CRCM and Beyond

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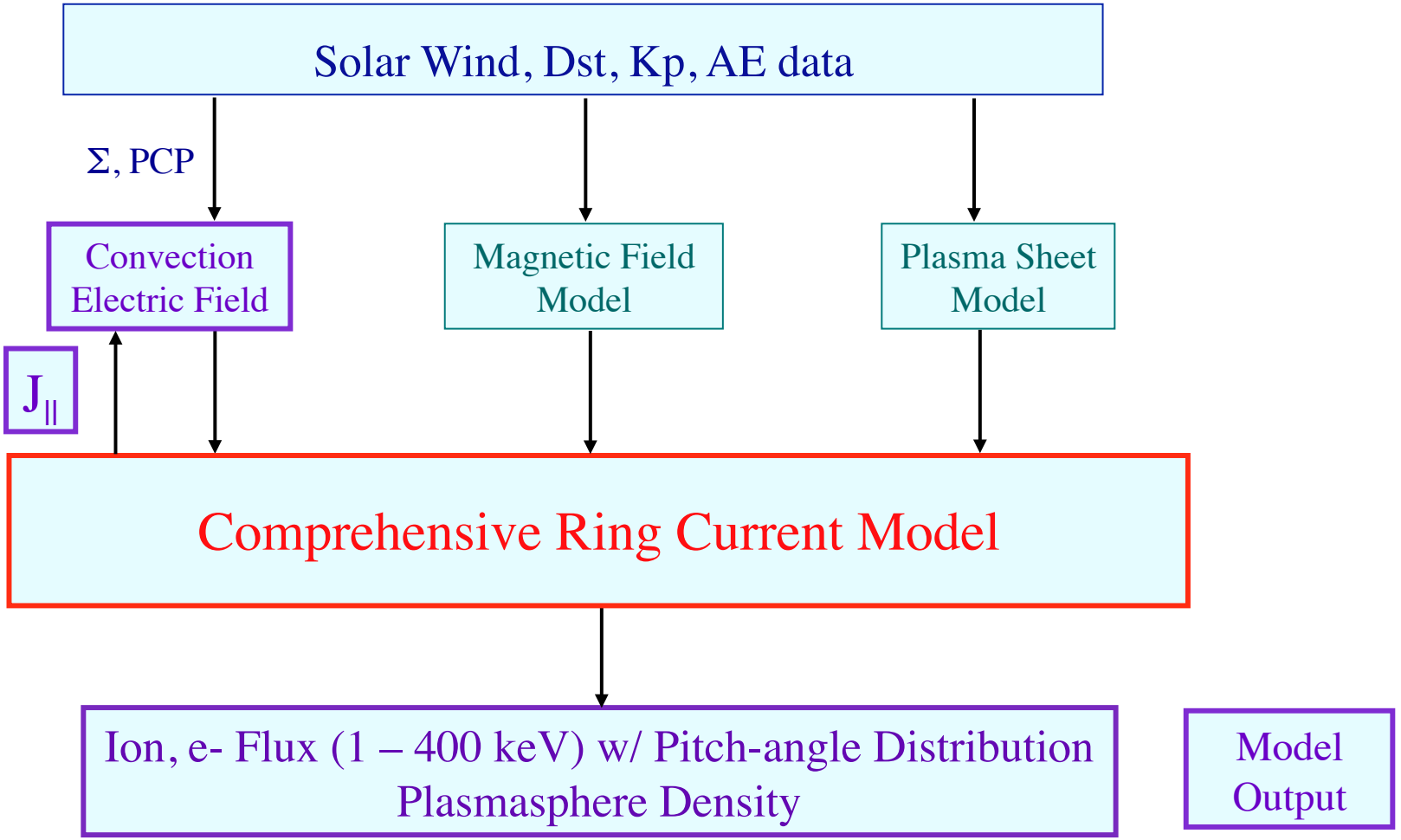
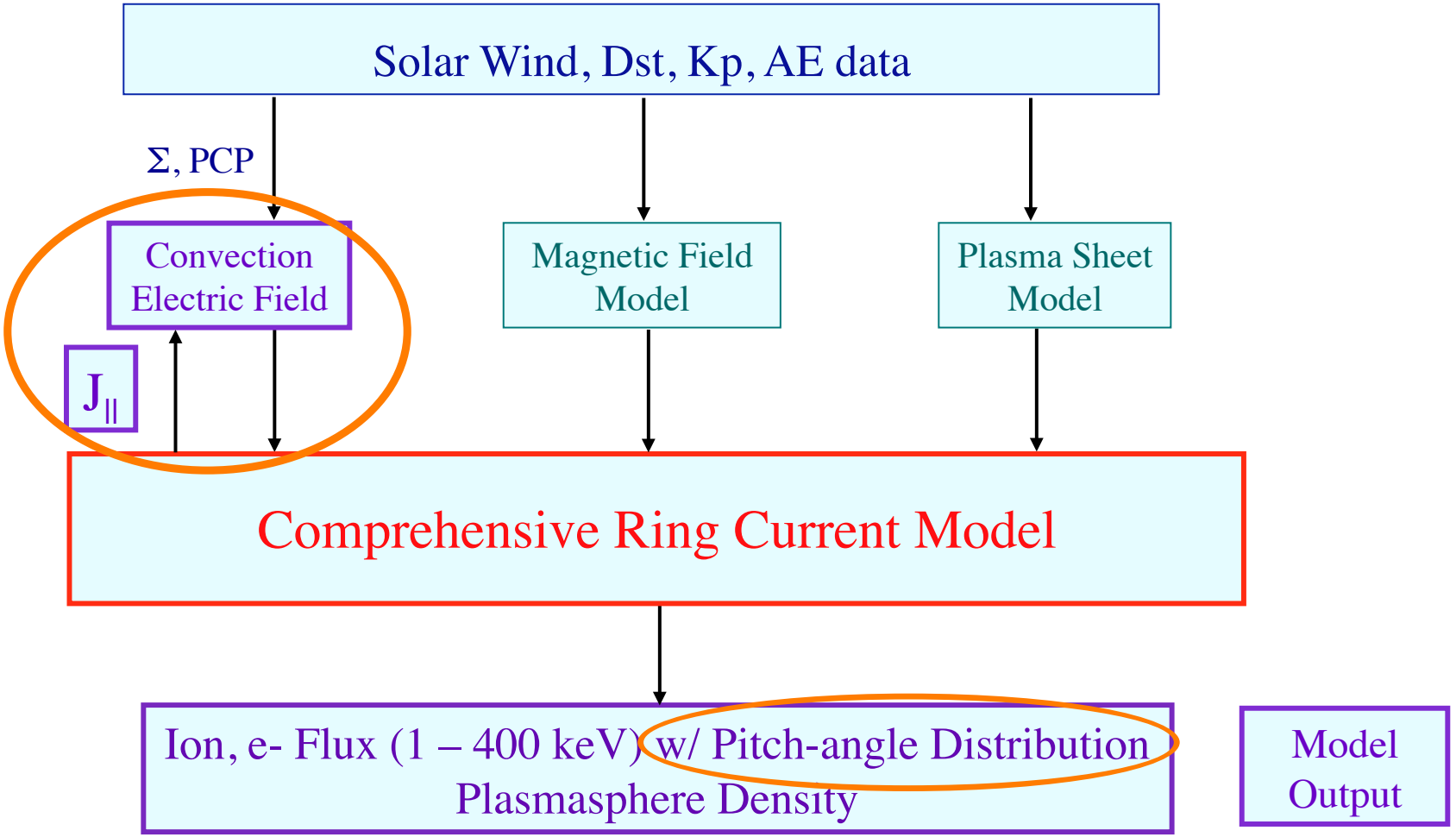
CRCM to CIMI

- CRCM: Comprehensive Ring Current Model
- RBE: Radiation Belt Environment Model
- CRCM + RBE → CIMI
  CIMI: Comprehensive Inner Magnetosphere-Ionosphere Model
- CIMI Simulation of a magnetic storm
- CIMI at CCMC

