WIND/STICS Level 2 Data Release Notes, revision D
Version N.NN

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1 Introduction

The Suprathermal Ion Composition Spectrometer (STICS) is a charge-resolving, time of flight – energy (TOF-E) ion mass spectrometer, capable of identifying mass and mass per charge for incident ions up to 230 keV/e. It uses an electrostatic analyzer to admit ions of a particular energy per charge (E/Q) into the TOF chamber. The E/Q voltage is stepped through 32 values, sitting at each value for approximately 24 sec., to measure ions over the full E/Q range of 6 - 230 keV/e. Ions then pass through a carbon foil and TOF chamber, before finally impacting on a solid-state detector (SSD) for total energy measurement. STICS combines these three measurements of E/Q, TOF and total energy, producing PHA event words. These are are assigned to individual ion species on the ground so that both ion mass and charge are resolved. This triple-coincidence technique greatly improves the signal to noise ratio in the data. Below the SSD low energy threshold (~35 keV), ion total energy and thus charge state cannot reliably be determined. These measurements of E/Q and TOF can still be used to determine ion mass per charge (m/q). These double-coincidence measurements are characterized by better statistics since ions whose energy does not allow them to be registered by the SSD can still be counted in double-coincidence measurements. However, ion identification in double-coincidence measurements are limited to a select number of ions that are well separated in E/Q - TOF space.

The STICS instrument provides full 3D velocity distribution functions, through a combination of multiple telescopes and spacecraft spin. The instrument includes 3 separate TOF telescopes that view 3 separate latitude sectors, as shown in Figure 1. In addition, the Wind spacecraft spins, allowing the 3 telescopes to trace out a nearly 4π steradian viewing area. The longitudinal sectors are shown in Figure 2. The solar direction is in sectors 8-10 while the earthward direction is in sectors 0-2.

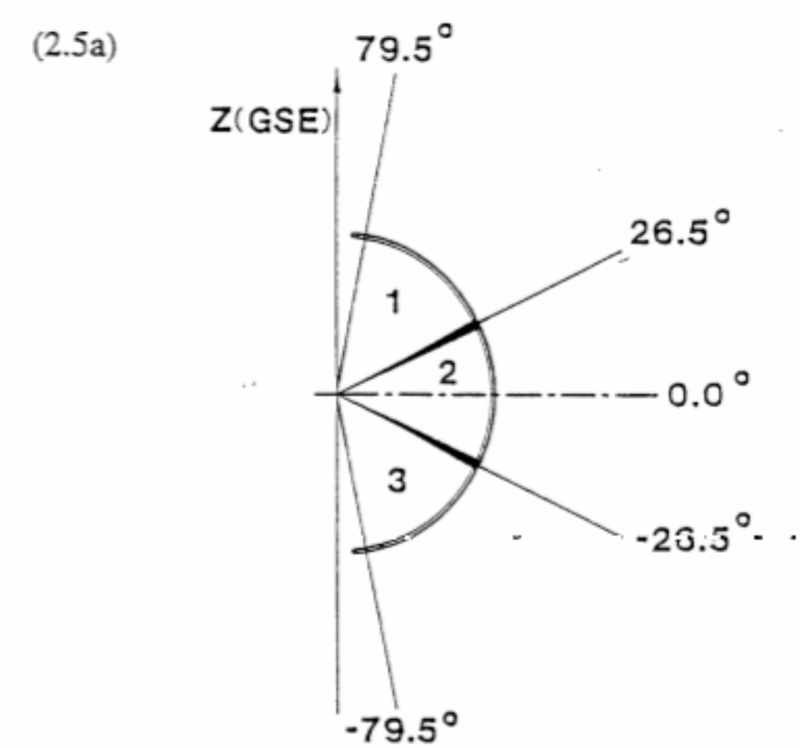

Figure 1. STICS is composed of 3 separate telescopes that view 3 different latitudinal ranges in and out of the ecliptic plane (Adapted from Chotoo et al. 1998).

