Space Weather and Its Impacts on Technological Systems

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Space Weather Definitions

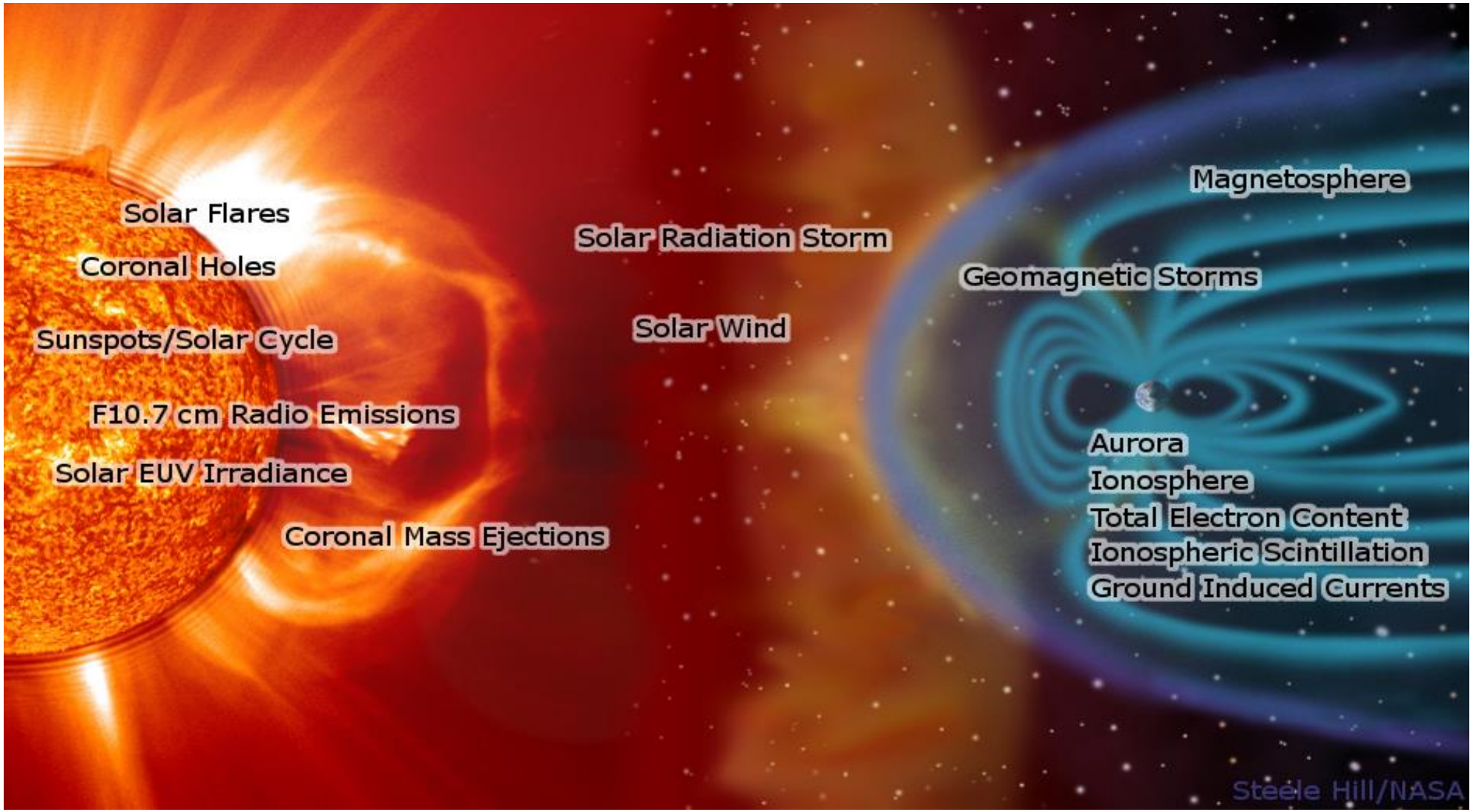
Broadly and specifically defined in several sources; and in general terms it refers to

What is happening in Space and how it influences space-based technology and societal applications that we rely on in our daily lives.

Textbook Reference: *An Introduction to Space Weather* by Prof Mark Moldwin (University of Michigan, USA

