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Magnetospheric Inputs of Poynting Flux to and Its Effects in the Ionosphere

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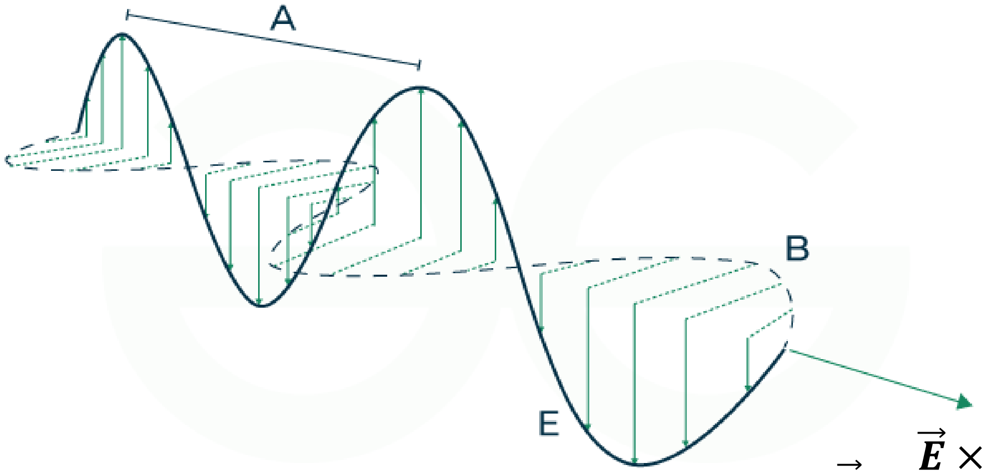
Poynting Vector and Theorem



$$\vec{S} = \frac{\vec{E} \times \vec{B}}{\mu_0}$$

- Poynting vector shows the direction of electromagnetic energy flow.
- $\nabla \cdot \vec{S} + \frac{\partial u}{\partial t} + \vec{J} \cdot \vec{E} = 0$

Poynting Flux in the Coupled Magnetosphere-Ionosphere

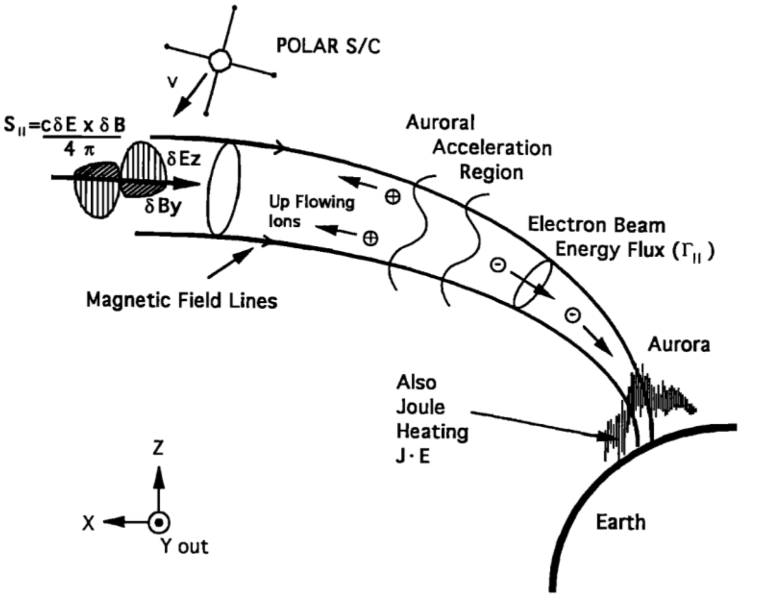


Figure 1. Illustration of a magnetic flux tube conjugate to the auroral acceleration region with incident Poynting flux and its conversion to energized particles and joule heating of the ionosphere. Wavelength of wave fluctuations not to scale.

