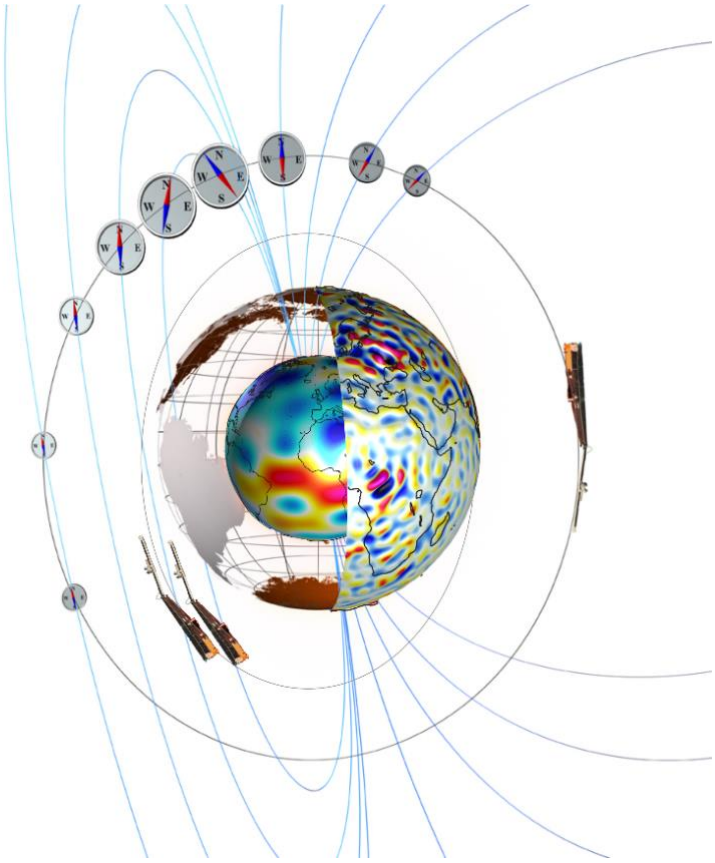
Data, Innovation, and Science Cluster

Swarm-PRISM Product Definition Document



Doc. no: SW-DS-GFZ-GS-003, Rev: 6, 08 Jul 2021

Prepared:

Balazs Heilig — Date 08 Jul 2021

Scientist

Approved: Claudia Stolle

Digitally signed by Claudia Stolle
Date: 2021.07.09 15:17:06 +02'00'

Claudia Stolle — Date 08 Jul 2021

Team Leader

Checked: Guram Kervalishvili

DN: cn=Guram Kervalishvili, o=GFZ German Research Centre for Geosciences, email=gmk@gfz-potsdam.de, c=DE
Date: 2021.07.09 15:00:54 +02'00'

Guram Kervalishvili — Date 08 Jul 2021

Scientist

Record of Changes

Reason	Description	Rev	Date
Initial vers.	Released.	1 dA	29 Jan 2020
Email from Line to Guram: 24.02.2020, 15h03	Text has been updated: sections 2.3, 3 and 4. Product descriptions have been updated: sections 4.1, 4.2 and 4.3.	1 dB	10 Mar 2020
Signature		1	11 Mar 2020
Updated input from GFZ	Updates in sections, 4.1, 4.2 and 4.3: capital letters in the Description; Dim, Uni and Notes; variable name “Position quality_ID” was changed to “Position_Quality_ID”, respectively; In sections 4.1 and 4.2: variable names “Poleward gradient” and “Equatorward gradient”, were changed to “PW_Gradient” and “EW_Gradient”, respectively. In section 4.1: variable name “Density drop rate” was changed to “DDR. In section 4.2: variable name “TEC drop rate” was changed to “TDR”. In section 4.3: variable name “PPI counter”, was changed to “Counter”.	2 dA	27 Apr 2020
Updated input from GFZ	Minor text updates in some parts of the text. Two new applicable documents are added (section 2.1). Abbreviation list is updated (section 2.3). Tables in sections 4.1, 4.2, 4.3 and have been updated.	2 dB	28 Oct 2020
Signature		2	30 Oct 2020
Email from Klaus to Guram: 04.11.2020 13h16	Sections 4.1, 4.2 and 4.3: Position_Quality_ID and Quality type changed to CDF_INT1; data volume text is updated. Sections 4.1 and 4.2: in Quality indicator the text description of Position_Quality_ID is updated.	3 dA	09 Nov 2020
Email from Lars to Guram: 10.11.2020 11h21	Sections 4.1, 4.2 and 4.3: Notes are updated (#4). Section 4.3: variable name “sigma” changed to “Sigma”	3 dB	11 Nov 2020

