Forecasting keV-electrons in the inner Earth's magnetosphere responsible for surface charging

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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.

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.

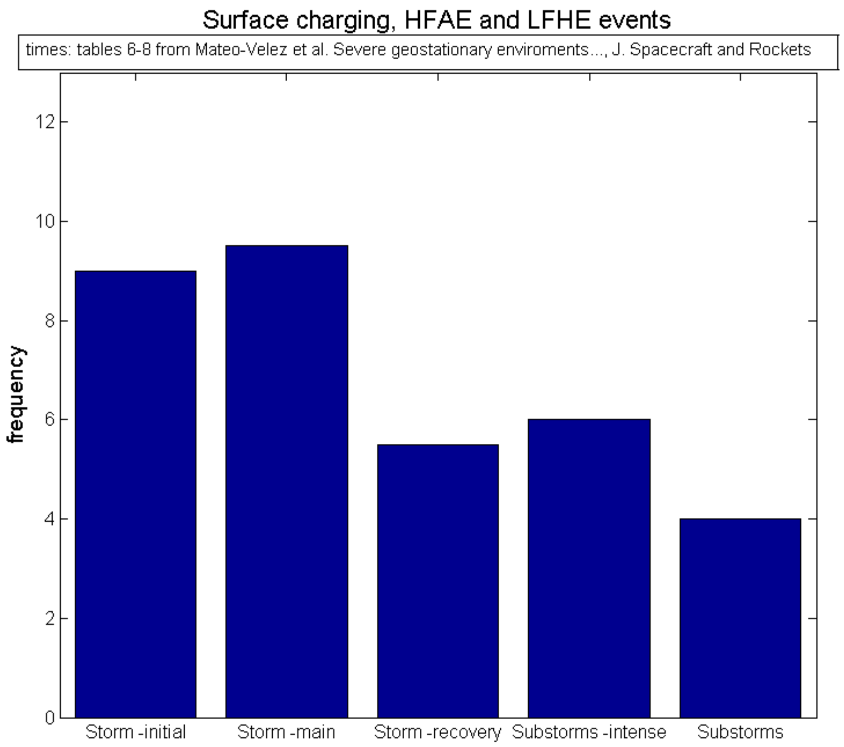
It is challenging to nowcast and forecast low energy electrons

It is NOT necessary to have even a moderate storm for significant surface charging event to happen

The keV electron flux is largely determined by convective and substorm-associated electric fields and varies significantly with geomagnetic activity – variations on time scales of minutes!
No averaging over an hour/day/orbit!

Correct models for electromagnetic fields, boundary conditions, losses are extremely hard to develop

Surface charging events vs. geomagnetic conditions



Matéo Vélez et al., Severe geostationary environments: from flight data to numerical estimation of spacecraft surface charging, *Journal of Spacecraft and Rockets, submitted, 2015*

Long-term variations of low energy electron fluxes: IMPTAM vs GOES 13 (Sep 2013 – Mar 2015)

IMPTAM long-term output of **omni-directional electron fluxes** compared statistically to GOES-13 MAGED fluxes for energies of 40, 75 and 150 keV for the period between September 2013 – March 2015.
http://satdat.ngdc.noaa.gov/sem/goes/data/new_avg/

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.

(available from NOAA Space Weather Prediction Center)

http://services.swpc.noaa.gov/text/

IMPTAM driving parameters:
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: electron lifetimes (Kp)

