A Model Analysis of the Northern Ionospheric Structure Observed at Mars

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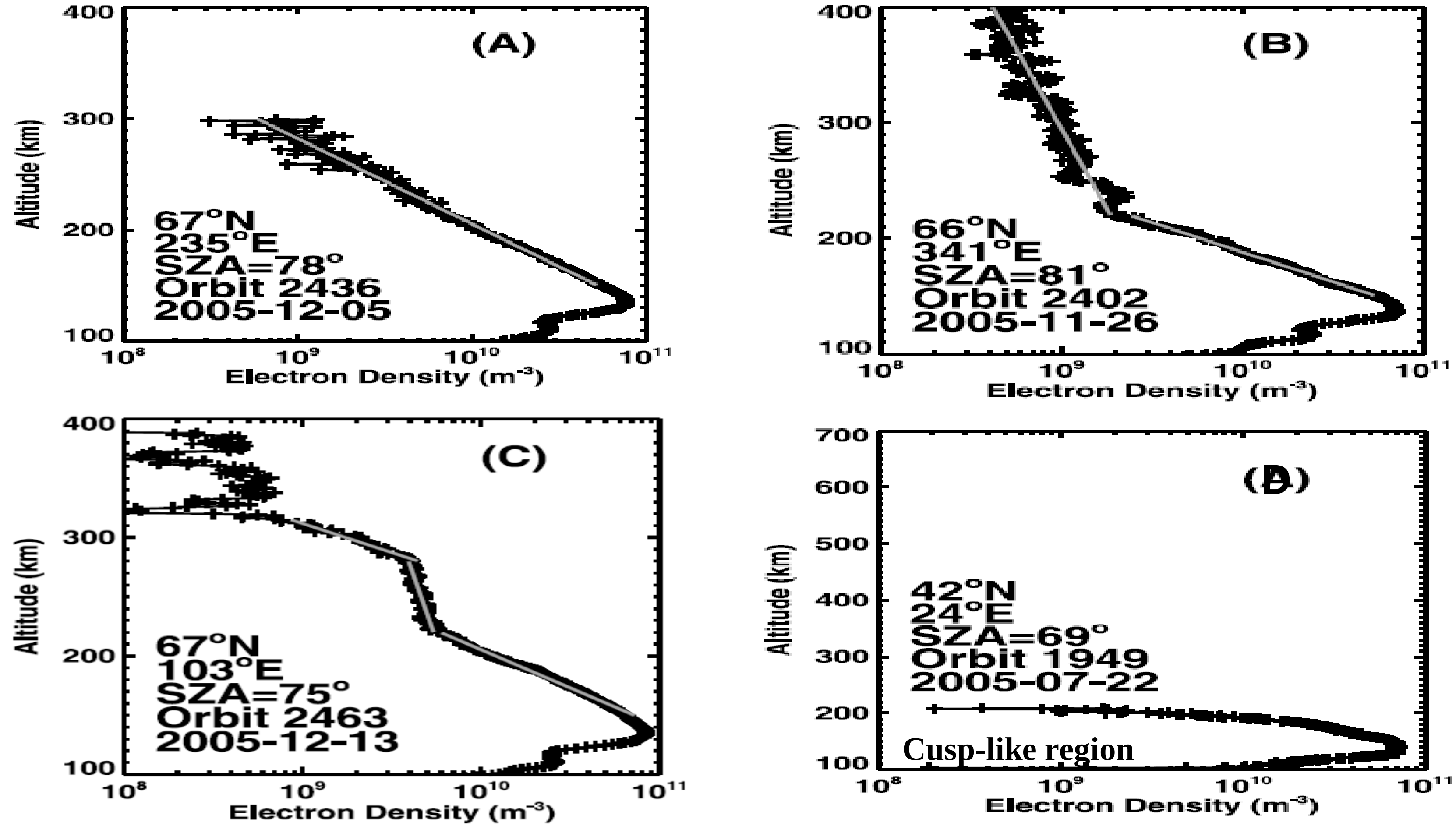
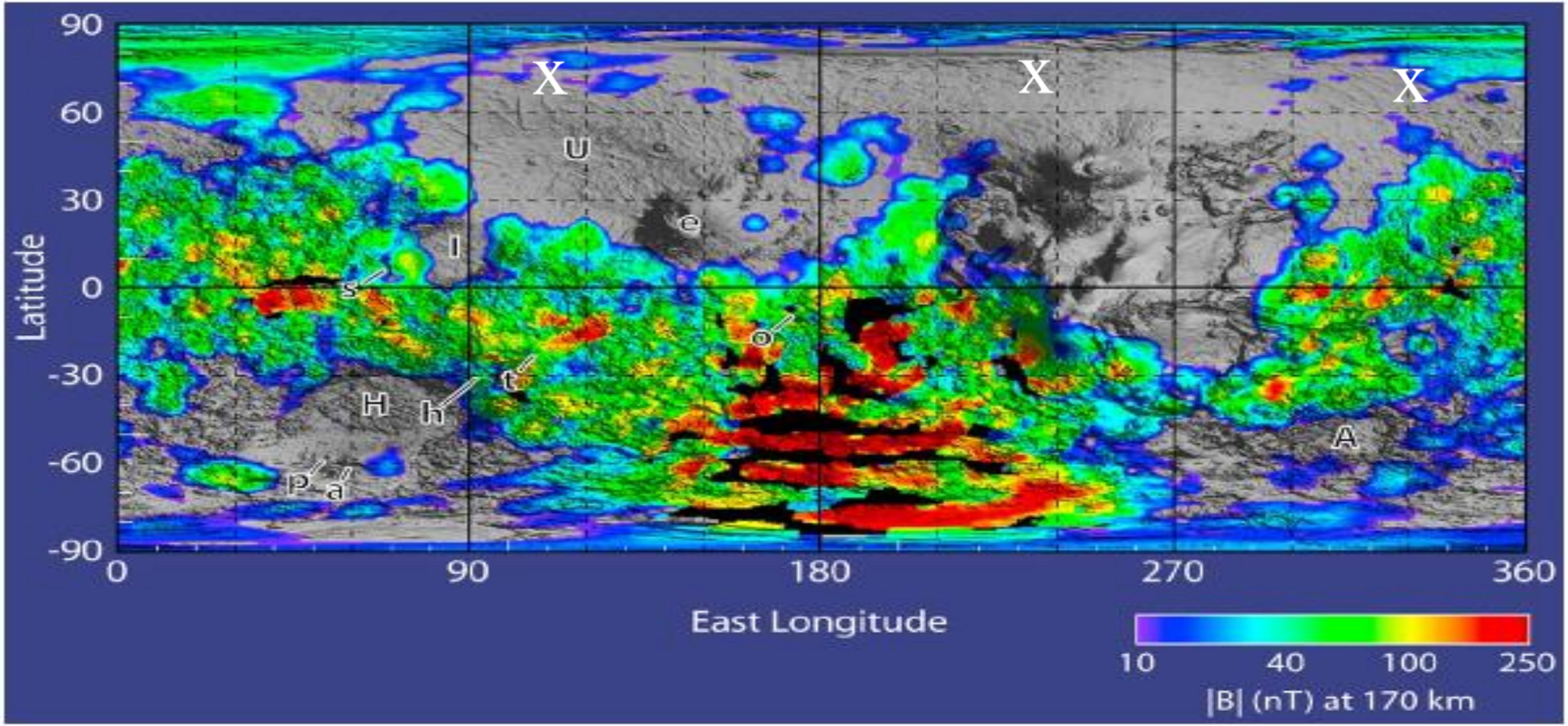
Introduction

