Solar Flares and Space Weather

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Solar Flare

2012, July 12  X1.4 class flare

EUV 19.3 nm

Active Region (AR)

Magnetogram - magnetic map of the solar surface
A powerful solar flare radiates across the whole electromagnetic spectrum.
Solar Flare Class

X1.4 class: \( \text{flux}(0.1-0.8\text{nm})[\text{Wm}^{-2}] = 1.4 \times 10^{-4} \)
Quick quiz

What is the flare class if

$$\text{flux}(0.1-0.8\text{nm}) = 7.8 \times 10^{-5} \text{ Wm}^{-2}$$
Flare Characteristics

• The solar flares occur in active regions, with the strong magnetic field concentration.

• Time scales: few minutes to few hours.

• Energy released $\sim 10^{25} \text{ J}$

Annual World energy consumption $\sim 10^{20} \text{ J}$
Flare Characteristics

• Flares tend to occur in isolation, localized in space and time but with strong correlations.

• Typically one active region will produce dozens of flares, especially during periods of magnetic flux emergence (often near the beginning of the lifetime of a given region, but not always).
Solar flares have been monitored by x-ray detectors on GOES satellites since 1976. The number of X-Class flares per month increases with the number of sunspots but big flares can occur anytime sunspots are present.
September 4 – 6, 2017 flares

13.1 and 19.3 nm
Flares and Coronal Mass Ejections

Powerful flares are often accompanied by CMEs in the active regions.
Quick quiz

What do you think is causing solar flare?
Physical Mechanism behind the Solar Flares

Magnetic Reconnection – the release of free magnetic energy, transformed to heat and particle acceleration

Active Region with simple magnetic configuration

Active Region with complex magnetic configuration
Flare: Space Weather impacts

Affect radio communications, GPS, directly by its radio noises at different wavelengths
Flare: Space Weather impacts - cont.

• Cause **disruptions/radio blackout** through changing the structures/composition of the ionosphere (sudden ionospheric disturbances) – X-ray and EUV emissions
Flare: Space Weather impacts - cont.

X-ray and EUV energy deposition would cause heating of the atmosphere and it’s expansion enhancing drag forces to low orbit satellites – ISS descends more than ~ 300 m/day when this happens.
Flare: Space Weather impacts - cont.

Energy in the form of hard x-rays can be damaging to spacecraft electronics.
Flare: Space Weather impacts - cont.

Contribute to Solar Energetic Particles (SEP) – proton radiation

The interplanetary space permeated with Sun’s magnetic field. Accelerated charged particles move along the interplanetary magnetic field lines and can reach planet or satellite if the active region is properly connected.
SEPs can impact the Earth’s magnetosphere and present radiation hazards for astronauts and spacecraft.

A measureable effect in a circuit caused by single incident ion with $E > 10$ MeV
The END.