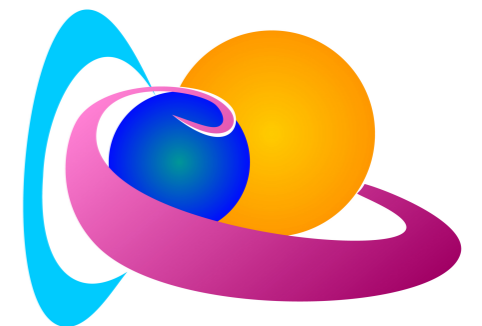


Space Weather impacts on Aviation

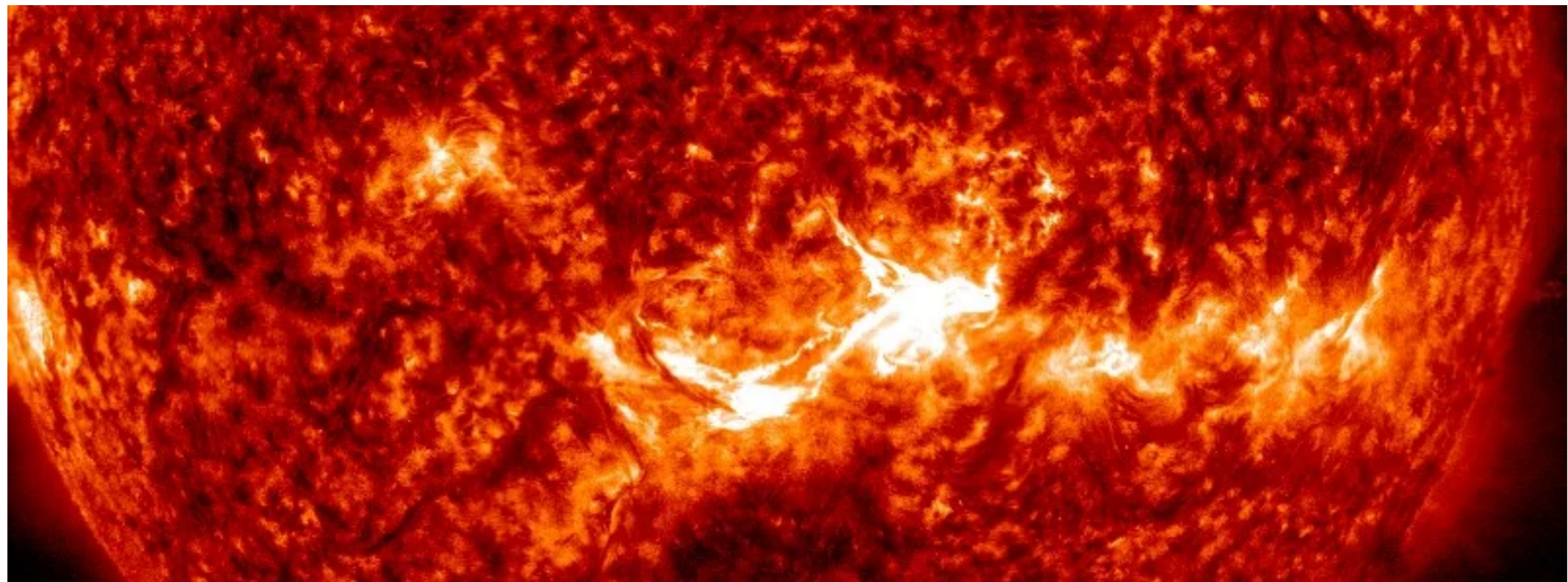
PECASUS advisories for ICAO

Course by the
Solar-Terrestrial Centre of Excellence

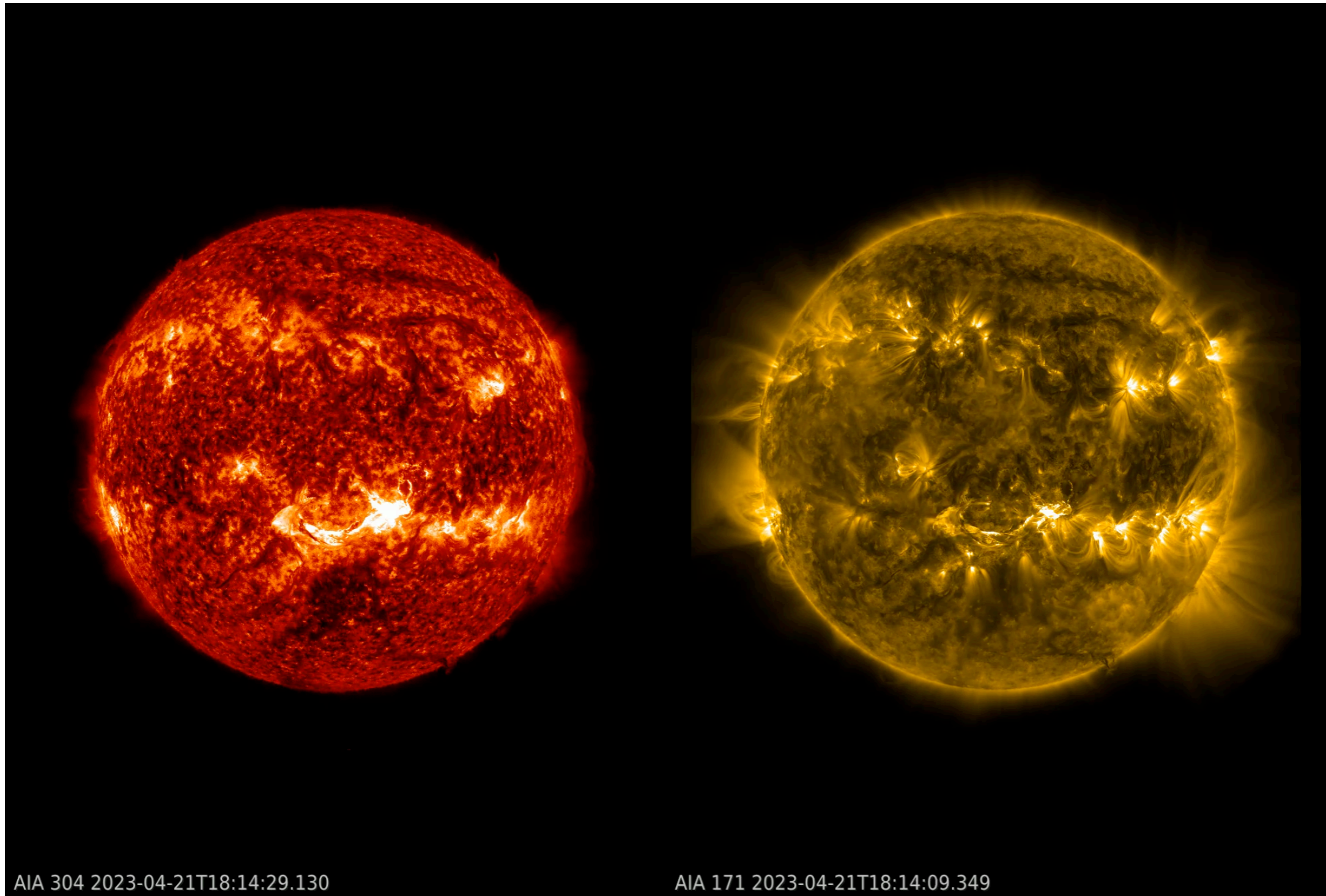


Solar and heliospheric storms impacting aviation

CASE STUDY - April 21, 2023



Solar Observations

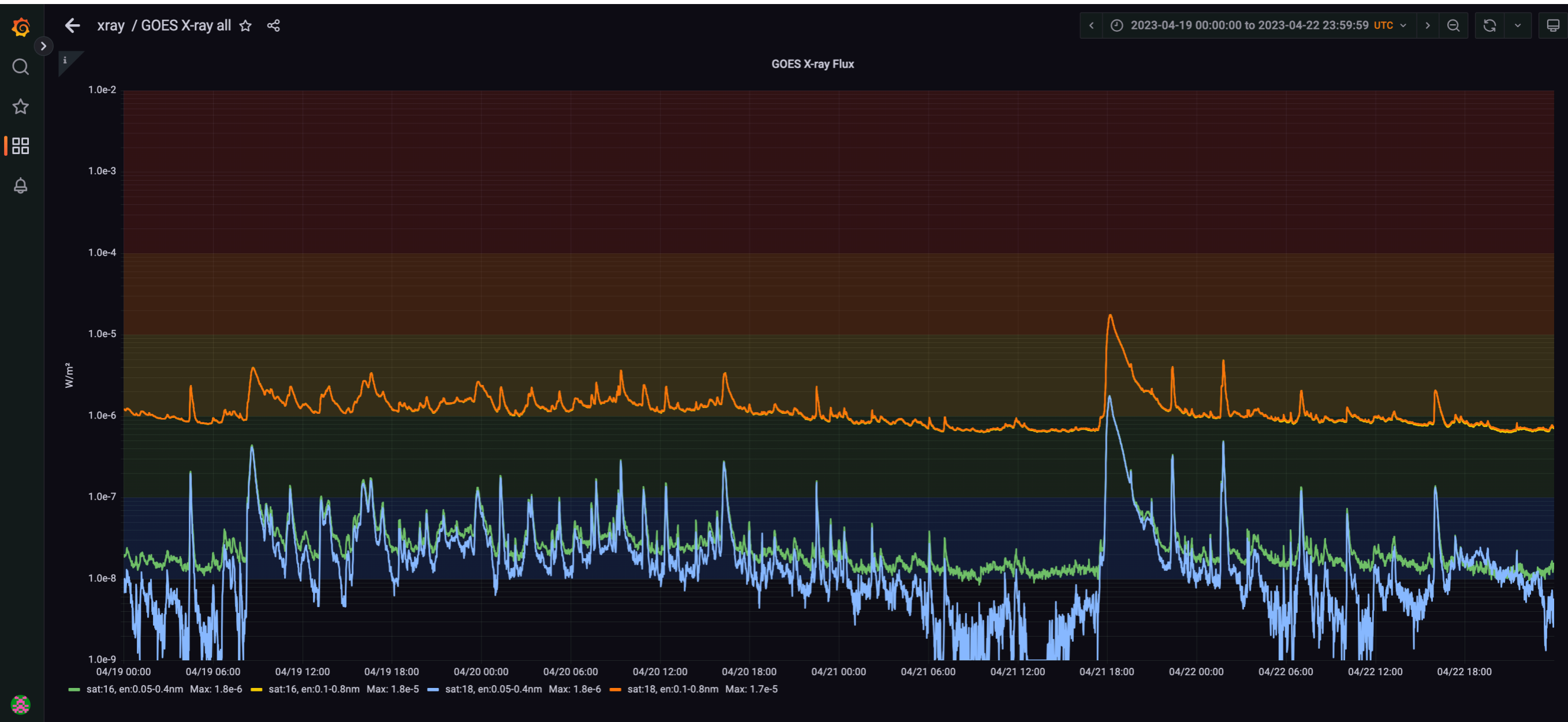


<https://www.jhelioviewer.org/>





