The Carrington Event of 1859

- History's Greatest Solar Storm and What It Means for the Modern World
- A Historical, Scientific, and Technological Analysis
- Presenter: Bryan Daniels K4RMY

Why the Carrington Event Matters

- • Understand how the event occurred
- • Learn about the observers
- • Examine effects on Earth
- • Compare with modern storms(handout)
- • Explore a 2026 scenario

The Active Sun

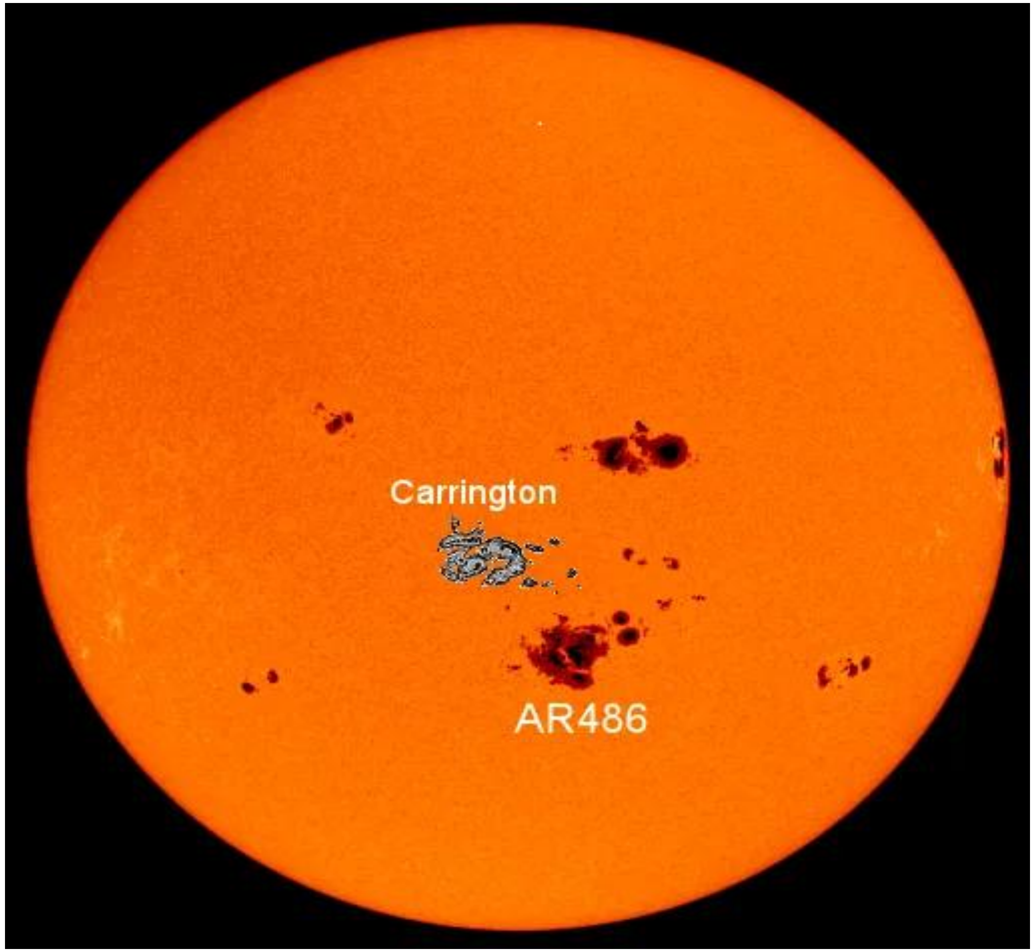
- • Magnetic star powered by nuclear fusion
- • Sunspots: dark patch on the Sun where an especially strong magnetic field prevents some heat from reaching the surface. It’s dark because it is cooler than surrounding area
- • Solar flares: flash of radiation
- • Coronal Mass Ejections (CMEs):a moving cloud of plasma
- • Space weather: caused by any/all of the above

Solar Cycle 10

- • Solar Cycle 10 (1855–1867)
- • ~11-year cycle
- • Carrington Event near solar maximum
- • Large active sunspot region

