

# Characteristics of magnetic dipolarizations in the vicinity of the substorm onset region observed by THEMIS

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# Outline

## 1. Motivations and introduction

Dipolarizations in the vicinity of substorm onset region

## 2. Observations in NECS and NEPS during the substorm.

Observations of three probes of THEMIS in near-Earth current sheet and near-Earth plasma sheet on 12 February 2008.

## 3. Summary

# Motivation

- **Magnetic dipolarization plays a key role in substorm onset triggering process. It is associated with the cross-tail current disruption/substorm current wedge, Pi2, and energetic particle dispersionless injection at substorm onset** [Akasofu,2004; Kan,1991; Lui,1996, 1999; McPherron et al.,1973; Nagai,1982; Nakamura et al., 2009; Roux et al.,1991; Saito et al.,2010; Rae et al., 2019; Duan et al., 2011;2012; 2016; 2021] .
- **Induced electric field caused by substorm dipolarization within substorm onset region can give rise to ion and electron dispersionless injection** [e.g., Reeves et al.,1990;Liu WW et al.,2007; He et al.,2016].
- **Simultaneous observations from multiple probes of THEMIS provide a good dataset to investigate the spatial and temporal features of substorm dipolarization** [e.g., Angelopoulos 2008; Duan et al.,2021].

# 1. Introduction

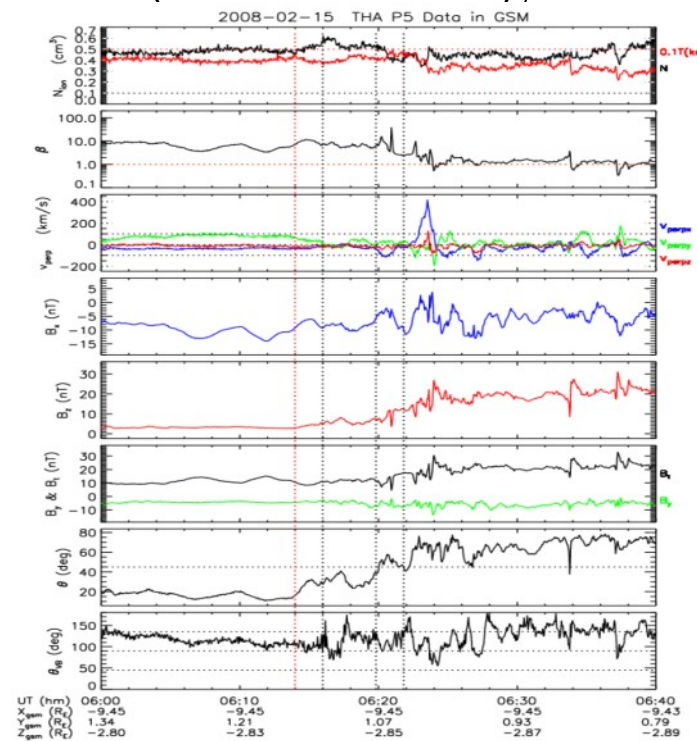
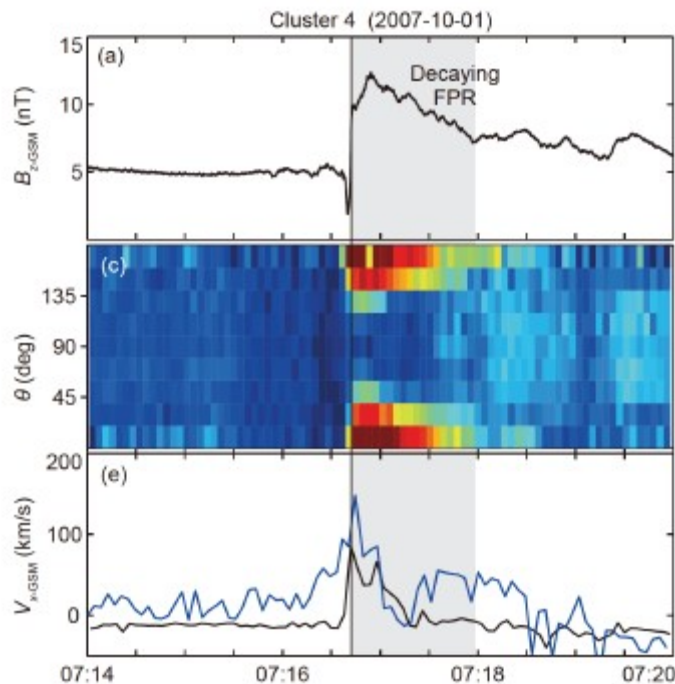
## ➤ Substorm magnetic dipolarizations

**Definition:** Bz component increase or the magnetic elevation angle increase  $\theta = \tan^{-1}(B_z / (B_x^2 + B_y^2)^{1/2})$

**Two types of magnetic dipolarizations during substorms:** [e.g., Lui, 2010, 2014; Duan et al., 2011; 2021; Fu et al., 2011; Nakamura et al., 2002, 2009; Runov et al., 2009; Takahashi et al., 1987]

1) Dipolarization Front (DF): Short duration (~1 min) and pulse-like form;

2) Dipolarization associated with CD/SCW: Long duration (a few minutes), significant magnetic fluctuations

