# Ionospheric convection signatures associated with magnetotail flux ropes


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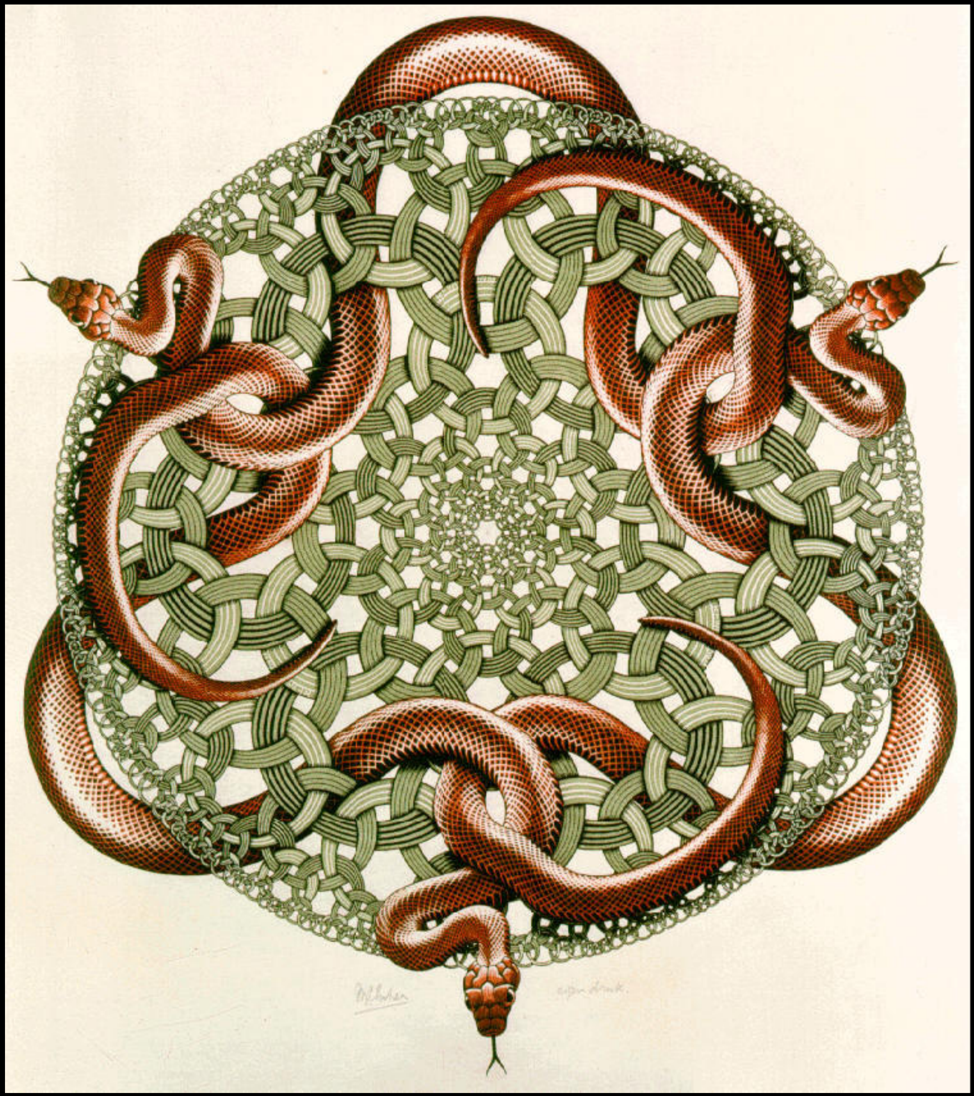
with thanks to the Cluster FGM and CIS teams

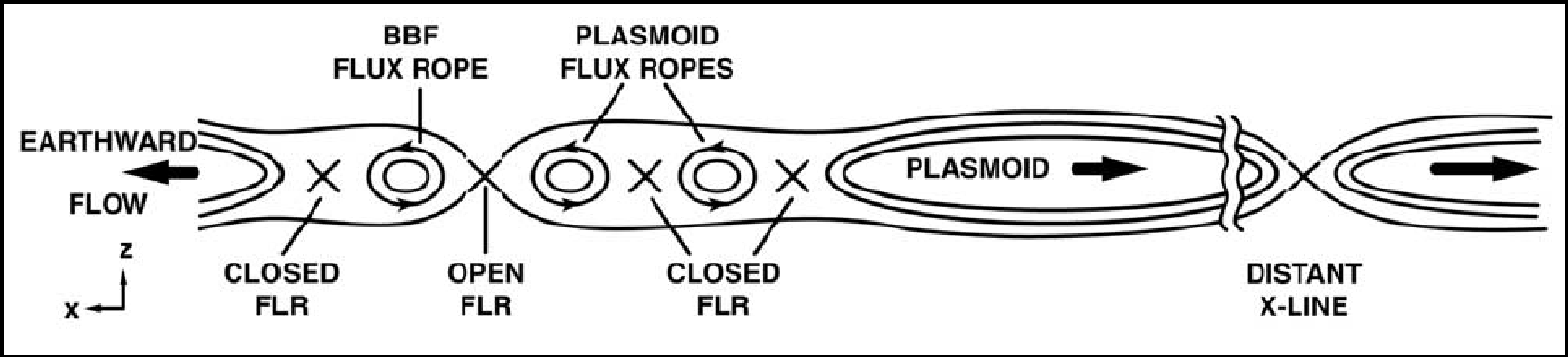
SuperDARN Workshop, Newcastle, Australia June 2008



"Snakes", M. C. Escher, 1969

# Flux Ropes: Background

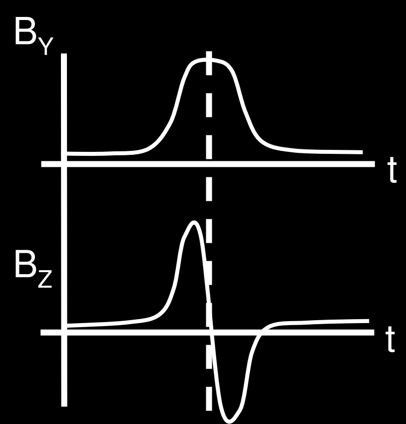
- Flux ropes are plasmoid like magnetic field structures which may propagate in a tailward or earthward direction

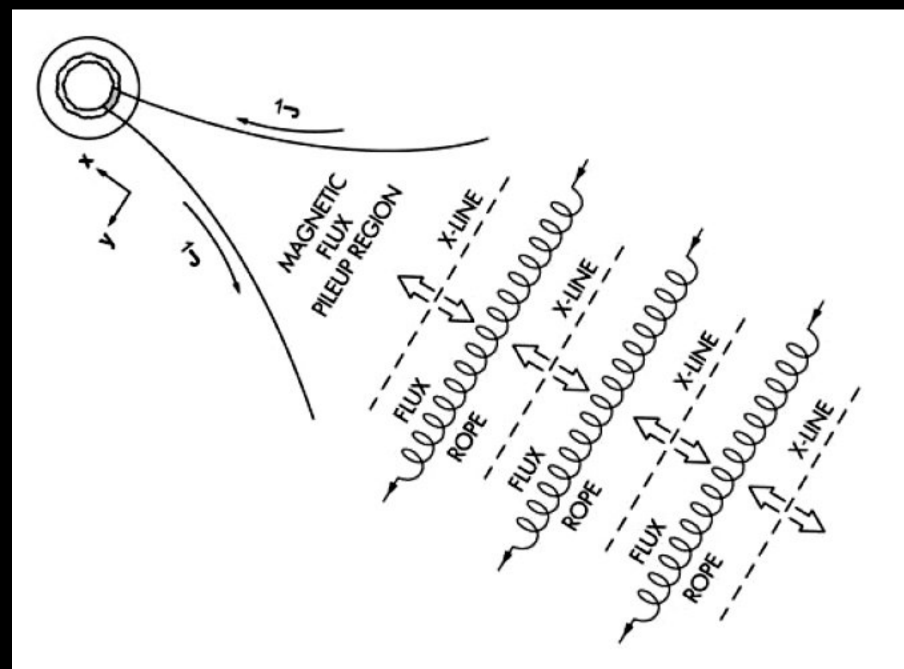



**from Slavin et al., JGR, 2003**

# Flux Ropes: Background

- Flux ropes are plasmoid like magnetic field structures which may propagate in a tailward or earthward direction
- Unlike plasmoids, which would be expected to have weak centre fields (Frank et al., 1994), flux ropes exhibit a strong cross-tail component resulting in a helical structure (Moldwin and Hughes, 1992; Lepping et al., 1995; Slavin et al., 1995)

