Radiation belts in the Near-Earth Space Environment

nustem

Abstract

The Earth is surrounded by radiation belts within its magnetosphere. The belts, are hostile to satellites and other entities, such as space craft, causing damage. Predicting changes in the radiation belts, is advantageous to the longevity of spacecraft in the region.

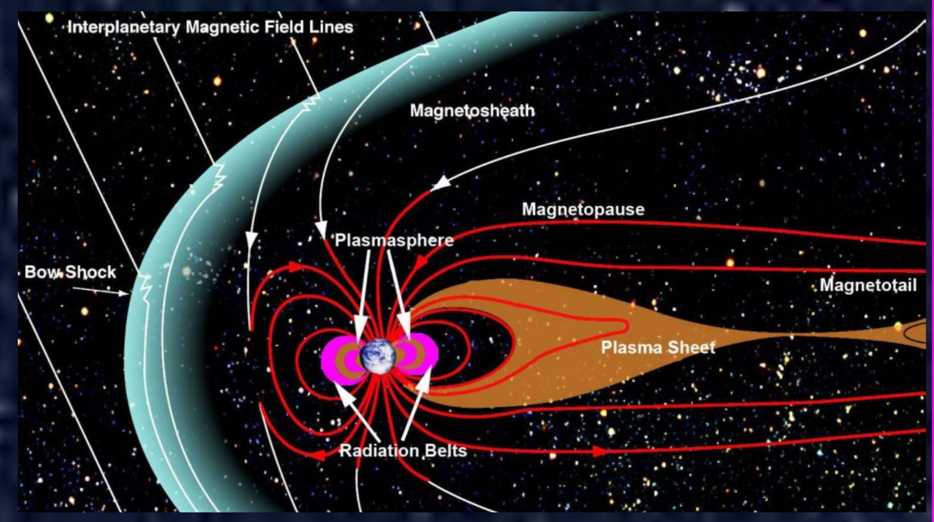

Fig.1 (2)-Diagram of the Earth's magnetosphere

General/ Background

The magnetosphere is the area of space, around the Earth, which is controlled by the Earth's magnetic field. The shape of the magnetosphere is caused directly by the solar winds. When the solar wind is enhanced- it can ' squash' the magnetosphere- causing a reduction in the placement of the plasmapause, causing plasma loss.

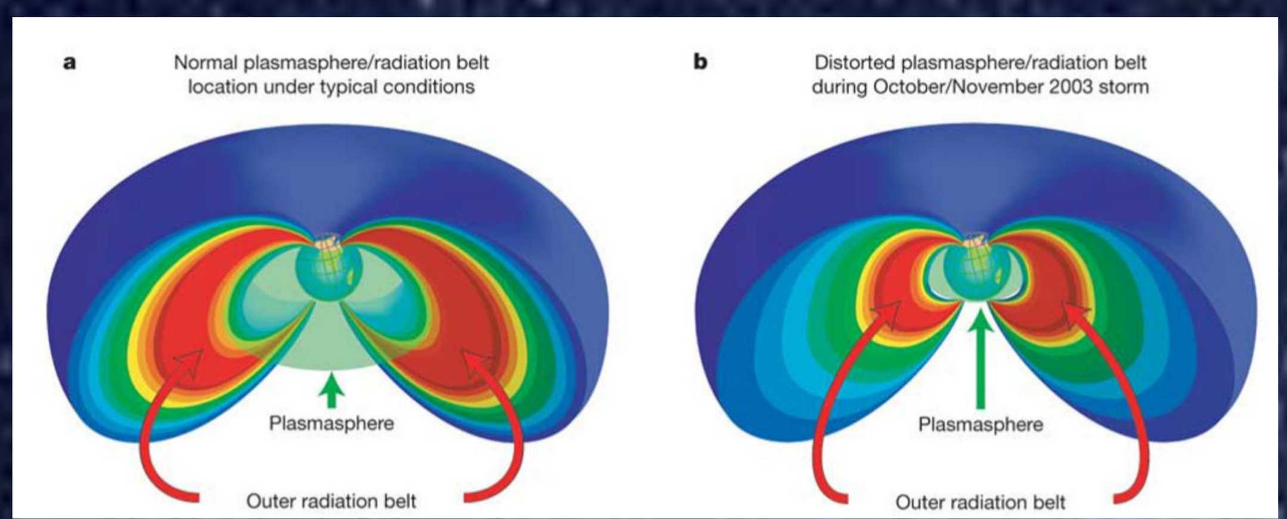

Fig.2 (3) . Graphic Showing the reduction in plasmasphere over the course of a solar storm

During a solar storm, energetic is removed in the same way as said above. The plasmasphere is then slowly refilled with plasma produced by ionosphere by photoionisation. The high energy plasma gradually decays and/or interacts with electromagnetic waves. Over time the magnetosphere returns back to its original state.

