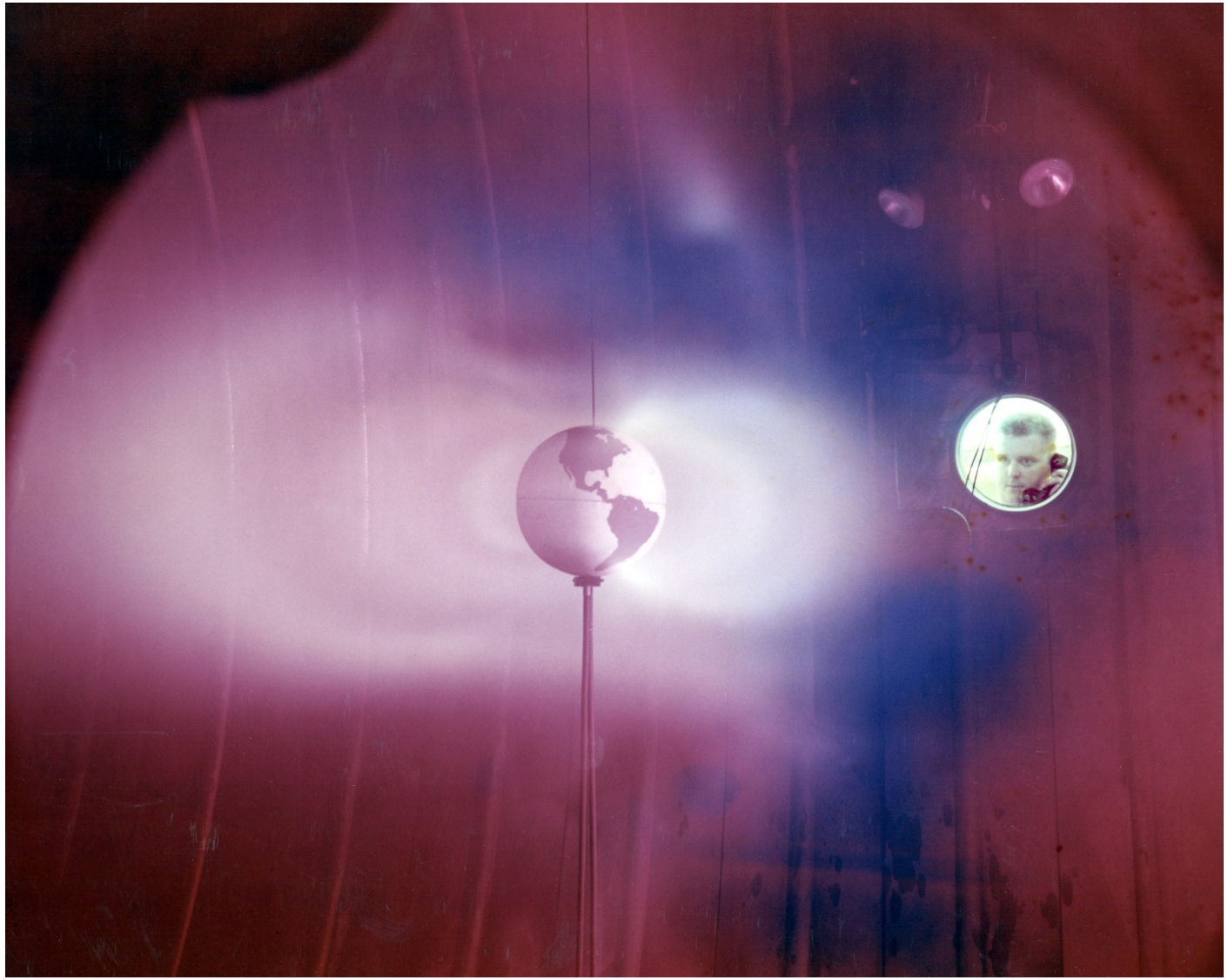
Variations of Whistler Mode Waves with Geomagnetic Activity and Magnetic Local Time

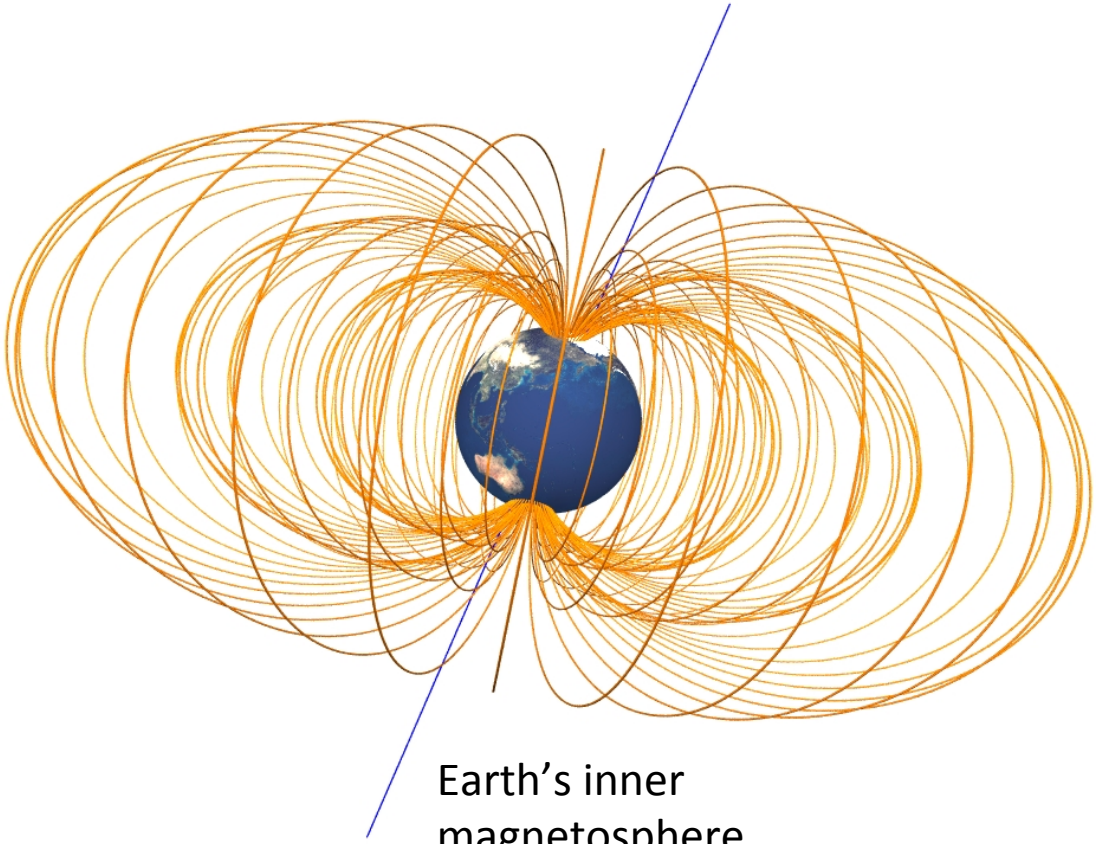
Cory Boulé, Keene State College
mentors: Allison Jaynes, David Malaspina,
Laboratory for Atmospheric and Space Physics



