Effects of Lower Magnetic Fields on the Thermosphere-Ionosphere

Erdal Yiğit[1], and Aaron J. Ridley[1]

[1] *University of Michigan*, Ann Arbor, USA
email: erdal@umich.edu

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Introduction - Science Question

This Study

How does

decreasing magnetic field impact

the thermosphere-ionosphere?

system

Introduction - Earth's Magnetic Field

- Tilted offset dipole field
- Variable: magnitude and distribution
- Magnitude decreased in the last 150 years 10-15% and still decreasing...
- Geophysical (dynamics, chemistry) and biological impacts (pigeons, bees).

Research Strategy & Outcome

This study

A **G**eneral **C**irculation **M**odel that simulates the thermosphere-ionosphere self-consistently

+

Lower the magnetic field density

↓

Quantify the changes in the thermosphere-ionosphere

Model description-I

Global Ionosphere Thermosphere Model (GITM)

- First principle nonhydrostatic general circulation model (GCM) described in the work by *Ridley et al.* (2006)
- Vertical extent: 100-∼650 km
- Variable time step 2-4 s.
- Variable flexible grid resolution, e.g., $5^\circ \times 5^\circ$, $0.3125^\circ \times 2.5^\circ$ (*Yiğit and Ridley*, 2011)
- GSWM, MSIS tidal forcing
- 2-way self-consistent thermosphere-ionosphere coupling
- Vertical momentum equation explicitly solved.
- Part of the Space Weather Modeling Framework (SWMF)

Model description-II

Global Ionosphere Thermosphere Model (GITM)

- Dynamics: ion drag, advection, tides, etc.
- Solar and Magnetospheric input:
  - Joule heating
  - Auroral heating
  - High-latitude electric fields
  - Interplanetary magnetic field (IMF)
  - Solar F10.7 flux
  - Solar wind speed
- Chemistry: Neutral densities of O, O_2, $N(^2P)$, $N(^2D)$, $S(^2P)$, N_2, and NO; and ion species $O^+(^2P)$,O_2^+, N^+,$O^+(^4S)$, $O^+(^2D)$, N_2^+, and NO^+

Model Configurations

Input

- Variable F10.7, hemispheric power, and IMF conditions from observations
- Empirical high-latitude electric fields (*Weimer*, 2005)
- Auroral particle precipitation (*Fuller-Rowell and Evans*, 1987)
- MSIS lower boundary fields

Model Configurations: Input

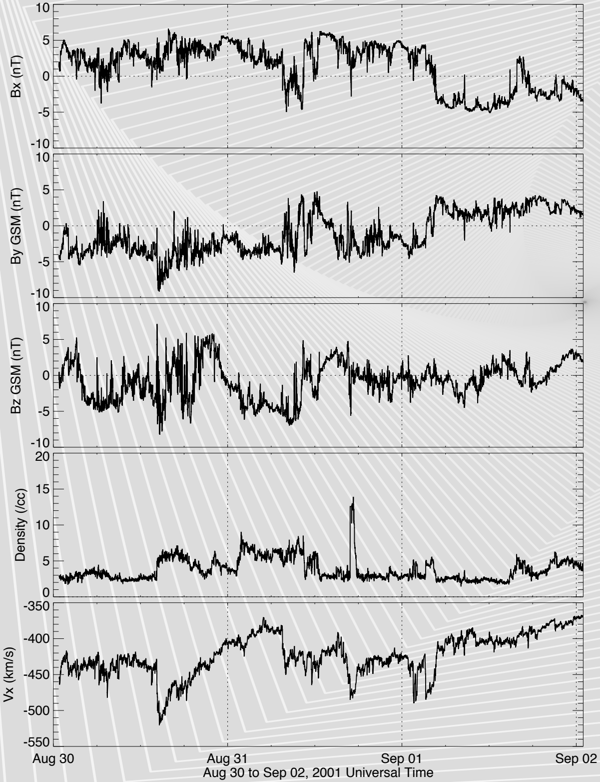


Figure 1: *Heliospheric variations from 30 Aug - 1 Sept 2008.*

Model Simulations and Methodology

Period of simulations

- 30 August - 1 September 2008
- Analysis of 1 September 2008

Reducing the magnetic field

I.	**B**	100%
II.	**B**	95%
III.	**B**	90%
IV.	**B**	85%
V.	**B**	80%

Then calculate the differences with respect to I.