GOES X-ray Flare Detection





Solar Demon Flare Detection

Detector 24h operating status:



Last processed image:

0 hours and 42 minutes ago (2023-04-27 12:36 UTC)

Last detected flare:

1 hours and 3 minutes ago (2023-04-27 12:15 UTC)

Animations and brightness graph

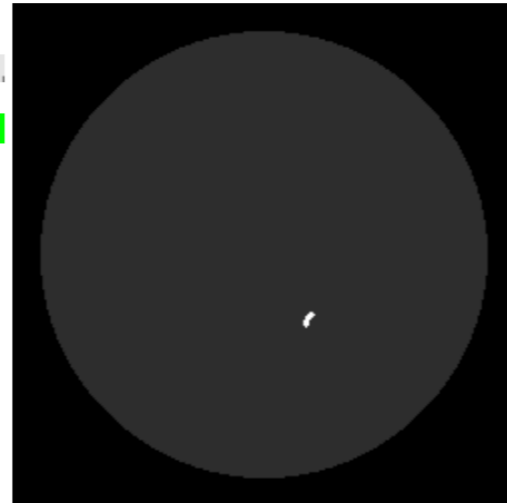
[fixed brightness](#)

[adaptive brightness](#)

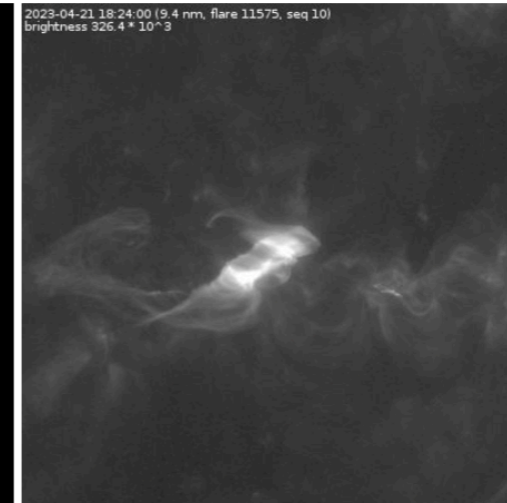
Navigation

Please send me [back](#).