Laboratory for Atmospheric and Space Physics
University of Colorado Boulder

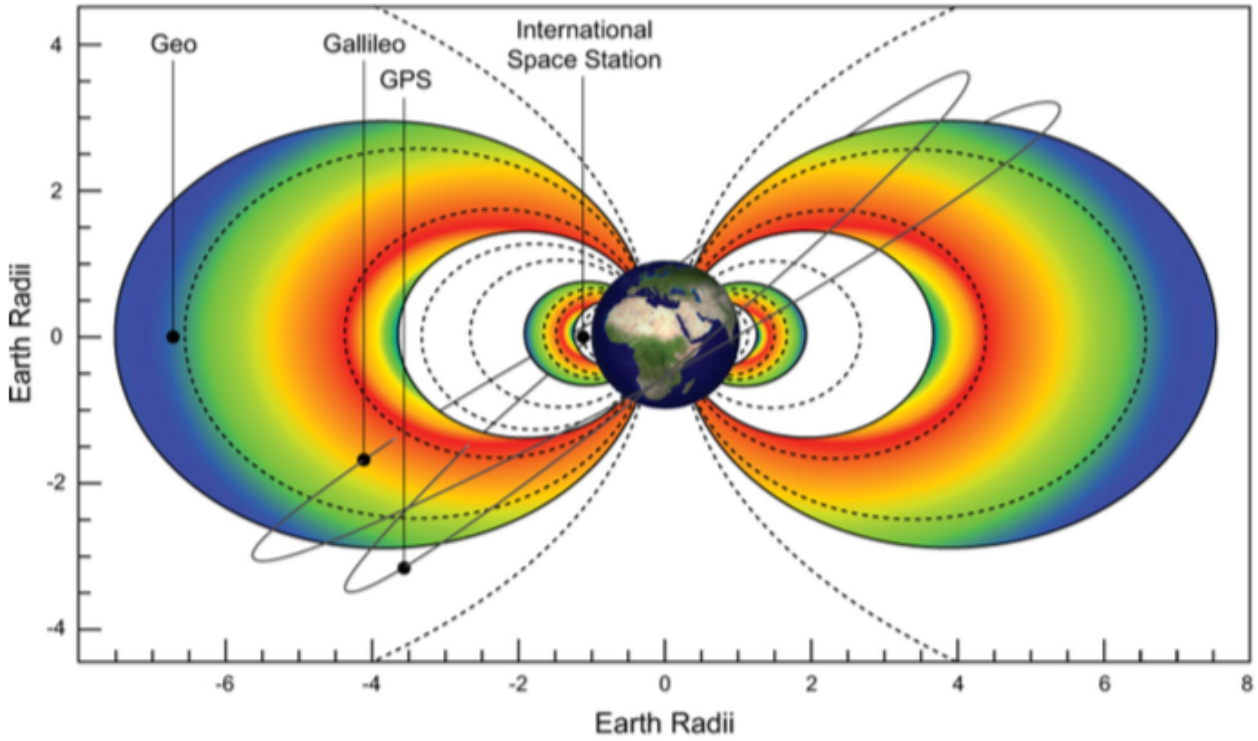
Van Allen Probes

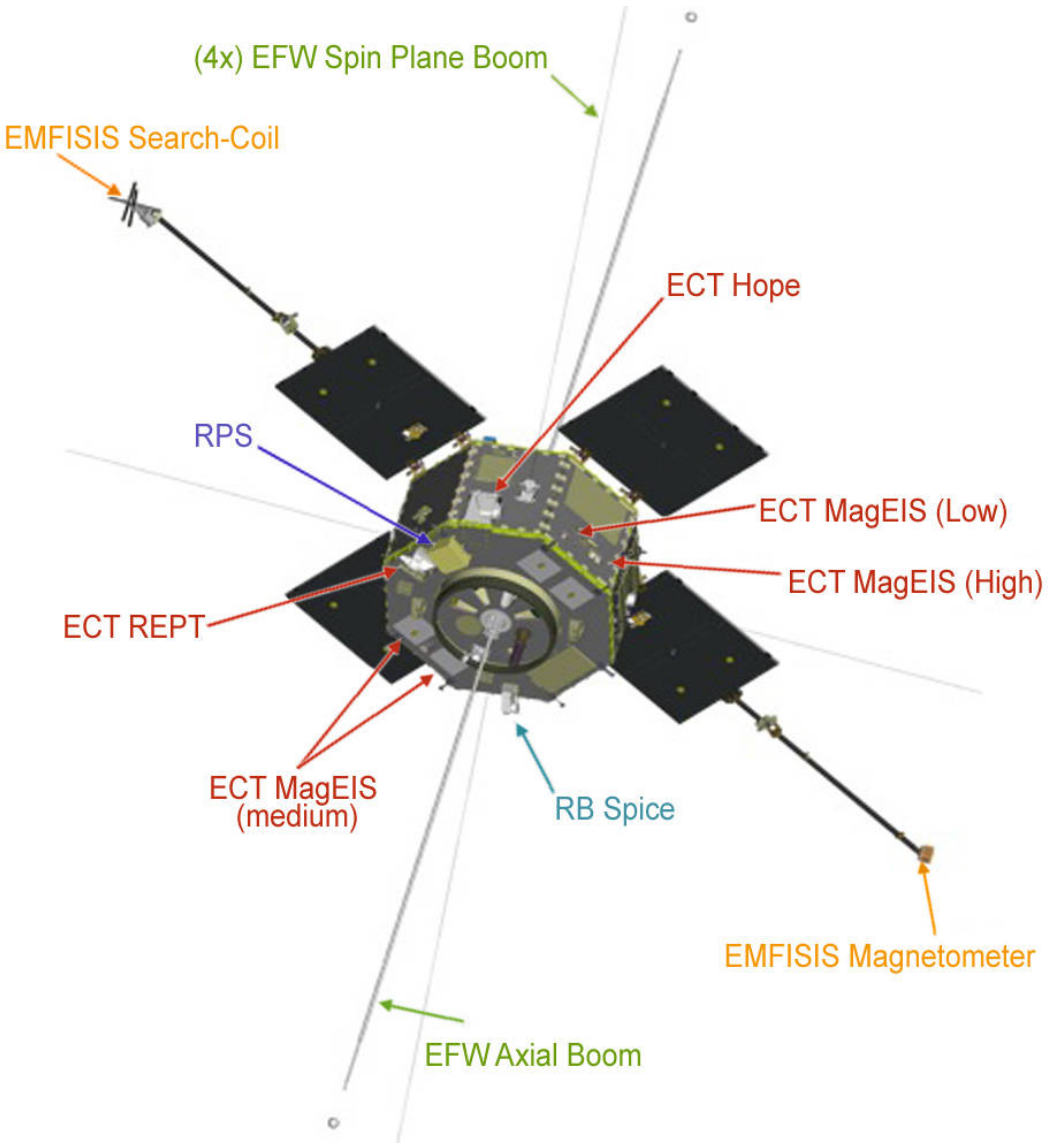
Keene STATE COLLEGE

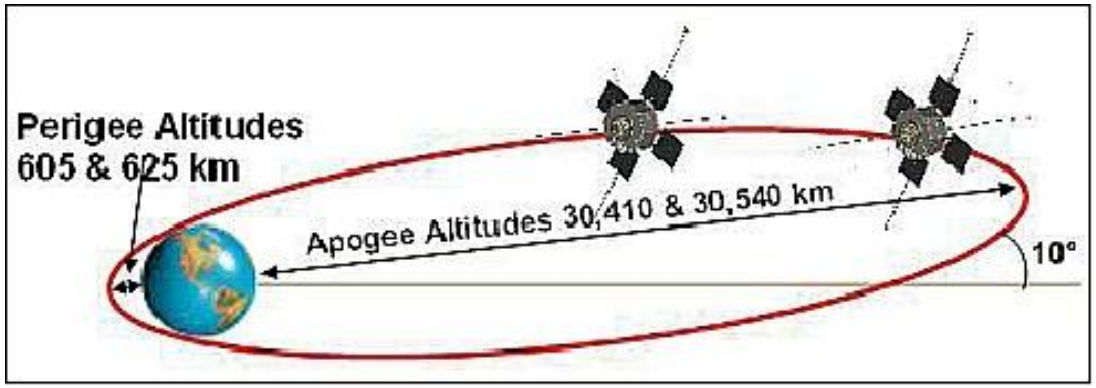


Earth’s inner magnetosphere

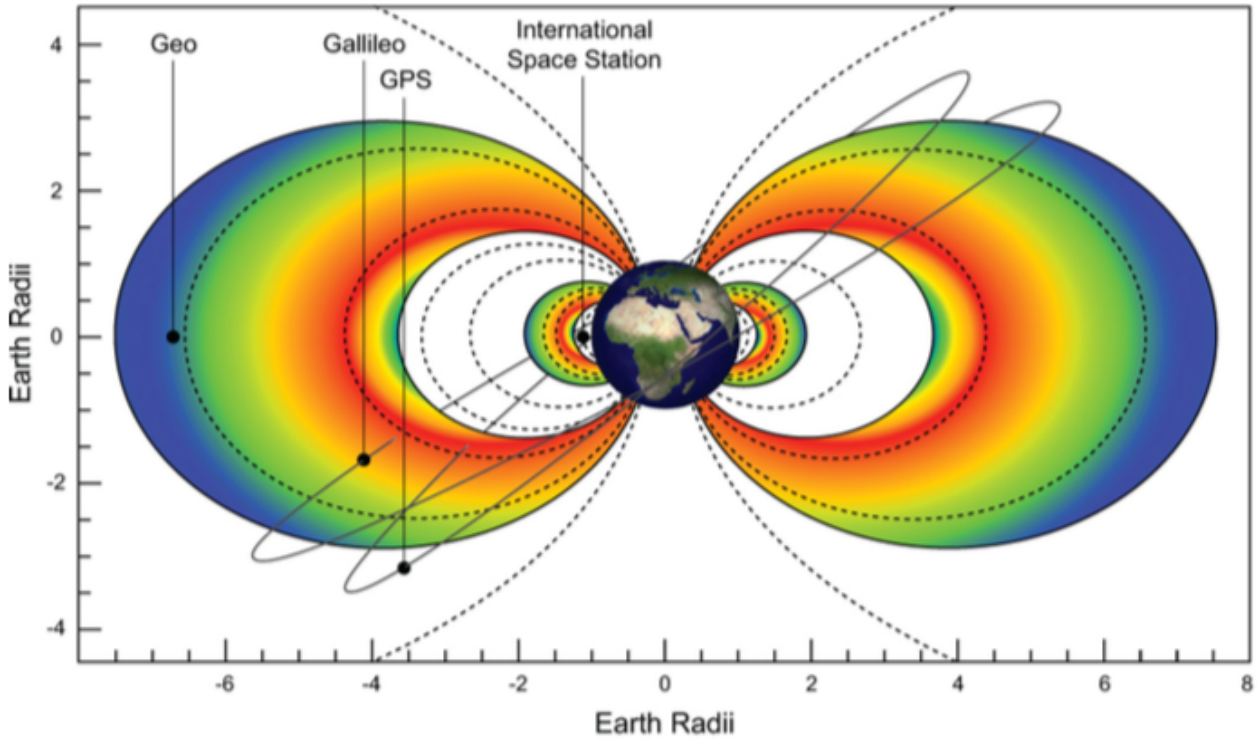
Earth’s radiation belts



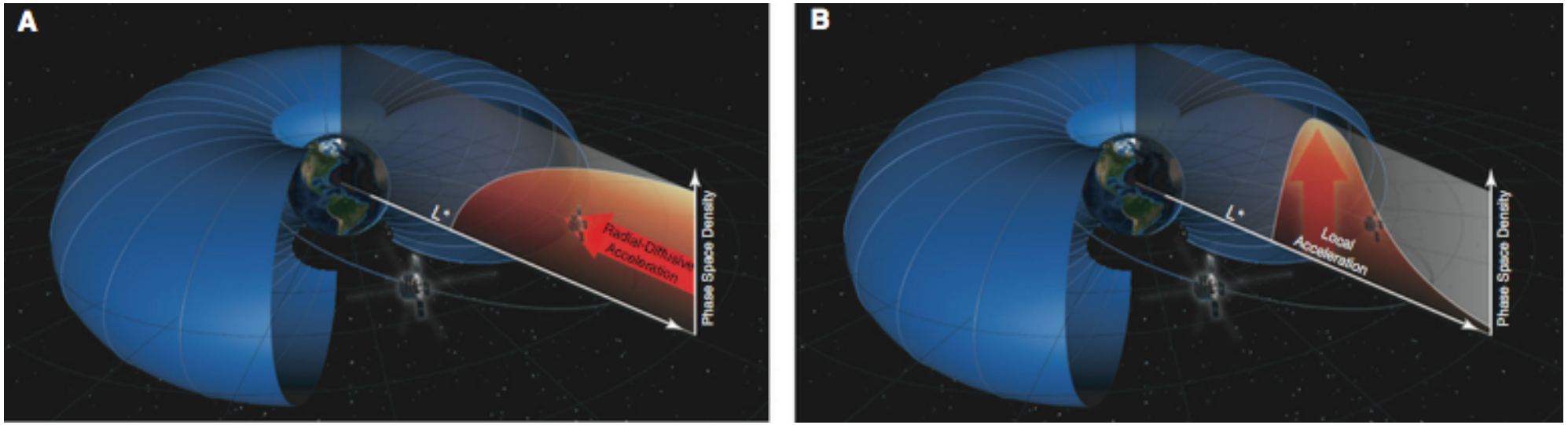




Earth's radiation belts



Electron acceleration to radiation belt energies: two proposed mechanisms

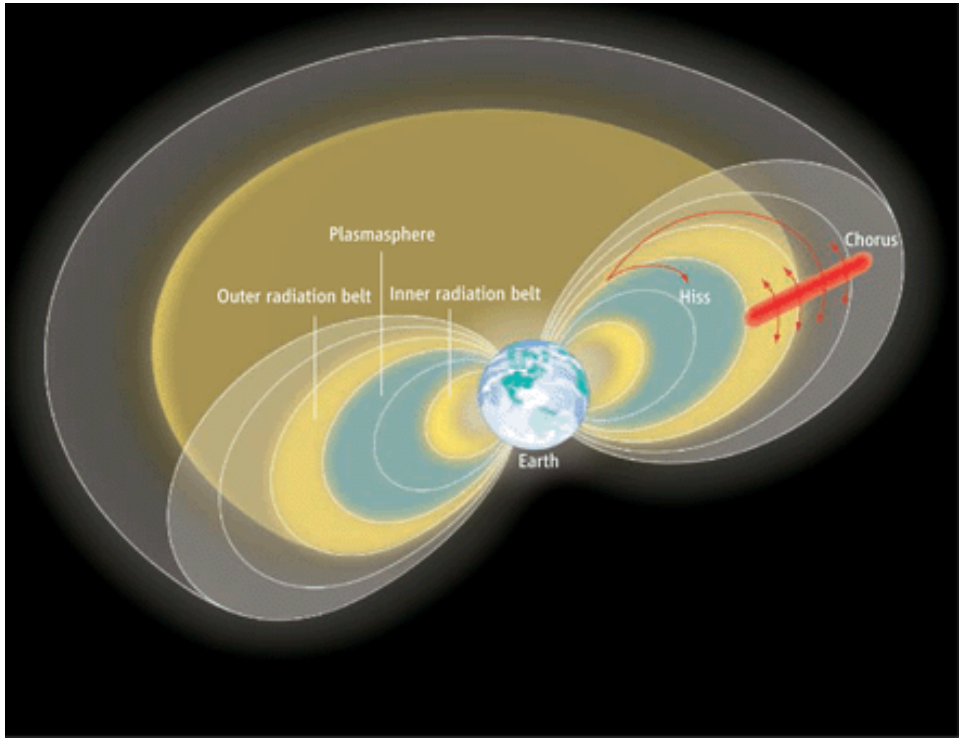


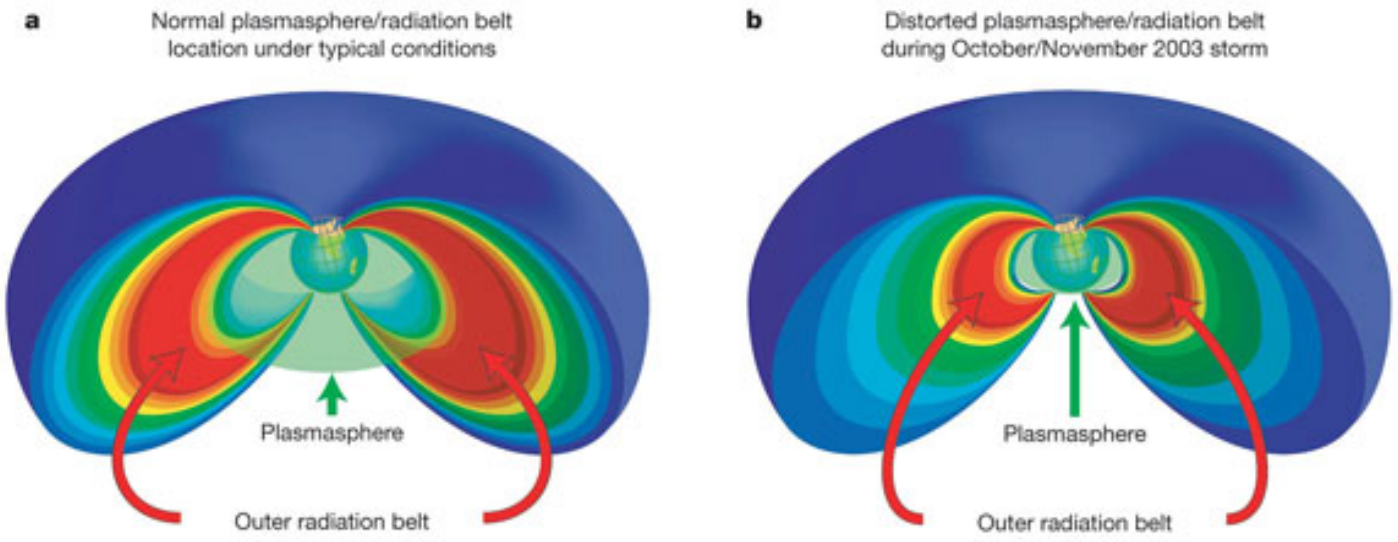
Reeves et al., ***Science*** vol. 341, pp 991

