RADIO PLASMA IMAGER OBSERVATION OF MAGNETOSTORM EFFECTS ON THE PLASMASPHERIC DENSITY DISTRIBUTION

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ABSTRACT

The Radio Plasma Imager (RPI) on the IMAGE spacecraft has conducted echo radio sounding experiments since April 2000. Our analysis shows that the strongest sharp echo traces observed by RPI in the plasmasphere are the result of field-aligned propagation. Therefore the entire electron density distribution along the magnetic field line through the spacecraft location is measured with one plasmagram. Consecutive Plasmagrams can then establish the plasma distribution as function of L value and magnetic latitude. The paper discusses the depletion and refilling of the plasmasphere as a result of the March 31, 2001 magnetic storm.

INTRODUCTION

Application of the radio sounding technique to the magnetosphere has provided the unprecedented capability of remotely measuring the global plasma density in the plasmasphere with high reliability. The Radio Plasma Imager (RPI) [1] on IMAGE [2] has conducted echo radio sounding experiments since April 2000. Using the relations between the sounding frequency and the local plasma density through the applicable dispersion relations and the measured time delays for echoes at different frequencies, one can determine the distance to the reflection point, and therefore the density distribution along the propagation path [3]. Our analysis shows that the strongest sharp echo traces observed by RPI in the plasmasphere are the result of field-aligned propagation. It is therefore possible to measure the plasma density distribution along the entire magnetic field line through the satellite with a single plasmagram within less than 1 minute. A plasmagram records the echo delay time and amplitude as function of frequency as illustrated in Figure 1a (the amplitude color code is not shown here). The delay time is multiplied by c/2 resulting in the virtual range, here given in units of Earth radii, R_E. Besides the short range direct echoes from the inner plasmasphere, the plasmagram shows two well defined echo traces, one from echoes reflected in the local (northern) hemisphere with virtual ranges extending to between 2 and 3 R_E. The trace with ranges between 8 and 5 R_E is formed by echoes that return along the field line after reflection in the conjugate (southern) hemisphere [4].

PLASMASPHERE DENSITIES IN MARCH 2001

The magnetic storm on 31 March 2001 emptied the plasmasphere from L =2.3 to L = 4. The Kp values exceeded 8 on that day (Fig. 2). Using RPI plasmagrams during the quiet periods before the storm we were able to derive an empirical model for the plasma distribution in the plasmasphere. Each plasmagram provides the profile along one L-shell, which is approximated by a fitting function shown by a dotted line in Fig. 1:

$$N(\lambda) = N_0 \sec^{\beta}\left(\frac{\pi}{2}\frac{1.25\lambda}{\lambda_{inv}}\right)$$

Here λ is the magnetic latitude, λ_{inv} the invariant latitude, N_0 the density at the equator, and β a parameter. Having found N_0 and β for different L values from a sequence of quiet time plasmagrams, we were able to determine $N_0(L)$ and $\beta(L)$ by a least squares fitting approach.

