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DATE: 20 – 22 August 2025

The impact of an Extreme space weather storm on GNSS applications in South Africa

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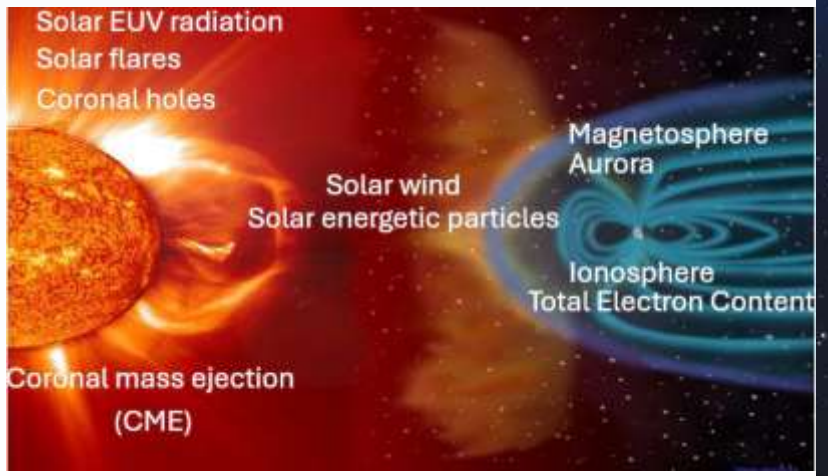
Space Weather

Space weather refers to the conditions on the Sun and in space including the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of technological systems both airborne and ground based.

- **WHY**
  - To protect critical infrastructure like **GNSS,** power grids, aviation, and communications.
  - South Africa through SANSA, has received designation a regional centre for space weather from the international Civil Aviation Organization (ICAO).
  - To aid with informed decision making and mitigation measures.
- **HOW**
  - Ground based and satellite-based instrumentation(Magnetometers, Ionosondes, SOHO ,GOES X-ray etc.).
  - Prediction models (WSA-ENLIL model, persistence)
  - Global and regional collaboration.
- **WHAT**
  - Space weather bulletin, **Alerts /Warnings(HF and GNSS)**, HF predictions, Research, Science Engagements.



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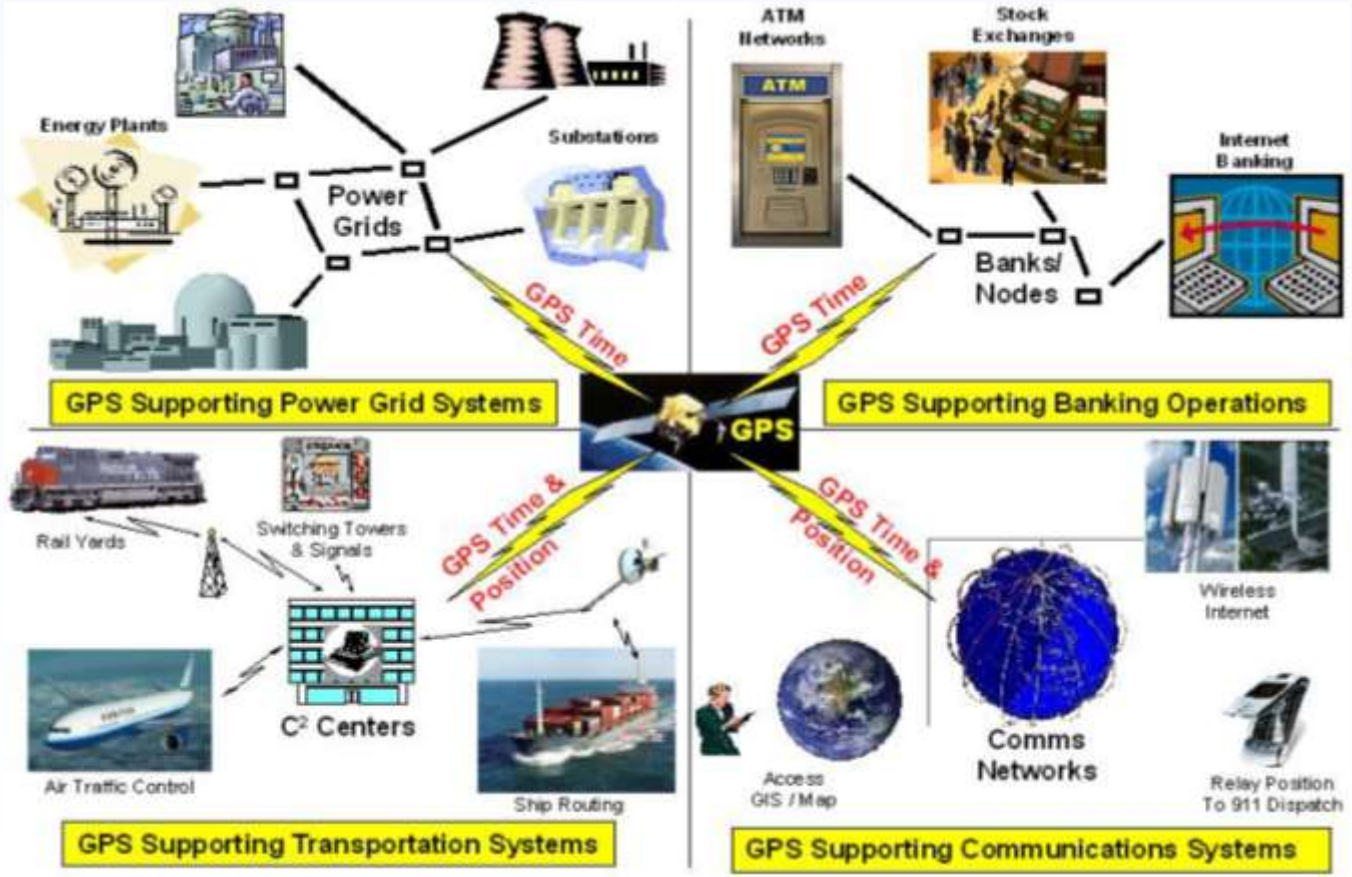
GNSS dependent systems

