

# The Belgian SWIFF Plasmasphere Model (BSPM) at the PITHIA e-Science Centre

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# Outline

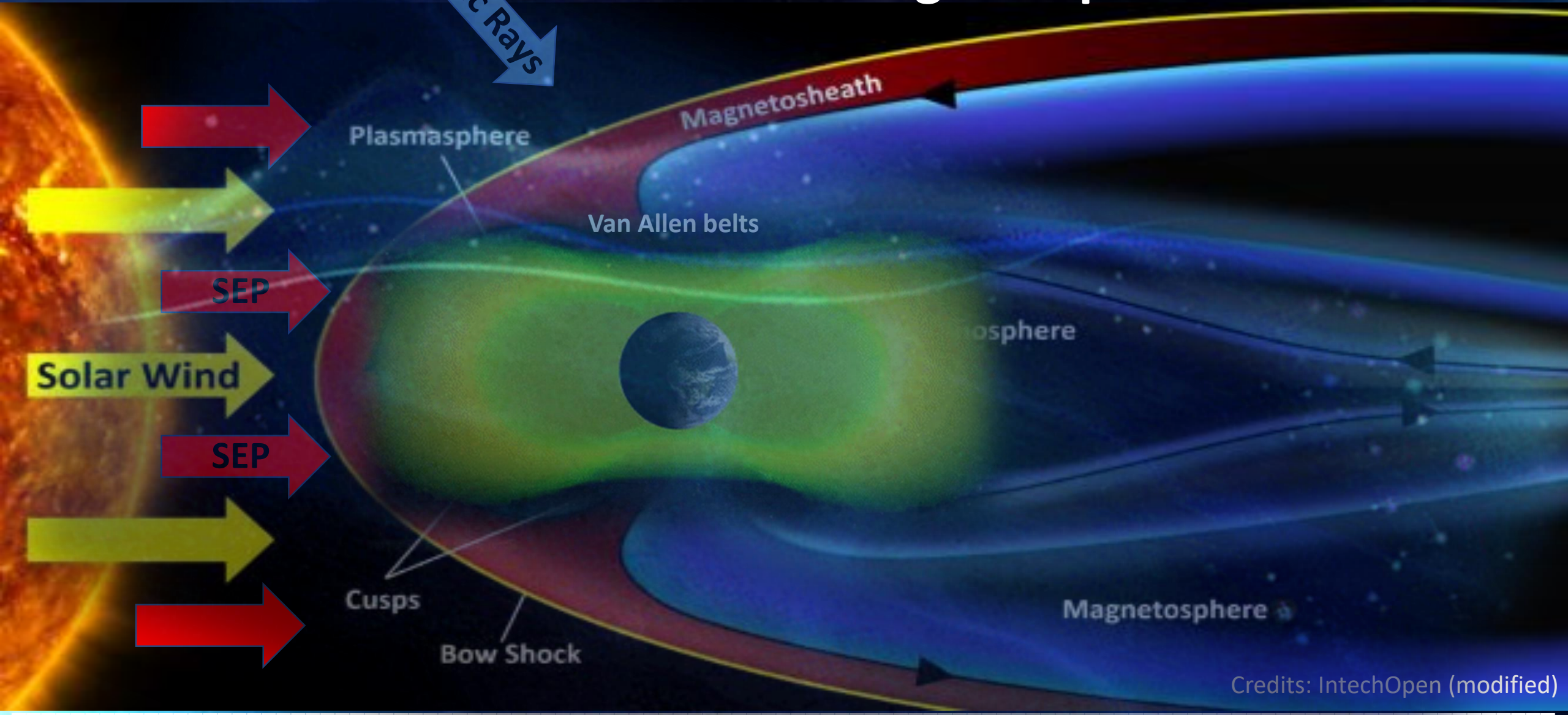
- 1. Earth inner magnetosphere**
- 2. The BSPM explained**
- 3. BSPM at open platforms**
- 4. Research on radiation belts**
- 5. Summary and perspectives**



