OpenGGCM-CTIM Study of Ionosphere and Thermosphere Energy Deposition under Northward IMF Condition

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GEM-CEDAR

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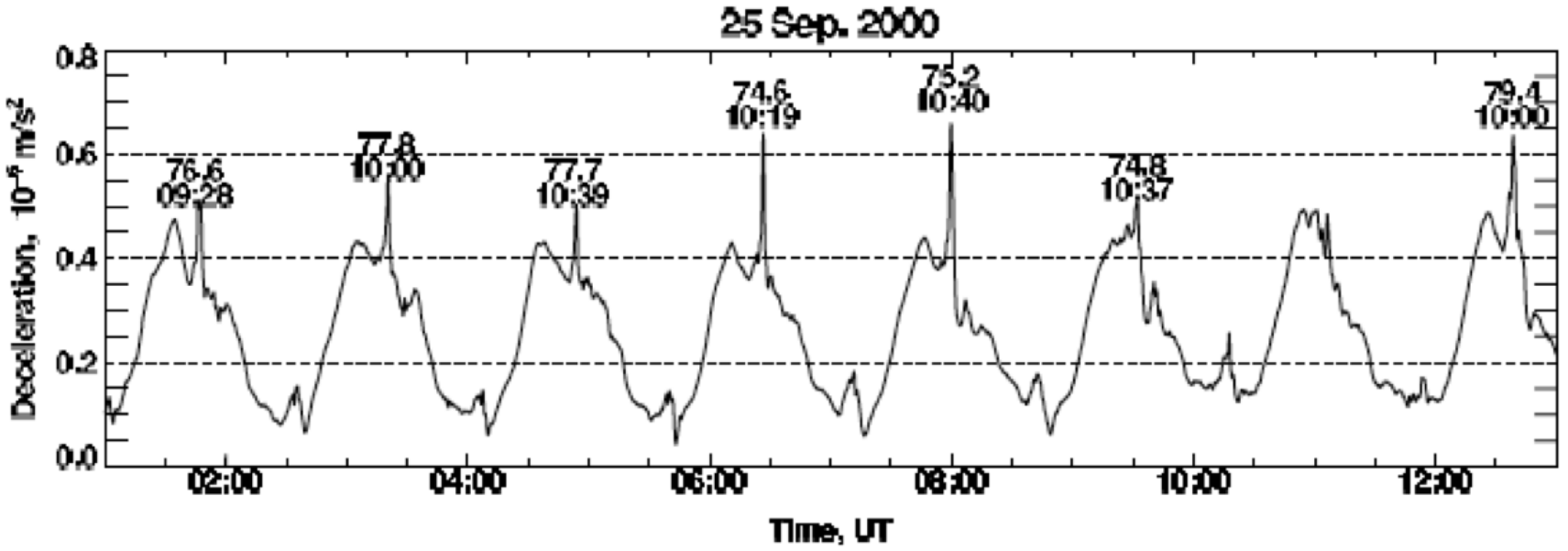
Outline

1. Challenging Minisatellite Payload (CHAMP) satellite observation of thermospheric density enhancement anomaly.
2. DMSP observation of strong Poynting flux.
3. OpenGGCM results.

High-latitude local thermosphere density enhancements

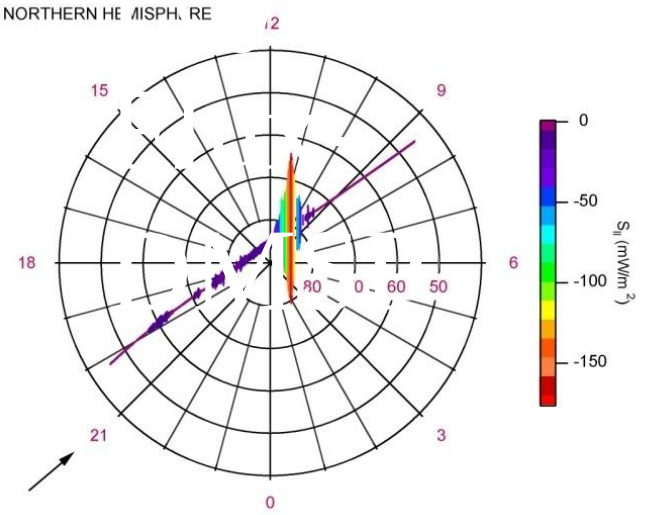
Lühr et al. [2004] showed that, under relatively quiet geomagnetic conditions, the CHAMP satellite often observes regions of enhanced density at ~ 400 km altitude in the noon sector at high latitudes correlated with small scale field-aligned currents (FACs) associated with the dayside cusp.



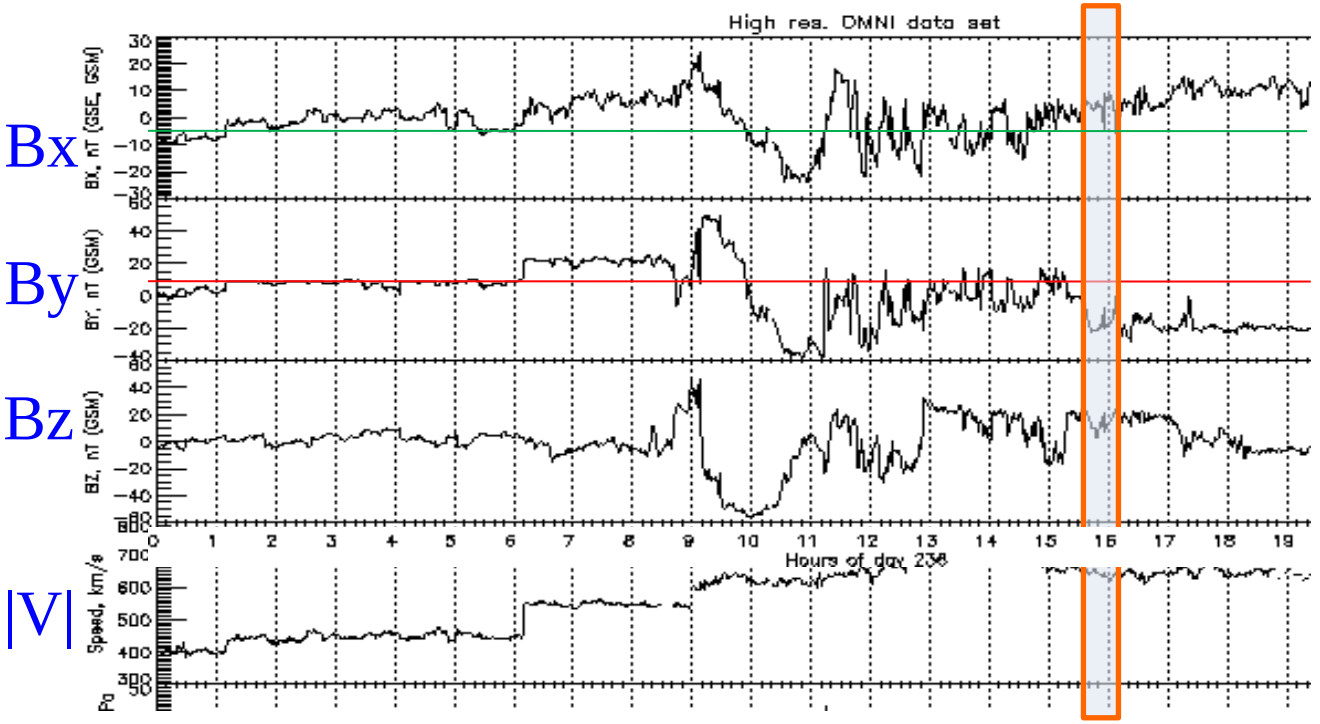
Air drag measured by the accelerometer on board CHAMP. The harmonic variations indicate the range of change over an orbit. Small-scale features are superimposed. The peaks in air drag are labeled by their corrected magnetic latitude and magnetic local time. (Adapted from *Lühr et al.*, 2004.)

DMSP Enhanced Poynting Flux (Knipp et al., 2011)

- Strong, localized Poynting flux is observed,
- near cusp region,
- during northward IMF with strong B_y component (quiet magnetosphere, Kp<2).



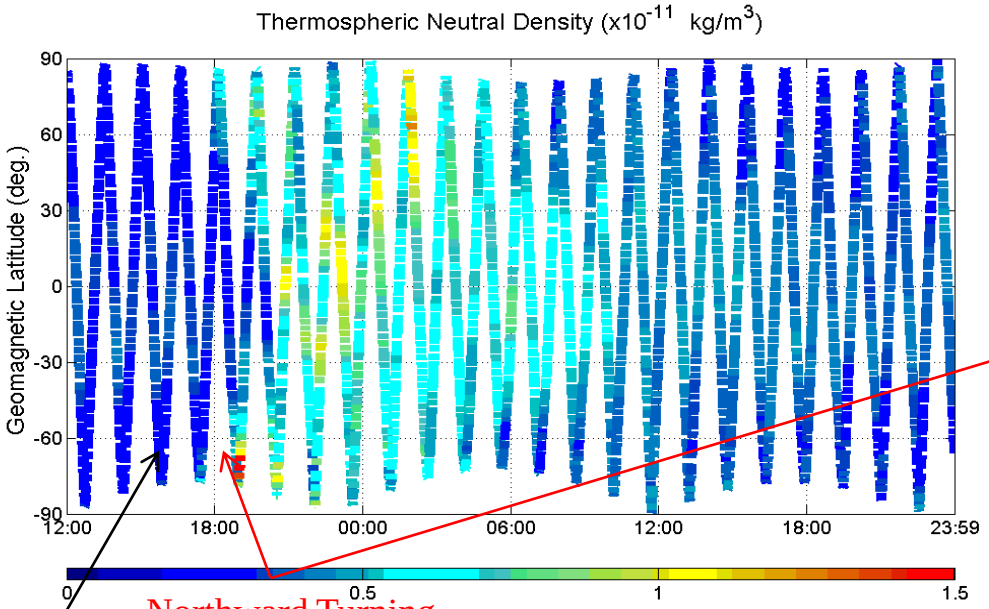
IMF and Solar Wind

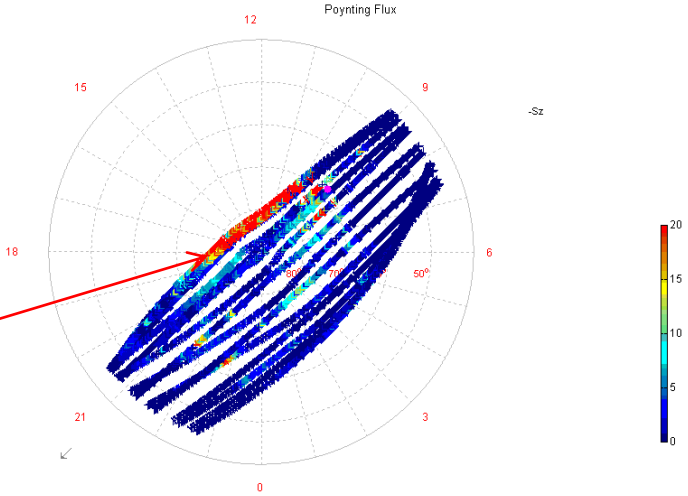


CHAMP Data: Neutral Density Enhancement

- The localized energy input has a profound effect on neutral density.

