OpenGGCM

Jimmy Raeder

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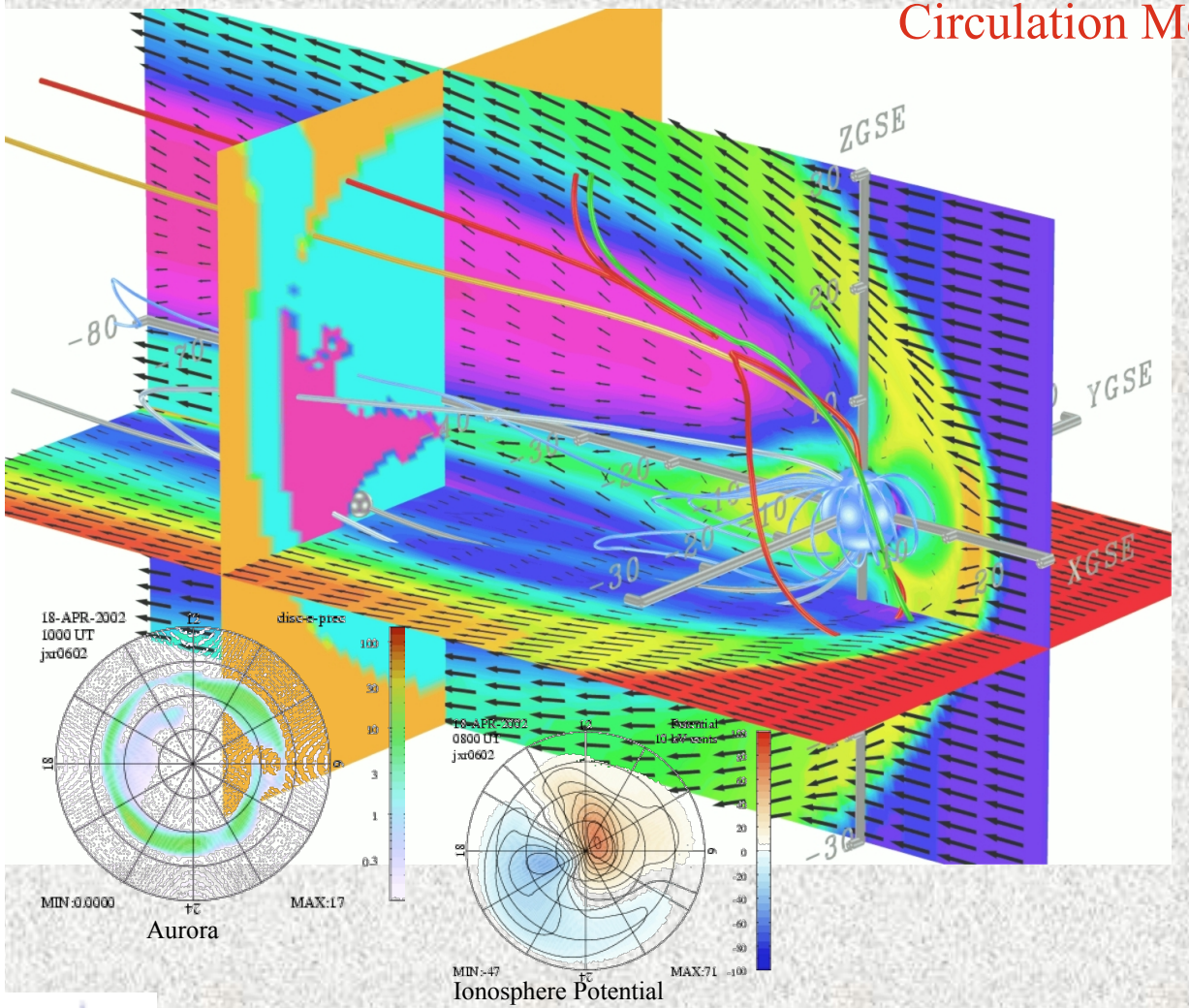
CCMC workshop, Annapolis, MD, April 1, 2014

OpenGGCM: Global Magnetosphere Modeling

The Open Geospace General Circulation Model:



- Coupled global magnetosphere - ionosphere - thermosphere model.
- 3d Magnetohydrodynamic magnetosphere model.
- Coupled with NOAA/SEC 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, M. Gilson, W. Li, A. Liwei Lin, K. Germaschewski, Y. Ge,, (UNH), T. Fuller-Rowell, N. Muriyama (NOAA/SEC), F. Toffoletto, A. Chan, B. Hu (Rice U.), M.-C. Fok, A. Glocer (GSFC), A. Richmond, A. Maute (NCAR)

Research Group

- Matt Gilson → Google
- Alex Vapirev → Leuven, Belgium
- Emmanuel Chane → Leuven Belgium
- Wenhui Li → back to China
- Yasong Ge → Chin. Acad. Sci. (later this year)
- Doug Cramer ← FIT
- 4 graduate students: Shiva Kavosi, Denny Oliveira, Bashi Ferdousi, Joseph Jensen
- Graduated: Hyun-Ju Connor, Matt Gilson
- Prof Kai Germaschewski + one graduate student: algorithms, computational efficiency.

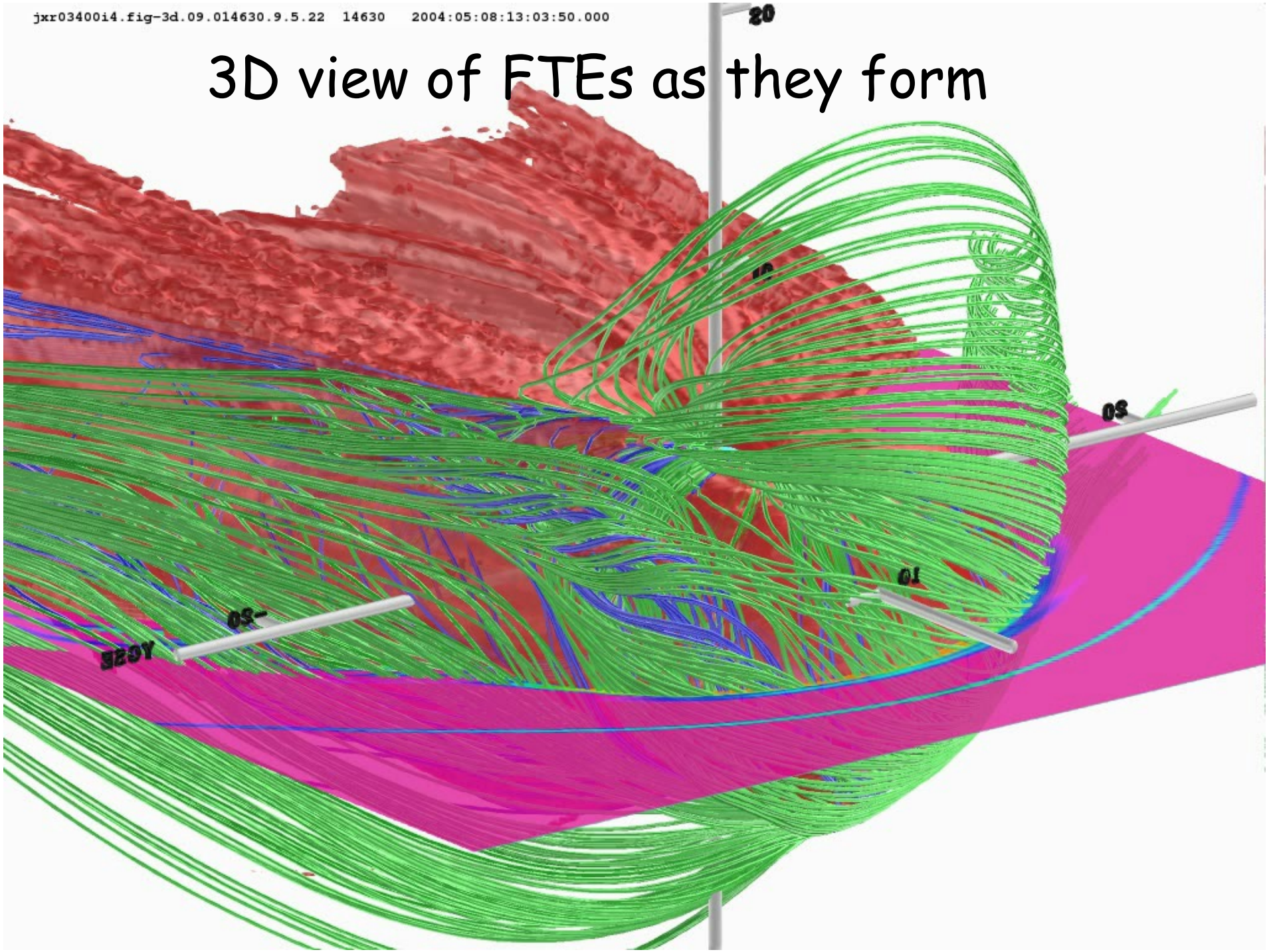
OpenGGCM activities

- Dipole rotation.
- Hall-MHD.
- Continued work on RCM, CRCM coupling.
- New grid generation scheme for better stability.
- New WENO/PPM numerics, still testing.
- Upgrades in CTIM code: NO cooling.
- New Cray: pushing resolution to ~500M cells: KH waves, Flux Transfer Events, Dipolarization Fronts.

