



Space Weather

Many Factors, Many Forecasts



Jon Mound, 11th April, 2022

Space Weather

A Science View

- Many phenomena
- Solar
- Terrestrial
- Interplanetary
- Complex Interactions
- Magneto Hydro Dynamics



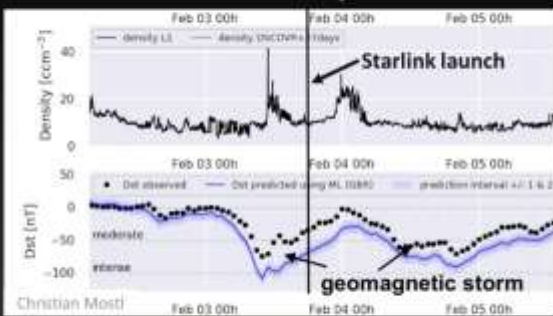
Space Weather

A Societal View

- Many phenomena
- Many systems
- Space
- Atmosphere
- Ground-level & sub-surface
- Complex Interactions



Satellite Impacts



“Unfortunately, the satellites deployed on Thursday were significantly impacted by a geomagnetic storm on Friday”

“up to 40 of the satellites will reenter or already have reentered the Earth’s atmosphere”



FEBRUARY 8, 2022

GEOMAGNETIC STORM AND RECENTLY DEPLOYED STARLINK SATELLITES



Space Weather Forecasts for Space Weather Impacts

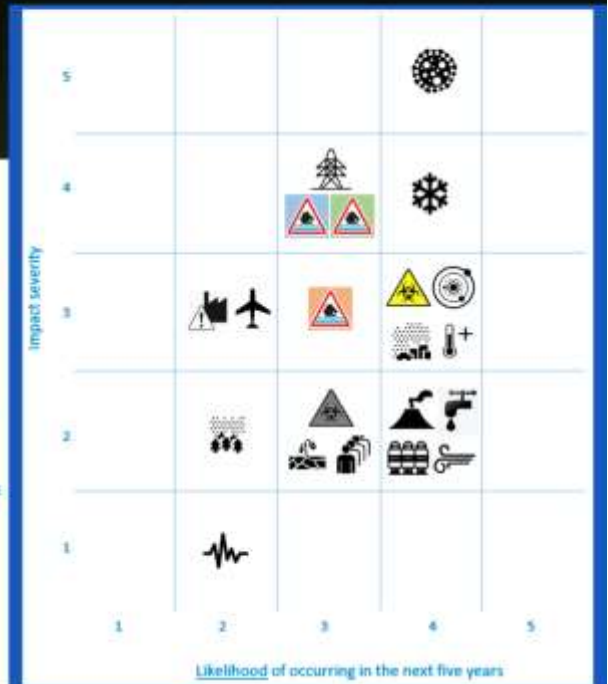
- Likelihood of events?
- Severity of impact?

UK National Risk Register (2017)

Natural hazards	Diseases
Coastal flooding	Pandemic influenza
River flooding	Emerging infectious disease
Surface water flooding	Animal disease
Storms and gales	
Cold and snow	Major accidents
Heatwave	Widespread electricity failure
Drought	Transport accidents
Space weather	Industrial and urban accidents
Volcanic eruptions	System failures
Poor air quality	Societal risks
Earthquakes	Industrial action
Wildfires	Public disorder

2017 UK National Risk Register

Science & Society



Space Weather Forecasts for Space Weather Impacts

- What will the Sun do?
- What will the solar wind do?
- What will the magnetosphere & ionosphere do?
- How will infrastructure react?
- How will the influence of Earth's magnetic field change?
- What are the likely events?
- What are the most extreme yet plausible events?



Space Weather

Studying the Science and Societal Impacts

Home Research Operations Data & services Education Contacts

British Geological Survey

Geomagnetism

Our Research

- Global Geomagnetic Models
- Space Weather and Geomagnetic Hazard
- High-frequency magnetometers
- Geostatic Ball monitoring
- Space Weather Impact on Ground-based Systems (SWIGS)
- Geomagnetic Virtual Observatories
- Publications List

Space Weather Impact on Ground-based Systems (SWIGS)

On 1st May 2017 the Geomagnetism Team will lead the kick-off of a major new space weather project called 'Space Weather Impacts on Ground-based Systems', or SWIGS. This is a £3M, four year NERC-funded consortium of ten institutes, 21 researchers and 7 post-docs, under the flagship Topic Funding Stream. This is a major investment by NERC in space weather and the consortium led by BGS comprises many of the major UK players in the subject.

One novel aspect of SWIGS is the bringing together of space physicists and geophysicists studying the solid Earth and upper atmosphere. Together with project partners in the US, Canada, Europe, New Zealand and China, as well as industry stakeholders, we will develop our understanding of how space weather and geomagnetic activity drives electric fields in the Earth and quantify the impacts of this on power grids, as well as pipeline and rail networks.

Background

Severe space weather is known to pose a significant hazard to ground based technologies, such as electrical transmission systems, pipelines and railways. Space weather is a consequence of solar magnetic activity that is carried to Earth in the Solar Wind, where it impacts the electrical currents and electromagnetic fields in near-Earth space and in the upper atmosphere. As a result of Faraday's law of induction, varying electrical currents in space cause a varying magnetic field at ground level, which induces a surface electric field in the Earth. This electric field acts as a 'battery' between earthing points in conducting structures, causing Geomagnetically Induced Currents (GIC) to flow to and from the ground through such networks.