location of flare 11575



Flare 11575



Details for flare #: 11575

time	seq #	brightness	size	lat	lon	X,Y in R _☉	dist. R _☉	Blooming	Img ID
2023-04-21 17:54:00	1	10.2	68	-20.4	12.8	0.21, -0.27	0.34	0	2763782
2023-04-21 18:00:00	2	123.9	631	-20.3	13.0	0.21, -0.27	0.34	0	2763787
2023-04-21 18:03:00	3	178.2	824	-20.4	12.9	0.21, -0.27	0.34	0	2763788
2023-04-21 18:06:00	4	211.8	933	-20.6	12.7	0.21, -0.27	0.34	0	2763789
2023-04-21 18:09:00	5	238.9	999	-20.7	12.7	0.21, -0.27	0.34	0	2763790
2023-04-21 18:12:24	6	278.7	1085	-20.9	12.5	0.20, -0.28	0.34	0	2763791
2023-04-21 18:15:00	7	310.6	1103	-21.0	12.4	0.20, -0.28	0.34	0	2763792
2023-04-21 18:18:00	8	337.0	1126	-21.1	12.4	0.20, -0.28	0.35	0	2763793
2023-04-21 18:21:00	9	340.6	1149	-21.3	12.3	0.20, -0.28	0.35	0	2763802
2023-04-21 18:24:00	10	326.4	1176	-21.5	12.2	0.20, -0.29	0.35	0	2763803
2023-04-21 18:27:00	11	304.0	1198	-21.8	12.0	0.20, -0.29	0.35	0	2763804
2023-04-21 18:30:00	12	272.8	1157	-22.0	11.9	0.19, -0.30	0.35	0	2763805
2023-04-21 18:33:00	13	241.4	1075	-22.3	11.8	0.19, -0.30	0.36	0	2763806
2023-04-21 18:36:00	14	217.6	998	-22.6	11.7	0.19, -0.31	0.36	0	2763807
2023-04-21 18:39:00	15	198.4	921	-22.8	11.7	0.19, -0.31	0.36	0	2763808
2023-04-21 18:42:00	16	192.9	932	-23.0	11.7	0.19, -0.31	0.36	0	2763809

Solar Demon estimated flare class:

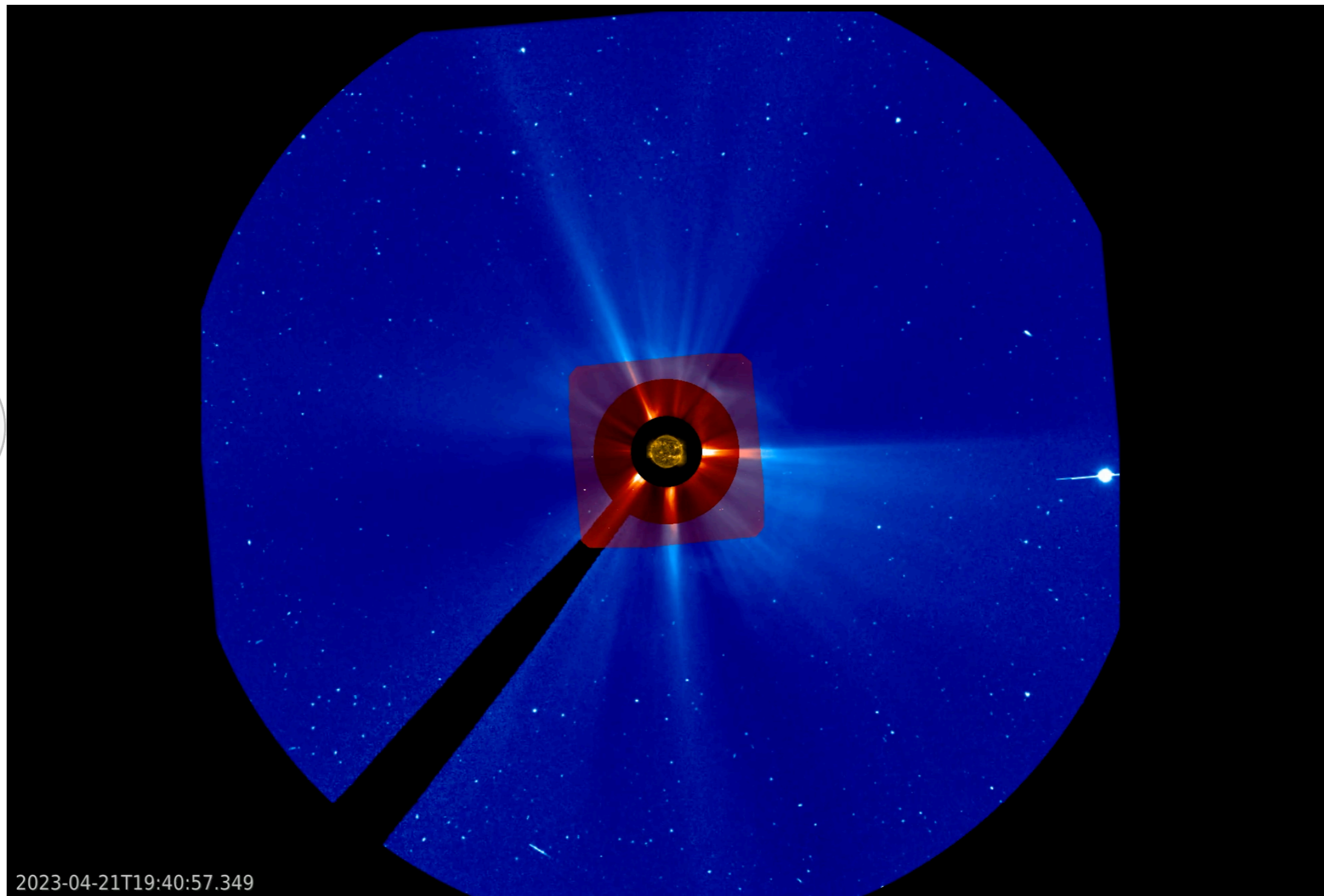


<https://www.sidc.be/solardemon/>





Coronagraph observations



<https://www.jhelioviewer.org/>





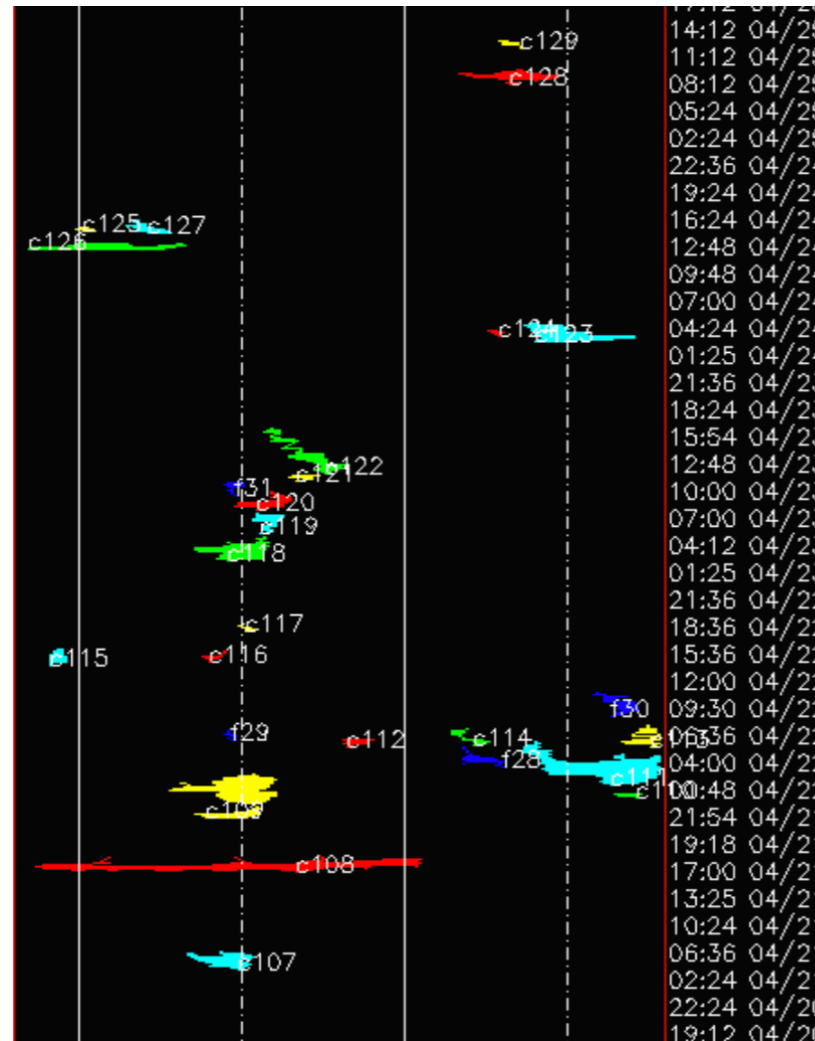
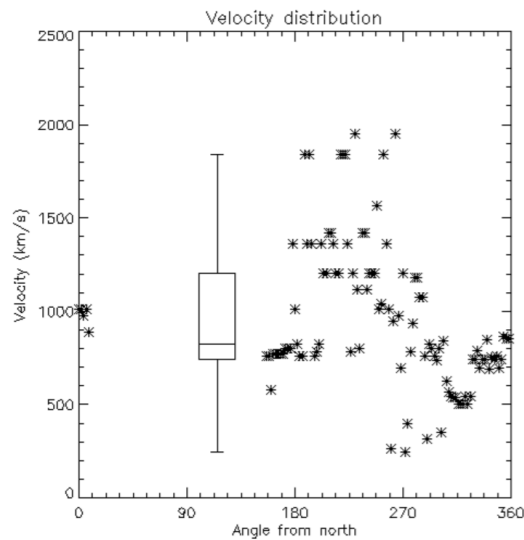
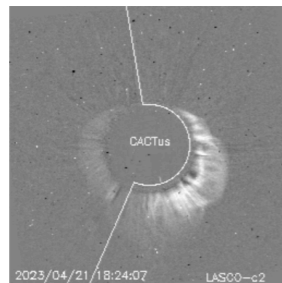
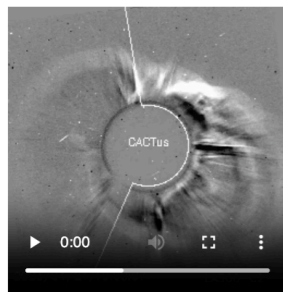
CACTus detection

Details and graphs for CME0108

# CME	t0	dt0	pa	da	v	dv	minv	maxv	halo?
0108	2023/04/21 18:12	01	263	212	0821	0375	0248	1838	III

CME Movie :: [Download](#) ::

Sample Image



Time	Date
14:12	04/25
11:12	04/25
08:12	04/25
05:24	04/25
02:24	04/25
22:36	04/24
19:24	04/24
16:24	04/24
12:48	04/24
09:48	04/24
07:00	04/24
04:24	04/24
01:25	04/24
21:36	04/23
18:24	04/23
15:54	04/23
12:48	04/23
10:00	04/23
07:00	04/23
04:12	04/23
01:25	04/23
21:36	04/22
18:36	04/22
15:36	04/22
12:00	04/22
09:30	04/22
06:36	04/22
04:00	04/22
00:48	04/22
21:54	04/21
19:18	04/21
17:00	04/21
13:25	04/21
10:24	04/21
06:36	04/21
02:24	04/21
22:24	04/20
19:12	04/20

:Issued: 2023 Apr 22 0202 UTC

:Product: documentation at <http://www.sidc.be/products/cactus>

#-----#

HALO CME ALERTS from the SIDC (RWC-Belgium), generated by CACTUS

#-----#

A halo or partial-halo CME was detected with the following characteristics:

t0	dt0	pa	da	v	dv	minv	maxv
2023-04-21T18:12:08.030	1.0	267	220	844	334	194	1838

t0: onset time, earliest indication of liftoff

dt0: duration of liftoff (hours)

pa: principal angle, counterclockwise from North (degrees)

da: angular width of the CME (degrees),

v: median velocity (km/s)

dv: variation (1 sigma) of velocity over the width of the CME

mindv: lowest velocity detected within the CME

maxdv: highest velocity detected within the CME

#-----#

Solar Influences Data analysis Center - RWC Belgium

Royal Observatory of Belgium

Website <http://www.sidc.be>

E-mail sidc-support@oma.be

To unsubscribe <http://www.sidc.be/registration/unsub.php>

#-----#

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#-----#



CACTUS

A software package for 'Computer Aided CME Tracking'