Wygant et al. [2000]

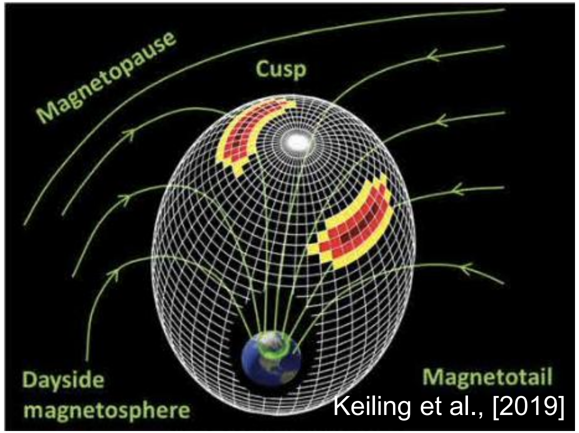
$$\vec{S}_{DC} = \frac{\vec{E}_0 \times d\vec{B}}{\mu_0}$$

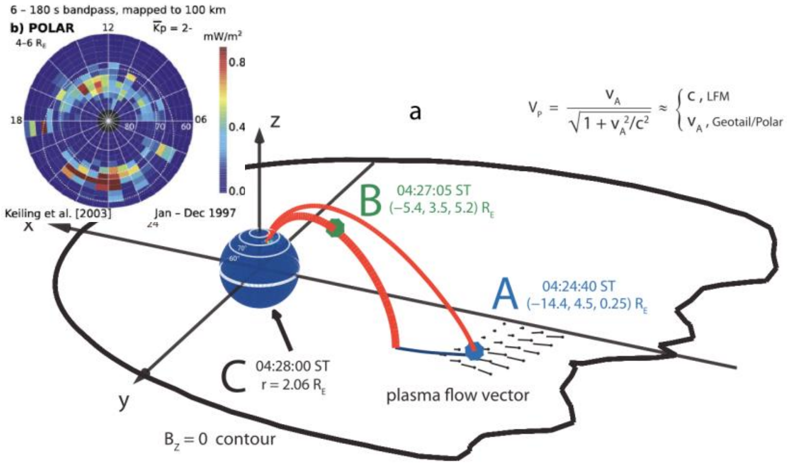
$$\vec{S}_{AC} = \frac{\delta\vec{E} \times \delta\vec{B}}{\mu_0}$$

Non-divergent background $\vec{B}_0$

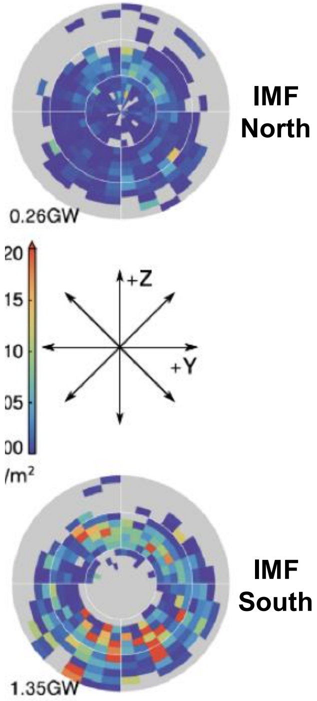
- A key agent transporting EM field and energy.
- Quasi-static (DC) vs Alfvenic (AC).

Alfvenic Poynting Flux





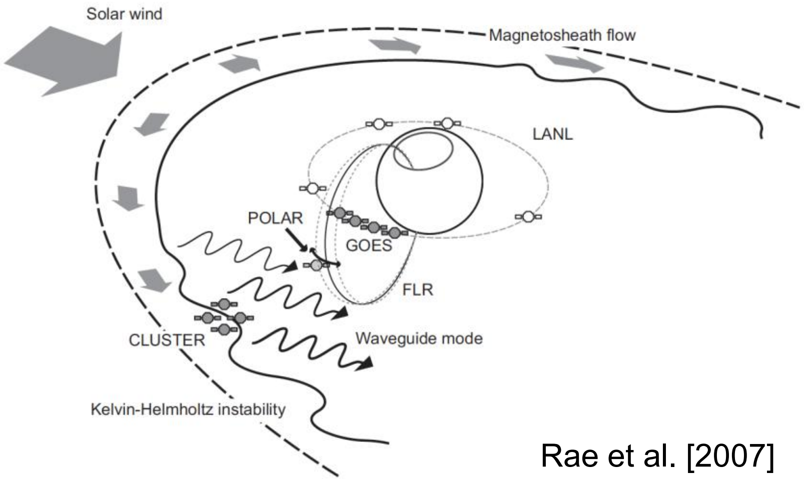
Bursty bulk flow braking
LFM modeling [Zhang et al. 2012]



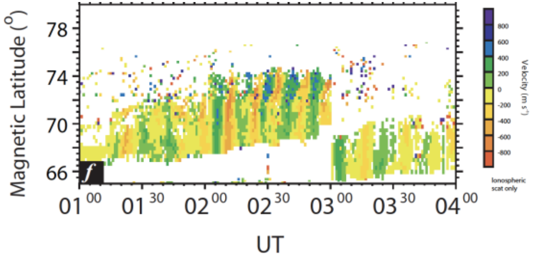
FAST statistics
[Hatch et al. 2017]

