



Australian Government
National Emergency Management Agency

Australian Institute for
Disaster Resilience



WEBINAR

Solar Tantrums: Why does space weather matter?

Special webinar for World Space Week

Acknowledgement of Country

AIDR acknowledges the Traditional Custodians of the various lands on which you all join us from today and the Aboriginal and Torres Strait Islander people participating in this event.

We pay our respects to Elders past and present and celebrate the diversity of Aboriginal peoples and their ongoing cultures and connections to the lands and waters across Australia.



Housekeeping

- You will remain muted and your camera will not be activated for the duration of today's event.
- Today's event will be recorded and made available after the event.
- Please enter questions for our speakers in the Q&A function, not the chat box.
- Please use the chat box to share any thoughts or reflections during the presentation
- Please be respectful to each other when posting your comments or questions.



Welcome

John Richardson

Executive Director

Australian Institute for Disaster Resilience (AIDR)



Australian Government

National Emergency Management Agency



What does this content mean for you?

How could you apply your learnings to your role?

One action you feel inspired to take.



Speaker Introductions

David Mitchell

Radio Astronomy Coordinator

Mount Burnett Observatory



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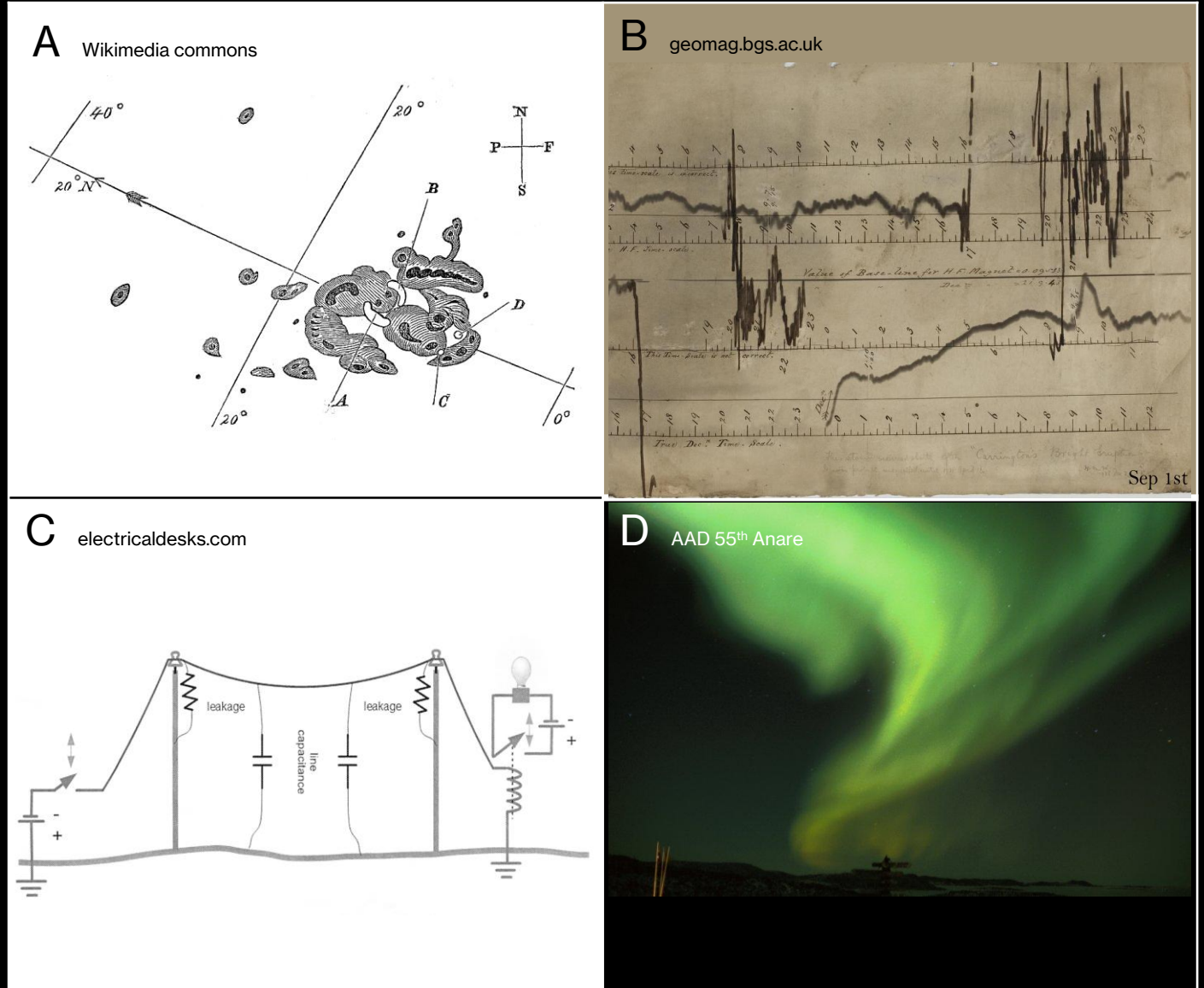


INTRODUCTION TO SPACE WEATHER

David Mitchell VK3KDM
Radio Astronomy
Mount Burnett Observatory

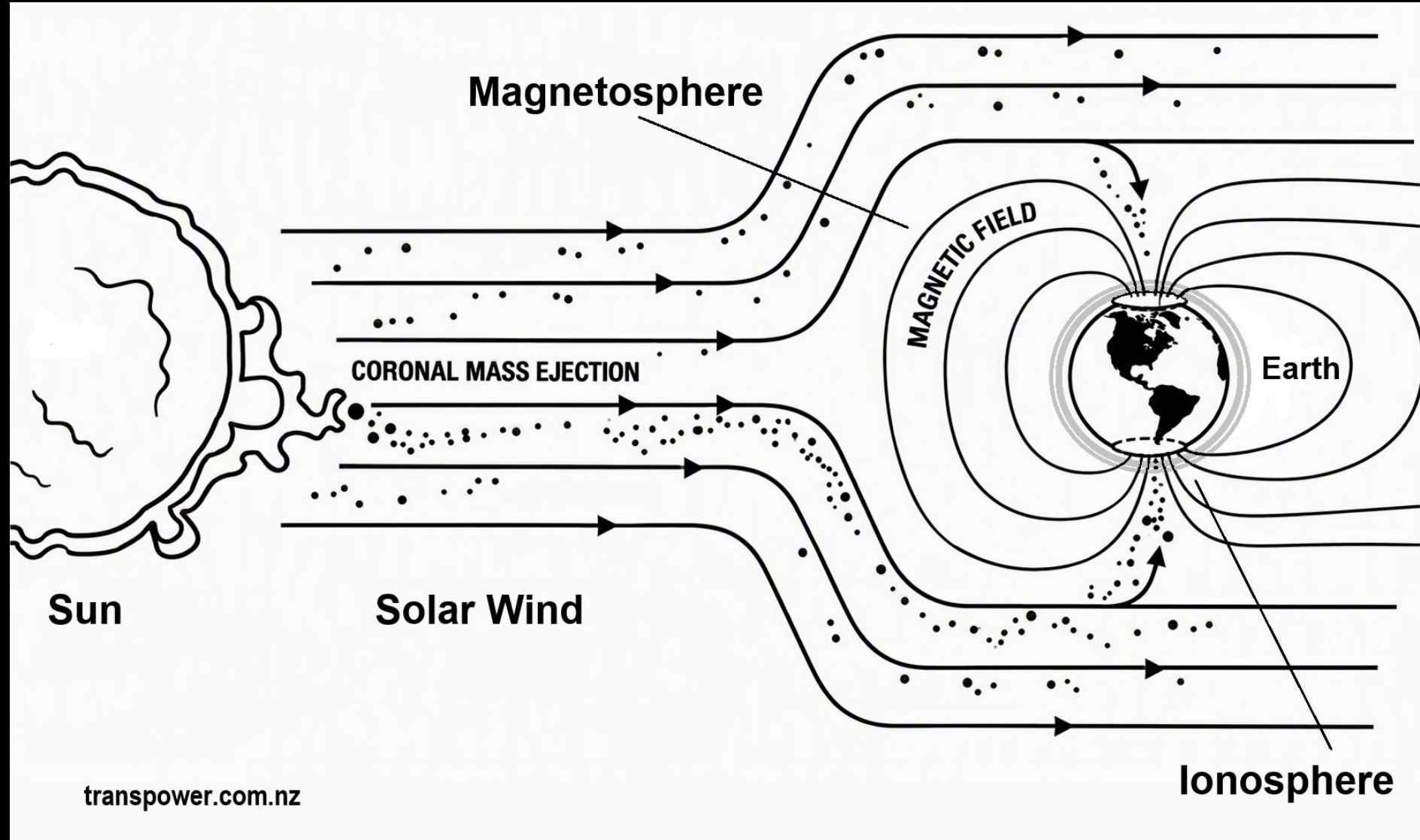
SEPTEMBER 1859

- Carrington observing sunspots records an unusual bright flash
- 17 hours later Earth experiences one of the largest geomagnetic storms
- Magnetometers move off-scale
- Telegraph systems fail and spark
- Aurora seen near the equator
- Why this 1859 event important..



