HSS Catalogue and prediction of their geoeffectiveness

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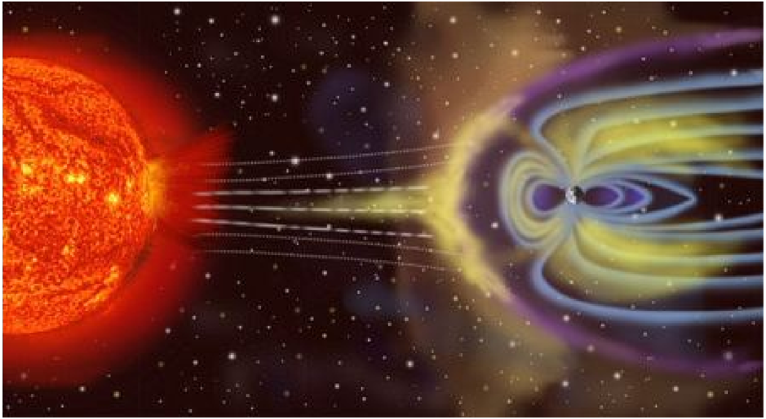
9 February 2022

Outline

SW – Continuous flux of particles



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We do not fully understand the origin of the slow SW, nor its region of acceleration/deceleration

Fast SW origin – coronal holes

It is highly variable.

History

- Mar 1716 - the first interpretation of an aurora based on exact sciences as a terrestrial phenomenon which involved geomagnetism (magnetic thunderstorms)
- Sep 1859 - solar flare in white light → geomagnetic storm
- Solar M regions recurrent geomagnetic storms (GSs) (27 days)
- Solar wind (Parker) 1956
- Spatial era 1957 - terrestrial magnetosphere, Van Allen radiation belts
- May 1973 - Skylab (corona in X-ray and white light)
  - Coronal Holes → recurrent GSs
  - Coronal Mass Ejections → major GSs
- Oct 1990 - ULYSSES – Sun at all latitudes
- Nov 1994 - WIND (SW data)

Coronal Holes

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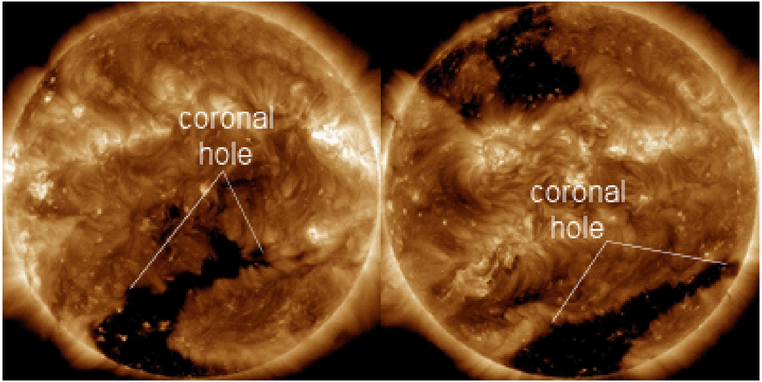
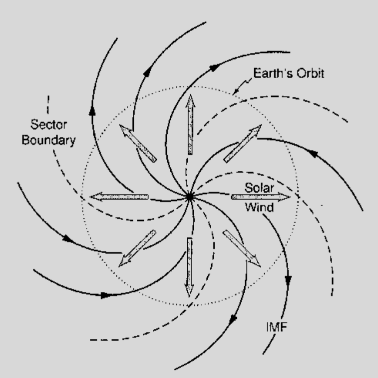
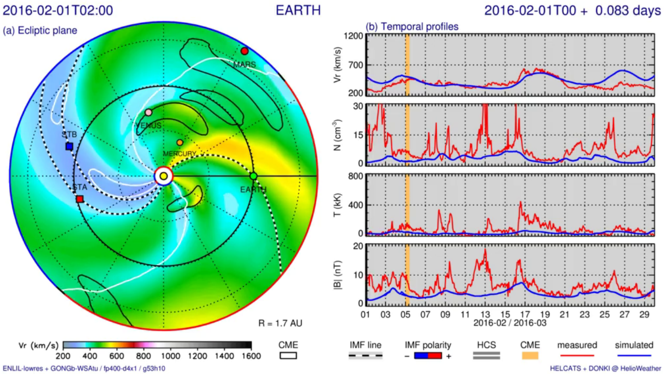


