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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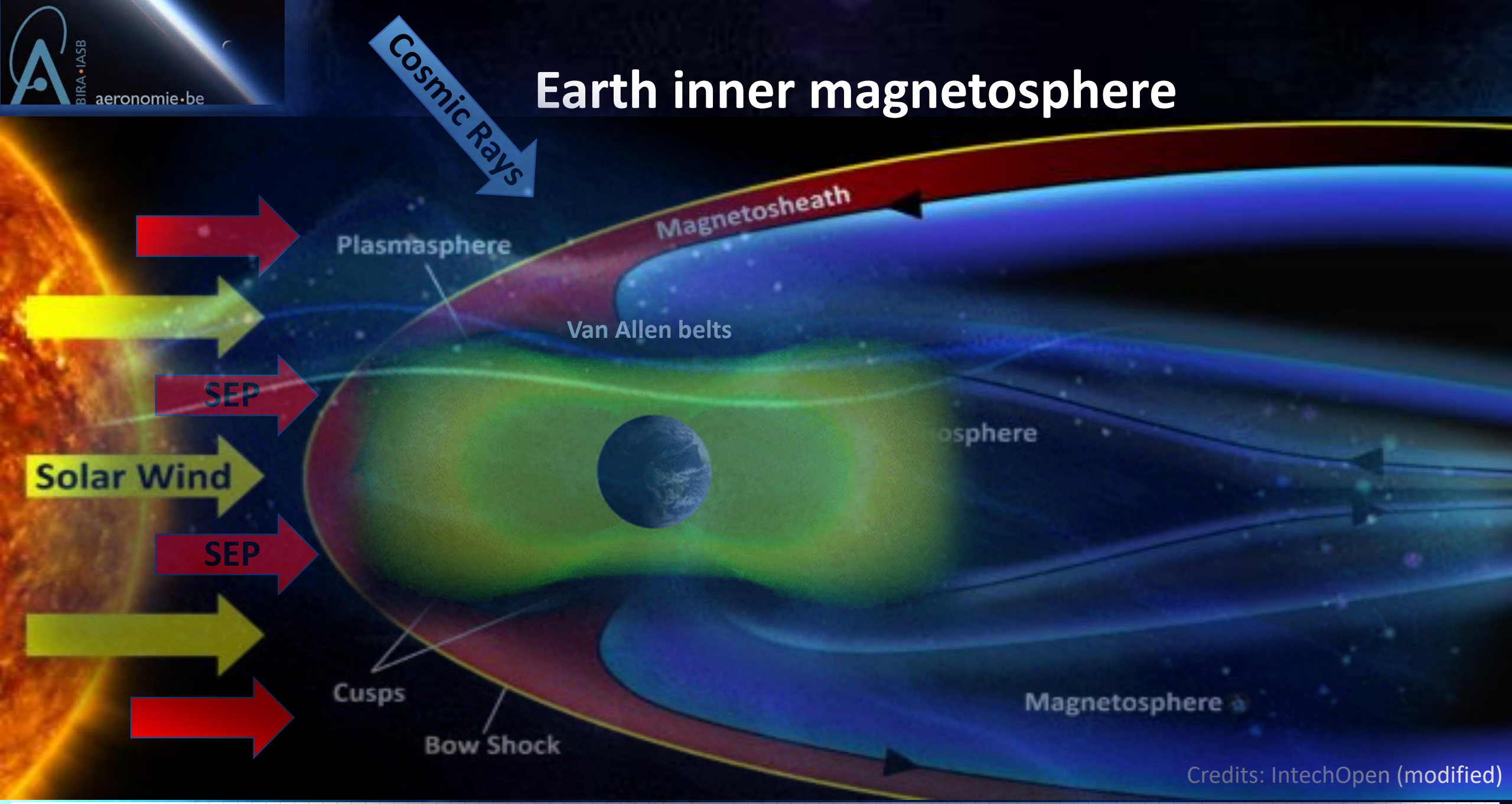
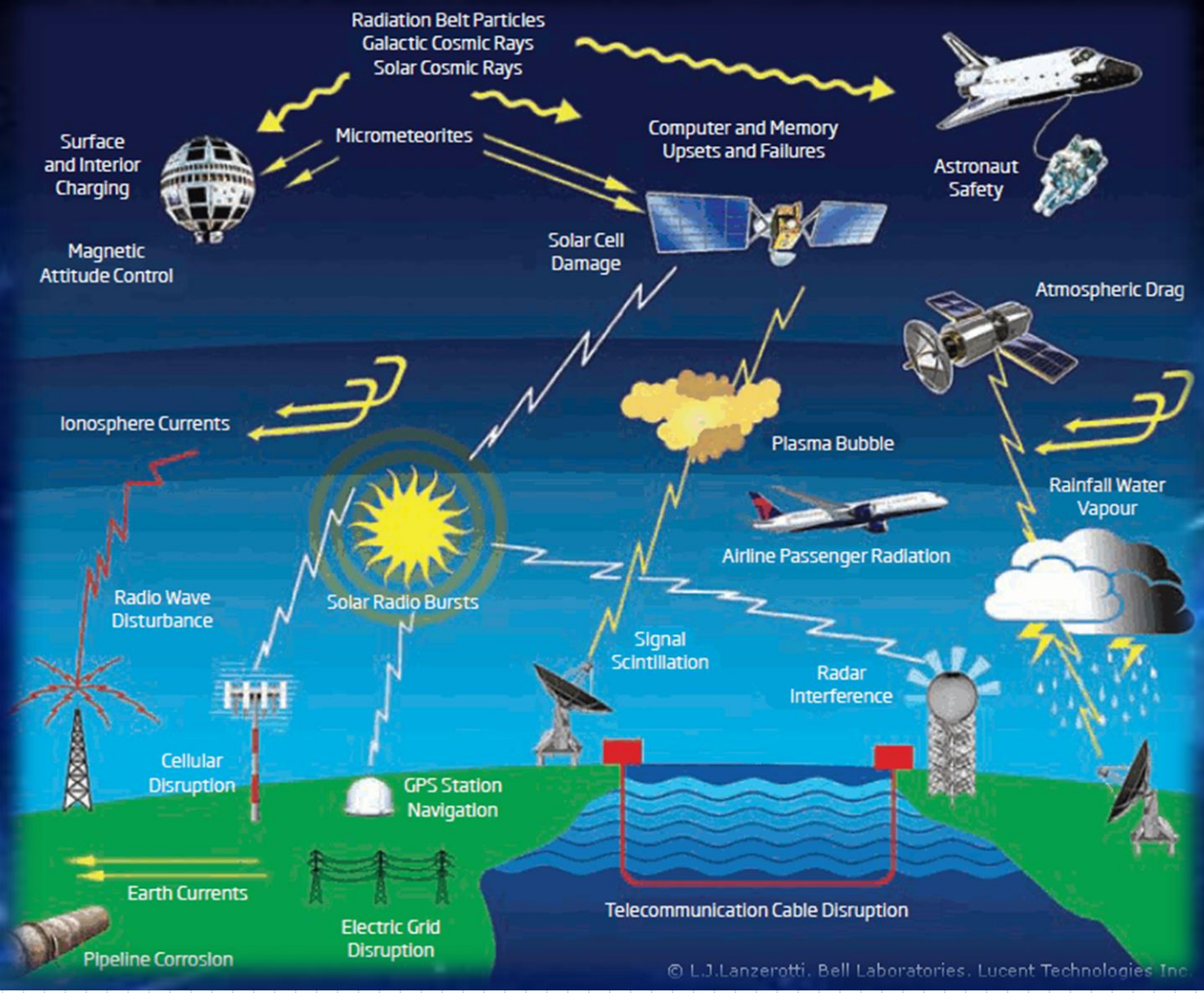
Earth inner magnetosphere



