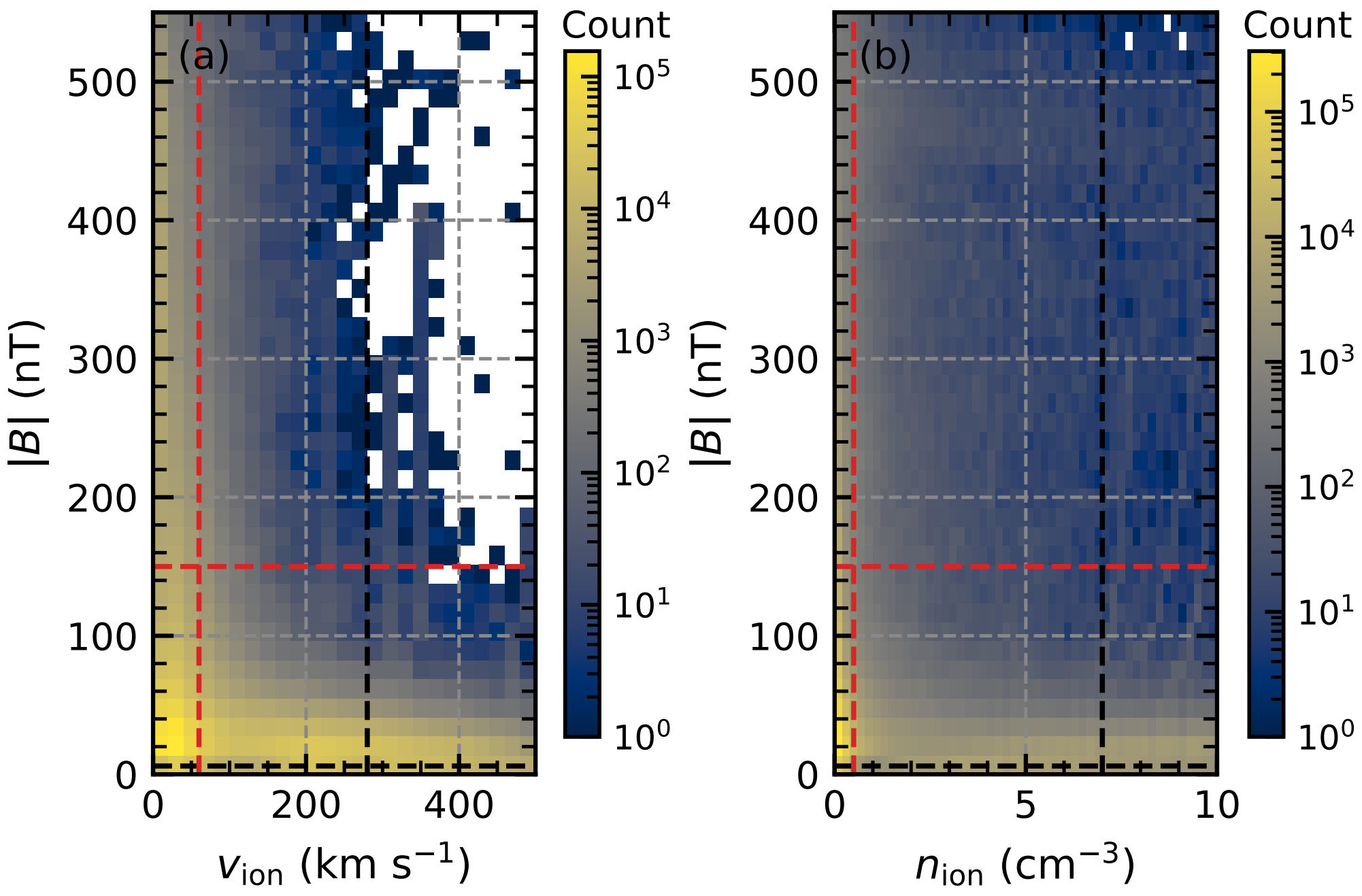
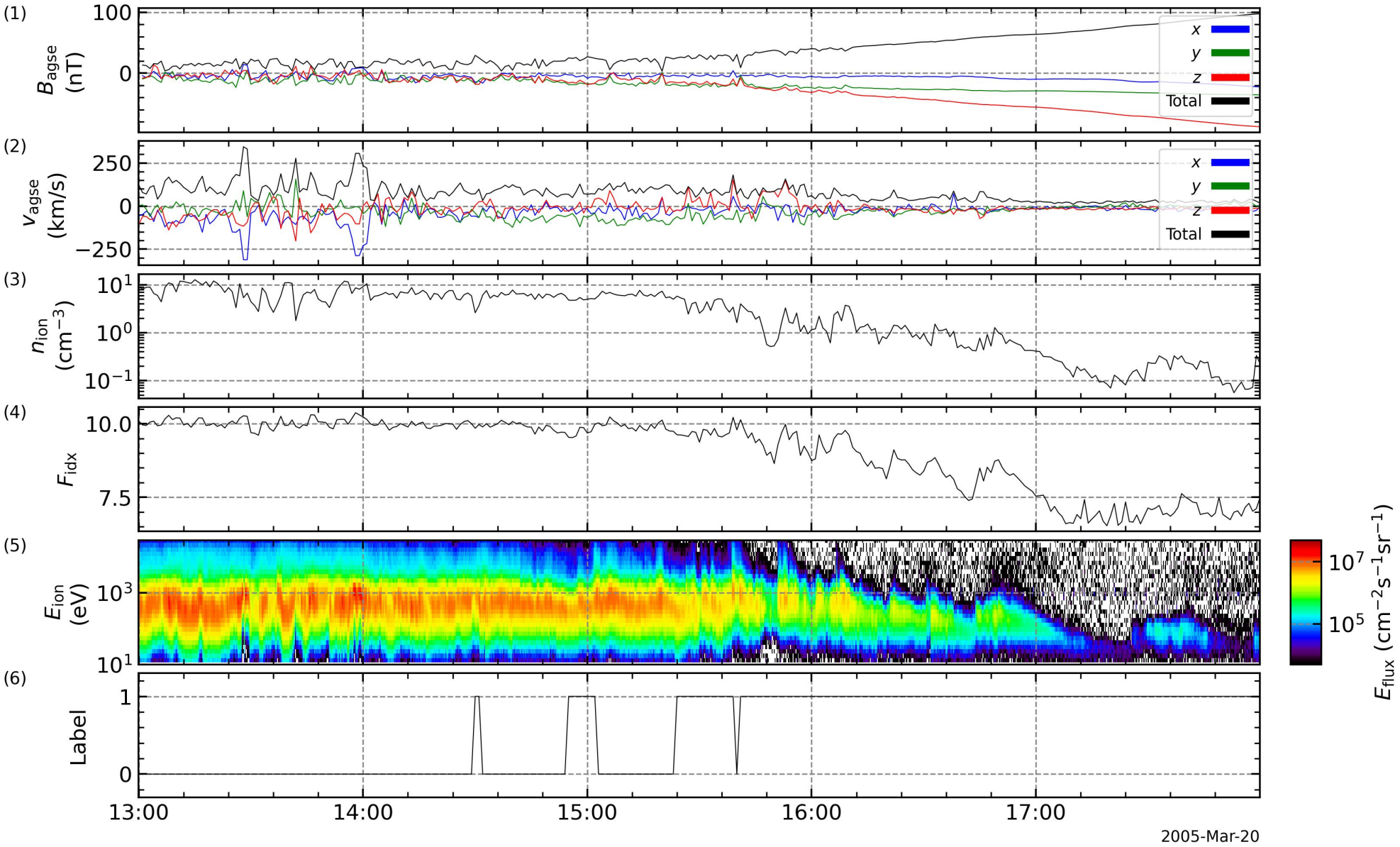
