Metrics of model performance for electron fluxes (<200 keV) at geostationary orbit

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The research leading to these results was partly funded by the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement No 606716 SPACESTORM

12th European Space Weather Week, November 23-27, 2015, Oostende, Belgium

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Near-real time IMPTAM model for low energy electrons (*Ganushkina et al., 2013, 2014, 2015*)

What do we present?

IMPTAM (Inner Magnetosphere Particle Transport and Acceleration model): nowcast model for low energy (< 200 keV) electrons in the near-Earth geospace, operating online at **http://fp7-spacecast.eu** and **imptam.fmi.fi**

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 locations and at all satellite orbits, when necessary, in the near-Earth space.

What are the drivers of the model?

The model is driven by the real time solar wind and Interplanetary Magnetic Field parameters with 1 hour time shift for propagation to the Earth's magnetopause, and by the real time geomagnetic activity index Dst.

http://fp7-spacecast.eu

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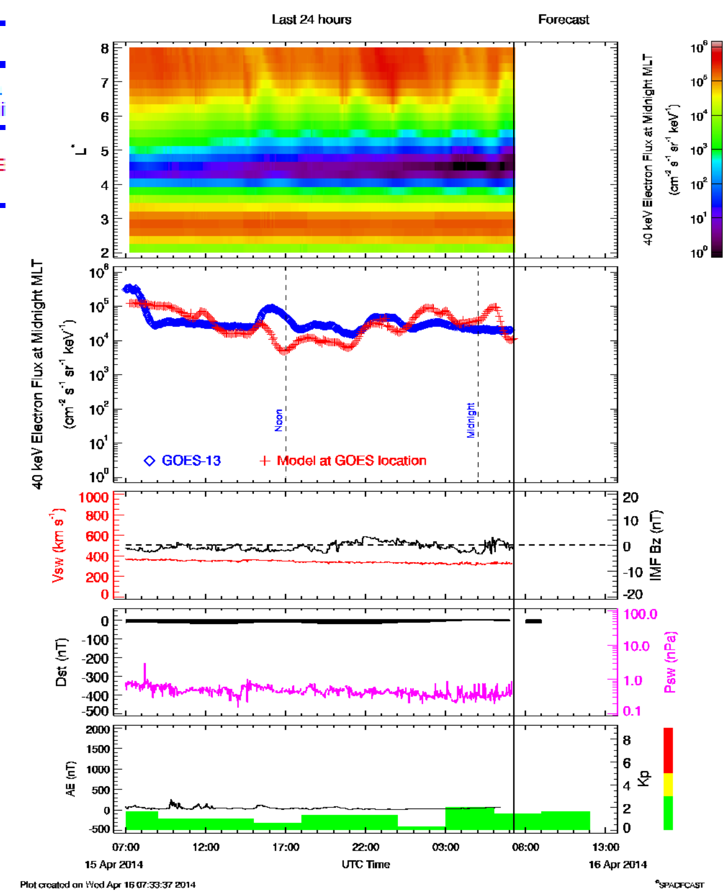
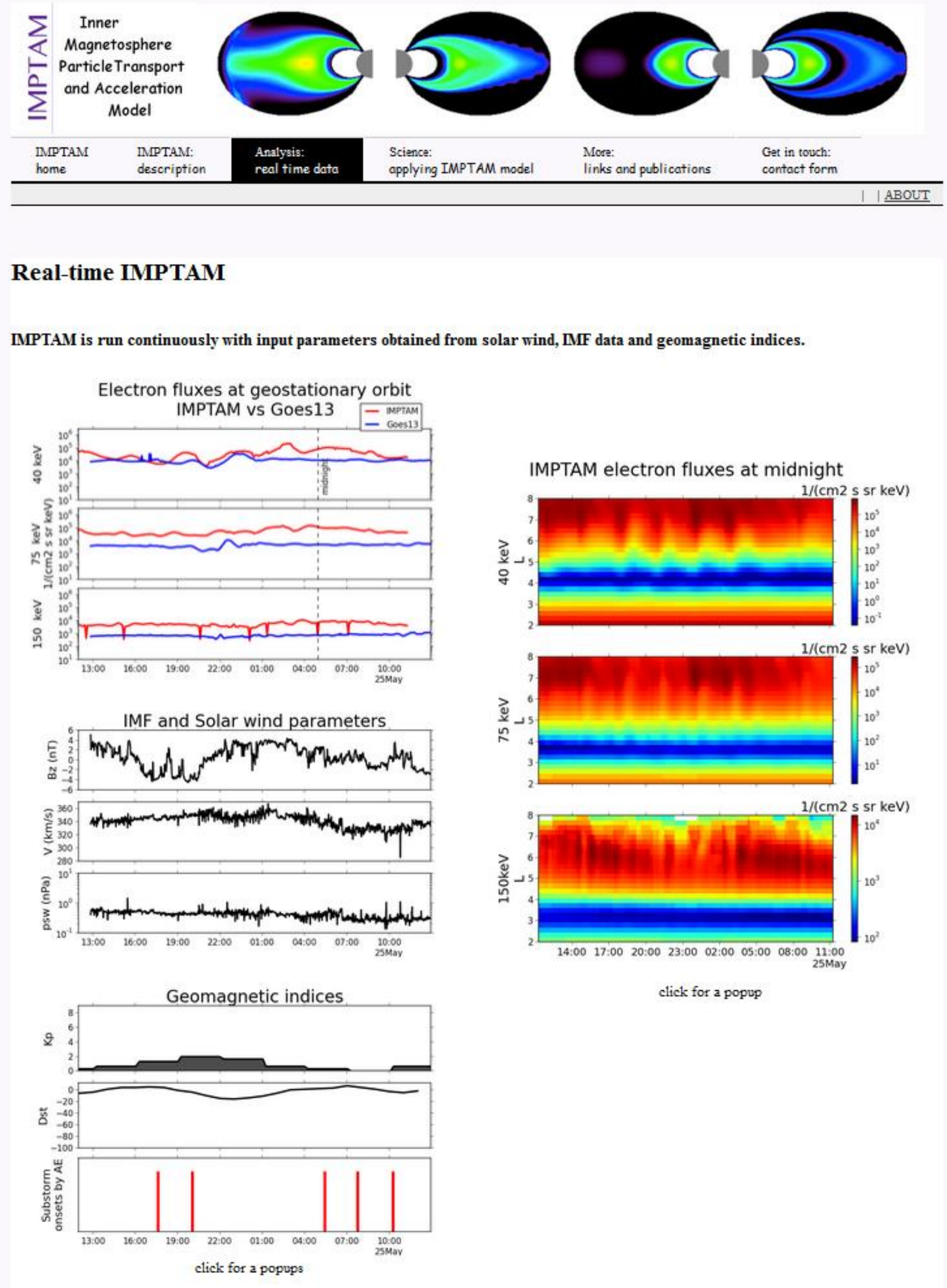
Detailed model results

