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Martian ionosphere response to solar wind variability during solar minimum

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Solar cycle variations in solar radiation create notable density changes in the Martian ionosphere. In addition to this long-term variability, there are numerous short-term and non-recurrent solar events that hit Mars which need to be considered, such as Interplanetary Coronal Mass Ejections (ICMEs), Co-Rotation Interaction Regions (CIRs), solar flares, or solar wind high speed streams. The response of the Martian plasma system to each of these events is often unusual, especially during the long period of extreme low solar activity in 2008 and 2009.

This work shows the long-term solar cycle impact on the ionosphere of Mars using data from The Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS), and The Analyzer of Space Plasma and Energetic Atoms (ASPERA-3), and with empirical and numerical models on Mars Express. Particular attention is given to the different ionospheric responses observed during the last, extended solar minimum. Mars' ionospheric response followed a similar pattern to the response observed in the Earth's ionosphere, despite the large differences related to the inner-origin of the magnetic field of both planets. The ionospheric temperature was cooler, the topside scale height was smaller and almost constant with altitude, the secondary ionospheric layer practically disappeared and the whole atmospheric total electron content (TEC) suffered an extreme reduction of about 30-40%, not predicted before by models. Moreover, there is a larger probability for the induced magnetic field to be present in the ionosphere, than in other phases of the solar cycle.

The short-term variability is also addressed with the study of an ICME followed by a fast stream that hit Mars in March 2008, where solar wind data are provided by ACE and STEREO-B and supported by simulations using the WSA-ENLIL Model. The solar wind conditions lead to the formation of a CIR centred on the interface of the fast and the slow solar wind streams. Mars' system reacted to the CME and CIR with a clear compression of the magnetosheath-ionosphere, as seen by the locations of the bow shock (BS) and magnetic pileup boundary (MPB). Also, the ionosphere was found to be extremely compressed and with a larger induced magnetic field. Also, the fast stream caused a compression in the Martian plasma system, but lower than the previous events, leading to fast MPB boundary movements that produced rapid variability in the thermal pressure of the ionosphere.