New Horizons Primary and Extended Missions: Solar Wind Parameters – Overview

The NH_SW_20081010_20200127 file of this data set provides the time information for a given pair of sweeps in the original CODMAC level 2 raw data file, the solar wind proton density, proton speed, proton temperature, proton dynamic pressure, and proton thermal pressure. It also has the spacecraft position in Heliographic Inertial (HGI), Heliocentric Aries Ecliptic (HAE-J2000), and Heliographic (HG).

The NH_PICKUPIONS_2008_11_16 file of this data set provides the interstellar pickup ion density, temperature, and pressure that are described in detail in McComas, et al. (2017).

Solar Wind Coverage

This data set specifically excludes SWAP data obtained while New Horizons was inside the Pluto system. The results provided here are for observations obtained when the solar wind beam was fully within the SWAP field of view. As explained by Heather Elliott (co-investigator):

> *The solar wind is very radial the vast majority of the time. Since we do not have much angular information, we assume the solar wind is radial to perform our analysis. Inside the Pluto system, we have no way of knowing the direction of the ions or if we are measuring the full distribution function. We did a separate analysis for Pluto and have already published those results in McComas, et al. (2016), but those results to our best knowledge only reflect the portion of the distribution function that we measure and are not true density, speeds, and temperatures. Since we believe we do measure the full distribution function of the solar wind when the instrument was pointed such that the solar wind beam was well within the SWAP FOV, we refer to those results as true density, speed, and temperature.*

Solar Wind Processing

The analysis of the count rate energy distributions (SWAP level 2 data archived at PDS) to produce solar wind parameters is described by Elliott, et al. (2016). This paper includes a lengthy discussion of all the calibration information used to forward model the count rate distributions, the use of Poisson errors in the fit procedure, and shows comparisons to 1 AU and Voyager 2 solar wind observations.

Interstellar Pickup Ions

In brief, they are found by fitting the functional form of a filled shell distribution, i.e., the Vasyliunas & Siscoe distribution. This shell distribution is coupled with SWAP instrument responses in order to simulate the measured count rate-energy per charge distribution function.

The fitting procedure minimizes the chi-square between the simulated and measured count rate-energy per charge distributions. After fitting the distribution to SWAP observations, the density, temperature, and pressure distributions are calculated by taking moments of the fitted distribution.

As described in McComas, et al. (2017), this data set was culled for times when the solar wind speed varied over the ~24 hour period by >1% (~13% of the samples). Additionally, SWAP energy distribution that experienced a failing in the fit were manually removed (see McComas, et al. (2017), Section 5 for more details). This resulted in a removal of ~2% of the remaining data. In total, ~85% of the spectra remain.

Reference Frame

Heliographic Inertial (HGI)

This system is a Sun centered with the X-axis along the intersection line of the ecliptic (zero longitude occurs at the +X-axis) and solar equatorial planes. The Z-axis is perpendicular to the solar equator, and the Y-axis completes the right-handed system. This coordinate system is also referred to as the Heliocentric Inertial (HCI) system.

Heliocentric Aries Ecliptic J2000 (HAE-J2000)

This coordinate system is a heliocentric system with the Z-axis normal to the ecliptic plane and the X-axis pointes toward the first point of Aries on the Vernal Equinox, and the Y-axis completes the right-handed system. This coordinate system is also referred to as the Solar Ecliptic (SE) coordinate system. The label 'J2000' refers to the time at which one defines the Vernal Equinox. In this case it is defined at the J2000 date, which is January 1, 2000 at noon.

Heliographic (HG)

This system is similar to the Heliographic Inertial one except the zero longitude is fixed on the surface of the Sun and rotates with a period of 25.38 days. Specifically, the zero was defined as the longitude at the ascending node of the equator in the ecliptic plane on January 1, 1854 at 12 UT. This system is also known as the Carrington system and is an intrinsic system to Spacecraft Planet Instrument C-matric Events (SPICE) toolkit denoted as IAU_SUN where IAU stands for International Astronomical Union.

