Space Weather for Amateur Radio

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N9WIB

Space Weather

- Why is this important?
- History
- Core concepts
- Solar indices

Why is Space Weather Important?

- Delicate balance for hams - better propagation versus radio blackouts.
- Disruption of communication
- Disruption of satellites and GPS navigation
- Transient to serious damage of power grids

History – Carrington Event

- Geomagnetic storm September 1st 1859
- Solar cycle 10
- Thought to be due to Coronal Mass Ejection
- Solar flare observed by British astronomers Richard Carrington and Richard Hodgson

History – Carrington Event

- Auroras visible in Florida
- Telegraph systems failed with sparks and flames at some stations
- Widespread blackouts, damage to power grid if occurred today

Other Events in History

- 774-775 AD
- Increased levels of carbon 14 in ancient trees discovered in study by Fusa Miyake a physicist from Japan
- Increased levels of beryllium 10 and chlorine 36 isotopes found in ice cores.

Other Events in History

- Increased isotopes suggest a cosmic event 10-100 times stronger than the Carrington event.
- Other data suggest that similar event occurred in 7176 and 5259 BC

More Recent Events

- Geomagnetic storm March 1989 resulted in 12 hour blackout in Quebec due to overloaded power grid.
- July 3rd, 2021 X-class flare significantly reduced HF propagation in North America for about an hour.
- Some estimates suggest chance of another Carrington event in the next decade could be 12%.

How Does Damage Occur?

- Time varying magnetic field can generate current in wire.
- A current carrying wire also produces a magnetic field.
- Earth’s magnetic field can produce stray current in power lines.
- Old telegraph operators noted current flow in equipment when no power was applied.

How Does Damage Occur?

- Geomagnetic storms can enhance and change the earth’s magnetic field and overload power lines and transformers by increasing current flow.
- Current frequency can change and be altered by spikes in magnetic field.
- Power grid operates on 60 Hz. Different frequency can trip or disrupt operation of electrical devices.

Basic Science

- The atmosphere according to ham radio
- The earth’s geomagnetic field
- The sun

Atmosphere - Troposphere

- Nitrogen 78%
- Oxygen 21%
- Argon and other gases less than 1%

Atmosphere - Troposphere

- Madison’s isthmus reference point
- Surface to 10 km (6 miles)
- Isthmus to west side of Madison
- Majority of weather occurs in troposphere

Atmosphere - Stratosphere

- 10 to 50 km (6-30 miles)
- West side of Madison to Mount Horeb
- 99% of atmospheric gases are in the troposphere and stratosphere

Atmosphere - Stratosphere

- Where airplanes fly
- Highest concentration of ozone (O_3)
- Majority of UV radiation absorbed in stratosphere

Atmosphere – Ionosphere

- 50 – 600 km (370 miles)
- LEO satellites 160-2,000 km above earth’s surface
- Hamosphere
- Janesville to St. Louis
- UV and Xray radiation cause ionization of atmospheric gases.
- Density of the ionosphere depends on amount of solar radiation reaching earth

Atmosphere – Ionosphere

- Divided into D,E,F layers
- Reflection, refraction and absorbance of radio waves.
- Composed of mesosphere, thermosphere, exosphere.

Atmosphere – Ionosphere

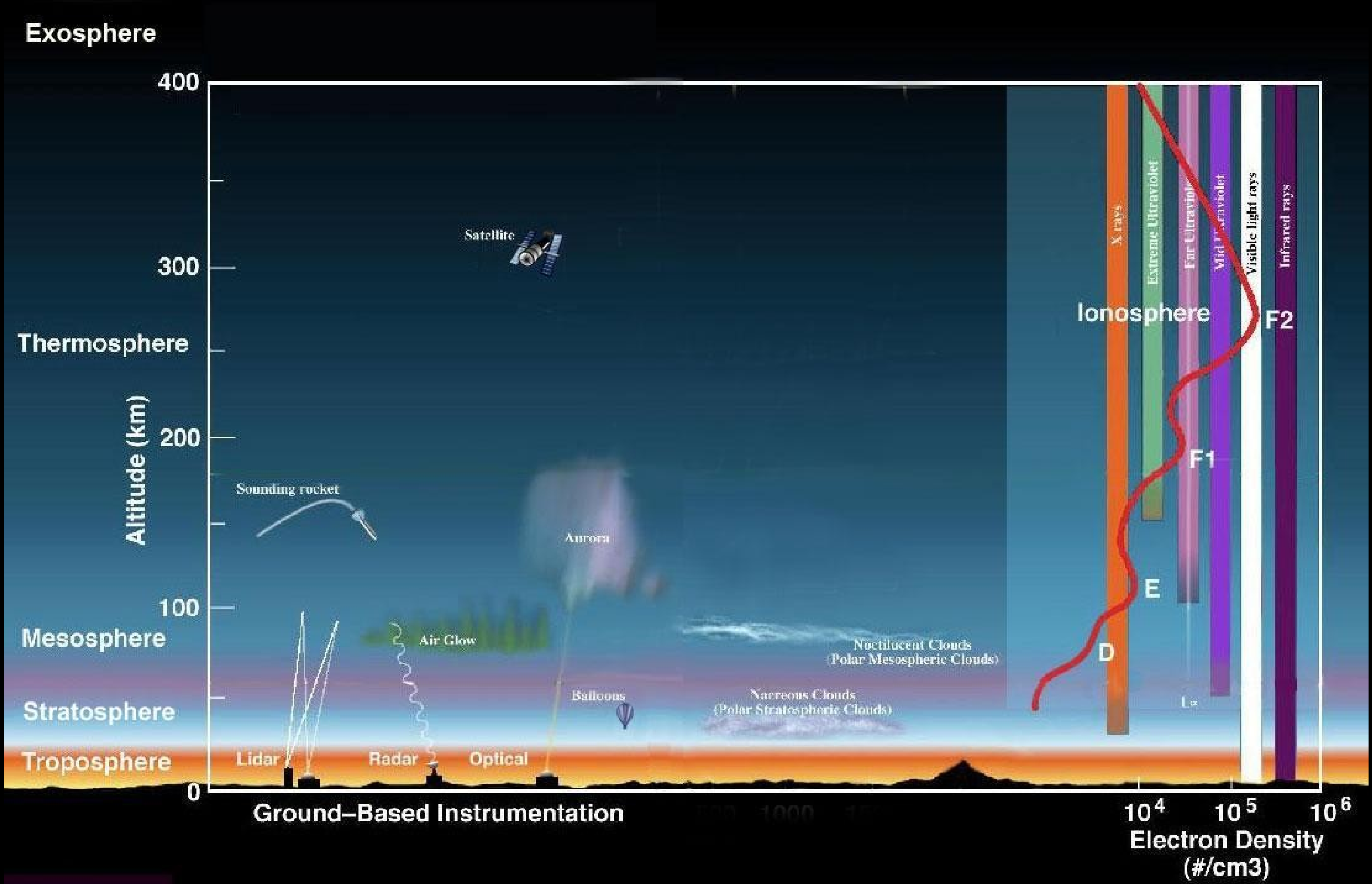
- D Layer 70 – 90 km
- Janesville to Beloit
- Ionized during the day and not at night

