Statistical Study of the Occurrence of POES Relativistic Electron Precipitation (REP) in Correlation with Electromagnetic Ion Cyclotron (EMIC) Waves

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Sponsored by NSF

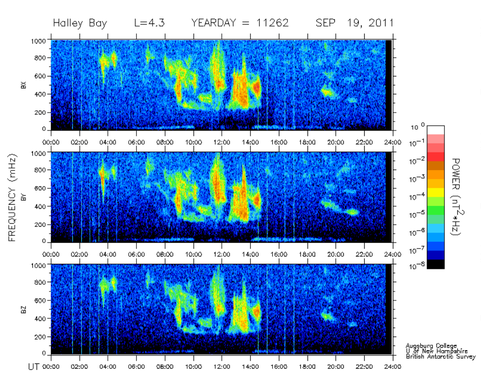
Abstract

Electromagnetic Ion Cyclotron (EMIC) waves are phenomena that exist within Earth's magnetosphere caused by an ion temperature anisotropy. The ideal conditions for EMIC wave growth occur during solar storms. In this statistical study, Polar Orbiting Environmental Satellites (POES) Relativistic Electron Precipitation (REP) data is compared to EMIC wave data from Halley Bay in the years ranging from 2008-2010. This statistical study will consider a specific type of EMIC wave events known as Intervals of Pulsations of Diminishing Periods (IPDP) to see whether this type of EMIC wave causes a statistically greater occurrence of REP. In this study, different types of IPDP are characterized based on the increase in frequency over time of each wave form. Another considered characteristic of the IPDP waves is whether the wave is continuous or appears to form discrete packets. The discrete packets may actually be separate events. IPDP events are cataloged and then compared to REP events from the POES data set. This study is complementary to a study done by Aaron Hendry et al. [2016] who compared REP from POES data to the presence of EMIC waves at Halley Bay.

Background

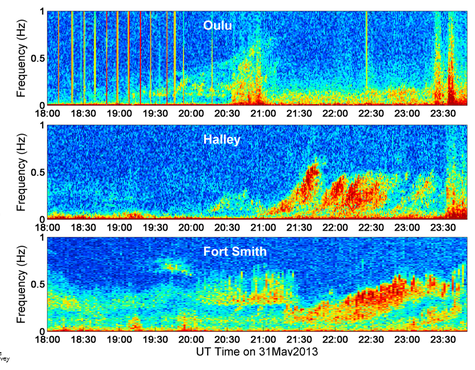
What are EMIC waves?

EMIC waves are Ultra Low Frequency (ULF) waves in the Pc1-Pc2 range generated in the equatorial region of the magnetosphere propagated to the ionosphere. An ion temperature anisotropy is created, causing the generation of these waves.



What are IPDP waves?

An IPDP is a type of structured EMIC wave which is a geomagnetic pulsation. IPDP's have been associated with electron precipitation. [Arnoldy et al 1979] IPDP generation is shown to occur when injected protons move westward and meet a densely populated area of the plasmasphere [Clilverd et al., 2013].



The figure above is an example of an IPDP observed by three different ground based observatories. [Clilverd et al 2015]

What are REP events?

Relativistic Electron Precipitation (REP) driven outside of the plasmapause is potentially generated by EMIC waves [Carson et al 2013]. REP occur more frequently during geomagnetic disturbances.

The Department of Physics at the University of Otago in New Zealand, developed an algorithm to sort POES data into EMIC wave drive associated electron precipitation. Carson et al., [2013] created an algorithm to find EMIC associated REP events: when the peak in the flux of relativistic electrons occurred at the same time as the peak in the flux of protons, the REP event precipitating at that time was considered to be correlated with an EMIC wave event.

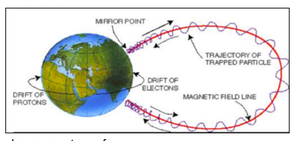
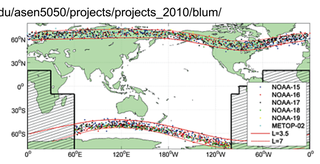


Image courtesy of: http://ccar.colorado.edu/asen5050/projects/projects_2010/blum/



The figure above is a map of events detected by the POES satellite. [Carson et al 2013]

Halley Bay

Halley Bay station is located in Antarctica at Lat. 75°35'0"S, Long. 26°39'36"W. In collaboration with the British Antarctic Survey and Augsburg College, the University of New Hampshire has a ULF search coil magnetometer system installed at Halley Bay. The Magnetic Local Time(MLT) at Halley Bay, which measures location, is ~3 hours behind the Universal Time(UT) at Halley Bay.

