Global distribution of EMIC waves derived from THEMIS observations

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Introduction

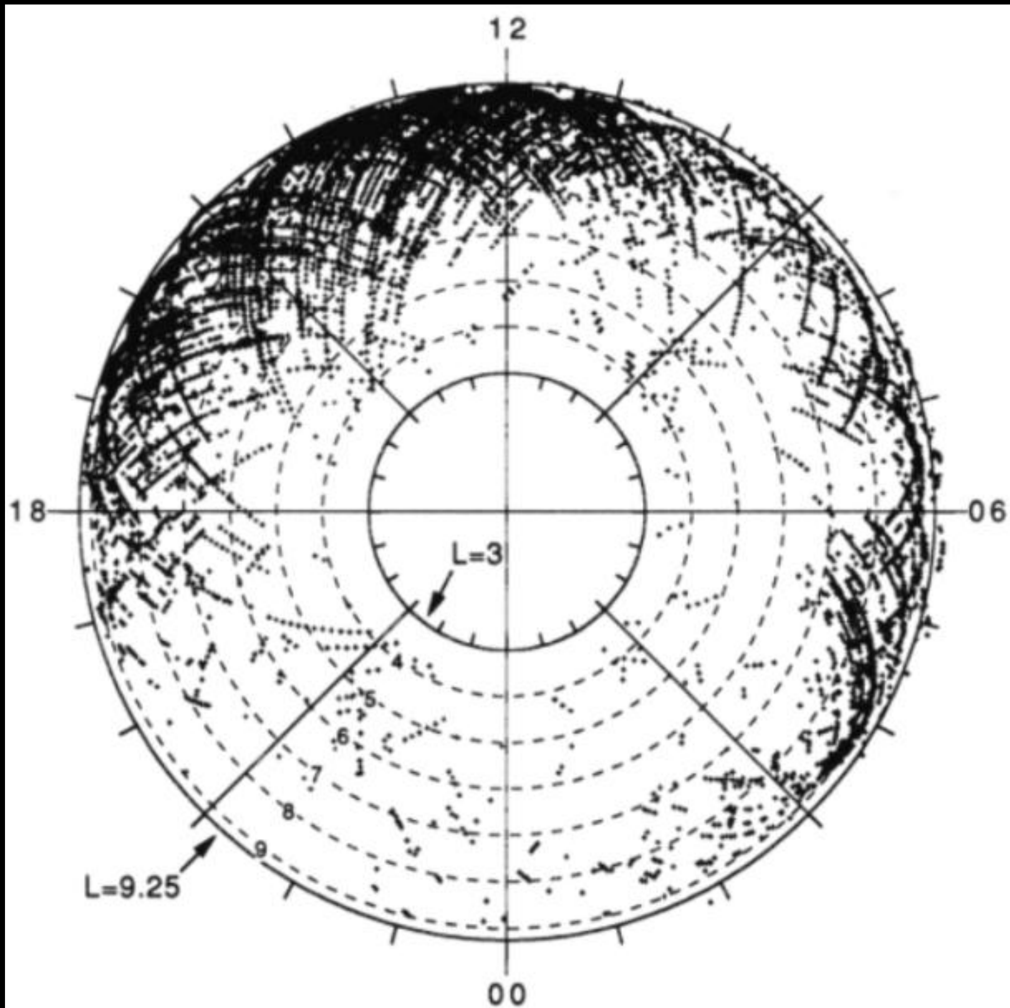
EMIC waves play an important role in pitch angle scattering of energetic ions and relativistic electrons into the loss cone, and the global distribution of EMIC waves is of interest.

AMPTE/CCE: [Anderson et al. 1992a,b]
- 3.5 < L < 9
- EMIC waves can occur in the entire magnetosphere, with increasing probability with radial distance.

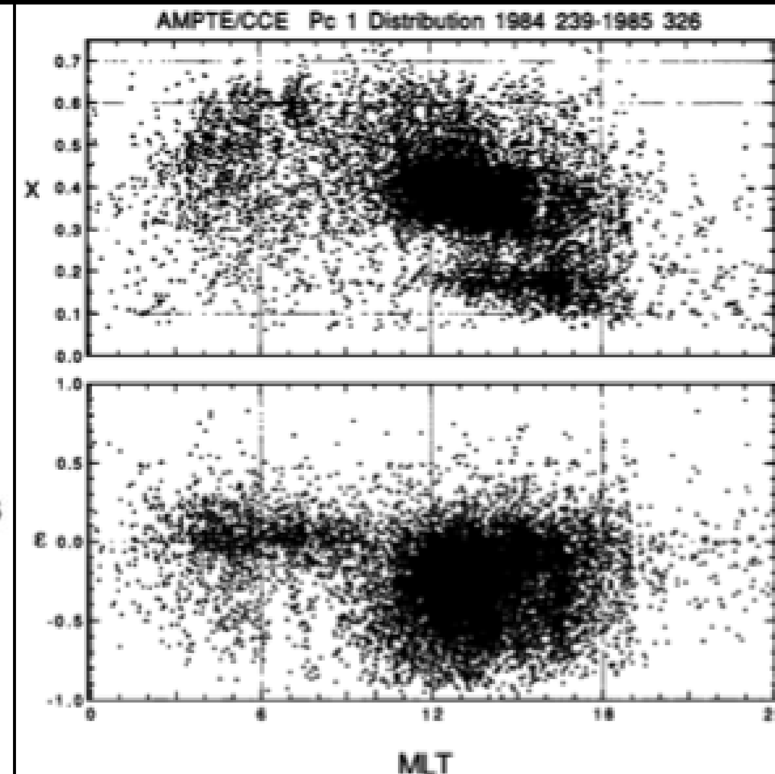
CRESS: [Fraser and Nguyen 2001]
- 3.5 < L < 8
- Waves dominate in the afternoon and increases with radial distance.
- The plasmapause is a region of wave generation and propagation.
- All wave polarizations (L/R, linear) are seen within 8 degree of the equator linear predominates over 20–30 degree latitude.

THEMIS: [Min et al. 2012]
- 6.6 < L < 14 or MP for hydrogen band waves, L> 4.1 for helium band

AMPTE/CCE [Anderson et al. 1992a]

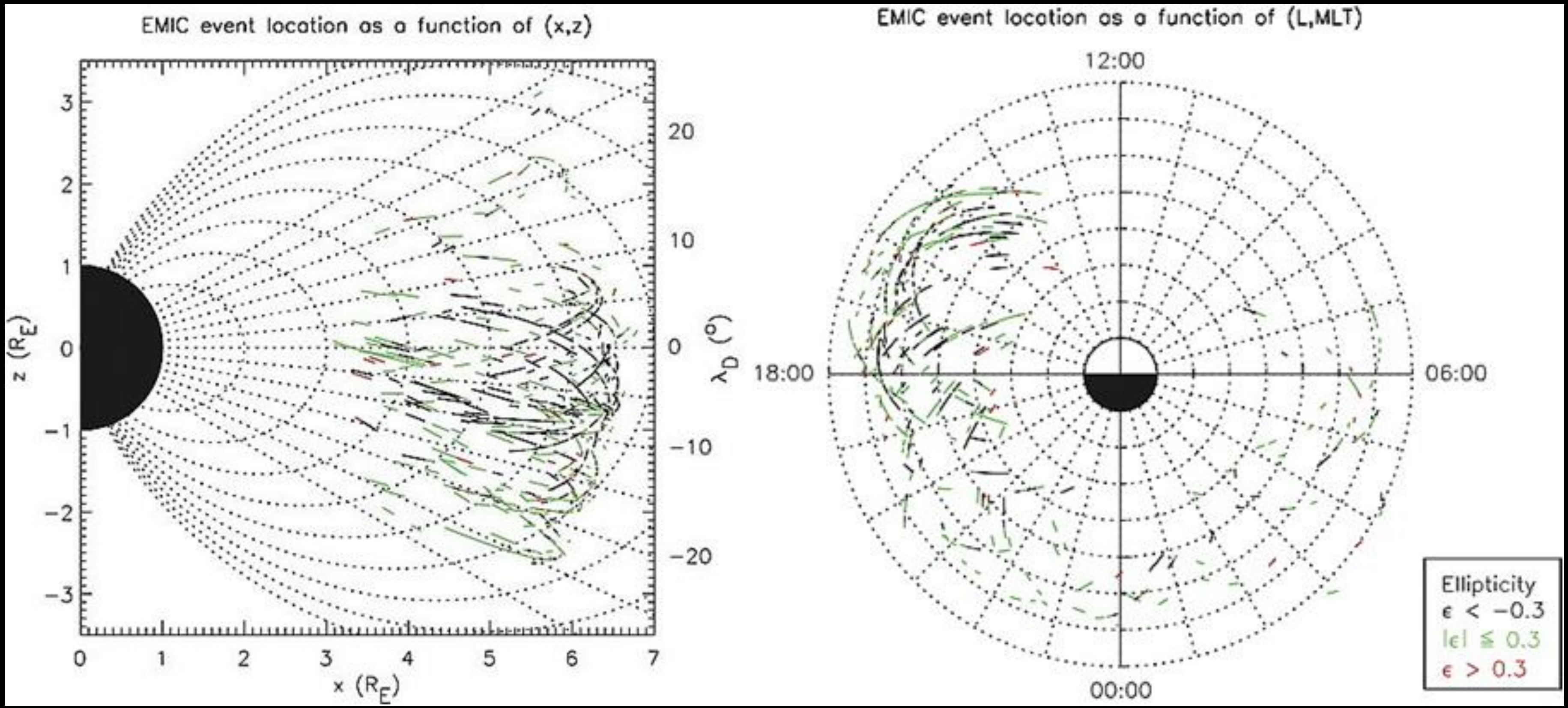


EMIC waves in the equatorial magnetosphere from L = 3.5 to L = 9 at all local times

