Magnetotail Substorm Features From Multi-Point Observations

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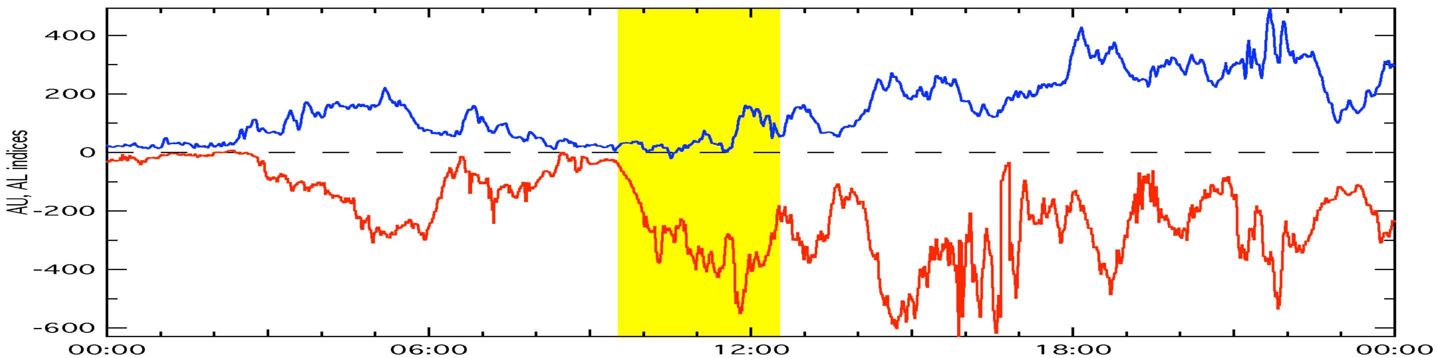
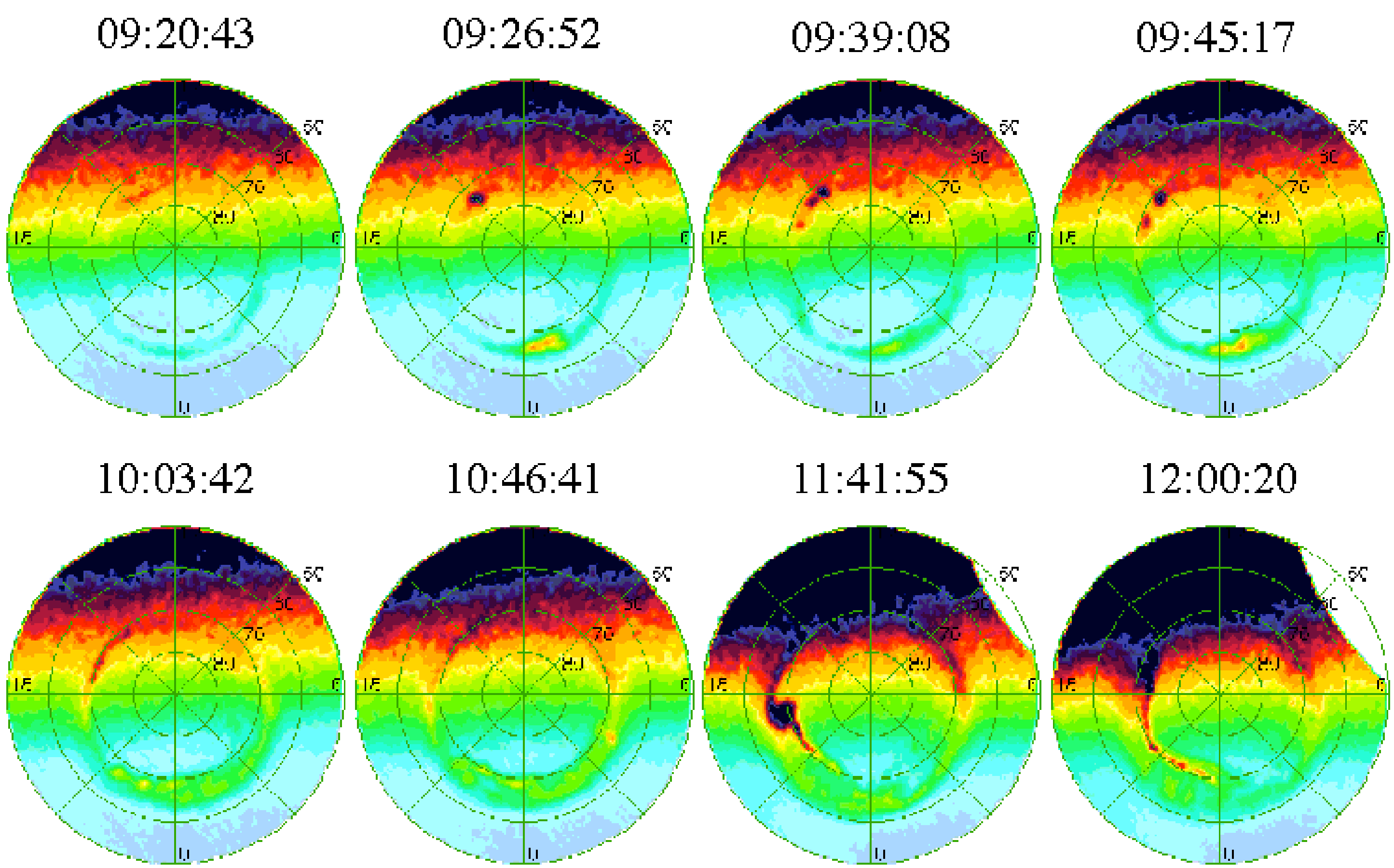
Outline

- **IMAGE/FUV global auroral observations**
- **Analysis of dipolarization, turbulence, and flow reversal regions in the tail from Cluster observations**
- **Implications**