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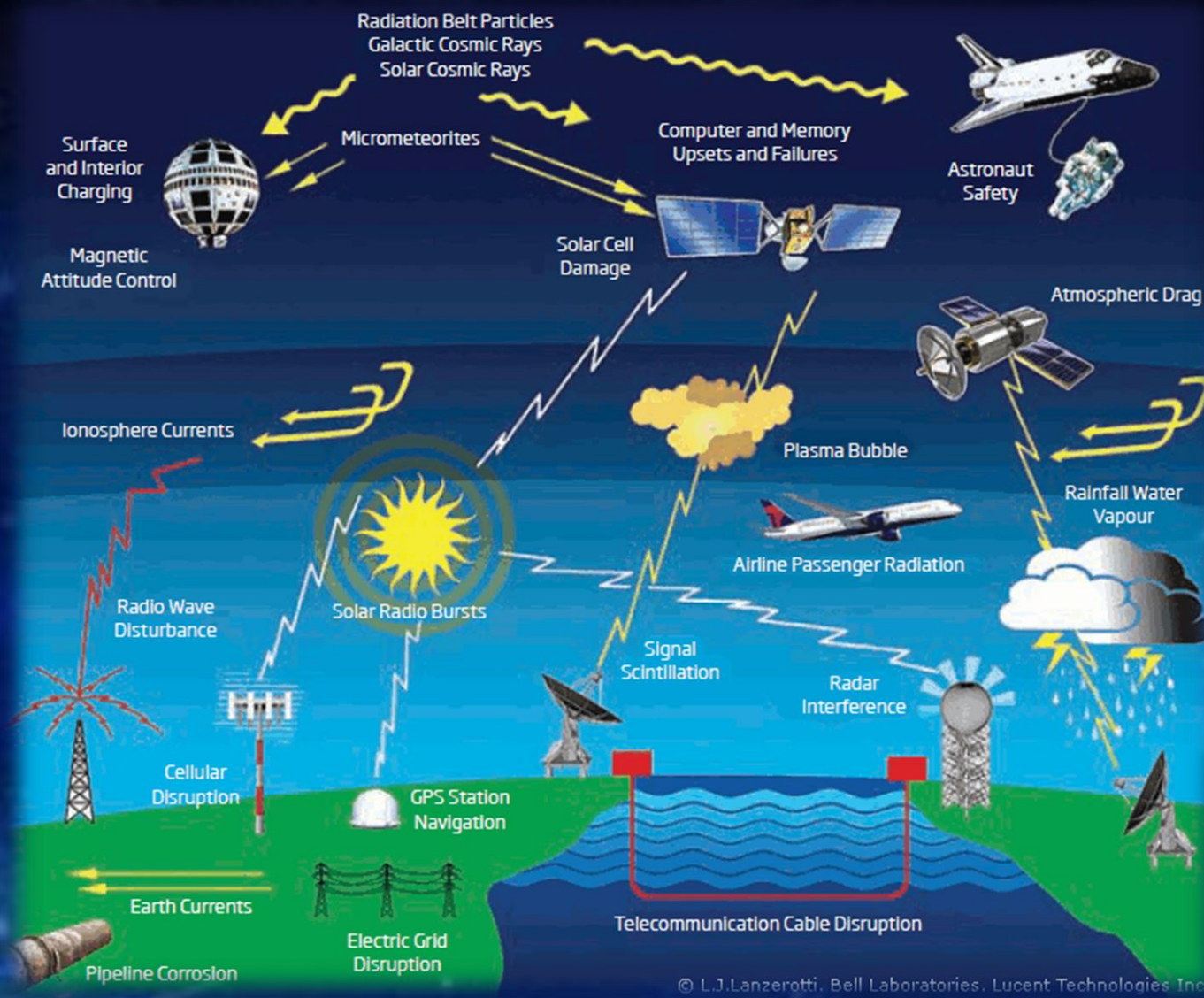
# Earth inner magnetosphere



Credits: IntechOpen (modified)



