Swarm IPIR
Product Definition Document
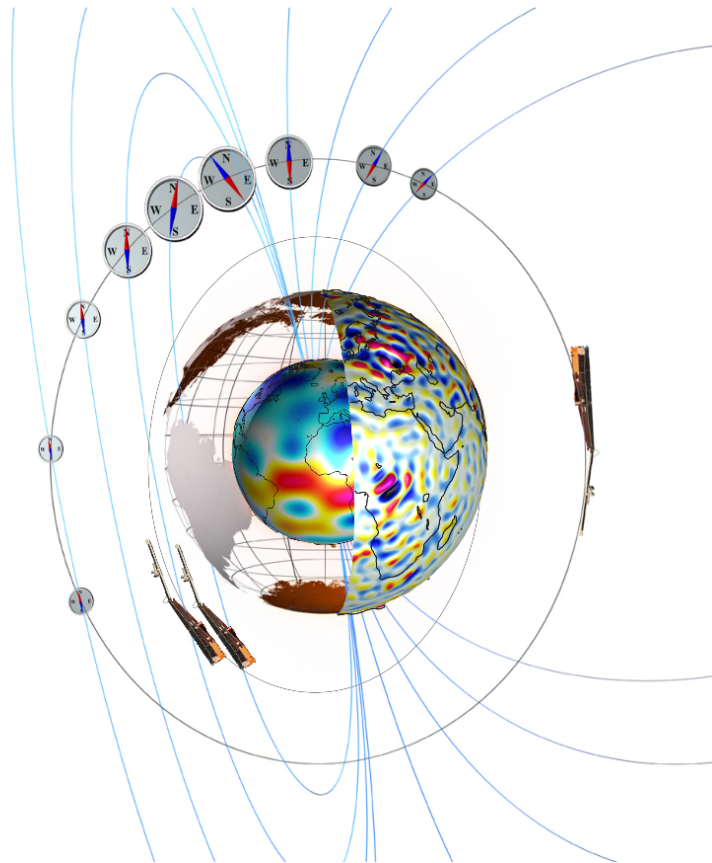
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Record of Changes

Reason	Description	Rev	Date
Initial vers.	Released	1 dA	05 May 2018
Corrections of entries	Released	2 dA	04 July 2018
Final version	Minor corrections of the entries, correction of the IPIR index, units of gradients. Issue 1A released.	1A	01 Sept. 2018
Final version	Table for CDF entries updated.	1B	02 Nov. 2018
Final version	Minor corrections for CDF entries to ensure compatibility with other products and with VirES.	1C	13 Aug. 2019
Final version	Minor corrections to the acronym list, references, and clarifying resolution of physical quantities.	1D	08 Sep. 2019
Final version	Minor corrections, added comment on processing of PCP, corrected resolution entry, and formatting of the units.	1E	13 June 2020

Table of Contents

1   Introduction

1.1   Scope and applicability

This document is the Swarm Level 2 (L2) IPIR - Ionospheric Plasma IRregularities characterised by the Swarm satellites - Product Definition Document (PDD) for the Swarm Data, Innovation and Science Cluster (Swarm DISC) consortium in response to the requirements of [AD-1]. PDD is to be published on the Swarm Data Handbook [AD-3]. Current or updated version of this document is available in the SVN folder: https://smart-svn.spacecenter.dk/svn/smart/SwarmDISC/DISC_Projects/ITT1_4_ionospheric_irregularities/Deliverables/.

2   Applicable and Reference Documentation

2.1   Applicable Documents

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

[AD-1]   IPIR-Swarm-IPIR-1-2017 – Ionospheric Plasma IRregularities characterised by the Swarm satellites.