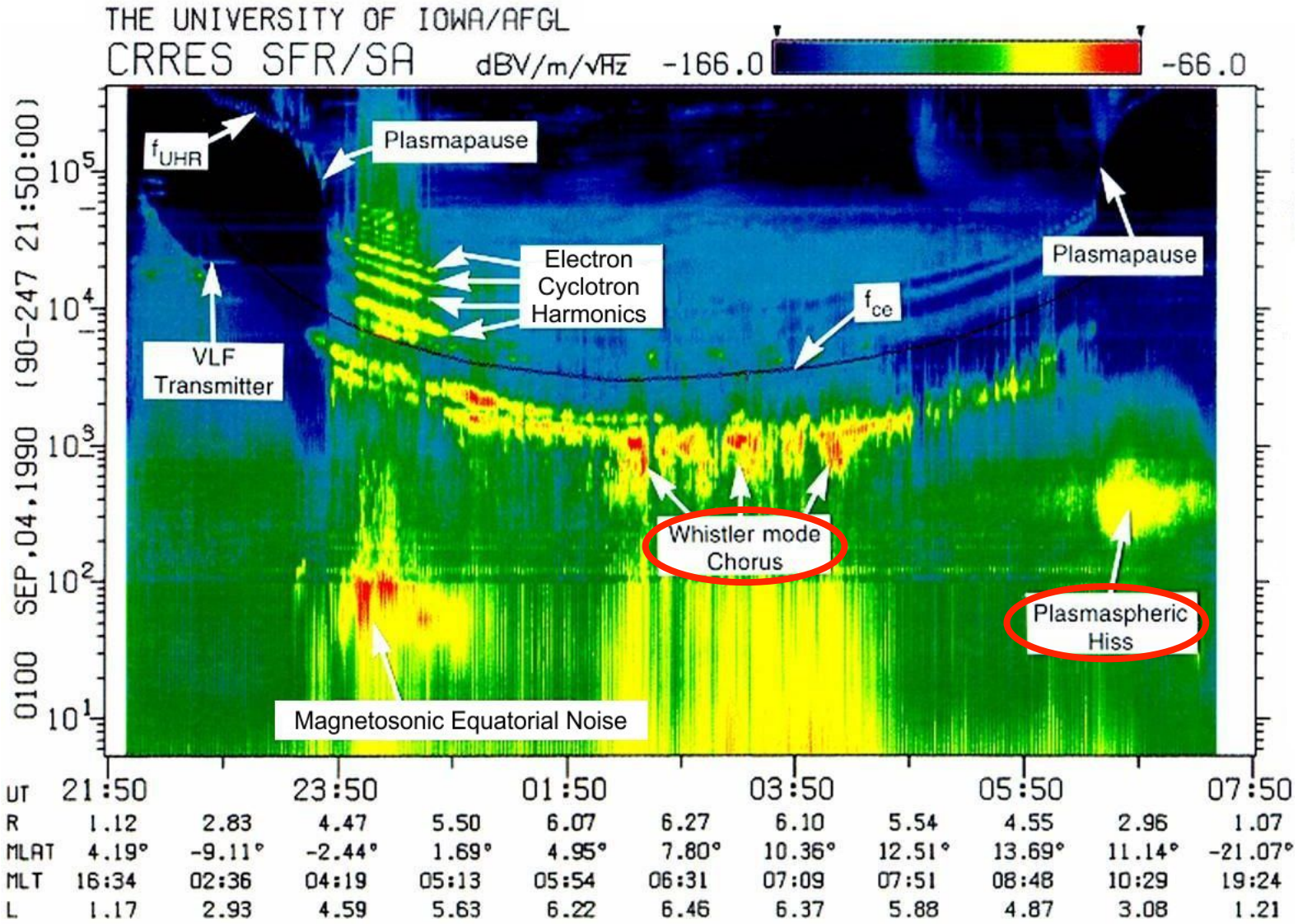
Radial-diffusive acceleration

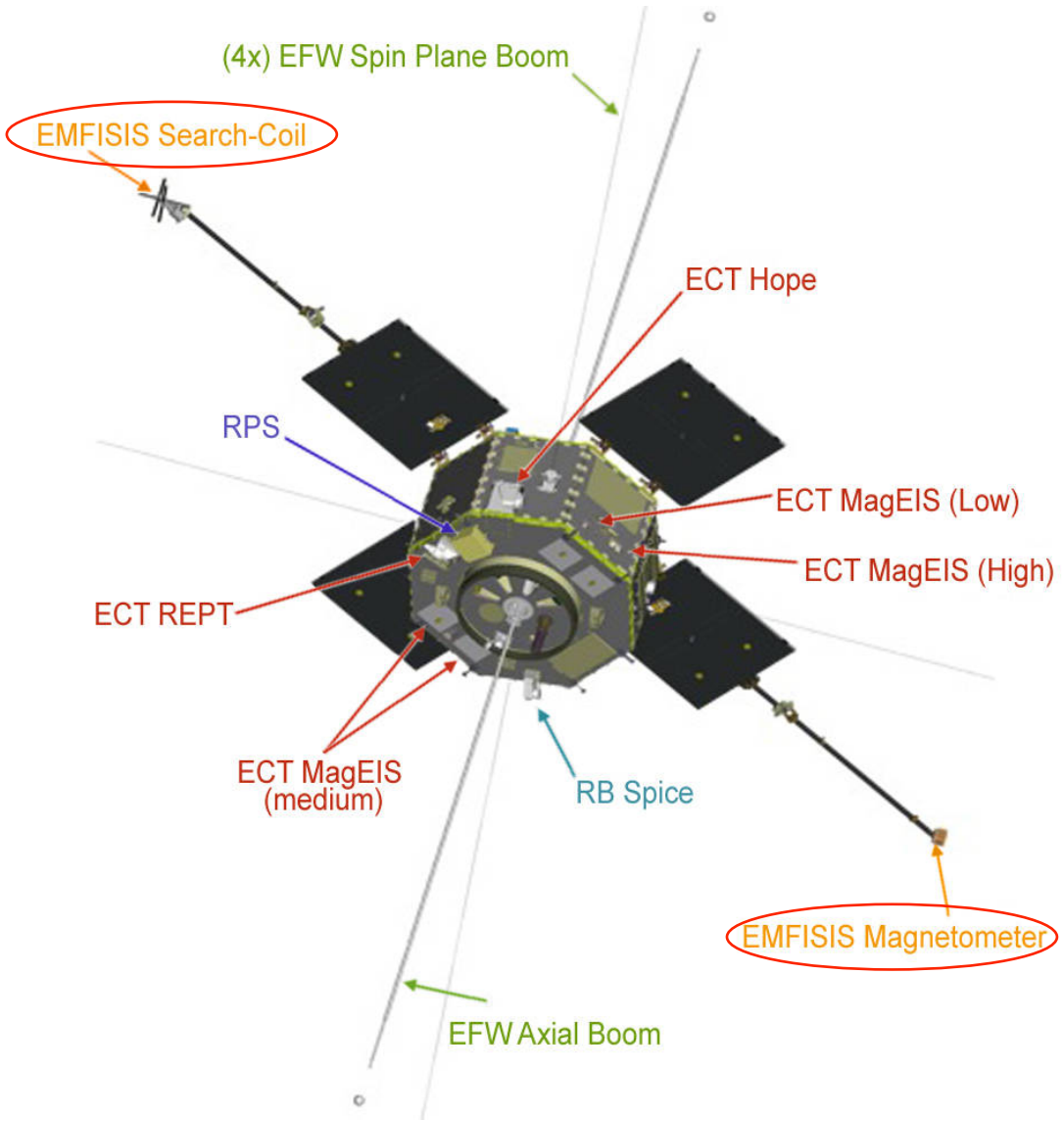
Local acceleration

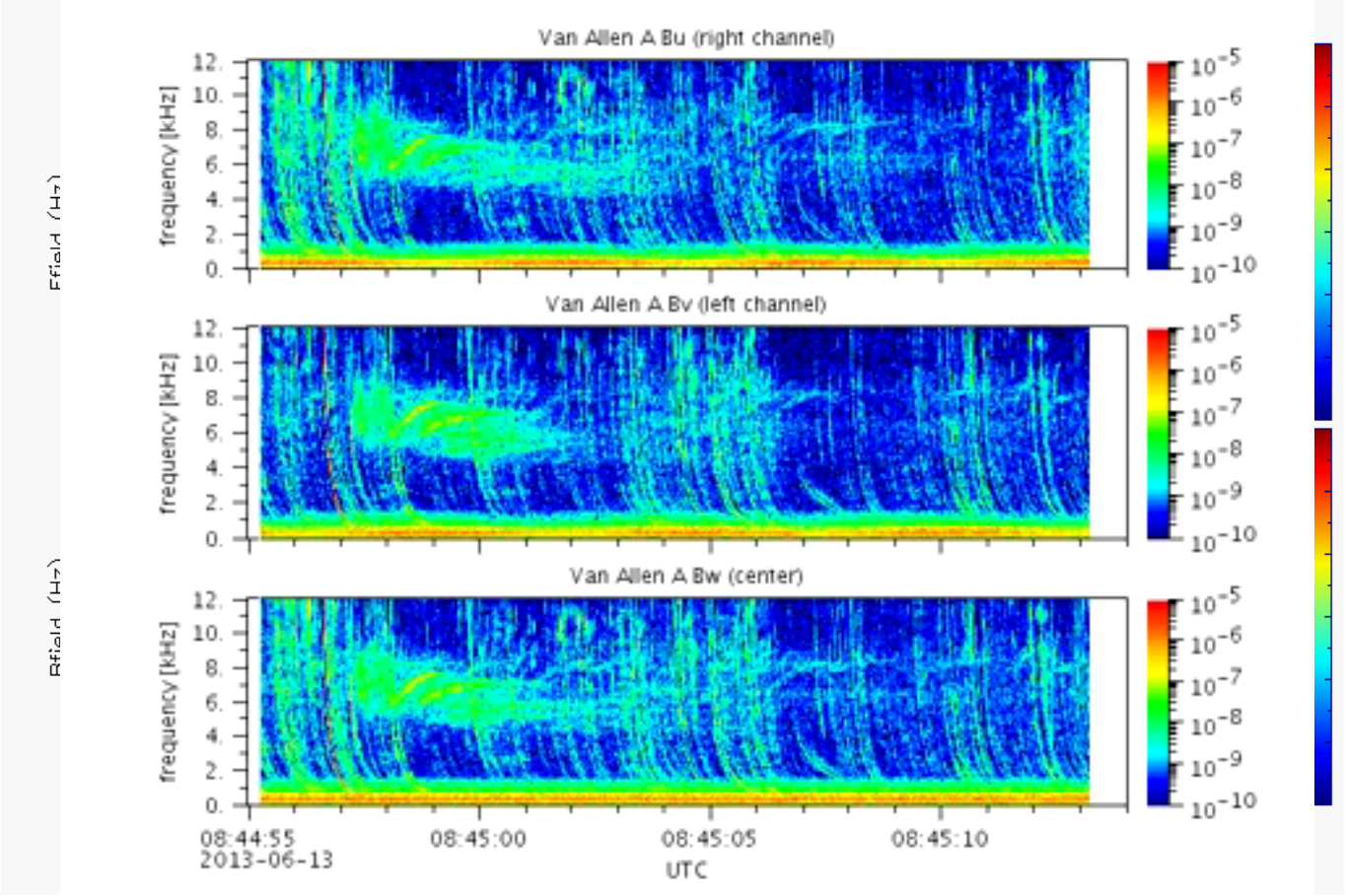
Further reading: Reeves G.D., Spence H.E., Henderson M.G., Morley S.K., Friedel R.H.W., Funsten H.O., Baker D.N., Kanekal S.G., Blake J.B., Fennell J.F. et al. 2013. Electron acceleration in the heart of the Van Allen radiation belts. Science 341: pp 991-994


Plasmasphere
Outer radiation belt
Inner radiation belt
Chorus
Hiss
Earth


a
Normal plasmasphere/radiation belt location under typical conditions
Plasmasphere
Outer radiation belt
b
Distorted plasmasphere/radiation belt during October/November 2003 storm
Plasmasphere
Outer radiation belt


THE UNIVERSITY OF IOWA/AFGL
CRRES SFR/SA
dBV/m/√Hz
-166.0
-66.0
0100 SEP,04,1990 (90-247 21:50:00)
10^5
10^4
10^3
10^2
10^1
f_{UHR}
Plasmapause
Electron Cyclotron Harmonics
f_{ce}
Plasmapause
VLF Transmitter
Whistler mode Chorus
Plasmaspheric Hiss
Magnetosonic Equatorial Noise
UT 21:50 23:50 01:50 03:50 05:50 07:50
R 1.12 2.83 4.47 5.50 6.07 6.27 6.10 5.54 4.55 2.96 1.07
MLAT 4.19° -9.11° -2.44° 1.69° 4.95° 7.80° 10.36° 12.51° 13.69° 11.14° -21.07°
MLT 16:34 02:36 04:19 05:13 05:54 06:31 07:09 07:51 08:48 10:29 19:24
L 1.17 2.93 4.59 5.63 6.22 6.46 6.37 5.88 4.87 3.08 1.21


(4x) EFW Spin Plane Boom
EMFISIS Search-Coil
ECT Hope
RPS
ECT MagEIS (Low)
ECT MagEIS (High)
ECT REPT
ECT MagEIS
(medium)
RB Spice
EMFISIS Magnetometer
EFW Axial Boom

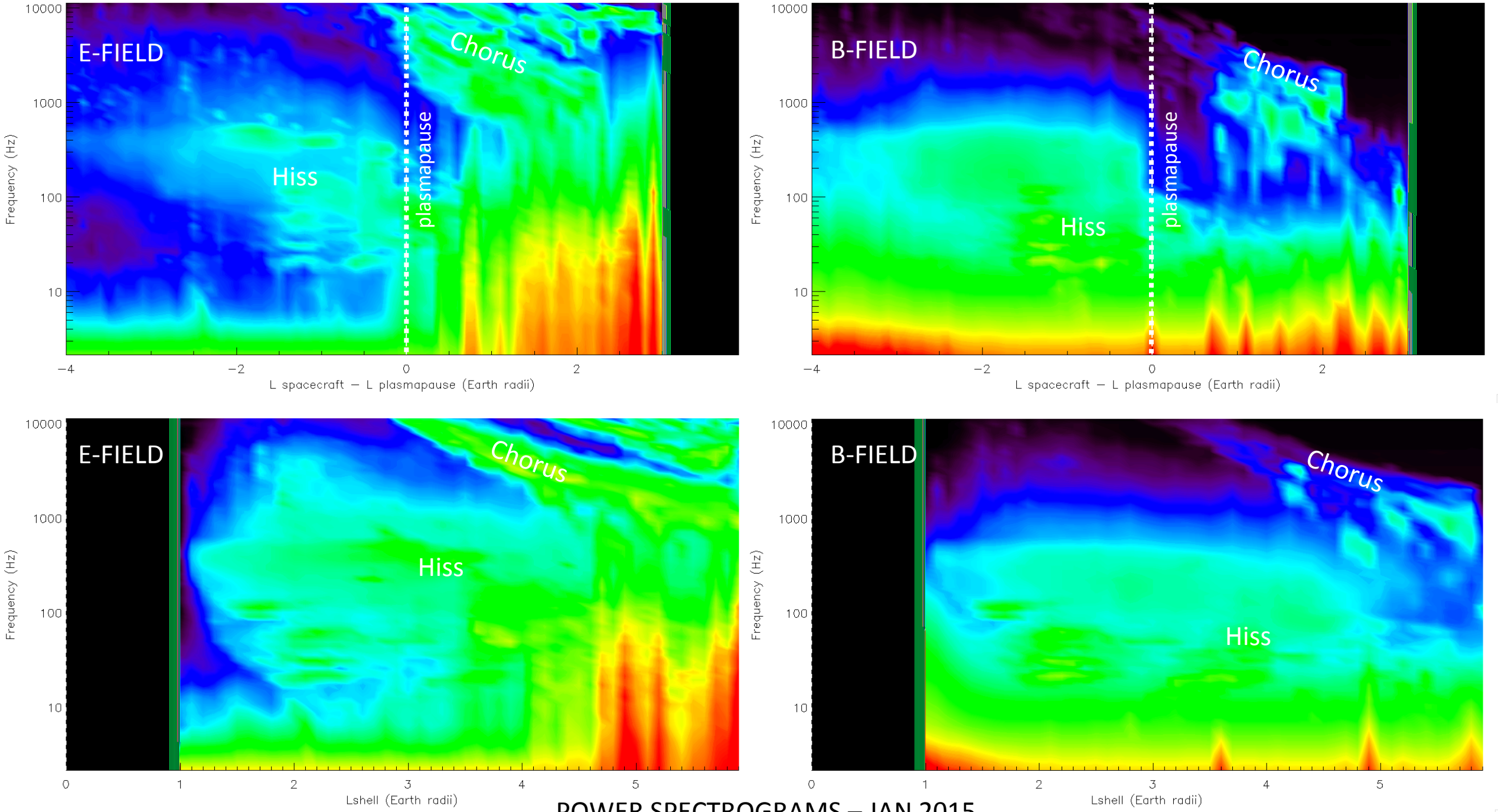

Van Allen A Bu (right channel)
Van Allen A Bv (left channel)
Van Allen A Bw (center)
frequency [kHz]
12.
10.
8.
6.
4.
2.
0.
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
08:44:55
2013-06-13
08:45:00
08:45:05
08:45:10
UTC

Important emission: Chorus

- Discrete, coherent whistler-mode emission
- Occurs in two distinct bands above and below one-half electron gyrofrequency
- Significant in the local acceleration and loss of electrons from the radiation belt to Earth's atmosphere
- Form outside of the plasmasphere

Important emission: Plasmaspheric hiss

- Incoherent whistler-mode emission
- Confined to the interior of the plasmasphere
- Believed to originate from chorus waves propagating to lower L where they become trapped within the plasmasphere
- Observed in plasmaspheric plumes during geomagnetic storms contributing to scattering loss of outer electrons



POWER SPECTROGRAMS – JAN 2015

Our work: Wave variations with AE and MLT

AE:

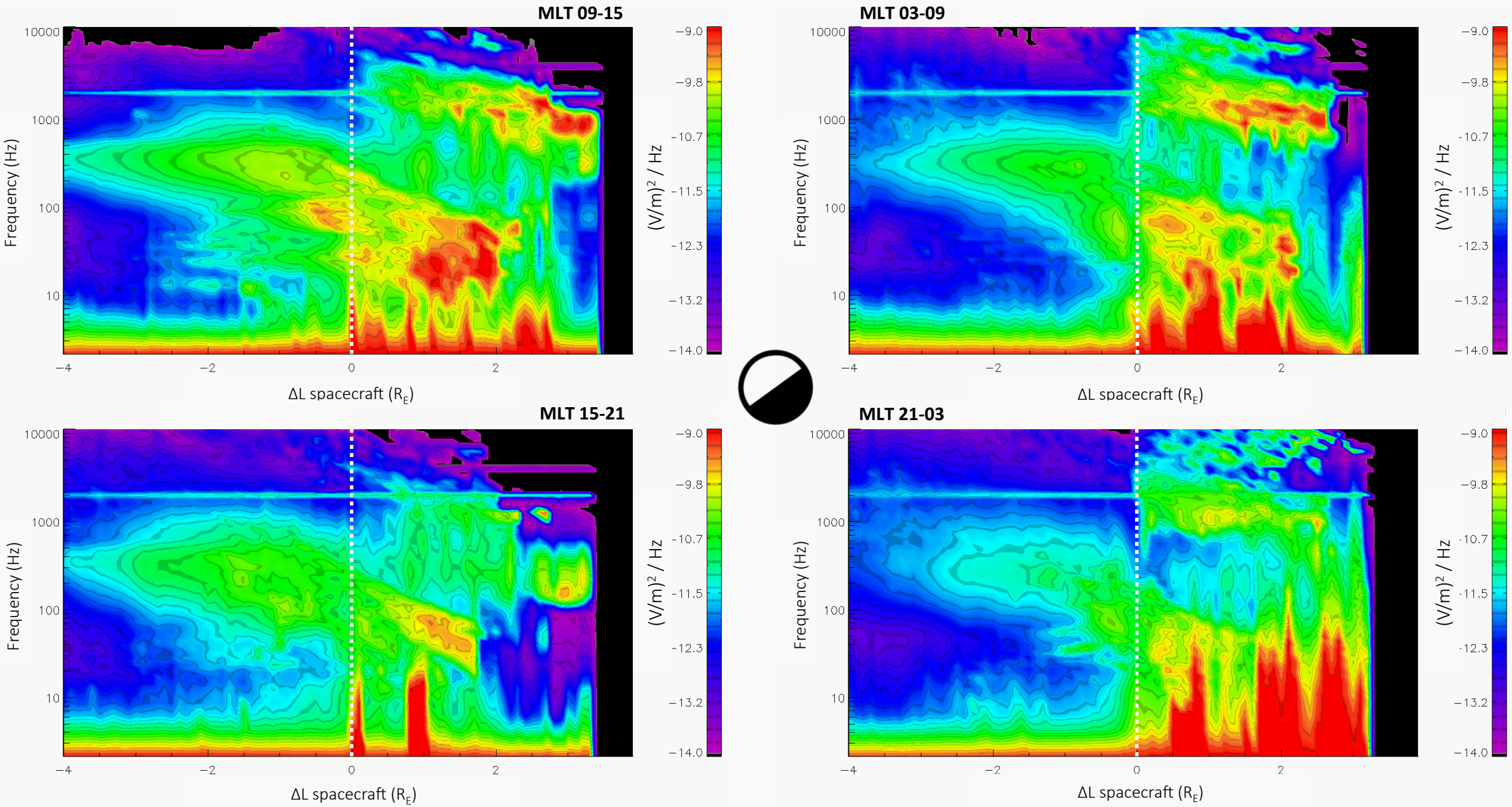
- Auroral electrojet index
- Measure of geomagnetic activity at a given time
- AE 0-150 (low activity), AE 150-300 (moderate activity), AE > 300 (high activity)

MLT:

- Magnetic local time
- Gives spacecraft position relative to the sun
- MLT 03-09 (dawn), MLT 09-15 (day) MLT 15-21 (dusk), MLT 21-03 (night)

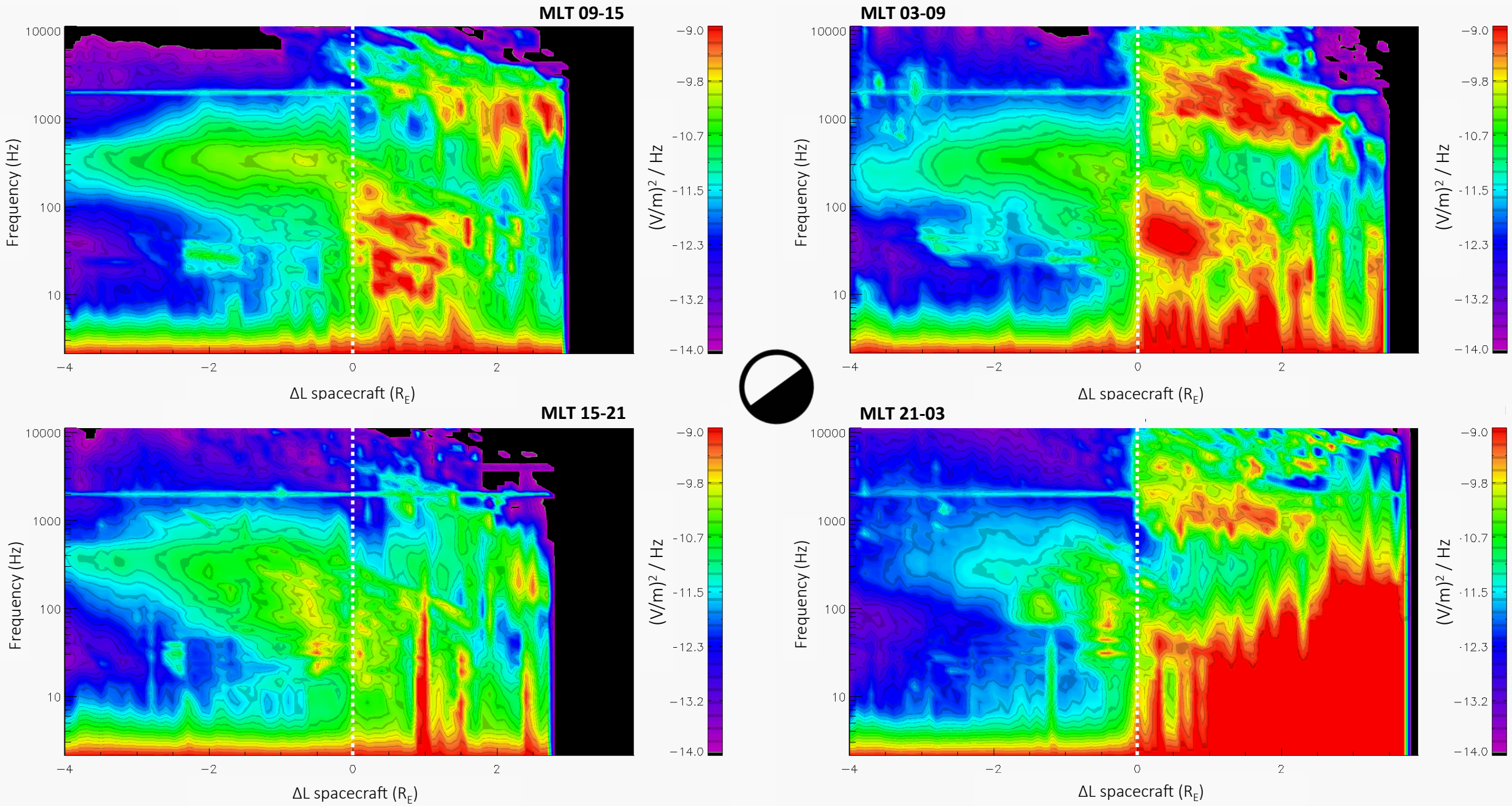
RBSP-A E-field wave power: Frequency vs spacecraft distance from plasmapause ***AE < 150***

