UNH-CCMC Collaboration

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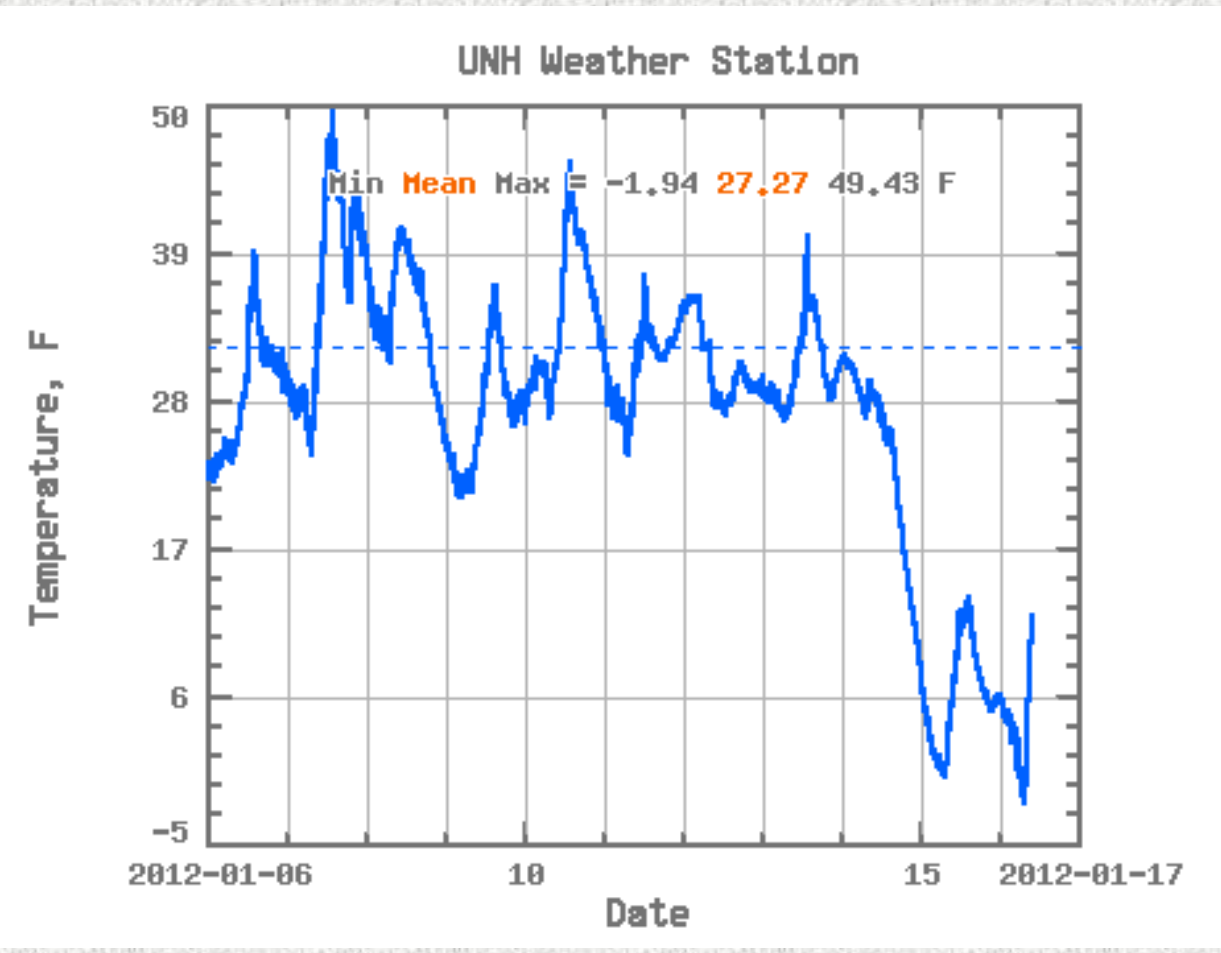
CCMC Workshop, Key Largo, FL, January 17, 2012

Why Are We Here?



Why Are We Doing This?

21 DECEMBER 2012
READY...OR NOT

Where will YOU be?
What will YOU do?
2012Pro.com

info.2012Pro.com

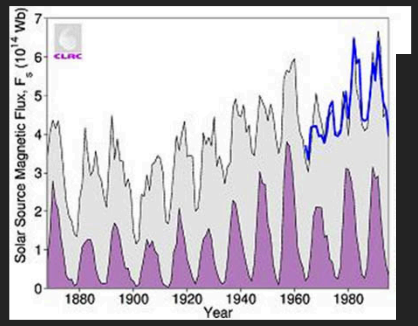
In 2012 Solar Flares expected to be strongest in centuries

Monday, January 16, 2012

In the last 100 years the Sun's magnetic field has changed significantly

According to Dr. Mike Lockwood from Rutherford Appleton National Laboratories in California, who has studied the Sun's activity for the last hundred years, since 1901 the overall magnetic field of the Sun has increased with 230%. The relevance to Earth and all life is not often well understood by scientists.

Graph from Lockwood's report:



The sunspot activity showed peaks in this last cycle, never recorded before in history. Richard Fisher, director of the Heliophysics division at NASA said "Obviously, the sun is Earth's life blood," said. "To mitigate possible public safety issues, it is vital that we better understand extreme space weather events caused by the sun's activity." In addition, nobody wants to spread panic in an already unstable global socio-economic climate.

The Sun is beginning another 11-year cycle of activity, NASA said

About every 11 years the Sun flip's its magnetic poles, which doesn't go by completely unnoticed by us here on Earth. However, with the magnetic field being so high currently, the upcoming polar shift in 2012 will certainly have its impact on the Earth and will lead to intense unfavorable climate changes and events.
Jimmy Raeder, researcher at NASA explains: "We're entering Solar Cycle 24. For reasons not fully understood, CMEs in even-numbered solar cycles (like 24) tend to hit Earth with a leading edge that is magnetized north. Such a CME (coronal mass ejection) should open a breach and load the magnetosphere with plasma just before the storm gets underway. It's the perfect sequence for a really big event."

Cyclic representation of the Sun's activity:

Be careful what you say at press conferences!

Who do we do this for?
For the taxpayer!

From: Caley Smith <fearoffifty@hotmail.com>
Subject:
Date: September 30, 2011 9:55:45 AM EDT
To: Jimmy Raeder <j.raeder@unh.edu>

Mr. Raeder,
I have some questions about solar storms.
1. How likely are we to have a *catastrophic* solar storm in the next 5 year?
2. Would a solar storm the size of the 1859 one knock out power to the whole country, or just certain areas?
3. How long would the power be out for?
4. Is there anything we can do to prevent power outages from solar storms, and do we have a plan?
5. Would a solar storm cause all the nuclear plants to meltdown?If so, how long would that take to happen?
6. Is it true that there is a big hole in the magnetosphere that will let in more solar storms?
7. Is it true that the sun has not only 11 year cycles but 22 year cycles that make it even stronger?
8. Is the sun really being quiter than usual?
9. How strong is this solar cycle supposed to be?
10. Most importantly, do you think jt would be the end of the world if this happened?
thank you.
-Caley Smith

Overview

- What is OpenGGCM, where does it come from?
- OpenGGCM at CCMC: 10y anniversary!
- OpenGGCM use:
  - Tail modes: Ballooning, KY0 mode.
  - Thermosphere heating.
  - Proton Aurora.
  - Dipolarization fronts.
  - Metrics.
- What's next?
  - Injections.
  - Kelvin-Helmholtz.
  - FTEs.
  - Data assimilation.
  - Tail plasma transport.

