Pc1/EMIC waves observed at geosynchronous orbit and subauroral latitude during sudden magnetospheric compressions

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Outline

- **Introduction**
  - Previous studies: Sudden commencement (SC)-associated EMIC/Pc1 waves

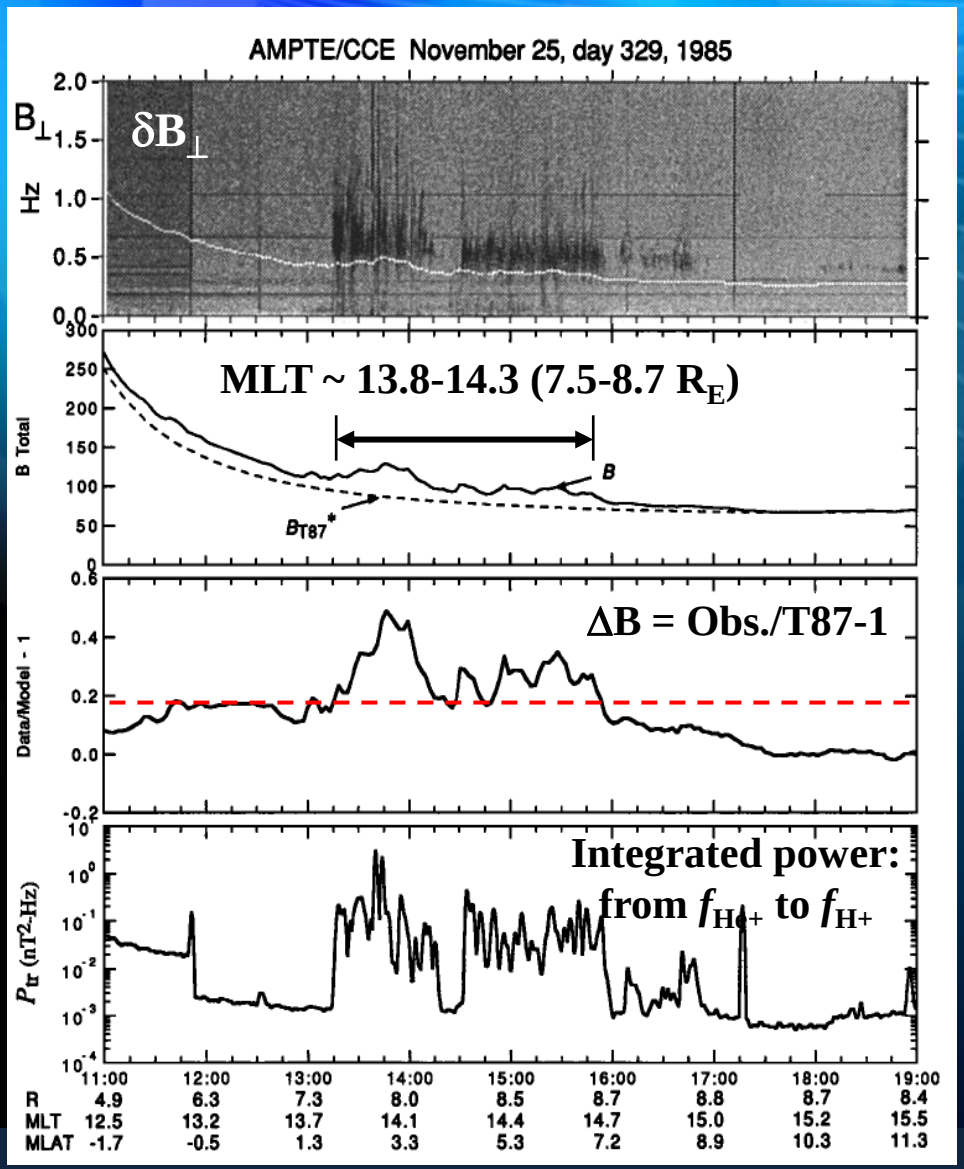
- **SC-associated EMIC/Pc1 waves :**
  - Case study: GOES observations in space and ground observation at Athabasca station, Canada (ATH: 54.7°N, 246.7°E, MLAT ~ 62°N, L ~ 4.6)

  - Statistical results: SC-associated EMIC/Pc1 waves at ATH station

- **Summary**

Magnetospheric compressions and EMIC waves

Anderson and Hamilton [1993]



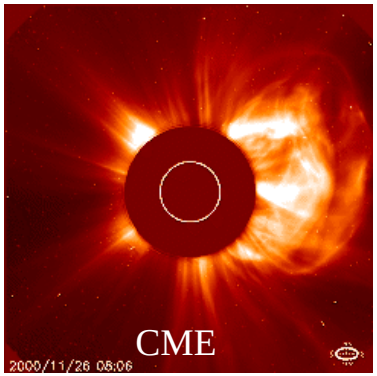
- The compression events not only increase the magnetospheric field but also convect plasma earthward.
- Thus the compression-Pc1 correlation can be caused by
  - inward motion of plasma previously unstable to EMIC waves (i.e., spatial convection of EMIC waves) or
  - temporal onset of EMIC waves

Data

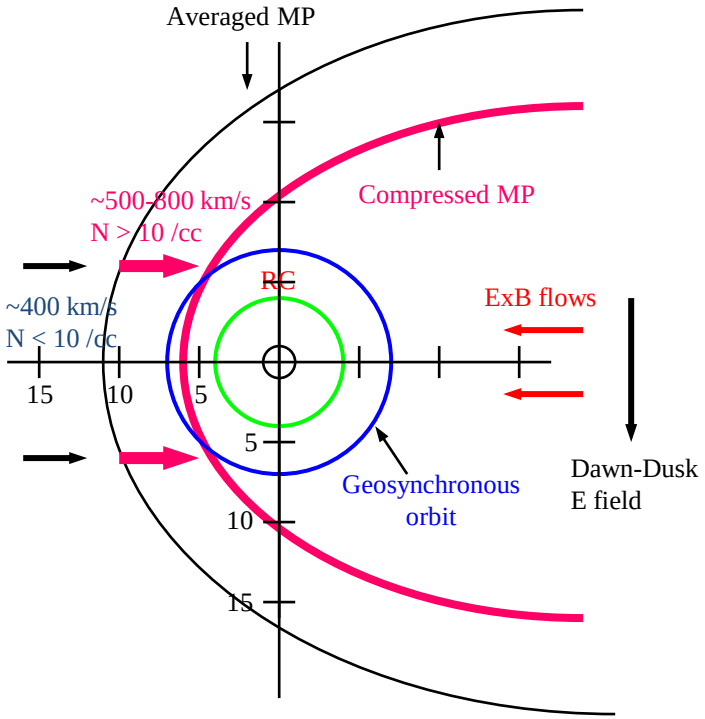
- **Case study: Sudden Commencement (SC) event on 19 November 2007**
  *** In space: Fluxgate magnetometer data (~0.6s) from GOES 10, 11, and 12.**
  *** On the Ground: Induction magnetometer (~0.02s) at Athabasca, Canada (ATH: 54.7°N, 246.7°E, MLAT ~ 62°N, L ~ 4.6) station and SYM-H to determine SC onset.**

- **Statistical study: SC-associated PC1 waves**
  *** Only used ATH ground data: Sept. 2005 ~ Aug. 2011**
  *** 47 SC events were identified.**