Project plan for SWIGS (click to enlarge)

Participants

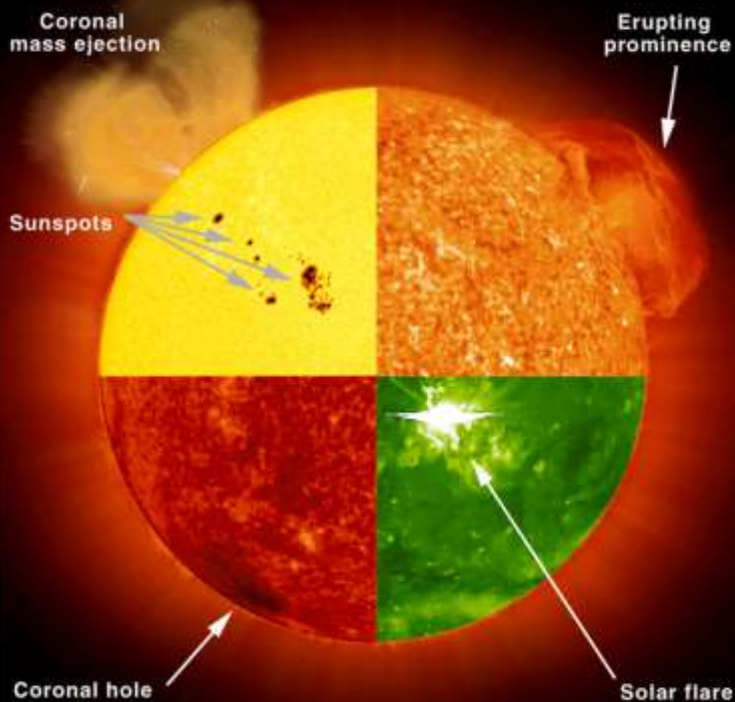
- British Geological Survey
- University of Edinburgh
- British Antarctic Survey
- University of Lancaster
- Imperial College London
- Rutherford Appleton Laboratory
- University of Southampton
- University of Leeds
- University of Reading
- University College London

UKRI Natural Environment Research Council

The Sun

A Source of Space Weather

- Sunspots
- Filaments
- Flares
- Coronal holes
- Prominences
- Coronal mass ejections



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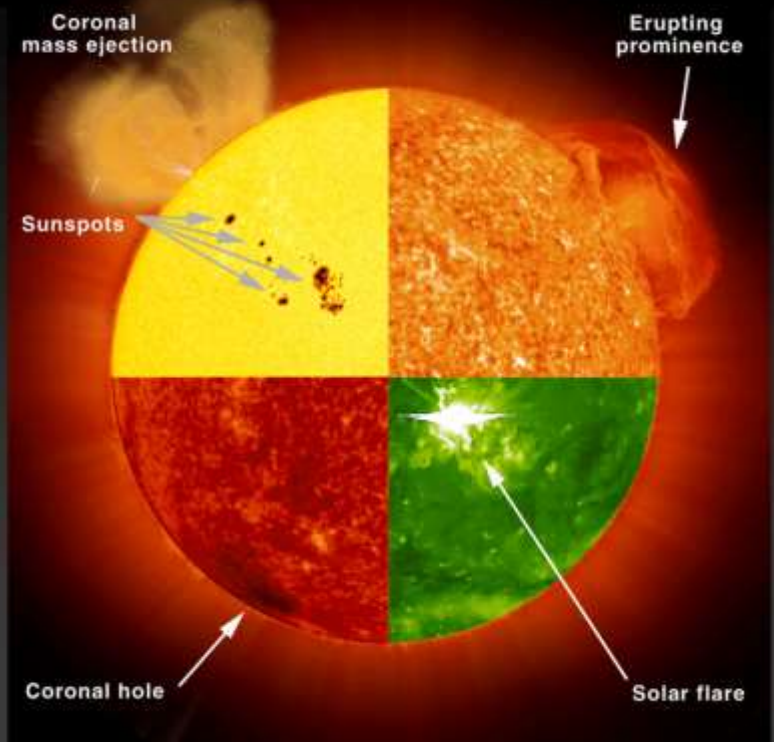
The Sun

A Source of Space Weather

- EM radiation
 - Visible & UV light
 - X-rays
 - Radio waves
- Charged particles ($v = 100$'s km/s)
 - electrons
 - protons
 - alpha particles
- Magnetic field



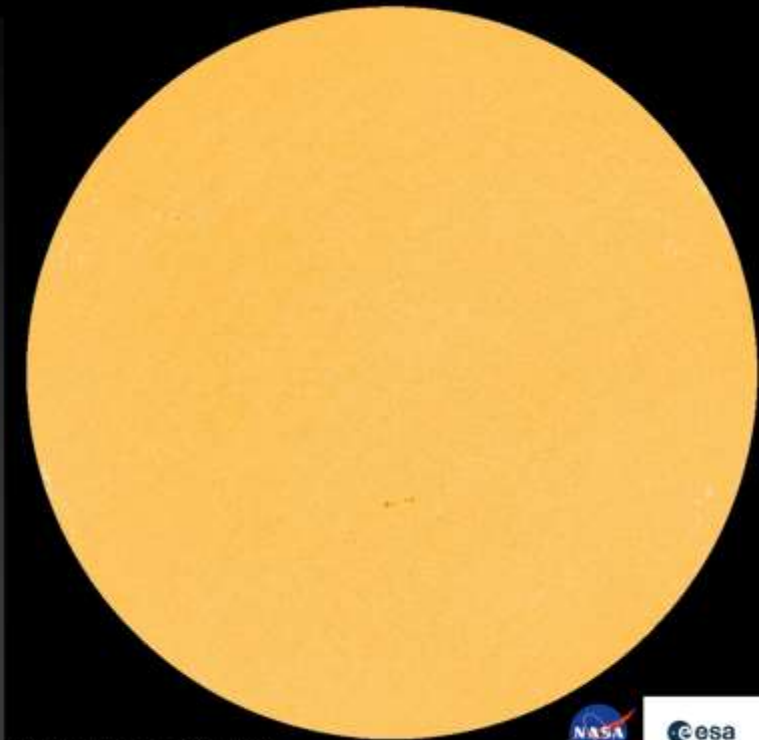
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The Sun "Today"

