

ULF Wave Modeling Challenge – First Results from Magnetosphere Simulations at the CCMC

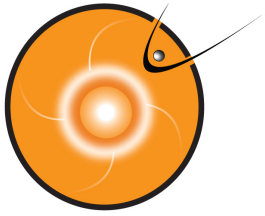
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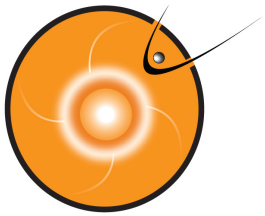
3 Code 673, NASA GSFC

The ULF Challenge will be discussed Wednesday from 1:30 PM to 3 PM in the Metrics and Validation Focus Group session.



Abstract

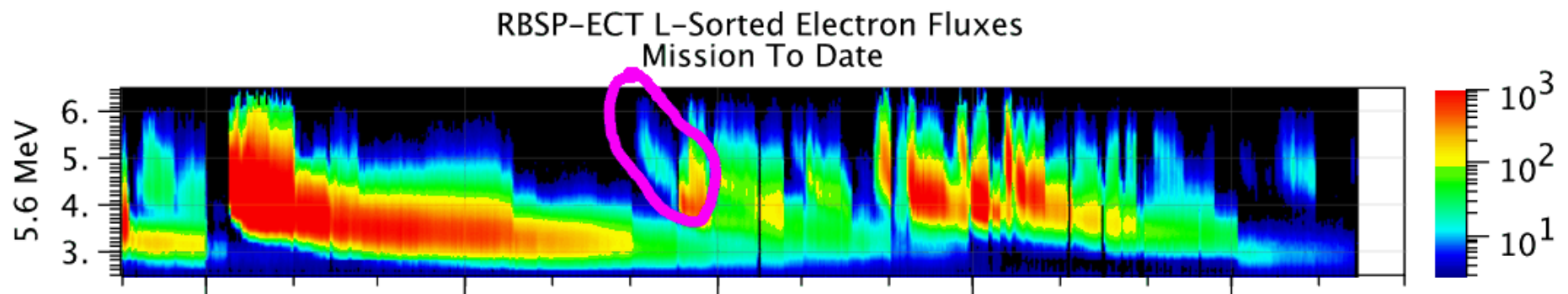
At the 2014 GEM Summer Workshop and the mini-GEM workshop, the Metrics and Validation Focus Group agreed to have an Ultra-Low-Frequency (ULF) wave modeling challenge using a monochromatic solar wind pressure driver (we start with 10 mHz frequency). Using methodology similar to Claudepierre (2010), we at the Community Coordinated Modeling Center (CCMC) analyzed MHD simulations performed by the SWMF, OpenGGCM and GUMICS models in addition to the LFM data provided by Claudepierre that were used for his paper. Similarities and differences between the four models are presented to start the discussion and to make further plans for the Challenge.

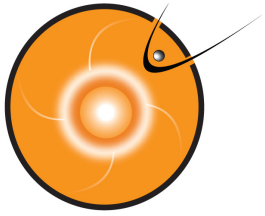


ULF Modeling Challenge

The Metrics and Validation Focus Group is organizing a modeling challenge to investigate the ability of global models to reproduce ULF wave fields in the magnetosphere.

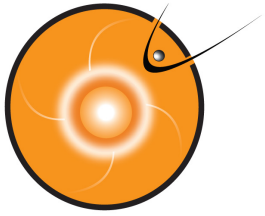
Ultimately, we would like to know if those ULF fields can radially diffuse in existing electron populations from $L \sim 5.5$ to $L \sim 4.5$ in two weeks (figure).





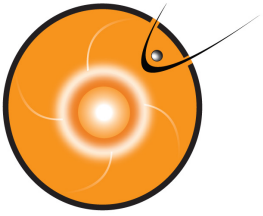
Open Questions

1. Can global models of the magnetosphere reproduce the observed persistent, solar wind driven, low mode number ULF wave fields in the magnetosphere?
2. Are those waves capable of producing the observed energetic radiation belt population evolution observed during the first two weeks of March 2013 as observed by Van Allen Probes?



