

Space Weather: Managing the Unpredictable

Prof. Martin Snow

msnow@sansa.org.za



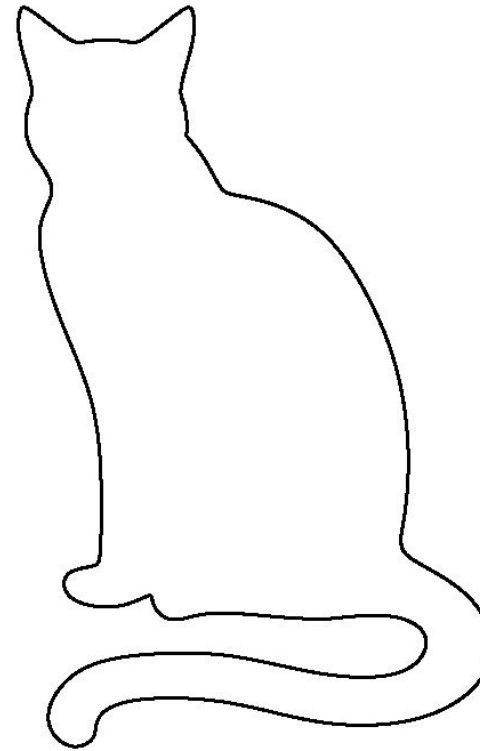
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Outline

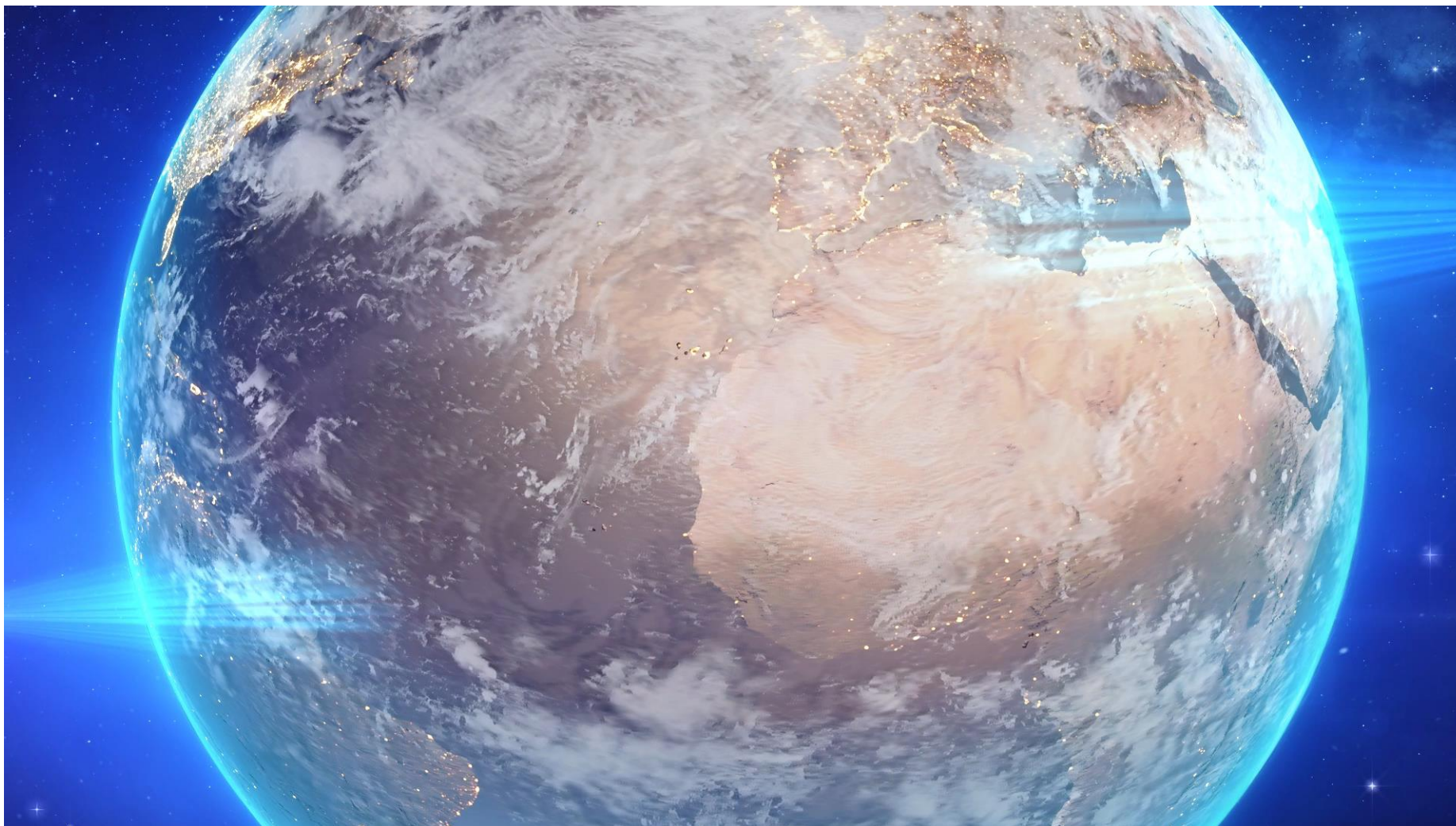
- Introduction
- The Sun
- Space Weather
- Managing the Space Weather project
 - Facilities
 - Forecasting & Communications
 - Science Engagement
 - Human Capital
 - Science Research
- Whew!



Who am I?

- Currently:
 - SANSA SARChI Research Chair in Space Weather
 - Extraordinary Professor, department of Physics and Astronomy, UWC
- Previously:
 - Research Scientist, University of Colorado Boulder. Laboratory for Atmospheric and Space Physics 
- Research Interests: ultraviolet solar spectral irradiance, space weather, interplanetary magnetic field, comets, lunar reflectance, space weathering, exospheric hydrogen, space climate...
- Mentoring student researchers!





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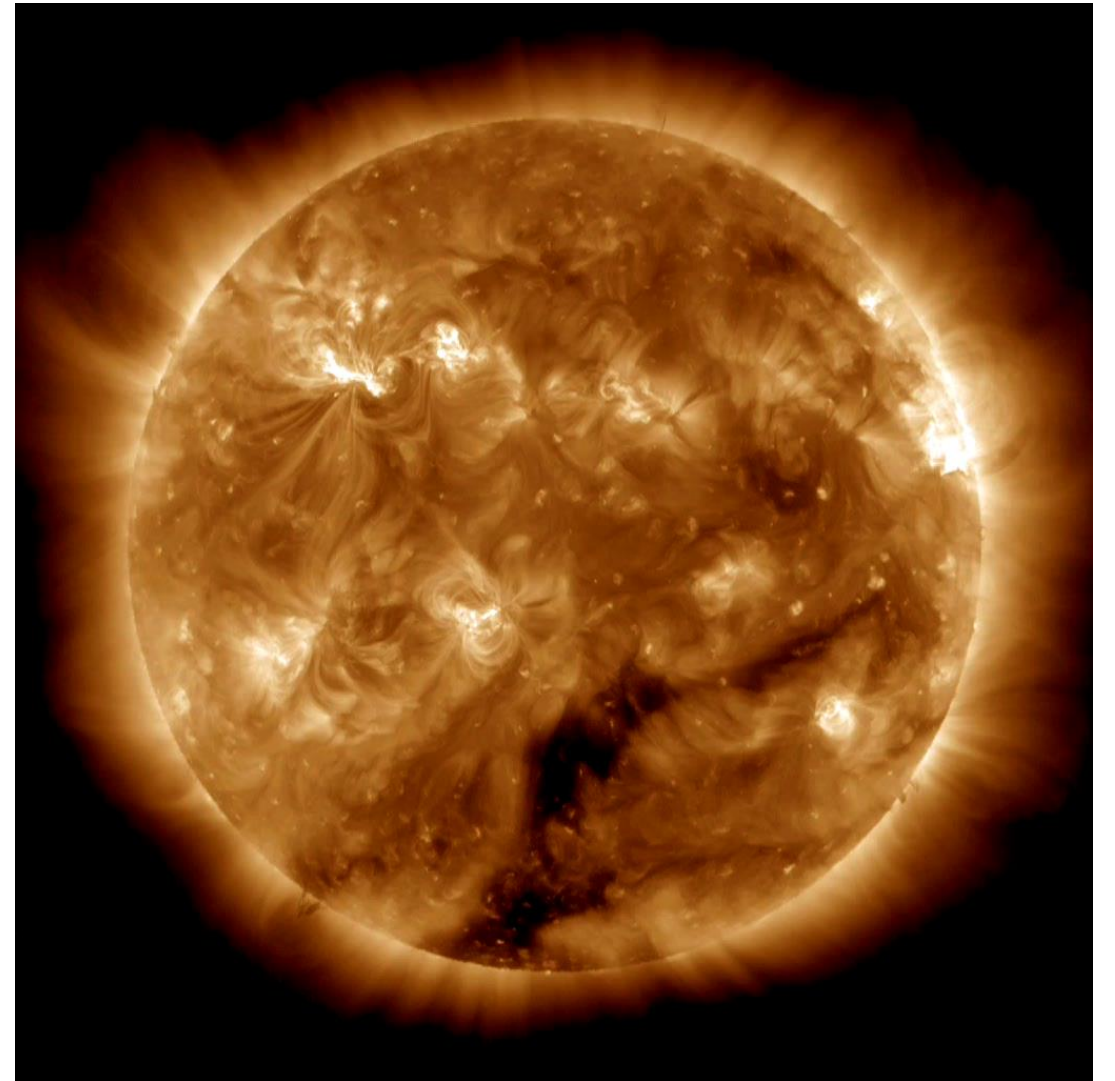
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What causes space weather?

The Sun has a dynamic magnetic field that varies on all time scales: from seconds to centuries.

It is the dominant source of energy to the Earth's climate system (by a factor of 100,000).



