Distribution of LB Chorus Wave Normal Angles and the Implications for the Chorus-Hiss Connection

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EMFISIS Observations

Lower Band Chorus Criteria:

0.075 $f_{ce} < f < 0.50\ f_{ce}$

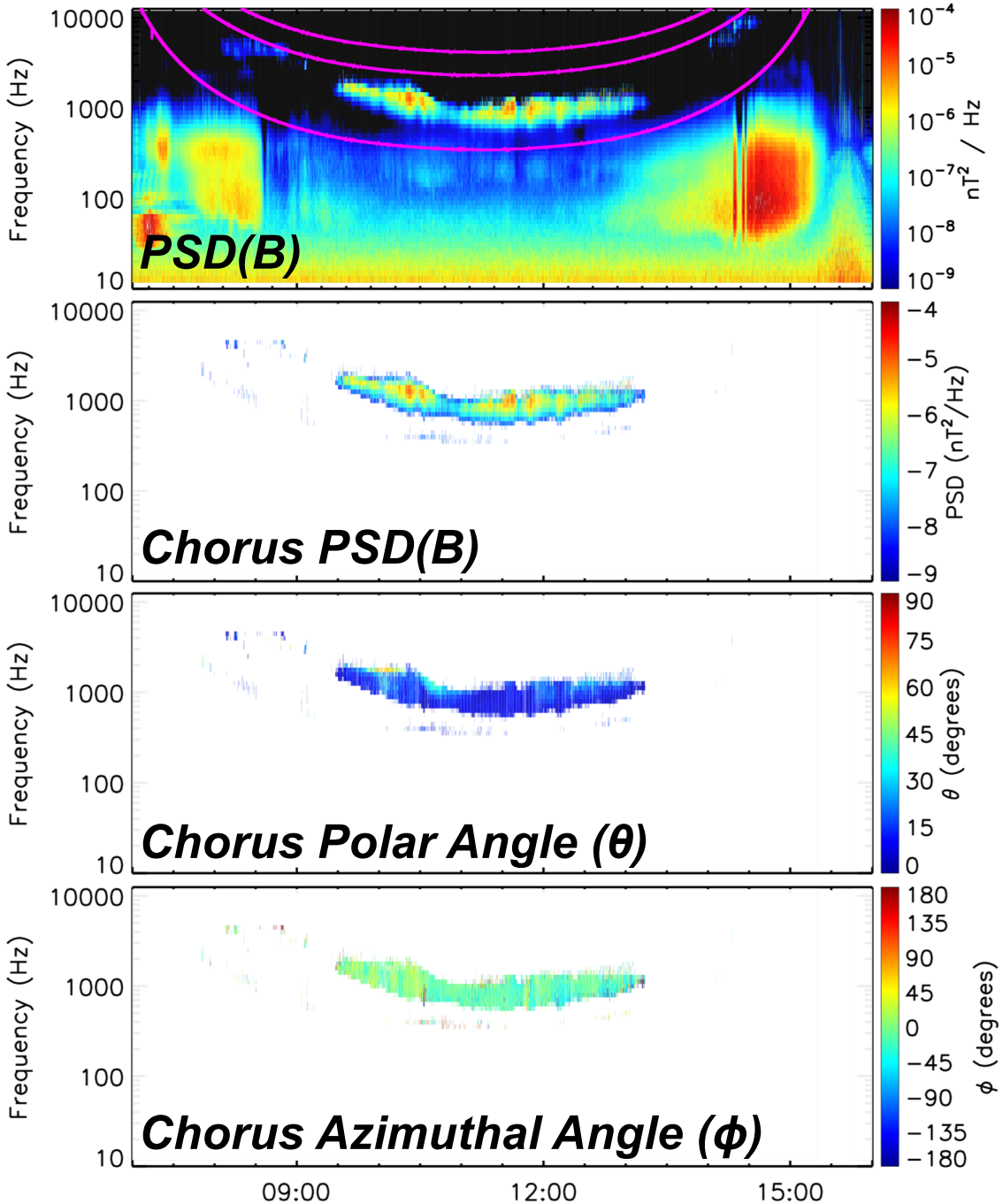
Density less than the minimum of: 10 x $(6.6/L)^4$ or 30 cm^{-3} (whichever is smaller)

