The nowcast model for low energy (< 200 keV) electrons in the inner magnetosphere

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Online nowcast model for low energy electrons (< 200 keV) in the inner magnetosphere (http://fp7-spacecast.eu)

What do we present?
IMPTAM (Inner Magnetosphere Particle Transport and Acceleration model): nowcast model for low energy (< 200 keV) electrons in the inner magnetosphere, operating online under the **SPACECAST and SPACESTORM project**

Why this model is important?
Low energy electron fluxes are very important to specify when hazardous satellite surface charging phenomena are considered. They constitute the low energy part of the seed population for the high energy MeV particles in the radiation belts

What does the model provide?
The presented model provides the low energy electron flux at all L-shells and at all satellite orbits, when necessary.

What are the drivers of the model?
The model is driven by the real time solar wind and IMF parameters with 1 hour time shift for propagation to the Earth’s magnetopause, and by the real time Dst index.

Inner Magnetosphere Particle Transport and Acceleration Model (IMPTAM) (*Ganushkina et al., 2005, 2012, 2013, 2014*)

- ♦ 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 2^{nd} 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.

IMPTAM for online nowcast

Magnetic field model: *Tsyganenko* T96 (Dst, Psw, IMF By and Bz)

Electric field model: *Boyle et al*. (1997) (Vsw, IMF B, By, Bz)

Boundary conditions at 10 Re: kappa distribution with number density and temperature given *by Tsyganenko and Mukai* (2003) model (Vsw, IMF Bz,Nsw)

Radial diffusion with diffusion coefficients D_{LL} (*Brautigam and Albert*, 2000)

$$D_{LL} = 10^{0.056Kp-9.325} L^{10}$$

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

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

(*Chen et al*., 2005)

Weak diffusion (L=2-6):

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

(*Shprits et al*., 2007)

Online nowcast model for low energy electrons (< 200 keV) in the inner magnetosphere

http://www.fp7-spacecast.eu/index.php?page=le_forecasts

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Detailed model results

	Panel Plots		
	Differential Flux at Midnight MLT	Daily 40 keV Flux	Differential Flux as a Function of Satellite Longitude
IMPTAM Model	40 keV 75 keV 150 keV	GEO MEO SLOT	GEO

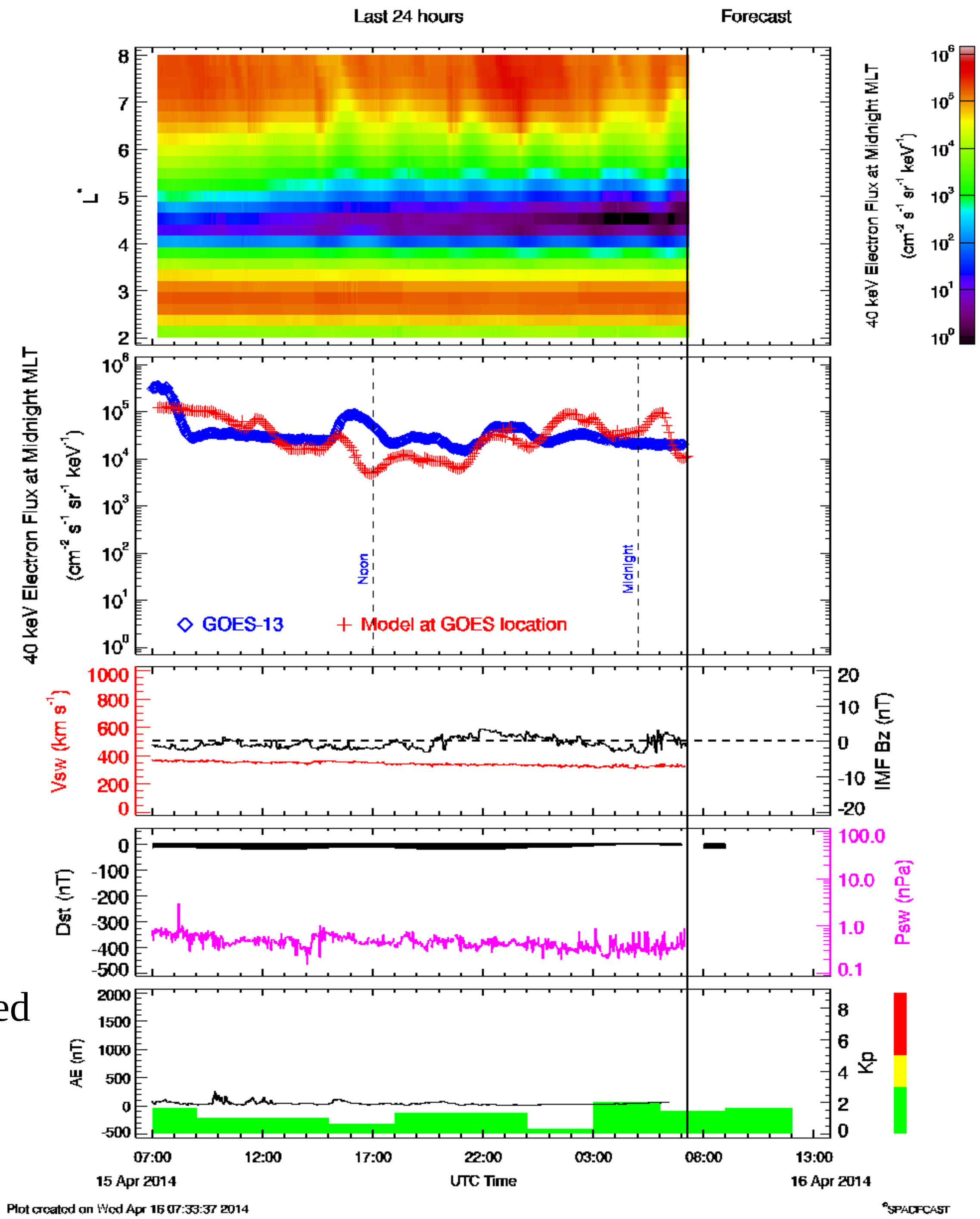
Please see our disclaimer!

