Poster #53

A statistical study of hydrogen-, helium-, and oxygen-band EMIC waves observed by Van Allen Probe A

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Abstract

Presented here is a statistical study of EMIC waves observed by the Van Allen Probes mission. Magnetic field measurements from the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) onboard Van Allen Probe A have been used to identify EMIC wave events from the beginning of the mission (September, 2012) to February, 2014. Statistical studies using *in situ* observations from other missions have been conducted, however the Van Allen Probes Mission allows much better resolution of lower frequencies (0.2-0.9 Hz), within which oxygen-band EMIC waves can occur in the inner magnetosphere. This allows us greater insight into the characteristics of this previously largely unavailable band of EMIC waves, and allows for the comparisons of the occurrence and spatial distribution of EMIC waves in different bands. Hydrogen, helium and oxygen bands of EMIC waves are examined with respect to their occurrence in the coordinates of L-values (L) and Magnetic Local Times (MLT).

Motivation

1.) Since EMIC waves can affect their nearby environment and particle dynamics (through energy excitation of heavy ions [*Zhang et al*., 2010; 2011], cause dropouts of relativistic electrons from the radiation belt [*Thorne and Kennel*, 1971; *Lyons and Thorne*, 1972; *Jordanova et al*., 2008; *Miyoshi* et al., 2008], auroral proton precipitation [*Sakaguchi et al*., 2008; *Yahnin et al*., 2009], and cause traveling convection vortices inside the magnetosphere [*Lockwood* et al., 1990; *Engebretson* et al., 2013]), *in situ* observations throughout the magnetosphere are needed.

2.) The Van Allen Probes allow us to perform a statistical study of EMIC waves occurring in the radiation belts. Particularly, in this study, it is possible to statistically examine oxygen-band EMIC waves for the first time since previous mission have often been contaminated with noise at lower frequencies.

3.) This study serves as an extension of a recently accepted GRL paper by *Zhang et al*. [2014], in which EMIC wave events on April 28, 2013 were focused on.

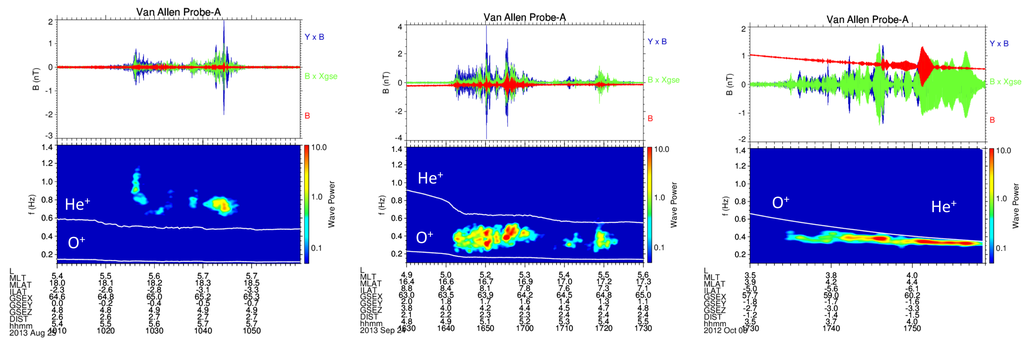
Instrumentation

1.) The Van Allen Probes (2012-present) are two identical spacecraft, denoted as A and B, which orbit in nearly identical, low inclination (10°), elliptical orbits between 1.1 and 5.8 Earth radii approximately every 9 hours.

2.) Each probe carries the EMFISIS fluxgate magnetometer which collects magnetic field data used in this study. The magnetometer takes high resolution (64 vectors/second) magnetic field data which allows us to examine frequencies between ~0-30 Hz.

EMIC waves observed by Van Allen Probe A

Proton-band EMIC Waves | Helium-band EMIC Waves | Oxygen-band EMIC Waves



1) Sample EMIC waves used in the study (waveforms and wave power in nT^2/Hz). The white lines through the wave power plots represent that respective local ion gyrofrequencies.
   - -A proton-band EMIC wave event (left) on August 25th, 1020-1050 UT
   - -A helium-band EMIC wave event (middle) on September 24th, 1640-1725 UT
   - -An oxygen-band EMIC wave event (right) on October 8th, 1735-1800 UT

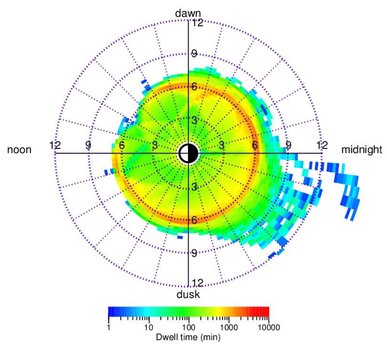
2) EMIC wave event selection criteria:
   - -An EMIC wave event must've been observed for at least 5 minutes.
   - -A wave power of at least 0.05 nT^2/Hz was used as a cutoff.
   - -Gyrofrequency lines were used to distinguish between bands.
   - -Events occurring over multiple bands were each counted as their own wave event.