Atmosphere – Ionosphere

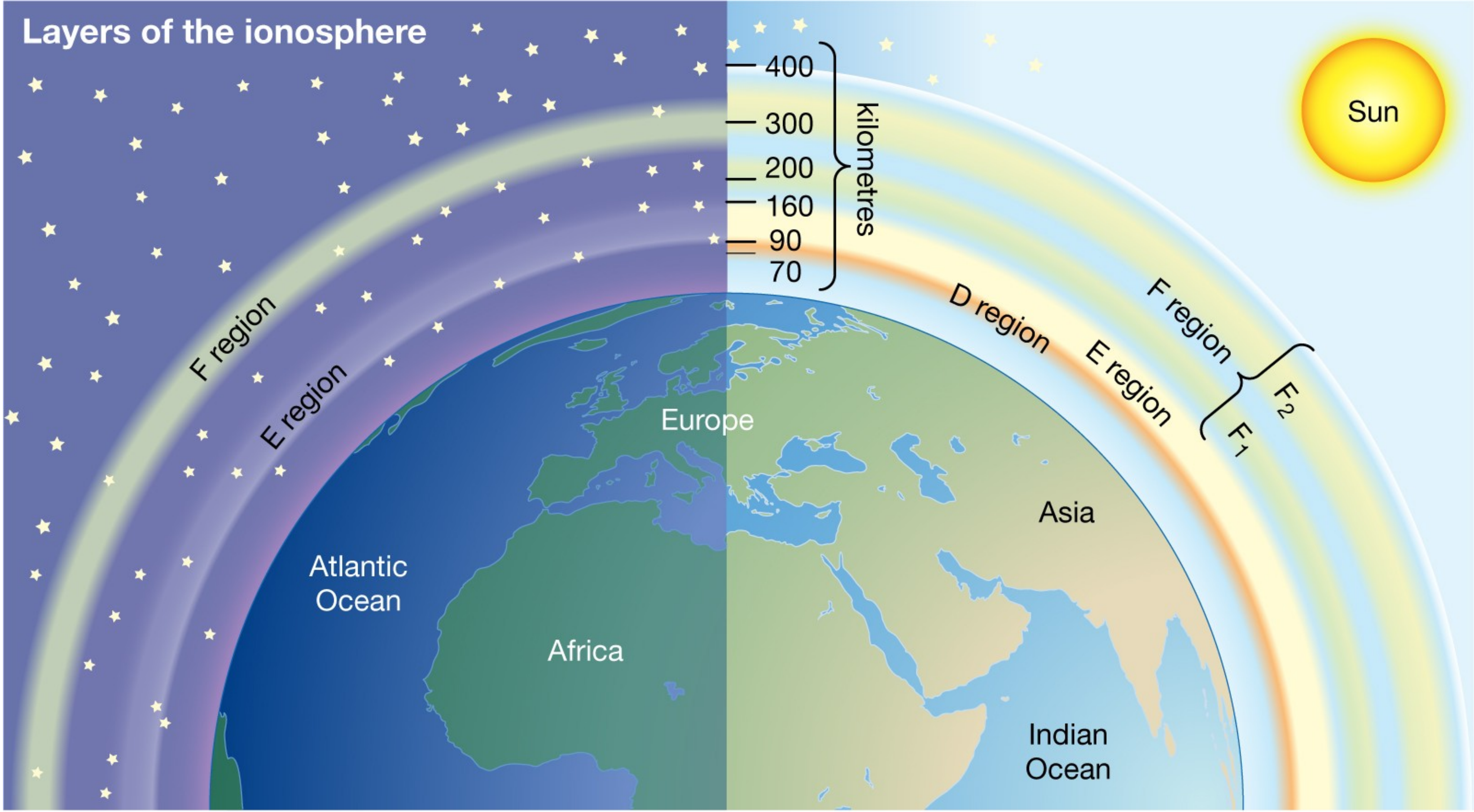
- E Layer 90 – 160 km
- Vicinity of Elgin
- Ionized during the day and less at night

Atmosphere – Ionosphere

- F Layer 160-600 km
- Elgin to St. Louis
- Greatest degree of ionization / free electrons
- F1F2 merge into F layer at night
- Usually reflect radio waves up to 35 MHz