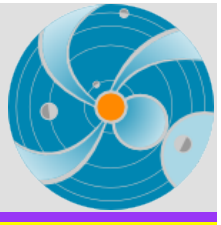
CRCM: Comprehensive Ring Current Model



CRCM: Comprehensive Ring Current Model

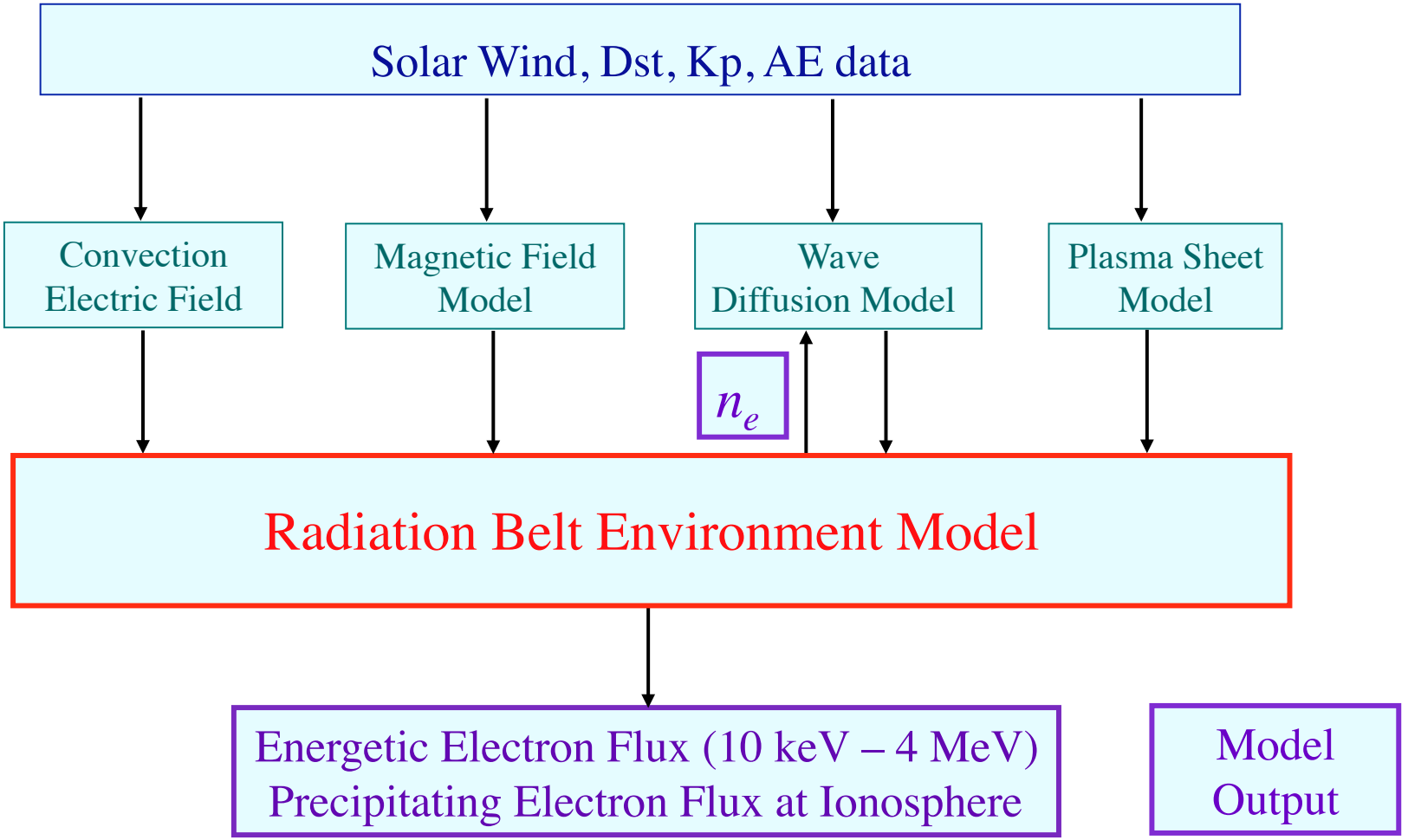


CRCM at CCMC



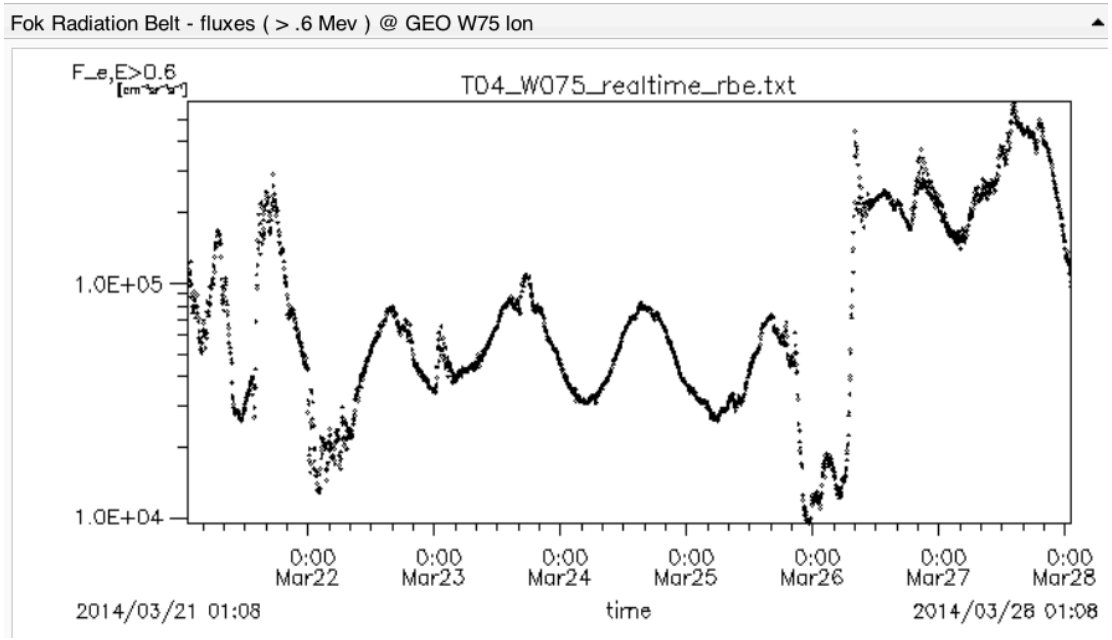
Model Name	Developer(s)	Institution	Model Class	Services Available				
				Runs on Request	Instant Run	Real Time Run	Widget	Source Code on ftp
Global Magnetosphere:								
LANL*	Yiqun Yu, Josef Koller	LANL			X			X
BATS-R-US	Dr. Tamas Gombosi et al.	CSEM	Physics-based MHD	X		X	X	
SWMF/BATS-R-US with RCM	Tamas Gombosi et al., Richard Wolf et al., Stanislav Sazykin et al., Gabor Toth et al.	CSEM	Physics-based MHD	X				
SWMF/BATS-R-US with CRCM	Tamas Gombosi et al., Mei-Ching Fok et al., Gabor Toth et al.	CSEM	Physics-based MHD	X				
OpenGGCM	Joachim Raeder, Timothy Fuller-Rowell	Space Science Center, UNH	Physics-based MHD	X				
GUMICS	Pekka Janhunen et.al.	FMI	physics-based MHD	X				
CMIT/LFM-MIX	John Lyon, Wenbin Wang, Slava Merkin, Mike Wiltberger, Pete Schmitt, and Ben Foster	Dartmouth College/NCAR-HAO/JHU-APL/CISM	physics-based MHD	X				
Plasmasphere	Viviane Pierrard	IASB-BIRA		X				
WINDMI	W. Horton, M. L. Mays, E. Spencer and I. Doxas	Univ. of Texas at Austin	physics-based		X	X		

RBE: Radiation Belt Environment Model



RBE at iSWA/CCMC

RBE e- flux
(> .6 MeV)
at GEO W75



RBE at iSWA/CCMC

RBE e- flux
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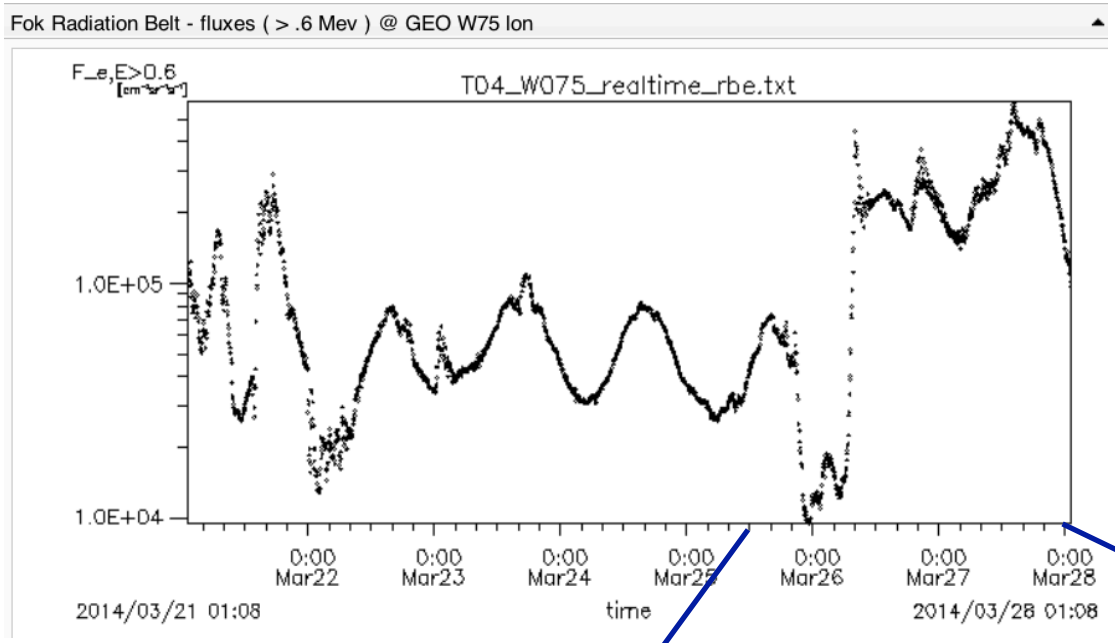
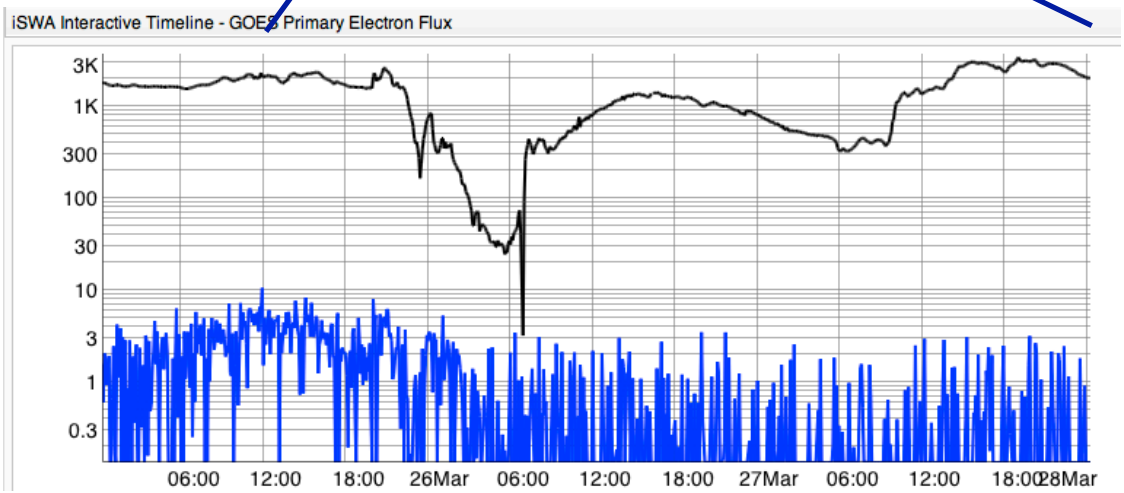


GOES electron flux
(> .8 MeV and > 2 MeV)



RBE at iSWA/CCMC

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(> .6 MeV)
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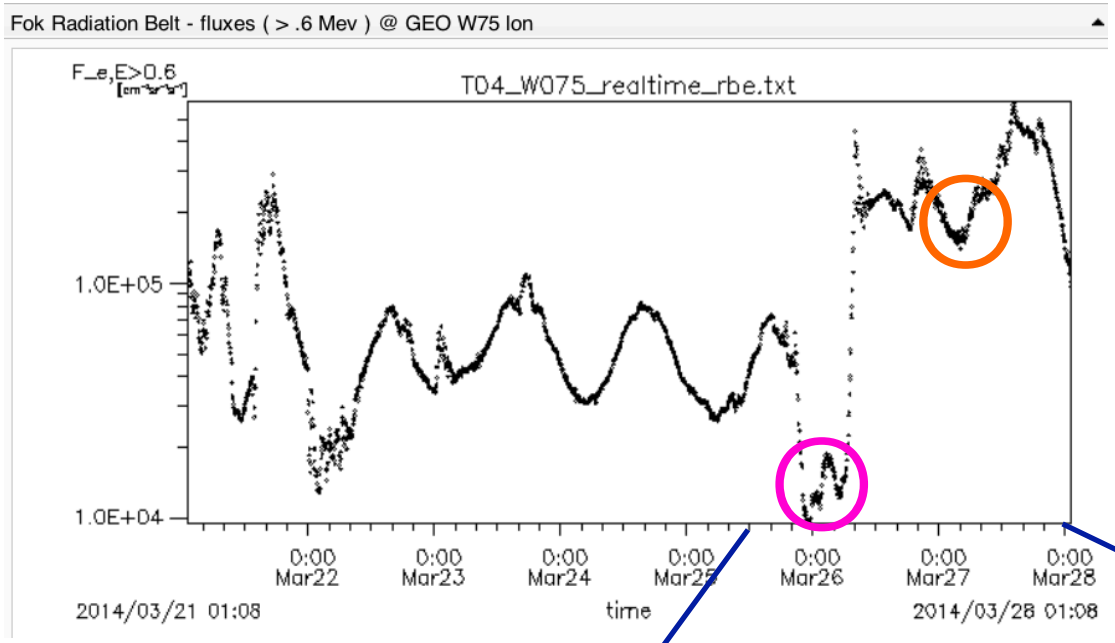

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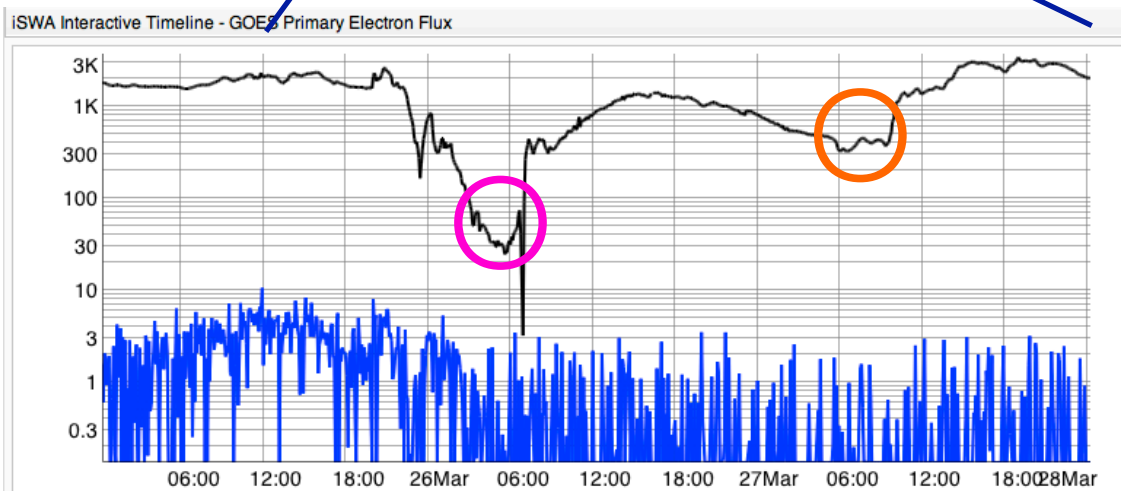
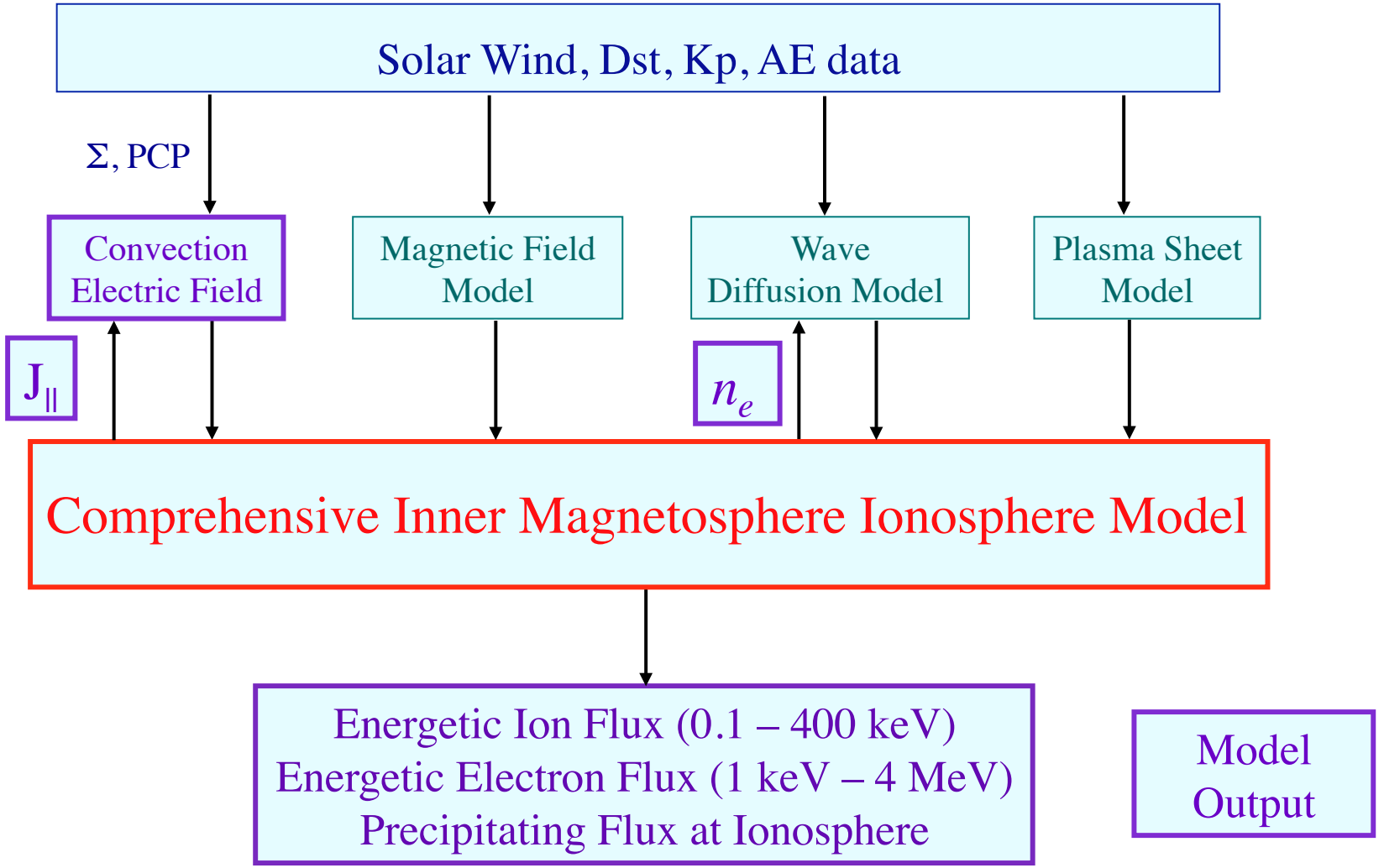