News

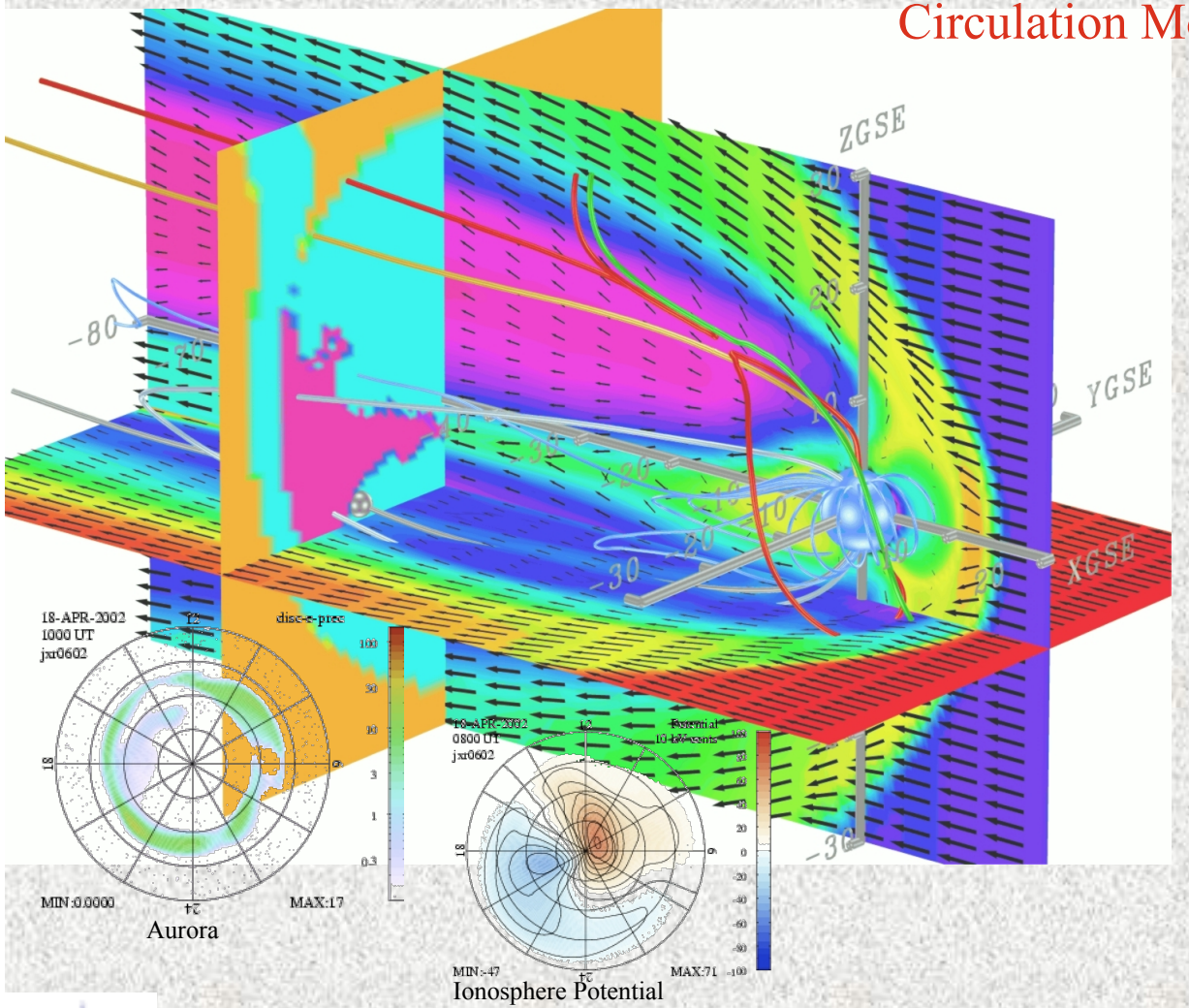
- Doug Larson and Alex Vapirev have left.
- Matt Gilson graduated and is now Research Scientist.
- Graduate students: Hyun-Ju Connor, Shiva Kavosi, Denny DeOlivera.
- THEMIS still going strong, but funding down 50%.
- PetaApps and LWS/SC ending.
- 2 new NASA SR&T.
- Many new proposal opportunities coming up: LWS/FG, LWS/SC, HGI, SR&T.

OpenGGCM V4.0

- Delivered to CCMC in early 2011.
- Resolved stability issues.
- Git version control.
- Has RCM and CRCM integrated, but that still needs testing.
- Moving dipole, finally.
- Many more output options.
- Continuing work on algorithms (Hall, code generation, …), see Kai's talk.
- 3D viz standard → paraview (as opposed to Visit, OpenDX, AVS).

OpenGGCM: Global Magnetosphere Modeling

The Open Geospace General Circulation Model:



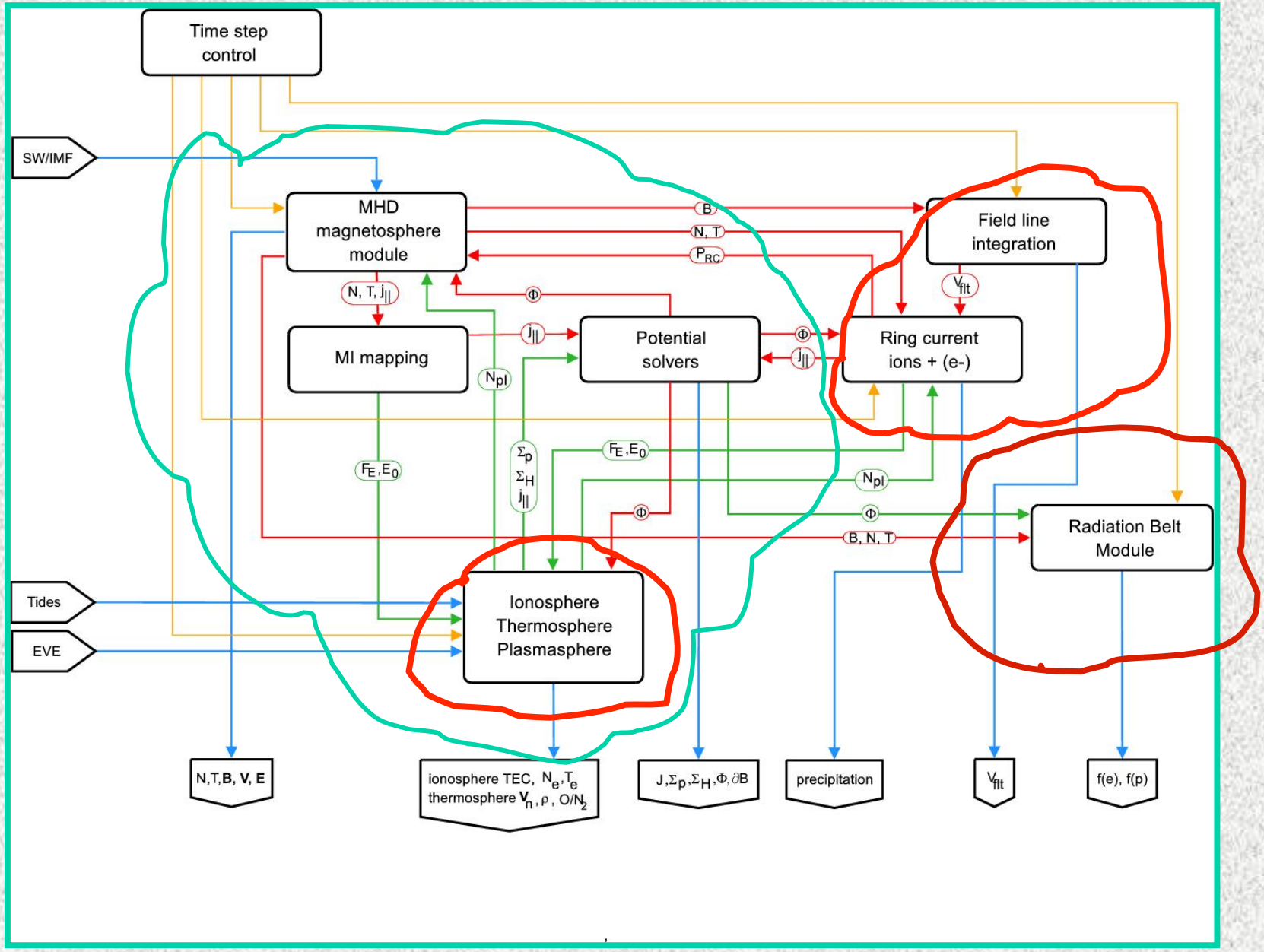
- Coupled global magnetosphere - ionosphere - thermosphere model.
- 3d Magnetohydrodynamic magnetosphere model.
- Coupled with NOAA/SEC 3d dynamic/chemistry ionosphere - thermosphere model (CTIM).
- Coupled with inner magnetosphere / ring current models: Rice U. RCM, NASA/GSFC CRCM.
- Model runs on demand (>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, D. Larson, W. Li, A. Vapirev, K. Germaschewski, L. Kepko, H.-J. Kim, M. Gilson, B. Larsen, H. Dai, (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)

