A statistical study of EMIC waves observed by Cluster

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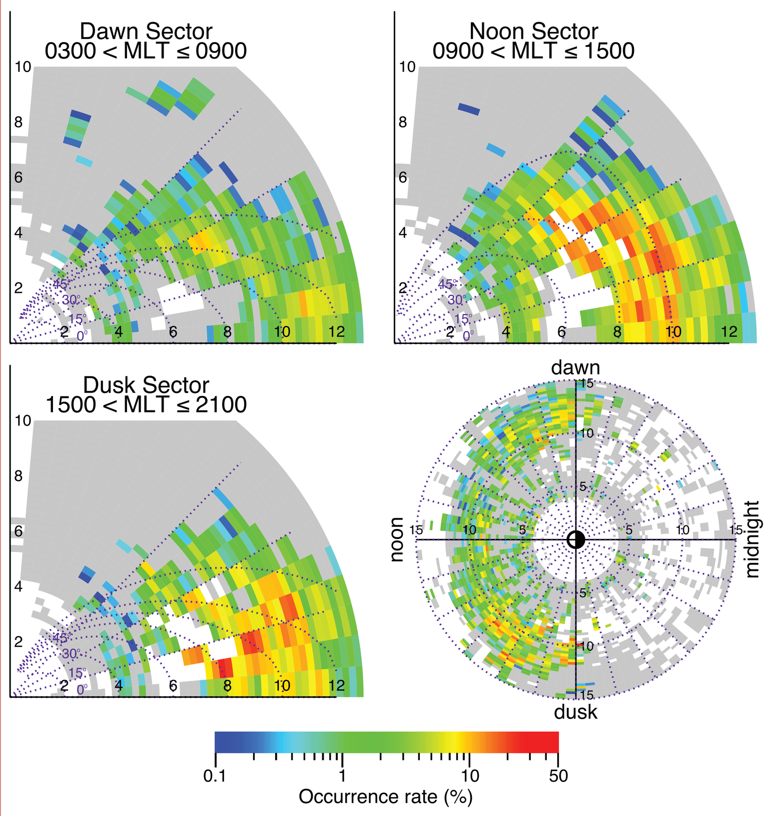
Abstract:

Electromagnetic ion cyclotron (EMIC) waves are an important mechanism for particle energization and losses inside the magnetosphere. In order to better understand the effects of these waves on particle dynamics, detailed information about the ellipticity, normal angle, energy propagation angle distributions, local plasma parameters, and wave generation proxies are required. Previous statistical studies have used *in situ* observations to investigate the distribution of these parameters in the MLT-L frame within a limited MLAT range. This poster will present selected results from a pair of recently submitted papers [*Allen et al.*, 2014a; 2014b], which performed a statistical analysis of EMIC wave properties using ten years (2001-2010) of data from Cluster, totaling 17,987 minutes of wave activity. Due to the polar orbit of Cluster, we are able to investigate EMIC waves almost at all MLATs and MLTs. This allows us to further investigate the MLAT dependence of various wave properties inside different MLT sectors and further explore the effects of Shabansky orbits on EMIC wave generation and propagation. From this analysis, three source regions of EMIC waves appear to exist: 1) The well studied overlap between cold plasmaspheric plume populations with hot anisotropic ring current populations in the post-noon to dusk MLT region; 2) Regions all along the dayside magnetosphere at high L-shells related to the dayside magnetospheric compressions; 3) Off-equator regions associated with the Shabansky orbits in the dayside magnetosphere.

Motivation:

1. Investigate the distribution of various wave parameters in the magnetic latitude.
2. Explore the effects of Shabansky orbits [*Shabansky*, 1971; *McCollough et al.*, 2012] on off-equator EMIC wave generation.
3. Expand on previous statistical studies that had limited MLAT coverage [e.g. *Loto'aniu et al.*, 2005; *Min et al.*, 2012; *Keika et al.*, 2013].

EMIC wave occurrence rate:



Number of minutes of wave activity over s/c dwell time in log scale.

Peaks are seen in three regions: 1) in the dusk sector at low MLAT and mid-L-shell; 2) all along the dayside magnetosphere at high L-shells near the magnetopause; and 3) off-equator at mid L-shells and mid to high MLATs

The Tsyganenko T01s magnetic model is used for both the L-shell calculations in the MLT panel, as well as the reference field lines (from nominal solar wind conditions) in the MLAT panels.