IMPTAM online nowcast for 40 keV electrons at GOES 13 orbit

Quiet time period.

40 keV electrons flux shows most variations compared to 75 and 150 keV.

Beginning: GOES 13 moving towards noon, 40 keV modeled and observed fluxes are very close
At noon: modeled flux an order of magnitude lower than observed.
At duskside and midnight: modeled fluxes are very close to observed.

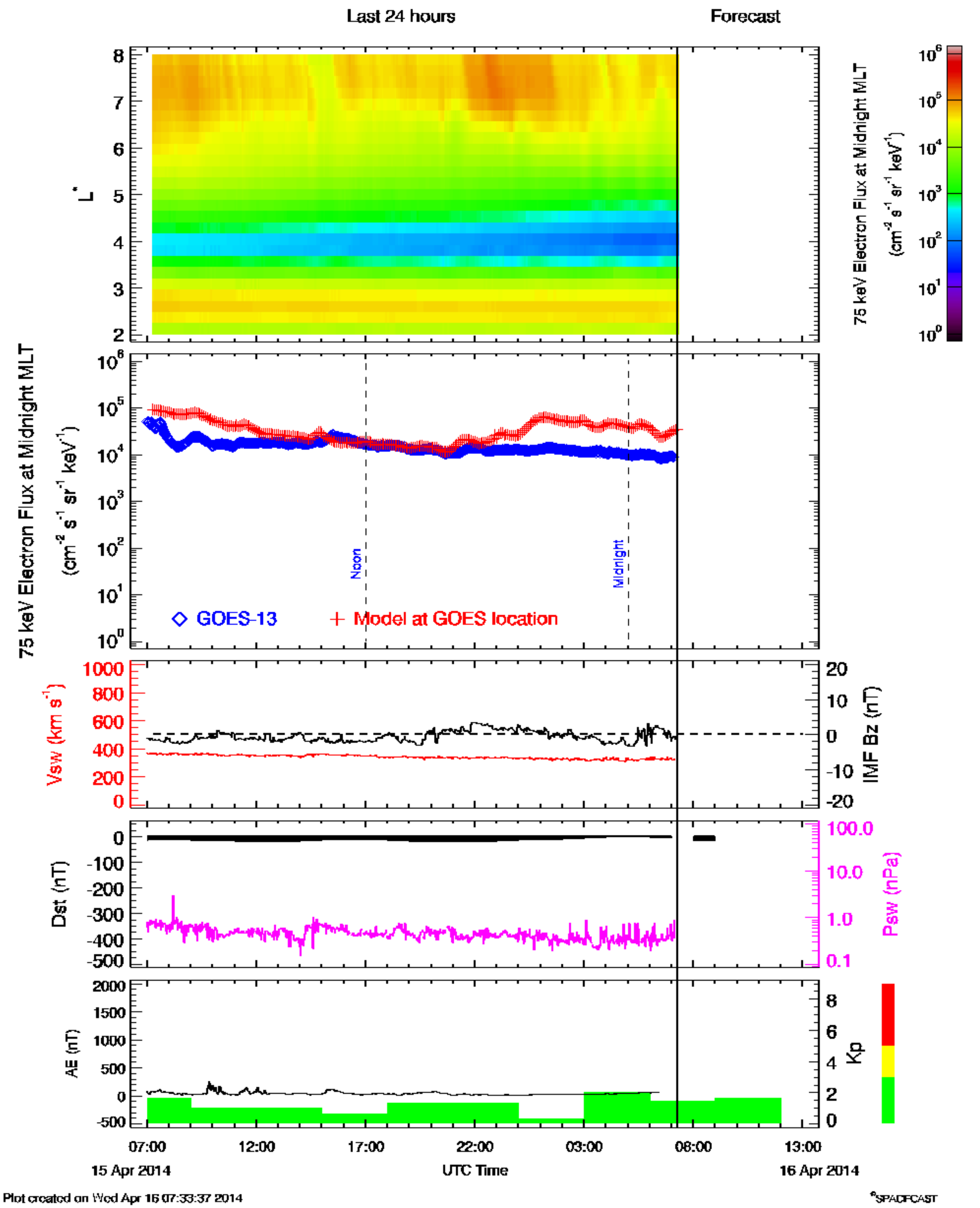


IMPTAM online nowcast for 75 keV electrons at GOES 13 orbit

For **75 keV electrons** the agreement is good although no significant variations observed.

