One Small Step — Understanding Propagation

BY N0UC

WITH CONTRIBUTIONS FROM K0JDD

Ver 1.4

Study of the Sun

The science surrounding the Sun is a life long endeavor and has been studied for centuries. Radio propagation affected by the Sun is a fairly new science and has been studied for less than 150 years. The development of internet access has allowed us quick access to real-time collection of this scientific information for analysis outside the scientific study community.

As the amateur radio community started gathering the available information many independent groups developed ways to help their fellow amateurs understand and use this information to be more successful without reinventing the science for themselves.

To use this information successfully there are a few things we need to understand including concepts, terms, and the available tools. We hope to address some, but not all of them here.

There is So Much to Know

With so much to know where do we start?

What do we want to accomplish with this knowledge?

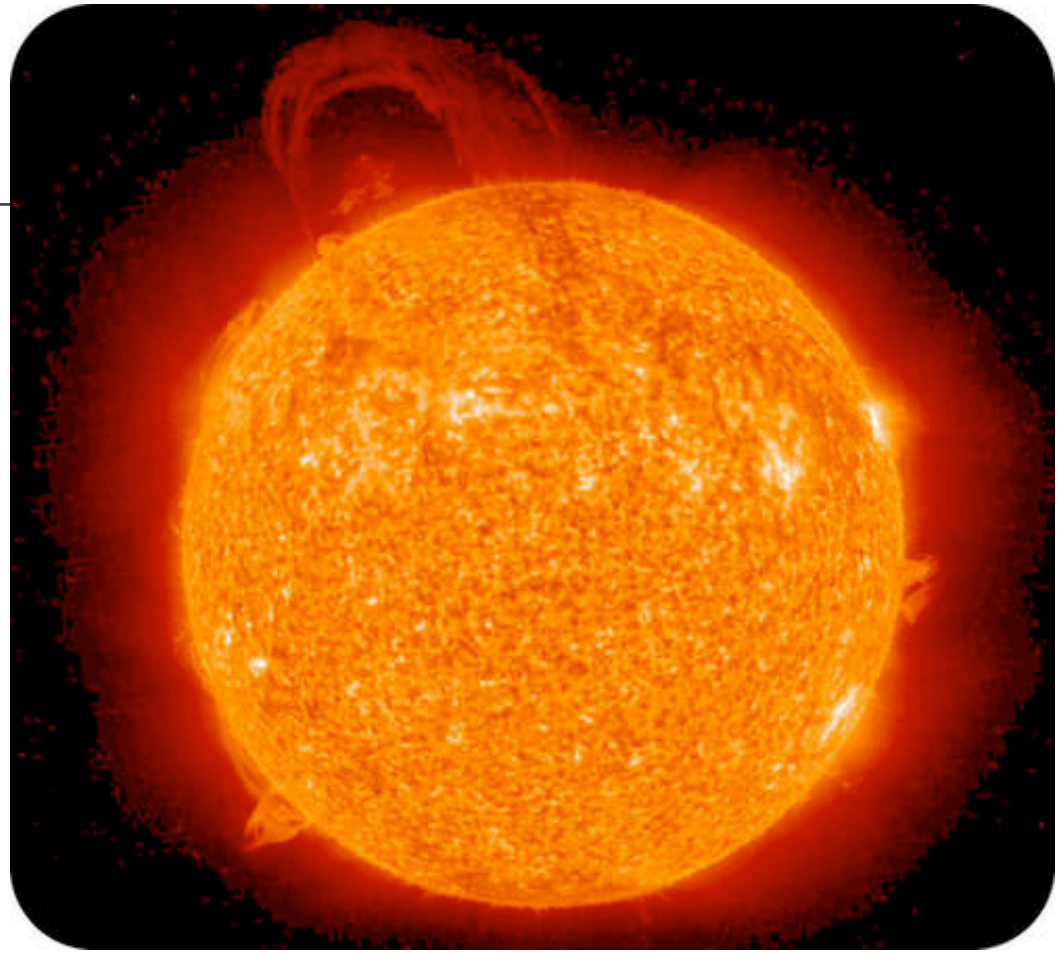
How are we expecting to put this to use in are daily routine operating our radio?

Answering these questions will help us decide.

