Space Weather

Submitted by Canada, United Kingdom & United States

SUMMARY

Executive Summary: Noting the current solar cycle and recent space weather events, this paper seeks to inform MSIP's of space weather considerations and encourages the WWNWS-SC and AG-WWMIWS-SC to consider issuing clearer guidance on the issuance of space weather warnings.

Action to be taken: See 5

Related documents: None

1. Background

1.1. Space weather, a consequence of the behaviour of the Sun and the nature of its interaction with the Earth's magnetic field and atmosphere, can have severe effects on the Earth, including interruptions to radio communications and Global Navigational Satellite Systems (GNSS). These effects can be enhanced during periods of high solar activity due to the electromagnetic energy, energetic particles and plasma released.

1.2. Some administrations have access to Space Weather Prediction Services from a variety of sources, but this is not the case for every maritime safety information provider (MSIP) ubiquitous and the information is not presented in a uniform manner. Where it is available, this information often takes the form of e-mail subscription services or the delivery of forecasts, alerts and warnings.

1.3. There are several main types of space weather event, including:

- Geomagnetic storms – disturbances of the Earth's magnetic field produced by electric currents in the ionosphere and magnetosphere, caused by solar activity. Affected systems include power systems, pipelines, submarine cables, magnetic surveys, and compass use.

- Ionospheric disturbances – formation of ionospheric irregularities or regions of extra ionization caused by the precipitation of charged particles into the ionosphere. These disturbances can affect high frequency radio wave propagation

and signals from the GNSS.

- Solar energetic particle events – large-scale eruptions which accelerate charged particles in the solar atmosphere to very high velocities. These energetic particles can affect space technology, cause ionospheric disturbances, and increase the intensity of radiation at commercial aircraft altitudes in the polar region.

- Radio fadeouts – bursts of X-ray and Extreme Ultraviolet radiation emitted from solar flares that increase ionization in the lower ionosphere affecting high frequency communication.

1.4. Space weather events vary in severity and can therefore have varying levels of impact on sensitive systems including radio communication, position, navigation, and timing, and satellite operation. Level of severity can be characterized by local or global geomagnetic indices (e.g. K-index, AE index, Kp index).

1.5. The solar cycle, also known as the solar magnetic activity cycle, sunspot cycle, or Schwabe cycle, is a nearly periodic 11-year change in the Sun's activity measured in terms of variations in the number of observed sunspots on the Sun's surface. Over the period of a solar cycle, levels of solar radiation and ejection of solar material, the number and size of sunspots, solar flares, and coronal loops all exhibit a synchronized fluctuation from a period of minimum activity to a period of a maximum activity back to a period of minimum activity.

1.6. Strong space weather events can have significant impacts on national infrastructure systems, such as power grids and degradation of communication services (see Annex A).

1.7. Various international organisations are tracking space weather, including the World Meteorological Organization (WMO), as part of their Space Weather Programme. The International Space Environment Service (ISES) is a collaborative network of space weather service-providing organizations around the globe and is organized and operated for the benefit of the international space weather user community.

2. Recent Space Activity

2.1. We are currently in Solar Cycle 25 which began in 2019 and it is anticipated that solar maximum will occur later in 2024 or early 2025.

2.2. In May 2024 a strong space weather event caused geomagnetic and ionospheric disturbances not observed since October 2003 and garnered significant media attention due to widespread viewing of the aurora at lower latitudes and the potential to impact systems. In March of 1989, an even stronger space weather event caused a blackout of the Hydro Quebec power system in Canada. During this even multiple NAVAREA's issued Navigational Warnings informing seafarers of the likelihood of degradation of GNSS, HF Radio and other navigationally significant services.

2.3. From 1st January 2024 to 30th June 2024 NAVAREA I has issued two Space weather warnings as a result of information provided by the UK Met Office (see examples in Annexes B and C).

2.4. NAVAREA IV/XII has promulgated 7 navigational warnings concerning space weather that had a strength of G3 or higher. This information was received from the United States National Oceanographic and Atmospheric Association (NOAA)'s Space Weather Prediction Center (SWPC). Due to the space weather forecasts from SWPC having a 72-hour validity period, the NAVAREA IV/XII navigational warnings had a 72-hour cancellation associated with the warning.

2.5. Throughout 2023 and 2024, NAVAREA XVII/XVIII has promulgated 2 navigational warnings concerning space weather. Canada receives its information from many sources, primarily the Natural Resources Canada (NRCan) Space Weather Forecast Centre's (CSWFC) Bulletins (see Annex D) and is in the process of developing national procedures for promulgation. The trigger process for issuing a NAVAREA warning is recommended to be when the bulletin changes from a WATCH to a WARNING which is in effect immediately and continues for a specified time period.

2.6. Impacts to GNSS and communications were experienced and reported by a number of sectors, although to the submitter's knowledge, no impacts or degradation was reported by seafarers to NAVAREA coordinators.

3. Guidance

3.1. The Joint IMO/IHO/WMO Manual on Maritime Safety Information, section 4.2.3, describes the following as being suitable for broadcast as NAVAREA warnings:

- significant malfunctioning of radio-navigation services and shore-based maritime safety information radio or satellite services.

