Statistical Properties of Plasmaspheric Hiss from Van Allen Probes

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EMFISIS Observations of Plasmaspheric Hiss

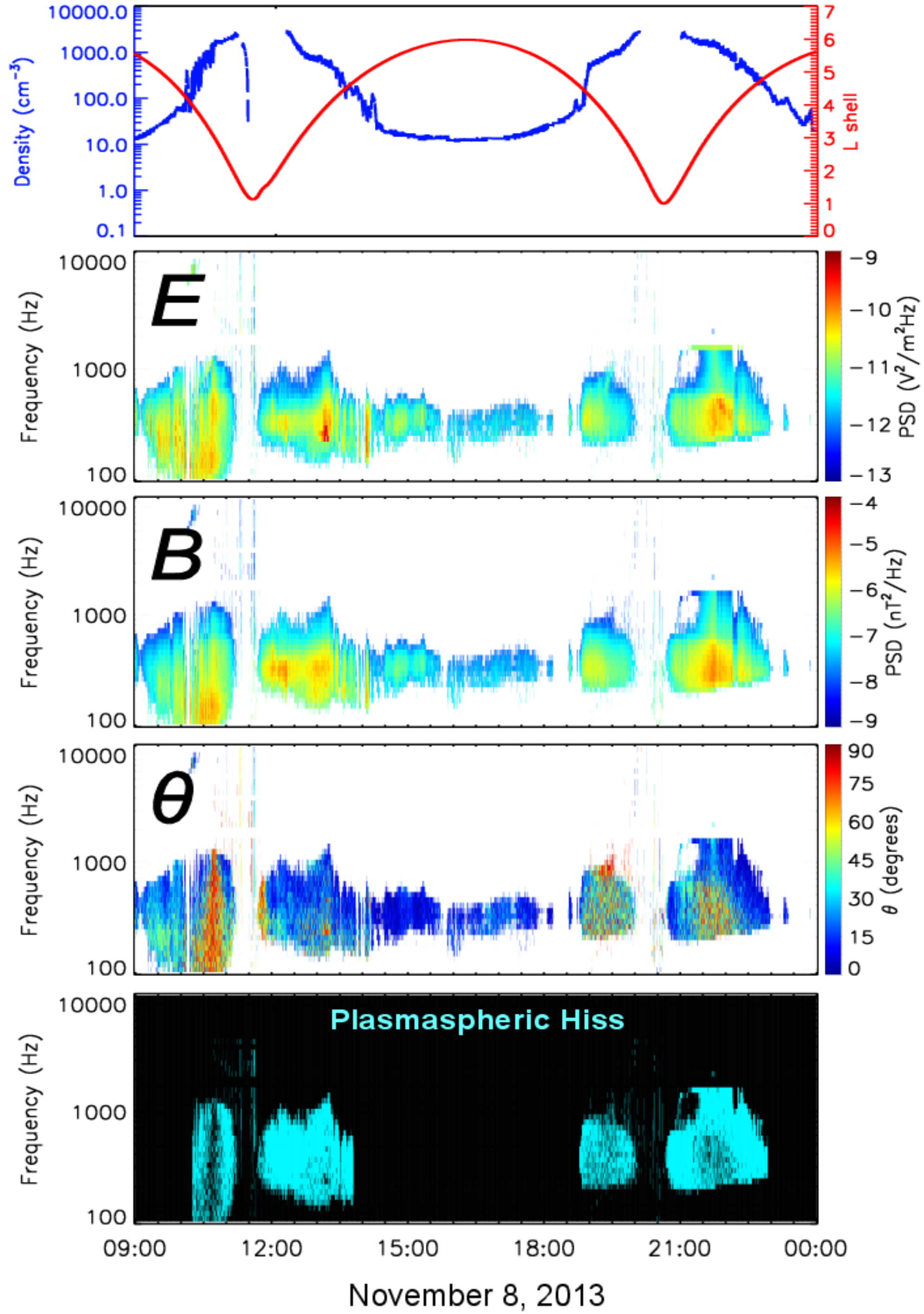
Criteria for defining plasmaspheric hiss:

100 Hz < *f* < 5 kHz

Spacecraft located inside of plasmasphere (inner edge determined visually based on density from upper hybrid line)

Both ***E*** and ***B*** signals > 10x instrument background levels

Ellipticity > 0.5 ***Polarization > 0.5***
(right-handed, near-circular polarization)



Planarity Limitation

SVD method (*Santolik et al., 2003*) of determining θ assumes presence of a single plane wave

Planarity, ***F***, lets us know how good this assumption is (***F = 1*** for plane wave)

In lower planarity cases, SVD wave normal angle estimates provide a weighted average of this more complex wave field

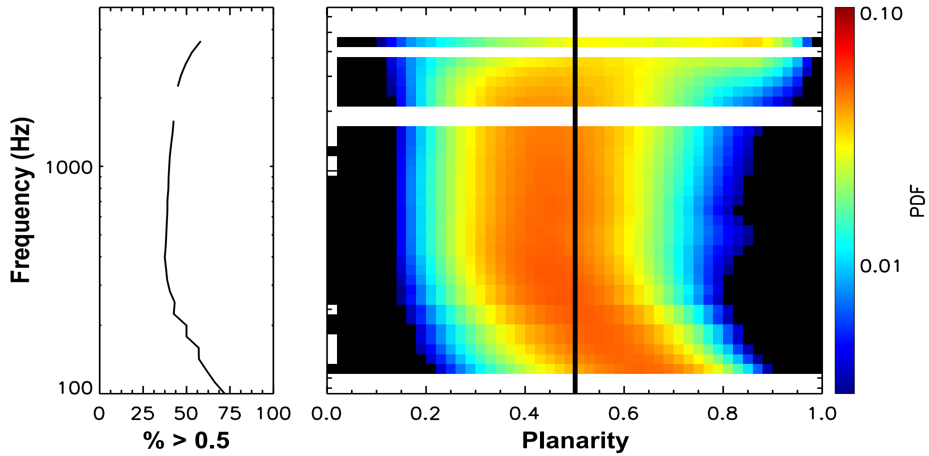
Hiss can often have low planarity – planarity threshold required to ensure validity of technique and results