Current Research Topics

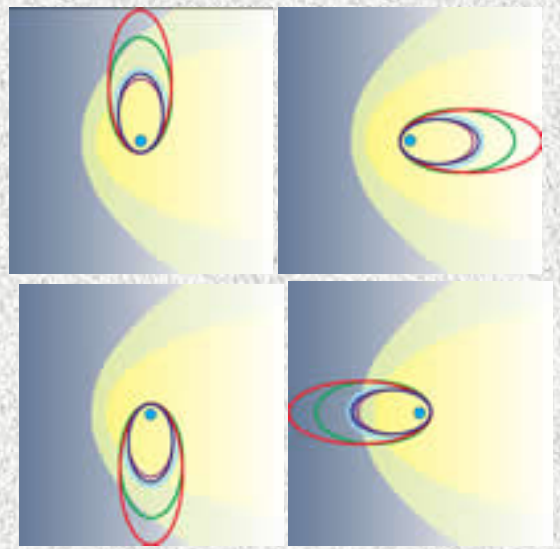
- Flux Transfer Events (FTEs)
- K-H waves (Shiva's thesis).
- IP shock impacts (Denny's thesis, Q.Q. Shi ← CCMC).
- Substorms/DF/BBF (Yasong's work).
- Storms/injections (Matt, Doug).
- Thermosphere heating, satellite drag (w/ Knipp, Ericksson (CU), Joseph's thesis).
- Ballooning modes (w/ Ping Zhu (U. Wisc.)).
- Magnetosphere x-ray / FUV imaging (w/ Sibeck, Eastman, Bashi's thesis).
- Cusp ion structures (continuing w/ former student HJC).
- Alfven wings at Earth (w/ Chane, Leuven).
- Data Assimilation – hoping for funding

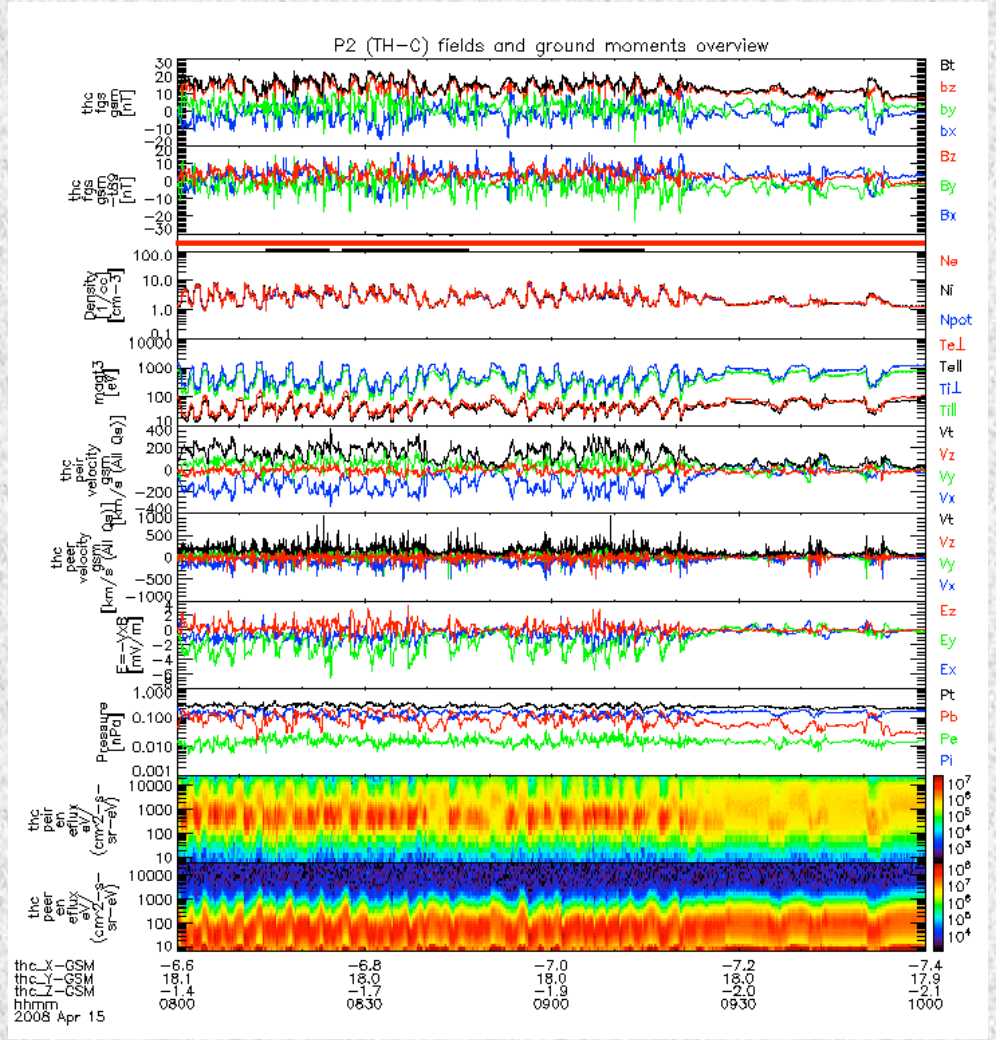
3D view of FTEs as they form



THEMIS observations of Kelvin-Helmholtz waves

- THEMIS orbits are ideal to observe flank magnetopause.
- THEMIS observes “wavy structures” during ~50% of MP crossings. Lately we determined ~25% are KH waves.
- Some periodic structures may be FTEs, some may be directly driven by the SW of foreshock waves, but most are KH.

