Low Energy Electrons (5-50 keV) in the Inner Magnetosphere

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Low energy electrons in the inner magnetosphere

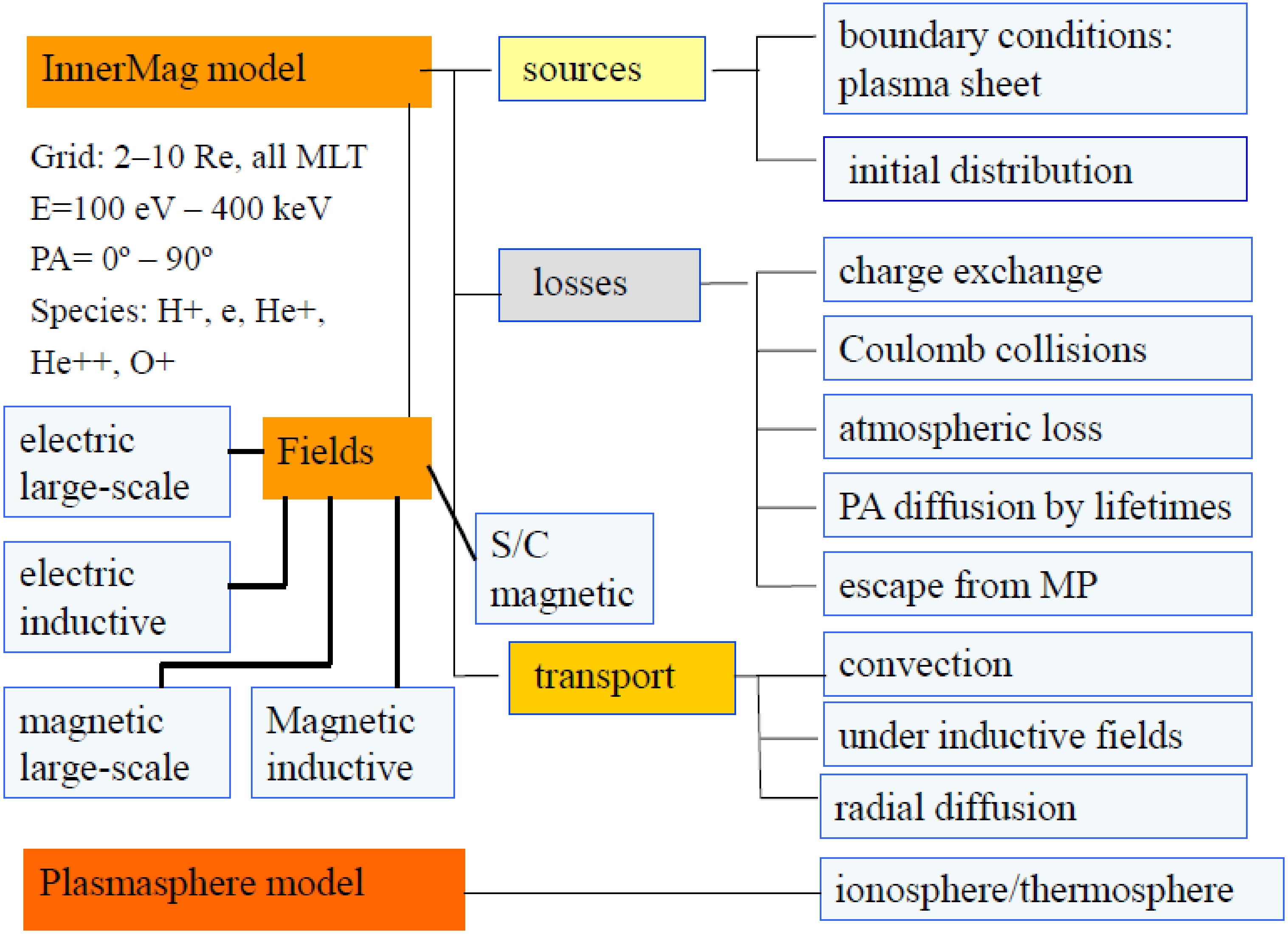
- The distribution of low energy electrons, the seed population (10 to few hundreds of keV), is critically important for radiation belt dynamics.

- Surface charging by electrons with < 100 keV can lead to discharges within and on the surface of the outer spacecraft layers that can cause significant damage and spacecraft anomalies.

- Satellite measurements cannot provide continuous measurements.

- With the development of the Inner Magnetosphere Particle Transport and Acceleration model (IMPTAM) for low energy particles in the inner magnetosphere [*Ganushkina et al.*, AnnGeo, *2005*, *JGR*, *2006*, AnnGeo, *2012*, *JGR*, *2013*], the computational view on the low energy electron fluxes important for radiation belts at L=2-10 is now feasible.