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

http://fp7-spacecast.eu

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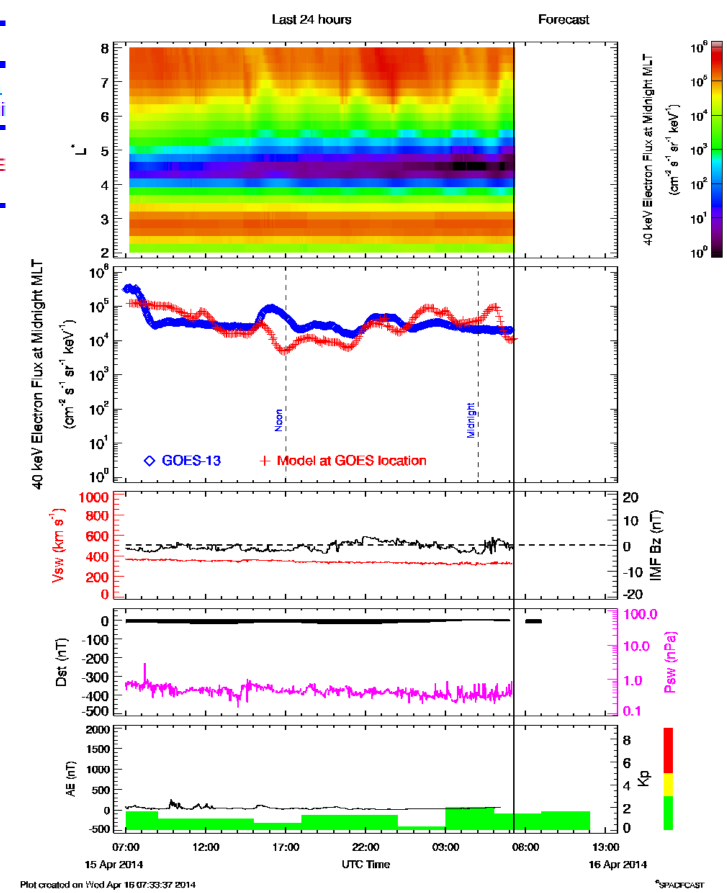
Detailed model results