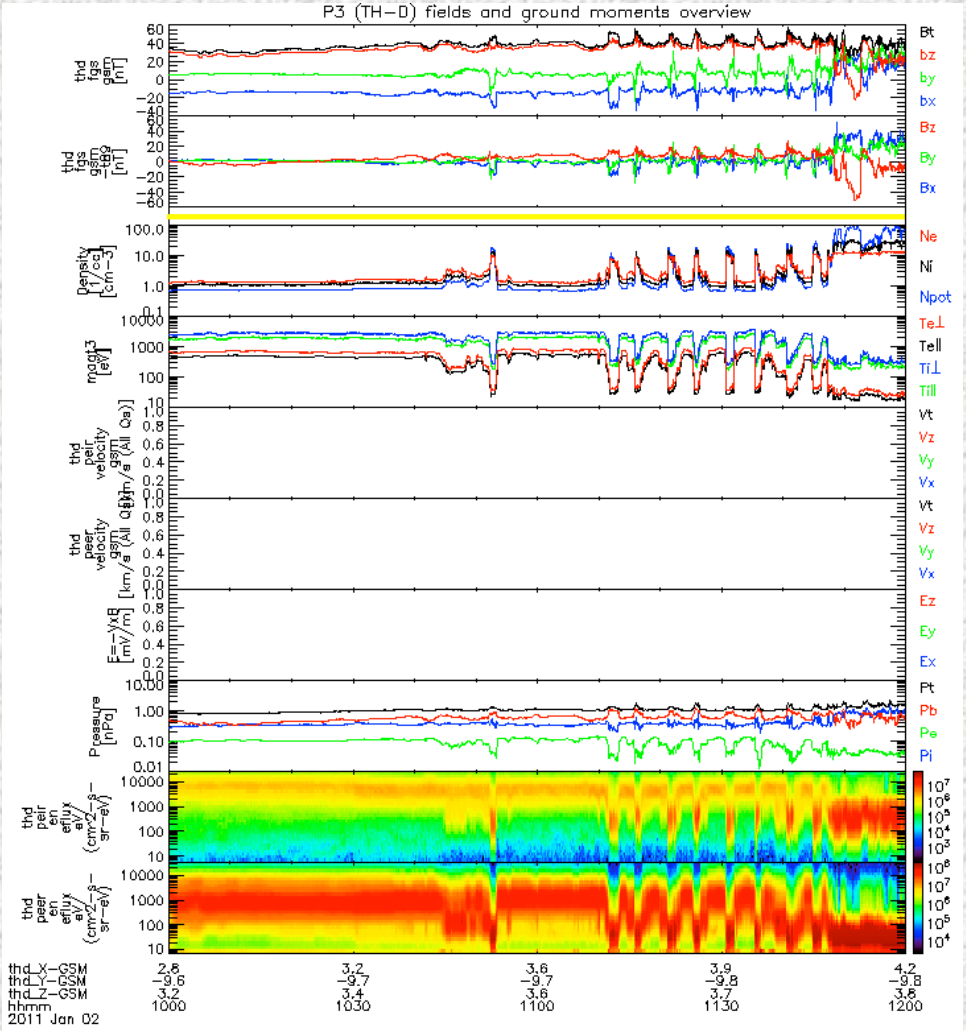




THEMIS-C, April 15, 2008 0800-1000 UT

Kelvin-Helmholtz or Flux Transfer Events?

- Sometimes periodic structures at flank MP have FTE signatures.
- Strong bipolar BN signatures and enhanced core field, but bipolar B_N separated by zero B_N intervals.
- FTEs possibly trigger KH.



THEMIS-D, January 2, 2011 1000-1200 UT

Kelvin-Helmholtz or Flux Transfer Events?

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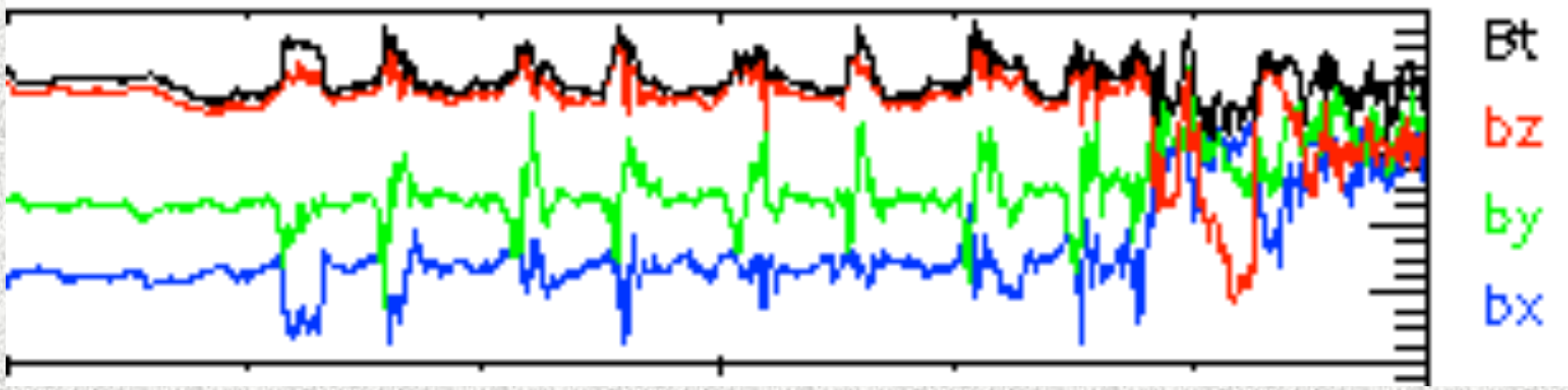
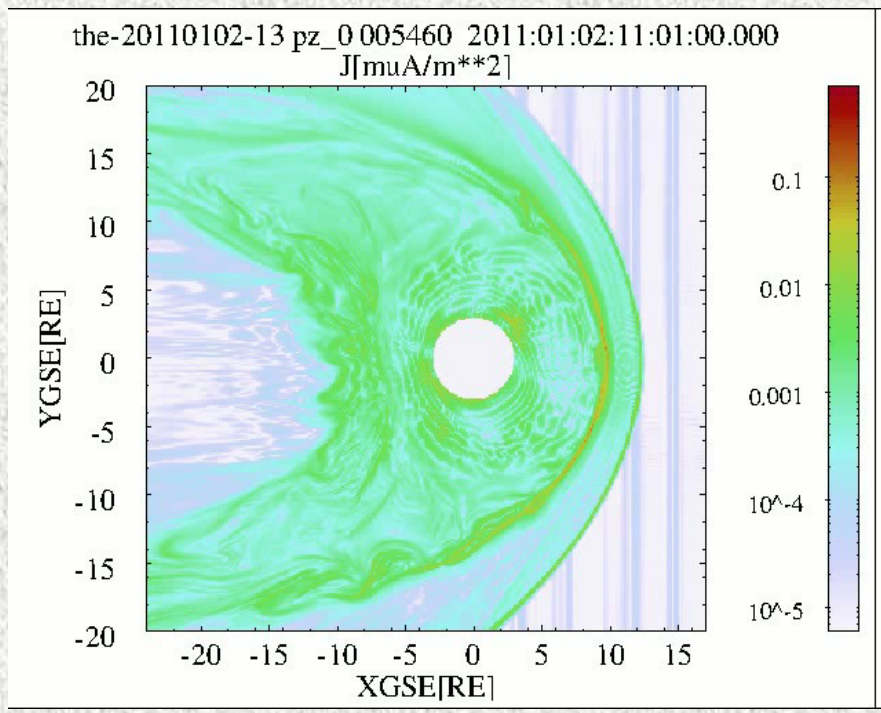
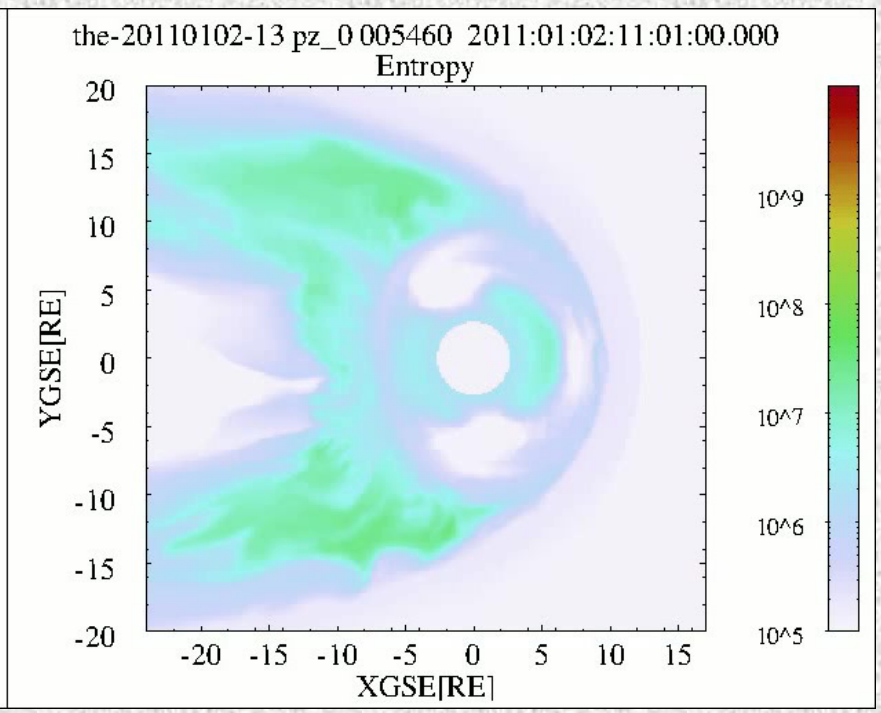