2012.10.02 - 2015.05.01



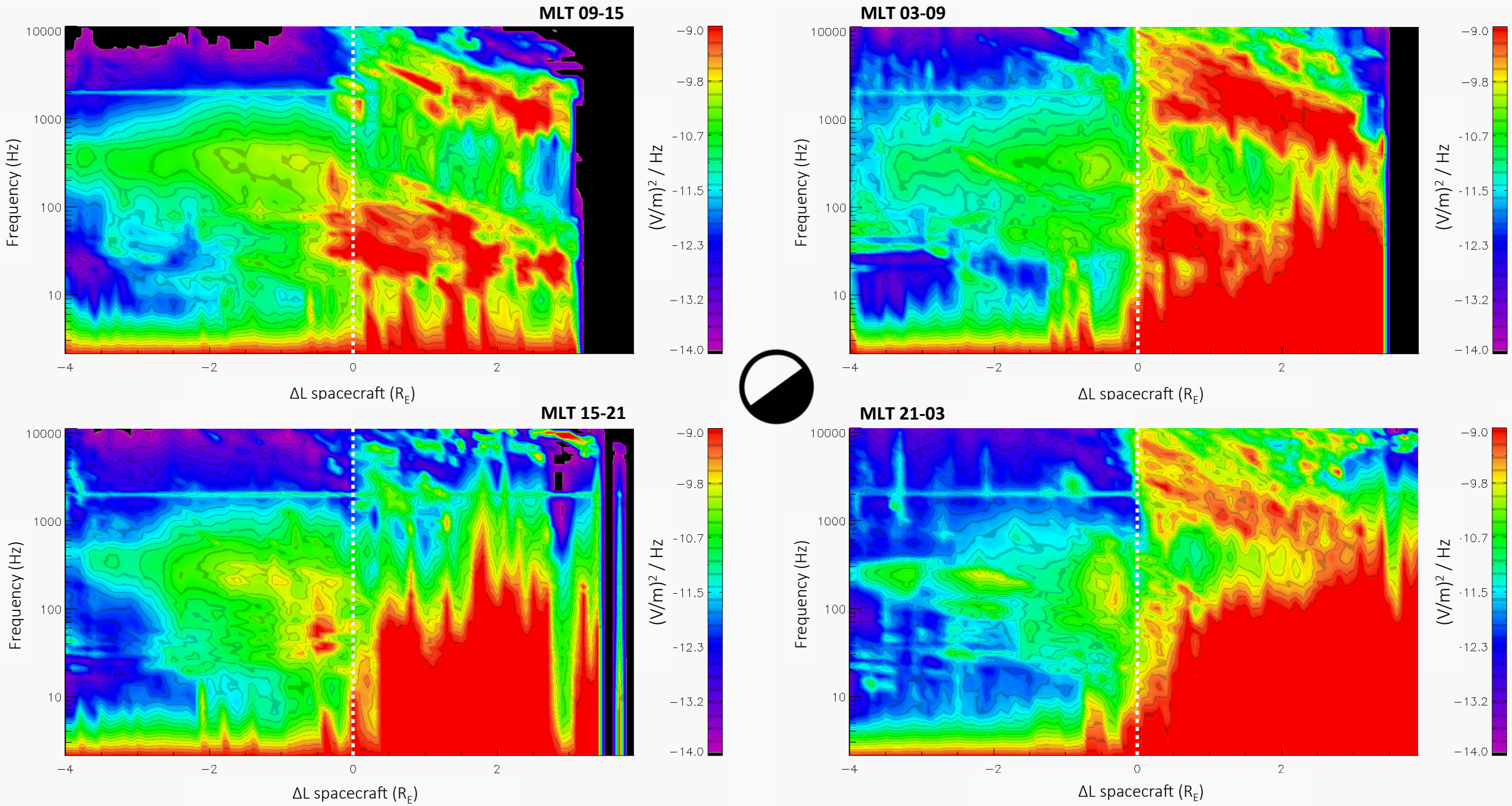
RBSP-A E-field wave power: Frequency vs spacecraft distance from plasmapause ***150 < AE < 300***

2012.10.02 - 2015.05.01



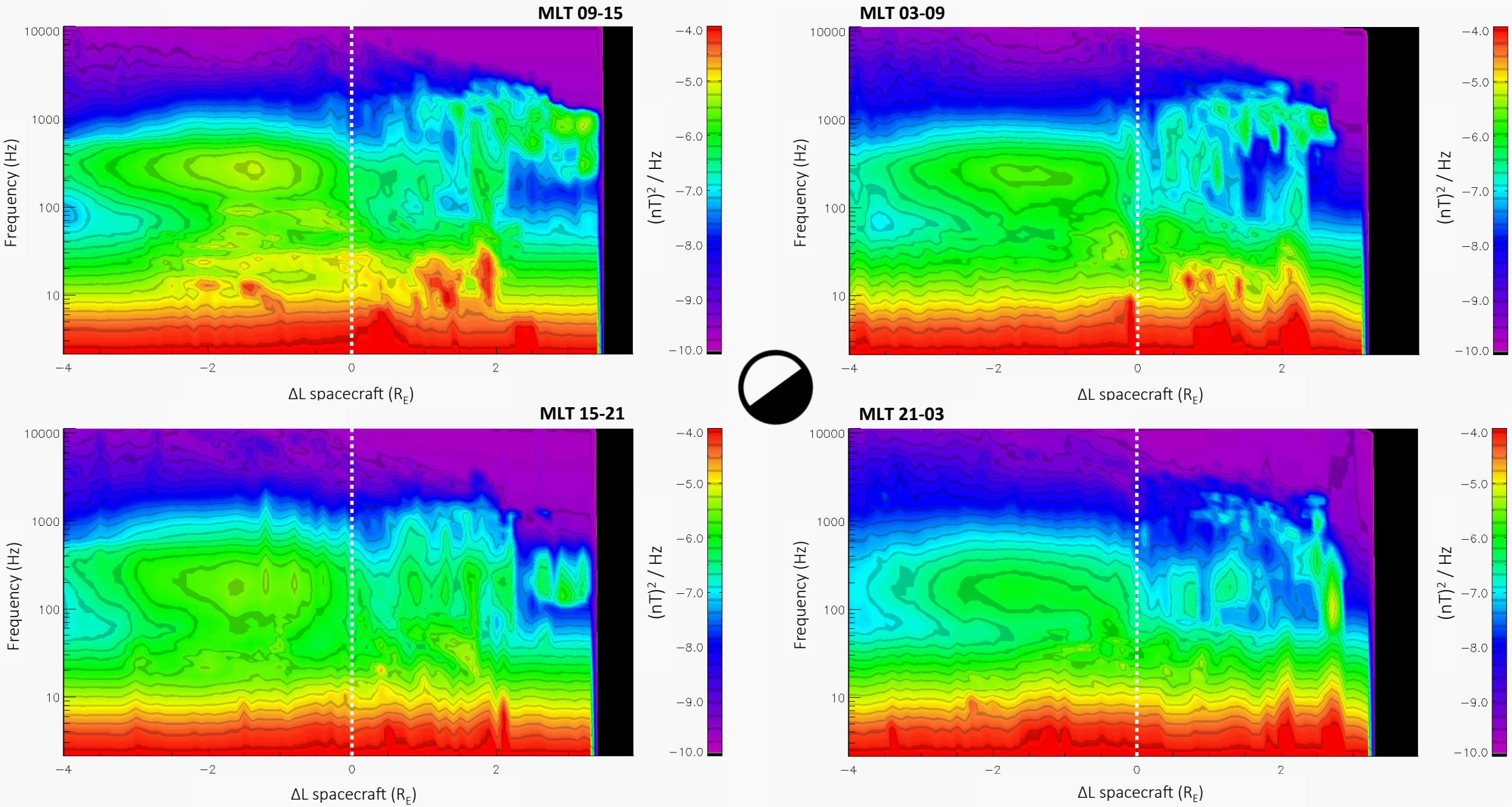
RBSP-A E-field wave power: Frequency vs spacecraft distance from plasmapause ***AE > 300***

2012.10.02 - 2015.05.01



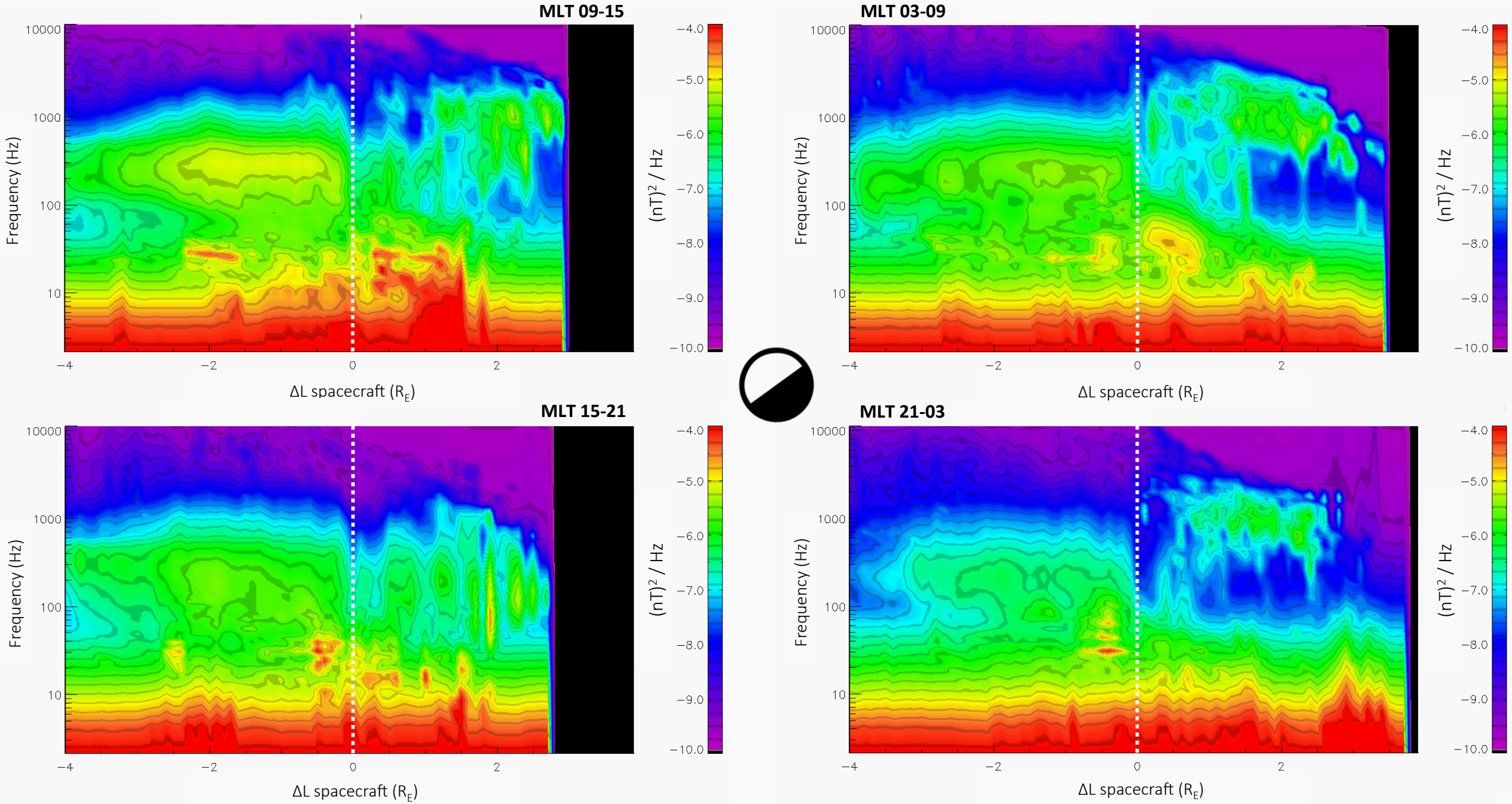
RBSP-A B-field wave power: Frequency vs spacecraft distance from plasmapause ***AE < 150***

2012.10.02 - 2015.05.01



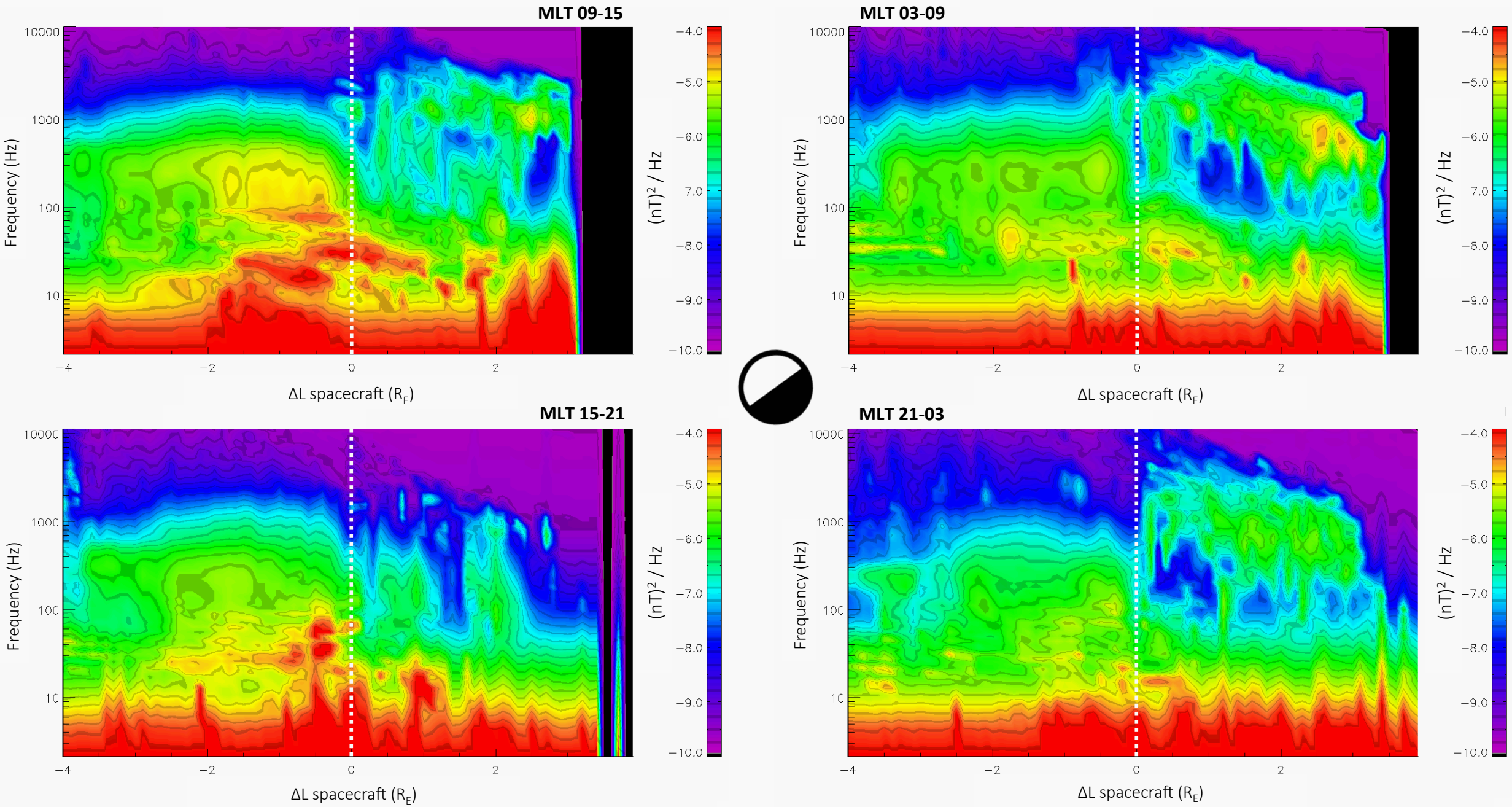
RBSP-A B-field wave power: Frequency vs spacecraft distance from plasmapause ***150 < AE < 300***

