SOLAR ORBITER RPW ROC

RPW TDS Data User Manual

Prepared by:	Function:	Signature:	Date
RPW TDS Team			13/03/2025

Change Record				
Issue	Rev.	Date	Authors	Modifications
1	0	13/03/2025	RPW TDS Team	First issue

CLASSIFICATION PUBLIC ☒ RESTRICTED ☐

1 GENERAL

1.1 Scope of the Document

This document is the science data user manual for the relevant RPW TDS data measured on-board the Solar Orbiter mission.

An exhaustive description of all the RPW data file content is presented in the "RPW Data Product Description Document" (DPDD) [RD1].

The detailed instrument description can be found in [RD2].

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-0009/2/4	Meta data definition for Solar Orbiter science data	SOC	02/09/2019
AD2				
AD3				

l'Observatoire de Paris LESIA
Laboratoire d'Études Spatiales et d'Instrumentation en Astrophysique

CNRS-Observatoire de PARIS
Section de MEUDON – LESIA
5, place Jules Janssen
92195 Meudon Cedex – France

1.3 Reference Documents

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

	Mark	Title of the document	Authors	Date
	RD1	RPW Data Product Description Document (DPDD)	X.Bonnin	16/09/2020
	RD2	The Solar Orbiter Radio and Plasma Waves (RPW) instrument	Maksimovic et al.	2020
	RD3	TDS-Calibration Procedures		
	RD4	CDF Web site	CDF Team	2024

2 RPW TDS RECEIVER'S OVERVIEW

The Time Domain Sampler (TDS), a medium frequency receiver dedicated to waveform measurements. TDS is designed to capture electromagnetic waveform snapshots in the frequency range from 200 Hz to 200 kHz, resolving plasma waves near the electron plasma frequency and in the range between the proton and electron plasma frequencies, as well as transient signals in antenna voltage, associated with interplanetary dust impacts.

TDS samples three analog signals from the high frequency preamplifiers of RPW antennas (V1, V2 and V3) and one signal from the high frequency winding of the SCM search coil (BMF) as schematically seen in Figure 1. The analog front end of TDS implements a bandpass filter between approximately 200 Hz and 350 kHz, and a configurable gain switch allowing to increase the analog gain by 12 dB comparing to the baseline low gain setting option. This gain is configured by a telecommand and can be set independently for each channel. Before digitization, the analog signals are routed through a multiplexer bank which select the signals to be digitized by each of the four analog to digital converters (ADC). For electric field measurements, the multiplexers can be used to choose between monopole antenna measurements, where the antenna voltage relative to the spacecraft potential is measured, or dipole measurements, where differential voltages between RPW antennas are sampled instead.

The high frequency analog signals are digitized by four 14-bit ADCs at a sampling frequency of 2097.1 kHz. This oversampled digital signal is afterwards decimated by a configurable factor of 4, 8, 16 or 32 after being processed by anti-aliasing FIR filters. The decimating filters are implemented in FPGA logic, but the filter coefficients are uploaded to the FPGA by the flight software and multiple sets with slightly different characteristics can be chosen by a telecommand. This decimated waveform is then used as the input digital signal for waveform snapshots and TDS statistical products. This configurable decimation allows the TDS sampling rate to be set to one of the four values: 524.275 ksps, 262.138 ksps, 131.069 ksps or 65.534 ksps.

A large number of input configurations is allowed by the TDS input multiplexers, but only three multiplexer settings listed in Table 1. are used routinely in scientific operations. This list includes the monopole configuration SE1 suitable for dust impact measurements, but the measurements contain more noise and spurious signals of spacecraft origin. The measurements in the DIFF1 dipole configuration are cleaner, but since the three RPW antennas lie in the same plane and essentially only allow to measure a projection of the electric field to the antenna plane, the three dipole measurements in the same plane are redundant and this configuration does not easily allow to study variations in antenna to spacecraft voltage required for dust impact measurements. The best compromise is offered by the XLD1 which combines two electric field dipoles in two channels and one monopole in the third channel.

Table 1. Standard configurations of TDS inputs used in science operations.

	Channel CH1	Channel CH2	Channel CH3	Channel CH4
SE1	V1	V2	V3	B_{MF}
DIFF1	V1 – V3	V2 – V1	V3 – V2	B_{MF}
XLD1	V1 – V3	V2 – V1	V2	B_{MF}

TDS supports all the operational modes of RPW ([RD2]). Survey NORMAL and BURST modes are implemented in the same way in TDS, but BURST mode has a separate configuration that can be applied when RPW switches to BURST mode. This typically includes higher rate products, such as the maximum amplitude (MAMP). In the selective burst modes SBM1, which shall be used during interplanetary shock crossings, and SBM2, to be used for in-situ type III

regions, TDS generates all the normal mode products but can generate additional periodic (in SBM1) or triggered (in SBM2) snapshots.

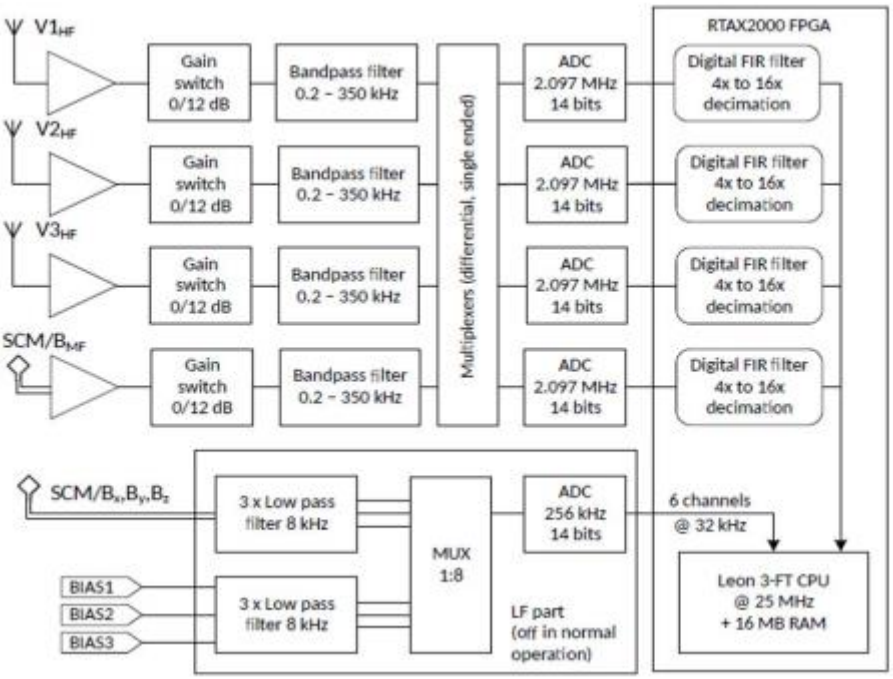

Figure 1. TDS block diagram.

2.1 On-board detection

The TDS flight software implements on-board processing and detection of the captured snapshots which allows the instrument to classify the observations into three categories: waves, dust impacts and other signals. This algorithm described here is used to select the most relevant waveform snapshots for transmission to the ground by assigning a quality factor and provides statistical characterization of processed snapshots. This algorithm efficiently distinguishes between coherent waves, such as Langmuir waves, characterized by a narrow bandwidth and small peak to median ratio, and isolated voltage spikes associated with impacts of interplanetary dust, which result in a very large peak to median ratio and wide bandwidth. In its nominal scientific operation (NORMAL, BURST or SBM1/SBM2 modes), the TDS acquires one waveform snapshot every second. Each snapshot is then processed in the following steps:

a. TDS calculates a maximum of the absolute value of all samples in the snapshot Vmax, an RMS value V_{rms} and a median absolute value V_{med}. This calculation, as well as all the subsequent steps, are only performed on one TDS channel selected by a telecommand.
b. If V_{max} is less than a configured minimum amplitude threshold, the snapshot is discarded as insignificant and no further processing is done.
c. A Fourier spectrum is calculated from the snapshot using the standard Welch method, by dividing the snapshot into blocks of 2048 points, applying a Hann window and a discrete Fourier transform (FFT) to each block and averaging all the FFT power spectra. Afterwards, the algorithm finds the largest peak in the spectrum (corresponding to the estimated wave frequency f_{wave}) and calculates its bandwidth BW at half of the peak amplitude.
d. A decision on event classification is made based on following conditions: if V_{max} $/V_{med} > T1_{dust}$ and $BW > T2_{dust}$ the event is classified as a dust impact. Otherwise, if

V_{max} /V_{med} ≤ $T1_{wave}$ and BW ≤ $T2_{wave}$ the event is a wave. Here, $T1_{dust,wave}$ and $T2_{dust,wave}$ are fixed thresholds configurable by telecommands. The criterion reflects the fact that wave observations are typically narrowband and the peak value in the snapshot is not much larger than the median value, while the opposite holds for sharp transients such as the dust impacts.

e. In the final step, the statistical values computed by TDS are updated. The wave, resp. dust, counter is incremented if a wave, resp. dust, event is identified. Maximum and RMS values of snapshot amplitudes are updated based on the processed snapshot. For waves, a special processing step is added, where wave specific properties (frequency, peak and RMS amplitude) are added to a special statistic restricted to wave events. These values are used to update the values for the STAT packet defined below and the on-board collected histograms. In this step we also assign a quality factor to the current snapshot, defined nominally as Q = V_{max} /BW. TDS can also use different quality factors, such as the amplitude alone.

3 RPW TDS DATA PRODUCTS OVERVIEW

3.1 Numerical data products

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

For more information about a specific data product can be found in the section 4.x<

3.1.1 Calibrated science data products (L2)

RPW L2 products are calibrated data, time-stamped (i.e., TT2000 Epoch time) and organized by sub-system, mode and type of measurement. The file format is CDF.

PRODUCT NAME	CONTENT
solo_L2_rpw-tds-surv-rswf-e	Regular (periodically captured) E-field waveform snapshots with variable length up to 65k samples sampled at 262 or 524 kHz.
solo_L2_rpw-tds-surv-tswf-e	Triggered (classified on board) E-field waveform snapshots with variable length up to 65k samples sampled at 262 or 524 kHz.
solo_L2_rpw-tds-sbm1-rswf-e	Burst mode (SBM1) E-field waveform snapshots with variable length up to 65k samples sampled at 262 or 524 kHz.
solo_L2_rpw-tds-sbm2-tswf-e	Burst mode (SBM2) E-field waveform snapshots with variable length up to 65k samples sampled at 262 or 524 kHz.
solo_L2_rpw-tds-surv-mamp	Time series of Maximum Absolute Amplitudes from up to four TDS channels with cadence between 8 and 250 milliseconds.
solo_L2_rpw-tds-surv-stat	TDS Statistics calculated on board from waveform snapshots and released every 16 seconds.
solo_L2_rpw-tds-surv-hist1d	TDS Statistics provided as 1D Histograms.
solo_L2_rpw-tds-surv-hist2d	TDS Statistics provided as 2D Histograms.

3.1.2 Uncalibrated science data products (L1R)

RPW L1R products contain uncalibrated data, time-stamped (i.e., TT2000 Epoch time) and organized by subsystem, mode and type of measurement. The file format is CDF.

PRODUCT NAME	CONTENT
solo_L1R_rpw-tds-rswf-b	Regular (periodically captured) B-field waveform snapshots with variable length up to 65k samples sampled at 262 or 524 kHz (uncalibrated).
solo_L1R_rpw-tds-tswf-b	Triggered (classified on board) B-field waveform snapshots with variable length up to 65k samples sampled at 262 or 524 kHz (uncalibrated).
solo_L1R_rpw-tds-sbm1-rswf-b	Burst mode (SBM1) B-field waveform snapshots with variable length up to 65k samples sampled at 262 or 524 kHz (uncalibrated).
solo_L1R_rpw-tds-sbm2-tswf-b	Burst mode (SBM2) B-field waveform snapshots with variable length up to 65k samples sampled at 262 or 524 kHz (uncalibrated).