Magnetospheric response to Interplanetary (IP) shock

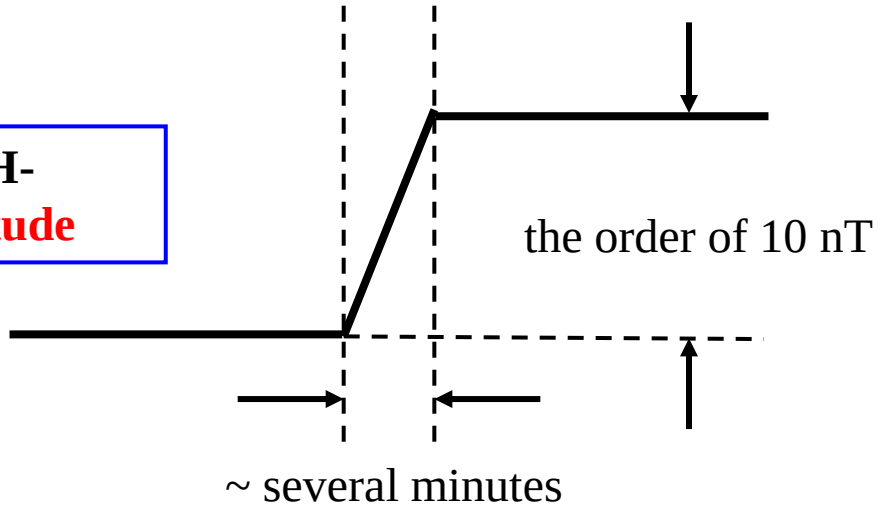


Interplanetary (IP) space:
Solar wind (V, N)/IMF (B) variations

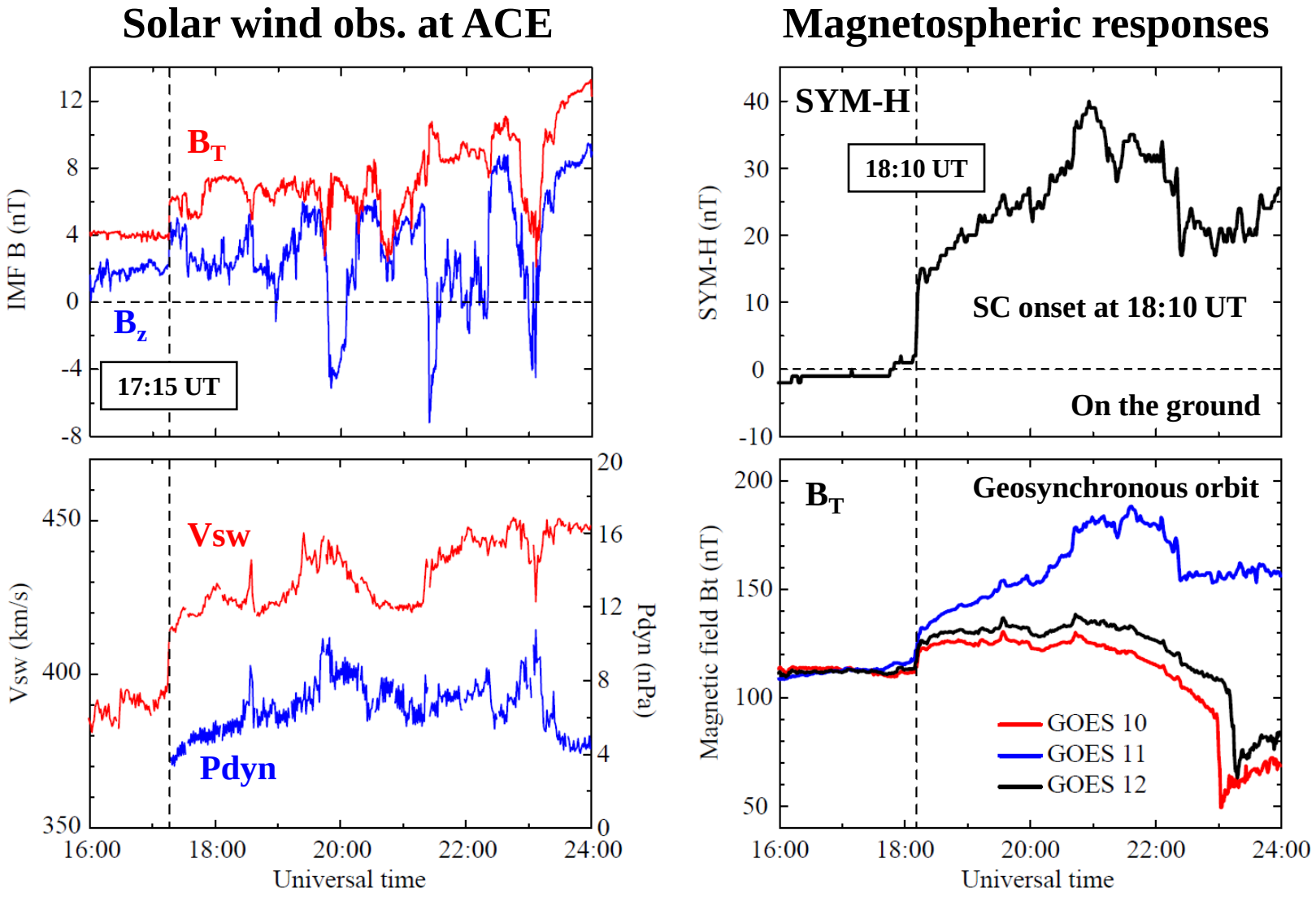


Sudden Commencement (SC): Ground observation

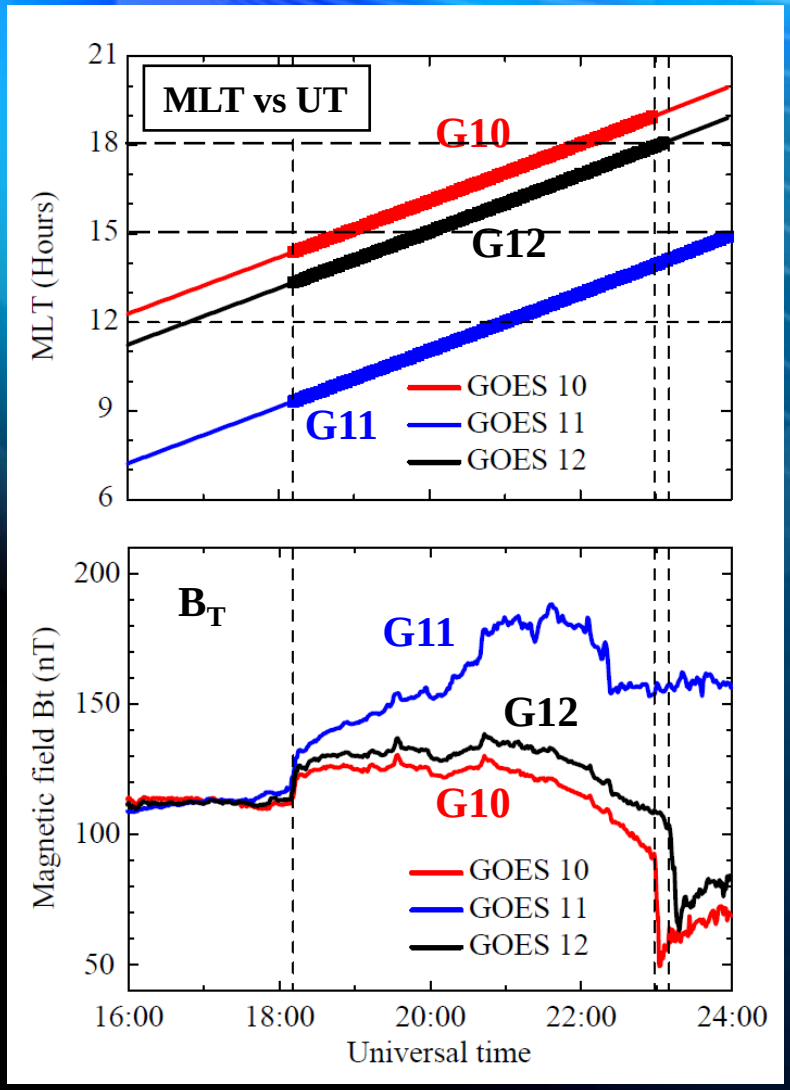
Sudden increase in H-component at low latitude

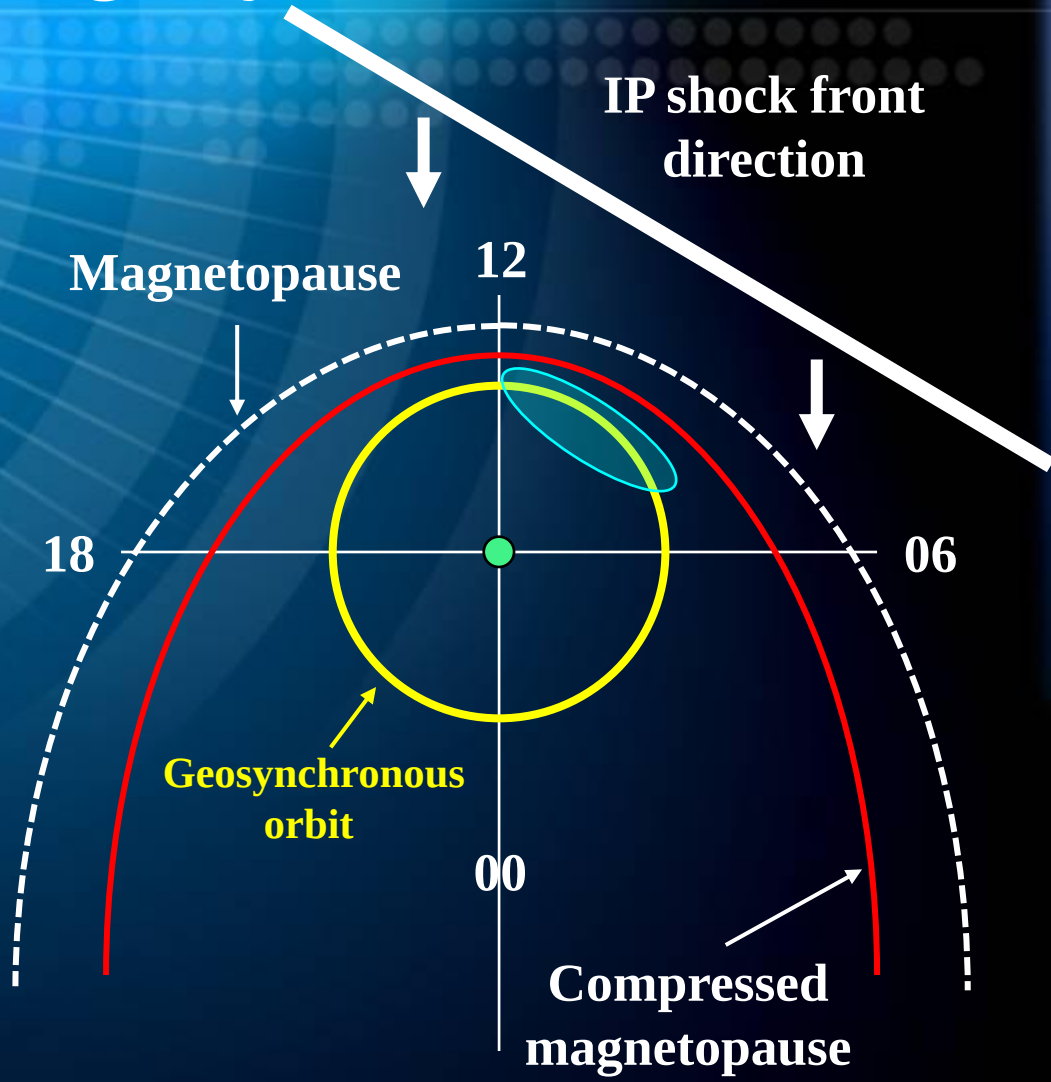


Case study: SC event on 19 Nov 2007

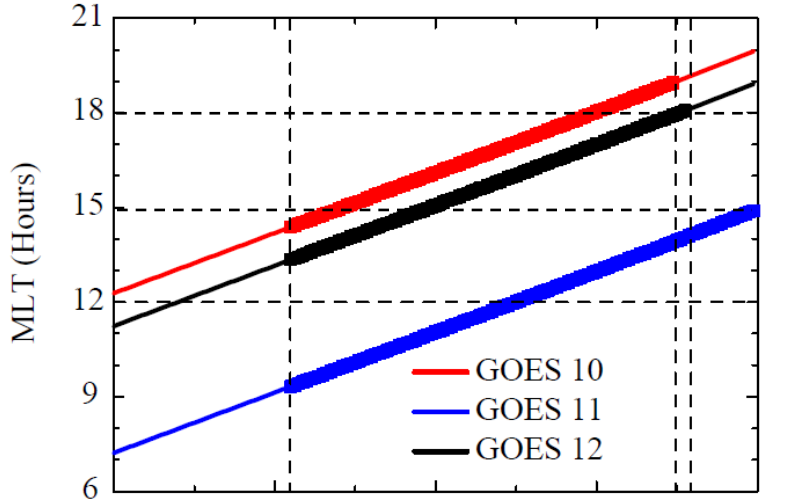


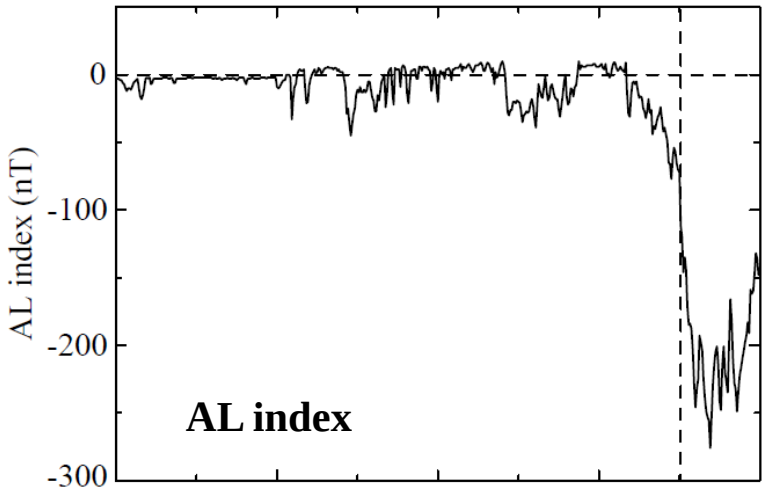
Comparison of B_T at geosynchronous orbit