February 15 and 19, 2016

Parker Spiral



Baumjohann and Treumann, 1996



ENLIL Solar Wind Prediction - ©http://helioweather.net/index.html

SW Types

1. Fast wind in high-speed streams
High speed – 400 - 800 km s-1; Low density – 3 cm-3
Low particle flux – 2 $\times$ 10^8 cm^{-2} s^{-1}; Helium content – 3.6% stationary
Source – coronal holes
Signatures – stationary for long times (days – weeks)

2. Low speed wind near activity minimum
Low speed – 250 - 400 km s^{-1}; High density – 10 cm^{-3}
High particle flux – 3.7 $\times$ 10^8 cm^{-2} s^{-1}; Helium content – below 2% highly variable
Source – helmet streamers near current sheet
Signatures – sector boundaries embedded

3. Low speed wind
Similar characteristics as 2., except for:
Helium content – highly variable; Source – related to active regions
Signatures – shock waves often embedded

4. Ejecta following interplanetary shocks
High speed – 400 - 2000 km s^{-1}; Helium content – up to 30%
Other constituents – often FeI6+ ions; in rare cases He+
Sign. of magnetic clouds in about 30% of cases
Sources – CMEs, erupting prominences, flares

High Speed Streams

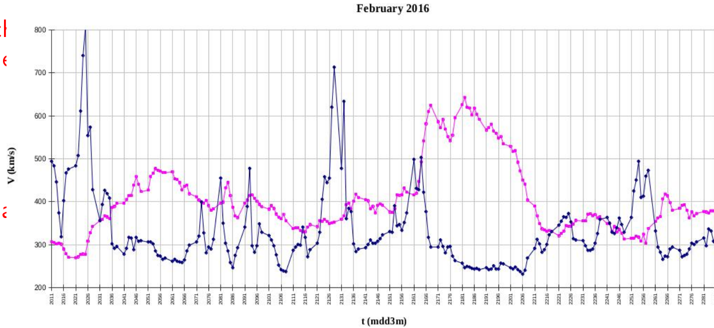
HSS definition:

"An increase of solar wind speed tl lasts several consecutive days (at le two)"

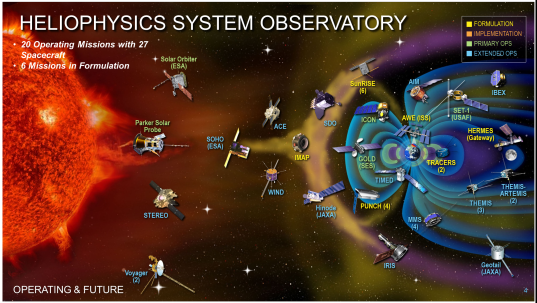
Principal selection criterion:

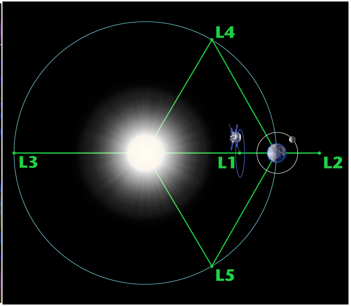
$\Delta V1 \geqslant 100$ km/s that lasts two da

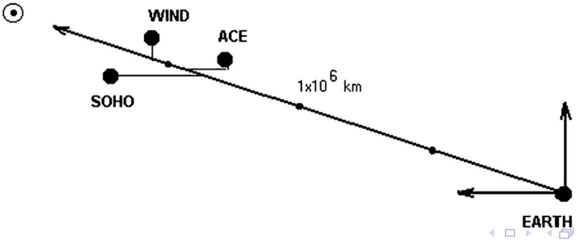
$\Delta V1 = V1 - V0$
V0 - the smallest 3h velocity for a given day
V1 - the largest one for the next



Data


HELIOPHYSICS SYSTEM OBSERVATORY
20 Operating Missions with 27 Spacecraft
6 Missions in Formulation
FORMULATION
IMPLEMENTATION
PRIMARY OPS
EXTENDED OPS
Solar Orbiter (ESA)
Parker Solar Probe
SOHO (ESA)
ACE
SDO
SunRISE (6)
AIM
IBEX
ICON
AWE (ISS)
SET-1 (USAF)
HERMES (Gateway)
IMAP
GOLD (SES)
TRACERS (2)
WIND
TIMED
THEMIS-ARTEMIS (2)
THEMIS (3)
STEREO
Hinode (JAXA)
PUNCH (4)
MMS (4)
IRIS
Geotail (JAXA)
Voyager (2)
OPERATING & FUTURE