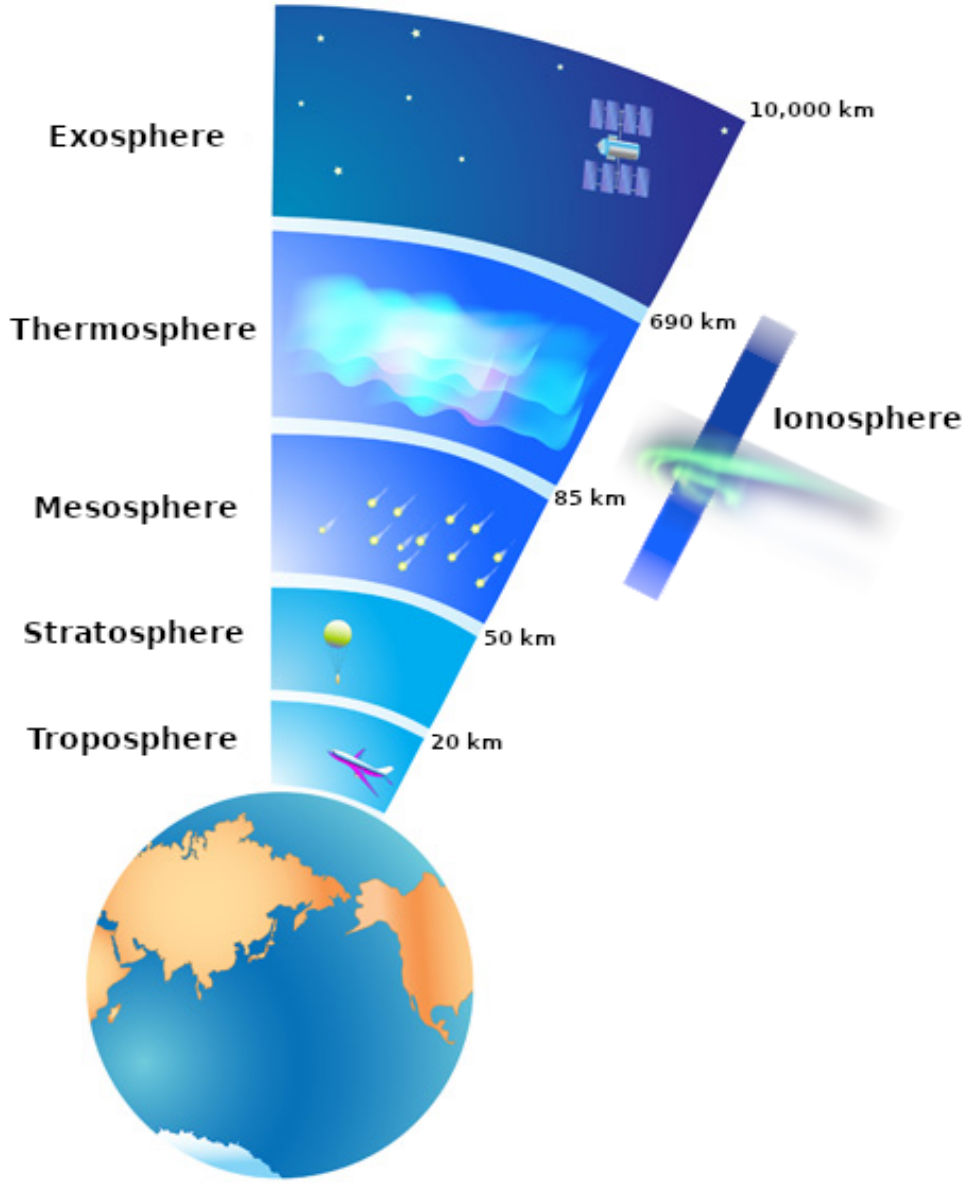
The Sun

The Sun is the primary source of electromagnetic radiation on Earth. The Earth is constantly bombarded with electromagnetic radiation (**EMR**), but before the electromagnetic energy from the Sun reaches the Earth's surface, it must pass through the atmosphere. The atmosphere protects us from exposure to higher energy radiation that can be harmful to life – i.e. X-Ray and Gamma Rays.

As the energy passes through the atmosphere, it interacts with the molecules and particles present in the atmosphere. In the atmosphere, EMR is scattered or reflected or absorbed, and a portion of the energy passes through the atmosphere to reach the Earth's surface.



The Atmosphere



What we should already know

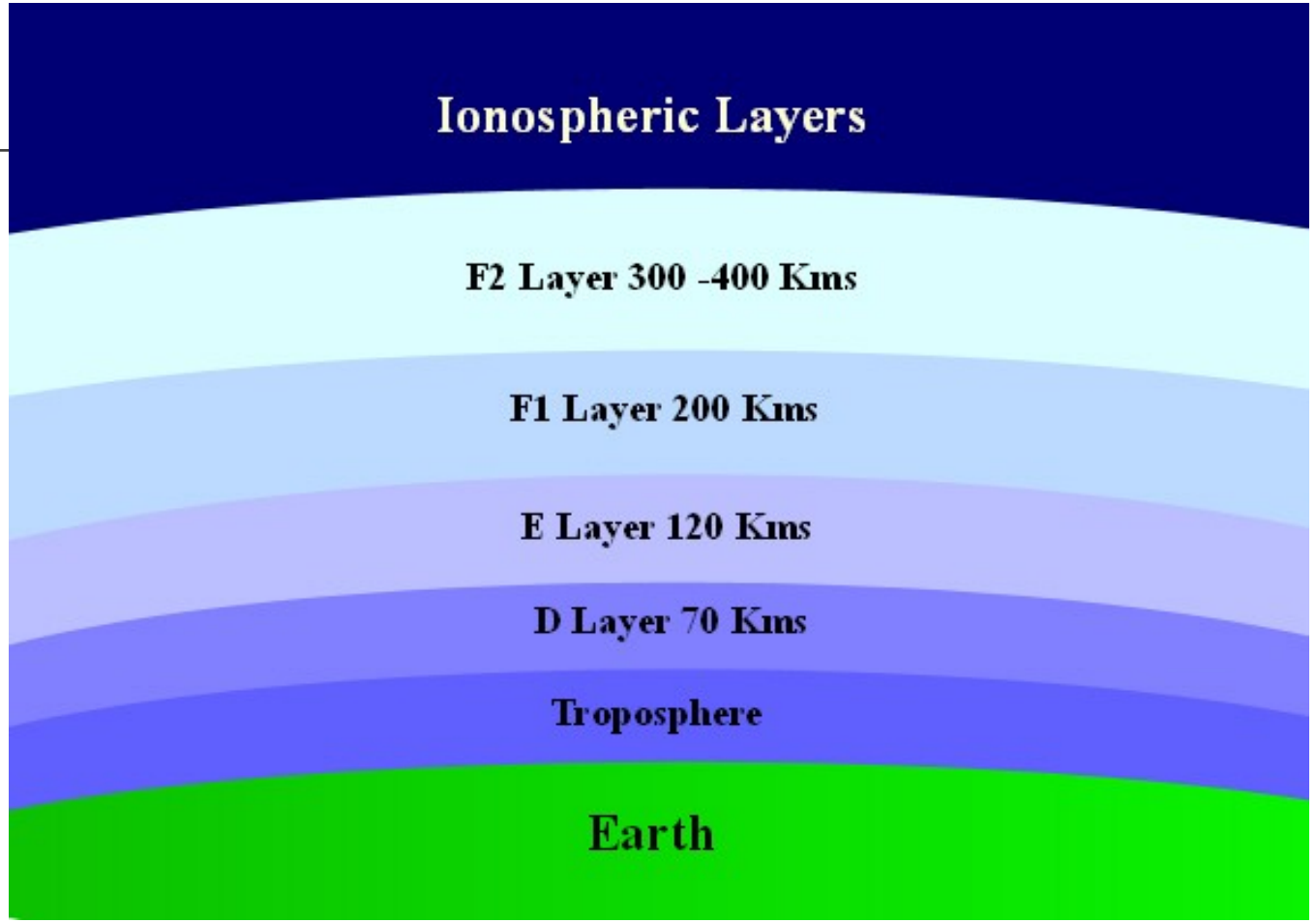
In studying for our amateur radio license we learned the basics of propagation so we don't need to go over that again. *Or do we?* Maybe our memory should be refreshed.

