Australian Government

Bureau of Meteorology

SPACE WEATHER SERVICES

SOLAR

AND

GEOPHYSICAL

SUMMARY

February 2023

Solar Activity

Solar activity was predominately at R1 levels this month, with several days with R2 and R3 levels. There were 49 M class flares observed and 2 X class flares observed. The largest flare for the month was a long-duration X2.2 flare on 17 February. Boulder Space Environment Center solar region number AR3229 underwent an increase in solar activity from 17 February to 28 February. This region rotated onto the solar disk on 16 February and rotated off disk on 01 March. It is due for possible return on 14 March, however decayed significantly as it rotated over the western limb.

AR3229 was responsible for the largest flare of solar cycle 25 (X2.2 - R3) and also produced several fast partial-halo CMEs associated with these flares. A fast partial-halo CME was observed following the X2.2 flare on 17 February. A mild proton enhancement (below S1 threshold) occurred on 24 February associated with a long duration M3 flare from AR3229. An S1 solar proton event was observed on 25 February following a long duration M6.7 flare from AR3229. A fast partial-halo CME was observed following the M3 flare on 24 February, and a second fast CME was observed following the M6.7 flare.

AR3234 showed strong magnetic complexity (beta-gamma-delta) as it transited across the solar disk, however did not produce any significant flares during February.

AR3217 was responsible for an X1.2 flare on 11 February, and also 10 R1 M-class flares during the month. This region showed some decay as it began rotating over the western limb on 20 February.

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

Please see our homepage https://www.sws.bom.gov.au for a link to an explanation of the Australian Space Weather Alert System (ASWAS) scales.

DATE	FLARES		FLARE MAX	FADEOUT POSSIBLE ON DAYLIGHT CIRCUIT
	CLASS M	CLASS X		
7 Feb 23	M1.5/1N		2007UT	
7 Feb 23	M6.3		2307UT	2305-2309UT
8 Feb 23	M2.0		0253UT	
8 Feb 23	M1.6/2N		1603UT	
8 Feb 23	M1.5/1N		2012UT	
8 Feb 23	M1.7/1F		2113UT	
9 Feb 23	M3.0		0310UT	0245-0328UT
9 Feb 23	M1.1/SF		0717UT	
9 Feb 23	M2.8		0907UT	
9 Feb 23	M1.5/1N		1456UT	
9 Feb 23	M1.4/SN		1525UT	
9 Feb 23	M1.8		1842UT	
10 Feb 23	M3.7/2N		0303UT	0245-0320UT
10 Feb 23	M1.4/SN		0805UT	
10 Feb 23	M1.1/SF		1455UT	
10 Feb 23	M1.6/SF		1600UT	
10 Feb 23	M1.2/1N		2241UT	
11 Feb 23	M2.2/1N		0808UT	
11 Feb 23	M1.0/1N		1058UT	
11 Feb 23	M1.4		1134UT	
11 Feb 23	M1.5		1209UT	
11 Feb 23	M1.1		1223UT	
11 Feb 23	M1.5		1240UT	
11 Feb 23		X1.1/2B	1548UT	1540-1554UT
11 Feb 23	M1.4/SF		1723UT	
12 Feb 23	M3.1/1B		0848UT	0835-0852UT
12 Feb 23	M1.4		0927UT	
12 Feb 23	M1.2		1334UT	
12 Feb 23	M1.0/SN		1538UT	
13 Feb 23	M1.0		0518UT	
13 Feb 23	M1.4		1556UT	
14 Feb 23	M1.8/1N		0203UT	
14 Feb 23	M2.6		1212UT	
15 Feb 23	M1.1		0447UT	
15 Feb 23	M2.0		0523UT	
15 Feb 23	M1.3		0705UT	
15 Feb 23	M1.0		2114UT	
16 Feb 23	M1.1		0032UT	
17 Feb 23		X2.2/2B	2016UT	1938-2050UT
20 Feb 23	M4.4/SF		1458UT	1447-1503UT
21 Feb 23	M4.7/SF		1123UT	1114-1131UT
21 Feb 23	M5.0		2017UT	1957-2030UT

22 Feb 23	M1.4	0512UT	
22 Feb 23	M2.6/SF	1350UT	
23 Feb 23	M1.5	0614UT	
23 Feb 23	M1.0	0848UT	
24 Feb 23	M1.1	1715UT	
24 Feb 23	M3.7/2B	2030UT	2003-2129UT
25 Feb 23	M1.0	1540UT	
25 Feb 23	M6.3/3N	1944UT	1840-2027UT
28 Feb 23	M8.6	1750UT	1735-1756UT