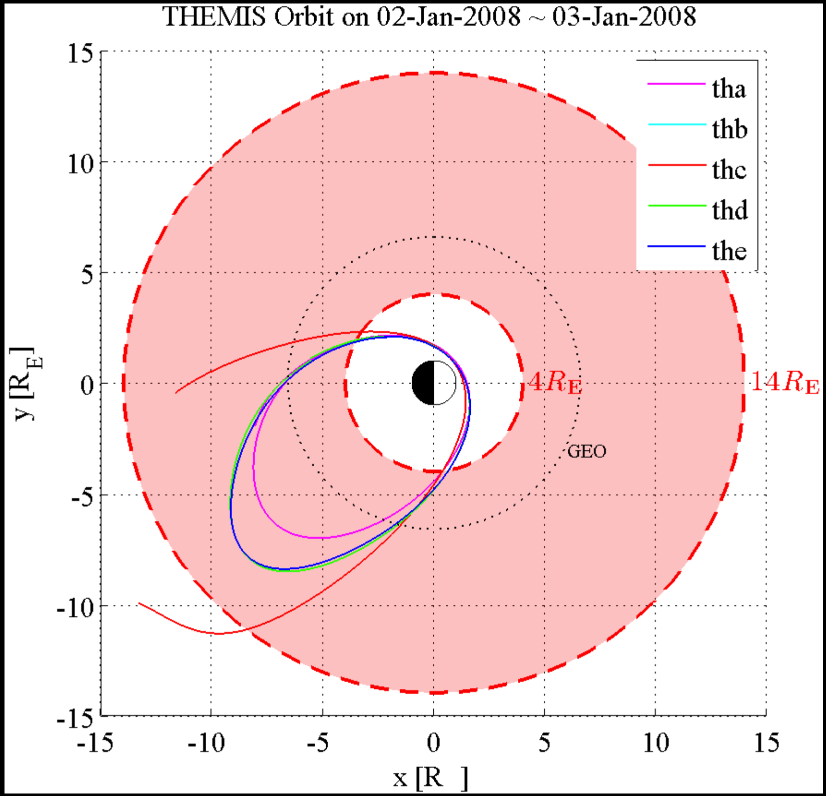


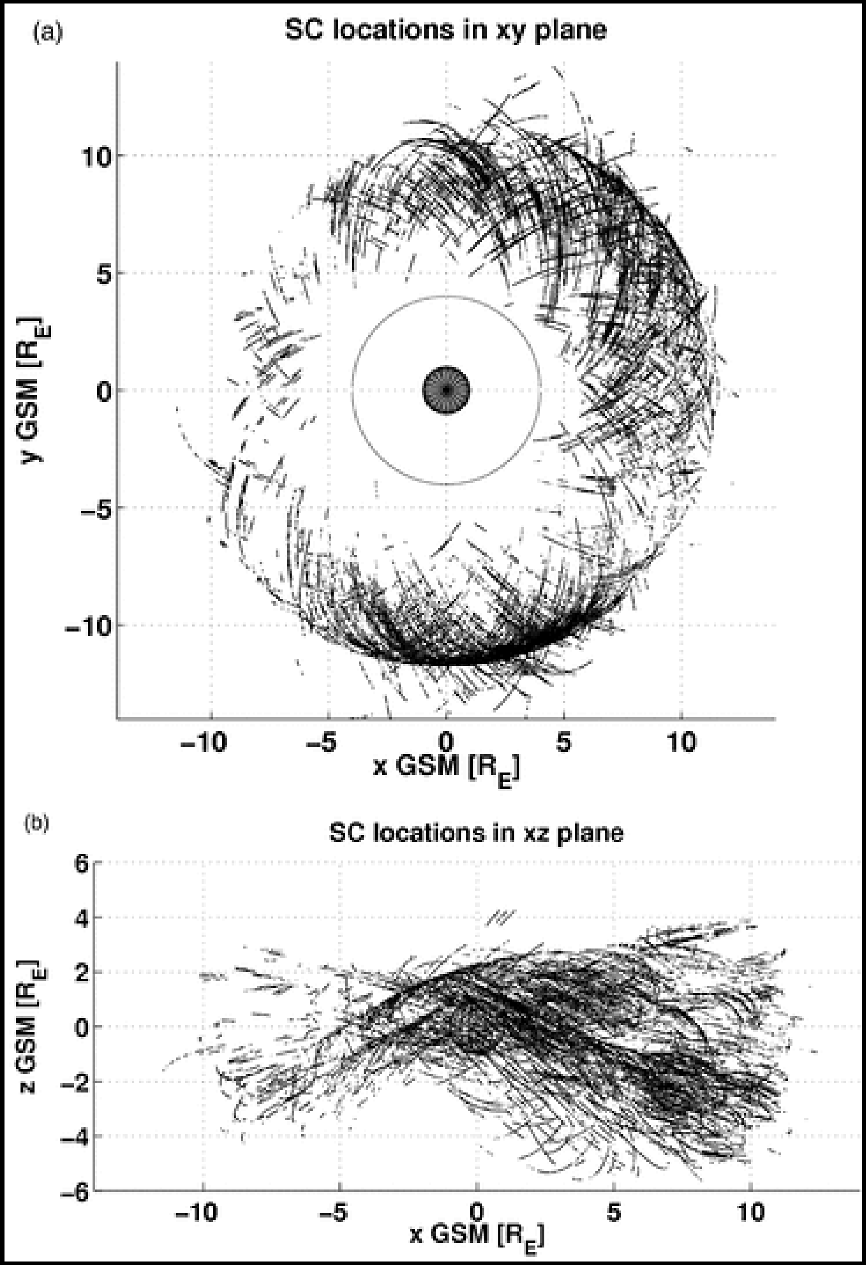
A Statistical Study of Pc 1-2 Magnetic Pulsations in the Equatorial Magnetosphere, 1. Equatorial Occurrence Distributions

Occurrence of EMIC Waves at CRRES:
14 months 1990-1991



More waves seen 14-18 MLT and L > 4 [Meredith et al. 2003]





Data:

4/1/2007 - 12/31/2010

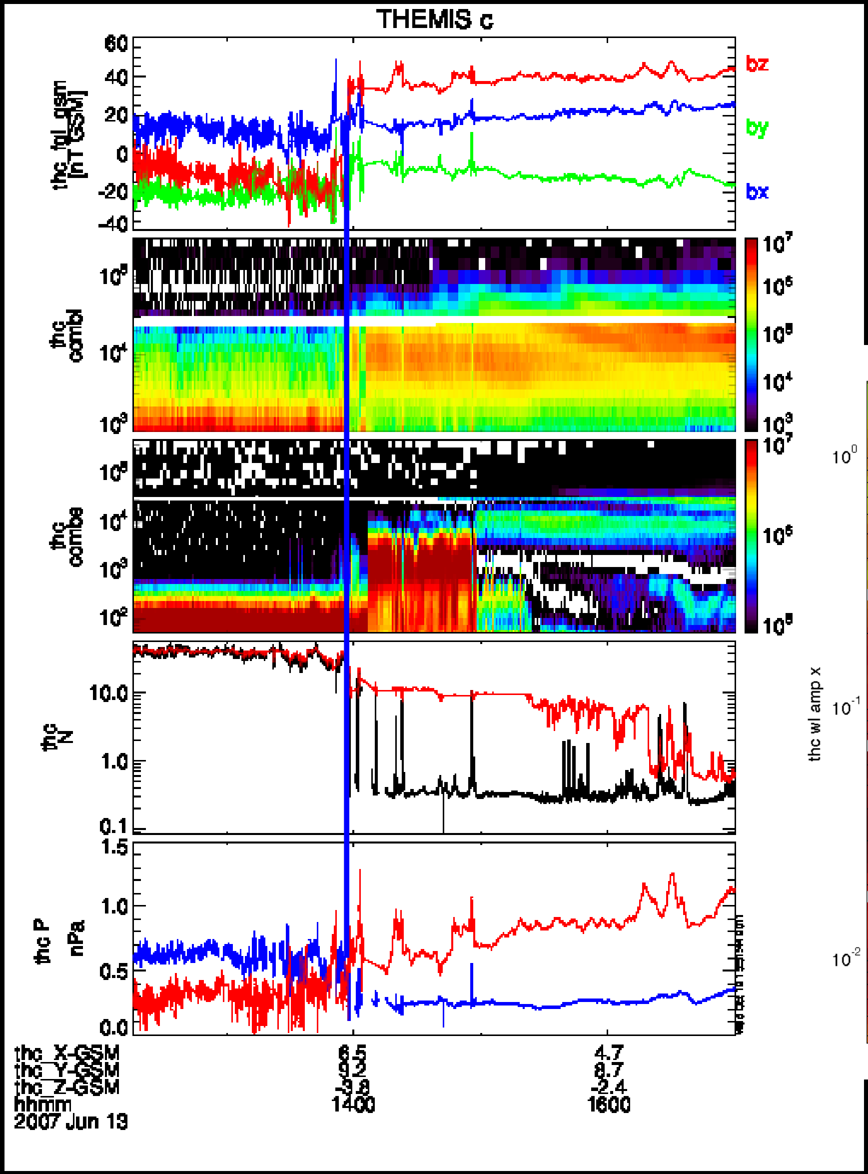
FGM (~0.25 s, f_{Nq} = 2 Hz)

Inner boundaries:

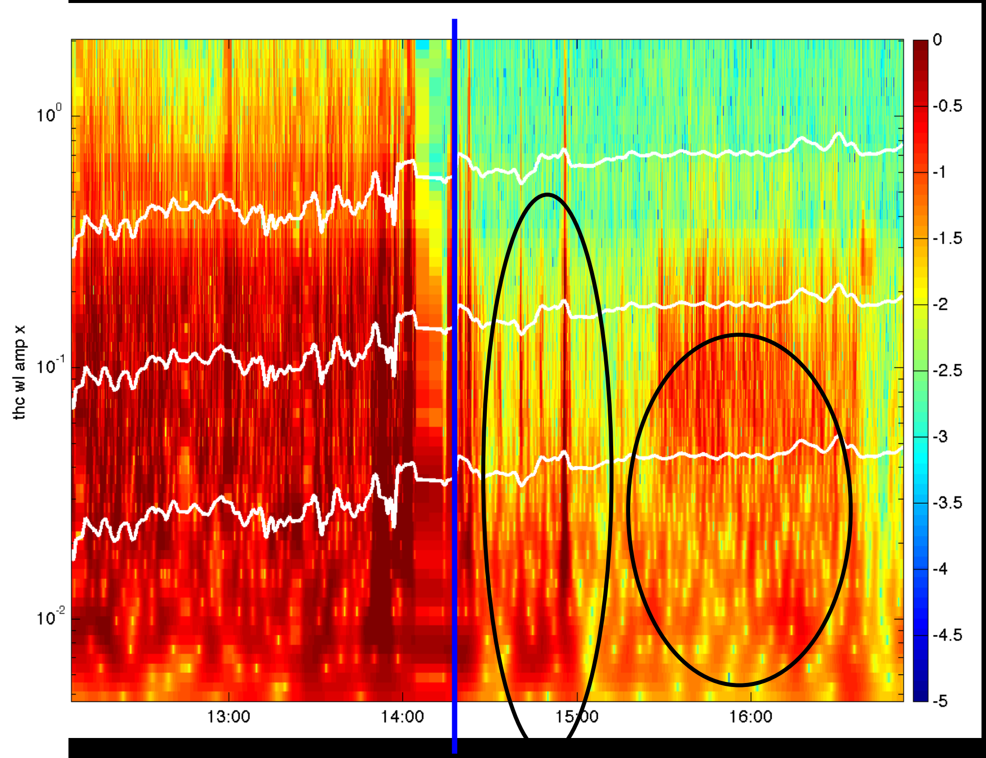
$f_{H+} > f_{Nq}$ -> L < 6.6

$f_{He+} > f_{Nq}$ -> L < 4.0

Outer boundary: 14 R_E?



Outer boundary should be the Magnetopause and we locate it by looking at magnetic field variation relative magnetic field variation, dB/B.

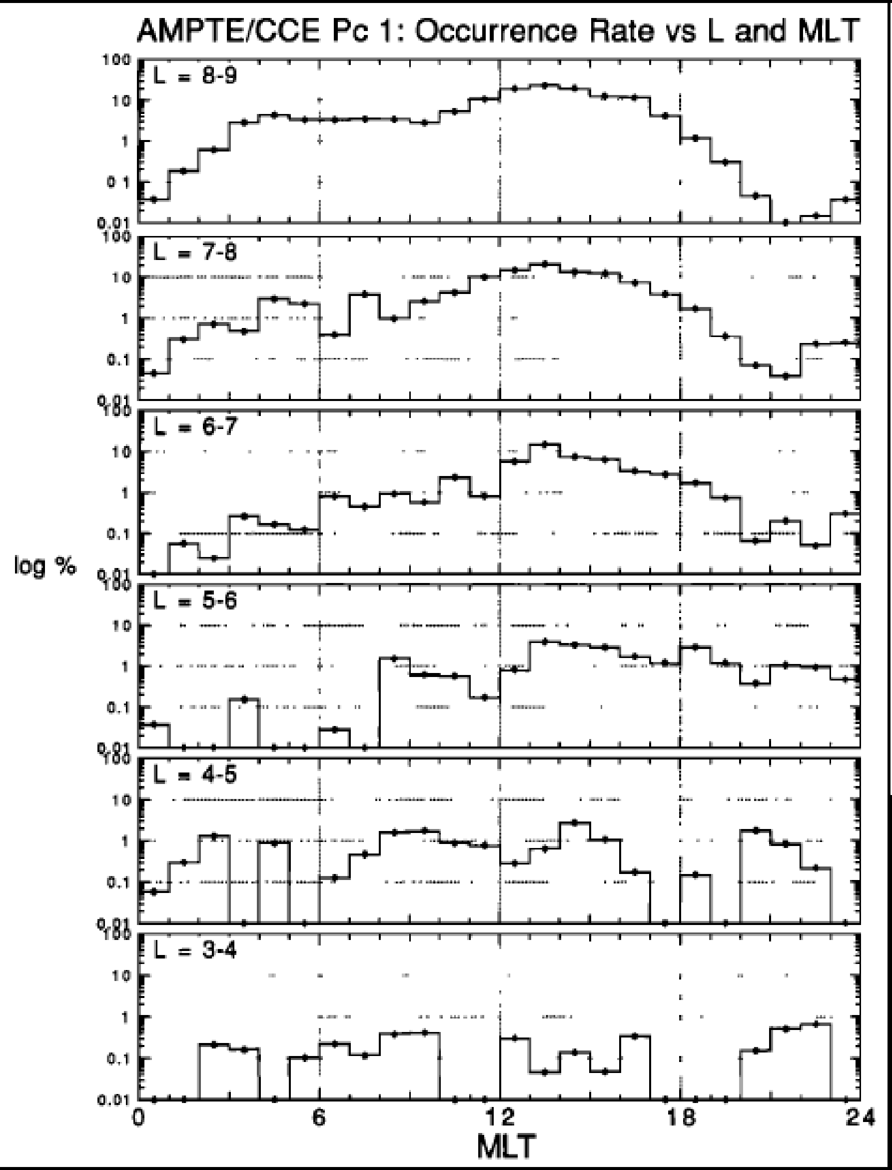


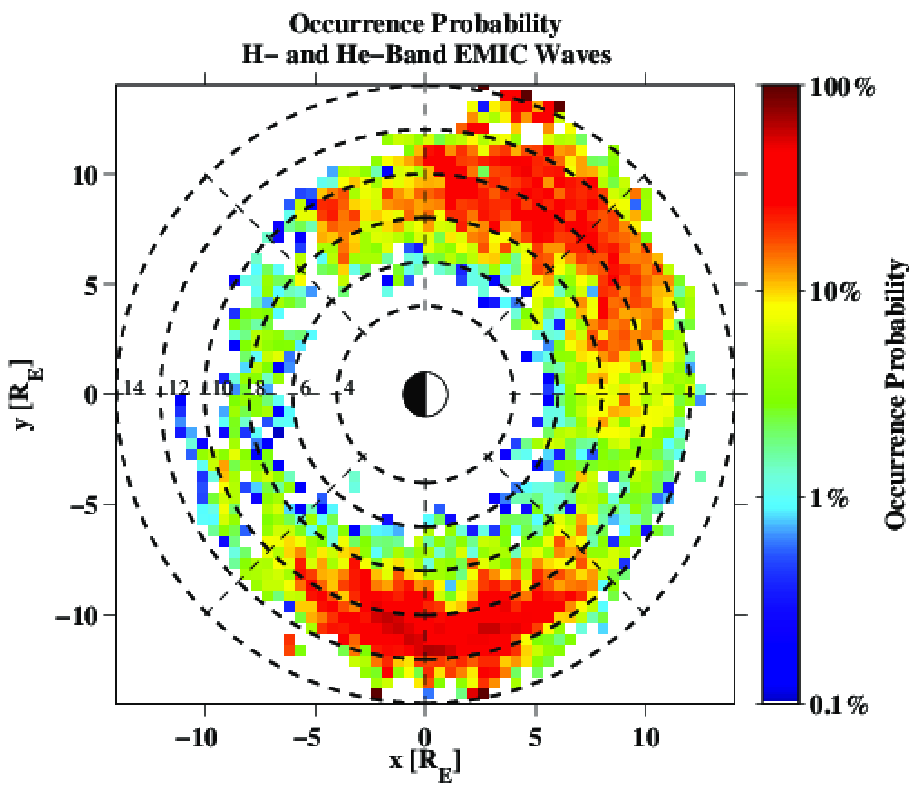
Magnetic field, ion and electron flux, density an pressure (left) , and FFT of Bx (right).