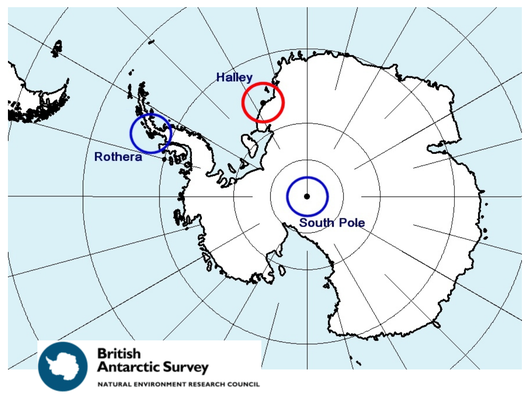


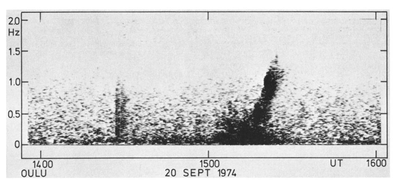
Image courtesy of: http://ail.usu.edu/data/Halley%20Bay/MainHalleyBayASI.html

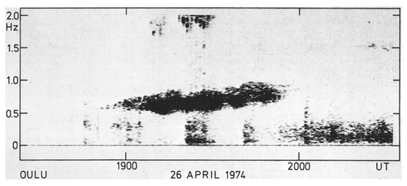
Hendry et al. [2016] Study

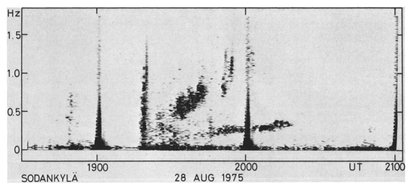
In the study by Hendry et al. [2016] the POES database of REP events was compared to ground based measurements of IPDP waves. 85% of POES triggers within +/- 2 degrees geographic longitude of Halley's magnetic conjugate point were correlated with an EMIC wave observation at Halley. When events within +/- 15 degrees longitude were considered, they found that 64.8% of these events corresponded to an EMIC wave event at Halley. Of these corresponding events, 63% were IPDP wave events. In our complementary study we first cataloged IPDP waves based on certain characteristics and then used the database of REP events from POES to see if there is a positive correlation.

IPDP Definition

In a paper from 1983 by Pikkarainen, IPDP waves were categorized by LT and latitude. They found waves measured at low latitude stations can extend beyond 1 Hz. Auroral stations observed IPDP waves occurring up to 1 Hz. IPDP waves are defined as waves that start at a frequency of .1 Hz to 1-2 Hz over the span of 30 minutes to 2 hours. However, some waves defined as IPDP do not start at that low of a frequency. IPDP waves more frequently occur between noon and midnight MLT. IPDP waves occur during injections of energetic protons. [Yahnin et al 2009] IPDP waves that occur in the dusk sector are steeper. Sometimes, consecutive IPDP waves occur. These consecutive events could be caused by an echo due to the westward drift of protons. In the evening and midnight sector the frequency of IPDP waves increases slowly. End frequencies of IPDP waves are usually lower than He+ gyrofrequency of field line of occurrence.







These three figures are from the 1983 paper by Pikkarainen et, al. which helped inform the definitive characteristics of the signature of an IPDP wave.

Substorm Injections

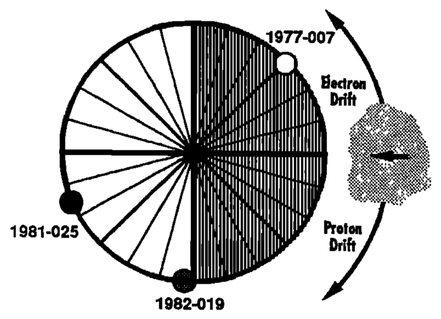
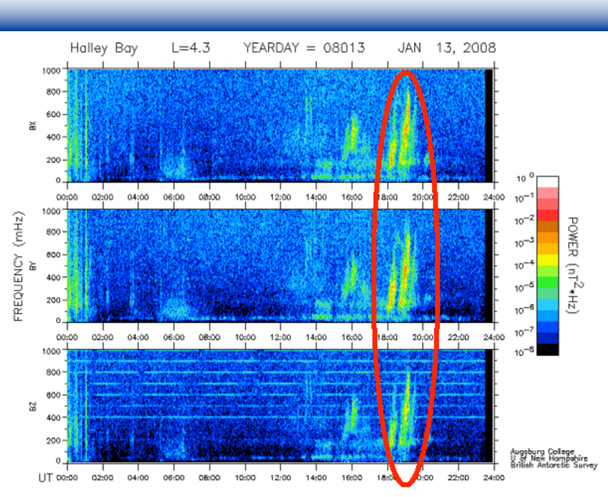