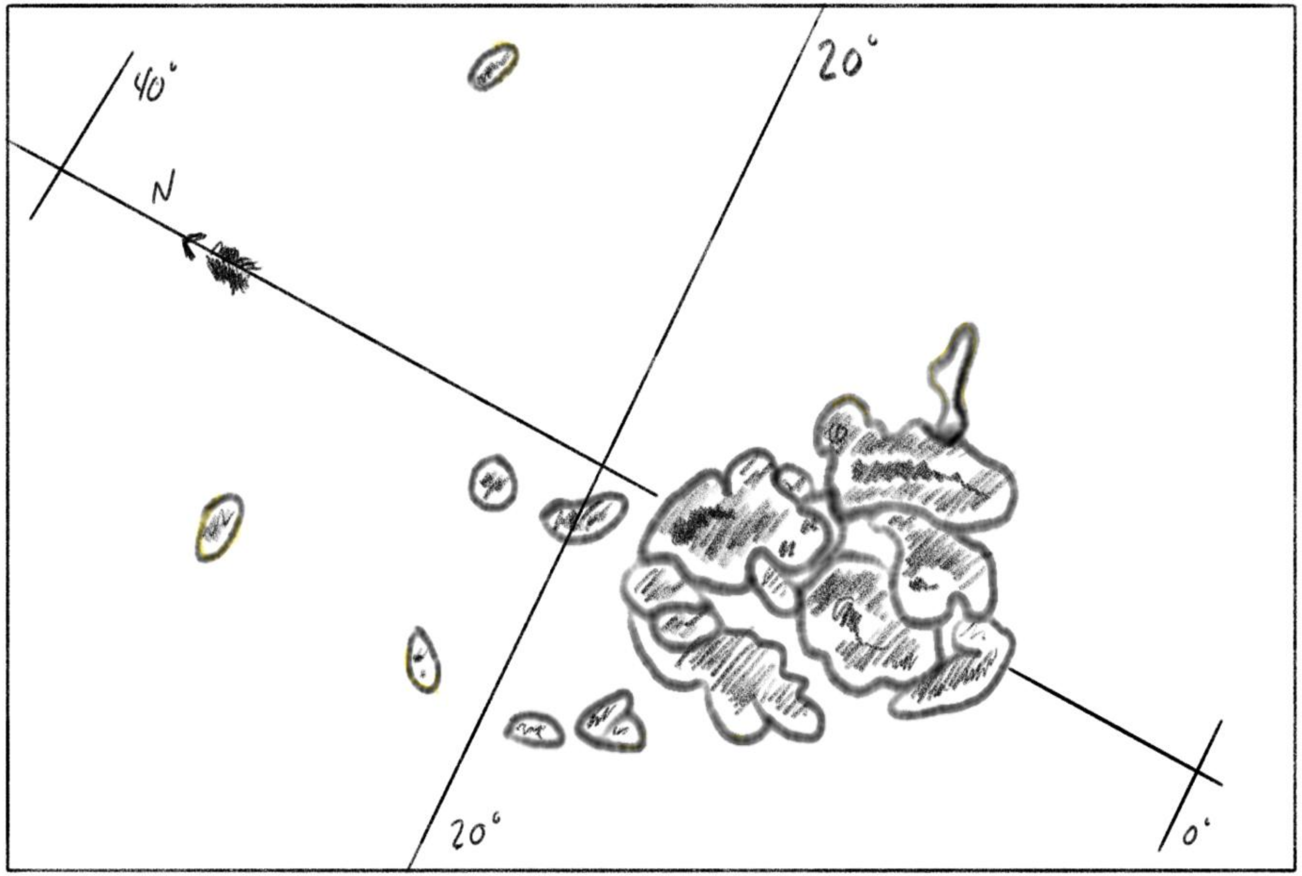
The Great Sunspot Group

- • Exceptionally large sunspot complex
- • Produced a white-light flare
- • Extremely fast CME
- AR486 was part of the Halloween storms of 2003



Richard Carrington

- • English astronomer
- • Systematic solar observer
- • First recorded white-light flare
- • Linked solar activity to geomagnetic storms