CRCM + RBE = CIMI



CIMI Simulations of the 5-9 April 2010 Storm

- CIMI runs with T04 model, chorus and hiss diffusion
- Electric Field

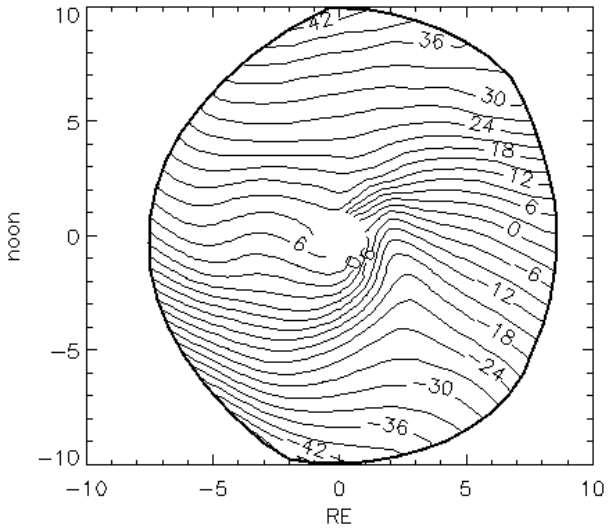
  Run 1: Self-Consistent Electric (SCE) field with M-I coupling

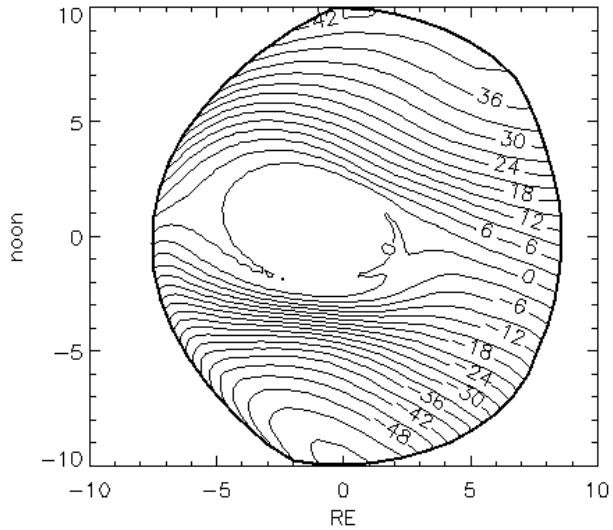
  Run 2: Empirical Weimer electric field model

Run 1: SCE field

Run 2: Weimer E field

Sun ←





CIMI Simulations of the 5-9 April 2010 Storm

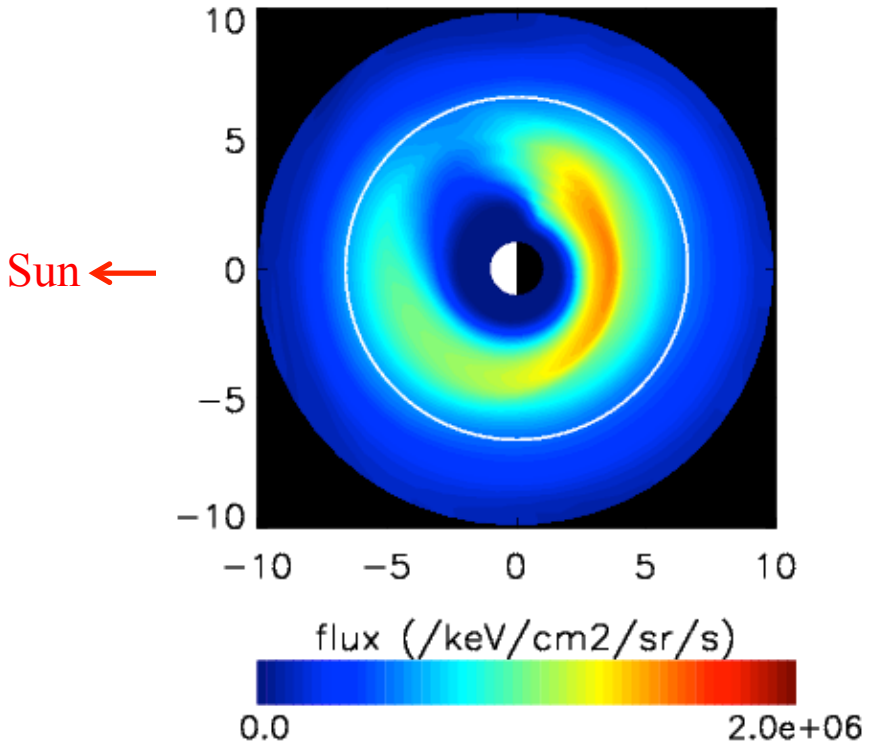
Ring Current Ion Flux at Equator

Run 1: Self-Consistent Electric (SCE) field with M-I coupling

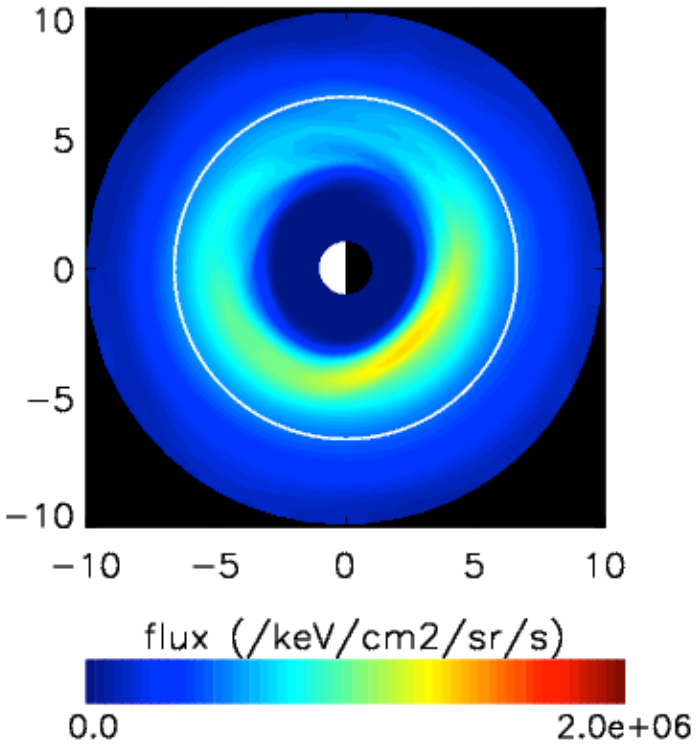
Run 2: Empirical Weimer electric field model

10-30 keV H^+

Run 1

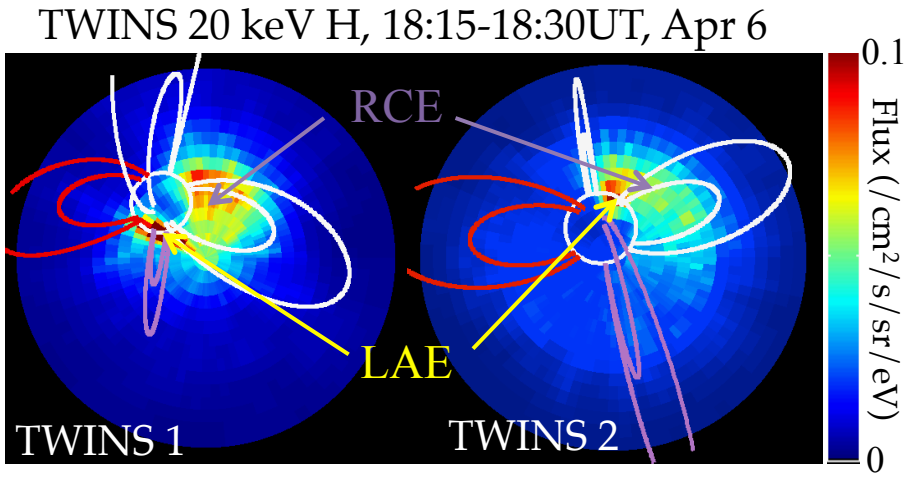


Run 2



Comparison with TWINS

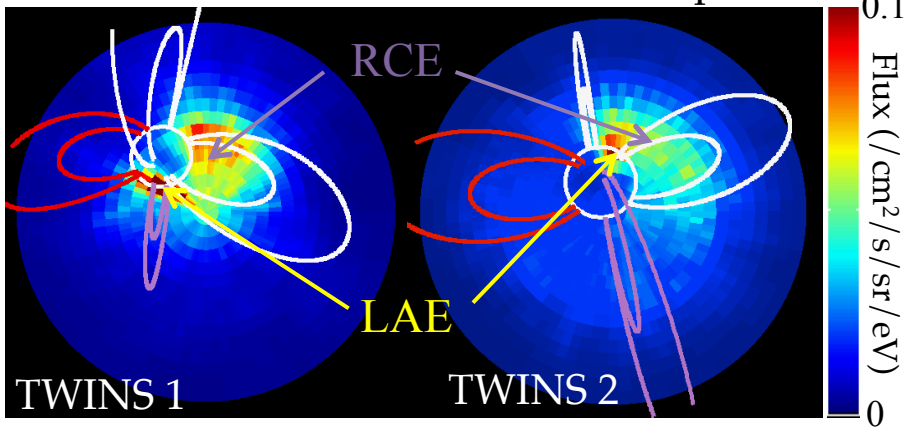
Storm Main Phase ~18:15 UT
on 6 April 2010



Comparison with TWINS

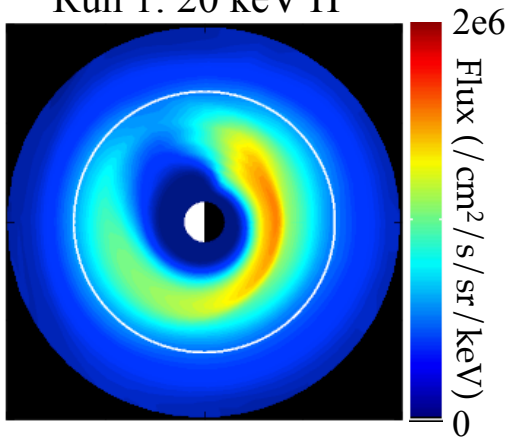
Storm Main Phase ~18:15 UT on 6 April 2010

