# SPACE WEATHER: An Overview

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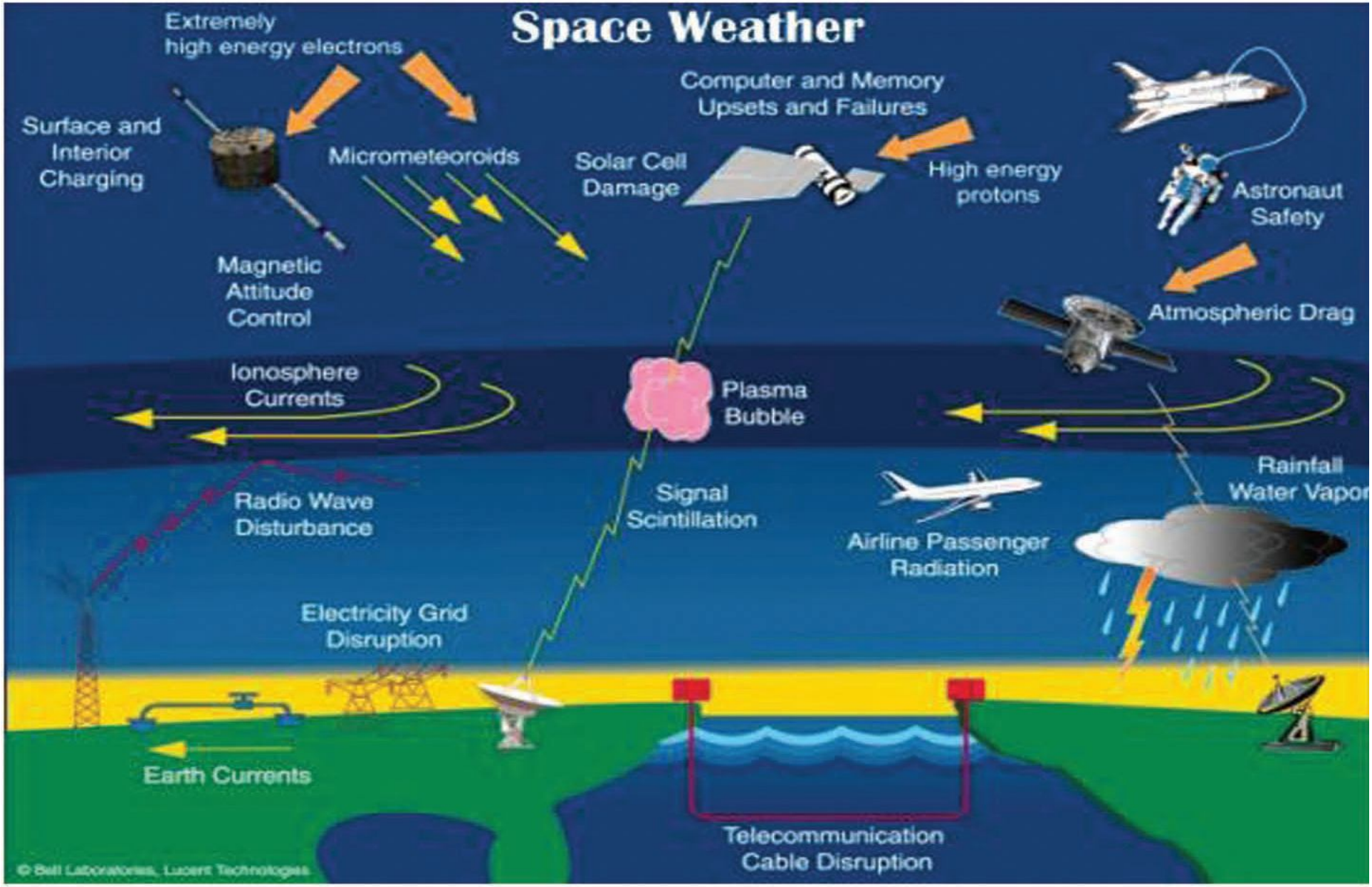
**Space** – a region above the Earth's atmosphere and all its constituents

The concept **"Space Weather" -** coined in 1994

**Earth's atmosphere viewed from space**

**SPACE WEATHER is the condition on the Sun, in the solar wind, in near-Earth space and in the upper atmosphere that can affect influence the performance and reliability of space-borne and ground-based technological systems, thereby affecting human life and endeavour.**