THEMIS-D, January 2, 2011 1000-1200 UT

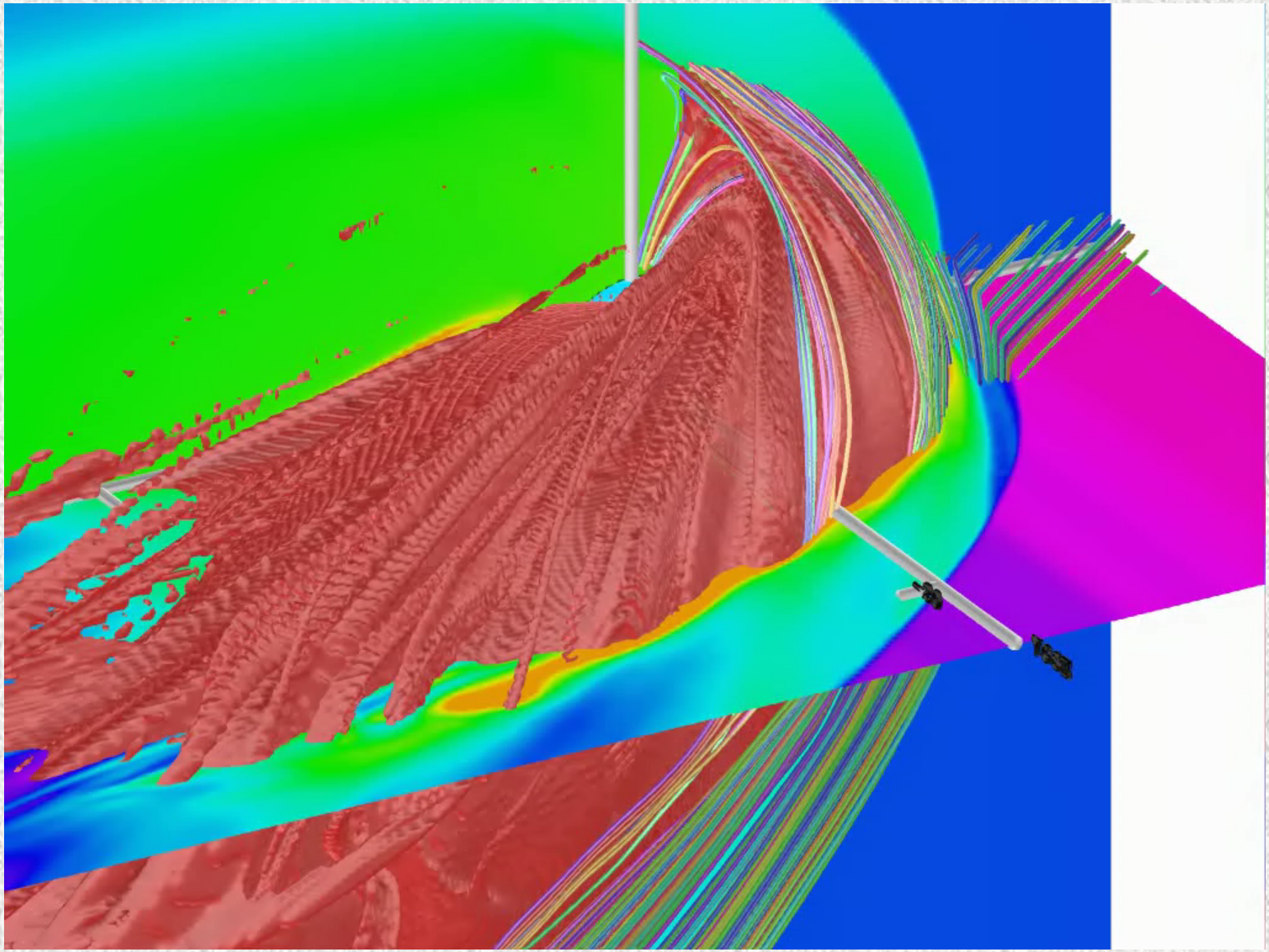
FTEs triggering KH?

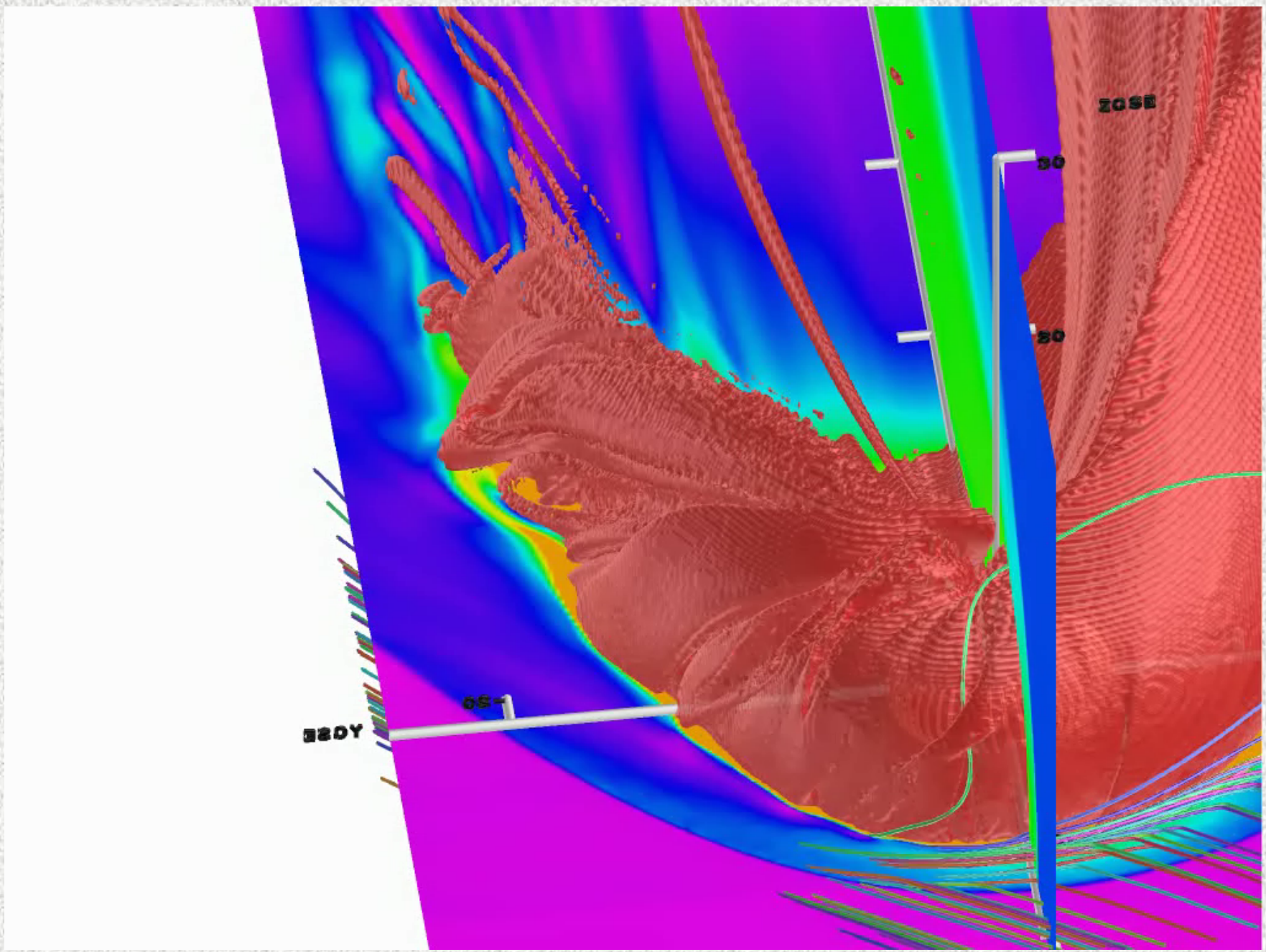
- OpenGGCM simulation shows structures first at nose of MP.
- As they move along flank, they turn into large amplitude waves
- Entropy shows waves clearly.