Background: We use our 1-D chemical diffusive model coupled with the Mars - Global Ionosphere Thermosphere Model (M-GITM) to interpret the northern upper ionospheric structure observed with the Mars Express radio occultation techniques. The primary source of ionization in the model is due to solar EUV radiation. Our model is a coupled finite difference primitive equation model which solves for plasma densities and vertical ion fluxes. The photochemical equilibrium for each ion is assumed at the lower boundary of the model, while the flux boundary condition is assumed at the upper boundary to simulate plasma loss from the Martian ionosphere. The crustal magnetic field at the measured N_e locations is weak and mainly horizontal and does not allow plasma to move vertically. We find that the variation in the topside N_e scale heights is sensitive to magnitudes of upward ion fluxes derived from ion velocities that we impose at the upper boundary to explain the topside ionospheric structure. The model requires upward velocities ranging from 50 ms^{-1} to 90 ms^{-1} for all ions to ensure an agreement with the measured N_e profiles. The corresponding outward fluxes in the range 1.1 x 10^6 – 5.8 x 10^6 cm^{-2} s^{-1} are calculated for O_2^+ compared to those for O^+ in the range 3.8 x 10^5 – 6.7 x 10^5 cm^{-2} s^{-1}. The model results for the northern N_e profiles will be presented in comparison with the measured N_e profiles.