	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



Low Energy Electrons Nowcast

40 keV

75 keV

150 keV

Compared to GOES 13 MAGED electron data

imptam.fmi.fi

Low Energy Electrons Nowcast
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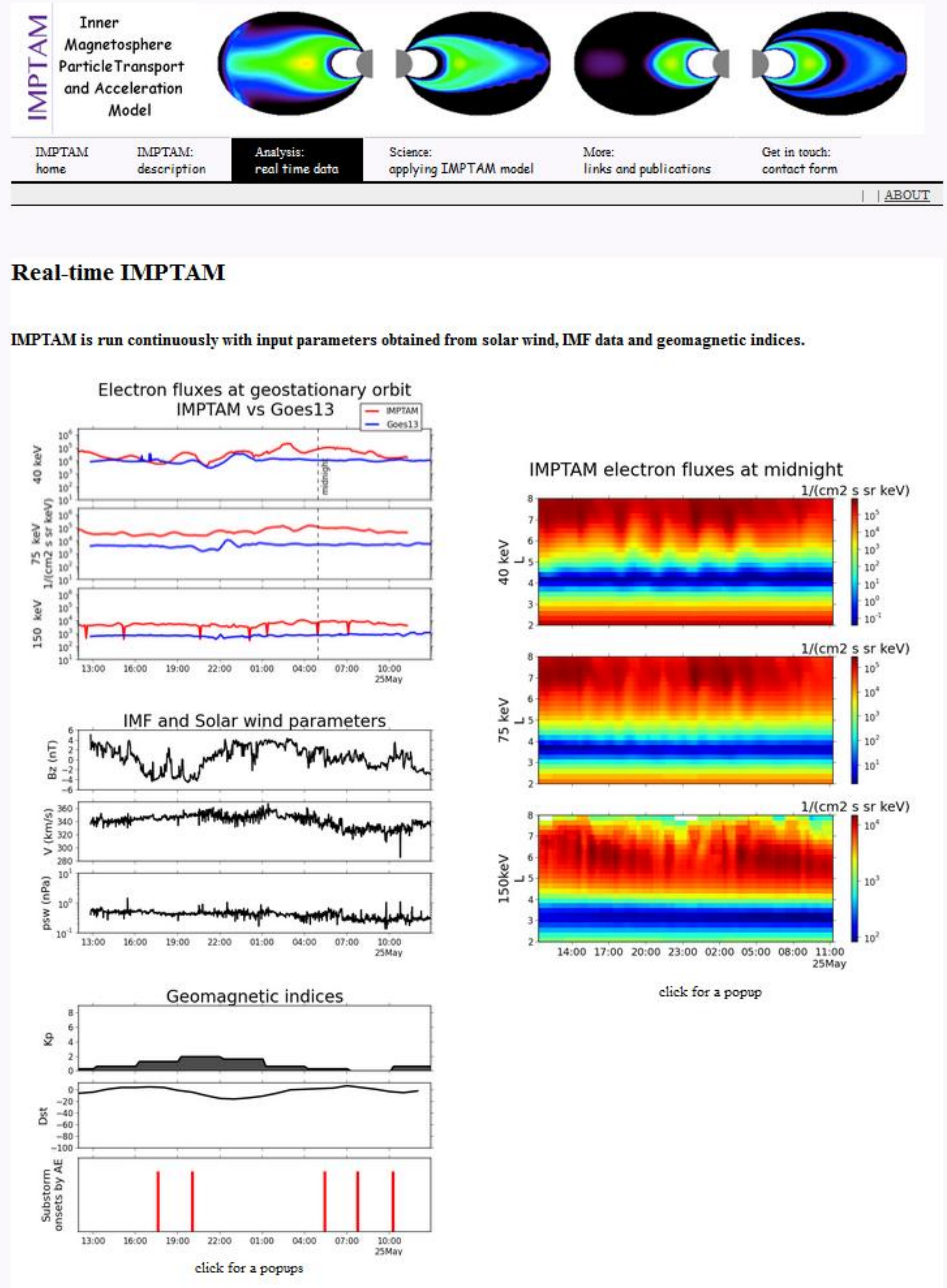
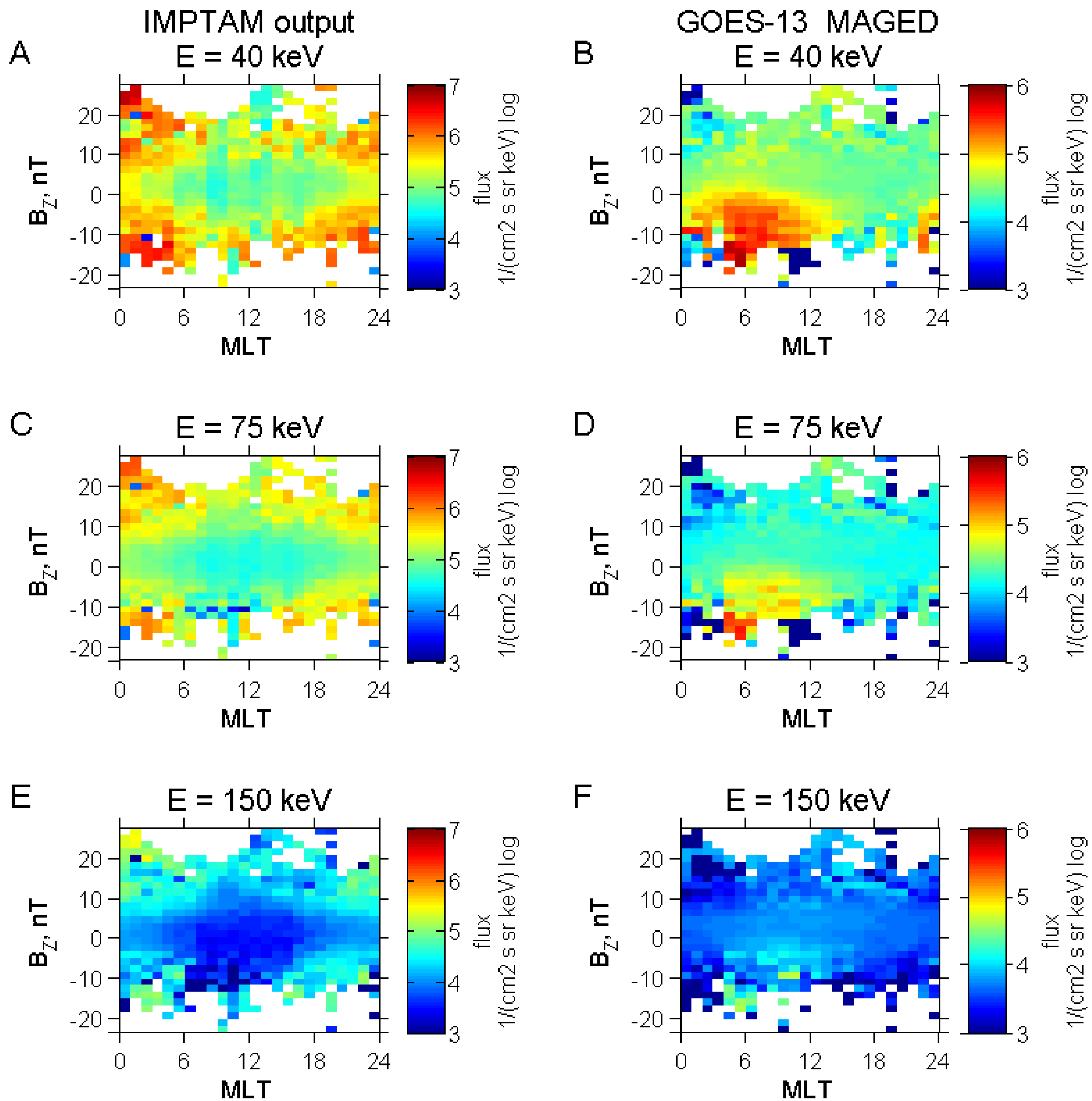