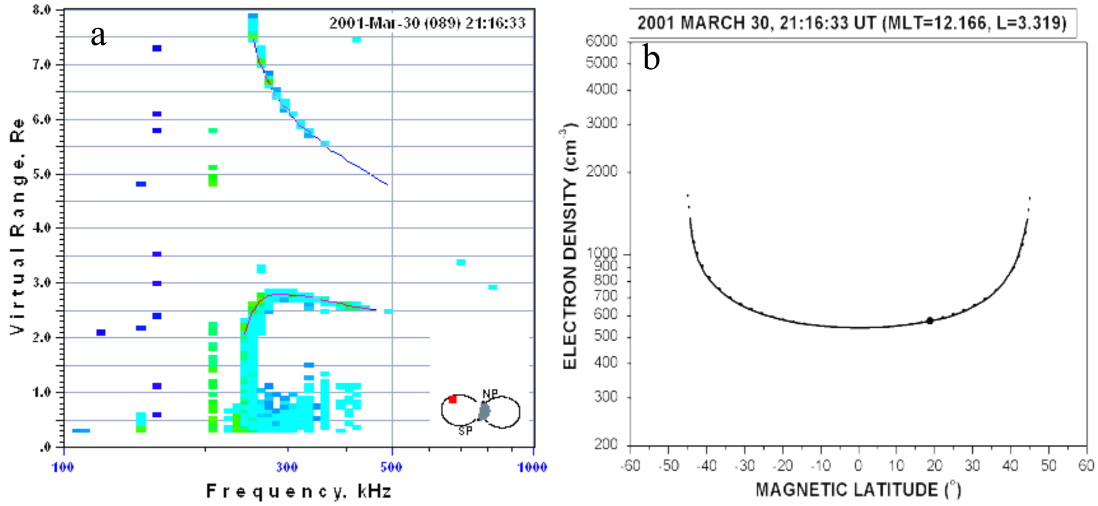

Fig. 1. a) The quiet time plasmagram shows sharp echo traces between 220 and 500 kHz with virtual ranges from 0.3 to 8 R_E. b) The electron density profile along the field line at L = 3.3. The location of the spacecraft at 20ºN is indicated by the dot. The dashed line is the fitting function.

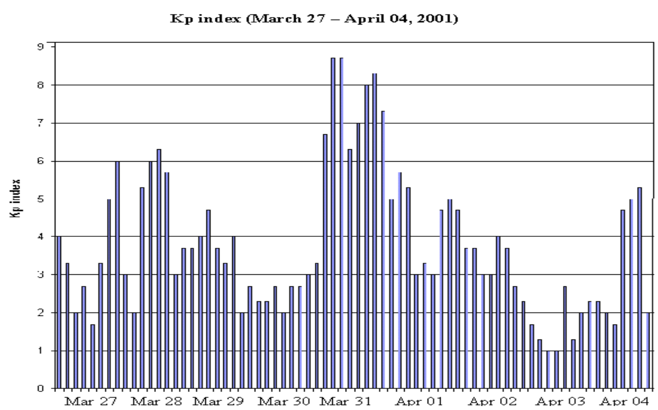

Fig. 2. Kp index for 27 March to 4 April 2001.

This produces the 2D empirical model of the quiet time plasmaspheric density distribution for March 2002, 1200 LT, shown in Fig. 3. Figure 4 illustrates the storm effects.

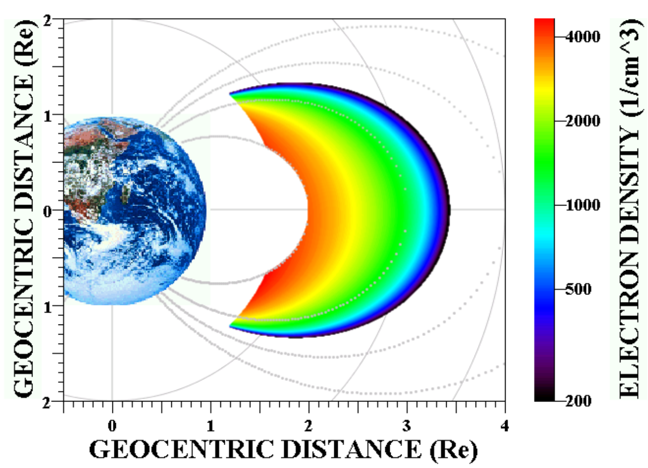

Fig. 3. Empirical noontime plasmasphere model before 31 March 2001 storm.

