IMPTAM

Inner Magnetosphere Particle Transport and Acceleration Model

IMPTAM Runs at CCMC

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IMPTAM
Inner Magnetosphere Particle Transport and Acceleration Model

Outline

1. IMPTAM, a brief history and overview
2. Current research with IMPTAM
3. IMPTAM is run in real-time: results at *http://imptam.fmi.fi, http://fp7-spacecast.eu, and http://csem.engin.umich.edu/tools/imptam/*
4. IMPTAM runs at CCMC
5. Outlook

1. IMPTAM, an overview

IMPTAM: Inner Magnetosphere Particle Transport and Acceleration Model

IMPTAM is a physical model of the inner magnetosphere developed at the Finnish Meteorological Institute by Natalia Ganushkina et al. (e.g., 2001, 2005, 2006, 2013, 2014, 2015).

The model traces electrons and ions in the keV range from the nightside plasma sheet into the inner magnetosphere and near the plasmasphere.

It is a well-established model in the community with dozens of papers and presentations.

IMPTAM for electrons has been run nearly continuously using realtime data since September 2013; results viewable at *http://imptam.fmi.fi*. *http://fp7-spacecast.eu*, and *http://csem.engin.umich.edu/tools/imptam/*

1. IMPTAM, an overview

IMPTAM
Inner Magnetosphere Particle Transport and Acceleration Model

IMPTAM traces **ions and electrons** with arbitrary pitch angles from the plasma sheet to the inner L-shell regions with energies 1 to 300 keV in time-dependent magnetic and electric fields

- traces a distribution of particles in the **drift approximation** under the conservation of the 1^{st} 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-associatedelectromagnetic fields

1. IMPTAM, an overview

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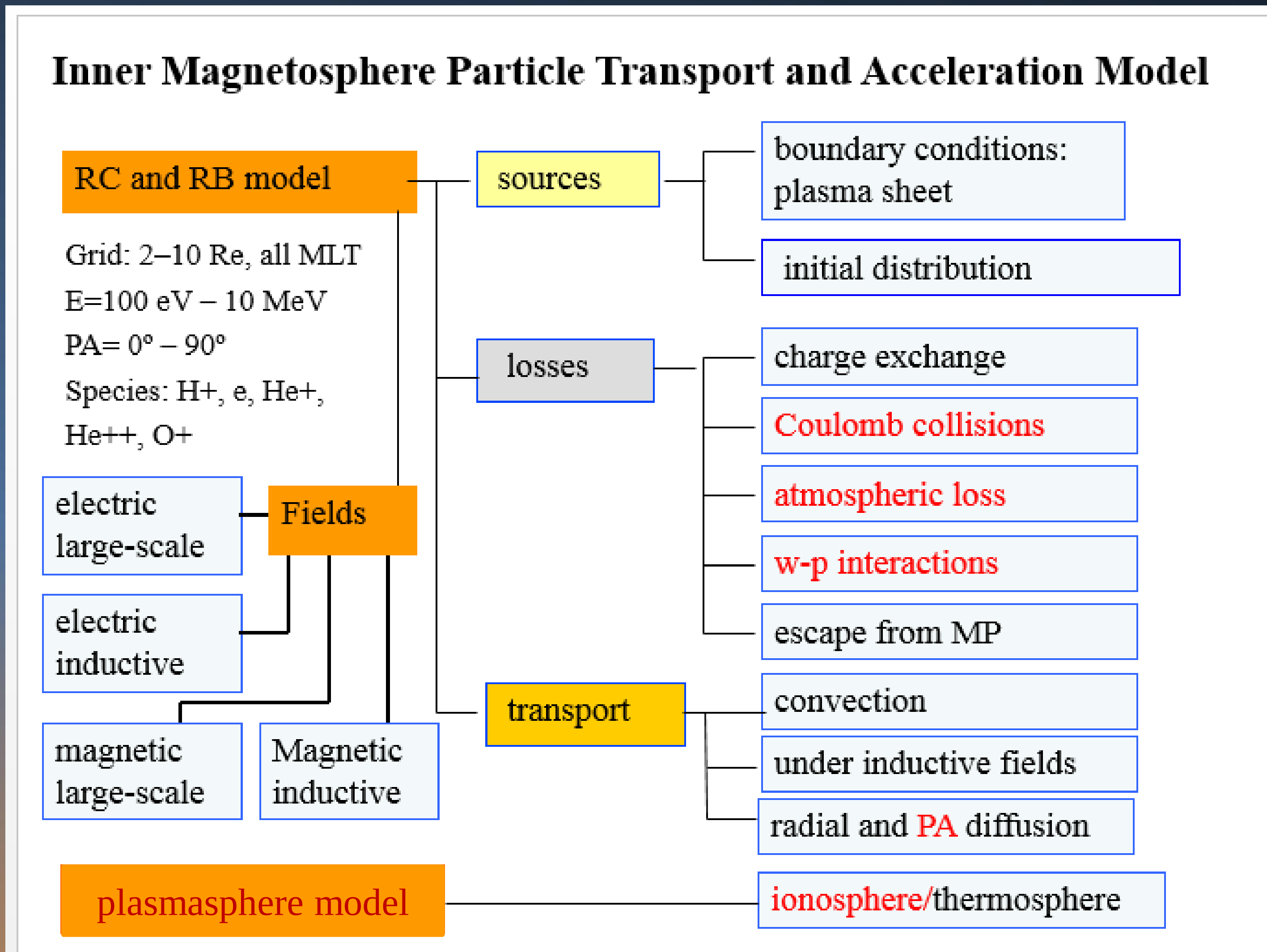
Inner Magnetosphere Particle Transport and Acceleration Model