Reason	Description	Rev	Date
Email from Lars to Guram: 11.11.2020 15h37	Sections 4.1, 4.2 and 4.3: SZA and SZA_ID variable ordering is updated. Sections 4.1, 4.2 and 4.3: Notes are updated (#4).	3 dC	12 Nov 2020
Updated input from GFZ	Minor text updates in some parts of the text and tables.	3 dD	05 Mar 2021
Signature		3	18 Mar 2021
Email from Klaus to Guram: 26.04.2021 12h47	Section 2.3 is updated. Sections 4.1, 4.2 and 4.3 are updated: table describing **Quality** in **Quality indicator** is moved and placed after the main table.	3 dA	03 May 2021
Signature		4	04 May 2021
Email from Klaus to Guram: 09.06.2021 10h05	Minor text updates according to reviewers' comments.	4 dA	18 Jun 2021
Signature		5	25 Jun 2021
Email from Klaus to Guram: 05.07.2021 11h45	The "Counter" variable description is updated in sections 4.1, 4.2 and 4.3 with the following text "… that are based on magnetic coordinates …".	5 dA	08 Jul 2021
Signature		6	08 Jul 2021

Table of Contents

1 Introduction

1.1 Scope and applicability

This document comprises the Description of Swarm Level 2 (L2) Swarm-PRISM products **MITx_LP_2F**, **MITxTEC_2F** and **PPIxFAC_2F** in response to the requirements of [AD-1].

Current or updated version of this document is available in the SVN folder: https://smart-svn.spacecenter.dk/svn/smart/SwarmDISC/DISC_Projects/ITT2_2_PRISM/Deliverables/.

2 Applicable and Reference Documentation.

2.1 Applicable Documents

The following documents are applicable to the definitions within this document.

[AD-1] SW-OF-GFZ-GS-122_2-2_PRISM_Proposal, Proposal for Swarm DISC ITT 2.2, Swarm-PRISM – Plasmapause Related boundaries in the topside Ionosphere as derived from Swarm Measurements.

[AD-2] SW-DS-GFZ-GS-006_2-2_PRISM_DPA, Swarm-PRISM Description of the Processing Algorithm.

[AD-3] SW-DS-GFZ-GS-007_2-2_PRISM_VR, Swarm-PRISM Validation Report.

[AD-4] CDF User's Guide, Version 3.7.1, February 20, 2019, Space Physics Data Facility, NASA / Goddard Space Flight Center, Greenbelt, Maryland 20771 (U.S.A.) available at https://spdf.gsfc.nasa.gov/pub/software/cdf/doc/cdf371/cdf371ug.pdf.

2.2 Reference Documents

The following documents contain supporting and background information to be taken into account during the activities specified within this document.

[RD-1] Grebowsky, J. M., Maynard, N. C., Tulunay, Y. K. and Lanzerotti, L. J. (1976), Coincident observations of ionospheric troughs and the equatorial plasmapause, Planet. Space Sci., 24 (12), 1177-1185, doi: 10.1016/0032-0633(76)90154-9.

[RD-2] Heilig, B. and Lühr, H. (2013), New plasmapause model derived from CHAMP field-aligned current signatures, Ann. Geophys., 31, 529-539, doi: 10.5194/angeo-31-529-2013

[RD-3] Heilig, B. and Lühr, H. (2018), Quantifying the relationship between the plasmapause and the inner boundary of small-scale field-aligned currents, as deduced from Swarm observations, Ann. Geophys. 36, 595-607, doi: 10.5194/angeo-36-595-2018

[RD-4] Lomidze, L., Knudsen, D. J., Burchill, J., Kouznetsov, A., and Buchert, S. C. (2018), Calibration and validation of Swarm plasma densities and electron temperatures using ground-based radars and satellite radio occultation measurements, Radio Science, 53, 15– 36, doi: 10.1002/2017RS006415.

[RD-5] Pedatella, N. M. and Larson, K. M. (2010), Routine determination of the plasmapause based on COSMIC GPS total electron content observations of the midlatitude trough, J. Geophys. Res., 115, A09301, doi: 10.1029/2010JA015265

[RD-6] Prölss, G. W. (2006), Subauroral electron temperature enhancement in the nighttime ionosphere, Ann. Geophys., 24, 1871-1885, doi: 10.5194/angeo-24-1871-2006

[RD-7] Yizengaw, E., Wei, H., Moldwin, M. B., Galvan, D., Mandrake, L., Mannucci, A. and Pi, X. (2005), The correlation between mid-latitude trough and the plasmapause, Geophys. Res. Lett., 32, L10102, doi: 10.1029/2005GL022954

2.3 Abbreviations

A list of acronyms and abbreviations used by Swarm partners can be found here. Some acronyms or abbreviations specific to this document can be found below.