<https://www.sidc.be/cactus/>



PRESTO

#-----#

:Issued: 2023 Apr 21 2235 UTC

:Product: documentation at <http://www.sidc.be/products/presto>

#-----#

FAST WARNING '**PRESTO**' MESSAGE from the SIDC (RWC-Belgium)

#-----#

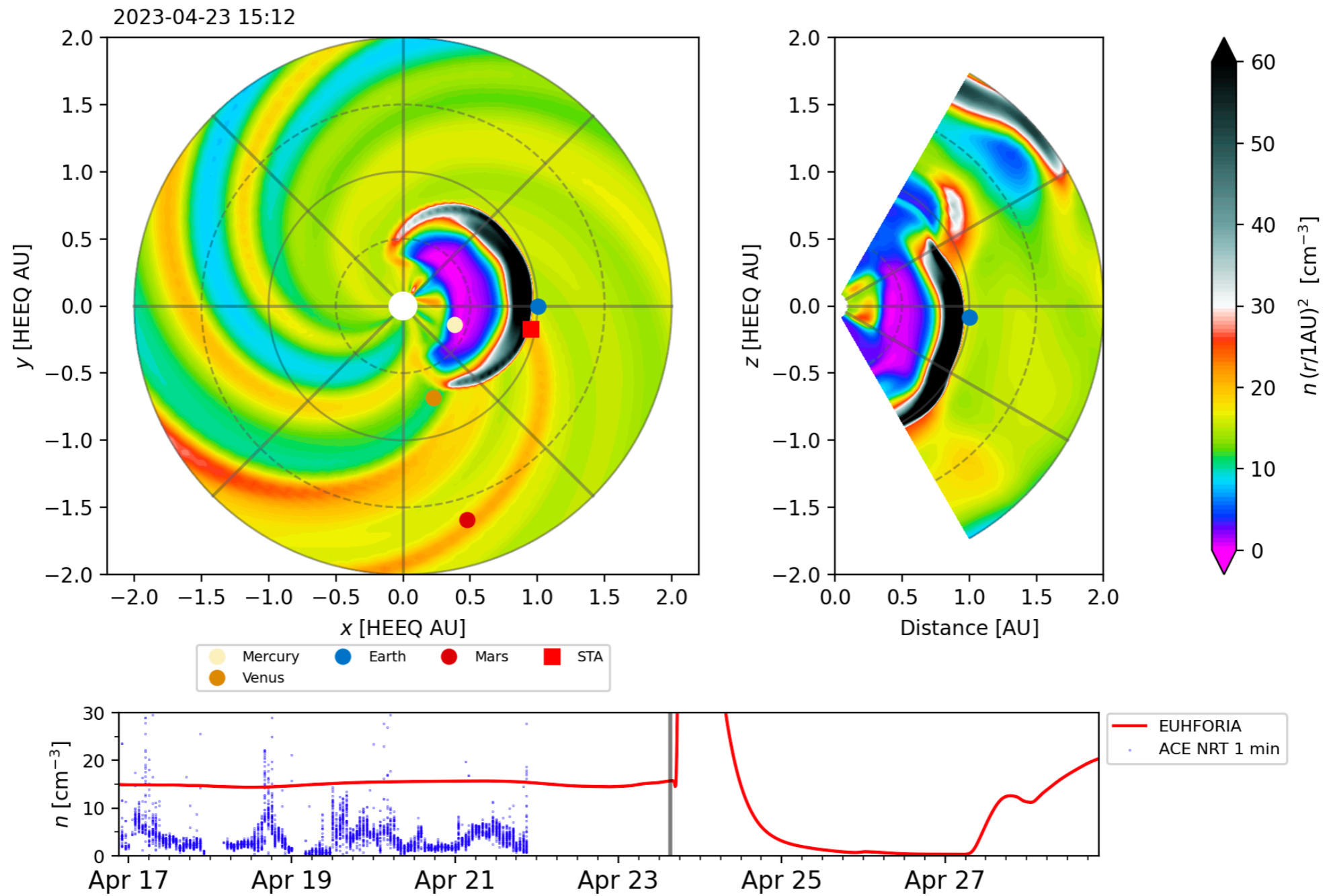
A fast **full halo** coronal mass ejection (CME) was first observed in the LASCO/C2 chronograph imagery around 18 UTC on April 21st. The CME was driven by a **long-duration M-class flare** from NOAA AR 3283 (beta): an M1.7 flare with start time 17:44 UTC, peak time 18:12 UTC, end time 18:37 UTC on April 21st, and related **filament eruption** on the central meridian close to the disc centre. The estimated projected velocity of the CME is above 1100 km/s and preliminary analysis suggests an estimated **arrival at Earth on April 24th**. Due to the fast nature and location of the CME, moderate to major **geomagnetic storms** could be anticipated during the arrival with chances of reaching severe storm levels. The greater than 10 MeV GOES **proton flux might also be enhanced** in the next days due to particle acceleration at the CME front shock.

#-----#





EUHFORIA CME modeling



SIDC **URSIGRAM** 30422

SIDC SOLAR BULLETIN 22 Apr 2023, 1234UT

SIDC FORECAST (valid from 1230UT, 22 Apr 2023 until 24 Apr 2023)

SOLAR FLARES : C-class flares expected, (probability >=50%)

GEOMAGNETISM : **Active conditions** expected (A>=20 or K=4)

SOLAR PROTONS : **Warning** condition (activity levels expected to increase, but no numeric forecast given)

PREDICTIONS FOR 22 Apr 2023 10CM FLUX: 148 / AP: 010

PREDICTIONS FOR 23 Apr 2023 10CM FLUX: 148 / AP: 018

PREDICTIONS FOR 24 Apr 2023 10CM FLUX: 148 / AP: 065

COMMENT: Solar flaring activity reached moderate levels in the past 24 hours with an isolated low M-class flaring from NOAA AR 3283 (beta), namely a **long duration M1.7 flare**, start time 17:44 UTC, peak time 18:12 UTC, end time 18:37 UTC on April 21st. This flaring activity was driven by a nearby filament eruption and no other significant flaring was observed from NOAA AR 3283. NOAA AR 3279 (alpha) was also triggered by the magnetic field reconfiguration during the previous eruptions and has produced multiple C-class flaring, the most significant one being a C4.8 flare, peak time 01:48 UTC on April 22nd. NOAA AR 3285 (beta) was numbered and has produced isolated low C-class flaring. NOAA AR 3282 (beta-gamma) remains the largest and most complex region on the visible solar disc, but has been quiet and inactive. The remaining active regions are relatively simple and have shown no significant flaring. The solar flaring activity is expected to be at low levels over the next 24 hours with **chances for further isolated M-class flaring**.

