Swarm Expert Support Laboratories

Extended EFI LP Data FP Release Notes

British Geological Survey (BGS)
National Space Institute – DTU Space (DTU)
Delft Institute of Earth Observation and Space Systems (DUT)
Helmholtz Centre Potsdam - German Research Centre for Geosciences (GFZ)
Eidgenössische Technische Hochschule Zürich (ETH)
Institut de Physique du Globe de Paris (IPGP)
The Swedish Institute of Space Physics (IRF)
Laboratoire d'électronique des technologies de l'information (Leti)
University of Calgary (UoC)
Aerospace Research And Test Establishment (VZLU)

with additional contributions from

NASA Goddard Space Flight Center (GSFC)
University of Colorado (CIRES)
Charles University Prague (CUP)

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Prepared:

S. Buchert Date 2017-08-22

EFI Scientist

Approved:

S. Buchert Date 2017-08-22

Team Manager

Record of Changes

Reason	Description	Rev	Date
Signature	Released	1	2016-02-19
Updated files to vers. 0102	Section 3.1: added last sentence; Table 1: added version 0102: Updated chapter 5.	2	2016-03-22
V0201 data files	New data release with a new, higher value for the face-plate area, corrected geodetic coordinates and initial data coverage until July 2017 (See [RD-3] and Figure 3)	3	2017-08-22

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1 Introduction

1.1 Purpose and Scope

The purpose of this document is to provide notes on the extended Swarm EFI Langmuir Probe (LP) data release, such that a user can technically work with the data, and understand their potential and limitations.

2 Applicable and Reference Documentation

2.1 Applicable Documents

[AD-1] SW-TN-IRF-EF-003, Level 1b Algorithms (LP)

[AD-2] SW-RS-DSC-SY-0007, Level_1b_Product_Definition, Issue 5.17

[AD-3] SWAM-GSEG-EOPG-TN-15-0003, Swarm Preliminary Plasma Dataset User Note

2.2 Reference Documents

[RD-1] Koichiro Oyama, DC Langmuir Probe for Measurement of Space Plasma: A Brief Review; J. Astron. Space Sci. 32(3), 167-180 (2015), http://dx.doi.org/10.5140/JASS.2015.32.3.167

[RD-2] J. D. Johnson and A. J. T. Holmes, Edge effect correction for small planar Langmuir probes, Rev. Sci. Instrum. 61, 2628 (1990); http://dx.doi.org/10.1063/1.1141849

[RD-3] L. Levan et al., Calibration and Validation of Swarm Plasma Densities and Electron Temperatures Using Ground-Based Radars and Satellite Radio-Occultation Measurements, submitted to Radio Science

2.3 Abbreviations

Acronym ***or abbreviation***	***Description***
EFI	Electric Field Instrument, including the TII and the LP
ESA	European Space Agency
ESL	Swarm Expert Support Laboratories
ITRF	International Terrestrial Reference Frame
L1b	Level 1b, first level of processed satellite data released for general use
LP	Langmuir Probe, part of the Electrical Field Instrument
SVN	SVN Repository with server located at DTU. For ESL members, presently, the following URLs apply: https://smart-svn.spacecenter.dk/svn/smart/SwarmESL-All
Swarm	Constellation of 3 ESA satellites, http://www.esa.int/esaLP/ESA3QZJE43D_LPswarm_0.html
TII	Thermal Ion Imager, part of the Electrical Field Instrument

Acronym ***or abbreviation***	***Description***
IRF	Swedish Institute of Space Physics (“Institutet för RymdFysik” in Swedish)
UoC	University of Calgary (CA)

3 Overview

This release note describes the extended Swarm EFI LP data derived from the faceplate. They include

- estimates of the electron density N_e from the faceplate current at 16 Hz resolution;
- the actual 16 Hz faceplate current measurements,
- geodetic coordinates of the satellite positions interpolated to the times of the current measurements.