Visible Light

- The Solar Dynamics Observatory (SDO) mission
- Data from the Helioseismic and Magnetic Imager (HMI)
- 617.3 nanometre (red light from Fe spectral line)
- View of "the surface"



SDO/HMI Quick-Look Composite: 20220201_120000

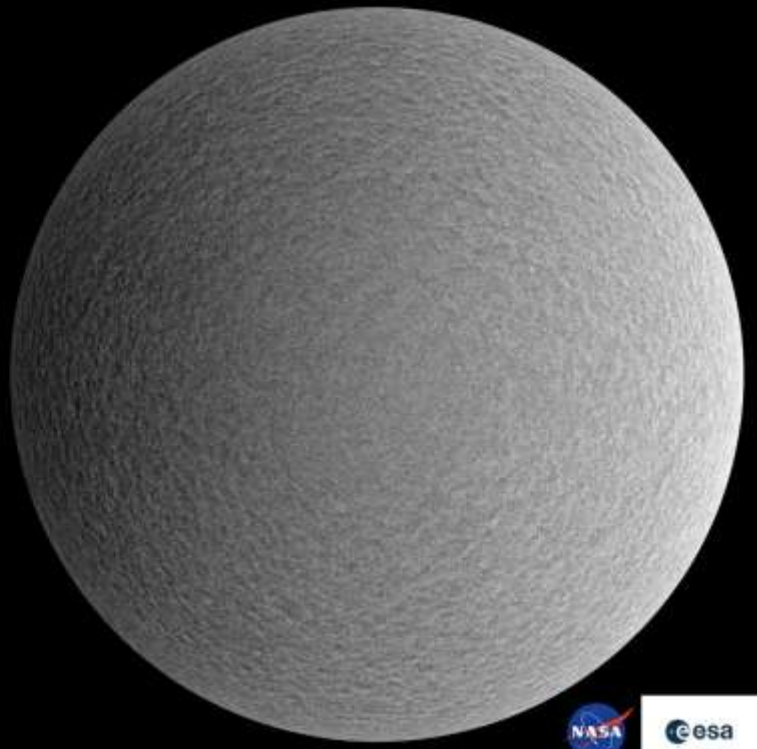


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The Sun "Today"

Visible Light

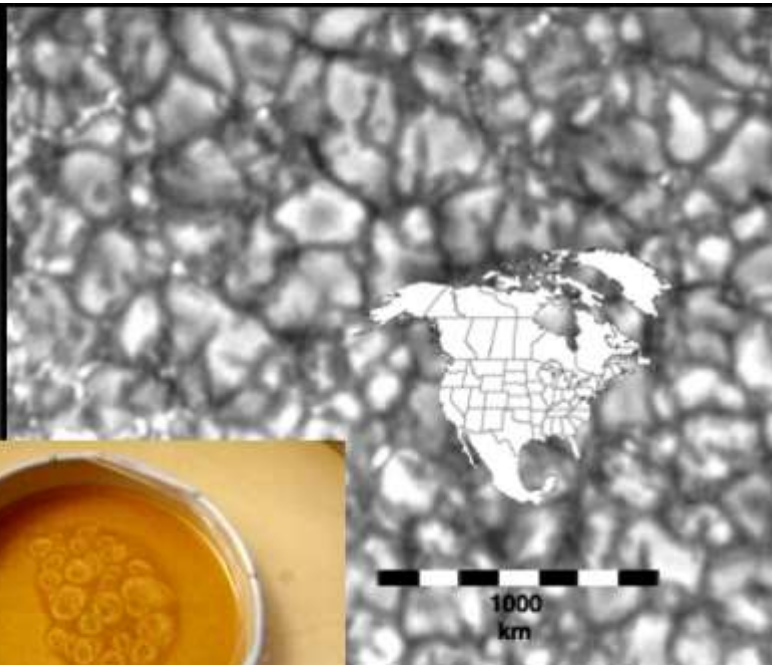
- The Solar Dynamics Observatory (SDO) mission
- Data from the Helioseismic and Magnetic Imager (HMI)
- **Helioseismology => doppler shift gives velocity**
- **View of waves on "the surface" and solar convection**



The Sun "Today"

Visible Light

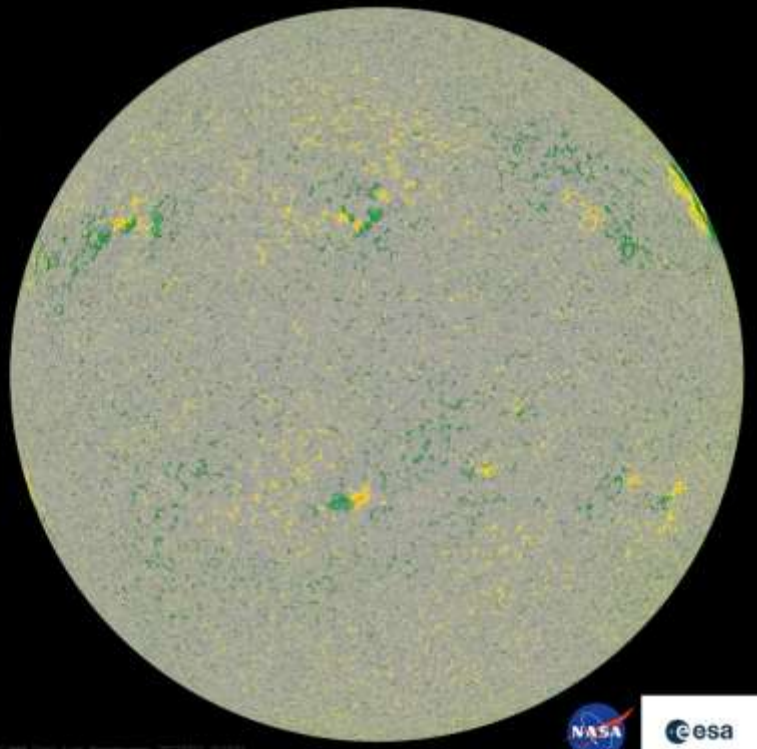
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The Sun "Today"