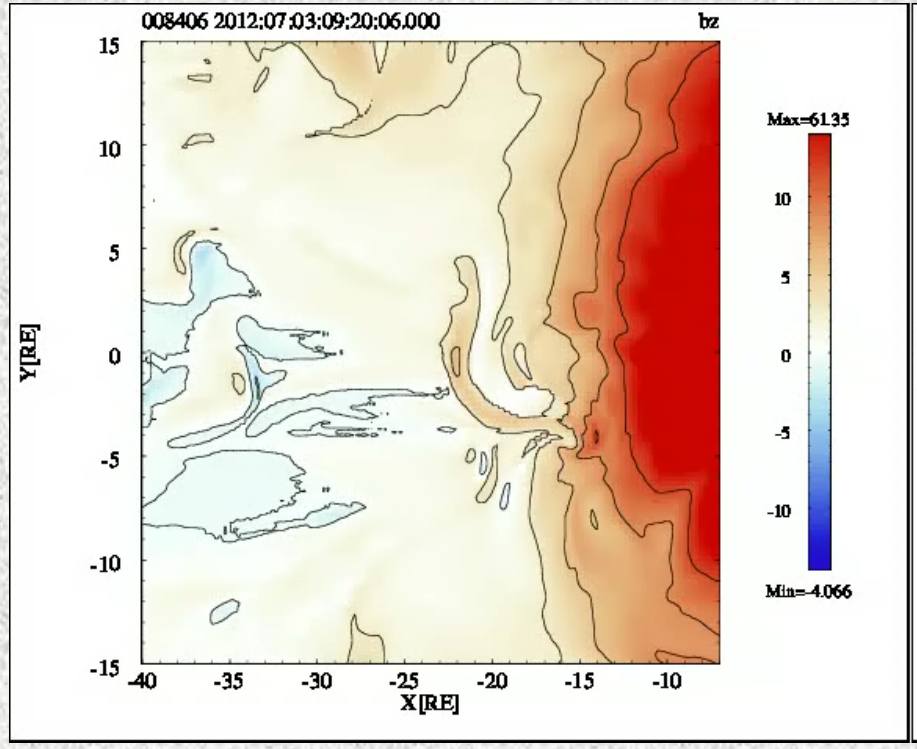
FTEs triggering KH?

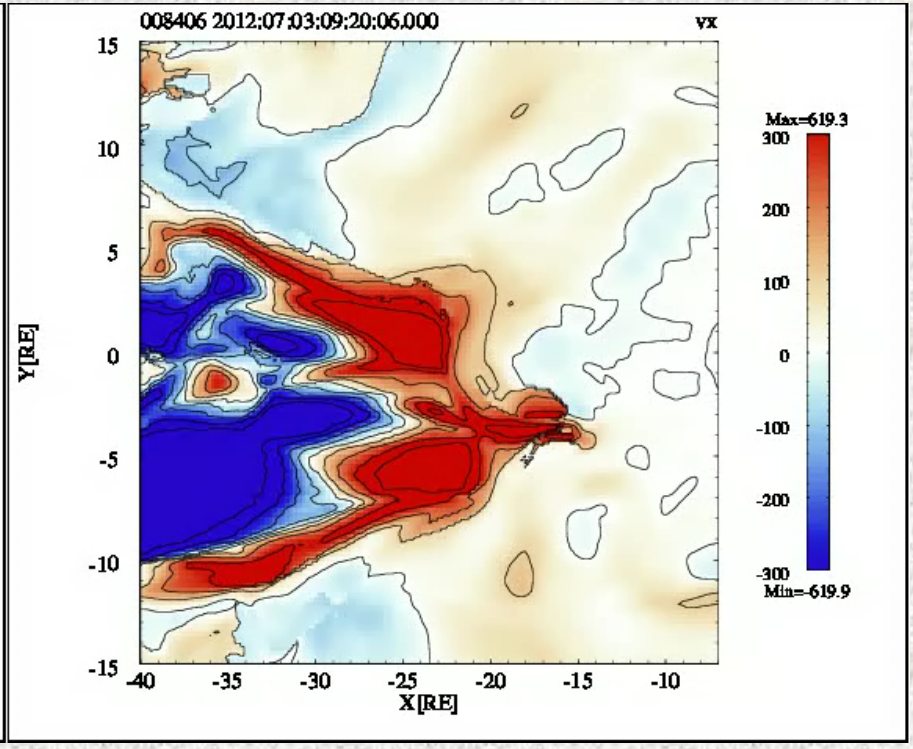



ZOSE
30
20
-50
32DY

BBF/DF Activity in the Tail Current Sheet

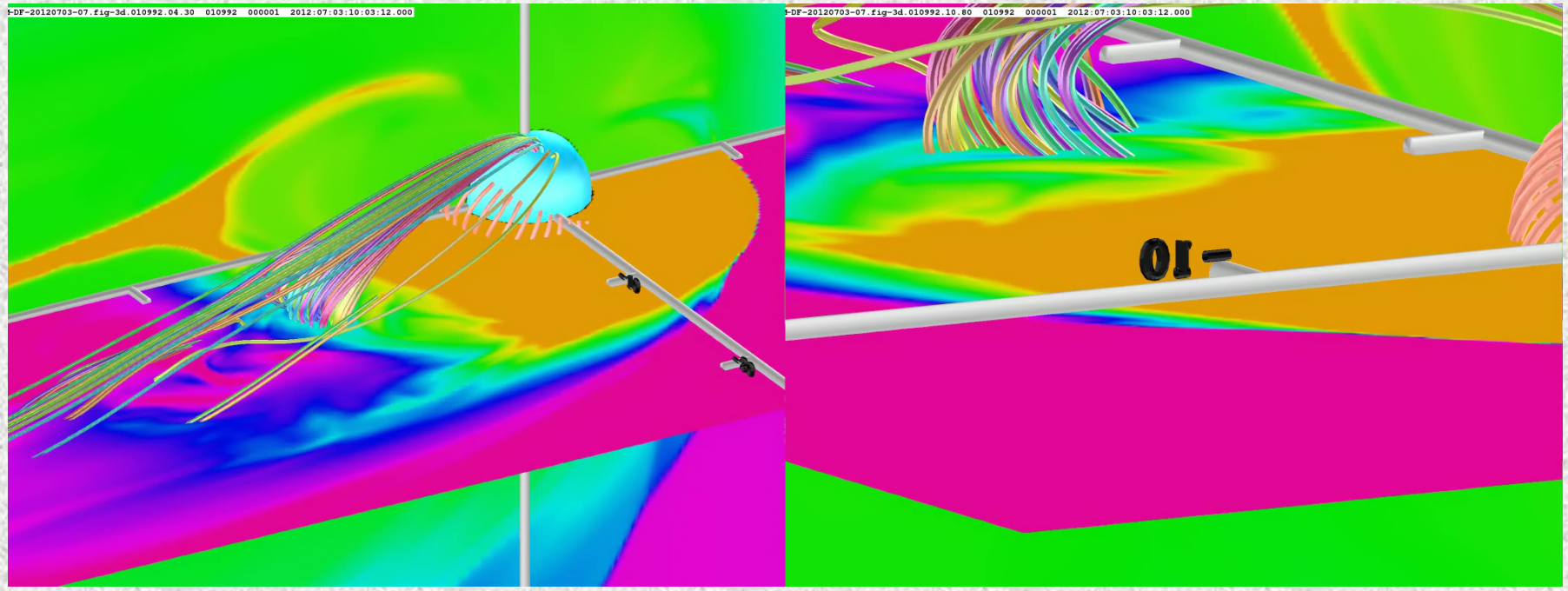
- OpenGGCM simulation of 2012/07/03 substorm (Same as Angelopoulos Science paper).
- Values taken at z(Bx=0).
- Most reconnection sites between x=-35 and x=-25 and flow channels are ~2-4 RE wide.
- Every BBF has a DF associated with it and some BBFs have a negative Bz precursor.
- Many DFs have a convex (mushroom-like) shape, but that is not universal.
- The dawn bias is in disagreement with THEMIS statistics (Imber et al., 2011).





3D Views

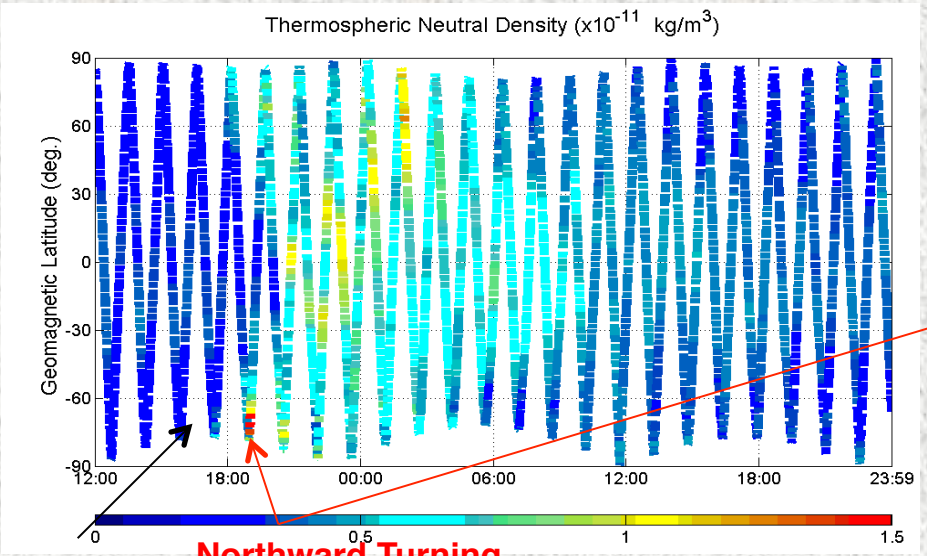
- A bunch of fluid particles is traced backwards from a DF that has hit the inner MSP.
- The field lines attached to those particles are drawn.
- Movie shows the forward motion.
- Field line selection is not optimal, but some of the FL start out open.
- They then reconnect and snap towards the Earth within the flow channel.
- In the end, the DF filed lines are concave, and thus the DF surface has a saddle shape.
- Consistent with (Liu, 2012) THEMIS findings.

