Ion heating by fast magnetosonic waves and ring current-electron radiation belt coupling

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Abstract

During the main phase of geomagnetic storms ions are transported across the geomagnetic field towards the Earth from the outer magnetosphere. Convective (and inductive) electric fields transport low energy ions of a few tens of keV through dawn towards the dayside while higher energy ions are transported through dusk by the curvature and gradient drift. The higher energy ions can be trapped by the magnetic field to form the partial, and total, ring current. Recent observations, and simulations, show that when the ion distribution function is observed on the dayside magnetosphere it has a ring type distribution perpendicular to the magnetic field as a result of the different drift paths of the ions, and as a result of loss processes. It has been shown that these ring distribution can excite plasma instabilities resulting in fast magnetosonic waves that propagate across the magnetic field at frequencies between the proton cyclotron frequency and the lower hybrid frequency. These waves can accelerate radiation belt electrons, and heat thermal ions, but their effects on the ion ring distribution and the ring current have yet to be assessed. Here we study the effects of the waves on the ion distribution. We present wave data from the CLUSTER spacecraft with very high frequency resolution which shows magnetosonic waves above half the lower hybrid frequency with a line structure that has frequency spacing comparable to the local proton cyclotron frequency. We use the Ring current Atmosphere Model (RAM) to simulate the development of the ring current during a storm and find that ion ring distributions are predicted by the model and that they are unstable to the generation of fast magnetosonic waves with multiple spectral peaks. By modelling the multiple peaked spectra, we show that these waves are very effective in diffusing the ions at energies between 10 and 100 keV, and that energy diffusion rates are two orders of magnitude higher than pitch angle diffusion. Since diffusion does not extend into the loss cone, the effect of the waves is to diffuse ions to lower energies where they help remove the ion ring and to higher energies where they form a high energy tail with a large anisotropy. We solve the Fokker Planck equation to study the evolution of the ion distribution function, and compare the timescale for ion heating with that for ion transport. We conclude that fast magnetosonic waves are very effective process for both heating the ring current ions, and discuss whether the resulting ion distribution could affect the generation of electromagnetic ion cyclotron waves on the dayside magnetosphere. Since EMIC waves can cause rapid loss of radiation belt electrons our results show that fast magnetosonic waves may play an important role in the coupling the ring current to the electron radiation belts.

978-1-4244-6051-9/11/$26.00