The data are intended for users with some experience and understanding of Langmuir probe data.

In the following of this note, we will often refer to the LP Level 1b products. Such products are also distributed by ESA and exist in two categories:

1) Preliminary Plasma Dataset (PPD from now on, directly produced by IRF and covering from beginning of mission up to August 2015, see [AD-3] for more details) and
2) Official Swarm Level 1b products, EFIx_PL_1B file type (L1B from now on, processed within ESA facilities and covering from July 2015 to present, see [AD-2] for more details). This is planned to become an LP (instead of Plasma) L1b product in the near future replacing also the PPD.

In addition, the extended LP data set described in this note is produced by IRF and distributed by ESA under folder "…`Advanced/Plasma_Data/2_Hz_Langmuir_Probe_Extended_Dataset/…`".

These data sets contain estimates of N_e obtained from the actual Langmuir probe instrument on Swarm, and the estimates of N_e should not be significantly different from each other (for the same satellite and time). In this data set N_e is estimated from the measurements of a different hardware "probe", the current of the faceplate. Some systematic differences between the probe and the faceplate estimates are being observed and discussed below. The faceplate estimates of N_e have a higher time resolution (16 Hz compared to 2 Hz), but do not cover times when the TII is active.

3.1 Data periods

We have processed all EFI L0 normal mode files available to us from December 9, 2013 and thereafter, but not EFI TII or LP calibration modes. We expect to implement an automatic daily update of the data set with the latest measurements in the near future. These updates may not be announced, files simply are added at the server.

The processed data include (rare) periods when the spacecraft were flown with unusual attitude or other unusual configurations that a user might want to exclude in his/her analysis. Generally this LP data set has only information about the state of the LP as well as satellite positions, but not for example satellite attitude. At the end of these notes is a list of email addresses and web site where more information can be obtained.

The 16 Hz electron density estimates are provided for times when the faceplate bias is below -2.5 V. Generally this is when the TII is inactive, and the bias then has been set to -3.5 V. When the TII is active, the faceplate is normally set to -1 V, and then the faceplate current has been found to be apparently unsuitable for estimating the electron density, see also section 4.3 and Figure 2. So no 16 Hz density estimates are provided for these times. The time lacking 16 Hz N_e estimates is normally within one interval of 4-6 orbits per day for Swarm A and B, fewer orbits for Swarm C.

The lowering of the faceplate bias to -3.5 V at each inactivation of the TII was started in October 2014, only from then onwards the 16 Hz N_e are available.

3.2 File format and names

Data are provided in daily ZIP-archived files with the following naming convention:

SW_EXTD_EFIX_LP_FP_YYYYMMDDTHHMMSS_yyyymmddThhmss_VVVV.CDF.ZIP

where

- EXTD indicates that the data are extended, and contain additional parameters, as compared to the official L1b products
- X is the satellite identifier, one of A, B or C;
- LP stands for Langmuir probe, FP for faceplate;
- YYYYMMDDTHHMMSS is the beginning of the interval;
- yyyymmddThhmmss is the end of the interval;
- VVVV maps to the following configurations:

Table 1 Interpretation of EXTD filename versions.

VVVV	Description
0101	Released on Feb 12, 2016 for general use
0102	16 Hz data are only produced when the bias<-2. 5 V, was available until Feb 2016
0201	Corrected geodetic coordinates latitude, longitude, height, without radius, initially produced until June 2017

Each file uncompresses to a CDF file with ending ".cdf".

3.3 Data fields

3.3.1 CDF file

The variables (or data fields) of the CDF files are listed in Table 2. Background and more details are provided in section 4.