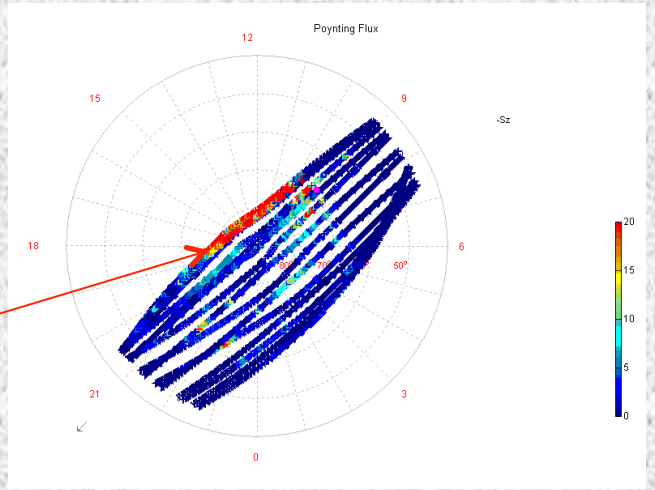


CHAMP Data: Neutral Density Enhancement

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

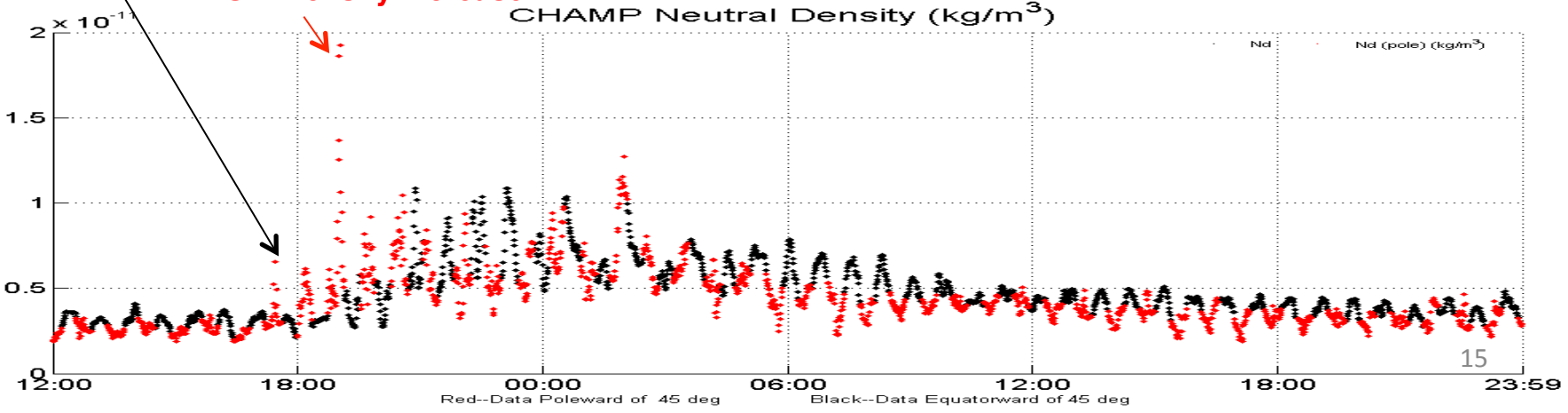
DMSP Poynting Flux



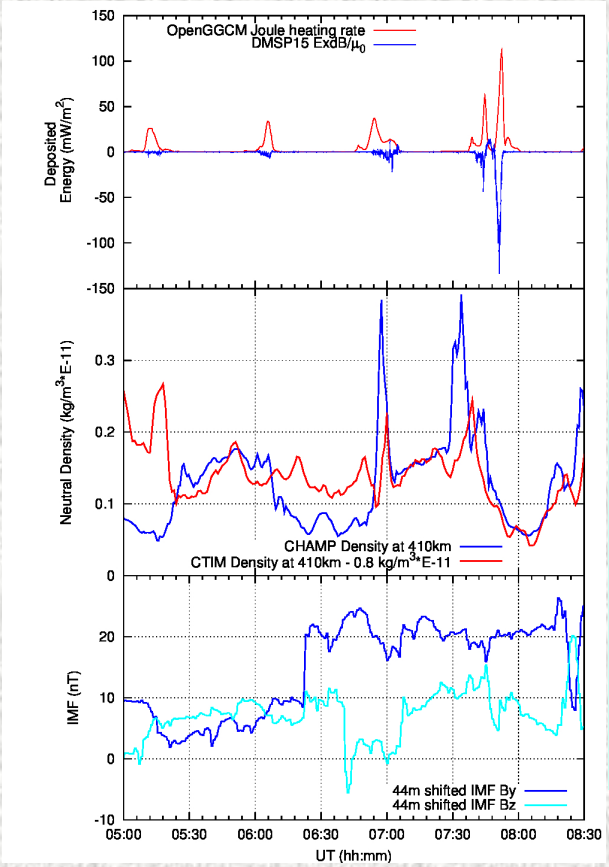


Shock Arrival

Northward Turning, SW Density Increase



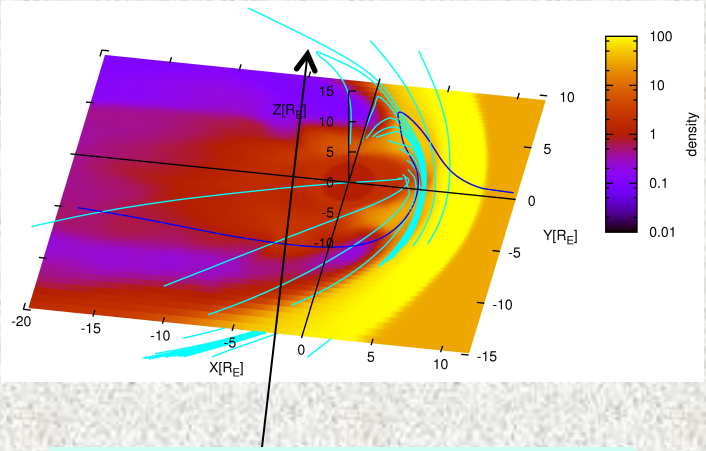
Intense Joule Heating and Enhanced Satellite Drag During Geomagnetically Quiet Times: OpenGGCM Simulations



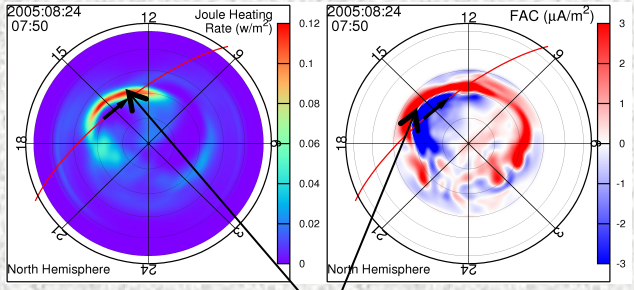
← DMSP observes extremely strong Poynting Flux into the ionosphere (blue line). OpenGGCM shows corresponding Joule heating (red line).

← CHAMP observes neutral density spikes that cause satellite drag. OpenGGCM simulation shows them too, but under-predicts (over-predicts in other cases, though).

← This all happens while the IMF is northward, with strong By-component, but the magnetosphere is quiet.