FLARE ALERT	SWF ALERT
07 Feb 23	2253 – 2323 UT
08 Feb 23	0254 – 0259 UT
09 Feb 23	0253 – 0351 UT
10 Feb 23	0255 – 0353 UT
11 Feb 23	
12 Feb 23	
13 Feb 23	0515 – 0531 UT
14 Feb 23	0200 – 0209 UT
15 Feb 23	0446 – 0458 UT
15 Feb 23	0518 – 0535 UT
16 Feb 23	
16 Feb 23	
18 Feb 23	
20 Feb 23	
21 Feb 23	
22 Feb 23	0503 – 0537 UT
23 Feb 23	
24 Feb 23	
25 Feb 23	
26 Feb 23	
27 Feb 23	
28 Feb 23	

PROTON ALERT

BEGIN DATE	BEGIN TIME	END DATE	END TIME	ENERGY THRESHOLD
25 Feb 2023	2100UT	26 Feb 2023	1830UT	10MeV at 5.88E+01 PFU (S1)
26 Feb 2023	1953UT	26 Feb 2023	2023UT	10MeV at 1.58+01 PFU (S1)
26 Feb 2023	2035UT	26 Feb 2023	2245UT	10MeV at 1.58+01 PFU (S1)

Ionospheric Activity

Ionospheric conditions were generally good for the month of February. Mild depressions were observed on 16 February and were associated with mild geomagnetic activity induced by the combination of coronal hole winds stream and a glancing blow from a CME. Moderate ionospheric depressions were observed on 28 February, following the impact of two CMEs in combination with an equatorial coronal hole. Sporadic-E was frequent at most sites briefly during local dawn hours.

Transpolar HF circuits may have experienced increased absorption on 25 and 26 Feb due to solar energetic proton events following strong flare activity on 24 and 25 Feb.

HF radio conditions were degraded over 27-28 February due to geomagnetic activity associated with M3 and M6 solar flares from AR3229.

The regional monthly T-index was predicted to be 75 but was recorded as 115 once the month finished. The T-index fell to a minimum value of 69 on 28 February following the geomagnetic activity induced by AR3229. Aside from the depressions induced by the geomagnetic activity on 16, 27 and 28 February, maximum usable frequencies (MUFs) were generally enhanced by 20-30% in the Australian region during local day hours.

Minor and major shortwave fadeouts were observed during the month in the Australian region associated with R1 and R2 solar flares observed on 07/2253-2323UT (R2), 08/0254-0259UT (R1), 09/0253-0351UT (R1), 10/0255-0353UT (R1), 13/0515-0531UT (R1),14/0200-0209UT (R1), 15/0446-0458UT (R1), 15/0518-0535UT (R1) and 22/0503-0537UT (R1).

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

IONOSPHERIC DISTURBANCES (MUFs for the Australian region)

06 Feb 23:	Southern region MUFs Depressed by 15%
07 Feb 23:	Southern region MUFs Depressed by 20%
09 Feb 23:	Southern region MUFs Depressed by 20%
10 Feb 23:	Southern region MUFs Depressed by 15%
12 Feb 23:	Southern region MUFs Depressed by 20%
13 Feb 23:	Northern region MUFs Depressed by 15%
	Southern region MUFs Depressed by 15%
16 Feb 23:	Southern region MUFs Depressed by 25%
27 Feb 23:	Northern region MUFs Depressed by 15%
28 Feb 23:	Northern region MUFs Depressed by 20%
	Southern region MUFs Depressed by 35%

RADIO COMMUNICATIONS WARNINGS			
DATE	Nº.	BEGIN	END
07 Feb 23	13	07 Feb 23	08 Feb 23
07 Feb 23	14	08 Feb 23	10 Feb 23
10 Feb 23	15	11 Feb 23	13 Feb 23
13 Feb 23	16	13 Feb 23	15 Feb 23
15 Feb 23	17	15 Feb 23	17 Feb 23
17 Feb 23	18	18 Feb 23	20 Feb 23
17 Feb 23	19	19 Feb 23	21 Feb 23
21 Feb 23	20	22 Feb 23	24 Feb 23
24 Feb 23	21	24 Feb 23	26 Feb 23
24 Feb 23	22	26 Feb 23	27 Feb 23
26 Feb 23	23	27 Feb 23	28 Feb 23

Geomagnetic Activity

The strongest disturbance for the month was observed on 27 February with a peak local Australian A index of 47 and a corresponding planetary A index of 109. On this day the Australian region geomagnetic field had overall peak K index of 6 (G2), however Hobart observed two periods of K indices of 7 (G3). The planetary K index for several periods was also 7 (G3). This activity was associated with the combination of a large equatorial coronal hole high speed wind stream, a CME first observed on 24 February associated with an M3 flare and a second CME first observed on 25 Feb associated with an M6 flare. Both CMEs impacted Earth on 27 February.