Northern N_e profiles from Mars Express (*Withers* et al., 2012)



Crustal magnetic field at chosen locations (X)



Model

The equations to be solved are the continuity equation for each of the ions (CO_2^+, CO^+, O_2^+, O^+, NO^+, and H^+).

$$\frac{\partial n_s}{\partial t} + \frac{\partial \phi_s}{\partial z} = P_s - L_s$$

The vertical flux for each ion is assumed to be given by

$$\phi_i = -D_{in}\left\{\frac{\partial n_i}{\partial z} + \frac{n_i}{H_i} + \frac{n_i}{n_e}\cdot\frac{T_e}{T_i}\cdot\frac{\partial n_e}{\partial z} + \frac{n_i}{T_i}\cdot\frac{\partial}{\partial z}(T_e + T_i)\right\}$$

Where n_e is electron density; n_i is density of the i^{th} ion; T_i is ion temperature; T_e is electron temperature; H_i is scale height of the i^{th} ion; D_{in} is diffusion coefficient of the i^{th} ion, z is vertical coordinate

The charge neutrality condition is assumed: $\Sigma\, n_i = n_e$

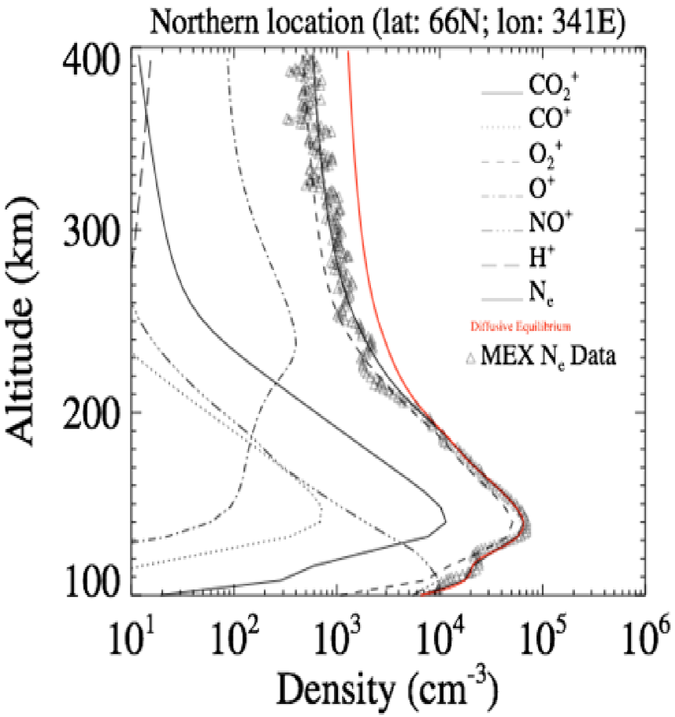
Ionization source and neutral atmosphere

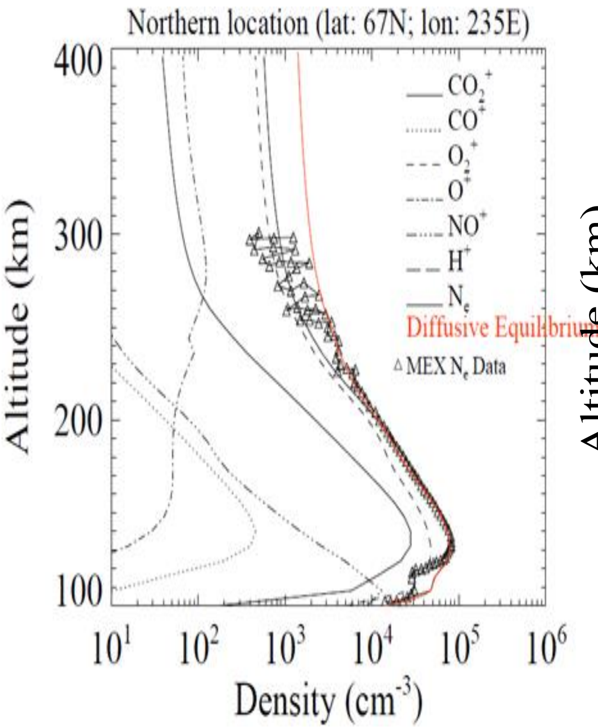
- The source of ionization in the model is due to solar EUV radiation (57Å<λ<950Å).