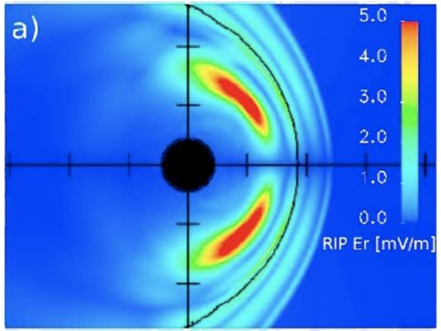
- Alfvenic power is preferred at two zones: dayside and nightside.
- Non-trivial dayside AC power under northward IMF.

Ultra-low frequency wave and field line resonance



Rae et al. [2007]

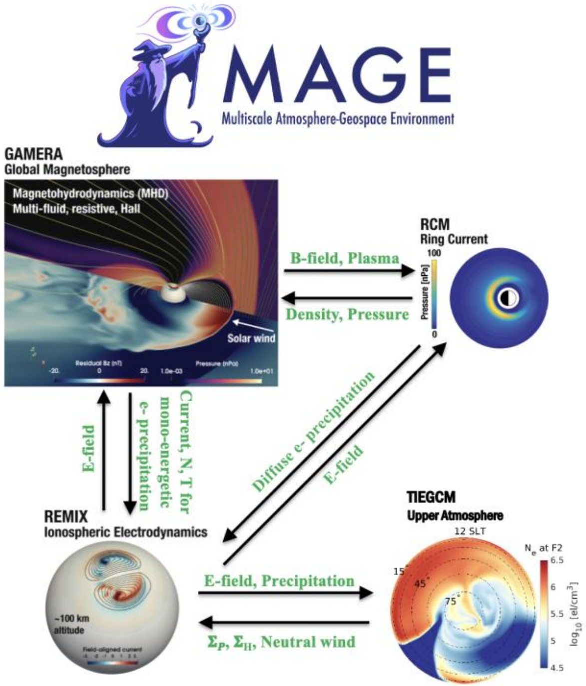


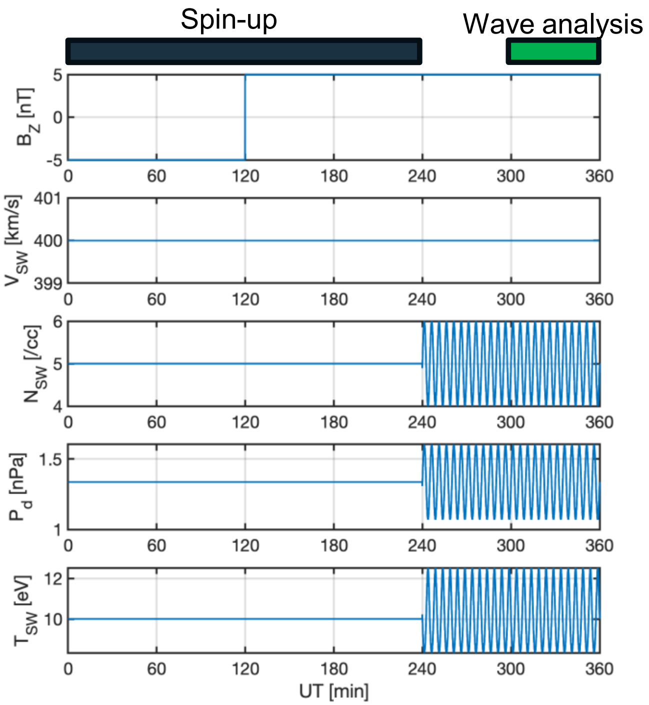


Claudepierre et al. [2010]

- Oscillating solar wind can excite magnetospheric ULF waves in the form of toroidal mode field line resonance.
- What is the role of solar wind fluctuation in powering the ionosphere?