A **fast full halo coronal mass ejection** (CME) was first observed in the LASCO/C2 chronograph imagery at 18:12 UTC on April 21st. The CME was driven by a long-duration M-class flaring from NOAA AR 3283 and a related filament eruption on the central meridian close to the disc centre. The estimated projected velocity of the CME is close to 1100 km/s and current analysis suggests an estimated arrival at Earth late April 23rd to early April 24th. **The nature and location of the CME suggest strong impact on Earth**. No other Earth-directed CMEs have been detected in the available coronagraph imagery.

Over the past 24 hours the greater than 10 MeV GOES proton flux was at nominal levels and is expected to register gradual enhancements over the next 24 hours with the **possibility of reaching minor radiation storm levels**. The greater than 2 MeV electron flux has been below the 1000 pfu threshold and is expected to remain so. The 24h electron fluence was at nominal levels and is expected to remain so over the next 24 hours.

Over the past 24 hours the solar wind parameters (ACE and DSCOVR) were mainly at background slow solar wind levels with an indication of a sector boundary crossing in the evening of April 21st. The solar wind velocity varied around 400 km/s and is currently reaching 450 km/s. The interplanetary magnetic field was weak with a maximum value of 6.6 nT and a minimum Bz of -6.5 nT. The B field was switching orientation between the positive and the negative sector (directed away from and towards the Sun). The solar wind conditions are expected to remain mostly at background slow solar wind regime over the next 24 hours with possible slight enhancements later today pending a mild high speed stream arrival from a narrow patchy negative polarity coronal hole, which crossed the central meridian on April 18th. **Strong solar wind disturbances are expected** on April 24th with the anticipated arrival of the full halo CME related to the M1.7-flaring from NOAA 3283 (beta) and a nearby filament eruption around 18:00 UTC on April 21st. **The CME-related shock might arrive late on April 23rd**.

The geomagnetic conditions over the past 24 hours were globally quiet to unsettled and locally registered an isolated active period over Belgium in the interval of 21-22 UTC after prolonged periods of negative Bz. Quiet to unsettled geomagnetic conditions are expected over the next 24 hours with probable active periods pending an anticipated mild high speed stream arrival. **Moderate to major geomagnetic storms might be expected in the night of April 23rd with chances for severe storm levels on April 24th due to an expected ICME arrival**.

TODAY'S ESTIMATED ISN : 109, BASED ON 15 STATIONS.

SOLAR INDICES FOR 21 Apr 2023

WOLF NUMBER CATANIA : 136

10CM SOLAR FLUX : 151

AK CHAMBON LA FORET : 014

AK WINGST : ///

ESTIMATED AP : 012

ESTIMATED ISN : 110, BASED ON 19 STATIONS.

NOTICEABLE EVENTS SUMMARY

DAY	BEGIN	MAX	END	LOC	XRAY	OP	10CM	Catania/NOAA	RADIO_BURST_TYPES
21	1744	1812	1844	S22W11	M1.7	2N	110	61/3283	II/3V/3IV/2

SIDC **URSIGRAM** 30423

SIDC SOLAR BULLETIN **23 Apr** 2023, 1230UT

SIDC FORECAST (valid from 1230UT, 23 Apr 2023 until 25 Apr 2023)

SOLAR FLARES : C-class flares expected, (probability $\geq 50\%$)

GEOMAGNETISM : **Major** (ISES: Severe) magstorm expected ($A \geq 100$ or $K \geq 7$)

SOLAR PROTONS : **Warning** condition (activity levels expected to increase, but no numeric forecast given)

PREDICTIONS FOR 23 Apr 2023 10CM FLUX: 140 / AP: 030

PREDICTIONS FOR 24 Apr 2023 10CM FLUX: 140 / AP: 082

PREDICTIONS FOR 25 Apr 2023 10CM FLUX: 140 / AP: 021

COMMENT: Solar flaring activity at low levels over the past 24 hours with only isolated low C-class flaring. There are six numbered active regions on the visible solar disc. The largest and most complex one, NOAA AR 3282 (beta-gamma), has remained stable and inactive. The strongest activity was a C2.2 flare, peak time 06:40 UTC on April 23rd, produced by NOAA AR 3279 (beta). The rest of the active regions, including a newly formed unnumbered region near NOAA AR 3285 (beta), have been stable and inactive. The solar flaring activity is expected to be at **low levels** over the next 24 hours with low chances for isolated M-class flaring.

No Earth-directed coronal mass ejections (CMEs) have been detected in the available coronagraph imagery over the past 24 hours. The halo CME related to M-class flaring and filament eruption on April 21st is **expected to arrive** to Earth over the next 24 hours.

Over the past 24 hours the greater than 10 MeV GOES proton flux was elevated, remaining well below radiation storm levels. The greater than 10 MeV GOES proton flux is expected to remain enhanced over the next 24 hours with the **chances of reaching minor radiation storm levels**. The greater than 2 MeV electron flux has been below the 1000 pfu threshold and is expected to remain so. The 24h electron fluence was at nominal levels and is expected to remain so over the next 24 hours.