Credits: IntechOpen (modified)

Earth inner magnetosphere (cont.)



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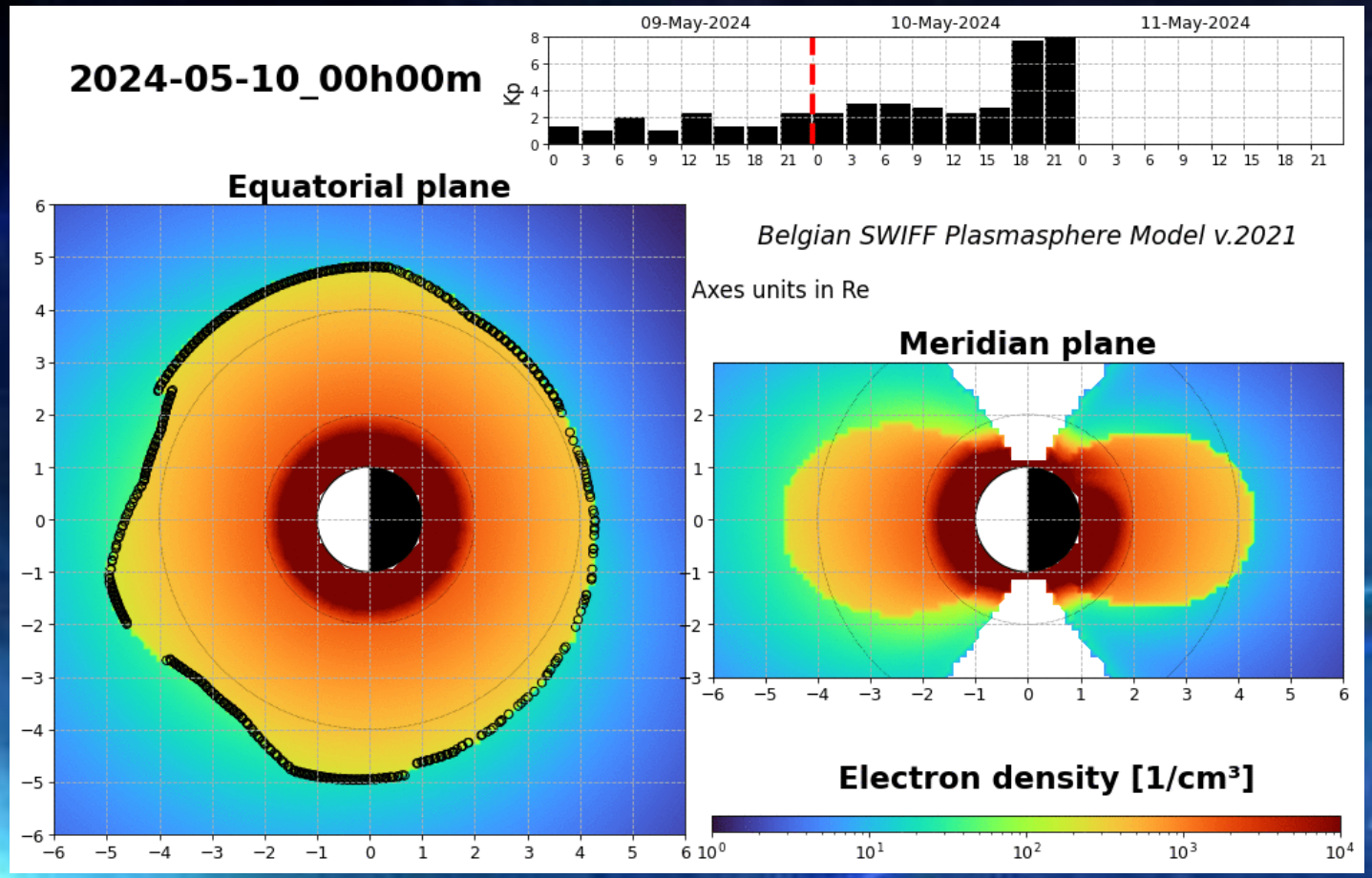
The BSPM explained



- **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]