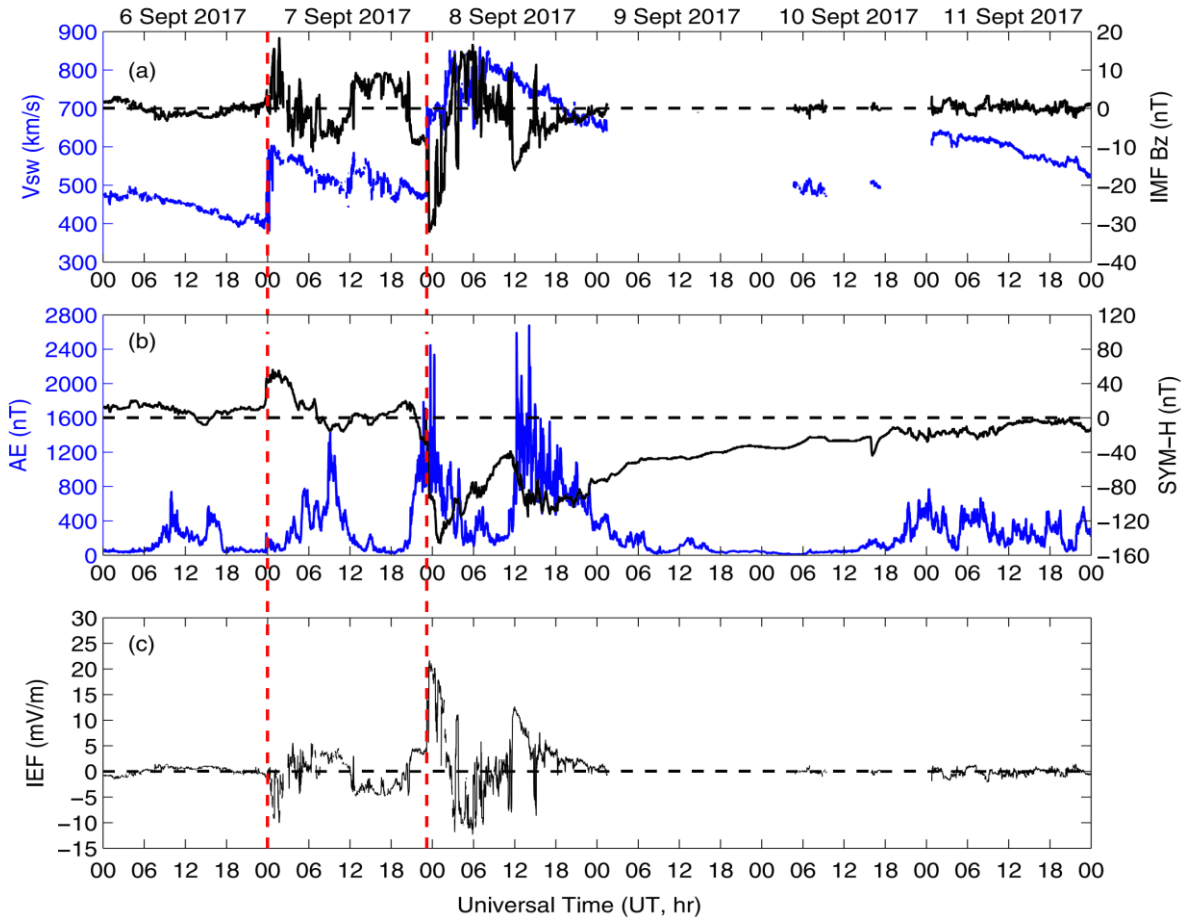
Space Weather Phenomena

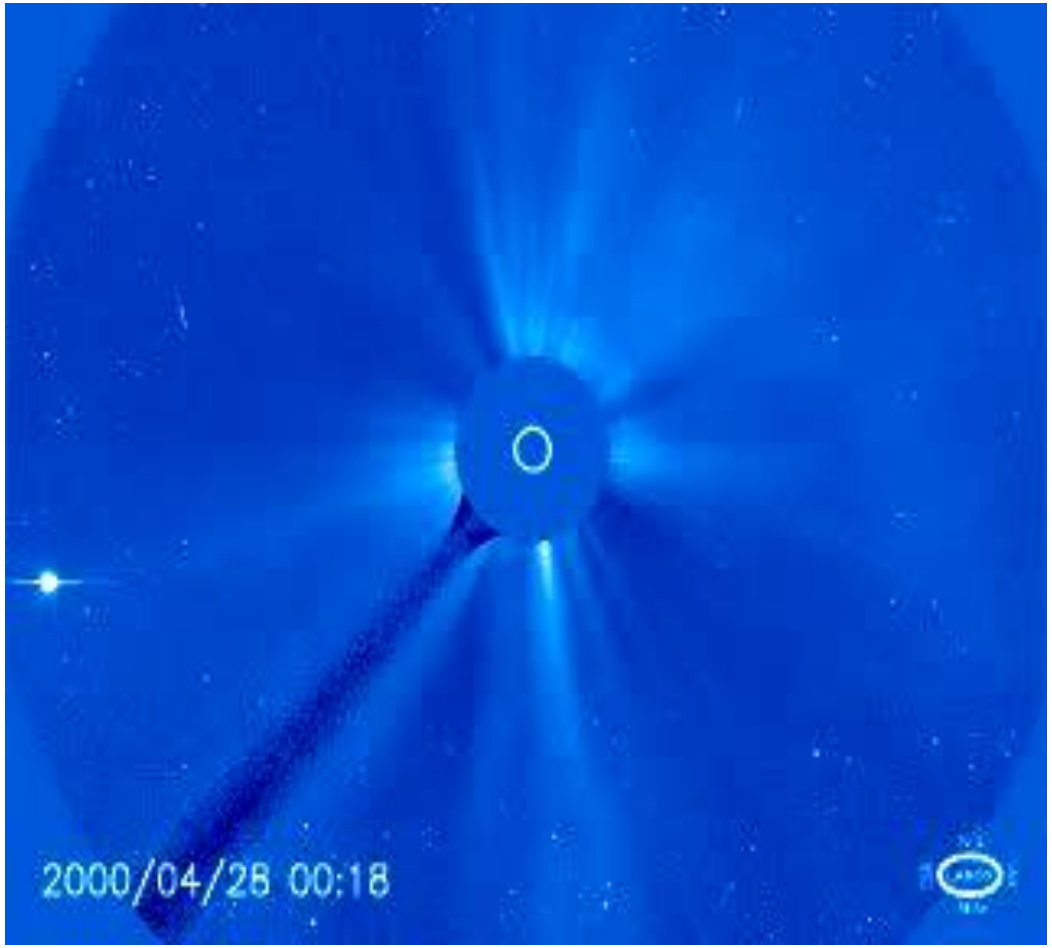
Credit: https://www.swpc.noaa.gov/phenomena



Coronal Mass Ejections

Large amounts of magnetic energy (and plasma) released from the Sun into the heliosphere.





When a CME hits the Earth's magnetosphere, it causes a geomagnetic storm (temporal disturbance of the Earth's geomagnetic field). In this case, the CME is classified as geoeffective.

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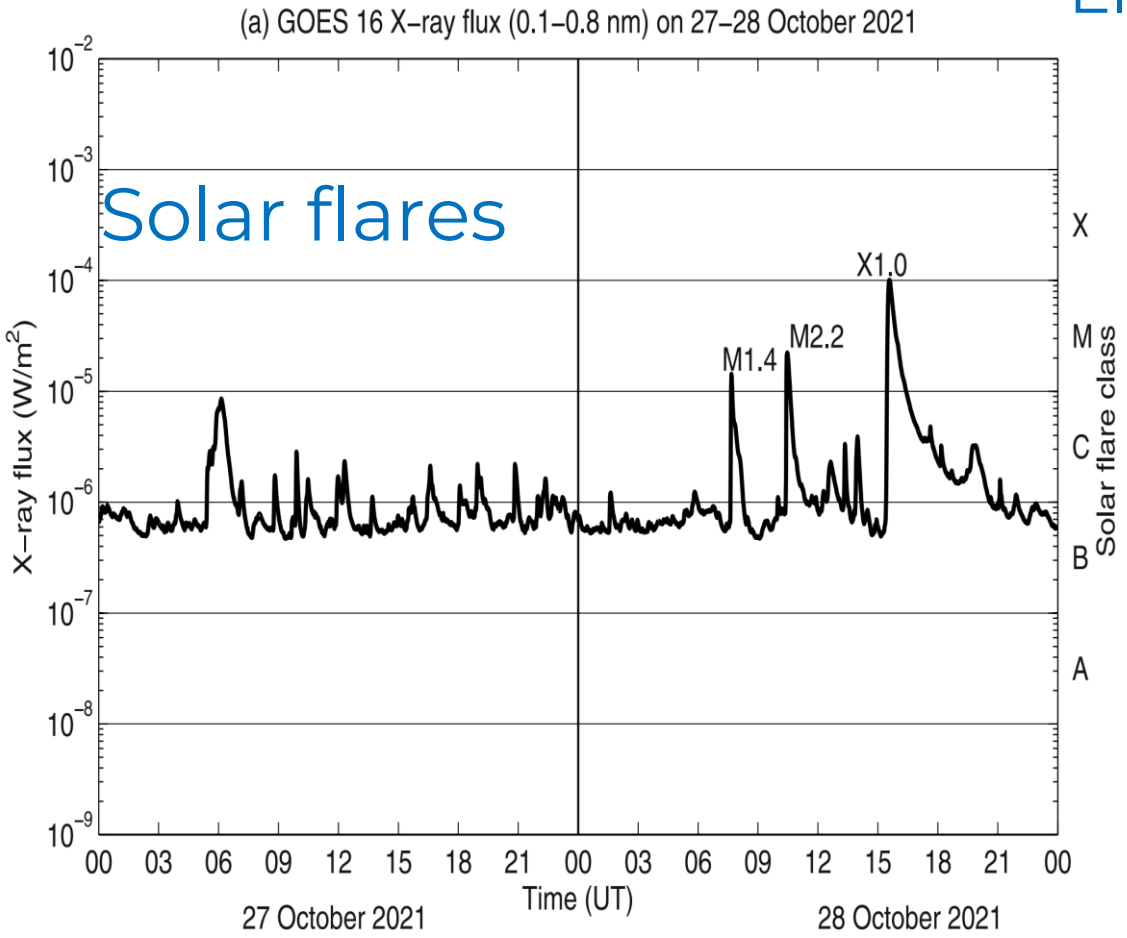
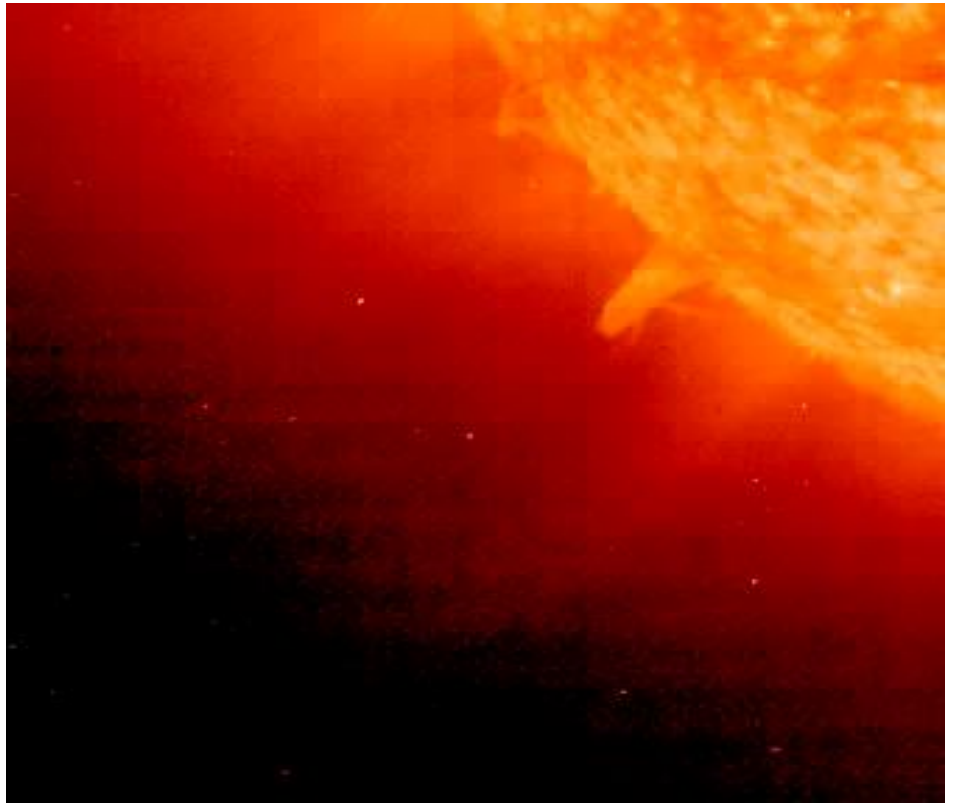
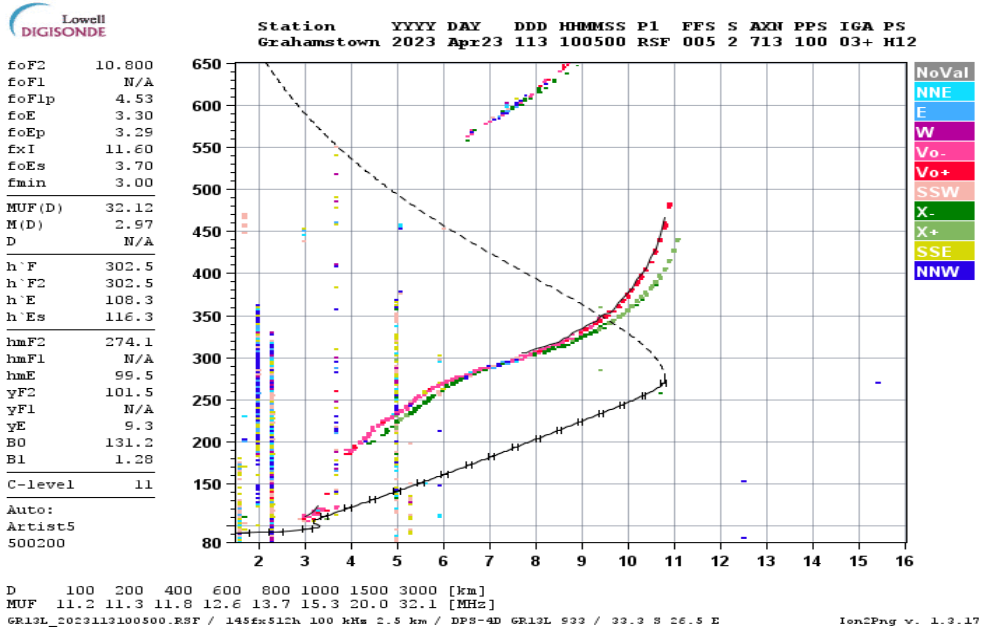
Electromagnetic radiation from the sun

