CRCM and RBE

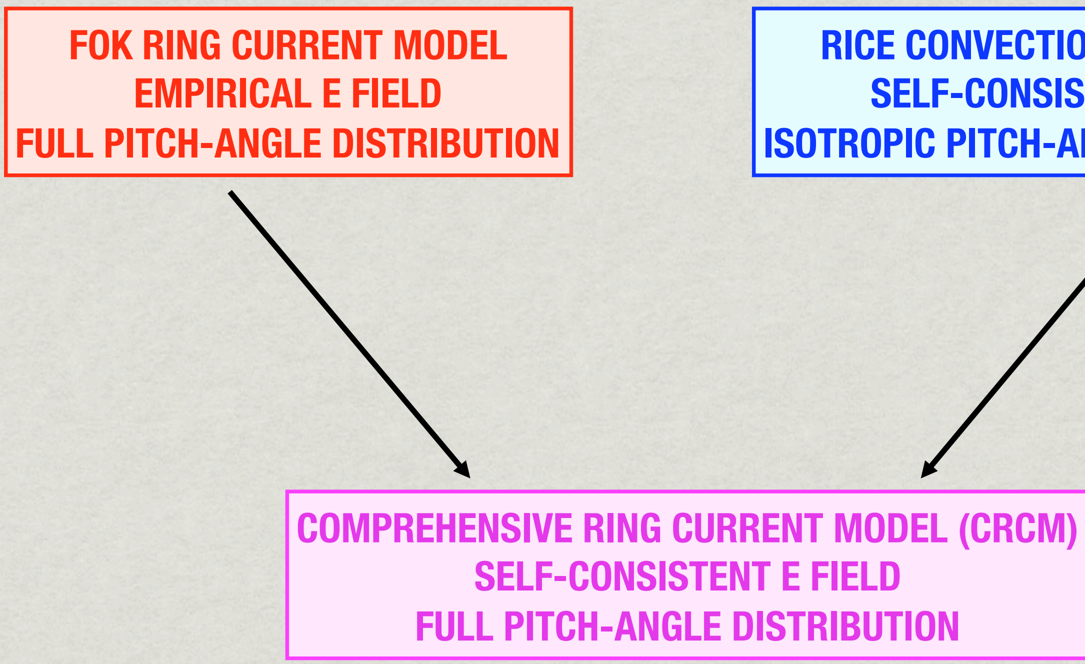
A Glocer, M-C Fok, and N Buzulukova

KEY LARGO, FL: CURRENT TEMPERATURE ??

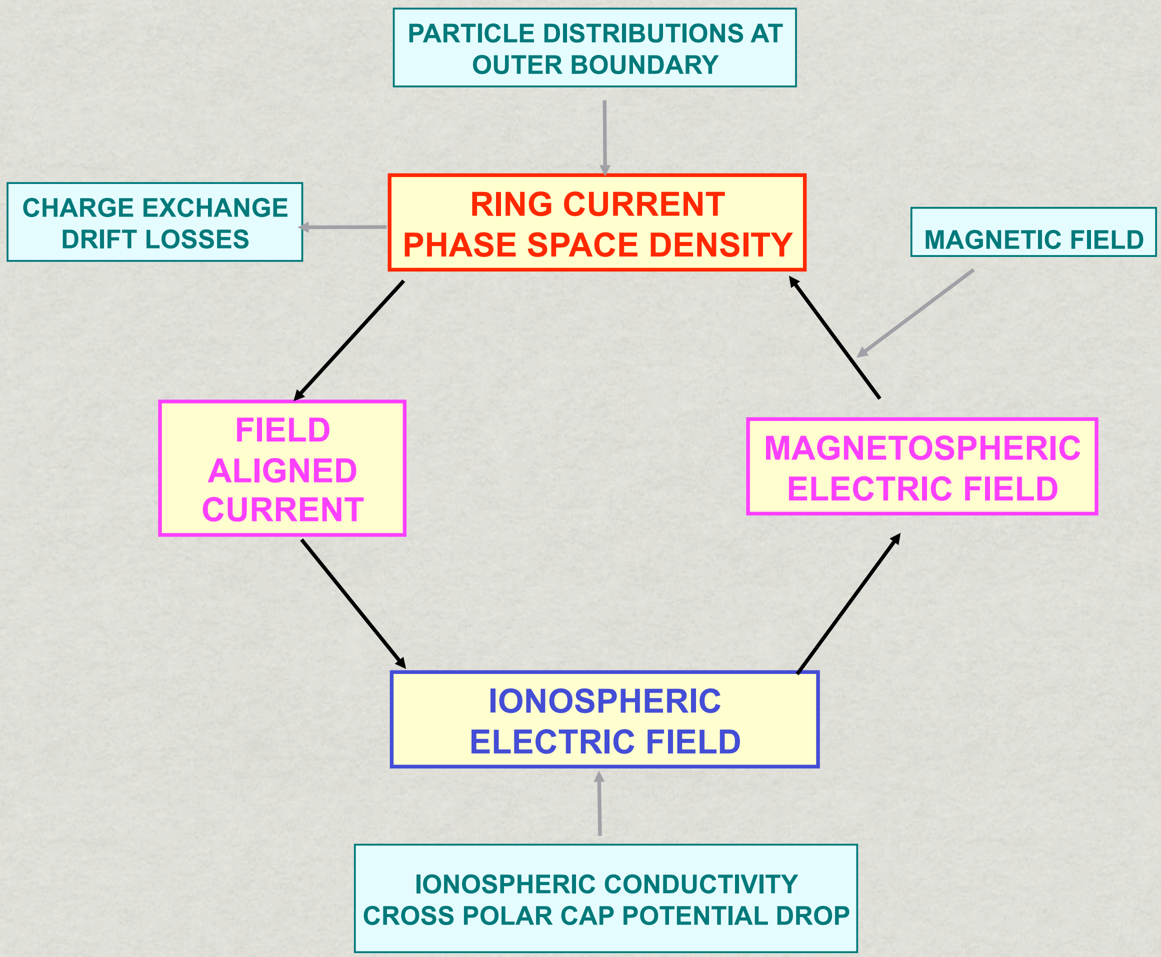
Outline

- Details of the CRCM: Description and Inputs
- Example ENA studies:
  - CRCM with T96: TWINS mission
  - CRCM with BATSRUS: IMAGE
- Details of RBE: Description and Inputs
- Example studies:
  - Real-time simulations of GOES observations.
  - SAMPEX and Akebono observations

The Comprehensive Ring Current Model (CRCM)



The Comprehensive Ring Current Model: Model Logic



The Compreshensive Ring Current Model (CRCM) Inputs

- Dst, Kp: Kyoto University Geomagnetic Data Service.
- Shifted solar wind, IMF data: ACE or WIND satellite
- Distribution at nightside boundary (8-10R_e)
- Magnetic field model: T96
- Ionospheric potential at polar boundary:Weimer Model
- Conductance: Background + Auroral (Hardy Model)

THE TWINS MISSION

Two Wide-angle Imaging Neutral-atom Spectrometers

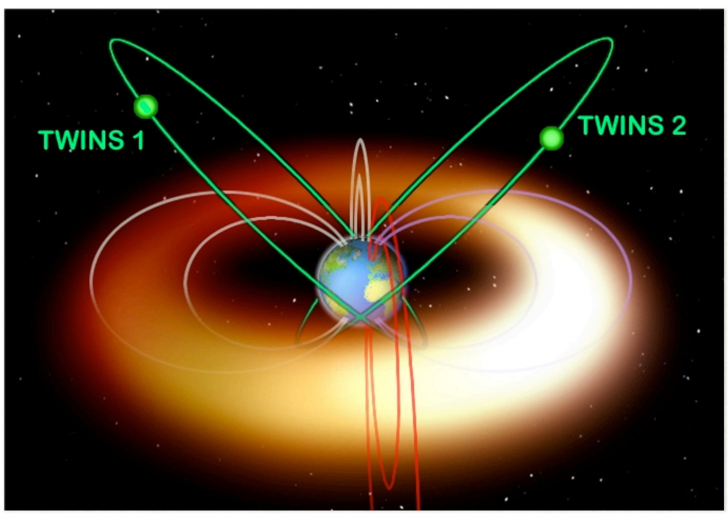
FIRST STEREOSCOPIC MAGNETOSPHERIC IMAGING MISSION

TWINS PROPOSED IN 1997, MOO (AO 97-OSS-03)

2 NADIR-VIEWING MOLNIYA-ORBIT SPACECRAFT

7.2 RE APOGEE, 63.4° INCLINATION, 12 HOUR ORBIT

ACTUATOR REPLACED S/C SPINNING



STEREO IMAGING BEGAN IN SUMMER OF 2008

AVAILABLE AT http://twins.swri.edu

TWINS TEAM:

PI: DAVE MCCOMAS (SWRI)

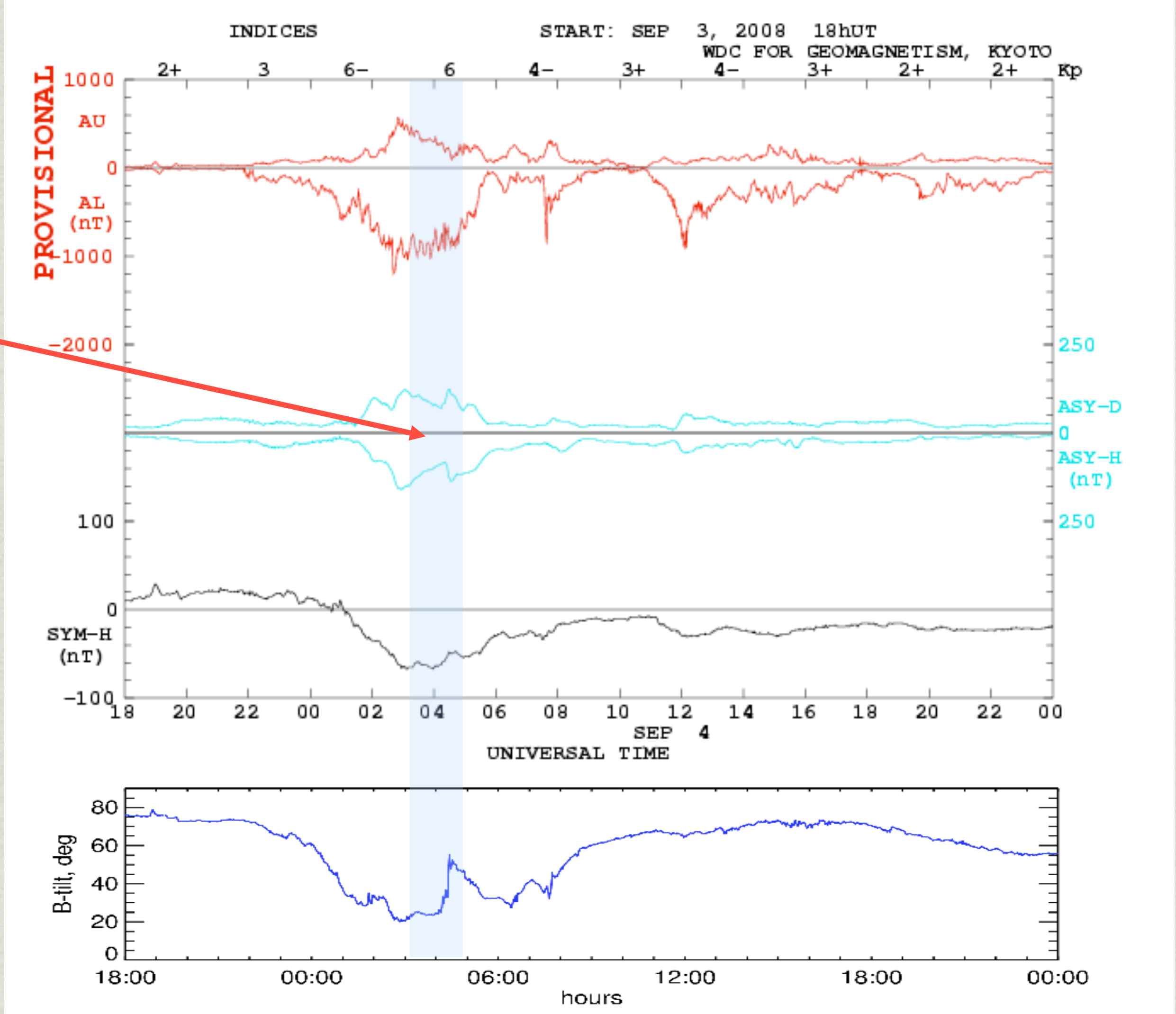
PROJECT SCIENTIST: MEI-CHING FOK (NASA)