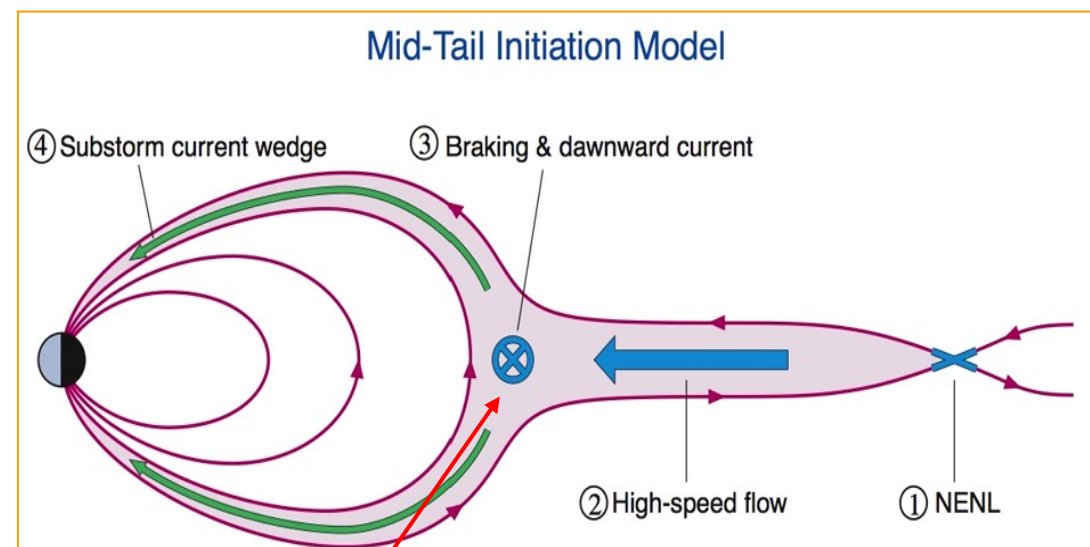
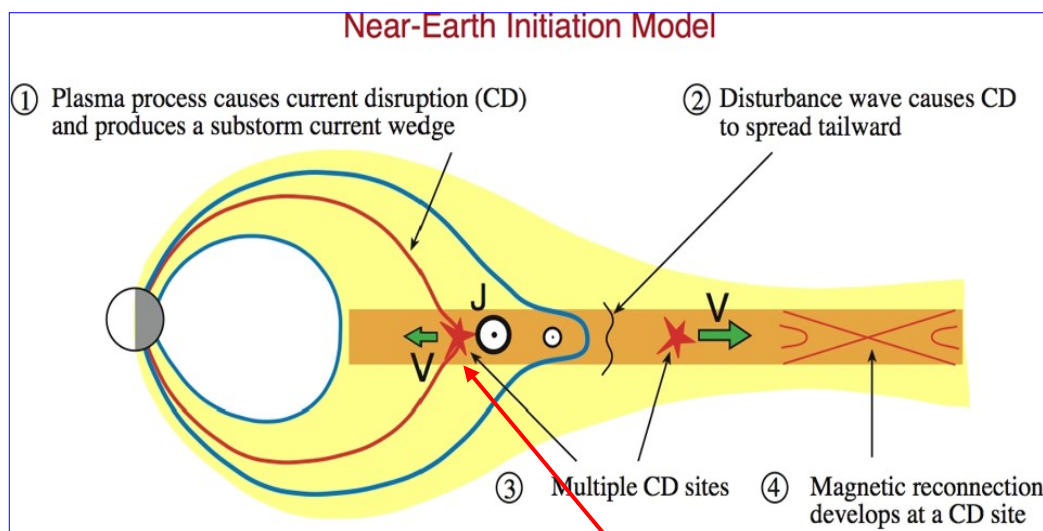


# 1. Introduction

## ➤ Substorm onset (SO) signatures in the near Earth plasma sheet (NEPS)

Substorm onset is initiated in the inner edge of the NECS ( $X \sim -8$  to  $-10 R_E$ ) with **the cross-tail current disruption/substorm current wedge, Pi2, energetic particle dispersionless injection and magnetic dipolarizations**:

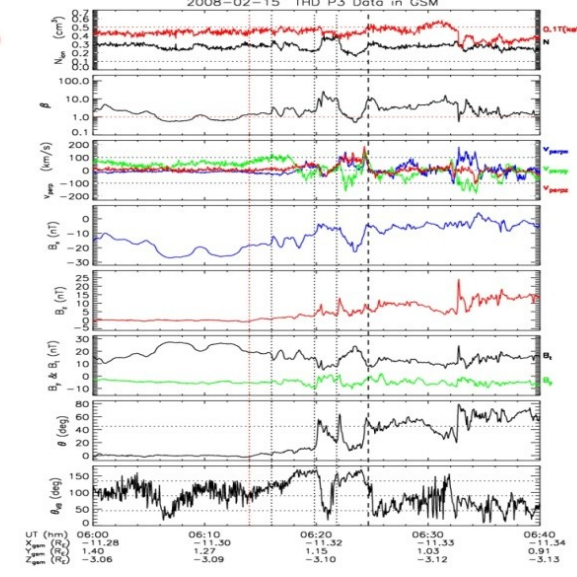
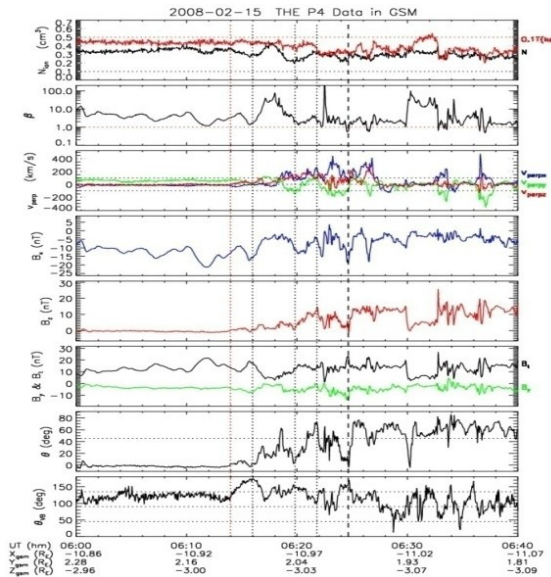
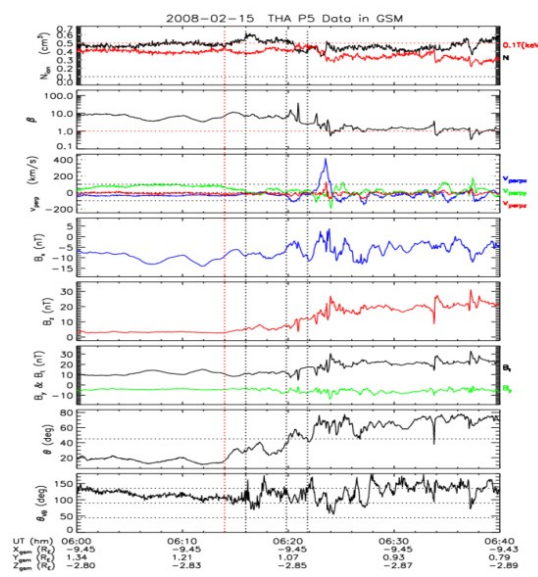
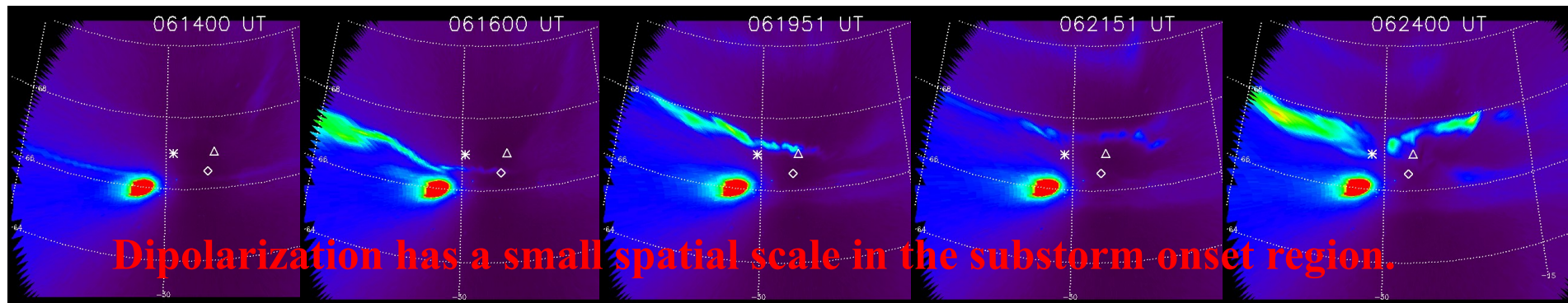
[e.g., Akasofu, 2004; Cheng, 2004; Duan et al., 2012; Lui, 1991, 1996; Ohtani et al., 1991; Rae et al., 2019].