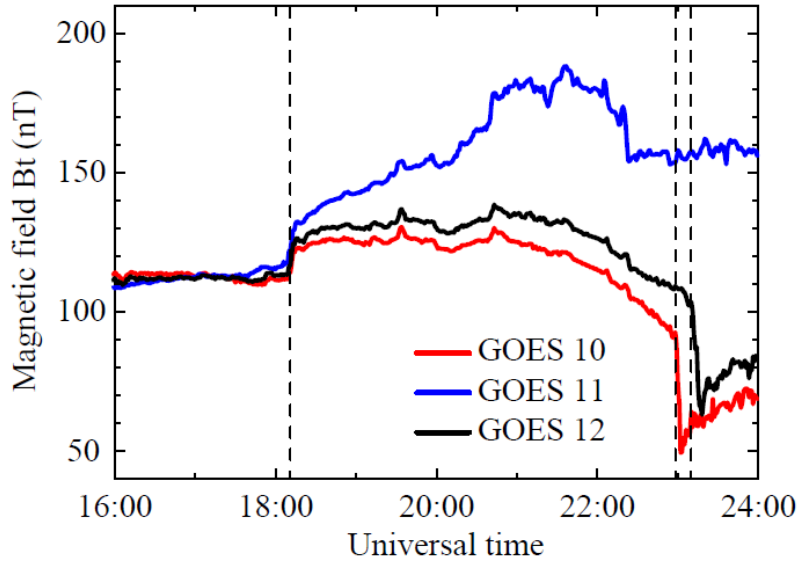


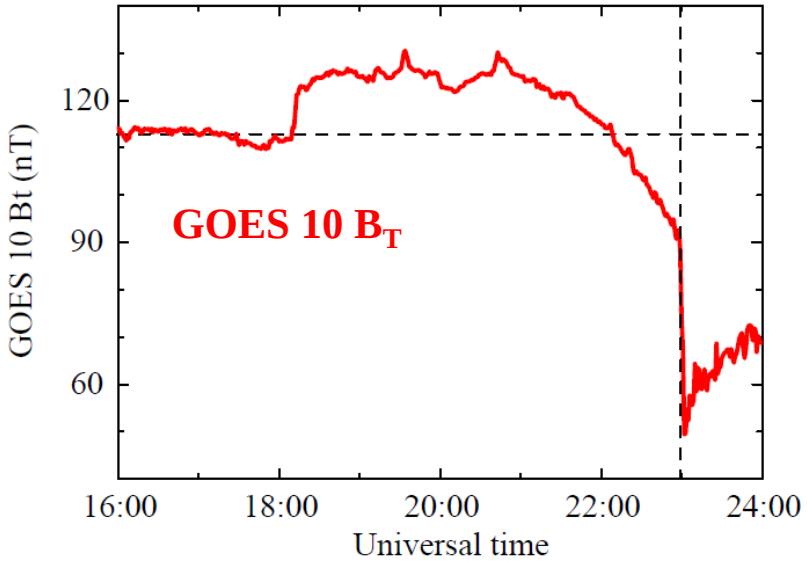


Sudden decrease in B_T at GOES 10 & 12

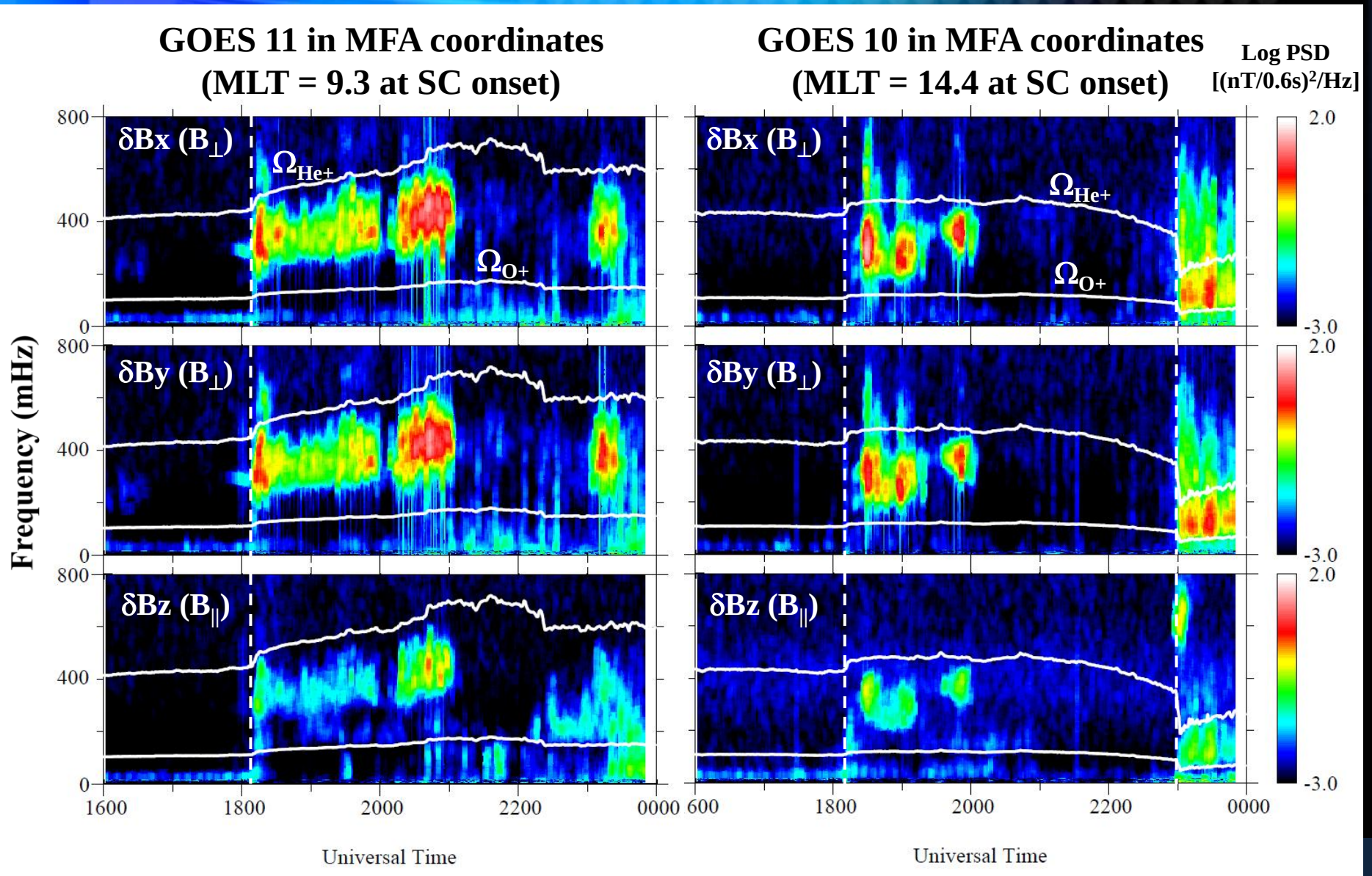




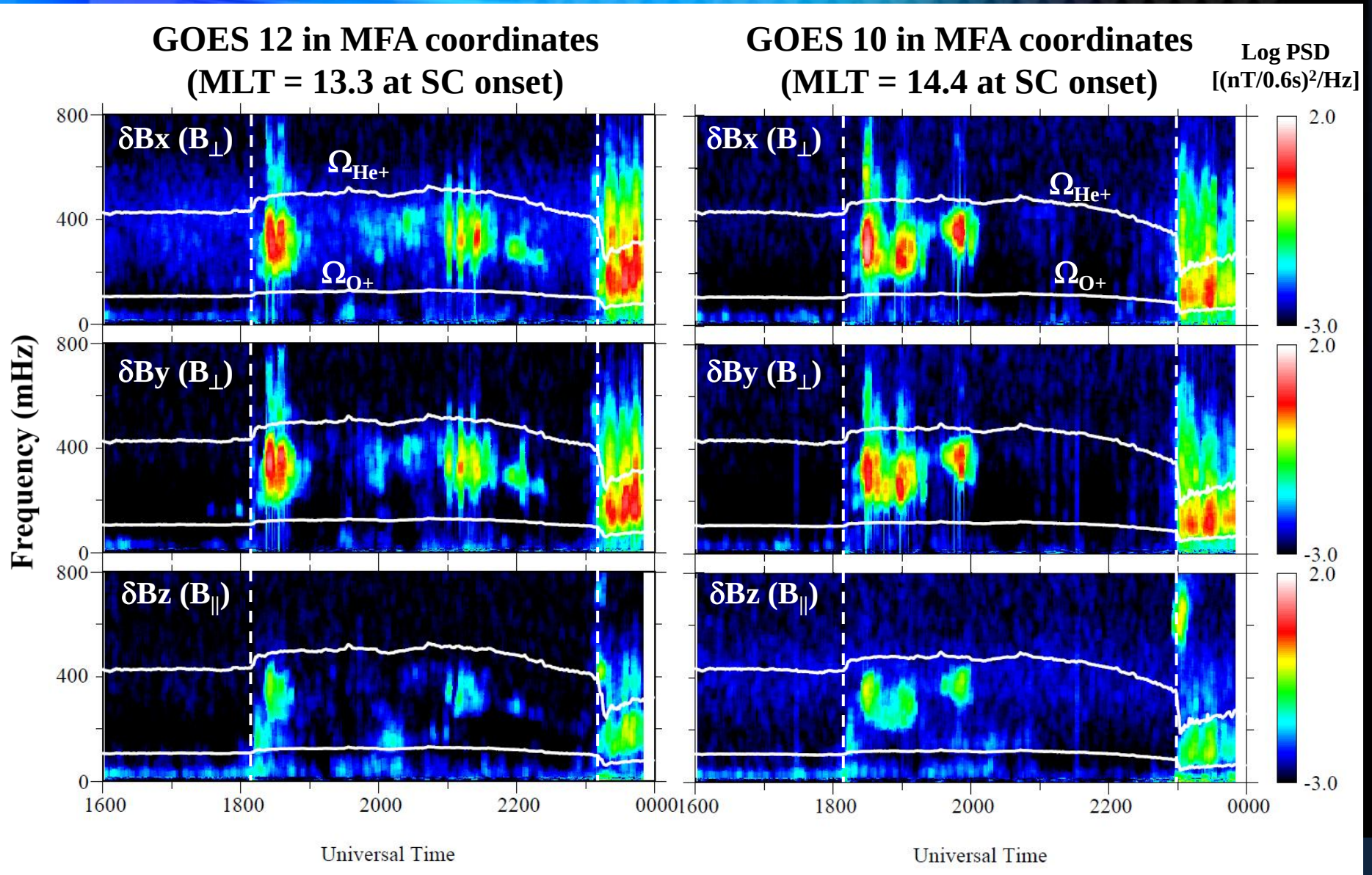




SC-associated EMIC/Pc1 waves at GOES S/C

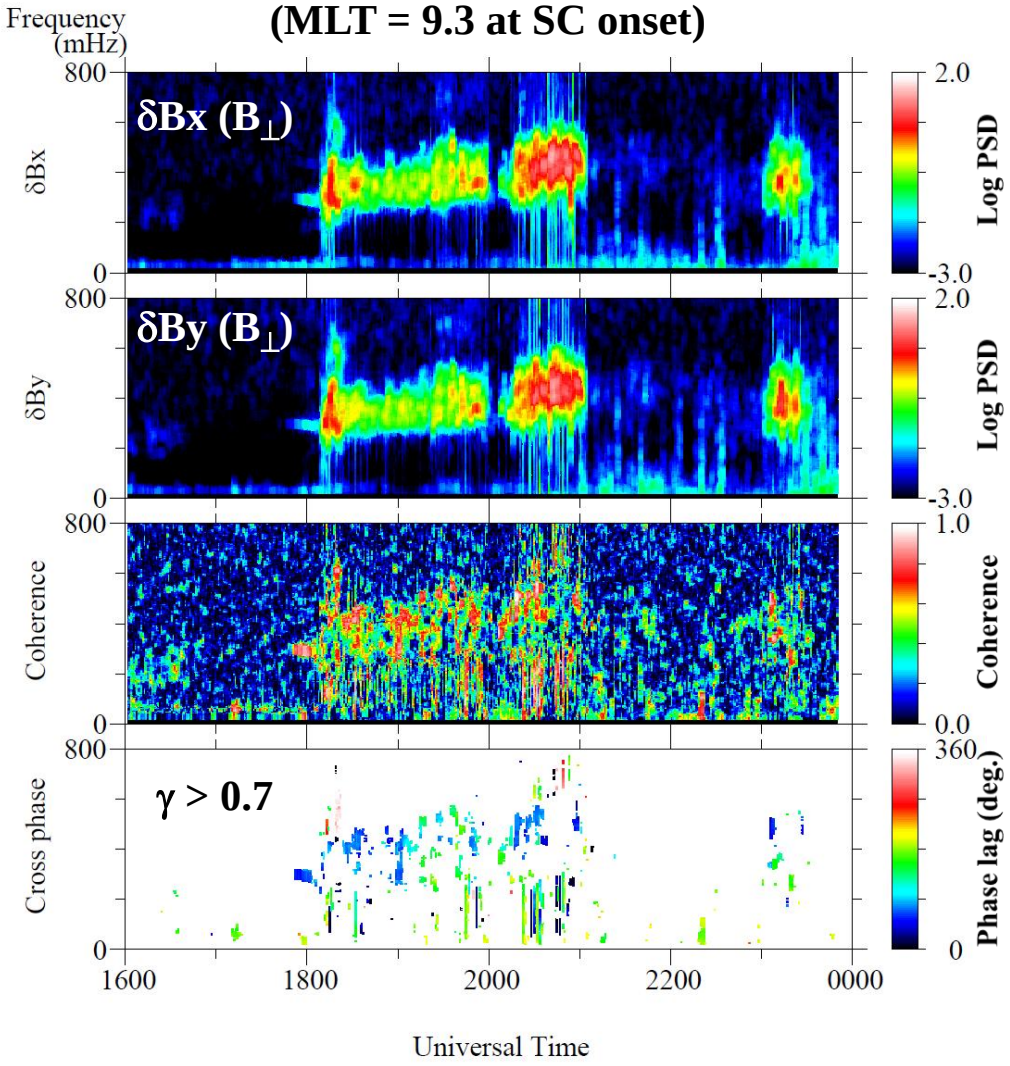


SC-associated EMIC/Pc1 waves at GOES S/C

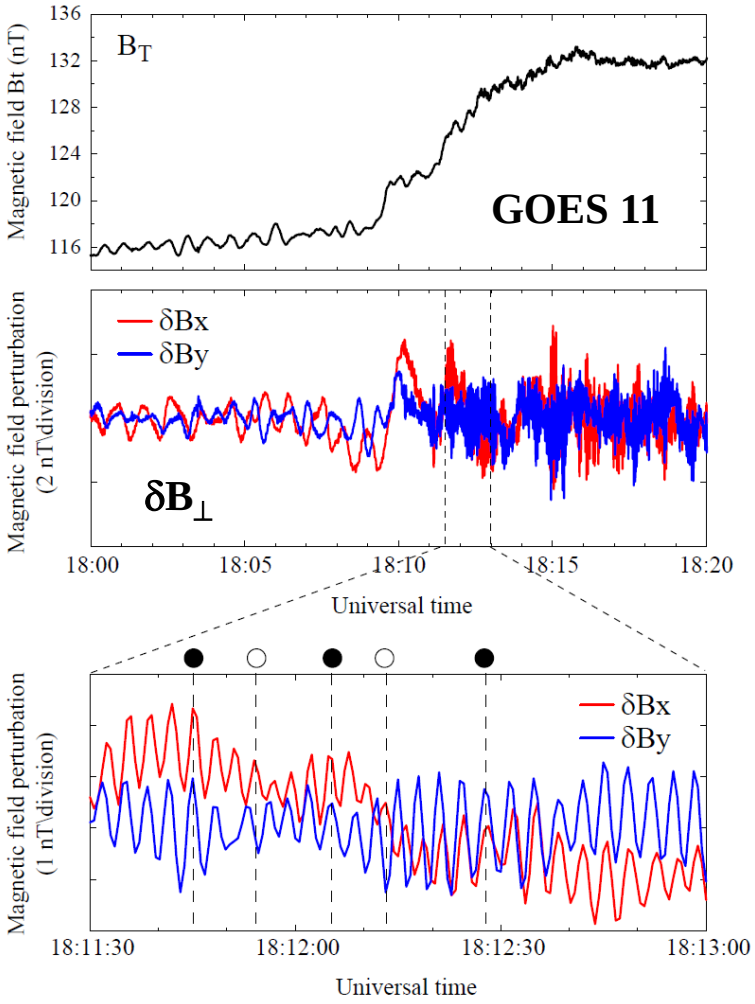


Coherence analysis of EMIC/Pc1 waves

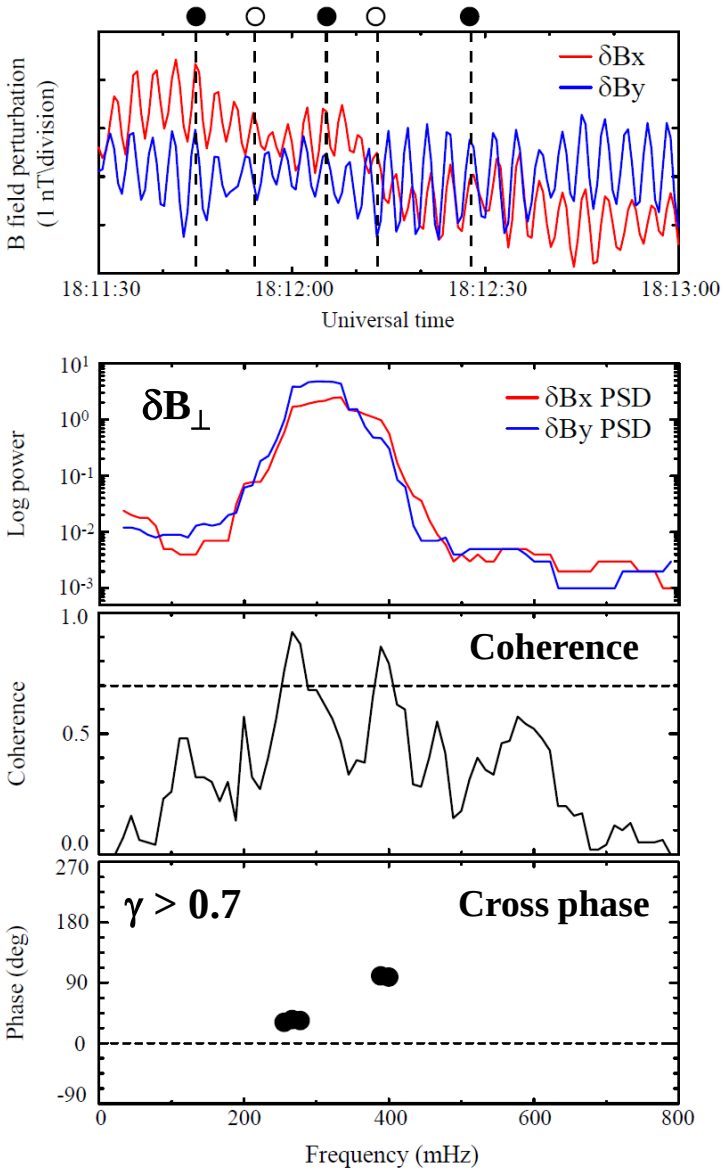
Transverse components at GOES 11 (MLT = 9.3 at SC onset)



Sample time series plots near SC onset time



Why low coherence between δBx and δBy?



