Temporal and spatial scales of a high-flux-electron disturbance in the cusp region: Cluster observations

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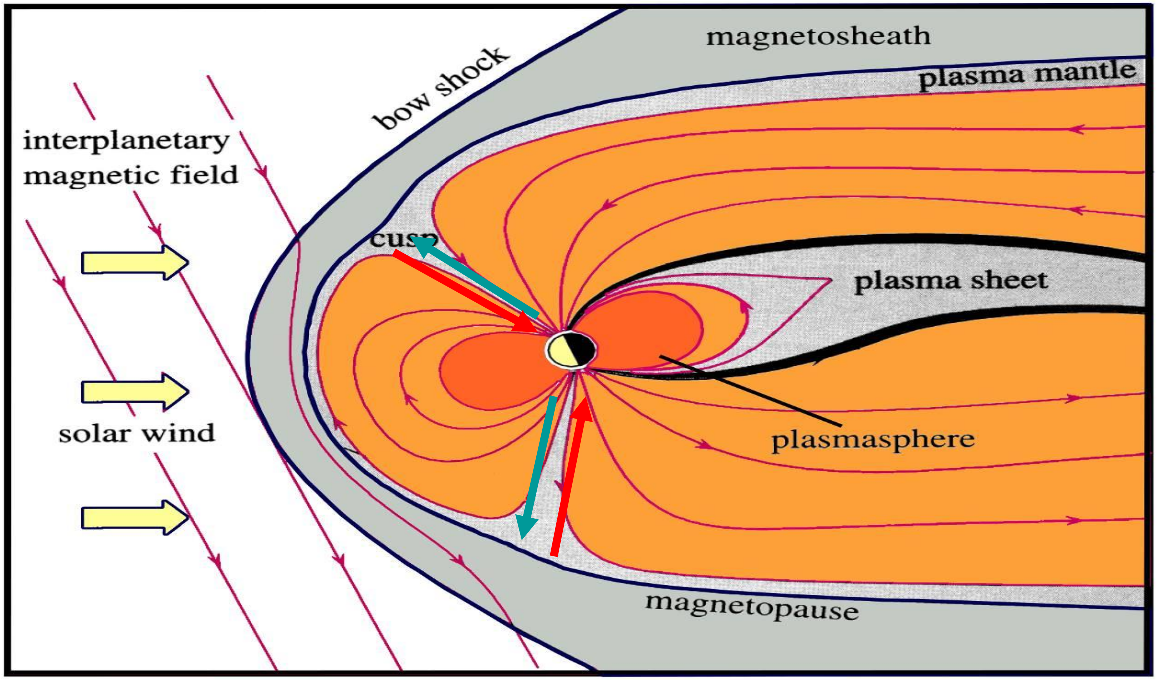
Outline

1 Introduction

The cusp is important to the solar wind -magnetosphere- ionosphere coupling.



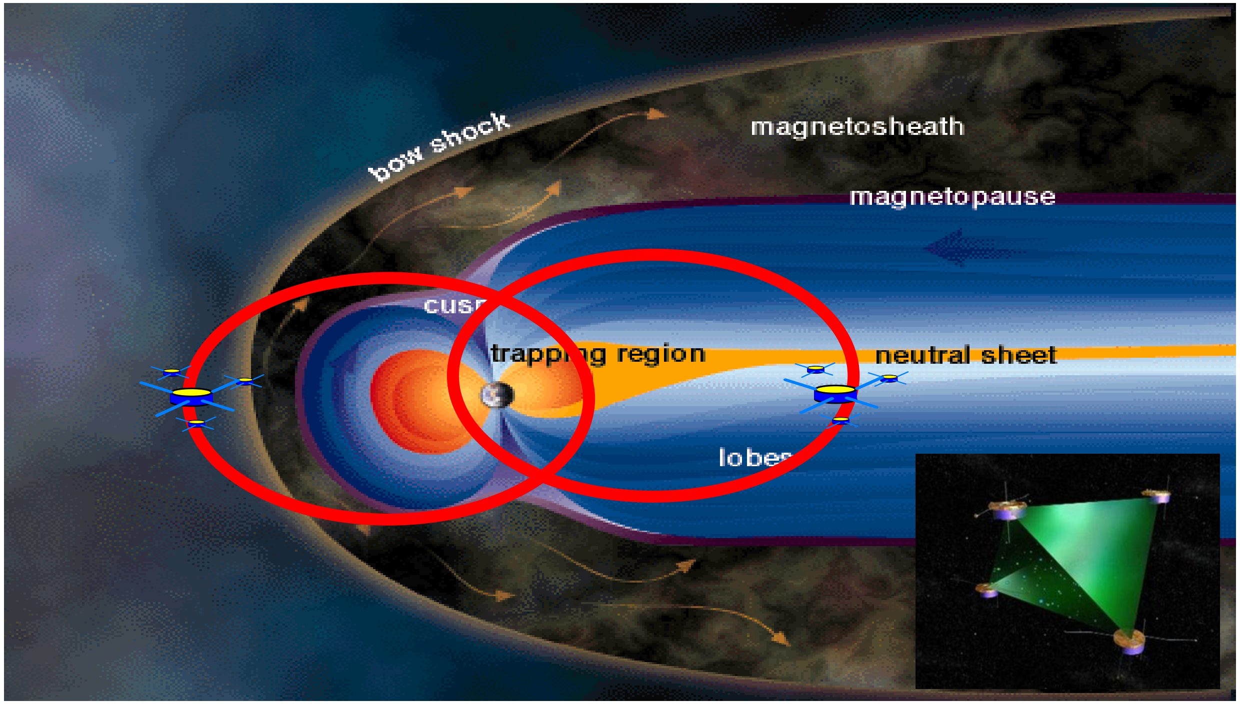
- Through the cusp, solar wind particles can entry into magnetosphere, and sometimes deeper into ionosphere.
- Ionospheric particles can go up into magnetotail and dayside magnetopause.
- Field-Aligned Electrons (FAEs) is active in the cusp region

Many authors have studied the FAEs in the cusp / polar region:

- In 1981, Zanetti et al reported the down-flowing FAEs in low-altitude (300-1000km) cusp region (AE-C and -D).
- In 1983, Burch et al reported up/down FAEs in the cusp above 1Re (DE-1).
- In 1990, Gosling et al reported that up / down FAEs exist in both in low- and high-latitude boundary of the cusp. 8-10 Re, ISEE
- In 1992, Crooker et al reported down-flowing electrons in the high-latitude boundary of the cusp during the northern IMF.（838-870km） DMSP
- In 1996, Smith and Lockwood reported down-flowing electrons in the low-latitude boundary of the cusp during the southern IMF. （838-870km） DMSP

Cluster Obrbit: Dayside season – high-altitude cusp (10Re)

