IMPTAM: Dst calculated in ring current modeling: Two methods, DPS and Biot-Savart integration

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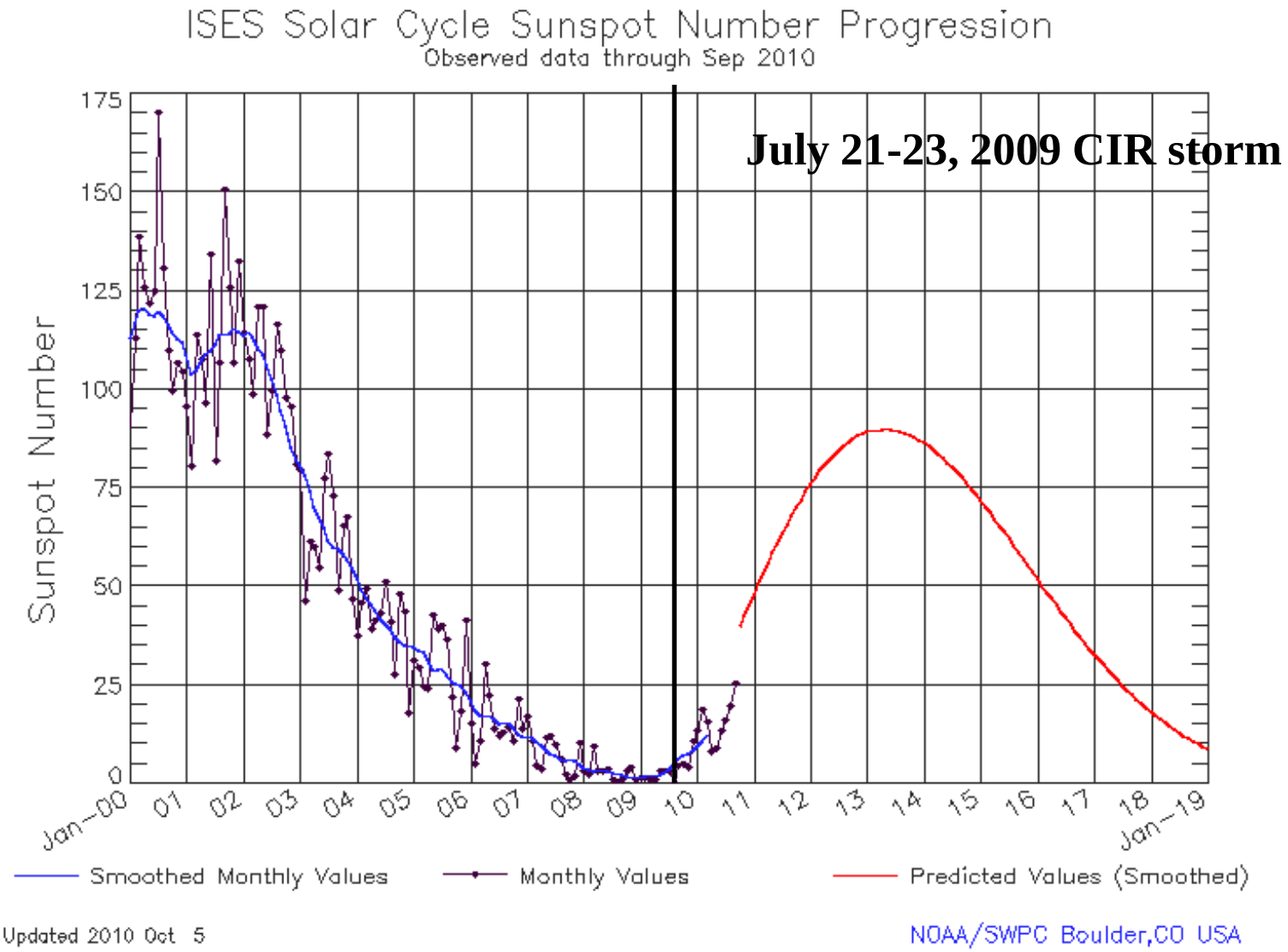
CIR-storm at the beginning of rising phases of solar cycle 24

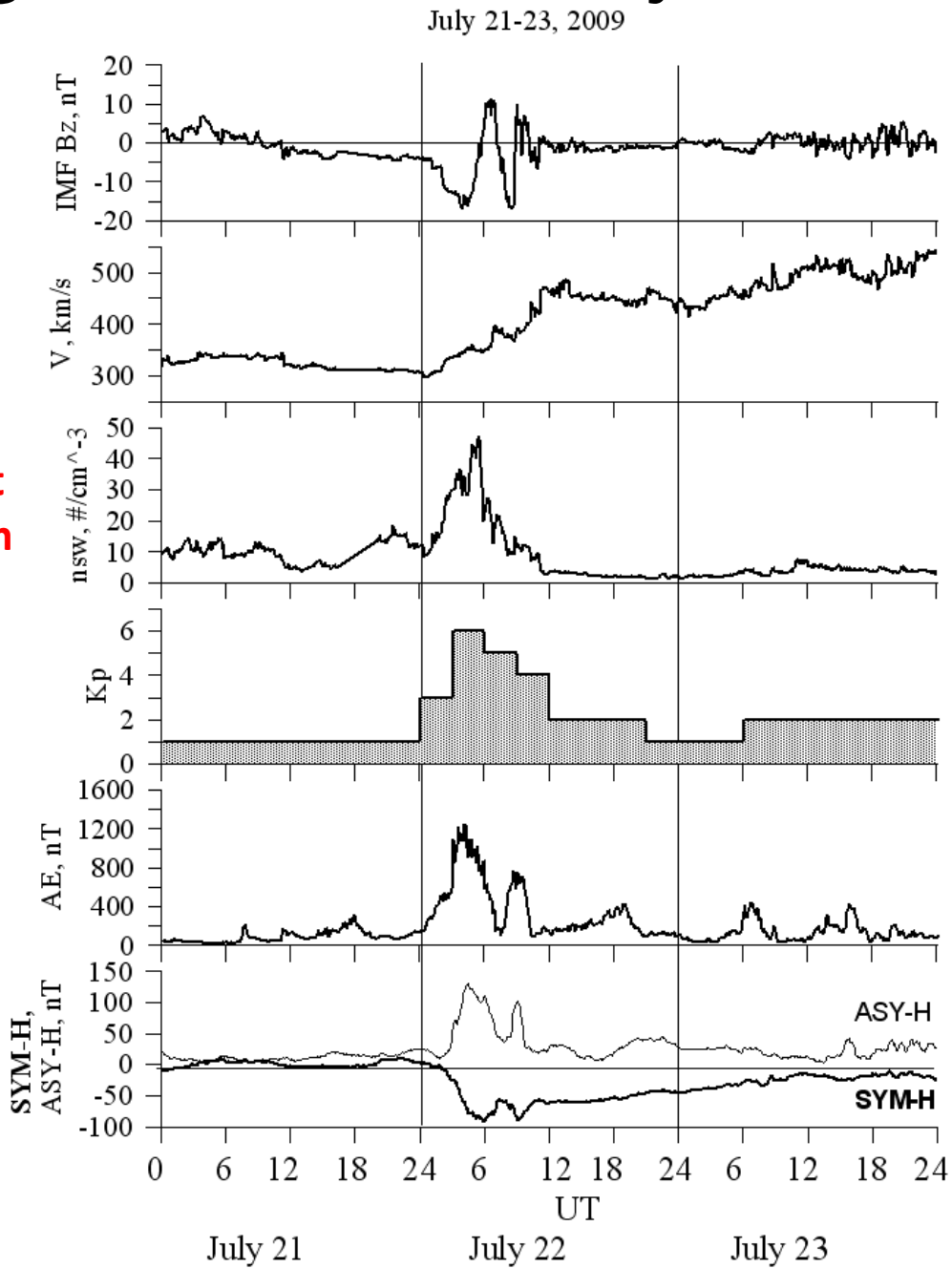


Magnetic storm on July 21-23, 2009

Smooth southward turning of IMF Bz

Density peak in front of High Speed stream

Small storm



High speed stream

Substorm activity

Long recovery

Inner Magnetosphere Particle Transport and Acceleration Model (1)

(*Ganushkina et al., AnnGeo, 2005, JGR, 2006***)**

- Changes in distribution function f and flux calculations for ions and electrons **with arbitrary pitch angles** using ***Liouville*'s theorem** taking into account **loss processes**.

$$\frac{df}{dt} = \frac{\partial f}{\partial \phi} \cdot V_\phi + \frac{\partial f}{\partial r} \cdot V_r + sources - losses$$

- **Boundary distribution**: at any location from 6.6 to 10 Re
- **Transport of particles**:
  - Drifts with velocities, radial and longitudinal, as sum of **ExB and magnetic drifts, 1**st and 2nd inv = const in **time-dependent magnetic and electric fields** with self-consistent magnetic field

$$\mathrm{Vdrift} = \frac{\vec{\mathrm{E}} \times \vec{\mathrm{B}}}{\mathrm{B}^2} + \frac{\mathrm{mv}_\perp^2}{2\mathrm{qB}^3}\left(\vec{\mathrm{B}} \times \nabla \mathrm{B}\right) + \frac{\mathrm{mv}_{\mathrm{II}}^2}{\mathrm{q}} \frac{\vec{\mathrm{R}}_\mathrm{c} \times \vec{\mathrm{B}}}{\mathrm{R}_\mathrm{c}^2 \mathrm{B}^2}$$

$$\left\langle v_0 \right\rangle = \frac{\mathbf{E}_0 \times \mathbf{B}_0}{B_0^2} + \frac{2p}{q\tau_b B_0} \nabla I \times e_0,$$

$$I = \int_{S_m}^{S_m'} \left[1 - B(s)/B_m\right]^{1/2} ds,$$

Inner Magnetosphere Particle Transport and Acceleration Model (2)

(*Ganushkina et al., AnnGeo, 2005, JGR, 2006***)**

Losses for ions:

- **charge exchange** with Hydrogen from geocorona;
- **Coulomb interaction** in dense thermal plasmas (plasmasphere);
- **convection outflow**, particle intersects the magnetopause and flows away along magnetosheath magnetic field lines.