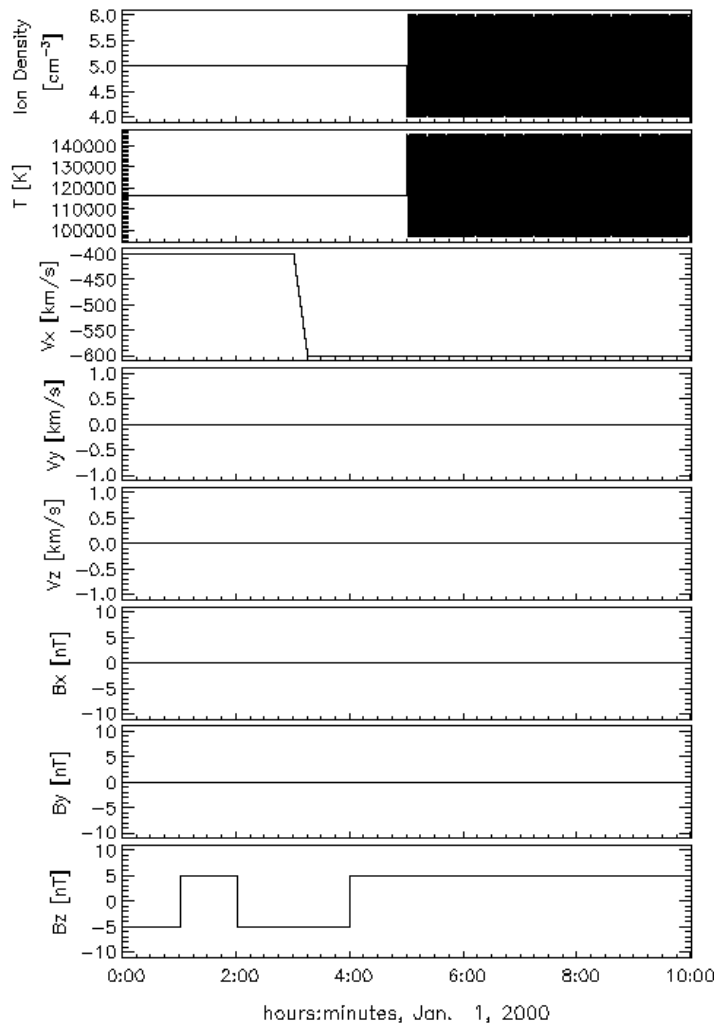
Getting Started

1. Single-frequency solar wind driver.
 - 10mHz oscillation in solar wind density,
 - Temperature adjusted to conserve thermal pressure
 - Model outputs every 30 seconds (Claudepierre et al 2010).
 - 30 mHz
2. Different frequencies
3. Continuum-noise driver



Solar Wind Inputs

6-hour preconditioning + 4 hours of run:



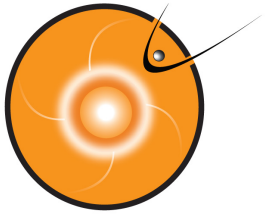
Solar wind density (dynamic pressure) oscillations (not time resolved) start at 05:00. Temperature varies to make solar wind plasma pressure constant.

Solar wind V_x speed changes from -400 km/s to -600 km/s around 03:00.

B_z : 4 hours of southward B_z (-5 nT), interrupted by 1 hour of northward B_z (+5 nT, 01:00--02:00).

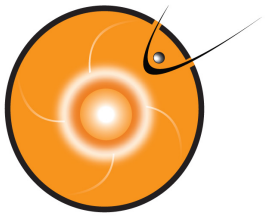
Northward (+5 nT) throughout the rest of the run (04:00 – 10:00).

FFT analysis for last 4 hours (06:00-10:00).



Processing at CCMC

- Reprocess Claudepierre's 10-mHz LFM run
 - Results agree mostly with publication
 - Similar distribution of spectral power
- Run other models with same solar wind driver
 - SWMF, OpenGGCM: runs completed
 - GUMICS: run in progress
 - Perform same analysis

