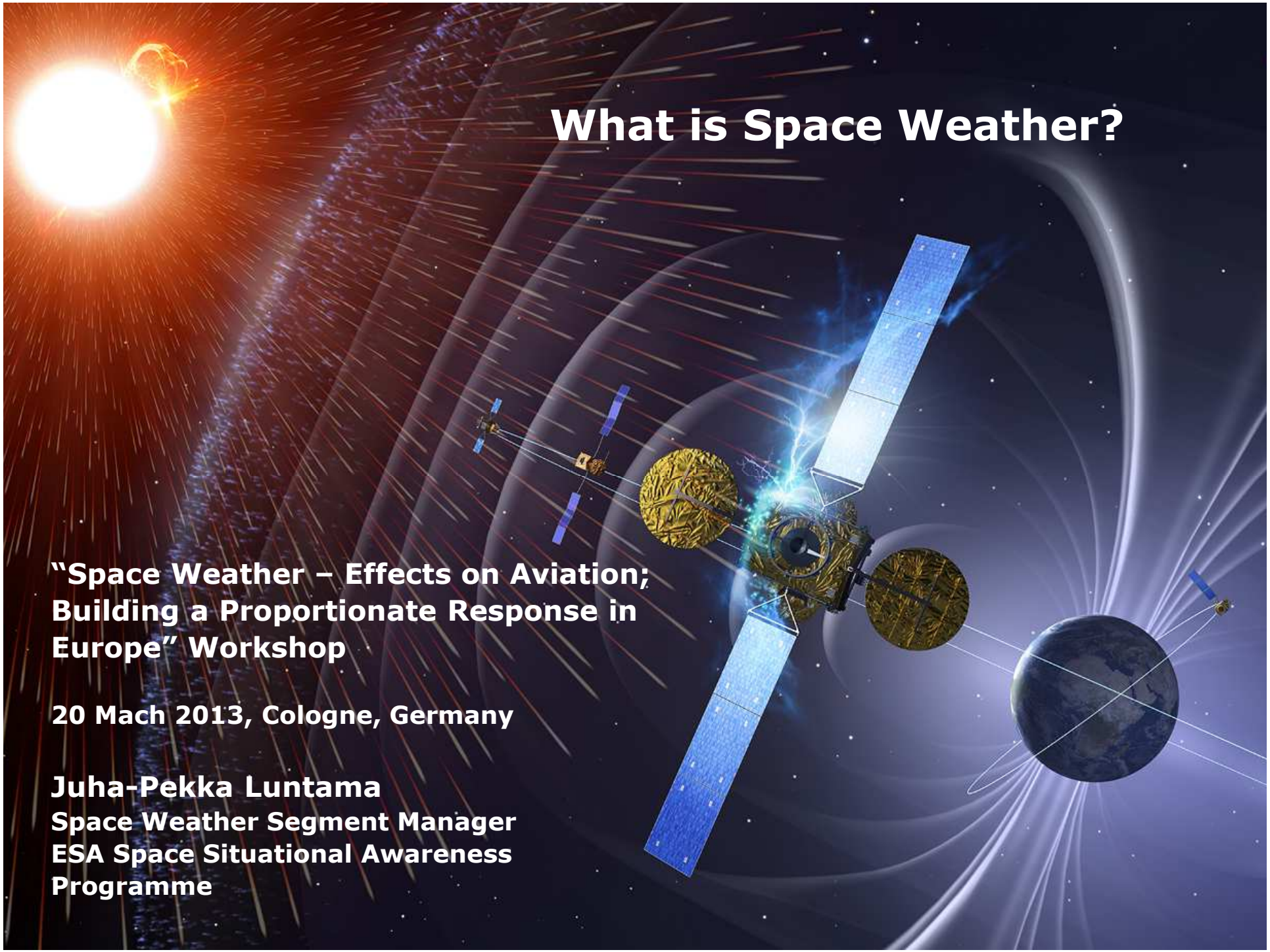
# What is Space Weather?



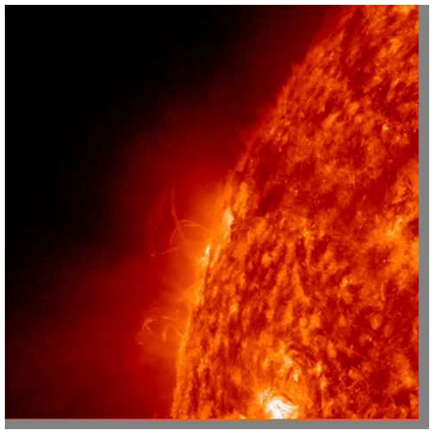
"Space Weather – Effects on Aviation; Building a Proportionate Response in Europe" Workshop

20 Mach 2013, Cologne, Germany

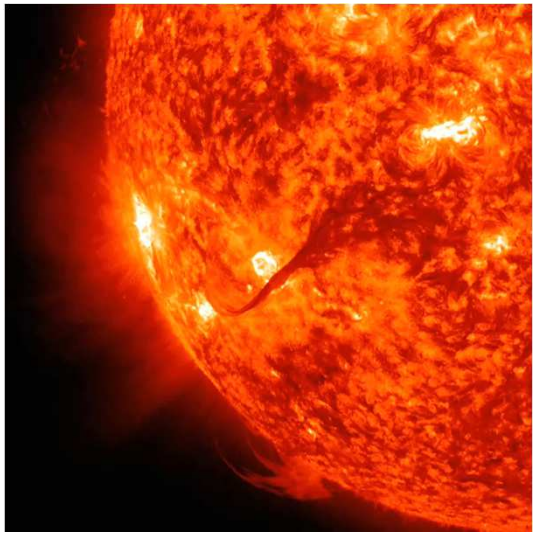
**Juha-Pekka Luntama**
Space Weather Segment Manager
ESA Space Situational Awareness Programme

# What is Space Weather?

Conditions on the Sun and in the solar wind, magnetosphere, ionosphere and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health.