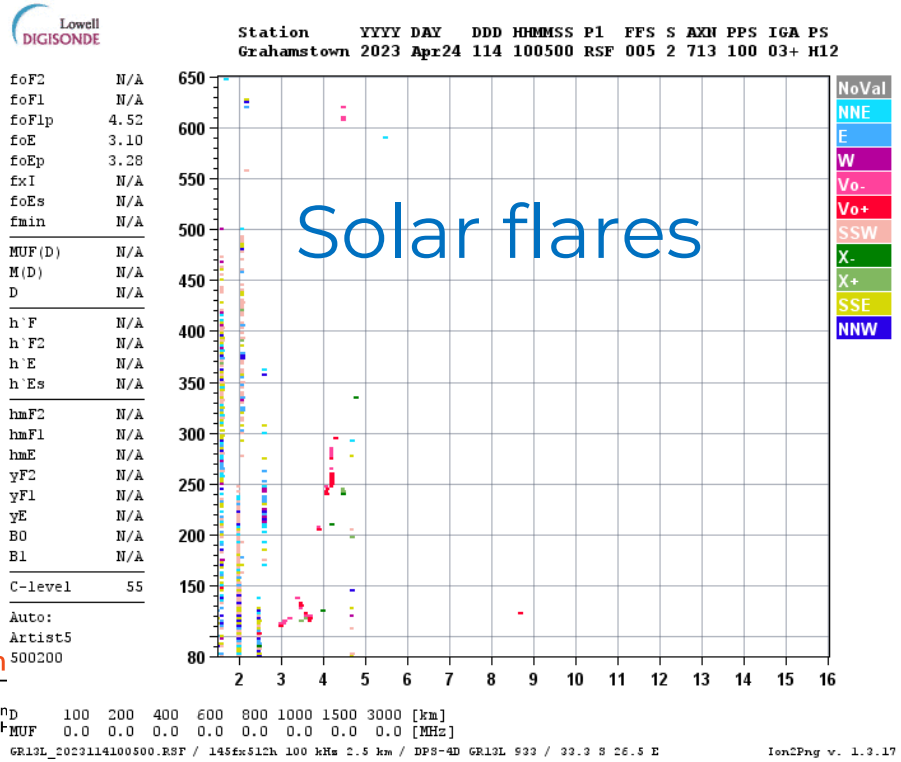




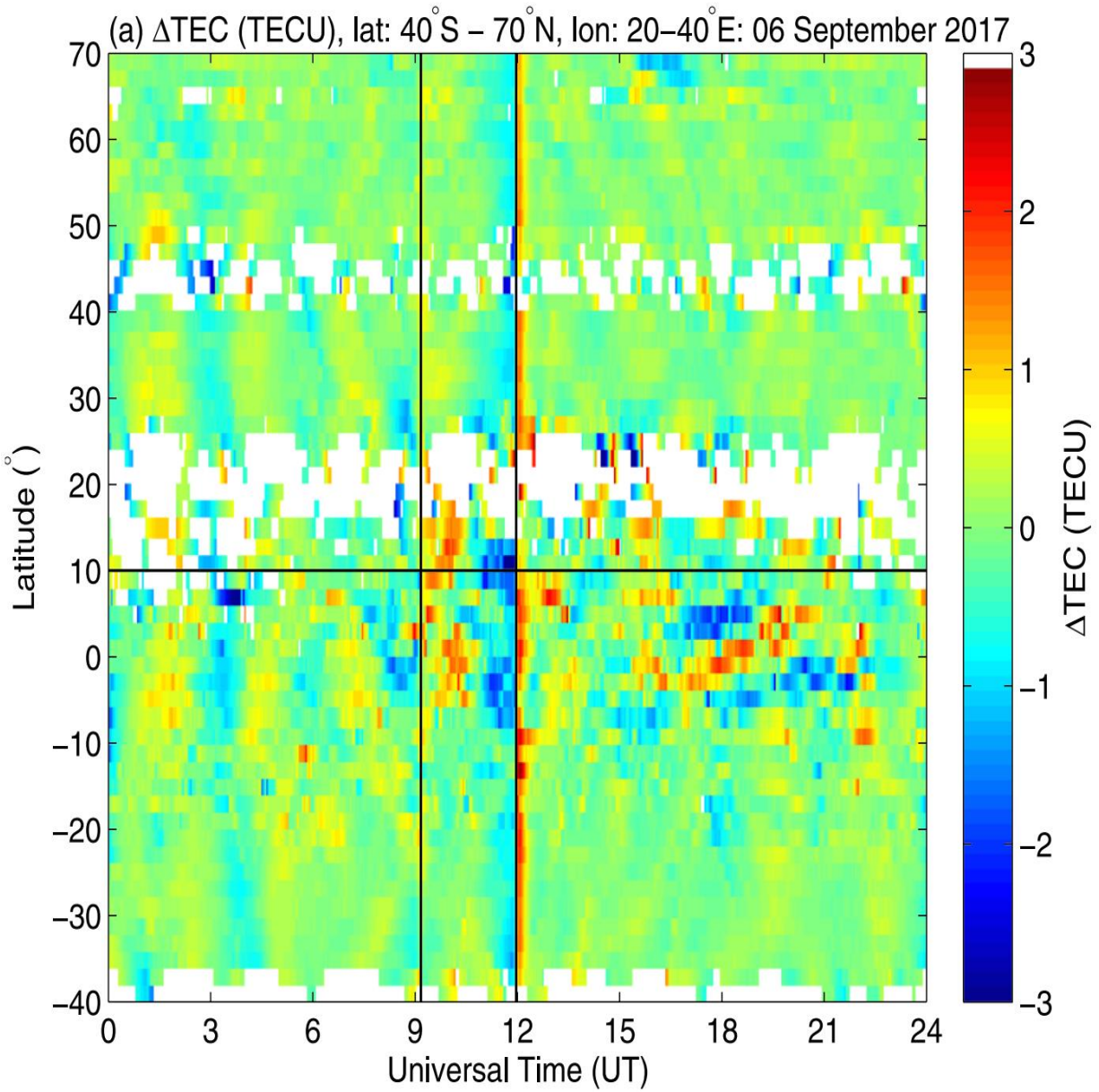
Habarulema et al (2022); Space Weather

Solar flares are usually classified according to the peak intensity of X-ray flux in the energy range of 0.1–0.8 nm as A, B, C, M and X class. It is now relatively understood that the first three classes (A, B and C) have little influence on the Earth's atmospheric effects especially on high frequency communication while the M- and X-class solar flares lead to varying magnitudes in ionospheric behavior on the sunlit side of the Earth.