# Earth inner magnetosphere (cont.)

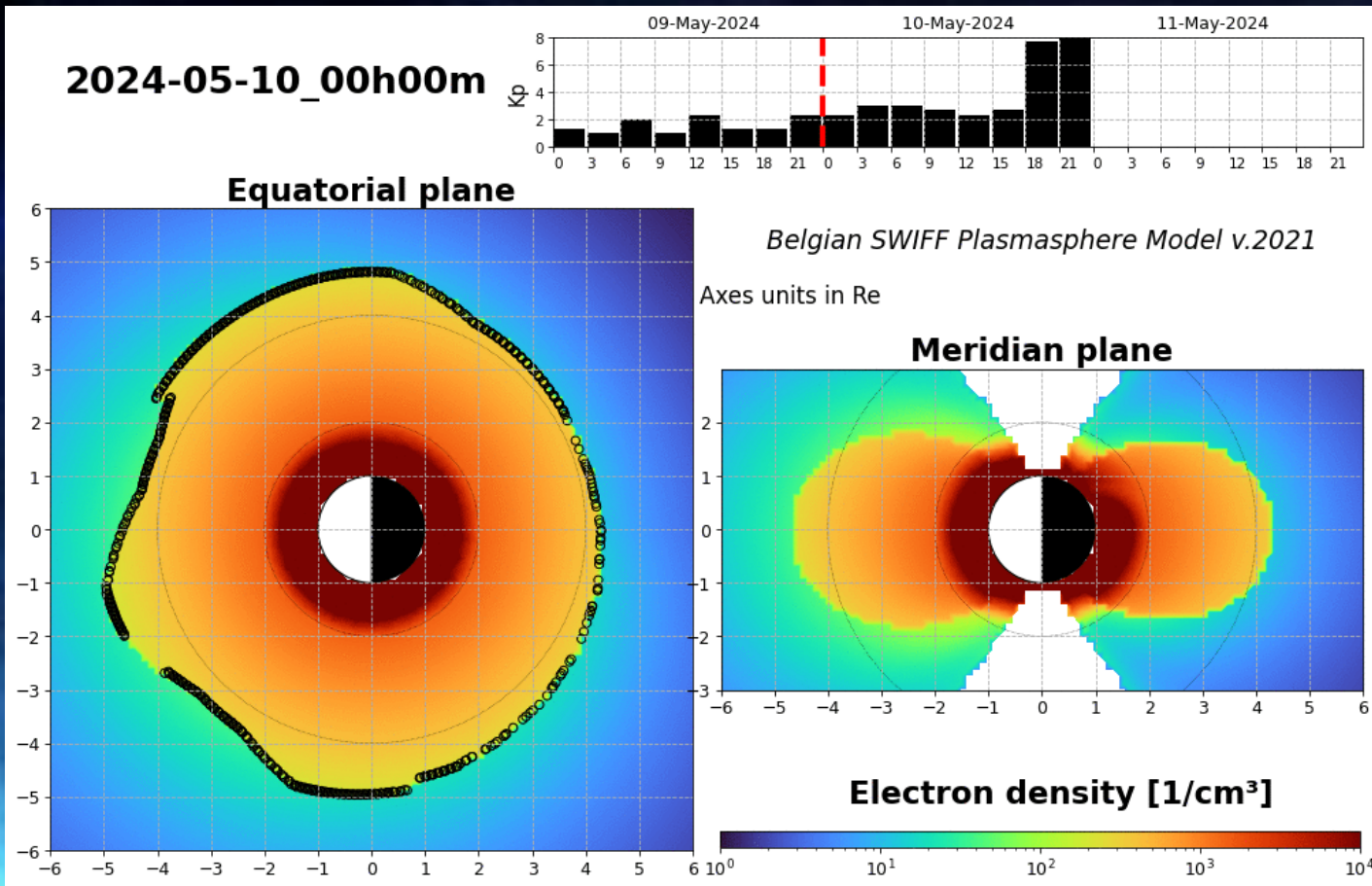


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# The BSPM explained



- **BSPM** → **3D dynamic kinetic model of the plasmasphere** first developed by [Pierrard & Stegen, 2008] based on [Carpenter & Anderson, 1992] parametrization → 2 series of equations (plasmasphere and plasmatrough) and completed for all MLT sectors and Latitude variation → **C&A\***
- Later **coupled to the IRI ionosphere model** [Pierrard & Voiculescu, 2011]
- Recent **reparametrization of the plasmatrough** using Van Allen probes data [Botek, Pierrard & Darrouzet, 2021]

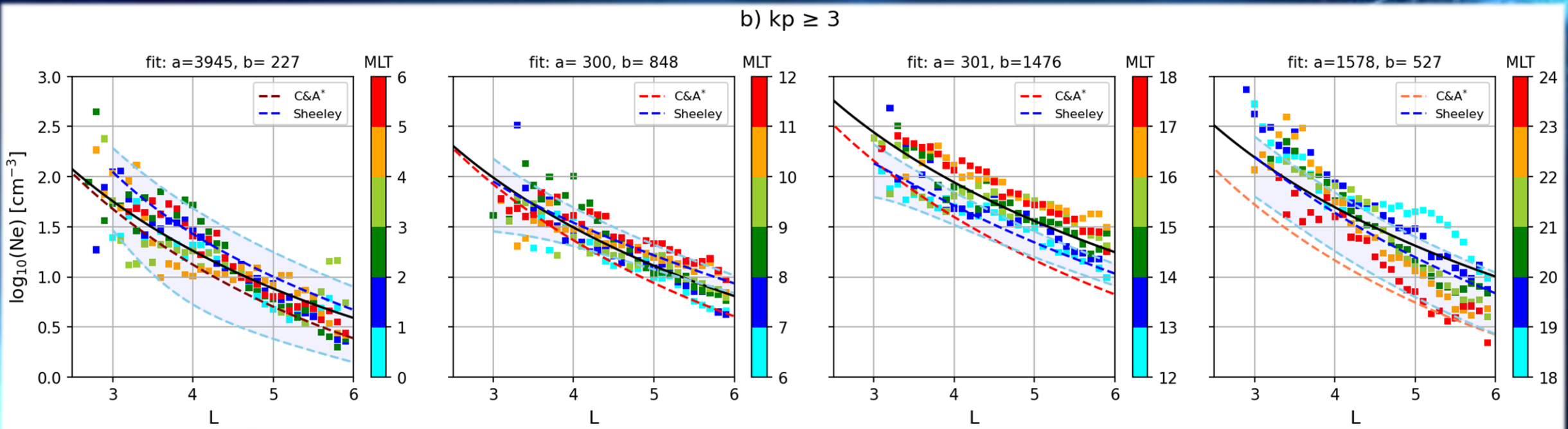
# The BSPM explained (cont.)