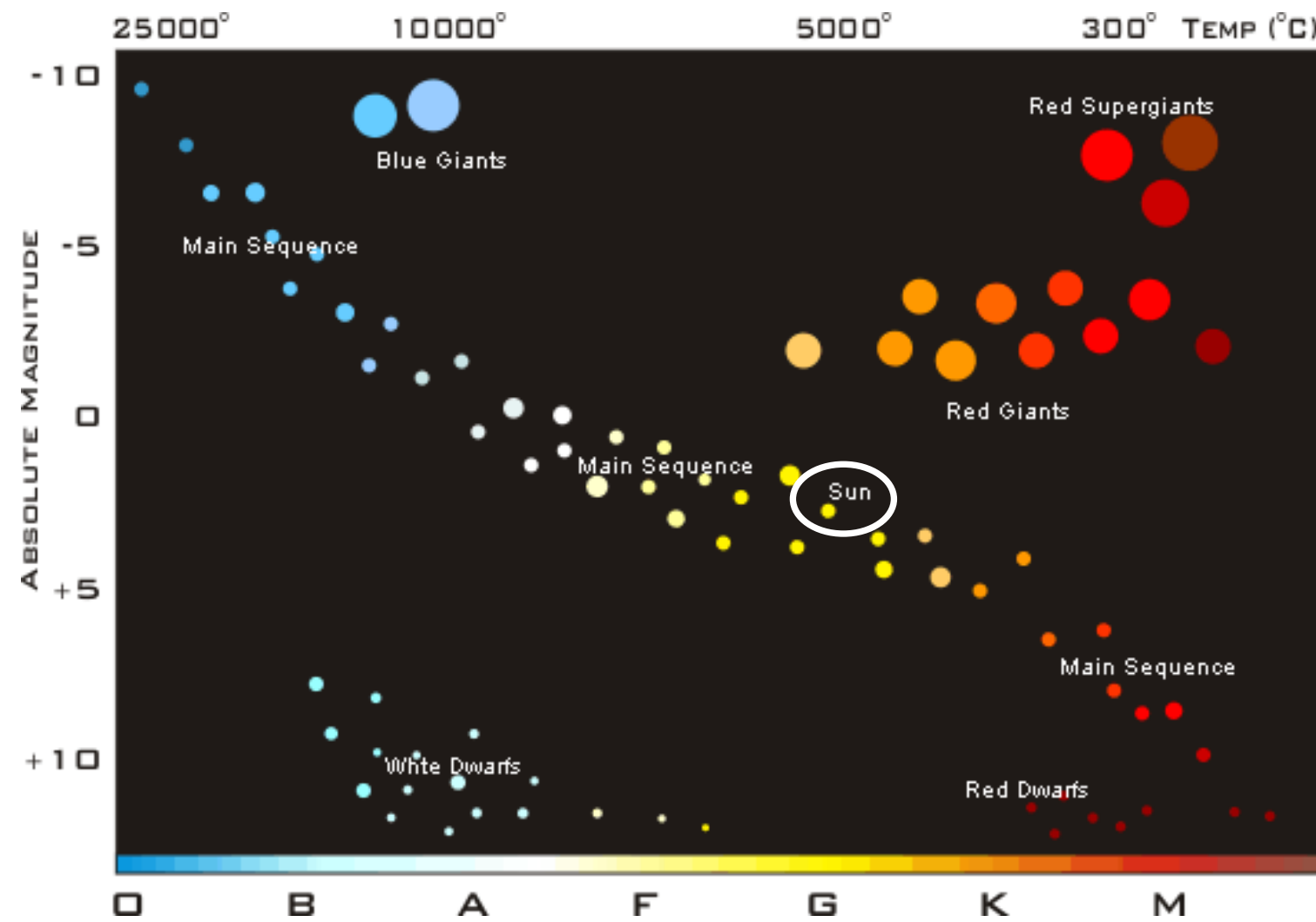
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Our star, the Sun

A fairly ordinary main sequence star halfway through its expected lifetime.

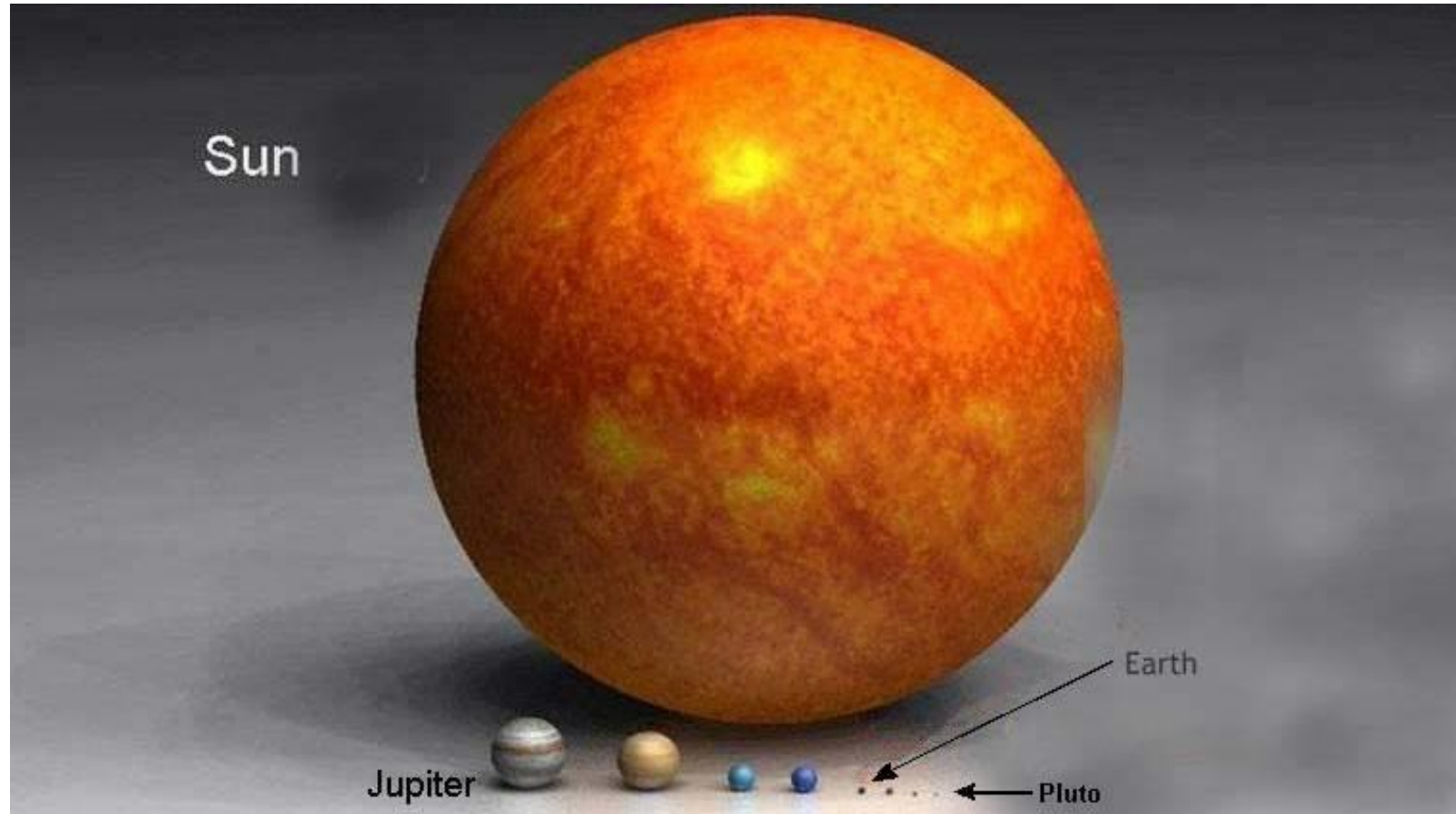


The Sun

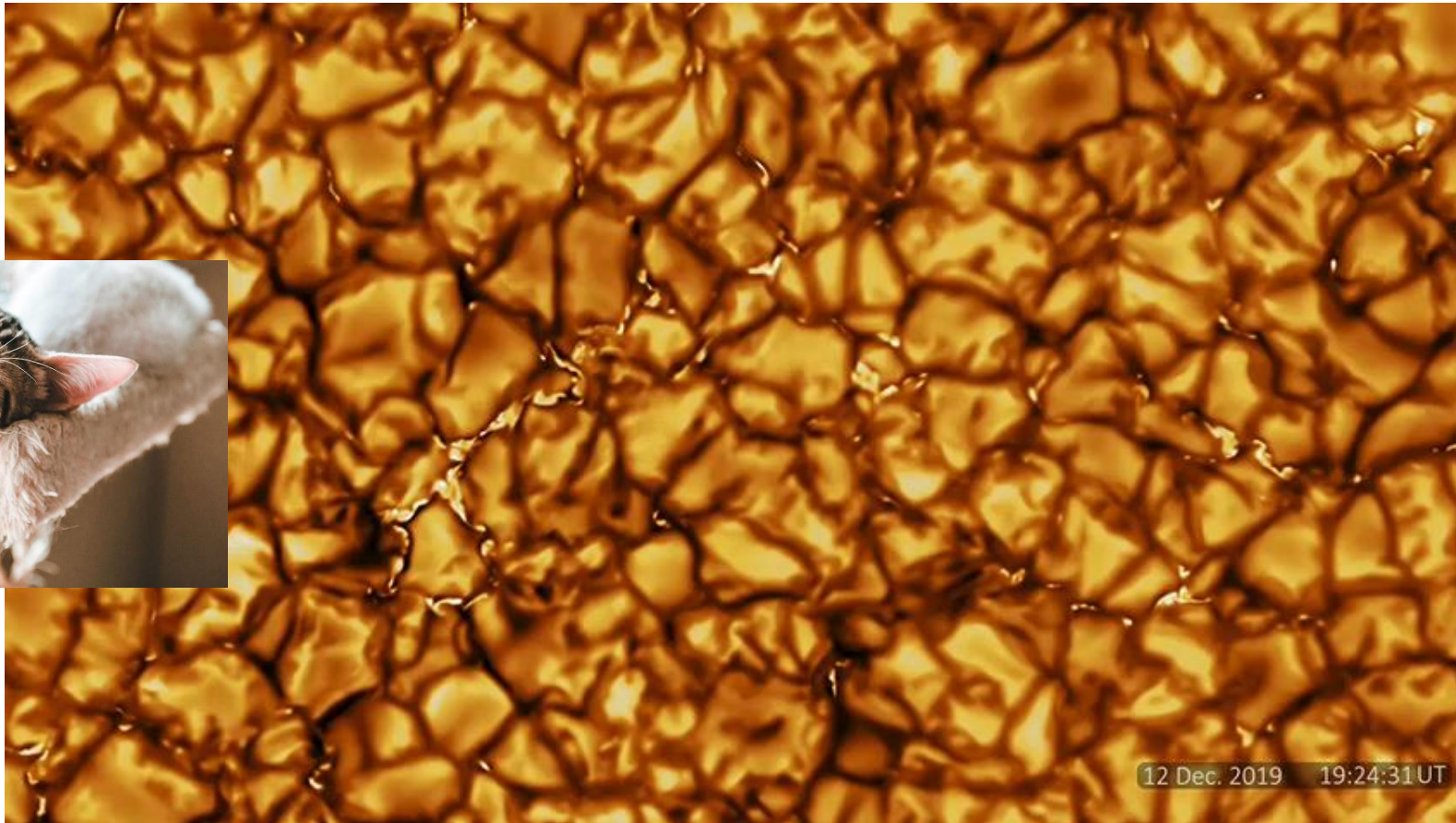
An ordinary star at the center of the solar system.