DMSP Poynting Flux



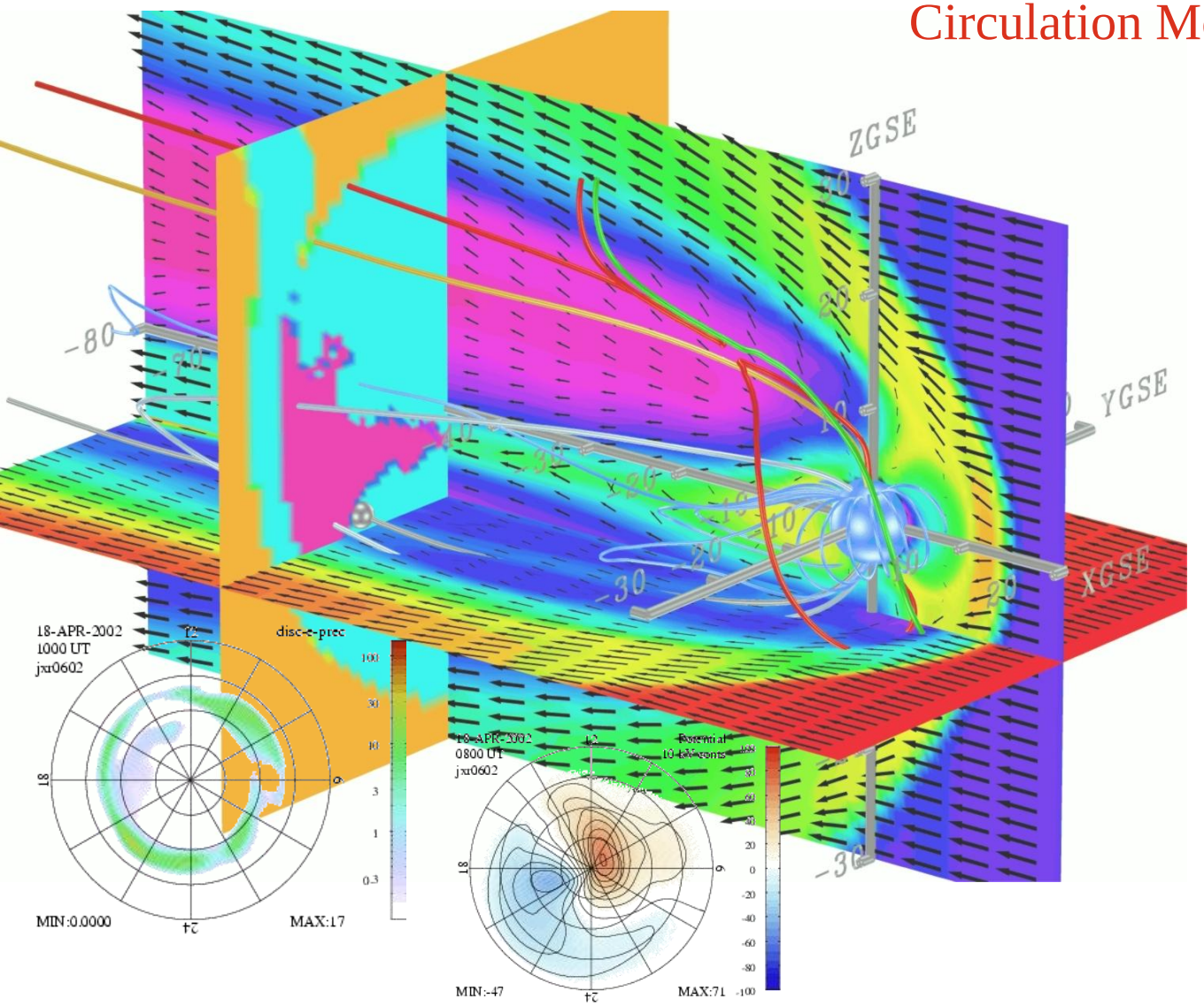


Northward Turning,
SW Density Increase

Shock Arrival

OpenGGCM: Global Magnetosphere Modeling

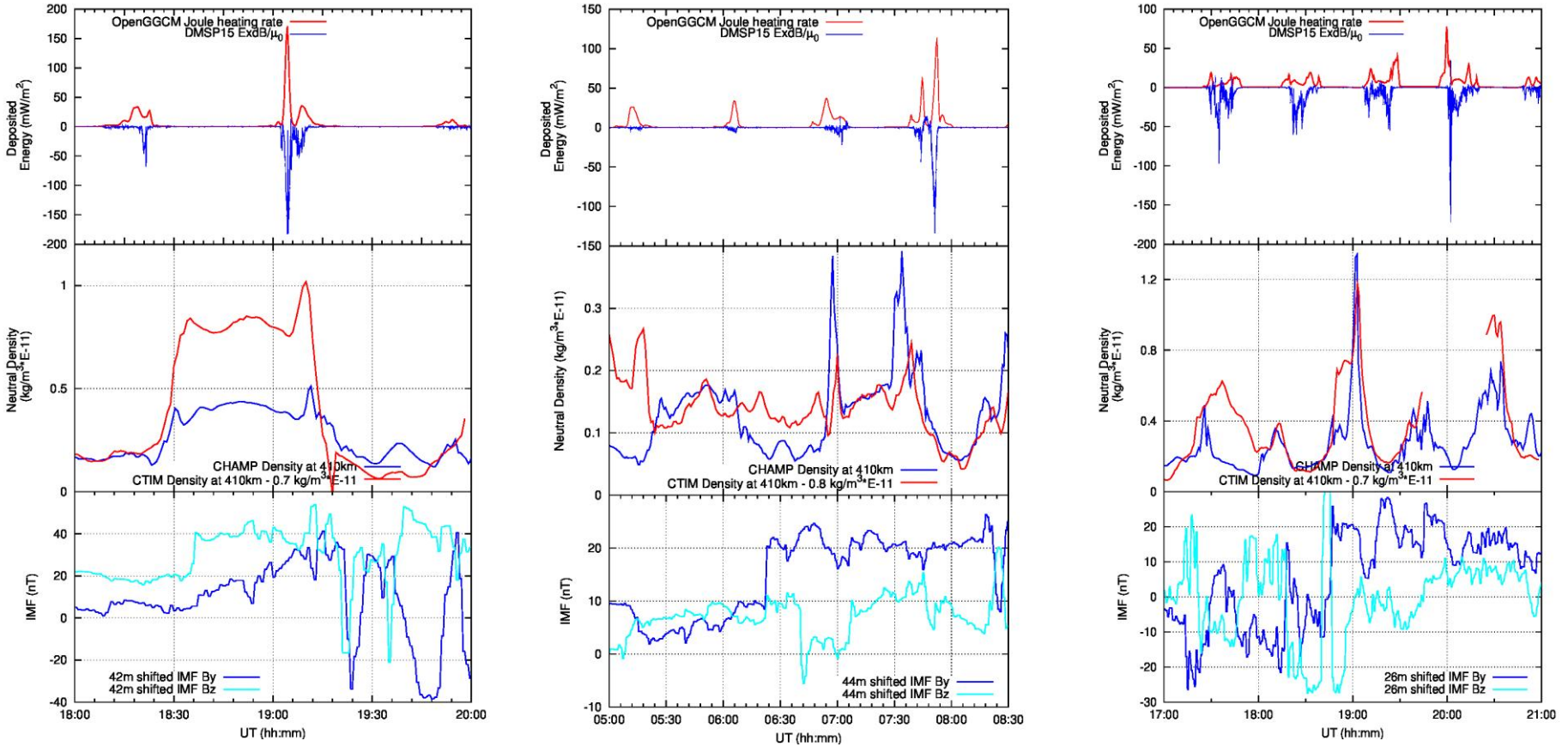
Open Geospace General Circulation Model



- 3d Magnetohydrodynamic magnetosphere model.
- Coupled with NOAA/SEC (*Fuller-Rowell*) 3d dynamic/chemistry ionosphere - thermosphere model (CTIM).
- Coupled with inner magnetosphere / ring current models: Rice U. RCM, NASA/GSFC CRCM.
- Model runs on demand (>300 so far) provided at the Community Coordinated Modeling Center (CCMC at NASA/GSFC). http://ccmc.gsfc.nasa.gov/
- Fully parallelized code, real-time capable. Runs on IBM/datastar, IA32/I64 based clusters, PS3 clusters, and other hardware.
- Used for basic research, numerical experiments, hypothesis testing, data analysis support, NASA/THEMIS mission support, mission planning, space weather studies, and Numerical Space Weather Forecasting in the future.
- Funding from NASA/LWS, NASA/TR&T, NSF/GEM, NSF/ITR, NSF/PetaApps, AF/MURI programs.

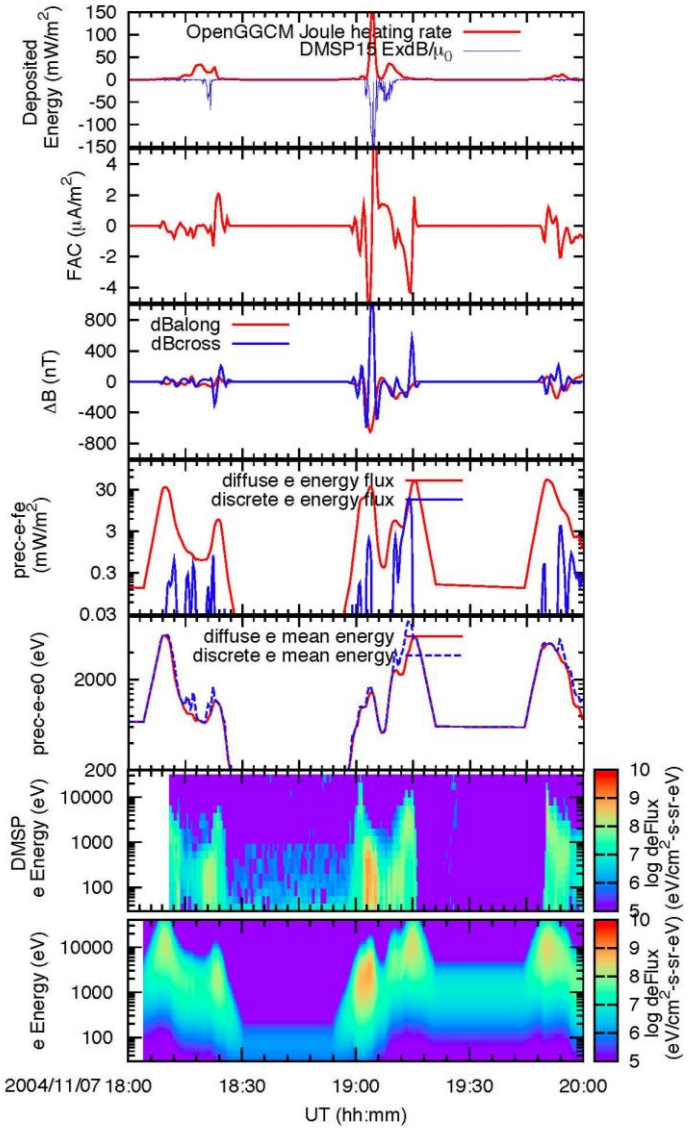
Personnel: J. Raeder, D. Larson, W. Li, A. Vapirev, K. Germaschewski, L. Kepko, H.-J. Kim, M. Gilson, B. Larsen, Y. Ge (UNH), T. Fuller-Rowell, N. Muriyama (NOAA/SEC), F. Toffoletto, A. Chan, B. Hu (Rice U.), M.-C. Fok (GSFC), A. Richmond, A. Maute (NCAR)

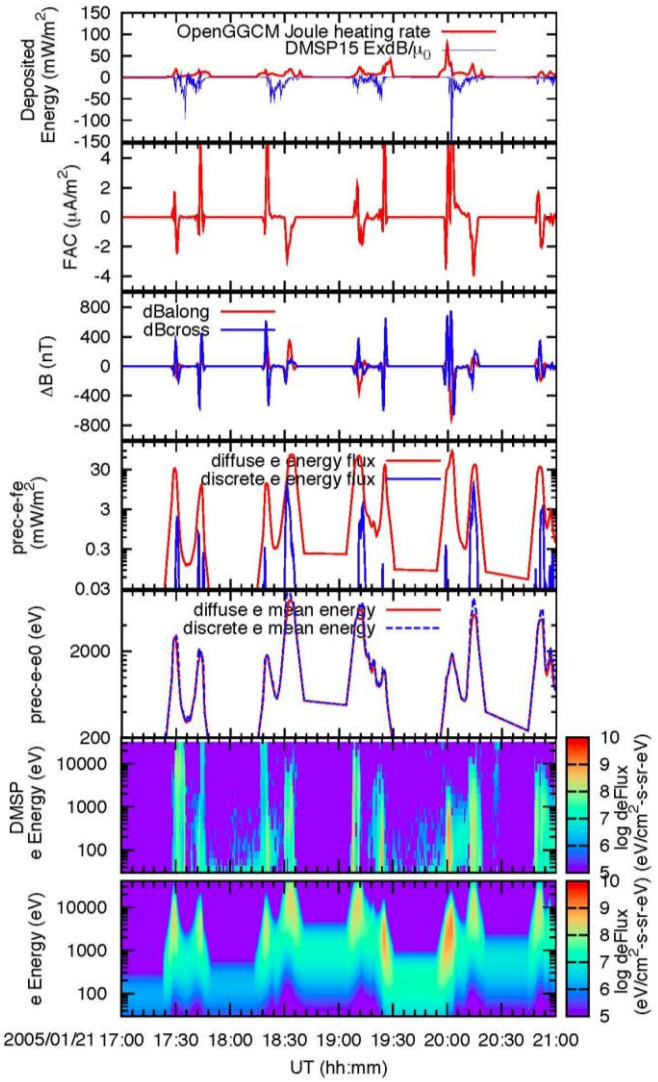
- DMSP (Knipp et al 2011) observations show very high Poynting flux near the cusps.
- CHAMP observes regions of strong, localized neutral density enhancements.
- IMF is northward, with large By component, geomagnetically quiet time.
- OpenGGCM-CTIM simulations of events reproduce both Poynting flux and neutral density “hot spots” for all 3 cases.