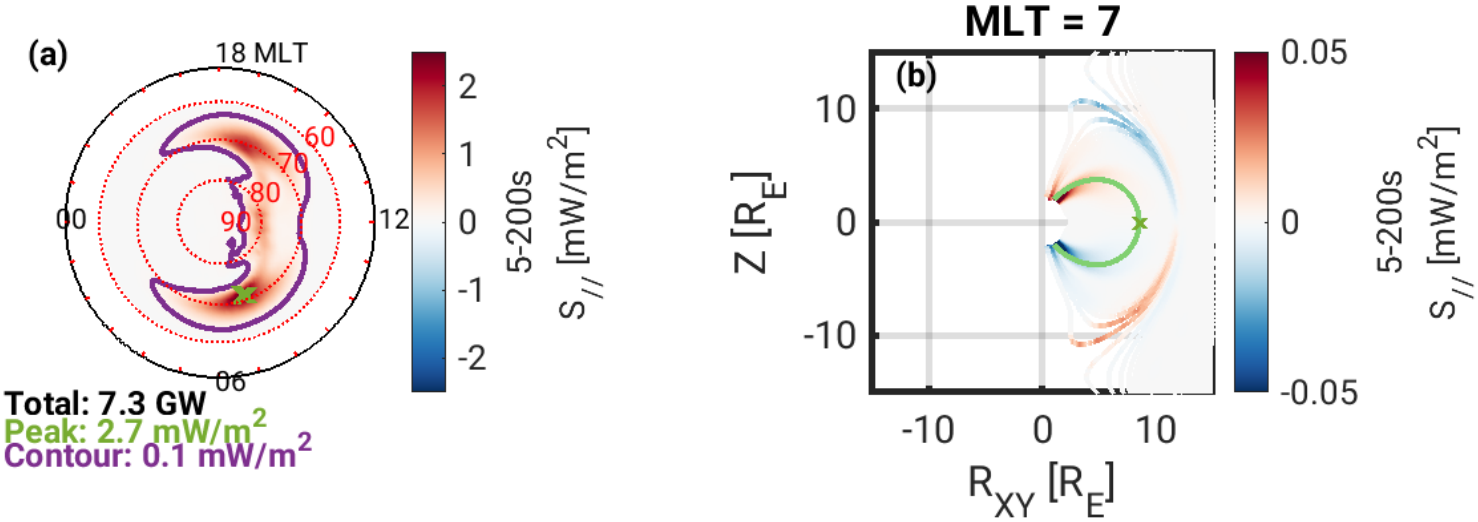
The Multiscale Atmosphere-Geospace Environment Model





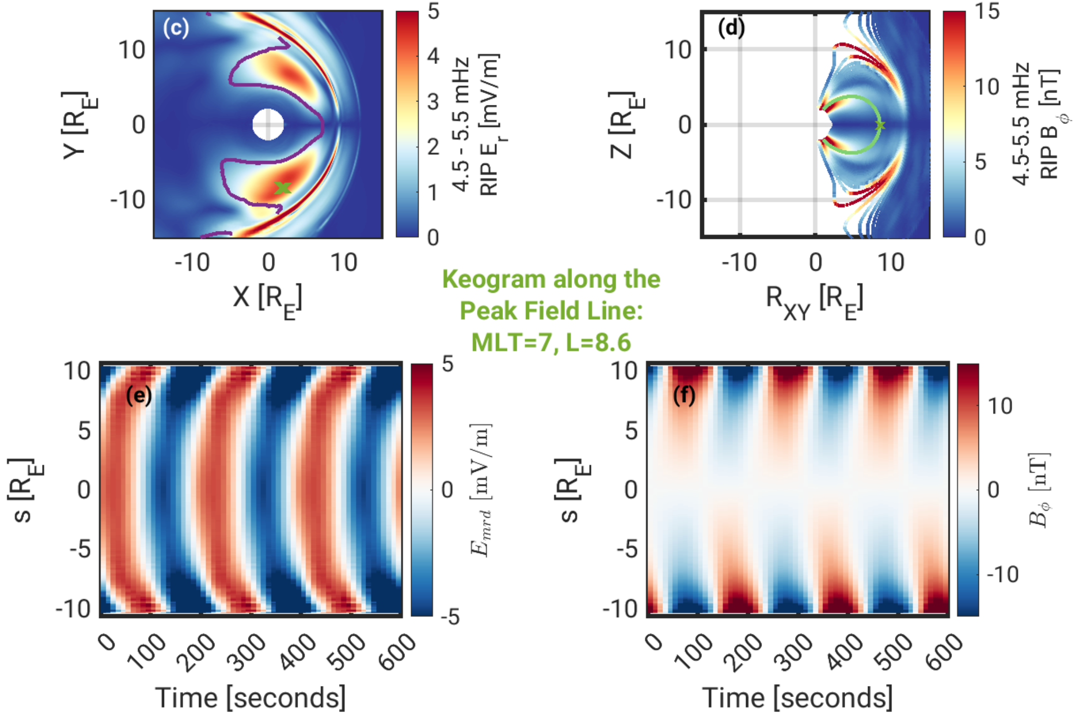
- GAMERA global MHD model.
- Idealized solar wind driving conditions.

