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Contents of GPS Energetic Charged Particle Data Product Files

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Request:
If you use these data products, we would appreciate an acknowledgement of the source. The preferred acknowledgement is: “The CXD team at Los Alamos National Laboratory” rather than any individual’s name. The three authors of this document are listed as points of contact if you have questions or comments about the data products, the CXD team is much larger. Because the historical GPS data products originate from instruments built and launched over a period of at least 25 years, the list of people who worked on the instruments is very long and has changed with time. The current members of the CXD team are listed at the end of this document.

Description of the contents of the data product files:

There are no detailed descriptions of most of these instruments in the literature – we will attempt to fix that problem in the future. The BDD instruments are described in [1]. One of the dosimeter sensors in the CXD instruments is described in [2]. These documents (or web links to them) and a few others are in this directory tree. The cross calibration of the CXD electron data with RBSP is described in [3].

Each row in the data product files contains the data from one time bin from a CXD or BDD instrument along with a variety of products derived from the data. Integration time bin steps are commandable, but 4 minutes is a typical setting. These instruments reside on many (but not all) GPS satellites that are currently in operation.

The data products originate from either BDD instruments on GPS Block IIR satellites (SVN41 and 48), CXD-IIR instruments on GPS Block IIR and IIR-M satellites (SVN53-61), or CXD-IIF instruments on GPS block IIF satellites (SVN62-73). The CXD-IIR instruments on block IIR are identical to those on GPS IIR(M) satellites.

Each data product file contains data products from one GPS satellite for one GPS week. GPS weeks start at 0:00 each Sunday morning (GPS time). GPS time differs from UTC time due to the addition of leap seconds since the start of GPS time. GPS time is counted from 00:00 on 6-Jan-1980 without adding any leap seconds. To get UTC from GPS time, one needs to subtract the difference is the number of leap seconds which have been added on the date in question and the number of leap seconds which had been added on 6-Jan-1980 – which was 9 seconds. For example, to convert GPS time on the date of this document (8-Dec-2016) you take the total number of leap seconds added prior to 8-Dec-2016, which is 27. Subtract the 9 seconds which had been added prior to 6-Jan-1980. The difference is 18 seconds. To convert the GPS time to UTC time, subtract 18 seconds from the GPS time. You can find information about the addition of leap seconds in various places on the web, such as https://en.wikipedia.org/wiki/Leap_second. The file name encodes the day the week started (YYMMDD). The file name also contains the SVN (Space Vehicle Navstar) number.

The file format is described in JavaScript Object Notation (JSON) – which is all in lines starting with a "#" -- just treat the lines that start with a "#" as comments if you are not using this information. These lines give a brief description of each quantity and the units.

The first lines give a little information about the software code version that produced the file. It also gives the SVN number -- you can find the translations between the various space vehicle numbering schemes associated with each satellite in a variety of places on the web, for example: https://en.wikipedia.org/wiki/List_of_GPS_satellites

Electron data are fit with a Maxwellian function to give a temperature and number density:

Maxwellian(n_e,T) = $n_e B \frac{p^2}{m_e^2} \exp\left(-\frac{E}{T}\right)$ (particles/(cm^2 sec MeV sr))

where

n_e = electron_density_fit (cm^{-3})
p = electron momentum (MeV/c)
m_e = electron mass (0.511 MeV)
E = electron kinetic energy (MeV)
B = c/(4πTK_2(m_e/T)exp(m_e/T)
c = speed of light (3x10^{10} cm/sec)
K_2 is a modified Bessel function

For SVN 53 and up, electron data are also fit with a more complex function which generally fits the data better than the single Maxwellian function (particles/(cm^2 sec MeV sr)):

flux = Maxwellian(par[0],par[1]) + Maxwellian(par[2],par[3]) + Maxwellian(par[4],par[5]) + Gauss(par[6],par[7],par[8])
where
Maxwellian(n_e,T) = the Maxwellian function given above

$$\text{Gauss}(N, P_0, \sigma_P) = N * exp\left(\frac{\left(\ln\left(\frac{p}{P_0}\right)\right)^2}{2\sigma_p^2}\right)$$

for SVN53 and up, proton data are fit with a function of this form (where proton_density_fit (N_0) and proton_temperature_fit (R_0) are given below):