3.1.3 Uncalibrated science data products (L1)

RPW L1 products contain uncalibrated data, time-stamped (i.e., TT2000 Epoch time) and organized by subsystem, mode and type of measurement. The file format is CDF.

PRODUCT NAME	CONTENT
solo_L1_rpw-tds-surv-rswf	Regular (periodically captured) E- and B-field waveform snapshots with variable length up to 65k samples sampled at 262 or 524 kHz (uncalibrated).
solo_L1_rpw-tds-surv-tswf	Triggered (classified on board) E- and B-field waveform snapshots with variable length up to 65k samples sampled at 262 or 524 kHz (uncalibrated).
solo_L1_rpw-tds-surv-stat	TDS Statistics calculated on board from waveform snapshots and released every 16 seconds (uncalibrated).
solo_L1_rpw-tds-surv-mamp	Time series of Maximum Absolute Amplitudes from up to four TDS channels with cadence between 8 and 250 milliseconds (uncalibrated).
solo_L1_rpw-tds-surv-hist1d	TDS Statistics provided as 1D Histograms (uncalibrated).
solo_L1_rpw-tds-surv-hist2d	TDS Statistics provided as 2D Histograms (uncalibrated).
solo_L1_rpw-tds-sbm1-rswf	Burst mode (SBM1) E- and B-field waveform snapshots with variable length up to 65k samples sampled at 262 or 524 kHz (uncalibrated).
solo_L1_rpw-tds-sbm2-tswf	Burst mode (SBM2) E- and B-field waveform snapshots with variable length up to 65k samples sampled at 262 or 524 kHz (uncalibrated).

3.2 Image data products

All RPW 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.

3.2.1 Daily summary plots

Table below gives the list of daily summary plots generated from RPW L2 data products.

PRODUCT NAME	CONTENT
solo_L3_rpw-tds-surv-rswf-e	Daily summary time-frequency spectrograms generated from solo L2_rpw-tds-surv-rswf-e E-field measurements.
solo_L3_rpw-tds-surv-tswf-e-spectrogram	Daily summary time-frequency spectrograms generated from solo_L2_rpw-tds-surv-tswf-e E-field measurements.
solo_L3_rpw-tds-surv-tswf-e-waveform	Daily summary waveform snapshots for the triggering channel generated from solo_L2_rpw-tds-surv-tswf-e E-field measurements.
solo_L3_rpw-tds-sbm1-rswf-e-spectrogram	Summary time-frequency spectrograms generated from solo L2_rpw-tds-sbm1-rswf-e E-field measurements on triggered interval.
solo_L3_rpw-tds-sbm2-tswf-e-spectrogram	Summary time-frequency spectrograms generated from solo_L2_rpw-tds-sbm2-tswf-e E-field measurements on triggered interval.
solo_L3_rpw-tds-sbm2-tswf-e-waveform	Summary waveform snapshots for the triggering channel generated from solo_L2_rpw-tds-surv-tswf-e E-field measurements on triggered interval.

4 RPW TDS NUMERICAL DATA PRODUCTS DESCRIPTION

This section provides a description of the RPW TDS numerical data products.

4.1 solo_L2_rpw-tds-surv-rswf-e

4.1.1 Overall description

The solo_L2_rpw-tds-surv-rswf-e data provide TDS regular waveform snapshots with up to three electric components, measured in both SURVEY NORMAL and BURST modes with a sampling frequency of 262 kHz or 524 kHz. The regular snapshots are collected periodically. The time cadence is configurable but typically one snapshot every 1-5 minutes.

The L2 files contain electric field waveform data calibrated to physical units both in antenna coordinates and in spacecraft reference frame (SRF) coordinate system (because the three RPW antennas are mounted in a single plane, only two components of electric field are provided. Furthermore, the waveforms are also provided with a simpler calibration, converted to voltage by a constant calibration factor. This is useful if the user prefers to apply a different antenna calibration matrix.

DOI: https://doi.org/10.57780/esa-3xcjd4w

Type of data	Time series
Units	V/m and V
Time resolution	variable
Data format	CDF (3.9.0)
Granularity	1 file per day

4.1.2 Data organization

Each CDF record in the file contains a waveform snapshot (time series) for up to three channels of the electric field, as indicated in CHANNEL_ON. The same waveform data are represented in multiple forms in the file:

- The calibrated electric field data (V/m) in sensor coordinates is stored in WAVEFORM_DATA variable. This data is calibrated to V/m using a frequency dependent calibration function, inverting the receiver and preamplifier transfer functions. Each component of the waveform corresponds to measurement from a single antenna (either monopole or differential, depending on input configuration). The individual components are thus not orthogonal.
- If applicable, the same calibrated E-filed also transformed into orthogonal Y-Z SRF components, stored in E_FIELD_Y_SRF and E_FIELD_Z_SRF variables. Since all RPW antennas are mounted in a single plane, only two orthogonal components are available.
- Additionally, calibrated voltage data is stored in WAVEFORM_DATA_VOLTAGE. This data corresponds to the same receiver channels as WAVEFORM_DATA, but it is only calibrated as voltage (either voltage between the antenna and the spacecraft in the case of monopoles or voltage difference between two antennas in the case of dipoles). This voltage calibration is done in a simpler way, using a constant, frequency independent factor for each antenna, corresponding to instrument gain at approximately 50 kHz.

The Epoch time of each record represents the acquisition time of the first data sample in the snapshot. To reconstruct the time vector for a given snapshot, the number of nanoseconds stored in EPOCH_OFFSET (INT4) must be added to Epoch (CDF_TIME_TT2000).

The snapshot length (in samples per channel) is stored for each snapshot in SAMPS_PER_CH variable (same length applies to WAVEFORM_DATA, E_FIELD_Y_SRF, E_FIELD_Z_SRF, and WAVEFORM_DATA_VOLTAGE). The dimensions of these variables are not necessarily constant across files and the length of the array can be larger than SAMPS_PER_CH in which case only the first SAMPS_PER_CH samples are valid, the rest should be FILLVAL. The global attribute WAVEFORM_DATA_LENGTH stores the maximum number of samples per snapshot for the given file.

The WAVEFORM_DATA and WAVEFORM_DATA_VOLTAGE variables contain in general multiple signal components from individual antennas, each component represented by one row of the matrix. The valid channels are indicated by a non-zero value in the corresponding element of CHANNEL_ON variable and the dipole/monopole antenna configuration for each channel can be found in CHANNEL_REF variable in numeric form or in CHANNEL_LABEL in text form. In a vast majority of cases, only the three standard configurations listed in Table 1 are used but sometimes only the first two components are stored.

Missing or invalid data samples are represented using FILLVAL.

Table 2. Overview of solo_L2_rpw-tds-surv-rswf-e zVariables. In the "TYPE" column, the expected size (i.e., number of elements along each dimension) of the zVariable for a CDF record is given in brackets (e.g., "[1]"). Non-record-variant zVariables are indicated.

NAME	TYPE	UNITS	DESCRIPTION
Epoch	CDF_TIME_TT2000	ns	Primary time used as a reference in the file. Corresponds to the time of the first sample of the snapshot.
EPOCH_OFFSET	CDF_INT8[65536]	ns	Time offset in nanoseconds for each data sample in the snapshot from the Epoch time.
CALIBRATION_TABLE_INDEX	CDF_UINT1[2]	unitless	Index of SWF calibration table
QUALITY_FLAG	CDF_UINT1	unitless	Flag to indicate the quality of the data. 0 – Bad data; 1 – Known problems, use at your own risk; 2 – Survey data, possibly not publication-quality; 3 Good for publication, subject to PI approval; 4 - Excellent data.
QUALITY_BITMASK	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level. Forwarded from L1 data.
L2_QUALITY_BITMASK	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level.
SURVEY_MODE	CDF_UINT1	unitless	Flag to indicate if the receiver in the SURVEY_BURST (=1) or SURVEY_NORMAL (=0) mode.
BIAS_ON	CDF_UINT1	unitless	Non-zero if BIAS powered on.
BIAS1_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT1.
BIAS2_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT2.
BIAS3_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT3.
BIAS_HV_ON	CDF_UINT1	unitless	Non-zero if BIAS High Voltage active.
BIAS_MUX_MODE	CDF_UINT1	unitless	BIAS MUX setting
RPW_THR_ON	CDF_UINT1	unitless	Non-zero value indicates THR was powered on.
RPW_LFR_ON	CDF_UINT1	unitless	Non-zero value indicates LFR was powered on.

RPW_ANT1_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 1 was powered on.
RPW_ANT2_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 2 was powered on.
RPW_ANT3_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 3 was powered on.
RPW_SCM_ON	CDF_UINT1	unitless	Non-zero value indicates SCM sensor was powered on.
RPW_SCM_CALIB	CDF_UINT1	unitless	Non-zero if SCM calibration signal is active.
SAMPLING_RATE	CDF_REAL4	Hz	Sampling rate of the snapshot in Hz (262 or 524 kHz).
CHANNEL_OVERFLOW	CDF_UINT1[4]	unitless	Channel overflow data. One byte per channel. If set to 1, the channel was saturated by out-of-range input during the snapshot.
BUFFER_OVERFLOW	CDF_UINT1	unitless	Normally zero. Non-zero value indicates TDS internal buffer overflow and possibly bad data.
FILTER_COEFS	CDF_UINT1	unitless	Index of the FIR digital filter used by TDS (1 to 3).
INPUT_CONFIG	CDF_UINT4	unitless	TDS input configuration word (a raw value not to be interpreted, use CHANNEL_REF /TDS_LOWGAIN instead)
TDS_LOWGAIN	CDF_UINT1[4]	unitless	One value per channel. For each channel indicates f the receiver is in the LOWGAIN (=1) or HIGHGAIN (=0) mode
TDS_CONFIG_LABEL	CDF_CHAR	unitless	Text representation of TDS input configuration. Can be: “SE1”, “DIFF1” or “XLD1''. See Table 1. for interpretation.
SNAPSHOT_SEQ_NR	CDF_UINT2	unitless	Sequential number of a snapshot incremented with every snapshot
CHANNEL_REF	CDF_UINT1[4]	unitless	Configuration of signal channels in the snapshot. Each element is a decadic number AB, where the digits A and B indicate a combination of RPW antennas in this channel (0=GND 1=V1, 2=V2, 3=V3). The number AB indicates that the

			corresponding channel contains a difference of 2 channels A-B. For example, value of 31 indicates dipole V3-V1.
CHANNEL	CDF_UINT1[4] (NRV)	unitless	Metadata referring to a channel axis.
CHANNEL_LABEL	CDF_CHAR[4] (NRV)	N/A	Labels for the channel axis.
SAMPS_PER_CH	CDF_UINT4	unitless	Number of samples per channel
CHANNEL_ON	CDF_UINT1[4]	unitless	If element X of the channel is non-zero, the corresponding channel X contains valid data.
WAVEFORM_DATA	CDF_REAL4[3, 65536]	V/m	Calibrated electric field waveform snapshots in antenna coordinates. Each component corresponds to one TDS channel.
WAVEFORM_DATA_VOLTAGE	CDF_REAL4[3, 65536]	V	The TDS waveform calibrated to voltage using a constant factor calibration.
E_FIELD_Y_SRF	CDF_REAL4[65536]	V/m	Y component of calibrated E-field in SRF coordinates.
E_FIELD_Z_SRF	CDF_REAL4[65536]	V/m	Z component of calibrated E-field in SRF coordinates.
RPW_ANTENNA_RTN	CDF_INT8[3, 3]	unitless	Matrix of vectors representing three effective directions and lengths of RPW antennas in RTN coordinates.
RPW_ANTENNA_RTN_LABEL_1	CDF_CHAR[4] (NRV)	N/A	Labels for a vector axis.
RPW_ANTENNA_RTN_LABEL_2	CDF_CHAR[4] (NRV)	N/A	Labels for a component axis.

4.1.3 Rules of use

Please read the text of the Rules_of_use global attribute in the CDF files.