1. Wave occurrence probability
2. Normalized frequency
3. Polarization
4. Power

We will present these quantities obtained from THEMIS in comparison with Anderson et al. [1992].

1. Occurrence probability

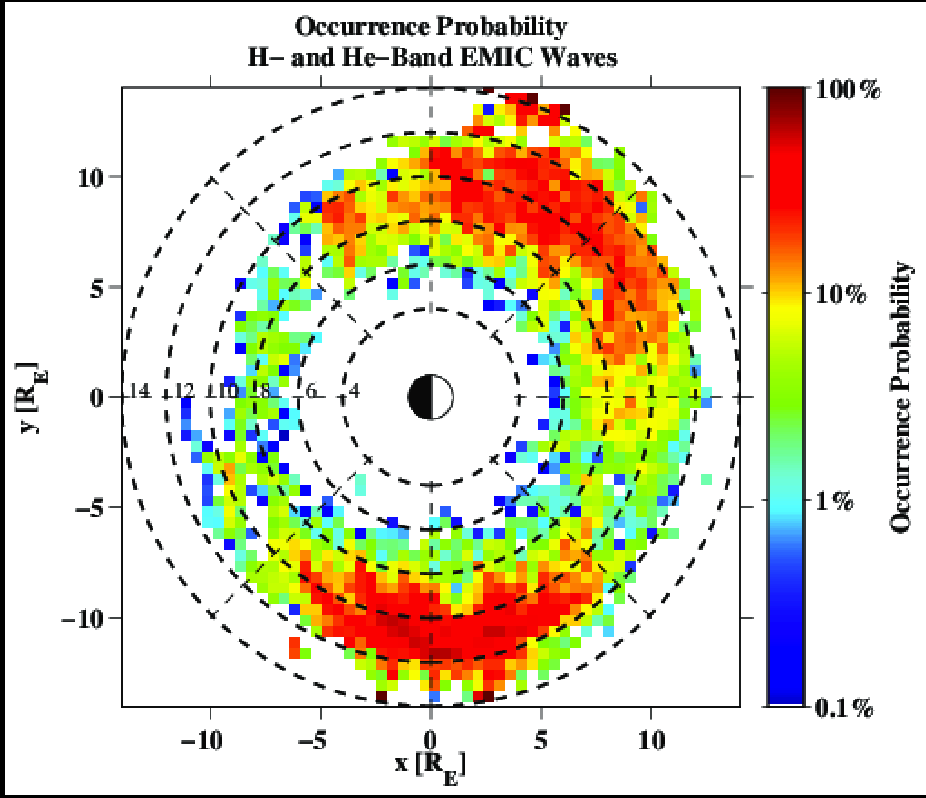


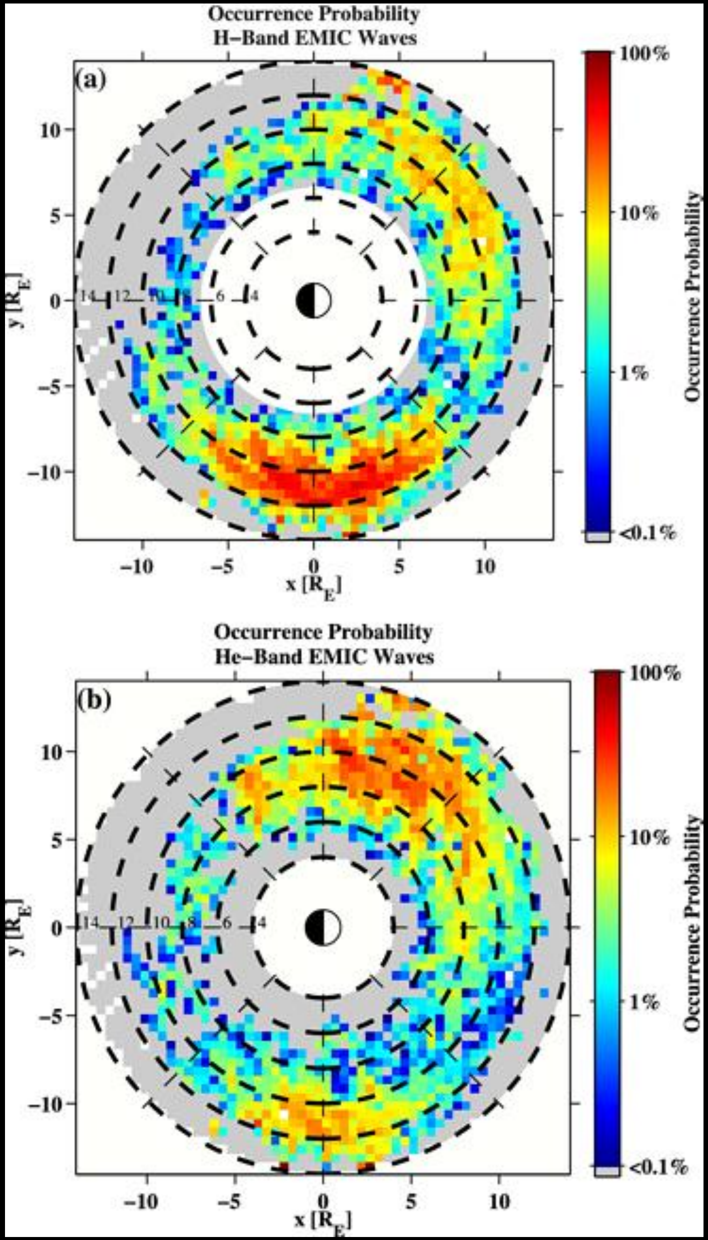


Up: distribution from THEMIS observations [Min et al. 2010]

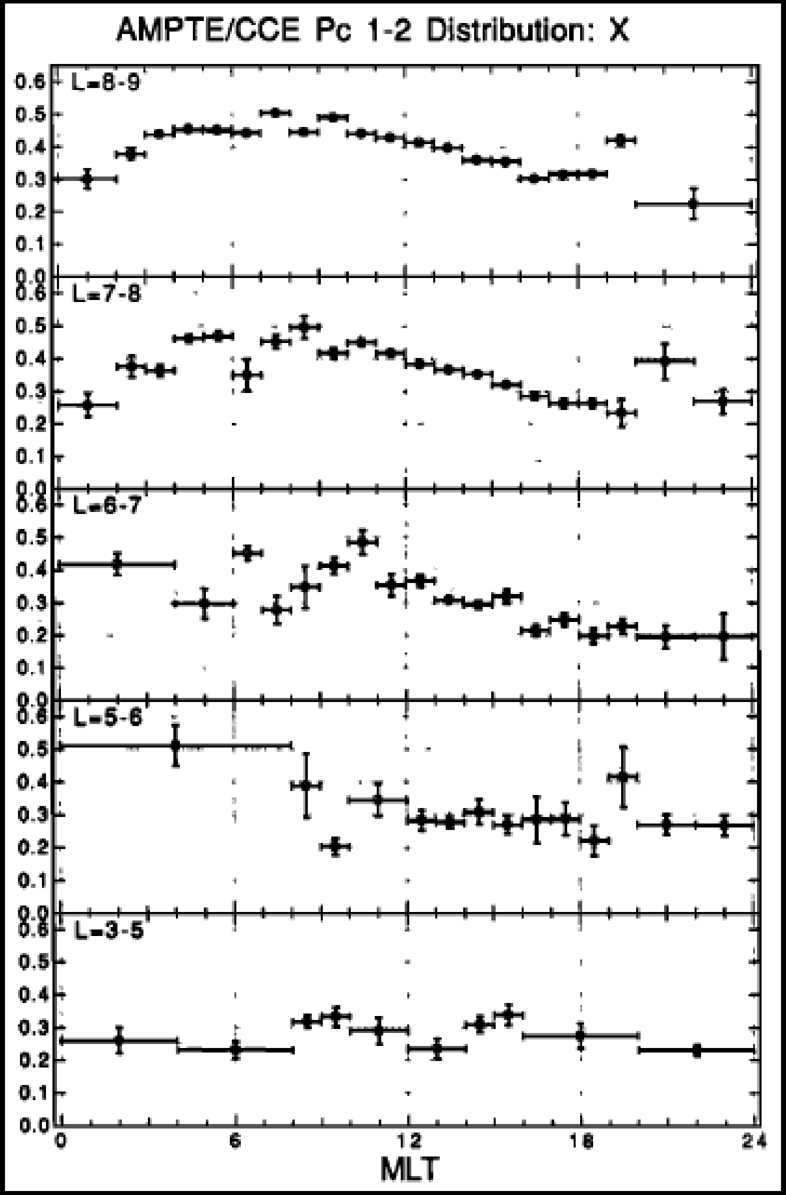
Left: AMPTE/CCE: normalized occurrence distribution of Pc 1-2 waves with peak to peak amplitudes > 0.8 nT versus MLT for six L ranges. Note that vertical scale is logarithmic. [Anderson et al. 1992]

- We found two peaks in the wave occurrence probability.
- Dusk: He-band waves dominates, peak at 8 < R < 12.
- Dawn: H-band waves dominates, peaks at 10 < L < 12.
- Night and 1000 MLT: low activity.