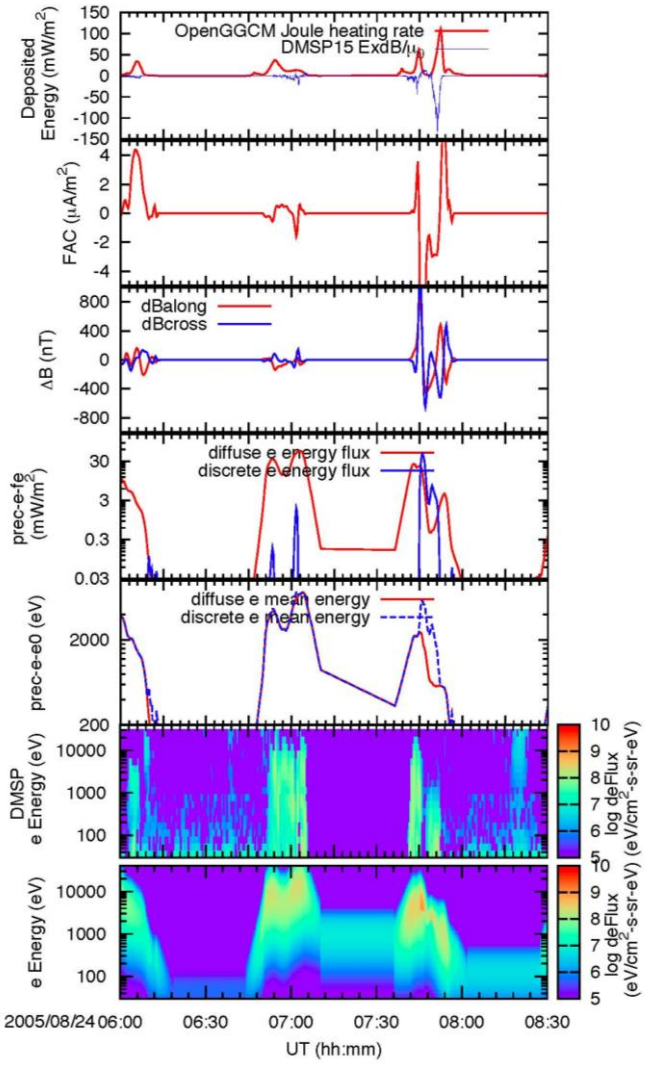


From top to bottom, the panels are: (negative downward) DMSP Poynting flux (blue) and OpenGGCM Joule heating rate (red, they should be equal in magnitude by Poynting’s theorem), CHAMP density (blue) and OpenGGCM-CTIM density at CHAMP (red), and IMF By and Bz.

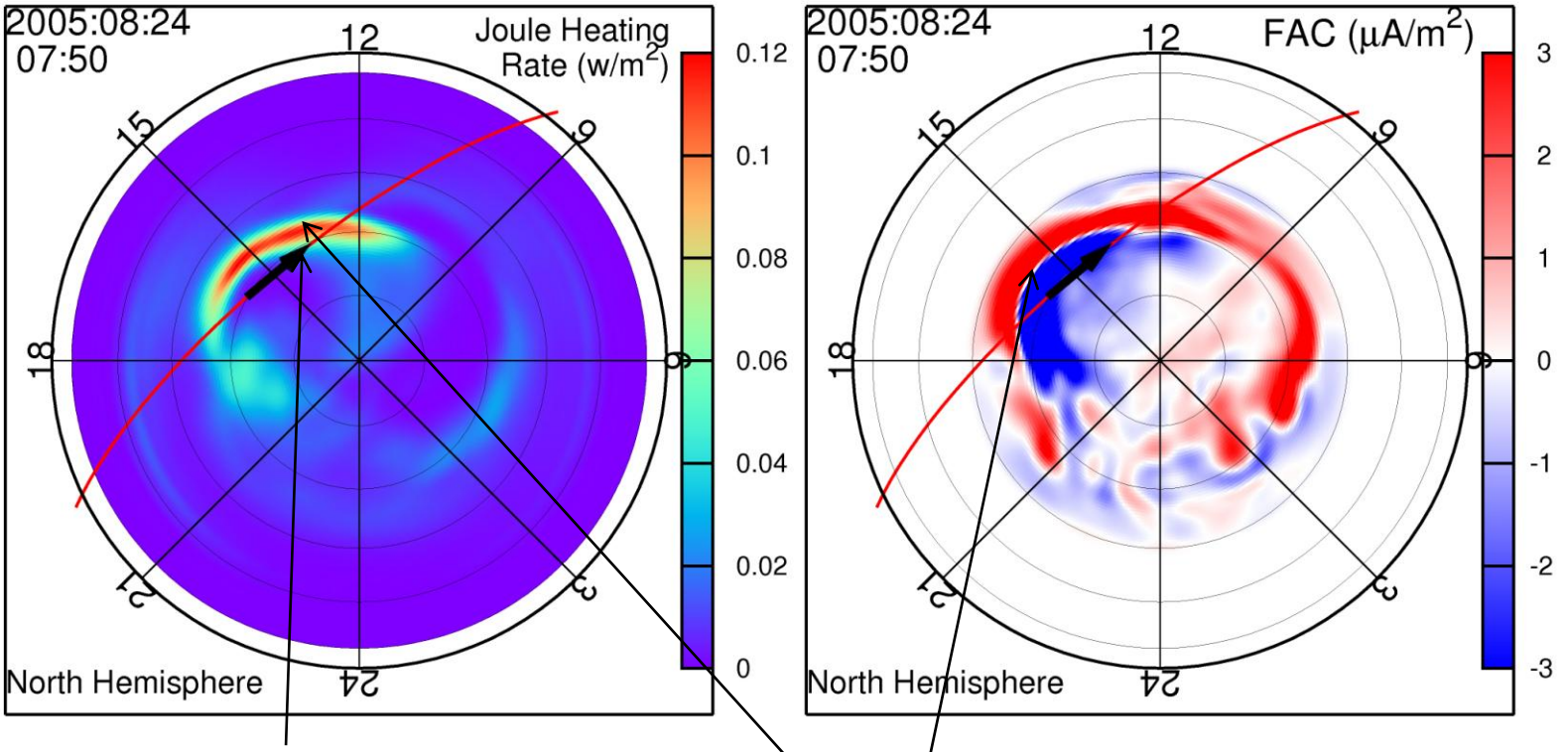
OpenGGCM vs DMSP



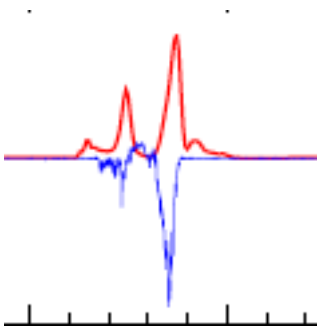




Intense Joule heating and FAC regions

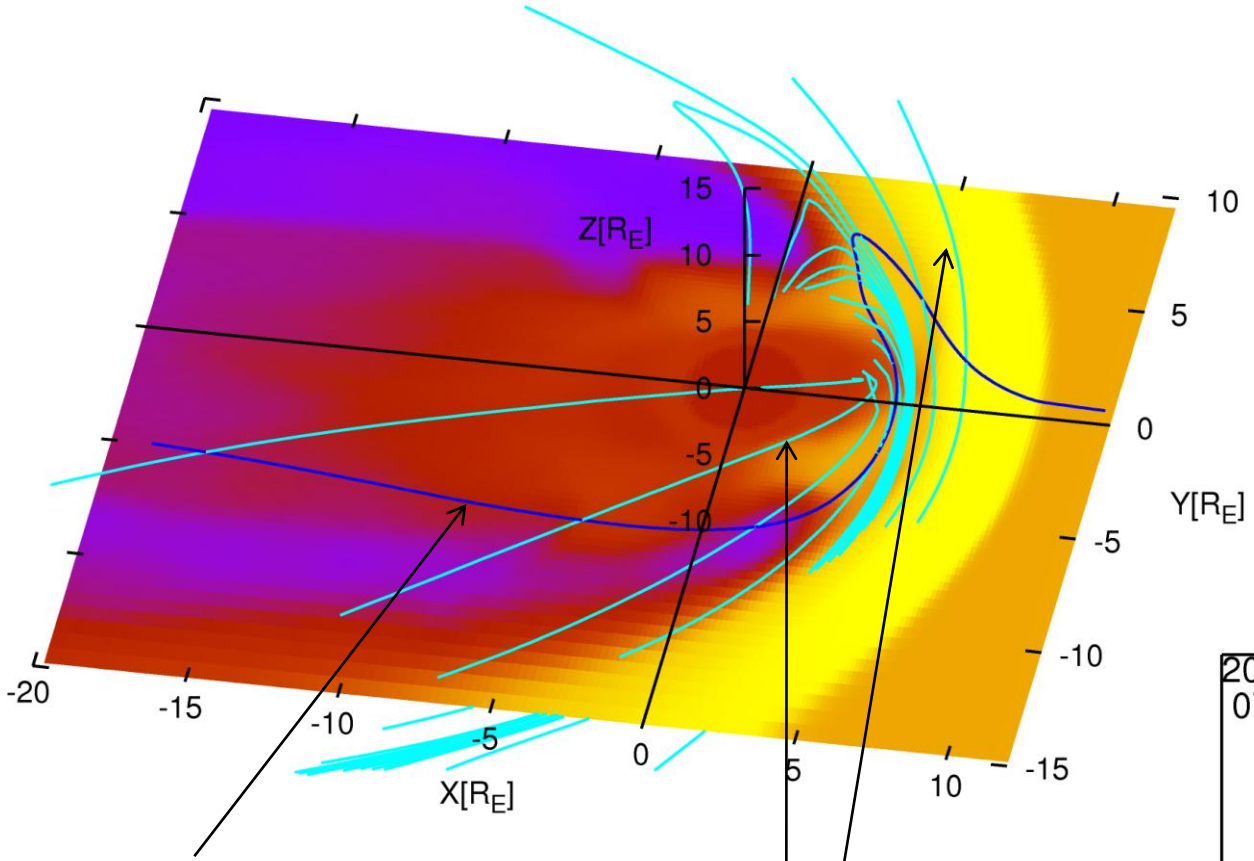


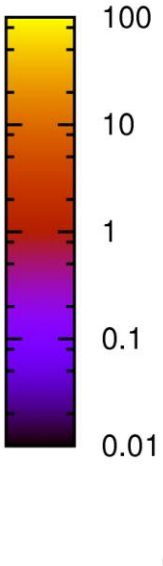
DMSPf15 at 07:50 UT

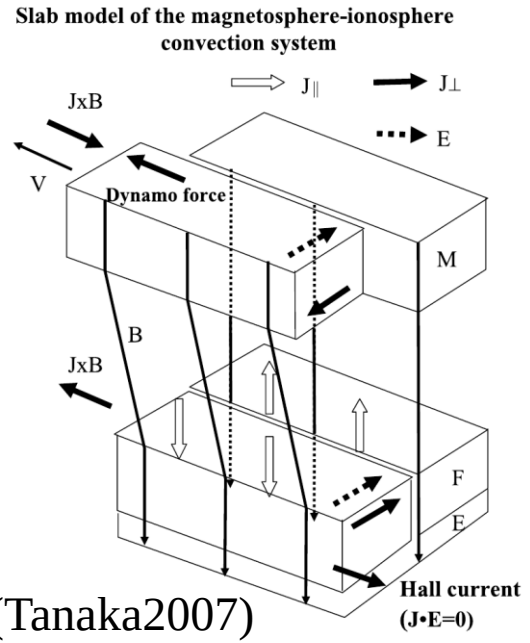


Intense Joule heating (Poynting flux) region flanked by a pair of opposite FACs (+:down)