Space weather can degrade and possibly deny access to satellite positioning, navigation and timing services which are key to operations many infrastructures.



Signal delay
Positioning errors
Geolocation errors
Reflection or distortion

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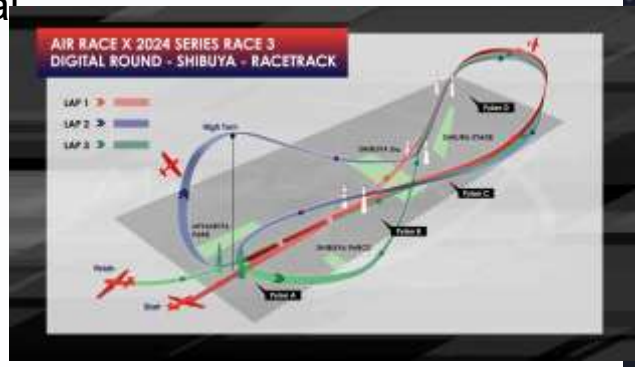
06-12 October 2024 Geomagnetic storm

- Multiple coronal mass ejections (CMEs) associated with filament eruption and flaring activity that occurred 03 and 09 impacted Earth on 06-12 October 2024.
- Geomagnetic condition reached G5/Extreme storm levels (Kp 9) on 10 October 2024.
- Impacts Globally: The Extreme storm may have resulted in an early re-entry of a Starlink satellite, SL 1089 (Oliveira *et al.*,2025).
- **Problem**: Limited of South African examples to show the regional impact.
- **Significance of Case study**: The South African National Space Agency was responsible for the provision of space weather information to Team 77 during the **AIR race X** competition qualifying rounds.