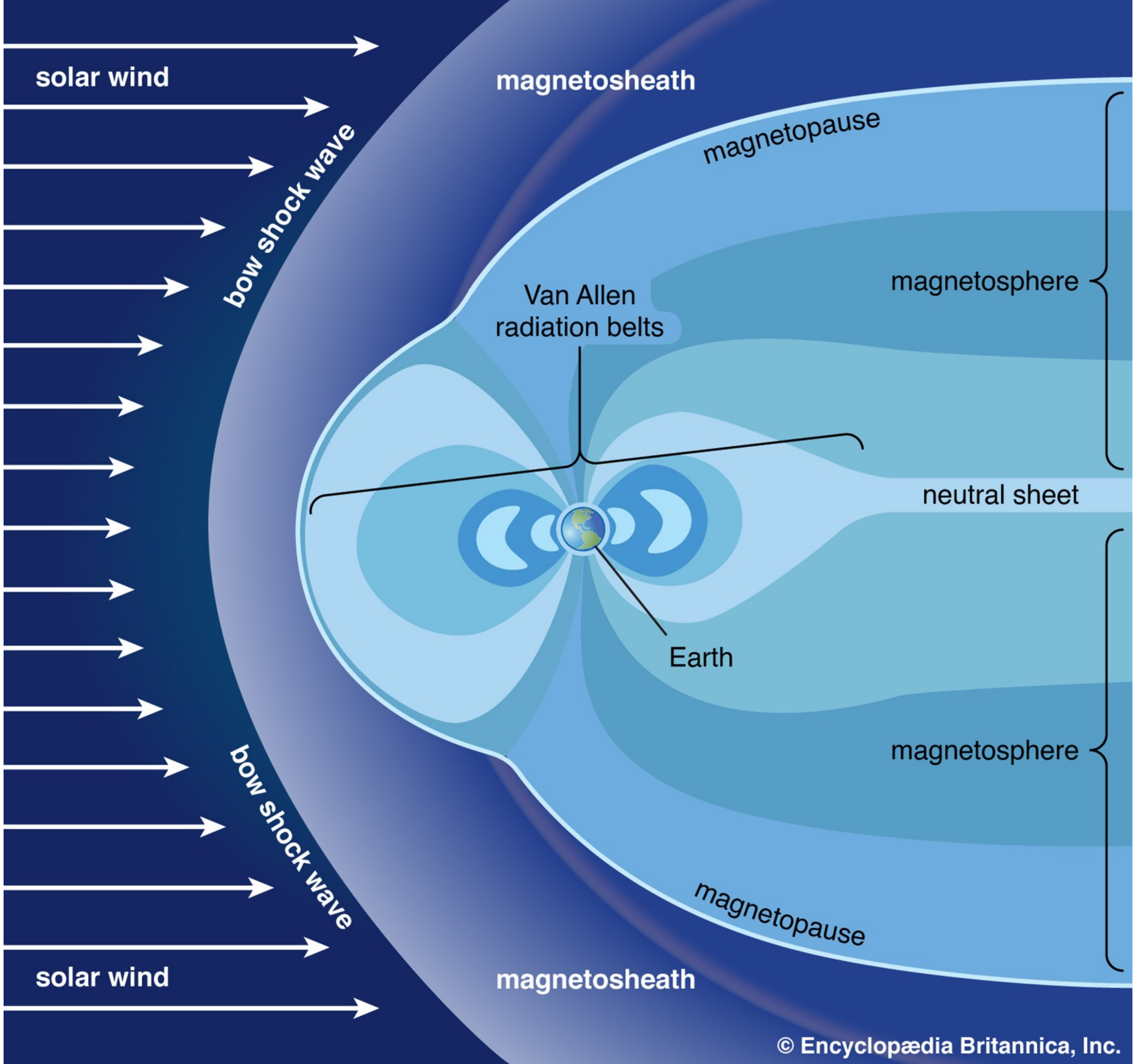


Exosphere
400
300
Thermosphere
Altitude (km)
200
100
Mesosphere
Stratosphere
Troposphere
0
Satellite
Sounding rocket
Aurora
Air Glow
Balloons
Lidar
Radar
Optical
Noctilucent Clouds
(Polar Mesospheric Clouds)
Nacreous Clouds
(Polar Stratospheric Clouds)
X rays
Extreme Ultraviolet
Visible light rays
Infrared rays
Ionosphere
F2
F1
E
D
Ground–Based Instrumentation
10 4
10 5
10 6
Electron Density
(#/cm3)


Layers of the ionosphere
400
300
200
160
90
70
kilometres
Sun
F region
E region
D region
F region
E region
F2
F1
Europe
Atlantic Ocean
Africa
Asia
Indian Ocean

Atmosphere – Magnetosphere

- Region of space where earth’s magnetic field interacts with solar wind.
- 600 – 160,000 km (370 to 100,000 miles)
- St. Louis to 12.5 times earth’s diameter
- Auroras occur between regions of ionosphere and magnetosphere
- Earth’s magnetosphere protects us from harmful cosmic and solar radiation


solar wind
magnetosheath
magnetopause
bow shock wave
magnetosphere
Van Allen
radiation belts
neutral sheet
Earth
magnetosphere
bow shock wave
magnetopause
solar wind
magnetosheath
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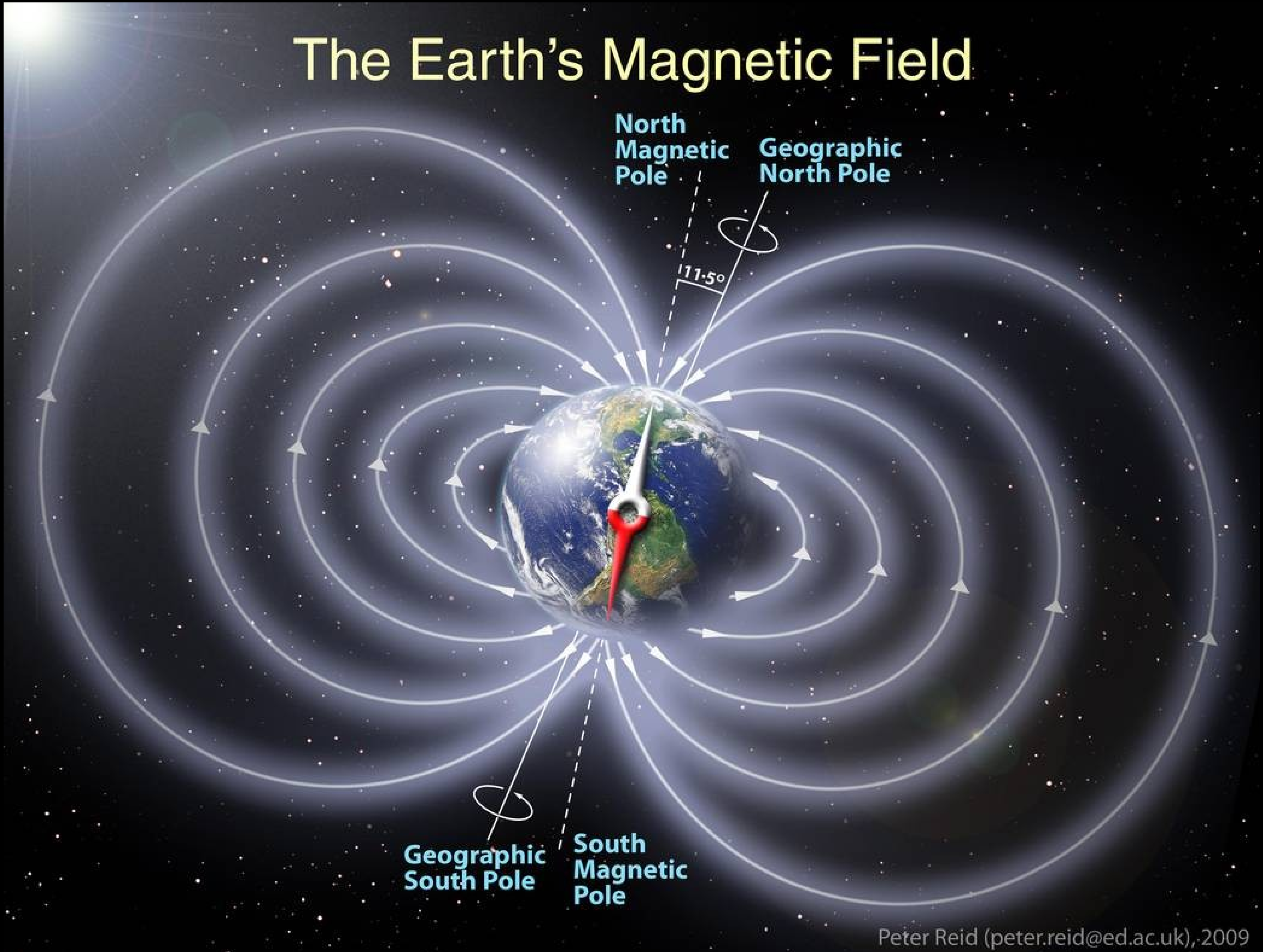
Earth’s Magnetic Field

