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Transport of Mass and Energy in Mercury's Central Plasma Sheet

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In situ magnetic field and plasma measurements from MESSENGER have shown that processes occurring in Mercury's magnetotail are qualitatively similar to Earth's, despite the differences in spatial and temporal scales, upstream conditions and internal plasma compositions. Mass, energy and magnetic flux are transported from Mercury's dayside magnetopause to its nightside magnetotail via an Earth-like Dungey cycle. The cycle is completed by the return flow of mass, energy and flux towards Mercury in the central plasma sheet (CPS) driven by magnetic reconnection in the cross-tail current sheet. To understand the nature and stability of the planetward flow in Mercury's magnetotail, it is important to know the relation between density and pressure in the plasma sheet and, hence, the polytropic index γ in the equation of state. Using four years of MESSENGER magnetic field and plasma data, we have performed a statistical survey on the H+ density and pressure in the CPS. We estimated the average polytropic index of the CPS to be $\sim$ 1.23. Since this estimated value of γ is smaller than the adiabatic index of 5/3 ($\sim$ 1.67), our results indicate that Mercury's central plasma sheet does not behave adiabatically. The most likely cause for this behavior is that the sinks of plasma (e.g., precipitation onto the nightside planetary surface) are greater than the sources (e.g., magnetic reconnection-driven injection) as the magnetic flux tube is transported into the near tail region. Our result shows that γ decreases with decreasing downtail radial distance with a minimum at XMSM $\sim$ -1.4 RM, which is consistent with the estimated location of the Hermean substorm current wedge from earlier Mercury's magnetotail study. This indicates connection between braking of planetward flow and observed minimum in γ. We also found a strong dependence of γ with substorm activity at Mercury and dawn-dusk asymmetry in γ with the value of γ higher on the dawn-side plasma sheet.