Magnetic reconnection behind the cusps create the FACs that ultimately heat the ionosphere and thermosphere



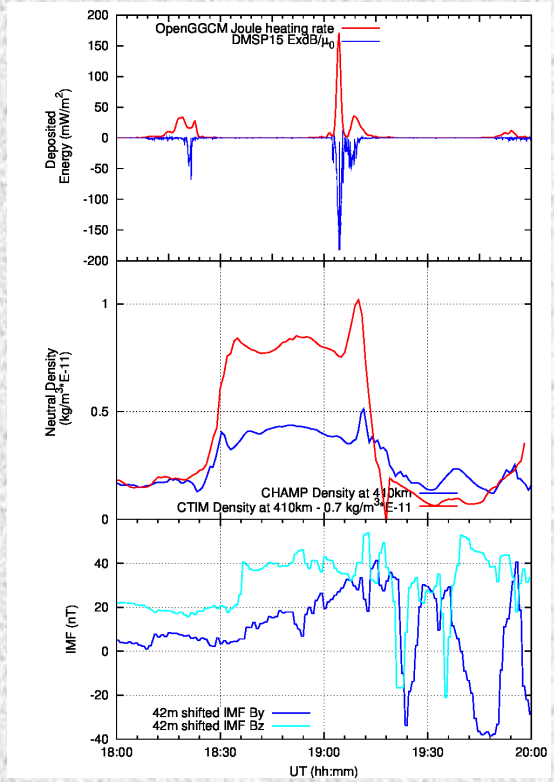
Intense Joule heating occurs between FAC current sheets, which is Essentially a short-circuit of the FACs in the ionosphere

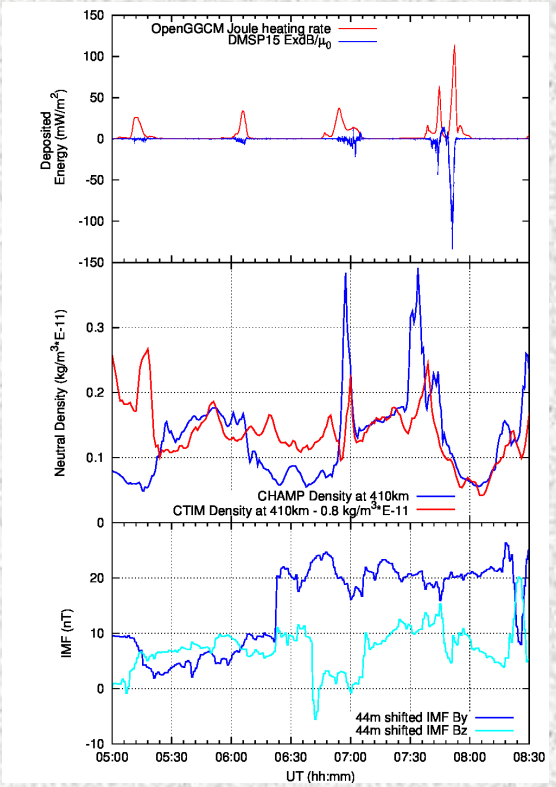
Framework for Understanding Global versus Local Energy Deposition into the Ionosphere and Thermosphere

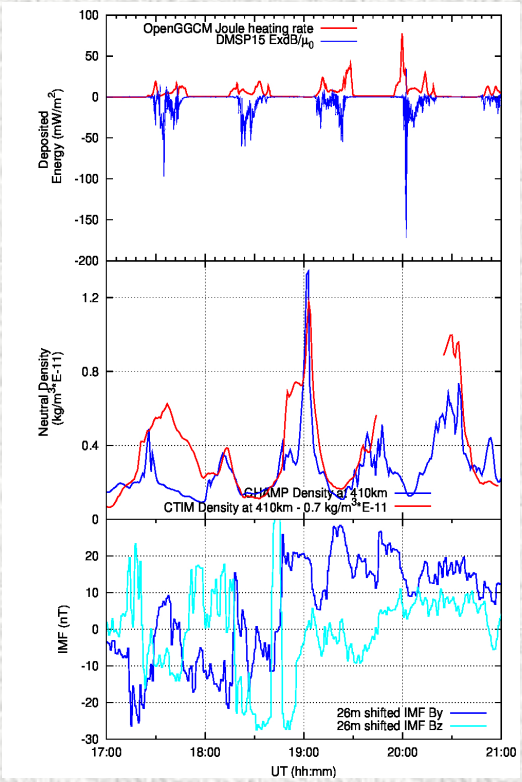
J. Raeder (UNH) and Delores Knipp (CU Boulder)

OpenGGCM - DMSP Comparisons

(negative) DMSP Poynting flux == (positive) OpenGGCM Joule heating rate
-> 3 northward Bz cases







Overprediction | Underprediction | On the $$

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.

Extra Slides

Computing:
Trillian

No, not her:

UNH/SSC, November 4, 2013

What's a Cray?

- John von Neumann → let's predict weather (1940's)
- Eckert/Mauchly → build ENIAC (1948)
- Tom Watson "the world needs no more than 7 computers" IBM gets into the game, eventually.
- Seymour Cray "this is all too slow" → Control Data Corporation

Seymour Roger Cray

Born	September 28, 1925 Chippewa Falls, Wisconsin, USA
Died	October 5, 1996 (aged 71) Colorado Springs, Colorado, USA
Fields	Applied mathematician, computer scientist, and electrical engineer
Institutions	Engineering Research Associates Control Data Corporation Cray Research Cray Computer Corporation SRC Computers
Alma mater	University of Minnesota
Known for	Supercomputers

How do you get a Cray?

Lot's of proposals:

(1) The UNH internal proposal
(2) The NSF/MRI proposal
(3) An indecent proposal:

Gitomer, Steven J <sgitomer@nsf.gov> June 13, 2012 10:09 AM
To: Jimmy Raeder <J.Raeder@unh.edu> Hide Details
Cc: Gitomer, Steven J <sgitomer@nsf.gov> , NSF-GEM
McCloud, Kathleen V. <kmccloud@nsf.gov>
RE: MRI proposal 1229408

Dear Professor Raeder:

Thanks for your e-mail message. We will be looking into all possibilities here are NSF. However, in order to be able to evaluate all options, we still need your input for one half, and two thirds scaled down budgets for your proposal. Please let me know about that as soon as possible, but no later than the end of the day Thursday, June 14th. Thanks.

Steve G.
6/13/2012

Much better:

Gitomer, Steven J <sgitomer@nsf.gov> July 18, 2012 7:43 AM
To: Jimmy Raeder <J.Raeder@unh.edu> Hide Details
Cc: Gitomer, Steven J <sgitomer@nsf.gov> and 2 more… System-RCI
RE: EPSCoR Cofunding Response - 1229408, submitted by Joachim Raeder

Dear colleague:

I wanted to let you know that we have recommended funding of your MRI submission at the original requested level, co-funded by the Physics Division and EPSCoR. Congratulations! As we move forward with the administrative steps here, we will need a new Abstract from you ASAP. Just send it along to me and I will enter it into the system. FYI … the abstract we used for your previous MRI is included below. Wishing you all the best with this new project and much success with the research that the new cluster will make possible.

Steve G.
7/18/2012

(4) A decent proposal:

(and the only one with a pretty face)