The cross correlation function:

$$R_{\alpha\beta}(\tau) = \lim_{T\to\infty} \frac{1}{T} \int_0^T \alpha(t)\beta(t+\tau)dt$$

The cross-spectral function $G_{\alpha\beta}(f)$: the Fourier transformation of $R_{\alpha\beta}(\tau)$

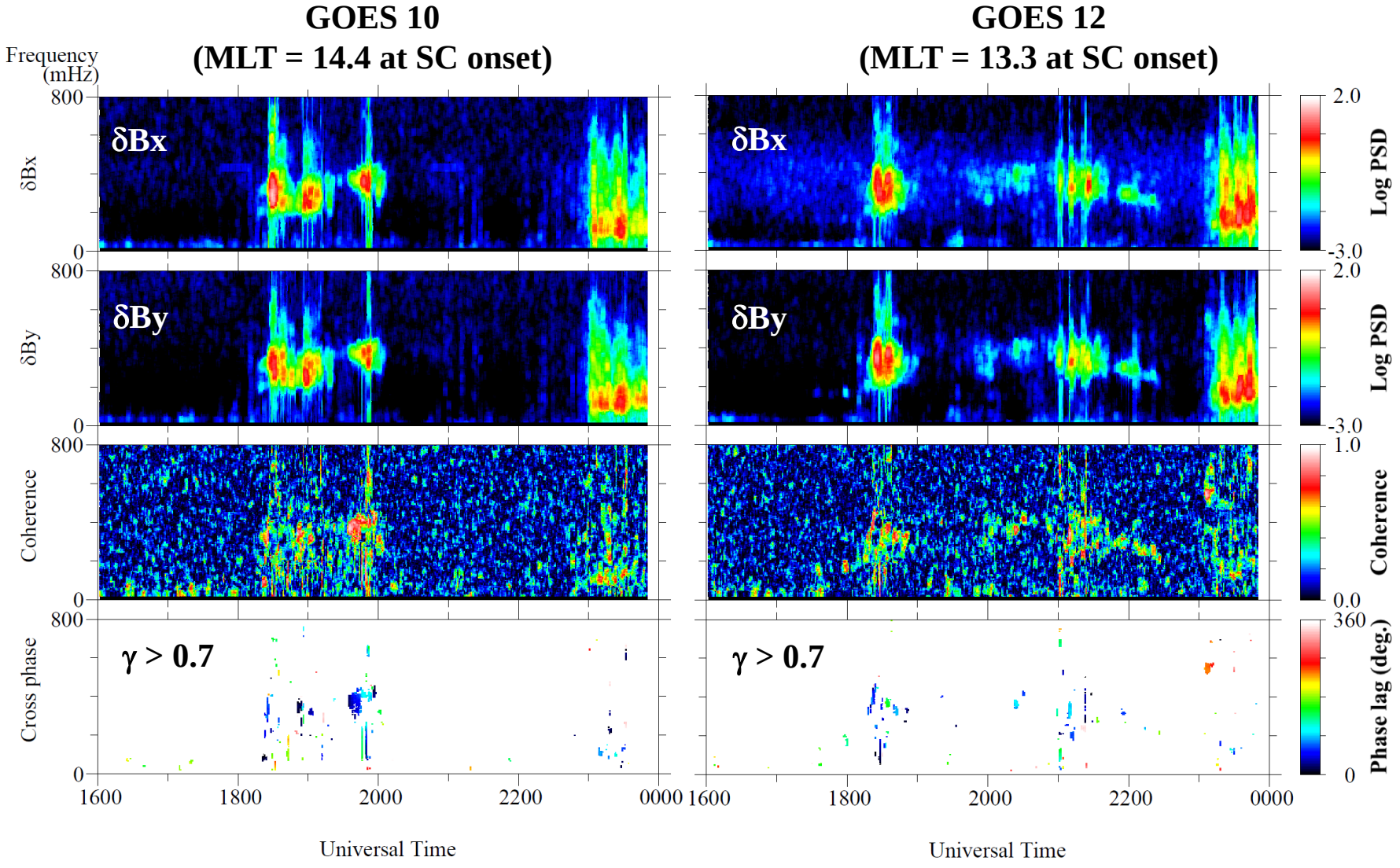
$$G_{\alpha\beta}(f) = C_{\alpha\beta}(f) - iQ_{\alpha\beta}(f)$$

$$\gamma_{\alpha\beta}(f) = \frac{\left|G_{\alpha\beta}(f)\right|^2}{G_\alpha(f)G_\beta(f)} \quad \text{: Coherence}$$

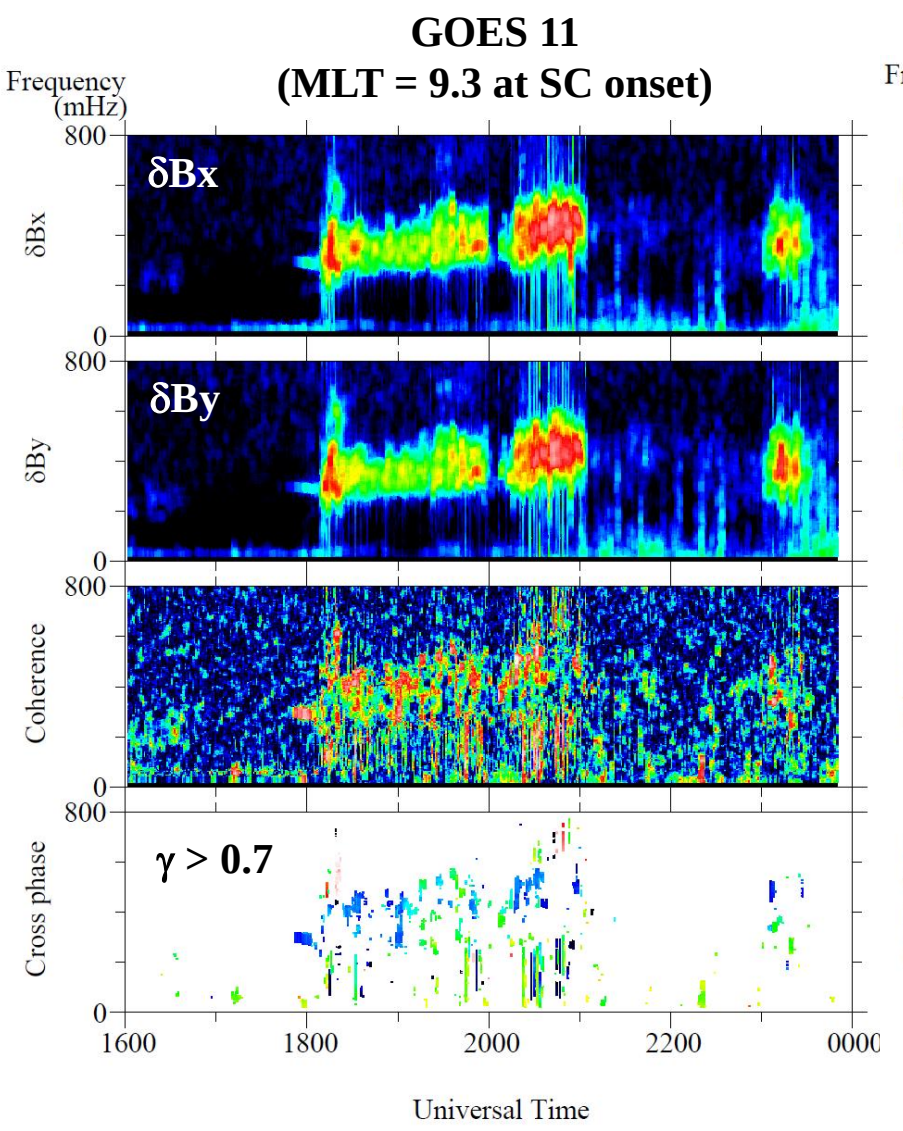
$$\theta_{\alpha\beta}(f) = \tan^{-1}\frac{Q_{\alpha\beta}(f)}{C_{\alpha\beta}(f)} \quad \text{: Cross phase}$$

