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Wave emissions and plasma heating inside equatorial plasma bubbles

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During the strong magnetic storms of November 7-11, 2004, May 15, 2005 and August 24, 2005, the DEMETER ionospheric satellite encountered several deeply depleted plasma bubbles with density drop of two or three orders of magnitude. We present an overview of the ELF and VLF wave measurements performed during these crossings. Below the proton gyrofrequency, trapped ELF electromagnetic emissions taking the form of a continuous wave train of several mV/m amplitude, sometimes similar to beat-like waveforms but most often with an irregular amplitude modulation, were continuously observed inside the bubbles with extremely sharp cut-off at the edges of the depletions. These waves are characterized by a rather sharp frequency spectrum extending between about the left-hand mode cutoff frequency and the ion-ion hybrid frequency in a bi-ion O^+ dominated plasma. Intense quasi-electrostatic electrostatic lower hybrid (LH) emissions triggered by lightning-generated electromagnetic whistlers are observed on almost every crossing; their characteristics support an excitation mechanism based upon scattering or mode conversion of whistlers by pre-existing small-scale electron density irregularities. An unexpected striking feature is the occurrence of LH solitons with sometimes amplitude up to 20 mV/m and typical duration of $\sim$ 20 ms, similar to LH solitary structures commonly observed on auroral field lines. The ion data from the retarding potential analyzer for time periods encompassing these LH events reveal the existence of a suprathermal population of O^+ and NO^+ ions with a density of about 3% of the thermal population and temperatures 10 to 30 times larger than the thermal ion temperature, which seems consistent with the occurrence of tail heating. Besides these emissions inside the bubbles, a broadband electrostatic ELF turbulence at frequencies from 0 up to about the proton gyrofrequency is observed at the edges of the bubbles, coincident with steep density gradients and fluctuations in the DC perpendicular electric field. Finally, sporadic electromagnetic emissions at frequencies below $\sim$50 Hz are recorded in the outermost parts of the bubble edges and often well dissociated from the electrostatic turbulence. We discuss the observations and propose plausible interpretations.