Space Weather and its Effects on the near-Earth Environment

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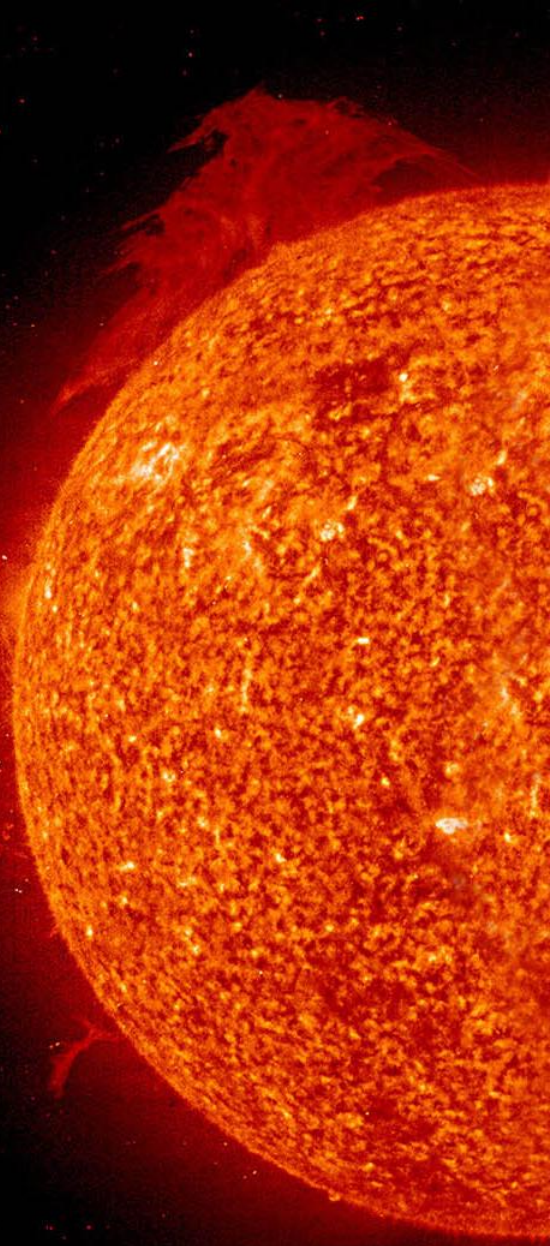

Space Weather

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."

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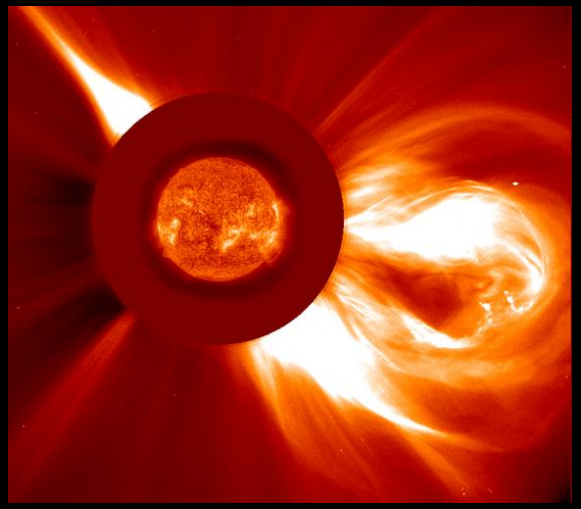
Space Weather

Space weather can affect us in a variety of ways:

- Particle effects on satellite systems
- Astronaut safety
- Induced currents in pipelines, electricity grids, etc
- Ionospheric variability
  - Affects radio systems that operate through or via the ionosphere
  - Effects most prevalent below 2 GHz



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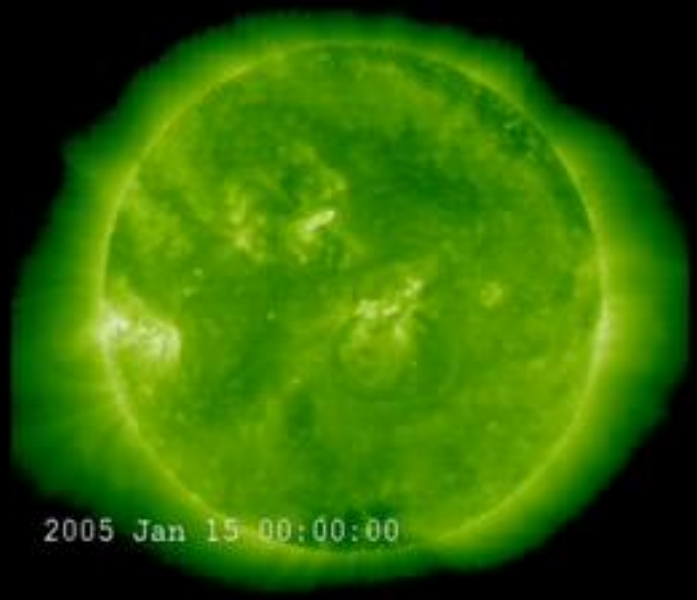
Solar Activity

- Solar cycle is ~11 years
- But there are longer “patterns”.
  - 87, 210, 2300 & 6000 year
- Sunspot numbers for the past 11,400 years have been estimated using dendrochronologically dated radiocarbon concentrations.



