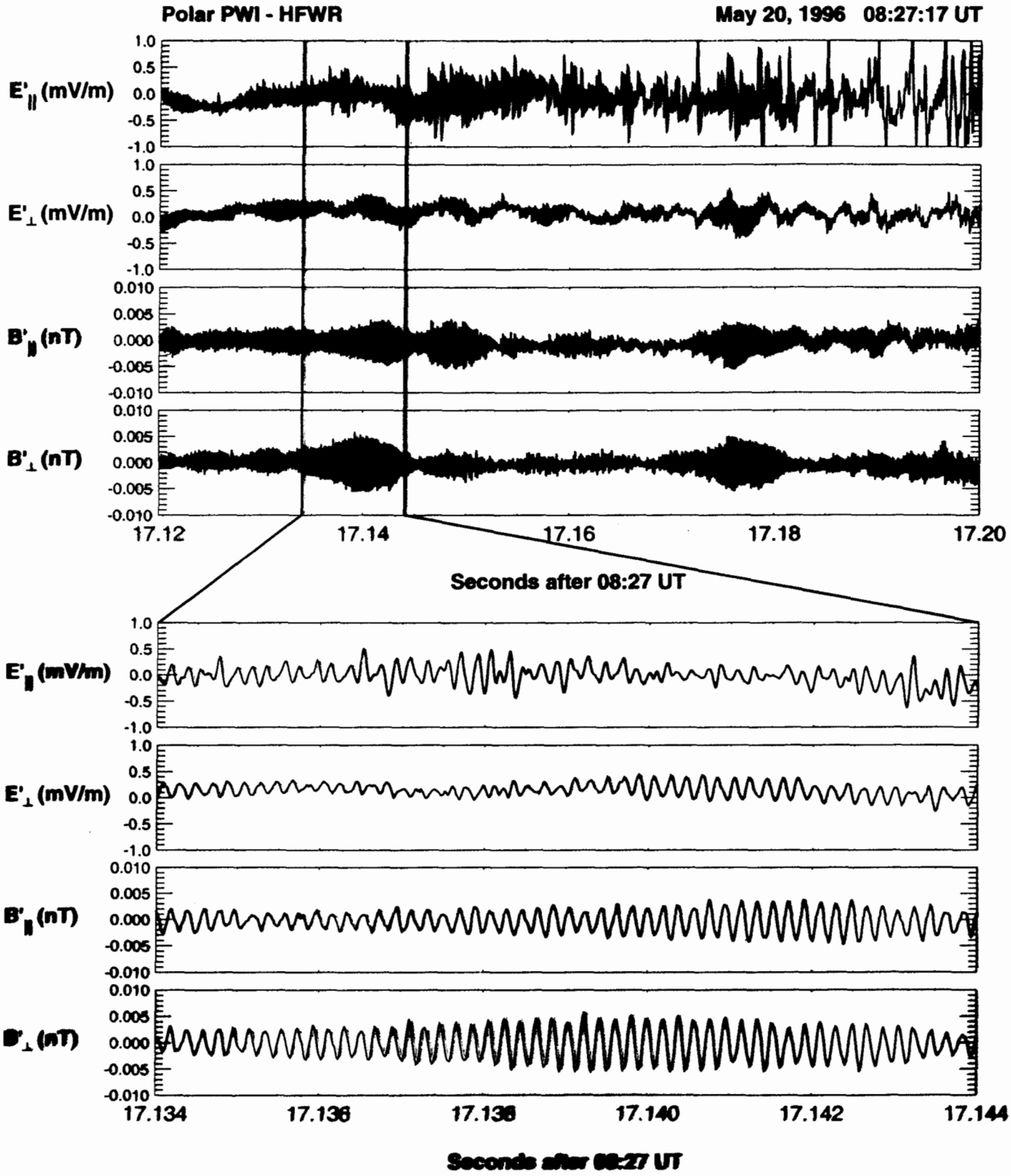
ISEE 1, DAY 314, NOV. 10, 1977

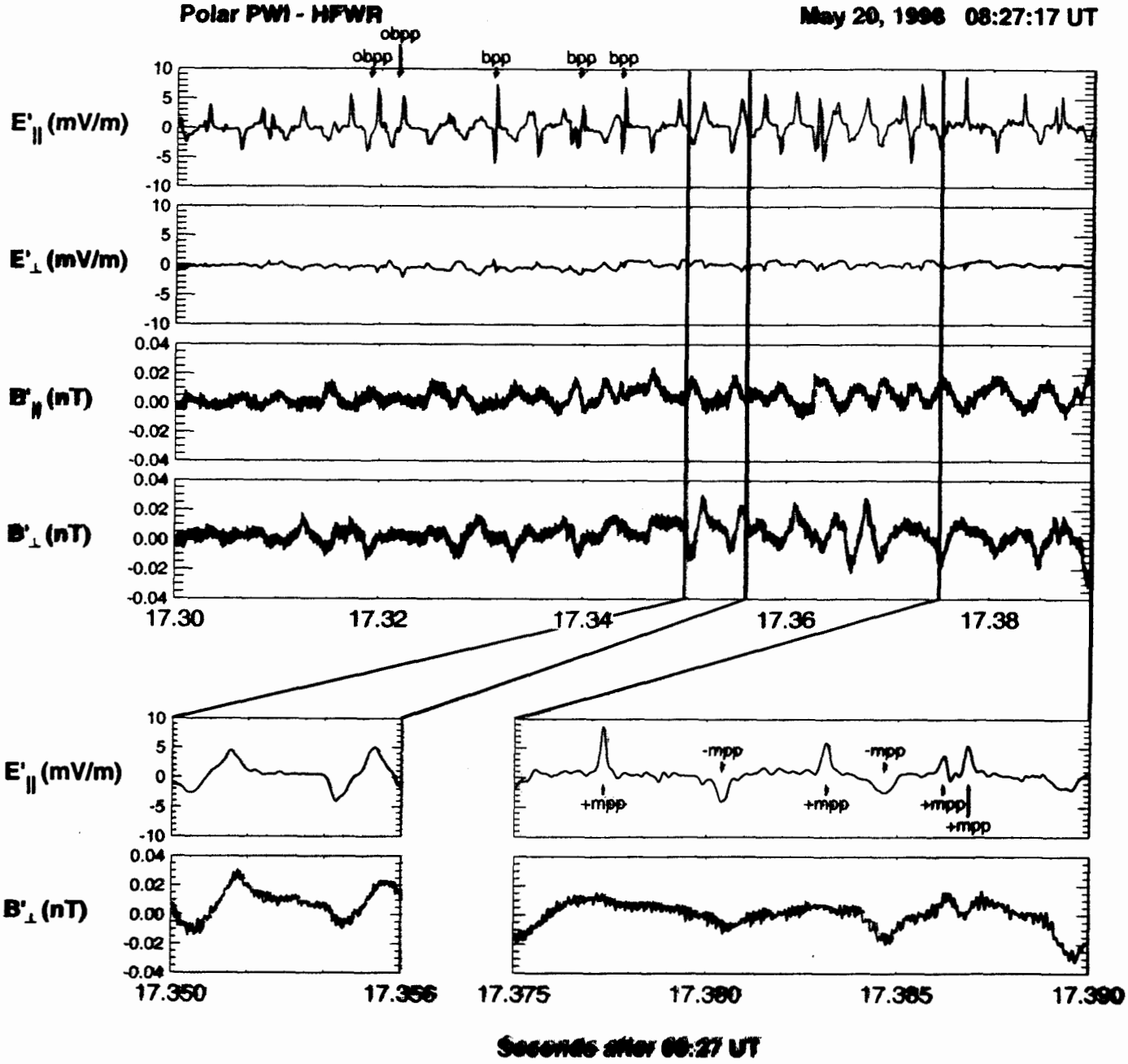

?
Mantle
Cusp
Closed Boundary Layer


Polar PWI MCA E Eu
April 7, 1996
Dayside PCBL
Nightside PCBL
Frequency (Hz)
10^5
10^4
10^3
10^2
10^1
(Volts/m)^2 Hz^{-1}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
10^{-14}
10^{-16}
10^{-18}
UT 00:00 04:00 08:00 12:00 16:00 20:00 00:00
R_E 4.302 4.980 8.398 8.755 6.257 2.568 7.521
λ_m 7.707 47.26 79.71 57.70 21.59 12.25 81.17
MLT 0.7827 12.71 17.56 23.02 0.3515 12.84 9.891
L 4.432 10.66 262.4 30.47 7.144 2.712 318.2