Summary

The reference frames above are based on SPICE defined reference frames and central bodies. See below for a summary of their definitions in terms of SPICE.

Description	SPICE Reference Frame Name	SPICE Central Body Name
Heliogr. Inertial (HGI)	HCI	Sun
Heliocentr. Aries Eclip. J2000 (HAE-J2000)	ECLIPJ2000	Sun
Heliographic (HG)	IAU_SUN	Sun

Epoch of Geometric Parameters

All geometric parameters provided in the data labels were computed at the epoch midway between the START_TIME and STOP_TIME label fields.

Error Notes

The instrument design for the Solar Wind Around Pluto (SWAP) instrument on New Horizons is described by McComas et al. (2008), and the overall fitting procedure for the SWAP solar wind observations is described by Elliott et al. (2016). This section provides a very brief summary to provide an indication of confidence level in the data as presented. Interested users should consult the referenced papers for full details.

This procedure includes the use of a very detailed forward instrument response model based on laboratory energy and angular calibrations, ion trajectory simulations, and inflight calibration of the detector sensitivity and gain. Elliott et al. (2016) used a new technique developed by Funsten et al. (2005) to perform an inflight absolute calibration of the final coincidence count rates using the individual primary and secondary CEM (Channel Electron Multiplier) detector count rate signals.

Typically, such inflight sensitivity calibrations are not performed for these kinds of observations; however, using this new technique Elliott et al. (2016) were able to perform an inflight absolute calibration of the coincidence rates. These final calibrated coincidence rates were used to derive the final solar wind density, speed and temperature values.

Elliott, et al. (2016) included two figures illustrating the Poisson count rate error bars used in the forward model count rate model analysis of the fit to obtain the solar density, speed, and temperature. The error bars for the solar wind protons were quite small since the count rates were quite high. In addition, Elliott et al. (2016) demonstrated for one fit how much the chi-square changes when the density, speed, and temperature fit parameters are adjusted relative to the final fit values. The chi-square is well minimized in speed and steeply drops within +/-5% of the final fit speed value. The minimization wells for temperature and density are more shallow and span +/-30%. This is consistent with the levels of agreement typically found at 1 AU when comparing ACE and WIND solar wind observations. ACE and WIND speeds typically are within 5 to 10% of one another, and the density and temperatures are typically within 30% of one another. Elliott et al. (2016) also compared propagated ACE, STEREO A, and STEREO B solar wind speeds and those were in high agreement with the observed New Horizons speeds. The radial trends in the density and temperature were in reasonable agreement with Voyager 2 observations as well.

References

Elliott, H.A., D.J. McComas, P. Valek, G. Nicolaou, S. Weidner, and G. Livadiotis, New Horizons Solar Wind Around Pluto (SWAP) Observations of the Solar Wind From 11-33 AU, The Astrophysical Journal Supplement Series, Volume 223, Number 2, doi:10.3847/0067-0049/223/2/19, April 2016.

Funsten, H. O., Harper, R. W., & McComas, D. J., 2005, Absolute detection efficiency of space-based ion mass spectrometers and neutral atom imagers, Review of Scientific Instruments, 76, 3301, doi:10.1063/1.1889465.

McComas, D., F. Allegrini, F. Bagenal, P. Casey, P. Delamere, D. Demkee, G. Dunn, H. Elliott, J. Hanley, K. Johnson, J. Langle, G. Miller, S. Pope, M. Reno, B. Rodriguez, N. Schwadron, P. Valek, and S. Weidner, 2008, The Solar Wind Around Pluto (SWAP) instrument aboard New Horizons, Space Sci. Rev., Volume 140, Numbers 1-4, pp. 261-313, doi:10.1007/s11214-007-9205-3.

McComas, D. J., et al., Pluto's interaction with the solar wind. Journal of Geophysical Research (Space Physics) 121, 4232-4246, 2016. doi:10.1002/2016JA022599

McComas, D. J., et al., Interstellar Pickup Ion Observations to 38 au. ApJS 233 8, 2017. DOI: 10.3847/1538-4365/aa91d2