PSD(B) > 10 x background

Ellipticity > 0.5

Polarization > 0.5

Planarity > 0.5

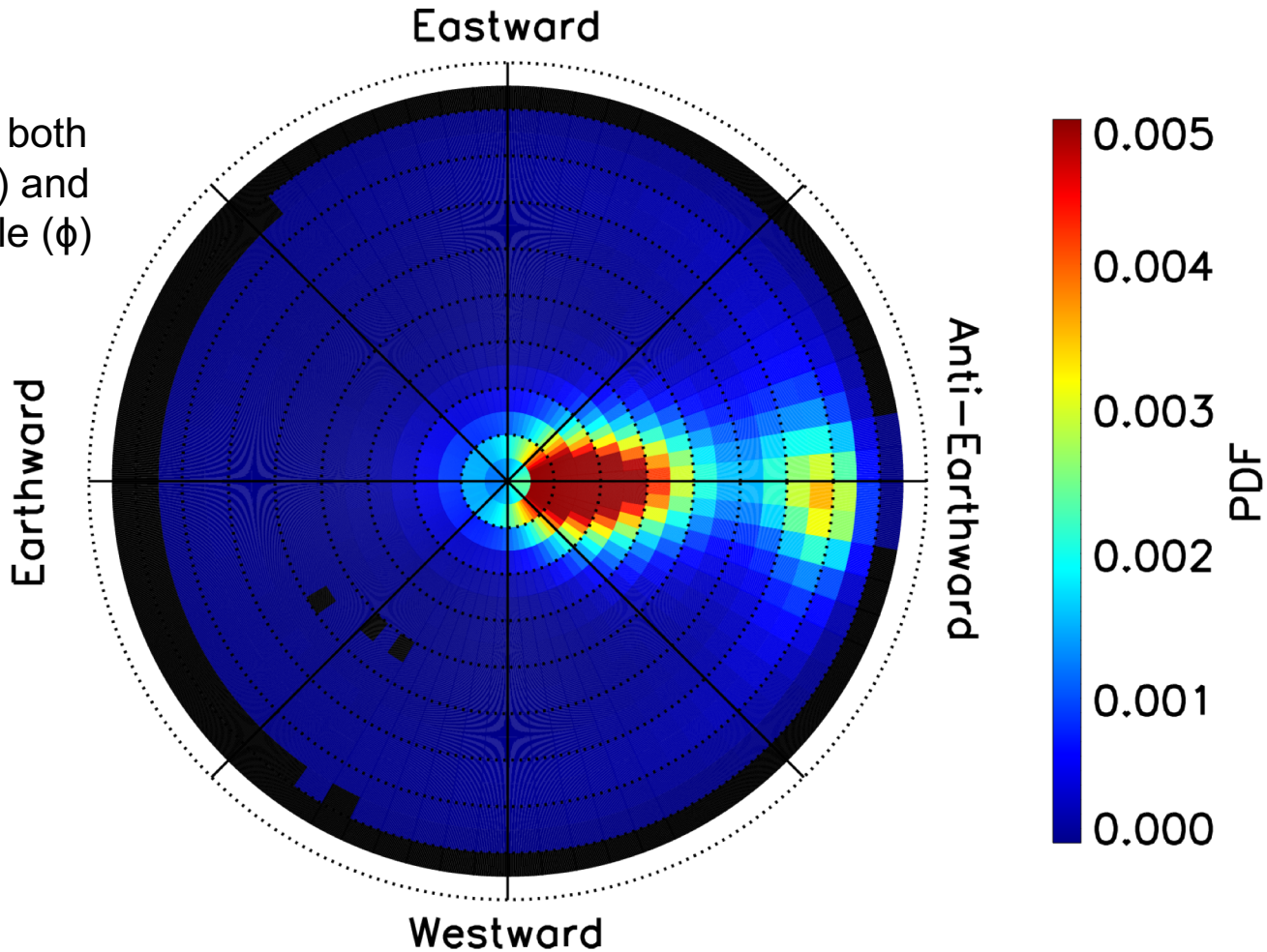


10th December 2013

LB Chorus Wave Normal Angle Maps

Evaluate statistics of the polar and azimuthal wave vector angles of chorus waves

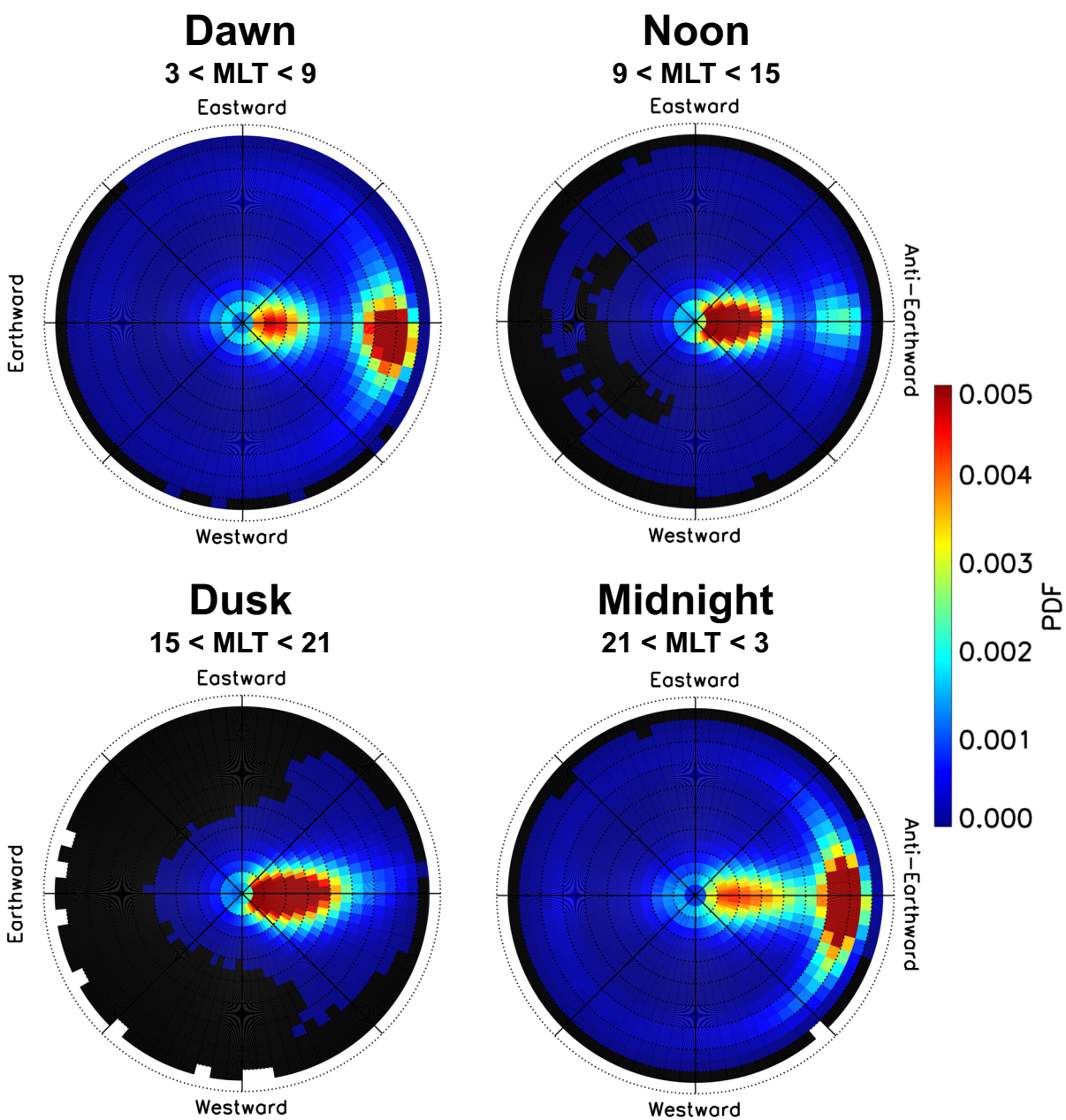
5° intervals of both polar angle (θ) and azimuthal angle (ϕ)



Most waves are near field-aligned (θ < 30°), smaller population of oblique waves (θ > 50°),

Almost all wave vectors are oriented in the anti-Earthward direction (-30° < ϕ < 30°)

Magnetic Local Time Dependence



Majority of chorus waves are near field aligned ($\theta < 30°$)

Highest occurrence rates of oblique chorus ($\theta > 50°$) are in the dawn and midnight sectors