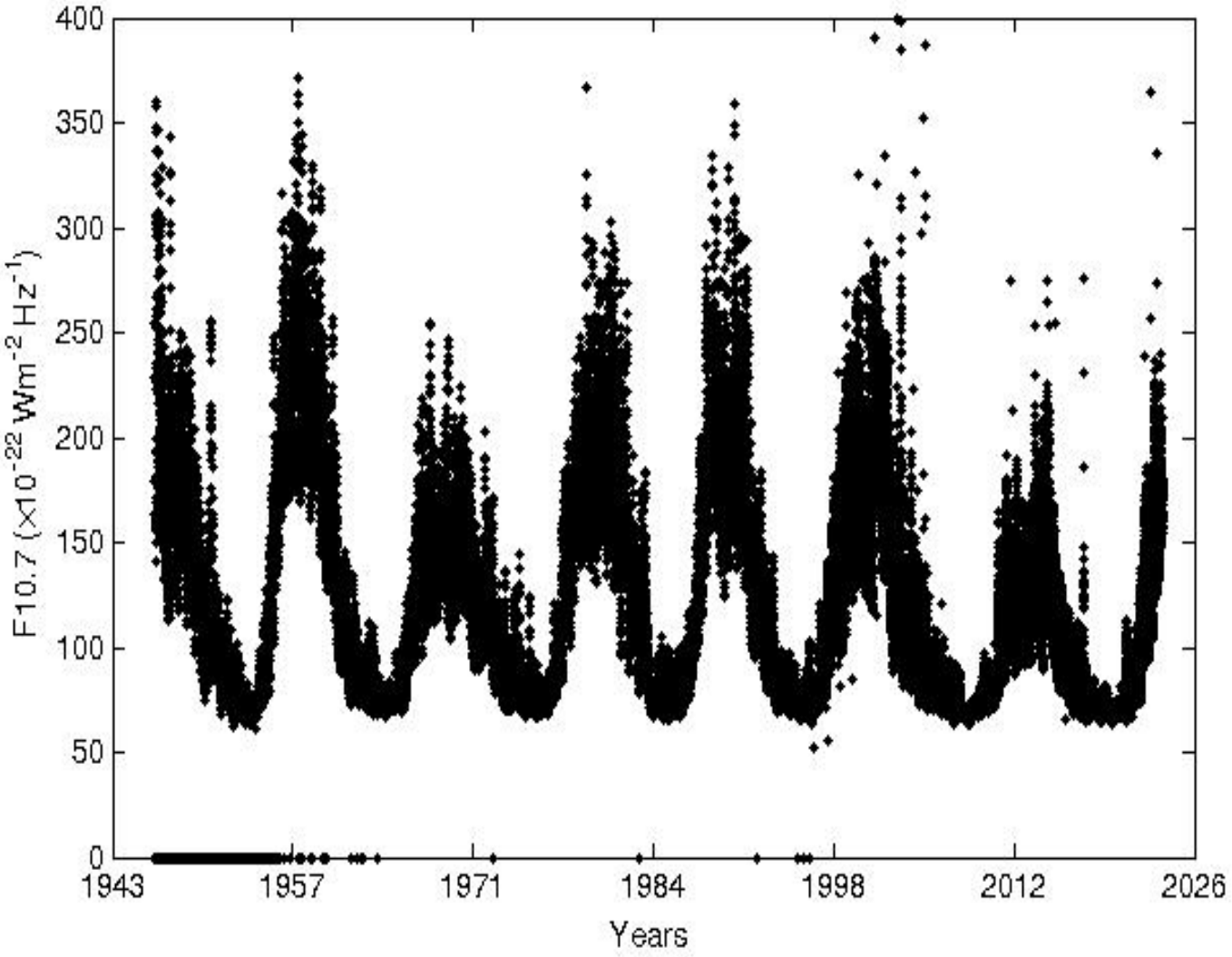


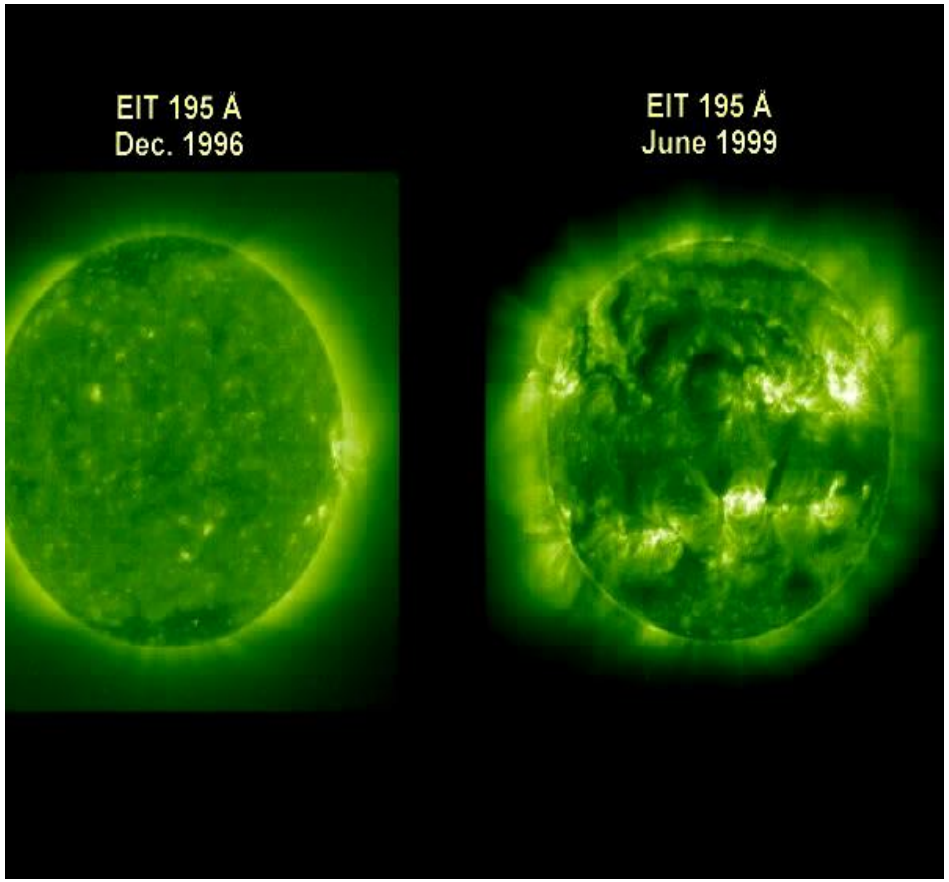
Solar flares



Habarulema et al (2020); JGR

Solar activity





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Downloaded from
https://lasp.colorado.edu/lisird/data/penticton_radio_flux