1. IMPTAM, an overview

IMPTAM — Inner Magnetosphere Particle Transport and Acceleration Model

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}

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

(*Brautigam and Albert,* 2000)

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):

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

(*Shprits et al*., 2007)

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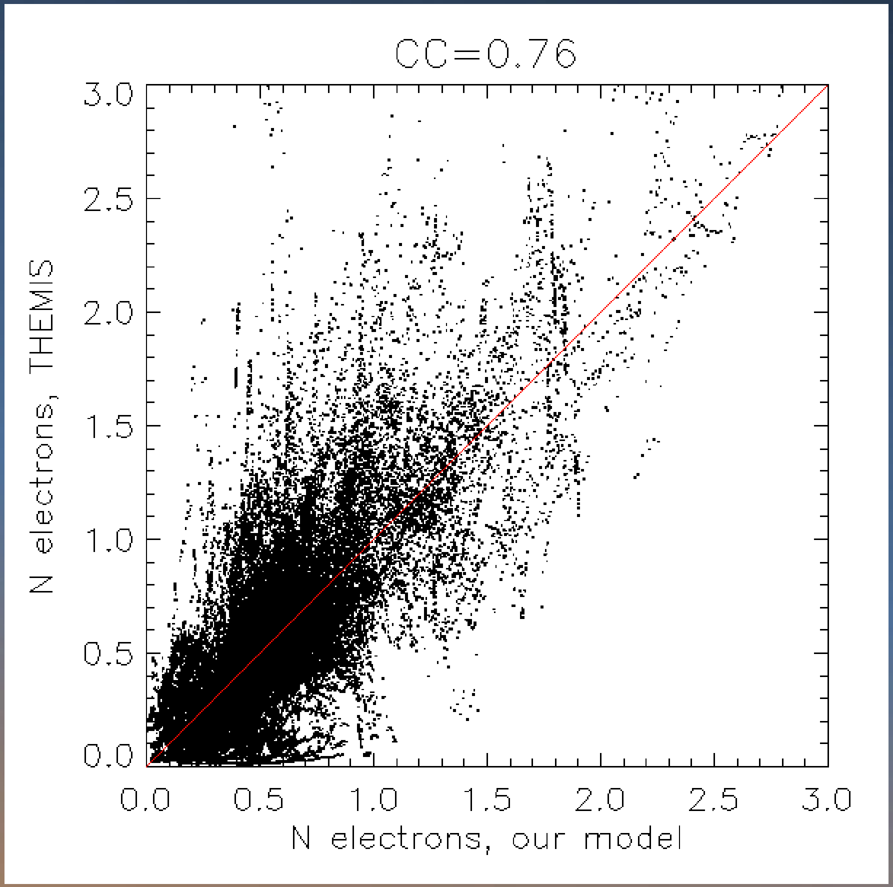
2. Current research with IMPTAM

