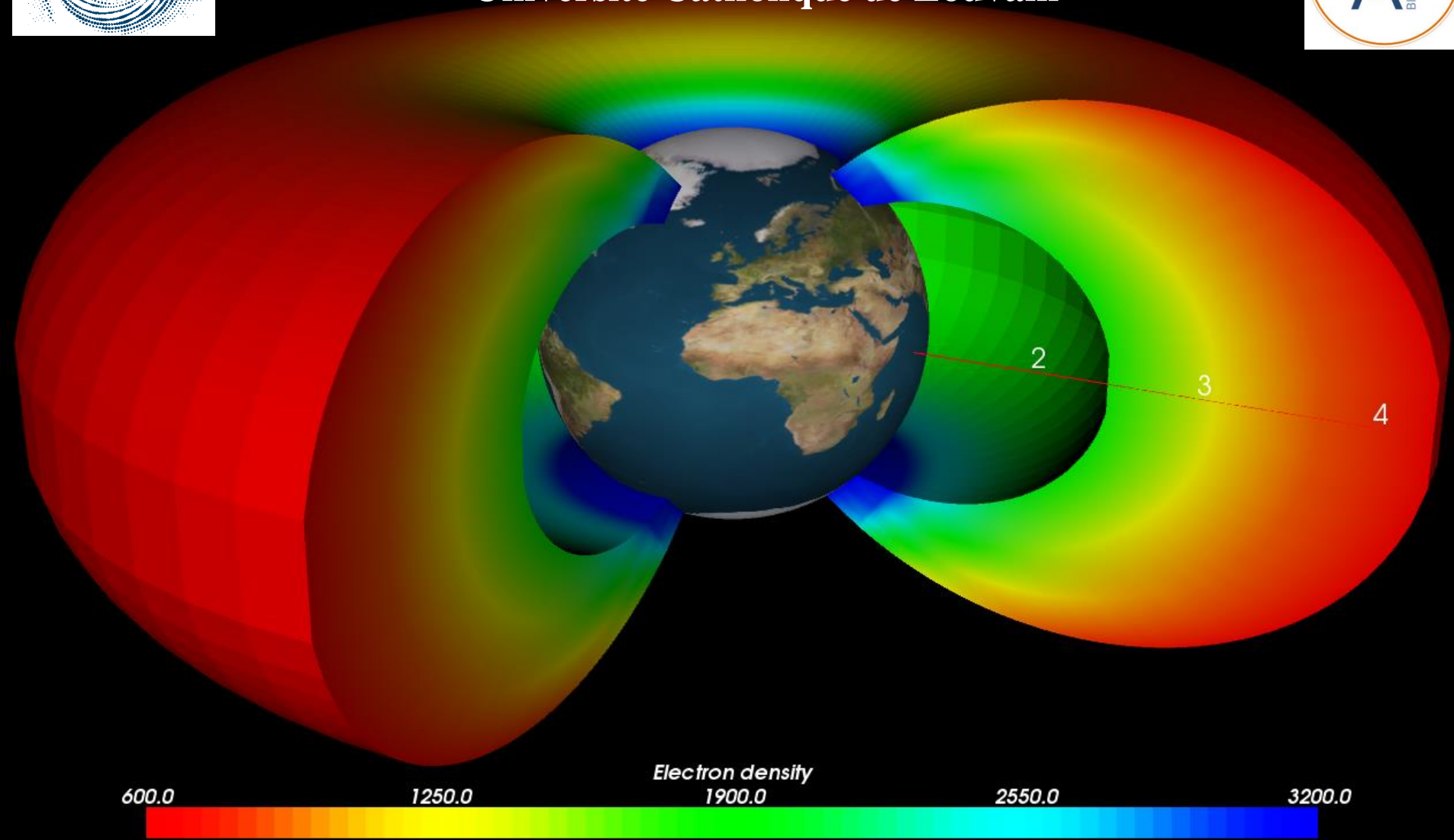# 3D dynamic kinetic model of the plasmasphere BSPM

Viviane Pierrard
Royal Belgian Institute for Space Aeronomy
Université Catholique de Louvain
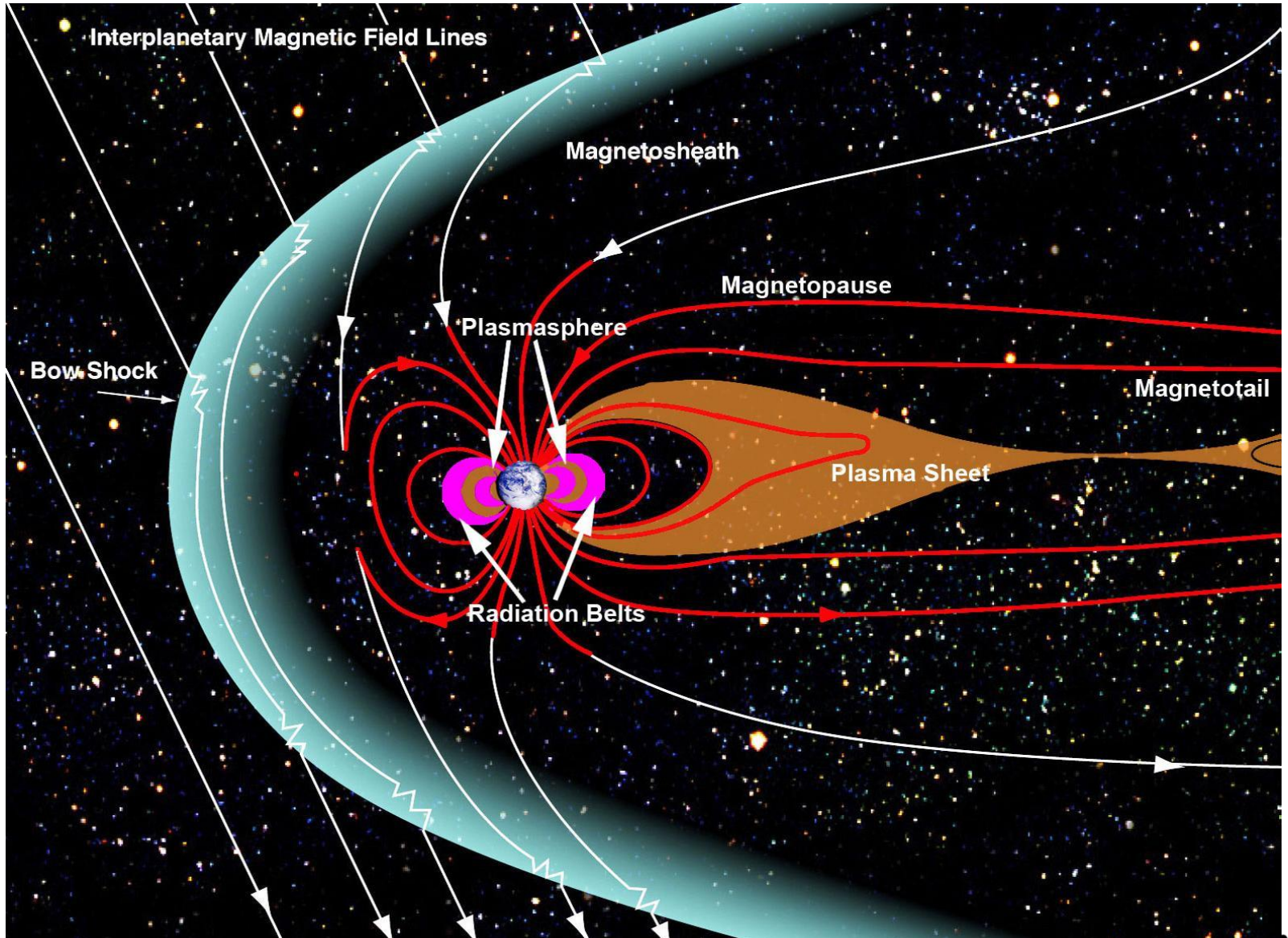
Electron density

| 600.0 | 1250.0 | 1900.0 | 2550.0 | 3200.0 |

Inner magnetosphere

cold plasma (low energy ~ 1-10 eV)   RB ($e^- > 500$ keV, $p^+ >$ MeV)
dense (10-10^4 electrons/cm^{-3}) **90% H$^+$, 10% He$^+$ (+ O$^+$, He^{++}, N$^+$, O^{++}, N^{++})**

The 3D dynamic kinetic model of the plasmasphere
Belgian SWIFF Plasmasphere Model

Input: date

https://esc.pithia.eu/

Output:

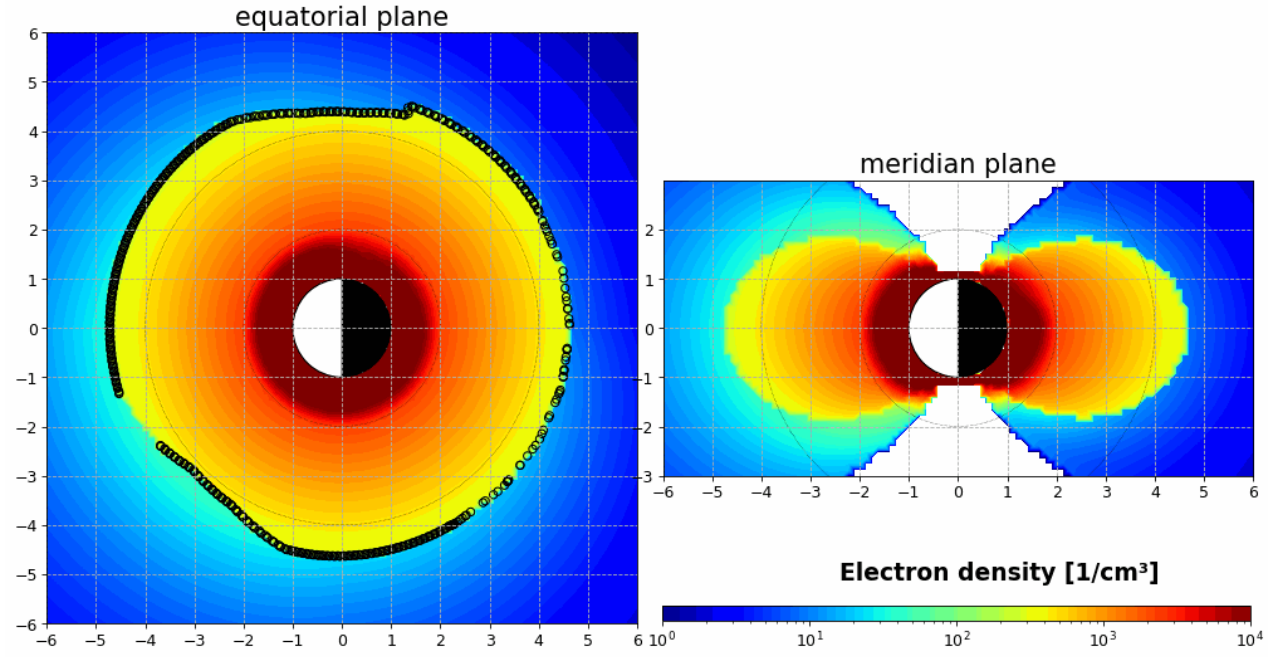Kp index
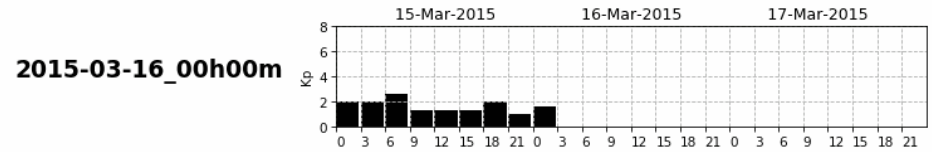
Plasmapause location