Moving open field lines resulting from cusp reconnection





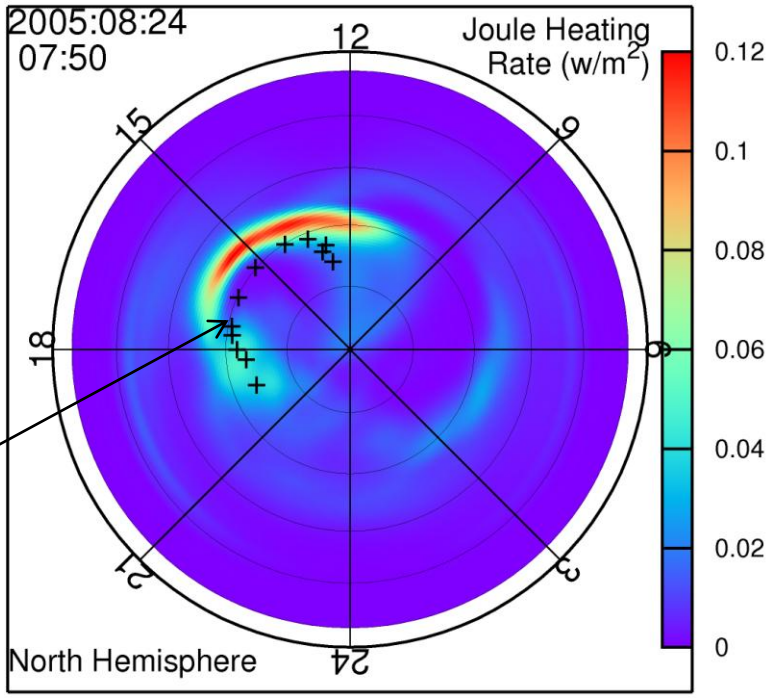


(Tanaka2007)

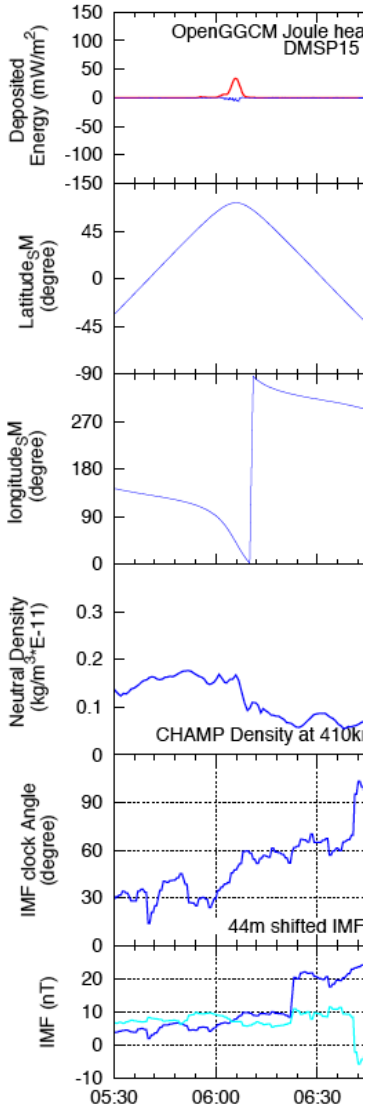
Path of a fluid element entering magnetosphere

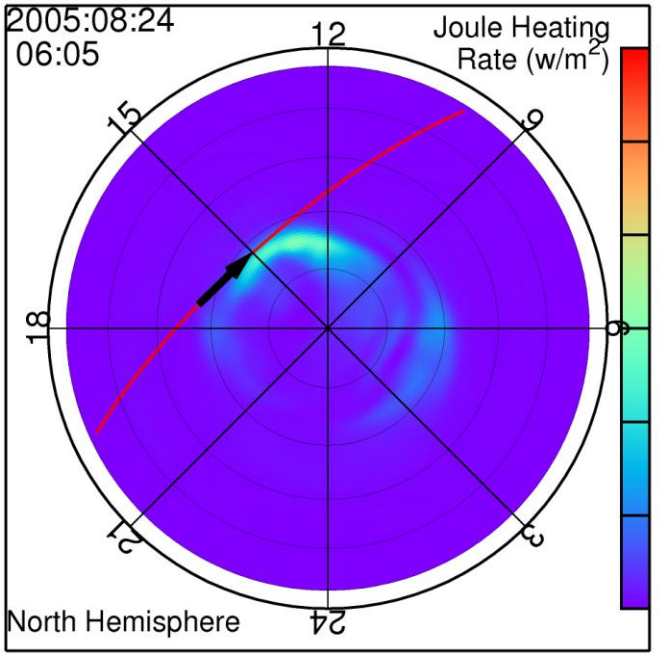
Field line attached to this fluid element

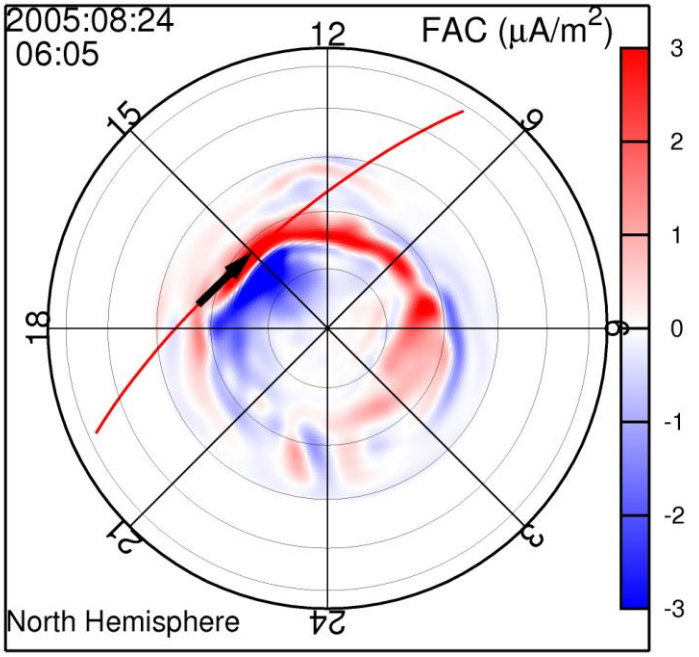
Foot points of these field lines



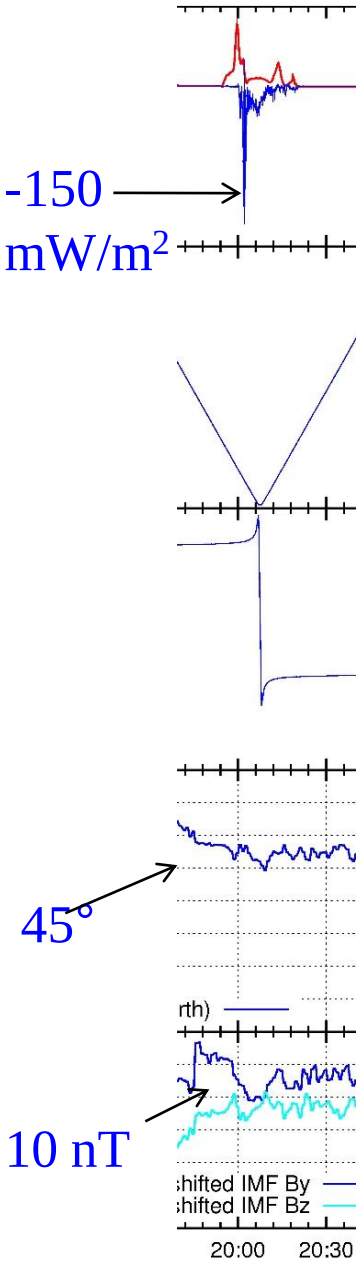
Small IMF clock angle and moderate IMF magnitude