PROGRAM SCIENTIST: BARBARA GILES (NASA)

SCIENCE ANALYSIS LEAD: JERRY GOLDSTEIN (SWRI)

September 04 2008, modest storm, end of main phase

TWINS 1 DATA



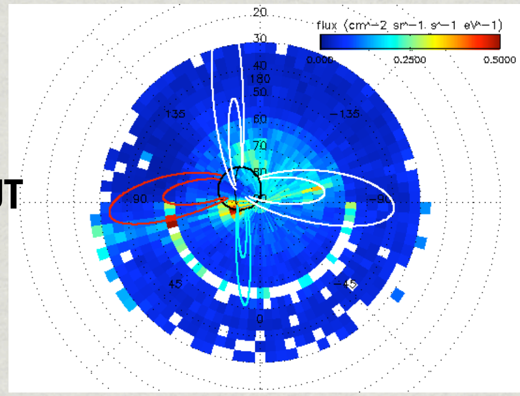
DIPOLARIZATION STARTS AT ~ 04:30 (GOES 12 , MLT ~ 23:30H)

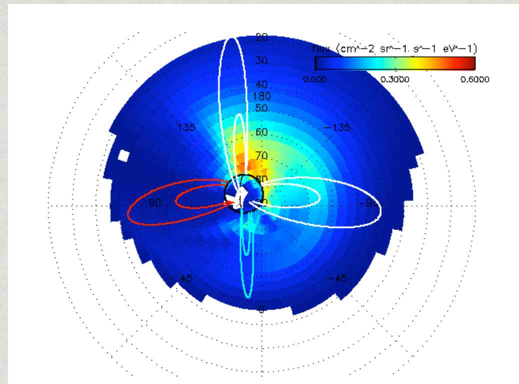
TWINS-CRCM Data-Model ENA comparison

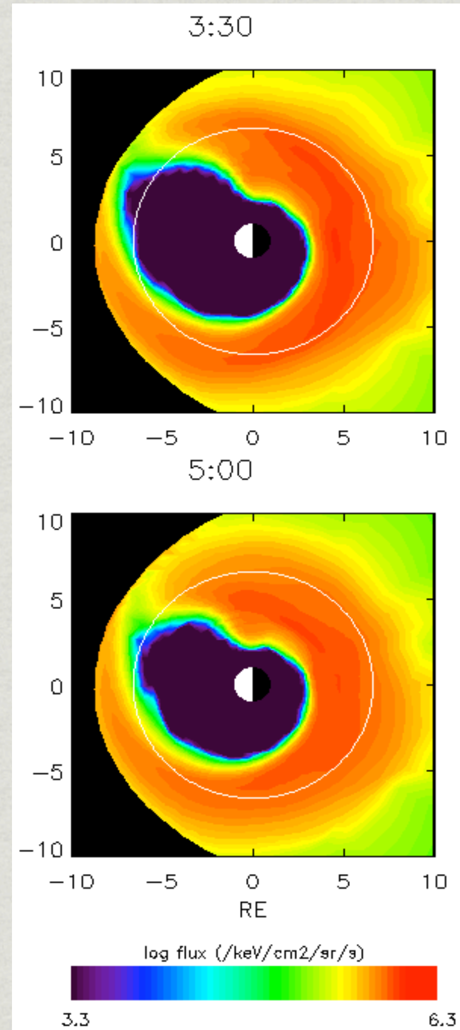
Ebihara&Ejiri model and T=10keV ENA / H+ energy = 12 keV

MAX = 0.5 **MAX = 0.6** **EQUATORIAL H+ FLUX**

03: 30 UT







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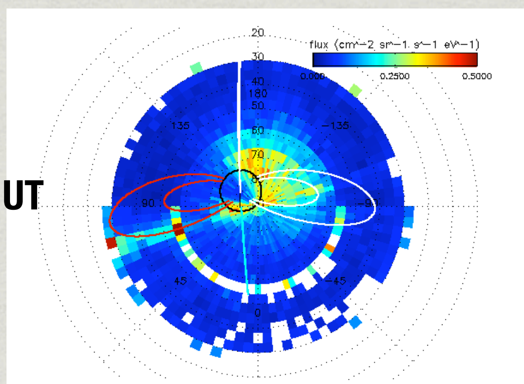
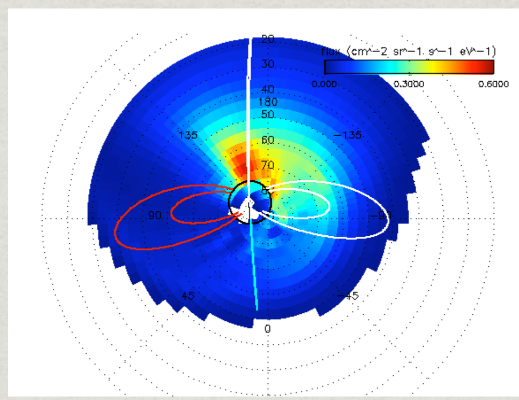
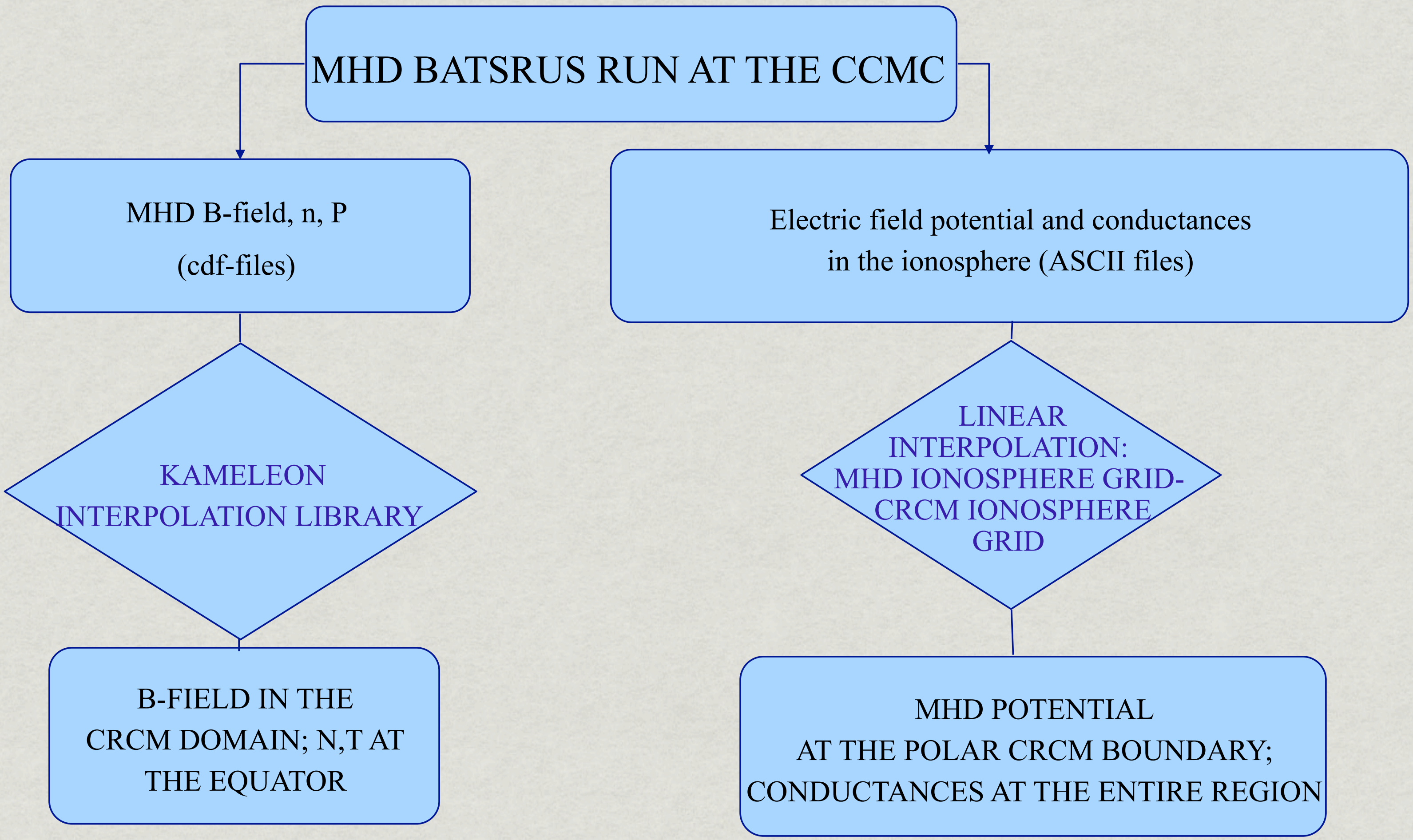