Empirical model for plasma sheet electrons at 6-11 R_e based on THEMIS data that now used for the plasma sheet source in IMPTAM



2. Current research with IMPTAM

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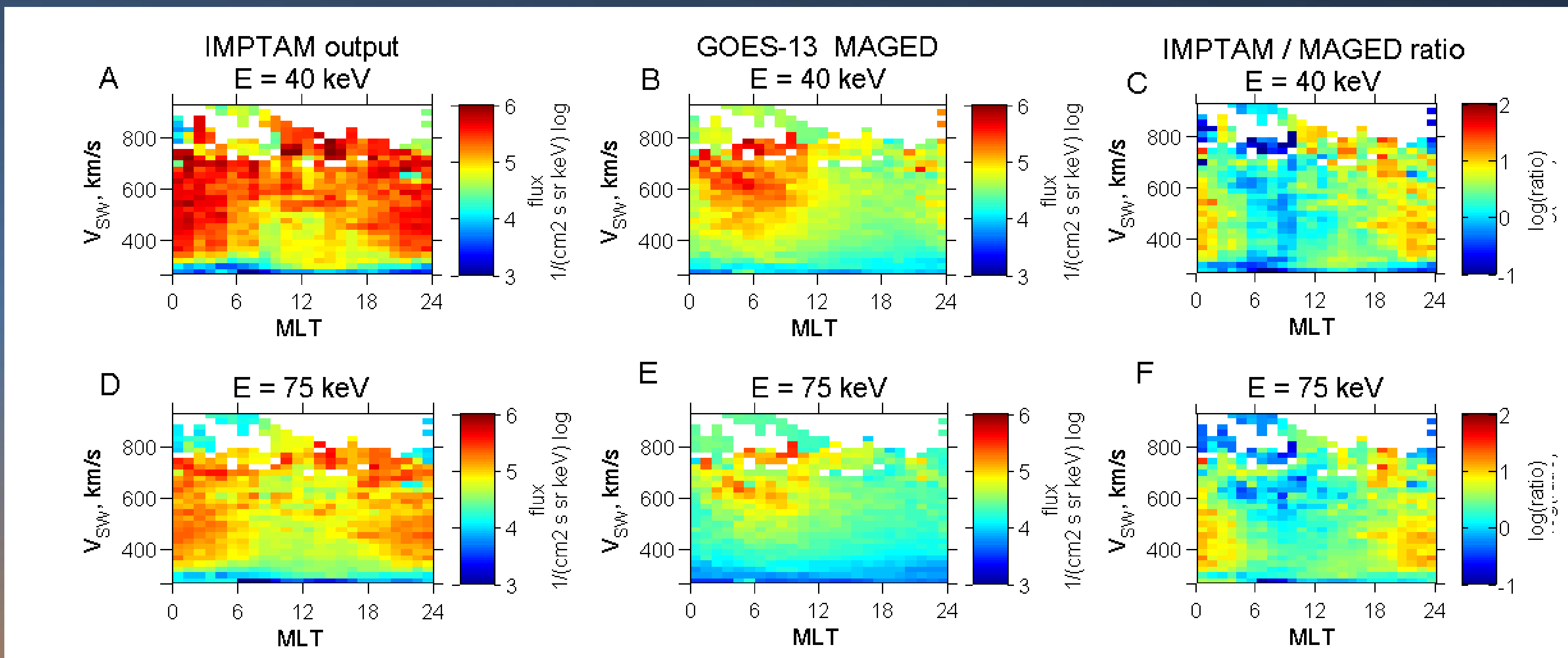
Comparison on two years of IMPTAM online results for Goes-13's geosynchronous orbit.