Table 2 CDF file contents of LP faceplate current

Variable	CDF Type	Unit	Note
Timestamp	CDF_EPOCH	ms	Milliseconds since Jan 1, 0000, 0 UTC
Latitude	CDF_DOUBLE	deg	Geodetic latitude, WGS84 ellipsoid

Variable	CDF Type	Unit	Note
Longitude	CDF_DOUBLE	deg	Geodetic longitude, WGS84 ellipsoid
Height	CDF_DOUBLE	km	Height above reference ellipsoid, WGS84
Current	CDF_DOUBLE	A	Calibrated measured faceplate current
Density	CDF_DOUBLE	cm^{-3}	Plasma density from the faceplate current

3.3.2 Header file

Unlike the L1b products, the extended LP data set files have no headers.

3.4 Latest version of the IRF LP processor

This release of the Swarm EFI extended LP data was processed using a software processor developed at the IRF. The code is also deposited at the ESL SVN repository.

4 Background and details

4.1 Time stamps

Unlike the 2 Hz LP densities (both PPD and L1B products), the time stamps of the high resolution, faceplate derived density have not been calibrated against 50 Hz VFM data. In case of 2Hz LP densities such a calibration resulted in a shift towards earlier by 20 milliseconds for all satellites, which is about 1/3 of the distance in time between high resolution 16 Hz density points. In case of the LP the origin of the time offset relative to VFM data is unknown. For the faceplate it could be different, therefore the LP offset is not used.

The numerical value of the time stamp is rounded to the full millisecond, the rounding error is much smaller than the uncertainty of the measurement time.

4.2 Geodetic coordinates

The coordinates are, as in the PPD, geodetic, while the L1B products contain spherical latitudes and longitudes. The satellite positions are retrieved from the L1B MODx_SC_1B files at 1 s resolution and then interpolated to the time stamps of high resolution 16 Hz density points. A future correction of time stamps, by calibration with 50 Hz VFM data, would then also update the geodetic coordinates. A shift by 20 msec, as it was found for the 2 Hz LP densities, would correspond to a spatial shift by about 150 m.

4.3 Density derived from the faceplate current

The basics of LPs have been described in many articles, for example [RD-1] provides an easy reading. In the case at hand here, the planar probe simply is an obstacle in a supersonic plasma flow past the orbiting satellite. Density is derived from the faceplate current assuming that the current is carried by ions hitting the faceplate due to the orbital motion of the spacecraft (the ions will not accumulate over time on the faceplate, they presumably leave again as neutrals). The trivial equation is

$$I_{fp} = -eAu_iN_i. \quad (1)$$

I_{fp} is the faceplate current in Ampere, e the electron charge, A the faceplate area, u_i the ion velocity normal to the faceplate surface, and N_i the ion density. Due to quasi-neutrality N_i must be equal to the electron density N_e. For u_i the satellite velocity in the inertial ITRF is used. For the equation being valid this velocity must be much larger than the ion thermal velocity. This is the case for O^+ ions and for ion temperatures as they normally occur in the ionosphere. Significant contributions from lighter H^+ ions and/or extremely high temperatures are not expected at Swarm altitudes. Exceptionally and predominantly at high latitudes, e.g. in the auroral zone, the plasma convection along the satellite orbit could reach large enough magnitude, such that N_i becomes over- or underestimated, depending on the direction of the plasma convection along the orbit. The anyway much slower plasma co-rotation with the Earth at mid- and low latitudes is across the orbit and would not affect the faceplate current. Effects from the edges of the faceplate are neglected. An edge effect could increase the effective plate area for relatively strongly negative bias, or decrease it for relatively positive bias [RD-2].

We have found that the so derived density variations generally agree very well with the LP density estimates, but the absolute value is roughly 20 % higher, corresponding to a higher current than expected according to equation (1). To illustrate this, in Figure 1 both densities are compared for a short time interval, where very briefly equatorial irregularities are seen and also quiet regions with practically no small scale variation. The faceplate derived density is consistently higher than the density derived from the probe, both in the quiet part and at the irregularities.