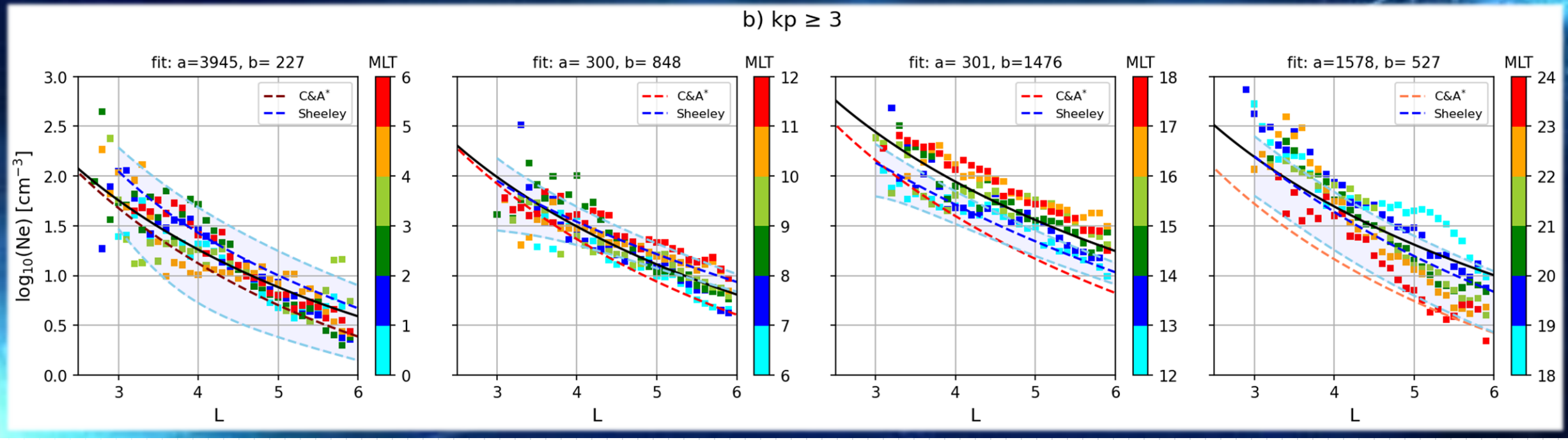
The BSPM explained (cont.)

- **Input: Kp** values from the previous day and current day of the simulation
- **Outputs: plasmapause position + proton/electron /ions density + temperature**

- **Principal features of BSPM:**
  - → **analytical model** adjusted to reproduce observations
  - → **plasmasphere rotation** and the **geomagnetic activity** → plasmapause position [Pierrard & Lemaire, 2004]
  - → **plasmasphere erosion** by perturbations and its **refilling**
  - → formation and evolution of **plumes**
- **Plasmasphere + Plasmapause extensively validated** → [Bandic & al., 2016, 2017; Verbanac & al., 2015, 2018] + ESA reports.

The BSPM explained (cont.)

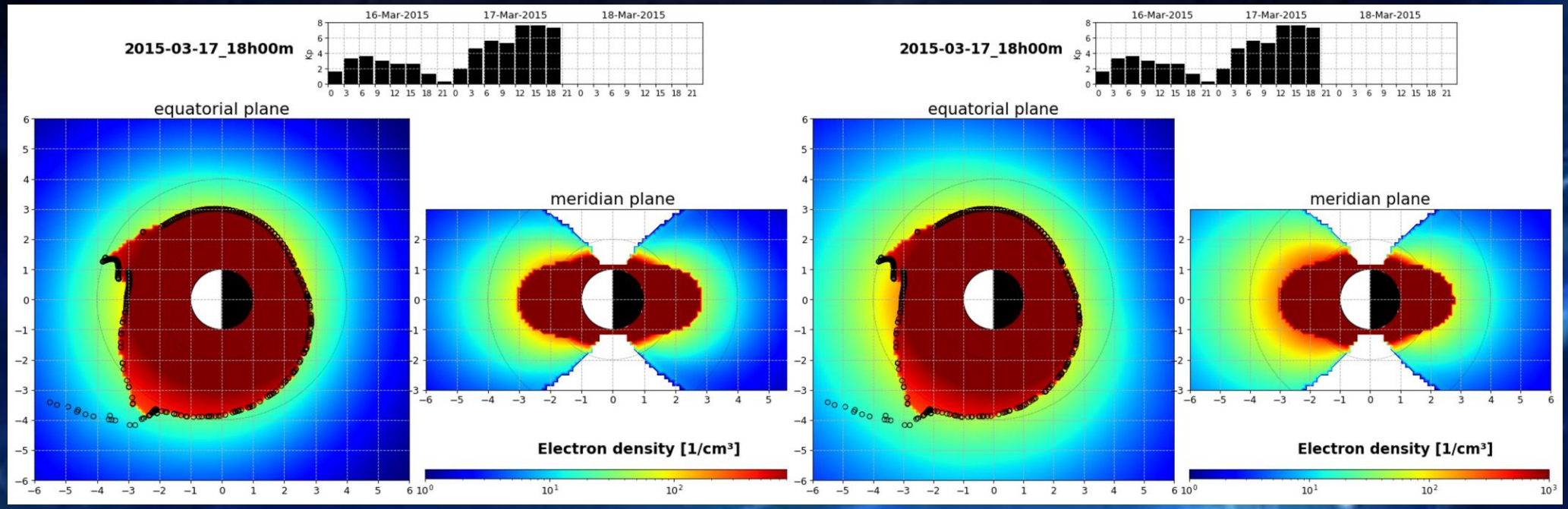
- **Plasmatrough reparametrized using VAP/EMFISIS data** [Botek & al., 2021]:
  → difficult due to broad observations distribution of very low densities
  → important for wave-particles interaction
  → impact on Radiation Belts high energy particles [Pierrard & al., 2020, 2021].
  → EMFISIS observations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

