O+ ionospheric outflow off the beaten path directly into the Inner Magnetosphere as observed by the Van Allen Probes

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The low-energy (eV to hundreds of eV) ion population in the inner magnetosphere, the warm plasma cloak, and in particular its heavy ion component, the O+ torus, is crucial to magnetospheric dynamics. Yet, although the effects of high latitude and cusp ionospheric O+ outflow and its subsequent transport and acceleration within the magnetotail and plasma sheet have been extensively studied, the source of low-energy O+ within the inner magnetosphere (already observed by the DE1 spacecraft in the 80s) remains a compelling open question. The HOPE instrument aboard each of the Van Allen Probes, moving in highly elliptical, equatorial orbits with apogee of 5.8 RE, has repeatedly detected low-energy O+ fieldaligned enhancements. We present a comprehensive study of one such event, where low energy O+ field-aligned intensity enhancements were observed, both at small and large pitch angles, during a geomagnetic storm. The energy spectrogram exhibited a dispersive signature and a banded structure, features that our simple particle tracing simulation demonstrated are due to O+ ions outflowing from both hemispheres of the night-side ionosphere directly into the magnetosphere within L = 4, and subsequently bouncing from one hemisphere to the other. These outflows are associated with field-aligned Poynting flux enhancements and field-aligned electron beams, as observed at the Van Allen Probes location, revealing energy transport from the magnetosphere to ionosphere as well as simultaneous fieldaligned electron heating. We also incorporate ionospheric measurements, such as field-aligned currents, as those are inferred by AMPERE data. The combination of unprecedented simultaneous magnetospheric and ionospheric observations allow us to investigate the processes that lead to an O+ outflow event from the lowlatitude, night-side ionosphere directly into the inner magnetosphere. The ubiquity of such events in the Van Allen Probes data might reveal one of the sources for the O+ torus.