See also in https://rpw-datacenter.obspm.fr/spip.php?article4.

4.1.4 Caveats and known issues

ISSUE	MITIGATION(S)
RPW MY (3) electrical antenna signal was lost intermittently between November 2023 and February 28, 2024. TDS acquisitions were impacted when measurements were performed on this antenna.	TDS receiver was switched into the monopole mode (SE1) configuration.

4.1.5 Release notes

See MODS global attribute in the CDF for an history of the data modifications.

4.1.6 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

4.1.7 References

- The Solar Orbiter Radio and Plasma Waves (RPW) instrument, Maksimovic et al., A&A, 2020 (https://doi.org/10.1051/0004-6361/201936214)
- Metadata Definition for Solar Orbiter Science Data, Helen R. Middleton, (https://s2e2.cosmos.esa.int/confluence/display/SOSP/Metadata+Definition+for+Solar+Orbiter+Science+Data)
- RPW Data Product Description Document (DPDD) (https://www.cosmos.esa.int/documents/3689933/11863517/ROC-PRO-DAT-NTT-00075-LES_Iss01_Rev03_%28RPW-Data-Product-Description-Document%29.pdf/02ec3da1-0acd-cf25-7cc1-0ac51f9f5bf4?t=1679312094778)
- NASA CDF Web portal (https://cdf.gsfc.nasa.gov/)

4.2 solo_L2_rpw-tds-sbm1-rswf-e

4.2.1 Overall description

The solo_L2_rpw-tds-sbm1-rswf-e data provides TDS regular waveform snapshots with up to three electric components, measured in the SBM1 mode. This data product has an identical structure as solo_L2_rpw-tds-surv-rswf-e (see Sec. 4.1).

4.3 solo_L2_rpw-tds-surv-tswf-e

4.3.1 Overall description

The solo_L2_rpw-tds-surv-tswf-e data provide TDS triggered waveform snapshots with up to three electric components, measured in both SURVEY NORMAL and BURST modes with a sampling frequency of 262 kHz or 524 kHz. The triggered snapshots are collected based on the on board classification described in Sec. 2.1. The time cadence is irregular and depends on selection, however the lower limit is 1 second.

DOI: https://doi.org/10.57780/esa-3xcjd4w

Type of data	Time series
Units	V/m and V
Time resolution	variable
Data format	CDF (3.9.0)
Granularity	1 file per day

4.3.2 Data organization

Each CDF record in the file contains a waveform snapshot (time series) for up to three channels of the electric field, as indicated in CHANNEL_ON. The same waveform data are represented in multiple forms in the file:

The internal data organization is the same as for solo_L2_rpw-tds-surv-rswf-e (see Sec. 4.1). Information for the classification on board (wave emission, dust impact or other) is provided

in **QUALITY_FACT**, **DOWNLINK_ALGO_CODE** and **DOWNLINK_REASON** variables.

Table 3. Overview of solo_L2_rpw-tds-surv-tswf-e zVariables. In the "TYPE" column, the expected size (i.e., number of elements along each dimension) of the zVariable for a CDF record is given in brackets (e.g., "[1]"). Non-record-variant zVariables are indicated.

NAME	TYPE	UNITS	DESCRIPTION
Epoch	CDF_TIME_TT2000	ns	Primary time used as a reference in the file. Corresponds to the time of the first sample of the snapshot.
EPOCH_OFFSET	CDF_INT8[65536]	ns	Time offset in nanoseconds for each data sample in the snapshot from the Epoch time.
CALIBRATION_TABLE_INDEX	CDF_UINT1[2]	unitless	Index of SWF calibration table
QUALITY_FLAG	CDF_UINT1	unitless	Flag to indicate the quality of the data. 0 – Bad data; 1 – Known problems, use at your own risk; 2 – Survey data, possibly not publication-quality; 3 Good for publication, subject to PI approval; 4 - Excellent data.
QUALITY_BITMASK	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level. Forwarded from L1 data.
QUALITY_FACT	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level.
L2_QUALITY_BITMASK	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level.
SURVEY_MODE	CDF_UINT1	unitless	Flag to indicate if the receiver in the SURVEY_BURST (=1) or SURVEY_NORMAL (=0) mode.
BIAS_ON	CDF_UINT1	unitless	Non-zero if BIAS powered on.

BIAS1_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT1.
BIAS2_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT2.
BIAS3_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT3.
BIAS_HV_ON	CDF_UINT1	unitless	Non-zero if BIAS High Voltage active.
BIAS_MUX_MODE	CDF_UINT1	unitless	BIAS MUX setting
RPW_THR_ON	CDF_UINT1	unitless	Non-zero value indicates THR was powered on.
RPW_LFR_ON	CDF_UINT1	unitless	Non-zero value indicates LFR was powered on.
RPW_ANT1_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 1 was powered on.
RPW_ANT2_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 2 was powered on.
RPW_ANT3_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 3 was powered on.
RPW_SCM_ON	CDF_UINT1	unitless	Non-zero value indicates SCM sensor was powered on.
RPW_SCM_CALIB	CDF_UINT1	unitless	Non-zero if SCM calibration signal is active.
SAMPLING_RATE	CDF_REAL4	Hz	Non-zero value indicates THR was powered on.
DOWNLINK_REASON	CDF_UINT1	unitless	Selection code of the down-linked packet, 1=WAVE, 2=DUST, 5=OTHERS
DOWNLINK_ALGO_CODE	CDF_UINT1	unitless	Onboard selection algorithm code
CHANNEL_OVERFLOW	CDF_UINT1[4]	unitless	Channel overflow data. One byte per channel. If set to 1, the channel was saturated by out-of-range input during the snapshot.
BUFFER_OVERFLOW	CDF_UINT1	unitless	Normally zero. Non-zero value indicates TDS internal buffer

			overflow and possibly bad data.
FILTER_COEFS	CDF_UINT1	unitless	Index of the FIR digital filter used by TDS (1 to 3).
INPUT_CONFIG	CDF_UINT4	unitless	TDS input configuration word (a raw value not to be interpreted, use CHANNEL_REF /TDS_LOWGAIN instead).
TDS_LOWGAIN	CDF_UINT1[4]	unitless	One value per channel. For each channel indicates f the receiver is in the LOWGAIN (=1) or HIGHGAIN (=0) mode
TDS_CONFIG_LABEL	CDF_CHAR	N/A	Text representation of TDS input configuration. Can be: “SE1”, “DIFF1” or “XLD1''. See Table 1. for interpretation.
SNAPSHOT_SEQ_NR	CDF_UINT2	unitless	Sequential number of a snapshot incremented with every snapshot
CHANNEL_REF	CDF_UINT1[4]	unitless	Configuration of signal channels in the snapshot. Each element is a decadic number AB, where the digits A and B indicate a combination of RPW antennas in this channel (0=GND 1=V1, 2=V2, 3=V3). The number AB indicates that the corresponding channel contains a difference of 2 channels A-B. For example, value of 31 indicates dipole V3-V1.
CHANNEL	CDF_UINT1[4] (NRV)	unitless	Metadata referring to a channel axis.
CHANNEL_LABEL	CDF_CHAR[4] (NRV)	N/A	Labels for the channel axis.
SAMPS_PER_CH	CDF_UINT4	unitless	Number of samples per channel
CHANNEL_ON	CDF_UINT1[4]	unitless	If element X of the channel is non-zero, the corresponding

			channel X contains valid data.
WAVEFORM_DATA	CDF_REAL4[3, 65536]	V/m	Calibrated electric field waveform snapshots in antenna coordinates. Each component corresponds to one TDS channel.
WAVEFORM_DATA_VOLTAGE	CDF_REAL4[3, 65536]	V	The TDS waveform calibrated to voltage using a constant factor calibration.
E_FIELD_Y_SRF	CDF_REAL4[65536]	V/m	Y component of calibrated E-field in SRF coordinates.
E_FIELD_Z_SRF	CDF_REAL4[65536]	V/m	Z component of calibrated E-field in SRF coordinates.
RPW_ANTENNA_RTN	CDF_REAL4[3, 3]	unitless	Matrix of vectors representing three effective directions and lengths of RPW antennas in RTN coordinates.
RPW_ANTENNA_RTN_LABEL_1	CDF_CHAR[4] (NRV)	N/A	Labels for a vector axis.
RPW_ANTENNA_RTN_LABEL_2	CDF_CHAR[4] (NRV)	N/A	Labels for a component axis.

4.3.3 Rules of use

Please read the text of the Rules_of_use global attribute in the CDF files.

See also in https://rpw-datacenter.obspm.fr/spip.php?article4.

4.3.4 Caveats and known issues

ISSUE	MITIGATION(S)
RPW MY (3) electrical antenna signal was lost intermittently between November 2023 and February 28, 2024. TDS acquisitions were impacted when measurements were performed on this antenna.	TDS receiver was switched into the monopole mode (SE1) configuration.

4.3.5 Release notes

See MODS global attribute in the CDF for an history of the data modifications.

4.3.6 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

4.3.7 References

- The Solar Orbiter Radio and Plasma Waves (RPW) instrument, Maksimovic et al., A&A, 2020 (https://doi.org/10.1051/0004-6361/201936214)

- Metadata Definition for Solar Orbiter Science Data, Helen R. Middleton, (https://s2e2.cosmos.esa.int/confluence/display/SOSP/Metadata+Definition+for+Solar+Orbiter+Science+Data)
- RPW Data Product Description Document (DPDD) (https://www.cosmos.esa.int/documents/3689933/11863517/ROC-PRO-DAT-NTT-00075-LES_Iss01_Rev03_%28RPW-Data-Product-Description-Document%29.pdf/02ec3da1-0acd-cf25-7cc1-0ac51f9f5bf4?t=1679312094778)
- NASA CDF Web portal (https://cdf.gsfc.nasa.gov/)

4.4 solo_L2_rpw-tds-sbm2-tswf-e

4.4.1 Overall description

The solo_L2_rpw-tds-sbm2-tswf-e data provides TDS regular waveform snapshots with up to three electric components, measured in the SBM1 mode. This data product has an identical structure as solo_L2_rpw-tds-surv-tswf-e (see Sec. 4.3).

DOI: https://doi.org/10.57780/esa-3xcjd4w

Type of data	Time series
Units	V/m and V
Time resolution	variable
Data format	CDF (3.9.0)
Granularity	1 file per day

4.4.2 Data organization

Each CDF record in the file contains a waveform snapshot (time series) for up to three channels of the electric field, as indicated in CHANNEL_ON. The same waveform data are represented in multiple forms in the file:
The internal data organization is the same as for solo_L2_rpw-tds-surv-tswf-e (see Sec. 4.3).

4.4.3 Rules of use

Please read the text of the Rules_of_use global attribute in the CDF files.

See also in https://rpw-datacenter.obspm.fr/spip.php?article4.

4.4.4 Caveats and known issues

ISSUE	MITIGATION(S)
RPW MY (3) electrical antenna signal was lost intermittently between November 2023 and February 28, 2024. TDS acquisitions were impacted when measurements were performed on this antenna.	TDS receiver was switched into the monopole mode (SE1) configuration.

4.4.5 Release notes

See MODS global attribute in the CDF for an history of the data modifications.