Electron density distributions - 1200 UT

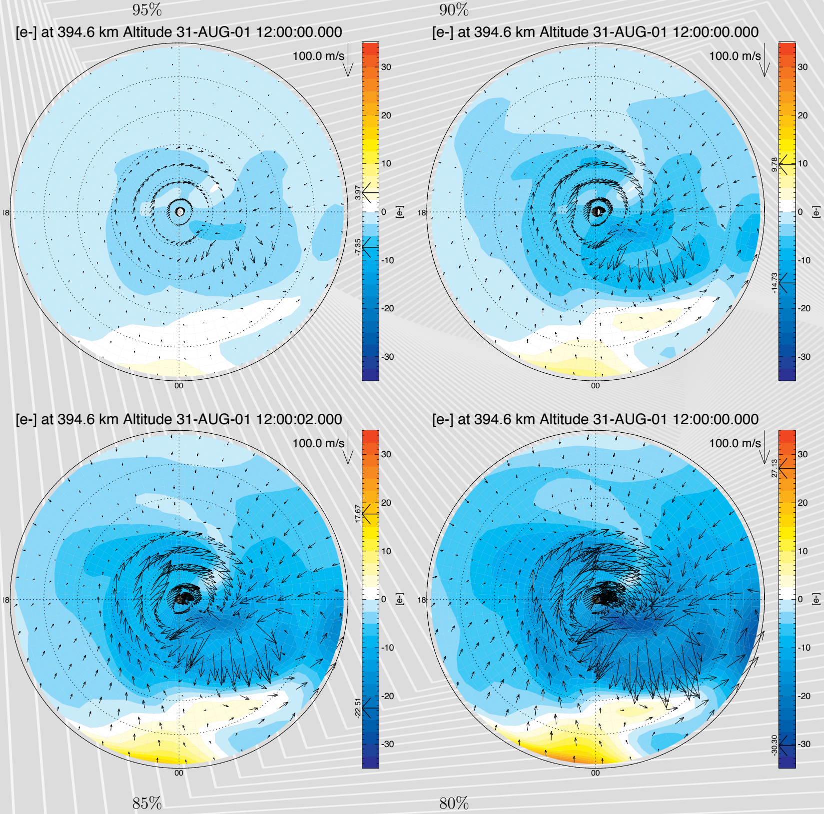


Figure 2: *Polar distributions of relative electron density changes in percentage for decreasing magnetic fields on 31 Aug 1200 UT. Relative changes ion flows are overplotted.*

- **v** enhanced dramatically at high-latitudes.
- n_e increases around midnight at midlatitudes, while everywhere else n_e decreases.

