Space weather in a resilient society

Harriet Turner

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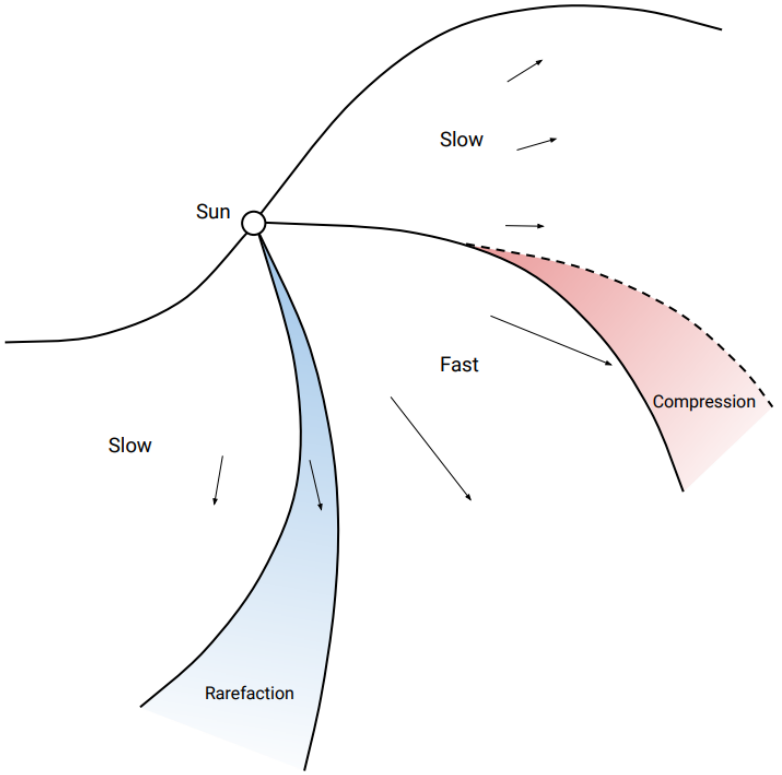
Space weather

"Space weather describes changing environmental conditions in near-Earth space." – Met Office

- Driven by the variability of the Sun.
- Interactions with the Earth's magnetic field can cause a variety of impacts.
- Severe space weather is in the National Risk Register.

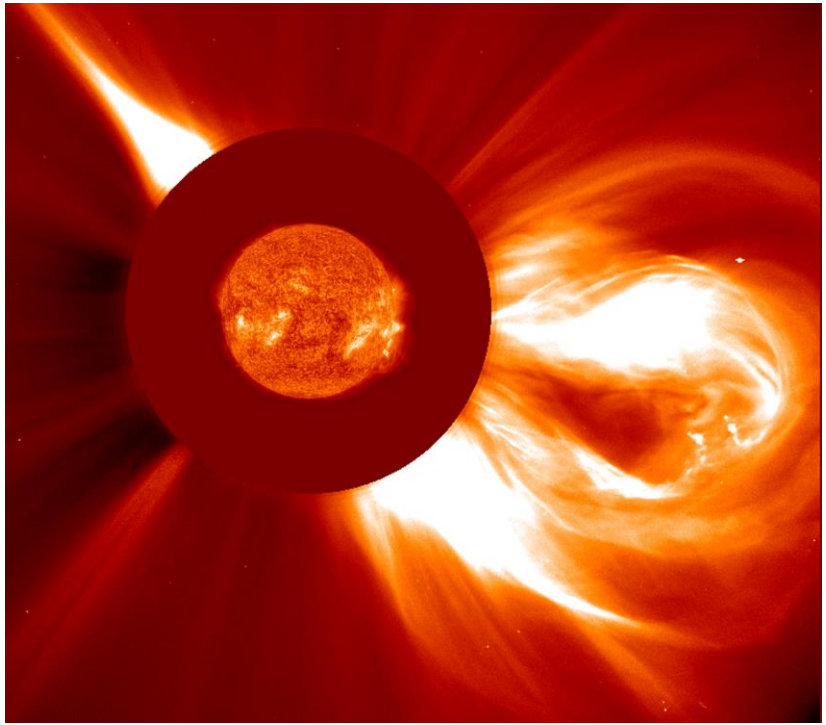
Solar wind

- Constant stream of charged particles flowing off the Sun.
- Drags with it the Sun's magnetic field.
- Streams of fast and slow solar wind, pulled into an Archimedean spiral shape.

