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Total Electron Content from Mars Express Topside Ionospheric Sounding

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Abstract

The Mars Advanced Radar for Subsurface and Ionosphere Sounding (MARSIS) is a dual-mode radar sounder on board the ESA Mars Express spacecraft. It has both a subsurface and Active Ionospheric Sounding (AIS) mode. In AIS mode, MARSIS is capable of measuring both the topside electron density profile (EDP) and the radar reflection from the surface of Mars. Both of these echoes contain information about the total electron content (TEC), the electron density integrated over the full height of the ionosphere. The TEC is a diagnostic useful in characterizing the state of the ionosphere. We here show how the TEC can be obtained from both the EDP and the surface reflection. The TEC is also calculated in processing of the subsurface mode reflections. We shall use selected orbits where subsurface and AIS modes are alternated every few minutes to compute results from the two modes operating over the Martian terminator. We show the essential consistency of the several methods and lay the groundwork for work combining both subsurface and ionospheric TECs.

1. TECs from MARSIS AIS

The total electron content (TEC) of an ionosphere is the integral of the electron density along a vertical path from the ground up through the entire height of the ionosphere. It can be used to show in broad outline the planet-wide structure of an ionosphere. As an example, [3] used TEC values computed from the MARSIS subsurface sounder data to illustrate ionozation associated with the Martian crustal magnetic fields.

Figure 1 shows a sample ionogram with the ionospheric trace and the surface reflection labeled. The ionospheric trace can be inverted to give the an electron density profile, as detailed in [1]. The electron density profile can in turn be integrated to give a "topside" value of the TEC. To complete this computation, a fit is done, using a Chapman ionosphere, which can then be integrated to give a TEC for the entire main ionospheric layer. The results of the inversion procedure are shown in Figure 2.

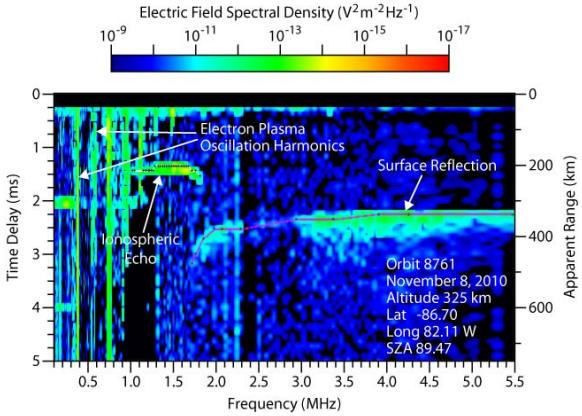

Figure 1: Sample MARSIS ionogram with ionospheric trace and surface reflection labeled.

Another feature of the MARSIS ionograms is the surface reflection. As seen in Figure 1, the surface reflection has curvature near the ionospheric peak plasma frequency.. This curvature gives us "leverage," with which to compute the TEC according to

$$T_{\rm delay} = \frac{2}{c}\int_0^Z dz \left[1 + \frac{1}{2}\left(\frac{f_{pe}}{f}\right)^2 + ...\right] \qquad (1)$$

The second term on the right-hand side of Equation 1 contains the vertical path integral of the square of the plasma frequency, *i. e.,* the TEC.

The subsurface and AIS modes of MARSIS do not operate simultaneously. To compare TECs from the

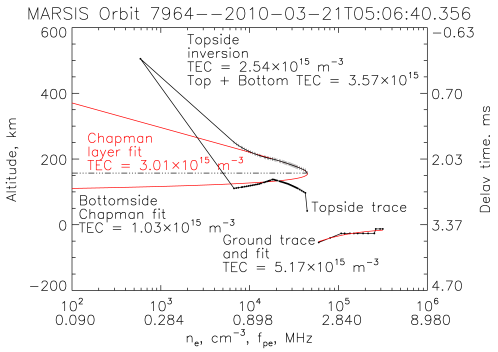

Figure 2: Sample electron density profile and surface reflection with TEC results.

two modes, we use so-called "switching mode" in which the subsurface and AIS modes are alternated. This is done over the Martian terminator, since this is where both modes are likely to give reliable results. Figure 3 shows how AIS data are interleaved between segments of subsurface data. The middle panel of this figure shows TEC computed from the subsurface processing [2].

The sample comparison shown in Figure 4 shows that, while results from different methods are broadly consistent, significant discrepancies remain. In this work we hope to resolve these issues and lay the groundwork for unified values of TEC from MARSIS subsurface, AIS density profile, and AIS surface reflection that will be useful over the entire planet of Mars.

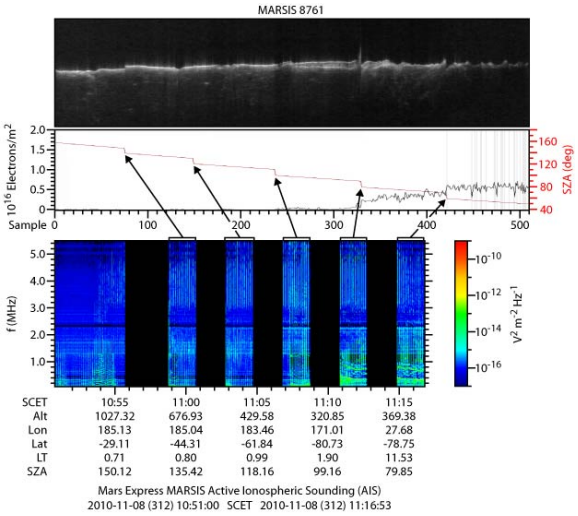

Figure 3: Top: Sample subsurface data. Middle: TECs from subsurface data. Bottom: AIS data with arrows showing where AIS is interleaved into gaps in subsurface data.

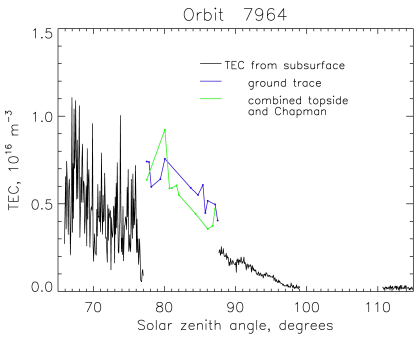

Figure 4: Comparison of three TEC computations: black, subsurface; green, AIS electron density profile; blue, AIS surface reflection.

References

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