HF Propagation

A quick and dirty overview Of Propagation

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NK7Z
11/03/17

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What will be covered

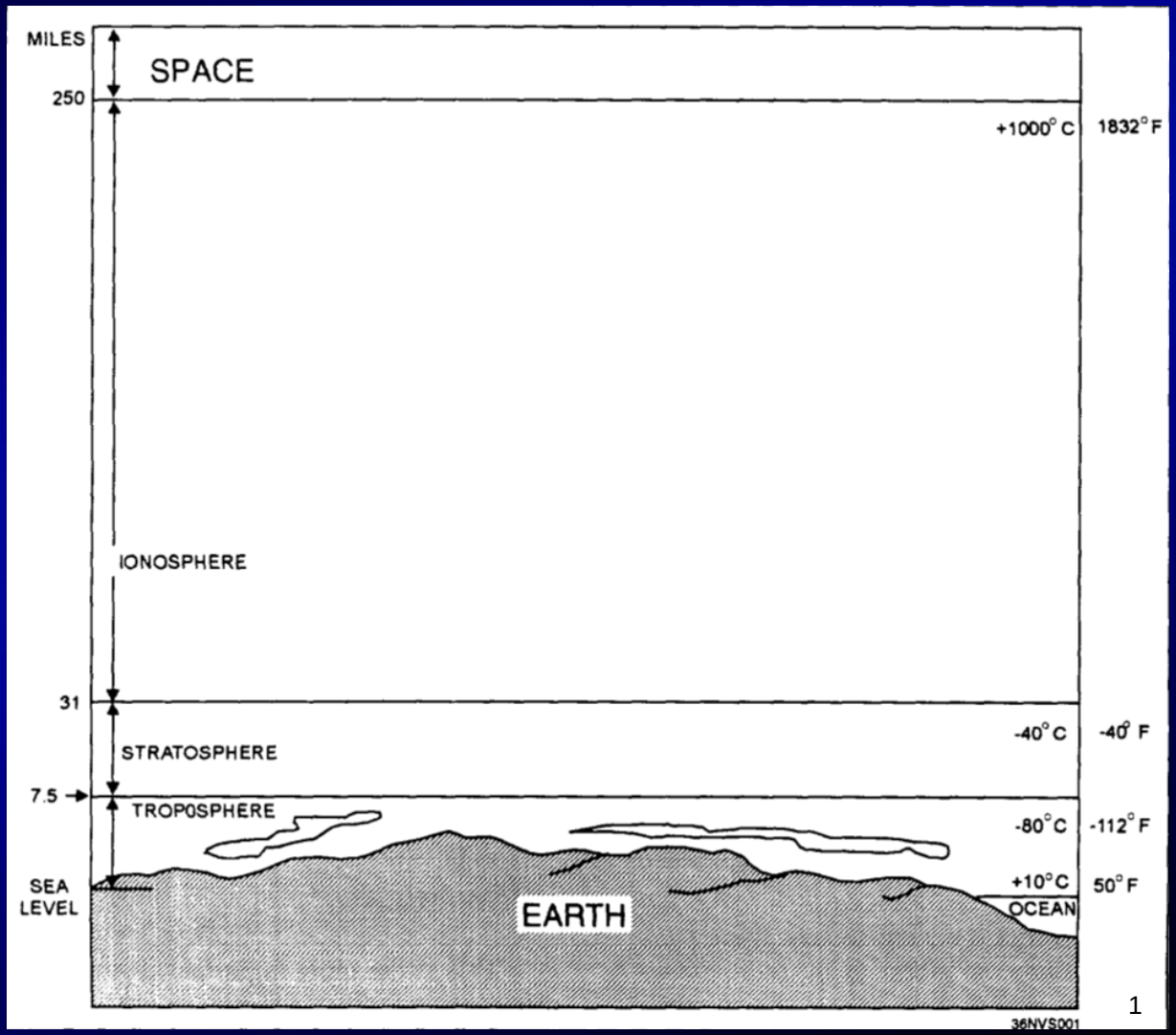
- The Earth's Atmosphere.
- What is the Ionosphere?
- Ionization.
- Recombination.
- Ionospheric Layers.
- Refraction.
- Skip distance and Zones.
- Reflection phase shift.
- Atmospheric effects.
- Other Phenomena.
- Transmission losses.
- Tool Box Review.
- The Sun.
- The Earth.
- Prediction Tools.
- Questions

The Earth's Atmosphere

- Radio in a uniform free space environment, is just that-- Free!
- Radio in an atmosphere is a very different story.
- Changes in propagation are caused by non-uniform conditions within a selected atmosphere.
  - For Earth, the three major non-uniform conditions are:
    - Height
    - Location
    - Time, (day, night, season, year)

The Earth's Atmosphere

- Atmospheric Regions
  - Ionosphere
    - Most Important Region:
      - Regular variations.
      - Irregular variations.
  - Stratosphere
    - Relatively calm.
    - No temp changes.
    - Nothing to see here, move along.
  - Troposphere
    - Least important region.
    - Weather happens here.
    - Nothing to see here, move along.



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Ionization

- What is Ionization:
  - Neutral gas atoms are floating around within the Ionosphere.
  - The Sun, among other things, emits high energy UV light.
  - When UV rays enter the atmosphere, (daytime), they strike some of these floating neutral gas atoms, knocking off electrons.
  - When electrons are knocked free from neutrally charged atoms, the affected atoms become positively charged, and are called Ions.
  - The electrons knocked off the atoms absorb some of the energy from the UV, and are then left floating around the Ionosphere.
  - Ionization rates are time dependent.
  - This is why that region of the atmosphere is called the Ionosphere.

Recombination

- What is recombination:
  - Recombination is the reverse of Ionization!
  - Free negatively charged electrons when located near positively charged Ions, recombine to form a neutral atom.
  - Ionization, and recombination run at different rates depending on the amount of UV present.
  - UV presence is dependent on how much sunshine there is.
  - Hence the ratio of free electrons to neutral atoms in the atmosphere is dependent on how much sunshine hits the Ionosphere.
  - Free electrons reflect radio waves, neutral atoms don’t.

Layers

- Why Layers:
  - UV light arrives at the atmosphere with many energy levels.
    - More energy penetrates deeper into the atmosphere.
    - Less energy penetrates less deeply into the atmosphere.
    - A process called “Photo Ionization” is partly responsible for layer formation
  - As the electrons are stripped from atoms, they also gain some energy.
  - This energy gain is based on the energy level of the medium doing the stripping.
  - The electrons then form layers based on the amount of energy they absorbed.
  - This is a very simplified explanation, if you want more, see:
    - B. Zolesi and L. R. Cander, Ionospheric Prediction and Forecasting

Layers

- Day vs. Night:
  - Like Ionization, recombination rates depend on time of day.
  - Early morning to late afternoon:
    - Ionization rates exceed recombination rates.
    - Layer density increases across this time frame.
    - Maximum influence on radio propagation.
  - Late afternoon to early morning:
    - Recombination rates exceed Ionization rates.
    - Layer density decreases across this time frame.
    - E layer effects on radio propagation diminish.

Layers

- D Layer:
  - 30 to 55 Miles in height.
  - Low ionization due to less UV penetration.
  - At low frequencies the D layer and ground act like a lossy waveguide.
  - From low to medium frequencies, the D layer is highly absorptive.
  - Above 3 MHz., the D layer becomes more and more transparent to RF.
  - Above 30 MHz., the D layer starts to absorb RF again.
  - At night the D layer dissipates because of rapid ion/electron recombination.
  - This is why 80, and 160 go long at night, and short during the day.

Layers

- E Layer:
  - 55 to 90 Miles in height.
  - Rapid recombination rate, this layer begins to dissipate after sunset and is gone by midnight.
  - The E layer Permits medium range communications on low to medium frequencies when present.
  - Sometimes the E layer shadows the F layer so radio waves never get to the F layer.
  - As you approach 150 MHz., the E layer becomes transparent to radio.
  - A solar flare may cause this layer to ionize over set areas on both the dark side of Earth, and the sunlit side of Earth. This is called Sporadic-E skip.

Layers

- F Layer:
  - 90 to 240 Miles in height.
  - During the day, the F layer normally separates into two layers, the F1, and F2 layers.
  - The F layers are maximally ionized during the afternoon hours.
  - The F layers effects on propagation are not as pronounced as the D and E layers if the D and E are present.
  - The F layer remain ionized longer after sunset than any other layer. During sunspot maximum the F layers can stay ionized overnight.
  - F layer is the highest layer, as such is responsible for the longest propagation.
  - Single hop F2 distance can be as great as 3000 miles. Longer propagation requires multi-hop F2.

Layers

D LAYER: reflects vlf waves for long-range communications; refracts lf and mf for short-range communications; has little effect on vhf and above; gone at night.

E LAYER: depends on the angle of the sun: refracts hf waves during the day up to 20 MHz to distances of 1200 miles: greatly reduced at night.

F LAYER: structure and density depend on the time of day and the angle of the sun: consists of one layer at night and splits into two layers during daylight hours.

F1 LAYER: density depends on the angle of the sun; its main effect is to absorb hf waves passing through to the F2 layer.