**Credit: NASA/SDO**



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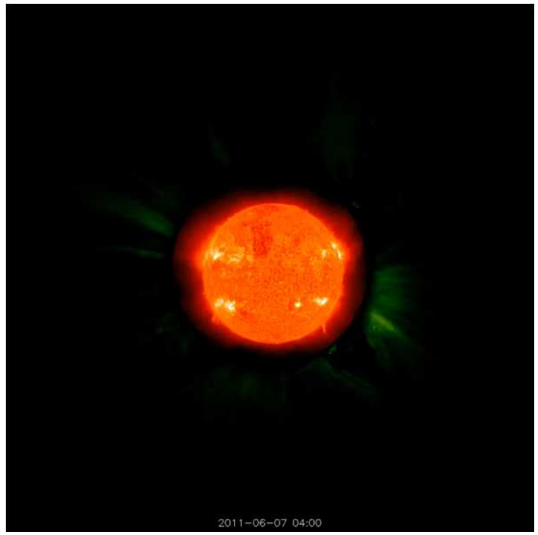
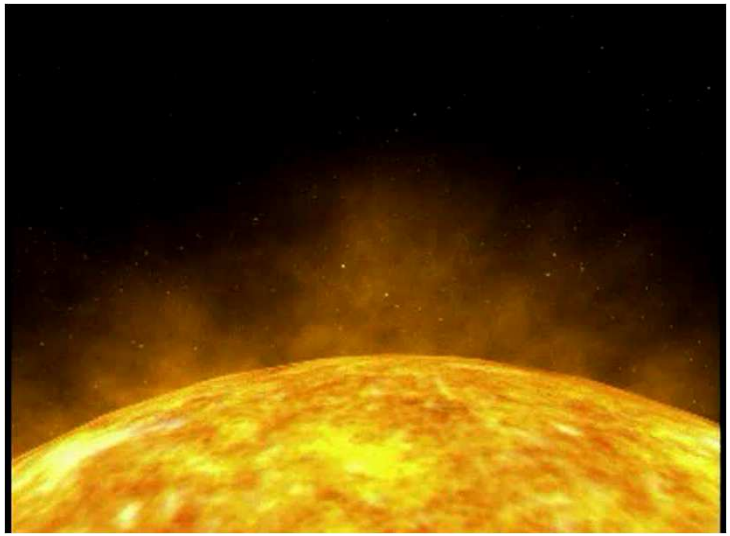
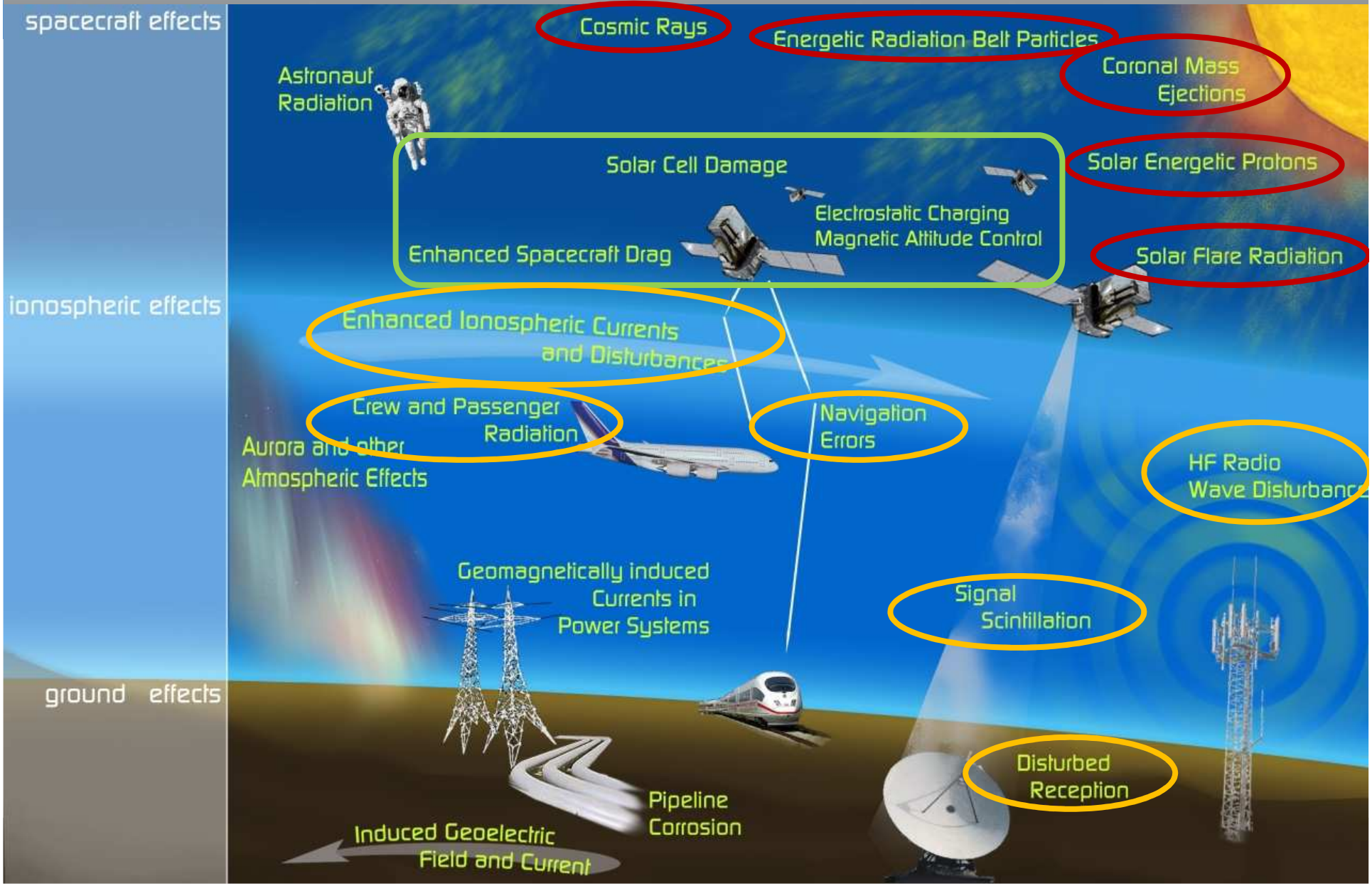