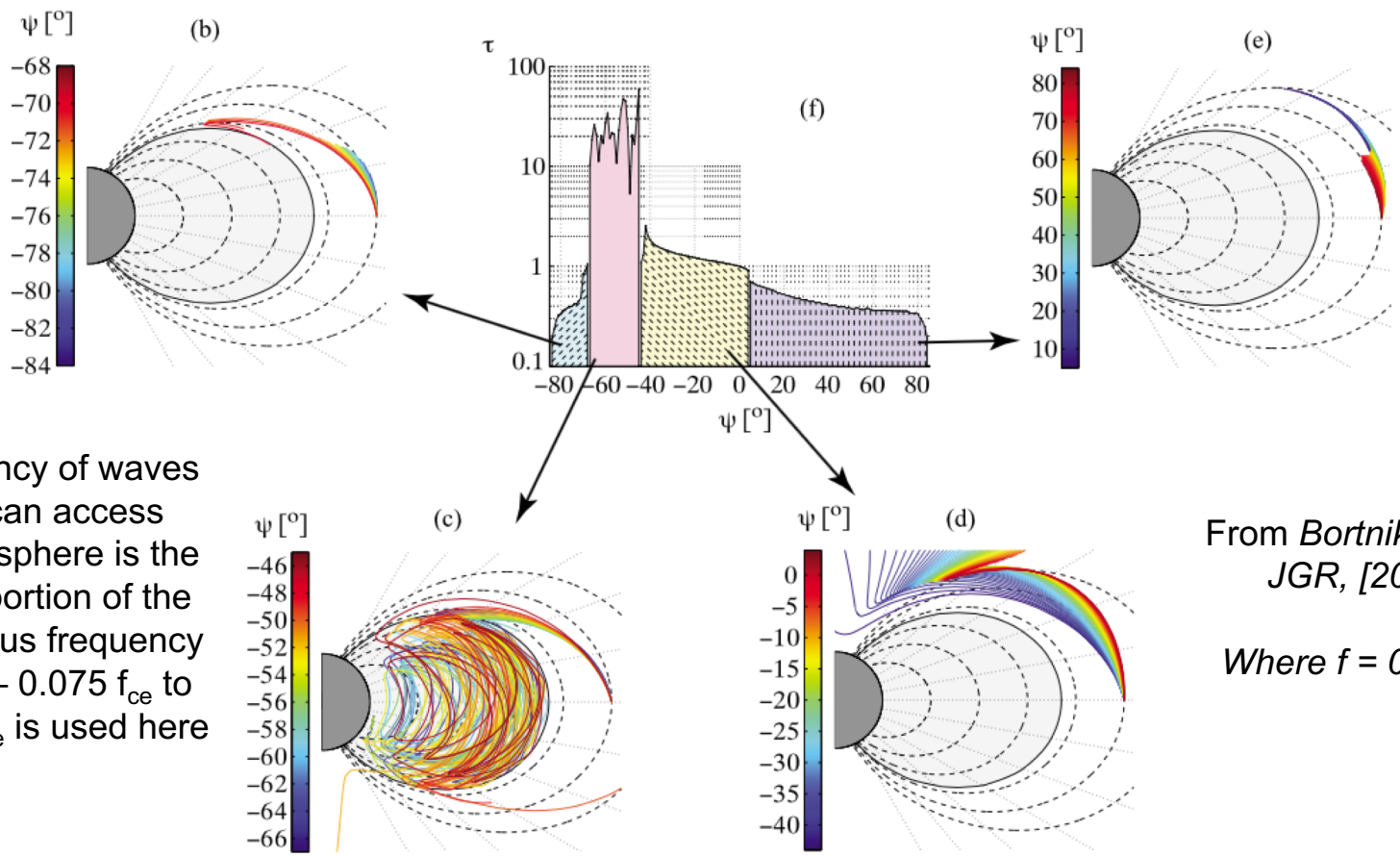
Almost all of waves are oriented anti-Earthwards ($-30° < \phi < 30°$) direction in all MLT sectors

Why Should We Care About the Orientation of Chorus Wave Vectors?

Why Should We Care About the Orientation of Chorus Wave Vectors?

2D ray tracing simulations require initially oblique polar wave vector angle and azimuthal component of the wave vector oriented Earthwards for a LB chorus wave to enter the plasmasphere and be a source of plasmaspheric hiss

Do waves with these required conditions exist? Where and how often do we see them?

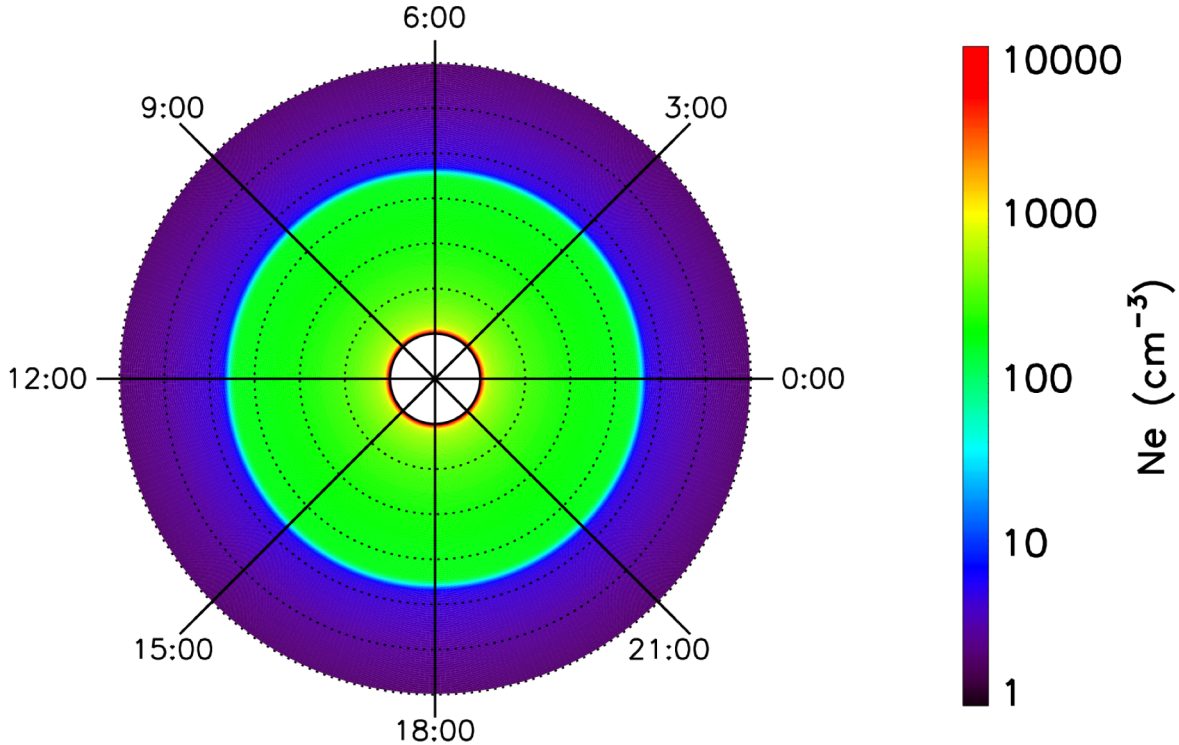


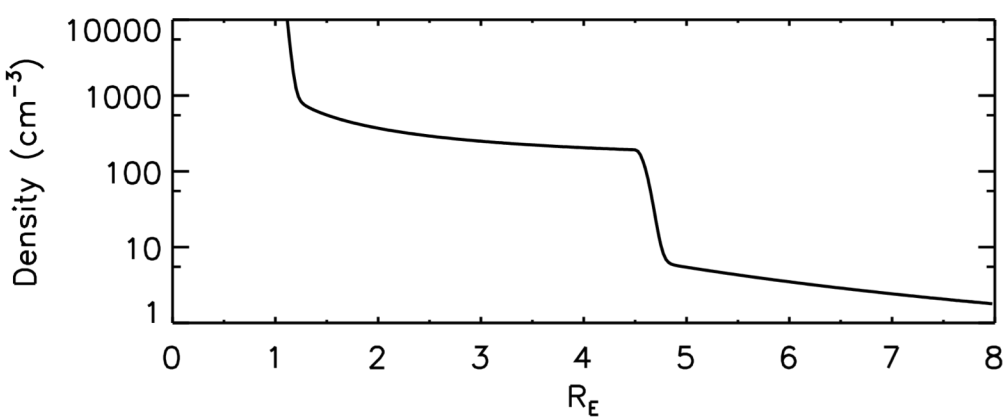
Frequency of waves that can access plasmasphere is the lower portion of the LB chorus frequency range – 0.075 f_{ce} to 0.225 f_{ce} is used here