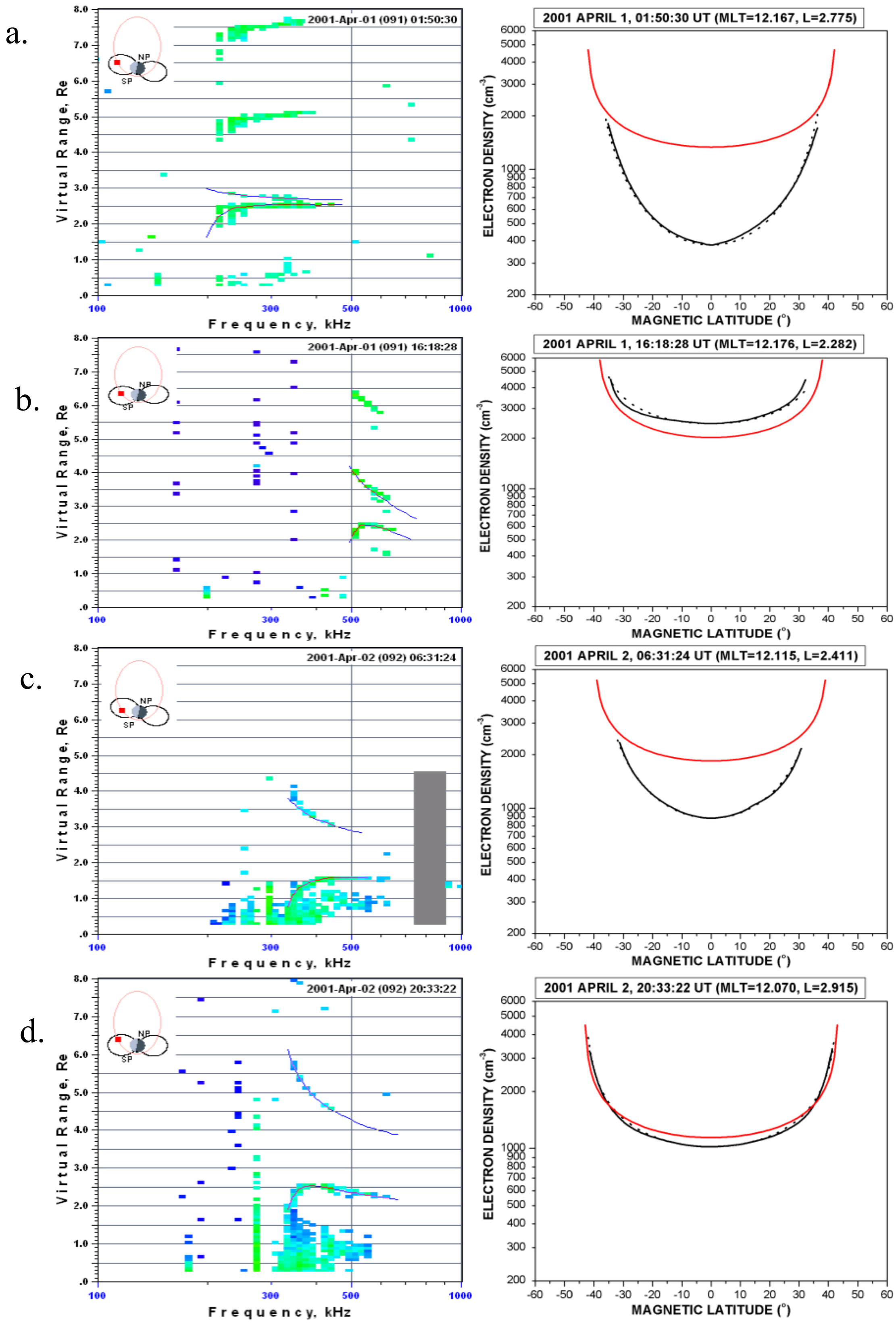

Fig. 4. Depletion and refilling of the dayside plasmasphere. The left panel shows the plasmagrams, the right panel the measured profiles (black solid curves; the dotted curve is the fitting function) together with the quiet time model (red). a) L = 2.76 at 0150 UT on 4/1, b) L = 2.28 at 1618 UT on 4/1, c) L = 2.41 at 0631 on 4/2, d) L = 2.92 at 2033 UT on 4/2.

A few selected profiles (black solid curves) are displayed on the right side of Fig. 4 to illustrate the development. At 0150 UT on April 1, IMAGE was at L = 2.76 (Fig. 4a). Comparison with the quiet day empirical model (red curve) shows that this L shell was strongly depleted. The equatorial value was reduced from ~1,600 cm^{-3} to ~390 cm^{-3}. During the next IMAGE orbit at 1618 UT the plasmagram recorded when IMAGE was at L = 2.28 (Fig. 4b) shows that this L shell was not effected by the storm, while the L = 2.4 shell (Fig. 4c) at 0631 on 4/2 is half empty with N_0 = 900 cm^{-3} compared to the quiet day value of 2,000 cm^{-3}. The profile for L = 2.92 at 2033 UT on 4/2 indicates that the plasmasphere has now refilled to its pre-storm densities. In the plasmagrams on the left side of Fig. 4 lines were drawn through the traces that were used for the profile inversion. The orbit inserts in the left upper corner of each plasmagram indicate the location of IMAGE (red dot) at the time of the measurement.

The depletion and refilling described here concentrated on the dayside plasmasphere, since no detailed analysis has yet been done fore the nightside. A quick analysis suggests a similar behavior at the nightside.

SUMMARY

Plasmasphere profile measurements with the radio plasma imager have shown the depletion and refilling of the plasmasphere in response to the March 21, 2001 magnetic storm. The L shells from L = 2.3 to the plasmapause were emptied to below half its quiet day densities. The refilling starts at 1600 UT on April 2nd and is completed 28 hours later.

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