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Pick-up ion distributions in the inner and middle Saturnian Magnetosphere

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Based on the entire dataset collected by the Cassini Plasma Spectrometer, we provide a comprehensive picture of the pitch angle and velocity distributions of pick-up ions (PUIs) in Saturn's inner and middle magnetosphere. We investigate the dependence of these distributions on Saturnian Local Time and magnetic latitude. We also search for correlations to the signatures of ion cyclotron waves observed by the Cassini magnetometer. Our survey reveals that ion pitch angle distributions have a pancake shape and their full width increases monotonically with magnetic latitude. This increase in angular width is anti-correlated with the observed amplitudes of ion cyclotron waves that are generated during the thermalization of the PUI distribution. We find no evidence of the observed, non-monotonic change of wave amplitudes with magnetic latitude mapping into the width of the pitch angle distributions. This suggests that only a small fraction of the energy deposited into the waves is transferred back to the ions to broaden the distribution. A possible reason for this is wave damping by the Maxwellian core of the distribution, formed by ions that have already been incorporated into the sub-corotating flow. In addition, wave propagation away from the magnetospheric field direction could reduce the efficiency of the energy transfer. When moving away from Saturn's magnetic equatorial plane, the observed half-width of the velocity distributions does not evolve appreciably with latitude and L shell value. This behavior changes only outside the orbit of Rhea where the observed velocity distributions begin to broaden due to elevated plasma temperatures.