Magnetic Field

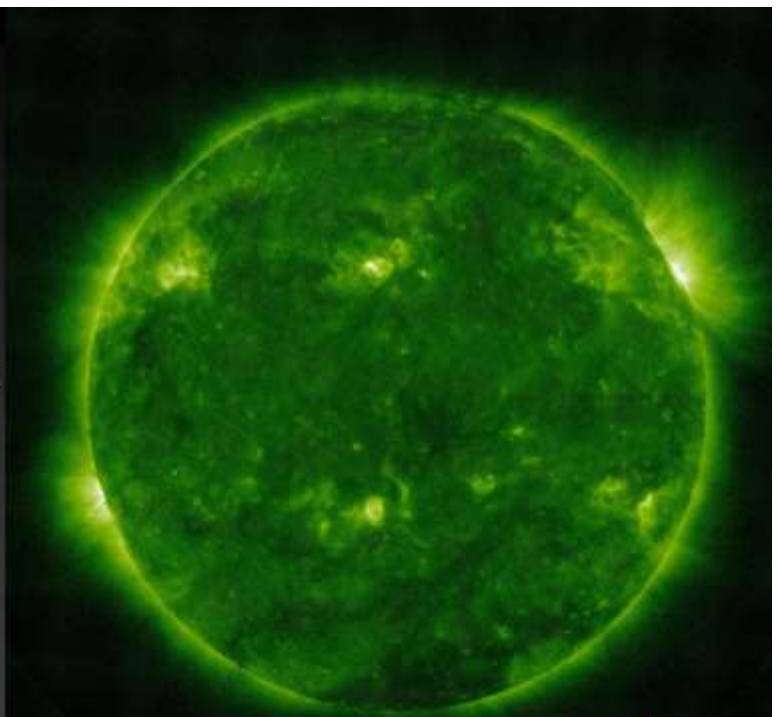
- The Solar Dynamics Observatory (SDO) mission
- Data from the Helioseismic and Magnetic Imager (HMI)
- **Magnetic Imager => spectral splitting due to presence of magnetic fields**
- View of the magnetic field at "the surface"



The Sun "Today"

UV Light

- The Solar Dynamics Observatory (SDO) mission
- Data from the Atmospheric Imaging Assembly (AIA)
- **19.3 nanometres**
- **~1.2 million K**
- **Higher T = higher in the solar atmosphere**



SDO/AIA 94 2022-03-21 00:05:00 UT



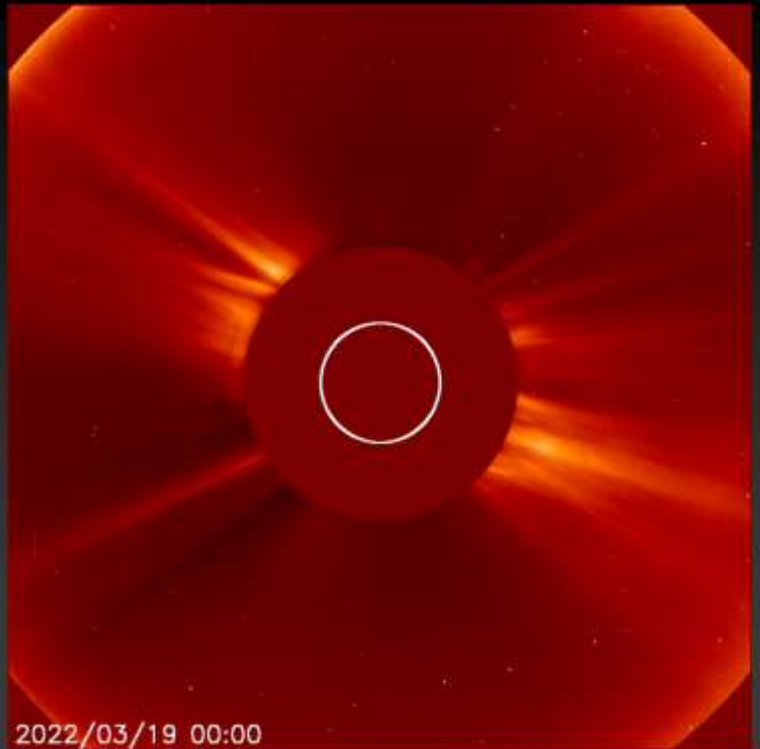
The Sun "Today"

A Source of Space Weather

- The SOLar and Heliospheric Observatory (SOHO) mission
- Data from the Large Angle and Spectrometric COronagraph (LASCO) instrument
- Disk to block the sun (white circle) to see what's happening nearby
- Close view



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2022/03/19 00:00

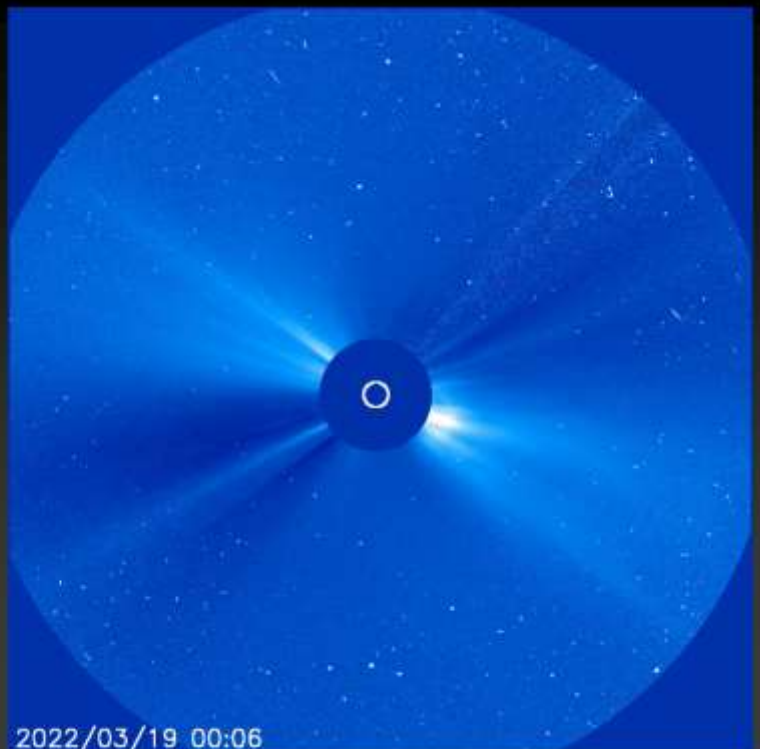
The Sun "Today"