Density

Temperature

Coupling with ionosphere IRI

Plasmatrough VAP
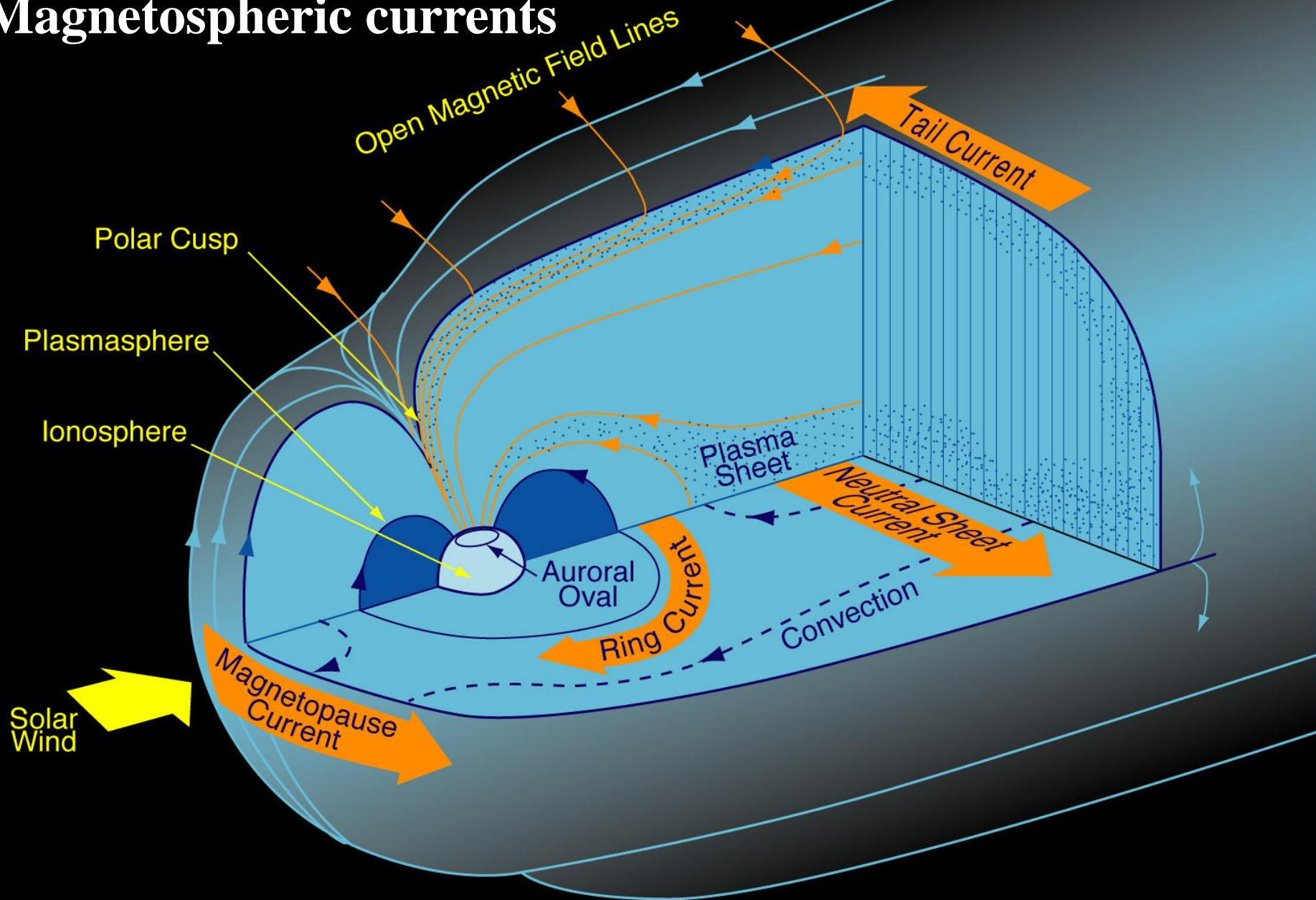
Plume

Physics-based and semi-empirical

In Python

Pierrard and Stegen, JGR, 113, A10209, 2008.
Pierrard and Voiculescu, GRL, 38, L12104, 2011
Pierrard et al., Frontiers. doi:10.3389/fspas.2021.681401, 2021

Kp obtained from B at the surface
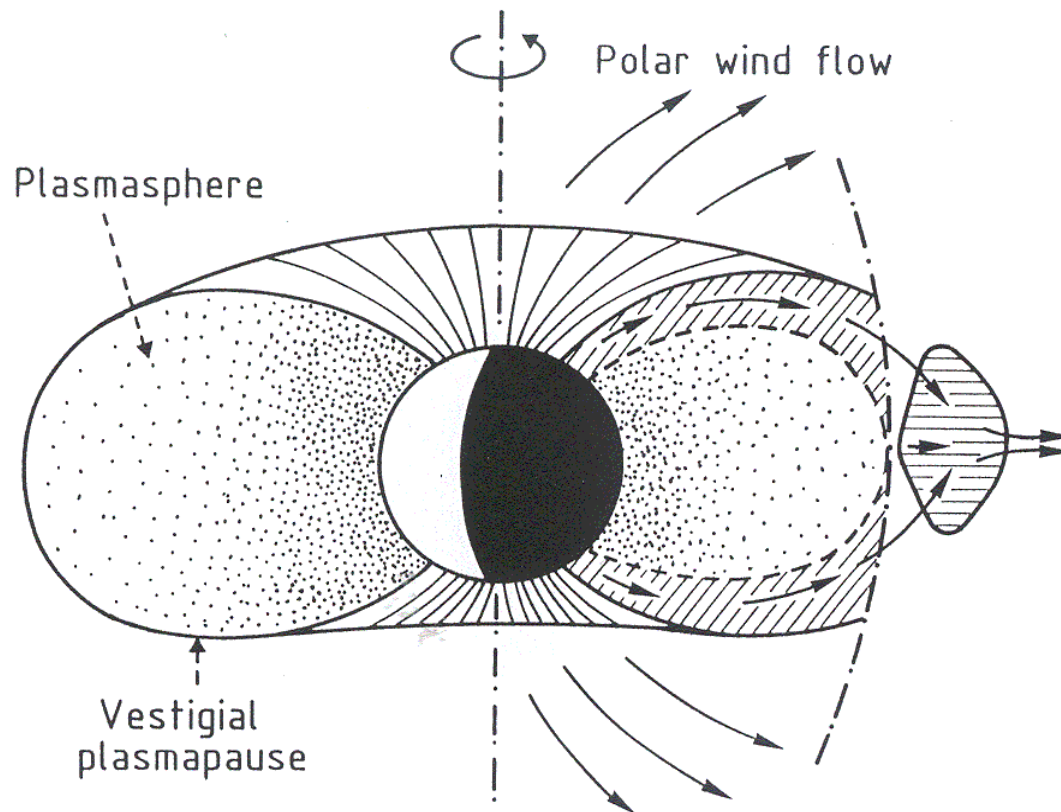# Magnetospheric currents

Plasmapause dynamics
3-7 Re

Sharp boundary due to interchange instability where the centrifugal force becomes larger than gravity

**High activity:
Plasmaspause closer
Plasmasphere eroded**

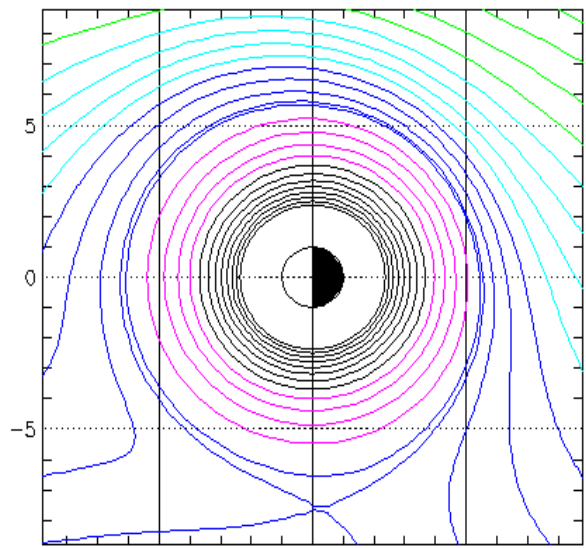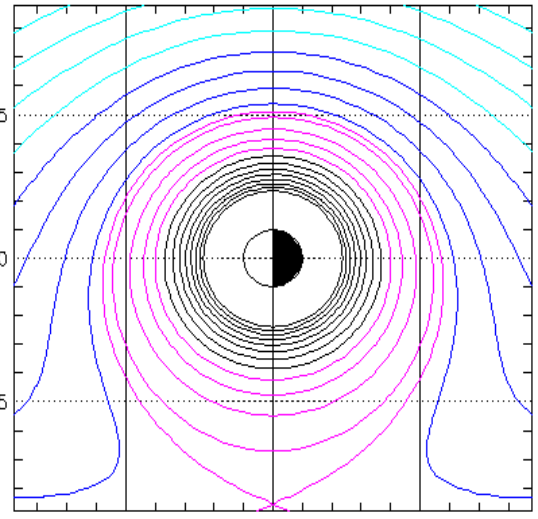# Electric potential in the geomagnetic equatorial plane
Erotation + Econvection (Kp)

Kp=1

Kp=6
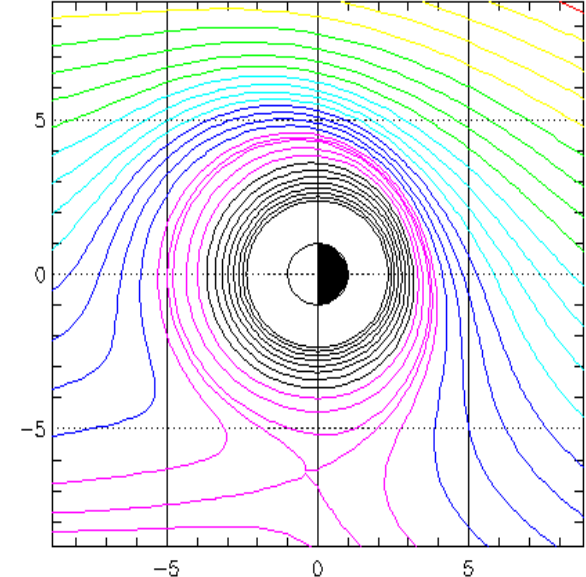
Volland-Stern from OGO3 and 5

E5D from ATS5 and 6
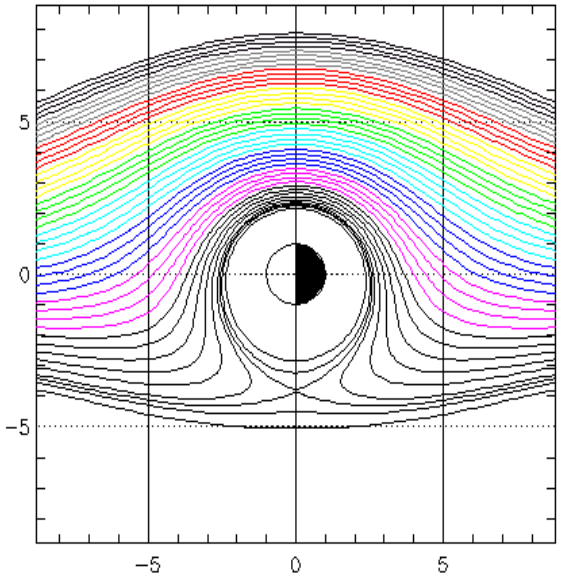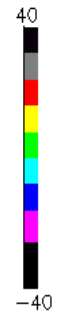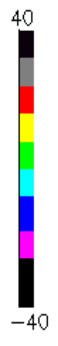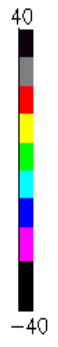
3D BSPM dynamic model

Number **density** (e, p, He) provided inside and outside the plasmasphere with MLT dependence, from analytical empirical relations, **coupling with ionosphere** (IRI2016) used below 700 km, circulating along B

H2020 PITHIA (plot, takes 30 min)

https://pithia-nrf.eu

Community Coordinated Modeling Center

NASA https://ccmc.gsfc.nasa.gov (takes 2 days)

BPIM (older version):

ESA SSA (nowcasting):

http://swe.ssa.esa.int   space radiation

ESA Virtual Space Weather Model Center

https://swe.ssa.esa.int/kul-cmpa-federated

Projects: H2020 SafeSpace

https://safespace.ufa.cas.cz/ (prediction 6h)

Pierrard and Voiculescu, GRL, 38, L12104, 2011
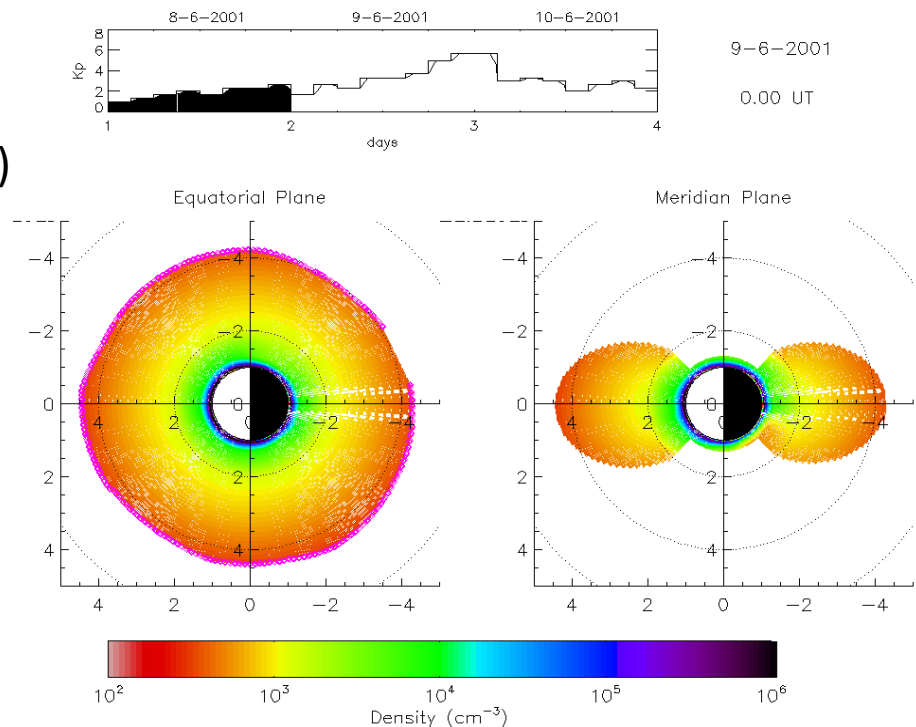
http://swe.ssa.esa.int   space radiation
SPM in real time or at a given date after 2017
(Fortran+idl)
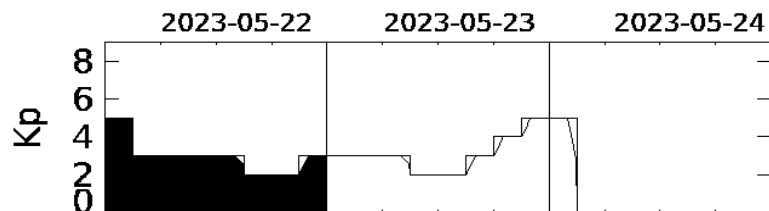
Density