**Credit: ESA/NASA/SOHO**



# Space Weather Impacts on Infrastructure

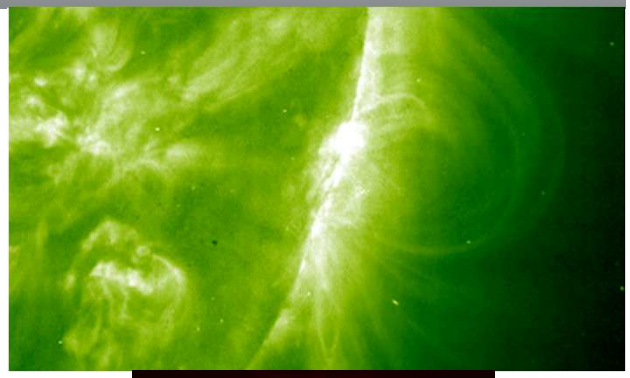


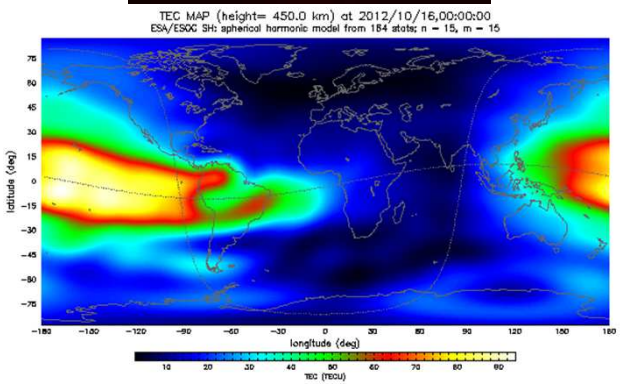
# Solar Flares and EM Radiation

- Solar flares are sudden releases of energy as EM radiation and particles from the Sun's surface
- Small direct impact on space systems
  - Solar cell degradation beyond normal levels
  - X-ray or (E)UV sensitive sensors can be damaged
  - Increased atmospheric drag impacts on LEO missions
- Radio bursts can cause radio blackouts
- Ionospheric disturbances can make space systems temporarily non-accessible