- Magnetic field extending from Earth’s interior to outer space
- Formed from convection of molten iron and nickel in Earth’s outer core
- Magnetic field lines similar to bar magnet or dipole
- Nearly horizontal field lines near Earth’s equator



The Earth's Magnetic Field
North Magnetic Pole
Geographic North Pole
11·5°
Geographic South Pole
South Magnetic Pole
Peter Reid (peter.reid@ed.ac.uk), 2009

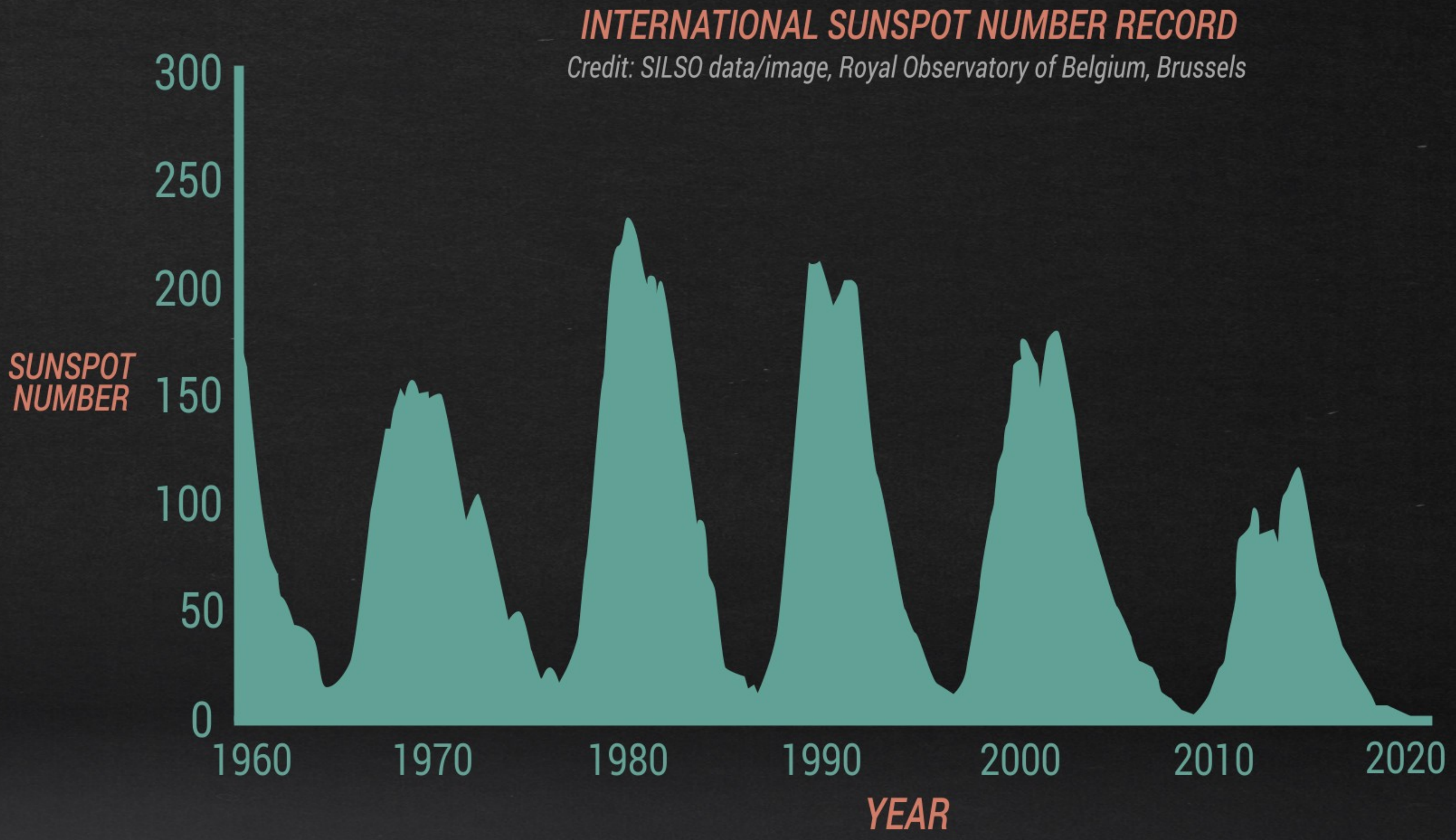
Interactive Questions

The Sun Fun Facts

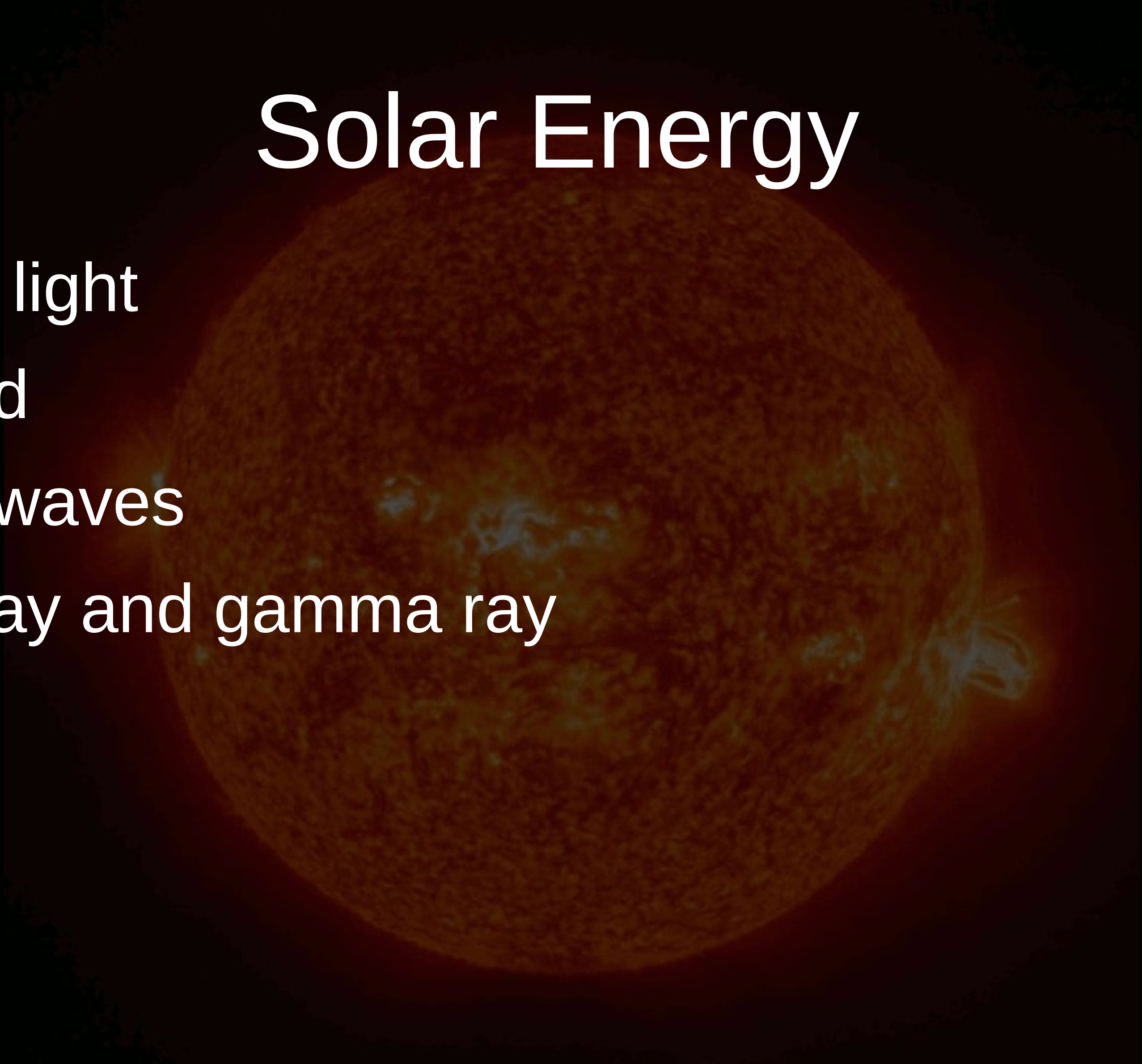
- Big ball of gas
- 93 million miles from earth on average. Equal to 1 AU or astronomical unit
- 12 thousand earth diameters away
- Takes light 8 minutes and 20 seconds to reach the earth
- 1 million earths can fit into the sun’s volume
- Produces energy via nuclear fusion by the conversion of hydrogen to helium & energy in the sun’s core.
- Temperature in the visible surface of the sun 7,600 to 10,300 F
- Sun’s power 3.86×10^{26} Watts far exceeding the legal limit of hams

Solar Cycle

- Sun’s activity varies based on an 11 year average cycle.
- Solar minimums average 3 years but could be as short as 1.5 or as long as 8 years.
- Currently in the beginning of solar cycle 25.


INTERNATIONAL SUNSPOT NUMBER RECORD
Credit: SILSO data/image, Royal Observatory of Belgium, Brussels
SUNSPOT NUMBER
300
250
200
150
100
50
0
1960
1970
1980
1990
2000
2010
2020
YEAR