SWIFF Plasmasphere model

Execution date: 2023-05-22

Temperature

equatorial plane

meridian plane

Electron Temperature K

SWIFF Plasmasphere model

Execution date: 2023-05-22
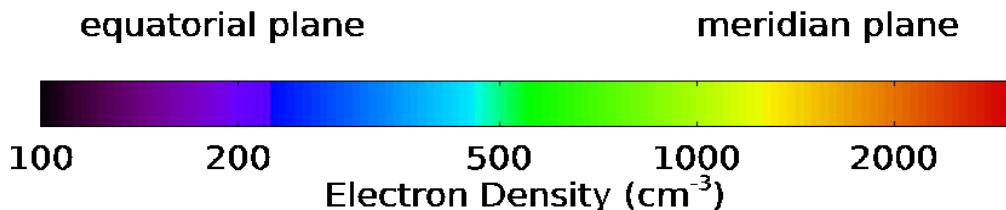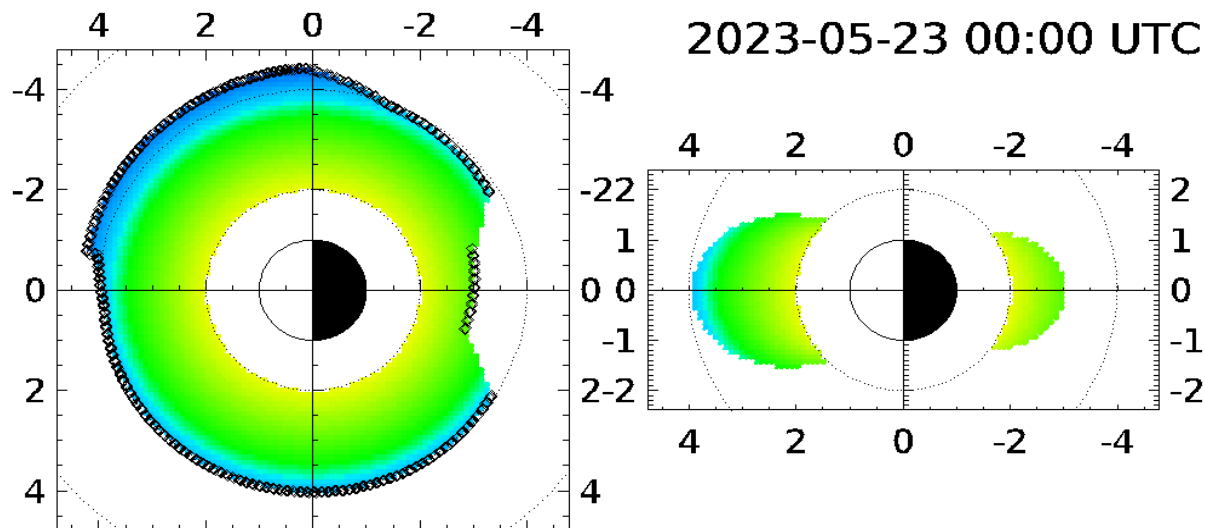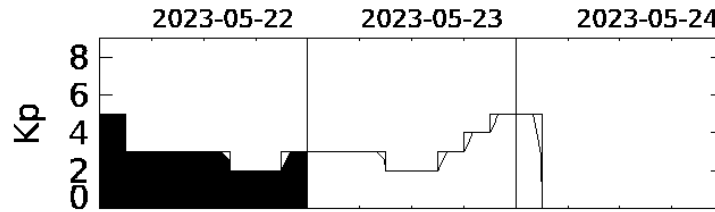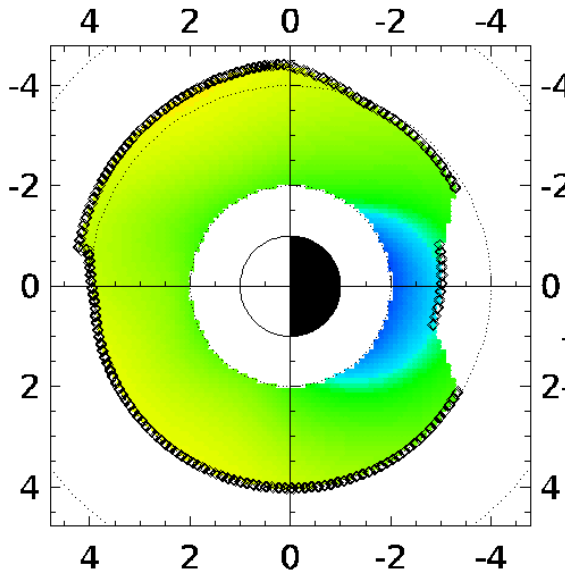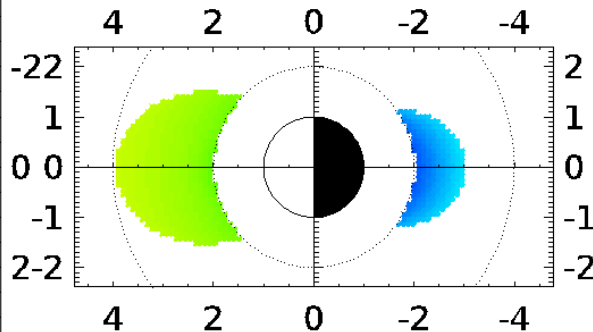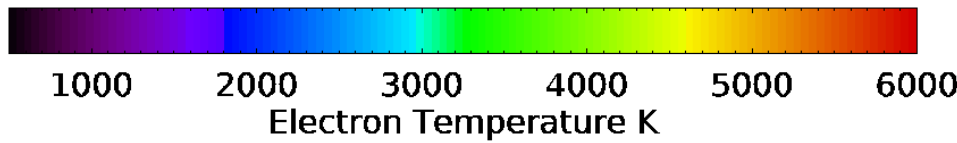
Coupled to International Reference Ionosphere 2016
(2001 on PITHIA)
Bilitza et al., 2022
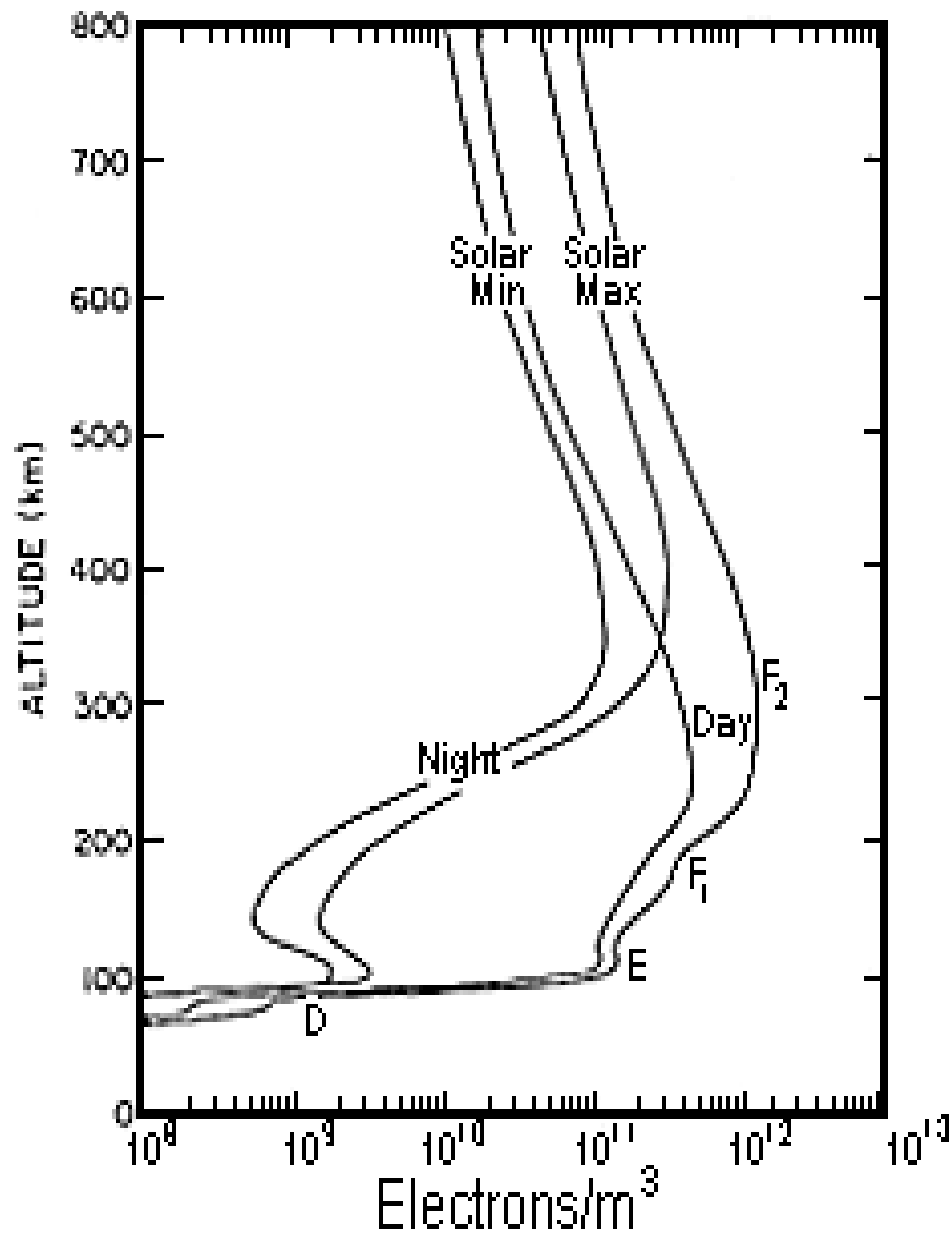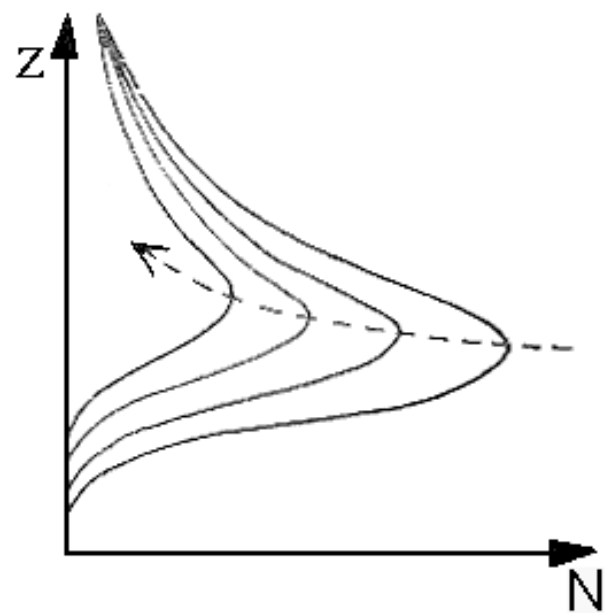
Temperatures