4.4.6 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

4.4.7 References

- The Solar Orbiter Radio and Plasma Waves (RPW) instrument, Maksimovic et al., A&A, 2020 (https://doi.org/10.1051/0004-6361/201936214)
- Metadata Definition for Solar Orbiter Science Data, Helen R. Middleton, (https://s2e2.cosmos.esa.int/confluence/display/SOSP/Metadata+Definition+for+Solar+Orbiter+Science+Data)
- RPW Data Product Description Document (DPDD) (https://www.cosmos.esa.int/documents/3689933/11863517/ROC-PRO-DAT-NTT-00075-LES_Iss01_Rev03_%28RPW-Data-Product-Description-Document%29.pdf/02ec3da1-0acd-cf25-7cc1-0ac51f9f5bf4?t=1679312094778)
- NASA CDF Web portal (https://cdf.gsfc.nasa.gov/)

4.5 solo_L2_rpw-tds-surv-stat

4.5.1 Overall description

The solo_L2_rpw-tds-surv-stat data provides TDS on-board statistics, measured in SURVEY NORMAL and BURST modes. This short data packet contains several statistical quantities describing the waveform snapshots processed by the TDS detection algorithm, including also those which were not selected for download as triggered snapshots. Nominally, TDS processes one waveform snapshot every second and the STAT packet transmitted every 16 seconds contains averages and counts accumulated over the past 16 seconds. Included is the number of detected waves and dust impacts, the peak and RMS amplitudes of detected waves, median value of the frequencies of detected waves, and the maximum absolute value and an RMS value calculated from all processed snapshots. The statistics is only calculated from one TDS channel selected by a telecommand.

DOI: https://doi.org/10.57780/esa-3xcjd4w

Type of data	Time series
Units	V/m, counts, Frequency
Time resolution	16 seconds
Data format	CDF (3.9.0)
Granularity	1 file per day

4.5.2 Data organization

Each CDF record in the file contains TDS statistics from one channel of the electric field, as indicated in CHANNEL_ON and CHANNEL_REF (selected by a telecommand). The calibrated values of the electric field data (V/m) in sensor coordinates are stored in WA_AMP_MAX, WA_AMP_MED, WA_AMP_RMS, SN_MED_MAX_E, and SN_RMS_E variables. The calibration is done by a constant, frequency independent factor for each antenna, corresponding to instrument gain at approximately 50 kHz.

The Epoch time (CDF_TIME_TT2000) of each record represents the acquisition time of the first data sample in the selection time interval.

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

Table 4. Overview of solo_L2_rpw-tds-surv-stat zVariables. In the "TYPE" column, the expected size (i.e., number of elements along each dimension) of the zVariable for a CDF record is given in brackets (e.g., "[1]"). Non-record-variant zVariables are indicated.

NAME	TYPE	UNITS	DESCRIPTION
Epoch	CDF_TIME_TT2000	ns	Primary time used as a reference in the file. Corresponds to the time of the first sample of the snapshot.
CALIBRATION_TABLE_INDEX	CDF_UINT1[2]	unitless	Index of SWF calibration table
QUALITY_FLAG	CDF_UINT1	unitless	Flag to indicate the quality of the data. 0 – Bad data; 1 – Known problems, use at your own risk; 2 – Survey data, possibly not publication-quality; 3 Good for publication, subject to PI approval; 4 - Excellent data.
QUALITY_BITMASK	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level. Forwarded from L1 data.
QUALITY_FACT	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level.
L2_QUALITY_BITMASK	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level.
SURVEY_MODE	CDF_UINT1	unitless	Flag to indicate if the receiver in the SURVEY_BURST (=1) or SURVEY_NORMAL (=0) mode.
BIAS_ON	CDF_UINT1	unitless	Non-zero if BIAS powered on.
BIAS1_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT1.
BIAS2_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT2.
BIAS3_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT3.

BIAS_HV_ON	CDF_UINT1	unitless	Non-zero if BIAS High Voltage active.
BIAS_MUX_MODE	CDF_UINT1	unitless	BIAS MUX setting
RPW_THR_ON	CDF_UINT1	unitless	Non-zero value indicates THR was powered on.
RPW_LFR_ON	CDF_UINT1	unitless	Non-zero value indicates LFR was powered on.
RPW_ANT1_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 1 was powered on.
RPW_ANT2_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 2 was powered on.
RPW_ANT3_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 3 was powered on.
RPW_SCM_ON	CDF_UINT1	unitless	Non-zero value indicates SCM sensor was powered on.
RPW_SCM_CALIB	CDF_UINT1	unitless	Non-zero if SCM calibration signal is active.
SAMPLING_RATE	CDF_REAL4	Hz	Non-zero value indicates THR was powered on.
SNAPSHOT_LEN	CDF_UINT4	samples	Length (in samples) of each snapshot processed by the TDS SW to build these statistics
TDS_CONFIG_LABEL	CDF_CHAR	unitless	Text representation of TDS input configuration. Can be: “SE1”, “DIFF1” or “XLD1''. See Table 1. for interpretation.
SNAPSHOT_SEQ_NR	CDF_UINT2	unitless	Sequential number of a snapshot incremented with every snapshot
CHANNEL_REF	CDF_UINT1	unitless	Configuration of the input signal for the statistics. A decadic number AB, where the digits A and B indicate a combination of RPW antennas in this channel (0=GND 1=V1, 2=V2, 3=V3). The number AB indicates that the corresponding

			channel contains a difference of 2 channels A-B. For example, value of 31 indicates dipole V3-V1.
SN_MED_MAX_E	CDF_REAL4	V/m	For each snapshot a maximum absolute value from all samples is calculated. This value gives the median value of these maxima from all snapshots.
SN_RMS_E	CDF_REAL4	V/m	RMS of E field over all proceeded snapshots.
SN_THRESHOLD	CDF_UINT1	unitless	Number of snapshots in the covered period where the maximum amplitude (maximum absolute value) exceeded the threshold from all samples is calculated. This value gives the median value of these maxima from all snapshots.
DU_NR_IMPACT	CDF_UINT1	counts	Total number of valid snapshots processed during the statistics collection period and identified as dust impacts from all samples is calculated. This value gives the median value of these maxima from all snapshots.
DU_MED_AMP	CDF_REAL4	V/m	Median amplitude of the dust spikes. For each snapshot identified as dust, TDS SW calculates the amplitude of the largest spike dust impacts from all samples is calculated. This

			value gives the median value of these maxima from all snapshots.
WA_AMP_MAX	CDF_REAL4	V/m	Maximum of maxima of the amplitude of waves. For each snapshot identified as a wave, a maximum absolute value from all samples is calculated
WA_AMP_MED	CDF_REAL4	V/m	Median of the peak amplitudes of waves. For each snapshot identified as a wave, a maximum absolute value from all samples is calculated
WA_RMS	CDF_REAL4	V/m	RMS value calculated form all waves
WA_NR_EVENTS	CDF_UINT1	counts	Total number of valid snapshots processed during the statistics collection period and identified as dust impacts from all samples is calculated. This value gives the median value of these maxima from all snapshots.
WA_MED_FREQ	CDF_REAL4	Hz	Median frequency of all identified waves. This value is calculated from the largest peak in the averaged FFT and encoded logarithmically in an 8-bit value

4.5.3 Rules of use

Please read the text of the Rules_of_use global attribute in the CDF files.

See also in https://rpw-datacenter.obspm.fr/spip.php?article4.

4.5.4 Caveats and known issues

ISSUE	MITIGATION(S)
RPW MY (3) electrical antenna signal was lost intermittently between November 2023 and February 28, 2024. TDS acquisitions were impacted when measurements were performed on this antenna.	TDS receiver was switched into the monopole mode (SE1) configuration.

4.5.5 Release notes

See MODS global attribute in the CDF for an history of the data modifications.

4.5.6 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

4.5.7 References

- The Solar Orbiter Radio and Plasma Waves (RPW) instrument, Maksimovic et al., A&A, 2020 (https://doi.org/10.1051/0004-6361/201936214)
- Metadata Definition for Solar Orbiter Science Data, Helen R. Middleton, (https://s2e2.cosmos.esa.int/confluence/display/SOSP/Metadata+Definition+for+Solar+Orbiter+Science+Data)
- RPW Data Product Description Document (DPDD) (https://www.cosmos.esa.int/documents/3689933/11863517/ROC-PRO-DAT-NTT-00075-LES_Iss01_Rev03_%28RPW-Data-Product-Description-Document%29.pdf/02ec3da1-0acd-cf25-7cc1-0ac51f9f5bf4?t=1679312094778)
- NASA CDF Web portal (https://cdf.gsfc.nasa.gov/)

4.6 solo_L2_rpw-tds-surv-mamp

4.6.1 Overall description

The solo_L2_rpw-tds-surv-mamp data provide Maximum Absolute Amplitudes from TDS measurements, sampled in survey normal and burst. This special product contains the maxima of an absolute value of the raw observed signals in each channel, sample at the original 2097.1 kHz frequency. The maxima are taken over 16384 samples (equivalent to 7.8 milliseconds) or a multiple of this interval. This yields a time series of up to 128 points per second per channel. This product is always enabled in BURST mode and sometimes in NORMAL mode when telemetry is available

DOI: https://doi.org/10.57780/esa-3xcjd4w

Type of data	Time series
Units	V/m
Sampling range	8 to 128 Hz
Time resolution	0.08 sec to 0.25 seconds
Data format	CDF (3.9.0)
Granularity	1 file per day

4.6.2 Data organization

Each CDF record in the file contains values for up to three channels of the electric field, as indicated in CHANNEL_ON. The calibrated absolute values of the electric field data (V/m) in sensor coordinates are stored in WAVEFORM_DATA variable. The calibration is done by a constant, frequency independent factor for each antenna, corresponding to instrument gain at approximately 50 kHz. Each component of the time series corresponds to measurement from a single antenna (either monopole or differential, depending on input configuration). The individual components are thus not orthogonal.

The Epoch time (CDF_TIME_TT2000) of each record represents the acquisition time of the first data sample in the selection time interval.

The WAVEFORM_DATA variable contains in general multiple signal components from individual antennas, each component represented by one component of the vector. The valid channels are indicated by a non-zero value in the corresponding element of CHANNEL_ON variable and the dipole/monopole antenna configuration for each channel can be found in CHANNEL_REF variable in numeric form or in CHANNEL_LABEL in text form. In a vast majority of cases, only the three standard configurations listed in Table 1 are used but sometimes only the first two components are stored.

Missing or invalid data samples are represented using FILLVAL.

Table 5. Overview of solo_L2_rpw-tds-surv-mamp zVariables. In the "TYPE" column, the expected size (i.e., number of elements along each dimension) of the zVariable for a CDF record is given in brackets (e.g., "[1]"). Non-record-variant zVariables are indicated.

NAME	TYPE	UNITS	DESCRIPTION
Epoch	CDF_TIME_TT2000	ns	Primary time used as a reference in the file
CALIBRATION_TABLE_INDEX	CDF_UINT1[2]	unitless	Index of SWF calibration table
QUALITY_FLAG	CDF_UINT1	unitless	Flag to indicate the quality of the data
QUALITY_BITMASK	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level
L2_QUALITY_BITMASK	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level.
BIAS_ON	CDF_UINT1	unitless	Non-zero if BIAS powered on.
BIAS1_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT1.
BIAS2_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT2.
BIAS3_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT3.
BIAS_HV_ON	CDF_UINT1	unitless	Non-zero if BIAS High Voltage active.
BIAS_MUX_MODE	CDF_UINT1	unitless	BIAS MUX setting
RPW_THR_ON	CDF_UINT1	unitless	Non-zero value indicates THR was powered on.