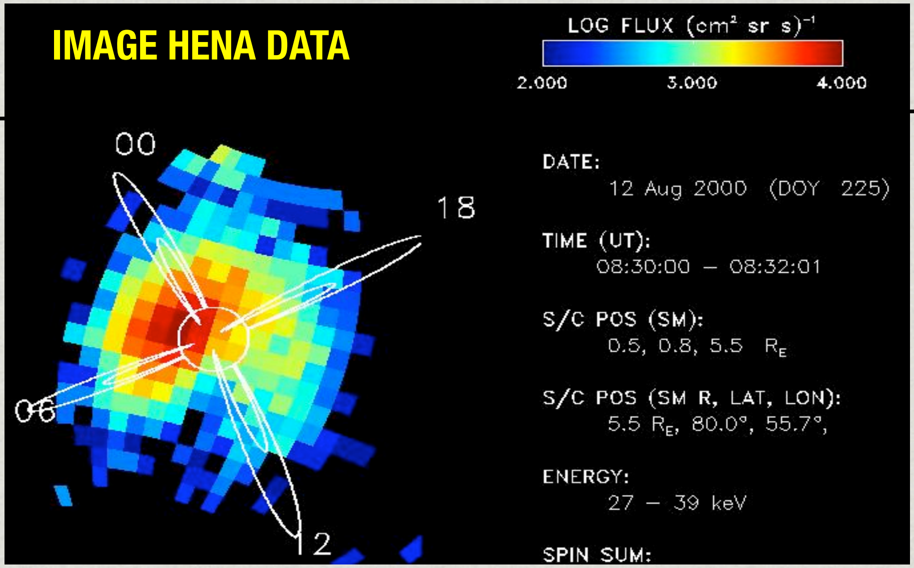
TWINS CRCM

CRCM-BATSRUS: One Way Coupling

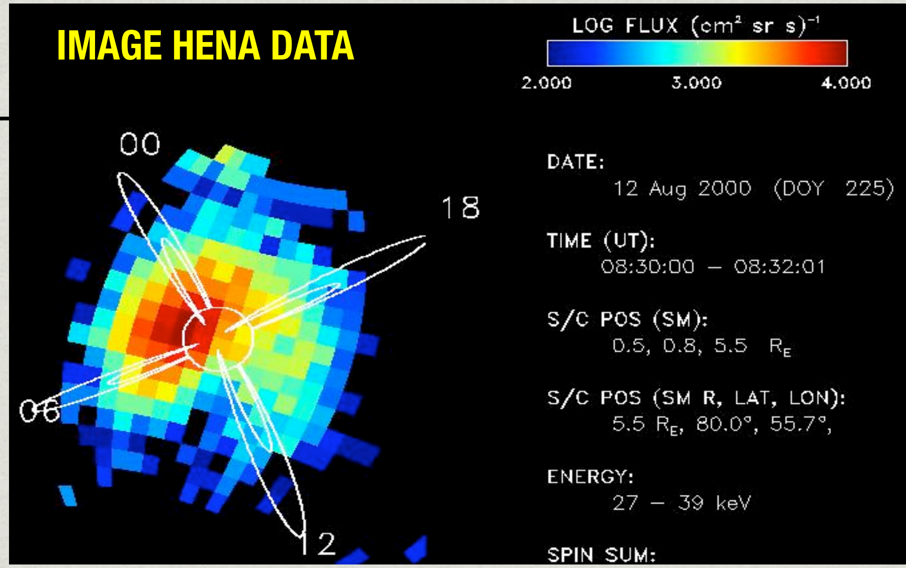


Buzulukova et. al. [2010], JGR, IN PRESS

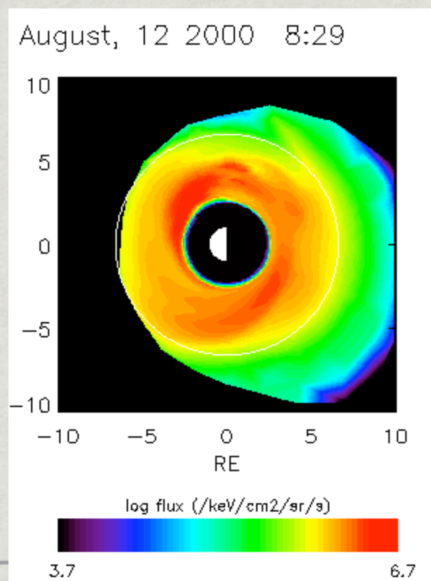
AUGUST 12 2000: POST-MIDNIGHT ENHANCEMENT OF THE RING CURRENT



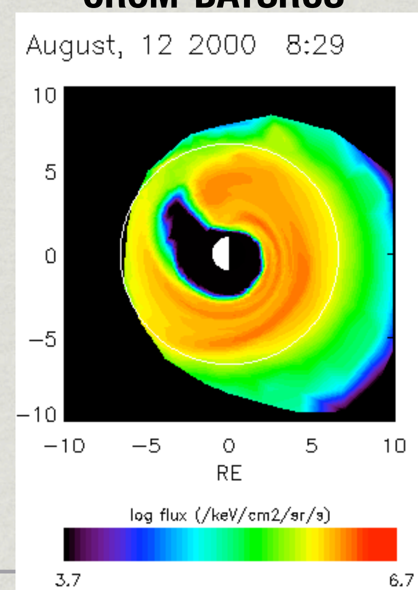
AUGUST 12 2000: POST-MIDNIGHT ENHANCEMENT OF THE RING CURRENT



FOK-BATSRUS

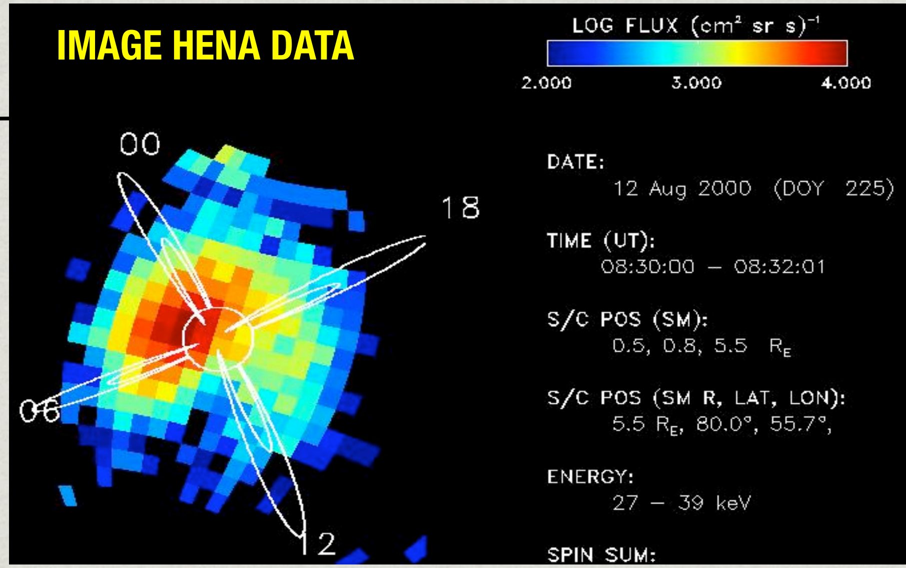


CRCM-BATSRUS

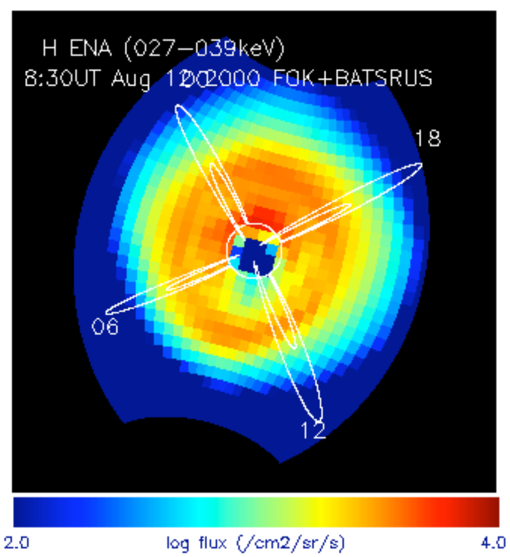


ION DISTRIBUTION

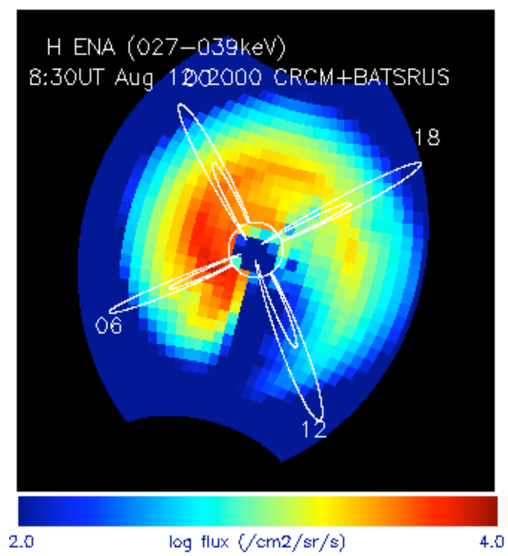
AUGUST 12 2000: POST-MIDNIGHT ENHANCEMENT OF THE RING CURRENT



FOK-BATSRUS

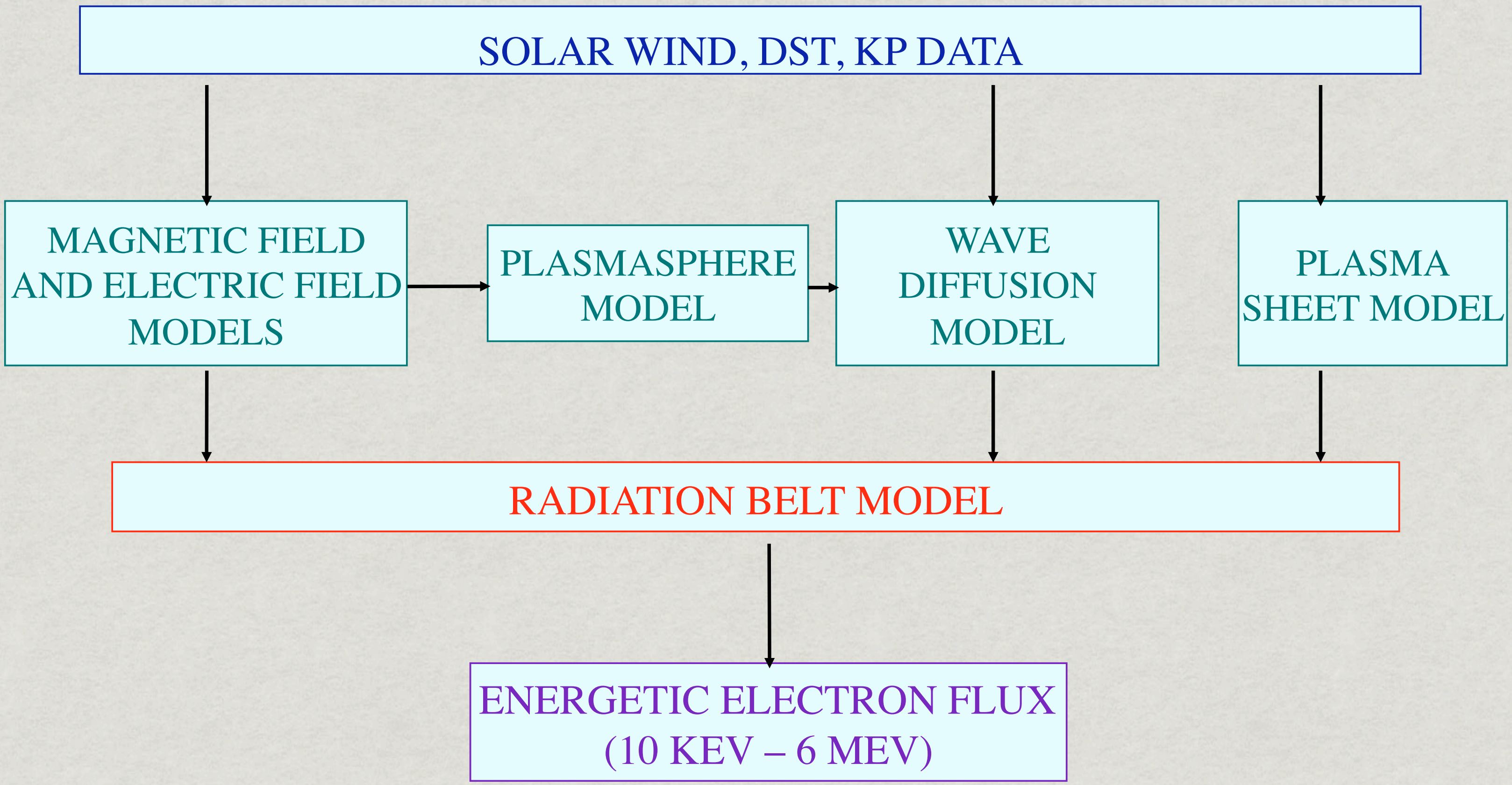


CRCM-BATSRUS



ENA EMISSION

The Radiation Belt Environment (RBE) model



Radiation Belt Environment model: Equations

$$\frac{\partial f_s}{\partial t} + \left\langle \dot{\lambda}_i \right\rangle \frac{\partial f_s}{\partial \lambda_i} + \left\langle \dot{\phi}_i \right\rangle \frac{\partial f_s}{\partial \phi_i} = \frac{1}{G} \frac{\partial}{\partial \alpha_o} \left[G \left(D_{\alpha_o \alpha_o} \frac{\partial f_s}{\partial \alpha_o} + D_{\alpha_o E} \frac{\partial f_s}{\partial E} \right) \right] +$$

$$\frac{1}{G} \frac{\partial}{\partial E} \left[G \left(D_{EE} \frac{\partial f_s}{\partial E} + D_{E \alpha_o} \frac{\partial f_s}{\partial \alpha_o} \right) \right] - \left(\frac{f_s}{0.5 \tau_b} \right)_{\substack{\text{loss} \\ \text{cone}}}$$

