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Radiation belt precipitation due to man-made VLF transmissions: satellite observations

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Previous studies have reported enhancements in drift-loss cone electron fluxes linked to powerful VLF transmitters. We examine the significance of the transmitter NWC on the inner radiation belt by combining DEMETER satellite observations with transmitter operation times. Enhancements in the ~100-260 keV drift-loss cone fluxes show a strong correlation to NWC operation and low (night-time) ionospheric absorption, and are only observed downstream of the transmitter. No enhancements are observed during daytime or when the transmitter is non-operational, while ~95% of downstream, night-time observations during transmitter operation show enhancements. This provides conclusive evidence linking drift-loss cone electron flux enhancements and transmitter operation. When contrasted with periods when NWC is non-operational, there are typically ~430 times more 100-260 keV resonant electrons present in the drift-loss cone across L=1.67-1.9 due to NWC transmissions. Almost no such enhancements are produced by the transmitter NPM, despite its low latitude and relatively high output power. The lack of any enhancement for L<1.6 suggests that non-ducted propagation is an inefficient mechanism for scattering electrons, which explains the lower cutoff in L of the NWC-generated enhancements and the lack of NPM-generated enhancements. Finally, we consider the significance of these results from the perspective of radiation belt remediation.