Planarity threshold limits the effect that power from outside of polarization plane can have on the SVD wave normal angle estimates

w_1, w_2, and w_3 are the wave power in each axis of the 3D magnetic field polarization ellipsoid (ascending order)

$$L_p = \frac{w_2}{w_3} \quad F = 1 - \sqrt{\frac{w_1}{w_3}}$$

For circular polarization, $w_3 = w_2$, $L_p = 1$, w_1 is the power outside of the polarization plane



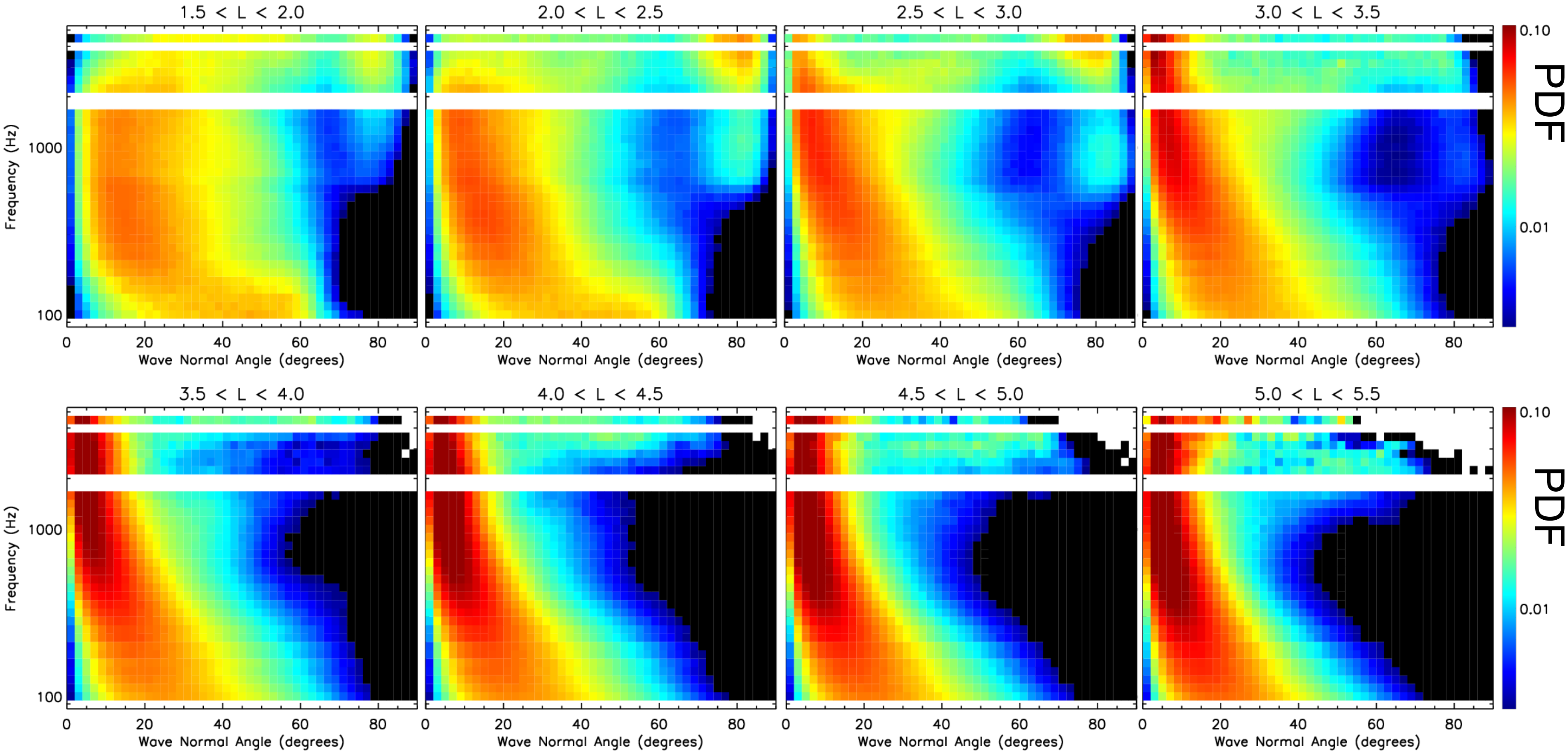
Additional criteria:

Planarity > 0.5

Planarity Threshold	> 0.7	> 0.7	> 0.5	> 0.5	> 0.3	> 0.3	> 0.2	No Threshold
Ellipticity Threshold	> 0.7	> 0.5	> 0.7	> 0.5	> 0.7	> 0.5	> 0.7	No Threshold
% of Total Power Permitted Outside of Polarization Plane	< 5%	< 6%	< 13%	< 14%	< 22%	< 25%	< 27%	< 33% Isotropic Noise