SPACE WEATHER OVERVIEW

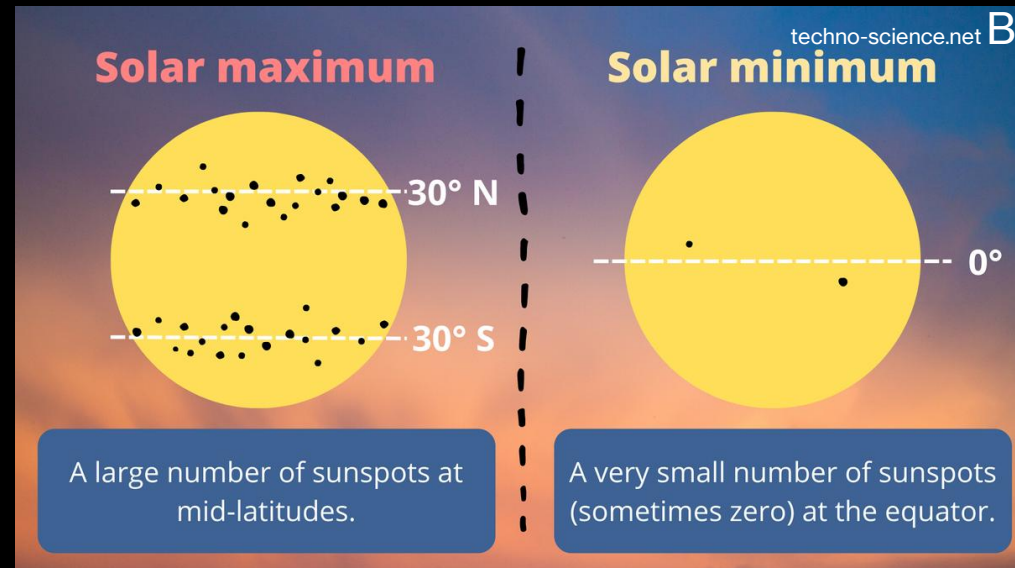
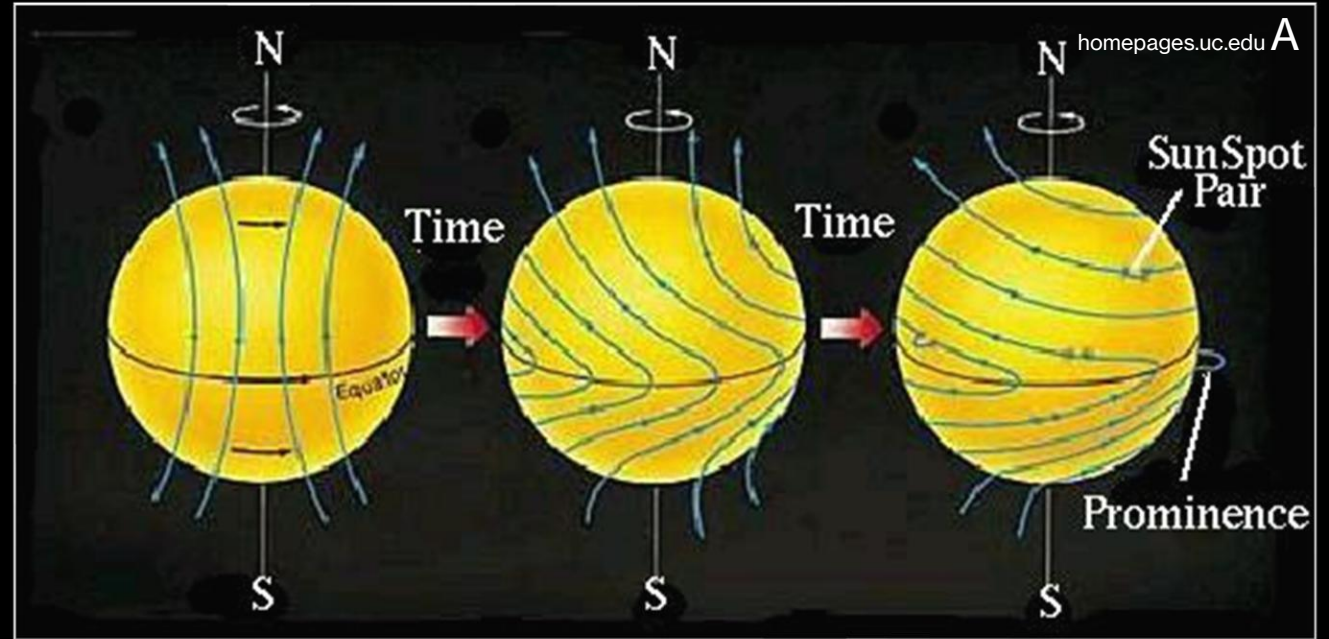
- SUN
- SOLAR WIND
- MAGNETOSPHERE
- IONOSPHERE
- EARTH



Space weather is not a single event. It is a chain of linked processes.

SUN AND SUNSPOTS

- Sunspots are regions of concentrated magnetic fields
- More sunspots generally means greater space weather activity
- Sun magnetic field becomes stressed/twisted over time.
- Approximately 11-year cycle
- Magnetic coronal loops can emerge from photosphere as a source of solar events
- A polarity 'flip' occurs at Solar Maximum, and reverses process



SOLAR EVENTS

Solar Flares

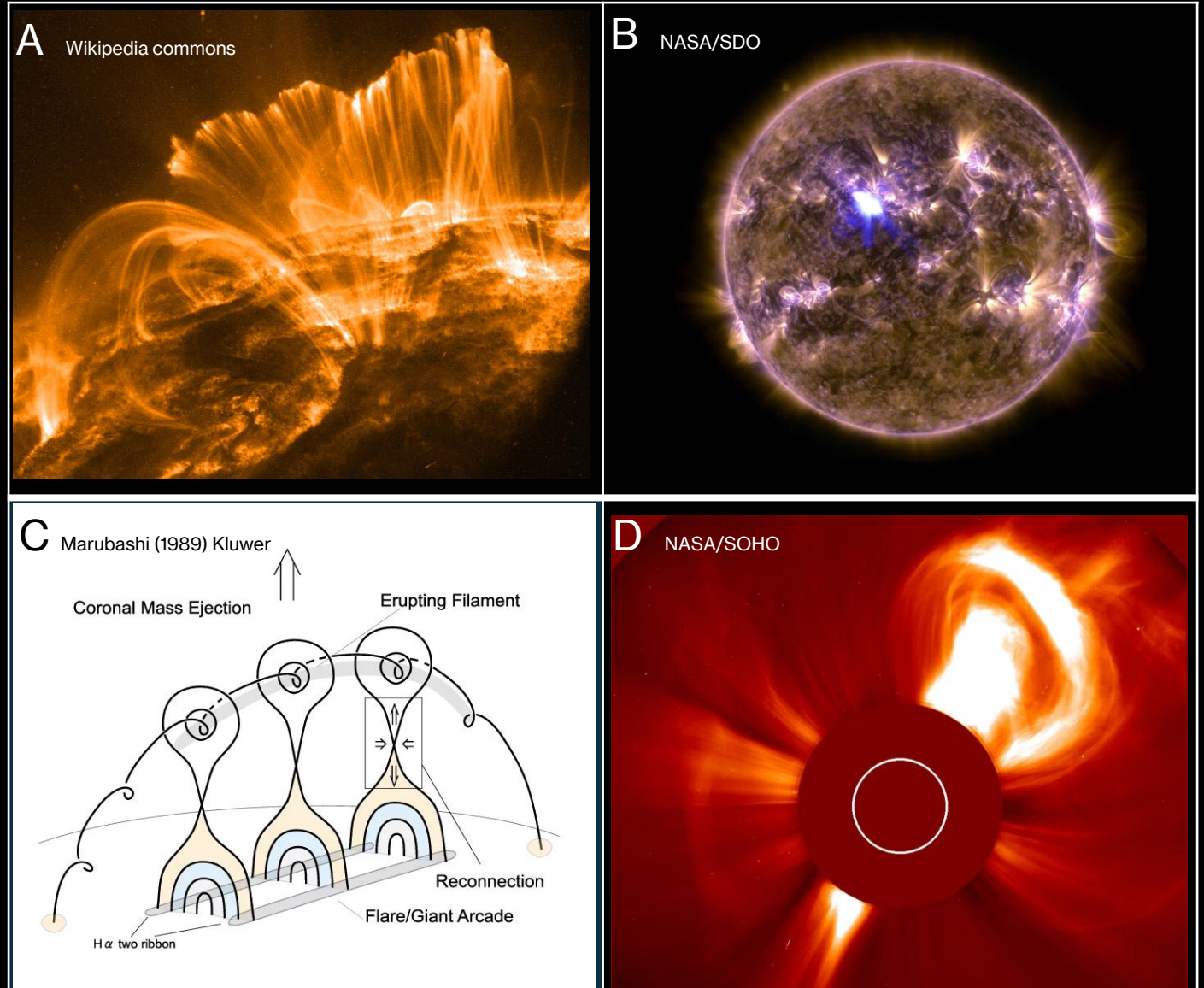
- Sudden release of energy – reconnection in coronal loop
- Electromagnetic radiation arrives at Earth in about 8 minutes

Coronal Mass Ejections (CMEs)

- Massive clouds of plasma and magnetic field
- Travel from Sun to Earth in many hours to days
- Main driver of severe geomagnetic storms
- Not every solar event affects Earth.