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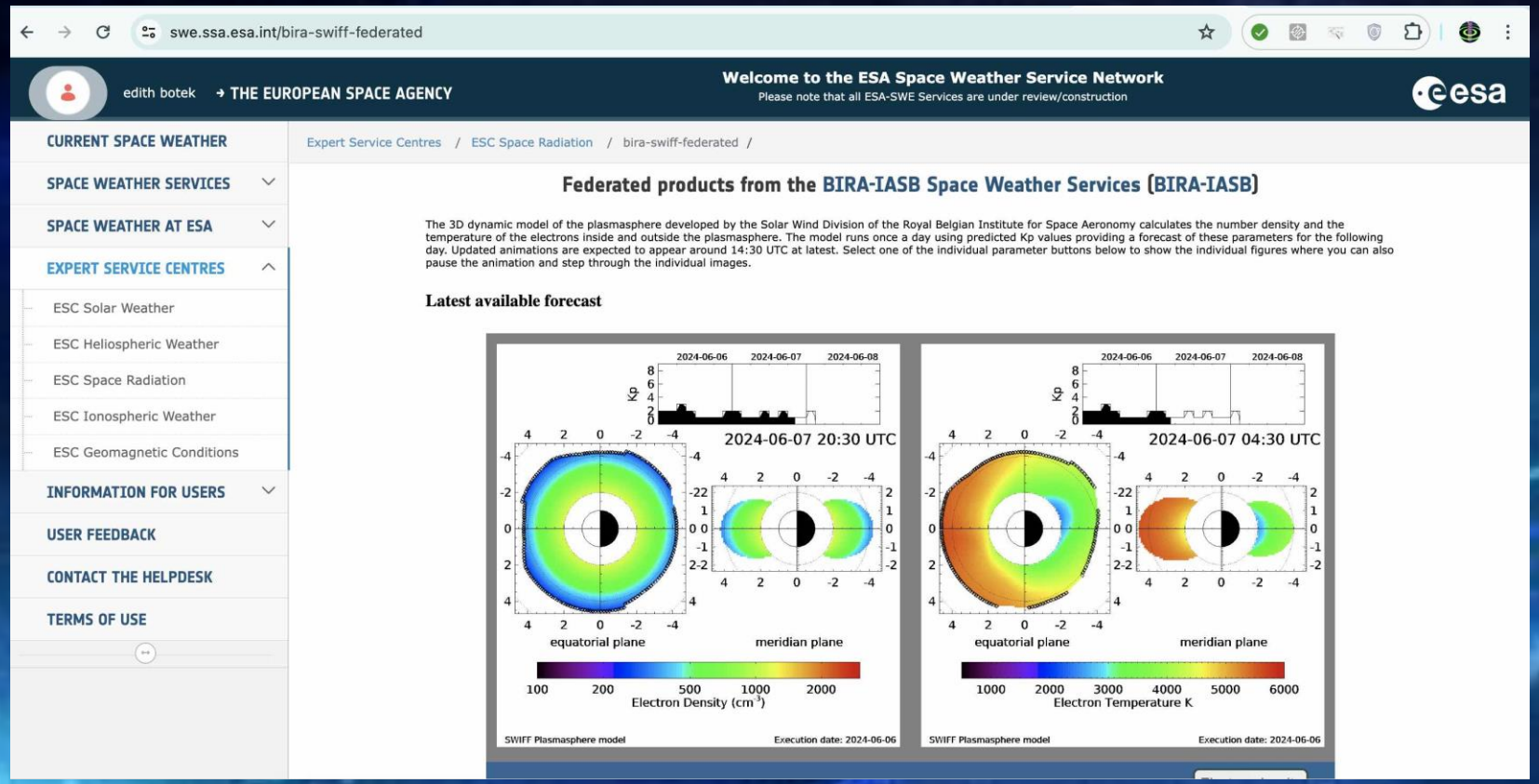
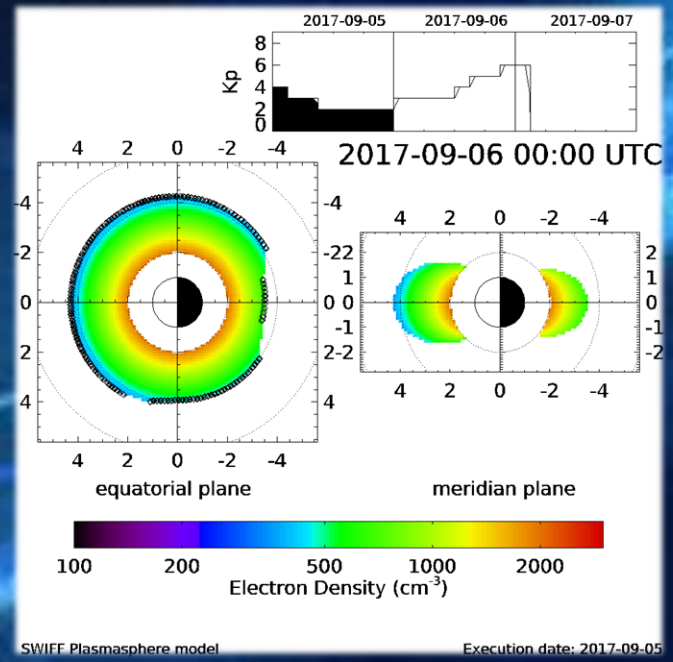
BSPM at open platforms