A Source of Space Weather

- The SOLar and Heliospheric Observatory (SOHO) mission
- Data from the Large Angle and Spectrometric COronagraph (LASCO) instrument
- Disk to block the sun (white circle) to see what's happening nearby
- Steady streams and occasional bursts



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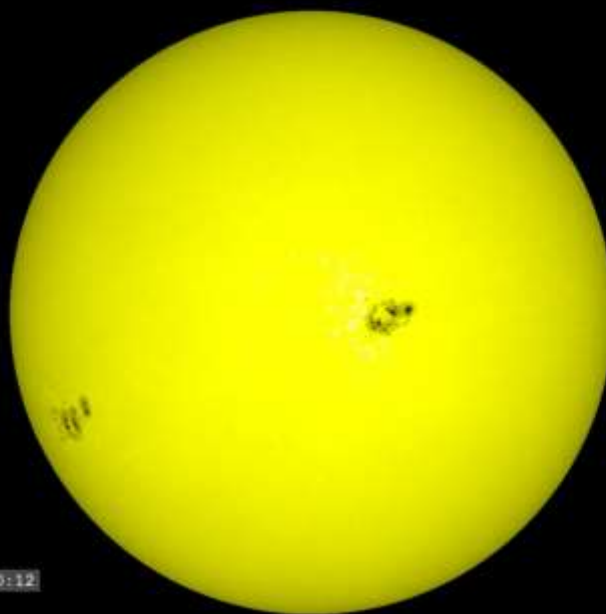


2022/03/19 00:06

The Sun "Today"



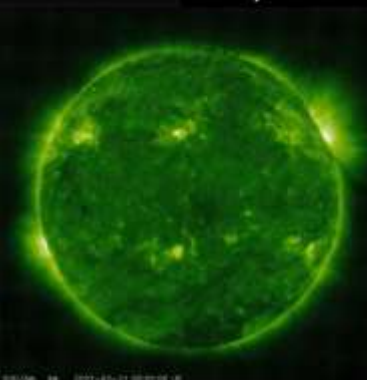
The 2003 Halloween Storm



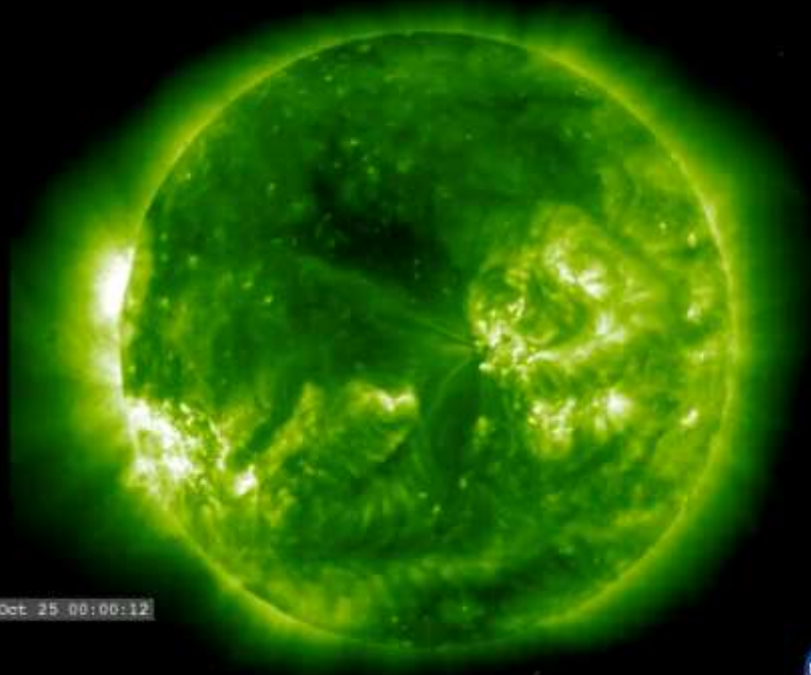
2003 Oct 25 00:00:12



The Sun "Today"



The 2003 Halloween Storm

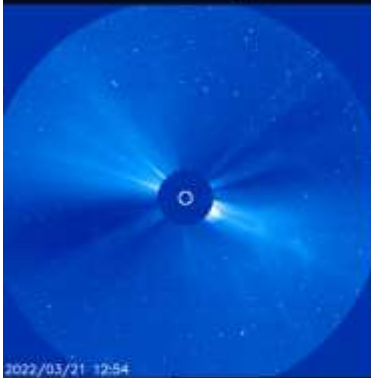


2003 Oct 25 00:00:12



The Sun "Today"

