User Guide for Parker Solar Probe SWEAP Investigation Data Products

Version 1.3 — January 28, 2020

This document is developed and updated by the Solar Wind Electrons Alphas and Protons (SWEAP) science team to provide an omnibus reference guide for users of SWEAP data. This is intended to be a "living document" that will be expanded as future data products, tutorials, and other helpful items are developed.

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1. Introduction

1.1 Overview of SWEAP

The data referenced here is available is from the SWEAP instrument suite. The SWEAP Suite aboard Parker Solar Probe primarily measures solar wind thermal plasma. The Solar Probe Cup (SPC) is a sun-pointing Faraday Cup instrument that primarily measures protons and alpha particles. It is periodically also configured to measure electrons. The Solar Probe ANalyzer instruments are electrostatic analyzers situated on either side of the spacecraft bus. The Solar Probe ANalyzers A ion (SPAN-ion) measures protons, alphas and other heavy ions. The Solar Probe Analyzer (A and B; SPAN-electron) measures electrons.

The SPC and SPAN instruments are designed to have overlapping, complementary fields of view for complete coverage— when the flow of the solar wind is not measurable by one instrument it will be measured by the other. In general, SPC is optimized for flows along the sun-spacecraft line (perpendicular to the heat shield, or spacecraft Z-axis) and SPAN are optimized for flows at wider angles.

The prime mission of Parker Solar Probe is to take data when within 0.25 AU of the Sun during its orbit. However, there has been some extended campaign outside of this distance. The data are available for those days that are within 0.25 AU as well as those days when the instruments were operational outside of 0.25 AU.

1.2 Data Providers and contact information

The SWEAP experiment is operated by scientists at the Smithsonian Astrophysical Observatory in Cambridge, MA, the Space Systems Laboratory at the University of California Berkeley, and the University of Michigan.

Questions regarding the use or interpretation of these data may be directed to the individuals listed below. A contact specific to each data set can also be found in the metadata ("General Attributes") of each data file.

Justin Kasper (jckasper@umich.edu)	Principal Investigator
Davin Larson (davin@ssl.berkeley.edu)	SPAN Instrument Lead
Kelly Korreck (kkorreck@cfa.harvard.edu)	Science Operations Lead

Anthony Case (tonycase@cfa.harvard.edu)	SPC Instrument Scientist
Phyllis Whittlesey (phyllisw@berkeley.edu)	SPAN-Electron instrument scientist
Roberto Livi (rlivi@berkeley.edu)	SPAN-Ion instrument scientist
Michael Stevens (mstevens@cfa.harvard.edu)	Science Data Center Lead

1.3 Data Use Policy

NASA open data policy applies— these data are made available **fully, openly, and without restrictions to all parties and for all purposes**. This includes, but is not limited to, use by the applications communities, private industry, academia, and the general public.

As part of the development of collaboration with the broader Heliophysics community, however, the mission has drafted a "Rules of the Road" to govern how PSP instrument data should be used. It is requested that scientists adhere to the following guidelines:

1. Users should consult with the PI (Justin Kasper) to discuss the appropriate use of instrument data or model results and to ensure that the Users are accessing the most recent available versions of the data and analysis routines. Instrument team SOCs and/or VOs should facilitate this process, serving as the contact point between PI and users in most cases. The SWEAP SOC points of contact are Kelly Korreck, kkorreck@cfa.harvard.edu and Michael Stevens, mstevens@cfa.harvard.edu).
2. Users should heed the caveats of investigators to the interpretation and limitations of data or model results. Investigators supplying data or models may insist that such caveats be published. Data and model version numbers should also be specified.
3. Browse products, Quicklook and Planning data are not intended for scientific analysis or publication and should not be used for those purposes without consent of the PI.
4. Users should acknowledge the sources of data used in all publications, presentations, and reports: "We acknowledge the NASA Parker Solar Probe Mission and SWEAP team led by Justin Kasper for use of data."
5. Users are encouraged to provide the PI a copy of each manuscript that uses the PI's data prior to submission of that manuscript for consideration of publication. On publication the citation should be transmitted to the PI and any other providers of data.

1.4 File naming conventions and glossary

All SWEAP data are named according to their contents as *source_descriptor_datatype_YYYYMMDD_vVV*, where YYYY, MM, and DD stand for the calendar year, month, and day of the measurement set, respectively, and VV stands for the version number of the data release. Acronyms/abbreviations are as follows:

Source elements

psp: Parker Solar Probe
swp: Solar Wind electrons alphas and Protons experiment
spc: Solar Probe Cup instrument
spi: Solar Probe Analyzer Ion instrument
spa: Solar Probe Analyzer Electron instrument (A)
spb: Solar Probe Analyzer Electron instrument (B)
spe: Solar Probe Analyzer Electron instrument (combined A and B)

Descriptor elements

sf0: for SPAN-E, corresponds to the first of two data production types for that instrument. This product will always have a higher number of dimensions compared ot sf1 See Whittlesey et al 2019/2020 and subsequent SPAN-E instrument papers for more information)
sf1: for SPAN-E, corresponds to the second of two data production types for that instrument. This product will always have a lower number of dimensions compared to sf0. See Whittlesey et al 2019/2020 and subsequent SPAN-E instrument papers for more information)
sf00:
sf0a:
pad: pitch angle distribution

Datatype elements

L2: level 2
l2i: level 2 (ion only)
L3: level 3
l3i: level 3 (ion only)
mom: moment
INST: instrument reference frame only
8Dx32Ex8A, and similar: range of phase space elements
(8 deflector settings, 32 energies, 8 angles).

1.5 Timing Conventions

Following the CDF data convention for spacecraft missions, all measurement variables are organized by time. The time variable, typically called EPOCH, is identified explicitly or implicitly as the first (0th) dependency for all measured quantities. It corresponds to the measurement time as recorded on board and then corrected to a standard terrestrial convention. This procedure is described in the appendix of this document.

IMPORTANT!

All SWEAP data products use the CDF_TT2000 epoch timing standard (long64 integer number of nanoseconds since J2000, with leap seconds included). Most commonly used CDF I/O utilities for Matlab, python, IDL, etc that predate this standard will fail, and will likely interpret SWEAP data files as though they are corrupt. SWEAP data files are *not* corrupt; this issue will generally be corrected with a software update. Attempting to open SWEAP files without a valid leap second table (up to and including 1-1-2017) will also likely fail.

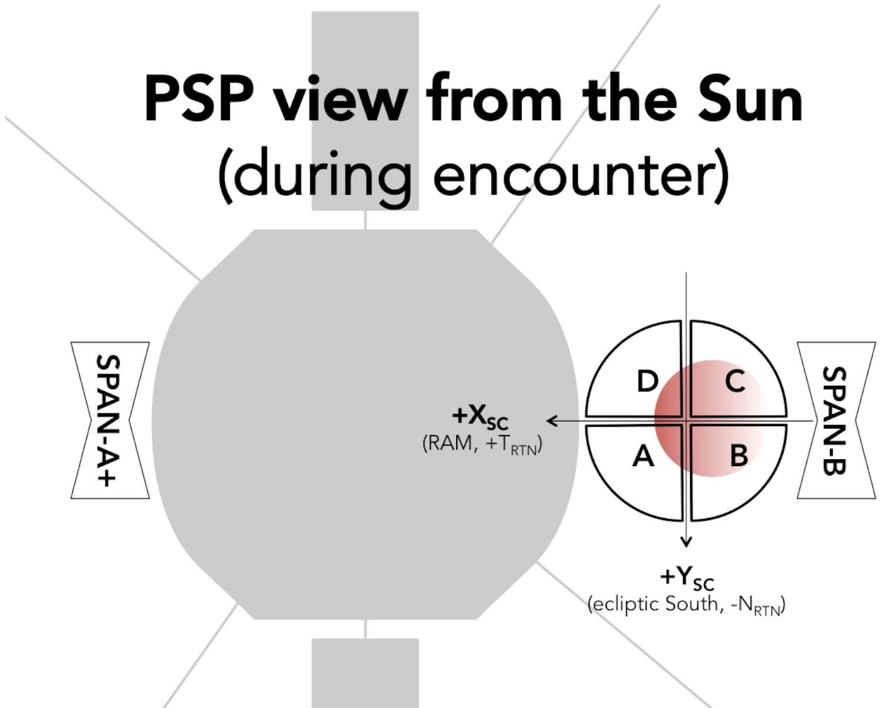
1.6 Reference Frames and approximate orientation of the sensors

1.6.1 The inertial RTN frame

This is a version of the Radial-Tangential-Normal heliospheric reference frame, which is widely used for interplanetary missions (e.g. *Voyager*, *Helios*, *Ulysses*, STeREO). This is a cartesian frame in which it is convenient to express the local velocity and magnetic field vectors.

This coordinate system is oriented such that the R basis vector points along the sun-spacecraft line, from the sun towards the instantaneous position of Parker Solar Probe. The T basis vector is the cross product of the solar rotation axis with R, and the N basis vector completes the triad.

This frame is inertial, i.e. it is the so-oriented inertial frame for the spacecraft's instantaneous position. Vector velocities in this frame are measured relative to the fixed stars. Velocities reported in this frame have been corrected for the motion of the spacecraft, which will be as fast ~175 km/s in future encounters. The aberration flow— the apparent speed of the solar wind in the spacecraft frame due to spacecraft motion— can be comparable to the solar wind flow itself at perihelia.



1.6.2 The PSP Spacecraft frame

The Parker Solar Probe observatory reference frame is oriented such that the heat shield normal points along +Z and the solar panels deploy along the Y-axis. The Solar Probe Cup instrument is situated on the -X side of the heat shield. The Solar Probe Analyzers A and B are situated on the +X and -X sides of the spacecraft bus, respectively.