Variation of θ with L shell

PDF: Normalized occurrences in each frequency bin



At low L shells, two populations are observable – one more field aligned and one more oblique

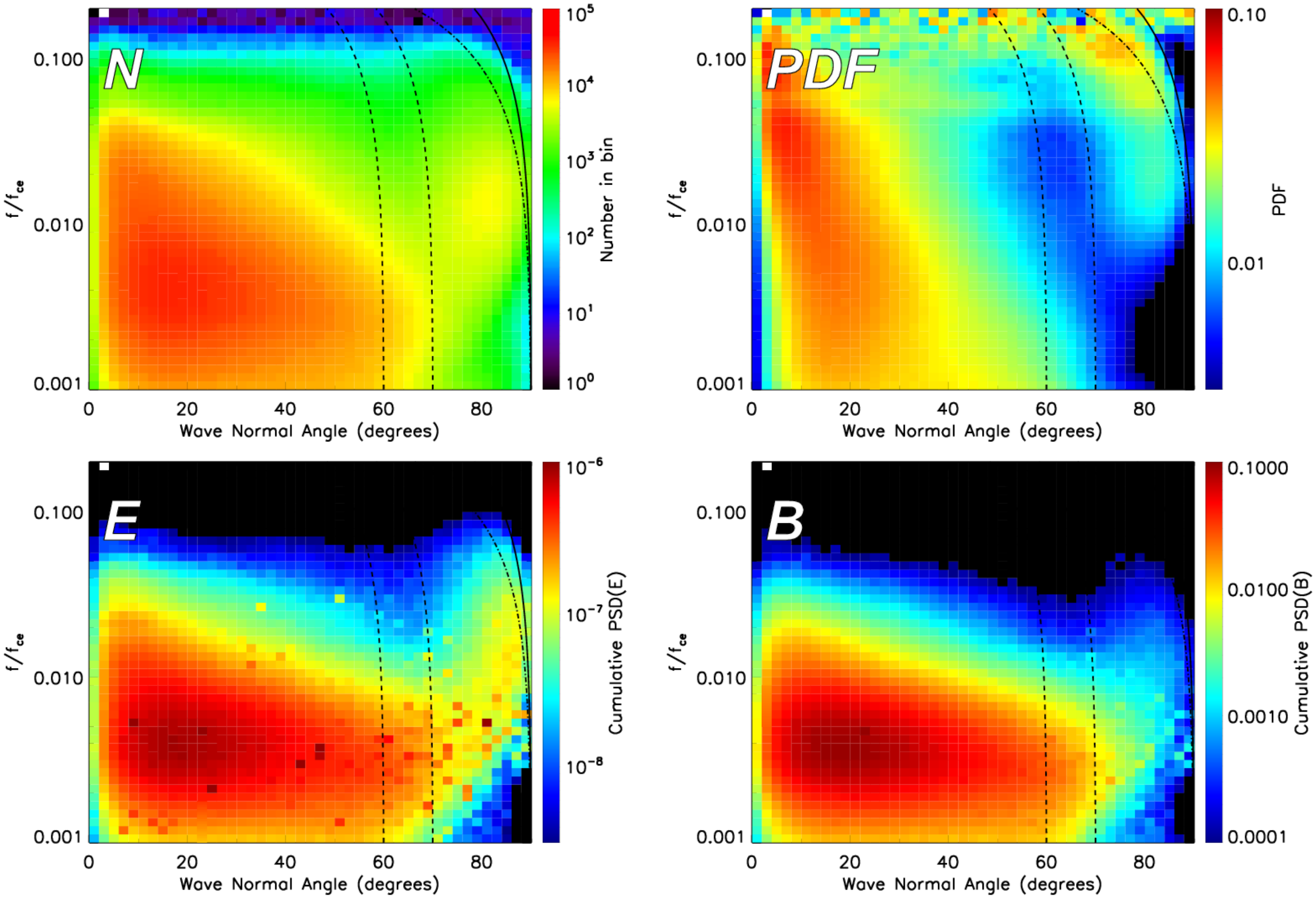
At larger L shells, oblique population no longer apparent – waves are predominantly field aligned

Results contrast to previous studies that reported bimodal distribution only in outer plasmasphere

Field aligned population spans all frequencies in plasmaspheric hiss range

Oblique population most apparent at 700 Hz < f < 5 kHz and L < 3 – focus on this region

Oblique Hiss Population (L < 3)



Oblique population most apparent at $f > 0.01\ f_{ce}$ (or 700 Hz)