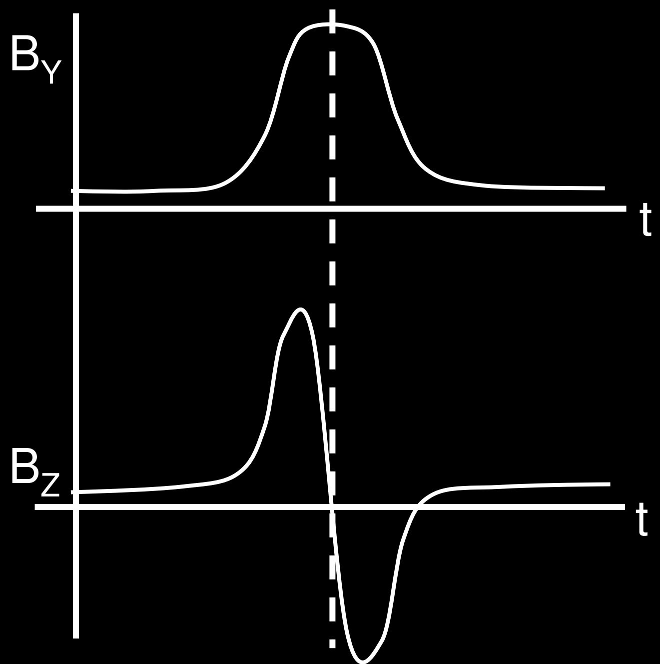


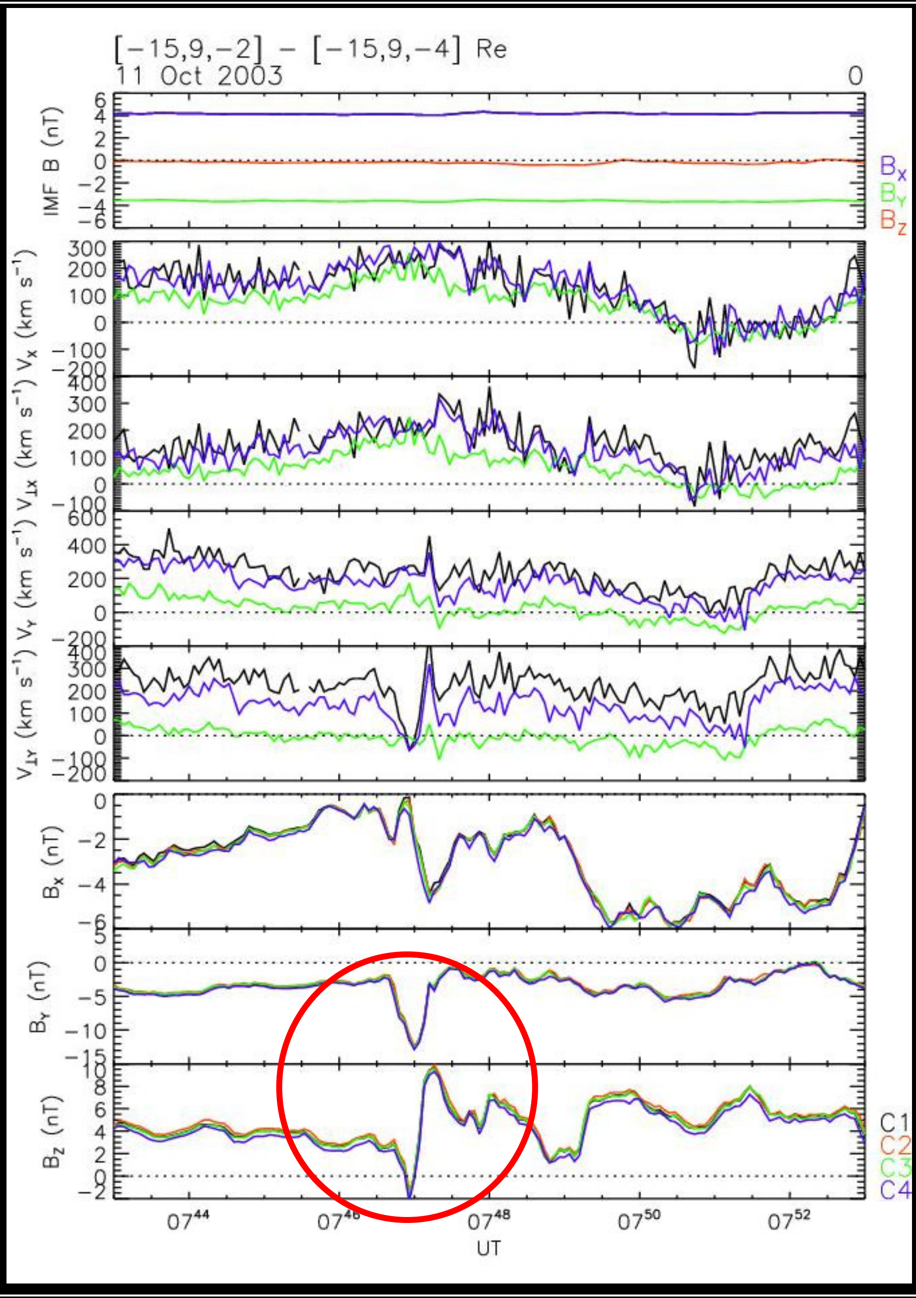




**from Slavin et al., JGR, 2003**

# Zhang et al., 2007

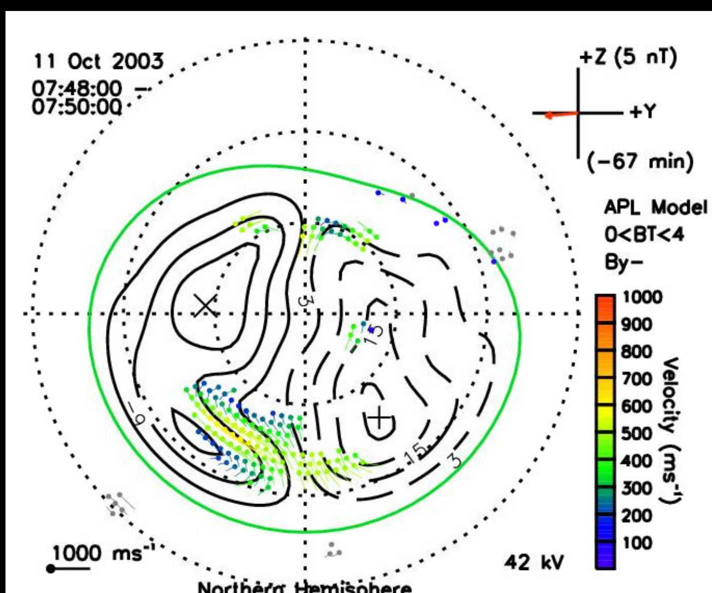
- Discussed observations of a "quiet time" flux rope