**Space Weather** is driven by **SOLAR ACTIVITY**

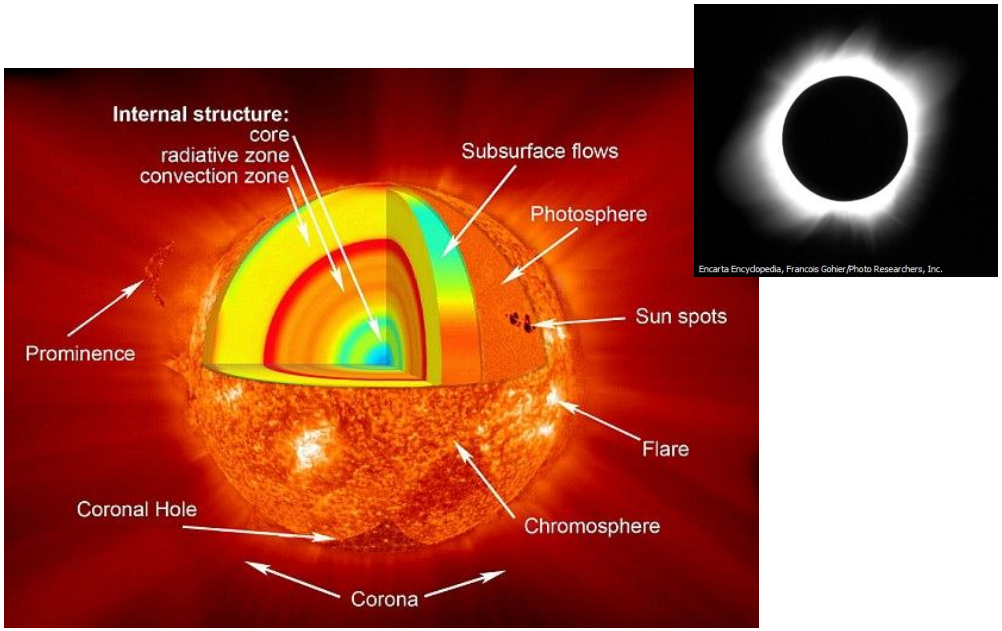



**Source**: University of Massachusetts Lowell – Centre for Atmospheric Research

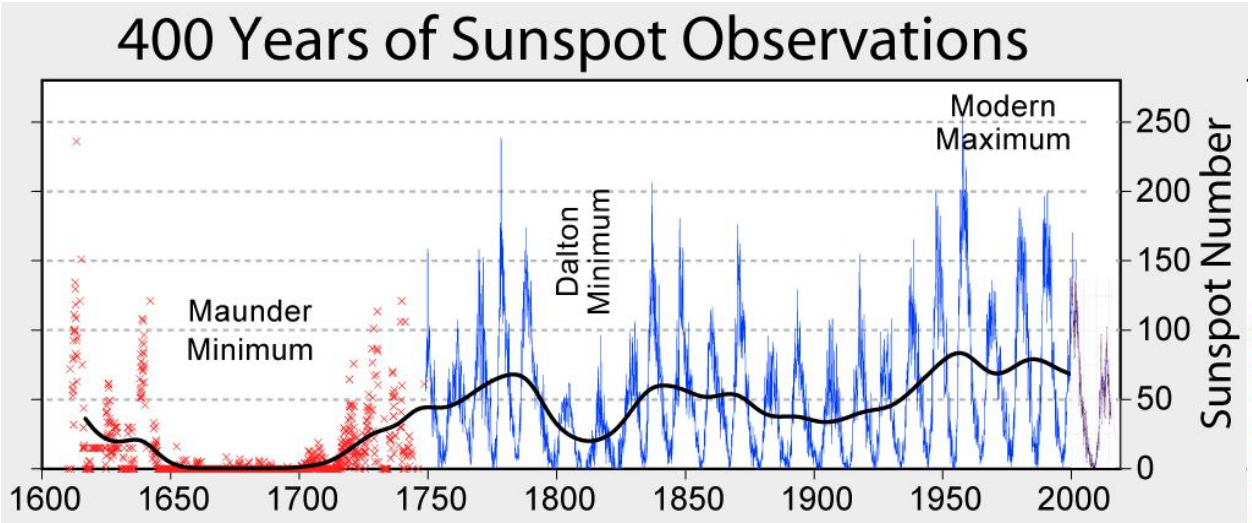
# THE SUN

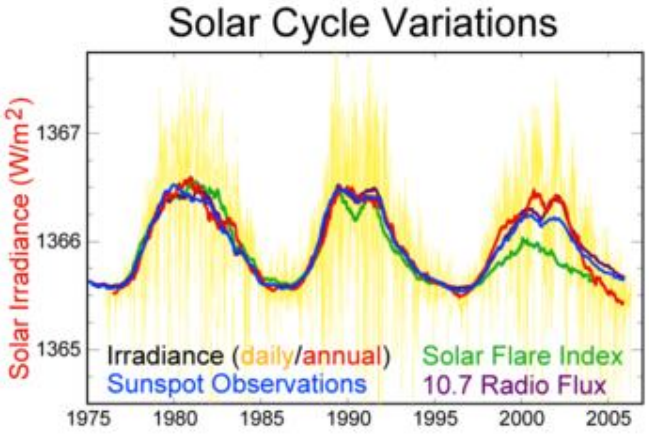
The Sun is an average star with a highly varying magnetic field.

- The Sun's diameter is about 1.4 x $10^6$ km.
- It is source of energy for all human activity.
- Temp. in the Sun's interior is 1.5 x $10^7$ K.
- Temperature at the surface is about 6000$^o$C