2012.10.02 - 2015.05.01



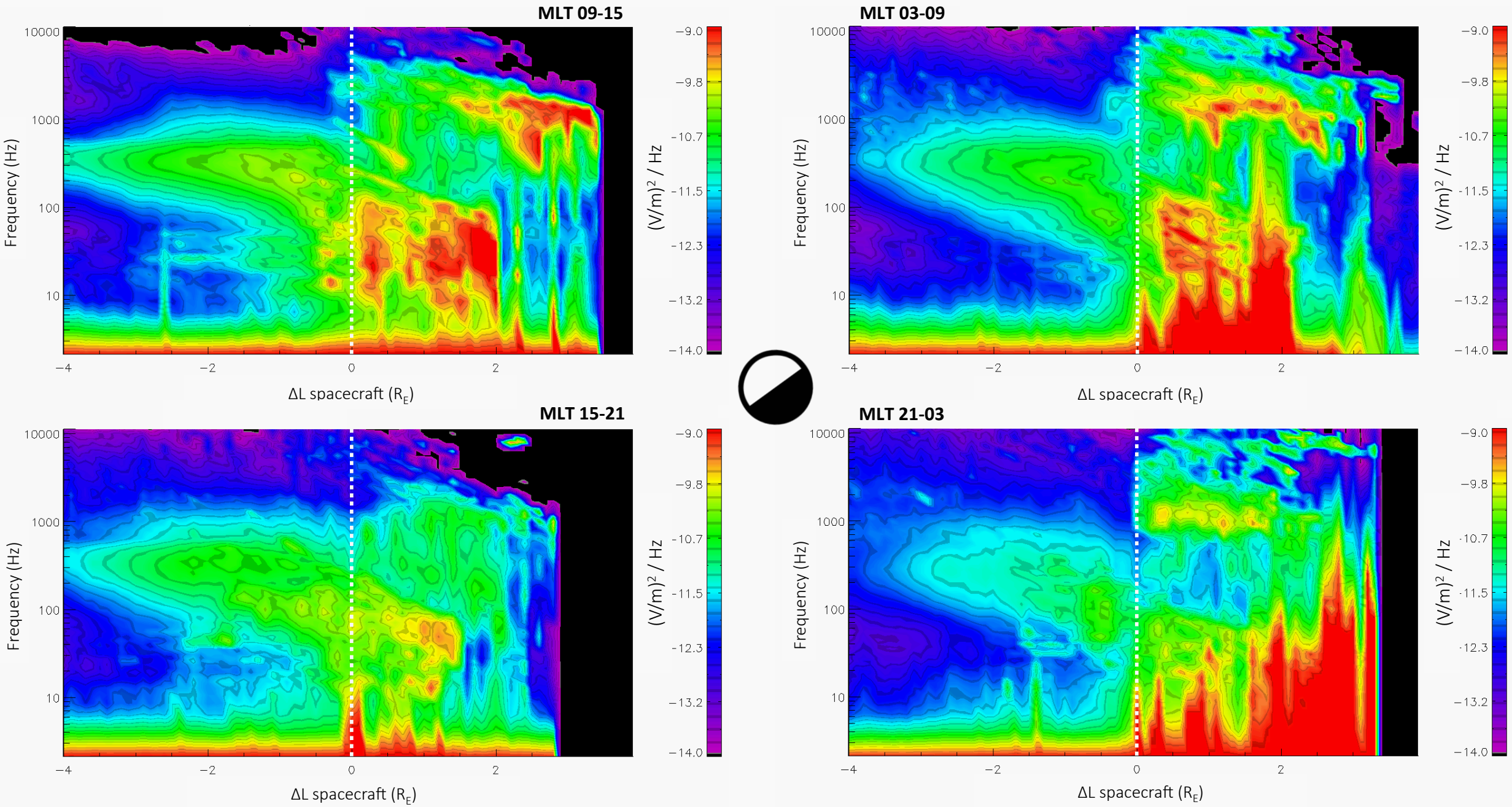
RBSP-A B-field wave power: Frequency vs spacecraft distance from plasmapause ***AE > 300***

2012.10.02 - 2015.05.01



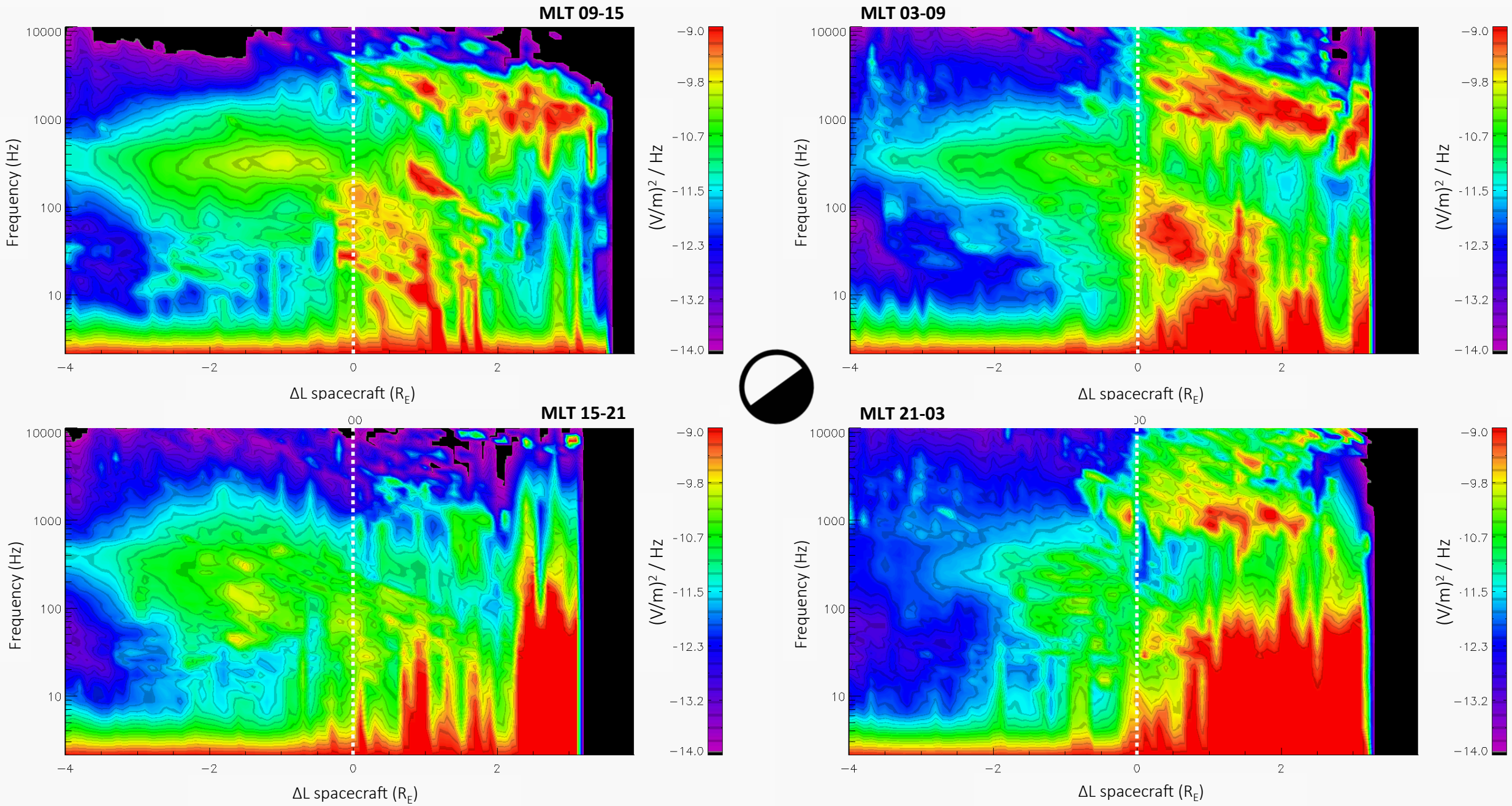
RBSP-B E-field wave power: Frequency vs spacecraft distance from plasmapause ***AE < 150***

2012.10.02 - 2015.05.01



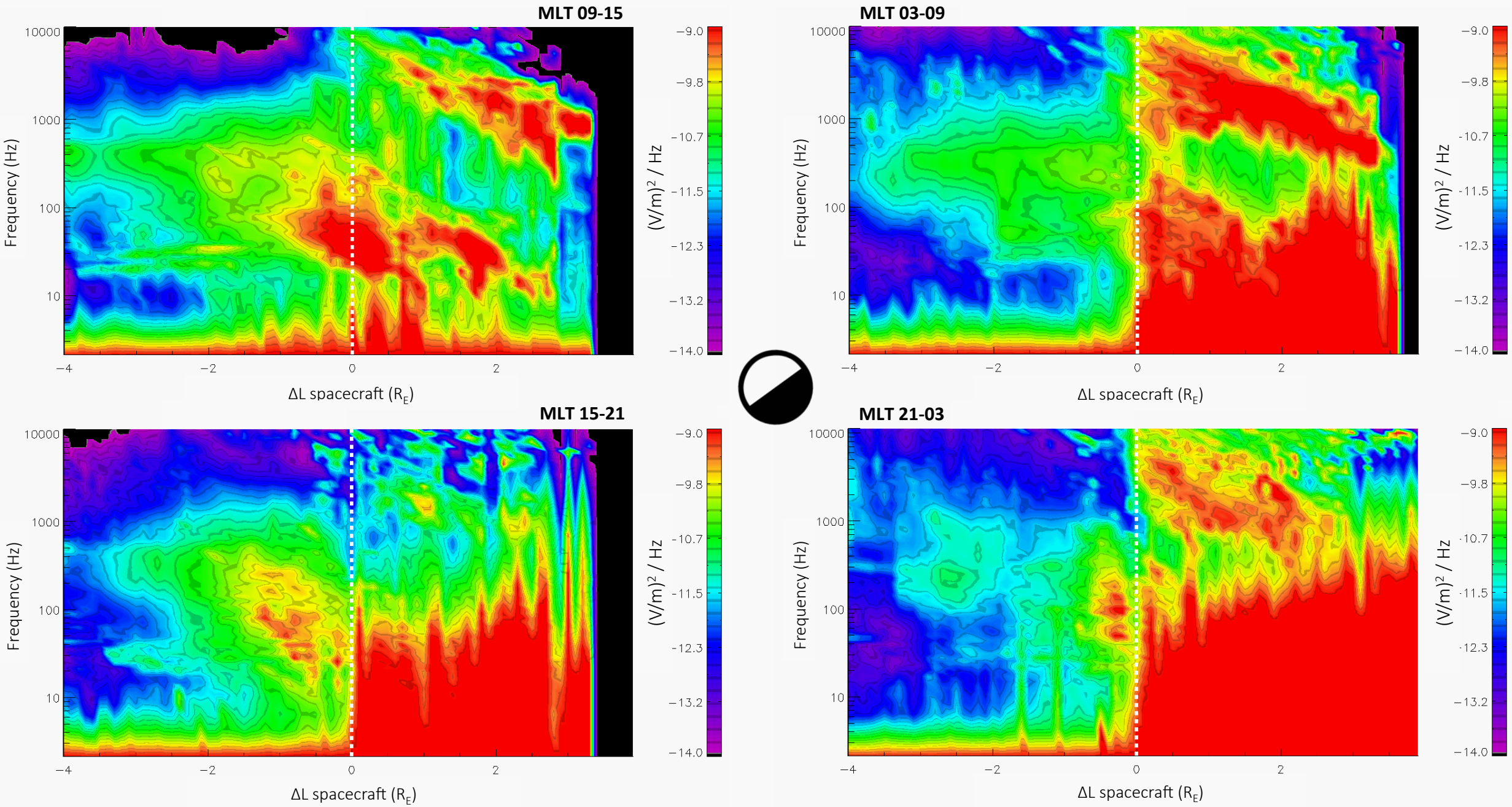
RBSP-B E-field wave power: Frequency vs spacecraft distance from plasmapause ***150 < AE < 300***

2012.10.02 - 2015.05.01



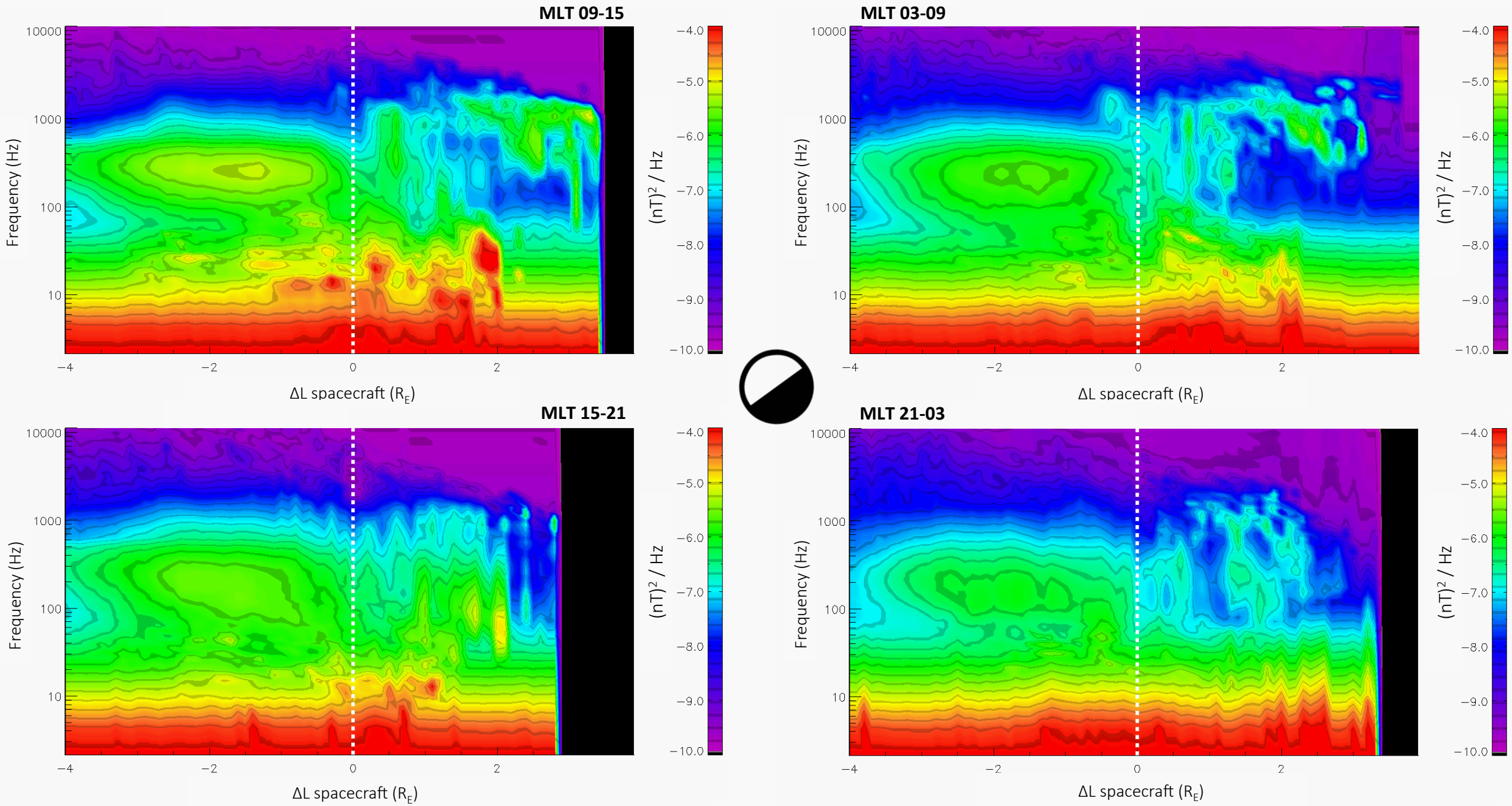
RBSP-B E-field wave power: Frequency vs spacecraft distance from plasmapause ***AE > 300***