Inner Magnetosphere Particle Transport and Acceleration Model (1)



InnerMag model

Grid: 2–10 Re, all MLT
E=100 eV – 400 keV
PA= 0º – 90º
Species: H+, e, He+, He++, O+

sources
- boundary conditions: plasma sheet
- initial distribution

losses
- charge exchange
- Coulomb collisions
- atmospheric loss
- PA diffusion by lifetimes
- escape from MP

Fields
- electric large-scale
- electric inductive
- magnetic large-scale
- Magnetic inductive
- S/C magnetic

transport
- convection
- under inductive fields
- radial diffusion

Plasmasphere model
- ionosphere/thermosphere

Inner Magnetosphere Particle Transport and Acceleration Model (2)

♦ traces **ions and electrons** with arbitrary pitch angles from the plasma sheet to the inner L-shell regions with energies up to **hundreds of keVs** in time-dependent magnetic and electric fields

♦ traces a distribution of particles in the **drift approximation** under the conservation of the 1st and 2nd adiabatic invariants. Liouville theorem is used to gain information of the entire distribution function

♦ for the obtained distribution function, we apply **radial diffusion** by solving the radial diffusion equation

♦ electron losses: convection outflow and pitch angle diffusion by the **electron lifetimes.**

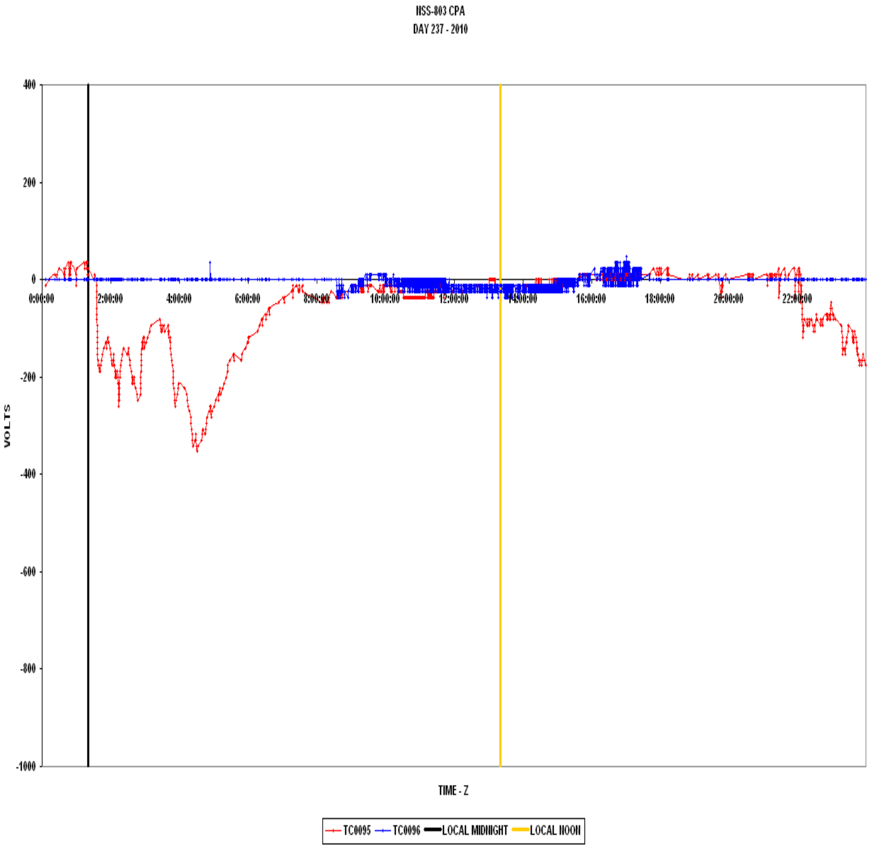
♦advantage of IMPTAM: can utilize any magnetic or electric field model, including self-consistent magnetic field and substorm-associated electromagnetic fields.

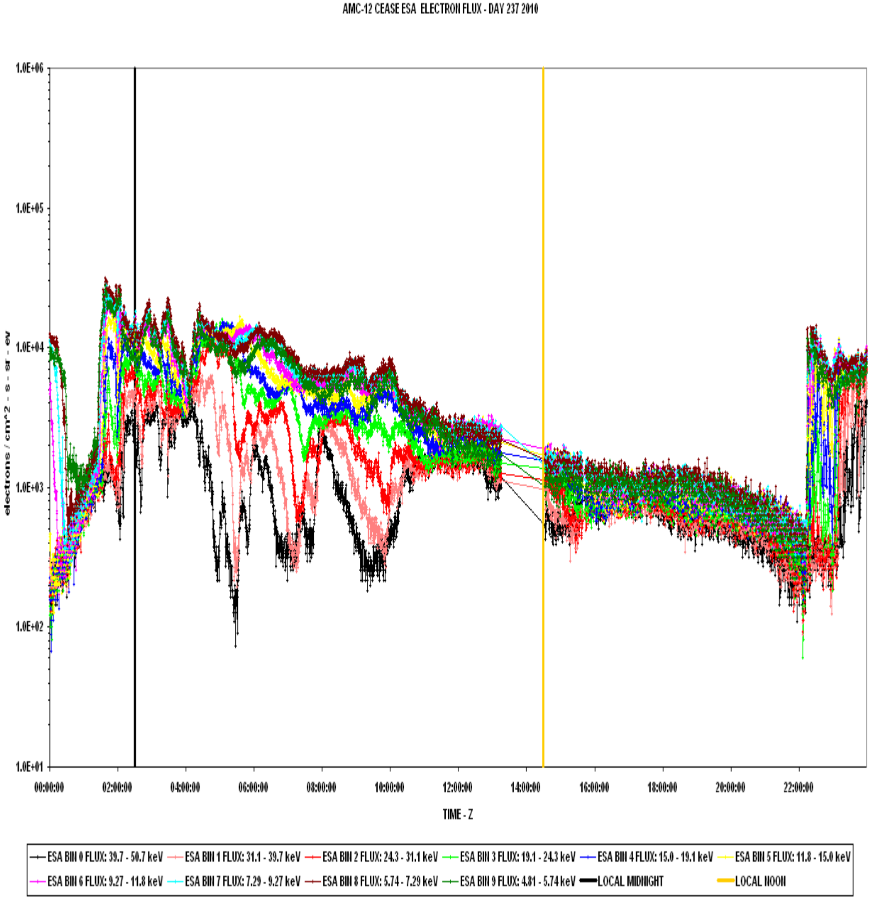
♦all details are given in

Ganushkina, N. Y., et al. (2013), Transport of the plasma sheet electrons to the geostationary distances, J. Geophys. Res., 118, doi:10.1029/2012JA017923.