In encounters, the RAM direction of the spacecraft is in the +X direction.

1.6.3 The SPC Instrument frame

The SPC Instrument reference frame is identical to the spacecraft frame. Measurements reported in the spacecraft frame have been made in the instrument frame and not transformed in any way.

1.6.4 The SPAN Instrument frames

1.7 CDF and general data structure

Each SWEAP data file includes a set of a particular type of measurements over a single observing day. Measurements are provided in [Common Data Format (CDF)](), a self-documenting data framework for which convenient open source tools exist across most scientific computing platforms. Users are strongly encouraged to consult the global metadata in each file, and the metadata that are linked to each variable. The metadata includes comprehensive listings of relevant information, including units, coordinate systems, qualitative descriptions, measurement uncertainties, methodologies, links to further documentation, and so forth.

For a typical measurement variable the actual measurements are found in the "**DAT**" field. Additional attributes may vary from variable to variable, but in general one will also find

- **DEPEND_0** indicating the independent variable to which measurements are referenced (i.e. the epoch time variable)
- **FILLVAL** indicating a value reserved to signify that no measurement was made (commonly the floating point NaN value or -1e31 is used)
- **UNITS** indicating the measurement units
- **VALIDMIN** and **VALIDMAX** indicating the range of valid values that the measurement can take
- **VAR_NOTES** containing descriptive or explanatory text
- **DELTA_PLUS_VAR** and **DELTA_MINUS_VAR** indicating the dependent variable(s), or values, containing the corresponding measurement uncertainties

2. Accessing the Data

2.1 Universal access from anywhere

All shareable SWEAP data are available to the public through an online database accessible at http://sweap.cfa.harvard.edu/pub/data and mirrored at http://sprg.ssl.berkeley.edu/data/spp/pub

2.2 Computer setup

Please verify that you have CDF version 3.7.0 or later installed (https://cdf.gsfc.nasa.gov). We cannot guarantee that any other version or CDF I/O tool will support the TT2000 timing standard.

Please also verify that your setup makes use of an up-to-date CDF leap Second Table before proceeding further (https://cdf.gsfc.nasa.gov/html/cdfleapseconds.html).

If using IDL with the tools provided by GSFC, make sure to compile the appropriate cdf libraries (https://spdf.gsfc.nasa.gov/CDAWlib.html)
IDL>@compile_cdfx.pro
IDL>@compile_cdaweb.pro

IDL>@compile_IDLmakecdf.pro

3. Solar Probe Cup (SPC) Data

These data are found at /pub/data/sci/sweap/spc. Efforts have been made to distill all exceptional conditions that can affect normal data analysis into the “GENERAL_FLAG” variable, which can be found in all of the l3i files. In all data quality flags, a value of 0 signifies “good/no condition present”. In this version, all data are organized as time series such that the set of time points, EPOCH.DAT, is the same in l2i and l3i for a given date.

3.1 Level 2 ion: psp_swp_spc_l2i_yyyymmdd_v01.cdf

3.1.1 Remarks

This data product contains measurements of ion charge flux as a function of the energy-per-charge carrier (the voltage barrier applied to a set of transparent grids upstream of the sensor). The measurements are organized into spectra, where one spectrum general comprises a set of consecutive, increasing steps up in voltage.

The SPC instrument has a wide field of view (~30º nominal, with coverage out to ~45º at reduced quality under most conditions). Under most circumstances the fraction of solar wind flow outside of it is negligible. Exceptions to this condition are indicated in the l3i quality flags. The SWEAP instrument suite is designed such that flows at the edges of and beyond the SPC field of view fall entirely within that of SPAN-A Ion. Such flows are expected with increasing frequency at perihelia.

Please refer to the instrument paper for details.

This data set covers all periods for which the instrument was turned on and taking data in the solar wind in ion mode. This includes maneuvers affecting the spacecraft attitude and orientation.

The MODE_FLAG variable contains information about the type of spectrum being measured. “Ion full scan” spectra are marked with MODE_FLAG.DAT = 1. These spectra comprise a broad energy range, typically with lower signal-to-noise than the more frequent “ion peak tracking” spectra, which are marked with MODE_FLAG.DAT = 0. In the most frequent operating mode, Ion full scans are executed once every ~30 seconds or whenever the peak signal from the solar wind is poorly defined.

3.1.2 Measurements

The independent variable for each scan is the voltage pair (MV_LO and MV_HI) describing the modulator setting. The modulator executes a sinusoidal oscillation in voltage between the MV_LO and MV_HI values. The corresponding current amplitude [at the modulator frequency], due to solar wind charge carriers crossing the oscillating potential barrier is measured. The dependent variables are these current amplitudes on each sensor plate (A,B,C,D). The sensor plates form four quadrants of a circle (see diagram). Both the voltages and the current amplitudes are recorded as 2D arrays, N_s x N_t, where N_s is the number of voltage steps per spectrum and N_t is the number of time points (epoch values) in the file.

The actual variable dimensions (except for the flow angles) are 128 x N_t, where not all 128 elements are used in each spectrum. In most cases, the first 30 of each 128-element array are used and the rest are set to fill. The variables in this file type are listed below.

- **MV_LO**, the lower bound of the oscillating potential barrier (in Volts)
- **MV_HI**, the upper bound of the oscillating potential barrier (in Volts)
- **{A,B,C,D}_CURRENT**, the measured current on each respective sensor (in picoAmperes)
- **FLOW_ANGLE**, a [rudimentary] estimate of the bulk flow angle into the sensor. This variable has dimensions 2 x N_t, where the first element is the azimuthal angle [in radians] and the second is the elevation angle [in radians]. This flow angle is estimated using the linear cold-plasma approximation and considering a three-point neighborhood in time at the peak flux measurement. It does not account for spreading of the beam in the instrument, which may be significant. Please refer to *Case et al. 2019*, and/or consult the instrument team regarding systematics in accuracy/precision for this quantity.
    - Positive azimuthal angles correspond to deflections towards sensors B and C and negative to deflections towards A and D. In encounter configuration, positive azimuth angles correspond to -T_{RTN} flows.
    - Positive elevation angles correspond to deflections towards sensors A and B and negative to deflections towards C and D. In encounter configuration, positive elevation angles correspond to -N_{RTN} flows.
- **DIFF_CHARGE_FLUX_DENSITY,** This is the charge flux density of the solar wind measured over the energy range defined by the modulator voltage pair. The [calibrated] effective area of the cup has been taken into account. This quantity is the equivalent of the total charge crossing a Z_{SC}-oriented unit area per unit time) due to charge carriers having energy-per-charge between MV_LO and MV_HI. This quantity is estimated the linear, cold-plasma approximation for the mean flow angle of the solar wind into the sensor (see remarks above). Appendix 3.1 provides a walk-through for estimating the reduced distribution function from this variable.

3.1.3 Note on noise and uncertainties

SPC measures Ion charge fluxes as amplitudes— specifically they are the fourier amplitudes of current upon the collector plates at the frequency of the modulator voltage (please refer to the instrument paper for details). As such, they are positive-definite. A noise floor is evident in most charged flux spectra, typically on the order of 1 picoAmpere per sensor (A,B,C,D). The uncertainties associated with measured amplitudes are thus symmetric at large amplitude, becoming increasingly one-sided as amplitudes approach the noise floor.

A correction has been applied to account for "cross talk"-- the weak stimulation of each sensor owing to capacitive coupling with its neighbors. Under some circumstances, this results in a slightly negative corrected measurement that is consistent with zero.

3.2 Level 3 ion: psp_swp_spc_l3i_yyyymmdd_v01.cdf

See Appendix 4 for a partial listing of data structure and metadata.

3.2.1 Remarks

Moments of and fits [using an isotropic Maxwellian distribution] to the SPC reduced ion velocity distribution function in v_{Z,SC}.

This data product contains derived measurements of ion properties in the solar wind, including density, temperature, velocity vector. These measurements correspond 1-to-1 with spectra in the psp_swp_spc_l2i file for the same date. It may be convenient for some applications to cross-reference the two — For example, the corresponding l3i file contains ephemeris and data quality flag information that may be useful for an investigator who is concerned only with l2i type measurements.

Conditions that impact measurement quality are documented in the "DQF" variable, which contains a 32 element flag array for each measurement time. Each element of the array is reserved to signify a specific condition. These conditions are described in the "DQF_FLAGNAMES" variable. In this version, for example, DQF_FLAGNAMES.DAT[23] is set to "spacecraft maneuver." If measurement i was made during a spacecraft maneuver, it is thus flagged with DQF.DAT[23,i] = 1.

In version 01, measurements are not provided (i.e. variables are set to fill) during spacecraft maneuvers, under conditions of low signal-to-noise, and during certain observed transients. Such conditions are rare during encounters, but increasingly frequent in interplanetary cruise. These are documented in the "DQF" variable. Remarks are also provided in the "SPC Reduced Data Quality Periods" table.

In version 01, the solar wind alpha particle component is not measured (i.e. variables are set to fill).

3.2.2 Measurements

Ion spectra are analyzed here in two ways— **moments** and **fits**. Each method produces an estimate for the density, temperature (thermal speed), velocity vector of a given ion population. Each measurement includes a linked estimate of the measurement uncertainty.

Velocity vectors are given in two frames of reference— “SC,” which is the spacecraft reference frame, and “RTN,” which is an inertial RTN system.

