Electrical Properties of the Dust-Loaded Ionosphere of Mars

G.J. Molina-Cuberos[1], S. Cardnell[2], O. Witasse[2], A.J. García-Collado[3], S. Toledo-Redondo[4], G. Déprez[5], F. Montmessin[5]

[1]Departmento de Electromagnetismo y Electrónica, Universidad de Murcia, Murcia, Spain, [2]European Space Agency, ESA/ESTEC Scientific Support Office, Directorate of Science, Noordwijk, The Netherlands. [3]Geomática, Teledetección y SIG Aplicados, Universidad Católica de San Antonio, Murcia, Spain. [4]Science Directorate, European Space Agency, ESA/ESAC, Villanueva de la Cañada, Spain, [5]Laboratoire Atmospheres, Milieux, Observations Spatiales, Guyancourt, France,

Introduction: The electrical properties of the lower part of the Martian atmosphere and on the ground have a high importance for any surface mission and their deep understanding and knowledge are crucial to prepare future manned missions. The electrical conductivity and ground charge conditions, together the low atmospheric dynamics rule all the atmospheric electricity phenomena, such as large scale electric current, electric discharges and Schumann resonances.

Below 70 km, the main ionization sources are galactic cosmic rays and, during daytime, photoionization of aerosols due to solar UV radiation [1]. Several ionospheric models have been developed for both day and night conditions. The results predict that both positive and negative cluster ions are the most abundant near ground [2, 3], which is similar to the terrestrial case. However, the presence of suspended dust can produce significant effects on the ion and electron densities [4]. In fact, the amount of dust can vary considerably and, therefore, it has an important effect.

The Model: The Martian ionosphere is modelled here by solving the continuity equations of positive ions, negative ions, electrons and charged aerosols [1]. Both positive ions and electrons are primary produced by cosmic rays and lost by ion-electron recombination and by attachment to aerosols. Therefore, aerosol particles can be positive or negative charged. Negative ions are produced by electron capture by oxygen (in the form of O, O_2 and O_3) and lost by ion-ion recombination and attachment to aerosols. During the daytime, aerosols can be charged also by photoionization (mainly UV radiation). Here we have followed the procedure described in Michael et al. [4] to calculate it. In the lower atmosphere of Mars transport phenomena can be neglected because the transport time is several orders of magnitude greater than the chemical lifetime [5]. The photoelectron production rate from aerosols was calculated by considering the attenuation of the solar flux through the atmosphere due to absorption and scattering of aerosols [1]. The attachment coefficient of electrons and ions to aerols was calculated using [6].

Results and Discussion: Figure 1 shows the cation, anion and electrons densities from 0 to 70 km for both low and high dust conditions.

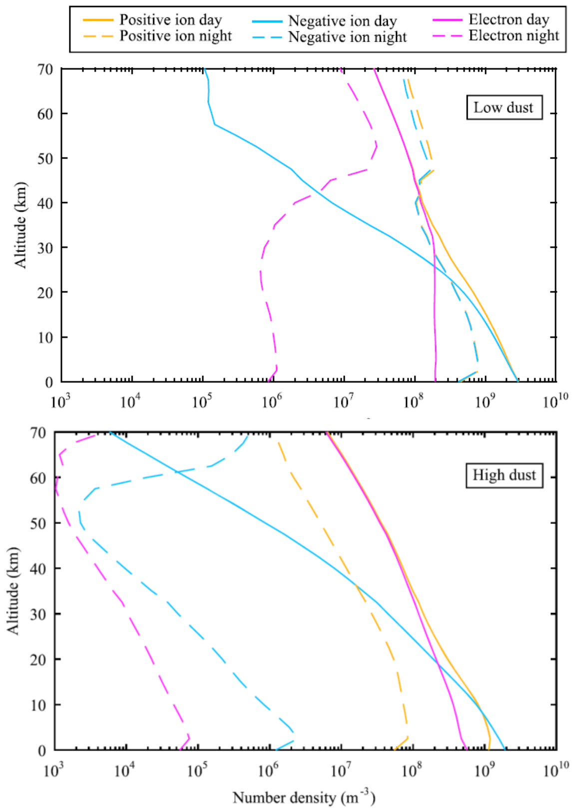

Figure 1: Cation (green lines), anion (blue lines) and electron (red lines) number densities for low and high dust scenarios during both day (solid lines) and nighttime (dashed lines) conditions [1].