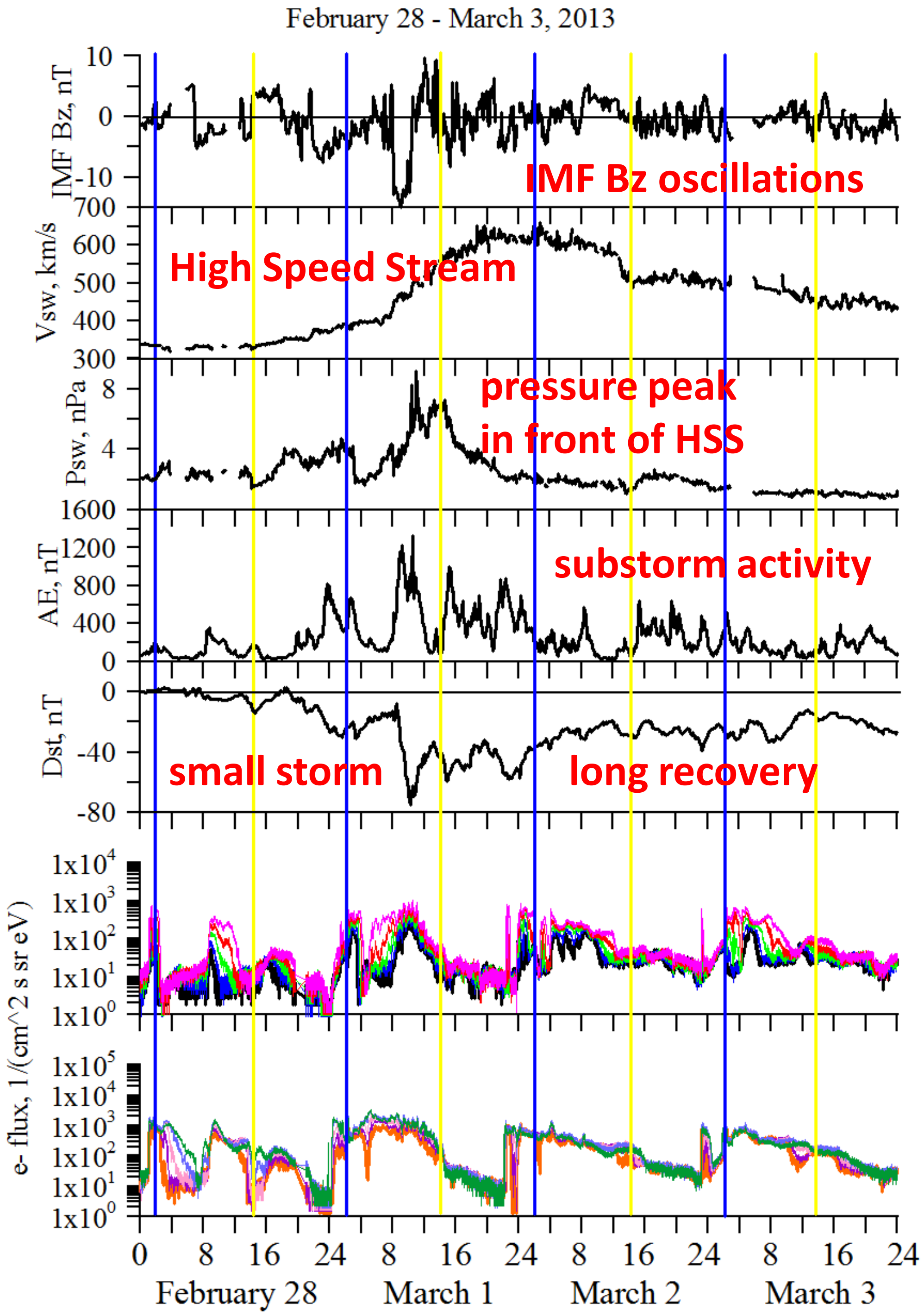
Ganushkina, N. Yu, Liemohn, M. W., and Pulkkinen, T. I., Storm-Time Ring Current: Model-Dependent Results, Annales Geophysicae, 30, 177-202, 2012.

Instrumentation and Data:
AMC 12 satellite, CEASE II ESA instrument





Modelled event 1



IMF Bz oscillations

High Speed Stream

pressure peak
in front of HSS

substorm activity

small storm

long recovery

Small, CIR-driven storm with **Dst of 75 nT**
IMF Bz of -5 -10 nT,
Vsw from 350 to 650 km/s,
Psw peak at 8 nPa,
AE peaks of 800-1200 nT

AMC12 electron data

- peaks in both 15-50 keV and 5-15 keV electron fluxes show clear correlation with AE peaks
- 2 orders of magnitude increase
- peaks for 15-50 keV more dispersed
- daily gradual decrease of fluxes from midnight to dawn-noon-dusk

Modelling

Main question: which variations in the observed electron fluxes are caused by

(1) Variations of SW and IMF parameters (used in time-dependent boundary conditions, magnetic and electric fields;

(2) Electron losses;

(3) Variations of electromagnetic fields associated with substorms.

