Space Weather Awareness in the Arctic

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Technology in the Arctic

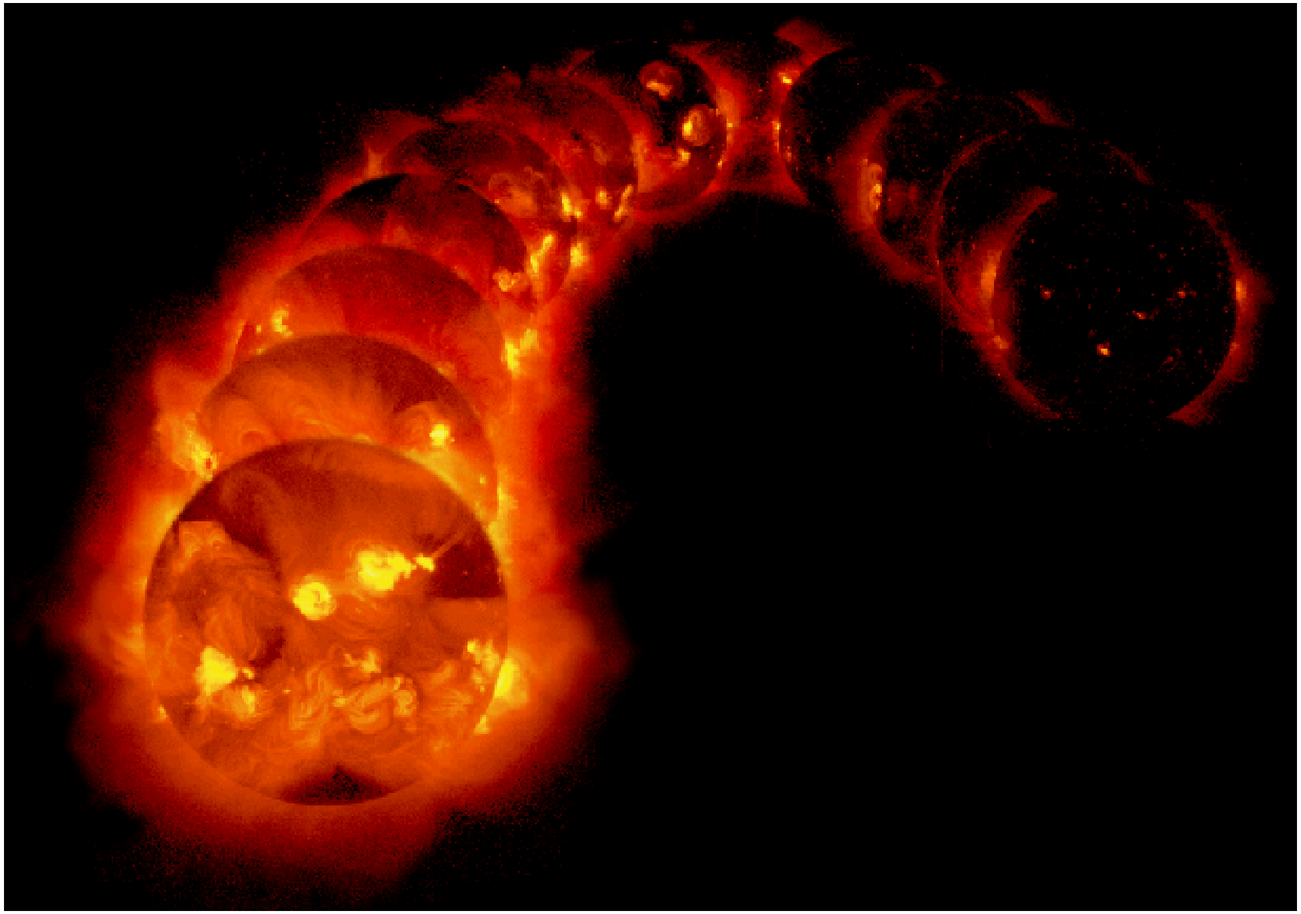
- There is significant potential
  - Resources
  - Tourism
  - ... helped by receding ocean ice

- There are severe challenges
  - Weather
  - Ice
  - Poor naval maps
  - Remoteness of the region
  - and
  - ... Space Weather...

