SOUTH AFRICAN NATIONAL SPACE AGENCY
(SANSA)

Space Weather: Operational Focus

Dr Mpho Tshisaphungo

Regional Seminar on Aeronautical Meteorology

4-6 June 2024

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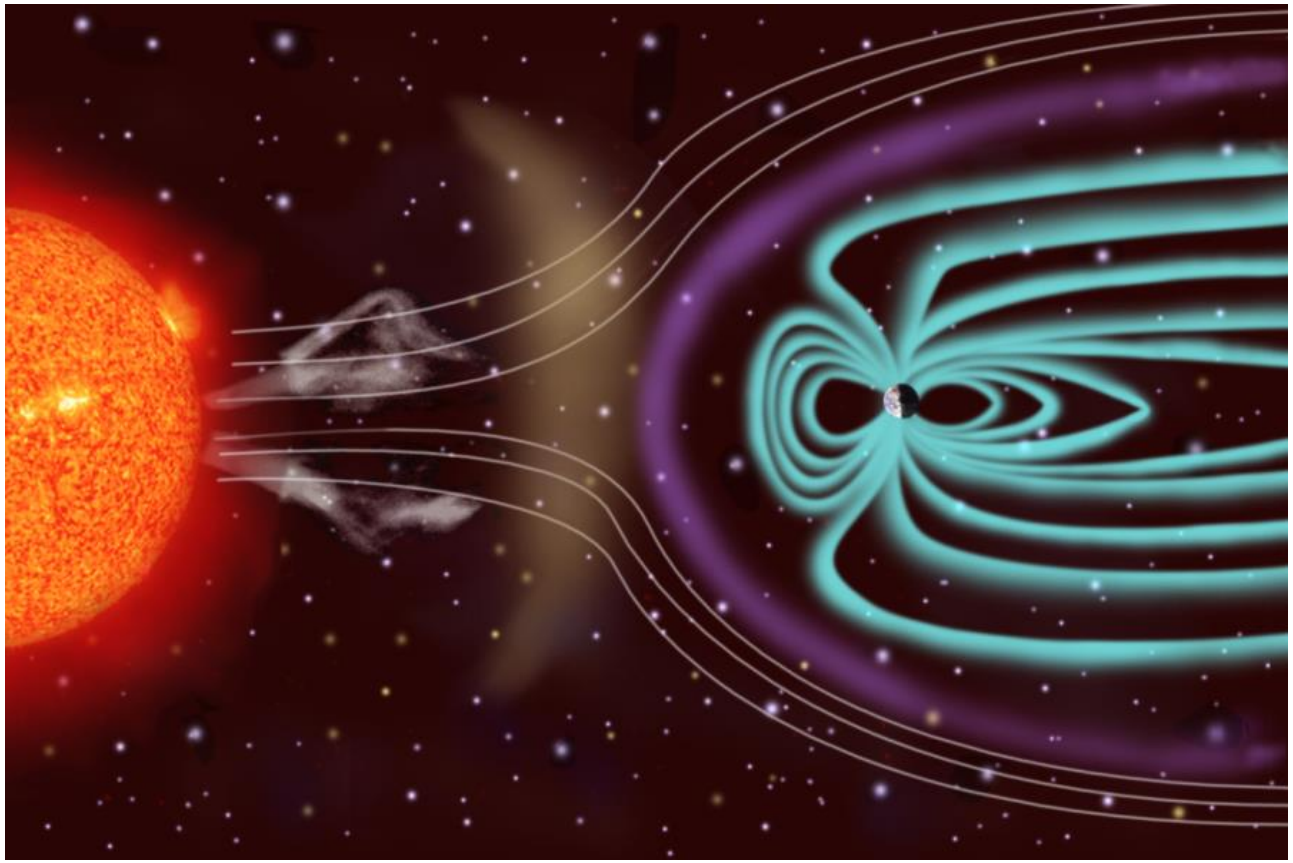
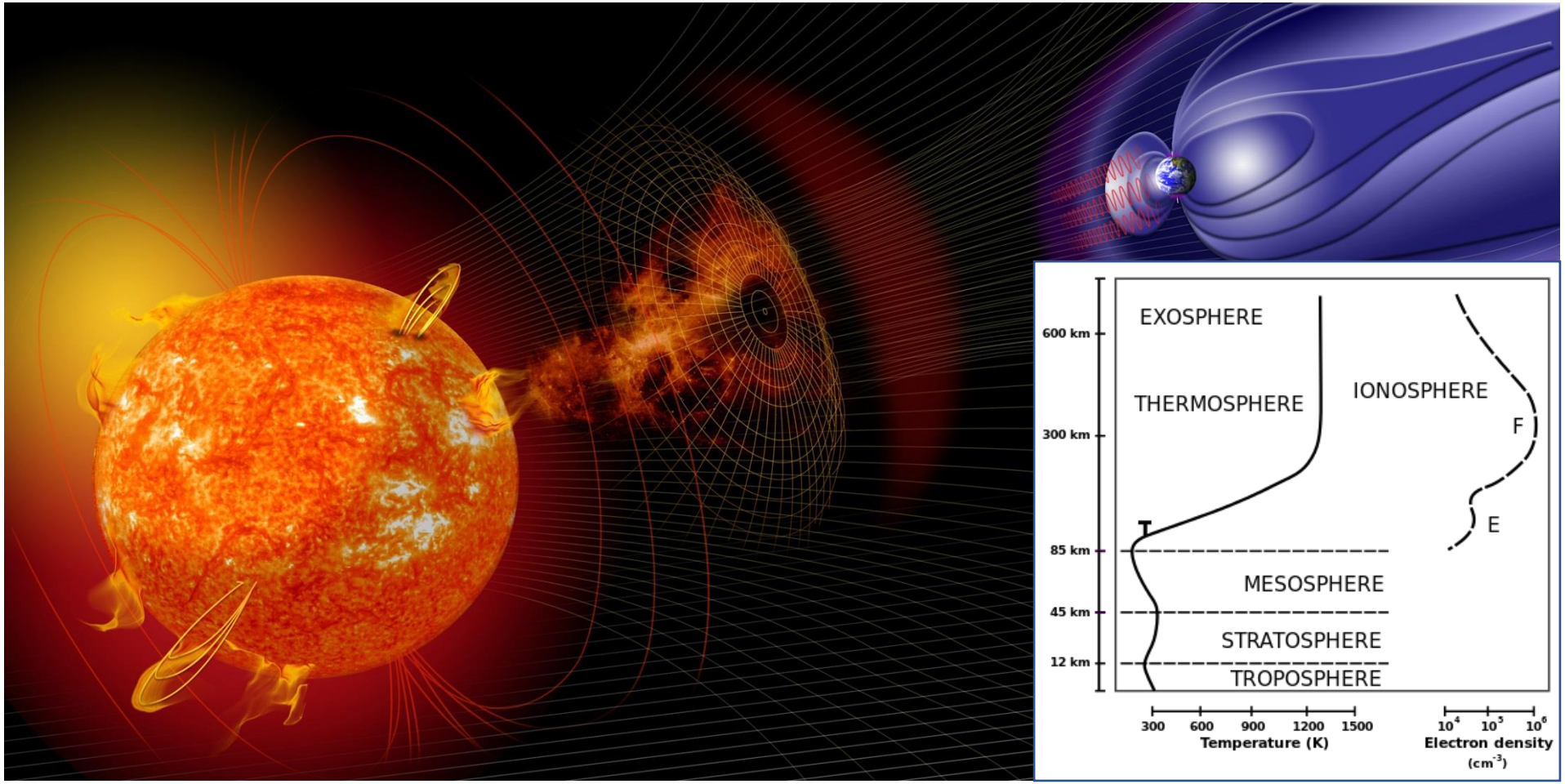
OUTLINE

- MONITORING AND FORECASTING
- SPACE WEATHER DATA
- SPACE WEATHER EVENTS
- CONCLUSION

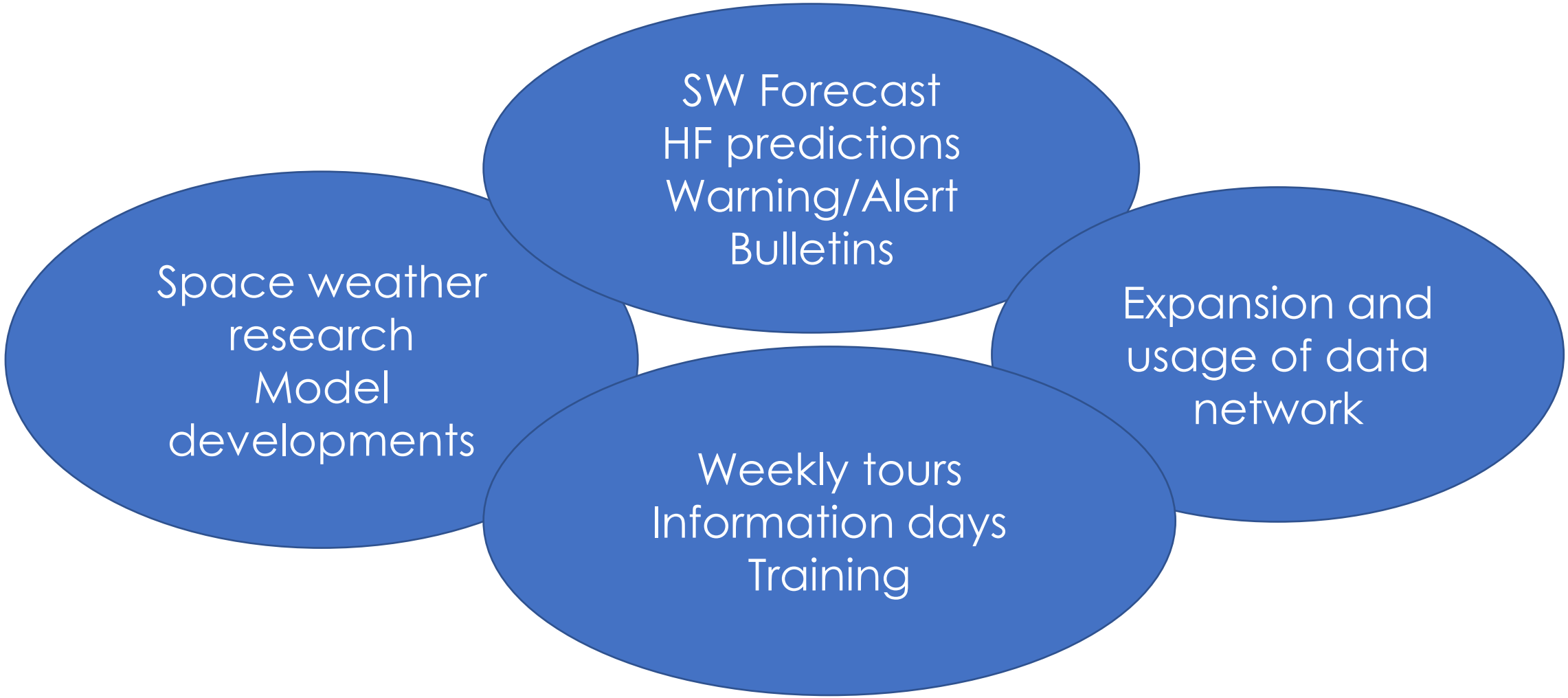


MONITORING AND FORECASTING (OPERATIONAL FOCUS)

WHAT ARE WE MONITORING AND WHERE IN SPACE ?



SPACE WEATHER CENTRE'S ACTIVITIES



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Space weather observations, monitoring, forecasting and prediction of space environment and its impact on technological systems

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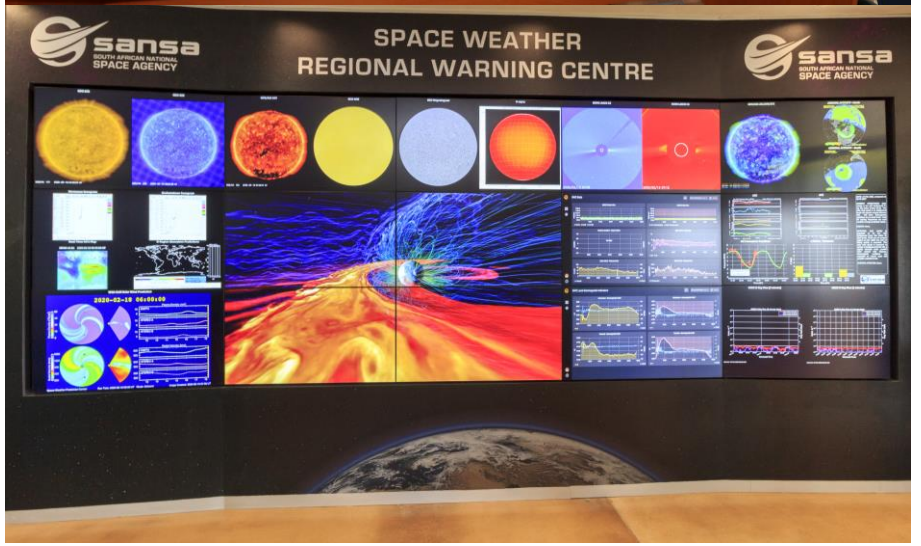
Operational Responsibilities of a Space Weather Forecaster

- Deliver space weather services to customers.
- Make use of available data and model results.
- Analyse current space weather conditions based on data and models.
- Prepare a forecast of what is likely to happen in the future based on space weather information.
- Package the space weather information as required by a customer.
- Send current information, warnings, and alerts to the end-users.
- Continuous monitoring of space weather conditions.
- Constant engagement with the end-users.



SPACE WEATHER DATA

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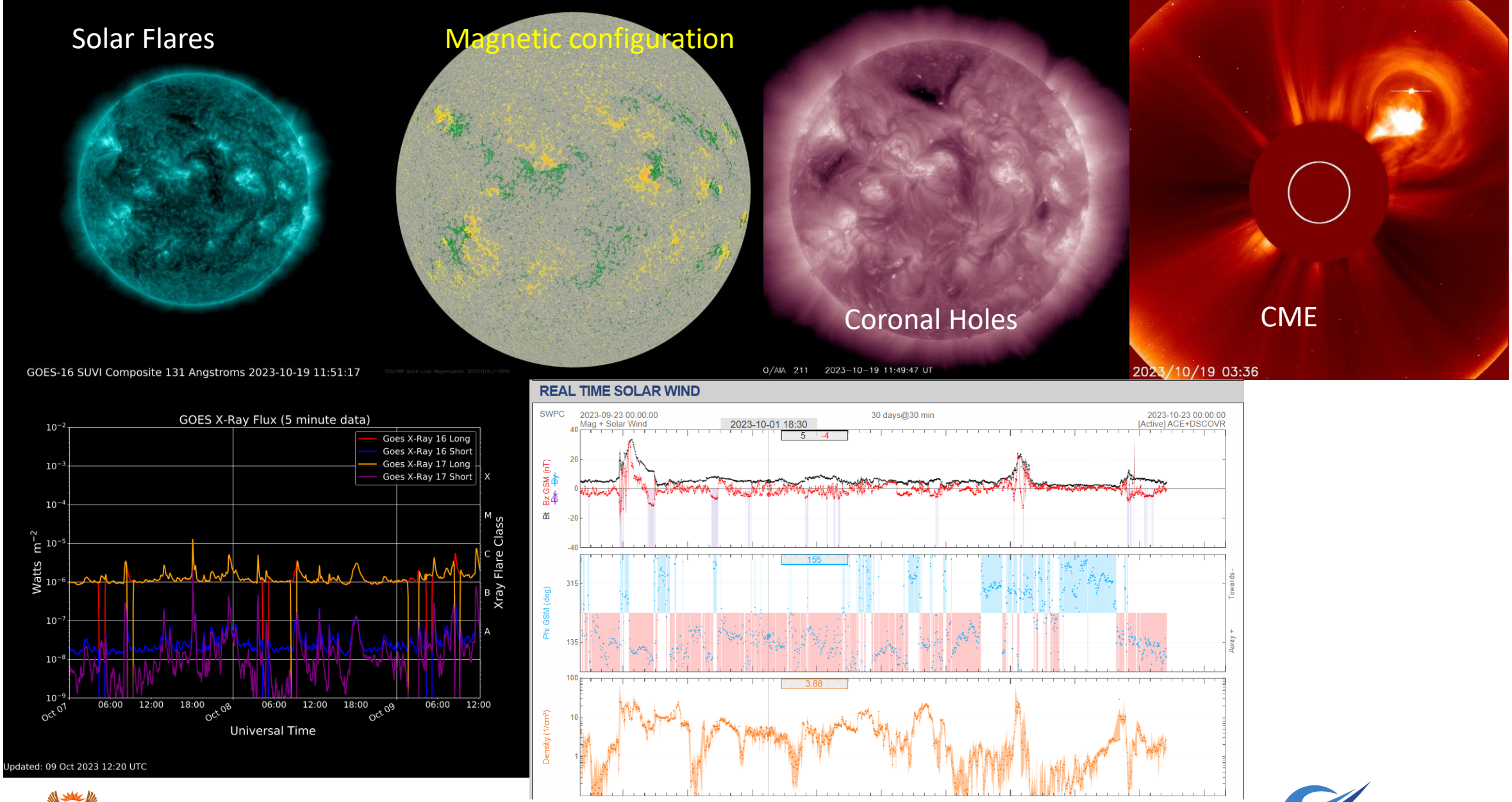

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Satellite data

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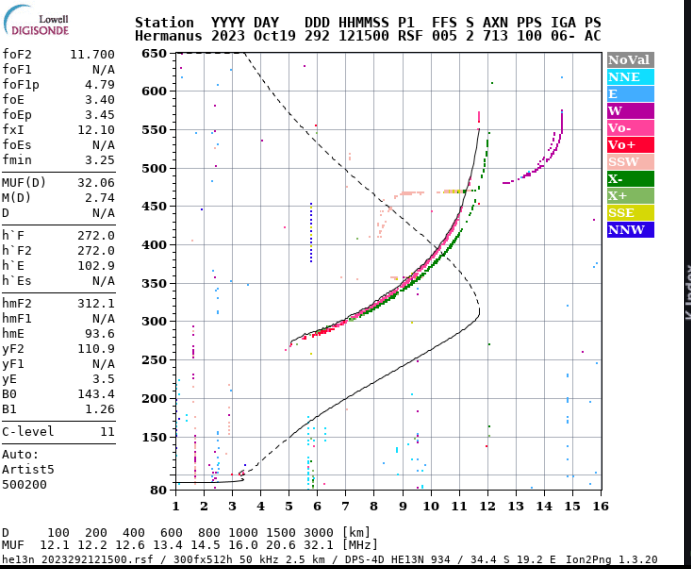