- **Input: Kp** values from the previous day and current day of the simulation
- **Outputs: plasmopause position + proton/electron /ions density + temperature**
- **Principal features of BSPM:**
  - **analytical model** adjusted to reproduce observations
  - **plasmasphere rotation** and the **geomagnetic activity** → plasmopause position [Pierrard & Lemaire, 2004]
  - **plasmasphere erosion** by perturbations and its **refilling**
  - formation and evolution of **plumes**
- **Plasmasphere + Plasmopause extensively validated** → [Bandic & al., 2016, 2017; Verbanac & al., 2015, 2018] + ESA reports.



# The BSPM explained (cont.)

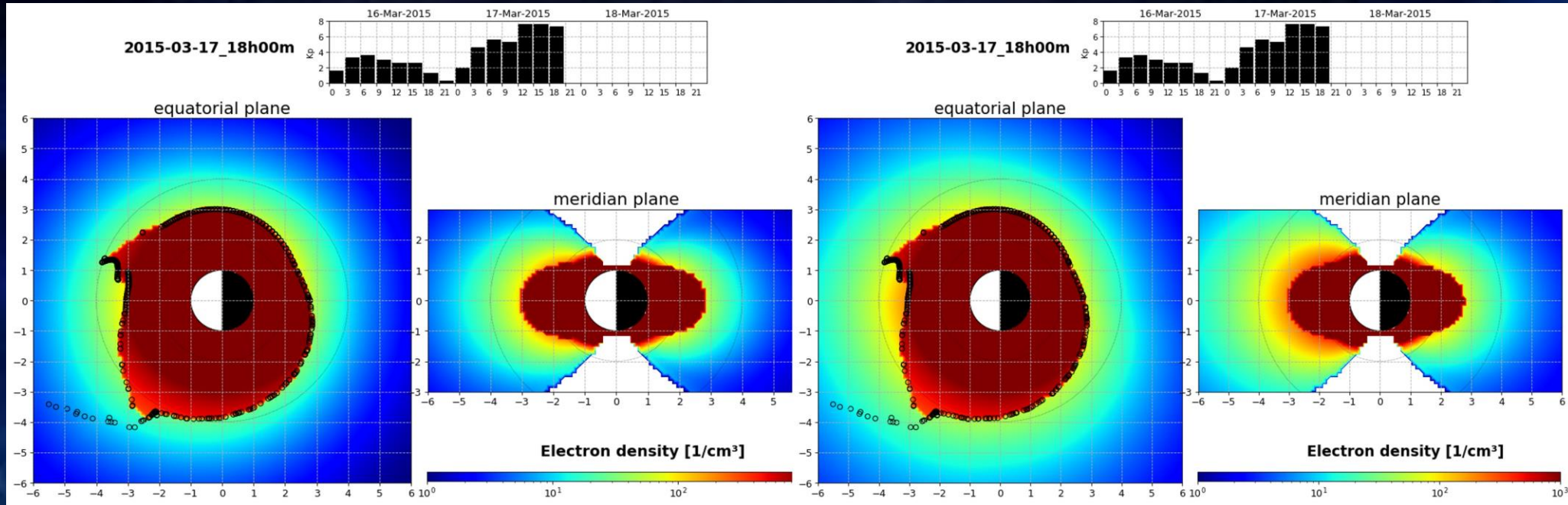
- **Plasmatrough reparametrized using VAP/EMFISIS data** [Botek & al., 2021]:
  - difficult due to broad observations distribution of very low densities
  - important for wave-particles interaction
  - impact on Radiation Belts high energy particles [Pierrard & al., 2020, 2021].
  - EMFISIS observations (2012-2019) with  $L > \text{BSPM } L_{pp}$  were retained



# The BSPM explained (cont.)

C&A\*

EMFISIS-fitted



- A slightly higher density of the plasmatrough with the new parametrization
- Validation against Arase/PWE data [Botek & al., 2021]
- SafeSpace EU project : BSPM inside a chain of models for a sophisticated model of Radiation Belts and a SW service prototype [Brunet & al. 2023]