Space Weather is Powered by the SUN

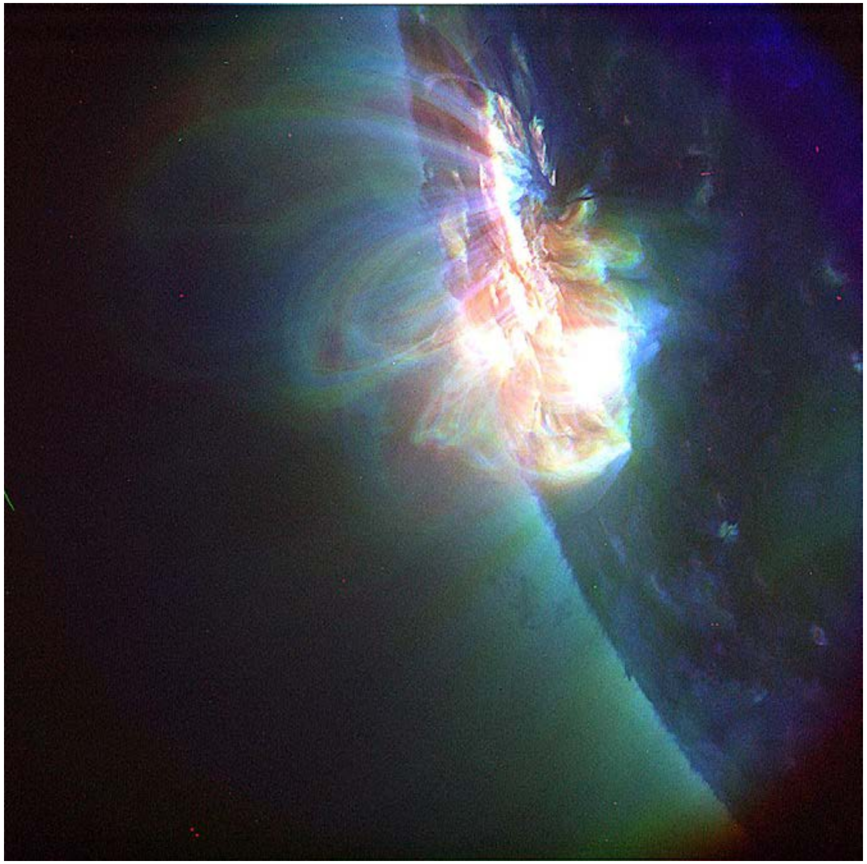
- The SUN emits electromagnetic radiation
  - The energetic radiation in the UV and X-ray bands varies in time
  - The radiation takes 8 min to reach Earth
- The SUN ejects matter
  - Electrons and protons that form the Solar Wind
  - Eruptions take ~30 min to a tens of hours to reach Earth
- Solar activity varies on timescales from minutes to many years