  => main impact on dayside at low to mid latitudes

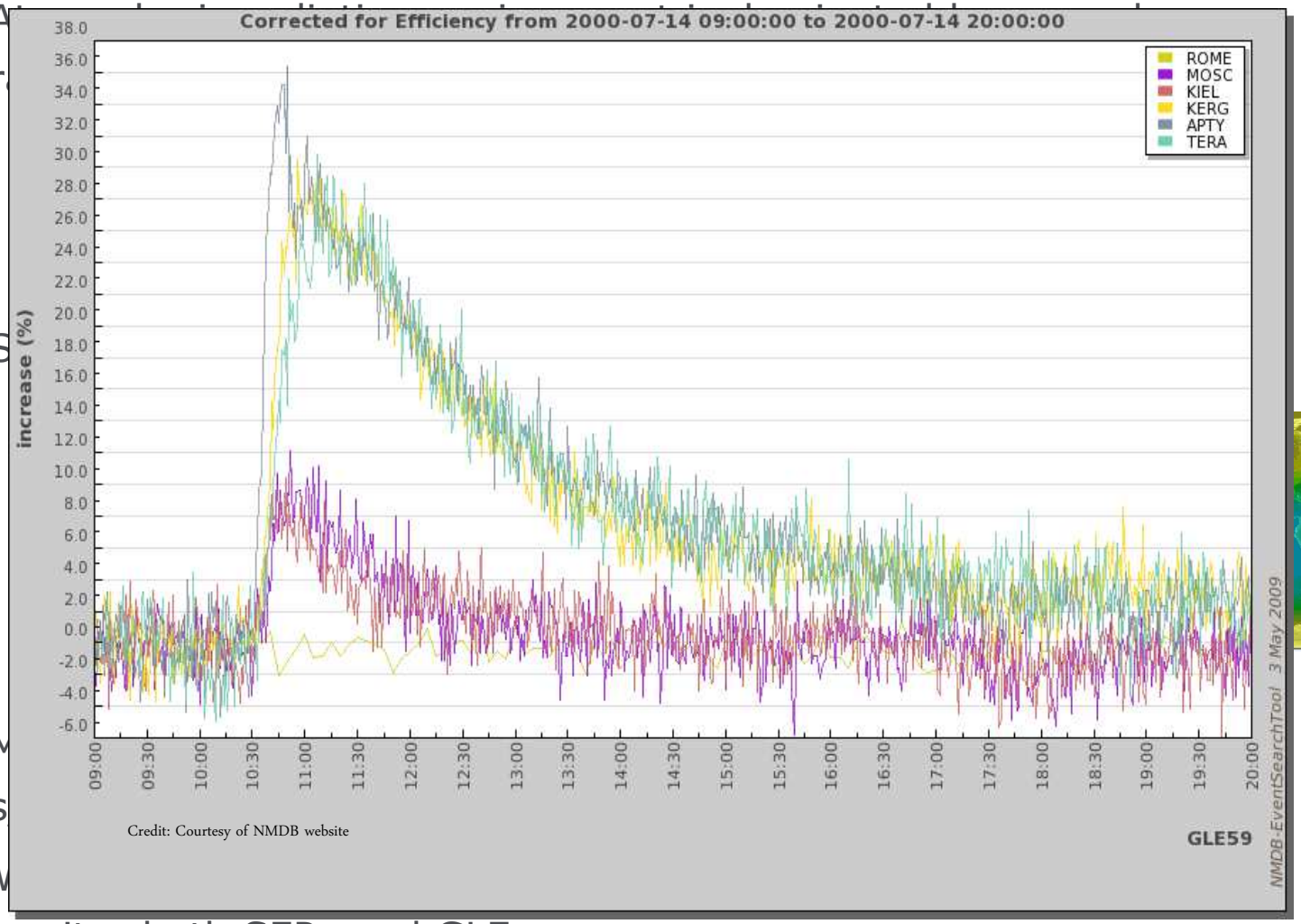
  => impact of a single flare disappears in 2-3 hours

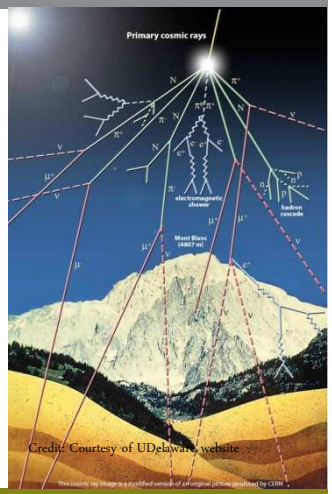


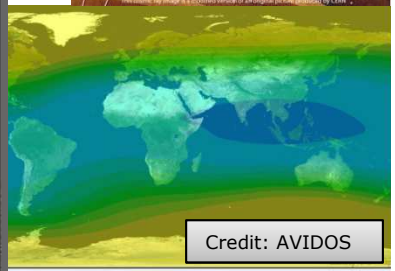


# Radiation Environment

- A
  r
- S
- M
  s
- W
  monitor both SEPs and GLEs



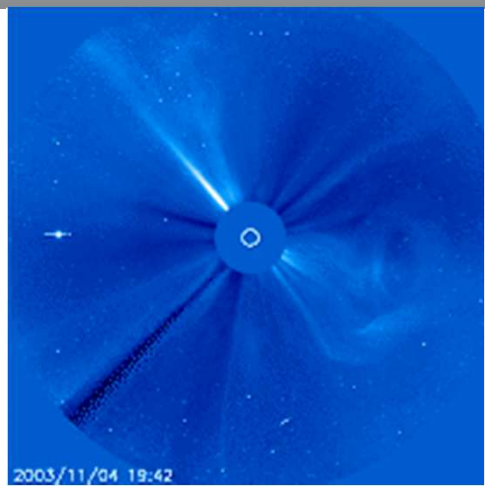




# Coronal Mass Ejections

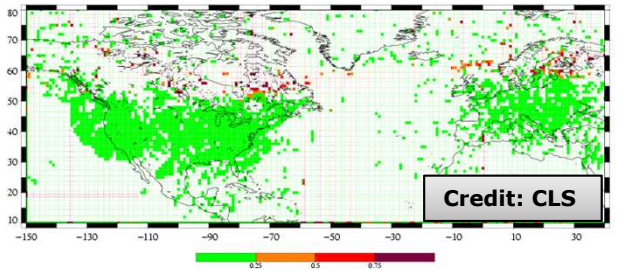
- Ejection of a massive cloud of plasma from the Sun
  - May trigger a geomagnetic storm and substorms
  - Impact depends on the direction of IMF
- Geomagnetic storm conditions can last over a day
- Spacecraft in GEO and LEO at risk
- Triggers ionospheric disturbances impacting telecommunication and satellite navigation
- Ionospheric scintillation in polar regions may cause transient satellite navigation failures
- CMEs are difficult to forecast reliably