# Outline

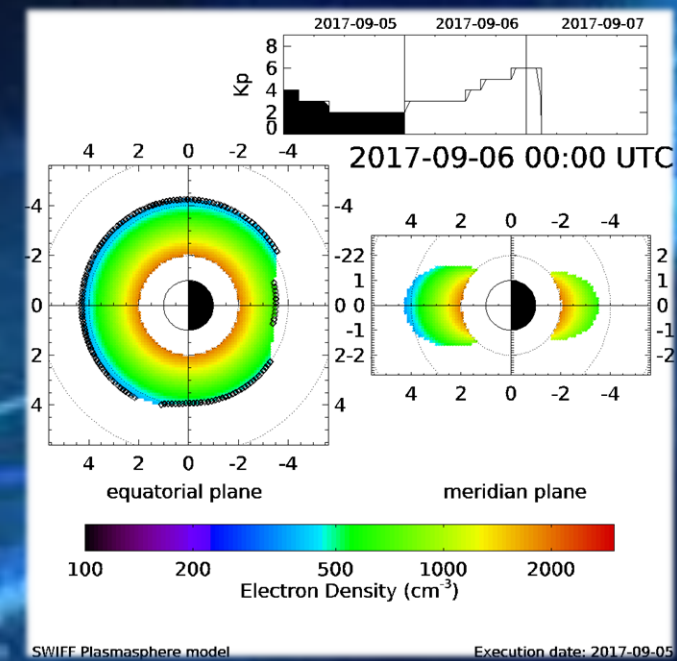
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# BSPM at open platforms

BSPM Fortran-IDL ancient version routinely running since 2017 at <https://swe.ssa.esa.int/bira-swiff-federated>

The screenshot shows the ESA Space Weather Service Network interface. The main content area is titled "Federated products from the BIRA-IASB Space Weather Services (BIRA-IASB)". It includes a description of the 3D dynamic model of the plasmasphere and a section for the "Latest available forecast".

The forecast section displays two sets of plots for different dates: 2024-06-07 20:30 UTC and 2024-06-07 04:30 UTC. Each set includes a Kp index plot at the top, an equatorial plane plot (left), and a meridian plane plot (right). A color scale at the bottom indicates Electron Density (cm<sup>-3</sup>) and Electron Temperature (K).

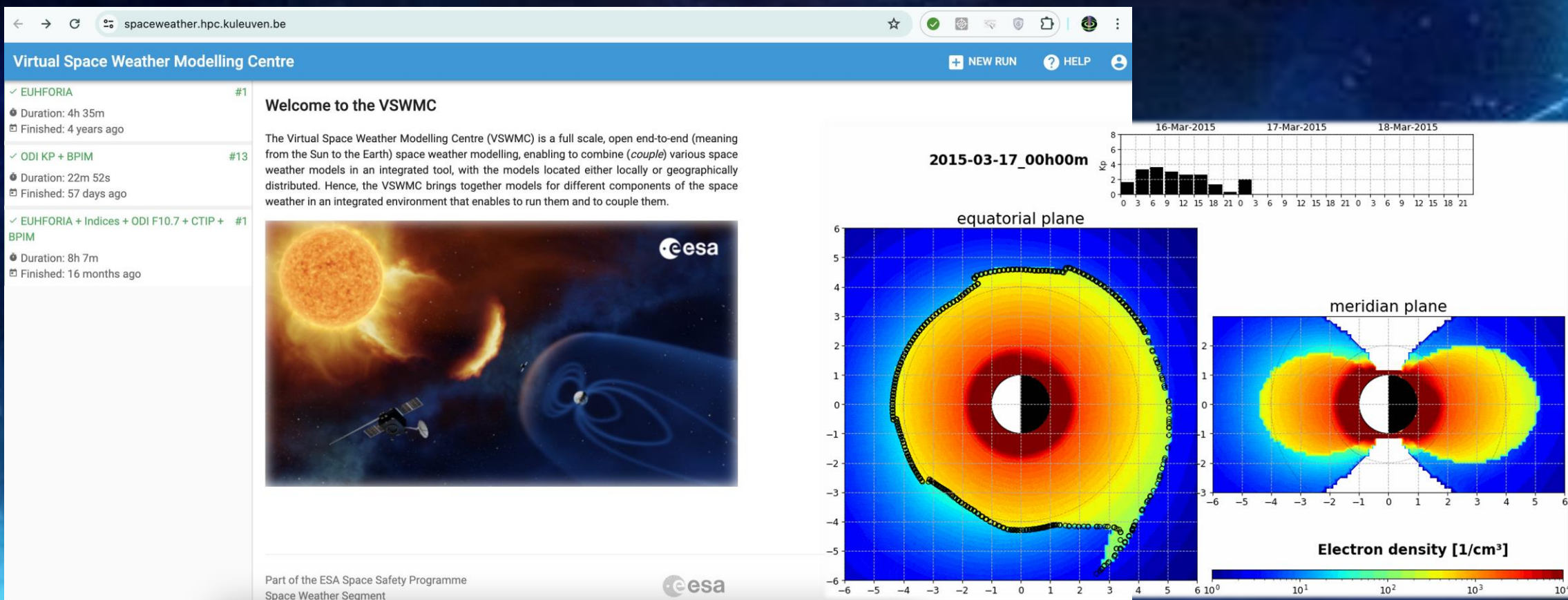


Only movies as output



# BSPM at open platforms (cont.)

BSPM Fortran-Python version available at the <https://swe.ssa.esa.int/kul-cmpa-federated> (VSWMC) for runs on request inside a chain of models. Outputs: images, movies, text files.