2012.10.02 - 2015.05.01



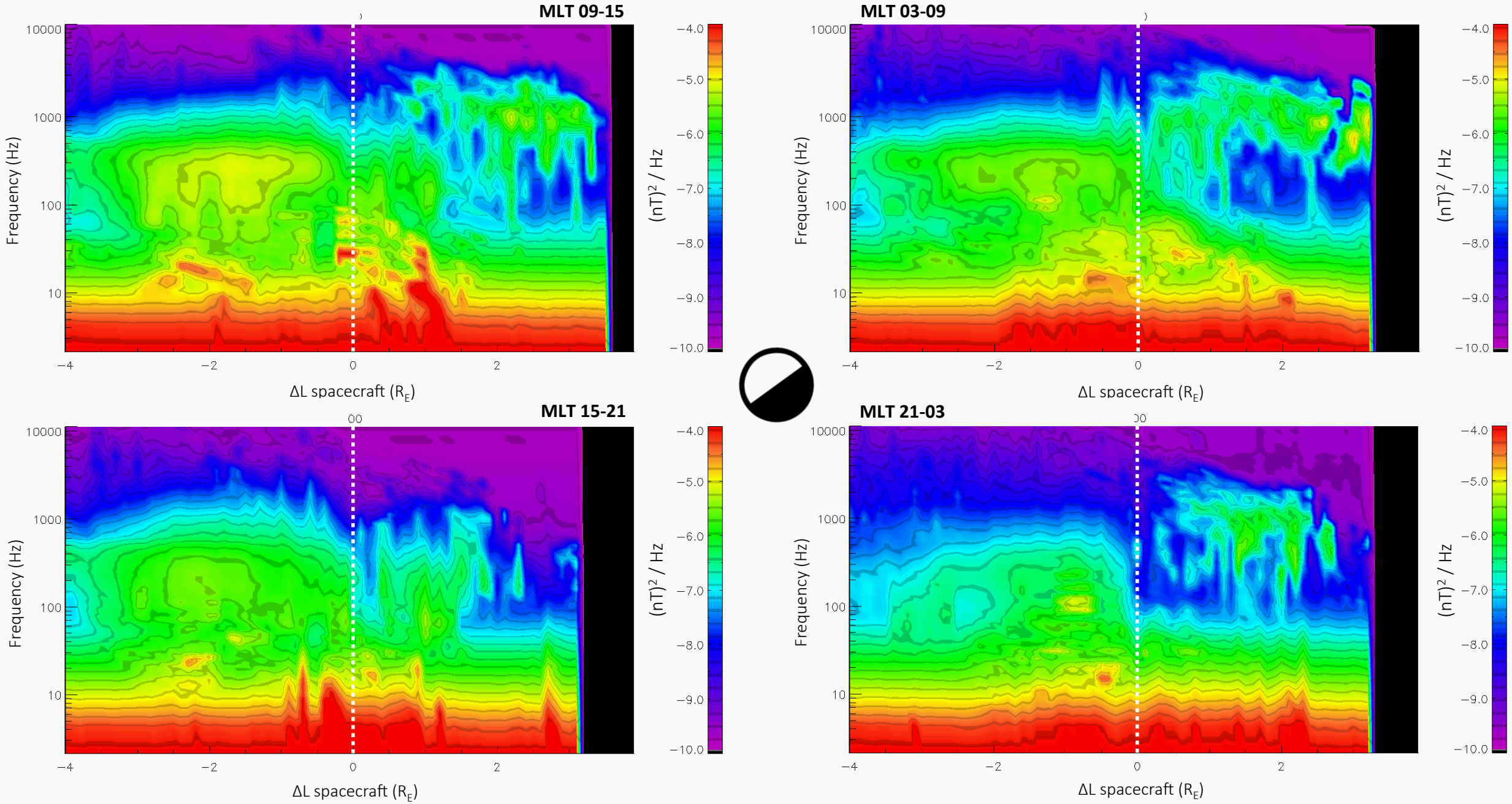
RBSP-B B-field wave power: Frequency vs spacecraft distance from plasmapause ***AE < 150***

2012.10.02 - 2015.05.01



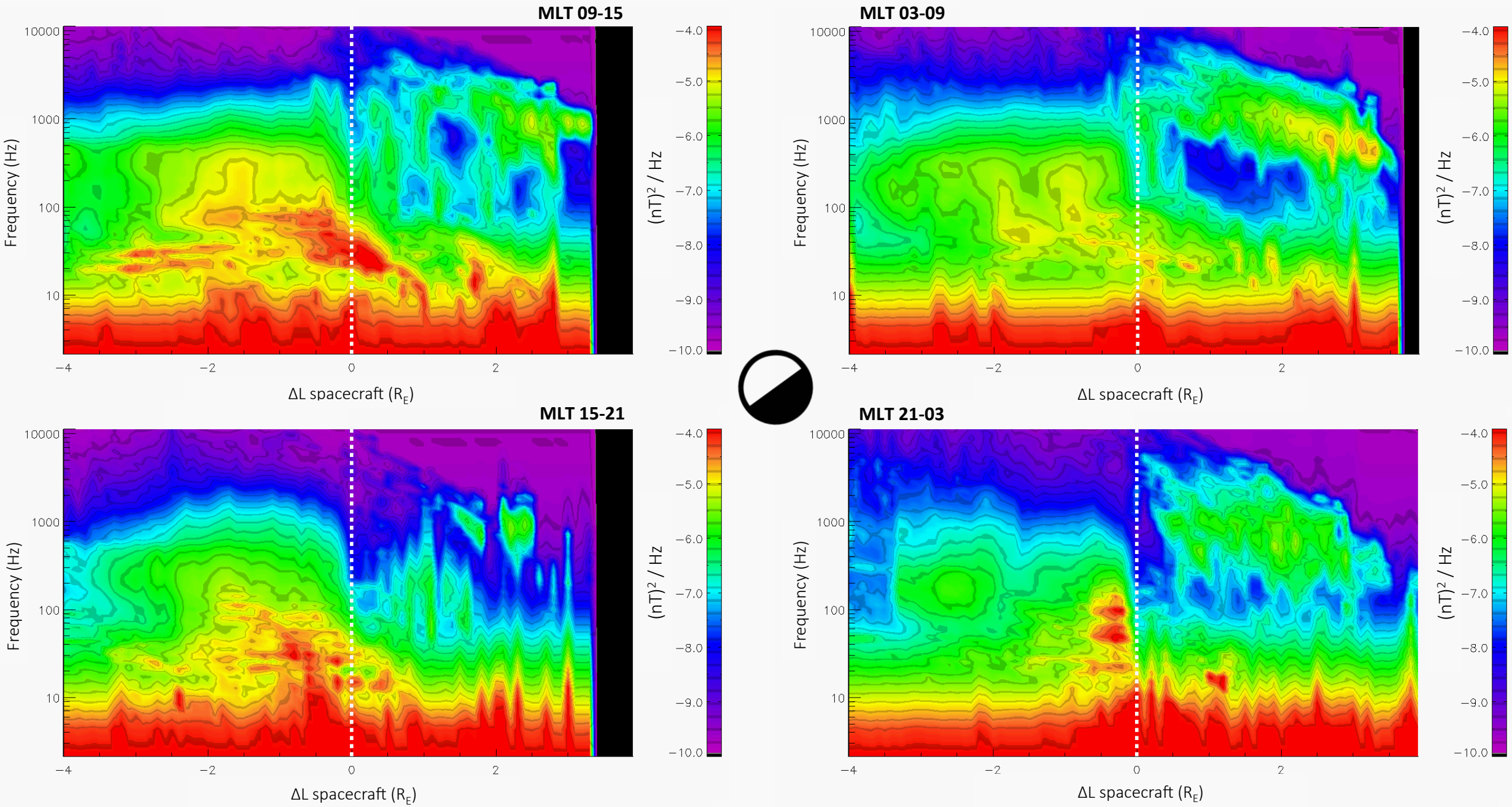
RBSP-B B-field wave power: Frequency vs spacecraft distance from plasmapause ***150 < AE < 300***

2012.10.02 - 2015.05.01

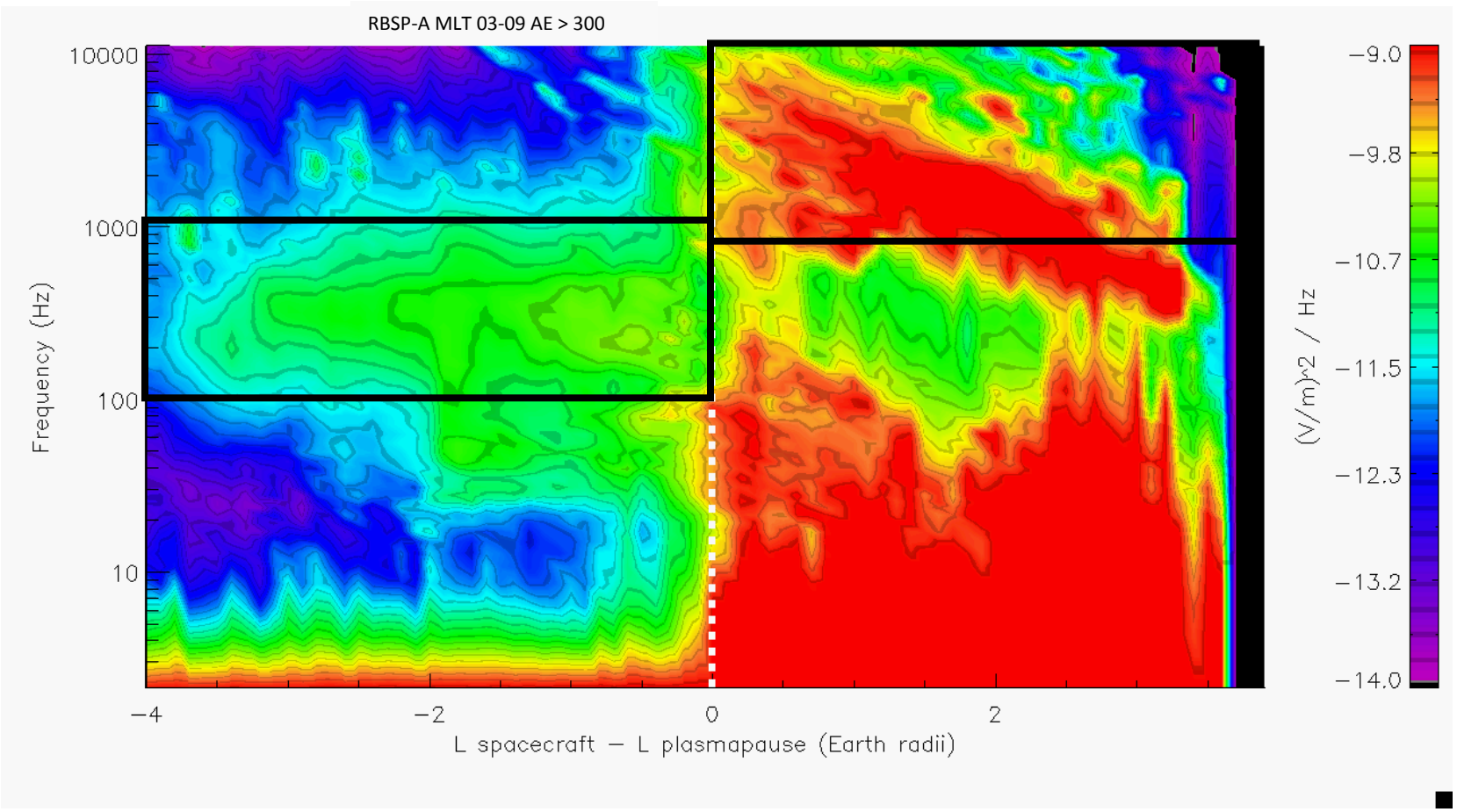


RBSP-B B-field wave power: Frequency vs spacecraft distance from plasmapause ***AE > 300***

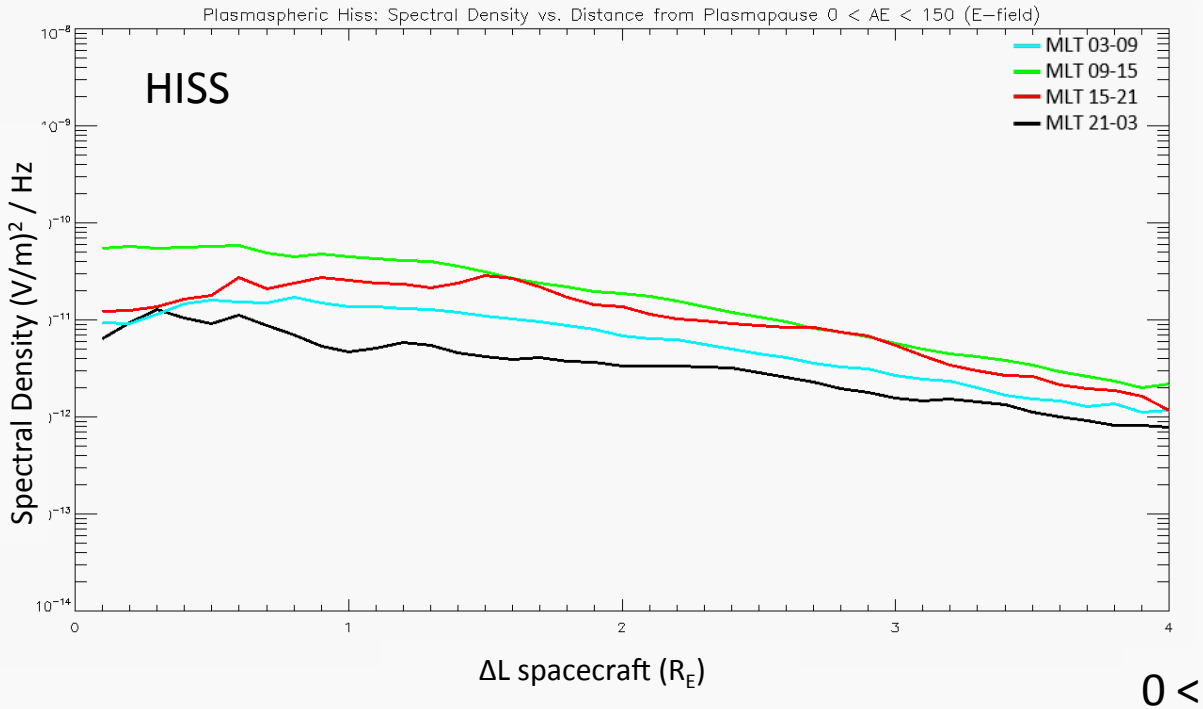
2012.10.02 - 2015.05.01

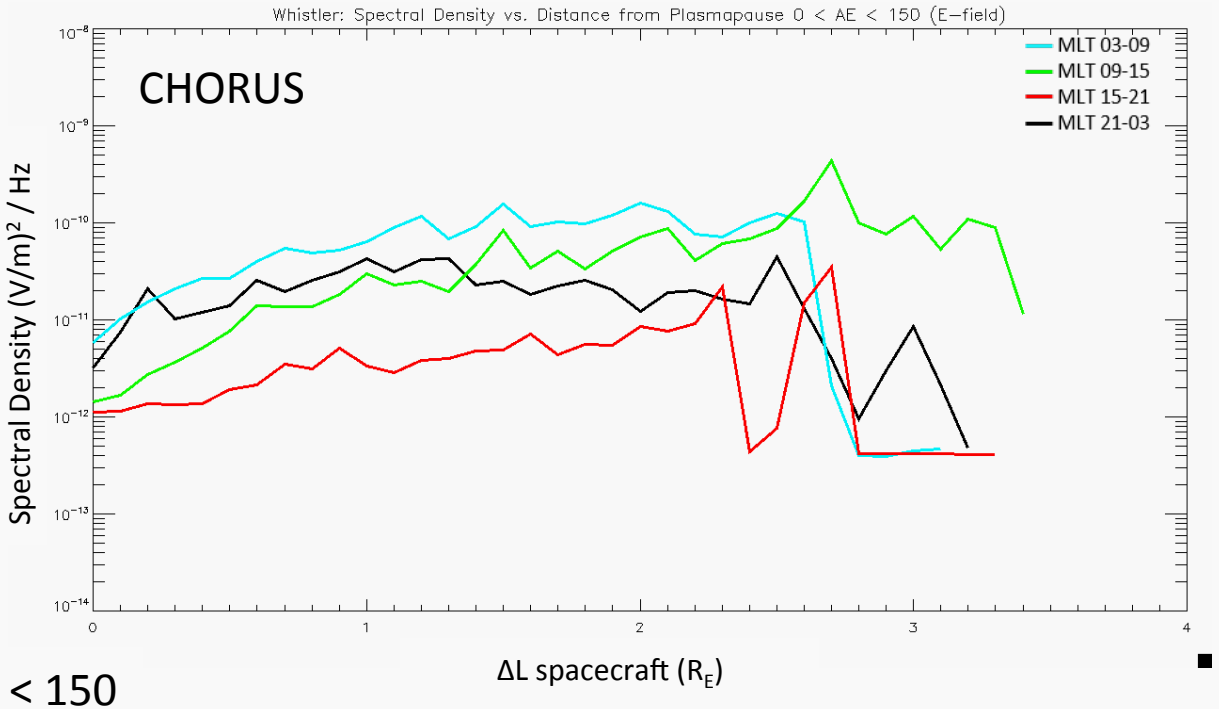


Further Analysis

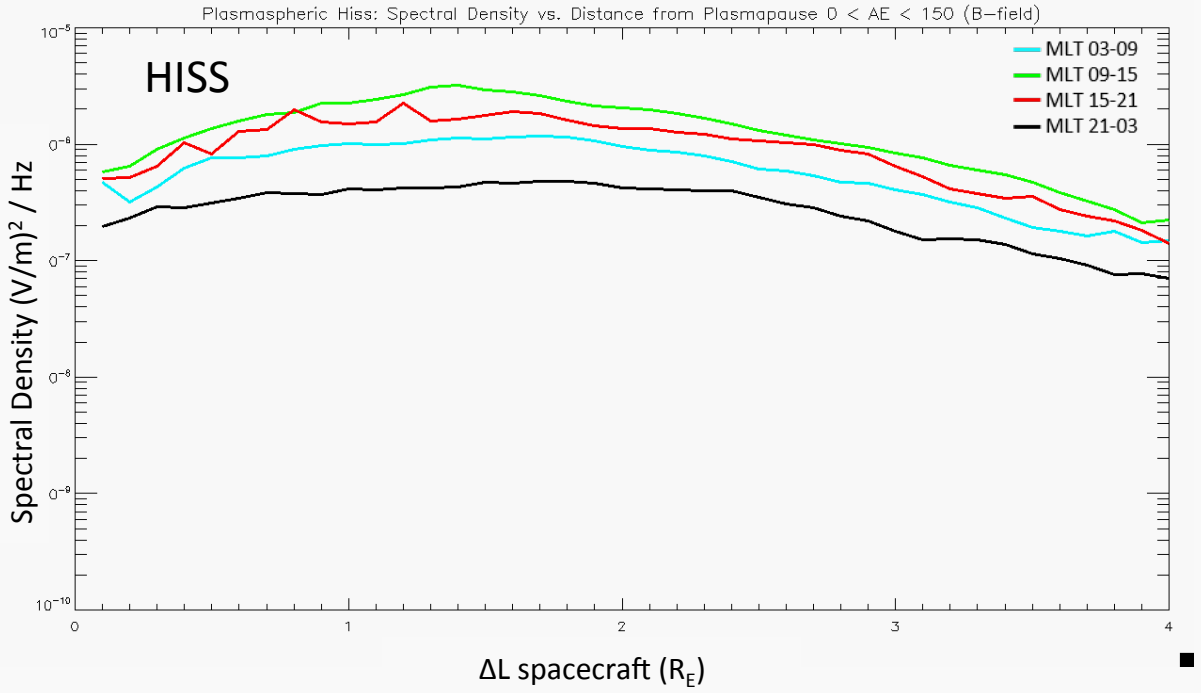


- Averaged wave power of 100 Hz to 1 kHz band and 800 Hz to 10kHz band for hiss and whistler spectral density with respect to distance from the plasmapause, again sorted by activity index and MLT