Acronym ***or abbreviation***	***Description***
AD	Applicable Document
AOB	Auroral Oval Boundaries
Aux	Auxiliary
EW	EquatorWard
GEO	Spherical GEOgraphic Reference Frame
FAC	Field-Aligned Current
h_R	Reference height, 110 km
L-value	The McIlwain L-parameter, distance of the field line apex from the centre of the Earth measured in Earth radii
MB	megabyte
MIT	Midlatitude Ionospheric Trough
Ne	electron number density
PP	PlasmaPause
PPI	PP Index
PRISM	Plasmapause Related boundaries in the topside Ionosphere as derived from Swarm Measurements
PW	PoleWard
R_E	Earth radius, 6371.2 km
RD	Reference Document
ROC	Rate Of Change
SETE	Subauroral Electron Temperature Enhancement
SSFAC	Small-Scale FAC
SZA	Solar Zenith Angle

Acronym ***or abbreviation***	***Description***
Te	electron temperature
WSA	Weddell-See Anomaly

3 Product Summary

The Swarm-PRISM [AD-1] product package consists of two independent groups of L2 products. The **MITx_LP_2F** and **MITxTEC_2F** products contain information on the location, size and shape (minimum, depth, width, poleward/equatorward edges of the poleward/equatorward walls) of the Midlatitude Ionospheric Trough [RD-1] [RD-5] [RD-7] both in geographic and QD magnetic coordinates, as well as in L-value , the corresponding LP measurements (Te, Ne) [RD-4] [RD-6], as well as auxiliary data. The **PPIxFAC_2F** product contains the equatorward boundary of SSFACs derived from FAC observations [RD-2], and the associated midnight Plasmapause index [RD-3], derived from SSFAC boundary position, an empirical SSFAC boundary model [RD-2] and adjusted for the SSFAC boundary and PP difference [RD-2].

MITx_LP_2F, **MITxTEC_2F** and **PPIxFAC_2F** products come as yearly files. Detailed descriptions of these products are provided in sections 4.1, 4.2 and 4.3, respectively.

4 Specification of Products

This section contains the detailed description of the Swarm-PRISM product package. The **MITx_LP_2F** and **MITxTEC_2F** products are described in Sections 4.1 and 4.2. The description of the **PPIxFAC_2F** product will be given in Section 4.3

4.1 Midlatitude Ionospheric Trough from Langmuir Probe

<table>
<tr><td>Product identifier</td><td>MITx_LP_2F</td></tr>
<tr><td>Definition</td><td>Midlatitude Ionospheric Trough Boundaries and Minima</td></tr>
<tr><td>Input Data</td><td>EFIx_LP_1B[1], TECxTMS_2F[1], FACxTMS_2F[1], AOBxFAC_2F[1], AUXxORBCNT</td></tr>
<tr><td>Input Time Span</td><td>Up to one year[2]</td></tr>
<tr><td>Spatial representation</td><td>One geographic and QD-latitude/longitude pair, the McIlwain L-value as well as radius for each output position at the nearest LP measurement for each trough crossing, i.e., up to four per orbit.</td></tr>
<tr><td>Time representation</td><td>Up to four records per orbit (up to one record per orbit quarter)</td></tr>
<tr><td>Units</td><td>see at Output Data below</td></tr>
<tr><td>Resolution</td><td>0.1 degree for coordinates, 0.01 for L-value</td></tr>
<tr><td>Uncertainty</td><td>~1° for coordinates, ~0.1 for L-value</td></tr>
<tr><td>Quality indicator</td><td>Quality vector flag values are integers ranging from 3 to -1. Positive values indicate good or acceptable observation, while -1 means a likely false observation. For all flags, a 0 value means that the information needed to derive the flag is not available. In general, greater numbers indicate higher quality. A detailed description of the derivation of these flags is given in [AD-2].
Position_Quality_ID describes the overall quality of the corresponding boundary/position identified by ID. The possible values and their meaning are 3: highest quality; 2: fair quality; 1: uncertain detection; -1: a likely false positive detection; -2: the corresponding boundary/position is not defined. A detailed description of the derivation of these flags is given in [AD-2].</td></tr>
<tr><td>Data volume</td><td>Up to 4.2 MB</td></tr>
<tr><td>Data format</td><td>CDF</td></tr>
<tr><td>Output Data</td><td>
<table>
<tr><th>Variable Name</th><th>Type</th><th>Dim</th><th>Unit</th><th>Description</th></tr>
<tr><td>Timestamp</td><td>CDF_EPOCH</td><td>1</td><td>ms</td><td>Time of observation, UTC</td></tr>
<tr><td>Counter</td><td>CDF_UINT4</td><td>2</td><td>-</td><td>Swarm orbit counter and quarter orbit (four per Swarm orbit) counter that are based on magnetic coordinates as defined in [AD-2] (Sect. 4.1.2.2)</td></tr>
<tr><td>Latitude</td><td>CDF_DOUBLE</td><td>1</td><td>deg</td><td>Position of the MIT minimum in ITRF – Geocentric latitude</td></tr>
<tr><td>Longitude</td><td>CDF_DOUBLE</td><td>1</td><td>deg</td><td>Position of the MIT minimum in ITRF – Geocentric longitude</td></tr>
</table>
</td></tr>
</table>

