International Space Weather Initiative: The way Forward

Austria (Vienna), 26-30 June 2023

TOPIC :

Effect of Turbulence of High-Speed Solar Winds upstream of the Earth's Magnetosphere: Case of the Outer Minima of Solar Cycles 20, 21, 22, 23 and 24.

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UNITED NATIONS
Office for Outer Space Affairs

International Space Weather Initiative ISWI

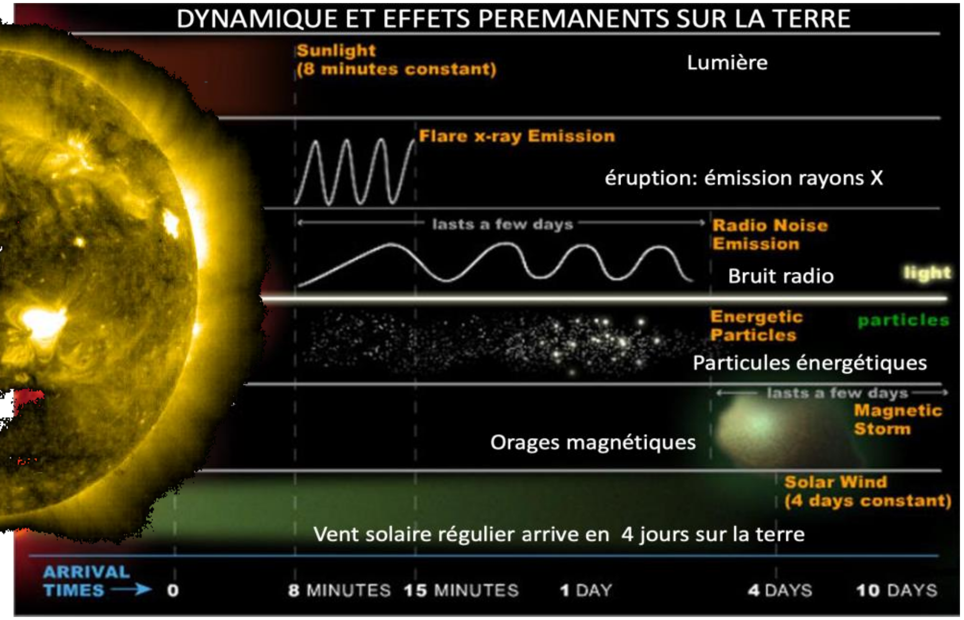
ICG International Committee on Global Navigation Satellite Systems

OUTLINE

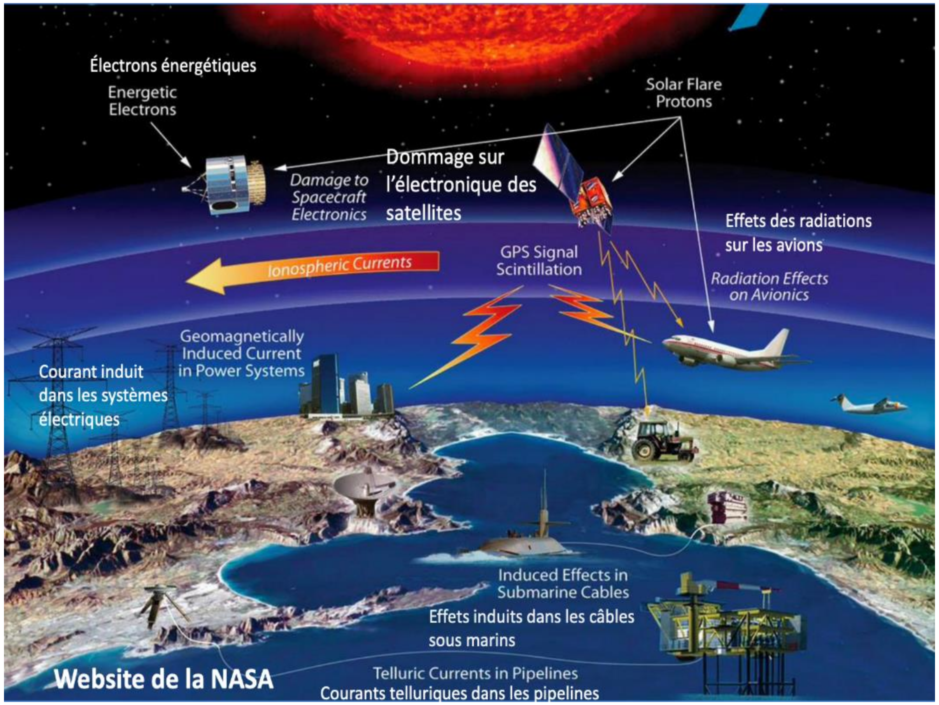
- Generalities, Earth-Sun relationship
- Data and methodology
- Results and discussion
- Conclusion