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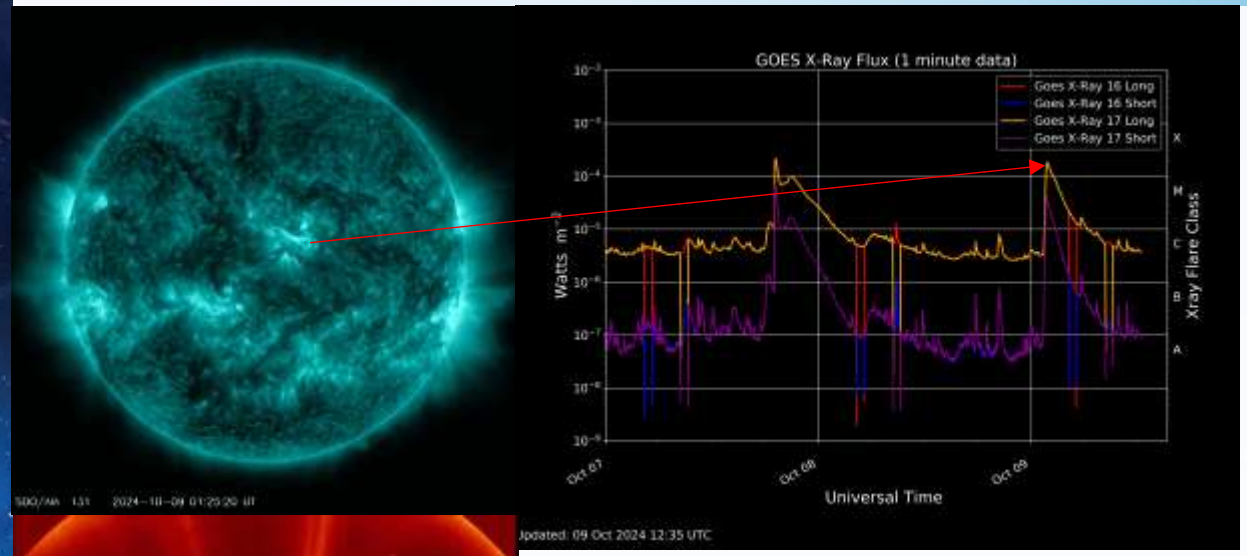
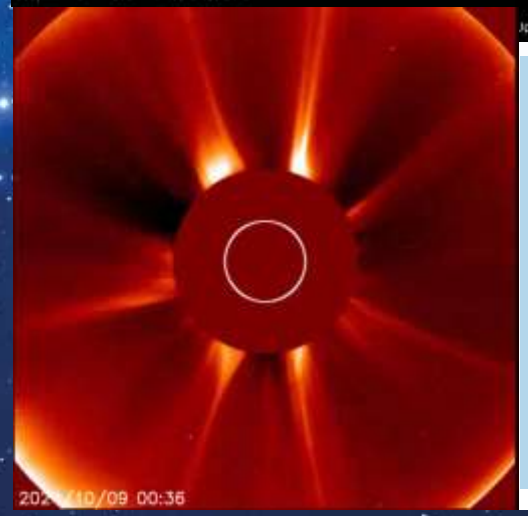
Observations from Sun





- Multiple CMEs associated with X-class flares and filament eruptions were observed on 03-09 October 2024.
- An X1.8 flare on 09 October 2024 at 01:56 UT resulted in an Earth directed CME.

Coronal mass ejection (CME)- an ejection of material from the sun's surface into interplanetary space.
Solar flare- A sudden bursts of magnetic energy in the form of electromagnetic radiation(X-ray and UV).Only has day side Impact.
Solar Energetic Particles -High energy electrically charged particles that can travel with speed close to the speed of light.
Filament- A mass of gas suspended over the chromosphere by magnetic fields.

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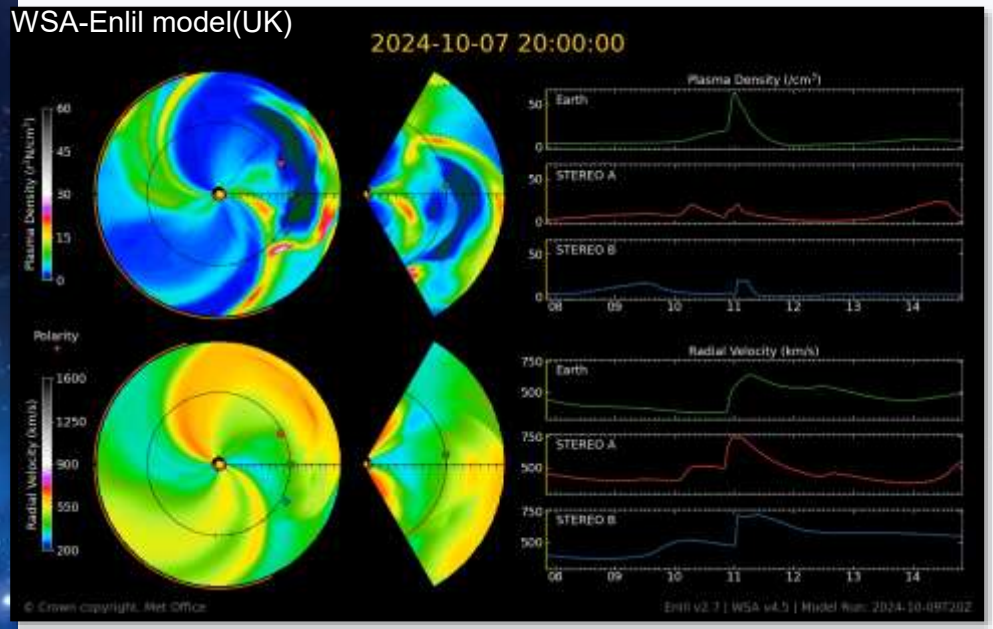
Predictions and Forecast

WSA-Enlil model(UK)



Space weather Prediction Centre (USA)

Geomagnetic Forecast(Met Office Space Weather Operational Centre)

Geomagnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	Yes	80	80	60	20
Strong	G3	No	40	50	20	1
Severe	G4	No	10	20	5	1
Extreme	G5	No	1	5	1	1

OUTLOOK; Issue date 10 October 2024

Geomagnetic activity is expected to be at quiet to active levels (Kp 1-4). This is due to continuous CME influences and/or new arrivals and the HSS from CH78/+.

