

SOLAR-1 SWiPS Data Release, Provisional Maturity

June 9, 2026

Read-Me for Data Users: Operational data

Maturity Status

The Space weather Observations at L1 to Advance Readiness (SOLAR-1, formerly SWFO-L1) Product Validation Review (PVR) for the Solar Wind Plasma Sensor (SWiPS) Provisional maturity was held on June 9, 2026. The review panel concluded that the SWiPS data products have reached Provisional maturity. On June 10, SOLAR-1 reached Initial Operational Capability, in part due to the SWiPS provisional-maturity status.

This Read-Me is intended for operational data. It will be later generalized to include retrospective data.

Instrument Description

SWiPS was developed by a Southwest Research Institute team led by Dr. Robert Ebert. Its heritage includes Rosetta/IES. The design features two oppositely oriented top-hat electrostatic analyzers (ESAs), with a common toroidal entrance aperture as shown in Figure 1. One is used operationally, while the other is in standby mode. The standby ESA is used for periodic cross-calibrations with the operational ESA to monitor changes in the operational sensor performance. The ESAs apply an electric field between two curved surfaces that allow ions in a narrow energy range access to the microchannel plate (MCP) detectors. The electric field is stepped rapidly through 128 fixed values providing measurements in an energy-per-charge range of 170-33,000 eV/q, corresponding to proton velocities of 180-2,510 km/s.

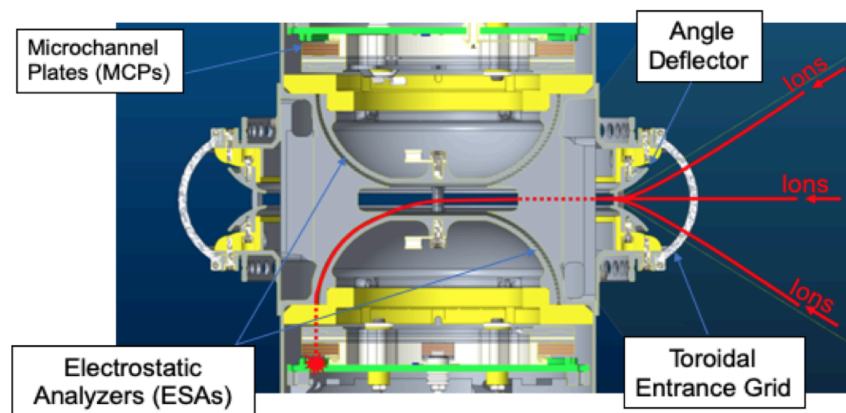


Figure 1. The Solar Wind Plasma Sensor is composed of two back-to-back electrostatic analyzers (image from SWiPS Ground Processing Algorithm Documentation, Document No. 26093-GPA-01, CDRL066, Rev 4 Chg 0.).

The SWiPS FOV is 90° in azimuth by 45° above/below the Solar ecliptic plane. The 45° elevation-angle coverage is obtained by sweeping a deflection voltage at the entrance aperture of the instrument through 19 steps. The ions are directed towards 14 azimuthally arrayed anodes spanning 90° during each deflection-angle step. Counts are accumulated in 128×14×19 energy-angle-angle bins with a full sweep taking 60.07 seconds. A 15th unilluminated background anode registers counts from high energy particles that penetrate the instrument. Background counts are subtracted from the ESA in-band counts in level-1a to level-1b ground processing. In SWiPS ground processing, density, velocity, and temperature moments are computed with discrete sums over velocity distribution functions derived from count rate measurements that are defined on the SWiPS 128 x 14 x 19 energy-angle-angle grid.

Based on SWFO Level 1 requirements (Table 1 below), SWiPS measurement range and accuracy requirements apply to Level-2 data proton density, velocity and temperature moments.

Cadence	60 seconds
Density	0.1 - 150 cm ⁻³ ±10%
Velocity	200-2500 km/s ±10%
Temperature	40,000 -2,000,000 K ±10%
SW Dynamic Pressure	1 - 100 nPa (Consistent with ranges for n and V)

Table 1. SWFO-L1 SWiPS measurement range and accuracy requirements (SWFO Level 1 Requirements Document).