IMPTAM vs GOES 13: IMF Bz

Higher fluxes (within 1 order of magnitude) occupy larger MLT areas than observed

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

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



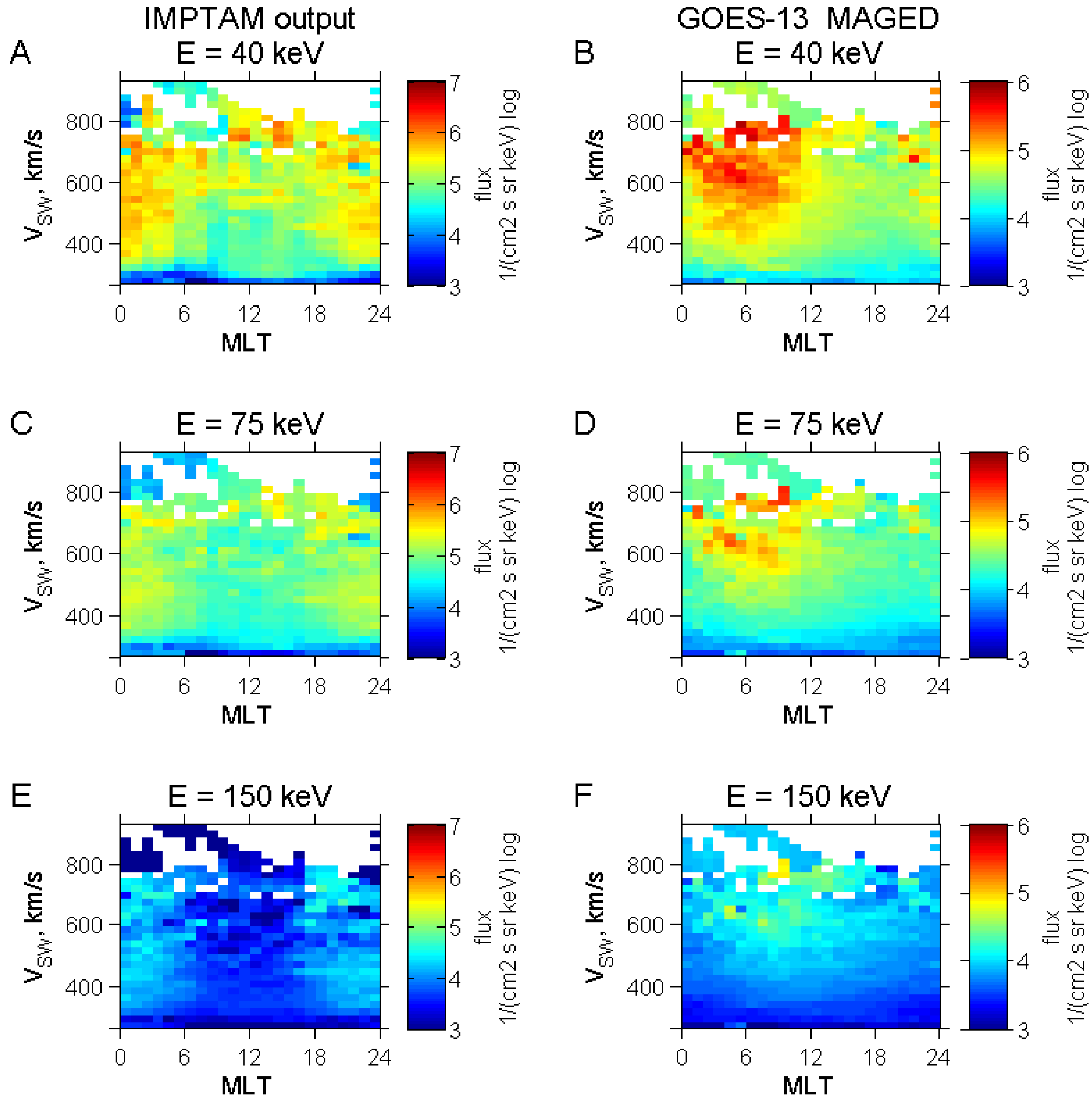
different scales

IMPTAM vs GOES 13: Vsw

Higher fluxes (within 1 order of magnitude) occupy larger MLT areas than observed