From *Bortnik et al., JGR, [2011]*

Where f = 0.10 f_{ce}

Ray Tracing in Azimuthally Symmetric Diffusive Equilibrium Density Model





Diffusive equilibrium density model with plasmapause at 4.5

Cold plasma ray tracing, so damping rate is not calculated

Ray trace in 5° intervals of azimuthal (ϕ) and polar angles (θ) of wave vector for 2 seconds from:

L = 5.0, 6.0

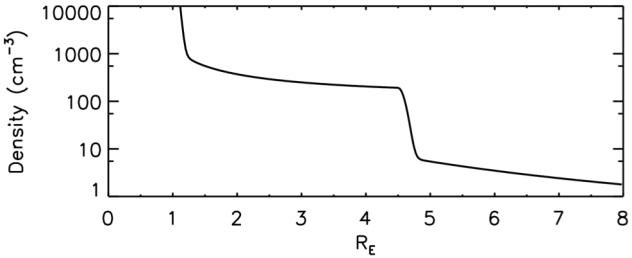
MagLat = 0°, 10°, 20°,

f/f_{ce} = 0.10, 0.15, 0.20

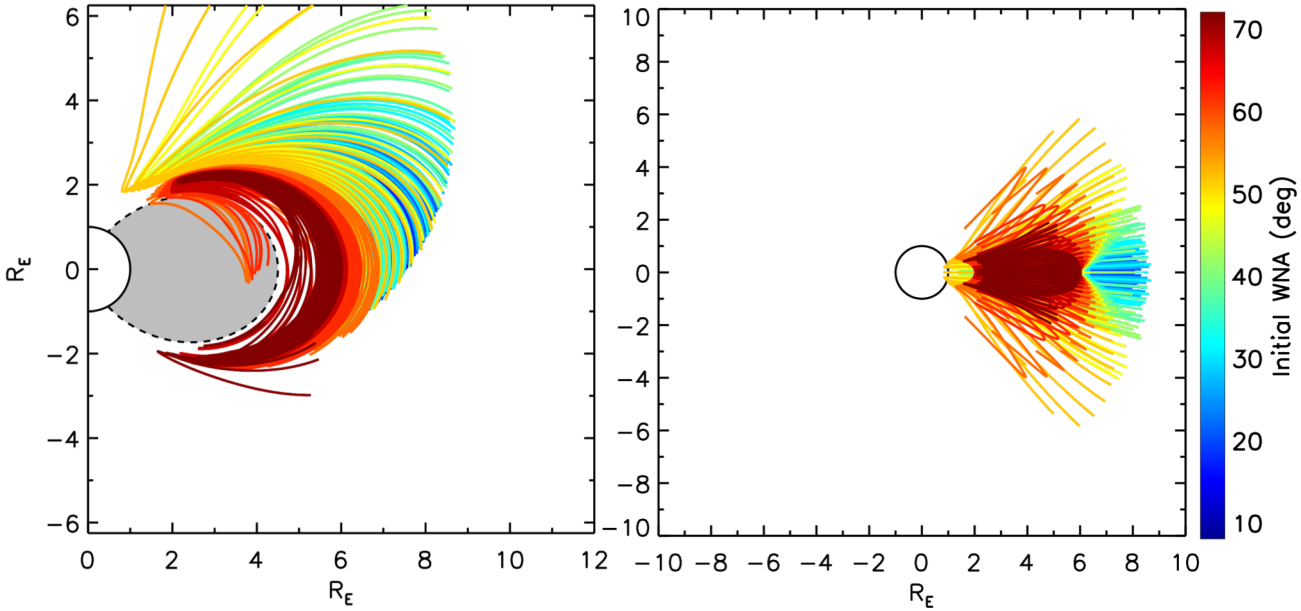
Determine which initial ϕ and θ values result in rays accessing plasmasphere and compare with observed WNA map

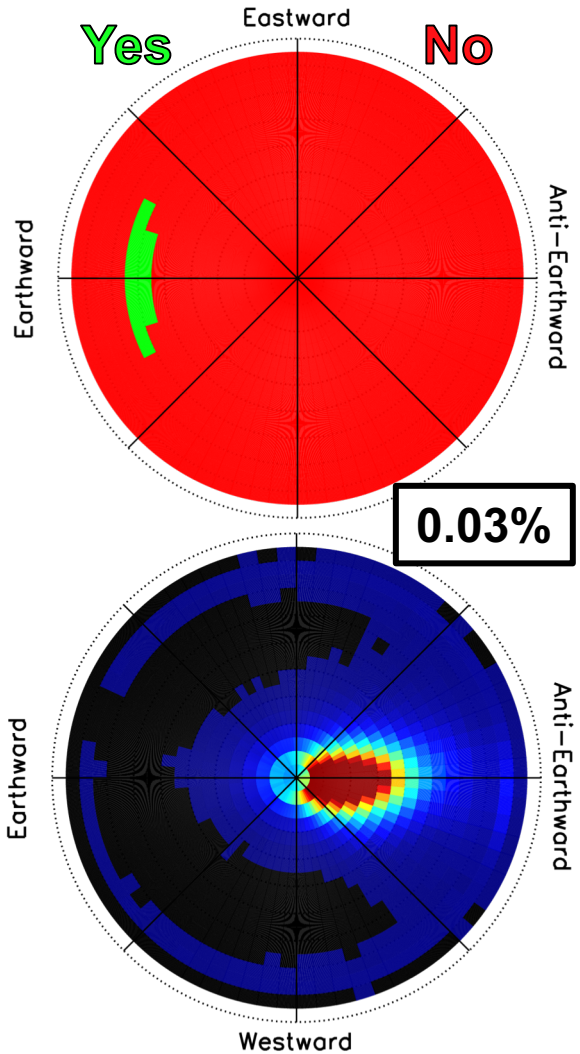
Since density model is azimuthally symmetric, MLT is not important for ray tracing, only for observed WNA map

Ray Tracing in Azimuthally Symmetric Density Model



Initial Conditions: MagLat = 0°, f/f_{ce} = 0.15, L = 6





Ray tracing used to obtain azimuthal and polar angles that can gain access to the plasmasphere - compare against chorus WNA maps

Do waves exist with the required initial conditions?