Atmospheric regions related to radio waves like D, E, F1 & F2

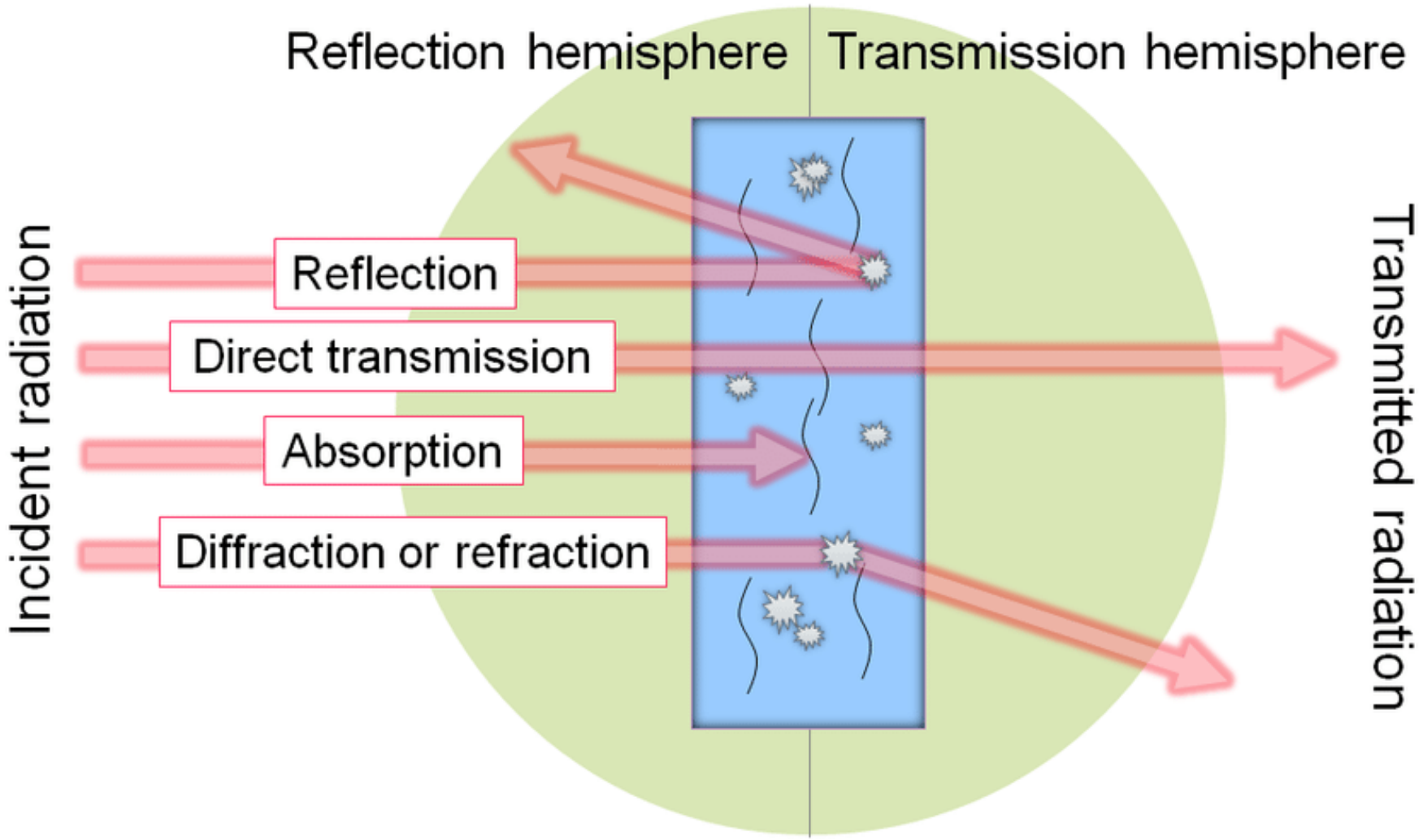
Terms: Ionosphere, absorption, reflection, refraction, scattering, diffusion, NVIS, Ground wave, Skywave, LOS, single-hop, skip zone, multi-hop, chordal-hop, ducting, sporadic Es, trans-equatorial skip, critical angle, take-off angle, critical frequency, MUF, digisonde, ionization, grey line

Note: The Time of Day, The Year, The Season, The Frequency, The Planetary Location, Planetary and Local Magnetic Disturbances, and QRN are all ***additional*** factors which exert their influence on propagation.