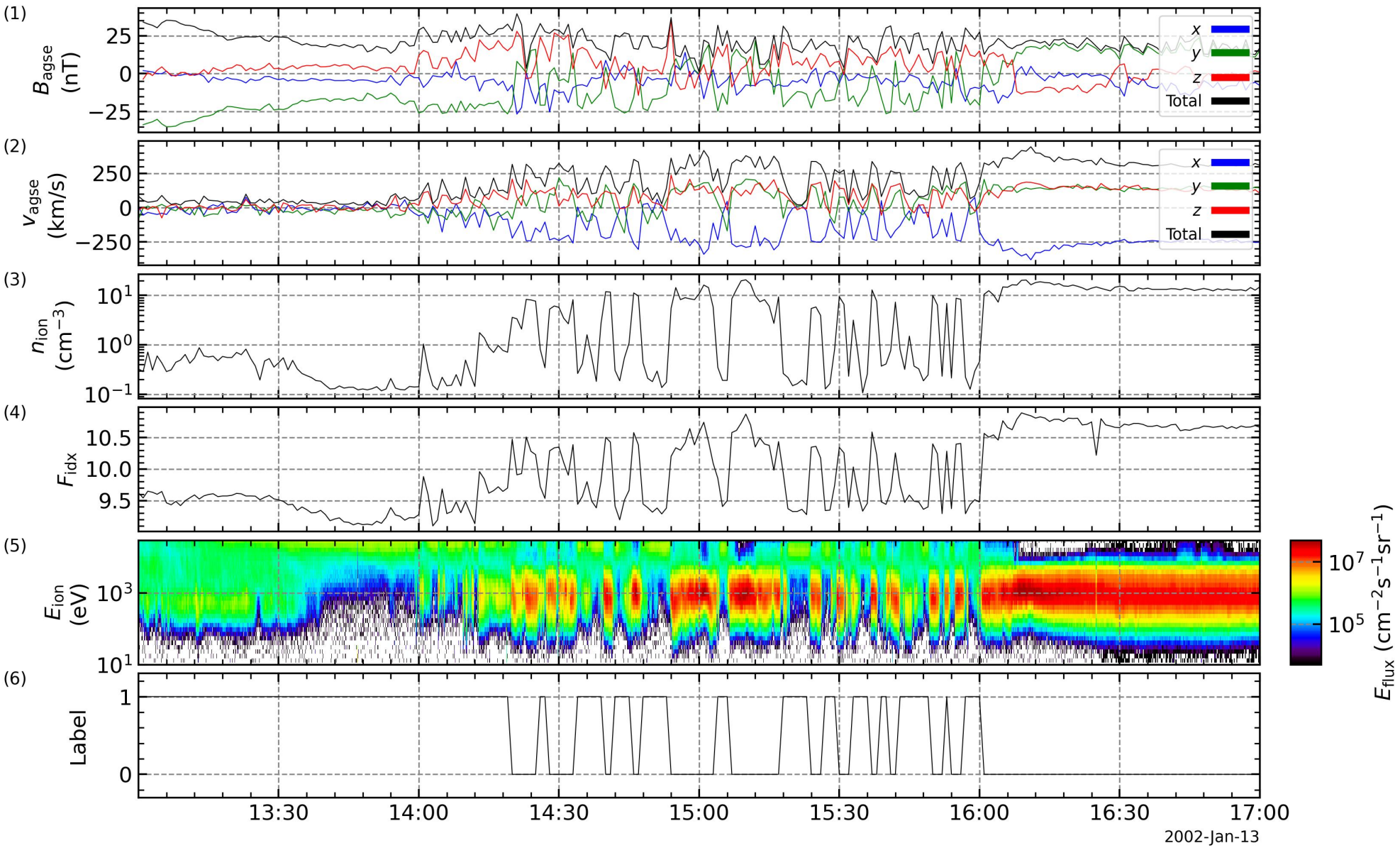

