Whistler Wave Activity in the Vicinity of the Polar Cusp: Cluster Observations

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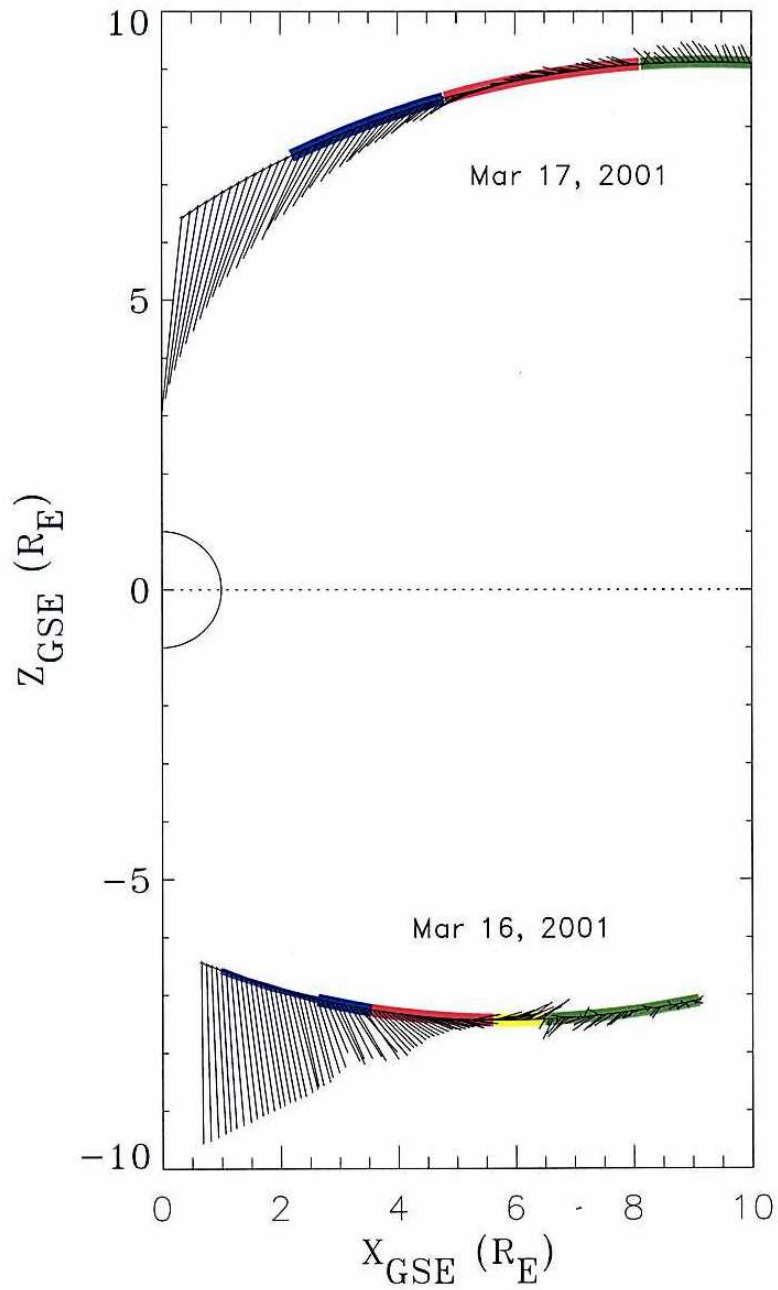
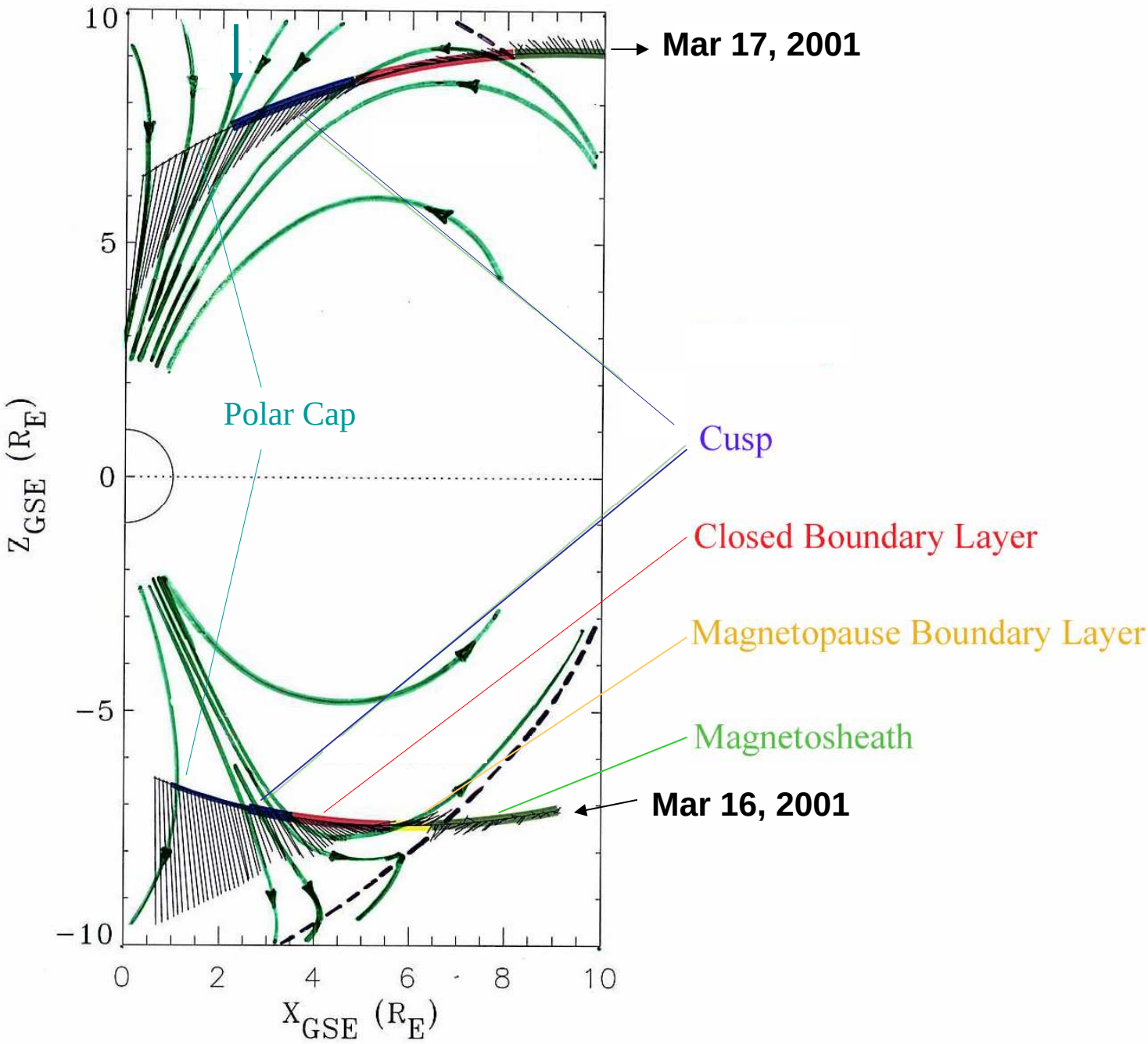
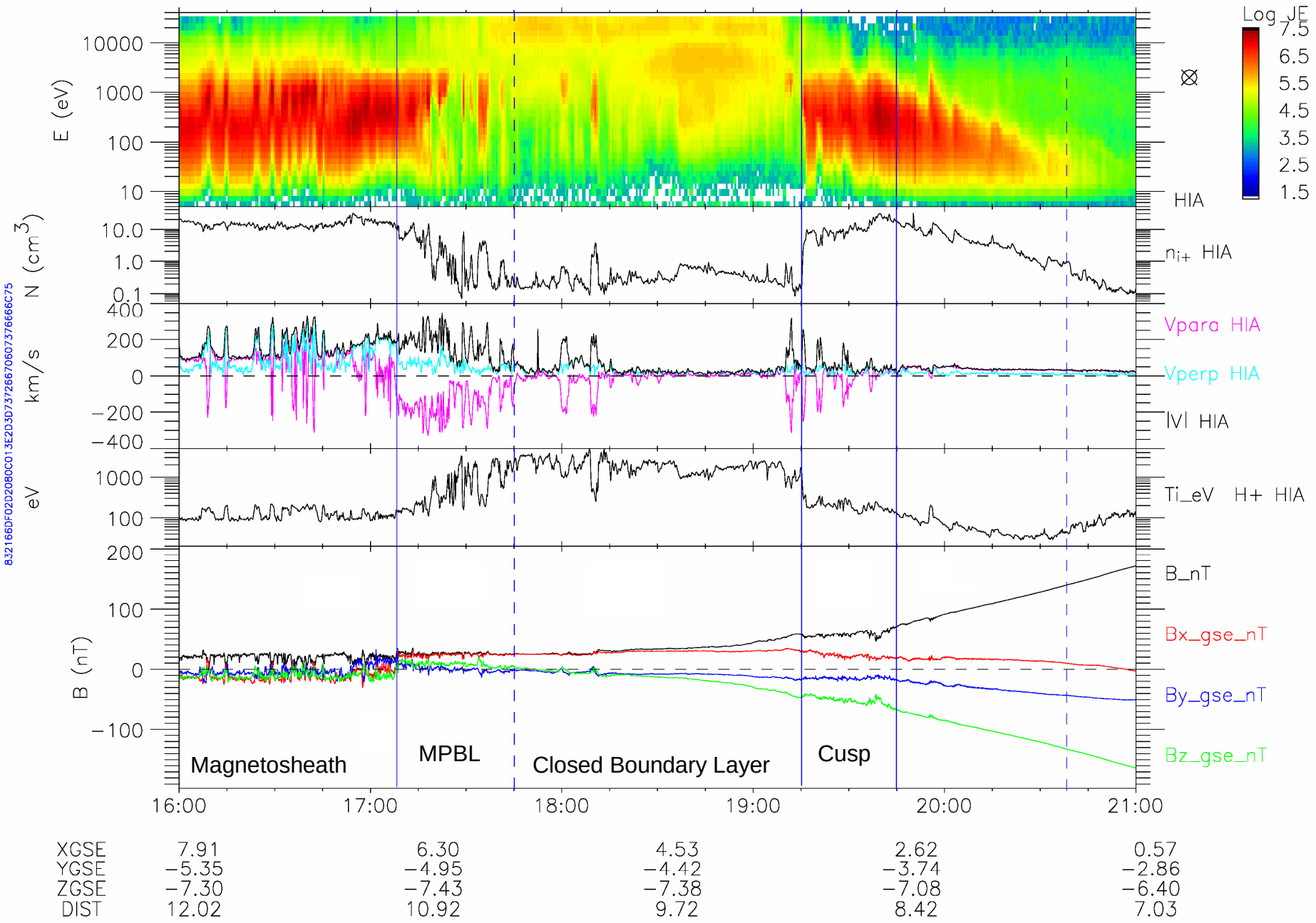
Outline

