1999 CEDAR Workshop
Boulder, Colorado
June 13-18, 1999

Tutorial Lecture

by Charles Richard Chappell
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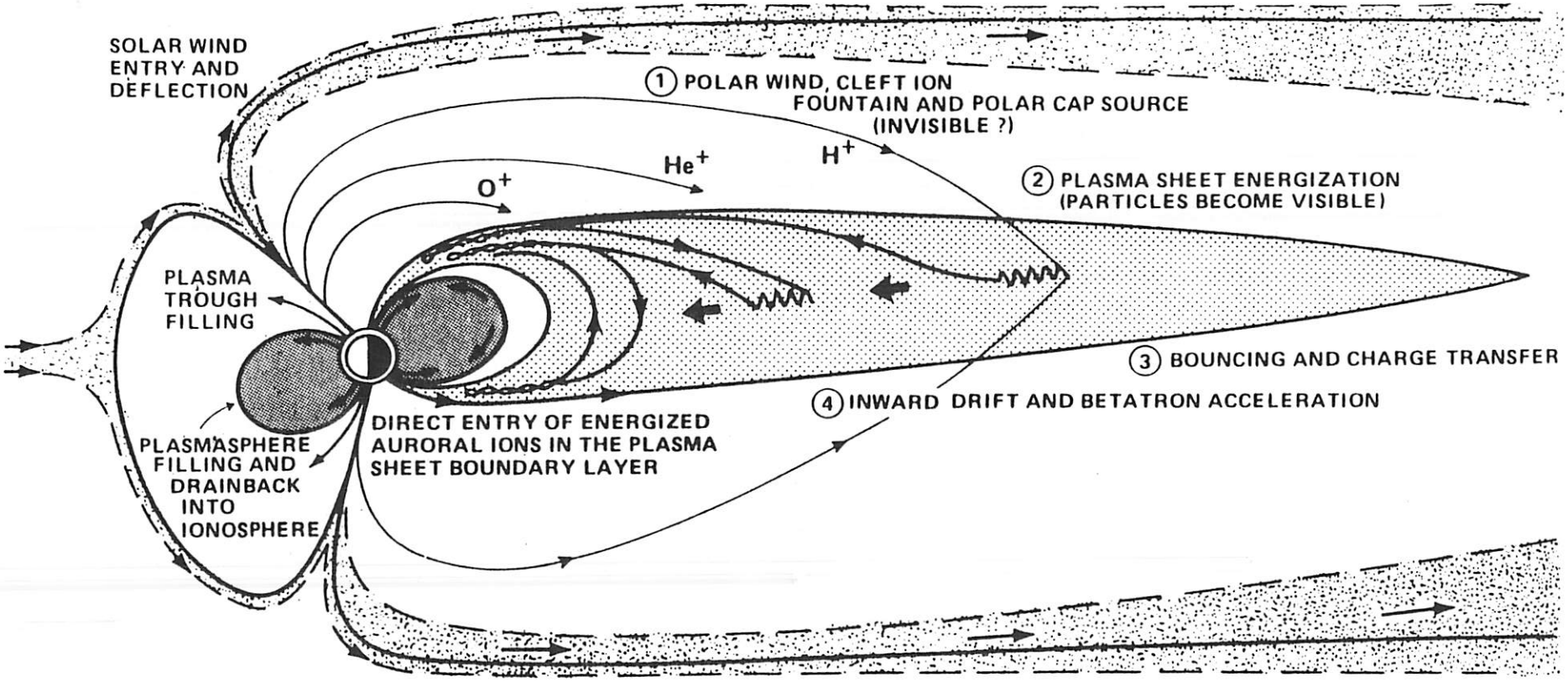
Polar Ion Outflow - Is there enough to fill the Magnetosphere?

Chappell, Moore and Waite, The Ionosphere as a Fully Adequate Source of Plasma for the Earth's Magnetosphere, JGR, 5896, 1987



Ionosphere source sends a flow of low-energy (few eV to 10's of eV) plasma up into magnetosphere.

Plasma is made up of H+, He+, O+ from the polar wind, cleft ion flountain, polar cap and auroral zone.

The plasma flows up through the polar cap and the "empty" lobes of the magnetotail to the plasma sheet.

TABLE 1. Total Ionospheric Source Strength

	Quiet			Active		
	H^+	He^+	O^+	H^+	He^+	O^+
Polar wind						
Solar maximum	15.0 (1×10^8)*	1.1 (7.05×10^6)		10.0 (6.5×10^7)	0.40 (2.61×10^6)	
Solar minimum	46.0 (3×10^8)	0.59 (3.85×10^6)		31.0 (2×10^8)	0.28 (1.82×10^6)	
Cleft ion fountain						
Solar maximum	0.33		1.6	0.43		4.8
Solar minimum**	0.63		0.73	0.43		1.9
Auroral zone						
Solar maximum	2.1		1.6	2.6		7.7
Solar minimum**	1.7		1.0	3.3		3.2
Polar cap						
Solar maximum	0.24		0.24	0.61		2.5
Solar minimum**	0.43		0.39	1.0		1.5

Each entry is to be multiplied by 10^{25} ions s^{-1}.

*The numbers in parentheses represent the polar wind fluxes in ions per square centimeter per second that were used for the different solar and magnetic conditions.

**The *Yau et al.* [1985] DE data were taken in two sets: one near solar maximum and one about half way between solar maximum and minimum (see Figure 1).

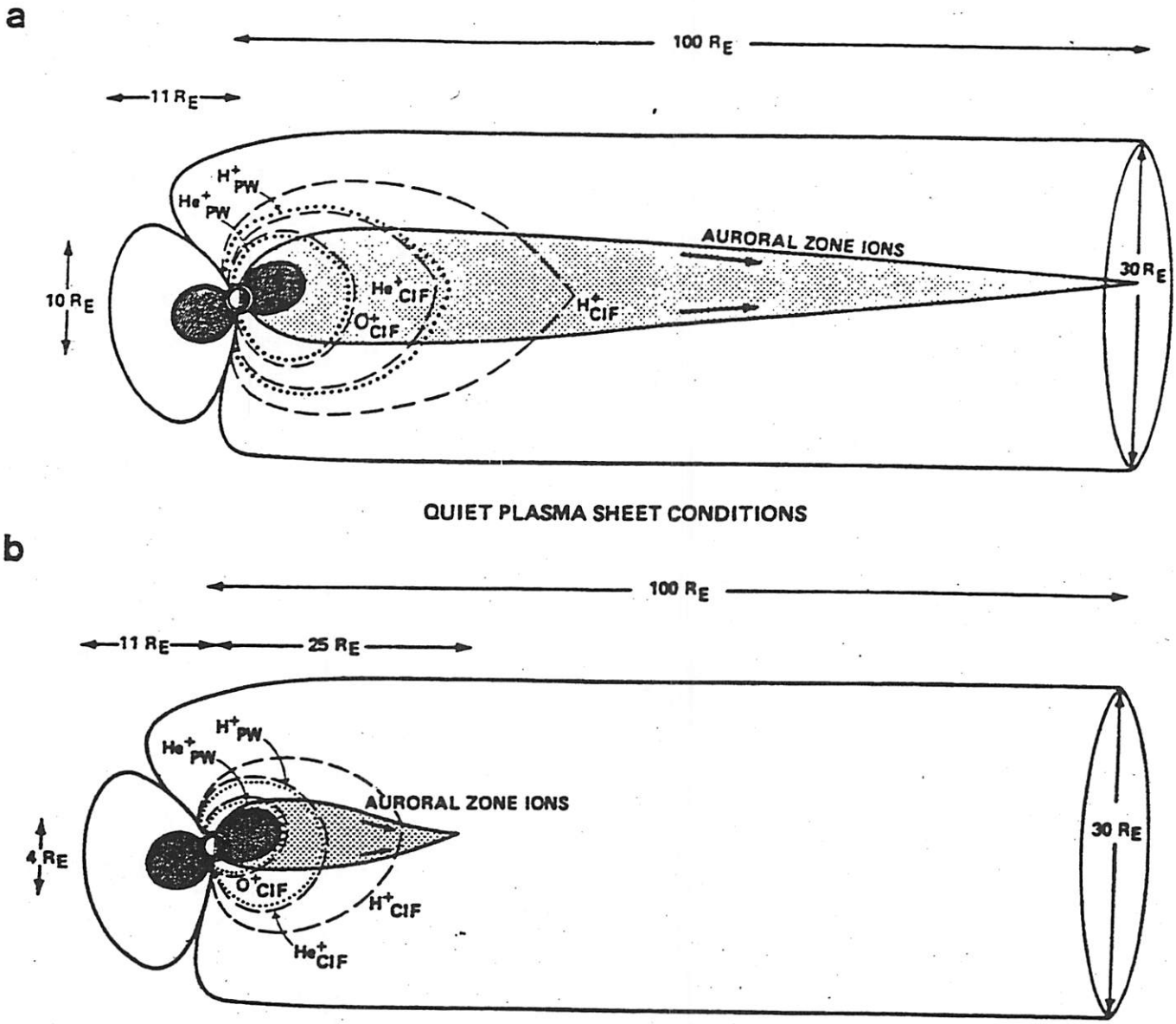
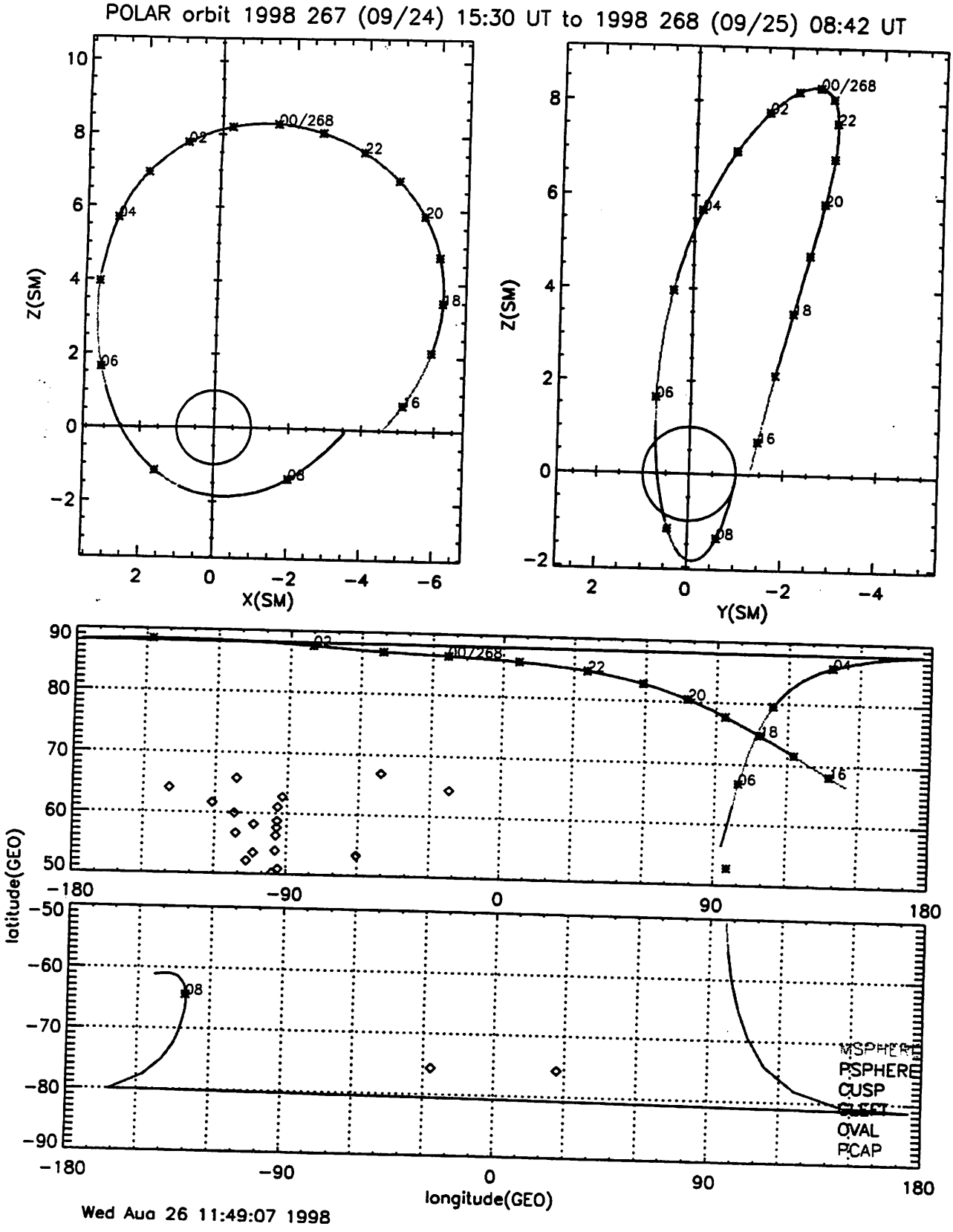