Alfvenic Poynting Flux



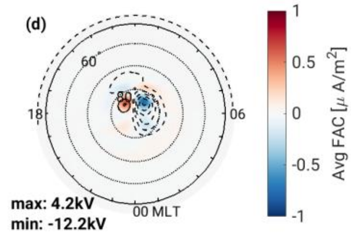
- Significant amount of Alfvenic Poynting flux enters the ionosphere driven by solar wind dynamic pressure fluctuations under northward IMF.

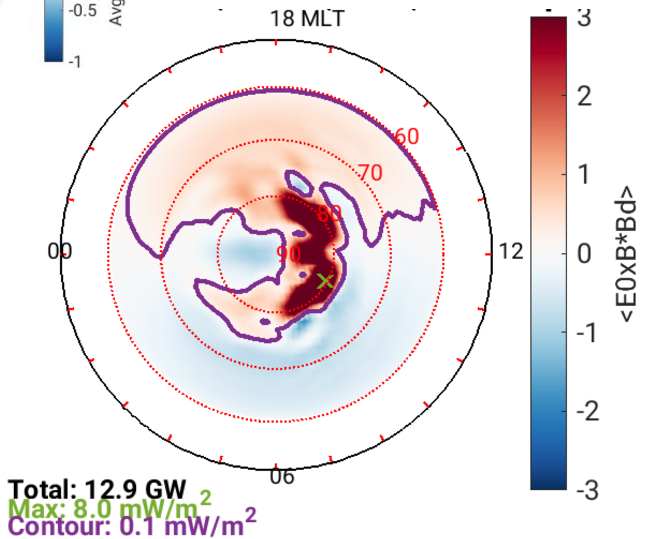
Wave mode analysis: toroidal mode FLR

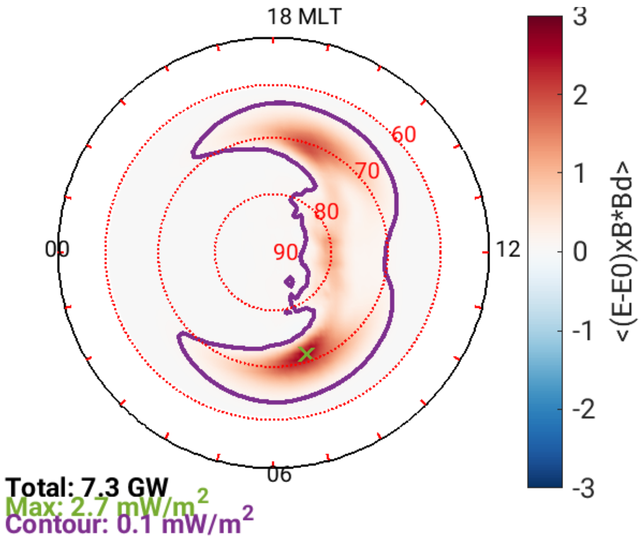


- Toroidal mode FLR where source frequency matches local magnetic field line eigen frequency.