Extreme ultraviolet Imaging Telescope (EIT) instrument on SOHO
Credit: NASA / ESA

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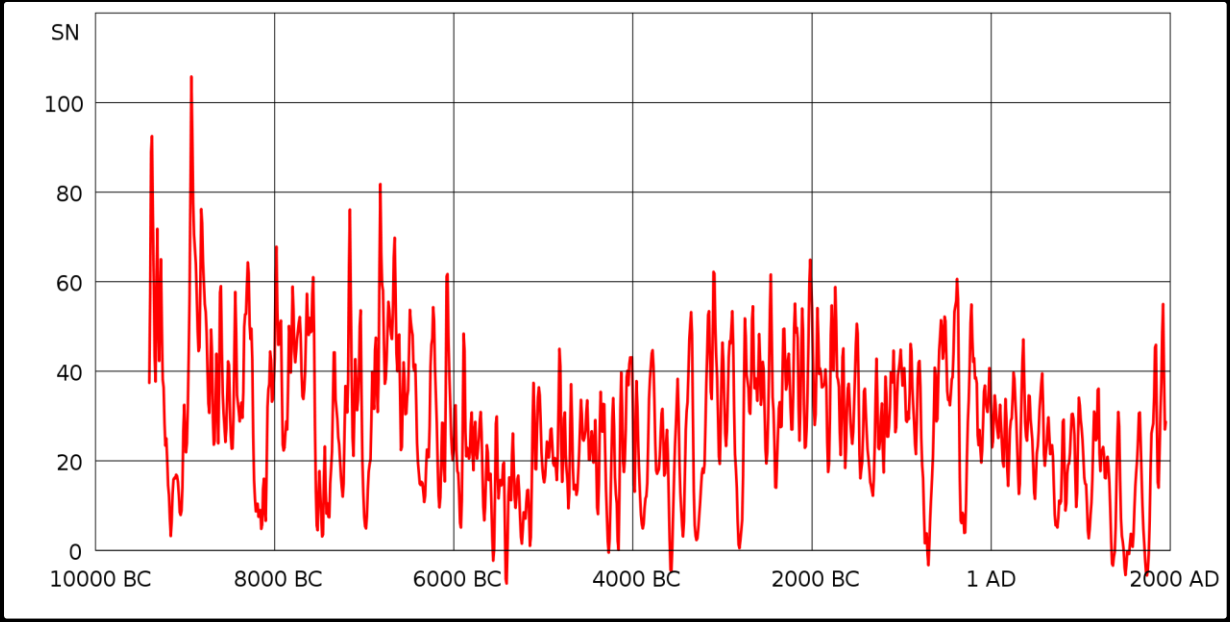
Sunspot Number

The past 70 years of solar activity have been abnormally high.

The last period of a similar magnitude occurred ~7 000 BC.

The Sun has been at a similar level of magnetic activity for ~10% of the last 11 400 years – and have usually been for a shorter period of time.



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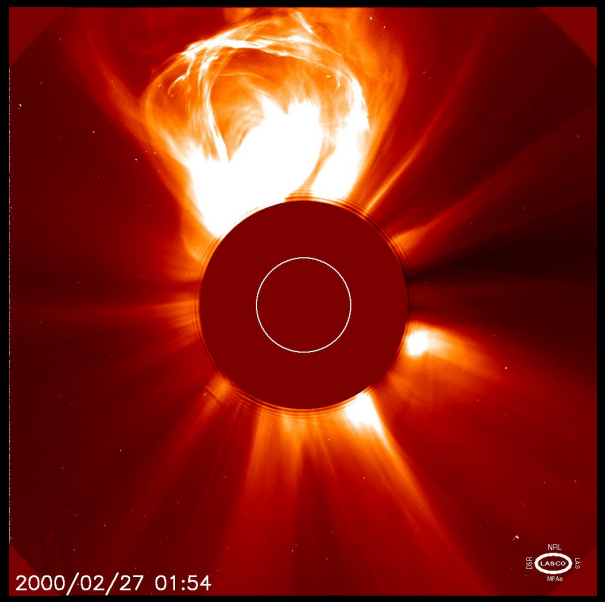
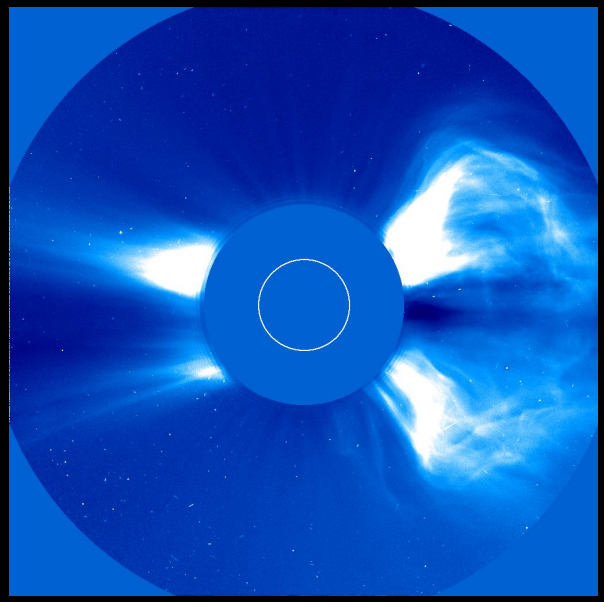
Solar Flares / Coronal Mass Ejection