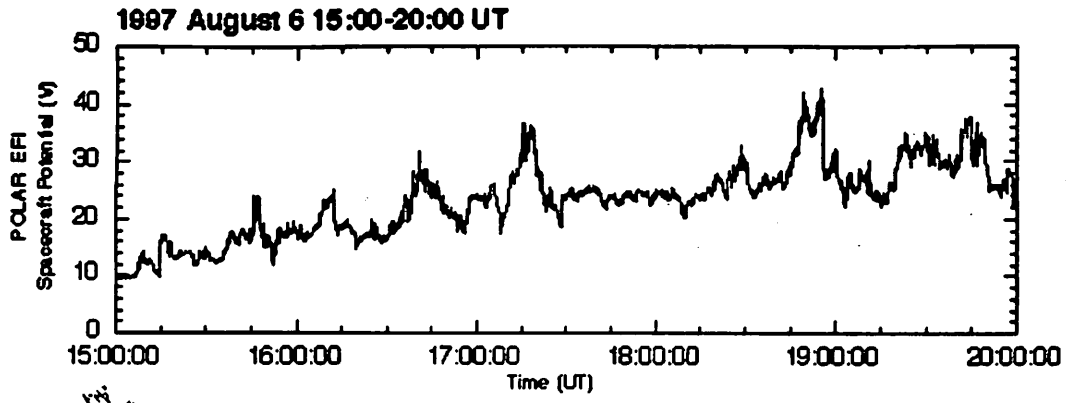
Figure 3. A sketch of the magnetosphere showing the assumed size of the plasma sheet used in the calculations for (*a*) quiet and (*b*) active magnetic conditions. The dotted and dashed lines show the outer flow boundary for polar wind and cleft ion fountain ions, respectively, from a source located near the polar cusp.

TABLE 2. Parameter Summary

Region	Volume, cm^3	Residence Time, s	Flux Range		Density	
			ions s^{-1}	(ions cm^{-2} s^{-1})	Calculated, ions cm^{-3}	Observed, ions cm^{-3}
Region I						
Inner plasmasphere	6.97×10^{27}	8.64×10^4 (1-day filling time)	8.0×10^{26} 1.7×10^{26}	(1.5×10^8) (3.25×10^7)	4930–1070	10,000–2000
Region II						
Outer plasmasphere	2.39×10^{28}	4.32×10^5 (5-day filling time)	9.3×10^{25} 2.0×10^{25}	(1.5×10^8) (3.25×10^7)	850–180	2000–100
Region III						
Dayside plasma trough	5.65×10^{29}	2.16×10^4 (6-hr convective drift)	1.31×10^{26} 2.91×10^{25}	(3×10^8) (6.5×10^7)	5.1–1.1	10.0–<1.0
Region IV						
a. Quiet plasma sheet	3.75×10^{30}	1.44×10^4 (4-hr convective drift)	1.9×10^{26} 1.1×10^{26}		0.73–0.42	1.1–0.4
b. Active plasma sheet	3.75×10^{29}	1.08×10^4 (3-hr convective drift)	2.2×10^{26} 2.1×10^{26}		6.3–6.0	0.4–0.2
Region V						
Tail lobe	7.0×10^{30}	6.5×10^3 (flow and drift time)	8.4×10^{25} 3.9×10^{25}		0.078–0.036	0.1–0.001

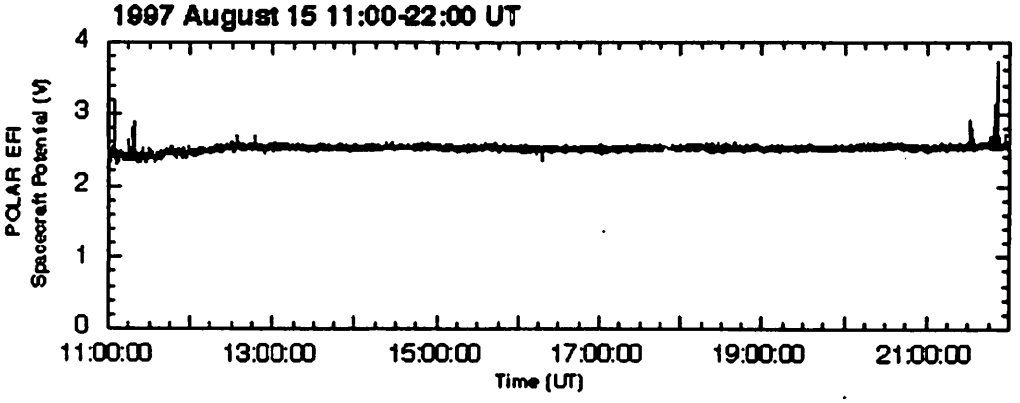

POLAR orbit 1998 267 (09/24) 15:30 UT to 1998 268 (09/25) 08:42 UT
Z(SM)
X(SM)
Y(SM)
00/268
02
04
06
08
16
18
20
22
latitude(GEO)
longitude(GEO)
MSPHERE
PSPHERE
CUSP
CLEFT
OVAL
PCAP
Wed Aug 26 11:49:07 1998

Spacecraft Potential for typical agogee pass of POLAR

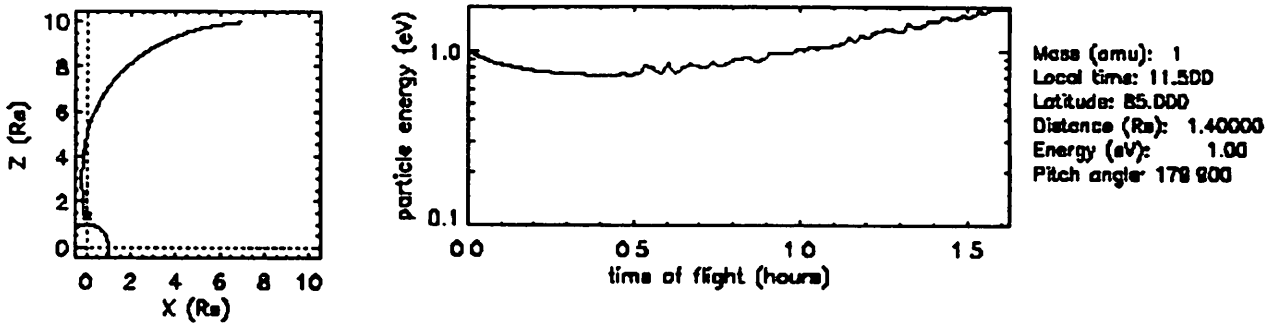


Scales differ by order of magnitude

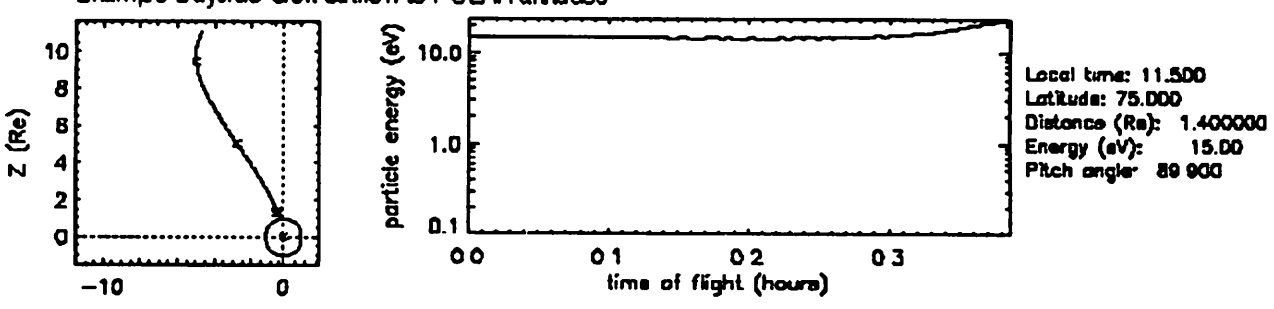
Spacecraft Potential for typical agogee pass of POLAR with PSI in operation