Present 3 events to illustrate

- Various regions near the polar cusp along Cluster trajectories in high altitude polar passes.
- Zoo of VLF waves in these regions.
- Examples of whistler waves associated with ~100 eV electron beams in closed boundary layer.
- Summary and comparison with previous observations.


10
5
0
−5
−10
0
2
4
6
8
10
Mar 17, 2001
Mar 16, 2001
Z_{GSE} (R_E)
X_{GSE} (R_E)


Mar 17, 2001
Polar Cap
Cusp
Closed Boundary Layer
Magnetopause Boundary Layer
Magnetosheath
Mar 16, 2001
10
5
0
−5
−10
0
2
4
6
8
10
Z_{GSE} (R_E)
X_{GSE} (R_E)



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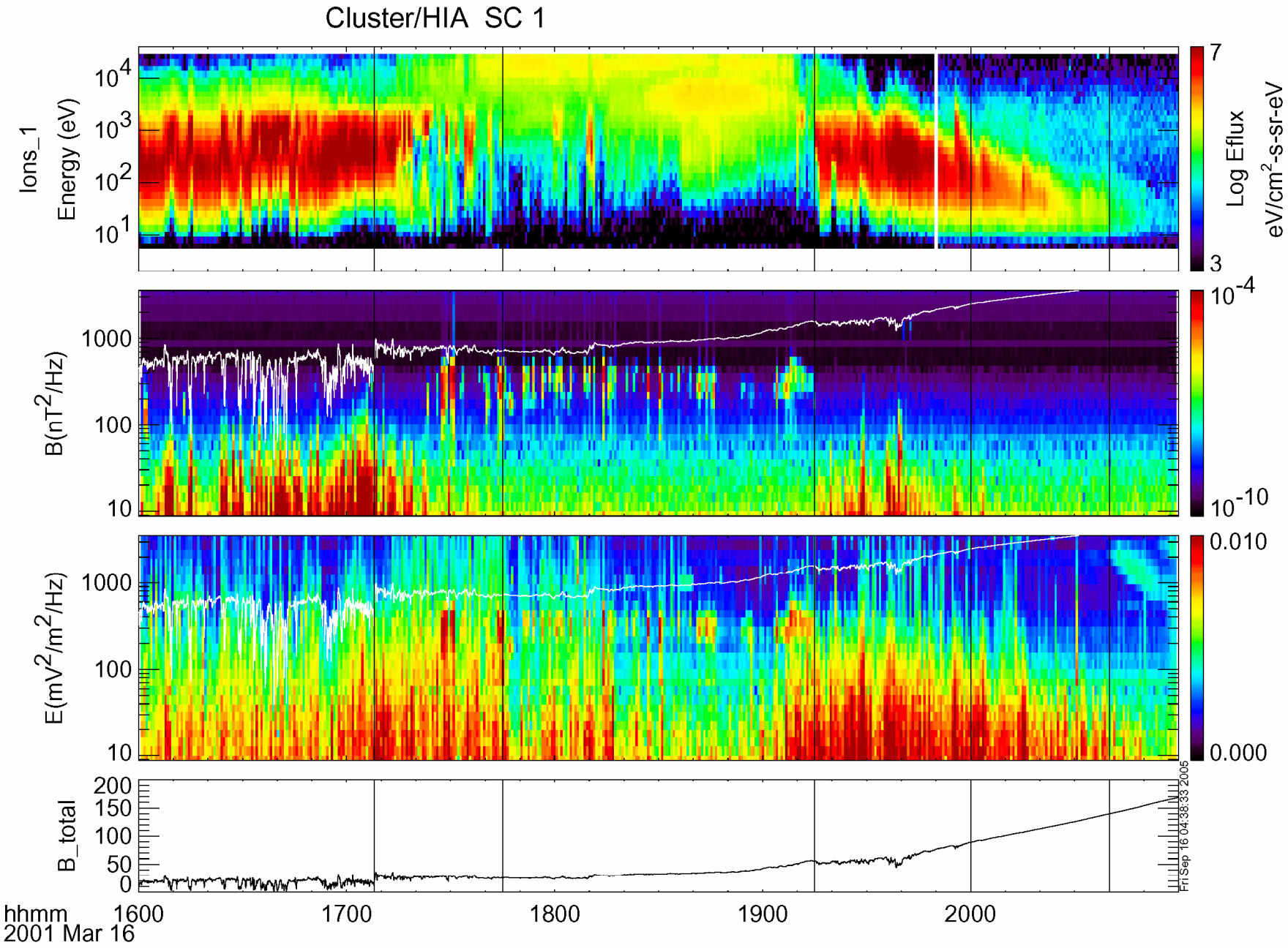
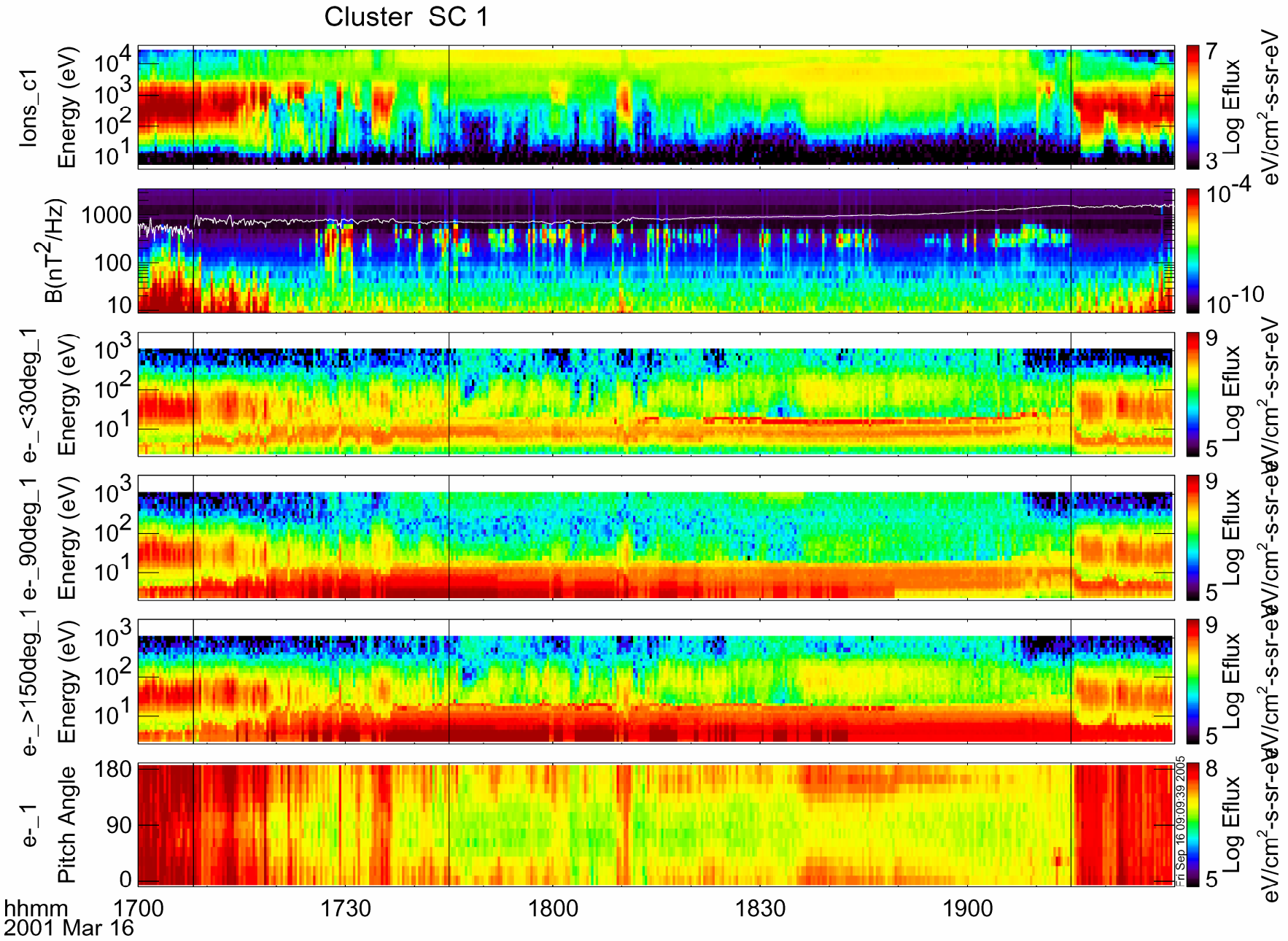