The screenshot shows the VSWMC web interface with the following details:

- Virtual Space Weather Modelling Centre** (spaceweather.hpc.kuleuven.be)
- NEW RUN** and **HELP** buttons.
- Run #1:** EUHFORIA, Duration: 4h 35m, Finished: 4 years ago.
- Run #13:** ODI KP + BPIM, Duration: 22m 52s, Finished: 57 days ago.
- Run #1:** EUHFORIA + Indices + ODI F10.7 + CTIP + BPIM, Duration: 8h 7m, Finished: 16 months ago.

**Welcome to the VSWMC**

The Virtual Space Weather Modelling Centre (VSWMC) is a full scale, open end-to-end (meaning from the Sun to the Earth) space weather modelling, enabling to combine (*couple*) various space weather models in an integrated tool, with the models located either locally or geographically distributed. Hence, the VSWMC brings together models for different components of the space weather in an integrated environment that enables to run them and to couple them.

**2015-03-17\_00h00m**

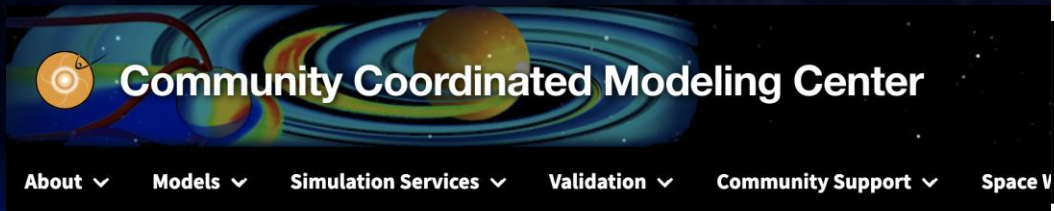
**equatorial plane**

**meridian plane**

**Electron density [1/cm<sup>3</sup>]**

Part of the ESA Space Safety Programme  
Space Weather Segment

# BSPM at open platforms (cont.)



[Home](#) > [Model Catalog](#)

## BSPM

Version: 2021

→ [Runs-on-Request](#)

The 3D dynamic model of the plasmasphere [1,2,3] is a semi-empirical model developed by the Solar Wind Division of the Royal Belgian Institute for Space Aeronomy.

Based on physical mechanisms for plasmopause formation and trajectories of particles trapped in the Earth's magnetic field, it provides the number density and the temperature of the electrons and protons inside and outside the plasmasphere, as well as the position of the plasmopause, as a function of the



### Edith\_Botek\_051124\_IM\_1

Run Status: Run Complete  
Status updated: 2024-05-11T14:30:39+0000

#### Run Metadata

Metadata Record: [View Full Run Metadata in the CCMC Metadata Registry](#) (  
Metadata as JSON: [View Full Run Metadata as JSON](#)

Model Domain: IM  
Model Name: BSPM  
Model Version: 2021  
Key Word: big geo storm

Run type: model  
DOY: 130  
Start time: 2024/05/10 00:00:00  
End time: 2024/05/11 00:00:00

#### Output Image (?)

**Output Image (?)**

2024-05-10\_00h00m

Equatorial plane

Meridian plane

Belgian SWIFF Plasmasphere Model v.2021

Axes units in Re

Electron density [1/cm<sup>3</sup>]

dens\_output

**Run Services**

- Request output data as a single archive file
- Browse output data

**Runs with Overlapping Dates**

Click on model name to expand the list

- + [SWMF](#)
- + [NRLMSIS](#)
- + [NAIRAS](#)
- + [IRI](#)

Runs on request at <https://ccmc.gsfc.nasa.gov/models/BSPM~2021/>


Outputs: images, movies, text files. Forecast runs are the next step.



# BSPM at open platforms (cont.)

New BSPM P  
for runs on r

ps/api/



Home > All Scientific Metadata

## BSPM: 3D-Ki

### Description

The BSPM (Belgian SWIFF Pl... the Solar Wind Division of the... on physical mechanisms for t... it provides the number densit... well as the position of the pla... geomagnetic storms, the pla... and Stegen, 2008). During qu... Reference Ionosphere (IRI) m... particles between 60 and 70k... conditions to provide the den... in the plasmatrugh region h... model is running in a near-re... (<https://swe.ssa.esa.int/bira->... evaluates the electron densit... equatorial and meridian plas... by the name of 'BPIM' is avail... (<https://swe.ssa.esa.int/kul-c>... a more updated version of the... plasmasphere, the ionospher... the requested day. Output of... BSPM version is also availabl... (<https://ccmc.gsfc.nasa.gov/>... dynamic kinetic model of the... Voiculescu, M., 2011. The 3D... 38(12); Pierrard V., E. Botek a... vol. 8, p. 69, Front. In Astron... F., 2021. Assessment of the E... electron density data. Journa

### Interact

Interaction Method	Des
API	Inte

**Download** Returns the ZIP file of all outputs, including .png and .csv files. ^

Download all the outputs by passing the execution date. ^

Returns the ZIP file of all outputs, including .png and .csv files.