Heritage

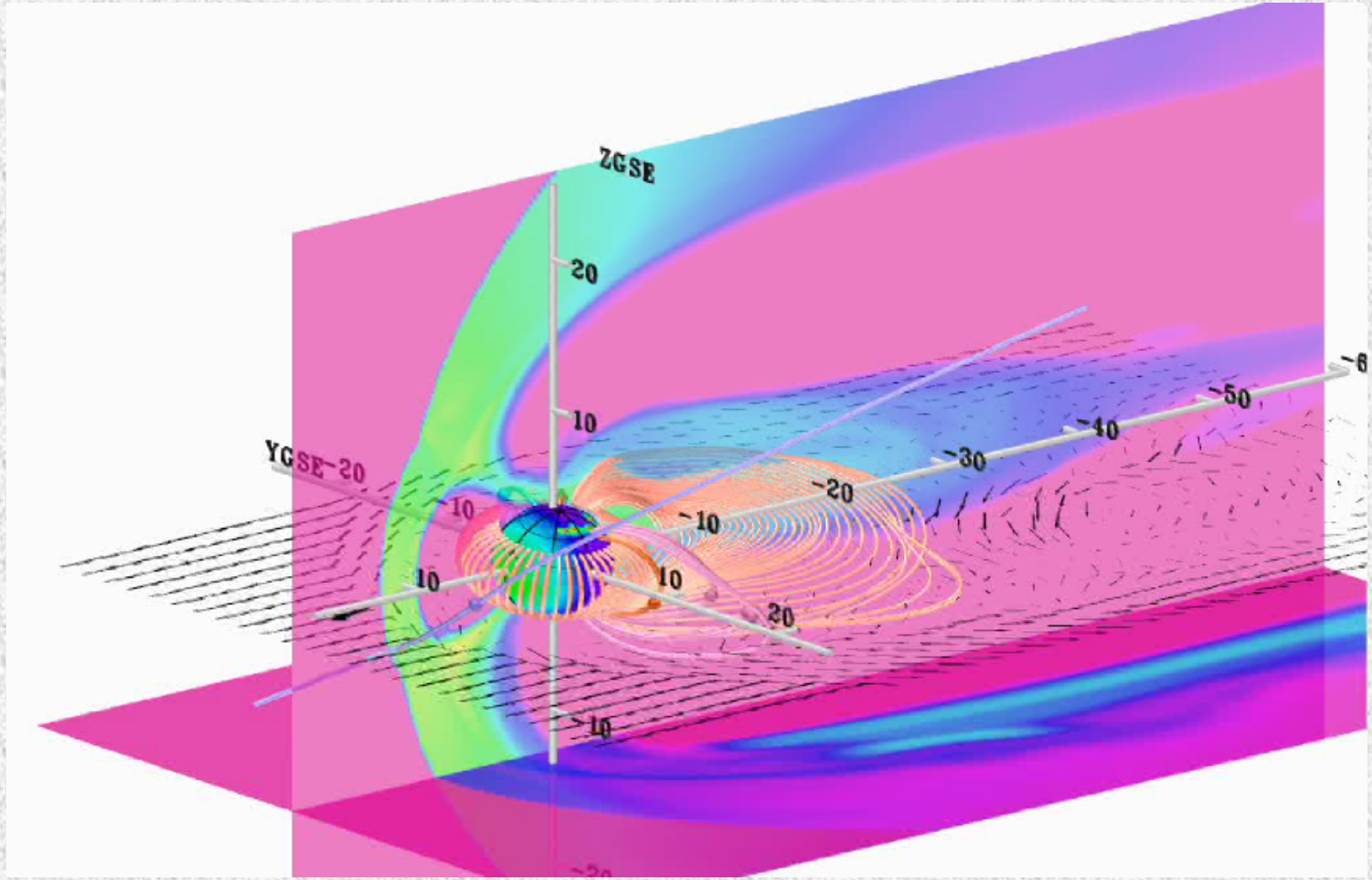
- (early 80's) First global magnetosphere MHD models: LeBouef, Ogino @UCLA, Lyon, Brecht, Fedder @NRL.
- (~1993) First parallelized global MHD magnetosphere model (UCLA-MHD).
- (~2000) UCLA global MHD model + NOAA/CTIM model ==> OpenGGCM.
- (2002) Second model to be implemented at the CCMC. >300(2010) >500(now) runs on demand at CCMC.
- (2005) Start RC coupling with RCM (NASA SR&T).
- (2006) NASA/NSF "Strategic Capabilities" funding for CTIPe/RB/ RCM/CRCM coupling and V&V.
- Current uses: mission planning (THEMIS, Swarm, Mag-Con), complement data analysis, study fundamental processes, numerical experiments.
- >30 data comparison studies in the refereed literature since 1995: tail physics, magnetopause, ionosphere, ground mags …
- Real-time capable with modest resources.

Model Data Flow



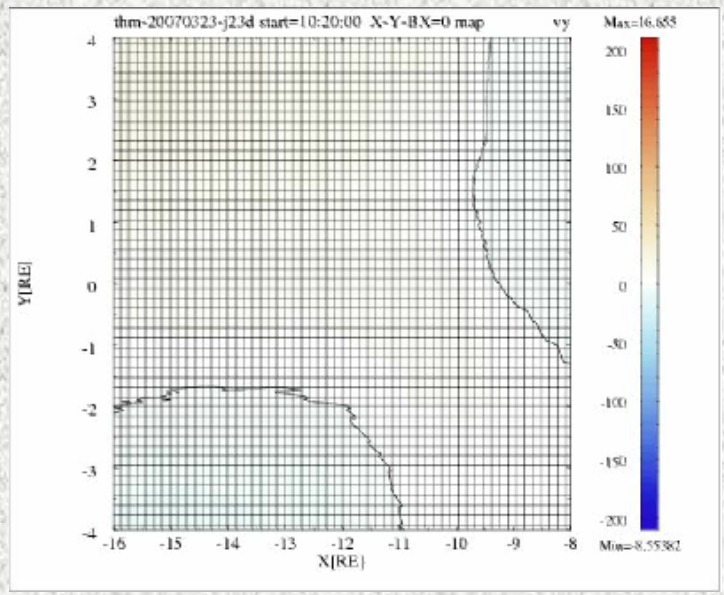
Substorms: What happens before reconnection ensues?

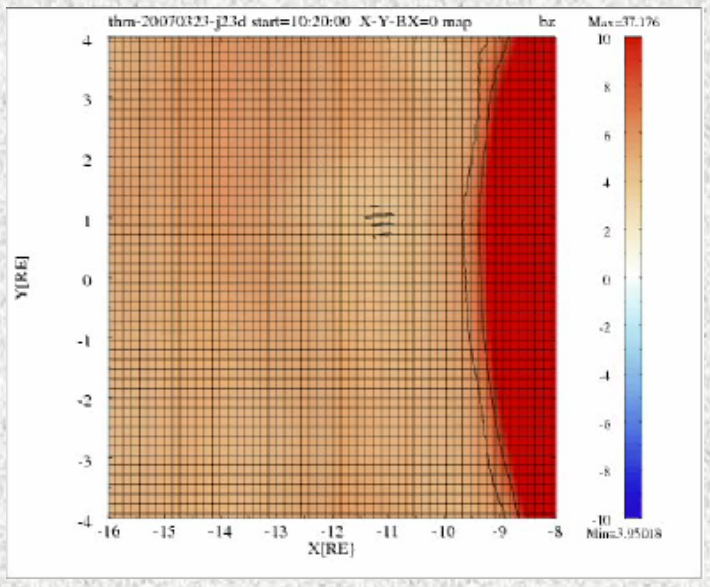
- Red iso-surface: force imbalance |grad(p)-JxB|.
- Green iso-surface: parallel E (what is reconnection?).
- → loss of equilibrium before reconnection sets in!
- First seen by G. Siscoe → CCMC success story!