L4
L3
L1
L2
L5


WIND
ACE
SOHO
1x10^6 km
EARTH

Software

IDL

Input data

- Bartels rotation number
- the SW plasma temperature (K)
- SW proton density (N/cm^3)
- SW plasma speed (km/s)

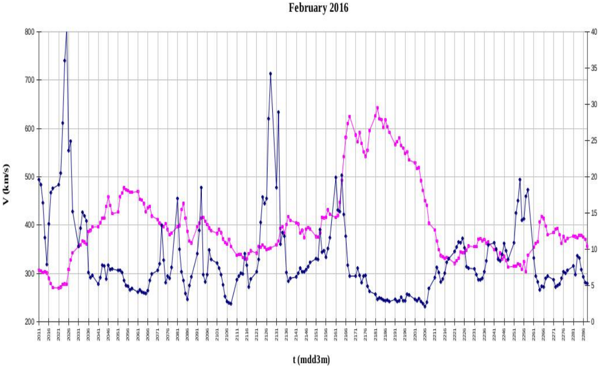
Output data

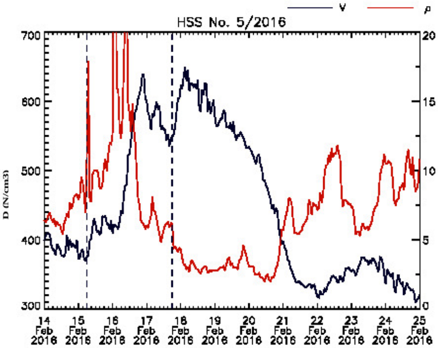
- list of numbered HSSs
- start time
- duration
- initial and maximum speed values
- the speed gradients

Algorithm

- 3-h mean values
- maximum (Vmax) and minimum (Vmin) values of the 3-h speed for each daily set
- Vmaxnext - Vmin > 100 km/s
- identification of the maximum speed Vmax
- identification of the end time of the event, when the speed decreased to (or near to) the V0 value from the beginning of the event
- new increase greater than 100 km/s appeared before the fall under the initial value V0 of the speed, it was considered that a new HSS event

High Speed Streams - Validation





Besliu-Ionescu, Maris Muntean, Dobrica, 2022

Sources

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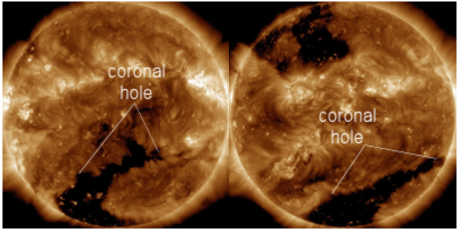

February 15 and 19, 2016

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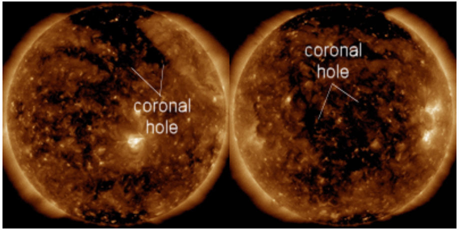