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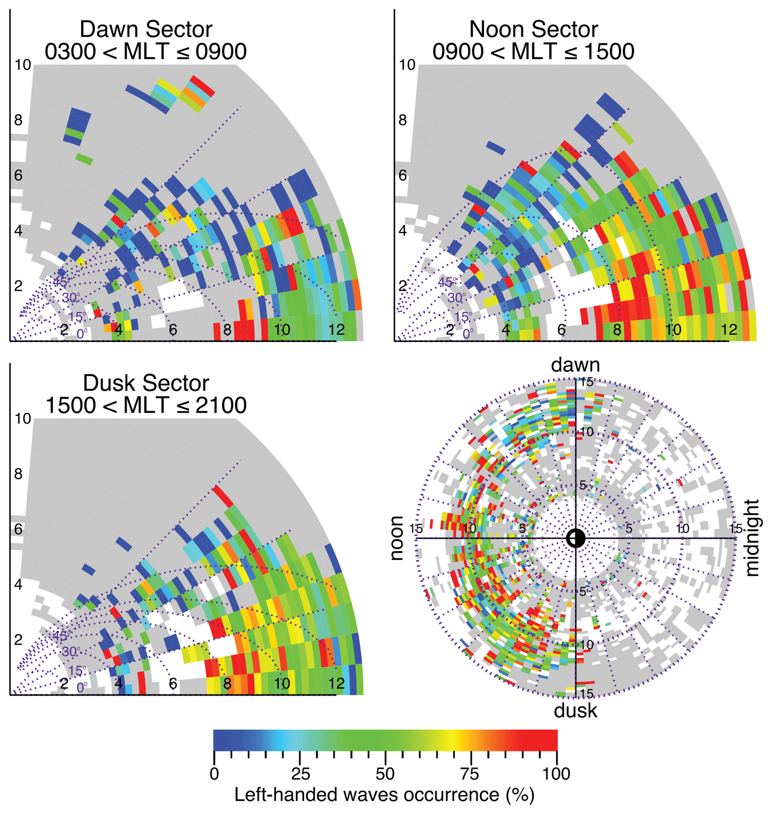
Left-handed wave occurrence rate:



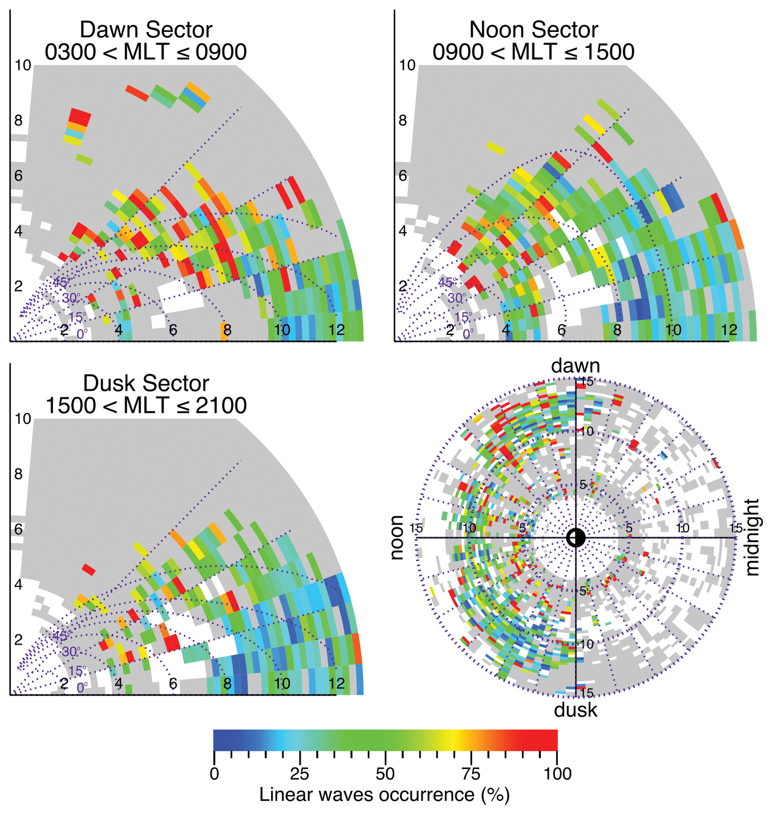
Number of left-handed wave (e<-0.1) bins over the total number of wave bins.

Peaks are observed primarily at lower MLATs and correspond to regions of higher wave occurrence.

Slight increase at off-equator peak in wave occurrence.

Slightly lower occurrence rate in dawn sector.