TWINS 20 keV H, 18:15-18:30UT, Apr 6

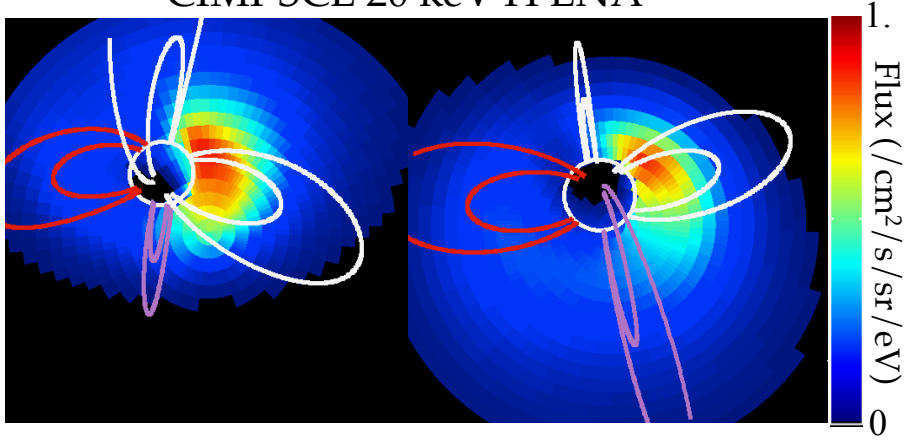


CIMI simulations

Run 1: 20 keV H^+



CIMI-SCE 20 keV H ENA



Comparison with TWINS

Storm Main Phase ~18:15 UT
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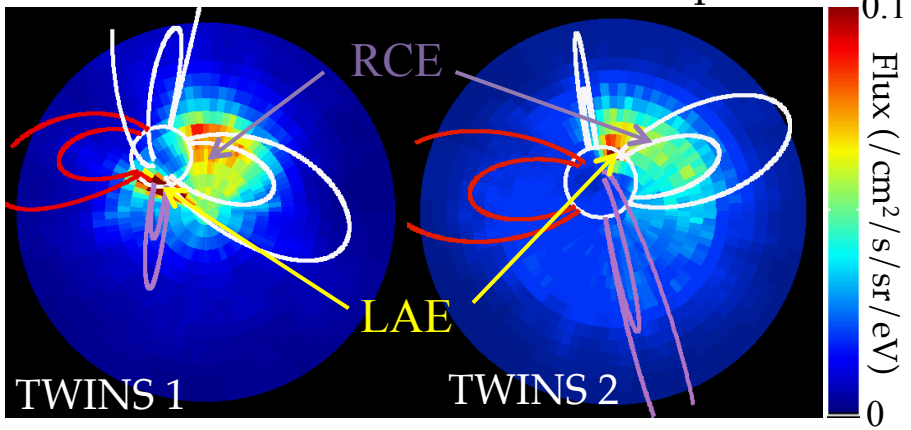
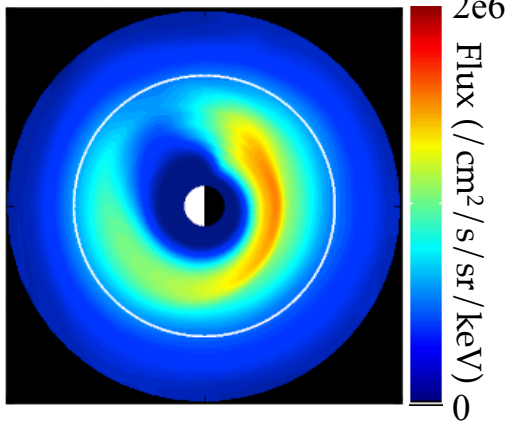
TWINS 20 keV H, 18:15-18:30UT, Apr 6

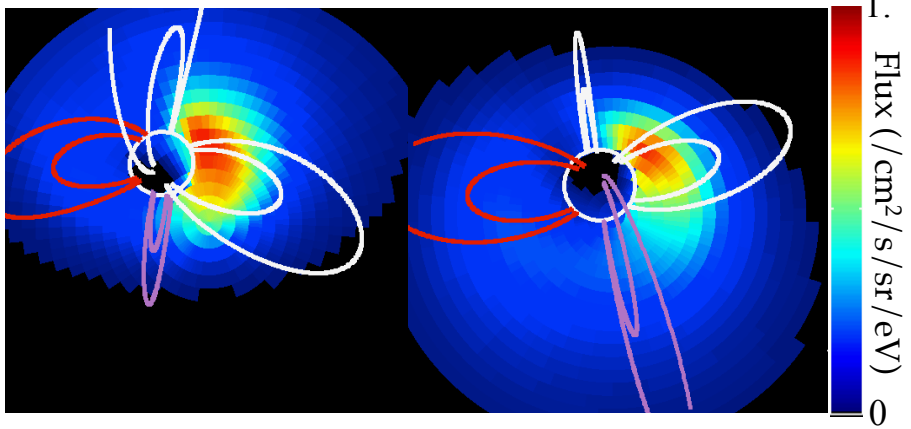


CIMI simulations

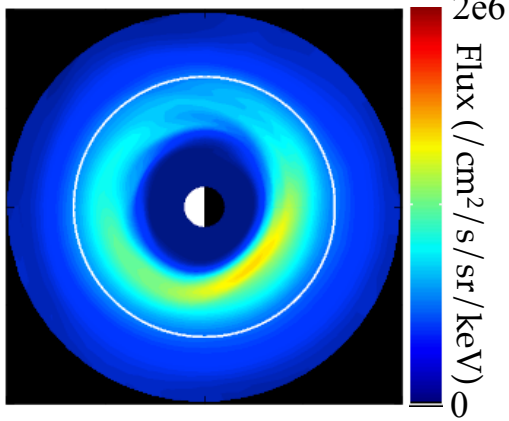
Run 1: 20 keV H^+



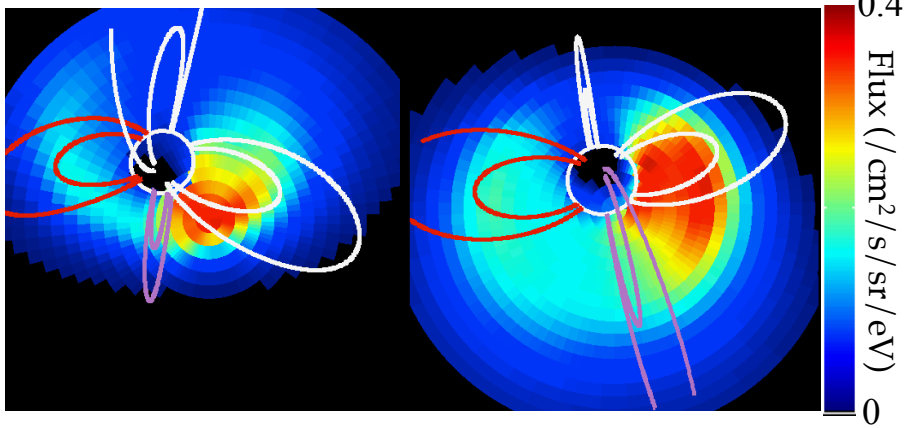
CIMI-SCE 20 keV H ENA



Run 2: 20 keV H^+



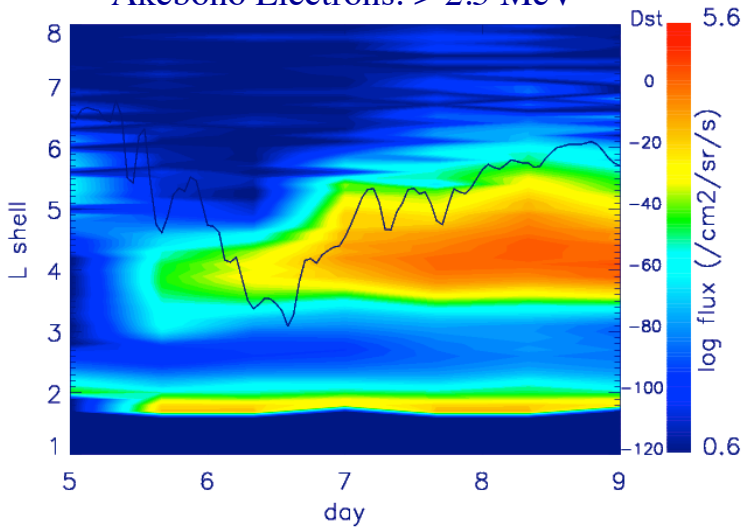
CIMI-Weimer 20 keV H ENA



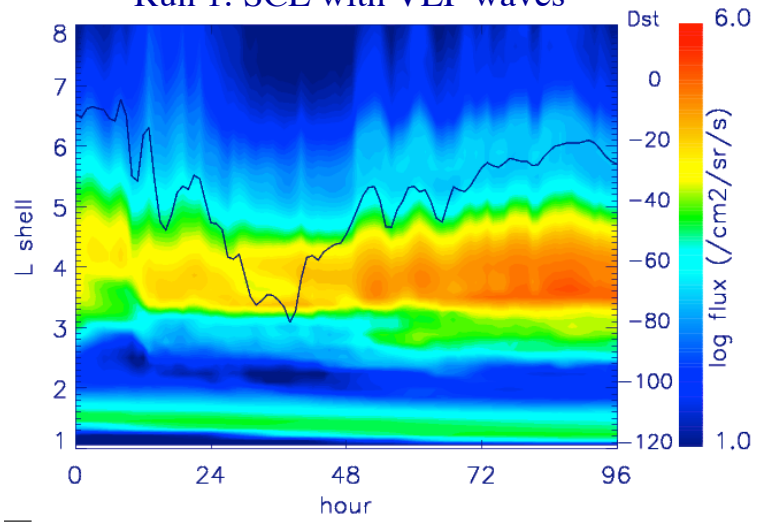
CIMI Simulations of the 5-9 April 2010 Storm

Comparison with Akebono Data

Akebono Electrons: > 2.5 MeV



Run 1: SCE with VLF waves



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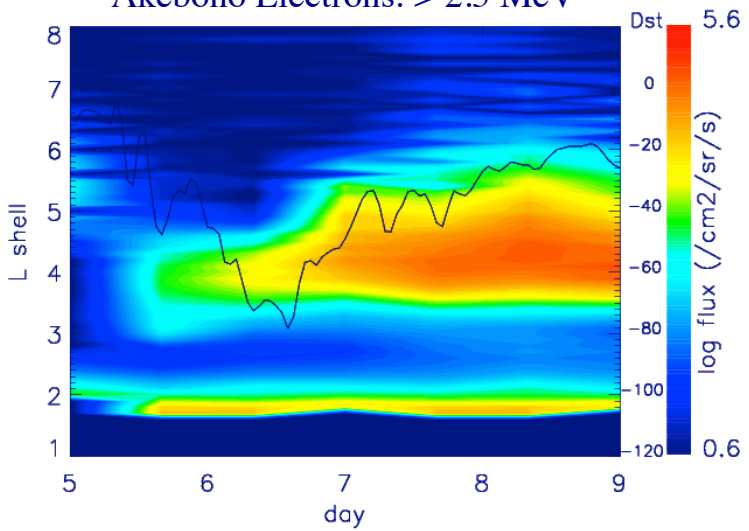

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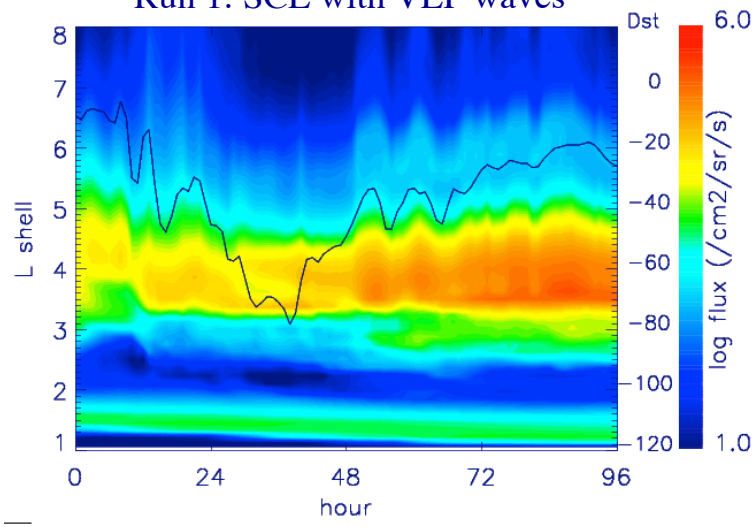
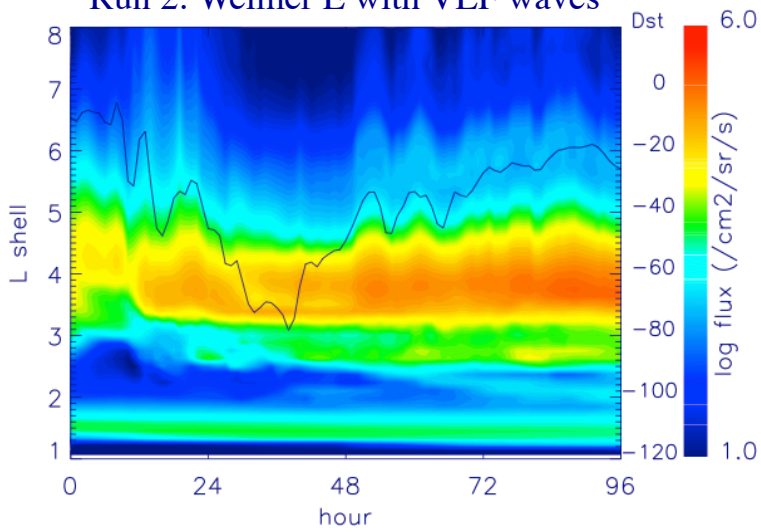