F2 LAYER: provides long-range hf communications; very variable; height and density change with time of day, season, and sunspot activity.

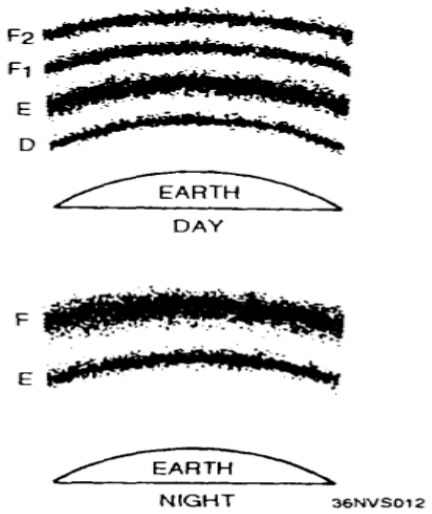

Figure 1-12.—Ionospheric layers.

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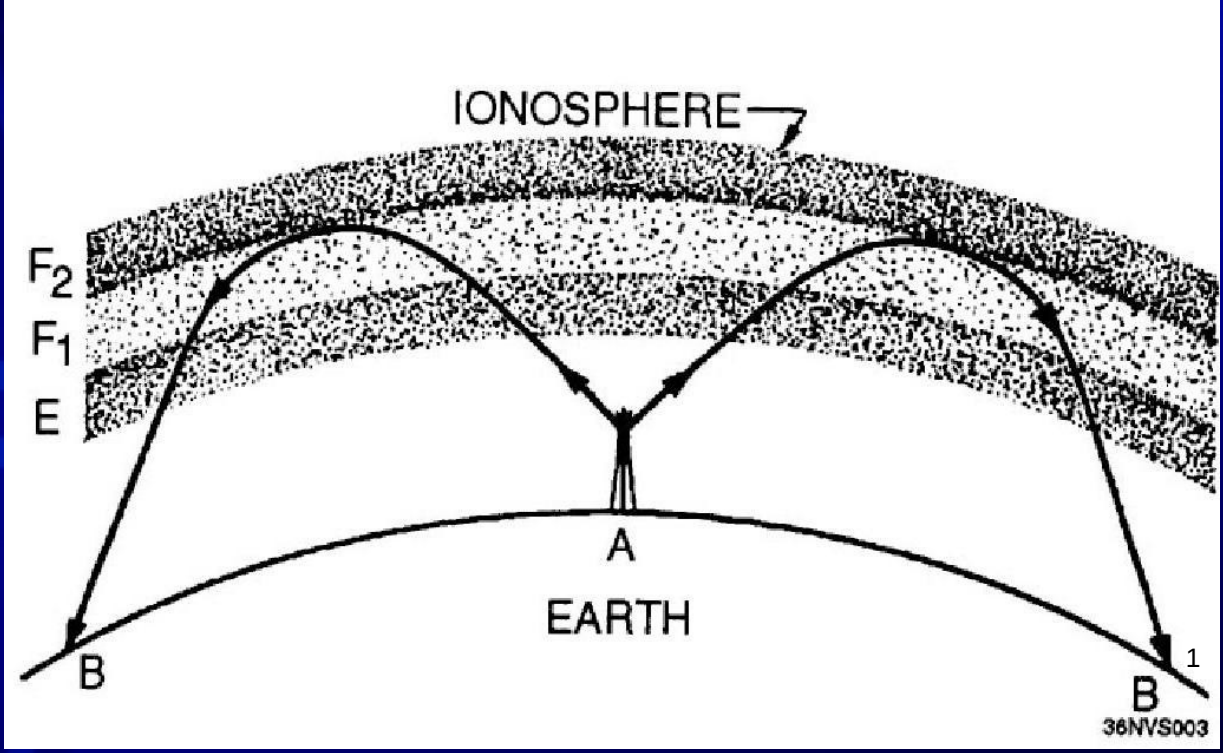
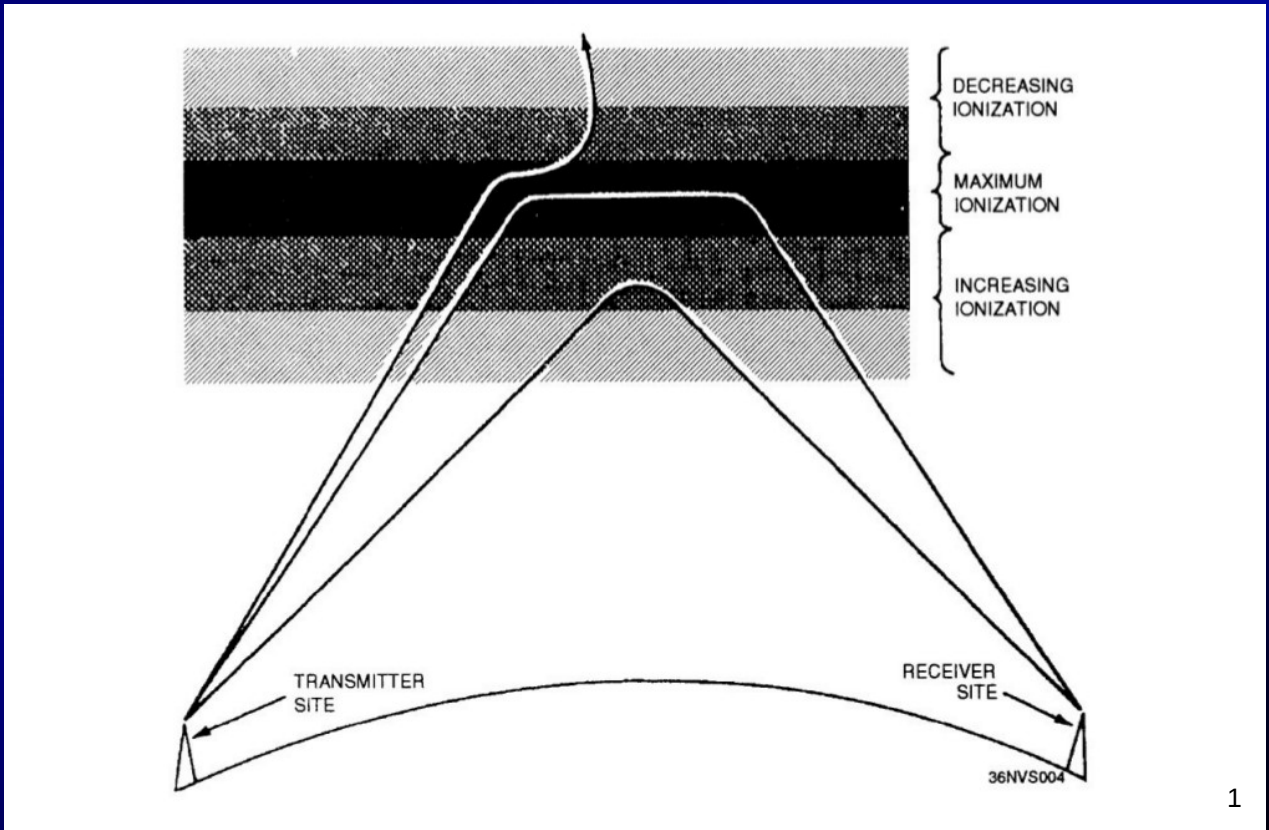
Refraction

- A radio wave transmitted into an ionized layer is always bent. This is called refraction.



Refraction

- Amount of refraction a ray undergoes depends on three main factors:
  - Ionization density.
  - Frequency.
  - Angle of entry.



