

# Ionospheric Impacts of Space Weather at Venus and Mars

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## Abstract

Space Weather impacts at Mars and Venus include ionospheric responses that reflect the relatively direct, global interactions of their atmospheres with interplanetary space. Observations, especially from the combination of PVO, Mars Express, Venus Express and MAVEN missions, have revealed changes related to flares and coronal mass ejections that in some ways resemble those at Earth. But a closer look at the ionospheric disturbances, auroras, and magnetic storms reveal key differences -not only from the Earth but also between Venus and Mars. Earth's ionosphere experiences space weather through the filter of its large magnetosphere, which determines both the physics and spatial distributions of 'storm' effects. For example, the north-south component of the interplanetary magnetic field exerts strong control over the consequences of a particular set of interplanetary conditions, and the aurora is, to a large extent, caused by internally energized particle populations. In contrast, Venus experiences essentially full exposure to the 'elements', including the enhanced plasmas, fields and energetic particle fluxes that are a hallmark of major space weather storms. And although Mars is much like Venus in the global scale of its solar wind interaction relative to its radius, its complex crustal magnetic fields make a difference in the details of its responses that are Earth-like in some respects. We summarize some of the key findings up to now on the space weather effects at Venus and Mars, including the observations of SEP-related auroras and ionospheric magnetic field changes. We also consider future prospects for studies during the next solar maximum, including Venus, where ground-based auroral observations and heliophysics monitoring will be primary resources for further studies.