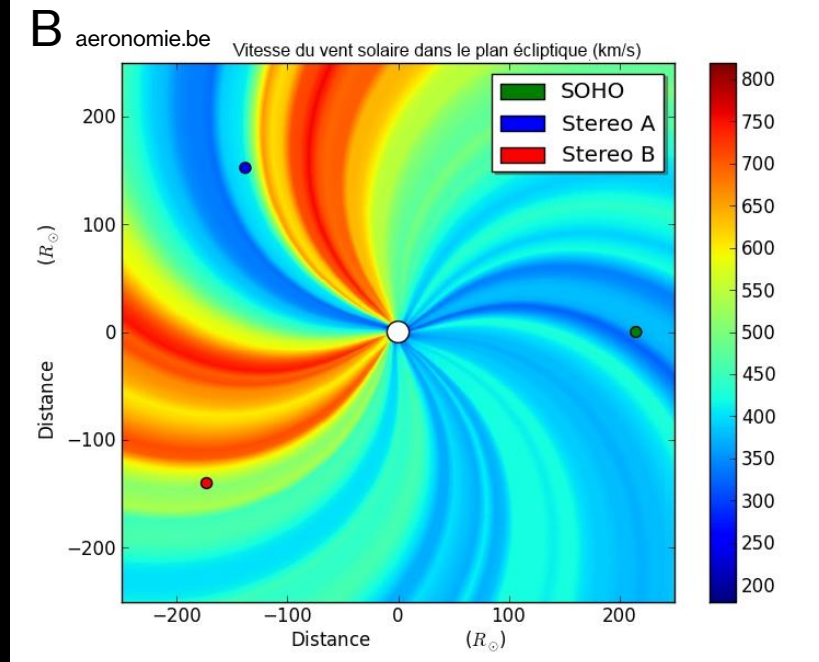
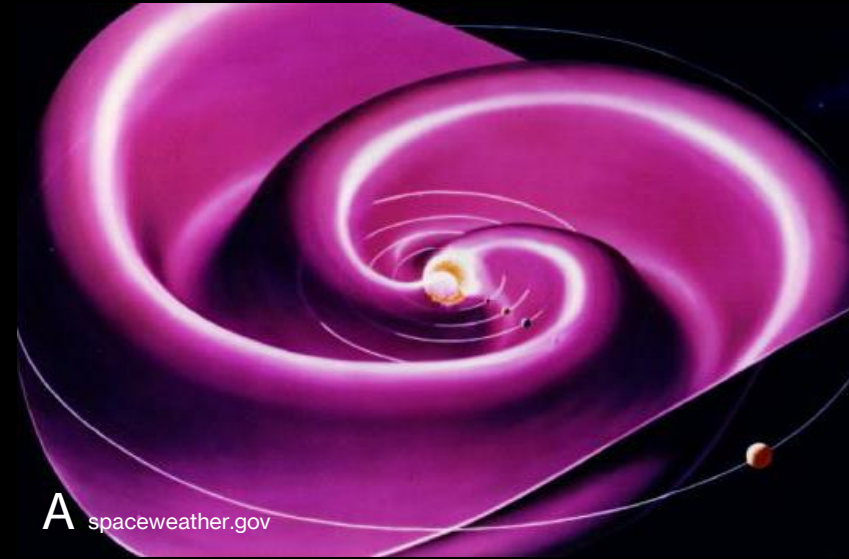
High Impact if:

- The eruption is Earth-directed
- The CME contains the right magnetic orientation to couple strongly with Earth's magnetic field



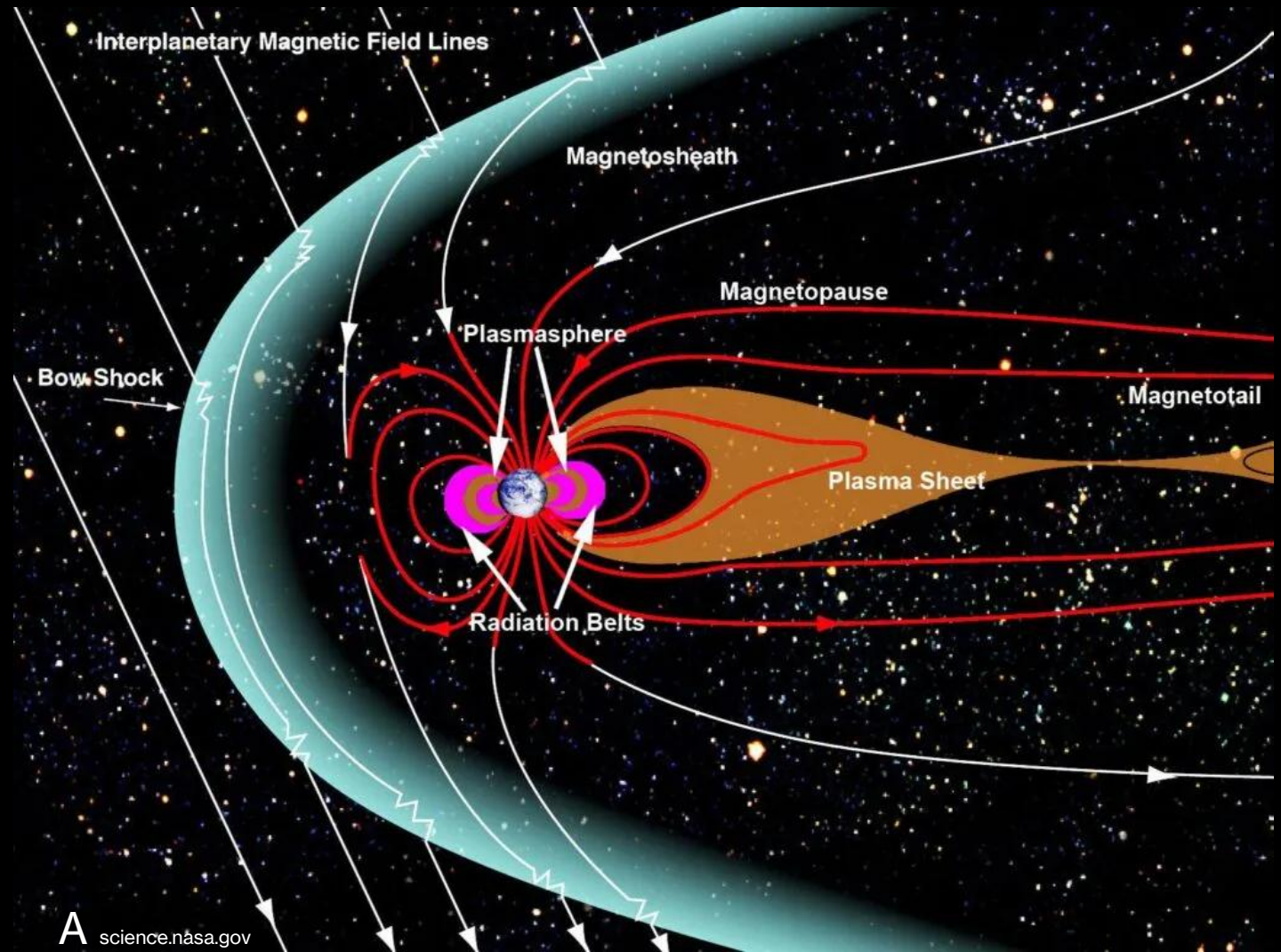
SOLAR WIND

- Continuous stream of charged particles from the Sun
- It is the "background weather" in space
- The particles are emitted radially at varying velocities and density
- The solar wind environment can impact the CME path



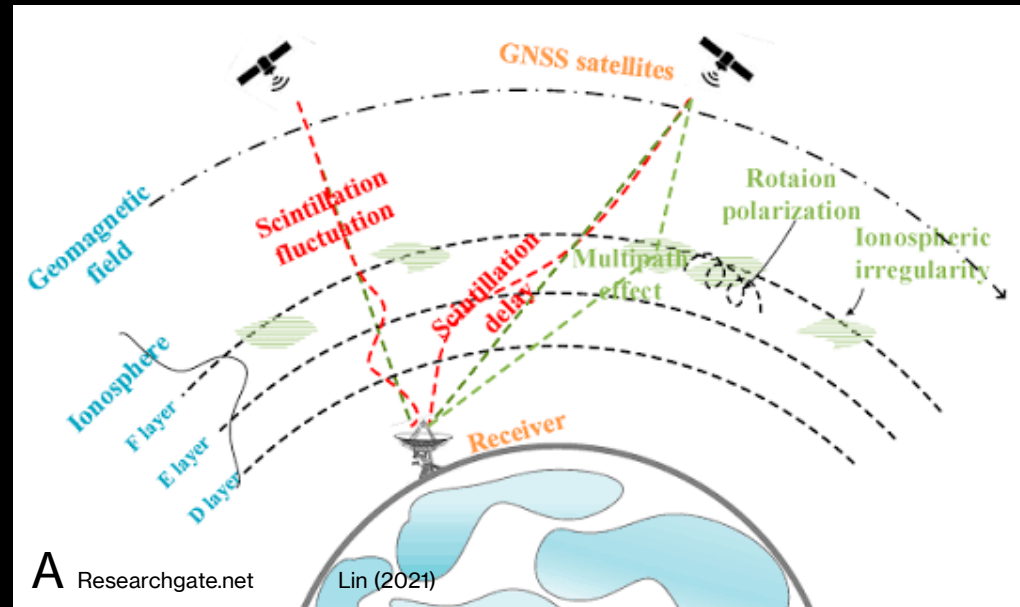
MAGNETOSPHERE

- Acts as Earth's first line of defence
- Deflects most solar wind particles
- Magnetosphere can become compressed and distorted
- These changes create Magnetic disturbances on Earth
- One of the processes that induces currents on Earth