GENERALITIES

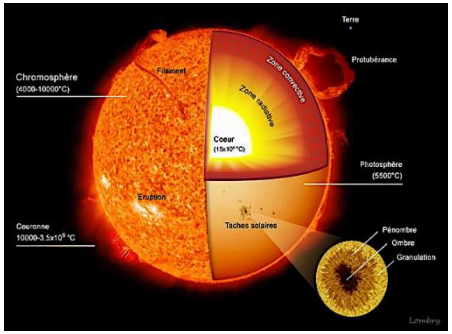
■ THE SUN: EMISSIONS & IMPACTS

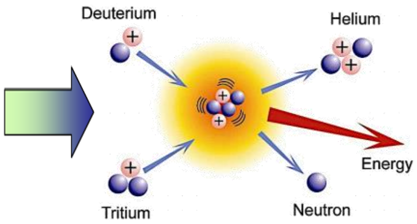


Impacts of solar events on the Earth.



Emissions from the Sun

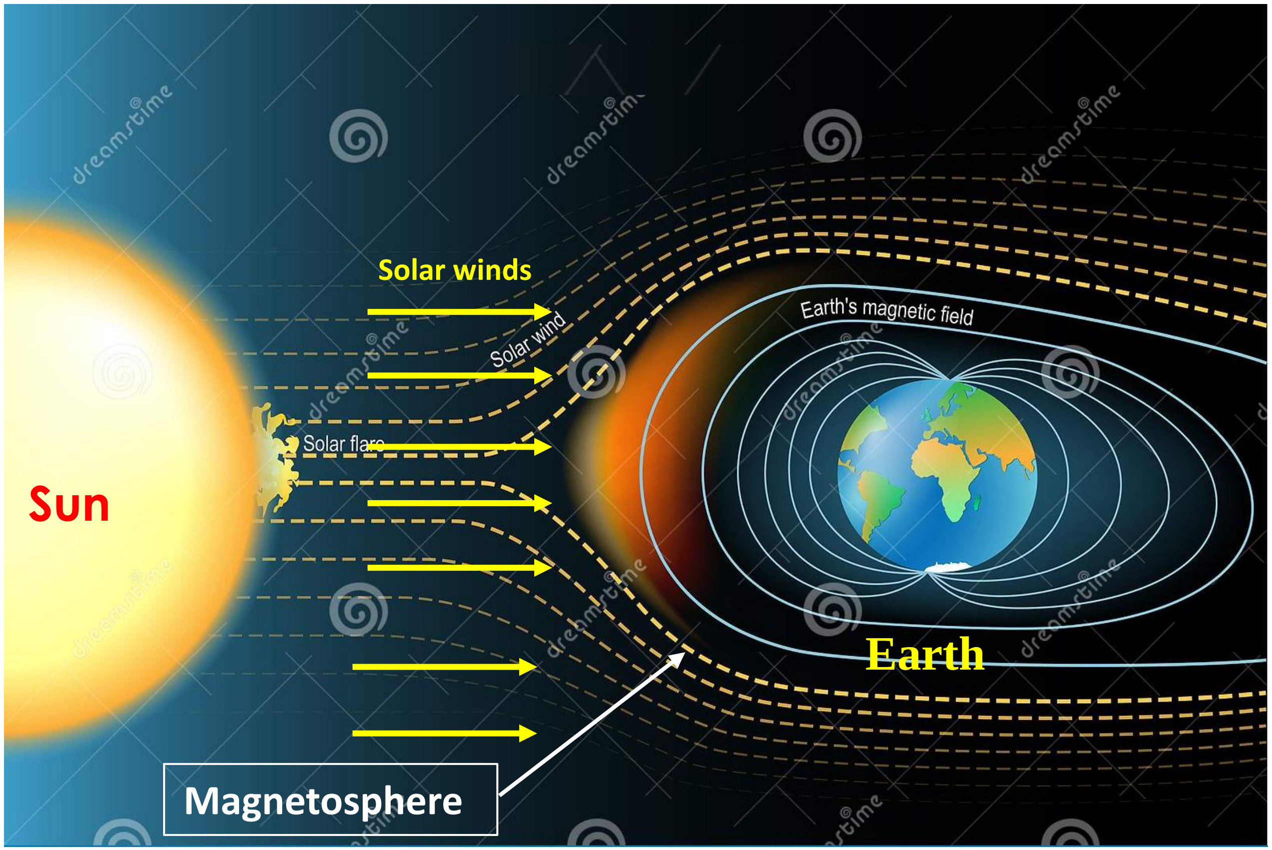


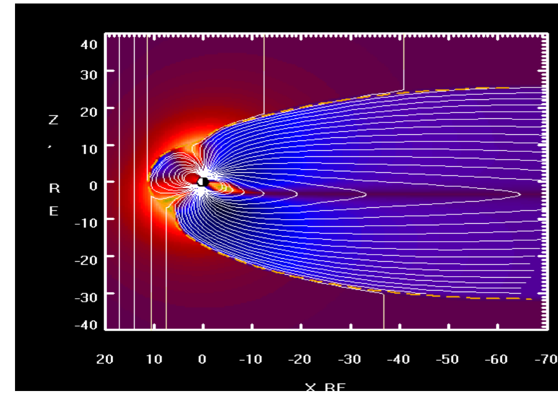


The energy of the Sun comes from nuclear reactions that occur at the center by fusion of H atoms into He. The average surface temperature is 5770 K. That of the nuclear core is estimated to be ≈ 15.10^6 ºC, perhaps a little more.
The Sun loses about 10^9 kg of plasma per second.

GENERALITIES

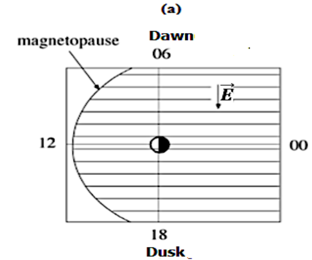
THE EARTH'S MAGNETOSPHERE :





SW movement is converted into electrical energy.

Total electric field : $\mathbf{E} = \mathbf{E}_M + \mathbf{E}_{cor}$



Magnetosphere :

Earth shield against solar energy ramparts, controlled by the Earth **B**.

OBJECTIVES OF THE STUDY

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GENERAL OBJECTIVE:

- Understanding the dynamics and structure of the Earth's magnetosphere via High-speed solar winds (HSSW) during the outer minima (descending phases) of solar cycles (SC) 20 to 24.

SPECIFIC OBJECTIVES:

- Extracting HSSW from 1964 to 2019 $\longmapsto$ **05 SC** (20, 21, 22, 23 & 24).
- Determine the outer minima of SC 20-24 from the Wolf number Rz
- Quantify solar fields and power upstream of the Earth's magnetosphere during the 05 peaks.

DATA & METHODOLOGY

■ DATA :

- ❖ **SIDC** : «https://www.sidc.be/SILSO/datafiles» ⟼ Rz
- ❖ **ISGI** : «http://isgi.unistra.fr/oi_data_download.php» ⟼ Aa
- ❖ **OMNIWeb** : «http://omniweb.gsfc.nasa.gov/form/dx1.html»⟼ V_x, Ey, B, Bz, n.