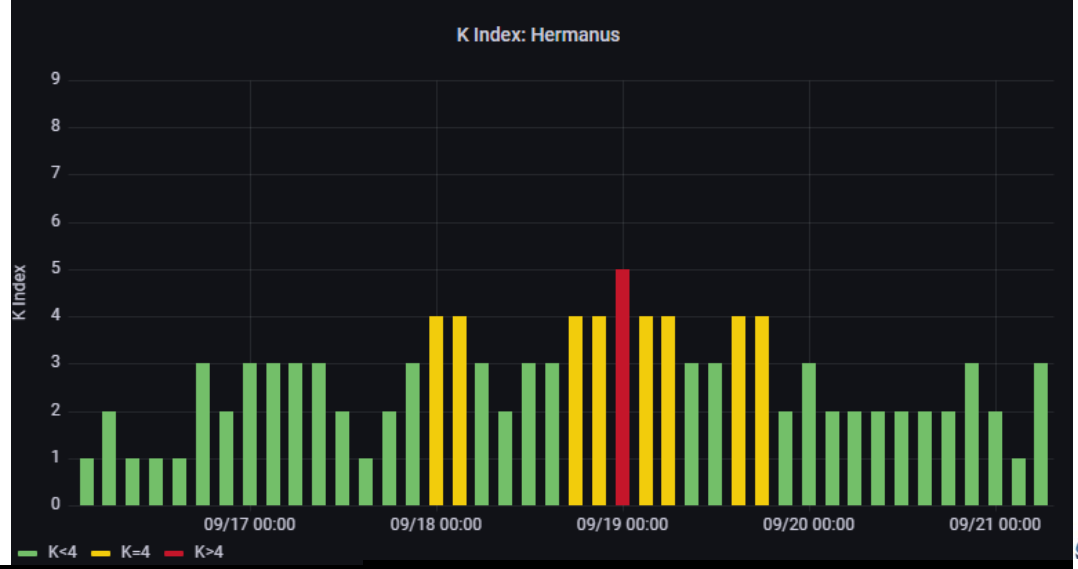

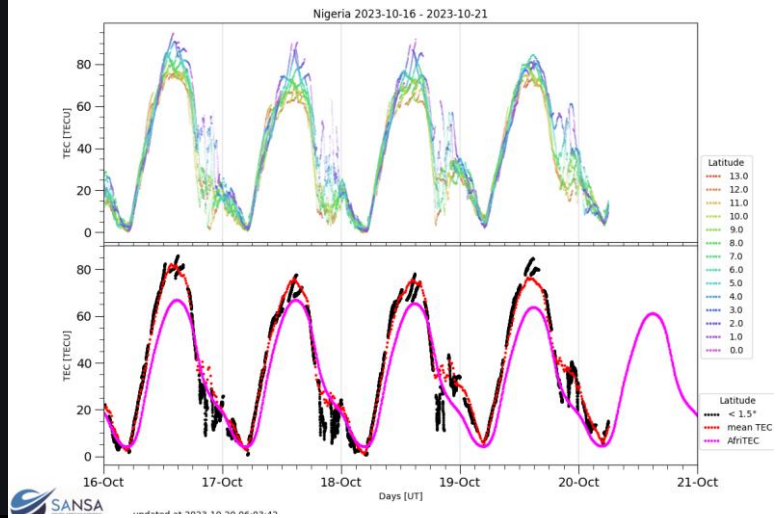

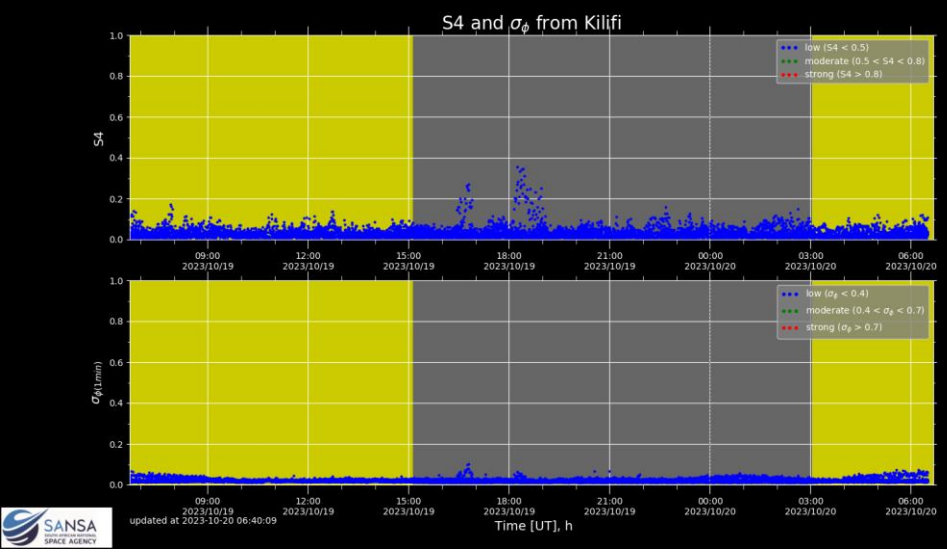

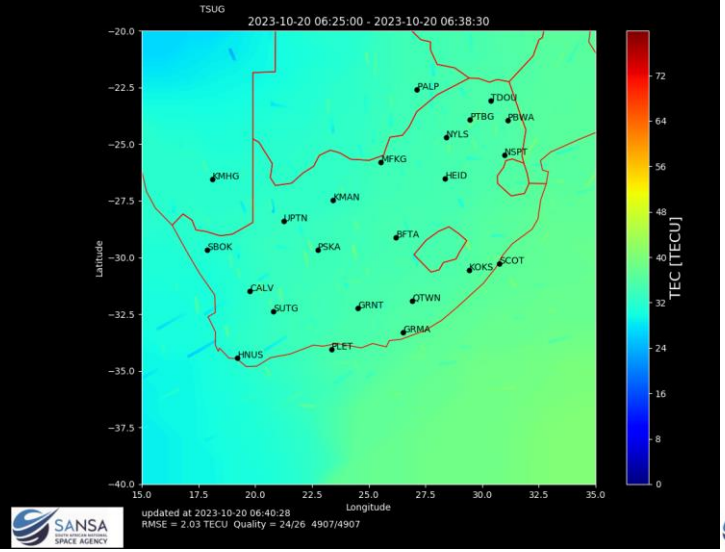

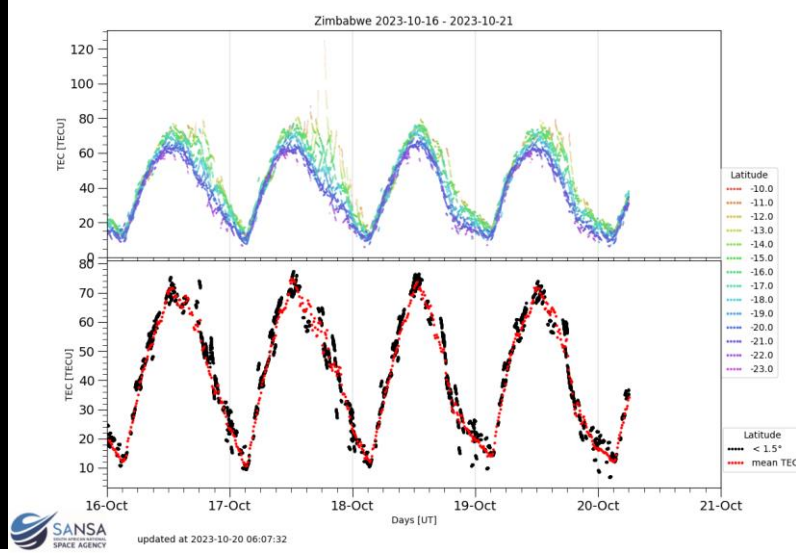

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Ground-based data

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AFRICAN PARTICIPATION – AIN

AFRICAN INSTRUMENTATION NETWORK

Current Partners:

Zimbabwe
Zimbabwe National Geospatial and Space Agency (ZINGSA)

Nigeria
University of Lagos (UNILAG)

Ethiopia
SSGI & EORC

South Africa
- South African National Space Agency (SANSA)
- National Geospatial Information (NGI) TRIGNET

Zambia
Kwame Nkrumah University (KNU)

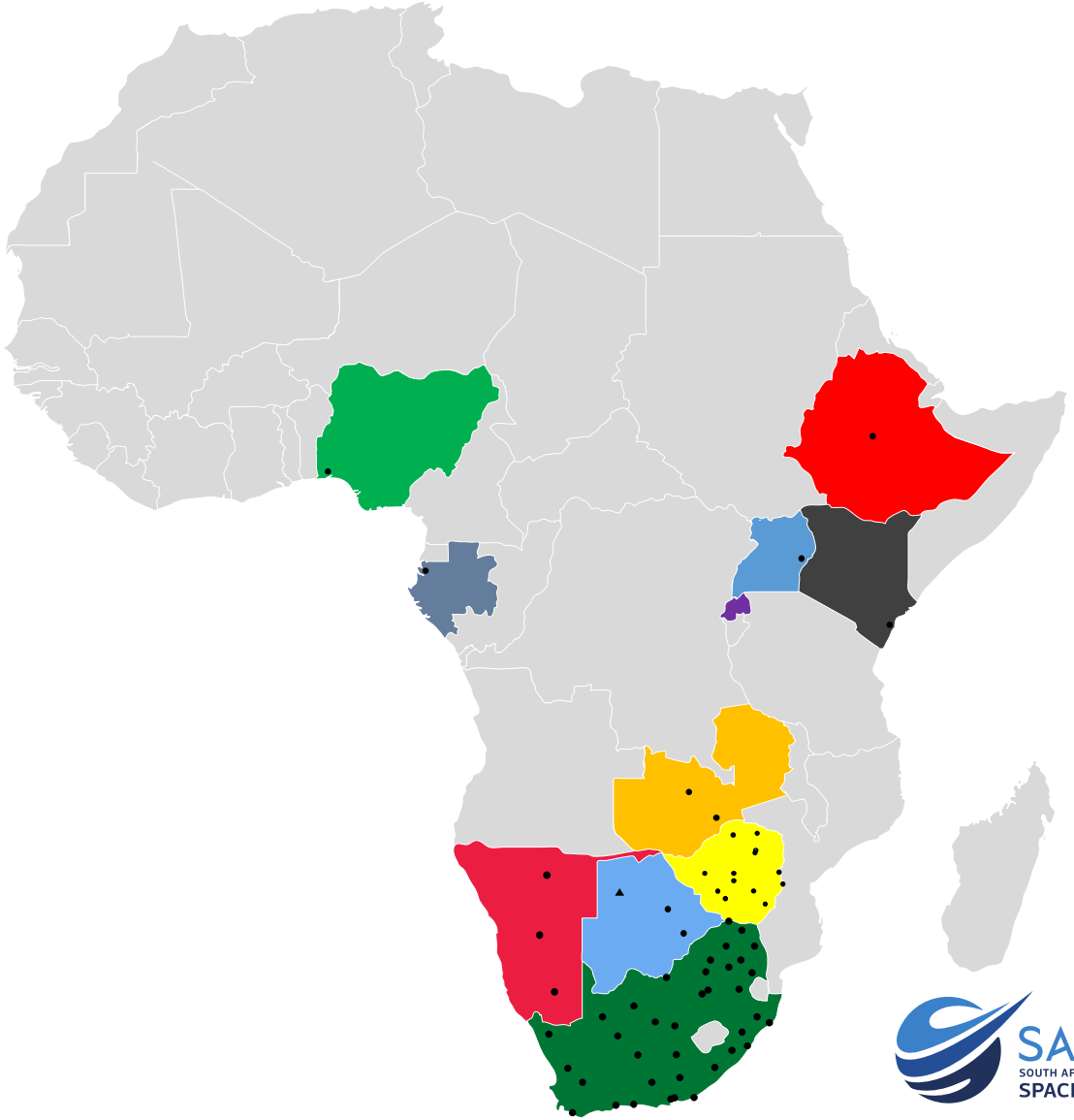
Namibia
Ministry of Mines and Energy (MME)

Uganda
Busitema University (BU)

Kenya
Pwani University (PU)
Kenyan Space Agency (KSA)

Gabon
L'Agence Gabonaise d'Etudes et d'Observations Spatiales (AGEOS).

Botswana
Botswana International University of Science and Technology (BIUST)



More to come!

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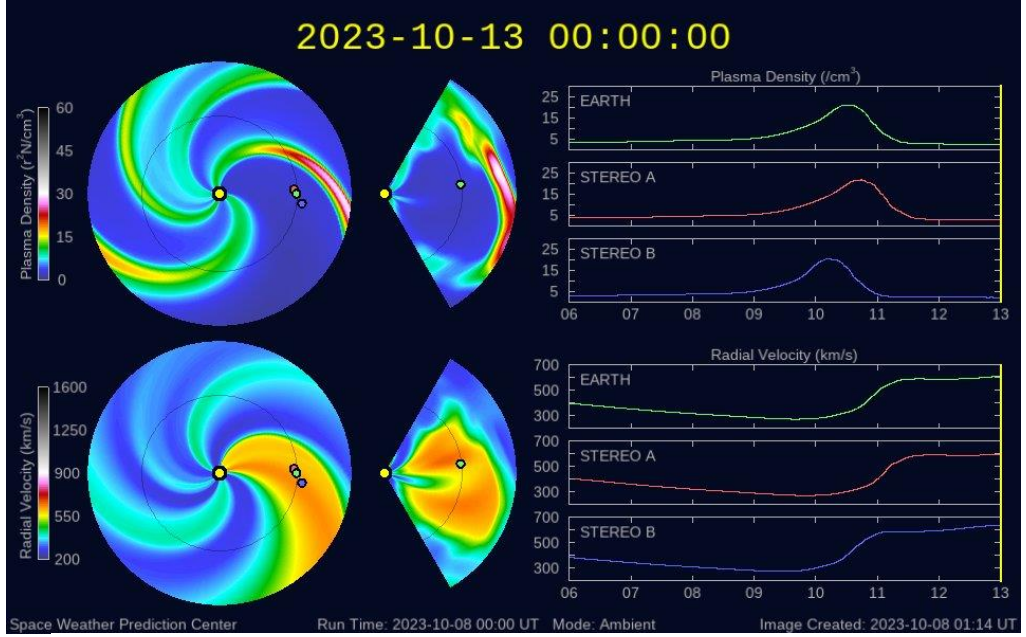
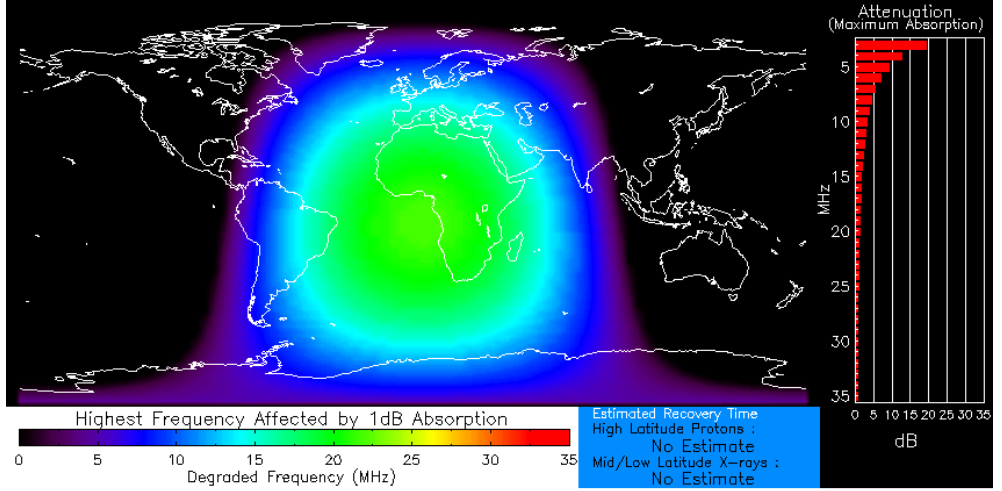
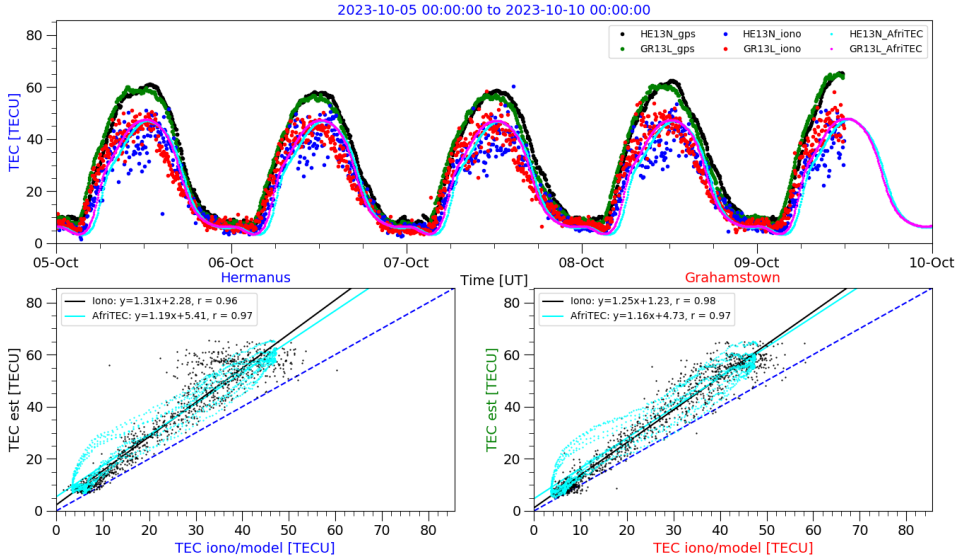
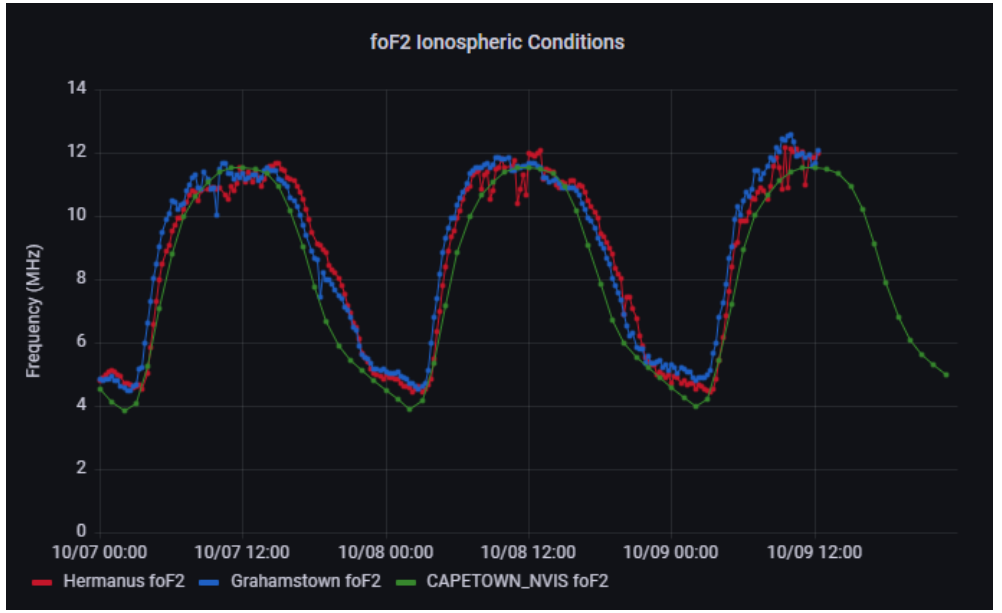