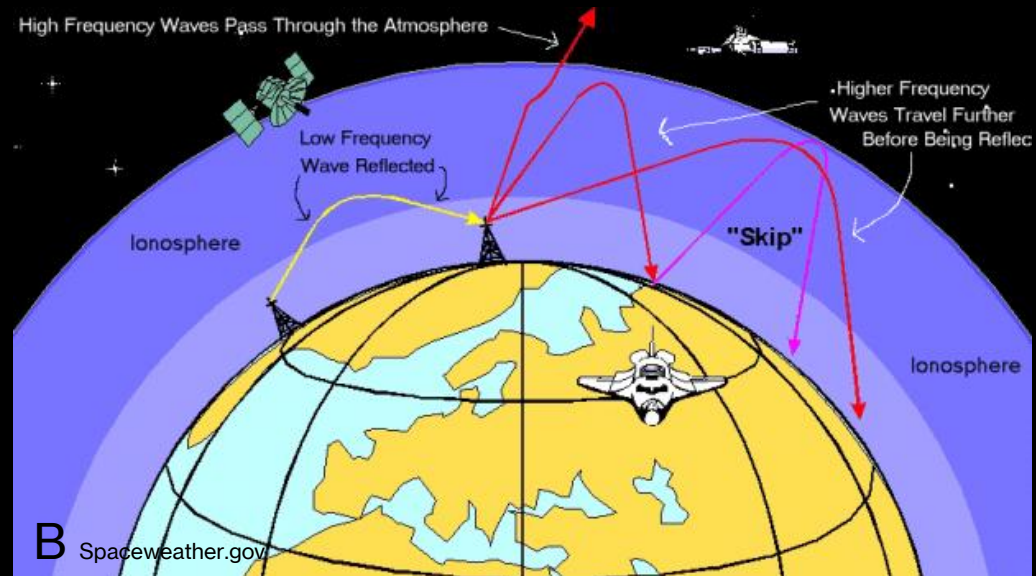
IONOSPHERE

- Electrically charged region of the upper atmosphere
- Protects earth from EUV & X-rays
- Different layers for day & night
- Solar flares increase the density of the ionosphere



Ionosphere impacts modern systems:

- HF radio (aviation, defence)
- GPS/GNSS
- Scintillation, delay, & signal/noise

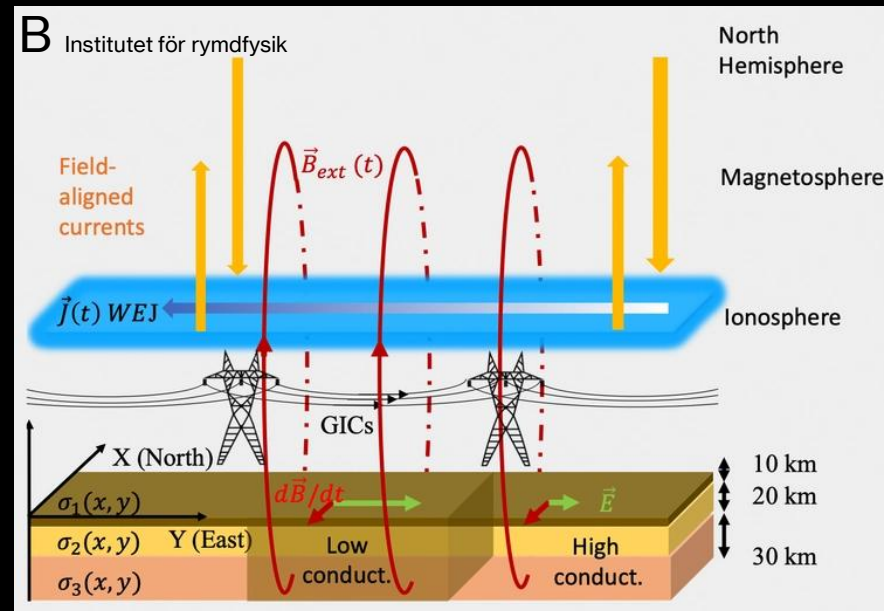
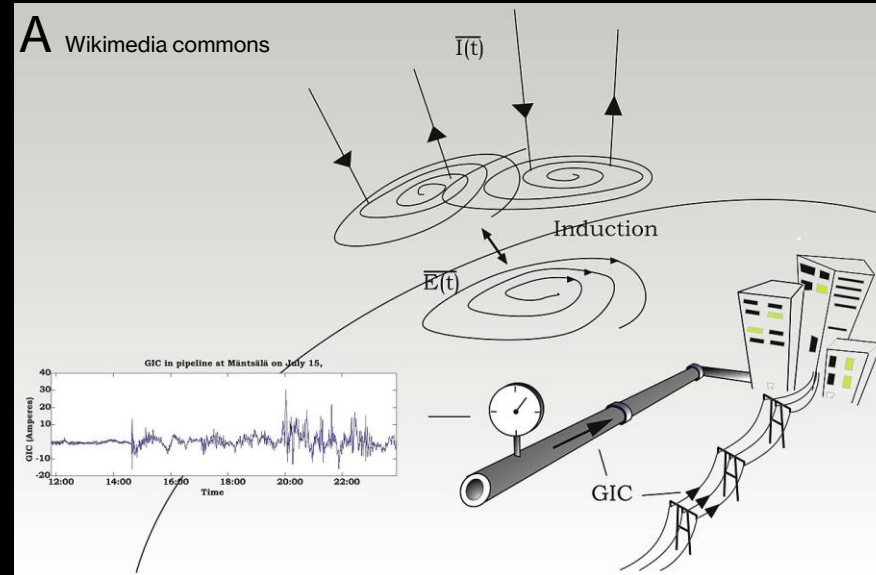


EARTH AND GIC'S

Changes in Earth's magnetic field create electric currents (Telluric) on the Earth's surface but larger changes occur in long low-resistance conductors (GIC's).

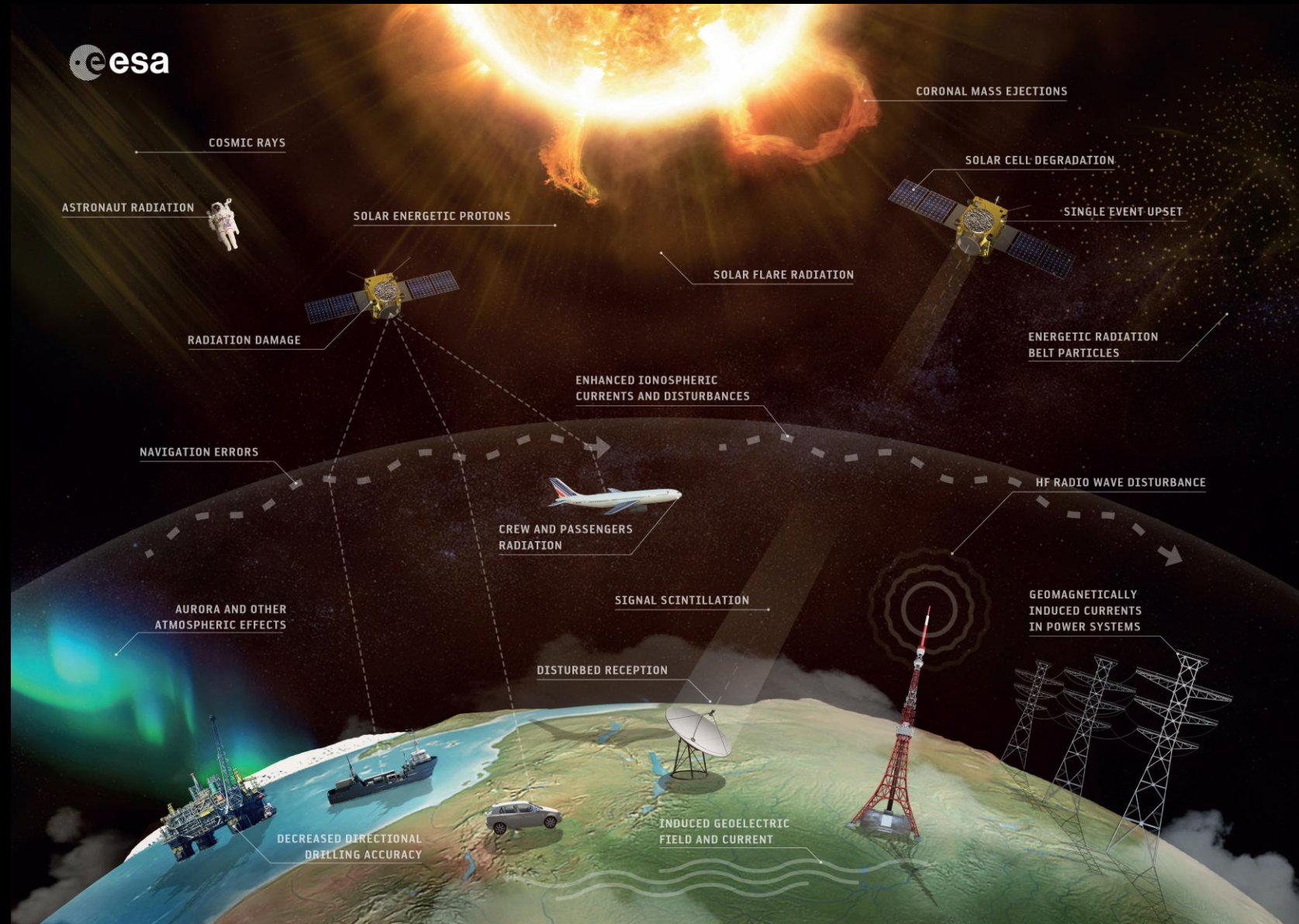
Affected systems:

- Power grids
- Pipelines
- Rail signalling
- Telecommunications infrastructure



SUMMARY

- The Space Weather starts on the Sun.
- It travels through a chain of connected space environments.
- The Magnetosphere and Ionosphere have a protective function but also impact technology.
- Impacts occur when those disturbances reach systems we depend on.
- The challenge is predicting when Space Weather Events are approaching and what we can do to reduce the impact.



Speaker Introductions

Professor Allison Kealy

Director Innovative Planet Research Institute

Swinburne University of Technology



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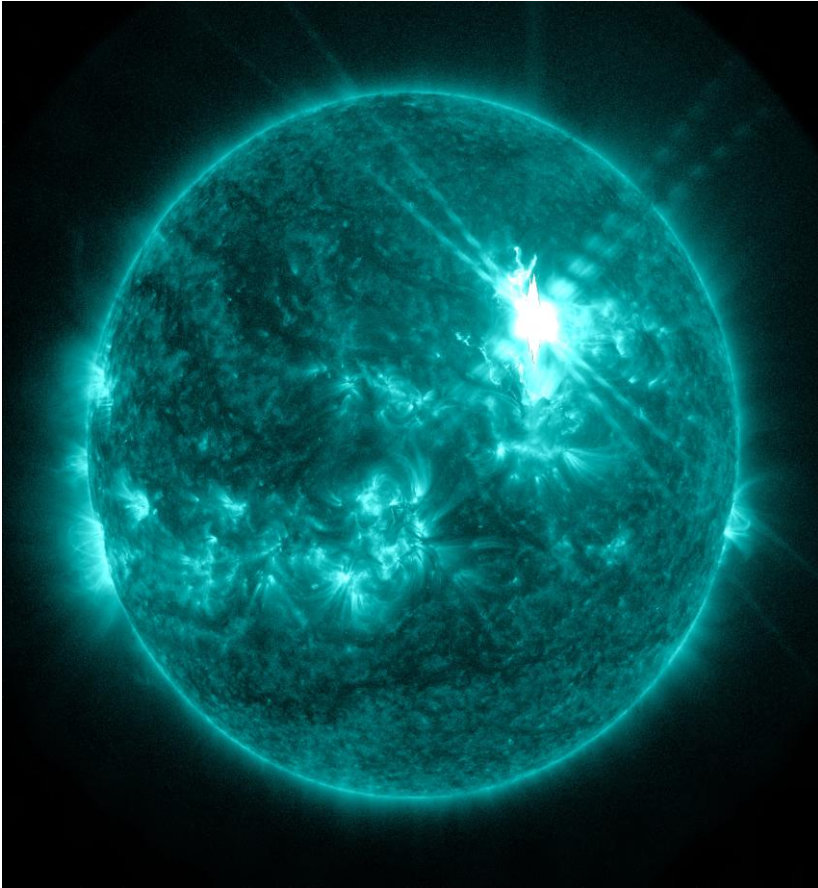
When the sun disrupts GPS

**Building Resilient Positioning, Navigation and
Timing for Australia's Critical Infrastructure**

Prof. Allison Kealy
6 October 2026

The same solar storm disrupted GPS in two different ways

An immediate radio-frequency effect was followed by hours of ionospheric disturbance.



NASA/SDO image of the X5.1 flare at 10:04 UTC

11 NOV · SOLAR FLARE + RADIO BURST

DAYLIGHT SIDE OF EARTH

Europe, Africa, the Middle East, much of Asia, eastern South America and western Australia

GNSS signal strength fell across monitored stations. Some receivers risked degraded tracking or loss of lock for **several minutes**.

12 NOV · GEOMAGNETIC STORM

>10 m GPS positioning errors

Multiple CMEs disturbed the ionosphere. Errors persisted for **hours** across parts of the United States and extended into Mexico.

Timing implication: loss of GNSS tracking can force a timing receiver into holdover. No confirmed timing outage was reported for this event.

Sources: NASA/SDO; Murrian et al. (2026); Yizengaw et al., GRL (2026)

Space weather can disrupt GPS in two different ways

The receiver can lose the signal completely, or continue tracking a signal that has been delayed and distorted

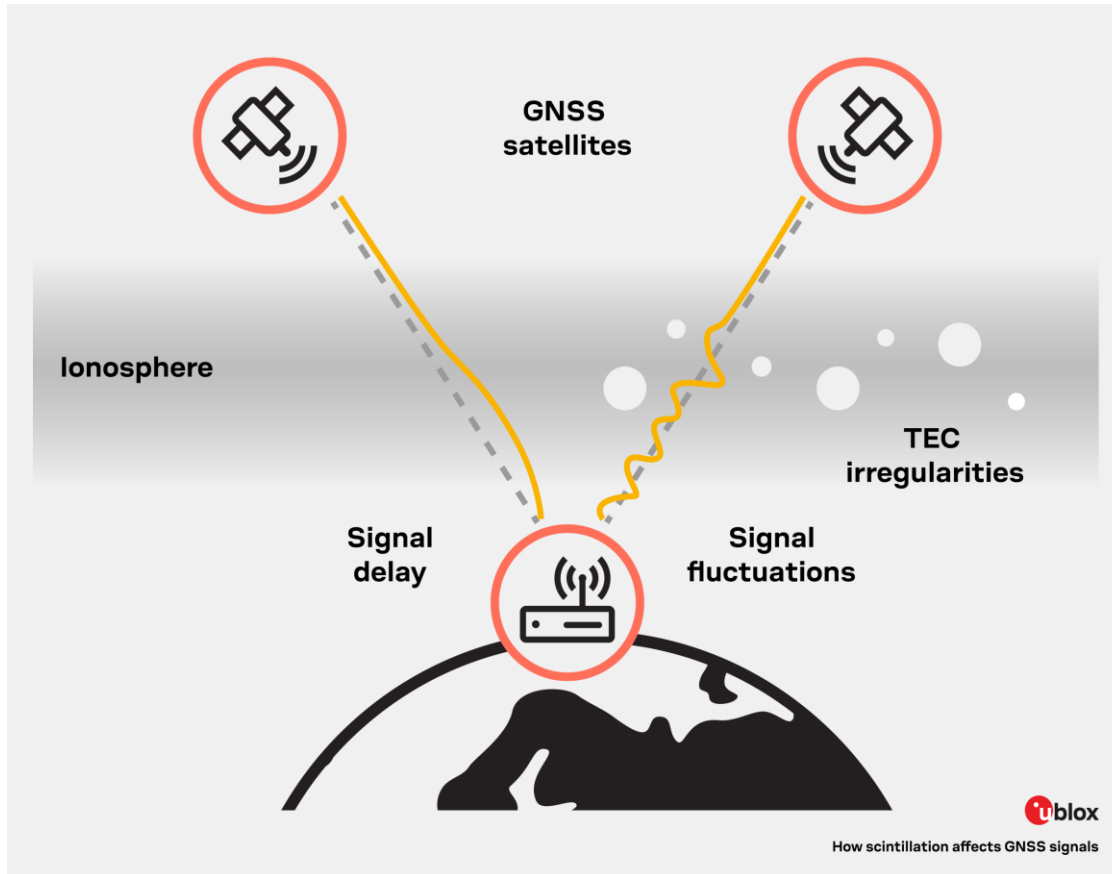


Diagram shows pathway 2. Solar radio noise reaches the antenna directly. Image: u-blox.

Source: u-blox (diagram); NOAA Space Weather Prediction Center (mechanisms)

1 SIGNAL OVERWHELMED

NO POSITION OR TIME

A solar radio burst raises the radio noise near GNSS frequencies. The receiver can no longer distinguish the weak satellite signals and loses lock.

Immediate effect on the daylight side. Usually lasts minutes.

2 SIGNAL DISTORTED

INACCURATE OR UNSTABLE POSITION OR TIME

A geomagnetic storm changes the ionosphere. Signals arrive late or fluctuate, causing position and timing errors, failed precision corrections or intermittent loss of lock.