The 2003 Halloween Storm



2022/03/21 12:54



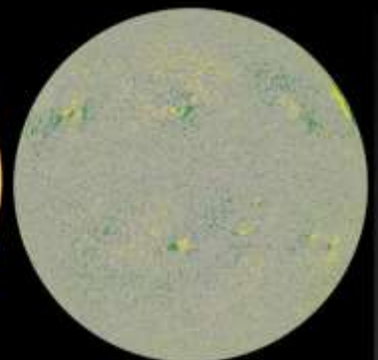
2003 Oct 25 00:00:12



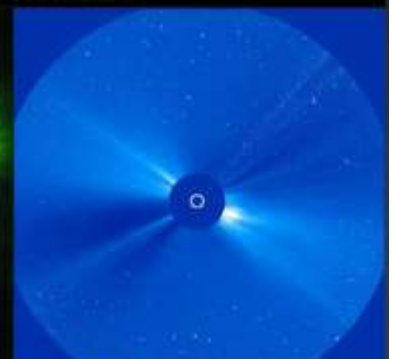
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The Sun "Today" A Source of Space Weather

- Different views for different features
- Each one is complex and dynamic
- The solar magnetic field plays a key role
- Interactions between different features



0002/04 04 2022-03-21 20:00:00 UT



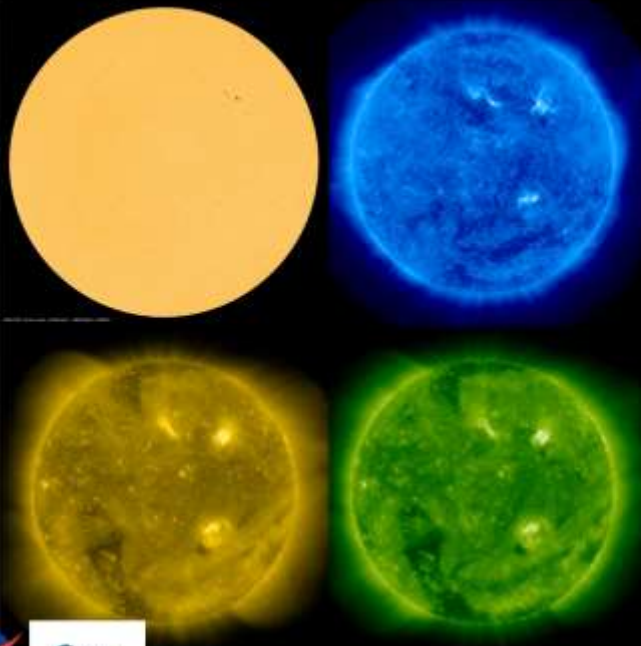
2022/03/19 00:00



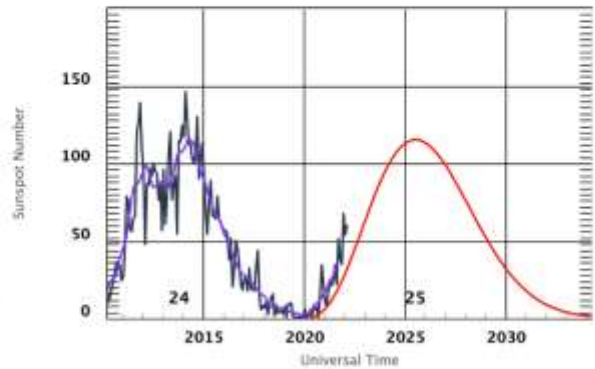
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Space Weather Forecasts

- What will the sun do?



ISES Solar Cycle Sunspot Number Progression



→ Monthly Values — Smoothed Monthly Values — Predicted Values
Space Weather Prediction Center

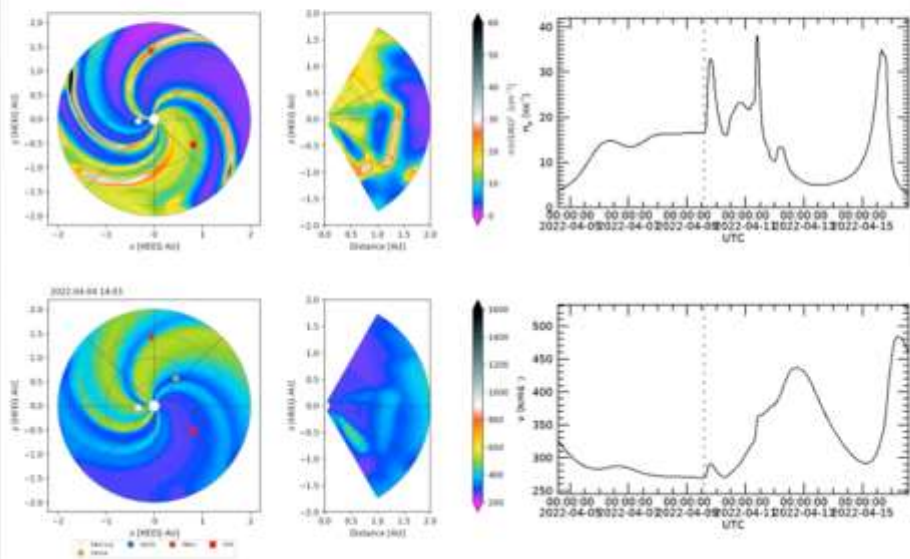
Space Weather Forecasts

- What will the solar wind do?

