The Sun's Solar Cycle
&
HF Radio Communications

Ken Larson KJ6RZ
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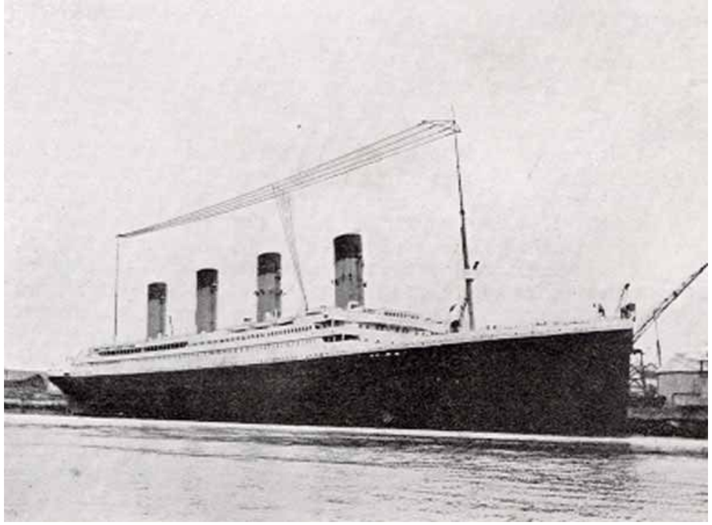
The Solar Cycle & HF Radio Communications

- We all know, that over the horizon HF communications is possible because of Earth's ionosphere
- This presentation focuses on the solar activity responsible for both
  - Creating and
  - Disrupting the ionosphere
- Once we know what is happening on the Sun, we can more effectively utilize the ionosphere by combining solar data with our understanding of:
  - Critical & maximum useable frequency
  - Maximum usable angle, skip distance & propagation modes
  - Fading, absorption & other phenomena
- But these are topics for a later discussion

Early Understanding of Radio Wave Propagation



(credit: astrosurf.com)

Commercial & government operating frequencies: 50 – 1000 KHz

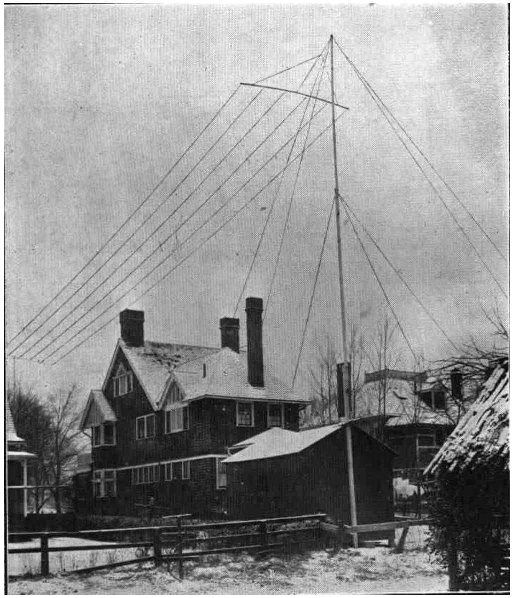
Marine distress freq: 500 KHz

Amateurs radio operators exiled to worthless frequency of 1.5 MHz (200 meters)

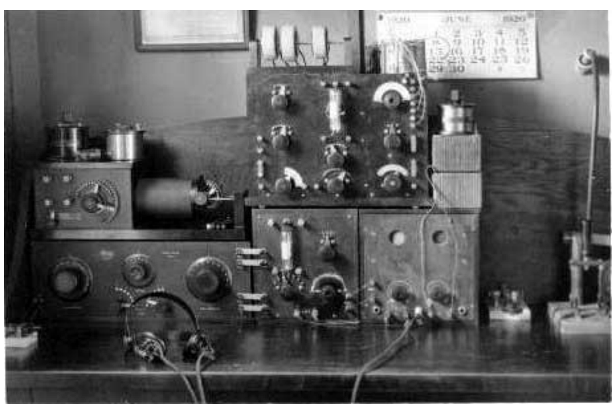
Can you imagine spending all of your amateur radio time on 160 meters?

- Early on it was known that radio signal strength and quality varied:
  - **Throughout the day**, and
  - **Seasonally**
- By 1910 maritime radio operators knew
  - Radio signals traveled further at night, and
  - Were less noisy in the winter.
- They believed that the quality of radio transmission was directly proportional to wavelength.
- Longer wavelengths = longer distance more dependable radio transmissions

Short Wave Radio and the Solar Sunspot Cycle



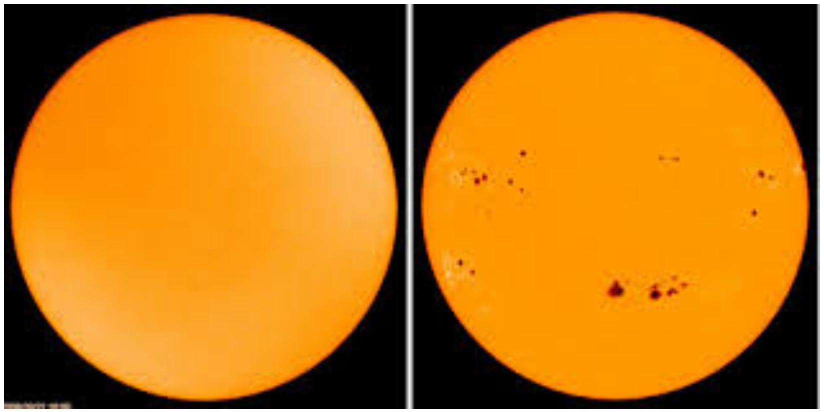
(credit: ARRL)

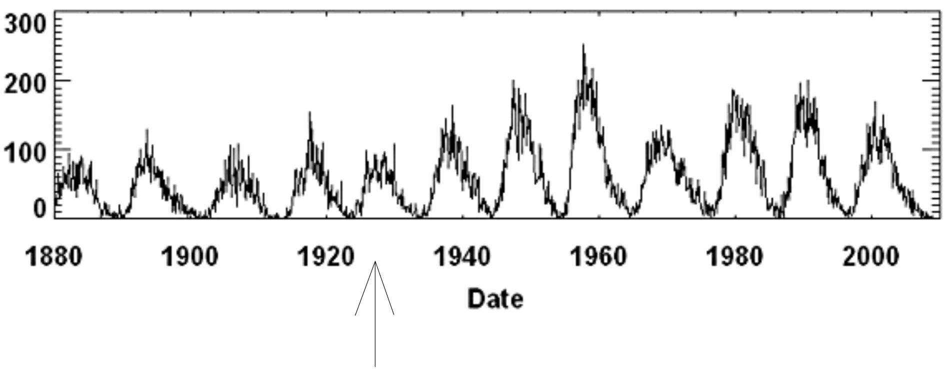


(credit: oldpassions.com)

- In October 1924 amateurs were given the short wave frequency bands of 80, 40, & 20 meters, even more worthless than 200 meters
- Some amateurs reluctantly moved to these new frequencies to avoid crowding on 200 meters
- The movement became a stampede when it was discovered that Europe, New Zealand, etc. could be reliably worked on 40 & 20 meters
- But the good times came to an end ---- by 1933 20 meters had become a dead band
- No one knew why, it just died
- By 1935 short wave radio bands came back to life
- It gradually became apparent that performance on the short wave bands was tracking the solar cycle.

What Is The Solar Cycle





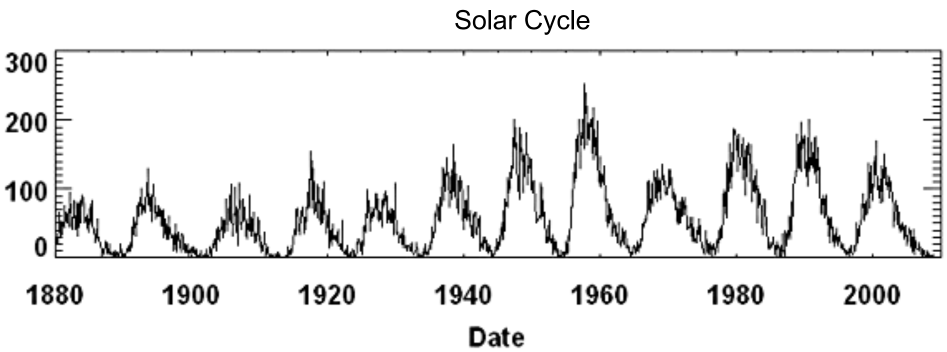
Cycle 16 peaked in 1928 with excellent long distance communications on 40 & 20 meters

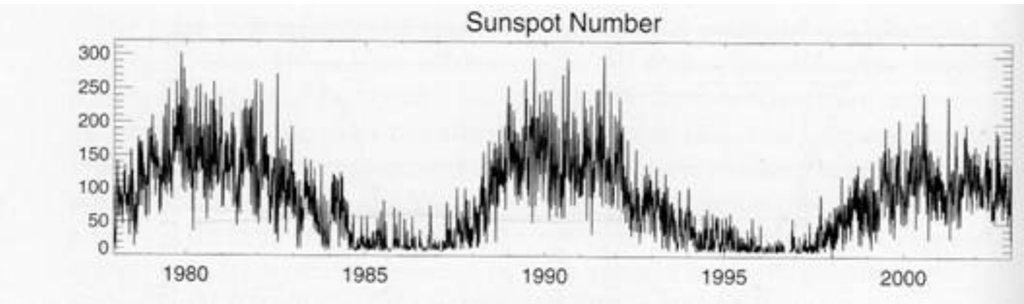
But 20 meters dead by 1933

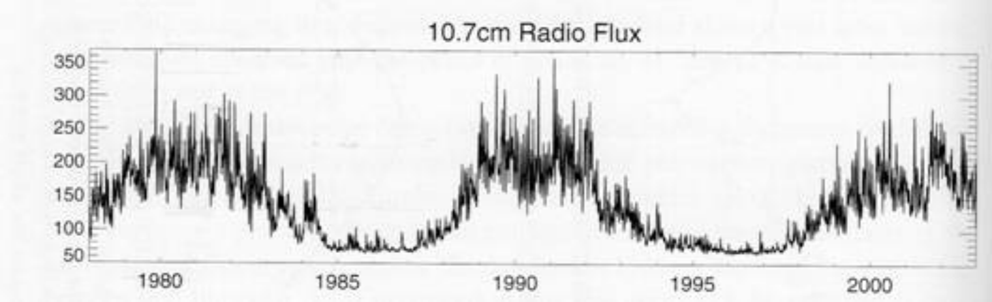
In 1935 short wave comm on 20m came roaring back

- The solar cycle is the variation in sunspots visible on the Sun from no sunspots, to large numbers of spots, back to no sunspots
- A solar cycle is roughly 11 years in duration, but ranges from 8 – 15 yrs
- It begins at sunspot minimum when few if any sunspots are visible.
- Increasing numbers of sunspots appear at a fairly rapid rate as the cycle progresses.
- The sunspot cycle reaches a maximum (large numbers of sunspots) in roughly 3 to 5 years.
- The number of sunspots then slowly decreases in 5 to 8 years reaching a minimum at the end of the cycle
- Solar cycles vary widely in
  - Amplitude (max number of sunspots)
  - Shape
  - Period

Counting Sunspots



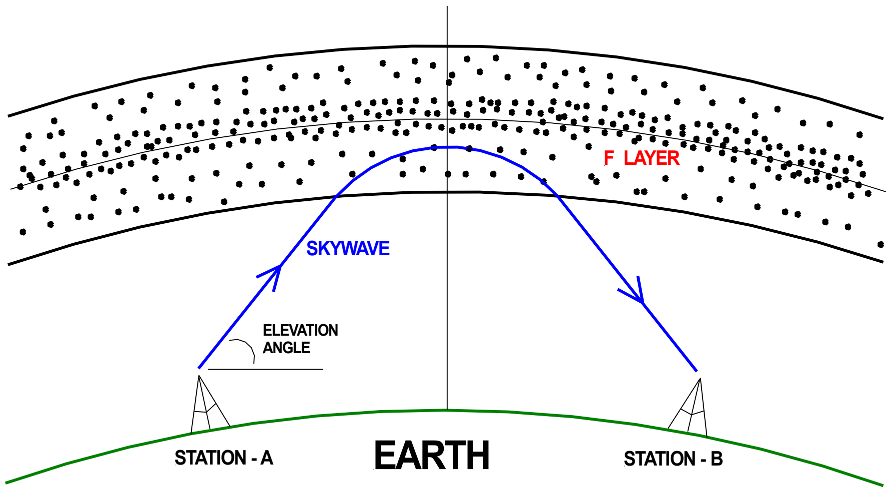


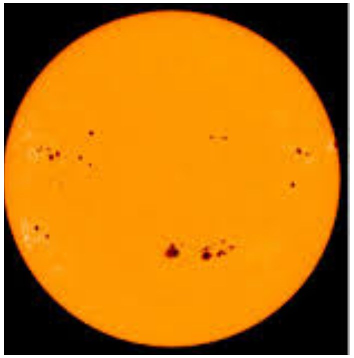


Solar Maximum SFI ~ 225
Solar Minimum SFI ~ 65

- In 1848 Rudolph Wolf established a standardized method for counting sunspots using the equation:
  - **R = k (10g + s)**
  - R = relative sunspot number
  - g = number of sunspot groups observed on the solar disk
  - s = total number of individual spots observed, including those in sunspot groups
  - k = a variable scaling factor
- The **10.7cm Solar Flux Index (SFI)** is a daily measurement of radio noise being produced by the Sun at a frequency of 2,800 MHz
- SFI is a very reliable modern technology method of measuring solar activity
- Note that the daily relative sunspot number and SFI track very closely

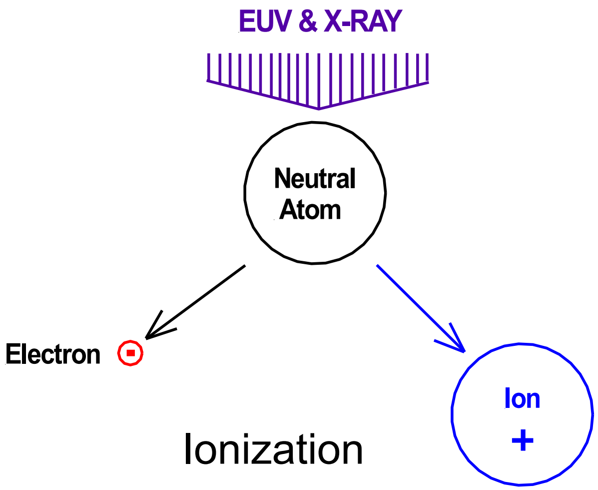
HF Skywave Propagation

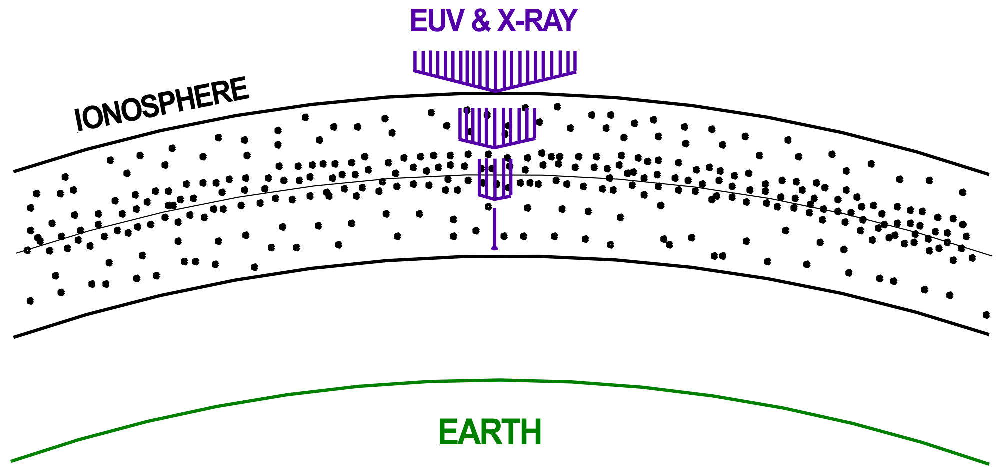




- In 1925 Edward Appleton proved that HF comm occurred by skywave propagation
- Before then no one really knew how radio communications occurred, it just did
- After the 40 & 20m rollercoaster experience from 1924 – 1935, the question became: why does the number of sunspots on the Sun, or lack there of, have such a tremendous impact on HF communications?
- To answer this question we first need to know two things:
  1. How and why the ionosphere forms in the Earth's upper atmosphere
  2. Why the ionosphere causes radio signals to bend back to Earth

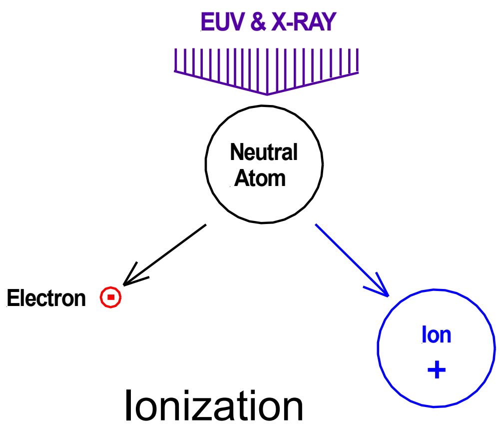
Formation of the Ionosphere

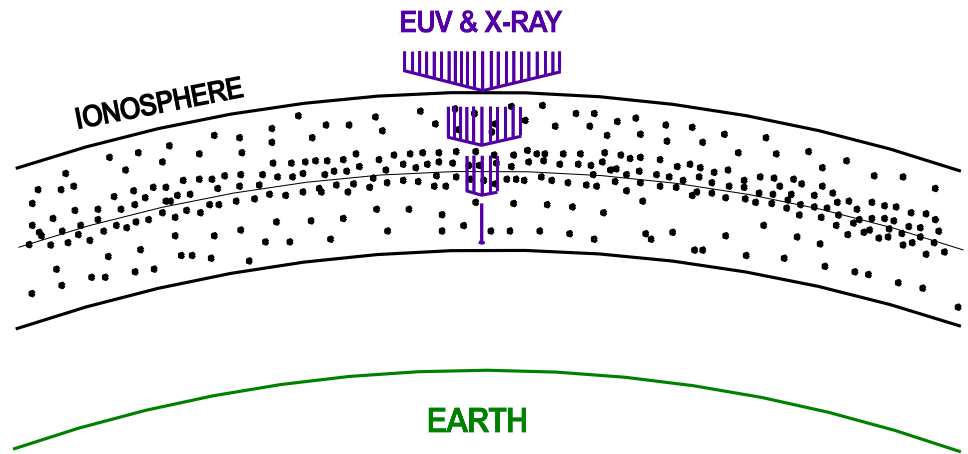




- EUV & X-ray radiation from the Sun ionizes atoms in the upper atmosphere.
  - Solar radiation absorbed by a neutral atom transferring energy to its electrons
  - **Occasionally** an electron is sufficiently energized that it breaks away from its parent atom forming a free electron and a positive ion (an atom that has lost one of its electrons)
  - There are 100 times more neutral atoms in the upper atmosphere than ions
  - The ionosphere is very thin, wispy, and easily blown around