Ionosphere

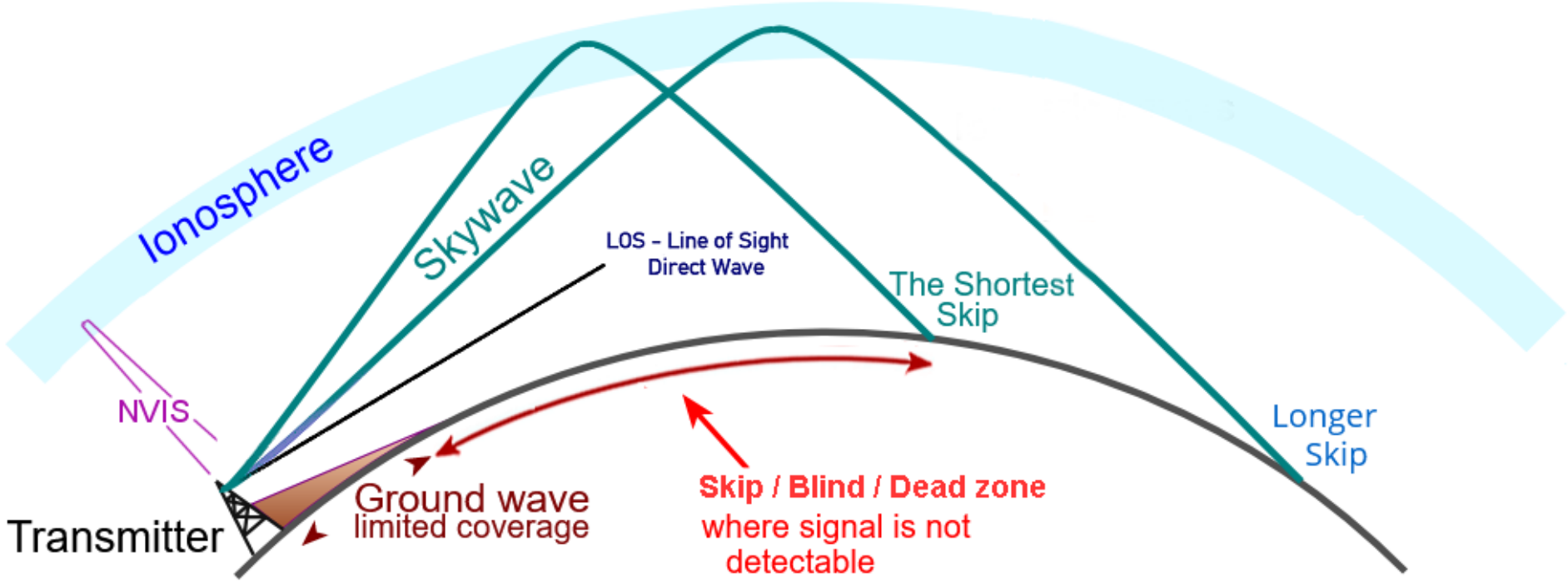

Ionospheric Layers
F2 Layer 300 -400 Kms
F1 Layer 200 Kms
E Layer 120 Kms
D Layer 70 Kms
Troposphere
Earth

Terms



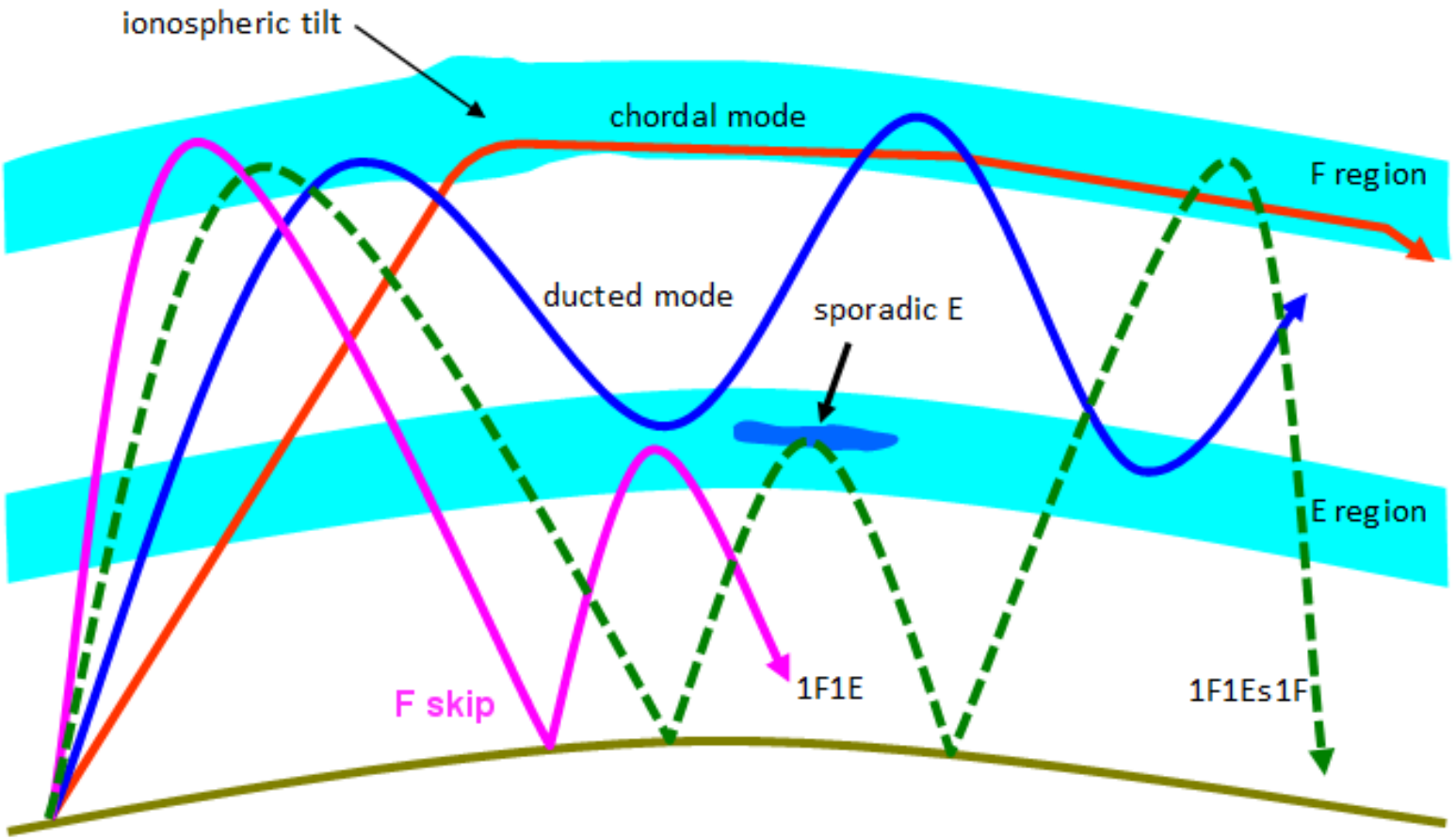
Absorption, reflection, refraction, scattering, diffusion