The SUN: X-ray activity 11-year cycle



The Yohkoh satellite

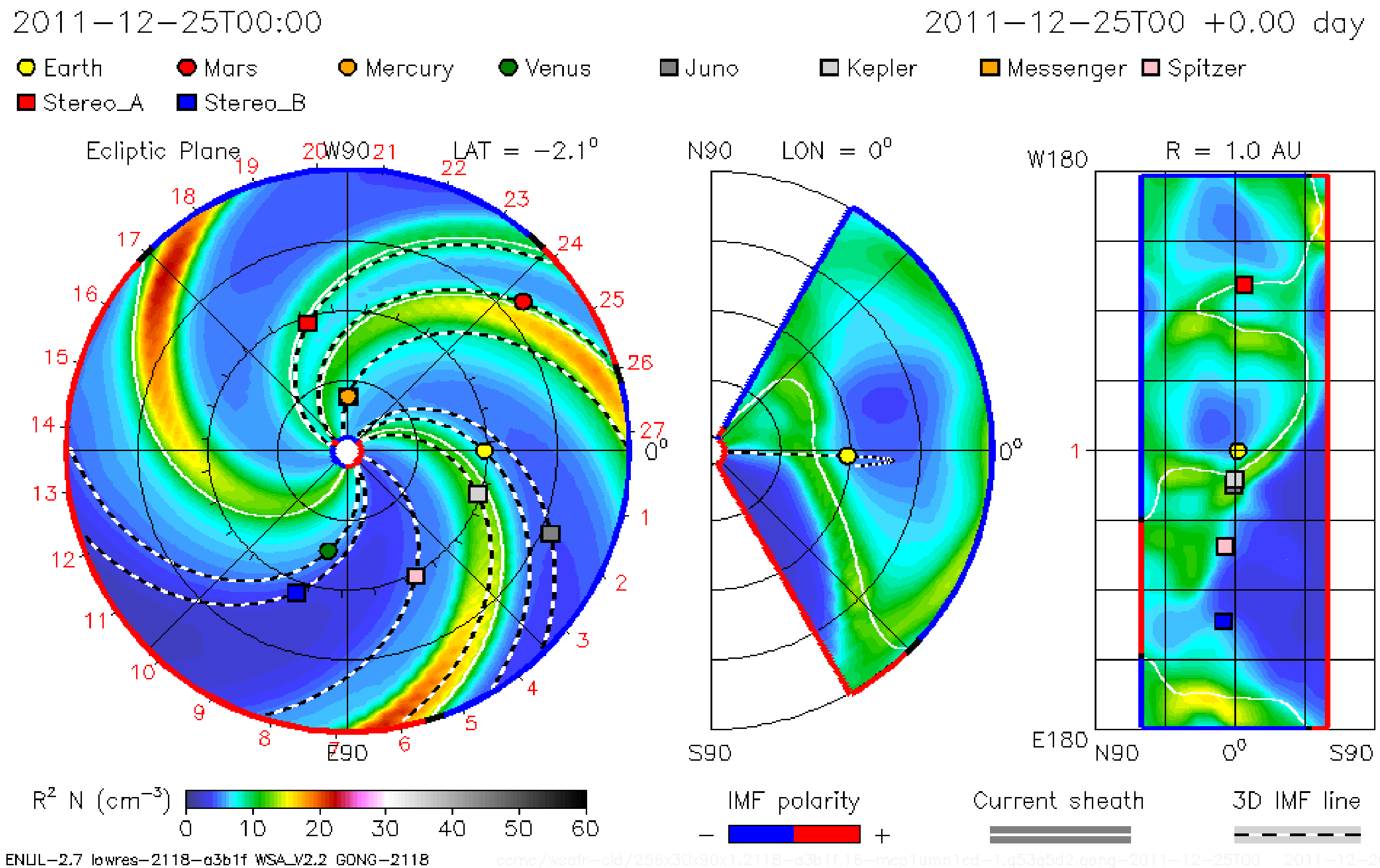
The SUN: Impulsive injection of particles