Can begin hours later and persist for hours across wide regions.

Both occurred in November 2025: radio burst first, geomagnetic storm next.

10–11 MAY 2024

The Gannon storm disrupted GNSS position and time

A geomagnetic storm affected farm guidance in the United States and GNSS-derived time in Mexico.



Precision agriculture GNSS display. Image: Kansas State Research and Extension.

2025 MODELLED EXPOSURE

US\$565m

potential Midwestern crop loss from the May 2024 storm. Modelled estimate, not verified claims.

10 MAY • POSITION • US MIDWEST

PLANTING DISRUPTED

Some producers lost precise guidance and delayed planting during a time-critical part of the season.

10 MAY • TIMING • MEXICO

~80 ns

GNSS-DERIVED TIME ERROR

The quiet-day error remained within ± 20 ns. On 10 May it almost reached 80 ns. No outage of Mexico's official time service was reported.

Why GNSS timing errors matter downstream

Critical infrastructure relies on GNSS clocks, but backup design determines whether an error becomes an outage

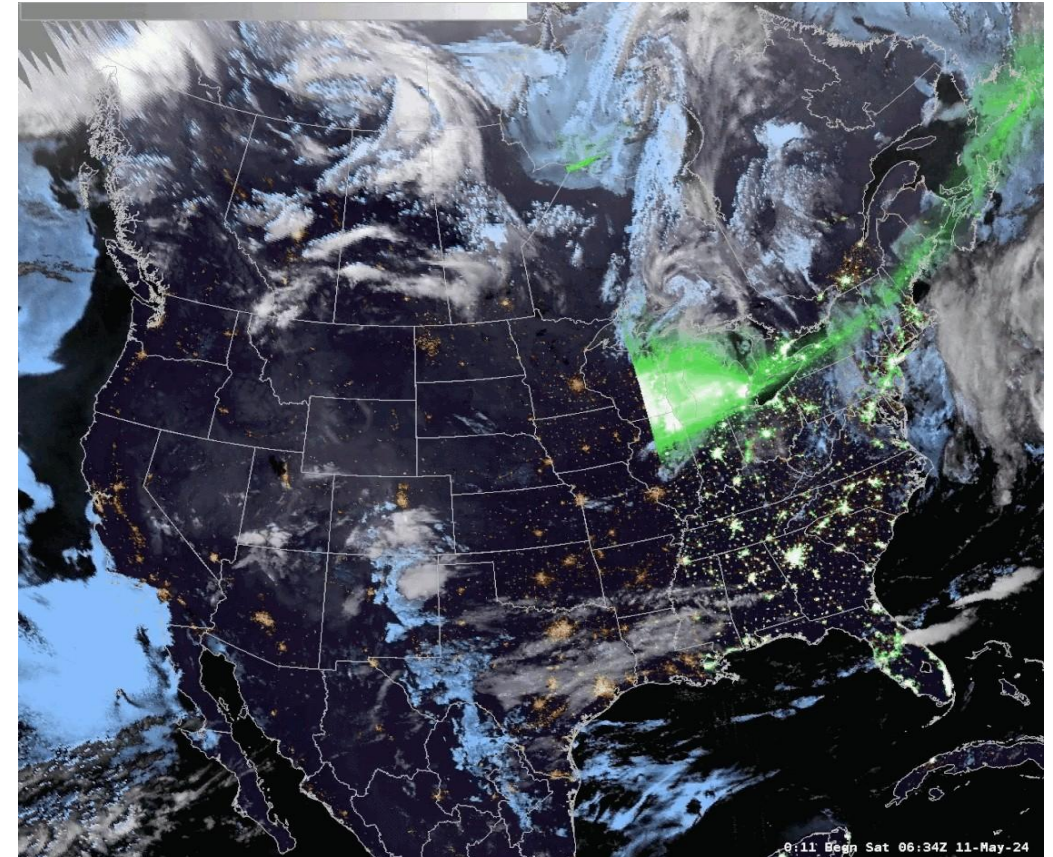
FROM RECEIVER TO SYSTEM

TIME ERROR

Telecom networks, power-grid monitoring and data systems rely on trusted timestamps.

The Gannon measurement shows the GNSS input can move. No operational outage was attributed to the ~80 ns error.

Source: [Gonzalez-Esparza et al. \(2024\)](#); Geoscience Australia



NOAA/NWS satellite aurora composite over North America, 11 May 2024.

Timing resilience is transport resilience

8 July 2026 · A GPS timing card sent a 2006 date into Telstra's mobile network

~04:00 · 8 JUL

mobile impacts begin

16:00 · 8 JUL

main network issue addressed

9 JUL & BEYOND

recovery varies by service

≈100

V/LINE TRAINS

in service halted for safety;
all regional trains suspended

HUNDREDS

SA TRAFFIC SIGNALS

lost adaptive control and ran
on basic programming

611

TRIPLE ZERO CHECKS

welfare checks following
emergency call errors

A\$200m+

ECONOMIC LOSS

expert estimate of lost
activity, not audited total

THE RIPPLE

NSW passenger & freight rail · EV charging · parcel delivery scanners

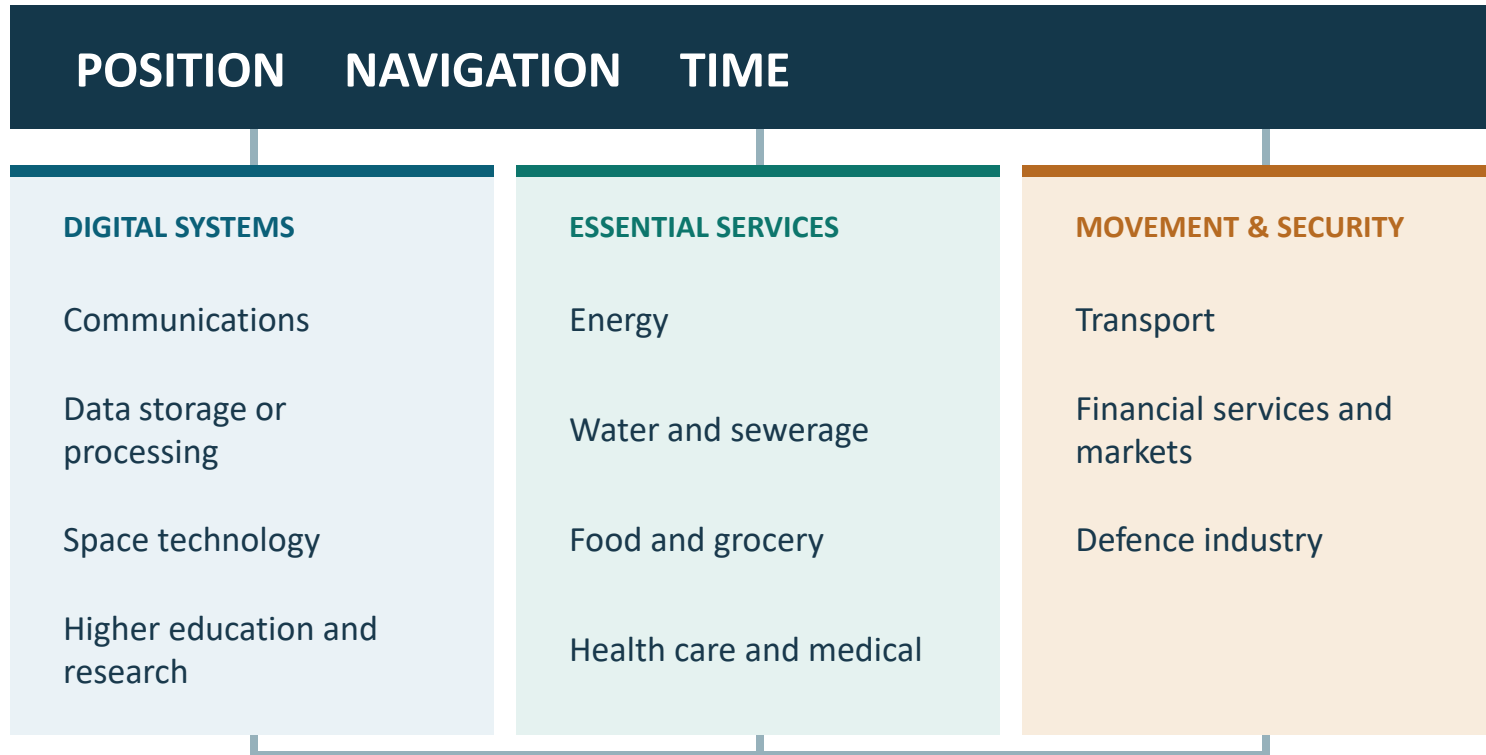
4G EFTPOS terminals · taxi and Uber work · 45% of mobile calls and data sessions at peak

V/Line resumed from midday 9 Jul; Triple Zero fix 13:30. SA signal restoration time unreported.

Why this matter to Australia?

A disruption can cascade through sectors that share networks, services and suppliers.

AUSTRALIA'S 11 CRITICAL INFRASTRUCTURE SECTORS



£1.4bn

Estimated UK economic loss from a 24-hour nationwide GNSS outage

+500%

Aviation GPS spoofing incidents, 2023 to 2024

Broader GNSS interference: +175%

One PNT fault can become a cross-sector disruption

The cascade depends on which systems fail and how long fallback capability lasts.