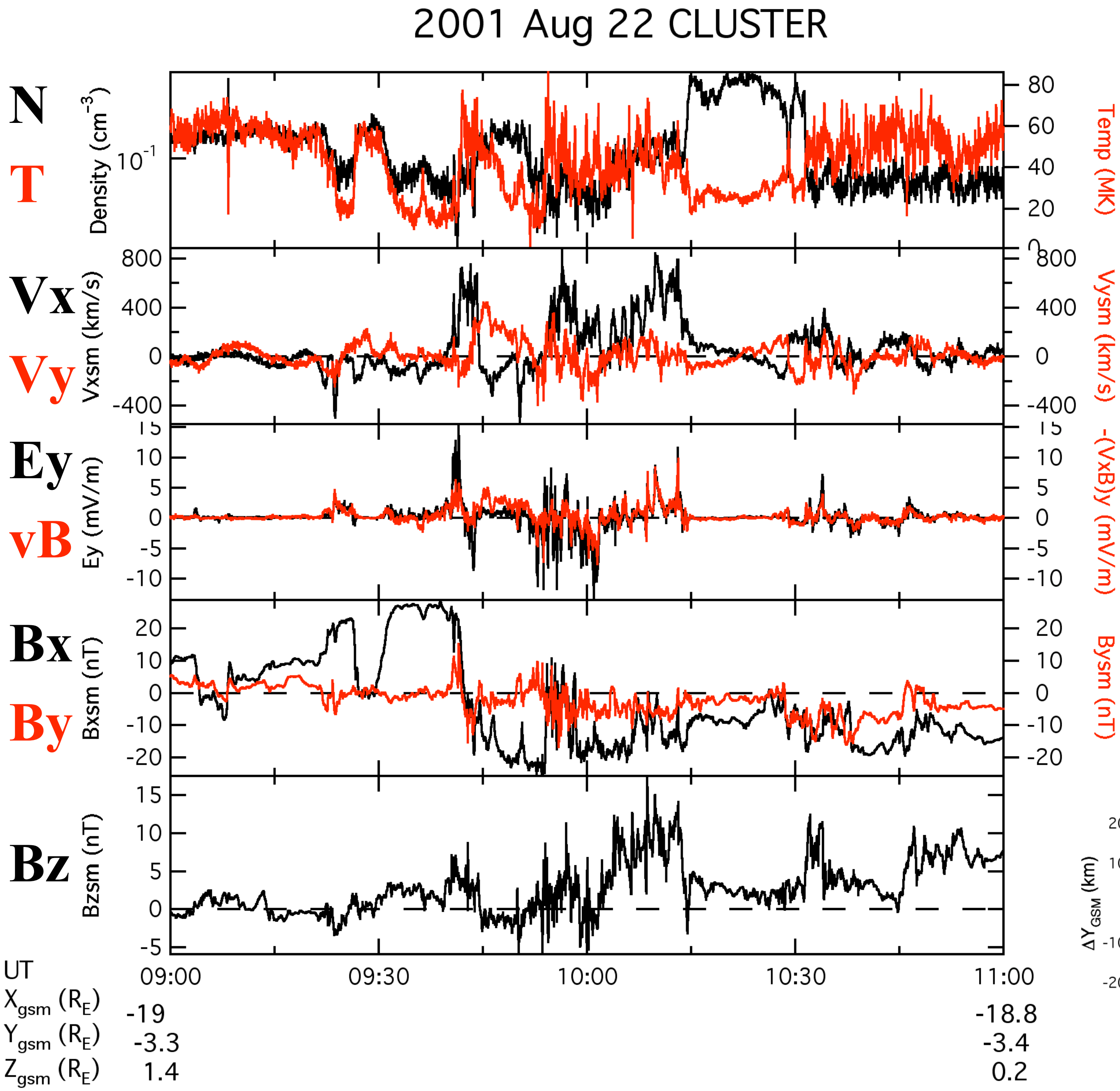
Overview of Substorm Activity





A substorm onset occurred at ~0920 UT on 2001 Aug 22, followed by multiple substorm intensifications. These activities were detected by the AE ground stations and by the IMAGE FUV imager.

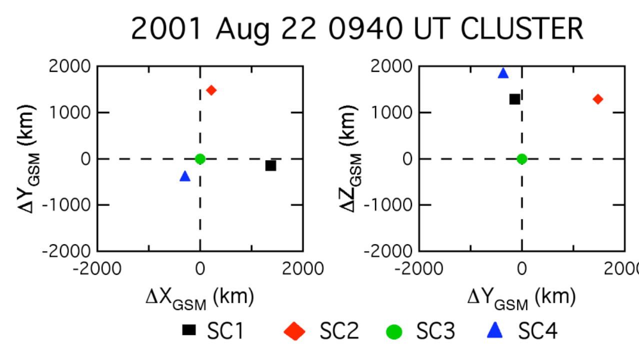
Overview of Tail Activity



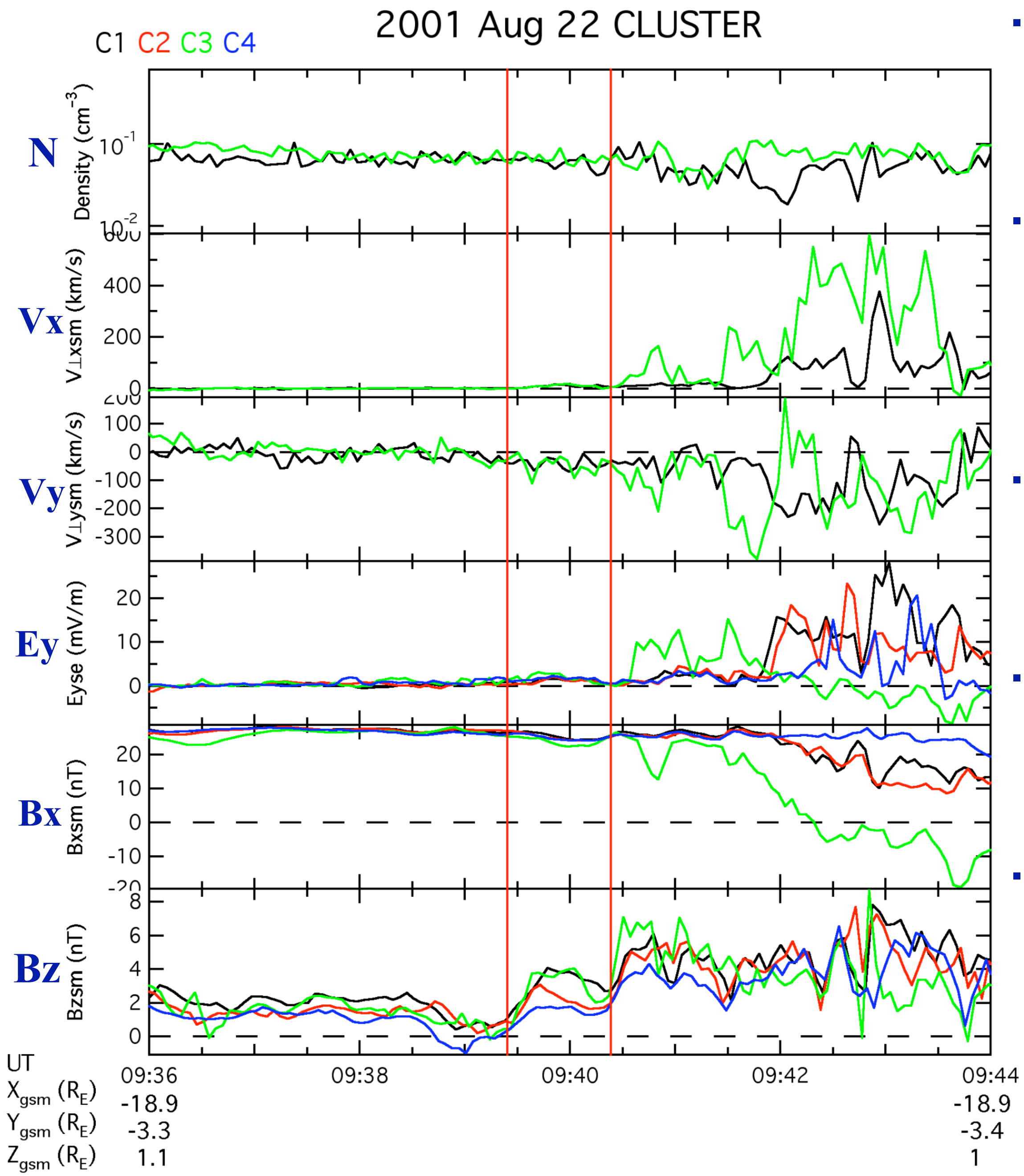
Cluster crossed from northern to southern tail, detecting several dipolarization, plasma flow reversals, and a magnetic flux rope at ~0950 UT

(C3 measurements shown).