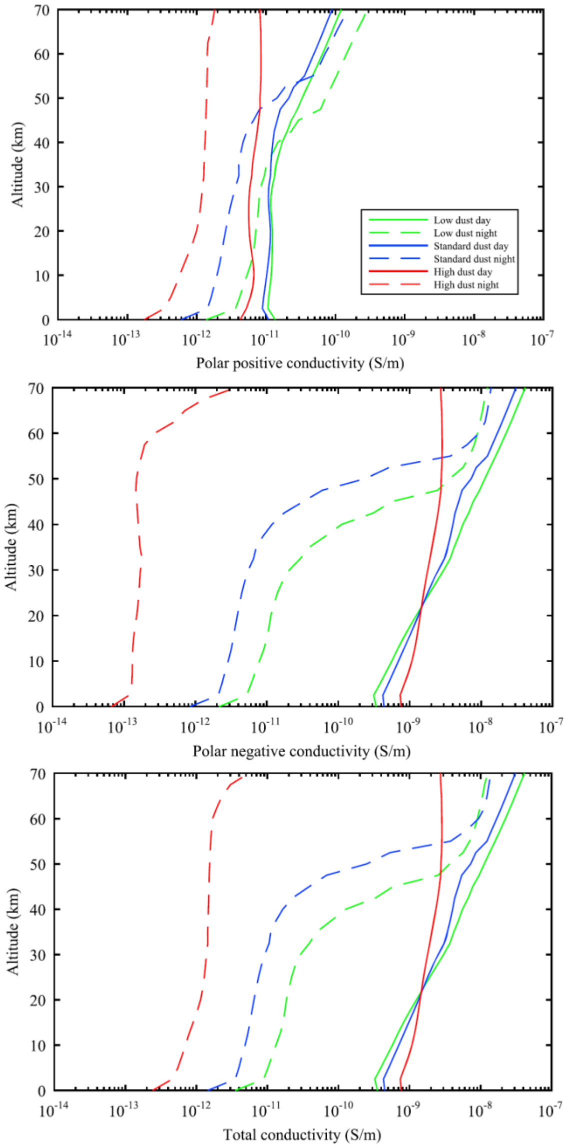

Figure 2. Polar and total electrical conductivity for different dust scenarios during day and nighttime conditions [1].

The model can be applied to different scenarios, and was tested for both day and nighttime conditions. We have made use of the Mars Climate Database (MCD) to obtain the meteorological variables corresponding to the expecting landing site of the ExoMars 2016 Schiaparelly module [7].

For the high dust scenario, the density of positive charges (cations) is not equals to that of negative charges (anions plus electrons), which means that same of the charge is accumulated on aerosols. The sign of the aerosol carge depends on the solar UV radiation. During nighttime, there are no photoelectrons emitted from aerosols and the attachment of electrons to aerosols is more effective than the attachment of positive ions because of the larger mobility of electrons. Therefore, aerosols tend to became negatively charged. During daytime, photoemission process outweighs electrons attachment and produces a net positive charge on the aerosols.

The daytime results obtained for the low dust scenario are similar to the ones obtained for aerosols-free models [3]. However, as the amount of dust increases, the density of electrons also increases, specially near the surface.

The total electric conductivity, as well as its positive and negative polar components are shown in Figure 2. The atmospheric conductivity varies in the 10^{-13} – 10^{-7} S/m range, depending on the altitude, dust scenario and local time.

Once the atmospheric conductivity profile is modeled, it is possible to calculate the Schumann resonances, which are the standing waves oscillating in the electromagnetic cavity formed by the lower ionosphere and the conducting surface of the planet. Toledo-Redondo et al. [8] found that the first resonance should be in the range between 9 Hz and 16 Hz, depending on the dust scenario and the local time position of the source and the observer, owing to the strong day-night asymmetry of the cavity. Their simulation also shows that the daytime conductivity profile does not allow the development of Schuman resonances at all, while the conductivity of the nightside, which is two orders of magnitude lower, does.

Acknowledgements: This work was supported by the Spanish Government (Project TEC2014-55463-C3-1-P) and by the European Commission (ERDF). O. Witasse and S. Cardnell acknowledge the ESA Young Graduate Trainee program.

References:

[1] Cardnell, S. et al., ***JGR***, 121, 2016. doi: 10.1002/2016JE005077

[2] Witten, R., et al., ***PSS***, 19, 1971. doi:10.1016/0032-0633(71)90203-0

[3] Molina-Cuberos, G.J., et al., ***JGR***, 107, 2002. doi:10.1016/S0032-0633(02)00197-6.

[4] Michael, M., et al., ***JGR*** 113, 2008. doi:10.1029/2006GL028434.

[5] Haider, S. A., et al, ***JGR***¸ 115, 2010. doi:10.1029/2010JA016125.

[6] Gunn, R., ***JAS***, 11, 1954. doi:10.1175/1520-0469(1954)011

[7] Vago, J., et al., ***Sol Syst Res*** 49, 2015. doi:10.1134/S0038094615070199.

[8] Toledo-Redondo, S., et al., ***GRL***, 44, 2017, doi:10.1002/2016GL071635.