■ QUANTITY CONTROLLING EARTH'S MAGNETOSPHERE:

(*Wu Lei and al., 1981; Revah and Bauer, 1982*)

$$E_M = 0.13 E_y + 0.09 \quad \{1\}$$

(*Wang et al., 2014*)

$$E_{in} = 3.78 \text{x} 10^7 n^{0.24} V^{1.47} B_T^{0.86} \left[\sin^{2.70}\left(\frac{\theta}{2}\right) + 0.25 \right] \quad \{2\}$$

(*Milan et al., 2012*)

$$\Phi_D = 3.3 \text{x} 10^5 \, V_x^{4/3} \, B_{yz} \sin^{9/2}\left(\frac{\theta}{2}\right) \quad \{3\}$$

DATA & METHODOLOGY

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PIXEL DIAGRAMS (BARTEL'S DIAGRAMS)

Current class

1-Jan	2017					<u>511</u>	404	434	461	601	691	686	675	647	570	487	396	365	368	334	317	311	474	592	546	499	508
23-Jan	439	348	341	419	586	520	438	440	626	681	663	627	566	579	562	505	456	419	419	396	347	329	313	307	366	481	512
19-Feb	556	503	430	405	471	599	512	419	369	397	509	685	680	655	620	604	576	533	520	467	391	392	340	332	351	376	345
18-March	321	315	315	496	642	609	552	476	387	531	673	642	625	670	584	488	420	419	412	470	422	531	486	427	435	438	394
14-April	399	334	340	312	321	408	553	552	690	723	672	593	524	462	404	378	372	378	410	379	344	382	344	349	368	367	364
11-May	373	387	320	321	431	568	488	405	457	655	631	545	508	449	373	323	326	360	360	483	399	361	373	398	425	369	350
7-June	336	308	315	290	329	445	496	469	411	477	479	561	475	376	336	330	336	375	439	516	465	425	408	346	373	449	419
4-July	357	317	336	387	335	461	558	583	480	395	359	327	449	520	541	431	406	614	569	586	635	586	580	455	436	407	361
31-July	339	378	391	373	567	667	613	500	432	404	393	403	550	573	475	401	378	481	573	672	696	585	554	467	404	348	340
27-Aug	336	294	330	363	529	602	584	506	492	529	446	526	740	585	498	593	499	459	438	664	676	644	617	512	459	413	361
23-Sept	361	336	367	320	486	654	592	502	461	427	403	365	384	422	398	412	362	323	414	513	579	668	595	543	460	379	392
20-Oct	420	389	413	375	437	592	542	445	380	341	307	284	292	348	396	406	364	315	444	609	540	632	547	457	388	383	401
16-Nov	479	424	397	367	359	551	502	415	371	382	318	387	432	396	458	460	403	340	329	506	540	500	433	373	332	402	469
13-Dec	446	400	352	342	511	603	522	434	380	328	346	468	486	448	430	389	366	372	358								

V (km/s)