Magnetic field model: T96 (Dst, Psw, IMF By and Bz)
Electric field model: Boyle (Vsw, IMF B, By, Bz)
Boundary conditions: Tsyganenko and Mukai (Vsw, IMF Bz,Nsw)

Losses: Kp, magnetic field
Strong diffusion (L=10-6):

$$\tau_{sd} = \left(\frac{\gamma m_0}{p}\right)\left[\frac{2\Psi B_h}{1-\eta}\right]$$

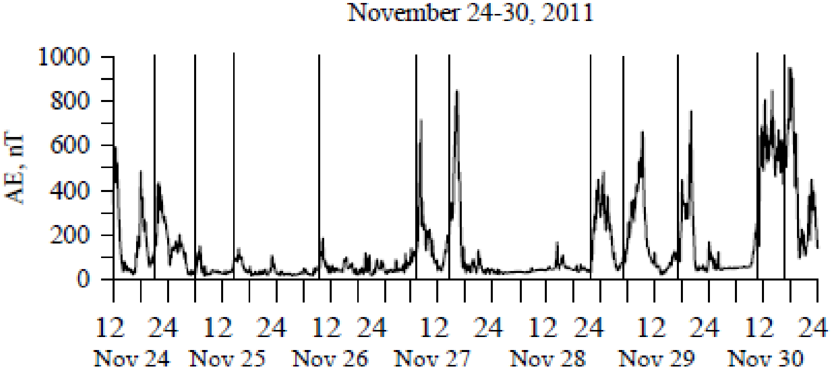
Weak diffusion (L=2-6):

$$\tau_{wd} = 4.8\cdot 10^4 B_w^{-2} L^{-1} E^2, \quad B_w^2 = 2\cdot 10^{2.5+0.18Kp}$$

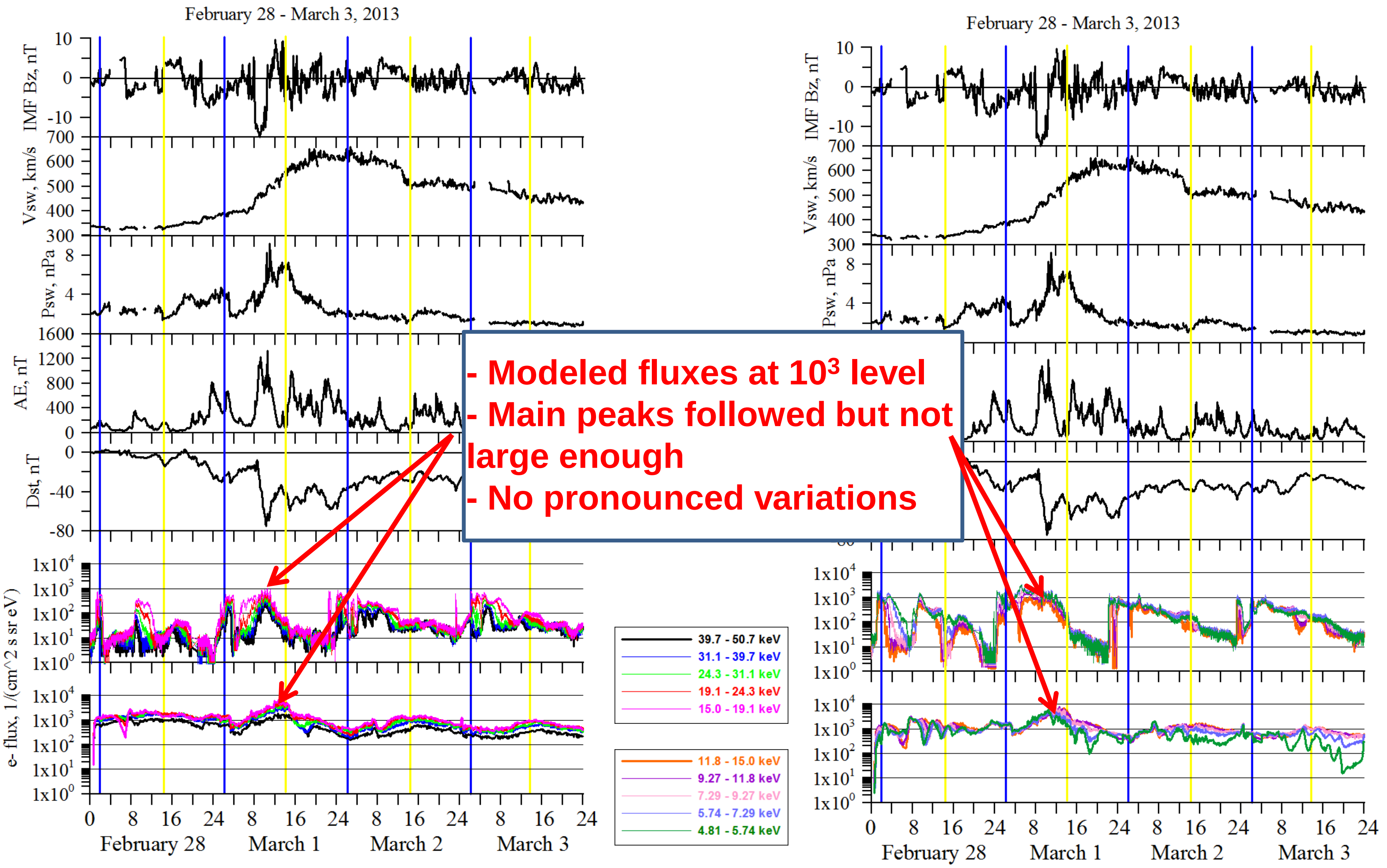
Electromagnetic pulses at substorm onsets:

$$\mathrm{E}_\phi = -\mathrm{E}_0\left(1+\mathrm{c}_1\cos(\phi-\phi_0)\right)^{\mathrm{p}}\exp\left(-\xi^2\right),$$