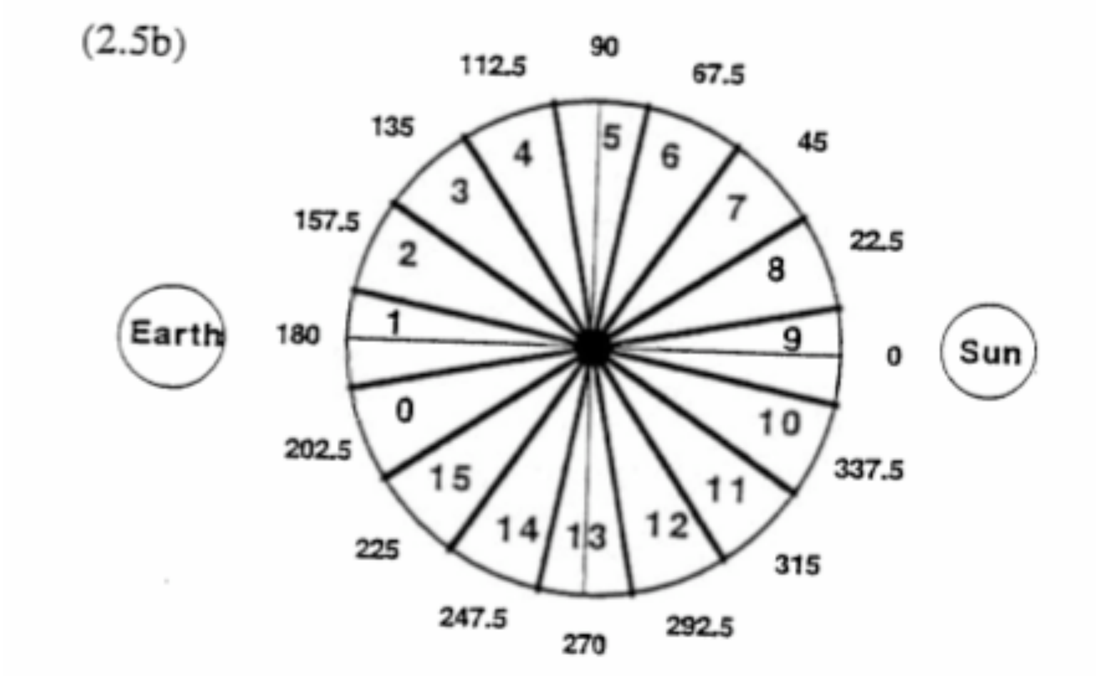

Figure 2. STICS spins through 360 degrees during one measurement cycle sweeping out 16 sectors in space. Sectors 8-10 include the solar direction (Adapted from Chotoo et al. 1998).

2 Method

Since STICS does not measure mass and mass per charge directly, some interpretation of the measurements is required to assign individual event counts to particular ions. Full event (PHA) words from an entire day of measurements are accumulated then assigned to individual ions via an inversion method, which preserves the statistical properties of the measurements. After assignment, these counts vs. E/Q curves are transformed to distribution function, phase space density as a function of velocity.

Though this analysis procedure is applicable to a wide range of ions, only proton distribution functions are currently released at the production level.

3 Instrumental effects

STICS does not apply a post-acceleration voltage to boost ion energy, so low mass ions do not have enough kinetic energy at the lower E/Q steps to trigger the solid state detector and produce a full, triple-coincidence measurement. This produces a sharp cutoff at E/Q values < 35 keV/e in the phase space density curve. This cutoff is m/q dependent, so that it varies in velocity units for different ions. The effect is less for heavy ions. Heavier ions have considerably more kinetic energy for a given E/Q and thus can be measured down to somewhat lower energies. Ions that do not have sufficient energy to produce a triple-coincidence measurement often produce a double-coincidence measurement, allowing extension of STICS distributions to lower energy, at the expense of increased noise and difficulty of assignment to particular ions. The type of measurement, triple coincidence (TC) or double coincidence (DC) is indicated in the file name, described below.