Gravity at the core is so strong that nuclear fusion turns hydrogen into helium. This energy works its way to the surface over thousands of years.

In the outer 1/3, energy is transported by convective overturning. This motion of ionized gas creates a magnetic field.



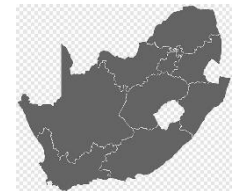
Close up of the surface: constant motion



Cat not to scale.



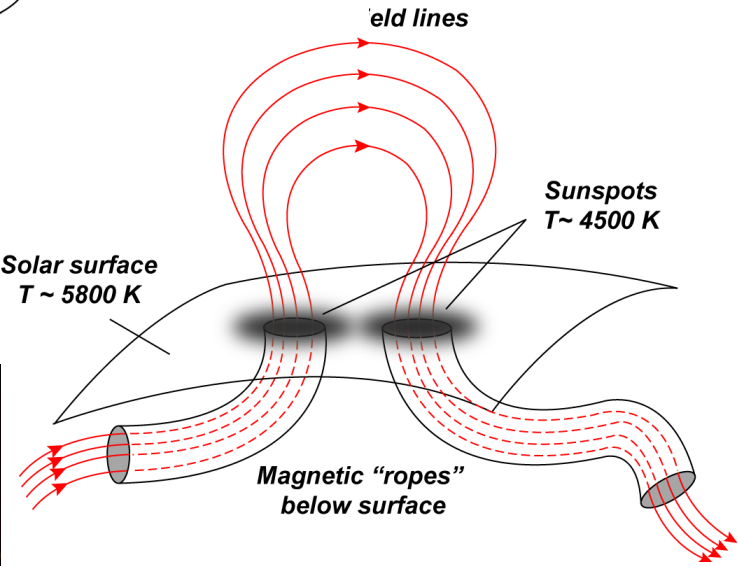
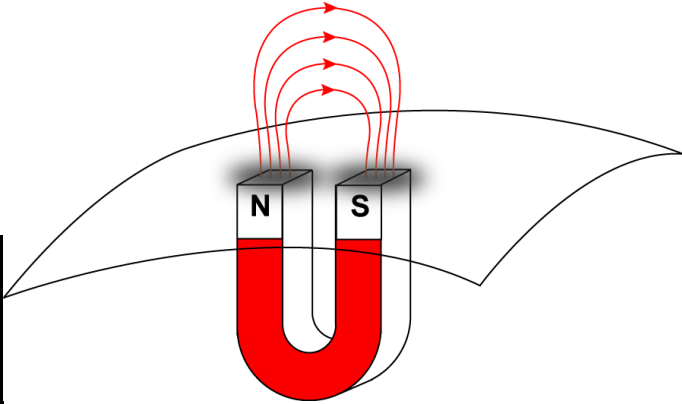
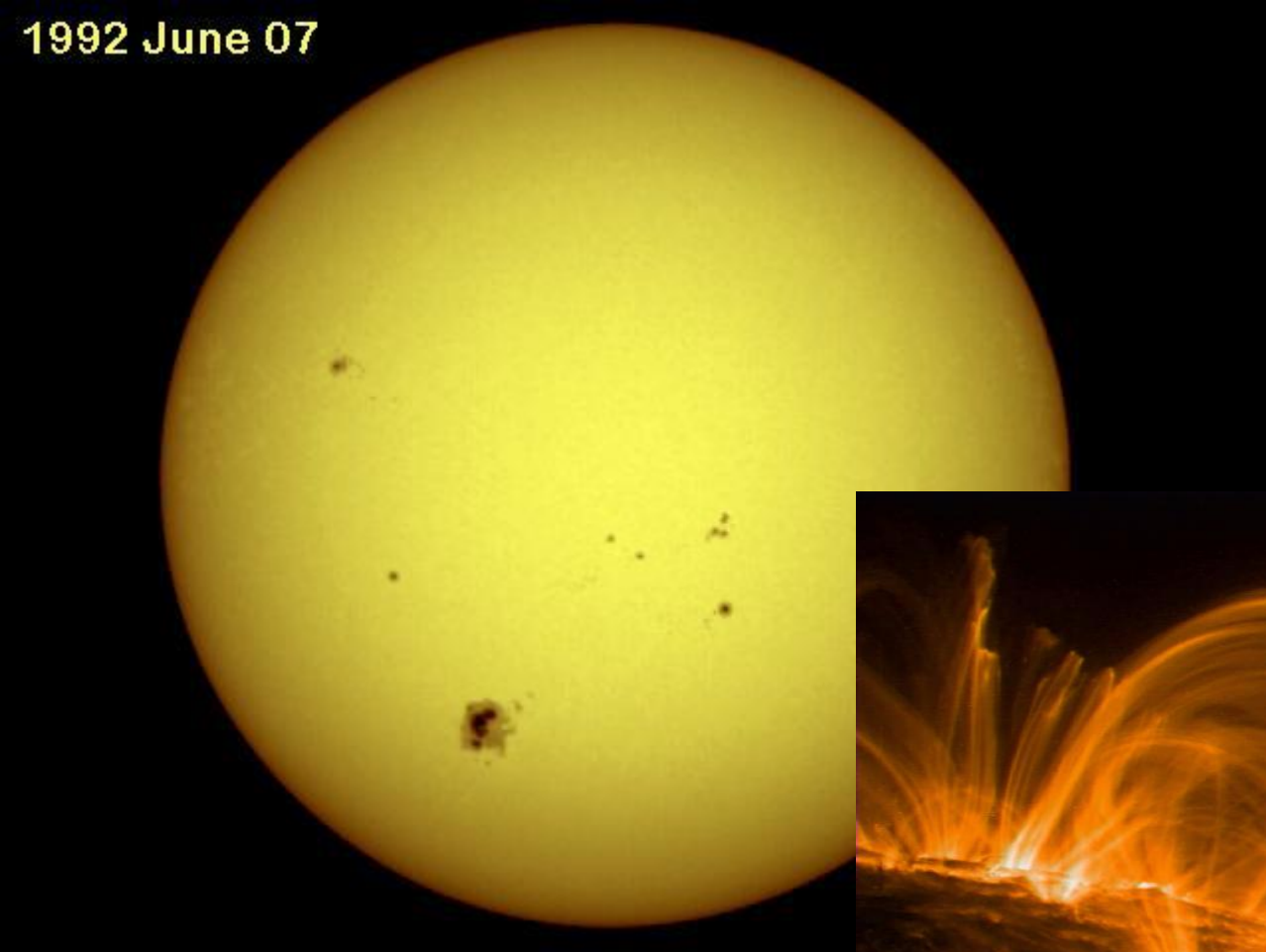
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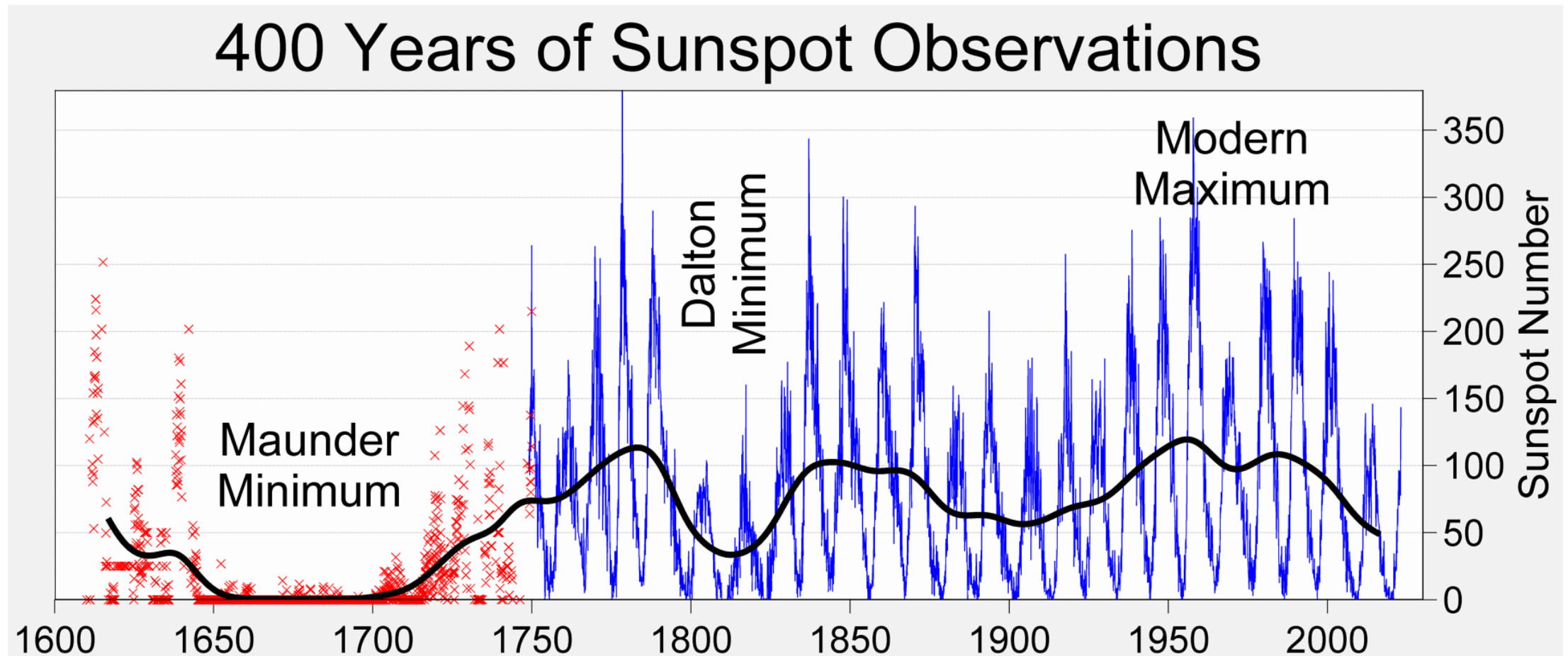
12 Dec. 2019 19:24:31 UT