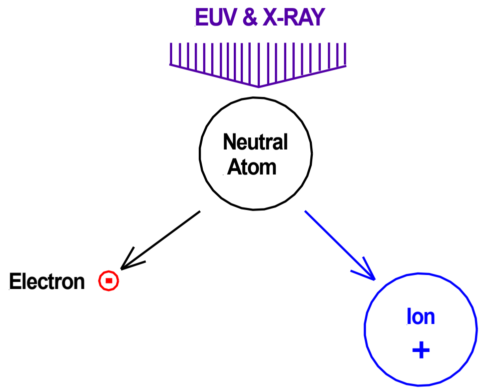
Formation of the Ionosphere

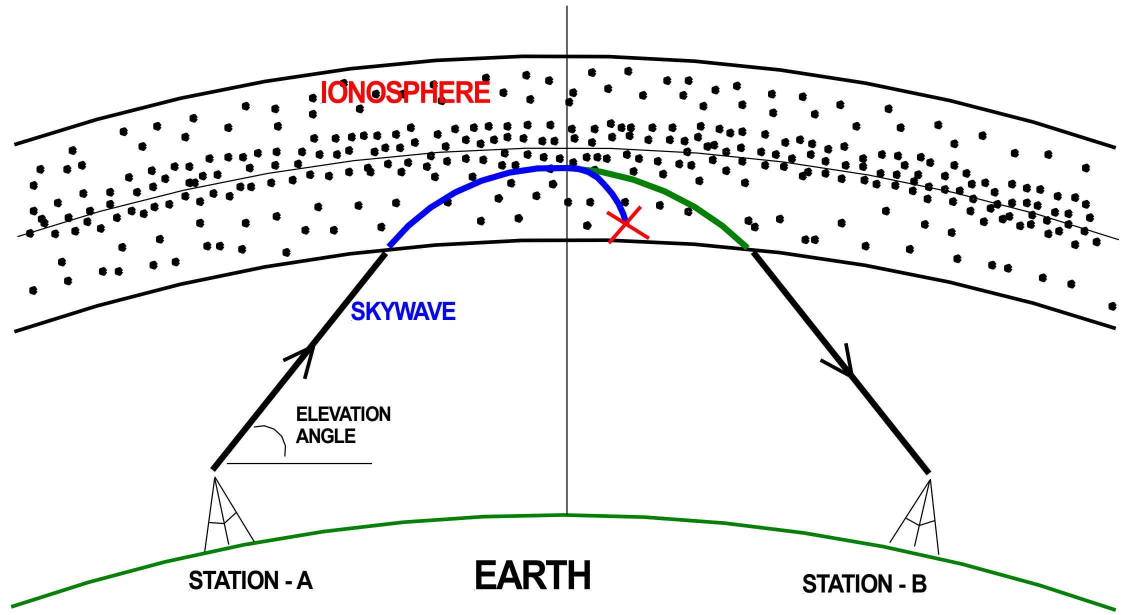




- Radiation is intense at the top of atmosphere but few atoms to ionize.
- As the radiation penetrates deeper into the atmosphere, it encounters more and more nitrogen & oxygen atoms resulting in higher levels of ionization.
- The ionization process weakens the EUV & X-ray radiation
  - The number of atoms keeps increasing as radiation penetrates further into the atmosphere
  - But levels of ionization decrease due to weakening radiation
  - Ionizations levels drop and eventually disappear.
- Note that ions are way too massive to be affected by our puny radio waves
- But tiny electrons interact readily with our radio waves – that is why electron densities are so important

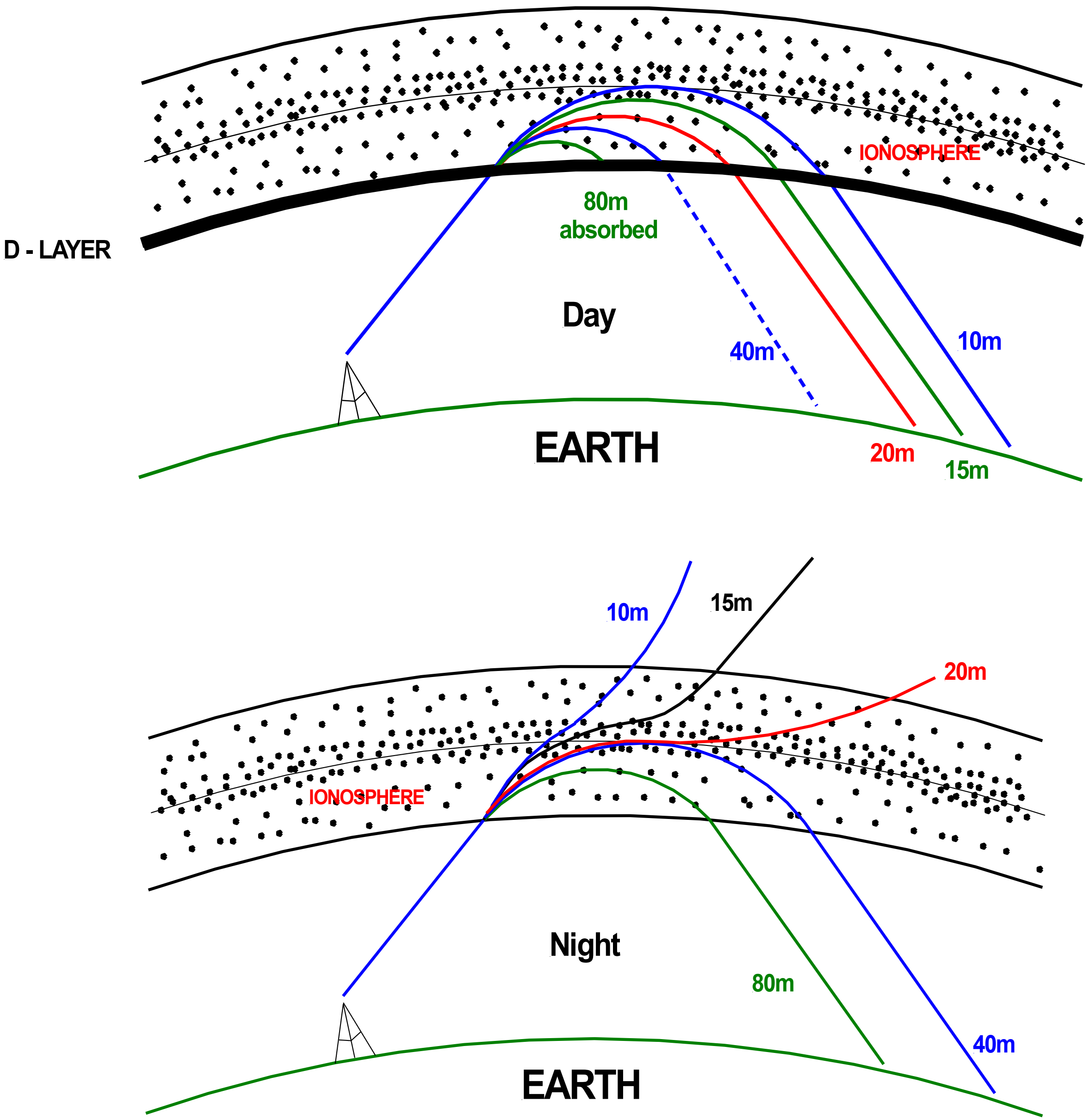
How Skywave Propagation Works

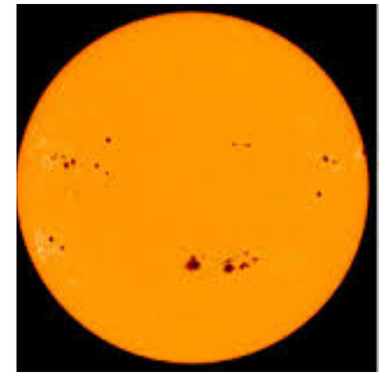




- Highest levels of ion and electron densities occur in middle of ionosphere
- Radio waves travel in a straight line from the transmitting antenna to the ionosphere
- They begin bending as soon as they enter the ionosphere, but in what direction
- **Radio waves bend toward the Earth as electron densities INCREASE**
- **Radio waves bend away from the Earth when electron densities DECREASE**
- After exiting the ionosphere they travel again in a straight line to the receiving antenna

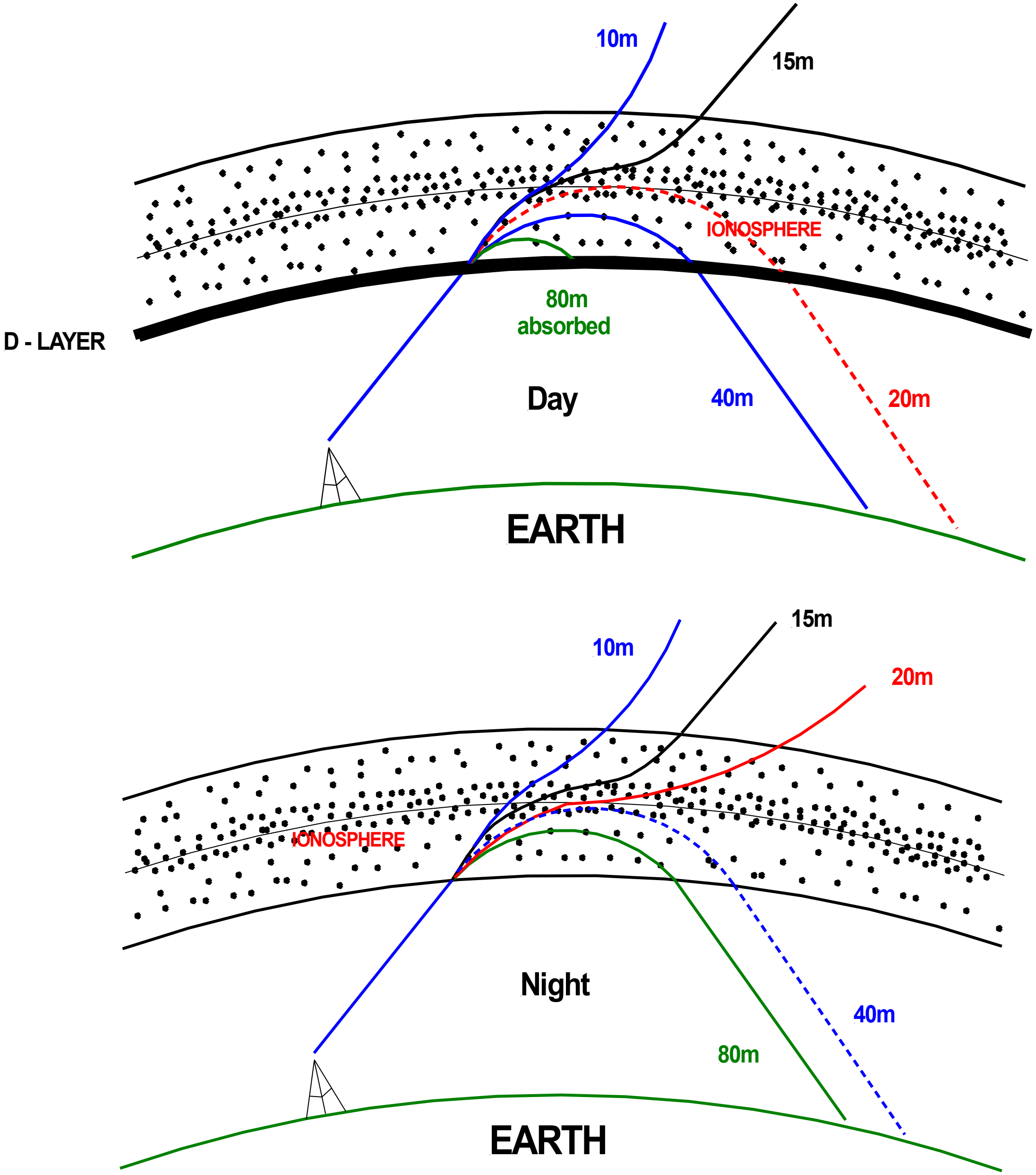
Trends in HF Communications During Solar Maximum





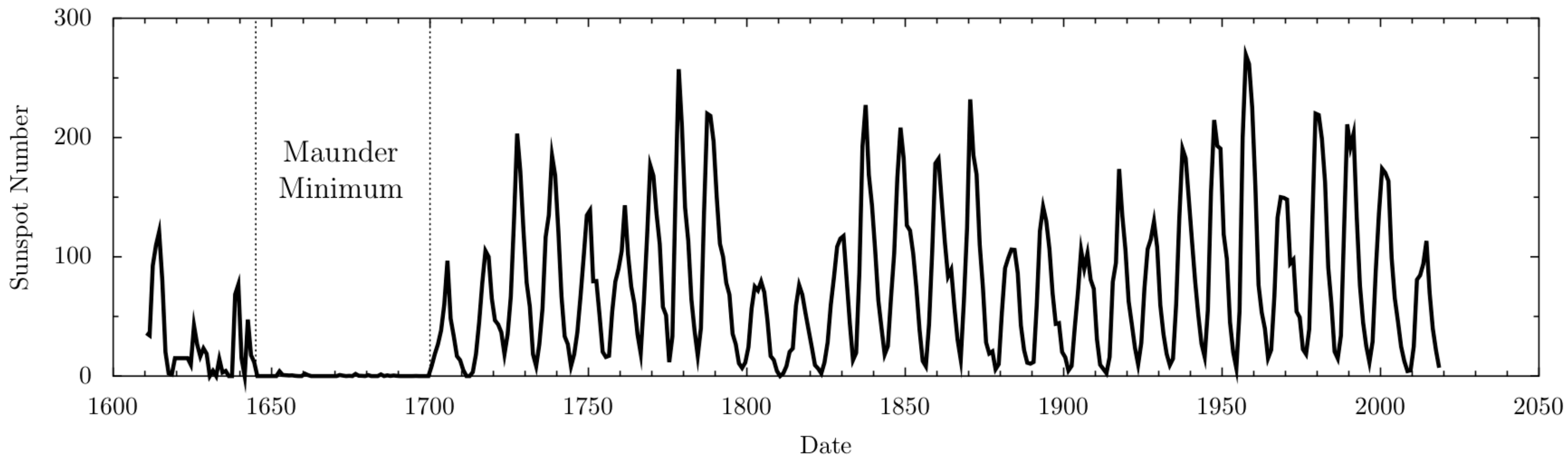
- The radiation from the Sun is intense during solar maximum when large numbers of sunspots are visible on the Sun
- The ionosphere becomes heavily ionized during the day
- At night levels of ionization drops, due to lack of sunlight, as electrons and ions recombine

Trends in HF Communications During Solar Minimum



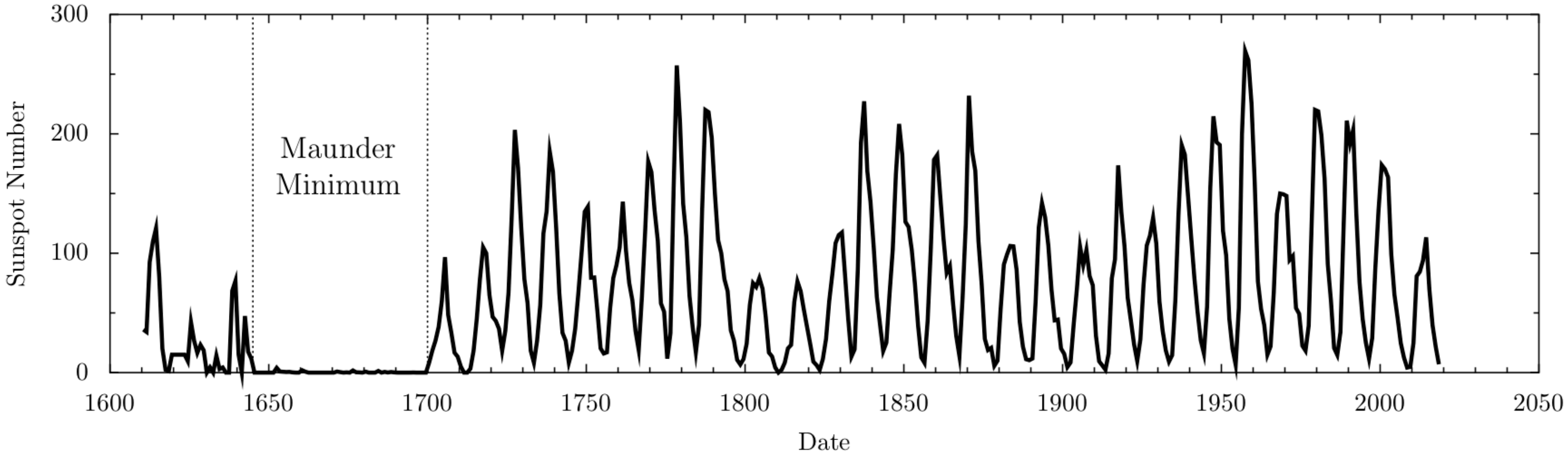
- Radiation from the Sun is weak during solar minimum when few if any sunspots are visible on the Sun
- The Earth's ionosphere is in turn weakly ionized during the day
- At night levels of ionization drop even further, due to lack of sunlight, as electrons and ions recombine

Sunspot Cycles
Have Been Observed & Recorded for a Long Time



- The number of sunspots have been studied for over 400 years.
  - 1610 Galileo began observing the Sun with his telescope
- What is interesting in this picture is
  - The Maunder Minimum
  - Periodic dips in the amplitude of solar cycles
- Periodic amplitude dips occur every 80 to 120 years
- Are we due for the next dip?