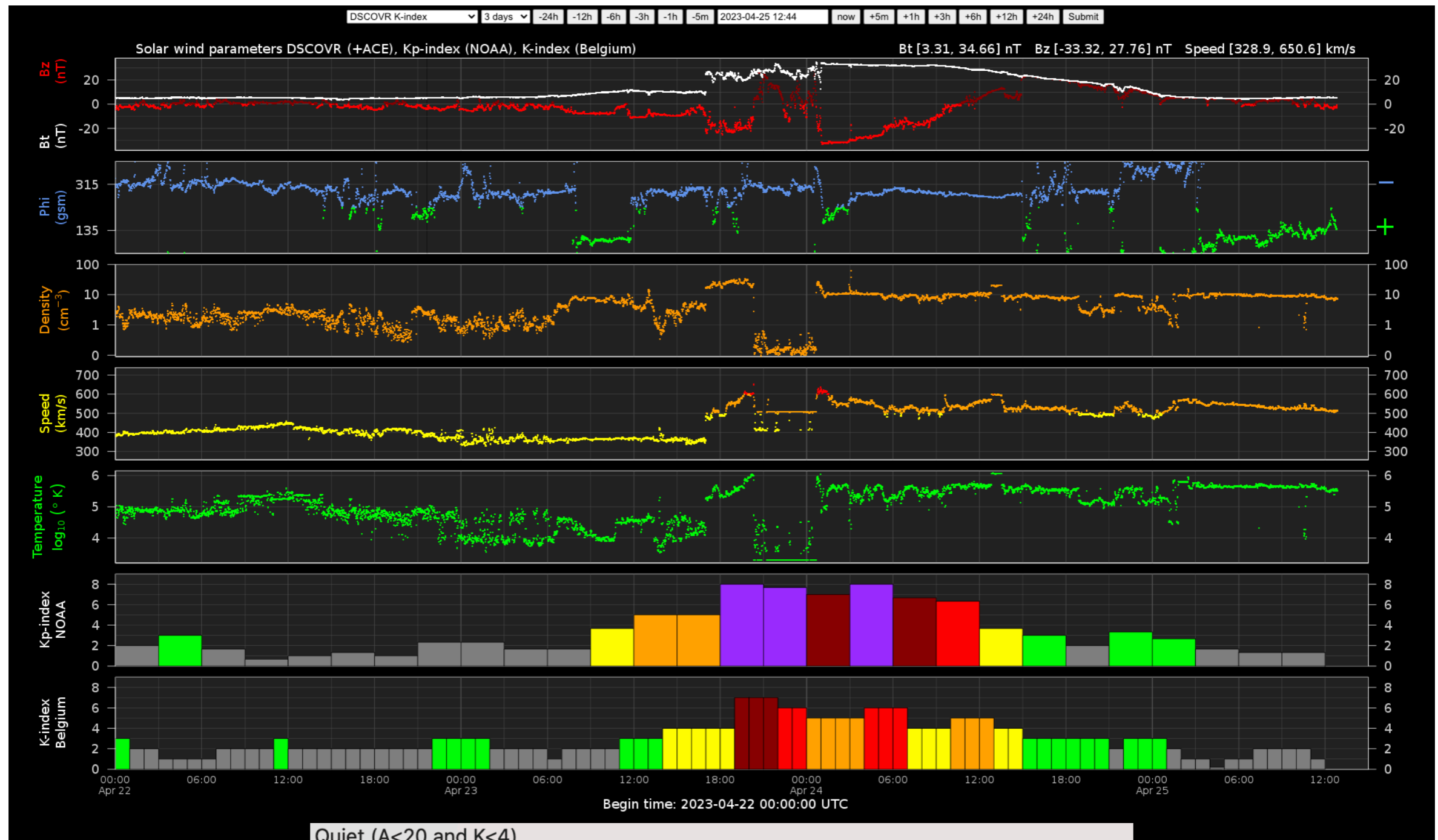
Over the past 24 hours the solar wind parameters (ACE and DSCOVR) were mainly at background slow solar wind levels until around 08:00 UTC on April 23rd when the beginning of an ongoing disturbance was first observed. It is **too early to determine the nature of this disturbance**, but it could be a precursor of the expected ICME arrival. The solar wind velocity varied from 329 km/s to 457 km/s. The interplanetary magnetic field reached a maximum value of 11.8 nT and a minimum B_z of -11.7 nT. The B field was mostly in the negative sector with some switch backs to the positive sector (directed away from the Sun). The solar wind conditions are **expected to be significantly perturbed** over the next 24 hours with an anticipated strong ICME arrival, related to the CME driven by M-flaring and filament eruption on April 21st.

The **geomagnetic conditions** over the past 24 hours were globally quiet and locally quiet to unsettled over Belgium. The geomagnetic conditions are expected to be significantly elevated over the next 24 hours with expected **moderate to major geomagnetic storms and chances for severe storm levels** due to an expected ICME arrival.

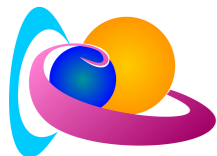


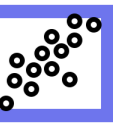


CME arrival



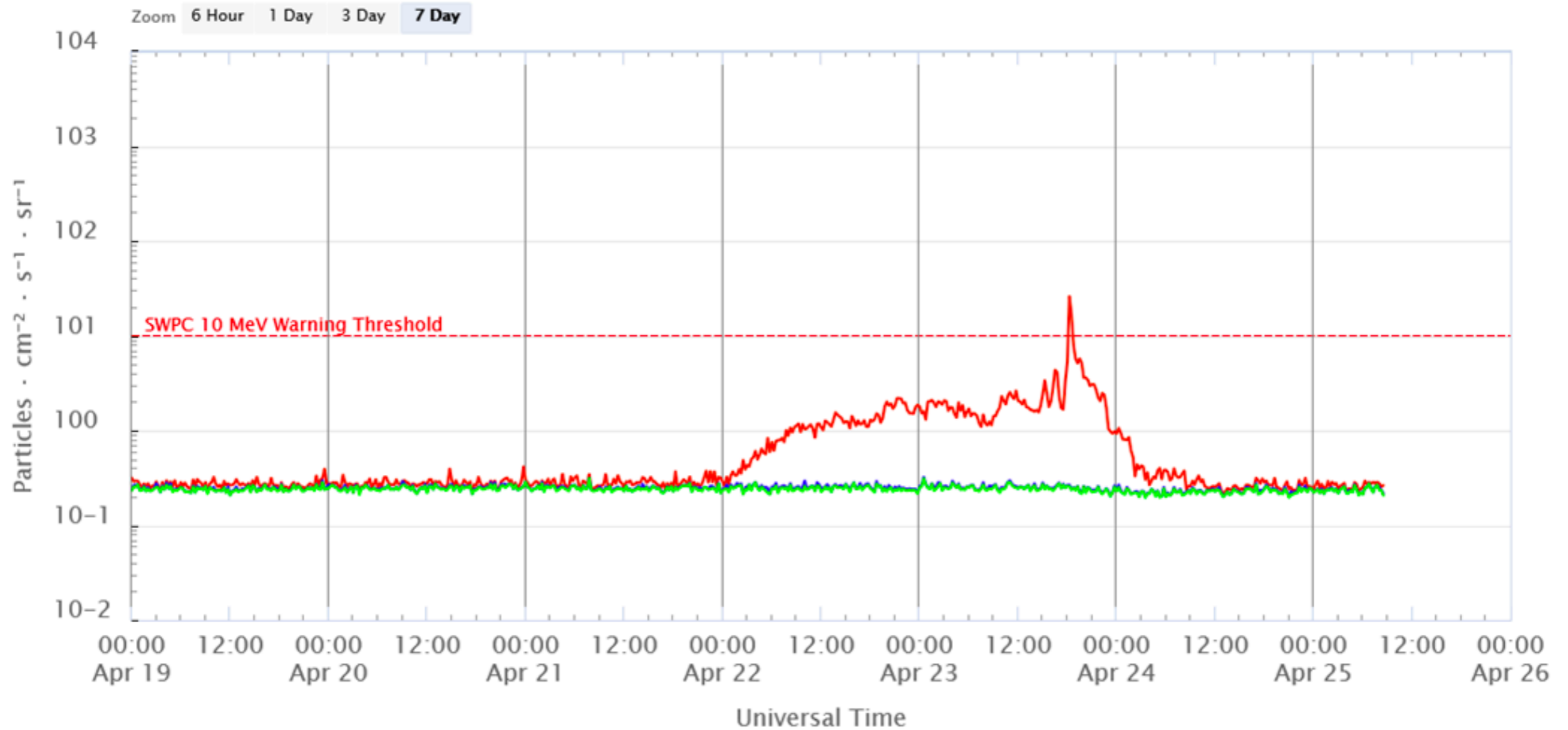
Quiet ($A < 20$ and $K < 4$)
Active conditions expected ($A \geq 20$ or $K = 4$)
Minor storm expected ($A \geq 30$ or $K = 5$)
Moderate (ISES: Major) magstorm expected ($A \geq 50$ or $K = 6$)
Major (ISES: Severe) magstorm expected ($A \geq 100$ or $K \geq 7$)
Warning condition (activity levels expected to increase, but no numeric forecast given)