9-6-2001   0.00 UT of day 2

Equatorial Plane   Meridian Plane
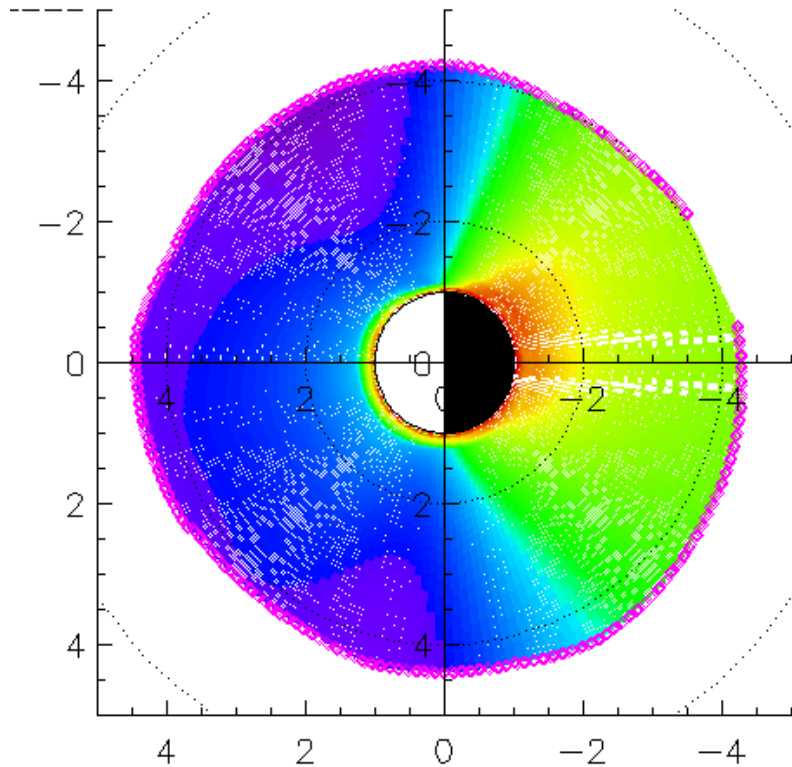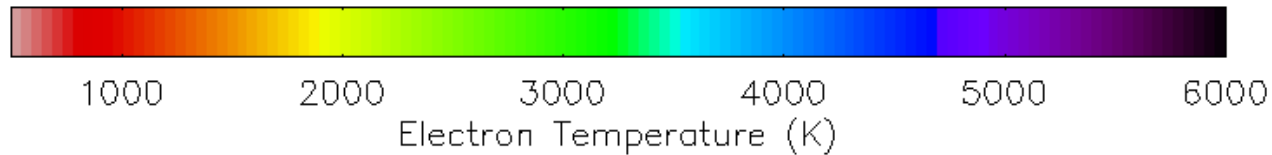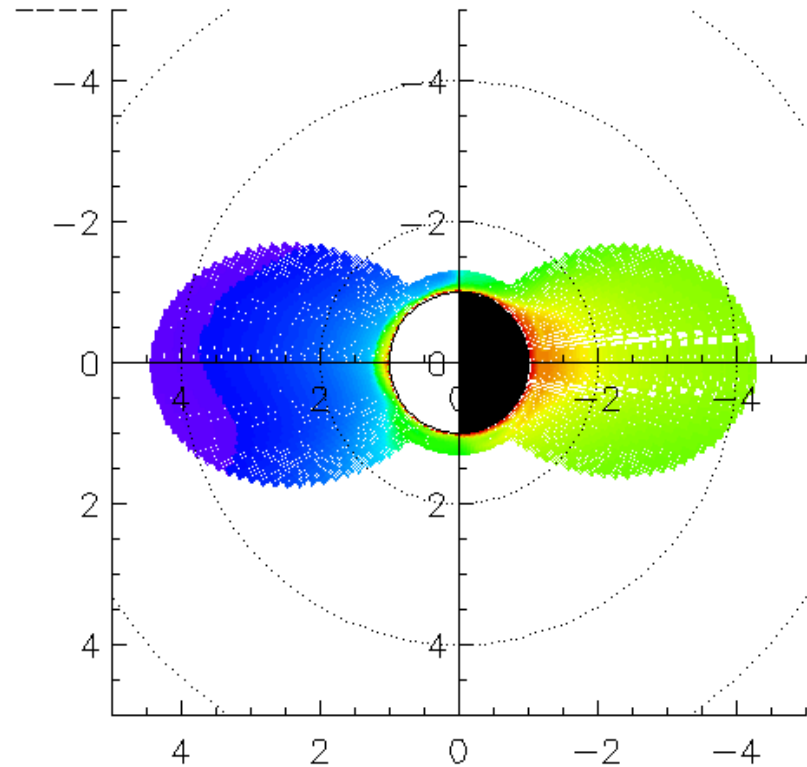
Electron Temperature (K)

Plume in co-rotation

2015-03-16_00h00m
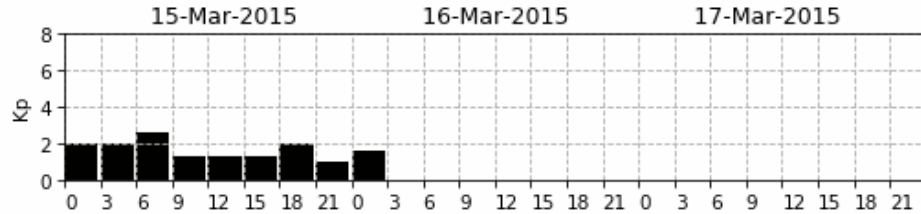
equatorial plane
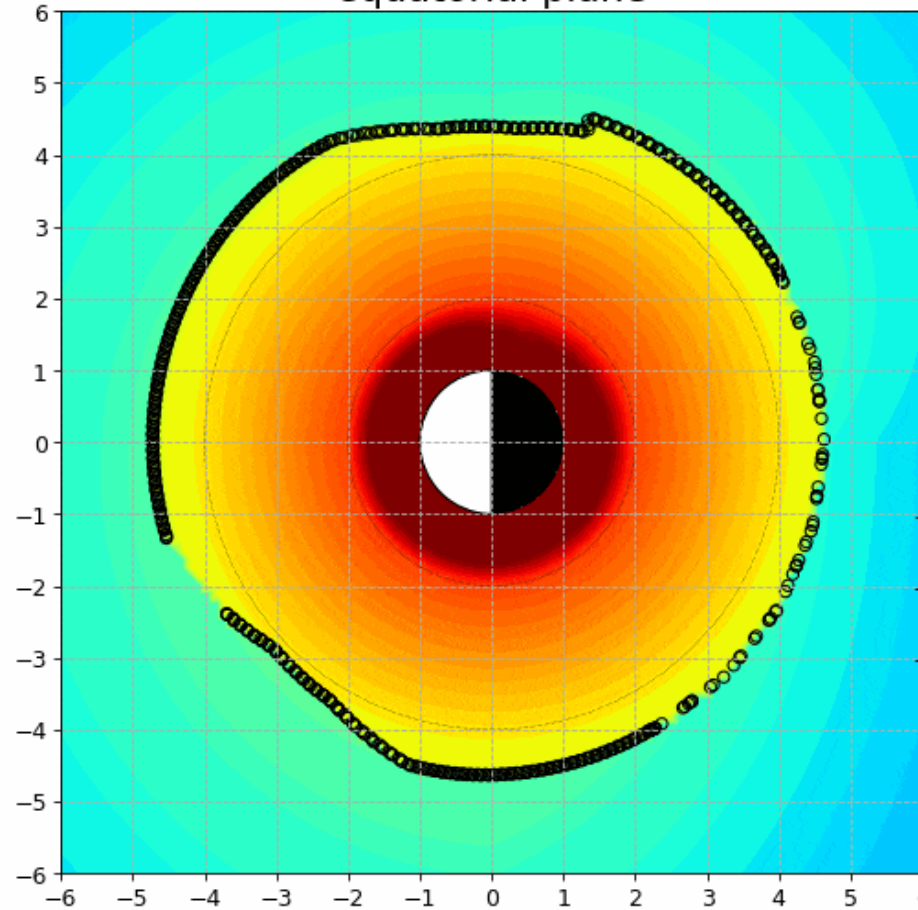
meridian plane
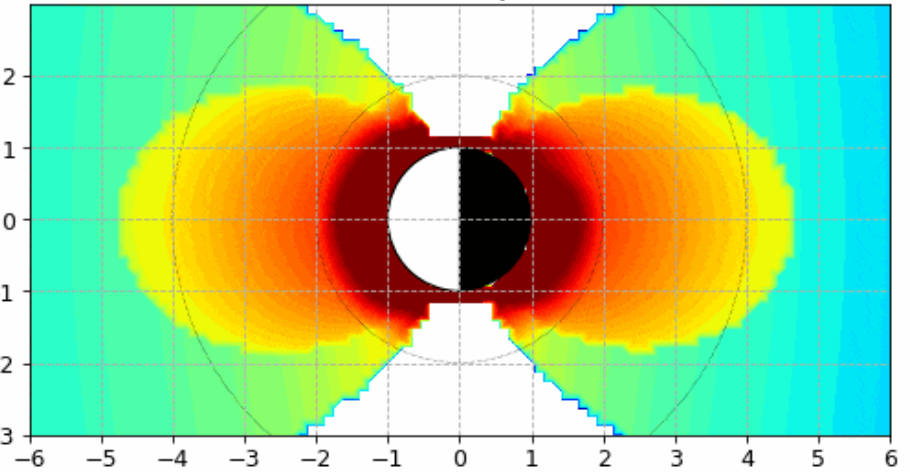
Electron density [1/cm³]
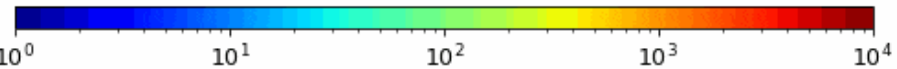
New model predictions based on Kp, compared and improved in the trough using RBSP   Trough BSPM: CA92 extrapolated to all MLT

Ne [cm^{-3}] for June 2015

RBSP-A/EMFISIS

Ne observed by RBSP

SPM

Ne predicted by BPIM model

kp_forecast (red) vs kp_definitive (green)
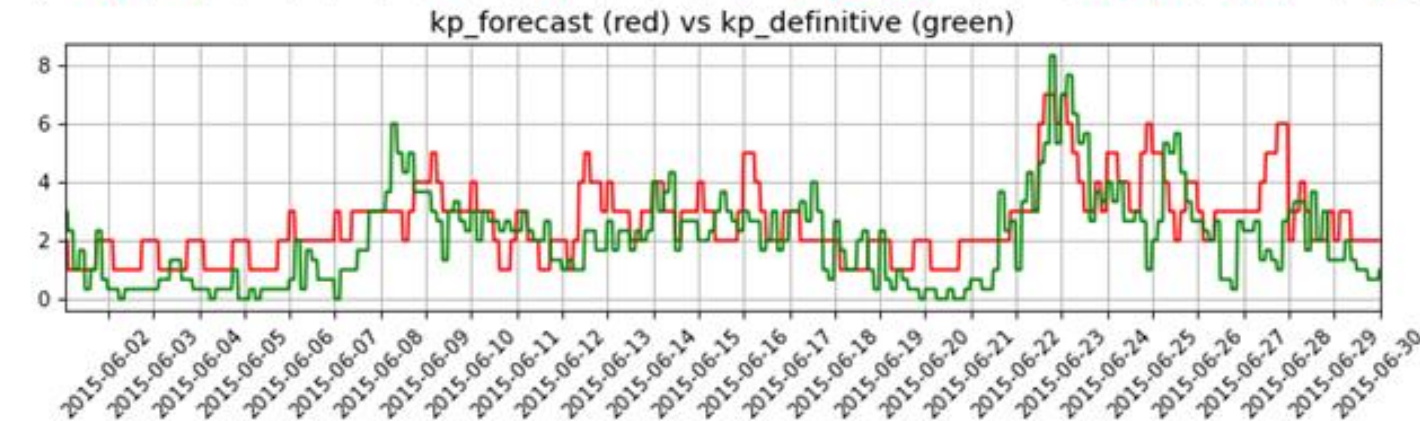
Kp forecast (NOAA)
Kp definitive (Potsdam)

Van Allen Probes observations

Low inclination (<20°) elliptical orbit ranging from 600 to 30 600 km

Plasmasphere density: EMFISIS and EFW

Fluxes in the radiation belts : ECT (MAGEIS)

Ripoll et al., Front. Astron. Space Sci. 10:1096595. doi: 10.3389/fspas.2023.1096595, 2023.