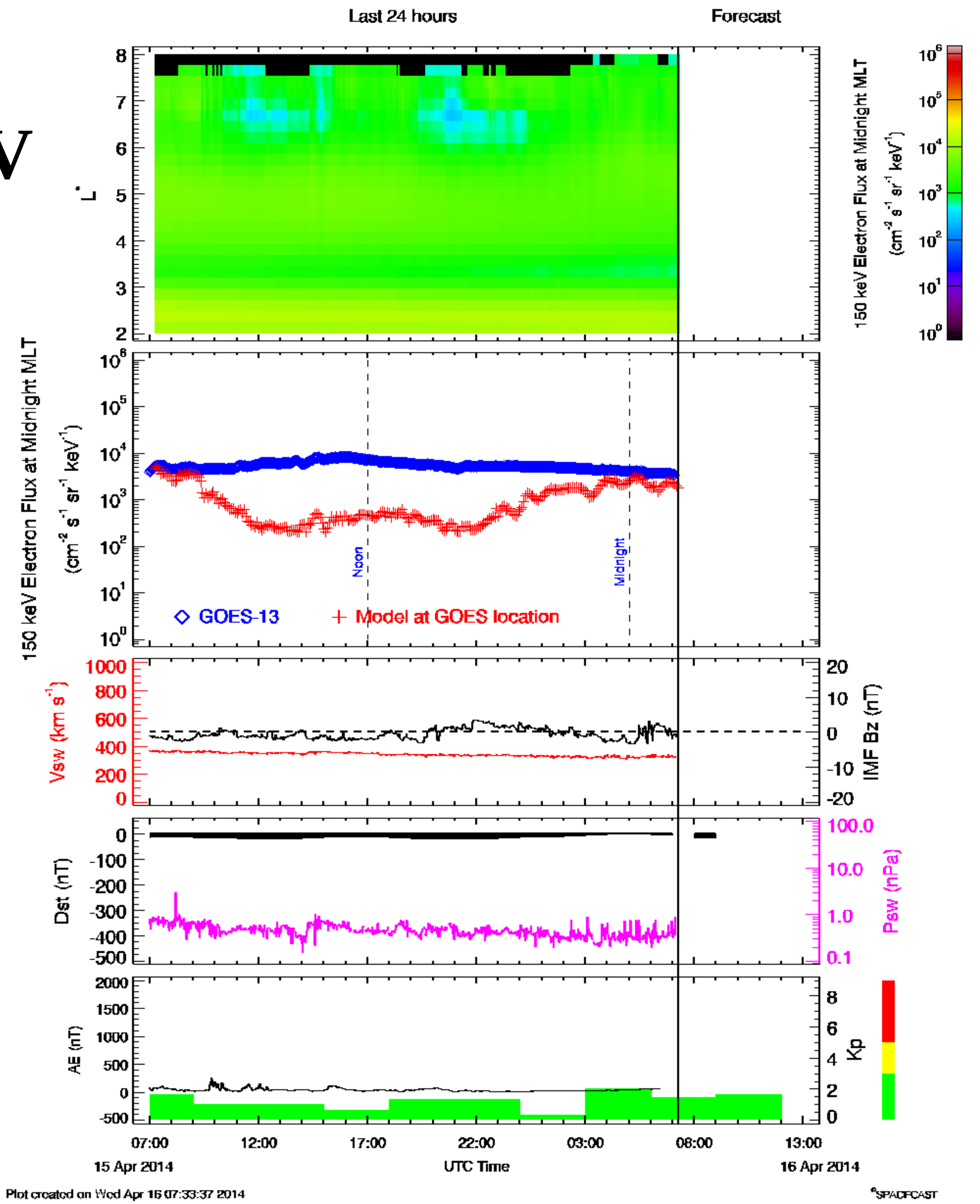
GOES13 moved towards noon: modeled flux very close to observed.

GOES 13 coming to midnight via dusk: modeled about 4 times higher than observed.



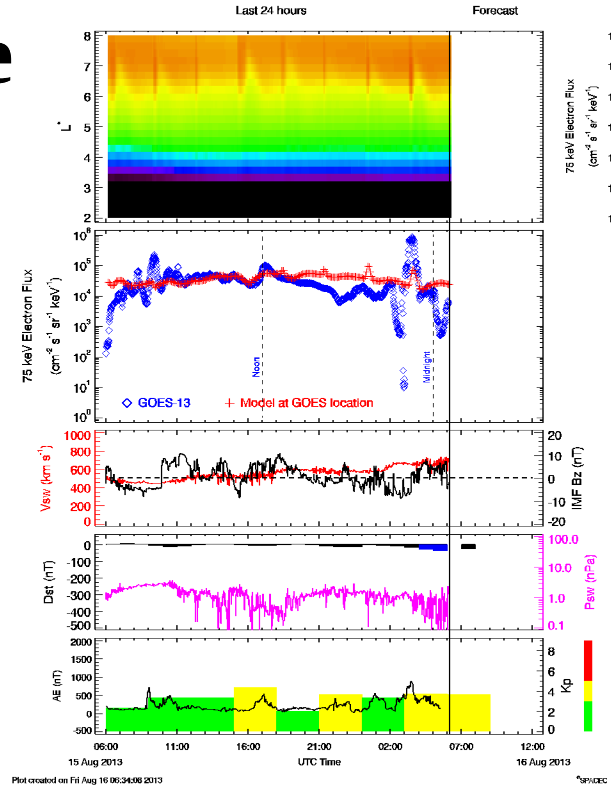
IMPTAM online nowcast for 150 keV electrons at GOES 13 orbit

For **150 keV electrons**, modeled flux close to observed only around midnight and 1.5 orders of magnitude lower at other local times.