(a)
(b)
Count
10^5
10^4
10^3
10^2
10^1
10^0
|B| (nT)
0
100
200
300
400
500
0
200
400
v_{ion} (km s^{-1})
0
5
10
n_{ion} (cm^{-3})

	Expanded MPCs	Compressed MPCs	Compressed MPCs (RDs)
B_x	$6.5{\cdot}10^{-1}$	$5.1{\cdot}10^{-3}$	$1.0{\cdot}10^{-1}$
B_y	$6.5{\cdot}10^{-1}$	$\mathbf{5.5 \cdot 10^{-4}}$	$8.4{\cdot}10^{-1}$
B_z	$3.3{\cdot}10^{-1}$	$\mathbf{1.0 \cdot 10^{-2}}$	$7.0 \cdot 10^{-2}$
$\lvert B \rvert$	$2.3{\cdot}10^{-1}$	$\mathbf{5.1 \cdot 10^{-3}}$	$3.6{\cdot}10^{-1}$
$\vartheta_{\mathrm{cone}}$	$\mathbf{5.6 \cdot 10^{-13}}$	$\mathbf{4.7 \cdot 10^{-12}}$	$5.1{\cdot}10^{-1}$
$\vartheta_{\mathrm{clock}}$	$\mathbf{3.6 \cdot 10^{-2}}$	$3.9{\cdot}10^{-1}$	$7.4{\cdot}10^{-1}$
u_{ion}	$\mathbf{3.4 \cdot 10^{-9}}$	$\mathbf{4.1 \cdot 10^{-7}}$	$9.2{\cdot}10^{-1}$
n_{ion}	$\mathbf{6.0 \cdot 10^{-5}}$	$\mathbf{3.7 \cdot 10^{-12}}$	$\mathbf{3.4 \cdot 10^{-2}}$
T_{ion}	$\mathbf{4.3 \cdot 10^{-9}}$	$\mathbf{1.5 \cdot 10^{-4}}$	$6.5{\cdot}10^{-1}$
p_{dyn}	$5.9{\cdot}10^{-1}$	$8.4 \cdot 10^{-2}$	$1.3{\cdot}10^{-1}$
M_A	$\mathbf{2.5 \cdot 10^{-2}}$	$\mathbf{1.9 \cdot 10^{-4}}$	$8.7 \cdot 10^{-2}$
β	$3.2{\cdot}10^{-1}$	$\mathbf{3.2 \cdot 10^{-9}}$	$1.2{\cdot}10^{-1}$


(1)
B_{agse} (nT)
100
0
x
y
z
Total
(2)
v_{agse} (km/s)
250
0
−250
x
y
z
Total
(3)
n_{ion} (cm^{-3})
10^1
10^0
10^{-1}
(4)
F_{idx}
10.0
7.5
(5)
E_{ion} (eV)
10^3
10^1
10^7
10^5
E_{flux} ($cm^{-2}s^{-1}sr^{-1}$)
(6)
Label
1
0
13:00
14:00
15:00
16:00
17:00
2005-Mar-20


(1)
B_{agse} (nT)
25
0
−25
x
y
z
Total
(2)
v_{agse} (km/s)
250
0
−250
x
y
z
Total
(3)
n_{ion} (cm^{-3})
10^1
10^0
10^{-1}
(4)
F_{idx}
10.5
10.0
9.5
(5)
E_{ion} (eV)
10^3
10^1
10^7
10^5
E_{flux} ($cm^{-2}s^{-1}sr^{-1}$)
(6)
Label
1
0
13:30
14:00
14:30
15:00
15:30
16:00
16:30
17:00
2002-Jan-13

Analysis of Cluster data with the publicly available GRMB (Geospace Region and Magnetospheric Boundary) dataset