STICS measures ions from an energy regime significantly above the normal solar wind. The flux of particles in this range will vary considerably with solar wind density, velocity and thermal velocity, as well as due to many other solar phenomena (e.g. CMEs). Lower statistics of suprathermal populations frequently result in distribution functions that are not continuous in v and time periods where there are insufficient counts from which to assemble quality distribution functions.

4 Data Description

This dataset contains several different products for a range of ions. Work is ongoing to define, validate and release additional ion species. The current version includes the following ions: H+, He2+, He+, O+, C+, C2+, C5+, O6+, and Fe10+.

The data is separated into data taken in the magnetosphere (until 2004) and solar wind (full mission) using the Wind bow shock crossing list [ref].

All data in this release in in the native STICS 3-minute time resolution. Users can build larger accumulations by simply averaging over multiple time steps.

Values that cannot be properly calculated are filled with value of -1.0 or left as 'nan' (not a number).

4.1 Velocity Distribution Functions (VDFs)

Velocity distribution functions (VDFs) provide the most information about a particular measured ion, separated by E/q, elevation angle and azimuthal angle bins at native resolution. Velocity space represents three of the six dimensions in phase space. The three position coordinates can be retrieved from the Wind spacecraft orbit and attitude data from SPDF.

The VDF files contain 3D velocity distribution functions in phase space density, differential flux and counts. There are 512 values for A(v) for each time step, corresponding to each directional sector (values 0-15 as shown above total 16 total directions) and each Deflection Voltage Step (DVS) corresponding to a set E/q value (32 total voltage steps per sector). Subsequent time steps follow the same pattern.

The columns in these files are as follows:

Column	*Description*
year	Calendar year
doy	Day of year of the measurement , e.g. doy 365 in 2015 is 31 December.
sector	Observation direction in the spin plane (as shown in Figure 2)
telescope	Observation direction perpendicular to the spin plane. See Figure 2 for details.
eoq	Energy per charge (keV/e), 32 steps in total
ion	Ion species
DF	Phase space density value in s^3/km^6
DF_error	Error in velocity distribution function value (same units)
counts	Counts
counts_error	Error in counts estimated assuming Poisson statistics ($\sqrt{N}$)
dJ	Differential flux, dJ/dE, in units of $(cm^2$ s sr eV/eV$)^{-1}$
dJ_error	Error in the differential flux value (same units)
delT	

4.2 Moments

Density and average energy moments are provided to facilitate browsing of the data.

Due to the nature of the instrument and the lower density of suprathermal tails (in both the solar wind and magnetosphere), STICS data values are often zero. Searching through the dataset using the VDFs is complicated by the fact that they files are large in size (even when zero), so that loading large ranges takes substantial computer memory. The moments, in contrast, are very small files so that years of data can easily be loaded.

These are the most appropriate moments for suprathermal ions as they do not assume any form of the distribution function, but simply provide a measure of its properties. They are formed by integrating the VDF over all three dimensions, E/q, elevation angle and azimuthal angle.

The columns in these files are as follows:

Column	*Description*
year	Calendar year
doy	Day of year of the measurement , e.g. doy 365 in 2015 is 31 December.
ion	Ion species
n	Density in cm-3
n_err	Error in the density value assuming Poisson statistics ($\sqrt{N}$) (same units)
v	Not used. Preserved for compatibility.
v_err	Not used. Preserved for compatibility.
E_ave	Average energy (cm^2 s sr eV/eV)$^{-1}$
E_ave_err	Error average energy value (same units)
DelT	Time difference since last time step.

4.3 Angular Flux Maps (AFMs)

Angular Flux Maps (AFMs) give the flow direction of the measured plasma in divided over azimuthal sectors and the three elevation bins. AFMs are formed by integrating the VDFs over E/q. Experience has shown that it is often easier to identify flow directions in this representation, since statistics are improved by integration over energy and since they are suited to 2D visualizations (such as Molleweide projections) which are intuitive to interpret. These are presented in the Geocentric Solar Ecliptic (GSE) coordinate system.