$$\text{flux} = N_0 \frac{\exp\left(\frac{43.33\frac{MeV}{c}}{R_0}\right)}{21.677} \frac{E_{tot}}{p} \exp\left(-\frac{p}{R_0}\right) \qquad \text{(protons/(cm^2 sec sr MeV))}$$

where
R_0 = proton_temperature_fit (MeV/c)
N_0 = proton_density_fit (protons/(cm^2 sec sr MeV))
p = proton momentum (MeV/c)
E_{tot} = proton total energy mass+kinetic (MeV)
21.677 = a dimensionless constant which is defined to normalize flux/N_0 = 1 at 1 MeV kinetic energy
43.33 MeV/c is the proton momentum corresponding to 1 MeV kinetic energy

Remaining quantities in the data product files are described in the table below.

Variable name	**type**	**Dim.**	**description**
decimal_day	double	1	GPS time, a number from 1 (1-Jan 00:00) to 366 (31-Dec 24:00) or 367 in leap years.
Geographic_Latitude	double	1	Latitude of satellite (deg)
Geographic_Longitude	double	1	Longitude of satellite (deg)
Rad_Re	double	1	(radius of satellite)/Rearth
rate_electron_measured	double	11	Measured rate (Hz) in each of the 11 CXD electron channels
rate_proton_measured	double	5	Measured rate (Hz) in each of the 5 CXD proton channels (P1-P5)
LEP_thresh	double	1	LEP threshold in E1 channels (0 means low, 1 means high)
collection_interval	double	1	dosimeter collection period (seconds)
year	int	1	year (e.g. 2015)
decimal_year	double	1	decimal year = year + (decimal_day-1.0)/(days in year)
SVN_number	int	1	SVN number of satellite
dropped_data	int	1	if =1 it means something is wrong with the data record, do not use it
b_coord_radius	double	1	radius from earth's dipole axis (earth radii)

b_coord_height	double	1	height above the earth's dipole equatorial plane (earth radii)
magnetic_longitude	double	1	Magnetic longitude (degrees)
L_shell	double	1	L_shell (earth radii) – currently this is the same as L_LGM_T89IGRF but this is intended to be our suggested choice for the L shell calculation in the long run.
L_LGM_TS04IGRF	double	1	LanlGeoMag L-shell McIlwain calculation, TS04 External Field, IGRF Internal Field.
L_LGM_OP77IGRF	double	1	LanlGeoMag L-shell McIlwain calculation, OP77 External Field, IGRF Internal Field (not currently filled)
L_LGM_T89CDIP	double	1	LanlGeoMag L-shell McIlwain calculation, T89 External Field, Centered Dipole Internal Field
L_LGM_T89IGRF	double	1	LanlGeoMag L-shell McIlwain calculation, T89 External Field, IGRF Internal Field
bfield_ratio	double	1	Bsatellite/Bequator
local_time	double	1	magnetic local time (0-24 hours)
utc_lgm	double	1	UTC (0-24 hours)
b_sattelite	double	1	B field at satellite (gauss)
b_equator	double	1	B field at equator (on this field line I think) (gauss)
electron_background	double	11	estimated background in electron channels E1-E11 (Hz)
proton_background	double	5	estimated background in proton channels P1-P5 (Hz)
proton_activity	int	1	=1 if there is significant proton activity
proton_temperature_fit	double	1	characteristic momentum -- R_0 in the expression given above (MeV/c)
proton_density_fit	double	1	N_0 parameter in fit to proton flux ((protons/(cm^2 sec sr MeV))
electron_temperature_fit	double	1	electron temperature from a one Maxwellian fit (MeV)
electron_density_fit	double	1	electron number density from a one Maxwellian fit (cm^{-3})
model_counts_electron_fit_pf	double	11	E1-E11 rates due to proton background based on proton flux fit -- currently not filled (all -1's)
model_counts_proton_fit_pf	double	5	P1-P5 rate from proton fit (using proton_temperature_fit, proton_density_fit)
model_counts_electron_fit	double	11	E1-E11 rates from the 9-parameter electron flux model
model_counts_proton_fit	double	5	P1-P5 rates from electron background -- currently not filled (all -1's)
proton_integrated_flux_fit	double	6	integral of proton flux (based on fit) above 10, 15.85, 25.11, 30, 40, 79.43 MeV (proton kinetic energy)