Nightside season – mid-altitude cusp (4-6Re) ✓

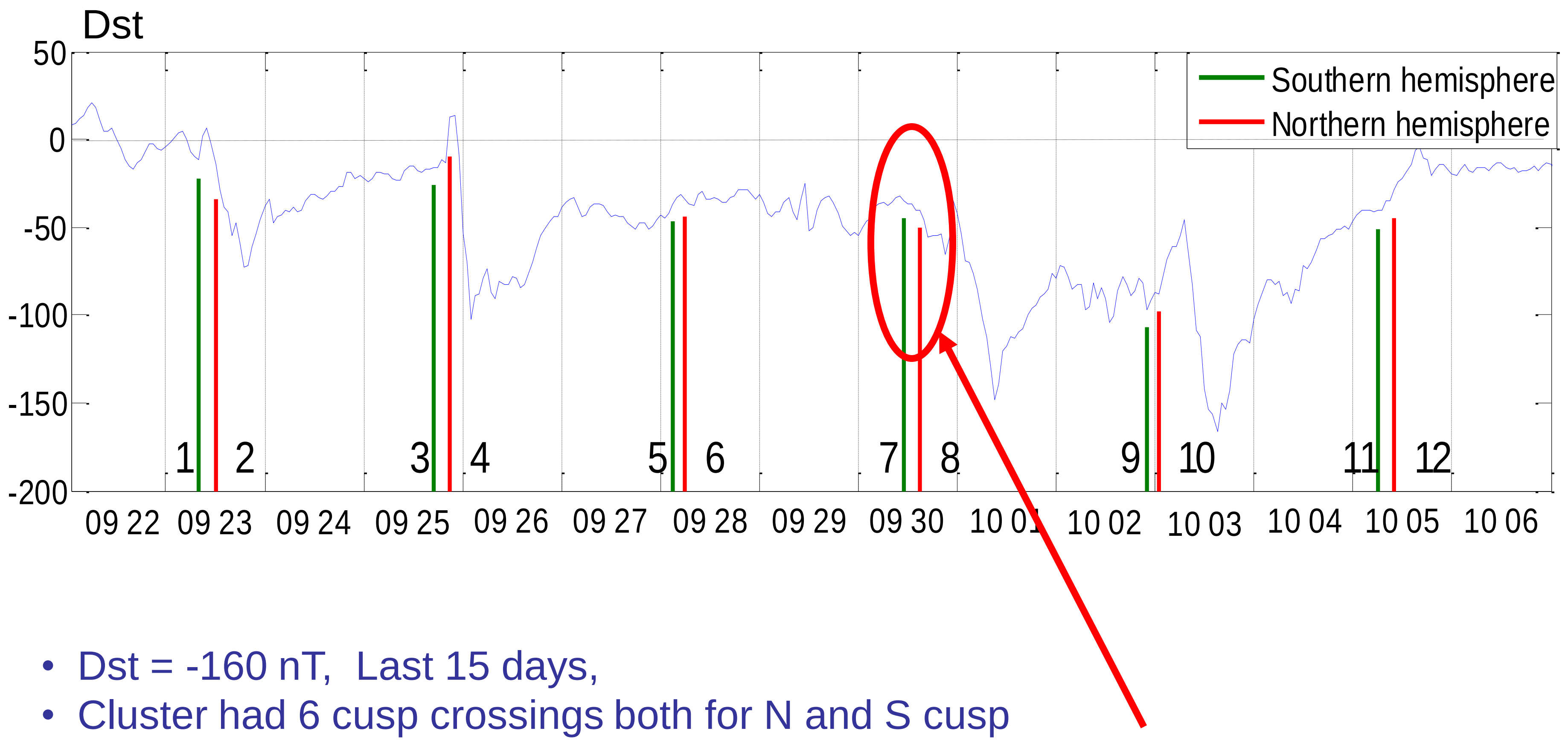


Cluster with its instrument provide a good opportunity to study the FAEs in the cusp and polar region

In this study, a high flux of the FAE disturbance in the cusp is presented with Cluster observation.

2 High flux electron disturbances

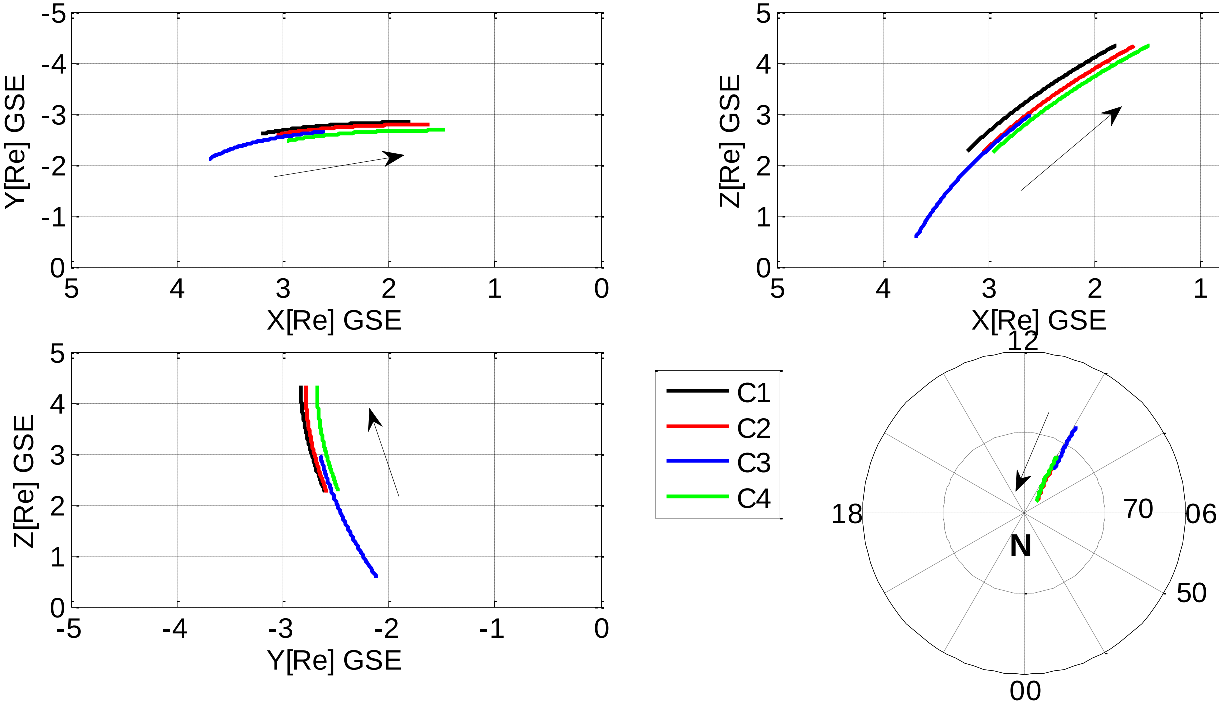
Storm from Sep. 22 to Oct. 6, 2001



- Dst = -160 nT, Last 15 days,
- Cluster had 6 cusp crossings both for N and S cusp
- A strongest (up to date) up-flowing FAEs observed on Sep. 30,2001.

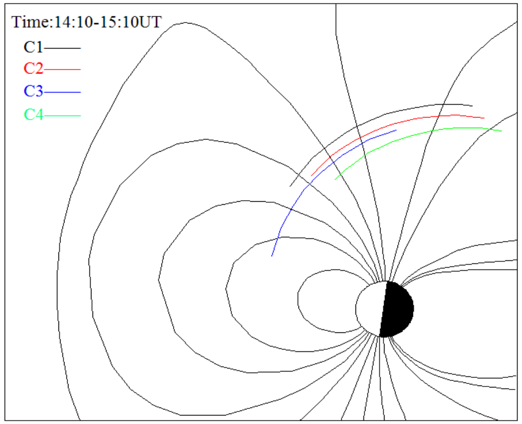
Cluster 4 S/Cs crossing the northern cusp on 30 September 2001