$f_s = f_s(t, \lambda_i, \phi_i, M, K)$: phase space density of electrons

λ_i: magnetic latitude at the ionosphere

ϕ_i: magnetic local time at the ionosphere

M : magnetic moment

K : longitudinal invariant

$\left\langle \dot{\lambda}_i \right\rangle, \left\langle \dot{\phi}_i \right\rangle$: drift velocities (convection + magnetic drift + corotation)

$G = T(\alpha_o) \sin 2\alpha_o (E + E_o) \sqrt{E(E + 2E_o)}$, E_o = rest mass energy, and $T(\alpha_o) = \frac{1}{2R_o} \int_{s_m}^{s_m^*} \frac{ds}{\cos \alpha}$

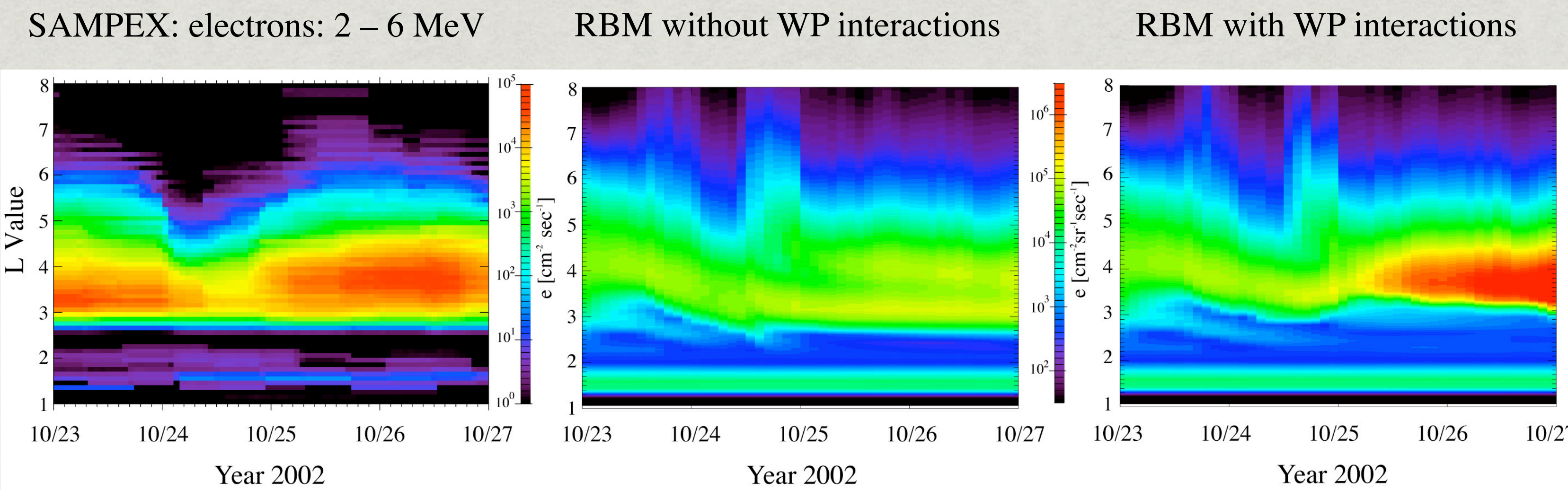
τ_b: bounce period

Radial diffusion is included implicitly in the time-varying magnetic and electric fields.

Radiation Belt Environment (RBE) Model: Inputs

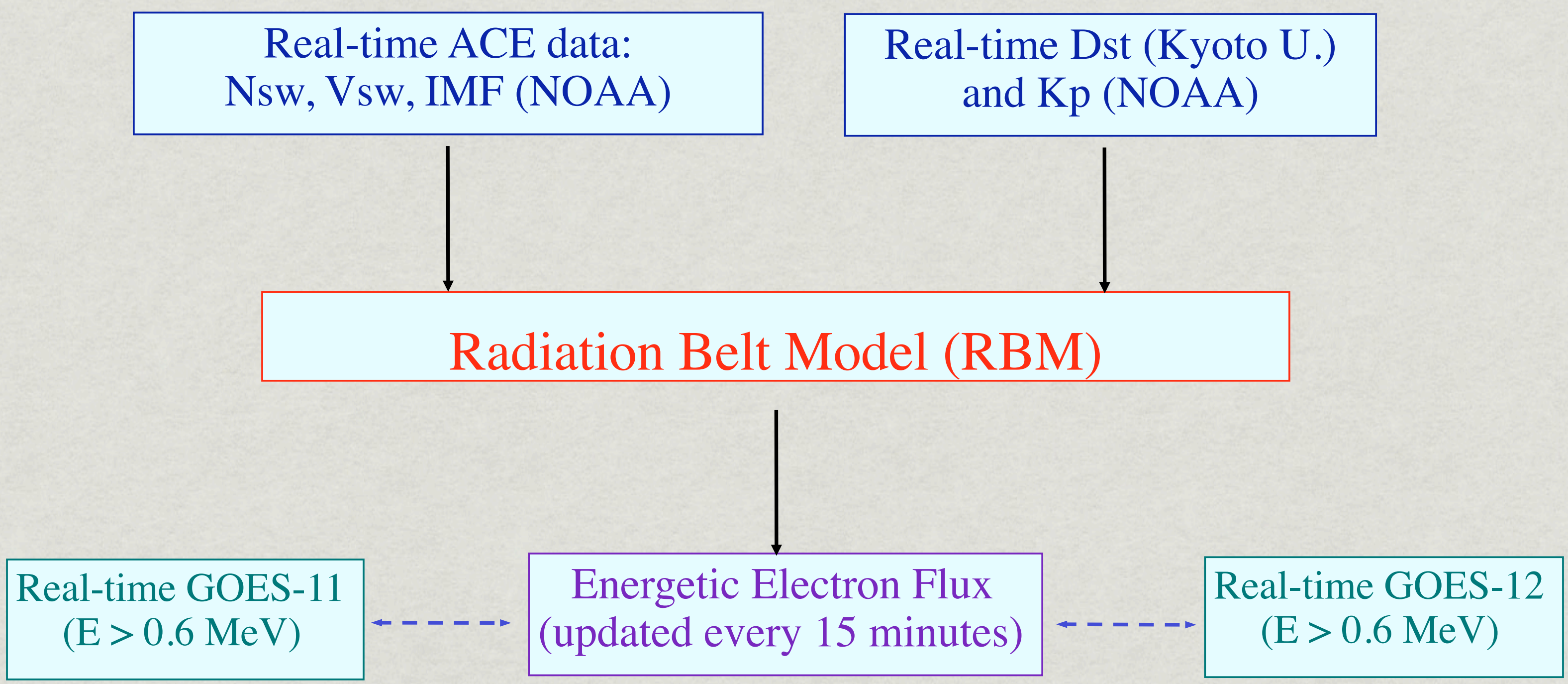
- Dst, Kp: Kyoto University Geomagnetic Data Service
- Shifted solar wind data: ACE or WIND Satellite
- Magnetic field model: T96 or T04 (updated 5min)
- Electric field model: Weimer Model (updated 3s)
- Plasmasphere model: Ober and Gallagher model
- Diffusion coefficients: Horne's PADIE code
- Distribution at outer boundary: Kappa distribution

RBE Simulation vs. SAMPEX data:
October 23-27, 2002

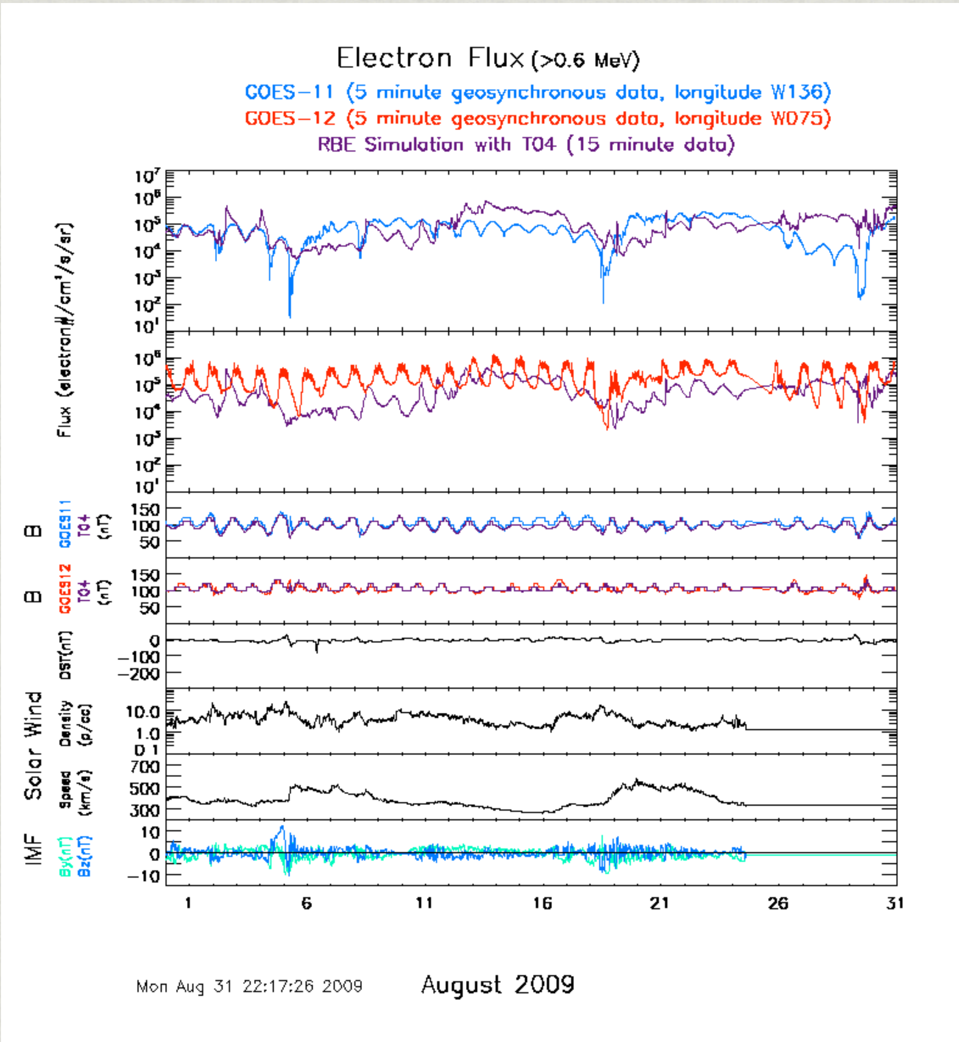


- Low initial flux in the RBE simulations are due to quiet-time initial condition
- RBE simulation without wave-particle interactions show little enhancement during storm recovery.