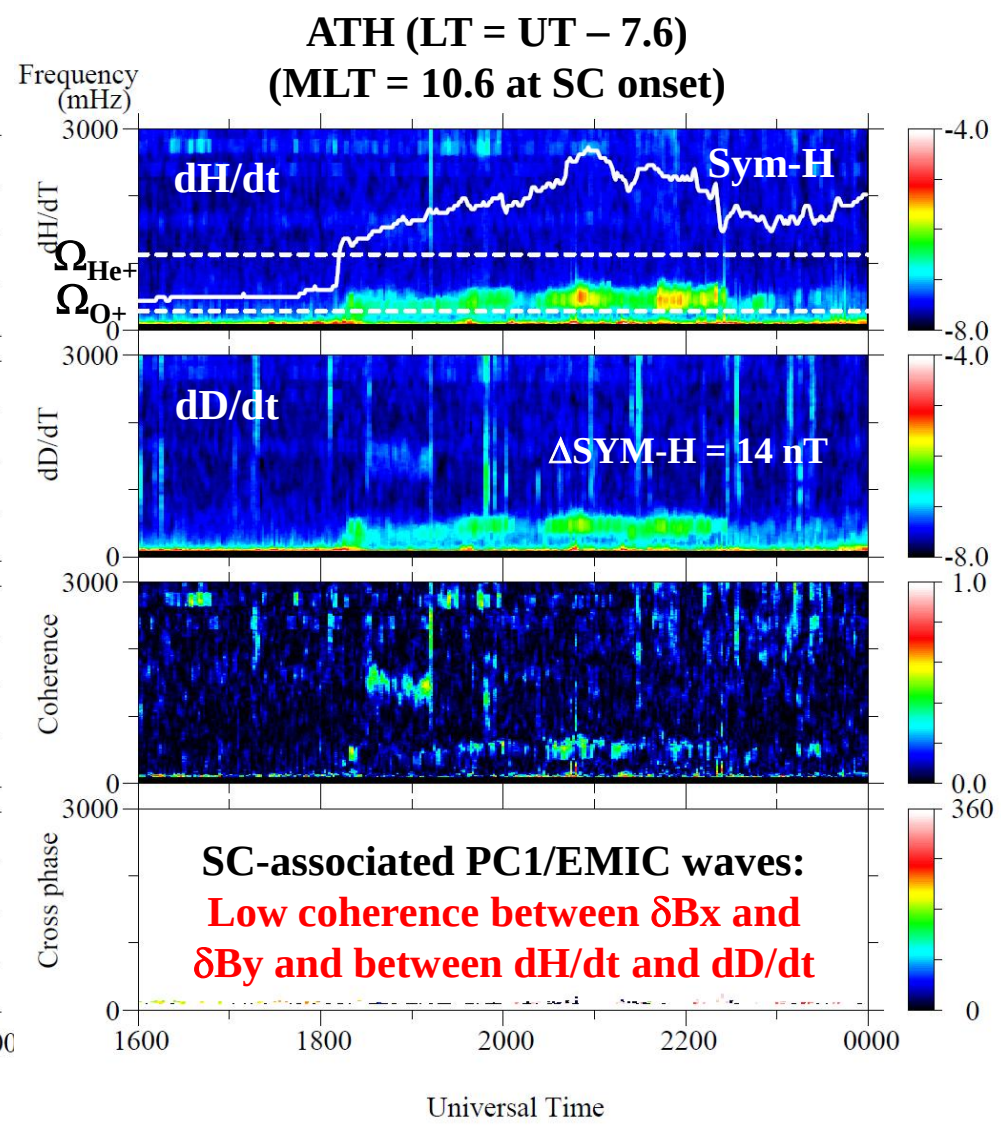
In order for α and β signals to produce high coherence both the phase delay and amplitude ratio need to remain constant.

Coherence analysis of EMIC/Pc1 waves

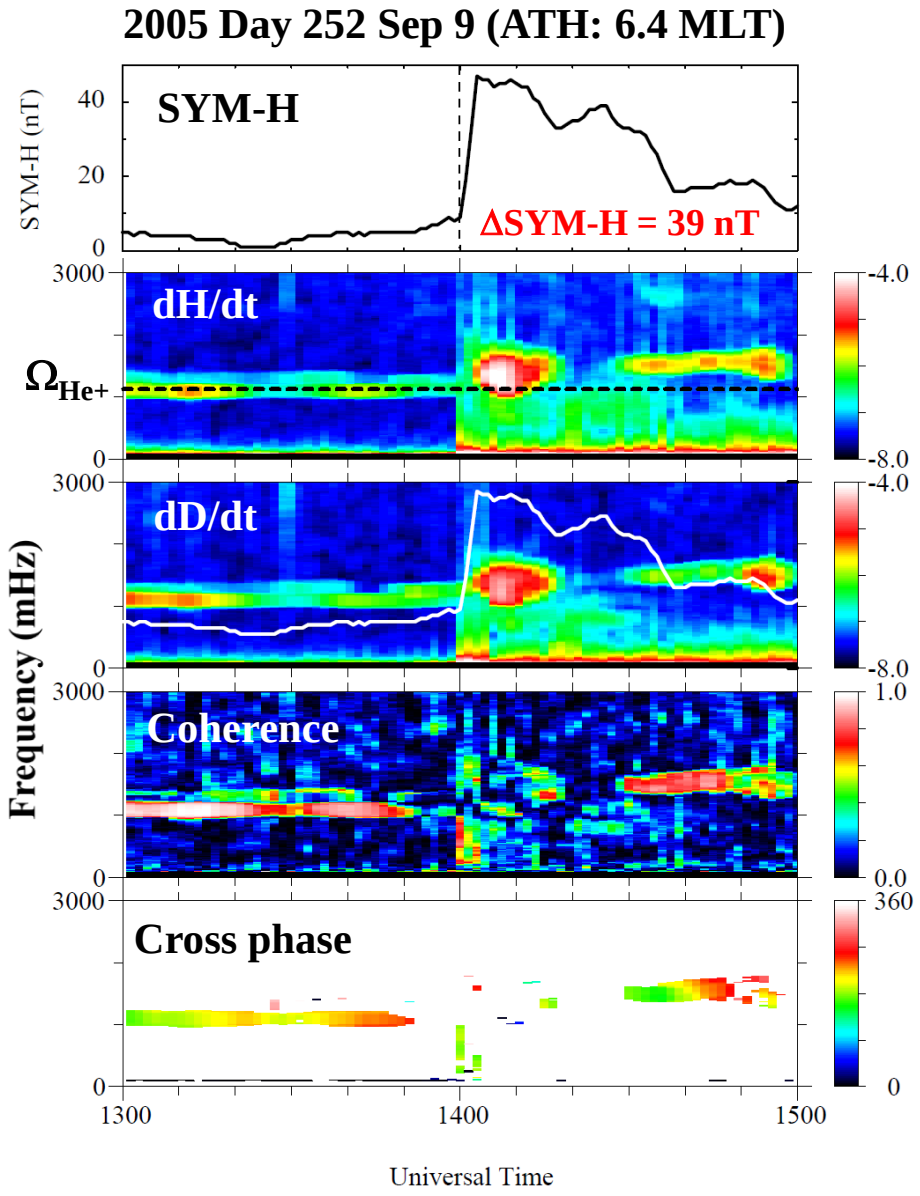


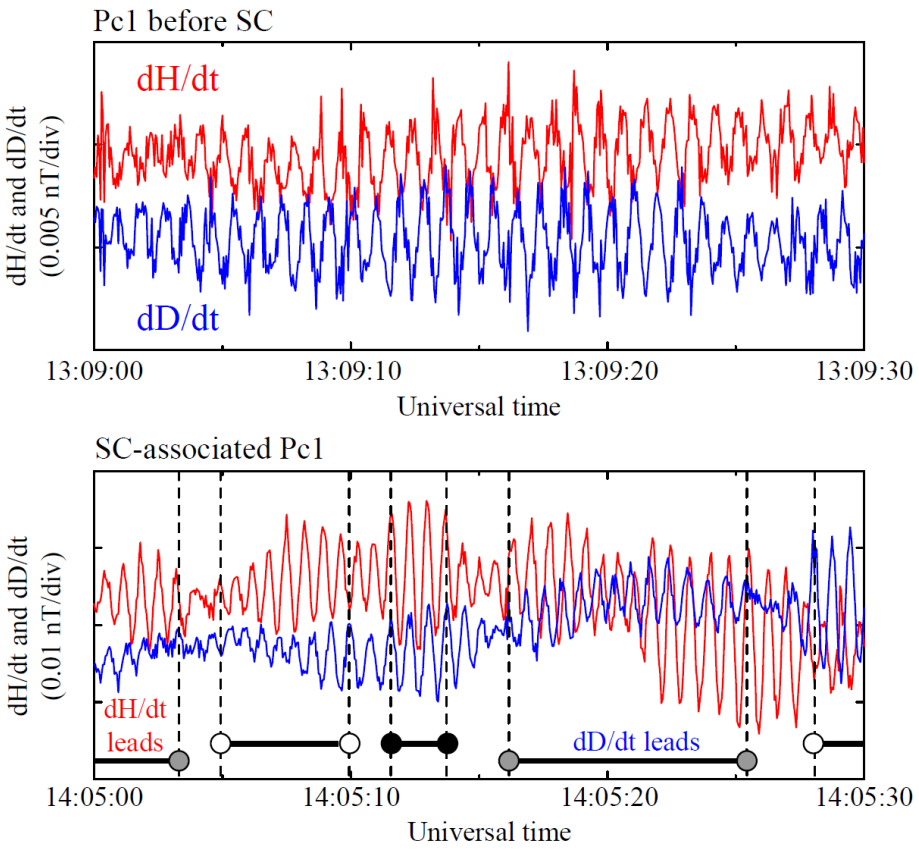
SC-associated Pc1 at ATH (L ~ 4.6, MLAT ~ 62°)





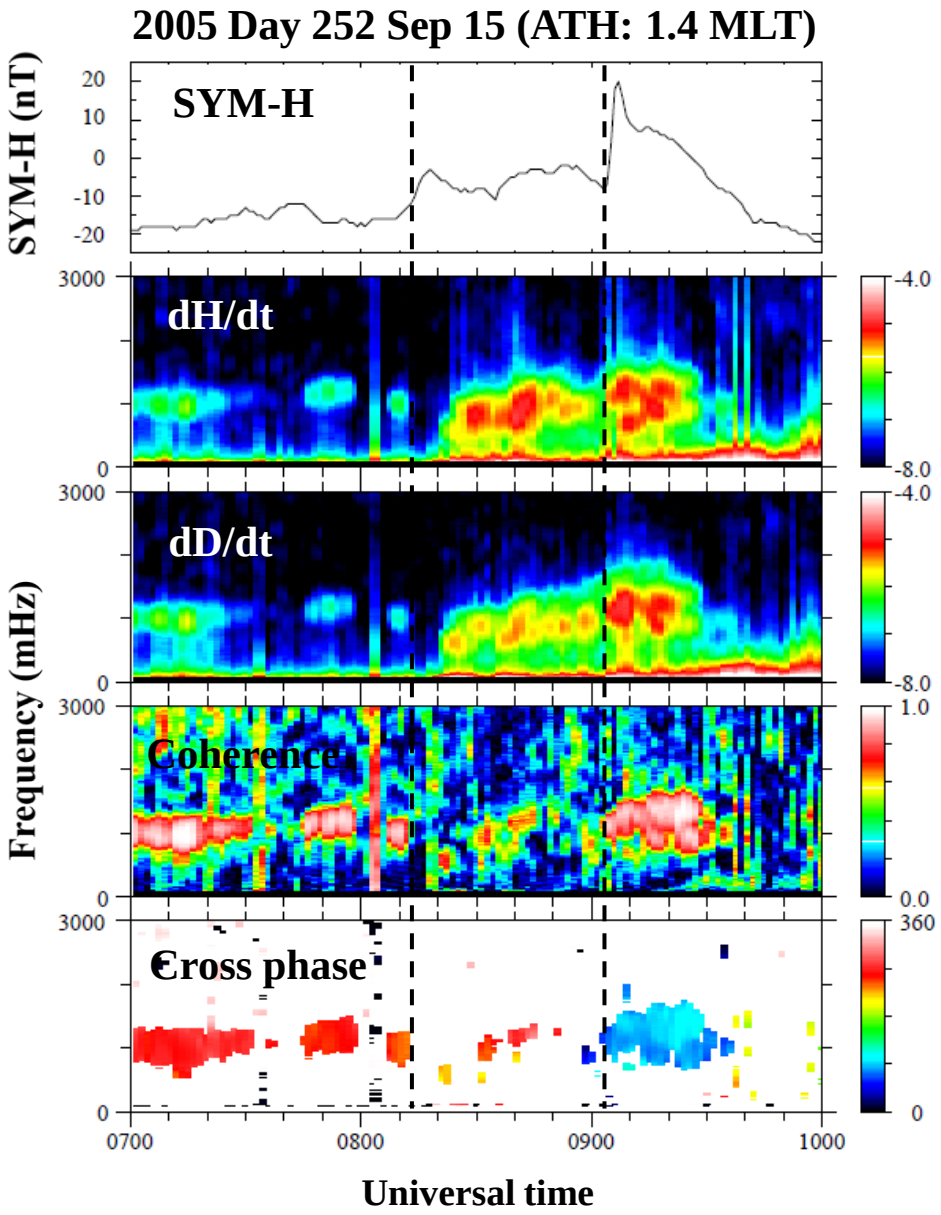
Pc1 observations at ATH (L ~ 4.6, MLAT ~ 62°)





Very complex SC-associated Pc1 waves could originate from sources on several different field lines.