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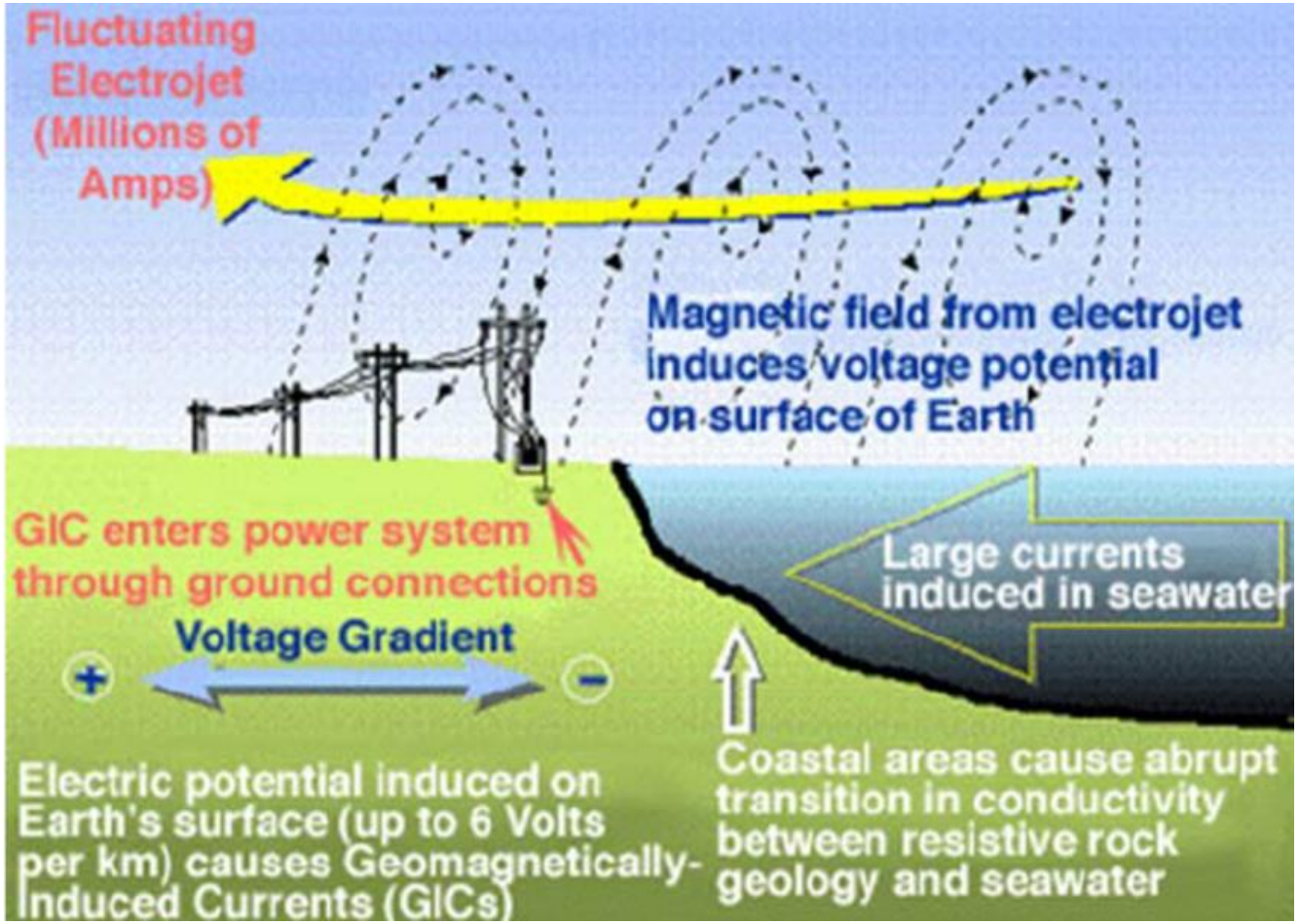
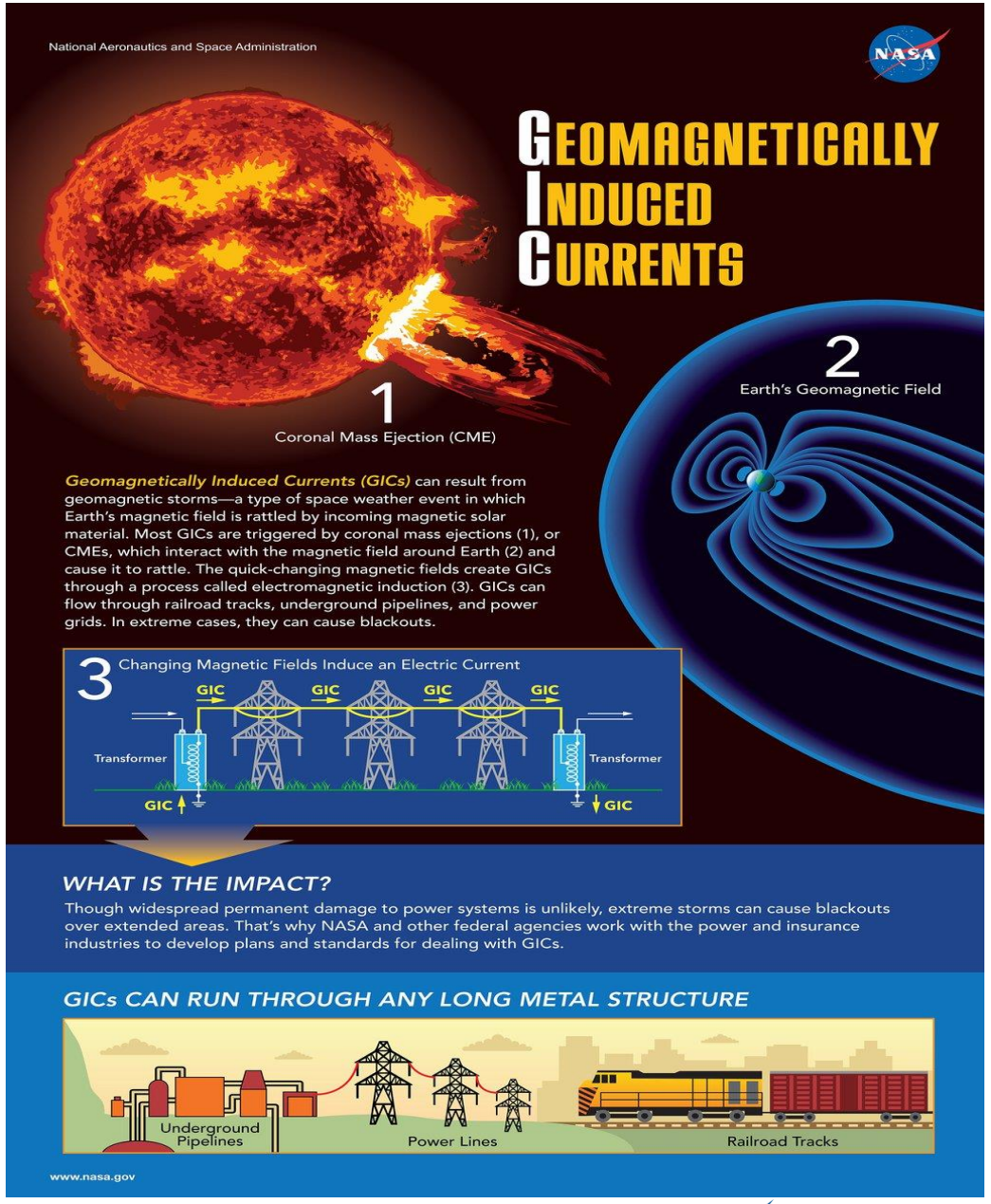
What are the effects of space weather? May be some!

GICs





Courtesy of John Kappenm

GICs introduce DC currents and thus change the linear input-output voltage system to non-linear one== transformer saturation== over heating [too simplified!]