The 4 Cluster satellites crossing the cusp from 14:10 to 15:10 UT

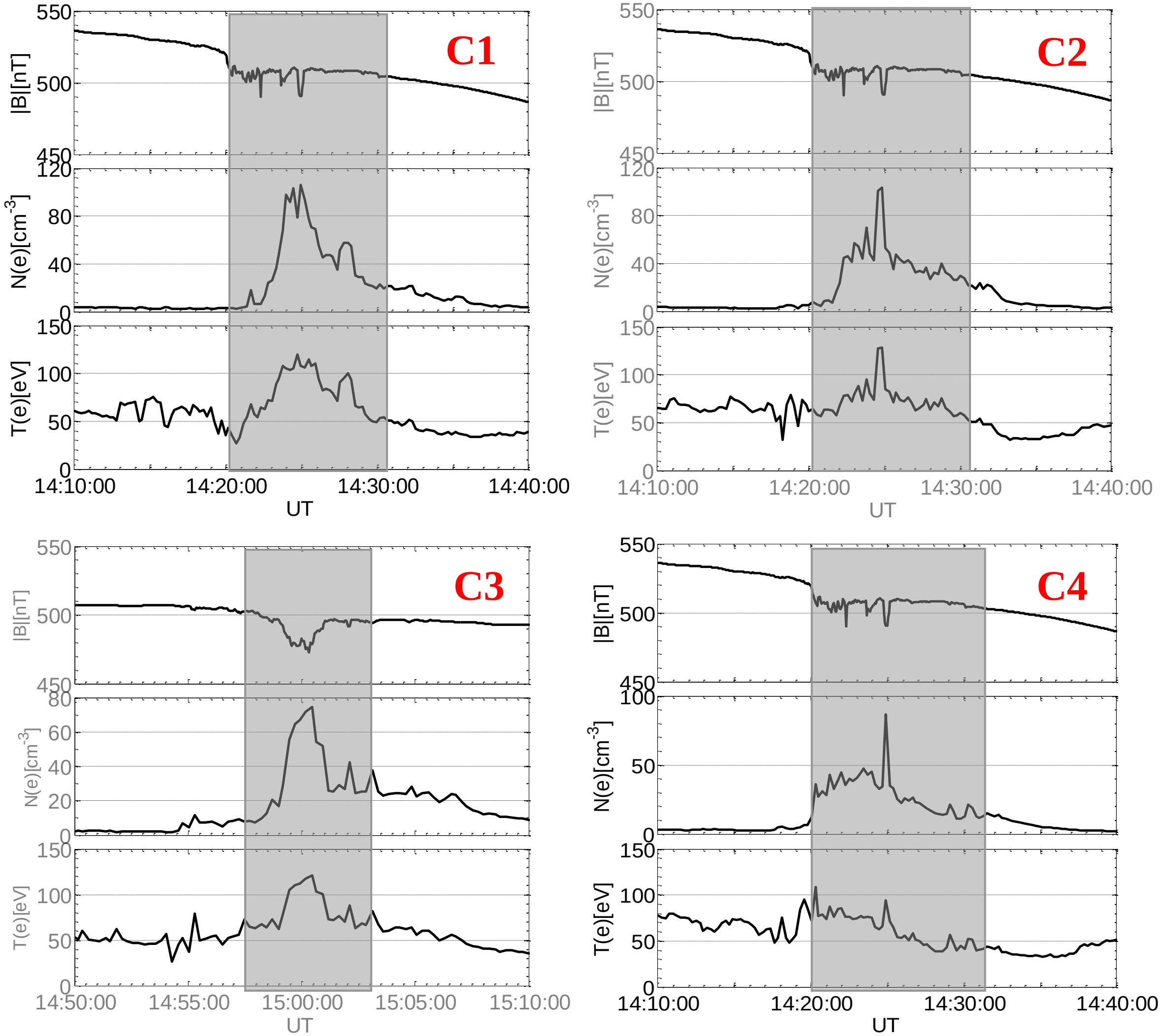


The 4 Cluster orbits projections on the X-Y, X-Z, and Y-Z plane and in ILAT-MLT coordinate system

The schematic diagram of 4 Cluster satellites crossing the cusp in the X-Z plane



Cusp identification



- Decrease of the magnetic field from background with disturbance
- Sudden increase in and electron density
- **E**lectron thermal energy disturbed