Plasmaspheric Hiss: Spectral Density vs. Distance from Plasmapause 0 < AE < 150 (E−field)
HISS
MLT 03-09
MLT 09-15
MLT 15-21
MLT 21-03
Spectral Density (V/m)² / Hz
ΔL spacecraft (R_E)


Whistler: Spectral Density vs. Distance from Plasmapause 0 < AE < 150 (E−field)
CHORUS
MLT 03-09
MLT 09-15
MLT 15-21
MLT 21-03
Spectral Density (V/m)² / Hz
ΔL spacecraft (R_E)

0 < AE < 150


Plasmaspheric Hiss: Spectral Density vs. Distance from Plasmapause 0 < AE < 150 (B−field)
HISS
MLT 03-09
MLT 09-15
MLT 15-21
MLT 21-03
Spectral Density (V/m)² / Hz
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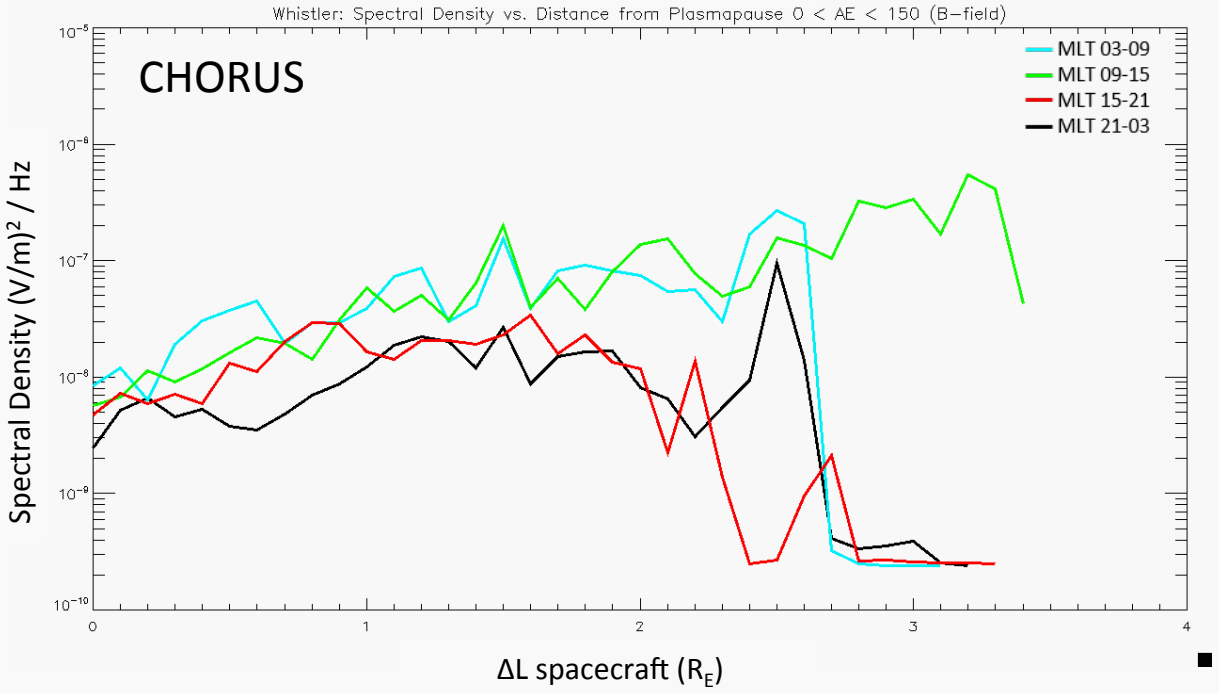
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CHORUS
MLT 03-09
MLT 09-15
MLT 15-21
MLT 21-03
Spectral Density (V/m)² / Hz
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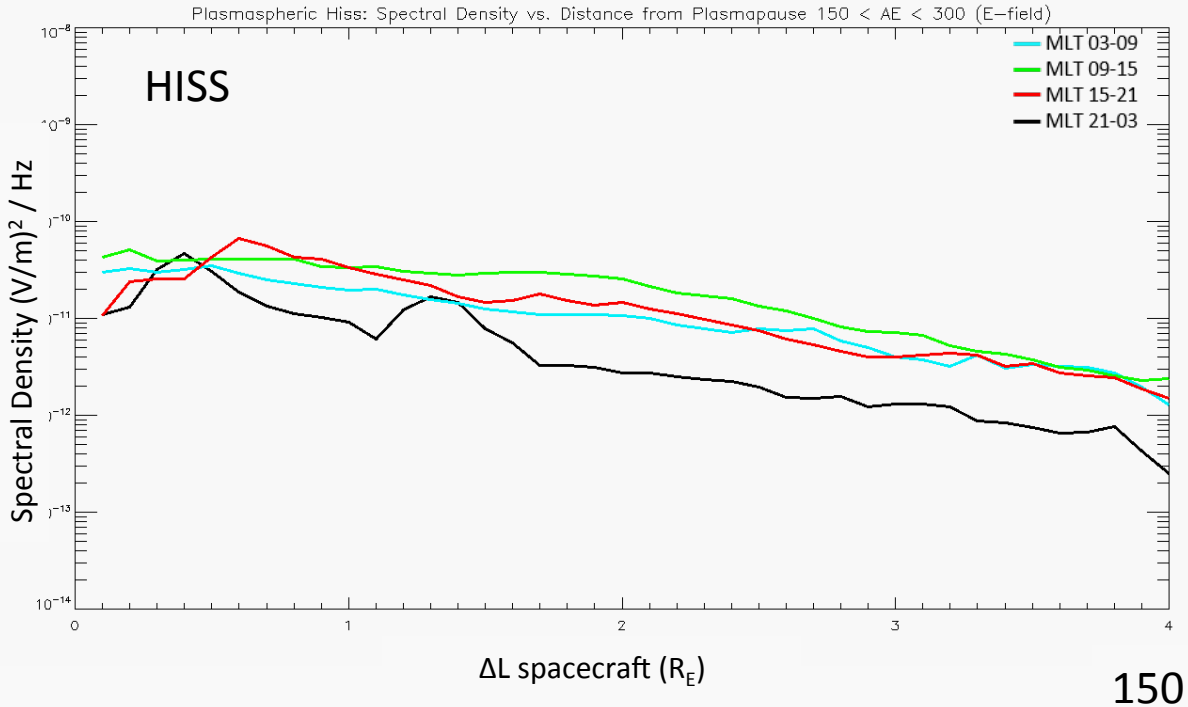
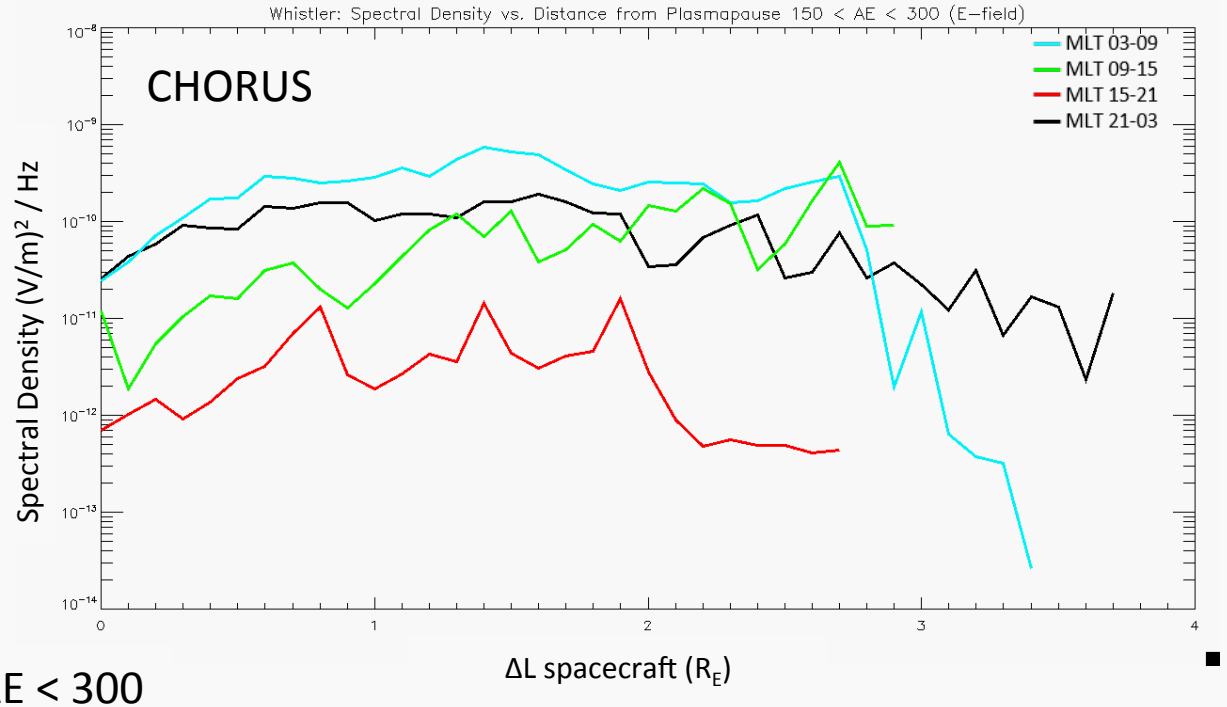

Plasmaspheric Hiss: Spectral Density vs. Distance from Plasmapause 150 < AE < 300 (E−field)
HISS
MLT 03-09
MLT 09-15
MLT 15-21
MLT 21-03
Spectral Density (V/m)² / Hz
ΔL spacecraft (R_E)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CHORUS
MLT 03-09
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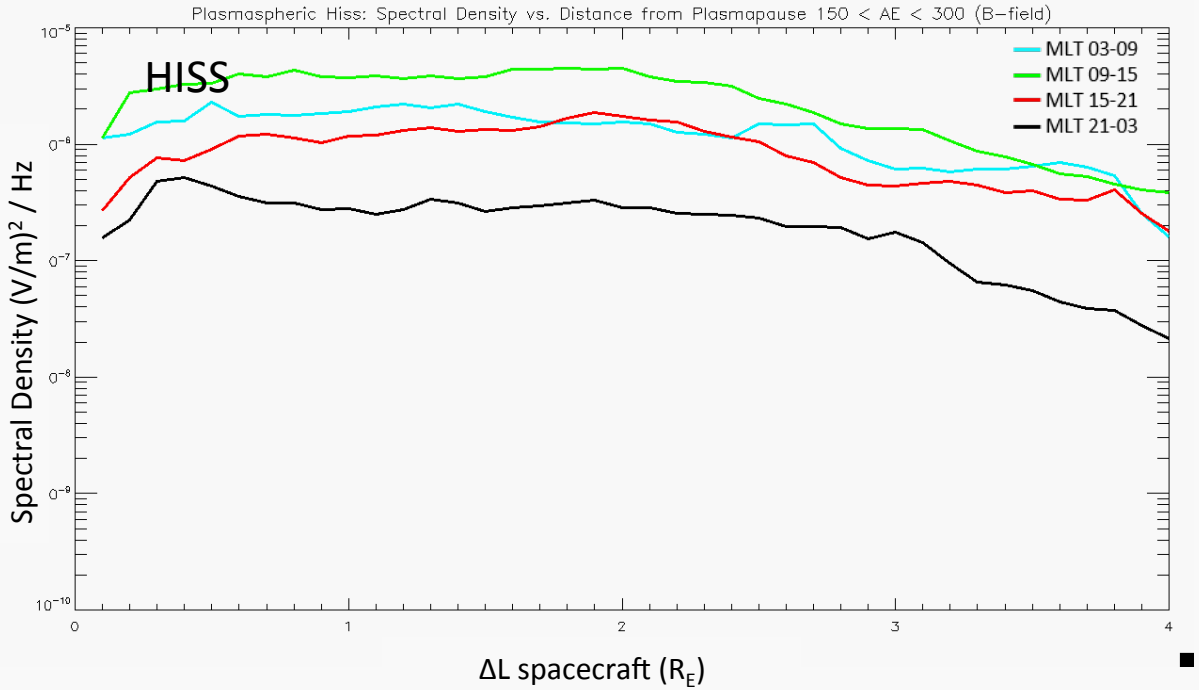
Spectral Density (V/m)² / Hz
ΔL spacecraft (R_E)