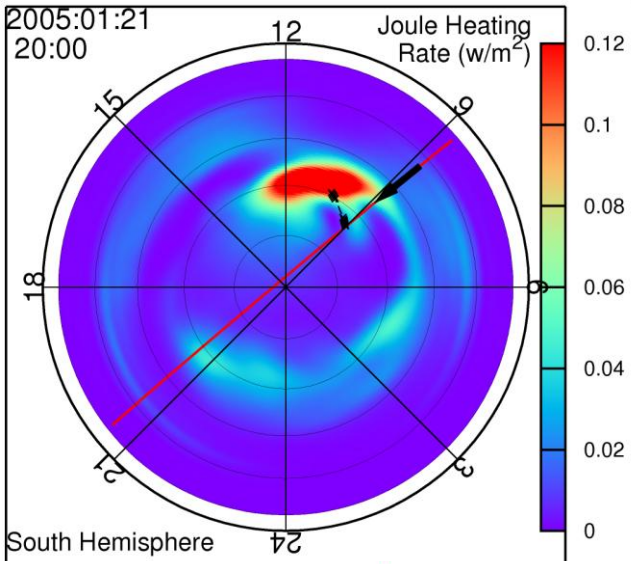


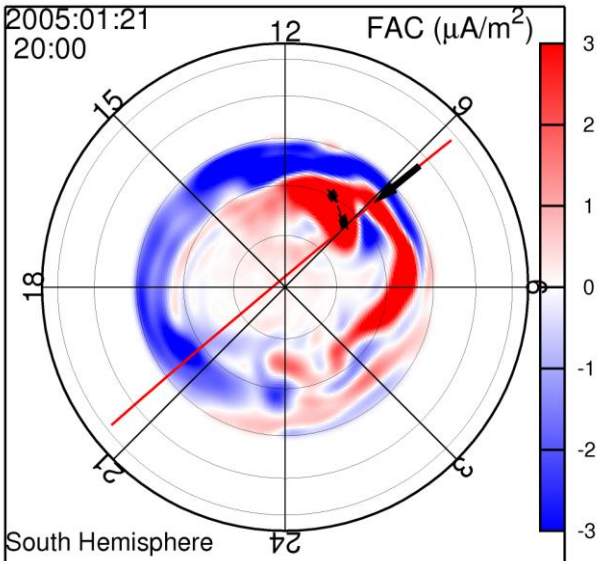


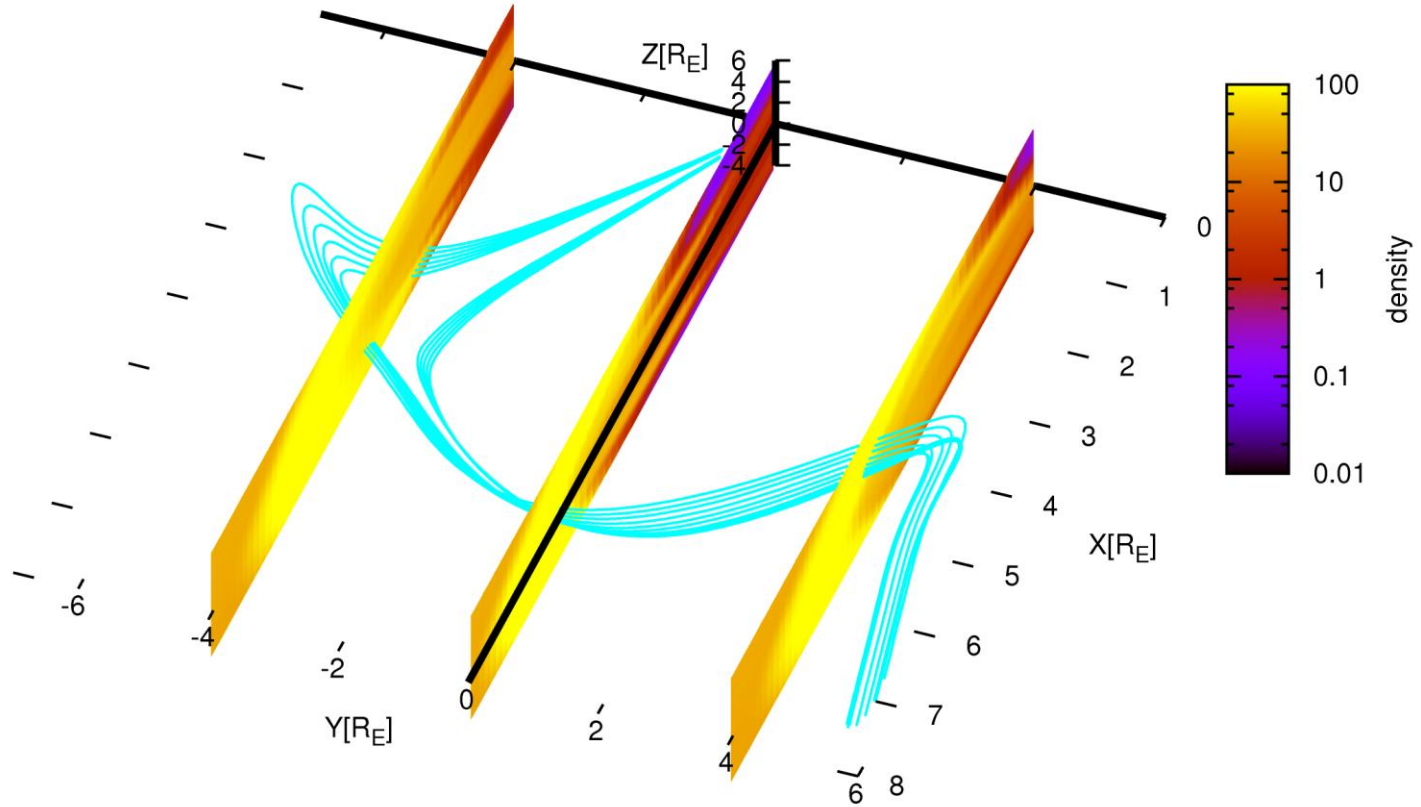


Southern Hemisphere on 21 January 2005









Joule Heating Hot Spot and Thermosphere Density Enhancement

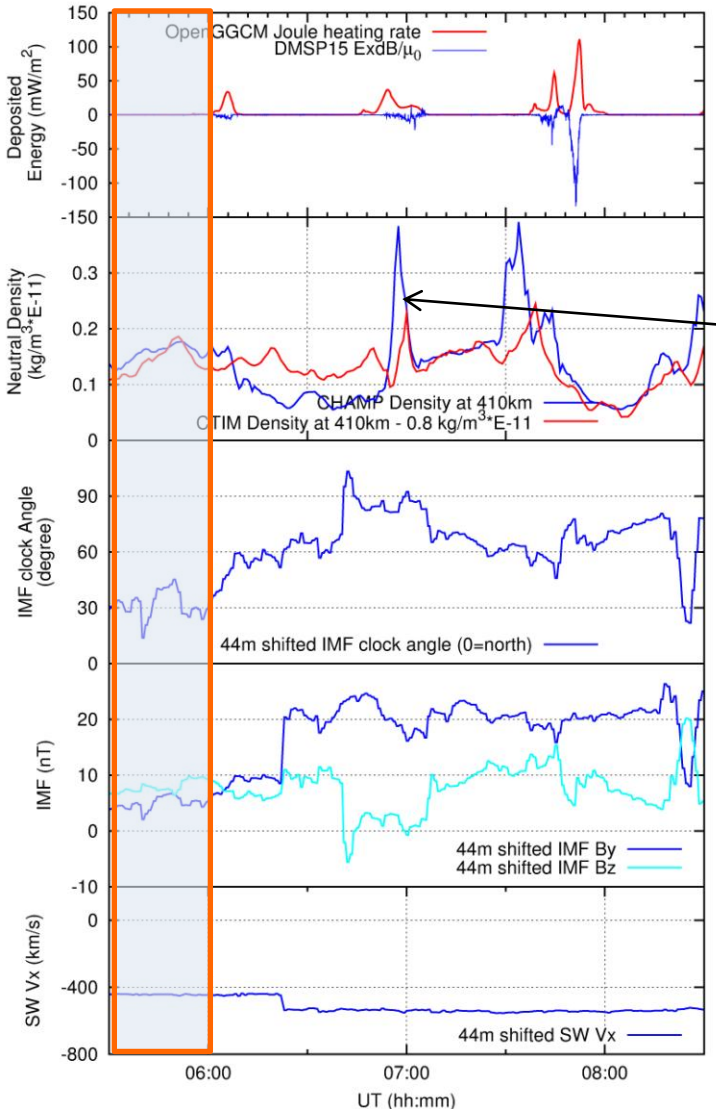
Event 2005-08-24

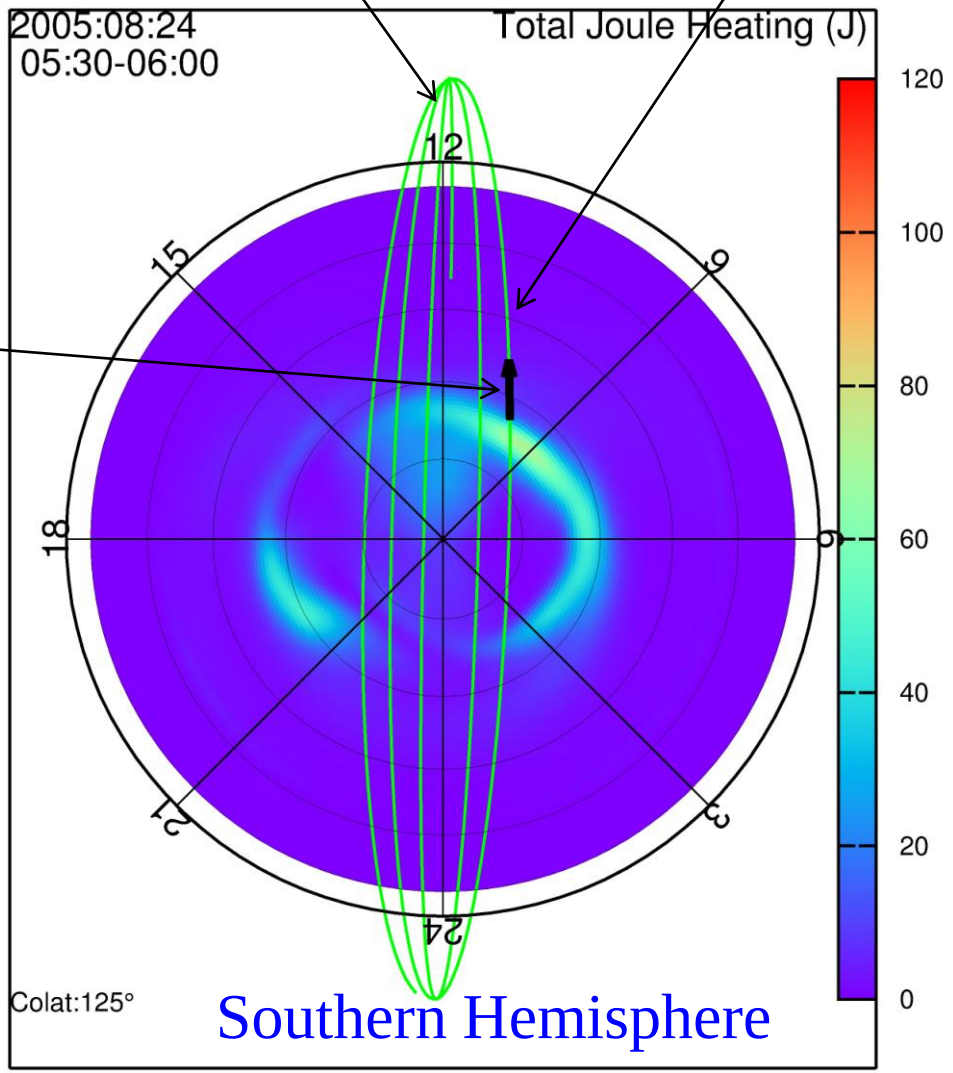
Moderate JH spot

Moderate N. IMF

CHAMP track UT 0400-0800

CHAMP southern pass





Joule Heating Hot Spot and Thermosphere Density Enhancement

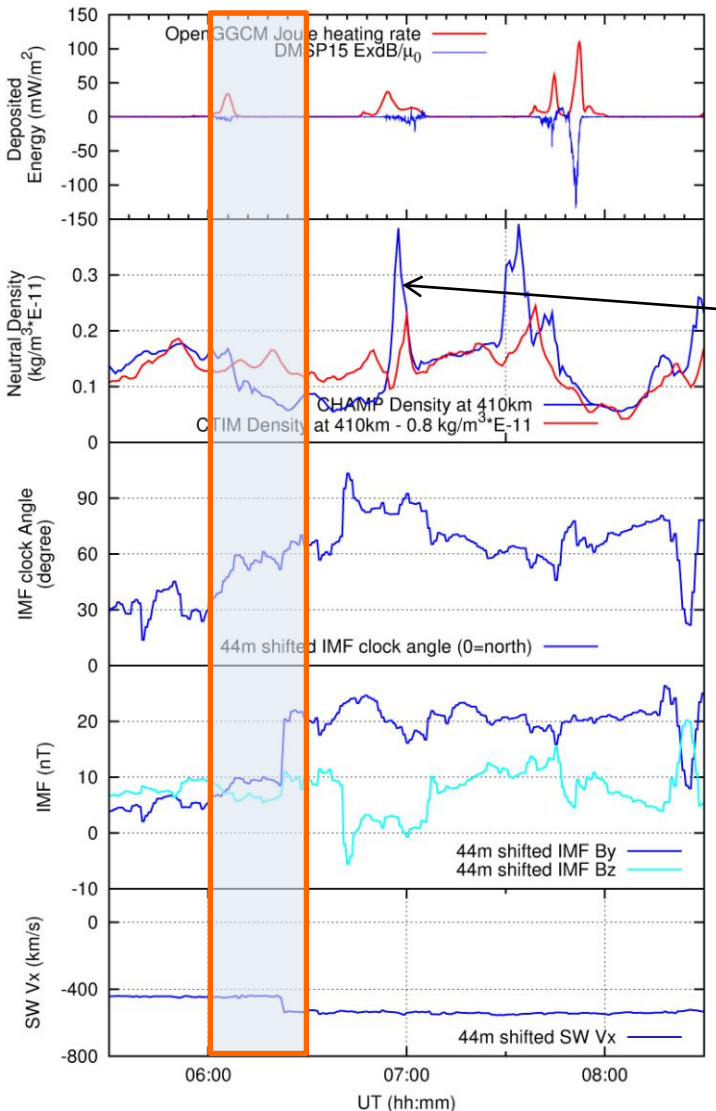