Real-Time Radiation Belt Simulations

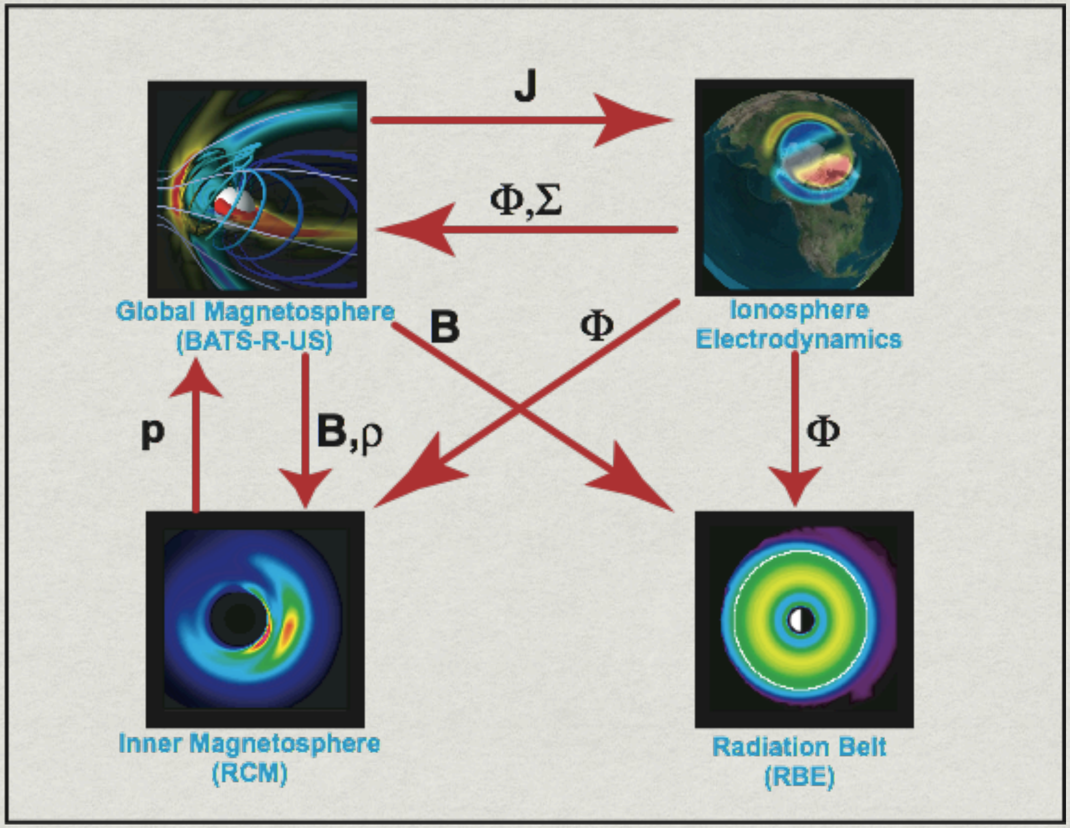


Real Time Example: November 2008



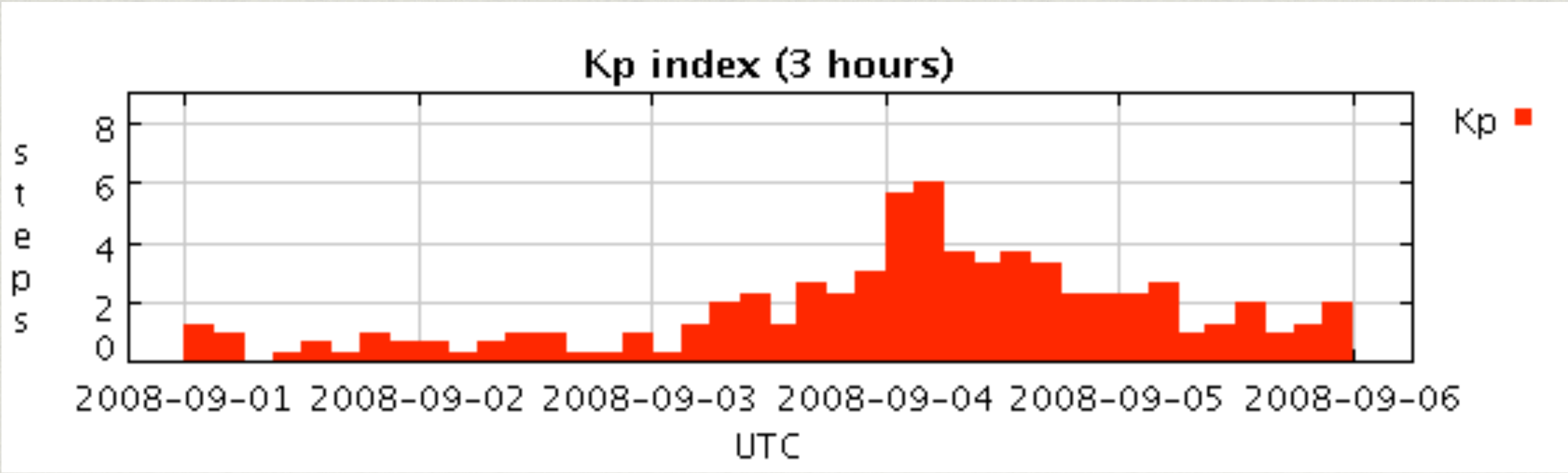
The disagreement between model and data mainly comes from lack of substorm features in the model

SWMF: Information Exchange



Glocer et al.,[2009], Journal of Atmospheric and Solar-Terrestrial Physics, 71, 1653–1663

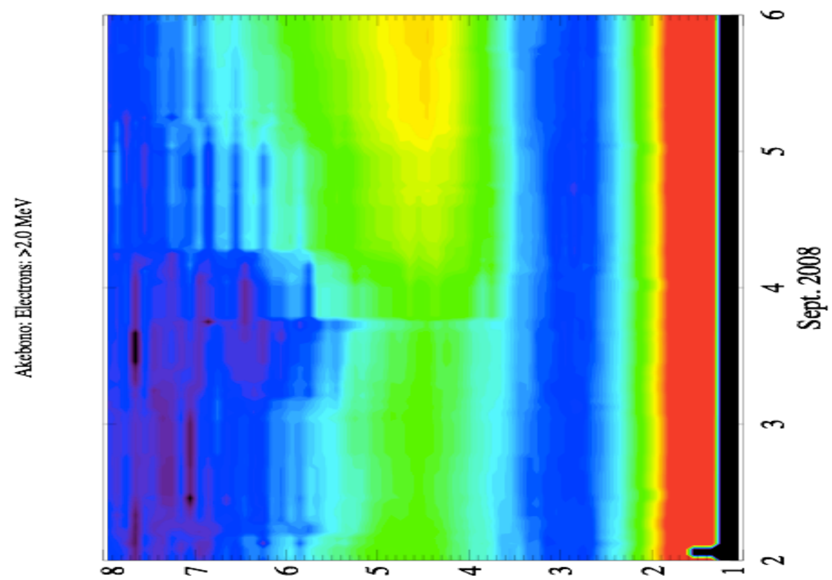
Case Study: Sept. 2008 Event

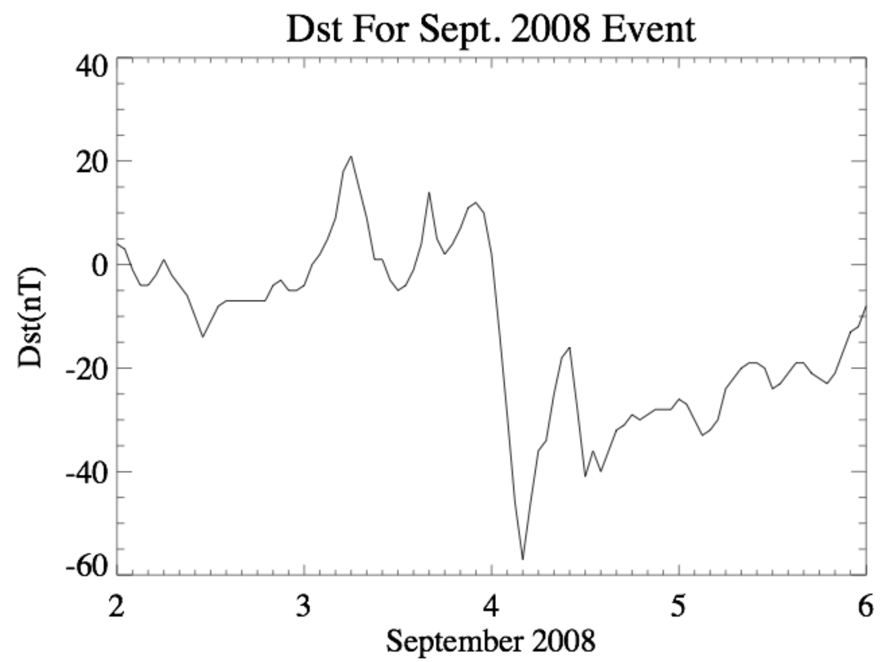


- On September 4, 2008 A moderate geomagnetic event occurred with Kp reaching as high as 6.
- Dst reaches a minimum of -55 early on the 4th.
- The Akebono spacecraft measures an increase in the >2 MeV electron flux.
- The outer belt electron flux reaches higher values after the Dst effect drop out (according to Akebono and GOES data).