CIS-HIA plasma data used.

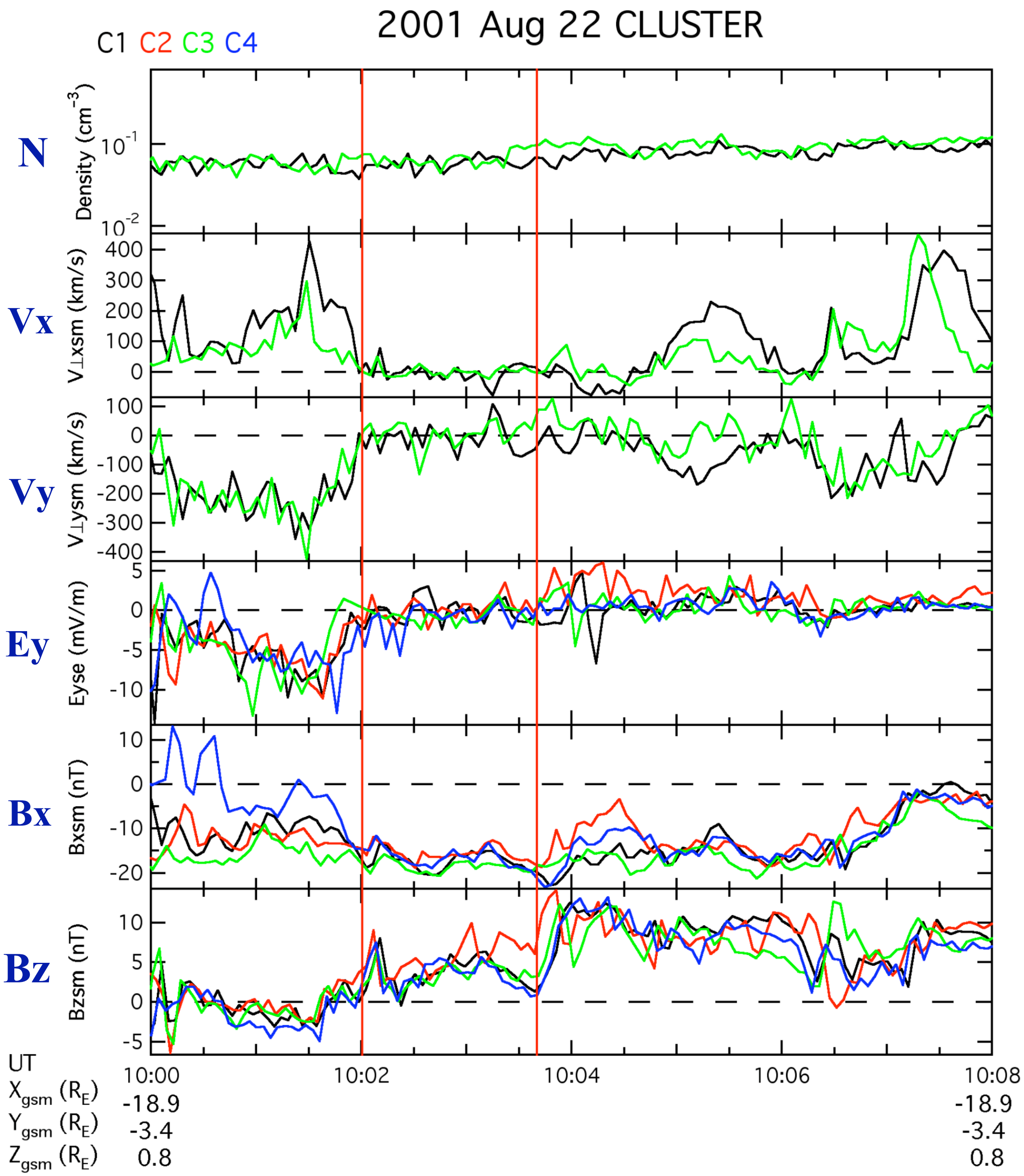


Dipolarization at ~0939 & ~0940 UT



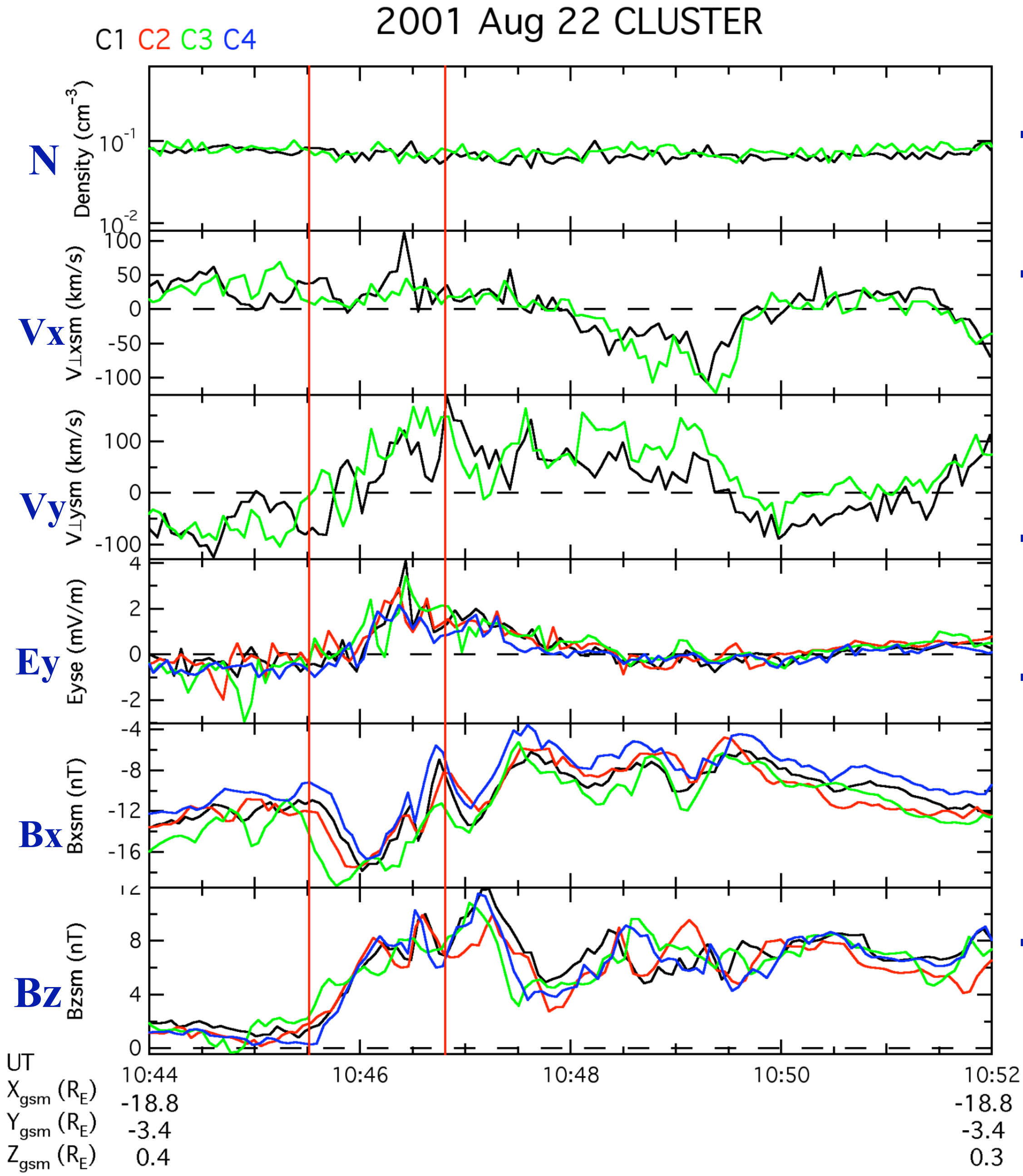
- Southward dipping of B at high latitude seen before dipolarization,
- Dipolarization at Cluster occurred after substorm onset seen by IMAGE/FUV,
- Dipolarization preceded the occurrence of fast plasma flow,
- Highly structured B and E fields detected after dipolarization front,
- Ey had opposite signs for northern and southern parts of the tail (see C3 measurements).

