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Unusually strong oblique reflections observed by the Mars Express MARSIS instrument and their causative mechanisms

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The Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) instrument on the European Space Agency's Mars Express spacecraft regularly detects reflections from the Martian ionosphere. In its active ionospheric sounding mode, MARSIS observes two kinds of echoes; from vertical and oblique directions. The vertical echoes are from the normal ionosphere while the oblique echoes are believed to come from bulges of ionization in magnetic anomaly regions. The peak frequencies of these two kinds of echoes are, in general, nearly equal. In the present study, we report the detection of oblique echoes whose peak frequencies are much greater than those of the vertical echoes. Four such events are observed within a span of a few solar longitudes (Ls). In all the events, the unusually strong oblique echoes are observed in regions of strong crustal magnetic fields. After correcting for ionospheric dispersion effects, the maximum electron density in the first event is found to be $3.75 \times 10\tilde{5}$ $cm\hat{}\tilde{-}3$ and is observed at an altitude of $\sim$88 km. In subsequent events, a gradual decrease in peak electron density and an increase in its altitude are observed. The causative mechanisms of these oblique echoes are examined by considering various forces from top and bottom. We found that during the time observations, there were no solar flares or meteor in fall to cause such strong electron densities. Other possible sources such as the solar energetic particles and dust storms are thoroughly investigated. Our analysis is bowing towards the possible role of both these sources in causing such unusually strong oblique echoes.