Ballooning Mode

Ballooning appears on the edge of the dipolarizing inner magnetosphere during expansion. Movies of Vy and P on Bx=0 surface:

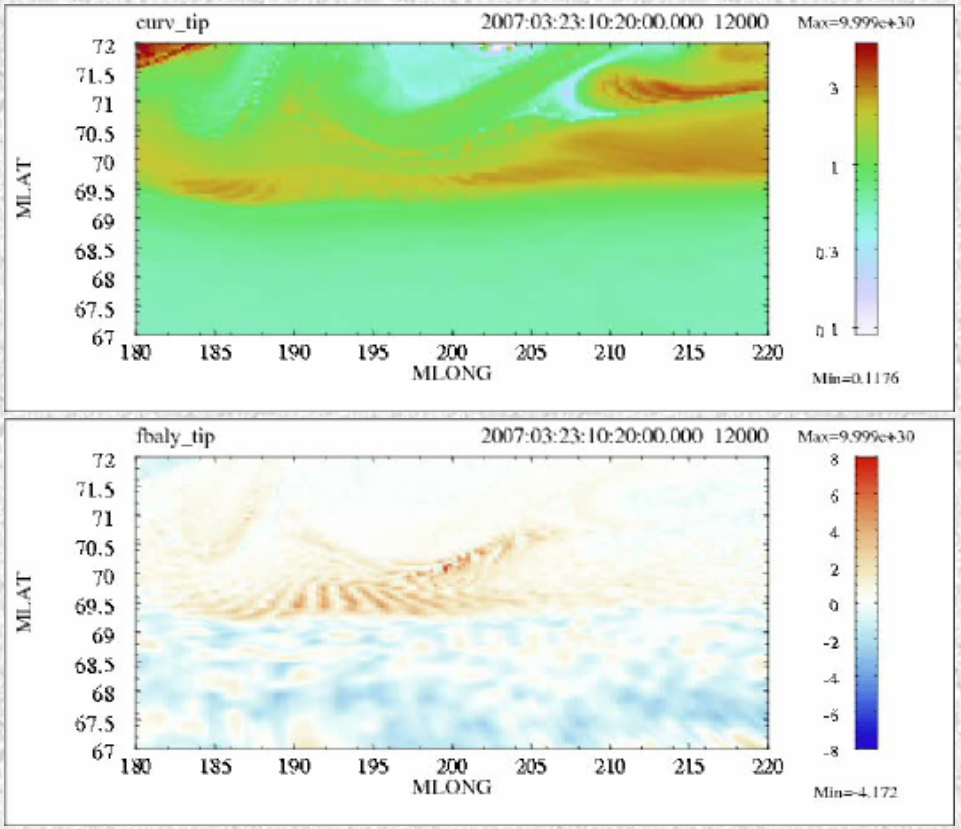




Ballooning wavelength: Ly ~ 0.5 RE, consistent with recent observations (Saito, 2009). Needs to be resolved with numerical grid: resolution, resolution, resolution!

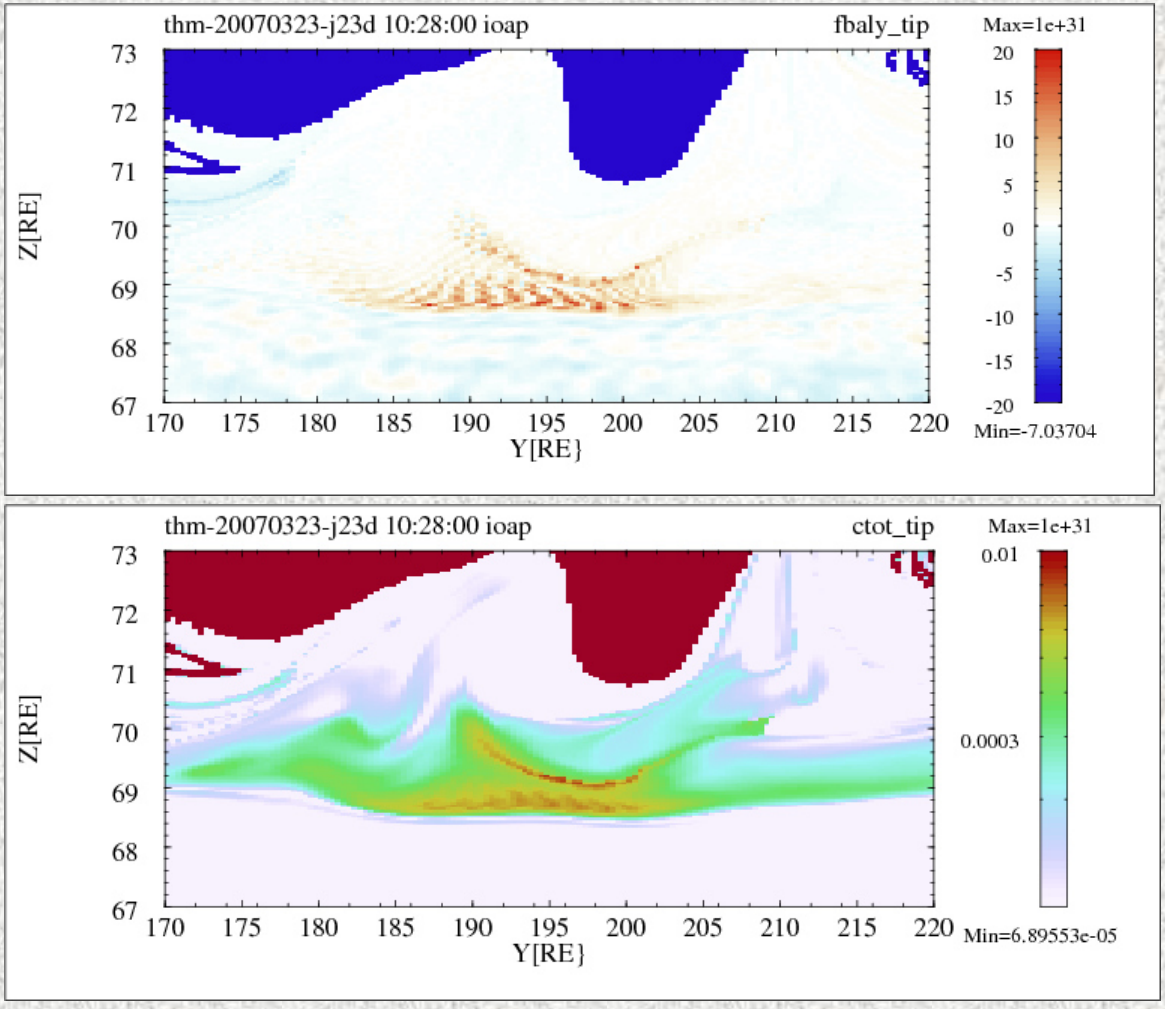
Auroral Signature

- We don't know how the ballooning mode would cause auroral emissions.
- At present we cannot resolve the physical quantities from the tail to the ionosphere: Converging magnetic field means 0.5 RE structures in the tail map to 0.005 RE (~50km) features at the ionosphere. However, we can map physical quantities along the filed lines.
- However, it is reasonable to assume that whatever process causes aurora will map along field lines and it will produce the same periodicity.



