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Energy Crisis at Saturn - The role of Thermosphere-Ionosphere Coupling

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Abstract

Saturn - like all other gas giants in our solar system - is known to have an upper neutral atmosphere (thermosphere/exosphere) far hotter than expected on the basis of solar EUV heating alone. Measured low to mid latitude exospheric temperatures on Saturn range from 320–470 K, while solar heating alone produces values of below 180 K. For the case of Jupiter, where the solar driven temperature shortfall is even more extreme, the discovery of waves by the Galileo probe prompted the idea of thermospheric heating by dissipating gravity wave. This process, which would effectively act to transport energy from the interior to the outer atmosphere, is still under debate since the altitude of energy deposition by waves is highly sensitive to the background atmosphere, which is largely unconstrained. While still remaining a possibility, the uncertainty in the wave heating theory justifies a closer look at alternative energy sources. The other main energy source on Saturn is magnetospheric currents which flow in the auroral (polar) regions and can deposit globally several tens of TW, more than 50 times the absorbed solar EUV value, as thermal energy, primarily via Joule heating. Previous studies with General Circulation Models (GCMs) have suggested that this energy however is trapped in the polar regions due to the strong zonal flow which is caused by Saturn's fast rotation and resulting strong Coriolis forces. In these previous GCM calculations, polar regions are heated to beyond 1000 K, but the equatorial regions still barely reached 200 K. It was therefore initially concluded that Joule heating would not provide the answer to the energy crisis.

This study will be revisiting the energy problem on Saturn, adding more recent observations from Cassini/ UVIS to the constraints and providing a new set of model calculations with the Saturn Thermosphere Ionosphere Model (STIM) which for the first time consider full ion-neutral drag as well as auroral ionization from precipitating energetic electrons. We find that including the effects of ion drag is crucial for redistributing energy from the polar to equatorial regions. As a result, polar temperatures are reduced, bringing them closer to temperature values observed from ground via H_3^+ emissions, while at the same time heating the low latitudes to temperatures closer to observed values. Our calculations suggest that Magnetosphere-Ionosphere-Thermosphere coupling may play a key role for solving the energy crisis of Saturn and other Gas Giants.