Sebeck et al., 2008

**Substorm onset is triggered in the inner edge of near-Earth current sheet.**

# Multi-type dipolarizations have been observed in the near-Earth plasma sheet by THEMIS during substorms.

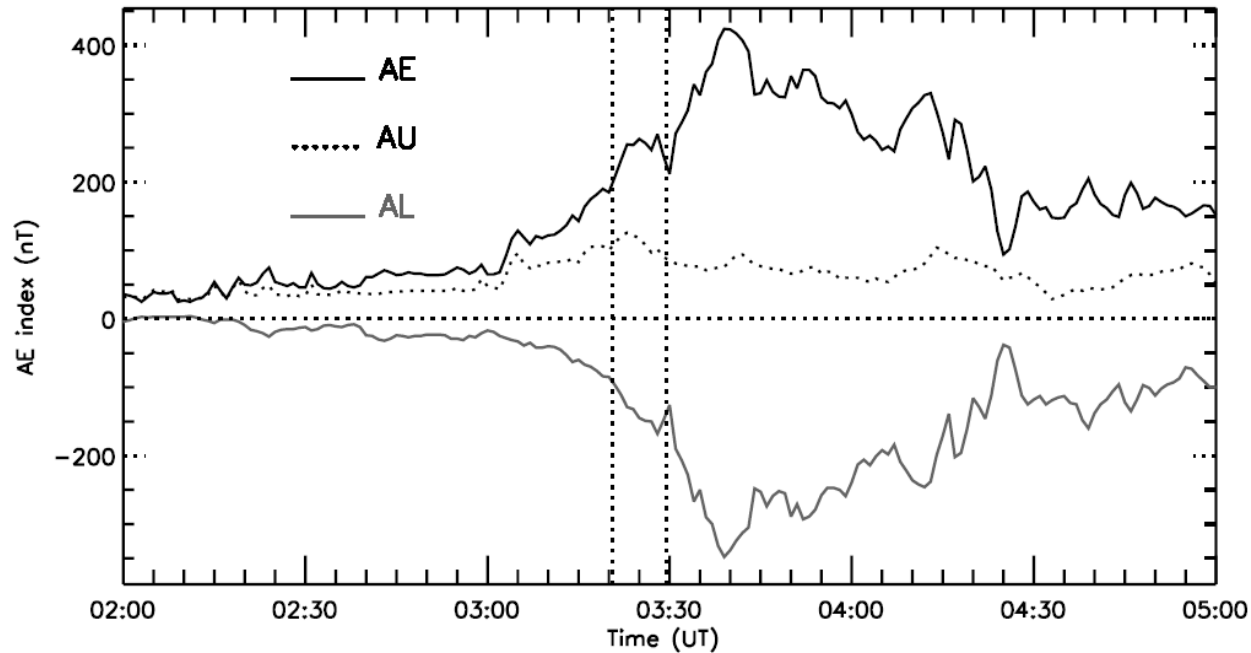


Duan et al., 2011

Dipolarization during substorm expansion phase lasts long time (10s min) with a large spatial scale.

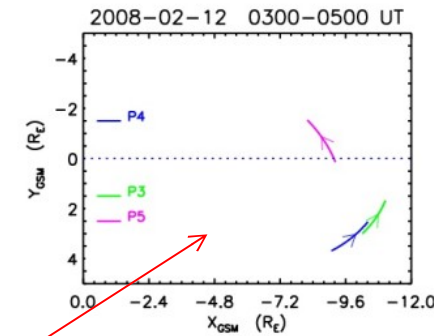
## 2. Observations: 2008-02-12 03:23 UT substorm

THEMIS Ground auroral IMAGE: KUUJ 03:23 UT.

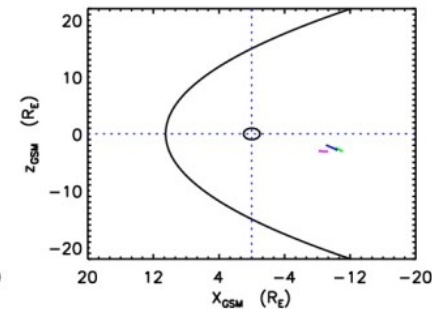
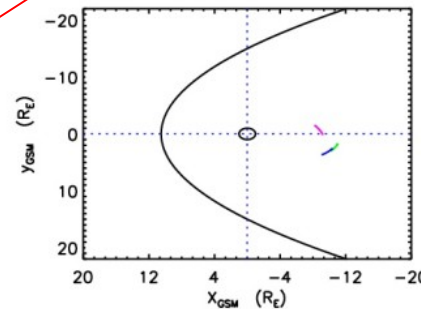
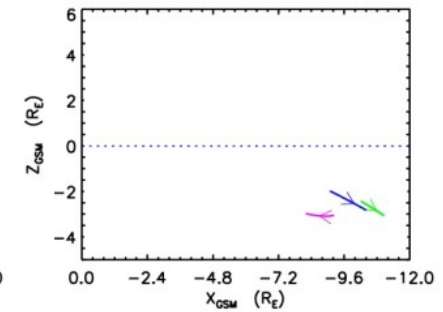


$AE_{\max} \sim 430 \text{ nT}$

Orbits of three probes of THEMIS (P3 P4 P5) during this substorm.

