MAG and RPW SCM Merged Magnetic Field Data User Manual

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1 GENERAL

1.1 Scope of the Document

This document is the science data user manual for the merged data from MAG and RPW-SCM waveforms on-board the Solar Orbiter mission.

A complete description of the MAG data is given in [RD1] and in the DOI: https://doi.org/10.5270/esa-ux7y320.

An exhaustive description of all of the RPW data file content is presented in the "RPW Data Product Description Document" (DPDD) [RD2] and in the DOI: https://doi.org/10.57780/esa-3xcjd4w.

The detailed instrument RPW description can be found in [RD4].

1.2 Applicable Documents

This document responds to the requirements of the documents listed in the following table:

Mark	Reference/Iss/Rev	Title of the document	Authors	Date
AD1	SOL-SGS-TN-0009/2/6	Meta data definition for Solar Orbiter science data	SOC	16/04/2024

1.3 Reference Documents

This document is based on the documents listed in the following table:

Mark	Reference/Iss/Rev	Title of the document	Authors	Date
RD1	SOL-MAG-DPDD/2/0	MAG Data Product Description Document	H.O'Brien	28/09/2020
RD2	ROC-PRO-DAT-NTT-00075-LES/1/2	RPW Data Product Description Document	X.Bonnin	29/09/2020
RD3	Astronomy & Astrophysics, doi 10.1051/0004-6361/201937257	The Solar Orbiter magnetometer	T.S. Horbury et al.	2020
RD4	Astronomy & Astrophysics, doi 10.1051/0004-6361/201936214	The Solar Orbiter Radio and Plasma Waves (RPW) instrument	Maksimovic et al.	2020
RD5	Journal of Geophysical Research: Space Physics, 126, e2020JA028543	Measurement of magnetic field fluctuations in the Parker Solar Probe and Solar Orbiter missions	Jannet, G. et al.	2021
RD6	ROC-PRO-DAT-NTT-00165-LPC/1/0	RPW SCM Waveform Data User Manual	RPW SCM Team	07/02/2025
RD7	ROC-PRO-DAT-NTT-00163-LPP/1/0	RPW LFR Data User Manual	RPW LFR Team	17/01/2025
RD8	Astronomy & Astrophysics, doi 10.1051/0004-6361/202554731	The Solar Orbiter merged magnetic field	M. Kretzschmar et al.	08/06/2025

RD9	https://cdf.gsfc.nasa.gov/	CDF Web site	CDF Team	2024

2 MAG INSTRUMENT

MAG is described in details in Horbury et al. (2021). MAG provides cleaned DC and low frequency calibrated magnetic field thanks to the careful calibration of two fluxgate magnetic sensors (inboard and outboard) accommodated on the boom of the Solar Orbiter. The noise requirement of MAG is 10 pT $Hz^{-1/2}$ at 1 Hz. The merged MAG-RPW-SCM magnetic field is produced using the calibrated level 2 MAG data available on SOAR. We refer to the MAG data user manual for more information. The MAG data product used in the L3 merged magnetic field are *solo_L2_mag-srf-burst_yyyymmdd_*.cdf*

3 RPW SCM SENSOR

The SCM consists of a compact set of three search-coil antennas that are orthogonally mounted on a non-magnetic support, enabling the measurement of the three components of the fluctuating magnetic.
The scientific requirements for Solar Orbiter mission are the measurement of the AC magnetic field between a few Hz and 10 kHz with intensities as low as 8 fT/ Hz around 2 kHz and a maximum intensity of 5 nT. The sensor includes one double-band antenna that covers the 10 kHz–500 kHz frequency range with a sensitivity of 50 fT/ Hz at 100 kHz. A block diagram of the SCM is shown in Figure 1.

The merged MAG-RPW-SCM magnetic field is produced using the calibrated level 2 RPW-LFR magnetic field data product. We refer to the SCM section of the Science data products description for more information about these products.

The RPW data product used in the L3 merged magnetic field are:
solo_L2_rpw-lfr-surv-swf-b (only data with sampling frequencies of 4096 Hz and 256 Hz)
solo_L2_rpw-lfr-surv-cwf-b (only data with sampling frequencies of 256 Hz)
solo_L2_rpw-lfr-sbm1-cwf-b (sampling frequencies of 4096 Hz)
solo_L2_rpw-lfr-sbm2-cwf-b (sampling frequencies of 256 Hz)

4 MAG-RPW-SCM DATA PRODUCTS OVERVIEW

4.1 Numerical data products

Tables below give the list of MAG-RPW-SCM numerical data products released publicly by the RPW PI team.

More information about a specific data product can be found in the section 4.

Added-value science data products (L3)

MAG-RPW-SCM L3 products are calibrated and time-stamped (i.e., TT2000 Epoch time) magnetic field data with a frequency content far more larger than individual MAG and RPW-SCM files. To avoid excessively large files, the merged magnetic field is provided in different files organized according to the reference frame in which it is expressed (SRF or RTN) and according to the data sampling rate (256 Hz or 4096 Hz). The file format is CDF.