Reproduction of original "Solar sketch, September 1, 1859, by R. C. Carrington"

Richard Hodgson

- • Independent observer on Sept 1, 1859
- • Confirmed Carrington's observation
- • Strengthened scientific evidence
- Both men had witnessed the same rare solar flare

Other Observers

- • England
- • France
- • Germany
- • United States
- • Magnetic observatories
- • Telegraph reports

Timeline

- • Aug. 28: Solar activity increases
- • Aug. 29–31: Sunspot group crosses disk
- • Sept. 1: Flare observed
- • Sept. 2: Geomagnetic storm

The First Observed Solar Flare

- • First white-light flare recorded
- • Foundation of space weather science
- • Benchmark for extreme solar storms

Coronal Mass Ejections (CMEs)

- • A CME is a massive eruption of magnetized plasma from the Sun.
- • The 1859 CME reached Earth in about 17 hours.
- • Fast CMEs compress Earth's magnetosphere and trigger geomagnetic storms.

Earth's Magnetic Field

- • Earth's magnetosphere deflects most solar wind.
- • Extreme CMEs compress the magnetosphere.
- • Geomagnetically induced currents can damage infrastructure.

Telegraph Systems in 1859

- • Telegraph networks were the first global electrical infrastructure.
- • Long wires acted as antennas for induced currents.
- • Operators experienced unexpected currents.

Telegraph Effects

- • Equipment sparked and overheated.
- • Operators received electrical shocks.
- • Some systems worked with batteries disconnected.

Worldwide Auroras

- • Auroras appeared far beyond polar regions.
- • Seen in the Caribbean, Hawaii, Europe, Australia, and North America.
- • Many mistook them for sunrise or fires.

Eyewitness Accounts

- • Newspapers described brilliant red, green, and white skies.
- • Observations came from around the world.
- • Historical records aid modern research.

Scientific Understanding

- • 1859: Cause unknown.
- • Today: Flares, CMEs, and magnetic reconnection explain the event.
- • Forecasting continues to improve.

The 1921 Railroad Storm

- • Major geomagnetic storm.
- • Railroad, telegraph, and telephone disruptions.
- • Often ranked second only to 1859.

March 1989 Storm

- • Hydro-Québec blackout.
- • Millions lost power.
- • Modern infrastructure proved vulnerable.

Halloween Storms (2003)

- • Multiple X-class solar flares.
- • Satellite anomalies and GPS degradation.
- • Airline rerouting and radio blackouts.

Sunspot AR486

Key Dates for Sunspot AR486

- **28 October 2003** — Produced an **X17 flare** and launched a fast Earth-directed CME.
- **29–30 October 2003** — Successive CMEs from AR486 triggered **back-to-back G5 geomagnetic storms**.
- **4 November 2003** — AR486 unleashed the **largest solar flare ever recorded**, estimated between **X28–X45**.
- Flare was off the side of the sun, so it was NOT a direct hit but a glancing blow

The July 2012 Near Miss

- • An extreme CME erupted on July 23, 2012. **AR 1520**.
- • Earth passed the impact point about one week earlier.
- • Studies suggest it was comparable in strength to the 1859 Carrington Event.

The May 2024 G5 Geomagnetic Storm

- • The strongest geomagnetic storm in over two decades.
- AR 13664 Produced repeated major flares and at least seven Earth-directed coronal mass ejections (CMEs). Several CMEs arrived close together and combined their effects.
- 8 X class flares X5.8 to X8.7
- The x8.7 was not directly aimed at the earth
- G5 event but not near a Carrington Event
- • Produced auroras at unusually low latitudes.
- • Caused satellite, GPS, and HF radio disruptions.

Current Research on the Carrington Event

- • Researchers study historical observations and modern models.
- • Tree rings, ice cores, and historical records provide clues.
- Seem to show there have been events in the past as strong or stronger than the Carrington Event
- • Computer simulations improve understanding of extreme solar storms.

Monitoring the Sun

- • Spacecraft continuously observe the Sun.
- • Solar imagery, magnetic fields, and solar wind are monitored.
- • Early warning is critical for protecting technology.