[AD-2]   SW-SW-DTU-GS-114, rev 1 Statement of Work for Swarm DISC ITT 1.4 "Ionospheric irregularities and fluctuations based on Swarm data"

[AD-3]   https://earth.esa.int/web/guest/missions/esa-eo-missions/swarm/data-handbook

2.2   Abbreviations

Acronym or abbreviation	Description
CDF	Common Data Format
DISC	The Data, Innovation and Science Cluster
ESA	European Space Agency
GFZ	The Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences, DE
IPIR	Ionospheric Plasma IRregularities characterised by the Swarm satellites
ITRF	International Terrestrial Reference Frame
L1b	Level 1b (satellite data)
L2	Level 2 (satellite data)
SVN	SVN Repository with server located at DTU. Presently, the following URLs apply: https://smart-svn.spacecenter.dk/svn/smart/SwarmDISC/DISC_Projects/ITT1_4_ionospheric_irregularities/Deliverables/
Swarm	Constellation of 3 ESA satellites, https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/swarm
UiO	The University of Oslo, Oslo, Norway

3   Product identifier

The product identifier is: **L2 Cat-1: IPDxIRR_2F**

L2, Cat-1   : IPIR is the level 2 fast track product, that is processed by UiO through the DISC consortium.

IPD   : stands for Ionospheric Plasma Density

x   : The product is derived separately for each of the three satellites, and x identifies the satellite used (A, B, C).

IRR   : stands for IRRegularities in the plasma density

2F   : signifies that this is a fast track product. The validation is performed by means of an internal quality check in the algorithms of the product, and the quality of the product is provided by a quality flag. It is released without a validation report.

4 Product definition

Product identifier	`IPDxIRR_2F`			
Definition	Time series of characteristics of the plasma density and plasma irregularities along the orbit from single satellite measurements. Time series of local plasma conditions, including background density and total electron content. Data related to geomagnetic regions in the ionosphere. Indication of severity of plasma irregularities for ground-based users provided.			
Input data	`EFIx_LP_1B, TECxTMS_2F, AOBxFAC_2F, IBIxTMS_2F,` `PCP – Polar Cap Products`			
Input time span	3 days			
Spatial representation	Data provided along entire orbits at positions of SwA, SwB, and SwC.			
Time representation	1 second time series (the electron density data are downsampled to 1 second resolution; the timestamp of the electron density and TEC data are rounded to the nearest integer UTC seconds). Note that density variations parameters at 1 second resolution are estimated using 2Hz plasma density data from EFIx_LP_1B.			
Units	See data format table			
Resolution	Ne and Te as EFIx_LP_1B, Background_Ne 10^{-4} cm^{-3}, Foreground_Ne 10^{-4} cm^{-3}, Grad_Ne 10^{-10} cm^{-3}/m, ROD 10^{-1} cm^{-3}/s, RODI 10^{-6} cm^{-3}/s, delta_Ne 0.05 cm^{-3}, mVTEC 10^{-8} TECU, TEC_STD 10^{-9} TECU, mROT 10^{-10} TECU/s, mROTI 10^{-10} TECU/s.			
Uncertainty	N/A			
Quality indicator	Quality flags are handed through from Level 1b and Level 2 processing which is used as input data.			
Data volume	ca.10 MB per day, per satellite			
Data format	CDF			
Output data	CDF file with time series			

Variable name	Data Type	Description	Unit
Timestamp	CDF_epoch	CDF epoch of the measurement	-
Latitude	CDF_DOUBLE	Position in ITRF – Latitude	deg
Longitude	CDF_DOUBLE	Position in ITRF – Longitude	deg
Radius	CDF_DOUBLE	Position in ITRF – Radius.	m
Ne	CDF_DOUBLE	Plasma density; copied from the Langmuir probe files, downsampled to 1Hz.	cm^{-3}
Background_Ne	CDF_DOUBLE	Background density; calculated from Ne using a percentile filter.	cm^{-3}
Foreground_Ne	CDF_DOUBLE	Foreground density; calculated from Ne using a percentile filter.	cm^{-3}

