Wind Solar Wind Experiment (SWE): reduced charge flux distributions

Data Release Notes

Version: 1.0
Format: CDF 3.4.0
Release date: June 10, 2012
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Summary of this data set:

This is a high-level data set that provides positive ion charge flux as measured by the Solar Wind Experiment (SWE) Faraday Cups on board the Wind spacecraft. These data span the duration of the experiment, from November 15, 1994 through the present release. Charge flux measurements [pA] are organized into spectra as a function of angle [^{o}] and energy-per-charge [V]. Each spectrum consists of 20 azimuth angles, 2 zenith angles (cup 1 and cup 2), and 31 energy-per-charge windows, for a total of 1240 independent measurements per spectrum. Spectra are provided at approximately 92-second intervals, ordered by the epoch time [ms] at the beginning of each measurement interval. A lookup table is provided for the effective area of the sensor as a function of incidence angle. The data files are indexed by day.

Overview of the Wind mission:

Wind is a spin-stabilized spacecraft that was launched on November 1, 1994. By various maneuvers, Wind observed the solar wind, the Earth's magnetosphere, the Earth's magnetotail, and the lunar wake from 1994-2004. From 2004 to present, Wind has been in a halo orbit around the L1 Lagrange point, more than 200 Re upstream of Earth, observing the unperturbed solar wind.

Independent Variables:

Epoch:

Default time at the beginning of the spectrum. The Epoch is defined as the number of milliseconds since 01-Jan-0000 00:00:00.000, as computed using the CDF library's internal date routines. "Year zero" is a convention chosen by NSSDC to measure epoch values. This date is more commonly referred to as 1 BC. Remember that 1 BC was a leap year. The CDF date/time calculations do not take into account the changes to the Gregorian calendar, and cannot be directly converted into Julian date/times. To convert CDF epochs into date/times and vice versa, you should only use the CDF_EPOCH routine with either the BREAKDOWN_EPOCH or CONVERT_EPOCH keywords.

This variable is a one-dimensional array of size equal to N, the number of spectra obtained in the given day.

Cup1_azimuth,
Cup2_azimuth:

Azimuth angle of the Faraday cup normal vector, in degrees, for cup 1 and cup 2, respectively. This is the angle formed by the ecliptic plane component of the cup normal and the XGSE unit vector. Positive angles correspond to deflection from XGSE into the YGSE direction. Each spectrum consists of 20 angles.

These variables are two-dimensional arrays of size equal to (20xN).

Cup1_Eperq,
Cup2_Eperq:

The Energy-per-charge of admitted ions, i.e. the potential of the Faraday cup bias grid (in Volts). For each potential, the bias oscillates over a small range. This is the central value of the range. Most spectra consist of 31 energy-per-charge ranges.

The energy-per-charge may be converted to the normal flow speed into the cup, v_n, if the charge-to-mass ratio of the ion species, x, is known. Specifically, v_n = sqrt(2x*Eperq).

These variables are two-dimensional arrays of size equal to (31xN).

Cup1_Eperq_DEL,
Cup2_Eperq_DEL:

The range of Energy-per-charge of admitted ions (in Volts). For each potential, the bias oscillates over a small range. This is the width of that range. Each spectrum consists of 31 energy-per-charge ranges.

These variables are two-dimensional arrays of size equal to (31xN).

Dependent Variables:

Cup1_qflux,
Cup2_qflux:

The total charge flux (current) measured on the Faraday cup collector grid, in picoAmperes. The noise limit of this measurement is approximately 0.69 pA.

Models of charge flow into the cup from oblique angles to the cup axis should account for projection of the aperture onto the collector. The calibrated effective area of the cup is given as a function of incidence angle in the lookup table.

These variables are three-dimensional arrays of size equal to (20x31xN).

Support Variables (operation modes):

Tracking:

Boolean signifying whether SWE is in peak-tracking mode (0=not tracking, 1=tracking). In tracking mode, the EperQ window with maximum current signal is identified and the EperQ scanning range is continuously adjusted such that the scan begins five windows below the peak (or at the minimum voltage).

Full_scan:

Boolean signifying whether SWE is in full-scan mode (0=limited scan, 1=full scan). In full scan mode, the EperQ scanning range is the full range of the instrument. In limited scan mode, the EperQ scanning range is smaller. Typically, limited scan mode is used in conjunction with tracking in order to best resolve the core distributions.