Timing and amplitude from AE index

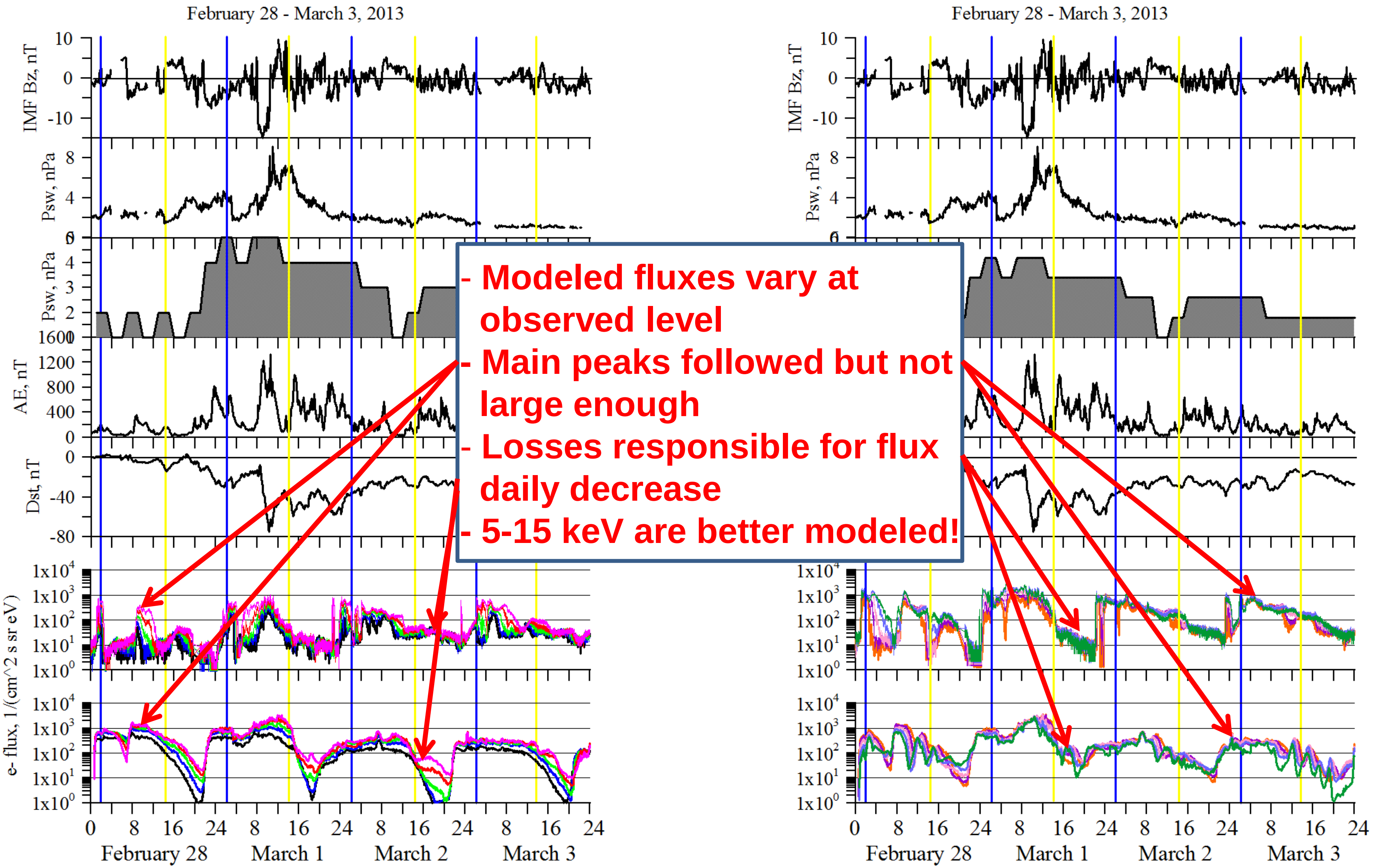


Modeling results: No losses, no pulses, all determined by SW and IMF variations



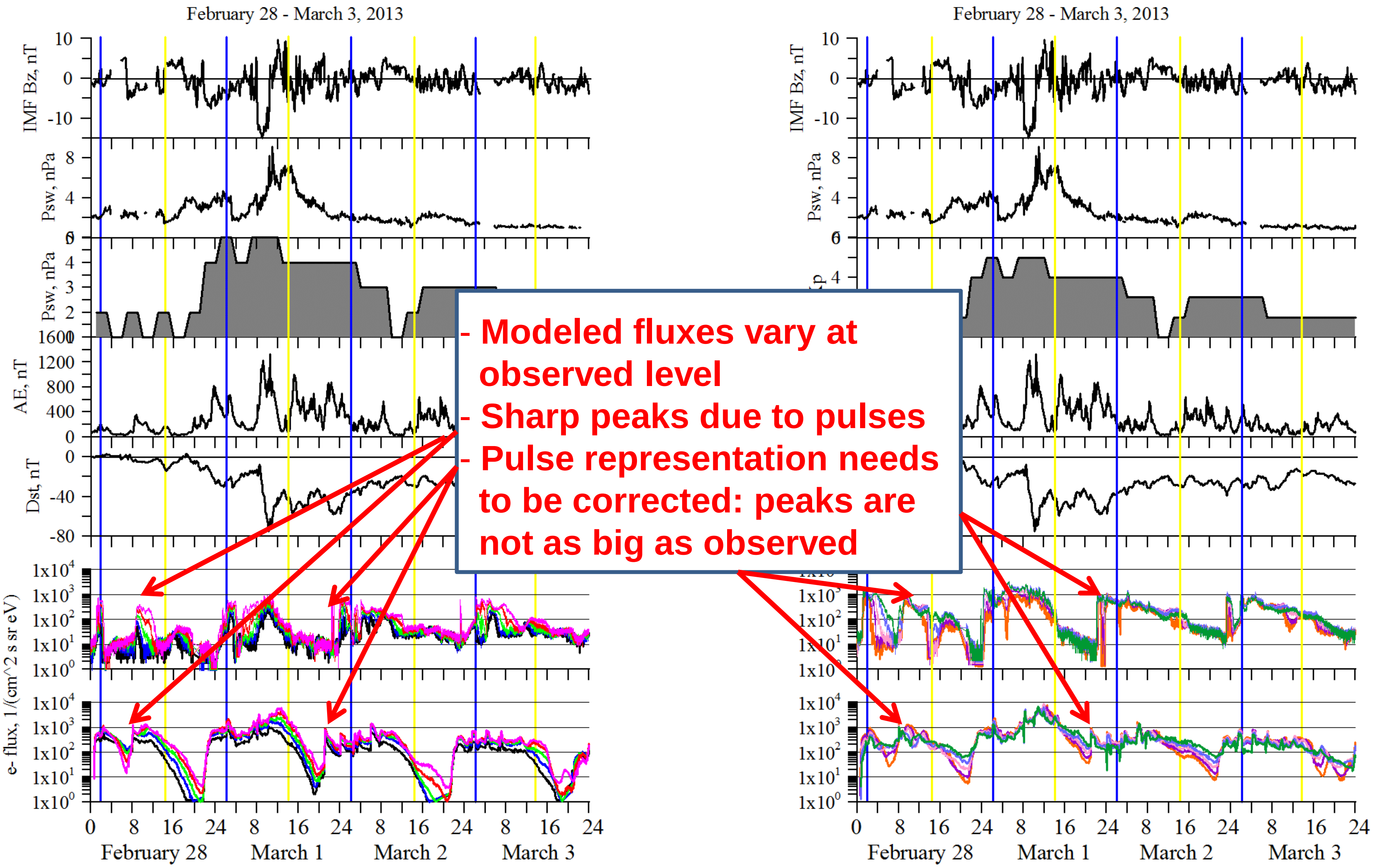
- Modeled fluxes at 10^3 level
- Main peaks followed but not large enough
- No pronounced variations