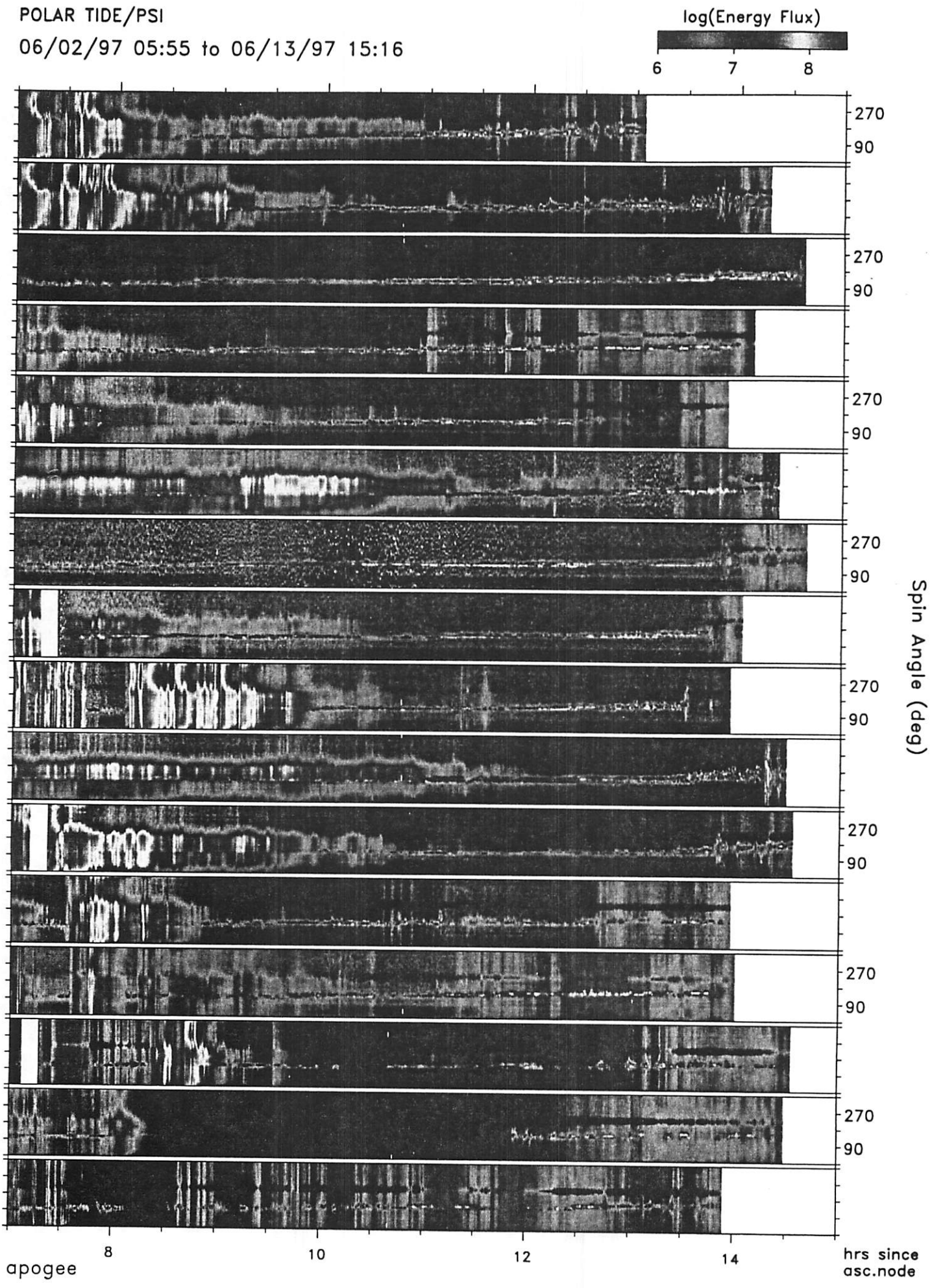


Example Polar Cap outflow to POLAR altitudes

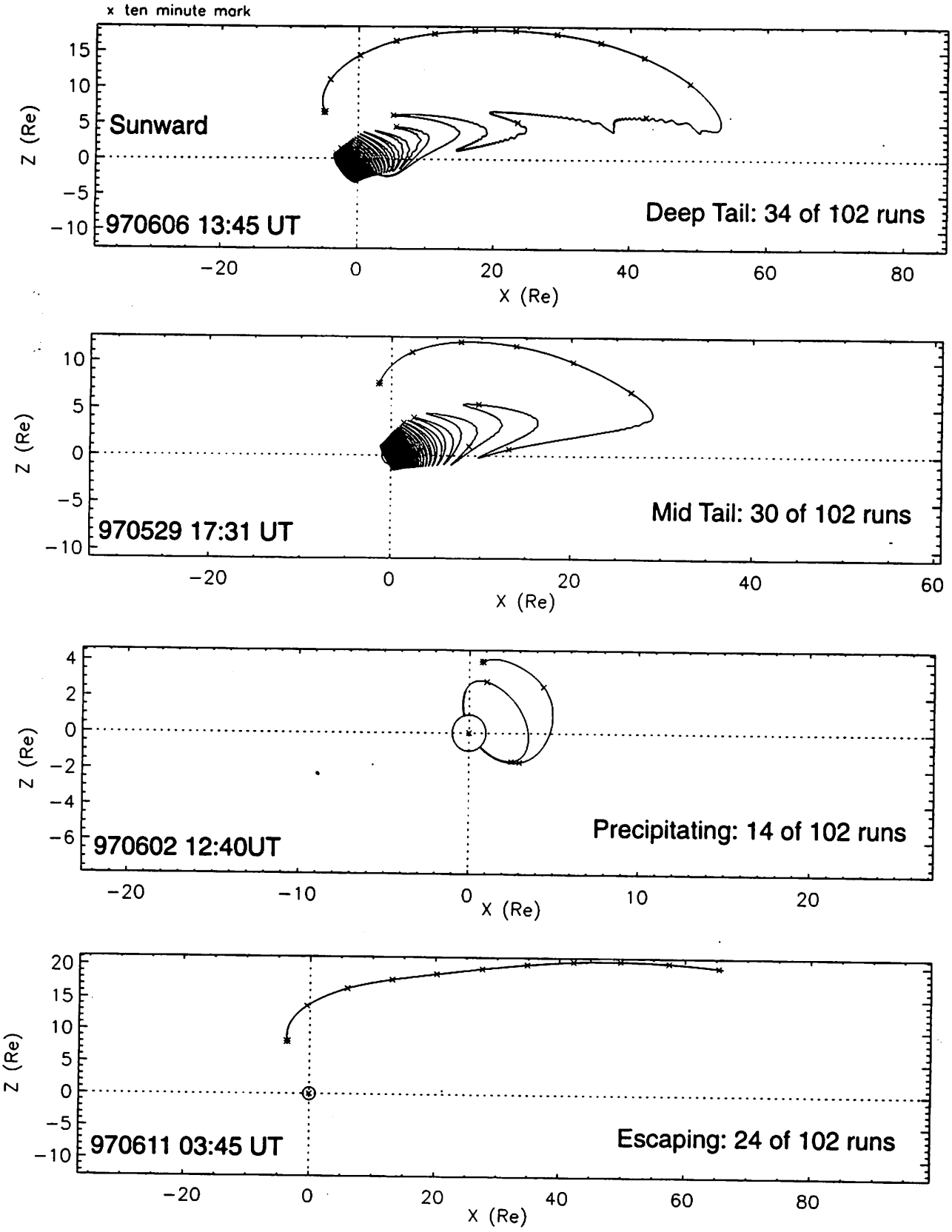


Example Dayside Cleft outflow to POLAR altitudes

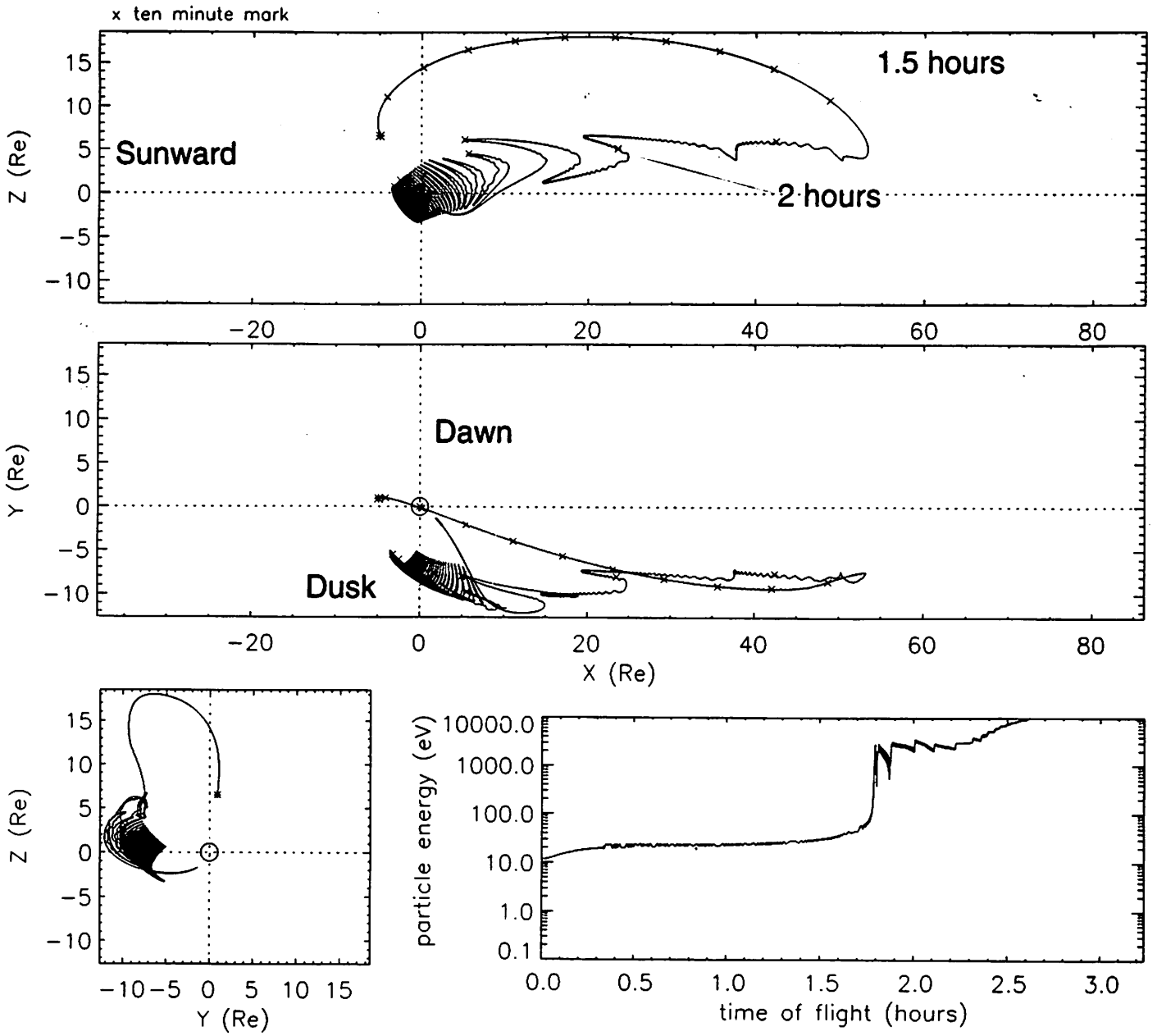



POLAR TIDE/PSI
06/02/97 05:55 to 06/13/97 15:16
log(Energy Flux)
6
7
8
270
90
Spin Angle (deg)
8
10
12
14
apogee
hrs since
asc.node