Sunspots – magnetic features

1992 June 07



Sunspot numbers rise and fall with a period of about 11 years. Variation over decades is known as Space Climate



CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=969067>



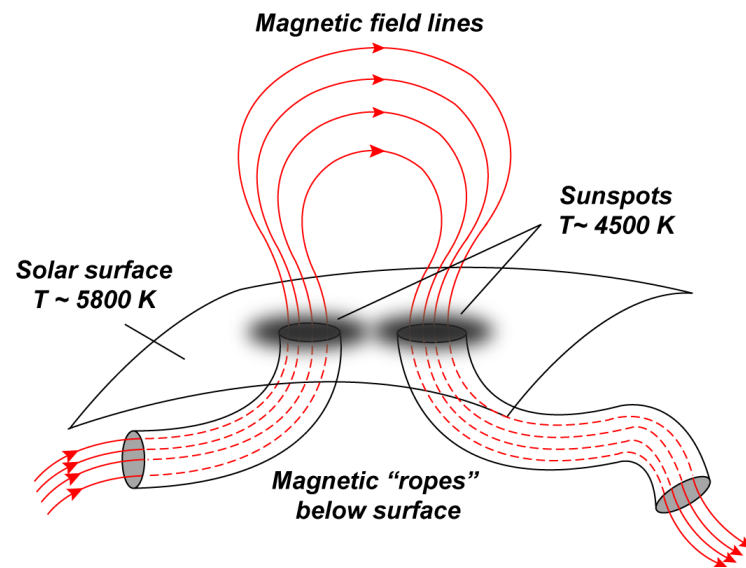
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SAASTEC 2024

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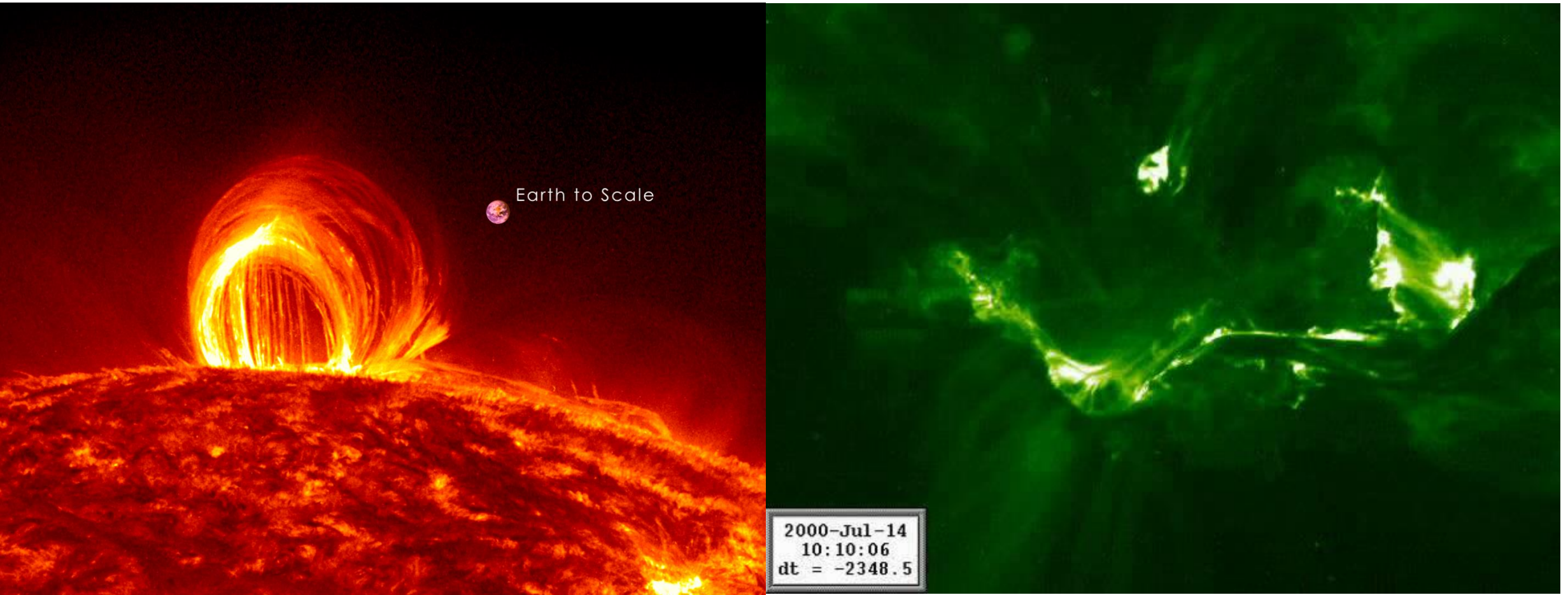


What happens when those magnetic loops get tangled?



The magnetic field lines can break, releasing stored energy

Space Weather!



There are three types of space weather events:

1. Radio Blackouts – burst of X-rays ionizes the upper atmosphere disrupting communication to aircraft and satellites.
2. Solar Radiation Storms – high-energy charged particles can damage spacecraft, pose a health risk to astronauts and passengers/crew of aircraft.
3. Geomagnetic Storms – electrical damage to spacecraft and power grids. Satellite navigation accuracy degraded.

What is in common? Only modern technology is affected.
We didn't know about Space Weather 100 years ago and didn't care.

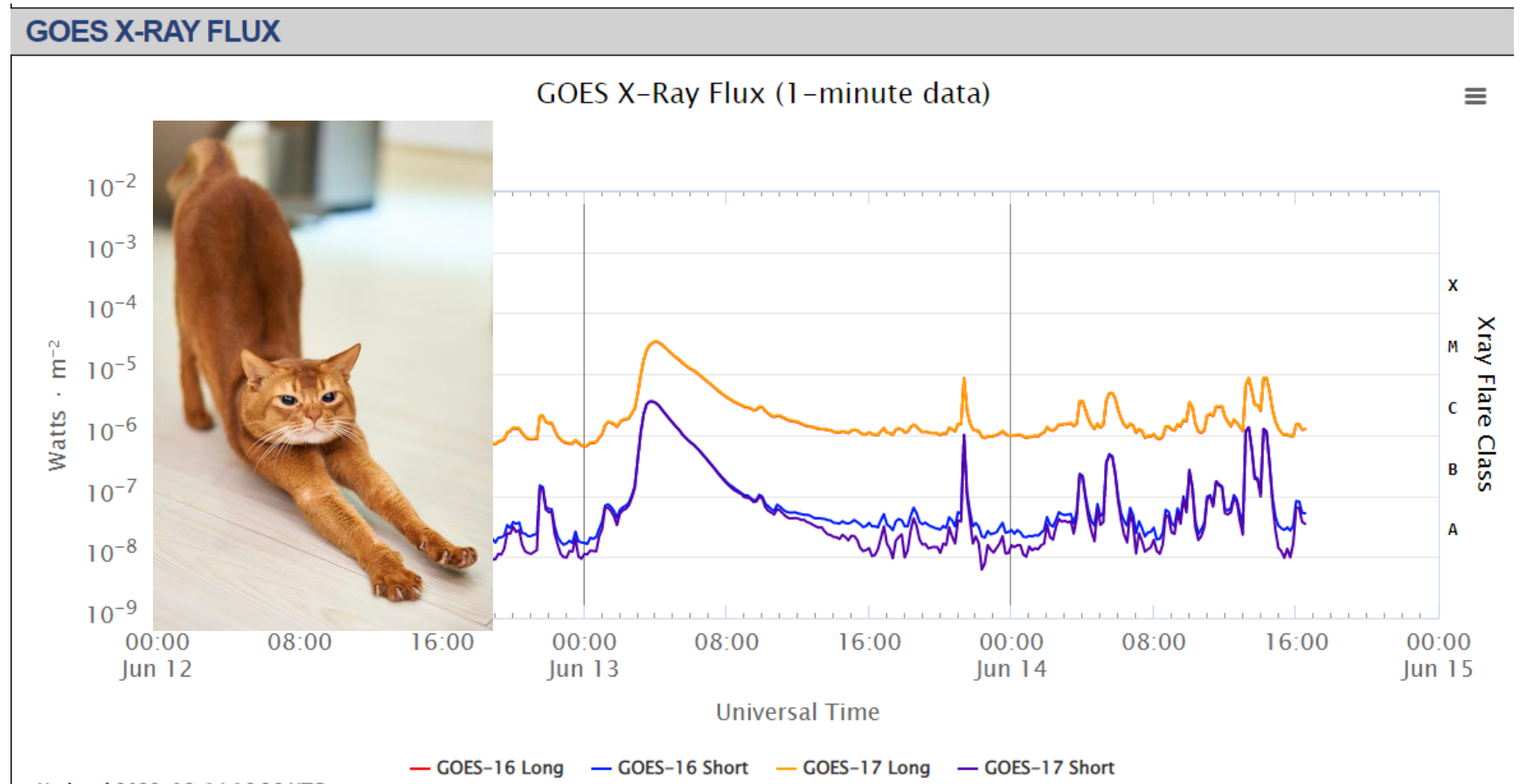


Solar X-ray Irradiance

X-ray flux can increase by a factor of 100 within minutes.

Currently no reliable way to predict flares in advance.

No warning before the arrival of the photons. They travel at the speed of light.