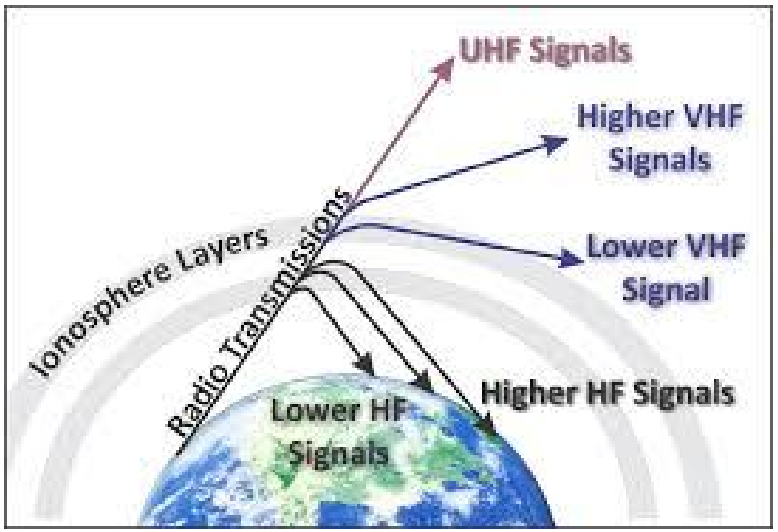



Some outer and inner structure of the Sun



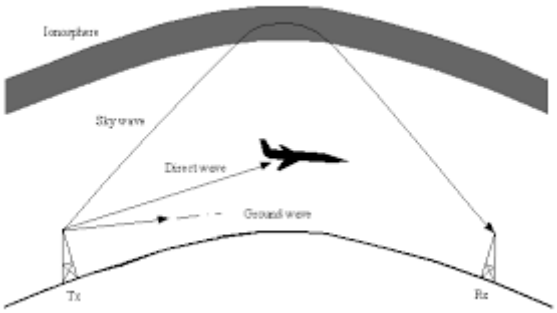



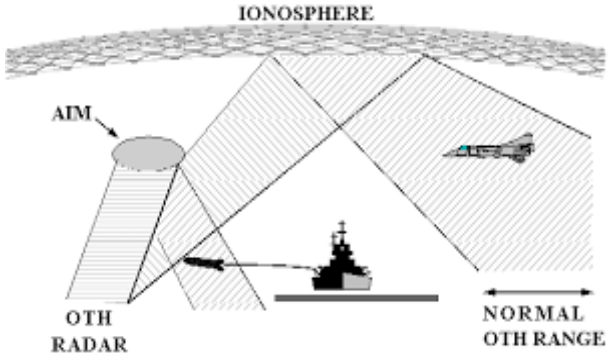
## •BENEVOLENT




**Long-distance radiowave communication**

- Territorial Security & Defence
- Emergency service
- Remote radio broadcast
- Aviation
- Maritime Operators



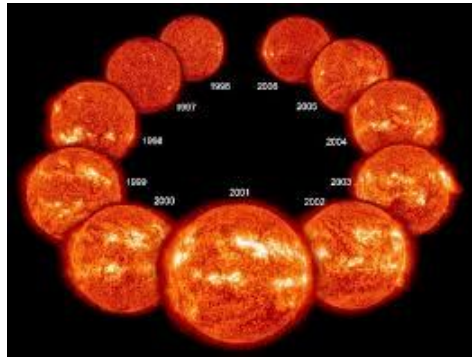

- **Human health and warmth**
- **Seasons** (Wind patterns, Precipitation, Insolation, Humidity)
- **Energy** (Biomass, Fossil, Wind, Tide)

# SOLAR ACTIVITY

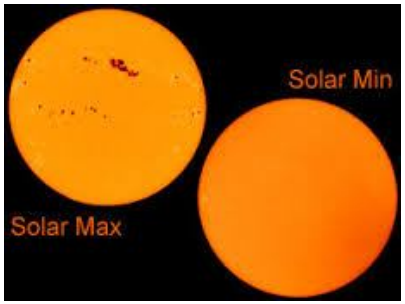
Solar activity (solar magnetic activity) is the activity of the Sun due to its varying magnetic field.

## Forms of solar activity

- **Solar Flare**
- **Coronal Mass Ejections (CME)**
- **High-speed solar wind**



SUNSPOT CYCLE

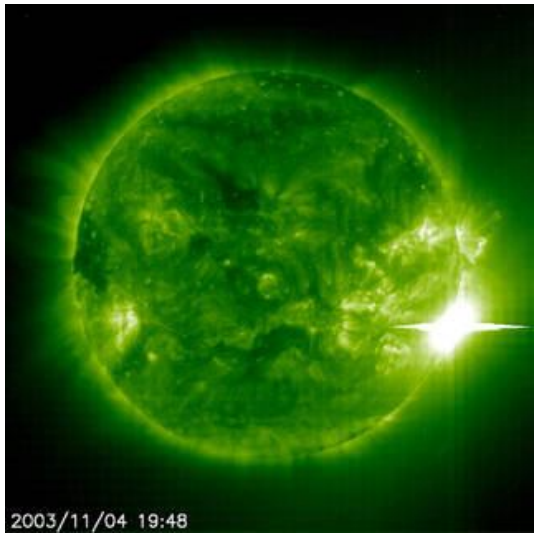



**These solar events influence the Earth (its magnetosphere, surface magnetic intensity, and atmosphere)*

# SOLAR FLARE

An intense/giant burst of radiation (radiowaves, x-rays, gamma rays) coming from the release of magnetic energy associated with sunspots.

- Flares can last from minutes to hours.
- It takes 8 minutes to reach Earth and the effect can last for days.




A flare on 4 November 2003. Captured by SOHO EUV imager (ESA&NASA/SOHO)

Flares may be accompanied by emission of electrons, protons, and heavier particles.

