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Numerical simulation of energetic electron microsignature drifts at Saturn: methods and applications

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Abstract

Most of Saturn's moons that reside in the inner and the middle magnetosphere of Saturn are very effective absorbers of energetic electrons. Since the resulting cavities cannot refill within the local, moon-magnetosphere interaction region, they propagate in the magnetosphere with the properties of the pre-depleted energetic electrons. These regions, called microsignatures, can survive up to 1.5 rotations around the planet, and for that reason they are excellent tools for tracing the shape of the magnetospheric particle drift shells. Such tracing studies have so far revealed the existence of a magnetospheric electric field, with an orientation fixed in local-time and the presence of time-varying azimuthal electric fields in Saturn's inner magnetosphere. In all cases, however, a substantial part of the tracing calculations were performed assuming a dipole field configuration and corotation-driven azimuthal electric fields, as the latter allow for straightforward, analytical solutions of the equations of motion. Most studies have also neglected technical issues related to the detection of the microsignatures, such as the finite (and sometimes large) energy width and complex response of the detector channels that record the relevant signals. In this study we demonstrate how all these assumptions and simplifications may introduce significant errors in the outcome of the microsignature analysis and how the use of the correct system of equations can help understand all major aspects of microsignatures (e.g. energy dependent position), enhance the output and allow for additional applications that are based on the use of the microsignature dataset. For that reason we developed numerical particle tracing techniques in which Saturn's moons are simulated as continuous "sources" of absorbed "pseudoparticles". The latter are traced in configurations comprising predefined magnetic field models and arbitrary electric fields. The simulation output is then compared with MIMI/LEMMS and CAPS/ELS energetic electron observations, in which we highlight the power of this approach in studying electric fields in Saturn's magnetosphere.