Enable

Name	Description
<p><b>date</b> * required</p> <p>string</p> <p>(query)</p>	<input style="width: 100%; height: 20px;" type="text" value="date"/>

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login/sign up

help & support

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# Research on radiation belts

## Energetic Particle Telescope (EPT)

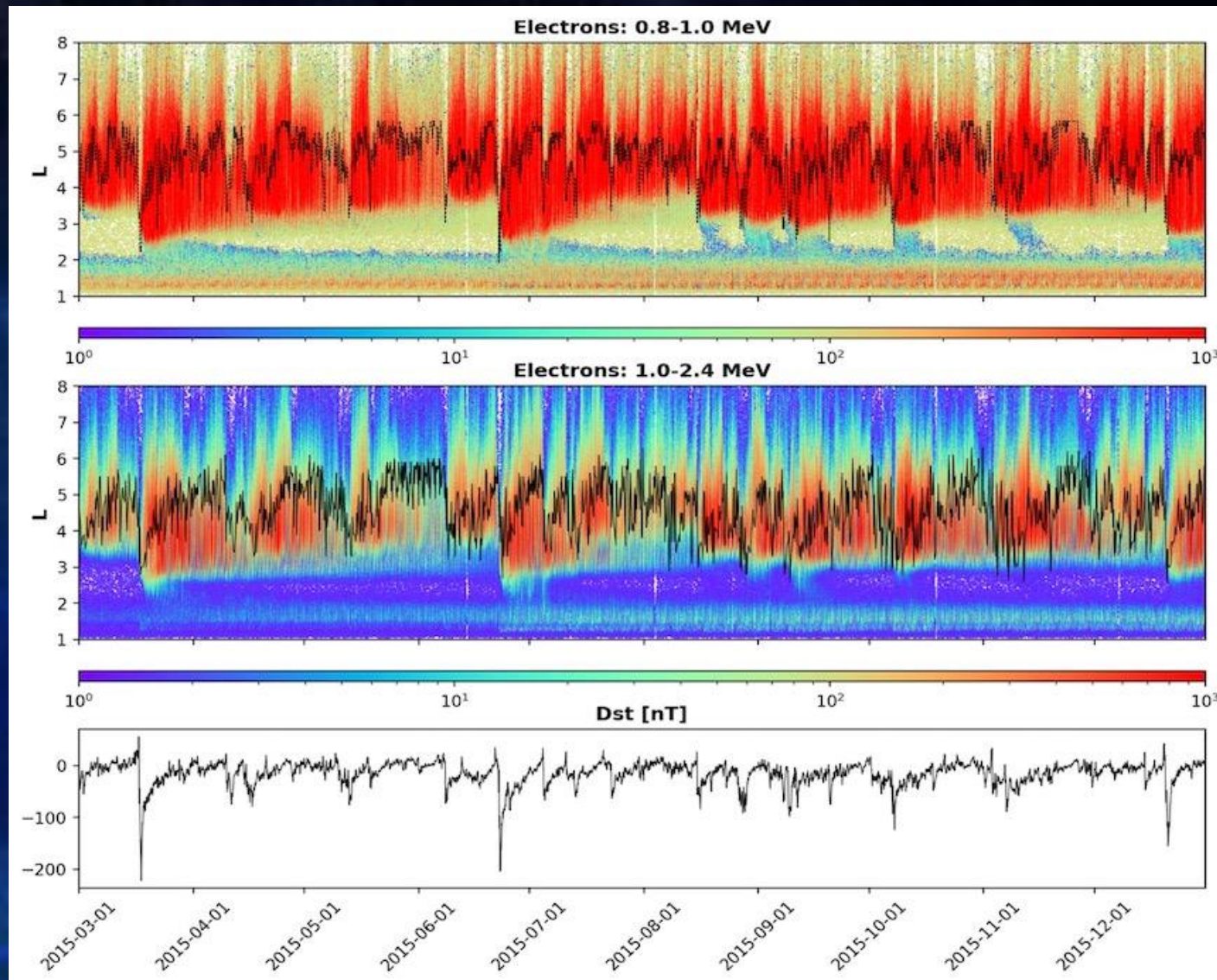
- ✓ Onboard ESA PROBA-V launched in 2013
- ✓ Polar Orbit of  $98^\circ$  inclination at 820 Km
- ✓ Period of 101 min
- ✓ 2s resolution particle fluxes in energy ranges:
  - electron 0.5-20 MeV
  - proton 9.5-300 MeV
  - He-ion 38-1200 MeV



# Research on radiation belts (cont.)

Electron fluxes in  
 $1/(\text{cm}^2 \text{ s sr MeV})$

PROBA-V/EPT data and  
plasmopause for the  
analysis of links  
between plasma and  
radiation belts  
dynamics  
[Pierrard & al. 2020]



