Australian Government

Bureau of Meteorology

SPACE WEATHER SERVICES

SOLAR

AND

GEOPHYSICAL

SUMMARY

March 2023

Solar Activity

Solar activity was predominately at R0-R1 levels this month, with isolated R2-R3 flare activity. R2 level flare activity observed on 04,05,06 and 30-Mar. R3 level activity was observed on 03-Mar and 29-Mar. The largest flare for the month was an R3 (X2.1) on 03-Mar, which was associated with a westward non Earth-directed CME. Another R3 (X1.2) flare was observed at 29/0233UT. This was a short duration flare. Most of the flare activity for the month was during the interval 4-6 Mar with only isolated R1 activity observed on other days of the month. A total 21 flares were observed. None of the flares during the month were associated with significantly Earth directed coronal mass ejections. At the start of the month solar region AR3234 contributed solar flare activity before rotating off disk on 05-Mar. Region AR3243 emerged on 03-Mar in the north west quadrant and contributed to flare activity early in the month before rotating off disk 08-Mar. Neither of these northern solar hemisphere located regions appeared to return as a region of significance. Another solar region AR3256 located in the southern solar hemisphere also produced a number of the stronger flares observed during the month, this region was still active as it rotated off disk and may return to the south east solar limb on 13-Apr.

Several solar filament eruptions were observed during the month and the disturbed conditions during 23-24 Mar are attributed to a slow CME from an erupting solar filament. The solar wind speed during March was elevated at the start of the month due to coronal hole wind streams, then generally declined toward the middle of the month. Solar wind speed increased on 14 and 15-Mar due to the arrival of CMEs associated with solar filament eruptions on 13-Mar, then subsequently declined before increasing again on 21-22 Mar due to coronal hole high speed wind streams. During the disturbance over 23-24 Mar the solar wind speed was not significantly elevated as the slow CME speed was not that significantly different to the background solar wind speed. However, the imbedded magnetic field in the slow CME was quite enhanced and exhibited a sustained southward orientation which caused the planetary G4 level activity.
The solar wind speed once again became elevated over 30-31 Mar due to a small equatorial coronal hole.

Very minor (with max flux ~22PFU) S1 solar proton threshold fluctuation crossings were observed during the interval 13-15 Mar. The proton flux is considered to be associated with a very strong and fast, far side (directed away from the Earth) CME observed on 13-Mar. Due to its direction this CME posed no threat to the Earth's geomagnetic field.

During the month saw the transit of several equatorial coronal holes. The largest hole was observed in the southern solar hemisphere crossing the solar central meridian over 21-24 Mar. This hole had a large longitudinal extent though due to most of its area being below 30 degrees south in solar latitude the effects from this hole were relatively minor.

M and X class flares for the month are listed below.

DATE	FLARES		FLARE MAX	FADEOUT POSSIBLE ON DAYLIGHT CIRCUIT
	CLASS M	CLASS X		
01 Mar 23	M1.0/SF		0107UT	
02 Mar 23	M3.8		2116UT	2105-2125UT
03 Mar 23	M3.2/1F		1032UT	1008-1049UT
03 Mar 23		X2.1	1752UT	1742-1759UT
04 Mar 23	M1.0/SN		0710UT	
04 Mar 23	M1.2/1F		1342UT	
04 Mar 23	M5.2		1557UT	1519-1626UT
05 Mar 23	M1.3/SF		0252UT	
05 Mar 23	M1.0/SF		1641UT	
05 Mar 23	M1.0		1701UT	
05 Mar 23	M5.0		2136UT	2129-2141UT
06 Mar 23	M5.8/2N		0228UT	0208-0235UT
06 Mar 23	M1.3		0912UT	
08 Mar 23	M1.1		1012UT	
08 Mar 23	M1.3/1N		2244UT	
17 Mar 23	M1.0/SN		1507UT	
20 Mar 23	M1.2		0148UT	
29 Mar 23		X1.2	0233UT	0218-0240UT
29 Mar 23	M1.2		1407UT	
29 Mar 23	M1.1		2347UT	
30 Mar 23	M5.4/1F		0737UT	0724-0743UT

FLARE ALERT	SWF ALERT
01 Mar 23	
02 Mar 23	
03 Mar 23	
04 Mar 23	
05 Mar 23	0251-0303 UT
06 Mar 23	0218-0335 UT
08 Mar 23	
17 Mar 23	
18 Mar 23	
20 Mar 23	
29 Mar 23	
30 Mar 23	0228-0306 UT
31 Mar 23	

PROTON ALERT

BEGIN DATE	BEGIN TIME	END DATE	END TIME	ENERGY THRESHOLD
13 03 2023	1400UT	15 03 2023	0515UT	10MeV (S1)

Frequent minor fluctuations over the S1 10PFU threshold 13-15Mar 2023.