Support Variables (constants):

Inclination_angle:

The inclination angles of the two cups. This is a two-element array giving the angle formed by the cup (1 & 2, respectively) normals with the solar ecliptic plane, in degrees.

Calibration_angle:

Incidence angle for the effective area calibration, in degrees. This is the independent variable of the effective area calibration table.

Calibration_effArea

Effective collecting area of the Faraday cup, in cm^2. This is the dependent variable of the effective area calibration table.

Ignore Data:

Angle index:
Bias index:

These are array subscripts for the azimuth and EperQ arrays, respectively.

What is NOT included in this data set:

This data set does not include spacecraft ephemeris, electron, or key parameter data. Spacecraft ephemeris is likely to be of particular relevance when using data from before 2004. Orbit information, along with additional spacecraft information, experiment descriptions, and comprehensive data listings, can be found at http://wind.nasa.gov.

How to use these data:

Using the information provided, charge fluxes can be converted into reduced ion distribution functions if assumptions are made about the ion species being measured. Denoting the ion velocity distribution function (VDF) for species *i* as $f_i(\vec{v})$, the charge flux incident on the cup aperture due to a differential element in velocity space is given by

$$dI = q_i f_i(\vec{v}) A(\theta_{vn}) \vec{v} \cdot \hat{n} d^3\vec{v} \, .$$

In the above, q_i denotes the charge per ion, $\hat{n}$ denotes the unit vector normal to the cup aperture, and *A* denotes the effective area of the sensor, which is a function of the incidence angle, the physical size of the limiting aperture, and the transparency of the wire grids within the instrument.

The dependent variables “Cup1_qflux” and “Cup2_qflux” may be expressed as integrals over the ion VDF. For an energy-per-charge range $(V, V + \Delta V)$, the charge flux measured due to species *i* can be expressed with full generality as

$$I_i(V, \Delta V) = q_i \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{v_z = \sqrt{\frac{2q_i}{m_i} V}}^{v_z = \sqrt{\frac{2q_i}{m_i}(V + \Delta V)}} f(v_x, v_y, v_z) A\left(\arccos\left(\frac{v_z}{\sqrt{v_x^2 + v_y^2 + v_z^2}}\right)\right) v_z dv_x dv_y dv_z \, ,$$

where the integral has been expressed in the Faraday Cup frame with $\hat{z}$ along the normal to the sensor. This expression is not uniquely invertible, and the VDF is therefore not recovered in its general form from charge flux measurements. In practice, the instrument response to a model ion VDF is calculated and compared to observation.

For measurements where the bulk ion velocity is well aligned with the cup normal, it may often be sufficient to approximate the effective area, *A*, as constant. Under such circumstances, one may approximate the reduced distribution function along the line-of-sight, $F_i(v_z)$, and re-express the charge flux as

$$I_i(V, \Delta V) = q_i A \int_{v_z = \sqrt{\frac{2q_i}{m_i} V}}^{v_z = \sqrt{\frac{2q_i}{m_i}(V + \Delta V)}} F_i(v_z) v_z dv_z \, , \text{ where } F_i(v_z) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} f(v_x, v_y, v_z) dv_x dv_y \, .$$

It is common, particularly near the proton and alpha peak fluxes, that one species is dominant and that the associated ion VDF varies slowly over the potential range being measured. In that limit, the reduced distribution function along the line of sight can be approximated directly from the measured current, $I(V, \Delta V)$, as

$$F_i(v^*) \approx \frac{I(V, \Delta V)}{A q_i v_i^* \Delta v_i^*} \, , \text{ where } v_i^* = \sqrt{\frac{2q_i}{m_i} V} \text{ and } \Delta v_i^* = \sqrt{\frac{2q_i}{m_i}(V + \Delta V)} - v_i^* \, .$$

References:

SWE, a comprehensive plasma instrument for the WIND spacecraft
K. W. Ogilvie, D. J. Chornay, R. J. Fritzenreiter, F. Hunsaker and J. Keller, et al.
Space Science Reviews, 1995, Volume 71, Numbers 1-4, Pages 55-77