The Trace Satellite

The SUN from ESAs Soho satellite

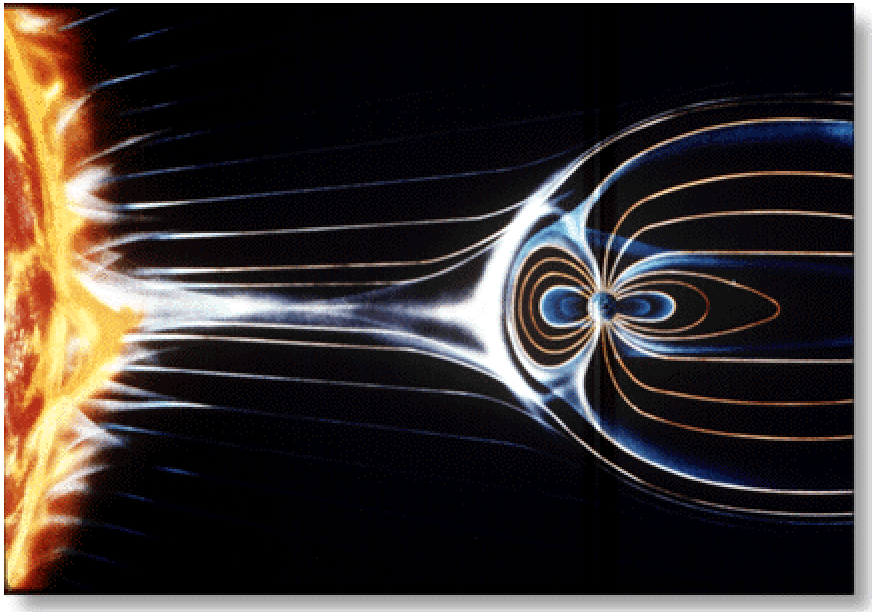
Disturbances travel to Earth



The Solar wind Reaches Earth

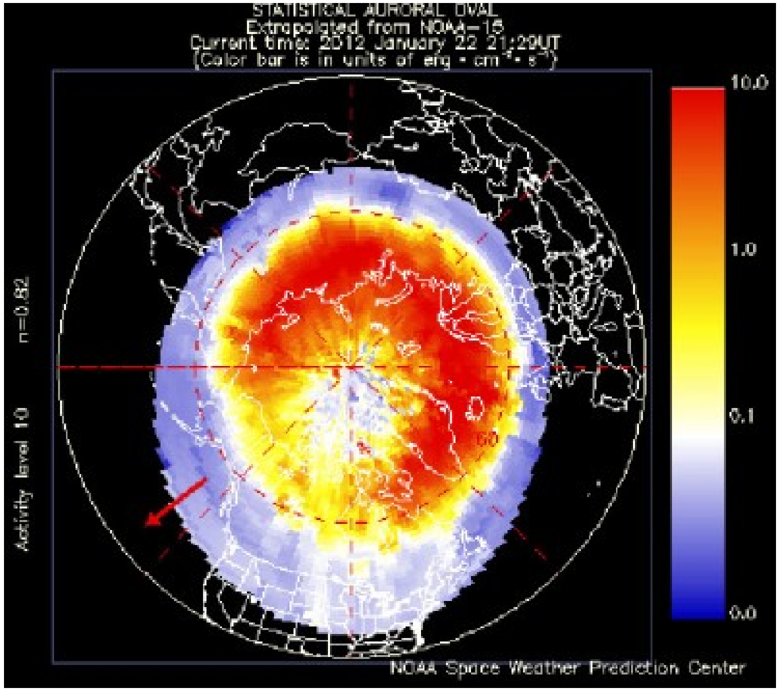
- The electromagnetic radiation is unaffected by the Earths magnetic field. It affects primarily the lower latitude regions

- The particles of the solar wind interacts with the magnetosphere. The effects are strong in the Arctic.