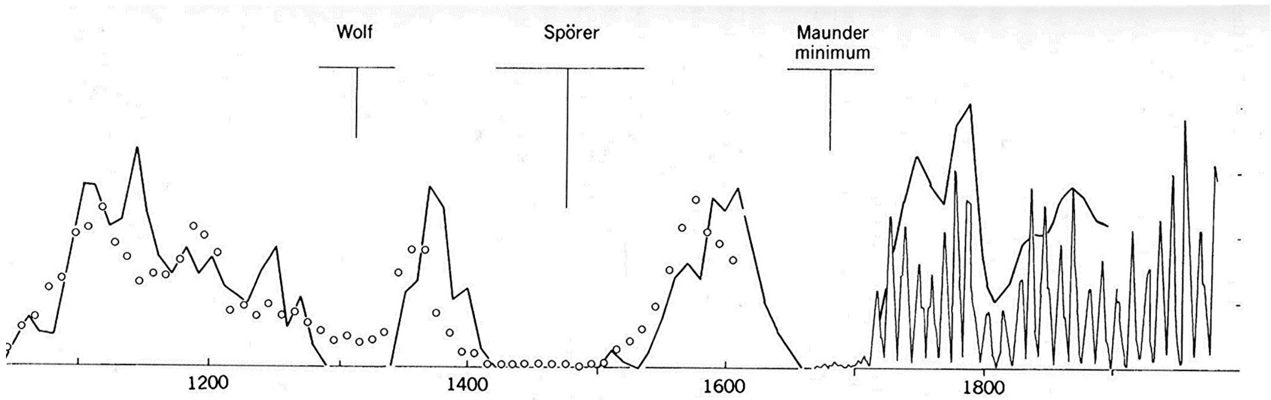
Maunder Minimum



(credit: D. Hathaway)

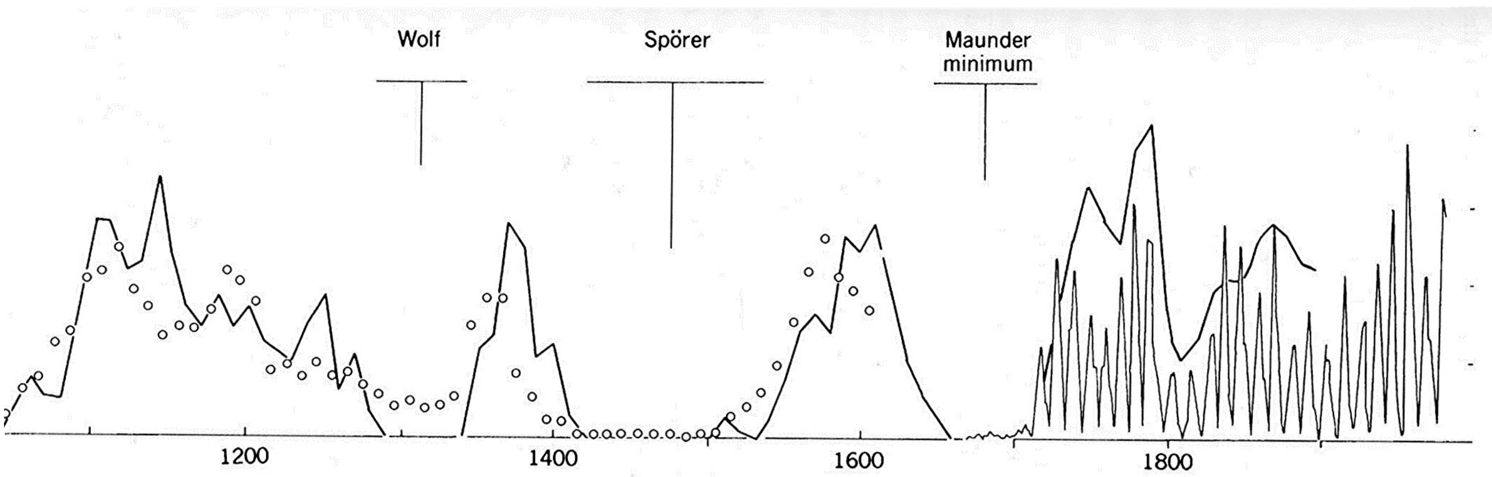
- For 70 years, from 1645 to 1715, there were few if any sunspots visible on the Sun.
- That was a long time ago.
- One could speculate that astronomers and scientists at the time were simply not vigilant in observing the Sun.
- However, records show that the Sun was continuously and carefully observed.
- There simply were not any sunspots.

Other Prolonged Solar Minimums



- There have been other prolonged solar minimums throughout history
- Evidence of earlier prolonged minimums provided by presence of carbon-14 in tree rings
  - Carbon-14 is produced by energetic cosmic rays colliding with nitrogen in Earth's upper atmosphere (cosmic rays = high-energy atomic nuclei moving at nearly the speed of light)
  - Carbon-14 makes its way down to the lower atmosphere, is absorbed by tree leaves through photosynthesis, and ends up in tree rings as trees grow.
  - During solar maximum the Sun's intensified magnetic field partially shields the Earth from cosmic rays resulting in less carbon-14 being produced.
  - **Solar Maximum = low levels of carbon-14 in tree rings**
  - **Solar Minimum = High levels of carbon -14**

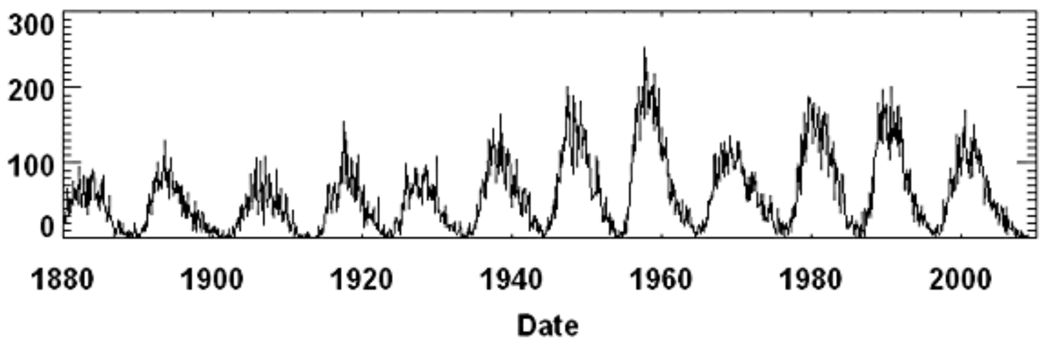
Implication



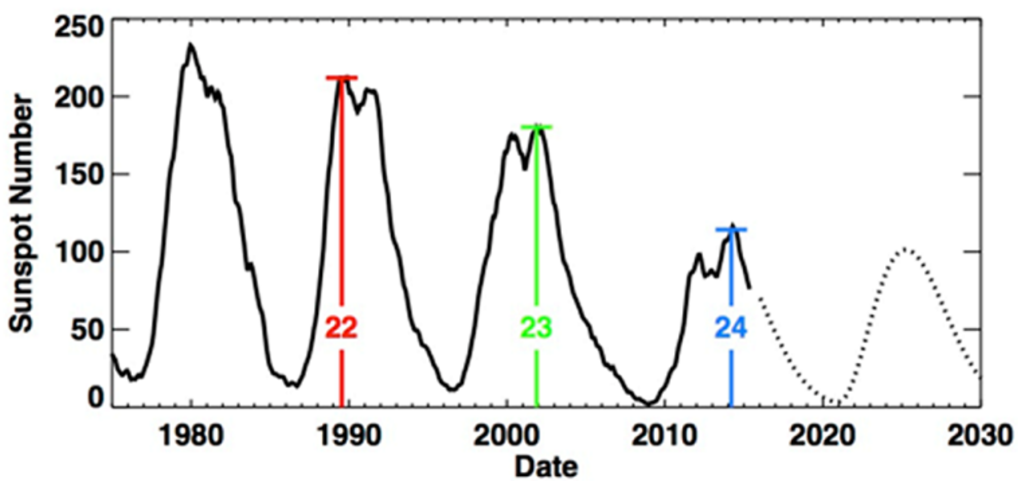
(Credit: J. Eddy)

- The fairly regular behavior of the sunspot cycle over the last 300 years may NOT be the norm.
- It appears that prolonged solar minimums occur at regular intervals
- We may be over due for the next prolonged minimum !

Sunspot Activity Weakening



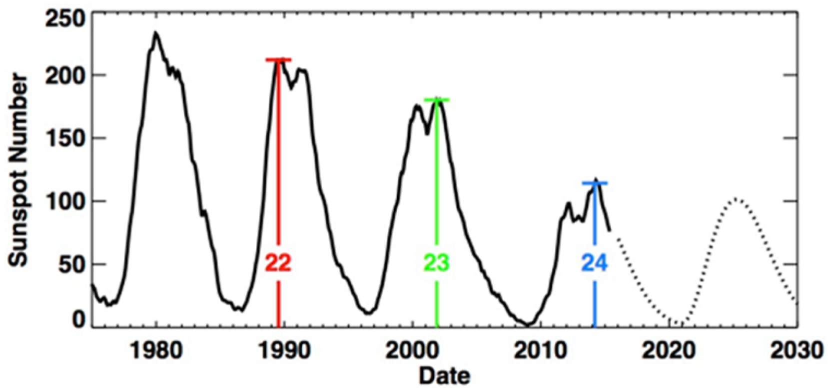
(credit: SpaceWeather.com)

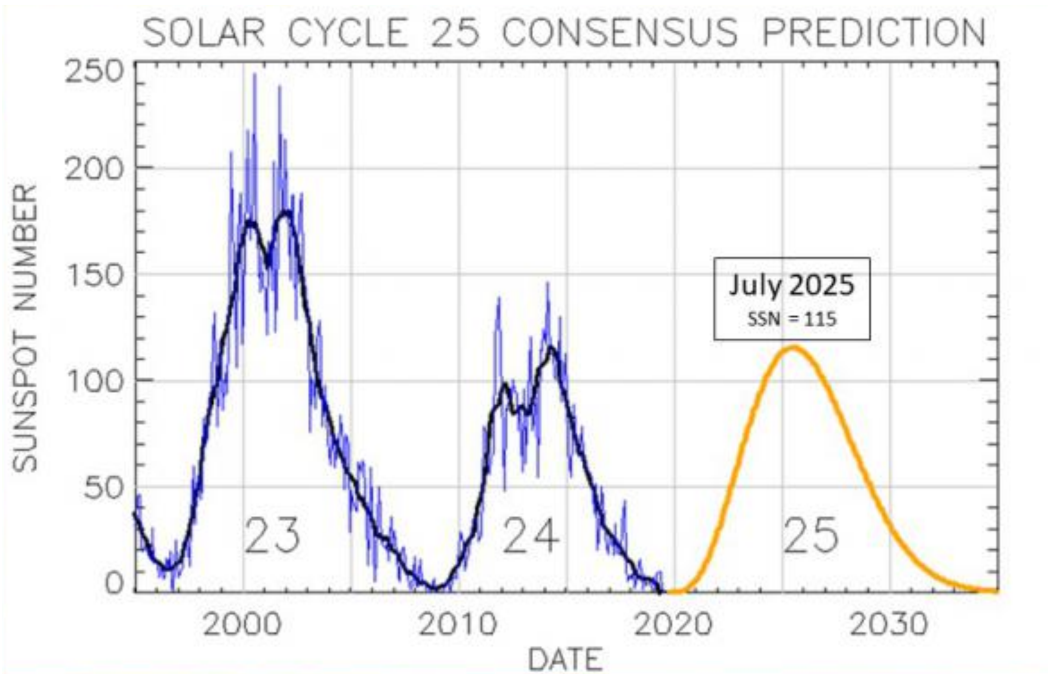


(credit: D. Hathaway)

- Sunspot cycles were relatively consistent from 1880 – 1928.
- Sunspot activity increased from 1928, peaking in 1957.
- Since 1980 sunspot activity has slowly declined.

Solar Cycle 25

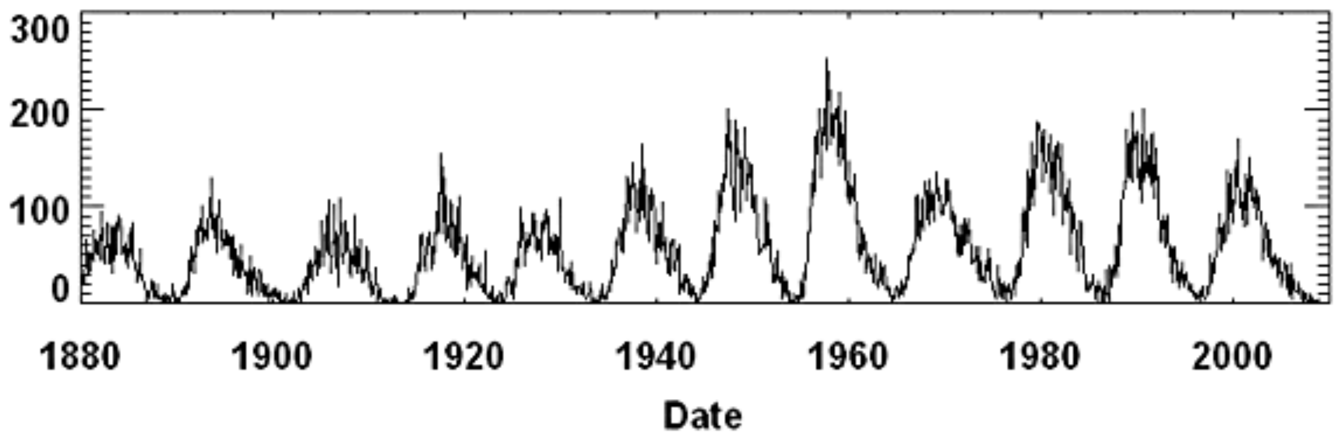




(credit: NOAA Space Weather Prediction Center)

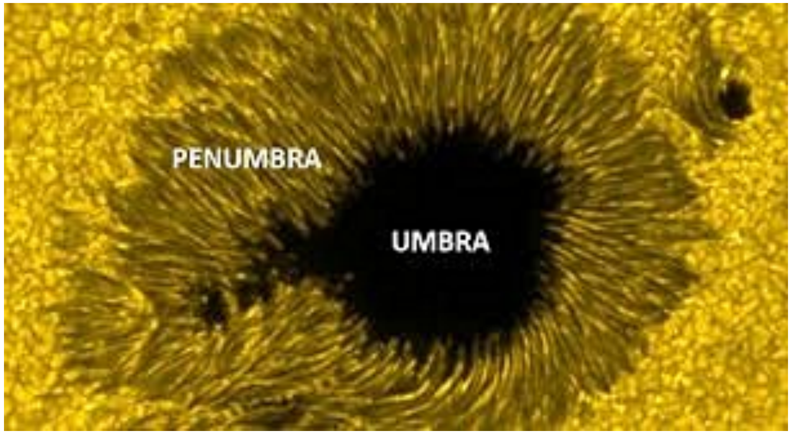
- Sunspot activity during Cycle 24 was about the same as early days of amateur radio.
- **Solar cycle 25, peaking in 2025, is expected to be similar to Cycle 24.**
- Will Solar Cycle 25 be an amplitude dip?

Sunspot Activity During WW-II



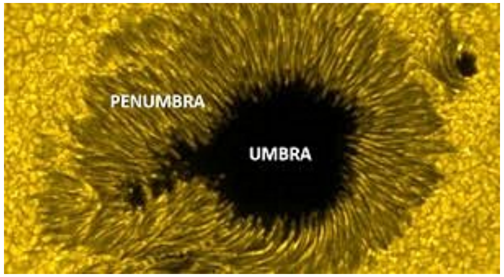
- Notice that a sunspot maximum occurred in 1937, just as WW-II was beginning, resulting in excellent world wide HF radio communications at the time.
- HF radio communications deteriorated throughout the war.
- Sunspot minimum occurred in 1944 and persisted through the last year of the war.
- Despite deteriorating conditions, radio operators learned how to deal with the situation and got their radio traffic through.
- They had to!
- At the time HF radio was the only means available for long distance communications

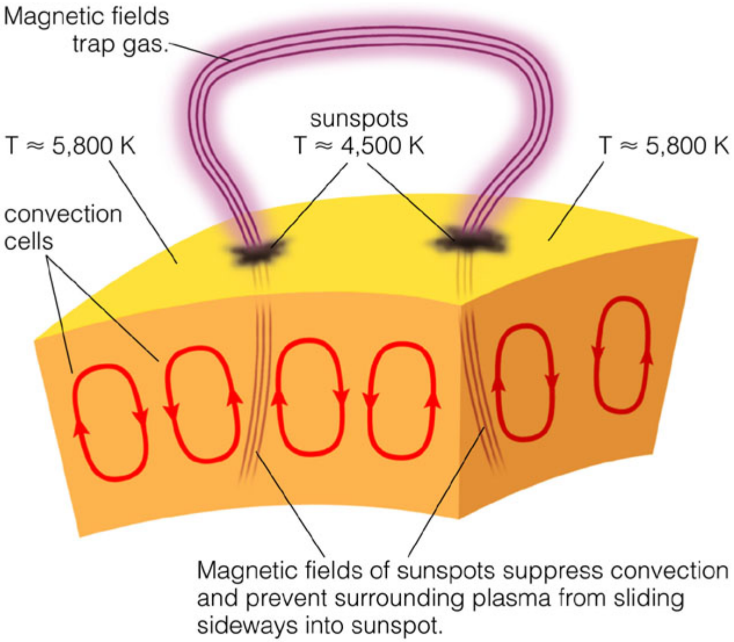
What Are Sunspots



- Sunspots are black blemishes visible on the Sun's "surface".
- A sunspot consists of a black center called the umbra and a lighter colored penumbra
- The Earth could be easily "dropped" into the umbra and disappear forever.
- Sunspots appear.
- Last several days.
- And then disappear.
- Some sunspots may last for several weeks.