Oblique population occurs relatively close to Gendrin Angle

More parallel oriented waves have strong power in both ***E*** and ***B***

More oblique waves have strong ***E*** and weaker ***B***

Similar results to those found by *Li et al., [2016]* for chorus waves

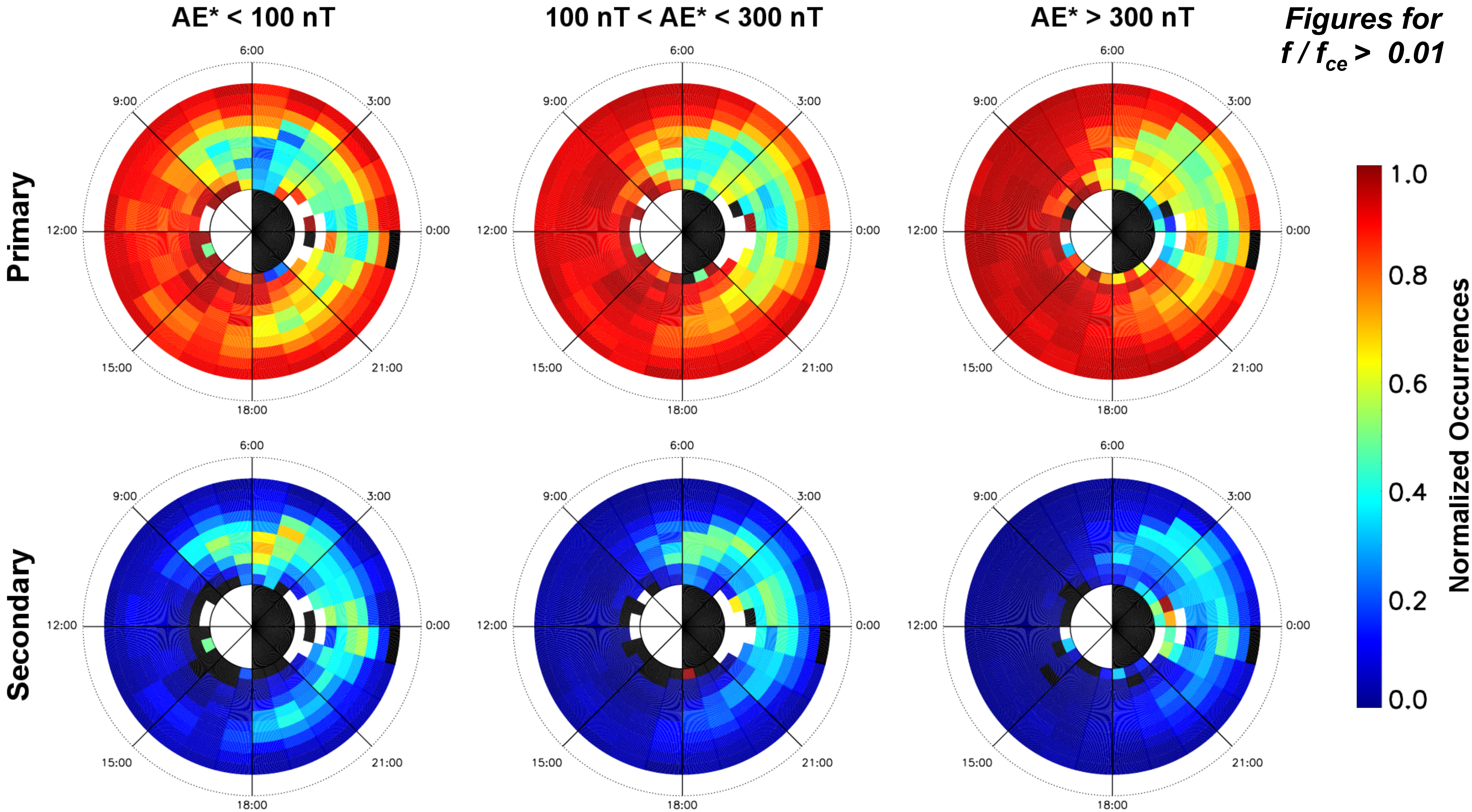
Resonance Cone
Gendrin Angle
Separation Angles

Distinguish between two populations:

Primary: $\theta < \theta_{res} - 30°$

Secondary: $\theta_{res} - 20° < \theta < \theta_{res}$

Geomagnetic Activity and MLT



Figures for $f / f_{ce} > 0.01$

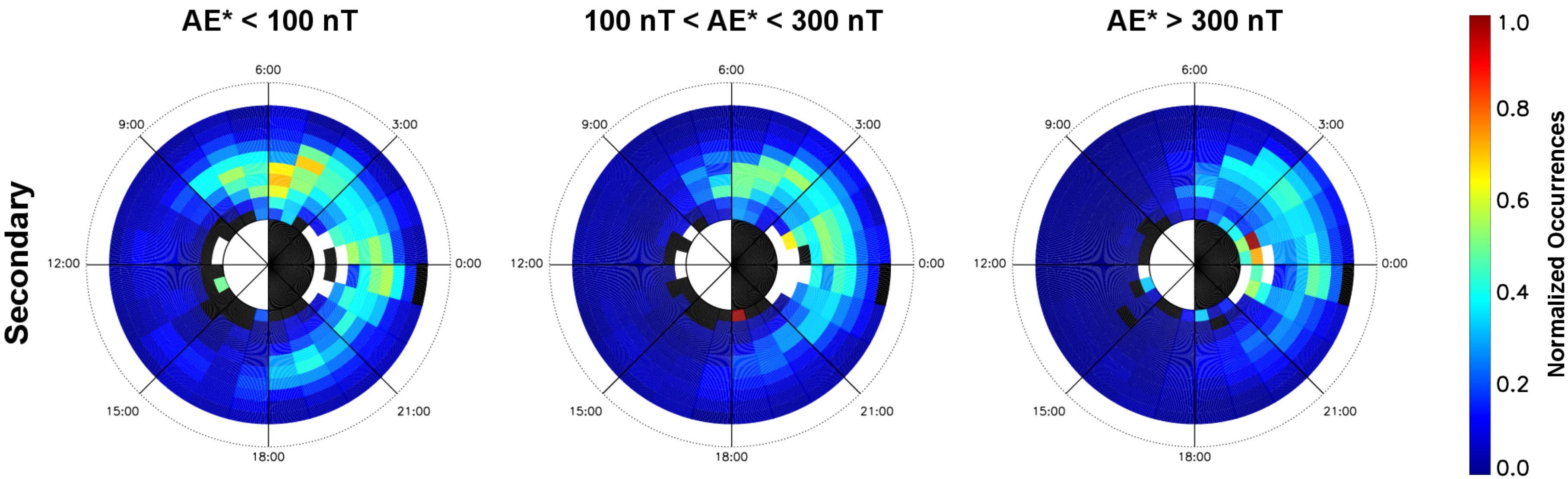
Primary: $\theta < \theta_{res} - 30°$
Secondary: $\theta > \theta_{res} - 20°$