Model-dependent Dst calculations during storms

1. Using **Dessler-Parker-Sckopke relationship**:

The energy in the ring current can be expressed by $\frac{\Delta\vec{B}}{B_E} = -\frac{2}{3}\frac{W_{RC}}{W_{mag}}\hat{k}$, where

$W_{mag} = \frac{4\pi}{3\mu_0} B_E^2 R_E^3$ is the total energy in the Earth's dipole magnetic field above the surface, B_E is the magnetic field at the Earth's surface, R_E is one Earth radii (6371 km).

$\Delta\vec{B}$ is the change in B measured at the surface of the Earth (Dst).

2. Calculating from the model ring current by **Biot-Savart law**:

The magnetic disturbance parallel to the earth's dipole at the center of the earth ΔB induced by the azimuthal component of $J_\perp$, is given by

$$\Delta B = \frac{\mu_0}{4\pi}\int_r \int_\lambda \int_\phi \cos^2\lambda J_\phi(r,\lambda,\phi)\,dr\,d\lambda\,d\phi$$

$$\vec{j}_\perp = \frac{\vec{B}}{B^2}\times\left(\nabla P_\perp + \frac{P_{II}-P_\perp}{B^2}\left(\vec{B}\cdot\nabla\right)\vec{B}\right)$$

Combinations of models for IMPTAM for July 21-23, 1997 storm

No self-consistency (special subject for separate study)

	Electric Field	Boundary conditions
dipole	Volland-Stern	Tsyganenko and Mukai, 2003
T89	Volland-Stern	Tsyganenko and Mukai, 2003
T96	Volland-Stern	Tsyganenko and Mukai, 2003
TS04	Volland-Stern	Tsyganenko and Mukai, 2003
dipole	Boyle et al., 1997	Tsyganenko and Mukai, 2003
T89	Boyle et al., 1997	Tsyganenko and Mukai, 2003
T96	Boyle et al., 1997	Tsyganenko and Mukai, 2003
TS04	Boyle et al., 1997	Tsyganenko and Mukai, 2003

Best fit with observed Dst for **dipole + T96 + VS** model combination

Modeled Dst for July 21-23, 2009

Model combination:

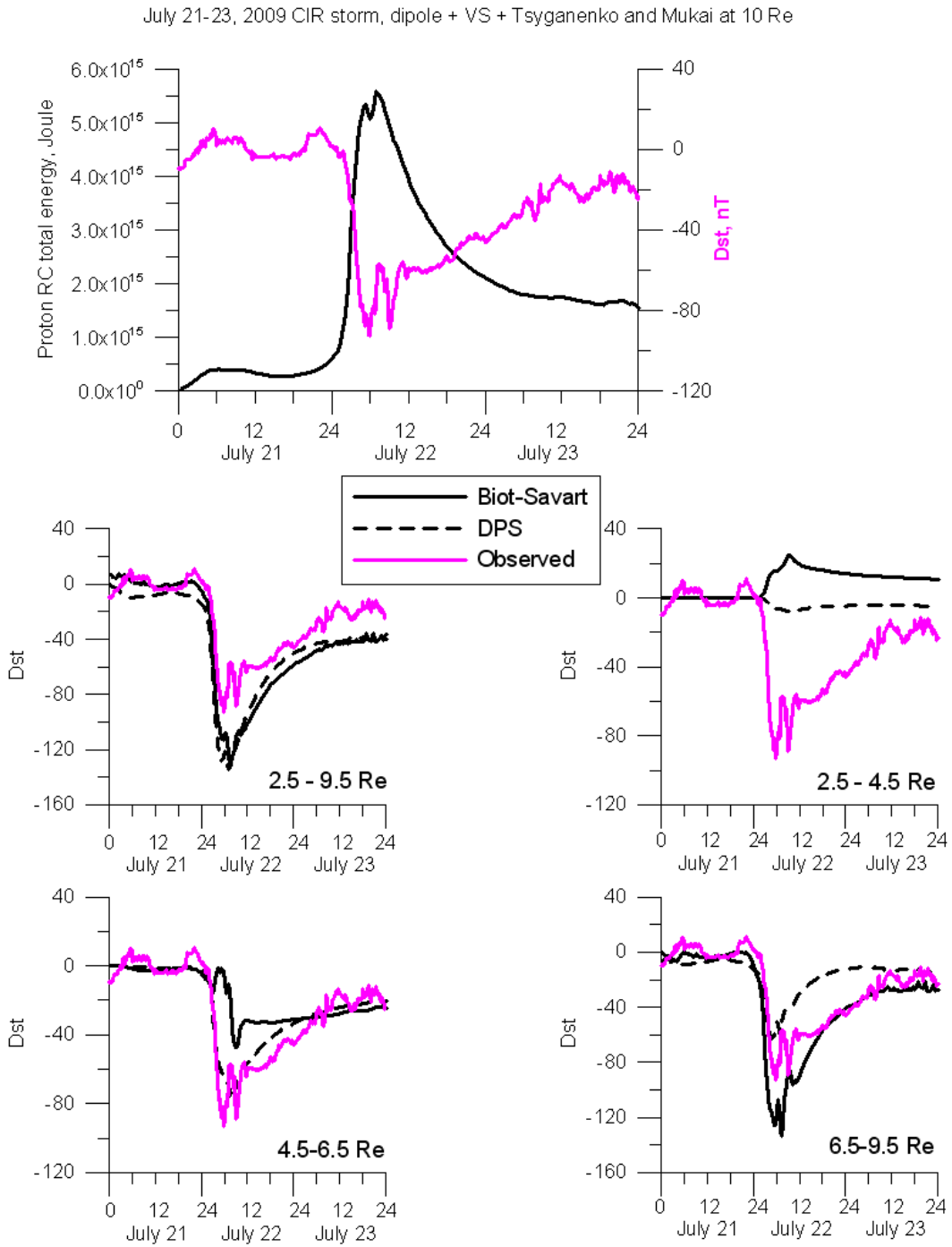
-**Dipole** magnetic field
-**Volland-Stern** electric field
- **Tsyganenko and Mukai**, 2003 boundary conditions at 10 Re

-overestimate by DPS and BS

-BS overestimates more

-ERC by BS, not by DPS

- large Dst from near-Earth ”tail” (not stretched, dipole field), larger by BS



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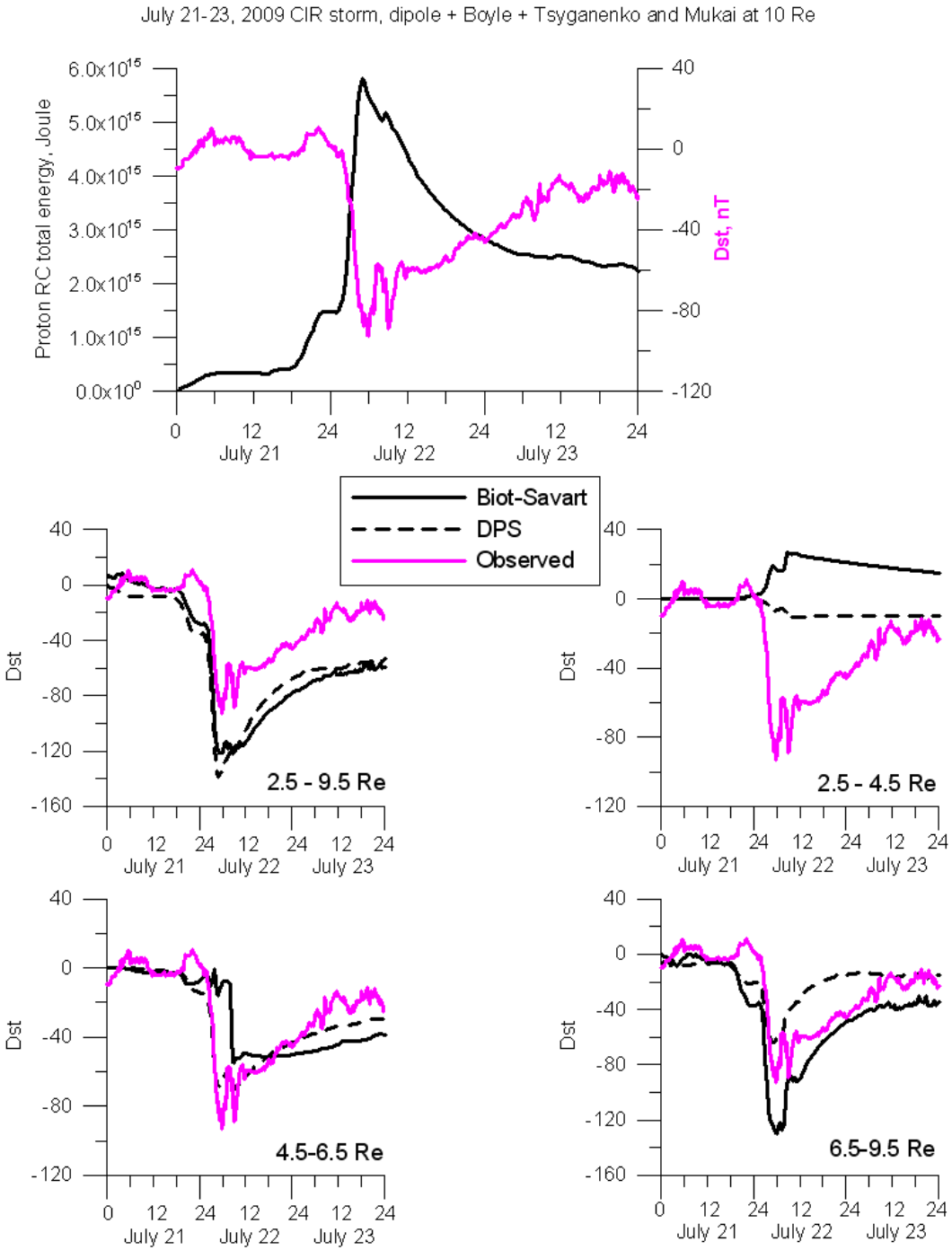
Electric field difference: similar



Modeled Dst for July 21-23, 2009

Model combination:

- **Dipole** magnetic field + **T89**
- **Volland-Stern** electric field
- **Tsyganenko and Mukai**, 2003 boundary conditions at 10 Re