Solar Flare – sudden, localized explosion on Sun's surface.

Coronal Mass Ejection (CME) – huge quantities of matter and EM radiation released from Sun's surface, mostly a plasma formed of electrons and protons.





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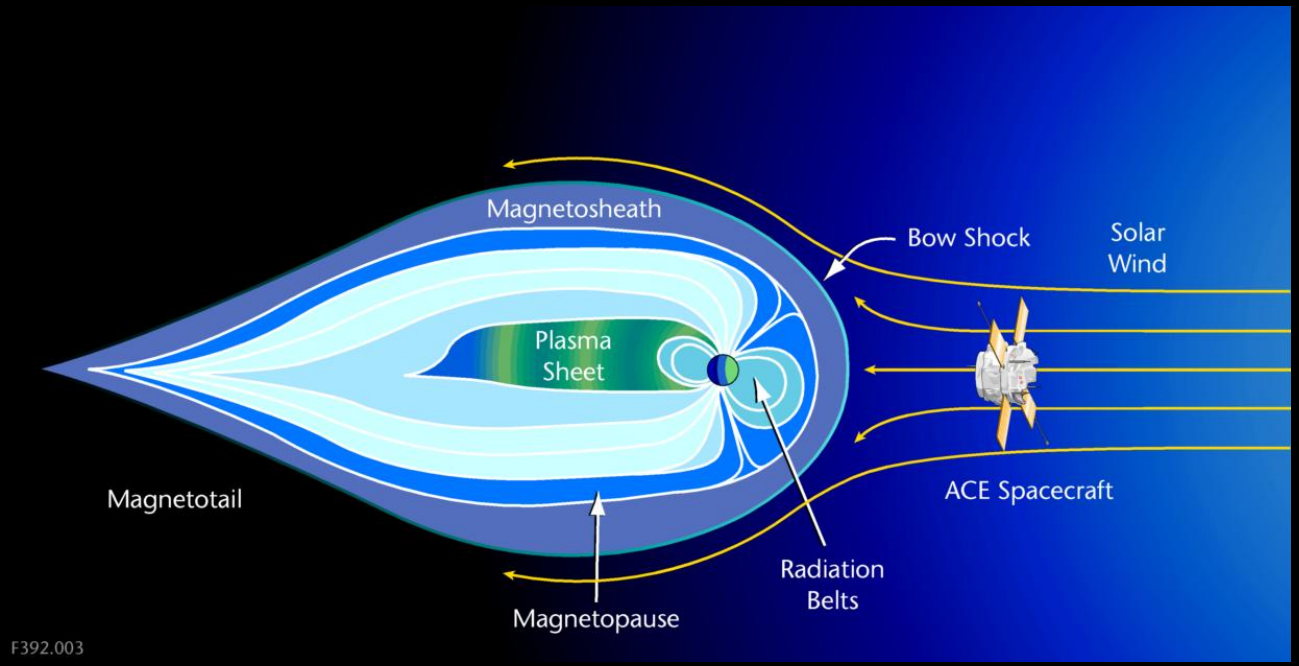
A 2D Magnetosphere