On Sep.30, 2001

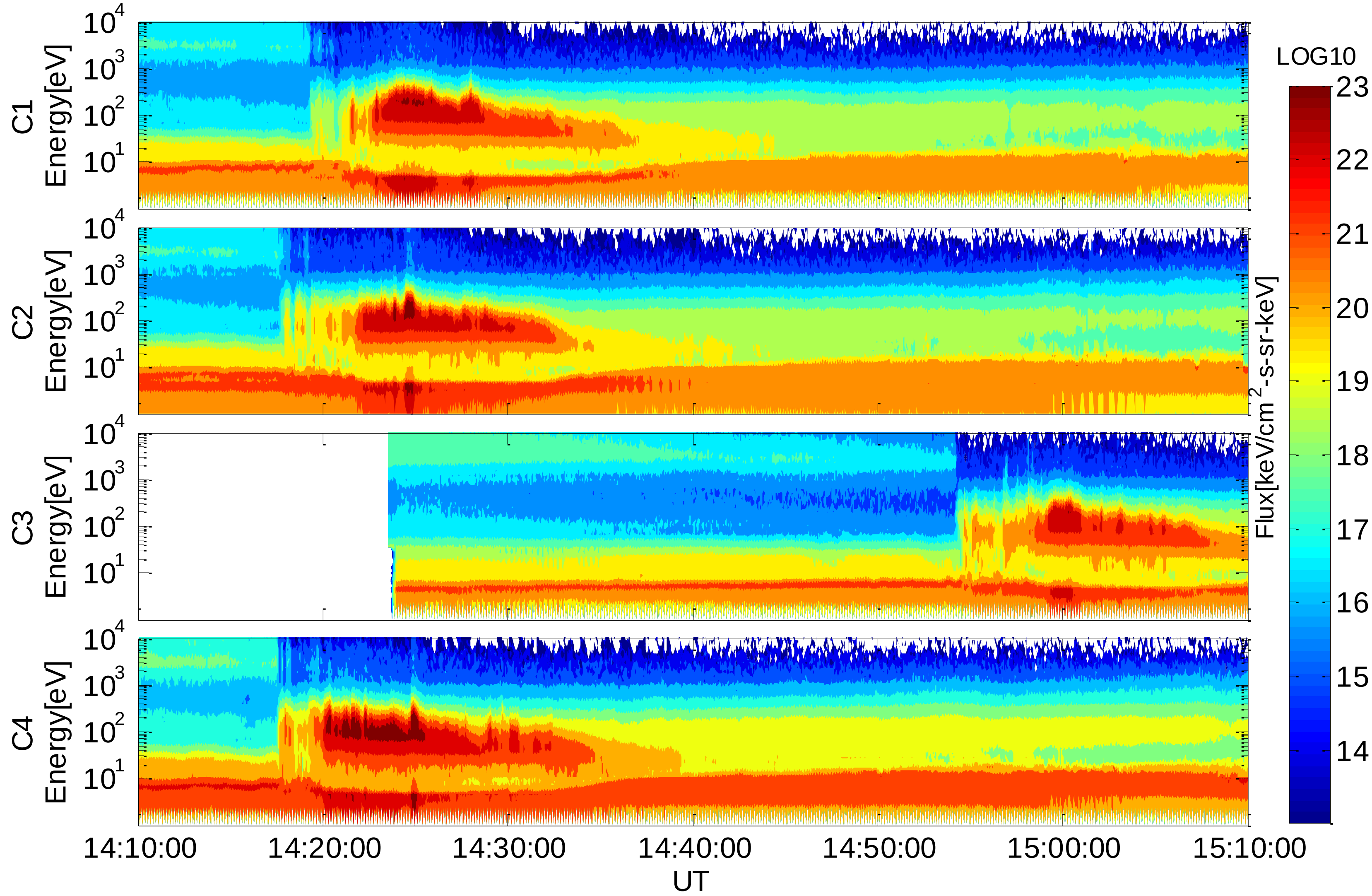
C1→ 14:20-14:32 UT

C2→ 14:20-14:32 UT

C3→ 14:58-15:02 UT

C4→ 14:18-14:32 UT

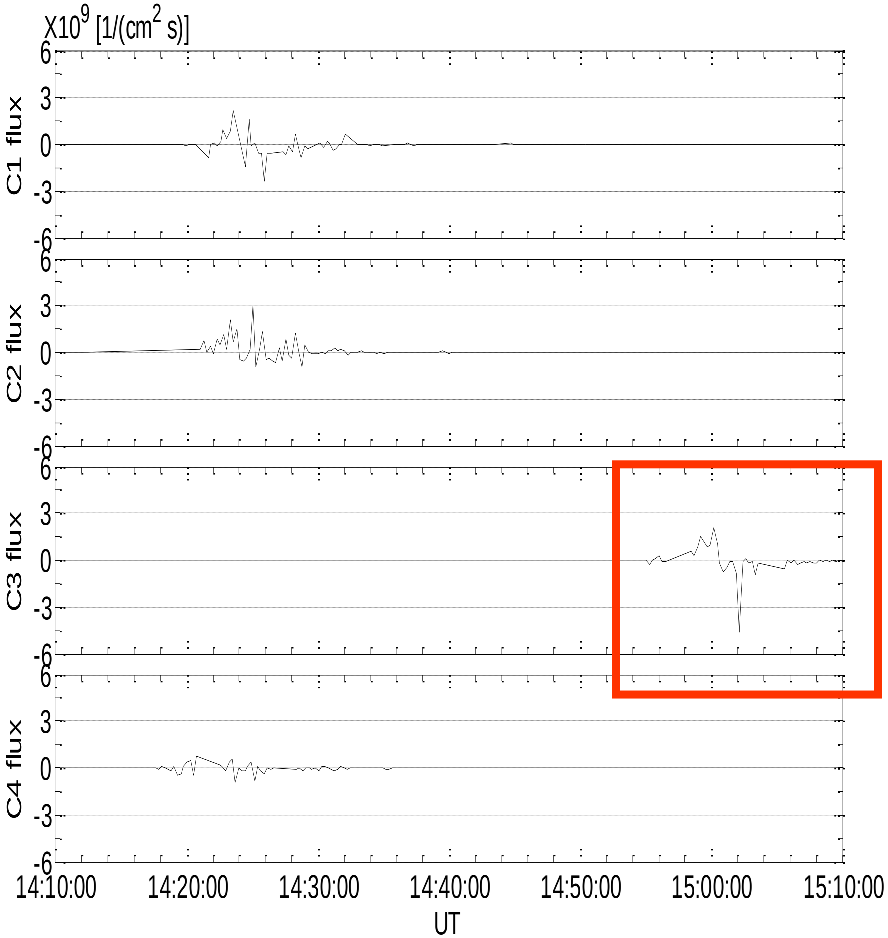
Sep 30, 2001, northern cusp, electron burst