Botek et al., JGR, doi: 10.1029/2021JA029737, 2021

Pierrard et al., Frontiers in Astronomy Space Sciences, 8, DOI: 10.3389/fspas.2021.728531, 2021
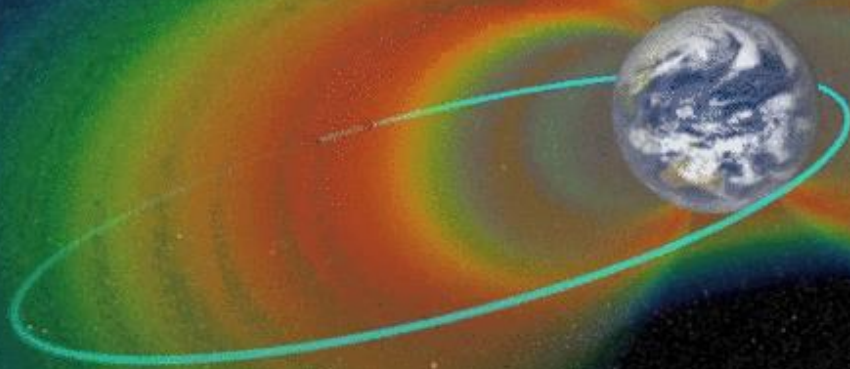
PITHIA
e-Science Centre

https://esc.pithia.eu/

Home

PITHIA e-Science Centre

Scientific Metadata

| Search Data Collections by Content | Data Collection Simple Search | Data Collections | Ca |

Input Selection

Features of Interest

Features of Interest

🔍 | Plasmasphere | **BSPM**

↕ Show All | ↟ Collapse All

⊟ All 27   ☑ 1 keyword match

▼ ☐ Earth
  ▼ ☐ Magnetosphere
    ▼ ☐ Inner
      ☑ Plasmasphere

BSPM: 3D-Kinetic plasmasphere model

The BSPM (Belgian SWIFF Plasmasphere Model) is a 3D-Kinetic semiempirical model of the plasmasphere developed by the Solar Wind Division of the Royal Belgian Institute for Space Aeronomy (Pierrard et al., 2021 for the last version). Based on physical mechanisms for the plasmapause 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 plasmapause, as a function of the geomagnetic activity driven by the Kp index. During geomagnetic storms, the plasmasphere is eroded and structures like plasma plumes and channels can appear (Pierrard and Stegen, 2008). During quiet times, the ionosphere refills the plasmasphere. The model is coupled to the International Reference Ionosphere (IRI) model (http://irimodel.org/ ⧉) used to determine the number density and temperatures of the particles between 60 and 700 km of altitude (Pierrard and Voiculescu, 2011). The values at 700 km are used as boundary conditions to provide the density and temperatures u

model consists of text files and figures for every hour of a simulated day. References. Pierrard, V. and Stegen, K., 2008. A three-dimensional dynamic kinetic model of the plasmasphere. Journal of Geophysical Research: Space Physics, 113(A10); Pierrard, V. and Voiculescu, M., 2011. The 3D model of the plasmasphere coupled to the ionosphere. Geophysical Research Letters, 38(12); Pierrard V., E. Botek and F. Darrouzet, 2021. Improving Predictions of the 3D Dynamic Model of the Plasmasphere, vol. 8, p. 69, Front. In Astron. Space Sci., 8:681401, doi:10.3389/fspas.2021.681401; Botek, E., Pierrard, V. and Darrouzet, F., 2021. Assessment of the Earth's cold plasmatrough modeling by using Van Allen Probes/EMFISIS and Arase/PWE electron density data. Journal of Geophysical Research: Space Physics, 126(12).

Interact

Interaction Method	Description	Data Format	Link
API	Interact with the BSPM model through an API.	N/A	Open API Interface in new tab

The BSPM is a 3D-Kinetic semiempirical model of the plasmasphere developed by the Solar Wind Division of the Royal Belgian Institute for Space Aeronomy.

Start typing to filter sections...

Execute
Run/Returns the status of execution by date: year-month-day ⌄

Retrieve Executions
Returns a list of executions completed by the user ⌃

Retrieve a list of user executions. ⌄

Plot
Returns the plot image ⌃

Execute the BSPM by passing the date.

Returns the status of execution by date: year-month-day

Parameters

Name	Description

date * required   Date in the format 'YYYY-MM-DD'

string

(query)

   date

Execute the BSPM by passing the date.

Returns the status of execution by date: year-month-day

Parameters

Cancel

Name	Description
date * required string *(query)*	Date in the format 'YYYY-MM-DD' 2022-12-12

Run /execute

Plot
Returns the plot image

Plot the output image by passing the execution date and hour.

Returns the plot image.

Parameters		Cancel

Name	Description
date * required string *(query)*	2022-12-12
hour * required integer *(query)*	3

Responses

Details

2022-12-12_03h00m
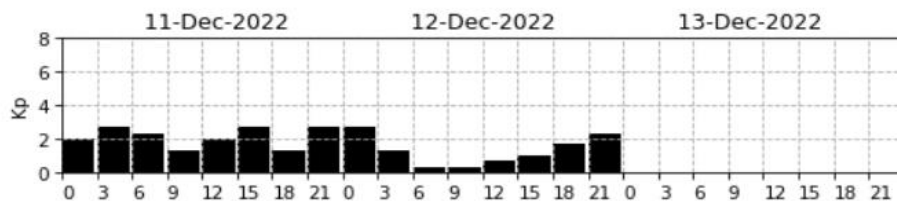
Equatorial plane
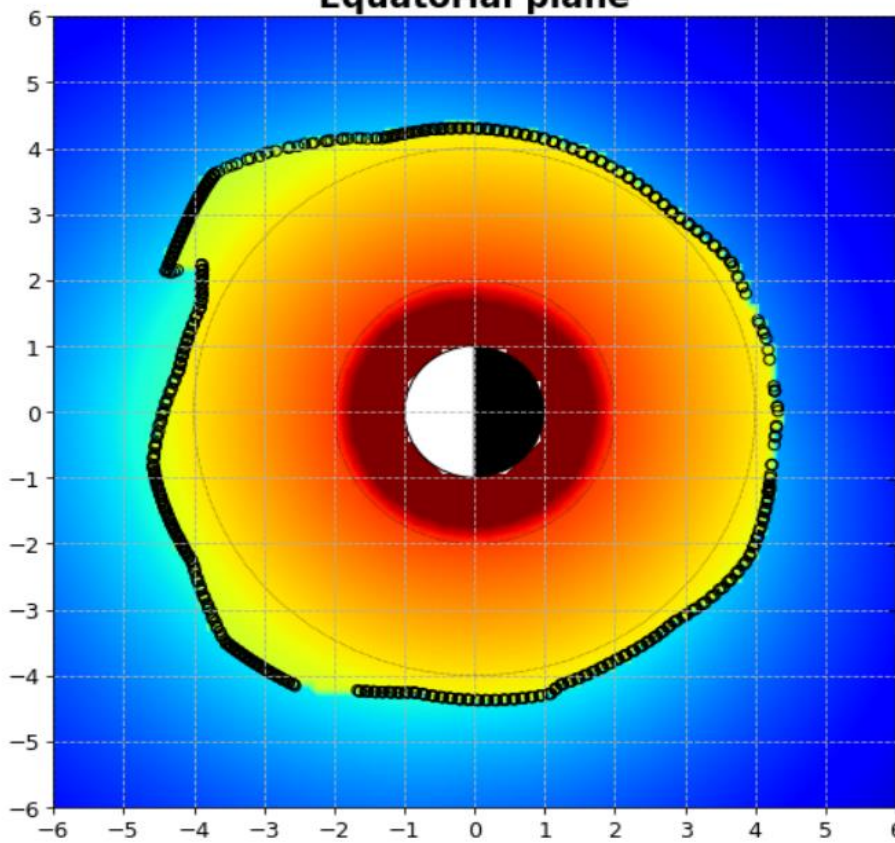
Belgian SWIFF Plasmasphere Model v.2021

Axes units in Re

Meridian plane
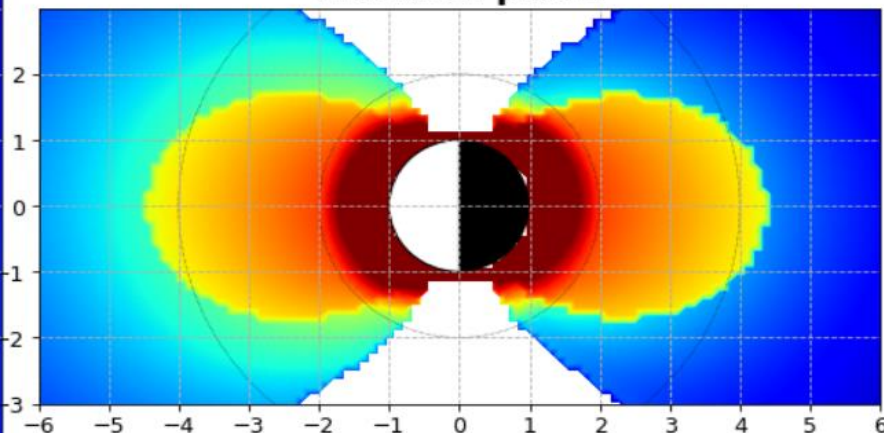
Electron density [1/cm³]
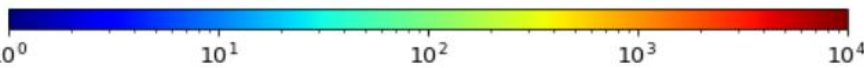
Download

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.

Parameters

Enable

Name	Description
date * required string (query)	date

	A	B	C	D	E	F	G	H	I	J
1	r[Re],MLT[hours],Lat[Deg],density_mer[1/cmÂ³]									
2	5.590,0.000,-26.565,2.052									
3	5.545,0.000,-25.622,2.131									
4	5.502,0.000,-24.664,2.219									
5	5.460,0.000,-23.691,2.315									
6	5.420,0.000,-22.703,2.418									
7	5.381,0.000,-21.701,2.528									
8	5.344,0.000,-20.684,2.643									
9	5.309,0.000,-19.654,2.764									
10	5.276,0.000,-18.610,2.890									
11	5.244,0.000,-17.554,3.018									
12	5.214,0.000,-16.484,3.149									

https://esc.pithia.eu/

Home

PITHIA e-Science Centre

Scientific Metadata

?	?	?	?
🔍 Search Data Collections by Content	🔍 Data Collection Simple Search	☰ Data Collections	Ca

Computational Models

B0B1_qModel

BSPM: 3D-Kinetic plasmasphere model

DTM2020-operational: semi-empirical thermosphere model

EPB_detectionTool

EUHFORIA: EUropean Heliospheric FORecasting Information Asset

hmF2_qModel

Mixed

EDP: Electron Density Profile

eSWua IONORING tool: Nowcasting TEC maps over Italy

to 10 Earth radii inside and outside the plasmasphere. The density in the plasmatrough region has recently been improved using observations of Van Allen Probes (Botek et al., 2021). The model is running in a near-real-time basis by the name of 'SPM' at the Space Situational Awareness site (https://swe.ssa.esa.int/bira-swiff-federated/ ⬈) of ESA (European Space Agency) using a previous IDL-Fortran version that evaluates the electron density and temperature without the ionosphere coupling, and providing animations of the equatorial and meridian plasmasphere dynamics for all the archived dates since 2017. A PYTHON-Fortran version BSPM by the name of 'BPIM' is available in the frame of the ESA Virtual Space Weather Modeling Center (https://swe.ssa.esa.int/kul-cmpa-federated/ ⬈) for on-demand executions. In the present implementation at the PITHIA eSC, a more updated version of the PYTHON-Fortran implementation is available providing the electron density of the plasmasphere, the ionosphere coupling as well as the electron density beyond the plasmapause, i.e., the plasmatrough for the requested day. Output of the model consists of text files and figures for every hour of a simulated day. References: Pierrard, V. and Stegen, K., 2008. A three-dimensional dynamic kinetic model of the plasmasphere. Journal of Geophysical Research: Space Physics, 113(A10); Pierrard, V. and Voiculescu, M., 2011. The 3D model of the plasmasphere coupled to the ionosphere. Geophysical Research Letters, 38(12); Pierrard V., E. Botek and F. Darrouzet, 2021. Improving Predictions of the 3D Dynamic Model of the Plasmasphere, vol. 8, p. 69, Front. In Astron. Space Sci., 8:681401, doi:10.3389/fspas.2021.681401; Botek, E., Pierrard, V. and Darrouzet, F., 2021. Assessment of the Earth's cold plasmatrough modeling by using Van Allen Probes/EMFISIS and Arase/PWE electron density data. Journal of Geophysical Research: Space Physics, 126(12).

SPACE WEATHER SERVICES ⌄

SPACE WEATHER AT ESA ⌄

EXPERT SERVICE CENTRES ⌃

ESC Solar Weather

ESC Heliospheric Weather

ESC Space Radiation

ESC Ionospheric Weather

ESC Geomagnetic Conditions

INFORMATION FOR USERS ⌄

CONTACT THE HELPDESK

TERMS OF USE

«

Federated products from the Centre for mathematical Plasma-Astrophysics (KUL)

esa space situational awareness
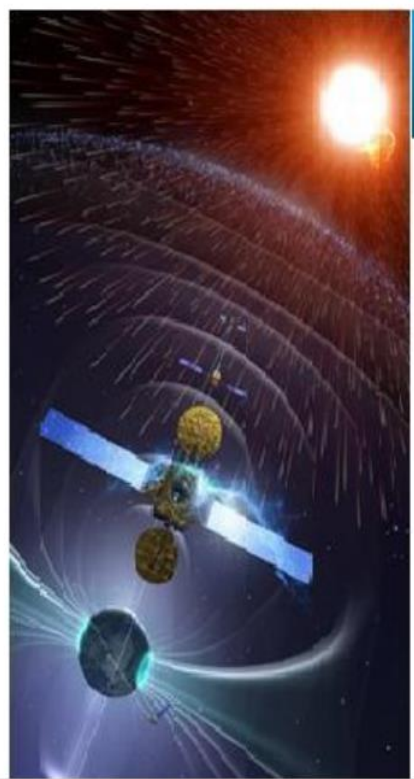
Sign in to OpenAM

User Name: viviane

Password: ••••••••

☐ Remember my username

Forgot password | Register Log in

belspo .be

Federated products from the **Centre for mathematical Plasma-Astrophysics** (KUl

Virtual Space Weather Modelling Centre ≣ HISTORY ➕ NEW RUN

Welcome to the VSWMC

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

eesa

SPACE WEATHER AT ESA ⌄

EXPERT SERVICE CENTRES ⌃

ESC Solar Weather

ESC Heliospheric Weather

ESC Space Radiation

ESC Ionospheric Weather

ESC Geomagnetic Conditions

INFORMATION FOR USERS ⌄

CONTACT THE HELPDESK

TERMS OF USE

«

belspo .be

kul-cmpa-federated - Space We ✕

https://swe.ssa.esa.int/kul-cmpa-federated/

Search

SPACE WEATHER SERVICES

SPACE WEATHER AT ESA

EXPERT SERVICE CENTRES

ESC Solar Weather

ESC Heliospheric Weather

ESC Space Radiation

ESC Ionospheric Weather

ESC Geomagnetic Conditions

INFORMATION FOR USERS

CONTACT THE HELPDESK

TERMS OF USE

«

Federated products from the Centre for mathematical Plasma-Astrophysics (KUL)

Virtual Space Weather Modelling Centre　　☰ HISTORY　　➕ NEW RUN

Which chain would you like to run?