Cluster/HIA SC 1
Ions_1
Energy (eV)
10^4
10^3
10^2
10^1
7
3
Log Eflux
eV/cm^2-s-sr-eV
B(nT^2/Hz)
1000
100
10
10^{-4}
10^{-10}
E(mV^2/m^2/Hz)
1000
100
10
0.010
0.000
B_total
200
150
100
50
0
Fri Sep 16 04:38:33 2005
hhmm
2001 Mar 16
1600
1700
1800
1900
2000


Cluster SC 1
Ions_c1
Energy (eV)
Log Eflux
eV/cm2-s-sr-eV
B(nT2/Hz)
e-_<30deg_1
e-_90deg_1
e-_>150deg_1
e-_1
Pitch Angle
hhmm
2001 Mar 16
1700
1730
1800
1830
1900
Fri Sep 16 09:09:39 2005

Waves observed:

In the cusp :

Broadband magnetic noise, at a few Hz to several hundred Hz, always<fce.

Broadband electrostatic emission.

In the high latitude magnetosheath near the cusp:

Broadband magnetic noise, at a few Hz to several hundred Hz, always<fce.

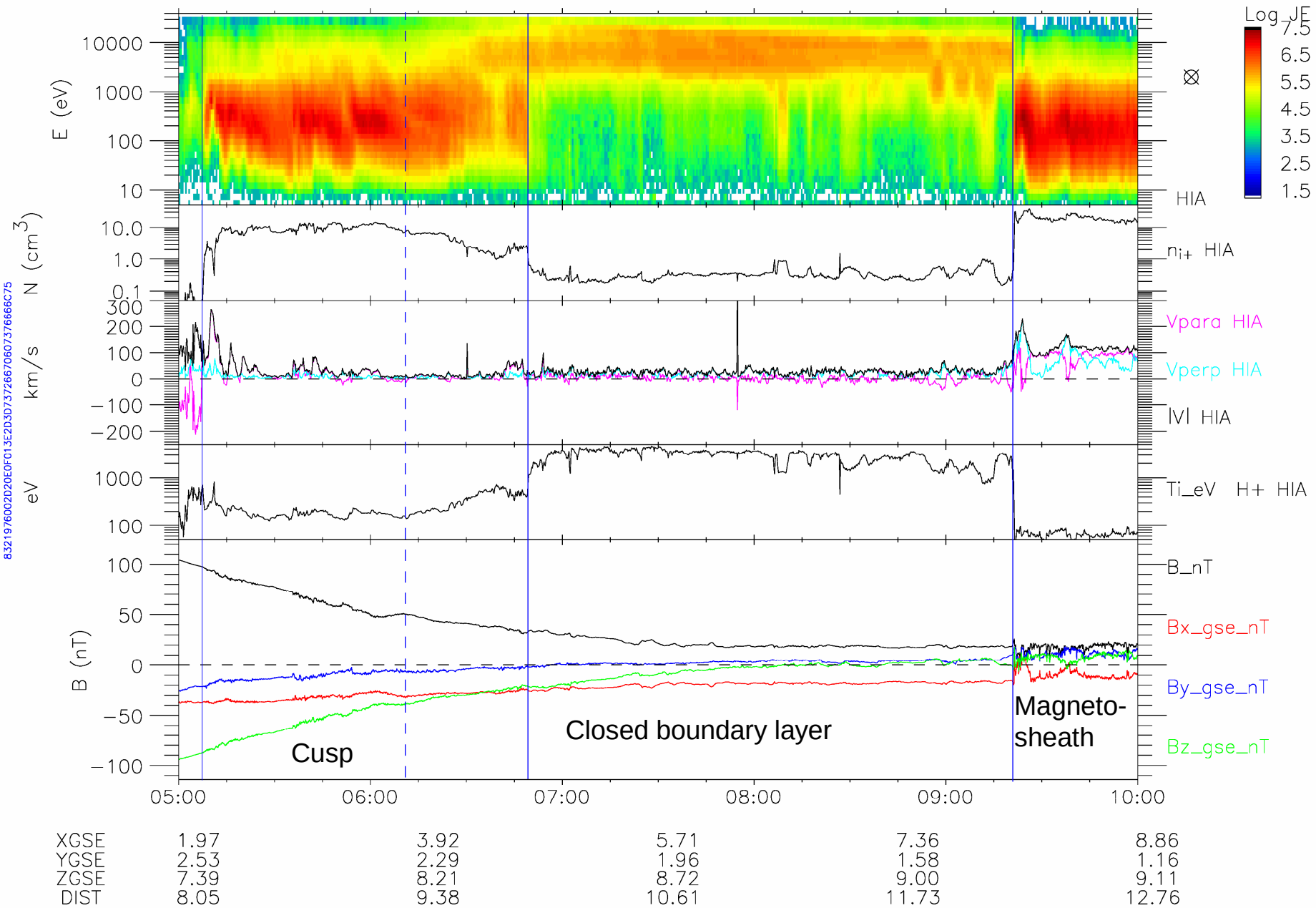
Broadband electrostatic emission.