Event 2005-08-24

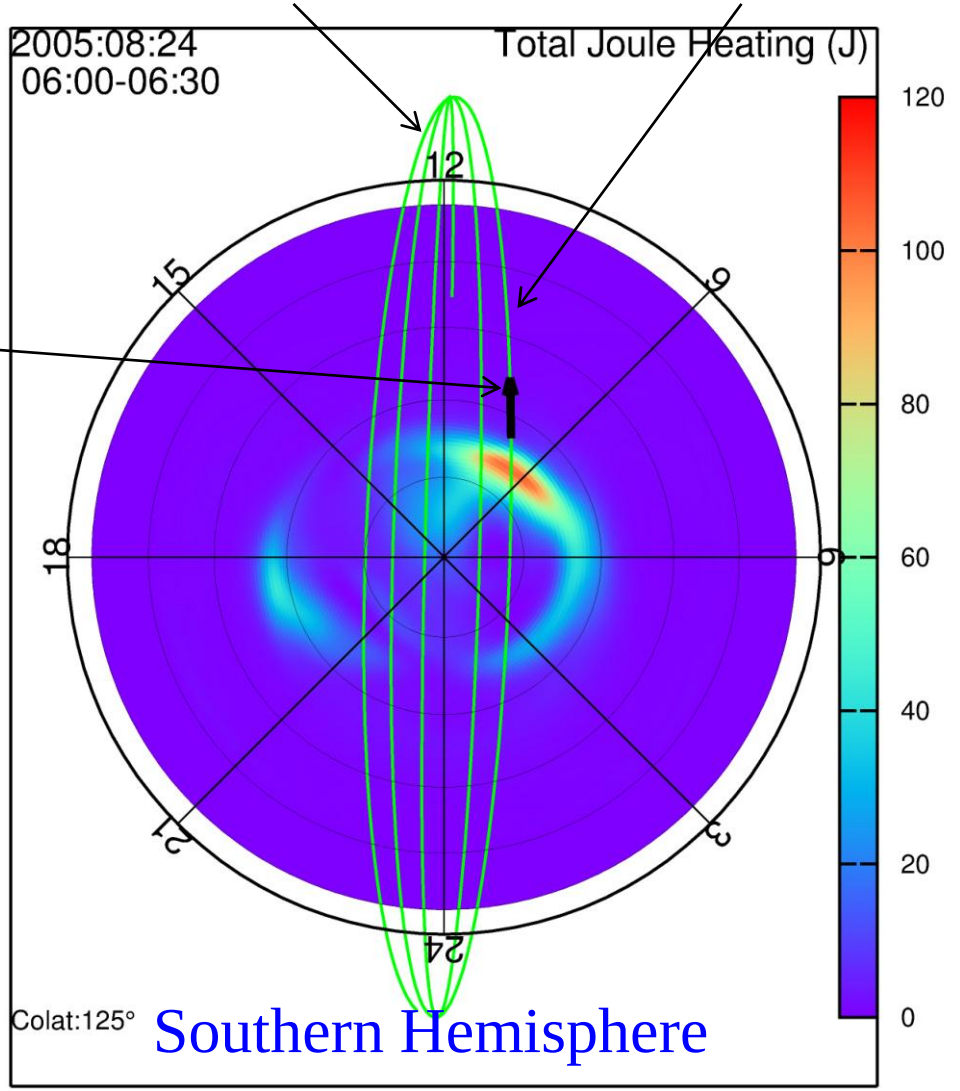
Hot JH spot

Large N. IMF By

CHAMP track UT 0400-0800

CHAMP southern pass





Joule Heating Hot Spot and Thermosphere Density Enhancement

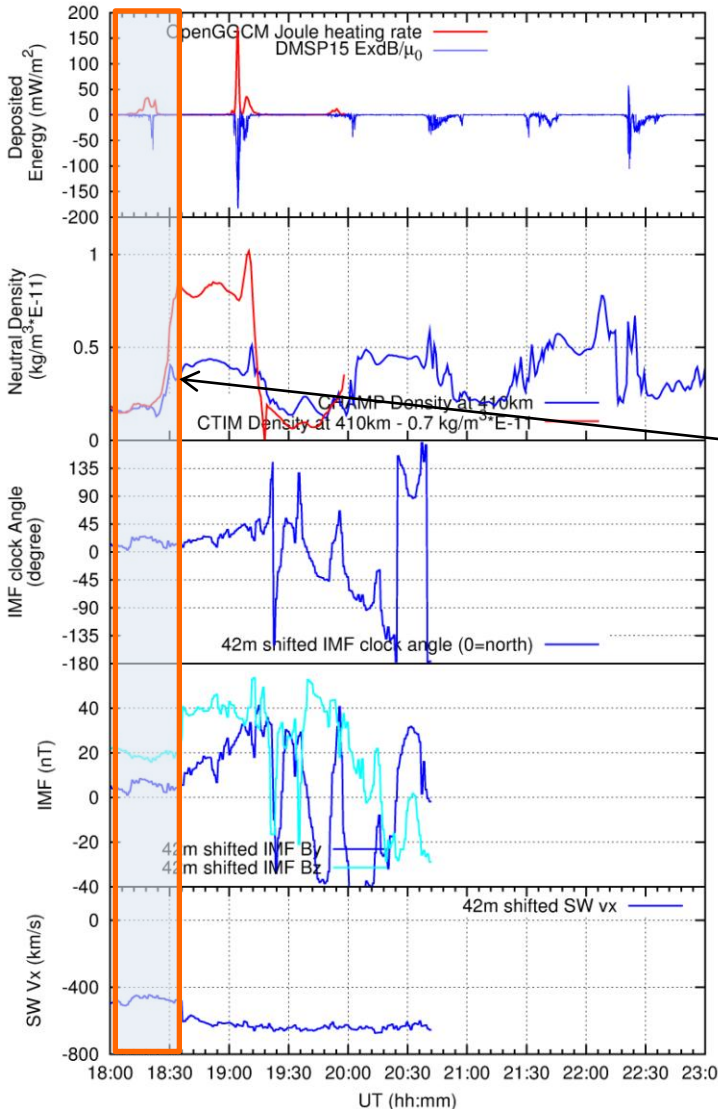
Event 2004-11-07

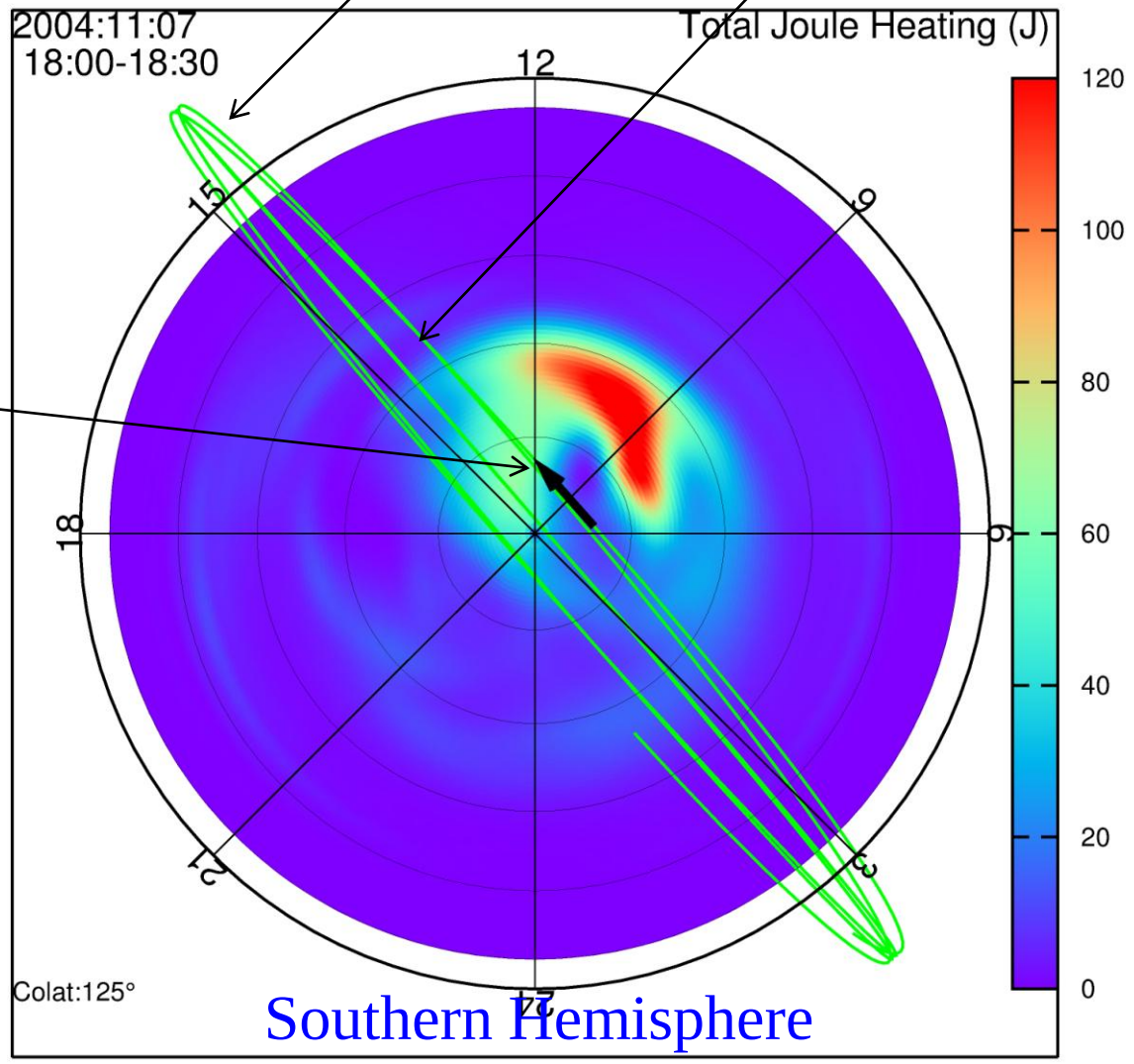
Strong N. IMF

Hot JH spot

CHAMP track UT 1800-2300

CHAMP southern pass





Southern Hemisphere

Joule Heating Hot Spot and Thermosphere Density Enhancement

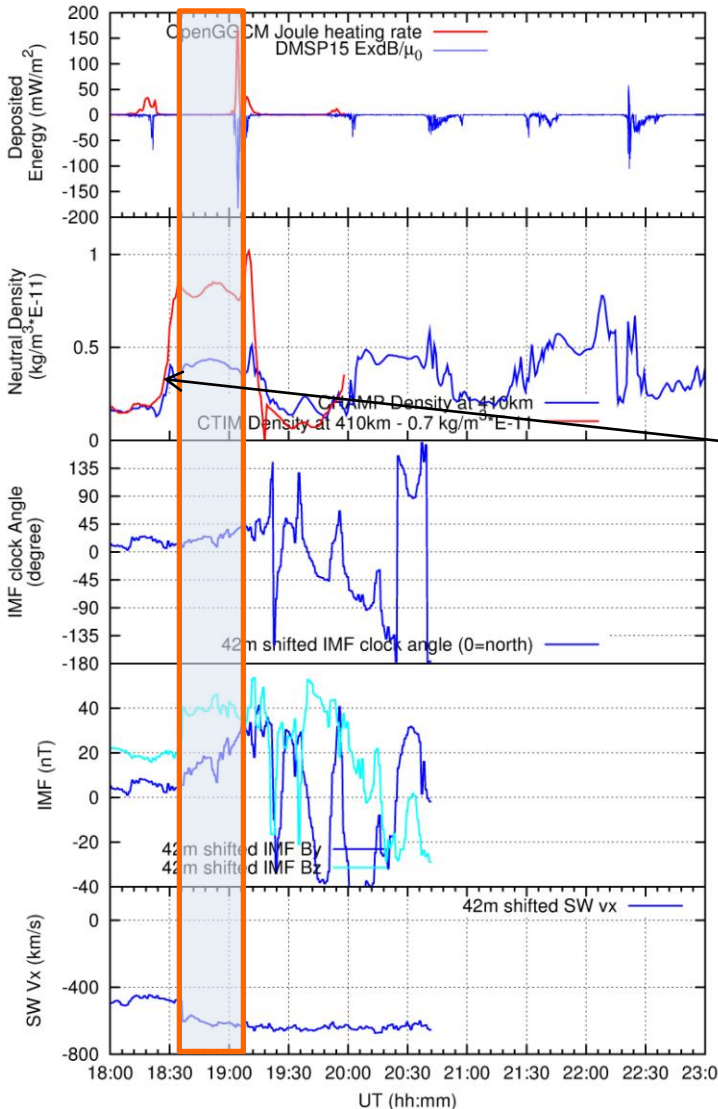