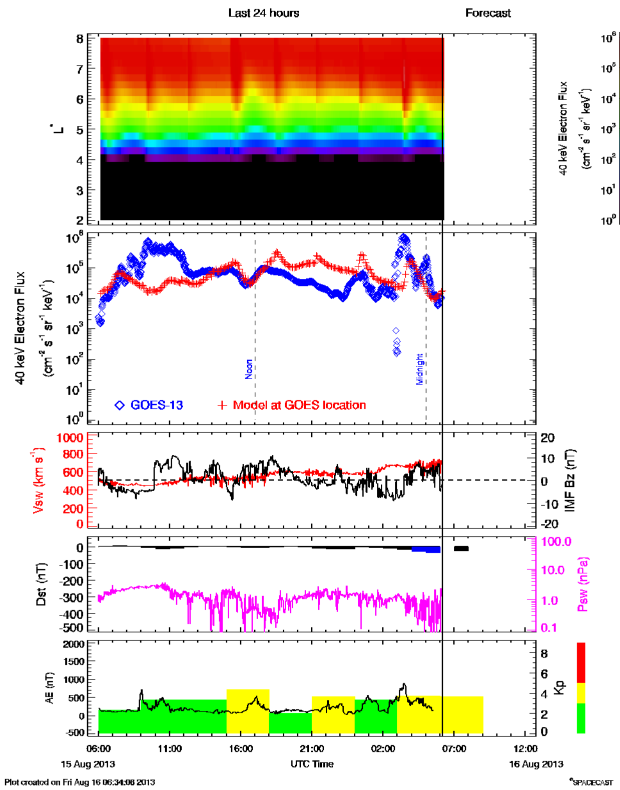
IMPTAM online nowcast at GOES 13 orbit

Moderately disturbed period with substorm activations



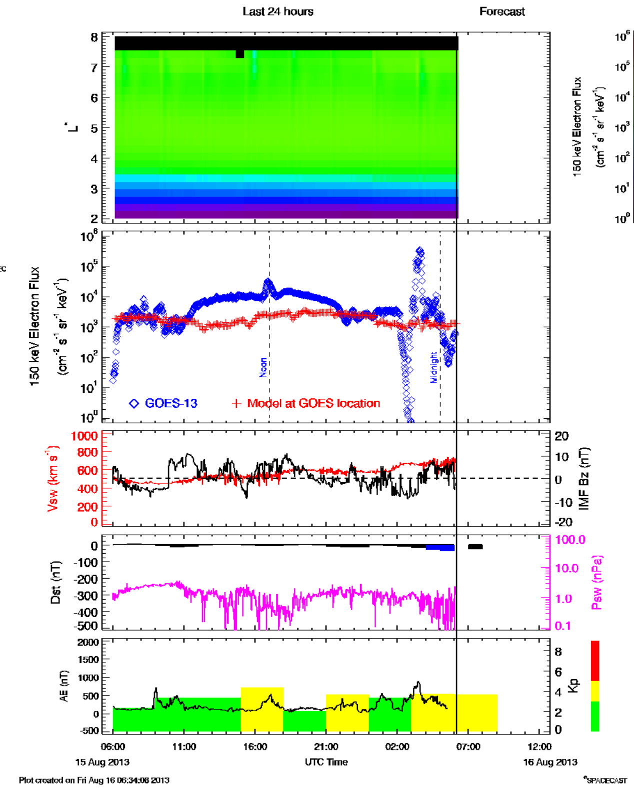
75 keV

At dusk: 40 keV electrons several times higher than observed.
Higher energies: modeled Fluxes same order,on average.
At midnight: peak and dropout not reproduced



40 keV

At dawn: electron fluxes well reproduced but not peak at 0930 UT. Substorms?
At noon: for < 100 keV modeled fluxes matched observed well but 150 keV fluxes underestimated by order.