The Sun has an 11 year cycle called the solar cycle. It has periods of being 'quiet' to being at a solar maximum. This involves solar flares and coronal mass ejections which are bursts of solar wind.

Solar wind from the sun has its own magnetic field. When in proximity to the Earth's magnetosphere, the two fields interact and generate EM waves, which interacts with the plasma in the plasmasphere, energising it.

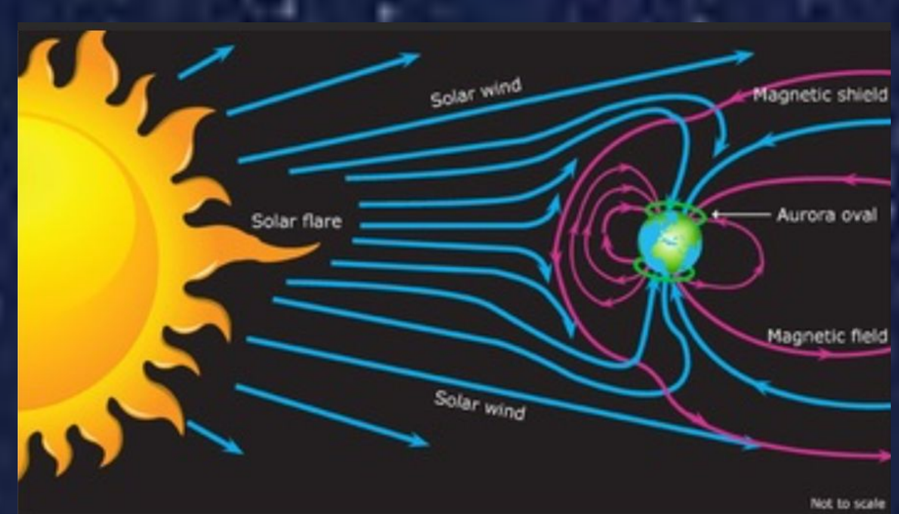

Fig.3 (4)- diagram showing solar flares interacting with Earth's magnetosphere

The excitation and acceleration of the electrons:

- electrons move into regions with a stronger magnetic field
- → the kinetic energies of these particles are increased
- → these particles are accelerated

- if the particles have a certain energy, they can interact with EM waves via resonant interations
- → This then transfers energy, causing excitation. Energy can also be transferred from the electrons to the waves, causing de-excitation
- → this causes the particles to be accelerated (or decellerated)

Method/ Results:

Two spacecrafts were launched in 2012 to understand the Van Allen radiation belts. They were designed to withstand the impacts of ultra-relativistic electrons, and stopped operating in 2019 as overtime they received gradual damage.

The van allen probes provided data on electron flux in the radiation belt during the November 2003 Solar storm. The data showed how the plasmapause moved much closer, reducing the size of the plasmasphere and displacing the plasma inside.

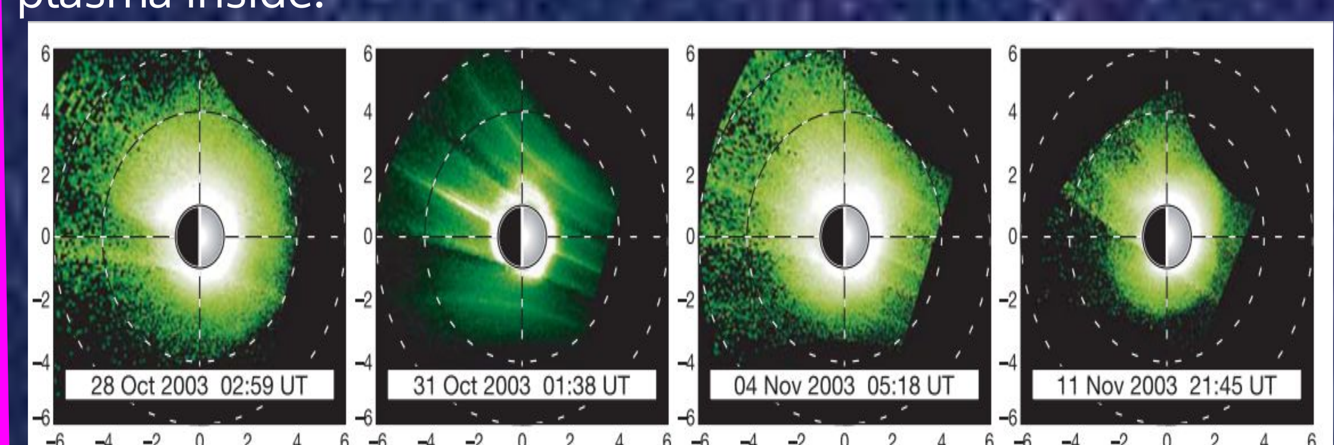

Fig.4 (3) - Diagram showing the change in the plasmasphere during the 2003 Halloween event

Discussion- why is it important?

