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Diurnal variations of Titan's ionospheric structure

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Abstract

We present our analysis of the diurnal variations of Titan's ionospheric structure based on a sample of INMS (Ion Neutral Mass Spectrometer) measurements obtained from several Titan flybys of Cassini. Distinct diurnal variations in ion distribution are observed, characterized by strong depletion of light ions and modest depletion of heavy ions at the nightside. We propose that these distinctions are associated with different chemical loss pathways for light and heavy ions, with the former primarily through “fast” ion-neutral chemistry and the latter through “slow” electron dissociative recombination. We propose a scenario in which the ions created at the dayside may survive well into the dark regions and contribute to the formation of a nightside ionosphere on Titan. Such a scenario is strongly supported by the tight correlation between the measured day-to-night ion density ratio and the associated ion life time. It is also supported by the clear asymmetry in the observed ion distribution between the morning and evening terminators.

Our scenario for the formation of Titan's nightside ionosphere implies the presence of day-to-night ion flow, which may cause departure in ion distribution from diffusive equilibrium. We test such an idea by solving the ion momentum equation for the diffusive equilibrium solution. Various force terms in the momentum equation are directly calculated with realistic measurements made with the Cassini RPWS (Radio Plasma Wave Science) and MAG (Magnetometer) instruments. The diffusive equilibrium solutions at both the dayside and nightside are then compared with the observed ion density profiles, which presents a general trend of dayside ion outflow and nightside ion inflow. From the difference between the ion fluxes at both sides, we estimate a horizontal day-to-night ion flow of $\sim 2\times 10^{24} s^{-1}$ in Titan's upper atmosphere.

Finally, we construct a time-dependent ion chemistry model to investigate the effect of ion survival from the dayside to the nightside, driven by ion coupling with a horizontal super-rotating wind of 100 m/s. For long-lived ions, the predicted diurnal variations have similar general properties to those observed. However, the nightside model densities of short-lived ions are significantly under-estimated. The interpretation of such a discrepancy requires either electron precipitation from Saturn's magnetosphere as an additional nightside ion source or horizontal ion transport faster than 100 m/s.