RPW_LFR_ON	CDF_UINT1	unitless	Non-zero value indicates LFR was powered on.
RPW_ANT1_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 1 was powered on.
RPW_ANT2_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 2 was powered on.
RPW_ANT3_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 3 was powered on.
RPW_SCM_ON	CDF_UINT1	unitless	Non-zero value indicates SCM sensor was powered on.
RPW_SCM_CALIB	CDF_UINT1	unitless	Non-zero if SCM calibration signal is active.
SAMPLING_RATE	CDF_UINT1	Hz	TDS sampling rate of the MAMP data (8, 16, 32, 64, or 128 Hz).
SURVEY_MODE	CDF_UINT1	unitless	Flag to indicate if the receiver in the SURVEY_BURST (=1) or SURVEY_NORMAL (=0) mode.
INPUT_CONFIG	CDF_UINT4	unitless	TDS input configuration word (a raw value not to be interpreted, use CHANNEL_REF /TDS_LOWGAIN instead)
TDS_CONFIG_LABEL	CDF_CHAR	unitless	Text representation of TDS input configuration. Can be: “SE1”, “DIFF1” or “XLD1’'. See Table 1. for interpretation.
SNAPSHOT_SEQ_NR	CDF_UINT2	unitless	Sequential number of a snapshot incremented with every snapshot
CHANNEL_ON	CDF_UINT1[4]	unitless	Status of signal channels in the snapshot (0=OFF, 1=ON). Indicates whether corresponding channel in waveform data contains valid data.
CHANNEL_OVERFLOW	CDF_UINT1[4]	unitless	Indicates ADC saturation for the respective channel in the snapshot (1=OVERFLOW)

BUFFER_OVERFLOW	CDF_UINT1	unitless	Status of buffer overflow (1=OVERFLOW)
CHANNEL_REF	CDF_UINT1[4]	unitless	Configuration of signal channels in the snapshot. Each element is a decadic number AB, where the digits A and B indicate a combination of RPW antennas in this channel (0=GND 1=V1, 2=V2, 3=V3). The number AB indicates that the corresponding channel contains a difference of 2 channels A-B. For example, value of 31 indicates dipole V3-V1.
CHANNEL	CDF_UINT1[4]	unitless	none
CHANNEL_LABEL	CDF_CHAR[4]	N/A	N/A
WAVEFORM_DATA	CDF_INT8[4]	V/m	TDS Maximum AMPlitudes sampled in up to four channels.

4.6.3 Rules of use

Please read the text of the Rules_of_use global attribute in the CDF files.

See also in https://rpw-datacenter.obspm.fr/spip.php?article4.

4.6.4 Caveats and known issues

ISSUE	MITIGATION(S)
RPW MY (3) electrical antenna signal was lost intermittently between November 2023 and February 28, 2024. TDS acquisitions were impacted when measurements were performed on this antenna.	TDS receiver was switched into the monopole mode (SE1) configuration.

4.6.5 Release notes

See MODS global attribute in the CDF for an history of the data modifications.

4.6.6 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

4.6.7 References

- The Solar Orbiter Radio and Plasma Waves (RPW) instrument, Maksimovic et al., A&A, 2020 (https://doi.org/10.1051/0004-6361/201936214)
- Metadata Definition for Solar Orbiter Science Data, Helen R. Middleton, (https://s2e2.cosmos.esa.int/confluence/display/SOSP/Metadata+Definition+for+Solar+Orbiter+Science+Data)
- RPW Data Product Description Document (DPDD) (https://www.cosmos.esa.int/documents/3689933/11863517/ROC-PRO-DAT-NTT-

00075-LES_Iss01_Rev03_%28RPW-Data-Product-Description-Document%29.pdf/02ec3da1-0acd-cf25-7cc1-0ac51f9f5bf4?t=1679312094778)

- NASA CDF Web portal (https://cdf.gsfc.nasa.gov/)

4.7 solo_L2_rpw-tds-surv-hist1d

4.7.1 Overall description

The solo_L2_rpw-tds-surv-hist1d data provide TDS on-board 1D histograms, measured in SURVEY NORMAL and BURST modes. As a part of the on board processing described in the section 2.1, TDS can also build on-board histograms from wave, dust and snapshot parameters calculated by the algorithm. The parameters that can be included in the statistics include peak and RMS amplitude of snapshots and of identified waves, wave frequency, and the amplitude and width of identified dust spikes. It is possible to choose via telecommand up to 4 parameters to include in histograms.

DOI: https://doi.org/10.57780/esa-3xcjd4w

Type of data	Histograms
Intensity units	Variable
Time resolution	0.1 sec to 5.4 seconds
Data format	CDF (3.9.0)
Granularity	1 file per day

4.7.1 Data organization

Each CDF record in the file contains one histogram from the TDS on board statistics accumulated over time in seconds indicated in HIST1D_COL_TIME variable. The statistic parameter is stored in HIST1D_PARAM and HIST1D_PARAM_LABEL. The number of histogram bins is given by HIST1D_BINS and histogram axis is stored in HIST1D_AXIS.

The Epoch time (CDF_TIME_TT2000) of each record represents the acquisition time of the first data sample in the accumulation time interval.

Missing or invalid data samples are represented using FILLVAL.

Table 6. Overview of solo_L2_rpw-tds-surv-hist1d zVariables. In the "TYPE" column, the expected size (i.e., number of elements along each dimension) of the zVariable for a CDF record is given in brackets (e.g., "[1]"). Non-record-variant zVariables are indicated.

NAME	TYPE	UNITS	DESCRIPTION
Epoch	CDF_TIME_TT2000	ns	Primary time used as a reference in the file
CALIBRATION_TABLE_INDEX	CDF_UINT1[2]	unitless	Index of SWF calibration table
QUALITY_FLAG	CDF_UINT1	unitless	Flag to indicate the quality of the data
QUALITY_BITMASK	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level

L2_QUALITY_BITMASK	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level.
BIAS_ON	CDF_UINT1	unitless	Non-zero if BIAS powered on.
BIAS1_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT1.
BIAS2_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT2.
BIAS3_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT3.
BIAS_HV_ON	CDF_UINT1	unitless	Non-zero if BIAS High Voltage active.
BIAS_MUX_MODE	CDF_UINT1	unitless	BIAS MUX setting
RPW_THR_ON	CDF_UINT1	unitless	Non-zero value indicates THR was powered on.
RPW_LFR_ON	CDF_UINT1	unitless	Non-zero value indicates LFR was powered on.
RPW_ANT1_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 1 was powered on.
RPW_ANT2_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 2 was powered on.
RPW_ANT3_ON	CDF_UINT1	unitless	Non-zero value indicates preamplifier on antenna 3 was powered on.
RPW_SCM_ON	CDF_UINT1	unitless	Non-zero value indicates SCM sensor was powered on.
RPW_SCM_CALIB	CDF_UINT1	unitless	Non-zero if SCM calibration signal is active.
SURVEY_MODE	CDF_UINT1	unitless	Flag to indicate if the receiver in the SURVEY_BURST (=1) or SURVEY_NORMAL (=0) mode.
SAMPLING_RATE	CDF_INT8	Hz	TDS sampling rate
INPUT_CONFIG	CDF_UINT4	unitless	TDS input configuration word (a raw value not to be interpreted, use CHANNEL_REF /TDS_LOWGAIN instead)
TDS_CONFIG_LABEL	CDF_CHAR	unitless	Text representation of TDS input configuration. Can be: “SE1”, “DIFF1” or “XLD1”. See

			Table 1. for interpretation.
SNAPSHOT_LEN	CDF_UINT4	samples	Length of snapshot in samples
CHANNEL_REF	CDF_UINT1	unitless	Configuration of the input signal for the histogram. A decadic number AB, where the digits A and B indicate a combination of RPW antennas in this channel (0=GND 1=V1, 2=V2, 3=V3). The number AB indicates that the corresponding channel contains a difference of 2 channels A-B. For example, value of 31 indicates dipole V3-V1.
HIST1D_ID	CDF_UINT1	unitless	An ID number of the histogram (1..4). Up to 4 histograms are collected simultaneously.
HIST1D_PARAM	CDF_UINT1	unitless	The parameter used to build this histogram.
HIST1D_PARAM_LABEL	CDF_CHAR	unitless	Label for the histogram.
HIST1D_AXIS	CDF_INT8[256]	unitless	Axis corresponding to this histogram
HIST1D_COL_TIME	CDF_UINT2	s	The duration of the time period (in seconds) over which this histogram has been built.
HIST1D_OUT	CDF_UINT2	unitless	Number of out-of-range values which were out of the limit specified by the current axis configuration.
HIST1D_BINS	CDF_UINT2	unitless	Number of bins in the histogram. Determines the length of the packet.
HIST1D_COUNTS	CDF_UINT2[256]	counts	Counts corresponding to each bin in the histogram

4.7.2 Rules of use

Please read the text of the Rules_of_use global attribute in the CDF files.

See also in https://rpw-datacenter.obspm.fr/spip.php?article4.

4.7.3 Caveats and known issues

ISSUE	MITIGATION(S)
RPW MY (3) electrical antenna signal was lost intermittently between November 2023 and February 28, 2024. TDS acquisitions were impacted when measurements were performed on this antenna.	TDS receiver was switched into the monopole mode (SE1) configuration.

4.7.4 Release notes

See MODS global attribute in the CDF for an history of the data modifications.

4.7.5 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

4.7.6 References

- The Solar Orbiter Radio and Plasma Waves (RPW) instrument, Maksimovic et al., A&A, 2020 (https://doi.org/10.1051/0004-6361/201936214)
- Metadata Definition for Solar Orbiter Science Data, Helen R. Middleton, (https://s2e2.cosmos.esa.int/confluence/display/SOSP/Metadata+Definition+for+Solar+Orbiter+Science+Data)
- RPW Data Product Description Document (DPDD) (https://www.cosmos.esa.int/documents/3689933/11863517/ROC-PRO-DAT-NTT-00075-LES_Iss01_Rev03_%28RPW-Data-Product-Description-Document%29.pdf/02ec3da1-0acd-cf25-7cc1-0ac51f9f5bf4?t=1679312094778)
- NASA CDF Web portal (https://cdf.gsfc.nasa.gov/)

4.8 solo_L2_rpw-tds-surv-hist2d

4.8.1 Overall description

The solo_L2_rpw-tds-surv-hist2d data provide TDS statistics 2D histograms, measured in SURVEY NORMAL and BURST modes. As a part of the on board processing described in the section 2.1, TDS can also build on-board histograms from wave, dust and snapshot parameters calculated by the algorithm. The parameters that can be included in the statistics include peak and RMS amplitude of snapshots and of identified waves, wave frequency, and the amplitude and width of identified dust spikes. It is possible to choose via telecommand up to two pairs of parameters to be used for building of two-dimensional histograms.

DOI: https://doi.org/10.57780/esa-3xcjd4w

Type of data	2D histograms
Intensity units	Variable
Time resolution	0.1 sec to 5.4 seconds
Data format	CDF (3.9.0)
Granularity	1 file per day

4.8.2 Data organization

Each CDF record in the file contains one histogram from the TDS on board statistics accumulated over time in seconds indicated in HIST2D_COL_TIME variable. The statistic parameter is stored in HIST2D_PARAM and HIST2D_PARAM_LABEL. The numbers of histogram bins is given by HIST2D_BINS1 and HIST2D_BINS2. Histogram axes are stored in HIST2D_AXIS1 and HIST2D_AXIS2.

The Epoch time (CDF_TIME_TT2000) of each record represents the acquisition time of the first data sample in the accumulation time interval.

Missing or invalid data samples are represented using FILLVAL.

Table 7. Overview of solo_L2_rpw-tds-surv-hist2d zVariables. In the "TYPE" column, the expected size (i.e., number of elements along each dimension) of the zVariable for a CDF record is given in brackets (e.g., "[1]"). Non-record-variant zVariables are indicated.