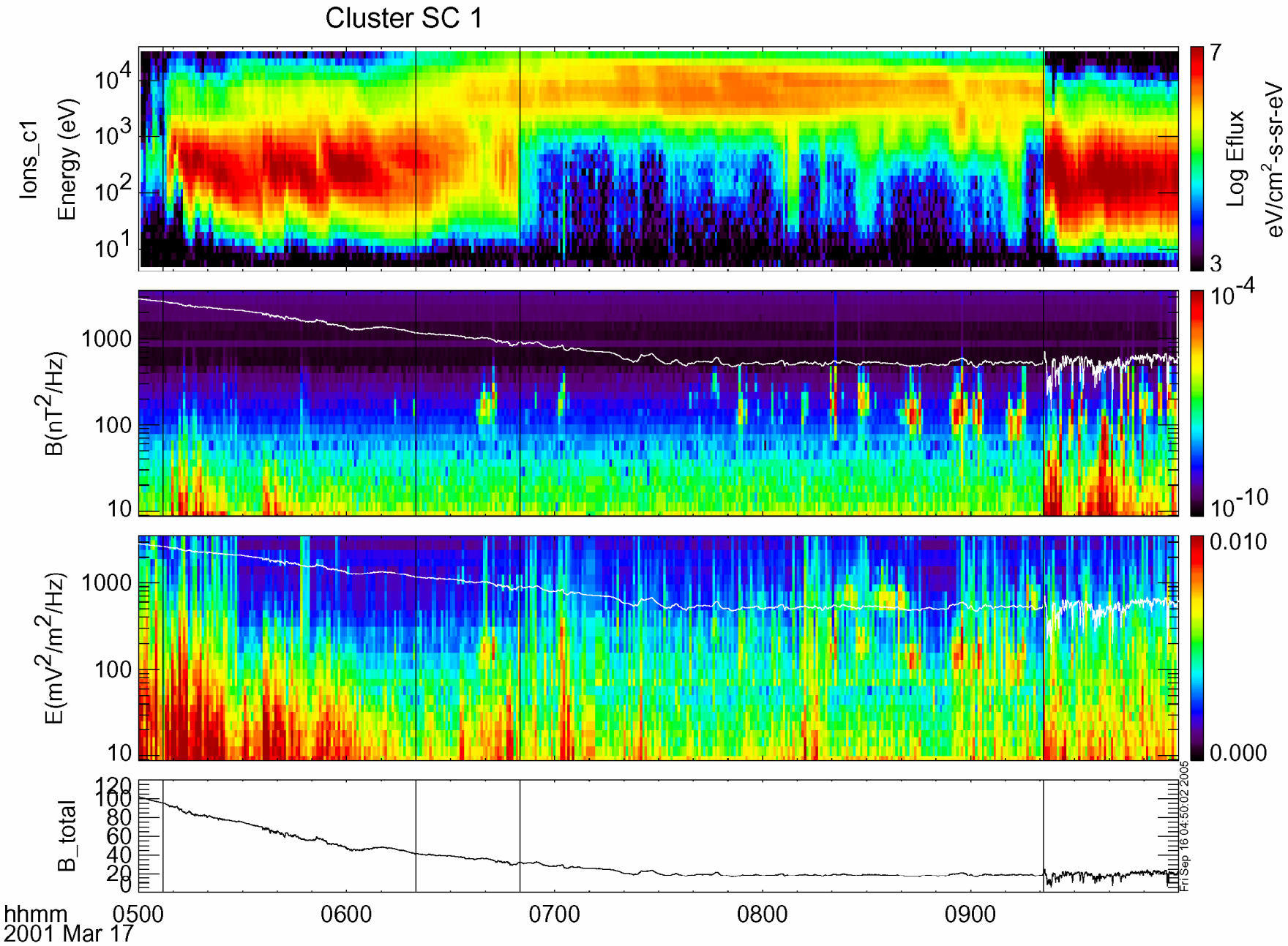
Lion roars.

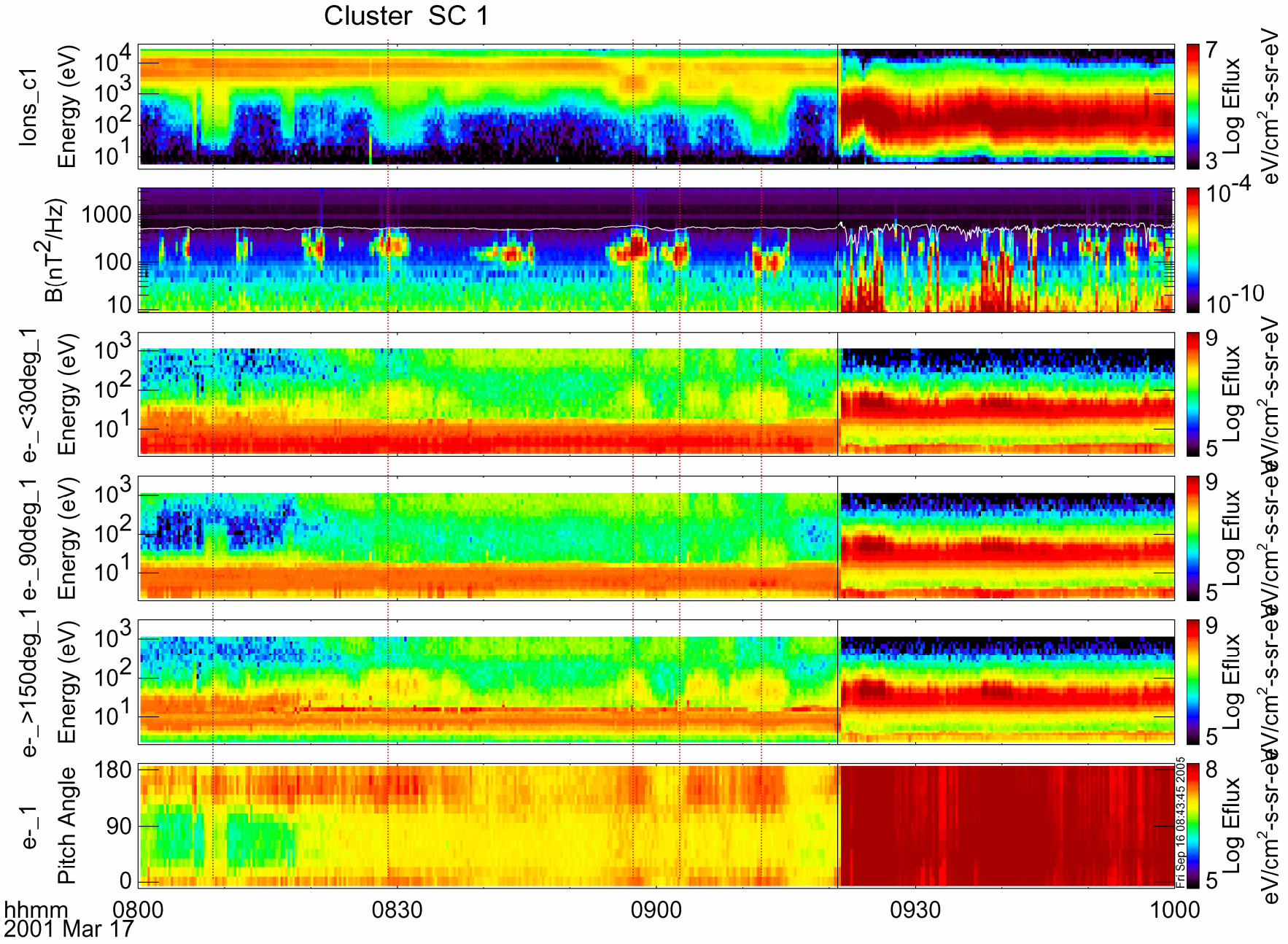
In the closed boundary layer:

Narrowband whistler waves associated with the electron beams of ~100 eV.