Why a Sunspot is Black

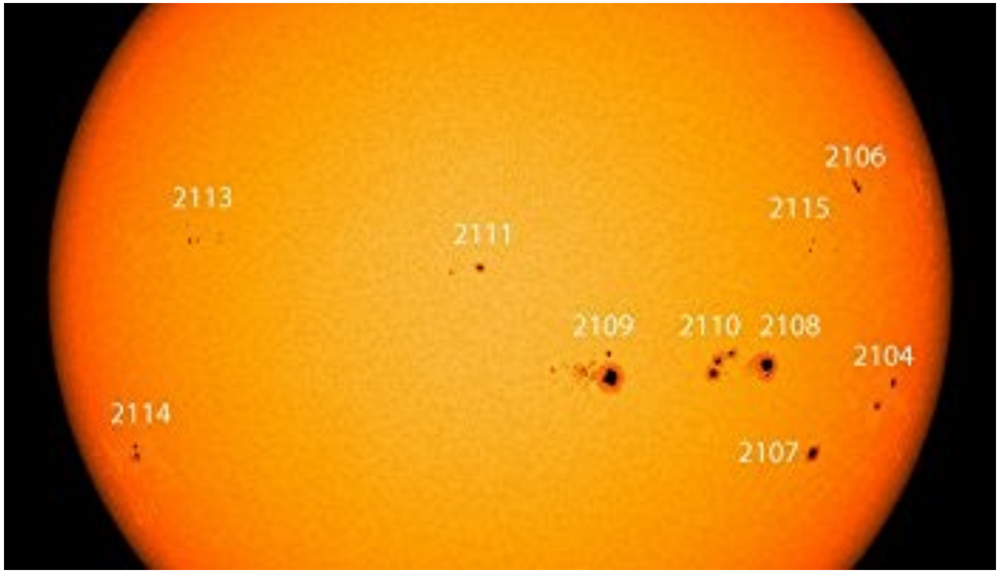




(Credit: Addison Wesley)

- Sunspots occur in pairs or groups
- A sunspot develops at a point where the Sun's magnetic field erupts through the photosphere (the Sun's visible surface).
- A second sunspot occurs were the magnetic field plunges back into the photosphere.
- The erupting magnetic field prevents hot plasma from deep within the Sun from reaching the photosphere at the eruption site.
- Consequently, the eruption site is cooler than the surrounding photosphere causing the site to appear as a black spot

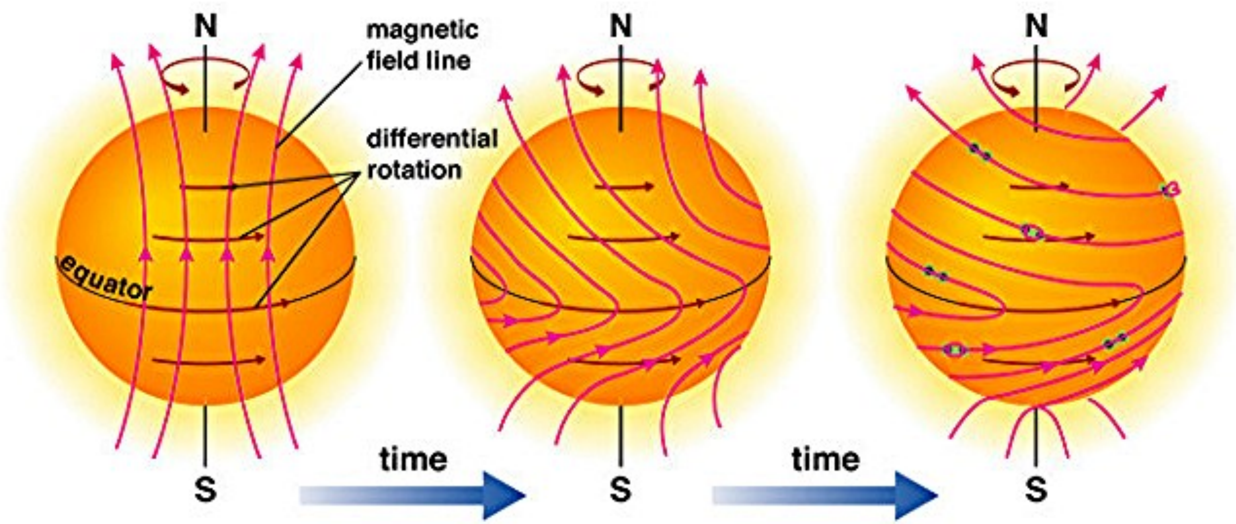
Sunspots Rotate With The Sun



(credit: NOAA Space Weather Prediction Center)

- Sunspots are part of the Sun's photosphere and thus rotate with the Sun.
- In the above picture, sunspots move from left to right.
- Sunspots that disappear around the right limb of the Sun may reappear about 13 days later at the left edge of the Sun

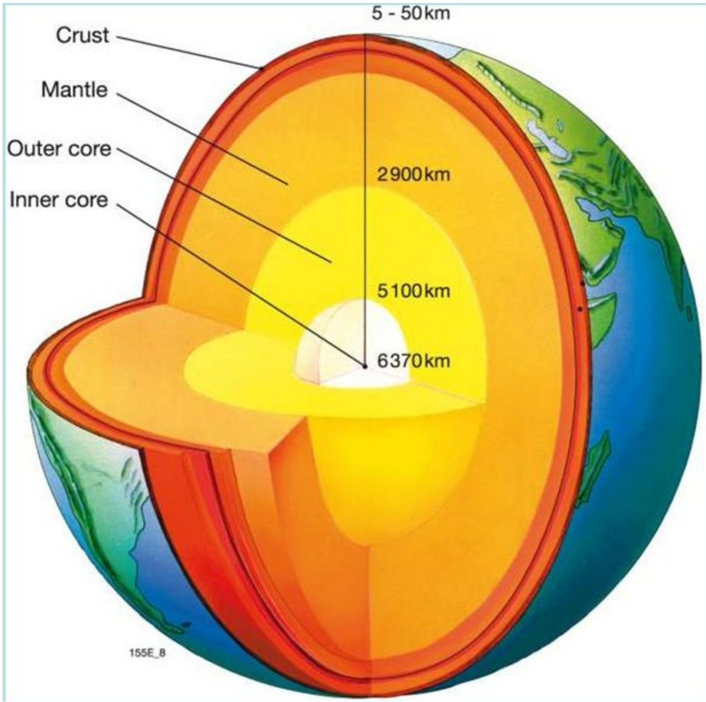
So Why Does The Solar Cycle Occur?

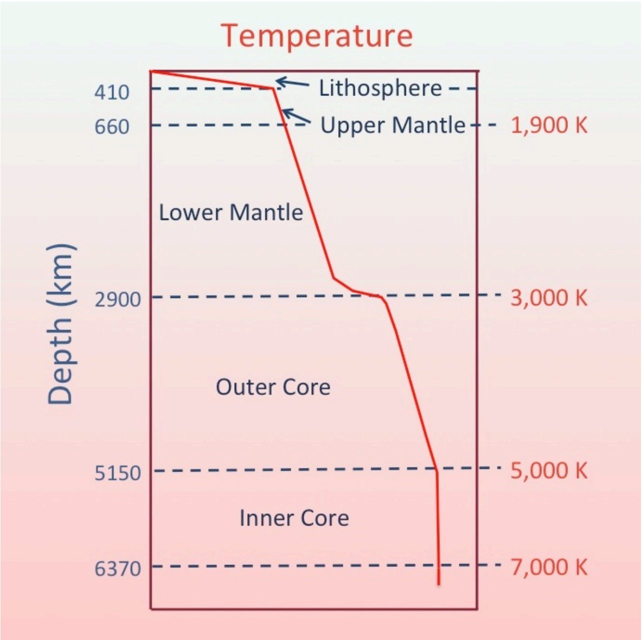


(skyandtelescope.com)

- **The answer is the Sun's very "twisted and tortured" magnetic field**
- Looking at how the Earth's stable well behaved magnetic field formed helps us to better understand the ciaos occurring on the Sun.

Earth's Structure

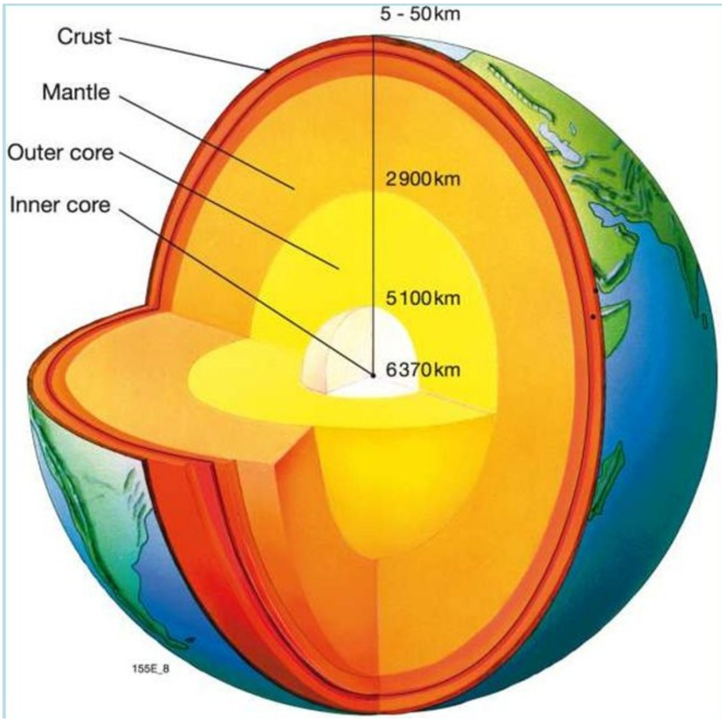


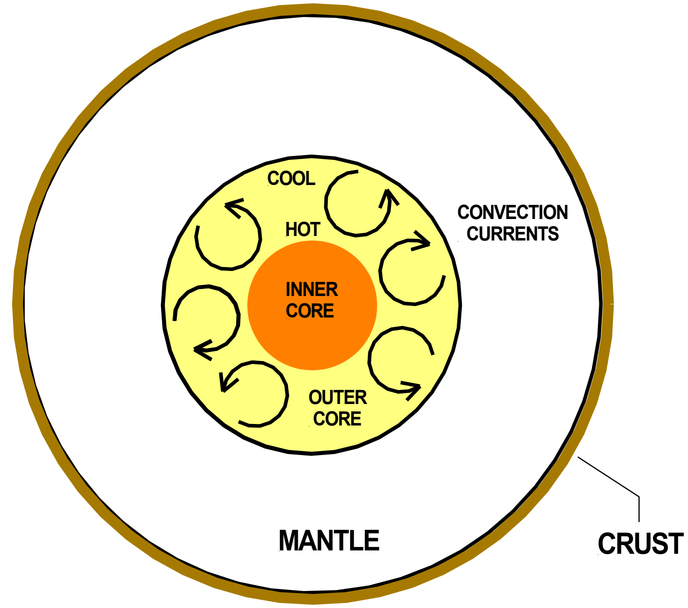


(credit: Wikipedia)

- The Earth's curst ranges from 5 – 70 km in depth and is the outermost layer.
- The Earth's mantle extends to a depth of 2,890 km, making it the thickest layer of the Earth. The mantle is composed of silicate rocks rich in iron and magnesium.
- The outer core is molten nickel-iron. High temperatures in the outer core cause some of the nickel-iron atoms to be ionized creating an electrically charged plasma.
- Temperatures in the Earth's inner core are extremely high. Despite its high temperature the inner core is compressed into solid nickel-iron by the Earth's gravity.

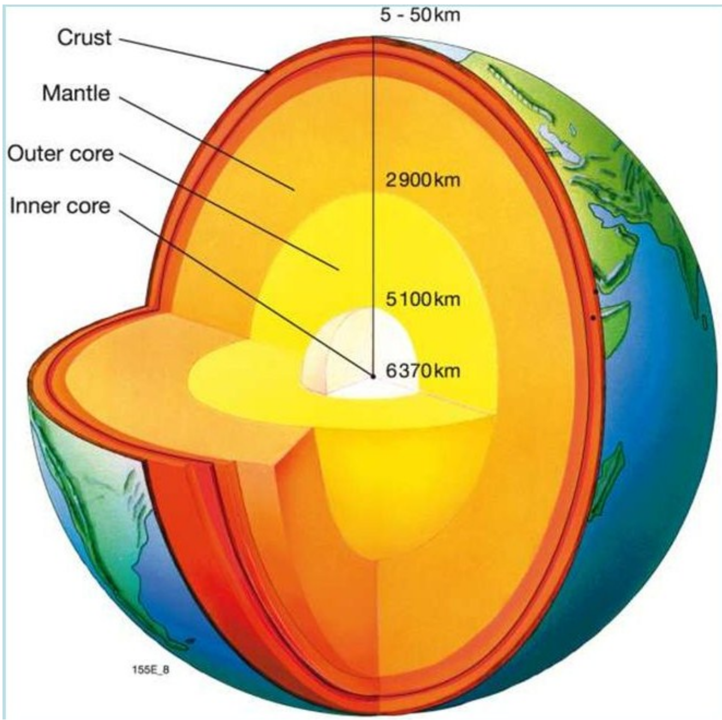
Convection Plasma Flow

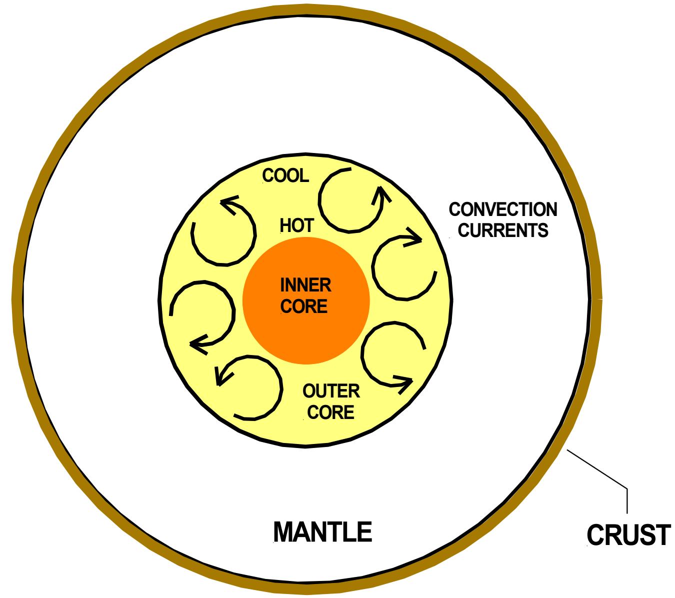




- Convection currents within the outer core transport hot molten nickel-iron from the region just above the inner core to the cooler mantle.
- The molten nickel-iron cools as it approaches the mantle and sinks back toward the inner core.
- As the molten nickel-iron sinks, it is heated, and again flows outward toward the mantle beginning a new cycle.

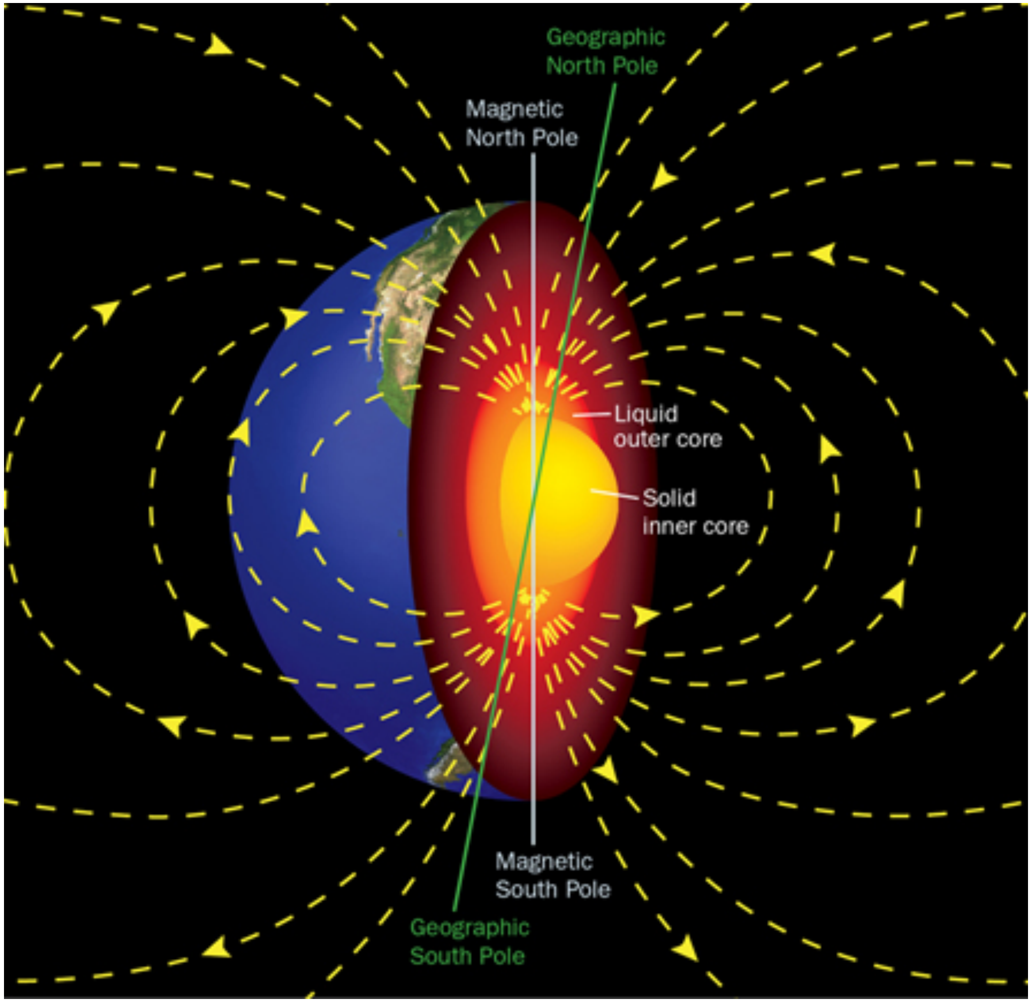
Circulating Electrical Currents





- Since the hot molten nickel-iron is a plasma with an abundance of positively charged ions and negative electrons, the convective flow of the plasma creates circulating electrical currents within the outer core.