Pc1 observations at ATH (L ~ 4.6, MLAT ~ 62°)



SC-associated EMIC/Pc1 waves

Sep 9, 2005 event: Low coherence

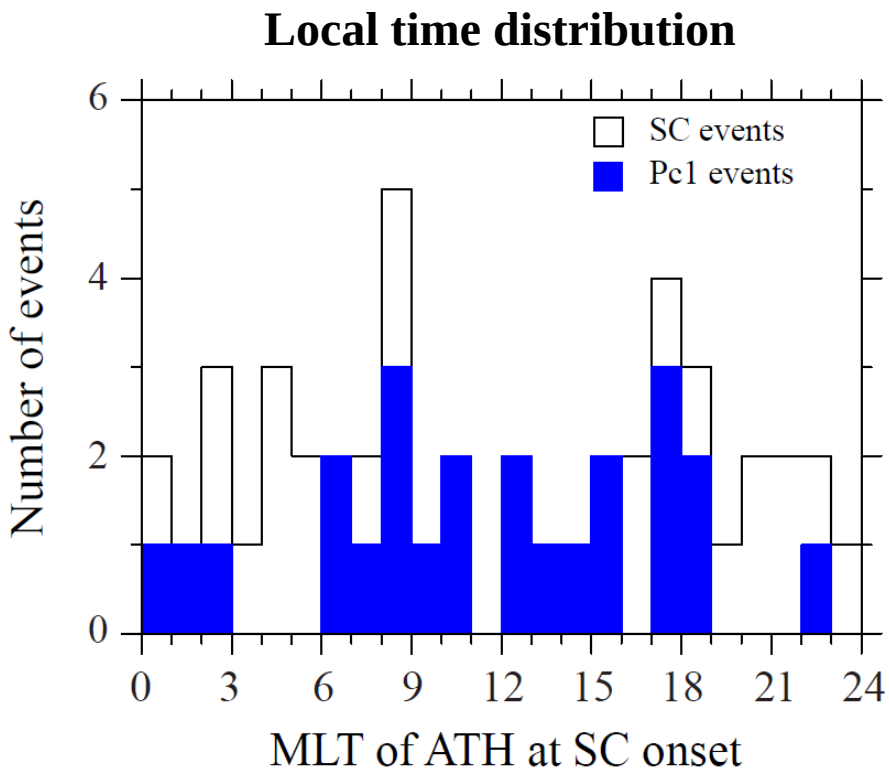
- ATH was in the early morning (MLT ~ 6.4) when SC occurred.
- SC-associated Pc1 waves in dH/dt and dD/dt with relatively broadband spectrum.
- Low coherence between dH/dt and dD/dt.

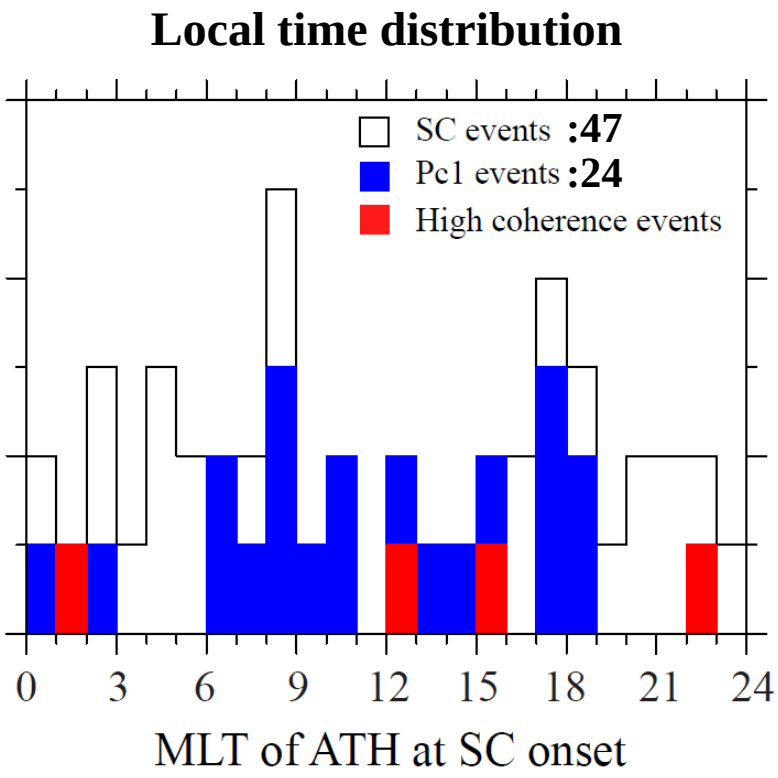
Sep 15, 2005 event: High coherence

- ATH was near the midnight (MLT ~ 1.4) when SC occurred.
- SC-associated Pc1 waves in dH/dt and dD/dt with broadband spectrum.
- High coherence between dH/dt and dD/dt.

Statistical results of SC-associated PC1 waves

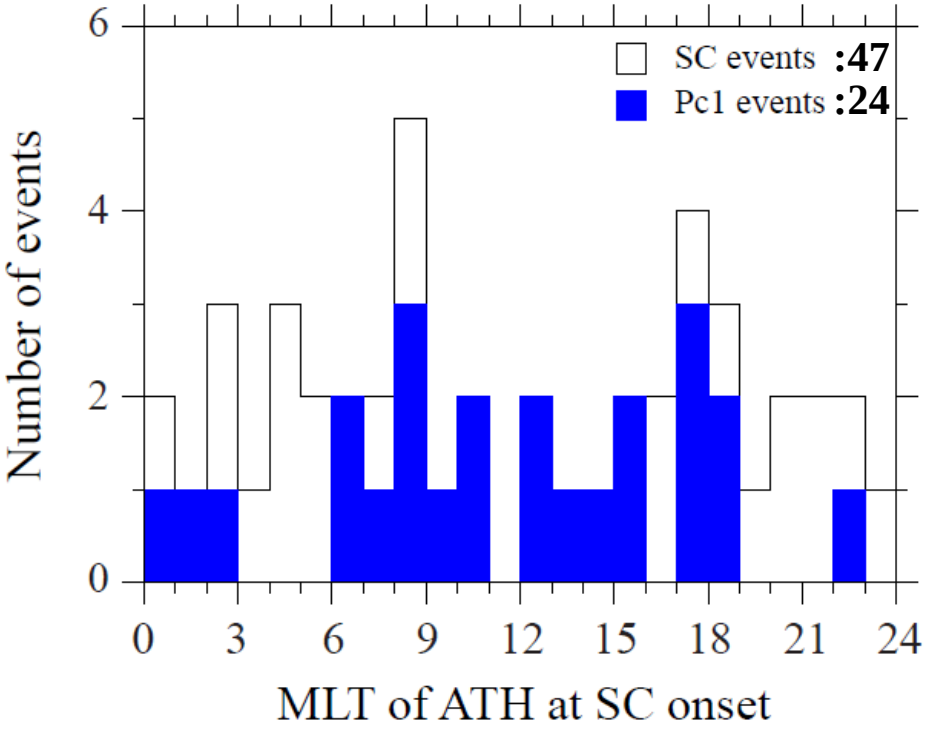
- 47 SC events for the time interval from September 2005 to August 2011.
- Out of 47 SC events, 24 SC-associated PC1 waves were observed at ATH station.
- Out of 24 SC-associated Pc1 events, only four events show high coherence between dH/dt and dD/dt.



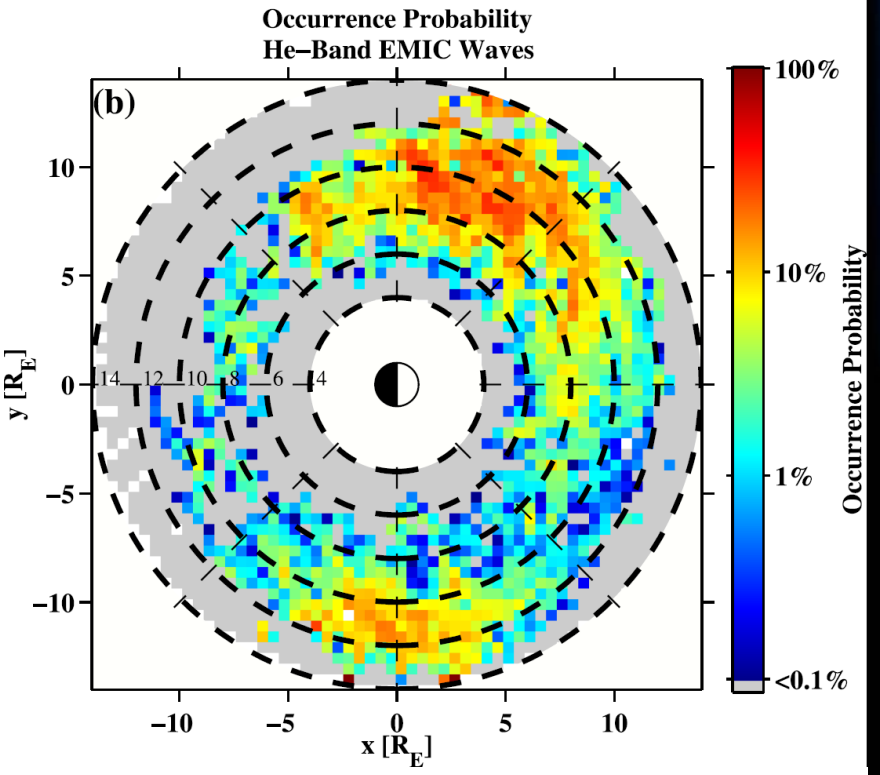


Comparison of EMIC/Pc1 and SC-associated EMIC/Pc1 wave occurrence probabilities

SC-associated Pc1 waves at ATH (L ~ 4.6)

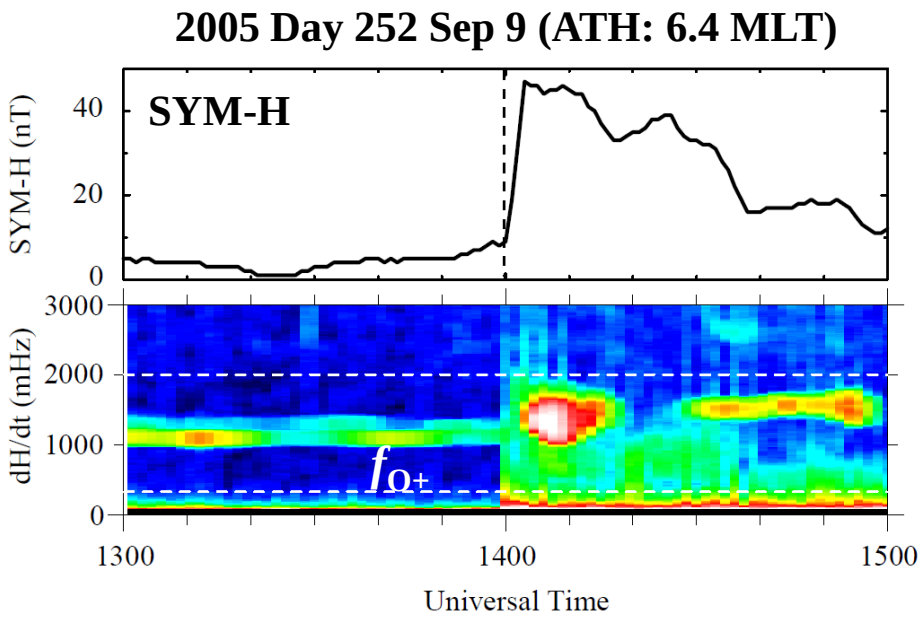


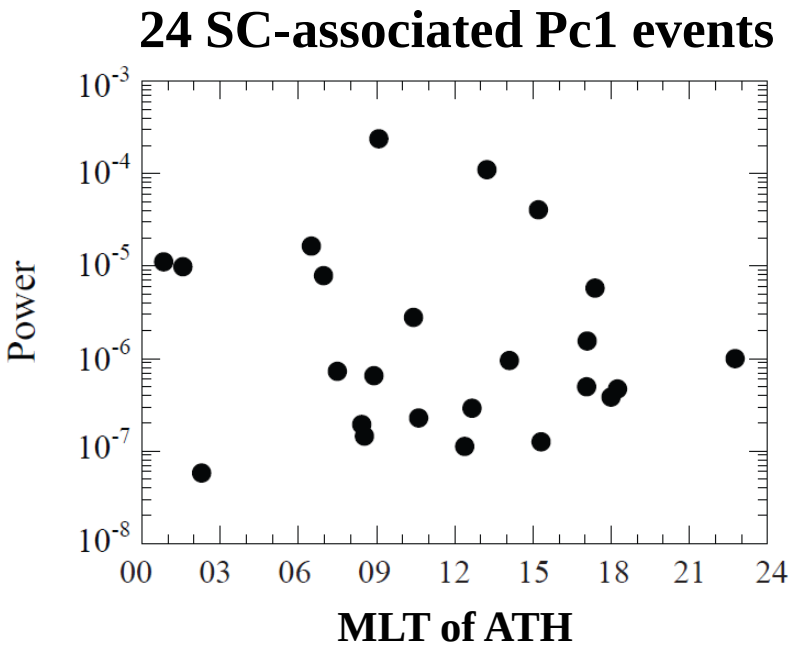
THEMIS Observations



Min et al. [2012]

