Equatorial spread F-related currents: 3-D simulations and observations

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Introduction

Equatorial spread F (ESF) refers collectively to a family of plasma irregularities that form in the equatorial F region ionosphere after sunset. Magnetometers are the only instruments able to measure perturbations in the ionospheric current system. In the last two decades, experimental evidence of magnetic perturbations associated with ESF has been shown by magnetometers onboard the San Marco-D and AE-2 [Aggon et al., 1992], CRES [Koons et al., 1997], CHAMP [Lühr, et al., 2002], and DEMETER satellites [Pottelette et al., 2007]. Bhattacharyya and Burke [2000], using a transmission line analogy, explained those magnetic perturbations in terms of field-aligned currents (FAC) generated by equatorial F region irregularities. Experimental observations made by the DEMETER satellite support this idea.

Open Question

A three-dimensional numerical simulation of plasma density irregularities in the post-sunset equatorial F region ionosphere leading to equatorial spread F (ESF) is described. Simulated satellite passes are compared with CHAMP magnetometer observations and show agreement. The main issue we address here is the degree to which it is possible to predict the current densities related to ESF and their relative contributions to space-based magnetometer measurements given an appropriate specification of the initial conditions and the forcing.

3-D Model

3-D Electrostatic potential

∇·[∇Φ] = ∇·[E₀ + U × B₀] + ∂t [V₀ + E₀] [g]

Force balance

0 = -nₑ [E₀ + V₁ × B₀] - nₑ Tₑ ∇nₑ
+ nₑ [mₑ][E₀ + V₁ × B₀] - ∑ₖₚ [Vₖₚ × Vₖₚ] - nₑ [V₁ × U] [g]

Continuity equation

∂nₑ / ∂t + ∇·[nₑ U] = Pₑ - Lₑ

• Monotone Upwind Scheme for Conservation Laws (MUSCL)

3-D Magnetostatic Solver

J = -Σ [E₀ + V₁ × B₀] + ∇×B₀ + g

Summary

– the divergence of the transverse currents generate field-aligned currents flowing poleward (equatorward) on the external edges of the western (eastern) walls of the depletions;
– magnetic perturbations parallel (transverse) to the main field are mainly due to diamagnetic (field-aligned) currents;
– it argues against an Alfvénic interpretation of all of the CHAMP mag. field observations in ESF.

Radar Observations

Simulated Currents and Magnetic Field Perturbations

Satellite Pass

Model Inputs

– Temperature and Neutral Densities → NRLMSISE-00;
– Electron Density → PIM;
– Ion Composition → IRI-2007 → Atomic (O²⁺);
– Neutral Winds → HWM-07 + Chemical release;
– Background electric fields → Scherließ-Fejer model.

References