4.1.1.1 Combined data-sets

The L2 files used to produce merged data are:

solo_L2_mag-srf-burst (sampled at 64 Hz or 128 Hz)
solo_L2_rpw-lfr-sbm1-cwf-b (sampled at 4096 Hz)
solo_L2_rpw-lfr-sbm2-cwf-b (sampled at 256 Hz)
solo_L2_rpw-lfr-surv-cwf-b (only when sampled at 256 Hz)
solo_L2_rpw-lfr-surv-swf-b (only snapshots at 256 Hz and 4096 Hz)

4.1.1.2 General algorithm

You can find a complete description of the merging algorithm in the paper [RD8].

The general picture of the algorithm is as follows:

- collect all continuous (gap-free) MAG and RPW-SCM intervals for the sampling frequency under consideration (256 hz or 4096 Hz),
- calculate intervals with both MAG and RPW-SCM data,
- for each common interval, transform the RPW-SCM data into the SRF frame (the one chosen for MAG)
    - delay MAG data so that MAG and RPW-SCM share the same time vector,
    - resample MAG to obtain the same sampling rate as RPW-SCM,
    - apply the transfer function to MAG to make the data comparable with RPW-SCM data (preserving MAG amplitude at very low freequencies),
    - apply a low-pass filter to MAG and a high-pass filter to RPW-SCM and sum the two to obtain merged data.
    - transform the merged data to RTN frame if necessary.

4.1.1.3 Separate data products for continuous and snapshot waveform

Formally, all MAG-RPW-SCM L3 CDF data products are continuous waveform (CWF). Nevertheless, note that daily files can contains gaps. Continuous waveform data are stored as one sample per CDF record (per channel).

PRODUCT NAME	CONTENT
solo_L3_multi-mag-rpw-scm-merged-rtn-256	Continuous magnetic waveform data covering frequencies from DC to 128 Hz: array *3* x *nt* with *nt* measurements of Br, Bt, and Bn waveform in the RTN frame and in nT, sampled at 256 Hz.
solo_L3_multi-mag-rpw-scm-merged-srf-256	Continuous magnetic waveform data covering frequencies from DC to 128 Hz: array *3* x *nt* with *nt* measurements of Bx, By, and Bz waveform in the SRF frame and in nT, sampled at 256 Hz.
solo_L3_multi-mag-rpw-scm-merged-rtn-4096	Continuous magnetic waveform data covering frequencies from DC to 2048 Hz: array *3* x *nt* with *nt* measurements of Br, Bt, and Bn waveform in the RTN frame and in nT, sampled at 4096 Hz.
solo_L3_multi-mag-rpw-scm-merged-srf-4096	Continuous magnetic waveform data covering frequencies from DC to 2048 Hz: array *3* x *nt* with *nt* measurements of Bx, By, and Bz waveform in the SRF frame and in nT, sampled at 4096 Hz.

4.2 Image data products

All MAG-RPW-SCM image data products are written in PNG format files.
Image files naming follows the same convention than numerical data for Solar Orbiter [AD1].
They are labelled as L3 data level products.

More information about a specific image data product can be found in the section 5.

Daily summary plots

Table below gives the list of daily summary plots generated from MAG-RPW-SCM L3 numerical data products. For each quick-look, there are two pages: the first shows the spectrograms of the three components of the magnetic field, and the second shows the median spectrum over the day, and the spectrogram from which the median spectrum has been subtracted.

PRODUCT NAME	CONTENT
solo_L3_mag-rpw-scm-merged-256	Daily summary plots generated from solo_L3_multi-mag-rpw-scm-merged-rtn-256 (2 pages)
solo_L3_mag-rpw-scm-merged-4096	Daily summary plots generated from solo_L3_multi-mag-rpw-scm-merged-rtn-4096 (2 pages)

5 MAG-RPW-SCM NUMERICAL DATA PRODUCTS DESCRIPTION

5.1 solo_L3_multi-mag-rpw-scm-merged-rtn-256

Overall description

SOLO_L3_MULTI-MAG-RPW-SCM-MERGED-RTN-256 data provides the merged magnetic field continuous waveforms of the three components from continuous up to 128 Hz.

The merged data are obtained using Burst data of the MAG instrument and the SCM data of LFR analyzer of the Solar Orbiter/RPW instrument. More specifically, it uses:

- solo_L2_mag-srf-burst (sampled at 64 Hz or 128 Hz)
- solo_L2_rpw-lfr-sbm2-cwf-b (sampled at 256 Hz)
- solo_L2_rpw-lfr- sbm1-cwf-b (sampled at 4096 Hz)
- solo_L2_rpw-lfr-surv-cwf-b (only when sampled at 256 Hz)
- solo_L2_rpw-lfr-surv-swf-b (only snapshots at 256 Hz)

This data product has been produced following the method described in [RD8].