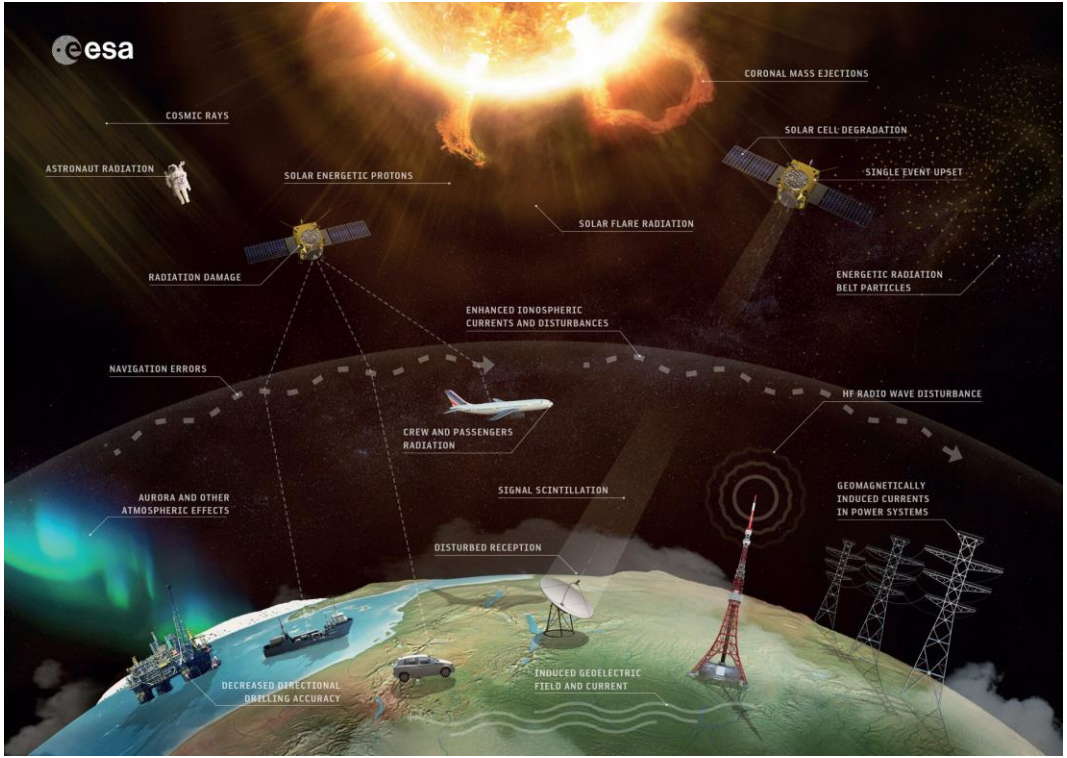


Coronal mass ejections

- CMEs are transient eruptions of plasma and magnetic field.
- They propagate through the solar wind, with the background conditions affecting their travel through space.