Space Weather Forecasting

- • Forecast centers issue watches, warnings, and alerts.
- • Utilities, satellite operators, and airlines use these forecasts.
- • Forecast accuracy continues to improve.

Modern Technological Vulnerabilities

- • Electric power grids
- • Satellites
- • GPS navigation
- • Internet infrastructure
- • Financial systems

Amateur Radio and Emergency Communications

- • HF radio is strongly affected by solar storms.
- • Auroral propagation can occur.
- • Amateur radio provides backup emergency communications.

Government and Industry Preparedness

- • Utilities develop mitigation plans.
- • Satellite operators protect spacecraft.
- • Governments conduct emergency exercises.

Remaining Scientific Questions

- • How often do Carrington-class storms occur?
- • Can even larger events happen?
- • How can forecasting be improved?

2026 Scenario

- • What would happen if a Carrington Event struck today?
- • The next section examines likely impacts and recovery challenges.

A Carrington Event in 2026

- • A Carrington-class CME reaches Earth in ~15–20 hours.
- • Warnings are issued by space-weather agencies.
- • Governments and industry activate emergency procedures.

Electric Power Grid Impacts

- • Geomagnetically induced currents enter long transmission lines.
- • High-voltage transformers overheat.
- • Regional or continental blackouts become possible.

Satellite Systems

- • Increased radiation threatens electronics.
- • Higher atmospheric drag affects low-Earth orbit satellites.
- • Communications and Earth-observation services are disrupted.

GPS and Navigation

- • GPS accuracy degrades.
- • Surveying, agriculture, shipping, and emergency response are affected.
- • Timing errors impact communications and finance.

Radio Communications

- • HF radio blackouts occur.
- • Auroral propagation changes signal paths.
- • Emergency communications become increasingly important.

Internet and Communications

- • Fiber-optic systems rely on powered repeaters.
- • Data centers depend on stable electricity.
- • Mobile networks may experience outages.

Aviation and Transportation

- • Polar flights may be rerouted.
- • GNSS disruption affects navigation.
- • Railroads and pipelines may experience induced currents.

Economic Consequences

- • Direct infrastructure damage.
- • Supply-chain interruptions.
- • Financial market disruption.
- • Recovery costs could reach trillions of dollars.

Emergency Response and Recovery

- • Utilities prioritize restoring critical services.
- • Governments coordinate emergency management.
- • Mutual aid and backup communications become essential.

Key Lessons for 2026

- • Extreme solar storms are inevitable.
- • Preparation greatly reduces risk.
- • International cooperation is essential.
- • Space-weather forecasting continues to improve.

Strengthening the Electric Grid

- • Install geomagnetic monitoring.
- • Use transformer protection systems.
- • Develop strategic transformer reserves.
- • Improve grid operating procedures.

Advances in Space Weather Forecasting

- • Continuous solar observations.
- • Improved computer models.
- • Better CME arrival-time predictions.
- • International data sharing.

International Cooperation

- • Space-weather information is shared globally.
- • Utilities, governments, and scientists coordinate responses.
- • Joint planning improves resilience.

Future Solar Research

- • Study magnetic reconnection.
- • Understand CME initiation.
- • Improve forecasting models.
- • Investigate extreme historical events.

Lessons from the Carrington Event

- • Extreme solar storms can affect the entire planet.
- • Technology increases vulnerability.
- • Preparedness reduces risk.
- • Scientific research is essential.

Key Takeaways

- • The Sun is dynamic.
- • Extreme events will occur again.
- • Modern society depends on vulnerable technologies.
- • Planning improves resilience.

Glossary

- • CME – Coronal Mass Ejection
- • GIC – Geomagnetically Induced Current
- • Magnetosphere
- • Solar Flare
- • Space Weather

Recommened Reading

- • NOAA Space Weather Prediction Center
- • NASA Heliophysics resources
- • Royal Astronomical Society publications
- • Peer-reviewed journals such as Space Weather and JGR: Space Physics

References

- • Primary historical papers by Richard Carrington and Richard Hodgson.
- • NASA educational resources.
- • NOAA Space Weather Prediction Center.
- • Recent peer-reviewed literature.

Questions and Discussion

- • Questions?
- • Discussion