Elevated X-ray flux
Product Valid At : 2023-10-09 11:43 UTC

Normal Proton Background
NOAA/SWPC Boulder, CO USA





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Space Weather Models

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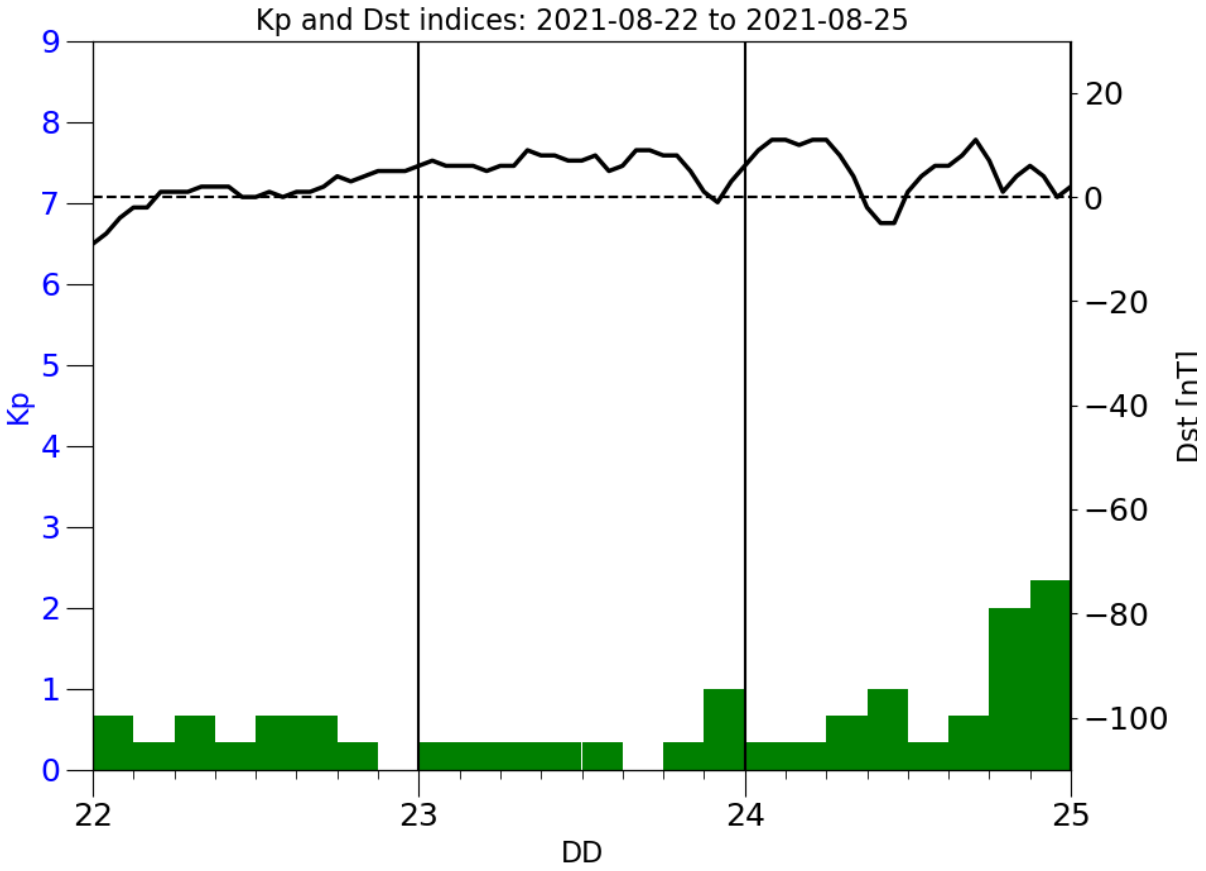
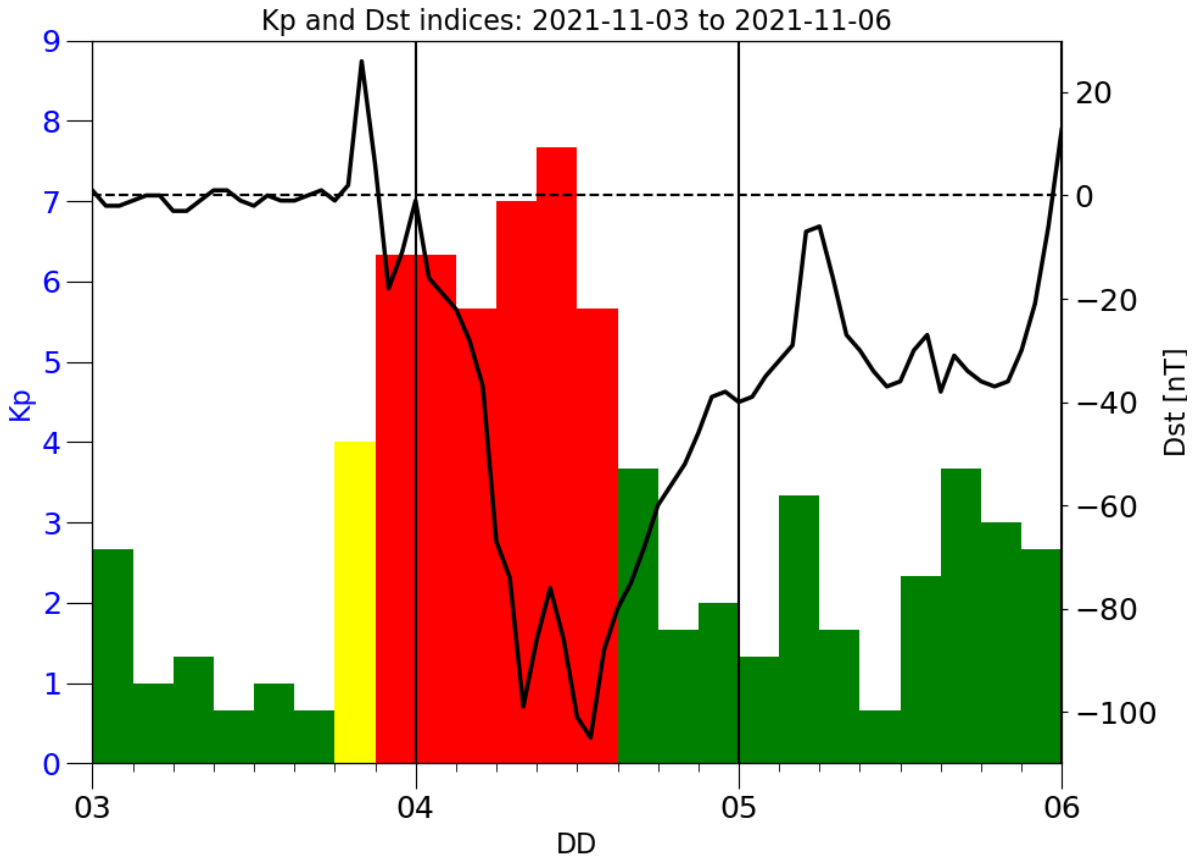
SPACE WEATHER EVENTS

Example: Kp and Dst Index for quiet and disturbed days





NOAA Scales Geomagnetic Storms					
Kp < 5	Kp = 5 (G1)	Kp = 6 (G2)	Kp = 7 (G3)	Kp = 8, 9- (G4)	Kp = 9o (G5)

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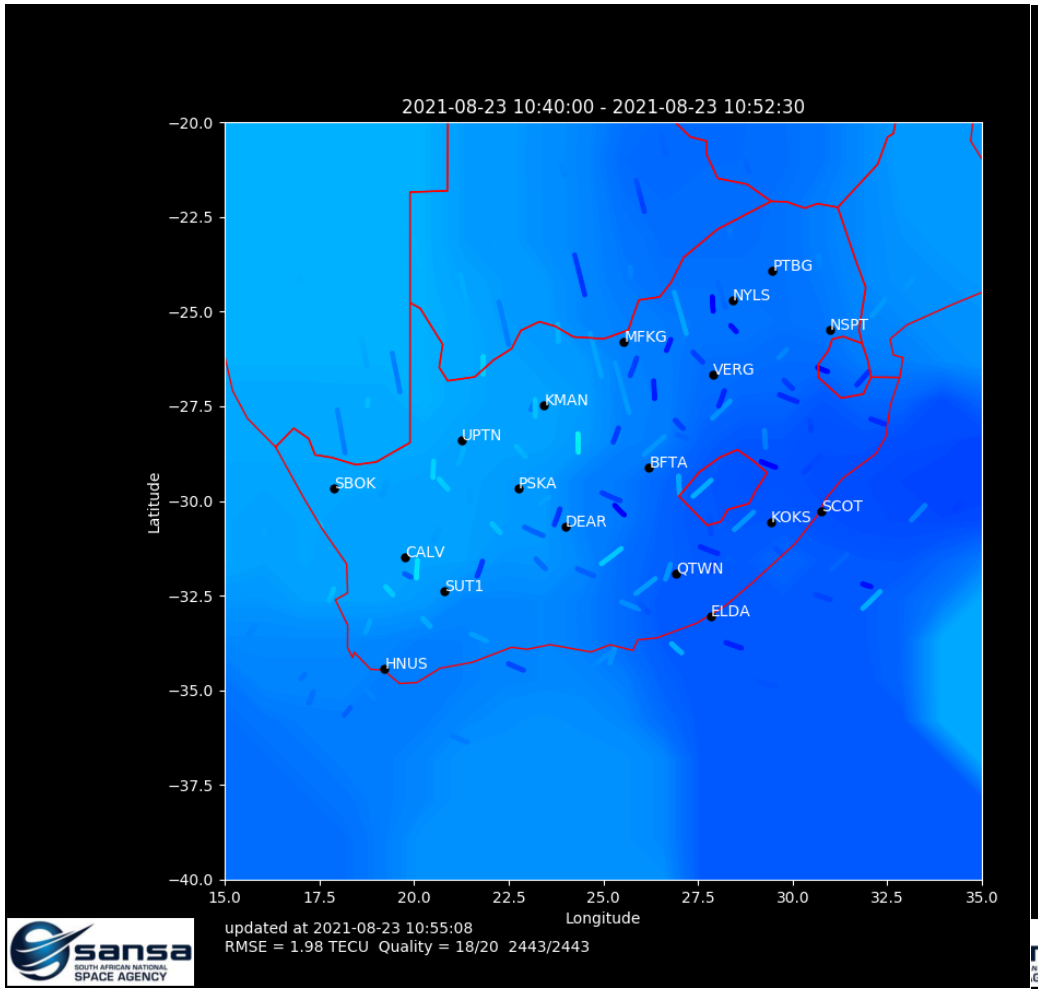
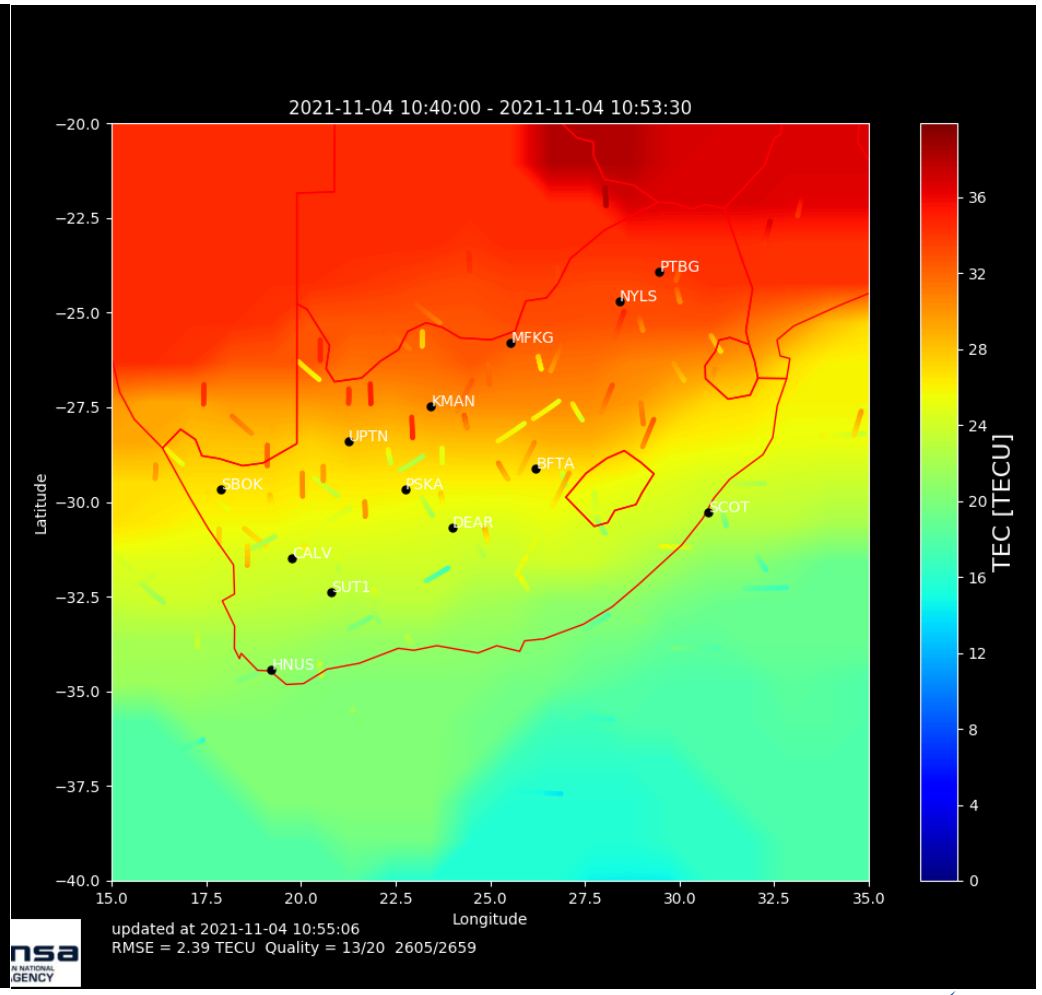
IONOSPHERIC VARIATION

Typical day, **Kp = 1 and Dst = 5 nT**



Disturbed day, **Kp = 8 and Dst = -104 nT**



The TEC maps are updated every 5 minutes.

Matamba, T. M., & Danskin, D. W. (2022). Development and evaluation of near-real time TEC and ancillary products for SANSA Space Weather. Space Weather, 20, e2021SW003013. https://doi.org/10.1029/2021SW003013

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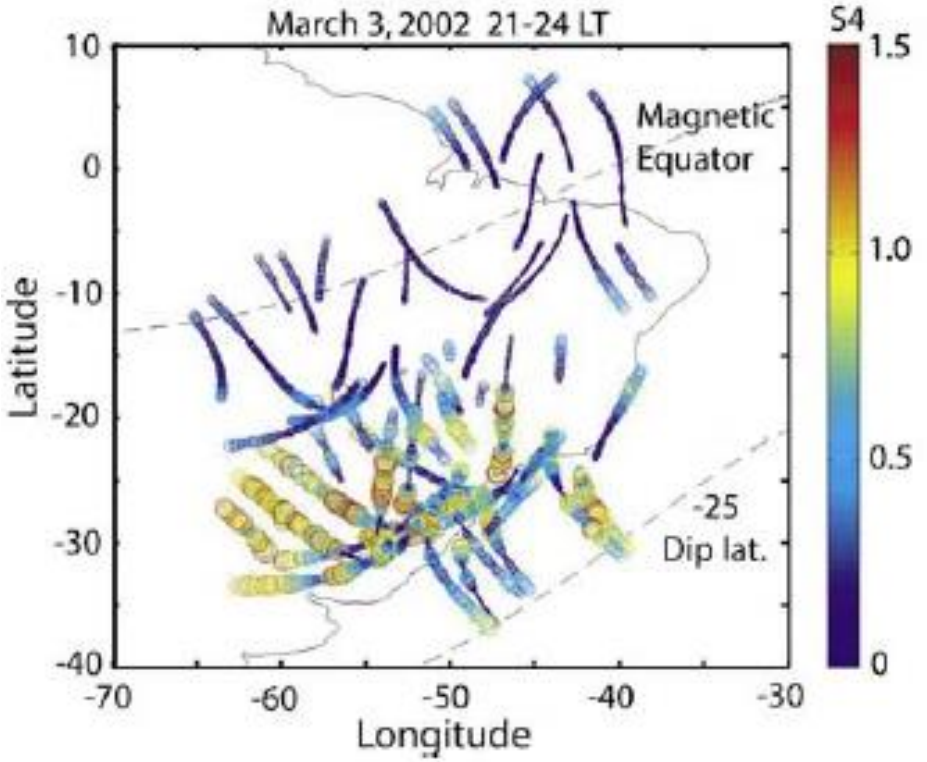
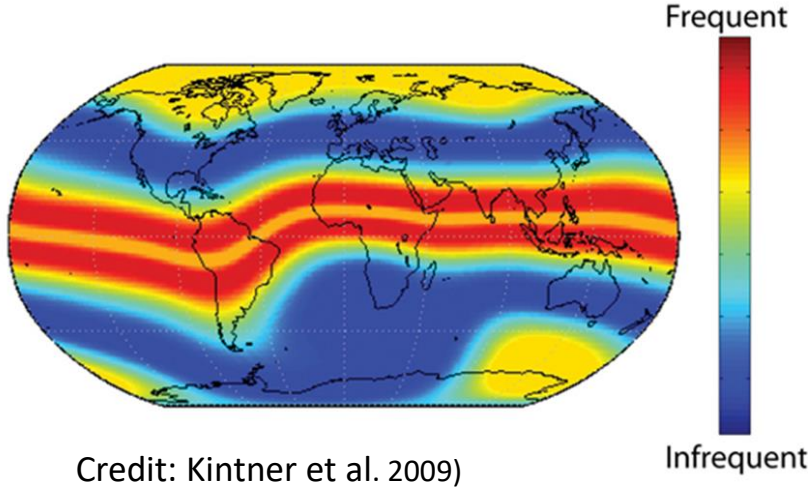
IONOSPHERIC SCINTILLATION

- ✓ Rapid fluctuation of radio waves caused by irregularities of the electron density
- ✓ Cycle slips and loss-of-lock on GPS satellite signals can increase the magnitude and frequency of errors in the position estimation
- ✓ Affects the power and phase of the signal
- ✓ Dependent on location, local time, season, geomagnetic activity, and solar cycle
- ✓ influenced by waves propagating through the ionosphere
- ✓ more prevalent at equatorial and high latitudes rather than mid-latitudes



S4 from Brazil (Kintner et al. 2007)



Credit: Kintner et al. 2009)

