PLASMA IRREGULARITY PRODUCTION IN THE POLAR CAP F-REGION IONOSPHERE

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Abstract

Plasma irregularities in the polar *F* region ionosphere are investigated primarily using ground based radars within the Super Dual Auroral Radar Network (SuperDARN) and the factors that contribute to the production and observation of these irregularities are considered. First, solar control on irregularity production is evaluated. A band of ranges where echoes are statistically most likely to be observed is identified. The location of this band varies diurnally and seasonally, but its motion relative to the radar can be explained by background density with solar illumination effecting radar beam propogation. The high observed occurrence of backscatter at night implies an additional source of nighttime plasma density that is not accounted for by traditional models. An example is presented that shows frequent polar patches may be the source of this density. Backscatter occurrence peaks at the terminator. Nighttime occurence is enhanced when a positive IMF By component is present, probably due to changes in the convection pattern creating a more favorable situation for gradient-drift instability growth.

The gradient-drift instability is modeled within the field of view of a SuperDARN radar to identify when the growth rate is largest and examine asymmetry around large-scale structures, such as polar patches. Dependencies on the relative directions of the gradient, plasma drift, and wavevector are all considered throughout the ionosphere. In the *F* region, the strongest asymmetry is found when an elongated structure is oriented along the radar's boresight and moving perpendicular to its direction of elongation. These results have implications for observations made with the SuperDARN network, but assume the directional dependencies predicted by linear GDI theory are applicable at decameter scales.

To test the accuracy of the predictions found from the model, irregularities surrounding a polar patch are analyzed in the context of linear gradient-drift instability theory. Backscatter power and occurrence from decameter scale irregularities are found using measurements from the SuperDARN radar at Rankin Inlet while background density gradients and electric fields are found from the north face of the Resolute Bay Incoherent Scatter Radar. Particular emphasis is placed on directional dependence and wether small-scale irregularities show any signs of anisotropy. While low powered echoes seem to follow the predictions of linear theory, higher power echoes quickly exhibit much more complicated, nonlinear behavior.

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Chapter 1
Introduction

The majority of mass in the universe exists as plasmas. Plasmas are fluid masses of charged particles, often formed when neutral atoms and molecules in a gas are ionized by external energy. Everyday examples of this is florecent lightbulbs, as well as flames. More exotic instances of plasma include nuclear fusion reactor experiments, most stars, nebula, and the interstellar medium. In fact, about 99% of matter in the known universe exists in the plasma state. Of particular interest to this thesis is the plasma in Earth's ionosphere.

Plasmas can be either fully ionized, where most particles in the plasma are ionized, or partially ionized, where only some fraction are ionized and the rest are neutral. Considering the dynamics of plasmas therefore requires not only collisions between particles to be considered but also charge-charge interactions and external electric and magnetic fields. These dynamics can generate waves in the plasma, which cause density perturbations. Additionally, variations in temperature and electric and magnetic field strength can occur on a variety of scales. This thesis focuses on mechanisms by which density variations in ionospheric plasma occur, often referred to as plasma structures.

1.1 The Solar-Terrestrial Environment

The solar terrestrial environment begins with the Sun in the center of the solar system. The Sun is composed of highly energized plasma that is gravitationally bound together. The surface of the Sun has sunspots, which are dark, relatively cool regions with intense magnetic fields, as well as coronal holes, which are low density areas characterized with a continuous outflow of plasma. The intense magnetic fields associated with sunspots can break down releasing a large amount of energy and plasma, known as a solar flare. Planet-sized masses of plasma known as coronal mass ejections (CMEs) can be ejected from the surface, which can be large enough to maintain an internal magnetic field as they travel through the solar system. The frequency of sunspots and large outbursts of plasma changes with the 11-year long solar cycle. A large number of sunspots, high occurrence of fast, dense plasma outbursts, and a highly variably magnetic field indicate solar maximum. Conversely, solar minimum is characterized by a low sunspot number and slow and relatively steady outflow. This thesis examines factors that control irregularity production in the Earth's ionosphere, which can be strongly influenced by solar activity.

The Sun interacts with the rest of the solar system through the solar wind, a continu-