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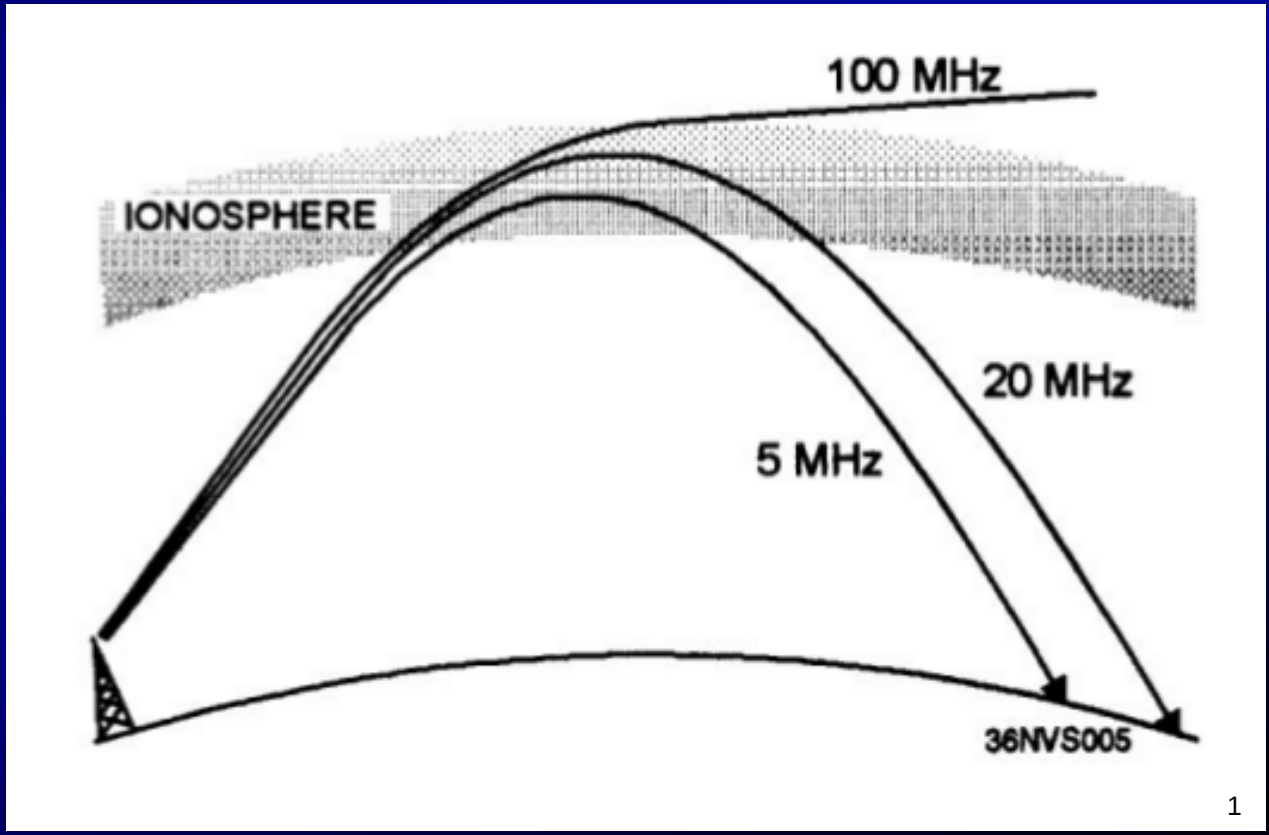

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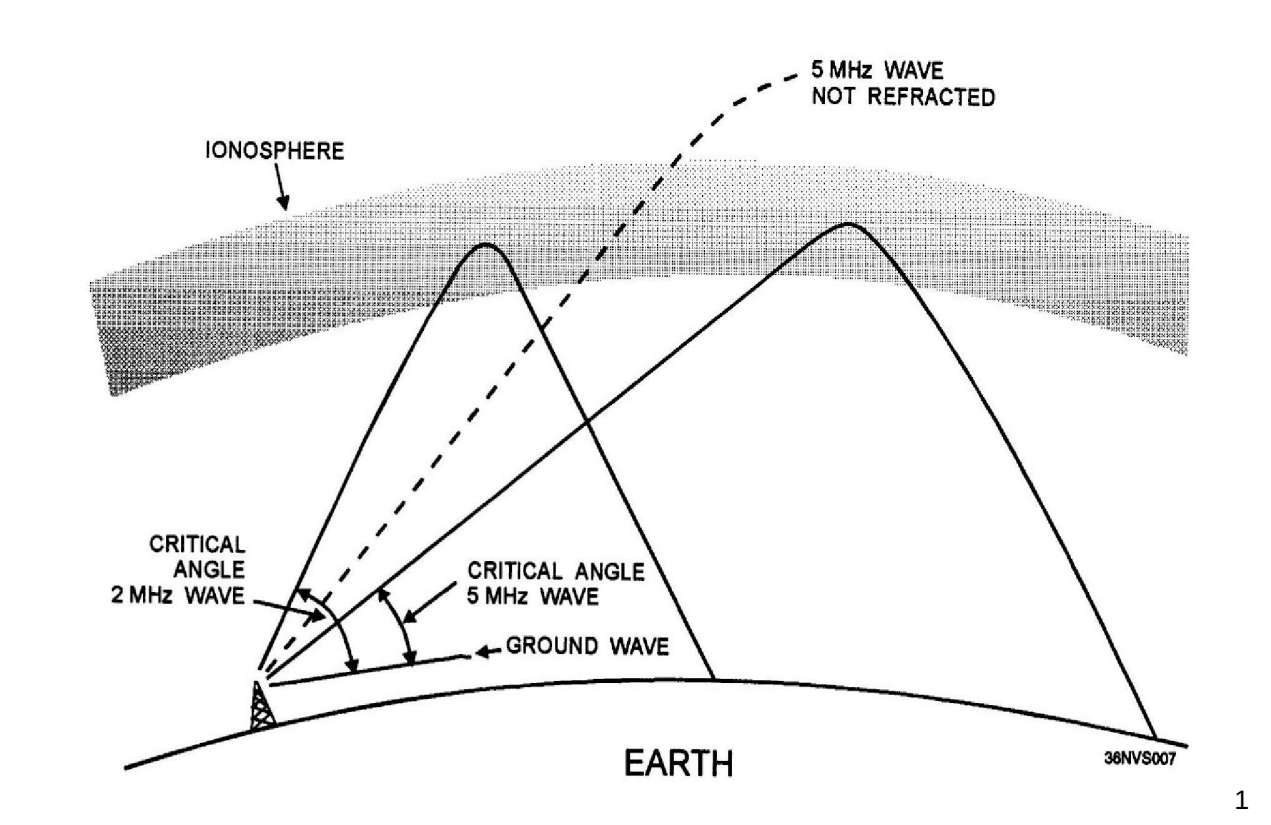

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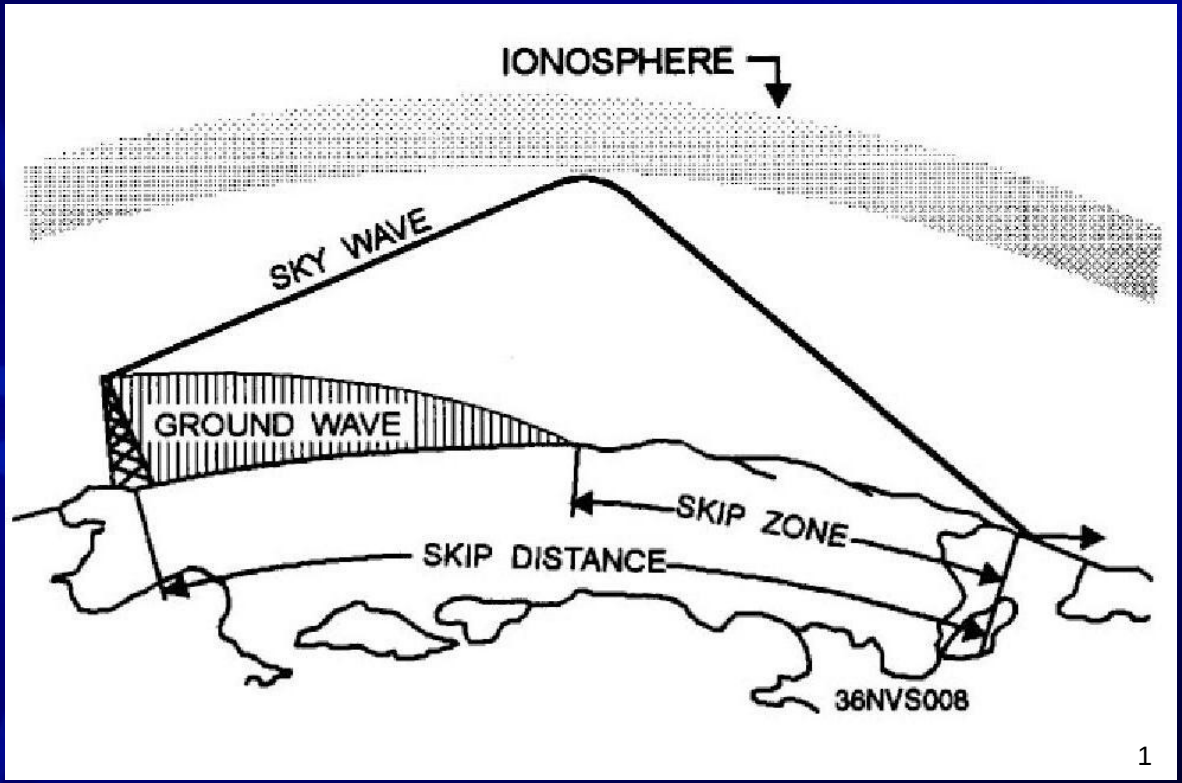
Skip Distance and Zones

- Relationship between Ground Wave, Sky Wave, Skip Distance, and Skip Zone.