	Panel Plots		
	Differential Flux at Midnight MLT	Daily 40 keV Flux	Differential Flux as a Longi
IMPTAM Model	40 keV 75 keV 150 keV	GEO MEO SLOT	GE



imptam.fmi.fi



Metrics for IMPTAM performance

Ganushkina et al., Space Weather, 2015

NRMSD

Normalized root-mean-square deviation
with the **standard deviations σ_{obs}**
of observations

$$\mathrm{RMSD} = \sqrt{\frac{\sum_{t=1}^{n} (x_{1,t} - x_{2,t})^2}{n}}$$

$$\mathrm{NRMSD} = \frac{\mathrm{RMSD}}{\sigma_{\mathrm{obs}}}$$

skilled prediction: NRMSD < 1
unskilled prediction: NRMSD > 1

0.0324 // 8.288×10^4 (40 keV);
0.0153 // 3.438×10^4 (75 keV);
0.0307 // 5.737×10^3 (150 keV)

Heidke Skill Score (HSS)

$$\mathrm{HSS} = \frac{2s(1-s)(H-F)}{s + s(1-2s)H + (1-s)(1-2s)F}$$

$$H = \frac{\mathrm{Hit}}{\mathrm{Hit} + \mathrm{Miss}} \qquad s = \frac{\mathrm{Hit} + \mathrm{Miss}}{\text{Sum of all events}}$$

Perfect skill: HSS=1,
the minimum: -1

- Significant flux dropouts not present
- 40 keV: rather small HSS but reasonable hit and false alarm rates
- Best Hit Rate for 75 keV e-
- 150 keV flux constantly smaller than the observed (1 order), hit rates reasonable, but the HSS is very small

Inner Magnetosphere Particle Transport and Acceleration Model (IMPTAM) for low energy electrons

(*Ganushkina et al., 2013, 2014, 2015*)

- traces **electrons** with arbitrary pitch angles from the plasma sheet to the inner L-shell regions with energies up to **300 keV** 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.

IMPTAM settings for long-term variations of low energy electron fluxes at geostationary orbit

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=6-10):

Weak diffusion (L=2-6):
$$\tau_{sd} = \left(\frac{\gamma m_0}{p}\right)\left[\frac{2\Psi B_h}{1-\eta}\right]$$

Electromagnetic pulses at substorm onsets:

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

(*Li et al.*, 1998; *Sarris et al.*, 2002)

Model driving parameters:

IMF By and Bz, IMF B, Vsw, Nsw, Psw, Kp, Dst

Long-term variations of low energy electron fluxes: IMPTAM vs GOES 13

IMPTAM long-term output of omni-directional electron fluxes compared statistically to GEOS-13 MAGED fluxes for energies of 40, 75 and 150 keV.

GOES MAGED fluxes are the only available data on electrons with energies less than 200 keV which can be compared to IMPTAM output in near-real time.

Time period: September 2013 - March 2015.