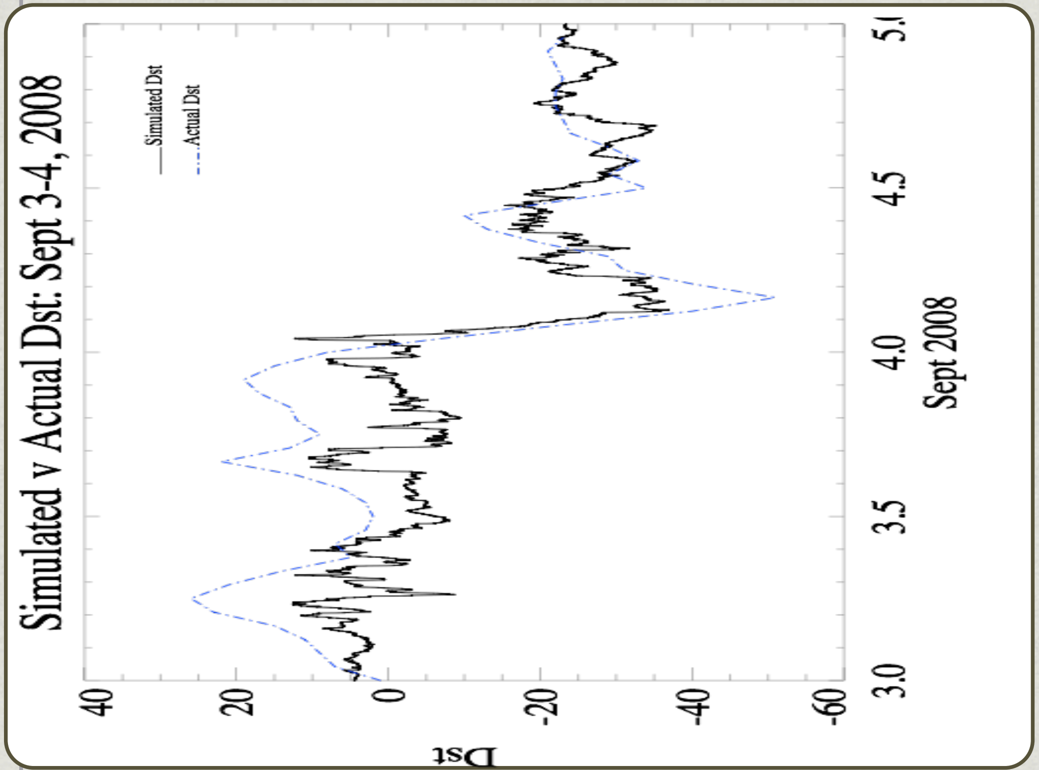
Sept. 2008: Dst and Akebono data

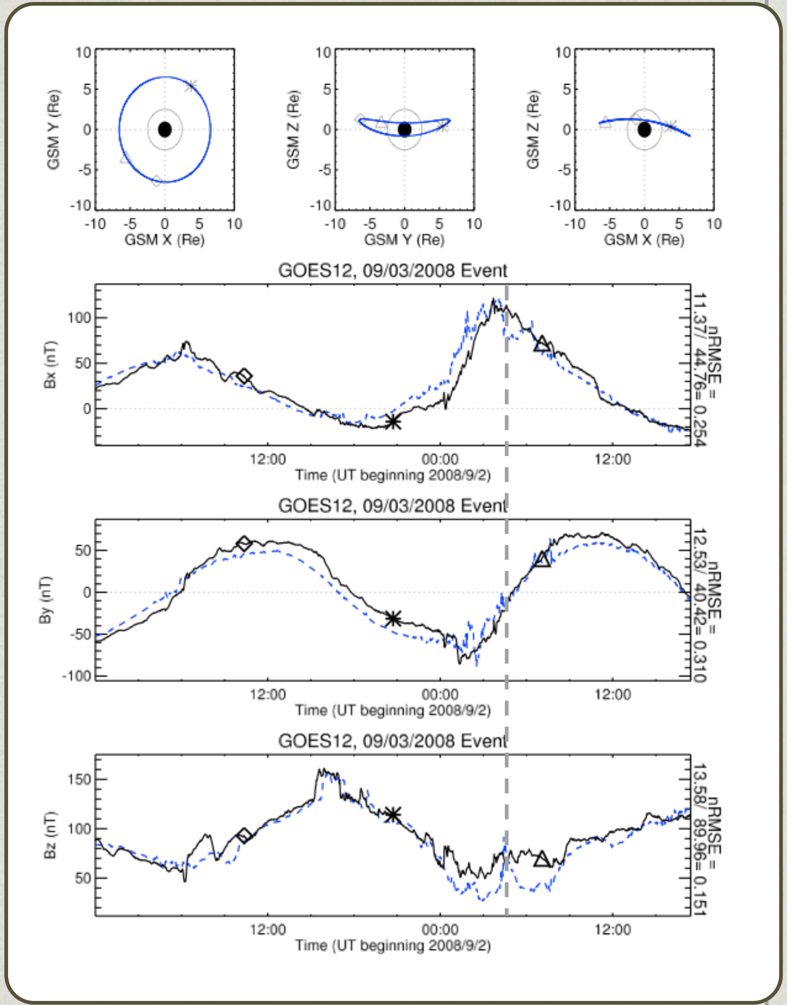
AKEBONO ELECTRONS: >2.0 MEV



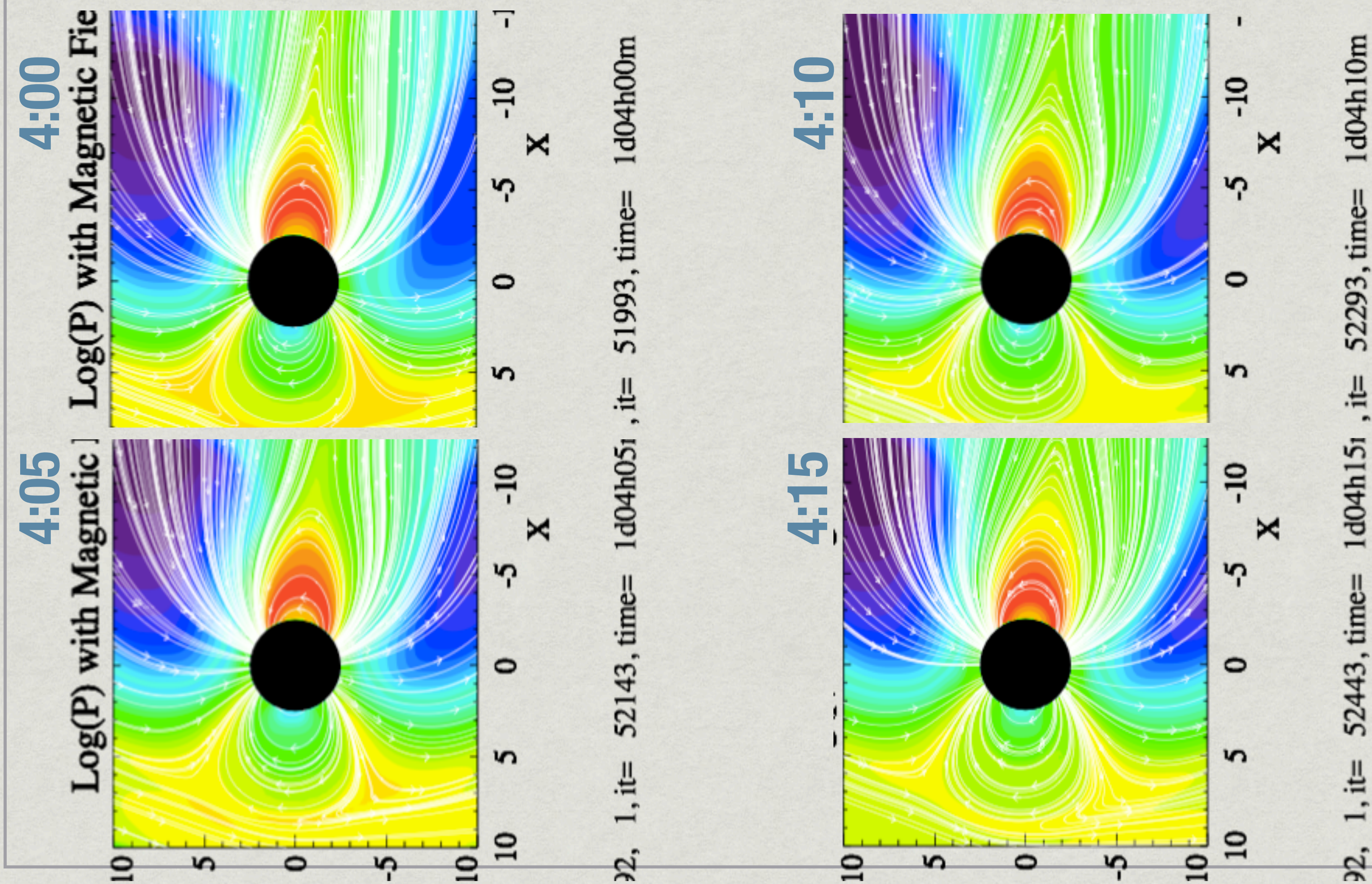


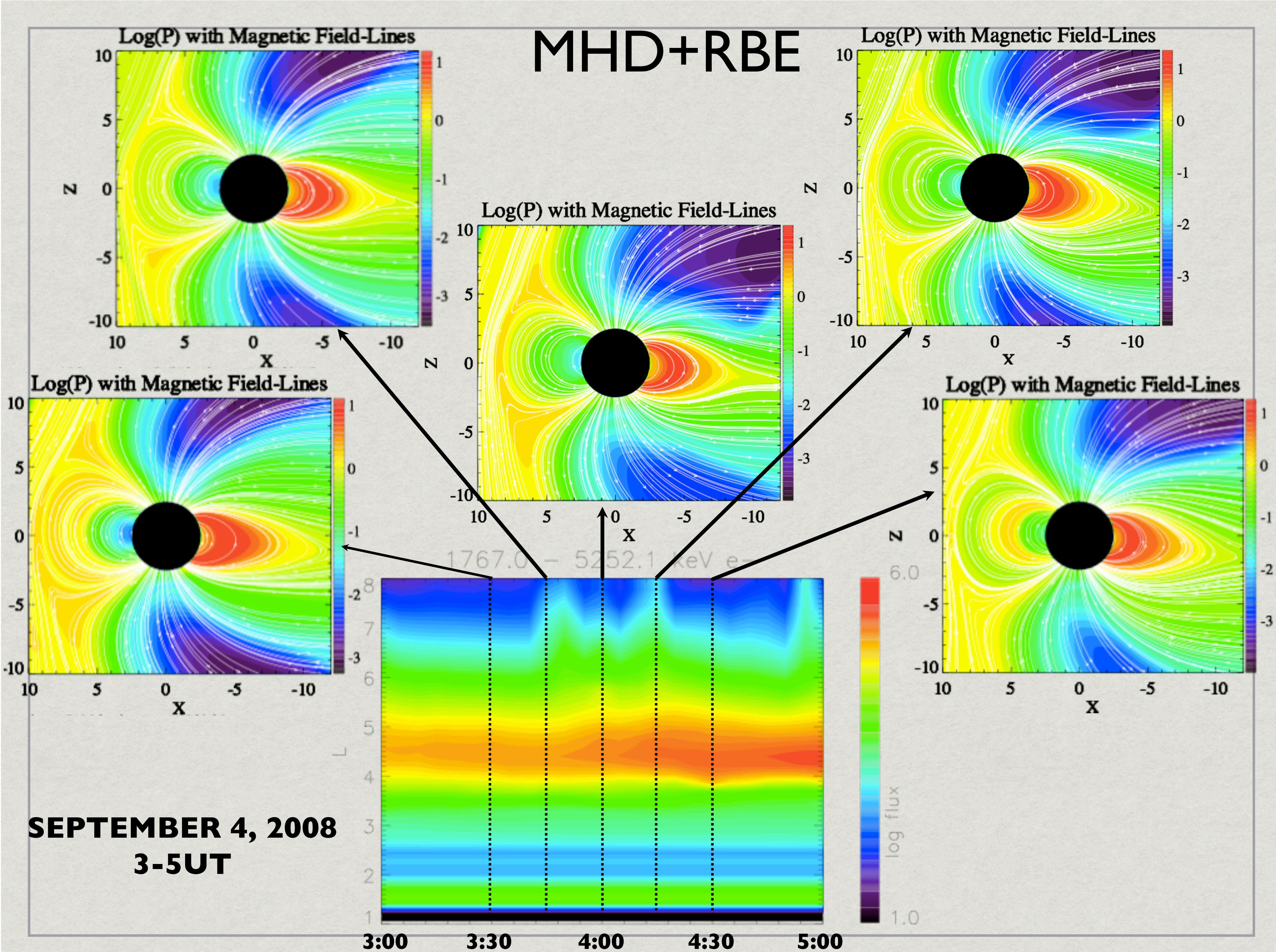
Simulated Dst and B-Field from MHD





Magnetic Field Configuration During Flux Increase




MHD+RBE
Log(P) with Magnetic Field-Lines
Log(P) with Magnetic Field-Lines
Log(P) with Magnetic Field-Lines
Log(P) with Magnetic Field-Lines
Log(P) with Magnetic Field-Lines
1767.0 – 5252.1 keV e-
log flux
6.0
1.0
L
3:00
3:30
4:00
4:30
5:00
SEPTEMBER 4, 2008
3-5UT

Conclusions

- The CRCM and RBE models can be used with both empirical fields, and MHD derived fields.
- We have used the CRCM with T96 and with BATSRUS in order to study ENAs observed by TWINS and IMAGE missions.
- We have used the RBE with T04 and BATSRUS to study energetic electron enhancements observed by Akebono and SAMPEX spacecrafts.
- Other notes:
  - Two way coupled CRCM - OpenGGCM is coming along well.
  - The coupled RBE-BATSRUS should be available at CCMC soon.

