Data Description

Sergio E. Vidal-Luengo, University of Michigan 01/20/2021

Article: Vidal-Luengo, S. E., Moldwin, M. B. (2021). Global Magnetosphere Response to Solar Wind Dynamic Pressure Pulses during Northward IMF Using the Heliophysics System Observatory, Journal of Geophysical Research: Space Physics. DOI: https://doi.org/10.1029/2020JA028587

Corresponding author: Sergio E. Vidal-Luengo. Email: svidal@umich.edu

Introduction

This document contains the description of the data used. This includes data and figures published in the paper, and also figures used during the study, but not published. CDAWeb (http://www.cdaweb.gsfc.nasa.gov/) is the source of the spacecraft observations, except for GOES which data are obtained from (https://satdat.ngdc.noaa.gov/sem/goes/data/full/). The ground-based observations are obtained from SuperMag (http://supermag.jhuapl.edu/). All spacecraft data are in GSE coordinates. The SuperMag ground-based magnetic field data correspond to daily baseline removed data in North, East, and Zenith coordinates.

1 Methodology

The data and figures presented in this data set are classified by “event”. Events consist in solar winds conditions that meet certain conditions: (1) a sudden increase in the solar wind dynamic pressure, and (2) the solar wind dynamic pressure increase occurs during northward interplanetary magnetic field conditions. In order to detect such events, we developed an algorithm that search for the following conditions: (1) the increase of the SYM-H index must be larger than 6 nT; (2) the rise time must be in less than 3 minutes; (3) the SYM-H increase must occur during northward interplanetary magnetic field that stay for at least 3 minutes. Details about the methodology used for the detection of the events are described in the paper. Table 1 contains a list of the events studied.

Event ID	Event date	IMF By	IMF Bz	IMF Bt	DPP speed	$\frac{\Delta P}{P}$	SI or SSC?
1	2011/02/18 01:30:00	0.9	4.0	5.7	-448	10.6	SSC
2	2011/06/05 05:55:00	-6.5	15.6	16.9	-544	2.8	N/A
3	2011/06/11 09:13:00	-4.5	6.0	7.6	-401	2.6	N/A
4	2011/08/04 21:53:20	-2.9	2.3	4.3	-398	4.0	SI
5	2011/10/05 07:36:37	3.8	3.4	5.2	-445	2.6	SI
6	2011/11/30 01:42:30	-3.2	5.8	6.9	-458	3.3	N/A
7	2012/01/24 15:00:05	-22.0	15.8	27.6	-625	7.6	SSC
8	2012/03/08 11:02:40	-0.3	9.2	10.4	-790	5.9	SSC
9	2012/04/23 03:20:20	5.8	1.3	5.9	-387	4.6	SSC
10	2012/05/21 19:35:35	-0.7	1.2	1.8	-388	3.2	SI
11	2013/01/19 17:32:00	2.3	2.9	4.6	-430	2.1	SI
12	2013/02/16 12:08:15	9.4	4.0	10.2	-388	2.0	SI
13	2013/03/18 06:12:00	-1.9	5.7	8.0	-572	1.6	N/A
14	2013/04/14 09:16:10	7.2	6.9	11.0	-520	1.3	N/A
15	2013/05/16 15:45:00	2.0	1.1	3.5	-410	1.4	N/A
16	2013/07/09 20:51:50	5.5	8.6	10.2	-415	3.4	SI
17	2013/12/01 13:07:20	1.8	7.2	8.2	-479	2.7	N/A
18	2013/12/13 13:23:00	-2.5	0.4	2.7	-320	2.8	SI
19	2014/01/09 20:10:20	-5.4	4.0	7.5	-460	3.2	SI
20	2014/03/20 10:16:30	-7.7	3.1	8.7	-347	1.6	N/A
21	2014/04/20 10:54:50	-0.6	8.2	8.3	-554	5.7	SSC
22	2014/05/03 17:47:15	-2.3	2.1	3.4	-330	1.4	SI
23	2014/06/07 16:51:45	-6.1	5.6	10.3	-420	4.7	SSC
24	2014/07/14 14:31:05	-1.9	8.3	8.9	-365	1.3	SI
25	2014/09/12 15:54:00	7.6	3.0	8.2	-600	9.1	SSC
26	2014/12/23 11:15:33	-11.5	3.3	13.5	-410	4.7	SI
27	2015/01/06 20:22:15	-3.8	7.7	8.6	-485	1.9	N/A
28	2015/01/07 06:16:00	1.8	7.4	7.9	-480	1.7	SSC
29	2015/03/17 04:44:00	10.7	15.6	19.0	-551	3.5	SSC
30	2015/03/31 08:32:10	-5.8	2.1	7.2	-360	2.3	SI
31	2015/06/25 05:30:00	-1.3	4.9	6.6	-652	1.4	N/A
32	2015/08/15 08:28:00	7.7	4.9	10.5	-450	2.2	SSC
33	2015/09/20 06:03:30	8.7	3.4	9.5	-498	2.3	SSC
34	2015/11/20 06:50:00	-4.6	2.2	5.3	-382	4.6	N/A
35	2017/07/02 20:53:30	-2.1	3.9	6.7	-435	1.1	N/A
36	2017/09/06 23:43:30	-3.4	2.5	4.7	-590	6.9	SSC
37	2017/11/25 00:33:55	2.5	4.4	5.4	-440	1.9	SI