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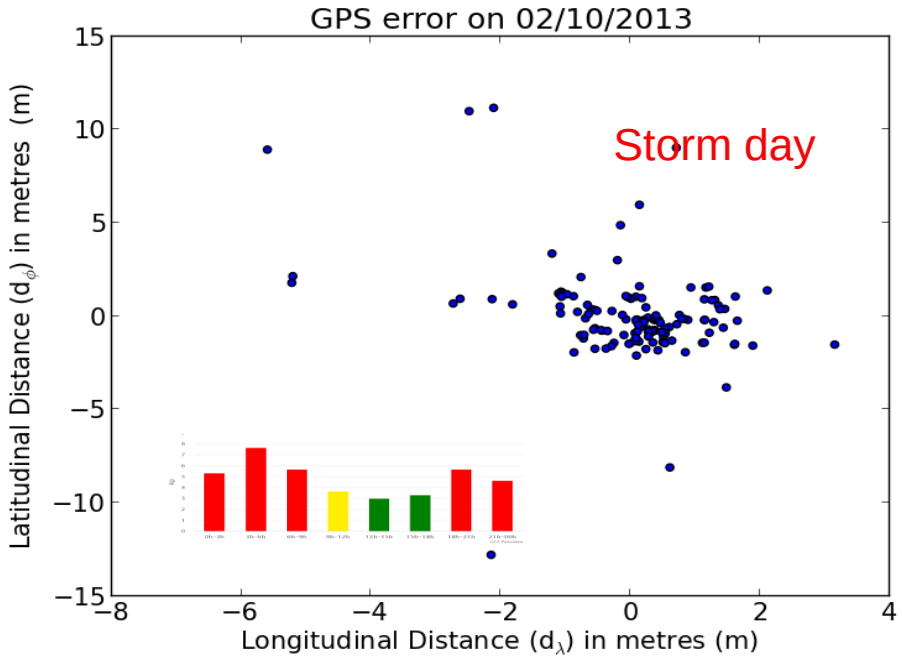
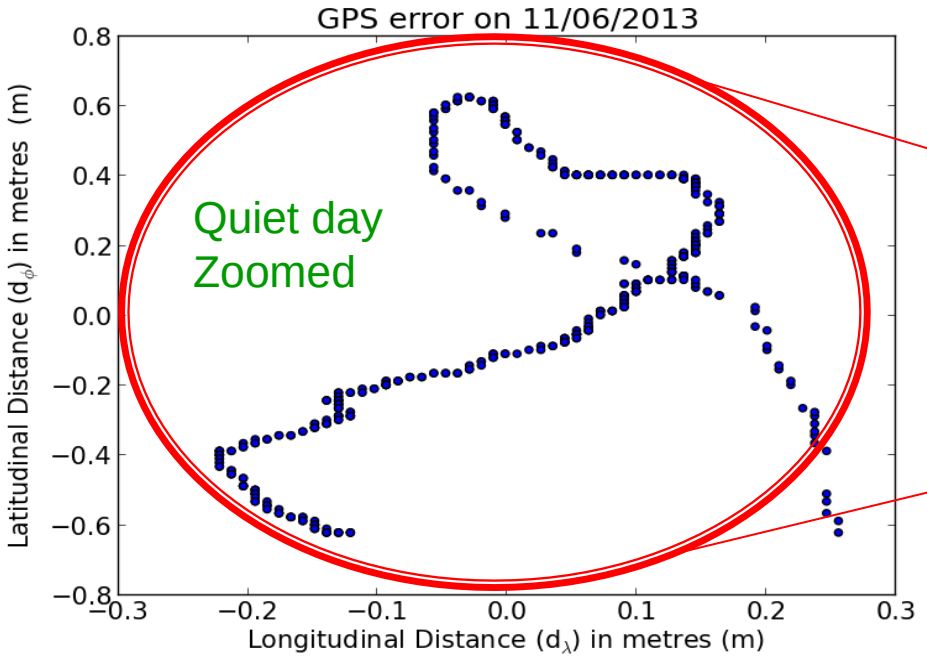
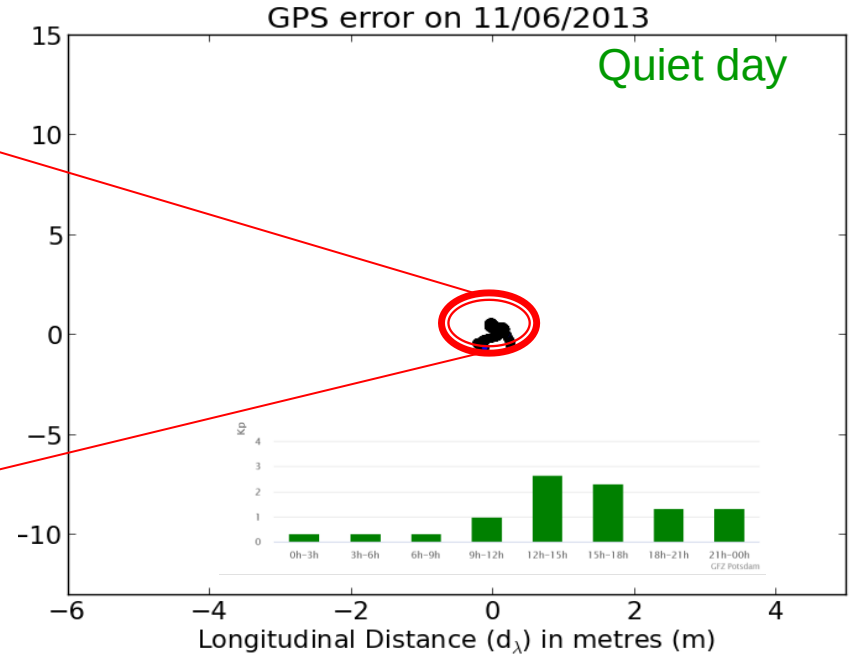
GPS errors due to ionospheric scintillation

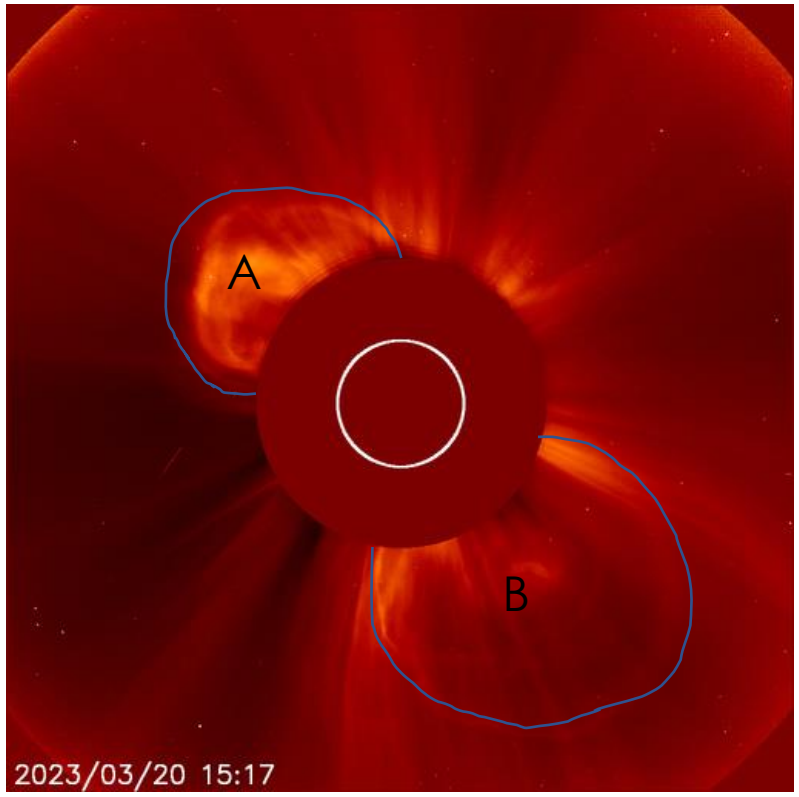
Single frequency handheld GPS receiver







CME ANALYSIS OF THE ARRIVAL TIME



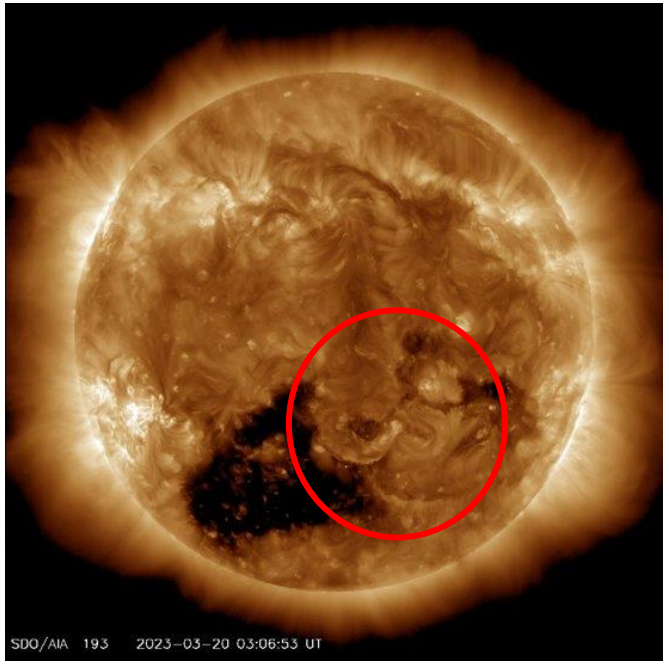
CME: 2023-03-20T02:41:00-CME-001

Actual Shock Arrival Time: 2023-03-23T09:10Z

Observed Geomagnetic Storm Parameters:

CME Note: [PRELIMINARY] Faint, wide CME seen to the southwest in SOHO LASCO C2 imagery during a STEREO A data gap and occurring during a subsequent STEREO campaign with limited imagery. Likely associated with a broad area of coronal restructuring, coronal dimming, destabilization, and filament eruptions seen in SDO 193 and 304 starting around 2023-03-20T01:53Z bounded by an area created by S10 to S30, W05 to W30. Arrival time (and arrival itself) are tentative as the arrival signature is under review as it may be associated with CME 2023-03-20T14:42Z instead or with combined front of these two CMEs. Waiting for assessment by LASSOS team.

Predicted Shock Arrival Time	Difference (hrs)	Confidence (%)	Submitted On	Lead Time (hrs)	Predicted Geomagnetic Storm Parameter(s)	Method	Submitted By	
2023-03-23T03:00Z (-7.0h, +7.0h)	-6.17	----	2023-03-20T13:28Z	67.70	Max Kp Range: 2.0 - 4.0	WSA-ENLIL + Cone (NASA M2M)	Chris Stubenrauch (M2M Office)	Detail
2023-03-23T01:00Z (-6.0h, +9.0h)	-8.17	40.0	2023-03-21T03:45Z	53.42	Max Kp Range: 2.0 - 5.0	WSA-ENLIL + Cone (Met Office)	Met Office (Met Office)	Detail
2023-03-23T02:00Z	-7.17	40.0	---	---	Max Kp Range: 2.0 - 4.5	Average of all Methods	Auto Generated (CCMC)	Detail



https://kauai.ccmc.gsfc.nasa.gov/CMEscoreboard/

- A CME expected to make a glancing blow on 23 March 2023
- High speed stream influence from a coronal hole

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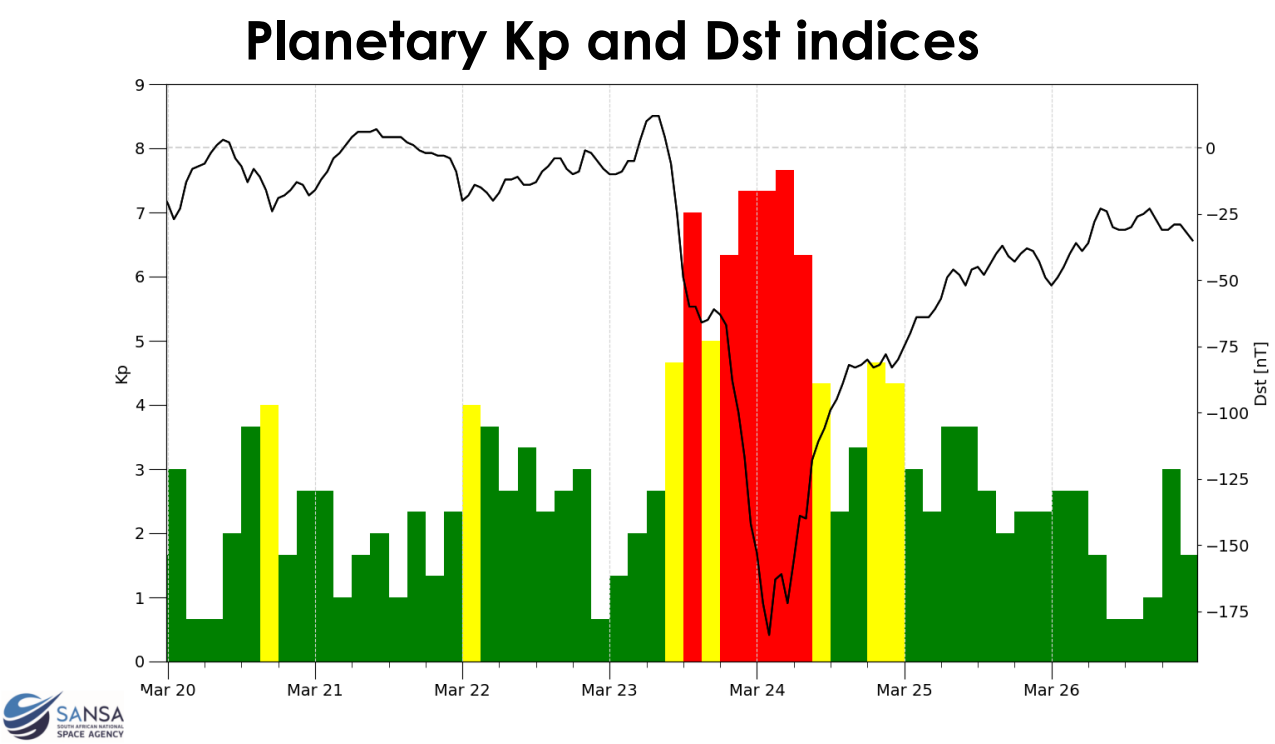
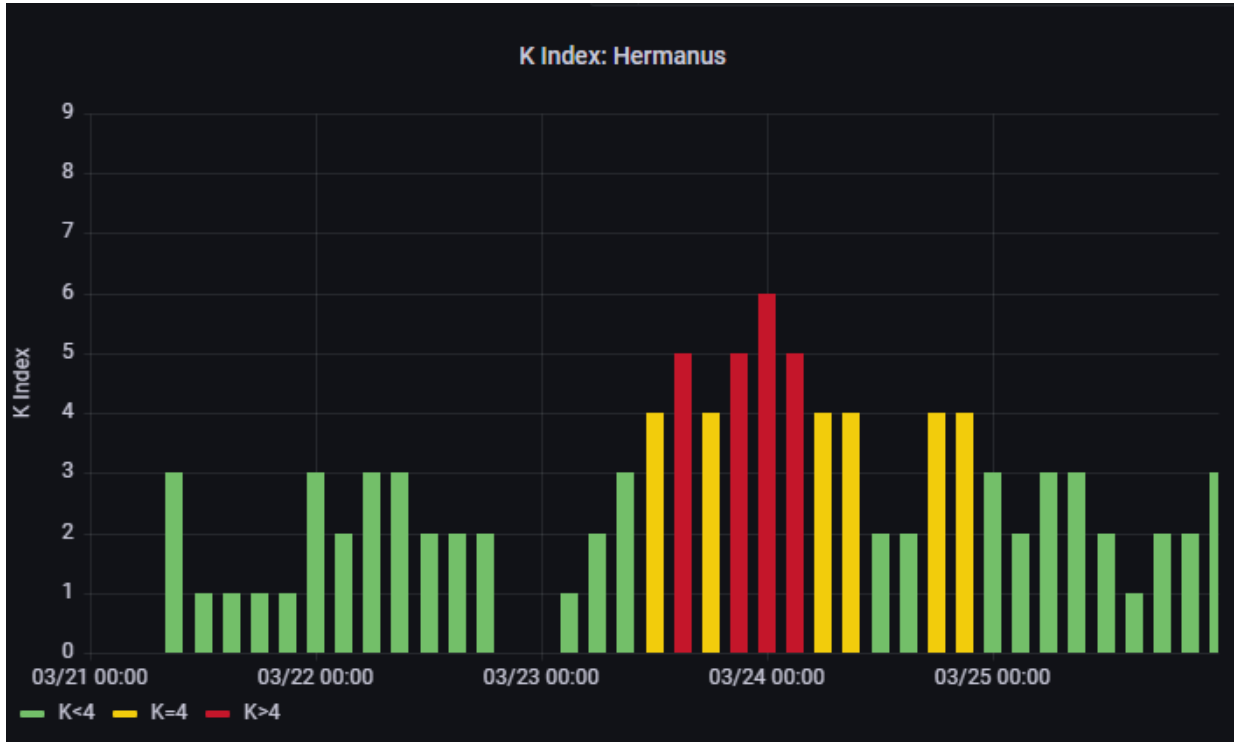
Geomagnetic Conditions on 23 – 25 March 2023





- Planetary Kp index reached 8-, a severe/G3 storm level. The recorded minimum Dst index was -184 nT at 03:00 UT on 24 March.
- Local Hermanus K-index reached K of 6 which is a moderate/G2 storm levels.