2. Current research with IMPTAM

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Video of a modeled 2005 January 02 charging event: electron fluxes

2. Current research with IMPTAM

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Inner Magnetosphere Particle Transport and Acceleration Model

Role of substorm associated electromagnetic pulses in the ring current formation during May 2-4, 1998 storm: modeled energy density for ions

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3. IMPTAM online

IMPTAM is continuosly run with real-time solar wind data and geomagnetic indices for nowcasting.

Currently the model is run hourly.

IMPTAM online has been running since Septemeber 2013, and it hasn’t had gaps in results for a full year.

The model responds to all changes in the solar wind and handles also extremes and storm times well.

The results are shown on our website *http://imptam.fmi.fi* as well as on Michigan University’s CSEM website and *www.fp7-SpaceCast.eu*

3. IMPTAM online

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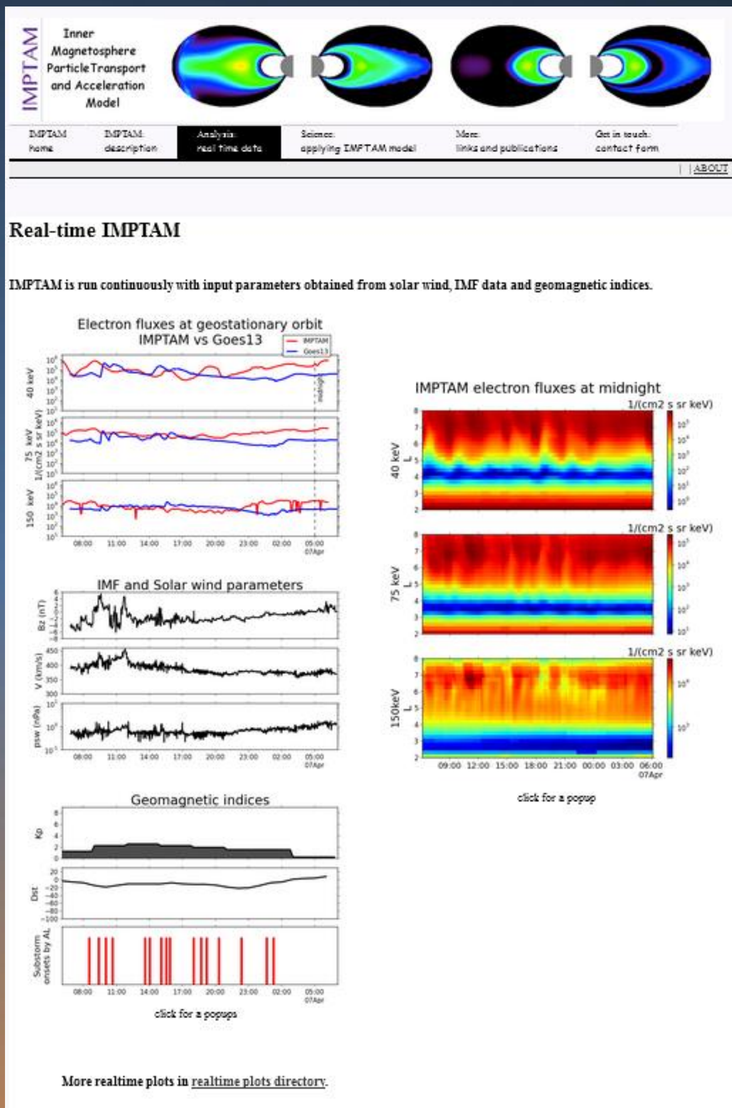
Inner Magnetosphere Particle Transport and Acceleration Model



IMPTAM webpage real time view

- Electron fluxes for the midnight from L= 2 to 8 are provided as well as for the Goes-13 location. IMPTAM electron fluxes are compared with Goes-13 MAGED instruments fluxes for energies of 40, 75 and 150 keV.
- Key input parameters from the solar wind and geomagnetic indices are also presented.