Table 1: Events found between 2007 and 2018 that meet the criteria described in the methodology section. IMF values are in nT and DPP speed in km/s. Event identifier, date, Interplanetary magnetic field By, Bz, and B total, dynamic pressure pulse speed, $\frac{\Delta P}{P}$, sudden impulse (SI) or sudden storm commencement (SSC).

2 Directory Tree

The folders are organized as follows:

```
main
├── all_events
│   ├── data
│   │   ├── event_01
│   │   │   ├── spacecraft
│   │   │   └── ground_magnetometers
│   │   ├── ...
│   │   └── event_37
│   │       ├── spacecraft
│   │       └── ground_magnetometers
│   └── figures
│       ├── event_01
│       │   ├── spacecraft
│       │   └── ground_magnetometers
│       ├── ...
│       └── event_37
│           ├── spacecraft
│           └── ground_magnetometers
└── figures_in_paper
    ├── data
    └── figures
```

3 Data and figures of all events analyzed

main/all_events/data

Location:

```
main
└── all_events
    └── data
        ├── event_01
        │   ├── spacecraft
        │   └── ground_magnetometers
        ├── ...
        └── event_37
            ├── spacecraft
            └── ground_magnetometers
```

In each *event_?* folder there are one file and two folders. The file named *event_?_OMNI_1MIN* contains the 1 minute time resolution OMNI data obtained from the CDAWeb. The *spacecraft* folder contains data files with spacecraft magnetometers observations obtained from CDAWeb. The *ground_magnetometers* folder contains one file with all the ground-based magnetometer observations obtained from SuperMag for that specific event. All the files are written in ASCII. The files in the *spacecraft* and the OMNI files includes a % symbol at the beginning of the first row, and the name and units of each one of the columns. These files were made to be read by MatLab, but they can be easily read by simple scripts written in any other language. The SuperMag files are exactly the same files that were downloaded from their website, each one

of the files includes detailed information about the data contained in the file itself.

The file name for the ground based magnetometer and the OMNI data files have a simple nomenclature that indicates the event number and *OMNI_1MIN* for the OMNI files, or *ground_magnetometers* for the ground-based magnetometer data. The spacecraft file names follow slightly more complex nomenclature. The first part of their file name indicates the event number. The second part indicates the spacecraft mission and spacecraft identifier. The third part indicates the type of data, which refers to the sampling mode, or resolution. Here are some examples for the file names that can be used as reference:

- **event_01_C1_spinres**: Indicates Cluster mission, spacecraft number 1 with spin time resolution observations performed during event number 1. It can be from C1, C2, C3, or C4.
- **event_01_g13_512ms**: Indicates GOES-13 spacecraft with 512 microseconds of time resolution observations performed during event number 1. It can be G13, or G15.
- **event_01_geotail_1min**: For spacecraft Geotail with 1 minute time resolution observations performed during event number 1.
- **event_01_tha_fgs**: For THEMIS-A spacecraft with FGS sampling mode providing spin time resolution observations performed during event number 1. It can be tha, thb, thc, thd, or the.
- **event_01_rspa_a_1sec**: Indicates Van Allen Probe A with a 1 second time resolution observations performed during event number 1. It can be rbsp_a, or rbsp_b.

The format of the OMNI files is very simple, each columns refers to a different value. The columns of the OMNI data have the following format:

yyyy: Year.
mm : Month.
dd : Day.
HH : Hour.
MM : Minute.
SS : Second.
SYMH: SYM-H index in nanoTesla, from WDC Kyoto.
BX : Bx component of IMF in nanoTesla.
BY : By component of IMF in nanoTesla.
BZ : Bz component of IMF in nanoTesla.
BT : Magnitude of IMF in nanoTesla.
DynP: Solar wind dynamic pressure in nanoPascal.
NP : Solar wind proton number density in $\#/cm^3$.