- overestimate by BS, but not by DPS

- DPS follows observed Dst

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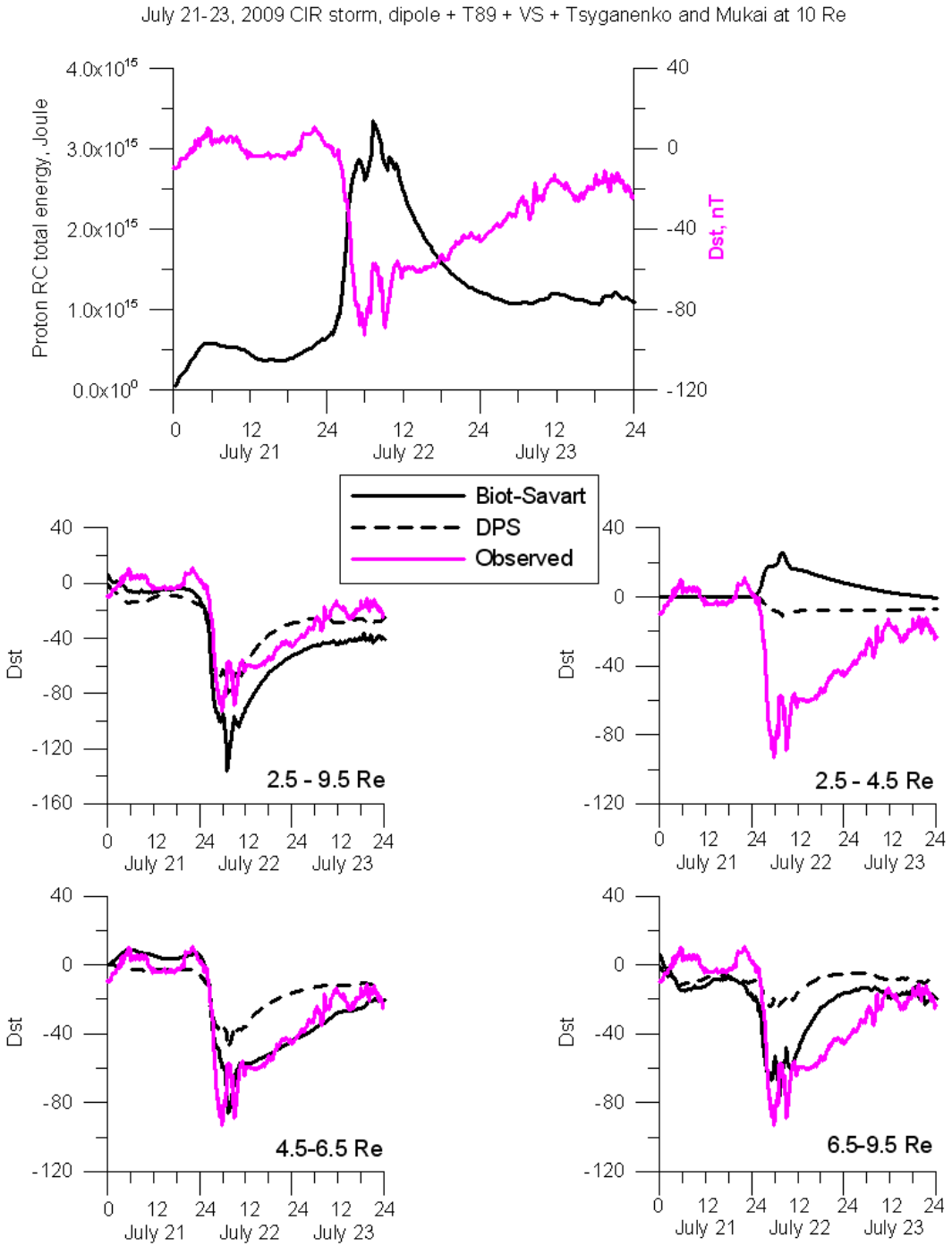
- large Dst from near-Earth ”tail” (but smaller than for dipole), larger by BS

Magnetic field difference



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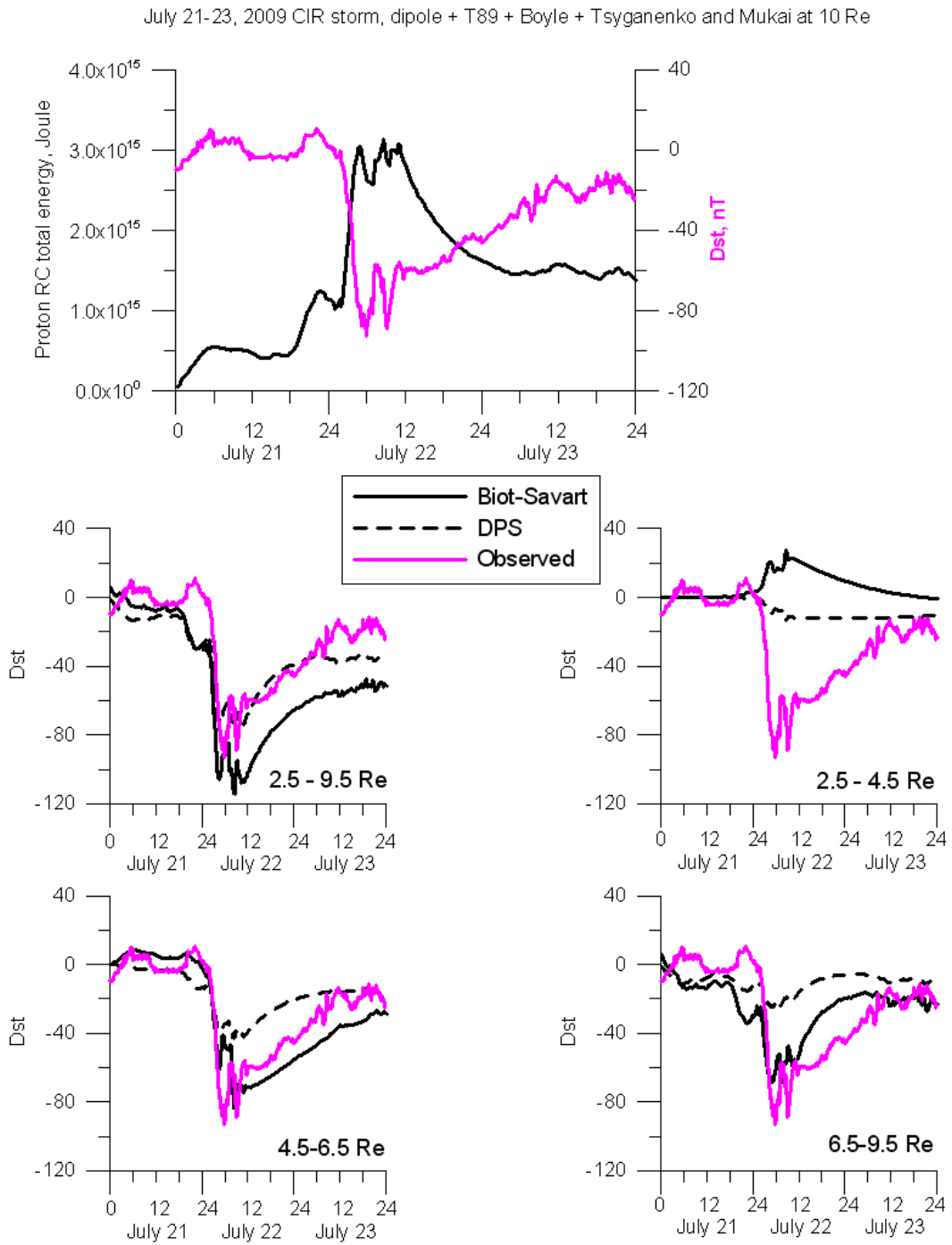

Modeled Dst for July 21-23, 2009

Model combination:

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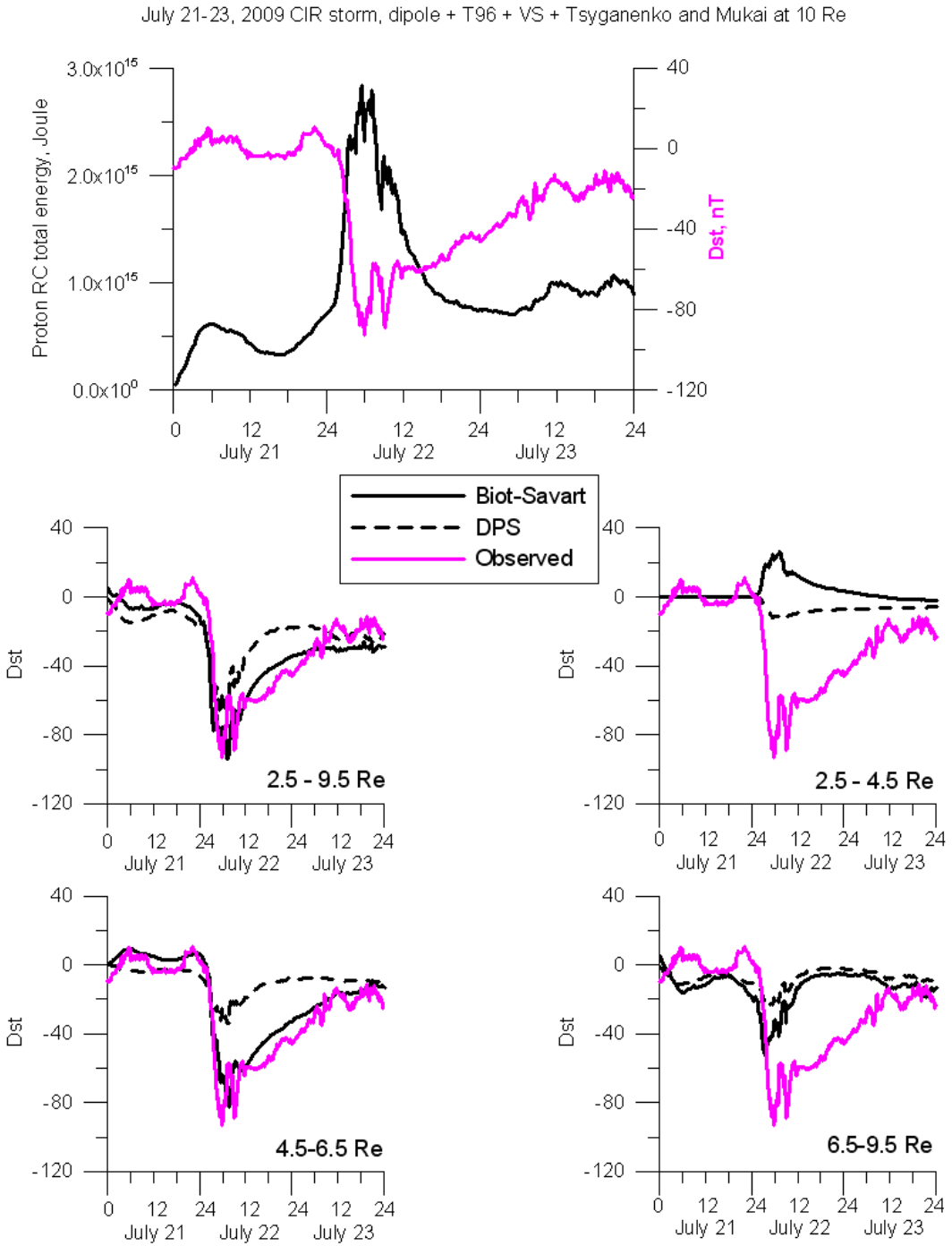
- Moderate Dst from near-Earth ”tail” (smaller than for T89), close values by BS and DPS