Dipolarization at ~1002 & ~1004 UT



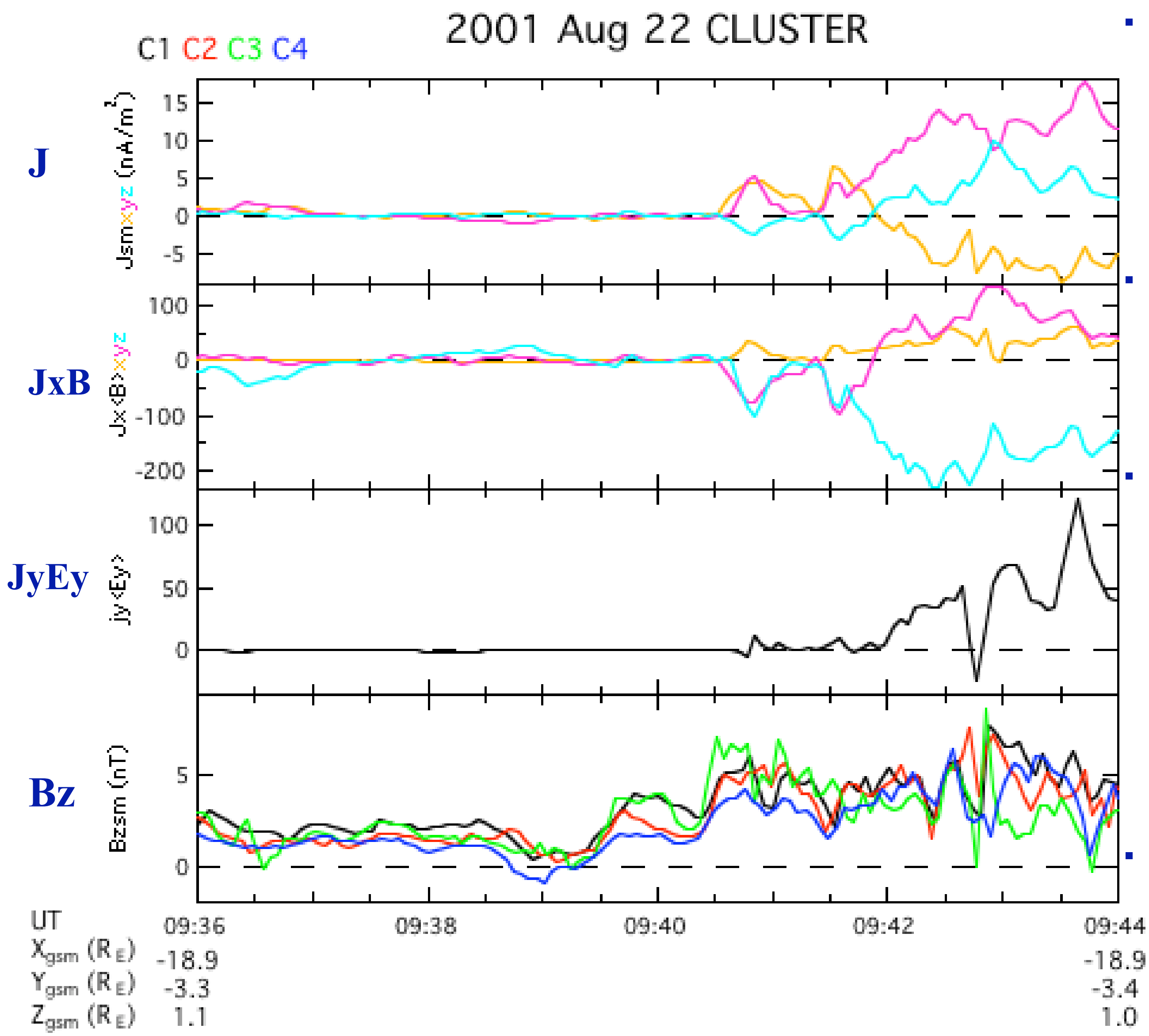
- **Southward B at low- and high-latitude seen before dipolarization,**
- **Dipolarization at Cluster occurred well into substorm expansion seen by IMAGE/FUV,**
- **Dipolarization occurred without fast plasma flow,**
- **Highly structured B and E fields detected after dipolarization front,**
- **Ey before dipolarization had opposite signs for northern and southern parts of the tail.**