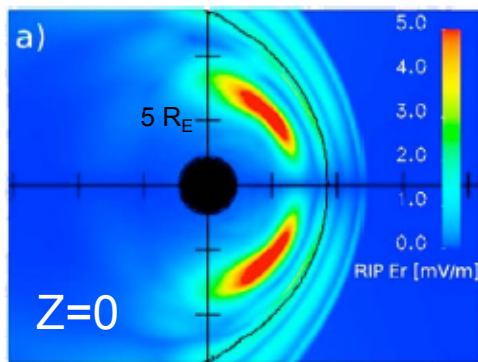


Results

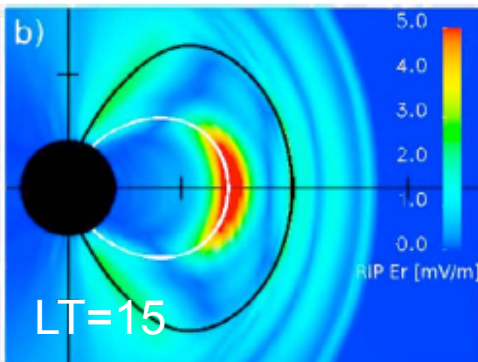
10 mHz with LFM:
Claudepierre (2010)

Verification of CCMC processing

CCMC (same LFM run)

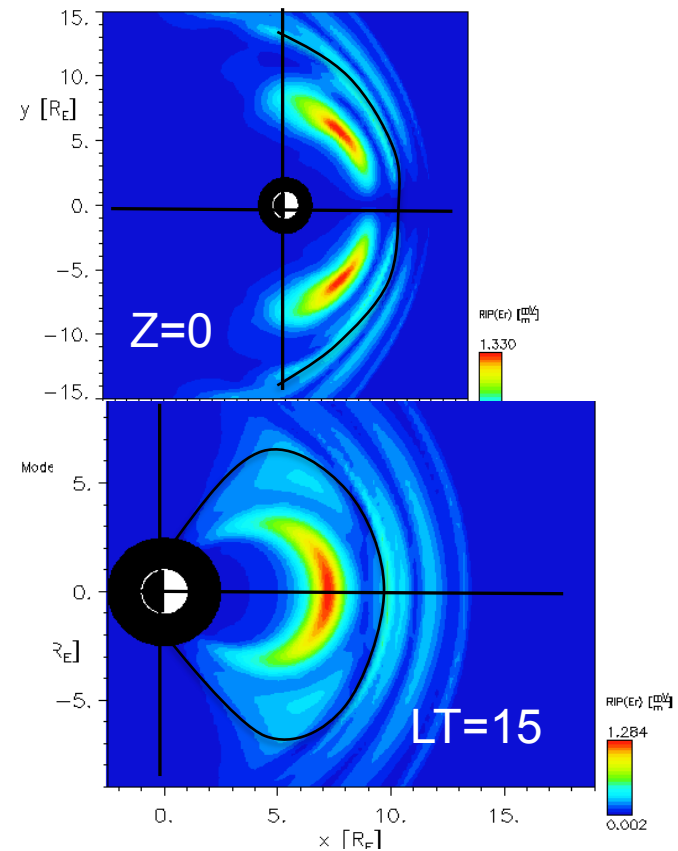


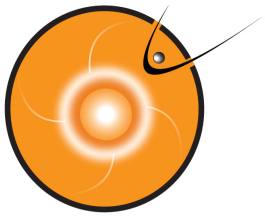
Z=0:
Pattern in CCMC plot
very similar
Color scale different:
max=1.33 for CCMC,
5 for paper.



15 MLT:
CCMC plot different:
Crescent shape
extends to inner
boundary,
lower altitude patterns
along field line absent

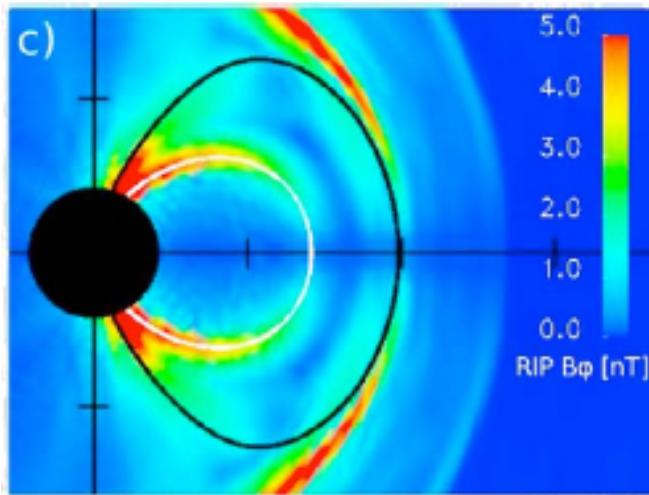
Root integrated Power
of E_r 9.5 to 10.5 mHz