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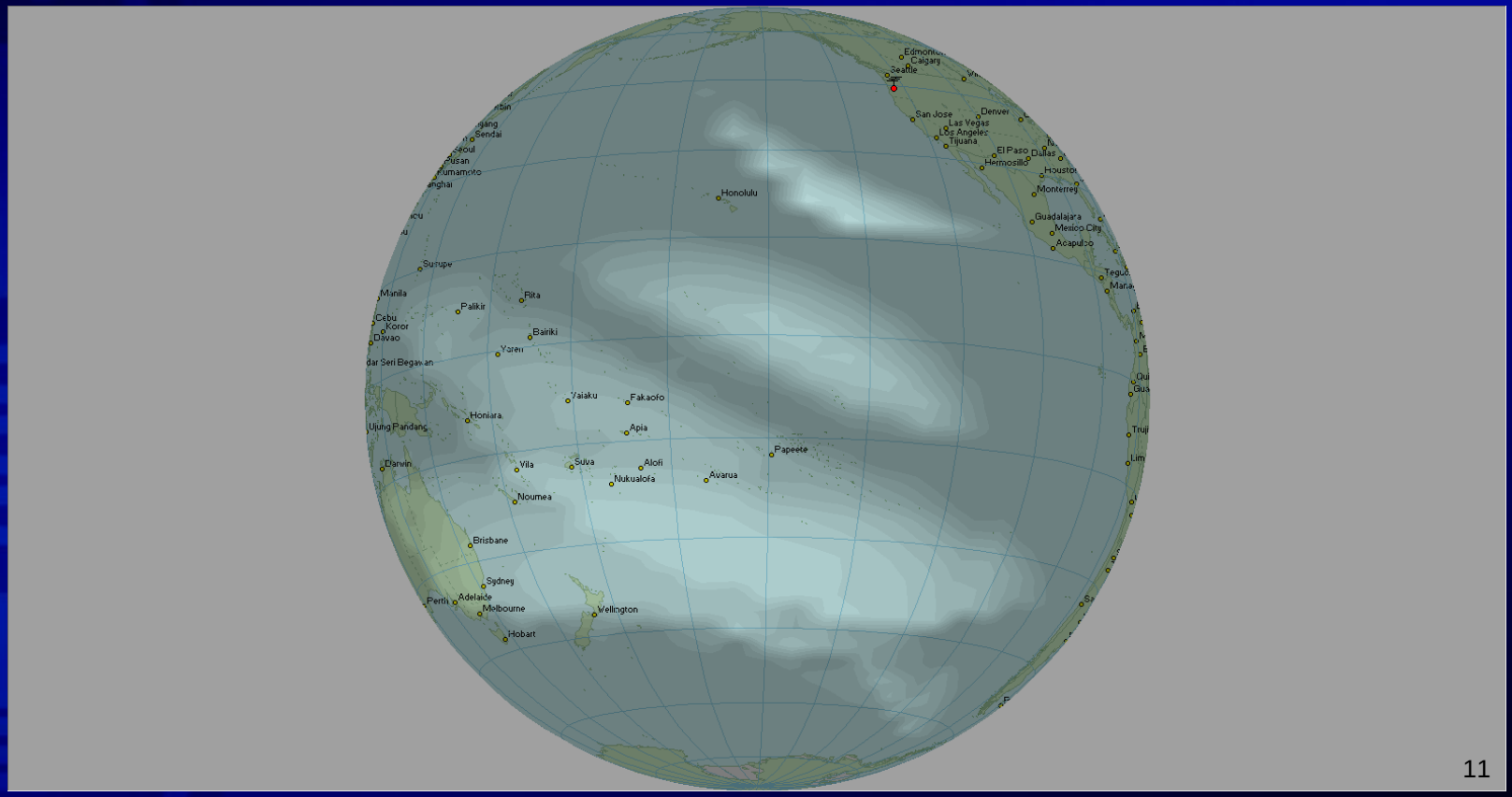

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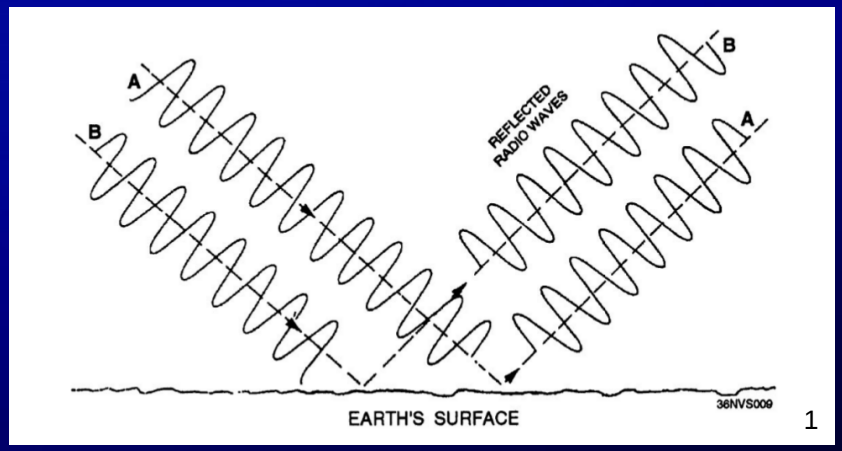
Reflection Phase Shift

- There are two types of reflections:
  - Earth
    - The Earth behaves like a mirror for the most part.
  - Ionospheric
    - The Ionosphere behaves much like a liquid fun house mirror, changing from moment to moment.



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Atmospheric effects on propagation

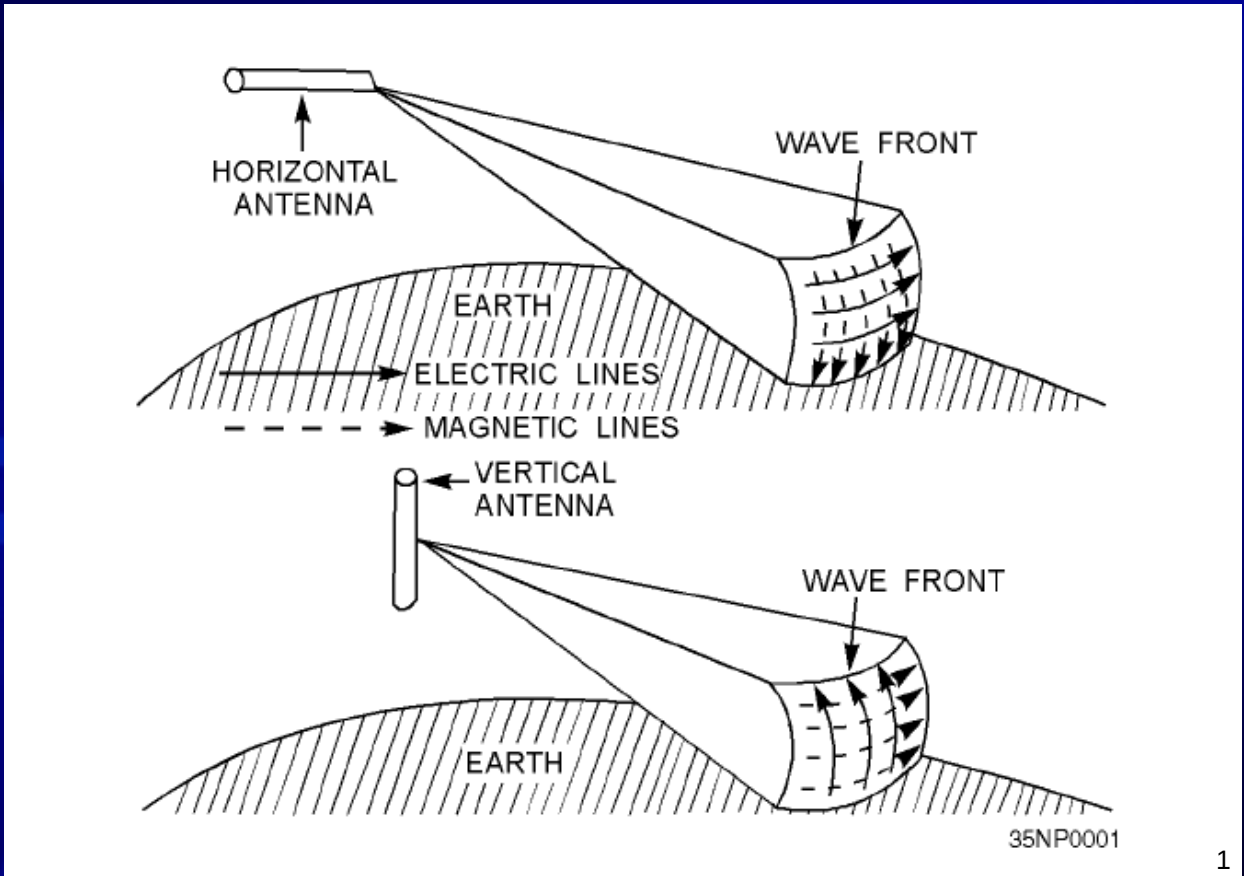
- As stated earlier, changes in atmospheric conditions can, and do cause major changes in propagation, these changes can result in:
  - Communications distances being increased.
  - Communications distances being decreased.
  - Fading of received signals.
  - Enhancement of received signals.
  - HF Blackouts.
  - Any/All combinations of the above.

Fading

- Fading occurs because of:
  - Polarization changes.
  - Ionospheric absorption.
  - Multipath fading.

Fading

- Up to 20 db can be lost to polarization changes.