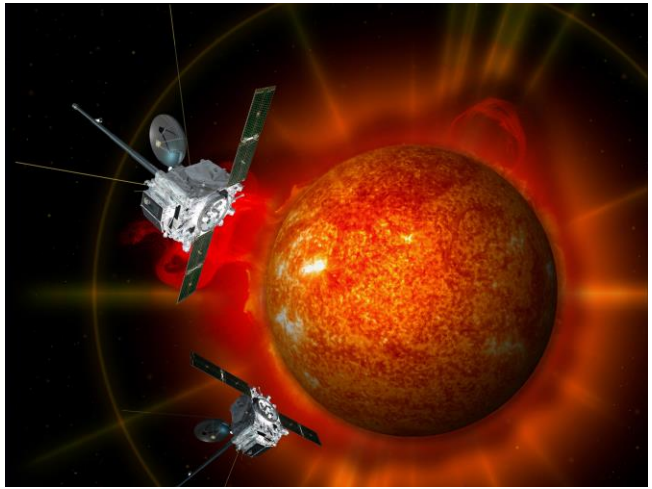


Space weather impacts



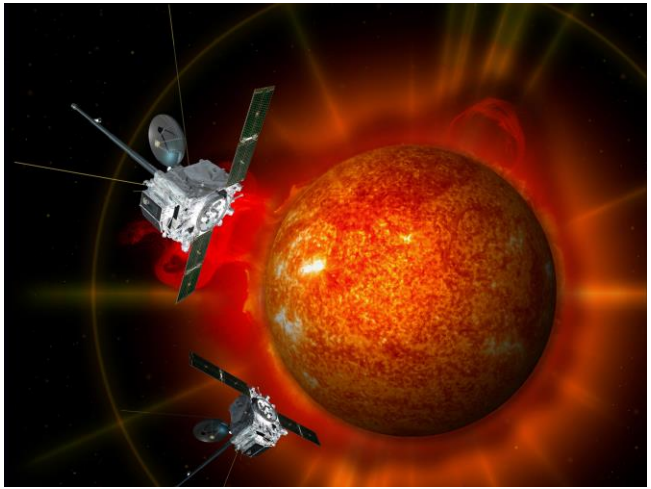
Spacecraft impacts

- Spacecraft charging can occur from electrons in the space environment.
    - Discharges across a spacecraft – ‘arcing’.
    - Deep dielectric charging occurs from high energy electrons.
- Single event upsets.
- Premature aging.
- Excessive drag in the upper atmosphere.



Mitigation

- Spacecraft can have radiation hardening built into their design.
  - Very mission dependent.
- Spacecraft can be switched off to allow excess charge to diffuse.
- Plan to use other systems if, for example, GPS is affected.



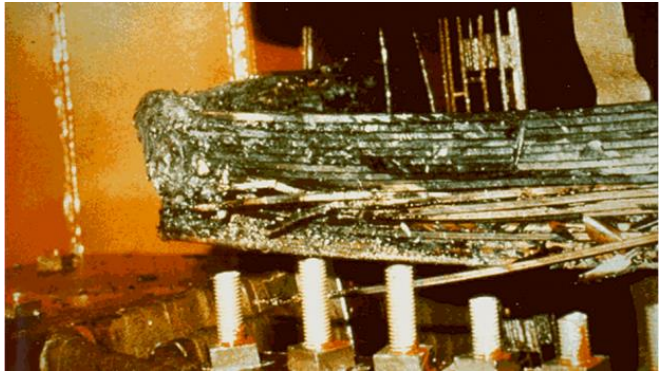
Human impacts

- Humans on the surface are mostly protected by Earth's magnetic field.
- Radiation effects those in space and on high-altitude flights.
    - Electromagnetic radiation or energetic particles.
- Damage or destroy living cells or damage DNA.
- Can cause reduction in white blood cells, nausea, hair loss, cancer and death.