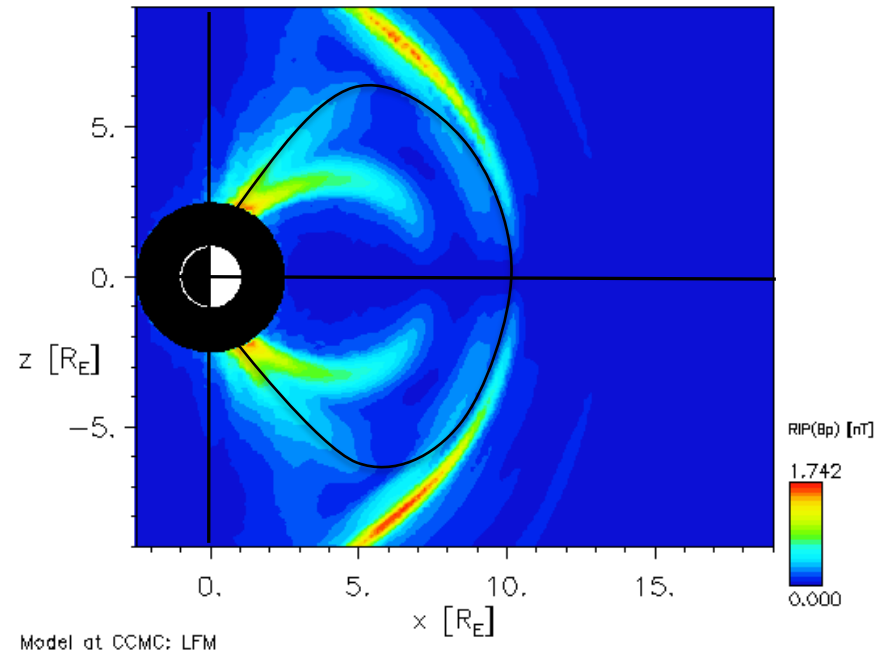


RIP(B_ϕ)

Claudepierre et al., 2010



CCMC

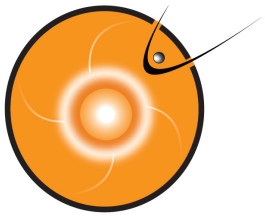


CCMC results similar globally.

Normalization: CCMC results by factor of ~ 3 smaller.

Spatial patterns: differences significant in places near the inner boundary.

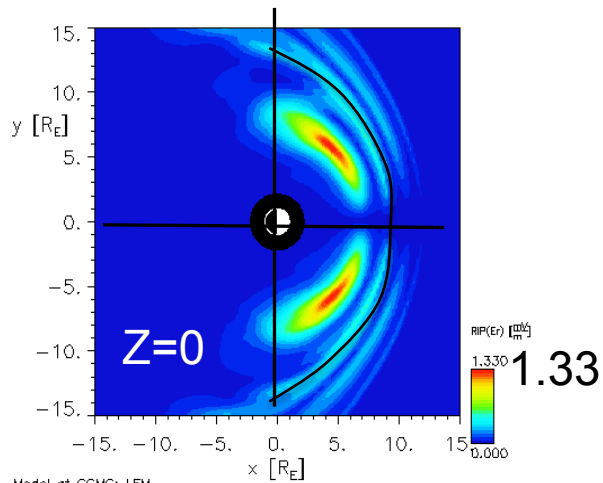
Claudepierre, S. G., M. K. Hudson, W. Lotko, J. G. Lyon, and R. E. Denton (2010), Solar wind driving of magnetospheric ULF waves: Field line resonances driven by dynamic pressure fluctuations, *J. Geophys. Res.*, 115, A11202, doi:10.1029/2010JA015399.