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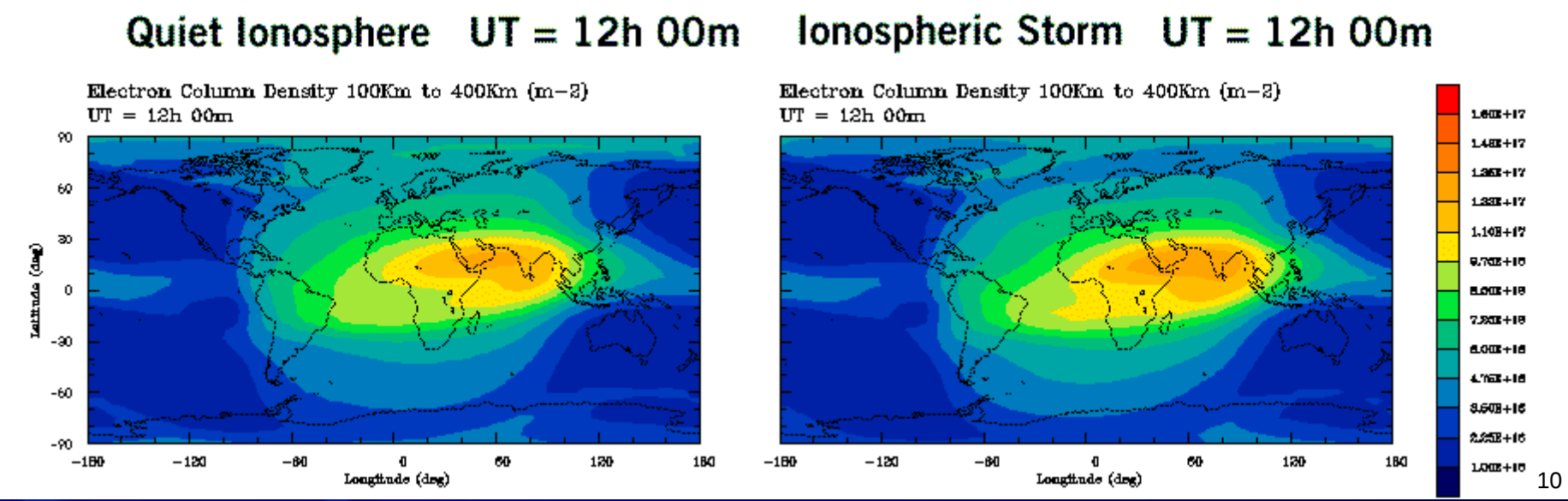
Fading

- Ionospheric absorption:



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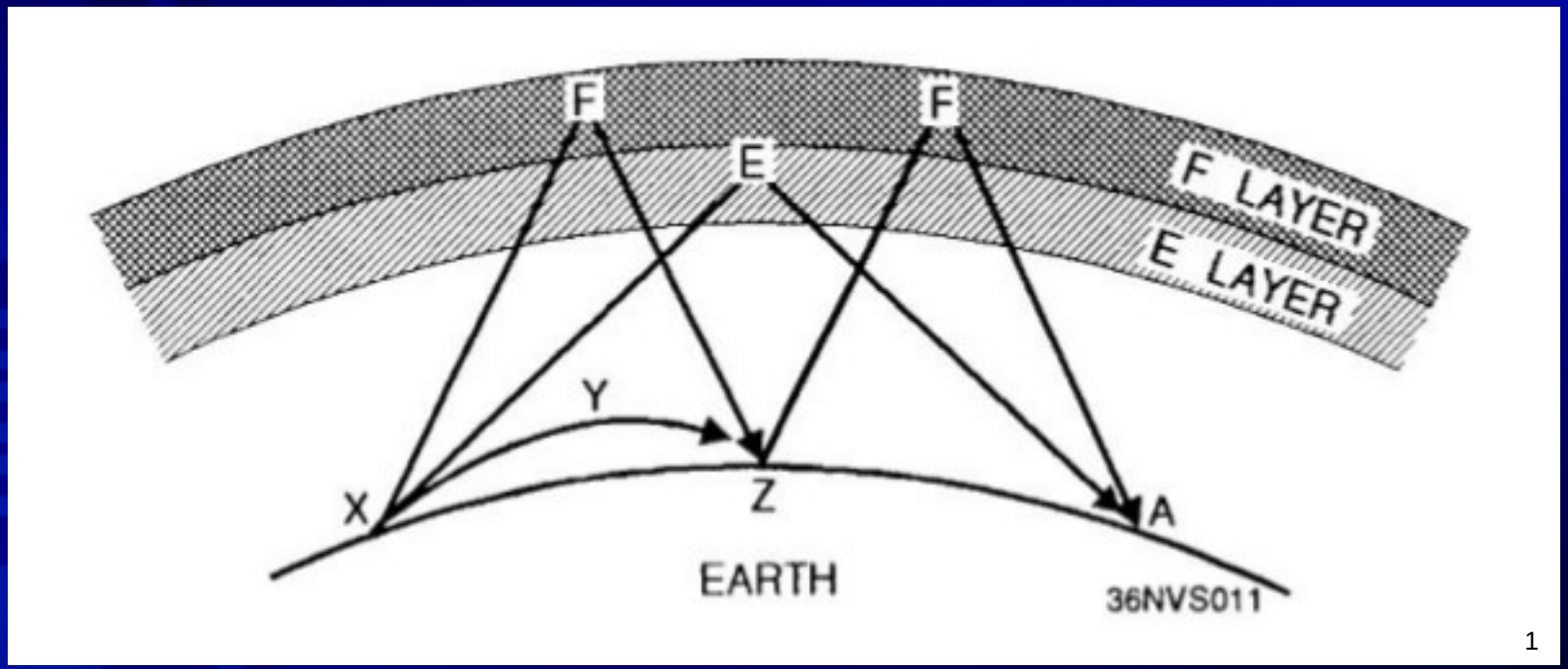
Fading

- Multipath fading:



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Other phenomena that affect the Ionosphere

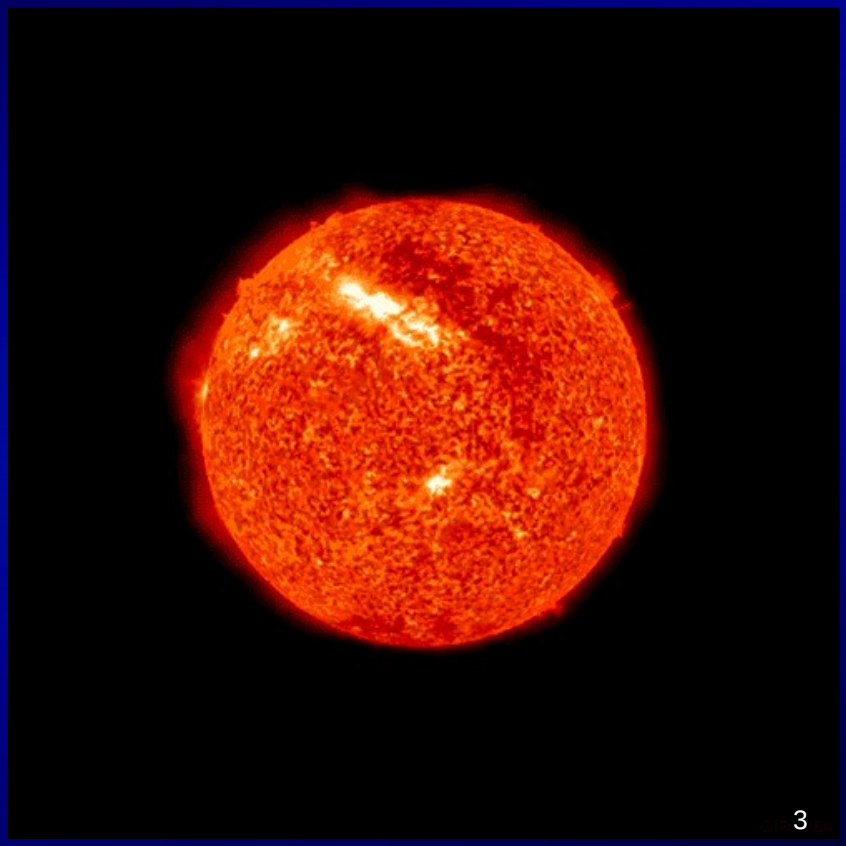
- Regular Variations
  - Are divided into four main classes:
    - Daily:
      - Based on changes occurring from day to day due to the earth's rotation.
        - Is it daytime, or nighttime?
    - Twenty Seven Day:
      - Based on the solar rotation:
        - Solar Storms rotating back into Earth view.
        - Sunspots rotating back into Earth view.
    - Seasonal:
      - Based on the earth's position relative to the Sun:
        - Sun light hits at different angles during different times of the year, on a set location.
    - Eleven Year:
      - Based on cyclic solar condition:
        - Around every 11 years the bands go to pot, then return four or five years later.

Other phenomena that affect communications

- Daily changes in the Ionosphere:
  - Daily changes in the Ionosphere play the largest role in propagation:
    - Is it daytime?
    - Is it nighttime?
    - How much ionization is happening at this moment?
    - What time is it now?
    - What is the distance to my target?