650

600

550

500

450

350

Figure 1: Pixel diagrams of 1974, 1986, 1994, 2003 and 2017 peaks

Solar flux structure and magnetospheric activities

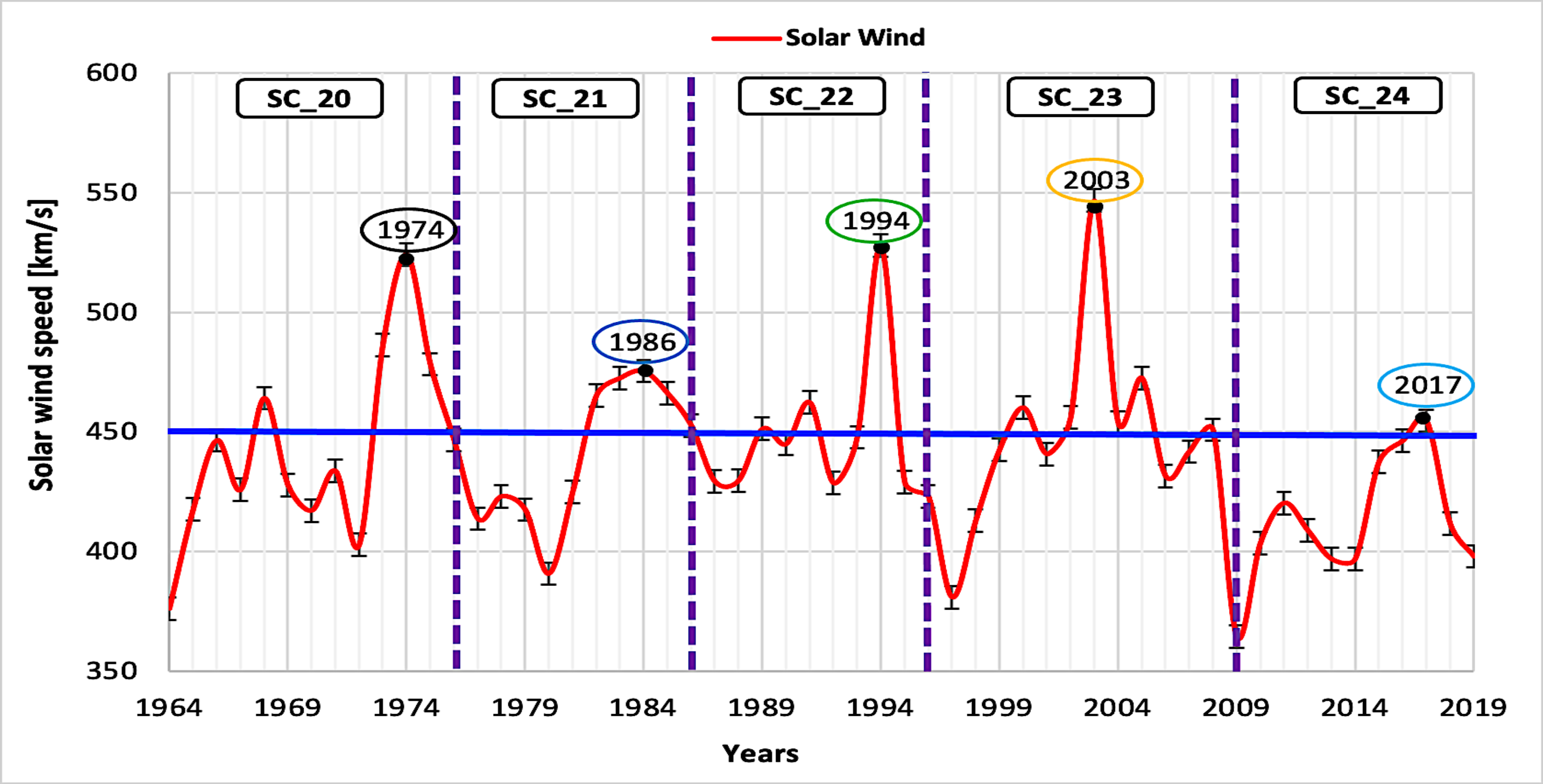

Figure 2: Annual evolution of the daily average solar wind speed from 1964-2019.

RESULTS AND DISCUSSION

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Solar flux structure and magnetospheric activities