Terms



Single-hop, NVIS, Ground wave, Skywave, LOS, skip zone

Terms

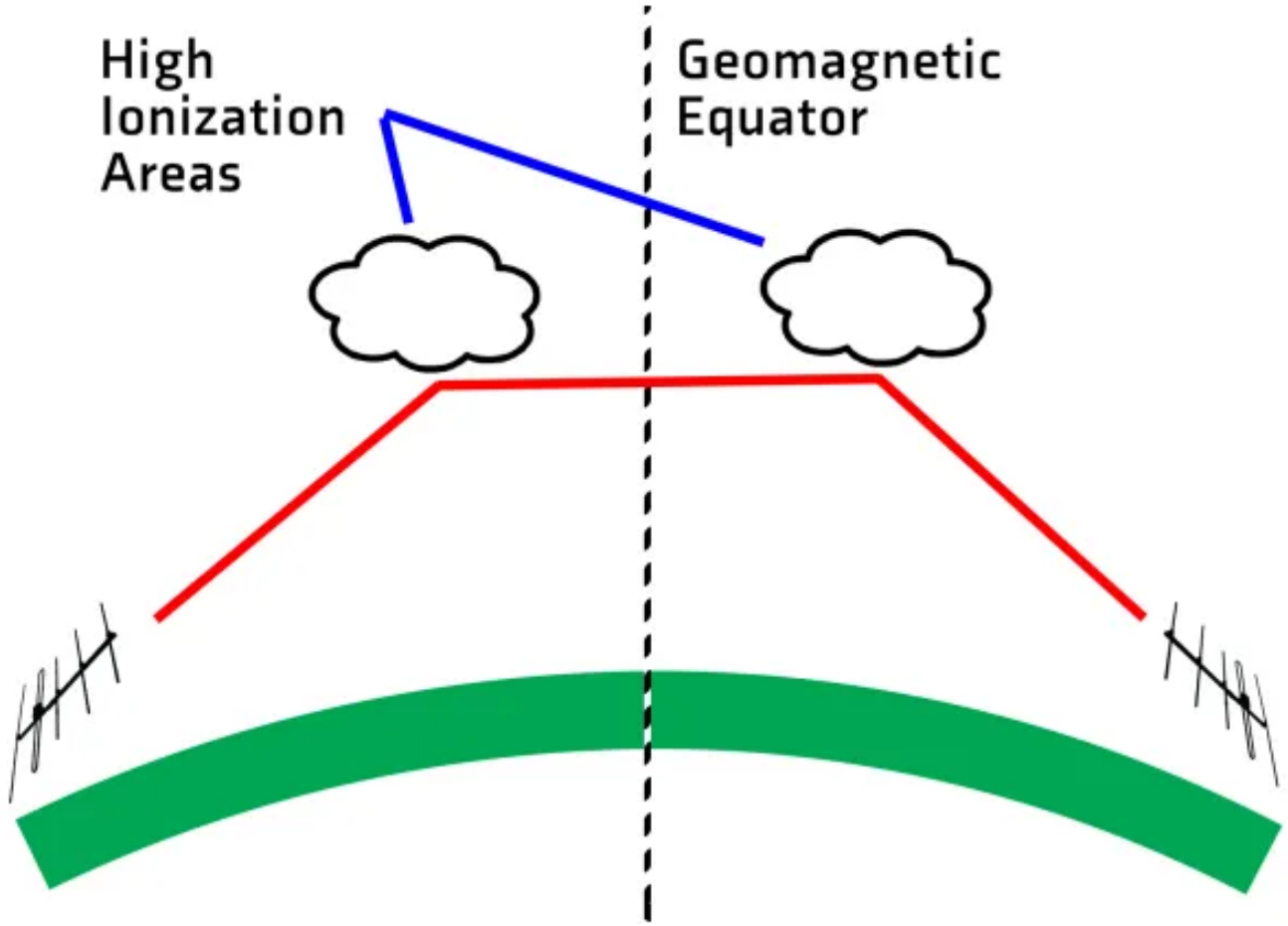


Multi-hop, Chordle-Hop, Ducting, Sporadic E, Complex-modes: 1F1E, 1F1Es1F

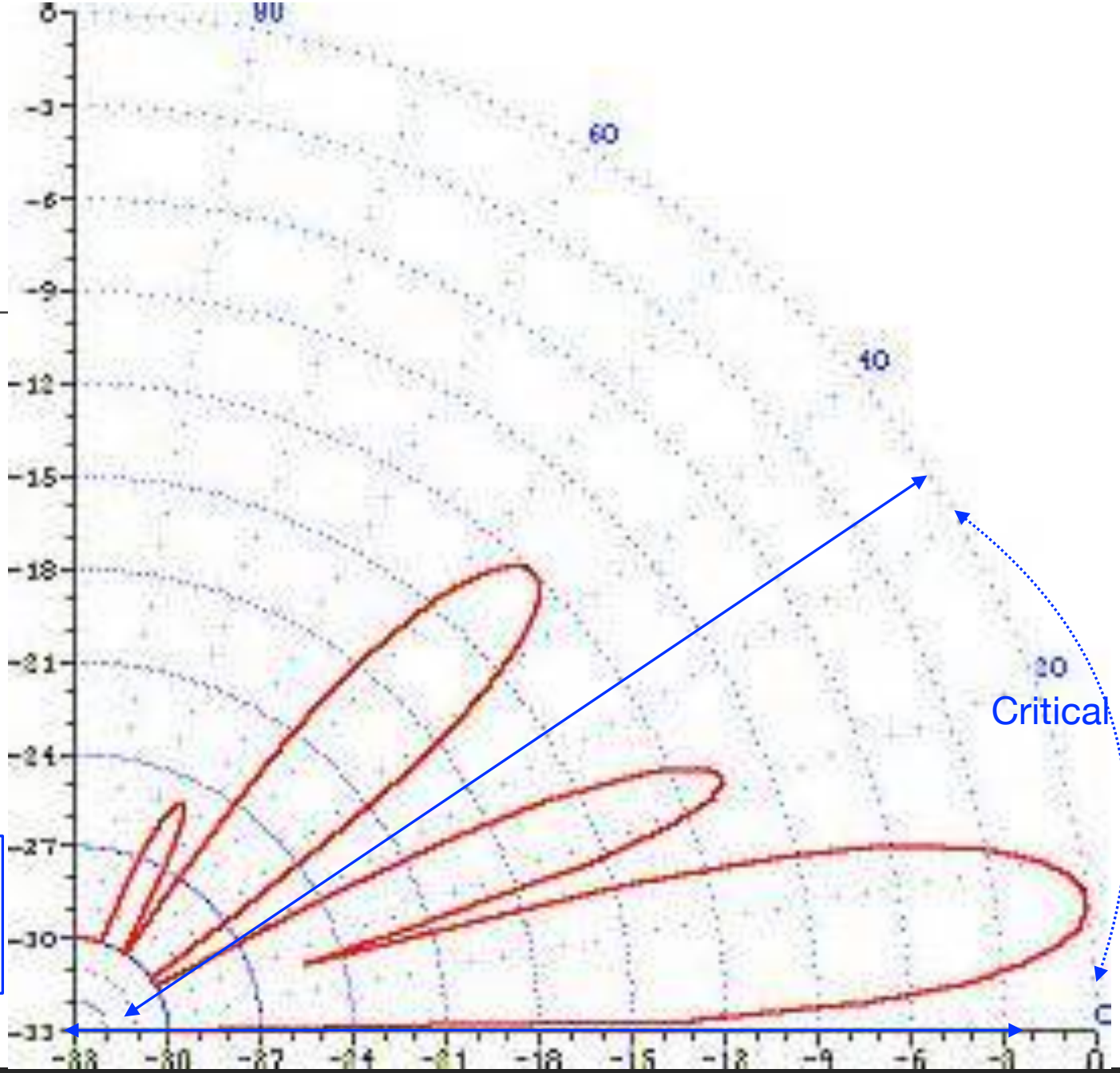
Terms

Trans-equatorial skip refers to a propagation phenomenon in radio wave transmission, particularly in the shortwave (HF) bands.