August 24 and 27, 2018

Example

No. crt.	Year	Month	Day	3-h	V0 (km/s)	V1 (km/s)	Δt1	Vmax (km/s)	Dur (days)	ΔV1 (km/s)	ΔVM (km/s)	I	Source	IMF	Dst_min (nT)	Dst_date (mm:dd:hh)	Bz_min (nT)	Bz_date (mm:dd:hh)	SSC_date (mm:dd:hh)	Energy estimate ΔWε (J)	Energy estimate ΔW (J)	SYM-H_min (nT)	SYM-H_date (mm:dd:hh:min)
1	2016	1	5	4	391	606.7	7	606.7	5.8	215.7	215.7	1251.06	CH708	+									
2	2016	1	11	2	409.3	569	6	604	4.1	159.7	194.7	798.27	CH709	-									
3	2016	1	20	6	342.3	520.7	10	554	6	178.4	211.7	1270.2	CH*	-	-93	01:20:16	-11.8	01:20:15	01:18:22	2.05E+17	1.18E+18	-95	01:20:16:42
															-39	01:21:15	-2.1	01:21:15				-41	01:21:15:28
4	2016	2	2	1	270	396.3	15	477	9	126.3	207	1863	CH713	+,+/-	-53	02:03:02	-8.3	02:03:01		9.18E+14	5.58E+16	-60	02:03:02:52
5	2016	2	15	2	375	624.3	14	642.7	6	249.3	267.7	1606.2	CH715	-	-57	02:16:19	-3.3	02:16:18		1.42E+17	1.04E+18	-58	02:16:19:44
															-57	02:18:00	-6.4	02:17:21		9.75E+15	8.80E+16	-60	02:18:00:28
															-33	02:19:07	-2.3	02:19:04				-33	02:19:06:25
6	2016	2	25	7	303.3	418	6	418	4.2	114.7	114.7	481.74	CH716	+									
7	2016	3	1	1	310	462.7	14	462.7	4	152.7	152.7	610.8	CH719	+									
8	2016	3	5	1	345	497.7	15	583.7	5.1	152.7	238.7	1217.37	CH718	-	-98	03:06:21	-12.7	03:06:19		6.36E+15	1.04E+17	-110	03:06:21:20
9	2016	3	11	2	309	555	6	555	3.5	246	246	861	CH720	+									
10	2016	3	14	6	373	538.3	2	570.3	6	165.3	197.3	1183.8	CH721	-	-49	03:15:07	-4.2	03:15:05	03:14:21			-62	03:15:17:18
															-56	03:16:23	-5.3	03:16:23		3.59E+15	9.58E+16	-69	03:16:23:41
11	2016	3	23	1	393.7	523	15	546.7	3.2	129.3	153	489.6	CH723	+									
12	2016	3	27	2	382	502	14	536.3	5.4	120	154.3	833.22	CH724	+									
13	2016	4	2	3	324.3	491.3	5	491.3	8.9	167	167	1486.3	CH726	-/+	-56	04:02:23	-6.4	04:02:22		2.22E+16	2.31E+17	-65	04:02:23:47
															-60	04:07:21	-11.6	04:07:19		7.61E+15	1.06E+17	-63	04:07:21:34
14	2016	4	11	2	340.7	473.3	14	609.3	8.4	132.6	268.6	2256.24	CH727	+	-55	04:13:05	-7.9	04:12:23		2.39E+16	4.15E+17	-69	04:13:04:44
															-59	04:14:20	-5.4	04:14:18	04:14:07	5.03E+15	2.74E+17	-68	04:14:20:29
															-55	04:16:21	-8.5	04:16:19		6.89E+15	1.75E+17	-64	04:16:20:47
15	2016	4	21	1	357.3	562.3	14	562.3	8.5	205	205	1742.5	CH729	+									
16	2016	4	30	2	347	455	14	571.3	6.1	108	224.3	1368.23	CH730	-	-37	05:02:03	-5.1	05:02:01				-56	05:02:03:19
17	2016	5	6	3	375.3	517.7	6	667.7	6.9	142.4	292.4	2017.56	CHs 732,733	-	-88	05:08:08	-11.2	05:08:05		1.06E+16	2.26E+17	-105	05:08:08:15
															-50	05:09:22	-4.3	05:09:19		1.08E+16	1.69E+17	-55	05:09:21:55
18	2016	5	14	7	324.3	446.3	8	527.7	5.8	122	203.4	1179.72	CH734	+									
19	2016	5	20	5	414	524.3	11	609.3	3.4	110.3	195.3	664.02	CH735	+									
20	2016	5	26	5	334	466	11	524	7.5	132	190	1425	CH737	-									
21	2016	6	4	6	289.3	592.7	10	622.7	5.6	303.4	333.4	1867.04	CH738	-	-44	06:06:06	-5.9	06:06:04				-55	06:06:06:47
22	2016	6	10	3	340.7	516	11	556.3	4.1	175.3	216.6	888.06	CH739	+									
23	2016	6	14	4	424.3	668.7	6	668.7	6.7	244.4	244.4	1637.48	CH740	+									
24	2016	6	22	3	340.7	463.7	13	523	8.2	123	182.3	1494.86	CHs741, 742	-	-30	06:24:02	-5.6	06:24:00				-40	06:24:02:24
25	2016	7	2	6	343.3	457	5	457	3.1	113.7	113.7	352.47	CH745	-									
26	2016	7	6	7	313.3	506.7	8	628.7	5.1	193.4	315.4	1608.54	CH746	+									
27	2016	7	11	8	455.3	621.3	7	659.3	6.6	166	204	1346.4	CH746	+	-31	07:12:09	-6.9	07:12:08				-44	07:12:10:11
28	2016	7	19	7	321.3	563	5	563	8.1	241.7	241.7	1957.77	CH750	-	-34	07:25:12	-5.1	07:25:10				-39	07:25:12:26
29	2016	7	27	8	325.3	536.3	8	598.7	4.6	211	273.4	1257.64	CH752	-	-30	07:28:19	-6.9	07:28:17				-42	07:28:19:30
30	2016	8	2	2	312	442.7	5	659.3	6.1	130.7	347.3	2118.53	CH753	+	-52	08:03:10	-15.1	08:03:09		5.86E+017	2.07E+018	-58	08:03:10:37
31	2016	8	8	3	465	618	10	641.7	5.2	153	176.7	918.84	CHs753, 754	+									
32	2016	8	16	1	284	399.7	12	400	5	115.7	116	580	CH*	-									