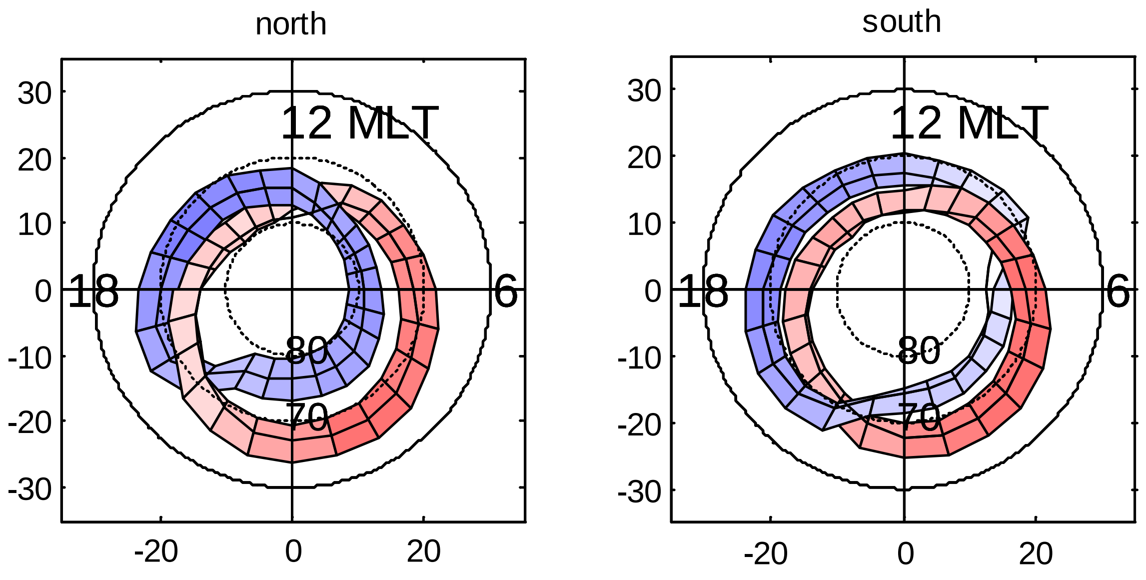
Effects in the Arctic – Ionosphere Density

- Impulsive energetic particles are dumped into the upper atmosphere creating enhanced ionisation and perturbations to the ionosphere
  - Disrupts HF communication
  - Affects GNSS accuracies



Effects in the Arctic – Electric Currents

- Impulsive currents are induced in the lower ionosphere (tens of kA)
  - currents are induce in the Earth's crust
  - .. and power grids
  - the magnetic field direction varies widely



The Space Weather Concerns

- The “normal” occurrence of Space Weather storms
  - Some aspects can be mitigated by proper design of technological systems
  - Other aspects needs warning:
    - Navigation
    - Communication
  - The challenge is to give high quality information on Space Weather conditions

- The Super Storm (Carrington)
  - August 28 to September 2, 1859 numerous sunspots and solar flares
  - September 1–2 the largest recorded geomagnetic storm with Aurorae around the world, even the Caribbean
  - Telegraph systems all over Europe and North America failed
  - This magnitude expected every 500 years, with events one-fifth as large, several times per century (1921 and 1960)

The Role of ESA for Arctic Space Weather

- Space infrastructure should ideally support:
  - Acquisition of data for development of needed models and predictive tools
  - Monitoring of Space Weather relevant parameters

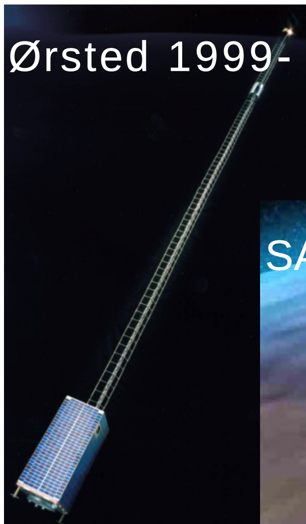
- The infrastructure could include
  - Observations (monitoring) of solar activity
  - Monitoring of the solar wind parameters (L1)
  - Low Earth Orbit satellites for monitoring of energetic particles and magnetic fields (ionospheric currents)