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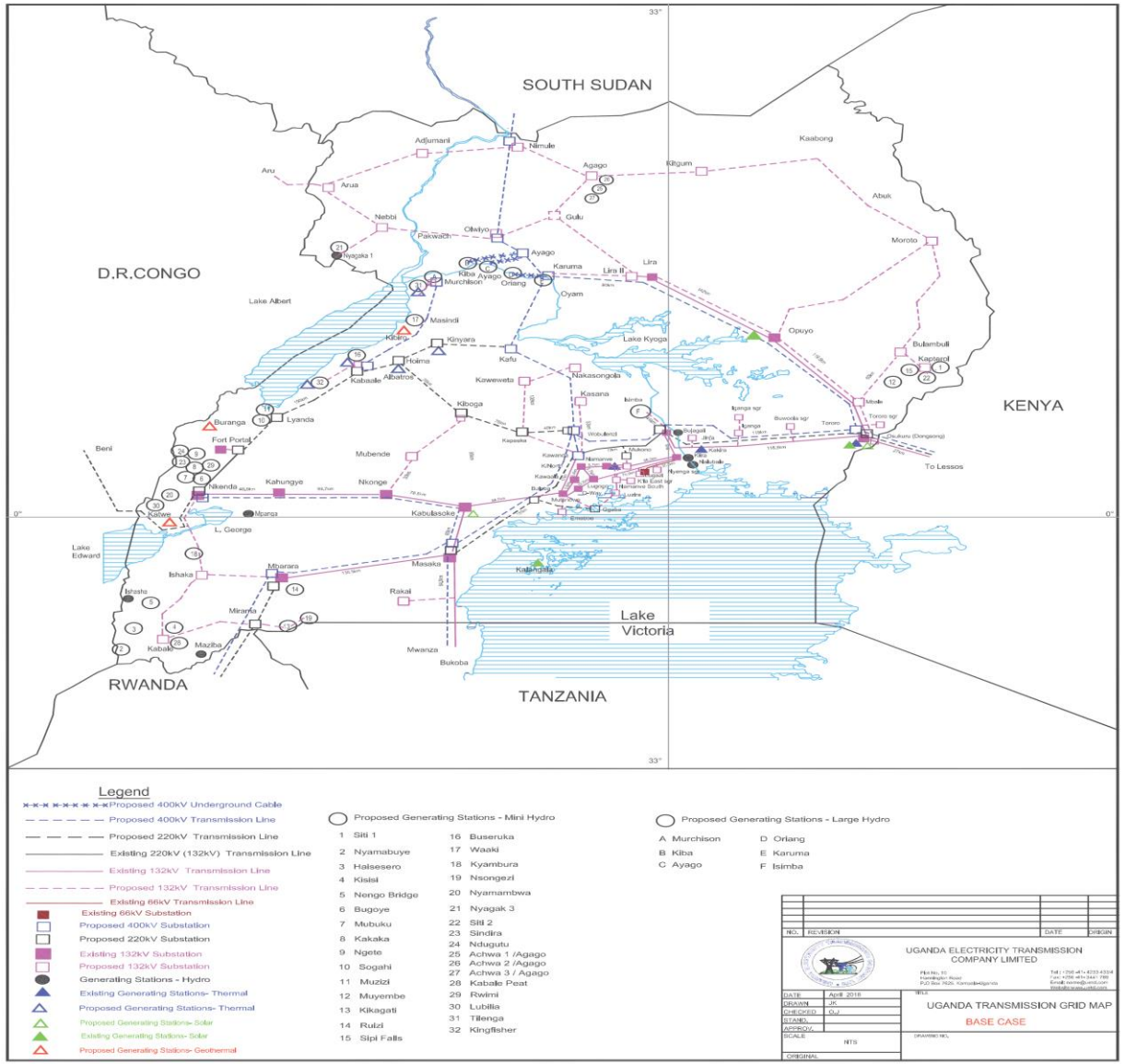
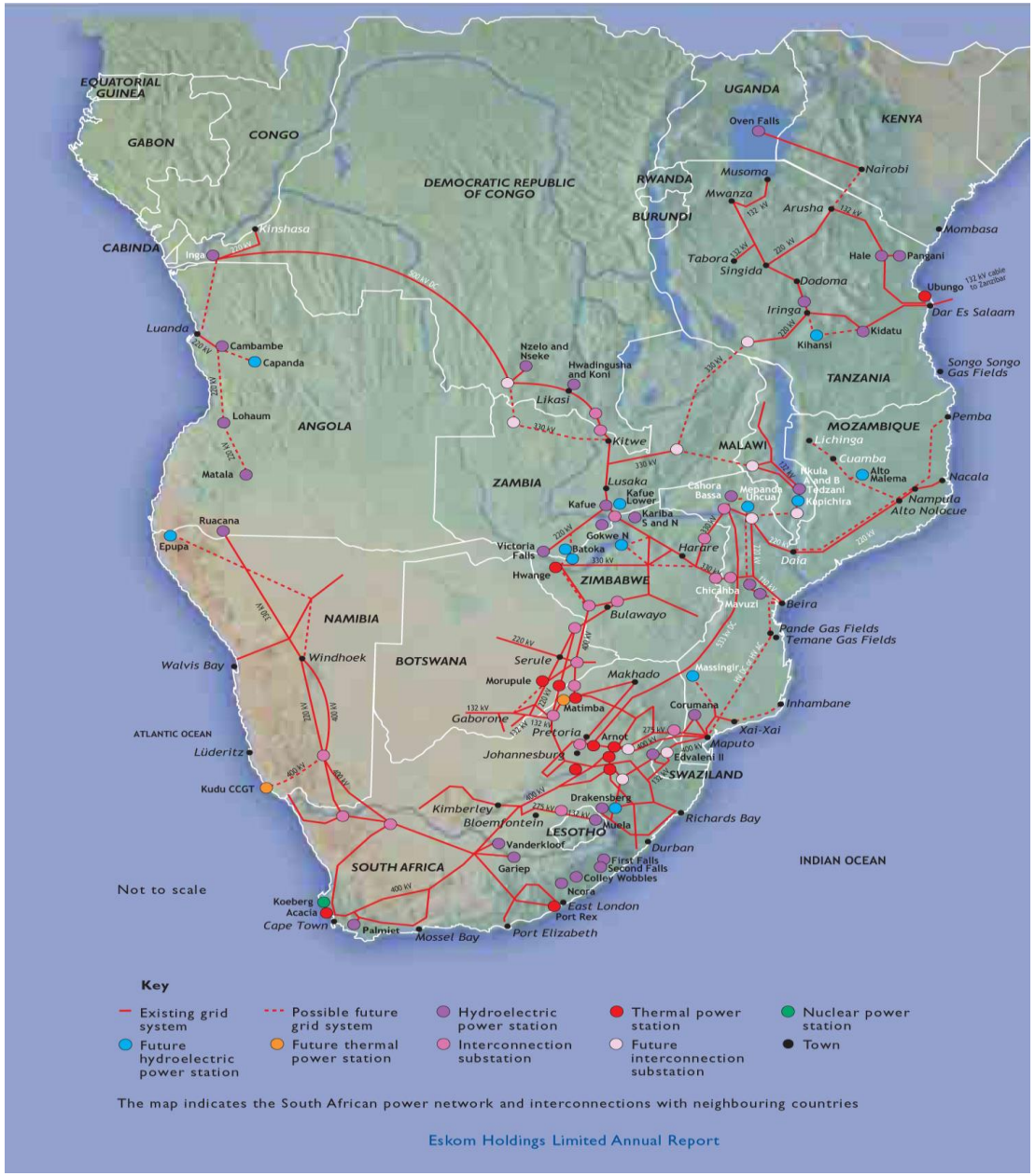
A.5.1 UGANDA POWER SYSTEM PRESENT AND FUTURE NETWORK





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Long distance electrical power transmission lines are excellent conductors
The longer the conductor and the lower its resistance, the easier the GIC can flow

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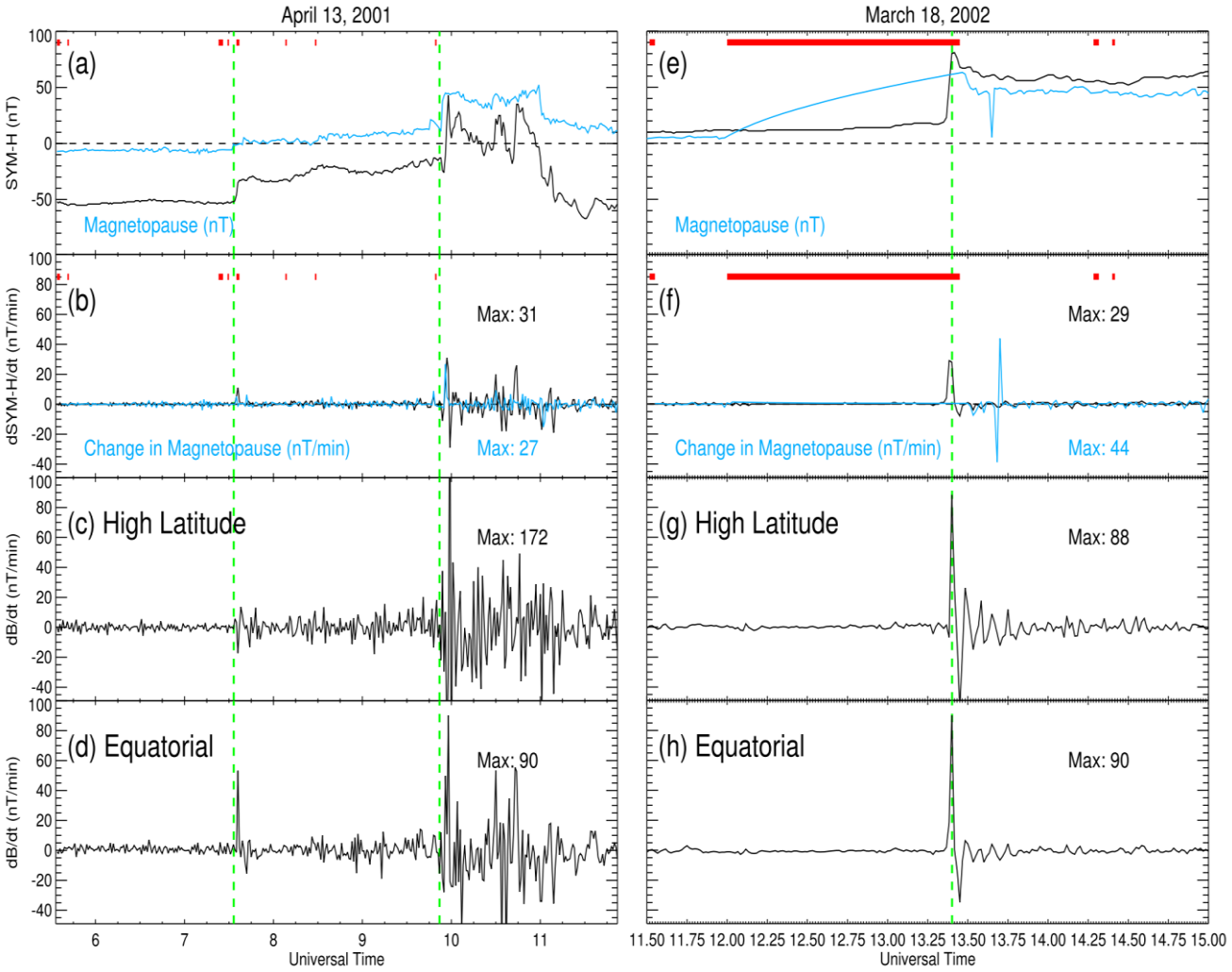
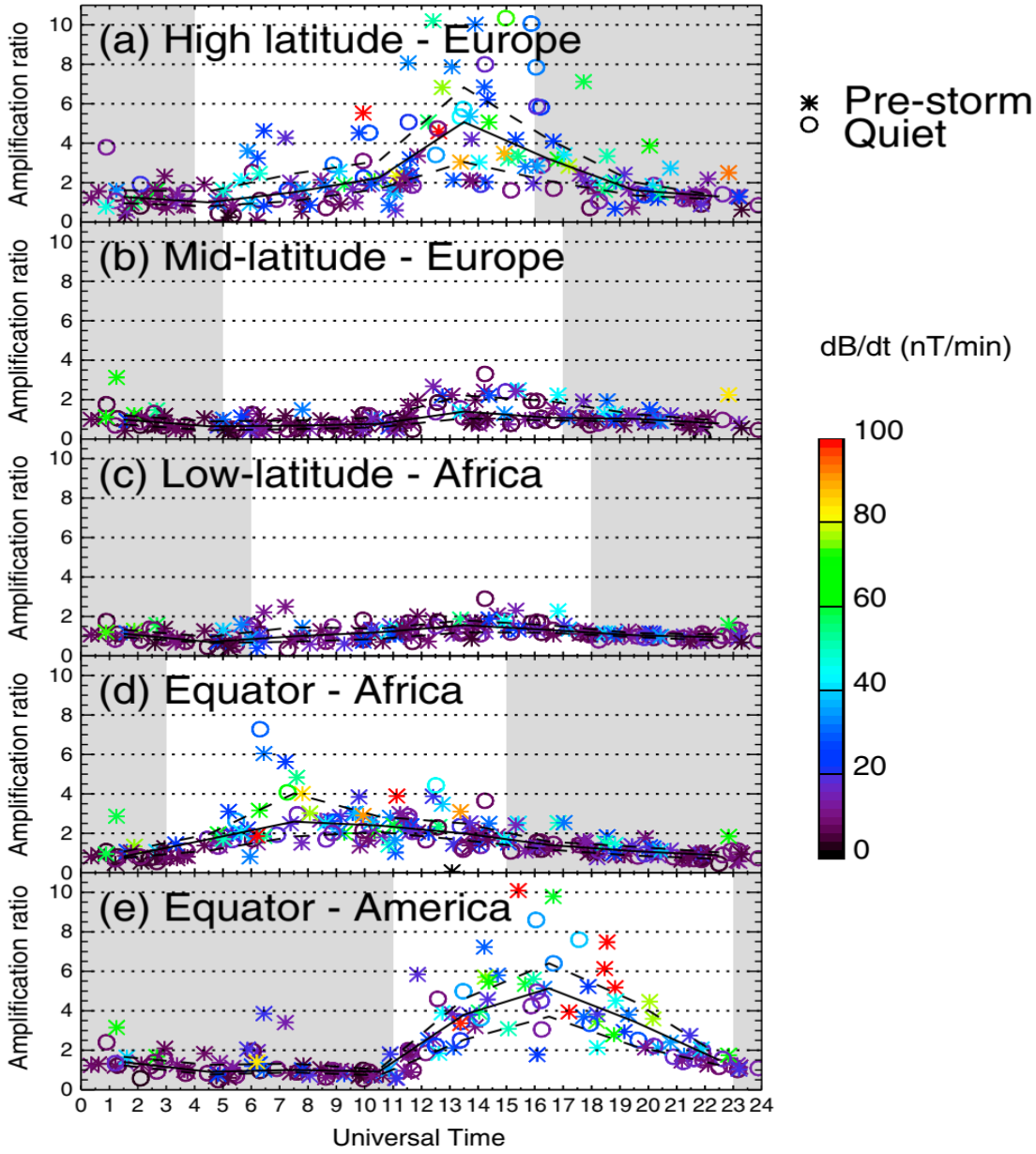
GICs in equatorial latitudes