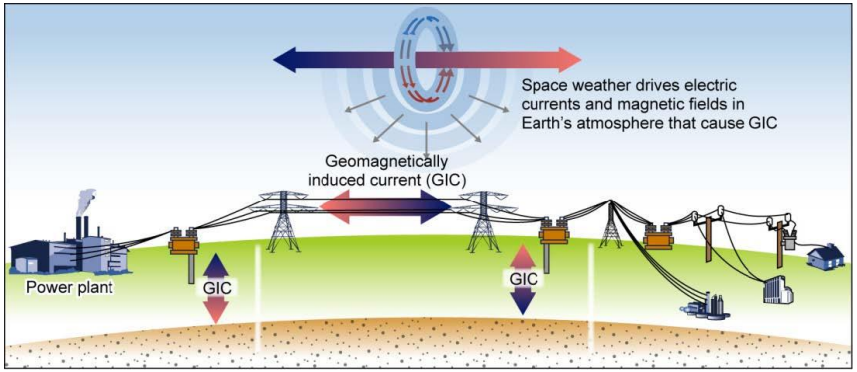
Mitigation

- Limiting the number of high-altitude flights (regulations for air crew).
- Rerouting flights during space weather events.
- Astronauts on ISS wear radiation monitoring devices.
- Astronauts can shield during events.

Power grid impacts

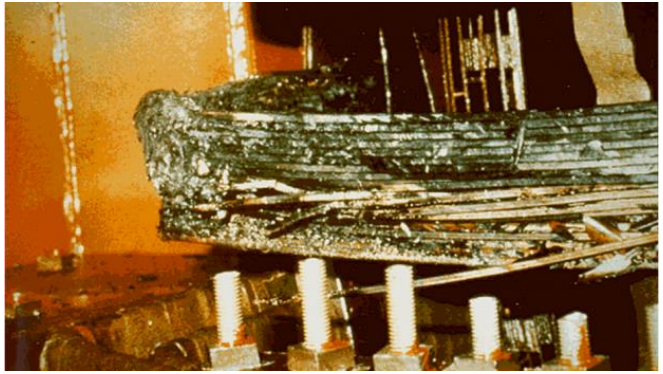


- Disruption in the Earth's magnetic field from space weather can induce currents at the surface.
- Magnetic effects from GICs can shut down transformers or damage them.
- Local to national black outs.
- Hydro-Quebec power station in Canada – 9-hour blackout and $13.2 million in damages.

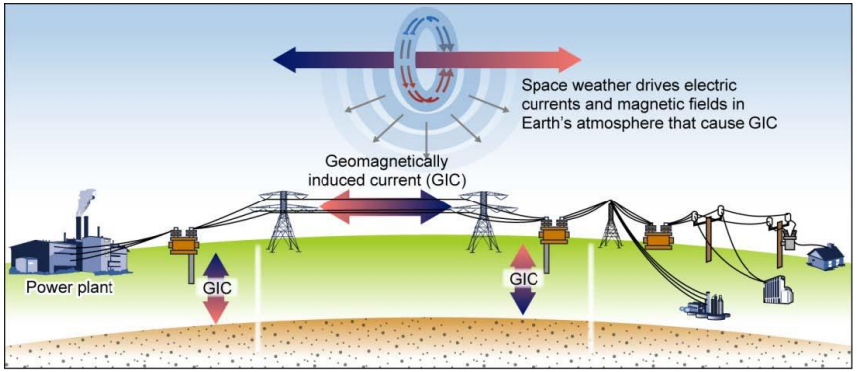


Sources: GAO (presentation); Art Explosion (images). | GAO-19-98

Mitigation



- Schedule maintenance around the solar cycle.
- Disconnection of parts of the network that are vulnerable.
- Capacitors to block GICs.



