Geophysical Research Abstracts
Vol. 13, EGU2011-6431, 2011
EGU General Assembly 2011

Trans-terminator flow in the ionospheres of Mars and Venus

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The upper ionospheres of Mars and Venus are permeated by the magnetic fields induced by the solar wind. It is a long-standing question whether these fields can put the dense ionospheric plasma into motion. If so, the transterminator flow of the upper ionosphere could explain a significant part of the ion escape from the planets atmospheres. But it has been technically very challenging to measure the ion flow at energies below 20eV. The only such measurements have been made by the ORPA instrument of the Pioneer Venus Orbiter reporting speeds of 1-5km/s for O+ ions at Venus above 300km altitude at the terminator (Knudsen, GRL 1982). At Venus the transterminator flow is sufficient to sustain a permanent nightside ionosphere, at Mars a nightside ionosphere is observed only sporadically. We here report on new measurements of the transterminator ion flows at Mars and Venus by the ASPERA-3 and -4 experiments on board Mars and Venus Express. For Mars we use support from the MARSIS radar experiment for some orbits with fortunate observation geometry. Here we observe a transterminator flow of O^+ and O_2^+ ions with a super-sonic velocity of around 5km/s and fluxes of $0.8 \cdot 10^9$/cm^{2}s. If we assume a symmetric flux around the terminator this corresponds to an ion flow of $3.1 \pm 0.5 \times 10^{25}/s$ half of which is expected to escape from Mars. This escape flux is significantly higher than previously observed on the tailside of Mars, we discuss possible reasons for the difference. Possible mechanism to generate this flux can be the ionospheric pressure gradient between dayside and nightside or momentum transfer from the solar wind via the induced magnetic field since the flow velocity is in the Alfvénic regime. For Venus there is no observation of the cold plasma density by Venus Express and we can infer properties of the plasma distribution only using stronger assumption than for Mars. We discuss the implication of these new observation for ion escape and possible extensions of the analysis to dayside observations which might allow us to infer the flow structure imposed by the induced magnetic field.