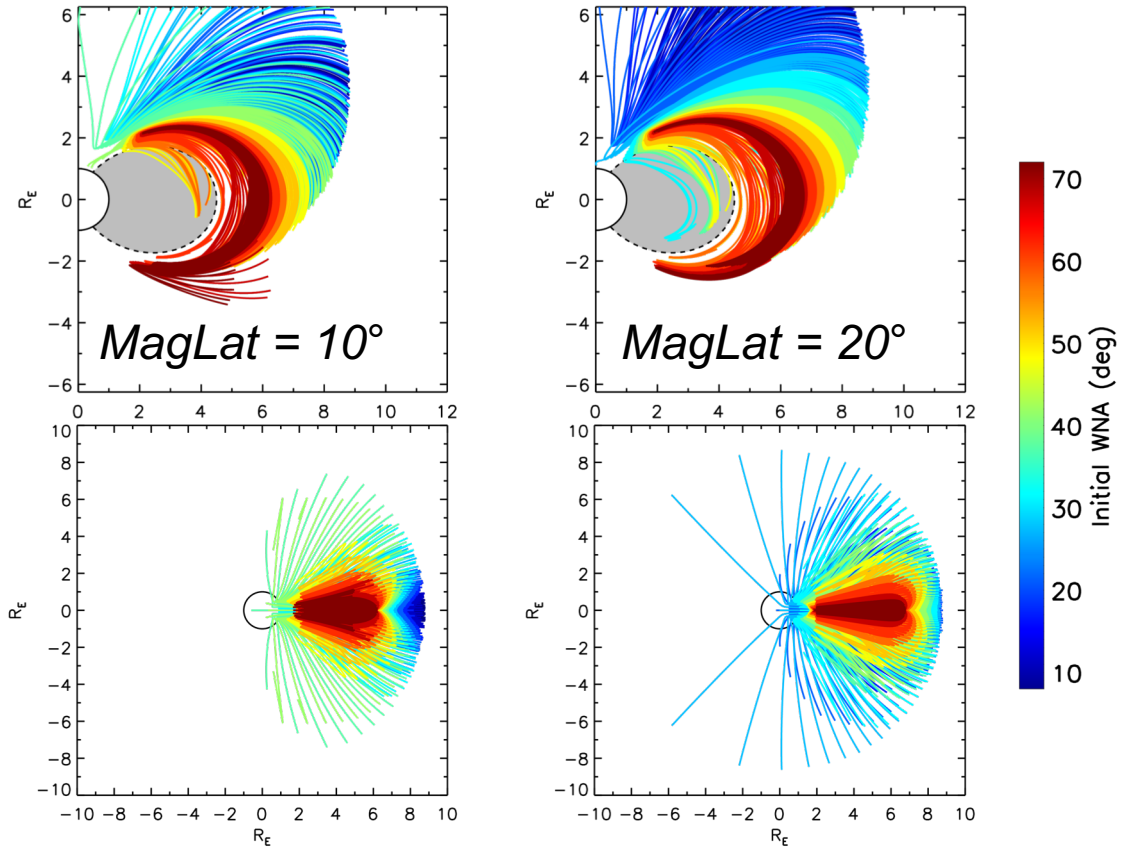
Of 2,565,747 data points, only 779 (or 0.03%) occur with initial ϕ and θ required for waves to propagate into the plasmasphere (-20° < MagLat < 20°, 0.1 < f/f_{ce} < 0.2, 5.5 < L < 6.5, 0 < MLT < 24)

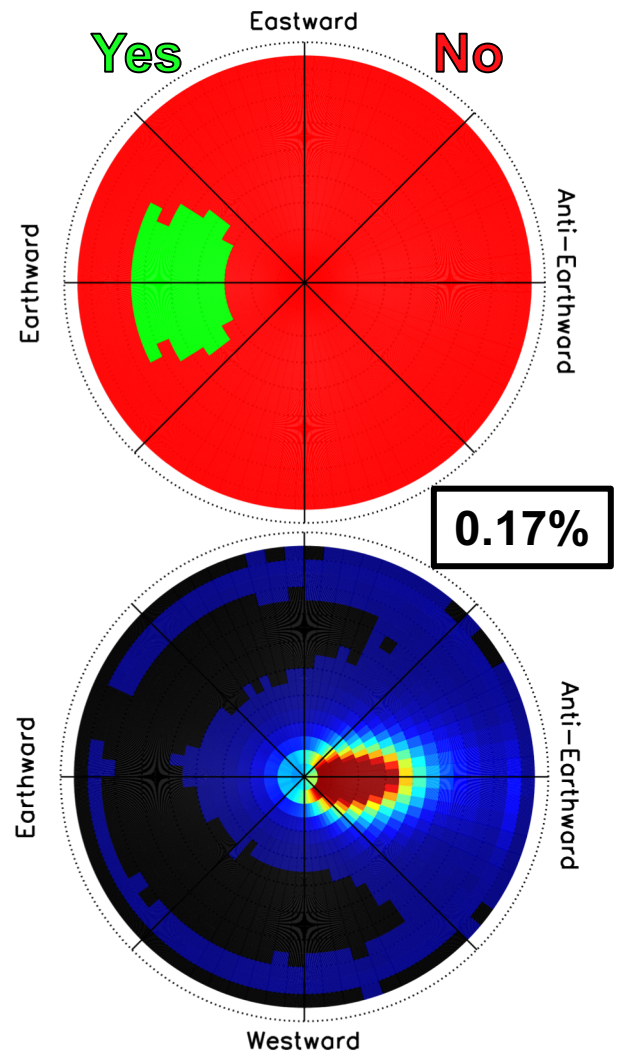
Yes, but not a significant fraction in this case…

Higher Latitude Source Locations

Van Allen Probes doesn't just measure at MagLat = 0°, we need to consider waves with higher latitude source locations between -20°< MagLat < 20°