Proton Event

GOES Proton Flux (5-minute data)



Updated 2023-04-25 08:40 UTC

Space Weather Prediction Center



Quiet
Proton event expected (10 pfu at >10 MeV)
Major proton event expected (100 pfu at >100 MeV)
Proton event in progress (>10 MeV)
Warning condition (activity levels expected to increase, but no numeric forecast given)



#-----#

:Issued: 2023 Apr 23 1833 UTC

:Product: documentation at <http://www.sidc.be/products/presto>

#-----#

FAST WARNING '**PRESTO**' MESSAGE from the SIDC (RWC-Belgium)

#-----#

A fast forward **shock** was observed in the solar wind at 17:00 UTC on April 23rd marking the expected arrival of a fast CME, which lifted off the solar surface on April 21st as a result of long duration M-class flaring triggered by a neighbouring filament eruption. The interplanetary magnetic field jumped from 9 nT to 26 nT with Bz reaching -24 nT. The solar wind velocity increased from 360 km/s to 480 km/s and the density jumped from 4.8 ppcc to 16.8 ppcc. The solar wind speed around 17:45 UTC has reached 527 km/s. The current **geomagnetic conditions** are active over Belgium and globally at minor storm levels. Moderate to major **storms** are expected in the upcoming hours with the ongoing ICME arrival. The greater than 10 MeV GOES **proton flux** has reached minor radiation storm levels and is expected to continue to increase, possibly reaching moderate radiation storm levels.

#-----#



#-----#

:Issued: 2023 Apr 23 2026 UTC

:Product: documentation at <http://www.sidc.be/products/presto>

#-----#

FAST WARNING 'PRESTO' MESSAGE from the SIDC (RWC-Belgium)

#-----#

A major geomagnetic storm has been registered over Belgium due to an ongoing ICME arrival. The solar wind velocity has exceeded 610 km/s with interplanetary magnetic field values of 27 nT and a minimum BZ component of -25 nT. The solar wind density has exceeded 32 ppcc and the temperature is above 1 MK. The geomagnetic conditions are expected to remain at moderate to major storm levels in the upcoming hours. The greater than 10 MeV GOES proton flux remains enhanced, but has decreased to below minor storm radiation levels. Related to the storm there are ongoing strong ionospheric scintillations and post storm depressions, as well as some polar cap and auroral absorptions.

#-----#



:Issued: 2023 Apr 24 0909 UTC

:Product: documentation at <http://www.sidc.be/products/presto>

#-----#

FAST WARNING '**PRESTO**' MESSAGE from the SIDC (RWC-Belgium)


#-----#

The Corona Mass Ejection (CME) arrival first reported yesterday continues to cause a major geomagnetic storm. Although the solar wind velocity has now dropped to 500 km/s and the North-South component of the interplanetary magnetic field (Bz) has now increased to -10 nT, the Kp index has reached the **severe level** (Kp=8, G4). The geomagnetic conditions are expected to gradually decrease in the next several hours. Currently severe post storm depressions have been observed in various locations, and high auroral absorption.

#-----#



Impacts



-24h -12h -6h -3h -1h -5m Submit 2023-04-23 20:00 now +5m +1h +3h +6h +12h +24h

PECASUS DASHBOARD on 2023-04-23 20:00 UTC

25/04/2023
08:32 UTC

STATUS
ODC

MAIN

GNSS

RADIATION

HF COM

ARCHIVE

Advisory

Daily Brief

Data

Procedures

Portfolio

CAO Docs

RWC

Contact

User Guide

Mute status
alerts on
Mattermost

GNSS	Moderate	Severe	Time UTC	Values	Status	Alert	Max-3h values	Max-3h status
<u>Amplitude Scintillation</u>	0.5	0.8	2023-04-23 20:00	0.38	QUIET		0.41	QUIET
<u>Phase Scintillation</u>	0.4	0.7	2023-04-23 20:00	0.26	QUIET		1.06	SEVERE
<u>Vertical TEC</u>	125	175	2023-04-23 20:00	132.14	QUIET		132.14	MODERATE

RADIATION	Moderate	Severe	Time UTC	Flags	Status	Alert	Max-3h flags	Max-3h status
<u>Effective Dose FL ≤ 460</u>	30	80	2023-04-23 20:00	0	QUIET		0	QUIET
<u>Effective Dose FL > 460</u>	/	80	2023-04-23 20:00	0	QUIET		0	QUIET

HF COM	Moderate	Severe	Time UTC	Values/Flags	Status	Alert	Max-3h values	Max-3h status
<u>Auroral Absorption (AA)</u>	8	9	2023-04-23 20:00	8.0	MODERATE		8.0	MODERATE
<u>Polar Cap Absorption (PCA)</u>	2	5	2023-04-23 20:00	2.35	MODERATE		4.64	MODERATE
<u>Shortwave Fadeout (SWF)</u>	x1.0	x10.0	2023-04-23 20:00	< M5 flare	QUIET		< M5 flare	QUIET
<u>Post-Storm Depression (PSD)</u>	30%	50%	2023-04-23 20:00	2	SEVERE		2	SEVERE

Sound alarm is triggered when MOD or SEV thresholds are exceeded or in case of data outages.