150 < AE < 300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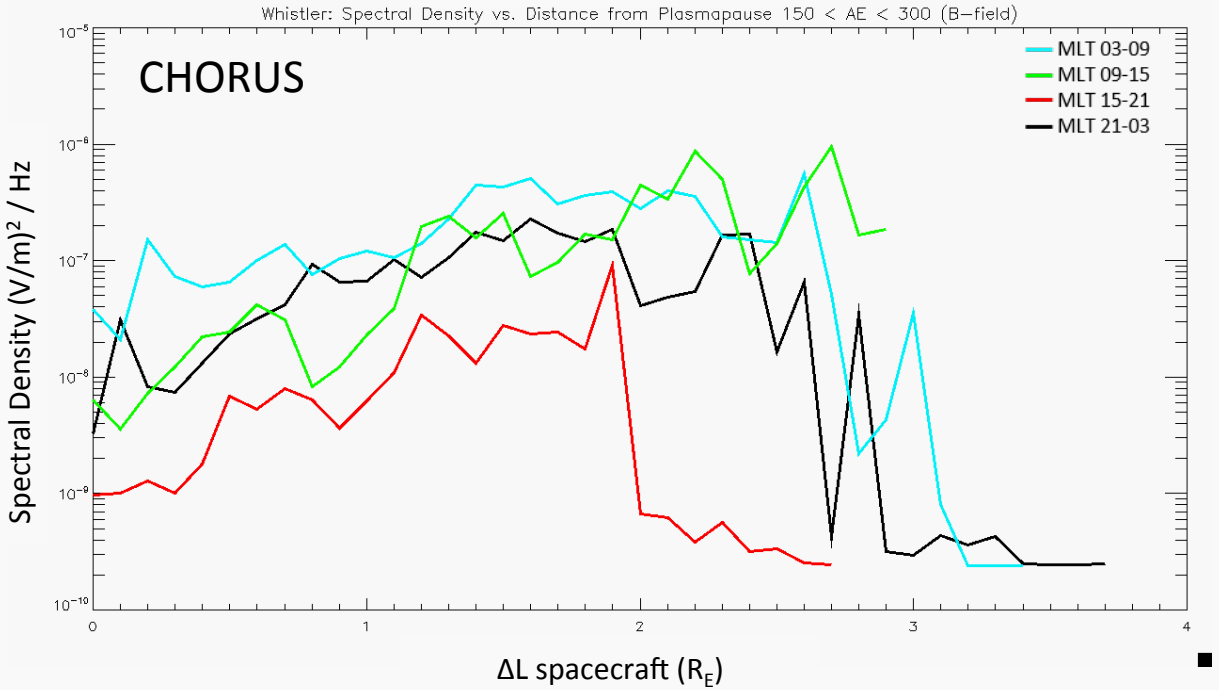
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Spectral Density (V/m)² / Hz
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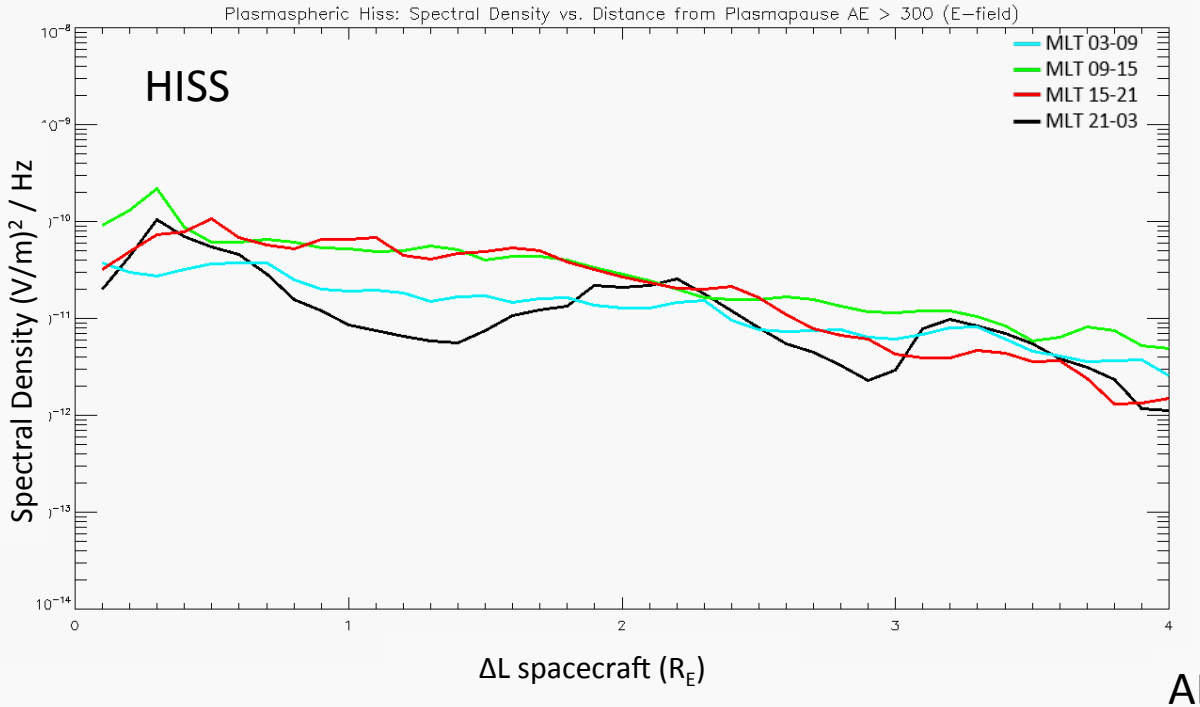
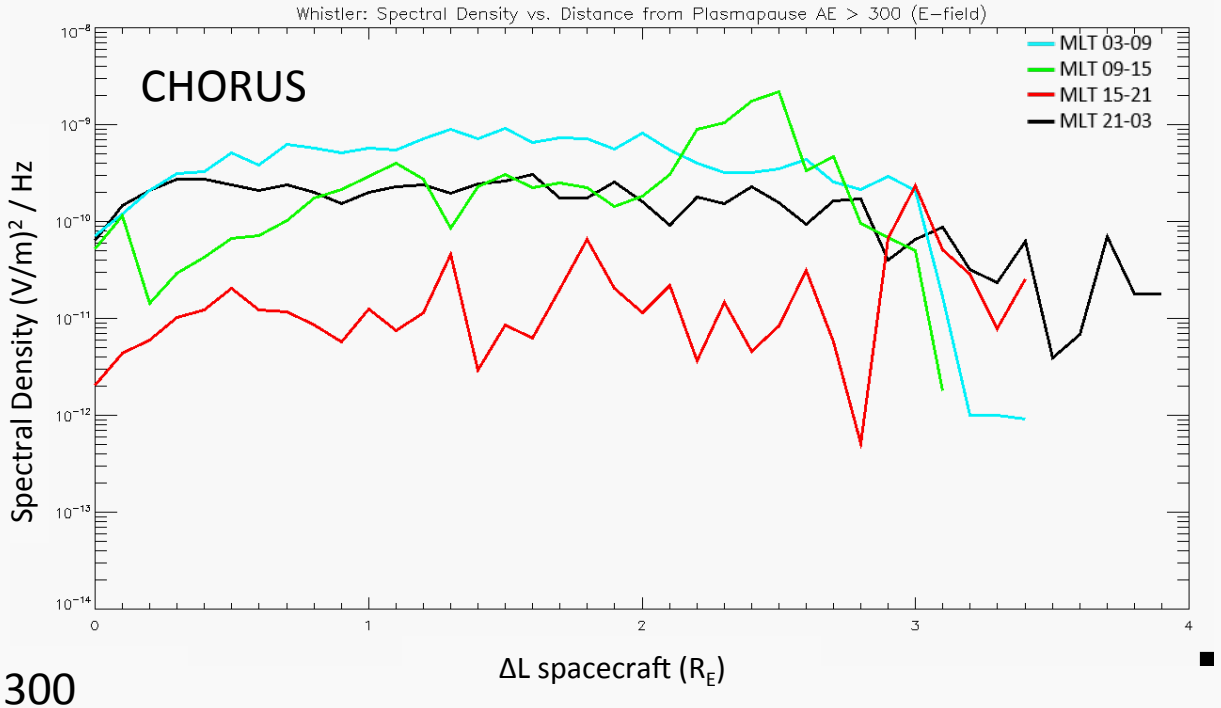
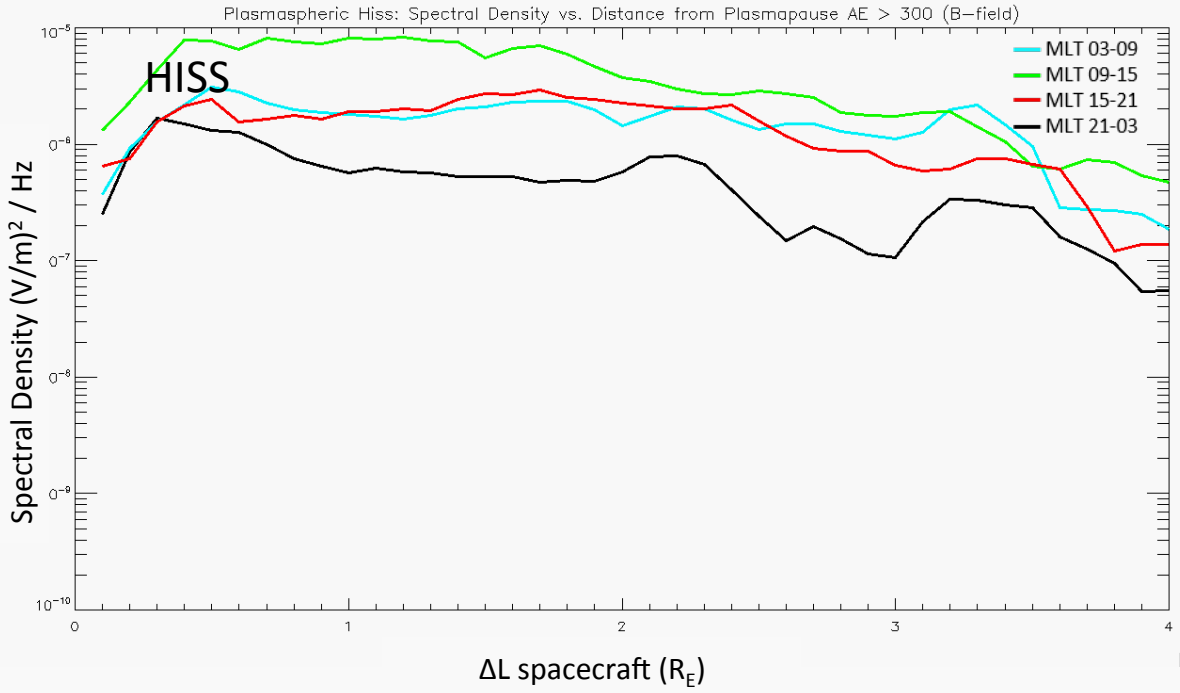

Plasmaspheric Hiss: Spectral Density vs. Distance from Plasmapause AE > 300 (E−field)
HISS
MLT 03-09
MLT 09-15
MLT 15-21
MLT 21-03
Spectral Density (V/m)² / Hz
ΔL spacecraft (R_E)


Whistler: Spectral Density vs. Distance from Plasmapause AE > 300 (E−field)
CHORUS
MLT 03-09
MLT 09-15
MLT 15-21
MLT 21-03
Spectral Density (V/m)² / Hz
ΔL spacecraft (R_E)

AE > 300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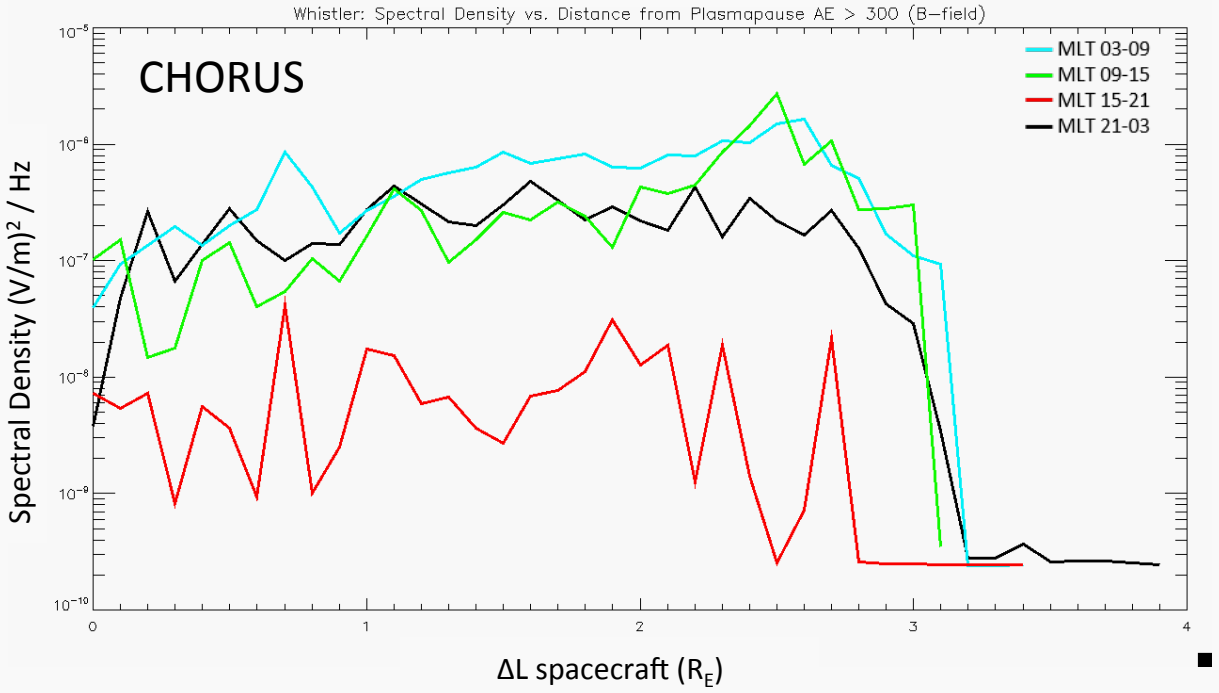
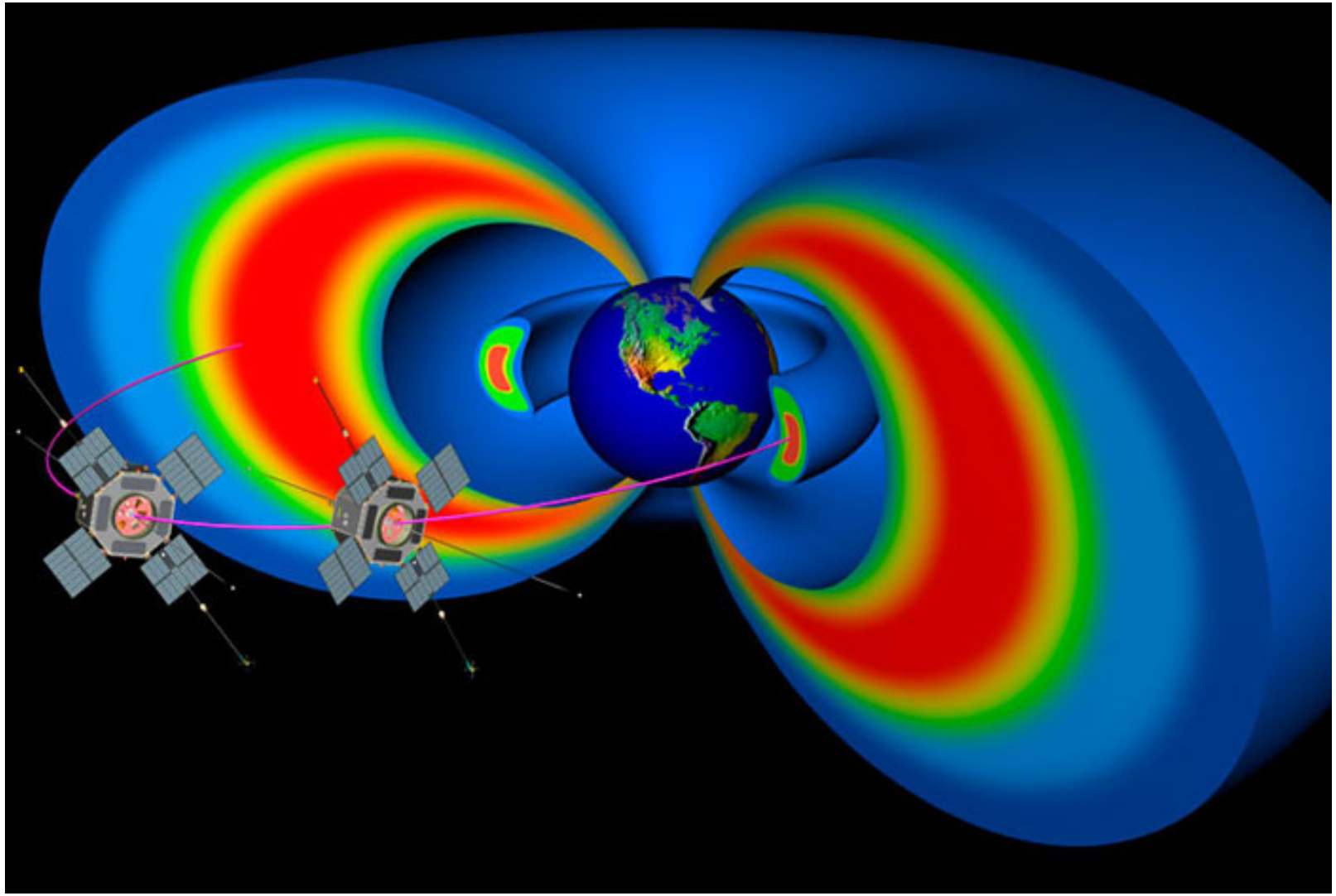

Whistler: Spectral Density vs. Distance from Plasmapause AE > 300 (B−field)
CHORUS
MLT 03-09
MLT 09-15
MLT 15-21
MLT 21-03
Spectral Density (V/m)² / Hz
ΔL spacecraft (R_E)

Conclusions

- Theoretical models of strongest hiss found at or near plasmapause confirmed explicitly by actual data
- Mysterious local maxima in B-field hiss spectral density plot at quiet geomagnetic activity (~1.5 RE)
- Earthward propagation of average hiss power with increased geomagnetic activity
- Further confirmation of greatest chorus power found in dawn MLT sector
- Noon time (MLT 09-15) hiss has greatest spectral density regardless of activity index while night time (MLT 21-03) has least spectral density
- Hiss nearly constant over MLT, but varies with activity index
- Chorus varies by orders of magnitude with both MLT and activity index

Future work

- Introduce new parameters to further explore whistler-mode wave variability (magnetic latitude, solar wind driving conditions, etc..)
- Develop a method for removing time domain structures that dominate lower E-field frequency bands ($f < \sim 1000$ Hz) where $\Delta L > 0$
- Further investigate the mysterious local maxima in B-field hiss spectral density plots

Questions?