Electron density distributions - 0000 UT

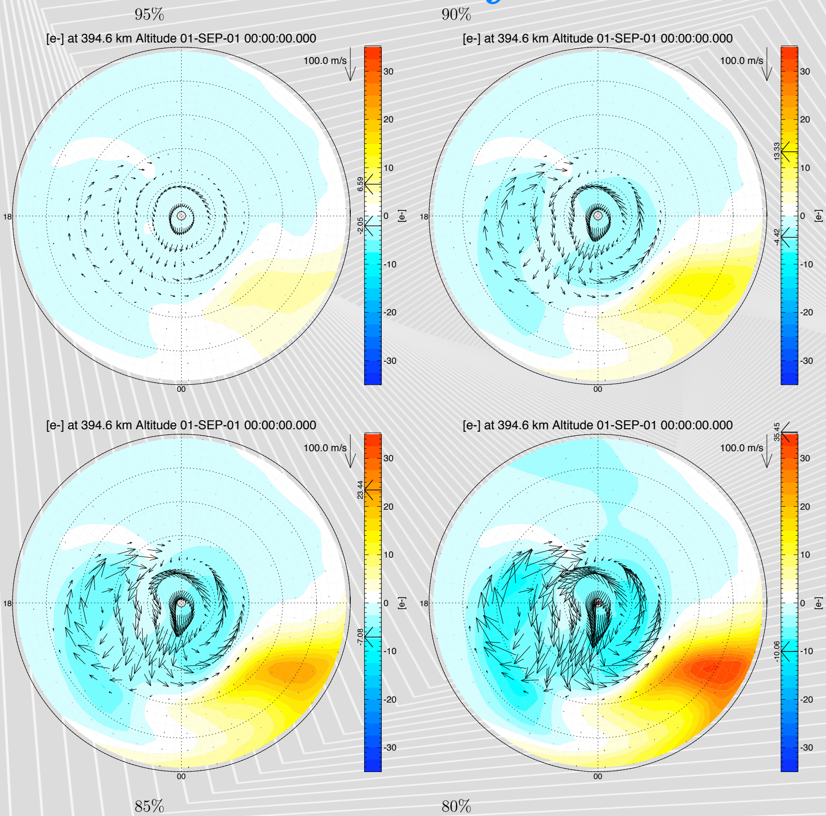
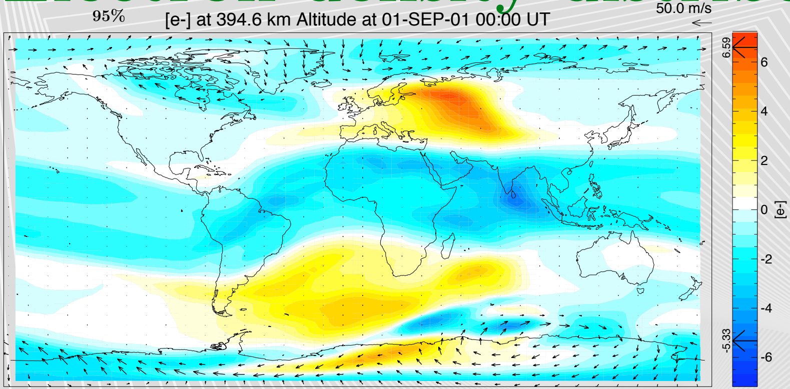


Figure 3: *Polar distribution of relative electron density change in percentage for decreasing magnetic fields on 1 Sept 0000 UT. Relative changes ion flows are overplotted.*

- **v** enhanced dramatically at high-latitudes!
- n_e increases around midnight-dawn at midlatitudes, while everywhere else n_e decreases.

Back
Close

Electron density distributions: Lat-lon



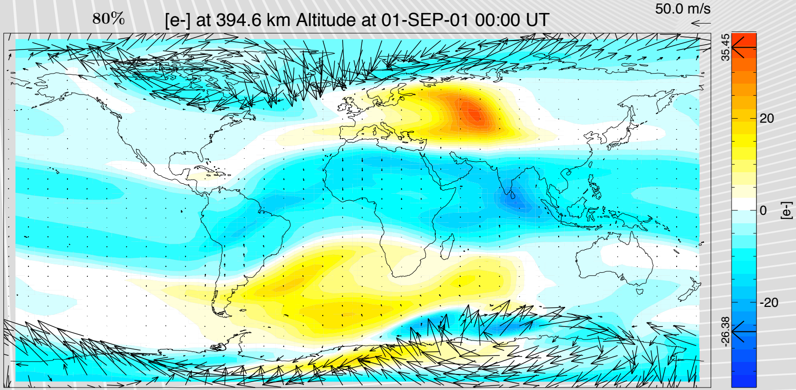


Figure 4: *Latitude-longitude distributions of relative electron density change in percentage for cases 95% and 80% magnetic fields. Relative changes ion flows are overplotted.*

- Electron density increase around midlatitudes and decrease at high-latitudes
- Ion flows are faster at high-latitudes.
- Hemispheric differences.