Initial Conditions: MagLat = 0°, 10°, 20°, f/f_{ce} = 0.15, L = 6



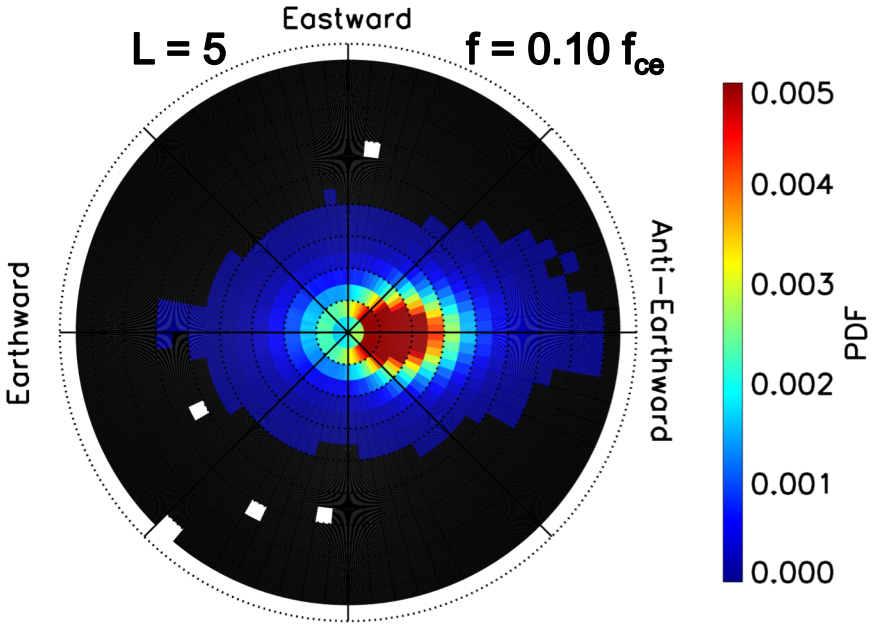


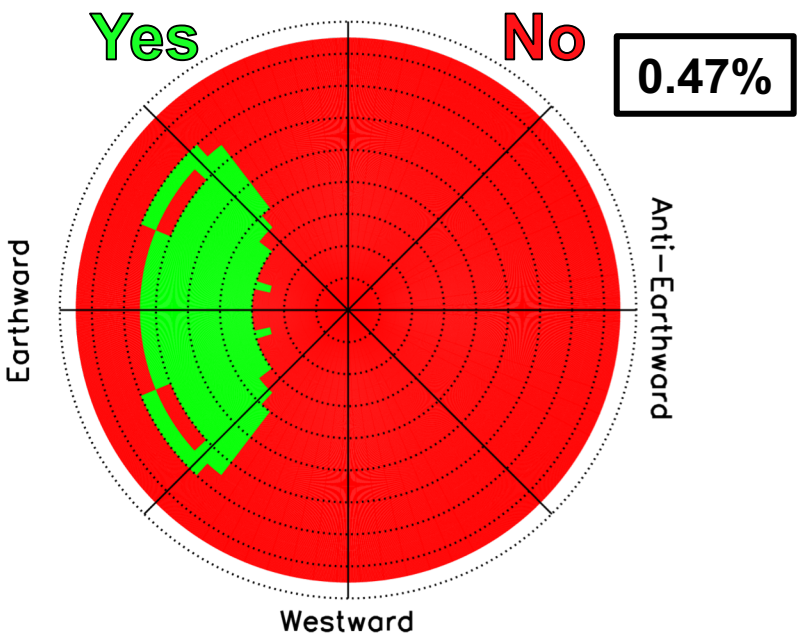
Of 2,565,747 data points, only 4,234 (or 0.17%) occur with the conditions required to propagate into the plasmasphere from a source location between -20°< MagLat < 20°, L = 6

Still not a significant fraction…

Source Locations at other L and f/f_{ce}?

L = 5	0.10 f/f_{ce}	0.15 f/f_{ce}	0.20 f/f_{ce}
N(p/sphere)	4,623	887	581
N(total)	993,977	395,322	292,581
%	**0.47%**	**0.22%**	**0.20%**
L = 6	**0.10 f/f_{ce}**	**0.15 f/f_{ce}**	**0.20 f/f_{ce}**
N(p/sphere)	6,313	1,951	873
N(total)	2,374,221	1,188,037	849,319
%	**0.27%**	**0.16%**	**0.10%**



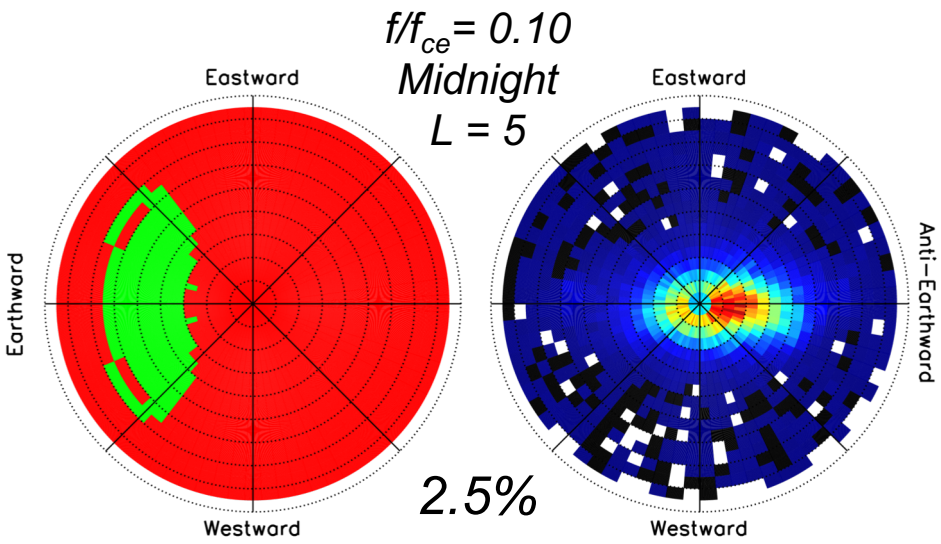


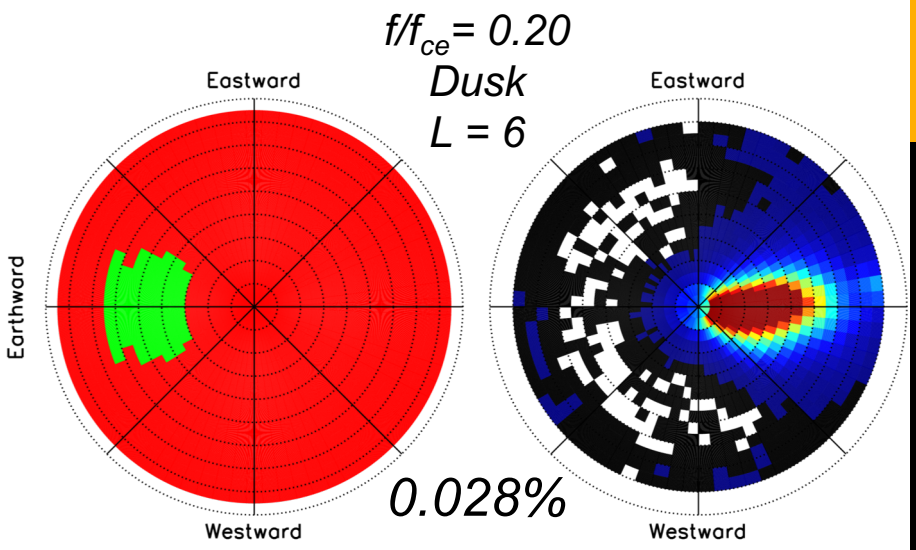
Percentages vary from 0.10% up to a maximum of 0.47% depending on source location and frequency

For all L and f/f_{ce} the occurrence rate of waves with the conditions required to gain access to the plasmasphere is not substantial (<0.5%)

How do these percentages vary for different MLT sectors?