Modeling results: With losses, no pulses, all determined by SW and IMF variations and Kp



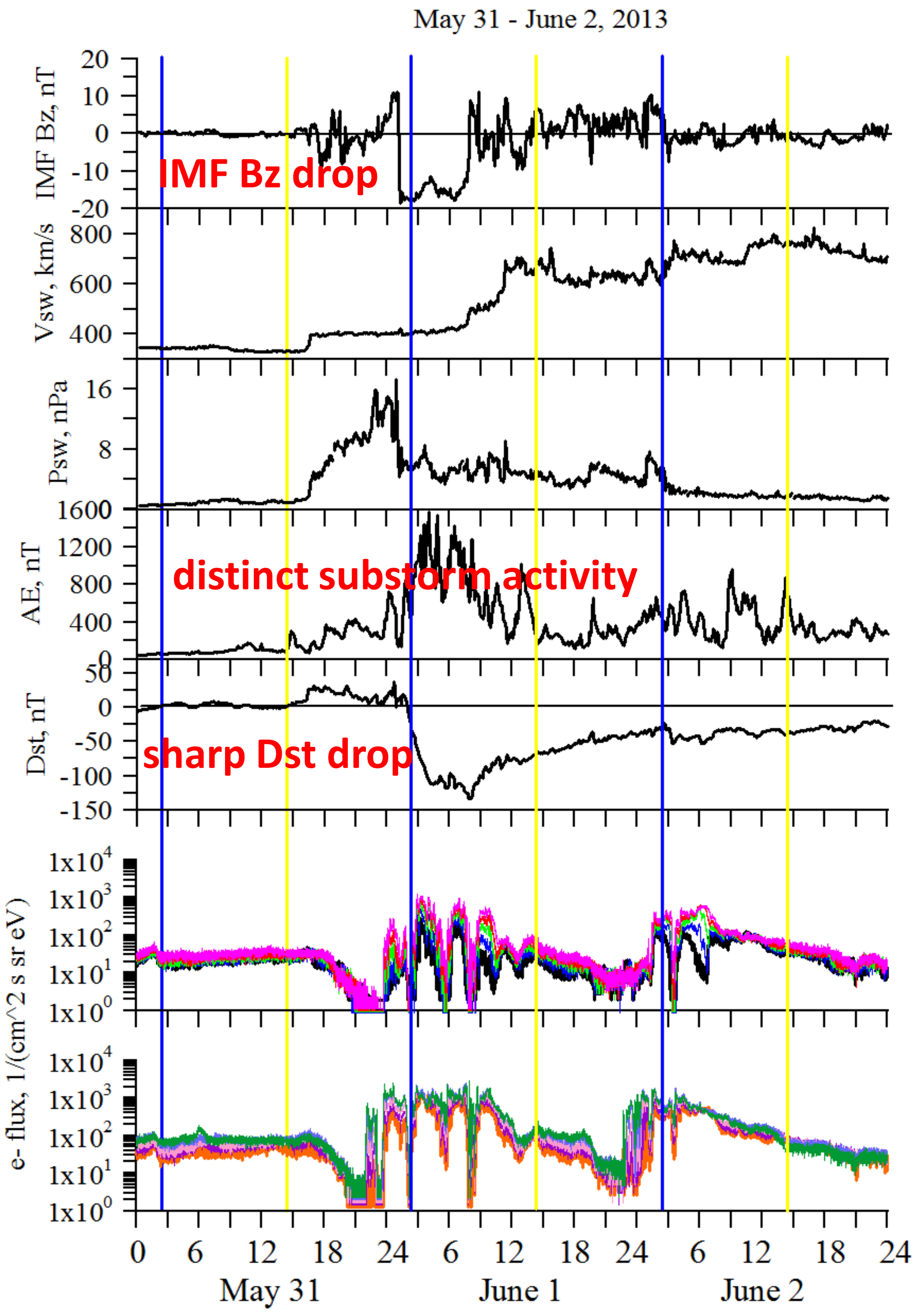
- Modeled fluxes vary at observed level
- Main peaks followed but not large enough
- Losses responsible for flux daily decrease
- 5-15 keV are better modeled!