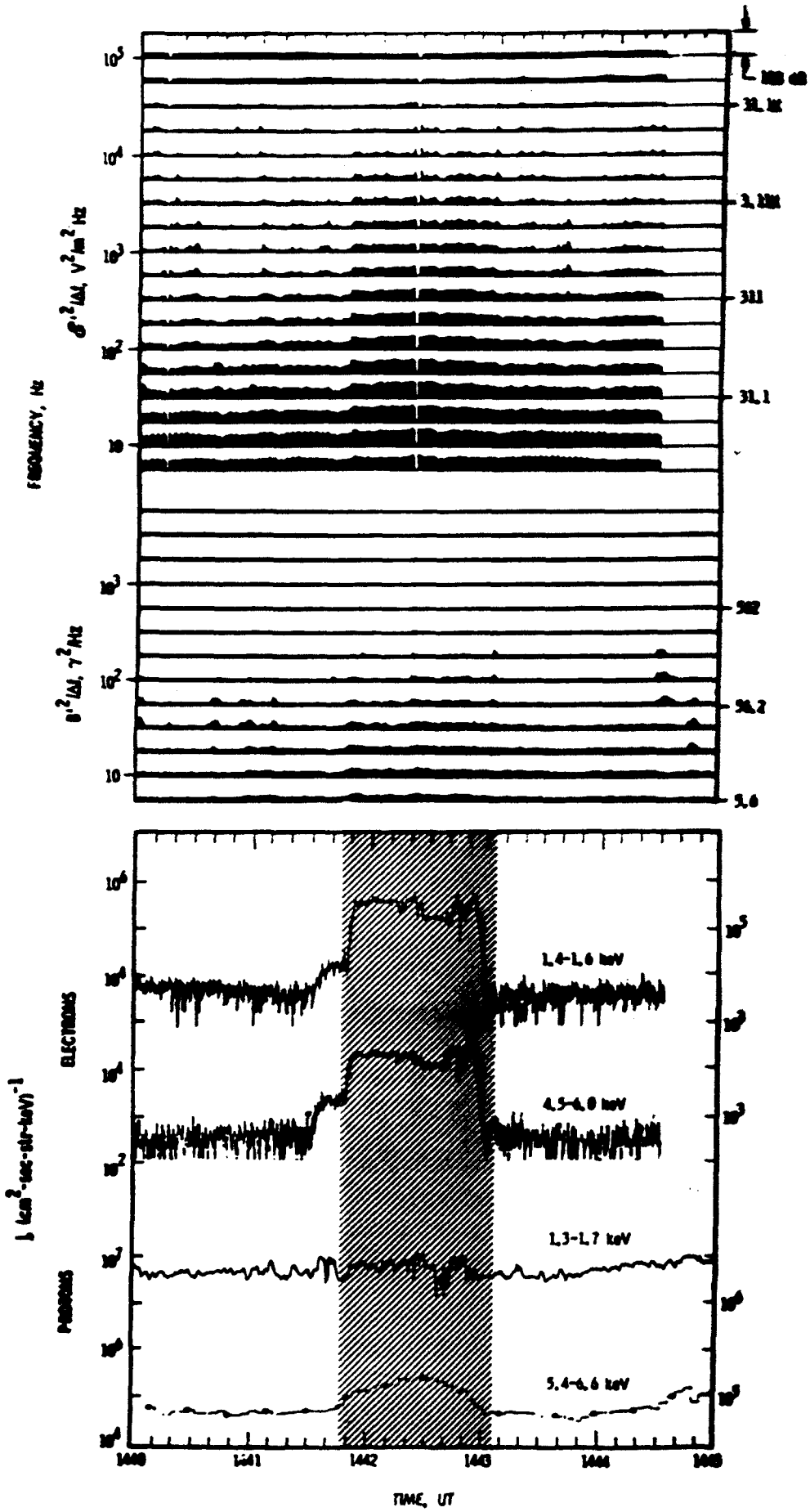

POLAR Mission
Polar Cap Boundary Layer Waves from 3/13/96 through 3/12/97
Geomagnetic Latitude (degrees)
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
0
2
4
6
8
10
12
14
16
18
20
22
Geomagnetic Local Time (hour)
Occurrence Rate (raw counts)
25
20
15
10
5
0

5/25/98


Polar PWI - HFWR
May 20, 1996 08:27:17 UT
E'∥ (mV/m)
E'⊥ (mV/m)
B'∥ (nT)
B'⊥ (nT)
1.0
0.5
0.0
-0.5
-1.0
0.010
0.005
0.000
-0.005
-0.010
17.12
17.14
17.16
17.18
17.20
Seconds after 08:27 UT
17.134
17.136
17.138
17.140
17.142
17.144
Seconds after 08:27 UT



BTT/JKA
July 1999



ISEE-1 DAY 333, 1977

Table 2. A comparison of the Jovian BL plasma wave spectra and the Earth's wave spectra

Spacecraft	Location	Date	B'	E'
ISEE 1[a]	Earth magnetopause	day 314, 1977	$\sim f^{-3.3}$	$\sim f^{-2.2}$
ISEE 1 and 2[b]	Earth magnetopause	1977	$(1 \times 10^{1}) f^{-3.9}$	$(3 \times 10^{-5}) f^{-2.8}$
ISEE 1 and 2[c]	Earth magnetopause	1977	$(7.9 \times 10^{-2}) f^{-2.9}$	$(6.3 \times 10^{-6}) f^{-2.2}$
GEOS 2[d]	Earth magnetopause	day 240, 1978	X: $(3.6 \times 10^{1}) f^{-2.6}$ Y: $(1.8 \times 10^{1}) f^{-2.4}$ Z: $(2.8 \times 10^{1}) f^{-2.7}$	$(1.2 \times 10^{-6}) f^{-2.6}$
ISEE 1[e]	Earth magnetopause	1977-79	$(3 \times 10^{-1}) f^{-3.3}$	$(6 \times 10^{-7}) f^{-2.1}$
Ulysses	Jupiter magnetopause	day 043, 1992	$(2 \times 10^{-4}) f^{-2.4}$	$(4 \times 10^{-9}) f^{-2.4}$