- tsunamis and other natural phenomena, such as abnormal changes to sea level.

3.2. Space weather is not specifically described as a subject suitable for broadcast as a NAVAREA warning, but is inferred by the above two subjects.

3.3. The Joint IMO/IHO/WMO Manual on Maritime Safety Information (section 7) gives a single example of space weather including general notes. See Annex E.

3.4. There is no specific international guidance to determine which types of space weather or at what severity warnings for space weather should be issued.

4. Conclusions

4.1. Space weather does not respect national boundaries or NAVAREA limits, so a coordinated approach is required to inform mariners of the risks associated with space weather.

4.2. There is a lack of clear guidance when space weather warnings should be issued and what the contents of space weather warnings should be.

4.3. Not all National coordinators or NAVAREA coordinators have access to space weather prediction services through their administrations.

5. Recommendations

5.1. Invite the sub-committee to note the paper.

5.2. Invite WWNWS-SC to work jointly with AG-WWMIWS to determine how space weather information can best be shared and coordinated.

5.3. WWNWS-SC to consider giving clearer guidance on the promulgation of Space Weather warnings in a standardised manner.

5.4. Invite the WWNWS-SC Space Activity Advisory Group to provide proposed guidance to the relevant bodies on changes to MSI documentation including.

Annex A: Met Office Potential Space Weather Impacts to Capability & NOAA Space Weather scales as used by UK Met office