EGU24-13267

Benjamin **Grison**[1], Fabien Darrouzet[2], Romain Maggiolo[2], Mykhaylo Hayosh[1], Matthew G. Taylor[3]
(1) Institute of Atmospheric Physics (IAP) of the Czech Academy of Sciences, (2) Royal Belgian Institute for Space Aeronomy (BIRA-IASB), (3) ESA/ESTEC

Abstract:
The Cluster mission consists of 4 identical spacecraft, each carrying 11 scientific experiments. The spacecraft were launched in July and August 2000 into near polar inclined, 19x4 RE elliptic orbits. All four spacecraft are still in operation 23 years later. The magnetosphere environment is highly dynamic and its regions cannot be accessed by the orbital information alone. The purpose of this study is to develop a comprehensive dataset, providing information on Geospace Region and Magnetospheric Boundaries (GRMB) crossed by each of the four Cluster spacecraft, and to deliver it to the Cluster Science Archive (CSA).
The GRMB dataset provides a classification useful for the scientific community. Therefore, the methodology does not define what is a bow shock or what is a magnetopause. The goal is to have labeled regions that contain the bow-shocks or magnetopauses. And then each user can apply its own definition on the appropriate label subset. The GRMB list contains two kinds of items:

- **Regions**: Magnetosphere, Magnetosheath, Lobe, Solar wind / Foreshock, Plasmasheet, Plasmasphere
- **Transition regions**: Bow shock TR, Magnetopause TR, Polar regions, Plasmasheet TR, Plasmapause TR

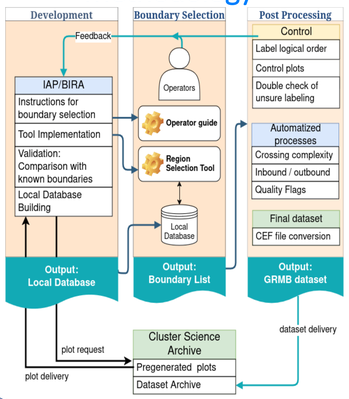
Transition regions can include properties matching several regions. For example, a bow shock TR can include short periods of solar wind or magnetosheath. Solar wind and magnetosheath should not include bow shock crossings.
The GRMB dataset is based on more than 40 data products available at CSA, taken from 7 instrument suites. The methodology relies on the visual identification of the boundaries between two consecutive GRMB items.
The methodology, the criteria applied for the boundary identification, and the dataset validation are presented. The dataset is not yet fully completed but the Cluster location is already available for more than 5 years per spacecraft.
The visualization of the regions, and their physical properties, crossed by the Cluster spacecraft during several years, illustrates the scientific interest of this dataset.

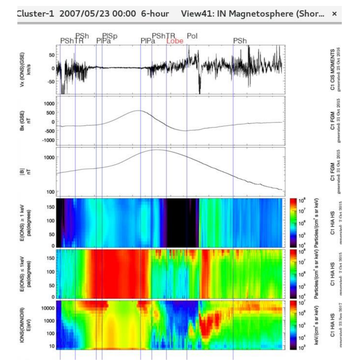
GRMB list: 15 items

Index	Label	Name
1	IN/UKN	INside the magnetosphere
2	IN/PLS	PLasmaSphere
3	IN/PPTR	PlasmaPause TR
4	IN/PSH	PlasmaSHeet
5	IN/PSTR	PlasmaSheet TR
6	IN/LOB	LOBe
7	IN/POL	POLar Regions
8	IN/MP	MagnetoPause
9	IN/MPTR	MagnetoPause TR
10	OUT/MSH	MagnetoSHeath
11	OUT/BSTR	Bow Shock TR
12	OUT/SWF	Solar Wind and Foreshock
13	OUT/UKN	OUTside the magnetosphere
14	UNKOWN	Unknown
15	N/A	Void

PLS: The plasma frequency is out of WHISPER range close to perigee
PPTR: the plasma density gradient close to perigee
PSH: high energy and isotropic plasma is observed
PSHTR is less homogeneous than PSH
LOB: low-plasma density region
POL: magnetosheath-like plasma (+ energy dispersion) observed inside the magnetosphere
MP: sharp magnetopause crossing
MPTR: complex magnetopause crossings
BSTR: (anti-)correlated abrupt changes in n, B (v) separating MSH and SWF