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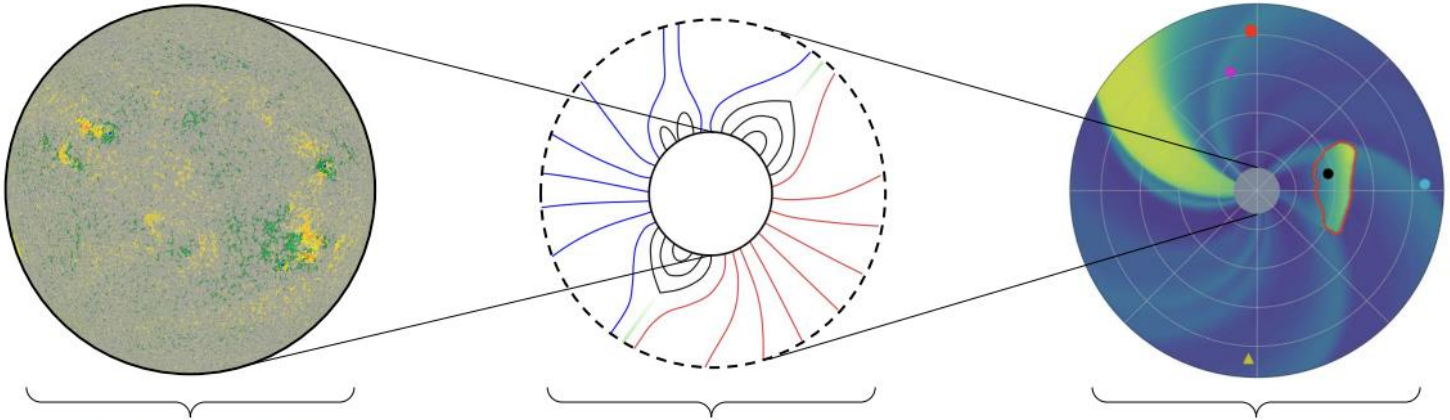
Aurora

- The aurora are caused precipitating particles colliding with native atmospheric species, causing them to glow.
- The aurora are enhanced and visible at lower latitudes during an intense space weather event.
- Large, Earth-directed CMEs caused the geomagnetic storm of May 2024, which saw visible aurora over much of the UK.