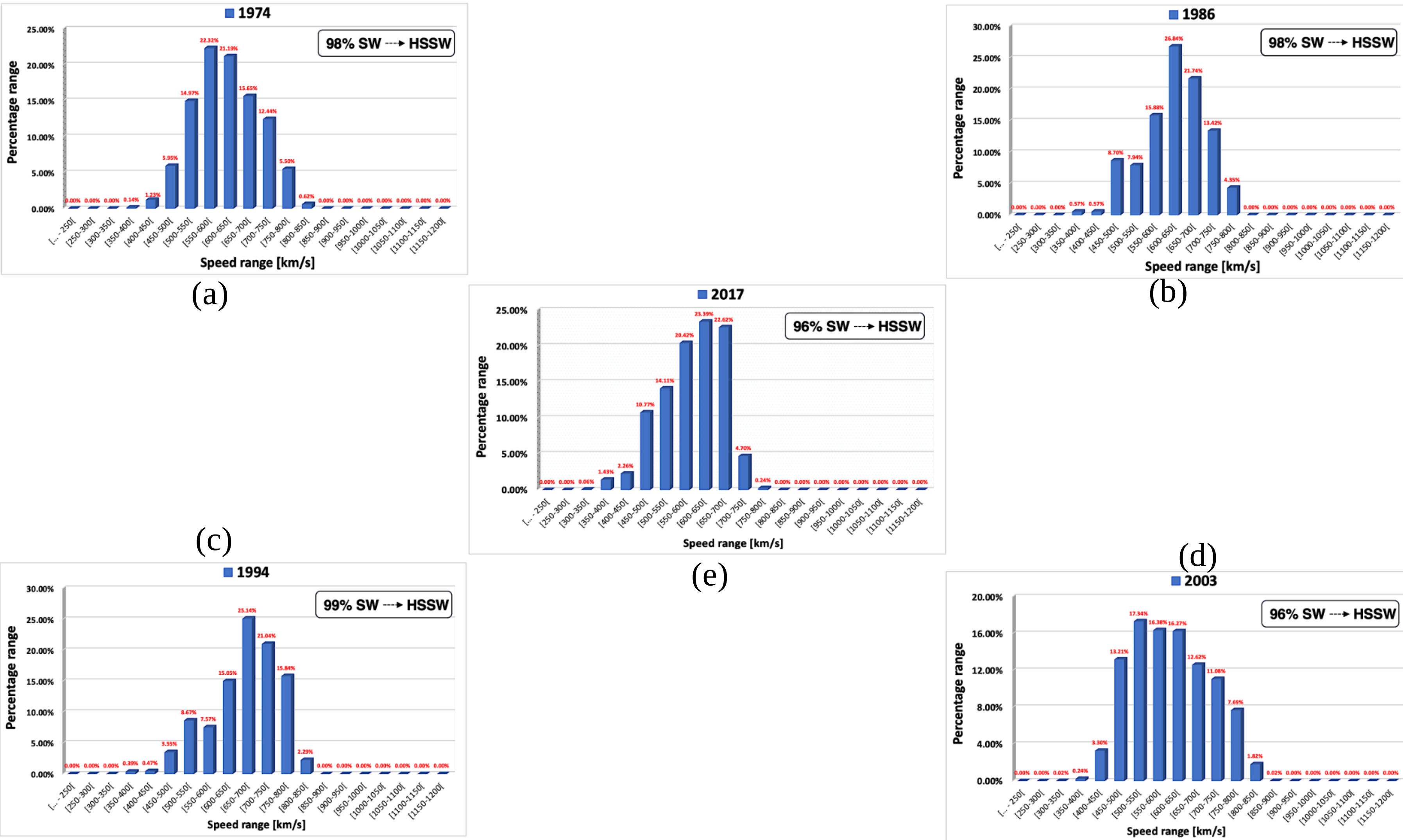

Figure 3: Annual evolution of the daily average solar wind speed from 1964-2019.

Solar flux structure and magnetospheric activities

Table 1: Summary of solar events of outer minima

	Outer Minima [year]				
	1974	1986	1994	2003	2017
Number of shocks	15	16	8	14	17
Number of recurring days	148	40	84	190	70
V_{sw} [km/s]	616.16	622.88	667.37	604.36	598.44
Dst [nT]	-16.31	-22.88	-32.70	-25.07	-19.96
Aa [nT]	37.27	33.03	45.42	41.12	34.06
By [nT]	-0.72	-1.15	-0.40	+0.12	+0.33
Bz	South	North	South	South	South

https://www.sidc.be/SILSO/monthlyhemisphericplot

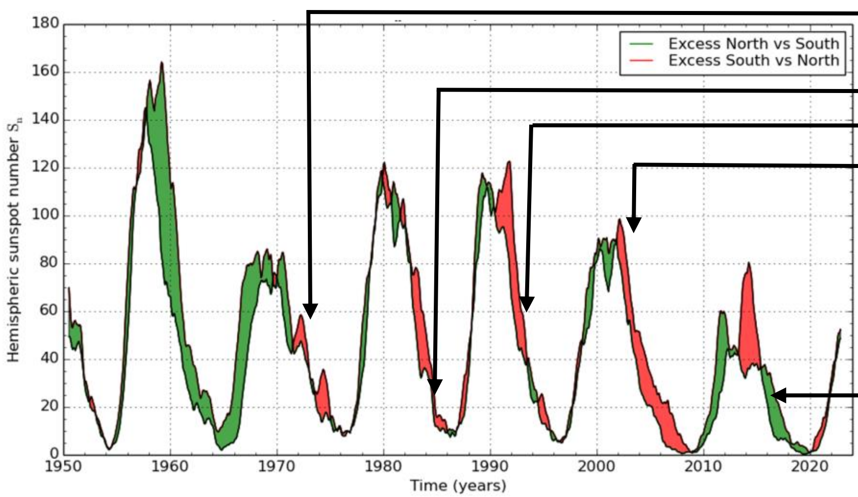

Figure 4: North-South fluctuations in sunspot numbers

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■ Geoeffectiveness of the outer minimum of SC 20-24.