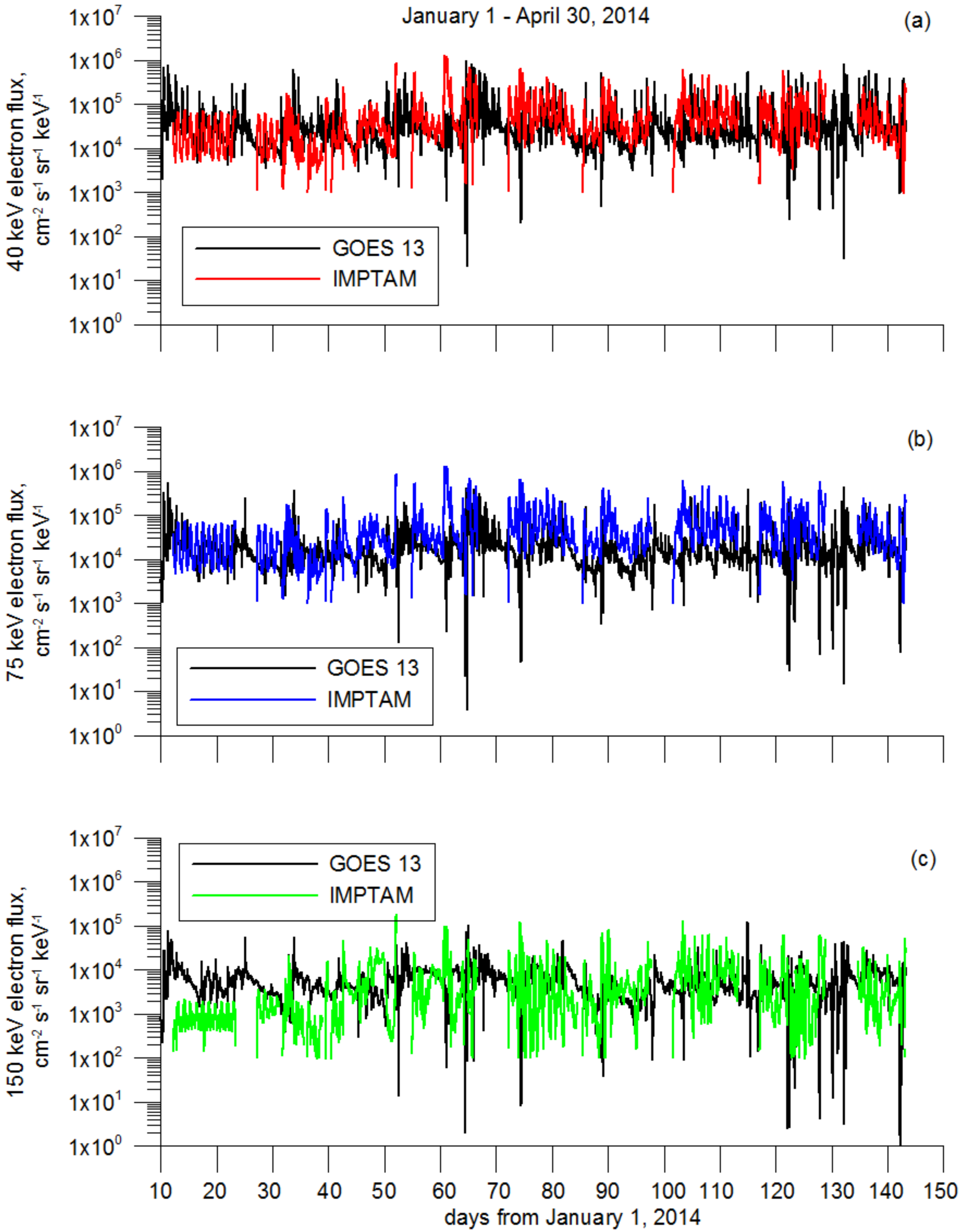
150 keV

Model performance

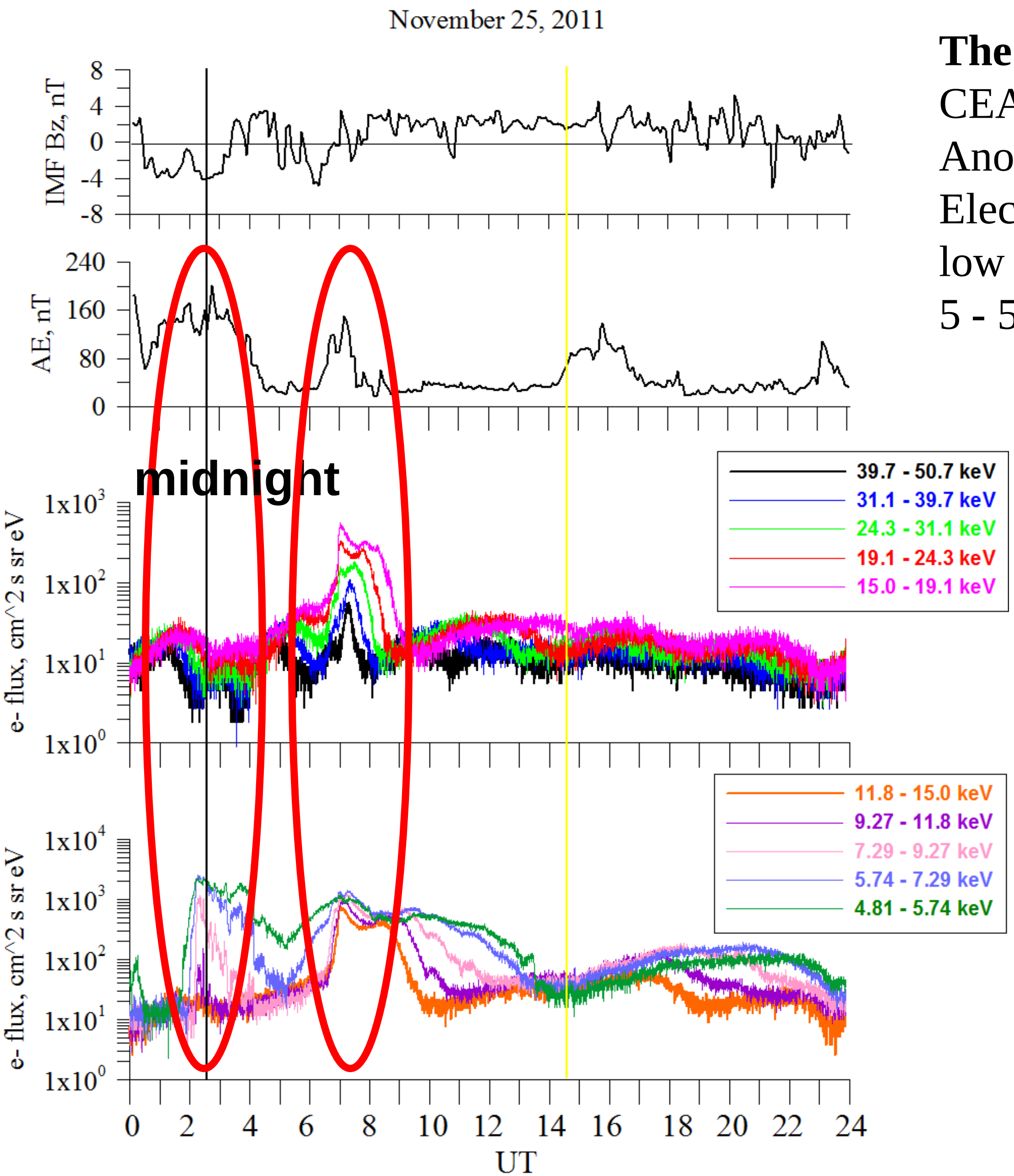
Modeled fluxes for <100 keV electrons are, on average, in very good agreement with observed fluxes.

Significant flux dropouts are not present in model fluxes.

For 150 keV electrons, modeled flux is constantly smaller than observed
.
The difference can reach one – one and a half order of magnitude.



5-50 keV electrons during quiet event



The data: AMC 12 geostationary satellite, CEASE-II (Compact Environmental Anomaly Sensor) instrument with Electrostatic Analyzer (ESA) for measuring low energy electron fluxes in 10 channels, 5 - 50 keV.