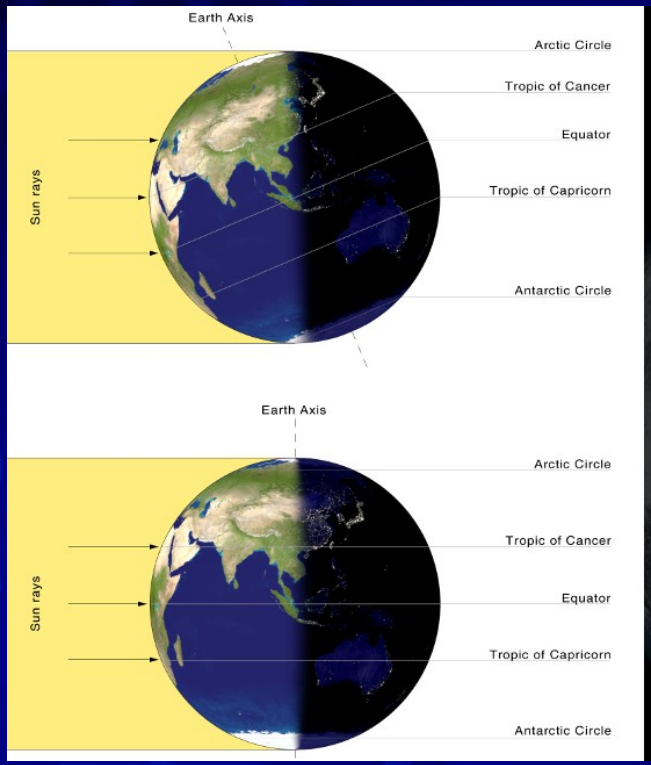
Other phenomena that affect communications

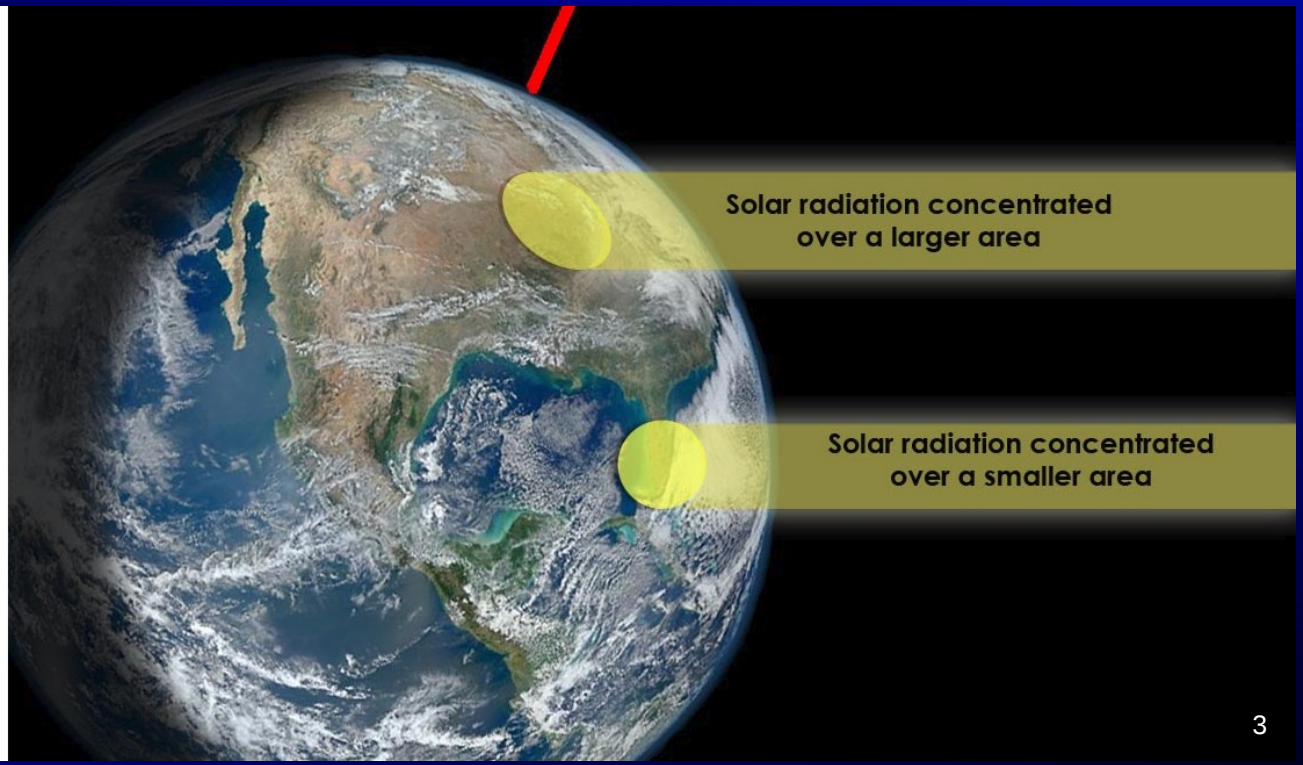
- Twenty Seven Day cycle is rotation based.



Other phenomena that affect communications

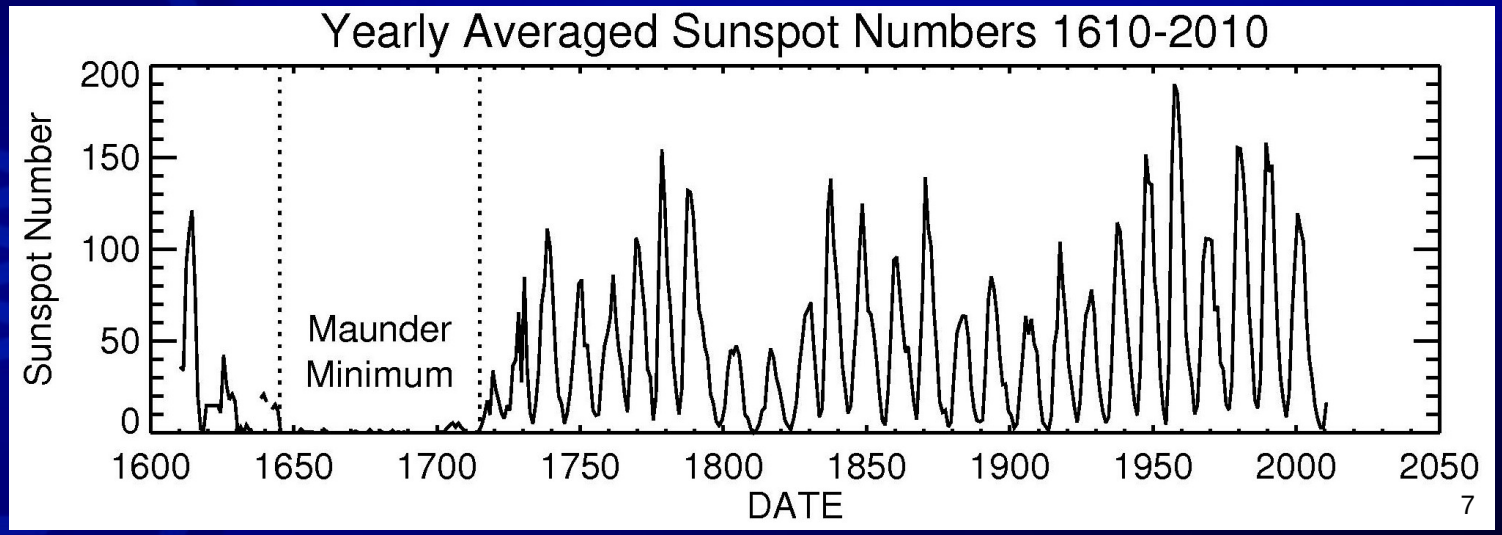
- Seasonal variations:





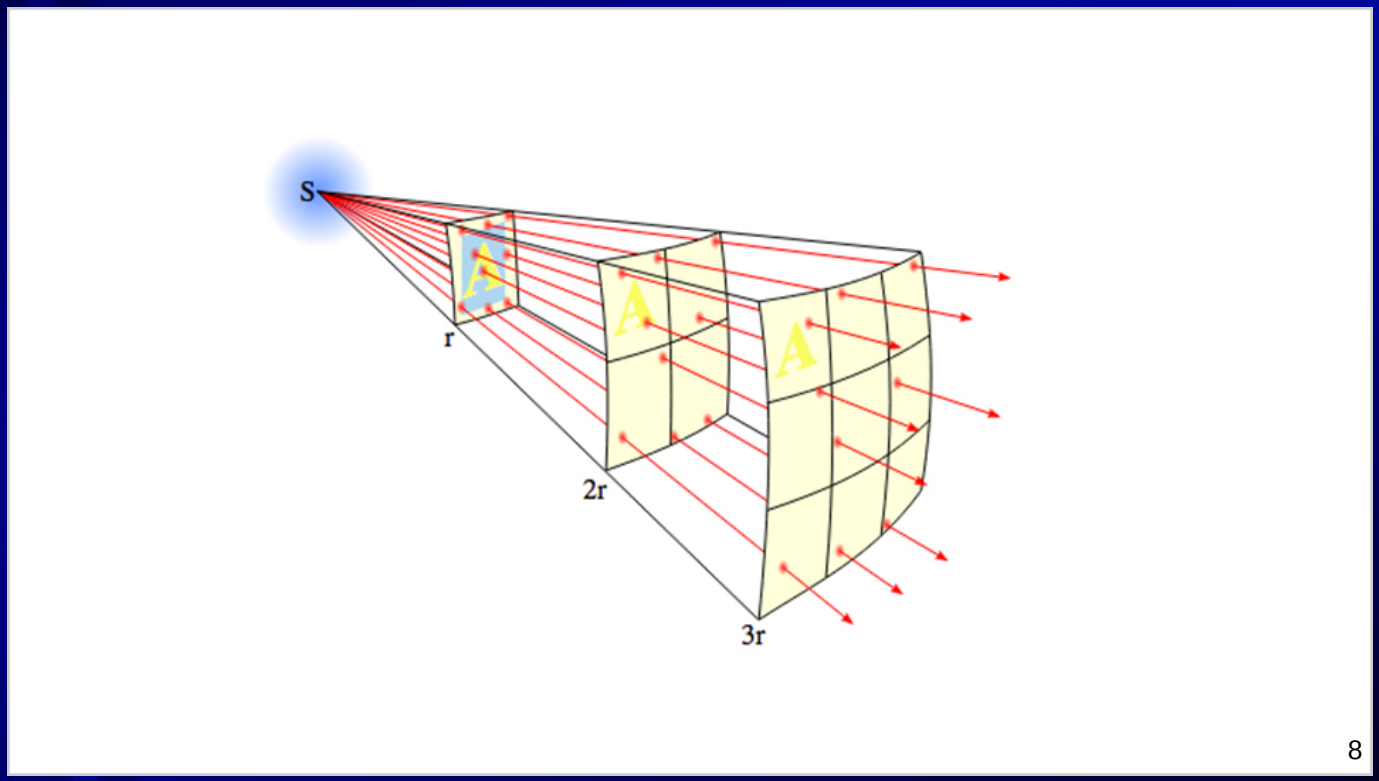
Other phenomena that affect communications

- Eleven Year:
  - The sunspot cycle is a regular cycle that has a minimum, and maximum level of activity approximately every 11 years.
    - During times of maximum activity, the ionization density of all layers increases.
    - Because of this the critical frequency of the D, F1, and F2 layers increase.



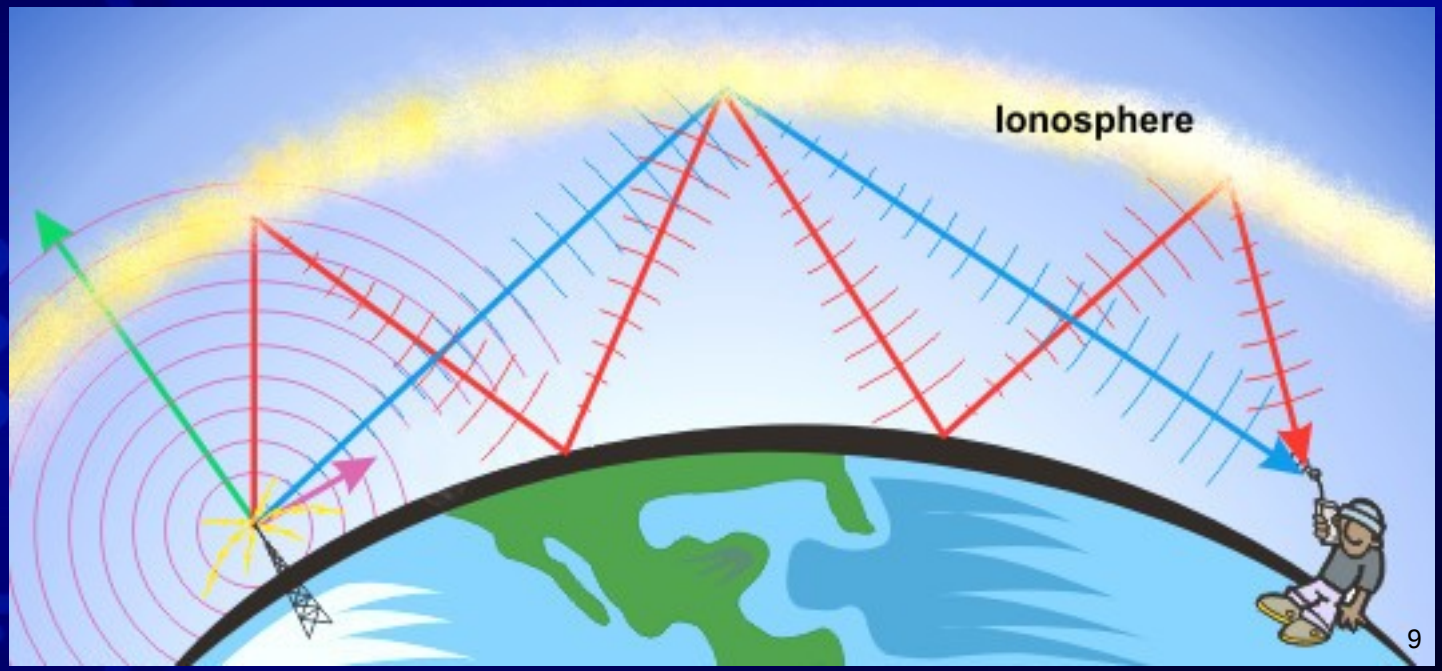
Transmission losses

- Free Space losses
  - The inverse square law



Transmission losses

- Reflection loss:
  - Each reflection costs db.
  - Water cost less, dirt more.

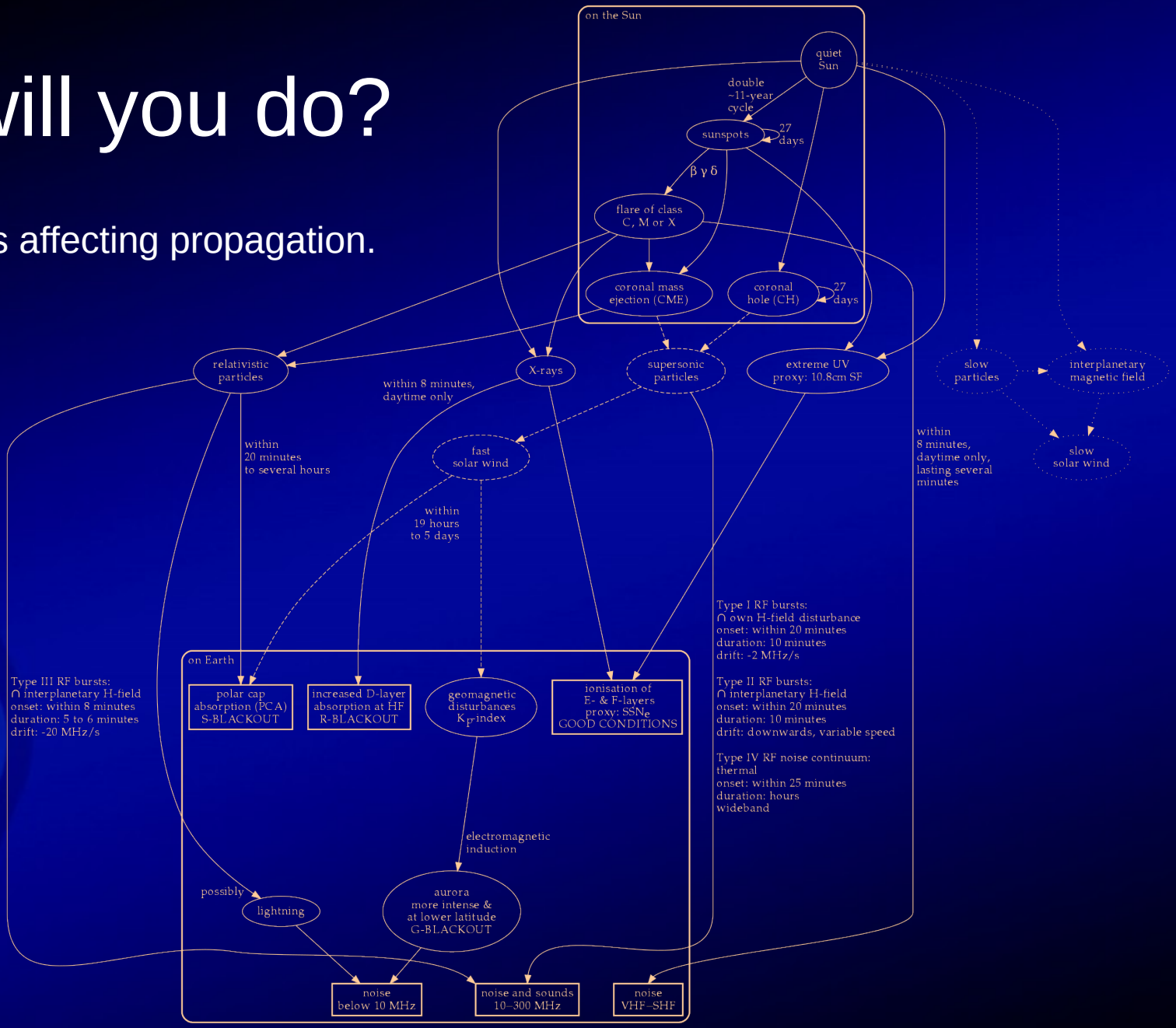


Toolbox Review

- Atmosphere, construction.
- Ionosphere, what is it.
- Ionization, how it happens.
- Recombination, why it is important.
- Ionospheric Layering, how layering happens,
- Refraction, how a signal bends in the ionosphere.
- Skip Distance and Zones, shadowed areas, etc.
- Reflection phase shift, it’s a mirror!
- Other phenomenon affecting propagation, sun, day/night, etc.
- Transmission losses, reflection, losses.