Auroral observations were reported in Tasmania, Victoria, the bottom of NSW, WA and SA on the night of 27 February.

On 10 February a filament eruption produced a CME which impacted Earth over 14-15 February, and produced G1 geomagnetic conditions over 15-16 February.

Several large equatorial coronal holes were observed over the month and contributed to enhanced geomagnetic activity on days when there was a CME impact. In particular, one coronal hole has persisted over the past two solar rotations.

Days of G1 and G2 storm levels were observed on the days below.

DATE	GEOMAGNETIC DISTURBANCES (for the Australian region)
15 Feb 23:	G1
16 Feb 23:	G1
26 Feb 23:	G2
27 Feb 23:	G2

GEOMAGNETIC WARNINGS AND ALERTS

DATE	Nº.	BEGIN	END	ISSUED
05 Feb 23	02	06 Feb 23	07 Feb 23	Warning
10 Feb 23	03	14 Feb 23	14 Feb 23	Warning
15 Feb 23	04	15 Feb 23	16 Feb 23	Warning
15 Feb 23				Alert
16 Feb 23				Alert
17 Feb 23	05	17 Feb 23	19 Feb 23	Warning
17 Feb 23	06	18 Feb 23	20 Feb 23	Warning
25 Feb 23	07	27 Feb 23	28 Feb 23	Warning
26 Feb 23	08	26 Feb 23	28 Feb 23	Warning
26 Feb 23				Alert
27 Feb 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 Feb	134	5	112	17 Feb	343	3	111
02 Feb	135	3	119	18 Feb	167	3	112
03 Feb	135	9	127	19 Feb	169	6	132
04 Feb	139	3	132	20 Feb	160	7	117
05 Feb	144	3	120	21 Feb	161	12	134
06 Feb	158	13	118	22 Feb	152	5	111
07 Feb	185	15	85	23 Feb	148	14	118
08 Feb	192	13	91	24 Feb	164	4	125
09 Feb	215	12	76	25 Feb	152	9	142
10 Feb	208	9	100	26 Feb	159	21	135
11 Feb	210	6	121	27 Feb	161	46	90
12 Feb	200	5	126	28 Feb	161	12	69
13 Feb	189	4	121				
14 Feb	180	5	145				
15 Feb	174	21	152				
16 Feb	163	20	80				

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
Mar 22	117.1	6.7	65.0	78.5	68.9	14
Apr 22	129.7	8.0	77.4	84.1	73.1	33
May 22	134.2	5.0	78.3	96.5	77.3	22
Jun 22	117.0	5.4	59.8	70.5	81.0	3
Jul 22	125.8	6.0	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	95.6	13
Oct 22	133.5	7.9	82.1	95.4	97.9	19
Nov 22	123.4	7.3	76.1	77.6	99.6	6
Dec 22	132.3	8.1	83.5	113.1	101.9	43
Jan 23	182.3	7.1	118.6	143.6	104.5	42
Feb 23	173.5	10.3	115.0	110.9	106.9	51
					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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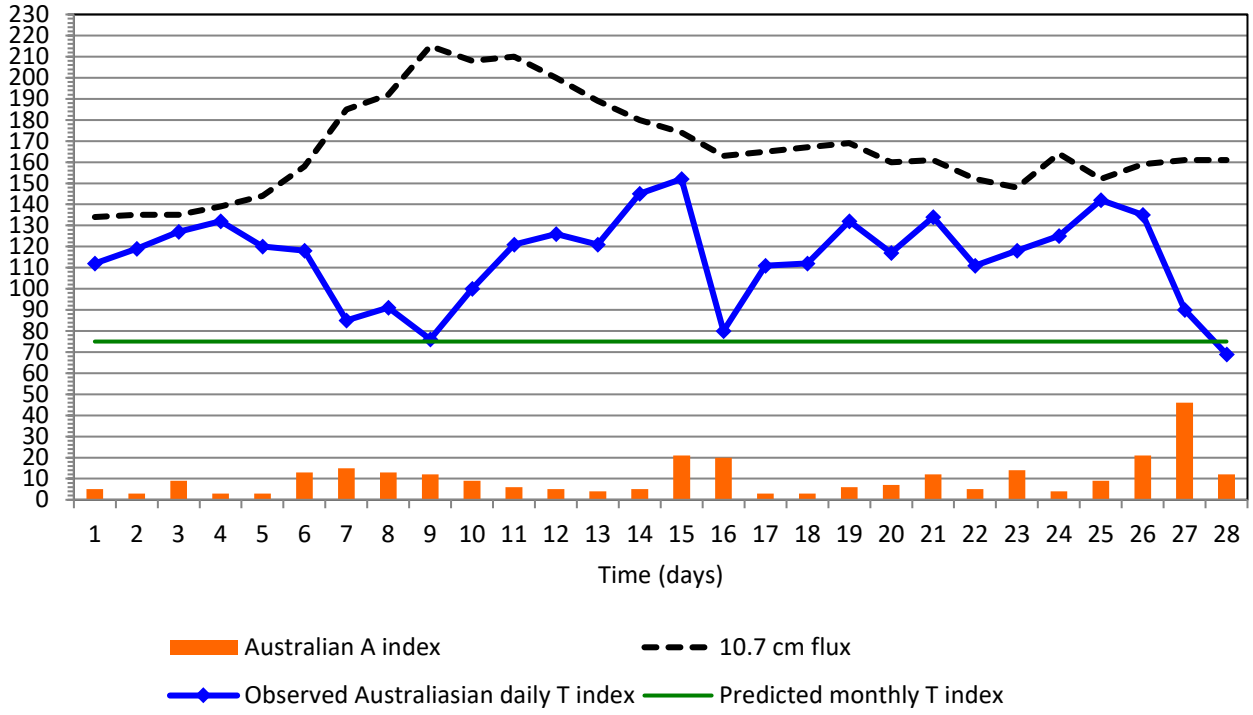
ASWFC WORLD T-INDICES