Moments

With this method, we estimate the speed, temperature, and density of the solar wind proton population by direct integration of the measured distribution. A reduced distribution function is derived from each l2i charged flux spectrum following the procedure described in Appendix A3. For each distribution, the locus of acceptably high signal-to-noise and low contamination with other ion species is determined, and the reduced distribution function is integrated over that locus. Upper and lower bounds are also derived by recalculating the moments using variations of the locus and estimates of the noise contribution. The derived parameters are

- **np_moment**, the proton density moment.
- **np_moment_deltahigh**, the estimated upper bound on the proton density from moment calculation
- **np_moment_deltalow**, the estimated lower bound on the proton density from moment calculation
- **wp_moment**, the proton thermal speed moment. Equal to sqrt(2kT/m).
- **wp_moment_deltahigh** the estimated upper bound on the proton thermal speed from moment calculation
- **wp_moment_deltalow** the estimated lower bound on the proton thermal speed from moment calculation
- **vp_moment_SC, vp_moment_RTN,** the proton velocity vector, estimated from the radial thermal speed moment and flow angle
- **vp_moment_SC_deltahigh, vp_moment_RTN_deltahigh,** the proton velocity vector component upper bounds from moment calculation
- **vp_moment_SC_deltalow, vp_moment_RTN_deltaow,** the proton velocity vector component lower bounds from moment calculation

Fits

With this method, we estimate the speed, temperature, and density of the solar wind proton population by fitting each spectrum to a single Maxwellian or a set of Maxwellian ion populations. The fit method is nonlinear least-squares, where the I2i measurements are directly fit to a function that models SPC's response to a Maxwellian distribution of ions. We use four sets of signifiers, described here:

p1
fit to the "primary" proton peak. This is the peak or largest amplitude observed in a given I2i spectrum. A locus of measurements is selected that includes the absolute maximum and at least the 1/e folding, if possible, on either side for this fit.

a
fit to the "primary" alpha particle (He++) peak, if resolved. For I3i measurements, this is "guessed" by searching for a secondary peak in each I2i spectrum in the neighborhood of twice the p1 peak energy.

3
if an additional high signal-to-noise feature is present in the I2i spectrum, typically due to a proton beam or shoulder but also potentially due to a cold minor ion population, a fit is attempted to the p1-subtracted residuals on this neighborhood. The POP3_MTOQ variable is used to indicate the species.

p
if p1 and 3 are successfully fit, and the 3 population is determined to be protons, this signifies the total proton parameters (np =total proton density, vp = center of mass velocity, wp = effective thermal speed, accounting for both populations and their relative drift).

For each population signifier, the following fit parameters are reported

- **n{p,p1,a,3} _fit**, the number density
- **n{p,p1,a,3}_fit_deltahigh**, the estimated upper uncertainty on the number density
- **n{p,p1,a,3}_fit_deltalow**, the estimated lower uncertainty on the number density
- **w{p,p1,a,3}_fit**, the thermal speed fit. Equal to sqrt(2kT/m).
- **w{p,p1,a,3}_fit_deltahigh** the estimated upper uncertainty on the proton thermal speed
- **w{p,p1,a,3}_fit_deltalow** the estimated lower uncertainty on the proton thermal speed
- **v{p,p1,a,3}_fit_SC, v{p,p1,a,3}_fit_RTN,** the velocity vector, estimated from the radial thermal speed fit and flow angle
- **v{p,p1,a,3}_fit_SC_deltahigh, v{p,p1,a,3}_fit_RTN_deltahigh,** the velocity vector component upper uncertainties
- **v{p,p1,a,3}_fit_SC_deltalow, v{p,p1,a,3}_fit_RTN_deltalow,** the velocity vector component lower uncertainties

An important note about fit uncertainties
Fit parameters are only accurate as measurements when the fit function is a good description of the data. Fit uncertainties are likewise only a good estimate of measurement uncertainty when the fit function is a good description of the data. The latter are even more sensitive to this validity condition than the former.
The Maxwellian distribution is generally a good enough model at 1 AU to characterize the bulk properties of the solar wind protons and alphas, but this is not universally true. It is expected to be less and less true at closer approach to the sun. This is why the fits, moments, and multi-component fits are attempted.

3.2.3 Data Quality Flags

An annotative data quality flag is provided in the “DQF” variable, with the corresponding conditions listed in the “DQF_FLAGNAMES” variable.

The “GENERAL FLAG” if a variable signifies, as broadly as possible, whether a given measurement has been made under ideal conditions and can be used without caveat. When this variable is set to 1, there is a condition present of which the user must be made aware. It is strongly recommended that users consult with the instrument team if they wish to draw inferences from flagged data.

Do not ignore the GENERAL_FLAG variable.

Do not ignore the GENERAL_FLAG variable

4. SPAN Ion

These data are found at /pub/data/sci/sweap/spi. Efforts have been made to distill all exceptional conditions that can affect normal data analysis into the “QUALITY_FLAG” variable, which can be found in all of the L2 files. In all data quality flags, a value of 0 signifies that the data product contains contamination from instrument operations, whereas a value of 1 signifies a good data product.

4.1 SPAN Ion L2 Data: Overview

The SPAN-Ai instrument forms a field of view covering +/- 60° in elevation and 247.5° in azimuth. The main obstruction in the FOV is the Thermal Protection Shield (TPS) which partially occultates the first 8° of the azimuthal direction and all it's associated deflection angles. The rotation matrices to convert into the spacecraft frame can be found in the individual CDF files, or in the instrument paper.

This data set covers all periods for which the instrument was turned on and taking data in the solar wind in "full sweep" mode. This includes maneuvers affecting the spacecraft attitude and orientation.

SPAN-Ion produces two sequential data products, the "Full" sweep mode that samples a coarse region of space phase and the "Targeted" sweep mode which focuses its phase space sweeping on the peak total counts. The two primary products are called "SF00" and "SF01", which represent the 3D distribution functions of proton and alpha populations, respectively. The "S" indicates a survey product, the "F" indicates a "full range" sweep over the current energy/deflection table loaded to the instrument, the second to last digit is the data type indicator, and the last digit refers to mass that is being observed, where "0" is protons, "1" is alphas, "2" are Alphas and "3" are a collection of heavier masses. All tables that generate these products are configurable by the instrument scientist.

The SPAN-I Level 2 data files contain measurements of the ion populations as a function of energy-per-charge. The measurements are organized into spectra of different dimensions, depending on the specific L2 data product.

5.1.1 Data Caveats in v01

4.2 SPAN Ion L3 Data

Data Acceptable for Scientific Analysis after Fall 2019.

5. SPAN Electron

This data is found on the website under /data/spa for SPAN A electron data and data/spb directory for the SPAN B electron data. Of particular note in all data files is the

“QUALITY_FLAG” variable, which indicates good or bad data for scientific analysis. A value of “0” indicates the data is “good”, whereas a “1” flag indicates data points that are not recommended for scientific analysis, either due to instrument anomaly or calibration checks.

5.1 SPAN Electron L2 Data: Overview

The SPAN-Ae and SPAN-B instruments together have fields of view covering >90% of the sky; major obstructions to the FOV include the spacecraft heat shield and other intrusions by spacecraft components. Each individual SPAN-E has FOV of +/- 60° in theta and 240° in phi. The rotation matrices to convert into the spacecraft frame can be found in the individual CDF files, or in the instrument paper.

This data set covers all periods for which the instrument was turned on and taking data in the solar wind in “full sweep” mode. This includes maneuvers affecting the spacecraft attitude and orientation. Measurements taken by SPAN-B when the spacecraft is pointed away from the sun are taken in sunlight.

Each SPAN-E sensor produces two data products simultaneously from the same instrument sweeps: these are called “SF0” and “SF1”. The “S” indicates a survey product, the “F” indicates a “full range” sweep over the current energy/deflection table loaded to the instrument, and the last digit is the data type indicator, configurable by the instrument scientist.

The SPAN-E Level 2 data files contain measurements of the electron populations as a function of energy-per-charge. The measurements are organized into spectra of different dimensions, depending on the specific L2 data product.

5.1.1 Data Caveats in v01

Users interested in field-aligned electrons should take care regarding potential blockages from the heat shield when B is near radial, especially in SPAN-Ae. Artificial reductions in strahl width can result.

Due to the relatively high electron temperature in the inner heliosphere, many secondary electrons are generated from spacecraft and instrument surfaces. As a result, electron measurements in this release below 30eV are not advised for scientific analysis.

The fields of view in SPAN-Ae and SPAN-B have many intrusions by the spacecraft, and erroneous pixels discovered in analysis, in particular near the edges of the FOV, should be viewed with skepticism. Details on FOV intrusion are found in the instrument paper, forthcoming, or by contacting the SPAN-E instrument scientist.

The instruments’ mechanical attentuators are engaged during the eight days around perihelia 1 and 2, which results in a factor of ~10 reduction of the total electron flux into the instrument. During these eight days, halo electron measurements are artificially enhanced in the L2 products as a result of the reduced instrument geometric factor and subsequent ground corrections.

A general note for Encounter 1 and 2 data: a miscalculation in the deflection tables loaded to both SPAN-Ae and SPAN-B resulted in over-deflection of the outermost theta angles during Encounters 1 and 2. As such, pixels at large thetas should be ignored. This error was corrected by a table upload prior to Encounter 3.

Lastly, when viewing time gaps in the SPAN-E measurements, be advised that the first data point produced by the instrument after a power-on is the maximum value permitted by internal instrument counters. Therefore, the first data point after powerup is erroneous and should be discarded, as indicated by quality flags.