Dipolarization at ~1045 & ~1047 UT



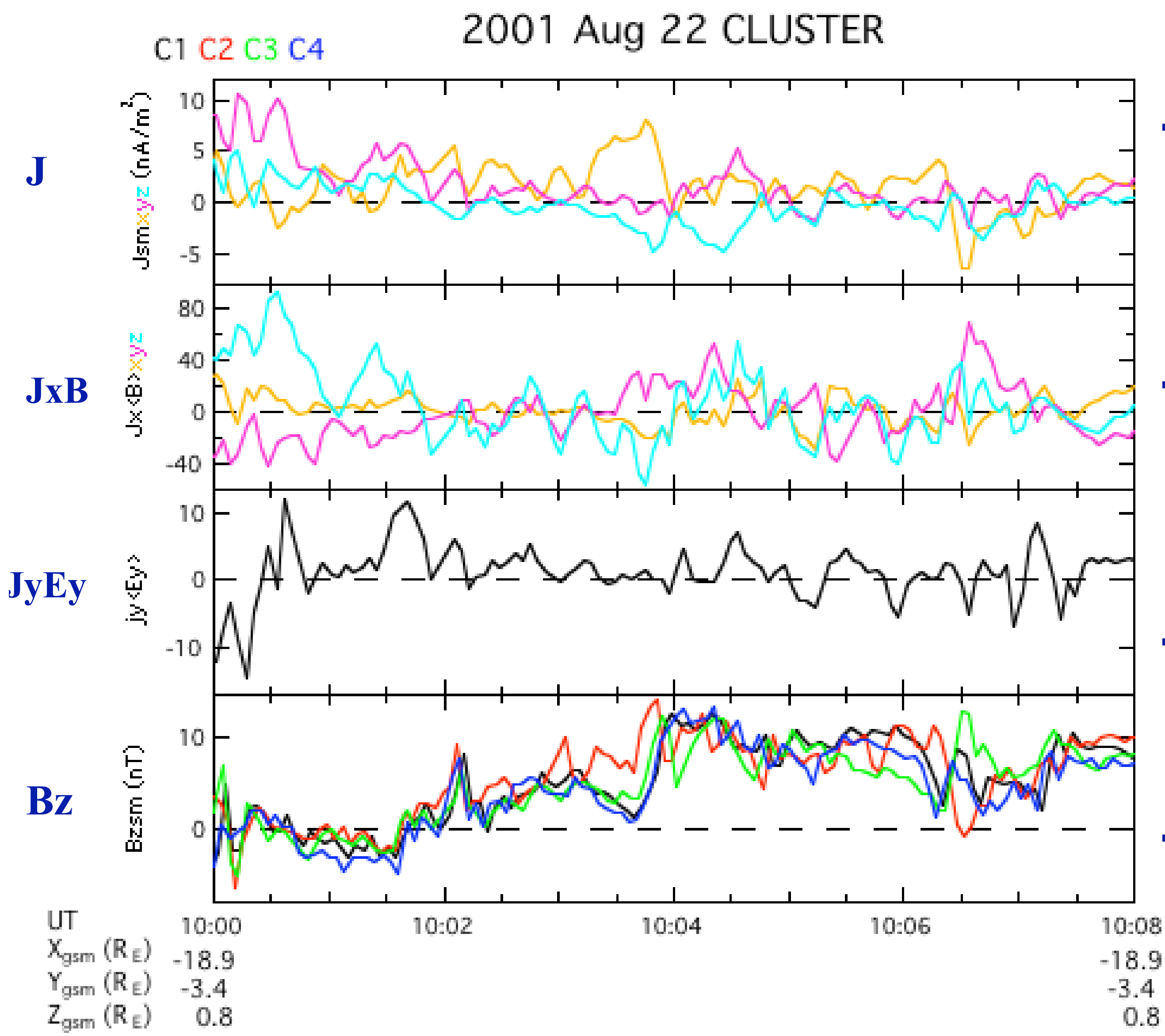
- **Southward dipping of B seen before dipolarization,**
- **Dipolarization at Cluster occurred when double oval was seen by IMAGE/FUV,**
- **Dipolarization occurred without fast plasma flow,**
- **Highly structured B and E fields detected after dipolarization front - wake region,**
- **Ey became duskward after dipolarization.**

Dipolarization at ~0939 & ~0940 UT



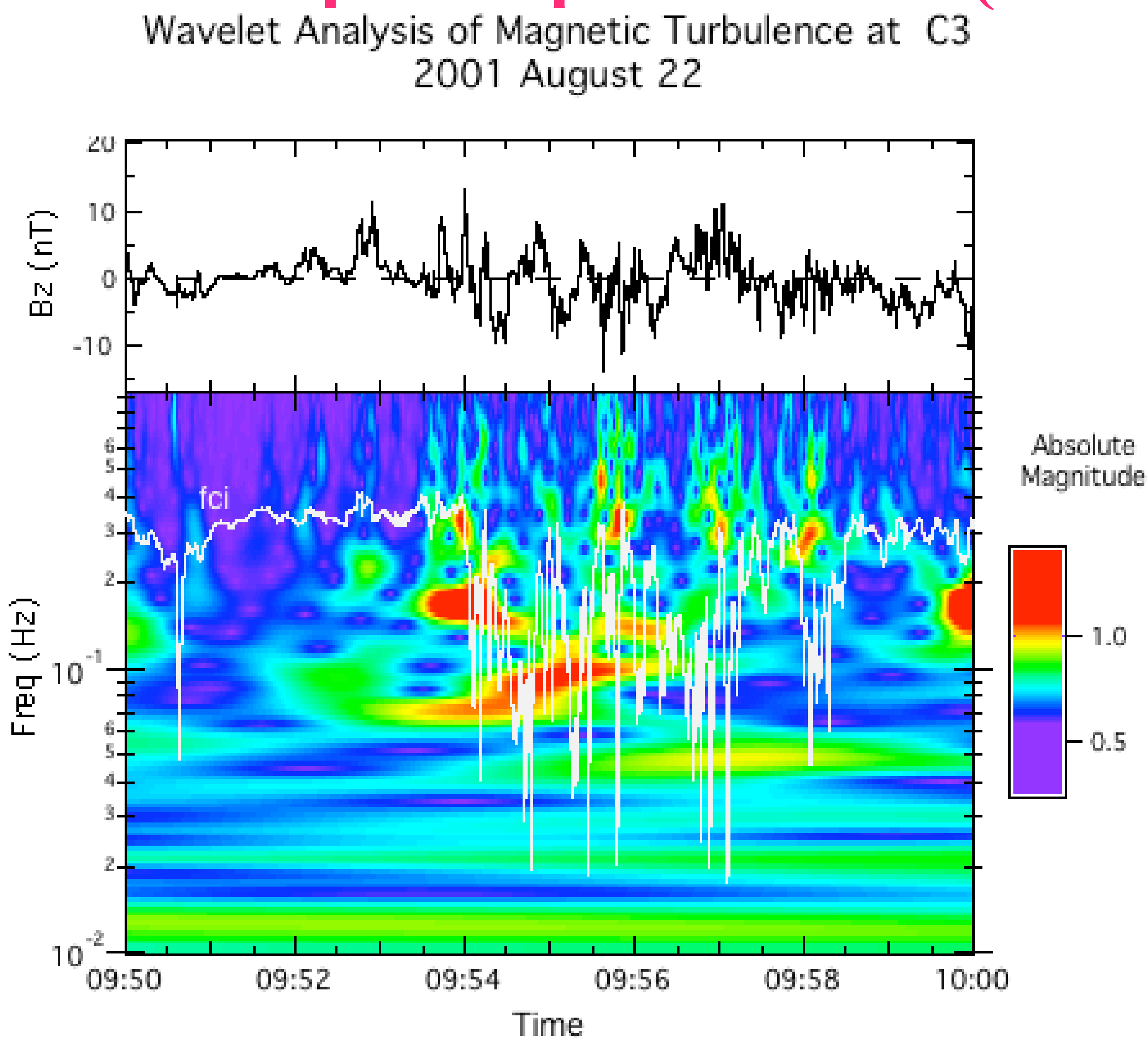
- **Significant changes in j, j×B, and jyEy occurred after dipolarization,**
- **jx, jz reversed sign, jy remained +ve after dipolarization,**
- **(j×B)z was -ve and most significant, (j×B)x > 0; (j×B)y reversed from -ve to +ve after dipolarization,**
- **jyEy was mainly +ve but was -ve occasionally.**