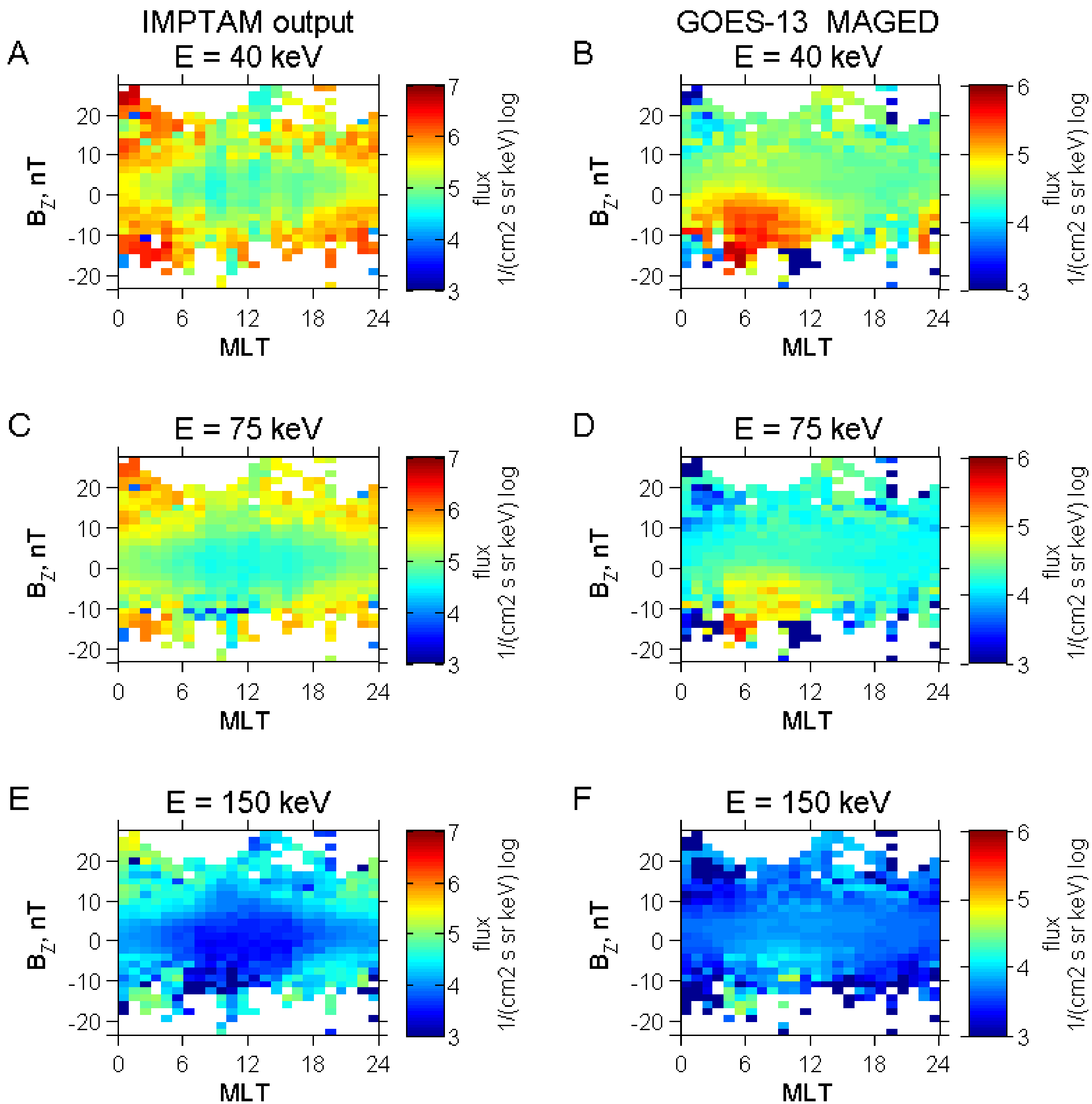
Statistics presented: MLT-dependent fluxes organized by IMPTAM's driving parameters, **IMF By and Bz, IMF B, Vsw, Nsw, Psw, Kp, Dst**