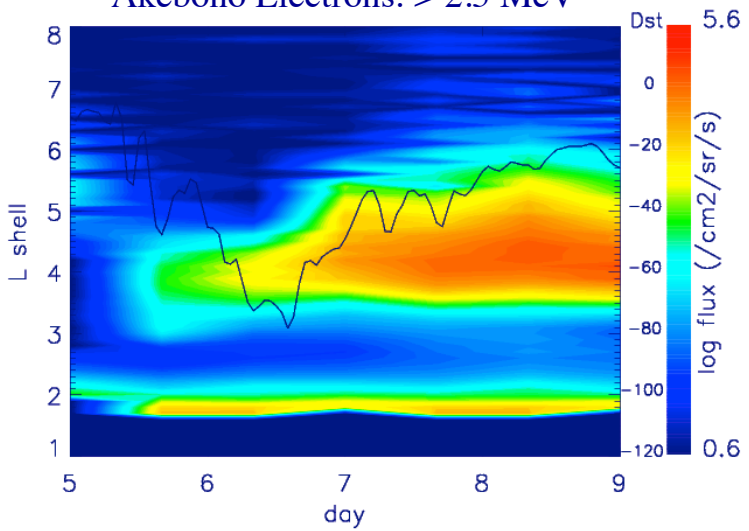
Run 2: Weimer E with VLF waves



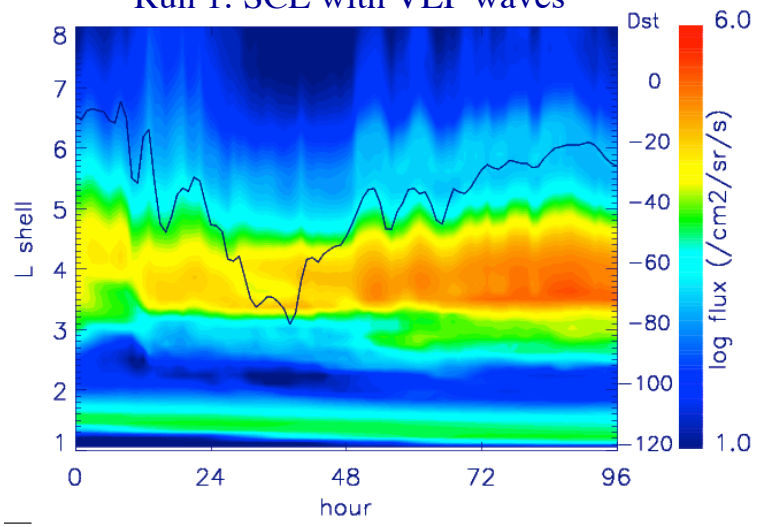
CIMI Simulations of the 5-9 April 2010 Storm