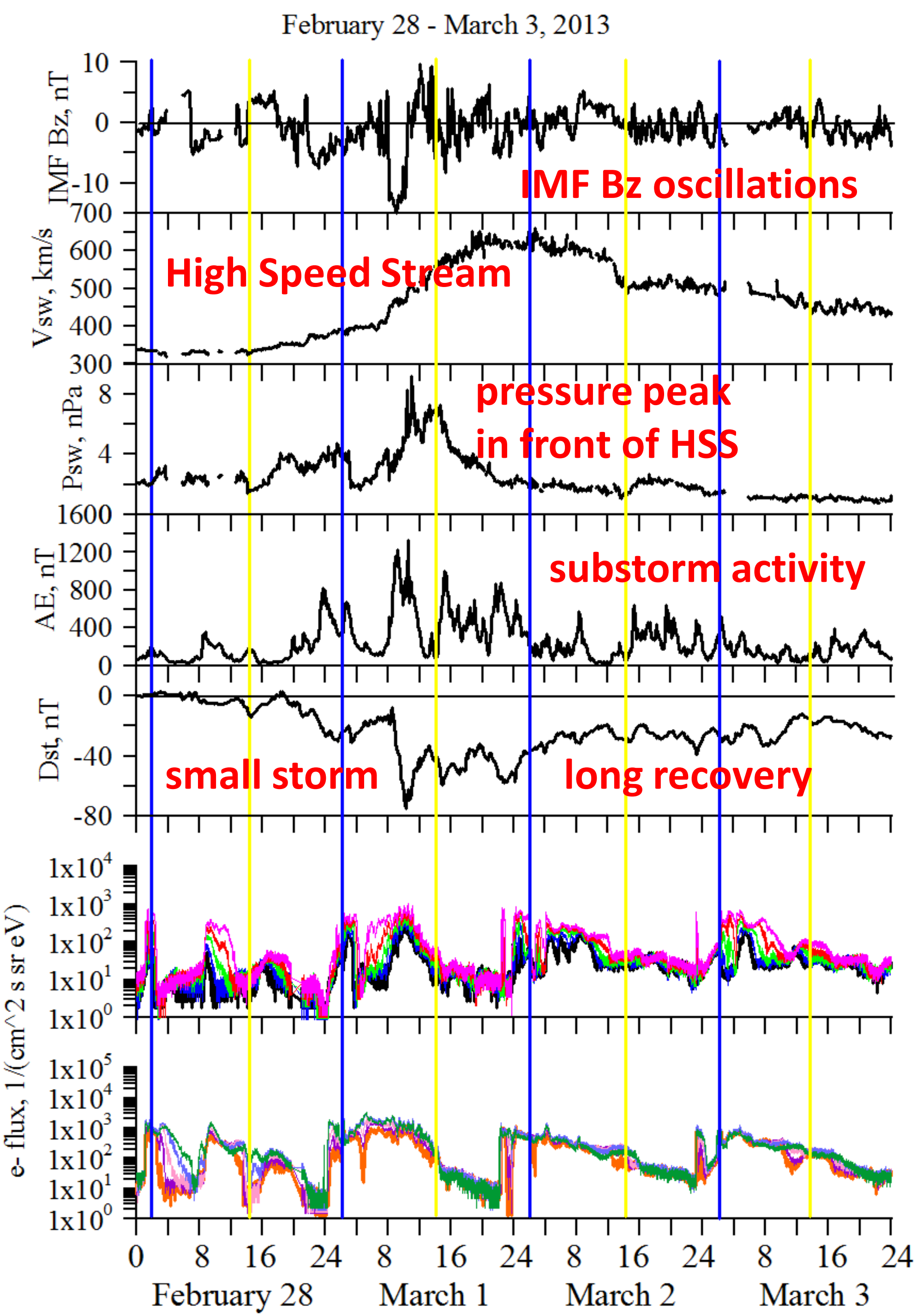
- **Flux increases** are related to **AE peaks** only (less than 200 nT, small, isolated substorms)

- The lower the energy, the large the flux and electrons of different channels behaves differently

- 1st peak (AE=200 nT) at midnight seen for energies > 11 keV

-2nd peak (AE=120 nT) at dawn, increase in all energies

Not a unique case



Storm event

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 800-1200 nT

AMC12 electron data

- peaks in both 15-50 keV and 5-15 keV electron fluxes show **correlation with AE**
- 2 orders of magnitude increase
- all energies increase at midnigth when AE is only 200 nT
- same order of increase for AE = 800 nT and even for 1200 nT
- peaks for 15-50 keV more dispersed
- daily gradual decrease of fluxes from midnight to dawn-noon-dusk
- peak in 15-50 keV at Dst min but not in 5-15 keV

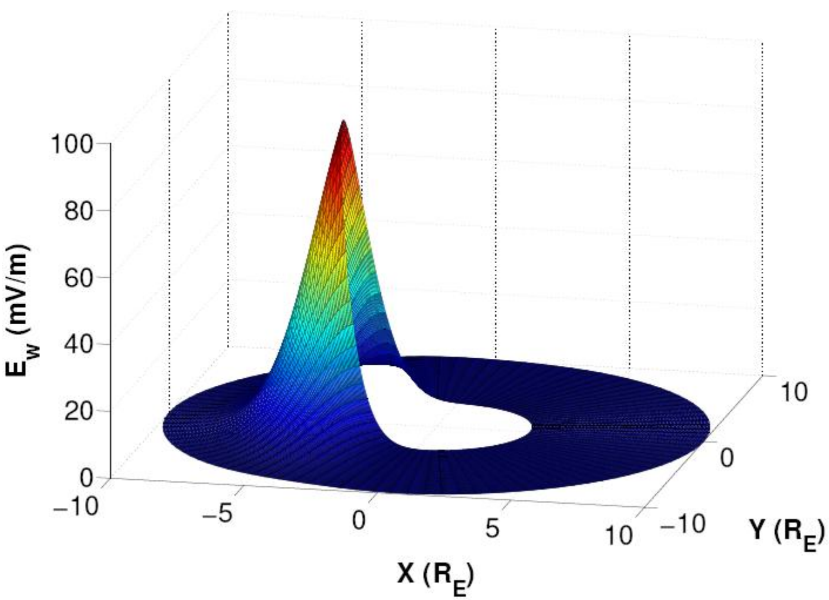
39.7 - 50.7 keV	11.8 - 15.0 keV
31.1 - 39.7 keV	9.27 - 11.8 keV
24.3 - 31.1 keV	7.29 - 9.27 keV
19.1 - 24.3 keV	5.74 - 7.29 keV
15.0 - 19.1 keV	4.81 - 5.74 keV