5.2 SPAN Electron L2 Data: psp_swp_spa_sf0_L2_16Ax8Dx32E_YYYYMMDD_v01.cdf

5.2.1 Remarks

The sf0 products are the “full 3D” spectra from each individual SPAN-E instrument (SPAN-Ae and SPAN-B). Units are in differential energy flux, degrees, and eV. One spectrum comprises decreasing steps in Energy specified by the number in the filename, alternating sweeps in theta/Deflection, also specified by the number in the filename, and a number of phi/Anode directions, also specified by the number in the filename. The sample filename above includes 16 Anodes, 8 Deflections, and 32 Energies.

5.1.2 Caveats

Due to the electron temperature in the inner heliosphere, many secondaries are generated off of spacecraft surfaces, and as a result measurements in this release below 30eV are not advised for scientific analysis.

Likewise, fields of view in SPAN-Ae and SPAN-B have intrusions by the spacecraft, and erroneous pixels discovered in analysis should be viewed with skepticism.

Finally, the instruments’ mechanical attentuators are engaged during the eight days around perihelion, which reduces the total electron flux into the instrument by a factor of ~10. During these eight days, halo electron measurements are artificially enhanced in the L2 products as a result of the reduced instrument geometric factor and subsequent corrections.

5.3 SPAN Electron L2 Data: psp_swp_spa_sf1_L2_32E_YYYYMMDD_v01.cdf

5.3.1 Remarks

The “sf1” product is an energy spectrum produced on the spacecraft by summing over the theta and phi directions. The units are differential energy flux and eV.

5.3.2 Caveats

The larger theta angles (deflection angles) are artificially enhanced in the “sf1” energy spectra data products due to the method of spectra production on the SPAN-E instrument (straight summing). Thus, SF1 energy spectra are not recommended for rigid statistical analysis.

Appendices

A1. Timing conventions for SWEAP and FIELDS data

Summary

This memo describes an agreed-upon procedure for deriving and reporting time stamps for Parker Solar Probe SWEAP and FIELDS data that are identical and properly synchronized across the experiments.

Definition

The standardized time variable, ***EPOCH***, shall be defined as spacecraft ephemeris nanoseconds from J2000, as calculated relative to the PSP epoch that is defined in the spacecraft clock kernel furnished to the instrument teams by the mission.

Procedure

Measurement times in the SWEAP and FIELDS data packets are generally stored in two fields:

(1) ***CCSDS_MET***

mission elapsed time, in seconds, from the PSP Epoch, which is defined to be January 1, 2010, 12:00:00 UTC).

(2) ***xxx_SUBSEC*** or similar

fractional seconds from the last tick of MET, typically in units of 2^{-16} seconds

The agreed-upon convention for public data and joint analysis shall be the following:

- At levels 2 and above, public CDF data files will include an ***EPOCH*** time as the primary reference for all time-dependencies. The DEPEND_0 attribute for typical measurements will point to this epoch.
- This ***EPOCH*** is equal to the Parker Solar Probe “spacecraft ephemeris time” elapsed from J2000, as calculated relative to the PSP epoch that is defined in the spacecraft clock kernel furnished to the instrument teams by the mission. For detailed astronomical definition, refer to the CSPICE “required reading.”
- The ***EPOCH*** time unit is nanoseconds
- The ***EPOCH*** time type is a 64-bit longword integer (LONG64)

The EPOCH time will be calculated identically by all instruments according to the following protocol:

1.) The ***met_string*** is constructed as

met_string = ***met_seconds*** + ':' + ***met_subseconds_base50000***

where:
- ***met_seconds*** is the ***CCSDS_MET*** value cast as an integer string with no whitespace
- ***met_subseconds_base50000*** is an "(I05)" format integer string formed by converting the ***xxx_SUBSEC*** value to units of 1/50000 second. For example, if the ***xxx_SUBSEC*** value is recorded in parts per 65536 of a second, the correct procedure would be to round 50000*(***xxx_SUBSEC***/65536) to the nearest integer* and cast as a string using the I05 format code

2.) The spacecraft ephemeris seconds from J2000, ***epoch_seconds***, is calculated using the spice routine "cspice_scs2e." In IDL, this is calculated as

cspice_scs2e, -96, ***met_string***, ***epoch_seconds***

where -96 is the NAIF integer code for Parker Solar Probe. Prior to performing this calculation, the current spacecraft leap seconds kernel (e.g. naif0012.tls) and spacecraft clock kernels (e.g. spp_sclk_xxxx.tsc) must be loaded. These kernels are provided by APL MOC data products. In IDL, kernels are loaded via the cspice_furnsh routine.

3.) Finally ***EPOCH*** is defined as ***epoch_seconds****10^9, cast as a LONG64, i.e. in IDL

EPOCH = long64(epoch_seconds*1d9)

In accordance with SPDF standards, this epoch is interpreted as a CDF_TT2000 time. It is acknowledged here that this epoch is not strictly equal to "terrestrial time" as it is defined in CDF_TT2000 documentation, nor is the calendar date interpreted by CDF_T2000 operation performed on this epoch strictly equal to UTC.

A2. Suggested Software Environments for Analysis

A2.1 IDL SPEDAS TDAS

A2.2 quick IDL tutorial for SPC plotting L2 data

This tutorial section walks you through plotting an charge flux density versus time from an SPC L2 file in IDL. It is not meant to show analysis just to familiarize the user with the SPC L2 CDF file.

For IDL (or python or matlab) users for SPC data, you need to compile and have installed the most recent copy of the CDAWlib from GSFC, which can be found at https://spdf.gsfc.nasa.gov/CDAWlib.html

Once you have verified that you have the most recent CDAWlib open an IDL session:

```
IDL>@compile_cdaweb
IDL>dat = read_mycdf(null, filename, /all) ; open an L2 file
IDL>this_spectrum = 0; ; select the first spectrum in the file (index 0)
IDL>volt = dat.mv_lo.dat[*,this_spectrum]
IDL>dcfd = dat.diff_charge_flux_density.dat[*,this_spectrum]
IDL>valid = where(volt ne dat.mv_lo.fillval and dcfd ne dat.diff_charge_flux_density.fillval, n)
IDL>plot,volt[valid], dat.dvfd[valid], $
        ytitle= ‘Differential Charge Flux Density [pA/cm^2], $
        xtitle='Voltage [V]'
```

A3. Some common procedures

A3.1 Converting SPC L2 spectra to velocity distribution functions

Our intention with the L2 data has been to make this as easy as possible without cutting off too many other avenues. You should have everything that you need in the data file (please get in touch if not).

In general, fluxes measured by SPC at/around twice the peak voltage include a significant He++ contribution. The following procedure ignores that fact, however, and assumes all charge flux is proton-dominated.

To account for He++ and certain higher-order effects, SAO uses an algorithm that is a bit more complex than the following to generate L3s. This is the simple version, which is adequate for analyzing the bulk proton distribution most of the time:

The "differential_flux_density" variable, which we'll shorthand with *Y*, in the L2 is the electric current due to positive solar wind ions, measured in the present energy interval, that would cross a square centimeter area oriented radially [note the units]. We've already done the geometry and taken the sensor calibration and all that into account at that step. In other words,

$$Y\ [\mathrm{pA\ cm^{-2}}] = q\ [\mathrm{C}] * v\ [\mathrm{m\ s^{-1}}] * F(V)\ [\#\ \mathrm{m^{-3}\ V^{-1}}] * dV\ [\mathrm{V}] * 10^{8}\ [\mathrm{pA\ cm^{-2}\ A^{-1}\ m^{2}}]$$

where q is the proton charge, v is the typical speed of protons in the energy range *[V - dV/2, V + dV/2]*, *F(V)* is the distribution function of protons with energy, and *dV* is the width of the energy interval.

With regards to the variables in the L2 file, the effective width of a energy interval is *dV = (mv_hi - mv_lo)/2* and the center voltage is *V = (mv_hi + mv_lo)/2*. Converting this to a speed for each interval is the only tricky part here. The expression you'd expect, $(1/2)*m_p*v\text{^}2 = q*V$, is not strictly correct because the measurement is an average over a voltage that modulates sinusoidally in time. The correct expression is

$$v = \text{\textbackslash sqrt}\{2*q*mv\_hi / m_p\} * (2/\pi) * E(mv\_lo / mv\_hi),$$

where this function *E()* is an alternative form of the complete elliptical integral of the second kind- see the approximator provided at the end of this section.

If you want to work in velocity space instead of energy space, the usual transformation applies: $F(V)dV = F(v)dv$. For the same reason as before, however, there is a little bit of nuance in calculating the differential dv. The correct expression for that is

$$dv = (4*(q/m_p)*V - v^2)^{(1/2)}.$$

You now have everything you need to convert a (mv_lo, mv_hi, differential_flux_density) point into a *(v, F(v))*.

If you start becoming interested in flow angles as a function of *v* or *V* (as opposed to the mean flow angles in the data file), you will need some additional info for the geometry. As a rough first approximation, you can estimate a flow angle (away from radial) like this:

$$\theta = (2\pi/180)^\circ * (a + d - c - b)/(a+b+c+d)$$
$$\phi = (2\pi/180)^\circ * (a + b - c - d)/(a+b+c+d)$$

Where a, b, c, d are shorthand for the L2 variables a_current, b_current, c_current, and d_current, respectively.