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

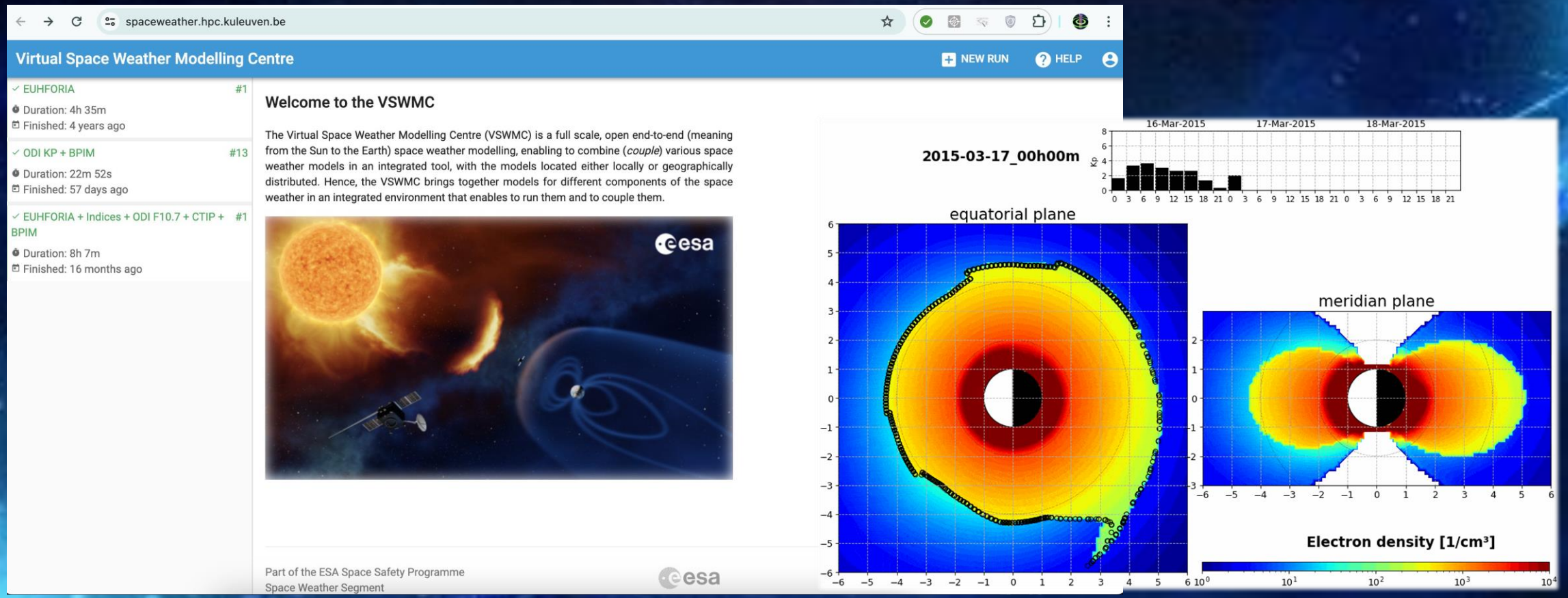




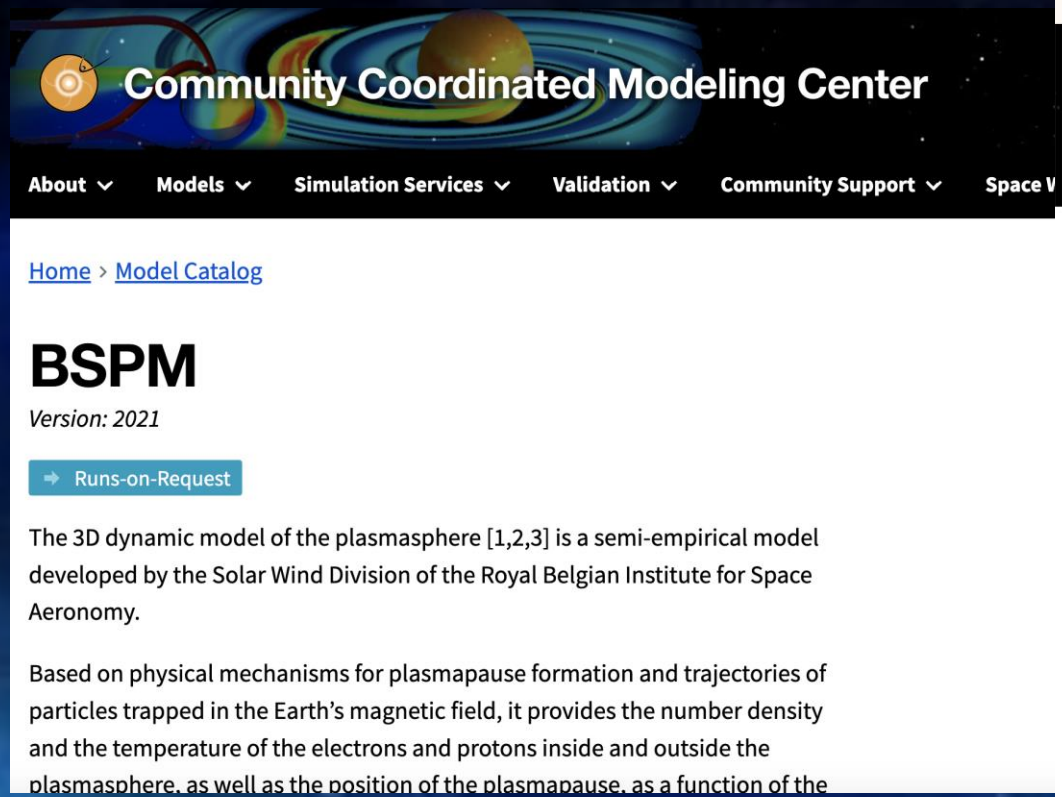
Only movies as output

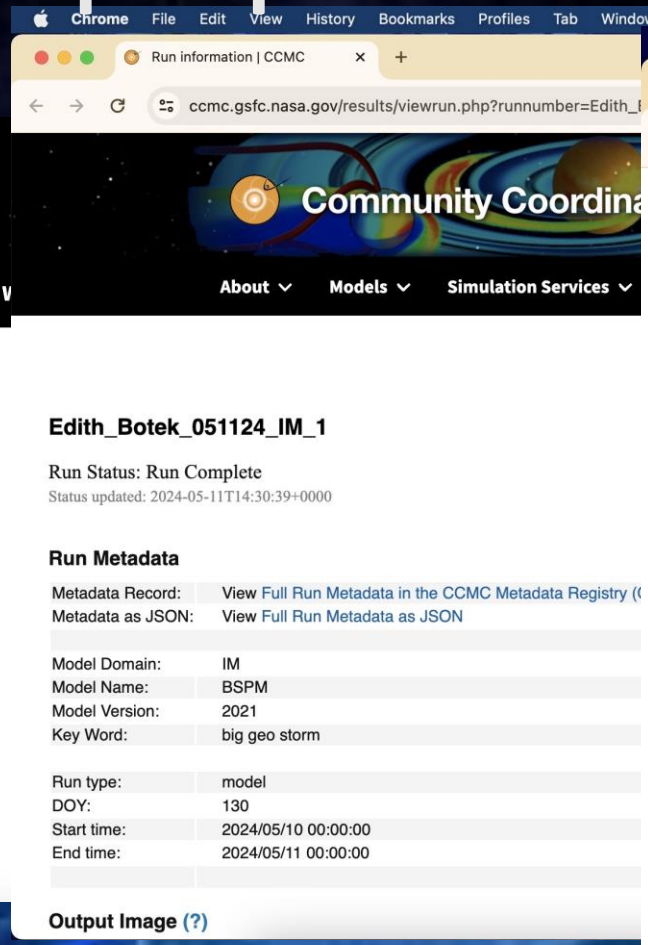
BSPM at open platforms (cont.)