C1,C2,C4 ~1000km, C3 ~12000km

Sep. 30,2001, northern cusp

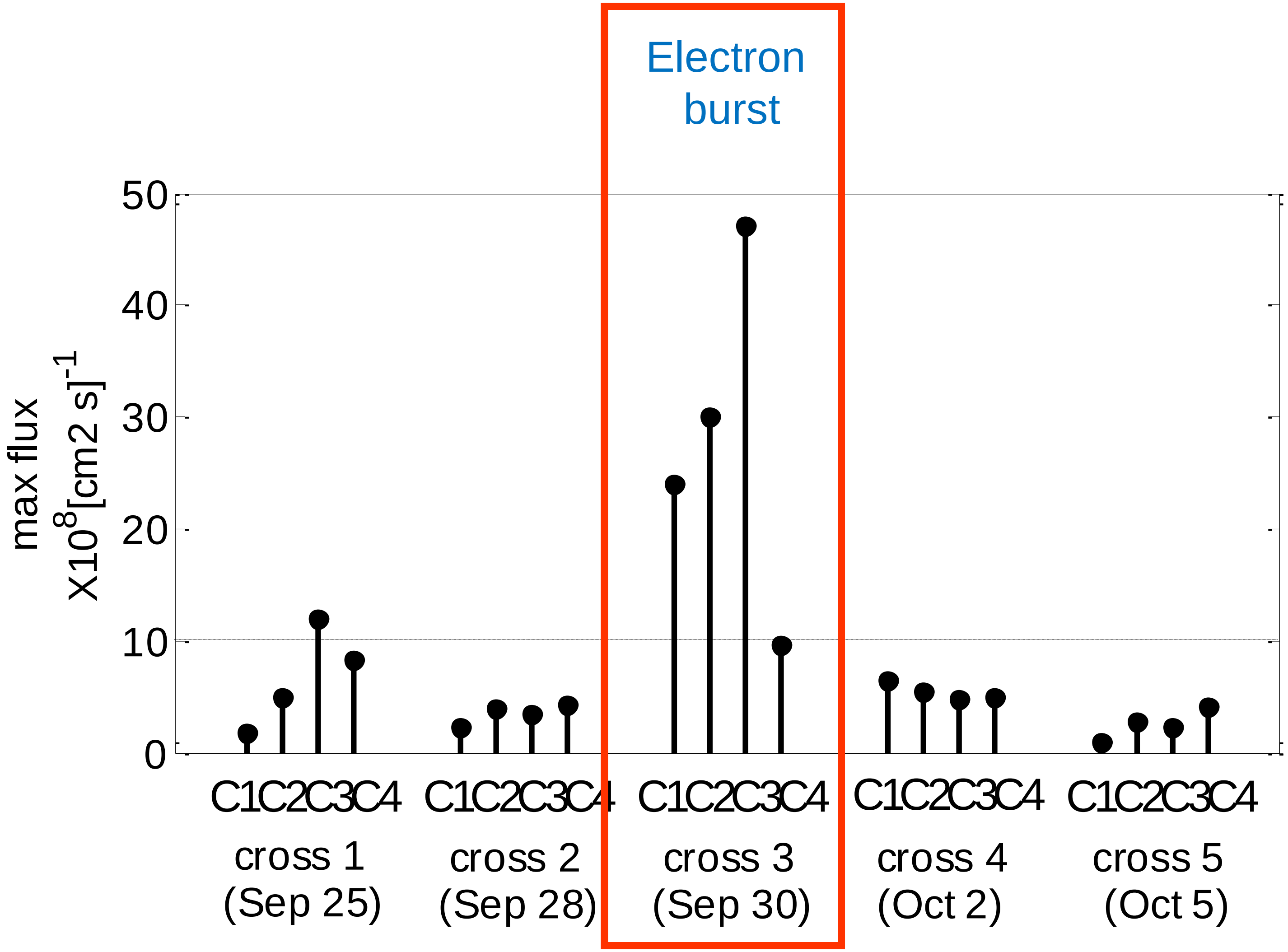
Field Aligned Electron Flux

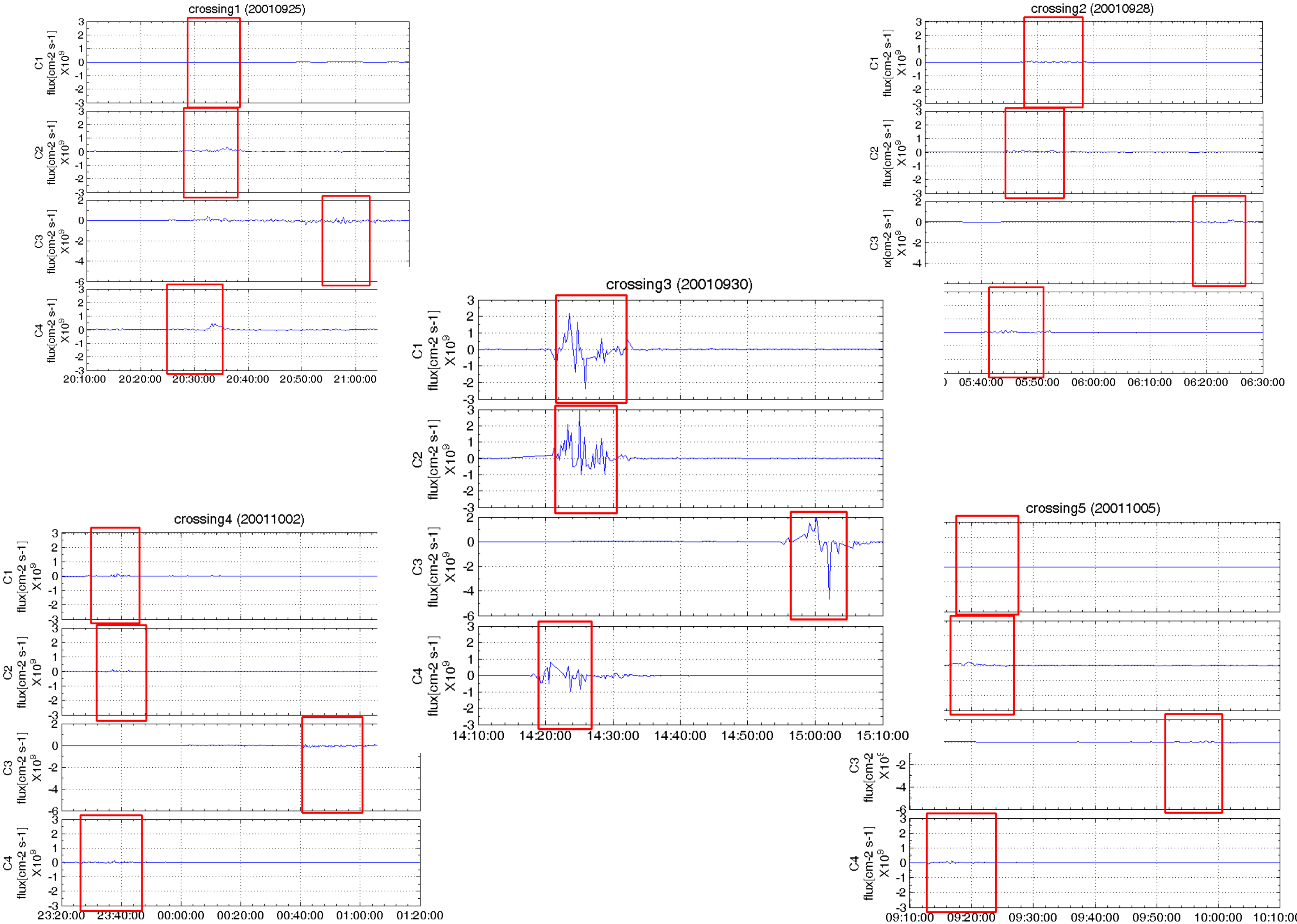


+： for downward, -- ： for upward

14:10-15:10UT

- All the 4 Cluster S/Cs observed the FAE disturbance when crossing the cusp.
- The Up-flowing flux ：
  4.70×10^9 (cm^2 . s)$^{-1}$ (Max.)
  The Down-flowing flux:
  2.10×10^9 (cm^2 . s)$^{-1}$ (Max.)
- The 4 S/Cs entered cusp in the different period
- The same FEA burst was observed by the 4 Cluster S/Cs

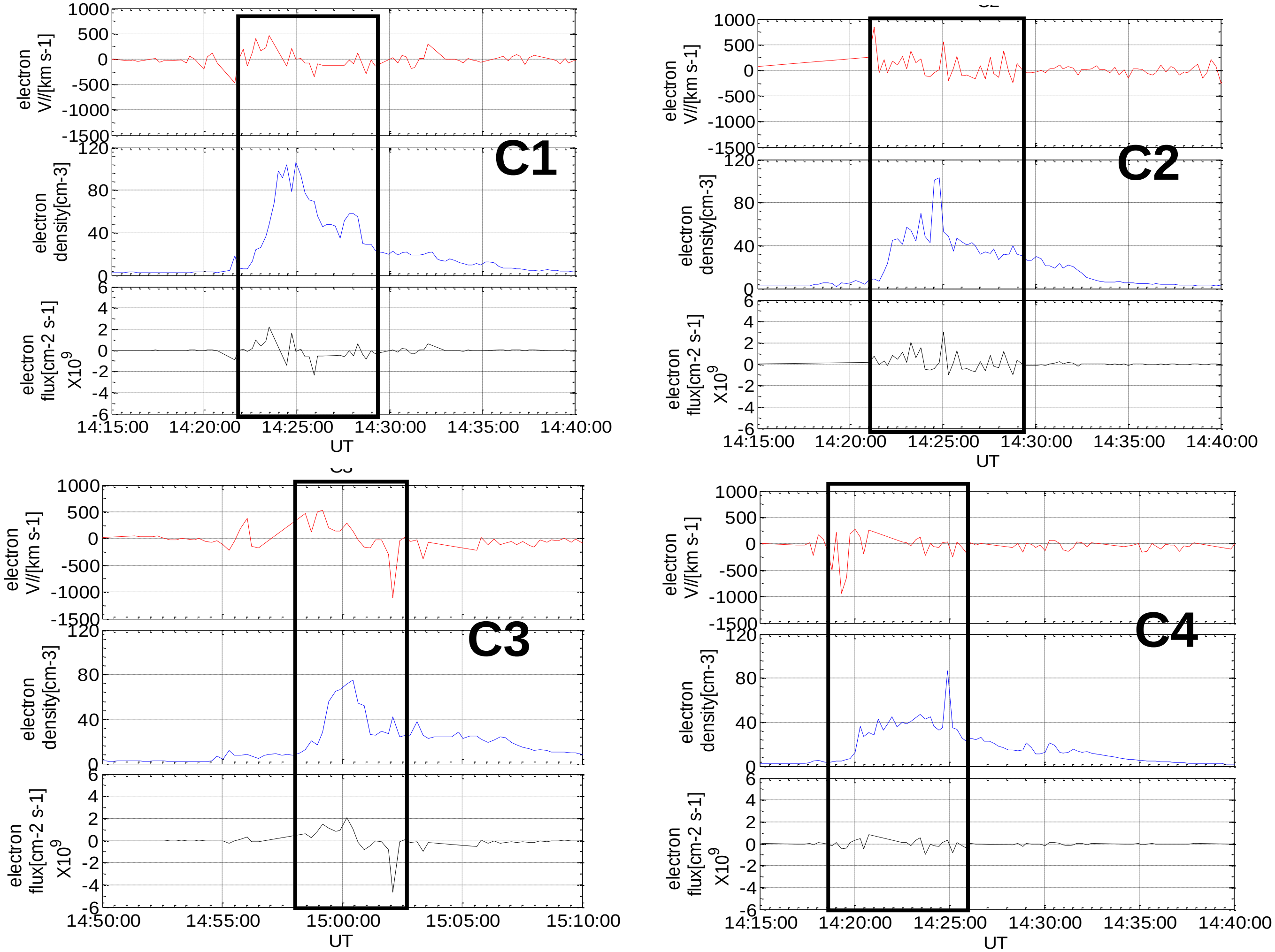

Electron
burst
50
40
30
20
10
0
max flux
X10^8[cm2 s]^-1
C1C2C3C4
C1C2C3C4
C1C2C3C4
C1C2C3C4
C1C2C3C4
cross 1
(Sep 25)
cross 2
(Sep 28)
cross 3
(Sep 30)
cross 4
(Oct 2)
cross 5
(Oct 5)



crossing1 (20010925)
crossing2 (20010928)
crossing3 (20010930)
crossing4 (20011002)
crossing5 (20011005)
C1 flux[cm-2 s-1] X10^9
C2 flux[cm-2 s-1] X10^9
C3 flux[cm-2 s-1] X10^9
C4 flux[cm-2 s-1] X10^9
20:10:00 20:20:00 20:30:00 20:40:00 20:50:00 21:00:00
05:40:00 05:50:00 06:00:00 06:10:00 06:20:00 06:30:00
14:10:00 14:20:00 14:30:00 14:40:00 14:50:00 15:00:00 15:10:00
23:20:00 23:40:00 00:00:00 00:20:00 00:40:00 01:00:00 01:20:00
09:10:00 09:20:00 09:30:00 09:40:00 09:50:00 10:00:00 10:10:00