Dipolarization at ~1002 & ~1004 UT



- Significant changes in j, j×B, and jyEy throughout the interval,
- jx was mainly +ve while jz was mainly -ve, jy had small values,
- all components of j×B were about equal in magnitude,
- jyEy fluctuated in sign.

Wavelets in the post-dipolarization (wake) region

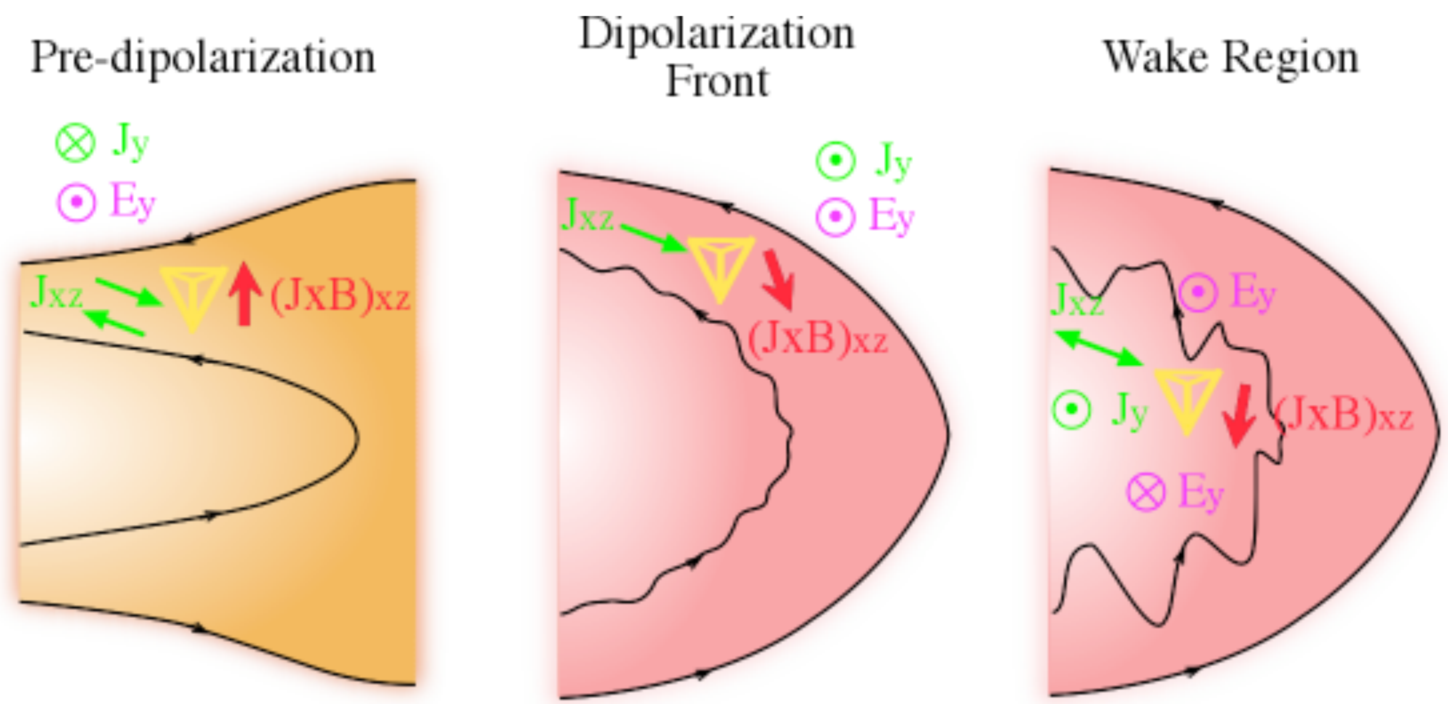


Multi-scale and intermittent fluctuations are seen, much like the near-Earth region (<10 Re) seen by CCE.