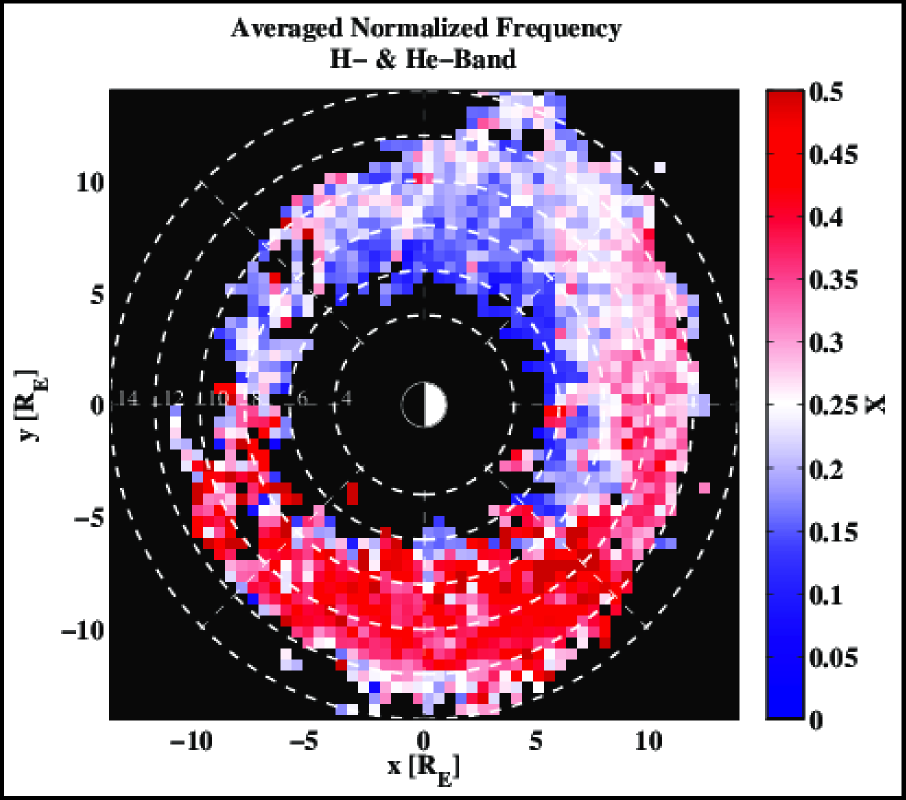




2. Normalized frequency



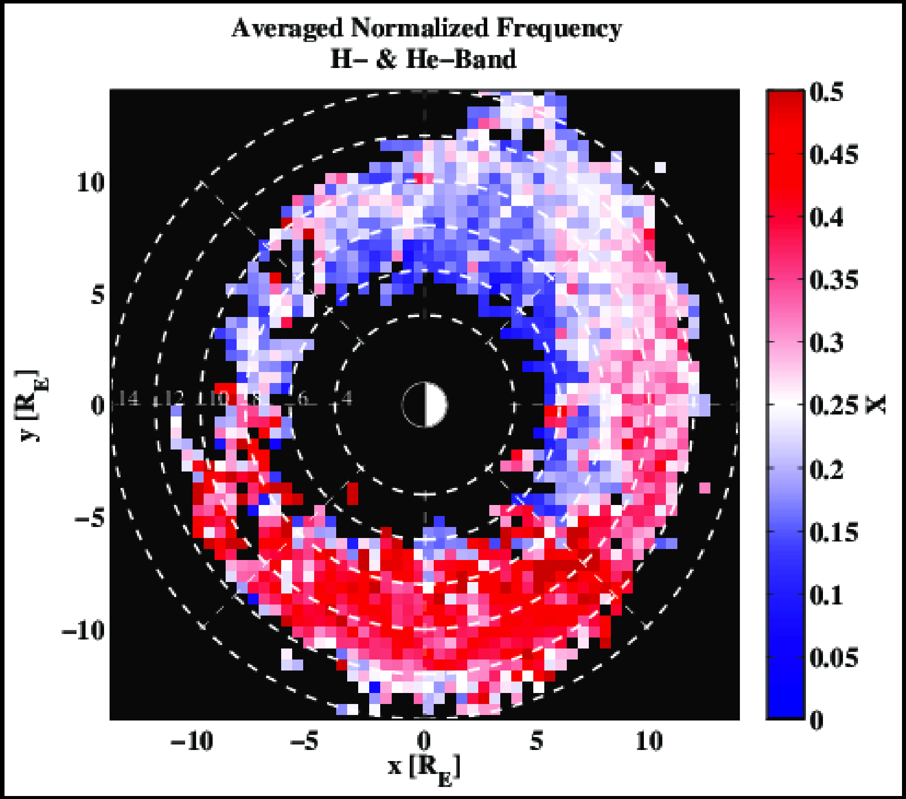
Anderson et al. 1992

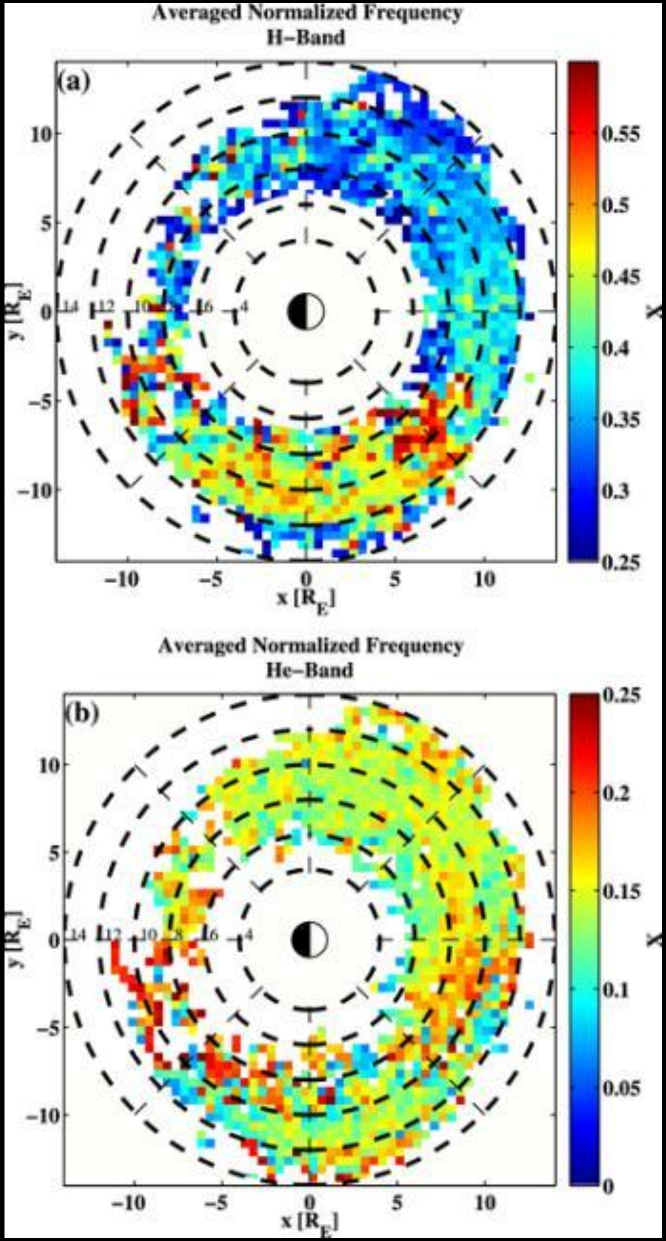


Normalized wave frequency, X = $f\,/\,f_{pc}$

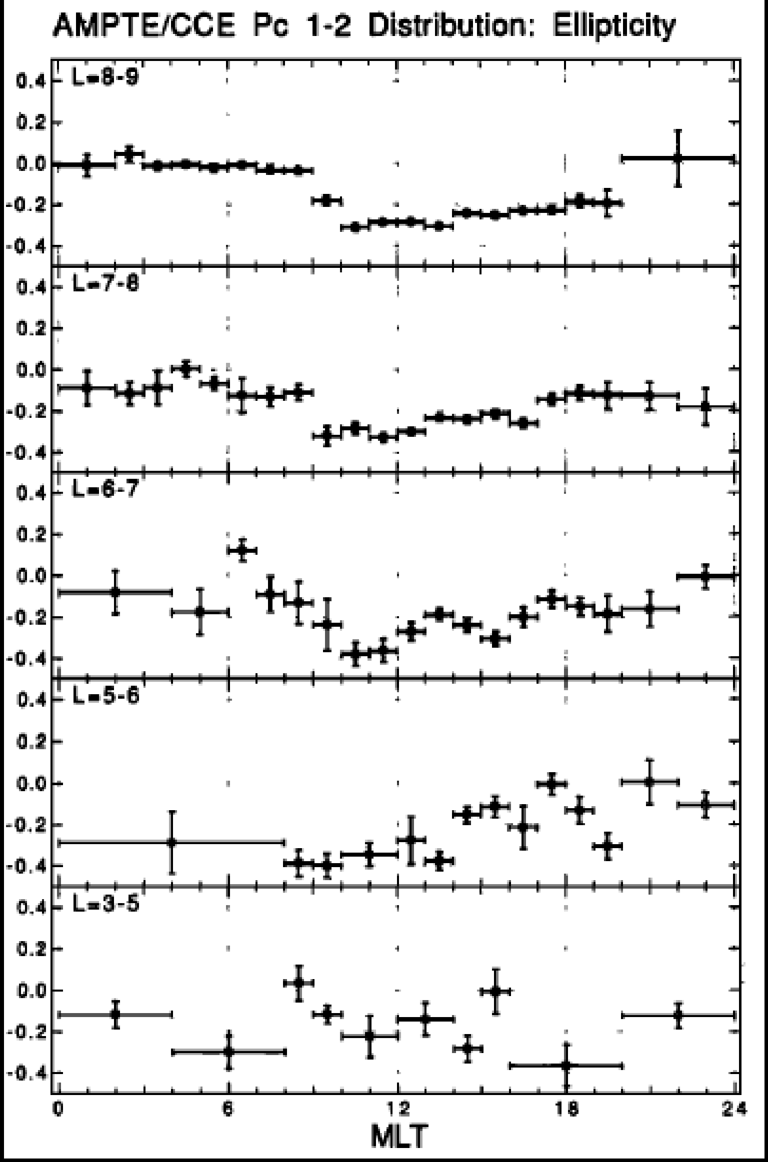
Min et al. 2010

- At dusk, He-band dominates.
- At dawn, H-band dominates.
- At noon, the wave frequency increases with radial distance.
- H-band wave frequency < 0.6
- Mean He-band wave frequency ~ 0.15

