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Determining the global coherence of plasmapheric hiss wave

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1. Introduction

- Hiss waves are a broadband (~50-2000 Hz) and structureless electromagnetic emission, which play an important role in radiation belt dynamics with gyro resonant wave-particle interactions.
- These interactions break the adiabatic invariant, leading to acceleration of the trapped particle population, pitch angle diffusion and potential loss of electrons to the atmosphere. [Lyons and Thorne 1973; Meredith et al., 2009]

- Several empirical models of pitch angle diffusion have traditionally been computed using the average magnetic field intensity. [e.g., Malaspina er al., 2020; Fok et al., 2011; Glauert et al., 2013; Subbotin & Shprits, 2009]
- However, recent modelling and data analysis work indicates that the efficacy of the diffusive process is increased if you take into account the variability in hiss wave parameters instead of simply using the average values. [Watt et al., 2019]

- **Therefore, in general, it is important to know how rapidly wave characteristics vary in order to model all wave-particle interactions in the Radiation Belt effectively**.

• 2.1 Objective and Data

- **Scientific Question**:

  How rapidly does the amplitude of plasmaspheric hiss vary?

- **Method:**

  Study the correlation of wave amplitudes across a range of frequencies that cover the plasmaspheric hiss band as a function of spacecraft separation and time lag.

- **Data** (2012-2015):

  RBSP-A&B EMFISIS (Mauk et al., 2012)

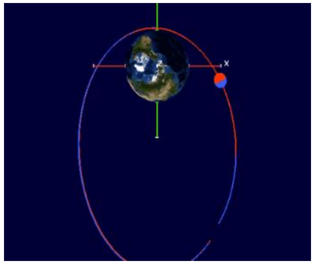
  Perigee: 618 km,

  Apogee: 5.8 R_E,

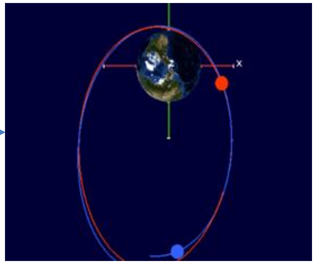
  Inclination: 10.2∘,

  Period: 537.1 min,

  Separation: ~0.01 to 5 RE.