Occurrence rate of oblique waves ($f > 0.01\ f / f_{ce}$ and $L < 3$) peaks between 19:00 and 9:00 MLT

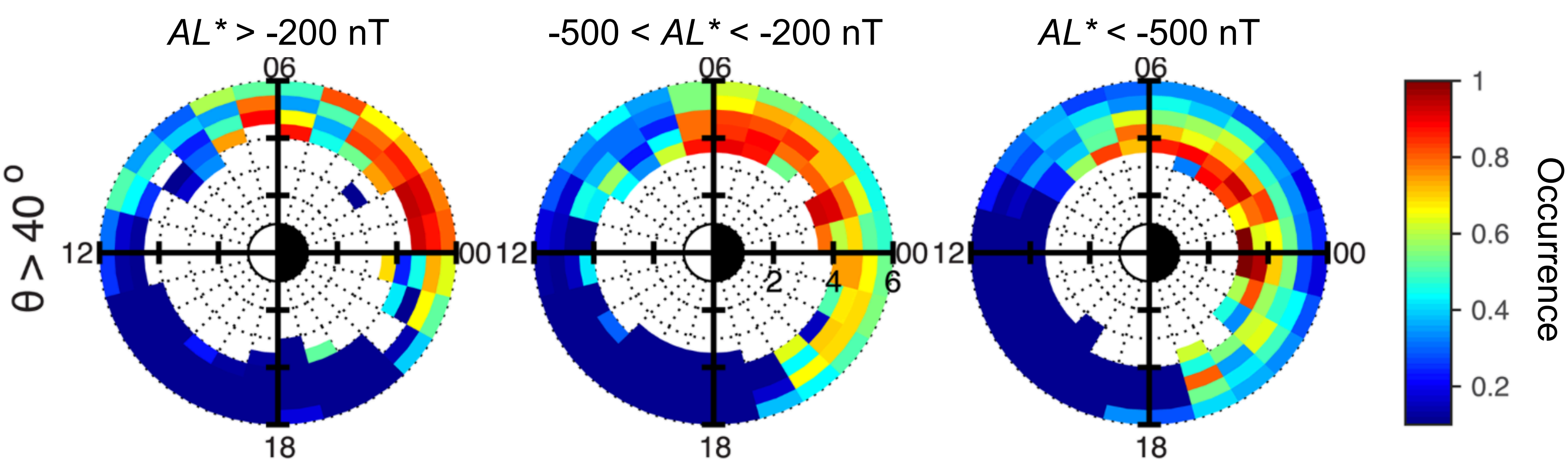
Using $f > 700$ Hz as lower limit yields similar results

Relation to Chorus Waves

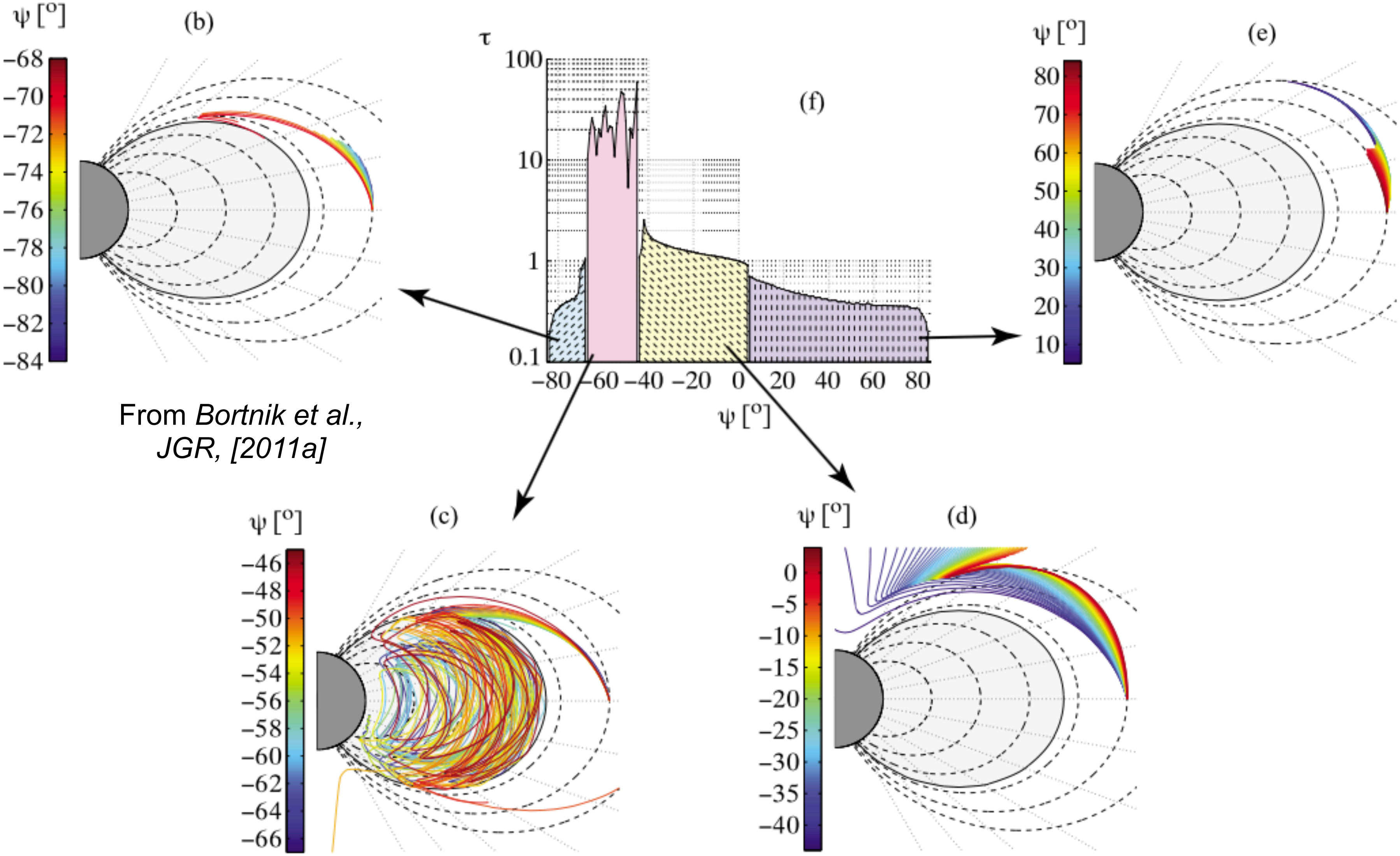
Occurrence rate of oblique $f > 0.01\ f/f_{ce}$ (or 700 Hz) hiss waves ($\theta > \theta_{res}$- 20°)