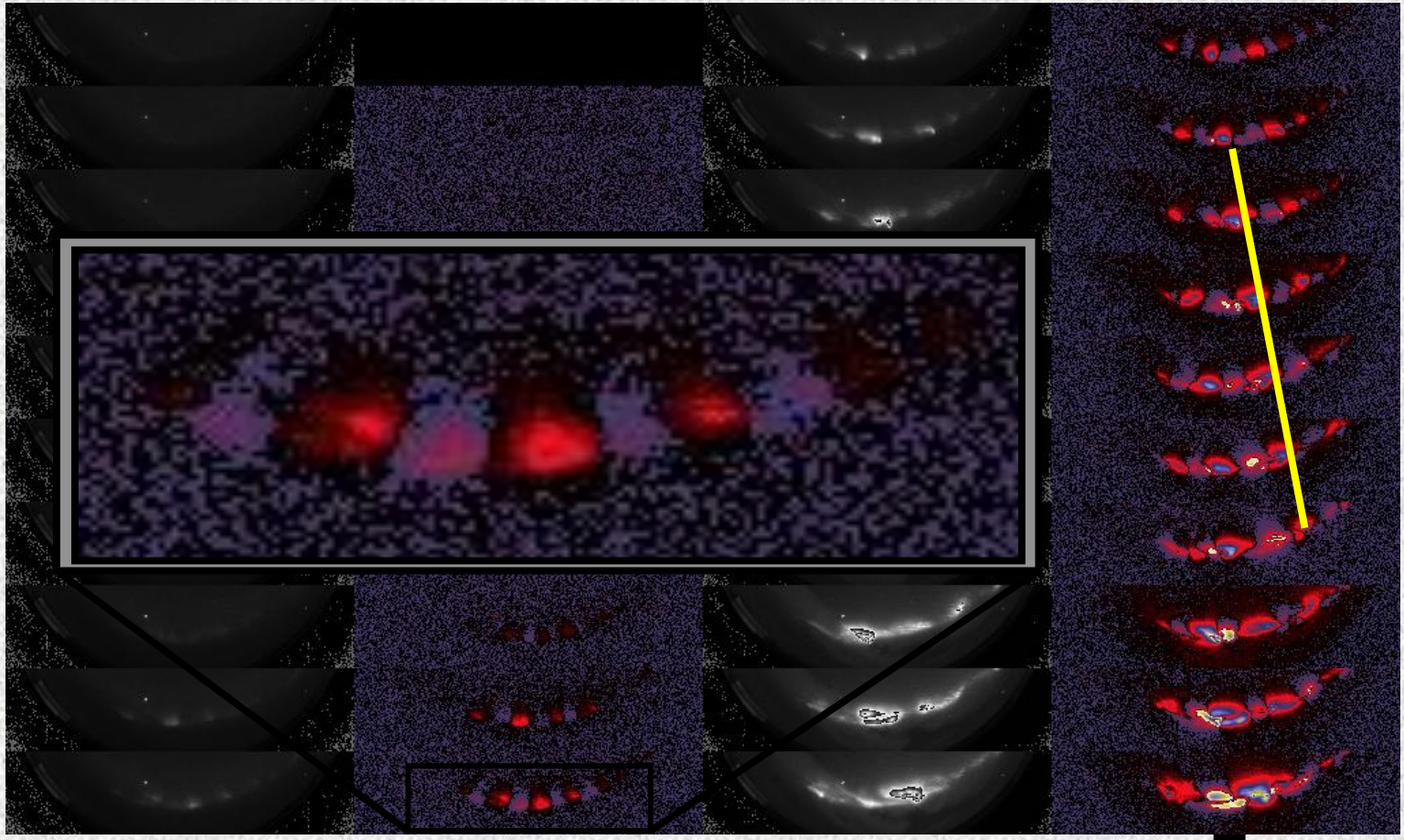
- Top: field line curvature at the tip of the field line. Bottom: Pressure imbalance at the tip of the field line.
- Auroral "beads" separation as expected.
- They are already present during the growth phase.
- The auroral breakup occurs poleward of the ballooning signature.

Auroral Signature



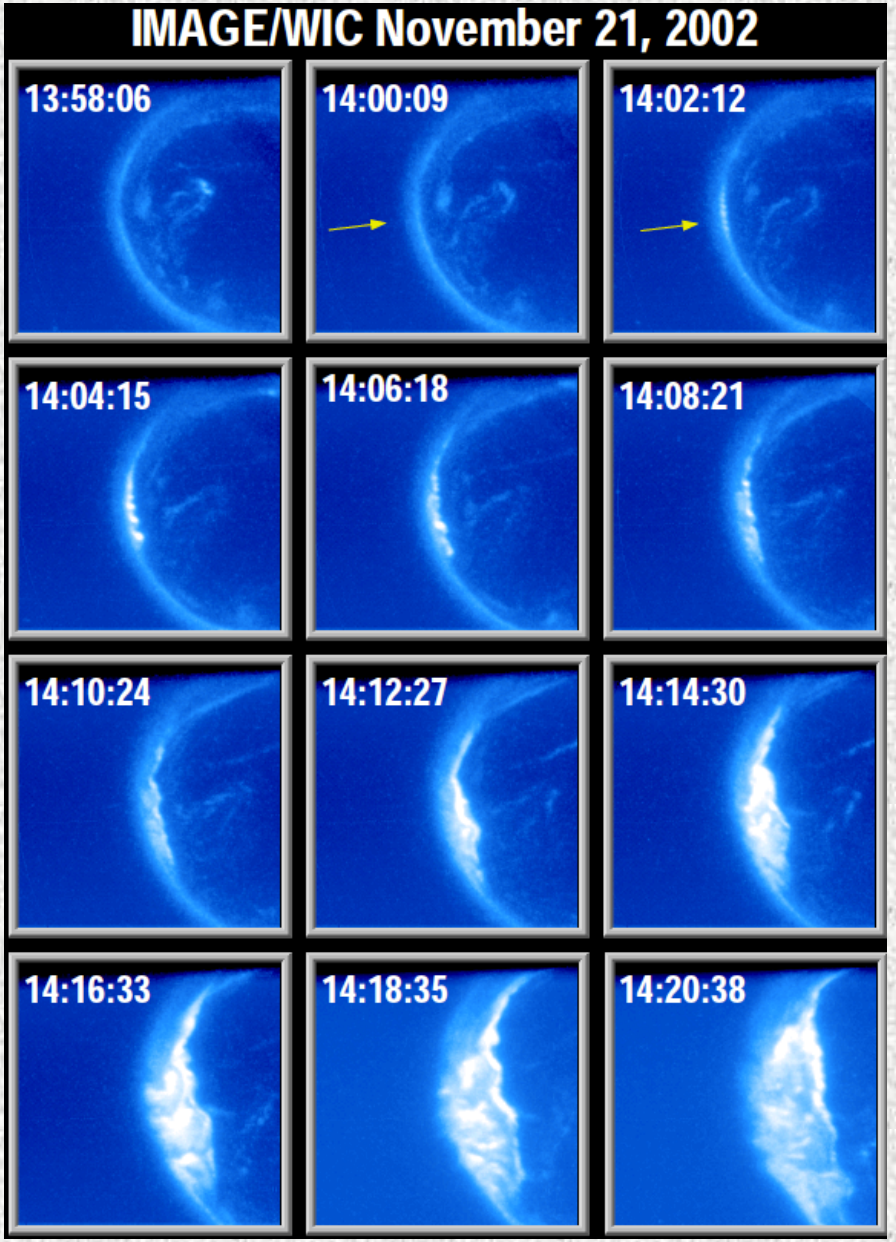
- Auroral “beads” are expected. Simple calculation gives wavelength in the ionosphere of 360Deg/ (2*pi*13RE/Ly) ~2.2Deg.
- Azimuthal wavenumber m~160.
- Beads extend ~0.5 Deg in latitude and seem to fan out from a point 2-4 Deg north.

