Magnetosphere – Ionosphere – Thermosphere coupling at Jupiter

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The Jovian system

➢ Largest planet ($R_J \sim 11R_E$)

➢ Atmosphere composed of molecular Hydrogen (~90%) and Helium (~10%)

➢ 4 Galilean moons: Io, Europa, Ganymede and Callisto

➢ Magnetosphere is largest object in solar system ($M_J \sim 20,000 M_E$)
The Jovian magnetosphere

- Magnetosphere is controlled by internal sources:
  - Rapid planetary rotation rate (~10 hrs)
  - Internal plasma source... Io (~1000 kg/s)

Credit: Fran Bagenal & Steve Bartlett
Why study the Jovian system?

Aurora:

➢ Main auroral emission at Jupiter is purely driven by internal processes - corotation enforcement currents

➢ Aurora due to electromagnetic interaction with Galilean moons

➢ Polar auroral emission is poorly understood
  - magnetospheric dynamics e.g. plasma release
  - Solar wind driven

➢ A lot of variability over different timescales

Credits: J. Clarke, J. Nichols and D. Grodent
Why study the Jovian system?

Gas giant energy crisis:

➢ Upper atmosphere is ~700 K hotter than expected

➢ Interaction with magnetosphere likely source:
  - Joule heating
  - Ion drag
  - Precipitation heating

➢ Current steady state modelling efforts can’t solve the problem
  - Many simplifying assumptions in models e.g. 1D/2D atmosphere
  - Time dependence not included
  - Some physics not included
What is magnetosphere-ionosphere coupling?

Describes how angular momentum and energy are transferred between a planet and its magnetosphere.
How do I study the Jovian system?

Simulate how Jupiter’s magnetosphere couples to its upper atmosphere (ionosphere + thermosphere) and how this coupling influences Jupiter’s

- coupling currents,
- aurora,
- thermosphere flows,
- thermosphere energy balance,

on both long and short time scales.
**Magnetosphere**

- 1-D
- 0.01 $R_J$ resolution
- Torque balance: *ionospheric and magnetospheric currents, electric fields*

**Optional Modules**

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<td>Inclusion of field-aligned potentials</td>
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<td>Local time selection (defaults to post-midnight)</td>
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**Atmosphere:**

- 3-D
- 0.4° x 10° lat x long resolution
- 0.4 pressure scale height resolution
- $H_2$, H and He atmosphere
- Continuity, momentum, and energy equations: *Joule heating, thermospheric temperatures & thermal winds, ion drag*
3D work: Main auroral emission

➢ Peak auroral emission ~74°

➢ Few 100 kR emission which is typically observed

➢ Slight poleward emission but magnetosphere is prescribed here

➢ Southern emission seems to be slightly greater than northern
3D work: Temperature distributions

➢ Atmosphere is warmer in 3D coupled case compared to 2D

➢ Mid-latitude sub-corotational jet is stronger in 3D

Current status:

➢ Small asymmetry between northern and southern hemispheres

➢ Polar regions are consistent with previous modelling and observations
Conclusions:
➢ Still in model development phase
➢ Polar region currents, aurora and neutral temperatures and winds are consistent with simpler models and observations

Future work:
➢ Locate and fix source of hemispheric asymmetry
➢ Begin inclusion of a realistic tilted magnetosphere model