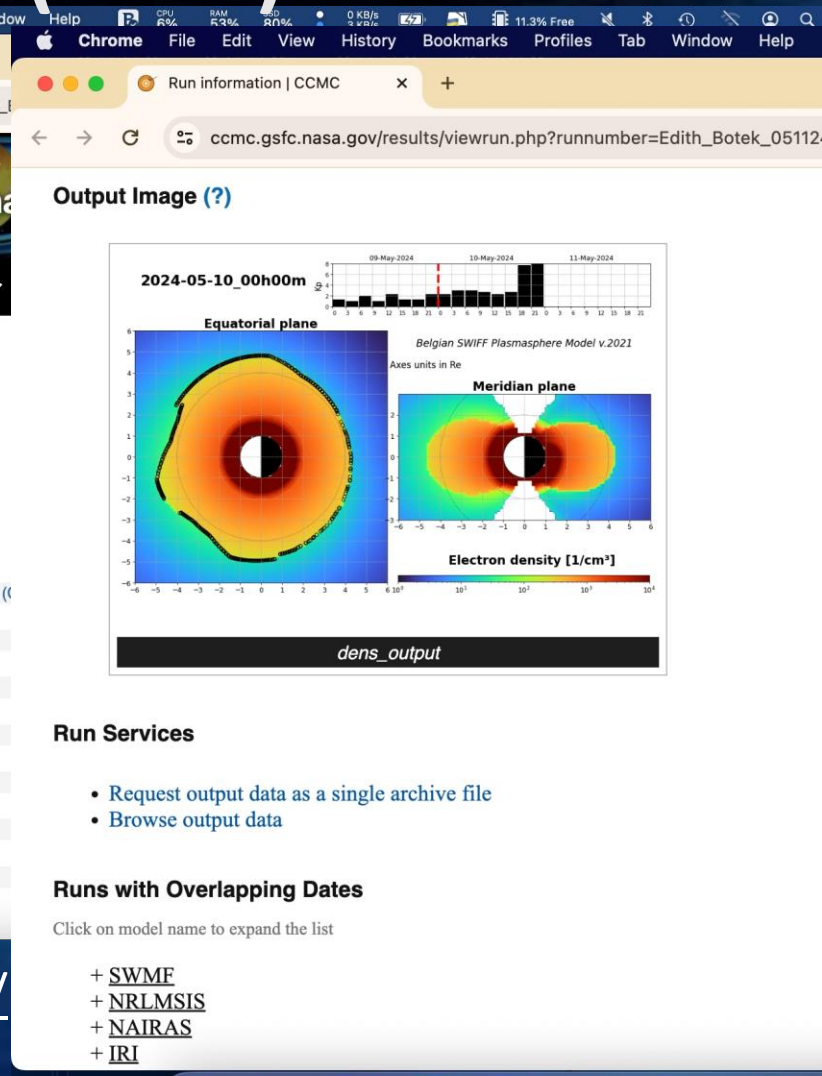
BSPM Fortran-Python version available at the **https://swe.ssa.esa.int/kul-cmpa-federated** (VSWMC) for runs on request inside a chain of models. Outputs: images, movies, text files.



BSPM at open platforms (cont.)