Modeling results: With losses, with pulses



- Modeled fluxes vary at observed level
- Sharp peaks due to pulses
- Pulse representation needs to be corrected: peaks are not as big as observed

Modelled event 2


May 31 - June 2, 2013

IMF Bz drop

distinct substorm activity

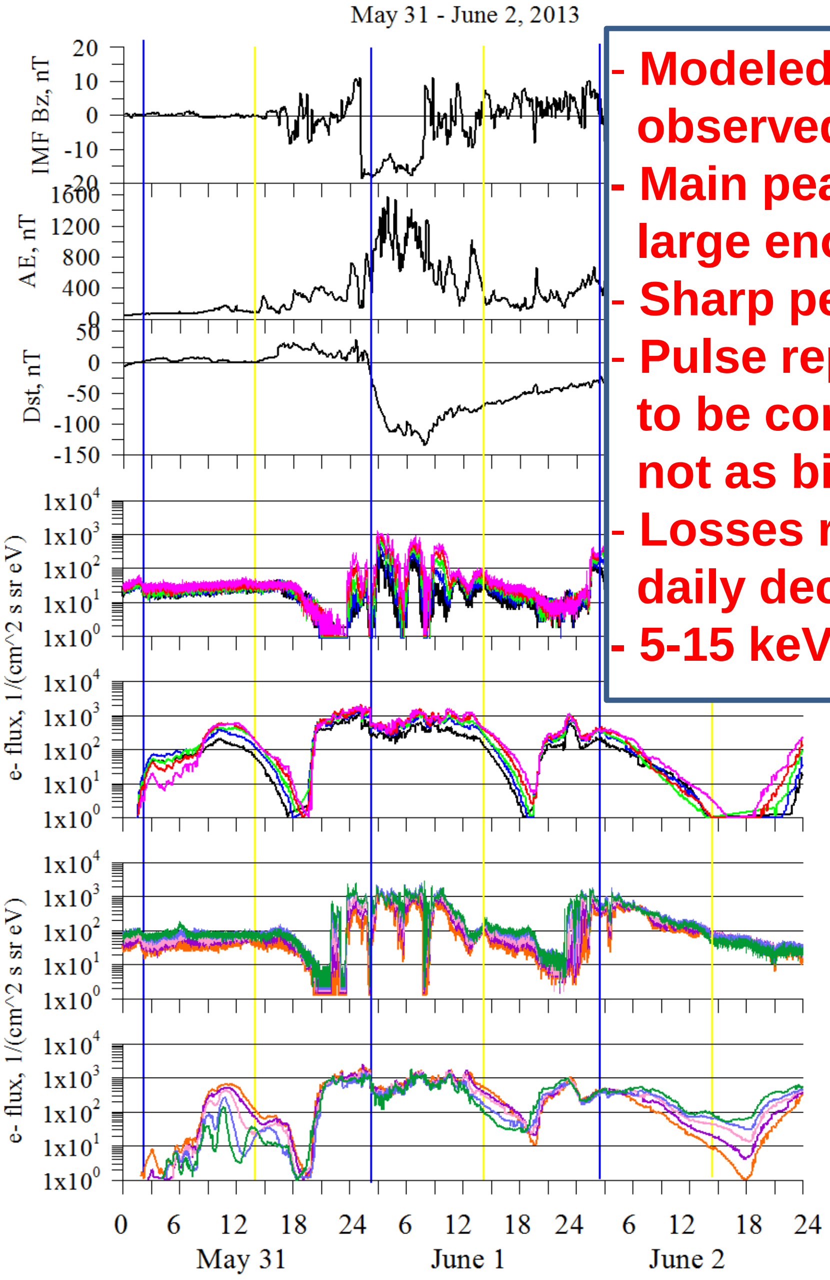
sharp Dst drop

Moderate, CME-driven storm with **Dst of 135 nT, IMF Bz reaching -20** nT, **Vsw** from 400 to 700, **Psw** peak at 16 nPa, **AE** peaks of 1600 nT

