SAAPS

Satellite Anomaly Analysis Prediction System

Technical Note 1

Exploration of data

Version 0.1

ESTEC Contract No. 11974/96/NL/JG(SC)

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Contents

1. Introduction

This document describes in detail the various data that are relevant to SAAPS. Part of the data shall be included in the SAAPS database as described in the URD for the Database and Database Tools.

The sections describing the data are organised according to the sources.

2. Database

Time of an observation is a key parameter to all the data, yet there is no generally accepted standard to represent time. Using year, month, day, hour, minute, second representation introduces the problem that one needs to keep track of several fields. Only the year field increases monotonically with time while the other fields are cyclic. The day field also has the problem that its maximum number depends on the month and year. If time instead can be represented as a series of numbers that increases monotonically with time things are simplified. There are several ways to achieve this. The Julian date is the number of days that has elapsed since noon GMT on January 1st 4713 B.C. In Matlab one can use the day number which is the number of decimal days since January 1st 0000. And finally, in Java time is represented as the number of milliseconds since January 1st 1970 UT00. Times before 1970 are negative numbers. For the data that goes into the SAAPS database time will be stored in the Java millisecond format. Routines to convert between the different time formats exist and are easily implemented.

For satellites and spacecraft, the position is another key parameter and it will be stored in the database when available. The coordinate system used can either be a cartesian (x,y,z) system or a spherical system with radius, longitude, and latitude. For geostationary satellites the simplest system is the spherical as all variables will be close to constant. The cartesian systems can be either the geocentric solar-magnetospheric (GSM) or the geocentric solar-ecliptic (GSE). The transformation between the different systems are given in Appendix 1.

2.1. GOES data: 1986–1997

The GOES data for the years 1986 through 1997 reside on two CD-ROMs. They contain 5 minute averages of the X-ray, energetic particle, and magnetic field data collected by GOES-05, -06, -07, -08, -09 between January 1986 and August 1997.

The data comes in 5 different versions and are indicated with letter G, Z, I, H, A as the first letter in the file names on the CDs. All versions contain the X-ray, magnetic field, and electron data. Then, depending on the version, they contain uncorrected proton channels (G), corrected proton channels (Z), corrected integral proton (I), HEPAD (H), and uncorrected alpha particles (A). The I and Z versions have been partially corrected for secondary responses in the particle data. The data that shall enter into the SAAPS database are the I version to conform it to the real time data. The parameters are summarised in Table 1.

Table 1: The GOES data

Name	Description	Units
XL	1-8 Å X-rays	W/m^2
XS	0.5-4 Å X-rays	W/m^2
E1	>2 MeV electrons	electrons / cm^2 sec sr

Table 1: The GOES data

Name	Description	Units
P1	>1 MeV protons	protons / cm^2 sec sr
P2	>5 MeV protons	protons / cm^2 sec sr
P3	>10 MeV protons	protons / cm^2 sec sr
P4	>30 MeV protons	protons / cm^2 sec sr
P5	>50 MeV protons	protons / cm^2 sec sr
P6	>60 MeV protons	protons / cm^2 sec sr
P7	>100 MeV protons	protons / cm^2 sec sr

The longitude positions of each satellite on each day at 0000UT are also available. The longitude is given in degrees west (l_W) of the central meridian. The longitude data stored in SAAPS are in eastern longitude and therefore the longitude is transformed according to $l = 360 - l_W$. The longitude positions for the GOES satellites are shown in Figure 1. It is seen that there are always two satellites present at any one time and the longitude spacing between the satellites ranges from 30 to 60 degrees or 2-4 hours local time.