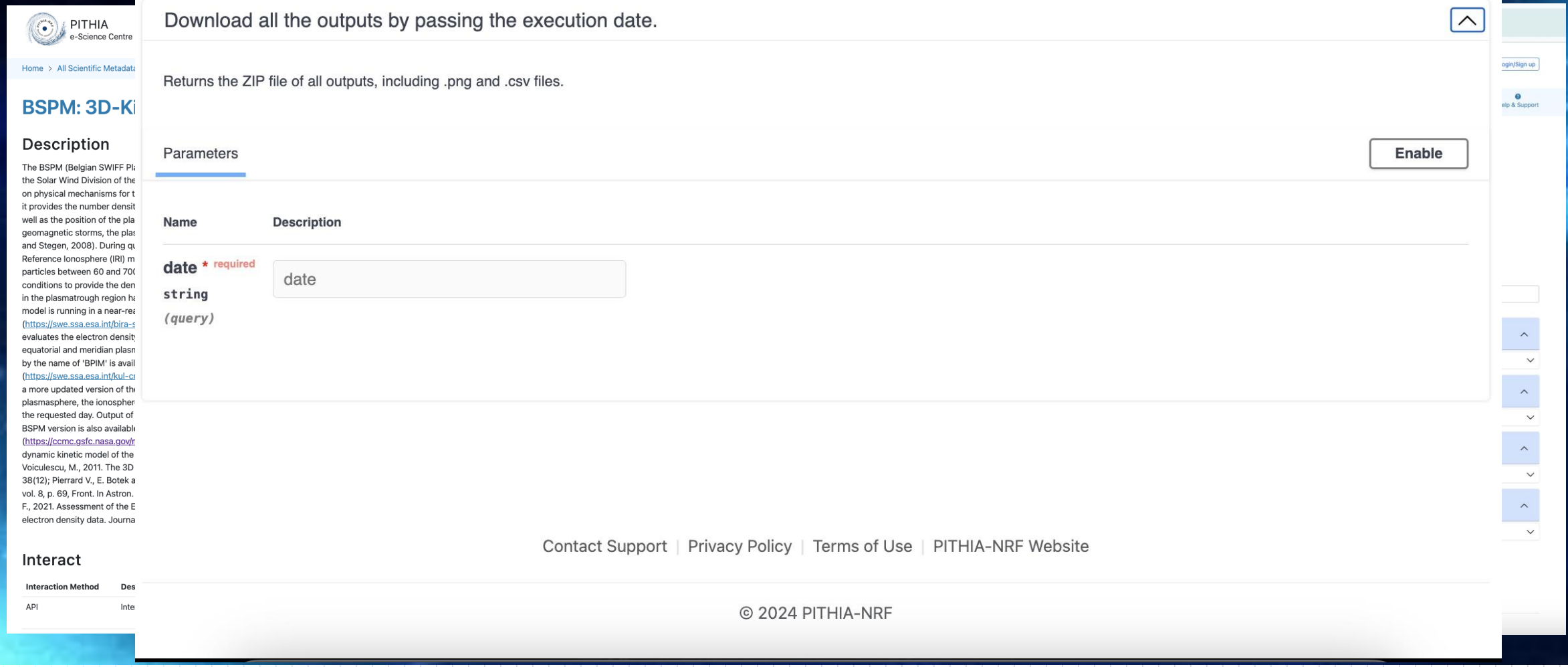


Runs on request at **https://ccmc.gsfc.nasa.gov/models/BSPM~2021/**

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

BSPM at open platforms (cont.)

New BSPM F … ps/api/
for runs on r …



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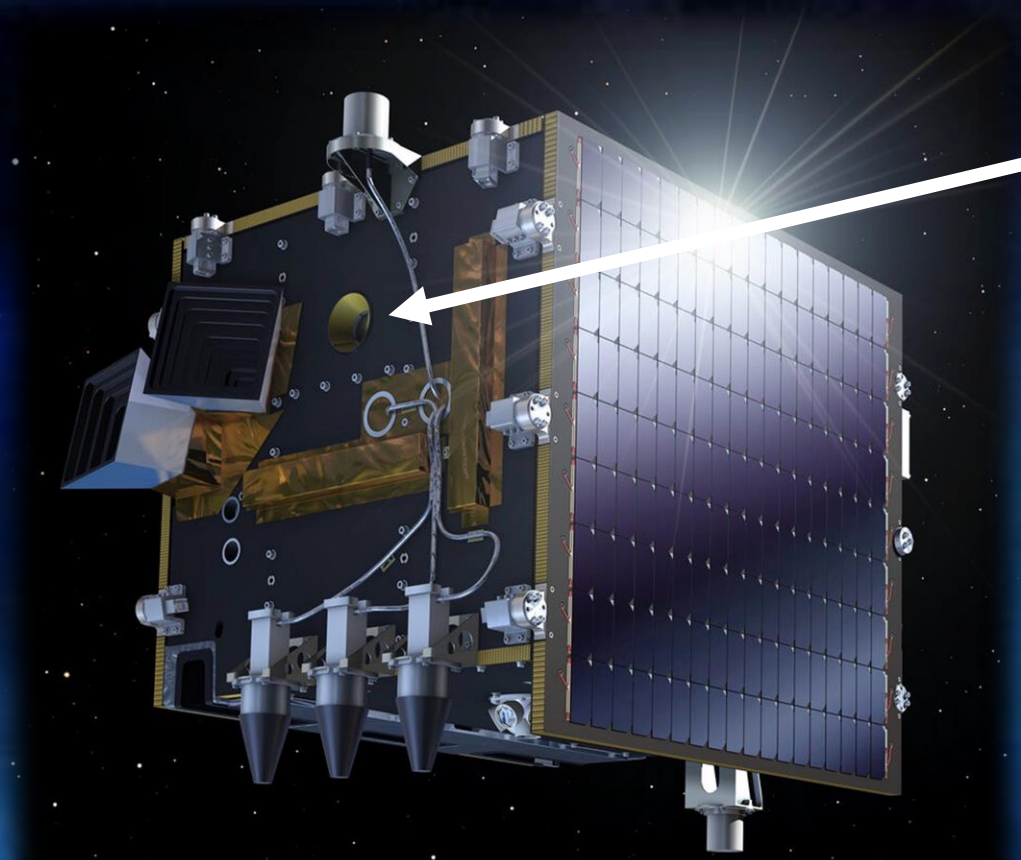
Research on radiation belts