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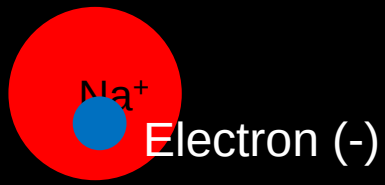
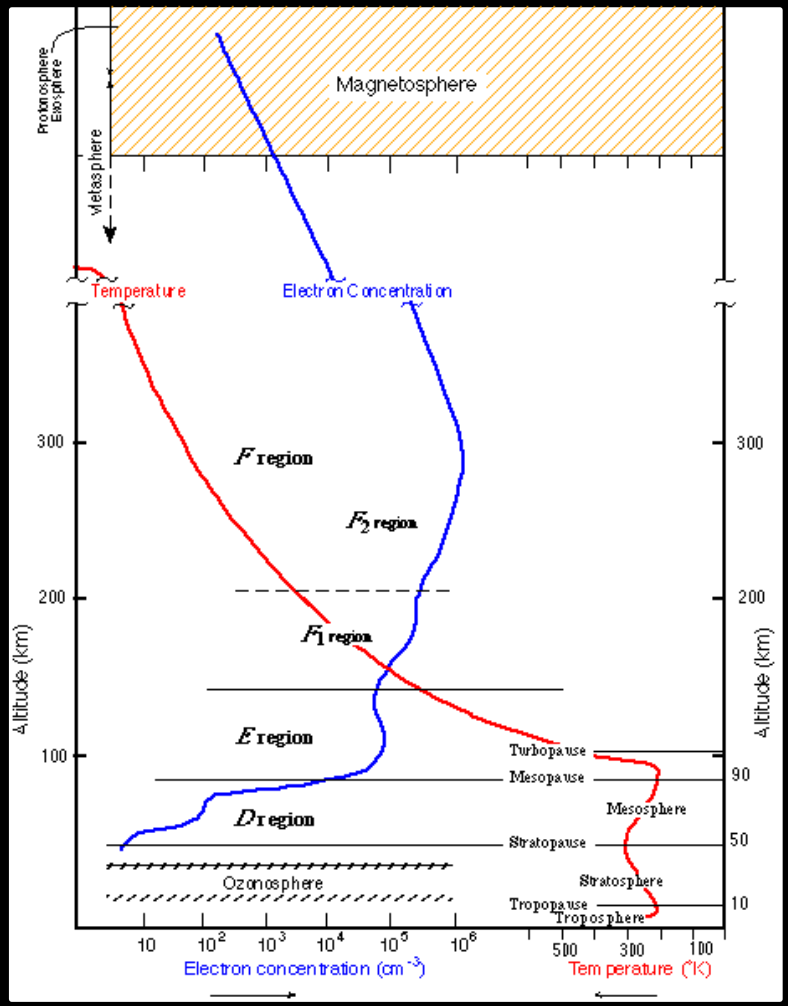
The Ionosphere

- The ionosphere is produced by the solar extreme UV radiation
- Results in layered ionosphere





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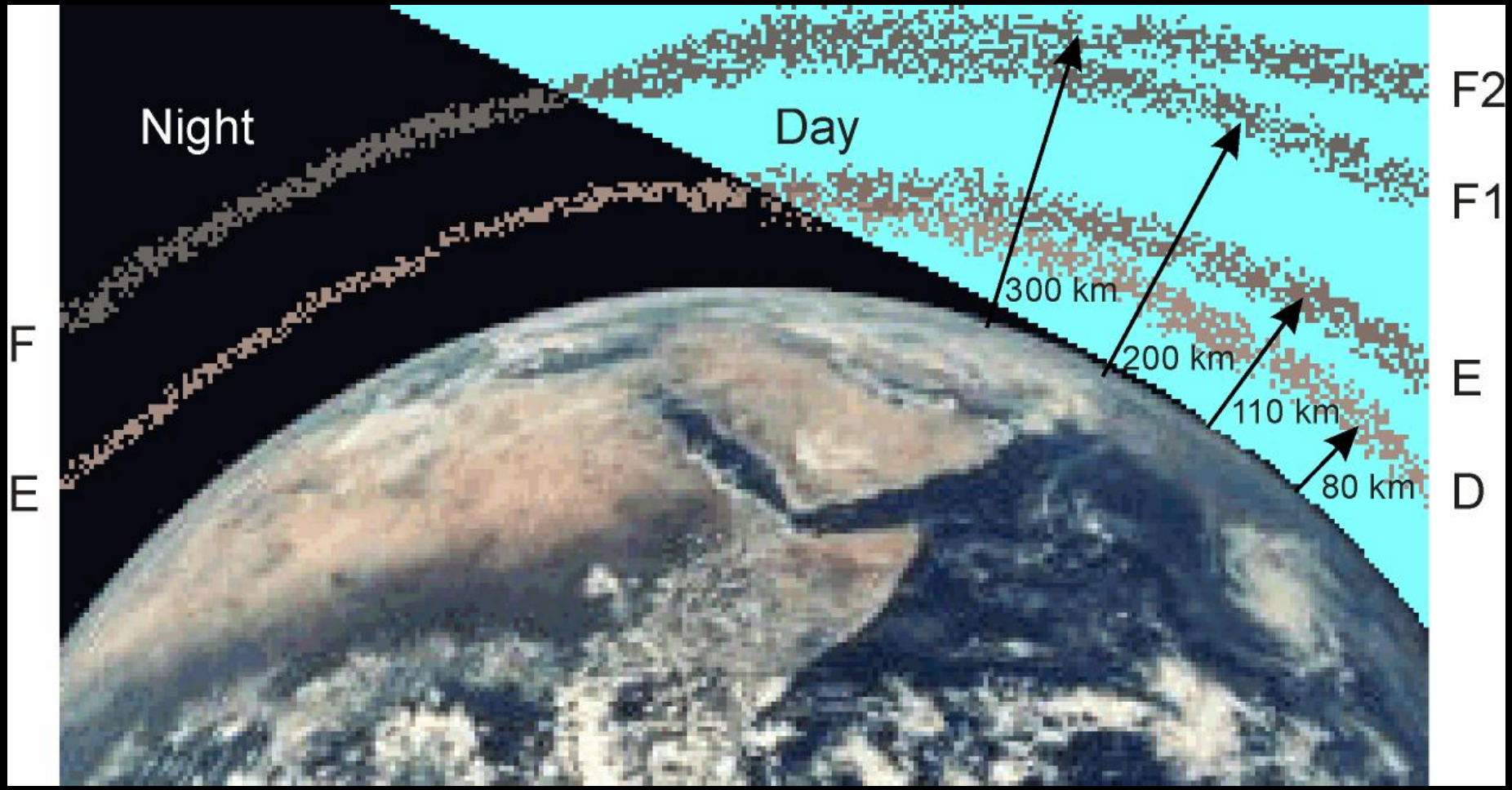
The Ionosphere