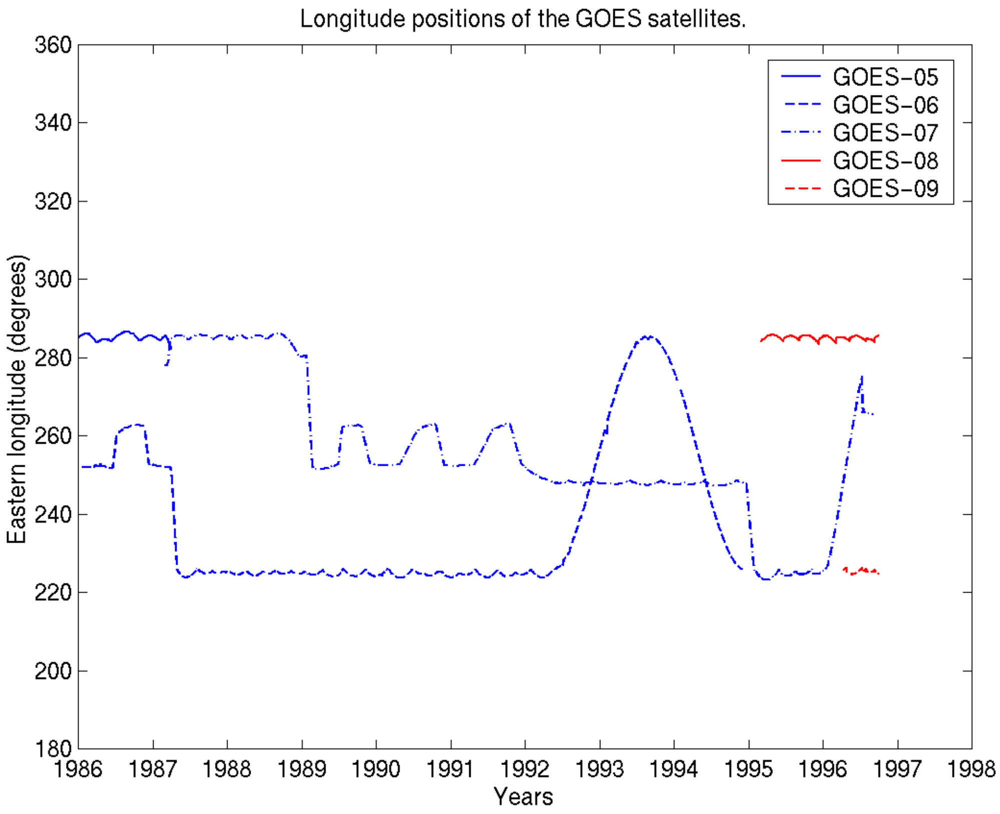

Figure 1: The positions of the GOES satellites for the period 1986 through 1996.

2.2. GOES data: 1997 to present

2.3. GOES data: latest data

The latest GOES data are available over the Internet from SEC. The data exist both in 1 minute and 5 minutes resolution. Data are available in separate files for each day about 1 month back in time. Also the latest two hours of data exist in a separate file. The header information in each file contains the location of the spacecraft in longitude west. The particle data and the X-ray data are kept in separate directories. The contents are given in Table 2.The latest 5 minute data are generally 5 to 10 minutes old.

Table 2: Internet based GOES data.

Description	Units
1-8 Å X-rays	W/m^2
0.5-4 Å X-rays	W/m^2
>0.6 MeV electrons	electrons / cm^2 sec sr

Table 2: Internet based GOES data.

Description	Units
>2 MeV electrons	electrons / cm^2 sec sr
>4 MeV electrons	electrons / cm^2 sec sr
>1 MeV protons	protons / cm^2 sec sr
>5 MeV protons	protons / cm^2 sec sr
>10 MeV protons	protons / cm^2 sec sr
>30 MeV protons	protons / cm^2 sec sr
>50 MeV protons	protons / cm^2 sec sr
>100 MeV protons	protons / cm^2 sec sr

2.4. LANL geosynchronous energetic particle data

The LANL geosynchronous energetic particle data comes from 10 different satellites flown over the period 1976 to present. The satellites are named by their international satellite designator number (ISDN) where the first four digits in the name are the year of the launch and the last three digits are the launch number. Typically data are available from 3-4 satellites simultaneously. The satellites operate at a circular 6.6R_E geosynchronous at the geographic equator. Data are acquired in real time at Los Alamos and then processed, formatted and put on line every night. Digital data are typically available within 24 hours.