2012-11-09



2012-11-30

• 2.2 Hiss event selection

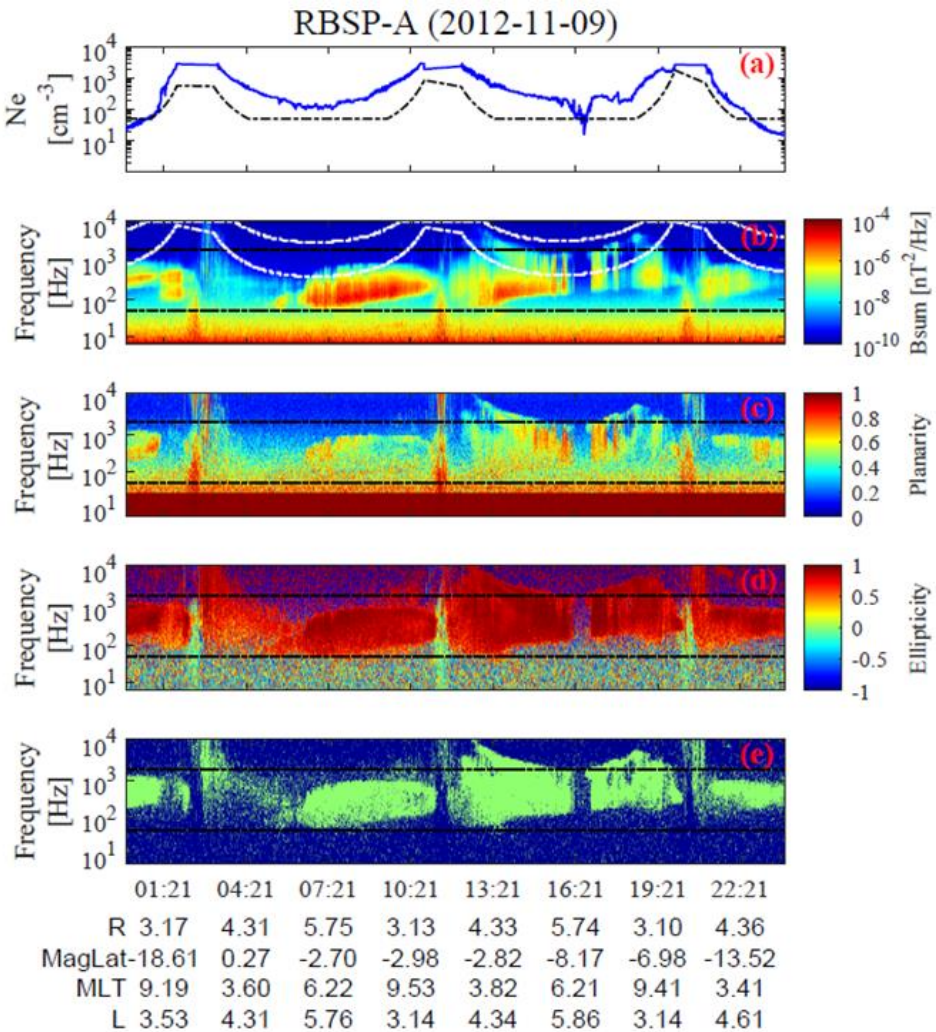


FIG 1

Criterions :

(a) Ne > max ($10 \times (6.6/L)^4$, 50 cm^{-3});
(b) Broad band in ~ 50 - 2000Hz;
(c) Planarity > 0.2;
(d) Ellipticity > 0.7;
(e) Bins that meet standards c & d.

(Li et al., 2010, 2015; Kim & Shprits,2018);

Exclude:

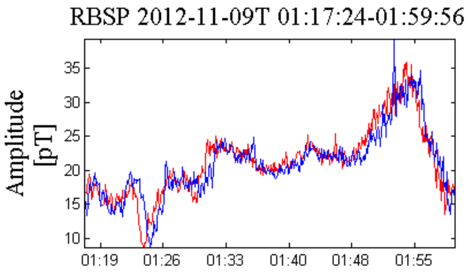
1, Chorus wave (with rising or falling tones between 0.1 - 0.8 fce);
2, Magnetosonic wave (ellipticity ~ 0).

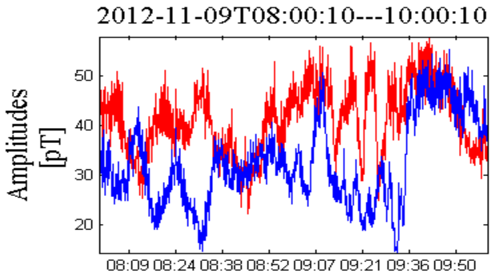
Hiss list:

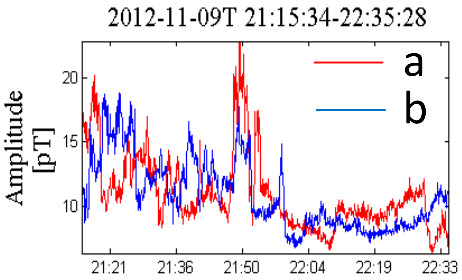
2012-11-09	00:37:11	02:01:38	~1. 5h
2012-11-09	06:29:31	11:01:47	~3. 5h
2012-11-09	12:21:51	15:47:08	~3. 5h
2012-11-09	16:57:01	19:35:43	~2. 5h
2012-11-09	21:05:59	22:31:53	~1. 5h

• 2.3 The correlation of hiss amplitudes between RBSP A&B

1. Get the Intergraded wave amplitudes across 50-2000 Hz.







2. For **Spatial** correlation (same time), the correlation coefficients are calculated between red and blue lines:

Coefficients:	0.8941	0.1310	0.4540
ΔR:	$0.03R_E$	$0.09R_E$	$0.26R_E$

3. For **Temporal** correlation (same position), we first get the time lag between RBSP A&B from their positions:

Time lag:	4(~24s)	41(~246s)	69(~414s)

Then we shift blue line by Time lag, and calculate the correlation coefficients between the red and shifted blue lines:

Coefficients:	0.9189	0.3495	0.3299

* The ratio of amplitudes between RBSP A&B can also be calculated.

