

## ***Interactive comment on “Retrieval of ionospheric profiles from the Mars Express MARSIS experiment data and comparison with radio-occultation data” by B. Sánchez-Cano et al.***

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The authors sincerely thank to the referee 2 all his comments and suggestions to improve our manuscript. Here we include a point-by-point response to each comment or suggestion.

RC: The English needs some improvements (see comments below; even if I am not the most qualified reviewer for that task).

AC: The English has been reviewed and the text is hopefully improved.

RC: A few references about the thermosphere and the ionosphere of Mars are miss-

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ing in the discussion part: the understanding of the processed data is better when important processes are known, such as: - the variation of the density of the upper atmosphere of Mars (e.g. Forget et al. 2009, Bougher et al., 2001; Withers et al., 2003 Simon et al., 2009, Zou et al. 2011 etc.). Which is the main parameter for the altitude of the ionosphere peak. (It is not the Mars-Sun distance, see the discussion in Zou et al. 2011).

AC: The references cited by the referee have been added. In the same way, we think that the part when the different parameters taken into a count into the model are explained could be confusing. So, it has been rewritten:

“In order to obtain and represent mathematically a more realistic behavior for the ionosphere of Mars, the contribution of different parameters has been gradually introduced. In the case of the electron density peak, the first parameter considered in our study has been the Sun-Mars distance. This characteristic is very important because Mars has the most eccentric orbit in the Solar System and therefore, the radiation that arrives at Mars depends a lot on the position of Mars with respect to the Sun. With this purpose in mind, and following the Chapman theory, the electron density of every AIS ionogram has been normalized to the electron density that it should have if the ionogram had been taken at the mean orbit distance (1.52 AU). The second parameter considered is the solar zenith angle. This is the most important factor with respect to the electron density of the main peak. The results show a clear exponential trend. The third parameter affecting the electron density peak is the solar activity, in particular, the F10.7 index. Other parameters, as the chemistry and temperature of the Martian upper atmosphere [Forget et al., 2009], the topographic control of the thermal tides in zonal structures [Withers et al., 2003] or the airglow on Mars [Simon et al., 2009], will be considered in a next step of the research. In the case of the altitude peak, as the Chapman theory predicts, the most relevant parameter to be considered is the solar zenith angle. The dependence on this parameter is so important that it may mask other parameter effects. Although, the dependence of the height on the solar flux [Mahajan

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et al., 2009] and on the neutral atmospheric density [Bougher et al., 2001 and Zou et al., 2011] is being studied, the solar zenith angle is the only parameter considered for the altitude peak at this stage of the empirical model”.

RC: - the variation of the ionosphere peak height is loosely related to the F107 parameter (it is dependent only through the variation of the neutral density), because the main models based on that parameters (e.g. EUVAC), have a small spectral dependence on it. But, the actual variations of the solar flux spectra can have impact on that altitude (e.g. <http://www.agu.org/journals/gl/gl0915/2009GL039454/> )

AC: We think that probably the redaction of this paragraph is confusing. It has been rewritten (see previous answer).

RC: -The theory of the ionosphere layers (e.g. Fox 2009). Concerning that point, page 98 line 25: you cannot say that ions can be loss by radiation and dissociation processes. You have recombination processes leading to the emission of radiation, or to the dissociation of the former molecular ion, but those are recombination processes. There is basically two way to 'loss' an ion: by recombination (chemical reactions) or by diffusion (also called transport) (the charge exchange just modify the parent atom or molecule of the ion, and therefore I do not consider it as a loss here). The fact that we have a Chapman layer means that the diffusion is negligible. We call that case a photochemical equilibrium. In Fox 2009, it is explained that this equilibrium is a good approximation when solar zenith angles are not too large.

AC: The paragraph has been rewritten:

“The  $\alpha$ -Chapman expression is the basis of this model. This assumes that the mean ionospheric layer is controlled by photo-chemistry only, and the vertical transport is negligible. Ions are created by photo-ionization and ion-neutral reactions, and disappear by radiative or dissociative recombination [Fox, 2009 and Sánchez – Cano et al., 2010]”

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RC: The authors discuss the possible errors in the procedure by comparing with the Marsis data. However, it would be interesting to have a discussion (and maybe an estimation) about the errors in the retrieval (including the data noise...).

AC: It has been added a new comment: “The electron density measure accuracy is about  $\pm 2\%$  and the uncertainty of the altitude apparent range is about  $\pm 6.8$  km. [Morgan et al., 2008]”.

RC: p 89 | 20: the sentence should be cut for a better understanding.

AC: It has been split into two sentences: “This technique, in the case of the ionospheric mode, is similar to the method used by digisondes on Earth. Its comparison with previous radio-occultation measurements allows us to improve the horizontal spatial resolution and to obtain data at solar zenith angles for which radio-occultation cannot be considered [Gurnett et al., 2008]”.

RC: p 90 | 8: “In both cases ...” should be replaced by something like ‘In both cases, the ionosphere is mainly composed of O<sub>2</sub>+.’

AC: It has been changed: “In both cases, the ionosphere is mainly composed of O<sub>2</sub>+”.

RC: p 94 | 22 : “To begin the inversion” also, for this paragraph, it may be interesting to explain in details (and/or to give a reference) how the local plasma density is computed from the harmonics.

AC: We have changed the text and added a reference: “To begin the inversion, it is necessary to know the plasma density in the vicinity of the spacecraft because the corrected range for each data point depends on the plasma density profile of the sounding wave path (Figure 1). This information can be obtained from the harmonics of the local plasma frequency as it is explained in Gurnett et al., 2008”.

RC: p 95: chap 3: I think it would be interesting to explain that MaRS is doing limb observations, which have also their drawbacks in term of averaging long path inside the ionosphere (especially in high-SZA situation). Moreover, in limb sounding techniques,

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the data below the peak always have high uncertainties.

AC: We think that “Limb” is not the best expression to describe the MaRS technique. Therefore, it has been added a small comparison between MARSIS and MaRS: “This procedure is completely different to the sounder method. In general terms, MARSIS sounder sends a sweep of vertical downward radio-signals and take direct measures of the delay time of those frequencies. In its turn, MaRS sends a radio-signal at two frequencies (described below) through the upper atmosphere along the spacecraft-Earth line just at the moment when the spacecraft is occulted to the Earth antennas by Mars. From the change in the propagation path and the Doppler Effect on the signals it is possible to retrieve the electron density profiles. Due to these differences in the technique, the profiles from MaRS are different from those given by MARSIS. While MaRS allows obtaining the full profile of the ionosphere, MARSIS only allows obtaining profiles from the topside to the maximum ionization peak. In addition, as MaRS requires an occultation, which occurs only during limited periods, and only once per orbit in the case of Mars Express, MARSIS provides a better planet coverage and horizontal spatial resolution, and can work in a larger solar zenith angle range”.

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