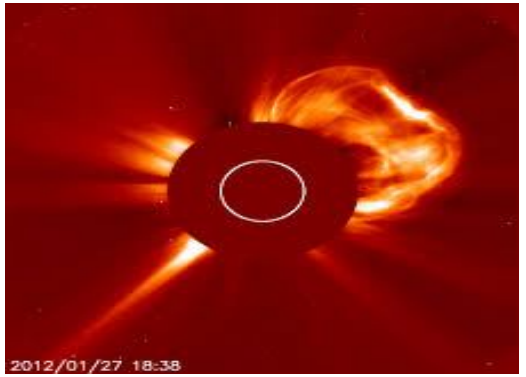
- **A** and **B**-class - $I < 10^{-6}$ W/m$^2$
- **C**-class - $10^{-6} \leq I < 10^{-5}$ W/m$^2$
- **M**-class - $10^{-5} \leq I < 10^{-4}$ W/m$^2$
- **X**-class - $I > 10^{-4}$ W/m$^2$

# CORONAL MASS EJECTION (CME)

This is a sudden and violent release of magnetized plasma (e.g. protons) from the Sun. CMEs occur when the sun's magnetic field forms a loop in the corona (the sun's atmosphere) and above the sunspot groups. Gases are then confined until they violently breaks the field and escapes into the interplanetary medium with a high velocity (400km/s).

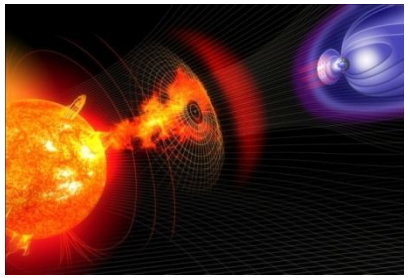
CMEs occuring with flares: "Eruptive events"
CMEs without flares: "Compact events"

CMEs can last for several hours, and the effect can last several hours to days.



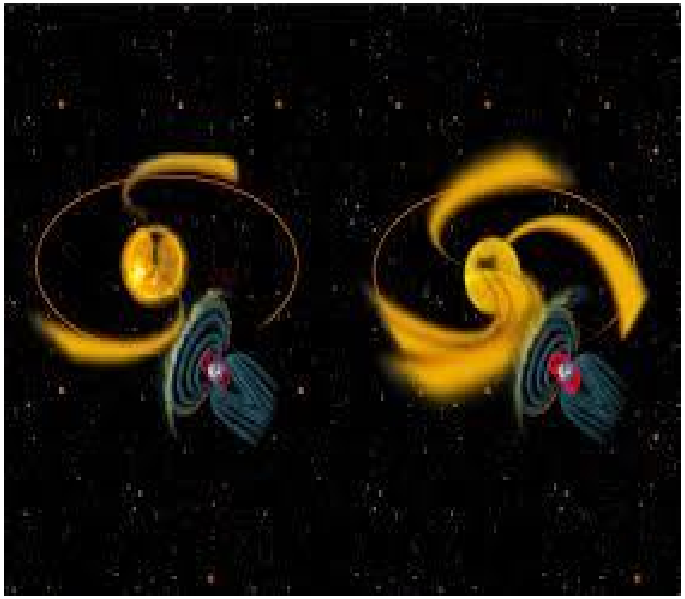


Source: *commons.wikimedia.org*



Source: *www.universetoday.com*

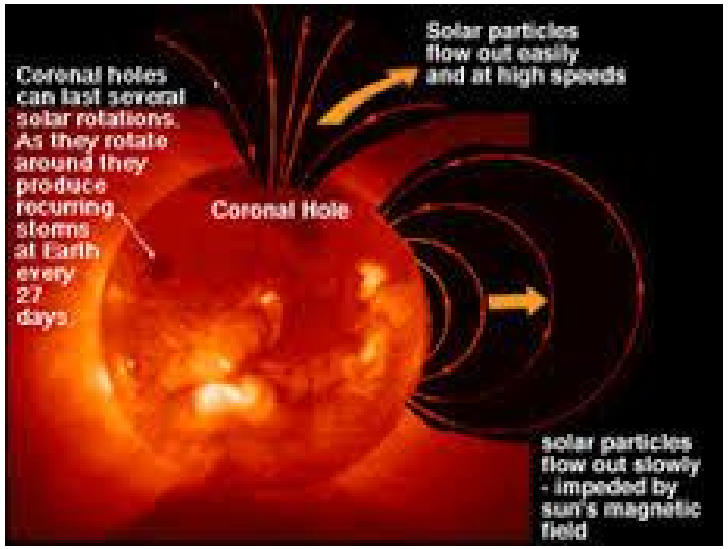
# HIGH SPEED STREAMS / CIRs



CIRs are formed due to high speed streams (or solar wind) from coronal holes pressing against slower ones from the quiet Sun.

CIRs are drivers of most weak and moderate storms that occurs during solar minimum

- Coronal holes are extended dark regions in the Sun's corona (best identified in X-ray images)
- They are regions of unipolar field
- Appears around the Sun's lower latitude during solar minimum and can last few solar rotation