• 2.3 The correlation of hiss amplitudes between RBSP A&B

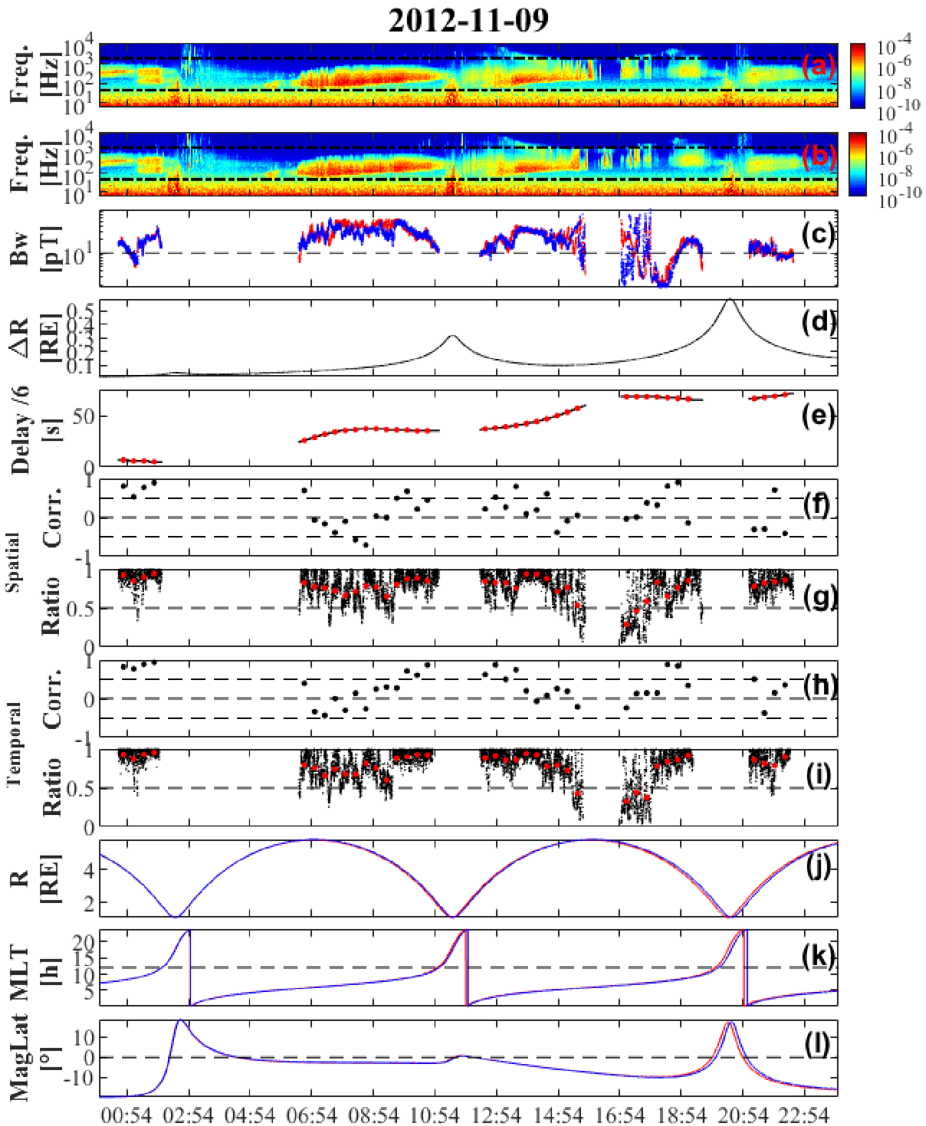


FIG 2

- **Spacecraft separation**
- **Spacecraft time lag**
- **Spatial correlation and ratio** of amplitudes in panel c;
- **Temporal correlation and ratio** of amplitudes.
- A total of 1923 events with small separation ($<1R_E$) were found during 2012-2015.

