The First Large-Scale Simulations of Farley-Buneman Turbulence in 3D

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In the E-region ionosphere, turbulent processes driven by strong ambient DC electric fields create plasma density irregularities responsible for type 1 radar echoes. These irregularities play a role in ionospheric conductivity, temperatures, and radio wave propagation and reflectivity. As a result they have been studied experimentally and theoretically for five decades. In the last decade, numerical simulations became an important tool in exploring the nonlinear behavior of E-region instabilities. However, these simulations were limited to 2-D and meshes resolving typically around 4096 (64 by 64) cells. Having improved the method of parallel processing of our Particle-In-Cell (PIC) code, EPPIC, we can now take advantage of supercomputers with thousands of processors to run simulations with enormous meshes in 2-D or 3-D (up to 512 x 512 x 512 in 3-D).

In this presentation, we will compare 2-D and 3-D simulations of FB turbulence. As predicted by theory, the 3-D simulations show the development of modes with a small component parallel to the geomagnetic field. Nevertheless, the 2-D and 3-D runs develop similar spectral features. We also can quantify the 3-D wave-driven electron heating, a phenomena clearly observed by radars. Finally, we will describe how these recent high-resolution simulations relate to measurements of type 1 waves.

For our current FB simulations we apply a kinetic algorithms to model both electron and ion dynamics and an appropriate collision algorithms to simulate the elastic and inelastic collisions. This allows us to explore thermal effects with great accuracy but requires us to resolve the Debye length and electron gyrofrequency. Hence, we use artificial values for electron mass ($m_{ion} \sim 625 m_e$) and adjust all other parameters appropriately. This also forces us to resolve short wavelengths, limiting our total resolution.