The magnetic field is expressed in the RTN frame of reference.

DOI: https://doi.org/10.57780/esa-f2565a8

Type of data	Continuous waveform of the magnetic field
Unit	nT
Sampling rate	256 Hz
Data format	CDF (3.9.0)
Granularity	1 file per day

Data organization

Table below gives the name, data type, units and description of the zVariables stored in the CDF file.

Table 1: SOLO_L3_MULTI-MAG-RPW-SCM-MERGED-RTN-256 CDF zVariables overview

NAME	TYPE	UNIT	Description
Epoch	CDF_TIME_TT2000	ns	Epoch time of the record
B_RTN	CDF_REAL4[3]	nT	3 entries array with magnetic field values (Br, Bt, Bn) in RTN frame
MERGED_BITMASK	CDF_UINT1		Origin of the merged data: - bit0: solo_L2_rpw-lfr-surv-swf-b sampled at 256 Hz - bit2: solo_L2_rpw-lfr-surv-cwf-b sampled at 256 Hz - bit3: solo_L2_rpw-lfr-sbm2-cwf-b sampled at 256 Hz - bit6: solo_L2_mag-srf-burst sampled at 64 Hz - bit7: solo_L2_mag-srf-burst sampled at 128 Hz.
QUALITY_BITMASK	CDF_UINT2		Flag to indicate any context or events that can alterate data - bit0: a very short input MAG vector was used, resampling may introduce artifacts - bit1: unexpected VECTOR_RANGE (0 or 1), incorrect MAG calibration
QUALITY_BITMASK_MAG	CDF_UINT2		This is a bitwise variable, meaning that multiple flagscan be set for a single time, by adding flag values: - bit0: INBOARDPRIMARY, L2 data is from inboard sensor - bit1: SCETUNSYNC, instrument time not synchronised with SC time - bit2: MAGHEATERON, MAG heater operating - bit3: TONEREMOVED, interference tones were detected and removed from this data point - bit4: THRUSTERREMOVED thrusters were firing and influence has been removed from this data point - bit5: SCINTERFERENCE, SC generated interference detected

			but not removed - bit6: SAMOVEMENT, solar array movement occurred - bit7: INSTRUMENTREMOVED, interference field signal from another instrument operation has been detected and removed; Refer to [RD1] for more information on how these flags are generated.
QUALITY_BITMASK_SCM	CDF_UINT2		Flag to indicate any context or events that can alterate data: - bit0: SCM outworking or unknown temperature - bit1: SCM heater on/off transition - bit2: LFR onboard calibration signal
QUALITY_FLAG	CDF_UINT1		Flag to indicate the quality of the data from 0: Bad to 4: Excellent
SAMPLING_RATE	CDF_REAL4	Hz	Sampling frequency = 256 Hz
CARTESIAN_REPRESENTATION	CDF_CHAR[3]		Cartesian representation of a magnetic vector
MAG_LABEL_RTN	CDF_CHAR[3]		Labels of the Magnetic fields components in the RTN frame = (Br, Bt, Bn)
MERGED_LABEL	CDF_CHAR[256]		Merged data in text form, indexed by MERGED_BITMASK (from 0 to 255)

Caveats and known issues

ISSUE	MITIGATION(S)
MAG L2 data is from inboard sensor	Bit0 of QUALITY_BITMASK_MAG is set to 1
MAG time not synchronised with SC time	Bit1 of QUALITY_BITMASK_MAG is set to 1
MAG heater operating	Bit2 of QUALITY_BITMASK_MAG is set to 1
Interference tone were detected in MAG frequency range and removed from this MAG data point	Bit3 of QUALITY_BITMASK_MAG is set to 1
Thrusters were firing and influence has been removed from this MAG data point	Bit4 of QUALITY_BITMASK_MAG is set to 1
SC generated interference tones were detected in MAG data but not removed	Bit5 of QUALITY_BITMASK_MAG is set to 1

Solar array movement occurred	Bit6 of QUALITY_BITMASK_MAG is set to 1
Interference field signal from another instrument operation has been detected in MAG data and removed	Bit7 of QUALITY_BITMASK_MAG is set to 1
The magnetic field is greatly disturbed when the SCM heaters are switched on and off.	When the heater signature could be located in the signal, it was subtracted before calibration, bit1 of QUALITY_BITMASK_SCM is set to 1 and QUALITY_FLAG is capped to 2
LFR calibration signal is sometimes superimposed on the interplanetary magnetic field	bit2 of QUALITY_BITMASK_SCM is set to 1 and QUALITY_FLAG is capped to 2
When the input MAG vector used is very short, the resulting data may be corrupted or lack precision.	bit0 of QUALITY_BITMASK is set to 1 and QUALITY_FLAG is capped to 2
When MAG uses unexpected VECTOR_RANGE (0 or 1) it results in incorrect MAG calibration	bit1 of QUALITY_BITMASK is set to 1 and QUALITY_FLAG is capped to 2
Interferences from spacecraft equipment are present above the sensitivity of SCM at 8 Hz, 16 Hz and harmonics. Other interferences can be noted at 1.3 Hz and harmonics	Peaks caused by these interferences are easily identifiable in the power spectrum

5.2 solo_L3_multi-mag-rpw-scm-merged-srf-256

Overall description

SOLO_L3_MULTI-MAG-RPW-SCM-MERGED-SRF-256 data provides the merged magnetic field continuous waveforms of the three components from continuous up to 128 Hz.