MLT dependence of PC1 wave power

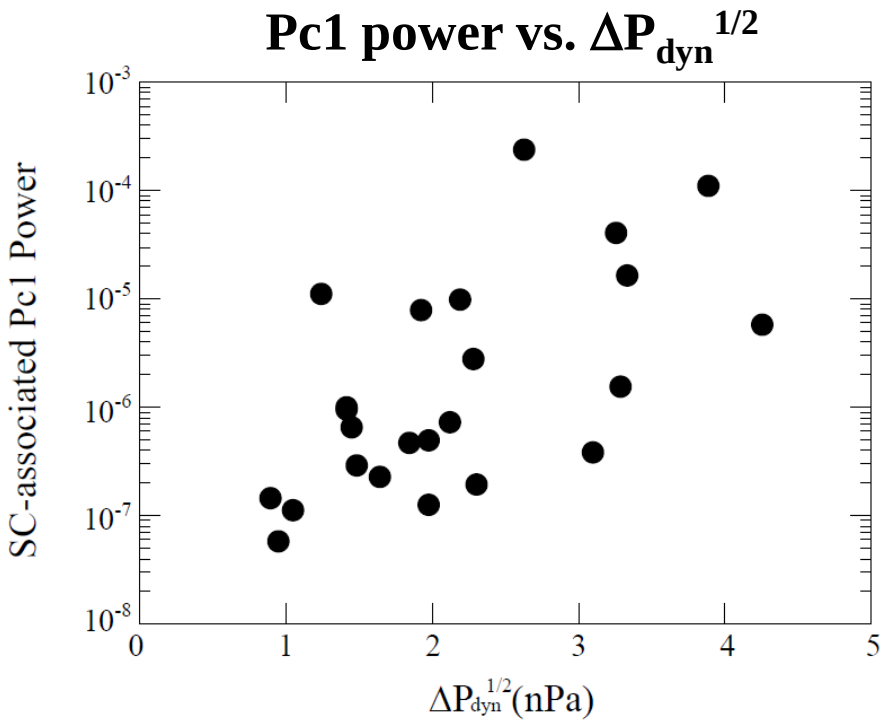


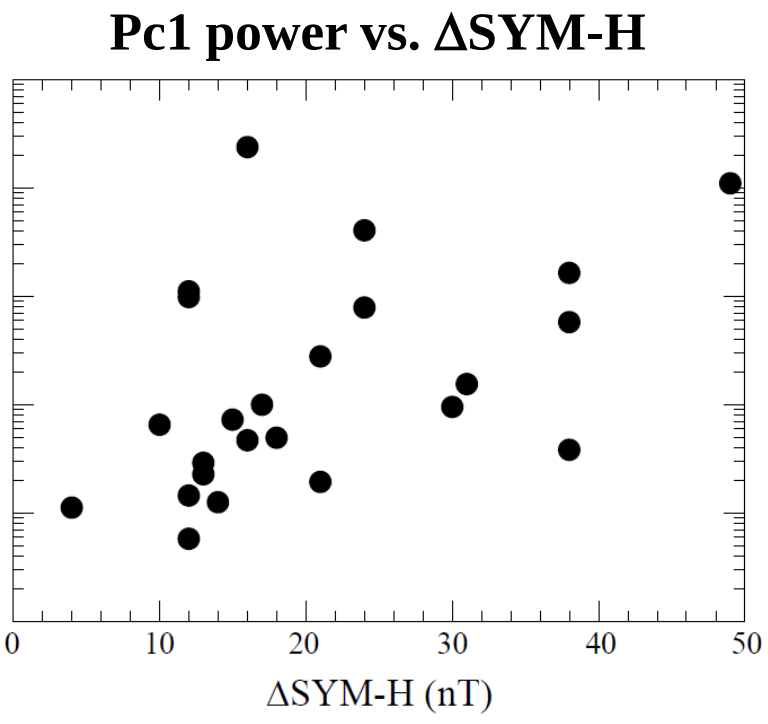


$$\text{Power} = \left(\int_{f_{O^+}}^{2Hz} PSD\_P_H(f)df \right)^{1/2}$$

No clear MLT dependence of Pc1 wave power

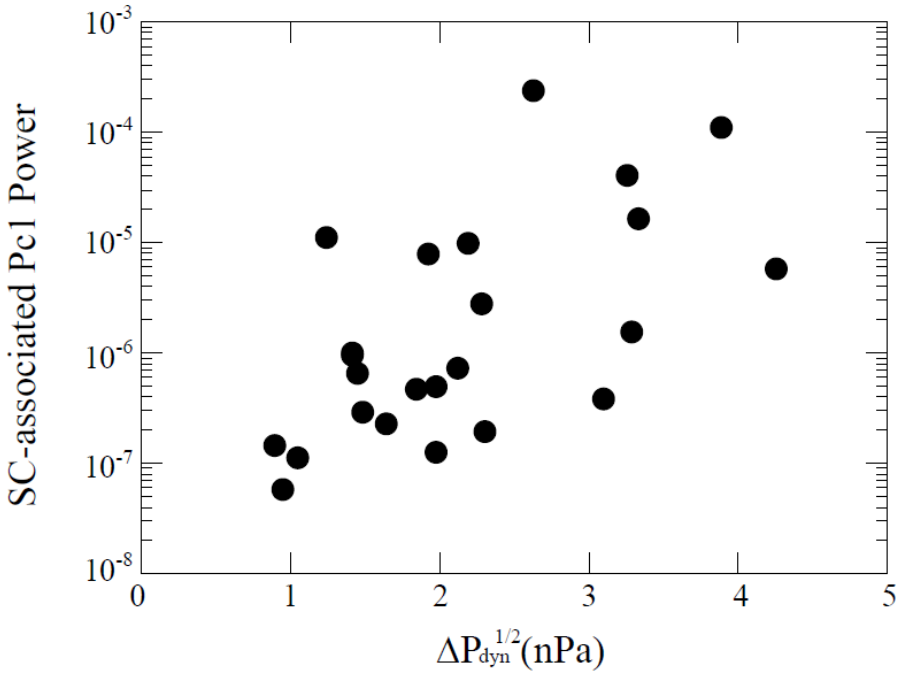
SC-associated PC1 wave power depending on solar wind dynamic pressure variation ($\Delta P_{dyn}^{1/2}$)



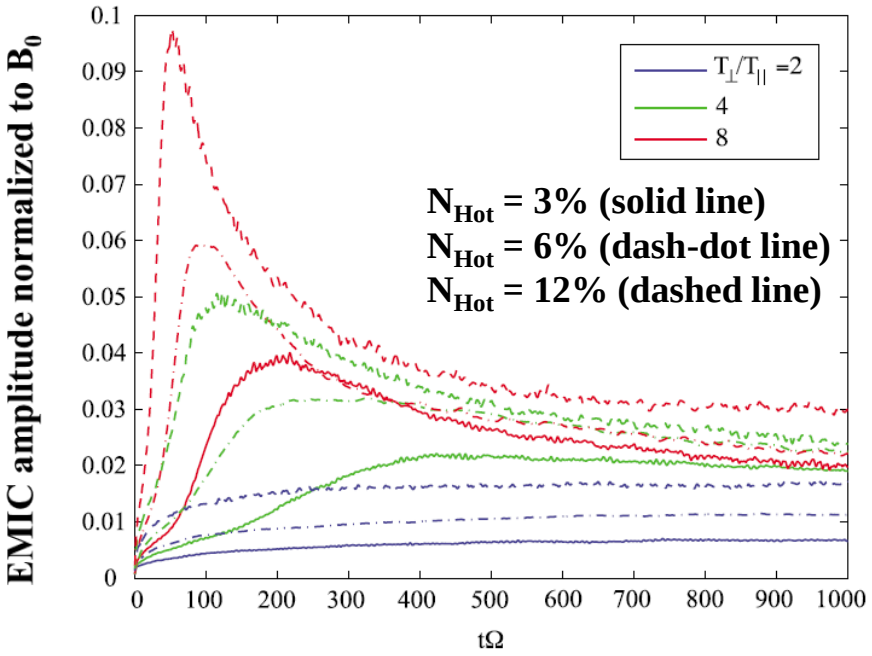


Magnetospheric compressions enhance EMIC/Pc1 wave activity: Q) By increasing the energetic proton temperature, anisotropy, and hot particle density?

Pc1 power vs. $\Delta P_{dyn}^{1/2}$

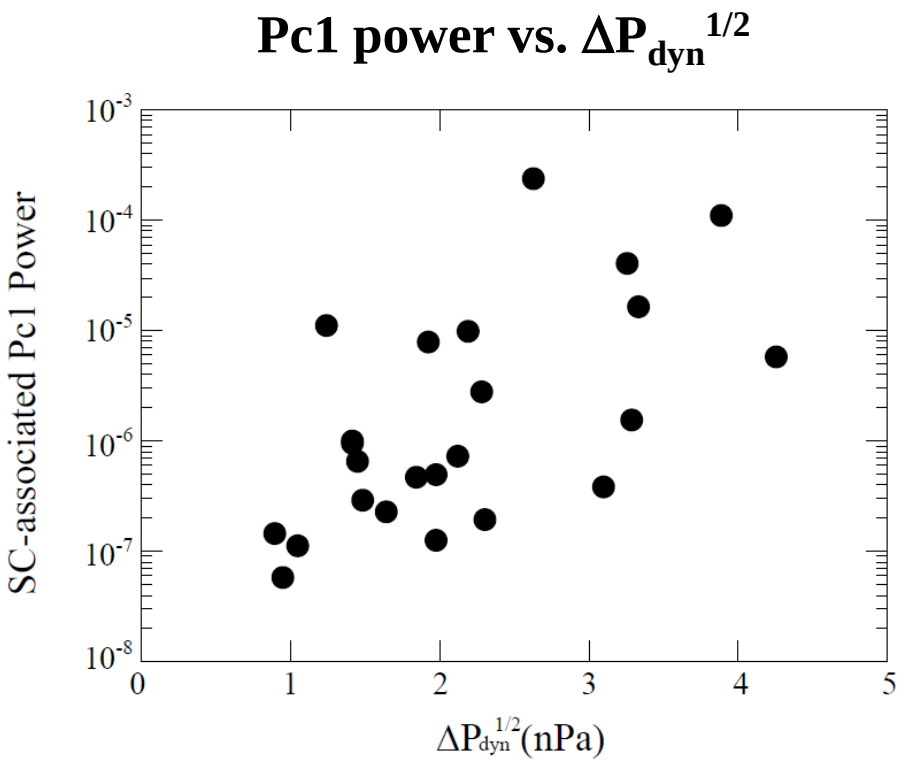


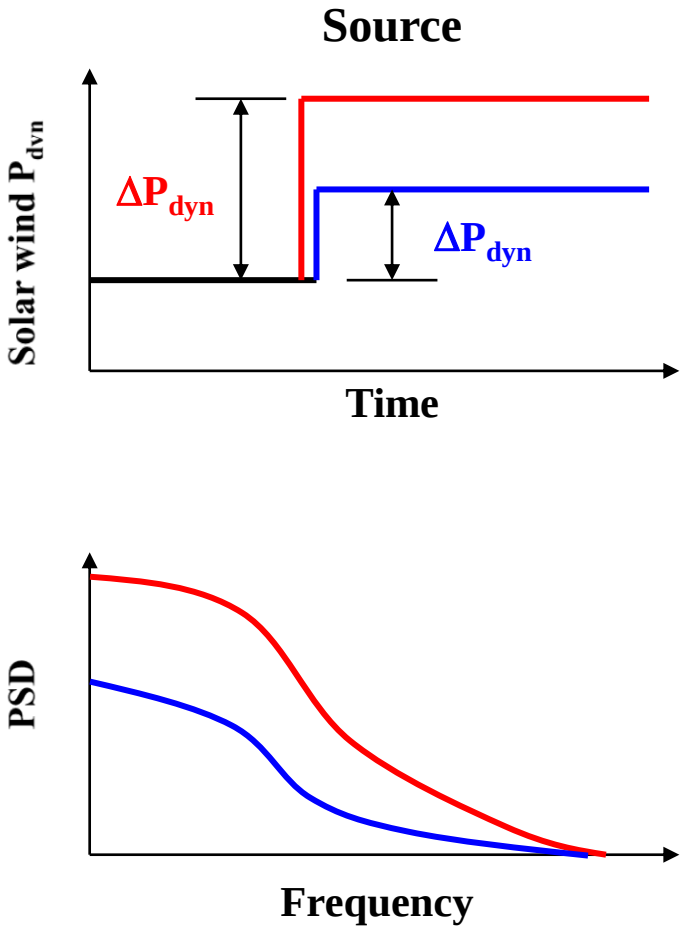
Hybrid code simulation



Bortnik et al. [2011]