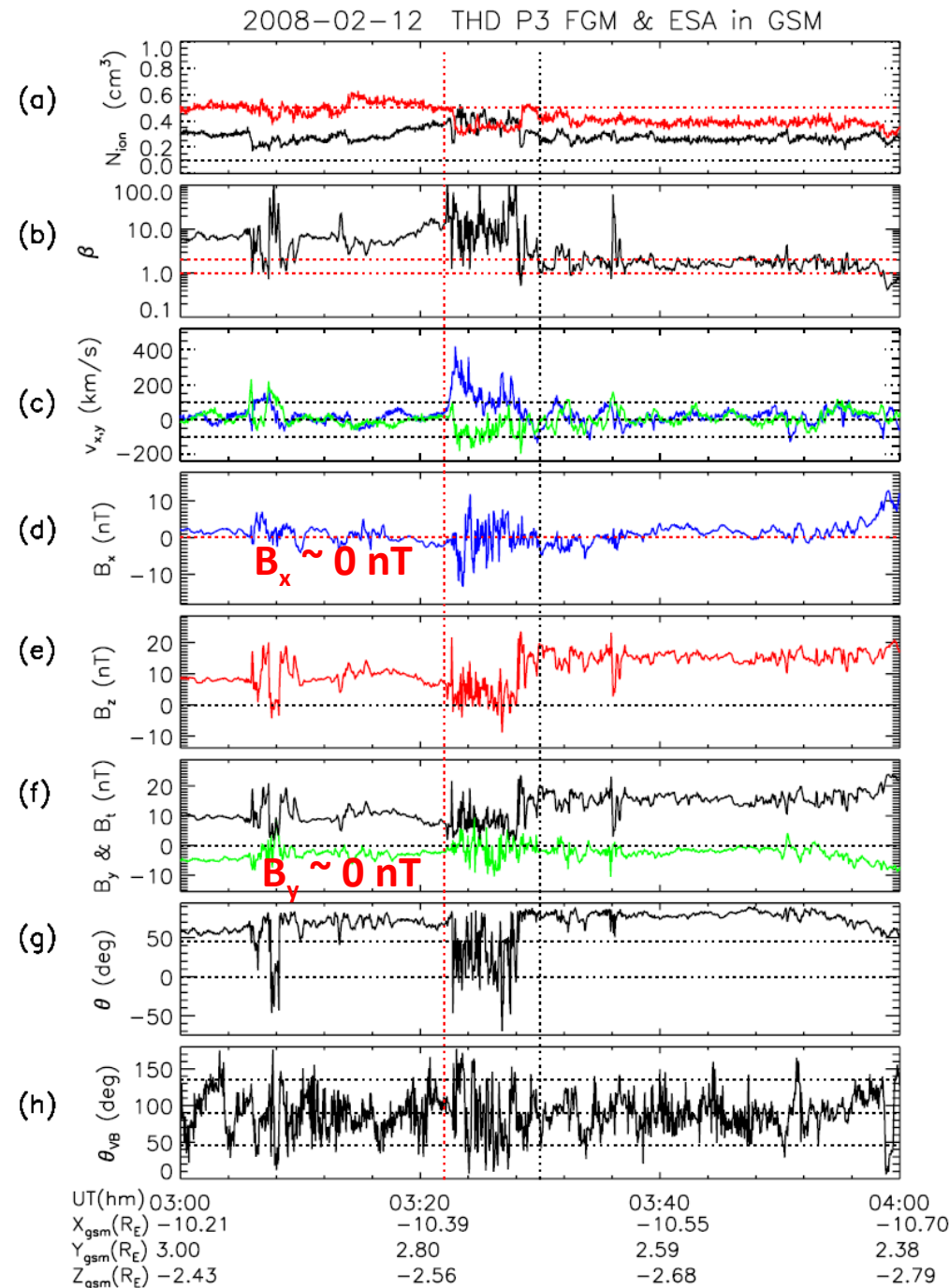


NEPS:  $X \sim -10 R_E$ ,  $Z \sim -2.5 R_E$



# THD was located in the near-Earth current sheet with very small $B_t \sim 10$ nT, large $\beta$ value.

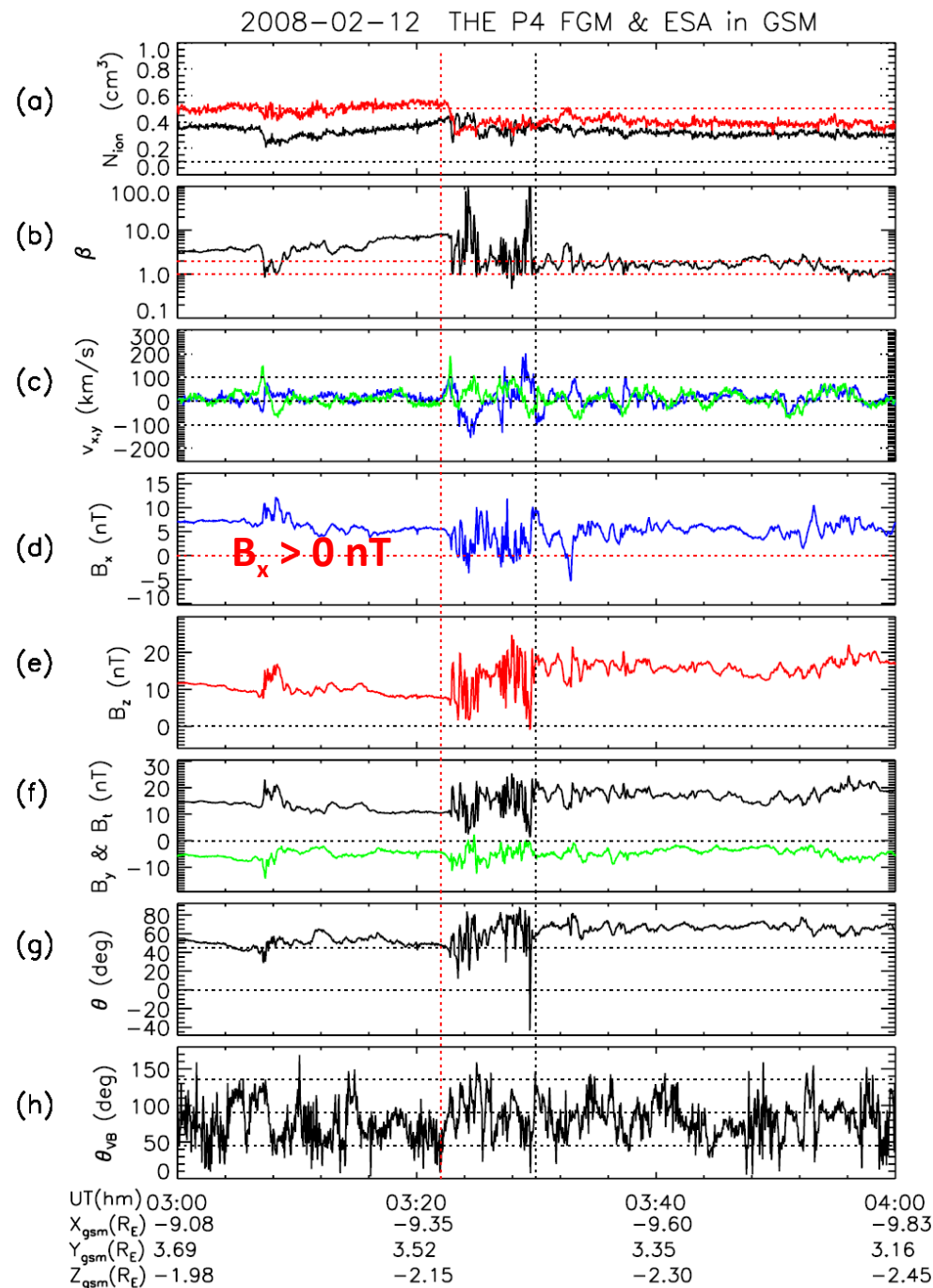
- Large initial magnetic field elevation angle,  $\theta > 60^\circ$ ;
- Significant fluctuations after substorm onset in the high  $\beta$  plasma.