Temperature and Neutral Flows

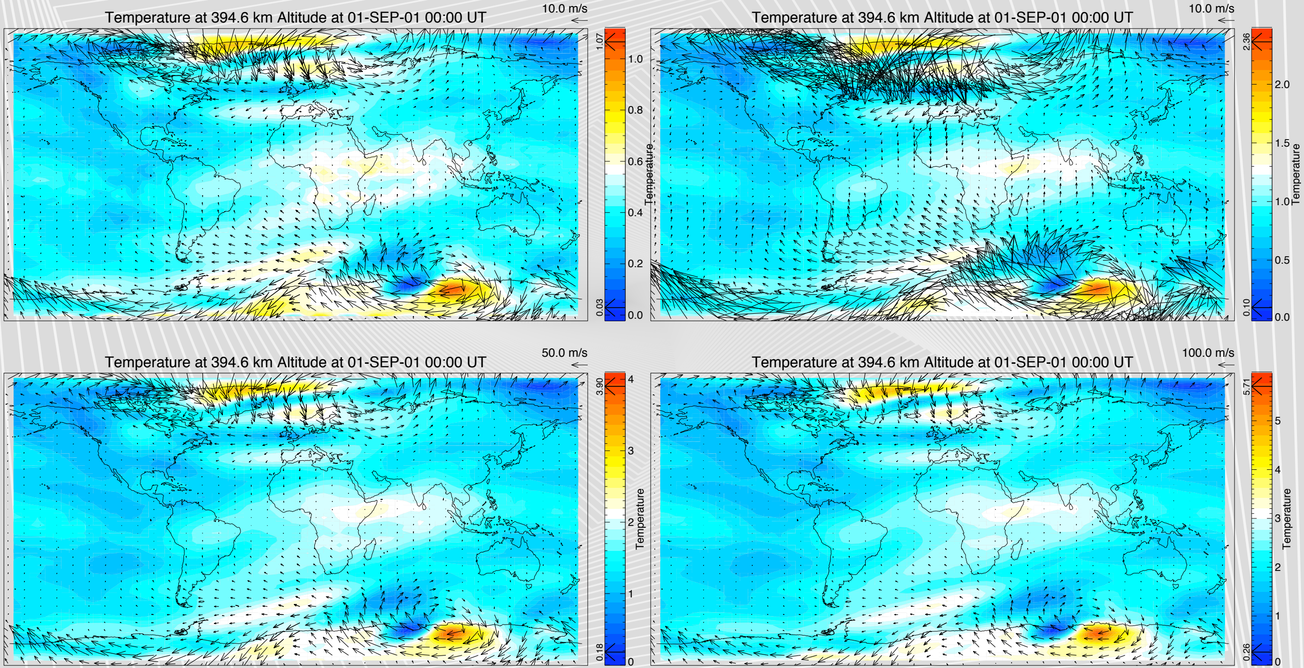


Figure 5: *Relative percentage difference in temperature. Difference in neutral flows are overplotted.*