Solar Energy



- Visible light
- Infrared
- Radio waves
- UV, Xray and gamma ray

Solar Energy

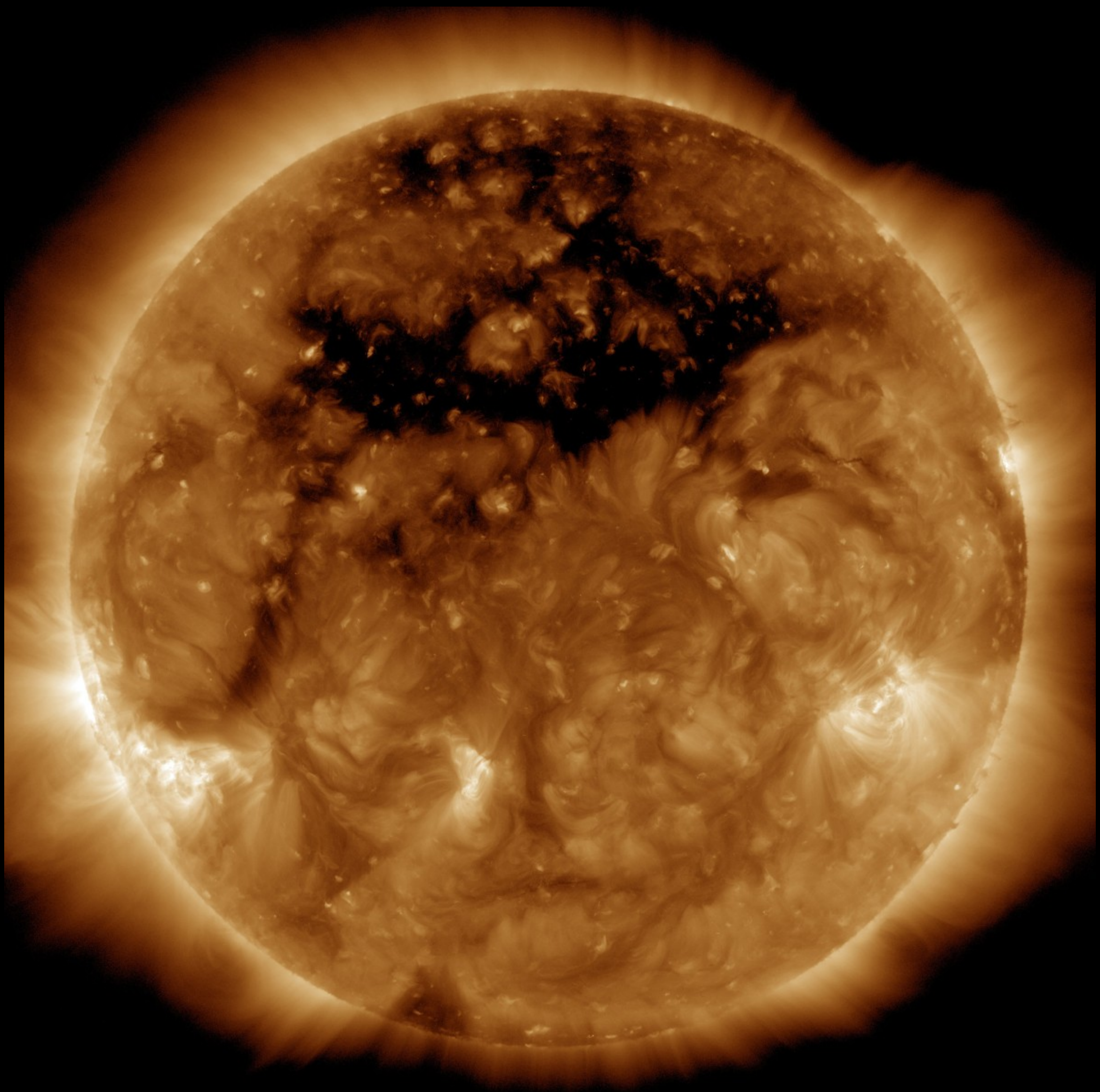
- Electromagnetic radiation takes less than 9 minutes to reach earth
- Solar wind full of charged particles takes 20 - 40 hours to reach earth.

Solar Wind

- Protons and electrons in plasma form along with magnetic field from sun
- Solar wind varies in speed typically 400 km/s
- Travel from Madison to Champaign-Urbana in 1 second
- The faster the solar wind the greater the effects to earth’s geomagnetic field and ionosphere.
- May cause geomagnetic storms and increased aurora activity

Coronal Holes

- Weak ares in the suns outer layer
- Coronal holes allow high speed stream of charged particles to escape sun (solar wind)
- Appear as dark areas on sun with extreme UV and x-ray solar imaging
- Coronal holes may persist through several 27-day period solar rotations



Coronal Mass Ejections

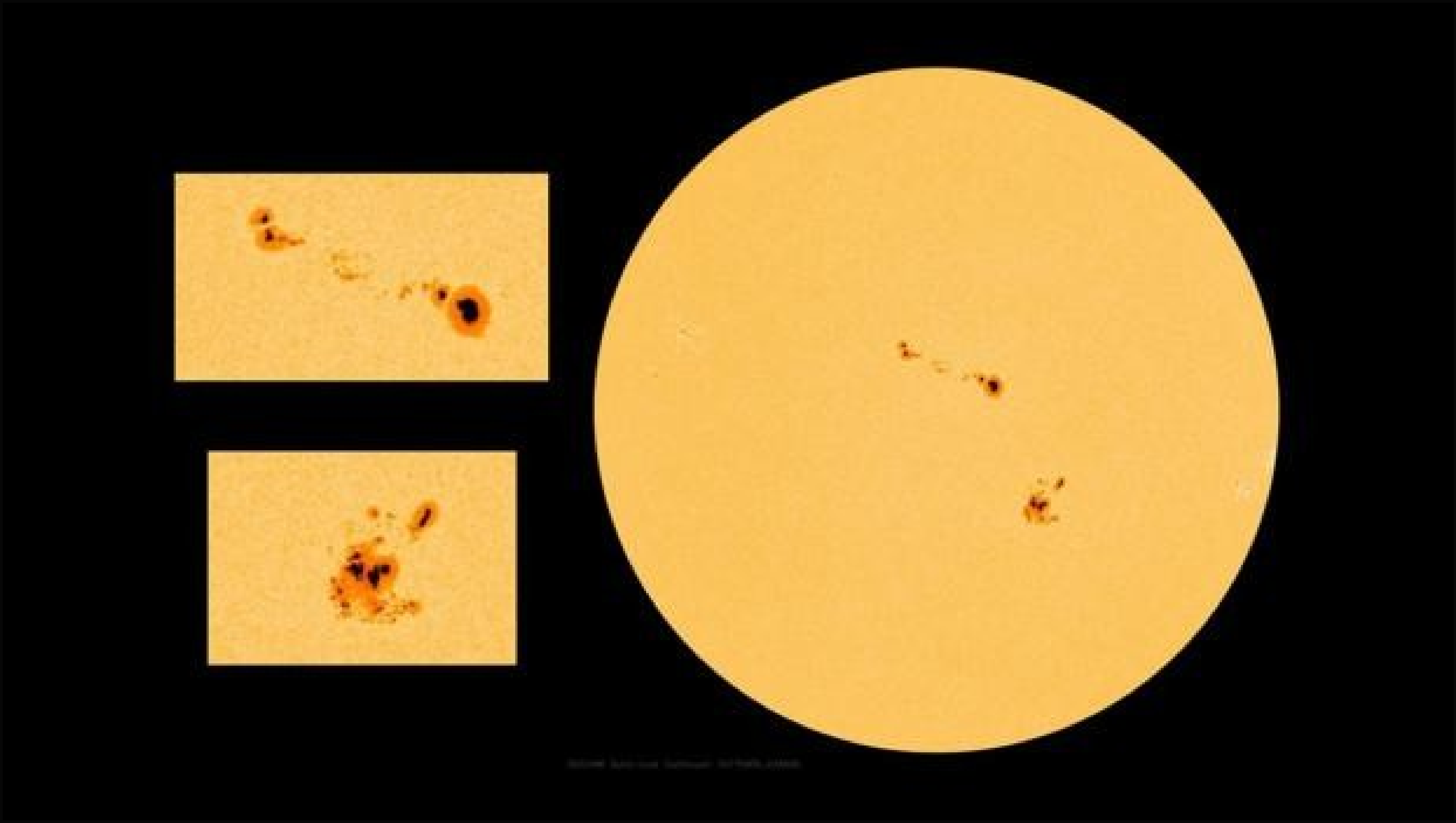
- Large expulsions of ionized particles, gas and magnetic field from the sun’s surface
- Can eject billions of tons of material
- Fastest CME can reach earth in 15-18 hours
- Satellites may provide 15-60 minutes of advanced warning
- May result in geomagnetic storms