Comparison with Akebono Data

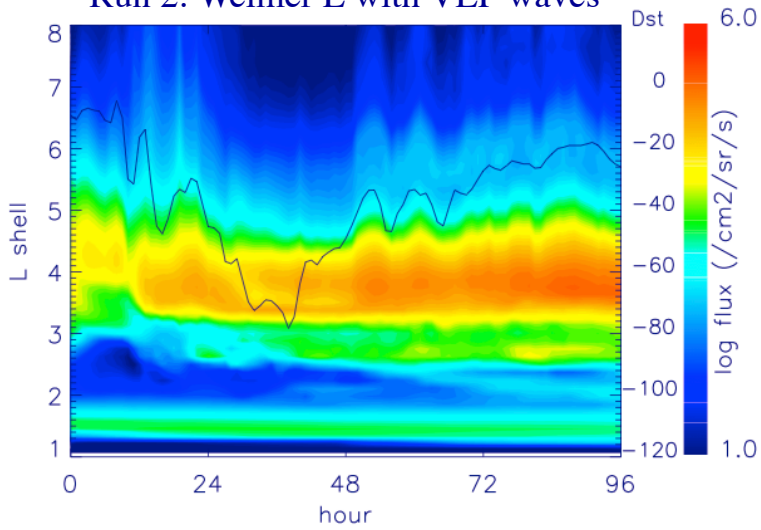
Akebono Electrons: > 2.5 MeV



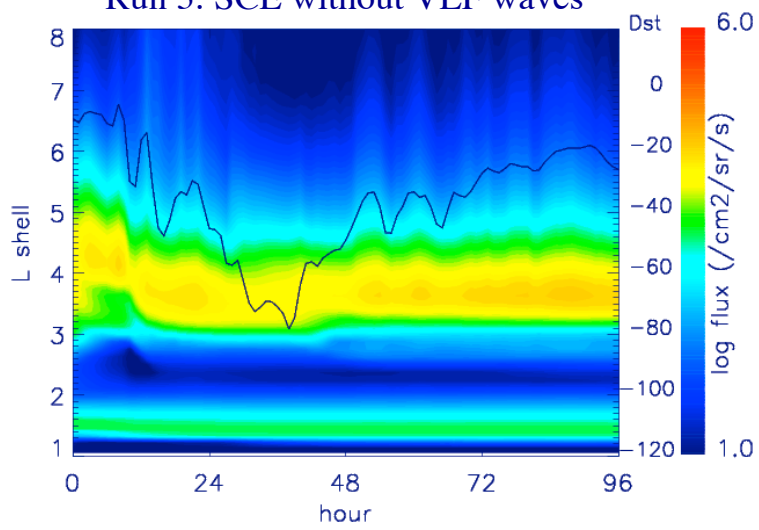
Run 1: SCE with VLF waves



Run 2: Weimer E with VLF waves

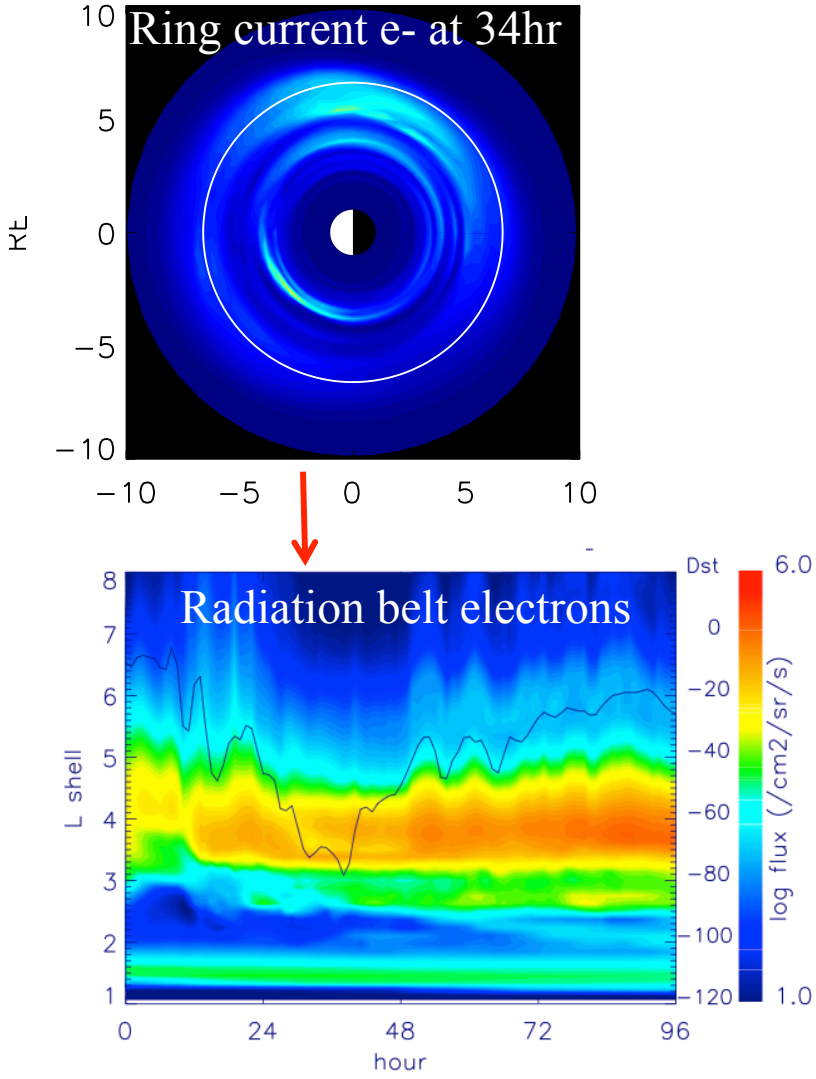


Run 3: SCE without VLF waves

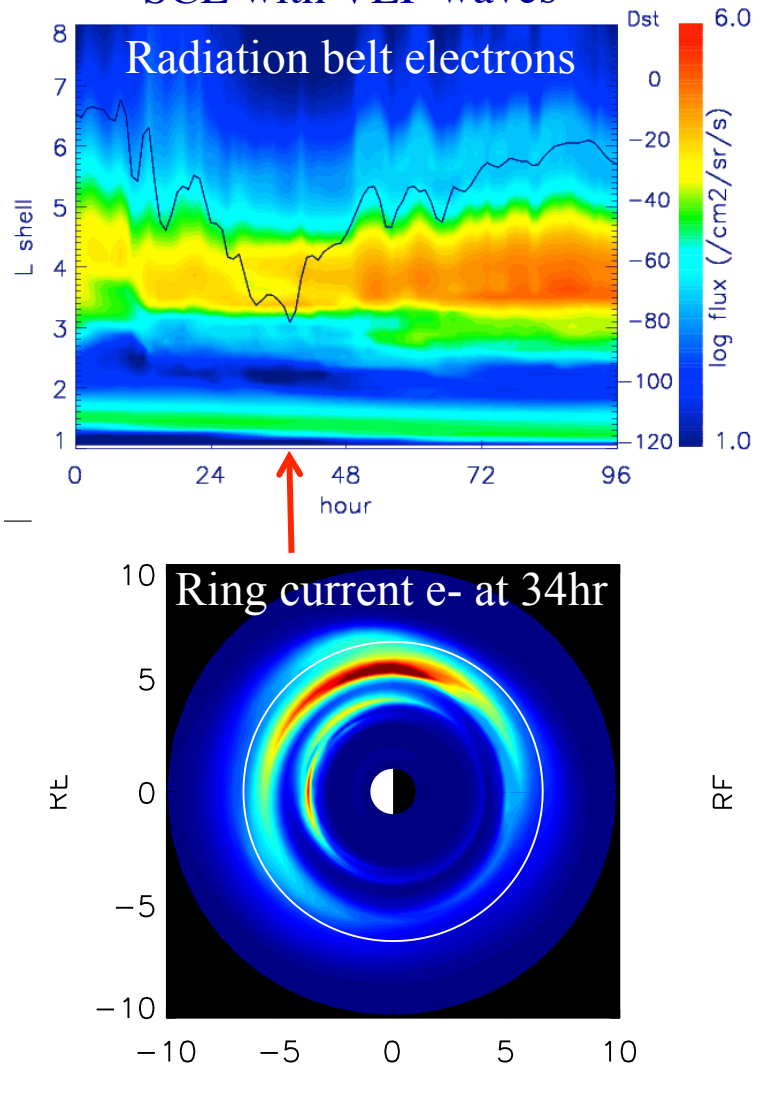


SCE Produces Seed Population for Wave Energization

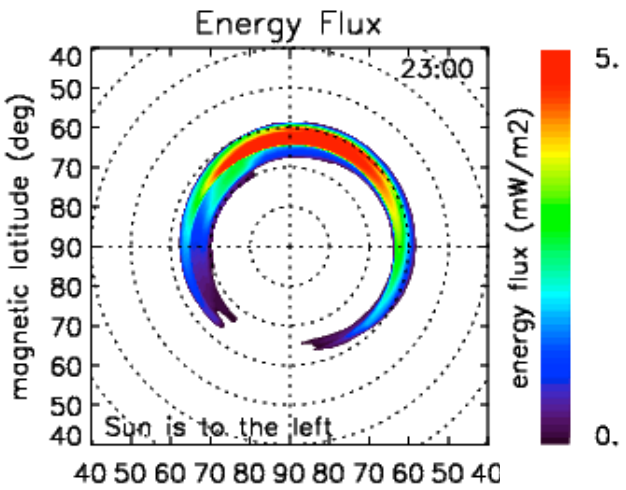
Weimer E with VLF waves

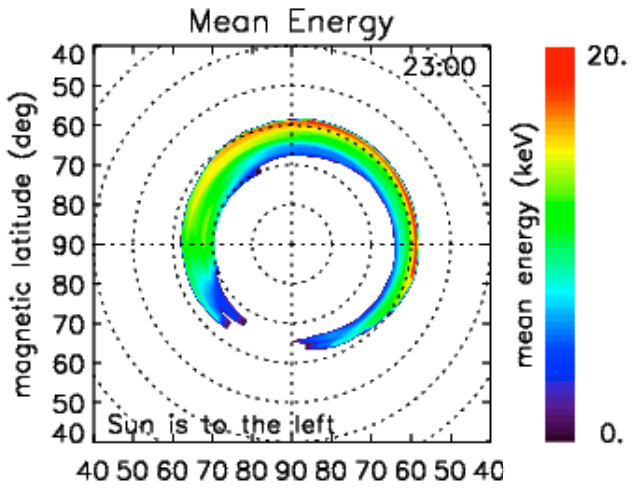


SCE with VLF waves

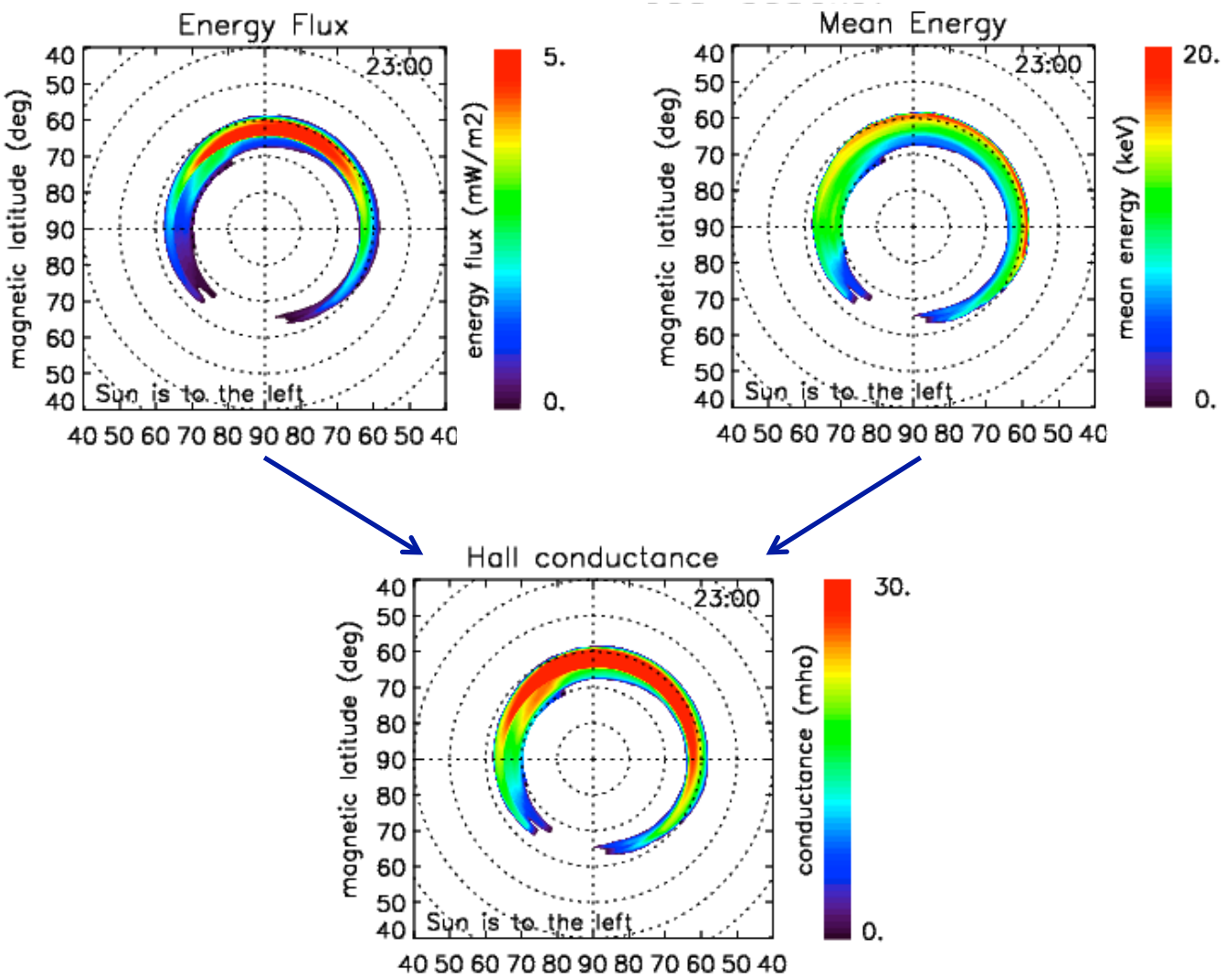


Energetic Electron Precipitation at Ionosphere

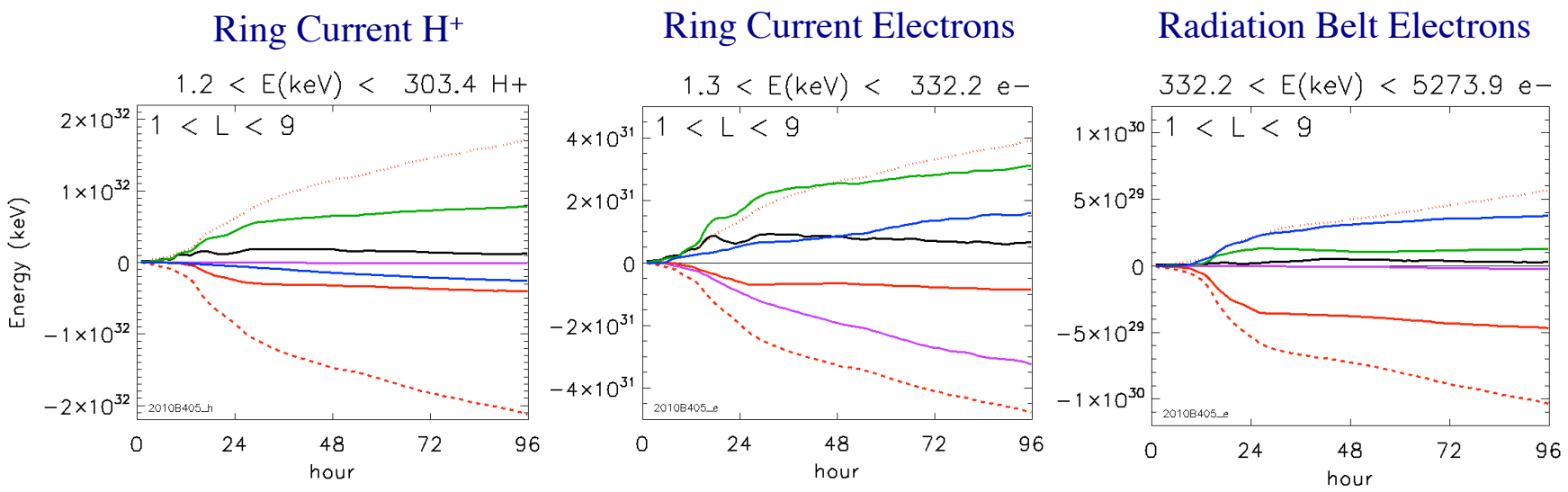




Electron Precipitation and Conductivity

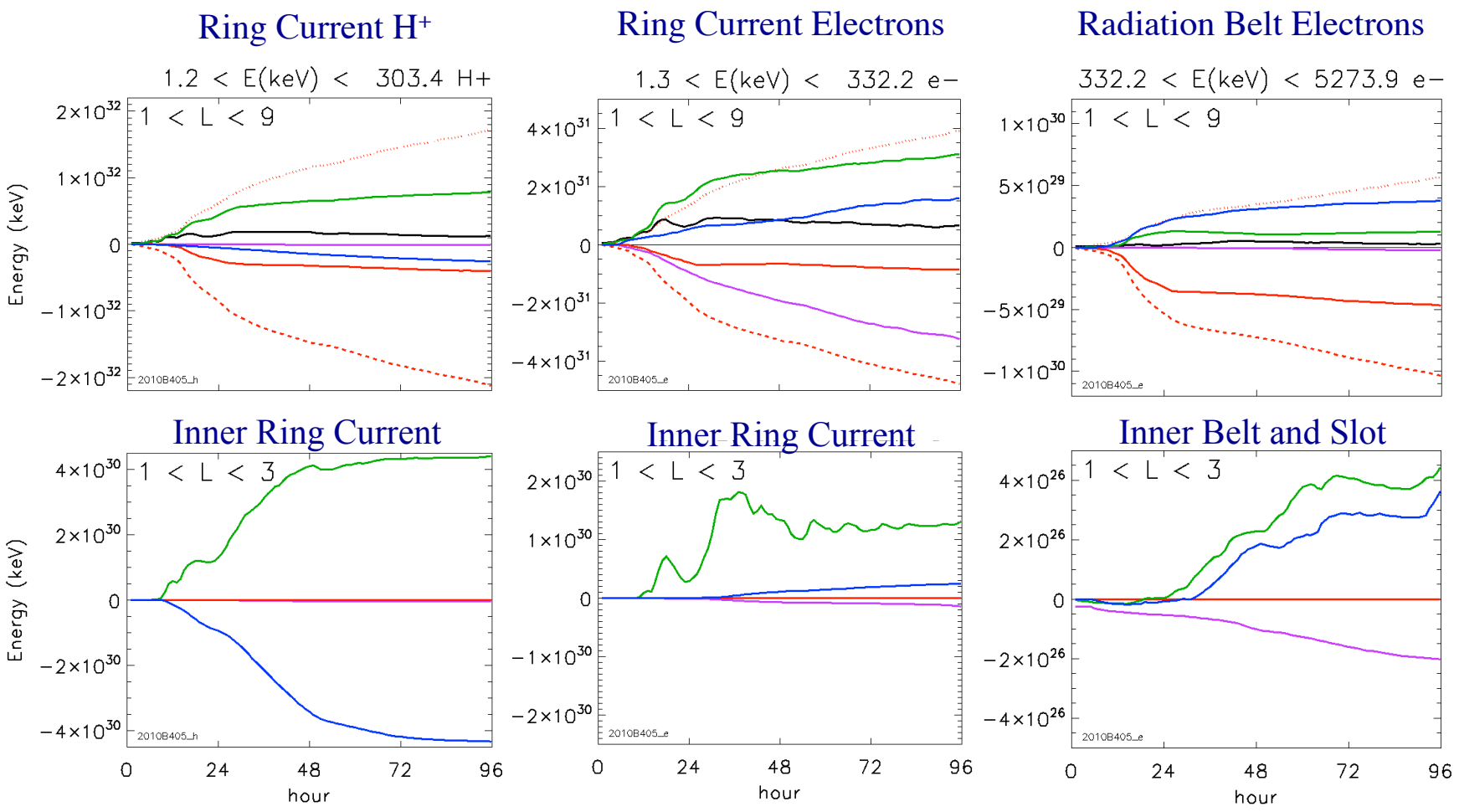


Identifying Loss & Energization Processes by CIMI



- total energy content
- drift-in gain
- drift-out loss
- net change from drift across model boundary
- energization from internal drift
- loss-cone loss
- change from charge exchange (ions) or wave diffusion (electrons)

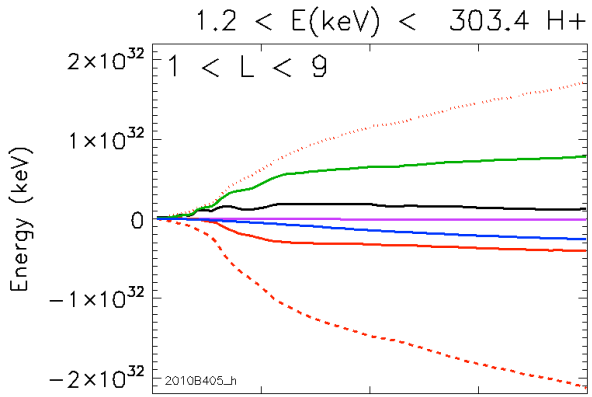
Loss & Energization at 1 < L < 3



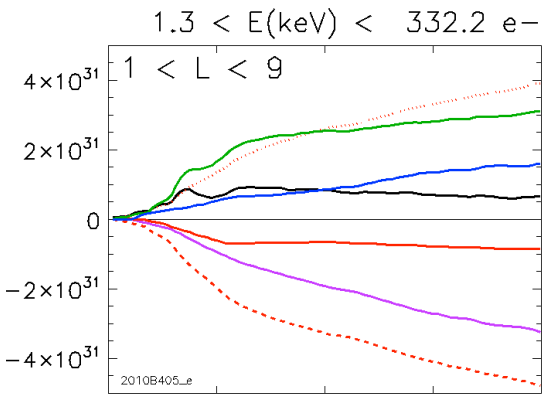
drift-in
drift-out
net
internal drift
loss-cone
charge exchange/wave diffusion

