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# Diffusion Modeling of Electrons in the Inner Zone and Slot Region

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Wave-particle interactions have long been considered central to the behavior of energetic electrons in the inner radiation belt and slot region. Plasmaspheric hiss constitutes one of the main components of the waves, but lightning and VLF ground transmitters also make important contributions to the wave population. Benchmark models for each of these types of waves, pre-VAP but post-CRRES, were given by Abel and Thorne [1998]. Much work on refining these estimates has been done since then, using wave measurements from VAP as well as Cluster, THEMIS, and others. (The bulk of these observations have been equatorial, though informed by ray tracing.) The effects of very low frequency hiss, highly oblique whistlers, and magnetosonic (MS) waves have come to be recognized as significant. MS waves particularly come into consideration in discussions of butterfly pitch angle distributions. Of greater global significance is the presence or absence of MeV electrons at L <= 2, for which wave-particle interactions are likely to be crucial. Indeed, one set of arguments is based on a "VLF bubble" tied to VLF transmitters.

To investigate these processes, AFRL is planning "active experiments" using a VLF transmitter on the DSX satellite, whose launch is imminent. Preparation has included extensive modeling of existing VLF ground transmitters. This includes the crucial stage of trans-ionospheric propagation, earlier models of which were found to require much more detailed treatment than traditionally assumed. The ensuing 3D ray tracing accounts for wave power intensification and attenuation as well as ray paths. The resulting quasi-linear pitch angle and energy diffusion coefficients were used in a recent study of butterfly pitch angle distributions at L=2 [1]. AFRL has also developed a global model of lightning-generated whistlers. This is based on the association between statistics of lightning flashes observed by the orbiting Optical Transient Detector/Lightning Imaging Sensor and corresponding electric fields measured by the Demeter satellite; wave propagation is also modeled by ray-and-power tracing to obtain diffusion coefficients [2]. Here, details of the modeling and comparison with other wave models and diffusion coefficients throughout the plasmasphere will be presented, and our current understanding of these processes and their implications will be assessed.

1. J. M. Albert, M. J. Starks, R. B. Horne, N. P. Meredith, and S. A. Glauert, "Quasi-linear Simulations of Inner Radiation Belt Electron Pitch Angle and Energy Distributions," *Geophysical Research Letters*, **43**, 2016, pp. 2381–2388, doi:10.1002/2016GL067938.

2. J. J. Colman and M. J. Starks, "VLF Wave Intensity in the Plasmasphere Due to Tropospheric Lightning," *J. Geophysical Research*: *Space Physics*, **118**, 2013, pp. 4471–4482, doi:10.1002/jgra.50217.