Ionospheric Activity

The deepest ionospheric depression for the month was observed on 24-Mar following coronal mass ejection induced geomagnetic storm activity, with southern Australian regional Maximum Usable Frequencies (MUFs) depressed by up to 50% on this day. Enhanced conditions of 30-40% followed on 25-Mar for the southern Australian region. Northern Australian region MUFs remained generally enhanced during the month. Occasional mild depressions were observed for southern Australian region MUFs during the month possibly in association with periods of mildly elevated geomagnetic activity from solar coronal hole wind streams. Minor shortwave fadeouts were observed 05/0251-0303UT and 06/0218-0335UT. Frequent brief periods of ionospheric scintillation were observed during local night hours during the month at Darwin, Weipa and Niue.

Ionospheric depressions listed below are calculated using foF2 data from the SWS ionosonde network.

IONOSPHERIC DISTURBANCES (MUFs for the Australian region)

03-05 Mar 23: Southern region MUFs Depressed by 25%
06 Mar 23: Southern region MUFs Depressed by 30%
09 Mar 23: Southern region MUFs Depressed by 15%
10 Mar 23: Southern region MUFs Depressed by 25%
15 Mar 23: Southern region MUFs Depressed by 15%
24 Mar 23: Southern region MUFs Depressed by 50%
31 Mar 23: Southern region MUFs Depressed by 25%

RADIO COMMUNICATIONS WARNINGS

DATE	Nº.	BEGIN	END
01 Mar 23	24	01 Mar 23	03 Mar 23
04 Mar 23	25	04 Mar 23	04 Mar 23
04 Mar 23	26	04 Mar 23	06 Mar 23
05 Mar 23	27	06 Mar 23	07 Mar 23
06 Mar 23	28	07 Mar 23	08 Mar 23
15 Mar 23	29	16 Mar 23	16 Mar 23
18 Mar 23	30	20 Mar 23	20 Mar 23
20 Mar 23	31	20 Mar 23	22 Mar 23
23 Mar 23	32	24 Mar 23	24 Mar 23
29 Mar 23	33	29 Mar 23	30 Mar 23

Geomagnetic Activity

The strongest disturbance for the month was observed over 23-24 Mar with the local Australian regional field reaching G2 and G1 levels respectively. The disturbance was stronger in the northern hemisphere with G3 and G4 levels reached. This geomagnetic storm activity was associated with a coronal mass ejection associated with a solar filament eruption. This slow CME contained a persistent southward IMF magnetic field orientation that resulted in a more intense disturbance. Auroral observations were reported from southern Australian sites during this geomagnetic storm period. Though the storm level reached G3-G4, activity was not sustained at this higher level, resulting in the observed planetary daily Ap indices for 23 and 24 Mar reaching 60 and 66 respectively, more towards the lower end of potential Ap index geomagnetic storm values. No distinct sudden impulse was observed at the start of this disturbed interval. Earlier in the month on 15-Mar a sudden impulse was observed from a faster CME that produced much weaker induced geomagnetic activity again associated with a solar filament eruption. An isolated G1 period was observed on 30-Mar associated with a coronal hole high speed wind stream.

Disturbances with Australian A indices greater than or equal to 16 are reported below.