AC vs DC

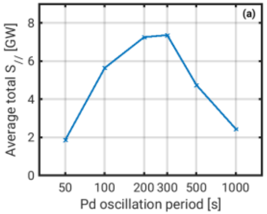


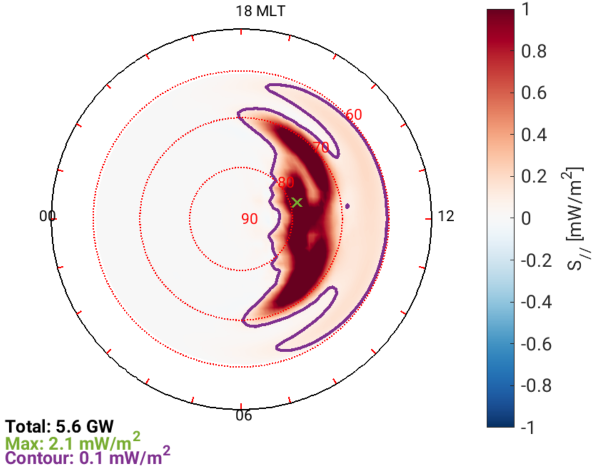




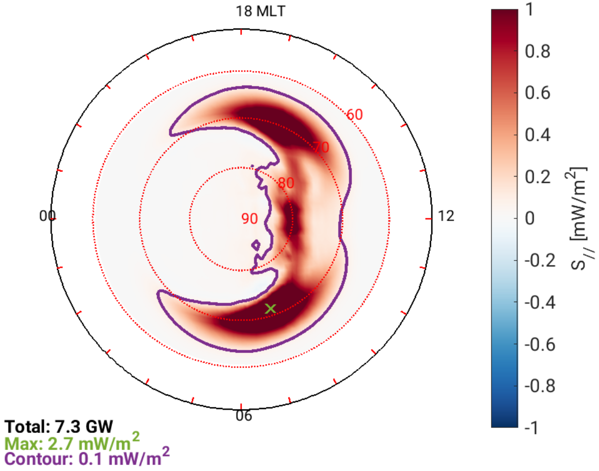
- Hemispheric integration of AC Poynting flux is more than half of DC Poynting flux

Source Period Dependence

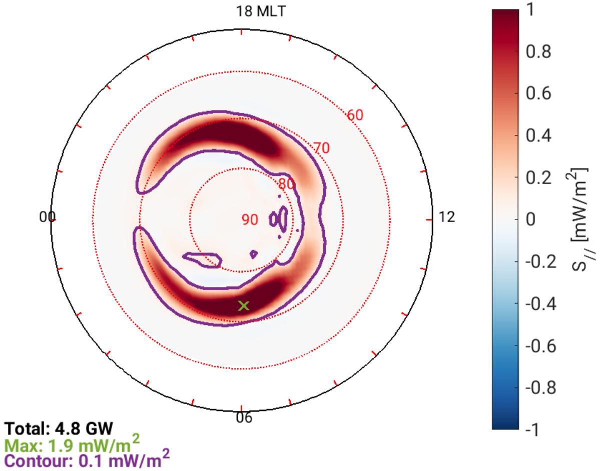




100s



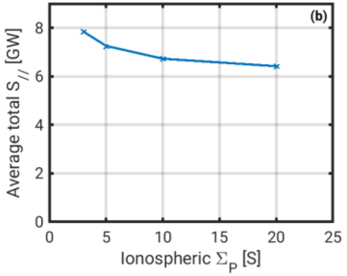
200s

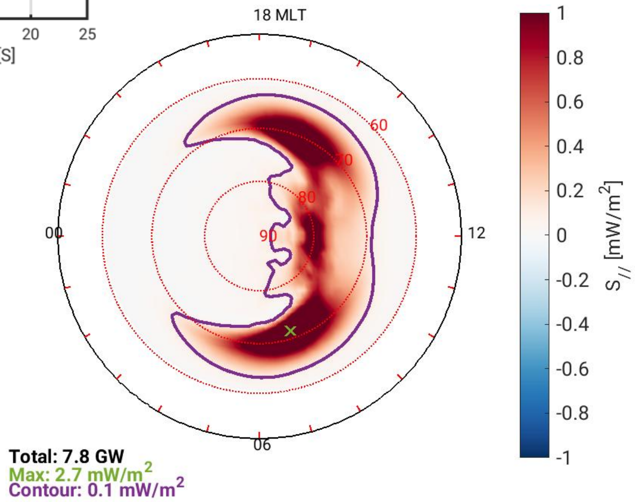


500s

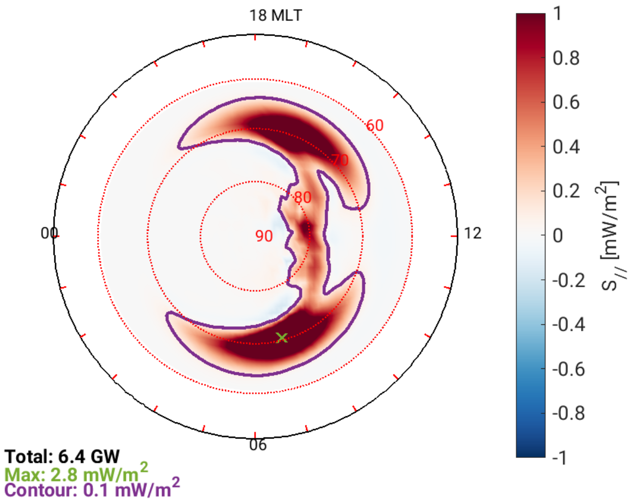
- There is an optimal period for AC Poynting flux to maximize:
  - Too short period waves need to propagate deeper to find a resonant field line;
  - Too long period waves can only resonate with the outer most field lines.