IMF

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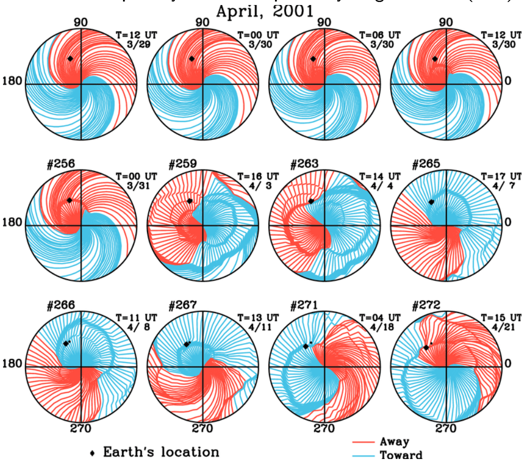
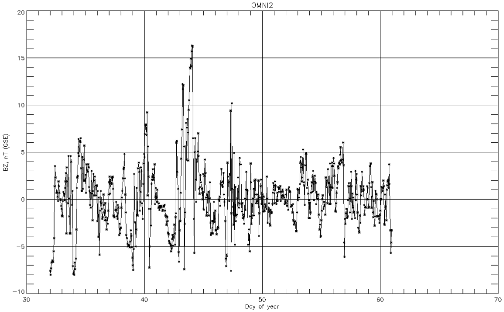
AIRA, 9 Feb 2022

the dominant polarity of the interplanetary magnetic field (IMF)



Fry et al. 2005

minimum Bz (value and time)



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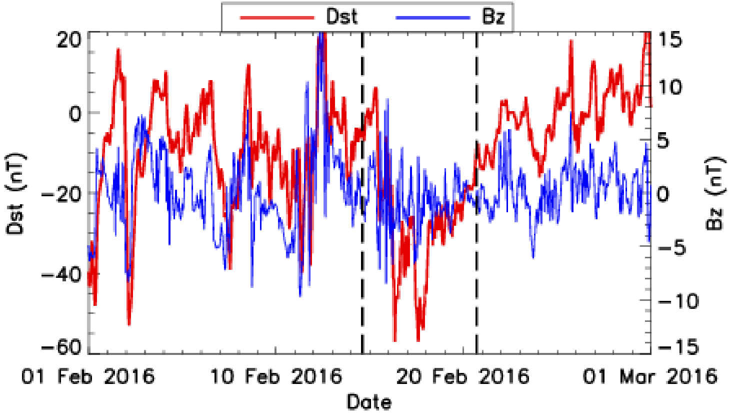
Geomagnetic Storm Association



Energy Estimation

$$\epsilon \quad = \quad 10^7 \; V \; B^2 \; l_0^2 \; sin^4\left(\frac{\theta}{2}\right) \quad [J/s]$$

Akasofu, 1981

$$E_{IN} = 3.78 \times 10^7 \, n_{sw}^{0.24} \; V_{sw}^{1.47} \; B_T^{0.86} \; \left(sin^{2.7}\left(\frac{\theta}{2}\right) + 0.25\right) \quad [J/s]$$