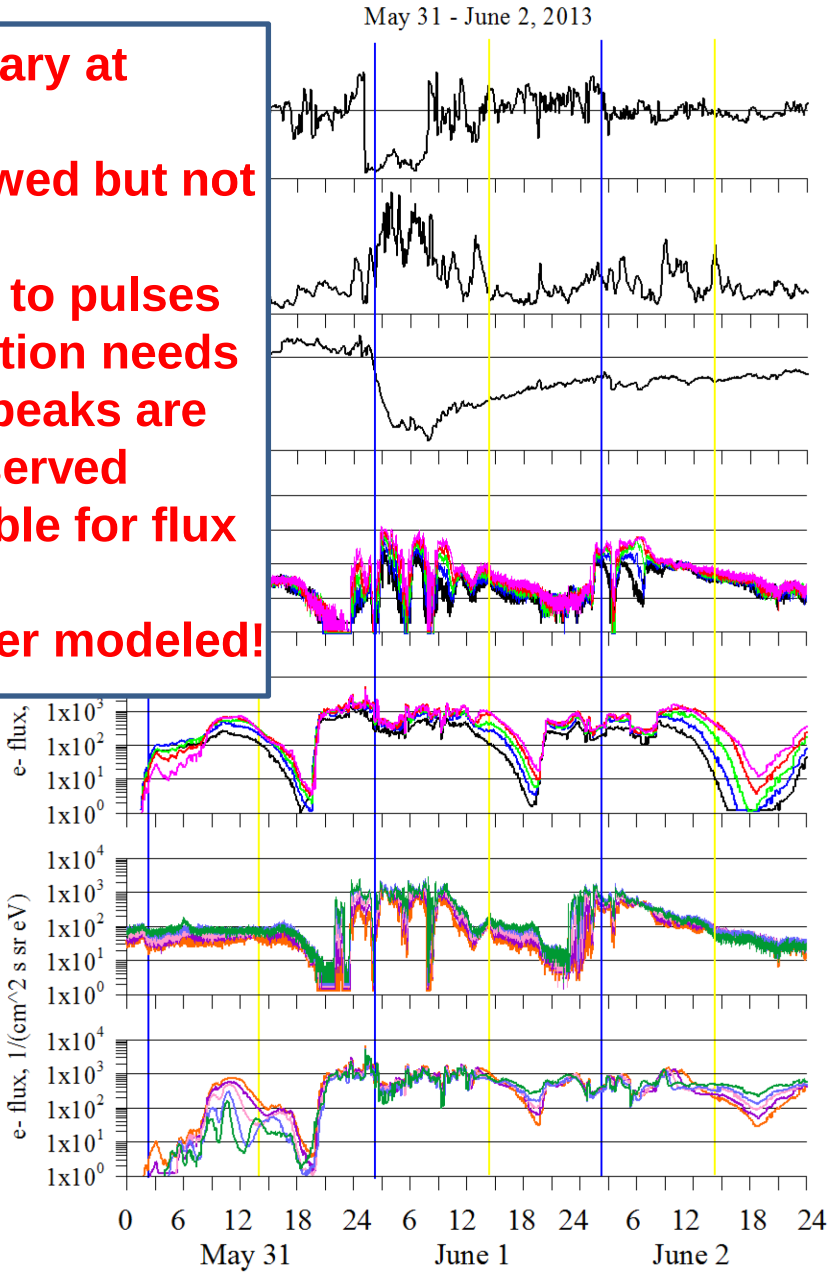
AMC12 electron data

- peaks in both 15-50 keV and 5-15 keV electron fluxes show clear correlation with AE peaks
- 2 orders of magnitude increase
- peaks for 15-50 keV more dispersed and more pronounced
- daily gradual decrease of fluxes from midnight to dawn-noon-dusk
- at storm main phase saw-tooth-like oscillations at midnight correlated with AE
- at storm recovery peaks with AE =700 nT similar to peaks with AE=1600 nT at storm main phase at midnight

With losses, no pulses



With losses, with pulses



- Modeled fluxes vary at observed level
- Main peaks followed but not large enough
- Sharp peaks due to pulses
- Pulse representation needs to be corrected: peaks are not as big as observed
- Losses responsible for flux daily decrease
- 5-15 keV are better modeled!

Summary

1. The variations of fluxes for **5-50 keV electrons** observed by CEASE II ESA instrument onboard AMC 12 satellite during one small CIR- and one moderate CME-storms analyzed and modeled.

2. The variations in the observed electron fluxes are caused by

   (1) **Variations of SW and IMF parameters** (used in time-dependent boundary conditions, magnetic and electric fields:
   only main peaks and general pattern,
   when SW and IMF variations are significant
   (From the analysis of quiet events: IMF Bz = -11 nT, Vsw = 530 km/s,
   Psw = 6 nPa, Kp = 4, AE = 500 nT, Dst = -20 nT).

   (2) **Electron losses** (represented as electron lifetimes, dependent on magnetic field and Kp index):
   main trends in flux daily decrease when going duskward via noon.

   (3) Variations of electromagnetic fields associated with **substorms**:
   needed to explain flux variations correlated with AE index peaks,
   uniform representation of electromagnetic pulse scaled by AE value can not be used, flux peaks are not dependent on AE magnitude.