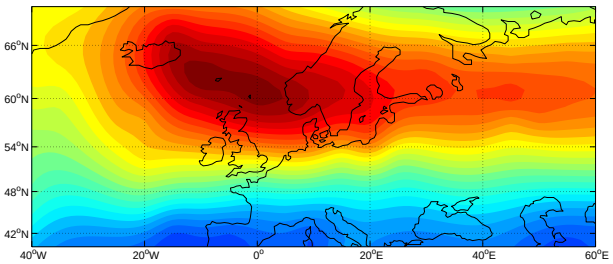
  => monitored with a coronagraph
- Propagation to the Earth takes 17 – 48 hours
- Geoimpact confirmed only by measurements at L1

  => final alert only 15 – 60 min before the impact




Empirical scintillation index (~1000 GPS stations) – 29 Oct.2003 – 17:00

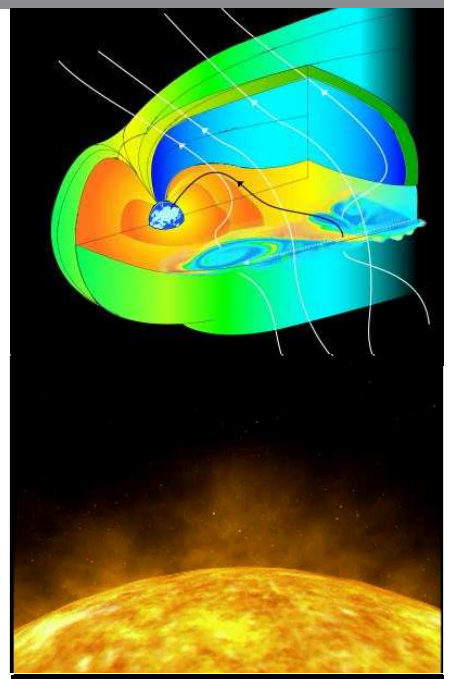


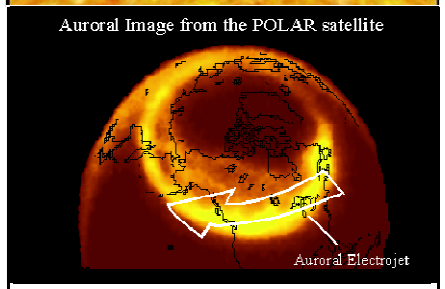



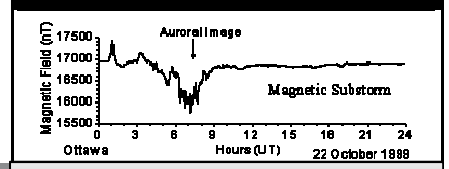
# Geomagnetic Environment

- Earth's magnetic field
  - protects the Earth from the solar wind
  - reverses polarity every 200 000 – 300 000 years
  - external field controlled by space weather forms a dynamic element of the geomagnetic environment
- CMEs can trigger a geomagnetic storm that
  - disturbs the geomagnetic field locally and globally
  - reduces the radiation protection of the magnetosphere
  - create "killer electrons" that damage satellite systems
  - Cause ionospheric disturbances impacting satellite signals and VHF/UHF radio communications
- Major geomagnetic storm can last several days

  => substorms at intervals of 1-3 hours with severe local effects





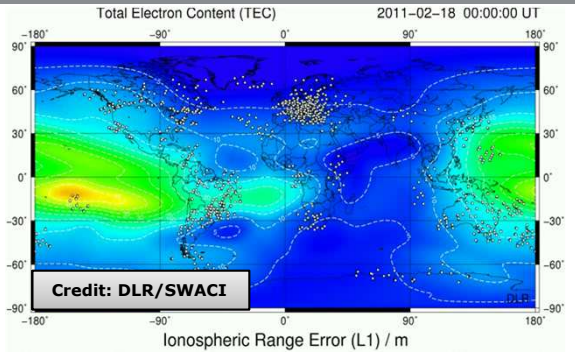



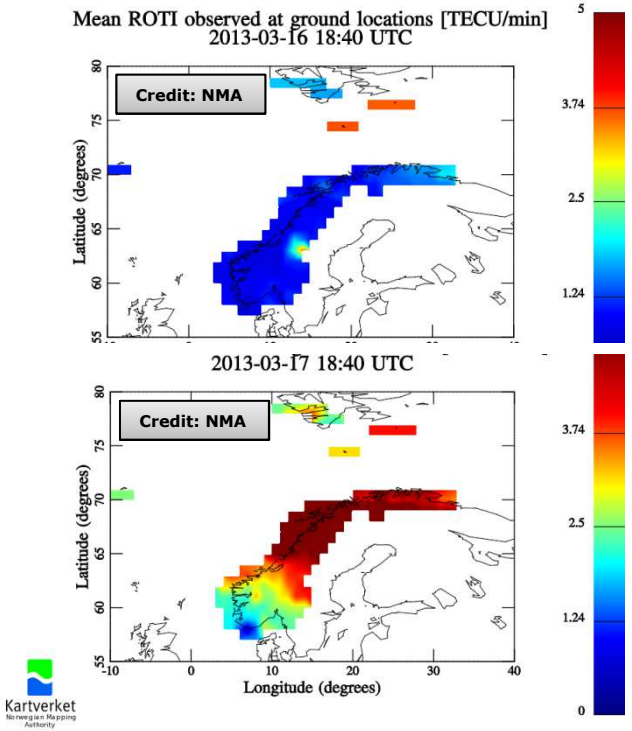

Credit: Space Weather Canda website

# Ionospheric Weather

- Lightly ionised upper part of the atmosphere
- Ionisation is caused
  - ➢ mostly by solar EUV and soft x-rays
  - ➢ contributions from electron precipitation and SEPs in the polar region
- Ionospheric plasma is conductive

