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A vortex in Saturn's upper atmosphere as the driver of electromagnetic periodicities at Saturn: Magnetospheric and ionospheric responses

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Abstract

We describe a magnetohydrodynamic (MHD) simulation of Saturn's coupled magnetosphere-ionosphere-thermosphere system in which a vortical flow is assumed to be present near 70 degrees south latitude in a rotating ionosphere-thermosphere. We find that the magnetosphere's response to this simple assumption regarding driving conditions produces the periodic magnetospheric phenomena that have been reported. We propose that the essence of our model is supported by powerful, albeit indirect, evidence of its validity and that more direct evidence of flow structures in the upper atmosphere should be sought.

1. Introduction

An MHD simulation [1] in which vortical flows in Saturn's rotating ionosphere/thermosphere generate field-aligned currents produces significant periodic phenomena in the magnetosphere. The imposed vorticity, centered about 70 degrees southern latitude, is illustrated in Figure 1. Here we focus on periodic responses of the system extracted from the simulation including magnetic field perturbations, azimuthal current perturbations, plasma phenomena, periodic plasma releases, oscillations of the magnetopause and bow shock, and the dependence of the intensity of upward field-aligned current on rotation phase.

2. Magnetospheric consequences of ionospheric vorticity

Our MHD model of Saturn's coupled ionosphere-magnetosphere is designed to apply to the southern summer conditions of the early portion of the Cassini mission at Saturn. Conductances are taken as 3 S in the south and 1 S in the north. We find that the currents linking the southern and northern ionospheres produce the signatures previously attributed to a rotating cam current [2] such as the rotating magnetic perturbations in the equatorial plane inside of 10-12 R_S fully characterized by Andrews et al. [3]. Other periodic features include a rotating mass density peak at low L-shells [4], a rotating partial ring current [5], periodic motions of the magnetotail plasma sheet [6], and periodic enhancement of the field-aligned current upward from the southern ionosphere as its ionospheric footprint rotates through the morning sector [7,8].

3. Is a vortex in the ionosphere/ thermosphere plausible as the primary source of periodicity?

It has previously been noted [7, 9, 10] that Saturn's upper atmosphere has sufficient inertia to maintain a close to constant period and phase of variations over time scales of many years, but is expected to couple to the magnetosphere sufficiently effectively that the observed ~1% per year frequency drift is plausible. It has been noted that seasonal effects on the atmosphere can account for the systematic changes of frequency that have been reported [9,10]. Thus, it is *ab initio* plausible that the driver of periodicities is located in the upper atmosphere, from which it must couple into the ionosphere. Ionospheric properties affect the magnetosphere most strongly by generating field-aligned currents, and vortical flows are an effective source of such currents. As the structure of flow in the high altitude atmosphere is not yet known, one must infer it indirectly. We propose that the magnetosphere is the tablet on which the upper atmosphere is writing, and that the periodic properties observed in the magnetosphere can be taken as evidence, only partially complete, of the behaviour of the upper atmosphere. We argue that it is imperative to undertake investigations of upper atmosphere flow in order to test the hypotheses of this paper.

4. Figures

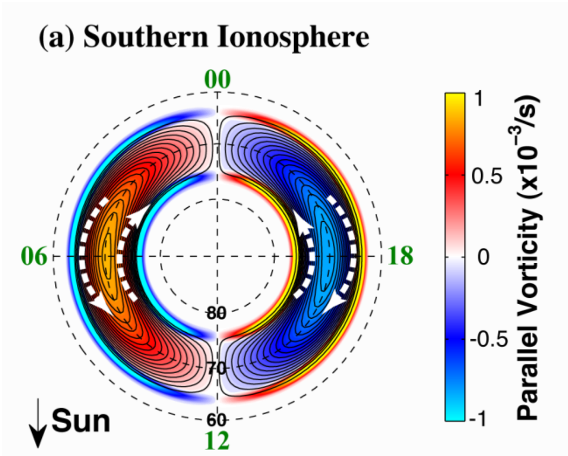

Figure 1: Model vorticity imposed in the southern ionosphere and set to rotate with a 10.7 hour in the simulation. Color represents the vertical vorticity, and dashed white arrows show flow directions. The image is viewed downward from the north.

5. Summary and Conclusions

An ionospheric vortex in the southern hemisphere can account for the primary periodicities observed in Saturn's magnetosphere and its kilometric radiation (SKR). A source linked closely to the upper atmosphere can account for the near steadiness of the periodicity while allowing for some drift. Further work is needed to introduce a source in the northern hemisphere to account for the distinct frequency linked to northern hemisphere sources [8, 9, 10, 11] and to test whether the phases are maintained following strong solar wind disturbances.

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