IMPTAM vs GOES 13: IMF Bz

Higher fluxes occupy larger MLT areas than observed

Peak shifted to **midnigh** instead of being at dawn as observed

High fluxes for **IMF Bz > 0** due to parameterization of models inside IMPTAM



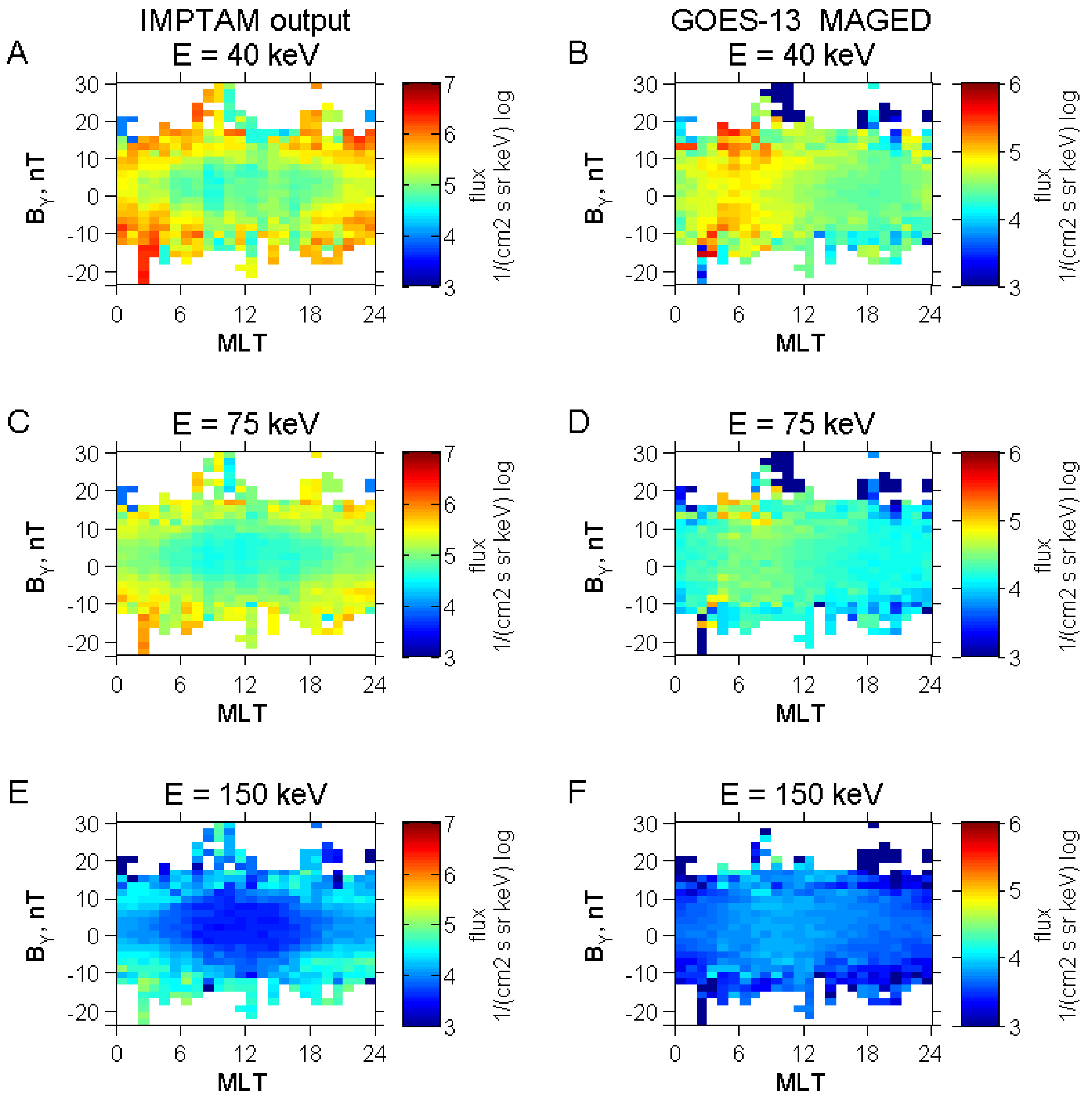
different scales

IMPTAM vs GOES 13: IMF By

