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Properties of energetic ion PSD during magnetic storms observed by Van Allen Probes

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It is observationally known that the contribution of O+ ions to the ring current increases with increasing size of magnetic storms, while H+ is the main component of the ring current ions during small storms. Ion injection from the magnetotail caused by substorms is considered as one of the principal mechanisms that supply energetic ions to the ring current region. However, the dependence of the ion injection properties on ion species (such as the depth of ion injection into the inner magnetosphere) is far from well understood as is the role of injection itself. To characterize the ion supply to the ring current during magnetic storms, we investigate in this study the properties of energetic H+ and O+ phase space densities (PSDs) during geomagnetic substorms observed by the Van Allen Probes mission. We examine substorms that occurred during the periods of April 23, 2013 to April 28, 2013, April 29, 2013 to May 5, 2013, and March 15, 2013 to March 20, 2013. Using energetic ion (greater than 50 keV) and magnetic field data obtained by the RBSPICE and EMFISIS instruments onboard Van Allen Probes, we study the temporal variations of H+ and O+ PSD spatial distributions and compare their properties during each of the substorm events.

We calculated the first adiabatic invariant, mu, and PSD for ions within a pitch angle range from 70 to 110 degrees. PSDs for specific mu values (mu = 0.3, 0.5 and 1.0 keV/nT) were obtained as a function of L for each ion species for each orbit of Van Allen Probes during each substorm. We identified a sudden increase in each PSD spatial distribution as an injection boundary. The results for the period of April 23-28, 2013 show that both H+ and O+ ions penetrated directly down to $L<5$ during the main phase of the magnetic storm (minimum Dst greater than -65 nT). The penetration boundary of H+ ions was located at smaller L at dusk than at dawn. We also find that H+ ions with smaller mu values (mu = 0.3 and 0.5 keV/nT) penetrated earlier than those with larger mu values (mu = 1.0 keV/nT). In contrast, the timing of O+ penetrations is almost the same for all O+ ions regardless of the mu values. The results also show that O+ ions penetrated more deeply in L and earlier in time than do the H+ ions. These results taken together suggest that the source of the injected O+ ions is located closer to Earth than that of the protons (the inner edge of the plasma sheet) and therefore suggest the importance of the contribution of subauroral O+ ions to the storm-time ring current.