The merged data are obtained using Burst data of the MAG instrument and the SCM data of LFR analyzer of the Solar Orbiter/RPW instrument. More specifically, it uses:

- solo_L2_mag-srf-burst (sampled at 64 Hz or 128 Hz)
- solo_L2_rpw-lfr-sbm2-cwf-b (sampled at 256 Hz)
- solo_L2_rpw-lfr-surv-cwf-b (only when sampled at 256 Hz)
- solo_L2_rpw-lfr-surv-swf-b (only snapshots at 256 Hz)

This data product has been produced following the method described in [RD8].

The magnetic field is expressed in the SRF frame of reference.

DOI: https://doi.org/10.57780/esa-f2565a8

Type of data	Continuous waveform of the magnetic field
Unit	nT
Sampling rate	256 Hz
Data format	CDF (3.9.0)
Granularity	1 file per day

Data organization

Table below gives the name, data type, units and description of the zVariables stored in the CDF file.

Table 2: SOLO_L3_MULTI-MAG-RPW-SCM-MERGED-SRF-256 CDF zVariables overview

NAME	TYPE	UNIT	Description
Epoch	CDF_TIME_TT2000	ns	Epoch time of the record
B_SRF	CDF_REAL4[3]	nT	3 entries array with magnetic field values (Bxsrf, Bysrf, Bzsrf) in SRF frame
MERGED_BITMASK	CDF_UINT1		Origin of the merged data: - bit0: solo_L2_rpw-lfr-surv-swf-b sampled at 256 Hz - bit2: solo_L2_rpw-lfr-surv-cwf-b sampled at 256 Hz - bit3: solo_L2_rpw-lfr-sbm2-cwf-b sampled at 256 Hz - bit6: solo_L2_mag-srf-burst sampled at 64 Hz - bit7: solo_L2_mag-srf-burst sampled at 128 Hz.
QUALITY_BITMASK	CDF_UINT2		Flag to indicate any context or events that can alterate data - bit0: a very short input MAG vector was used, resampling may introduce artifacts - bit1: unexpected VECTOR_RANGE (0 or 1), incorrect MAG calibration
QUALITY_BITMASK_MAG	CDF_UINT2		This is a bitwise variable, meaning that multiple flagscan be set for a single time, by adding flag values: - bit0: INBOARDPRIMARY, L2 data is from inboard sensor - bit1: SCETUNSYNC, instrument time not synchronised with SC time - bit2: MAGHEATERON, MAG heater operating - bit3: TONEREMOVED, interference tones were detected and removed from this data point - bit4: THRUSTERREMOVED thrusters were firing and influence has been removed from this data point - bit5: SCINTERFERENCE, SC generated interference detected

			but not removed - bit6: SAMOVEMENT, solar array movement occurred - bit7: INSTRUMENTREMOVED, interference field signal from another instrument operation has been detected and removed; Refer to [RD1] for more information on how these flags are generated.
QUALITY_BITMASK_SCM	CDF_UINT2		Flag to indicate any context or events that can alterate data: - bit0: SCM outworking or unknown temperature - bit1: SCM heater on/off transition - bit2: LFR onboard calibration signal
QUALITY_FLAG	CDF_UINT1		Flag to indicate the quality of the data from 0: Bad to 4: Excellent
SAMPLING_RATE	CDF_REAL4	Hz	Sampling frequency = 256 Hz
CARTESIAN_REPRESENTATION	CDF_CHAR[3]		Cartesian representation of a magnetic vector
MAG_LABEL_SRF	CDF_CHAR[3]		Labels of the Magnetic fields components in the SRF frame = (Bxsrf, Bysrf, Bzsrf)
MERGED_LABEL	CDF_CHAR[256]		Merged data in text form, indexed by MERGED_BITMASK (from 0 to 255)

Caveats and known issues

ISSUE	MITIGATION(S)
MAG L2 data is from inboard sensor	Bit0 of QUALITY_BITMASK_MAG is set to 1
MAG time not synchronised with SC time	Bit1 of QUALITY_BITMASK_MAG is set to 1
MAG heater operating	Bit2 of QUALITY_BITMASK_MAG is set to 1
Interference tone were detected in MAG frequency range and removed from this MAG data point	Bit3 of QUALITY_BITMASK_MAG is set to 1
Thrusters were firing and influence has been removed from this MAG data point	Bit4 of QUALITY_BITMASK_MAG is set to 1
SC generated interference tones were detected in MAG data but not removed	Bit5 of QUALITY_BITMASK_MAG is set to 1