Product identifier	MITx_LP_2F				
	Radius	CDF_DOUBLE	1	m	Position of the MIT minimum in ITRF – Geocentric radius (from the Earth centre)
	Latitude_QD	CDF_DOUBLE	1	deg	QD latitude of the MIT minimum
	Longitude_QD	CDF_DOUBLE	1	deg	QD longitude of the MIT minimum
	MLT	CDF_DOUBLE	1	h	Magnetic Local Time of the MIT minimum
	L_value	CDF_DOUBLE	1	-	L-value of the MIT minimum
	SZA	CDF_DOUBLE	1	deg	Solar zenith angle of the MIT minimum
	Ne	CDF_DOUBLE	1	cm^{-3}	LP electron density of the MIT minimum
	Te	CDF_DOUBLE	1	K	LP electron temperature of the MIT minimum
	Depth	CDF_DOUBLE	1	cm^{-3}	Depth of the MIT
	DR	CDF_DOUBLE	1	%	Relative change in density within the MIT
	Width	CDF_DOUBLE	1	deg	Width of the MIT calculated from QD latitudes
	dL	CDF_DOUBLE	1	-	Width of the MIT calculated from L-values
	PW_Gradient	CDF_DOUBLE	1	$log(cm^{-3})/deg$	Change in log electron density at the poleward wall of the MIT divided by QD latitude difference
	EW_Gradient	CDF_DOUBLE	1	$log(cm^{-3})/deg$	Change in log electron density at the equatorward wall of the MIT divided by QD latitude difference
	Quality	CDF_INT1	8	-	Characterises the detection quality of the MIT as a whole (see quality indicator)
	Timestamp_ID[3, 4]	CDF_EPOCH	7	ms	Vector of times of observation, UTC
	Latitude_ID	CDF_DOUBLE	7	deg	Vector of positions in ITRF – Geocentric latitude
	Longitude_ID	CDF_DOUBLE	7	deg	Vector of positions in ITRF – Geocentric longitude

<table>
<tr><td>Product identifier</td><td>MITx_LP_2F
<table>
<tr><td>Radius_ID</td><td>CDF_DOUBLE</td><td>7</td><td>m</td><td>Vector of positions in ITRF – Geocentric radius (from the Earth centre)</td></tr>
<tr><td>Latitude_QD_ID</td><td>CDF_DOUBLE</td><td>7</td><td>deg</td><td>Vector of QD latitudes</td></tr>
<tr><td>Longitude_QD_ID</td><td>CDF_DOUBLE</td><td>7</td><td>deg</td><td>Vector of QD longitudes</td></tr>
<tr><td>MLT_ID</td><td>CDF_DOUBLE</td><td>7</td><td>h</td><td>Vector of Magnetic Local Times</td></tr>
<tr><td>L_value_ID</td><td>CDF_DOUBLE</td><td>7</td><td>-</td><td>Vector of L-values in Earth radii</td></tr>
<tr><td>SZA_ID</td><td>CDF_DOUBLE</td><td>7</td><td>deg</td><td>Vector of solar zenith angles</td></tr>
<tr><td>Ne_ID</td><td>CDF_DOUBLE</td><td>7</td><td>cm^{-3}</td><td>Vector of LP electron densities</td></tr>
<tr><td>Te_ID</td><td>CDF_DOUBLE</td><td>7</td><td>K</td><td>Vector of LP electron temperatures</td></tr>
<tr><td>Position_Quality_ID</td><td>CDF_INT1</td><td>7</td><td>-</td><td>Vector of quality indicators characterising the detection quality of each single positions (see Quality indicator)</td></tr>
</table></td></tr>
<tr><td>Output time span</td><td>Up to one year[2]</td></tr>
<tr><td>Update rate</td><td>Daily</td></tr>
<tr><td>Latency</td><td>< 5 minutes</td></tr>
<tr><td>Notes</td><td>[1] Version information of Input Data are available in the CDF global attributes.
[2] Product always contains data from the start of the first boundary crossing of the first day until the end of the last boundary-crossing starting the latest day available for that year, i.e., may contain data from the next day if boundary crossing occurs around midnight.
[3] The meaning of ID:
1 – LP MIT equatorward edge of the equatorward wall
2 – LP MIT poleward edge of the equatorward wall
3 – LP MIT equatorward edge of poleward wall
4 – LP MIT poleward edge of the poleward boundary
5 – LP SETE equatorward bounding position
6 – LP Te peak position
7 – LP SETE poleward bounding position
[4] NaN values: if an ID is not identified Timestamp_ID is set to {the value of} Timestamp and corresponding variable values will be set to NaNs, while the corresponding Position_Quality_ID is set to -2.</td></tr>
</table>

The meaning of the elements of the **Quality** vector of flags for the above table (see **Quality indicator**) is given below (a detailed description of their derivation is given in [AD-2]).