SYSTEMS THAT MAY BE AFFECTED;

HF communication and GNSS.

Text from SANSA space weather Centre Bulletin

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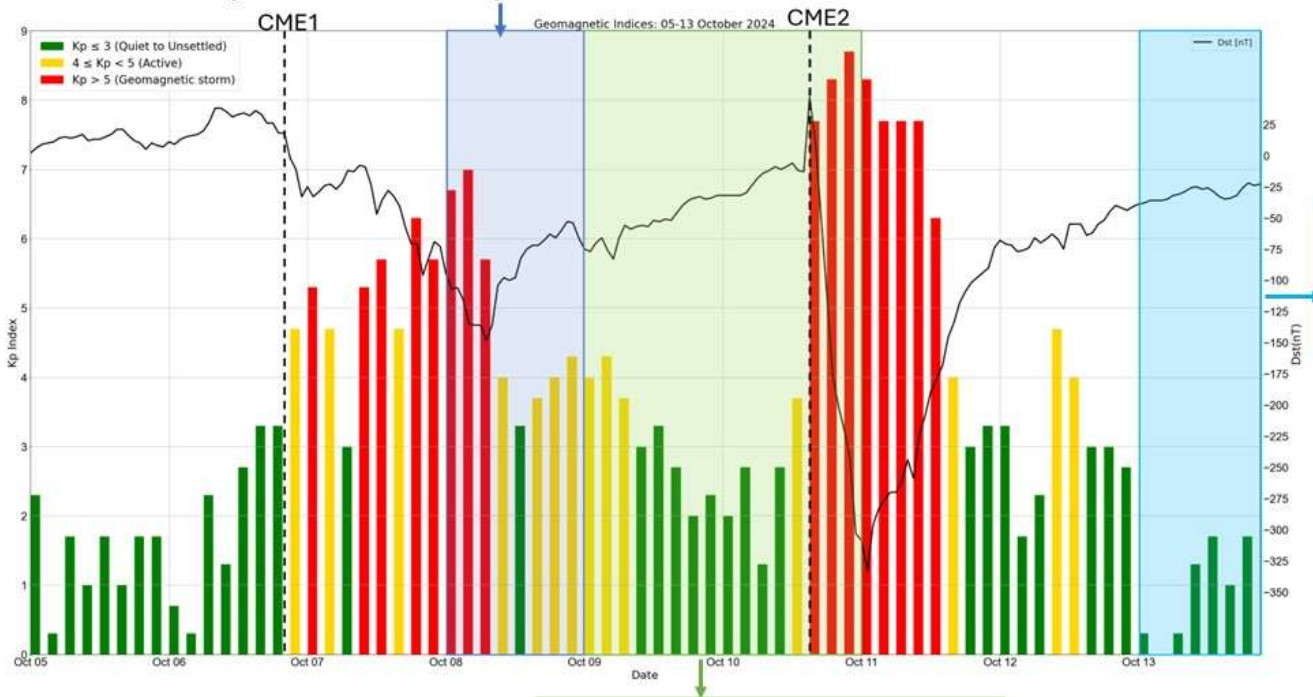
Ground based observations

- Storm1:Practice Run 1 to confirm that pylon markers were in the correct place.
- Practice run 2 and 3 to collect data to plot collect lines to fly.



Two days of practice with 11 rounds, two aborted missions ,16 penalties and no clean run.