The energetic particle data from the LANL satellites comes from two different instruments. The CPA instruments was used on satellites launched between 1976 to 1987 and the last operation was in 1995. The instrument measures electrons from 30 keV to 2 MeV in 12 energy channels and protons from 75 keV to 200 MeV in 26 channels. The SOPA instrument is used on satellites launched from the beginning of 1989. It measures electrons from 50 keV to 26 MeV in 16 channels and protons from 50 keV to >50 MeV in 15 channels. It also measures heavier ions. The 16 electron energy channels of the SOPA instrument are listed in Table 3.

Table 3: The SOPA electron energy channels

Channel name	Nominal energies
E1	50-75 keV
E2	75-105 keV
E3	105—150 keV
E4	150—225 keV
E5	225—315 keV
E6	315—500 keV
E7	500—750 keV

Table 3: The SOPA electron energy channels

Channel name	Nominal energies
E8	0.75—1.1 MeV
E9	1.1—1.5 MeV
E10	>1.5 MeV
ESP1	0.7—1.8 MeV
ESP2+3+4	1.8—3.5 MeV
ESP5+6	3.5—6.0 MeV
ESP7	6.0—7.8 MeV
ESP8	7.8—10.8 MeV
ESP9	10.8—26 MeV

2.5. OMNI solar wind data

From the NSSDC OMNIweb the hourly averages of the solar wind magnetic field and plasma data are available. The data comes from several different satellites flown over the period 1963 to present. The satellites are IMP 1 to 8, AIMP 1 and 2, HEOS 1 and 2, VELA 3, OGO 5, merged LANL VELA Speed Data (July 1964 - March 1971), merged LANL IMP T,N,V (Including all IMP 8 LANL Plasma), ISEE 1 to 3, PROGNOZ 10, and WIND. The data are organised into files holding one year each. There are two types of data files. The first type uses the GSE or GSM coordinate systems for the magnetic field vectors and the solar wind vectors. The second type is a transformation from the GSE system to the RTN system. In addition to the solar wind data the files also contain solar and geomagnetic data. The different parameters are summarised in Table 4.

Table 4: The OMNI data set.

Description	Units
Field Magnitude Average $\lvert \boldsymbol{B} \rvert$	$\frac{1}{N}\sum \lvert \boldsymbol{B} \rvert$, nT
Magnitude of Average Field Vector	$\sqrt{B_x^2 + B_y^2 + B_z^2}$
Lat.Angle of Aver. Field Vector	Degrees (GSE coords)
Long.Angle of Aver.Field Vector	Degrees (GSE coords)
Bx GSE, GSM	nT
By GSE	nT
Bz GSE	nT
By GSM	nT
Bz GSM	nT

Table 4: The OMNI data set.

Description	Units
sigma|B|	RMS Standard Deviation in aver- age
sigma B	RMS Standard Deviation in field
sigma Bx	RMS Standard Deviation in GSE
sigma By	RMS Standard Deviation in GSE
sigma Bz	RMS Standard Deviation in GSE
Plasma temperature	Degrees, K
Ion Density	N/cm^3
Plasma (Bulk) speed	km/s
Plasma (Bulk) Flow Long. Angle	Degrees, GSE*, i.e.
Plasma (Bulk) Flow Lat. Angle	Degrees, GSE,
sigma T	Degrees, K
sigma N	N/cm^3
sigma V	km/s
sigma phi V	Degrees
sigma theta V	Degrees
Kp	Planetary Geomagnetic Activity Index
C9	Geomagnetic activity index (0 to 9)
R	Sunspot number
DST Index	nT
Proton flux	number/cmsq sec sr >1 Mev
Proton flux	number/cmsq sec sr >2 Mev
Proton flux	number/cmsq sec sr >4 Mev
Proton flux	number/cmsq sec sr >10 Mev
Proton flux	number/cmsq sec sr >30 Mev
Proton flux	number/cmsq sec sr >60 Mev

2.6. ACE solar wind data

The ACE spacecraft was launched on August 25 1997 and was placed in a halo orbit at the Lagrange L1 point. There are 9 instruments on the spacecraft. The two instruments relevant for

SAAPS are the magnetometer instrument (MAG) and the solar wind electron, proton, and alpha monitor (SWEPAM). The on-line data are listed in Table 5. Both historic and real time data are available over the Internet. The historic data are available from the CDAWeb where a request can be made for data from specific instruments, time resolution, and time period and then be acknowledged. The latest month of data in 1 or 5 minute resolution are available from SEC. The real time data are also available at SEC with a one minute time resolution covering two hours back in time. The latest observation of the real time data is generally 4 to 5 minutes old.