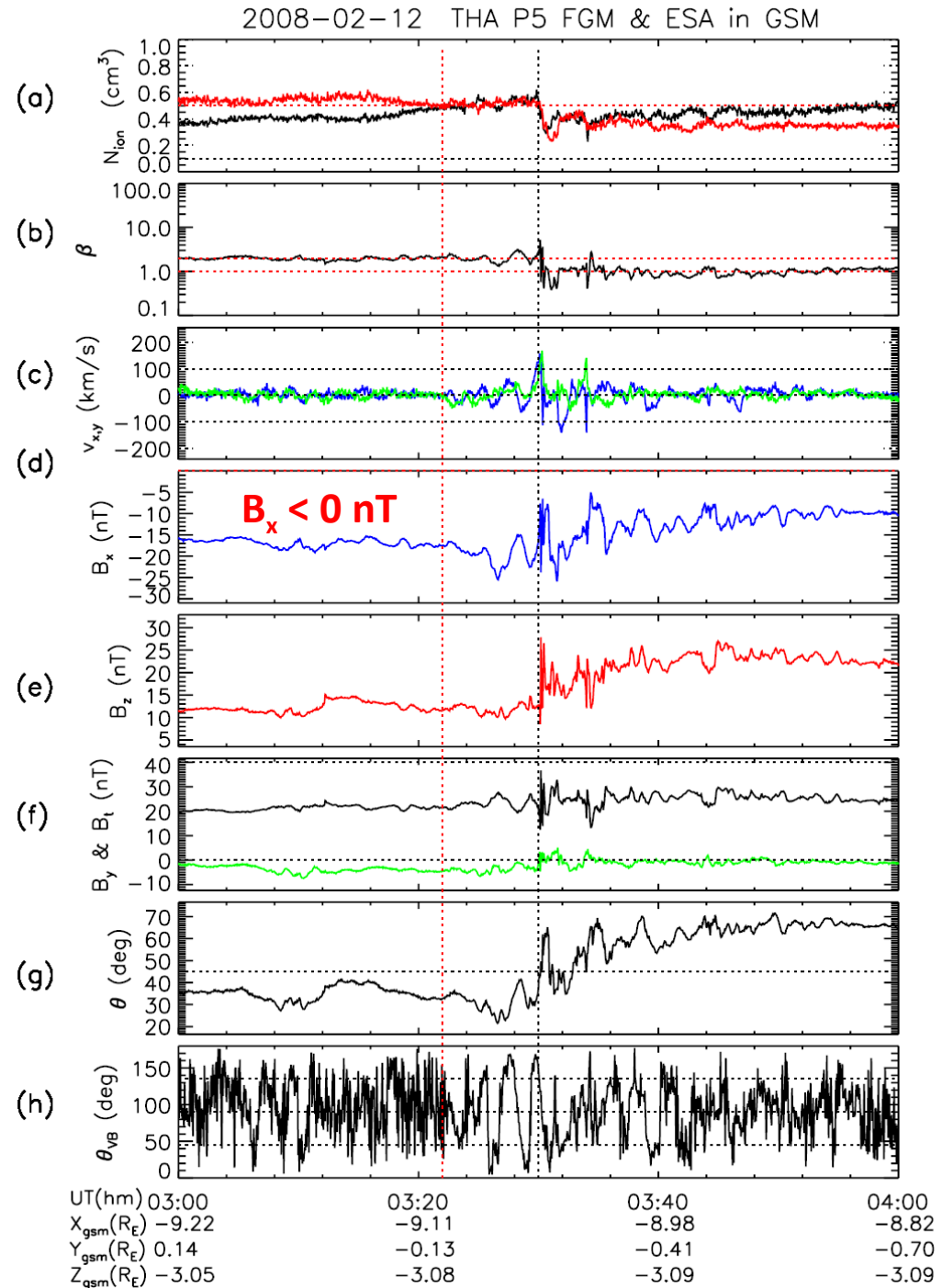
## THE was located Northward the NECS With $B_x \sim 5$ nT, $B_t > 10$ nT.

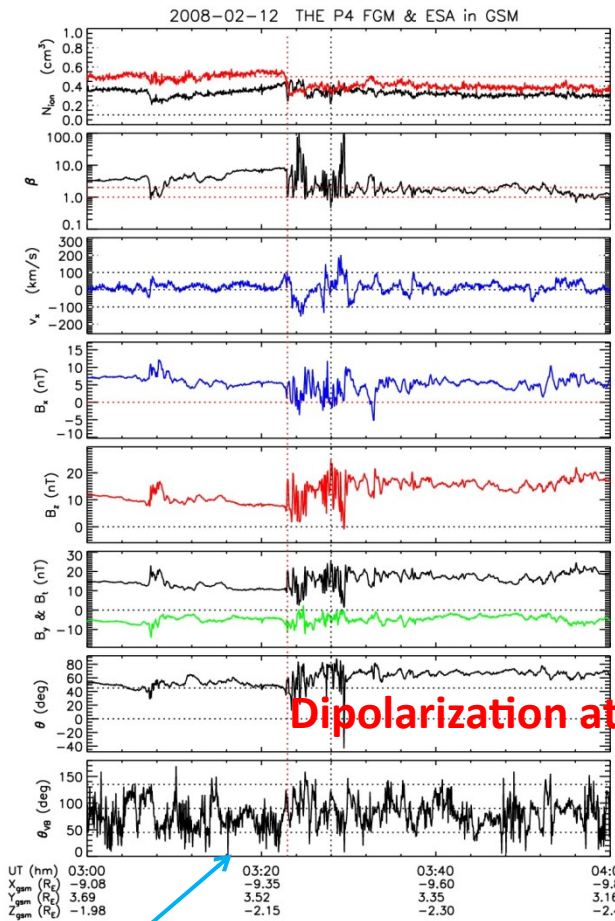
- Large initial magnetic field elevation angle,  $\theta \sim 45^\circ$ ;
- Strong fluctuations after substorm onset in the high  $\beta$  plasma.



