3D Simulations of Farley-Buneman Turbulence Demonstrates Anomalous Electron Heating

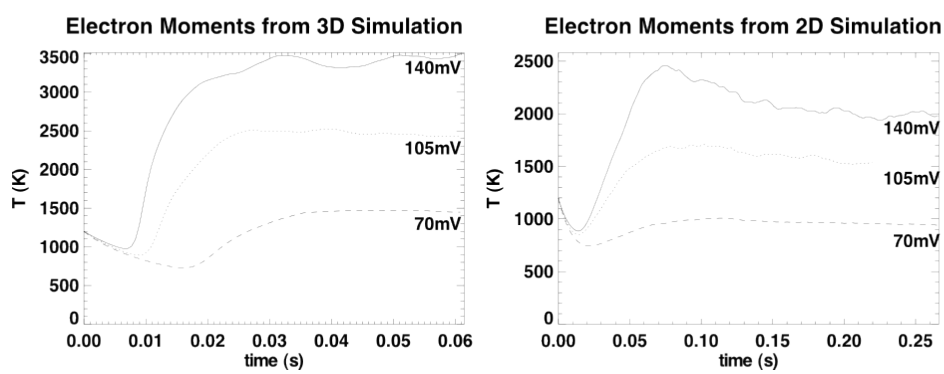
M. M. Oppenheim[1] **and Y. S. Dimant**[1]

[1]Center for Space Physics, Boston University, 725 Commonwealth Ave., Boston, MA, 02215, USA
(meerso@bu.edu and dimant@bu.edu)

Abstract

Field aligned currents flow from the magnetosphere to the E-region ionosphere where they drive auroral electrojets. These currents often cause Farley-Buneman (FB) instabilities to develop and become turbulent. These irregularities substantially affect ionospheric conductivity, temperatures, and VHF and UHF radio wave propagation. Many of the observed characteristics of radar measurements of this region result from the nonlinear behavior of this unstable plasma. While FB waves have been studied experimentally and theoretically for five decades, about fifteen years ago, numerical simulations became an important tool in exploring the nonlinear behavior of E-region instabilities. Parallel processing now allows Particle-In-Cell (PIC) codes, to to run simulations with enormous meshes in either 2-D or 3-D [1].

This talk will present recent 3-D PIC simulations showing anomalous electron heating due to FB turbulence, a phenomenon clearly observed by radars [2]. The resulting temperatures can rise over an order of magnitude (Fig. 1). These simulations also show the saturated amplitude of the waves; coupling between linearly growing modes and damped modes; the evolution of the system from shorter to longer wavelengths; and phase velocities close to the acoustic speed. These simulations reproduce many of the observational characteristics of type 1 radar echoes. As predicted by theory, the 3-D simulations show the development of modes with a small electric field component parallel to the geomagnetic field and this field causes the majority of the anomalous electron heating.



1. Electron temperatures elevated by simulated FB turbulence at ~105km altitude. Both panels compare the evolution of three simulations driven by large-scale electric fields while holding all other parameters constant. Though the background neutral temperature was set at 300K, the plasma temperature was initialized to 1200K for computational reasons. Initially, the temperature drops as the plasma loses energy through collisions with neutrals then, as the instability evolves, the temperature rises primarily due to anomalous electron heating.

References

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