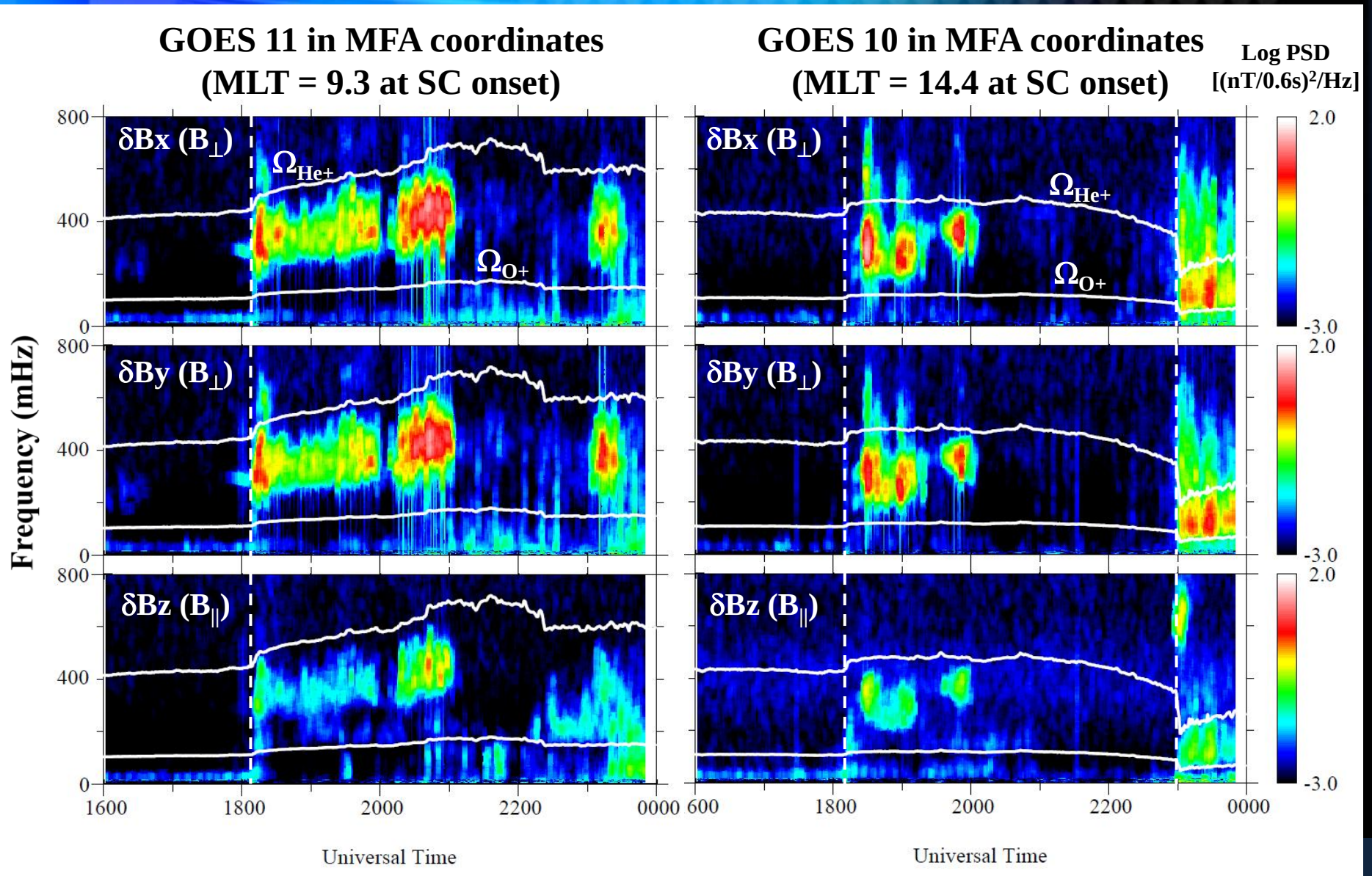
Magnetospheric compressions enhance EMIC/Pc1 wave activity: Q) By enhanced compressional power?



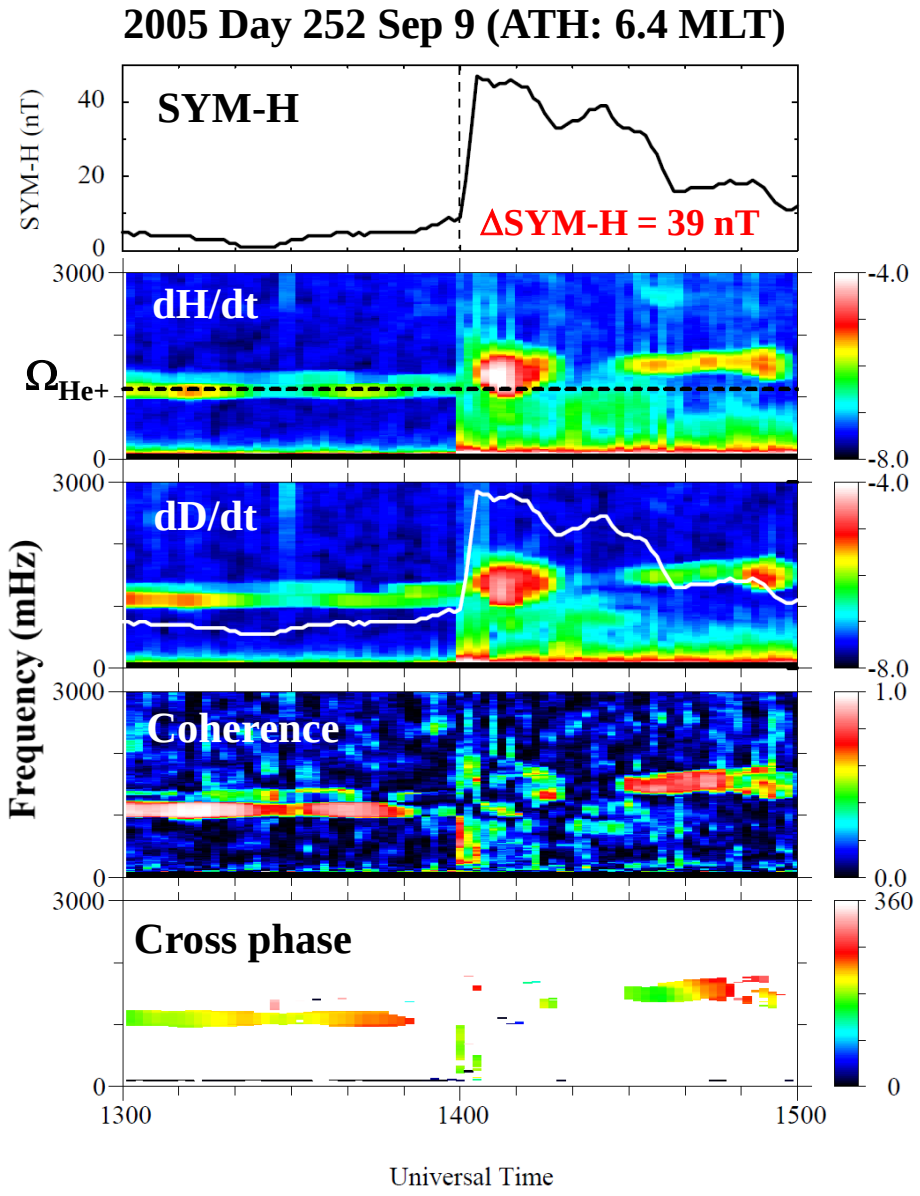


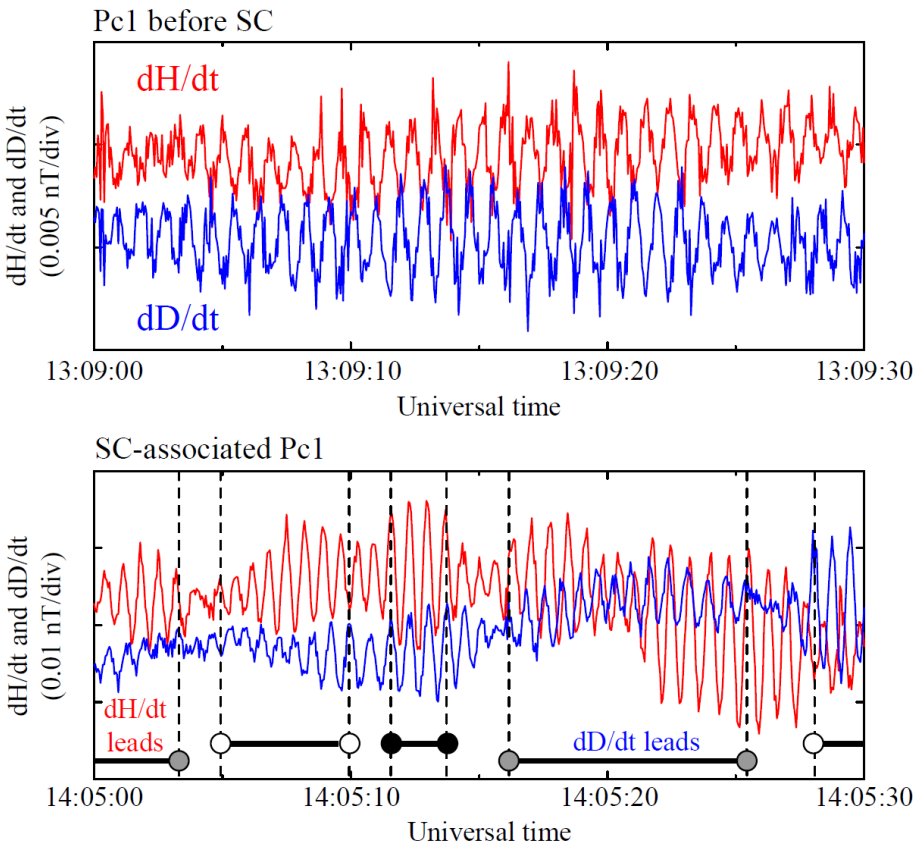
It is well known that intensifications in ground ULF wave power are related to increases in the solar wind dynamic pressure.

SC-associated EMIC/Pc1 waves at GOES S/C



Pc1 observations at ATH (L ~ 4.6, MLAT ~ 62°)





Very complex SC-associated Pc1 waves could originate from sources on several different field lines.

Summary

SC-associated EMIC/Pc1 waves:

- **Low coherence between transverse components (i.e., δBx and δBy) at geosynchronous orbit and between dH/dt and dD/dt at ATH ground station (L ~ 4.6).**

- **Low coherence is due to the fact that the phase delay between δBx and δBy (dH/dt and dD/dt) is not constant during the interval of SC-associated EMIC/Pc1 wave enhancement (i.e., the very complex waves originated from sources on several field lines).**

- **Positive correlation between EMIC/Pc1 wave power and solar wind dynamic pressure variation (ΔP_{dyn}).**