Table 5: The ACE on-line MAG and SWEPAM data.

Name	Units	Description
Bx	nT	Magnetic field x-component in GSM
By	nT	Magnetic field y-component in GSM
Bz	nT	Magnetic field z-component in GSM
Bt	nT	Total magnetic field
n	cm^{-2}	Protons density
V	km/s	Bulk flow speed
T	K	Ion temperature

The hourly average solar wind data from the ACE spacecraft are one hour lagging averages. This means that for the horly average data value at time *t* the data for the time period *t*-1 hours to *t* has been used. The difference between the lagging average and the central average is illustrated in Figure 2.

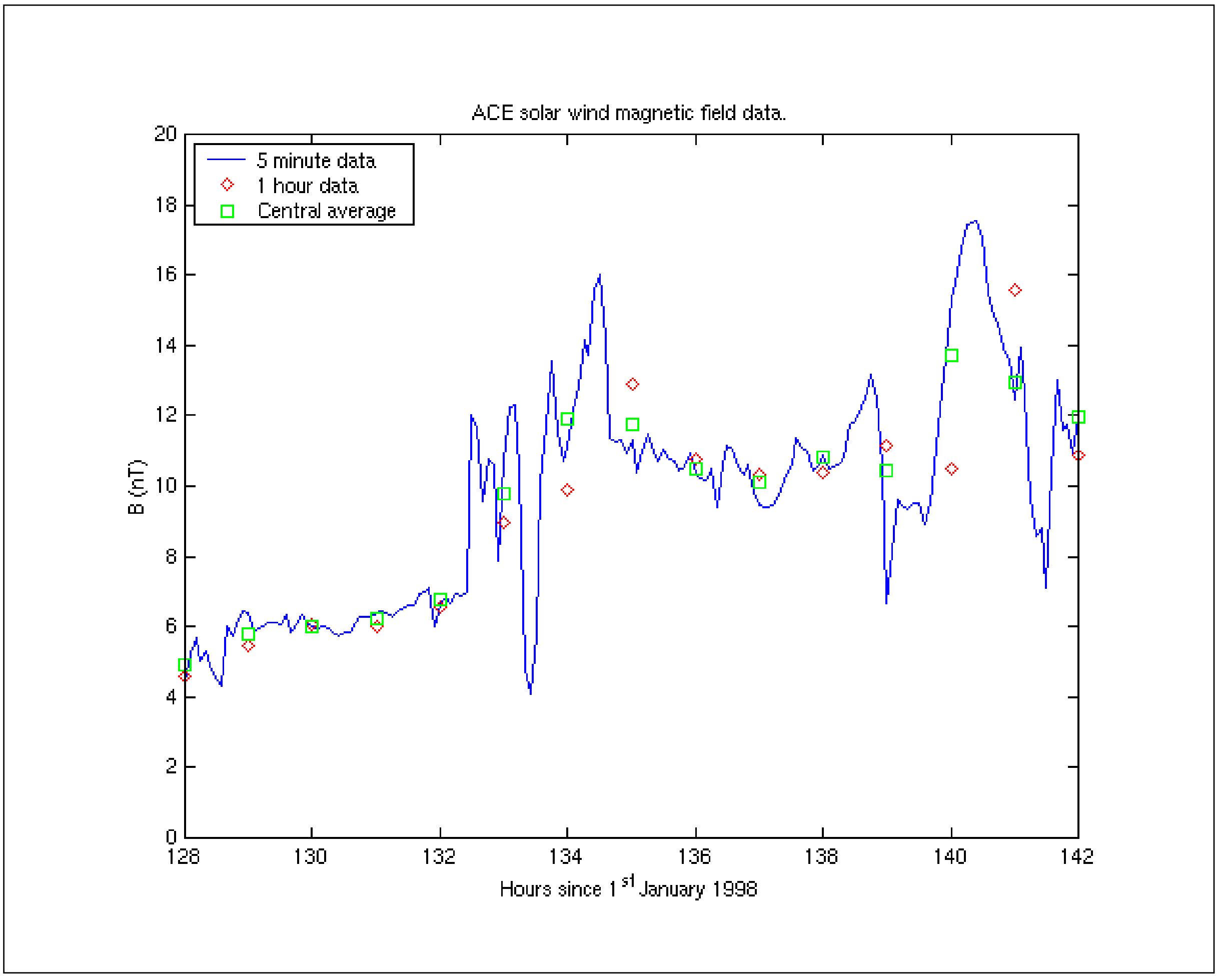

Figure 2: The relation between the ACE 5 minute data, hourly data, and central average hourly data.

2.7. Geomagnetic indices

3. The relation between different data sets

3.1. The solar wind data

The solar wind data in the OMNI data set come from a number of near-Earth solar wind spacecraft. The aim of the OMNI set is to compile the data from several sources and to make the set as compatible as possible. The data comes from spacecraft that has mainly been close to the Earth, like the IMP-8 that was in an $30 \times 40\ R_E$ geocentric orbit. The cross-correlation between the different parameters for different spacecraft was then examined, and when the systematic