Magnetic field difference



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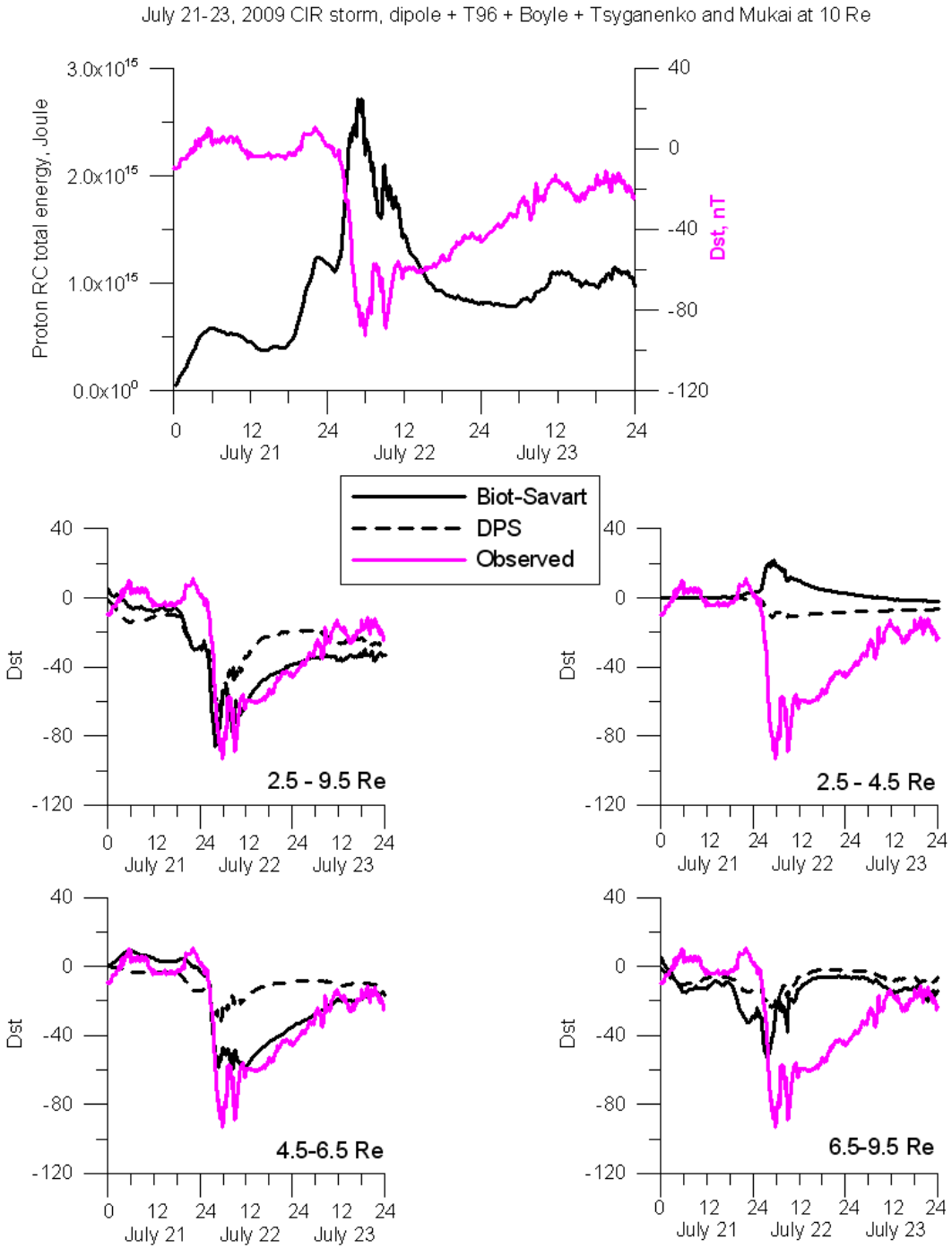


Modeled Dst for July 21-23, 2009

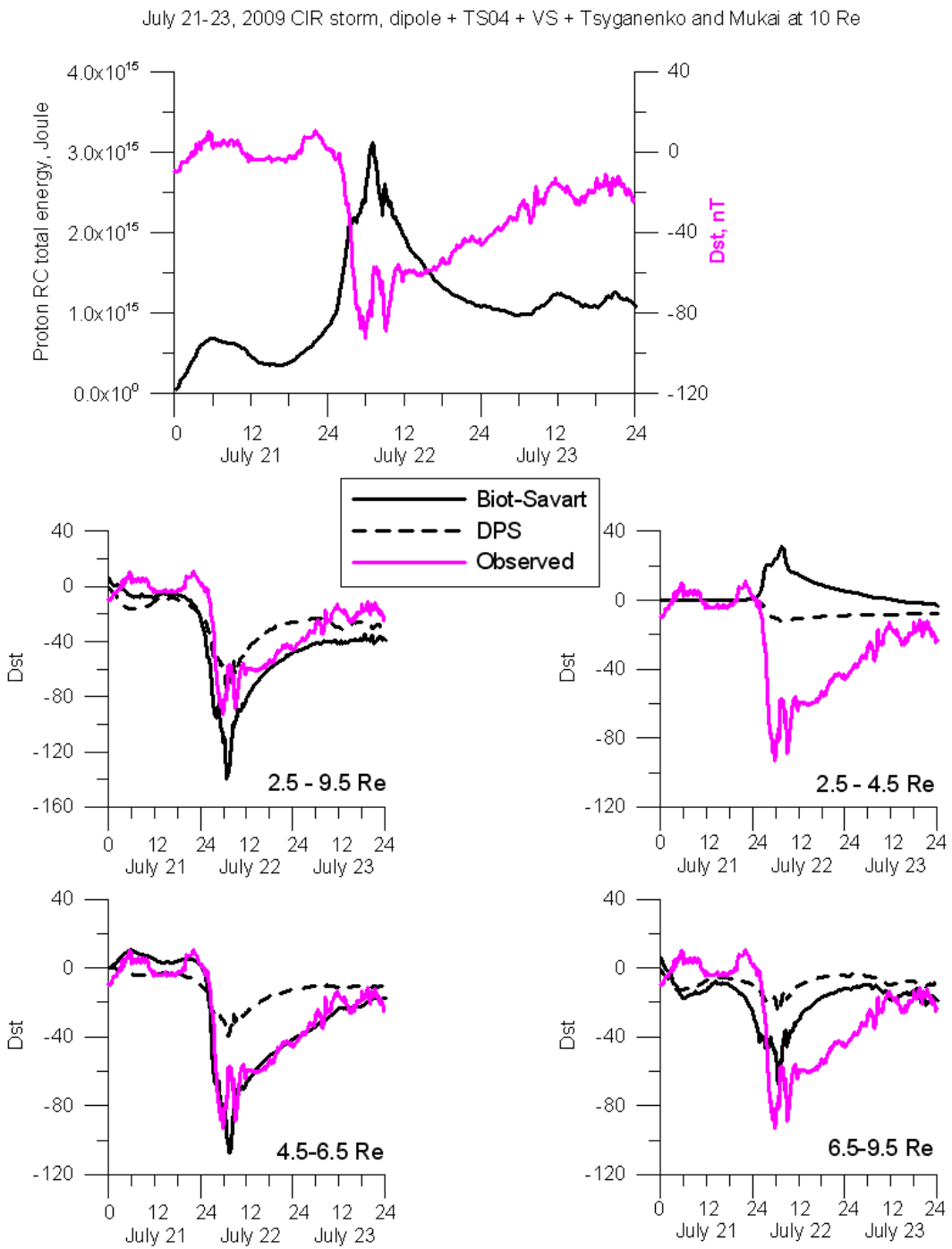
Model combination:

- **Dipole** magnetic field + **TS04**
- **Volland-Stern** electric field
- **Tsyganenko and Mukai**, 2003 boundary conditions at 10 Re

- underestimate by DPS, but over estimate by BS

- ERC by BS, not by DPS

- Large Dst from near-Earth ”tail” (smaller than for T89), larger by BS



Modeled Dst for July 21-23, 2009

Model combination:

- **Dipole** magnetic field + **TS04**
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- **Tsyganenko and Mukai**, 2003 boundary conditions at 10 Re