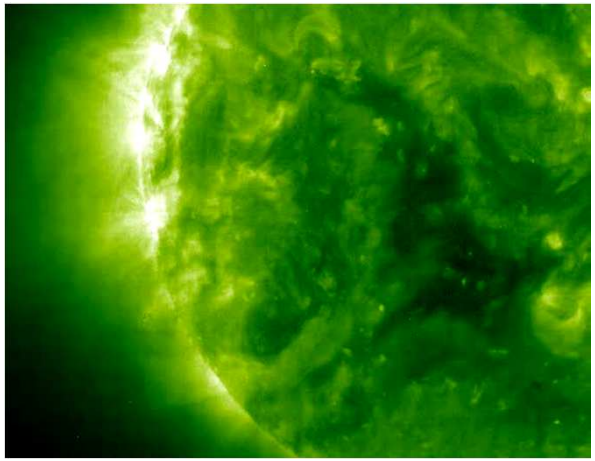
  => interacts with radio signal propagation
- Mid-latitude ionosphere is normally well behaving
- Ionospheric irregularities are mainly due to
  - solar flares: equatorial disturbances spreading to higher latitudes
  - CMEs: polar disturbances moving to mid latitudes
- Worst case scenario for telecommunications: CME arrival with a simultaneous strong flare

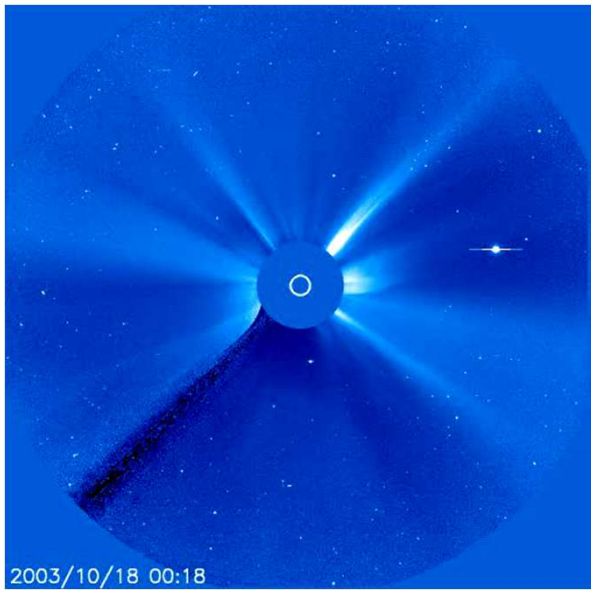


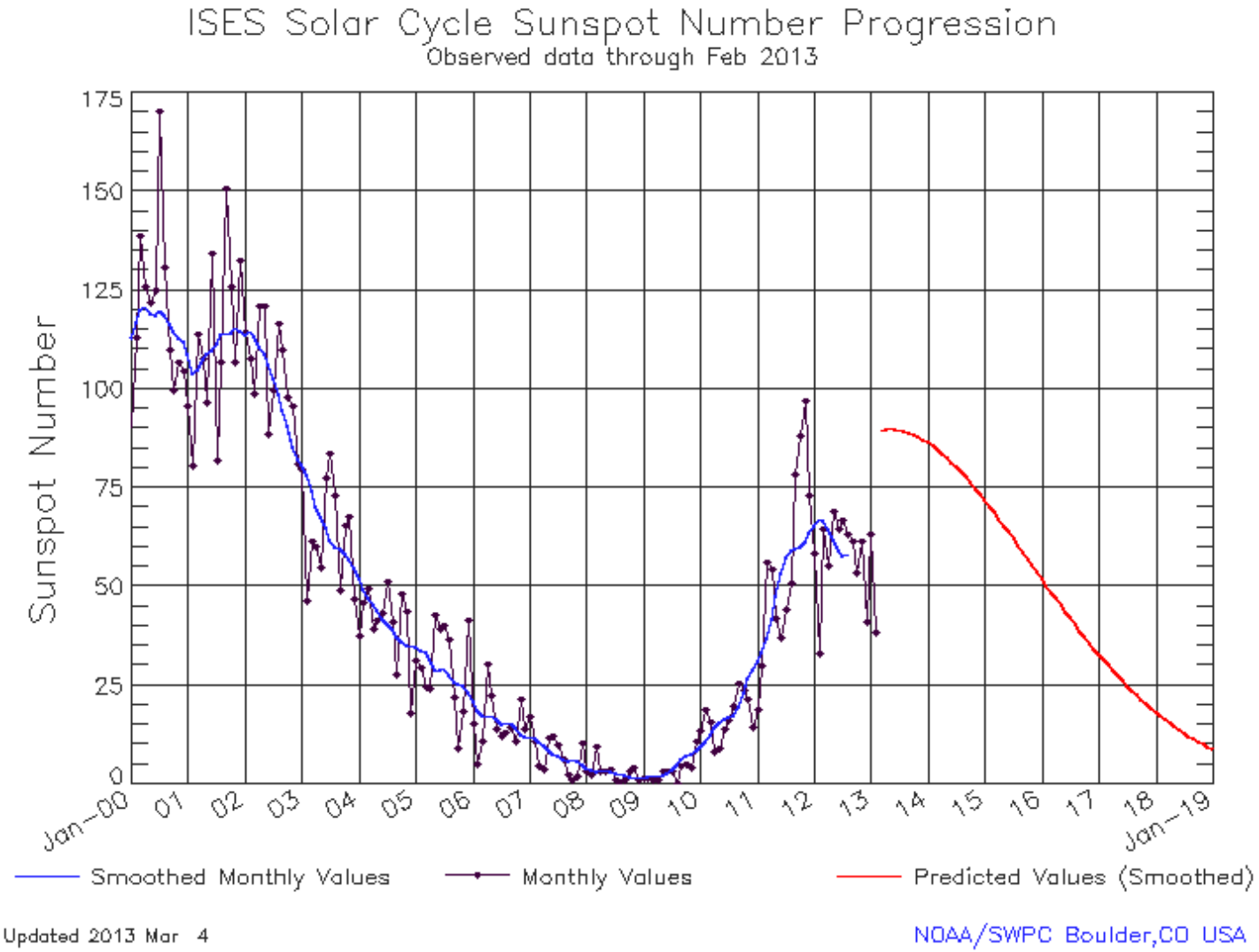
# What is a major solar event?