Position	Name	Description
1	Flag_MIT	The main flag characterising the overall quality of the product. It is derived from the other flags and other information. 3: highest quality, 2: fair quality, 1: uncertain detection, 0: no quality information available, -1: likely false positive detection)
2	Flag_PPI	Based on the L-value distance between the SSFAC boundary and the MIT minimum. Since, this difference highly depends on MLT, first, the linear MLT-trend is removed. The flag thresholds are associated with the [0.025 0.10 0.25 0.75 0.90 0.975] quantiles of the detrended difference. The quantiles-defined intervals ([0.0025 0.10], [0.10 0.25], [0.25 0.75], etc.) correspond to the 1, 2, 3, 2, 1 flag values, respectively
3	Flag_ROC	Based on the rate of change (change per orbit) of the L-value of the MIT mini-mum. The flags 3, 2, and 1 are derived from the ROC the same way as for Flag_PPI, and in addition, ROC value below the 0.025 or above the 0.975 quantiles is flagged by -1. To derive Flag_ROC, first, the available closest of the three preceding observation is used to define a flag (Flag_ROCa). Then similarly, a flag corresponding to the change between the current and the following orbit (Flag_ROCp) is calculated. The maximum of the two (Flag_ROCa and Flag_ROCp) is taken as Flag_ROC
4	Flag_TEC	Based on the L-value distance between the MIT minima derived from LP and TEC observations. The flag is derived the same way as Flag PPI. A detrended difference below the 0.025 or above the 0.975 quantiles is flagged by -1
5	Flag_Te	Gives information on the relative position (L-value) of the Te peak wrt the MIT. This flag is 3 when the Te peak is within the MIT and closer than 0.5 to the MIT minimum, otherwise, if the peak is inside the MIT but the distance is greater than 0.5, the flag value is 2. A value 1 means the Te peak is outside the MIT but closer to its edge than 0.5. -1 indicates that the Te peak is further than 0.5 from MIT
6	Flag_AOB	Depends on the mutual position of the AOB boundary and the MIT minimum (1: AOB is poleward of the MIT minimum, -1: otherwise)
7	Flag_SZA	Calculated from the solar zenith angle at the MIT minimum (3: SZA>110°; 2: 110≥SZA>100°, 1: 100≥SZA>90°; -1: SZA≤90°)
8	Flag_WSA	Indicates if the detection is made in the region potentially affected by the Weddell-See ionisation Anomaly. 1: detection outside the risk region, -1: detection in-side the risk region. The region potentially affected by the WSA is defined with the following parameters: QD_Longitude is between 10° W and 150° W, QD_Longitude is between 30° S and 55° S, and day of the year is ≤90 or ≥305

4.2 Midlatitude Ionospheric Trough from GPS TEC

Product identifier	MITxTEC_2F
Definition	Midlatitude Ionospheric Trough Boundaries and Minima from TEC
Input Data	TECxTMS_2F[1], EFIx_LP_1B[1], FACxTMS_2F[1], AOBxFAC_2F[1], AUXxORBCNT
Input Time Span	Up to one year[2]
Spatial representation	One geographic and QD-latitude/longitude pair, the McIlwain L-value as well as radius for each output position at the nearest TEC measurement for each trough crossing, i.e., up to four per orbit.
Time representation	Up to four records per orbit (up to one record per orbit quarter)
Units	see at Output Data below