Narrow band electrostatic emissions.


CIS–HIA
RUMBA (SC 1)
17/Mar/2001
E (eV)
10000
1000
100
10
Log_JE
7.5
6.5
5.5
4.5
3.5
2.5
1.5
HIA
N (cm3)
10.0
1.0
0.1
ni+ HIA
km/s
300
200
100
0
−100
−200
Vpara HIA
Vperp HIA
|V| HIA
eV
1000
100
Ti_eV H+ HIA
B (nT)
100
50
0
−50
−100
B_nT
Bx_gse_nT
By_gse_nT
Bz_gse_nT
Cusp
Closed boundary layer
Magneto-sheath
05:00
06:00
07:00
08:00
09:00
10:00
XGSE 1.97 3.92 5.71 7.36 8.86
YGSE 2.53 2.29 1.96 1.58 1.16
ZGSE 7.39 8.21 8.72 9.00 9.11
DIST 8.05 9.38 10.61 11.73 12.76


Cluster SC 1
Ions_c1
Energy (eV)
10^4
10^3
10^2
10^1
Log Eflux
eV/cm^2-s-sr-eV
7
3
B(nT^2/Hz)
1000
100
10
10^{-4}
10^{-10}
E(mV^2/m^2/Hz)
1000
100
10
0.010
0.000
B_total
120
100
80
60
40
20
0
Fri Sep 16 04:50:02 2005
hhmm
2001 Mar 17
0500
0600
0700
0800
0900


Cluster SC 1
Ions_c1
Energy (eV)
Log Eflux
eV/cm2-s-sr-eV
B(nT2/Hz)
e-_<30deg_1
e-_90deg_1
e-_>150deg_1
e-_1
Pitch Angle
Fri Sep 16 08:43:45 2005
hhmm
2001 Mar 17
0800
0830
0900
0930
1000

Examples of Whistler waves associated with electron beams

Interval1: 3/16/2001 1840-1843 UT

f~280 Hz, B~30nT, N~0.8

cB/E~42, Vphi~0.023c, Te~132 eV

(Estimated index of refraction

$n=[f^2/f(f_{ce}\cos 0-f)]^{1/2} \sim 20$)

Interval2: 3/17/2001 0855-0858 UT

f~200 Hz, B~20nT, N~0.5

cB/E~64, Vphi~0.02c, Te~100 eV

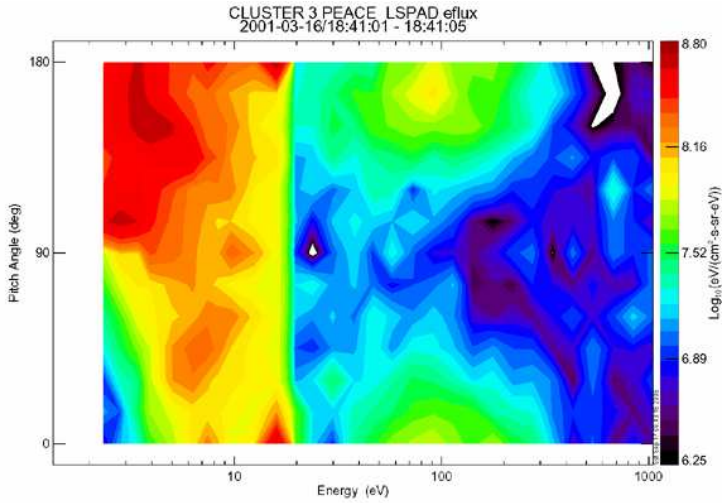
(Estimated index of refraction n~23)

Interval2: 3/17/2001 0910-0915 UT

f~100 Hz, B~20nT, N~0.4

cB/E~94, Vphi~0.01c, Te~25 eV

(Estimated index of refraction n~25)