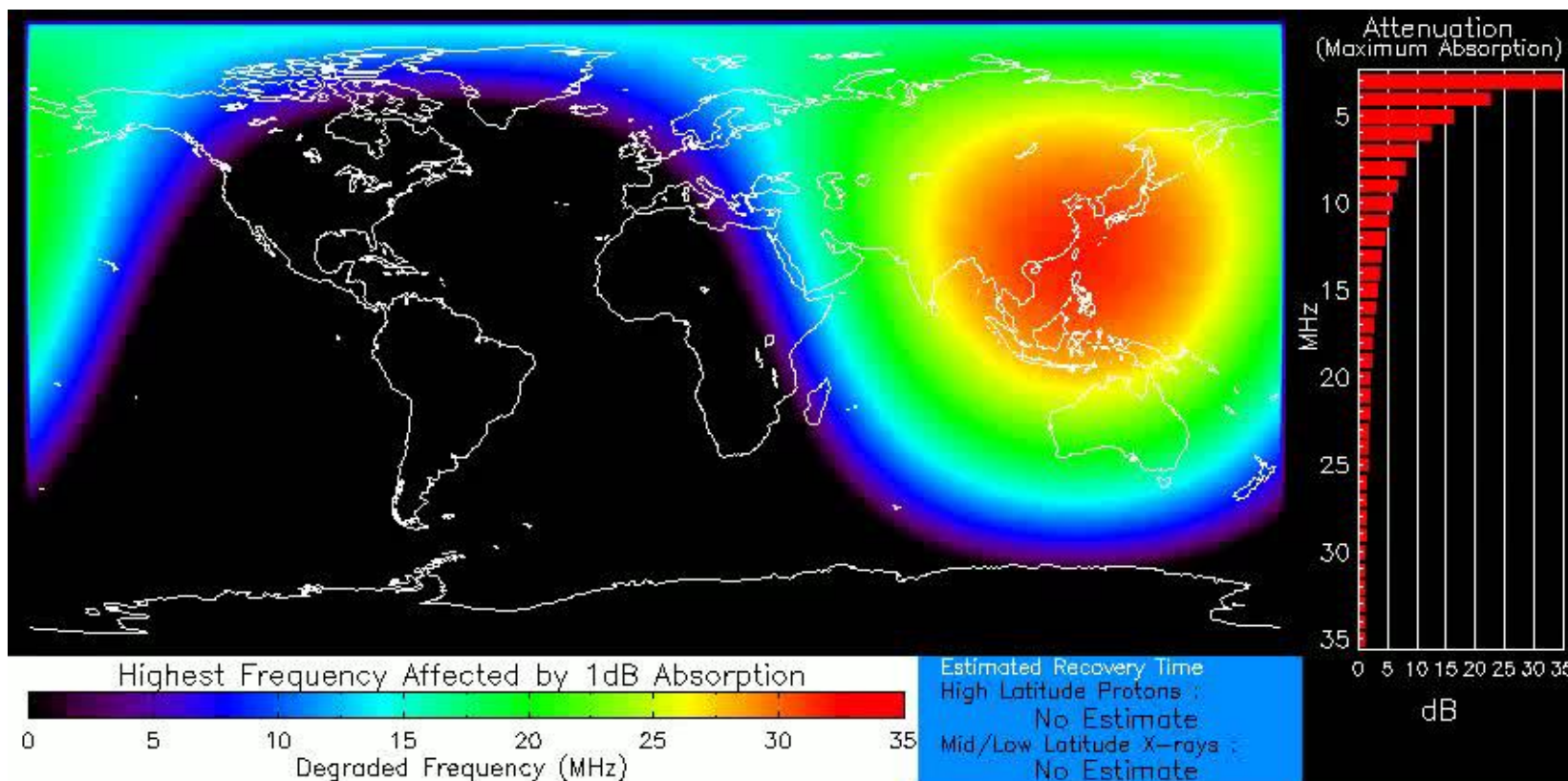


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Radio Blackout

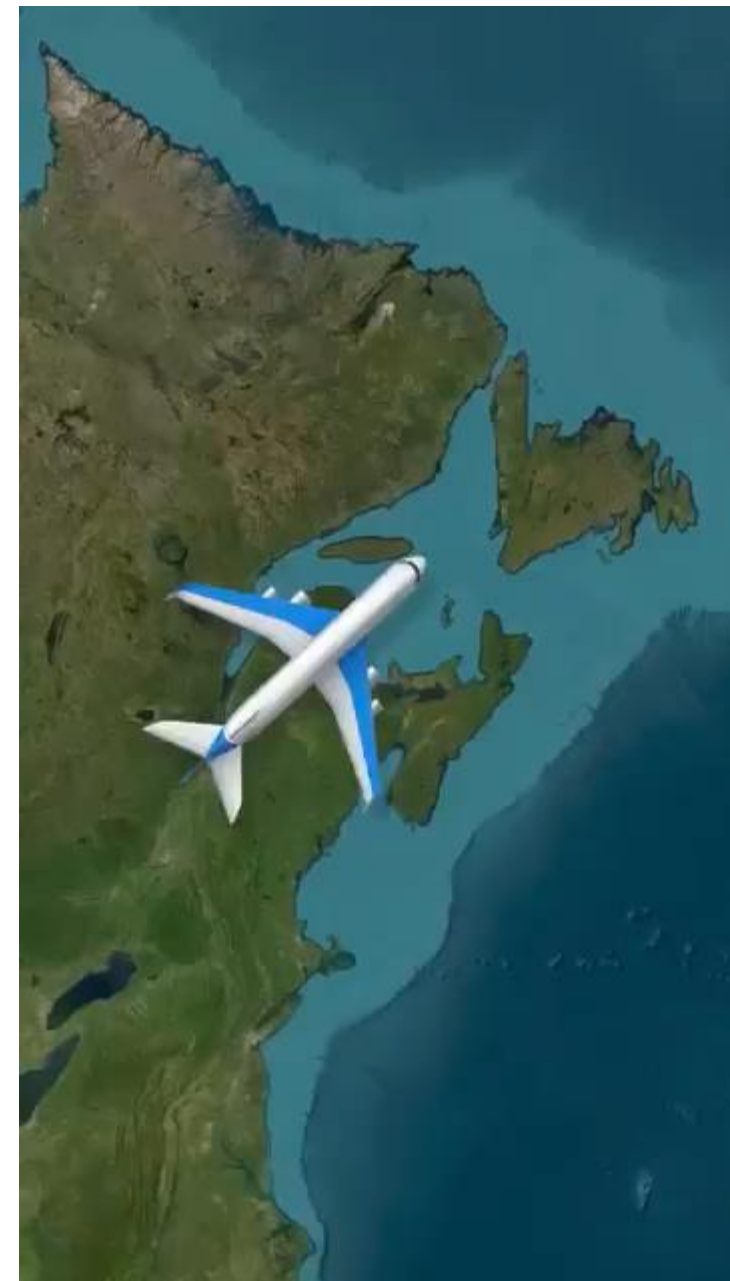


Minor X-ray flux
Product Valid At : 2022-06-13 03:59 UTC

Normal Proton Background
NOAA/SWPC Boulder, CO USA



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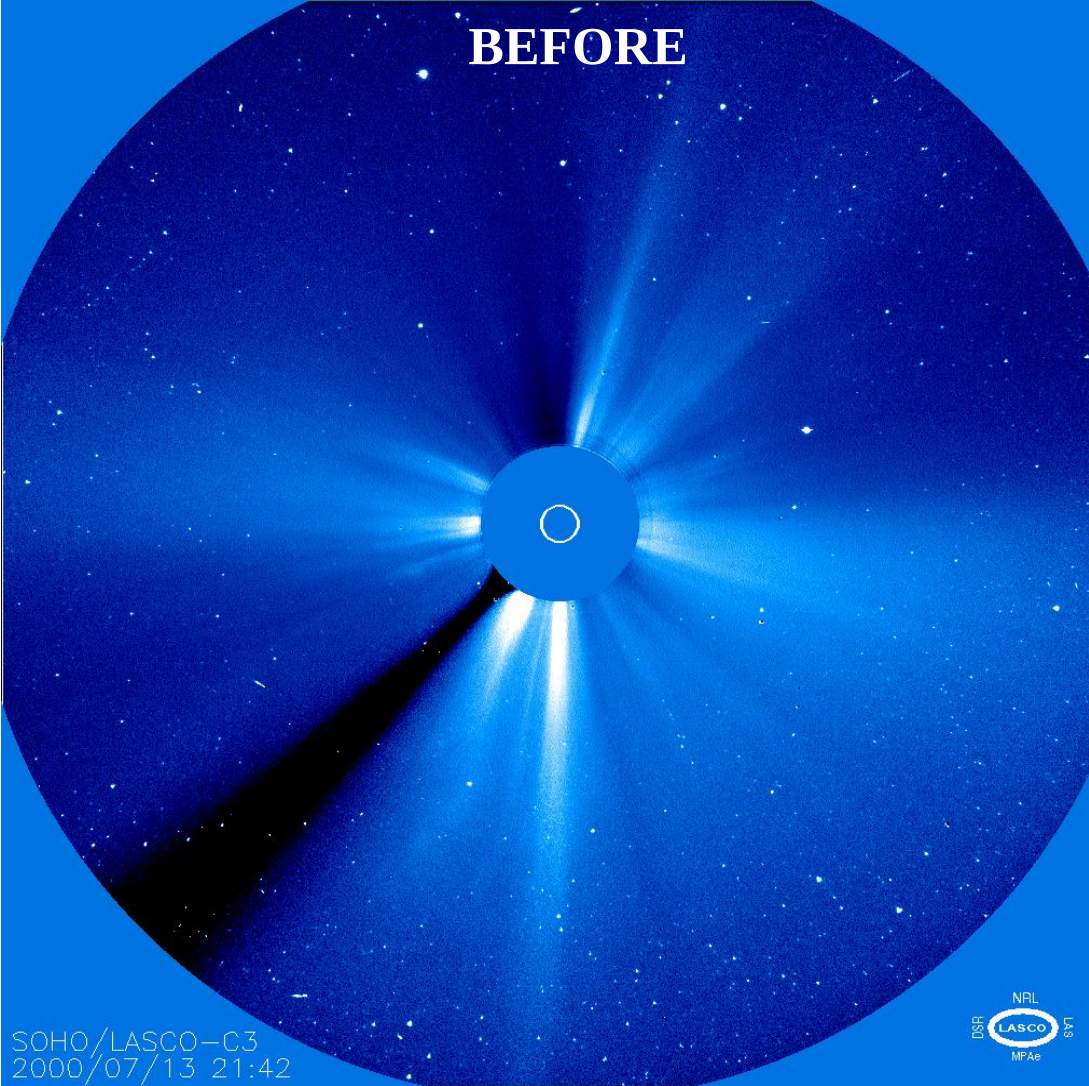