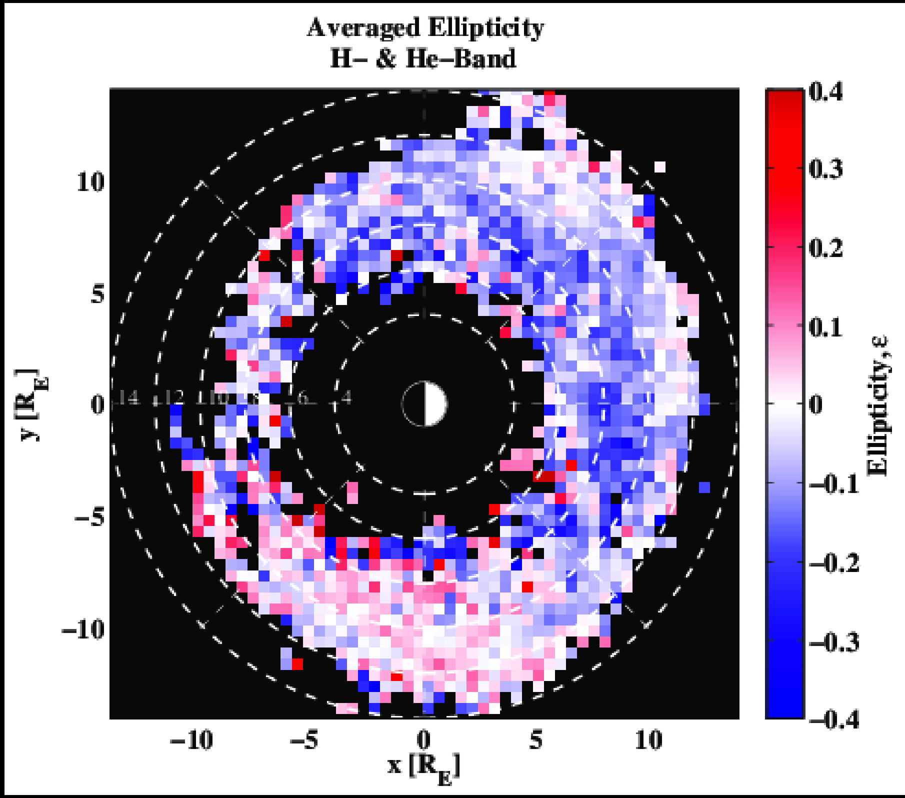




3. Ellipticity



Anderson et al. 1992



Equatorial distribution of average wave ellipticity, ε

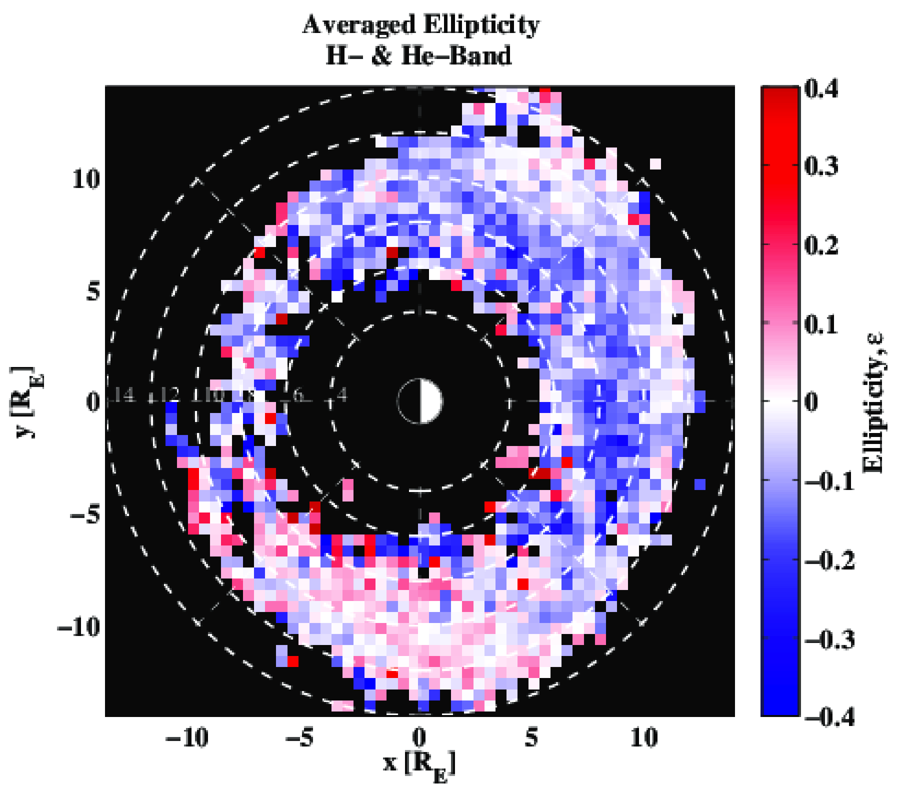
ε < 0 left hand polarized, blue

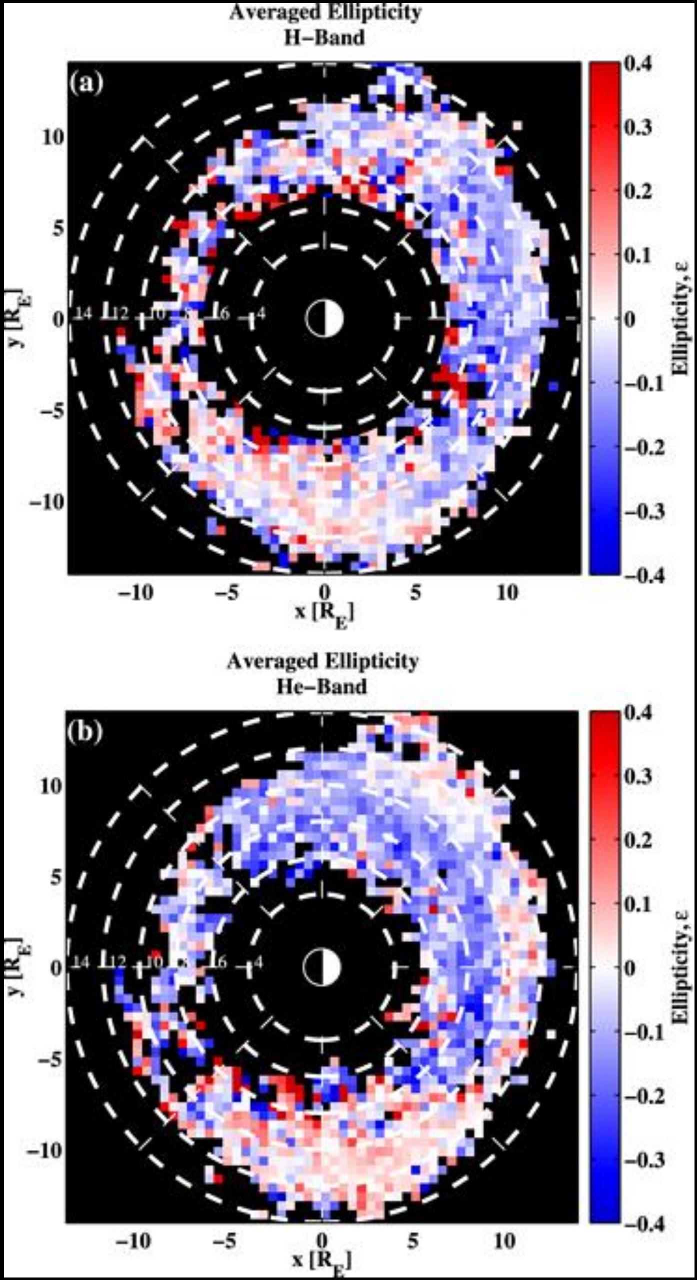
ε = 0 linearly polarized, white

ε > 0 right hand polarized, red

Min et al. 2010

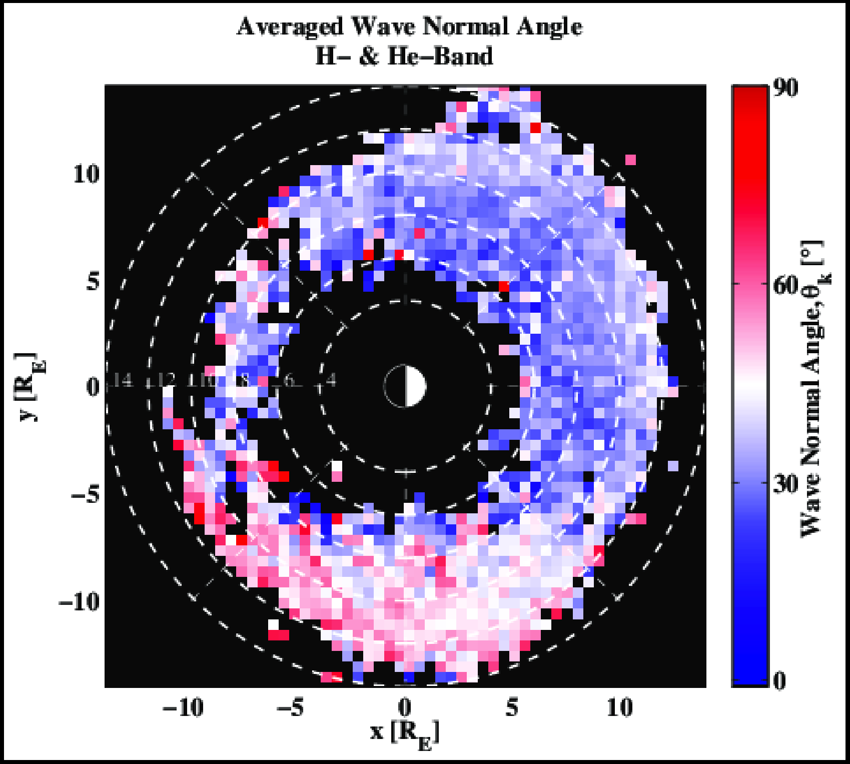
- At noon and dusk, mostly L-polarized, although He-band waves for R>12RE tends to be linearly polarized.
- At dawn, mostly linearly polarized.
- Wave polarization depends not on the frequency band, but largely on MLT.

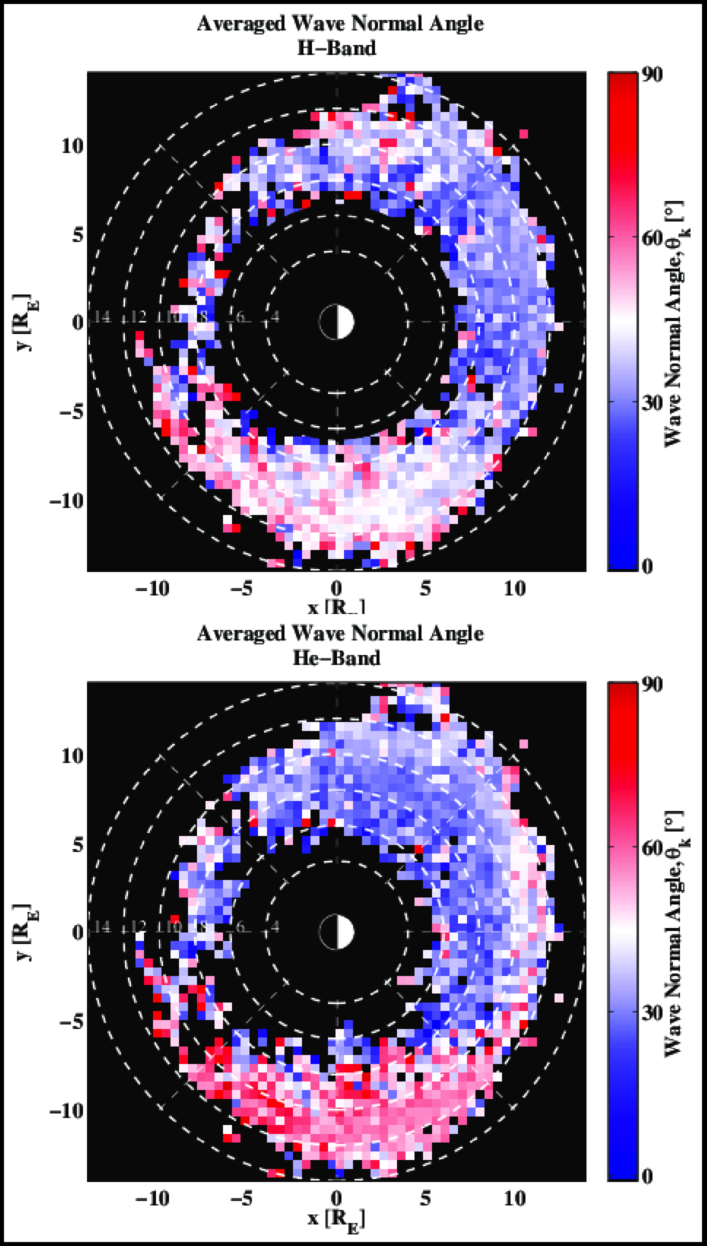




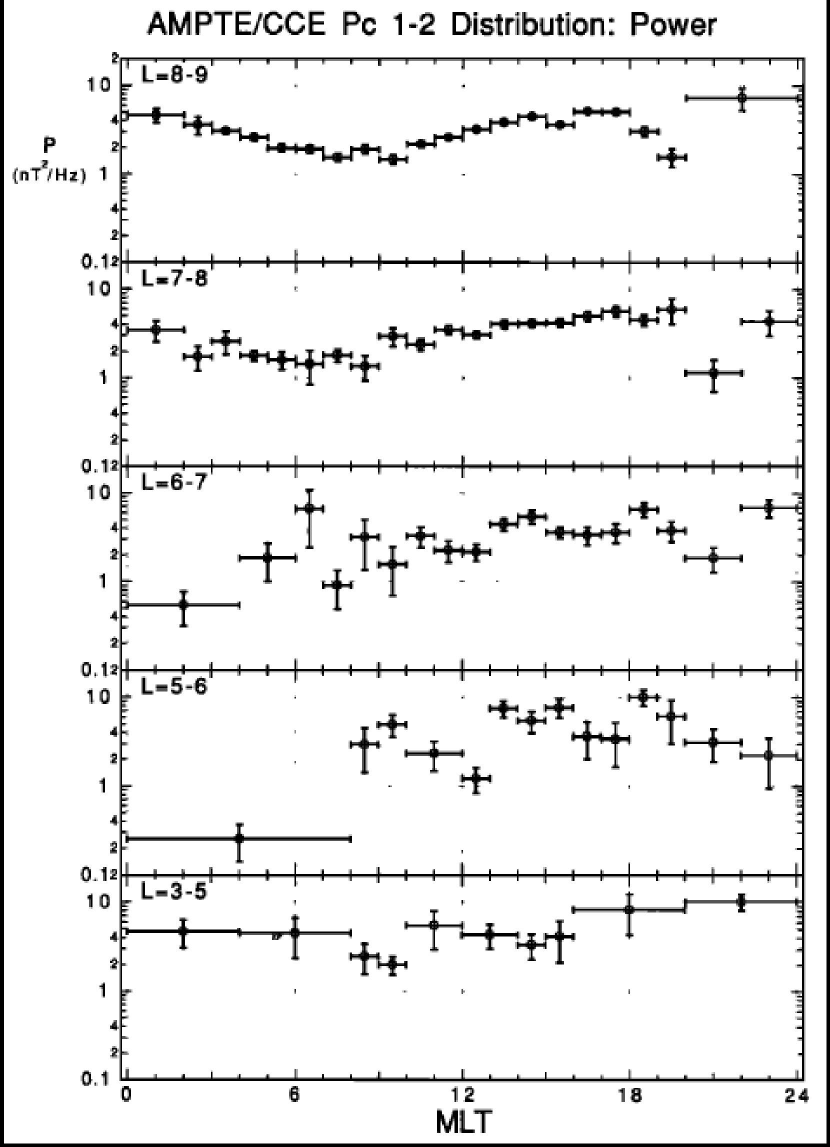
Wave Normal Angle

- Dawn waves are more oblique (θ > 45˚) than noon and dusk waves (θ < 30˚).
- He-band waves at dawn are more oblique (θ ~ 60˚) than H-band waves (θ ~ 45˚).

