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Swarm as an EMIC Wave Monitor: Applications for Radiation Belt Modelling and Specification

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The outer belt electron radiation belt is highly dynamic, responding to a superposition of a variety of acceleration and loss processes imposed along the electron drift orbits to produce increases and decreases in flux on timescales from minutes, to hours, days and years. These trapped relativistic so-called ‘satellite killer’ electrons can penetrate spacecraft shielding and cause damage to internal electronics and single-event upsets. Understanding and predicting the radiation belt environment, therefore, is valuable for the understanding and mitigation of these potentially catastrophic impacts. Magnetic measurements from the constellation of Swarm satellites in low-Earth orbit (LEO) can be used to monitor the populations of electromagnetic ion cyclotron (EMIC) waves along their orbits. This is significant for radiation belt applications since these waves are believed to be potentially responsible for some fast losses of radiation from the Van Allen belts through fast scattering into the loss cone. Despite being far from the equatorial plane where most of the radiation belts are trapped, the propagation of EMIC waves along field lines allows an assessment of these wave populations from LEO, Swarm and similar satellites in LEO traversing the radiation belts four times in each approximately 90-minute orbit. Here we demonstrate how Swarm can be used to detect and characterize the EMIC wave populations, and compare the observed EMIC wave populations to simulations of two strong magnetic storms where radiation belt modeling based on radial diffusion demonstrated the likelihood of a missing fast loss process and which might be explained by EMIC wave-particle interactions. The current state-of-the-art for the incorporation of EMIC-related wave losses is based on empirical means, related for example to solar wind compressions. Here we investigate, despite the often spatio-temporally localized character of some EMIC wave populations, whether magnetic field data from the Swarm constellation could be used in an observational data-constrained approach for the inclusion of EMIC wave losses in radiation belt modelling. LEO satellites have the advantage over high-apogee near-equatorial satellites in that the latter only cross L-shells comparatively slowly; similarly, the interpretation of EMIC wave location from ground-based magnetometer networks is complicated by propagation in the ionospheric duct. Through the use of multi-spacecraft techniques, and/or those which utilise electric and magnetic data together, we demonstrate how it is possible to reliably disentangle EMIC waves from nearby field-aligned currents. Such techniques provide hitherto unprecedented observation capability for the specification of EMIC waves from LEO for use in radiation belt modelling. Future work could examine the utility of such data for both improving the accuracy of radiation belt models, and for the nowcasting and even forecasting of

belt dynamics.