Image courtesy of: Reeves et al. 1990

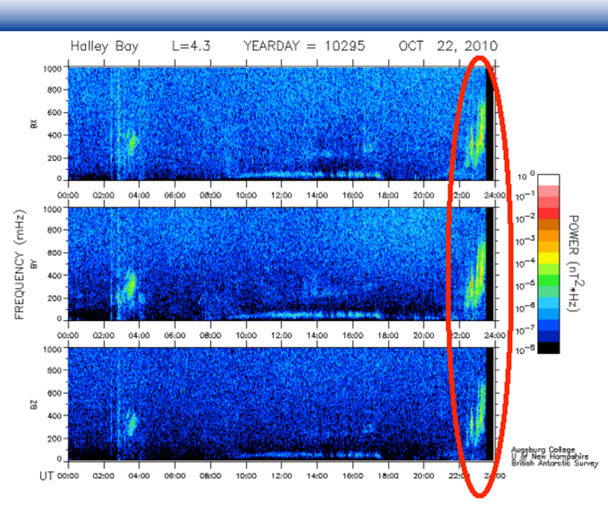
In a paper by Reeves et al. [1990] they discussed a substorm injection event occurring on Feb 3, 1983. They found the event to be consistent with the substorm injection model; ions and electrons were injected simultaneously. However, due to the directionality of particle drift, there was a spatially dependent difference between the electron and ion populations. As shown in the graphic, after the substorm injection the electrons drift eastward and the ions drift westward.

Carson et al. [2013] assumes that both electron and ion particle populations are available to be scattered by EMIC waves. Their assumption would imply the simultaneous precipitation of REP and ions during an EMIC wave event. However a substorm injection is one example which causes spatiality dependent differences in electron and ion population. When an EMIC wave precipitates particles, are both electron and ion populations always present? Hypothetically, could REP precipitate in the absence of ion precipitation?

Correlated IPDP events



A REP event occurs at 19:14 UT at the same time as an IPDP EMIC wave, less than a degree geographic longitude away from the magnetic conjugate point of Halley Bay.



A REP event occurs at 23:29 UT at the same time as an IPDP EMIC wave, less than three degrees geographic longitude away from the magnetic conjugate point of Halley Bay.

Conclusions

Percentage REP correlated with EMIC waves	**77%**
Of the REP correlated with EMIC waves, what percent of these waves are IPDP?	**29%**
Percentage of IPDP EMIC waves correlated with REP	**5%**

- In our study IPDP EMIC waves were identified at Halley Bay.
- Using POES data, REP events precipitating +/- 15 degrees from the Northern magnetic conjugate point were identified.

- In the Hendry et al. [2016] study they determined correlations between REP events and EMIC waves, beginning with the list of REP events precipitating +/- 15 degrees from the Northern magnetic conjugate point.
- Halley data was examined for any type of EMIC wave signature that occurred within one hour UT.
- They found that 64.8% of these events corresponded to an EMIC wave event at Halley. Of these corresponding events, 63% were IPDP wave events.

- For consistency we repeated the Hendry et al. [2016] study for the years 2008-2010 and found that 77% of these events corresponded to an EMIC wave event at Halley. Of these corresponding events, 29% were IPDP wave events.

- In our study we determined correlations between IPDP EMIC waves and REP events, beginning with the list of identified IPDP waves at Halley Bay.
- From POES data, REP events precipitating +/- 15 degrees from the Northern magnetic conjugate point were examined for any REP event that occurred during an IPDP wave and within 1 hour UT of an IPDP wave.
- We found that only 5% of IPDP EMIC wave events were correlated with a REP event located near the magnetic conjugate point of Halley Bay.
- **We have shown the existence of IPDP EMIC waves that do NOT precipitate particles.**

References:

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Acknowledgment: Research at the University of New Hampshire was supported by the NSF as well as the BAS (Richard Horne and Nigel Meredith).