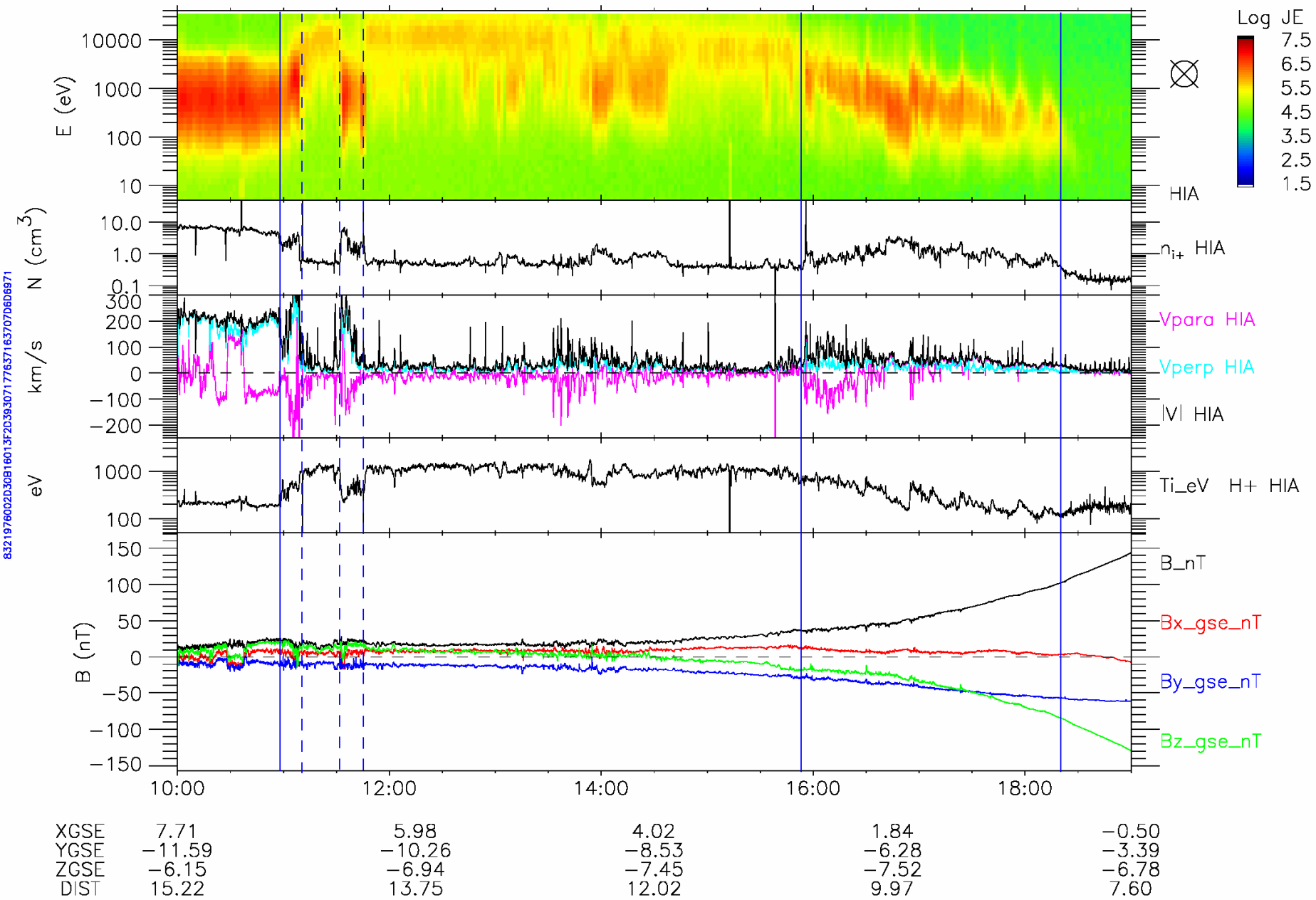


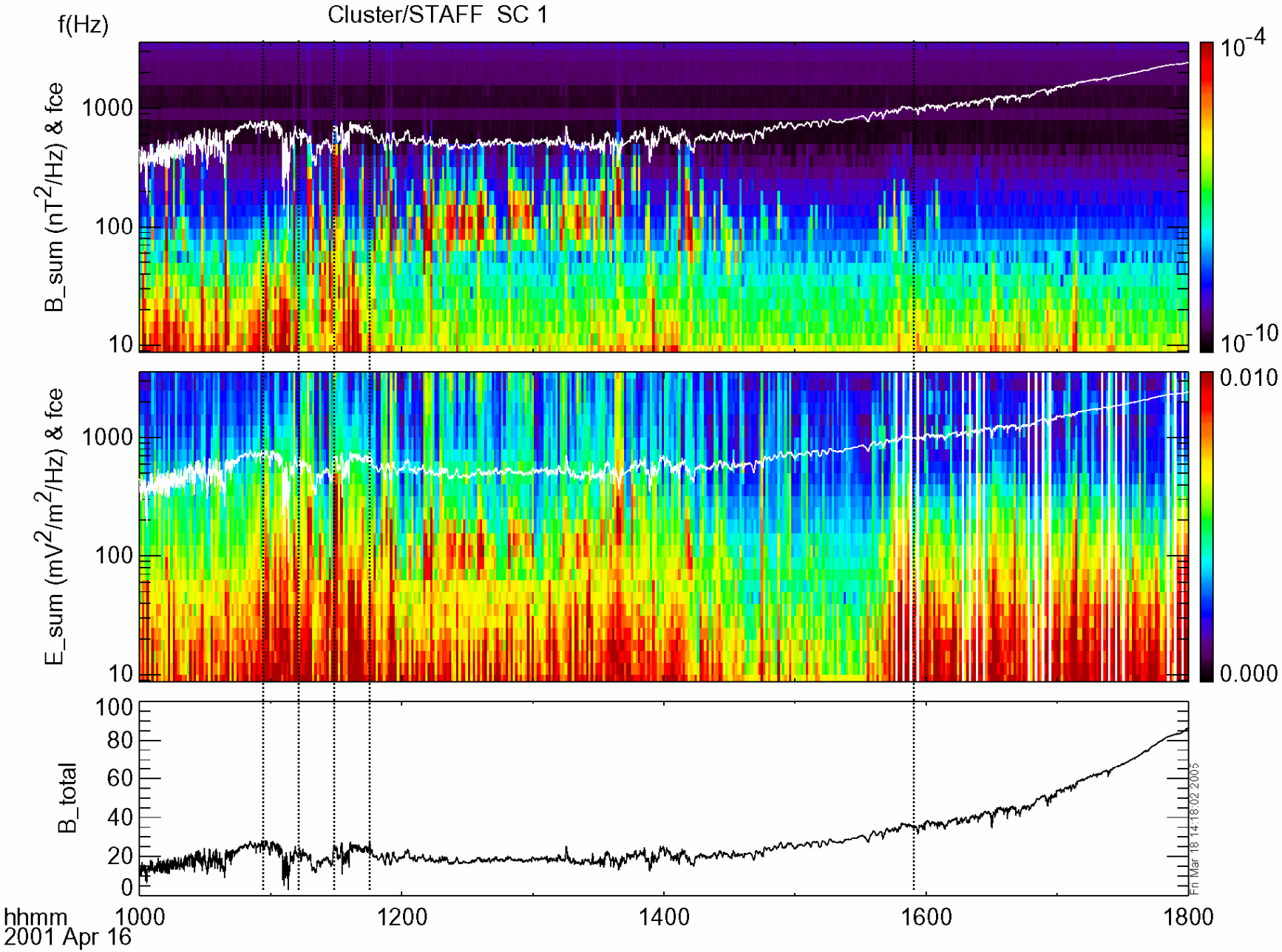
Previous observations of Whistler in Polar Cap Boundary Layer (Tsurutani et al.,1998):