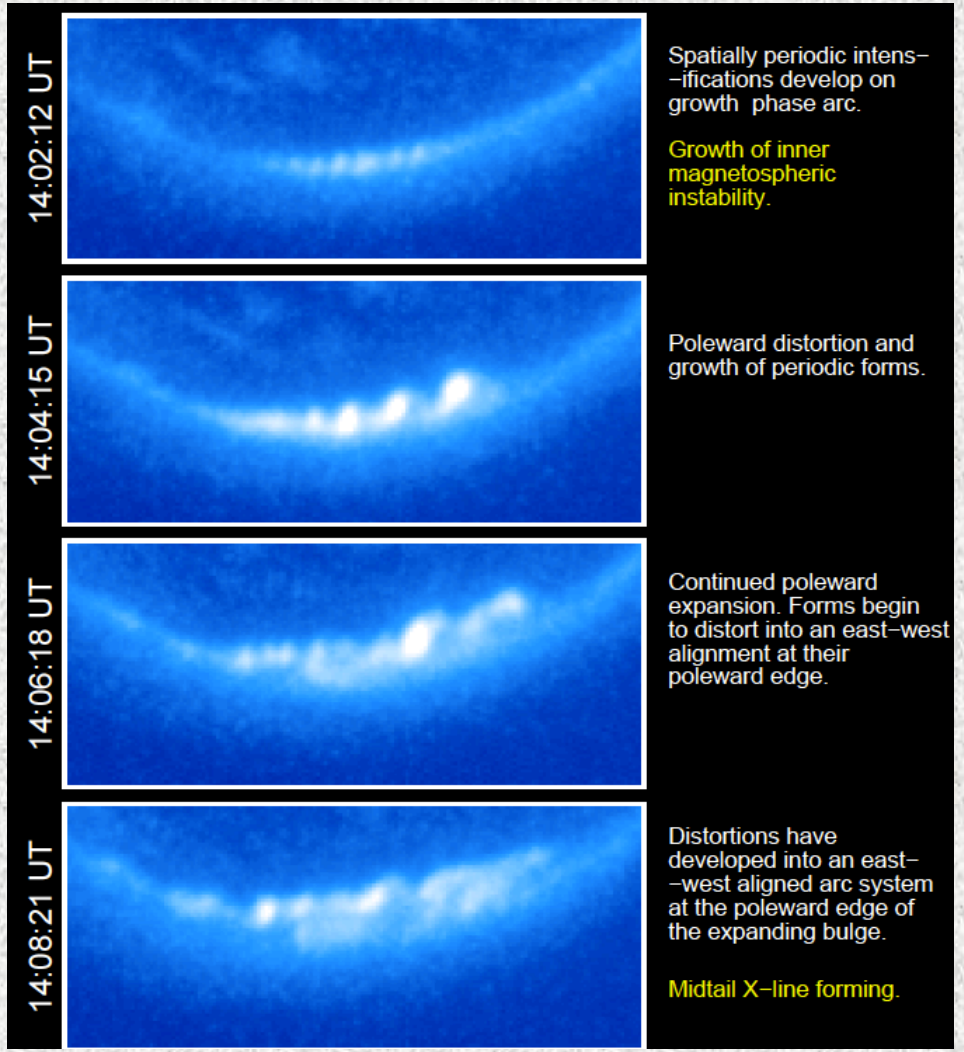
THEMIS/ASI observations



THEMIS/ASI observations courtesy of Eric Donovan and Jun Liang: Beads with wavenumber m=100-300, Ly=1.2-3.6Deg. There is even a hint of the fan-like structure. Consistent with simulation.

And older observations:

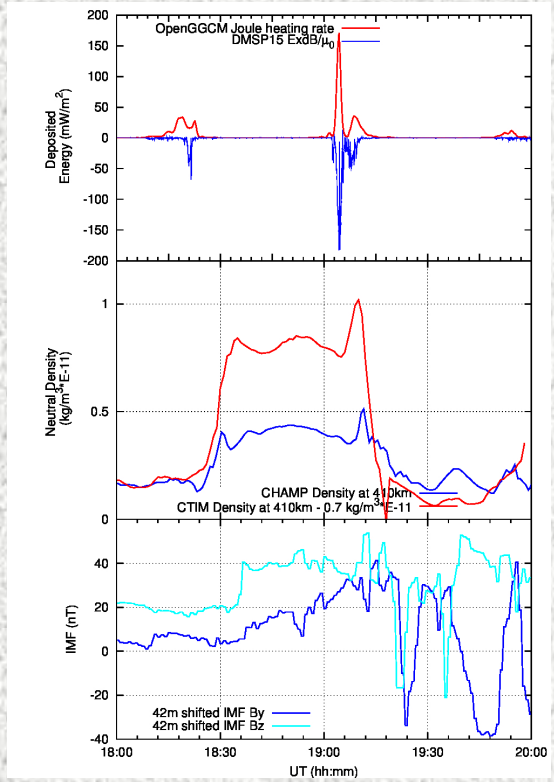


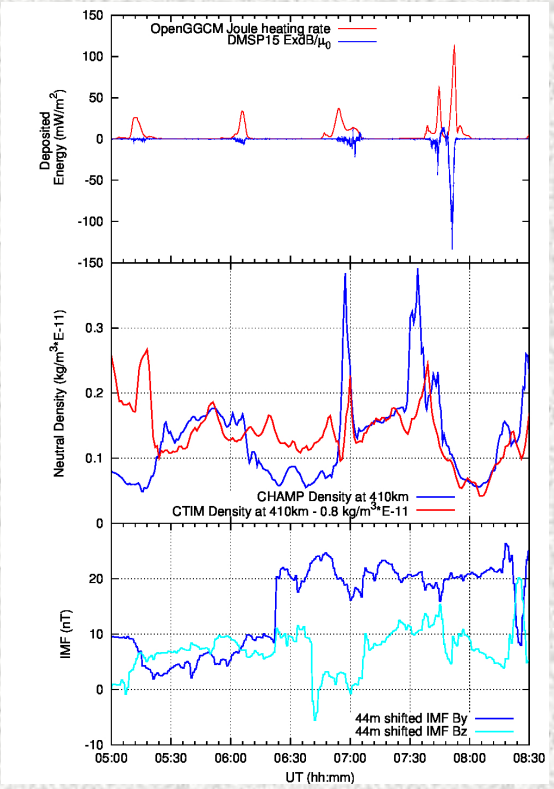


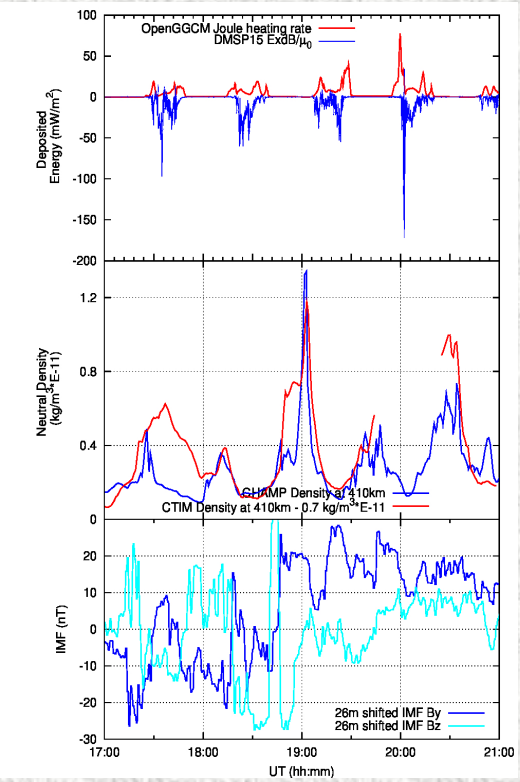
Henderson et al., AG, 27, 2129,2009

NBZ Poynting Flux and Ionosphere/Thermosphere Heating

- DMSP 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 simulations of events reproduce both Poynting flux and neutral density "hot spots" for all 3 cases.