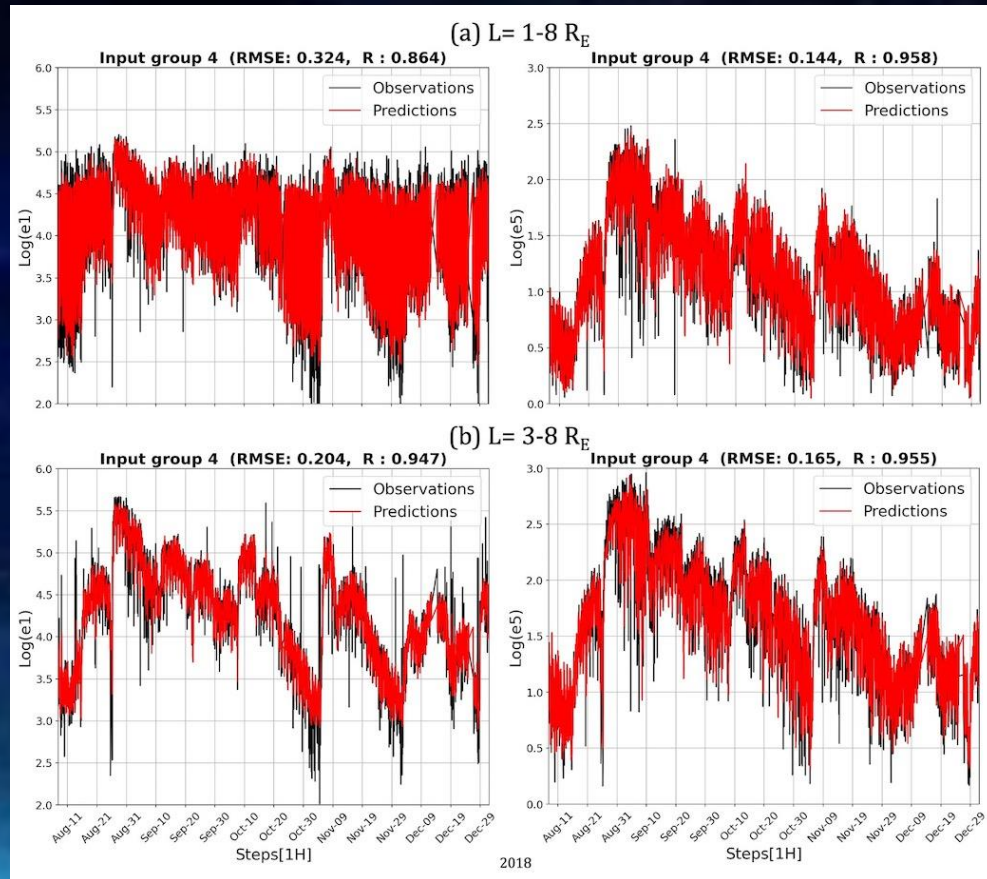
Plasmopause  
3D BSPM model

Plasmopause  
VAP/EMFISIS



# Research on radiation belts (cont.)

## LSTM NN model for predicting electron fluxes at LEO using EPT data



Hourly fluxes in  $\#/(cm^2 s sr MeV)$  with a look-back of 48 hours and 1 hour ahead.

**Botek, Pierrard & Winant. (2023). *Space Weather*, 21(7), e2023SW003466.**

	Log(e1)		Log(e5)	
Hs ahead	RMSE	r	RMSE	r
1	0.241	0.926	0.223	0.917
2	0.260	0.915	0.235	0.907
3	0.256	0.917	0.238	0.905
4	0.277	0.904	0.237	0.906
5	0.264	0.911	0.247	0.898
6	0.275	0.902	0.252	0.892
7	0.287	0.893	0.265	0.881
8	0.286	0.893	0.270	0.876
9	0.300	0.883	0.273	0.874
10	0.289	0.890	0.277	0.870
11	0.297	0.885	0.281	0.866
12	0.299	0.882	0.281	0.866

$L=3-8 R_E$  considering 48 hours look-back and 12 hours ahead for  $e1= 0.5-0.6 MeV$  and  $e2=1.0-2.4 MeV$  fluxes

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# Summary and perspectives

- Earth Magnetosphere environment → complex multiscale coupled system
- BSPM developed since early 2000's → plasmasphere+plasma pause+plasma trough (+ionosphere). New recent plasma trough parametrization.
- BSPM available in open platforms: ESA SWSN (routine runs), VSWMC, CCMC and PITHIA e-Science Centre (runs on request).
- Development of a Neural Network prediction model of radiation belts at low altitude using EPT data + future 3-DEES → available in the near future ...

# Thank you for your attention!



**Thanks to:** *Fabien Darrouzet  
and Johan De Keyser (BIRA)*

**Thanks to**



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