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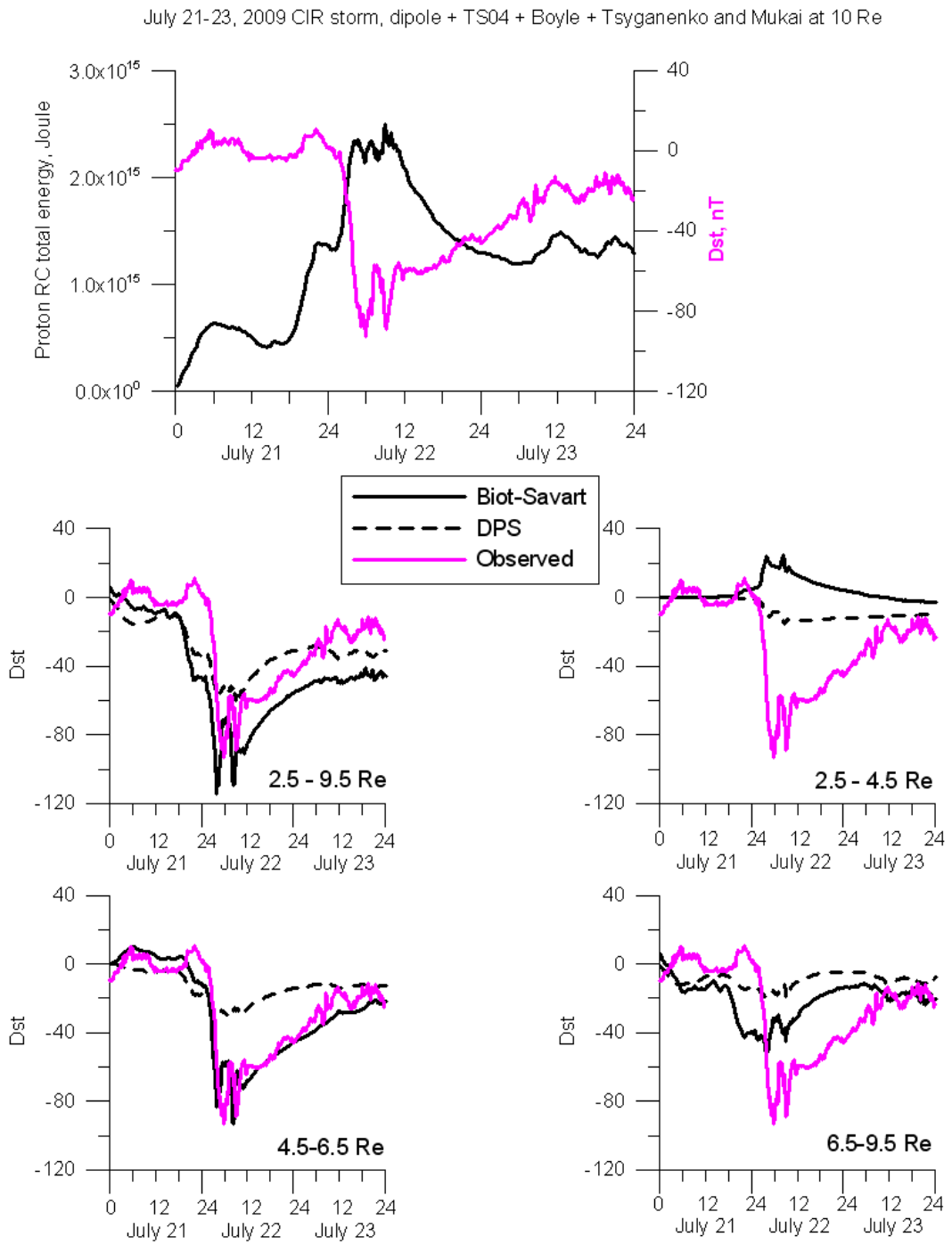
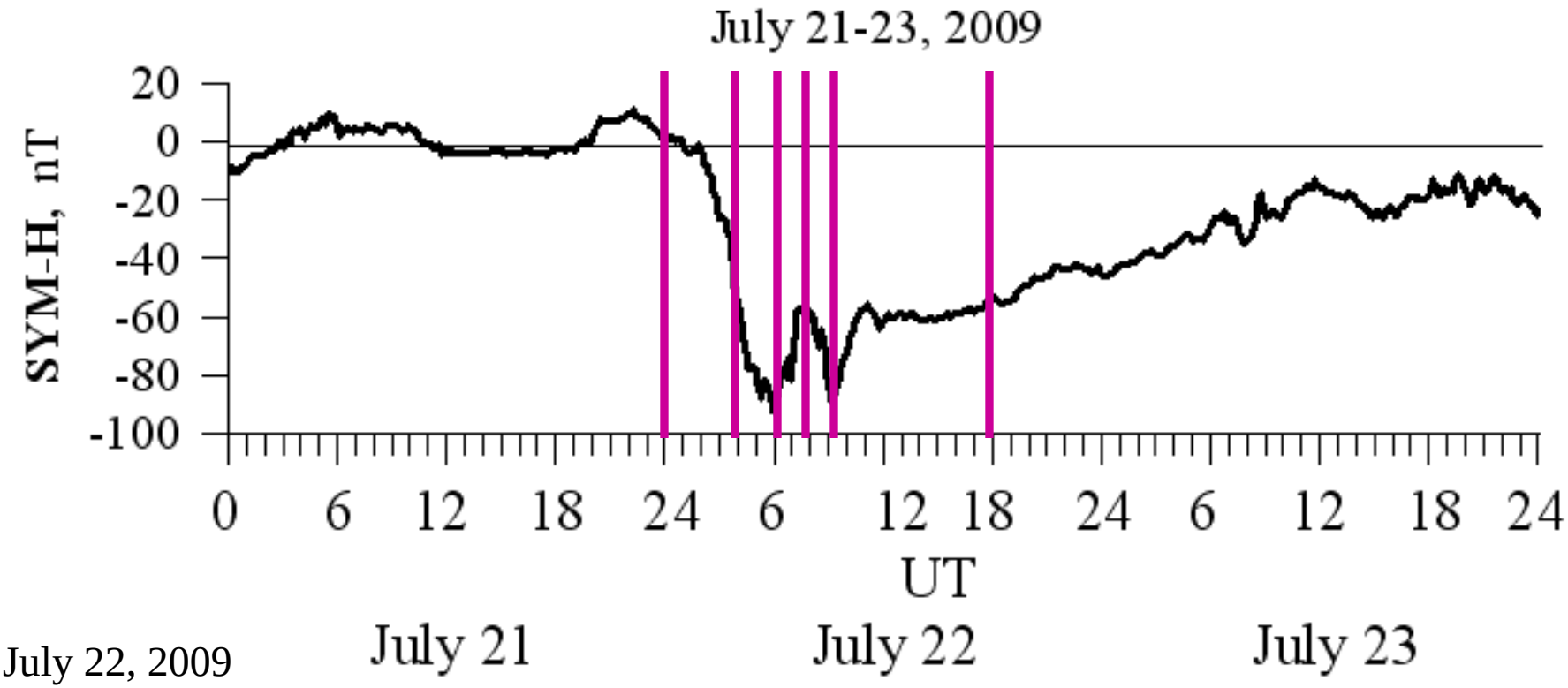


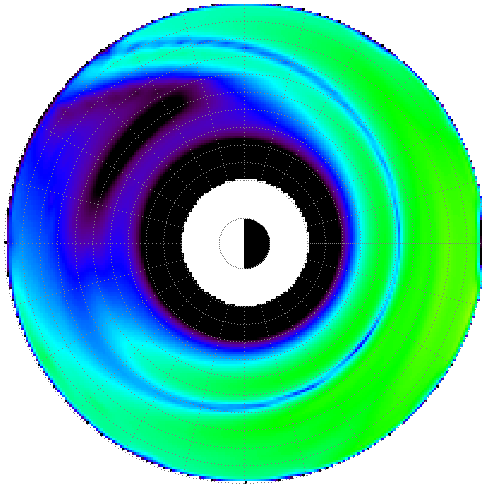
Time moments for July 21-23, 2009 storm



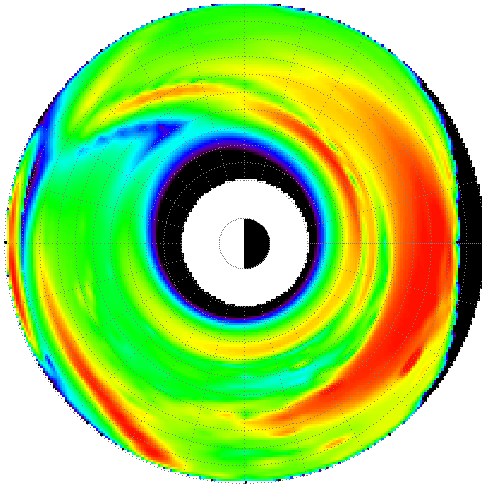
July 22, 2009
0000 UT, SYM-H = 2nT
0400 UT, SYM-H = -59nT
0555 UT, SYM-H = -92nT
0730 UT, SYM-H = -57nT
0905 UT, SYM-H = -89nT
1800 UT, SYM-H = -53nT