Particle trajectory categories for TIDE Observations - 1997 May29 to June 11



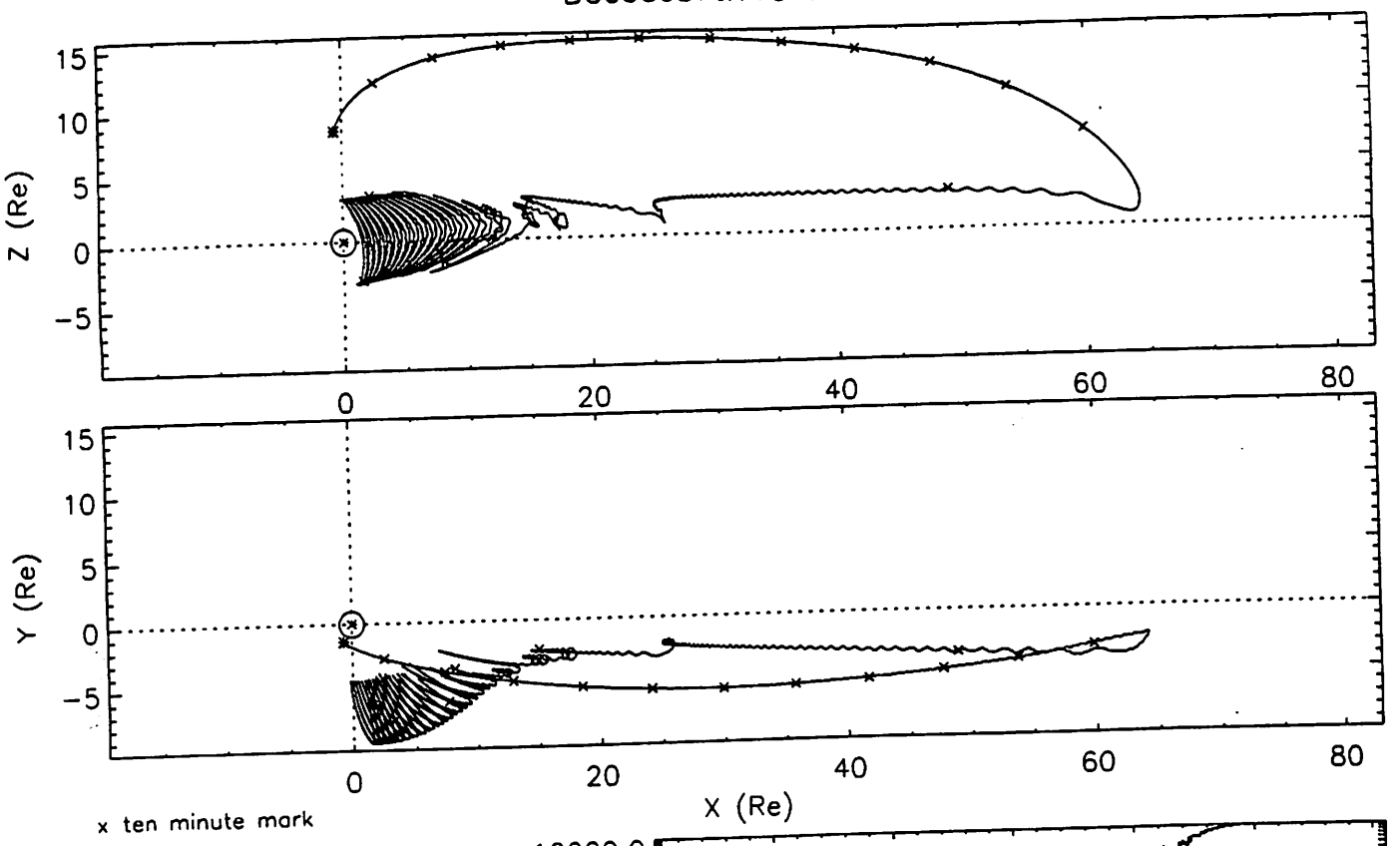
Particle trajectory simulation for TIDE Observations, 1997 June 6 13:45UT

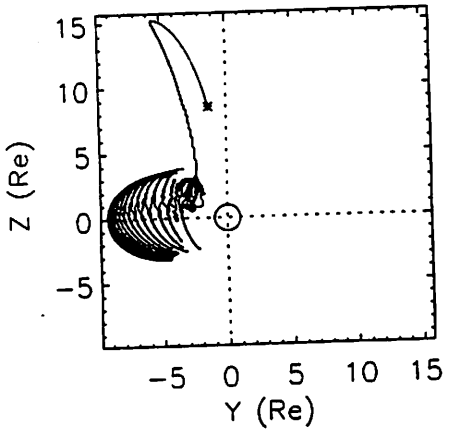


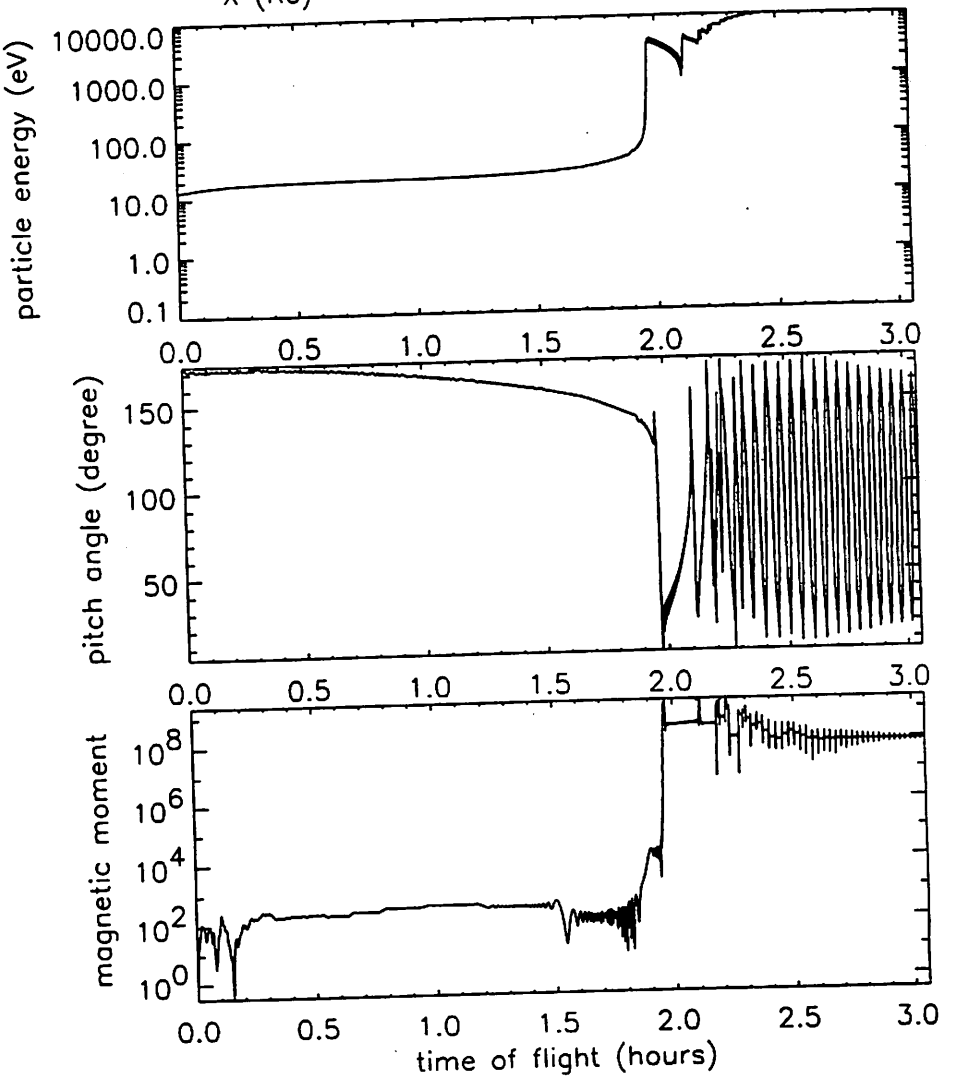
start parameters:

Kp level: 3
Local time: 9.173
Latitude: 80.510
Distance (Re): 8.181000
Energy (eV): 11.03
Pitch angle: 179.900
Tilt angle: 33.310