13 October-First qualifying run logged in ,with the pilot securing his spot for the final round as part of the top 3.

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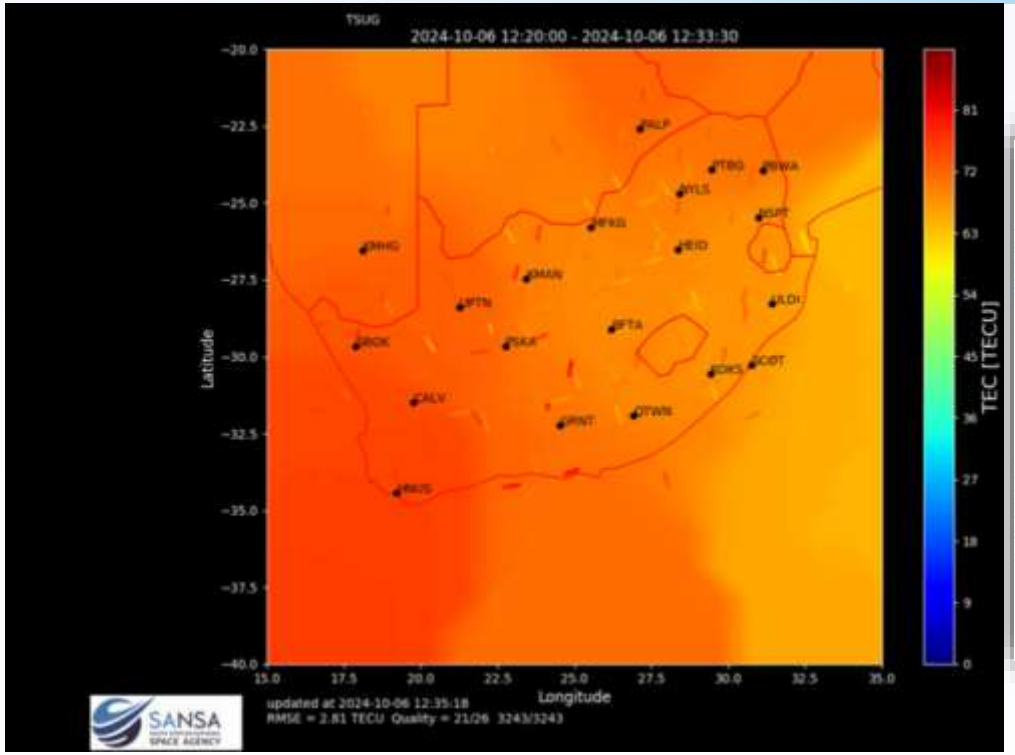
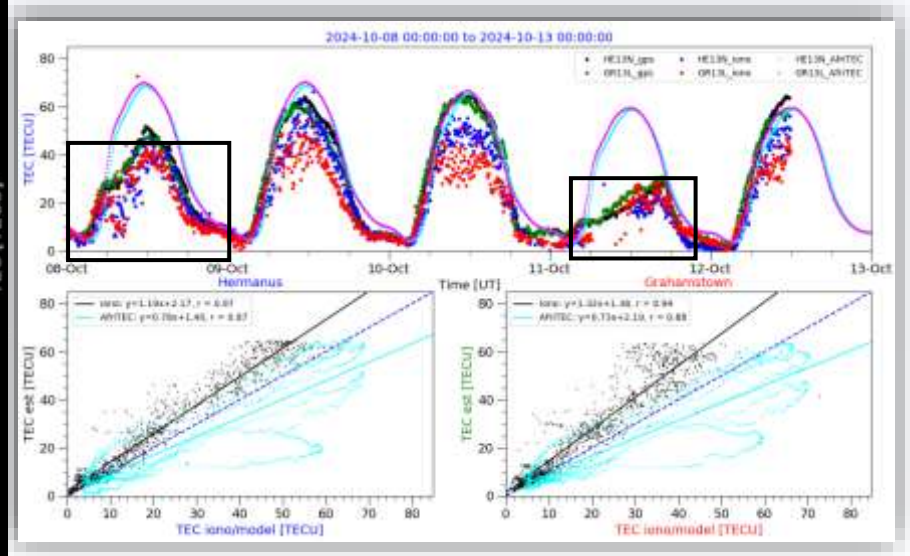
Ionospheric Conditions





SANSA Near Real time TEC map and Evaluation (Matamba and Danskin,2022)

- A negative ionospheric storm effect which refers to a decrease in ionospheric electron density was observed on 08 and 11 October 2024.
- This affected the reliability and accuracy of GNSS.

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Conclusion

- It is important to understand space weather impact modern technologies as society is increasingly reliant on them.
- To ensure the resilience of GNSS dependent technologies , continuous monitoring, forecasting, and development of predictive models for space weather are essential.
- The 2024 October Extreme geomagnetic storm demonstrates that space weather can also have significant regional impact ,particularly in South Africa.
- Space weather products and service were used a support tool to make an informed decision during the geomagnetic storm.
- Regular user feedback helps link their data with space weather data in turn improving development of more tailored product and services.

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