Solar array movement occurred	Bit6 of QUALITY_BITMASK_MAG is set to 1
Interference field signal from another instrument operation has been detected in MAG data and removed	Bit7 of QUALITY_BITMASK_MAG is set to 1
The magnetic field is greatly disturbed when the SCM heaters are switched on and off.	When the heater signature could be located in the signal, it was subtracted before calibration, bit1 of QUALITY_BITMASK_SCM is set to 1 and QUALITY_FLAG is capped to 2
LFR calibration signal is sometimes superimposed on the interplanetary magnetic field	bit2 of QUALITY_BITMASK_SCM is set to 1 and QUALITY_FLAG is capped to 2
When the input MAG vector used is very short, the resulting data may be corrupted or lack precision.	bit0 of QUALITY_BITMASK is set to 1 and QUALITY_FLAG is capped to 2
When MAG uses unexpected VECTOR_RANGE (0 or 1) it results in incorrect MAG calibration	bit1 of QUALITY_BITMASK is set to 1 and QUALITY_FLAG is capped to 2
Interferences from spacecraft equipment are present above the sensitivity of SCM at 8 Hz, 16 Hz and harmonics. Other interferences can be noted at 1.3 Hz and harmonics	Peaks caused by these interferences are easily identifiable in the power spectrum

5.3 solo_L3_multi-mag-rpw-scm-merged-rtn-4096

Overall description

SOLO_L3_MULTI-MAG-RPW-SCM-MERGED-RTN-4096 data provides the merged magnetic field continuous waveforms of the three components from continuous up to 2048 Hz.

The merged data are obtained using Burst data of the MAG instrument and the SCM data of LFR analyzer of the Solar Orbiter/RPW instrument. More specifically, it uses:

- solo_L2_mag-srf-burst (sampled at 64 Hz or 128 Hz)
- solo_L2_rpw-lfr-sbm1-cwf-b (sampled at 4096 Hz)
- solo_L2_rpw-lfr-surv-swf-b (only snapshots at 4096 Hz)

This data product has been produced following the method described in [RD8].

The magnetic field is expressed in the RTN frame of reference.

DOI: https://doi.org/10.57780/esa-f2565a8

Type of data	Continuous waveform of the magnetic field
Unit	nT
Sampling rate	4096 Hz
Data format	CDF (3.9.0)
Granularity	1 file per day

Data organization

Table below gives the name, data type, units and description of the zVariables stored in the CDF file.

Table 3: SOLO_L3_MULTI-MAG-RPW-SCM-MERGED-RTN-4096 CDF zVariables overview

NAME	TYPE	UNIT	Description
Epoch	CDF_TIME_TT2000	ns	Epoch time of the record
B_RTN	CDF_REAL4[3]	nT	3 entries array with magnetic field values (Br, Bt, Bn) in RTN frame
MERGED_BITMASK	CDF_UINT1		Origin of the merged data: -bit1: solo_L2_rpw-lfr-surv-swf-b sampled at 4096 Hz -bit4: solo_L2_rpw-lfr-sbm1-cwf-b sampled at 4096 Hz -bit6: solo_L2_mag-srf-burst sampled at 64 Hz -bit7: solo_L2_mag-srf-burst sampled at 128 Hz.
QUALITY_BITMASK	CDF_UINT2		Flag to indicate any context or events that can alterate data - bit0: a very short input MAG vector was used, resampling may introduce artifacts - bit1: unexpected VECTOR_RANGE (0 or 1), incorrect MAG calibration
QUALITY_BITMASK_MAG	CDF_UINT2		This is a bitwise variable, meaning that multiple flagscan be set for a single time, by adding flag values: - bit0: INBOARDPRIMARY, L2 data is from inboard sensor - bit1: SCETUNSYNC, instrument time not synchronised with SC time - bit2: MAGHEATERON, MAG heater operating - bit3: TONEREMOVED, interference tones were detected and removed from this data point - bit4: THRUSTERREMOVED thrusters were firing and influence has been removed from this data point - bit5: SCINTERFERENCE, SC generated interference detected but not removed - bit6: SAMOVEMENT, solar

			array movement occurred - bit7: INSTRUMENTREMOVED, interference field signal from another instrument operation has been detected and removed; Refer to [RD1] for more information on how these flags are generated.
QUALITY_BITMASK_SCM	CDF_UINT2		Flag to indicate any context or events that can alterate data: - bit0: SCM outworking or unknown temperature - bit1: SCM heater on/off transition - bit2: LFR onboard calibration signal
QUALITY_FLAG	CDF_UINT1		Flag to indicate the quality of the data from 0: Bad to 4: Excellent
SAMPLING_RATE	CDF_REAL4	Hz	Sampling frequency = 4096 Hz
CARTESIAN_REPRESENTATION	CDF_CHAR[3]		Cartesian representation of a magnetic vector
MAG_LABEL_RTN	CDF_CHAR[3]		Labels of the Magnetic fields components in the RTN frame = (Br, Bt, Bn)
MERGED_LABEL	CDF_CHAR[256]		Merged data in text form, indexed by MERGED_BITMASK (from 0 to 255)