Pedersen Conductance Dependence





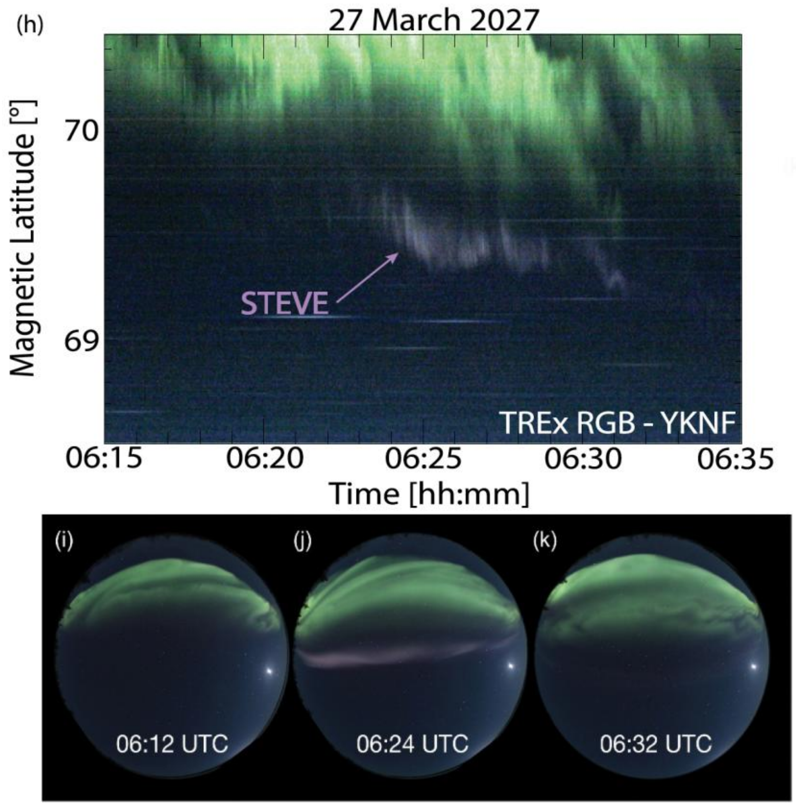
3 S



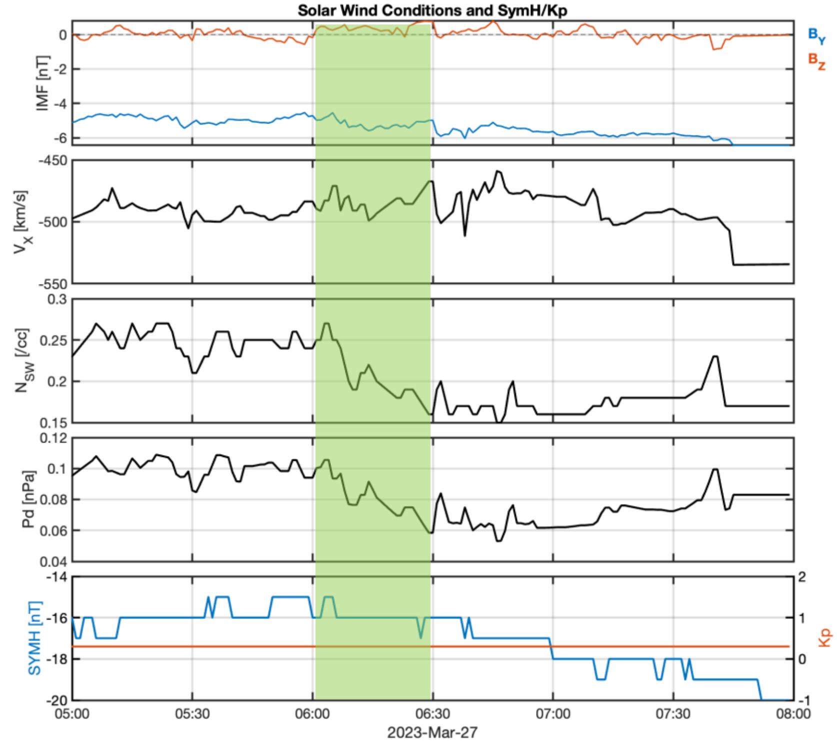
20 S

- More conducting, more reflective.

