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Response of Jovian atmospheric heating to a transient 'pulse' in solar wind pressure

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Abstract

We simulate the response of atmospheric heating and auroral signatures to transient variations in solar wind pressure by coupling a simplified magnetosphere model with an azimuthally symmetric global circulation model. We present the ensuing response in terms of thermospheric heating and auroral signatures. We find that the power dissipated by the magnetosphere into the atmosphere and Joule heating increase by $\sim$1200 % and $\sim$67 %, respectively, whilst that dissipated by ion drag is essentially halved.

1. Introduction

Jupiter's upper atmospheric temperature is considerably higher than that predicted by solar Extreme Ultraviolet (EUV) heating alone (e.g. [1] and [2]). Studying the time-dependence of Jovian energy balance may provide answers to this 'energy crisis' that has been under debate for four decades.

2. Model details

To model the time-dependent effects of a solar wind pulse on the Jovian thermospheric energy budget we employ a coupled axisymmetric magnetosphere, auroral conductivity and Global Circulation Model (GCM) model ([3] and [4]). In our simulations the magnetosphere is compressed, from an initial expanded steady-state, over a period of 90 minutes, moving inward from a magnetodisc standoff distance of 85 $\mathrm{R_J}$ to 45 $\mathrm{R_J}$. If this compression occurs on time scales of $\lesssim$3 hours, we can assume the conservation of plasma angular momentum to be valid [5]. The 'transient' plasma angular velocity $\Omega_M(\theta_i, t)$ profile is given by

$$\Omega_M(\theta_i, t) = \Omega_M(\theta_i, t{=}0)\left(\frac{\rho_e(\theta_i, t{=}0)}{\rho_e(\theta_i, t)}\right)^2, \quad (1)$$

where θ_i is the ionospheric co-latitude, ρ_e is the equatorial radial distance from Jupiter and t is time. The dependence on $t{=}0$ and t denote the initial steady state (SS) and transient state (TS), respectively.

The thermosphere (modelled by the GCM) is then allowed to respond to the changes in Ω_M. It is important to note that we make no assumptions about the response time of the thermosphere.

3. Results

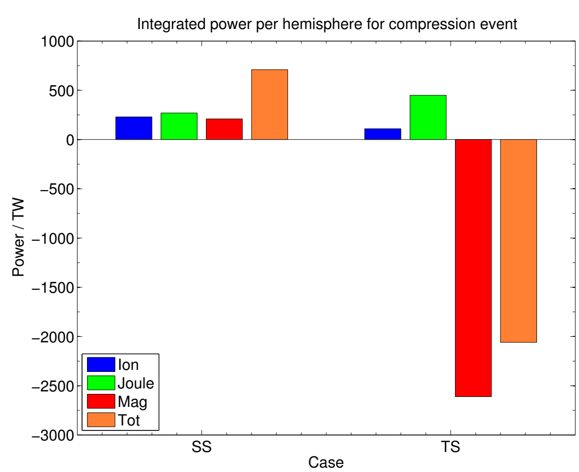

Figure 1: Integrated ionospheric powers per hemisphere for cases SS and TS. Ion drag, Joule heating and magnetospheric power are represented by blue, green and red bars respectively. The orange bar represents the total power (sum of all above).

In Figure 1 we show integrated ionospheric powers per hemisphere for cases SS and TS respectively. The power dissipated in the atmosphere consists of Joule heating (green bar) and ion drag (blue bar). Magnetospheric power (red bar), is the power used to accelerate the magnetospheric plasma towards rigid corotation with Jupiter.

We see that the total power dissipated in the atmosphere increases by $\sim 12\,\%$ from case SS to TS. This increase is entirely due to an enhancement in Joule heating, caused by the super-corotation of the magnetosphere with respect to the thermosphere and planet.

In case TS, a large amount of magnetospheric power is dissipated in the atmosphere (expressed by the negative power in Figure 1). This is due to the super-corotation of the magnetosphere with respect to the thermosphere. Overall, in case SS, energy is transferred to the magnetosphere from the atmosphere; in case TS, the opposite occurs i.e. energy is transferred from the magnetosphere to the atmosphere.

4. Conclusions

In summary, we show that a transient compression of the Jovian magnetosphere significantly increases the energy deposited in the Jovian thermosphere. In particular, the magnetosphere deposits on the order of $2500\,\mathrm{TW}$ into the thermosphere at the point of maximum compression, compared to the $\sim 200\,\mathrm{TW}$ that was used by the thermosphere to accelerate the sub-corotating magnetosphere in the steady state. These transient increases in deposited energy lead to local temperature increases of $\sim 40\,\mathrm{K}$. We also find that the main auroral oval is ~ 4.5 brighter in our transient case.

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References

[1] Yelle, R. V. and Miller, S.: Jupiter's thermosphere and ionosphere, Jupiter. The Planet, Satellites and Magnetosphere, 2004.

[2] Melin, H., Miller, S., Stallard, T., Smith, C. and Grodent, D.: Estimated energy balance in the jovian upper atmosphere during an auroral heating event, Icarus, Vol. 181, pp. 256-265, 2006.

[3] Yates, J. N., Achilleos, N. and Guio, P.: Influence of upstream solar wind on thermospheric flows at Jupiter, Planetary and Space Sciences, Vol. 61, pp. 15-31, 2012.

[4] Yates, J. N., Achilleos, N. and Guio, P.: Response of the Jovian thermosphere to a transient 'pulse' in solar wind pressure, Planetary and Space Sciences, in prep.

[5] Cowley, S. W. H., Nichols, J. D. and Andrews, D. J: Modulation of Jupiter's plasma flow, polar currents, and auroral precipitation by solar wind-induced compressions and expansions of the magnetosphere: a simple theoretical model, Annales Geophysicae, Vol. 25, pp. 1433-1463, 2007.