Plasmasphere Tomography

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The key to plasmasphere tomography is that (1) the electromagnetic energy from individual lightning in the ELF/VLF range (1-10 kHz) enters the ionosphere over a range of latitudes (λm ~10°- 45°) and propagates to a magnetospheric satellite by numerous paths that cover a large part of the plasmasphere; (2) the energy is received on the satellite as a multicomponent whistler (multiple traces) whose dispersion and frequency cutoffs depend on the distribution of electron density and ion composition in the plasmasphere. Application of a ray tracing inversion method, developed for whistler-mode radio sounding from the IMAGE satellite [Sonwalkar et al., JGR, 116, pp. A11211, 2011], to the analysis of multicomponent whistler has led to two-dimensional (2D) images of plasmaspheric electron density and ion composition (H+, He+, O+). We demonstrate our results by applying the method to whistlers observed on Van Allen Probes (RBSP-B) on 29 October 2012 when the satellite was at L=2.15, λm = 2.24°S, MLT = 1.1. In this case, the plasmasphere tomography provided electron density and ion composition in the magnetic meridional plane of the satellite for the L-shell range of L~1.2 - 2.8, magnetic latitude range of λm ~ ±40 deg, and altitude range covering ~90 – 11,500 km. The electron density obtained by plasmasphere tomography agrees with RBSP-B along the orbit in situ electron density measurements from upper hybrid frequency measurements. The O+/H+ transition height obtained from tomography is consistent with past measurements.

Plasmasphere tomography provides 2-D images of plasma density with a temporal resolution of ~10-20 s. The method applied to whistler measurements along a satellite orbit or from multiple satellites should provide electron density and ion composition with increased accuracy, wider coverage, and synthesis of 3-D images from 2-D meridional plane images. The method applies to whistler data from the past, current, and future satellites (e.g., DE-1, Van Allen Probes, CLUSTER, ARASE, DSX). Plasma density and ion composition are crucial parameters in key magnetospheric processes. We discuss potential applications of plasmasphere tomography in the study of wave-particle interactions (e.g., hiss and slot region generation), plasmasphere refilling, and magnetosphere-ionosphere-thermosphere coupling.

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