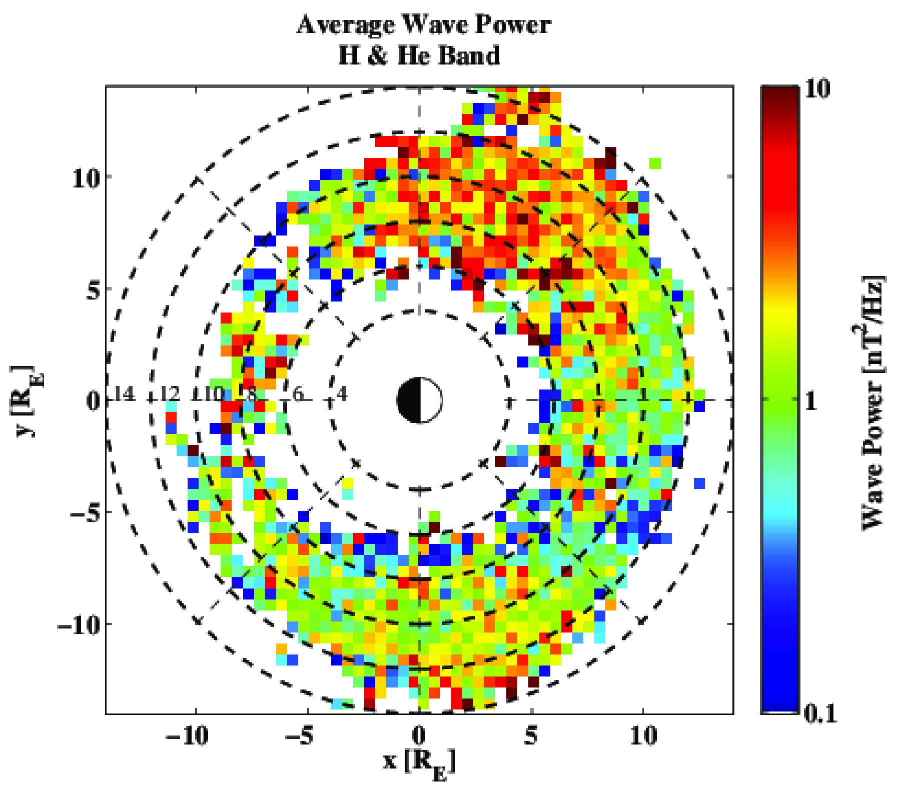




4. Spectral Power

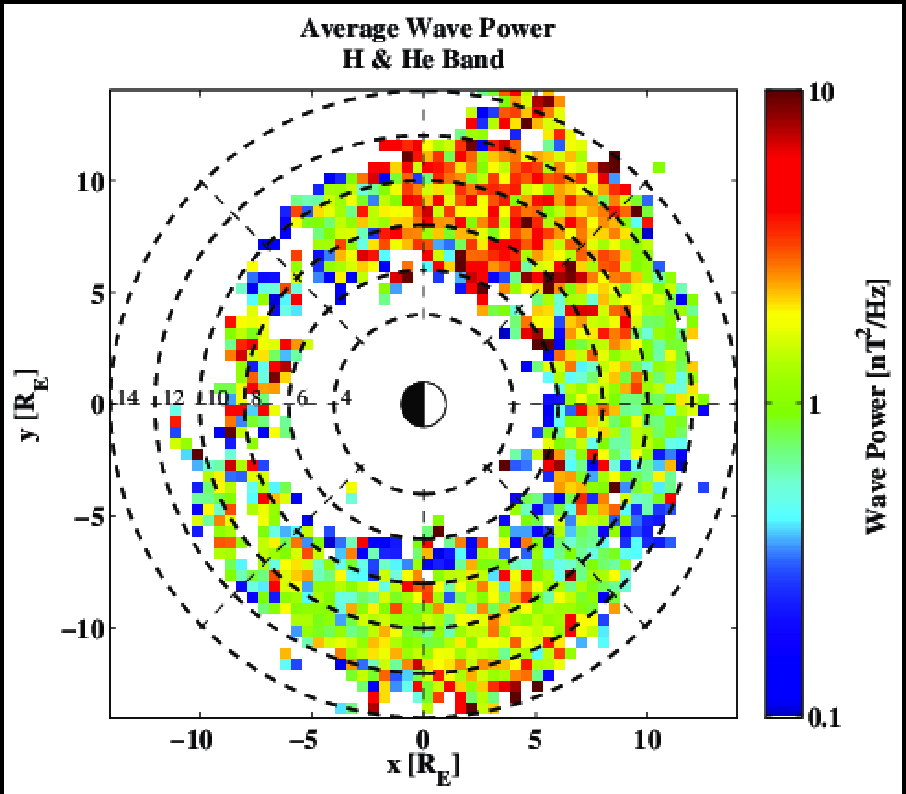


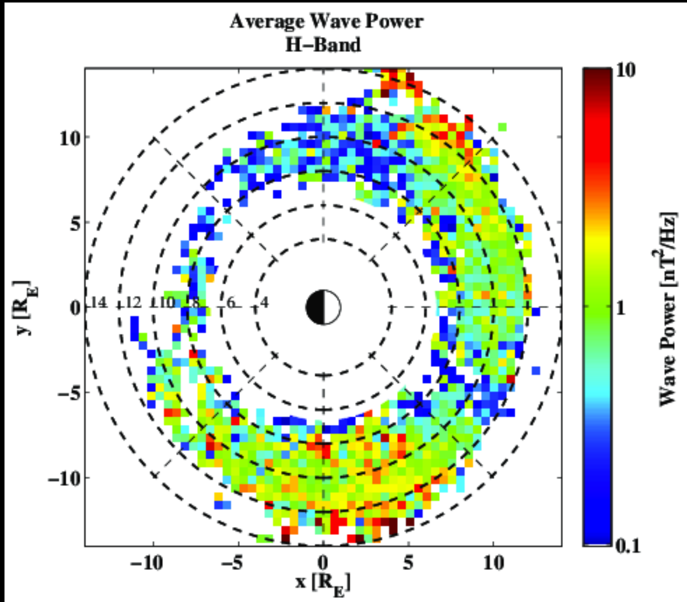
Anderson et al. 1992

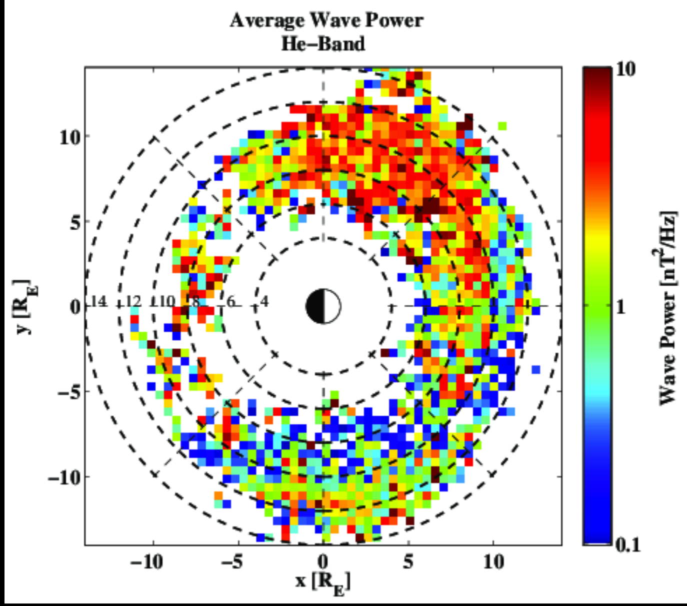


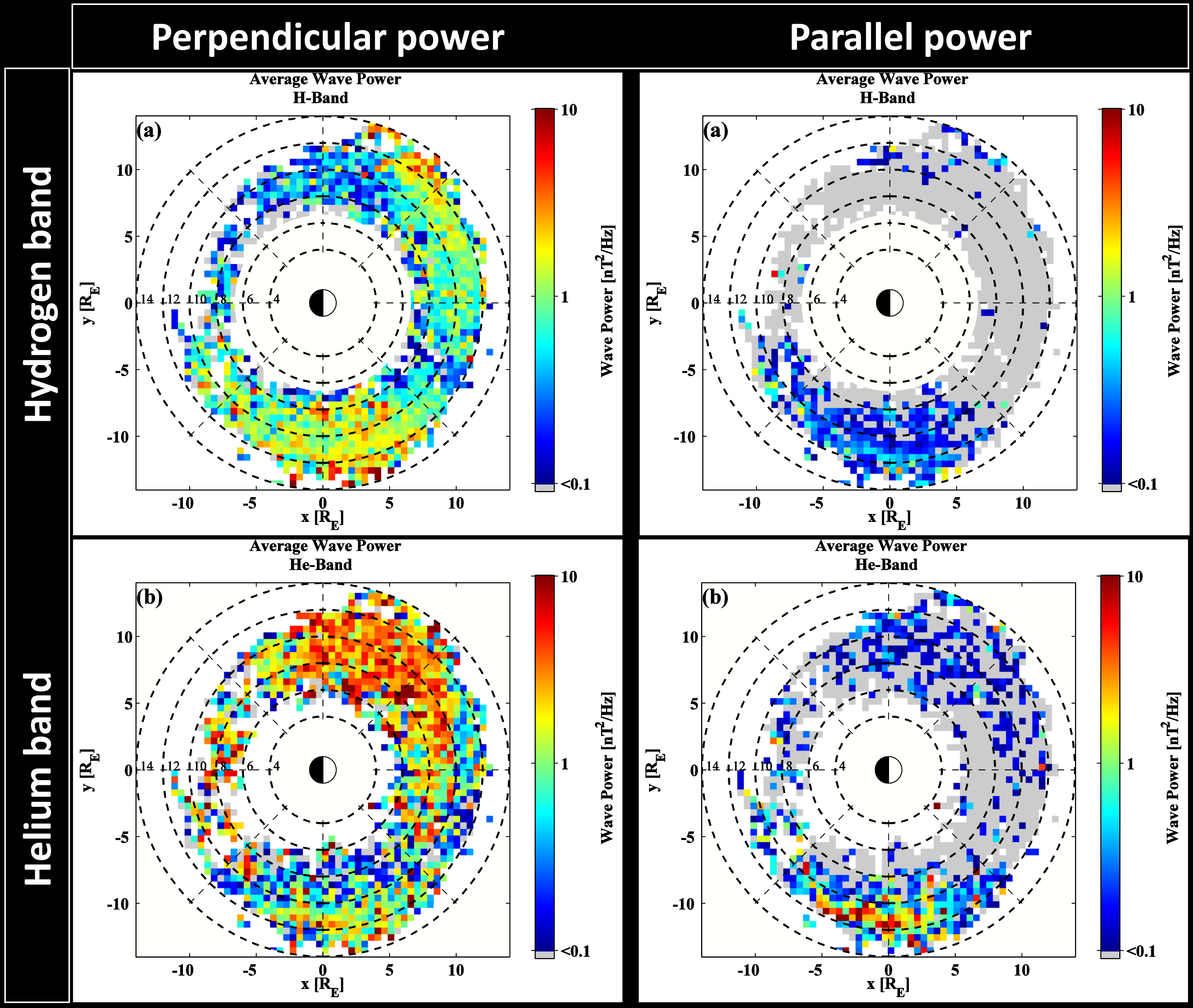
The equatorial distribution of average wave power spectral density.
Min et al. 2010

- Spectral power of EMIC waves is strongest at dusk.
- Another strong peak at dawn with dominated by H-band, but weaker than H-band waves by a factor of ~3.