Extra Slides

CRCM ENAs for three runs (12 keV)

Tsyganenko&Mukai PS model

Ebihara&Ejiri density temperature T =10keV

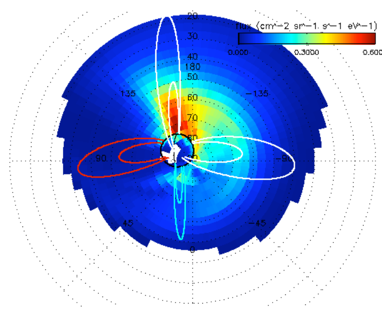
Ebihara&Ejiri density temperature T=3keV

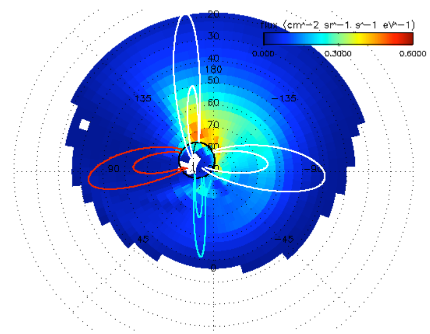
Max = 0.6

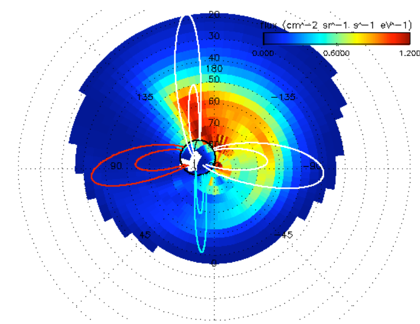
Max = 0.6

Max = 1.2

03:30 UT







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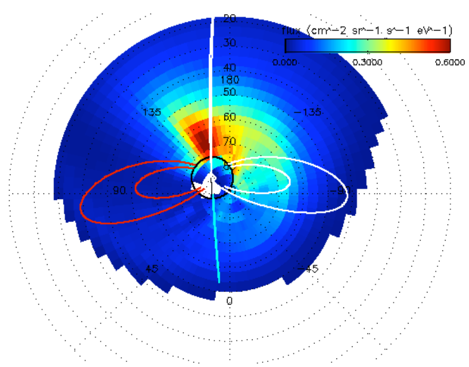
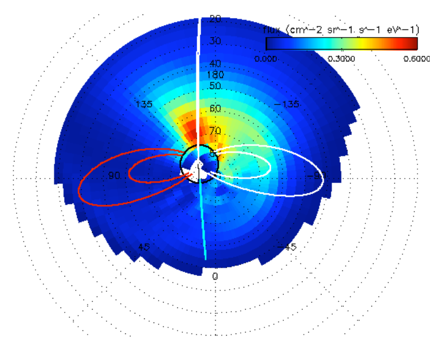
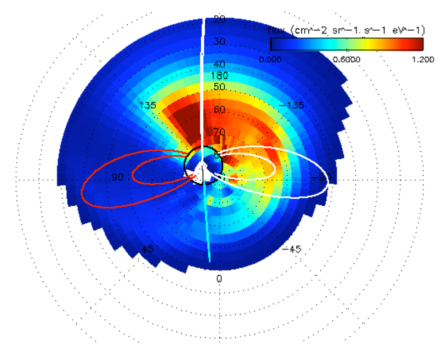




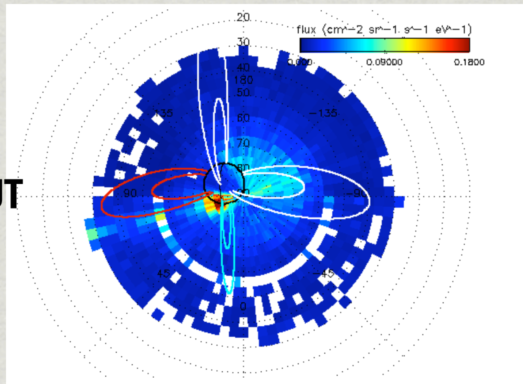


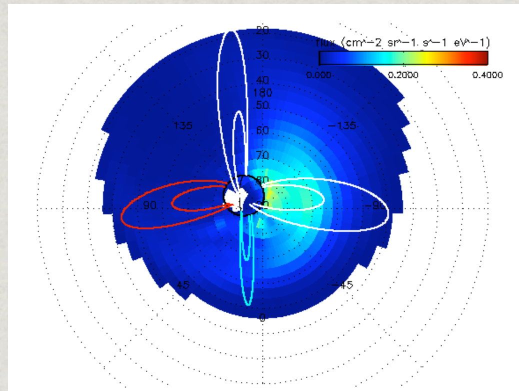
TWINS-CRCM DATA-MODEL COMPARISON DENSITY

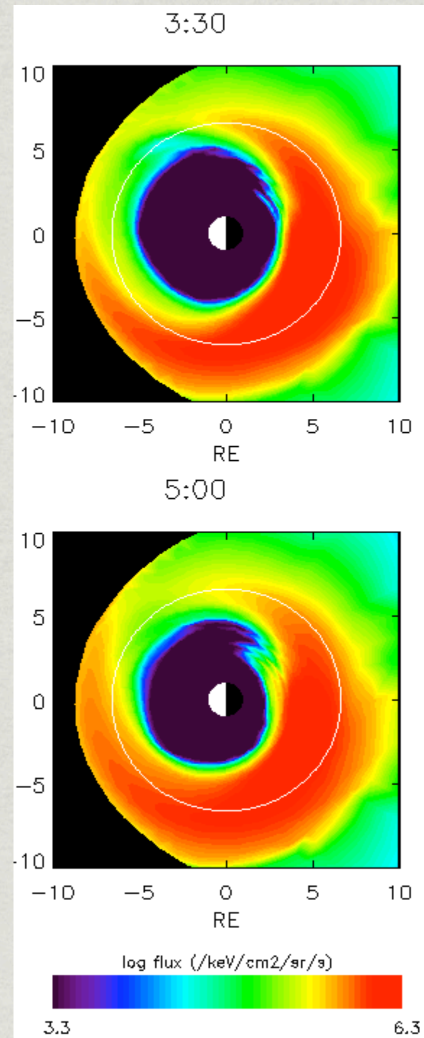
Ebihara&Ejiri model and T=10keV ENA / H+ energy = 30 keV

MAX = 0.18 | **MAX = 0.4** | **EQUATORIAL H+ FLUX**

03: 30 UT







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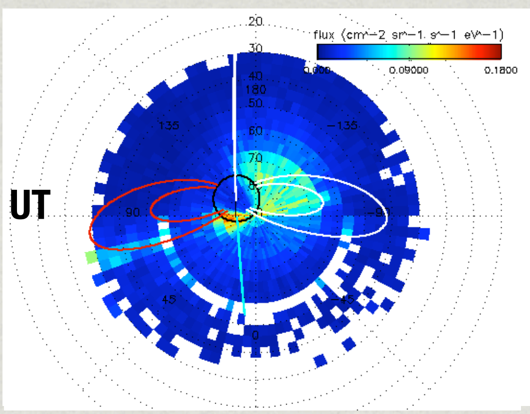
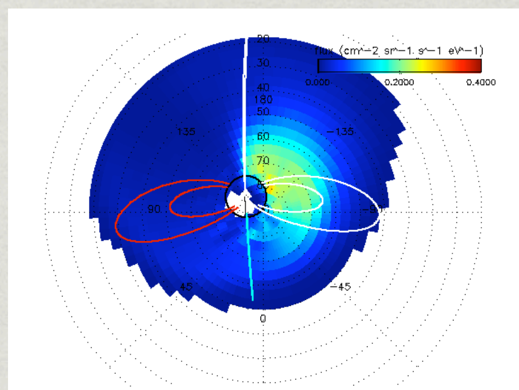