errors were larger than the random errors a cross-normalization was adopted. It was found that only the density and temperature needed to be cross-normalized, whereas the IMF parameters and the flow speed always had systematic differences smaller than the random errors. As the ISEE-3 spacecraft was located at the Lagrange L1 point about 240 R_E upstream from the Earth this data was time shifted to a near-Earth location. The time shifts are corotation

$$\tau_{\text{rot}} = \frac{x}{v}\left\{\frac{1 + \frac{v}{R\Omega}\frac{y}{x}}{1 - \frac{v_E}{R\Omega}}\right\},$$

and convection

$$\tau_{\text{vec}} = \frac{x_2 - x_1}{v}.$$

It is now interesting to study the relation between the OMNI data and the ACE data. Figure 3 shows the correlation between the OMNI magnetic field data and the ACE magnetic field data for 1998. The quantity plotted is the average field magnitude

$$F = \langle|\boldsymbol{B}|\rangle,$$

where the angle brackets denote the time average. The two data sets show a good agreement. The majority of the data points lie along the y=x line.

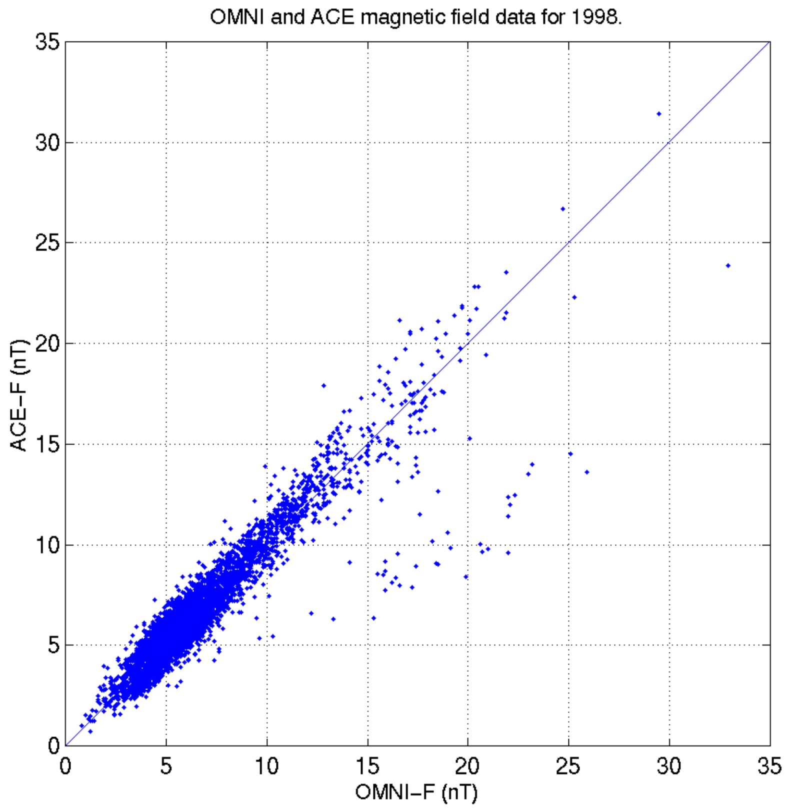

Figure 3: Correlation plots between the hourly OMNI magnetic field data and the ACE magnetic field data over the year 1998. The figure shows the average field magnitude ($\langle|\boldsymbol{B}|\rangle$).