Filter chains　　　　　　　　　　　　　　　　　　　By mode

Name

EUHFORIA

EUHFORIA + Indices

EUHFORIA + Indices + GUMICS4

belspo .be

kul-cmpa-federated - Space We...

https://swe.ssa.**esa**.int/kul-cmpa-federated/

Federated products from the Centre for mathematical Plasma-Astrophysics (KUL)

SPACE WEATHER AT ESA

EXPERT SERVICE CENTRES

ESC Solar Weather

ESC Heliospheric Weather

ESC Space Radiation

ESC Ionospheric Weather

ESC Geomagnetic Conditions

INFORMATION FOR USERS

CONTACT THE HELPDESK

TERMS OF USE

«

Virtual Space Weather Modelling Centre

≣ HISTORY

➕ NEW RUN

Which chain would you like to run?

Filter chains

Name

By mode

☑ BPIM

☐ CTIP Init

☐ CTIP Step

☐ EUHFORIA

☐ EUHFORIA

☐ Geoeffect D

☐ Geoeffect D

EUHFORIA + Indices + ODI F10.7 + CTIP + BPIM

EUHFORIA + SNGI (NARMAX) + ODI F10.7 + CTIP + BPIM

ODI KP + BPIM

belspo .be

kul-cmpa-federated - Space We   ×

https://swe.ssa.esa.int/kul-cmpa-federated/

SPACE WEATHER AT ESA

EXPERT SERVICE CENTRES

ESC Solar Weather

ESC Heliospheric Weather

ESC Space Radiation

ESC Ionospheric Weather

ESC Geomagnetic Conditions

INFORMATION FOR USERS

CONTACT THE HELPDESK

TERMS OF USE

Virtual Space Weather Modelling Centre   ☰ HISTORY   ➕ NEW RUN

Parametrize ODI KP + BPIM

Start Date

Date *   📅

The model ODI datasets start from 1932-01-01T00:00:00 UTC. The
2023-09-06T09:00:00 UTC.

The infrastructure for this run is provided free of charge under a fair-use policy. Runs may g
when they show signs of excessive use or when the system is undergoing maintenance.

Runs can take time, please check the help pages for model-specific information.

SPACE WEATHER AT ESA

EXPERT SERVICE CENTRES

ESC Solar Weather

ESC Heliospheric Weather

ESC Space Radiation

ESC Ionospheric Weather

ESC Geomagnetic Conditions

INFORMATION FOR USERS

CONTACT THE HELPDESK

TERMS OF USE

Virtual Space Weather Modelling Centre   ≡ HISTORY   ➕ NEW RUN

My Simulations

Name	Latest Run
EUHFORIA Corona	#1 success 3 years ago
EUHFORIA	#1 success 3 years ago
ODI KP + BPIM	#9 success 3 months ago
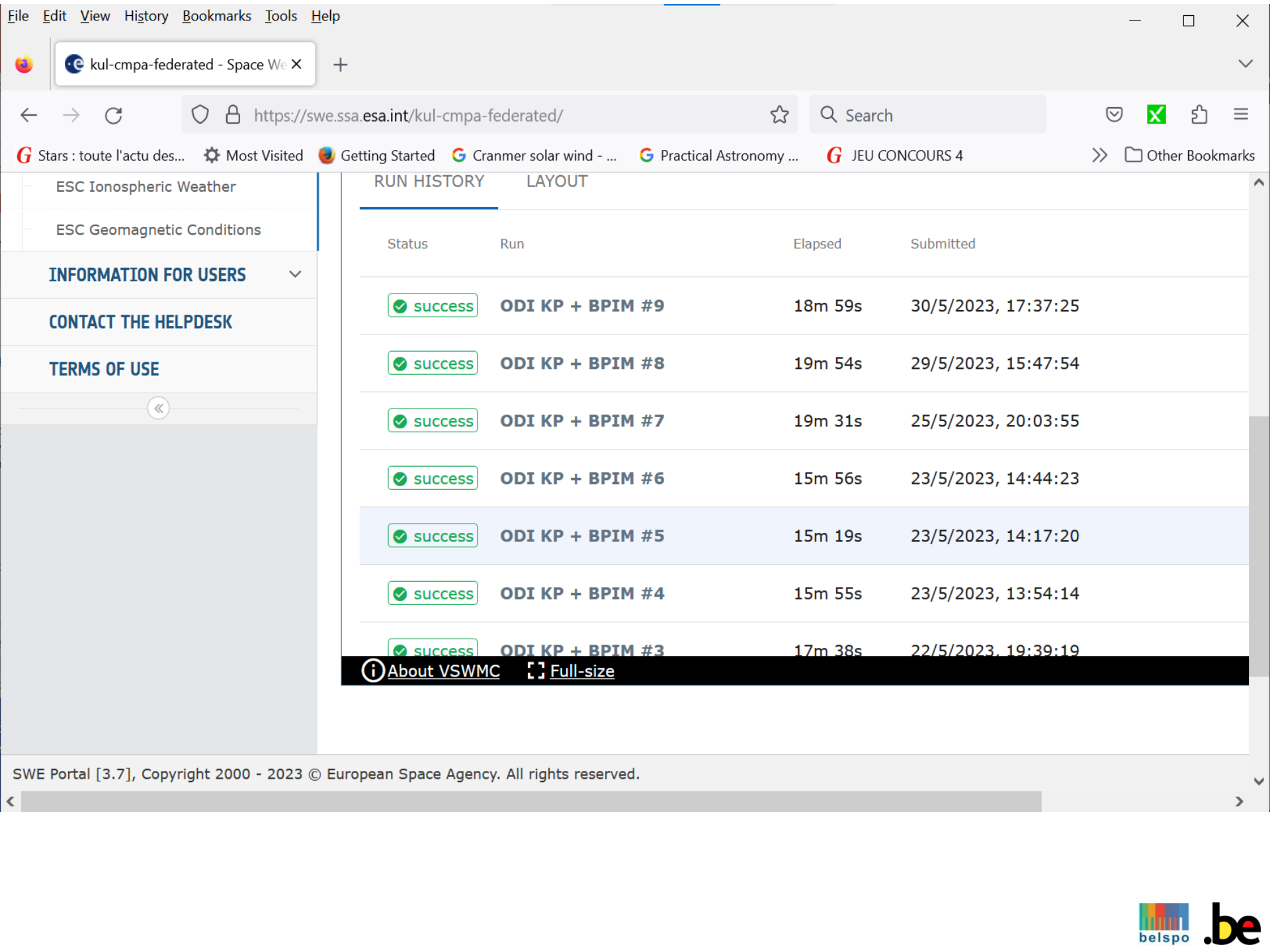
belspo   .be

https://swe.ssa.**esa.int**/kul-cmpa-federated/

ESC Ionospheric Weather

ESC Geomagnetic Conditions

INFORMATION FOR USERS   ⌄

CONTACT THE HELPDESK

TERMS OF USE

«

RUN HISTORY   LAYOUT

Status	Run		Elapsed	Submitted
✅ success	**ODI KP + BPIM #9**		18m 59s	30/5/2023, 17:37:25
✅ success	**ODI KP + BPIM #8**		19m 54s	29/5/2023, 15:47:54
✅ success	**ODI KP + BPIM #7**		19m 31s	25/5/2023, 20:03:55
✅ success	**ODI KP + BPIM #6**		15m 56s	23/5/2023, 14:44:23
✅ success	**ODI KP + BPIM #5**		15m 19s	23/5/2023, 14:17:20
✅ success	**ODI KP + BPIM #4**		15m 55s	23/5/2023, 13:54:14
✅ success	**ODI KP + BPIM #3**		17m 38s	22/5/2023, 19:39:19

ⓘ About VSWMC   ⛶ Full-size

belspo   .be

kul-cmpa-federated - Space We ✕   +

🦊   https://swe.ssa.esa.int/kul-cmpa-federated/   🔍 Search

G Stars : toute l'actu des...   ⚙ Most Visited   🦊 Getting Started   G Cranmer solar wind - ...   G Practical Astronomy ...   G JEU CONCOURS 4   ≫   📁 Other Bookmarks

ESC Heliospheric Weather

ESC Space Radiation

ESC Ionospheric Weather

ESC Geomagnetic Conditions

INFORMATION FOR USERS   ⌄

CONTACT THE HELPDESK

TERMS OF USE

«

← **ODI KP + BPIM #6**   Started by viviane at 23/5/2023, 14:44:23

PARAMETERS   LOG   **RESULTS**

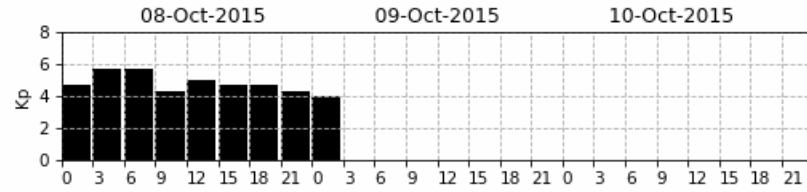| ODI.txt | 23/5/2023, 14:44:29 | 452 Bytes | Plain Text |
dens (24 files...)	-	-	Slideshow 👁
dens_eq_2015-10-09_00h00m_at_2023-05-23_14h46m.csv	23/5/2023, 14:47:09	194.1 KB	-
dens_eq_2015-10-09_01h00m_at_2023-05-23_14h47m.csv	23/5/2023, 14:47:42	194.1 KB	-
dens_eq_2015-10-09_02h00m_at_2023-05-23_14h48m.csv	23/5/2023, 14:48:45	194.1 KB	-
dens_eq_2015-10-09_03h00m_at_2023-05-23_14h48m.csv	23/5/2023, 14:49:18	194.1 KB	-
dens_eq_2015-10-09_04h00m_at_2023-05-23_14h48m.csv	23/5/2023, 14:49:51	194.2 KB	-
dens_eq_2015-10-09_05h00m_at_2023-05-23_14h49m.csv	23/5/2023, 14:50:24	194.2 KB	-

belspo .be

CONTACT THE HELPDESK

TERMS OF USE

«

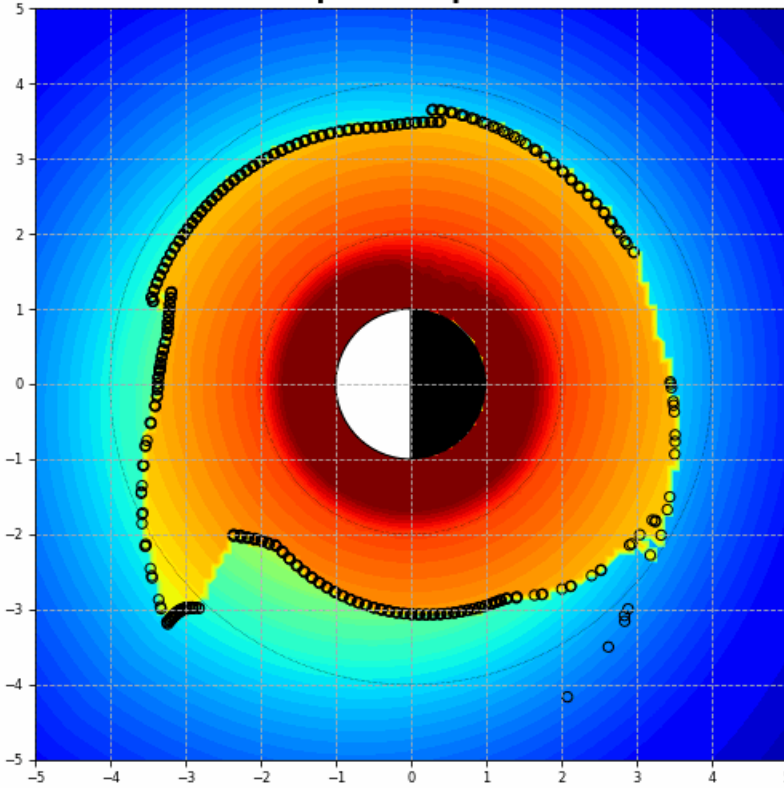| dens_mer_2015-10-09_18h00m_at_2023-05-23_14h56m.csv	23/5/2023, 14:57:02	132.5 KB	-	⬇ Download
dens_mer_2015-10-09_19h00m_at_2023-05-23_14h56m.csv	23/5/2023, 14:57:35	132.4 KB	-	⬇ Download
dens_mer_2015-10-09_20h00m_at_2023-05-23_14h57m.csv	23/5/2023, 14:58:08	132.2 KB	-	⬇ Download
dens_mer_2015-10-09_21h00m_at_2023-05-23_14h57m.csv	23/5/2023, 14:58:41	132 KB	-	⬇ Download
dens_mer_2015-10-09_22h00m_at_2023-05-23_14h58m.csv	23/5/2023, 14:59:14	131.9 KB	-	⬇ Download
dens_mer_2015-10-09_23h00m_at_2023-05-23_14h58m.csv	23/5/2023, 14:59:14	131.8 KB	-	⬇ Download
movie.gif	23/5/2023, 14:59:47	5.2 MB	Image ⊙	⬇ Download