3. Statistical results of the spatial and temporal correlation

• 3.1 Hiss is uniform or not (A total of 1923 events)

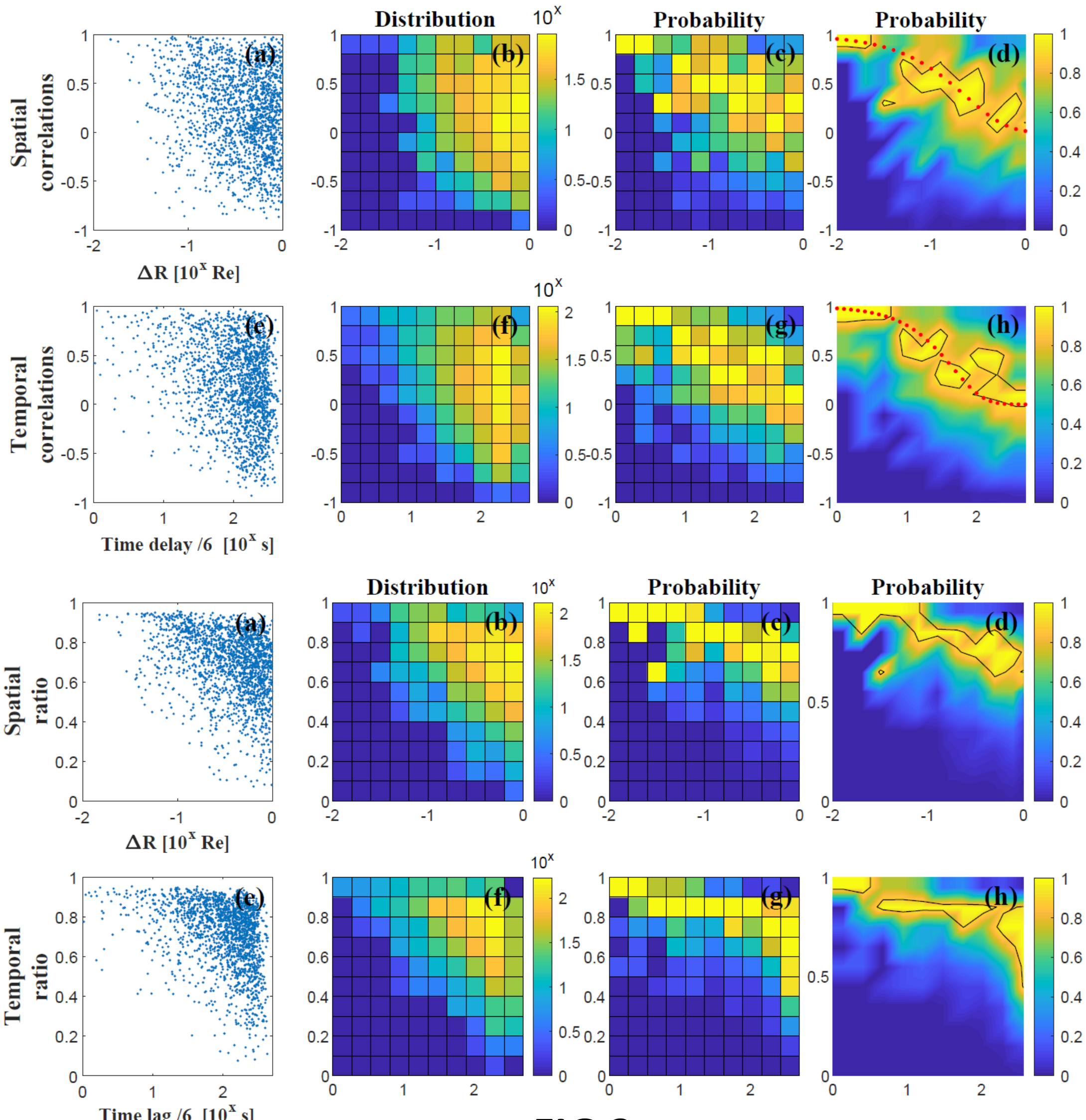


FIG 3

- **Hiss is not always uniform in plasmasphere (~8% coefficients > 0.8, fewer events in the lower left part).**
- **As separation and time delay increase, both the correlation coefficients and ratios of amplitudes decreased significantly.**
- Before analyzing when the hiss becomes incoherent, we need to check the effects of L-shell, MLT and AL*, which will be shown in next slides.

• 3.2 The effects of L-shell, MLT, AL*

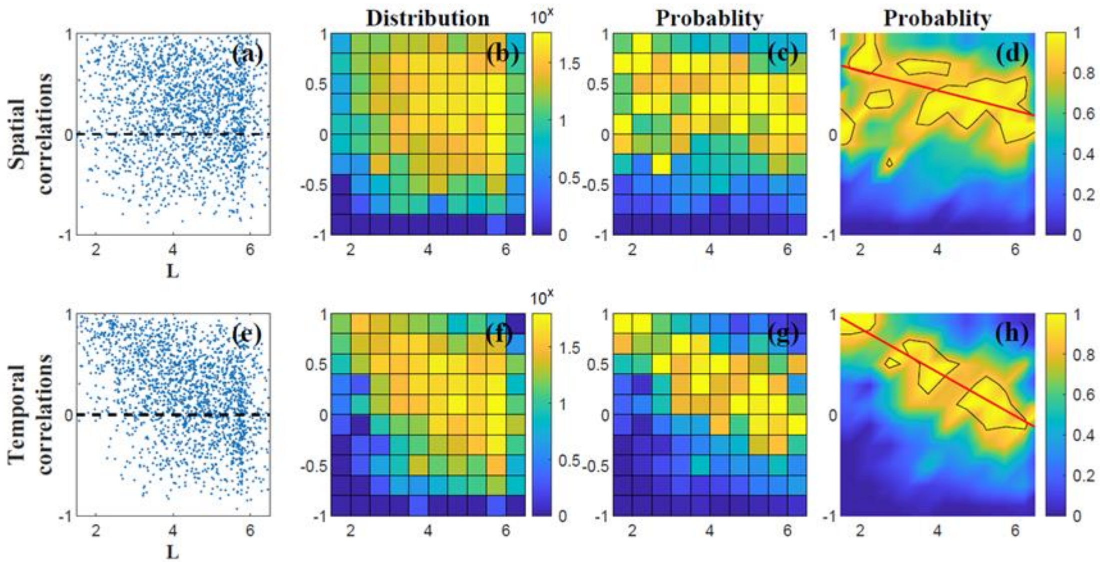
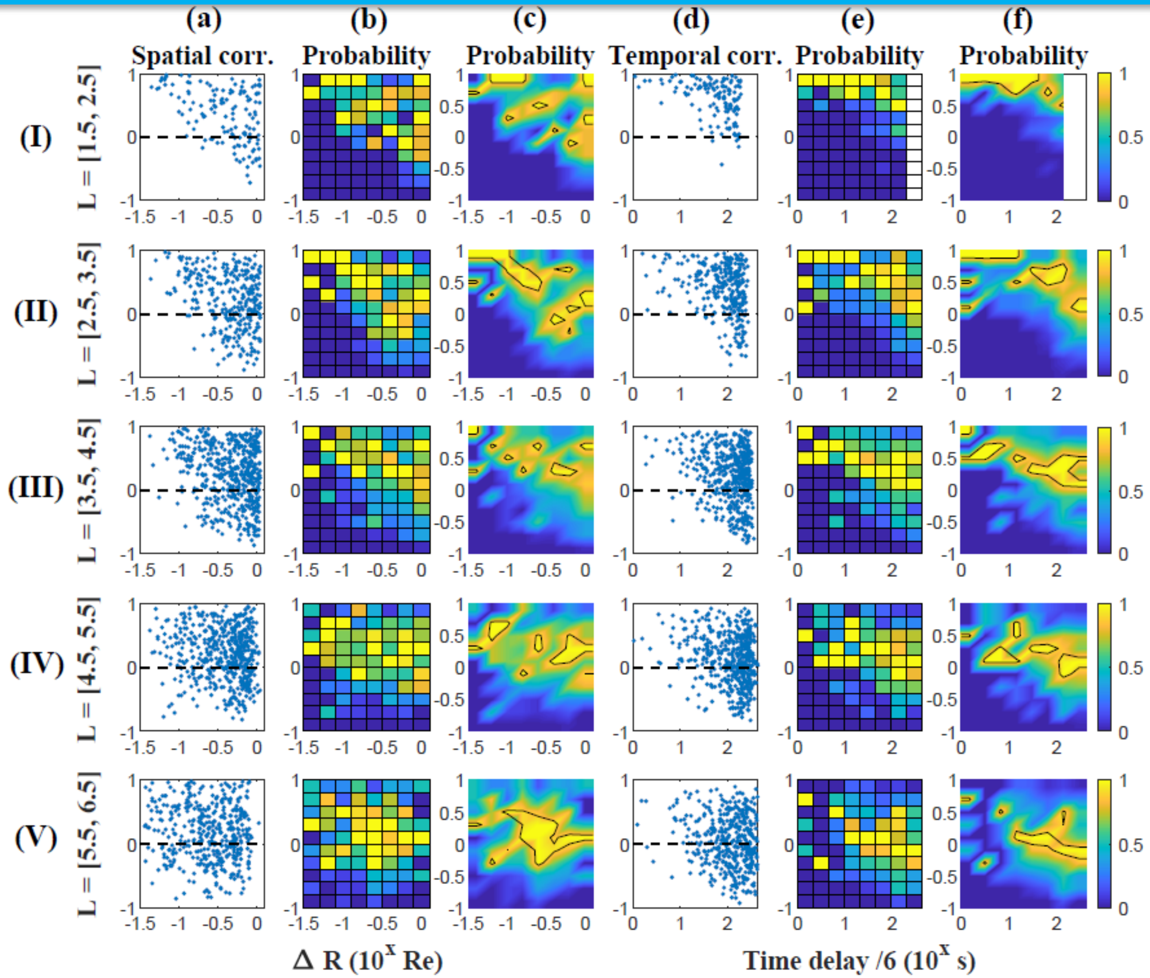