A polynomial approximation for the elliptic integral function *E(x)* follows, taken from *Schlawin et al. (2010).*

$$E(x) = 1+x*(a1+x*(a2+x*(a3+x*a4))) + x*(b1+x*(b2+x*(b3+x*b4)))*ln(1/x),$$

where

```
a1=0.44325141463
a2=0.06260601220
a3=0.04757383546
a4=0.01736506451
b1=0.24998368310
b2=0.09200180037
b3=0.04069697526
b4=0.00526449639
```

A4. Select metadata listings

A4.1 psp_swp_spc_l2i_YYYYMMDD_vVV

EPOCH

CATDESC: Time in TT2000 format
UNITS: nanoseconds
DIM_SIZES: 0
VAR_NOTES:
TT2000 time is measured in nanoseconds from J2000, with leap seconds included. Please refer to CDF TT2000 documentation with regards to this convention. This time corresponds to the first measurement of the spectrum. Owing to frequent changes in the operating mode, this is usually NOT regular cadence.

MEASUREMENT_TIME

CATDESC:
Time of flux measurement, in nanoseconds, from beginning of spectrum (Epoch)
UNITS: nanoseconds
DIM_SIZES: 128
VAR_NOTES:
This variable gives the time that each specific flux measurement was made within the spectrum, counting up from the time that is specified in the "Epoch" variable

MV_HI

CATDESC: Upper measurement voltage
UNITS: Volts
VALIDMIN: -8000.00
VALIDMAX: 8000.00
DELTA_PLUS_VAR: mv_hi_DELTA_VAR
DELTA_MINUS_VAR: mv_hi_DELTA_VAR
DIM_SIZES: 128
VAR_NOTES:
Measurements of charge flux are made with respect to an AC discriminator voltage that oscillates between two values, which are denoted MV_LO and MV_HI.

MV_HI_DELTA_VAR

CATDESC: Uncertainty in the upper measurement voltage
UNITS: Volts
VALIDMIN: 0.00000

VALIDMAX: 8000.00
DIM_SIZES: 128
VAR_NOTES:
Measurements of charge flux are made with respect to an AC discriminator voltage that oscillates between two values, which are denoted mv_lo and mv_hi.

MV_LO

CATDESC: Lower measurement voltage
UNITS: Volts
VALIDMIN: -8000.00
VALIDMAX: 8000.00
DELTA_PLUS_VAR: mv_lo_DELTA_VAR
DELTA_MINUS_VAR: mv_lo_DELTA_VAR
DIM_SIZES: 128
VAR_NOTES:
Measurements of charge flux are made with respect to an AC discriminator voltage that oscillates between two values, which are denoted mv_lo and mv_hi.

MV_LO_DELTA_VAR

CATDESC: Uncertainty in the lower measurement voltage
UNITS: Volts
VALIDMIN: 0.00000
VALIDMAX: 8000.00
DIM_SIZES: 128
VAR_NOTES:
Measurements of charge flux are made with respect to an AC discriminator voltage that oscillates between two values, which are denoted mv_lo and mv_hi.

A_CURRENT

CATDESC: Current measured by sensor A, in picoAmperes
UNITS: picoAmperes
VALIDMIN: -1.00000e+06
VALIDMAX: 1.00000e+06
DELTA_PLUS_VAR: a_current_DELTA_VAR
DELTA_MINUS_VAR: a_current_DELTA_VAR
DIM_SIZES: 128
VAR_NOTES:
This current represents the differential charge flux upon the sensor, as a function of the time and modulator voltage pair.

B_CURRENT

CATDESC: Current measured by sensor B, in picoAmperes
UNITS: picoAmperes

VALIDMIN: -1.00000e+06
VALIDMAX: 1.00000e+06
DELTA_PLUS_VAR: b_current_DELTA_VAR
DELTA_MINUS_VAR: b_current_DELTA_VAR
DIM_SIZES: 128
VAR_NOTES:
This current represents the differential charge flux upon the sensor, as a function of the time and modulator voltage pair.

C_CURRENT

CATDESC: Current measured by sensor C, in picoAmperes
UNITS: picoAmperes
VALIDMIN: -1.00000e+06
VALIDMAX: 1.00000e+06
DELTA_PLUS_VAR: c_current_DELTA_VAR
DELTA_MINUS_VAR: c_current_DELTA_VAR
DIM_SIZES: 128
VAR_NOTES:
This current represents the differential charge flux upon the sensor, as a function of the time and modulator voltage pair.

D_CURRENT

CATDESC: Current measured by sensor D, in picoAmperes
UNITS: picoAmperes
VALIDMIN: -1.00000e+06
VALIDMAX: 1.00000e+06
DELTA_PLUS_VAR: d_current_DELTA_VAR
DELTA_MINUS_VAR: d_current_DELTA_VAR
DIM_SIZES: 128
VAR_NOTES:
This current represents the differential charge flux upon the sensor, as a function of the time and modulator voltage pair.

A_CURRENT_DELTA_VAR

CATDESC: Uncertainty in the current measured by sensor A, in picoAmperes
UNITS: picoAmperes
VALIDMIN: 0.00000
VALIDMAX: 1.00000e+06
DIM_SIZES: 128
VAR_NOTES:
Sources of uncertainty include the measurement digitization error, the voltage pair and waveform error, non-stationarity of conditions during the measurement period, and the propagated uncertainty in absolute calibration.

B_CURRENT_DELTA_VAR

CATDESC: Uncertainty in the current measured by sensor B, in picoAmperes
UNITS: picoAmperes
VALIDMIN: 0.00000
VALIDMAX: 1.00000e+06
DELTA_PLUS_VAR:
DELTA_MINUS_VAR:
DIM_SIZES: 128
VAR_NOTES:
Sources of uncertainty include the measurement digitization error, the voltage pair and waveform error, non-stationarity of conditions during the measurement period, and the propagated uncertainty in absolute calibration.

C_CURRENT_DELTA_VAR

CATDESC: Uncertainty in the current measured by sensor C, in picoAmperes
UNITS: picoAmperes
VALIDMIN: 0.00000
VALIDMAX: 1.00000e+06
DIM_SIZES: 128
VAR_NOTES:
Sources of uncertainty include the measurement digitization error, the voltage pair and waveform error, non-stationarity of conditions during the measurement period, and the propagated uncertainty in absolute calibration.

D_CURRENT_DELTA_VAR

CATDESC: Uncertainty in the current measured by sensor D, in picoAmperes
UNITS: picoAmperes
VALIDMIN: 0.00000
VALIDMAX: 1.00000e+06
DIM_SIZES: 128
VAR_NOTES:
Sources of uncertainty include the measurement digitization error, the voltage pair and waveform error, non-stationarity of conditions during the measurement period, and the propagated uncertainty in absolute calibration.

FLOW_ANGLE

CATDESC: angle of the mean flow into the cup, in radians, in SPC coordinates
UNITS: radian
VALIDMIN: -1.57080 -1.57080
VALIDMAX: 1.57080 1.57080
DELTA_PLUS_VAR: flow_angle_DELTA_VAR
DELTA_MINUS_VAR: flow_angle_DELTA_VAR

DIM_SIZES: 2
VAR_NOTES:
This flow component is across the sensor with respect to the sensor coordinate system

FLOW_ANGLE_DELTA_VAR

CATDESC:
Uncertainty in the angle of flow into the cup, in radians, in the SPC coordinate system
UNITS: radian
LABL_PTR_1: azimuth elevation
VALIDMIN: 0.00000 0.00000
VALIDMAX: 1.57080 1.57080
DIM_SIZES: 2
VAR_NOTES:
Sources of uncertainty can include propagated calibration uncertainty, propagated current measurement uncertainty, non-stationarity of the flow angle over the period of measurement, and confusion between multiple ion species.

DIFF_CHARGE_FLUX_DENSITY

CATDESC: differential charge flux density, in pA*cm**-2
UNITS: pA*cm**-2
VALIDMIN: -1.00000e+30
VALIDMAX: 1.00000e+30
DELTA_PLUS_VAR: diff_charge_flux_density_DELTA_VAR
DELTA_MINUS_VAR: diff_charge_flux_density_DELTA_VAR
DIM_SIZES: 128
VAR_NOTES:
This is the charge flux density of the solar wind measured over the energy range defined by the modulator voltage pair. The [calibrated] effective area of the cup has been taken into account.

DIFF_CHARGE_FLUX_DENSITY_DELTA_VAR

CATDESC: DIFF_CHARGE_FLUX_DENSITY_DELTA_VAR
UNITS: pA*cm**-2
VALIDMIN: 0.00000
VALIDMAX: 1.00000e+06
DIM_SIZES: 128
VAR_NOTES:
Sources of uncertainty include all propagated uncertainties, plus uncertainty associated with the effective area of the sensor at the estimated flow angle

MODE_FLAG

CATDESC: Flag signifying the SPC operating mode at the time of measurement.
VALIDMIN: 0

VALIDMAX: 254
DIM_SIZES: 0
VAR_NOTES:
0 - ion peak tracking 1 - ion full scan 2 - ion flux-angle mode 3 - ion calibration mode 4 - electron peak tracking 5 - electron full scan 6 - electron flux-angle mode 7 - electron calibration mode

SPC_FRAME

DIM_SIZES: 2
VAR_NOTES:
positive elevation angles correspond to deflections towards sensors A and B and negative to deflections towards C and D. Positive azimuthal angles correspond to deflections towards sensors B and C and negative to deflections towards A and D.

A4.2 psp_swp_spc_l3i_YYYYMMDD_vVV

EPOCH

CATDESC: CDF TT2000 time [ns]
UNITS: ns
DIM_SIZES: 0
VAR_NOTES:
Spacecraft ephemeris time, expressed as the number of nanoseconds since J2000 (2000-01-01T12:00:00.000000000) with leap seconds included.
Please refer to CDF TT2000 documentation with regards to this convention.
This time corresponds to the first measurement of the spectrum. Owing to frequent changes in the operating mode, this is usually NOT regular cadence.