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

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



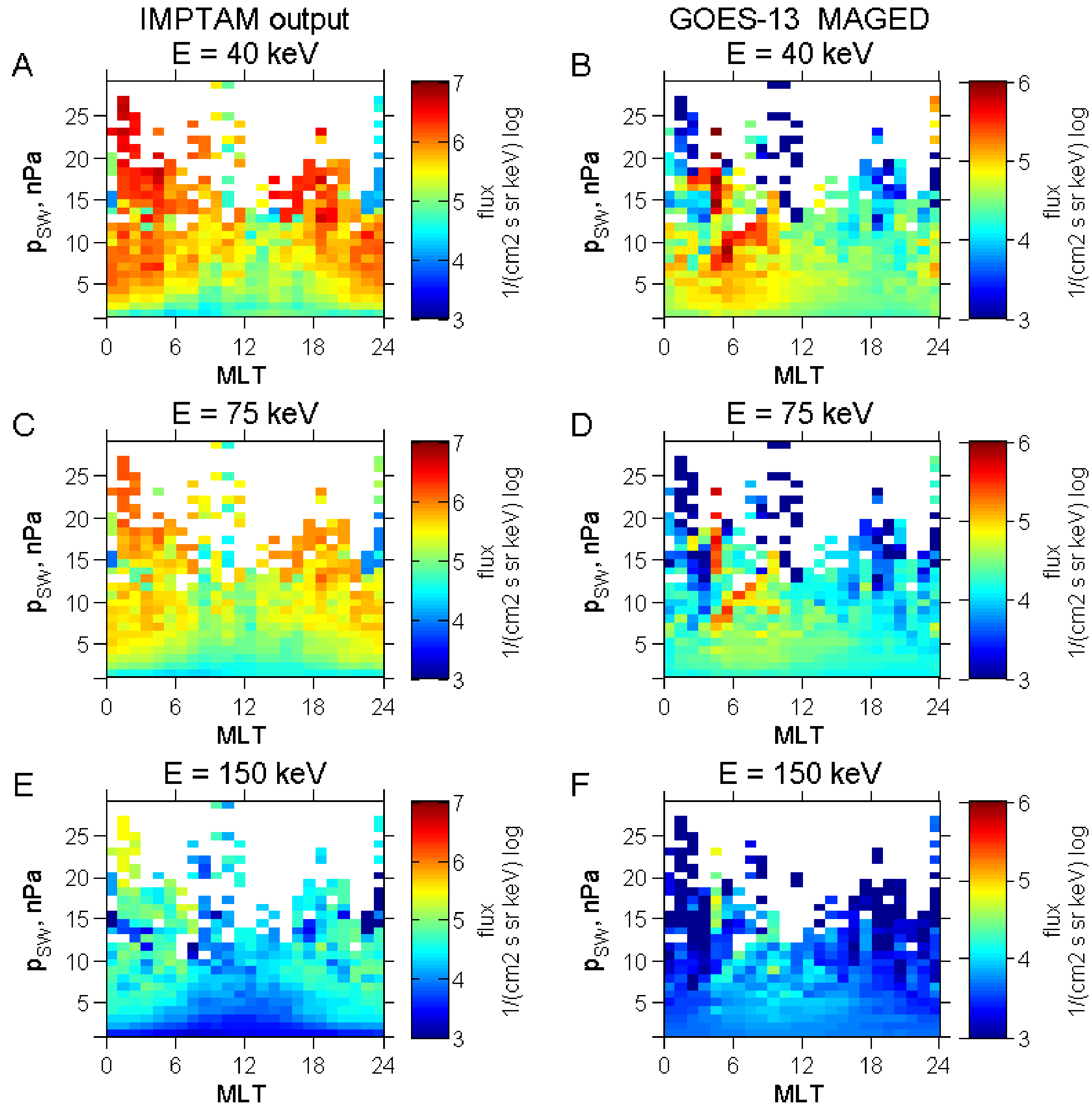
different scales

IMPTAM vs GOES 13: Psw

Higher fluxes (within 1 order of magnitude) 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