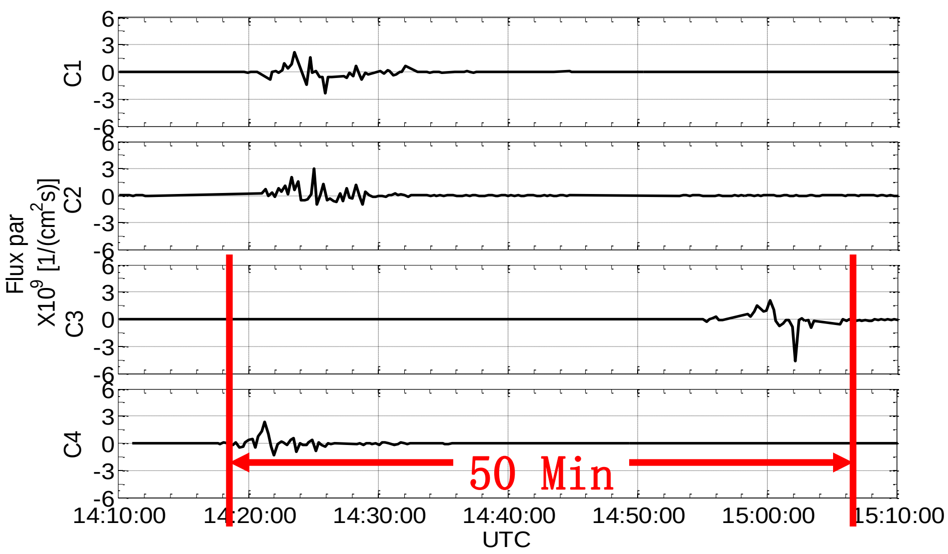
Sep. 30, 2001

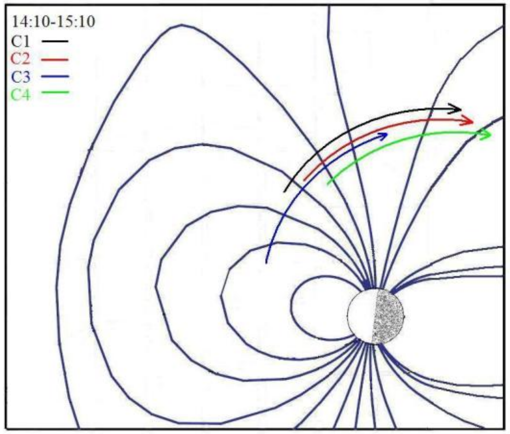
The electron parameters observed in the cusp.



The high flux disturbances were associated the high density and speed

Scale of the FAE disturbance



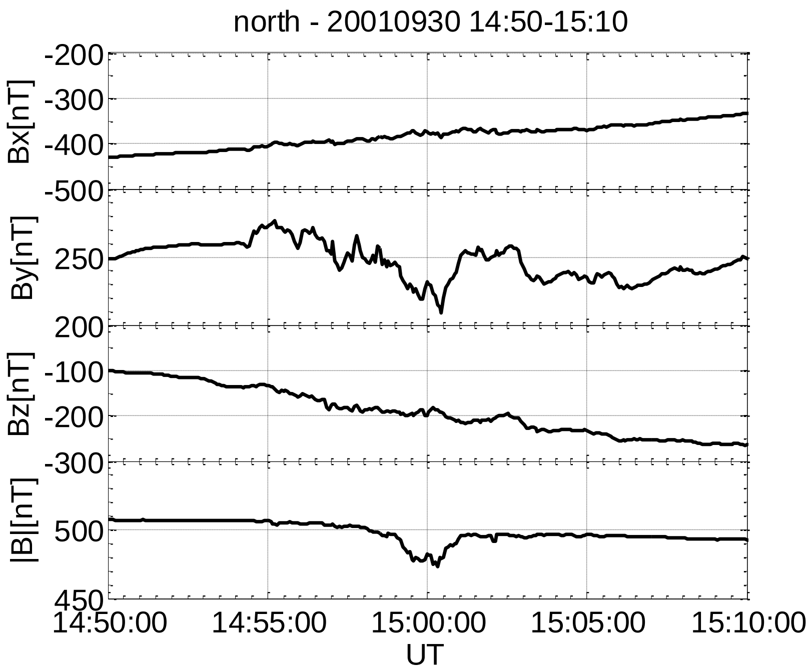


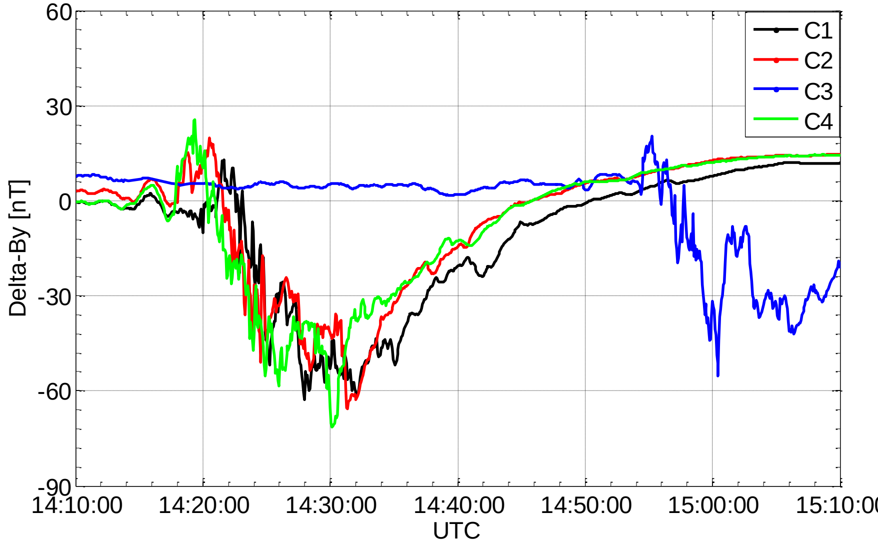
The altitude of the S/C was $4.5R_E$

- Each S/C observed the FAE in 12 minutes
- The temporal scale of this FAE disturbance was at lest 50 minutes
- Spatial scale of this event: > 540km in the obit direction, >1800km in local time extent

- It is the first time to obtain the FAE disturbance in the cusp with multi observations
- The temporal and spatial scales of the electron burst are the largest observed in the cusp by all satellites up to date.

Sep. 30, 2001, Northern cusp





3-component of the geo-magnetic filed observed by C3

The △By observed by C!, C2, C3, and C4

Bx kept nearly linear increasing.
Bz kept nearly linear decreasing.
Only By was much disturbed.
It was associated FAC during the crossing.

According to the By, the estimated FAC was at the order of 1 μA m^{-2} 。

Sep. 30, 2001, Northern cusp, C3

$$\vec{j}_e = \sum_{p=i,e} n_p q \vec{v}_p$$

△By

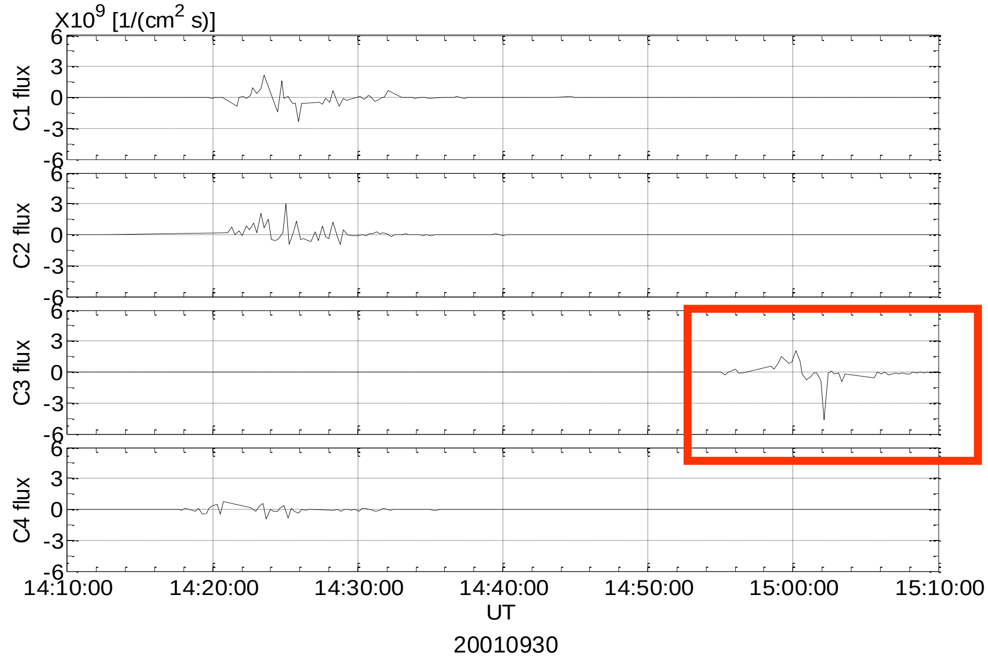
	Flux[cm^{-2} . s^{-1}]	je[μAm^{-2}]	j[μAm^{-2}]
Down-flowing electron	2.0×10^9	3.2	3.97
Up-flowing electron	4.5×10^9	7.2	1.95