Next we consider the magnitude of the average magnetic field and the magnetic field components. Figure 4 shows the correlation plots for the same data set as in Figure 3 and the different symbols will be explained later. It is again seen that the majority of data points cluster around the y=x line. However, there is also a second cluster which have larger values in the ACE data as compared to the OMNI data. We select all points with $B_{ACE} - B_{OMNI} > 5$ nT and plot them with the open symbols. The two clusters in *B* then becomes clear. Taking the same data points and plotting them with open symbols for *Bx*, *By*, and *Bz* makes it clear that all the data points for the four variables that deviate largely from the y=x line belong to the same samples.

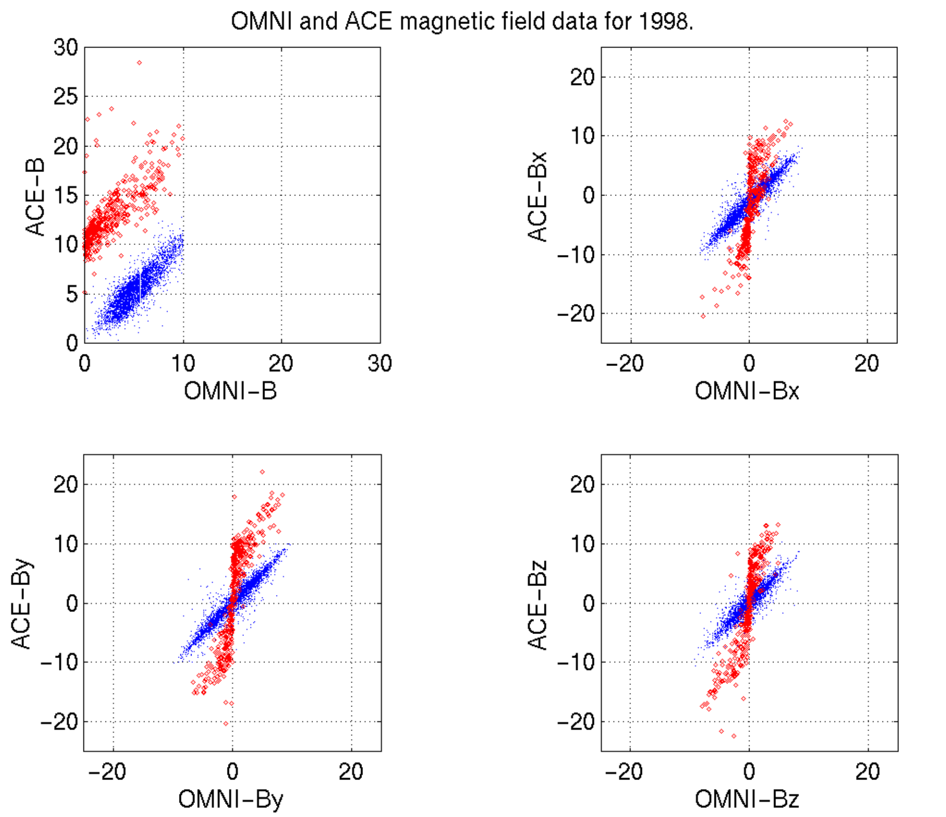

Figure 4: Correlation plots between the hourly OMNI magnetic field data and the ACE magnetic field data over the year 1998. The figures show the magnitude of the average magnetic field (B), and the magnetic field components (Bx,By,Bz).

4. References

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Reeves, G. D., R. D. Belian, T. C. Cayton, R. A. Christensen, M. G. Henderson, and P. S. McLachlan, Los Alamos Space Weather Data Products: On Line and On Time, *Proc. of ICS-3, Versailles France, 12-17 May*, 689-694, 1996.

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