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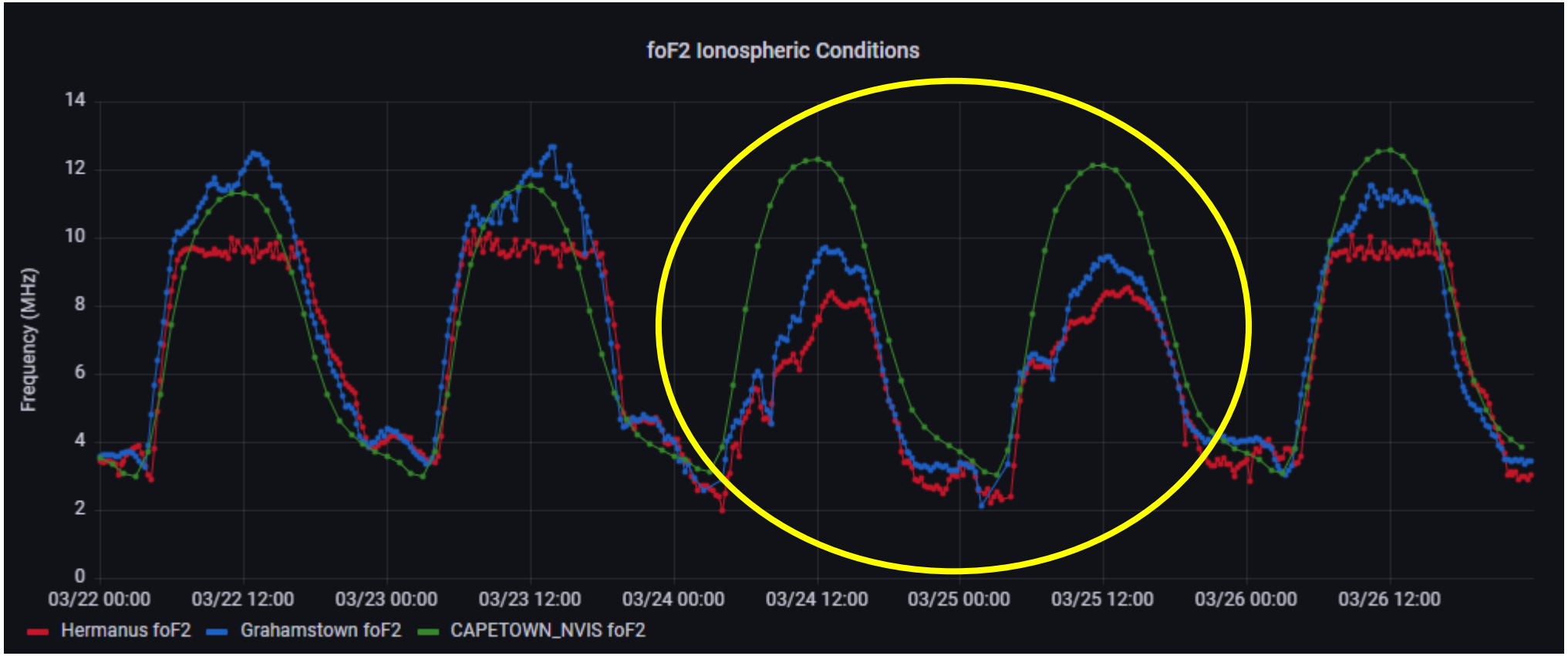
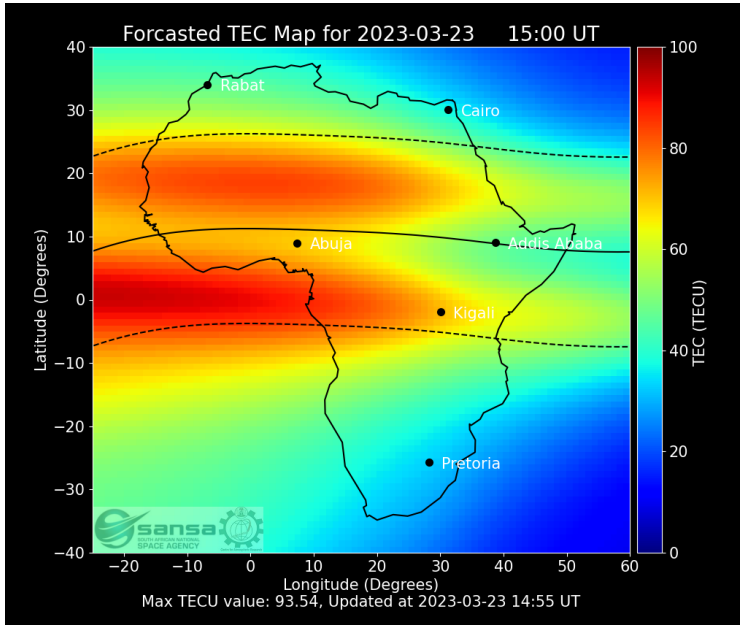
Ionospheric Conditions

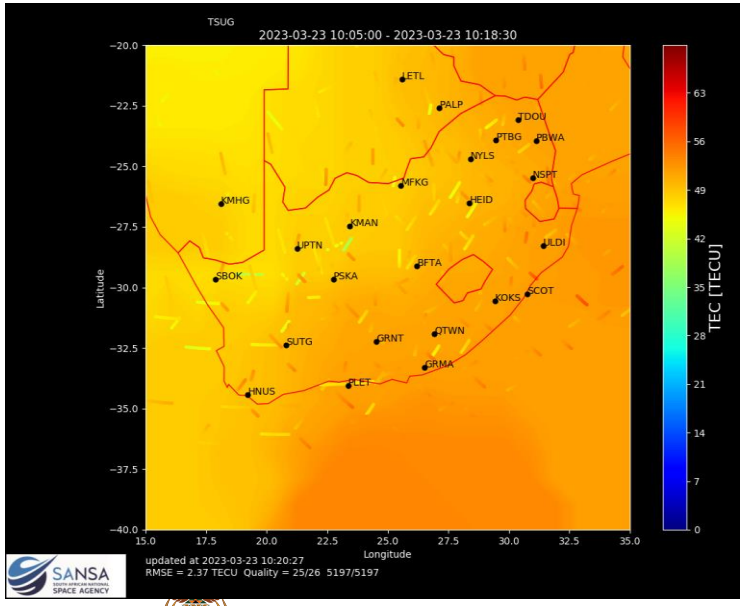


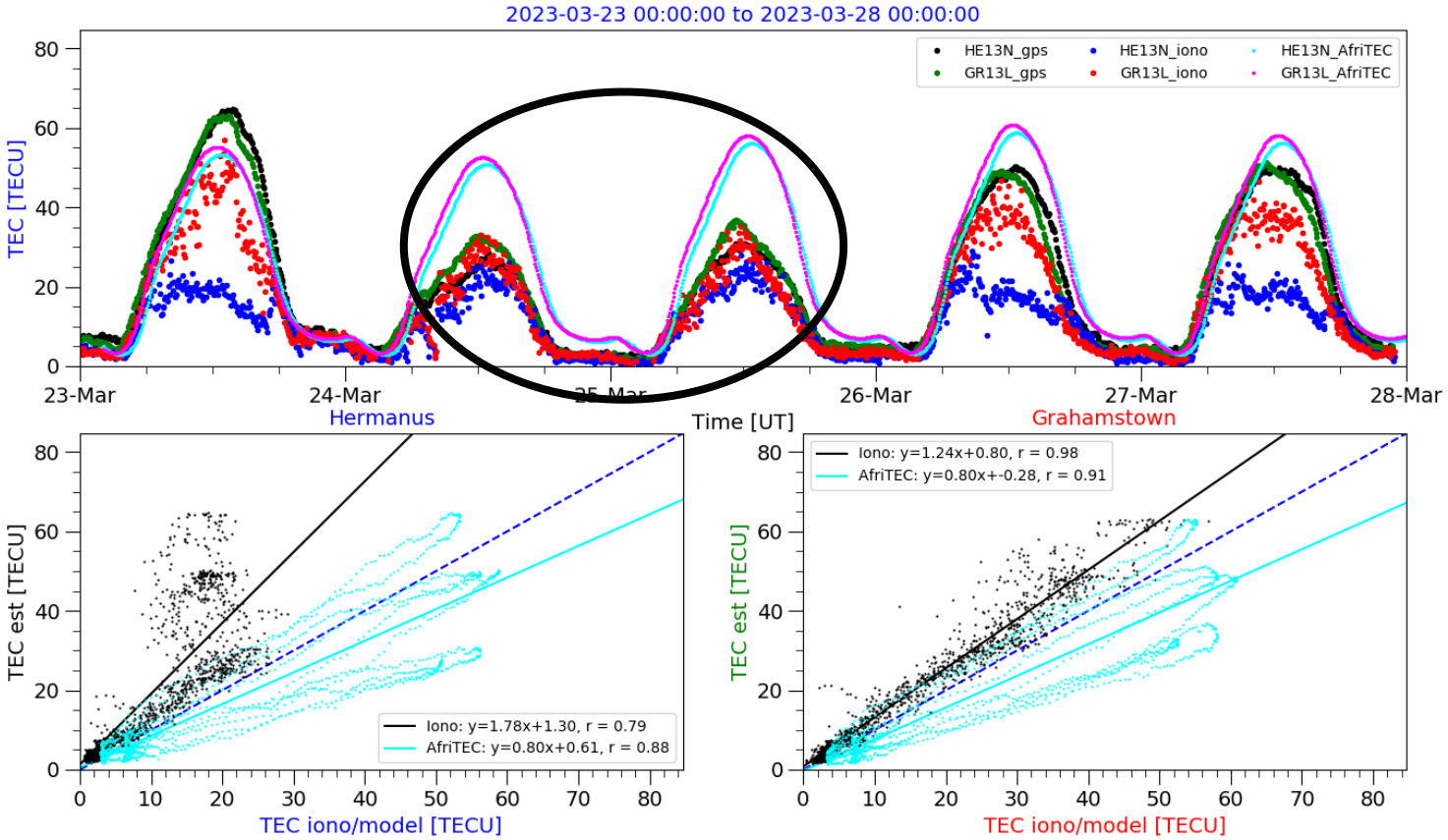
- Negative ionospheric storm effect for both Hermanus and Grahamstown

Ionospheric Conditions - TEC



https://doi.org/10.1029/2019JA027065





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2024 MOTHER'S DAY STORM EVENT

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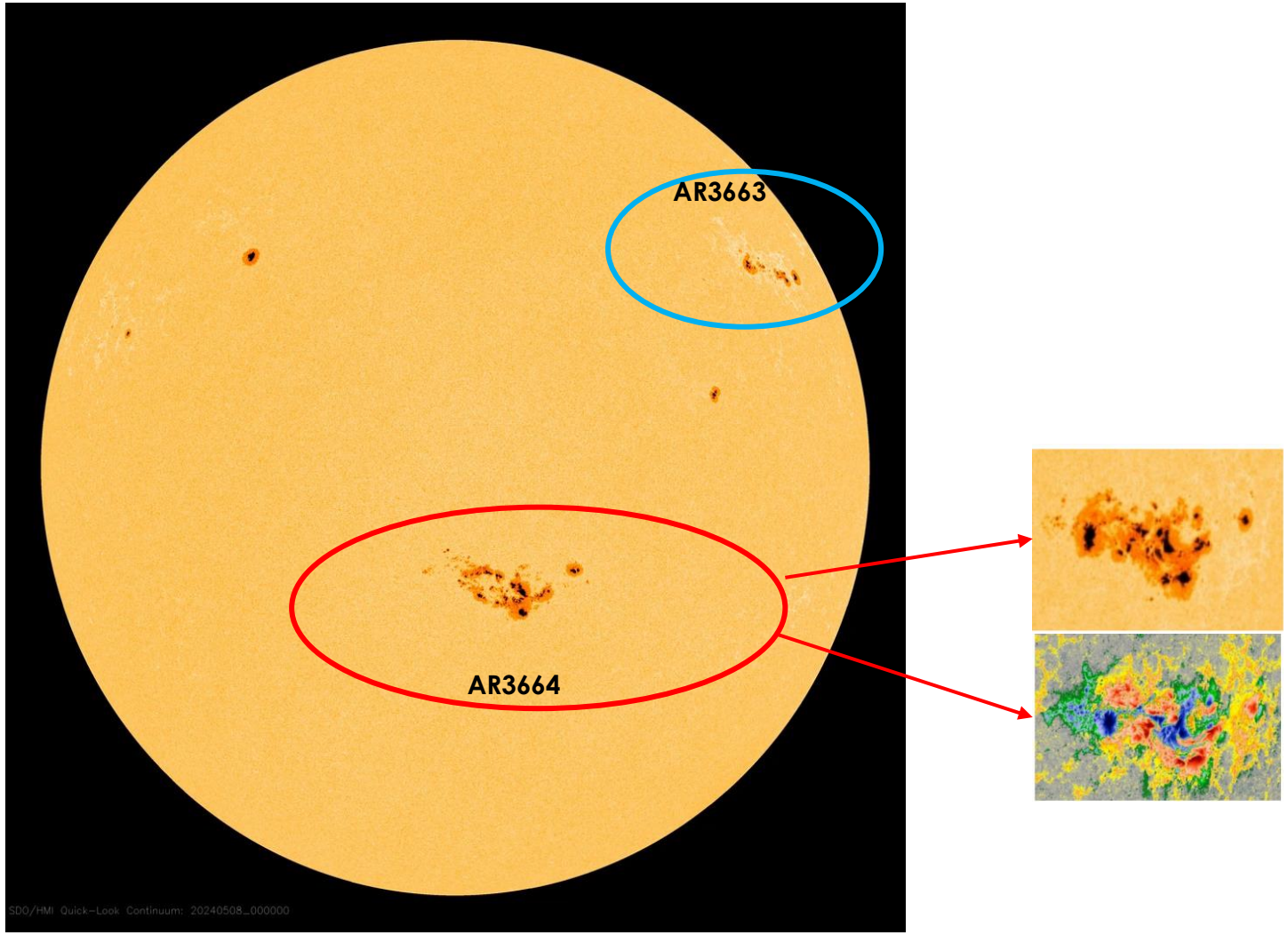
The Most Active Sunspot Regions

AR3664

- Currently one of the most complex regions responsible for the major flares. It is the most active and complex region.

AR3663

- The region complex (Beta-gamma-delta) configuration.
- This region was responsible for most of the M-class and X-class flares.



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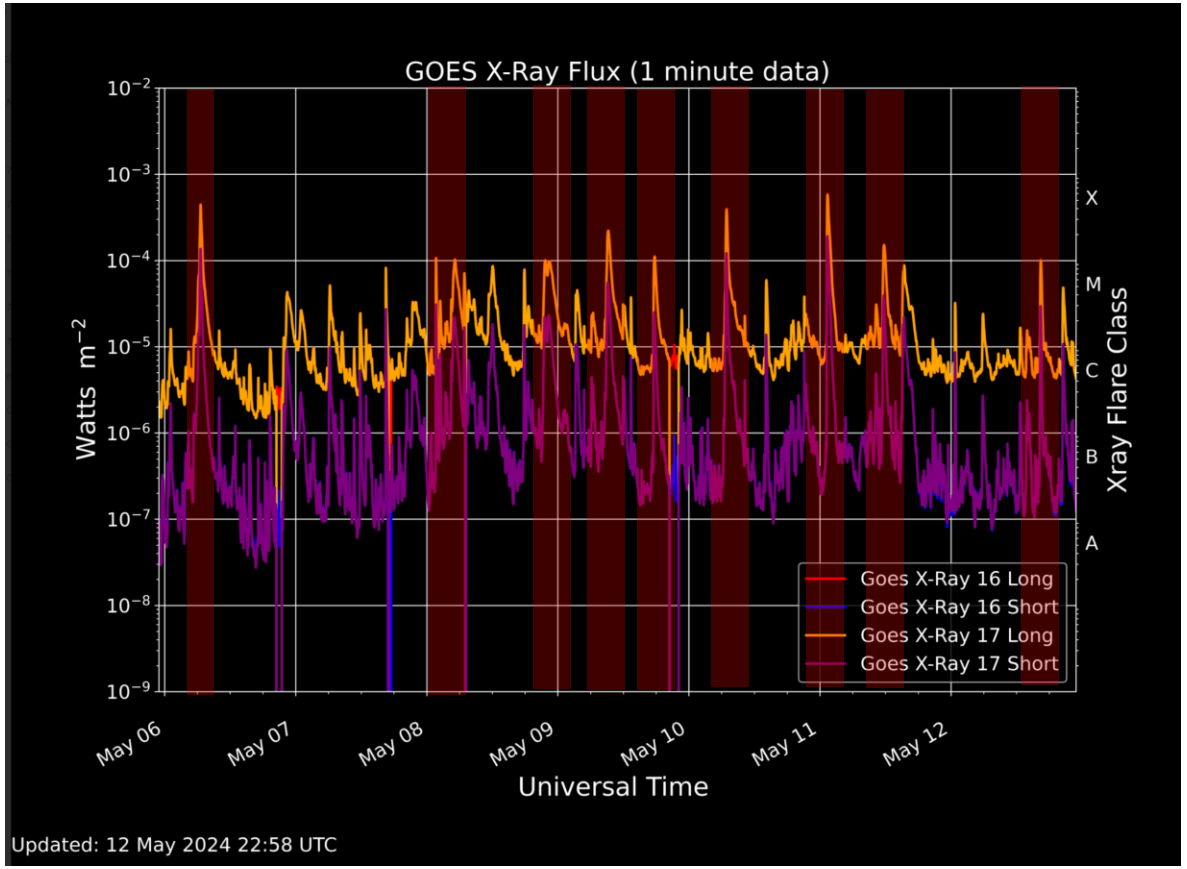
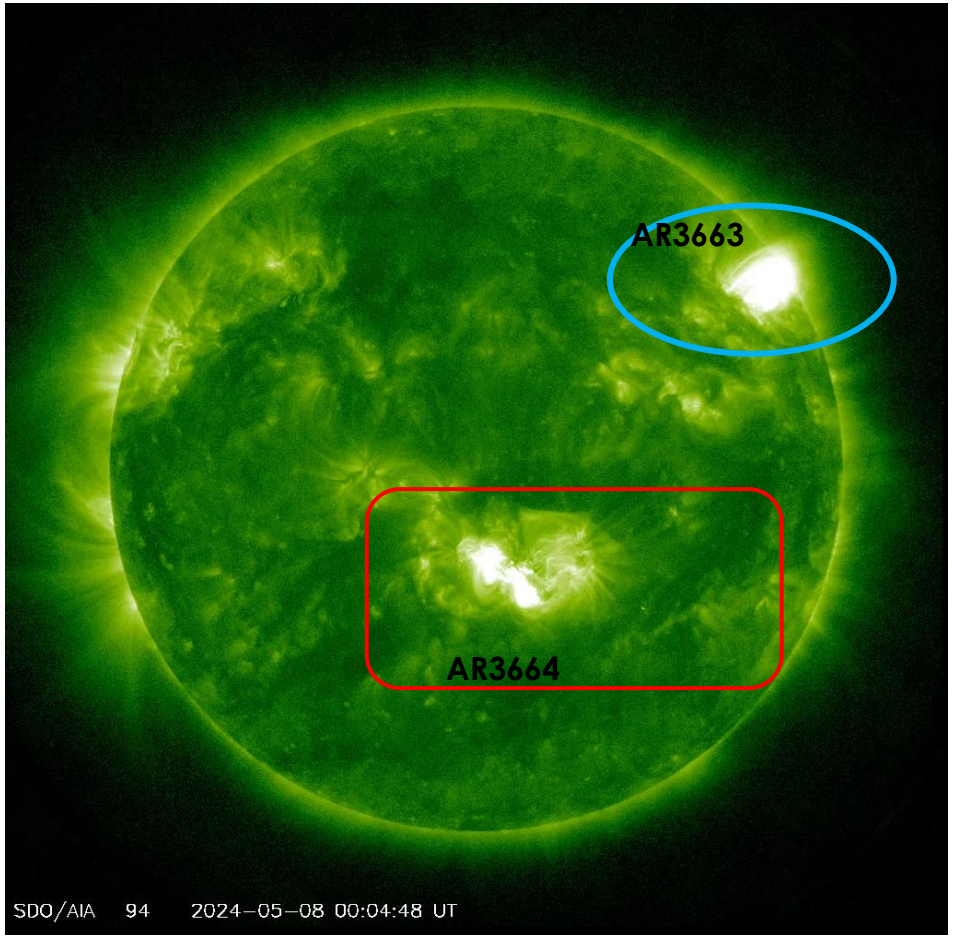
Solar Activity – GOES X-Ray Flux

- Solar activity was high with background X-ray flux at upper C- and M-class levels.





GOES X-ray flux showing solar flares for the period 06 – 12 May 2024.

