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Use ion cyclotron wave observations and particle simulations to constrain the mass-loading region of Enceladus

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Abstract

Enceladus plays an important role in the Saturnian system, by releasing large amounts of mass in the inner magnetosphere. Cassini observations have revealed that the moon's south plume releases hundreds of kilograms of water-group neutrals every second. Ion cyclotron waves are generated by the ionization of these neutrals, because these ions have unstable pitch angle distributions in velocity space which provide free energy for wave growth. The amplitude of these waves is related to the number of particles ionized per second; thus we can use the waves observed by Cassini magnetometer to estimate the mass-loading rate and to examine the extent of the mass-loading region. We use a Monte-Carlo particle tracing simulation to study the transport of ions and neutrals away from the Enceladus plume. The model assumes that the neutral gas produced by Enceladus is ionized and accelerated by the corotational electric field, and then drifts away from the source region. These ions are later neutralized via charge exchange with the background neutral cloud and move across magnetic field lines as fast neutrals. These fast neutrals may either be re-ionized or escape from the Saturnian system. Both observations and model results show that the neutrals and ions originated from Enceladus can travel slightly upstream and largely downstream from the moon. The model shows that fast neutrals travel largely outward from the Enceladus orbit and could escape the Saturnian system. Furthermore, we study the wave observations during each Enceladus pass to contrain the size of the region with strong mass-loading rate. And we use the model to investigate if the mass-loading rate and the region size are significantly controlled by the plume geometry, the initial velocity of particles in the plume, and variability of the ion production rate.