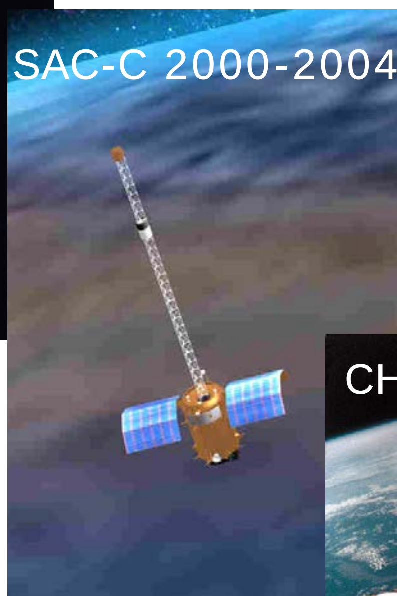
The Role of DTU Space

- DTU Space activities are coordinated in our Space Weather Center
  - We deploy and operate instruments in Denmark and Greenland
  - collect and calibrate measurements
  - develop models and data products
  - communicate with users, the research community, and the public

- The center builds on DTU Space expertise
  - Scientific
    - Solar wind and its interactions with the Earth's magnetic field
    - The interactions of the magnetosphere processes with the ionosphere
    - The Earth's geomagnetic field
  - Instrumentation
    - Magnetic field sensors on ground and in space
    - GPS technology and its use for ionospheric monitoring

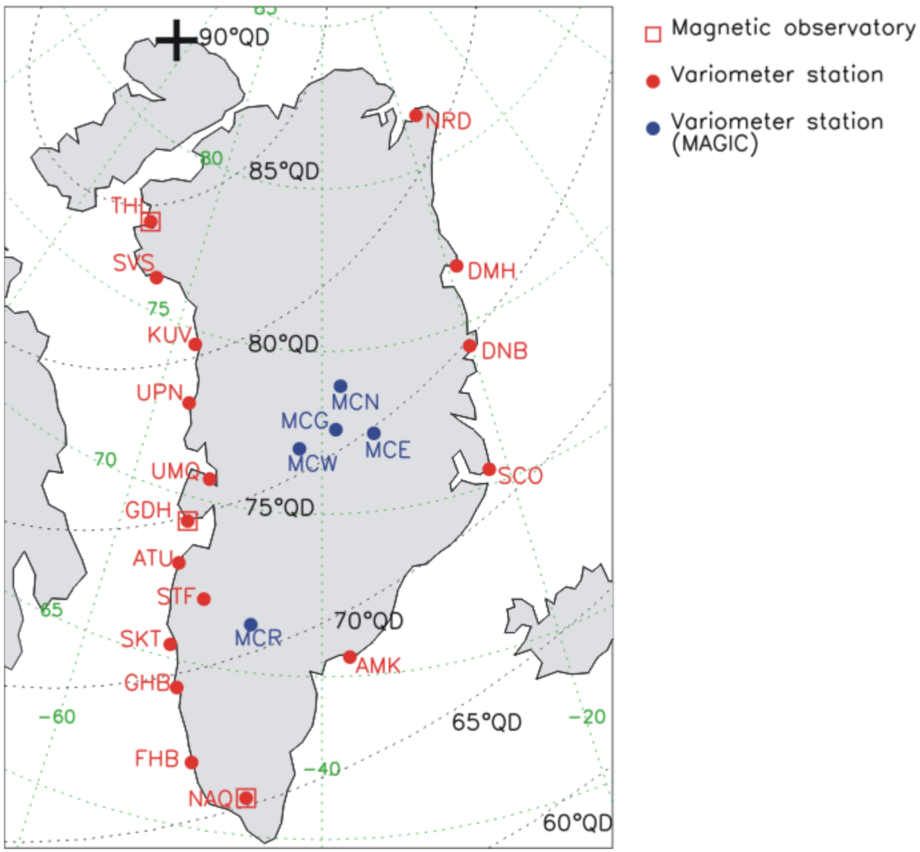
High-precision magnetometry missions with DTU Space instruments





Satellites are in low Earth, polar orbit providing accurate measurements of Space Weather magnetic perturbations (electric currents)

Ground observations



- GPS (ionosphere)
- Magnetometers (magnetic field fluctuations)