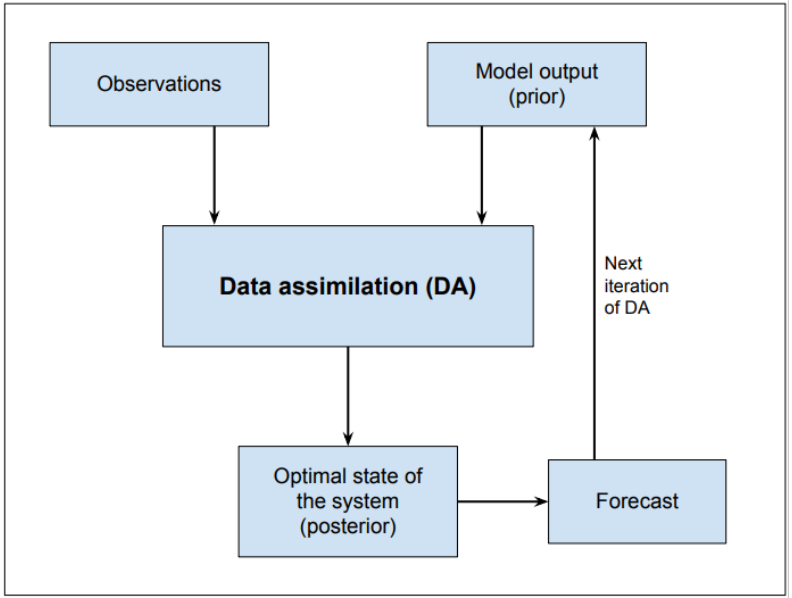
Hound Tor, Dartmoor
May 2024

Space weather forecasting



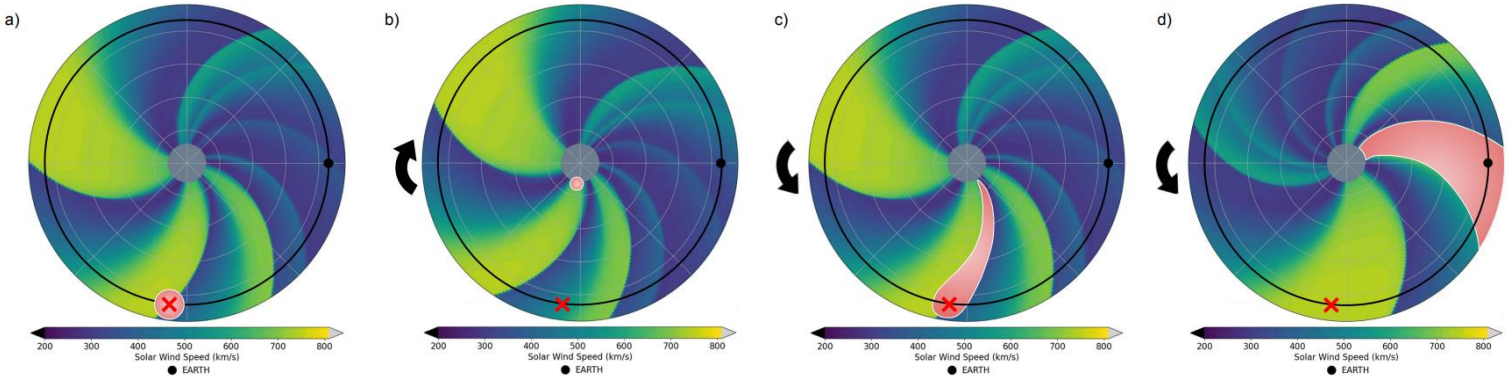
Data assimilation

- DA combines model output with observations to form an optimum estimation of reality.
- Led to large forecast improvements in terrestrial weather forecasting but has been underused in space weather.



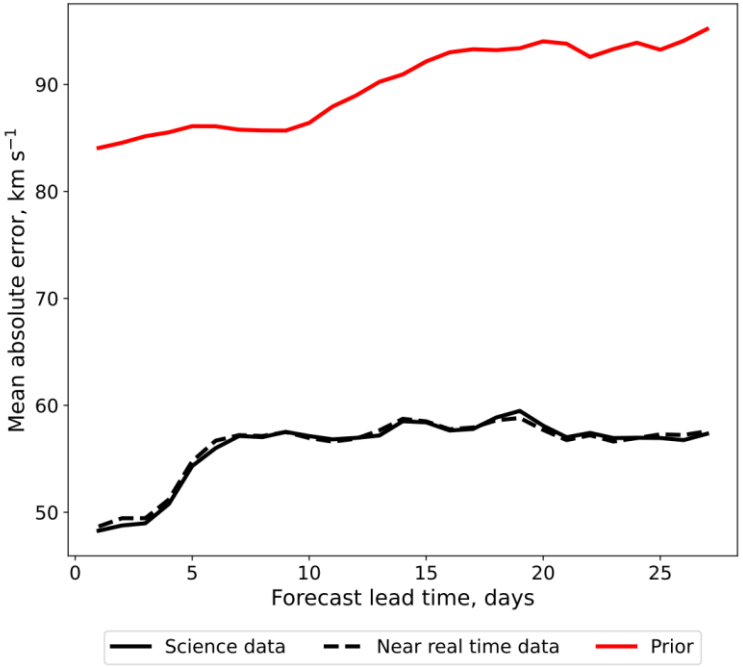
BRaVDA

Burger Radius Variational Data Assimilation



Forecast improvement

- Using DA improves solar wind forecasts, particularly for lead times of less than 5 days.
  - Most important for space weather forecasting.
- Improving the knowledge of the background conditions should improve CME forecasts.



Resilient society

- Enhancing space weather forecasting capabilities can help us become more resilient.
  - Improving CME speed and arrival time accuracy.
  - Increased lead time of events gives more time for mitigation.
- Future missions – e.g. Vigil mission
- Future projects and research
  - Space Weather Instrumentation, Measurement, Modelling and Risk (SWIMMR) project is an example of a programme to enhance UK space weather resilience.


Met Office
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harriet.turner2@metoffice.gov.uk
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