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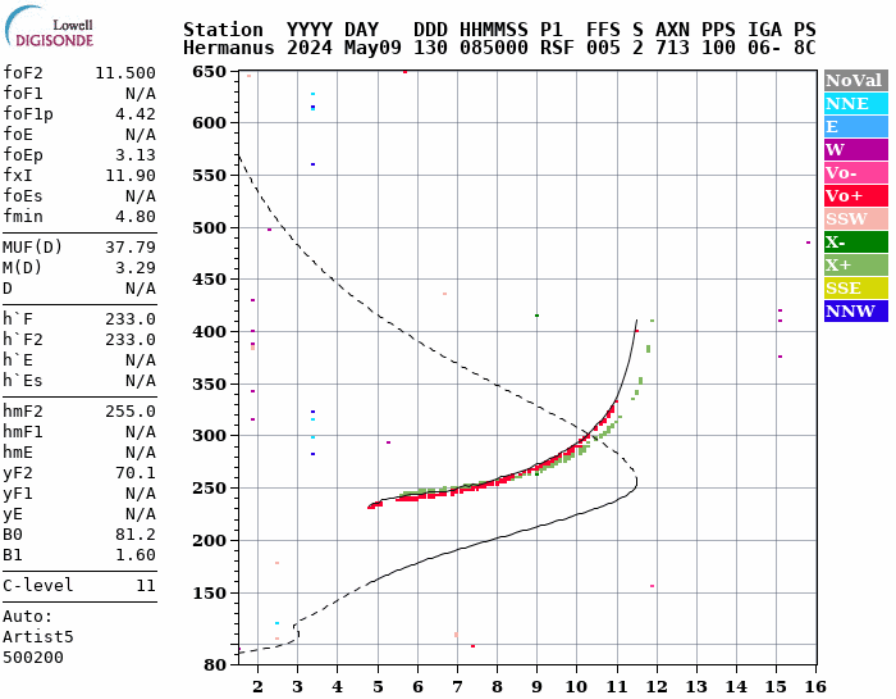
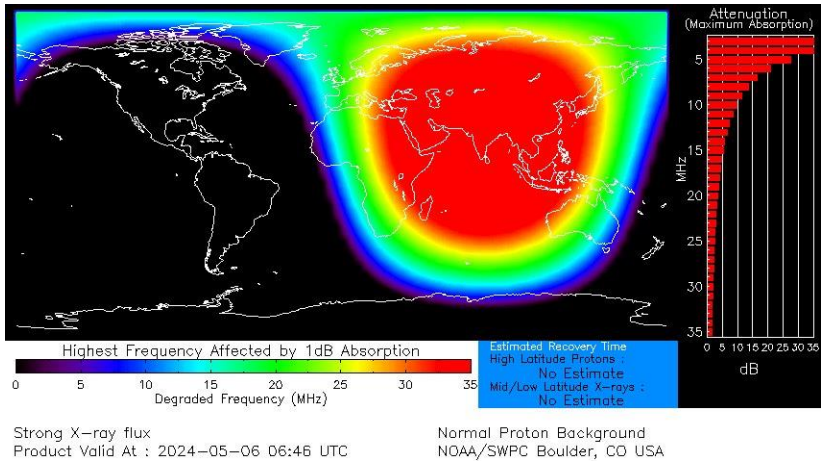
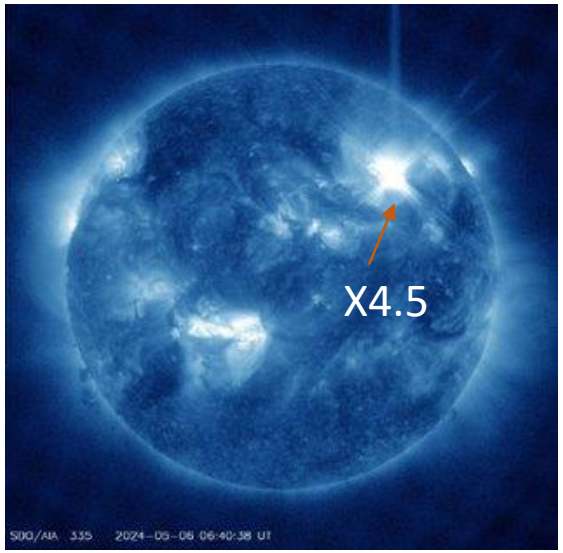
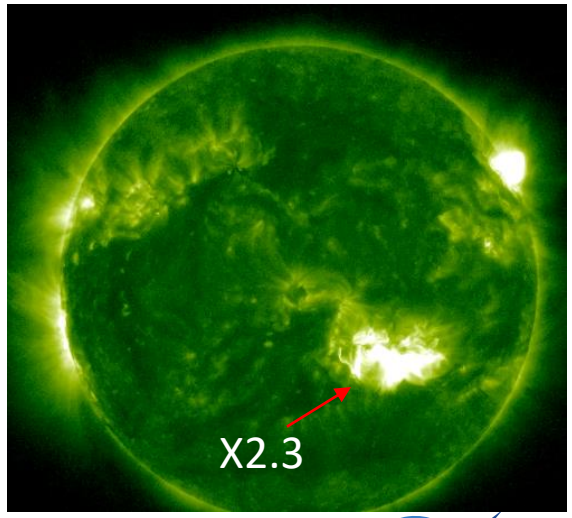
Significant Solar Flares on the Dayside over the African region

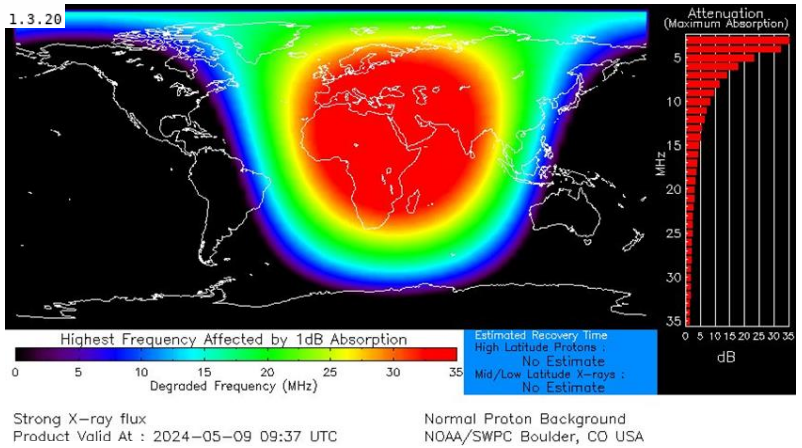






An X4.5 flare from AR3663 at 06/06:35 UT





An X2.3 solar flare from AR3664 UT at 09/09:13 UT .

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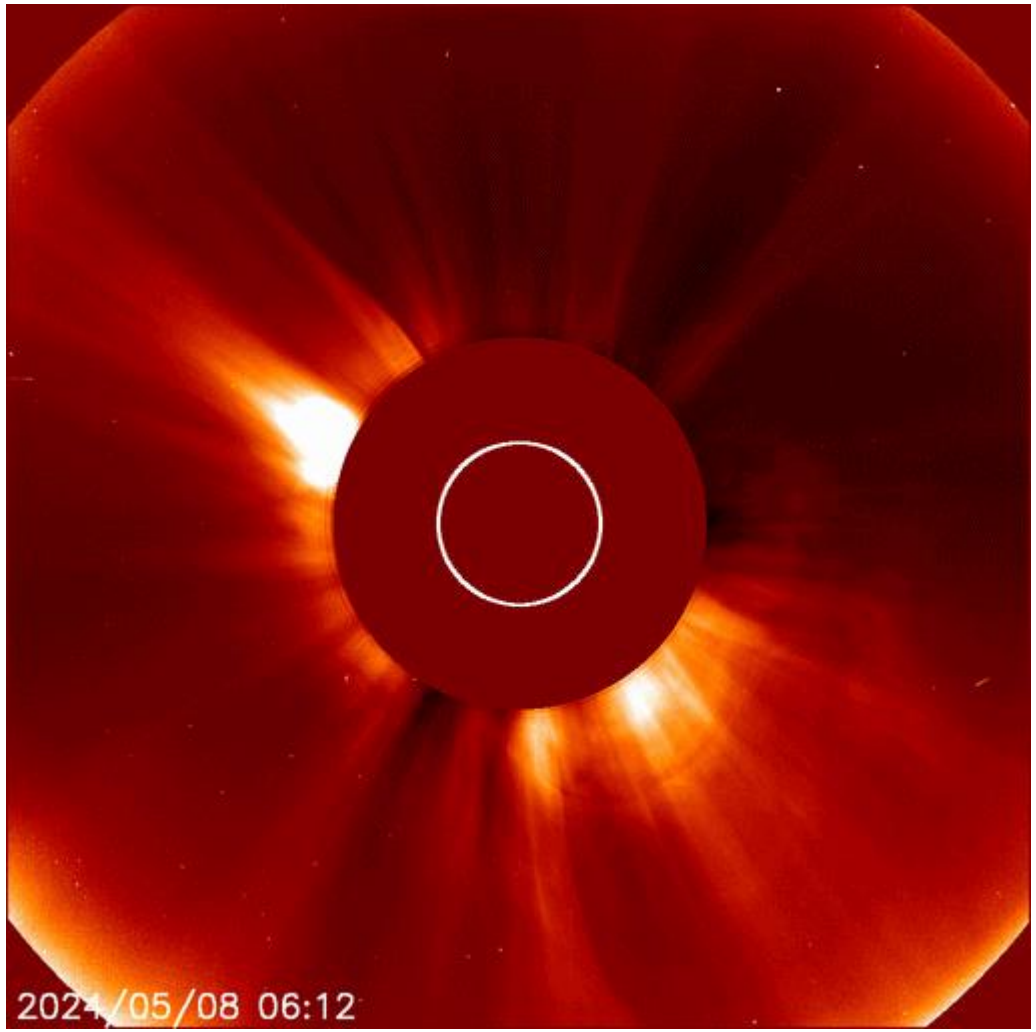
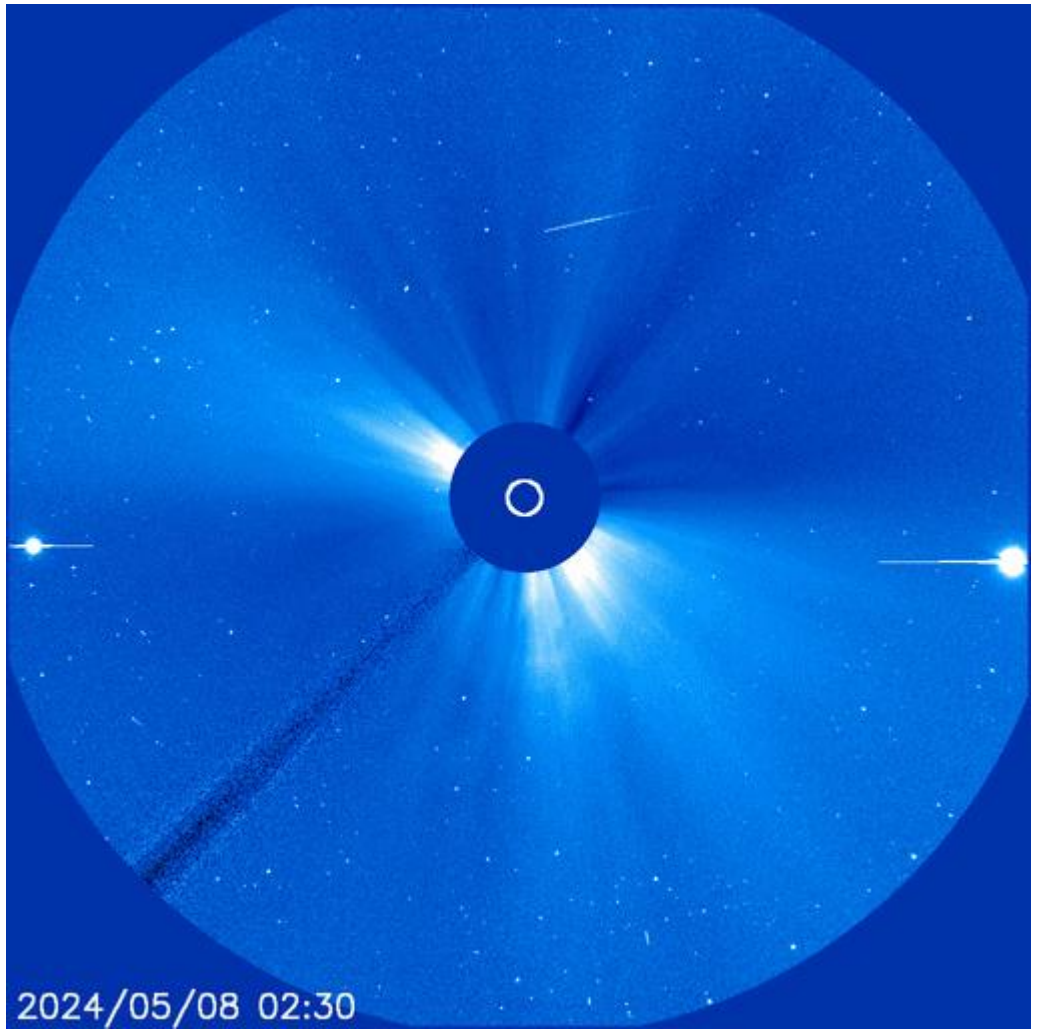
Anticipated CMEs





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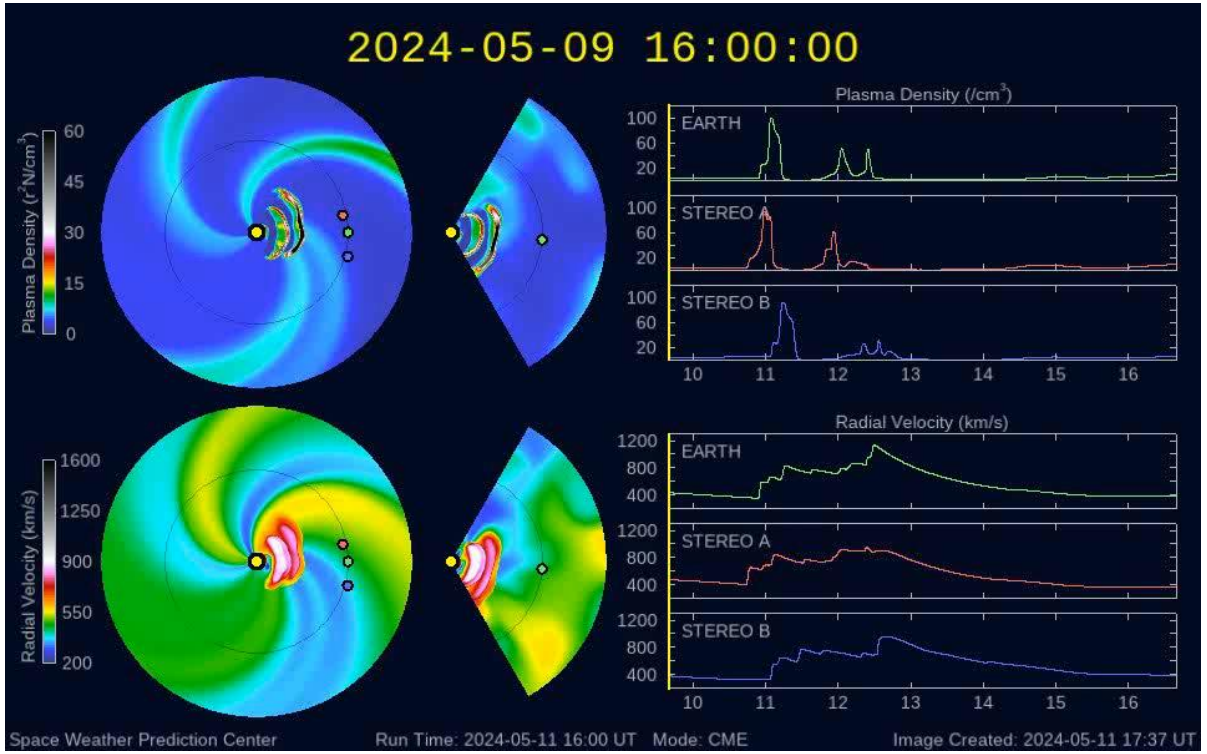
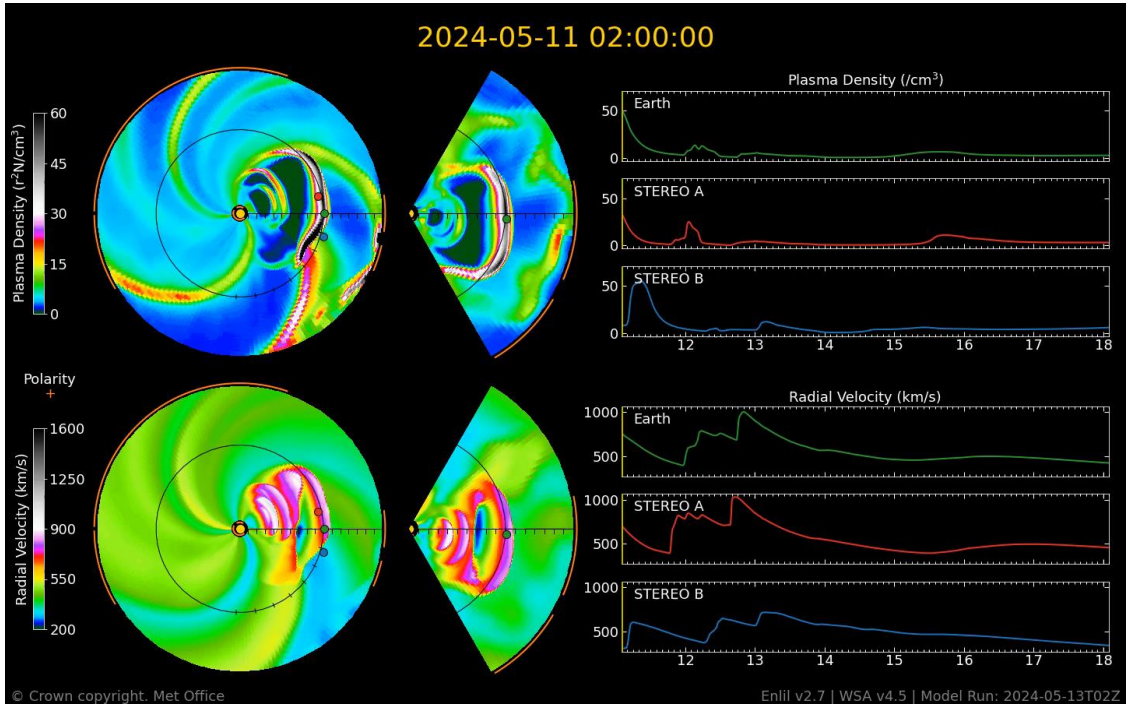
Solar Wind Enlil Model

- SWPC and MOSWOC Enlil model forecasted an increase in solar wind speed to strong levels from the 11th to 13th due to the arrival of multiple CMEs that were mentioned above.



SWPC Enlil model created 11 May 2024.



MOSWOC Enlil model created 13May 2024.

