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## 1. Space Weather Impacts on Climate

All weather on Earth, from the surface of the planet out into space, begins with the Sun. Space weather and terrestrial weather (the weather we feel at the surface) are influenced by the small changes the Sun undergoes during its solar cycle.

The most important impact the Sun has on Earth is from the brightness or irradiance of the Sun itself. The Sun produces energy in the form of photons of light. The variability of the Sun's output is wavelength dependent. Sun is emitted in the visible wavelengths (approximately 400 – 800 nanometers (nm)). The output from the sun in these wavelengths is nearly constant and changes by only one part in a thousand (0.1%) over the course of the 11-year solar cycle. At Ultraviolet or UV wavelengths (120 – 400 nm), the solar irradiance variability is larger over the course of the solar cycle, with changes up to 15%. This has a significant impact on the absorption of energy by ozone and in the stratosphere and have impact on the climate of Earth.

There are other types of space weather that can impact the atmosphere. Energetic particles penetrate into the atmosphere and change the chemical constituents. These changes in minor species such as Nitrous Oxide (NO) can have long lasting consequences in the upper and middle atmosphere, it is possible have a major impact on the global climate of Earth.

The duration of solar minimum may also have an impact on Earth's climate. During solar minimum there is a maximum in the amount of Cosmic rays, high energy particles whose source is outside our Solar system, reaching earth. There is a theory that cosmic rays can create nucleation sites in the atmosphere which seed cloud formation and create cloudier conditions. If this were true, then there would be a significant impact on climate, which would be modulated by the 11-year solar cycle.

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## **2. Effects on Satellites and Spacecraft**

Increased radiation from the Sun and occurrence of geomagnetic storms (i.e. severe distortion of geomagnetic field of the Earth) may cause disturbances such as increases in density in the Earth's upper atmosphere. These result in a greater drag on the movement of satellites and spacecraft, causing a slow-down or even a change in orbit. Their useful life may also be reduced. Operators of these facilities are highly concerned because of these high operation and maintenance costs.

Charged particles from the Sun may strike the spacecraft and satellites and make direct physical damage to the equipment. Also, charge accumulation may occur on the electronics on board satellites and spacecraft, resulting in a build-up of the electric field. When an electrical discharge eventually happens, the electronics may be damaged, hence affecting the operation of the satellites and spacecraft.

In May of 1998, intense electron fluxes were released from the Sun. During that time, an American communication satellite, Galaxy-4, failed, leading to the suspension of paging service for 45 million people. It was believed that electrical discharge between electronic components onboard the satellite was the main cause of the failure.

## **3. Effects on human body**

The intense radiation from violent space weather can affect human DNA or cell replications. Astronauts in space, if not properly protected from the dangerous radiation, may be adversely affected. Flight at high altitudes may also result in a higher dose of radiation at the height of solar activity.

#### **4. Effects on Communication and Navigation Systems**

To enable long-distance communication, many telecommunication systems transmit radio signals via the ionosphere. Electromagnetic waves produced by solar flares may disturb the ionosphere and interfere with radio signals, resulting in degraded communication quality.

Maritime and aviation navigation systems use low frequency signals to locate vessels or aircraft. Intense solar activity may generate inaccuracy in information in these systems, causing errors in the positioning of vehicles.

#### **5. Effects on Electric Power and Pipelines**

Occurrence of geomagnetic storms (i.e. severe distortion of geomagnetic field of the Earth) can induce electric current in oil pipelines and electric cables. Flow meters may be affected, giving incorrect reading. The rate of corrosion of pipeline may also increase. The abnormal current induced in power grids may damage transformers because of overheating. During the great geomagnetic storm in 1989, transformer failures resulted in electricity suspension for 9 hours in Quebec (city in Canada).