Higher fluxes occupy larger MLT areas than observed

Peak shifted to **midnight** instead of being at dawn as observed

BUT:
Very **similar pattern, in general**



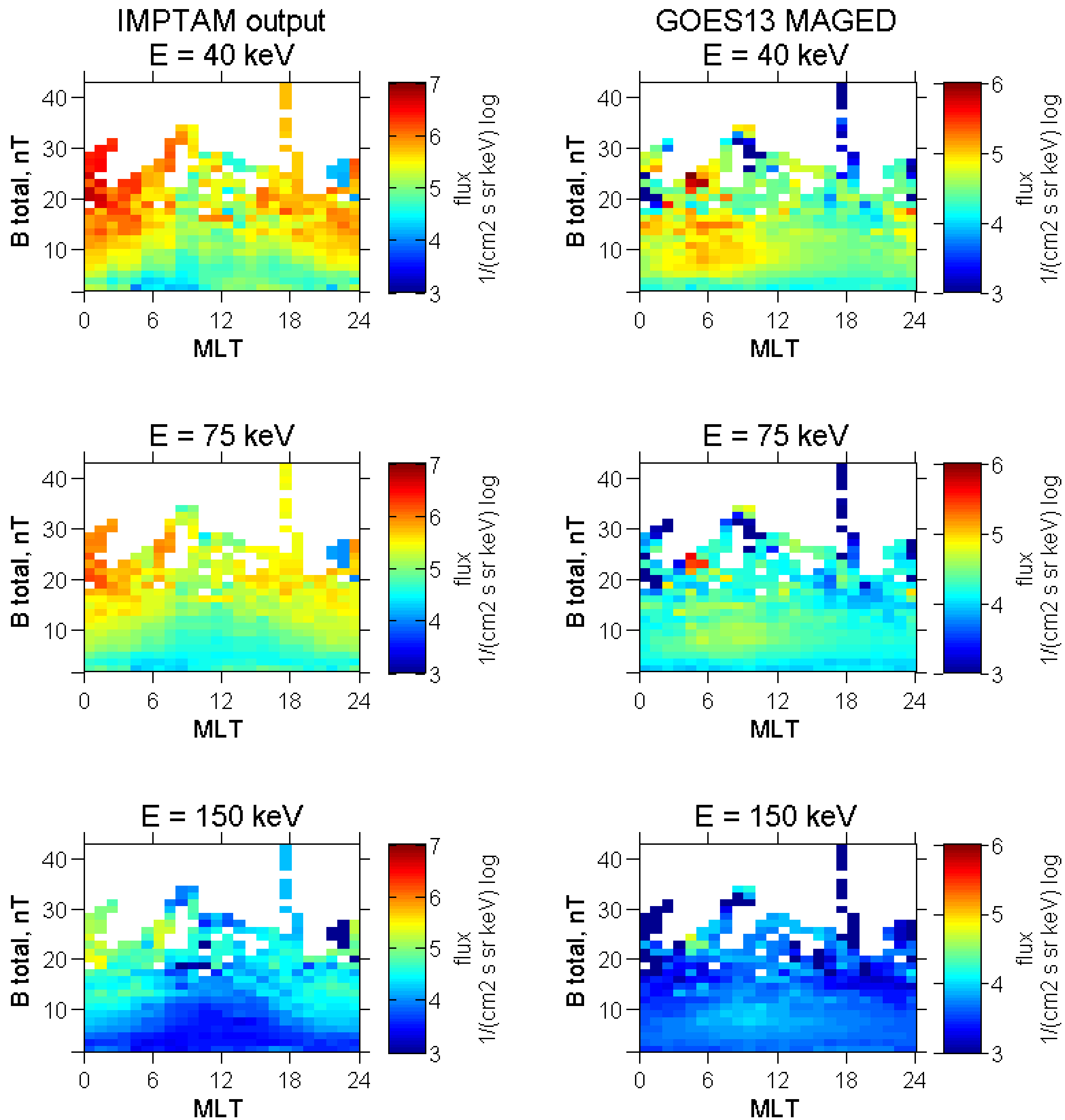
different scales

IMPTAM vs GOES 13: IMF B

Higher fluxes occupy larger MLT areas than observed