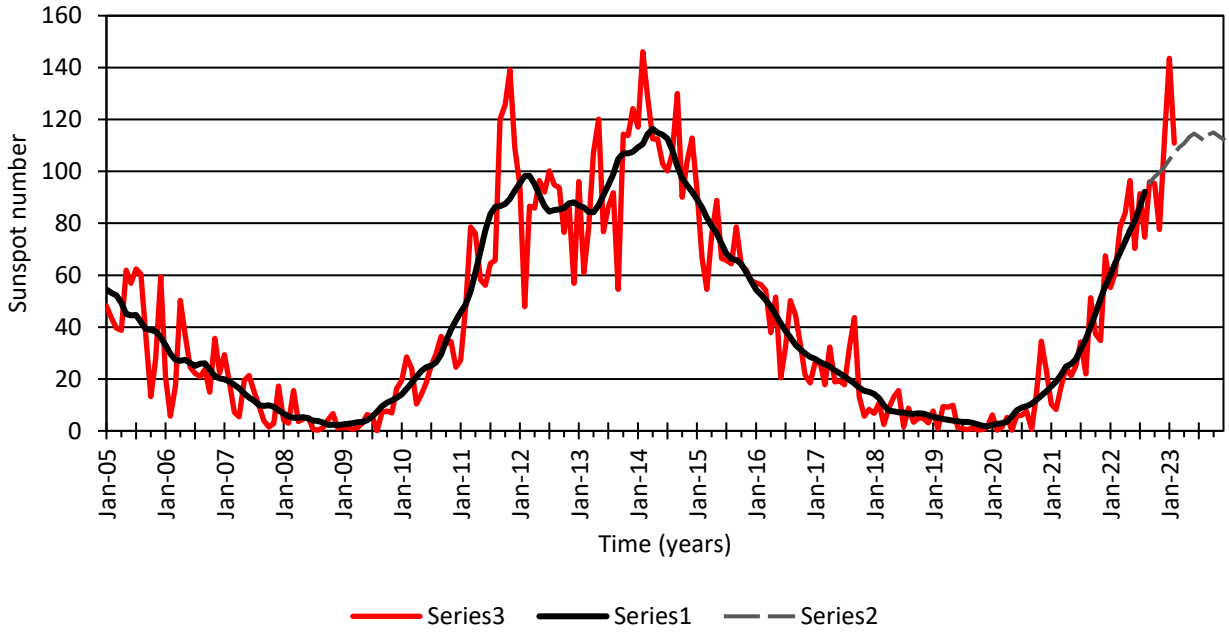
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	8	2	3	-2	-6	-3	-3	-8	-6	-10	-15	-9
2019	-5	-3	-4	-4	-9	-14	-11	-14	-11	-14	-16	-12
2020	-2	-5	2	-1	-7	-7	-9	-2	-6	-6	7	12
2021	12	4	10	6	6	12	21	12	23	23	17	28
2022	41	52	63	71	81	65	67	56	72	75	65	71
2023	107	114*	80	80	81	81	81	78	77	78	79	79
		SWS predicted T-index			* New observed data. T-index value may have changed							

Solar and Geophysical Indices - February 2023



Note: The observed Penticton 10.7cm solar radio flux on 17th of February 2023 was actually 343SFU, which is likely to have been an enhanced value due to a solar flare. An interpolated daily value is shown on the graph above.

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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