Linear wave occurrence rate:

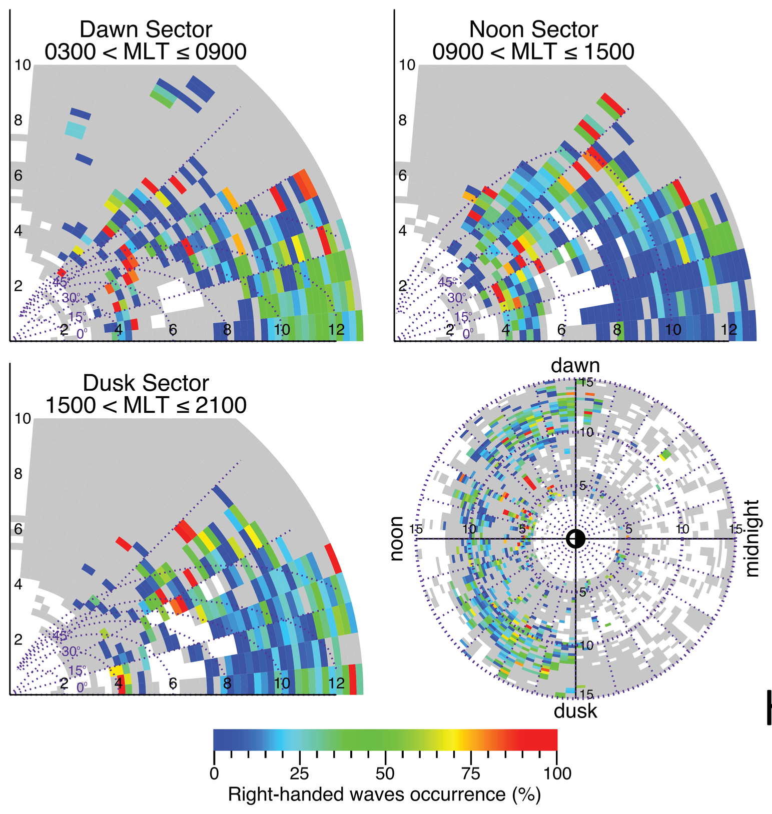


Number of linear wave bins (|e|<0.1) over the total number of wave bins.

Higher occurrence rates are observed at higher MLATs.

This enhancement could be an effect of EMIC waves that have passed through the cross-over frequency.

Right-handed wave occurrence rate:

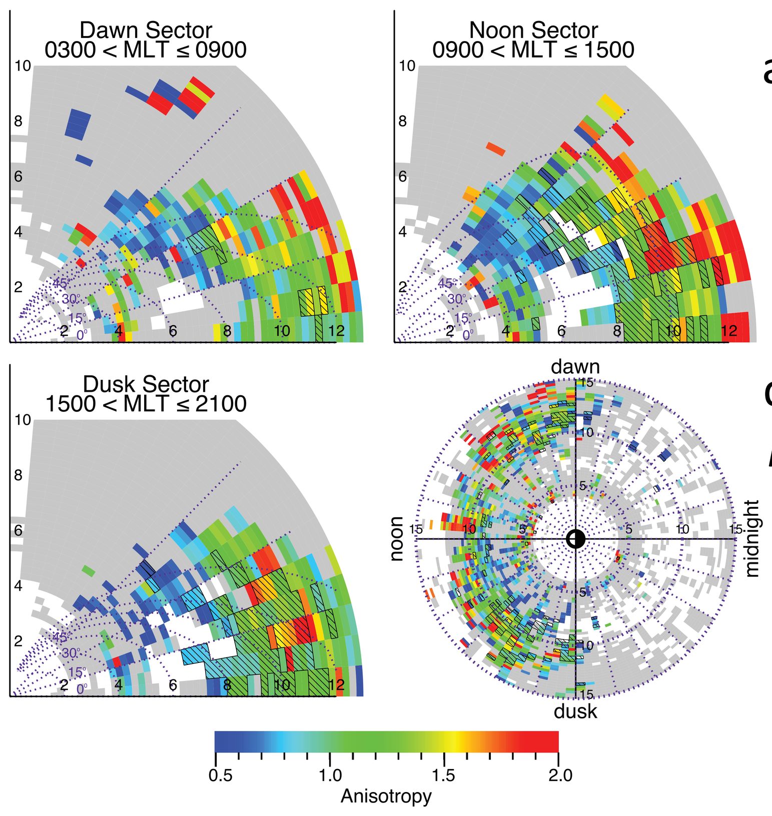


Number of right-handed wave (e>0.1) bins over the total number of wave bins.

Higher occurrence rates of right-handed waves are observed in the dawn sector.

This could be due to a low He^+ abundance causing waves to be generated with high normal angle and linear to right hand ellipticity.

Hot proton (10-40 keV) anisotropy:



Hot proton (10-40 keV) anisotropy ($T_\perp/T_\parallel - 1$) observed during wave events.