Particle Density

Particle Velocity

EUHFORIA (Earth) - 2022-04-04T14:03:26



Space Weather

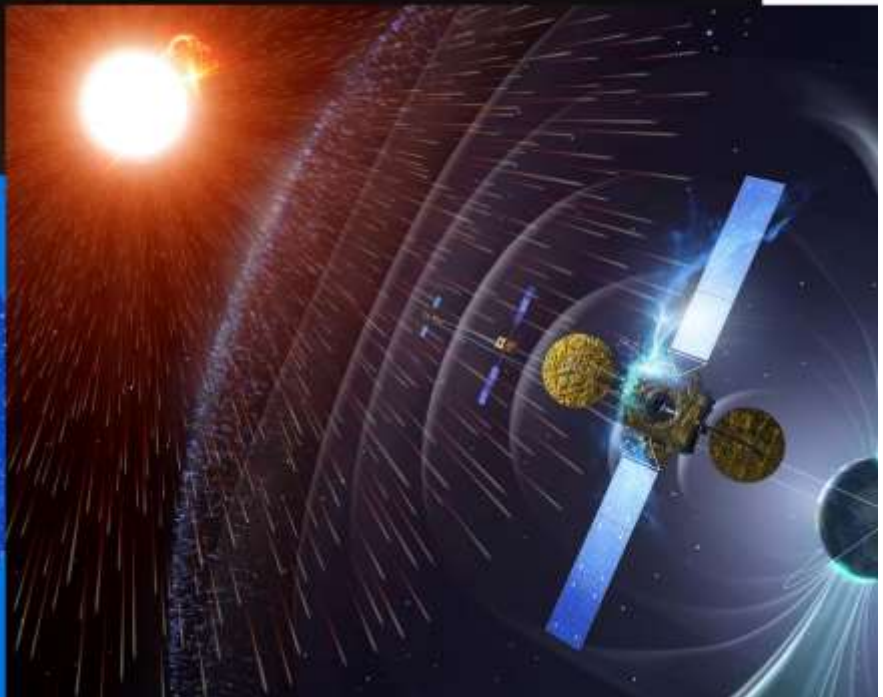
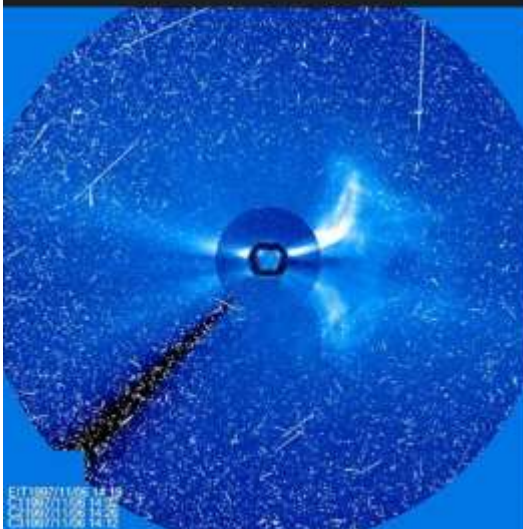
A Societal View

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- Many systems
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- Ground-level & sub-surface
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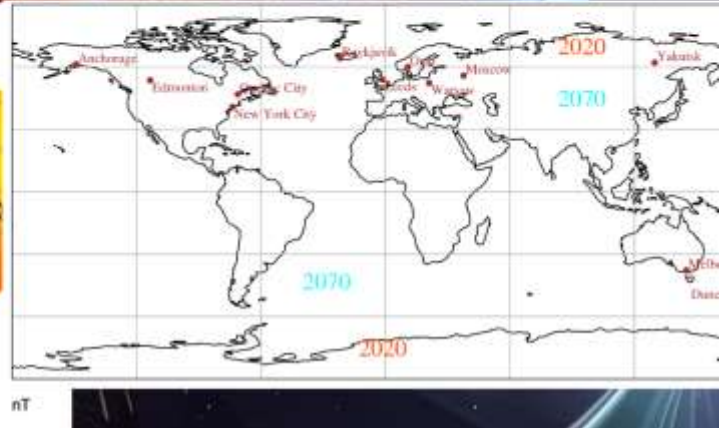
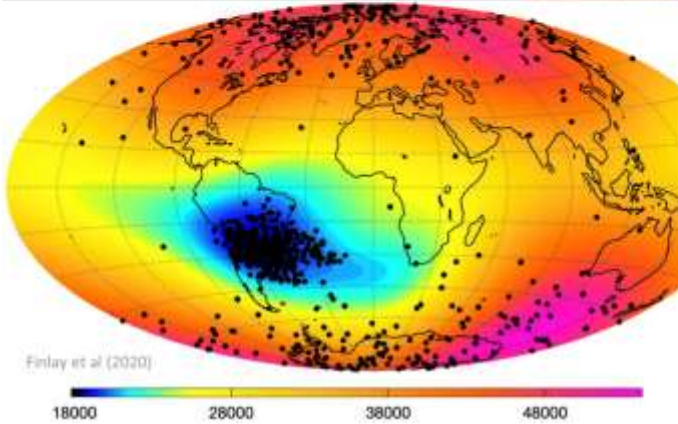
Space Weather Impacts: Satellites

- Solar wind disrupts satellite operations



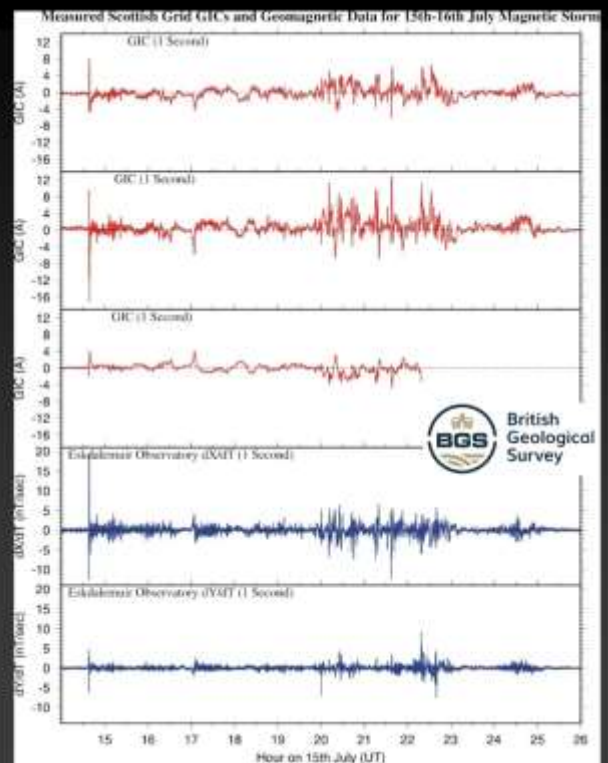
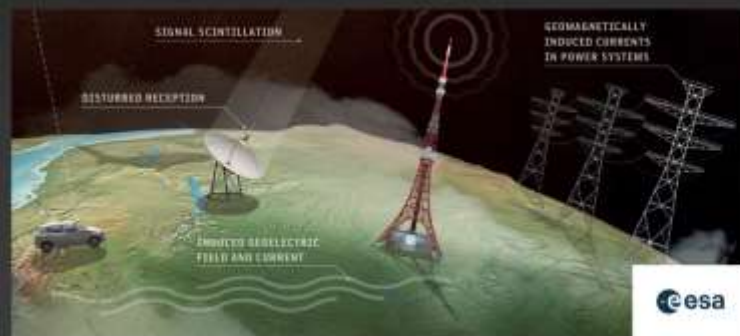
Space Weather Impacts: Satellites

