SEVENTH MEETING OF THE PACIFIC METEOROLOGICAL COUNCIL (PMC-7)

"At the Frontline of Weather, Climate, Water, and Ocean Action in the Pacific"

17-19 September 2024, Warwick Le Lagon-Vanuatu Resort, Port Vila, Vanuatu

Agenda Item 9.3: Space Weather – Overview and Potential Impacts

Purpose:

- To provide the Meeting with an overview of space weather and its potential impacts.
- To inform the Meeting of the space weather forecast and warning information sources available, including the ICAO space weather advisories for aviation.

Space weather overview:

Space weather describes the various phenomena that occur in space as a result of variable conditions on the Sun and, in particular, those phenomena that can negatively impact systems and technologies in orbit and on Earth. Space weather phenomena manifest within varying time scales (as well as frequency and magnitude) during a space weather event. Solar flares arrive in eight minutes, while coronal mass ejections (CMEs) can take between 12 hours and a few days. While forecasting can help predict likely time of arrival, their magnitude can be difficult to accurately assess ahead of time. This, coupled with the short (potentially 12-hour) strategic warning window, means it is paramount that effective readiness, response and recovery plans are in place ahead of time.

The Sun's magnetic field goes through a solar cycle approximately every 11 years, with solar activity rising and falling over that time. Our current cycle's solar maximum (representing peak solar activity and a greater probability of space weather events) is estimated to occur in the middle of 2025[1] and is tracking at a higher activity level than was initially expected.

It is important to note that while space weather events are more frequent near the solar maximum and the downward phase, they can occur at any point in the solar cycle. In May 2024, several large solar flares and a series of CMEs were directed towards Earth,

[1] https://www.swpc.noaa.gov/products/solar-cycle-progression

resulting in the largest space weather storm in 21 years, with impacts observed globally - especially in the Northern Hemisphere.

ICAO space weather advisory system

The ICAO space weather advisory information service to support international air navigation was implemented on 7 November 2019, the provisions first included in Amendment 79 to Annex 3 *Meteorological Services for International Air Navigation*[2]. Four global space weather advisory centres[3] are designated to provide moderate and severe[4] advisories for observed impacts on global navigation satellite systems (GNSS), high-frequency radio communications (HF COM) and radiation (RAD).

- GNSS signals may be degraded during a space weather event, or even lost during severe events, impacting aviation navigation (and of course other services/sectors requiring GNSS).
- Space weather events can result in changes to ionospheric density and structure, modifying the transmission path (or even block transmission) of HF radio signals (again, an issue for more than just the aviation sector).
- Radiation storms may impact aviation at cruising altitudes (usually in polar regions, but can extend equatorward in an extreme event), resulting in heightened radiation exposure to passengers and crew, as well as possible damage to avionics microelectronic circuitry through 'single event effects'[5].

There is also ICAO provision for advisories to be issued on satellite communications impacts, however the threshold for issuing this advisory type is not yet agreed.

Unlike for volcanic ash and tropical cyclone advisories, there is **no** SIGMET service for space weather events. Further, there is no requirement for NOTAM[6] to be issued. This is due to the potential information overload for aviation, if all States with meteorological watch offices or NOTAM offices all issue the exact same advice. While space weather advisories have sections for **forecast** impacts, currently only the **observed** section is utilised, due to the difficulty in providing accurate 6-hour granularity of forecast detail as defined by ICAO. This means the ICAO system currently has no advance warning

[2] See the Australian Bureau of Meteorology 'Knowledge Centre' brochures on Space Weather Impacts on Aviation and on ICAO Space Weather Advisories.

[3] The 215th session of the ICAO Council (2018) agreed on the designation of the three global space weather centres: the ACJF (Australia, Canada, France and Japan) consortium, PECASUS (Finland, Belgium, UK, Austria, Germany, Italy, Netherlands, Poland, Cyprus) consortium, and the United States, with the China/Russian Federation consortium added as a fourth centre in 2021. The space weather centres operate on a duty roster basis, where each centre has a two-week period on duty, then rotates through backup and maintenance periods.

[4] The alerting thresholds that define when an advisory should be issued can be found in Manual on Space Weather Information in Support of International Air Navigation (ICAO Doc 10100)

[5] https://radhome.gsfc.nasa.gov/radhome/see.htm

[6] A notice containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.

capacity and users must instead use various national space weather centre-based products to ensure situational awareness. Consideration is being given to issuing space weather advisories that include situational awareness information in a remark (RMK) field.

For situational awareness products, many national space weather forecast centres offer websites and/or free email subscriptions for their warning products, such as the United States of America's Space Weather Prediction Center, the Australian Space Weather Forecasting Centre and the United Kingdom's Met Office Space Weather Operations Centre. All these websites contain useful educational material, including an excellent video from the Australian Bureau of Meteorology.

It is worth noting that while the ICAO space weather advisory contains information on the direct impacts on aviation, there are many second and third order impacts that could result in considerable disruption to both transport sectors and wider public services. These are well described in documents such as the Australian Space Weather Alert System and of significant concern is the impact on national power grids. This is due to the effect of a geomagnetic storm inducing currents along long conducting lines such as power transmission lines – potentially resulting in a destroyed transformer. It has been estimated that an extreme geomagnetic storm could result in global power blackouts for up to three years, due to the time it would take to rebuild power grids.

Another significant impact that may occur due to space weather, is the potential damage to satellites – critical for not only weather forecasting, but also positioning and communications, as well as providing timing information for financial transactions. In coordination with power outages, while planes may be physically able to fly, in an extreme event they will likely not be able to check in or screen passengers and cargo, plan for flights or likely even refuel aircraft. The impacts are likely to be similar for other transport sectors.

The Panel, in discussing space weather, noted the criticality of Samoa's contribution to the monitoring of geomagnetic data, via the Apia magnetic observatory. It was noted that the Apia observatory is one of the few magnetic observatories in the South Pacific, alongside those in Easter Island and Papeete, with others in locations such as Port Moresby and Kiribati having closed some decades ago[7]. In the North Pacific, the US Geological Service operates magnetic observatories in Guam and Honolulu.

Given the importance of geomagnetic monitoring to observing the impacts of space weather, the Panel invites the PMC to consider the utility of reviewing the suitability of the density of the observation network across the Pacific for geomagnetic monitoring. Further, it is important to consider how that data is shared globally, to ensure it is available in near real time for maximum use for space weather warnings.

[7] From the British Geological Survey World Data Centre for Geomagnetism Data Portal

Recommendations:

The Meeting is invited to:

- **Note** the risk to transport and public infrastructure operations posed by significant space weather events.
- **Encourage** the sharing of information on space weather with relevant government organisations for effective planning for extreme space weather impacts.
- **Recommend** capacity building for Pacific Island meteorological services in their understanding of space weather.
- **Recommend** a review of the suitability of the density of the observation network across the Pacific for geomagnetic monitoring, and how that data is shared globally.