Sorting by Magnetic Local Time Sectors



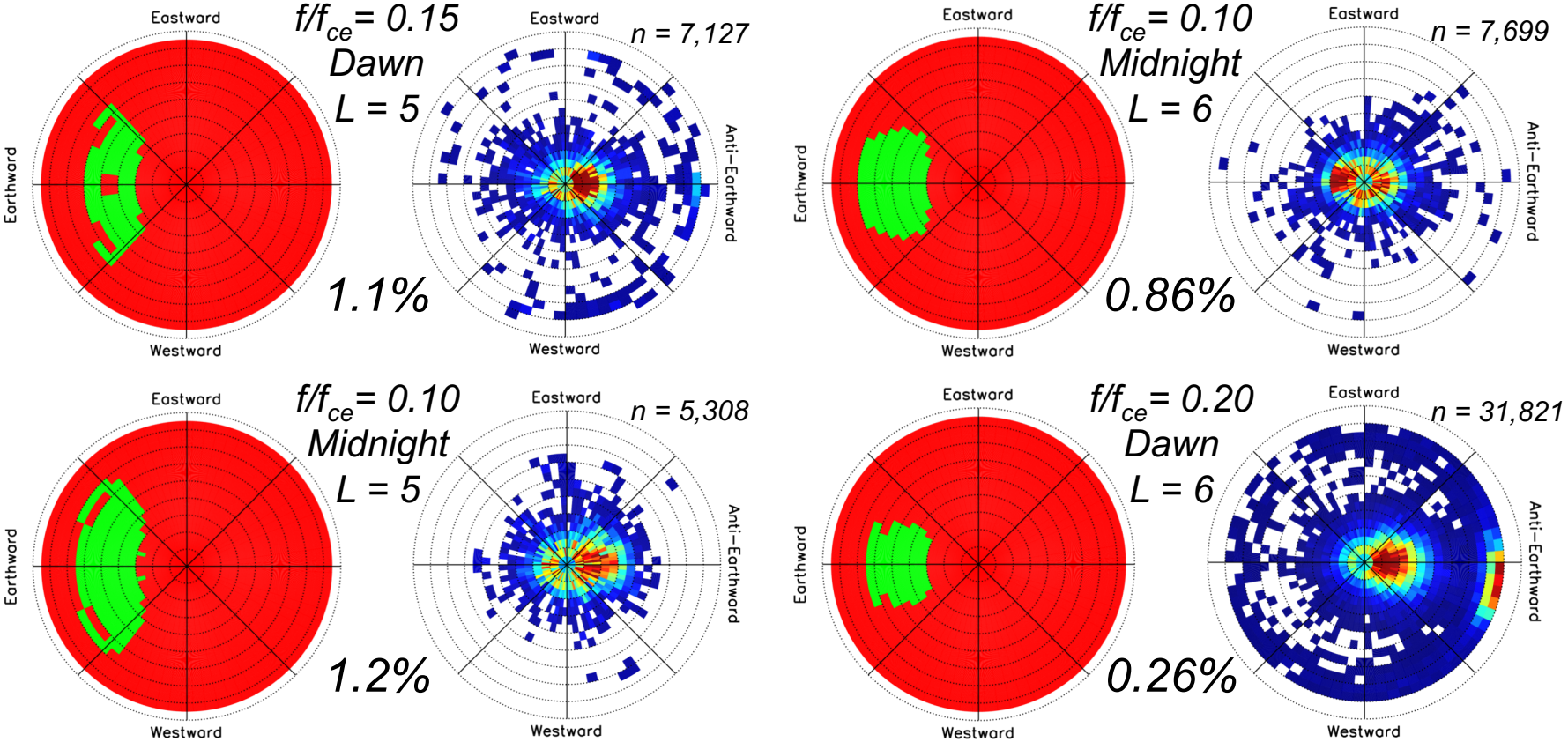


	L = 5				L = 6		
	0.10 f/f_{ce}	0.15 f/f_{ce}	0.20 f/f_{ce}		0.10 f/f_{ce}	0.15 f/f_{ce}	0.20 f/f_{ce}
Dawn	0.95%	0.91%	0.54%	Dawn	0.60%	0.53%	0.34%
Noon	0.27%	0.096%	0.16%	Noon	0.19%	0.047%	0.047%
Dusk	0.25%	0.035%	0.053%	Dusk	0.16%	0.11%	0.028%
Midnight	2.5%	0.86%	0.32%	Midnight	1.1%	0.52%	0.29%

Occurrence rates may be low, but if the waves that can access the plasmasphere are higher power waves then the process could still be significant for hiss

Are the waves that occur with these conditions skewed towards higher power waves?

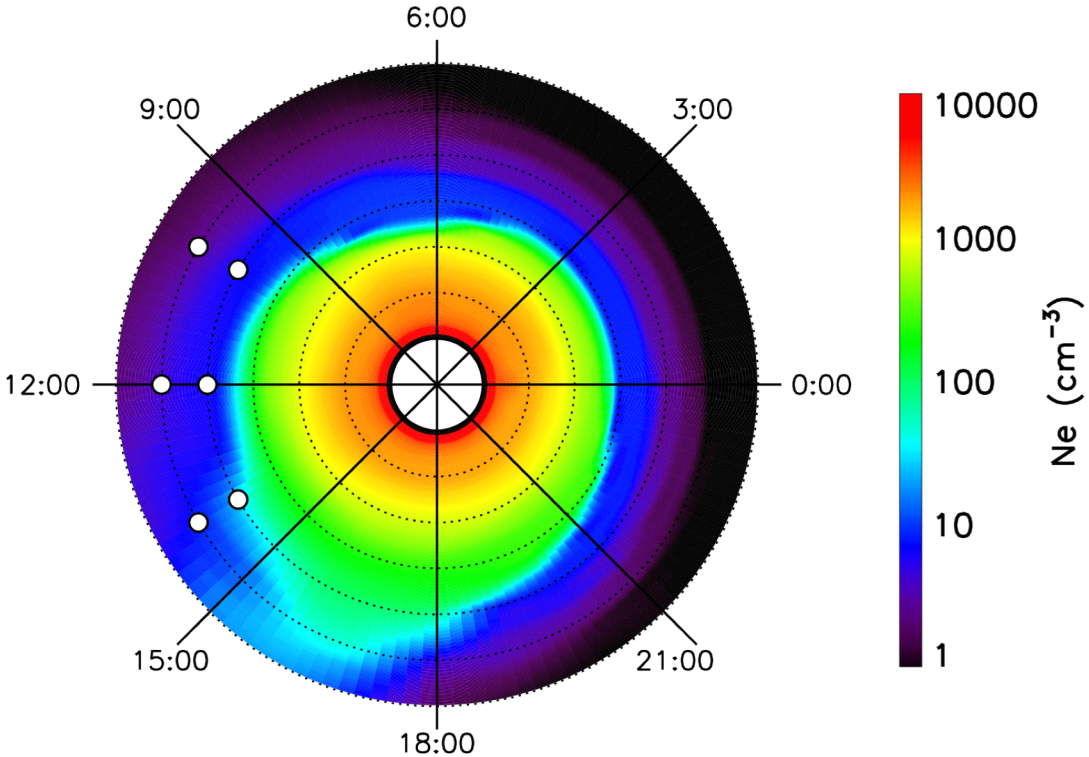
Higher Power Waves (PSD > 10^{-6} nT^2/Hz)

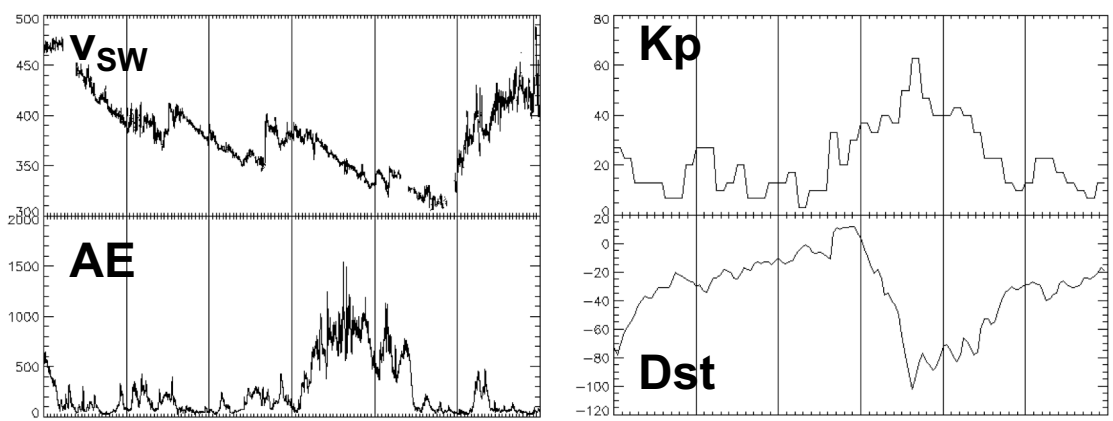


	L = 5				L = 6		
	0.10 f/f_{ce}	0.15 f/f_{ce}	0.20 f/f_{ce}		0.10 f/f_{ce}	0.15 f/f_{ce}	0.20 f/f_{ce}
Dawn	1.1%	1.1%	0.66%	Dawn	0.44%	0.30%	0.26%
Noon	0.14%	0.34%	0.62%	Noon	0.076%	0.063%	0.061%
Dusk	0.11%	0.051%	0.042%	Dusk	0.049%	0.019%	0.0094%
Midnight	1.2%	0.30%	0.16%	Midnight	0.86%	0.33%	0.26%