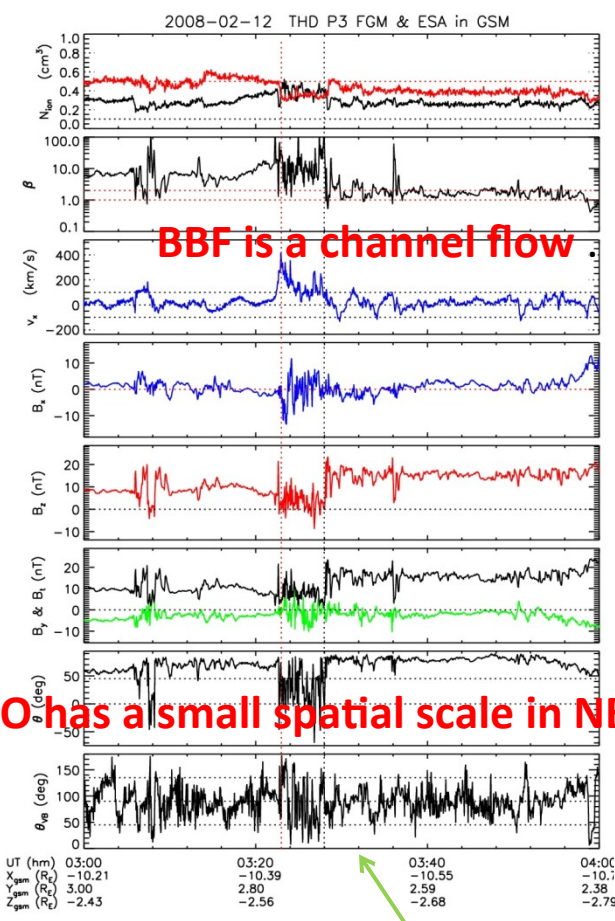
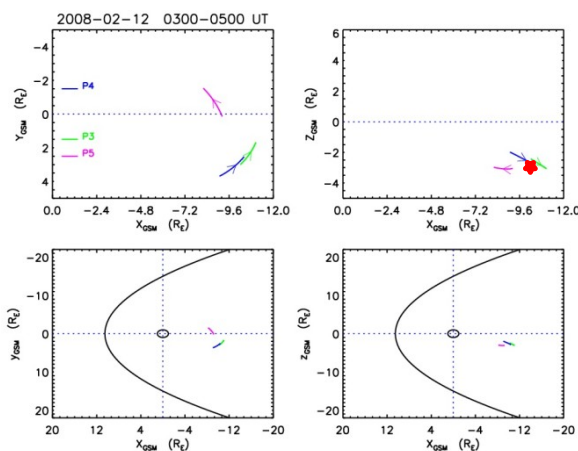
# THA was located Southward the NECS With $B_x \sim -15$ nT, $B_t > 20$ nT.

- Small initial magnetic field elevation angle,  $\theta \sim 30^\circ$ ;
- Multi-step dipolarizations during substorm expansion phase.