Results: SWMF and OpenGGCM

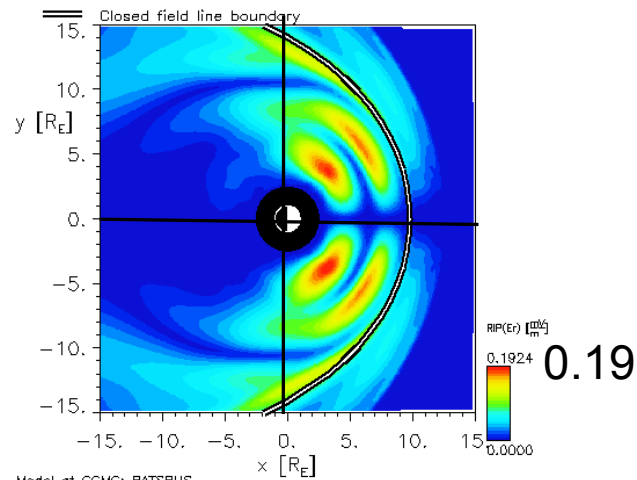
RIP (E_R), $f_0=9.5$, $f_1=10.5$

LFM



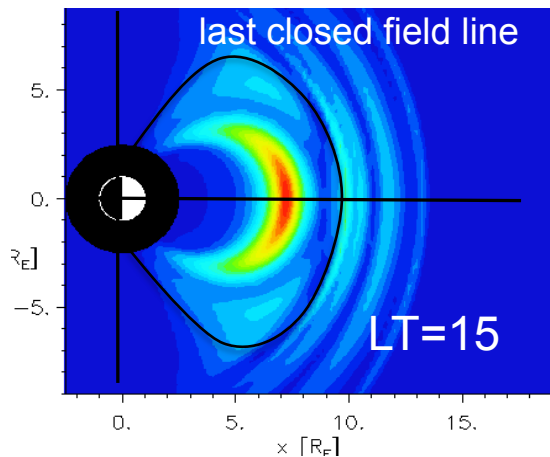
Model at CCMC: LFM

SWMF

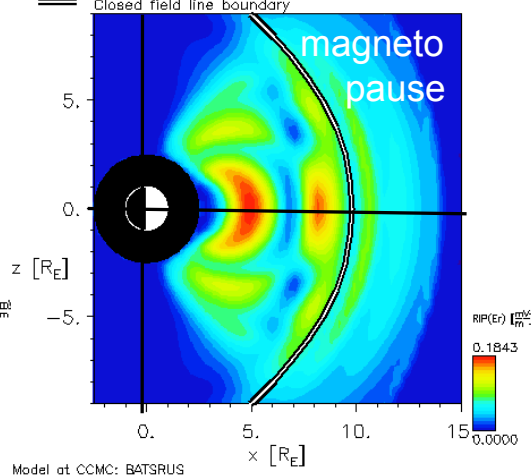


Model at CCMC: BATSRUS

OpenGGCM

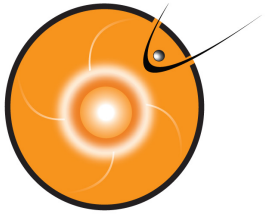


Model at CCMC: BATSRUS



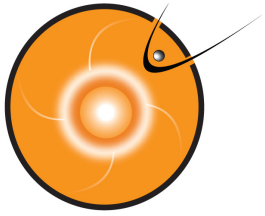
Model at CCMC: BATSRUS

The processing of OpenGGCM outputs had an error that was identified and corrected only after the conference.



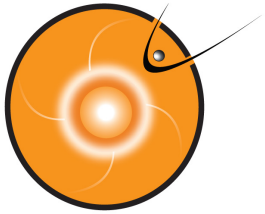
Processing at CCMC

- Run magnetosphere model
- Generate time stack:
 - Small grids (< 2M cells):
 - Entire grid, 480 time steps
 - Data limited to about 10 Gbytes
 - Large grids (> 2 million cells)
 - Collect model outputs in inner magnetosphere
 - Region: $-30 < X < 15$, $-15 < Y, Z < 15$
 - OpenGGCM: select cells and outputs of original model grid
 - Other models: equidistant grid with $0.25 R_E$ spacing



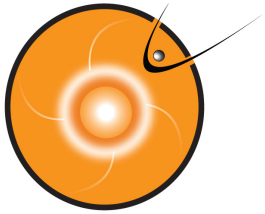
Processing at CCMC (cont'd)

- Compute power spectrum $P(f)$
 - Time stack: 480 steps, spaced $DT=30$ s apart
 - Subtract time average of E_r , B_p at each position
 - FFT:
 - $f_{\max} = 16 \frac{2}{3} \text{ mHz} = 1000/(2*DT)$
 - $df = f_{\max}/240 = 0.0694 \text{ mHz}$
- Visualization:
 - Calculate Root Integrated Power (RIP)
$$\text{RIP} = \sqrt{\sum_{f_0}^{f_1} P(f)df}$$
from power spectrum $P(f)$.