3. IMPTAM online

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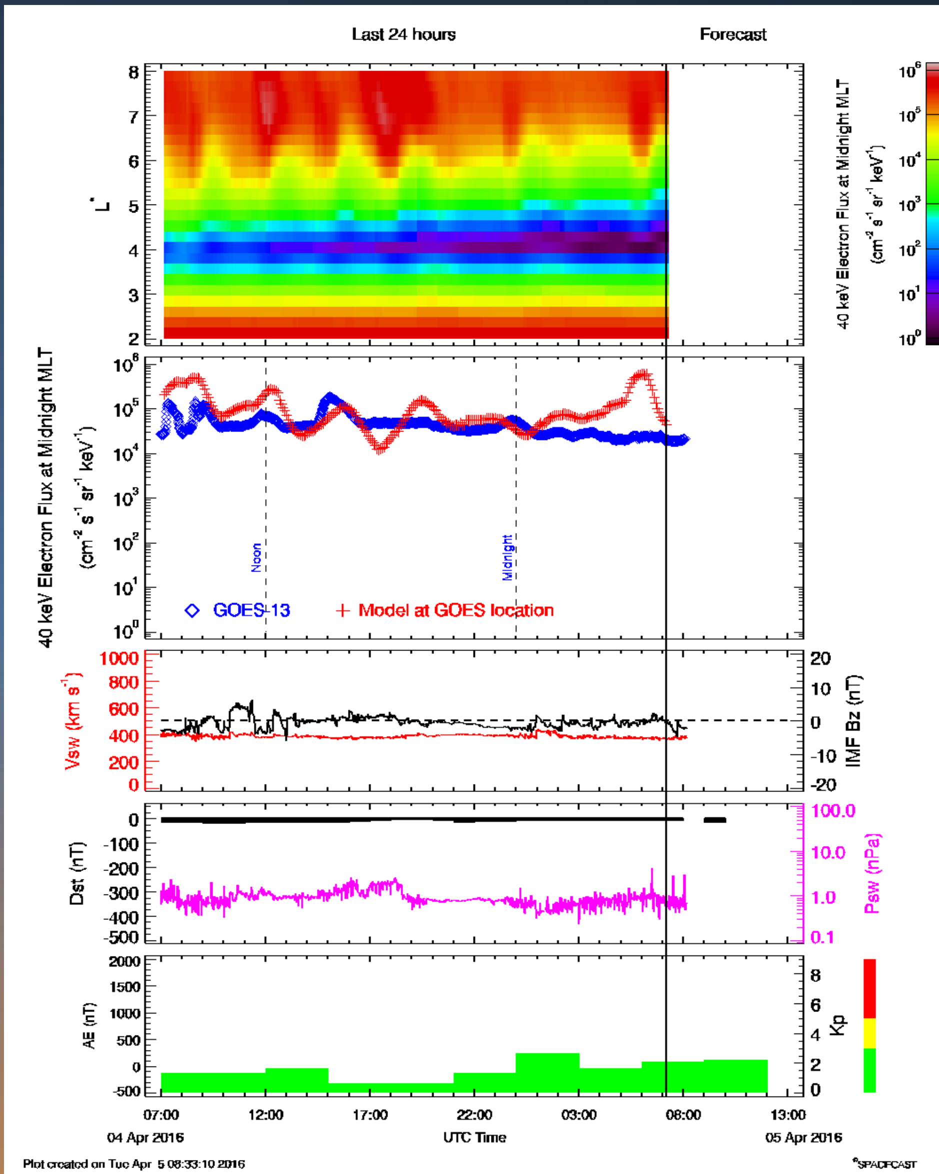


<u>SpaceCast webpage real time view of 40 keV electrons</u>

Electron fluxes for the midnight are provided. IMPTAM fluxes are compared with Goes-13 MAGED instruments fluxes for electron energies of 40, 75 and 150 keV.

Key solar wind and geomagnetic indices are also presented.