		Te	CDF_DOUBLE	Electron temperature; copied from the Langmuir probe files, downsampled to 1Hz.	K
		PCP_flag	CDF_INT4	The polar cap patch flag	-
		Grad_Ne_at_100km	CDF_DOUBLE	The electron density gradient in a running window calculated via linear regression over 27 data points for the 2 Hz electron density data.	cm^{-3}/m
		Grad_Ne_at_50km	CDF_DOUBLE	The electron density gradient in a running window calculated via linear regression over 13 data points for the 2 Hz electron density data.	cm^{-3}/m
		Grad_Ne_at_20km	CDF_DOUBLE	The electron density gradient in a running window calculated via linear regression over 5 data points for the 2 Hz electron density data.	cm^{-3}/m
		Grad_Ne_at_PCP_edge	CDF_DOUBLE	The linear electron density gradient calculated over the edges of a patch; non-zero only at the edges of polar cap patches.	cm^{-3}/m
		ROD	CDF_DOUBLE	Rate Of change of Density	cm^{-3}/s
		RODI10s	CDF_DOUBLE	Rate Of change of Density Index (RODI) is the standard deviation of ROD over 10 seconds	cm^{-3}/s
		RODI20s	CDF_DOUBLE	Rate Of Density Index (RODI) is the standard deviation of ROD over 20 seconds.	cm^{-3}/s
		delta_Ne10s	CDF_DOUBLE	Derived by subtracting Ne by its median filtered value in 10 seconds; indicates the electron density fluctuations smaller than 75 km.	cm^{-3}
		delta_Ne20s	CDF_DOUBLE	Derived by subtracting Ne by its median filtered value in 20 seconds; indicates the electron density fluctuations smaller than 150 km.	cm^{-3}
		delta_Ne40s	CDF_DOUBLE	Derived by subtracting Ne by its median filtered value in 40 seconds; indicates the electron density fluctuations smaller than 300 km.	cm^{-3}
		num_GPS_satellites	CDF_INT4	Total number of tracked GPS satellites above 20 degrees.	-
		mVTEC	CDF_DOUBLE	Median of VTEC from all available GPS satellites above 30 degrees.	TECU
		mROT	CDF_DOUBLE	Median of Rate Of TEC (ROT) from all available GPS satellites above 30 degrees.	TECU/s
		mROTI10s	CDF_DOUBLE	Median of Rate Of TEC Index (ROTI) from all available GPS satellites above 30 degrees. The ROTI of each satellite is the standard deviation of ROT over 10 seconds.	TECU/s

	mROTI20s	CDF_DOUBLE	Median of Rate Of TEC Index (ROTI) from all available GPS satellites above 30 degrees. The ROTI of each satellite is the standard deviation of ROT over 20 seconds.	TECU/s
	IBI_flag	CDF_INT4	Plasma Bubble Index, copied from the level-2 Ionospheric Bubble Index product, IBIxTMS_2F.	-
	Ionosphere_region_flag	CDF_INT4	0: equator, 1: mid-latitudes; 2: auroral oval; 3: polar cap.	-
	IPIR_index	CDF_INT4	0-3 low, 4-5 medium, and > 6 high level of fluctuations in the ionospheric plasma density.	-
	Ne_quality_flag	CDF_INT4	Quality flag for the Ne data and the derived data from Ne, e.g., background density, foreground density etc. It is a mixture of the LP and TII QFlags. It is calculated as LP_QFLAG*1000 + TII_QFLAG.'	-
	TEC_STD	CDF_DOUBLE	Standard deviation of VTEC from GPS satellites.	TECU

Output time span	1 day
Latency	10 min
Update rate	1 per day
Notes	1. The meanings of the PCP_flag are as follows: 0 if the plasma density measurement occurred outside a polar cap patch. 1 if the plasma density measurement occurred at one of the edges of a polar cap patch (no plasma velocity measurements are available). 2 if the plasma density measurement occurred at the leading edge of a polar cap patch. 3 if the plasma density measurement occurred at the trailing edge of a polar cap patch. 4 if the plasma density measurement occurred inside a polar cap patch proper. When no ion drift data is available, the leading and trailing edges cannot be distinguished. In this case the polar cap patch flag is set to 4 throughout the patch proper and to 1 throughout both edges. 2. PCP_flag and Grad_Ne_at_PCP_edge are calculated using the Altitude-Adjusted Corrected Geomagnetic coordinates v2.6 (AACGM v2.6) 3. No cdf files are generated if TEC data is missing for the entire calendar day. If the data is missing only for a part of the day, the missing data values are denoted by "NaN". 4. Positions of the satellites are taken from `TECxTMS_2F` and interpolated in case of missing datapoints.