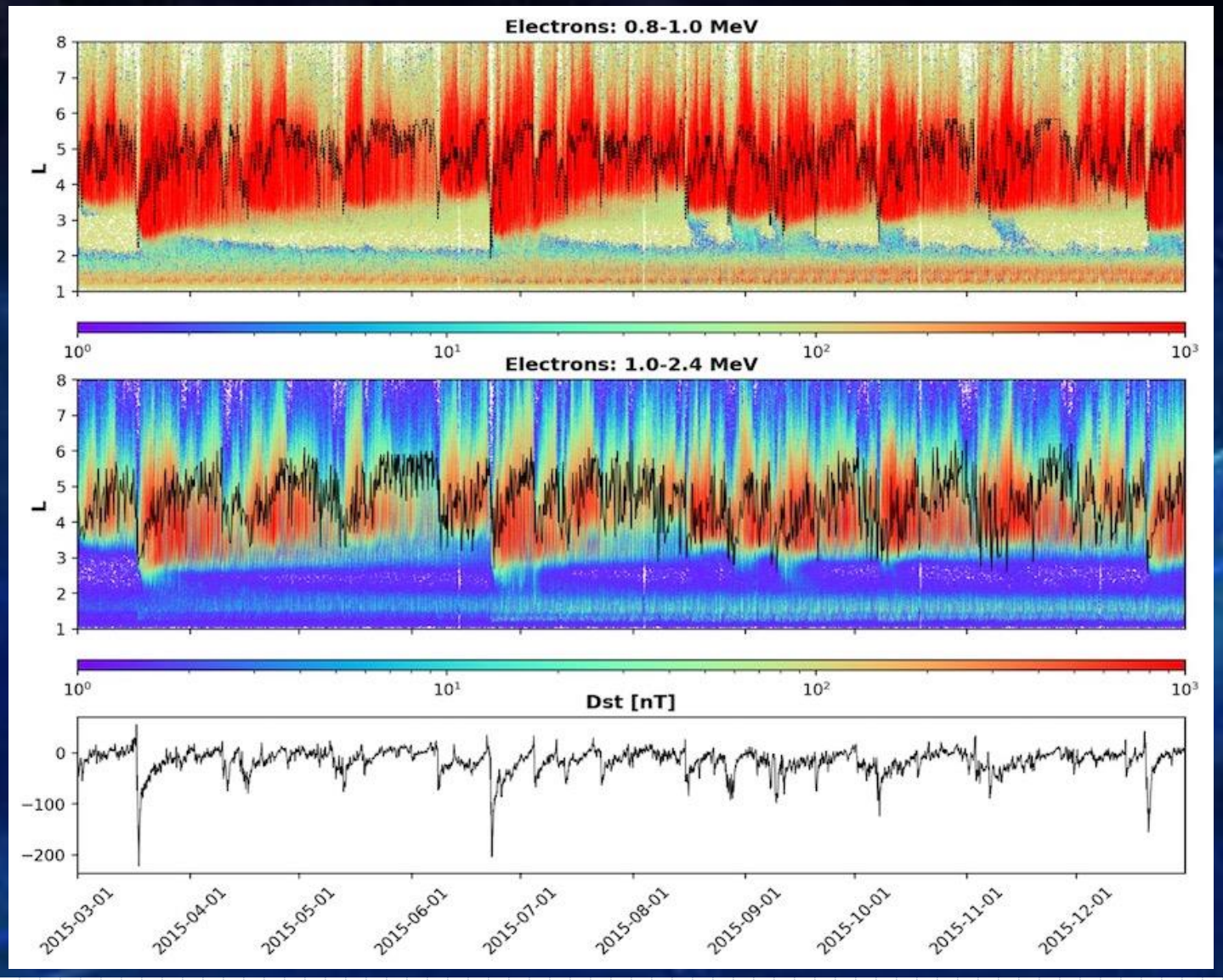
Energetic Particle Telescope (EPT)

- ✓ Onboard ESA PROBA-V launched in 2013
- ✓ Polar Orbit of 98° 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/(cm² s sr MeV)

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

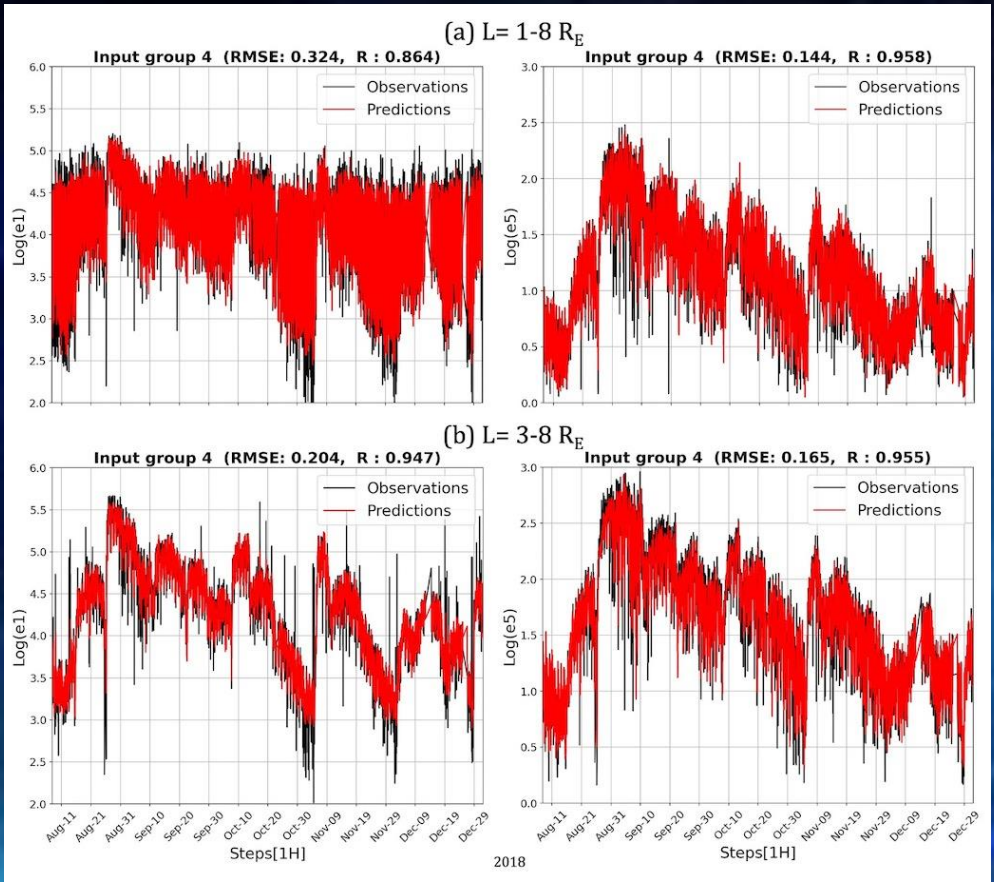


Plasmapause 3D BSPM model

Plasmapause 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.

	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

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

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Summary and perpectives

- Earth Magnetosphere environment → complex multiscale coupled system
- BSPM developed since early 2000's → plasmasphere+plasmapause+plasmatrough (+ionosphere). New recent plasmatrough 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 …

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