Near the magnetic equator, there is often a phenomenon known as the equatorial anomaly, where electron density in the ionosphere is higher…

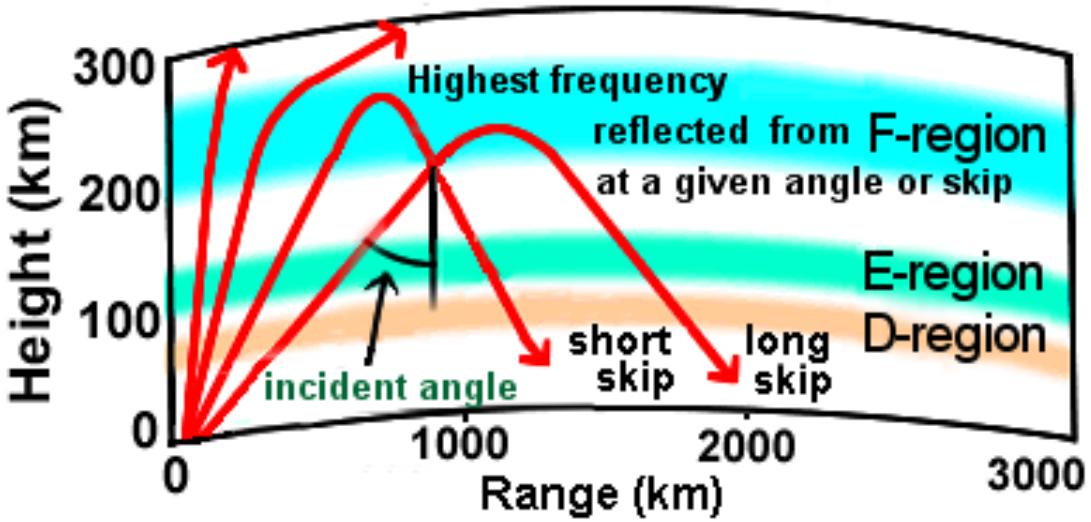


Terms

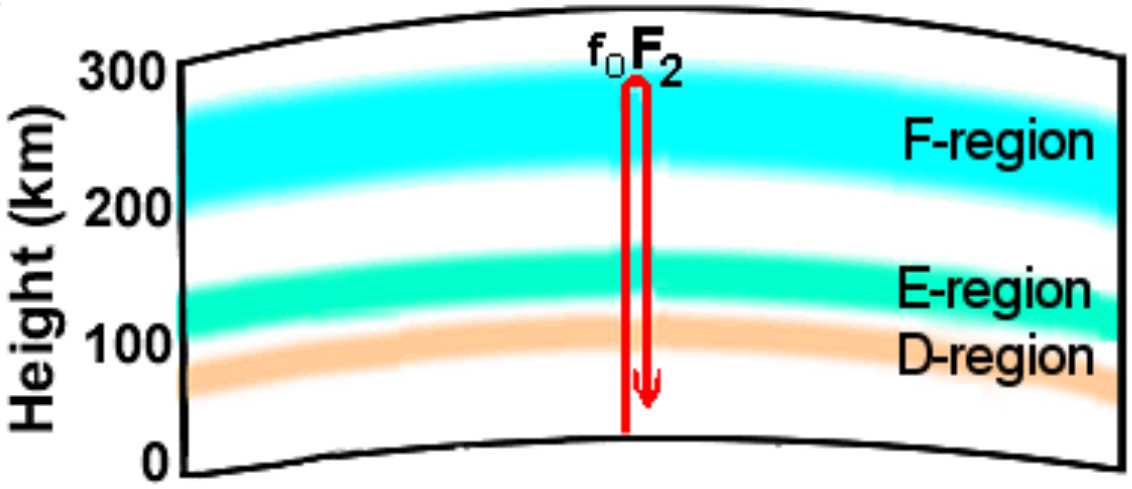


For Antenna X:
Multiple Take-off Angle(s)
vs. Critical Angle

Terms



Maximum Usable Frequency (MUF) – the highest frequency at which reliable radio communications via ionospheric propagation can be maintained over a given path

