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Subrelativistic Electron Precipitation Driven by Electromagnetic Ion Cyclotron (EMIC) Waves: Multi-Event Analysis Using Multi-Satellite Observations

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Many observations, simulations and theories show that electromagnetic ion cyclotron (EMIC) waves can scatter ~10s–100s keV protons and ~MeV electrons into the Earth's upper atmosphere, representing an important loss mechanism for radiation belt electrons in the Earth's magnetosphere. However, the minimum energy of electrons that can be subject to efficient EMIC wave scattering is still an outstanding open question. Evidence of sub-relativistic EMIC-driven precipitation has been suggested by a few studies [1, 2, 3], while satellite measurement limitations (e.g., proton contamination) make it challenging to provide direct unambiguous observational evidence. In this presentation, we use coordinated measurements of satellites to correlate EMIC wave activity with precipitation observed at low orbit. We analyze all available magnetic conjunctions (>~ 2000) between Van Allen Probes, POES and FIREBIRD-II and select those that show clear EMIC-driven precipitation signatures. Van Allen Probes (on the magnetic equator) provide wave and particle data in the magnetosphere, while POES and FIREBIRD-II satellites (at low Earth orbit) observe the particle precipitation resulting from wave-particle interactions. We found an interesting case study (21 November 2019) in which a clear EMIC-driven precipitation signature was observed during a magnetic conjunction between MetOp-01 and FIREBIRD Unit 3: protons were precipitating simultaneously with subrelativistic (down to ~265 keV), relativistic (>700 keV) and ultrarelativisitic (>3 MeV) electrons. In addition, several passes of other POES satellites and one pass of the other FIREBIRD Unit revealed persistent precipitation for ~2 hours, which spatially shifted over L shells of 4 – 5.5, but remained localized in a single precipitation event. We expanded our study to 38 EMIC-driven precipitation intervals occurring during conjunctions (5-6 years of data). Clear EMIC-driven precipitation events were easily identifiable within $L \sim 7$, and located between 15 and 24 magnetic local time (MLT), in agreement with a higher occurrence of EMIC waves near dusk. Although the precipitation region covered a rather wide L-MLT area, the extent of each precipitation event was fairly small (on average ~0.3 L), indicating that EMIC waves drive precipitation in a localized L shell region. These two findings suggest that EMIC waves scatter electrons in localized patches, but can likely scatter multiple precipitation patterns within the excitation region where resonance conditions are met. Most of the precipitation events showed that EMIC waves systematically scatter electrons not only at ~MeV energies, as expected, but also in the subrelativistic regime (down to ~200–300 keV). Our study provides direct evidence of electron precipitation in the subrelativistic regime in a systematic way (with no modeling assumptions or proton contamination limitations).

References

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