Carter et al., (2015) GRL

Requirement: Ground-based magnetometers for GIC studies

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Pipeline Corrosion due to GICs (Marshall et al., (2010) SW)

https://www.arepa.com/resources/blog/corrosion-vs-rust-what-s-the-difference/

- Infrastructure pipelines for oil and gas transportation are sometimes made of steel.
- To prevent corrosion, the pipelines are usually coated in an insulating material and maintained at a negative electric potential with respect to Earth using cathodic protection units.
- During space weather events (geomagnetic storms), potential differences between the pipeline and surrounding soil (referred to as pipe-to-soil potentials, PSPs) may exhibit large voltage swings which place the pipeline outside the recommended “safe range” and at an increased risk of corrosion.
- The PSP variations result from the geoelectric field at the Earth’s surface and associated geomagnetic field variations==Essentially electromagnetic induction responsible for GICs

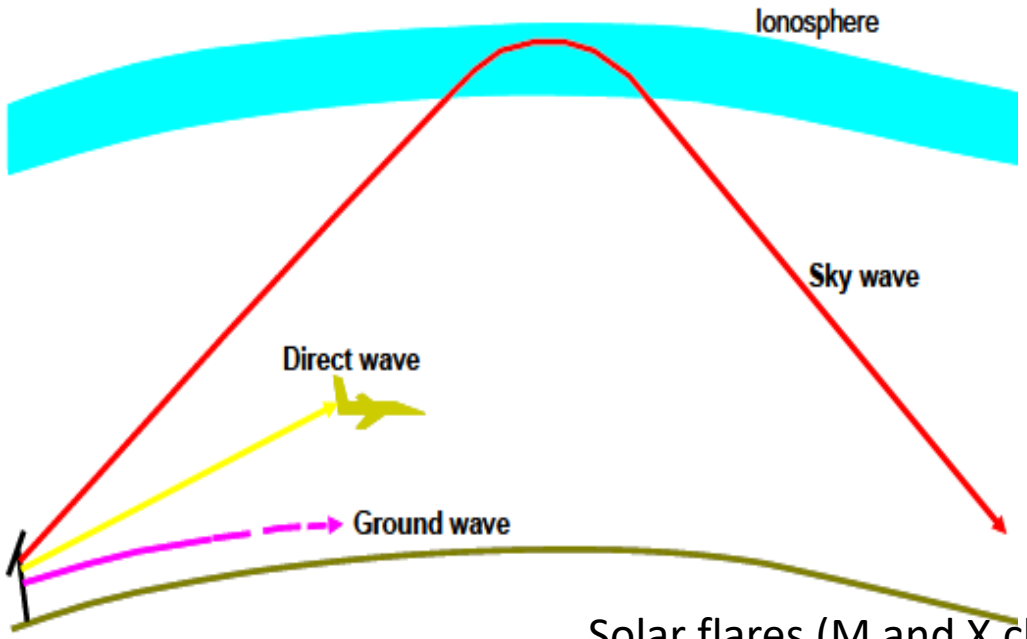
The PSP is the result of the geoelectric field integrated over the distance between grounding points so the ratio of the geoelectric field to the geomagnetic field can be regarded as effective impedance

Pipeline corrosion erodes the infrastructure and reduces the lifetime.

Communication; such as HF

HF can propagate via:

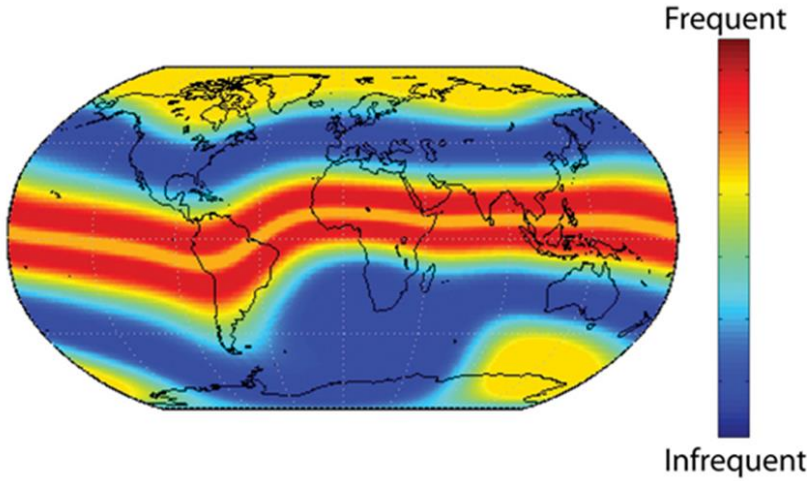
1. Ground wave: travels near the ground for short distances.
2. Direct or line-of-sight wave
3. Sky wave: reflected by the ionosphere and covers long distances