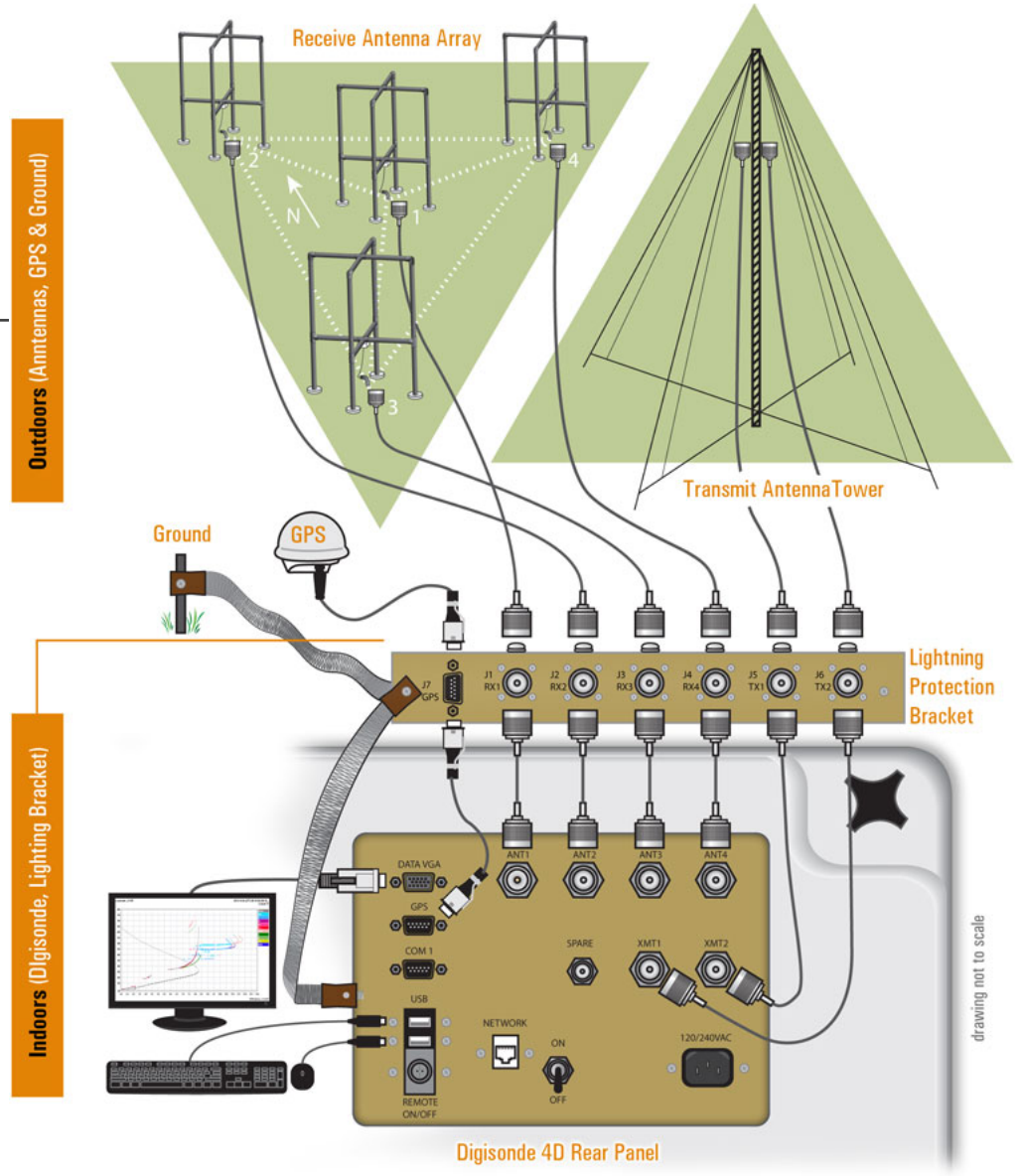


Critical Frequency – the highest frequency at which a signal transmitted straight up at 90 degree elevation angle is returned to earth.

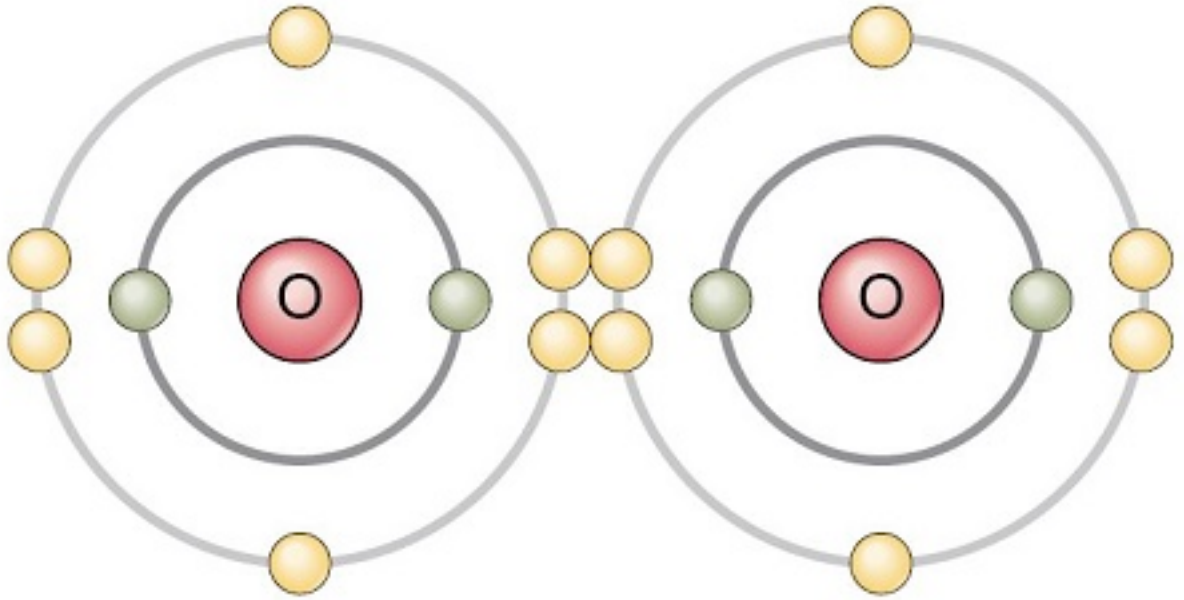
Terms

Digisonde Station can operate in the multi-beam sounding mode using six digitally synthesized off-vertical reception beams in addition to the vertical beam. For each frequency and height on a multi-beam ionogram, the raw data from the four receive antennas are collected and processed to form seven beams , separately for the O-mode and X-mode echoes. For each frequency-range pixel, the beam with the maximum amplitude is selected, and the amplitude and beam numbers are recorded in the output data. This information is use to form an ionogram report from that station.