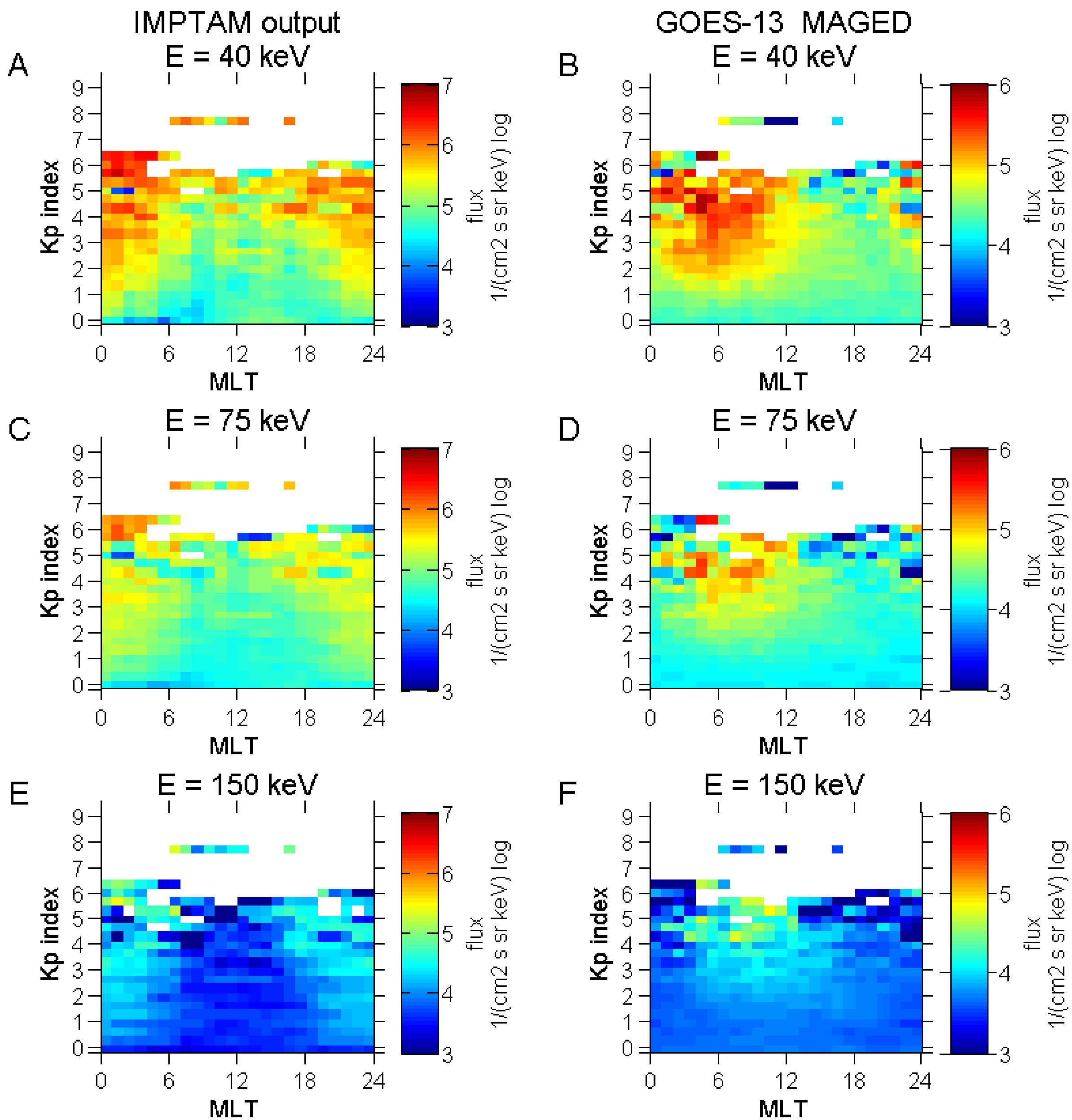
different scales

IMPTAM vs GOES 13: Kp

Higher fluxes (within 1 order of magnitude) occupy larger MLT areas than observed