NAME	TYPE	UNITS	DESCRIPTION
Epoch	CDF_TIME_TT2000	ns	Primary time used as a reference in the file
CALIBRATION_TABLE_INDEX	CDF_UINT1[2]	unitless	Index of SWF calibration table
QUALITY_FLAG	CDF_UINT1	unitless	Flag to indicate the quality of the data
QUALITY_BITMASK	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level
L2_QUALITY_BITMASK	CDF_UINT2	unitless	Flag to indicate any context information or status at the receiver or experiment level.
BIAS_ON	CDF_UINT1	unitless	Non-zero if BIAS powered on.
BIAS1_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT1.
BIAS2_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT2.
BIAS3_ON	CDF_UINT1	unitless	Non-zero if biasing active on ANT3.
BIAS_HV_ON	CDF_UINT1	unitless	Non-zero if BIAS High Voltage active.
BIAS_MUX_MODE	CDF_UINT1	unitless	BIAS MUX setting
SURVEY_MODE	CDF_UINT1	unitless	Flag to indicate if the receiver in the SURVEY_BURST (=1) or SURVEY_NORMAL (=0) mode.
SAMPLING_RATE	CDF_INT8	Hz	TDS sampling rate
INPUT_CONFIG	CDF_UINT4	unitless	TDS input configuration word (a raw value not to be interpreted, use CHANNEL_REF

			/TDS_LOWGAIN instead)
TDS_CONFIG_LABEL	CDF_CHAR	unitless	Text representation of TDS input configuration. Can be: “SE1”, “DIFF1” or “XLD1''. See Table 1. for interpretation.
SNAPSHOT_LEN	CDF_UINT4	samples	Length of processed snapshot in samples
CHANNEL_REF	CDF_UINT1	unitless	Configuration of the input signal for the histogram. A decadic number AB, where the digits A and B indicate a combination of RPW antennas in this channel (0=GND 1=V1, 2=V2, 3=V3). The number AB indicates that the corresponding channel contains a difference of 2 channels A-B. For example, value of 31 indicates dipole V3-V1.
HIST2D_ID	CDF_UINT1	unitless	An ID number of the histogram (1 or 2).
HIST2D_PARAMS	CDF_UINT1	unitless	The combination of parameters used to build this histogram.
HIST2D_PARAMS_LABEL	CDF_CHAR	unitless	Label for hist2D parameters.
HIST2D_COL_TIME	CDF_UINT2	s	The time period over which this histogram has been built.
HIST2D_AXIS1	CDF_REAL4[128]	unitless	The X-axis (first parameter) of the histogram.
HIST2D_AXIS2	CDF_REAL4[128]	unitless	The Y-axis (second parameter) of the histogram
HIST2D_BINS1	CDF_UINT1	unitless	Number of X bins in the histogram.
HIST2D_BINS2	CDF_UINT1	unitless	Number of Y bins in the histogram.
HIST2D_TOT_SNAPSHOT	CDF_UINT2	unitless	Total number of snapshots processed when producing the histogram
HIST2D_COUNTS	CDF_UINT2[128, 128]	Counts	Counts corresponding to each bin in the histogram

4.8.3 Rules of use

Please read the text of the Rules_of_use global attribute in the CDF files.

See also in https://rpw-datacenter.obspm.fr/spip.php?article4.

4.8.4 Caveats and known issues

ISSUE	MITIGATION(S)
RPW MY (3) electrical antenna signal was lost intermittently between November 2023 and February 28, 2024. TDS acquisitions were impacted when measurements were performed on this antenna.	TDS receiver was switched into the monopole mode (SE1) configuration.

4.8.5 Release notes

See MODS global attribute in the CDF for an history of the data modifications.

4.8.6 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

4.8.7 References

- The Solar Orbiter Radio and Plasma Waves (RPW) instrument, Maksimovic et al., A&A, 2020 (https://doi.org/10.1051/0004-6361/201936214)
- Metadata Definition for Solar Orbiter Science Data, Helen R. Middleton, (https://s2e2.cosmos.esa.int/confluence/display/SOSP/Metadata+Definition+for+Solar+Orbiter+Science+Data)
- RPW Data Product Description Document (DPDD) (https://www.cosmos.esa.int/documents/3689933/11863517/ROC-PRO-DAT-NTT-00075-LES_Iss01_Rev03_%28RPW-Data-Product-Description-Document%29.pdf/02ec3da1-0acd-cf25-7cc1-0ac51f9f5bf4?t=1679312094778)
- NASA CDF Web portal (https://cdf.gsfc.nasa.gov/)

5 RPW TDS IMAGE PRODUCTS DESCRIPTION

5.1 solo_L3_rpw-tds-surv-rswf-e

5.1.1 Overall description

The solo_L3_rpw-tds-surv-rswf-e data product is generated from solo_L2_rpw-tds-surv-rswf-e data described in Sec. 4.1 to display the E-field dynamical spectra over the full TDS frequency range.

Backgrounds and polluted signals are not cleaned from L2 data.

DOI: https://doi.org/10.57780/esa-3xcjd4w

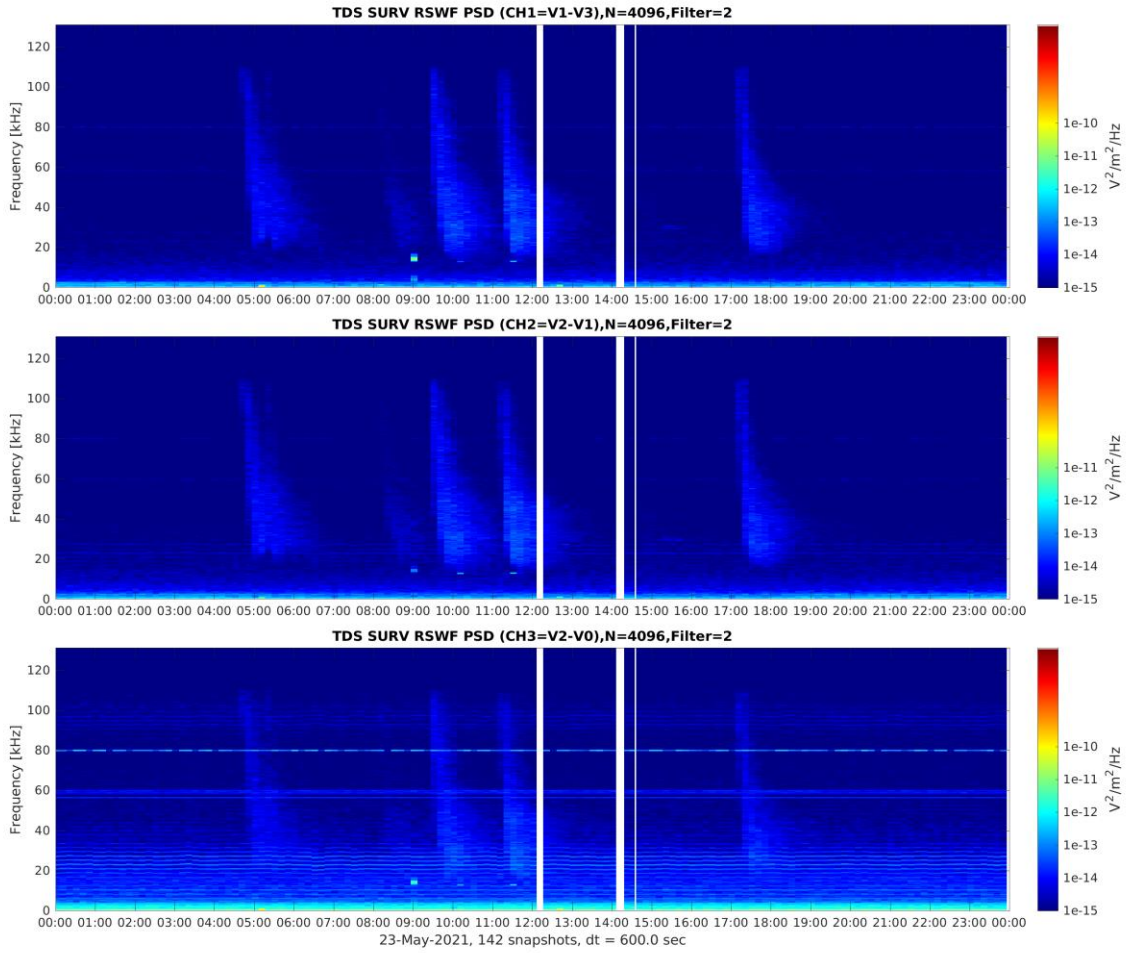

Figure 2. An example of TDS SURV-RWSF-E spectrogram.

Type of data	Time series
Intensity units	V^2/m^2/Hz
X-axis quantity	Time
X-axis units	Decimal hours of day (UTC)
X-axis resolution	10 to 300 seconds
X-axis range	[00:00, 24:00]
X-axis scale	Linear
Y-axis quantity	Frequency
Y-axis units	kHz
Y-axis resolution	0 Hz to 131 or 262 kHz
Y-axis range	[0, 131] or [0, 262]
Y-axis scale	Linear
Data format	PNG
Granularity	1 file per day

5.1.2 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

5.2 solo_L3_rpw-tds-surv-stat

5.2.1 Overall description

The solo_L3_rpw-tds-surv-stat data product is generated from solo_L2_rpw-tds-surv-stat data described in Sec. 4.5 to display on-board collected statistics over the 1 second TDS snapshots with the time cadence of 16 seconds.

Backgrounds and polluted signals are not cleaned from L2 data.

DOI: https://doi.org/10.57780/esa-3xcjd4w

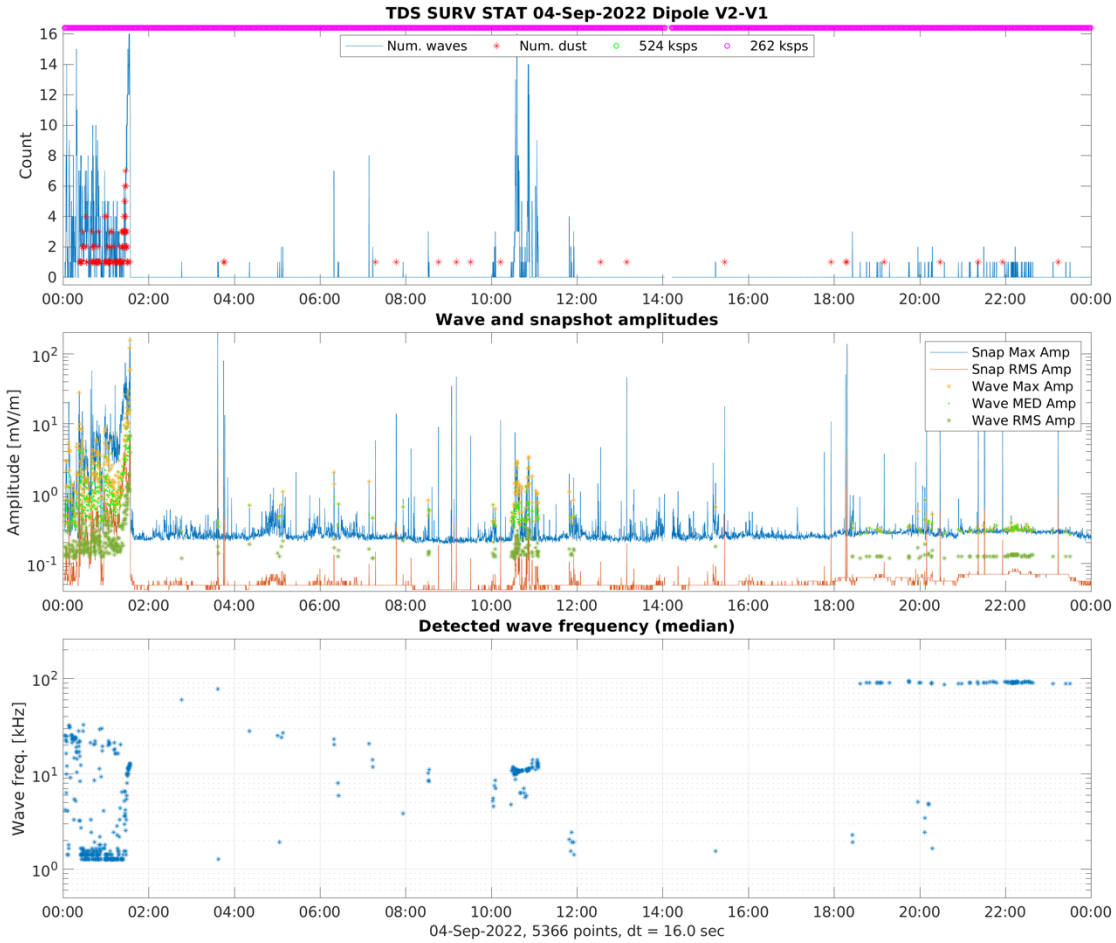

Figure 3. An example of TDS Survey Statistics.