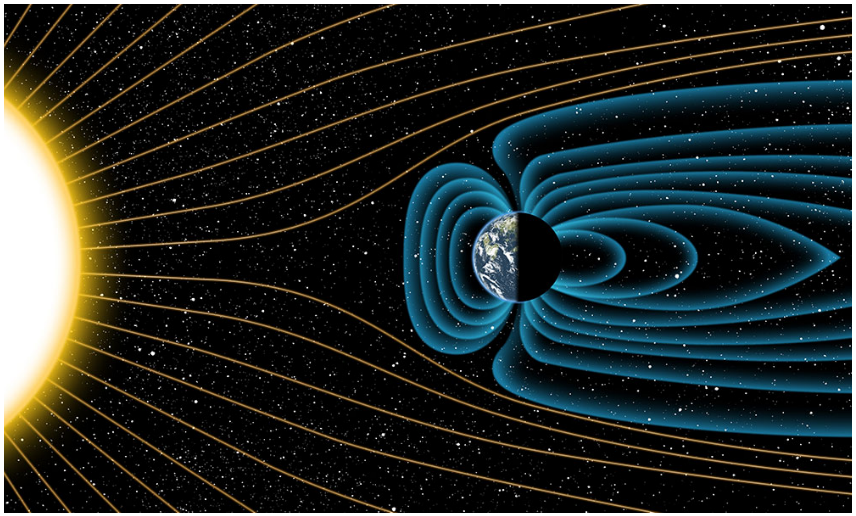
Formation of Earth's Magnetic Field



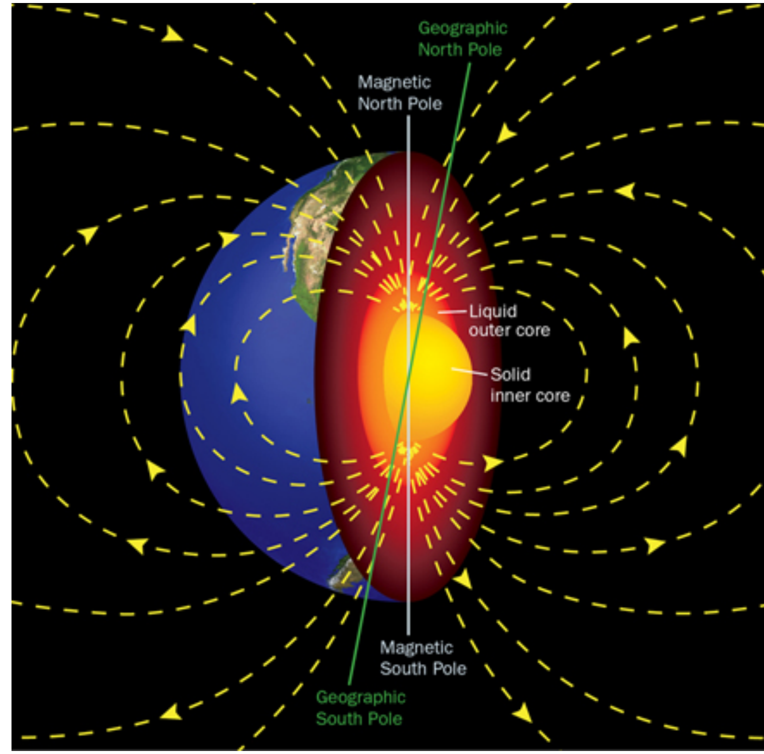
(credit: Quora)

- The circulating electrical current creates a magnetic field in accordance with Ampere's Circulation Law.
- In this case, the Earth's magnetic field.
- Note that this field is created deep within the Earth.
- The Earth's magnetic field changes slowly over time, but is stable for millions of years.

Earth’s Magnetic Field is Important to Us

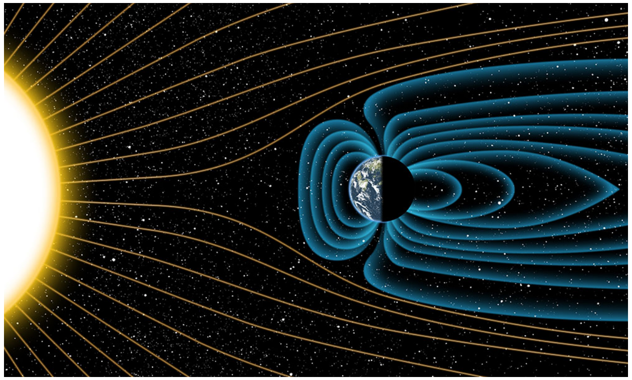


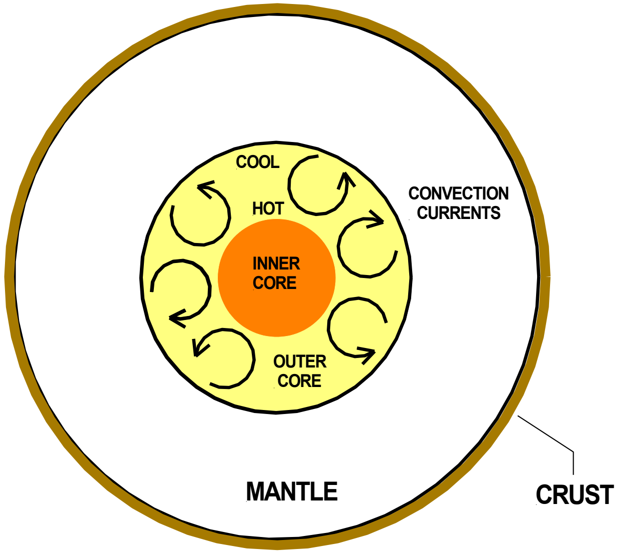
(credit: University of Rochester)



- Earth’s magnetic field creates a protective sheath around the Earth diverting the Sun’s harsh solar winds away from Earth’s surface.

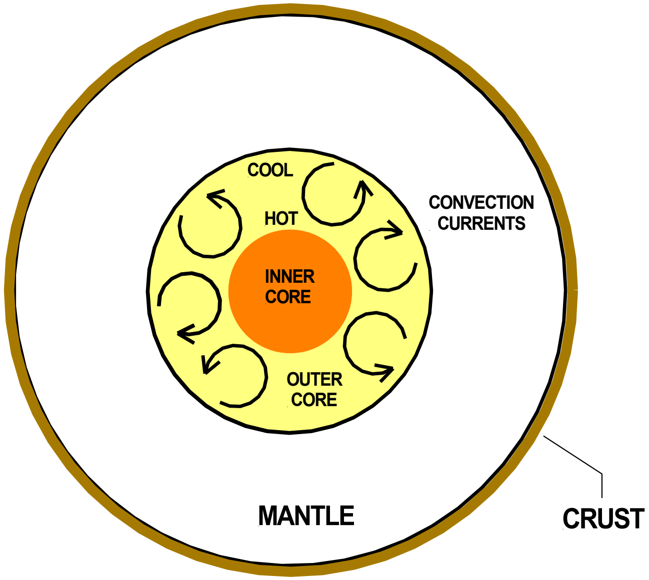
Mars Lost Its Magnetic Field

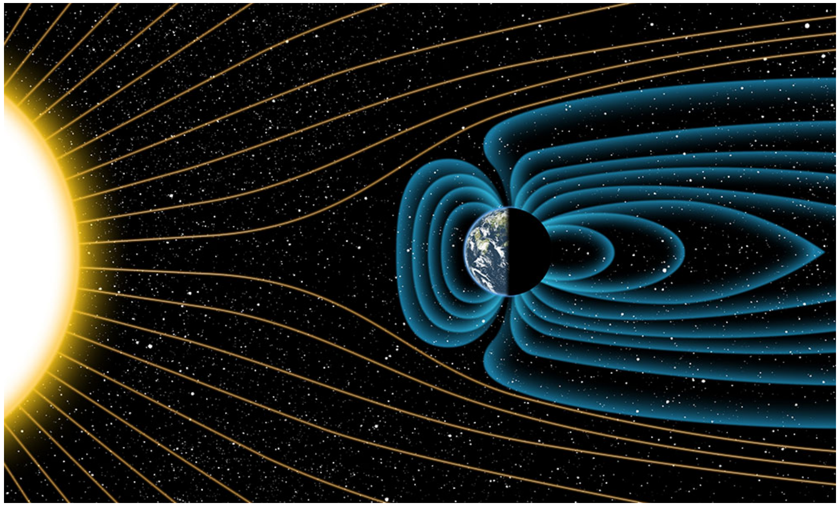




- Mars was once similar to Earth.
  - It had rivers, lakes, and oceans.
  - It also had a magnetic field created by its hot convective core.
  - But Mars is much smaller than Earth and cooled quickly.
  - As it cooled its convective core also cooled and solidified preventing it from producing the circulating electrical currents needed to generate its magnetic field.
  - Mars lost its magnetic field exposing it to the full fury of the solar winds.
  - The winds stripped Mars of its atmosphere, dried up its lakes and oceans, and left Mars a dead planet.

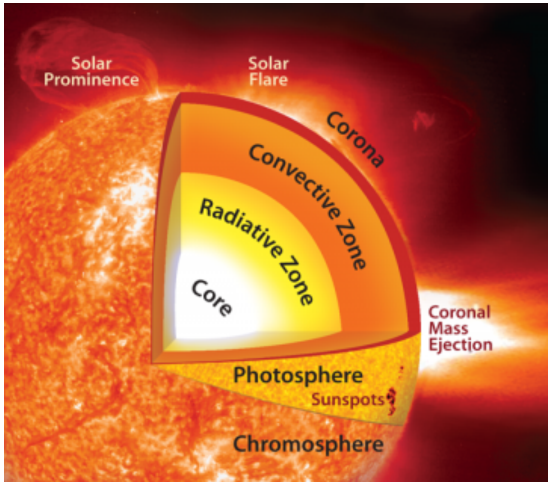
Criteria for Creating a Magnetic Field





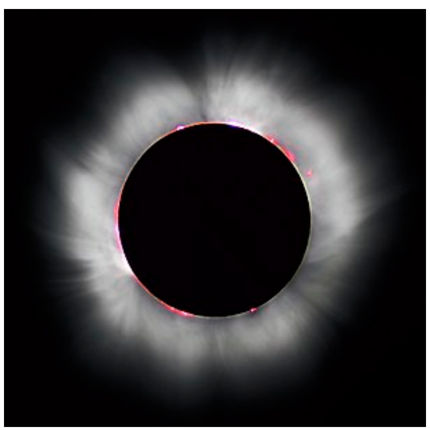
- **Important conclusion**
- To have a magnetic field a planet must have a hot convective region of circulating electrical currents somewhere within the planet.
- The same criteria applies to the Sun as well.

Structure of the Sun

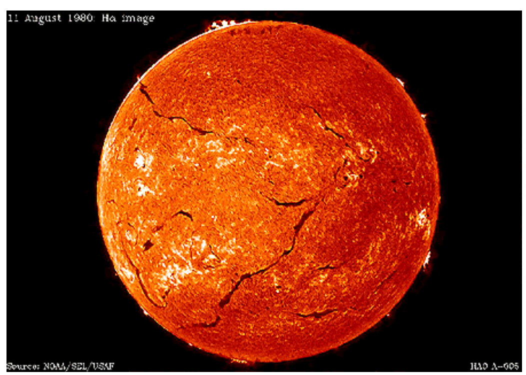


Structure of the Sun
(credit: Earth Magazine)

Photosphere



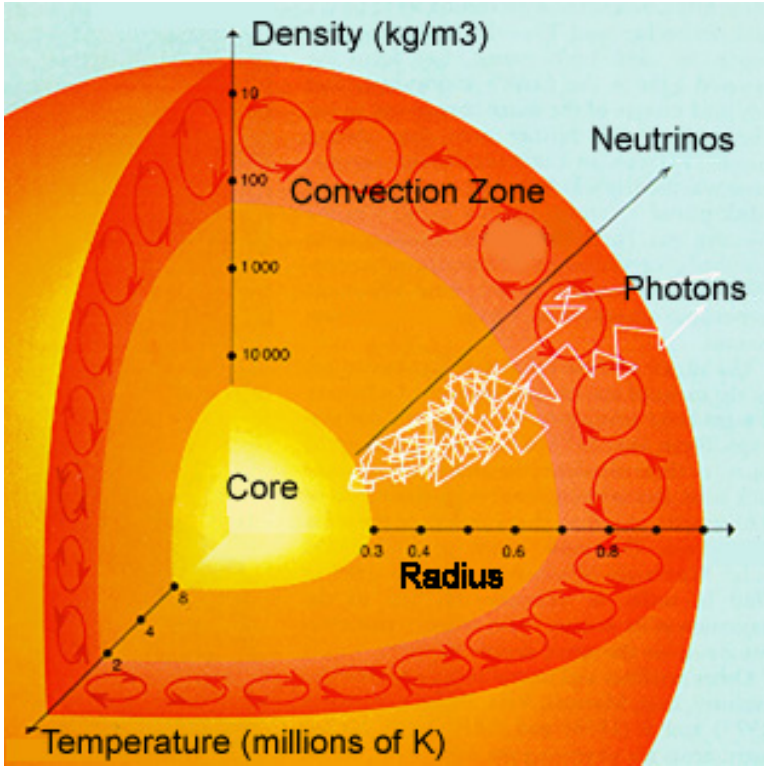
Solar Eclipse



Chromosphere seen
with H-alpha filter

- The Sun consists of 6 major regions
  - Core
  - Radiation Zone
  - Convection Zone
  - Photosphere
  - Chromosphere
  - Corona
- Photosphere is the part of the Sun that we see in ordinary sunlight
- Density of photosphere is much less than Earth’s atmosphere
- Chromosphere & corona can only be seed during a solar eclipse or with special telescope filters
- Density of chromosphere about the same as Earth’s upper atmosphere
- Density of Corona about the same as 500 km above Earth where ISS orbits

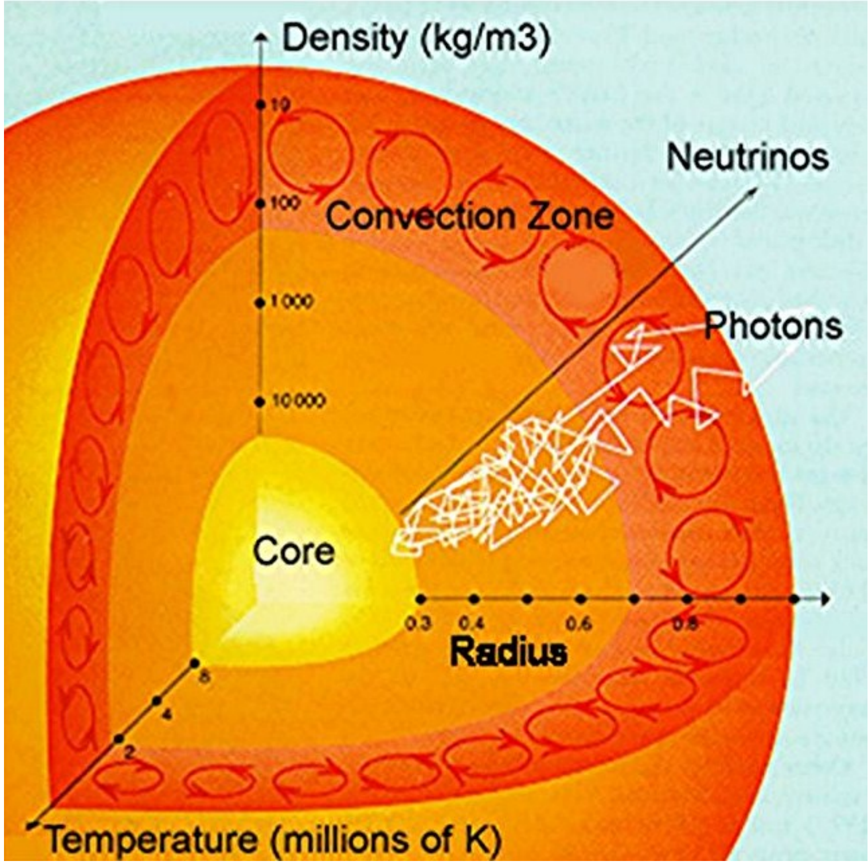
The Sun's Core



(credit: University of Oregon)

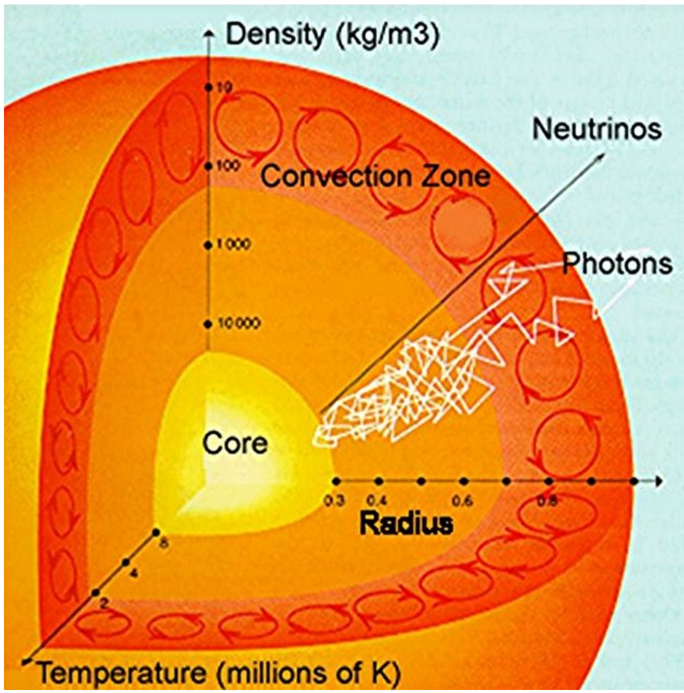
- Unlike the Earth, the Sun is composed almost entirely of hydrogen & helium gas.
  - By mass: H = 71% He = 27%
  - By abundance: H = 92.1% He = 7.8%
  - Trace amounts of all other elements in the periodic table
- Gravity resulting from the Sun's immense size squeeze the hydrogen and helium gas into a core where temperatures reach 15 million degrees Kelvin
- At these temperatures and pressure thermal nuclear reaction spontaneously occurs converting hydrogen into helium and releasing an enormous amount energy in the process.
- The outward flow of energy just balances the inward force of gravity, maintaining the Sun in a stable configuration for billions of years.