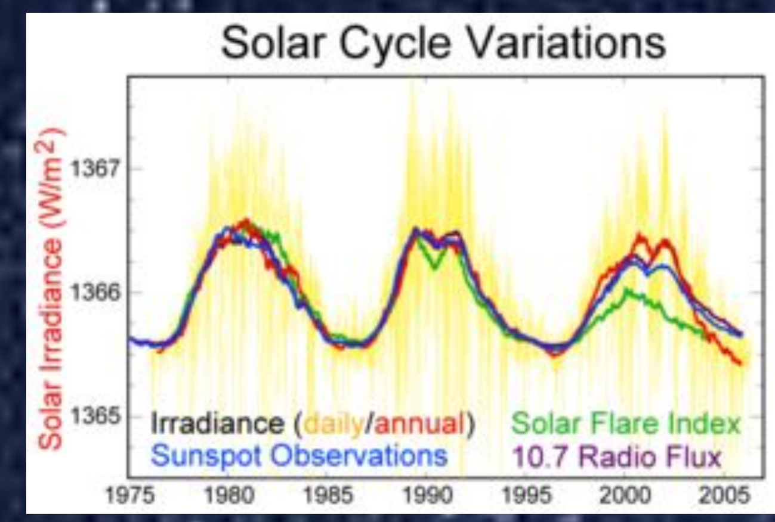

Fig 5 - Solar Cycle from 1975-2005

The radiation belts and the effects on them from solar flares and coronal mass ejections can cause dramatic impacts for here on the Earth's surface. Most impacts are due to space weather, this can cause large problems here on Earth. Some of these problems are:

Power grid/ supply- Geometrically induced currents- commonly associated with geometric storms- are likely to cause damage to physical infrastructure and introduce voltage instabilities that can lead to a black out as well as interfere with protection systems.

Communications- Mobile network performance can be affected by solar flare radio noise. Certain mobile networks may also be affected by loss of global navigation satellite system timing information.

Satellite infrastructure and systems-

Satellites are at risk from the space environment, energetic electrons trapped in the outer radiation belt cause electrostatic charging and discharging. This can damage sensitive electronic equipment and solar panels.

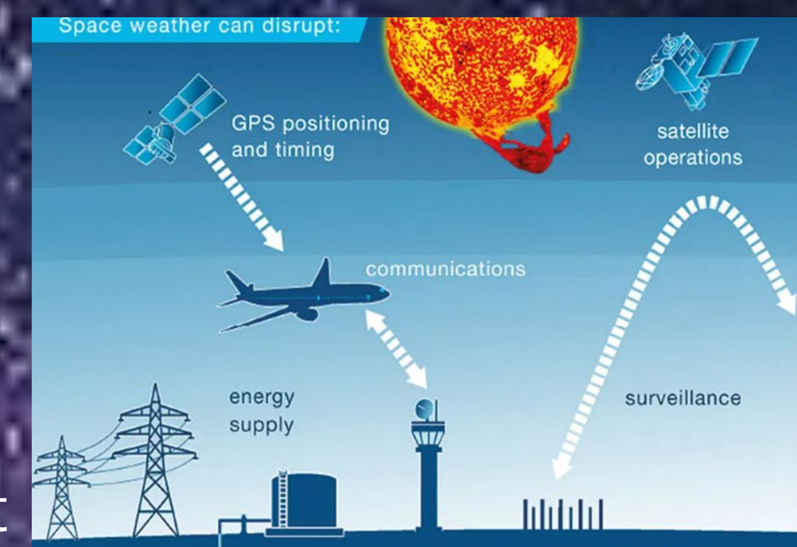

Fig.6(7)- infographic demonstrating the impact of solar weather on technology

The Carrington event- september 1859

This event is one of the largest on record. It consisted of a solar flare, a geometric storm and an energetic particle flux which made it so extreme. There were telegraph poles caught on fire due to the intense current hitting Earth. The probability of a Carrington like event occuring in the next decade for us is estimated to be 12%.

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