BGcode87t.v101.for





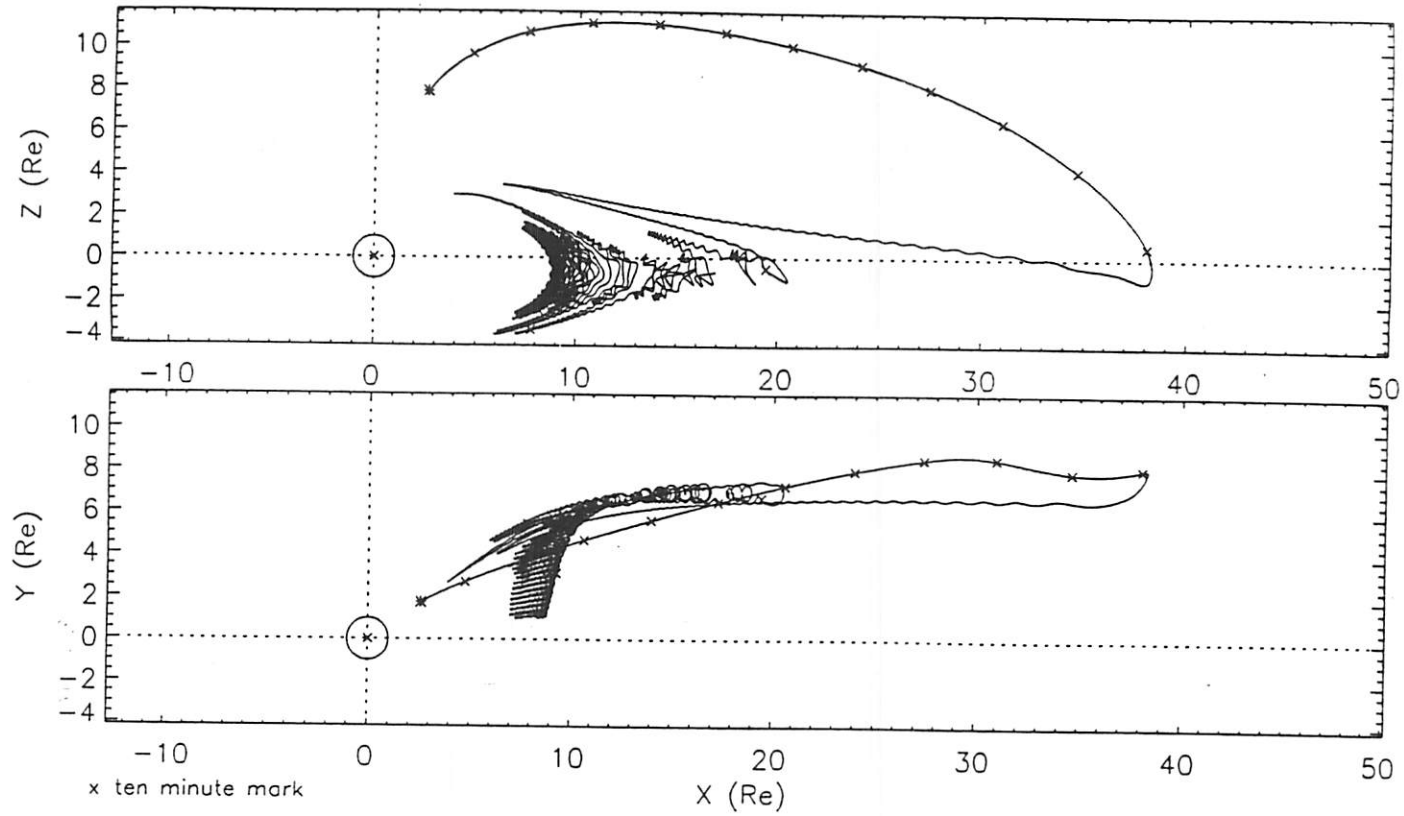


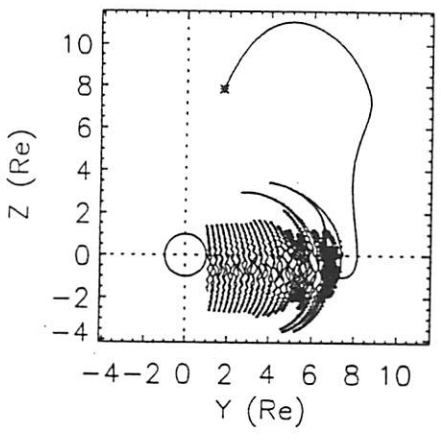
start parameters:

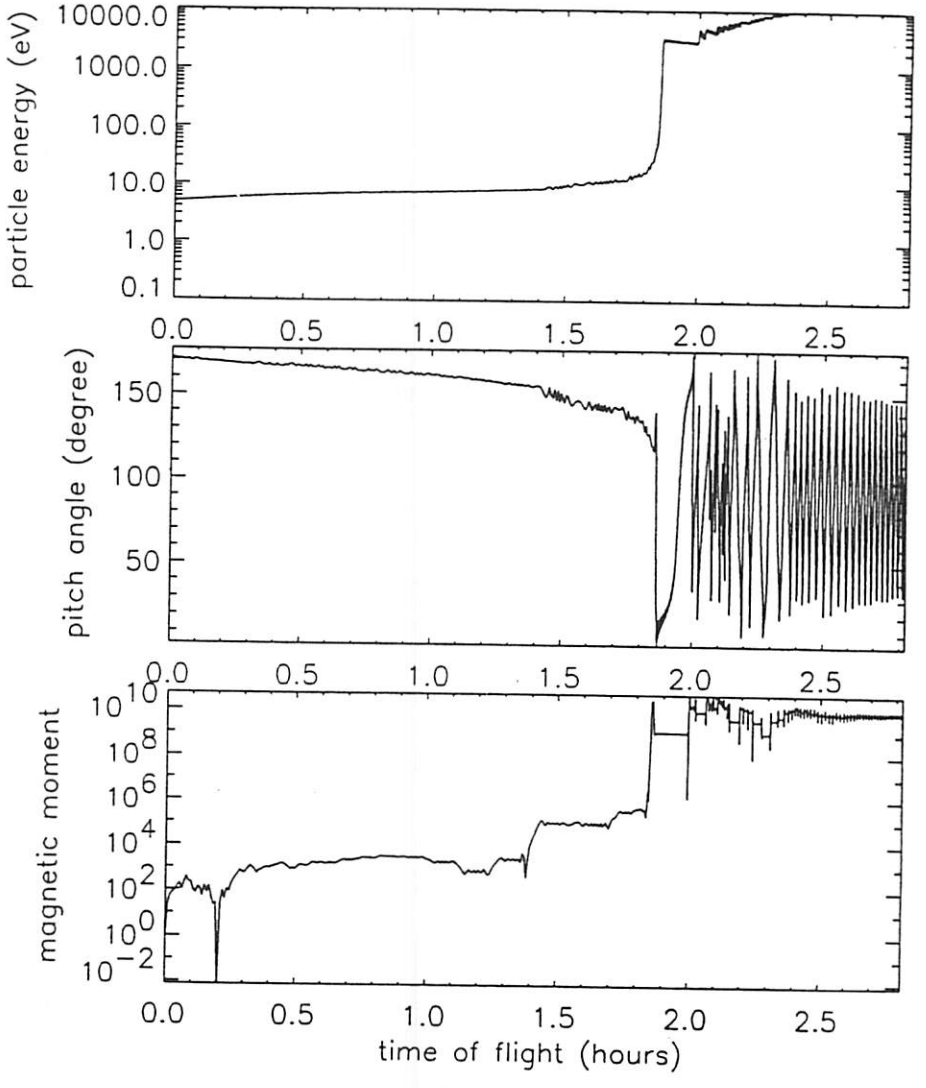
Kp level: 2
Mass (amu): 1
Local time: 19.790
Latitude: 79.730
Distance (Re): 8.660000
Energy (eV): 13.35
Pitch angle: 179.900
Phase angle: 0.000
Tilt angle: 9.153
iback, itilt, istop: 0 1 0
file: t970317-1558f.dat

Sun Nov 15 16:49:04 1998

BGcode87t.v101.for







start parameters:

Kp level: 1
Mass (amu): 1
Local time: 2.980
Latitude: 72.900
Distance (Re): 8.419999
Energy (eV): 4.77
Pitch angle: 179.900
Phase angle: 0.000
Tilt angle: −5.753

iback, itilt, istop: 0 1 0

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Tue Nov 17 17:17:25 1998

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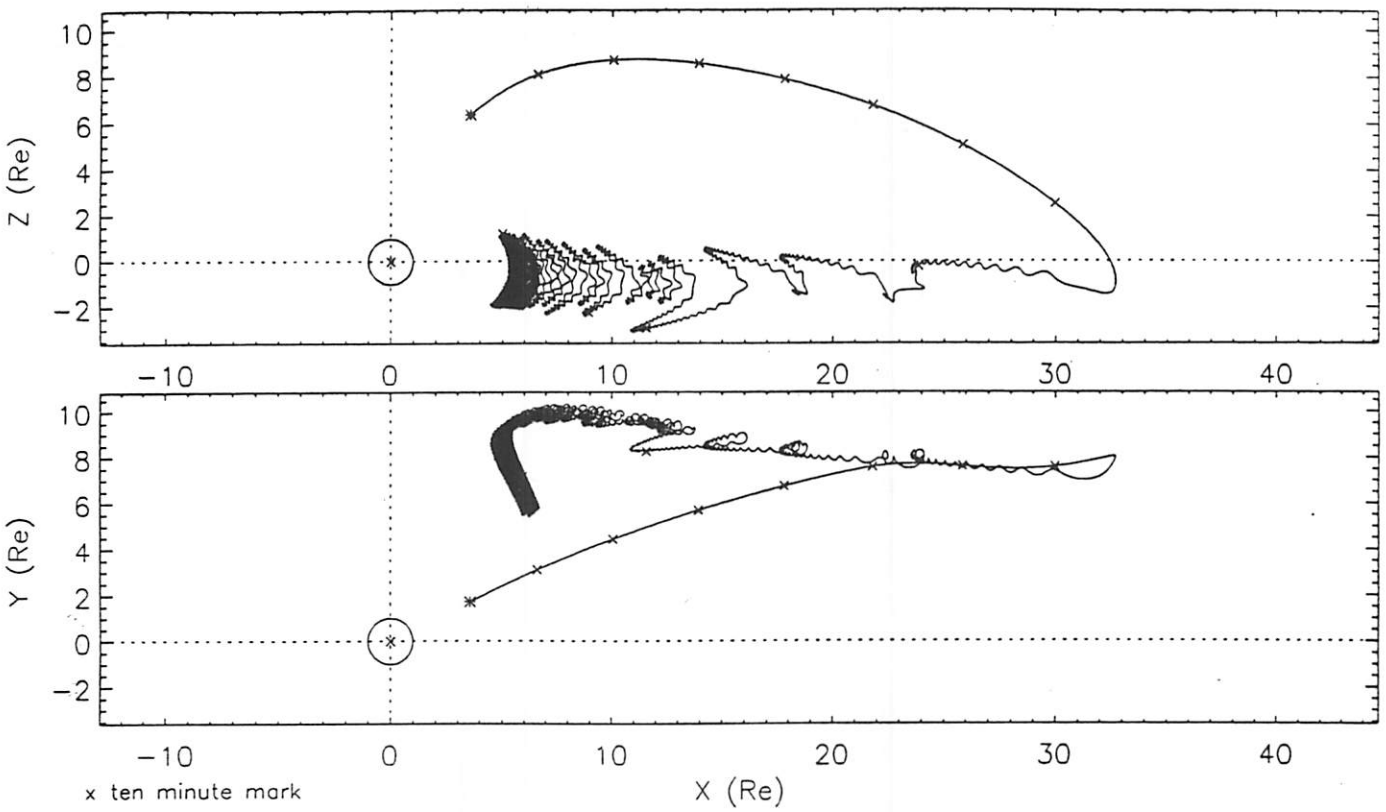

