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On the Low Energy (< keV) O+ Ion Outflow directly into the Inner Magnetosphere

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The development of low energy (< keV) O+ ions in the inner magnetosphere is a crucial issue for various aspects of magnetospheric dynamics: i) Recent studies have suggested that low energy O+ can be locally accelerated to few keV energies inside geosynchronous orbit, and thus can constitute a significant source of the storm-time ring current O+ that could dominate the energy density during storms, ii) Mass loaded densities are important for accurate location of the plasmapause, which, in turn, is necessary for meaningful calculation of the field line resonance radial frequency profiles of ULF hydromagnetic waves in plasmasphere, iii) since O+ is only of ionospheric origin, its outflow from ionosphere into the magnetosphere is a manifestation of fundamental processes concerning energy and mass flow within the coupled Magnetosphere – Ionosphere system. Although a lot of progress has been made on O+ outflow at high latitudes and its subsequent transport and acceleration within the magnetotail and plasma sheet, the source of low-energy O+ within the inner magnetosphere remains a compelling open question. The Helium Oxygen Proton and Electron (HOPE) mass spectrometer instrument aboard Van Allen Probes, which move in highly elliptical, low inclination orbits with apogee of 5.8 RE, has repeatedly detected field aligned flux enhancements of eV to hundreds of eV O+ ions, which indicate O+ outflow directly into the inner magnetosphere. We systematically investigate, throughout the duration of the Van Allen Probes mission (2012 – 2019), the occurrence of such events with respect to L and MLT, the dependence of their directionality (bi-directional or unidirectional) and the lowest and highest energies involved on L, MLT and MLAT. We categorize the outflow events with respect to plasmapause location (when its determination is possible) and identify whether there is enhancement of O+ density. This categorization is important because if the outflows occur close to the plasmapause location, and depending on the density enhancement they cause, they could be responsible for the formation of O+ torus, whose source has been under debate for years. Finally, in order to identify the physical processes that lead to the ionospheric outflow, we also examine whether there are dipolarizations and/or enhancements of the field-aligned poynting flux associated with these outflow events.