

ESTIMATION OF MARS IONOSPHERE TOTAL ELECTRON CONTENT USING MARSIS RADAR SURFACE ECHO.

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Introduction: Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) started collecting echoes from the surface of Mars on June 21, 2005. The radar waves travel through the ionosphere and atmosphere of Mars before and after reflection from the surface. MARSIS radar waves are distorted by the ionosphere of Mars. The level of distortion is so large that science analysis is not possible unless ionospheric distortions are removed. The process of removing the ionospheric effect can yield information about the ionospheric parameters such as total electron content which are valuable by themselves in the study of the Mars ionosphere and are complementary to the MARSIS ionospheric experiment.

MARSIS Specifications: The MARSIS instrument is a multi-band wideband radar with on-board synthetic aperture processing capability. In its subsurface operation mode, the instrument can operate, simultaneously, in any two of four 1-MHz frequency bands between 1.3 and 5.5 MHz. MARSIS has a free-space range resolution of approximately 150 m [1]. The cross-track and the along-track footprint range in size from 10 to 30 km and 5 to 10 km, respectively. The radar radiates ~10 Watts using its 40 m dipole antenna. A typical MARSIS subsurface observation lasts for ~30 minutes which is the time when the S/C is within 900 km of the surface.

Ionospheric Distortion: The ionosphere's effect on the radar wave is frequency dependent. Since MARSIS bands are relatively wide (20%-50% fractional bandwidth) the signal width changes noticeably [2]. There is also group delay which makes the radar tracking task very difficult. Figure 1, shows the differences in signal shape and group delay for the same observation with (a) and without (b) ionospheric correction. In the example shown, the solar zenith angle is constantly varying from low to high resulting in a constantly decreasing group-delay and pulse

broadening as we complete the observation in the post-terminator (SZA>90 degree).

The first order correction based on signal contrast enhancement will improve the signal intelligibility significantly but there will still be small variations that are due residual ionospheric phase distortions. In order to correct for these, we take advantage of MOLA topography knowledge and constrain the MARSIS first return to the first expected return from the known topography. Since the first radar return in a give echo is not necessarily from the nadir point of the S/C, we take advantage of MARSIS echo simulator tool [3]

Fig. 2 shows a typical total electron content estimate based on a single orbit data. The data indicate a total electron content of $1 \times 10^{16} \text{ m}^{-2}$ at solar zenith angle of 70 degrees. The total electron content drops to a level of $0.1 \times 10^{16} \text{ m}^{-2}$ at SZA > 100 degrees. The curve also shows a TEC calculated based on a Chapman model derived by Gurnett et al [4].

Other workers [5] have demonstrated some level of connection between the electron distribution in the Mars ionosphere to the remnant magnetic field. A preliminary look at our data supports the idea that the TEC is impacted by the presence of a magnetic field.

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References: [1] Picardi G. et al. (2005) *Science*, 310, 1925-1928. [2] Safaeinili et al. (2003) *Planetary and Space Science* 51, 505-515, [3] Nouvel et al (2003) *Planetary and Space Science*, 51, p 505-515, [4] Gurnett et al (2005) *Science*, 310, 1929-1932, [5] D. L. Mitchell et al.(2001), *J. Geophys. Res.* 106, 23,419.

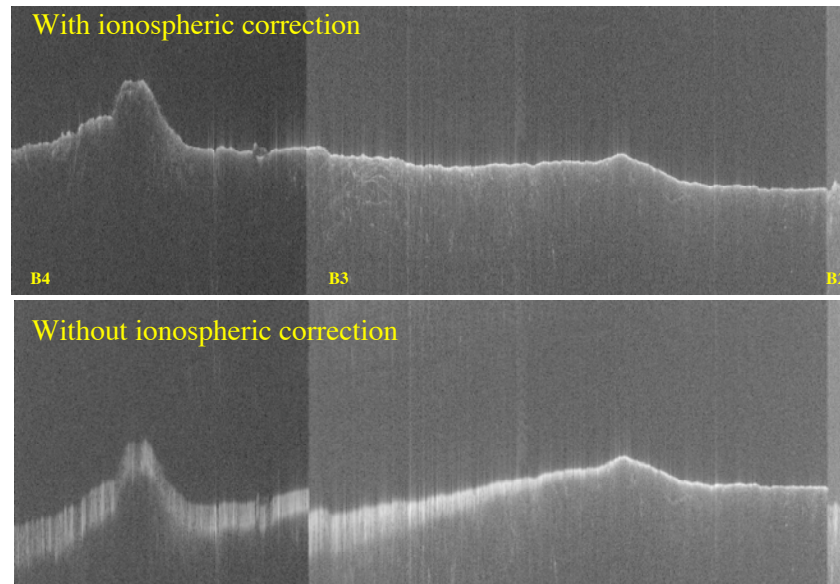


Figure 1. Radargrams showing MARSIS data for one orbit (Top) MARSIS radargram after a first-order ionospheric correction is applied, (Bottom) The same radargram before the correction; The solar zenith angle is increasing from left to right resulting in lower levels of group delay and pulse broadening on the right-side. Note when there is a shift in frequency band from the 5 MHz B4 to 4 MHz B3, there is a visible discontinuity in the data due to increased group delay and pulse broadening at lower frequency for the same level of TEC

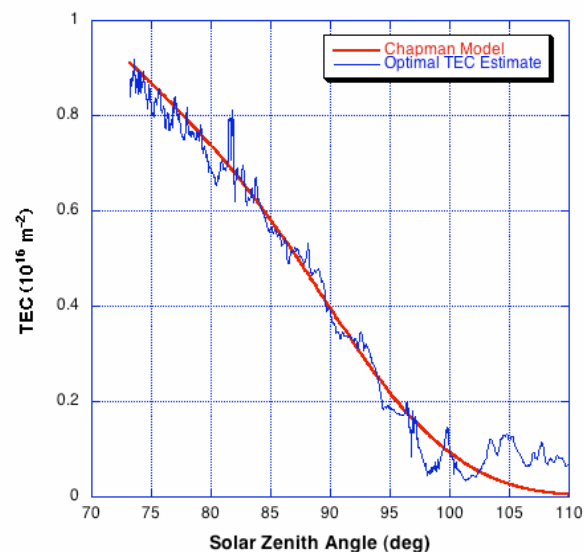


Figure 2. Comparison of an estimate TEC (blue curve) against the modeled value as described by the best-fit Chapman model. While there are significant similarities there is also noticeable differences. This ionospheric correction corresponds to MARSIS orbit 1903.