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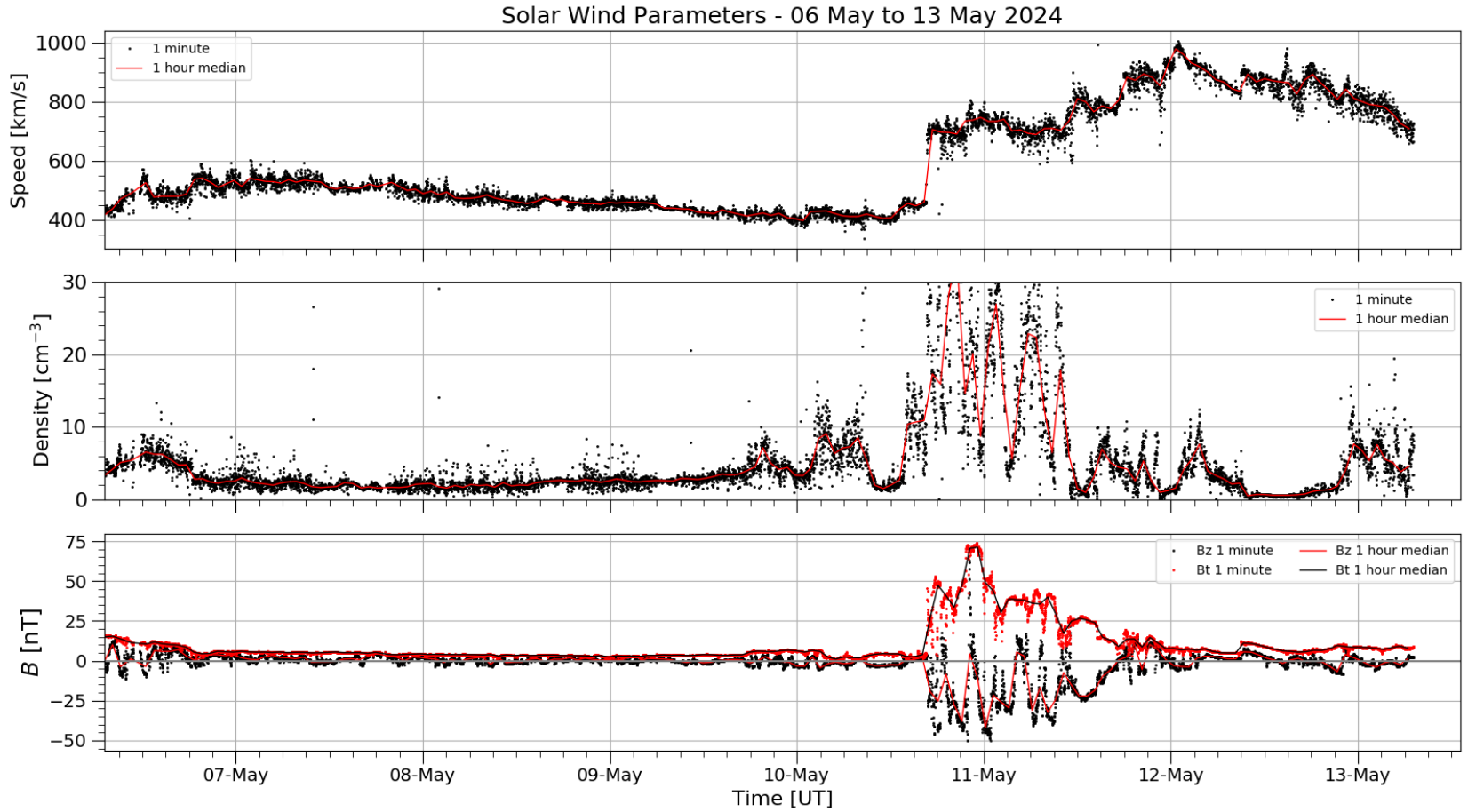
Background levels (< 400 km/s)
Slightly elevated (400-500 km/s)
Elevated (500-600 km/s)
Strong (> 600 km/s)

Solar Wind and IMF Bz



- The solar wind speed started at background levels , increased to elevated on the 7th due to HSS from CH33+.
- It increased to strong levels when the multiple CMEs impacted Earth from the 10th.
- Bz reached ~ -50 nT on 10 May due to arrival of multiple CMEs that left the Sun on 08 and 09 May 2024 resulting up to a G5/Severe storm.

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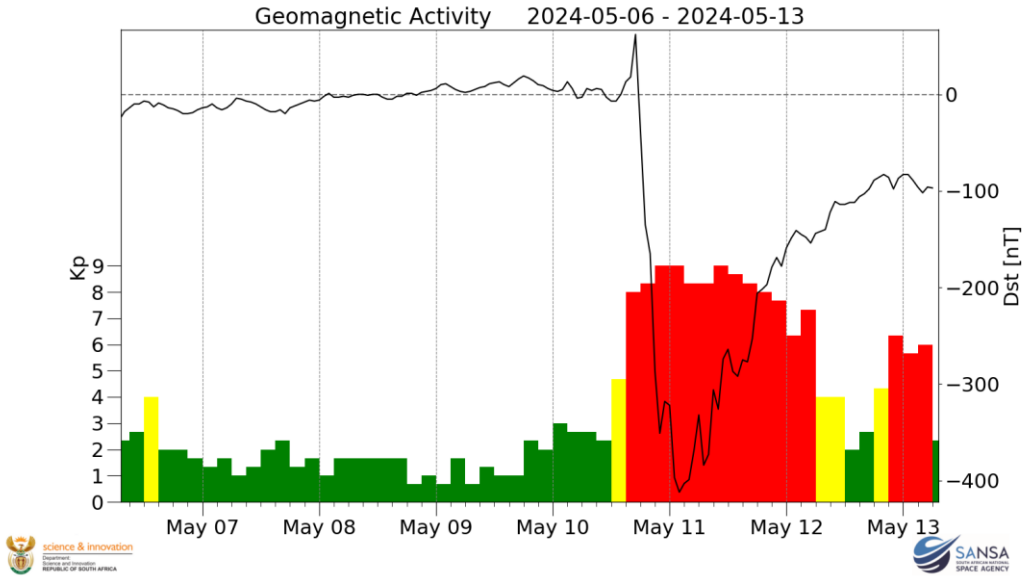
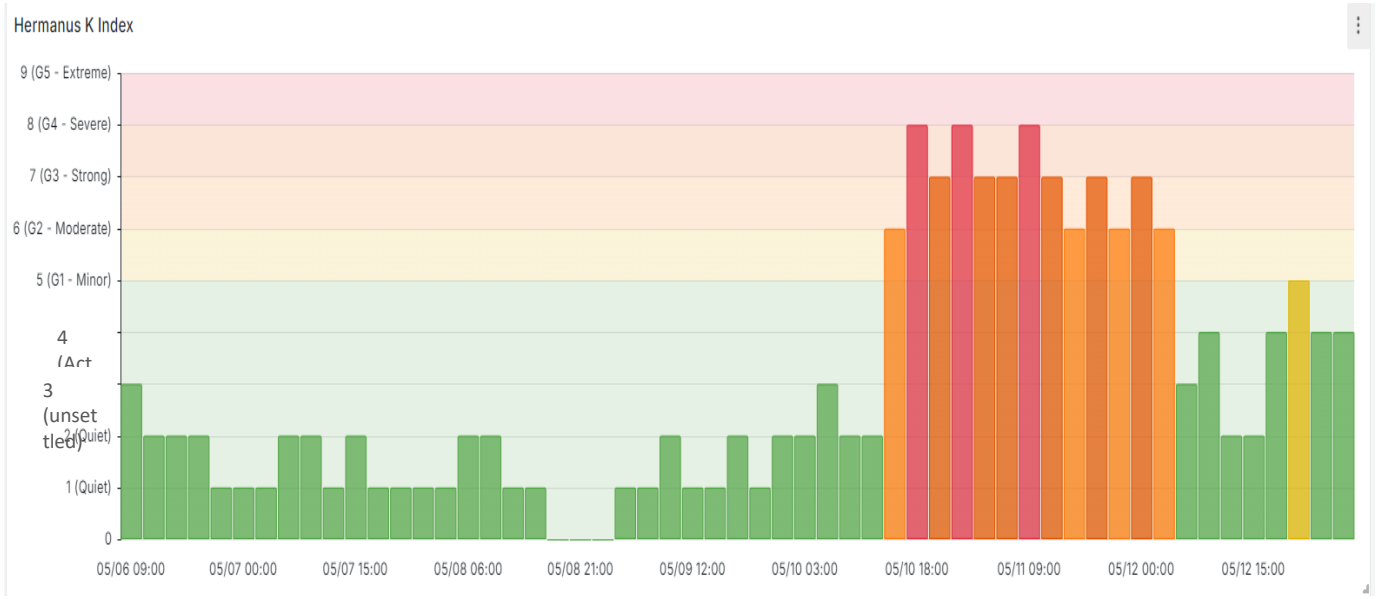
Geomagnetic Conditions



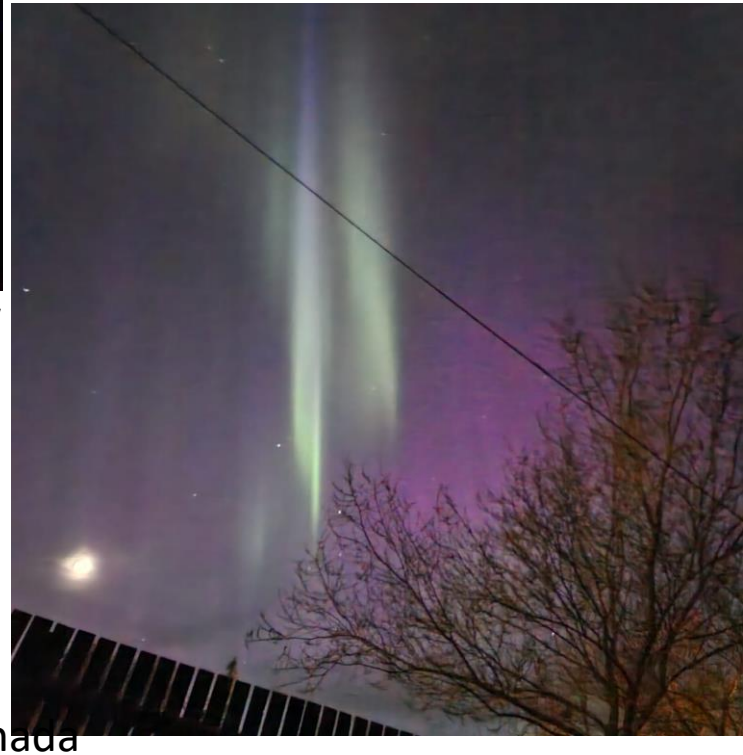


- Global geomagnetic conditions were mostly at quiet to extreme levels during the week.
- Active to G1/Minor storm Interval was observed on 06 May 2024 due to the HSS arrival.
- Active to G5/Extreme storm interval were observed on 10-13 May due to arrival of multiple CMEs from 08, 09 and 10 May 2024
- The Dst Index reached a minimum value of -412 nT on 11 May 2024

Auroras Visible in South Africa

Gansbaai

Bettys Bay



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UK

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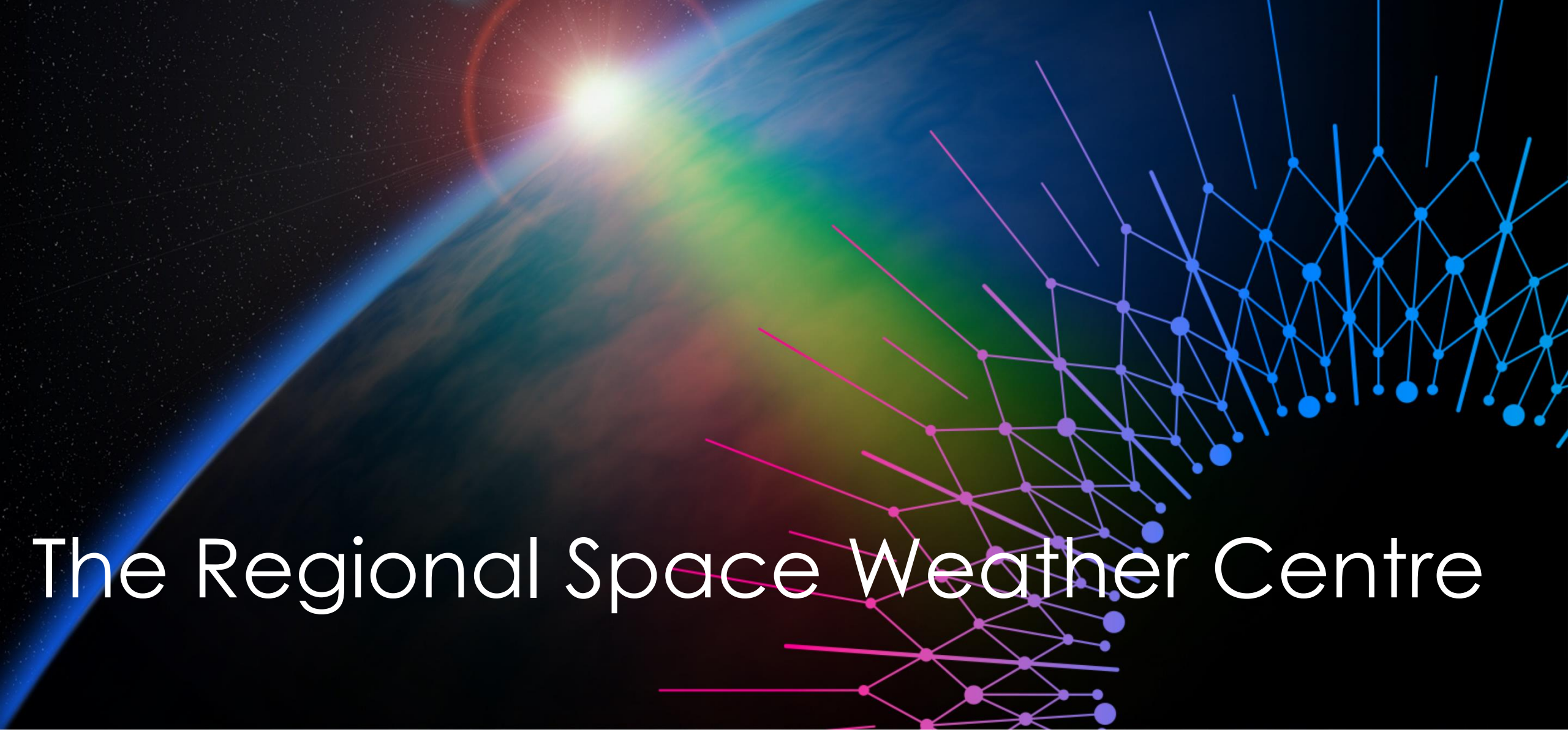
CONCLUSION

SPACE WEATHER OPERATIONAL FOCUS

- ✓ Space weather data is key
- ✓ Expand the coverage of ground-based data within the African region.
- ✓ Model development
- ✓ Space weather research, needs analysis and impact studies
- ✓ Space weather information and forecasting (interpretation for end-users)

24/7 Operational Space Weather Centre



The Regional Space Weather Centre

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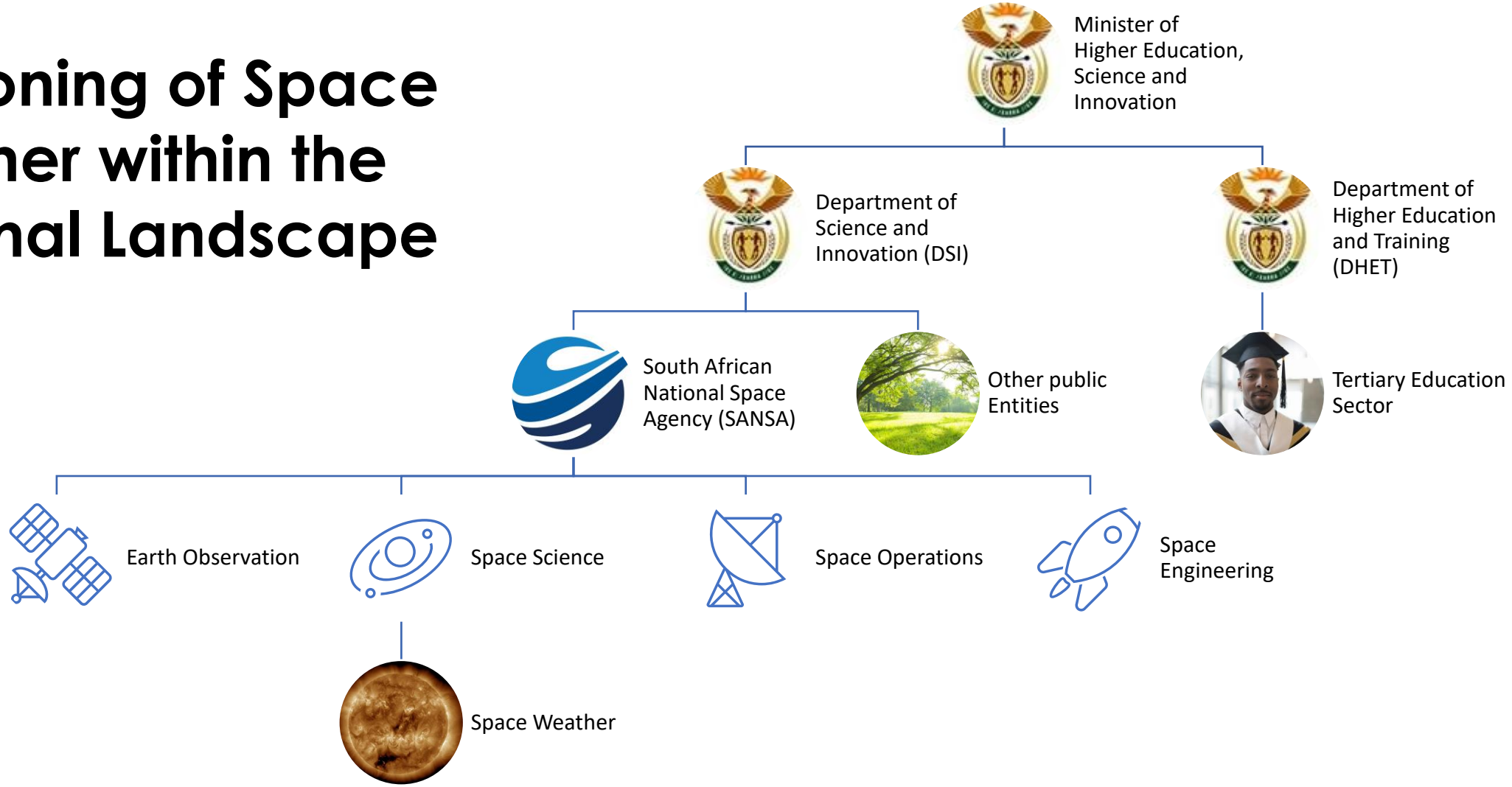
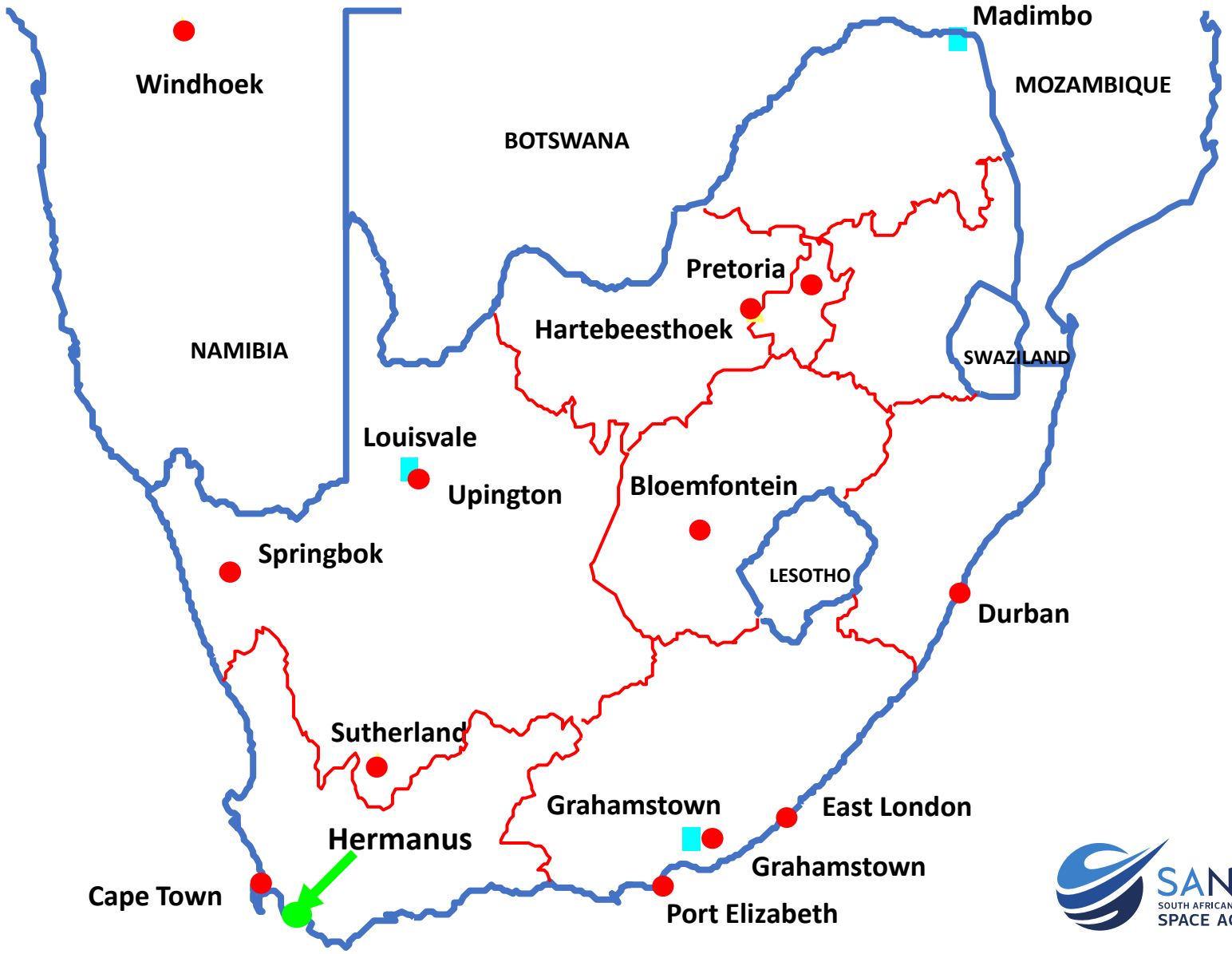
SANSA OVERVIEW