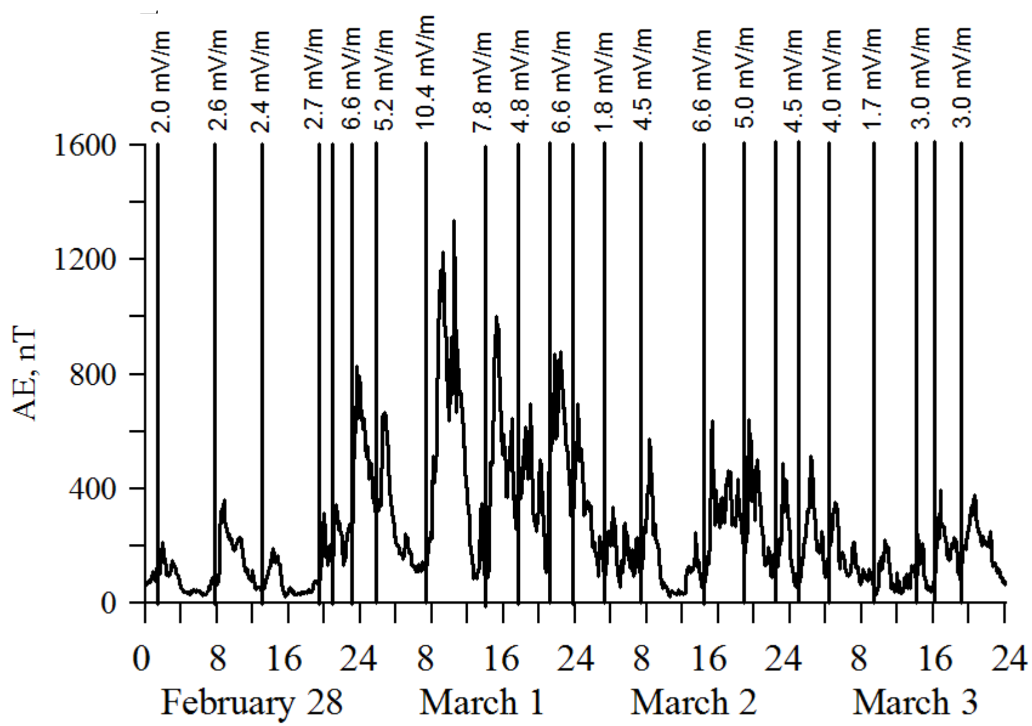
Electric field pulse model

Time varying fields associated with dipolarization in magnetotail, modeled as an electromagnetic pulse (*Li et al., 1998; Sarris et al., 2002*):

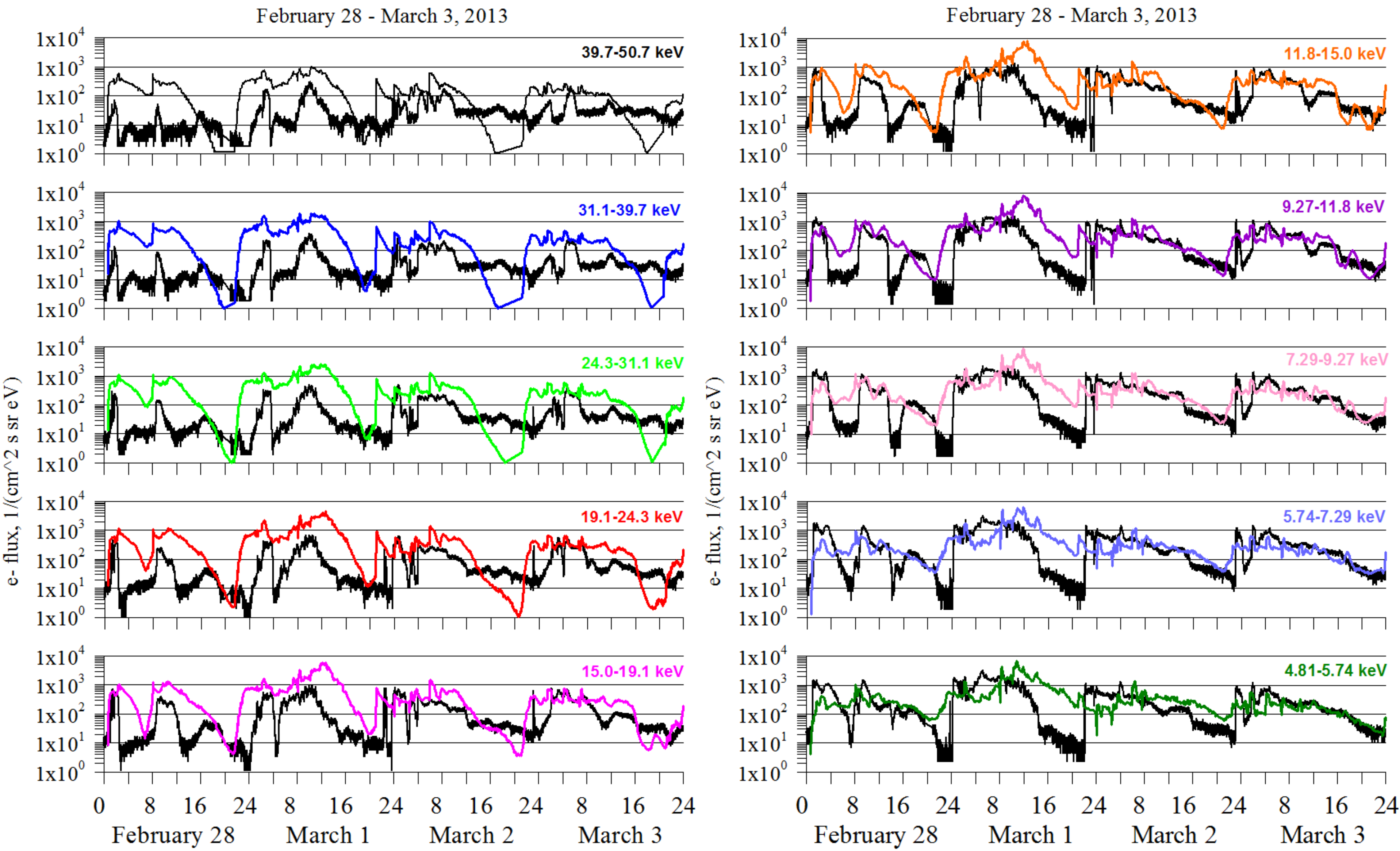
- Perturbed fields propagate from tail toward the Earth;
- Time-dependent Gaussian pulse with azimuthal E;
- E propagates radially inward at a decreasing velocity;
- decreases away from midnight.