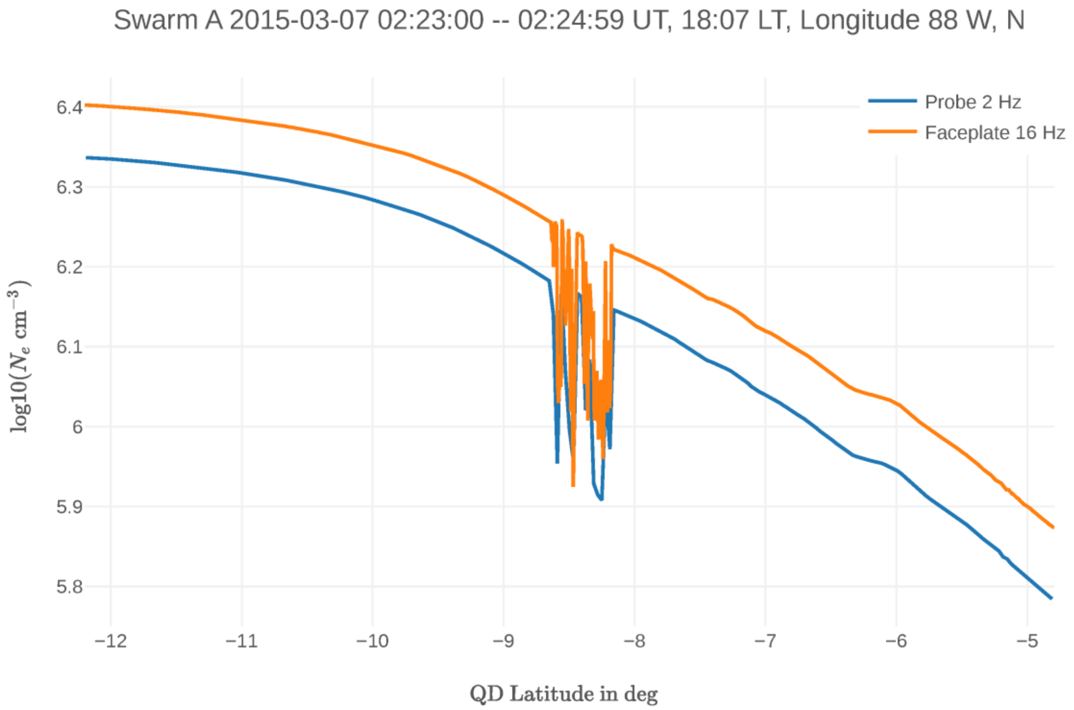

Figure 1: Comparison of densities from the faceplate and probe currents for a short period of 2 minutes.

When the TII is active, the bias needs to be set to – 1 V for its best performance. This bias value seems to result in a much smaller faceplate current, moreover it gets apparently modulated by the 2 Hz bias cycle of the LP harmonic submode, and effects of LP sweeps are seen, see Figure 2. Faceplate densities are produced only for times when the bias is below -2.5 V. Then such effects have not been noticed.