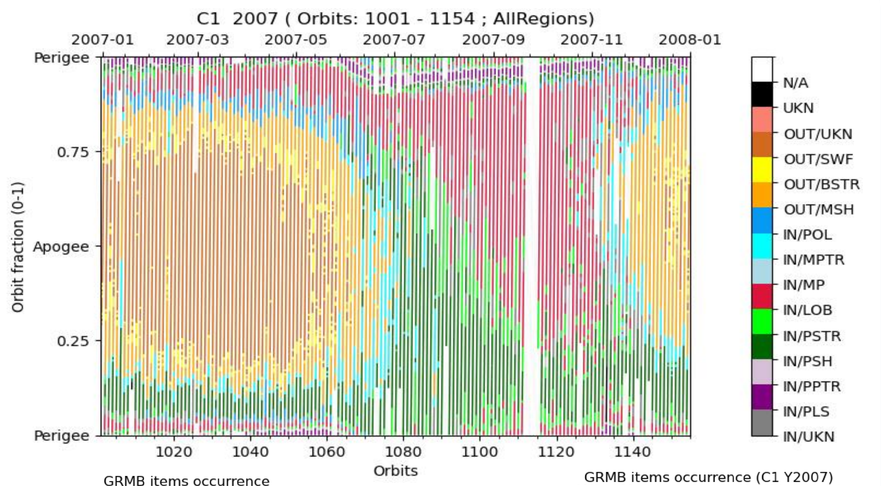
Methodology

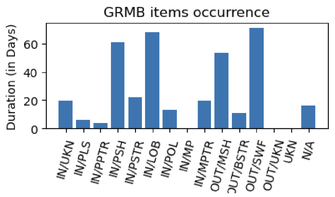




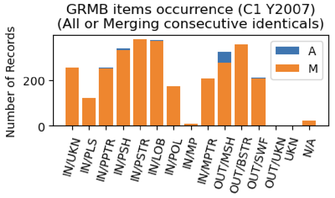
Snapshot from the GRMB region selection tool software

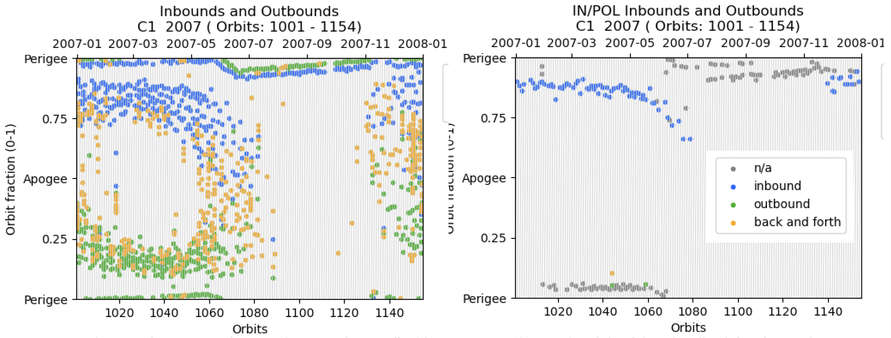
GRMB preliminary dataset: Year 2007 output for Cluster-1





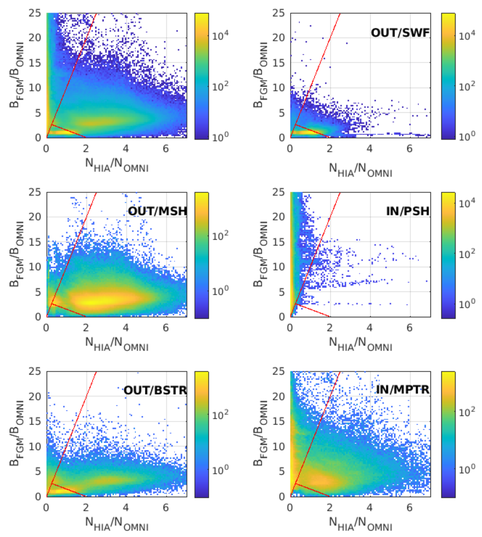
In 2007, C1 spent most of the time in the LOB, SWF, PSH and MSH regions





Inbound_vs_outbound crossings (left). Separation of mid-altitude (in blue) and high-altitude (in grey) polar regions (right).

Item properties: B and n



Two-dimensional histograms (2007/C1) of the magnetic field (FGM) divided by the IMF magnitude (OMNI) as a function of the density (CIS/HIA) divided by the solar wind density. The red lines correspond to separatrix between the magnetosphere (left), the solar wind (bottom left) and the magnetosheath (right) as defined by *Nguyen et al.* (2022, JGR).

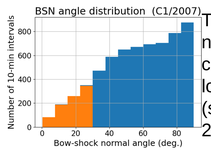
Methodology Validation

The comparisons with reference lists (magnetopause: *Trattner et al*. (ESA) with MPTR/MP/POL; bow shocks: *Kruparova* et al. (2007, JGR) with BSTR; cusps: *Pitout et al*. (2006) with POL; plasmapauses: *Darrouzet et al*. (2013, AnnGeo) with PPTR) show a very good agreement with the GRMB dataset (90%). The main limitation is the minimum resolution of the pre-generated plots (1-hour): some short back and forth boundary crossings are not detected.

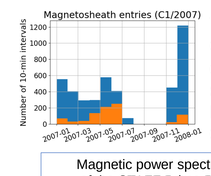
The comparison with the automatic list ECLAT (*Boakes et al*., 2006, JGR) is difficult due to the different time resolution (regions shorter than about 20 min are not resolved in the GRMB dataset).

IN/MSH insights

IN/MSH entries are split into 10-minutes interval.

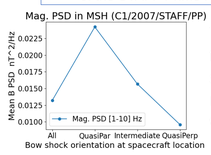


The bow shock normal angle is computed at the C1 location in IN/MSH (see *Soucek et al.*, 2014, JGR)

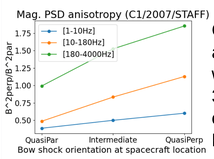


The BS angle: QuasiPar (0-30 deg), QuasiPerp (60-90 deg) and Intermediate (30-60 deg).