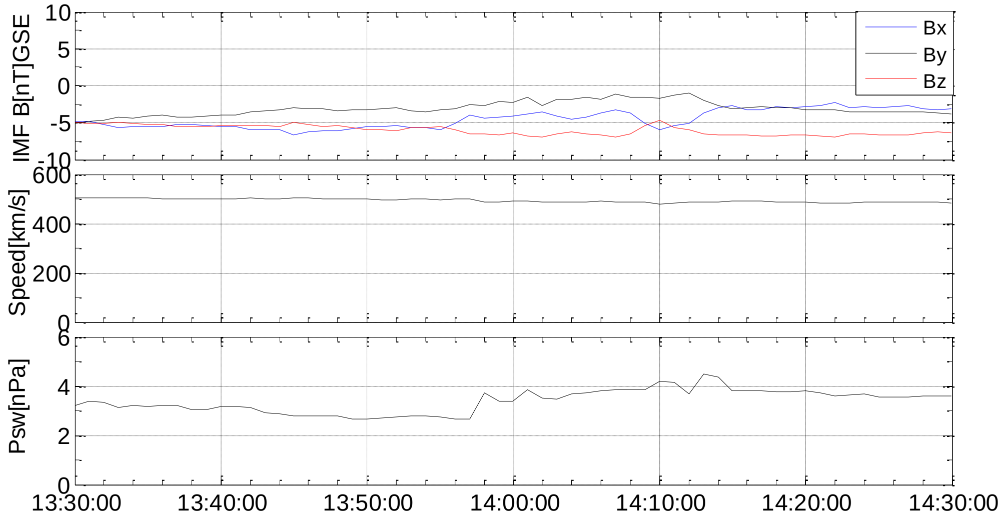
- Both for the upward and downward electron, Je and the J from By was near the same as the average value.

- It implies that the field-aligned electron is the major carrier of FAC in this event.

For C1, C2, and C4, it is the same

3. Discussion





IMF, solar wind speed and solar wind dynamic pressure from ACE at L1, the Cluster crossing time should be 49 min lagged

Sep. 30, 2001, C1, C2, C3, and C4, northern cusp

+ : for Down

-- : for Down

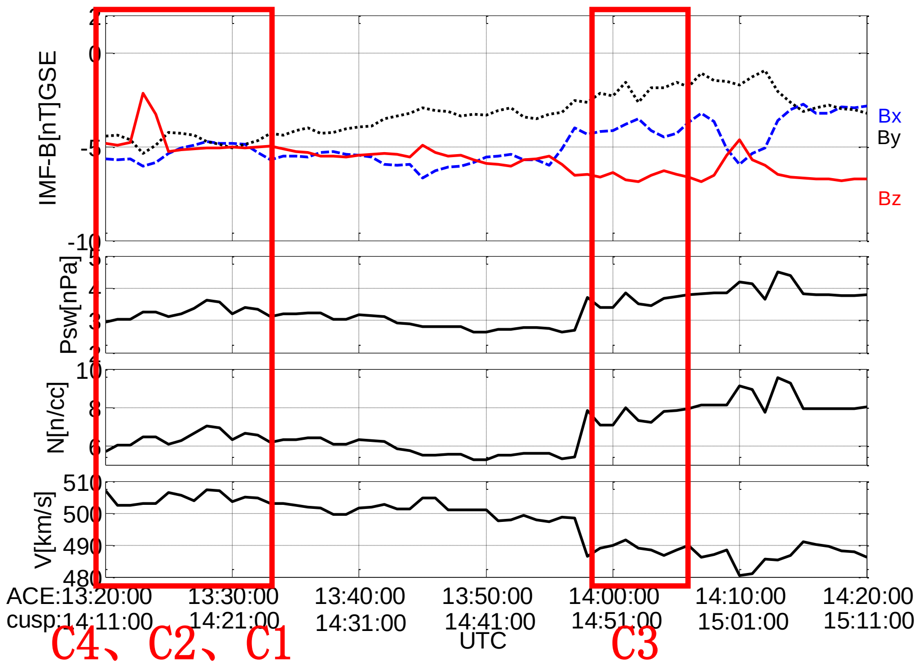
- IMF Bz ~-7nT.
  Vsw, ~500km/s.
  Psw ~ more than 4nPa.

- The FEAs concerned IMF

Bz < 0, increased Psw

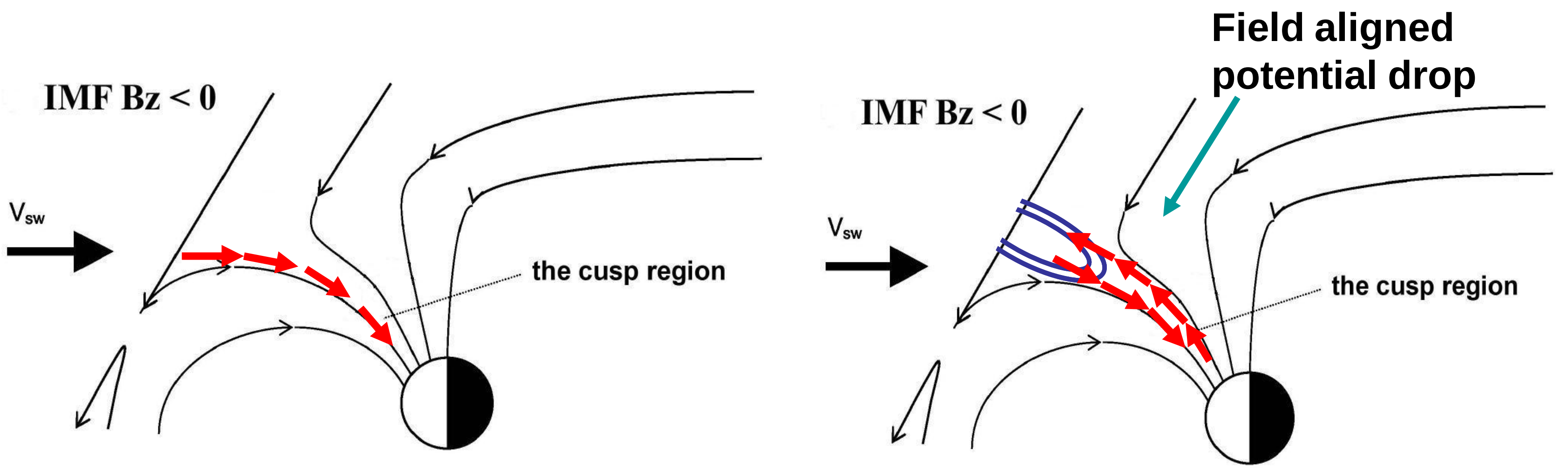
The high flux electron disturbance taking place in a big storm time （Dst = -148）