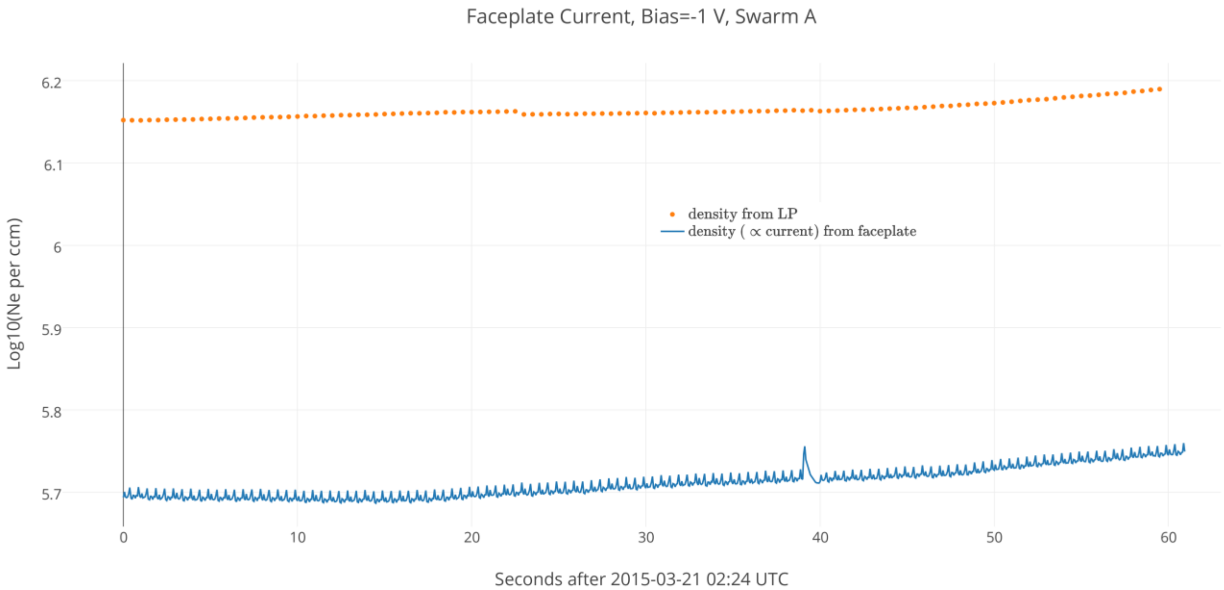

Figure 2: Comparison of densities from the faceplate and probe currents when the faceplate bias is -1V. A sweep occurs just before second 40. Here the old value for the faceplate area was still used resulting in a larger difference of the absolute value.

In Figure 3 densities from the faceplate and probe currents are compared statistically over a period of about 7 days, which includes passes over the equatorial region with high densities as well as with irregularities. The data align nicely along a straight line indicating that the scaling between probe and faceplate densities is constant over the whole range of densities. However, the data group themselves along two lines, indicating that there is a small offset in one or both groups of data. The origin of these offsets is not yet understood.

