Project Details

ROSES ID: NNH10ZDA001N
Selection Year: 2011
Program Element: Focused Science Topic

Topic: Low-To Mid-Latitude Ionospheric Irregularities and Turbulence

Project Title:
Kinetic 2D and 3D simulations and theory of low- to mid-latitude ionospheric irregularities

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Summary:
Plasma turbulence in the ionosphere often disrupts and distorts GPS and radio communication between space and Earth. Typically, this arises when solar-terrestrial interactions create strong density gradients or wind shears that, in turn, drive plasma instabilities. The Boston University (BU) research group proposes to contribute to a Focus Team Effort by exploring the development, evolution, and effects of ionospheric turbulence on spatial scales ranging from centimeters to kilometers and temporal scales from milliseconds to minutes. They will do this using large-scale kinetic simulations, theory and modeling. This will help scientists and engineers better understand fundamental physical processes of the space environment and further adapt our space-based technological systems.

The BU team can most easily contribute to the first two types of investigations outlined in section 1.2.1(a) of the ROSES "Living With a Star Targeted Research and Technology Simulations:"

1. Theoretical studies of the linear and nonlinear development of ionospheric instabilities,

2. First-principle modeling of ionospheric irregularities and turbulence in 2D and 3D

They can also contribute to "observational studies identifying regions of ionospheric irregularities and possible causal mechanisms, "particularly as users of Jicamarca Radio Observatory (JRO) data. Their research should advance all of the measures of success listed in 1.2.1(a), but in particular their research will enhance the following:

1. Development of improved models of E and F region plasma instabilities and turbulence;

2. Understanding of the connection between large-scale ionospheric processes and the development of electron density irregularities (e.g., equatorial spread F); and

3. Development of a predictive capability for irregularity onset and evolution.

The research group at BU has developed an electrostatic, massively parallel, particle-in-cell (EPPIC) plasma simulator that also has the ability to apply hybrid techniques (e.g., PIC ions & fluid electrons). It works equally well in 1D, 2D and 3D and has been used for a broad range of plasma problems. This code runs efficiently on some of the world s largest super-computers, scaling to tens of thousands of processors. It allows them to simulate ionospheric plasmas spanning a range of scales that were impossible until the current generation of supercomputers came on-line.

Due to its effects on communication and GPS, Equatorial Spread-F (ESF) is the most important of these instabilities. While there are currently computer models that simulate the evolution of large-scale spread-F phenomena (1000km-to-kilometer), no such models exist for medium and short-scale irregularities (kilometer-to-meter). These small irregularities are what radars and spacecraft instruments measure, and they have a direct impact on the propagation of radio waves. This project aims to fill this gap by simulating ESF from the smallest physically important scale (~10 cm) to kilometer scales and develop a better understanding of how these irregularities evolve and dissipate. In order to accurately model short wavelength dissipation, such

computations must be kinetic, at least for ions. As a secondary investigation, the BU team can also explore E-region instabilities. In particular, they can study the evolution of large-scale gradient-drift waves and also at how mid-latitude shear-driven sporadic-E irregularities develop, evolve, and couple to the F-region. For all investigations, they will compare simulation and model results to measurements, both spectrally and spatially. This will allow them to appraise the accuracy of their techniques and to suggest new approaches and measurements. These studies will further scientist s ability to model and predict the onset, evolution, and effects of ionospheric irregularities.

Publication References:

Summary: no summary

Reference: Dimant, Y. S.; Oppenheim, M. M.; (2011), Magnetosphere-ionosphere coupling through E region turbulence: 1. Energy budget, Journal of Geophysical Research, Volume 116, Issue A9, CiteID A09303, doi: 10.1029/2011JA016648

Summary: no summary

Reference: Oppenheim, Meers M.; Dimant, Yakov S.; (2016), Photoelectron-induced waves: A likely source of 150 km radar echoes and enhanced electron modes, Geophysical Research Letters, Volume 43, Issue 8, pp. 3637-3644, doi: 10.1002/2016GL068179