For L < 10, all observations are consistent with anisotropy increasing from dusk to dawn, as reported by *Min et al.* [2012] and *Denton et al.* [2005].

For L > 10, the anisotropy is roughly steady and enhanced, all along the dayside magnetosphere.

Intro to Linear Theory:

Linear Theory states that for an EMIC wave to occur, the wave growth parameter, Σ_h, must be larger than the instability threshold, S_h [*Gary et al.*, 1994]. Where,

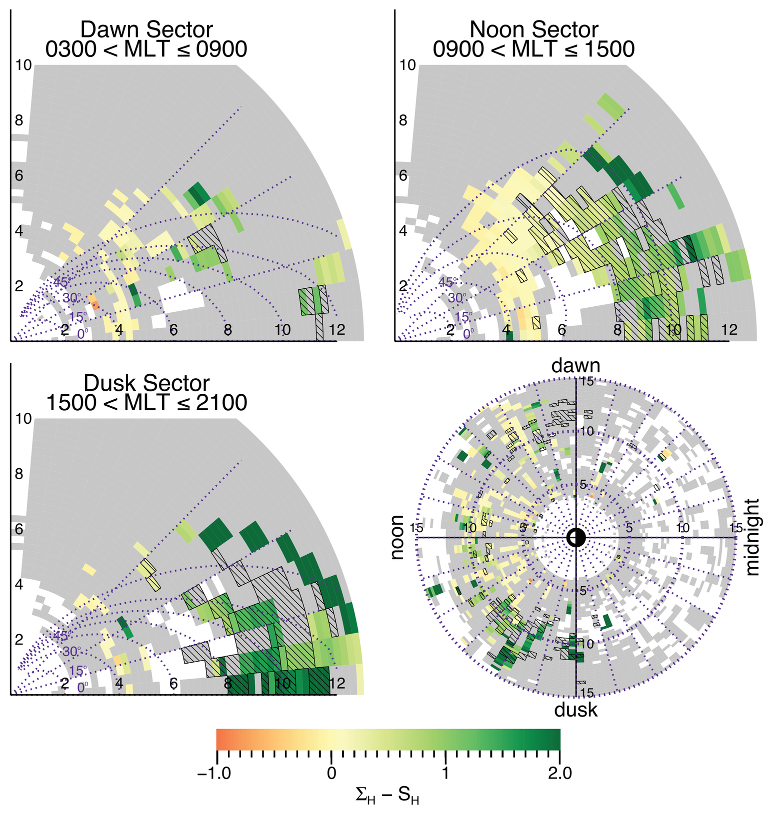
$$\Sigma_h = \left(\frac{T_\perp}{T_\parallel} - 1\right)\beta_{\parallel h}^{\alpha_h} \qquad S_h = \sigma_0 + \sigma_1 \ln\left(\frac{n_{hp}}{n_e}\right) + \sigma_2\left[\ln\left(\frac{n_{hp}}{n_e}\right)\right]^2$$

$$\alpha_h = a_0 - a_1 \ln\left(\frac{n_{hp}}{n_e}\right) - a_2\left[\ln\left(\frac{n_{hp}}{n_e}\right)\right]^2$$

with σ_0 = 0.429, σ_1 = 0.124, σ_2 = 0.0118 and α_0 = 0.409, α_1 = 0.0145, and α_2 = 0.00028 [*Blum et al.*, 2009].

Thus, by looking at $\Sigma_h - S_h$ during the events, we are able to see whether the observed waves are in a predicted source region.

Linear theory:



The linear wave growth parameter exceeds the instability threshold in regions of peak wave occurrence.

This would imply that the regions of peak wave occurrence are also regions of wave generation.

Discussions &Conclusions:

Occurrence rate	Peaks are seen in three regions: 1) in the dusk sector at low MLAT and mid-L-shell 2) all along the dayside magnetosphere at high L-shells near the magnetopause 3) off-equator at mid L-shells and mid to high MLATs.
Ellipticity occurrences	Left-handed: High occurrence in all dayside sectors for low to mid MLATs.
	Linear: Enhanced occurrence in high MLATs.
	Right-handed: Occurrence peaks in the dawn sector.
Hot proton Anisotropy	For L-shells < 10: Increasing anisotropy moving from dusk to dawn. For L-shells > 10: Steady levels of high anisotropy
Linear theory	Satisfied in the regions of peak wave occurrence. This indicates those regions are likely wave generation regions.

For more analysis of these parameters, as well as others, see the two upcoming JGR publications by *Allen et al.* [2014a; 2014b]

References:

Allen et al. (2014a), JGR, [submitted]
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