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Three-dimensional structure of the Martian nightside Ionosphere

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Abstract

The night side ionosphere of Mars is known to be highly variable: essentially nonexistent in certain regions, while occasionally nearly as strong as the photoionization-produced dayside ionosphere in others [1, 2]. The factors controlling its structure include thermospheric densities, temperatures and winds, day-night plasma transport, plasma temperatures, current systems, solar particle events, magnetic field geometry and topology and electron precipitation, none of which are not adequately understood at present [2]. Using a kinetic approach called MarMCET (Mars Monte Carlo Electron Transport) [3], we model the dynamics of precipitating electrons on the nightside of Mars to study the effects of these last two factors on ionospheric structure over the geographic region with the strongest crustal magnetic field (140°-220°E, 20°-70°S). As input, we use nightside precipitating electron energy spectra and pitch angle distributions from the Mars Global Surveyor (MGS) Magnetometer & Electron Reflectometer (MAG/ER), as well as a vector sum of a typical external tail-lobe magnetic field and crustal magnetic field model. We thus calculate ionization rate in 3 dimensions, both for specific observations and average cases.

We find that magnetic topology (via pitch angle distributions) plays an important part in determining peak ionization rates. Also, we see large geographic differences in average precipitating electron spectra, likely due to the dynamical coupling of the rotating planet-fixed crustal field with the draped interplanetary magnetic field[4]. This leads to differences in peak ionization rates of more than 4 orders of magnitude across this region of the Martian nightside (see figures 1 and 2). We also see a strong dependence of peak ionization rate on magnetic elevation angle measured at MGS mapping orbit altitude of 400 km, as precipitating fluxes are generally lower in regions of closed magnetic topology where magnetic field is generally horizontal at this altitude (see figure 3).

Electron impact ionization pattern follows crustal magnetic field

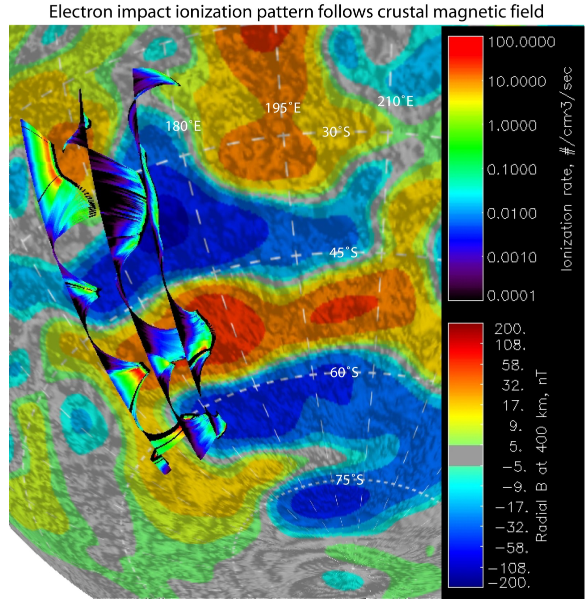

Figure 1: the 3-dimensional pattern of nightside ionization rate over a portion of the Martian southern hemisphere resulting only from precipitating electrons measured by MGS MAG/ER during 3 orbital passes in June of 2001. These are shown in relation to a sphere whose colors represent the radial component of the Martian crustal magnetic field at 400 km altitude.

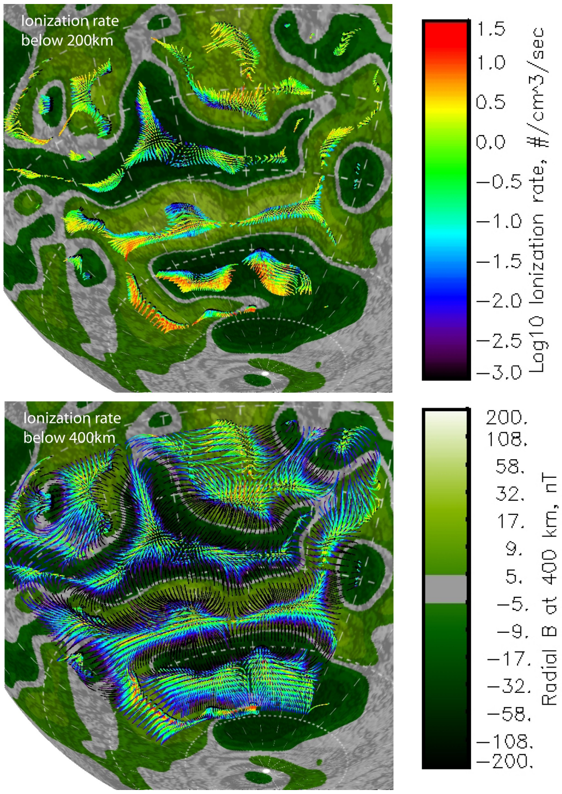

Figure 2: the average 3-dimensional pattern of nightside ionization rate over a portion of the Martian southern hemisphere, calculated using average precipitating electron pitch angle distributions and energy spectra from MGS MAG/ER These are shown in relation to a sphere whose colors represent the radial component of the Martian crustal magnetic field at 400 km altitude. The top panel shows only ionization below 200 km while the bottom panel shows ionization below 400 km.

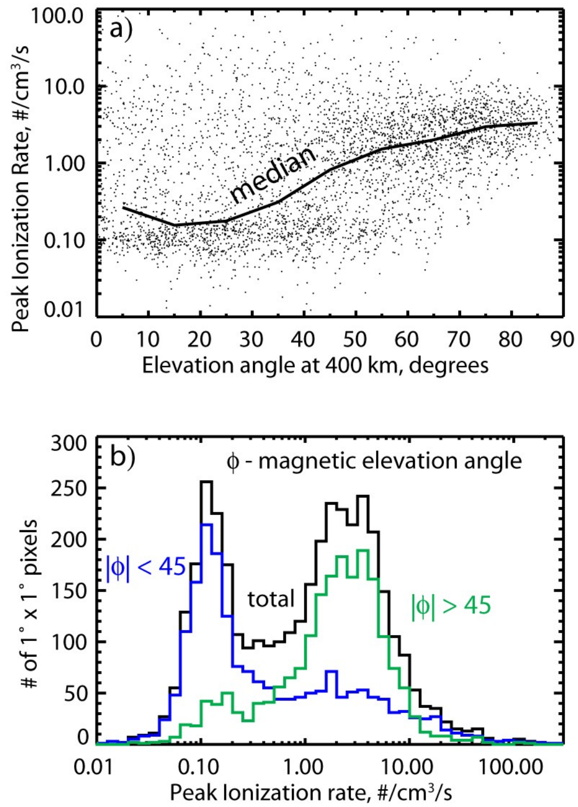

Figure 3: Dependence of calculated peak ionization rate on magnetic elevation angle measured at 400 km, traced from all altitude. Panel a) shows all peak ionization rates from all 4000 1° x 1° pixels in the geographic range (140°-220°E, 20°-70°S), as well as their median, while panel b) shows a histogram of all peak ionization rates, with sub-histograms shown separately for magnetic elevation angles <45° and >45°.

References

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