Type of data	Time series
X-axis quantity	Time
X-axis units	Decimal hours of day (UTC)
X-axis resolution	16 seconds
X-axis range	[00:00, 24:00]
X-axis scale	Linear
Y-axis quantity	Number of detected waves and dust impacts

Y-axis units	Counts
Y-axis resolution	0.5
Y-axis range	[-0.5, 16]
Y-axis scale	Linear
Data format	PNG
Granularity	1 file per day

Type of data	Time series
X-axis quantity	Time
X-axis units	Decimal hours of day (UTC)
X-axis resolution	16 seconds
X-axis range	[00:00, 24:00]
X-axis scale	Linear
Y-axis quantity	Amplitude
Y-axis units	mV/m
Y-axis resolution	Variable
Y-axis range	Variable
Y-axis scale	Log
Data format	PNG
Granularity	1 file per day

Type of data	Time series
X-axis quantity	Time
X-axis units	Decimal hours of day (UTC)
X-axis resolution	16 seconds
X-axis range	[00:00, 24:00]
X-axis scale	Linear
Y-axis quantity	Frequency
Y-axis units	kHz
Y-axis resolution	Variable
Y-axis range	[5e-1, 131 or 262]
Y-axis scale	Log
Data format	PNG
Granularity	1 file per day

5.2.2 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

5.3 solo_L3_rpw-tds-surv-tswf-e-spectrogram

5.3.1 Overall description

The solo_L3_rpw-tds-surv-tswf-e-spectrogram data product is generated from solo_L2_rpw-tds-surv-tswf-e data to display E-field dynamical spectra in the TDS frequency range.

DOI: https://doi.org/10.57780/esa-3xcjd4w

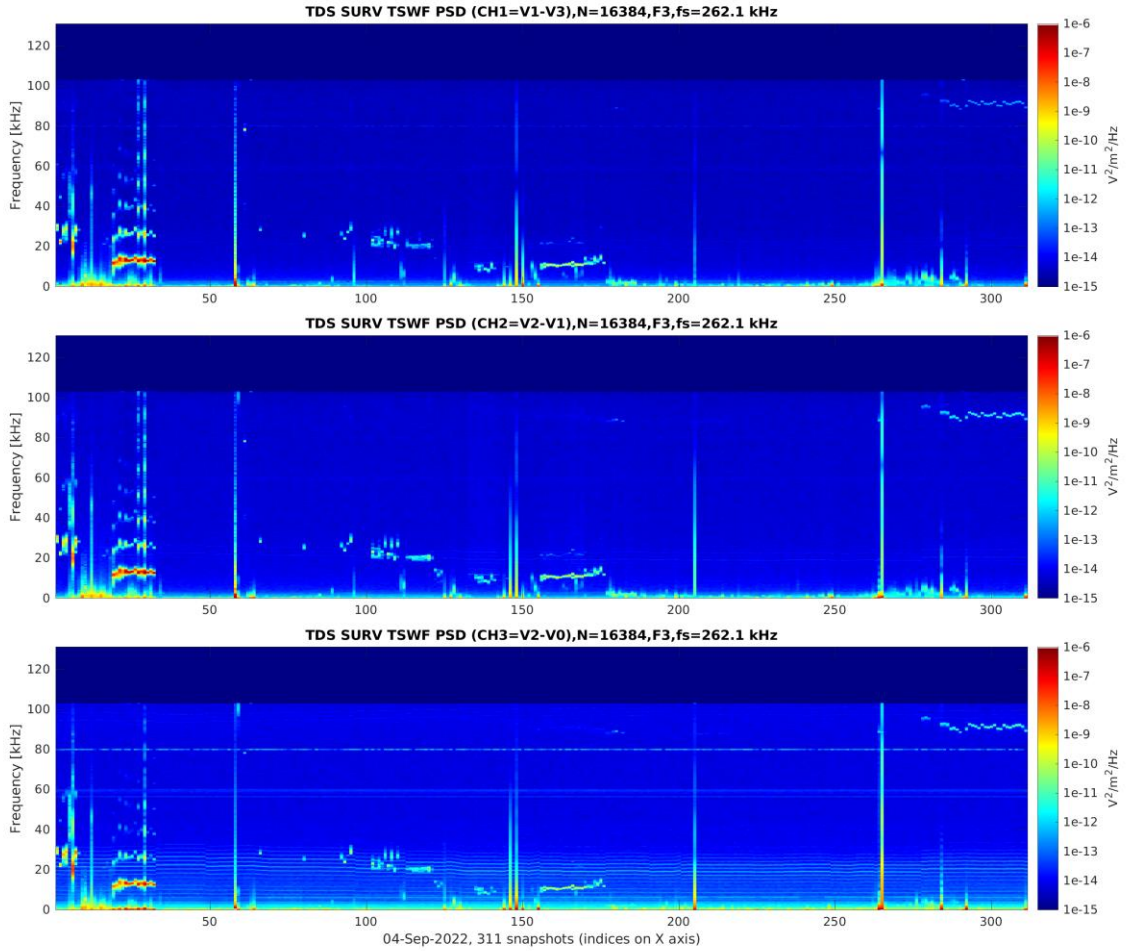

Figure 4. An example of TDS SURV-TSWF-E spectrogram.

Type of data	Spectrogram
Intensity units	V^2/m^2/Hz
X-axis quantity	Snapshot number
X-axis units	n/a
X-axis resolution	1
X-axis range	Variable
X-axis scale	Linear
Y-axis quantity	Frequency

Y-axis units	kHz
Y-axis resolution	Variable
Y-axis range	0 Hz to 131 or 262 kHz
Y-axis scale	Linear
Data format	PNG
Granularity	1 file per day

5.3.1 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

5.4 solo_L3_rpw-tds-surv-tswf-e-waveform

5.4.1 Overall description

The solo_L3_rpw-tds-surv-tswf-e-waveform data product is generated from solo_L2_rpw-tds-surv-tswf-e data to display on board selected E-field waveform snapshots.

DOI: https://doi.org/10.57780/esa-3xcjd4w

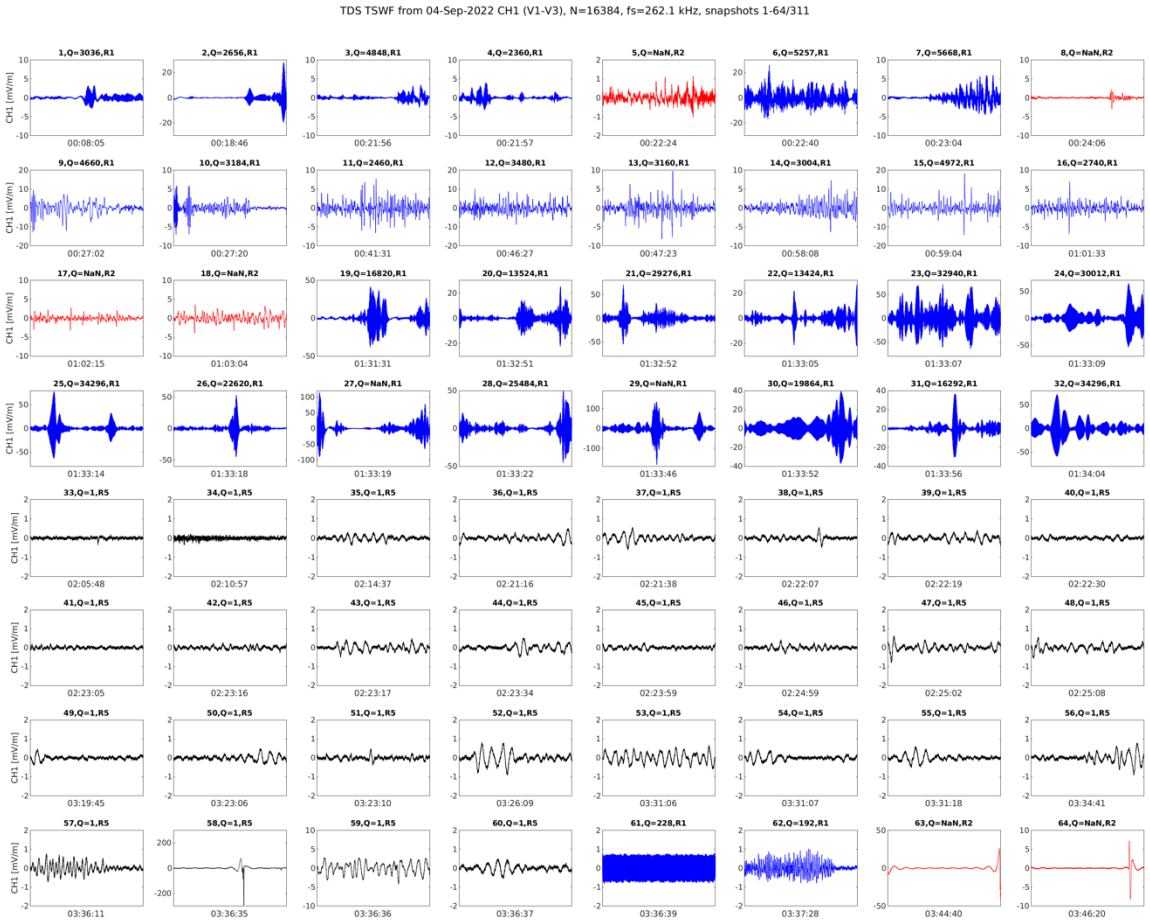

Figure 5. An example of TDS TSWF-E waveform snapshots.

Type of data	Time series

X-axis quantity	Time
X-axis units	milliseconds
X-axis resolution	Variable
X-axis range	[0, up to 62.5]
X-axis scale	Linear
Y-axis quantity	Amplitude
Y-axis units	mV/m
Y-axis resolution	Variable
Y-axis range	Variable
Y-axis scale	Linear
Data format	PNG
Granularity	1 file per day

5.4.2 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

5.5 solo_L3_rpw-tds-sbm1-rswf-e-spectrogram

5.5.1 Overall description

The solo_L3_rpw-tds-sbm1-rswf-e-spectrogram data product is generated from solo_L2_rpw-tds-sbm1-rswf-e data to display E-field dynamical spectra in the TDS frequency range.

DOI: https://doi.org/10.57780/esa-3xcjd4w

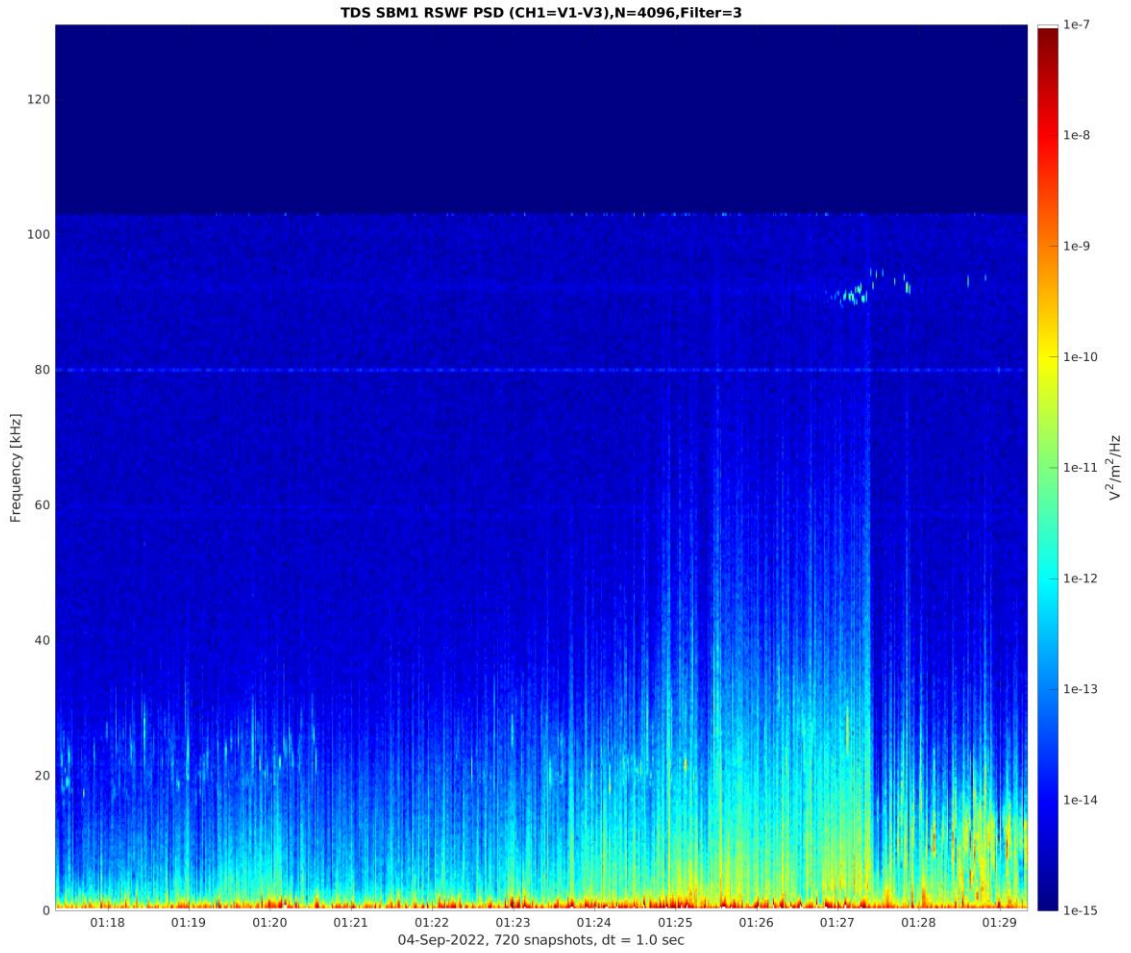

Figure 6. An example of TDS SBM1-RSWF-E spectrogram.