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SPACE AGENCY

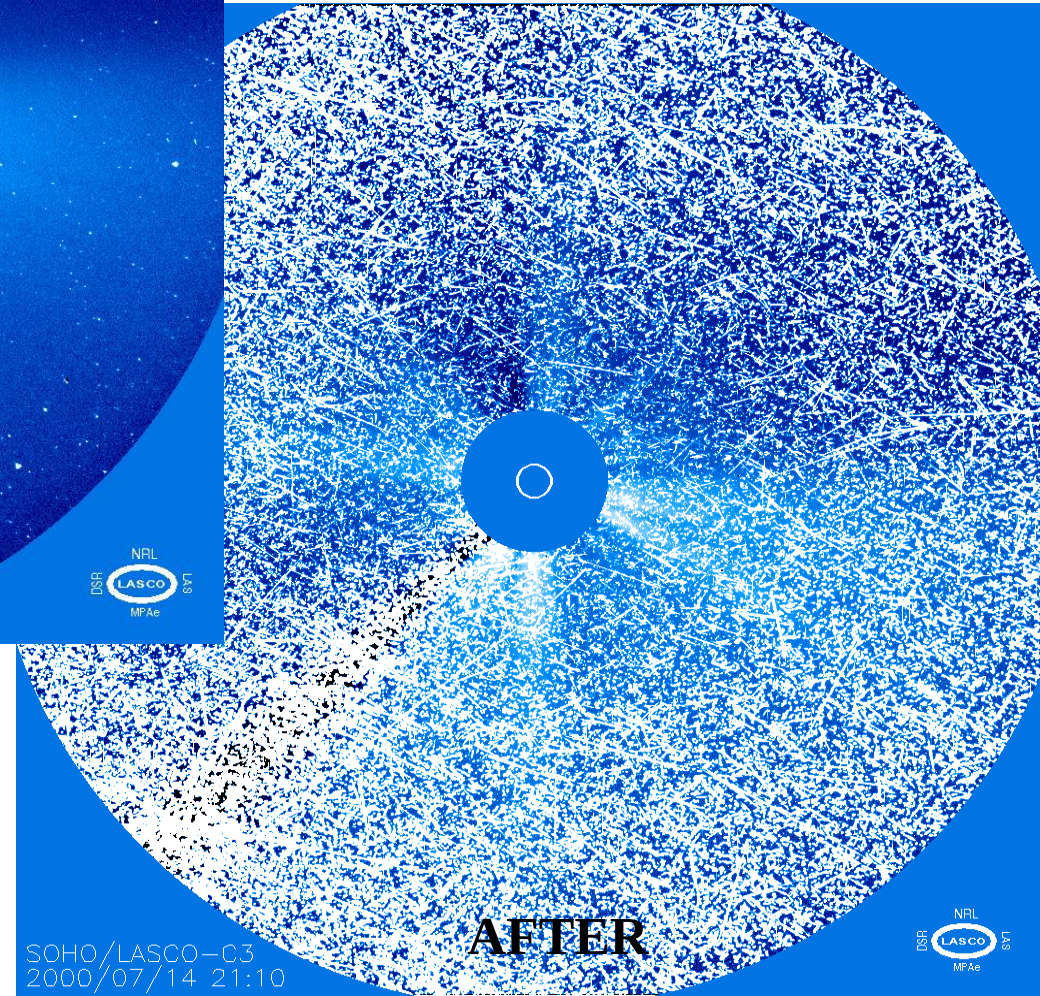
BEFORE

Solar Radiation Storms

SOHO/LASCO - C3
2000/07/14 21:10UT



SOHO/LASCO - C3
2000/07/13 21:42UT



AFTER

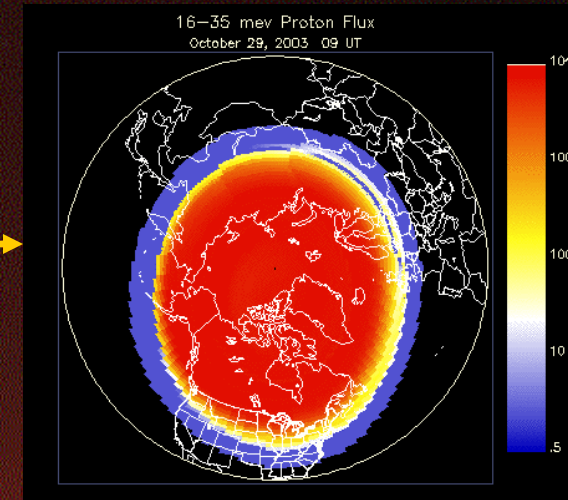
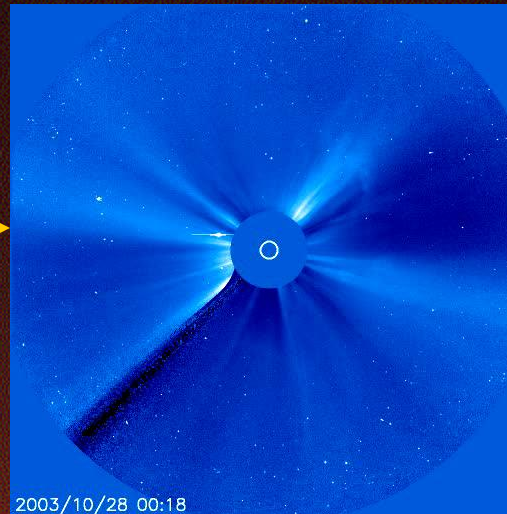
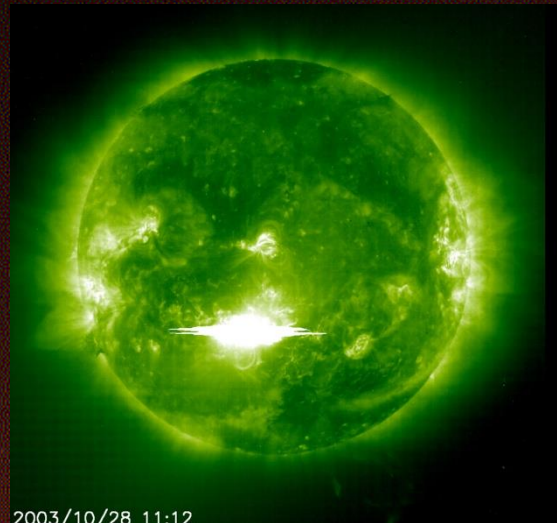


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Solar Radiation Storms (S Scale)

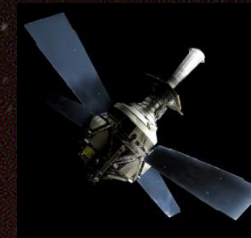


- Arrival: 30 minutes to several hours
- Duration: hours to days

Impacts...

- High latitude communications
- Satellite Operations (range from loss of data to loss of satellite)
- Manned spaceflight (exposure concerns)
- Spacecraft launch operations
- Aviation (communications and exposure concerns)

Space Missions - Mitigating actions



- Instruments and/or spacecraft turned off or safed
- Maneuver planning (avoid any maneuvers during solar activity)
- Increased spacecraft and instrument monitoring for health and safety during solar storms
- Launch of spacecraft delayed



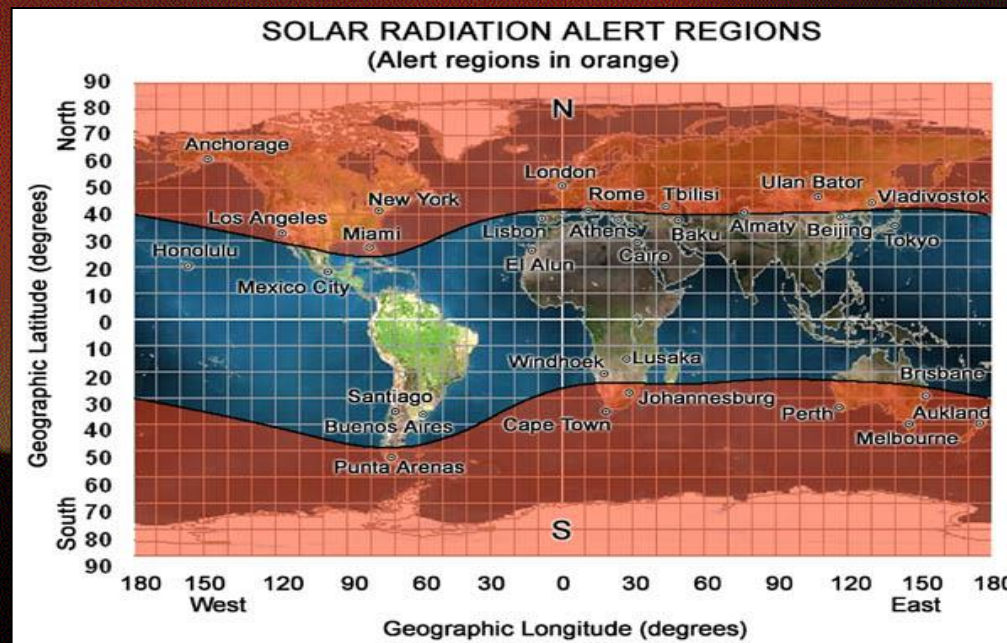
Airlines avoid polar routes during Radiation Storms due to both exposure and communications concerns

Low latitude concerns also exist:

ALERT: Solar Radiation Alert at Flight Altitudes Conditions Began: 2003 Oct 28 2113 UTC