ⓘ About VSWMC　⛶ Full-size

Type here to search
21°C　ENG
10:21
06/09/2023

2015-10-09_00h00m

08-Oct-2015   09-Oct-2015   10-Oct-2015

Equatorial plane

Axes units in Re

Meridian plane
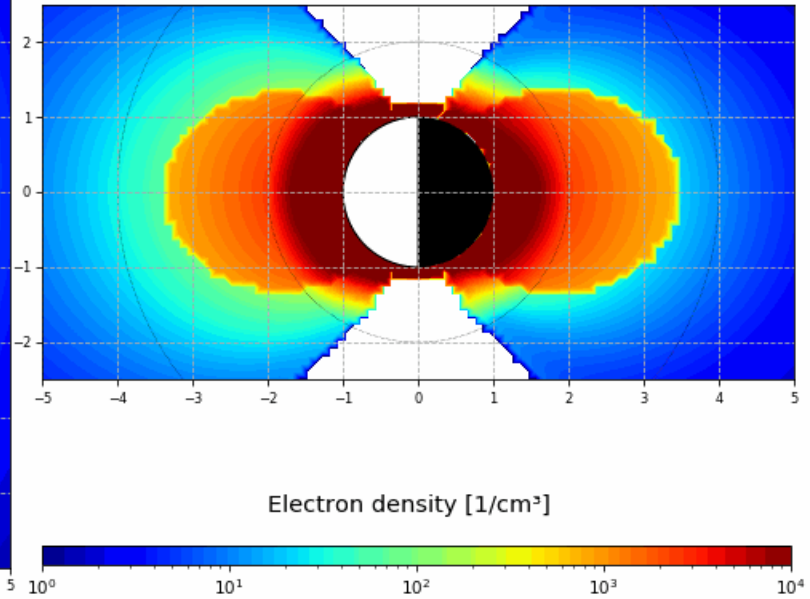
Electron density [1/cm³]
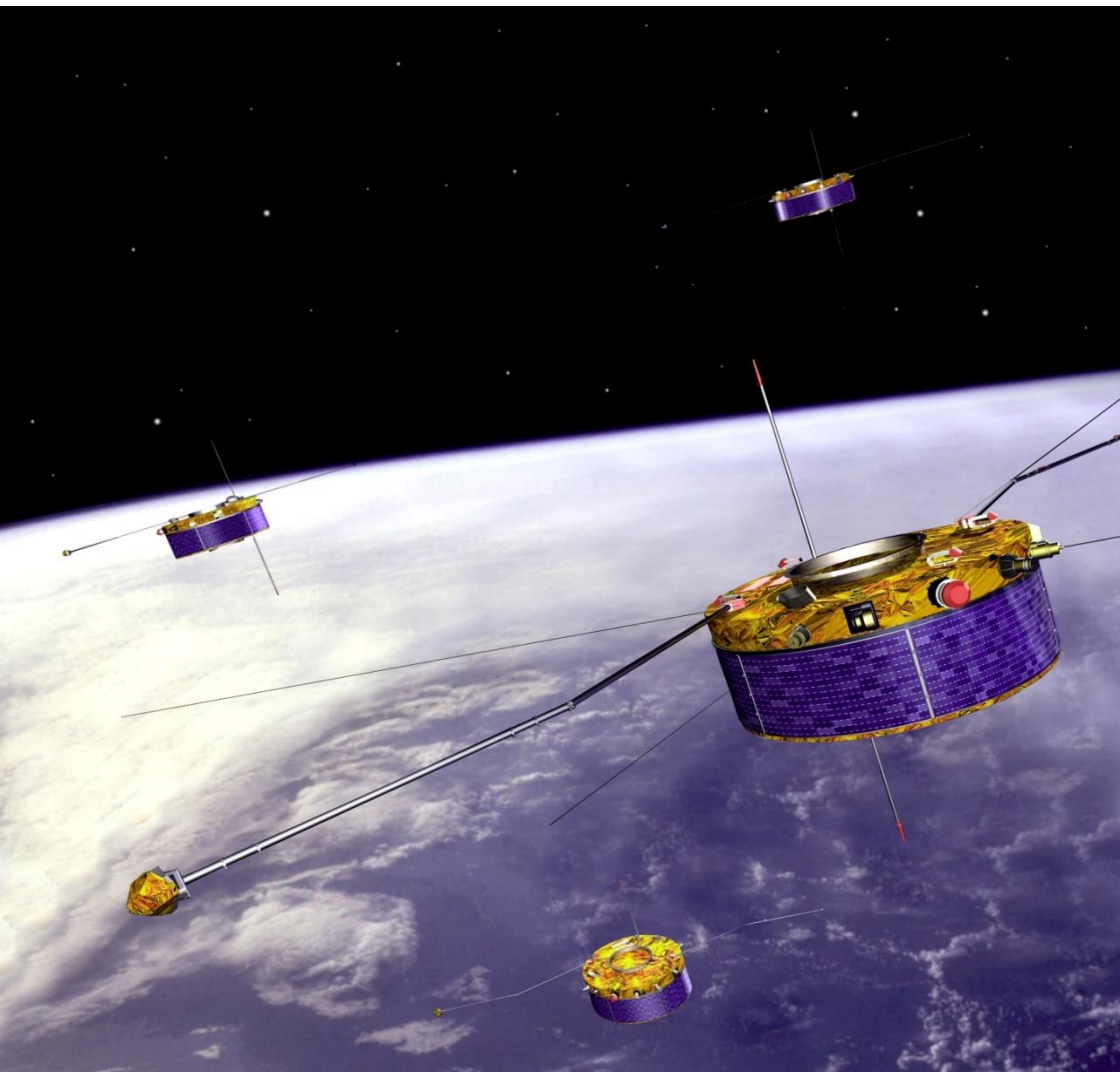
CLUSTER

4 satellites launched in July and
August 2000
Polar elliptic orbit
Perigee: 19000 km (4 Re)
Apogee: 119000 km (19 Re)
Period: 57 h

Results

🔍 Cluster   [Search]

☐ Exact match

Found 2 results for "*Cluster*".

ActivityIndicator: Collection of Kp, ap, and Ap indices by GFZ, with F10.7 from DRAO and Sn from WSC SILSO

No description

WHISPER/Cluster collection of Electron Density and Electron Plasma Frequency in the Plasmasphere

No description

Role (from Related Party **(1/2)** > Responsible Party Info)

Role (from Related Party **(2/2)** > Responsible Party Info)   [Data Provider](#)

Party (from Related Party **(2/2)** > Responsible Party Info)   [Royal Belgian Institute for Space Aeronomy](#)

Result Time   *Not used*

Name (from Collection Results > Source > Online Resource)   Cluster Science Archive (CSA) Landing Page

URL (from Collection Results > Source > Online Resource > Linkage)   https://csa.esac.esa.int/csa-web/ ⧉

Protocol (from Collection Results >   HTTPS

Cluster Science Archive

CSA 3.4.0

esa

Time (begin/end)

2001-05-14T00:00:00Z   📅   -   2001-05-15T00:00:00Z   📅

Duration

| 1 | ∨ | 0 | ∨ | 0 | ∨ |

Days   Hours   Minutes

🗑 Clear   《   ⚙ Plot   》
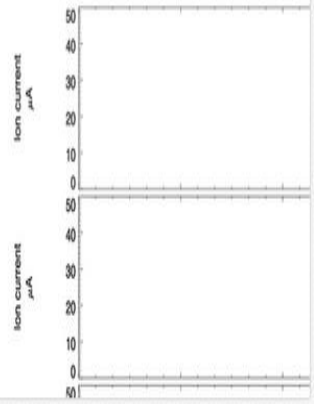
Q   **PLOTS**   **X**

⬇ PS

14 May

CSA_CG_PREGEN_1DAY_pierrard_20240

2001-05-14T00:00:00Z

Cluster   **DoubleStar**

| ASPOC | AUX | CIS | DWP | EDI | EFW | FGM | PEACE | RAPID | STAFF | WBD | **WHISPER** |

C1	C2	C3	C4	All	Product Name
◉	◉	◉	◉		ELECTRON DENSITY
○	○	○	○		WAVE SPECTROGRAM (NATURAL: 2-80 KHZ) - ELECTRIC FIELD

Also on PITHIA:

WHISPER/CLUSTER:

Plasmapause

Waves of HIgh frequency and Sounder for Probing of Electron density by Relaxation

$$N(cm^{-3}) = f_p^2(kHz)/81$$

Time-frequency electric field spectrograms for a plasmasphere crossing
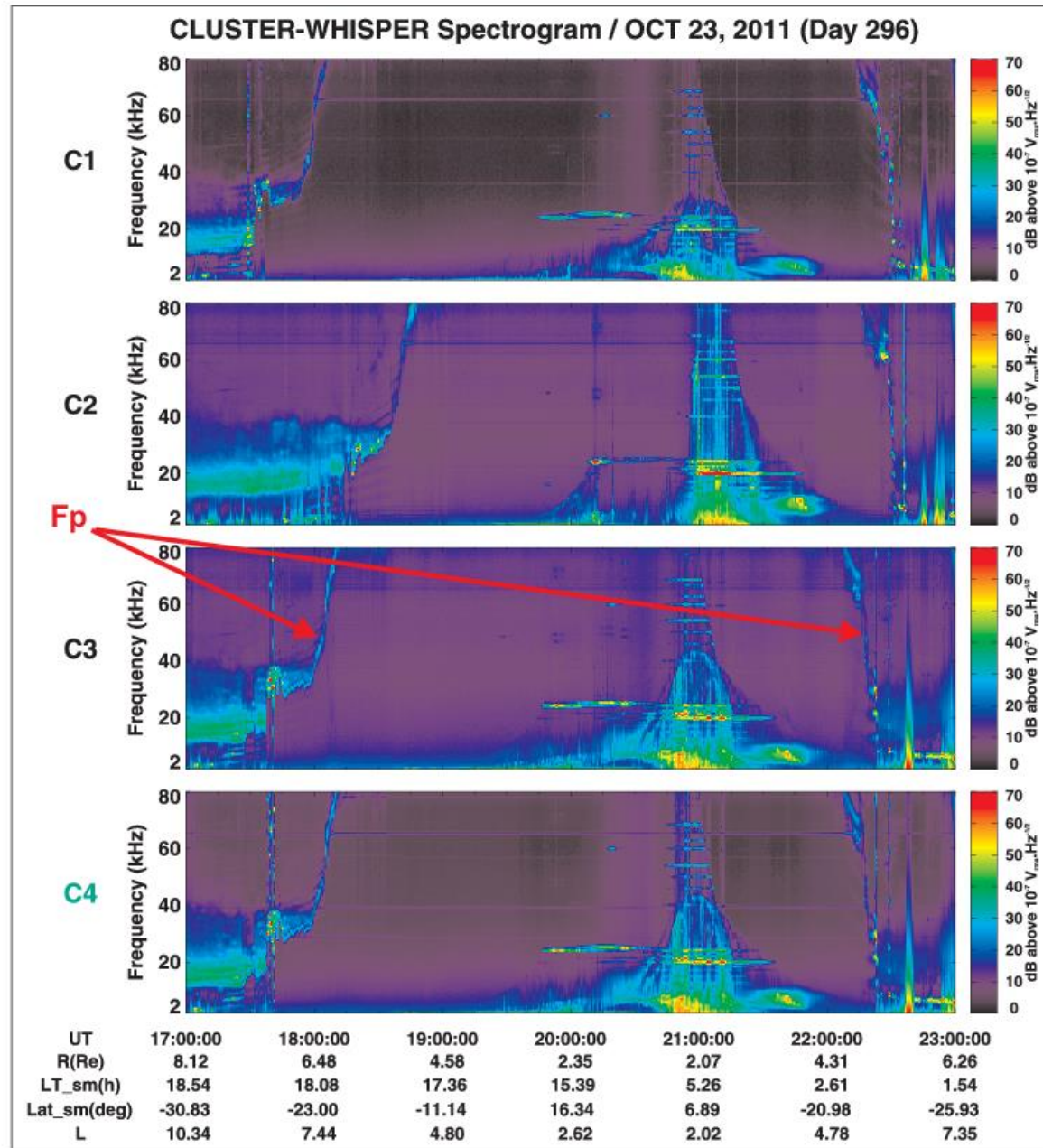
CLUSTER-WHISPER Spectrogram / OCT 23, 2011 (Day 296)