Coronal Mass Ejections

- Radiation storm
- Protons from CMEs may reach earth slower than the speed of light but faster than other particles.
- Protons interact with earth’s magnetic field and are funneled towards the poles.
- May cause damage to electronic equipment in space and DNA.
- Pose risk to astronauts and high altitude flights.
- Cause ionization in atmosphere releasing free electrons and disrupting HF radio communications.

Sun Spots

- Areas on sun’s surface that appear dark
- Are cooler than surrounding areas and have increased magnetic activity
- The more sunspots the more solar activity
- Sunspot numbers are calculated daily and are not just a count
- Sunspot number takes into account number of spots, size and grouping



Solar Flares

- Large eruptions of electromagnetic radiation from sun’s surface lasting minutes to hours
- Travels at the speed of light
- Increased EUV and X-ray on sunlit side of earth result in increased atmospheric ionization
- D-layer of ionosphere becomes more dense absorbing HF radio waves and causing disruptions in communication
- Primarily effects 3-30 MHz

Solar Flares

- Solar flares classified in intensity based on peak emissions in 0.1 – 0.8 nm spectral range monitored by satellites
- A, B, C, M, X level of flares

Solar Flares Class

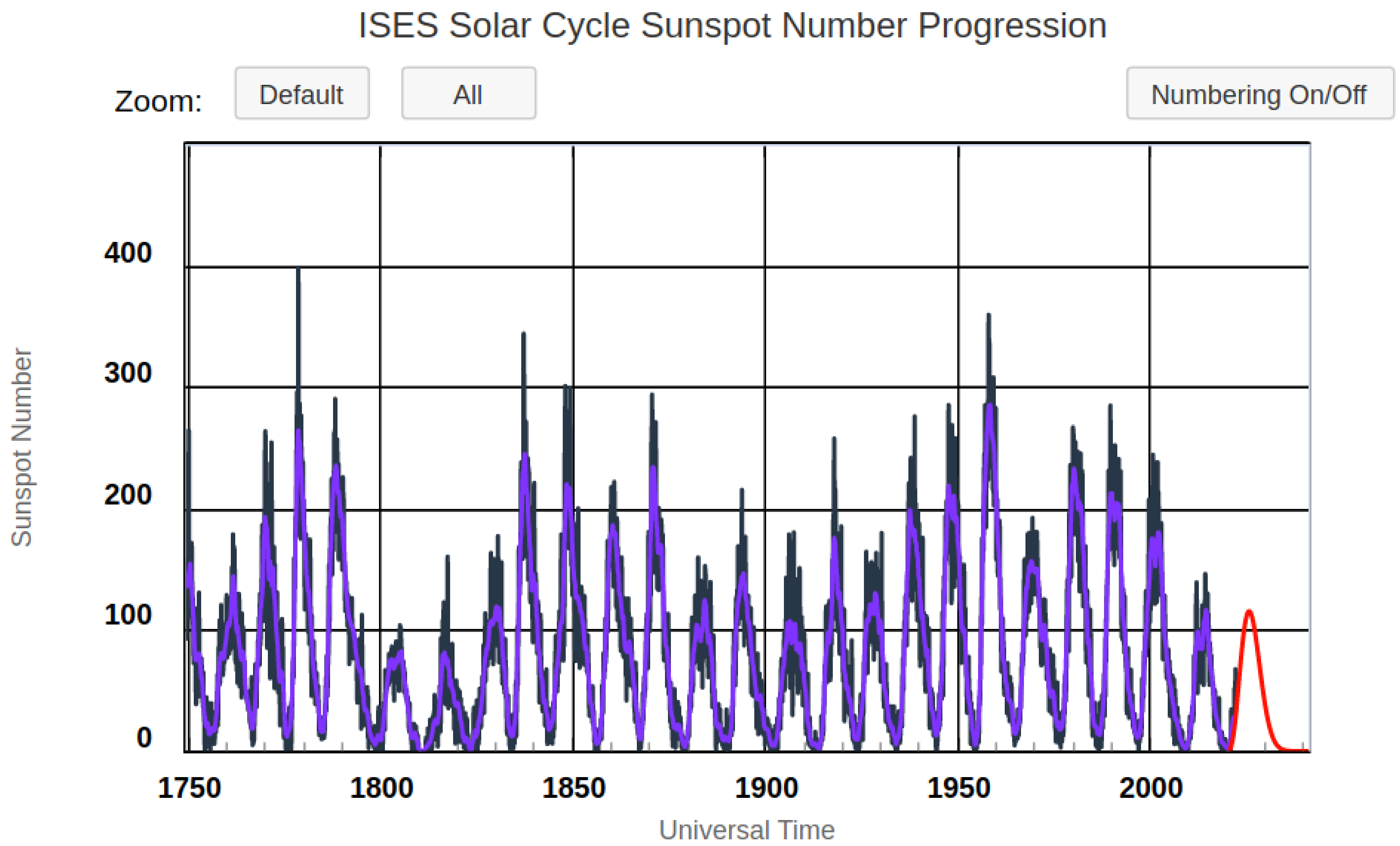
- M1 – minor radio blackout
- M5 – moderate radio blackout
- X1 – strong radio blackout
- X10 – severe radio blackout
- X20 – extreme radio blackout

Measuring Solar Activity

- Difficult to directly measure on earth
- Most radiation absorbed in atmosphere
- Satellite data
- Indirect measurements

Sun Spot Number

- International sunspot number
- Correlates with 11 year solar activity
- Average of direct solar observation at several locations
- Number of sunspots, grouping, scaling factor that accounts for method of observation