The Sun's Radiation Zone



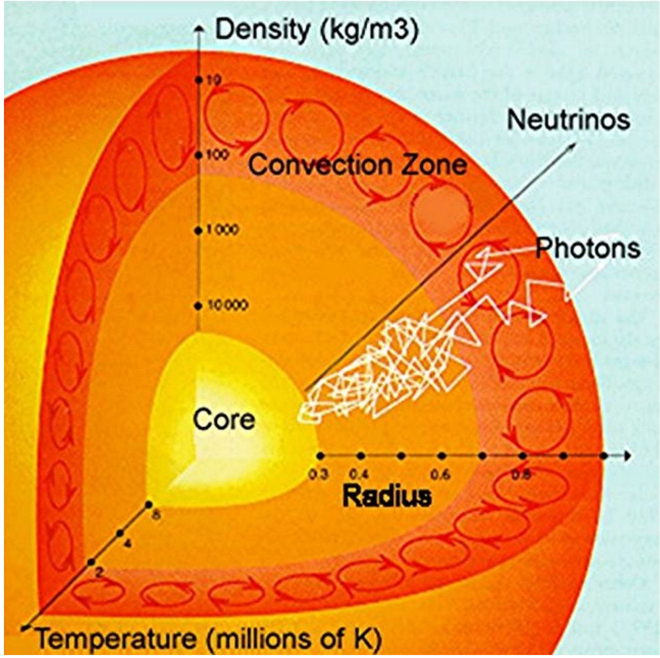
- The interior of the sun is radically different from that of the Earth.
- Instead of being surrounded by a hot molten outer core of circulating plasma, the Sun's core is encapsulated in the radiation zone, a hot thick blanket of hydrogen and helium gas 348,000 km deep
- Temperature gradients in the radiation zone guarantee that its plasma is frozen in place
- There are no circulating electrical currents within the radiation zone needed to generate a magnetic field

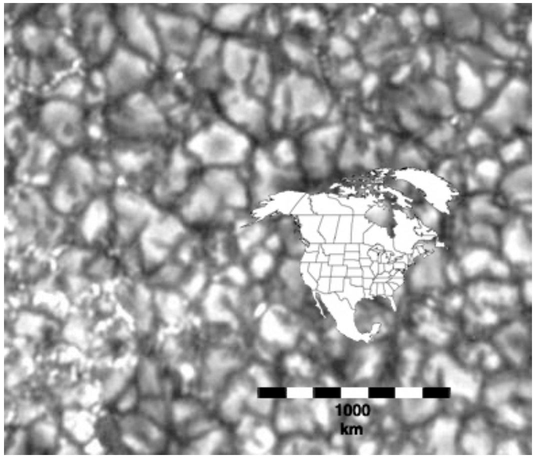
The Sun's Radiation Zone



- Instead, the radiation zone transports heat in the form of high energy photons away from the core.
- The density of hydrogen and helium ions in the radiation zone is so high that photons can only travel a very short distance before colliding with plasma particles.
- Because of the continuous collisions and scattering, it takes a photon 170,000 years to traverse the radiation zone.
- Photons travel quickly through the convection zone and take only 8 minutes to travel from the Sun to Earth.
- Today's sunlight began its journey in the Sun's core about the time modern man (homo sapien) first appeared on the planet 200,000 years ago
- After traveling through all of human history, the sunlight finally arrived today

The Sun's Convection Zone

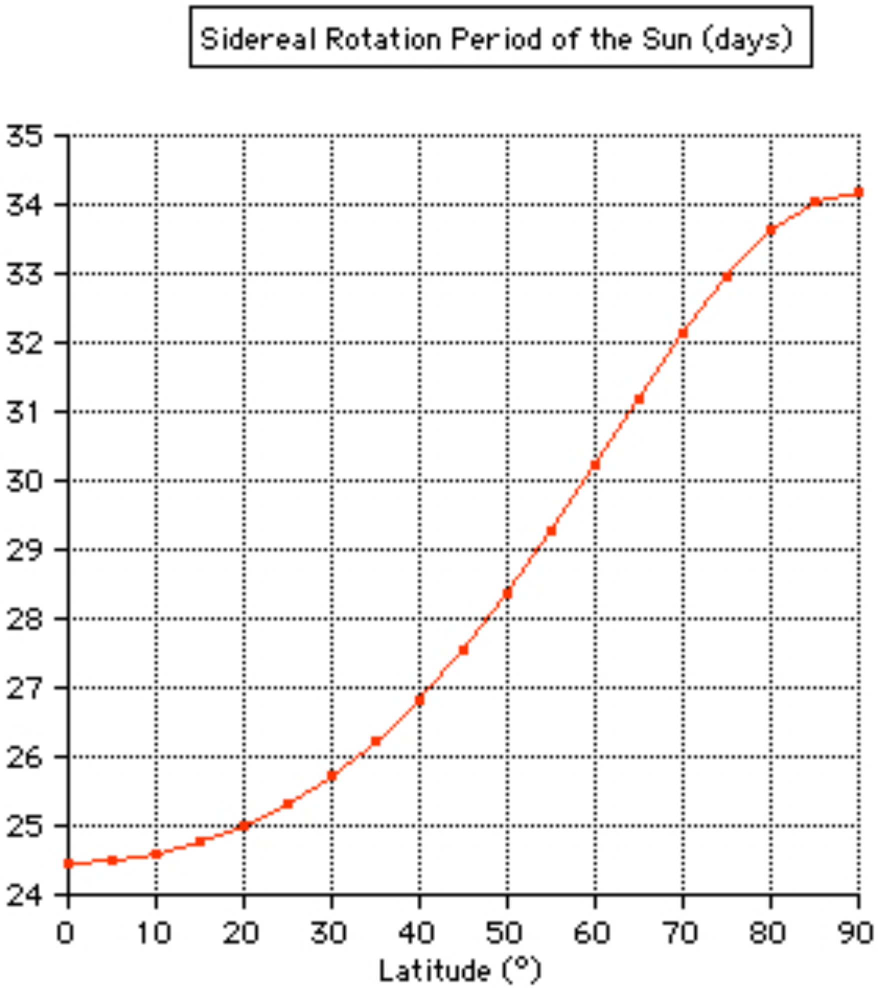




Thermal cells (granules) reaching the photosphere and sinking back into the convection zone

- The convection zone is much different
- The convection zone is similar to Earth's outer core
- Hot plasma around 2 million deg in temperature floats outward from the radiation zone, appears as granules at the sun's surface, and sink back toward the radiation zone
- The hot highly ionized circulating plasma creates strong electrical currents in the convection zone
- These circulating electrical currents produce the Sun's magnetic field
- But, unlike the Earth, the Sun's magnetic field is formed in the outer part of the Sun, near its surface, instead of deep within the Sun.
- **This is part of the problem!**

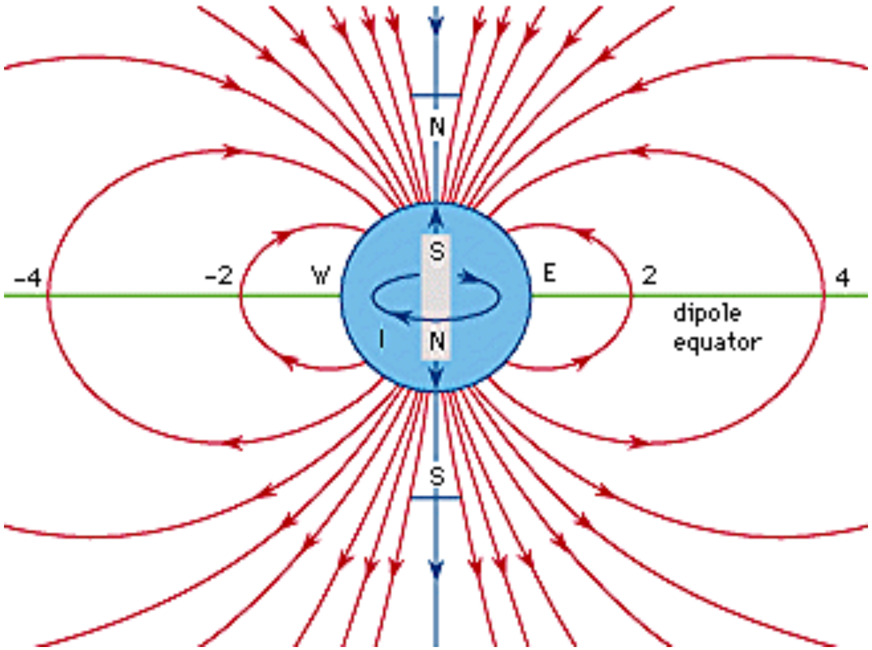
Sun’s Differential Rotation



(credit: jgiesen.de)

- The Sun is not solid.
- It is a huge rotating ball of gas
- In addition, its equator rotates faster than its poles
  - Equator rotates in 24.5 days
  - Poles rotate in 34 days
- **The Sun’s differential rotational rate is the other part of the problem.**

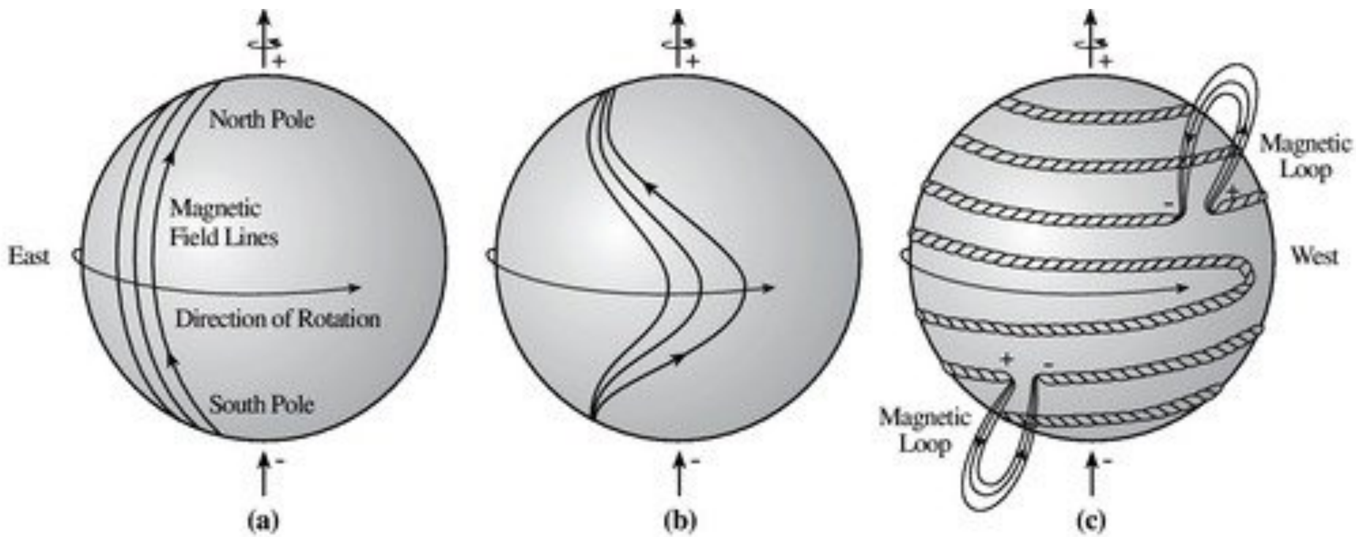
Sun's Quiet Magnetic Field



(Encyclopedia Britannica)

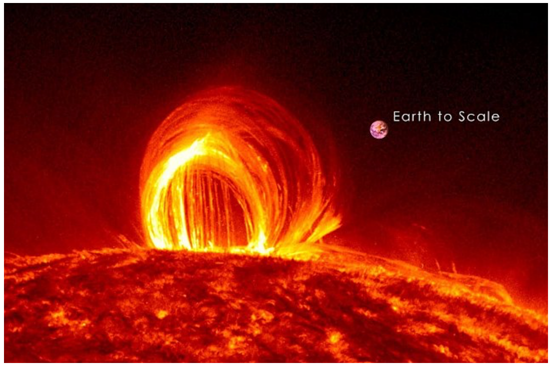
- The Sun's magnetic field begins as a "quiet" north – south magnetic field similar to that of Earth's magnetic field.
- Earth's magnetic Field = 0.2 gauss
- Sun's quiet magnetic field = 1.0 gauss
- The Sun's quiet magnetic field is not that much different from the Earth's magnetic field

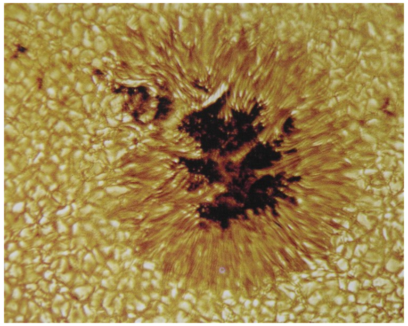
The Sun's Magnetic Field Becomes Twisted & Distorted

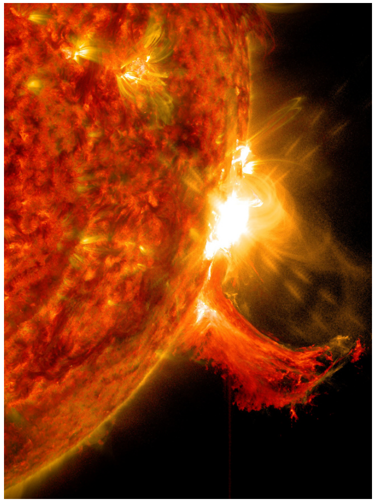


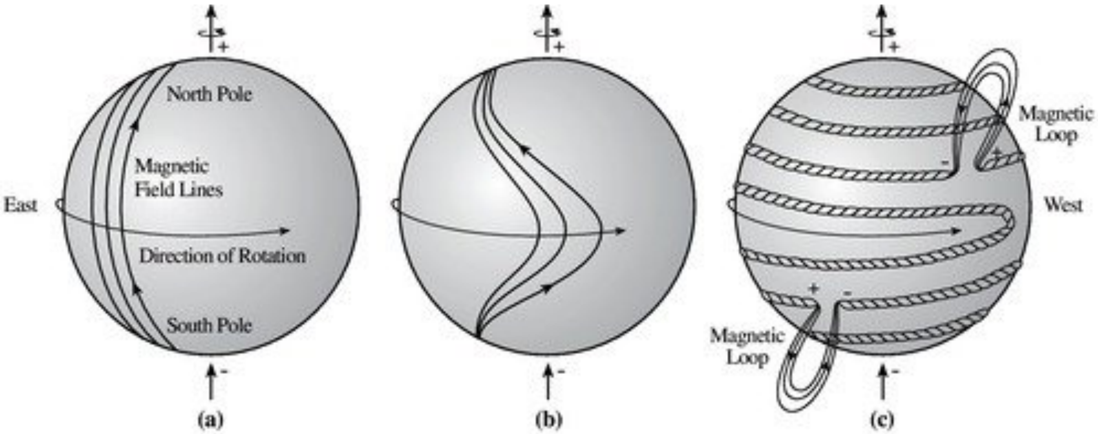
- Over a period of 3 to 6 years the Sun's differential rotation slowly drags and winds the magnetic field around the Sun.
- The magnetic field at the equator is dragged around the Sun faster than the magnetic field at the poles winding the original bipolar field into a toroidal field
- In addition, convection zone turbulence twists the magnetic field lines into ropes which become knotted.
- Winding the magnetic filed around the Sun in tighter ever increasing numbers of turns is not a sustainable process
- **Something has to break, and it does!**

Stressed Magnetic Field Erupts Through Photosphere





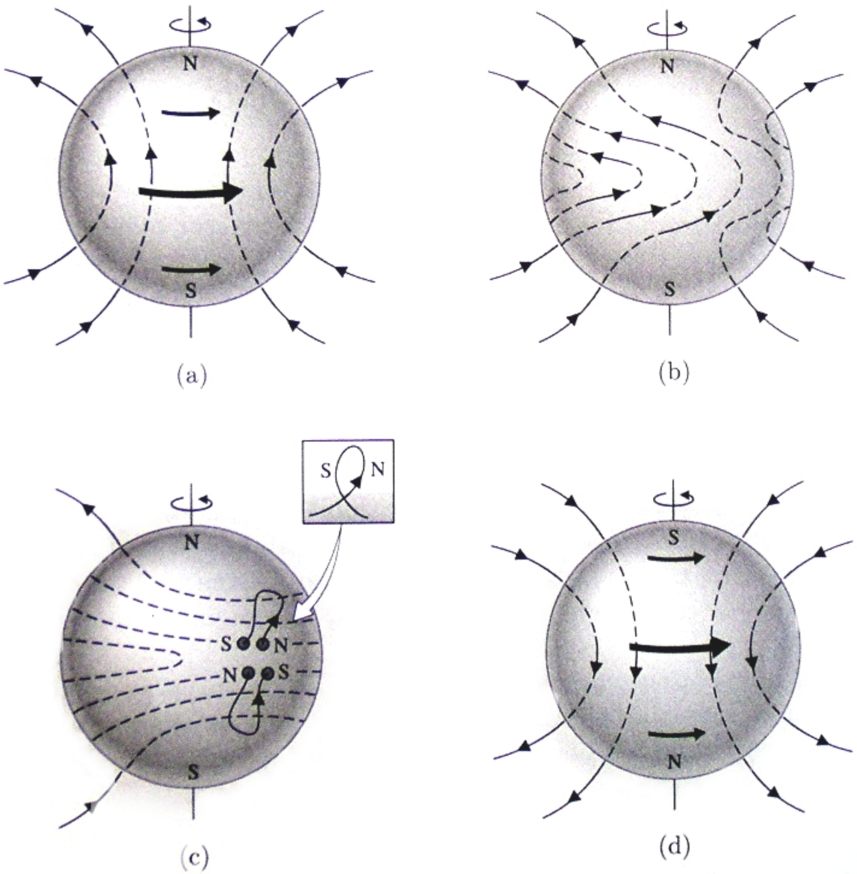




(credit maas museum)

- Continued winding, twisting, and knotting creates tremendous stress in the magnetic field driving field intensities to well over 3,000 gauss
- The enormous stress eventually causes the field to rupture
- As it does so high arching prominences, sunspots, solar flares, and other calamities erupt from the Sun
- The Sun reaches solar maximum during this very turbulent phase of the solar cycle with large numbers of sunspots visible on the solar surface.