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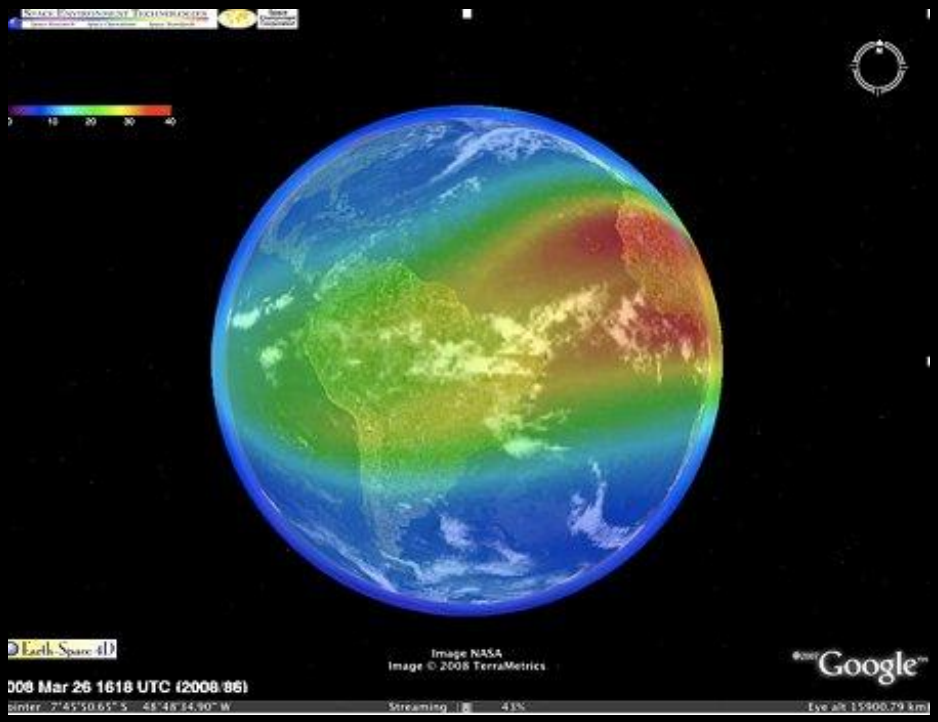
Total Electron Content (TEC)

This is the total number of electrons, along a path, between two points.