DATE	GEOMAGNETIC DISTURBANCES (for the Australian region)
05 Mar 23:	G0
15 Mar 23:	G1 – sudden impulse observed 15/0427UT
23 Mar 23:	G2
24 Mar 23:	G1
30 Mar 23:	G1

GEOMAGNETIC WARNINGS AND ALERTS

DATE	Nº.	BEGIN	END	ISSUED
03 Mar 23	09	05 Mar 23	06 Mar 23	Warning
13 Mar 23	10	15 Mar 23	15 Mar 23	Warning
13 Mar 23	11	15 Mar 23	16 Mar 23	Warning
15 Mar 23				Alert
18 Mar 23	12	19 Mar 23	20 Mar 23	Warning
22 Mar 23	13	23 Mar 23	24 Mar 23	Warning
23 Mar 23	14	24 Mar 23	24 Mar 23	Warning
23 Mar 23				Alert
24 Mar 23				Alert
28 Mar 23	15	31 Mar 23	01 Apr 23	Warning
30 Mar 23				Alert

Solar And Geophysical Indices

DATE	10cm FLUX	AUSTRALIAN A-INDEX	AUSTRALIAN T-INDEX	DATE	10 cm FLUX	AUSTRALIAN A-INDEX	AUSTRALIAN T-INDEX
01 Mar	162	6	116	16 Mar	135	3	136
02 Mar	169	9	141	17 Mar	134	4	137
03 Mar	175	14	101	18 Mar	140	7	133
04 Mar	182	11	110	19 Mar	143	6	146
05 Mar	180	17	122	20 Mar	156	9	144
06 Mar	188	12	98	21 Mar	152	4	136
07 Mar	180	7	123	22 Mar	159	10	143
08 Mar	182	6	128	23 Mar	151	30	141
09 Mar	179	10	138	24 Mar	158	26	89
10 Mar	171	5	113	25 Mar	160	9	139
11 Mar	157	3	145	26 Mar	159	6	137
12 Mar	150	5	150	27 Mar	158	1	137
13 Mar	143	1	142	28 Mar	159	4	146
14 Mar	139	14	163	29 Mar	148	3	137
15 Mar	136	20	112	30 Mar	140	16	151
				31 Mar	129	10	121

DATE	10cm FLUX	AUSTRALIAN A-INDEX	AUSTRALIAN T-INDEX	SUNSPOT NUMBER		FLARES
	Monthly Average	Monthly Average	Monthly Average	Monthly Average	13-month smoothed	>M1.0
Apr 22	129.7	8	77.4	84.1	73.1	33
May 22	134.2	5	78.3	96.5	77.3	22
Jun 22	117	5.4	59.8	70.5	81	3
Jul 22	125.8	6	63.9	91.4	84.9	7
Aug 22	118.1	6.9	52.5	75.4	92.2	29
Sep 22	135.1	7.9	74.6	96.3	96.2	13
Oct 22	133.5	7.9	82.1	95.4	99.1	19
Nov 22	123.4	7.3	76.1	77.6	100.8	6
Dec 22	132.3	8.1	83.5	113.1	103.1	43
Jan 23	182.3	7.1	118.6	143.6	105.7	42
Feb 23	173.5	10.3	115	110.9	108.2	51
Mar 23	157.2	9.3	131.5	122.6	110.5	21
					Predicted sunspot numbers	

SPECIAL NOTE
In June 2015, WDC-SILSO, Royal Observatory of Belgium, Brussels, adjusted their original observed sunspot numbers (Version 1.0) to a Version 2.0 series in which the sunspot numbers are higher. In the Version 1.0 data series, some of the sunspot numbers were weighted. The new (Version 2.0) sunspot numbers are unweighted sunspot number counts (for more information see: www.sidc.be/silso/home). The Bureau of Meteorology SWS solar cycle prediction is now based on the Version 2.0 values. As a result of this recalibration, the observed monthly and observed and predicted smoothed sunspot numbers are higher in the monthly table and solar cycle graph.