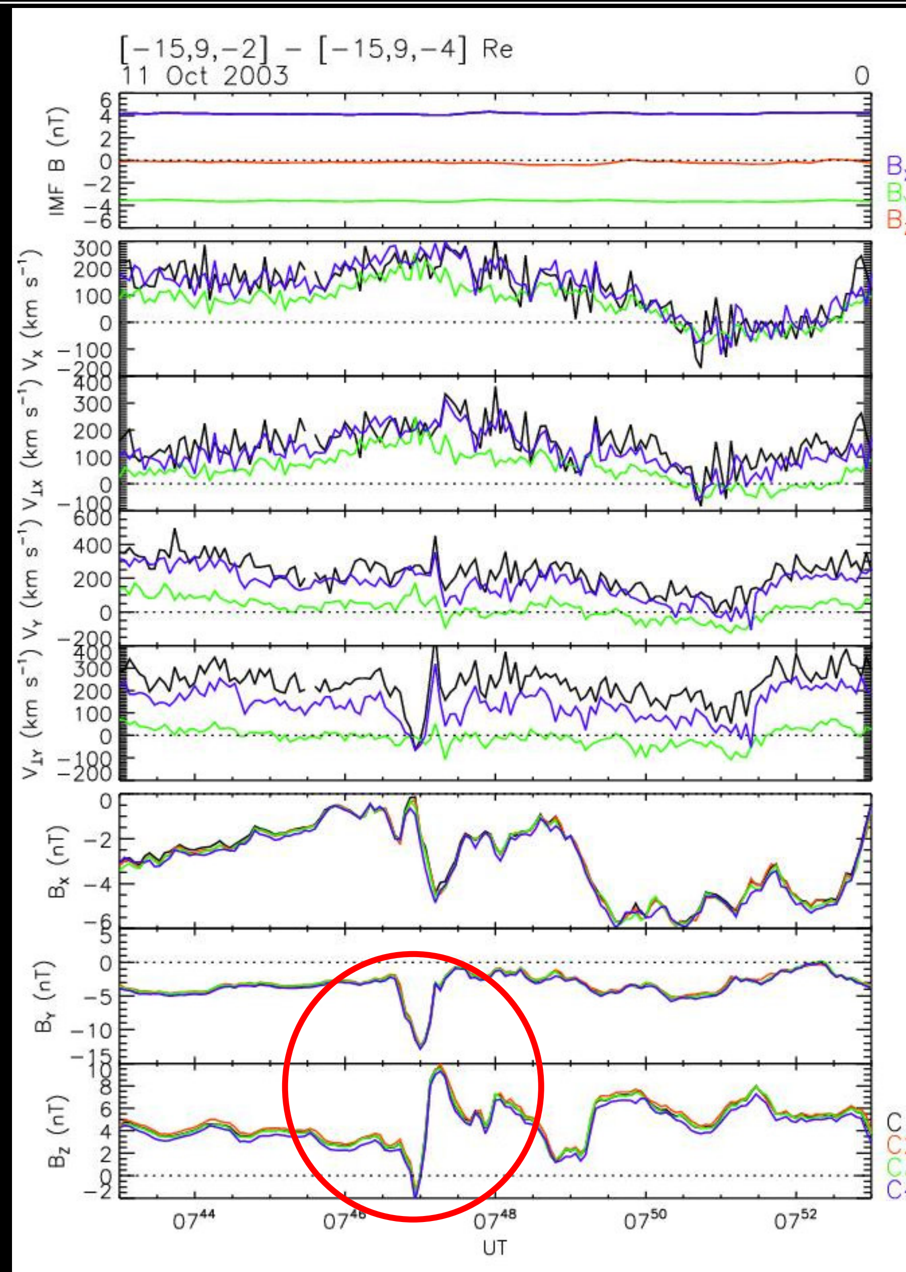


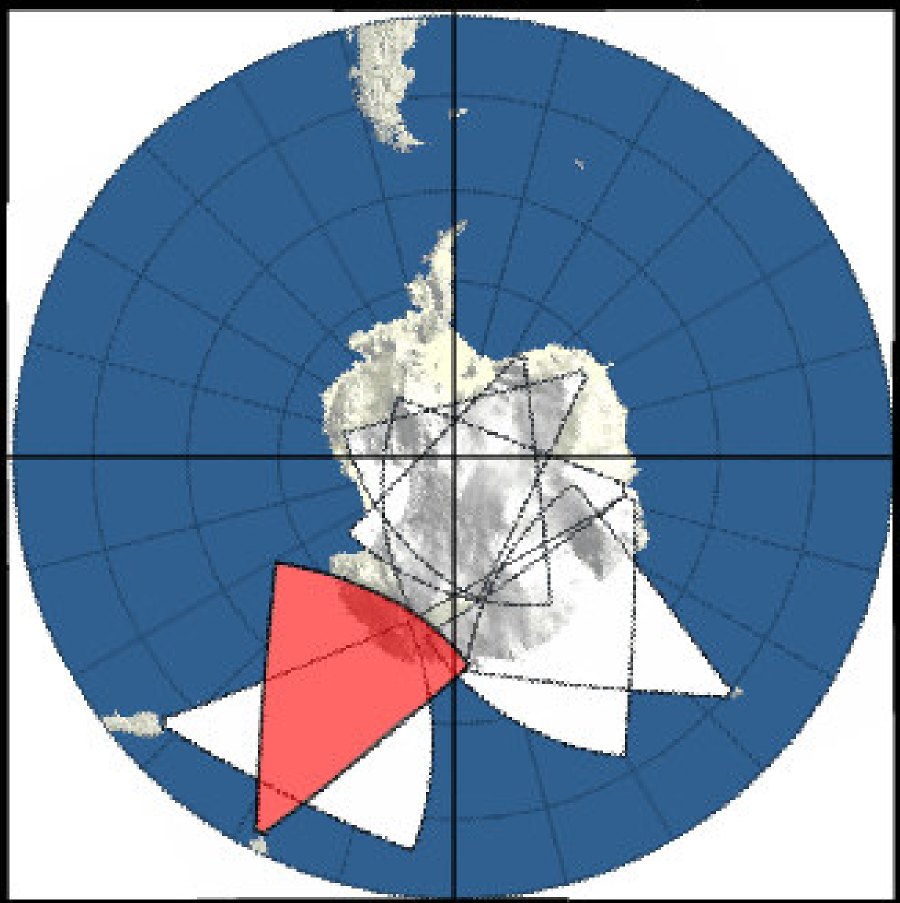



# Zhang et al., 2007

- Discussed observations of a "quiet time" flux rope
- However, moderate flux transport (~200 km s$^{-1}$) in the magnetotail is evident
- Associated ionospheric flow enhancement reveals localised nightside flow vortex