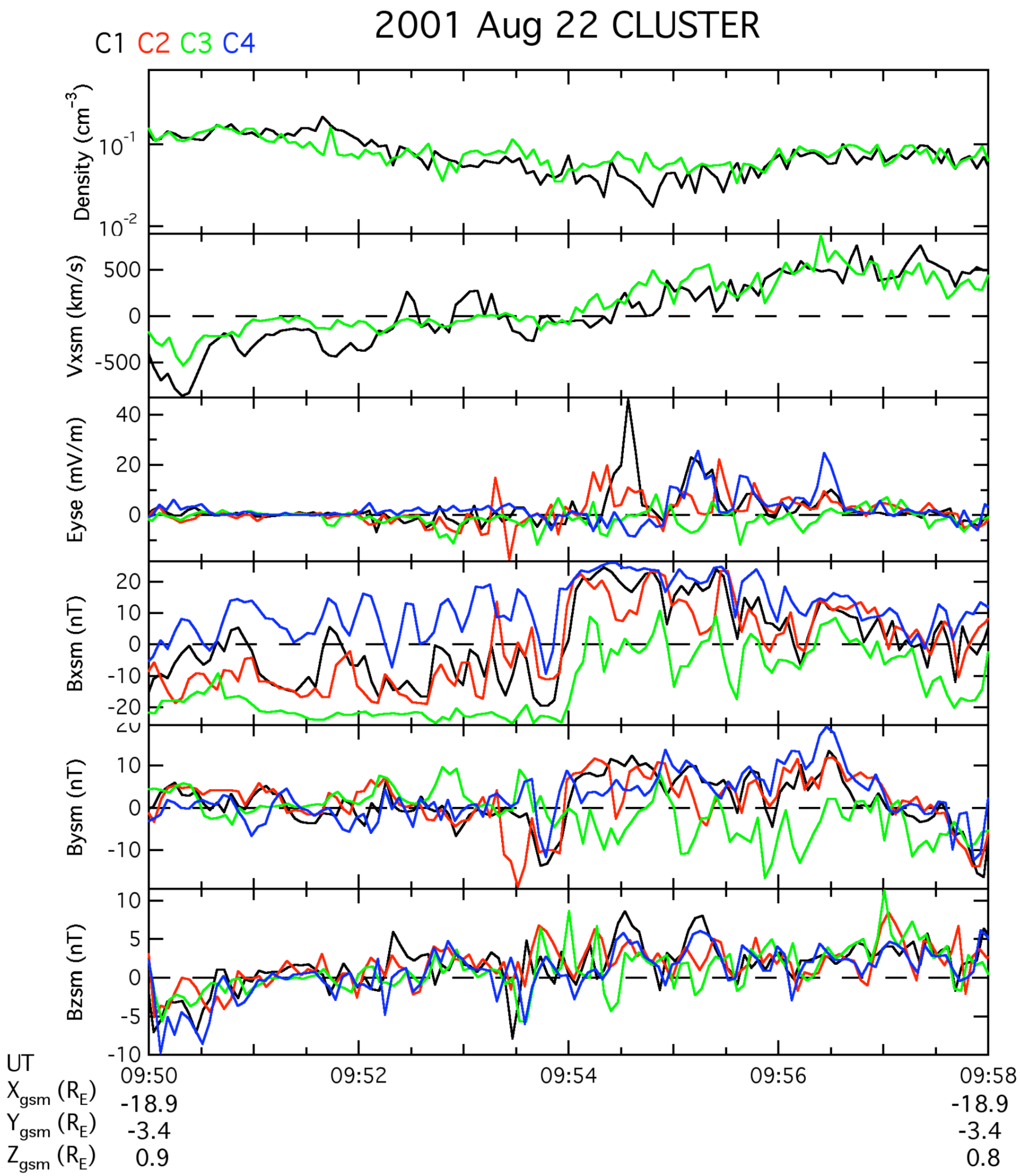
Summary of Common Dipolarization Features

- **Southward dipping of B developed prior to dipolarization - possibly indicating thinning of current sheet progressing tailward.**
- **No fast (>300 km/s) perpendicular plasma flow appeared at dipolarization time - possible indication of a kinetic process responsible for dipolarization.**
- **Dipolarization was episodic, consisting of multiple increases and decreases of Bz. Each of these dipolarization fronts was followed by an interval of highly variable Bz, Ey, j×B force, and jyEy (load/dynamo).**