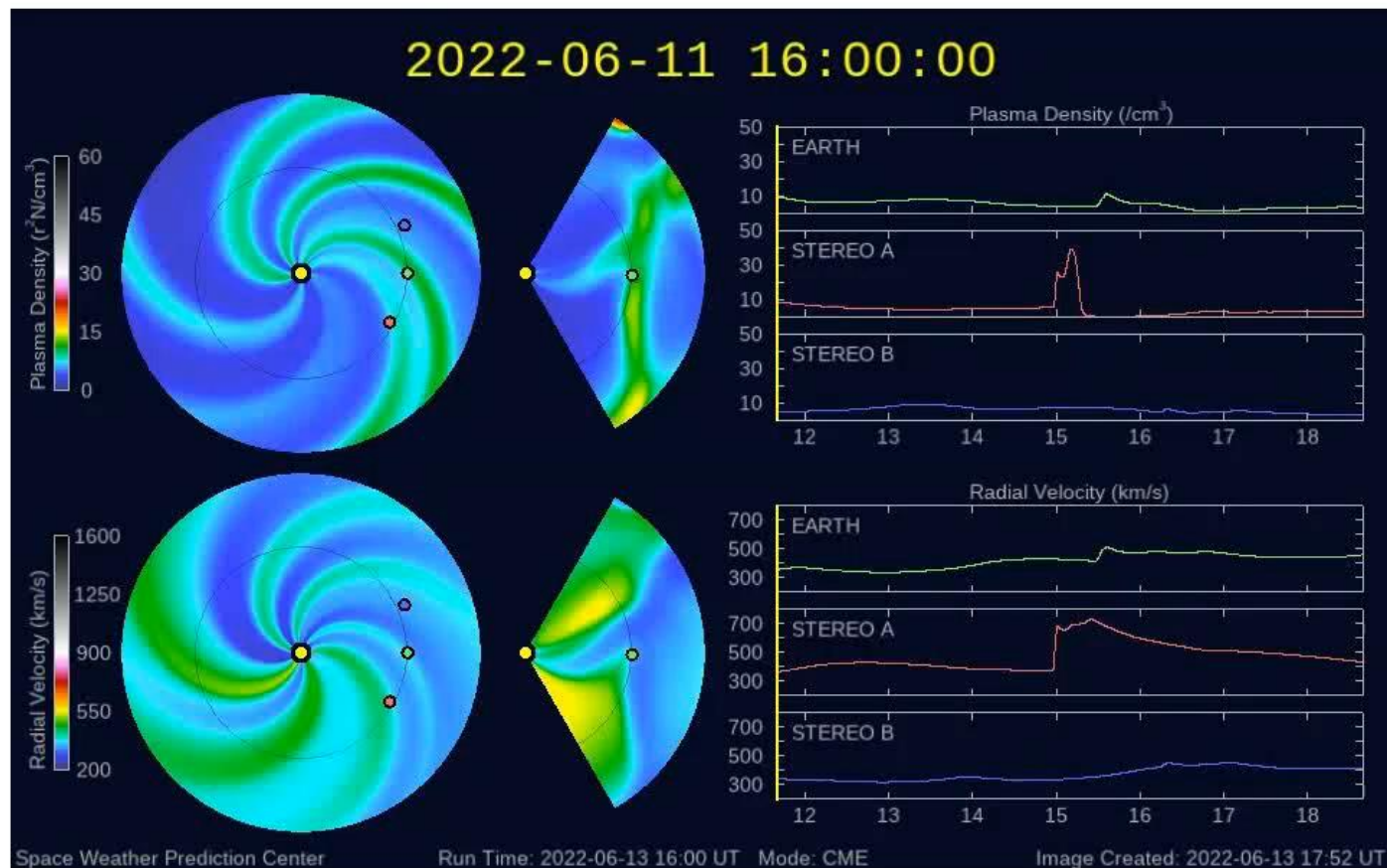
Comment: Satellite measurements indicate unusually high levels of ionizing radiation, coming from the sun. This may lead to excessive radiation doses to air travelers at Corrected Geomagnetic Latitudes above 35 degrees north, or south.

(Federal Aviation Administration)



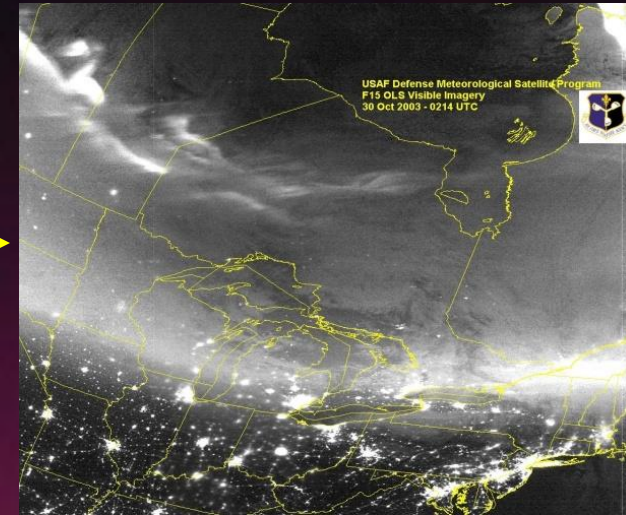
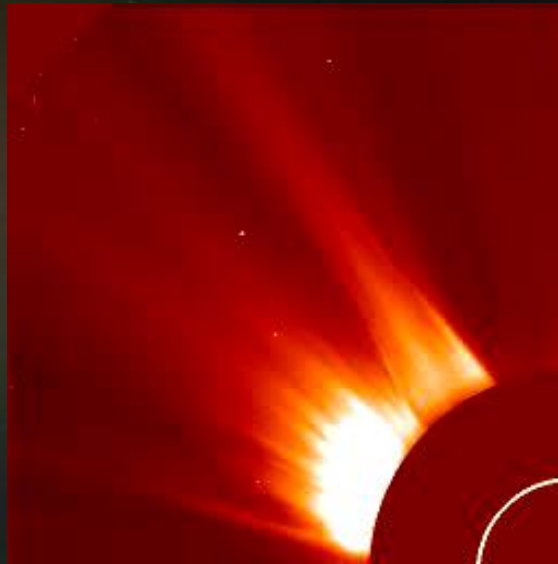
Solar Wind

Since the Sun is rotating, the solar wind looks bent in a spiral pattern.
Slow solar wind 400 km/s -- Fast solar wind 800 km/s



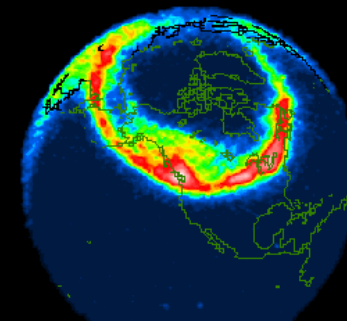
Geomagnetic Storms (G Scale)

Coronal Mass Ejections (CMEs) create geomagnetic storms



VIS Earth Camera
99/295 07:08 UT

- Arrival: 20 – 90 hours
- Duration: hours to a day
- Creates Ionospheric storms



Visible Imaging System
The University of Iowa

Polar Spacecraft
NASA/Goddard Space Flight Center

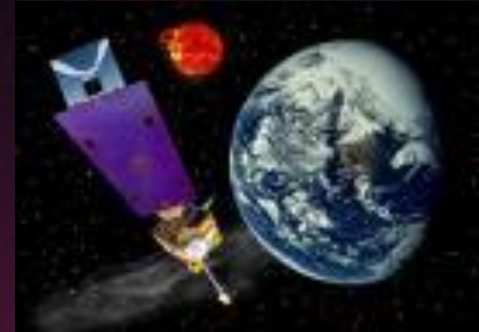


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Earth-directed CMEs result in Geomagnetic Storms

Impacts from geomagnetic storms are wide-ranging with potentially significant consequences.



Satellite Operations



Manned Spaceflight



GPS



Power Grid Operations



Aircraft Operations

ESKOM Network reports - 5 Stations, $\pm$ 15 Transformers damaged

Station 4 Transformer 6 HV winding failure



Station 3 Transformer 6 LV exit lead overheating



Station 5 Transformer 2



Station 3 Gen Transformer 4 damage

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Station 3 Gen. Transformer 5 overheating

23



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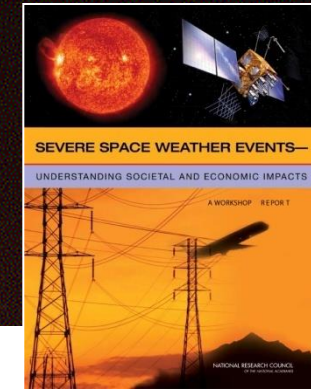
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Worst Case...