DQF

CATDESC: Array of SPC data quality indicators.
VALIDMIN: -2
VALIDMAX: 127
DIM_SIZES: 32
VAR_NOTES:
All flags are encoded as follows:

= 0, good/nominal/condition not present/etc
> 1, bad/problematic/condition present/etc
= -1, status not determined ("don't know")
< -1, status does not matter ("don't care")

-1 ("don't know") is the default value for all flags.

The 0th flag array element is the [standardized] global quality flag, signifying whether the data are suitable for use without caveate. It is repeated in the "general_flag" variable.

DQF_FLAGNAMES

CATDESC: The names of the data quality array fields.
DIM_SIZES: 32
VAR_NOTES:
The 0th flag array element is the [standardized] global quality flag, signifying whether the data are suitable for use without caveate. Refer to the SPC science data center documentation for descriptions of other elements and value definitions.

GENERAL_FLAG

CATDESC:
Global quality flag, signifying whether the data for this epoch are suitable for use without caveate.
VALIDMIN: -2
VALIDMAX: 127
DIM_SIZES: 0
VAR_NOTES:
All flags are encoded as follows:

= 0, good/nominal/condition not present/etc
> 1, bad/problematic/condition present/etc
= -1, status not determined ("don't know")
< -1, status does not matter ("don't care")

-1 ("don't know") is the default value for all flags.
The user is advised to consider the quoted measurement uncertainties, particularly when the general quality flag is zero.

NP_MOMENT

CATDESC:
Proton density estimate from the 0th moment of the reduced distribution function
UNITS: cm^{-3}
VALIDMIN: 0.0100000
VALIDMAX: 10000.0
DELTA_PLUS_VAR: np_moment_deltahigh
DELTA_MINUS_VAR: np_moment_deltalow
DIM_SIZES: 0
VAR_NOTES:

This moment is a model-independant estimate of the proton density, but it is subject to confusion with alpha particles when present. Error bars represent estimated upper and lower limits.

NP_MOMENT_DELTAHIGH

CATDESC:
upper uncertainty associated with the 0th moment of the reduced distribution function
UNITS: cm^{-3}
VALIDMIN: 0.00100000
VALIDMAX: 10000.0
DIM_SIZES: 0
VAR_NOTES:
This moment is a model-independant estimate of the proton density, but it is subject to confusion with alpha particles when present. Error bars represent estimated upper and lower limits.

NP_MOMENT_DELTALOW

CATDESC:
lower uncertainty associated with the 0th moment of the reduced distribution function
UNITS: cm^{-3}
VALIDMIN: 0.00100000
VALIDMAX: 10000.0
DIM_SIZES: 0
VAR_NOTES:
This moment is a model-independant estimate of the proton density, but it is subject to confusion with alpha particles when present. Error bars represent estimated upper and lower limits.

WP_MOMENT

CATDESC:
Proton radial [most probable] thermal speed estimate from the 2nd velocity moment of the reduced distribution function
UNITS: km/s
VALIDMIN: 1.00000
VALIDMAX: 1000.00
DELTA_PLUS_VAR: wp_moment_deltahigh
DELTA_MINUS_VAR: wp_moment_deltalow
DIM_SIZES: 0
VAR_NOTES:
This moment is a model-independant estimate of the proton most-probable thermal speed, but it is subject to confusion with alpha particles when present. Error bars represent estimated upper and lower limits.

WP_MOMENT_DELTAHIGH

CATDESC:
upper uncertainty associated with the 2nd velocity moment of the reduced distribution function
UNITS: km/s
VALIDMIN: 0.00100000
VALIDMAX: 10000.0
DIM_SIZES: 0
VAR_NOTES:
This moment is a model-independant estimate of the proton most-probable thermal speed, but it is subject to confusion with alpha particles when present. Error bars represent estimated upper and lower limits.

WP_MOMENT_DELTALOW

CATDESC:
lower uncertainty associated with the 2nd velocity moment of the reduced distribution function
UNITS: km/s
VALIDMIN: 0.00100000
VALIDMAX: 10000.0
DELTA_PLUS_VAR:
DELTA_MINUS_VAR:
DIM_SIZES: 0
VAR_NOTES:
This moment is a model-independant estimate of the proton most-probable thermal speed, but it is subject to confusion with alpha particles when present. Error bars represent estimated upper and lower limits.

VP_MOMENT_SC

CATDESC:
proton bulk velocity from the 1st moment of the reduced distribution function, in the spacecraft frame
UNIT_PTR: km/s km/s km/s
VALIDMIN: -1000.00   -1000.00   -2000.00
VALIDMAX: 1000.00   1000.00   0.00000
DELTA_PLUS_VAR: vp_moment_SC_deltahigh
DELTA_MINUS_VAR: vp_moment_SC_deltalow
DIM_SIZES: 3
VAR_NOTES:
This moment is a model-independant estimate of the proton bulk speed, but it is subject to confusion with alpha particles when present. Error bars represent estimated upper and lower limits.

VP_MOMENT_SC_DELTAHIGH

CATDESC:

upper uncertainty associated with the the 1st moment of the reduced distribution function, in the spacecraft frame

UNIT_PTR: km/s km/s km/s

VALIDMIN: 0.00000 0.00000 0.00000

VALIDMAX: 2000.00 2000.00 2000.00

DIM_SIZES: 3

VAR_NOTES:

This moment is a model-independant estimate of the proton most-probable thermal speed, but it is subject to confusion with alpha particles when present. Error bars represent estimated upper and lower limits.

VP_MOMENT_SC_DELTALOW

CATDESC:

lower uncertainty associated with the the 1st moment of the reduced distribution function, in the spacecraft frame

UNIT_PTR: km/s km/s km/s

VALIDMIN: 0.00000 0.00000 0.00000

VALIDMAX: 2000.00 2000.00 2000.00

DIM_SIZES: 3

VAR_NOTES:

This moment is a model-independant estimate of the proton most-probable thermal speed, but it is subject to confusion with alpha particles when present. Error bars represent estimated upper and lower limits.

VP_MOMENT_RTN

CATDESC:

proton bulk velocity from the 1st moment of the reduced distribution function in [inertial] RTN coordinate system

UNIT_PTR: km/s km/s km/s

VALIDMIN: 0.00000 -1000.00 -1000.00

VALIDMAX: 2000.00 1000.00 1000.00

DELTA_PLUS_VAR: vp_moment_RTN_deltalow

DELTA_MINUS_VAR: vp_moment_RTN_deltahigh

DIM_SIZES: 3

VAR_NOTES:

This moment is a model-independant estimate of the proton bulk speed, but it is subject to confusion with alpha particles when present. Error bars represent estimated upper and lower limits.

VP_MOMENT_RTN_DELTAHIGH

CATDESC:

upper uncertainty associated with the the 1st moment of the reduced distribution function in [inertial] RTN coordinate system
UNIT_PTR: km/s km/s km/s
VALIDMIN: 0.00000   0.00000   0.00000
VALIDMAX: 2000.00   2000.00   2000.00
DIM_SIZES: 3
VAR_NOTES:
This moment is a model-independant estimate of the proton most-probable thermal speed, but it is subject to confusion with alpha particles when present. Error bars represent estimated upper and lower limits.

VP_MOMENT_RTN_DELTALOW

CATDESC:
lower uncertainty associated with the the 1st moment of the reduced distribution function in [inertial] RTN coordinate system
UNIT_PTR: km/s km/s km/s
VALIDMIN: 0.00000   0.00000   0.00000
VALIDMAX: 2000.00   2000.00   2000.00
DIM_SIZES: 3
VAR_NOTES:
This moment is a model-independant estimate of the proton most-probable thermal speed, but it is subject to confusion with alpha particles when present. Error bars represent estimated upper and lower limits.

NP_FIT

CATDESC: [total] proton density, from 1-dimensional Maxwellian fitting.
UNITS: cm^{-3}
VALIDMIN: 0.0100000
VALIDMAX: 10000.0
DELTA_PLUS_VAR: np_fit_uncertainty
DELTA_MINUS_VAR: np_fit_uncertainty
DIM_SIZES: 0
VAR_NOTES:
the bulk proton population in the solar wind is fit to a group of convected Maxwellian models.

NP_FIT_UNCERTAINTY

CATDESC:
1-sigma error associated with [total] proton density in Maxwellian fitting.
UNITS: cm^{-3}
VALIDMIN: 0.00100000
VALIDMAX: 10000.0
DIM_SIZES: 0
VAR_NOTES:

This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
This variable reflects *precision* uncertainty from fitting, summed in quadrature with the *accuracy* uncertainty associated with the absolute responses of the SPC sensors.

WP_FIT

CATDESC:
proton radial [most probable] thermal speed component, from 1-dimensional Maxwellian fitting.
UNITS: km/s
VALIDMIN: 1.00000
VALIDMAX: 1000.00
DELTA_PLUS_VAR: wp_fit_uncertainty
DELTA_MINUS_VAR: wp_fit_uncertainty
DIM_SIZES: 0
VAR_NOTES:
the bulk proton population in the solar wind is fit to a group of convected Maxwellian models.

WP_FIT_UNCERTAINTY

CATDESC:
1-sigma error associated with proton thermal speed in Maxwellian fitting.
UNITS: km/s
VALIDMIN: 0.00100000
VALIDMAX: 10000.0
DIM_SIZES: 0
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
This variable reflects *precision* uncertainty from fitting, summed in quadrature with the *accuracy* uncertainty associated with the absolute responses of the SPC sensors.