<table>
<tr><td>Product identifier</td><td>MITxTEC_2F</td></tr>
<tr><td>Resolution</td><td>0.1 degree for coordinates, 0.01 for L-value</td></tr>
<tr><td>Uncertainty</td><td>~1 degree for coordinates, ~0.1 for L-value</td></tr>
<tr><td>Quality indicator</td><td>Quality vector flag values are integers ranging from 3 to -1. Positive values indicate good or acceptable observation, while -1 means a likely false observation. For all flags, a 0 value means that the information needed to derive the flag is not available. In general, greater numbers indicate higher quality. A detailed description of the derivation of these flags is given in [AD-2].
Position_Quality_ID describes the overall quality of the corresponding boundary/position identified by ID. The possible values and their meaning are 3: highest quality; 2: fair quality; 1: uncertain detection; -1: a likely false positive detection; -2: the corresponding boundary/position is not defined. A detailed description of the derivation of these flags is given in [AD-2].</td></tr>
<tr><td>Data volume</td><td>Up to 2.5 MB</td></tr>
<tr><td>Data format</td><td>CDF</td></tr>
<tr><td>Output Data</td><td>
<table>
<tr><th>Variable Name</th><th>Type</th><th>Dim</th><th>Unit</th><th>Description</th></tr>
<tr><td>Timestamp</td><td>CDF_EPOCH</td><td>1</td><td>ms</td><td>Time of observation, UTC</td></tr>
<tr><td>Counter</td><td>CDF_UINT4</td><td>2</td><td>-</td><td>Swarm orbit counter and quarter orbit (four per Swarm orbit) counter that are based on magnetic coordinates as defined in [AD-2] (Sect. 4.1.2.2)</td></tr>
<tr><td>Latitude</td><td>CDF_DOUBLE</td><td>1</td><td>deg</td><td>Position of the MIT minimum in ITRF – Geocentric latitude</td></tr>
<tr><td>Longitude</td><td>CDF_DOUBLE</td><td>1</td><td>deg</td><td>Position of the MIT minimum in ITRF – Geocentric longitude</td></tr>
<tr><td>Radius</td><td>CDF_DOUBLE</td><td>1</td><td>m</td><td>Position of the MIT minimum in ITRF – Geocentric radius (from the Earth centre)</td></tr>
<tr><td>Latitude_QD</td><td>CDF_DOUBLE</td><td>1</td><td>deg</td><td>QD latitude of the MIT minimum</td></tr>
<tr><td>Longitude_QD</td><td>CDF_DOUBLE</td><td>1</td><td>deg</td><td>QD longitude of the MIT minimum</td></tr>
<tr><td>MLT</td><td>CDF_DOUBLE</td><td>1</td><td>h</td><td>Magnetic Local Time of the MIT minimum</td></tr>
<tr><td>L_value</td><td>CDF_DOUBLE</td><td>1</td><td>-</td><td>L-value of the MIT minimum</td></tr>
<tr><td>SZA</td><td>CDF_DOUBLE</td><td>1</td><td>deg</td><td>Solar zenith angle of the MIT minimum</td></tr>
<tr><td>TEC</td><td>CDF_DOUBLE</td><td>1</td><td>TECU</td><td>Total electron content at the MIT minimum</td></tr>
<tr><td>Depth</td><td>CDF_DOUBLE</td><td>1</td><td>TECU</td><td>Depth of the MIT</td></tr>
</table>
</td></tr>
</table>

Product identifier	MITxTEC_2F				
	DR	CDF_DOUBLE	1	%	Relative change in density within the MIT
	Width	CDF_DOUBLE	1	deg	Width of the MIT calculated from QD latitudes
	dL	CDF_DOUBLE	1	-	Width of the MIT calculated from L-values
	PW_Gradient	CDF_DOUBLE	1	TECU /deg	Change in TEC at the poleward wall of the MIT divided by QD latitude difference
	EW_Gradient	CDF_DOUBLE	1	TECU /deg	Change in TEC at the equatorward wall of the MIT divided by QD latitude difference
	Quality	CDF_INT1	8	-	Characterises the detection quality of the MIT as a whole (see quality indicator)
	Timestamp_ID[3, 4]	CDF_EPOCH	4	ms	Vector of times of observation, UTC
	Latitude_ID	CDF_DOUBLE	4	deg	Vector of positions in ITRF – Geocentric latitude
	Longitude_ID	CDF_DOUBLE	4	deg	Vector of positions in ITRF – Geocentric longitude
	Radius_ID	CDF_DOUBLE	4	m	Vector of positions in ITRF – Geocentric radius (from the Earth centre)
	Latitude_QD_ID	CDF_DOUBLE	4	deg	Vector of QD latitudes
	Longitude_QD_ID	CDF_DOUBLE	4	deg	Vector of QD longitudes
	MLT_ID	CDF_DOUBLE	4	h	Vector of Magnetic Local Times
	L_value_ID	CDF_DOUBLE	4	-	Vector of L-values in Earth radii
	SZA_ID	CDF_DOUBLE	4	deg	Vector of solar zenith angles
	TEC_ID	CDF_DOUBLE	4	TECU	Vector of TEC values
	Position_Quality_ID	CDF_INT1	4	-	Vector of quality indicators characterising the detection quality of each single positions (see Quality indicator)
Output time span	Up to one year[2]				
Update rate	Daily				
Latency	< 5 minutes				
Notes	[1] Version information of Input Data are available in the CDF global attributes.				

Product identifier	MITxTEC_2F
	[2] Product always contain data from the start of the first boundary crossing of the first day until the end of the last boundary crossing starting the latest day available for that year, i.e., may contain data from the next day if boundary crossing occurs around midnight. [3] The meaning of ID: 1 – TEC MIT equatorward edge of the equatorward wall 2 – TEC MIT poleward edge of the equatorward wall 3 – TEC MIT equatorward edge of poleward wall 4 – TEC MIT poleward edge of the poleward boundary [4] NaN values: if an ID is not identified Timestamp_ID is set to {the value of} Timestamp and corresponding variable values will be set to NaNs.