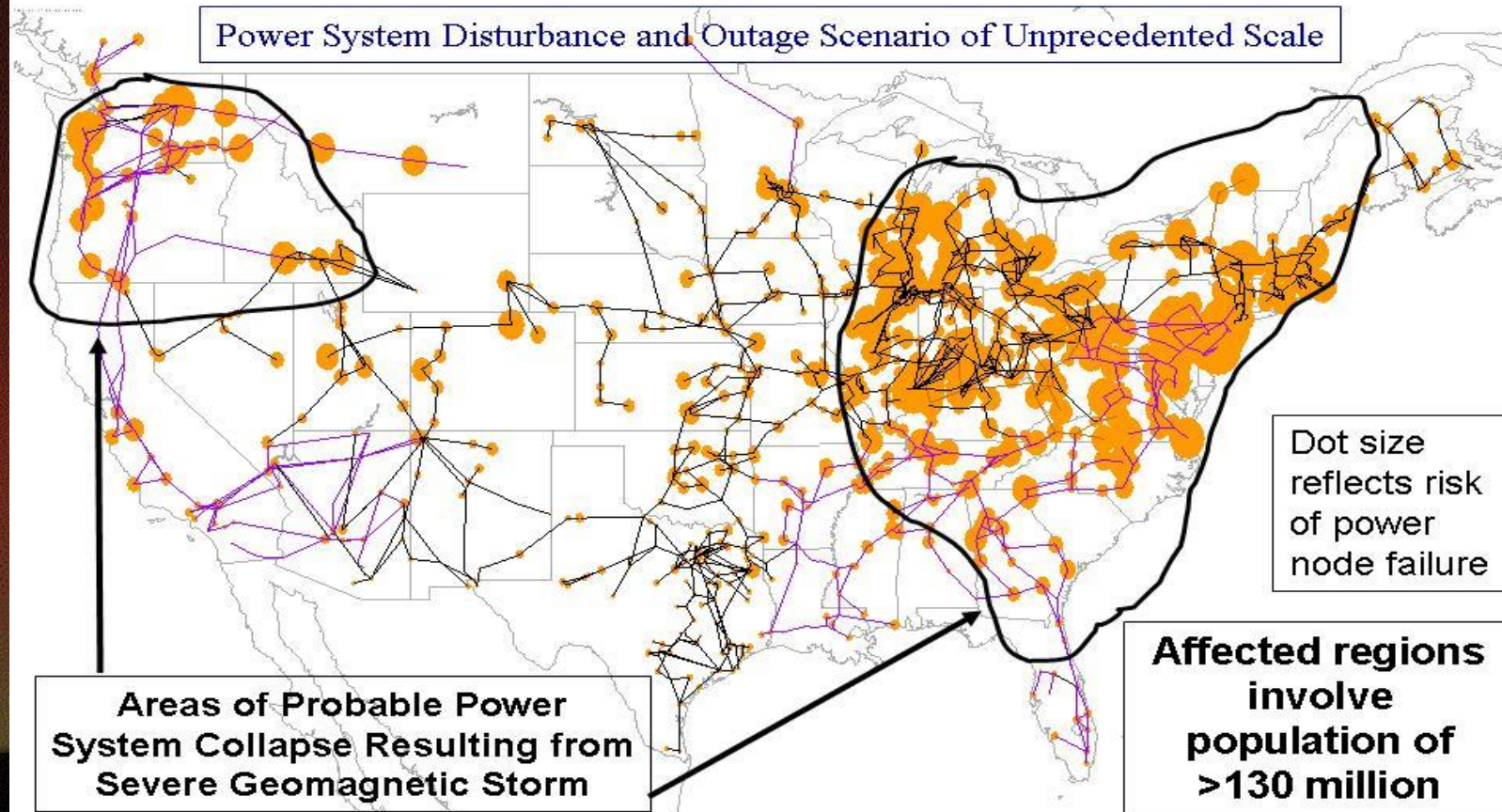
\$1-2 Trillion – Cost of blackout

4-10 years - Recovery time



From National Research Council (NRC) report, "Severe Space Weather Events" (2008)

Power System Disturbance and Outage Scenario of Unprecedented Scale



SPACE WEATHER EFFECTS ON TECHNOLOGY



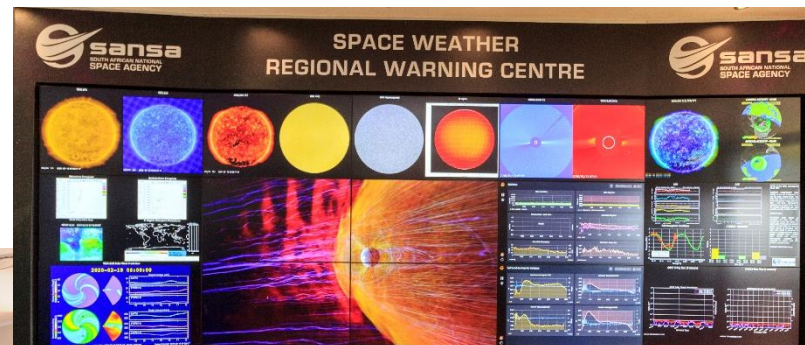
So how do we warn people of the danger?



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2007

Member of ISES
(Space Weather
Community)

2010

Space Weather Regional
Warning Centre for Africa

2018

Space Weather Regional
Warning Centre Upgrade

2022

24/7 Operational
Space Weather
Centre



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LAUNCH OF Operational SPACE WEATHER CAPABILITY



THE VILLAGE NEWS

SANSA opens state-of-the-art facility

By [Name] Photographer
[Name]

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 alerts to the global aviation community.

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 Jannaker, SANSA Project Lead for Space Weather; Christopher Denny, Owner Director; Edge-to-Edge; Deputy Mayor Lindile Ntsebe; Wesley Dingley, Principal Contractor; Edge-to-Edge; Heidi McAllister, Associate Architect; AVNA Architects; Mayor Anne-Rie Rabie; Dr Lee-Anne McKinnell, SANSA Hermanus Managing Director; Gideon Schoonraad, Architect and Principal Agent; and Sakkie Franken, Mayor of the Overberg District Municipality.

Nzimande said he 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 highlighted the fact that the business case study which included a cost recovery model and revenue generation for the Space Weather Centre.

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 said the new facility will also create awareness and low in terms of cost.

Dr McKinnell said the new facility will also create awareness and low in terms of cost.

PROJECT IMPACTS

Project Investment
= R 107 million

Indirect Impacts

Public interest in Science
& Technology
Knowledge generation
International Prestige &
Standing

Direct Impacts

15 Professional Jobs
45 Temporary Construction Jobs
10 Subcontractors
Local housing rental in Hermanus
for 18 months
All material local content with
70% from Hermanus suppliers

Induced Impacts

Secondary spend in the local
community through jobs
created and increase in
local income
Associated upgrades to the
SANSA Hermanus Facility (a
national platform)



Space Weather Forecasters

- Issue daily bulletins
- Issue warnings during events
- Communicate with media
- Support stakeholder workshops
- 24/7 operation
-



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SANSA's Science Engagement Unit

- Focus on Space Science and Space Weather
- Programmes:
 - In-house – activities for Grade R through University
 - Mobile lab – bring activities to previously disadvantaged communities
- Engage 10 000+ learners per year
- Workshops for educator development 120+ teachers per year
- Public Tours (weekly)
- Public Talks (monthly)
- Public Open Day (yearly)
- Accredited facility (level 2)



Human Capital Development



Training postgraduates
BScHons
MSc
PhD



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SPACE AGENCY

Space Science Research

Advancing our understanding of the Sun-Earth connection through “blue skies” research on the Sun, the Atmosphere, and the near-Earth environment.

Solar Physics (2022) 297:55
<https://doi.org/10.1007/s11207-022-01984-9>

SOLar-STellar Irradiance Comparison Experiment II (SOLSTICE II): End-of-Mission Validation of the SOLSTICE Technique

Martin Snow^{1,2,3}  · William E. McClintock¹  · Thomas N. Woods¹  · Joshua P. Elliott¹ 

Matamba et al. *Earth, Planets and Space* (2023) 75:142
<https://doi.org/10.1186/s40623-023-01894-5>

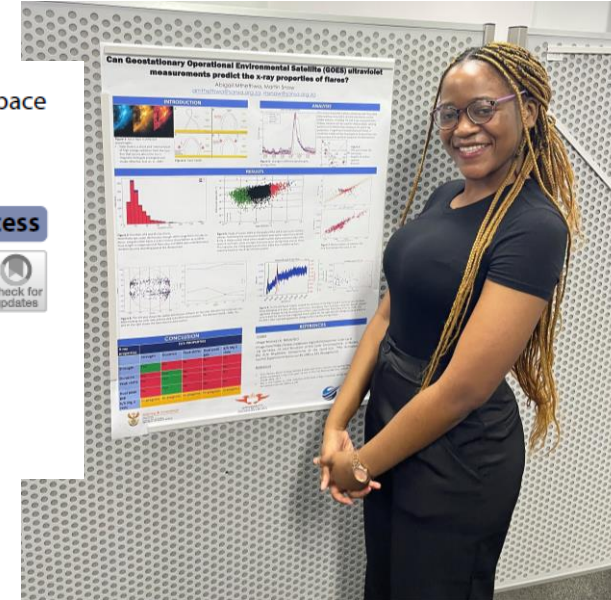
Earth, Planets and Space

FULL PAPER

Open Access

Space weather impacts on the ionosphere over the southern African mid-latitude region

Tshimangadzo Merline Matamba^{1*} , Donald W. Danskin¹, Rendani R. Nndanganeni¹ and Mpho Tshisaphungo¹



Geophysical Journal International

Geophys. J. Int. (2024) **239**, 192–200
Advance Access publication 2024 August 1
GJI Geomagnetism and Electromagnetism

<https://doi.org/10.1093/gji/ggae264>

A comparative investigation of geomagnetic jerks across the SAA during the period 2000–2020

A.E. Nel¹  and P.B. Kotzé^{2,3}

¹Space Science, South African National Space Agency, Hermanus 7200, South Africa. E-mail: anel@sansa.org.za

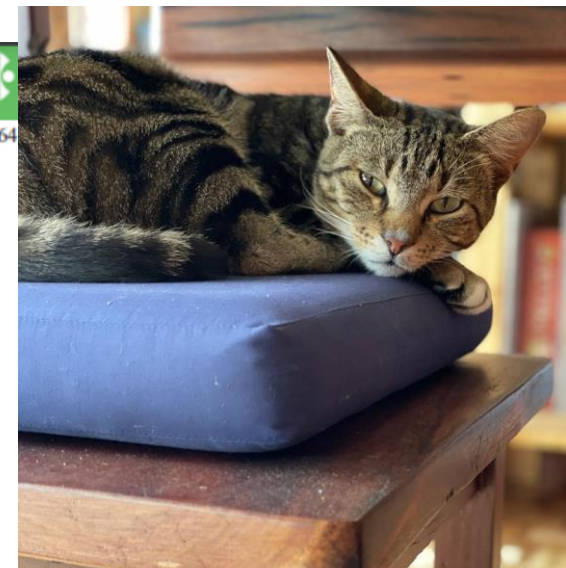
²Center for Space Research, North-West University, Potchefstroom 2522, South Africa

³Physics Department, Stellenbosch University, Stellenbosch 7602, South Africa



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LIFE BEYOND THE KÁRMÁN LINE

Outer Space

PLANETS | GALAXIES | BLACK HOLES | ROCHETS | ROVERS | TELESCOPES

WRITTEN BY

DR THABANI MAZIBUKO



It investigates the transformative power of space travel, the search for extraterrestrial life, and our evolving perception of our place in the universe.



Managing the Space Weather Enterprise: also known as herding cats



SANSA Space Science isn't just about providing a Space Weather Forecasting service to Africa

- Educating potential clients about why they need the service
- Human Capital Development (starting with learners) to expand STEM skills in South Africa
 - Science Outreach
 - Funding scholarships for postgraduates
 - Talks/tours for the public
- Build international collaborations in science
- Develop local aerospace industry through collaboration



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THANK YOU & Questions?

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