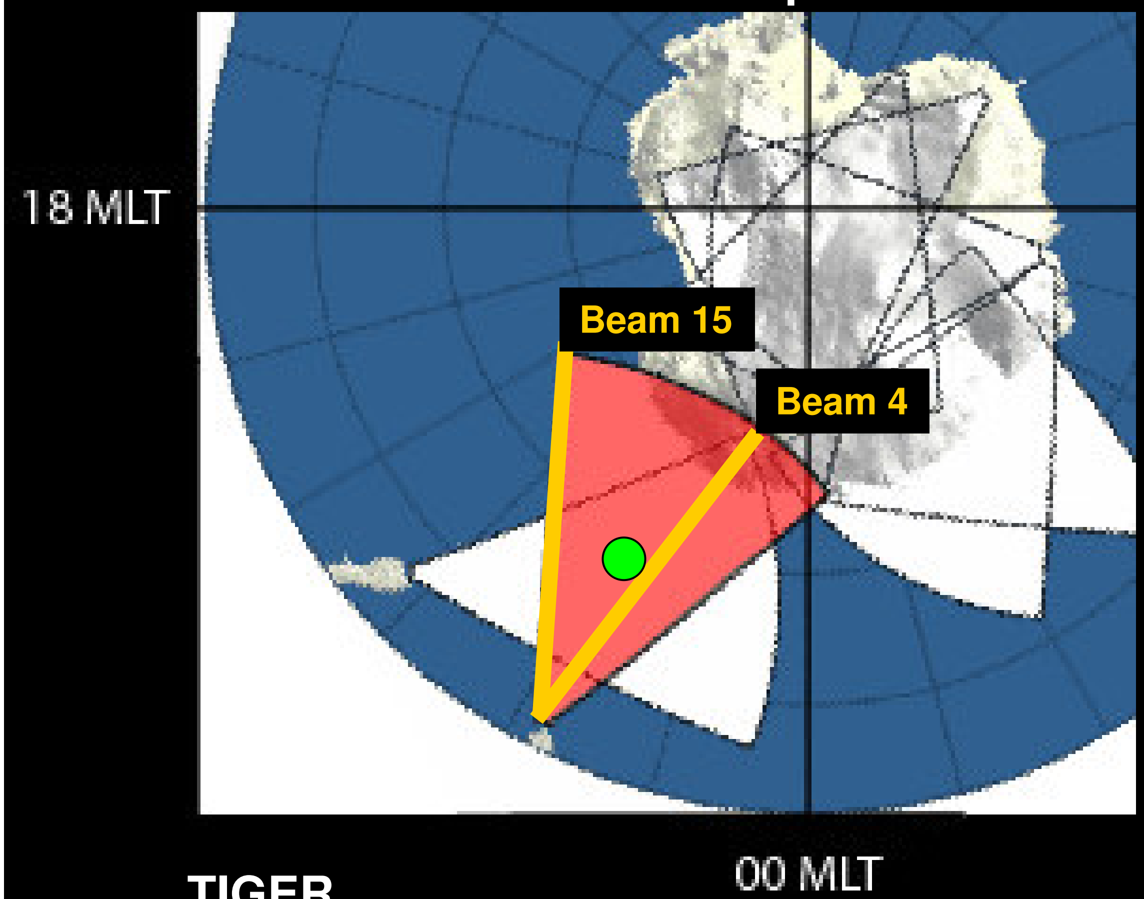



**TIGER**
Tasman International Geospace Environment Radars

## 30 September 2002

- 1000 – 1200 UT
- TIGER pre-midnight

## Southern Hemisphere

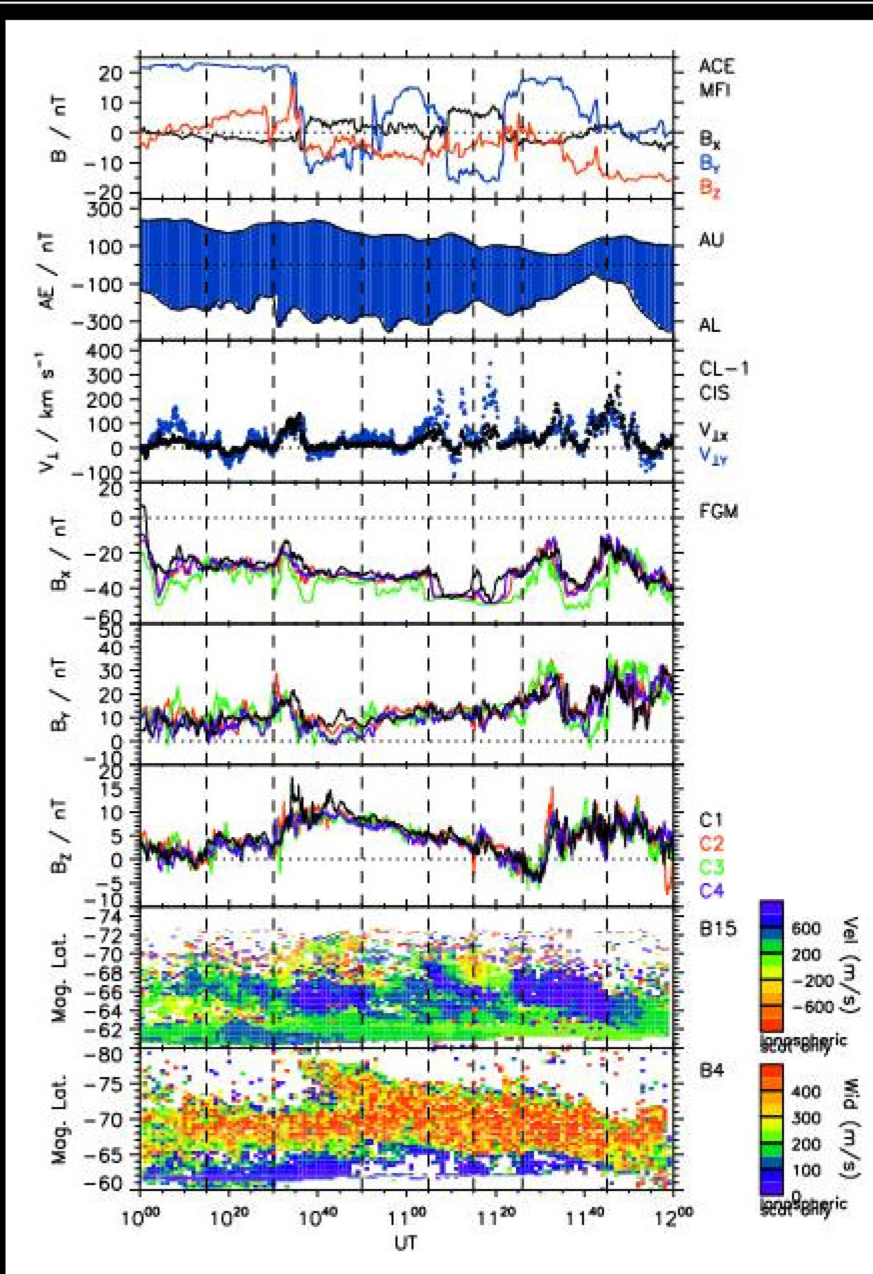



**TIGER**

Tasman International Geospace Environment Radars

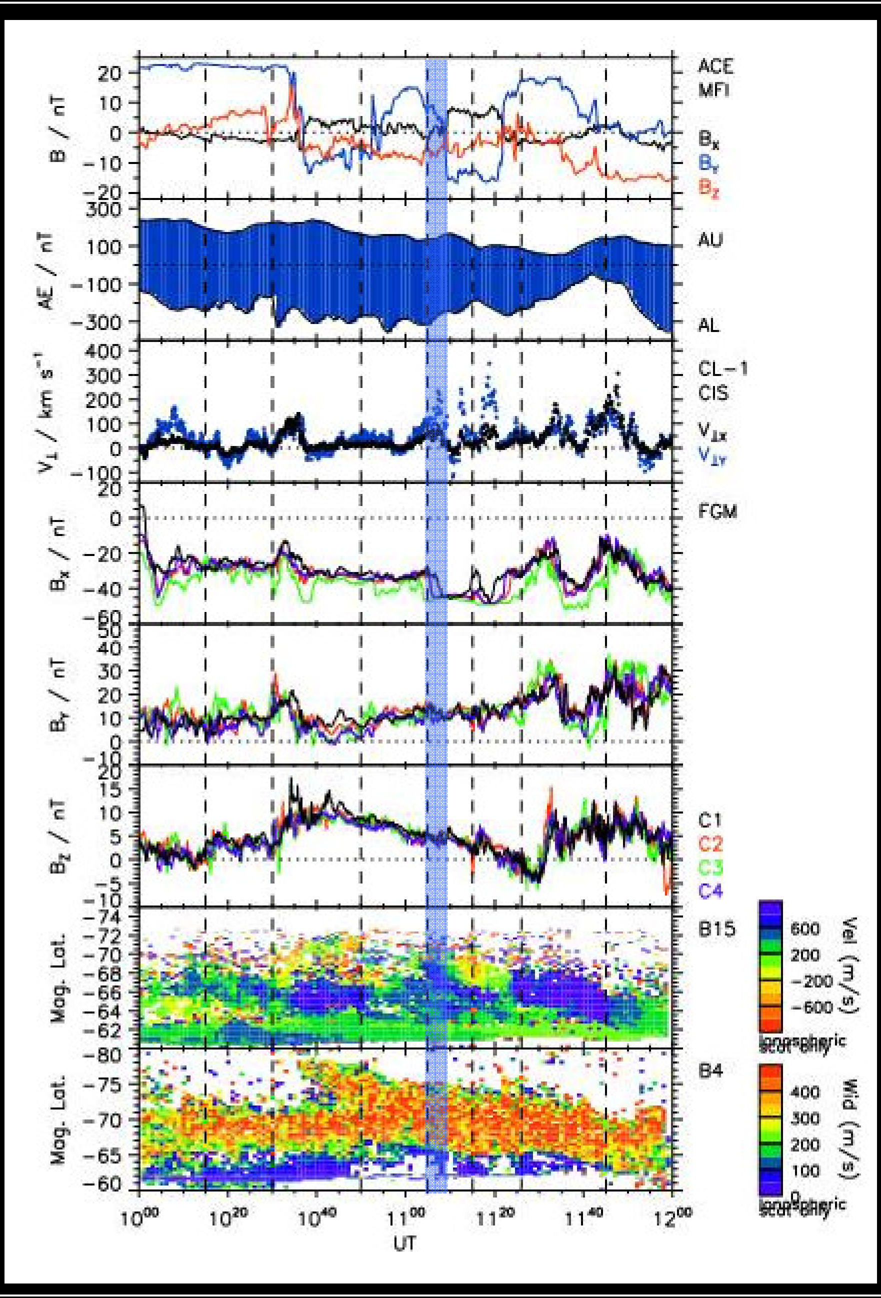
## 30 September 2002

- 1000 – 1200 UT
- TIGER pre-midnight
- L-O-S data from 2 beams
- Cluster was located at GSE (X, Y, Z) ~ (-17, 6, 3) Re at 1100 UT
- Cluster maps into TIGER field-of-view at 1100 UT




# 30 September 2002

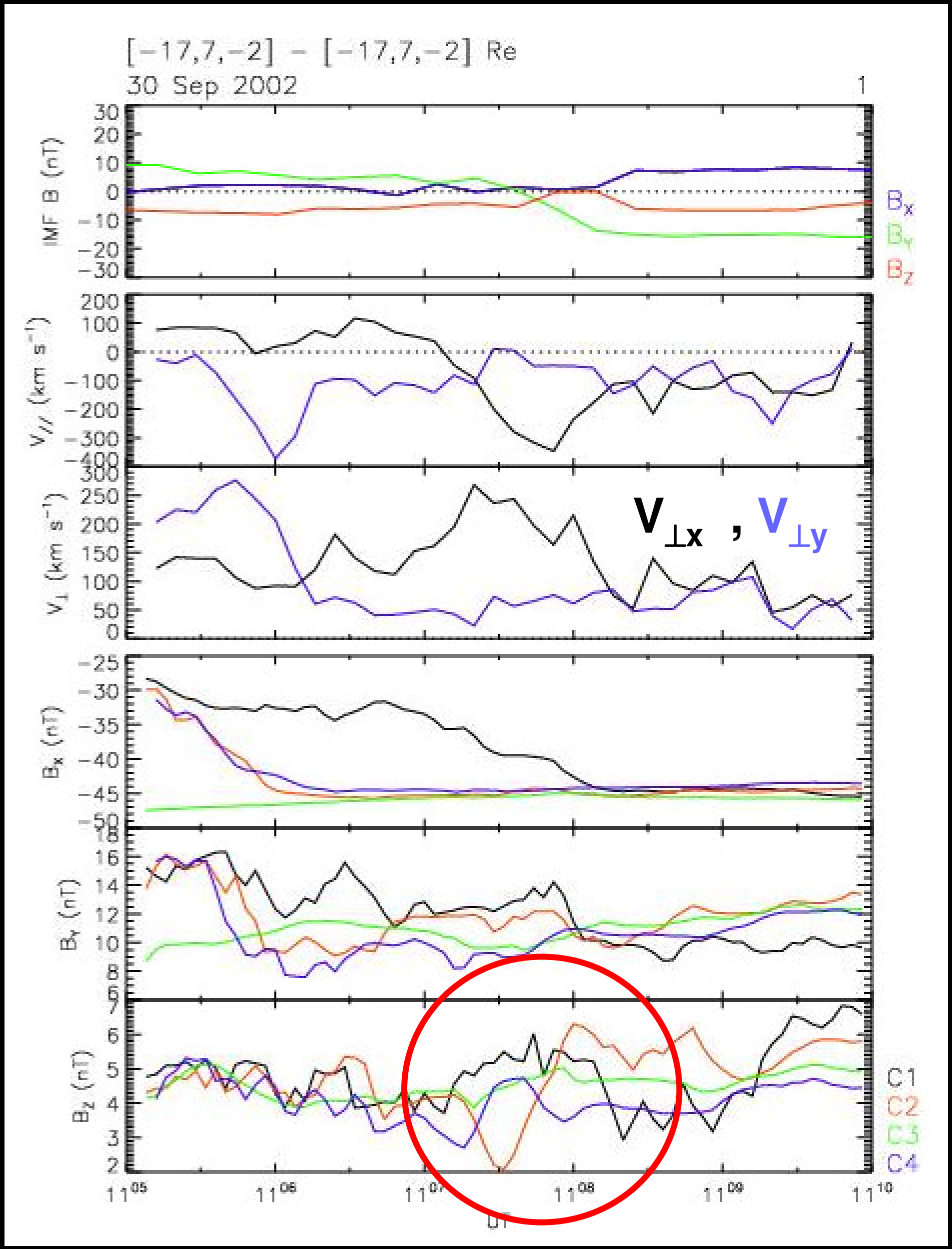
- 2-hour interval from 1000-1200 UT
- IMF variable but $B_Y$-dominated
- AE very active, up to ~500 nT
- Next substorm onset during 12 UT
- Multiple small magnitude BBFs
- Multiple B field / flux rope signatures.
- Multiple HF radar flow enhancements




