EMIC Wave Association With Geomagnetic Storms, the Plasmasphere, and the Radiation Belts

By

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I hereby certify that the work embodied in this thesis has been done in collaboration with other researchers, or carried out in other institutions. I have included as part of the thesis a statement clearly outlining the extent of collaboration, with whom and under what auspices.

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I hereby certify that the work embodied in this thesis contains a published paper/s/scholarly work of which I am a joint author. I have included as part of the thesis a written statement, endorsed by my supervisor, attesting to my contribution to the joint publication/s/scholarly work.

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Abstract

Electromagnetic Ion Cyclotron (EMIC) waves have recently been considered an important process in the magnetosphere and in particular contribute to electron loss in the radiation belts. Here we describe the characteristics of EMIC waves under different magnetospheric conditions, their relationship to the plasmasphere and plasmaspheric plumes, and start examining the ability of EMIC waves to resonate with radiation belt electrons using data from the Combined Release and Radiation Effect Satellite (CRRES). The CRRES mission was operational from 25 July, 1990 until 21 October, 1991. It had an orbital period of 9 hrs and 52 minutes and was able to observe the magnetospheric region of $3 < L < 8$, magnetic local times (MLT) between 14:00 - 08:00 hr, and magnetic latitudes (Mlat) between $\pm 30°$. CRRES observed 913 EMIC waves and 124 geomagnetic storms. Due to the lack of coverage around noon, the majority of EMIC waves were found to occur in the dusk sector at MLT = 15 hr and at L = 6. The highest occurrence rates for EMIC waves occurred during the main phase of geomagnetic storms, when it is expected that there may be overlap between the cold plasmaspheric plasma and the hot ring current plasma.

The role of the cold plasmaspheric plasma has been examined. It was found that EMIC waves were observed in regions with enhanced cold plasma densities under all magnetospheric conditions except for the pre-onset phase of a geomagnetic storm, which may be due to the small number of events. As CRRES was not always able to observe the boundaries of either the plasmasphere or a plasmaspheric plume during each orbit, a superposed epoch was created of the observed densities at L-values between 3 and 8 for the region between 14 hr$<$ MLT $<$18 hr, the region where plasmaspheric plumes are expected to be observed, for each phase of the 124 geomagnetic storms observed by CRRES. During the main phase of the geomagnetic storms, an increase in the plasmaspheric number density was observed between $5 < L < 7$. This is consistent with the idea of plasmaspheric plumes forming during this phase. However, the mean location of the EMIC wave events during the main phase of a geomagnetic storm falls in the middle of the plume, not on the boundary as suggested by some theories. It has been predicted that EMIC waves need negative density gradients in order to grow to observable levels and to propagate effectively through the magnetosphere. No significant correlation between local density gradients and the occurrence of EMIC waves was found.

EMIC waves have been suggested as a mechanism for electron particle loss in the radiation belts. It was found that for electrons with energies of 1.25 - 10 MeV, there were EMIC wave events where the pitch angle diffusion extended into the loss cone. It is expected that after bounce averaging the diffusion coefficients will exceed the strong diffusion regime under most magnetospheric conditions for electron energies between 1.25 and 2 MeV. On average the highest diffusion coefficients were observed during the main phase of geomagnetic storms.

CRRES has greatly increased the communities understanding of EMIC waves and their role within the Earth-Space environment. It has been shown where and when to expect to see these waves, how plumes, but more importantly enhanced cold plasma densities, play a large role in EMIC wave occurrence, and how EMIC waves are able to resonate with radiation belt electrons contributing to the main phase loss in the radiation belts. This thesis concludes with a look towards continuations of this work and future research projects which will help address some of the raised and unanswered questions throughout the thesis.