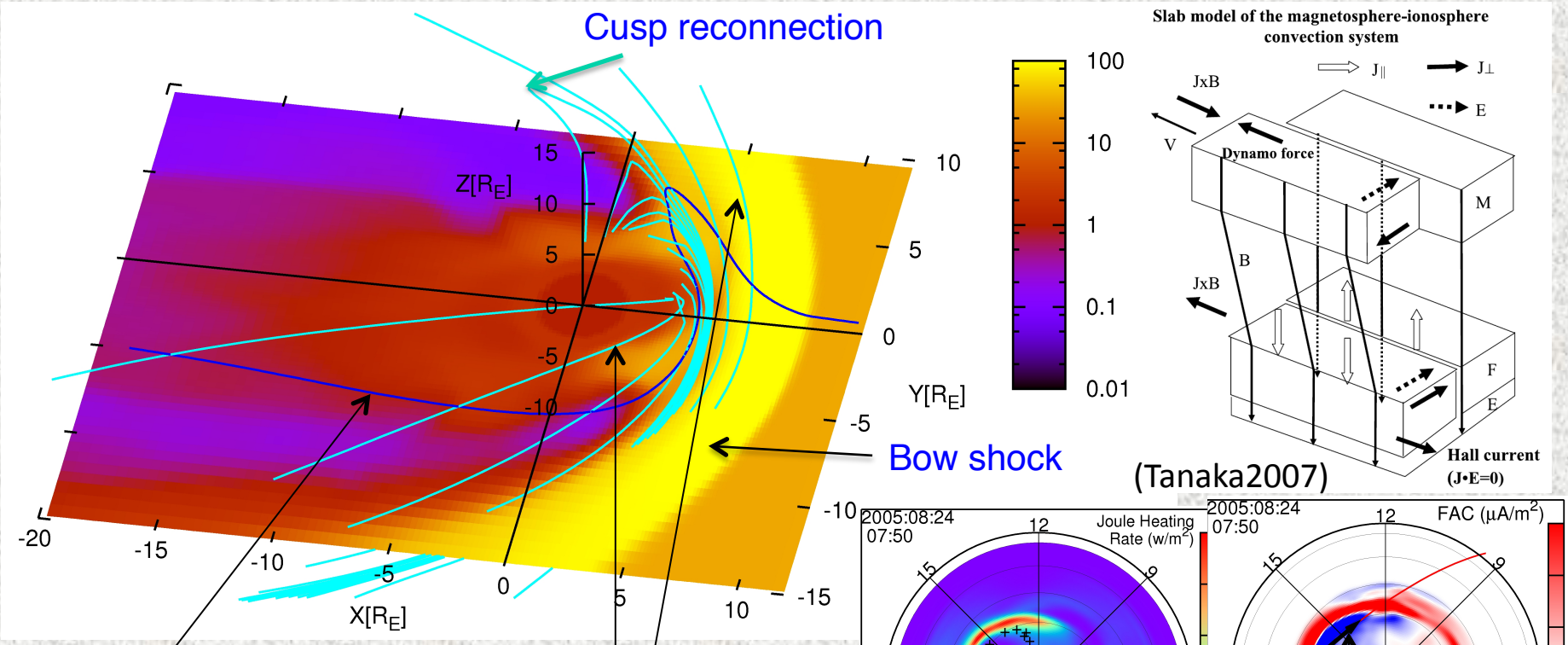




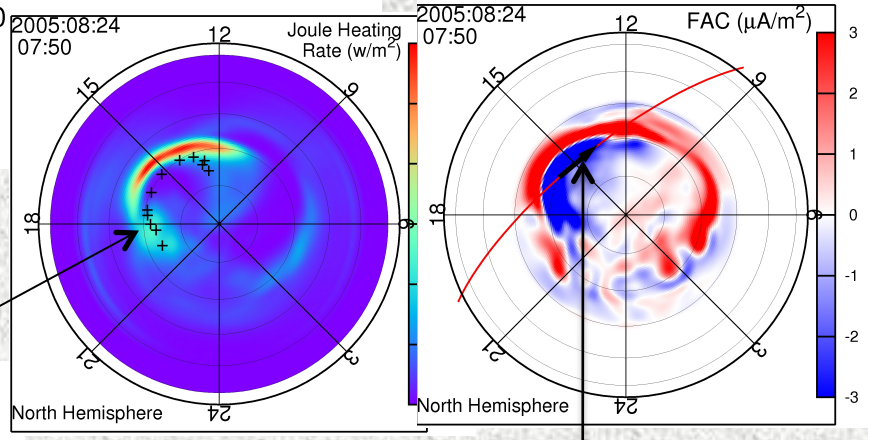
From top to bottom, the panels are: (negative downward) DMSP Poynting flux (blue) and OpenGGCM Joule heating rate (red, they should be equal in magnitude by Poynting's theorem), CHAMP density (blue) and OpenGGCM-CTIM density at CHAMP (red), and IMF By and Bz.

Jimmy Raeder and Wenhui Li, Space Science Center, University of New Hampshire, 2012

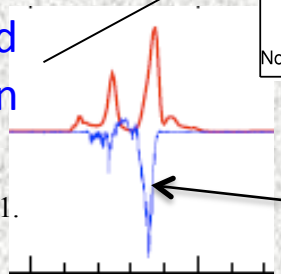
OpenGGCM simulation reveals causes: cusp reconnection produces twisted field lines (=FACs, Poynting flux), FACs close in ionosphere to produce Joule heating. Alternative view (mechanical): cusp reconnection produces open field lines, solar wind drags them through the ionosphere, thereby heating it.



(Tanaka2007)



Foot point of the moving field line moves from dusk to noon



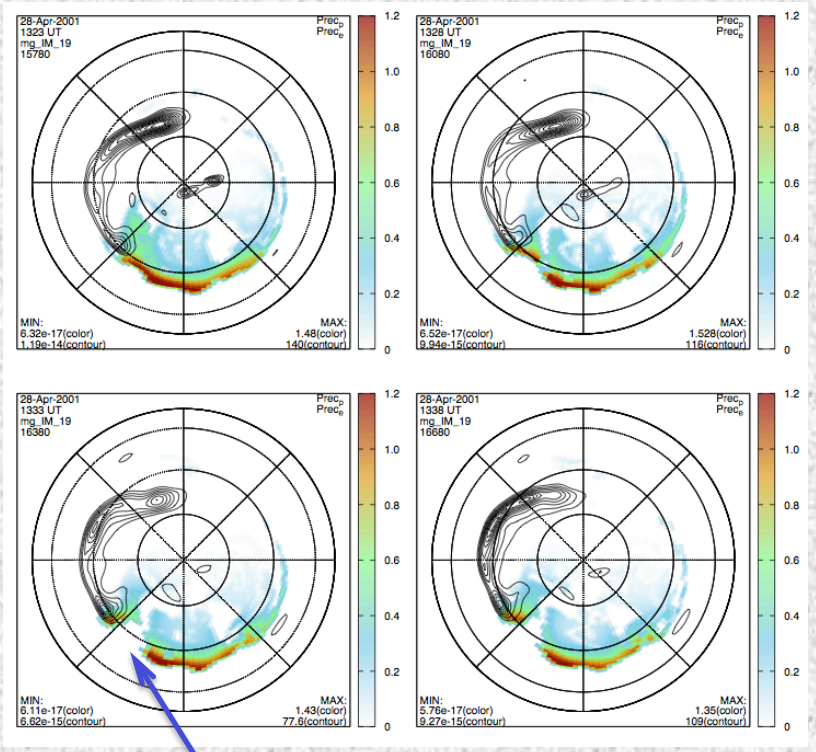
Intense Joule heating (Poynting flux) region flanked by a pair of opposite FACs (+:down)