FS : Solar wind flow speed in km/s.

The columns of the spacecraft data have the following format:

yyyy: Year.
mm : Month.
dd : Day.
HH : Hour.
MM : Minute.
SS : Second.
FFF : Millisecond.
BX : Bx component B field measured by spacecraft in nanoTesla.
BY : By component B field measured by spacecraft in nanoTesla.
BZ : Bz component B field measured by spacecraft in nanoTesla.
BT : Magnitude of magnetic field in nanoTesla.

The spacecraft coordinates files changes events have different amount of spacecraft available at the time of the event. Each row represent the X, Y, Z GSE coordinates in Earth radii units of one of the spacecraft, in the order given in the header of each file.
The figures for all these files are located in *main/all_events/figures/*

4 Data and Figures in the paper

main/figures_in_paper/figures/

```
main
├── all_events
└── figures_in_paper
    └── data
```

4.1 Figure 1, location of spacecraft in XY plane, GSE coordinates

The data file has a very simple format and contains coordinates of the spacecraft in Earth GSE coordinates and radii units. The values were extracted from the same source the magnetic field values. The magnetopause is drawn as reference using Shue et al., 1998. With Bz = 2.0 nT, and dynamic pressure = 2.00 nPa.

$\mathbf{X_{GSE}}$: spacecraft X coordinate location in GSE.
$\mathbf{Y_{GSE}}$: spacecraft Y coordinate location in GSE.
$\mathbf{Z_{GSE}}$: spacecraft Z coordinate location in GSE.

4.2 Figure 2, summary of the events histograms

The data file contains data from the solar wind during each one of the events, such as the IMF clock angle in degrees, IMF cone angle in degrees, d(SYM-H)/dt in nT/min, and dP/P dimensionless ratio.

ClockAngle: IMF clock angle in degrees.
ConeAngle: IMF cone angle in degrees.
Delta d(Sym-H)/dt: SYM-H increase in nT/min.
dP/P: Solar wind dynamic pressure increase ratio with respect previous dynamic pressure.

4.3 Figure 3, spacecraft location and solar wind parameters

There are four files of data for this figure. The first three are necessary to built panel (a). (*figure_3_spacecraft_locations_event_36*, *figure_3_TSY_North_event_36*, and *figure_3_TSY_South_event_36*) contain the spacecraft coordinates, magnetic field lines generated by Tsyganenko T89 model using a Kp index of 3.3, one for field lines above the equator and one for field lines below the equator. The rest of the panels from (b) to (f) are built using the file *figure_3_OMNI_1MIN_event_36*, that contains all the OMNI data (solar wind parameters) for the event. In the same format given in section 3. The figure is located in *main/figures_in_paper/figures*.

4.4 Figure 4, spacecraft total magnetic field

The total magnetic field data for Figure 4 can be found in *main/figures_in_paper/data/*, because each spacecraft mission has a different sampling resolution, each spacecraft data written in a independent file. The respective figure is located at *main/figures_in_paper/figures*.

4.5 Figures 5-11, spacecraft observations

The magnetic field data for Figures 5-11 can be found in *main/figures_in_paper/data/* and their respective figures in *main/figures_in_paper/figures*

4.6 Figure 12, station example and RMSD

The north component of the Ministik Lake magnetometer station is located in *main/figures_in_paper/data/*. The polynomial fitting before and after the sudden increase of the magnetic field are also located in the same folder. The root-mean-square-deviation computed between the real data and the fitting curve is located there too.

4.7 Figure 13, time-of-flight plot, and histogram

There are four files necessary to build this figure. The first (*figure_13_SATS_X_GSE*), contains the X coordinate of all the spacecraft. The second file (*figure_13_tr_sp*), contains the transient

speed computed. The third file (*figure_13_tr_sp_l*) contains the upper error bar. The fourth file (*figure_13_tr_sp_r*) contains the lower error bar.

Acknowledgements

We acknowledge to the SuperMAG and their collaborators (http://supermag.jhuapl.edu/info/?page=acknowledgement), and the Space Physics Data Facility, NASA for IMF, MMS, THEMIS, Cluster, Van Allen probes and Geotail data obtained from the CDAWeb (https://cdaweb.gsfc.nasa.gov/). We also thank to the National Centers for Environmental Information for the GOES data (https://www.ngdc.noaa.gov/stp/spacecraft/goes/). Finally, we also thank to the Observatori de l'Ebre for their catalogue of geomagnetic variations.