1 TEC Unit (TECU) is 10^16 electrons/m^2.



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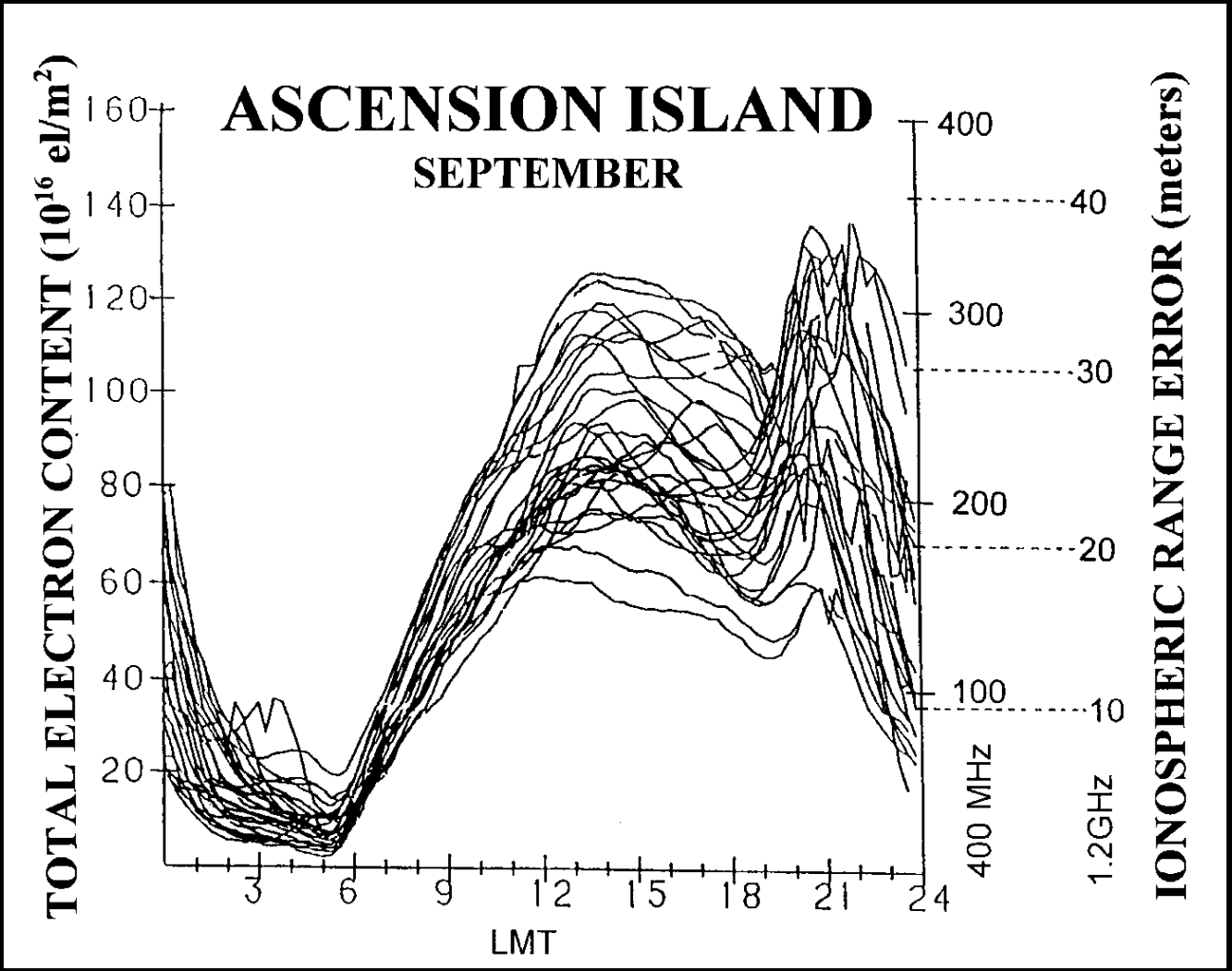
The Ionosphere – stable?



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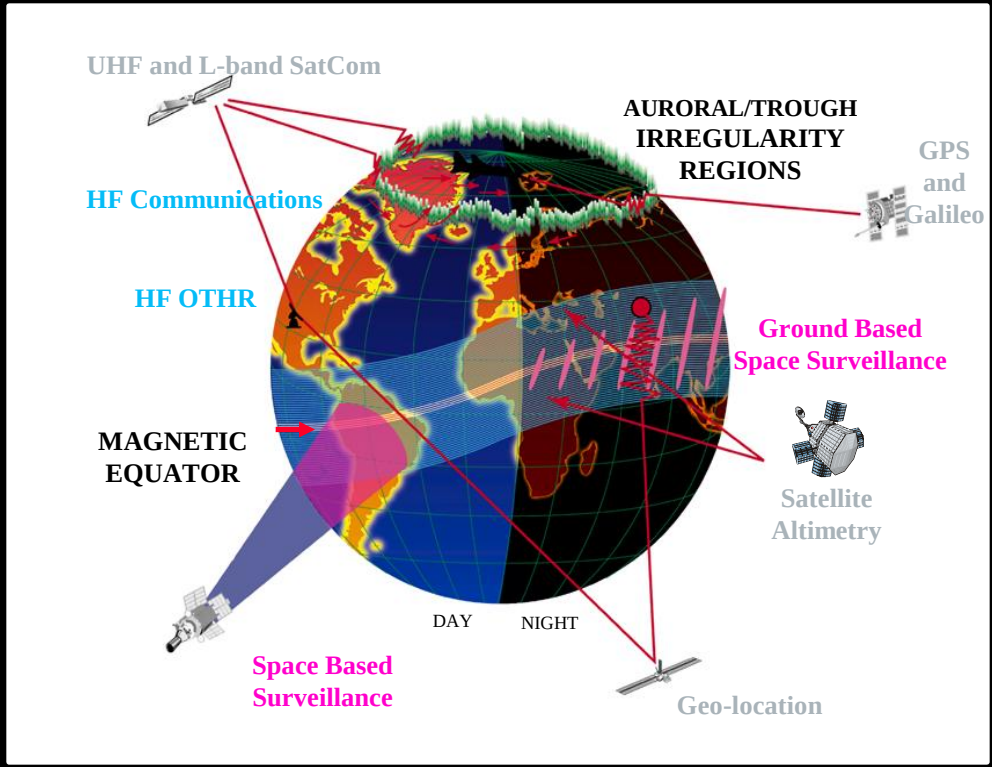
Effects on RF systems