Magnetic power spectral density (PSD) of the STAFF Prime Parameters (PP).

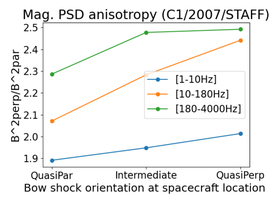


The high PSD in the quasi-parallel sector is probably related to turbulent wave activity.



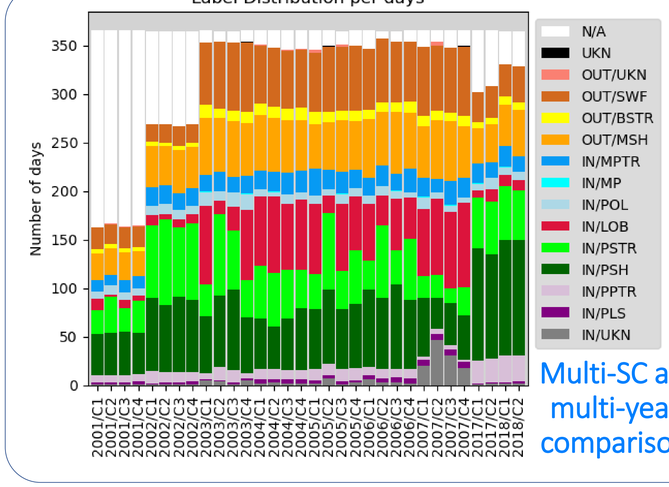
Comparison of the anisotropy of the wave activity in the 3 frequency bands of the Prime Parameters.

Magnetic wave activity in IN/MPTR, OUT/MSH , OUT/BSTR , and OUT/SWF



Entries are split in 10-minutes interval. In each frequency band of the STAFF PP the median value is the highest in the OUT/BSTR, and the lowest in OUT/SWF.

Label Distribution per days



Multi-SC and multi-years comparisons

Output: CEF file description

The CEF file of the GRMB dataset encloses seven variables :

- ***time tags*** : time interval [start ; end]
- ***location_label*** : GRMB item short name (string)
- ***location_code***: GRMB item index (int)
- *quality_location_label :* displayed panels at selection (string)
- *quality_location_code*: based on product availability (int)
- ***inbound_vs_oubound***: inbound or outbound crossing (int)
- *crossing_complexity*: operator's appreciation (bool)

Summary

The GRMB dataset will provide a continuous coverage of the Cluster location of each of the four spacecraft for the whole mission duration.

15 labels are considered.

The first years of the dataset (2001-2007) will be made available via the Cluster Science Archive (https://csa.esac.esa.int/csa-web) in May.

This dataset aims to support the scientific community not only by providing the location, but also to perform statistical studies. For example, the user can select the BSTR region to apply his/her own selection criteria for bow shock identification inside this transition region.

The realization of the GRMB dataset is funded by ESA Contract No. 4000139126/22/ES/CM Geospace Region and Magnetospheric Boundary Identification using the Cluster Science Archive C1/STAFF/ PP have been downloaded from AMDA (https://amda.irap.omp.eu/)

Cluster locations in the geospace revealed by the GRMB (Geospace Region and Magnetospheric Boundary) dataset

SM51E-2610

Benjamin **Grison**[1], Fabien Darrouzet[2], Romain Maggiolo[2], Mykhaylo Hayosh[1], Matthew G. Taylor[3]
(1) Institute of Atmospheric Physics (IAP) of the Czech Academy of Sciences, (2) Royal Belgian Institute for Space Aeronomy (BIRA-IASB), (3) ESA/ESTEC

Abstract:
The Cluster Mission consists of four identical spacecraft, each carrying 11 scientific experiments. The spacecraft were launched in July and August 2000 into near polar inclined, 19x4 R_E elliptic orbits and all four spacecraft are still in operation. The magnetosphere environment is highly dynamic and its regions cannot be accessed by the orbital information alone. The purpose of study is to develop a comprehensive dataset, providing information on Geospace Region and Magnetospheric Boundaries (GRMB) made for each of the four Cluster spacecraft, and deliver it to the Cluster Science Archive (CSA).
The GRMB dataset aims at providing a classification useful for the scientific community. For example, the methodology does not define what is a bow shock or what is a magnetopause. The goal is to have labeled regions that contain the bow-shocks or magnetopauses. And then each user can apply its own definition on the appropriate label subset.
The GRMB list contains two kind of items:

- **Region**: Magnetosheath, Lobe, Solar wind and foreshock, Plasmasheet, Plasmasphere
- **Transition regio**n (TR): Bow shock TR, Magnetopause TR, Polar Regions, Plasmasheet TR, Plasmapause TR

Transition regions can include properties matching several regions. For example, Bow shock TR can include short periods of solar wind or magnetosheath. Solar wind and magnetosheath should not include bow shock crossings.
The GRMB dataset is based on more than 40 data product available at CSA, taken from seven instrument suites. The methodology relies on the visual identification of the boundaries between two consecutive GRMB items.
The methodology and the criteria applied for the boundary identification are presented. The validation is made by comparing regions crossed by different spacecraft during the same period and by comparing the regions with published list of plasmapause, magnetopause, bow-shock crossings, etc... Comparisons made with output from ECLAT automatic classification method highlights the difference in visual classification and automatic classification.
The visualization of the regions crossed by the Cluster spacecraft during several years illustrates the scientific interest of this dataset. As a first application, the dataset is used to compare physical properties between regions.