Data Products

The SWiPS data products are based on Level 0 packet data and include:

- Level 0a (SWPC): Raw binary CCSDS packets
- Level 0b (SWPC): Raw counts binned on 128 x 14 x 19 energy-angle-angle grid.
- Level 1a (NCEI, SWPC): Counts rates on 128 x 14 x 19 energy-angle-angle grid.
- Level 1b (NCEI, SWPC): Velocity distribution functions on 128 x 14 x 19 energy-angle-angle grid.
- Level 2 (NCEI, SWPC): 1-minute-cadence density, velocity and temperature moments – Measurement accuracy requirements apply to L2 data.
- Level 3 (SWPC): Density, velocity and temperature moments interpolated onto an on-the-minute time grid using a zeroth-order interpolation, also called nearest grid point (NGP) method.

The SWiPS density, velocity and temperature moments in level-2 and -3 operational data are expected to be of most interest to data users. SWiPS level-2 and -3 operational data includes the following NetCDF variables:

- proton_v_uncorr_eci, ..._gse, ..._gsm – Proton bulk velocities (km/s) in Earth Centered Inertial (ECI), Geocentric Solar Ecliptic (GSE) and Geocentric Solar Magnetospheric (GSM) coordinates
- proton_n_uncorr – Proton density ($\#/cm^3$)
- proton_t_uncorr – Proton temperature (K)
- alpha_v_uncorr_eci, ..._gse, ..._gsm – Alpha-particle bulk velocities (km/s) in ECI, GSE and GSM coordinates
- alpha_n_uncorr – Alpha-particle density ($\#/cm^3$)
- alpha_t_uncorr – Alpha-particle temperature (K)
- combined_v_uncorr_eci, ..._gse, ..._gsm – Bulk velocities (km/s) computed from the full ion distribution function (assuming protons), expressed in ECI, GSE and GSM coordinates
- alpha_dynamic_pressure – Alpha-particle dynamic pressure (Pa)
- proton_dynamic_pressure – Proton dynamic pressure (Pa)
- total_dynamic_pressure – Combined dynamic pressure (Pa)
- sweep_start_time – Sweep start time in microseconds since 1958-01-01T00:00:00 UTC
- sweep_mid_time – Sweep midpoint time in microseconds since 1958-01-01T00:00:00 UTC
- sweep_end_time – Sweep end time in microseconds since 1958-01-01T00:00:00 UTC
- final_packet_time – Creation time of final CCSDS packet included in sweep data
- attitude_quaternions – SOLAR-1 spacecraft attitude quaternions in ECI coordinates
- spacecraft_velocity – SOLAR-1 spacecraft velocity (km/s) in ECI coordinates

Unused variables are currently set to masked and/or fill values. All products are in NetCDF file format.

Provisional Data Quality and Related Issues

The SOLAR-1 SWiPS Provisional-maturity data products have been validated through comparisons with the Solar Wind Electron, Proton, and Alpha Monitor (SWEPAM) instrument on the Advanced Composition Explorer (ACE) spacecraft, and the 3D Plasma (3DP) and SWE instruments onboard the Wind Satellite. The products are made available for public use. The products continue to undergo testing, calibration, and validation. NCEI continues to work with the NOAA SWPC forecast office and the instrument contractor to improve the products. Therefore, changes in ground processing algorithm (GPA) are expected in the future.

The near-real-time data products are processed at NOAA's National Weather Service (NWS) Space Weather Prediction Center (SWPC). The retrospective, or scientific, data products are processed at NOAA's National Centers for Environmental Information (NCEI). Users who do not require low-latency observations are encouraged to use the retrospective data which are the more scientifically authoritative data.

General Note on Other Operational Data Sources

NCEI currently provides SWiPS operational data from June 9, 2026 to present via the NESDIS Space Weather Portal (SPOT). Operational solar wind data in JSON format is available from SWPC at <https://services.swpc.noaa.gov/json/rtsw/>. These files contain the last 24 hours of realtime solar wind data from SOLAR-1, as well as realtime solar wind data from ACE and IMAP. These data are equivalent to the operational data in NetCDF file format available from SPOT. SWiPS operational data text files can also be obtained from SWPC's Solar Wind Observations Display at <https://www.spaceweather.gov/products/solar-wind> by clicking on the gear symbol in the upper right corner and selecting "Download as Text". SWiPS data covering Nov. 2025 to present is available via this link, but the quality of the earlier data is very poor in some cases, and a number of significant instrument and processing issues have been fixed since the beginning of 2026; e.g., a factor of five increase in solar wind density due to an update of the geometric factors used in ground processing is seen on 2026-03-13. Additional data caveats pertaining to operational data after 2026-06-09 are included below. Issues affecting the operational data before 2026-06-09 are not fully described by this document. Reprocessed SWiPS data from 2026-01-03 to present, using the most up-to-date version of the SWiPS GPA available, will be made available from NCEI in the coming months.