Occurrence of lower band chorus waves with $\theta > 40°$ (from *Li et al., 2016*)



Relation to Chorus Waves



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

Chorus waves at L = 6 require initial -67° < *θ* < -45° to gain access to the plasmasphere and evolve into hiss – link between chorus and hiss is nothing new…

Comparison to Previous Results

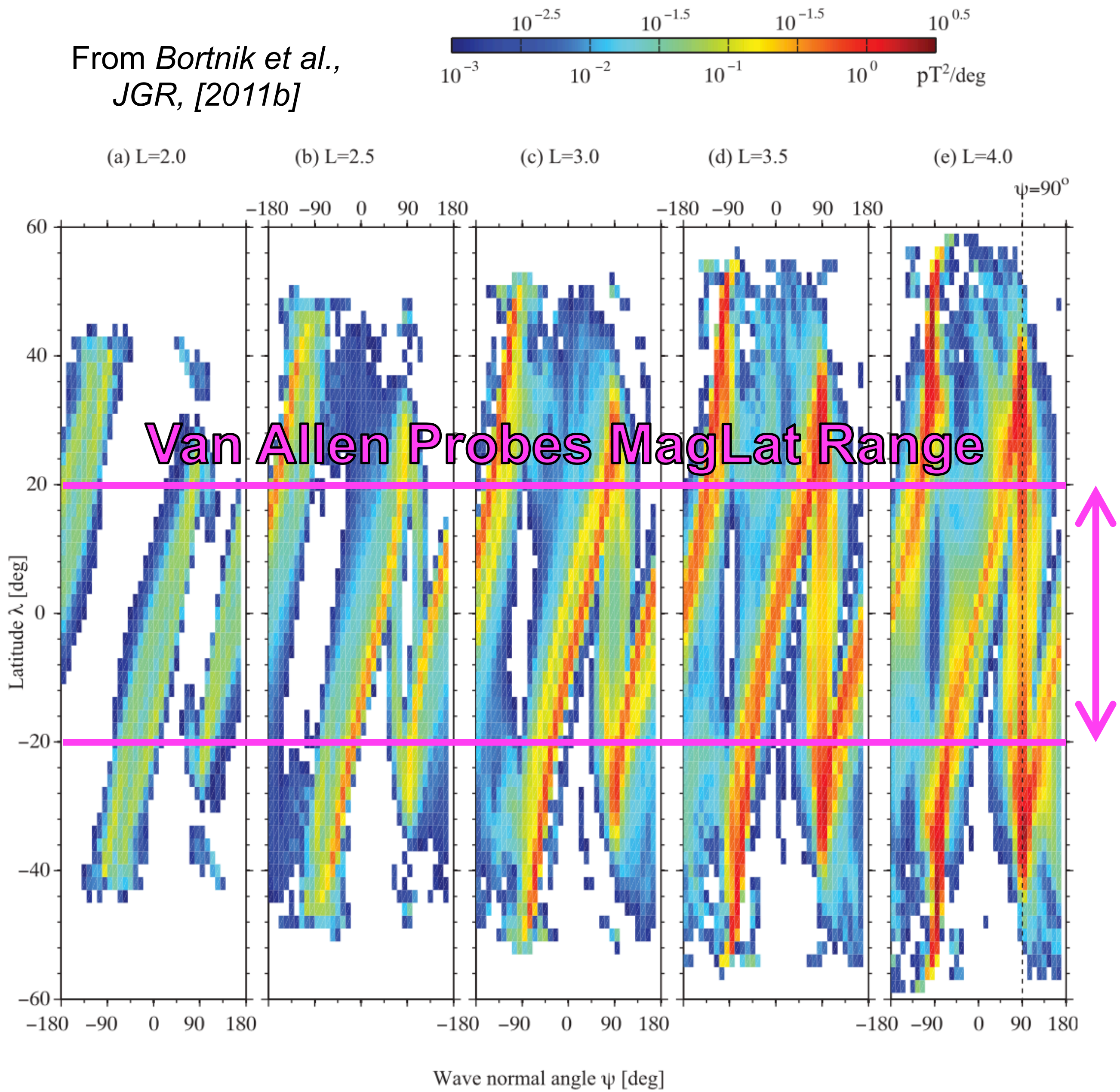
Bimodal distribution of wave normal angles has been reported – but only in the outer plasmasphere close to the plasmapause