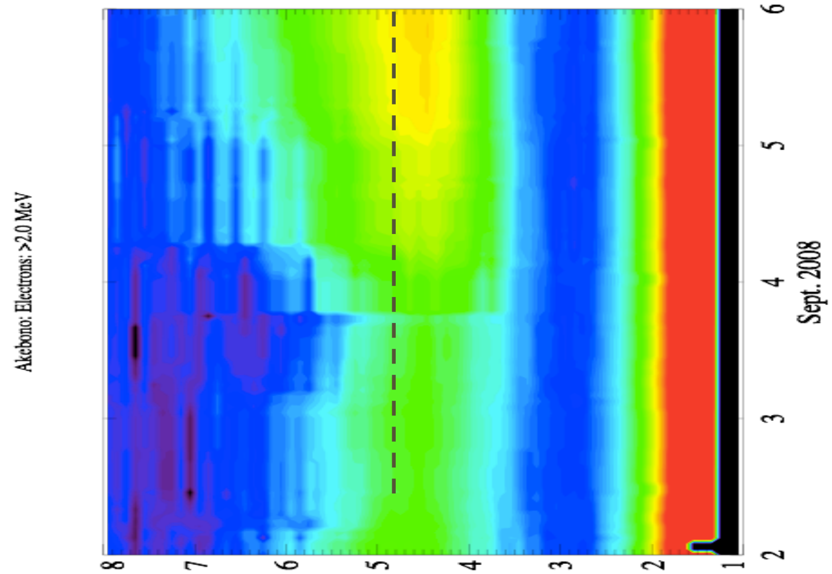


TWINS

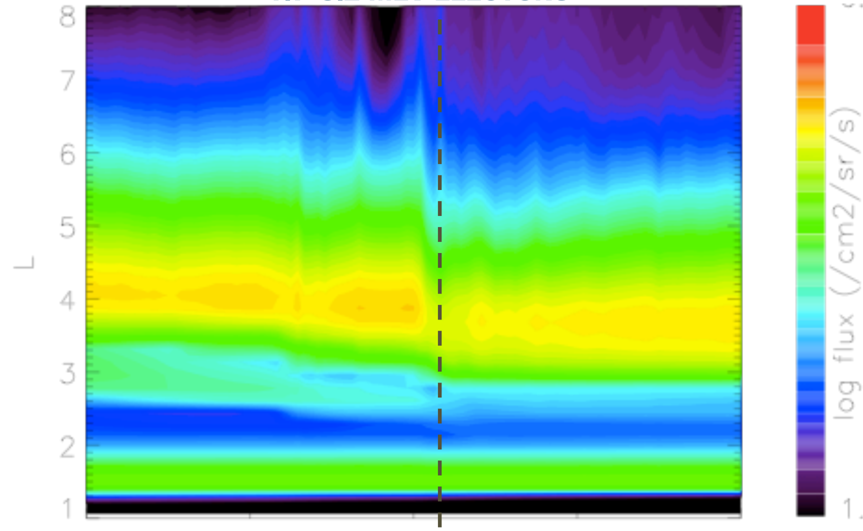
CRCM

Sept. 2008: No Waves

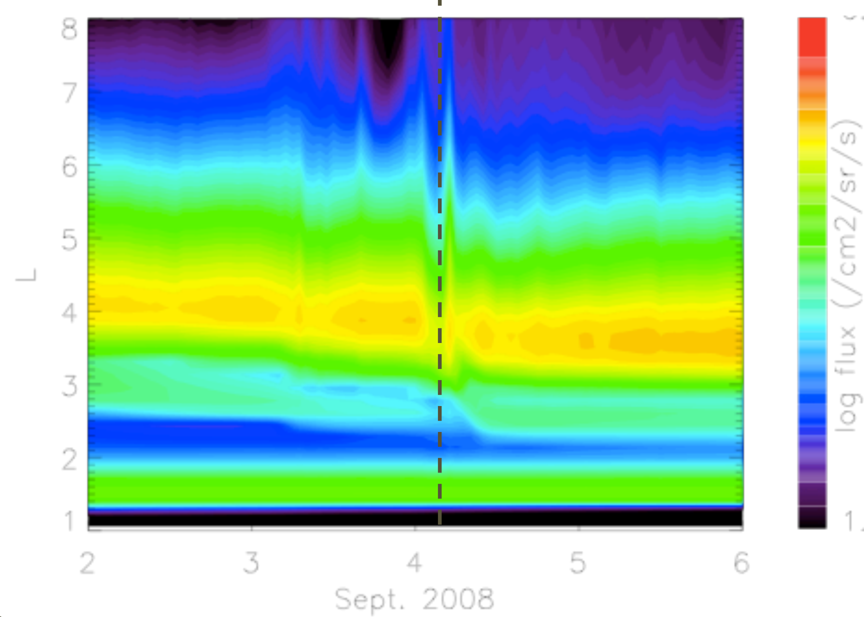
AKEBONO ELECTRONS: >2.0 MEV



1.7-5.2 MEV ELECTONS

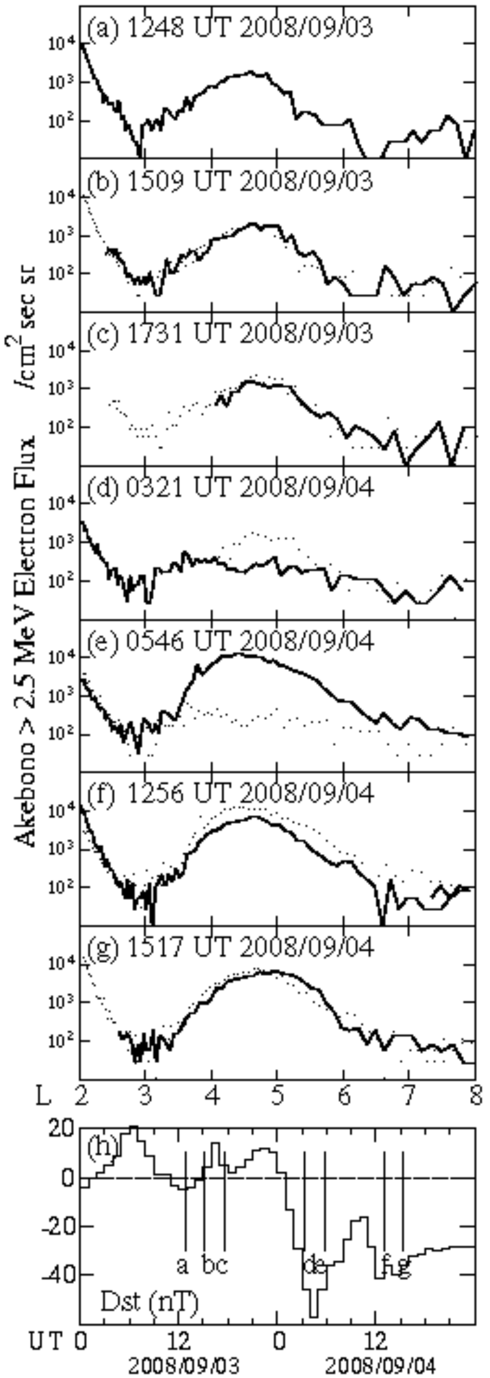


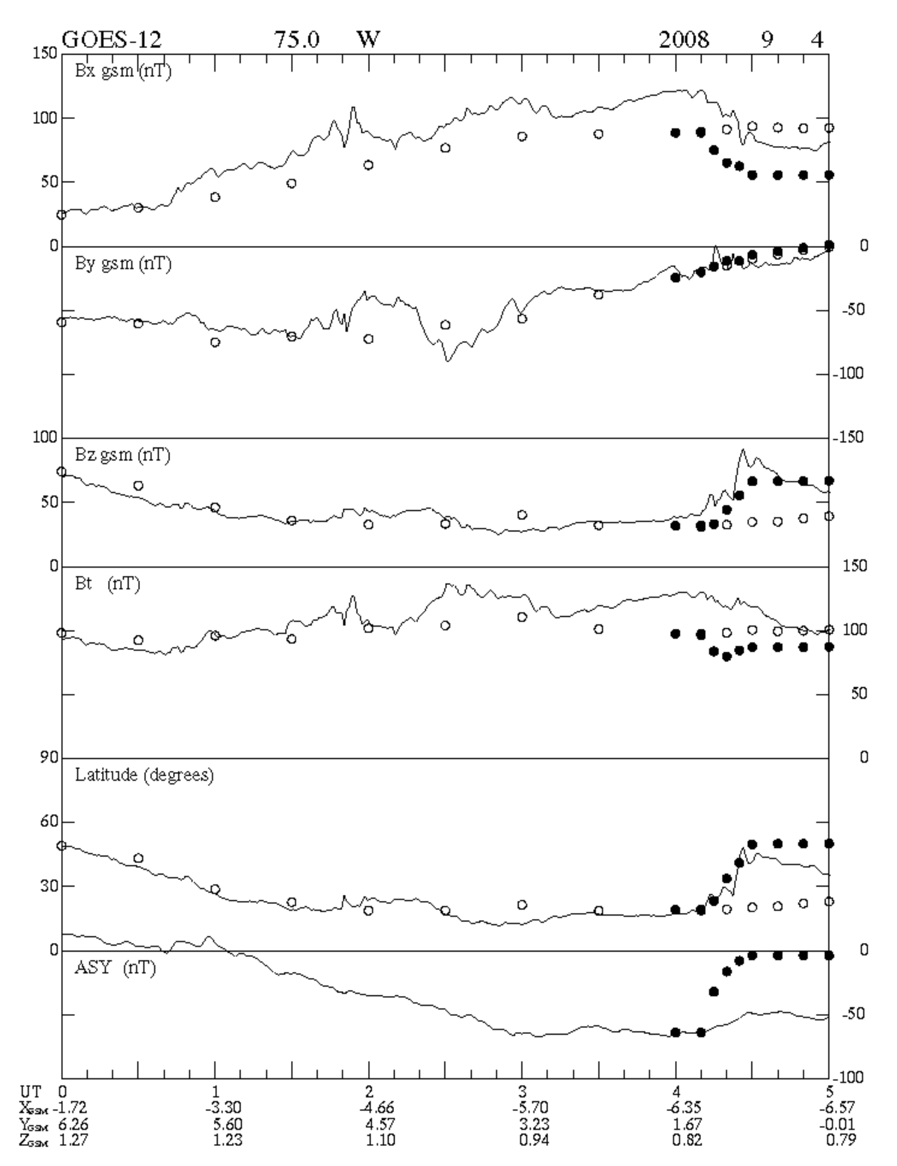
MODIFIED B: 1.7-5.2 MEV ELECTONS



- RBE with no waves as compared to Akebono.
- B-Field from T04 using original and modified inputs
- Dipolarization of B-field has a large effect!

Dipolarization?

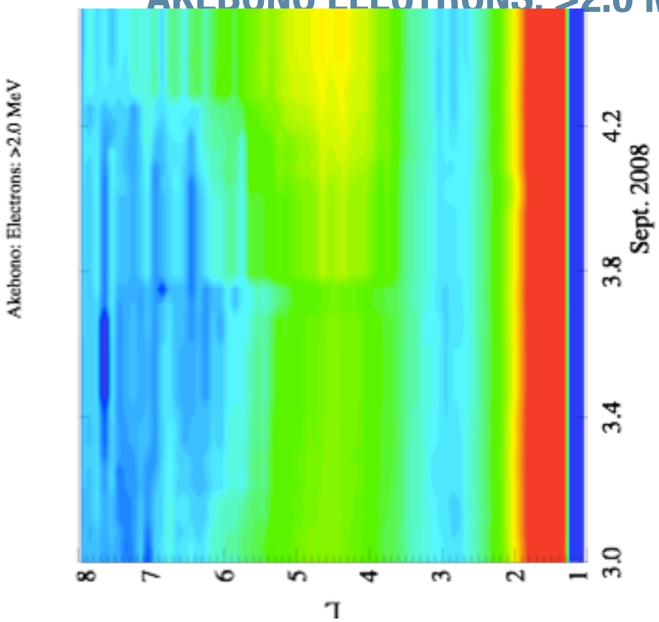




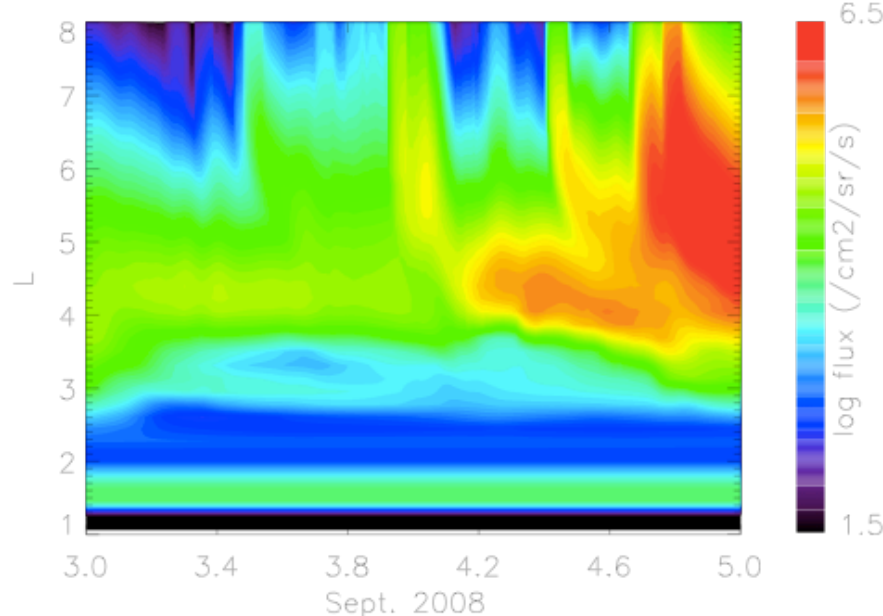
COURTESY OF T. NAGAI

Sept. 2008: RBE with MHD B-Field

AKEBONO ELECTRONS: >2.0 MEV



MHD: 1.7-5.2 MEV ELECTONS



- RBE without waves as compared to Akebono.
- B-Field from MHD with updates provided every 10 seconds (See *Glocer et al.* [2009] for coupling details)
- The timing of the enhancement is well predicted.
- Dynamic magnetic field model leads to a dynamic radiation belt electron population.