Dipolarization Sequence

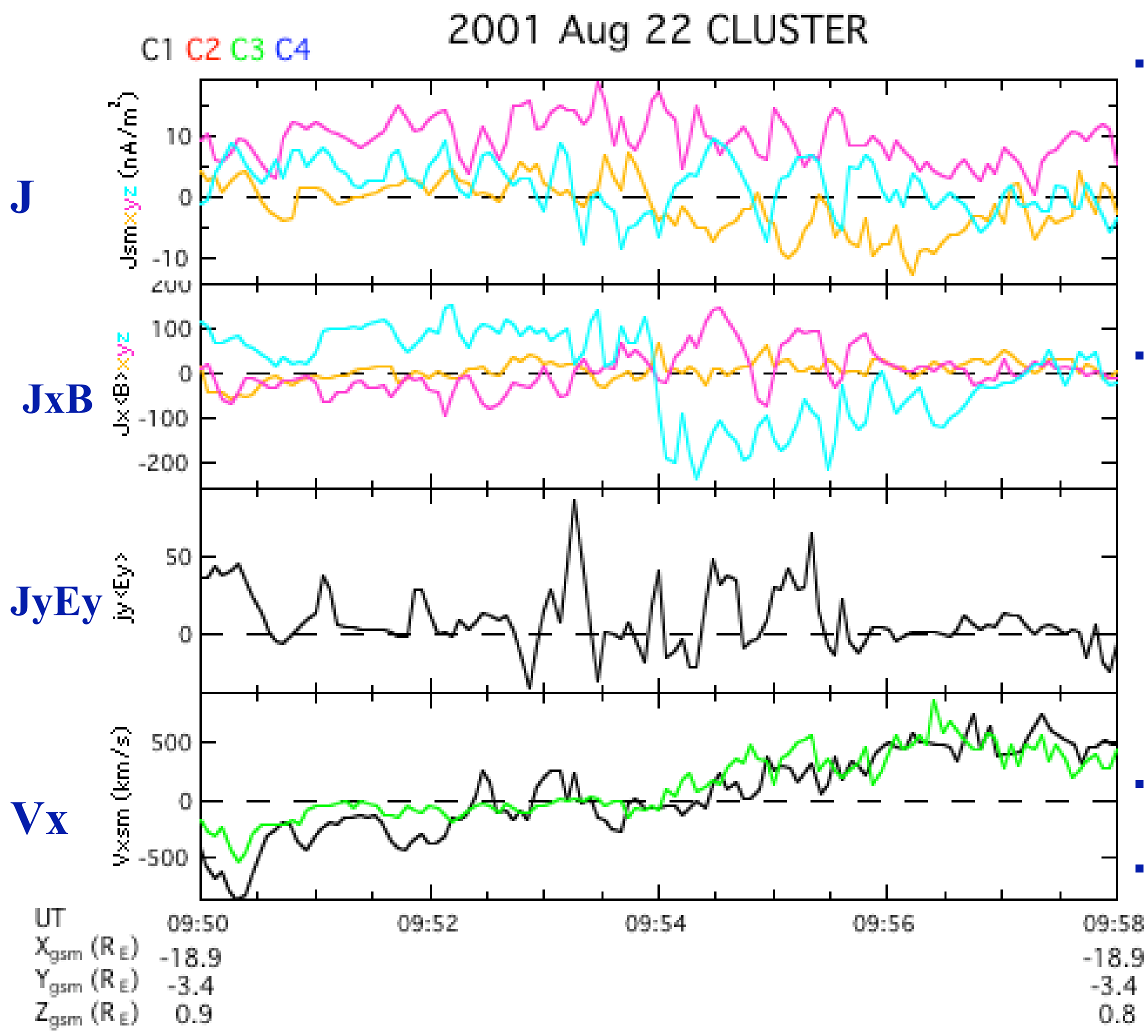


Plasma Flow Reversal - 1



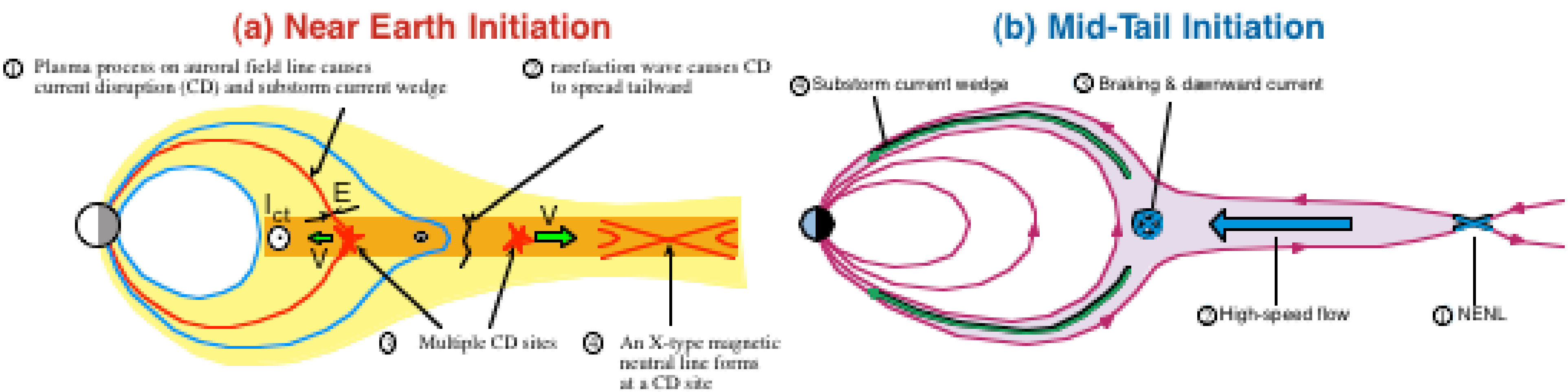
- Vx reversed from tailward to earthward - a signature often viewed as tailward retreat of NENL,
- Bx had small values at C1 but did not observed significant Ey at flow reversal time,
- instead Ey at C1 was large when Bx was large while Bx was small at C3 and Ey was also small,
- these seem to suggest activity at multiple sites rather than movement of a single activity site.

Plasma Flow Reversal - 2



- jx reversed from mainly +ve to mainly -ve at flow reversal; jy stayed +ve; jz was variable,
- (j×B)y reversed from mainly -ve to mainly +ve at flow reversal; (j×B)z reversed from +ve to -ve at flow reversal; (j×B)x was variable,
- jyEy was variable,
- these also seem to suggest activity at multiple sites rather than movement of a single activity site.

Two Substorm Scenarios for Flow Reversal



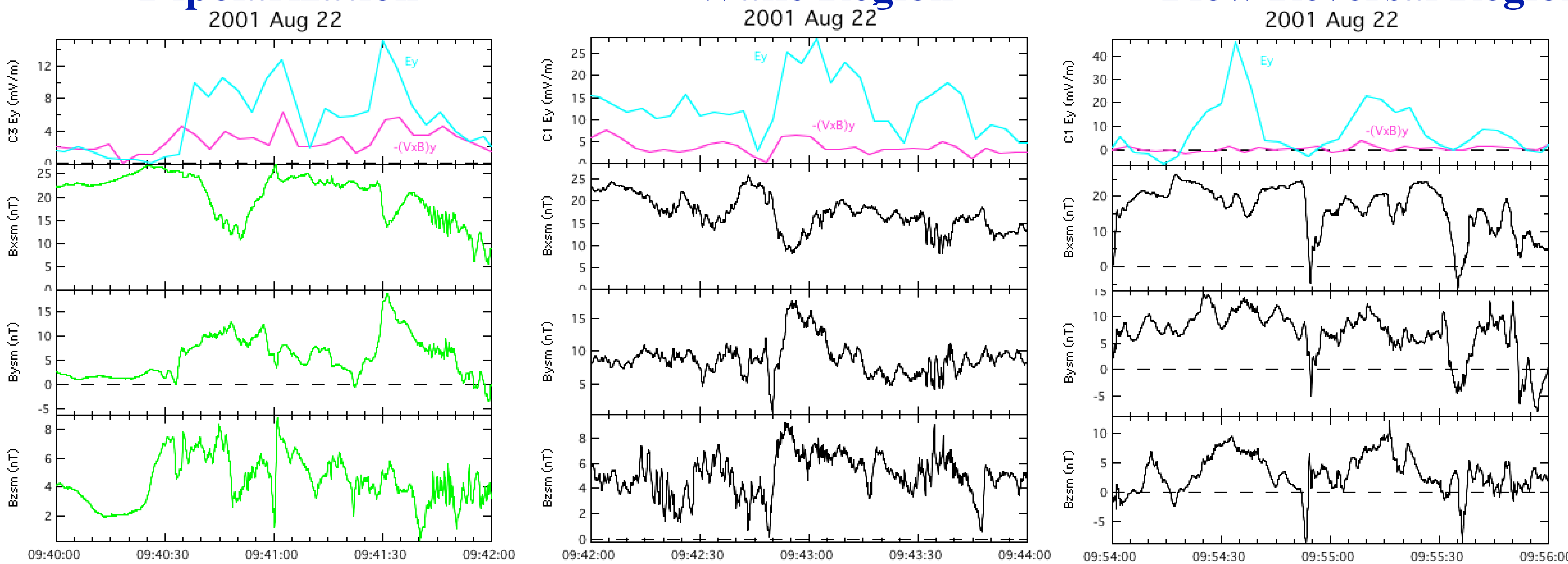
(a) NEI - multiple activity sites progressively appear tailward.

(b) MTI - a magnetic reconnection site moves tailward.

- No indication of (j×B)x changed direction with flow reversal,
- (j×B)y and (j×B)z forces changed directions with flow reversal, suggesting activity site shifted in y- and z-location.

Breakdown of Frozen-in Condition

Dipolarization | **Wake Region** | **Flow Reversal Region**



From an evaluation of the various terms in the generalized Ohm's law, we find that the Hall term, followed by the electron pressure term to be significant in contributing to the non-MHD behavior. The role of anomalous resistivity is unclear. Note that *B* and B_z had large values, indicating the breakdown of frozen-in condition occurred in strong magnetic fields and not near plasma sheet boundary because B_z was large.

$$E_y+(V\times B)_y= (n/\varepsilon_o\omega_{pe}^2)d(J_y/n)/dt+\eta J_y+(J\times B)_y/nq-(\text{div } P_e)_y/nq$$

Summary

Tail features during substorm activity on 2001 August 22 are examined with Cluster data at X ~ -19 Re:

- **Southward dipping of B lasting for ~1 min appeared prior to dipolarization, possibly indicating tailward propagation of a thinning wave.**
- **No fast (>300 km/s) perpendicular plasma flow appeared at dipolarization time - possible indication of a kinetic process responsible for dipolarization.**
- **Dipolarization was episodic pulse-like, consisting of multiple relaxation and stretching of the magnetic field.**
- **Characteristics of plasma flow reversal suggest that multiple sites are activated rather than movement of a single activity site.**