Spatial distribution of EMIC waves

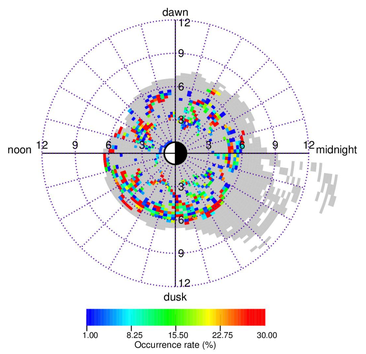
Displayed to the right are the total number of EMIC wave events per band observed by Van Allen Probe A. In parenthesis is the number of EMIC wave events per band that occurred without another EMIC wave event being observed in another band.

Band	Number of waves observed
Proton	79 (53)
Helium	169 (129)
Oxygen	30 (27)

Van Allen Probe A data coverage



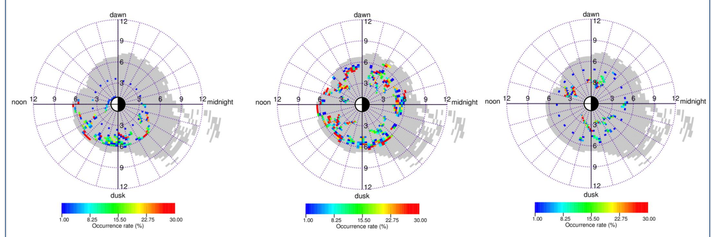
EMIC waves observed by Van Allen Probe A



Displayed here is the coverage (left) and the distribution of all EMIC wave events observed by Van Allen Probe A (right). The coverage plot represents the amount of time that Van Allen Probe A has been in that particular region. It takes the Van Allen Probes about 2 years to complete its precession around Earth. This study has only used data from the first 17 months of the Van Allen Probes mission, as such the Van Allen Probes have not had enough time to cover all regions equally (i.e., the morning sector).

Spatial distributions of EMIC waves by band

Proton-band EMIC Waves | Helium-band EMIC Waves | Oxygen-band EMIC Waves



1) Proton-band waves (left):
   - -Wave occurrence peaks during the dusk sector. Dawn, midnight, and noon sectors (MLT: 0-12) are barren.
   - -Majority of waves occur at approximately L= 5-6. *Halford et al.* [2010] (CRRES data) observed a mean L = 6.07 and a mean MLT = 15.
   - -*Min et al*. [2012] (THEMIS data) and *Allen et al.* [2014] (Cluster data) show peak proton-band occurrence in the dawn sector at approximately L=10.
2) Helium-band waves (middle):
   - -Wave occurrence is symmetric in MLT.
   - -Majority of waves occur at approximately L = 5-6. *Halford et al.* [2010] (CRRES data) observed a mean L = 6.07 and a mean of MLT = 15.
   - -*Min et al*. [2012] (THEMIS data) and *Allen et al.* [2014] (Cluster data) show peak helium-band occurrence in the dusk sector at approximately L = 10.
3) Oxygen-band waves (right):
   - -Waves occur mostly at L < 5.
   - -Half the noon sector (MLT: 12-16) and midnight regions haven't observed EMIC waves despite proper coverage.

Summary & Discussion

1.) In the present preliminary study, we have reported 278 EMIC wave events detected by Van Allen Probe A from September 2012 to February 2014, i.e., in the first 17 months of the mission.

2.) The spatial distributions of the EMIC waves are distinctly different among the 3 bands. Proton-band waves have only been observed in the dusk sector. Helium-band waves appear to have a symmetric distribution in MLT. Oxygen-band waves have only been observed in the dusk, pre noon, and dawn sectors.

3.) Local plasma conditions, such as the composition of cold ion populations that originate from the plasmasphere or plasmaspheric plumes, can impact wave growth. Different wave growth can be attributed to the different spatial distributions of the 3 wave bands.

4.) This study provides a more complete picture of the occurrence of EMIC waves in the global magnetosphere along with previous results, e.g.,

i.) *Min et al.* [2012] and *Allen et al.* [2014] observe peak proton-band occurrence in the dawn sector at higher L shell. Both also show peak helium-band occurrence in the dusk sector while our study shows a symmetric distribution. Note that both studies looked primarily at higher L shells using THEMIS and Cluster data, respectively.

ii.) *Halford et al.* [2010], using CRRES data, observed a mean L = 6.07 for EMIC wave observation and a mean MLT = 15 which our results support.

Future Work

1.) To further examine the spatial distribution and temporal evolution of EMIC waves by combining wave observations on Van Allen Probe B
2.) To determine the wave properties for all EMIC wave events (normal angle, ellipticity, polarization, etc.)
3.) To analyze plasma conditions associated with these events
4.) To cross check all wave events with solar wind conditions
5.) To perform a Poynting vector analysis for observed EMIC waves during which high-resolution electric field measurements are available

References

Allen *et al*., 2014
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Engebretson *et al*., 2013
Halford, Fraser, and Morley, 2010
Jordanova *et al*., 2008
Lockwood *et al*., 1990
Lyons and Thorne, 1972
Miyoshi *et al*., 2008
Min *et al*., 2012
Sakaguchi *et al*., 2008
Thorne and Kennel, 1971
Yahnin *et al*., 2009
Zhang *et al*., 2010
Zhang *et al*., 2011
Zhang *et al*,. 2014

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