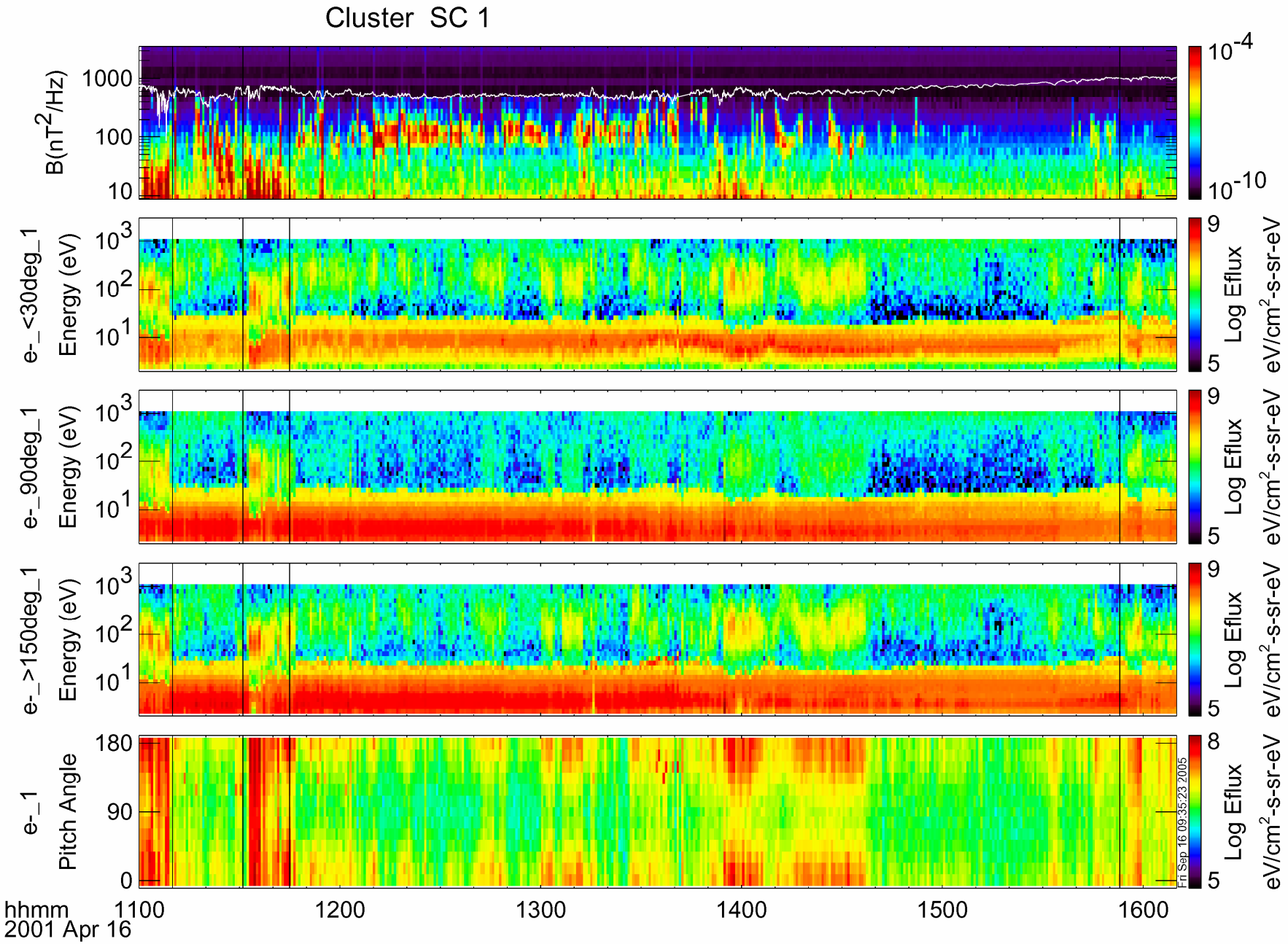
At r~6-7 R_E, f<fce,

Vphi ~0.01c

Te ~ 100 eV


CIS–HIA
RUMBA (SC 1)
16/Apr/2001
Log JE
7.5
6.5
5.5
4.5
3.5
2.5
1.5
E (eV)
10000
1000
100
10
HIA
N (cm3)
10.0
1.0
0.1
ni+ HIA
km/s
300
200
100
0
−100
−200
Vpara HIA
Vperp HIA
|V| HIA
eV
1000
100
Ti_eV H+ HIA
B (nT)
150
100
50
0
−50
−100
−150
B_nT
Bx_gse_nT
By_gse_nT
Bz_gse_nT
10:00
12:00
14:00
16:00
18:00
XGSE 7.71 5.98 4.02 1.84 −0.50
YGSE −11.59 −10.26 −8.53 −6.28 −3.39
ZGSE −6.15 −6.94 −7.45 −7.52 −6.78
DIST 15.22 13.75 12.02 9.97 7.60


Cluster/STAFF SC 1
f(Hz)
B_sum (nT²/Hz) & fce
1000
100
10
10⁻⁴
10⁻¹⁰
E_sum (mV²/m²/Hz) & fce
1000
100
10
0.010
0.000
B_total
100
80
60
40
20
0
hhmm
2001 Apr 16
1000
1200
1400
1600
1800
Fri Mar 18 14:18:02 2005


Cluster SC 1
B(nT2/Hz)
1000
100
10
10-4
10-10
e-_<30deg_1
Energy (eV)
10^3
10^2
10^1
9
5
Log Eflux
eV/cm2-s-sr-eV
e-_90deg_1
e-_>150deg_1
e-_1
Pitch Angle
180
90
0
8
Fri Sep 16 09:35:23 2005
hhmm
2001 Apr 16
1100
1200
1300
1400
1500
1600

Summary

(1) Broadband magnetic noise at a few Hz to several hundred Hz, always<fce, are observed in the cusp and in the high latitude magnetosheath near the cusp. Most likely to be whistler mode waves.

It is similar to "ULF-ELF magnetic noise" of the cusp in Hawkeye observations [Gurnett and Frank, 1978], which was suggested as uniquely associated with the cusp.

(2) Broadband electrostatic emission at several Hz to above several kHz, with maximum intensity below 100 Hz, occur in the cusp and in the magnetosheath.

(3) Narrowband whistler waves slightly below fce occur in the closed boundary layer. These waves are associated with the electron beams of ~100 eV. These waves are similar to the whistler waves observed at night-side Polar Cap Boundary Layer [Tsurutani et al., 1998].

(4) Narrow band electrostatic emissions at slightly above fce mostly seen in the closed boundary layer.

Gurnett and Frank (1978) observed similar waves occurring in the cusp and extended to the magnetosphere and polar cap region. (electron cyclotron waves)

Menietti et al., (2002) Polar observations: generated by low energy electron beams (< 1keV).

(5) "Lion roars" are also observed in the high latitude magnetosheath in the dips of mirror mode waves (Maksimovic et al., 2001).

These waves are commonly observed in high altitude polar passes of Cluster spacecraft. Observations of these waves may serve as indicators of various regions in the vicinity of the cusp.