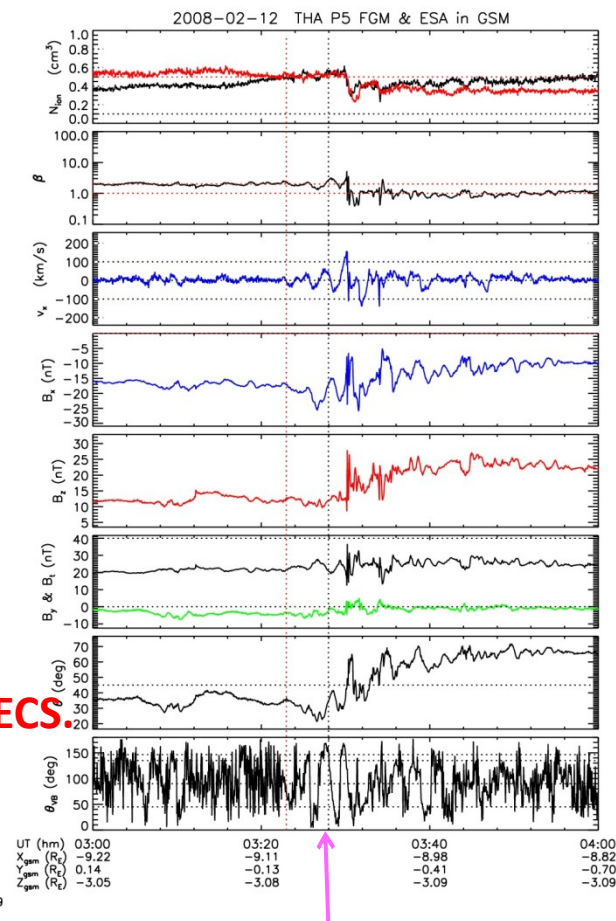




P4 Northward of CS:  
B<sub>x</sub> > 0, θ<sub>s</sub> ∼ 45deg



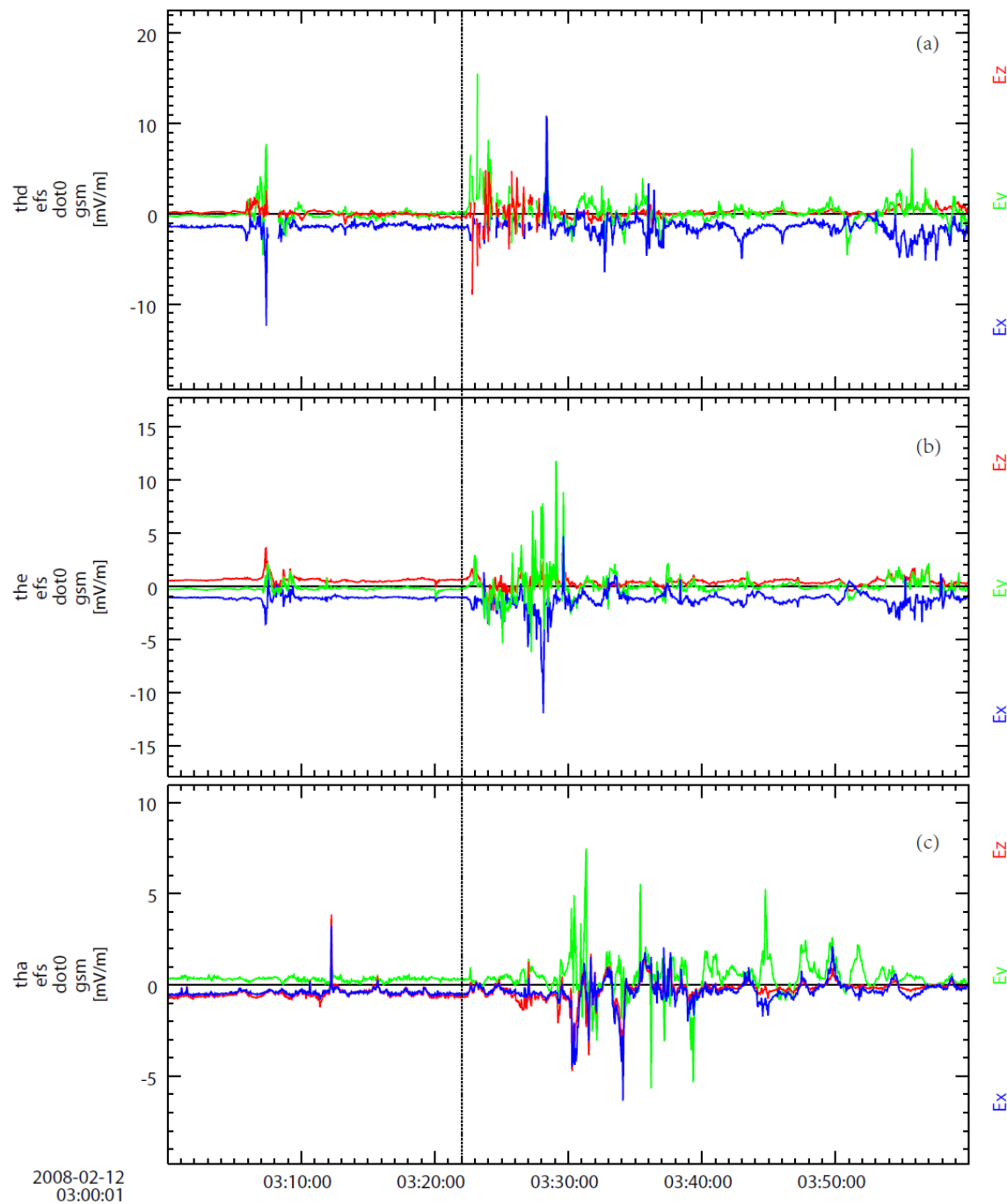
P3 Within CS at onset:  
B<sub>x</sub> ∼ 0, B<sub>y</sub> ∼ 0  
θ<sub>s</sub> ∼ 70deg



P5 Southward of CS:  
B<sub>x</sub> < 0, θ<sub>s</sub> ∼ 30deg,  
Dipolarization delay  
4 min.

**Dipolarization at SO has a small spatial scale in NECS.**

Intense electric fields detected in the substorm onset region.