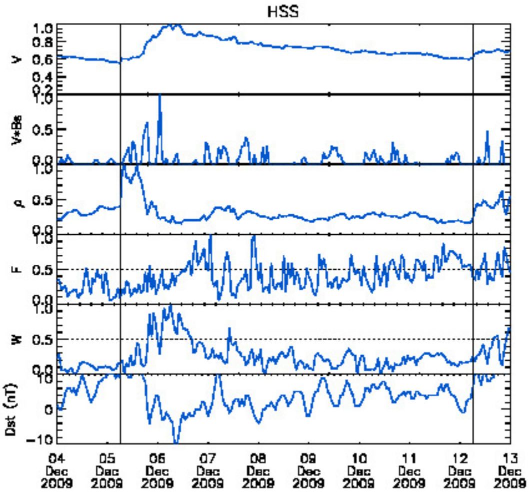
Wang et al., 2014

$$W_\epsilon \quad = \quad \int_{MPH} \epsilon \; dt \quad [J]$$

$$W_{Ein} \quad = \quad \int_{MPH} E_{IN} \; dt \quad [J]$$

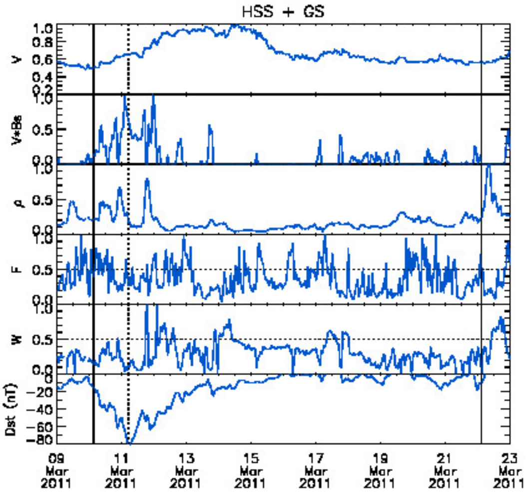
Example – non geoeffective HSS

(Besliu-Ionescu, Maris Muntean, Dobrica, 2022)



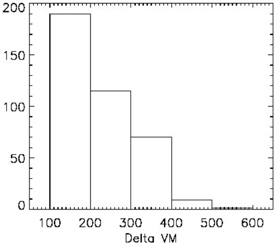
Example - cont – geoeffective HSS

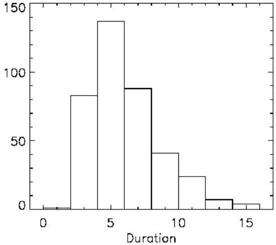
(Besliu-Ionescu, Maris Muntean, Dobrica, 2022)

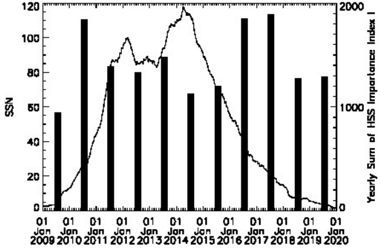


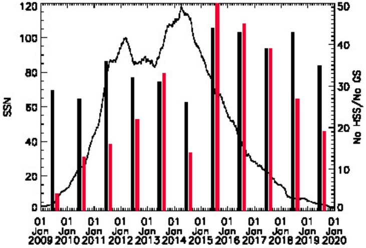
Statistics

(Besliu-Ionescu, Maris Muntean, Dobrica, 2022)









HSS geoeffectiveness

Method based on Besliu-Ionescu et al. (2019)
Summary of regression coefficients

Regression Coefficient	Corresponding Value
V0	-0.9988
VMax	0.0051
Δ VMax	-0.0061
dur	0.0053
Bz_min	0.1425
IMF	0.0843
b0	7.6450

21% success rate – training set
24% success rate – validation set

Besliu-Ionescu and Maris Muntean, 2020

Summary

- Online Catalogue of CH driven HSS for SC24
- 385 streams
- 178 HSS associated with 282 GSs
- 207 non-geoeffective HSSs
- minimum phases of the 11-yr solar cycles are not quiet intervals
- Probability computation of HSSs geoeffectiveness needs improvements
- higher probability of geoeffective HSSs during the descending phase

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D.Besliu-Ionescu,

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Thank you for your attention!

Acknowledgments

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www.geodin.ro/varsiti