The columns in these files are as follows:

Column	*Description*
year	Calendar year
doy	Day of year of the measurement , e.g. doy 365 in 2015 is 31 December.
telescope	Observation direction perpendicular to the spin plane. See Figure 2 for details.
Sec 0-15	Observation direction in the spin plane (as shown in Figure 2)

4.4 Energy-resolved pitch-angle distributions (ERPAs)

Energy-resolved pitch-angle distributions (ERPAs) organize the data by the angle relative to the magnetic field, in 7.5 degree bins. The energy separation preserved is preserved at the native resolution. Magnetic field data is from the Wind/MFI instrument. These are presented in the Geocentric Solar Ecliptic (GSE) coordinate system.

The columns in these files are as follows:

Column	***Description***
year	Calendar year
doy	Day of year of the measurement , e.g. doy 365 in 2015 is 31 December.
eoq	Energy per charge (keV/e), 32 steps in total
PA 0-11	Phase space density in specified pitch angle bin, 0-11, each 7.5 degrees wide. PA 0 is a 0 degree angle from the magnetic field.

5 File Naming Convention

The files are named as follows:

wstics_LV2_SCFrame_H+_VDF_3D_TC_SW_20151231-20151231.dat

(1) (2) (3) (4) (5) (6) (7)

1. Data source and level: We use the string ‘wstics_LV2’ to signify the type of data.
2. Frame: The data is in the spacecraft frame (‘SCFrame’); the information in figure 2 can be used to transform it to an arbitrary frame.
3. Ion species: This file contains data for H+ ions.
4. Data product: These are 3D velocity distribution functions (‘VDF_3D’).
5. Measurement type: This file is for triple coincidence (‘TC’) data. Double coincidence data would be denoted by ‘DC’.
6. Region: This data taken in the solar wind.
7. Time range: The filenames include the date of the observations, in yyyymmdd format. For example, measurements in the above file were collected on 31 Dec 2015. The first date is the start date; the second one is the stop date. These dates are the same for the daily files delivered in this distribution.

These files replace older versions, named wtdcLV2_distfunc*.dat wtlv2_deliv_distfunc*.dat files. Improvements in our analysis techniques have led to the latest release.

6 Calibration Notes

STICS was calibrated prior to launch with ion accelerators at both NASA GSFC and at the University of Bern in Switzerland (facility details can be found in Ghielmetti et al.,1983). Goddard tests included measuring the instrument response to H+, He+, C+, C2+, N+, N2+, O2+, and Ne2+. Beam measurements at Bern included H+, He+, C+, O+, Ne+, Ne3+, Ar4+, and Kr5+. Post-launch, it was cross calibrated with helium solar wind data from WIND-MASS and WIND-EPACT-STEP. The Time-of-Flight efficiencies were compared with those on Geotail EPIC-STICS (heritage) and Ulysses SWICS.

Further SMS calibration details can be found in Chotoo, 1998.

7 Contacts

For science questions relating to STICS, contact Sue Lepri (slepri@umich.edu), SMS Principle Investigator. For data and instrument operations questions, contact Jim Raines (jraines@umich.edu), SMS Instrument Scientist.

8 References

Gloeckler, et. al., "The Solar Wind and Suprathermal Ion Composition Investigation on the WIND Spacecraft", Space Science Reviews, 71, p79-124, 1995.

Ghielmetti, A. G., et al., Calibration System for Satellite and Rocket-borne Ion Mass Spectrometers in the Energy Range from 5 eV/charge to 100keV/charge, Rev. Sci. Instr., 54(5), 425-436, 1983.

Chotoo, K., Measurements of H+, He2+, He+ in Corotating Interaction Regions at 1 AU, PhD Thesis, 1998.

9 <u>Revision History</u>

Rev	Date	Author(s)	Description
	04Dec2007	JMR/STL	Initial writing.
A	18Dec2007	STL	Addition of calibration notes.
B	01Apr2010	STL/JMR	Release of double coincidence measurements.
C	10May2018	JMR/STL	Release of new data version and file format.
D	01Jun2019	JMR/STL	Release of additional data products (moments, AFM and ERPA) as well as heavy ions.