Meridional Flow & Electron Density

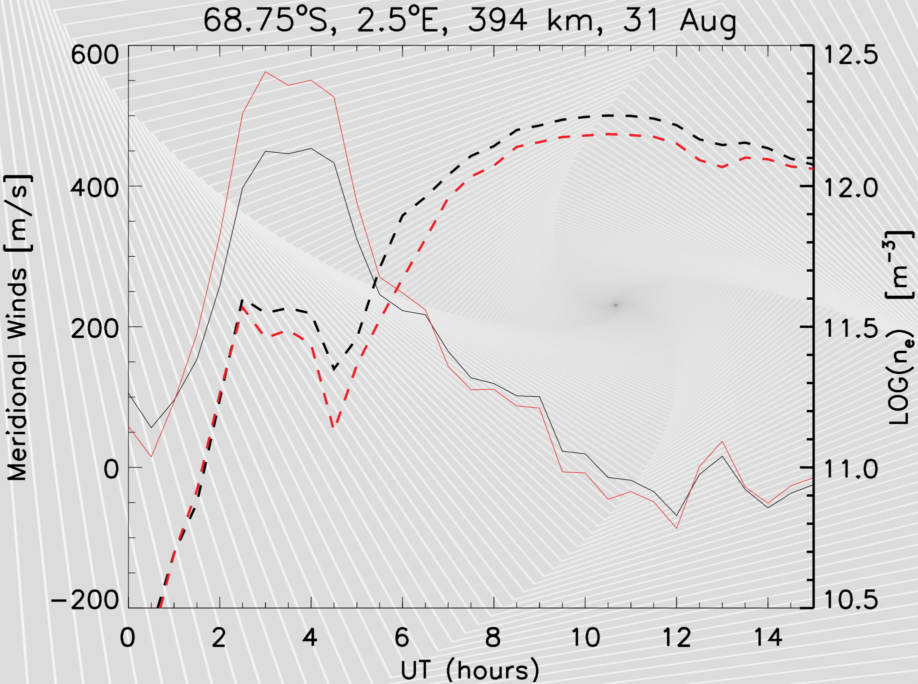


Figure 6: *Merisional flow and electron density at a high-latitude.*

Temperature Variations

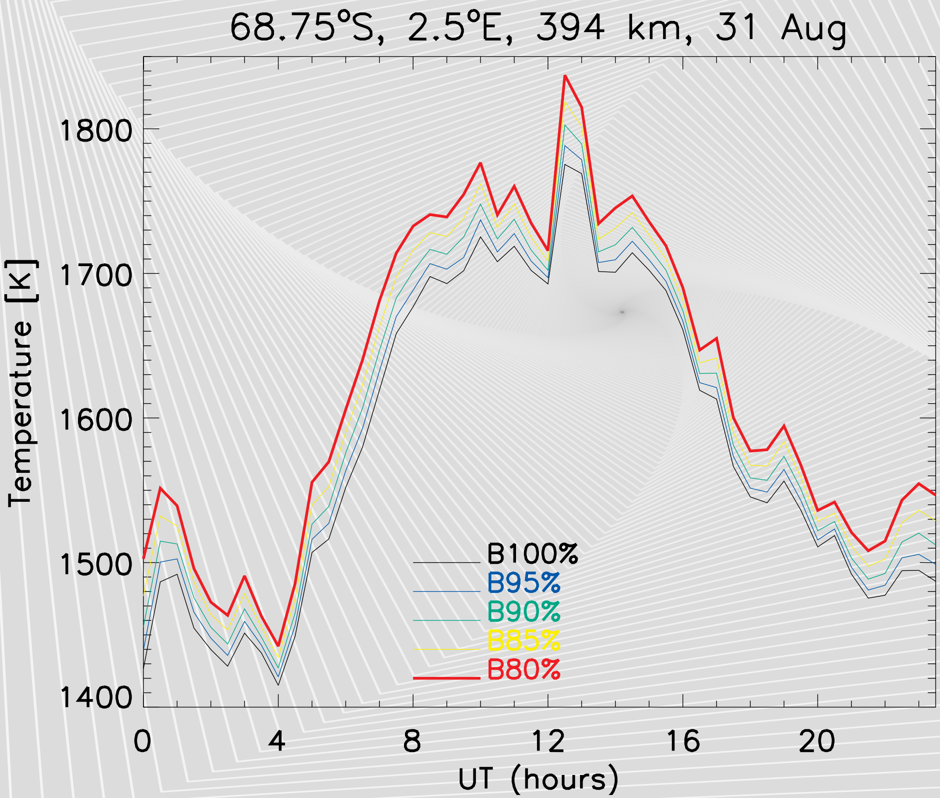


Figure 7: *Universal time variation of neutral temperature at 68.75°, 2.5° E at 394 km on 31 August.*

Summary and Conclusion

Ion flows

- With decreasing magnetic field, the ions become faster $\mathbf{E} \times \mathbf{B}/B^2$
  $\rightarrow$ Variations in ion drag and Joule heating are expected!
  $\rightarrow$ Changes in dynamics and heat balance
- Variability (future work)

Electron density distributions

With decreasing **B** from 100 to 80%

- 6-35% increase in n_e at midlatitudes at night
- Up to –35% change in n_e at high-latitudes

Summary and Conclusion (cont'd)

Temperature and neutral flows

- Temperatures increase overall up to 5% (SH high-latitudes)
- Neutral flows are enhanced with decreasing **B** becoming more equatorward during the night.
  $\rightarrow$ effects on chemistry
- Ion drag and Joule heating probably play a great role (future study).

Future Work

- Modeling the Sun-Earth connection.
- Impact of solar variability at various scales.
- Observational implications
- Ion drag and Joule heating.

References

Fuller-Rowell, T. J., and D. S. Evans (1987), Height-integrated Pederson and Hall conductivity patterns inferred from TIROS-NOAA satellite data, *J. Geophys. Res.*, *92*, 7606–7618.

Ridley, A. J., Y. Deng, and G. Tóth (2006), The global ionosphere–thermosphere model, *J. Atmos. Sol.-Terr. Phys.*, *68*, 839–864.

Weimer, D. R. (2005), Improved ionospheric electrodynamic models and application to calculating Joule heating rates, *J. Geophys. Res.*, *110*, A05306, doi:10.1029/2004JA010884.

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