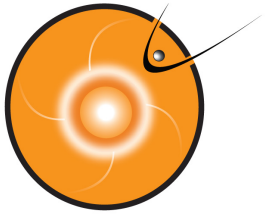
CCMC Visualization: Recent Advances

- Spherical vector components (e.g., E_r , B_φ) available from Cartesian vectors
 - available online
- Interpolation in oblique slice available
 - constant local time shown in presentation
 - not yet available online
- Calculate RIP over arbitrary frequency range

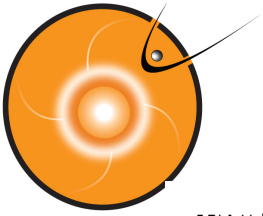


CCMC Visualization: Features to be Added

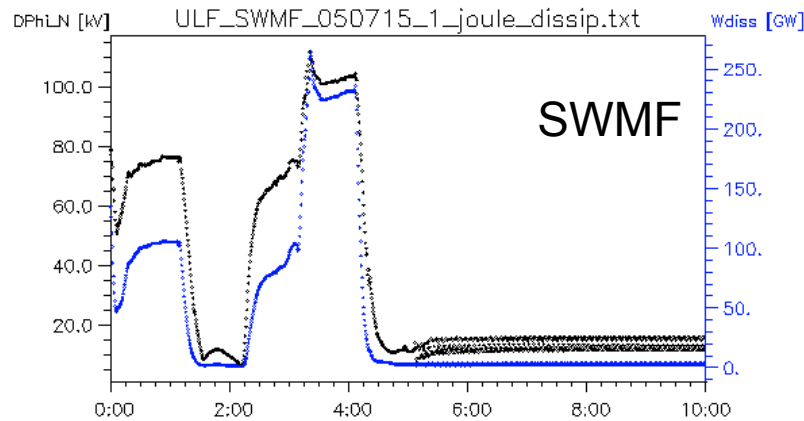
- Display oblique slices
 - User may select local time (LT) or magnetic local time (MLT)
 - LT=15 hours: plane normal: $[-1/\sqrt{2}, 1/\sqrt{2}, 0]$
- Use other than model's coordinate system:
 - GSM or GSE \rightarrow SM: magnetic local time plots,
 - GSM \leftrightarrow GSE \leftrightarrow SM: comparison between models,
 - Convert vectors between coordinate systems,
 - Render projections of vectors onto plane.
- Plot root integrated power (RIP) online where power spectrum has been calculated.



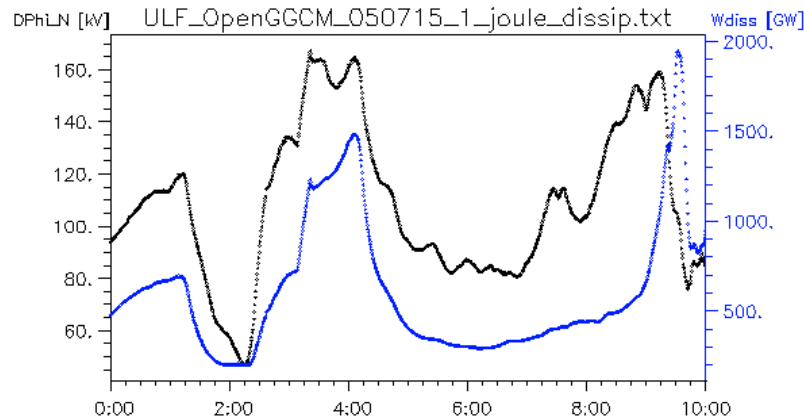
Additional slides



Model Responses



2000/01/01 00:00 time 2000/01/01 10:00
Model at CCMC: SWMF



2000/01/01 00:00 time 2000/01/01 10:00
Model at CCMC: OpenGGCM

Time series of CCMC runs:

Cross Polarcap Potential
(north, dPHI_N)

and

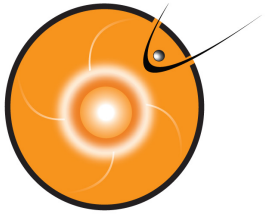
Integrated Joule heat (Wdiss)

OpenGGCM

Model response similar to SWMF
during first 5 hours (longer quiet-
down times).

Something went wrong after
06:00:

Increase in activity not expected.



Magnetosphere model runs

- SWMF and OpenGGCM:
 - Runs complete
 - Postprocessing and calculations of power spectrum in progress.
- GUMICS:
 - Simulation run half done.