Peak shifted to **midnight** instead of being at dawn as observed

BUT:
Very **similar pattern, in general**



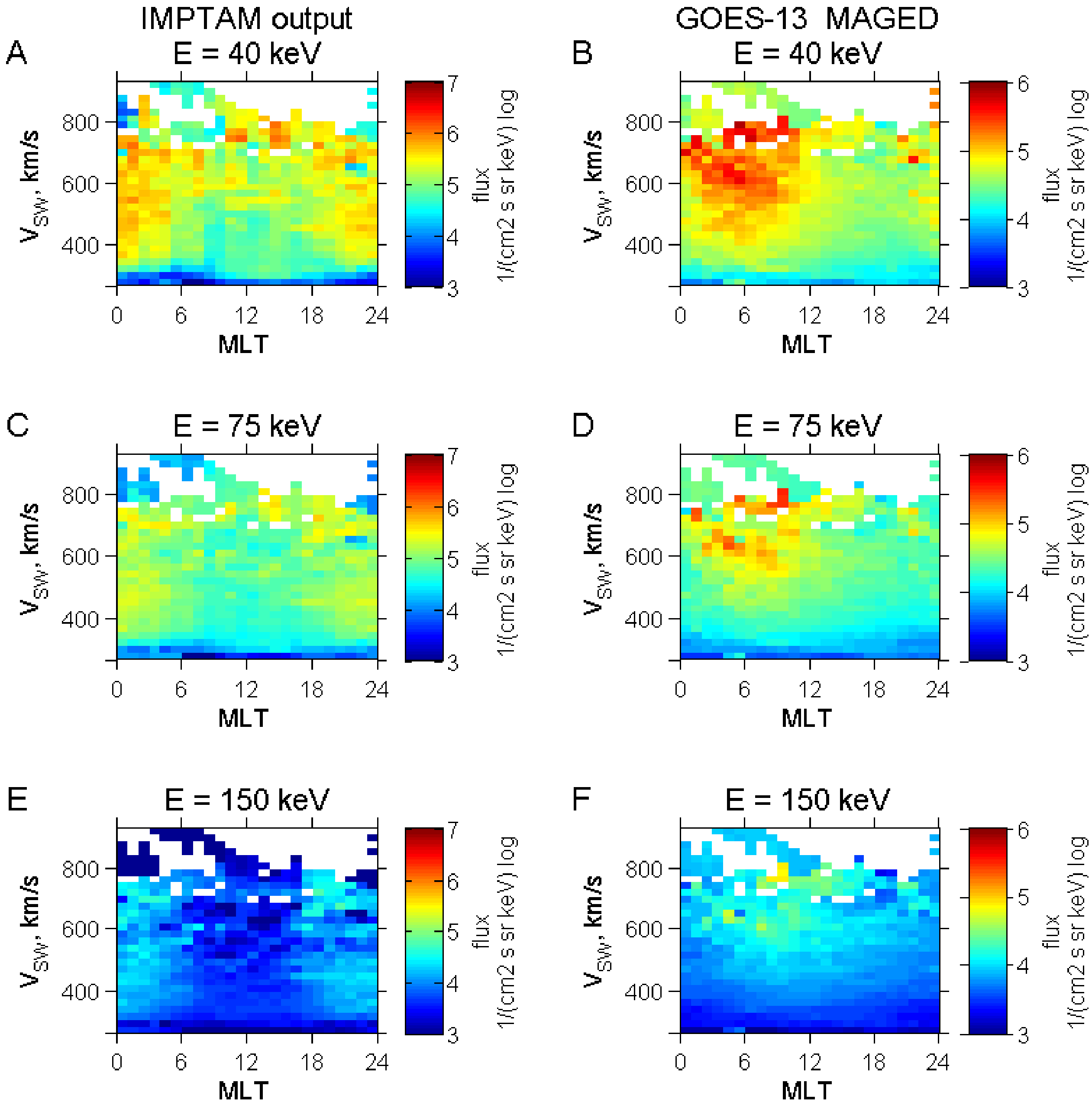
different scales

IMPTAM vs GOES 13: Vsw

Higher fluxes occupy larger MLT areas than observed

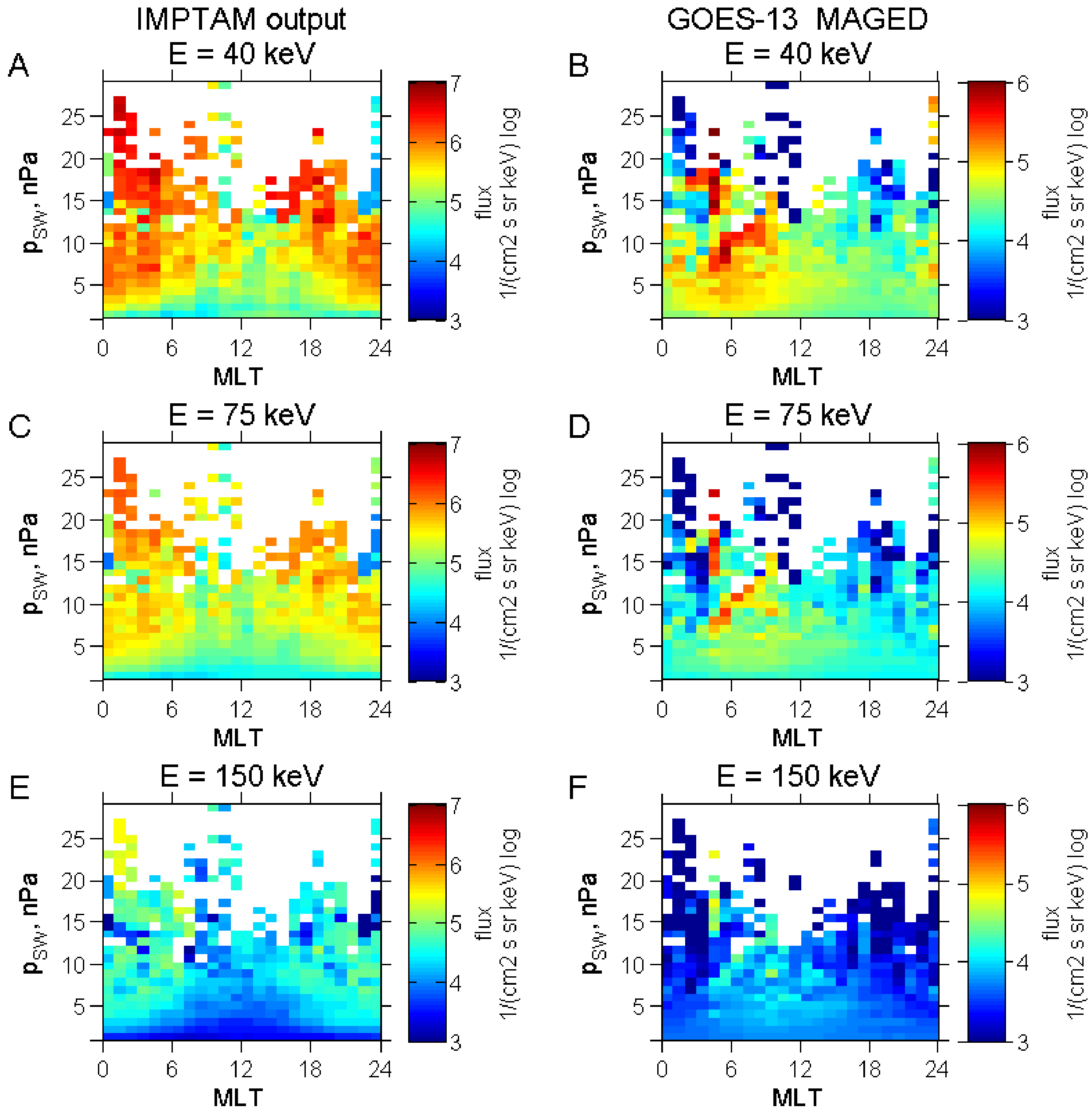
Peak shifted to **midnight** instead of being at dawn as observed