Event 2004-11-07

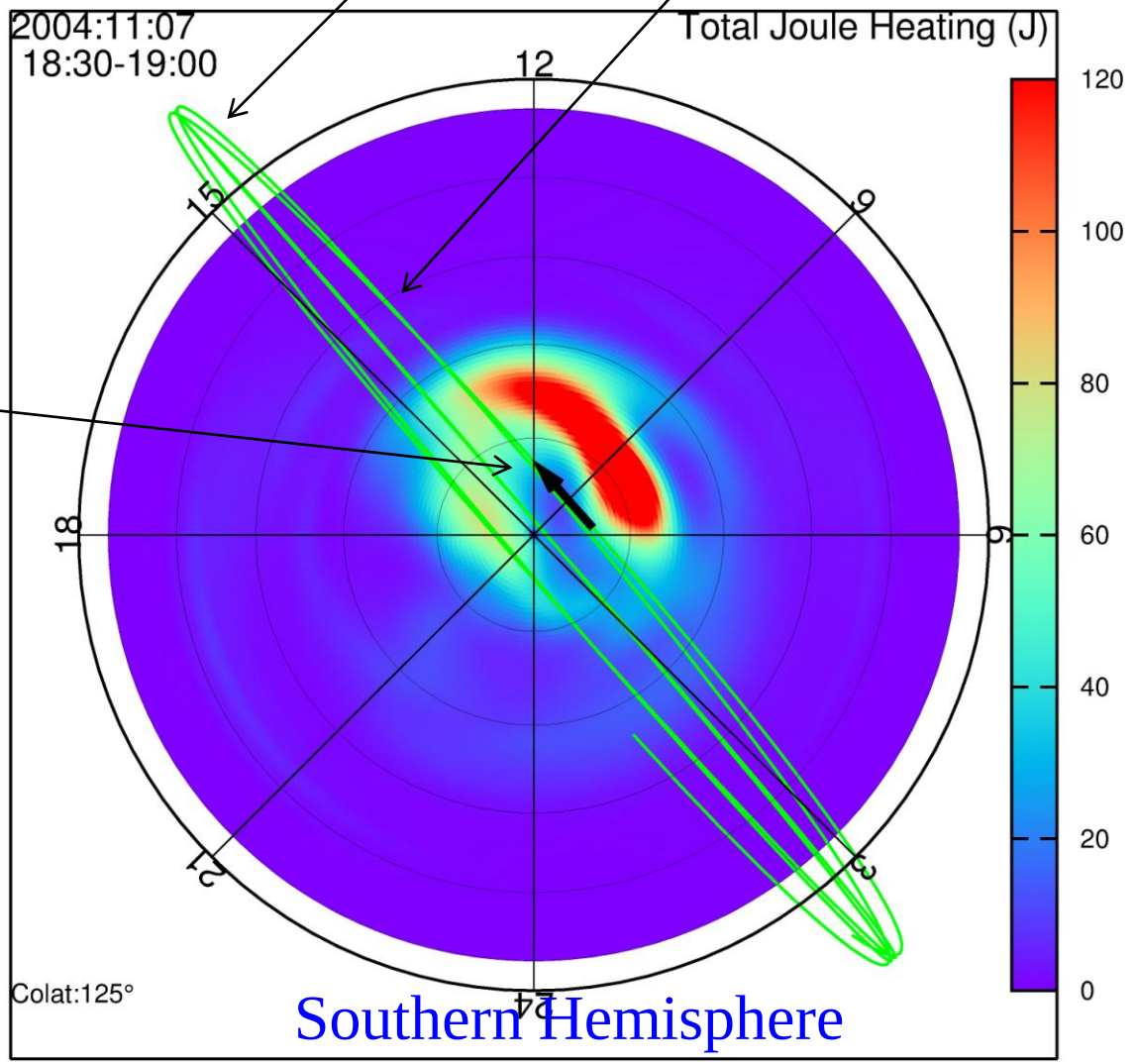
Extremely strong N. IMF

Hot JH spot

CHAMP track UT 1800-2300

CHAMP southern pass





Southern Hemisphere

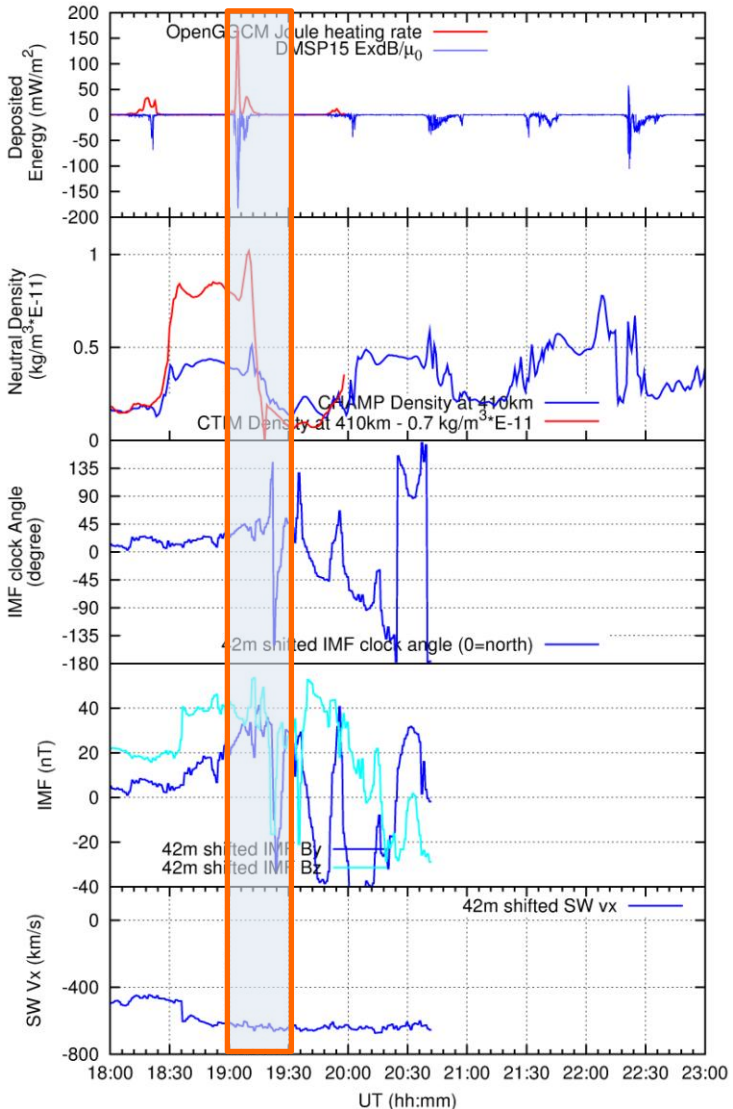
Joule Heating Hot Spot and Thermosphere Density Enhancement

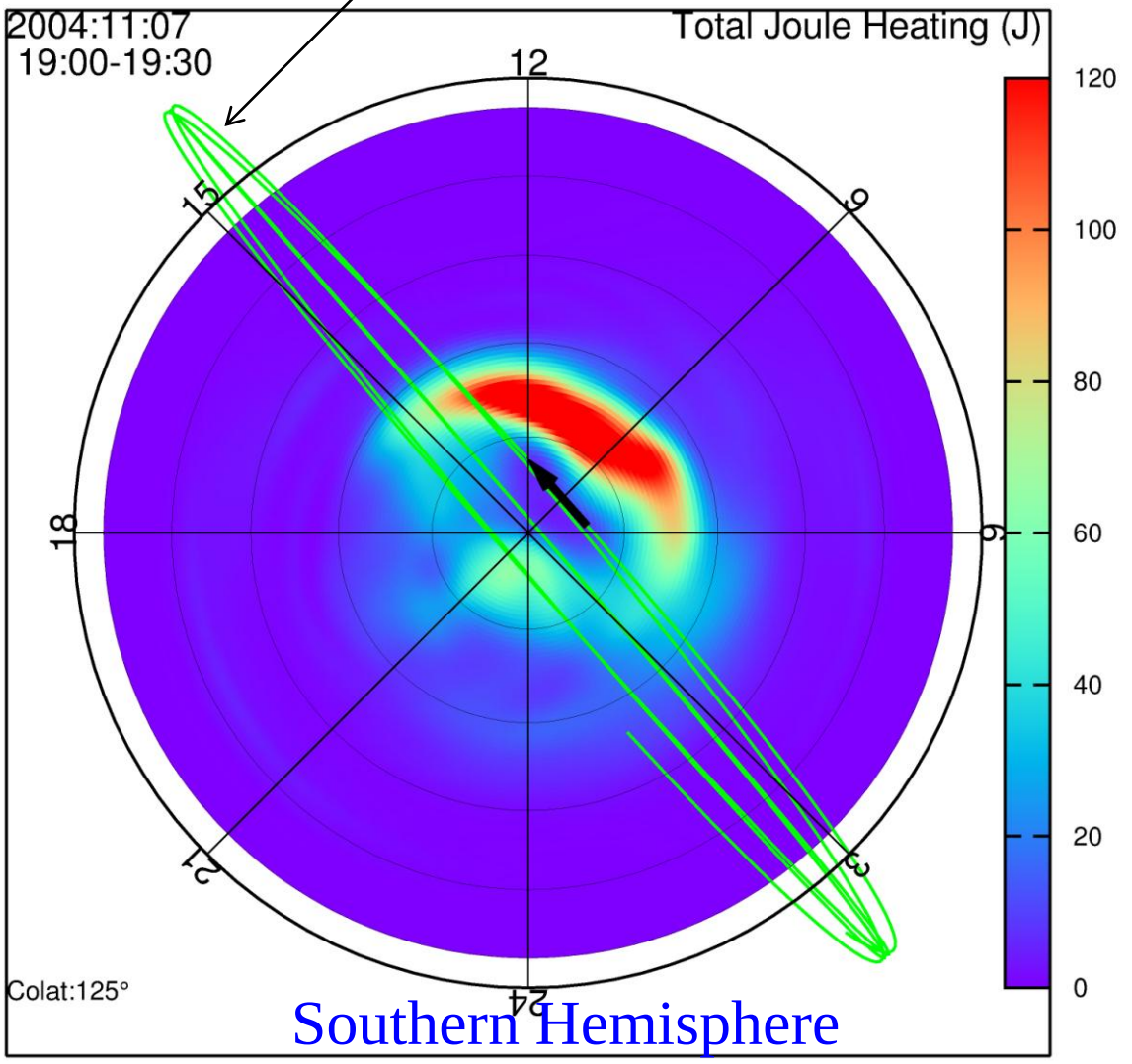
Event 2004-11-07

Extremely strong N. IMF

Hot JH spot

CHAMP track UT 1800-2300





Southern Hemisphere

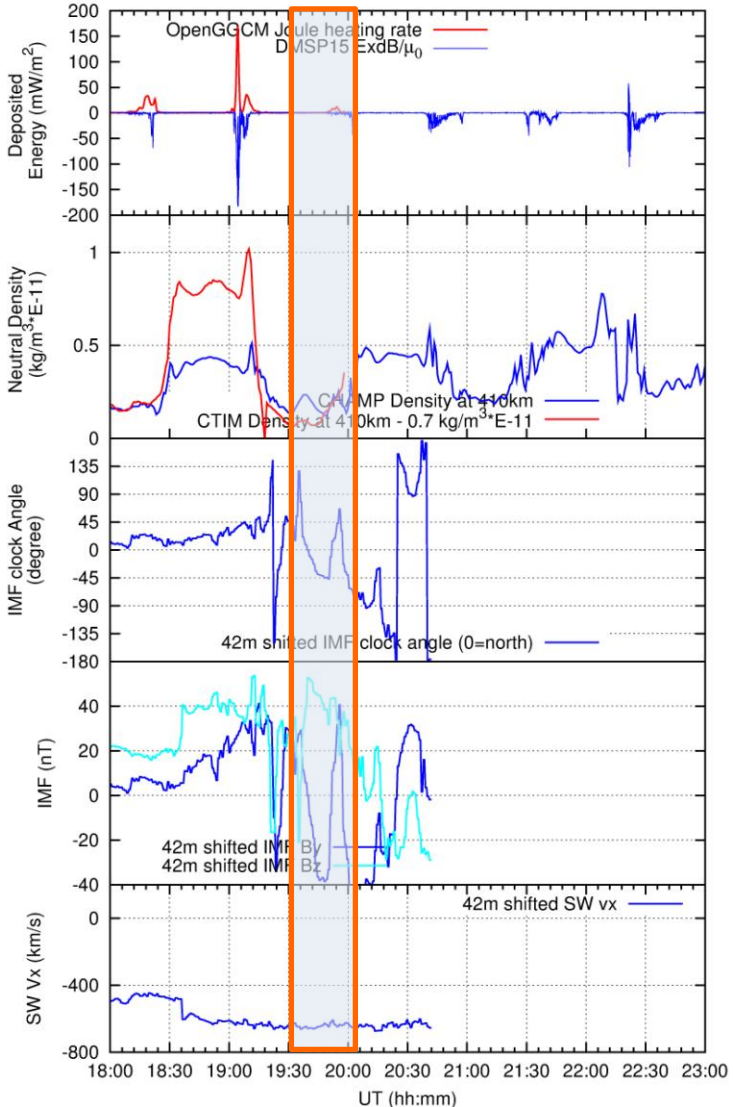
Joule Heating Hot Spot and Thermosphere Density Enhancement