VP_FIT_SC

CATDESC:
Proton bulk velocity, from 1-dimensional Maxwellian fitting, in the spacecraft frame
UNIT_PTR: km/s km/s km/s
VALIDMIN: -1000.00 -1000.00 -2000.00
VALIDMAX: 1000.00 1000.00 0.00000
DELTA_PLUS_VAR: vp_fit_SC_uncertainty
DELTA_MINUS_VAR: vp_fit_SC_uncertainty
DIM_SIZES: 3
VAR_NOTES:

the bulk proton population in the solar wind is fit to a group of convected Maxwellian models.

VP_FIT_SC_UNCERTAINTY

CATDESC:

1-sigma error associated with proton bulk velocity components in Maxwellian fitting.

UNIT_PTR: km/s km/s km/s

VALIDMIN: 0.00000 0.00000 0.00000

VALIDMAX: 2000.00 2000.00 2000.00

DELTA_PLUS_VAR:

DELTA_MINUS_VAR:

DIM_SIZES: 3

VAR_NOTES:

This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.

The flow angles relative to the SPC are obtained by comparing fluxes upon the four sensor quadrants. This uncertainty incorporates uncertainties in the absolute responses of the respective sensors.

VP_FIT_RTN

CATDESC:

Proton bulk velocity, from 1-dimensional Maxwellian fitting, in the [inertial] RTN frame

UNIT_PTR: km/s km/s km/s

VALIDMIN: 0.00000 -1000.00 -1000.00

VALIDMAX: 2000.00 1000.00 1000.00

DELTA_PLUS_VAR: vp_fit_RTN_uncertainty

DELTA_MINUS_VAR: vp_fit_RTN_uncertainty

DIM_SIZES: 3

VAR_NOTES:

the bulk proton population in the solar wind is fit to a group of convected Maxwellian models.

VP_FIT_RTN_UNCERTAINTY

CATDESC:

1-sigma error associated with proton bulk velocity components in Maxwellian fitting, in the [inertial] RTN frame

UNIT_PTR: km/s km/s km/s

VALIDMIN: 0.00000 0.00000 0.00000

VALIDMAX: 2000.00 2000.00 2000.00

DIM_SIZES: 3

VAR_NOTES:

This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
The flow angles relative to the SPC are obtained by comparing fluxes upon the four sensor quadrants. This uncertainty incorporates uncertainties in the absolute responses of the respective sensors.

NP1_FIT

CATDESC:
Primary proton population density, from 1-dimensional Maxwellian fitting.
UNITS: cm^{-3}
VALIDMIN: 0.0100000
VALIDMAX: 10000.0
DELTA_PLUS_VAR: np1_fit_uncertainty
DELTA_MINUS_VAR: np1_fit_uncertainty
DIM_SIZES: 0
VAR_NOTES:
The strongest signal peak, which generally corresponds to the bulk proton population in the solar wind, is fit to a convected Maxwellian model.

NP1_FIT_UNCERTAINTY

CATDESC:
1-sigma error associated with primary proton density in Maxwellian fitting.
UNITS: cm^{-3}
VALIDMIN: 0.00100000
VALIDMAX: 10000.0
DIM_SIZES: 0
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
This variable reflects *precision* uncertainty from fitting, summed in quadrature with the *accuracy* uncertainty associated with the absolute responses of the SPC sensors.

WP1_FIT

CATDESC:
Primary proton population radial [most probable] thermal speed, from 1-dimensional Maxwellian fitting.
UNITS: km/s
VALIDMIN: 1.00000
VALIDMAX: 1000.00
DELTA_PLUS_VAR: wp1_fit_uncertainty
DELTA_MINUS_VAR: wp1_fit_uncertainty
DIM_SIZES: 0
VAR_NOTES:

The strongest signal peak, which generally corresponds to the bulk proton population in the solar wind, is fit to a convected Maxwellian model.
This measurement most accurately represents the thermal width of the reduced phase-space-distribution function along the SPC-normal direction. This roughly corresponds to the radial component of the temperature tensor.
This is a most probable thermal speed, i.e. the model distribution goes like exp(-v^2/w^2).

WP1_FIT_UNCERTAINTY

CATDESC:
1-sigma error associated with primary proton thermal speed in Maxwellian fitting.
UNITS: km/s
VALIDMIN: 0.00100000
VALIDMAX: 10000.0
DELTA_PLUS_VAR:
DELTA_MINUS_VAR:
DIM_SIZES: 0
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
This variable reflects *precision* uncertainty from fitting, summed in quadrature with the *accuracy* uncertainy associated with the absolute responses of the SPC sensors.

VP1_FIT_SC

CATDESC:
Primary proton population velocity, from 1-dimensional Maxwellian fitting, in the spacecraft frame
UNIT_PTR: km/s km/s km/s
VALIDMIN: -1000.00 -1000.00 -2000.00
VALIDMAX: 1000.00 1000.00 0.00000
DELTA_PLUS_VAR: vp1_fit_SC_uncertainty
DELTA_MINUS_VAR: vp1_fit_SC_uncertainty
DIM_SIZES: 3
VAR_NOTES:
The strongest signal peak, which generally corresponds to the bulk proton population in the solar wind, is fit to a convected Maxwellian model.

VP1_FIT_SC_UNCERTAINTY

CATDESC:
1-sigma error associated with primary proton velocity components in Maxwellian fitting.
UNIT_PTR: km/s km/s km/s
VALIDMIN: 0.00000 0.00000 0.00000
VALIDMAX: 2000.00 2000.00 2000.00

DIM_SIZES: 3
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
The flow angles relative to the SPC are obtained by comparing fluxes upon the four sensor quadrants. This uncertainty incorporates uncertainties in the absolute responses of the respective sensors.

VP1_FIT_RTN

CATDESC:
Primary proton population velocity, from 1-dimensional Maxwellian fitting, in the [inertial] RTN frame
UNIT_PTR: km/s km/s km/s
VALIDMIN: 0.00000 -1000.00 -1000.00
VALIDMAX: 2000.00 1000.00 1000.00
DELTA_PLUS_VAR: vp1_fit_RTN_uncertainty
DELTA_MINUS_VAR: vp1_fit_RTN_uncertainty
DIM_SIZES: 3
VAR_NOTES:
The strongest signal peak, which generally corresponds to the bulk proton population in the solar wind, is fit to a convected Maxwellian model.

VP1_FIT_RTN_UNCERTAINTY

CATDESC:
1-sigma error associated with primary proton velocity components in Maxwellian fitting.
UNIT_PTR: km/s km/s km/s
VALIDMIN: 0.00000 0.00000 0.00000
VALIDMAX: 2000.00 2000.00 2000.00
DIM_SIZES: 3
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
The flow angles relative to the SPC are obtained by comparing fluxes upon the four sensor quadrants. This uncertainty incorporates uncertainties in the absolute responses of the respective sensors.

NA_FIT

CATDESC: alpha particle density, from 1-dimensional Maxwellian fitting.
UNITS: cm^{-3}
VALIDMIN: 0.0100000
VALIDMAX: 10000.0
DELTA_PLUS_VAR: na_fit_uncertainty
DELTA_MINUS_VAR: na_fit_uncertainty

DIM_SIZES: 0
VAR_NOTES:
The alpha particle (He++) peak in the solar wind, when clearly distinguishable, is fit to a convected Maxwellian model.

NA_FIT_UNCERTAINTY

CATDESC:
1-sigma error associated with primary alpha density in Maxwellian fitting.
UNITS: cm^{-3}
VALIDMIN: 0.00100000
VALIDMAX: 10000.0
DIM_SIZES: 0
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
This variable reflects *precision* uncertainty from fitting, summed in quadrature with the *accuracy* uncertainty associated with the absolute responses of the SPC sensors.

WA_FIT

CATDESC:
alpha particle radial [most probable] thermal speed, from 1-dimensional Maxwellian fitting.
UNITS: km/s
VALIDMIN: 1.00000
VALIDMAX: 1000.00
DELTA_PLUS_VAR: wa_fit_uncertainty
DELTA_MINUS_VAR: wa_fit_uncertainty
DIM_SIZES: 0
VAR_NOTES:
The alpha particle (He++) peak in the solar wind, when clearly distinguishable, is fit to a convected Maxwellian model.
This measurement most accurately represents the thermal width of the reduced phase-space-distribution function along the SPC-normal direction. This roughly corresponds to the radial component of the temperature tensor.
This is a most probable thermal speed, i.e. the model distribution goes like exp(-v^2/w^2).

WA_FIT_UNCERTAINTY

CATDESC:
1-sigma error associated with primary alpha thermal speed in Maxwellian fitting.
UNITS: km/s
VALIDMIN: 0.00100000
VALIDMAX: 10000.0

DELTA_PLUS_VAR:
DELTA_MINUS_VAR:
DIM_SIZES: 0
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
This variable reflects *precision* uncertainty from fitting, summed in quadrature with the *accuracy* uncertainty associated with the absolute responses of the SPC sensors.

VA_FIT_SC

CATDESC:
alpha particle velocity vector, from 1-dimensional Maxwellian fitting, in the spacecraft frame
UNIT_PTR: km/s km/s km/s
VALIDMIN: -1000.00 -1000.00 -2000.00
VALIDMAX: 1000.00 1000.00 0.00000
DELTA_PLUS_VAR: va_fit_SC_uncertainty
DELTA_MINUS_VAR: va_fit_SC_uncertainty
DIM_SIZES: 3
VAR_NOTES:
The alpha particle (He++) peak in the solar wind, when clearly distinguishable, is fit to a convected Maxwellian model.