These results have been reproduced through extensive ray-tracing simulations

New statistical results from Van Allen Probes show that bimodal wave normal angle distribution is only apparent in the inner plasmasphere L < 3

Is it possible to get oblique hiss at low L shells using the existing chorus-to-hiss theory?

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

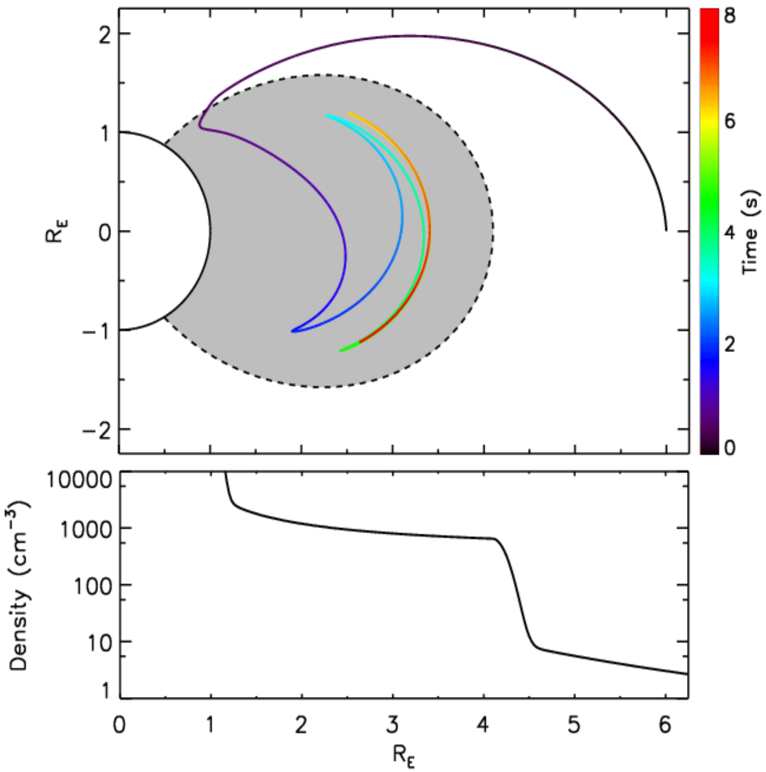


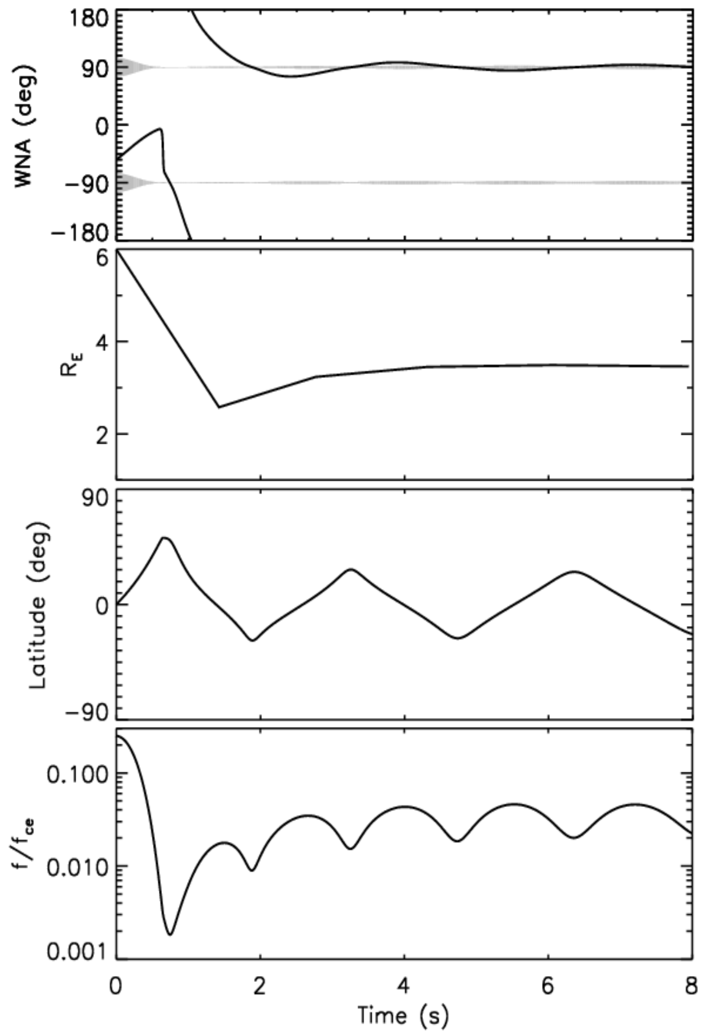
Can we get oblique hiss at low L?