ISES Solar Cycle Sunspot Number Progression
Zoom:
Default
All
Numbering On/Off
Sunspot Number
0
100
200
300
400
1750
1800
1850
1900
1950
2000
Universal Time

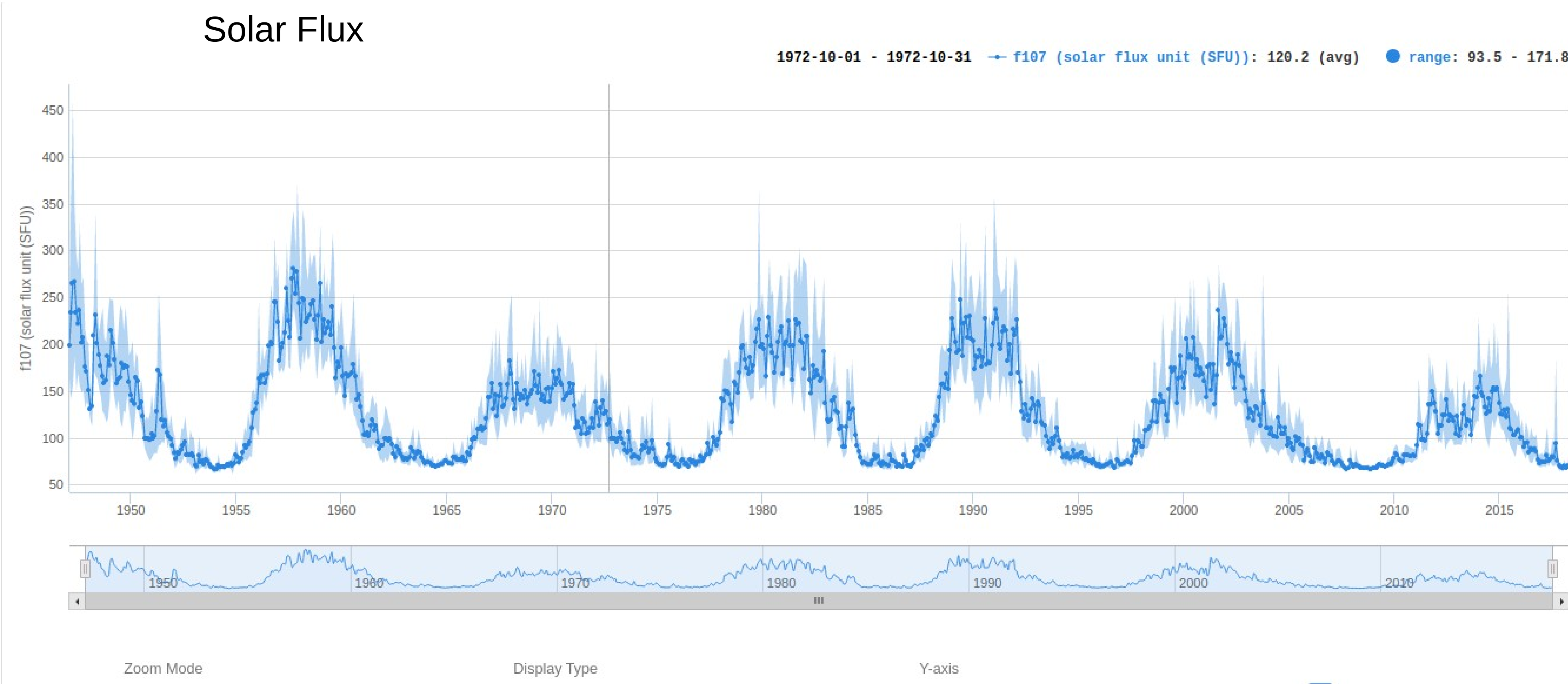
Solar Radio Flux 10.7 cm

- Radio signal 2800 MHz originating in solar atmosphere directly observable on earths surface.
- Not affected by weather
- High correlation between sunspot number and EUV values

Solar Radio Flux 10.7 cm

- Measured in solar flux units
- Measured in Canada since 1947
- Vary between below 50 sfu to over 300 sfu
- Measured in British Columbia and other parts of the world

Solar Flux



https://lasp.colorado.edu/lisird/data/noaa_radio_flux/

Magnetic Field Monitoring

- Planetary K-Index
  - Quantifies disturbances in earths magnetic field
  - Data obtained from worldwide magnetometers
  - Updated every 3 hours
  - 0 to 9 range
  - Geomagnetic storm warnings issued when predicted values 4 or above

Satellite Monitoring

- GOES-R satellites
  - Geostationary Operational Environmental Satellite
  - Solar Ultraviolet Imager SUVI full solar disk image
  - Extreme UV and X-ray Irradiance Sensor EXIS
  - The Space Environment In-Situ Suite (SEISS) measures proton, electron and heavy ion fluxes in the near earth-space environment.
  - Magnetometers measure magnetic field strength

SPACE WEATHER CONDITIONS on NOAA Scales

24-Hour Observed Maximums

R	S	G
none	none	none

R (None) Radio Blackout Impacts

No R-Scale Radio Blackouts

More about the NOAA Space Weather Scales

R – Radio Blackouts
S – Solar Radiation Storm Impacts
G – Geomagnetic Storm Impacts

1 – Minor
2 – Moderate
3 – Strong
4 – Severe
5 – Extreme

Ham Sci

- Personal Space Weather Station (PSWS)
- Citizen-science network of monitors
- Magnetometers to monitor earths magnetic field
- University of Scranton
- Dr. Nathaniel A. Frissell, W2NAF

Resources

- Space Weather Prediction Center – NOAA
- Spaceweather.com
- Dr. Tamitha Skov Space Weather Woman

Summary

- Powerful solar events have disrupted life on earth in the past when technology was in its infancy.
- A similar event today could cause serious and widespread disruption of modern life.

Summary

- Electromagnetic radiation and charged particles emanate from the sun and interact with earth’s magnetic field and ionosphere.
- Delicate balance between enjoyment of increased radio wave propagation to disruption of communications.

Summary

- Many ways of monitoring solar activity
- Direct observation of sun through satellites EUV, X-ray and ionized particle measurement.
- Orbiting and earth bound methods of measuring geomagnetic field
- Sun spot number and solar flux measurement at 10.7 cm

The End

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