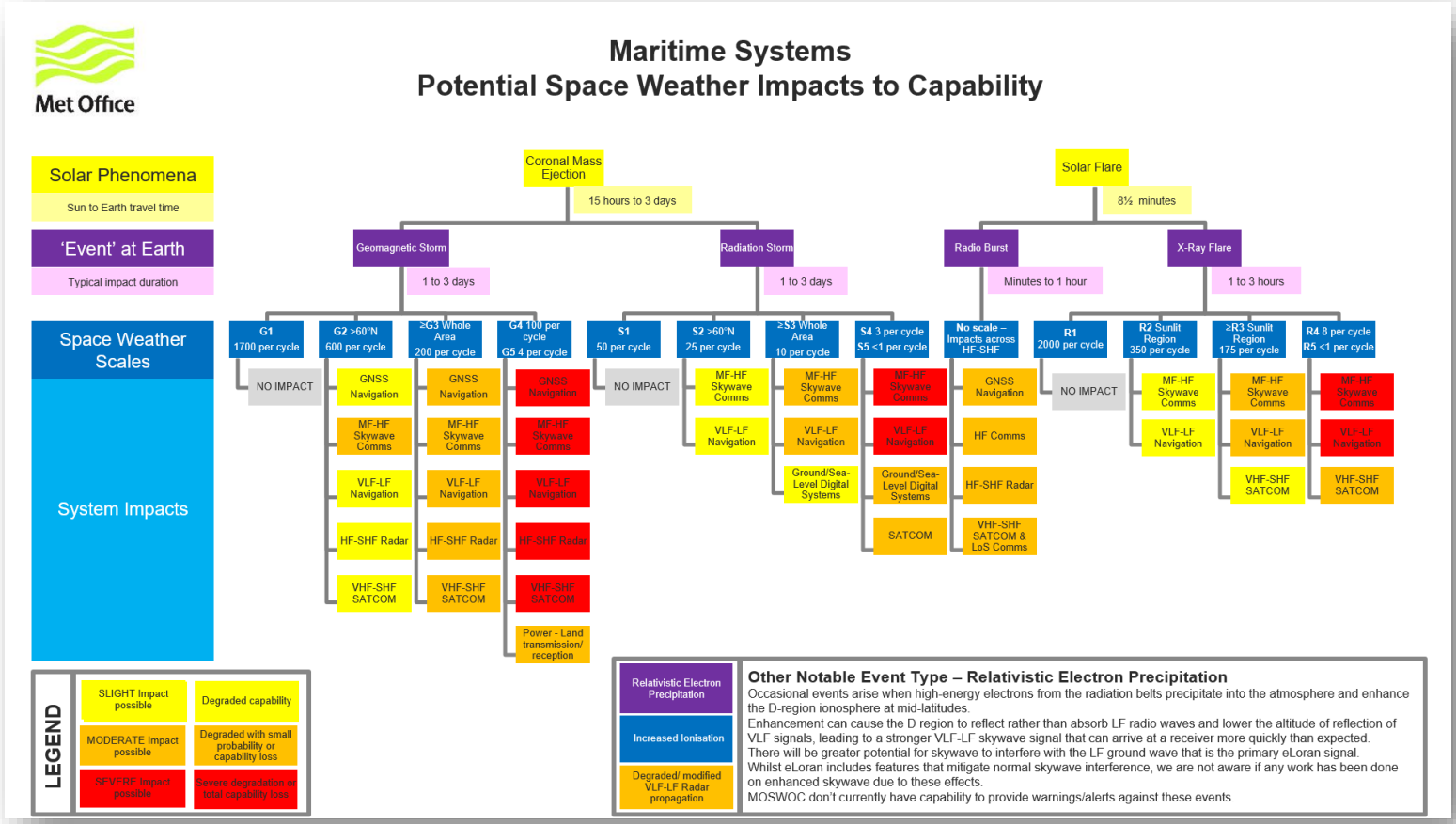

Fig 1. Met Office Potential Space Weather Impacts to Capability

Scale	Description	Effect
G 5	Extreme	**Power systems:** Widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. **Spacecraft operations:** May experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. **Other systems:** Pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.).
G 4	Severe	**Power systems:** Possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. **Spacecraft operations:** May experience surface charging and tracking problems, corrections may be needed for orientation problems. **Other systems:** Induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.).
G 3	Strong	**Power systems:** Voltage corrections may be required, false alarms triggered on some protection devices. **Spacecraft operations:** Surface charging may occur on satellite components, drag may increase on low-Earth-orbit satellites, and corrections may be needed for orientation problems. **Other systems:** Intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.).
G 2	Moderate	**Power systems:** High-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. **Spacecraft operations:** Corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. **Other systems:** HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.).
G 1	Minor	**Power systems:** Weak power grid fluctuations can occur. **Spacecraft operations:** Minor impact on satellite operations possible. **Other systems:** Migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine).

Fig 2. Geomagnetic storm effects

Ref: NOAA Space Weather Scales | NOAA / NWS Space Weather Prediction Center

Annex B: Met Office Watch, Alerts and Warning Examples

NAVAREA I

Space Weather.

A PERIOD OF STRONG ACTIVITY MAY IMPACT RADIO AND SATELLITE COMMUNICATION, AND NAVIGATION SERVICES. VALID 102100 TO 112100.

NAVAREA I

Space Weather.

G2 GEOMAGNETIC STORM NOW CEASED. CANCEL THIS MSG 131245 UTC MAY 24

Annex C: Example Space Weather Warnings

NAVAREA I 070/24
SPACE WEATHER.
SOLAR STORM IN PROGRESS FROM 102100Z MAY 24
RADIO AND SATELLITE NAVIGATION SERVICES MAY BE AFFECTED.

Annex D: Natural Resources Canada Space Weather Bulletin

Space Weather Bulletin - 2024-05-10 issued at 14:04 UT (10:04 EDT)

Summary

- A solar energetic particle (proton) event WARNING is in effect from 10 MAY 2024 13:45 UT. The solar energetic particles can affect space technology, cause ionospheric disturbances, and increase the intensity of radiation at commercial aircraft altitudes in the polar region.
- A major geomagnetic storm WATCH is in effect from 10 MAY 2024 23:00 UT to 11 MAY 2024 23:00 UT.
- Solar flares and ejections of the Sun's material (coronal mass ejections) were observed during 08-10 MAY 2024. The ejected material is Earth directed and is expected to affect Earth on 10-11 MAY 2024, resulting in disturbed geomagnetic conditions.
- See our website for current information: https://www.spaceweather.gc.ca/forecast-prevision/cond-en.php (updated every 15 minutes)

Current Conditions (13:45 UT)

24 Hour Forecast

Ionospheric Activity:

- polar ionosphere: disturbed
- auroral ionosphere: quiet
- sub-auroral ionosphere: quiet

Possible Impacts on Technology:

- HF Radio Systems: HF radio system degradation event possible with the potential to impact HF radio systems in the polar cap zone at high latitudes. Strongest effects on the dayside. Further periodic loss of HF radio systems possible.

Detailed Information

Solar

- A long duration X (large) solar x-ray flare erupted at 10 MAY 2024 06:54 UT near the centre of the solar disk.

Interplanetary

- A solar energetic proton event started on 10 MAY 2024 13:45 UT. Current levels are moderate.

Ionospheric

- Over the next 24 hours ionospheric activity impacting HF radio systems is expected to be disturbed on the dayside in the polar cap zone.
- Visit https://www.spaceweather.gc.ca/data-donnee/ionosphere/index-en.php for the TEC maps.

Annex E: Space weather guidance.

SPACE WEATHER

Note:

i) *Space Weather encompasses the conditions and processes occurring in space, including on the sun, in the magnetosphere, ionosphere and thermosphere, which have the potential to affect the near-Earth environment.*

The effects of Space Weather can range from damage to satellites arising from charged particles to disruption of power during geomagnetic storms, or disturbance of satellite positioning systems.

ii) *Space weather should include:*
- *Geomagnetic Storms,*
- *Solar Radiation Storms, and*
- *Radio Blackouts.*

Message element	Example 1
1. Message series identifier	NAVAREA IV 43/14 SPACE WEATHER. 1. STRONG SOLAR RADIATION STORM IN PROGRESS UNTIL 081000 UTC MAR 14. RADIO AND SATELLITE NAVIGATION SERVICES MAY BE AFFECTED. 2. CANCEL THIS MSG 081100 UTC MAR 14.
2. General area	
3. Locality	
4. Chart number	
5. Key subject	
6. Geographical position	
7. Amplifying remarks	
8. Cancellation details	

Fig 3. Extract from MSI Manual