Current densities for July 21-23, 2009

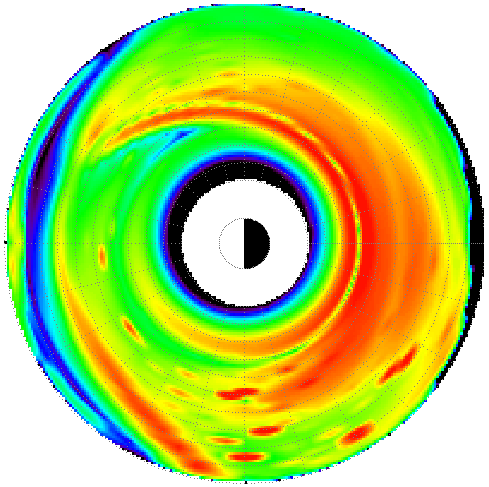
July 22, 00 UT



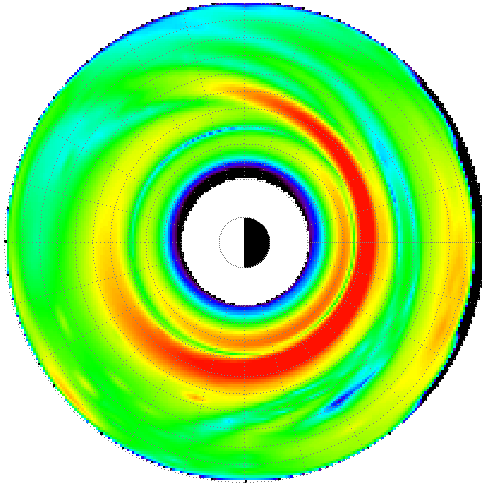
July 22, 04 UT



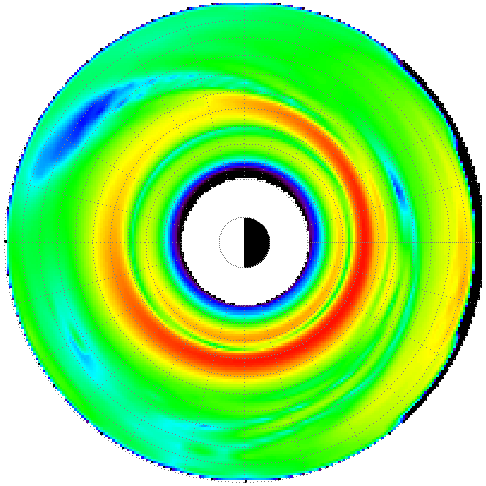
July 22, 06 UT



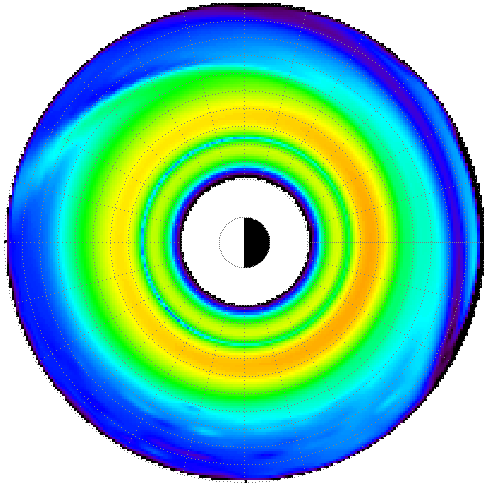
July 22, 08 UT



July 22, 0915 UT



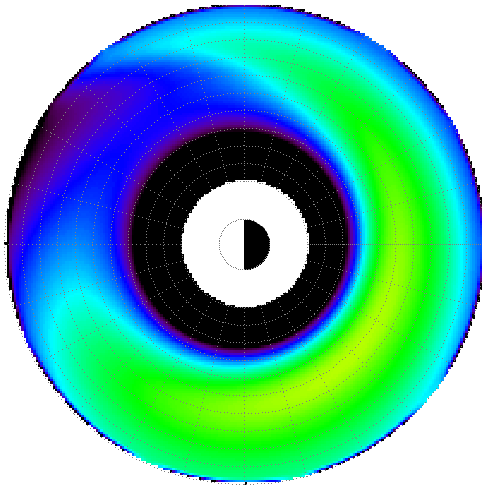
July 22, 18 UT



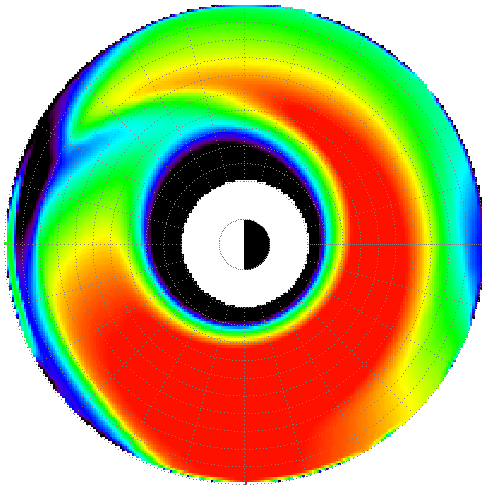
Combination of models: dipole + TS04 + Boyle, Tsyganenko and Mukai at 10 Re

Perpendicular pressure for July 21-23, 2009

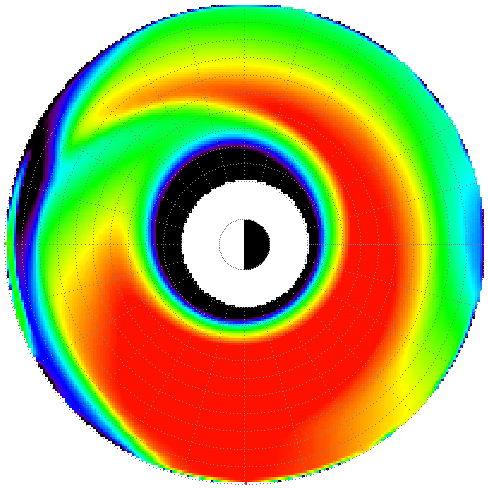
July 22, 00 UT



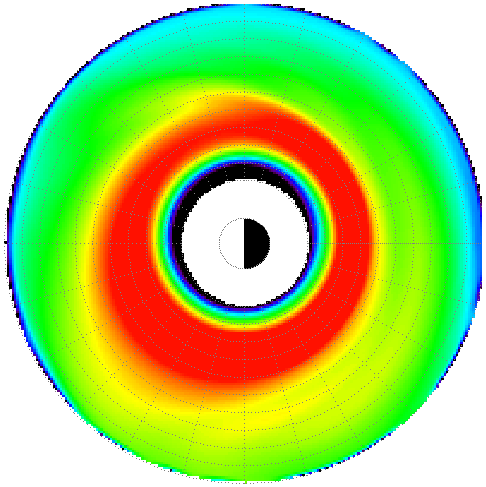
July 22, 04 UT



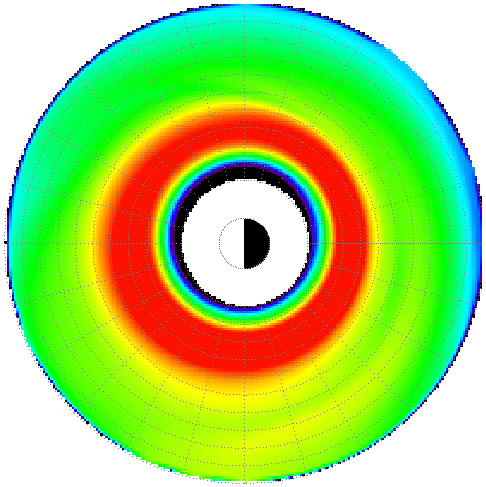
July 22, 06 UT



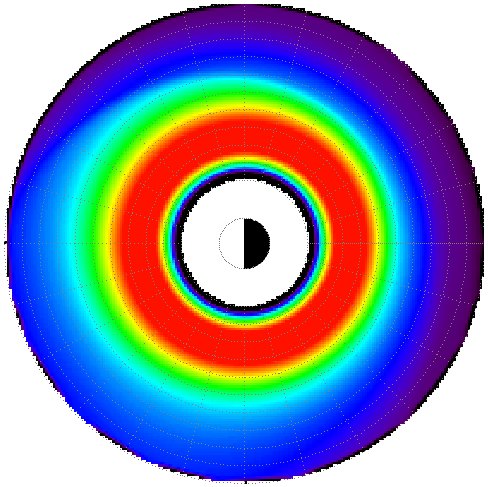
July 22, 08 UT



July 22, 0915 UT



July 22, 18 UT

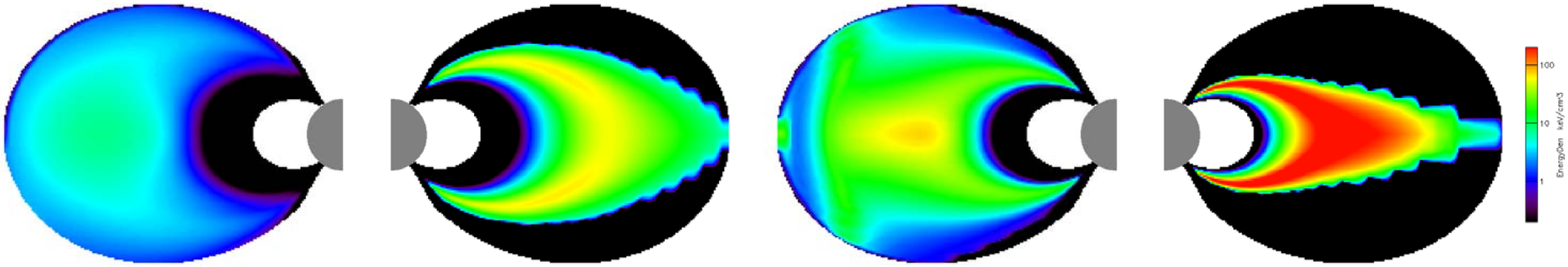


Combination of models: dipole + TS04 + Boyle, Tsyganenko and Mukai at 10 Re

Energy density for July 21-23, 2009

July 22, 00 UT

July 22, 04 UT



July 22, 06 UT

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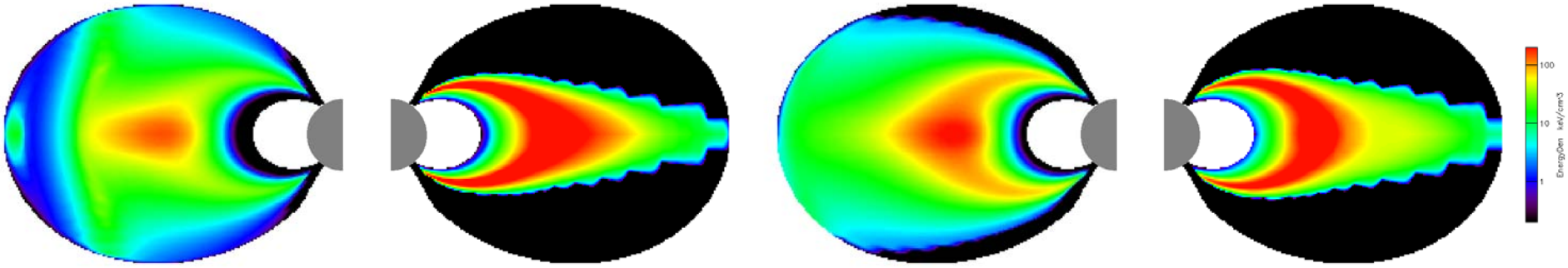