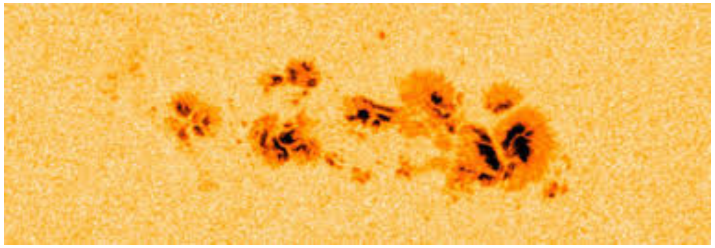
22 Year Long Solar Cycle

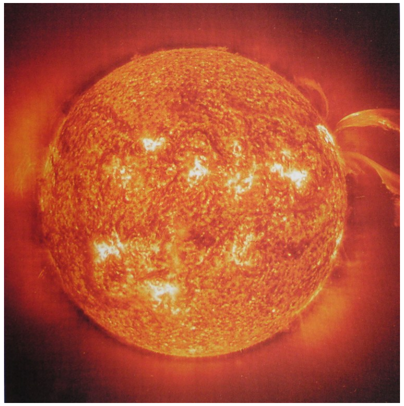


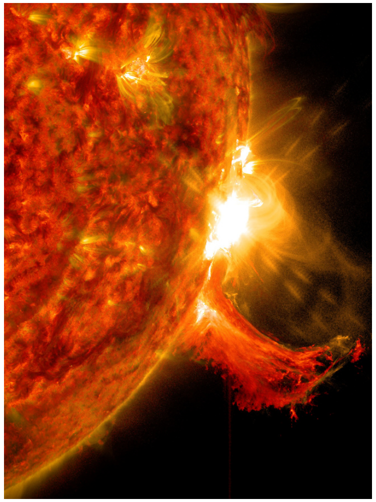
(credit: Modern Astrophysics)

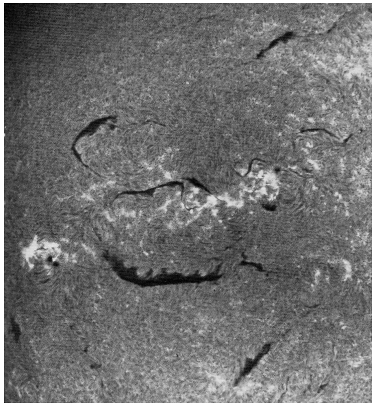
- As the magnetic field disintegrates, sunspots gradually disappear and the Sun again approaches solar minimum with a quiet north-south magnetic field
- However, as the field unwinds, the Sun's magnetic poles flip
- The original north pole becomes the new south pole and visa versa
- The poles flip again at the end of the next solar cycle creating a 22 year cycle
- The Earth's magnetic poles also flip but over periods of 100,000 to 50 million years.

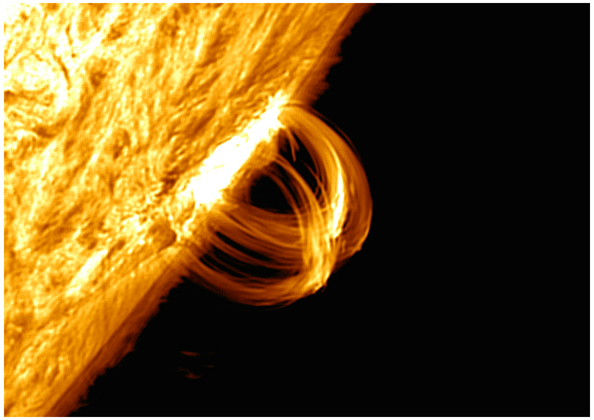
Sun’s Active Atmosphere





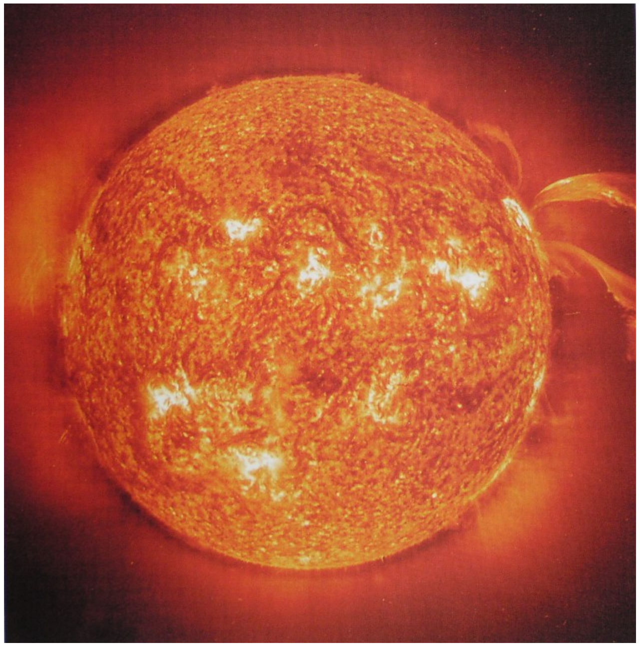






- Other than the solar cycle itself, all of the phenomena that affect HF communications occur in the Sun’s atmosphere
- These phenomena include
  - Prominences
  - Filaments
  - Sunspots
  - **Plages**
  - **Solar Flares**

Plages

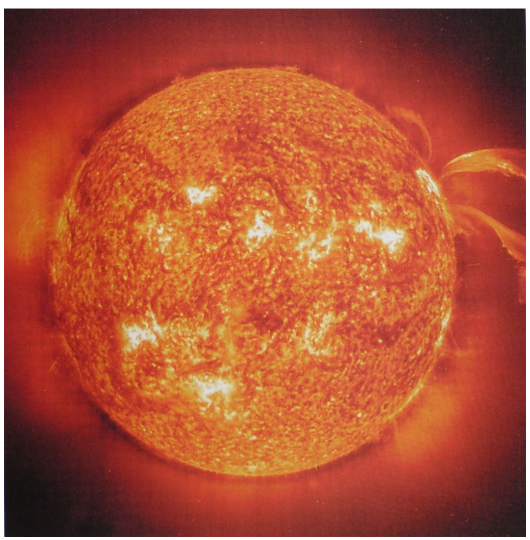


Sun at H alpha wavelength

- Plages are hot bright irregularly shaped regions in the chromosphere seen with a telescope using a Hydrogen - alpha filter
- Plages form in areas of intense radial magnetic fields and typically last long periods of time.
- Plages usually, but not always, are found near sunspots.
- Plages form before sunspots appear, and disappear some time after sunspots in the region have vanished.
- **Plages emit copious amounts of extreme ultra violate radiation (EUV) needed to ionize Earth's upper atmosphere**

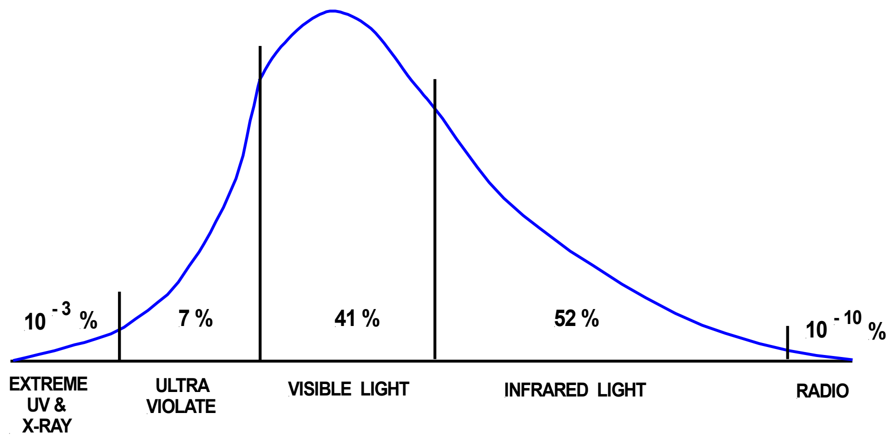
The Sunspot Connection

Sun in visible light



Sun at H alpha wavelength

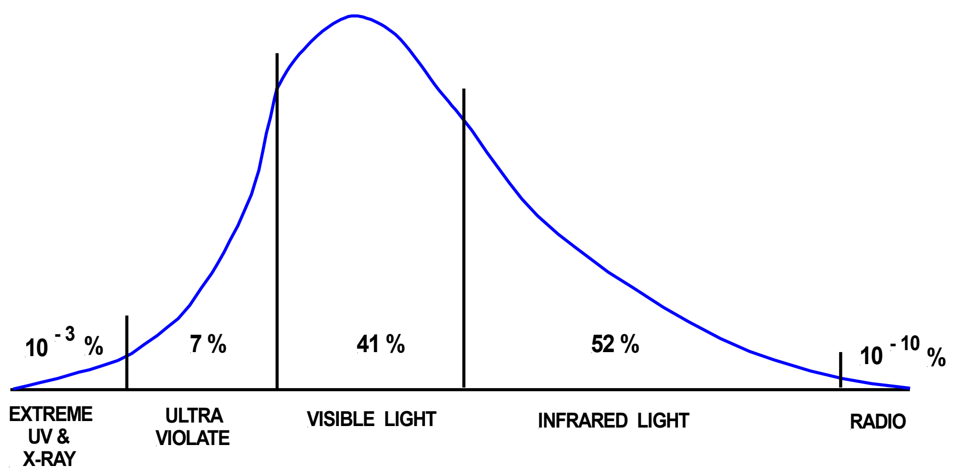
- While there is a strong correlation between sunspot activity and long distance HF radio propagation
- **It turns out that sunspots have little to do with HF radio communications**
- **The intense EUV radiation needed to ionize Earth's upper atmosphere is produced by plages.**
- Sunspots are too low in temperature to generate the needed EUV radiation
- However, plages can not be seen in normal sunlight because the photosphere is too bright.
- But sunspots can easily be seen
- Thus sunspots act as markers for plages.
- **A large number of sunspots means a large number of plages, high EUV levels, strong ionization of the Earth's ionosphere, and good radio communications**



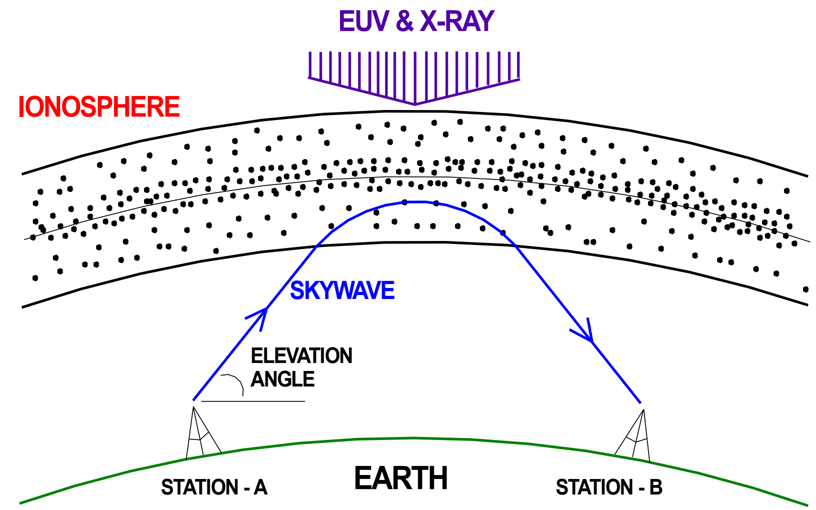
Energy Output of the Sun

- The EUV radiation responsible for Ionizing Earth's upper atmosphere accounts for only 0.001% of the Sun's total energy output.
- The Sun's energy output remains incredibly stable over thousands of years
- However, the Sun's EUV energy output is NOT stable at all !
- The EUV energy output varies considerably over the 11 year solar cycle
- Consequently the level of ionization in Earth's upper atmosphere also varies over the same time period.
- EUV energy output is greatest during solar maximum when there are large numbers of sunspots, and consequently large numbers of EUV emitting plagues
- EUV energy output is lowest during solar minimum when there are few if any sunspots and only a few randomly scattered plagues

A Closer Look At Earth's Ionosphere

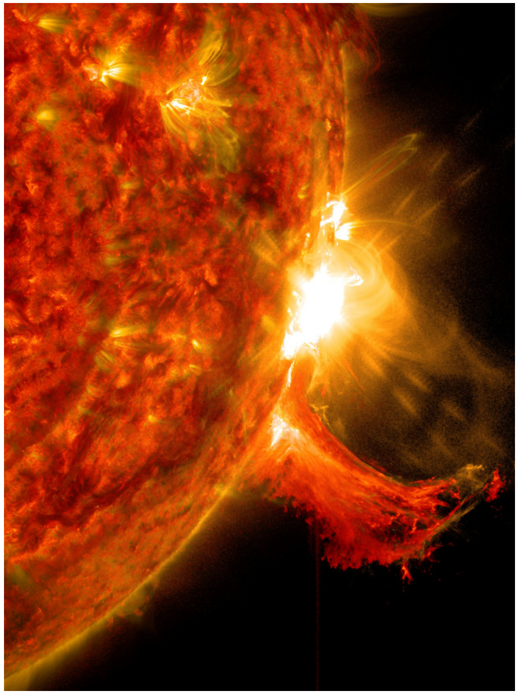


Solar Spectrum



- The ability of the Ionosphere to support long distance HF radio communications is wonderful. It lets us enjoy our hobby
- However, the Sun's EUV & X-Ray radiation is extremely deadly.
- It is the Earth's Ionosphere that shields us from the Sun's EUV & X-Ray radiation making live as we know it possible on Earth.

Solar Flares

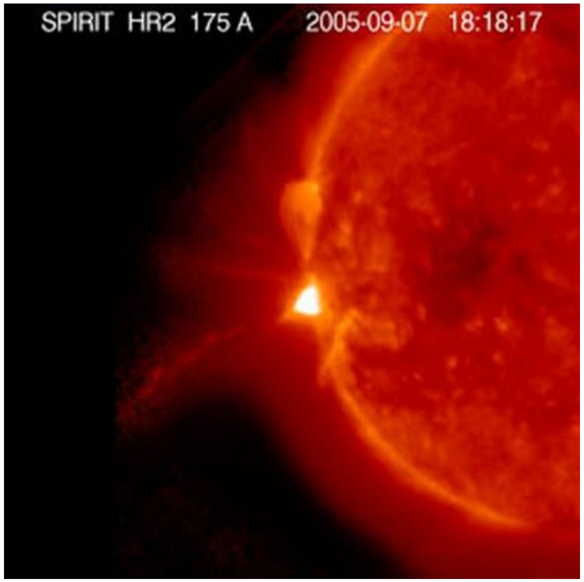


Credit: NASA/SDO

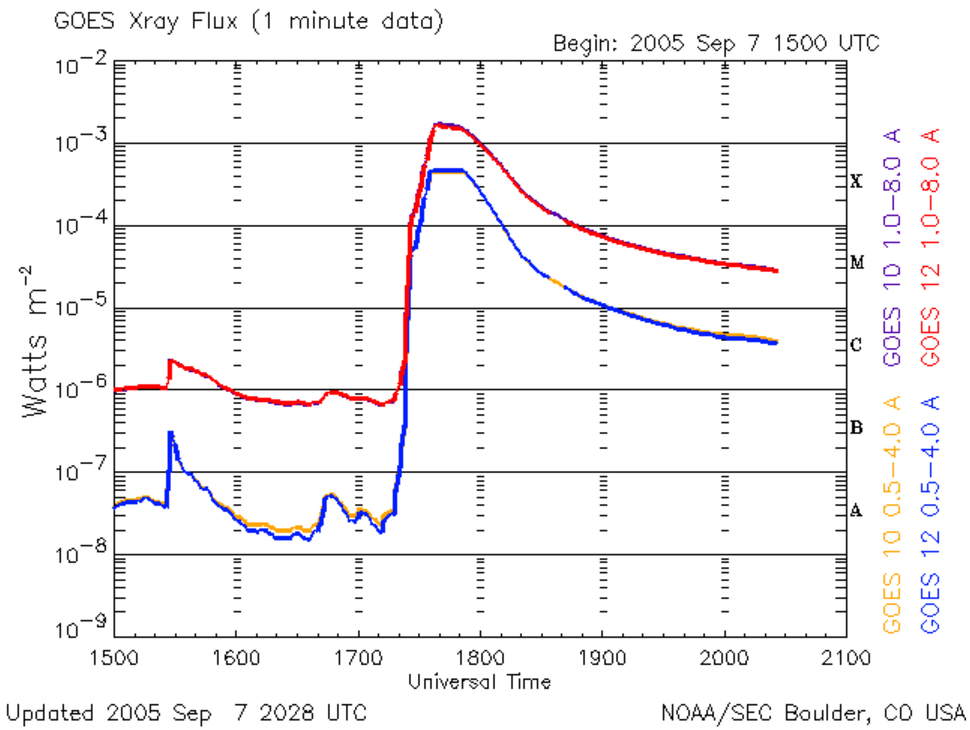
The X-ray and EUV radiation from a solar flare reach the Earth in about 8 minutes. High energy particles can arrive in as little as 30 minutes. Shock waves and coronal mass ejections arrive in 1 to 4 days