FIG 4

- **The spatial coherence is slightly higher at smaller L than larger L.**
- **The temporal coherence is clearly higher at smaller L than larger L.**
- Spatial and temporal ratios also show similar distributions, not shown here.
- The effects of MLT & AL* have also been investigated, while no clear effects are found.

• 3.3 The effect of different L-shells in detail

FIG 5

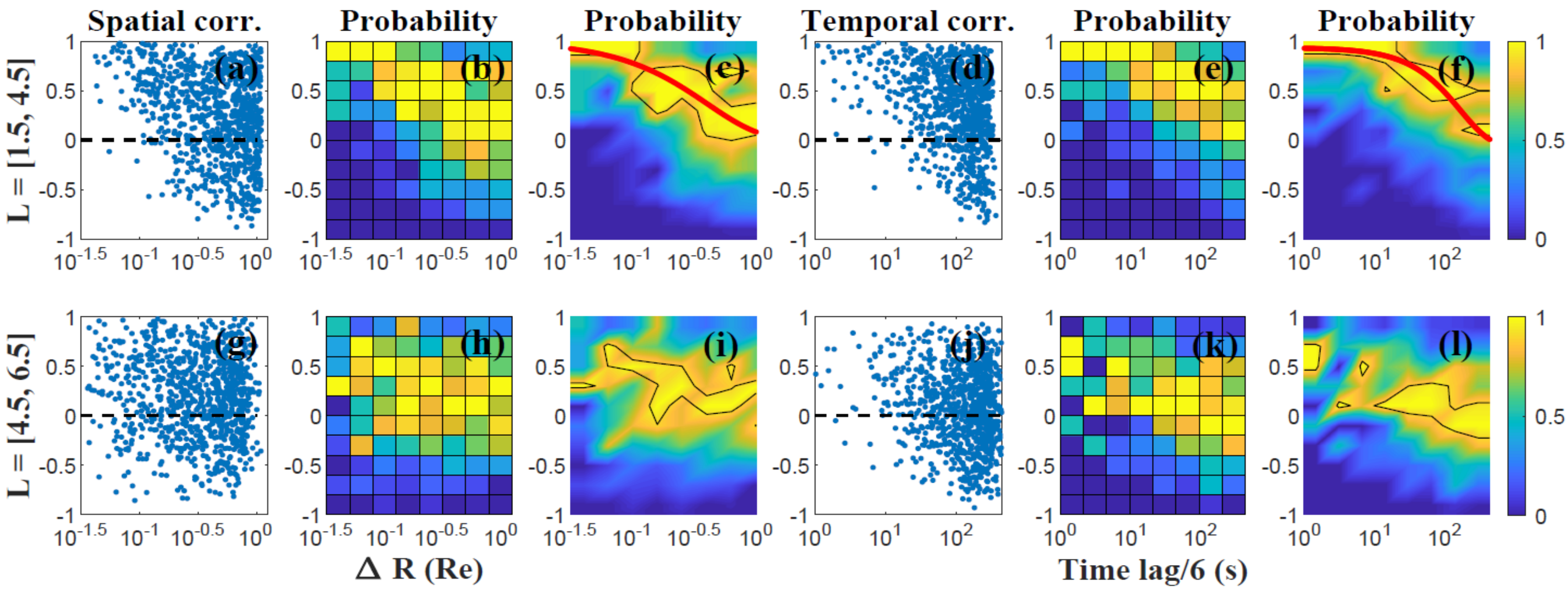


- Both spatial and temporal coherence are higher at smaller L-shell than larger L-shell;
- **Hiss is almost spatial and temporal incoherence at L > ~4.5.**
- **Both spatial and temporal coherence decreases with increasing ΔR and Time Lag at L < 4.5.**

• 3.4 How rapidly the correlation decreasing

Fitting model (weighted):
f(x) = e^kx^

FIG 6



Corr.-spatial $= e^{-2.486 * \Delta R}$ R-square= 0.3586

Corr.-temporal $= e^{-0.006002 * lag}$ R-square= 0.5669

L<4.5:

- **Both spatial and temporal coherence decreases with increasing ΔR and Time Lag.**
- **Hiss is spatial incoherence (<0.3) when ΔR > ~0.48 R_E;**

  temporal incoherence (<0.3) when Time lag/6 > ~200 (20min).

L>4.5:

- **Hiss is nearly spatial and temporal incoherence.**

Conclusion

- The global coherence of plasmaspheric hiss wave is analyzed statistically using data from EMFISIS instruments on board the RBSP spacecraft during the period from 2012 to 2015. We find:

- Both the spatial and temporal coherence of plasmaspheric hiss are decreasing with increased L-shell and close to 0 when L > ~4.5.

- For L < 4.5, both the spatial and temporal coherence show a clear downward trend as separation and time lag increase, and the hiss becomes incoherent when ΔR > ~0.48 RE and Time lag > ~20 min.
- No significant influence from different MLT and substorm activity to the global coherence of the plasmaspheric hiss.

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THANKS