Initial Wave Parameters

θ_k = -54°

f = 0.25f_{ce} (~1kHz)





Ray enters p/sphere at low L, becomes increasingly oblique

Performs multiple magnetospheric reflections and propagates outwards in L

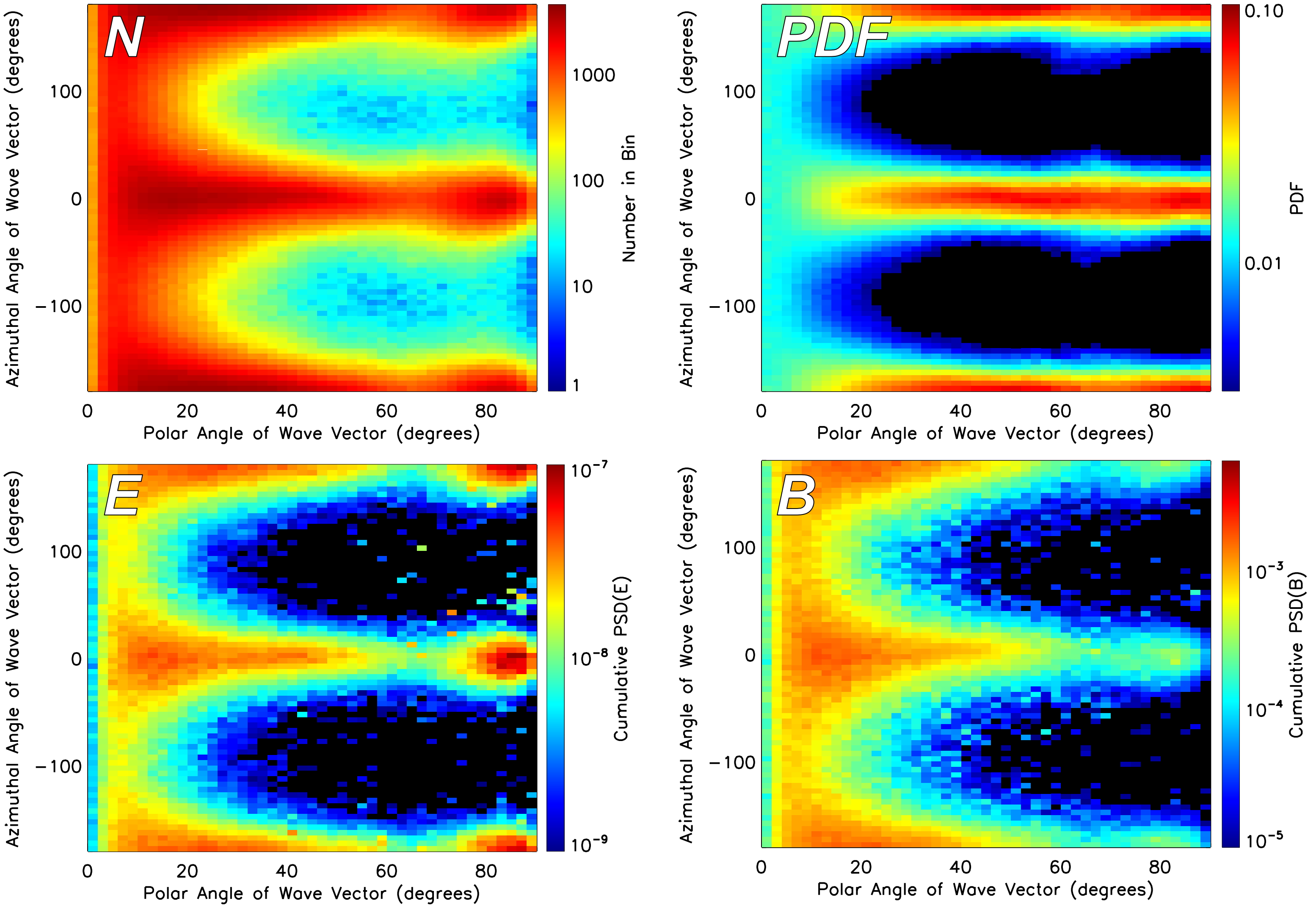
Once wave reaches certain L, it remains at fixed L for many traversals

Would be observed as oblique wave at low L shell (initial p/sphere entry or after very low number of reflections)

No longer observed at higher L shell due to Landau damping of oblique waves (wave power drops below 10x background threshold to be included in study)

Is 2D ray tracing sufficient?

Azimuthal wave vector angle either earthward, *0°*, or anti-earthward, *180°*, (*L* < 3, $f/f_{ce} > 0.01$)



Implies that waves must come from chorus in same MLT sector – consistent with observations
Oblique hiss has stronger *E* (weaker *B*) – important factor for particle interactions with oblique hiss

Summary and Conclusions

Two distinct populations of plasmaspheric hiss have been observed; one more field aligned and one more oblique, particularly in the inner plasmasphere ($L < 3$) – in contrast to previous observational results

Oblique hiss has been shown to be most prevalent during low geomagnetic activity (AE* < 100 nT), frequencies greater than 0.01 f/f_{ce} (or 700 Hz), and between 1900 and 0900 MLT: similar to distribution of oblique chorus waves

Plausibility of direct link between oblique chorus outside of plasmasphere and oblique plasmaspheric hiss at low L shells has been confirmed using HOTRAY ray tracing – similar MLT to oblique chorus with earthward/anti-earthward azimuthal angle of wave vector

Despite the different location of this oblique population compared to previous studies, oblique hiss in the inner plasmasphere is compatible with the existing theory of chorus as the source of plasmaspheric hiss