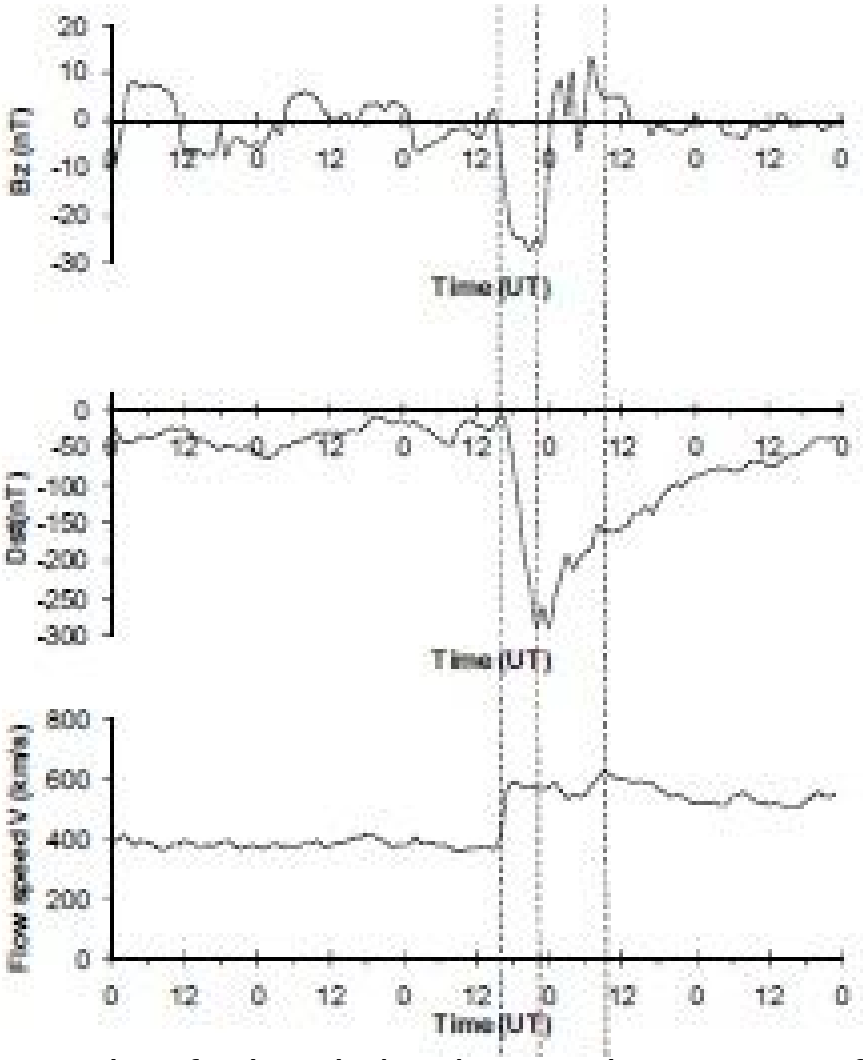

Coronal holes and active regions are seats of solar mass emission in the form of solar wind and CME

# CLASSES OF GEOMAGNETIC STORMS

| Geomagnetic conditions | K index | Ap index |
|---|---|---|
| Very Quiet | 0 | 0-2 |
| Quiet | 1 | 3-5 |
| Quiet | 2 | 6-11 |
| Unsettled | 3 | 12-21 |
| Active | 4 | 22-38 |
| Minor storm | 5 | 39-66 |
| Major storm | 6 | 67-110 |
| Severe storm | 7 | 111-178 |
| Very severe storm | 8 | 179-299 |
| Extreme storm | 9 | 300-400 |

**Dst index classification** (measured in nT)

- **peak Dst ≥ -30** (No disturbance)
- **-50 ≤ peak Dst < -30** (Weak)
- **-100 ≤ peak Dst <-50** (Moderate)
- **-250 ≤ peak Dst < -100** (Intense/strong)
- **-350 ≤ peak Dst < -250** (v. intense/ severe)
- **peak Dst < -350** (Great)

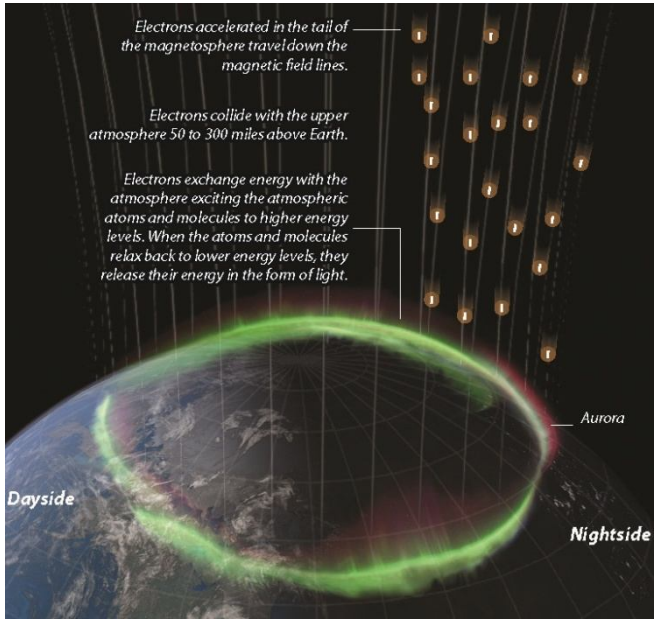



Plot of solar wind and magnetic parameters for 4-8 April,2000.

## Space Weather effects (cont'd)

**•FASCINATING**

- **Aurora -** *'aurora polaris'*
  - in the south 'Aurora Australis'
  - in the north 'Aurora Borealis'




http://sohodata.nascom.nasa.gov/cgi-bin/soho_movie_theater (SOHO movie theatre)

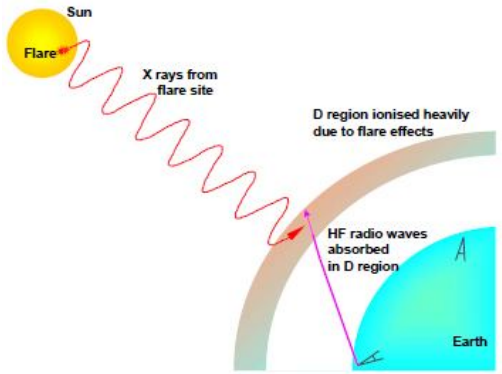
# Space Weather effects (cont'd)

## •MALEVOLENT

▪ Damaged transformer at Quebec, Canada (due to March 13, 1989 sever magnetic storm, around 0244 LT)
▪ Transmission lines
▪ Piplines