- Earth's magnetic field helps to shield satellites from the solar wind (except where it doesn't)



Space Weather Impacts: Geomagnetically Induced Currents

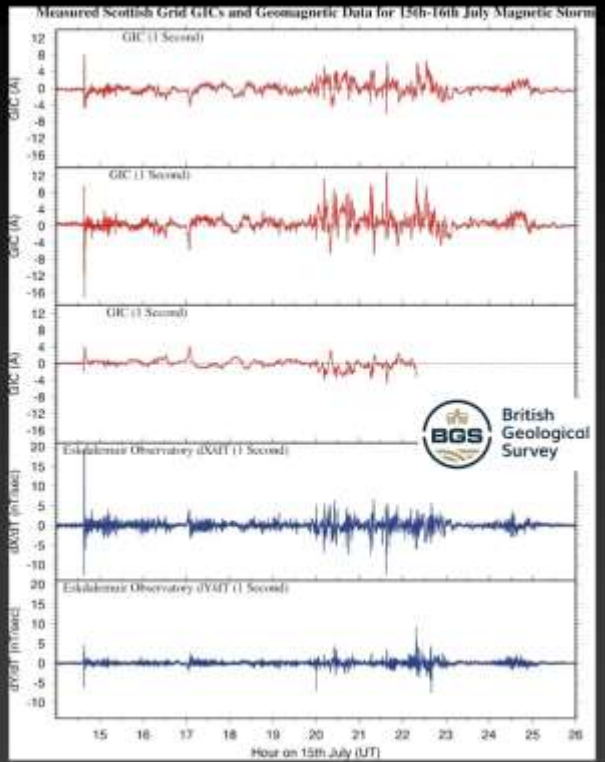
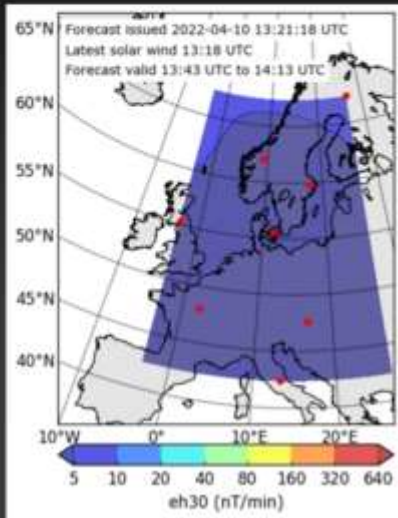
- Charge particles of the solar wind distort Earth's magnetic field
- Rapid changes in the magnetic field induce electric currents in the ground
- Can disrupt power grids (e.g. Quebec Blackout 13/03/1989)



Space Weather Impacts:

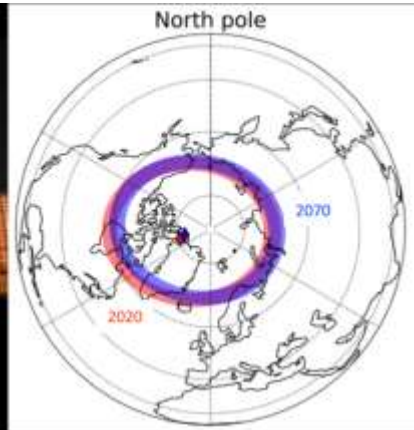
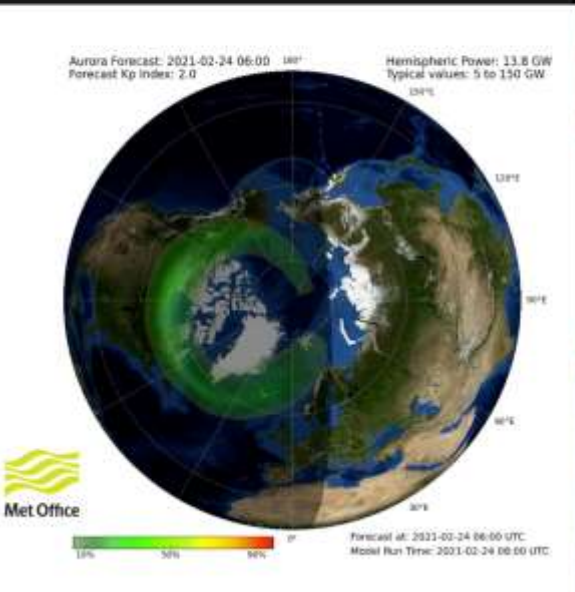
Geomagnetically Induced Currents

- Rapid changes in the magnetic field induce electric currents in the ground



Space Weather: Aurora

- Earth's magnetic field influences where aurora occur



Space Weather

Some Resources

- ESA space weather service
<https://swe.ssa.esa.int/current-space-weather>
- NOAA space weather prediction centre
<https://www.swpc.noaa.gov/>
- BGS geomagnetism group
<http://www.geomag.bgs.ac.uk/>
- Met Office space weather
<https://www.metoffice.gov.uk/weather/specialist-forecasts/space-weather>

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