The meaning of the elements of the **Quality** vector of flags for the above table (see **Quality indicator**) is given below (a detailed description of their derivation is given in [AD-2]).

Position	Name	Description
1	Flag_MIT	The main flag characterising the overall quality of the product. It is derived from the other flags and other information. 3: highest quality, 2: fair quality, 1: uncertain detection, 0: no quality information available, -1: likely false positive detection)
2	Flag_PPI	Based on the L-value distance between the SSFAC boundary and the MIT minimum. Since, this difference highly depends on MLT, first, this linear trend is removed. The flag thresholds are the [0.025 0.10 0.25 0.75 0.90 0.975] quantiles of the detrended difference derived from statistics. The quantiles-defined intervals correspond to the 1, 2, 3, 2, 1 flag values, respectively
3	Flag_ROC	Based on the rate of change (change per orbit) of the L-value of the MIT minimum. The flags 3, 2, and 1 are derived from the ROC the same way as for Flag_PPI, and in addition, ROC value below the 0.025 or above the 0.975 quantiles is flagged by -1. To derive Flag_ROC, first, the available closest of the three preceding observation is used to define a flag (Flag_ROCa). Then similarly, a flag corresponding to the change between the current and the following orbit (Flag_ROCp) is calculated. The maximum of the two (Flag_ROCa and Flag_ROCp) is taken as Flag_ROC
4	Flag_Ne	Based on the L-value distance between the MIT minima derived from LP and TEC observations. The flag is derived the same way as Flag PPI. A detrended difference below the 0.025 or above the 0.975 quantiles is flagged by -1
5	Flag_Te	Gives information on the relative position (L-value) of the LP Te peak wrt the MIT. This flag is 3 when the Te peak is within the MIT and closer than 0.5 to the MIT minimum, otherwise, if the peak is inside the MIT but the distance is greater than 0.5, the flag value is 2. A value 1 means the Te peak is outside the MIT but closer to its edge than 0.5. -1 indicates that the Te peak is further than 0.5 from MIT
6	Flag_AOB	Depends on the mutual position of the AOB boundary and the MIT minimum (1: AOB is poleward of the MIT minimum, -1: otherwise)
7	Flag_SZA	Calculated from the solar zenith angle at the MIT minimum (3: SZA>110°; 2: 110≥SZA>100°, 1: 100≥SZA>90°; -1: SZA≤90°)

Position	Name	Description
8	Flag_WSA	Indicates if the detection is made in the region potentially affected by the Weddell-See ionisation Anomaly. 1: detection outside the risk region, -1: detection in-side the risk region. The region potentially affected by the WSA is defined with the following parameters: QD_Longitude is between 10° W and 150° W, QD_Longitude is between 30° S and 55° S, and day of the year is ≤90 or ≥305

4.3 Midnight Plasmapause Index

Product identifier	**PPIxFAC_2F**
Definition	Equatorward boundary of SSFACs and the associated midnight PP index
Input Data	FACxTMS_2F[1], EFIx_LP_1B[1], TECxTMS_2F[1], AOBxFAC_2F[1], AUXxORBCNT
Input Time Span	Up to one year[2]
Spatial representation	One geographic and QD-latitude/longitude pair, the McIlwain L-value as well as radius for each output position at the nearest FAC measurement for each trough crossing, i.e., up to four per orbit.
Time representation	Up to four records per orbit (up to one record per orbit quarter)
Units	see at Output Data below
Resolution	0.1 degree for coordinates, 0.01 for L-value
Uncertainty	~1 degree for coordinates, ~0.1 for L-value
Quality indicator	**Quality** vector flag values are integers ranging from 3 to -1. Positive values indicate good or acceptable observation, while -1 means a likely false observation. For all flags, a 0 value means that the information needed to derive the flag is not available. In general, greater numbers indicate higher quality. A detailed description of the derivation of these flags is given in [AD-2]. **Position_Quality_ID** describes the overall quality of the corresponding boundary/position identified by ID. These flags are defined based on the parameter's sigma and SZA. 3: sigma<0.25, 2: 0.25≤sigma<0.5, 1: 0.5≤sigma AND SZA>90°, -1: 0.5≤sigma AND SZA≤90°.
Data volume	Up to 1.9 MB
Data format	CDF
Output Data	

Variable Name	Type	Dim	Unit	Description
Timestamp	CDF_EPOCH	1	ms	Time of observation of the SSFAC boundary, UTC
Counter	CDF_UINT4	2	-	Swarm orbit counter and quarter orbit (four per Swarm orbit) counter that are based on magnetic coordinates as defined in [AD-2] (Sect. 4.1.2.2)
Latitude	CDF_DOUBLE	1	deg	Position of the SSFAC boundary in ITRF – Geocentric latitude