- Each individual element of a solar storm is potentially dangerous for the infrastructure
- An extreme solar event is likely to contain multiple solar storms
- Halloween storm 19 Oct – 5 Nov 2003
  - 18 X-ray events: M5.0 – X28.0
  - 18 radio blackout events: R1 – R5
  - 5 CMEs with geoimpacts: Kp 6 – 9
  - 5 SEP events
- Series of storms are likely to cause
  - Increasing anomalies in s/c potentially leading into mission failures or satellites placed in safe mode
  - Increasing risk of SEEs in electronics including aircraft
  - Continued telecommunication problems globally
  - Increased radiation levels at aircract cruise altitudes

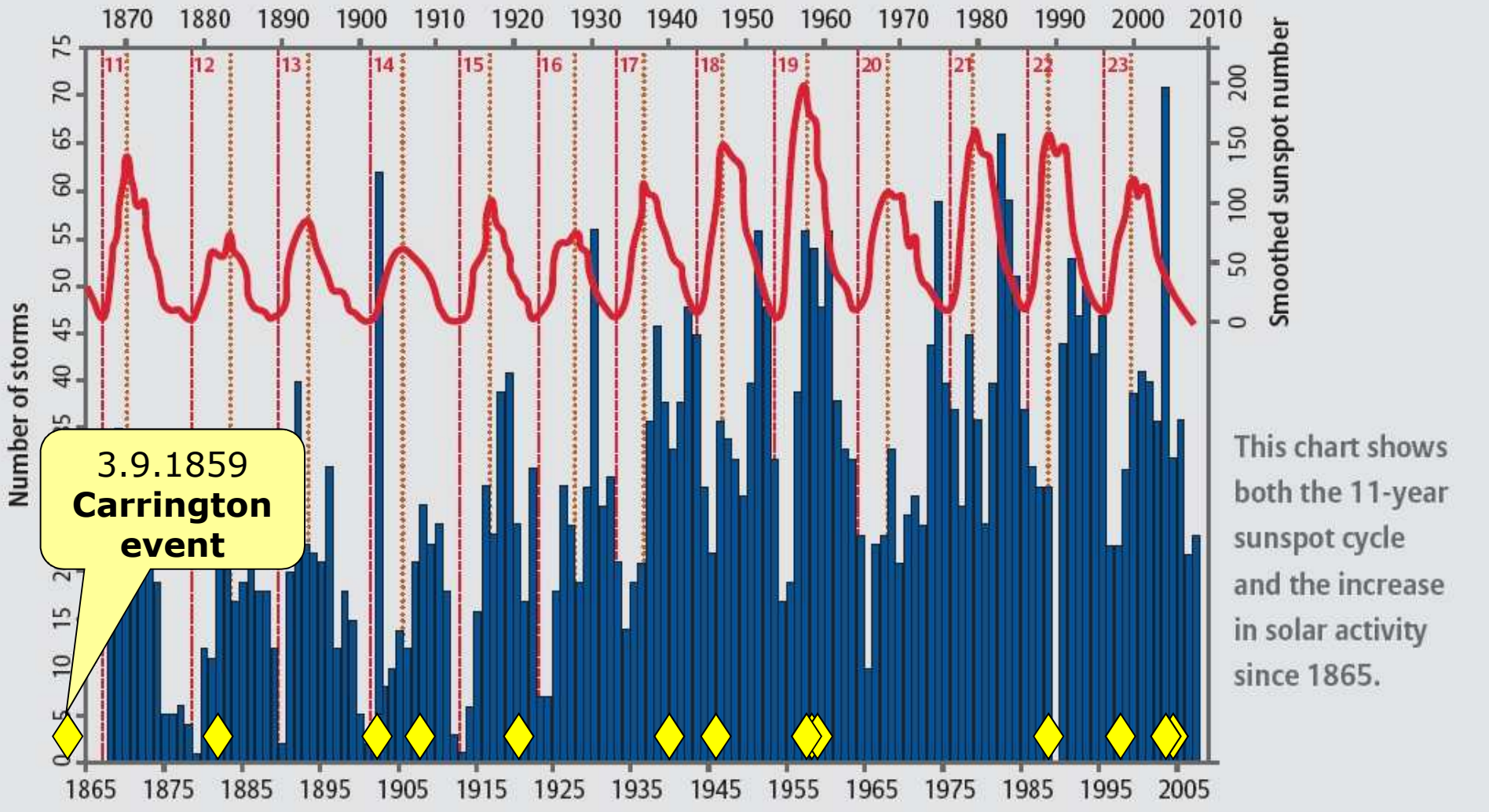




# Current Solar Cycle



# Major Geomagnetic Events since 1865

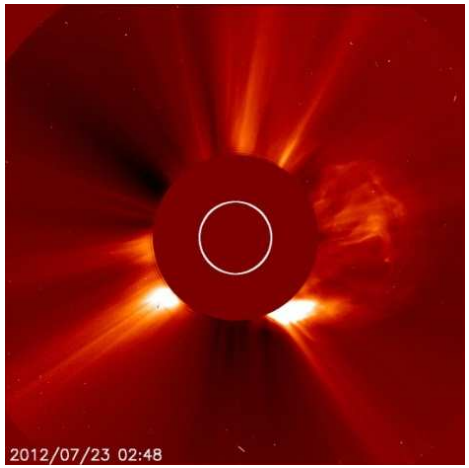



Source: British Geological Survey

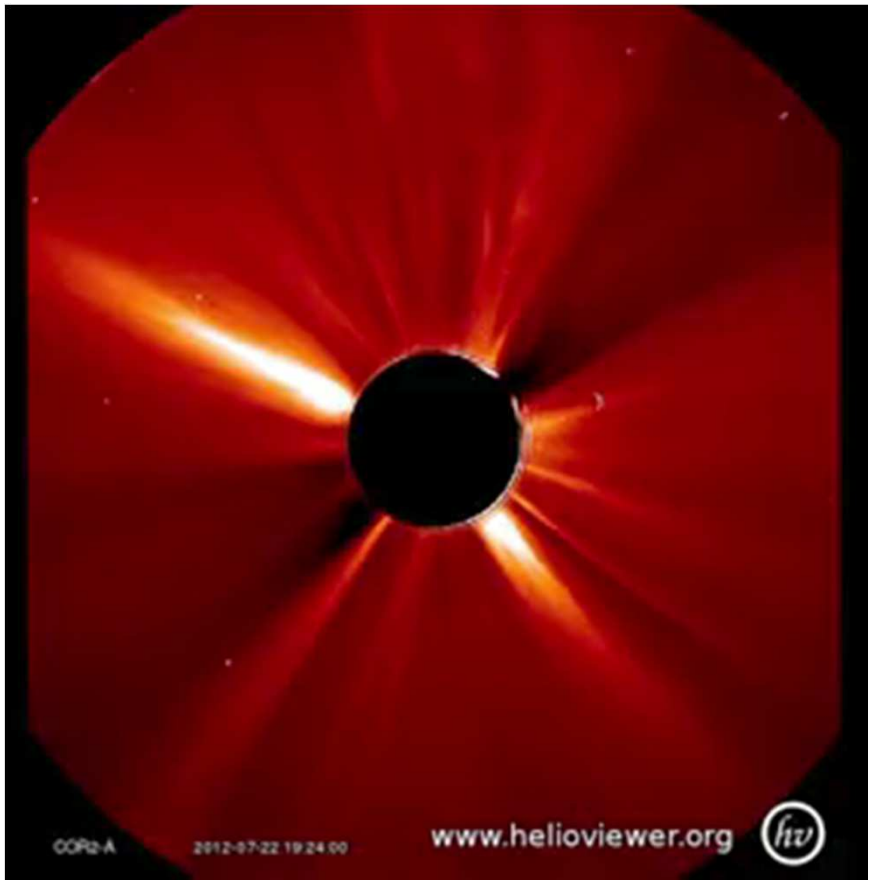
# A Major Solar Event in 2012

## July 23, 2012

- CME reached Stereo-A in 17 hours
- 80 nTesla magnetic field
- IMF southwards
- Associated proton event
- Same AR had been creating smaller storms for over a week



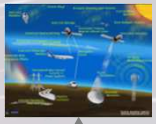

**Credit: ESA/NASA/SOHO**

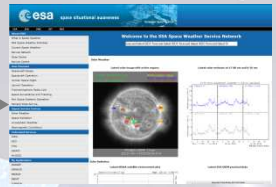



**Credit: NASA/STEREO**

# SSA/SWE Precursor System in 2013

SSA-SWE Users





SSA-SWE Service Portal: swe.ssa.esa.int

SWE Data Centre Redu, Belgium

SWE Service Coordination Centre, Space Pole, Belgium

## SWE Expert Service Centres

| Solar Weather | Ionospheric Weather | Space Radiation | Geomagnetic Conditions | Heliospheric Weather |
|---|---|---|---|---|
| ROB, Belgium (coord.)<br>Uni. Graz, Austria | DLR, Germany (coord.)<br>NMA, Norway<br>NOA, Greece<br>CLS, France | BIRA, Belgium (coord.)<br>AIT, Austria<br>UOA, Greece | TGO, Norway (coord.)<br>FMI, Finland | TBD |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