## 30 September 2002

- Three primary events identified:

1. "small": 1105 UT




# 30 September 2002

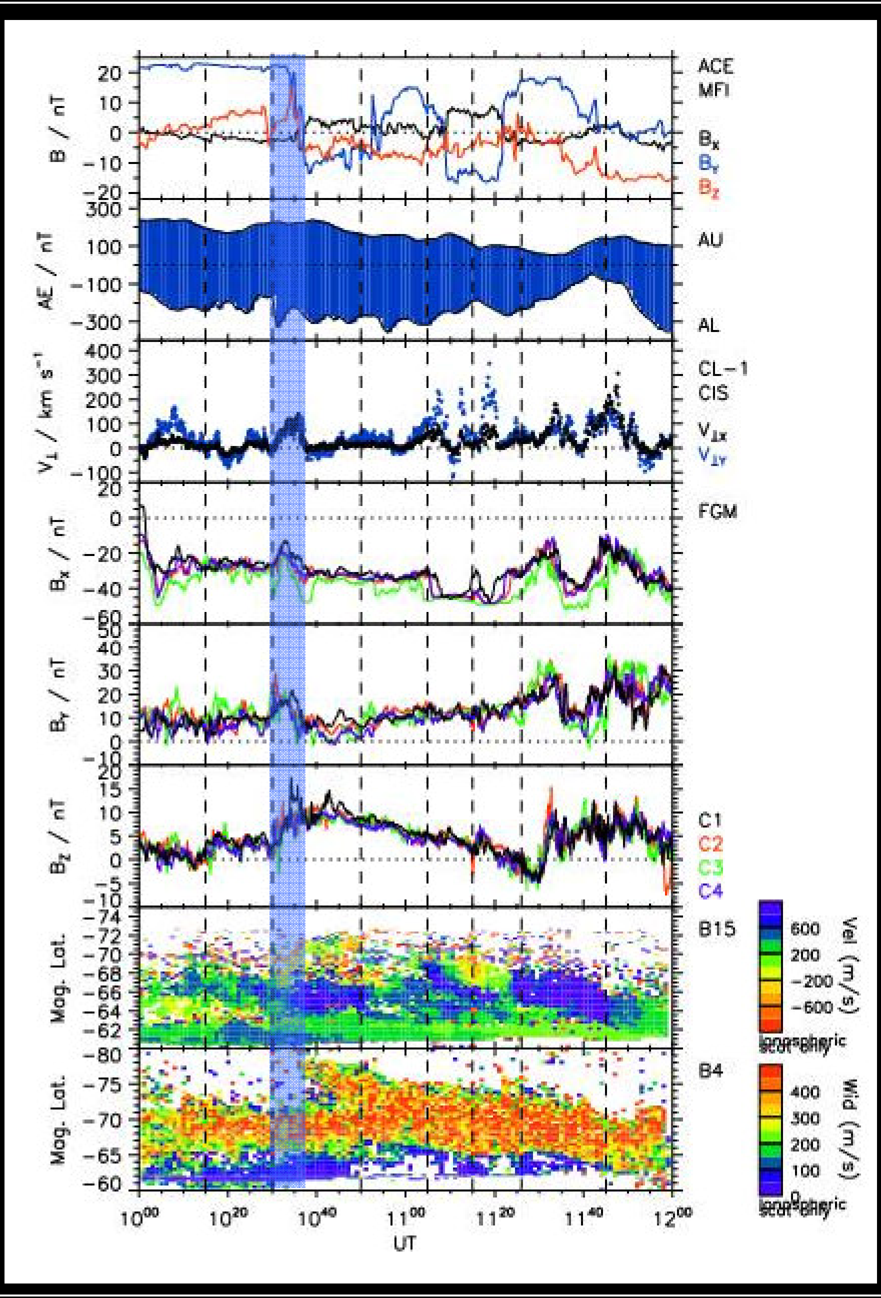
- Three primary events identified:

1. “small”: 1105 UT
   - Clear bipolar $B_Z$
   - Less distinct $B_Y$ enhancement

t ~3 mins duration

$V_{\perp X}$ ~200 km s$^{-1}$

$B_Y$ ~12 nT

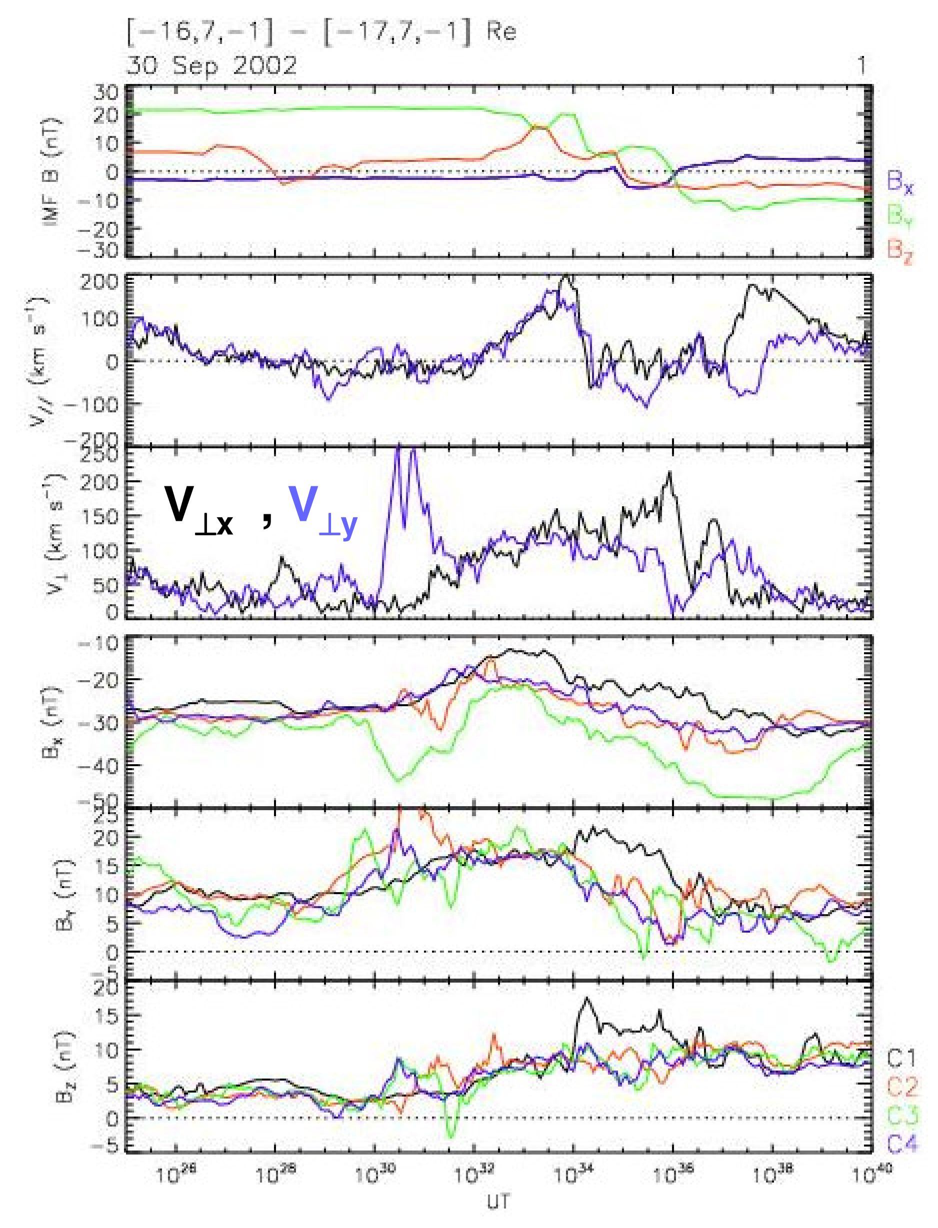



# 30 September 2002

- Three primary events identified:

1. "small": 1105 UT

2. "medium": 1030 UT




# 30 September 2002

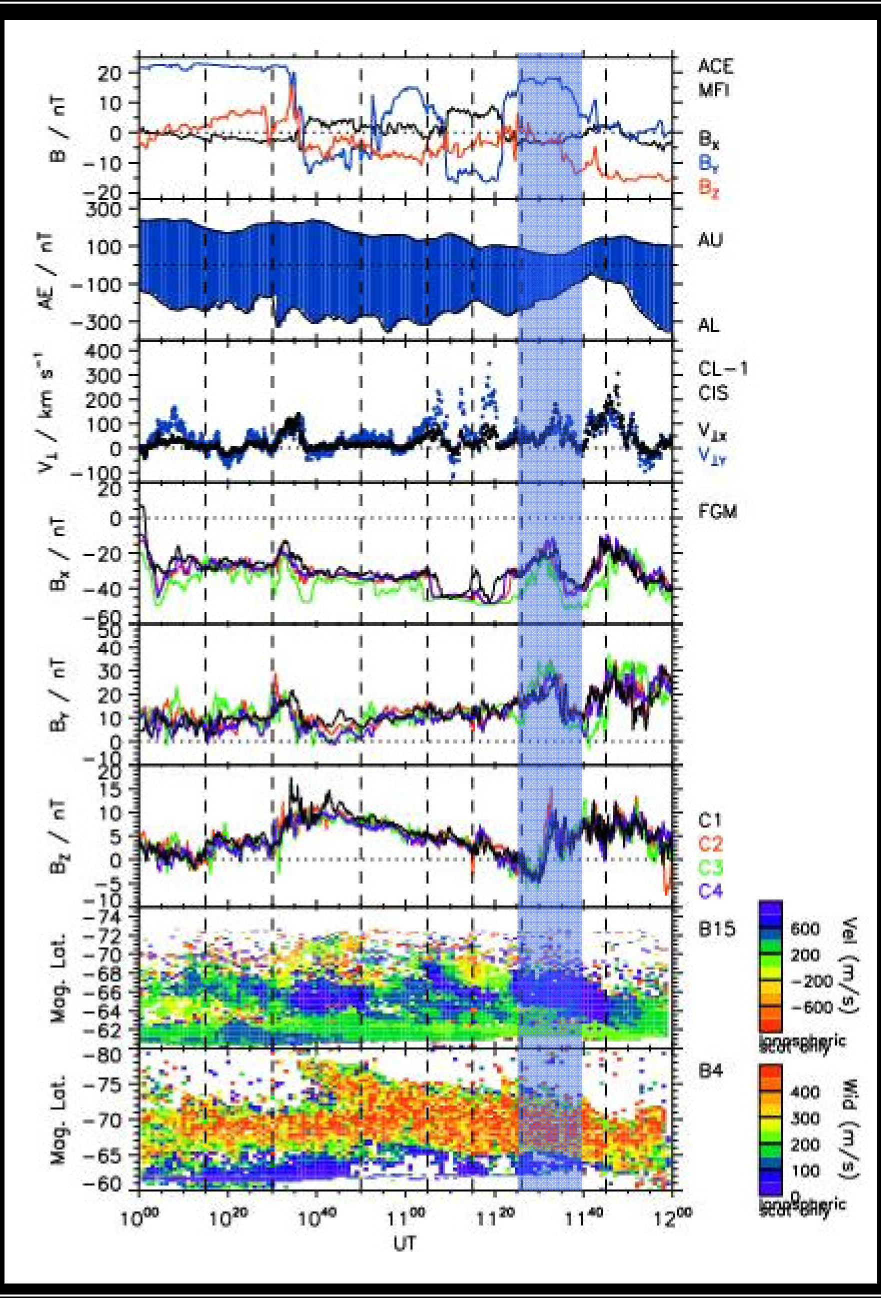
- Three primary events identified:

1. "small": 1105 UT
2. "medium": 1030 UT
   - Clear $B_Y$ enhancement
   - Less distinct $B_Z$ signature

t ~7 mins duration

$V_{\perp X}$ ~200 km $s^{-1}$

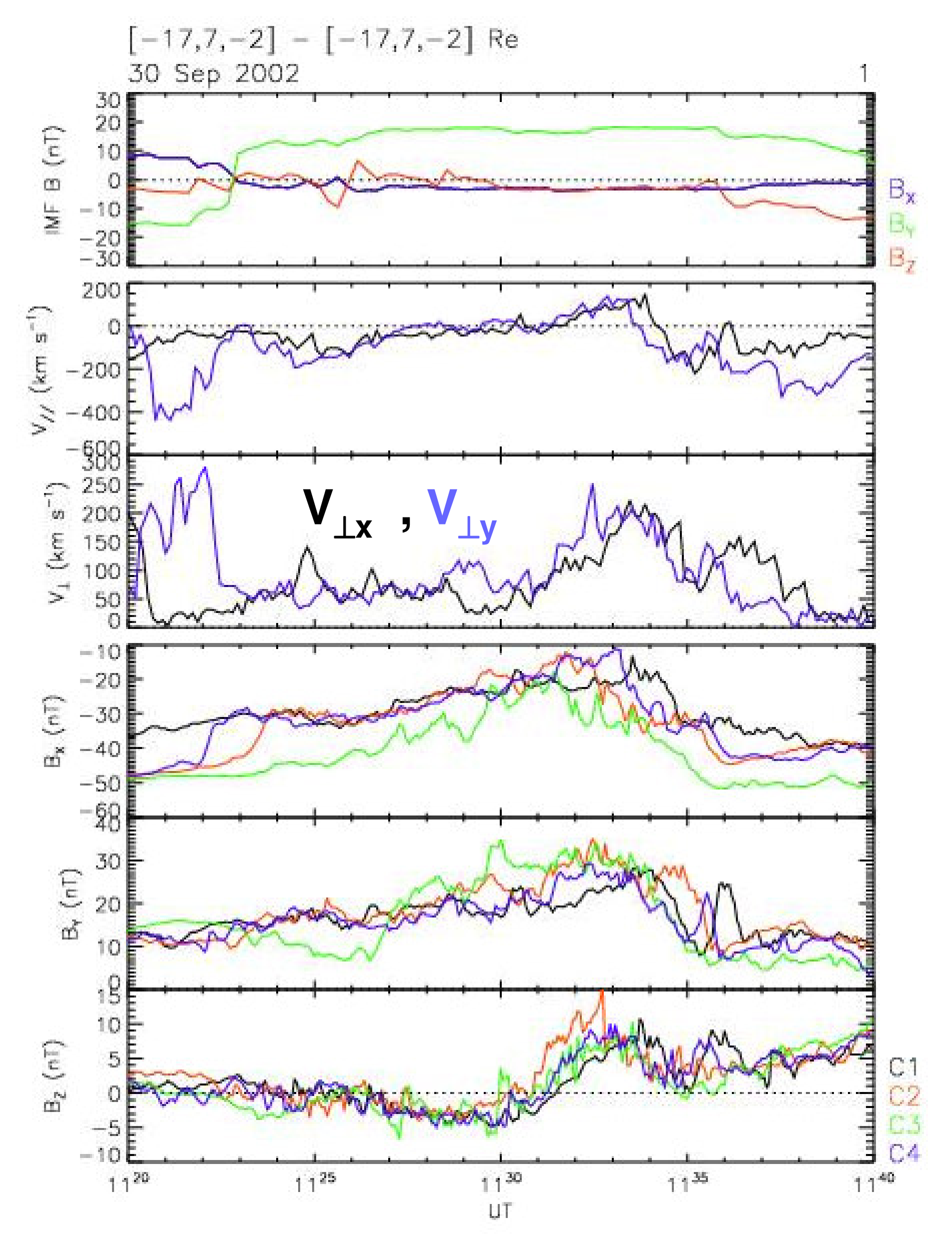
$B_Y$ ~20 nT




# 30 September 2002

- Three primary events identified:

1. "small": 1105 UT
2. "medium": 1030 UT
3. "large": 1130 UT




## 30 September 2002

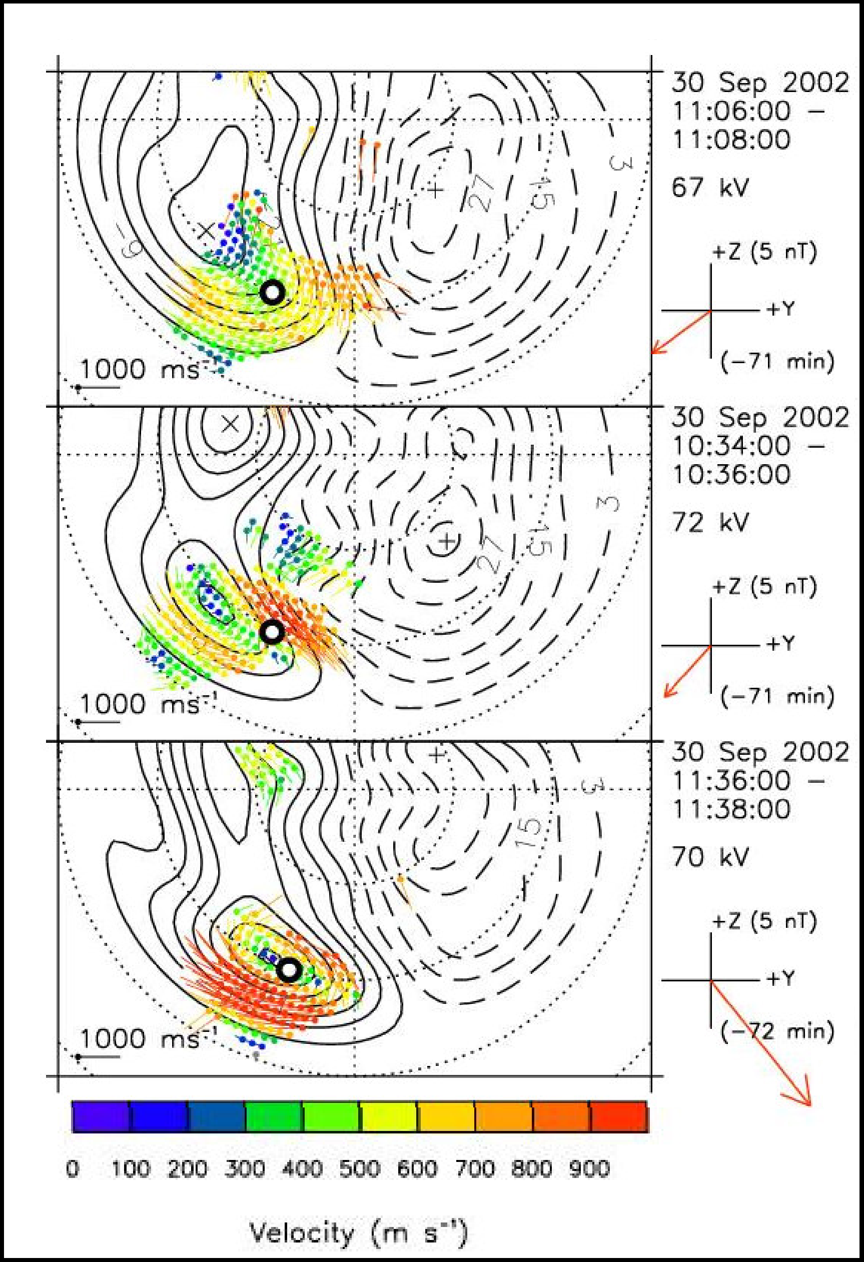
- Three primary events identified:

1. "small": 1105 UT
2. "medium": 1030 UT
3. "large": 1130 UT
   - Gradual but clear $B_Y$ and $B_Z$ signatures

