Chapter 7

Summary and Conclusions

In Chapter 1, we describe the magnetospheres of Mercury, Earth, Jupiter, Saturn, Uranus and Neptune. Venus and Mars have no magnetospheres. The solar wind is able to penetrate directly into the atmospheres of these planets. Pluto is very small in size; therefore, it may have also a magnetic interaction with interplanetary magnetic field similar to that of Venus and Mars or Comets. Among these planets, Mars is the current interest of present Thesis. In absence of Mars own magnetic field, its ionosphere is strongly influenced by solar wind/interplanetary magnetic field.

Chapter 2 describes five theoretical models. These models are (1) AYS approach, (2) continuity and momentum equations, (3) MTGCM, (4) Hybrid model and (5) Steady state Kinetic model. In the present thesis AYS approach, continuity and momentum equations and Steady state Kinetic model are solved. The results obtained from AYS approach and continuity and momentum equations are compared with experimental data measured by MGS/Viking spacecrafts and other calculations carried by MTGCM and Hybrid model.

In Chapter 3, ER measurements carried on 2 April, 1998 by MGS at energy range 10-1000 eV are described in the dayside and nightside Martian atmosphere. For the comparison of these measurements photoelectron and secondary electron fluxes are calculated in the dayside and nightside atmosphere respectively. These calculations are
made using AYS approach. There has been found good agreement between these calculations and ER measurements. In this Chapter, the nightglow emissions are also described. At Mars, most of the airglow informations come from the missions of Mariner 6, 7 and 9, but they were concentrated on the measurements of the ultraviolet dayglow (cf. Barth et al., 1992). The only published results which are related to the nightside of Mars are those of Mars 5 spectroscopic observations which set an upper limit of ~50 Rayleighs for the dark limb of the planet in the wavelength region 3000-8000 Å. In order to compare this limit, nightglow emission intensities were calculated for OI 5577 Å and 6300 Å lines (The calculated secondary electron spectra are used in this calculation). There are no direct measurements for OI 5577 Å and 6300 Å airglow in the nighttime ionosphere of Mars. In absence of nightglow measurements at these wavelength regions, our calculations can be used as a diagnostic tool for future design of Mars aeronomy payloads and for the subsequent data analysis to confirm the presence of nightglow in the Martian atmosphere. These calculations show that in the vicinity of the peak altitudes, the excitation/emission of atomic oxygen after the electron impact dissociation of CO₂ is the main source of 5577 Å emission while the dissociative recombination of molecular oxygen ion is the major source of 6300 Å emission after the solar wind electron impact excitation/emission of atomic oxygen.