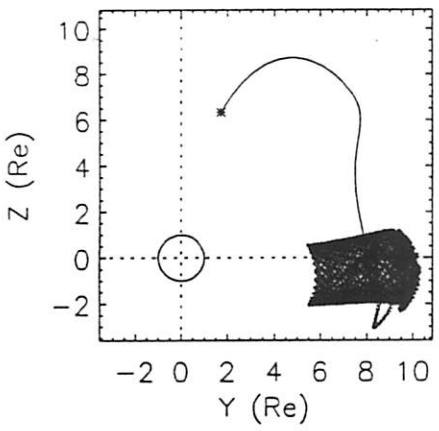

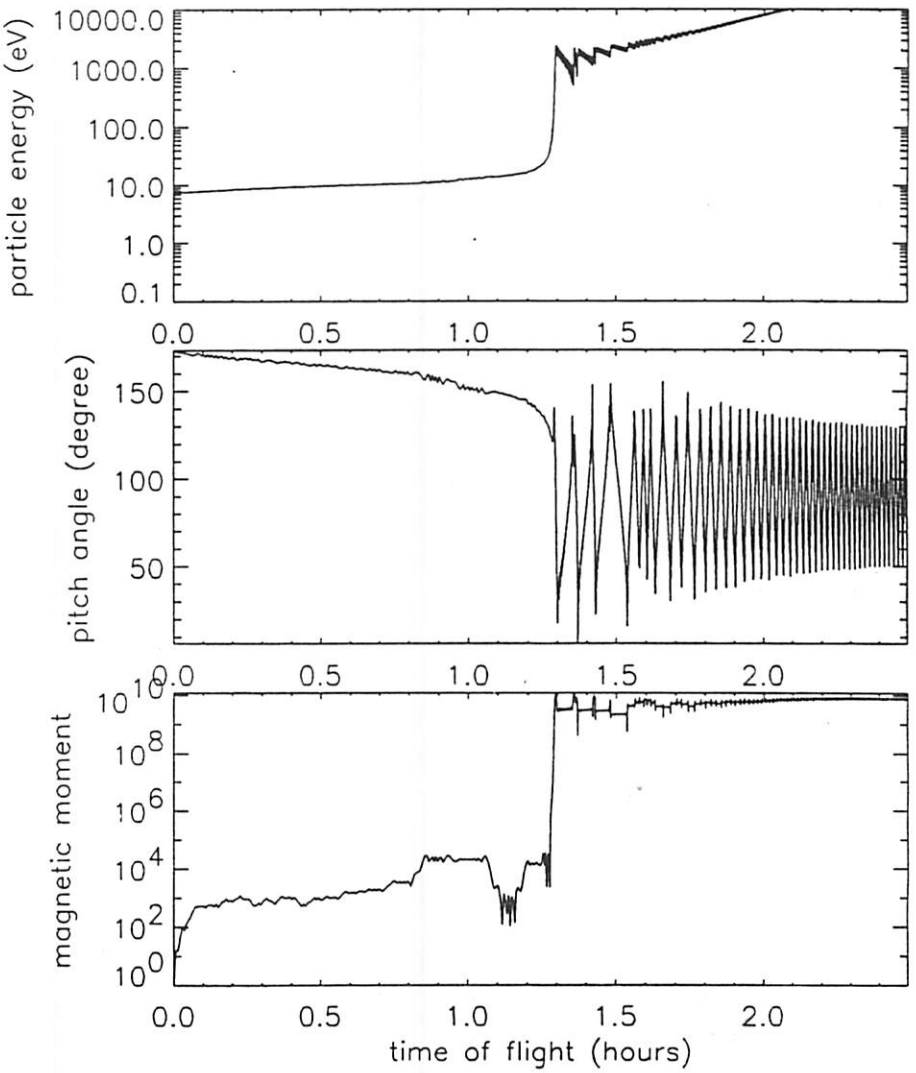

start parameters:

Kp level: 1
Mass (amu): 1
Local time: 2.280
Latitude: 65.930
Distance (Re): 7.470000
Energy (eV): 7.40
Pitch angle: 179.900
Phase angle: 0.000
Tilt angle: −9.047

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file: t970320−0240f.dat

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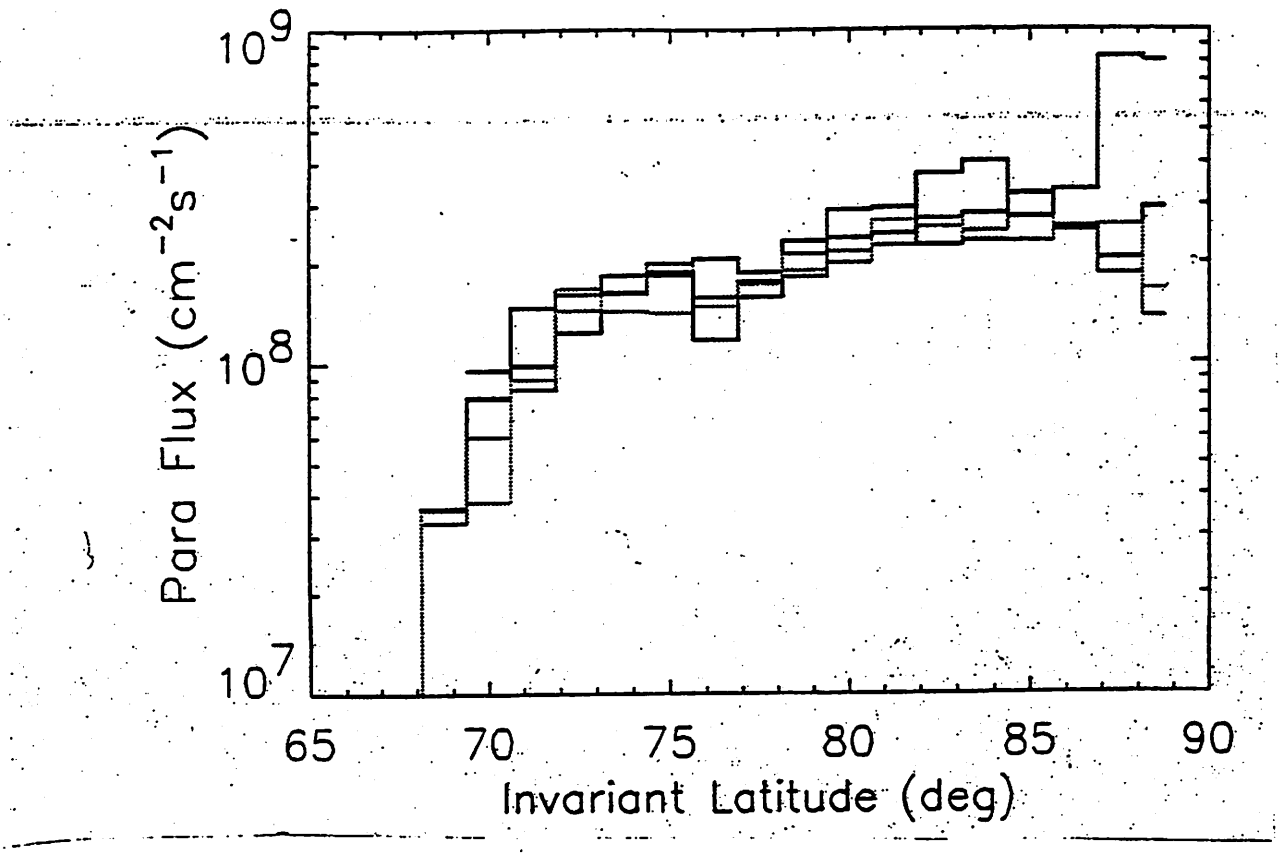
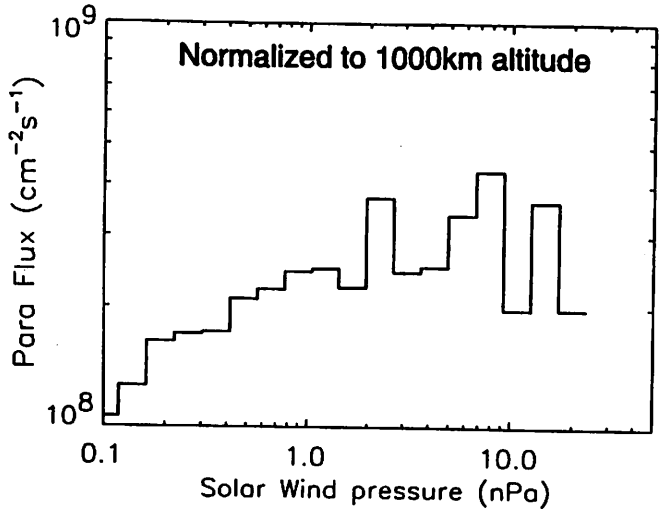
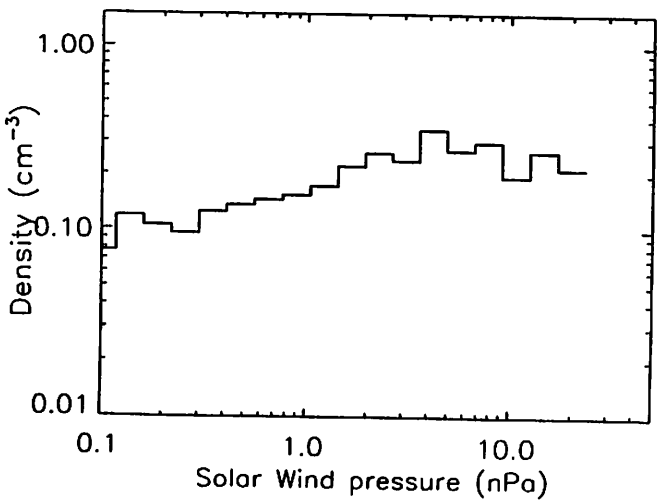
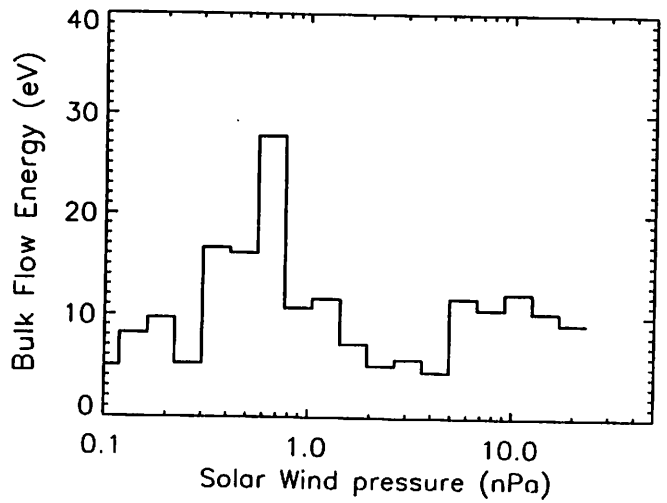