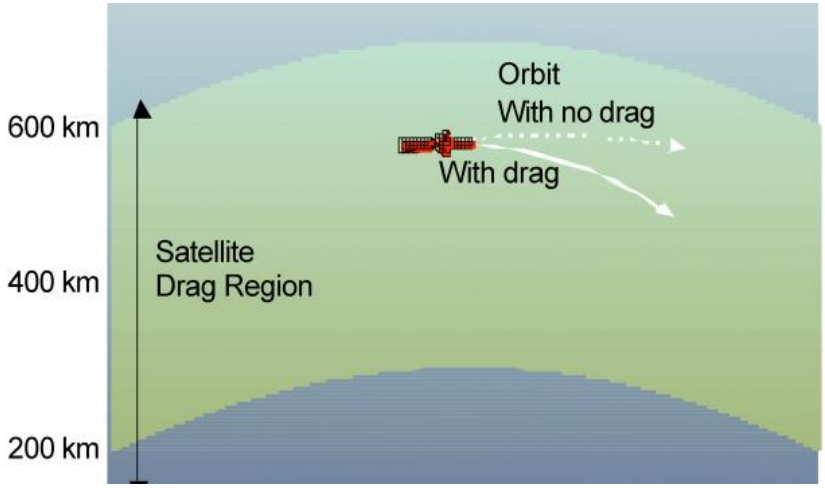
Damage to GPS satellite in geosynchronous orbit

Degraded performance of GPS receivers/ total loss of lock



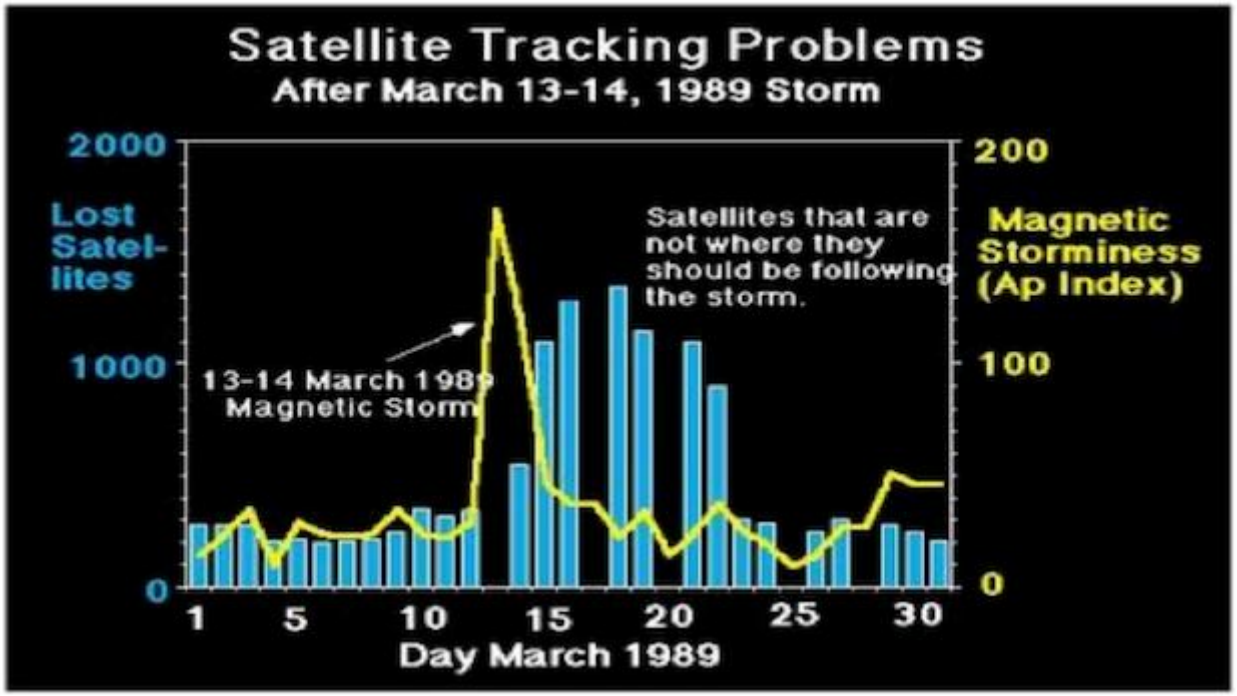

▪ Short Wave Fade-outs (SWF) (Radio wave attenuation due to intense D-layer ionization)
▪ Polar Cap Absorption

▪ An Astronaut in Space will be at risk during solar storm
▪ Passengers during flight in high latitude