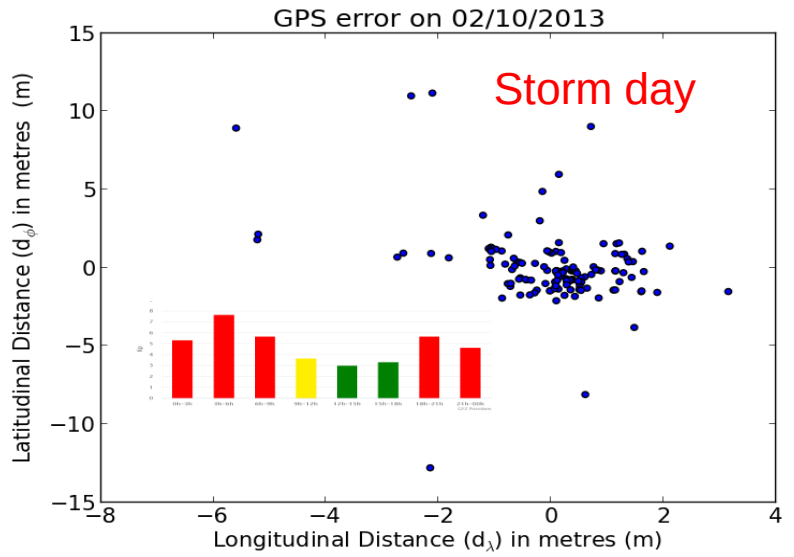
Solar flares (M and X classes) usually cause total absorption of the HF band during local daytime (sunlit longitude sectors), while the effect of geomagnetic storms is more complex

Scintillation, Navigation and positioning applications

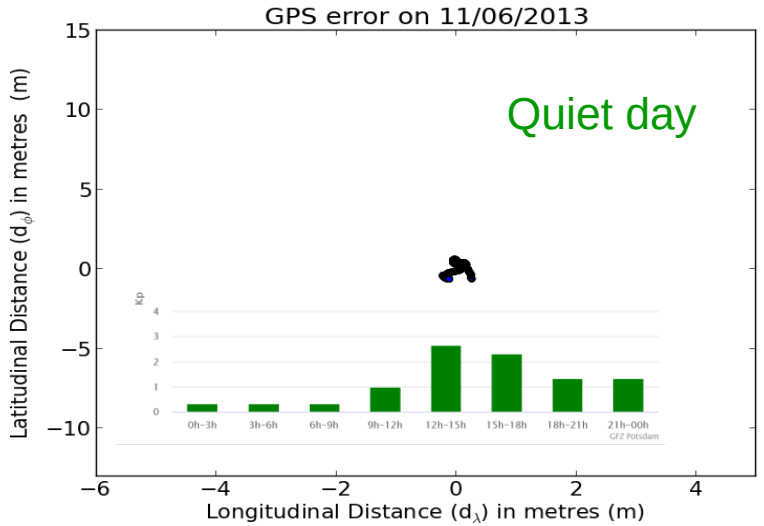
- ✓ Rapid fluctuation of radio waves caused by irregularities of the electron density
- ✓ Cycle slips and loss-of-lock on GNSS satellite signals can increase the magnitude and frequency of errors in the position estimation
- ✓ Affects the power and phase of the signal
- ✓ Dependent on location, local time, season, geomagnetic activity, and solar cycle

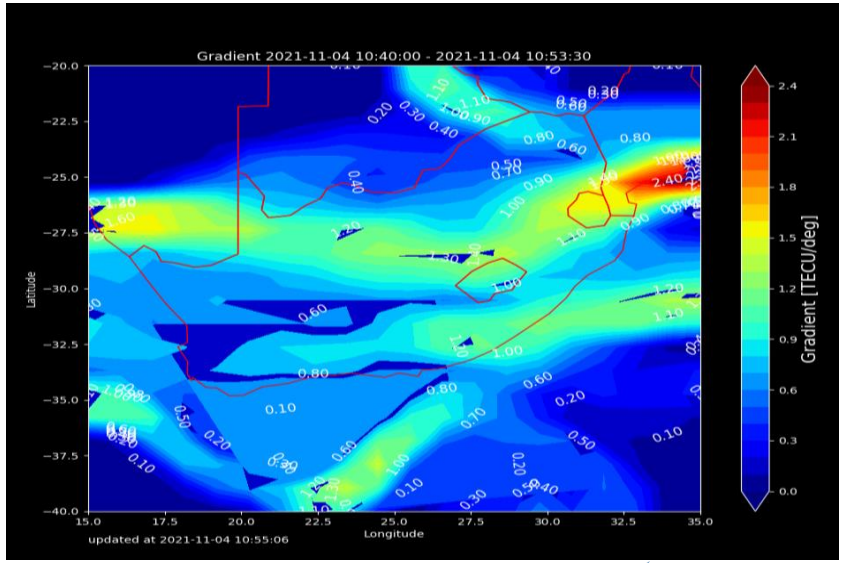


Kintner, (2009)



Single frequency handheld GPS receiver





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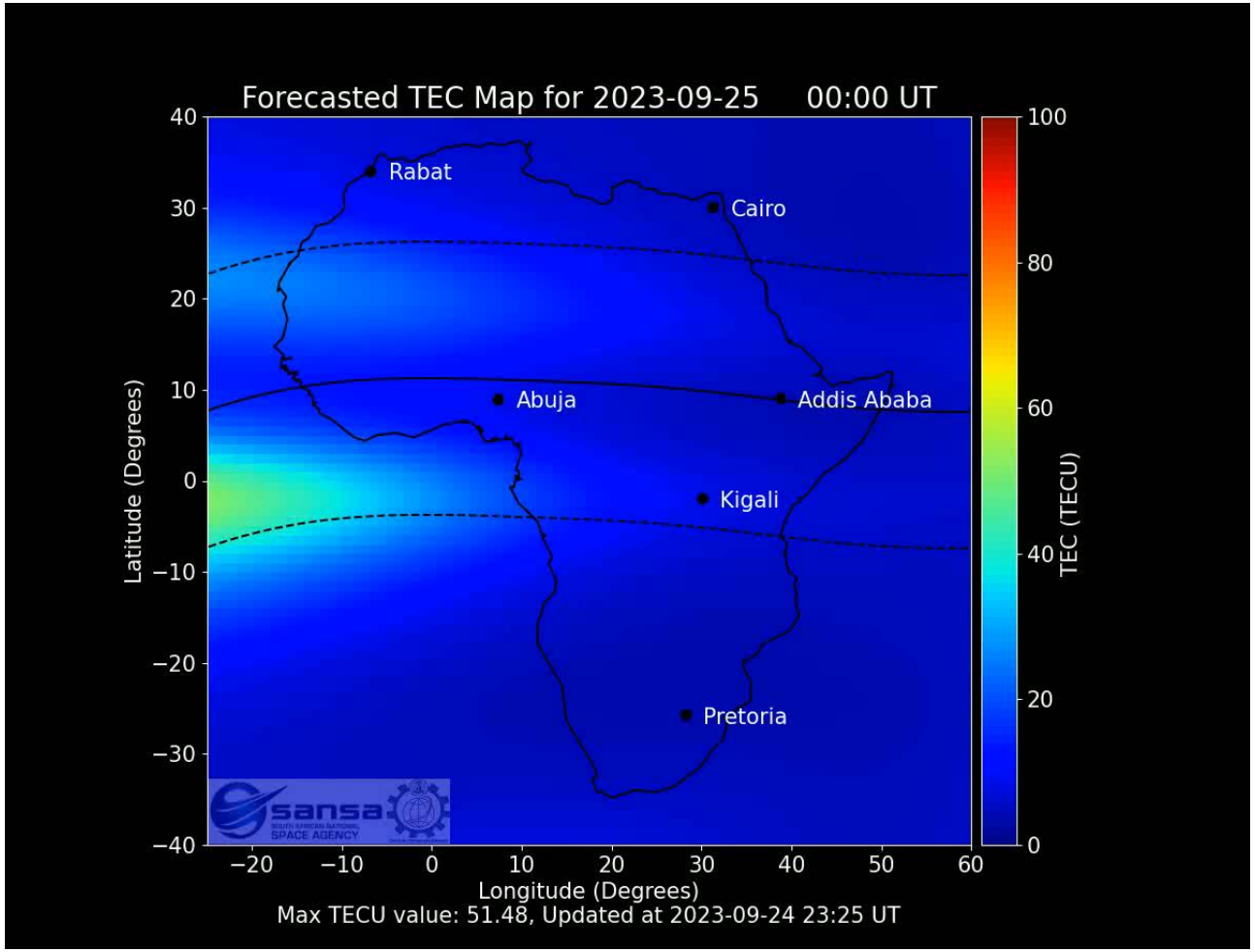
Is it important for each region to understand Space Weather?

When a space weather event occurs, it is global, but the effects are localized. This is because

1. Different longitude sectors respond differently depending on the local time. For a solar flare, the sun lit hemisphere experiences HF signal absorption.
2. Seasonal dependence play a major role. Background thermospheric/electron density in the northern and southern hemispheres differ even on the same day and local time.
3. Mid latitude and low latitude Physics considerably vary… Equatorial ionization anomaly in low latitudes, existence of scintillation, plasma bubbles, pre-reversal enhancement, etc
4. Ground conductivities are not the same and power configurations, infrastructure, etc.. AND so many more!



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