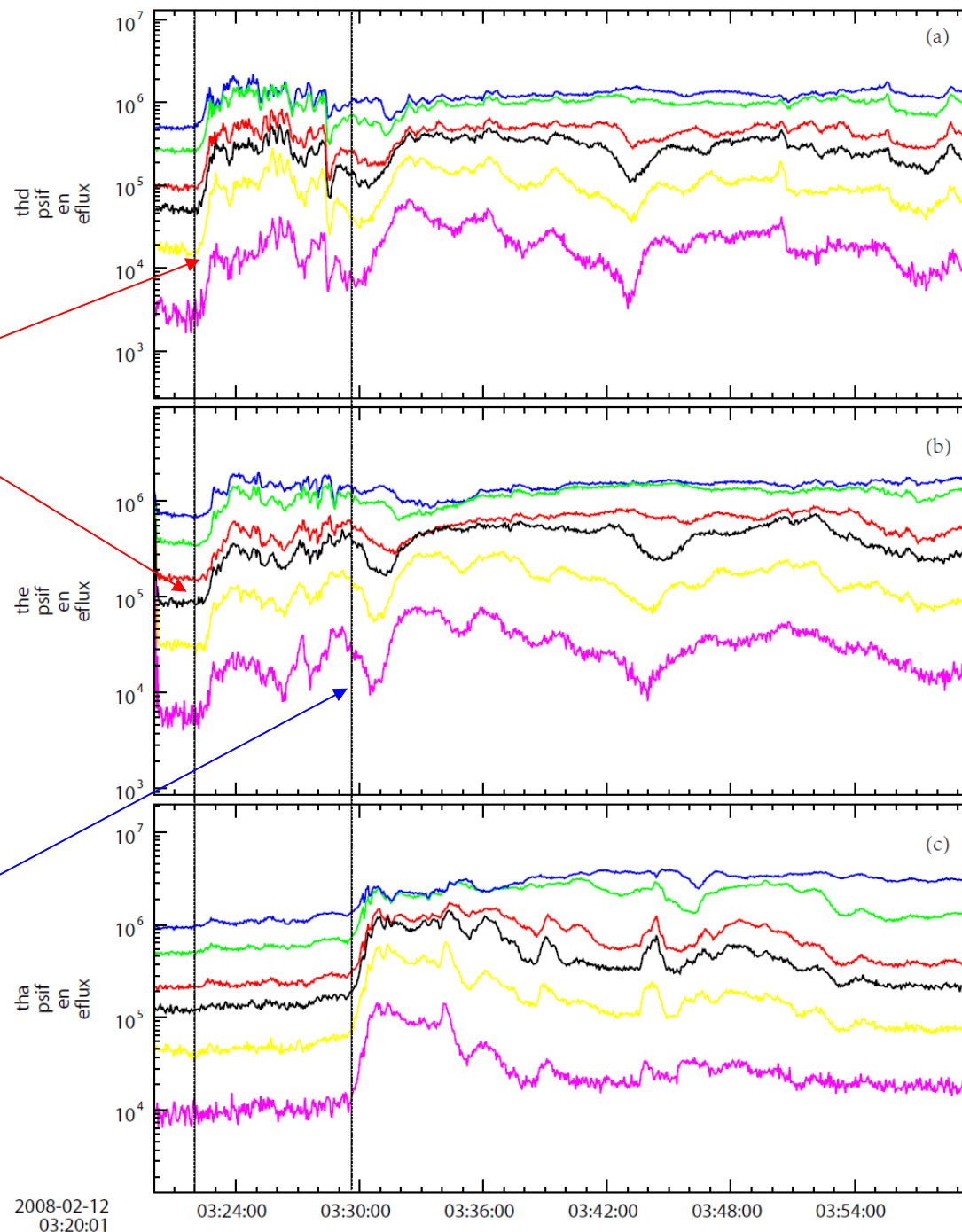


2008-02-12  
03:00:01

29.3 keV  
 42.0 keV  
 58.5 keV  
 81.0 keV  
 112.5 keV  
 156.7 keV

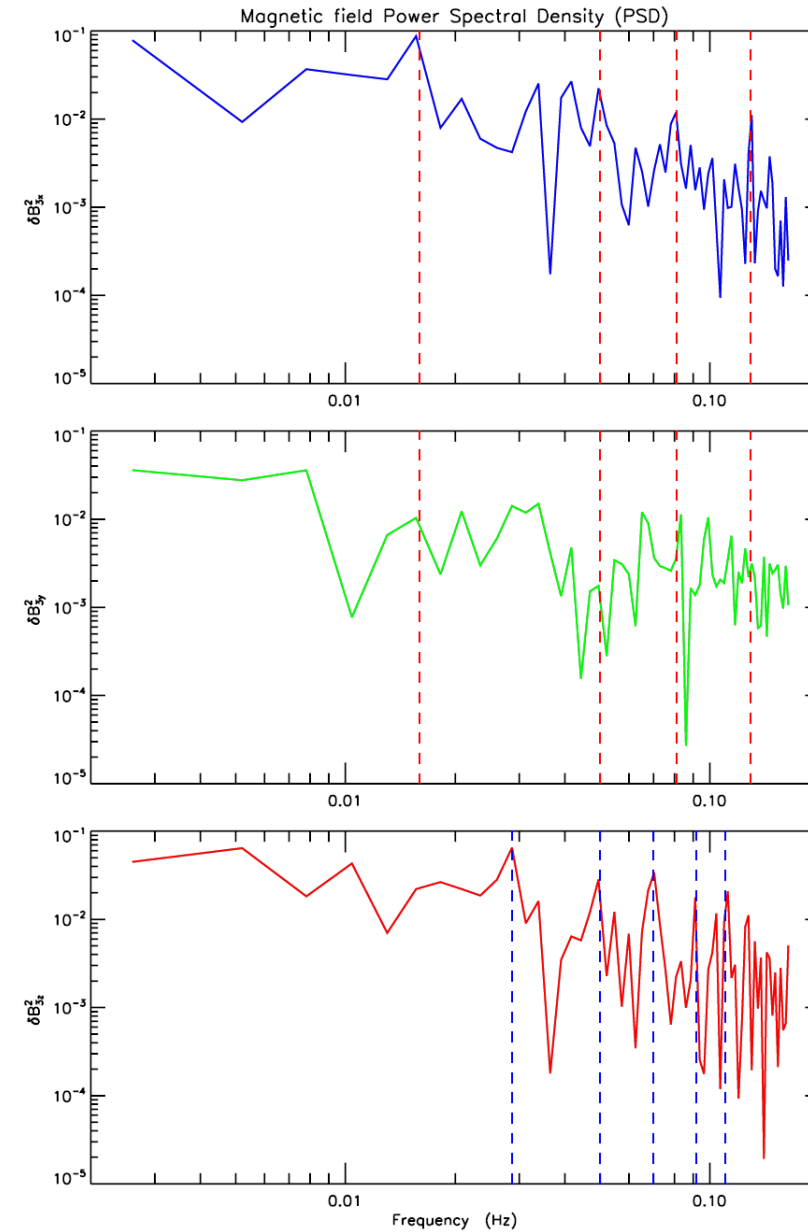
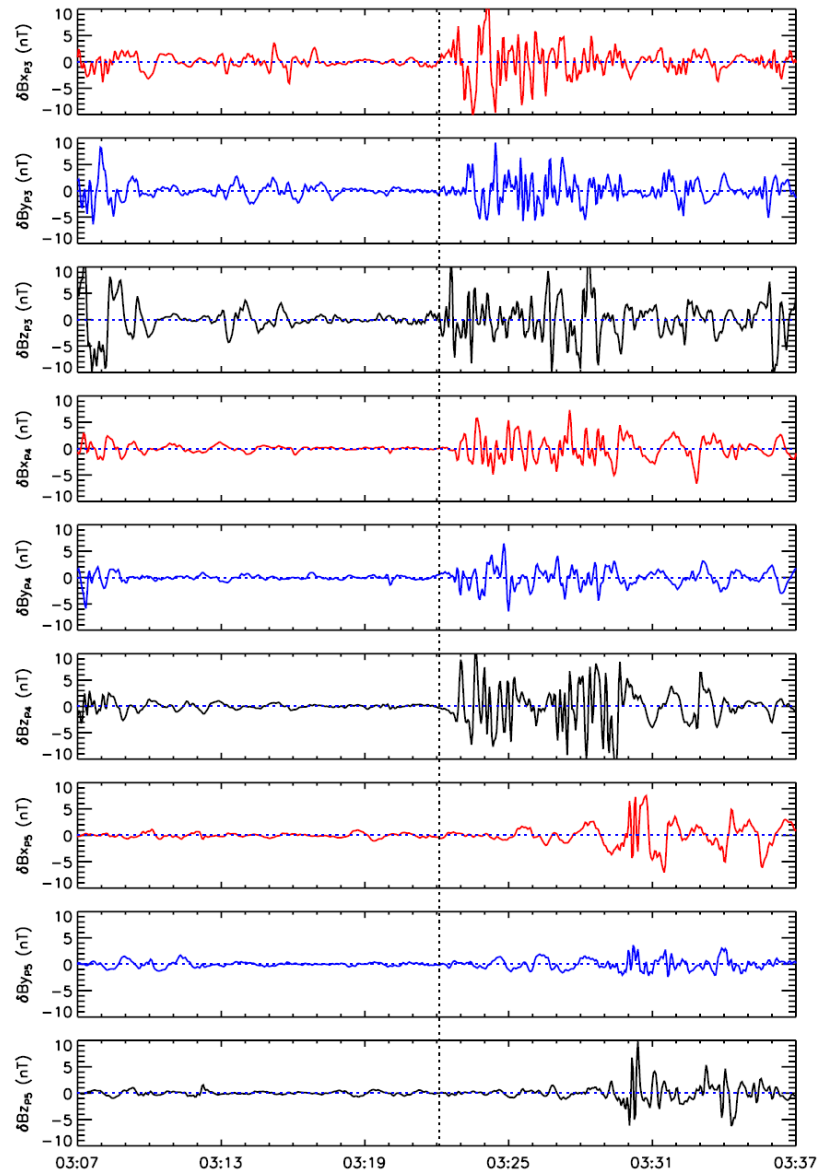
Dispersionless injections  
 of energetic ions in the  
 substorm onset region.

Dispersion injections of  
 energetic ions during the  
 substorm enhancement.



2008-02-12  
 03:20:01

# Broadband LFWs in substorm onset region : Pi1/Pi2 bands.



### 3. Summary

- **Dipolarization in the substorm onset region has a large beginning elevation angle ( $> 60^\circ$ ) followed by significant magnetic fluctuations.**
- **Dipolarization outside the substorm onset region has multi-step increases in the elevation angle with a small beginning elevation angle ( $< 45^\circ$ ).**
- **A new indicator is proposed to identify the substorm onset location in the near-Earth plasma sheet.**

# Thank you for attention!