Now what will you do?

The various components affecting propagation.



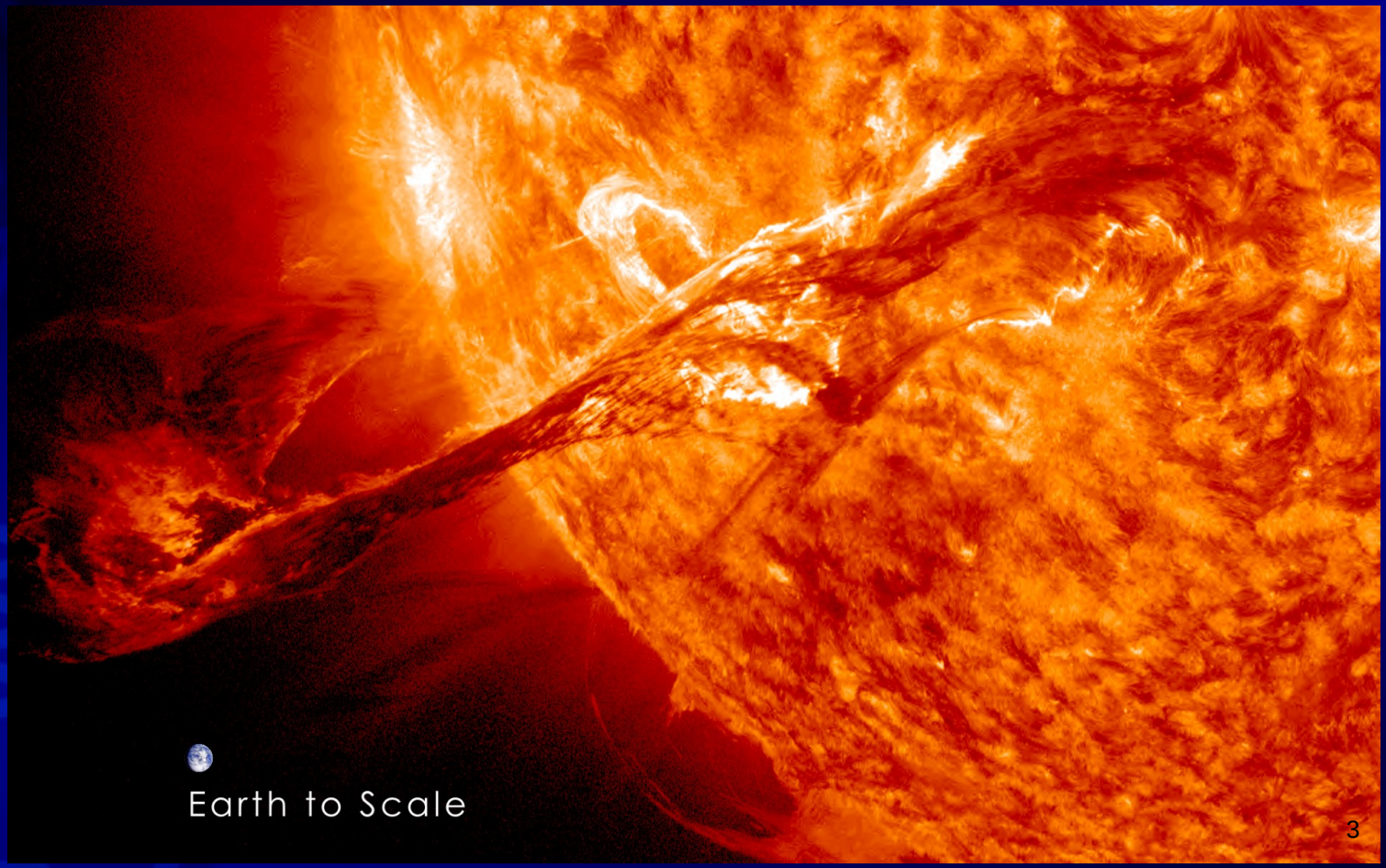
The Sun

- Solar Flux:
  - Solar flux is a measure of radio noise at 2800 MHz. Or 10.7 cm. It is called SFI.
  - Increasing SFI generally mean better propagation.
  - Increasing SFI also mean more noise.
  - Increasing SFI means more ionization, and the higher the MUF becomes.

The Sun

- X-Ray Flux:
  - Measured as A0.0 to X9.9.
    - The letters A, B, C, M, and X, represent increasing energy levels of X-Rays hitting the ionosphere.
  - Primarily impacts the D layer.
  - Increasing X-Ray flux means more D layer absorption, and hence less DX.
  - Decreasing X-Ray flux means less D layer absorption, and more DX.

The Sun



The Earth

- Components affecting propagation:
  - Geomagnetic indices:
    - K Index
      - A measure of the disturbance in the earth's magnetic field.
      - K indices are measured all across the planet.
      - No two K indicies are even close to each other.
      - All are averaged to give the K index.

The Earth

- Major components affecting propagation:
  - Geomagnetic indices:
    - Kp Index
      - Ranges from 0 to 9
        - 0-1 Quiet no degradation in conditions.
        - 2-4 Unsettled, some degradation of conditions.
        - 5 Signifies a minor storm
        - 6-8 Increasingly higher storm levels
        - 9 Major storm, HF blackout.

The Earth

- Major components affecting propagation:
  - Geomagnetic indices:
    - A Index:
      - The A index is a measure of the stability of the Earth's magnetic field.
      - It is derived from the K index by scaling to give a linear value then averaged over a single day period, from multiple locations on Earth.
      - It ranges from 0-400.
      - 100 is storm level.
      - 400 represents a severe geomagnetic storm.

The Earth

- A and K are related to Solar Flux:
  - The higher the SFI, the worse the A and K get.
  - The lower the SFI, the better the A and K get.
  - Best times are after a flare:
    - The rolling 90 day SFI holds high, while the A and K drop faster. You end up with high rolling SFI, and low A and K, so little noise, and good propagation...

The Earth

- How A and K relate:

AP INDEX	KP INDEX	DESCRIPTION
0	0	Quiet
4	1	Quiet
7	2	Unsettled
15	3	Unsettled
27	4	Active
48	5	Minor storm
80	6	Major storm
132	7	Severe storm
208	8	Very major storm
400	9	Very major storm

11

The Earth

- Geomagnetic indices:
  - Bz component:
    - A measure of the direction of the interplanetary magnetic field.
    - +50 to -50.
    - Measured in nT, or nano Teslas.
    - Plus mean interplanetary field is aligned with earth's magnetic field.
    - Minus means interplanetary field is opposite of the earth's magnetic field.
    - When minus, the earth's magnetic field is canceled somewhat, this increases the effects of solar particles on the Ionosphere.
    - Plus Bz equals good DX, minus equals bad DX conditions.

The Earth

- Geomagnetic indices:
  - Solar Wind:
    - Amount, and speed of solar particles hitting the Earth.
    - High speed/density solar wind crushes the Ionosphere down towards the Earth.
    - Low speed/density solar wind allows the ionosphere to expand.

What is a good DX day?

- What makes a good day DX wise?:
  - A high SFI.
    - Higher is better.
  - Slow less dense Solar Wind.
    - Less wind, is better.
  - No geomagnetic storms.
    - No storm is best.
  - A plus Bz.
    - Plus good.
    - Minus bad.

Prediction Tools

- Tools:
  - Spaceweather:
    - spaceweather.com
  - NOAA Space Weather Conditions:
    - http://www.swpc.noaa.gov/communities/space-weather-enthusiasts
  - Jet Propulsion Labs
    - https://iono.jpl.nasa.gov/

Prediction Tools

- Tools:
  - VOCAP:
    - http://www.voacap.com/p2p/index.html
  - N0NBH:
    - http://www.hamqsl.com/solar3.html
  - ARRL Propagation Charts:
    - http://www.arrl.org/propagation
  - Online HF Propagaton Prediction:
    - http://www.stroobandt.com/propagation/en/index.html

Prediction Tools

- Tools:
  - Usable HF Frequiencies:
    - http://www.hfpropagation.com/
  - Ham Cap:
    - http://www.dxatlas.com/hamcap/
  - Band Conditions:
    - http://www.bandconditions.com/
  - Propagation:
    - http://dx.qsl.net/propagation/

Questions

Citations

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3) NASA, GSFC

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5) "Fading" https://www.revolvy.com/main/index.php?s=Fading&uid=1575

6) "Vertical total electron content map" https://iono.jpl.nasa.gov/RT/latest_rti.gif

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