In Chapter 4, the flux, ion production rates, ion and electron densities are calculated due to impact of solar EUV and electron-proton-hydrogen atom with the atmosphere of Mars. These calculations were made using AYS approach and hybrid simulation based on Monte Carlo technique. The photoelectron and secondary electron fluxes are calculated at different altitudes and solar zenith angles along the trajectory of
MGS. The secondary electrons were produced in nighttime due to precipitation of solar wind electrons. The calculated electron fluxes are found in good agreement with ER measurements made by MGS on 2 April 1998. In these calculations, solar wind electron flux, photon flux, and neutral atmosphere were taken at nearly same areophysical conditions of measurements. The present calculation suggests that in the vicinity of main ionization peak the photon and solar wind electron impact ionizations are dominant processes in the dayside and nightside ionosphere of Mars respectively. The fast hydrogen atoms penetrate deeper in the Martian atmosphere and loose their energy at low altitude as compared to photoionization and solar wind electron impact ionization processes. Above 200 km, the solar EUV radiation was found to be an important process that contributes about 30-40% photoelectron fluxes in the nighttime ionosphere. As expected, proton impact process does not provide substantial source as much as solar EUV radiation produces near the main peak altitude region in the dayside ionosphere. In the dayside ionosphere, the first major peak is produced by photoionization and photoelectron impact ionization processes due to absorption of solar EUV radiation (1-102.57 nm), while second peak is associated mainly by ionization of soft X-ray photons (1-9 nm). There is a good agreement between calculations and radio measurements made by MGS in the dayside ionosphere. It is found that solar wind electron and proton provide substantial source in the nightside ionosphere. In the vicinity of peak ionization, the proton impact produces peak values smaller by factor of 1.4 to 2.0 with Mars 5 and Viking 1 measurements. The dynamic transport processes are not included in these calculations. These processes are reported to be important in the Martian ionosphere above ~ 180 km (cf. Shinagawa and Bougher, 1999).
In chapter 5, the accelerometer data of 120 orbits (# P0790 to P0910) are used to derive neutral densities of \( \text{CO}_2 \), \( \text{N}_2 \), \( \text{O}_2 \), \( \text{O} \), \( \text{NO} \), \( \text{CO} \) and \( \text{N} \) in the dayside Martian atmosphere. The densities of major gases \( \text{CO}_2 \), \( \text{N}_2 \) and \( \text{O} \) are compared with the calculation made by MTGCM. Later, the longitudinal distribution of ion production rates, photoelectron spectra and electron densities are calculated at low latitude using these densities under photochemical controlled region. These calculations were made by AYS approach at two wavelength ranges, 1-9 nm and 9-102.57 nm using soft X-ray and EUV radiations respectively. The ionosphere caused by EUV radiation produces two peaks at altitudes 135 km and 108 km. The X-ray produced ionosphere peaks at altitude \( \sim \) 124 km. These electron densities are compared with MGS radio science measurements and other model calculations made by MTGCM at low and high latitudes. These calculations are carried out for the month of December, 1998 in northern spring season when accelerometer and radio science measurements were made at Mars during MGS Phase-2 aerobraking period. It has been found that electron densities calculated by these two models at low latitude are not matching well in the vicinity of main ionization peak (AYS calculates peak value, a factor of 1.5-2 smaller than that of MTGCM at low latitude region between 0 and 25° N). This difference may arise due to use of different techniques in both model calculations. MTGCM calculates neutral densities, ion/electron densities, wind and temperatures self consistently. Thus, this method solves time dependent continuity-momentum and energy equations simultaneously. In this model, ion production rates and solar EUV/ UV/ X-ray fluxes are obtained through parameterization methods based upon \( f_{10.7} \) and 81-day average indices. AYS approach is highly dependent on electron impact inelastic cross sections and solar EUV/ UV/ X-ray fluxes. The
inelastic cross sections calculated/ measured by various researchers are not consistent with each other and a factor of 2 or more variations is clearly seen among the cross section values. Moreover, the experimental observations of solar EUV/ UV/ X-ray fluxes also depict in strong variations and consensus has not yet been reached. Thus, the disagreement between two model calculations can be incorporated using large cross section and solar flux values in AYS approach.

In chapter 6, a steady state kinetic model is used to calculate parallel electron current density at different potential differences in the exosphere of Mars. For this calculation it is assumed that the ionosphere of Mars is connected to the plasmasheet/magnetotail through the weak dipole magnetic field lines. It is found that for zero potential difference, the field aligned current is positive flowing towards the ionosphere of Mars. At this limit the precipitating flux of plasmasheet electrons is approximately equal to $5.79 \times 10^8$ cm$^{-2}$ s$^{-1}$ corresponding to the parallel electric current density of $1.0 \times 10^6$ Amp/m$^2$. This is in close agreement with the total electron flux of $5.0 \times 10^8$ cm$^{-2}$ s$^{-1}$ measured by HARP experiment in the Martian magnetosphere. For infinite potential difference, the electron current will be negative flowing towards the plasmasheet from the ionosphere of Mars. At zero current density, the precipitating flux of plasmasheet electrons is approximately equal to maximum escape flux of thermal electrons. The maximum escape flux of thermal electrons at exospheric electron temperature 2000 K is obtained $3.0 \times 10^8$ cm$^{-2}$ s$^{-1}$, matching well with the electron flux measured by HARP experiment in the plasmasheet of Mars.