Cray Inc. Proposal to

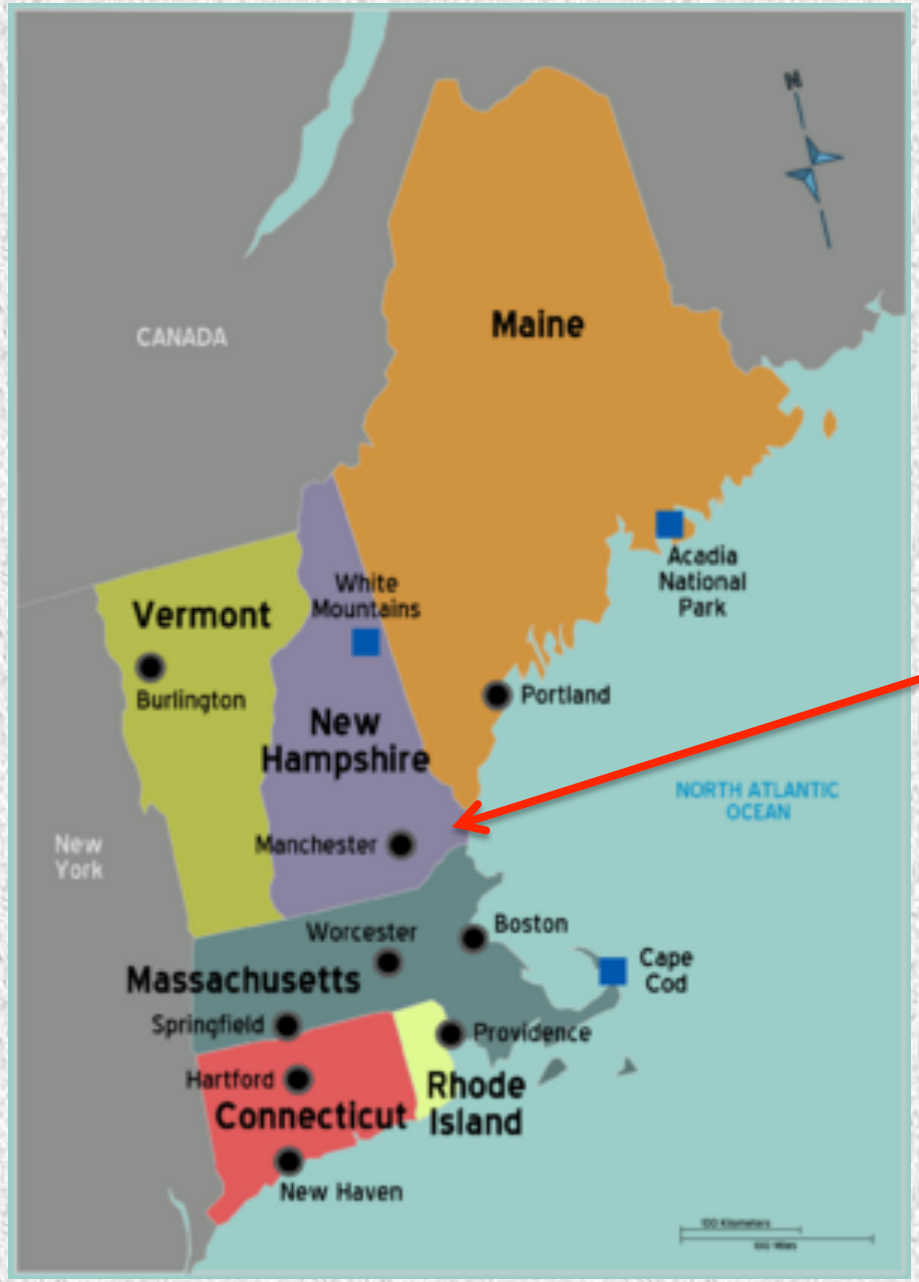
RFX #100031

The University System of New Hampshire (USNH)

Computer Cluster for Space Science Center at UNH - Supply & Install (10556)

Tony Gelsomini
Cray Sales
tel 603.425.2473
tonyg@cray.com

CRAY



And then you have:

The only Cray in New England!

But you need help:

- Co-Is: A. Bhattacharjee, B. Chandran, G. Chini, F. Ebrahimi, K. Germaschewski, J. Gibson, N. Schwadron, B. Vasquez
- Admin: J. Nisbeth, K. Cataneo, H. Spence, S. Mukasa, S. Asselin, M. Puchlopek
- RCI: P. Messer, T. Baker, M. Maciolek, R. Andrerson, J. Sorrel, S. Cartabora

Why a Cray?

Zaphod got old:

← →
Official BBC pictures

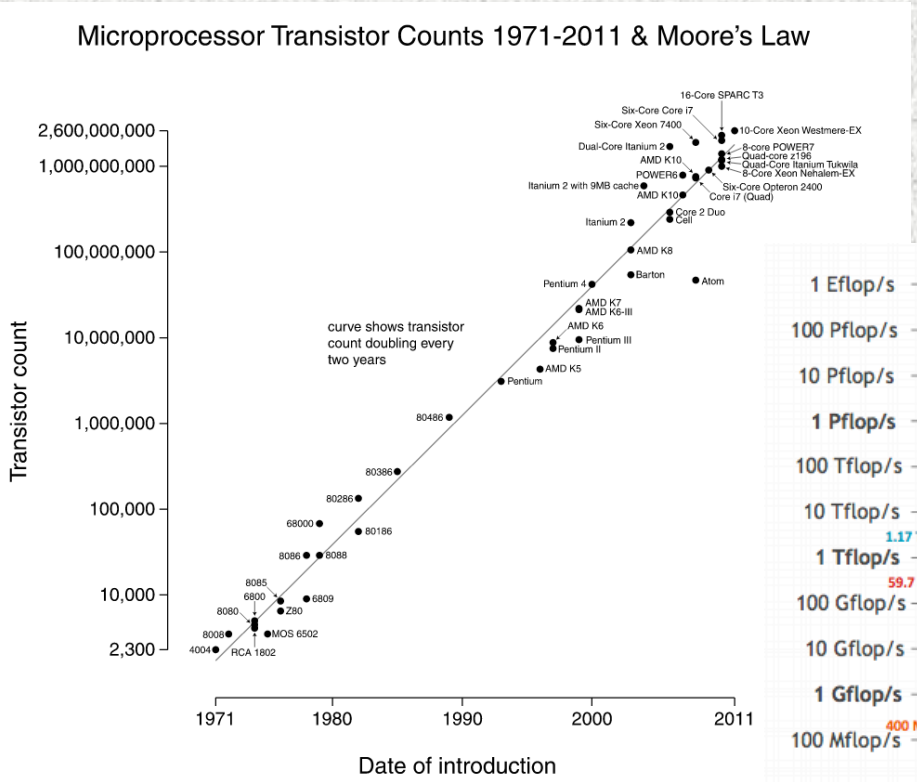
- 320 cores
- 600 GB memory
- 10 TB storage

Trillian is prettier (and faster):

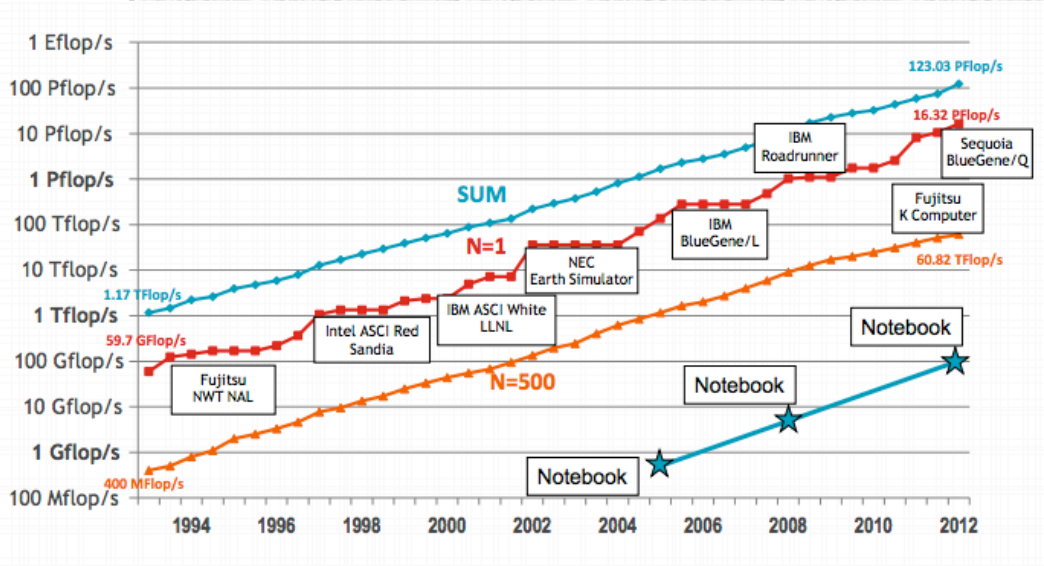
- 4200 cores
- 4300 GB memory
- 163 TB storage

Why a Cray?

Computational greed!



← Transistor count goes up



Speed doubles → every 18 months

I started on CDC7600/Cray-XMP/YMP:

CDC 7600 (1983) Cray Y-MP (1993) smartphone (2013)

Y-MP: 4 processors, 1000 MIPS, 2GB memory
Your cell Phone, 20y later: 4 cores, >4000 MIPS, >2GB mem

Y-MP in 1993 → your smartphone today

→ ?

Trillian (2013)

smartphone (2033)

100 kW → ?

100 kW in your pocket:

Not a good idea!

Thank You!

And enjoy the tour!