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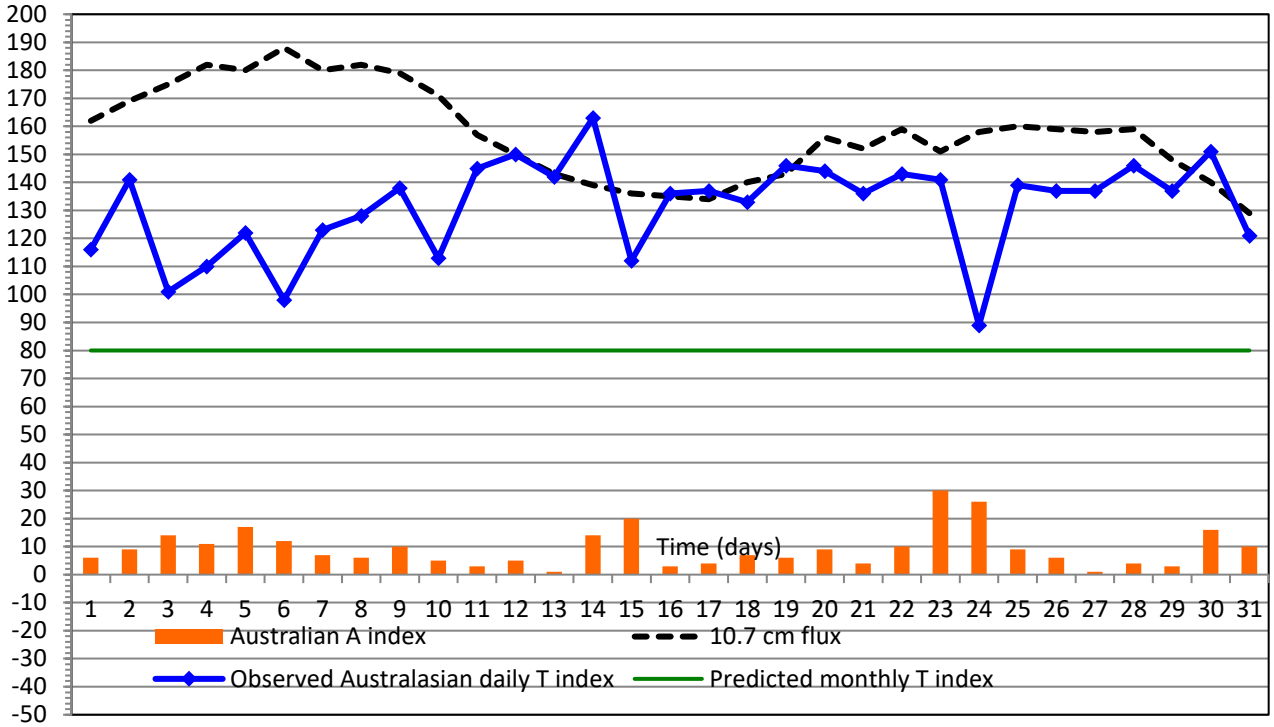
SWS WORLD T-INDICES

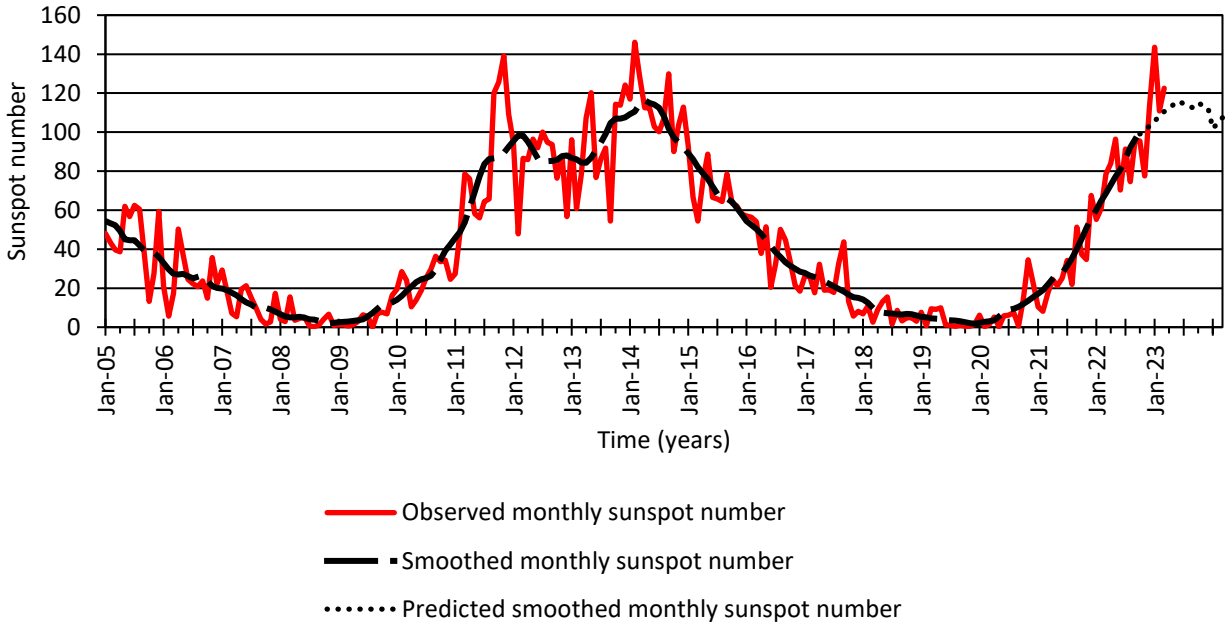
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	8	2	3	-2	-6	-3	-3	-8	-6	-10	-15	-9
2019	-5	-3	-4	-4	-9	-14	-11	-14	-11	-14	-16	-12
2020	-2	-5	2	-1	-7	-7	-9	-2	-6	-6	7	12
2021	12	4	10	6	6	12	21	12	23	23	17	28
2022	41	52	63	71	81	65	67	56	72	75	65	71
2023	107	114	119*	84	84	85	85	82	79	78	79	80