BUT:
Very **similar pattern, in general**



different scales

IMPTAM vs GOES 13: Psw



Higher fluxes occupy larger MLT areas than observed

Peak shifted to **midnight** instead of being at dawn as observed

High fluxes for **Large Psw** due to parameterization of models inside IMPTAM

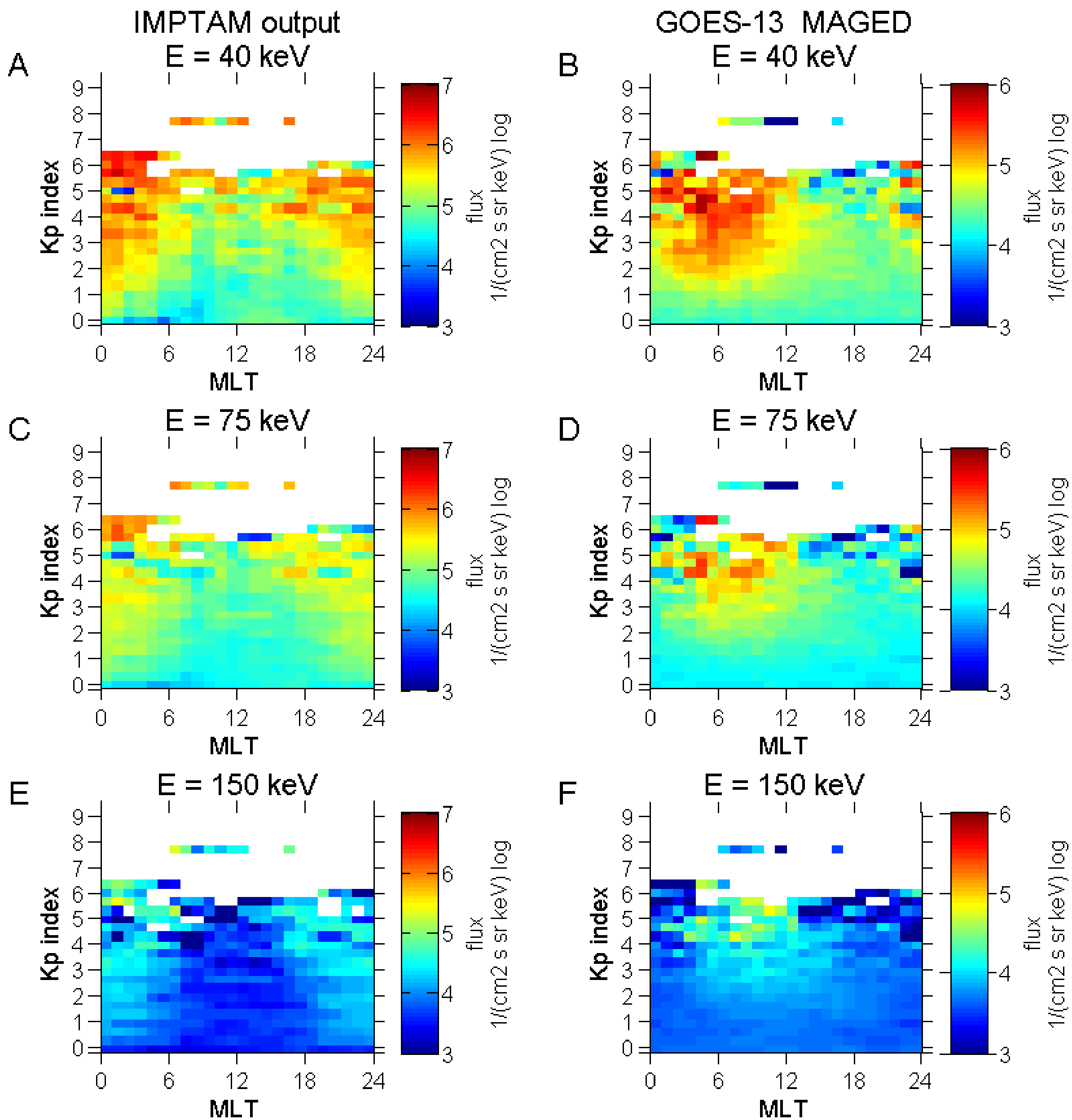
different scales

IMPTAM vs GOES 13: Kp

Higher fluxes occupy larger MLT areas than observed

Peak shifted to **midnight** instead of being at dawn as observed

BUT:
Very **similar pattern, in general**



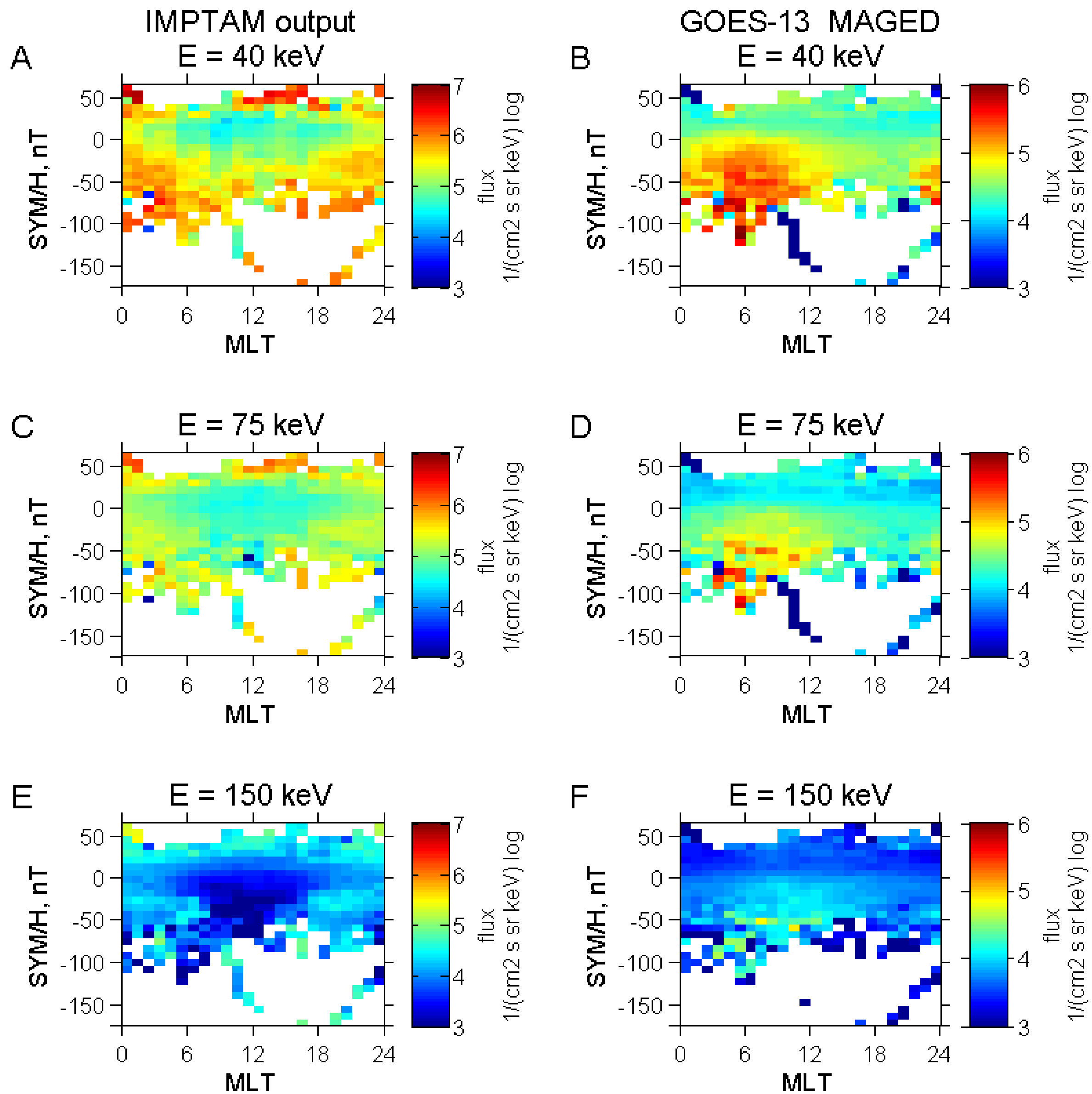
different scales

IMPTAM vs GOES 13: SYM-H

Higher fluxes occupy larger MLT areas than observed

Peak shifted to **midnight** instead of being at dawn as observed

BUT:
Very **similar pattern, in general**



different scales

Summary

IMPTAM nowcast model for low-energy (< 200 keV) electrons in the inner magnetosphere operates online in near real time at http://fp7-spacecast.eu and imptam.fmi.fi.

Real-time geostationary GOES 13 or GOES 15 (whenever available) MAGED data on electron fluxes for three energies of 40, 75, and 150 keV are used for comparison and validation of IMPTAM in statistical sense by dependencies on IMF and SW parameters and activity indices.

Notes on model performance:

On average, the model provides reasonable agreement with the data, the basic level of the observed fluxes is reproduced.

For all dependencies: Higher fluxes occupy larger MLT areas than observed;

Peak shifted to **midnight** instead of being at dawn as observed;

Presence of high fluxes in contrast to observations due to parameterization of models in IMPTAM

BUT: Very **similar patterns, in general**

Missing: realistic boundary conditions, loss processes, substorms