Drag on satellite in the LEO

Noise/anomaly in geophysical survey data

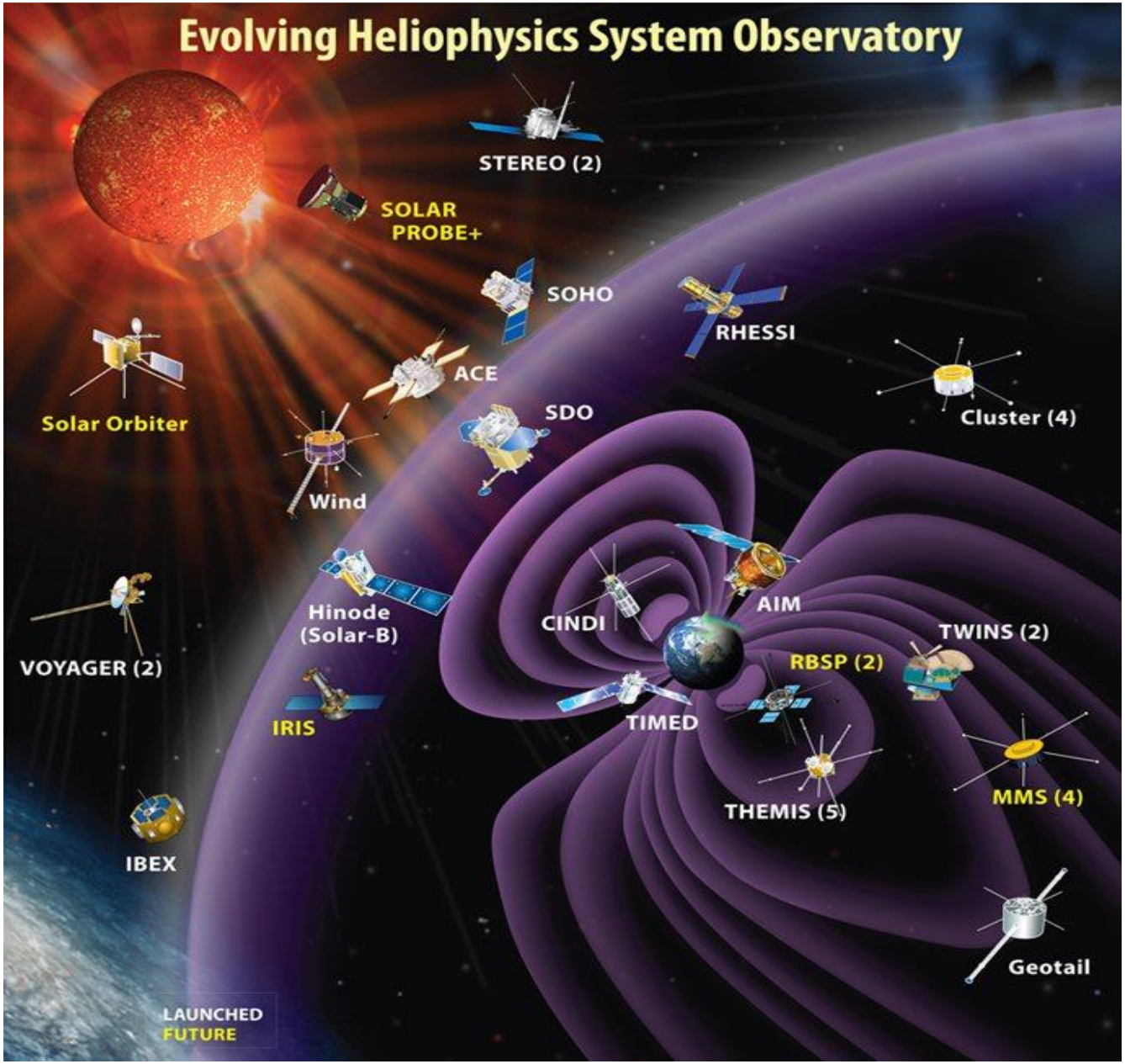




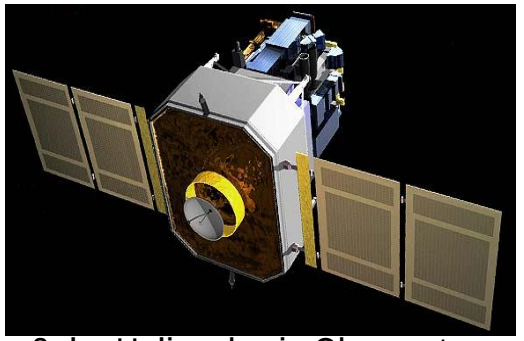
## PERCULIARITY OF SPACE-WEATHER EFFECTS

- **Variation in time scale**
- **Seasonal variation**
- **Geographical variation**
- **Solar cycle variation**