IMF and solar wind

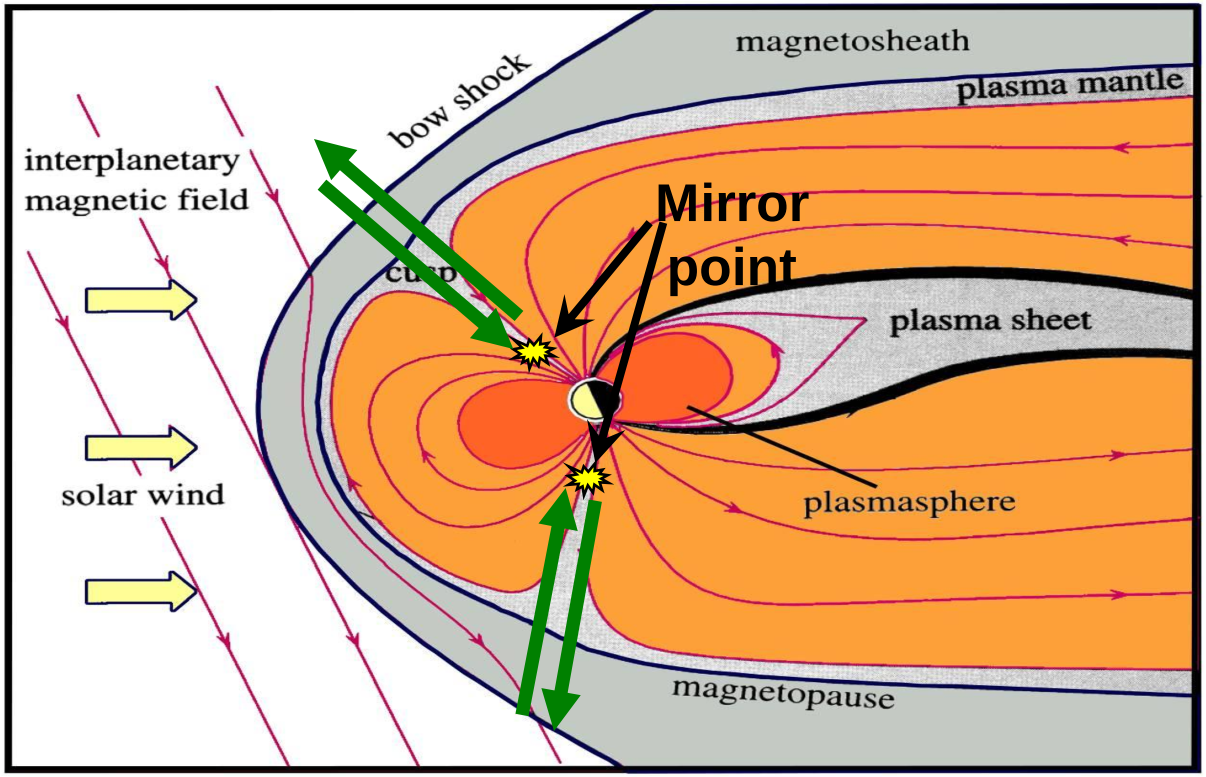


High solar wind dynamic pressure during persistent southward IMF is the main cause for the high flux electron disturbances

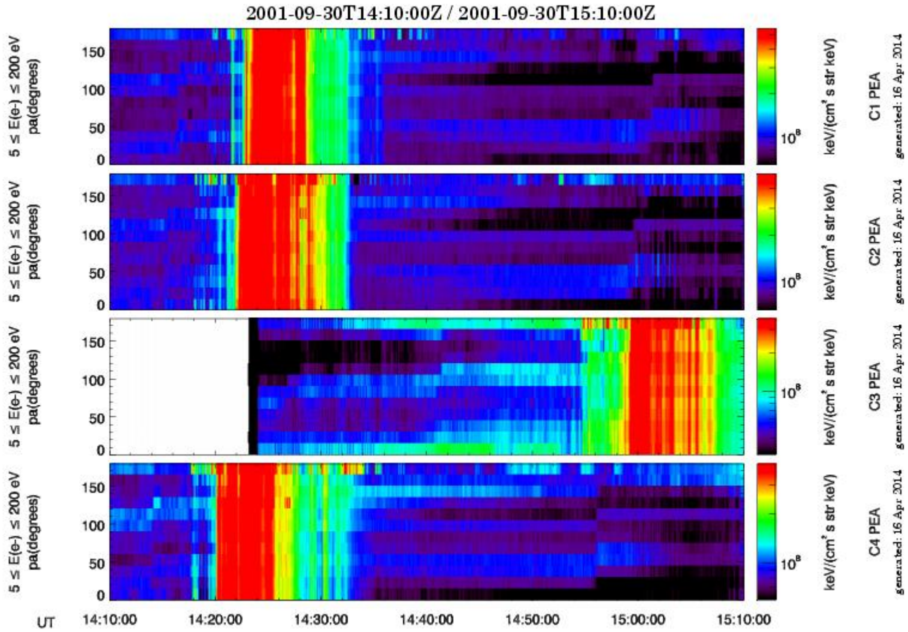
- The down flowing electrons are from:
  - -- solar wind electron
  - -- ionospheric electrons reflected in the structure of potential drop



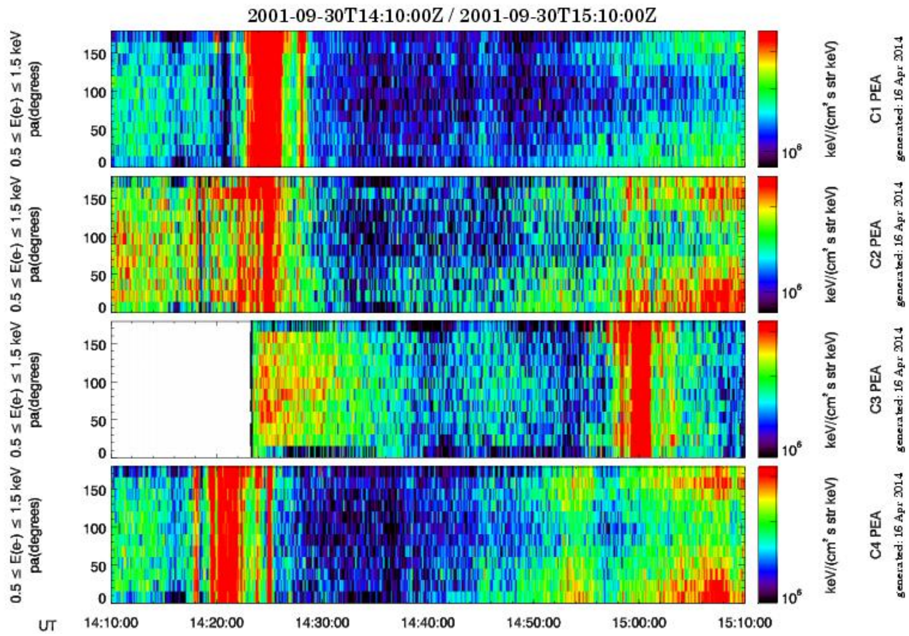
- The up-flowing electrons in the cusp may be resulted from
  -- mirroring of the solar wind,
  -- ionospheric up-flowing electrons that have been accelerated.



5-200eV electrons



500-1500eV electrons



- High Electron energy flux is mainly from the low energy electrons
- In the low energy range, up-flowing flux is more than the down flowing
- The up-flowing electrons were mainly form the ionosphere

4. Summary

- On Sep. 30, 2001，the 4 S/C of Cluster observes an high flux electron disturbance, the flux was one order more than that in the general.
- Temporal scale of the high flux electron disturbance was at lest 50 minutes, the spatial scale was about 540km in the orbit direction, and 1800km in the local time extent. It is the largest electron disturbance evebt in the cusp observed by all satellites to date.
- The field aligned electron is the main carrier for the FAC in this event.
- High solar wind dynamic pressure and persistent southward IMF are the main cause for the high flux electron disturbances.
- The downward electrons were mainly form the solar wind, the upward electrons were mainly from the up-flowing ionospheric electrons.

(Shi, et. al., JGR, 2014)

Thanks for Attention！