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Oblique ionospheric reflections in the MARSIS data set

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Abstract

In addition to reflections from the Martian ionosphere along the nadir direction, the Mars Advanced Radar for Sub-surface and Ionospheric Sounding (MARSIS), on board ESA's Mars Express (MEX) orbiter, frequently detects additional oblique reflections from targets off the nadir direction. Such oblique reflections have been attributed to the presence of anomalous horizontal structures within the ionosphere, possibly arising as the result of increases in the ionospheric scale height in regions where Mars' remnant crustal magnetic field has a 'open' or cusp-like configuration. This spatial structuring results in constant-density surfaces which are not parallel to the planet's surface, from which the MARSIS sounding pulse can be specularly reflected back to the spacecraft at what would otherwise be oblique incidence. Here, employing the substantial MARSIS data set, we examine both the spatial distribution and repeatability of detection of these oblique reflections, and relate these observations to the underlying structures producing them. We utilise the regularity of the MEX orbit to compare measurements made in closely spaced regions of longitude and identical latitudes and solar illumination angles.

1. Introduction

Previous research into the origin of these oblique reflections has shown that they are relatively common features in the Martian ionosphere, often occurring over regions where Mars's remnant crustal magnetic field is close to vertical [1, 3, 2]. Plotting the reflected intensity at a specific frequency, corresponding to a fixed ionospheric plasma density, the oblique reflections exhibit a distinctive hyperbolic shape in a time vs. apparent altitude plot (Figure 1, taken from [1]).

2. The MEX orbit

MEX is in a highly-inclined orbit. Since the start of the mission, and more so since ∼2008, MEX's orbital period has approached a 7:2 resonance with the planet's rotation period, such that every 7th orbit traverses a very similar path in latitude, longitude and surface solar zenith angle (Figure 2). We use this feature of the orbit to examine the repeatability of the structures producing oblique echoes, by studying them over multiple orbits under the same solar illumination and viewing conditions.

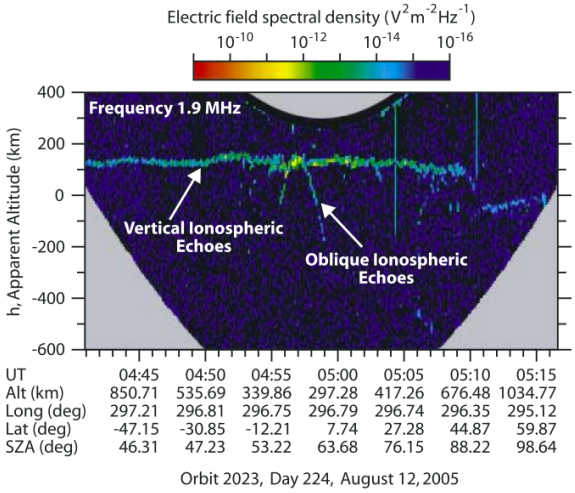

Figure 1: Oblique echo in MARSIS data, taken from [1] (their Figure 1).

3. Example of results

We show an example of our initial results in Figure 3, for orbits 6804, 6811, and 6811. At least two recurrent oblique echoes are visible, shifting gradually in their position along orbit, probably in response to the slow change in longitude between orbits. We aim to complete a fuller survey of the available data to find further such examples, where possible examining available solar wind measurements to ascertain the factors that influence the underlying ionospheric structures that give rise to these oblique echoes.

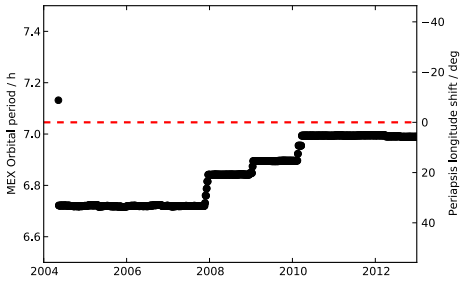

Figure 2: MEX orbital period, and the resulting separation in planetographic longitude between every 7th orbit.

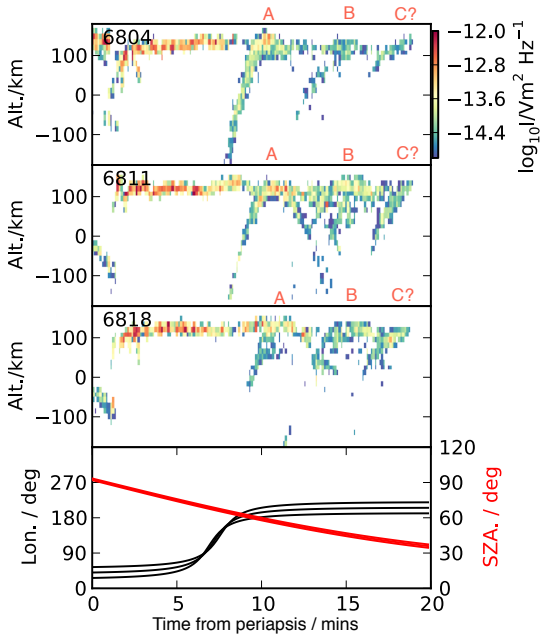

Figure 3: MARSIS reflected intensity vs. apparent altitude and time is shown for three orbits for 20 minutes post-periapsis. Longitude (black) and solar zenith angle (red) for each orbit is shown in the lower panel. Two, possibly three, recurrent oblique echoes can seen over regions of strong crustal fields near $\sim$180° longitude.

Acknowledgements

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