Caveats and known issues

ISSUE	MITIGATION(S)
MAG L2 data is from inboard sensor	Bit0 of QUALITY_BITMASK_MAG is set to 1
MAG time not synchronised with SC time	Bit1 of QUALITY_BITMASK_MAG is set to 1
MAG heater operating	Bit2 of QUALITY_BITMASK_MAG is set to 1
Interference tone were detected in MAG frequency range and removed from this MAG data point	Bit3 of QUALITY_BITMASK_MAG is set to 1
Thrusters were firing and influence has been removed from this MAG data point	Bit4 of QUALITY_BITMASK_MAG is set to 1
SC generated interference tones were detected in MAG data but not removed	Bit5 of QUALITY_BITMASK_MAG is set to 1
Solar array movement occurred	Bit6 of QUALITY_BITMASK_MAG is set to 1

Interference field signal from another instrument operation has been detected in MAG data and removed	Bit7 of QUALITY_BITMASK_MAG is set to 1
The magnetic field is greatly disturbed when the SCM heaters are switched on and off.	When the heater signature could be located in the signal, it was subtracted before calibration, bit1 of QUALITY_BITMASK_SCM is set to 1 and QUALITY_FLAG is capped to 2
LFR calibration signal is sometimes superimposed on the interplanetary magnetic field	bit2 of QUALITY_BITMASK_SCM is set to 1 and QUALITY_FLAG is capped to 2
When the input MAG vector used is very short, the resulting data may be corrupted or lack precision.	bit0 of QUALITY_BITMASK is set to 1 and QUALITY_FLAG is capped to 2
When MAG uses unexpected VECTOR_RANGE (0 or 1) it results in incorrect MAG calibration	bit1 of QUALITY_BITMASK is set to 1 and QUALITY_FLAG is capped to 2
Interferences from spacecraft equipment are present above the sensitivity of SCM at 8 Hz, 16 Hz and harmonics. Other interferences can be noted at 1.3 Hz and harmonics	Peaks caused by these interferences are easily identifiable in the power spectrum

5.4 solo_L3_multi-mag-rpw-scm-merged-srf-4096

Overall description

SOLO_L3_MULTI-MAG-RPW-SCM-MERGED-SRF-4096 data provides the merged magnetic field continuous waveforms of the three components from continuous up to 2048 Hz.

The merged data are obtained using Burst data of the MAG instrument and the SCM data of LFR analyzer of the Solar Orbiter/RPW instrument. More specifically, it uses:

- solo_L2_mag-srf-burst (sampled at 64 Hz or 128 Hz)
- solo_L2_rpw-lfr-sbm1-cwf-b (sampled at 4096 Hz)
- solo_L2_rpw-lfr-surv-swf-b (only snapshots at 4096 Hz)

This data product has been produced following the method described in [RD8].

The magnetic field is expressed in the SRF frame of reference.

DOI: https://doi.org/10.57780/esa-f2565a8

Type of data	Continuous waveform of the magnetic field
Unit	nT
Sampling rate	4096 Hz
Data format	CDF (3.9.0)
Granularity	1 file per day

Data organization

Table below gives the name, data type, units and description of the zVariables stored in the CDF file.

Table 4: SOLO_L3_MULTI-MAG-RPW-SCM-MERGED-SRF-4096 CDF zVariables overview

NAME	TYPE	UNIT	Description
Epoch	CDF_TIME_TT2000	ns	Epoch time of the record
B_SRF	CDF_REAL4[3]	nT	3 entries array with magnetic field values (Bxsrf, Bysrf, Bzsrf) in SRF frame
MERGED_BITMASK	CDF_UINT1		Origin of the merged data: -bit1: solo_L2_rpw-lfr-surv-swf-b sampled at 4096 Hz -bit4: solo_L2_rpw-lfr-sbm1-cwf-b sampled at 4096 Hz -bit6: solo_L2_mag-srf-burst sampled at 64 Hz -bit7: solo_L2_mag-srf-burst sampled at 128 Hz.
QUALITY_BITMASK	CDF_UINT2		Flag to indicate any context or events that can alterate data - bit0: a very short input MAG vector was used, resampling may introduce artifacts - bit1: unexpected VECTOR_RANGE (0 or 1), incorrect MAG calibration
QUALITY_BITMASK_MAG	CDF_UINT2		This is a bitwise variable, meaning that multiple flagscan be set for a single time, by adding flag values: - bit0: INBOARDPRIMARY, L2 data is from inboard sensor - bit1: SCETUNSYNC, instrument time not synchronised with SC time - bit2: MAGHEATERON, MAG heater operating - bit3: TONEREMOVED, interference tones were detected and removed from this data point - bit4: THRUSTERREMOVED thrusters were firing and influence has been removed from this data point - bit5: SCINTERFERENCE, SC generated interference detected but not removed - bit6: SAMOVEMENT, solar array movement occurred - bit7: INSTRUMENTREMOVED, interference field signal from another instrument operation has