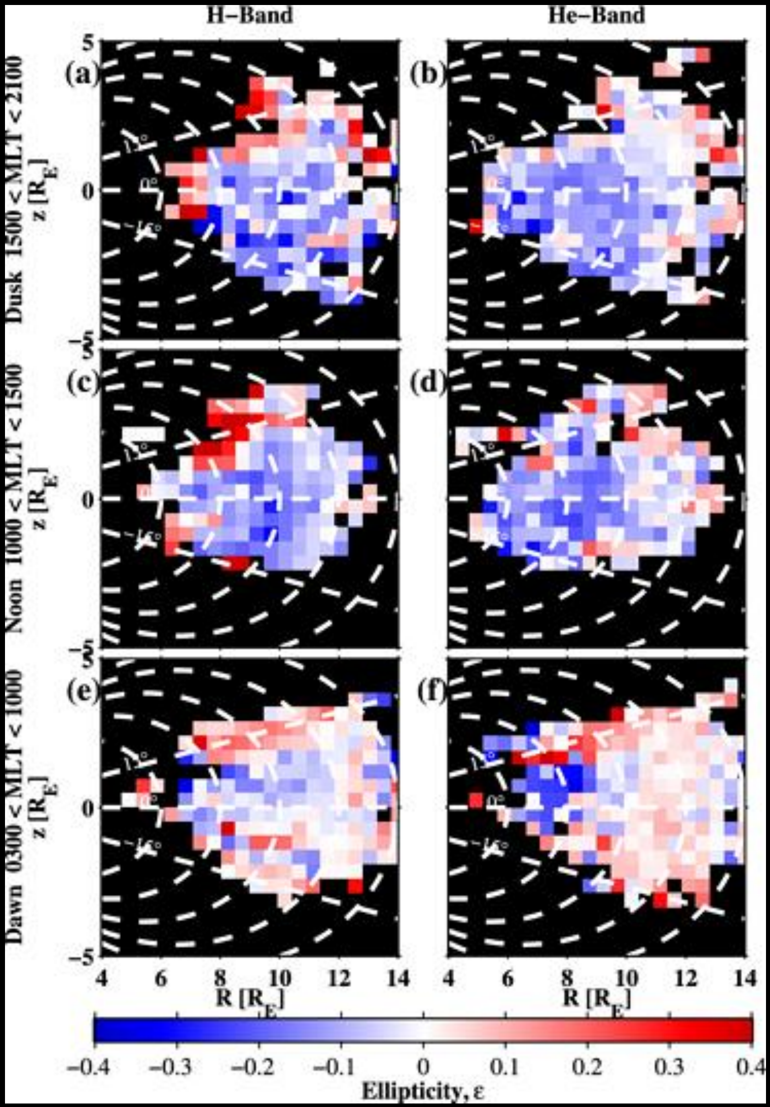


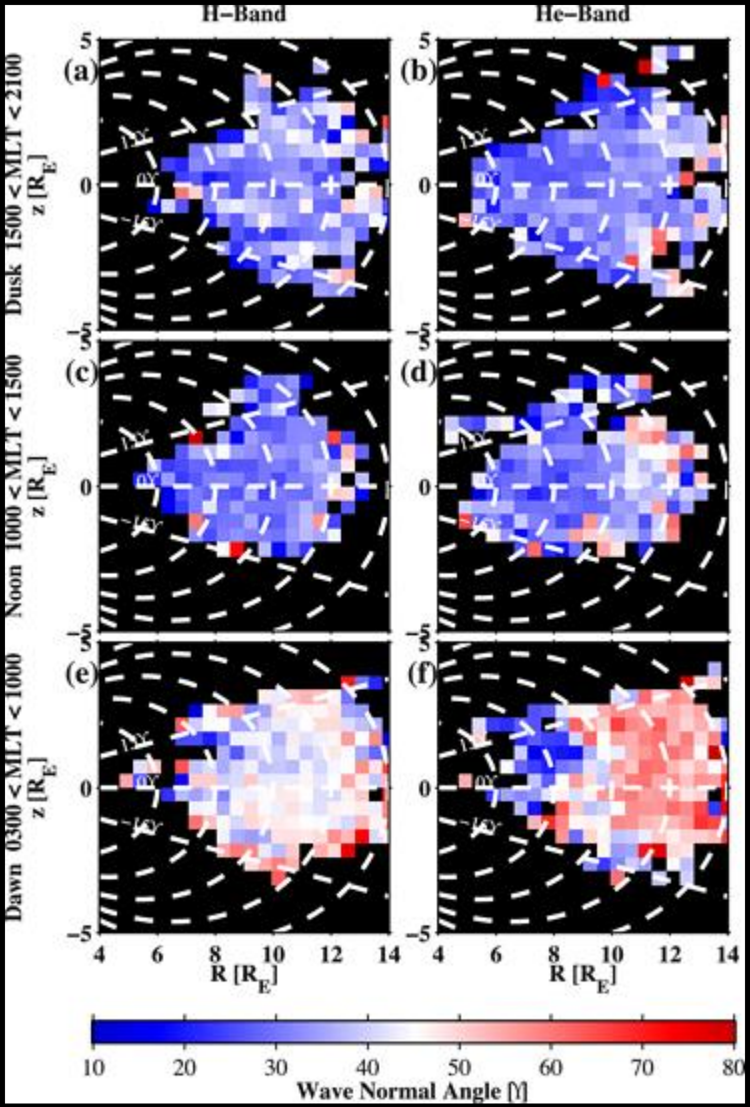




	Perpendicular power	Parallel power
Hydrogen band		
Helium band		

MLAT dependence of polarization



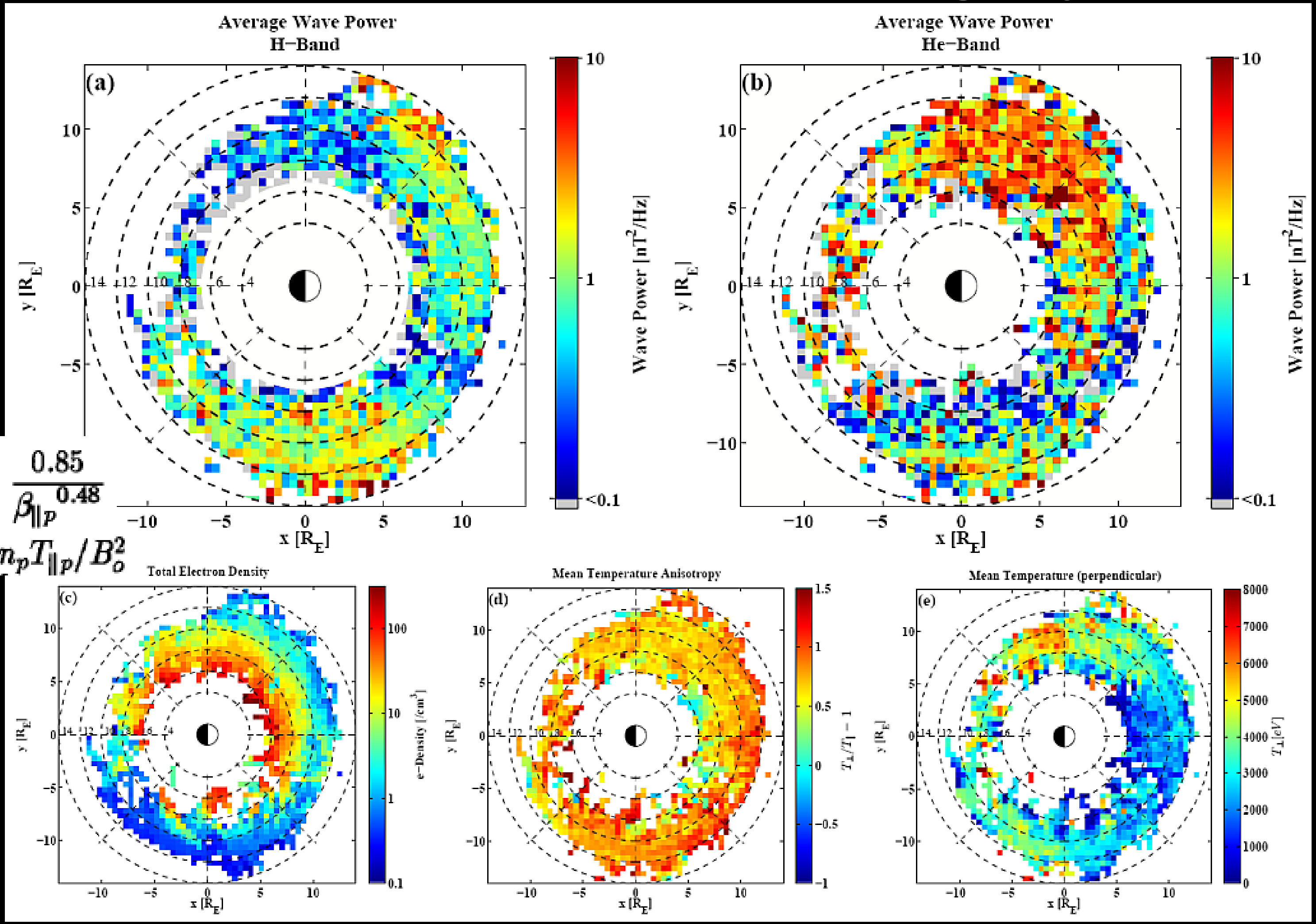


Meridional distribution of ellipticity (left panel) and wave normal angle (right). The left (right) column: H (He) band. From top to bottom, dusk, noon and dawn sectors.

Regions where the EMIC waves have the strongest power and why?

$$\frac{T_{\perp p}}{T_{\parallel p}} - 1 = \frac{0.85}{\beta_{\parallel p}^{\ 0.48}}$$

$$\beta_{\parallel p} \equiv 8\pi n_p T_{\parallel p} / B_o^2$$

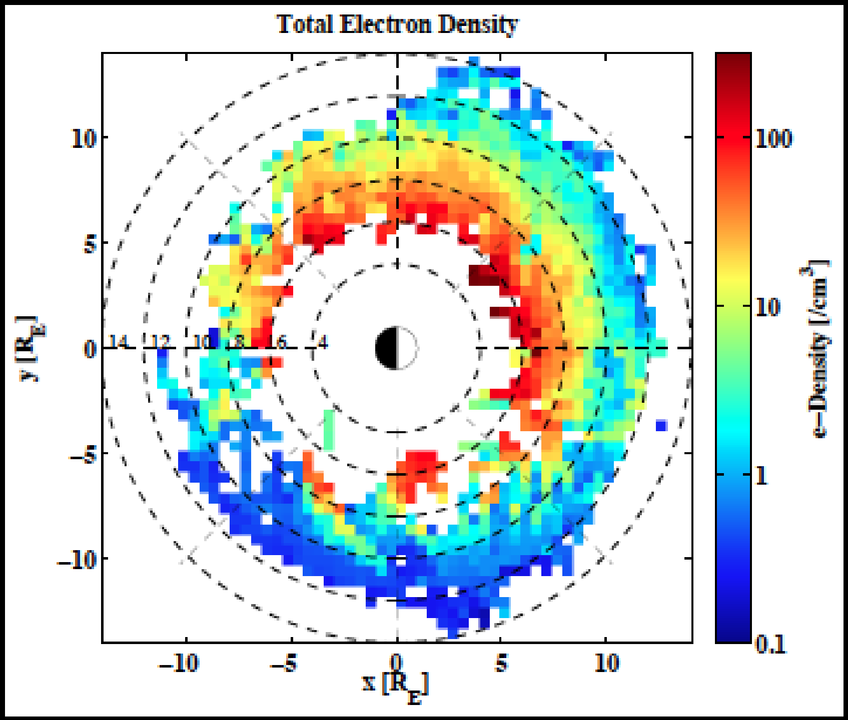


EMIC waves are expected to grow fast in regions with denser background plasma (panel c) and higher anisotropy of ion temperatures (panel d). Ion temperature perpendicular to the magnetic field (panel e) should be hot.

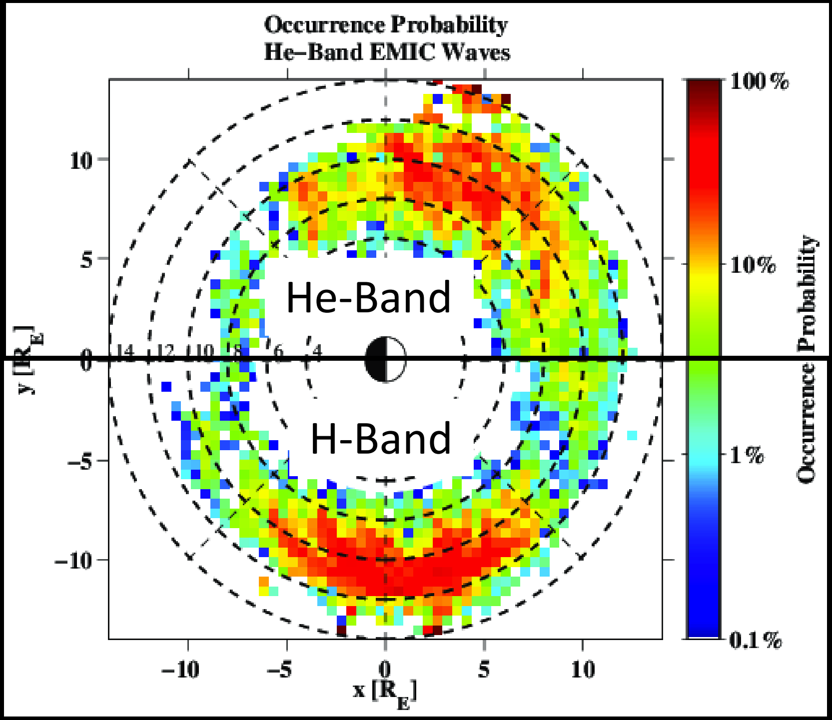
Why H or He dominates in one region?

- Electron Density Distribution (Horne and Thorne 1994)

Electron Density



Occurrence probability



- Electron density is inferred from spacecraft potential.
- Only during EMIC wave activities.
- Available only after June, 2008.
- Dusk has higher density (> 10/cc at 10 RE) by almost a factor of 10 than that dawn.
- He-band waves are well associated with high density while H-band waves with low density.

Comparison with Convective instability model (Horne & Thorne 1994)

Frequency and Power of dusk events

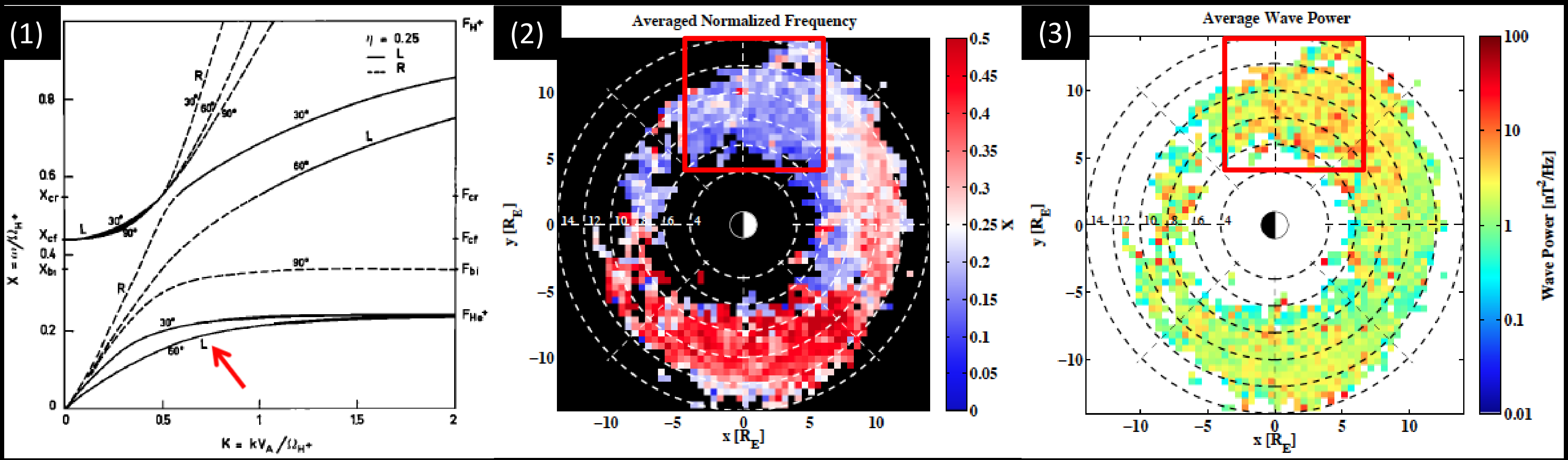
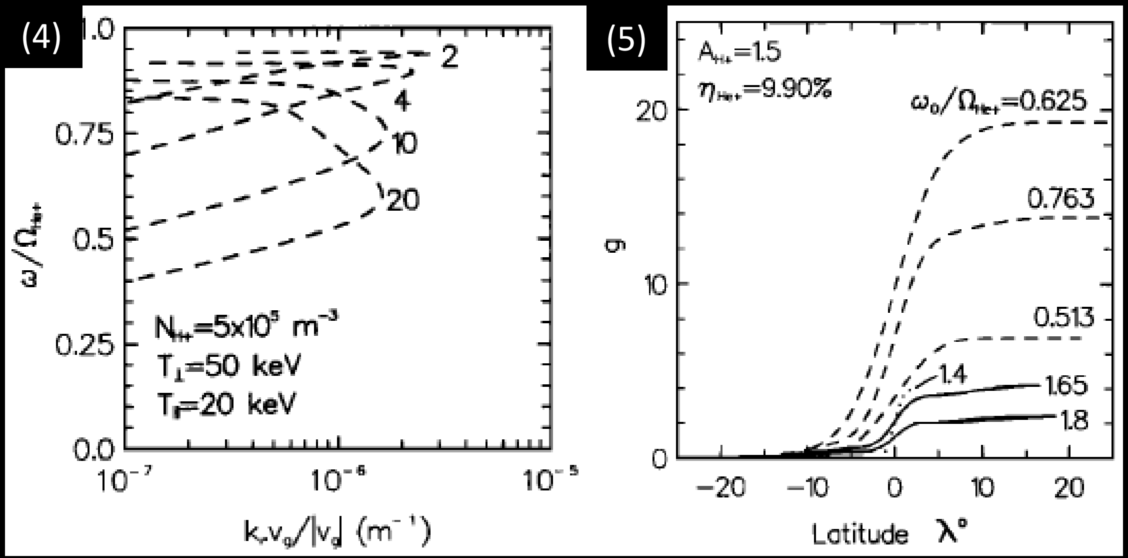


Fig. (1) Dispersion relation [Young et al., 1981], (2) X and (3) wave power.