The ionosphere can affect:

- Ground and space based trans-ionospheric sensors
  - Space track radar, space based radar (e.g. synthetic aperture radar)
- Global Navigation Satellite System (GNSS)
  - GPS, GLONASS, Galileo, etc.
- High Frequency (HF, 2-30MHz) radio systems (comms, radar, direction finding)
- UHF satellite communications systems



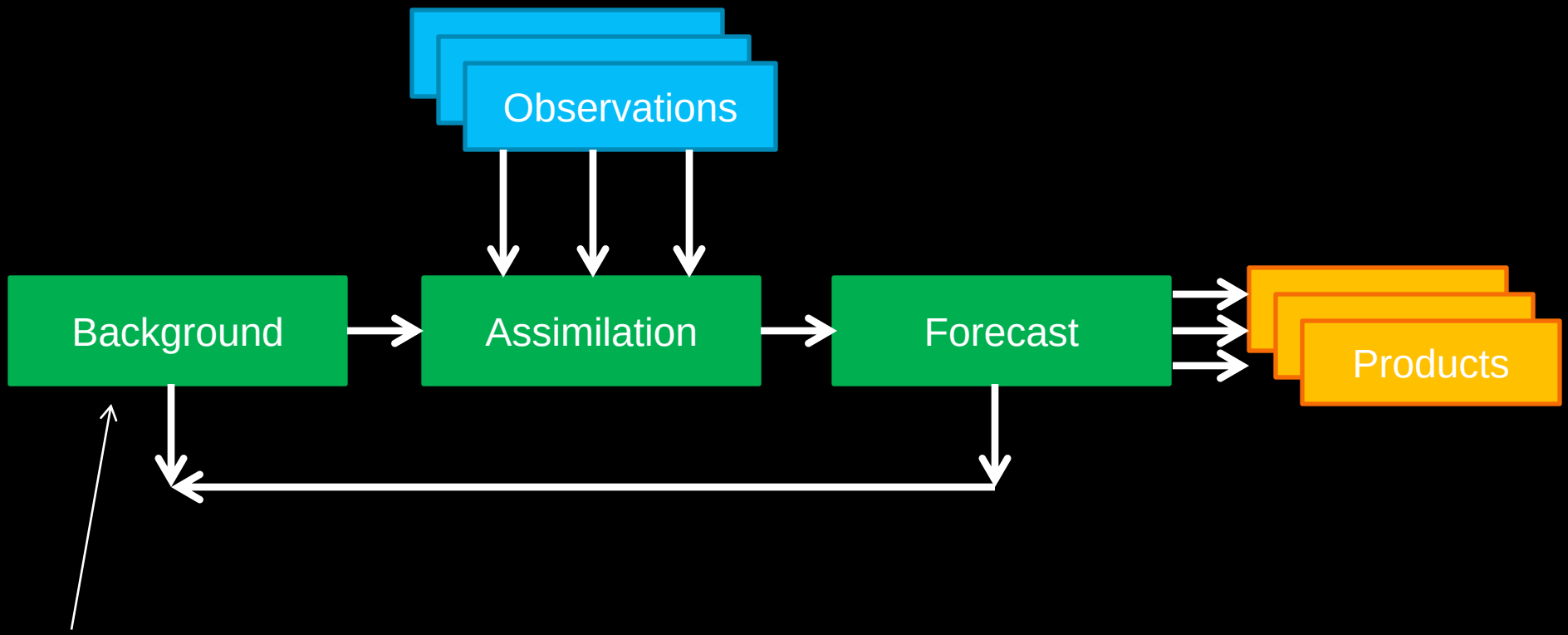
Ionospheric Modelling

Why develop it?

