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Simulations of the response of the Mars ionosphere to solar flares and solar energetic particle events

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Recent observations by the Mars Global Surveyor and Mars Express spacecraft have shown that the ionosphere of Mars responds strongly to solar flares and solar energetic particle events. Radio occultation observations of vertical electron density profiles show that increases in extreme ultraviolet and soft X-ray emission during solar flares cause electron densities below about 120 km to increase significantly. The relative enhancement in electron density increases with decreasing altitude, consistent with the hardening of the solar spectrum during a flare. MARSIS topside radar sounder measurements of radio wave attenuation show that the low altitude (below 130 km) plasma content of the ionosphere increases during solar energetic particle events, although these observations alone do not constrain the magnitude or vertical extent of the enhancement in plasma densities. Here we report the results of two projects simulating these effects.

We investigate the ionospheric effects of a solar energetic particle (SEP) event at Mars, specifically the 29 September 1989 event. We use its energy spectrum and a steady-state ionospheric model to simulate vertical profiles of ion and electron densities. The ionospheric response to this large event would have been readily observable. It caused electron densities to exceed 1E4 per cubic centimeter at 30-170 km, much larger densities than typically observed below 100 km. It also increased the ionosphere's total electron content by half of its subsolar value and would have caused strong attenuation of radio waves. The simulated attenuation is 462 dB at 5 MHz, which demonstrates that SEP events can cause sufficient attenuation (> 13 dB) to explain the lack of surface reflections in some MARSIS topside radar sounder observations.

We modify an existing model of the ionosphere of Mars to incorporate time-dependent solar irradiances and use it to simulate ionospheric conditions during the X14.4 and M7.8 solar flares of 15 and 26 April 2001, respectively. Simulations were validated by comparison to Mars Global Surveyor radio occultation measurements of vertical profiles of ionospheric electron density. Adjustments to the model's representation of the neutral atmosphere and electron-impact ionization were required to adequately reproduce the observations before and during these solar flares. Simulated enhancements in the electron density are largest and persist the longest in the M1 region. We predict that the peak electron density in the M1 region can exceed that of the M2 region for short periods during intense solar flares.