			been detected and removed; Refer to [RD1] for more information on how these flags are generated.
QUALITY_BITMASK_SCM	CDF_UINT2		Flag to indicate any context or events that can alterate data: - bit0: SCM outworking or unknown temperature - bit1: SCM heater on/off transition - bit2: LFR onboard calibration signal
QUALITY_FLAG	CDF_UINT1		Flag to indicate the quality of the data from 0: Bad to 4: Excellent
SAMPLING_RATE	CDF_REAL4	Hz	Sampling frequency = 4096 Hz
CARTESIAN_REPRESENTATION	CDF_CHAR[3]		Cartesian representation of a magnetic vector
MAG_LABEL_SRF	CDF_CHAR[3]		Labels of the Magnetic fields components in the SRF frame = (Bxsrf, Bysrf, Bzsrf)
MERGED_LABEL	CDF_CHAR[256]		Merged data in text form, indexed by MERGED_BITMASK (from 0 to 255)

Caveats and known issues

ISSUE	MITIGATION(S)
MAG L2 data is from inboard sensor	Bit0 of QUALITY_BITMASK_MAG is set to 1
MAG time not synchronised with SC time	Bit1 of QUALITY_BITMASK_MAG is set to 1
MAG heater operating	Bit2 of QUALITY_BITMASK_MAG is set to 1
Interference tone were detected in MAG frequency range and removed from this MAG data point	Bit3 of QUALITY_BITMASK_MAG is set to 1
Thrusters were firing and influence has been removed from this MAG data point	Bit4 of QUALITY_BITMASK_MAG is set to 1
SC generated interference tones were detected in MAG data but not removed	Bit5 of QUALITY_BITMASK_MAG is set to 1
Solar array movement occurred	Bit6 of QUALITY_BITMASK_MAG is set to 1
Interference field signal from another instrument operation has been detected in MAG data and removed	Bit7 of QUALITY_BITMASK_MAG is set to 1
The magnetic field is greatly disturbed when the SCM heaters are switched on and off.	When the heater signature could be located in the signal, it was subtracted before calibration, bit1 of

	QUALITY_BITMASK_SCM is set to 1 and QUALITY_FLAG is capped to 2
LFR calibration signal is sometimes superimposed on the interplanetary magnetic field	bit2 of QUALITY_BITMASK_SCM is set to 1 and QUALITY_FLAG is capped to 2
When the input MAG vector used is very short, the resulting data may be corrupted or lack precision.	bit0 of QUALITY_BITMASK is set to 1 and QUALITY_FLAG is capped to 2
When MAG uses unexpected VECTOR_RANGE (0 or 1) it results in incorrect MAG calibration	bit1 of QUALITY_BITMASK is set to 1 and QUALITY_FLAG is capped to 2
Interferences from spacecraft equipment are present above the sensitivity of SCM at 8 Hz, 16 Hz and harmonics. Other interferences can be noted at 1.3 Hz and harmonics	Peaks caused by these interferences are easily identifiable in the power spectrum

6 RPW SCM IMAGE PRODUCTS DESCRIPTION

6.1 solo_L3_mag-rpw-scm-merged-256

Overall description

The solo_L3_mag-rpw-scm-merged-256 data product is generated from solo_L3_multi-mag-rpw-scm-merged-rtn-256 to display the magnetic field spectra evolution below 128 Hz of the 3 components in the RTN frame.

There are two pages: the first shows the density spectrograms of the three components of the magnetic field, and the second shows the median spectrum over the period and the spectrogram of density ratios relative to the median spectrum.

On each spectrogram, the magnetic field curve is superimposed with its own scale on the right.

DOI: https://doi.org/10.57780/esa-f2565a8

Type of data	Density Spectrum of the magnetic field	Magnetic field
Intensity units	log(nT^2/Hz) for page 1, log(ratio) for page 2	nT
X-axis quantity	Time	
X-axis units	Hours, Minutes, Seconds (HH:MN:SS)	
X-axis resolution	40 s when continuous data ; otherwise from 22 s to 300 s	0.0625 s when continuous data ; otherwise from 22 s to 300 s
X-axis range	[first sample time, last sample time]	
X-axis scale	Linear	
Y-axis quantity	Frequency	Amplitude
Y-axis units	Hz	nT

Y-axis resolution	0.025 Hz when continuous data ; otherwise 0.125 Hz	adaptive
Y-axis range	[0 Hz, 128 Hz]	adaptive: ~ twice the global range
Y-axis scale	Logarithmic	Linear
Data format	PNG	
Granularity	1 file per day	

6.2 solo_L3_mag-rpw-scm-merged-4096

Overall description

The solo_L3_mag-rpw-scm-merged-4096 data product is generated from solo_L3_multi-mag-rpw-scm-merged-rtn-4096 to display the magnetic field spectra evolution below 2048 Hz of the 3 components in the RTN frame.