Positioning of Space Weather within the National Landscape



LOCATION OF SANSA



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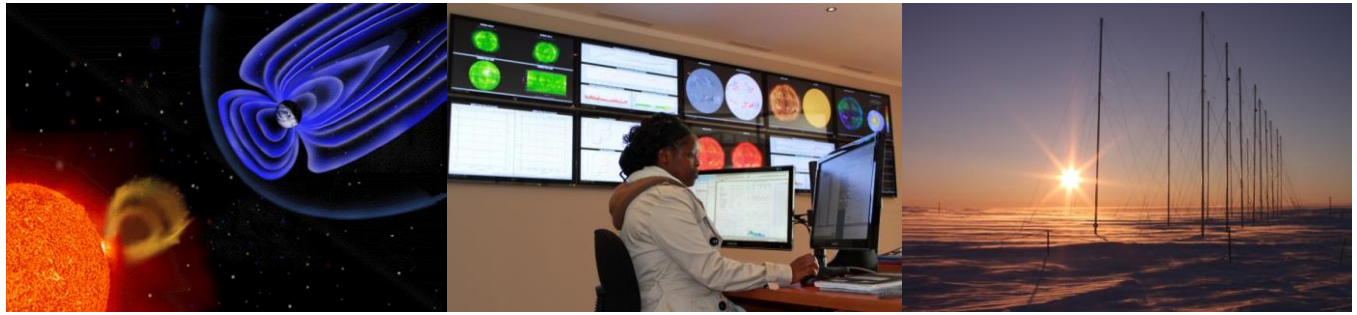
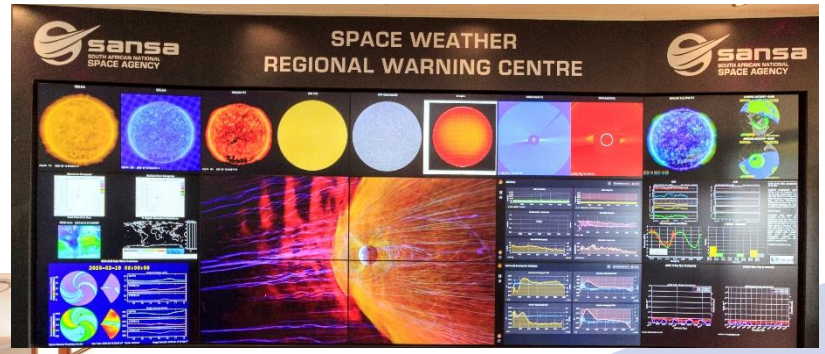
Key Functions & Roles – Hermanus Facility

- ✓ Responsible for the Space Science Programme within SANSA
- ✓ Fundamental and Applied Space Science Research
- ✓ Provision of a science and applications data platform through the operation of a distributed network of geophysical instruments
- ✓ Space Weather Applications, products and services
- ✓ Provision of Magnetic Technology products and services
- ✓ Postgraduate science student training and other skills development
- ✓ Science Engagement



Space Weather Centre Journey



2007

Member of ISES (Space Weather Community)

2010

Space Weather Regional Warning Centre for Africa

2018

ICAO Designated Regional Space Weather Centre for Aviation

2022

24/7 Operational Space Weather Centre

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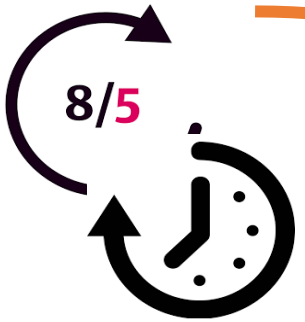
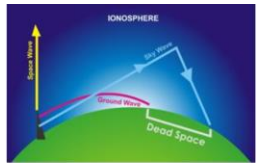
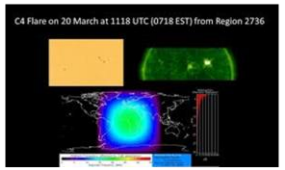
24/7 Operational Space Weather Project

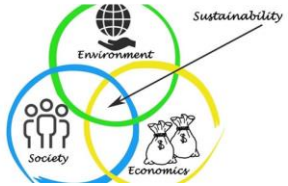


Upgrade to 24/7 operational centre



Increase products & services





Meet user requirements

Ensure required foundation for services

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DEVELOPING A CAPABILITY

- ✓ develop capability
- ✓ derive economic benefit
- ✓ provide a national platform
- ✓ ensure credibility
- ✓ fill the expertise gap
- ✓ provide quality services
- ✓ contribute to the knowledge economy
- ✓ create opportunities & partnerships
- ✓ increase the value proposition of space science

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Provide 24/7 operational space weather services to the African region by October 2022

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SKILLS DEVELOPMENT

- Space Weather Forecaster Training Objective
- The role of a Space Weather Forecaster
- Technical Training
- Soft Skills Training
- Assessment and Evaluation

LAUNCH OF SPACE WEATHER CAPABILITY

THE VILLAGE NEWS

NSA opens state-of-the-art facility

& Photographer
ette Yell

The design of the brand-new SANSA Space Weather Station in Hermanus is a reflection of the fascinating and interesting spaces SANSA studies between the sun and the earth. The new building features curved lines throughout to emulate space.

This state-of the art regional Space Weather Centre was launched on Thursday 3 November by Minister of Higher Education, Science and Innovation, Blade Nzimande, who said the space weather station will provide space weather services, including solar storm forecasts and warnings to the global aviation

ce Weather Warning
nent, it will work
and its activ-
space

Nzimande she values his commitment to research as she's a research junkie herself. "If there's no research, we won't go places." Rabie thanked the minister for choosing Hermanus. He also highlighted the fact that

and their current and potential customer base was one of the questions put forward during a media briefing shortly before lunch. Dr Lee-Anne McKinnell, Managing Director at SANSA explained they compiled a business case study which included a cost recovery model and revenue gen-

International Civil Aviation Organisation said they would work with the regional and global centres to develop a cost recovery model so we can provide them with the customised service they want."

Dr McKinnell

The initial concept for the Hermanus Space Weather Station was yet another plain square building. The new building is anything but, with hanging circular acoustic discs inside and curved lines outside. The team that worked tirelessly to finish on budget and on time are Dean Harris, Associate Contractor: Edge To Edge; Keenan Janneker, SANSA Project Lead for Space Weather; Christopher Denny, Owner-Director: Edge-to-Edge; Deputy Mayor Lindile Ntsabo; Wesley Dingley, Principal Contractor: Edge-to-Edge; Heidi McAllister, Associate Architect: AVNA Architects; Mayor Annelie Rabie; Dr Lee-Anne McKinnell, SANSA Hermanus Managing Director; Gideon Schoonraad, Architect and Principal Agent; and Sakkie Franken, Mayor of the Overberg District Municipality.

also to create awareness
low in terms of

Dr McK

NOVEMBER 2022

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ICAO DECISION (13 Nov 2018)

GLOBAL CENTRES

(provide information from 2019)

1. ACFJ consortium (formed by Australia, Canada, France and Japan)
2. PECASUS consortium (formed by Austria, Belgium, Cyprus, Finland, Germany, Italy, Poland, Netherlands and United Kingdom)
3. United States

REGIONAL CENTRES

(provide information no later than November 2022)

1. China/Russian Federation consortium *(later converted to Global)*
2. South Africa

South Africa, through SANSA, has received designation as a Regional Centre for Space Weather Information Provision from the International Civil Aviation Organisation (ICAO)

ICAO - Summary of Annex 3 Amendments 78

Provider States need to be able to:

A) monitor relevant ground-based, airborne and space-based observations to detect, and predict, when possible, the existence and extent of space weather conditions that have an impact in the following areas:
- high frequency (HF) radio communications;
- Satellite communications;
- GNSS-based navigation and surveillance; and
- radiation exposure at flight levels;

B) Issue advisory information

C) Supply the advisory information to appropriate aviation channels

D) Maintain a 24-hour watch

E) Ensure active collaboration with other regional centres and global centres to ensure a continuity of information

ICAO – Space Weather Advisory Information

ZCZC 001
FNXX01 LFPW 120323
SWX ADVISORY
DTG: 20240512/0319Z
SWXC: ACFJ
ADVISORY NR: 2024/219
SWX EFFECT: GNSS MOD
OBS SWX: 12/0245Z HNH HSH W180 - E180
FCST SWX +6 HR: 12/0900Z NOT AVBL
FCST SWX +12 HR: 12/1500Z NOT AVBL
FCST SWX +18 HR: 12/2100Z NOT AVBL
FCST SWX +24 HR: 13/0300Z NOT AVBL
RMK: SWX EVENT (SCINTILLATION) INPR POSSIBLY IMPACTING GNSS PER. COULD LEAD TO DEGRADATION OF TIMING AND POSITIONING PER. INTST GENERALLY STRONGER ON THE NIGHTSIDE.
NXT ADVISORY: WILL BE ISSUED BY 20240512/0919Z=
NNNN

ZCZC 001
FNXX01 EFKL 100437
SWX ADVISORY
DTG: 20221110/0438Z
SWXC: PECASUS
ADVISORY NR: 2022/62
SWX EFFECT: GNSS SEV
OBS SWX: 10/0430Z EQS W075 - W030
FCST SWX +6 HR: 10/1100Z NOT AVBL
FCST SWX +12 HR: 10/1700Z NOT AVBL
FCST SWX +18 HR: 10/2300Z NOT AVBL
FCST SWX +24 HR: 11/0500Z NOT AVBL
RMK: SPACE WEATHER EVENT (IONOSPHERIC DISTURBANCE) IN PROGRESS. IMPACT ON GNSS PERFORMANCE POSSIBLY LEADING TO LOSS OF GNSS SIGNALS AND/OR DEGRADATION OF TIMING AND POSITIONING PERFORMANCE.
NXT ADVISORY: WILL BE ISSUED BY 20221110/1030Z=
NNNN

SANSA – Designated Regional Space Weather Information Provider

- ✓ 24/7 Operational Centre & capability was launched on 3 November 2022
  - →ICAO Compliant
  - →ISO 9001: 2015 Certified

- ✓ Research, Forecasting and Prediction in the domains of
  - →GNSS (navigation)
  - →Communications (HF and Satellite)
  - →Radiation Exposure

- ✓ Training, Interpretation and User Requirements
- ✓ SANSA is the lead on MET Project 3

NATIONAL PARTNERS - Aviation

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- ✓ Air Traffic and Navigation Services (ATNS)
- ✓ South African Weather Services (SAWS)
- ✓ Department of Transport

AIR TRAFFIC & NAVIGATION SERVICES
ATNS

South African Weather Service

- ✓ A **National Space Weather Working Group** under the ATMS ATM/cns implementation committee was set up in 2018 to coordinate national efforts to implement the ICAO Space Weather Information requirements.
- ✓ Establishment of **Met Project 3** in 2021 with **AFI Region** to ensure the provision of the space weather service information.

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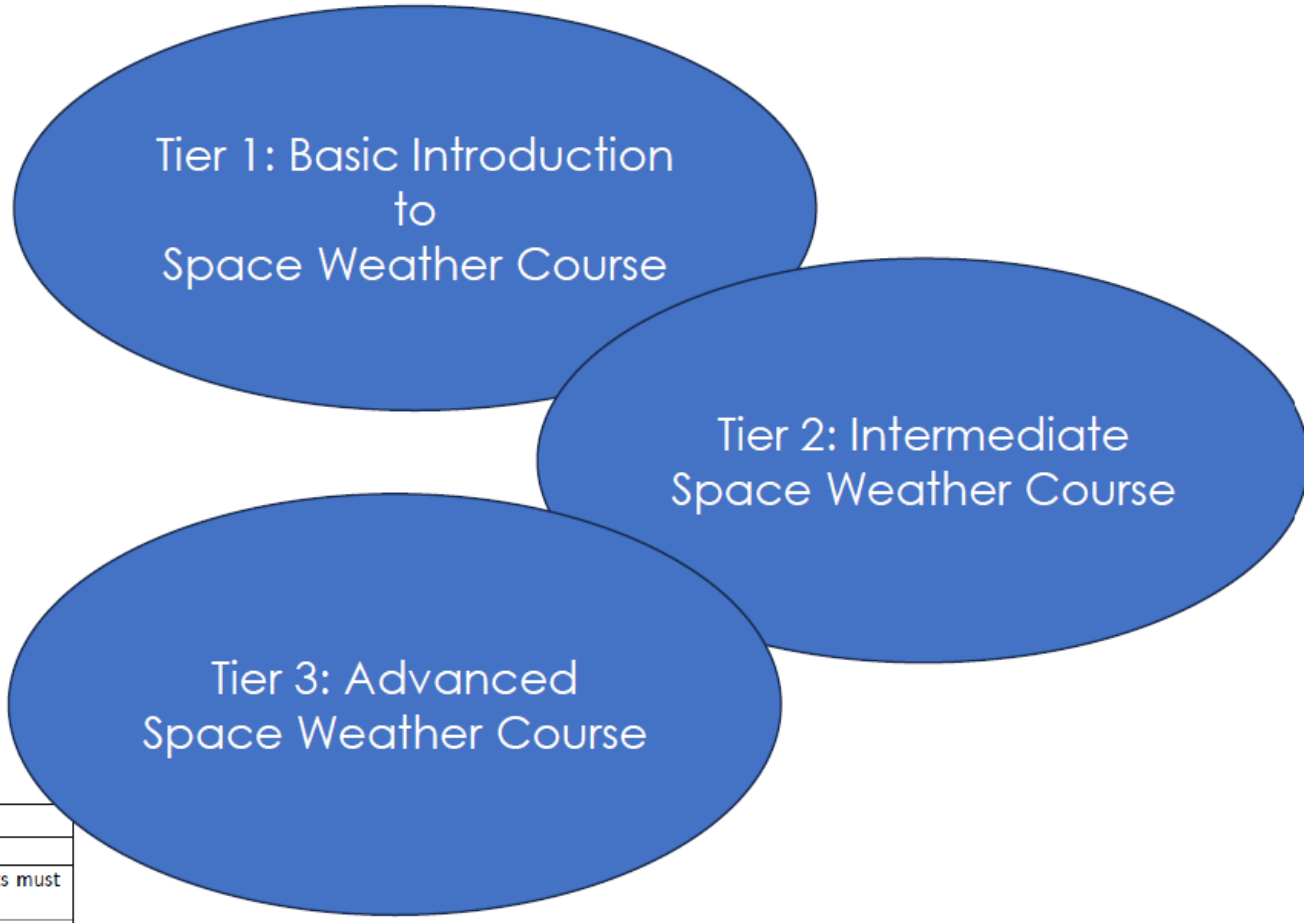
NATIONAL, REGIONAL, AND INTERNATIONAL PARTNERS

- ✓ Air Traffic and Navigation Services (ATNS)
- ✓ South African Weather Services (SAWS)
- ✓ Department of Transport
- ✓ National Universities
- ✓ Space Science Institutes and Universities within the African region
- ✓ African Space Agencies
- ✓ ICAO Regional Office
- ✓ SANSA is leading the AFI Region project for the African Aviation Sector (MET Project 3)
- ✓ National SWx Working Group
- ✓ Member of International Space Environment Service.
- ✓ Designated ICAO Regional Space Weather Information Provider
- ✓ Former Co-Chair of WMO Expert Group on Space Weather
- ✓ Other International Space Weather Centre and Space Agencies

TRAINING CURRICULUM FOR SPACE WEATHER

Introduction to Space Weather for Aviation Personnel		
COURSE AIM	:	To provide the participant with the necessary knowledge, skills and abilities to demonstrate an understanding of the International Civil Aviation Organisation Regulations pertaining to Space Weather requirements and operations, and where relevant to demonstrate competence in the application of the Regulations.
COURSE DURATION	:	3 weeks
	:	1-week self-study
	:	2 weeks (classroom lectures)
METHODOLOGY	:	Training methods employed may consist of a Hybrid model instructor-led classroom lectures and Virtual (Online study) , group discussions, self-study deemed necessary by the instructional facilitators. Methods employed will enhance learning and be appropriate to the learning experience.
LANGUAGE	:	The course will be conducted in the English language.
ENTRY REQUIREMENTS	:	The participant should: • Air Traffic Service Personnel, ATSEP, Pilots and Aerodrome Operators.
NUMBER OF LEARNERS	:	Minimum - 5
		Maximum - 15

ASSESSMENT CRITERIA AND COMPETENCE REQUIREMENT
To successfully complete the course, participants must attend the course for the entire duration. Participants must demonstrate the basic understanding of the course through a written evaluation listed below:
ASSESSMENTS



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Working in Partnership with ATNS

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SUMMARY

Develop an African Space Weather Capability

- Builds on a research and development legacy
- Meets the requirements for international compliance
- Provides a domestic capability to enable risk mitigation and empowered decision making
- Contributes towards the development of a national capability in critical skills that improve domestic and regional expertise
- Demonstrates the value in research to operations
- Space weather training and awareness for industry
- Positions Africa to make a significant contribution to the global challenge of Space Weather

THANK YOU

QUESTIONS?

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