Product identifier	PPIxFAC_2F				
	Longitude	CDF_DOUBLE	1	deg	Position of the SSFAC boundary in ITRF – Geocentric longitude
	Radius	CDF_DOUBLE	1	m	Position of the SSFAC boundary in ITRF – Geocentric radius (from the Earth centre)
	Latitude_QD	CDF_DOUBLE	1	deg	QD latitude of the SSFAC boundary
	Longitude_QD	CDF_DOUBLE	1	deg	QD longitude of the SSFAC boundary
	MLT	CDF_DOUBLE	1	h	Magnetic Local Time of the SSFAC boundary
	L_value	CDF_DOUBLE	1	R_E	L-value of the SSFAC boundary
	SZA	CDF_DOUBLE	1	deg	Solar zenith angle of the SSFAC boundary
	dL	CDF_DOUBLE	1	-	Boundary width in Earth radii
	Sigma	CDF_DOUBLE	1	-	Standard deviation of the linear fit of S at the boundary [RD-2]
	PPI	CDF_DOUBLE	1	R_E	Midnight Plasmapause index
	Quality	CDF_INT1	7	-	Quality indicators of SSFAC boundary detection (see quality indicator)
	Timestamp_ID[3]	CDF_EPOCH	2	ms	Time vector of observations, UTC
	Latitude_ID	CDF_DOUBLE	2	deg	Position in ITRF – Geocentric latitude
	Longitude_ID	CDF_DOUBLE	2	deg	Position in ITRF – Geocentric longitude
	Radius_ID	CDF_DOUBLE	2	m	Position in ITRF – Geocentric radius (from the Earth centre)
	Latitude_QD_ID	CDF_DOUBLE	2	deg	QD latitude
	Longitude_QD_ID	CDF_DOUBLE	2	deg	QD longitude
	MLT_ID	CDF_DOUBLE	2	h	Magnetic Local Time
	L_value_ID	CDF_DOUBLE	2	-	L-value in Earth radii
	SZA_ID	CDF_DOUBLE	2	deg	Solar zenith angle
	Position_Quality_ID	CDF_INT1	2	-	Vector of quality indicators characterising the detection quality of each single positions (see quality indicator)

Product identifier	PPIxFAC_2F
Output time span	Up to one year[2]
Update rate	Daily
Latency	< 5 minutes
Notes	[1] Version information of Input Data are available in the CDF global attributes. [2] Product always contain data from the start of the first boundary crossing of the first day until the end of the last boundary crossing starting the latest day available for that, i.e., may contain data from the next day if boundary crossing occurs around midnight. [3] The meaning of ID: 1 – Equatorward edge of SSFAC boundary 2 – Poleward edge of SSFAC boundary [4] NaN values: if an ID is not identified Timestamp_ID is set to {the value of} Timestamp and corresponding variable values will be set to NaNs.

The meaning of the elements of the **Quality** vector of flags for the above table (see **Quality indicator**) is given below (a detailed description of their derivation is given in [AD-2]).

Position	Name	Description
1	Flag_PPI	The main flag characterising the overall quality of the product. It is derived from the other flags and other information. 3: highest quality, 2: fair quality, 1: uncertain detection, 0: no quality information available, -1: likely false positive detection
2	Flag_ROC	Based on the rate of change (change per orbit) of the L-value of the SSFAC boundary. The flag thresholds are the [0 0.025 0.10 0.25 0.75 0.90 0.975 1] quantiles of the ROC values derived from statistics. The quantiles-defined intervals correspond to the -1, 1, 2, 3, 2, 1, -1 flag values, respectively. To derive Flag_ROC, first, the available closest of the three preceding observation is used to define a flag (Flag_ROCa). Then similarly, a flag corresponding to the change between the current and the following orbit (Flag_ROCp) is calculated. The maximum of the two (Flag_ROCa and Flag_ROCp) is taken as Flag_ROC
3	Flag_Ne	Based on the L-value distance between the SSFAC boundary and MIT minimum derived from LP observations. Since this difference is highly depends on MLT, first, this linear trend is removed. The flag thresholds (quantiles) and the associated flag values are the same as for Flag_ROC
4	Flag_Te	Based on the L-value distance between the SSFAC boundary and the Te peak derived from LP observations. The flag is derived the same way as Flag Ne
5	Flag_TEC	Based on the L-value distance between the SSFAC boundary and the MIT minimum derived from GPS TEC observations. The flag is derived the same way as Flag Ne
6	Flag_AOB	Depends on the mutual position of the AOB boundary and the SSFAC boundary (1: AOB is poleward of the SSFAC boundary, -1: otherwise)
7	Flag_SZA	Calculated from the solar zenith angle at the SSFAC boundary (3: SZA>110°; 2: 110≥SZA>100°, 1: 100≥SZA>90°; -1: SZA≤90°)