Type of data	Spectrogram
Intensity units	V^2/m^2/Hz
X-axis quantity	Time U
X-axis units	seconds
X-axis resolution	Variable
X-axis range	Variable
X-axis scale	Linear
Y-axis quantity	Frequency
Y-axis units	kHz
Y-axis resolution	Variable
Y-axis range	0 Hz to 131 or 262 kHz
Y-axis scale	Linear
Data format	PNG
Granularity	1 file per triggered time interval

5.5.2 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

5.6 solo_L3_rpw-tds-sbm2-tswf-e-spectrogram

5.6.1 Overall description

The solo_L3_rpw-tds-sbm2-tswf-e-spectrogram data product is generated from solo_L2_rpw-tds-sbm2-tswf-e data to display E-field dynamical spectra in the TDS frequency range.

DOI: https://doi.org/10.57780/esa-3xcjd4w

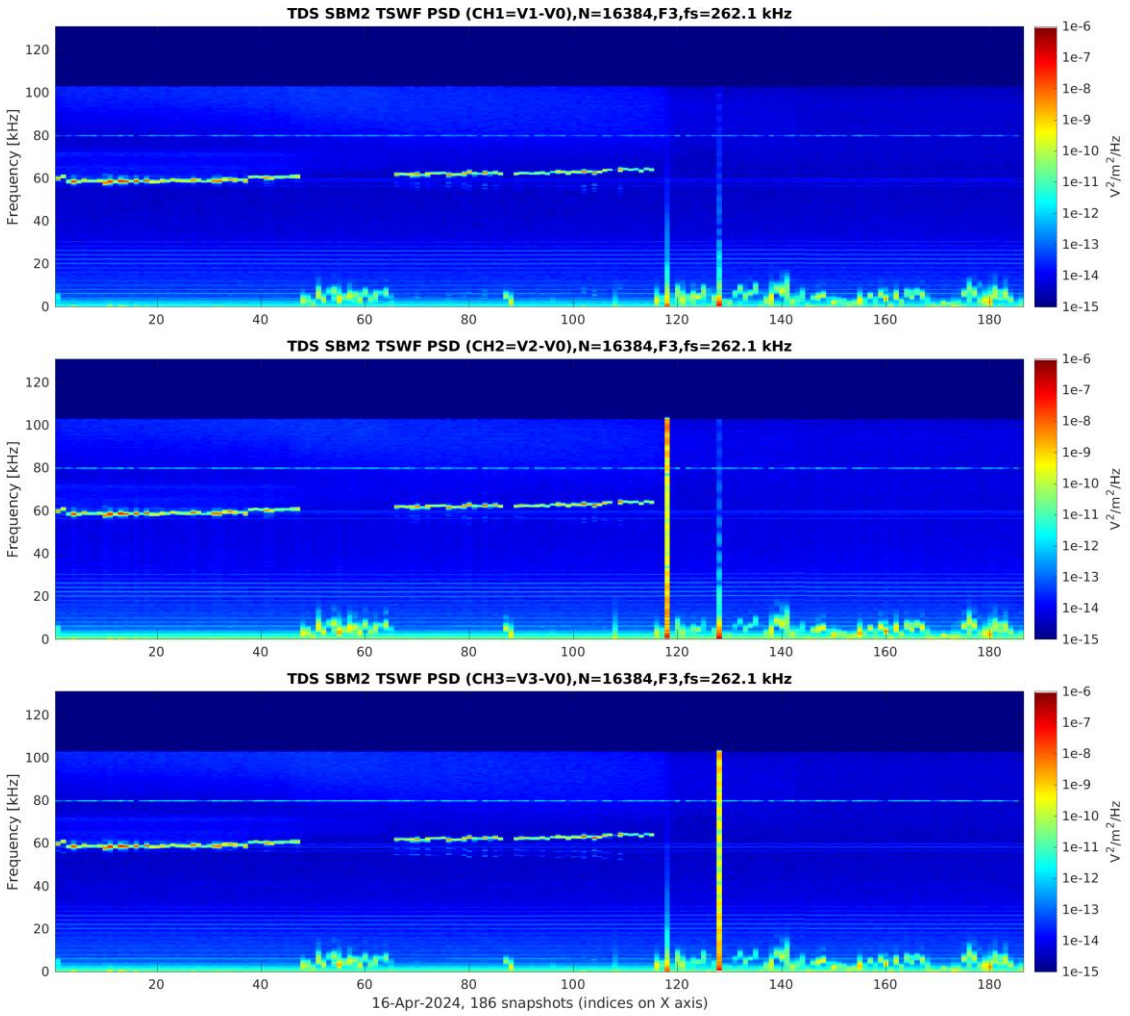

Figure 7. An example of TDS SBM2-TSWF-E spectrogram.

Type of data	Spectrogram
Intensity units	V^2/m^2/Hz
X-axis quantity	Time U
X-axis units	seconds
X-axis resolution	Variable
X-axis range	Variable
X-axis scale	Linear

Y-axis quantity	Frequency
Y-axis units	kHz
Y-axis resolution	Variable
Y-axis range	0 Hz to 131 or 262 kHz
Y-axis scale	Linear
Data format	PNG
Granularity	1 file per triggered time interval

5.6.2 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

5.7 solo_L3_rpw-tds-sbm2-tswf-e-waveform

5.7.1 Overall description

The L3_rpw-tds-sbm2-tswf-e-waveform data product is generated from L2_rpw-tds-sbm2-tswf-e data to display on board selected E-field waveform snapshots.

DOI: https://doi.org/10.57780/esa-3xcjd4w

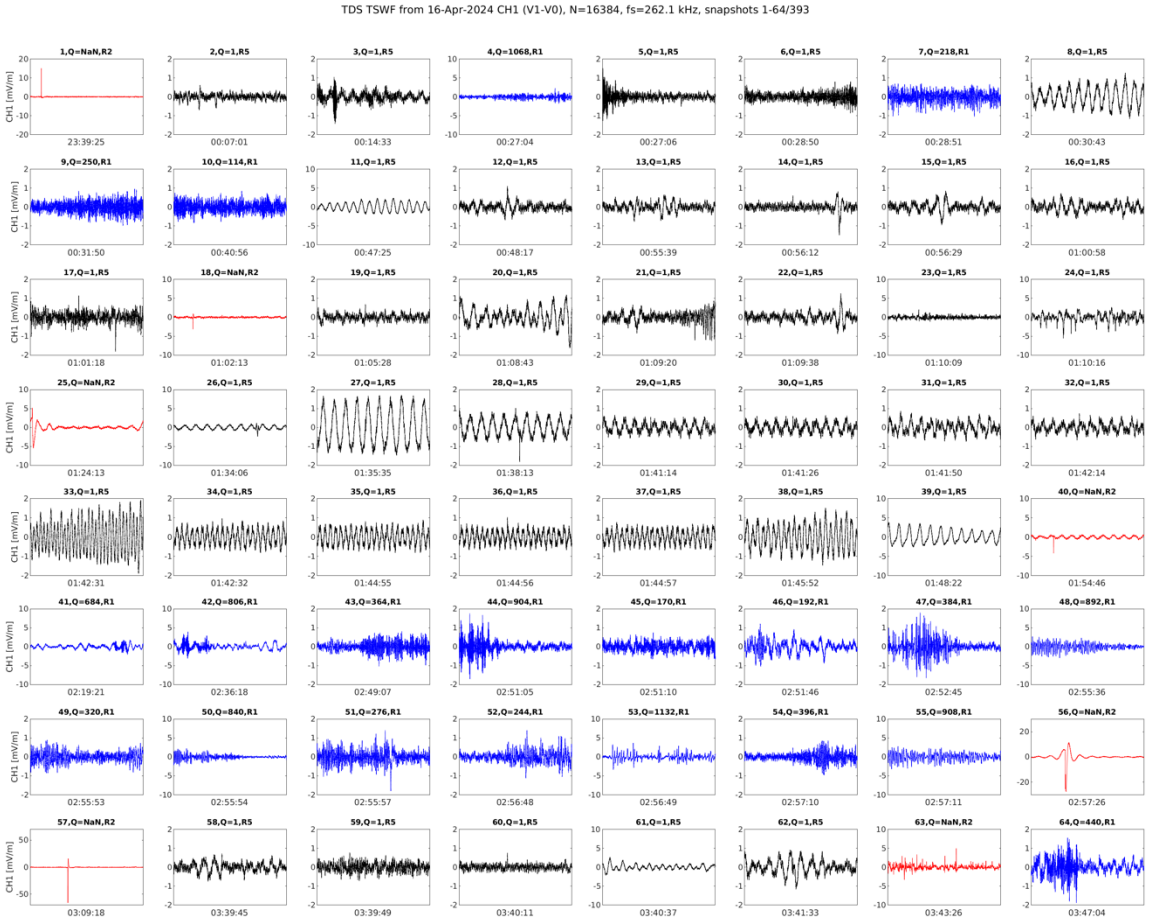

Figure 8. An example of TDS SBM2-TSWF-E waveform snapshots.

Type of data	Time series
X-axis quantity	Time
X-axis units	milliseconds
X-axis resolution	Variable
X-axis range	[0, up to 62.5]
X-axis scale	Linear
Y-axis quantity	Amplitude
Y-axis units	mV/m
Y-axis resolution	Variable
Y-axis range	Variable
Y-axis scale	Linear
Data format	PNG
Granularity	1 file per triggered time interval

5.7.2 Authors

David Pisa (dp@ufa.cas.cz), and Jan Soucek (soucek@ufa.cas.cz).

APPENDICES

6 LIST OF ACRONYMS

Acronym	Definition
ANC	Ancillary data
CDF	Common Data Format
CDPP	Centre de Données de Physique des Plasma
CWF	Continuous Waveform
ESA	European Space Agency
ESAC	European Space Astronomy Center
HFR	High Frequency Receiver
IAP	Institute of Atmospheric Physics of the Czech Academy of Sciences
ID	Identifier
L1R	Level 1 Receiver level of data processing
L2	Level 2 data processing
LFR	Low Frequency Receiver
MAMP	TDS Maximum AMPlitudes

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
SBM	Selected Burst Mode
STAT	TDS Statistics
SCM	Search Coil Magnetometer
SOLO	Solar Orbiter