SWS predicted T-index * New observed data. T-index value may have changed

Solar and Geophysical Indices - March 2023



Solar Cycle



Observed monthly sunspot numbers courtesy of WDC-SILSO, Royal Observatory of Belgium, Brussels (www.sidc.be/silso/home)

NOTES - notes - NOTES - notes - NOTES - notes

a. Times quoted in this publication are all Universal Time (UT).

b. The values of all indices are provisional. Final values are not available for several months.

c. M or X class flares refer to the X-ray classification system for solar flares. In this system, X class flares are more energetic than M class flares.

FLARE CLASS	X-RAY FLUX DENSITY	
	Ergs/cm^2/sec	W/m^2
M	0.01-0.1	10^{-5} to 10^{-4}
X	>0.1	> 10^{-4}

d. Class M flares, particularly the less energetic ones, are likely to cause a fadeout on only the lowest frequencies. Class X flares are likely to cause a fadeout over the entire HF spectrum. It should be noted that a fadeout will only occur on those circuits having a reflection point in the daylight hemisphere of the earth. Circuits having only night hemisphere reflection points will not be affected no matter the energy of the solar flares.

e. The 10cm flux is the radio power of the sun at a frequency of 2800 MHz (wavelength 10.7 cm). This flux is a good indicator of solar activity and is widely used in place of the sunspot number. The values are measured by the Penticton radio observatory, Canada. Unlike the sunspot number, the 10cm flux never drops to zero even during solar minimum. With no sunspots visible on the solar disk, the 10cm flux will still have a value of around 67. The table below gives a (statistical) comparison between 10cm flux and sunspot number. The 10cm flux is measured in solar flux units (10^{-22} W m^{-2} Hz^{-1}).

SUNSPOT No.	10 cm FLUX
0	67
20	78
40	93
60	110
100	147
150	195
200	243

f. Ionospheric disturbances refer to measurements made across Australia, but are generally applicable to mid-latitude Southern Hemisphere conditions. Spread F conditions indicate tilts in the ionosphere, which may result in multipath fading on some HF circuits.

g. The magnetic A-indices are for the Australian region. Large values for the A index correspond to disturbed conditions. Levels of magnetic disturbances are described in the following terms.

A INDEX VALUE	DESCRIPTION
0 up to 7	Quiet
8 up to 15	Unsettled
16 up to 24	Active
25 up to 35	Minor Storm
36 and above	Major Storm

h. The Australian daily T-index is a measure of the average of the ionospheric critical frequencies available on a particular day - the higher the value of the T-index, the higher the ionospheric critical frequencies (and Maximum Usable Frequencies on HF circuits) for that day. The T-index is based on data from Australian ionospheric stations and so is most applicable to HF circuits with reflection points in the Australian region.

i. The SWS monthly observed T-index is derived from the observed monthly median values of foF2 for each hour from ionospheric stations worldwide.

The predicted smoothed monthly T-indices are computed by using a statistical analysis of the observed monthly T-indices for all solar cycles since 1938.

The SWS T-indices may not be updated each month but only when sufficient new data becomes available.

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