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

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



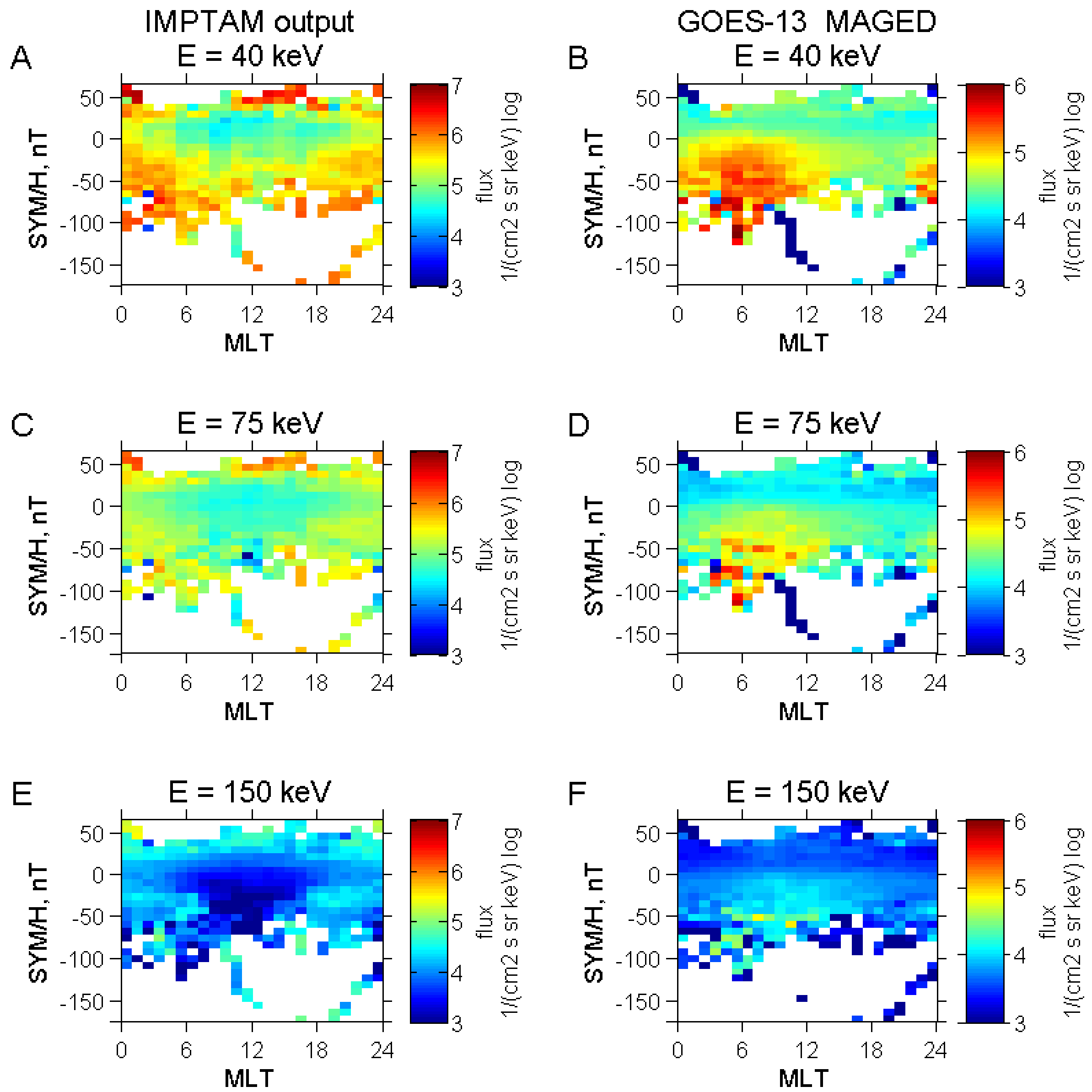
different scales

IMPTAM vs GOES 13: SYM-H

Higher fluxes (within 1 order of magnitude) 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 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 for time period between September 2013 and March 2015.

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 (within 1 order of magnitude) occupy wider MLT areas than observed;

Peak shifted more towards **midnight** instead of being at dawn as observed

Deviations are due to parameterization of models in IMPTAM!

Ongoing IMPTAM-online improvement: introducing empirical model for boundary conditions in the plasma sheet based on THEMIS data, launching electromagnetic pulses on substorm onsets determined by AE index in real time.

Good performance model for keV electron fluxes for surface charging effects!

Current IMPTAM output compared to GOES MAGED 40 and 75 keV electron fluxes