VA_FIT_SC_UNCERTAINTY

CATDESC:
1-sigma error associated with primary alpha velocity components in Maxwellian fitting, in the spacecraft frame
UNIT_PTR: km/s km/s km/s
VALIDMIN: 0.00000 0.00000 0.00000
VALIDMAX: 2000.00 2000.00 2000.00
DIM_SIZES: 3
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
The flow angles relative to the SPC are obtained by comparing fluxes upon the four sensor quadrants. This uncertainty incorporates uncertainties in the absolute responses of the respective sensors.

VA_FIT_RTN

CATDESC:
alpha particle velocity vector, from 1-dimensional Maxwellian fitting, in the [inertial] RTN frame
UNIT_PTR: km/s km/s km/s

VALIDMIN: 0.00000 -1000.00 -1000.00
VALIDMAX: 2000.00 1000.00 1000.00
DELTA_PLUS_VAR: va_fit_RTN_uncertainty
DELTA_MINUS_VAR: va_fit_RTN_uncertainty
DIM_SIZES: 3
VAR_NOTES:
The alpha particle (He++) peak in the solar wind, when clearly distinguishable, is fit to a convected Maxwellian model.

VA_FIT_RTN_UNCERTAINTY

CATDESC:
1-sigma error associated with primary alpha velocity components in Maxwellian fitting, in the [inertial] RTN frame
UNIT_PTR: km/s km/s km/s
VALIDMIN: 0.00000 0.00000 0.00000
VALIDMAX: 2000.00 2000.00 2000.00
DIM_SIZES: 3
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
The flow angles relative to the SPC are obtained by comparing fluxes upon the four sensor quadrants. This uncertainty incorporates uncertainties in the absolute responses of the respective sensors.

N3_FIT

CATDESC: population 3 particle density, from 1-dimensional Maxwellian fitting.
UNITS: cm^{-3}
VALIDMIN: 0.0100000
VALIDMAX: 10000.0
DELTA_PLUS_VAR: n3_fit_uncertainty
DELTA_MINUS_VAR: n3_fit_uncertainty
DIM_SIZES: 0
VAR_NOTES:
The population 3 particle peak in the solar wind, when clearly distinguishable, is fit to a convected Maxwellian model.
Population 3 most typically characterizes a proton shoulder or beam (mtoq=1)

N3_FIT_UNCERTAINTY

CATDESC:
1-sigma error associated with population 3 density in Maxwellian fitting.
UNITS: cm^{-3}
VALIDMIN: 0.00100000
VALIDMAX: 10000.0

DIM_SIZES: 0
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
This variable reflects *precision* uncertainty from fitting, summed in quadrature with the *accuracy* uncertainty associated with the absolute responses of the SPC sensors.

W3_FIT

CATDESC:
population 3 particle radial [most probable] thermal speed, from 1-dimensional Maxwellian fitting.
UNITS: km/s
VALIDMIN: 1.00000
VALIDMAX: 1000.00
DELTA_PLUS_VAR: w3_fit_uncertainty
DELTA_MINUS_VAR: w3_fit_uncertainty
DIM_SIZES: 0
VAR_NOTES:
The population 3 peak in the solar wind, when clearly distinguishable, is fit to a convected Maxwellian model.
Population 3 most typically characterizes a proton shoulder or beam (mtoq=1)
This measurement most accurately represents the thermal width of the reduced phase-space-distribution function along the SPC-normal direction. This roughly corresponds to the radial component of the temperature tensor.
This is a most probable thermal speed, i.e. the model distribution goes like exp(-v^2/w^2).

W3_FIT_UNCERTAINTY

CATDESC:
1-sigma error associated with population 3 thermal speed in Maxwellian fitting.
UNITS: km/s
VALIDMIN: 0.00100000
VALIDMAX: 10000.0
DIM_SIZES: 0
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
This variable reflects *precision* uncertainty from fitting, summed in quadrature with the *accuracy* uncertainy associated with the absolute responses of the SPC sensors.

V3_FIT_SC

CATDESC:

population 3 velocity vector, from 1-dimensional Maxwellian fitting, in the spacecraft frame
UNIT_PTR: km/s km/s km/s
VALIDMIN: -1000.00 -1000.00 -2000.00
VALIDMAX: 1000.00 1000.00 0.00000
DELTA_PLUS_VAR: v3_fit_SC_uncertainty
DELTA_MINUS_VAR: v3_fit_SC_uncertainty
DIM_SIZES: 3
VAR_NOTES:
The population 3 peak in the solar wind, when clearly distinguishable, is fit to a convected Maxwellian model.
Population 3 most typically characterizes a proton shoulder or beam (mtoq=1)

V3_FIT_SC_UNCERTAINTY

CATDESC:
1-sigma error associated with population 3 velocity components in Maxwellian fitting, in the spacecraft frame
UNIT_PTR: km/s km/s km/s
VALIDMIN: 0.00000 0.00000 0.00000
VALIDMAX: 2000.00 2000.00 2000.00
DIM_SIZES: 3
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
The flow angles relative to the SPC are obtained by comparing fluxes upon the four sensor quadrants. This uncertainty incorporates uncertainties in the absolute responses of the respective sensors.

V3_FIT_RTN

CATDESC:
population 3 velocity vector, from 1-dimensional Maxwellian fitting, in the [inertial] RTN frame
UNIT_PTR: km/s km/s km/s
VALIDMIN: 0.00000 -1000.00 -1000.00
VALIDMAX: 2000.00 1000.00 1000.00
DELTA_PLUS_VAR: v3_fit_RTN_uncertainty
DELTA_MINUS_VAR: v3_fit_SC_uncertainty
DIM_SIZES: 3
VAR_NOTES:
The population 3 peak in the solar wind, when clearly distinguishable, is fit to a convected Maxwellian model.
Population 3 most typically characterizes a proton shoulder or beam (mtoq=1)

V3_FIT_RTN_UNCERTAINTY

CATDESC:
1-sigma error associated with population 3 velocity components in Maxwellian fitting, in the [inertial] RTN frame
UNIT_PTR: km/s km/s km/s
VALIDMIN: 0.00000 0.00000 0.00000
VALIDMAX: 2000.00 2000.00 2000.00
DIM_SIZES: 3
VAR_NOTES:
This uncertainty may be invalid when the Maxwellian is a poor model for the data. Refer to the data quality flags.
The flow angles relative to the SPC are obtained by comparing fluxes upon the four sensor quadrants. This uncertainty incorporates uncertainties in the absolute responses of the respective sensors.

POP3_MTOQ

CATDESC:
Species identifier for third population fit (in addition to primary proton and alpha peaks)
UNITS: u/e
VALIDMIN: 1.00000
VALIDMAX: 1000.00
DIM_SIZES: 0
VAR_NOTES:
When the n3_fit, w3_fit, and/or v3_fit variables are valid, they indicate that a third ion population has been measured in addition to the primary proton and alpha particle populations. This variable indicates the estimated mass-per-charge for that population, in fundamental units (i.e. protons=1/1=1, alphas=4/2=2, O6=16/6=2.67). Population 3 most typically characterizes a proton shoulder or beam (mtoq=1)

SC_POS_HCI

CATDESC: PSP Spacecraft position in the Heliocentric Inertial system, in km
UNITS: km
VALIDMIN: -3.00000e+08 -3.00000e+08 -3.00000e+08
VALIDMAX: 3.00000e+08 3.00000e+08 3.00000e+08
DIM_SIZES: 3
VAR_NOTES:
Also called Ecliptic J2000. Z is the solar north rotational axis, and X is the solar ascending node on the J2000 ecliptic.

SC_VEL_HCI

CATDESC: PSP Spacecraft velocity in the Heliocentric Inertial system, in km/s
UNITS: km/s
VALIDMIN: -300.000 -300.000 -300.000

VALIDMAX: 300.000 300.000 300.000
DELTA_PLUS_VAR:
DELTA_MINUS_VAR:
DIM_SIZES: 3
VAR_NOTES:
Also called Ecliptic J2000. Z is the solar north rotational axis, and X is the solar ascending node on the J2000 ecliptic.

CARR_LATITUDE

CATDESC: Carrington Latitude
UNITS: degrees
VALIDMIN: -90.0000
VALIDMAX: 90.0000
DIM_SIZES: 0
VAR_NOTES: spacecraft position degrees Latitude from solar equator

CARR_LONGITUDE

CATDESC: Carrington Longitude
UNITS: degrees
VALIDMIN: -180.000
VALIDMAX: 180.000
DIM_SIZES: 0
VAR_NOTES: spacecraft position degrees longitude from solar prime meridian

SC_FRAME

CATDESC: The Parker Solar Probe spacecraft coordinate system.
DIM_SIZES: 3
VAR_NOTES:
This coordinate system is aligned with the Solar Probe Cup. In encounter orientations, the X-axis points in the spacecraft RAM direction, the Z-axis points [roughly] towards the sun, and the Y-axis points south relative to the solar ecliptic plane.
This system is roughly, but not strictly aligned with the heliographic RTN system (R = -Z_SC, T = X_SC, N = -Y_SC) in encounters.
Note that this system is co-moving with the spacecraft. Flows from the sun appear aberrated and shifted in the spacecraft frame according to the instantaneous velocity of the spacecraft.

RTN_FRAME

CATDESC: The inertial Radial-Tangential-Normal frame
DIM_SIZES: 3
VAR_NOTES:

This coordinate system is oriented such that the R basis vector points along the sun-spacecraft line. The T basis vector is the cross product of the solar rotation axis with R, and the N basis vector completes the triad.
This frame is inertial, i.e. it is the so-oriented inertial frame for the spacecraft's instantaneous position. Vector velocities in this frame are measured relative to the fixed stars.