Loss & Energization at 3 < L < 5

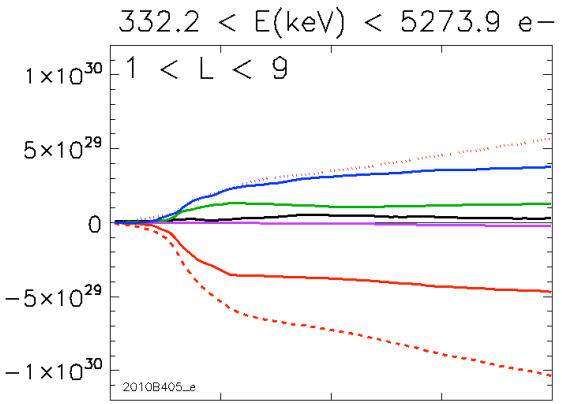
Ring Current H^+



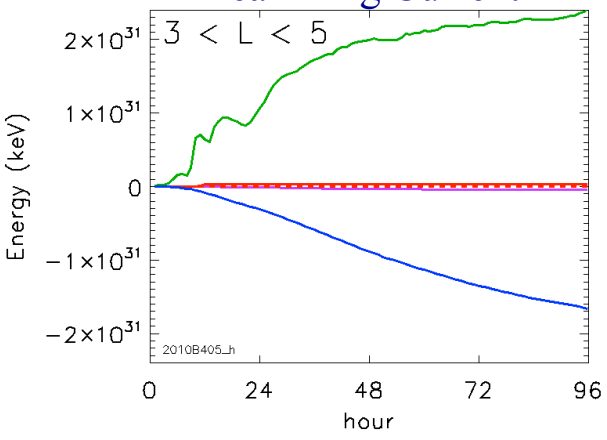
Ring Current Electrons



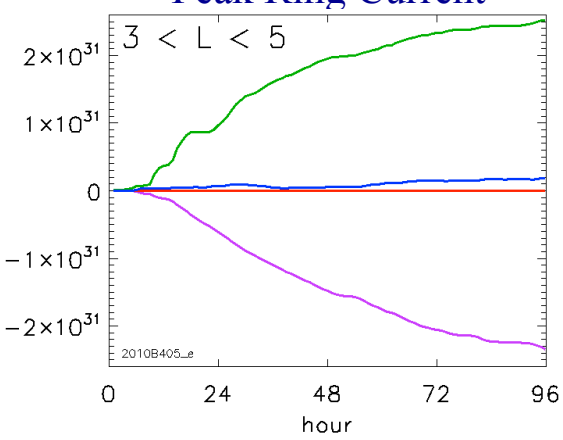
Radiation Belt Electrons



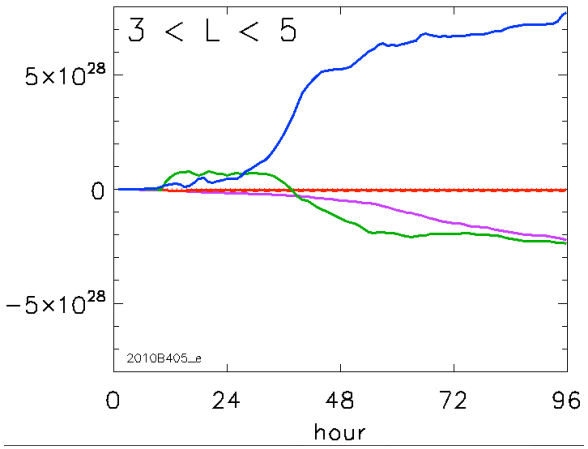
Peak Ring Current



Peak Ring Current

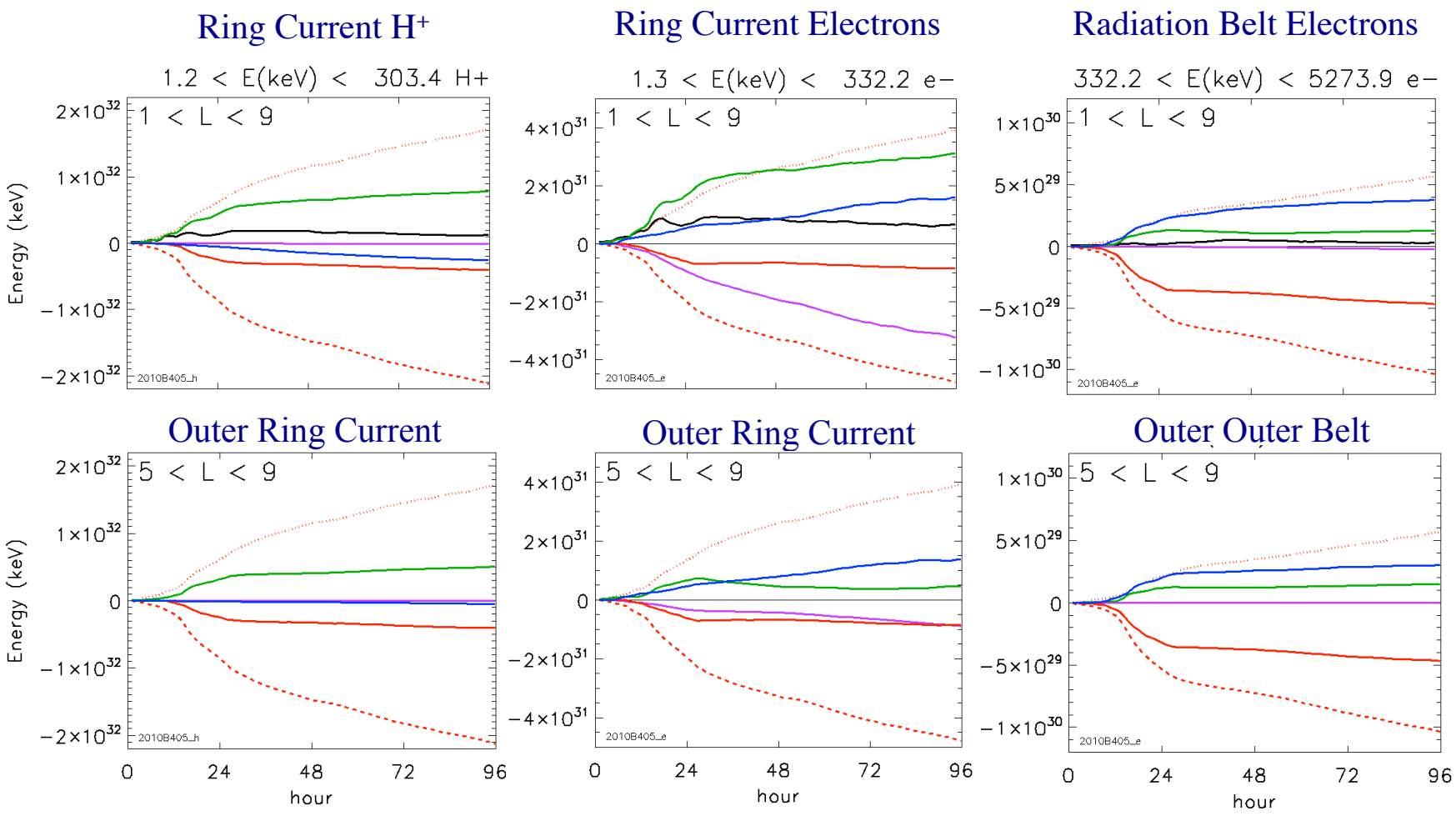


Peak Outer Belt



drift-in
drift-out
net
internal drift
loss-cone
charge exchange/wave diffusion

Loss & Energization at 5 < L < 9



CIMI at CCMC

Model Name	Developer(s)	Institution	Model Class	Services Available				
				Runs on Request	Instant Run	Real Time Run	Widget	Source Code on ftp
Inner Magnetosphere:								
RCM	Stanislav Sazykin, Richard A. Wolf	Department of Physics and Astronomy, Rice University		X				
SWMF/BATS-R-US with RCM	Tamas Gombosi et al., Richard Wolf et al., Stanislav Sazykin et al., Gabor Toth et al.	CSEM	Physics-based MHD	X				
Fok Ring Current	Mei-Ching H. Fok	NASA, GSFC	Physics-based	X			X	
Plasmasphere	Viviane Pierrard	IASB-BIRA		X				
CIMI	Mei-Ching H. Fok, Natalia Buzulukova	NASA, GSFC	Bounce-averaged drift-kinetic modeling of electrons, protons and oxygen ion particle distributions.	X				
UPOS Radiation Belt	Tony Lui, Syau-Yun Hsieh	JHU/APL	Physics-based					

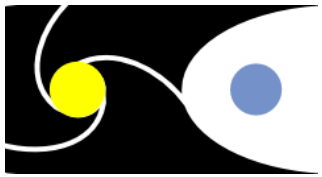
Summary

* CIMI: CRCM and beyond

* CIMI output:
  - energetic ion (0.1 – 400 keV) and electron (1 keV – 4 MeV) flux
  - precipitating electron flux
  - plasmasphere density
  - convection field
  - Region 2 currents

- CIMI is able to identify energization and loss processes in ring current and radiation belts

* CIMI is available for ‘Runs on Request’ at CCMC



Backup Slides

CIMI: Model Equations

f_s: radiation belt – ring current particle distribution function

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

$$\frac{1}{G}\frac{\partial}{\partial E}\left[G\left(D_{EE}\frac{\partial f}{\partial E}+D_{E\alpha_o}\frac{\partial f_s}{\partial \alpha_o}\right)\right]-\mathrm{v}\sigma_{sH}\left\langle n_H \right\rangle f_s-\left(\frac{f_s}{0.5\tau_b}\right)_{\substack{\text{loss}\\ \text{cone}}}$$

Φ: ionosphere potential; $J_{\parallel}$: field-aligned current

$$\nabla\cdot\left(-\vec{\vec{\Sigma}}\nabla\Phi\right)=J_{\parallel}\sin I$$

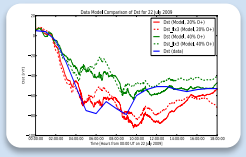
N: plasmaspheric electron content per unit magnetic flux

$$\frac{\partial N}{\partial t}+\left\langle \dot{\lambda}_i \right\rangle \frac{\partial N}{\partial \lambda_i}+\left\langle \dot{\phi}_i \right\rangle \frac{\partial N}{\partial \phi_i}=\frac{F_N+F_S}{B_i}$$

CIMI: Input Models

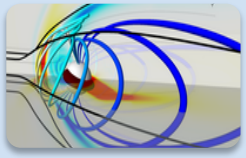
Solar Wind Input

- ACE and WIND satellites



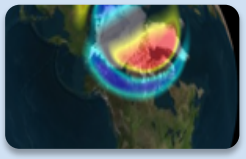
AE, Dst, Kp Indices

- Kyoto Geomagnetic Data Service
- U.S. Geological Survey (USGS)



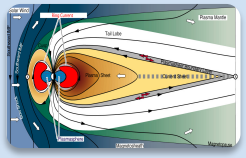
Magnetic Field

- Empirical T04, T96 Model
- Physics Based MHD Model



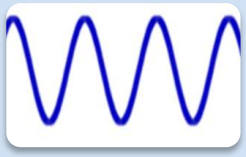
Electric Field

- Empirical Weimer Model (at polar boundary)
- Physics Based MHD Model



Plasma sheet Distribution

- Empirical Maxwellian or Kappa distribution
- Test particle, MHD Model



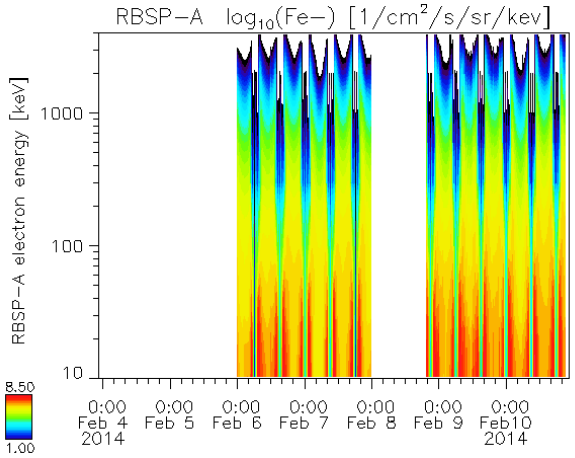
Wave Power and Diffusion Coefficients

- Gaussian fits to CRRES and THEMIS data
- Diffusion coefficients from QLT (Qiuhua Zheng, Jay Albert)

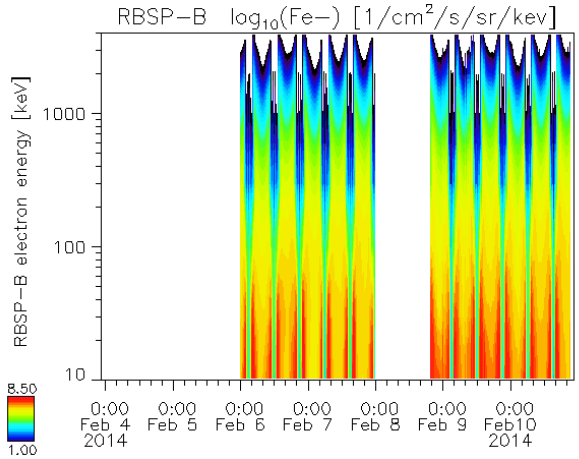
Real-Time CIMI Flux Along VAP Orbits at CCMC

