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The Martian Ionosphere's Response to Solar drivers

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Abstract

A six week time period of NASA Mars Atmosphere and Volatile EvolutioN (MAVEN) mission data have be analyzed to gain a greater understanding of the conditions under which the Sun can most effectively drive observable changes in the Martian ionosphere. Seven different types of solar events were analyzed in detail, and were ascribed the following names: magnetic reconnection, pressure pules, solar flare, ICME, low solar wind density, magnetosonic waves, and FAC associated with Martian crustal fields. These events were evaluated based how effectively the conditions in the lower ionosphere changed. One interesting observation was that for the pressure pulse case the lower ionosphere was shielded off, resulting in an almost unperturbed lower ionosphere. The reconnection and the FAC events can drive observable changes but due to their nature they are localized and short lived temporally, decreasing their importance. Based on these events, the magnetosonic waves case was the most effective at modifying the lower ionosphere and lead to significant atmospheric loss.

1. Introduction

The physical processes that drive atmospheric loss at Mars both now and in the past are not fully understood. The main purpose of the MAVEN mission is to study the current day active atmospheric loss processes at Mars and to evaluate which processes could be dominant in the planet's past [1]. The MAVEN mission has demonstrated that neutral atomic oxygen is the dominant loss path for Mars today. But in the past the dominant oxygen loss may have been through ion loss [2].

Therefore, it is important to understand what processes/solar events drive the largest oxygen ion loss at present day Mars. Up to now the focus has mainly been on solar EUV irradiance levels and the solar wind pressure.

The presented study has identified a time period where many different types of solar events are observed, and has evaluated how important each event was in driving observable changes in the lower (<~300 km) Martian ionosphere. Since the study was conducted over a limited time period the ionospheric measurements are made in the same region and under similar EUV conditions, allowing the events to be inter-compared. If a longer time period were to be used then the large ionospheric variability with respect to local time would need to be taken into consideration, resulting in a much more difficult data set to evaluate.

2. The Events

The data are taken from the August – September 2017 time period where the events were selected based on the in-situ measured EUV intensity, and plasma conditions in the upstream sheath region. Six different type of events were identified, as shown in Figure 1, and labeled magnetic reconnection event, pressure pulse, solar flare, ICME, low solar wind density, magnetosonic waves, and FAC associated with crustal fields.

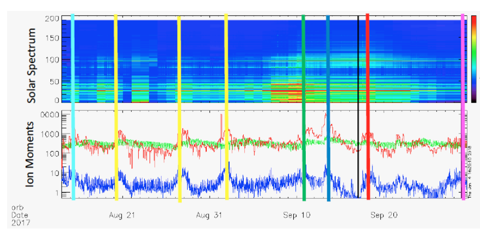

Figure 1: The normalized EUV intensity (top panel) and solar wind (bottom panel) information of the time period of interest. The vertical lines are: reconnection (no 1), pressure pules (no 2,3 and 4), solar flare (no 5), ICME (no 6), low density (no 7), magnetosonic waves (no 8) and FAC (no 9).

The spacecraft orbit was such that inbound segments of periapsis were over the dusk terminator, while the outbound segments were over north pole. The orbit geometry allowed the plasma to be evaluated as terminator transport, and the magnetic field orientation could be used to infer the draped magnetic field configuration.

3. Ionospheric Shielding

For the three pressure pulse the orbit configuration provided evidence that the lower ionosphere can be magnetically shielded from the upper ionosphere. This resulted in the upper ionosphere, where oxygen densities are relatively low, being significantly modified, but no obvious effects were observed in the lower ionosphere where oxygen densities are much larger.

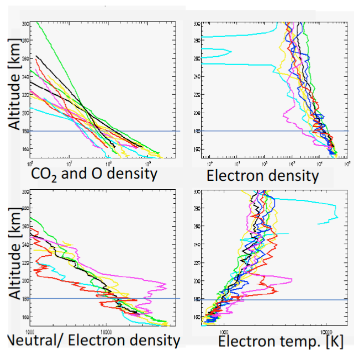

Figure 2: Altitude profiles for the different events identified in Figure 1.

For the ICME event the same was inferred, but not definitely observed. The lower ionosphere was not significantly affected, however, the energy content of the ICME, and variability of the solar wind, were much greater than for the pressure pulse, and this shielding is thus inferred.

4. Most Effective Event

The event most effective at driving changes in the lower ionosphere was that identified as magnetosonic waves. In Figure 2 the neutral and plasma conditions are presented color coded based on the vertical lines in Figure 1.

The magnetosonic wave event is shown by the pink line indicating an over-dense ionosphere with respect to the neutral atmosphere and is associated with enhanced electron temperatures. As has been shown, magnetosonic waves can heat the plasma [3], and with the observed plasma transport here these waves are the most effective way to drive ions from the lower Martian ionosphere, for the events studied here.

The FAC event is shown as the red line and is an outlier. The event is driven by pressure in the solar wind. The observed profiles indicate an under-dense ionosphere with respect to the neutral atmosphere and as a result enhanced electron temperatures are present to refill the flux tube. Since the FAC event is localized in space and temporally short, one can expect that the effect is minor. The reconnection event which occurred on the outbound pass impacted the ionosphere on a short timescale over a localized region only.

5. Summary and Conclusions

Using MAVEN data, the effectiveness of solar events at driving changes in the lower ionosphere are contrasted against each other. Contrary what is expected, an enhanced pressure pulse in the solar wind did not increase the ion outflow from the lower ionosphere. The most effective way, as identified, was the presence of magnetosonic waves that heat the lower ionosphere and drive significant ion loss. Therefore, the occurrence and duration of such wave heating events should be evaluated over Mars' history when considering atmospheric loss over time.

Acknowledgements

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