- To provide a high accuracy and timely specification of the ionosphere for use in RF systems
- Increased accuracy of ground and space based trans-ionospheric sensors
  - Space track radar, space based radar (SAR, AMTI/GMTI)
- Improved accuracy of navigation systems
  - GPS, Galileo

- Royal Academy of Engineering published report on the impact of extreme space weather this year (raeng.org.uk)

Data Assimilation



Starting point: can be either a climatological model or a physics based model

Electron Density Assimilation Model (EDAM)

- International Reference Ionosphere used for background model
  - Electrons only
- Designed to be scalable
  - Can assimilate single or multiple measurements
- Low demands on computer resources
- Simple evolution
  - Exponential decay of electron density grid differences

- Part of ESPAS (http://www.espas-fp7.eu/)

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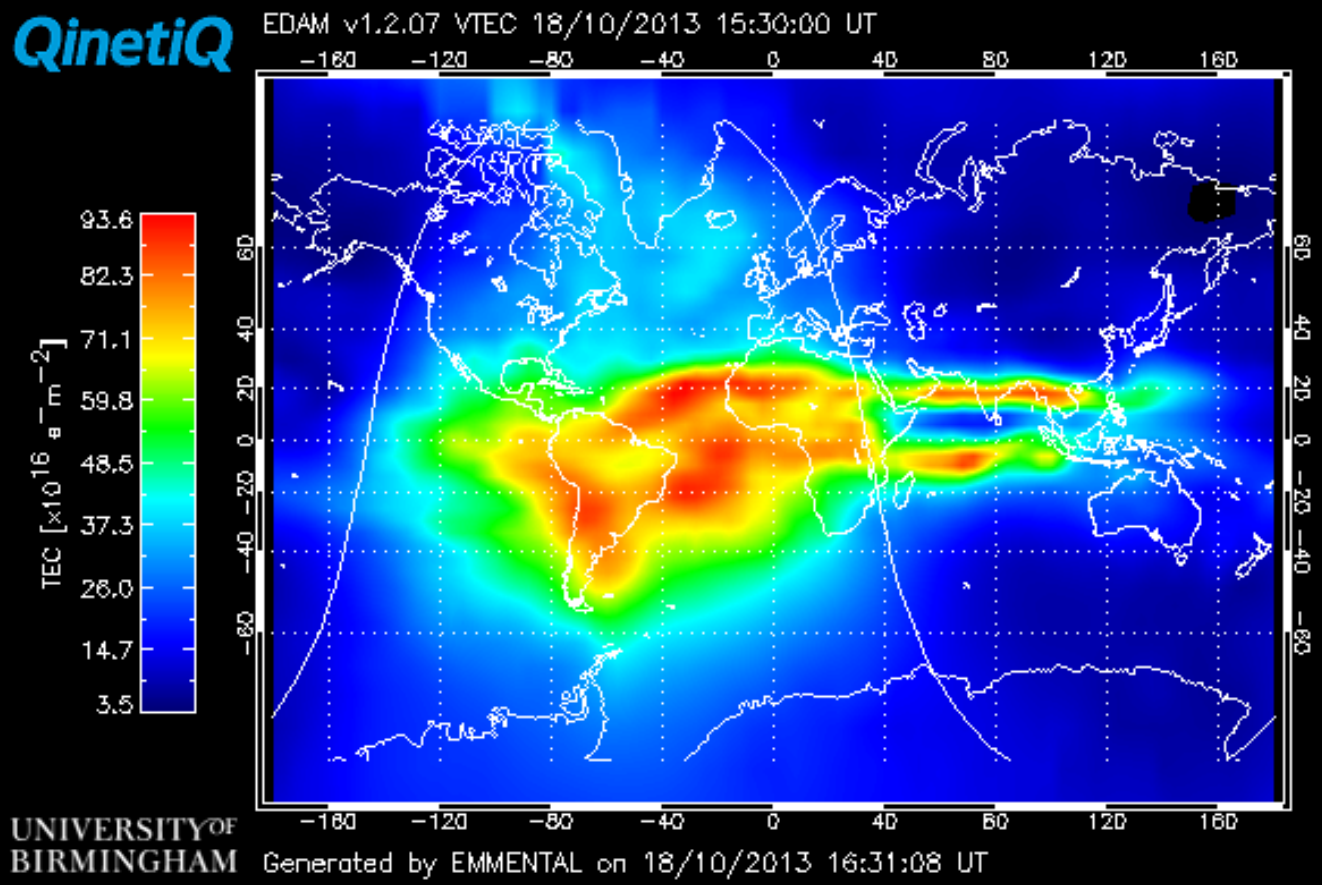
Recent EDAM Image



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Satellite Orbit Trajectories

- Satellites crucial to modern day society & defence.
- Atmospheric density a key component in orbital trajectory predictions.
- Altering by 80% diurnally and 2-3 orders of magnitude during geomagnetic storms.
- Kessler Syndrome potentially by 2030.

Image Credit: NASA

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Aurora

- aurora borealis [*sic*]

- Named after Roman goddess Aurora, and Greek name for the north wind, Boreas.

- Caused by atoms returning from an excited state to their ground state.

- Excited by solar activity.

Credit: NASA / ESA