DMSP F15 at 07:50 UT

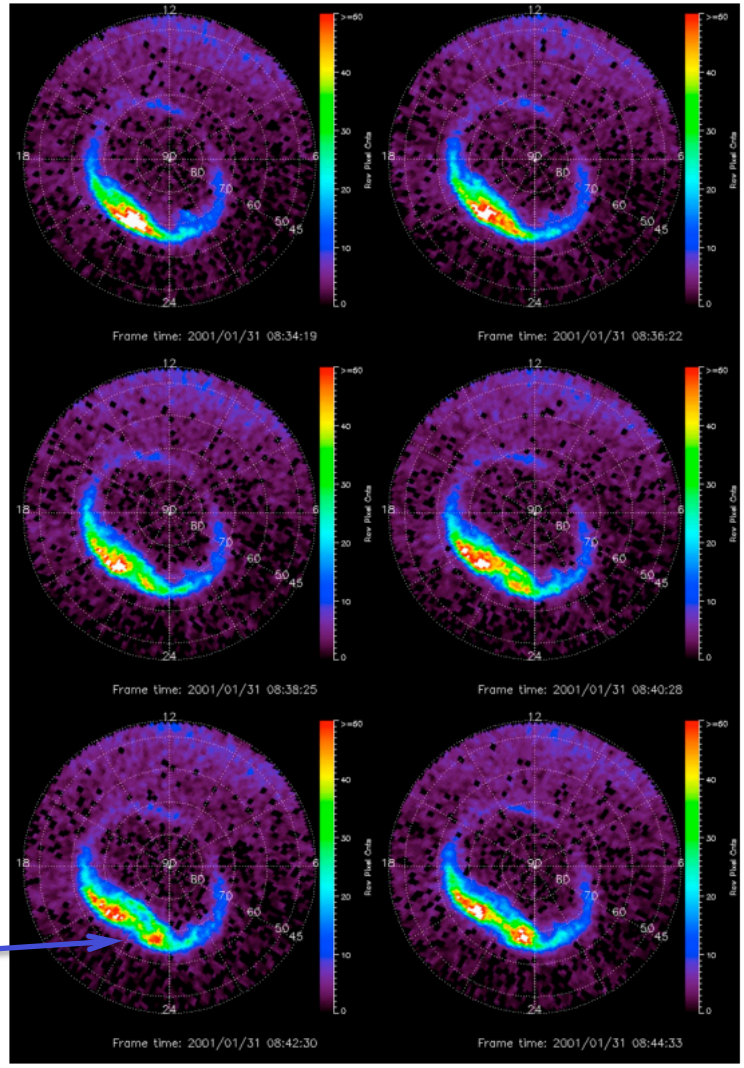
Li, W., D. Knipp, J. Lei, and J. Raeder, JGR, 116, A08301, 2011.

Proton Aurora Splitting

- First seen in OpenGGCM simulations: p-aurora splits at substorm onset.
- Statistical study with IMAGE S12 data shows it happens all the time.



p-aurora gap



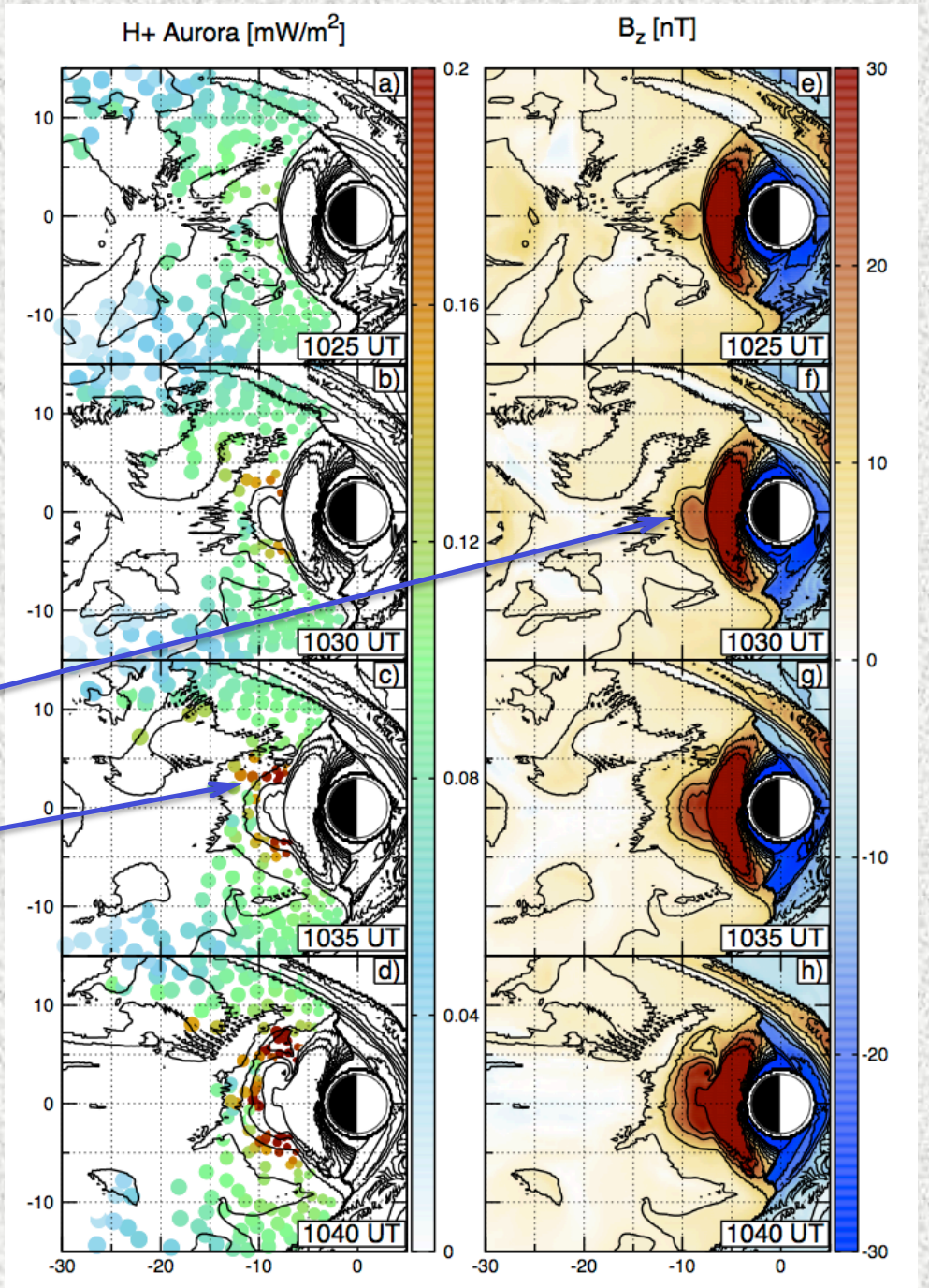
Gilson, M., J. Raeder, E. Donovan, Y. S. Ge, and E. L. Kepko,
Global Simulation of Proton Precipitation due to Field Line Curvature During Substorms, submitted, 2012.
Gilson, M., J. Raeder, E. Donovan, Y. S. Ge, and S. Mende, JGR, 116, A08226, 2011.

Proton Aurora Splitting

- OpenGGCM simulation reveals the process: pitch angle scattering where $\kappa (=R_c/\rho)^{1/2} > 3$ (Buechner & Zeleny, 1987; Sergeev et al., 1983).
- Field line curvature R_c increases as magnetic field dipolarizes.
- Larmor radius ρ also increases as plasma heats, but lees than curvature.
- Scattering is most intense at the edges of the dipolarization region.

Dipolarization

Scattering



Gilson, M., J. Raeder, E. Donovan, Y. S. Ge, and E. L. Kepko, Global Simulation of Proton Precipitation due to Field Line Curvature During Substorms, submitted, 2012.

Other developments

- Code now completely under git control.
- Bug reporting system: http://fishercat.sr.unh.edu/trac/openggcm
- Compiling with autoconf/make.
- Ultra-high resolution runs for ballooning (1200x600x600, Ping Zhu, U. Wisconsin). KY0 mode nature, bubble-blob mechanism.
- Including Hall physics (LWS grant, Bhattacharjee, Germaschewski).
- Particle tracing / reconstruction of f(v) (for now cusp ion structures, grad student project).
- New student projects: Kelvin-Helmholtz, IP shock impact, tail transport and entropy, …

See you in 2012!