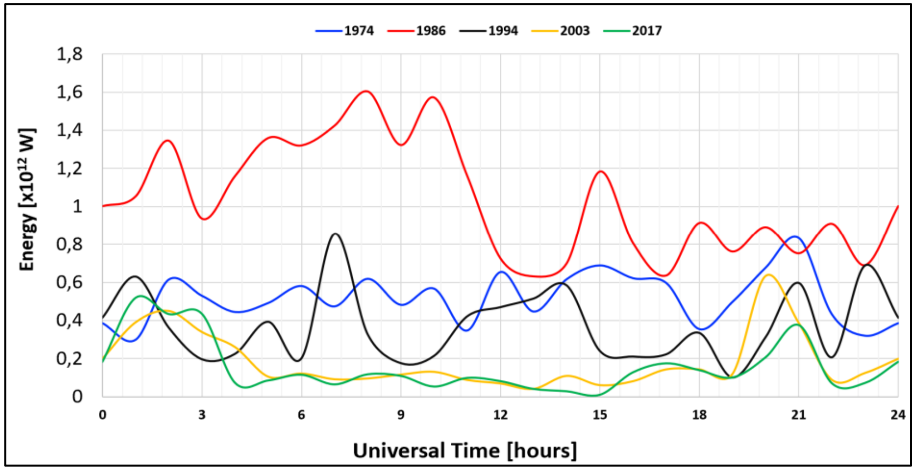

Figure 5: Power upstream of the Earth's magnetosphere

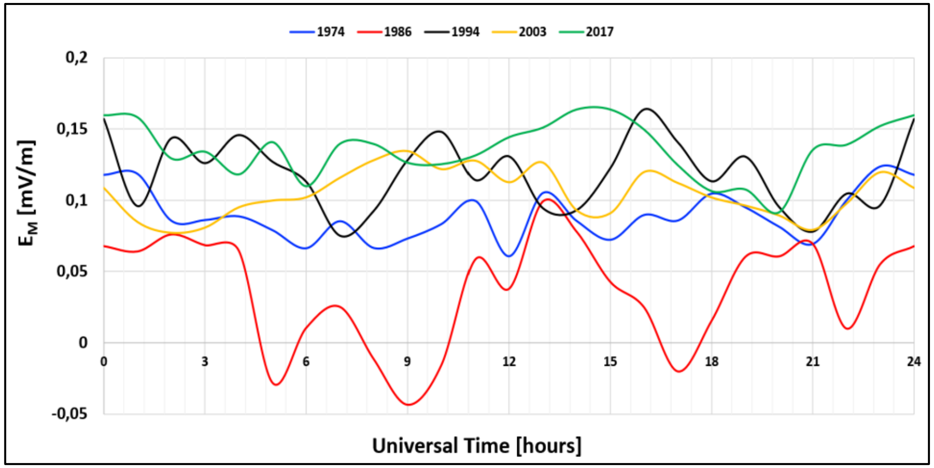

Figure 6: Daily variation in E_M field

Table 2: Correlation of some solar wind parameters

	Outer Minima [year]				
	1974	1986	1994	2003	2017
Bz[nT]	-0.02	0.65	-0.33	-0.22	-0.60
E_M [mV/m]	0.09	0.04	0.12	0.10	0.12
E_{in} [$x10^{12}$ W]	1.58	1.52	1.88	1.70	1.65
E_{in} & E_M	60%	76%	-59%	64%	56%

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- **Geoeffectiveness of the outer minimum of SC 20-24.**