Time-dependent B from the pulse is calculated by Faraday's law.





February 28 – March 3, 2013 modeling results for 15-50 keV (AMC 12 geostationary)



Summary

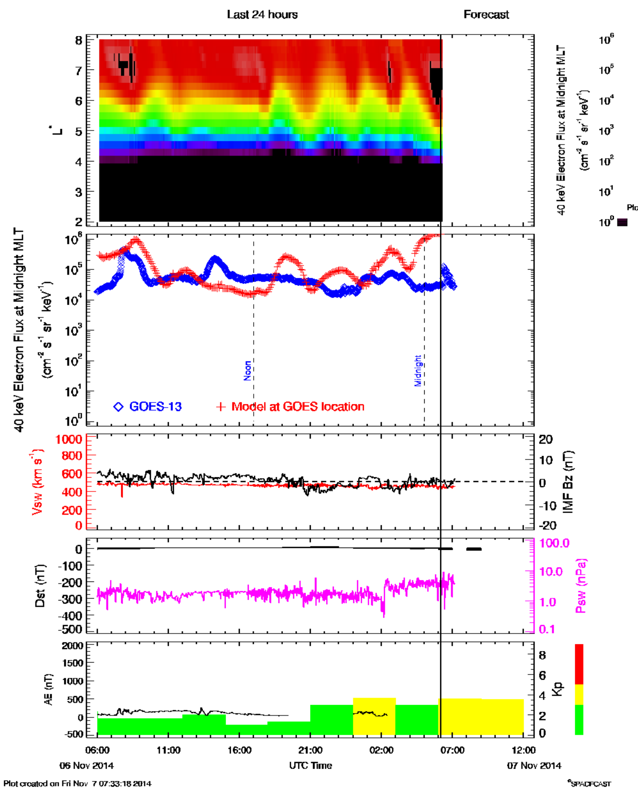
1. We presented the nowcast model for low energy (< 200 keV) electrons in the inner magnetosphere, operating online in near-real time under the SPACECAST and SPACESTORM projectS (http://fp7-spacecast.eu). The model provides the low energy electron flux at all L-shells and at all satellite orbits, when necessary. The model is driven by the real time solar wind and IMF parameters with 1 hour time shift for propagation to the Earth's magnetopause, and by the real time Dst index.

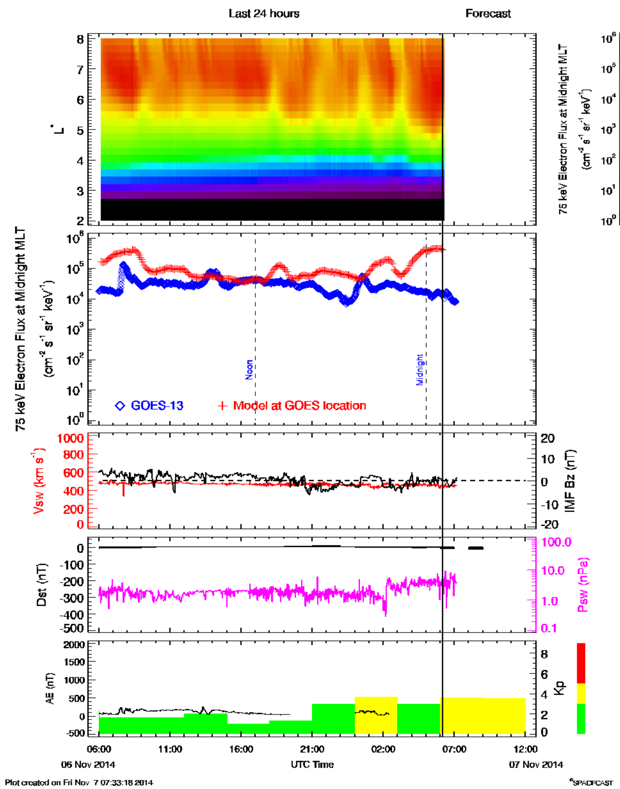
2. The model provides very good agreement with the data, the basic level of the observed fluxes is very well reproduced. The best agreement between the modeled and the observed fluxes are found for <100 keV electrons. At the same time, not all the peaks and dropouts in the observed electron fluxes are reproduced. For 150 keV electrons, the modeled fluxes are often smaller than the observed ones by an order of magnitude.

This is the first attempt to model low energy electrons in real time at 10 minutes resolution.

3. Case studies: The variations of fluxes for **5-50 keV electrons** observed by CEASE II ESA instrument onboard AMC 12 satellite were analyzed and reproduced by IMPTAM. 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.

40 keV





75 keV

150 keV