SWiPS instrument resolution and dynamic range impose limits on the achievable accuracy of the reported densities, velocities and temperatures. Simulations using forward modeling were used to determine the regions of density-velocity-temperature space where the SWiPS measurement requirements are not met and estimate error bounds in these regions. The results are included in the SWiPS Measurement accuracy waiver. Generally, approximate bounds on error exceedances are as follows.

- Velocity errors do not exceed 30% when densities $> 0.2 \text{ #/cm}^3$, speeds $> 300 \text{ km/s}$ and temperatures $< 1.e6 \text{ K}$
- Density errors do not exceed 15% when densities $> 0.4 \text{ #/cm}^3$, speeds are in range $300\text{-}1875 \text{ km/s}$ and temperatures $< 1.e6 \text{ K}$
- Temperature errors do not exceed 28% when densities $> 0.2 \text{ #/cm}^3$, speeds are in the range $300\text{-}950 \text{ km/s}$, and temperatures in the range $5.2e4\text{-}9.1e5 \text{ K}$

Out-of-band contamination from high-energy particles is estimated based on the count rates from the unilluminated background anode. Background anode counts are subtracted from the in-band ESA counts in level-1a to level-1b ground processing. Post-launch test results, using data from the November 2025 and January 2026 solar particle events, show that in-band counts near the velocity distribution peak remain more than an order of magnitude above backgrounds ensuring good signal to noise ratio in background-subtracted count rates.

Comparisons with ACE/SWEPAM and Wind/3DP

In general, reported solar wind densities, velocities and temperatures from different instruments can differ significantly. SWiPS solar wind measurements have been quantitatively compared

with ACE/SWEPAM and Wind/3DP measurements during 3 January – 23 April 2026. A summary of the systematic differences with ACE/SWEPAM and Wind/3DP measurements at nominal solar wind density, speed and temperature (5 #/cc, 400 km/s, 1.e5 K) during this interval is provided below

- SWiPS operational data speeds are $\approx 3\%$ lower than SWEPAM.
- SWiPS operational data densities are a factor of ≈ 2.8 higher than SWEPAM.
- SWiPS operational data reports $\approx 50\%$ higher temperatures than SWEPAM.
- SWiPS operational data speeds are $\approx 6\%$ lower than 3DP.
- SWiPS operational data densities are a factor of ≈ 2 higher than 3DP.
- SWiPS operational data temperatures are $\approx 30\%$ lower than 3DP.
- At higher temperatures, approaching and greater than 1.e6 K, SWiPS reports higher temperatures than both ACE/SWEPAM and Wind/3DP.

Anomalously high temperatures and densities reported by SWiPS are thought to be due to GPA and/or calibration errors. At the time of writing, work on the SWiPS GPA to resolve this and other issues is ongoing. Future updates to the SWiPS GPA and reprocessed NCEI data are expected.

Additional Issues

In the SWiPS level-2 operational data NetCDF files, float variable fill values are currently set to -9999; however, -9999.99 are used as fill values in the GPA resulting in unmasked bad values. Frequently values ≈ -9999.99 in velocity components are accompanied by zeros in density and temperature moments.

There are many outliers in the operational density, velocity and temperature data. The more extreme outliers can be easily removed with a thresholded spike-removal scheme; however, there may be bad data values that are less obvious, especially near data gaps or intervals of bad data that are due to instrument commissioning and maintenance activities.

Occasionally there are sequences of unflagged and unmasked bad density, velocity and/or temperature values, where a given sweep may have physically unrealistic measurements in one variable that are accompanied by plausible values in another variable. In these cases, plausible measurements from the same sweep should also be treated as bad/missing data (i.e., set all data in 1-minute sweep to fill and/or masked values).

For More Information

NOAA NCEI contact information on the SOLAR-1 SWiPS data:

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