- A solar flare is a massive, sudden, explosive release of energy stored in strong magnetic fields that extend from the photosphere deep into the corona.
- Solar flares are the most powerful eruptions in the solar system
- A flare can last from a few minutes to several hours heating the corona plasma in the vicinity of the explosion to well over ten million degrees
- Solar flares emit huge bursts of electromagnetic radiation:
  - Gamma rays,
  - X-rays
  - EUV radiation
  - Visible light
  - Radio waves
- Solar flares can also eject large quantities of coronal and chromospheric material into space as well as shock waves that can disrupt Earth's magnetic field

Solar Flare Detection

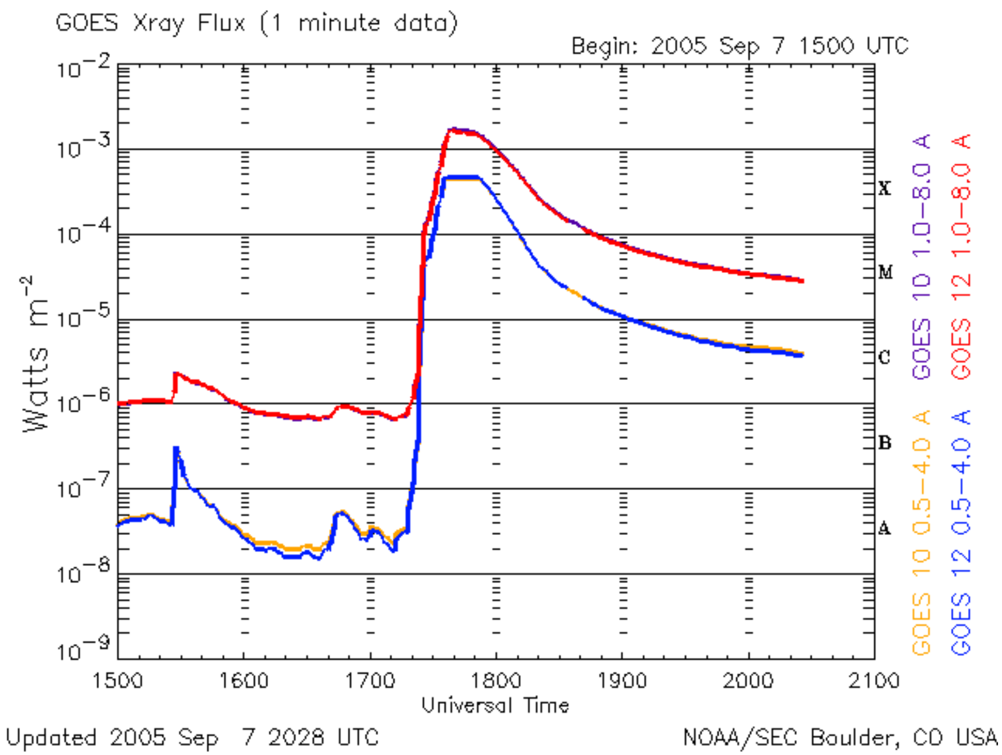


Russian Journal of Earth Sciences.ISSN: 1681–1208

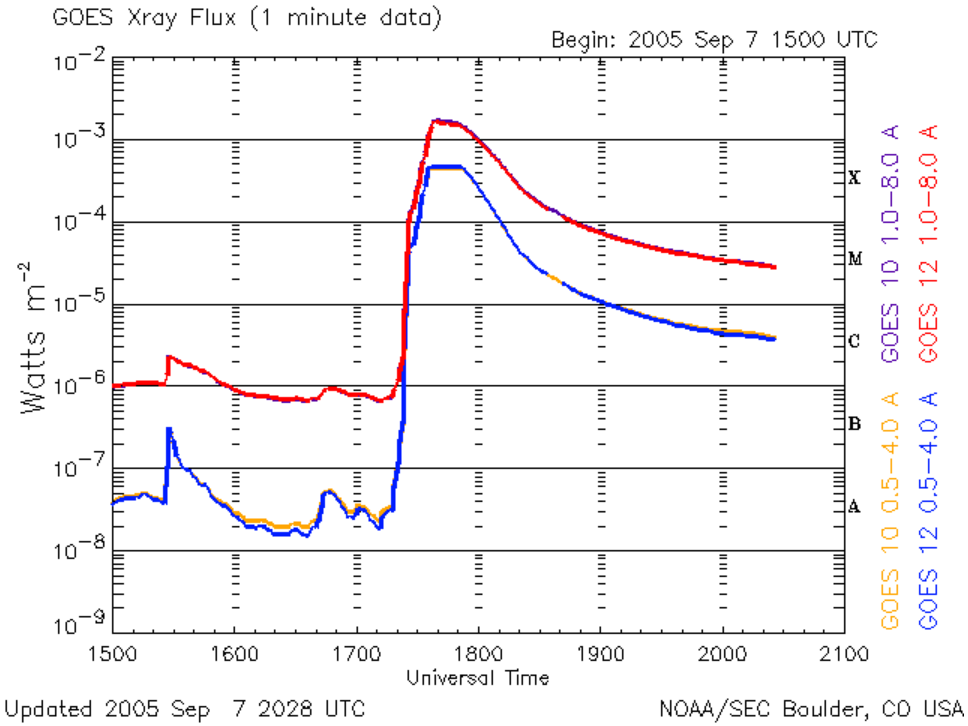


- A solar flare is detected by a rapid increase in solar X-ray energy from the Sun
- The increase occurs in minutes followed by a gradual decline which can occur over tens of minutes to several hours
- The image and graph show a large flare occurring on Sept 7, 2005

Magnitude of Solar Flares

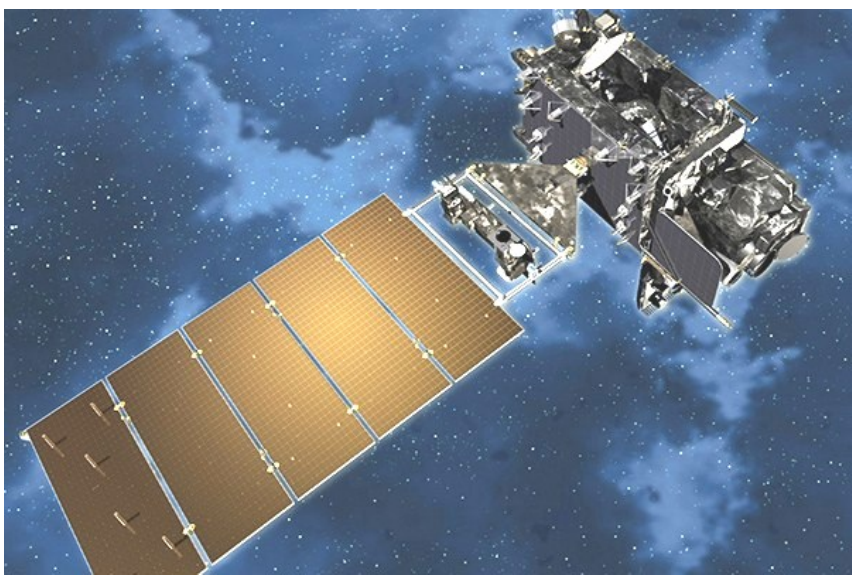


- The magnitude of solar flares are classified by their peak X-ray flux in watts per square meter as measured by the GOES spacecraft
- Levels of X-ray flux are classified on a logarithmic scale as
  - Class - A: typical background X-ray flux levels
  - Class - B: elevated background X-ray flux levels
  - Class - C: small minor flare with few noticeable affects on Earth
  - Class - M: medium size flare that may cause brief HF radio blackouts which may be followed by minor radiation storms
  - Class - X: major flare event that can cause large scale HF radio blackouts and long lasting radiation storms



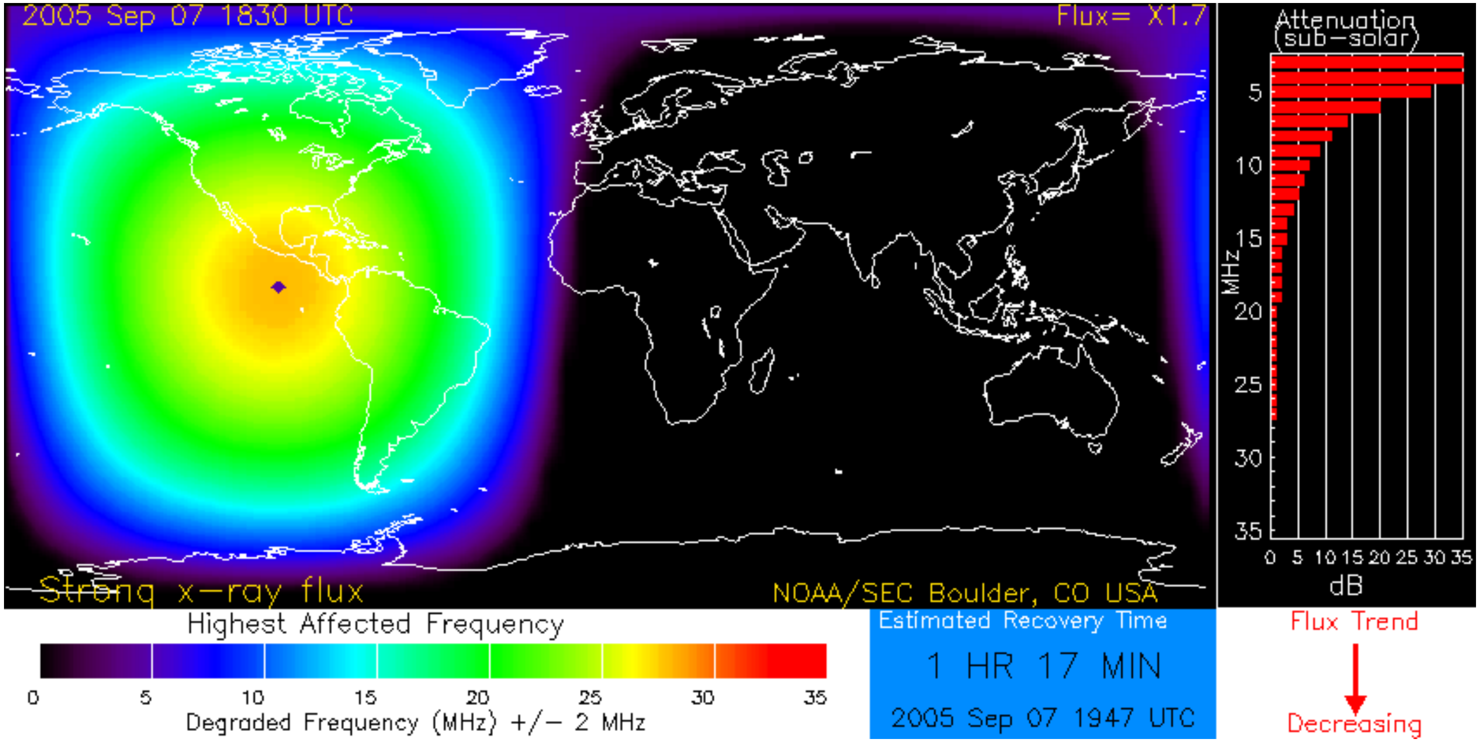
Magnitude of Solar Flares continued

- Each class has a peak flux 10 times greater than the preceding class
- The classification of flares is thus similar to the measurement of earthquakes on the Richter scale (a magnitude 6 earthquake is 10 times more powerful than a magnitude 5 quake)
- Each class of X-ray flux has nine logarithmic subdivisions, for example B1 through B9. The next level above B9 is C1

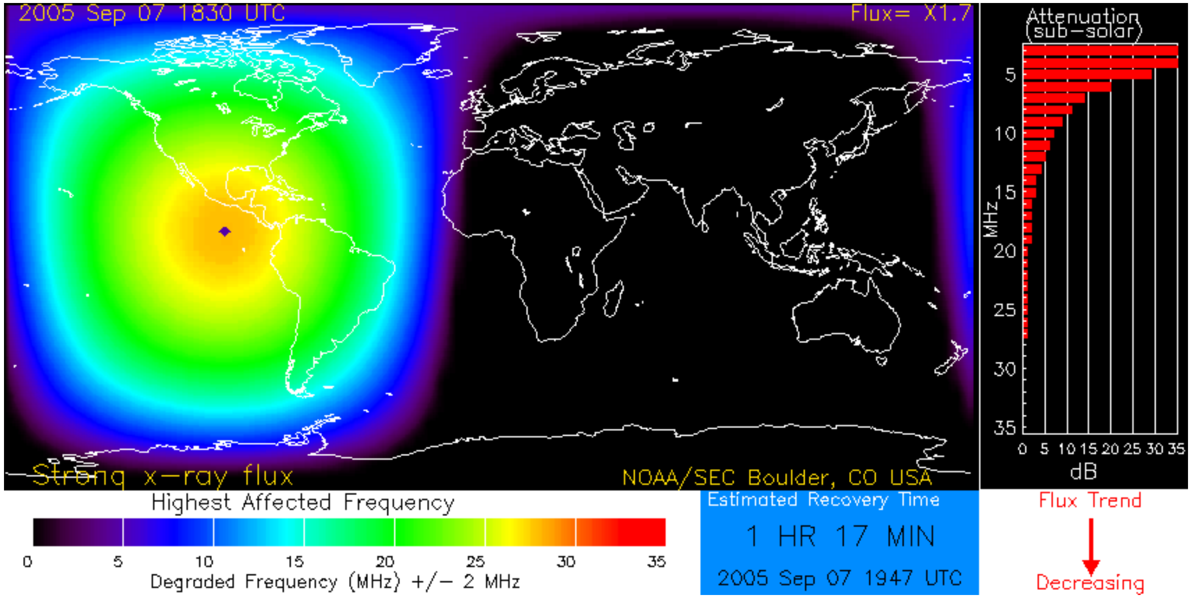


GOES 16 Spacecraft
(credit: NOAA)

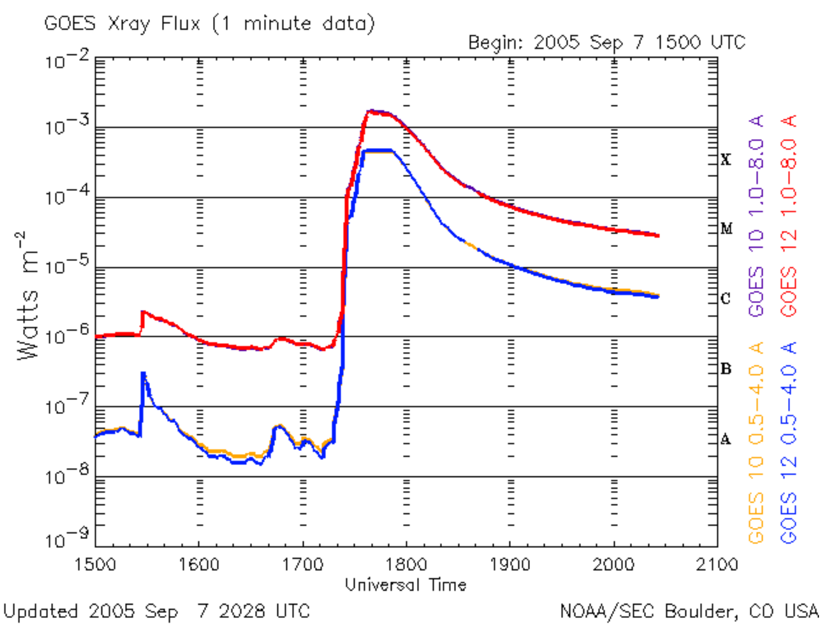
Earth's Ionosphere Reacts Badly to Large Flares



- X-ray radiation from the strong flare on September 07, 2005 heavily ionized the D – Layer of the Ionosphere
- This in turn cause wide spread radio blackouts

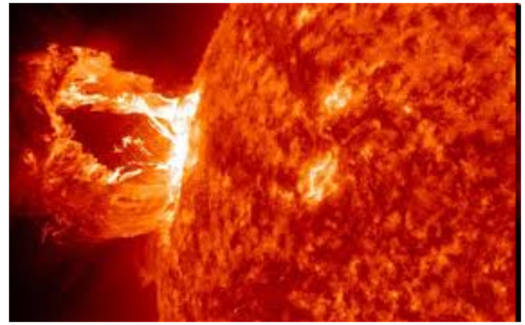


Flare Detected Moment That It Occurred



- A couple of us working in the Radio Room detected this flare when it first occurred following the CES net
- WWV / WWVH strong on 5, 10, 15, 20 MHz before the net
- Immediately after the net 5 MHz gone, 10 MHz erratic, 15 & 20 MHz still OK
- Tuned back down in frequency, 5, 10, 15 MHz gone
- Tuned back up in frequency 5, 10, 15, 20 MHz where all gone
- We concluded we had a problem

Conclusion



- HF communications is very exciting and rewarding
- It is also very important in rural, mountainous, and remote areas of our country where there are no other means of communications for hundreds of miles
- Important becomes critical following a natural disaster when all the infrastructure, including our own towers and beams, have been wiped out
  - Being able to get an antenna up and operating under portable power becomes imperative
- Understanding what is happening on the Sun right now, how that is affecting the ionosphere, and knowing what to do about it is part of what makes us good at what we do
- Enabling us to provide communications when no one else can!

Information

- Some Important URLs
  - Solar Ham: www.solarham.net
  - Space Weather Prediction Center (NOAA): www.swpc.noaa.gov
  - Australian Space Weather Service: www.sws.bom.gov.au/HF_Systems/6/5
  - HF Propagation & Solar-Terrestrial data: www.hamqsl.com/solar2.html
- Partial Reference List
  - Foukal, Peter; “Solar Astrophysics third edition”
  - Carroll, Bradley W. and Ostlie, Dale A; “An Introduction to Modern Astrophysics”
  - Davies, Kenneth; “Ionospheric Radio”
  - Yeang, Chen-Pang; “Probing The Sky With Radio Waves”
  - DeSoto, Clinton B., “200 Meters & Down”
- My background
  - Education: BS engineering degree University of Michigan 1967
  - Profession: 33 yrs as digital design & system development engineer in data communications
  - First licensed in 1959 as K8MEV
  - Licensed again as KJ6RZ in 1989
  - Interests: HF ionospheric communications
  - Enjoy experimenting with reliable communications [any time, from any where, under any conditions]