# SPACE WEATHER MONITORING



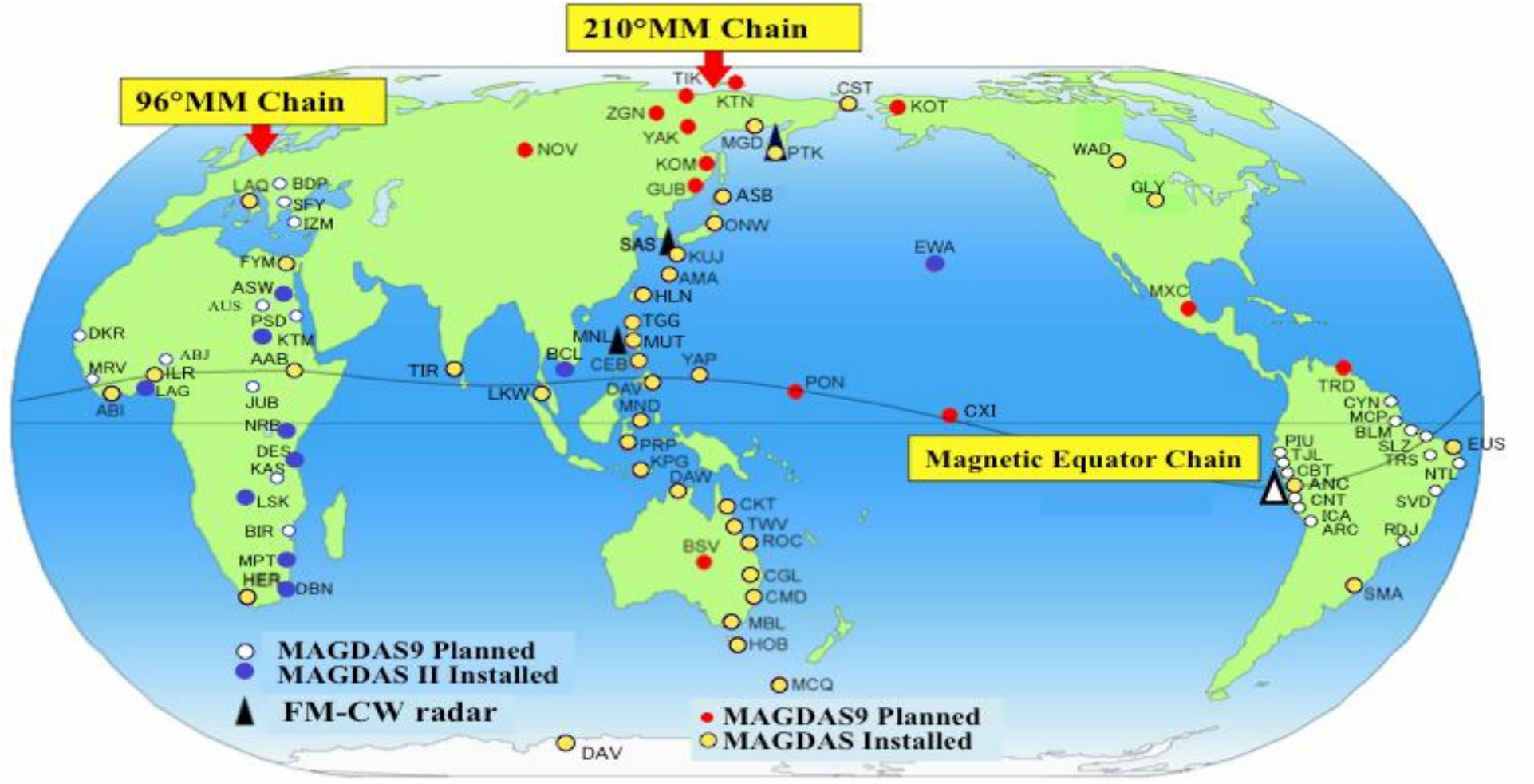

https://commons.wikimedia.org/wiki/File:Evolving_Heliophysics_System_Observatory.jpg (25th April 2016)



Solar Heliospheric Observatory (SOHO) (1995)

Advanced Composition Explorer (ACE) (1997)

Solar Dynamics Observatory (SDO) (2010)




**MAGDAS/CPMN (MAGnetic Data Acquisition System/Circum-pan Pacific Magnetometer Network).**
[Source: *YUMOTO and the MAGDAS/CPMN Group (2009)*]



Global distribution of digisondes (Global Ionospheric Radio Observatory - GIRO) as at February 2014 (The broken lines marks the magnetic EIA region) [Source: http://www.digisonde.com] (Accessed: March 22, 2014)

**Digisonde DPS (1993)**

# HOW IMPORTANT ?

Three Senators introduced legislation on 19th April 2016 to clarify federal agency responsibilities for space weather research and forecasting. Senators Gary Peters (D-MI), Cory Gardner (R-CO) and Cory Booker (D-NJ) introduced S. 2817, which allocates specific roles to NOAA, DOD, NASA, NSF and the Department of Homeland Security (DHS)…
**[UPDATE: The Senate Commerce committee announced it will mark up the bill on Wednesday, April 27.]**

- NOAA and DOD would provide operational space weather forecasts;
- NASA and NSF would conduct basic heliophysics research, develop next generation technologies, and transfer findings, data and models to operational forecasters;
- NOAA would immediately begin planning for back-up solar observations to prevent a single point of failure in the current satellite fleet (SOHO's age is of particular concern);
- the four agencies would begin planning for next-generation observations and science missions;
- the agencies would develop space weather benchmarks to characterize the nature, frequency, and intensity of expected space weather events; and
- the DHS would assess the vulnerability of critical infrastructure to space weather events.

http://www.spacepolicyonline.com/news/bipartisan-senate-bill-clarifies-space-weather-responsibilities-promotes-research (24Ap2016)

Space Research – comprising of fields such as Astronomy, Astrophysics, Heliophysics, Aeronomy, Ionospheric Physics, Magnetospheric Physics is becoming very important.

Our sensitivity to magnetic activities going on in the solar interior marked by its appearance is becoming more important. This is because our daily lives is increasingly dependent on technologies (space-based and ground-based), which are susceptible to Earth-directed solar events.

As well the exploration of our deep space for peaceful uses and better understanding of our planet and solar system is also dependent on our ability to predict space weather events.

Space weather events can cause HF radio blackout due to increased intensity of X-ray emission. It can destroy satellite electronics and cause electrical due to penetration of solar energetic particles (SEP), astronauts can also be exposed to lethal dose of radiation. Power grid operations can be stalled and accuracy of navigation systems degraded.

# THANK YOU

*for your*

# LISTENING ATTENTION

# at Leisure !!!

http://sohodata.nascom.nasa.gov/cgi-bin/soho_movie_theater (SOHO movie theatre)

http://www.swpc.noaa.gov/communities/space-weather-enthusiasts

## REFERENCES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http://scied.ucar.edu/sunspot-cycle (Accessed: 24th April 2016)

http://www.digisonde.com] (Accessed: March 22, 2014)