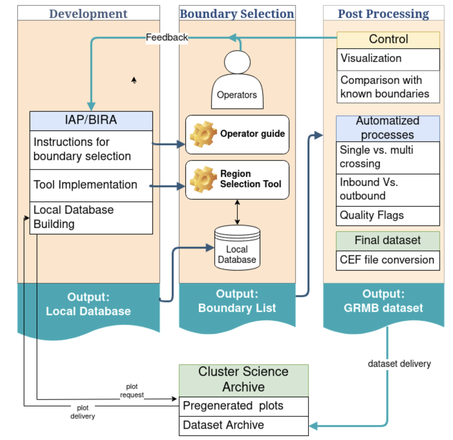
GRMB list: 15 items

Index	ShortName	Name
1	IN/UKN	INside the magnetosphere
2	IN/PLS	PLasmaSphere
3	IN/PPTR	PlasmaPause TR
4	IN/PSH	PlasmaSHeet
5	IN/PSTR	PlasmaSHeet TR
6	IN/LOB	LOBe
7	IN/MP	MagnetoPause
8	IN/MPTR	MagnetoPause TR
9	IN/POL	POLar Regions
10	OUT/MSH	MagnetoSHeath
11	OUT/BSTR	Bow Shock TR
12	OUT/SWF	Solar Wind and Foreshock
13	OUT/UKN	OUTside the magnetosphere
14	UNKOWN	Unknown
15	N/A	Void

Basic item description:
PLS: The plasma frequency is out of WHISPER range close to perigee
PPTR: the plasma density gradient close to perigee
PSH: high energy and isotropic plasma is observed
PSHTR is less homogeneous than PSH
LOB: low-plasma density region
MP: sharp magnetopause crossing
MPTR: complex magnetopause crossings
POL: magnetosheath-like plasma (+ energy dispersion) observed inside the magnetosphere

BSTR: (anti-)correlated abrupt changes in n, B (v) separating MSH and SWF

Methodology



This is a join project between IPA and BIRA.

Input: CSA pre-generated plots.

Output: Continuous coverage of the spacecraft location.

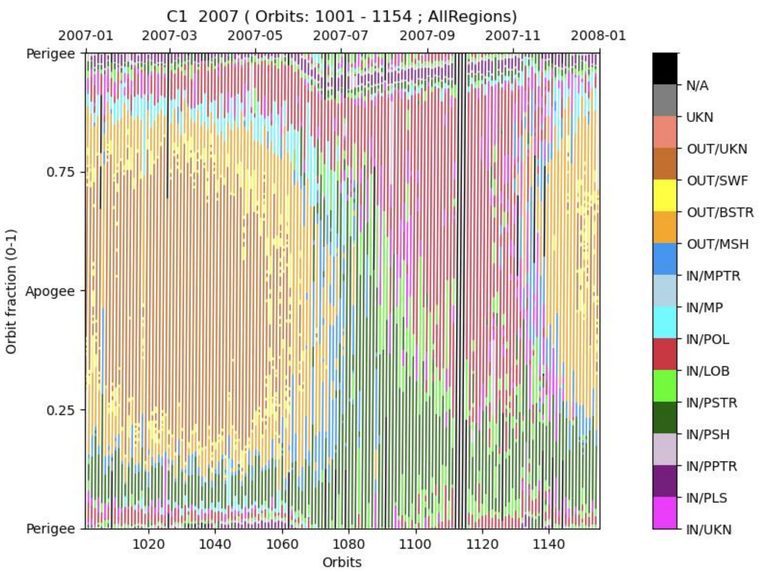
The plot time resolution is 1-day, 6 hours and 1 hour.

The dataset identifies sharp boundaries.

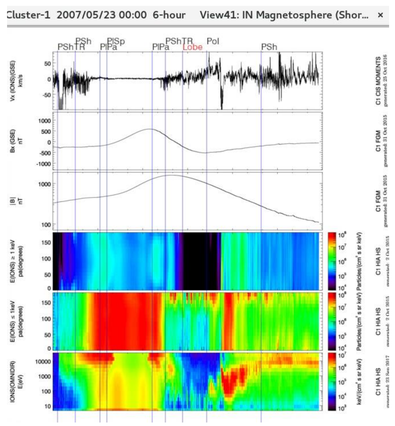
Otherwise, the time resolution is about 20 min.

Internal check relies on orbit comparisons and the order of region crossings.