proton_flux_fit	double	31	intended to be proton flux at 31 energies, not filled currently
proton_fluence_fit	double	6	not filled currently
integral_flux_instrument	double	30	(based on 9 parameter fit) integral of electron flux above integral_flux_energy[i] particles/(cm^2 sec)
integral_flux_energy	double	30	energies for the integral of integral_flux_instrument (MeV)
electron_diff_flux_energy	double	15	energies for the fluxes in electron_diff_flux_energy (MeV)
electron_diff_flux	double	15	(based on 9 parameter fit) electron flux at energies electron_diff_flux[i] (particle/(cm^2 sr MeV sec))
Efitpars	double	9	fit parameters for 9 parameter electron fit
Pfitpars	double	4	Fit parameters for 4 parameter proton fit. These are still a work in progress. The parameters are here as placeholders until we finalize the fit function and parameters.

SVN41 and 48 have slightly different data products, as described in the following table.

Variable name	type	Dim.	Description
decimal_day	double	1	GPS time -- a number from 1 (1-Jan 00:00) to 366 (31-Dec 24:00) or 367 in leap years
Geographic_Latitude	double	1	Latitude of satellite (deg)
Geographic_Longitude	double	1	Longitude of satellite (deg)
Rad_Re	double	1	(radius of satellite)/Rearth
rate_electron_measured	double	8	Measured rate (Hz) in each of the 8 BDD electron channels (E1-E8)
rate_proton_measured	double	8	Measured rate (Hz) in each of the 8 BDD proton channels (P1-P8)
collection_interval	double	1	dosimeter collection period (seconds)
year	int	1	year (e.g. 2015)
decimal_year	double	1	decimal year = year + (decimal_day-1.0)/(days in year)
svn_number	int	1	SVN number of satellite
dropped_data	int	1	if =1 it means something is wrong with the data record, do not use it
b_coord_radius	double	1	radius from earth's dipole axis (earth radii)
b_coord_height	double	1	height above the earth's dipole equatorial plane (earth radii)
magnetic_longitude	double	1	Magnetic longitude (degrees)

L_shell	double	1	L_shell (earth radii) -- I do not clearly understand the origin of the calculation, but it seems to be a dipole field/T-89
bfield_ratio	double	1	Bsatellite/Bequator
local_time	double	1	magnetic local time (0-24 hours)
b_sattelite	double	1	B field at satellite (gauss)
b_equator	double	1	B field at equator (on this field line I think) (gauss)
Diffp	double	1	No longer used
sigmap	double	1	No longer used
electron_background	double	8	estimated background in electron channels E1-E8 (Hz)
proton_background	double	8	estimated background in proton channels P1-P8 (Hz)
proton_activity	int	1	=1 if there is significant proton activity
electron_temperature	double	1	electron temperature from a one Maxwellian fit (MeV)
electron_density_fit	double	1	electron number density from a one Maxwellian fit (cm^{-3})
model_counts_electron_fit	double	8	E1-E8 rates from the 2-parameter Maxwellian fit to the electron data
dtc_counts_electron	double	8	Dead time corrected electron rates (from data, not fit)
integral_flux_instrument	double	30	(based on 2 parameter Maxwellian fit) integral of electron flux above integral_flux_energy[i] particles/(cm^2 sec)
integral_flux_energy	double	30	energies for the integral of integral_flux_instrument (MeV)
electron_diff_flux_energy	double	15	energies for the fluxes in electron_diff_flux_energy (MeV)
electron_diff_flux	double	15	(based on 2 parameter Maxwellian fit) electron flux at energies electron_diff_flux[i] (particle/(cm^2 sr MeV sec))

References:

[1] Tuszewski *et al,* NIM A482, 653 (2002)
[2] Tuszewski *et al*. (2004), "Bremsstrahlung effects in energetic particle detector," Space Weather, 2, S10S01, doi:10.1029/2003SW000057, 2004.
[3] S. K. Morley *et al*. (2016), "The Global Positioning System constellation as a space weather monitor: Comparison of electron measurements with Van Allen probes data," Space Weather, 14, 76-92, doi:10.1002/2015SW001339.

Current members of the CXD team:

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