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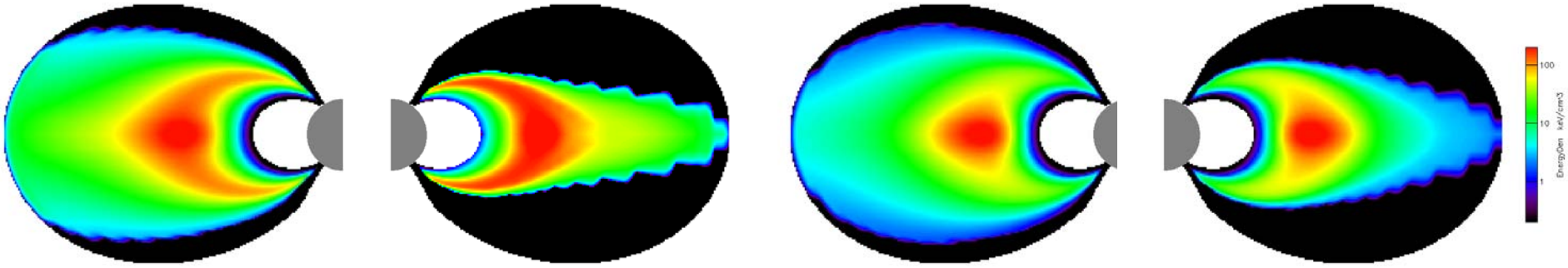
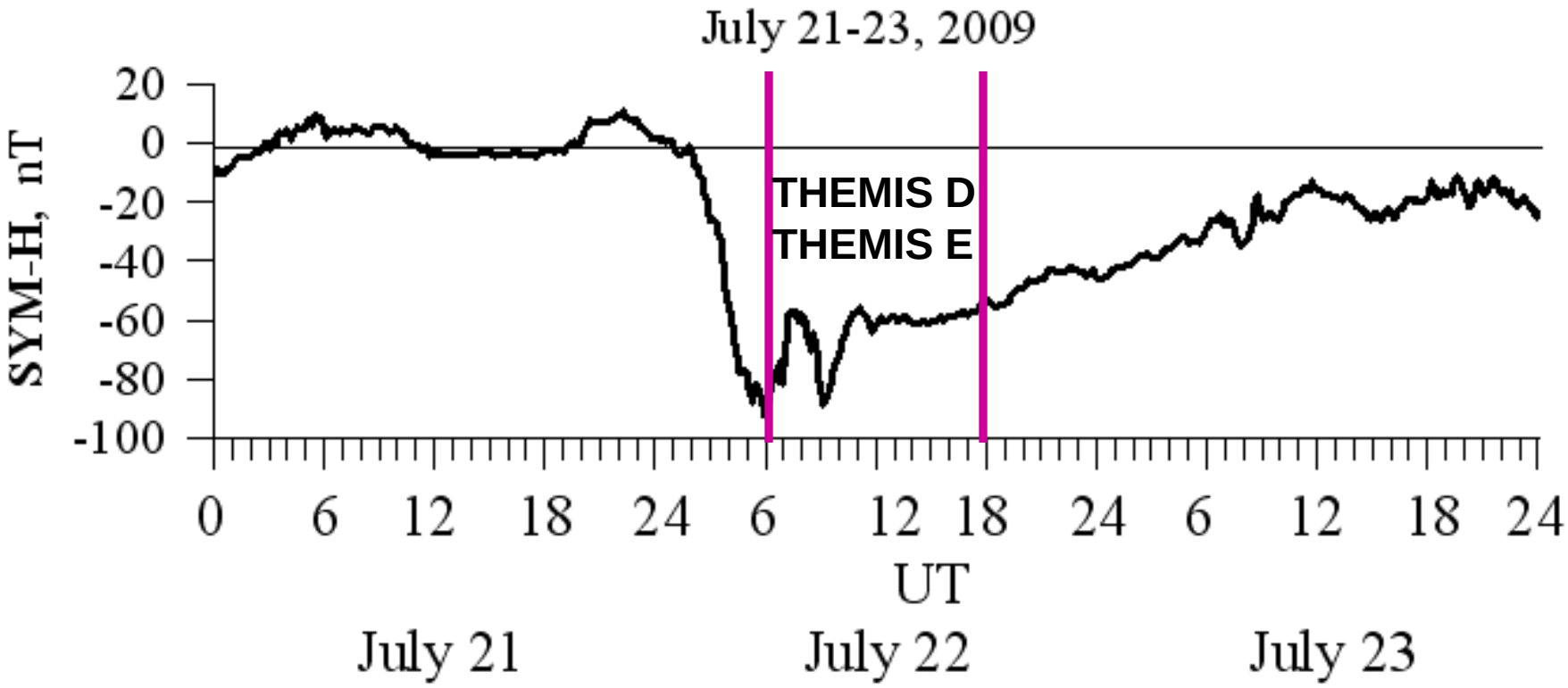
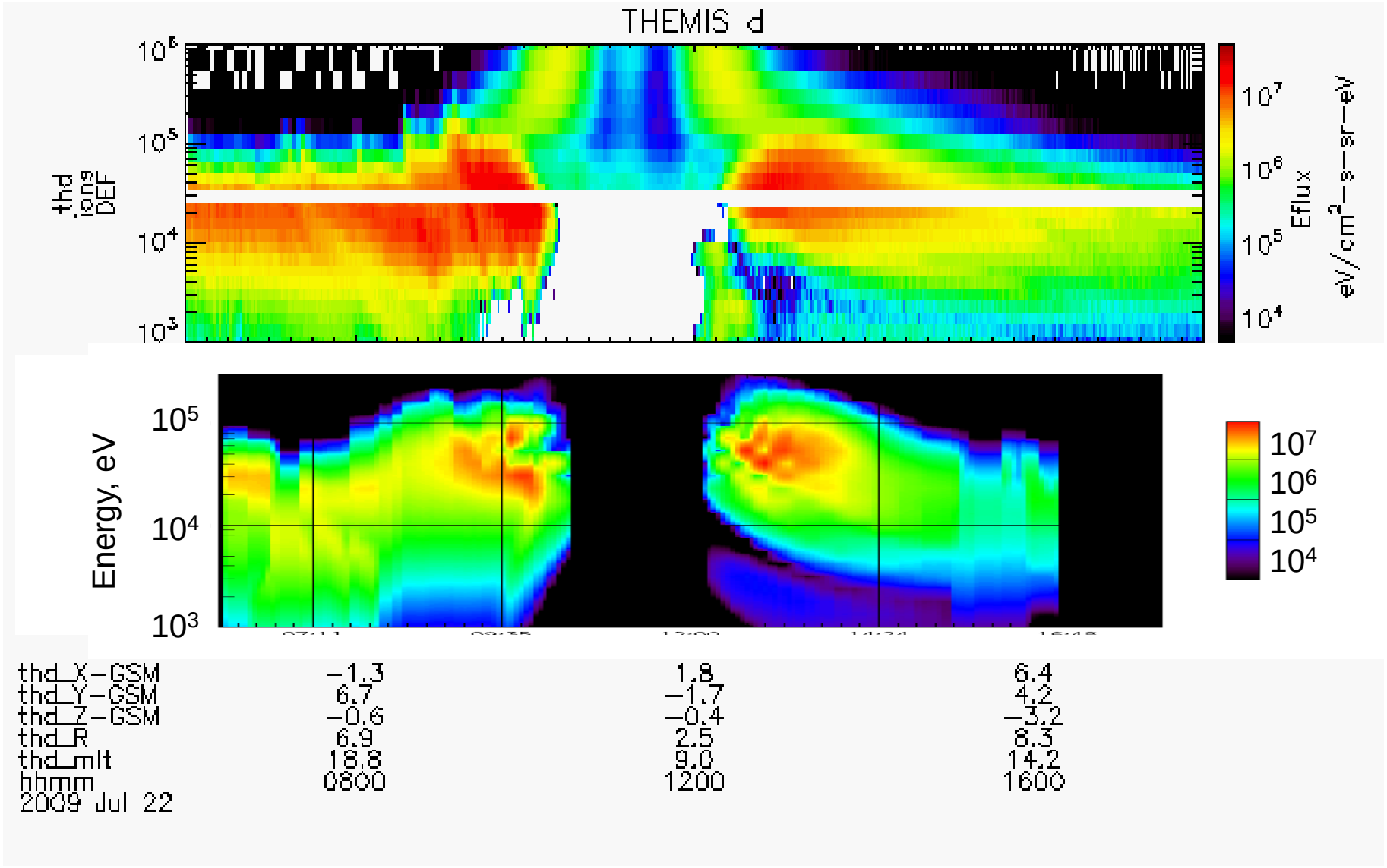