Other documented GNSS disruptions

Research measurements show which part of the service can fail

2006

Up to 60 m

Vertical position errors were reported as receivers struggled to track GPS during a solar radio burst.

[Research paper](#)

2011

>255 s

Age of orbit and clock corrections at 14 monitored locations during a burst; some position filters reset.

[Research paper](#)

2017

3 constellations

European stations saw effects on GPS, Galileo and GLONASS. L2/L5 signal strength fell.

[Research paper](#)

These studies measure signal or service performance; they do not establish a global economic loss for each event.

Source: [Sreeja et al. \(2014\)](#); [Sato et al. \(2019\)](#)

The resilience question is operational

A storm is consequential when a GNSS fault reaches a user who cannot maintain service

KNOW WHEN

Monitor space weather and GNSS performance; alert users to loss of confidence.

KEEP WORKING

Provide alternative positioning or timing and a workable fallback procedure.

PROVE RECOVERY

Test the full operational chain against realistic storm conditions.

The Gannon storm illustrates all three: a shared disturbance, different receiver outcomes, and impacts shaped by the work happening that day.

Source: Synthesis of cited studies and Kansas State extension assessment



SHIELD CRC

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Speaker Introductions

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Space Weather Forecaster

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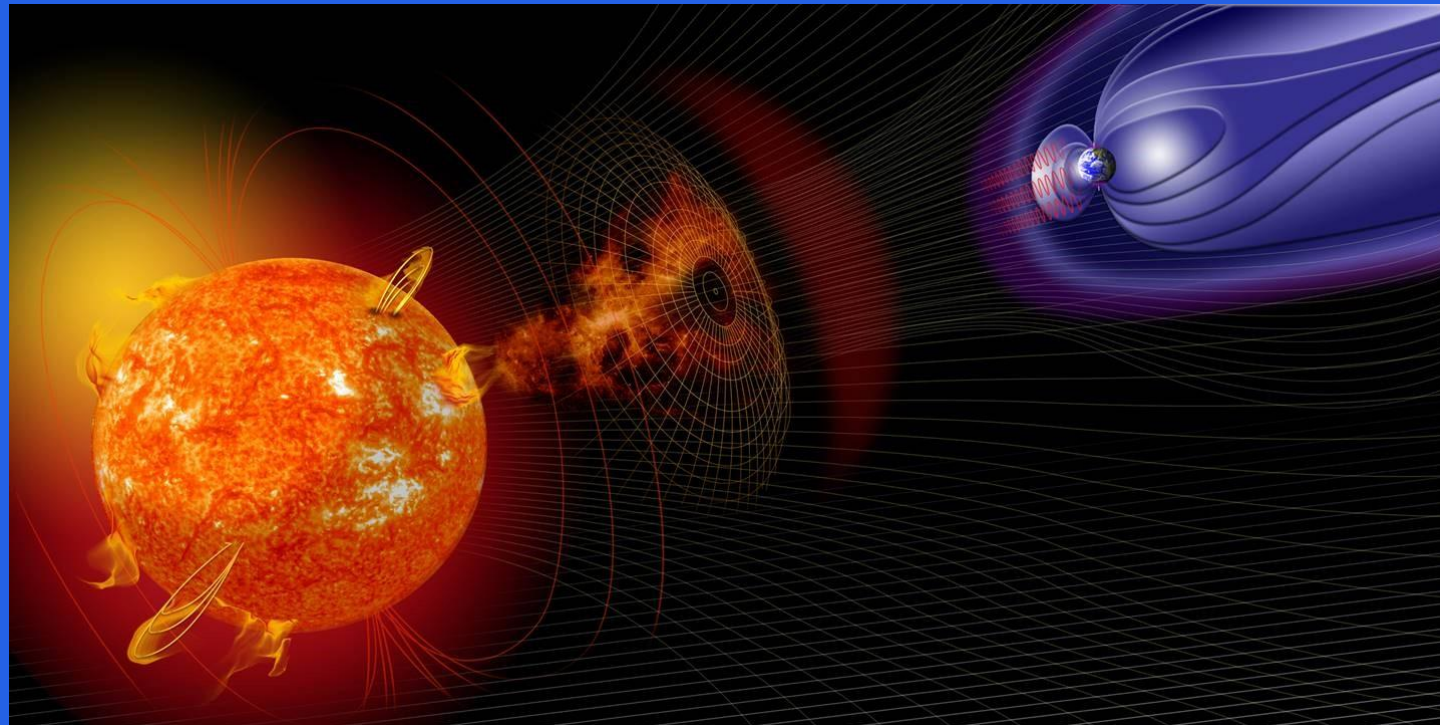
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Significant Space Weather Events

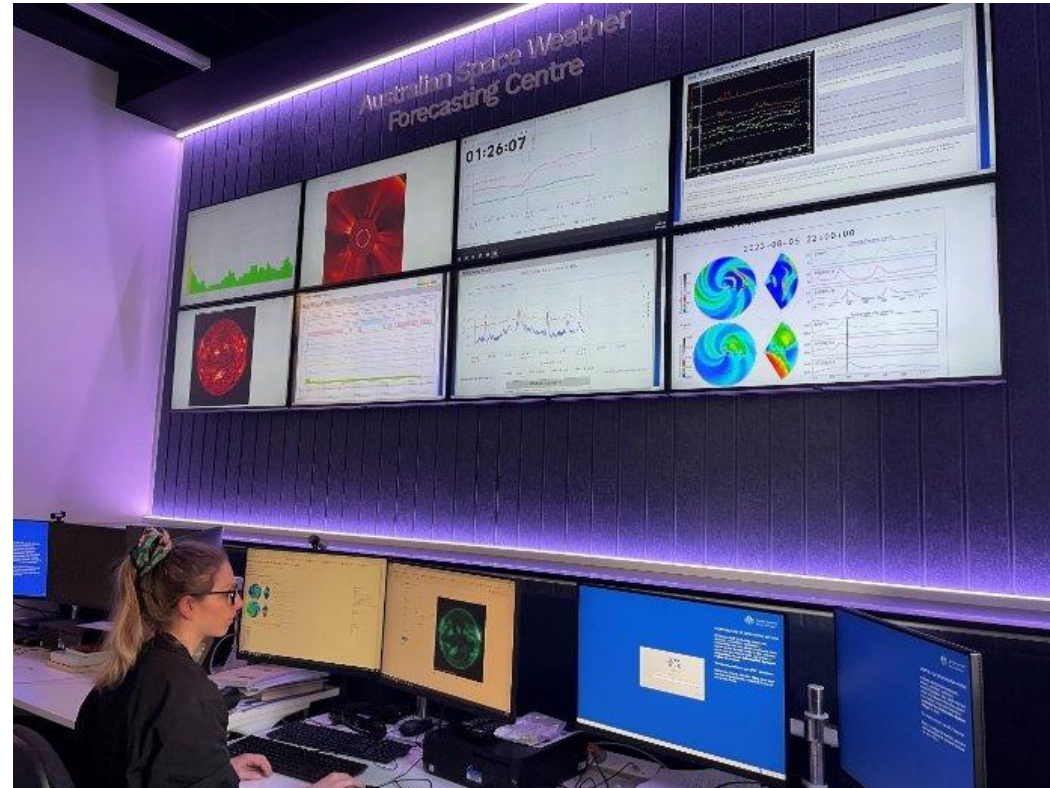
By the Bureau of Meteorology



The Australian Space Weather Forecasting Centre

The Bureau's Australian Space Weather Forecasting Centre (ASWFC) operates under the authority of the *Meteorology Act 1955*, as the official source of space weather alerts, warnings, and forecasts in Australia

1. Solar monitoring
2. The Sun launches a flare or CME
3. Forecast level of impact
4. Issue warnings
5. Space weather event begins
6. Updated alerts and warnings



Australian Space Weather Alert System (ASWAS)

There are three scales used in Australia and internationally:

- The '**R**'-scale, for radio black-outs,
- The '**S**'-scale, for solar radiation storms, and
- The '**G**'-scale, for geomagnetic storms