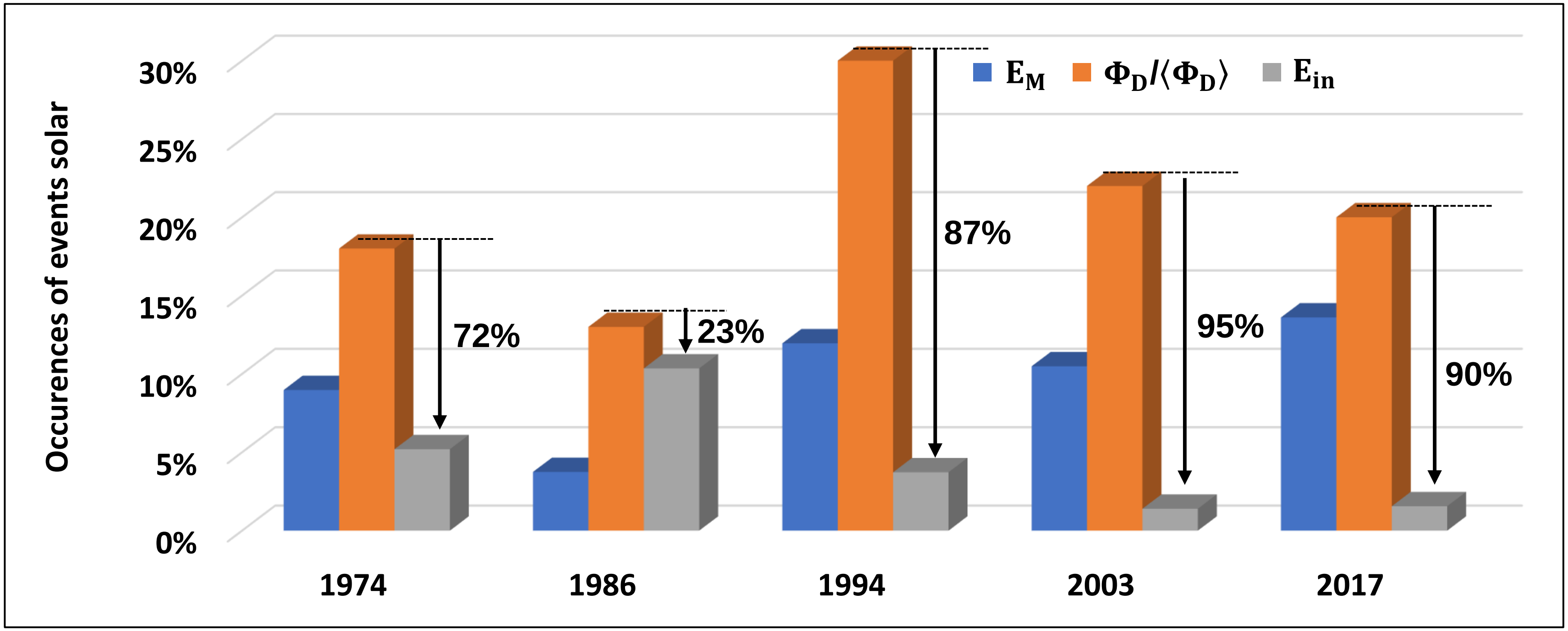

Figure 7: Occurence E_M field, E_{in} and $\Phi_D/\langle\Phi_D\rangle$

Table 3: Correlation of some solar wind parameters.

	Outer Minima [year]				
	1974	1986	1994	2003	2017
$\Phi_D/\langle\Phi_D\rangle$	18%	13%	30%	22%	20%
E_{in} & E_M	60%	76%	-59%	64%	56%

CONCLUSION

- During the peaks of the outer minima of SC :
  - At high speeds, the normalized daytime reconnection rate is likely to be improved when the IMF-Bz is antiparallel to the geomagnetic field.
  - Significant geomagnetic activity is sometimes present even in the absence of such important ICMEs.
  - HSSW represent the stability criterion for areas that are particularly close to the outer minimum of solar cycles.
  - For high By intensities with a north-pointing CMI-Bz, the trapping and energization of HSSW particles in the Earth's magnetic cavity has an enhanced influence on the magnetospheric convection electric field.

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