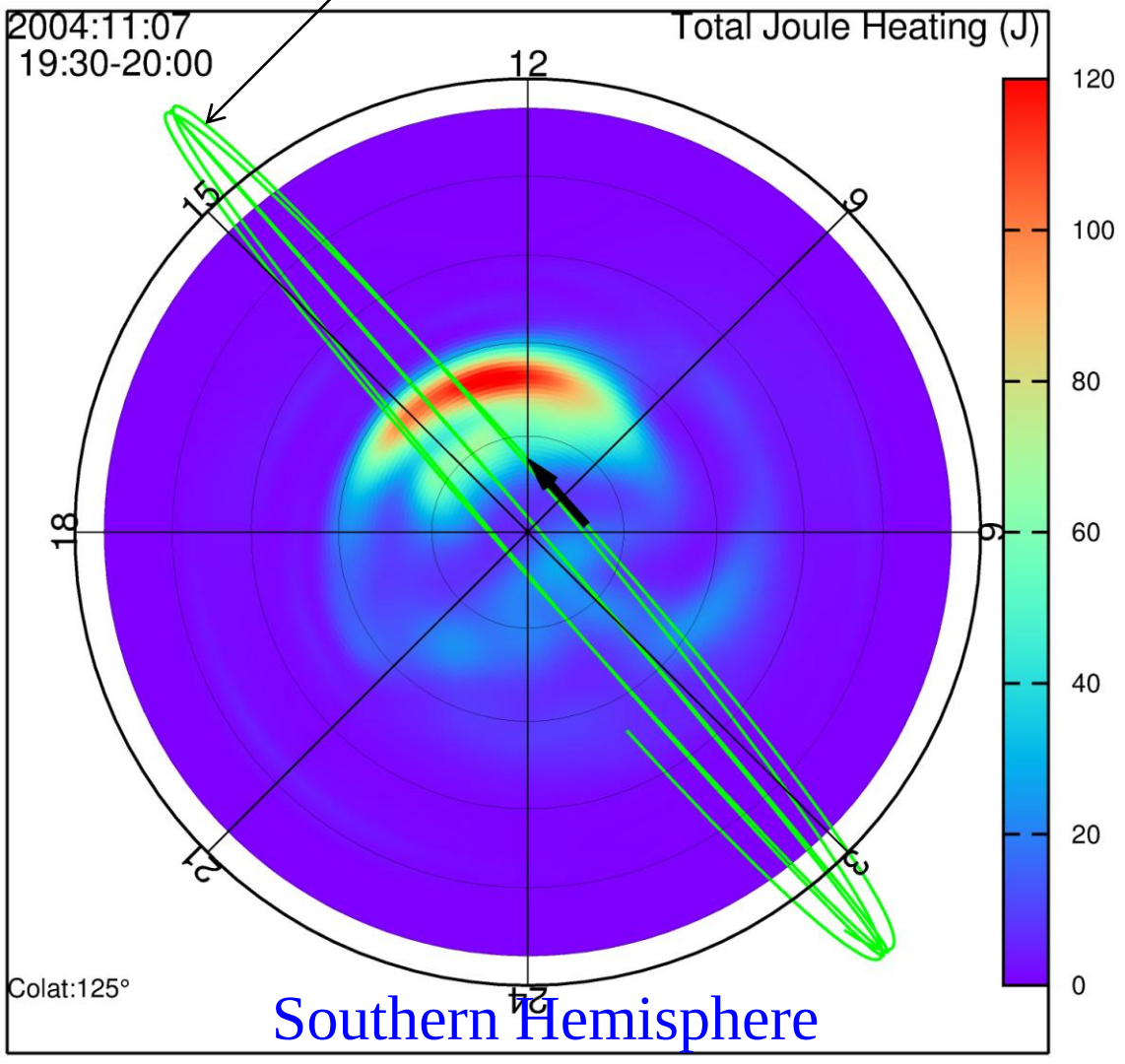
Event 2004-11-07

strong N. IMF

Hot JH spot

CHAMP track UT 1800-2300



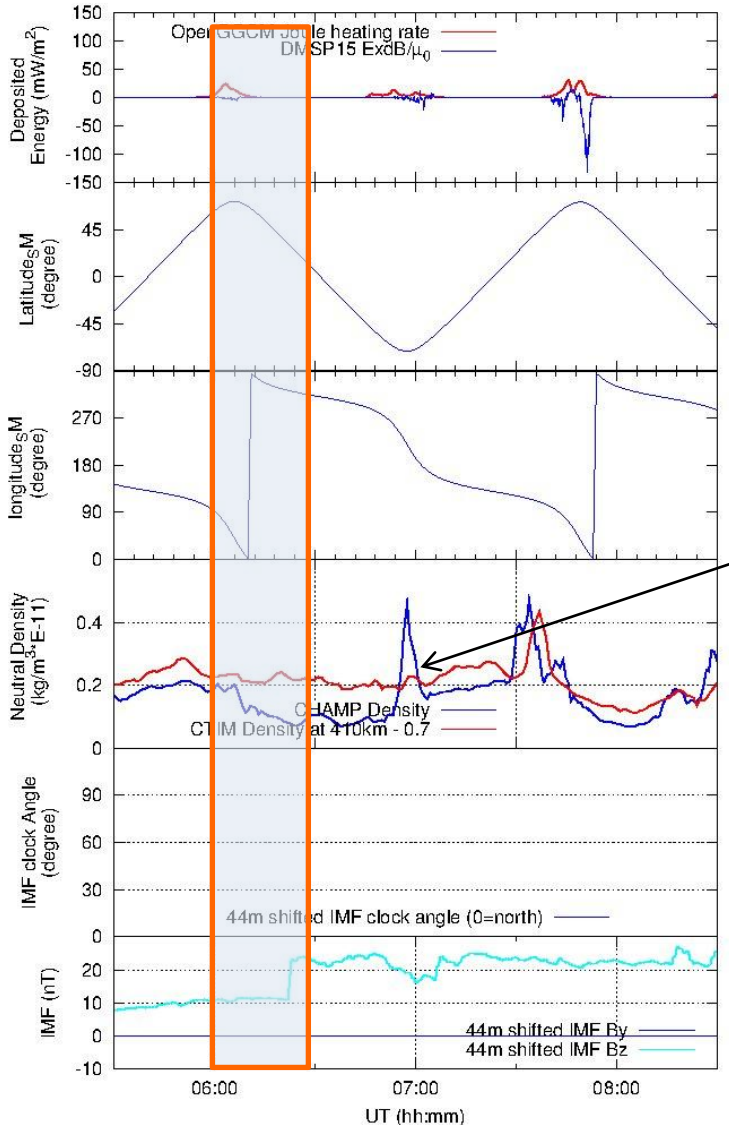


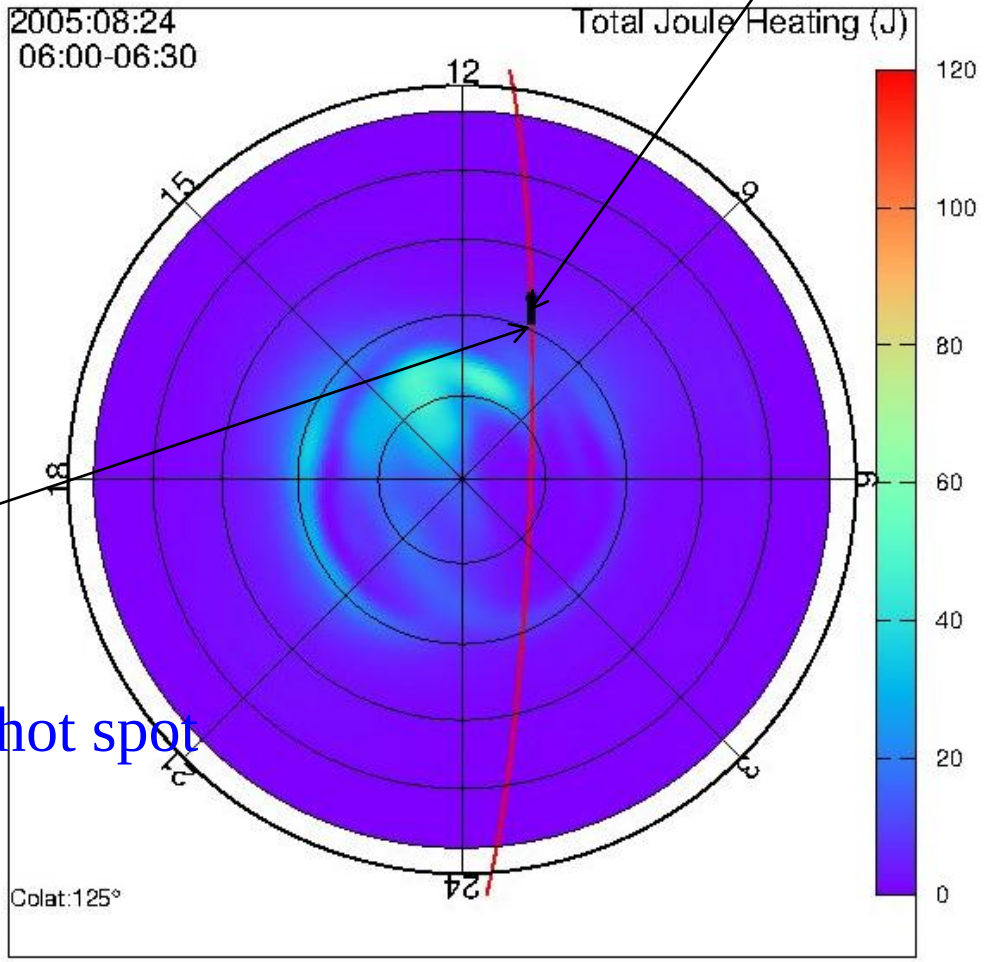
Southern Hemisphere

Joule Heating Hot Spot and Thermosphere Density Enhancement

Event 2005-08-24, simulated with 0 clock angle

CHAMP southern pass





No JH hot spot

Southern Hemisphere

Summary

- Strong northward IMF with large clock angle (> ~40°) causes an extended latitudinal intense Joule heating (Poynting flux) and FAC region mostly in the dayside.
- This region is caused by the movement of the newly created open field lines resulting from cusp reconnection.
- The local high-latitude thermosphere density enhancements are highly correlated with the intense ionosphere Joule heating caused by cusp reconnection when the IMF is northward and has strong y component.

References

Wenhui Li, Delores Knipp, Jiuhou Lei, and Joachim Raeder,"The relation between dayside local Poynting flux enhancement and cusp reconnection", JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, A08301, doi:10.1029/2011JA016566, 2011

D. Knipp, S. Eriksson, L. Kilcommons, G. Crowley, J. Lei, M. Hairston and K. Drake,"Extreme Poynting flux in the dayside thermosphere: Examples and statistics", GEOPHYSICAL RESEARCH LETTERS, VOL. 38, L16102, doi:10.1029/2011GL048302, 2011