Dusk events:

Strong growth rate and wave gain of guided mode waves below f_{He+} lead to high wave power.

Fig. (4) spatial growth rate and (5) convective wave gain for high density PM model [from Horne and Thorne, 1994].

Comparison with Convective instability model (Horne & Thorne 1994)

Frequency and Power of dawn events

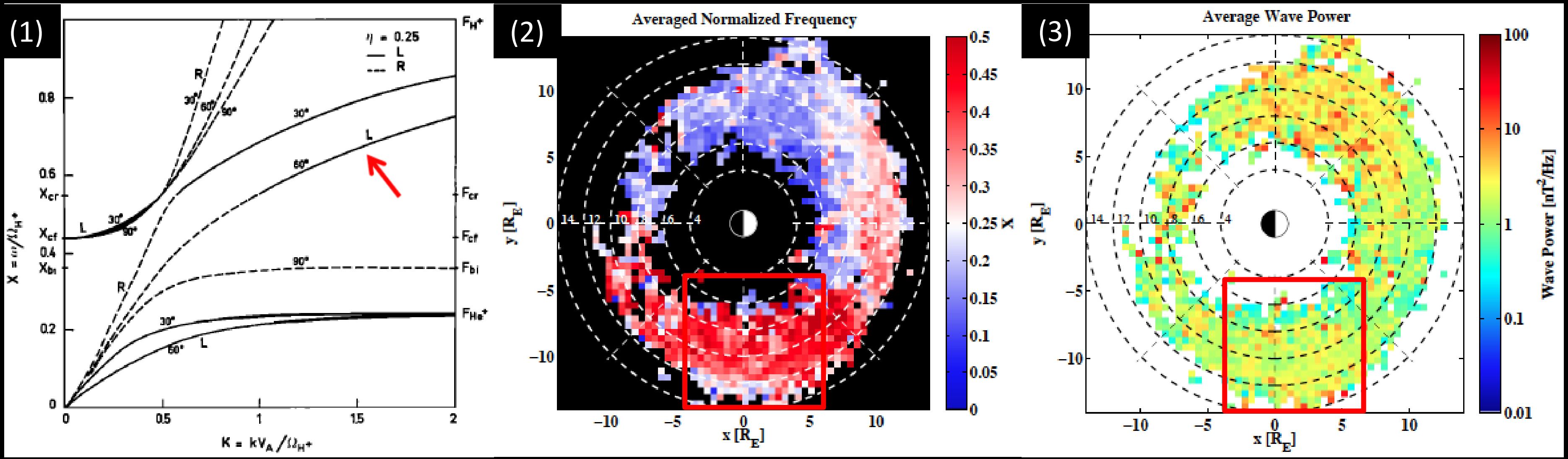
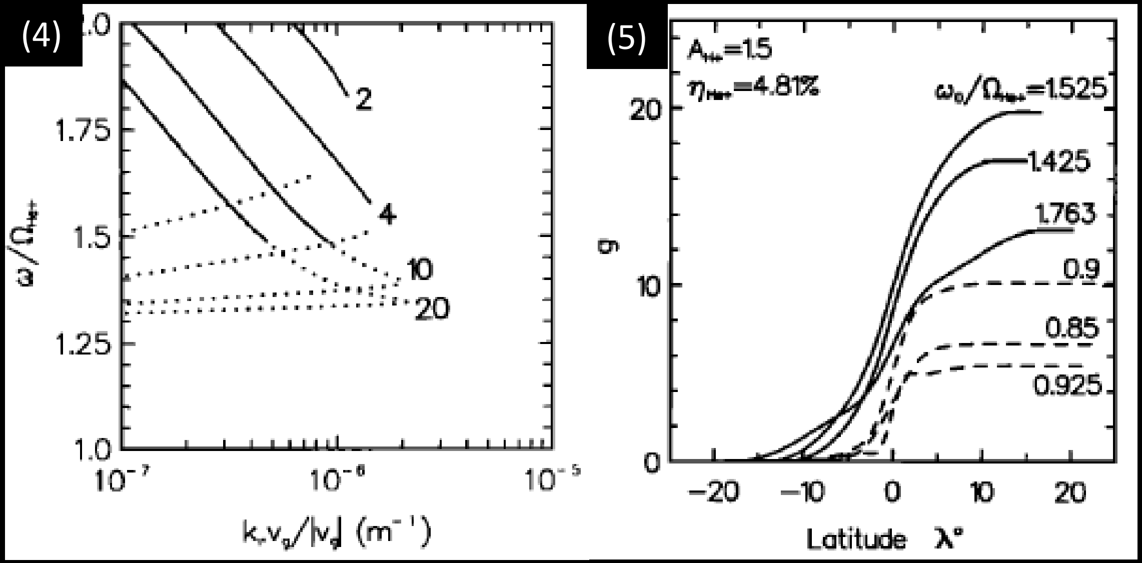


Fig. (1) Dispersion relation [Young et al., 1981], (2) X and (3) wave power.

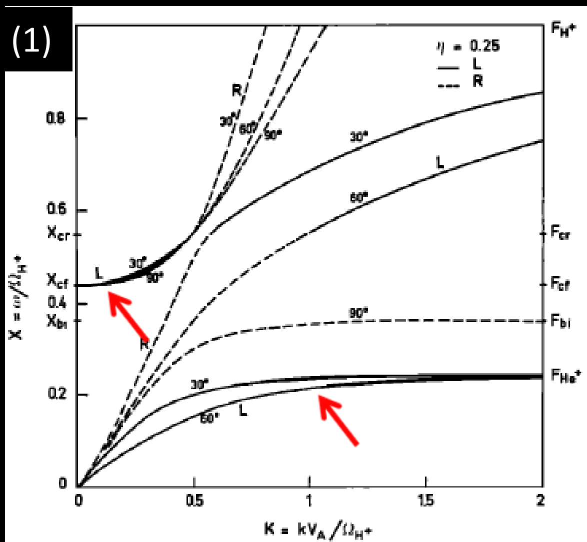


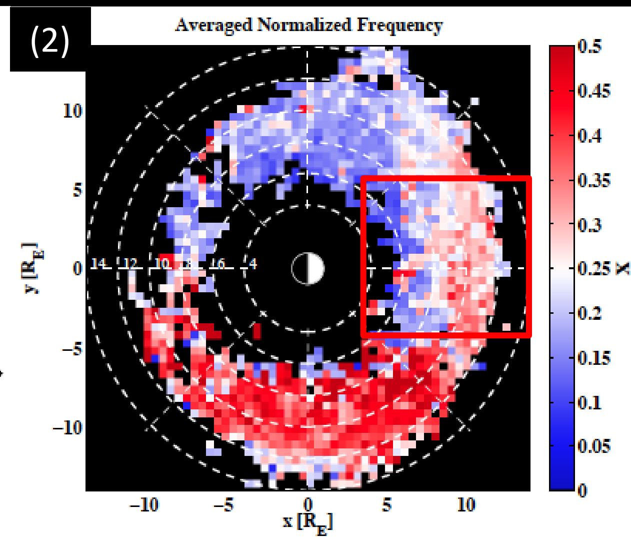
- Strong growth rate and wave gain of guided mode waves above f_{cr} leading to high power but lower than dusk power.

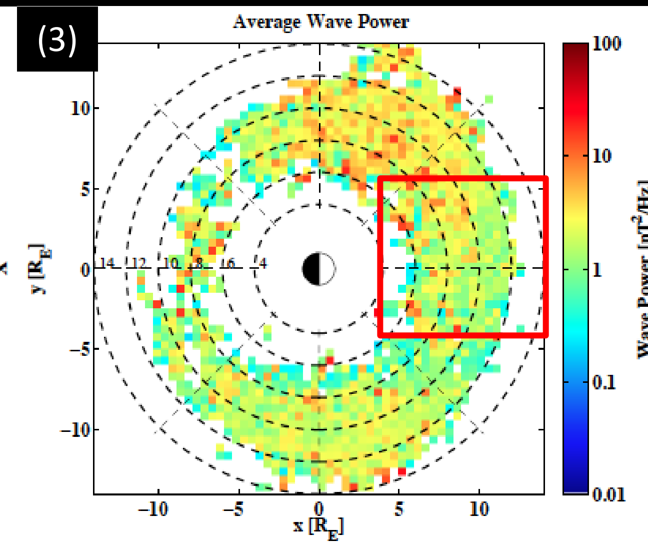
Fig. (4) spatial growth rate and (5) convective wave gain for lower density AM model [from Horne and Thorne, 1994].

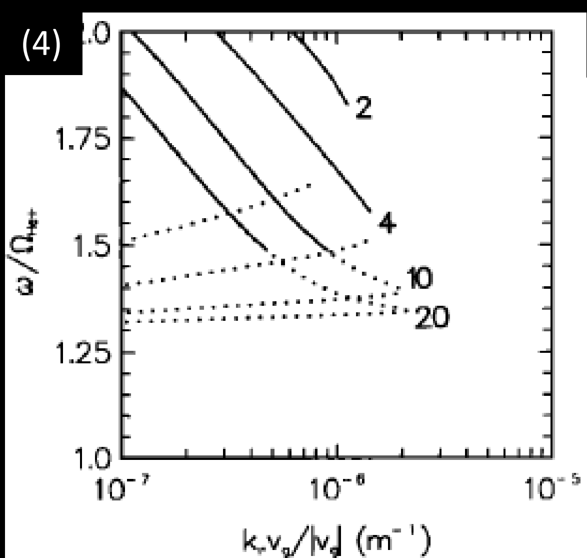
Comparison with Convective instability model (Horne & Thorne 1994)

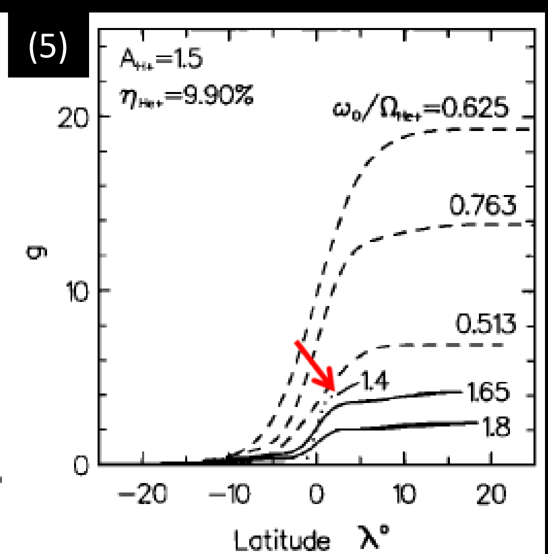
Frequency and Power of Noon waves











- Strong wave growth and small path-integrated wave gain lead to relatively low power.
- Wave frequency changed from L-mode below f_{He+} to unguided mode above f_{co}, which may lead to power reduction.

Summary

We used THEMIS observations to explore distribution over wider L range and investigated H/He bands separately.

1. L-dependence
   Two major peaks in the occurrence probability: (1) at dusk and 8–12 RE where the He band dominates and (2) at dawn and 10–12 RE where the H band dominates. Both are comparable to each other. cf. Anderson et al. [1992]

2. MLT-dependence (band dependency ~ plasma density)
   Dusk: He band, parallel propagating, left-hand polarized waves,
   Dawn: H band, obliquely propagating, linearly polarized waves.
   Night, 1000 MLT: low activity.

3. MLAT-dependence
   Our result for dawn shows a change of polarization with latitude for H band whereas Anderson et al. [1992b] found the linear polarization dominates at all magnetic latitudes.

Thank You!