t ~12 mins duration

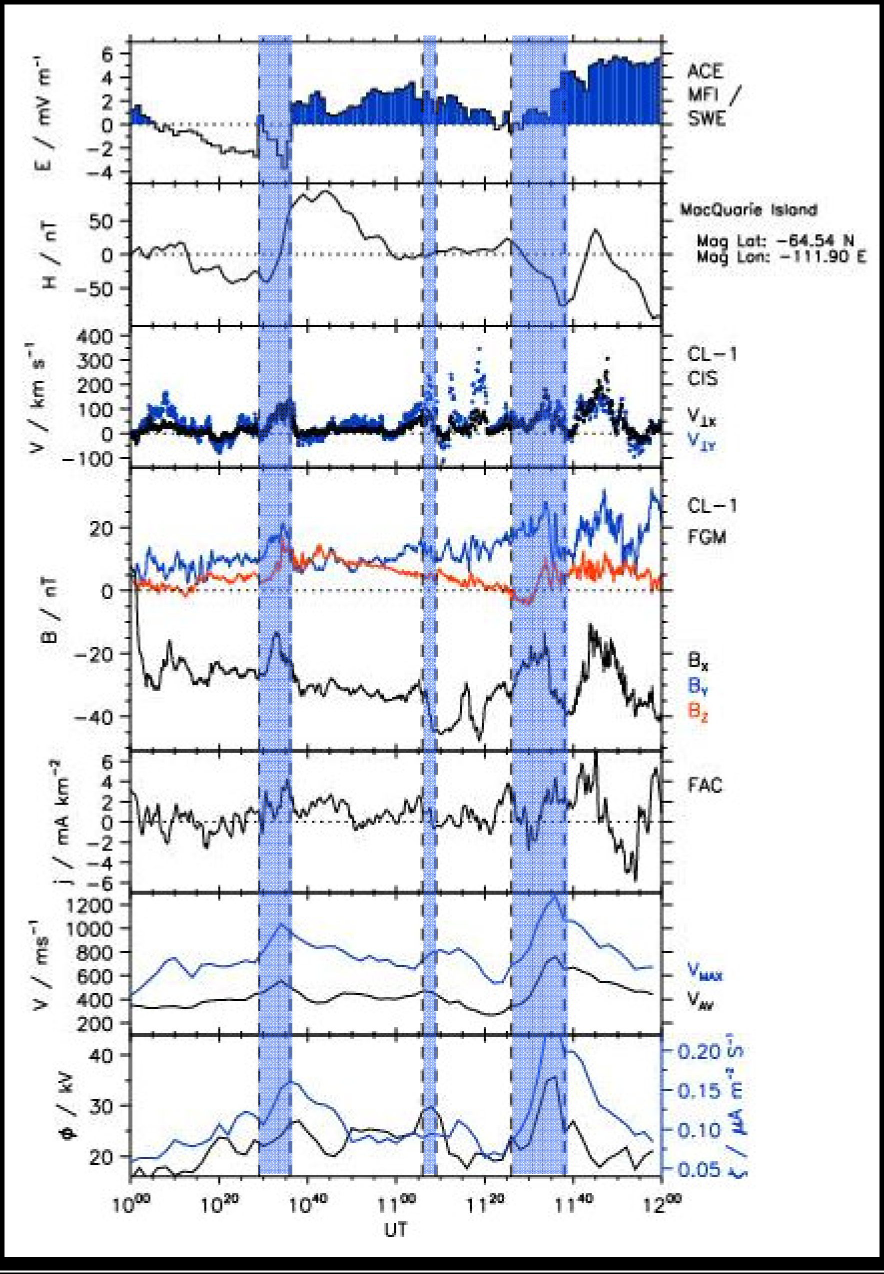
$V_{\perp X}$ ~200 km s$^{-1}$

$B_Y$ ~30 nT




## 30 September 2002

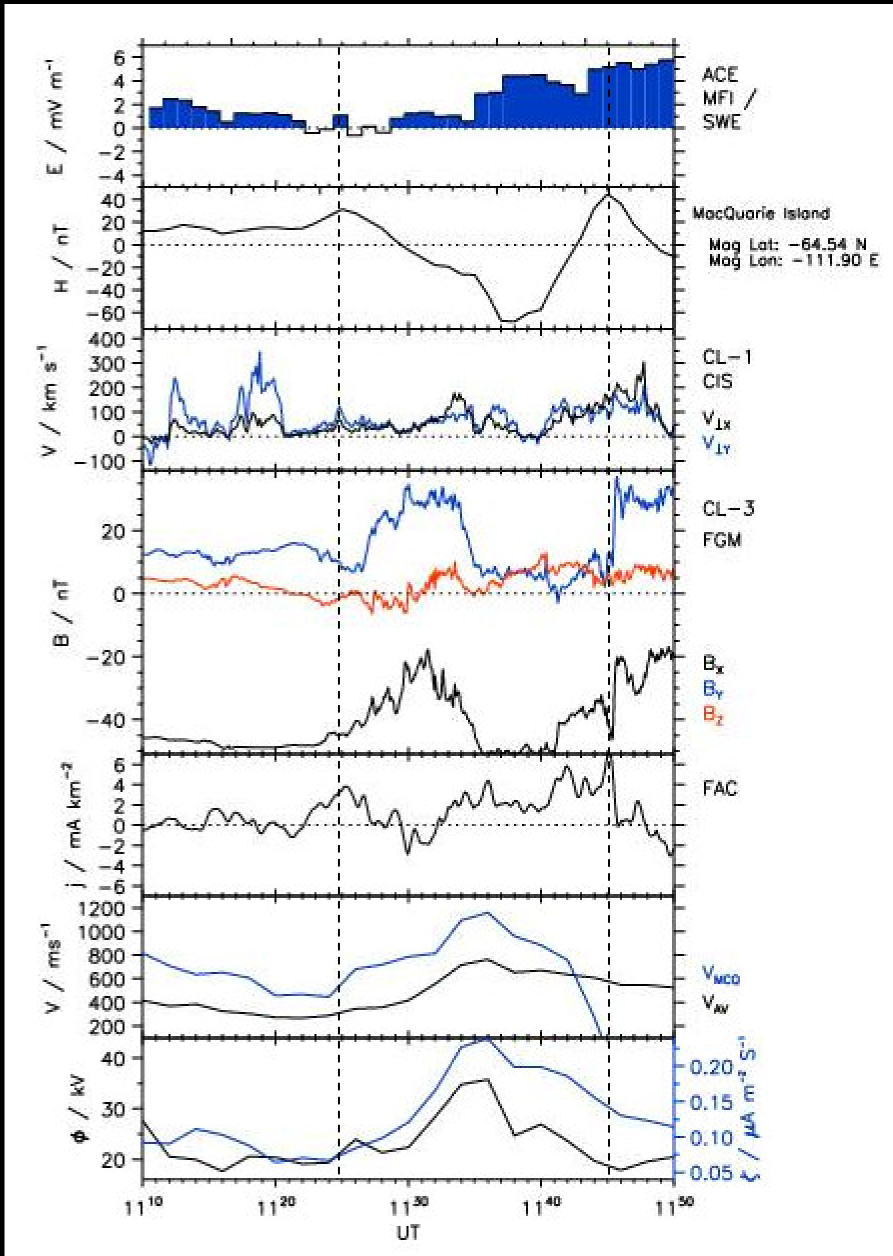
- Convection maps from the times of the 3 flux rope signatures reveal 2 main features:
- 1) localised vortical flow enhancements in the pre-midnight sector
- 2) Varying vortex magnitude corresponding to the different magnitude of the corresponding magnetospheric activity
- 3) ALSO corresponding level of vorticity




# 30 September 2002

The relationship between the main features of the different datasets are illustrated here

1. No clear direct dependence of ionospheric or magnetospheric activity on solar wind input
2. No requirement for major magnetospheric activity to occur during substorm expansion
3. No requirement for traditional “fast” BBFs to produce significant large-scale convection
4. Main ionospheric flow enhancements related specifically to magnetotail field structures and field-aligned currents
5. Flow vorticity enhancement significant as well as velocity




# 30 September 2002

| | | |
|---|---|---|
| $j_{FA\text{-}mag\text{-}meas}$ | 5 mA km$^{-2}$ | 3 mA km$^{-2}$ |
| $j_{FA\text{-}iono\text{-}inf}$ | 5 μA m$^{-2}$ | 3 μA m$^{-2}$ |
| $\zeta_{iono}$ | 0.1 μA m$^{-2}$ S$^{-1}$ | 0.25 μA m$^{-2}$ S$^{-1}$ |
| $\Sigma_P$ | 50 S | 12 S |

$$curl\mathbf{B} = \mu_0 \mathbf{j} \quad \Rightarrow \quad \mathbf{j} = \frac{\nabla \wedge \mathbf{B}}{\mu_0}$$

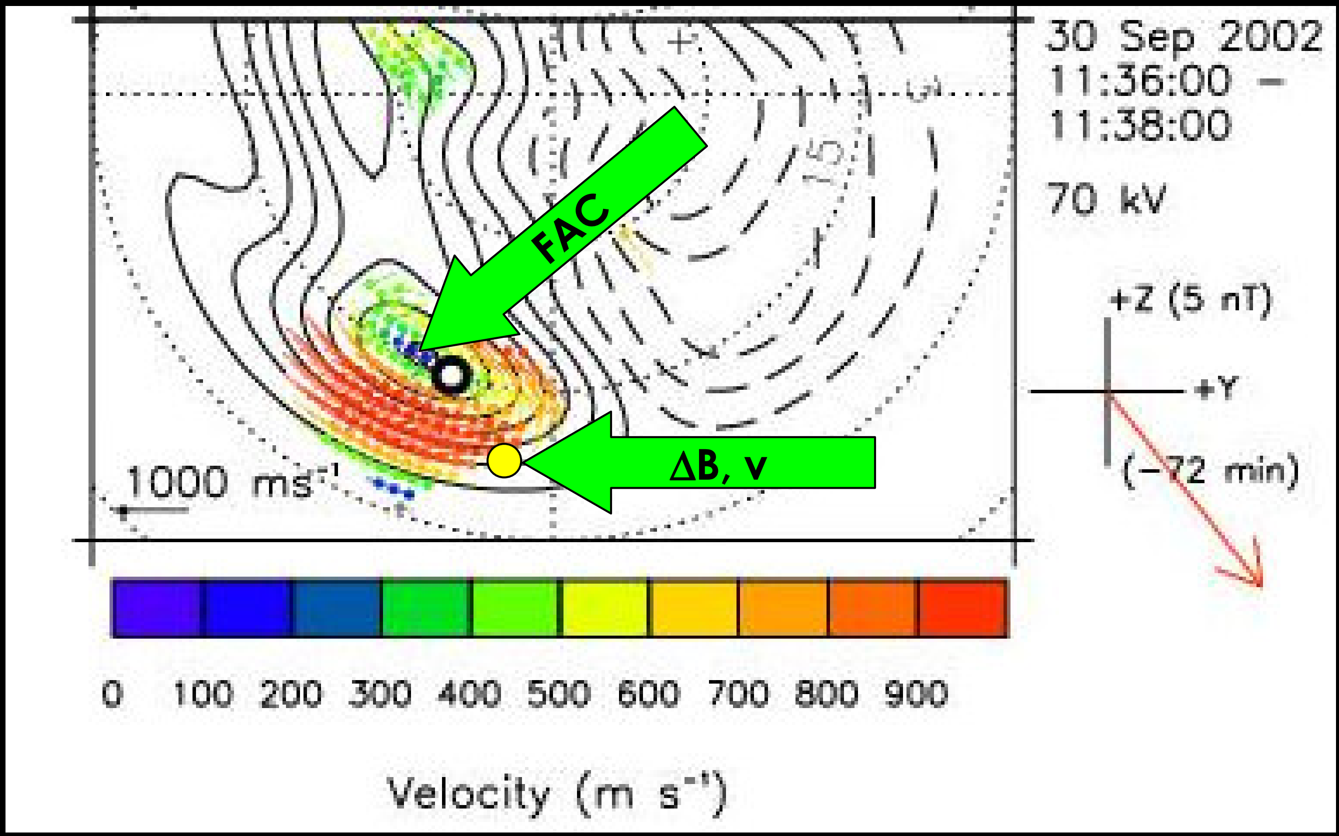
$$\mathbf{i} = \int \mathbf{j} \cdot dz \quad \Rightarrow \quad i_Y = \frac{2\Delta B_X}{\mu_0} \; (1)$$

considering only horizontal components

$$\mathbf{i}_H = \Sigma_H \hat{\mathbf{b}} \wedge \mathbf{E} \Rightarrow \quad \Sigma_H = \frac{i_Y}{v_Y B} \; (2)$$

$$(1) + (2) \Rightarrow \Sigma_H = \frac{2\Delta B_X}{\mu_0 v_Y B}$$

| | | |
|---|---|---|
| $\Delta B_X$ | ~100 nT | ~100 nT |
| $v_Y$ | 500 ms$^{-1}$ | 1000 ms$^{-1}$ |
| $\Sigma_H$ | 6.4 S | 3.2 S |




- Ground measurement made in high-flow, low-conductivity region
- FAC maps to low-flow, high-conductivity region?
- v < 100 m $s^{-1}$ in the centre of the vortex could give $\Sigma_P > 30$ S
  if $\Delta B_X$ is higher in this region then $\Sigma_P$ could be even larger

## Conclusions

- Magnetospheric disturbances resembling flux ropes of varying size and duration have been related to ionospheric convection vortices
- Larger, longer duration magnetospheric signatures are associated with "tighter" faster, convection vortices and larger field aligned currents
- The magnetic disturbances are accompanied by small BBF-type signatures which seem small compared to the large magnitude of the ionospheric flows
- Relatively localised high-flow low-conductivity vortex implies very localised distribution of FAC – in agreement with optical studies (e.g. Lui et al., 1998) which revealed isolated arc of azimuthal extent ~2 h MLT

## Questions

- What is the exact nature of the relationship between flux ropes and concurrent ionospheric vortices?
- Are flux ropes a result of a change in magnetic field topology, rather than bulk movement of flux?
- Could they be related to plasma sheet thinning and x-line formation during substorm growth phase?