10^9
10^8
10^7
Para Flux ($cm^{-2}s^{-1}$)
65
70
75
80
85
90
Invariant Latitude (deg)

Ionosphere outflow correlations with solar wind plasma parameters





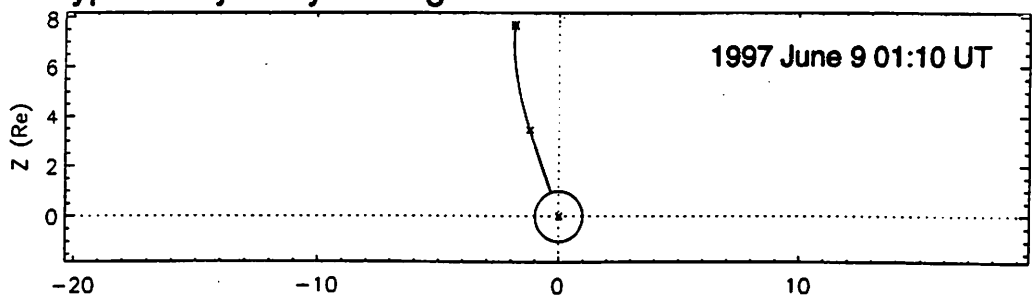


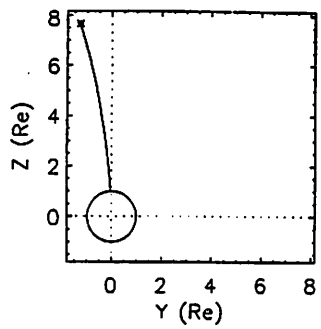
#samples = 9899

PSI Operation Periods: 1997 Mar 17-29, Apr 16-19, May 14-15, May 29-31, Jun 1-11, Aug 13-27, Nov 5-18

ORIGINS OF THE HIGH ALTITUDE THERMAL PLASMA

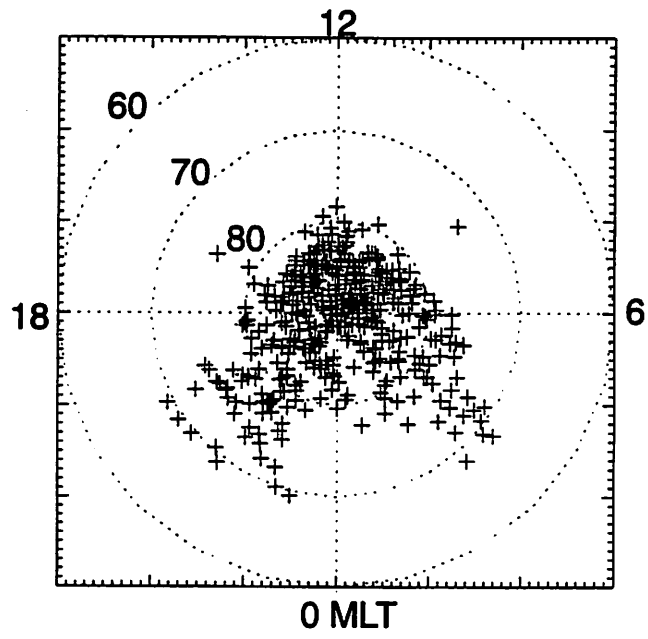
Typical trajectory tracing





start parameters:
Kp level: 6
Mass (amu): 1
Local time: 19.100
Latitude: 80.270
Distance (Re): 7.989000
Energy (eV): 11.24
Pitch angle: 179.900
Tilt angle: 16.420

Footpoints of all trajectories



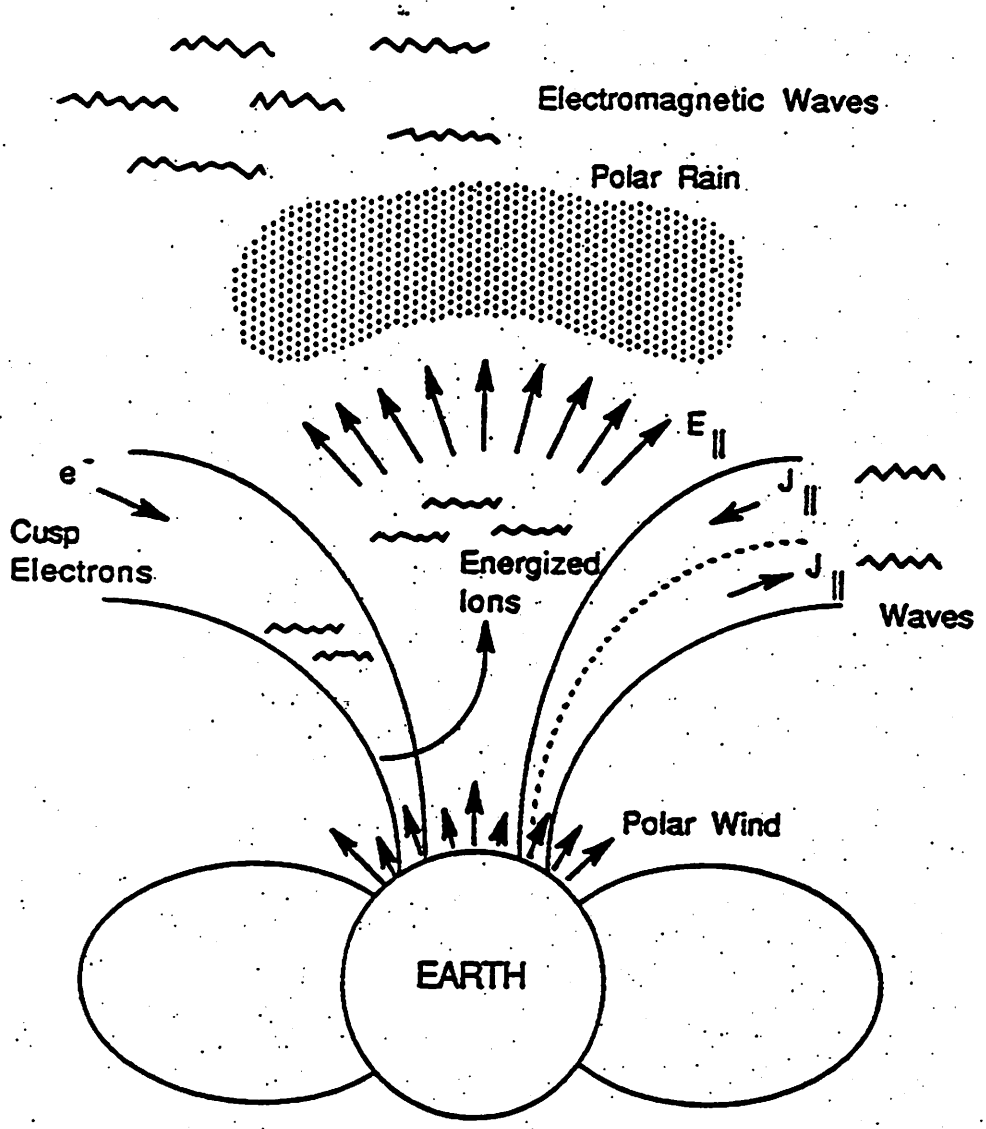


Figure 4. Schematic diagram showing the nonclassical processes that may affect the polar wind. From *Schunk and Sojka* [1997].