COMMUNITY COORDINATED MODELING CENTER

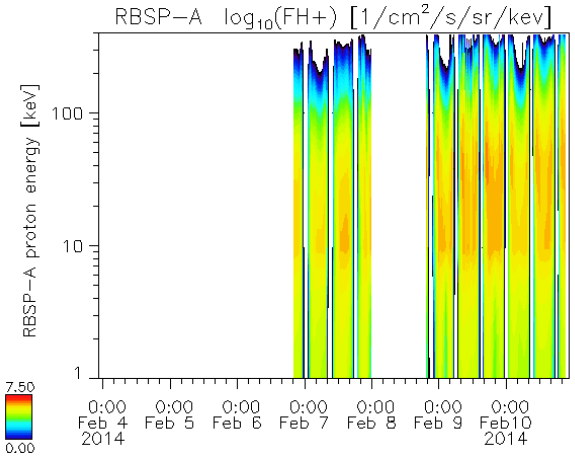
Electrons at RBSP-A



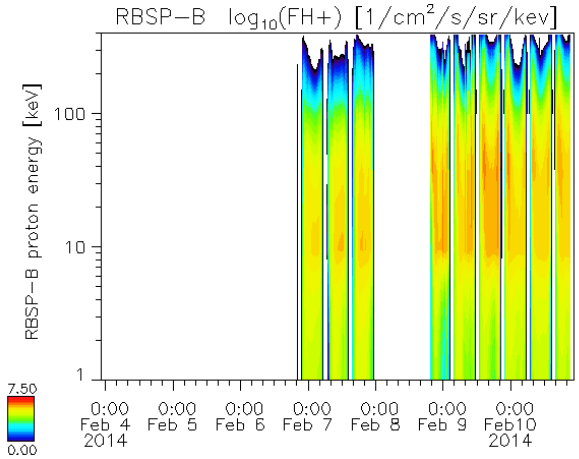
Electrons at RBSP-B



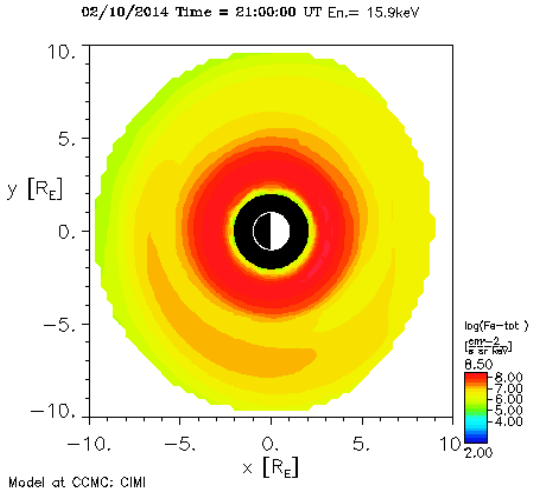
Protons at RBSP-A



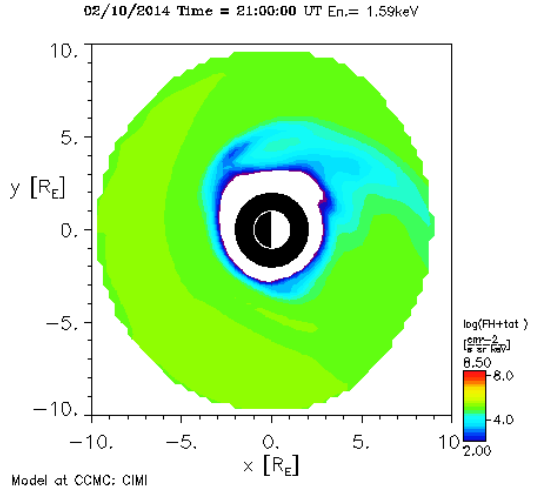
Protons at RBSP-B



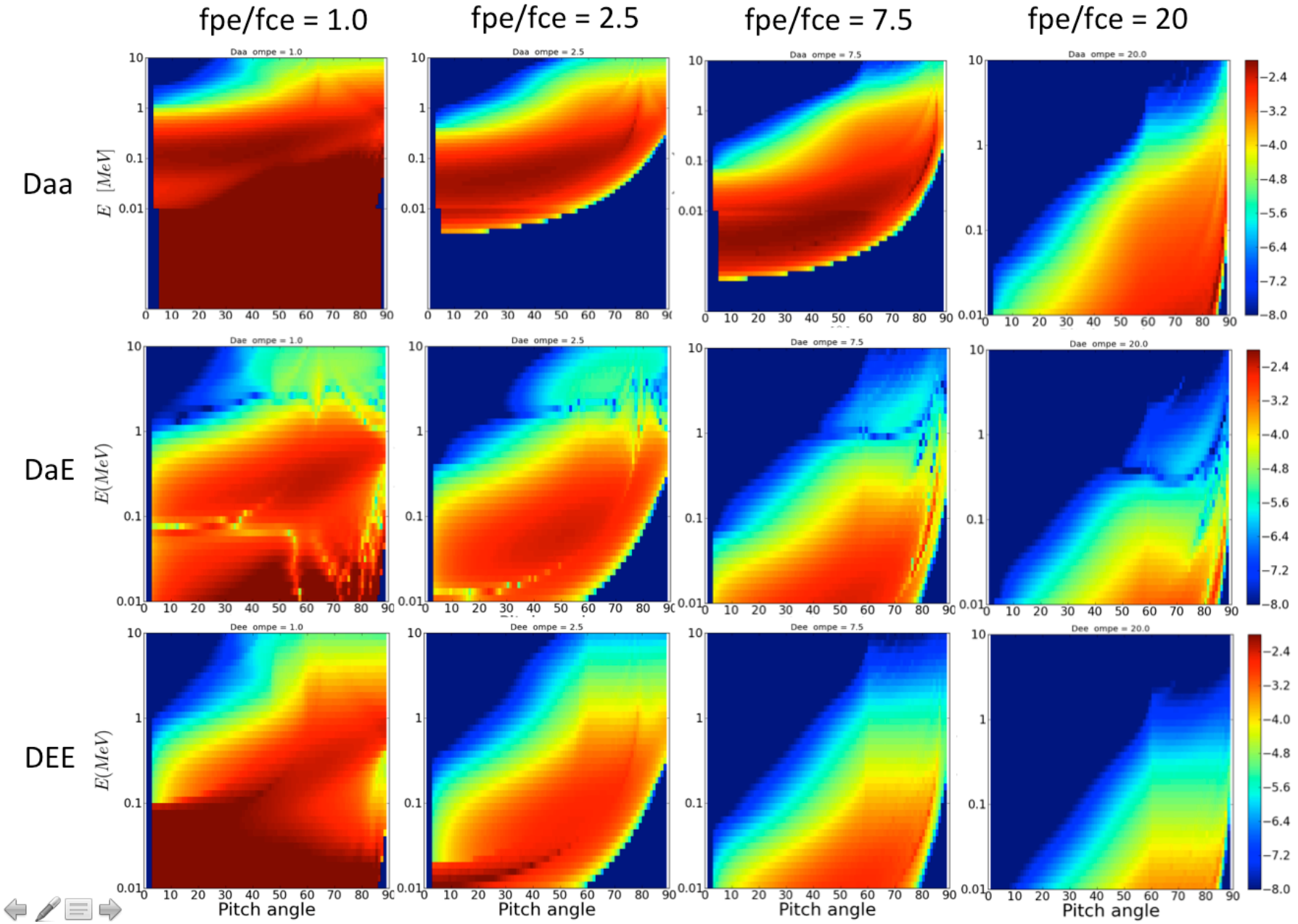
Electron energy channel 05: 15.9keV



Proton energy channel 05: 1.59keV

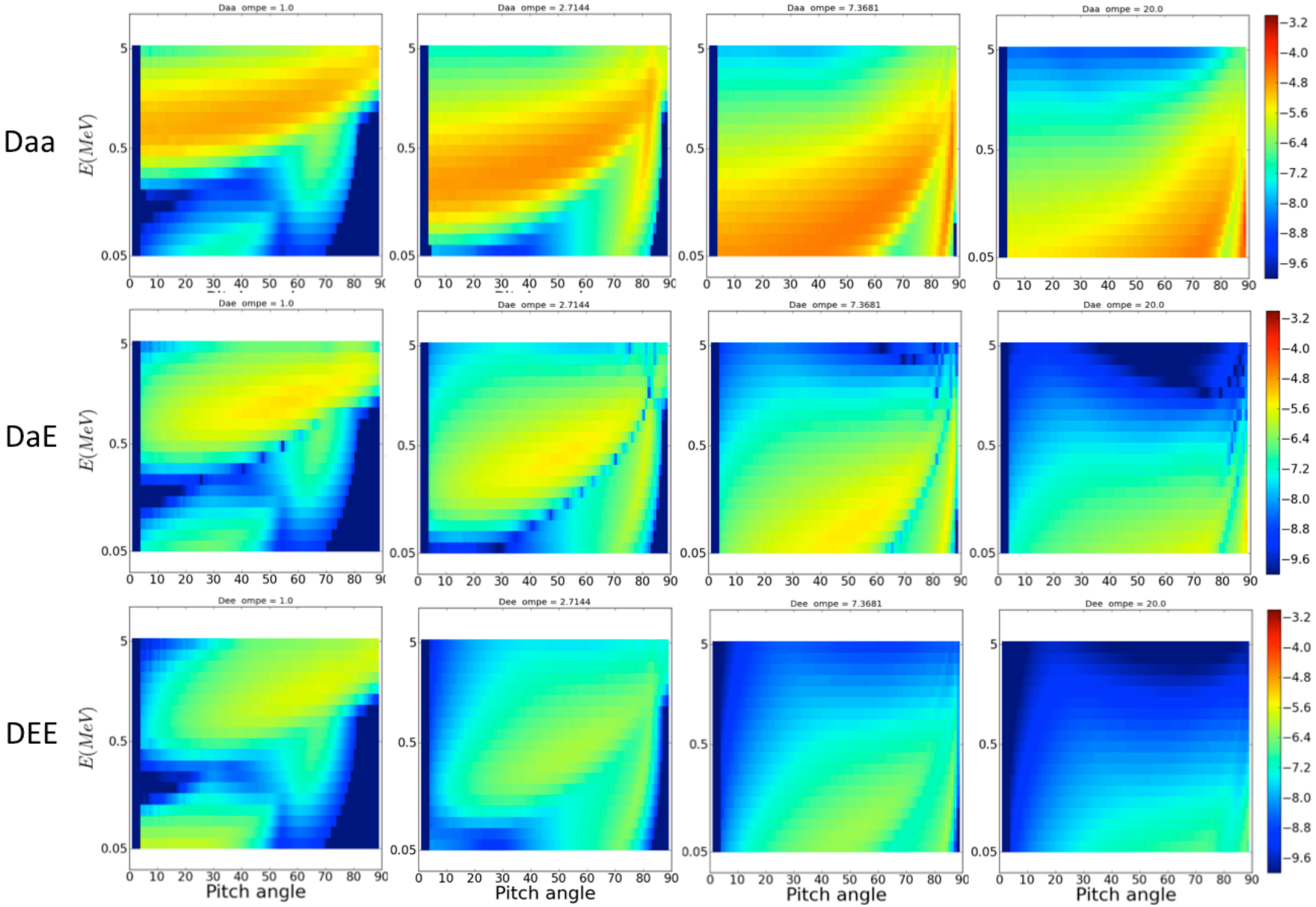


Electron Diffusion Coefficients with Lower-Band Chorus at L = 6.5: Extended Energy

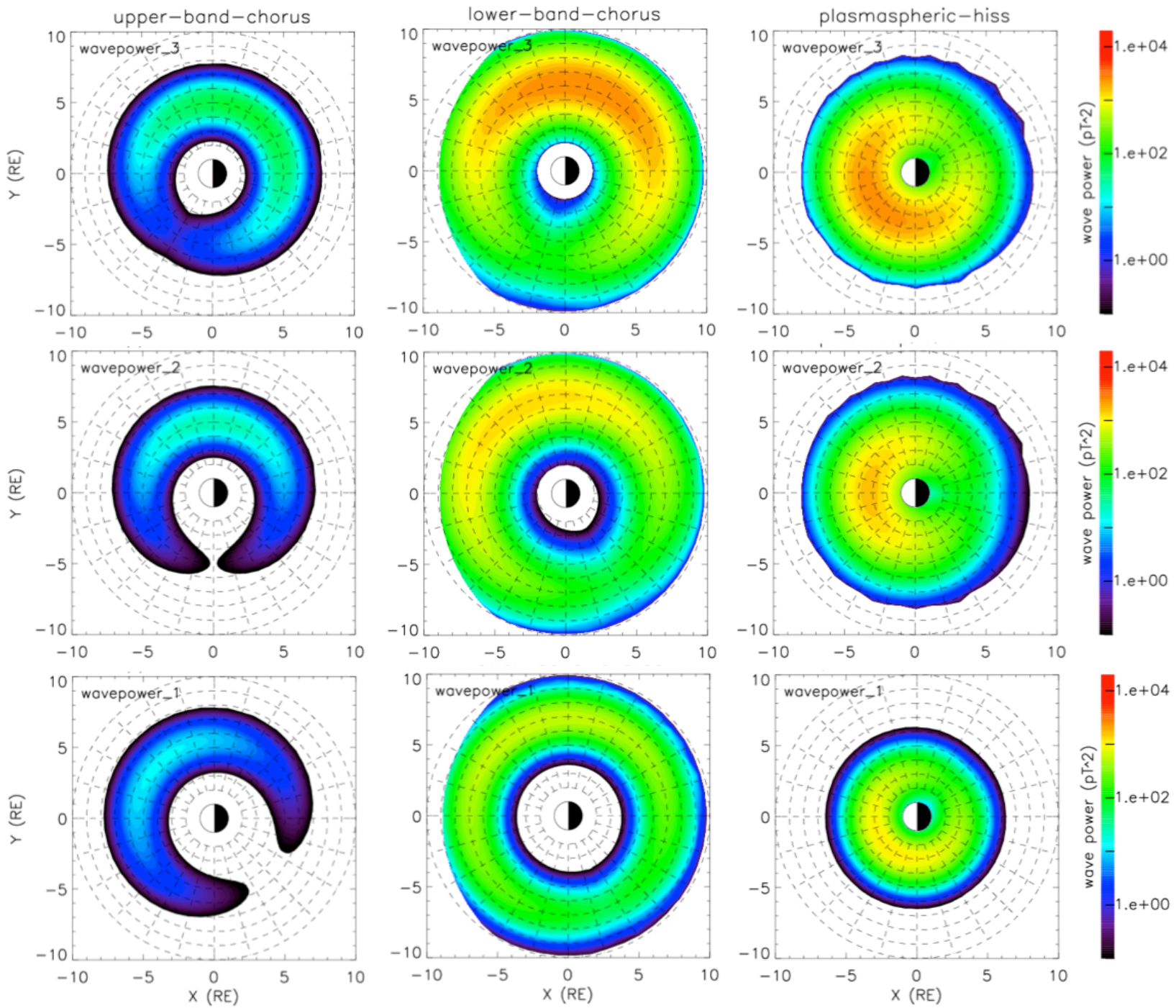


Coefficients based on chorus power of $(100pT)^2$

Electron Diffusion Coefficients with hiss at L = 5.5



Coefficients based on hiss power of $(10pT)^2$


upper−band−chorus
lower−band−chorus
plasmaspheric−hiss
wavepower_3
wavepower_2
wavepower_1
Y (RE)
X (RE)
wave power (pT^2)
1.e+04
1.e+02
1.e+00
−10
−5
0
5
10