Increasing Solar Activity and the Effect on GNSS Positioning

Global Navigation Satellite Systems (GNSS) have revolutionised the way we navigate and locate ourselves on the surface of the Earth. However, GNSS signals are prone to interference and one of the most significant sources of interference is increased ionospheric activity.

Increased ionospheric activity is correlated with the following factors:

- Sunspot activity – increased ionospheric activity linked with the 11-year solar cycle.
- Solar and magnetic storms – cause an increase in the ionospheric activity.
- Geographic location – highest activity along the geomagnetic equator and in auroral (polar) regions.
- Seasonal variations – increased activity at the vernal and autumnal equinoxes.
- Diurnal (daily) variations – maximum effects normally experienced one hour after local sunset until midnight.

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. Below shows a graph of activity produced by the Space Weather Prediction Center (www.swpc.noaa.gov).

The current solar cycle 25 started in December 2019 and will continue to around 2030 with an expected peak in July 2025. This cycle is already showing signs of exceeding the predicted levels with significantly increased levels of solar activity escalating faster than expected.

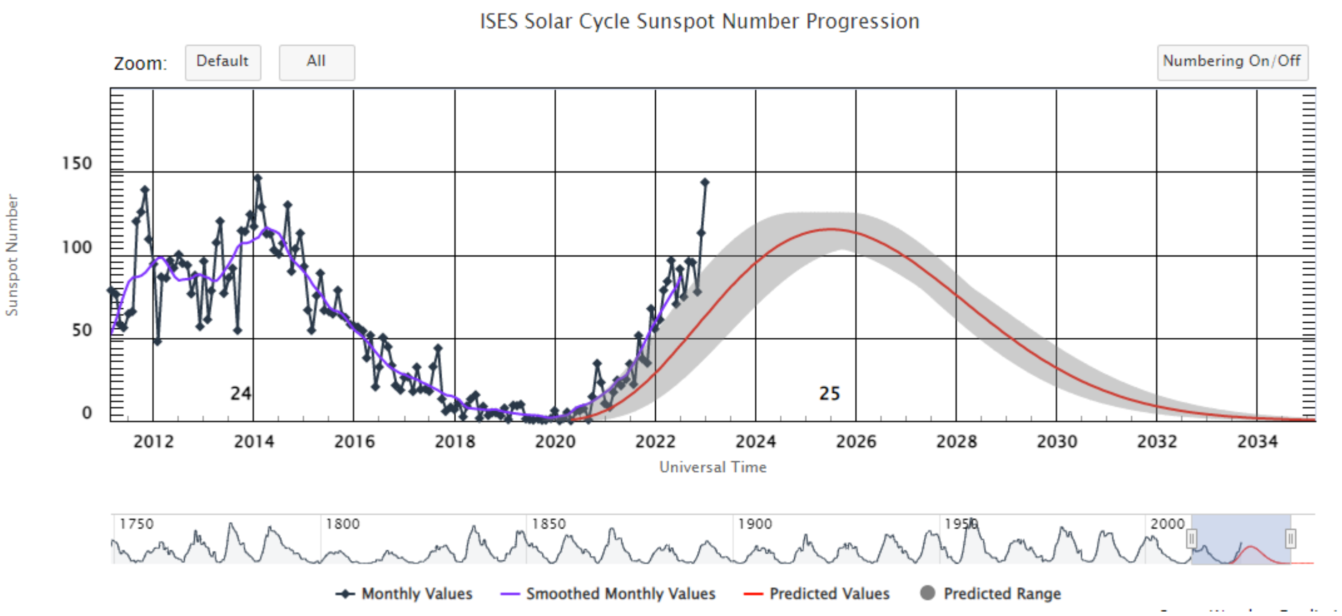

Figure 1 – Predicted Sunspot Activity

GNSS signals are prone to interference as they travel through the Earth's ionosphere. The ionosphere is a layer of the Earth's atmosphere that contains a high concentration of ionized gas molecules. As GNSS signals pass through the ionosphere, they may be refracted or slowed down. The ionosphere is not uniform, and the density of the ionized gas varies with location and time. The variation in the ionosphere is amplified during periods of increased solar activity and there are two different effects that are experienced by the user of GNSS systems:

1 Increased ionospheric activity can introduce large errors/biases (up to 15 metres) into single frequency DGNSS because of the failure in the differential process to cancel the effects of the ionospheric delay between the reference station and the user.

These effects can be mitigated by the use of dual or multi frequency GNSS systems which don't model but instead measure the ionospheric error. However, dual frequency is not a guarantee of preventing DGNSS from dropping out.

2 The second effect is scintillation which is the rapid fluctuation in the amplitude and phase of the GNSS signals as they pass through the ionosphere. These fluctuations can have a significant effect on the accuracy of the GNSS positioning and can even cause complete loss of signal. Scintillation occurs mainly in the evening along the geomagnetic equator. It has the effect of causing fluctuations in the amplitude and phase of the carrier phase signal, introducing noise, or causing loss of lock to the satellite. This results in a reduced number of usable GNSS satellites and occasionally a reduction in the L-band communications link strength, causing intermittent reception of the augmentation data. Scintillation effects are normally seen in a period of six hours after sundown but are not predictable.

Although there is no way to eliminate the effects of scintillation, the following steps may help mitigate the impact of scintillation:

- Use of multi-constellation, multi-frequency GNSS solutions to increase the number of observations available to the position solution (will help in the majority of situations but not all).
- Use of multi beam L-band (at least two independent downlink satellites) to ensure that corrections can still be received if lock to one satellite is lost.
- Selection and use of GNSS receivers and services from different service providers to benefit from any temporary improvement in performance associated with differences in hardware, firmware, or software.
- Use of GNSS+INS solutions to minimize any impact on position solution if satellite tracking impacted. However, these INS solutions are time dependant and will degrade until the DGNSS signal is restored.

Although these steps may mitigate the effects of scintillation, in some extreme circumstances all GNSS and L-band signals may be lost, resulting in total loss of GNSS positioning. The following steps are recommended:

- The impact of increased ionospheric activity and the potential to lose both stable satellite and L-band communications is taken into consideration during risk assessments when planning critical offshore activities.
- Selection and use of additional non-GNSS DP positioning reference systems to mitigate the potential for loss or instability of GNSS position during risk periods (e.g., integration of Inertial Navigation Systems (INS) or use of additional acoustic, optical, radar or other reference systems).
- Increased vigilance of DP operators for scintillation effects, especially after sunset.

If the vessel owner does not have these options, the operator should be cautious and make sure that the offshore management teams are aware of the potential for GNSS positioning disruption due to increased ionospheric activity and scintillation. To reduce the operational impact of these events, ASOG and CAM configurations should continue to be strictly adhered to in terms of diversity of position reference systems. The DP vessel and offshore crew must be prepared for GNSS failure. Something that occurred for several hours during the previous cycle in 2013-2014.

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Related Guidance

- IMCA M 220 – *Guidance on Operational Activity Planning*
- IMCA M 252 – *Guidance on Position Reference Systems and Sensors for DP Operations*
- IMCA S 013 – *Deep Water Acoustic Positioning*
- IMCA S 015 – *Guidance for GNSS Positioning in the Oil and Gas Industry*
- IMCA S 024 – *Guidance on Satellite-based Positioning Systems for Offshore Applications*
- IMO/MSC 645/ 1580
- www.swpc.noaa.gov
- https://www.septentrio.com/en/company/septentrio-gnss-technology/iono-ionospheric-scintillation-monitoring
- www.gnssplanning.com