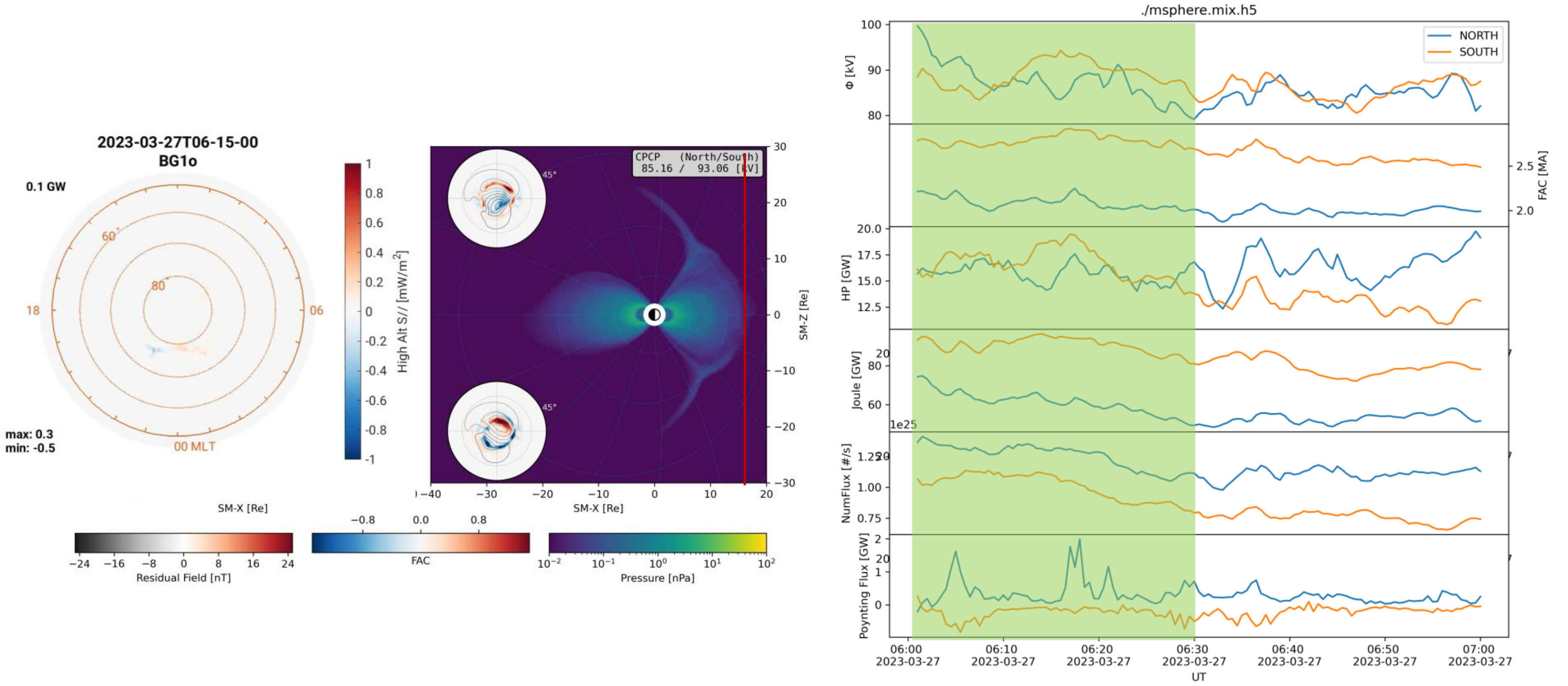
An Unexpected STEVE event at high latitude during quiet times



Gallardo-Lacourt et al. [2024]



- Nsw/Pd dropped by 40%.



- Enhanced nightside Alfvenic Poynting flux during brief magnetospheric expansion.

Conclusions

- Solar wind dynamic pressure fluctuations drive electromagnetic energy input to the ionosphere on the dayside.
- Pd fluctuations excited toroidal mode FLR converts into field-aligned Poynting flux.
- The AC Poynting flux makes up more than half of DC Poynting flux input.
- Pd fluctuations driven S// is dependent on Pd frequency and ionospheric conductance.
- Enhanced AC Poynting flux during a brief magnetospheric expansion may account for the observed unexpected high latitude STEVE during a quiet time.