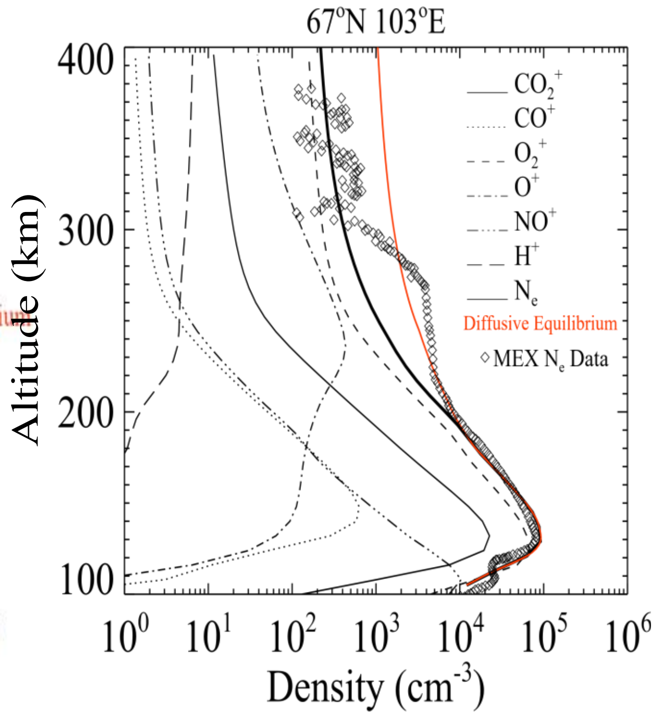
- Neutral model atmosphere (O_2, O, CO, CO_2 densities, T_n, T_i, and T_e) is inputted in the model [*Bougher et al.*, 2015]

- The model is run for many Martian days to get steady-state vertical distributions of ions and electrons.