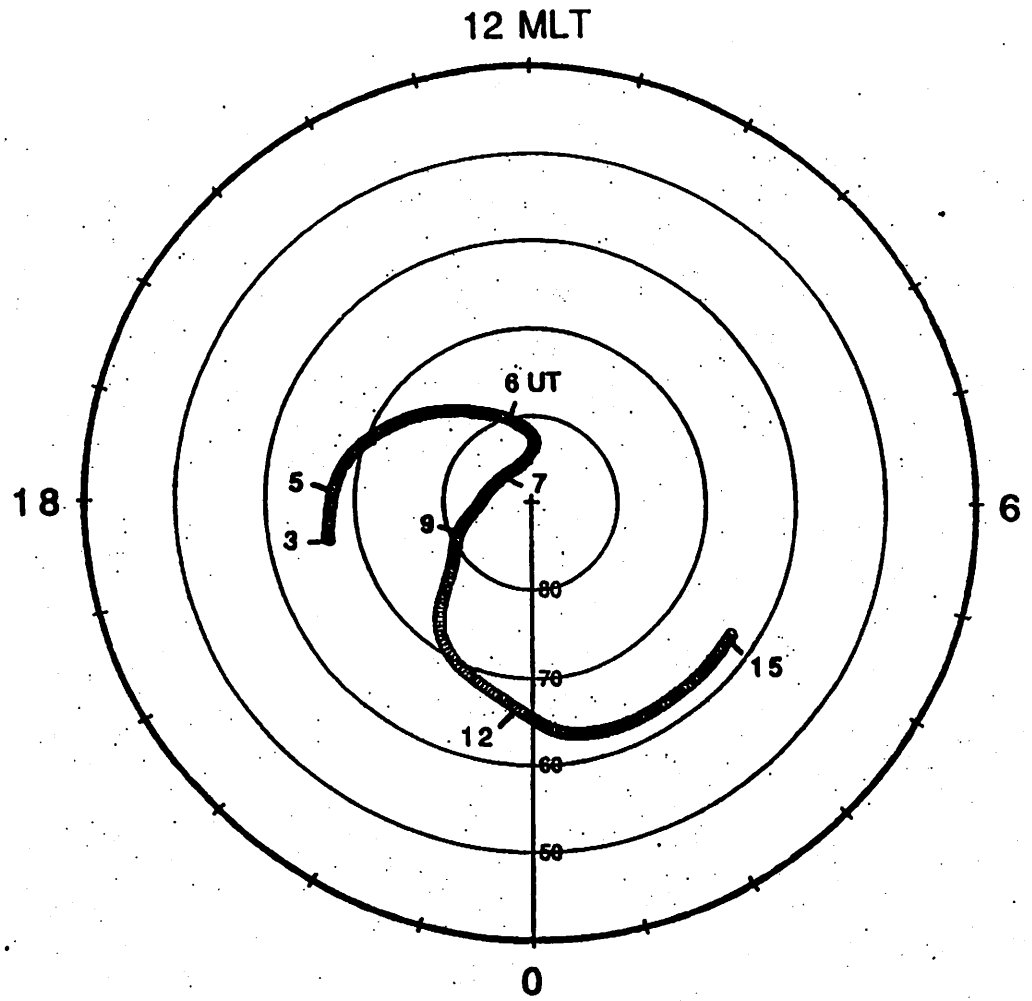


Figure 4. Convection trajectory of a representative flux tube of plasma during changing magnetic activity. At the start of the simulation the flux tube is located at about 1900 MLT and 67° magnetic latitude, as shown by the solid dot in Figure 3. The tick marks along the trajectory indicate the times in universal time hours.

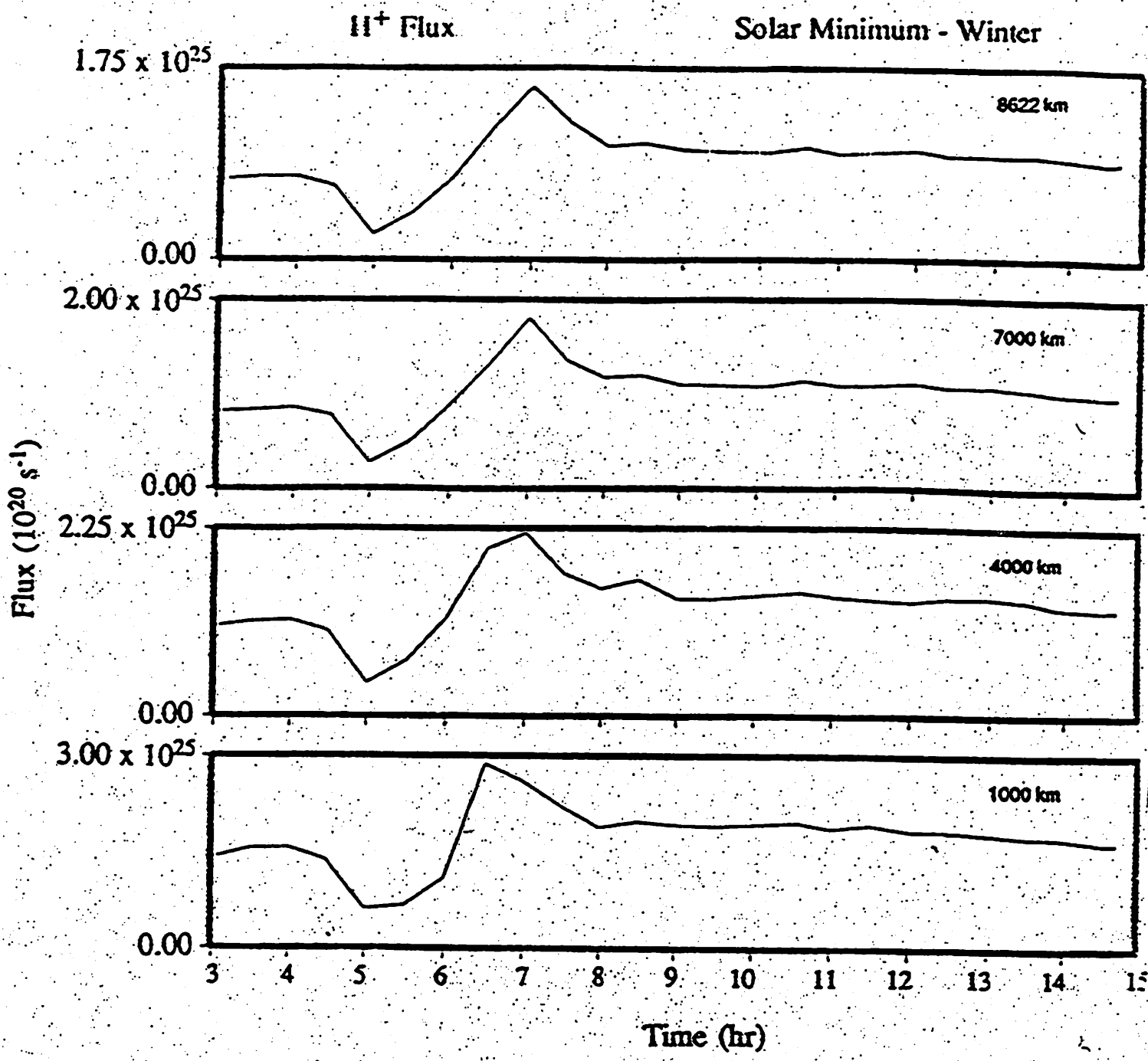
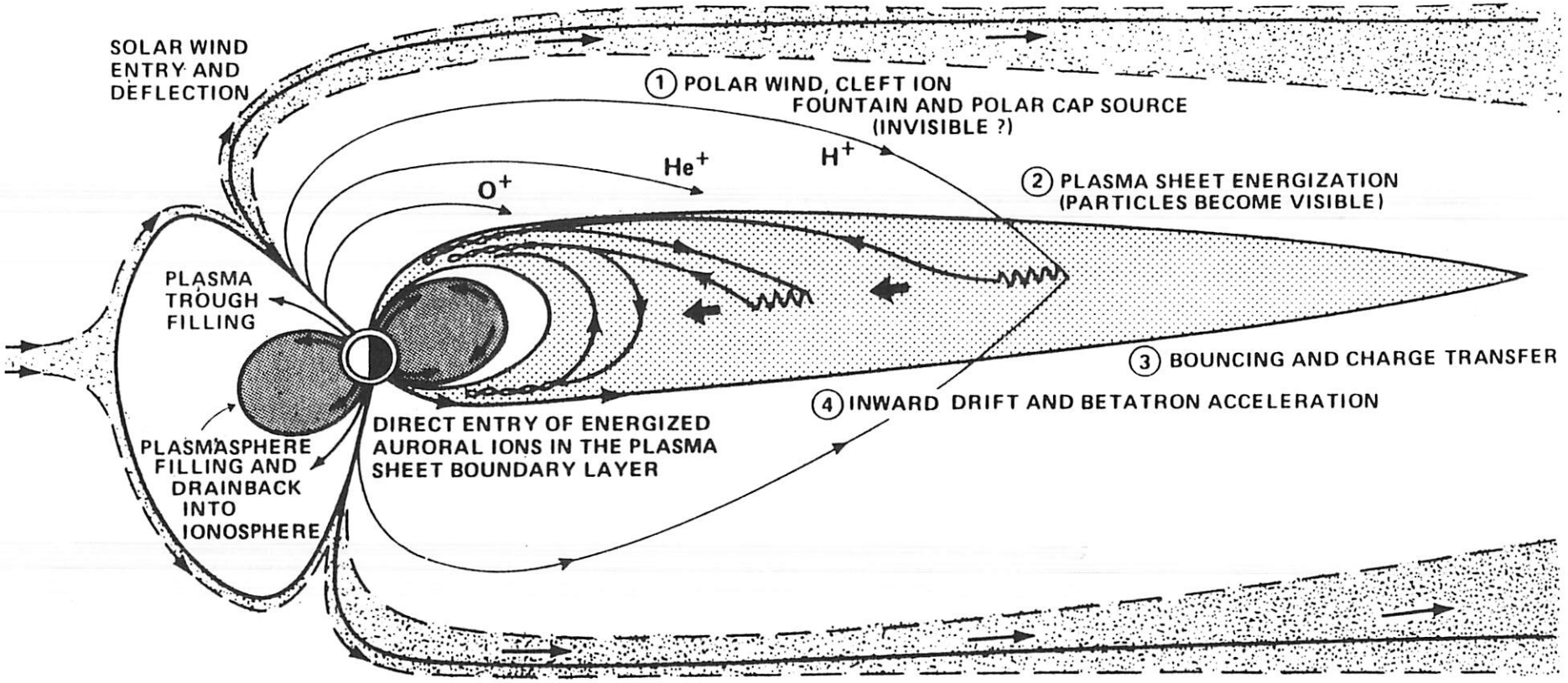


Figure 3. Total H^+ outflow rate (ions s^{-1}) versus time at selected altitudes. The outflow rate is obtained by integrating the H^+ flux over the entire polar region at each altitude. From *Schunk and Sojka* [1997].

Chappell, Moore and Waite, The Ionosphere as a Fully Adequate Source of Plasma for the Earth's Magnetosphere, JGR, 5896, 1987



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Plasma is made up of H+, He+, O+ from the polar wind, cleft ion flountain, polar cap and auroral zone.

The plasma flows up through the polar cap and the "empty" lobes of the magnetotail to the plasma sheet.