There are two pages: the first shows the density spectrograms of the three components of the magnetic field, and the second shows the median spectrum over the period and the spectrogram of density ratios relative to the median spectrum.

On each spectrogram, the magnetic field curve is superimposed with its own scale on the right.

DOI: https://doi.org/10.57780/esa-f2565a8

Type of data	Density Spectrum of the magnetic field	Magnetic field
Intensity units	log(nT^2/Hz) for page 1, log(ratio) for page 2	nT
X-axis quantity	Time	
X-axis units	Hours, Minutes, Seconds (HH:MN:SS)	
X-axis resolution	4 s when continuous data ; otherwise from 22 s to 300 s	4 ms when continuous data ; otherwise from 22 s to 300 s
X-axis range	[first sample time, last sample time]	
X-axis scale	Linear	
Y-axis quantity	Frequency	Amplitude
Y-axis units	Hz	nT
Y-axis resolution	0.25 Hz when continuous data ; otherwise 2 Hz	adaptive
Y-axis range	[0 Hz, 2048 Hz]	adaptive: ~ twice the global range
Y-axis scale	Logarithmic	Linear
Data format	PNG	
Granularity	1 file per day	

7 RULES OF USE

This data is publicly available. Please cite the relevant papers (Solar Orbiter merged magnetic field paper [RD8], MAG paper [RD3], RPW paper [RD4], SCM paper [RD5], and) when using these data in publications and presentations, and acknowledge the PI's of this data product. Read carefully the caveats attached to the data and send information on the use of this data as well as questions and comments to M. Kretzschmar.

See also in https://rpw-datacenter.obspm.fr/spip.php?article4 the Data policy and credits for RPW products.

8 RELEASE NOTES

Please read MODS global attribute in the CDF files for a history of the science data modifications.

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10 REFERENCES

- The Solar Orbiter magnetometer, T. S. Horbury et al., A&A, 2020 (https://doi.org/10.1051/0004-6361/201937257)
- The Solar Orbiter Radio and Plasma Waves (RPW) instrument, Maksimovic et al., A&A, 2020 (https://doi.org/10.1051/0004-6361/201936214)
- Jannet, G., Dudok de Wit, T., Krasnoselskikh, V., Kretzschmar, M., Fergeau, P., Bergerard-Timofeeva, M., et al. (2021). Measurement of magnetic field fluctuations in the Parker Solar Probe and Solar Orbiter missions. *Journal of Geophysical Research: Space Physics*, *126*, e2020JA028543 (https://doi.org/10.1029/2020JA028543)
- M. Kretzschmar, J.-Y. Brochot, T.S. Horbury, K. Rackovic, M. Maksimovic, O. Alexandrova, X. Bonnin, G. Jannet, H. O'Brien, A. Crabtree, J. Morris, V. Krasnoselskikh, T. Dudok de Wit, O. Le Contel, T. Chust, P.-M. De Gelis, L. Da Silva Gonçalves, E. Fauchon-Jones. The Solar Orbiter merged magnetic field. A&A, 2025 (https://doi.org/10.1051/0004-6361/202554731)
- Metadata Definition for Solar Orbiter Science Data [AD1]
- MAG Data Product Description Document [RD1]
- RPW Data Product Description Document [RD2]
- RPW SCM Waveform Data User Manual [RD6]
- NASA CDF Web portal (https://cdf.gsfc.nasa.gov/)

APPENDICES

11 LIST OF ACRONYMS

Acronym	Definition
AC	Alternating Current
CDF	Common Data Format

DPDD	Data Product Description Document
CWF	Continuous Waveform
ESA	European Space Agency
HFR	High Frequency Receiver
L2	Level 2 data processing
L3	Level 3 data processing
LFM	Low Frequency Mode
LFR	Low Frequency Receiver
LPC2E	Laboratoire de Physique et Chimie de l'Environnement et de l'Espace
LPP	Laboratoire de Physique des Plasma
NASA	National Aeronautics and Space Administration
PNG	Portable Network Graphics
ROC	RPW Operation Centre
RPW	Radio and Plasma Waves
RTN	Radial Tangential Normal reference frame
RSWF	Regular Snapshot Waveform
TDS	Time Domain Sampler
TNR	Thermal Noise Receiver
TSWF	Triggered Snapshot Waveform
SBM1	Selected Burst Mode 1
SBM2	Selected Burst Mode 2
SCM	Search Coil Magnetometer
SWF	Snapshot Waveform
SOC	Science Operation Centre
SOLO	Solar Orbiter
SRF	Solar orbiter Reference Frame