4. IMPTAM Instant Run

IMPTAM Inner Magnetosphere Particle Transport and Acceleration Model

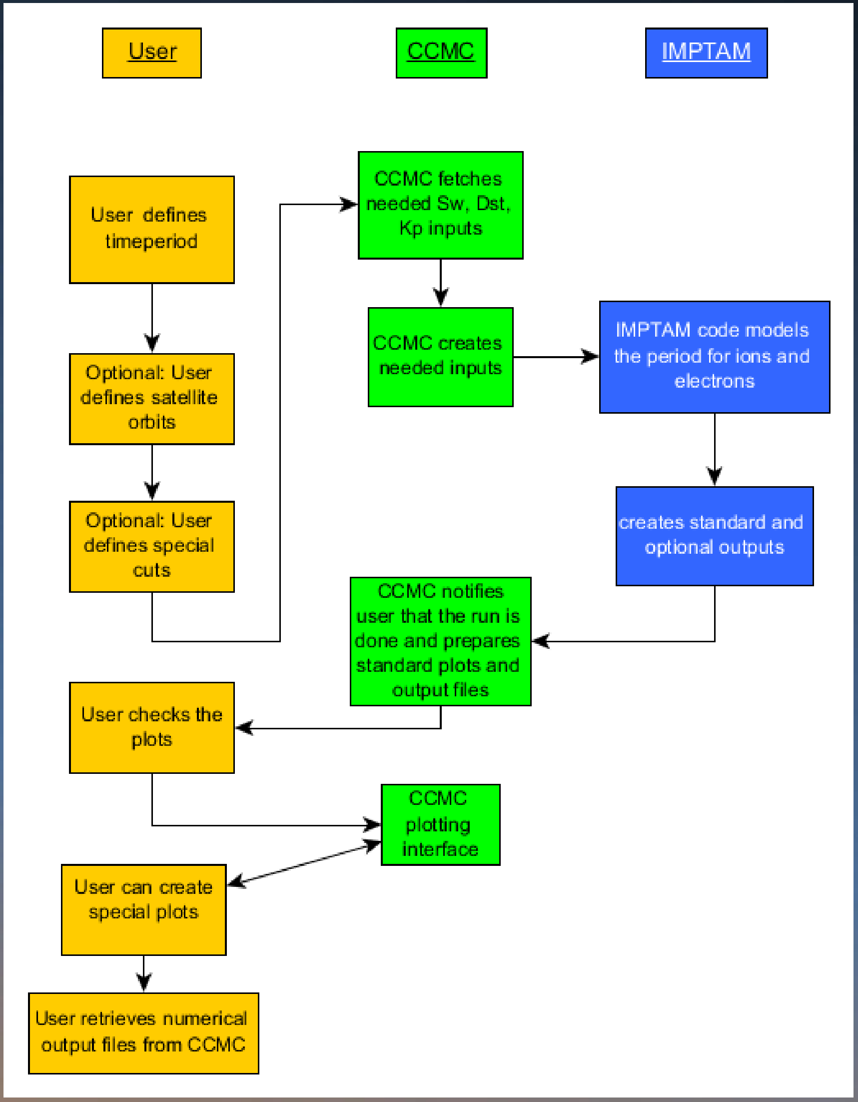
IMPTAM is to be setup for CCMC Instant Run.

The only needed input will be the time selected for the simulation run.

Geomagnetic indices and Solar Wind data for the period will be automatically retrieved.