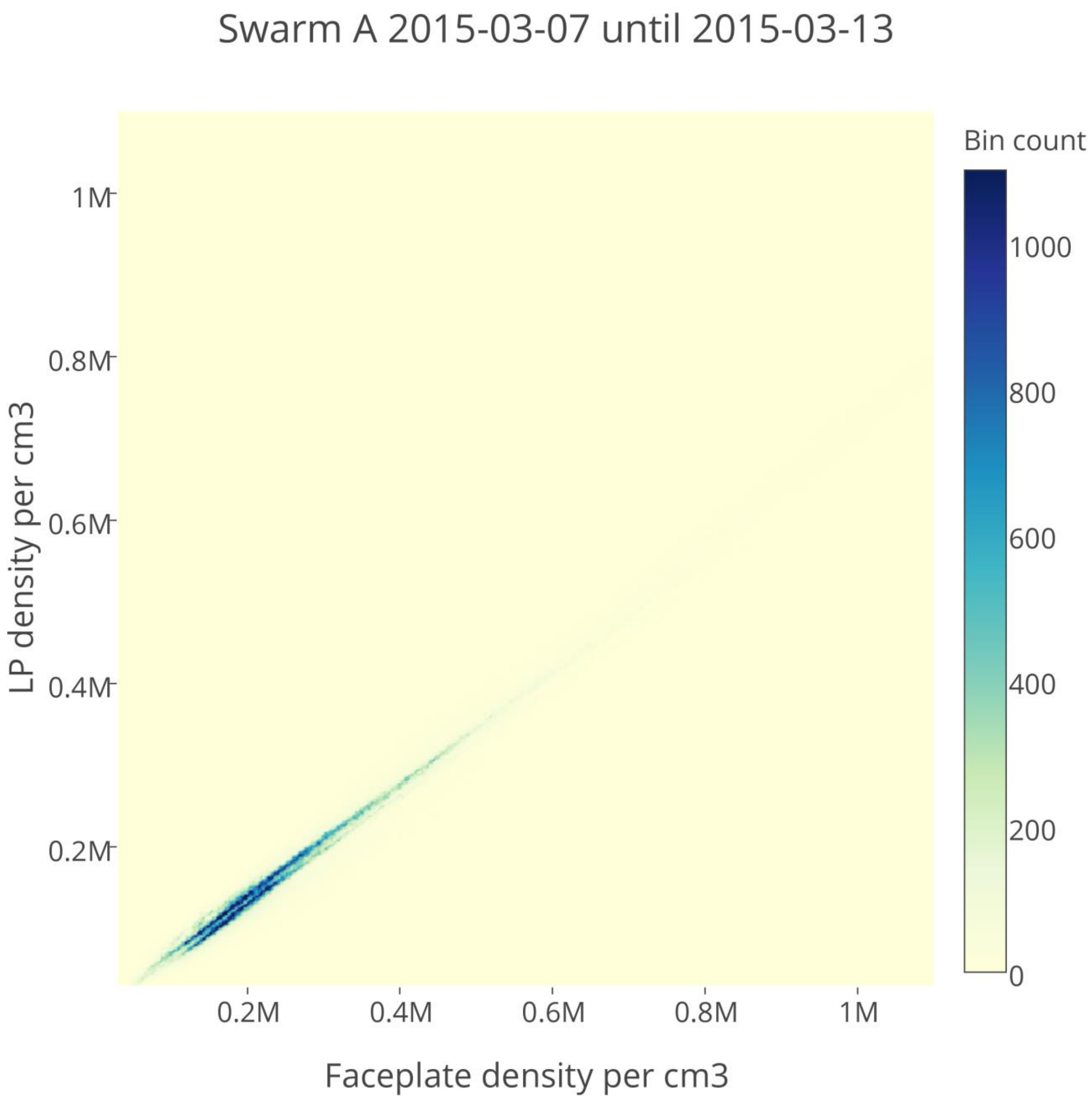

Figure 3: 2d histogram of densities from the probe and faceplate currents

This would be harmless for many different types of data analysis (for example spectra), but the user should as usual interpret any results with care.

A recent comparison with ground-based radars and GPS occultations [RD-3] found that the probe densities seem to be underestimated by about 10 %. With this the faceplate estimated values for N_e would actually be nearer to the real values than the probe estimates. We have also noticed, that in some regions of very low density the faceplate value becomes considerably larger than the probe value, which is still under investigation.

4.4 Faceplate current

For completeness also the faceplate current in Ampere is given. It could be used to get a corrected density, if u_i is known to be different from the orbital velocity, for example, during events of high plasma convection as deduced from external measurements (radars etc).

5 Dataset Versions

5.1 Dataset Version 0101

The initial release. By mistake it contains data when the bias was -1 V and the density estimate is not reliable. Please use a dataset with version code “0102” or higher.

5.2 Dataset Version 0102

Filtering out data with a bias more positive than -2.5 V was corrected.

A few months after the release it was noted that the orbit timestamp had been used with an offset by 17, 18, or 19 s, the difference between GPS time and UTC, and consequently the geodetic positions in data versions 0101 and 0102 are not correct.

5.3 Dataset Version 0201

Correct orbit time stamps are used, consequently the geodetic positions should be correct now. The “radius” variable in the CDF was omitted (it is not part of geodetic coordinates and has only little relevant information in addition to the geodetic height). Initially all data from October 2014 until June 2017 were produced.

6 Further information

For information on LP data quality and content, and on LP instruments:

Stephan Buchert and Thomas Nilsson, Swarm ESL team, IRF, Uppsala, (scb@irfu.se and thoni@irfu.se)

For general information about the Mission, instruments, data availability, and general data quality please refer to the following Web page:

https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/swarm

In case of further doubts please contact: eohelp@esa.int