They each sit on a scale from 0-5

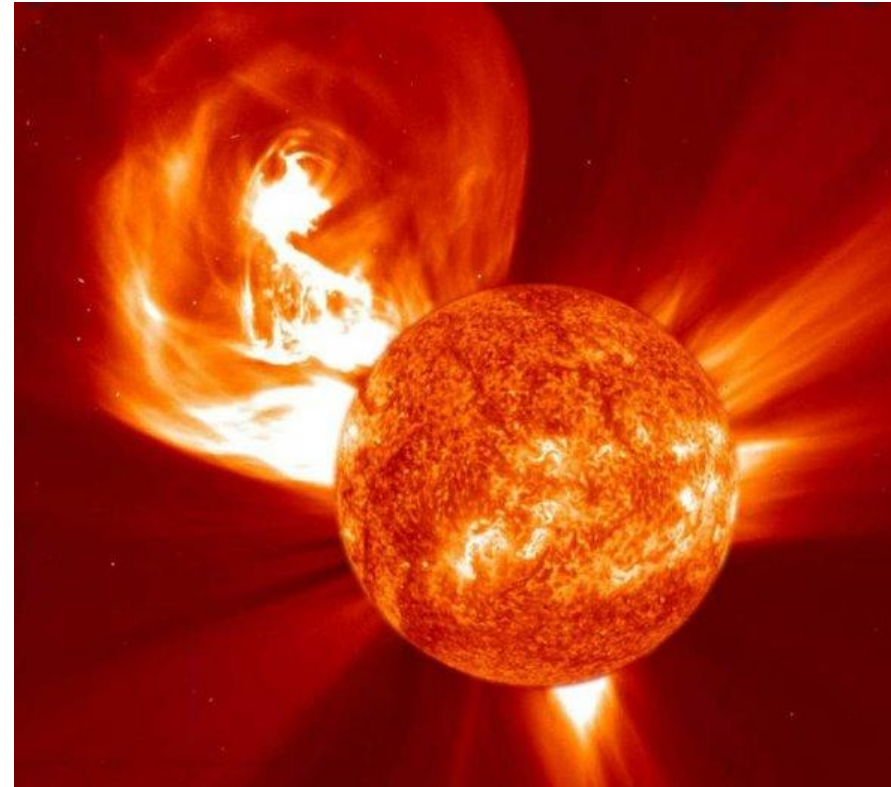
The ASWAS scales describe the likely frequency and possible impact at each level to relevant sectors



Significant event procedure

The Significant Event Procedure is about getting a clear and succinct message out as quickly as possible

- Perform situational awareness
- Write Critical Event Briefing (CEB)
- Heads-up phone calls
- Issue CEB
- Issue Severe Space Weather WATCH (if necessary)
- Monitor conditions
- Send update CEBs as needed/ if conditions change
- Answer any enquiries about the event (from customers, media, the public, etc)
- Briefings where required



Case study

- Large number of strong solar flares
- Accompanied by 5 fast and dense CMEs
- Significant event procedure activated
- 8 CEBs issued
- Over 30 warnings and alerts issued
- Impacts affecting radio and satellite communications, power grids, satellite orbits, GPS and navigation
- Auroras seen up to Queensland

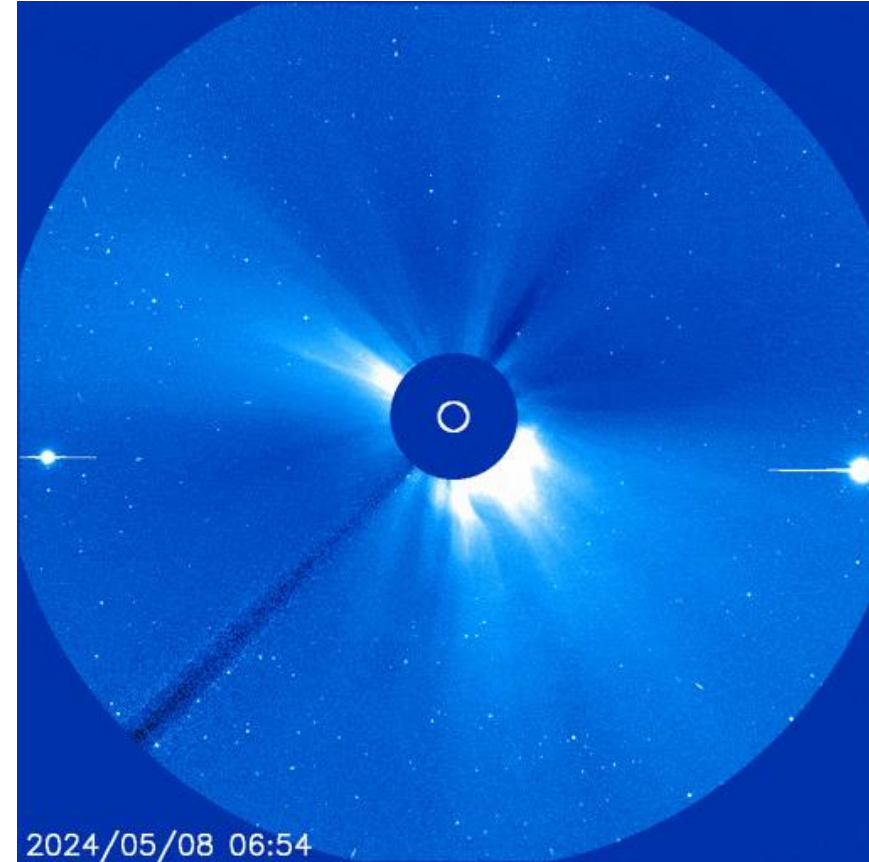
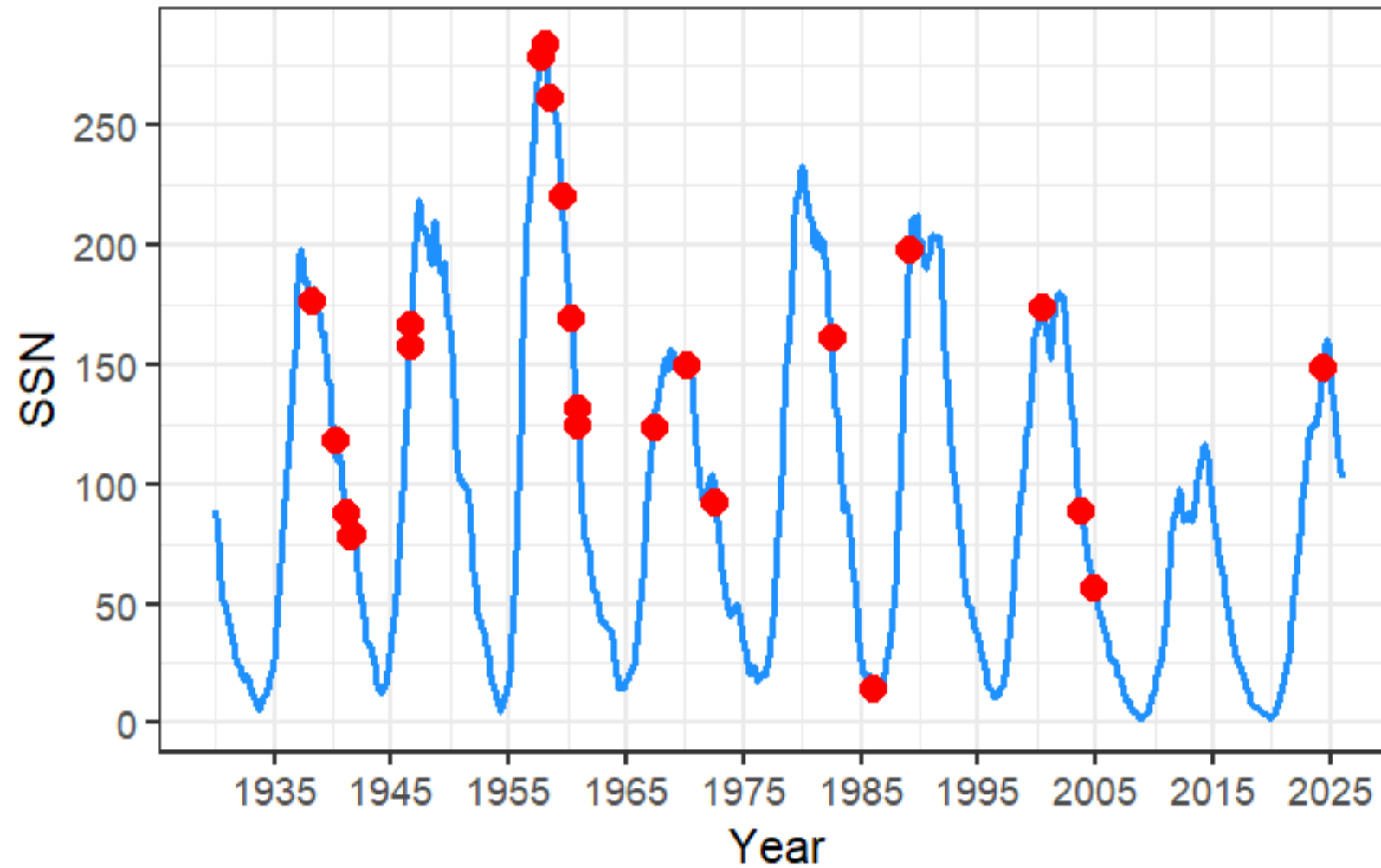


Image courtesy of NASA/ SOHO showing several (halo) CMEs coming towards the Earth.

Any final comments

G5 events since 1930



A dramatic sky scene featuring a bright yellow-green light source, possibly the sun or moon, partially obscured by clouds. A vibrant pinkish-purple glow, resembling an aurora or a meteor trail, streaks across the upper portion of the sky. The foreground shows a dark, silty landscape with patches of white, possibly snow or sand.

Thank you

Q&A

Don't forget to put your questions in the Q&A function



Australian Government
National Emergency Management Agency

Event concludes

Thank you for attending today's webinar.

Next event:

Special webinar | United Nations International Day
for Disaster Risk Reduction: Resilience begins at home

Tuesday 13 October 2026,
1.00pm-2.00pm AEDT



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