Optional input 1: a satellite orbit file or several files

Optional input 2: user-defined magnetospheric cuts



4. IMPTAM Instant Run

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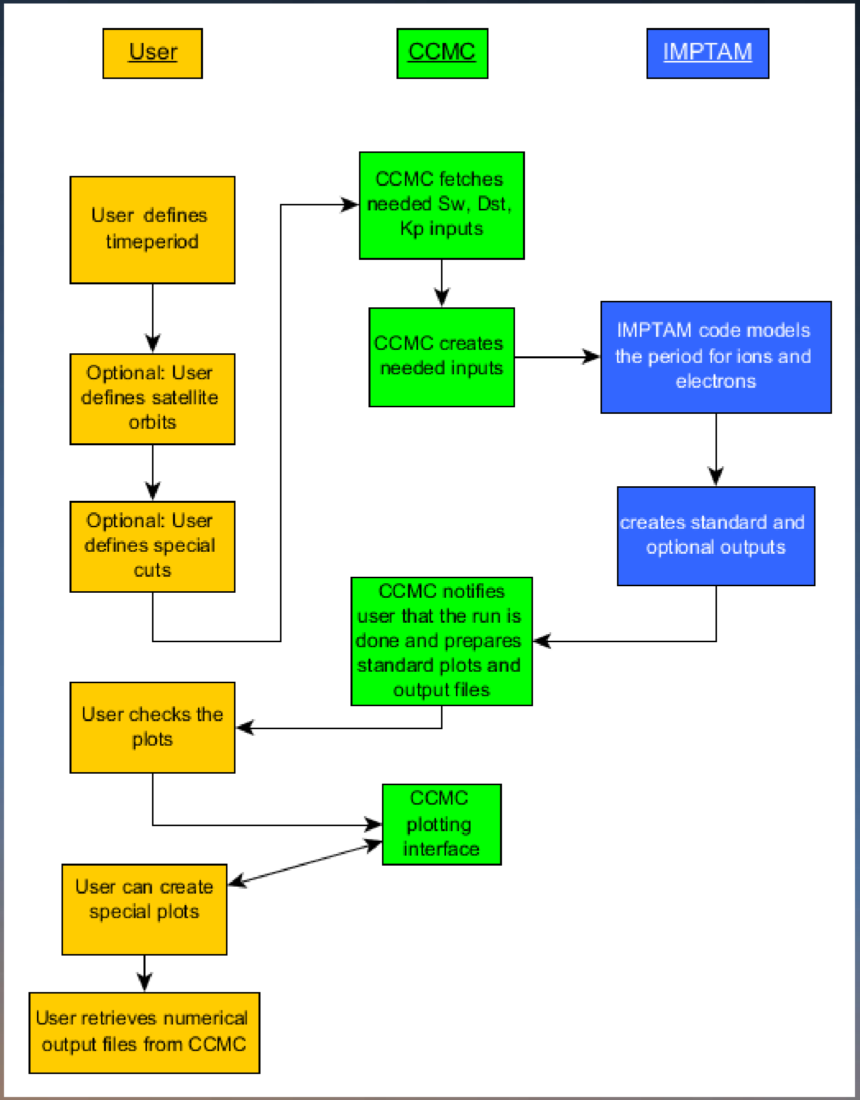
An IMPTAM run with CCMC Instant Run will provide as output

both ion and electron fluxes

anywhere inside 10 R_E:

- any cuts, any orbits
- all energies 1-300 keV
- all pitch angles



5. Summary and Outlook

IMPTAM Inner Magnetosphere Particle Transport and Acceleration Model

IMPTAM is well suited for CCMC Instant Run framework:

- The model is robust with all solar wind and geomagnetic conditions.
- It is an established scientific tool in space weather research.
- It is being actively developed.

Future developments:

Automated substorm pulse generation from realtime AL index:

After it has been tested with IMPTAM online,

IMPTAM code for CCMC Instant Run will feature the same.

Additional options for input parameters.

Additional Slides 1

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Some IMPTAM papers:

1. Sillanpää et al., Long-term variations of electron fluxes at geostationary orbit: GOES MAGED data and IMPTAM, in preparation.
2. Ganushkina et al., Nowcast model for low-energy electrons in the inner magnetosphere, Space Weather, 13, 2015.
3. Ganushkina et al., Low energy electrons (5-50 keV) in the inner magnetosphere, J. Geophys. Res., 119, 2014.
4. Ganushkina et al., Transport of the plasma sheet electrons to the geostationary distances, J. Geophys. Res.: Space Physics, 118, 2013.
5. Ganushkina et al., Storm-time ring current: model-dependent results, Ann. Geophys., 30, 2012.
6. Ganushkina et al., Evolution of the proton ring current energy distribution during 21–25 April 2001 storm 2006, J. Geophys. Res., 111, 2006.
7. Ganushkina et al., Role of substorm-associated impulsive electric fields in the ring current development during storms, Ann. Geophys., 23, 2005.
8. Ganushkina et al., Formation of intense nose structures, Geophys. Res. Lett., 28, 2001.