THEMIS spectrograms for comparisons for July 21-23, 1997 storm



Comparisons with THEMIS spectrograms



Combination of models: dipole + TS04 + Boyle, Tsyganenko and Mukai at 10 Re

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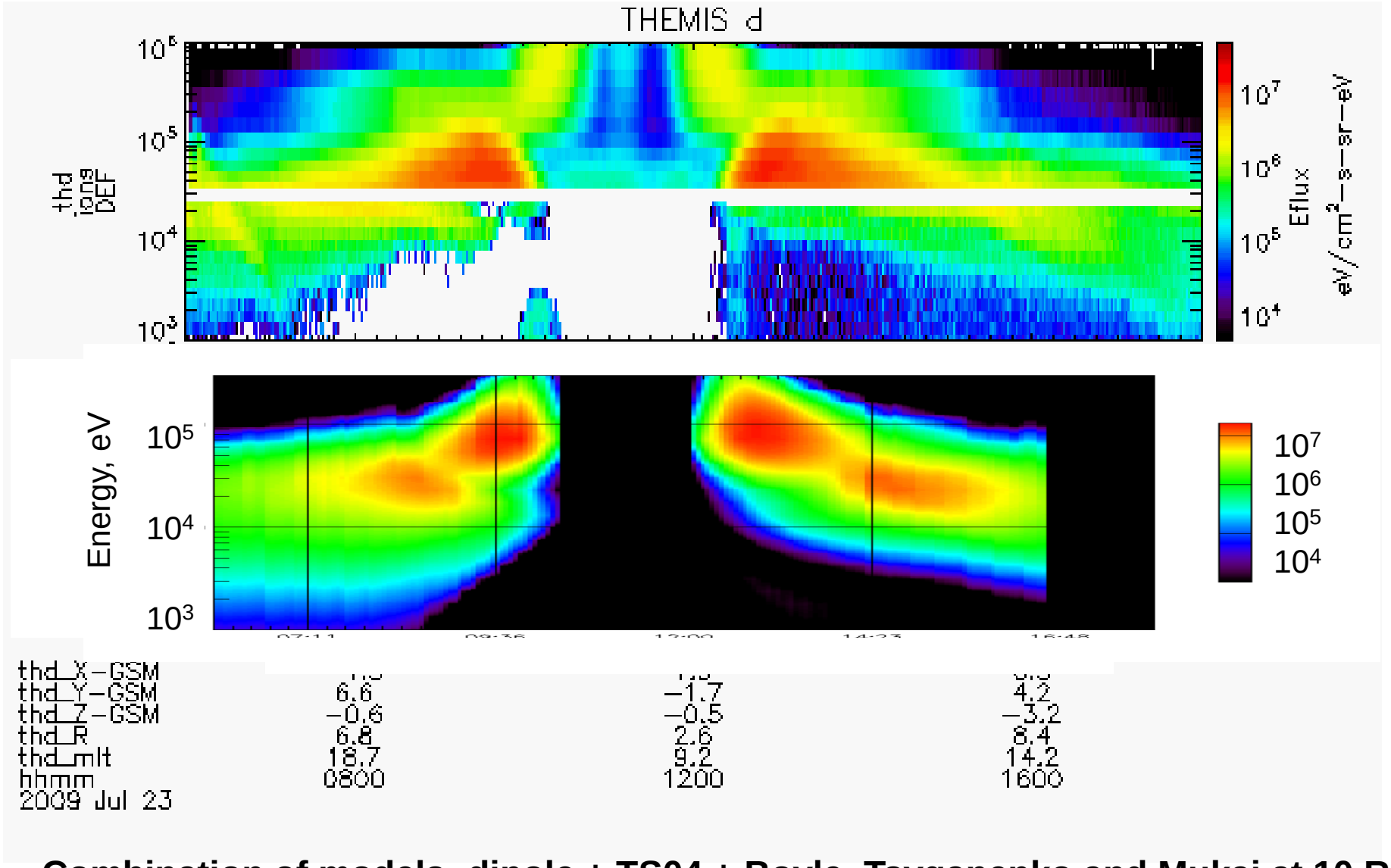

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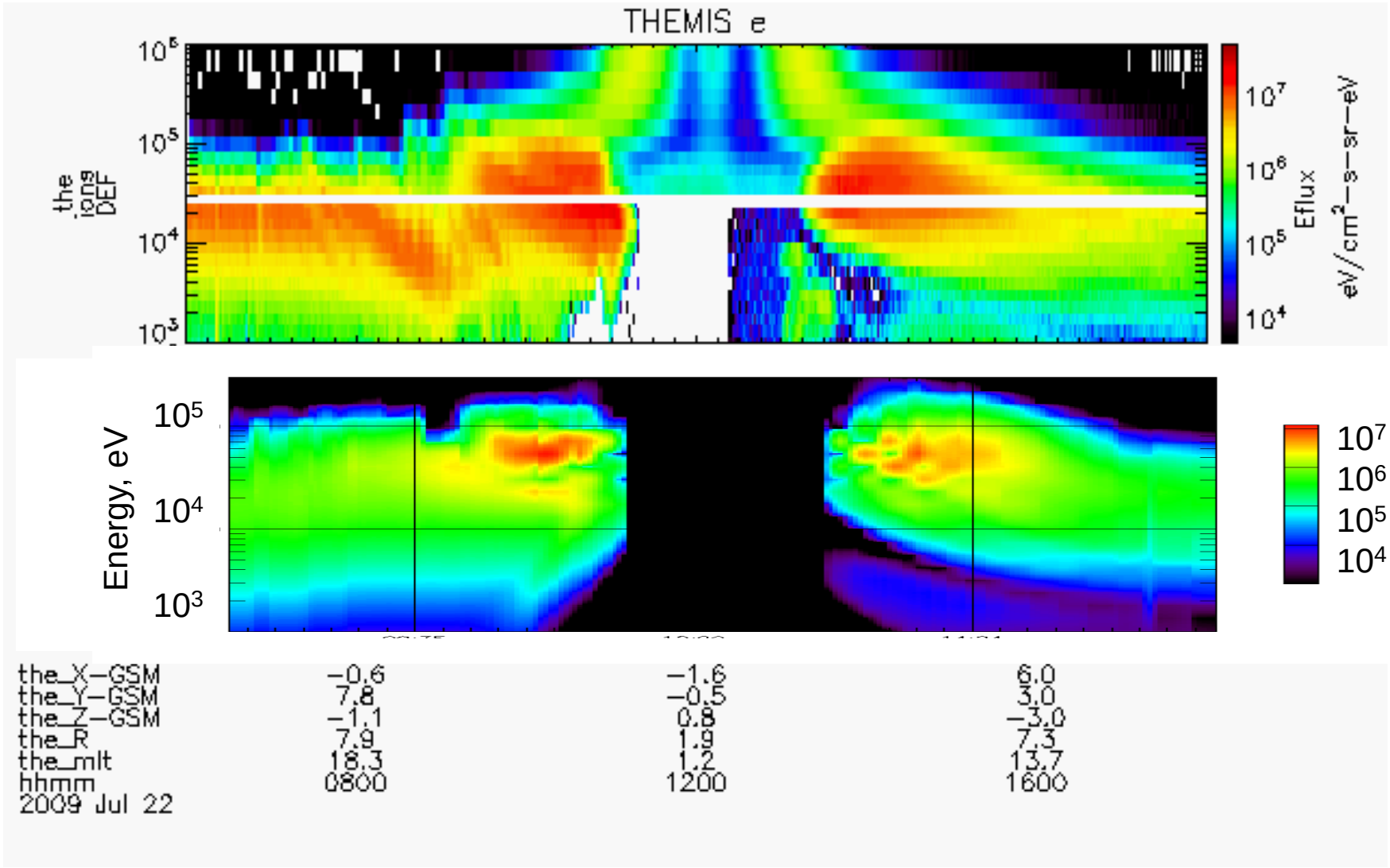

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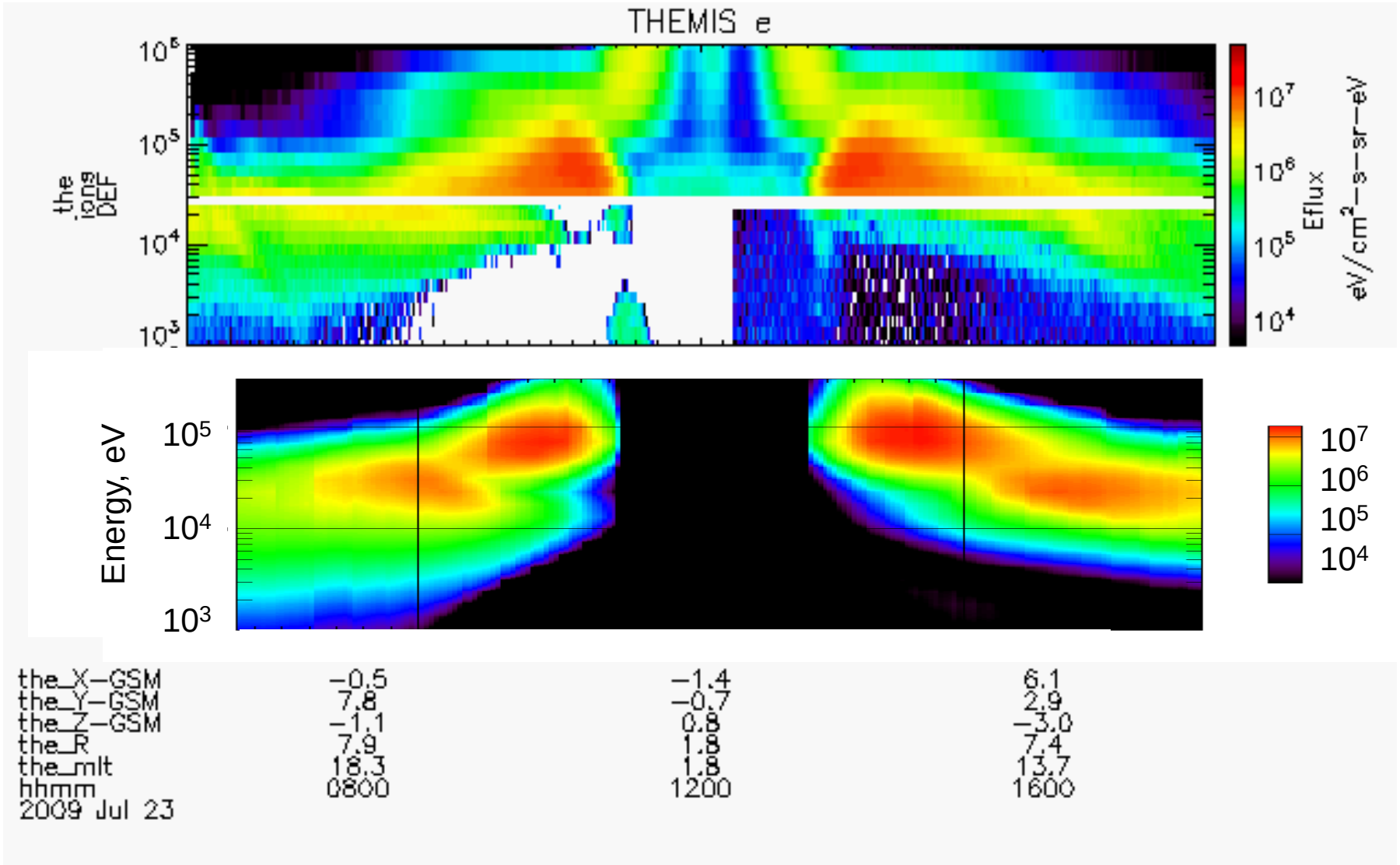

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