Percentages for higher power waves are comparable to those obtained for all chorus waves

Asymmetric Density Model (Plume)





April 19 – April 24, 2001

Use ray tracing results from *Chen et al., [2009]* who implemented an asymmetric density model to account for storm-time plume

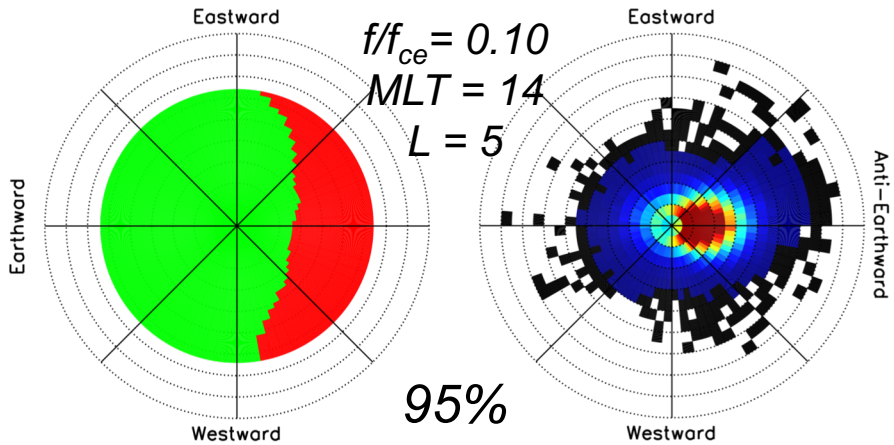
Model driven by electric field from Rice Convection Model (RCM) for main phase of April 21, 2001 storm

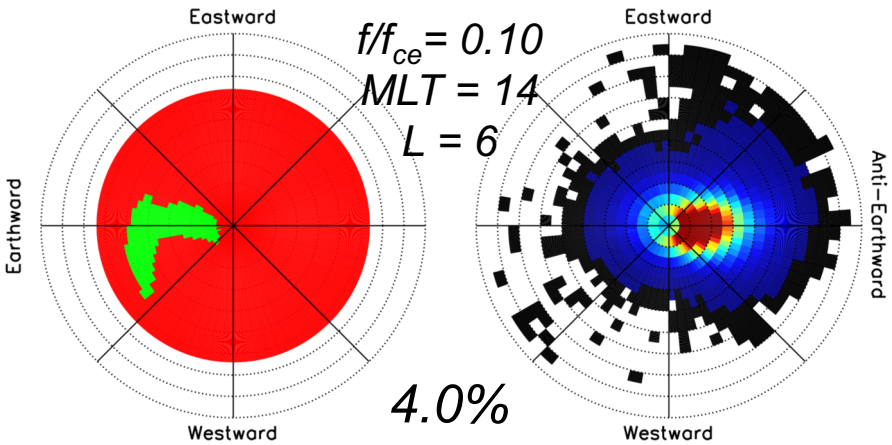
CRRES data for AE > 300 nT used to model the suprathermal electron distribution – damping rates explicitly calculated

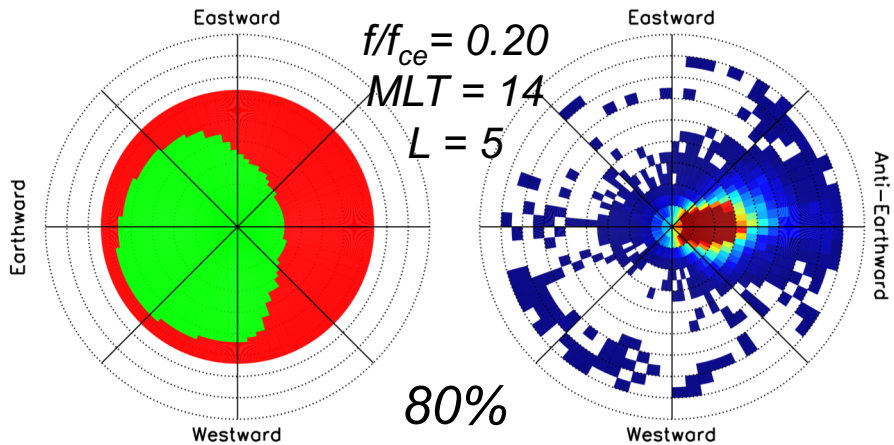
Ray trace for all azimuthal (ϕ) and polar angles (θ) from:
L = 5.0, 6.0 MagLat = 0°
f/f_{ce} = 0.10, 0.15, 0.20
MLT = 10, 12, 14

Determine which initial ϕ and θ values result in waves accessing plasmasphere and compare with observed WNA map

Ray Tracing with Asymmetric Density







For MLT = 14 and L = 5, (right on the edge of the plume) the majority of the observed chorus population can propagate into plasmasphere (due to the strong azimuthal density gradient)

The percentage of waves that can access the plasmasphere decreases substantially as we move radially outwards from the plume to L=6 (less of an azimuthal density gradient)

	L = 5				L = 6		
	0.10 f/f_{ce}	0.15 f/f_{ce}	0.20 f/f_{ce}		0.10 f/f_{ce}	0.15 f/f_{ce}	0.20 f/f_{ce}
MLT = 10	0.0032%	0%	0%	MLT = 10	0.0042%	0%	0%
MLT = 12	0.17%	0.049%	0.026%	MLT = 12	0%	0%	0%
MLT = 14	95%	90%	80%	MLT = 14	4.0%	0%	0%

Summary and Implications

With azimuthally symmetric density model the observed occurrence rates of chorus waves with the initial conditions required to enter the plasmasphere are not substantial

With asymmetric density model there is only a small range of L, MLT, and f/f_{ce} where the observed occurrence rates of waves with the required conditions are substantial

Results from this study show that in most MLT sectors, there are very few occurrences of chorus with the conditions required to enter the plasmasphere

Only in a small MLT sector and small range of L (duskside near plume) does a substantial fraction of the chorus exist with the conditions required to enter the plasmasphere

Conditions with the highest percentages identified in this study:

L = 5	***MLT = 14***	***f/f_{ce} = 0.10-0.20***	***80-95% of observed waves***
L = 6	***MLT = 14***	***f/f_{ce} = 0.10***	***4% of observed waves***

Strong azimuthal density gradients are a requirement if a significant population of chorus waves are to enter the plasmasphere and evolve into plasmaspheric hiss