UT	17:00:00	18:00:00	19:00:00	20:00:00	21:00:00	22:00:00	23:00:00
R(Re)	8.12	6.48	4.58	2.35	2.07	4.31	6.26
LT_sm(h)	18.54	18.08	17.36	15.39	5.26	2.61	1.54
Lat_sm(deg)	-30.83	-23.00	-11.14	16.34	6.89	-20.98	-25.93
L	10.34	7.44	4.80	2.62	2.02	4.78	7.35

07 May 2002
Plume

IMAGE/EUV 2002/05/07 08:31

CLUSTER-WHISPER Spectrogram / MAY 07, 2002 (Day 127)

UT	08:20:00	09:00:00	09:40:00	10:20:00	11:00:00
R(Re)	4.88	4.49	4.35	4.50	4.90
Lat_gse(deg)	-37.85	-18.78	3.13	24.91	43.58
LT_gse(h)	20.82	20.16	19.58	18.98	18.24
Lat_Inv(deg)	68.99	63.13	60.76	64.33	71.34
L	7.78	4.90	4.19	5.33	9.77
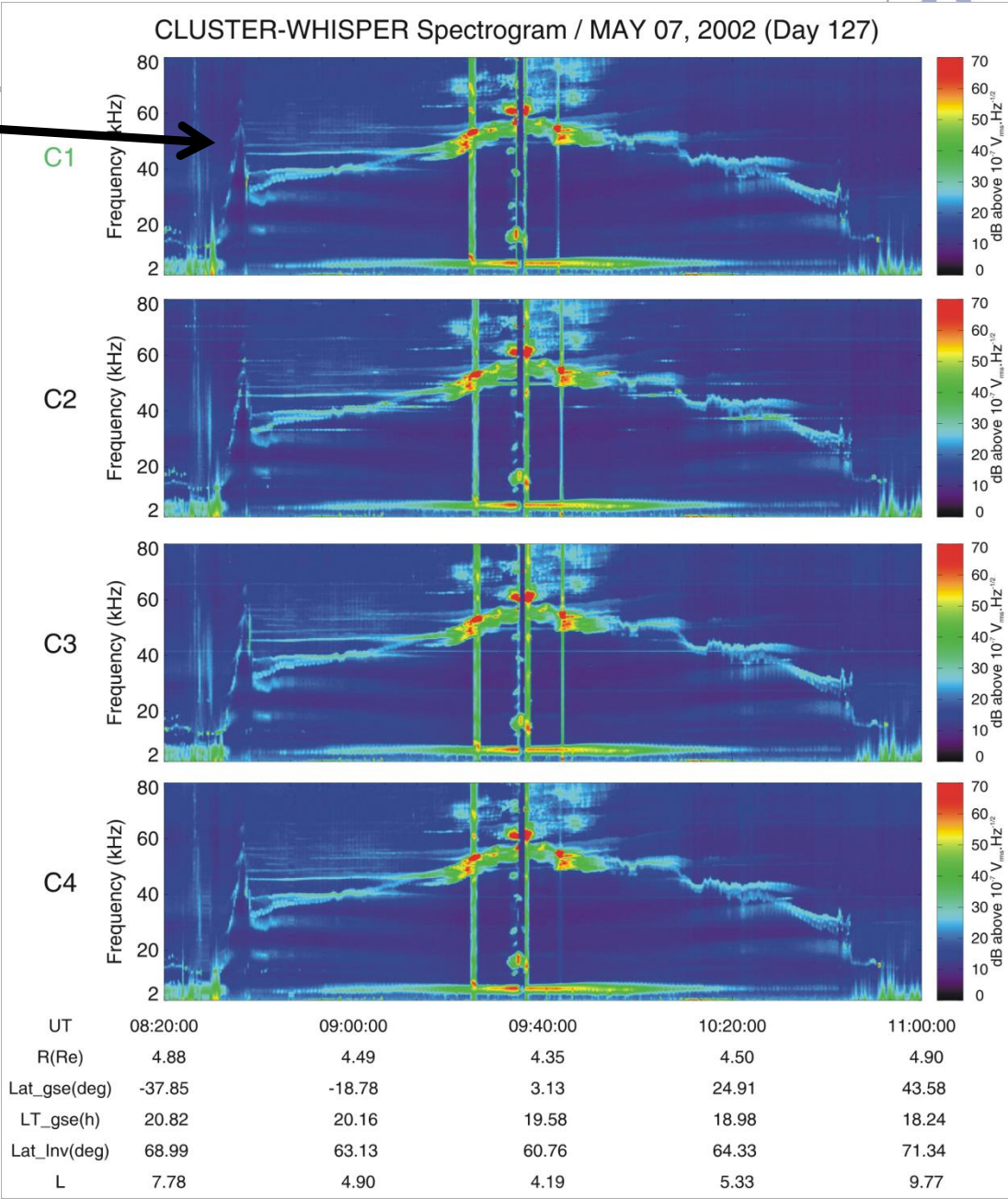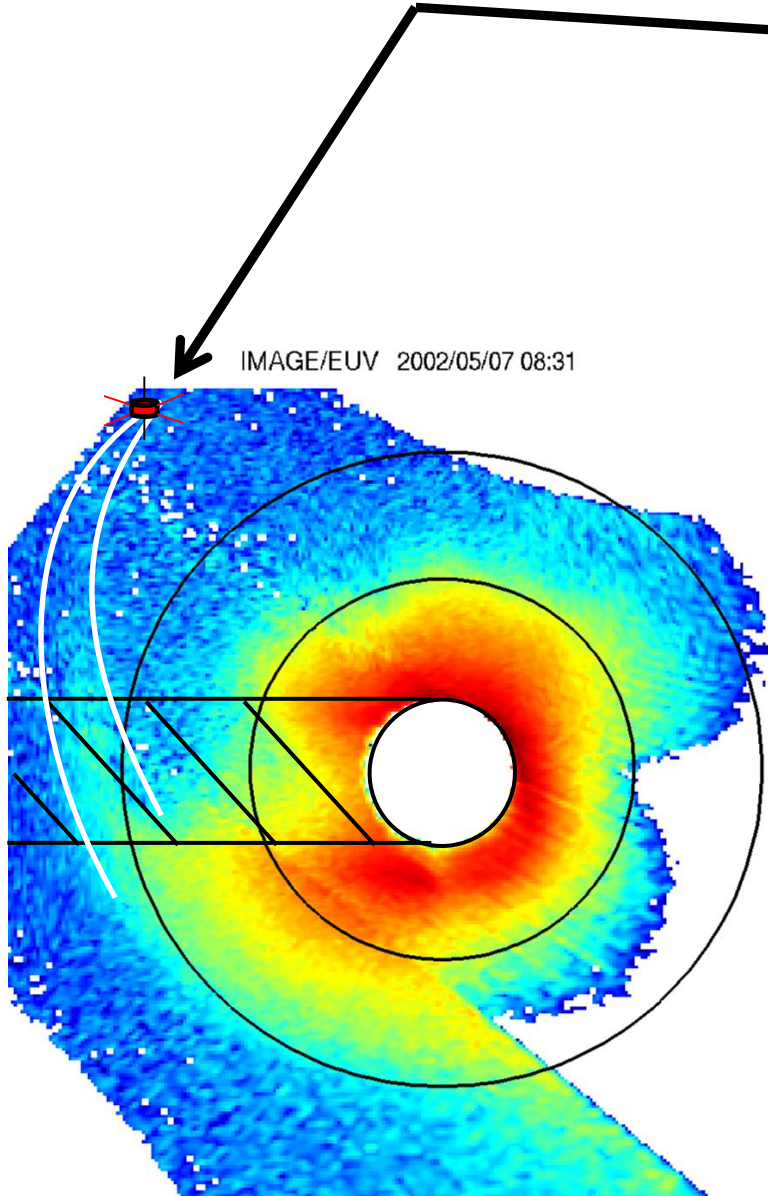
Conclusions
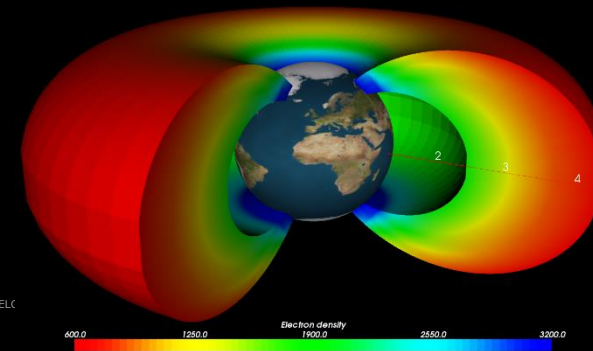
Plasmasphere BSPM model available on https://esc.pithia.eu/
NASA BSPM https://ccmc.gsfc.nasa.gov
ESA BPIM http://swe.ssa.esa.int/space-radiation

- Input: date, time (for Kp PP and coupling with IRI)

- Output: Density, temperature inside PS, outside (trough)
- Plasmapause by interchange instability
- Animated PS in equatorial and meridian planes + data files
- Semi-empirical Kp dependent McIlwain E-field
- Plasmaspheric wind and refilling on request
  viviane.pierrard@aeronomie.be

Pierrard, Botek, Darrouzet, Front. doi:10.3389/fspas.2021.681401, 2021 (PS)
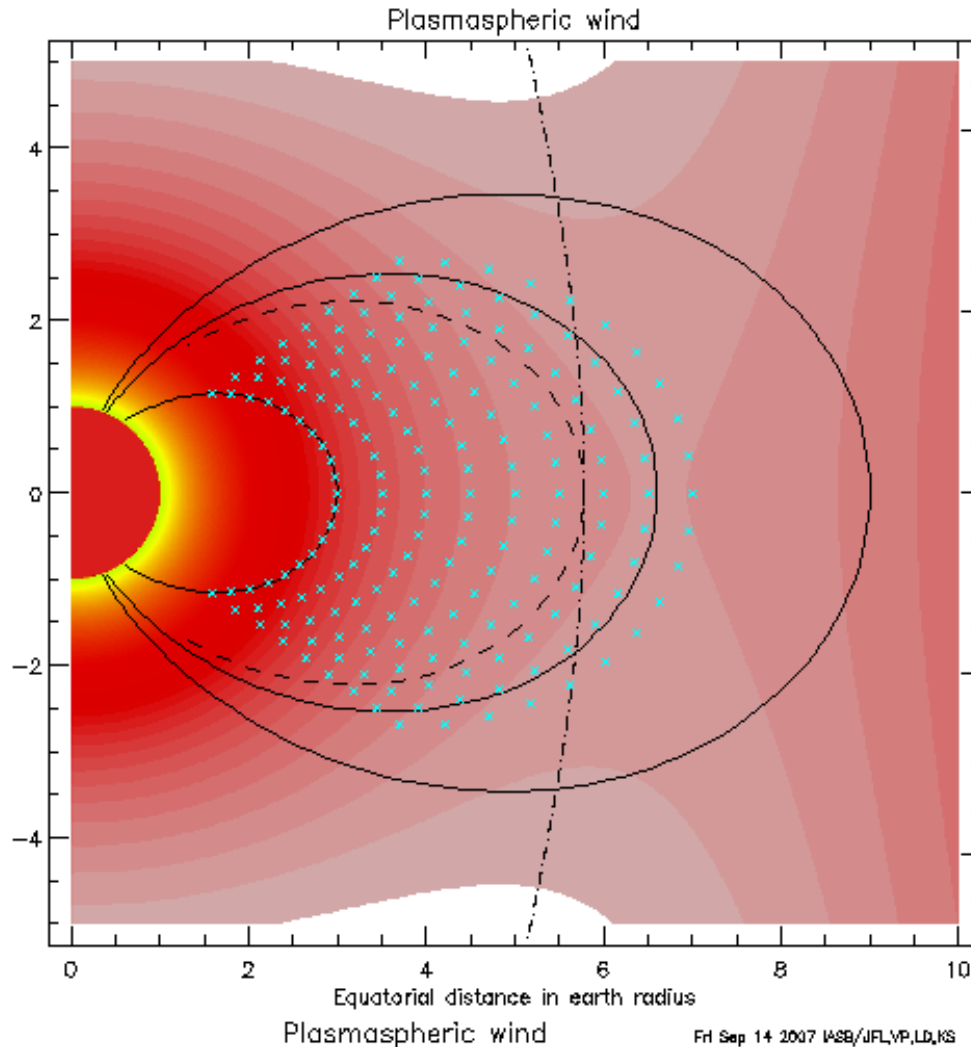Botek et al., JGR, doi: 10.1029/2021JA029737, 2021 (trough)
Pierrard et al., Frontiers, doi: 10.3389/fspas.2021.728531, 2021 (Aurora, RB, PP)

Plasmaspheric wind

During prolonged quiet periods: plasmaspause further from the Earth
Need Kp during several days

Plasmaspheric wind

Pierrard et al., Frontiers. doi:10.3389/fspas.2021.681401, 2021