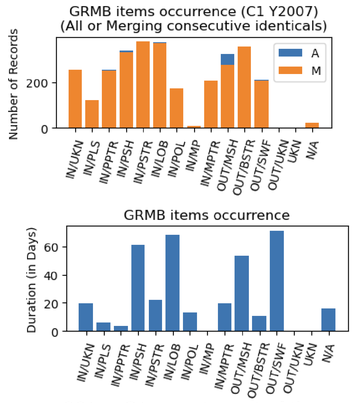
GRMB preliminary dataset: Year 2007 output for Cluster-1



Item Selection



Snapshot from the GRMB region selection tool software

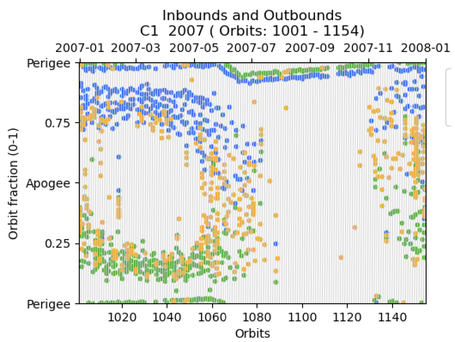


In 2017, C1 spent most of the time in the LOB, SWF, PSH and MSH regions

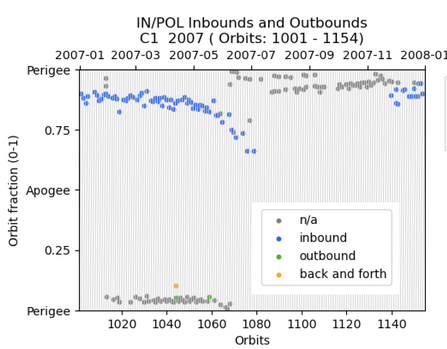
Output: CEF file description

The preliminary CEF file of the GRMB dataset encloses seven variables :

- ***time tags*** : time interval [start ; end]
- ***location_label*** : GRMB item short name (string)
- ***location_code***: GRMB item index (int)
- *quality_location_label :* displayed panels at selection (string)
- *quality_location_code*: GRMB item short name (string)
- ***inbound_value***: inbound or outbound crossing (int)
- *crossingcomplexity_value*: operator's appreciation (bool)



inbound_value is defined in accordance with the Cluster orbit



inbound_value also allows to separate mid-altitude (in blue) and high-altitude (in grey) polar regions

Methodology Validation

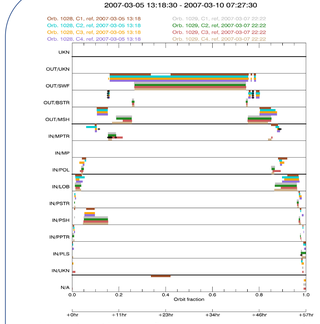
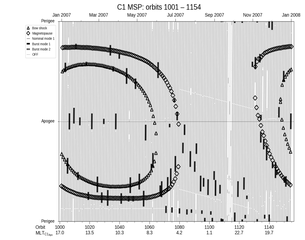


Illustration of comparison with reference list events (black circles)

PSH	ECLAT	match	PSTR	PSH	LOBE
C1	9812	6344 (65%)	3069 (31%)	6344 (65%)	<5%
C3	10420	6124 (59%)	3928 (38%)	6124 (59%)	<5%
PSTR	**ECLAT**	**match**	**PSTR**	**PSH**	**LOBE**
C1	10222	5985 (59%)	5985 (59%)	2346 (23%)	1650 (16%)
C3	9406	6570 (70%)	6570 (70%)	1840 (20 %)	748 (8%)
LOBE	**ECLAT**	**match**	**PSTR**	**PSH**	**LOBE**
C1	5287	1772 (33%)	3154 (60 %)	<7 %	1772 (33 %)
C3	4756	1045 (22%)	3184 (67 %)	<11%	1045 (22%)

Comparison with ECLAT dataset (year 2003)

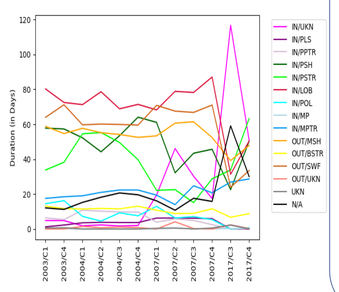


Comparison with Bryant's plot

The comparisons with reference lists (magnetopause: Trattner et al. (ESA); bow shocks: Kruparova et al. (2007); cusps: Pitout et al. (2006); plasmapauses: Darrouzet et al.(2013)) show a very good agreement with the GRMB dataset (90%). The main limitation is the minimum resolution of the pre-generated plots (1-hour): some short back and forth boundary crossings are not detected.

The comparison with the automatic list ECLAT (Boakes et al., 2006) is difficult due to the different time resolution (regions shorter than about 20 min are not resolved in the GRMB dataset).

Multi-SC and multi-years comparisons



Summary

The GRMB dataset will provide a continuous coverage of the Cluster location of each of the four spacecraft for the whole mission duration.

15 labels are considered.

The dataset will be made available via the Cluster Science Archive.

The visual selection is double-checked.

This dataset aims to support the scientific community not only by providing the location, but also to perform statistical studies. For example, the user can select the BSTR region to apply his/her own selection criteria for bow shock identification inside this transition region.

The realization of the GRMB dataset is funded by ESA Contract No. 4000139126/22/ES/CM Geospace Region and Magnetospheric Boundary Identification using the Cluster Science Archive