Results

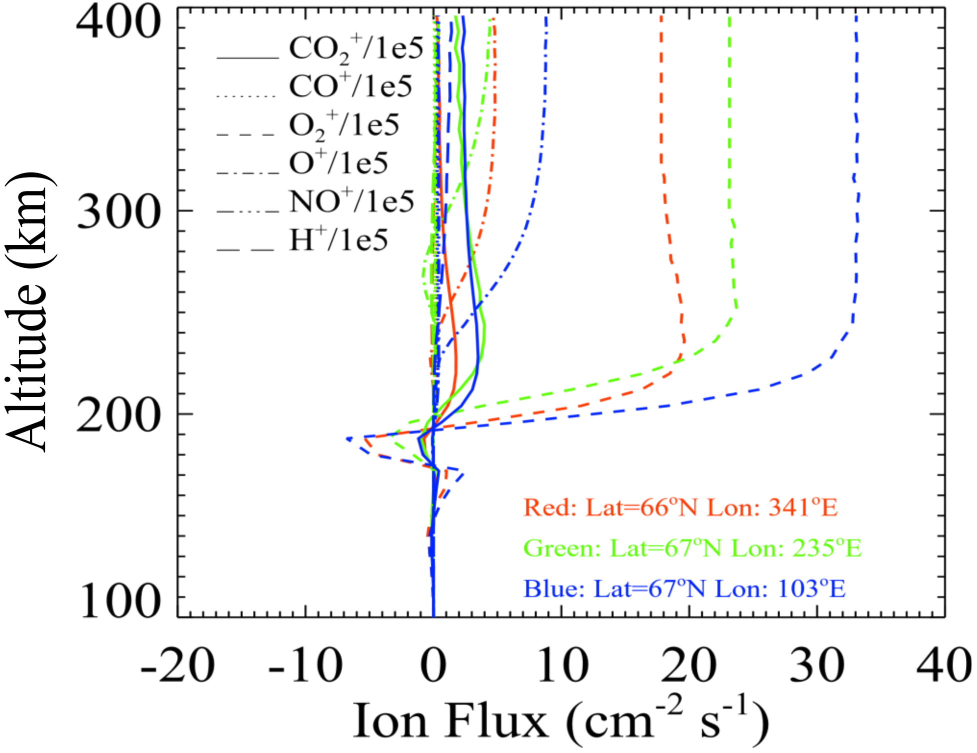




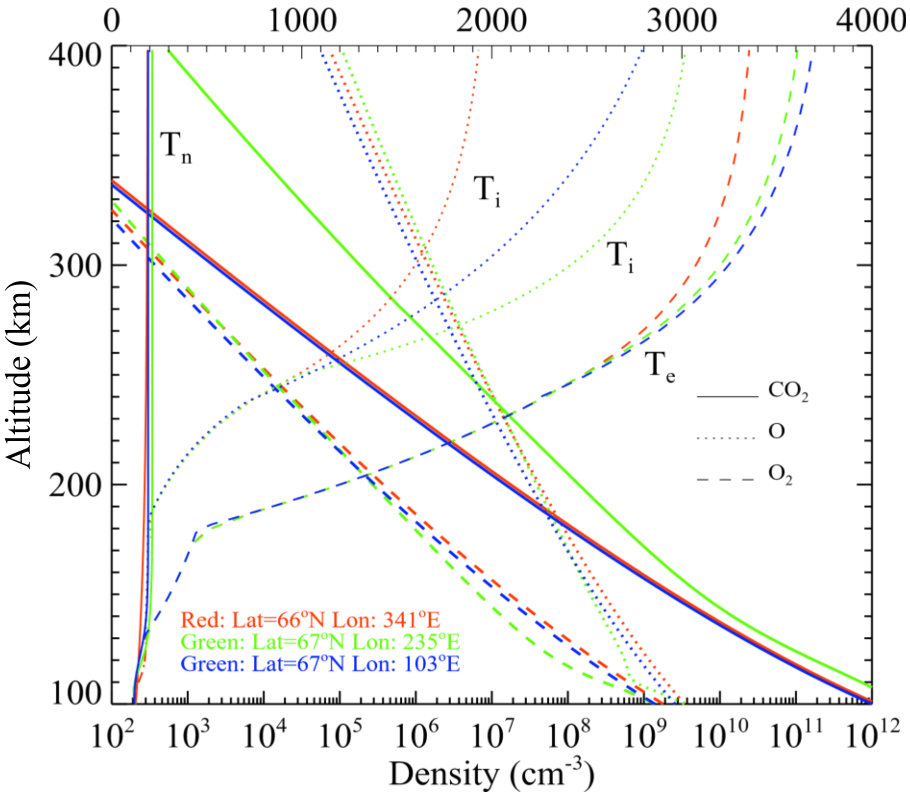


The model N_e profile with $\phi i = 0$ (assuming the ionosphere is in diffusive equilibrium) is shown by red solid curve. Clearly, there is a disagreement between the measured and model N_e profiles for altitudes > 200 km (transport region). The outflowing ion fluxes ($\phi i \neq 0$) are used as upper boundary conditions in the model to obtain best fits.

Results



Ionospheric fluxes for the best model N_e fits (denoted by color). Most dominant escaping ions are O_2^+ and O^+.



Atmospheric densities and neutral, ion, and electron temperatures [*Bougher et al.*, 2015] inputted in the ionospheric model.

Conclusions

- We use our 1-D chemical diffusive model with fixed ion flux as upper boundary condition to explain N_e profiles observed at two northern locations with Radio Science experiments on board Mars Express.

- The crustal magnetic field lines are negligibly small and nearly horizontal at the two locations of almost the same latitudes but different longitudes.

- Estimated loss rates for O^+, O_2^+ (s^{-1})are listed in Table:

Location:	**O+**	**O2+**	**Total**
341ºE	7.4×10^{23}	2.5×10^{24}	3.36×10^{24}
235ºE	7.4×10^{23}	3.2×10^{24}	3.93×10^{24}
103ºE	1.0×10^{24}	5.9×10^{24}	6.9×10^{24}
Brecht et al. 2014	1.0×10^{24}	3.50×10^{24}	4.50×10^{24}
Lundin et al. 2013	- -	-	$\sim 1.0 \times 10^{24}$

Thank you