[K0JDD Translation: Complicated gizmo to measure stuff…]



Oxygen



Molecule of oxygen gas (O_2)

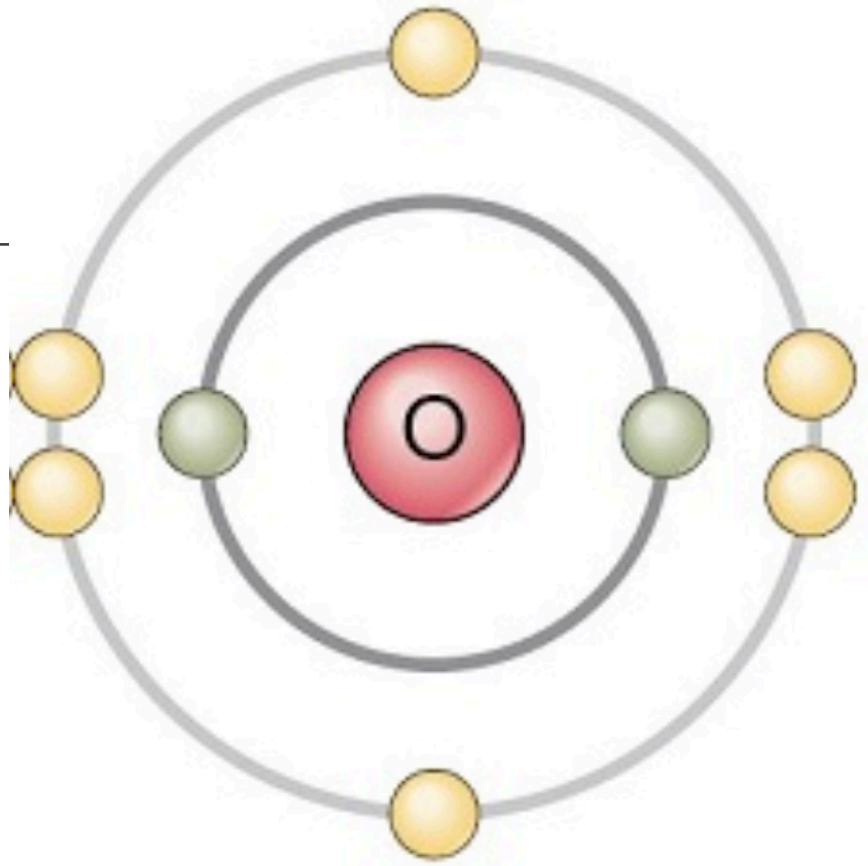
At the surface of the earth we breath O_2 gas, which is the created by the double covalent bonding of two Oxygen atoms.

Little known Fact: Brian McInerney studied AP Physics and Chemistry under *Sister Mary-Marie Curie*.

Continuing

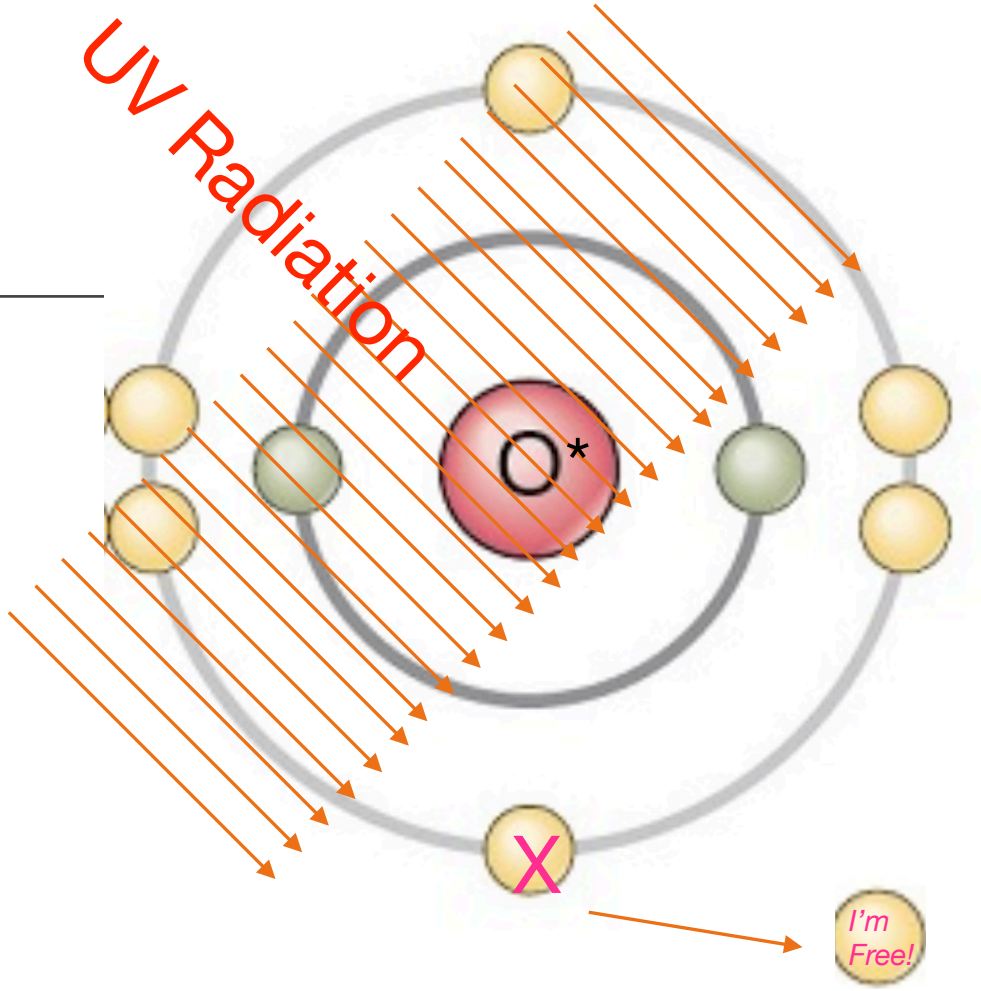
Elements In the Universe:
Hydrogen (most abundant)
Helium (second most abundant)
Oxygen (third most abundant)

Ratios:
Hydrogen to Helium: 3:1
Hydrogen to Oxygen: 6:1



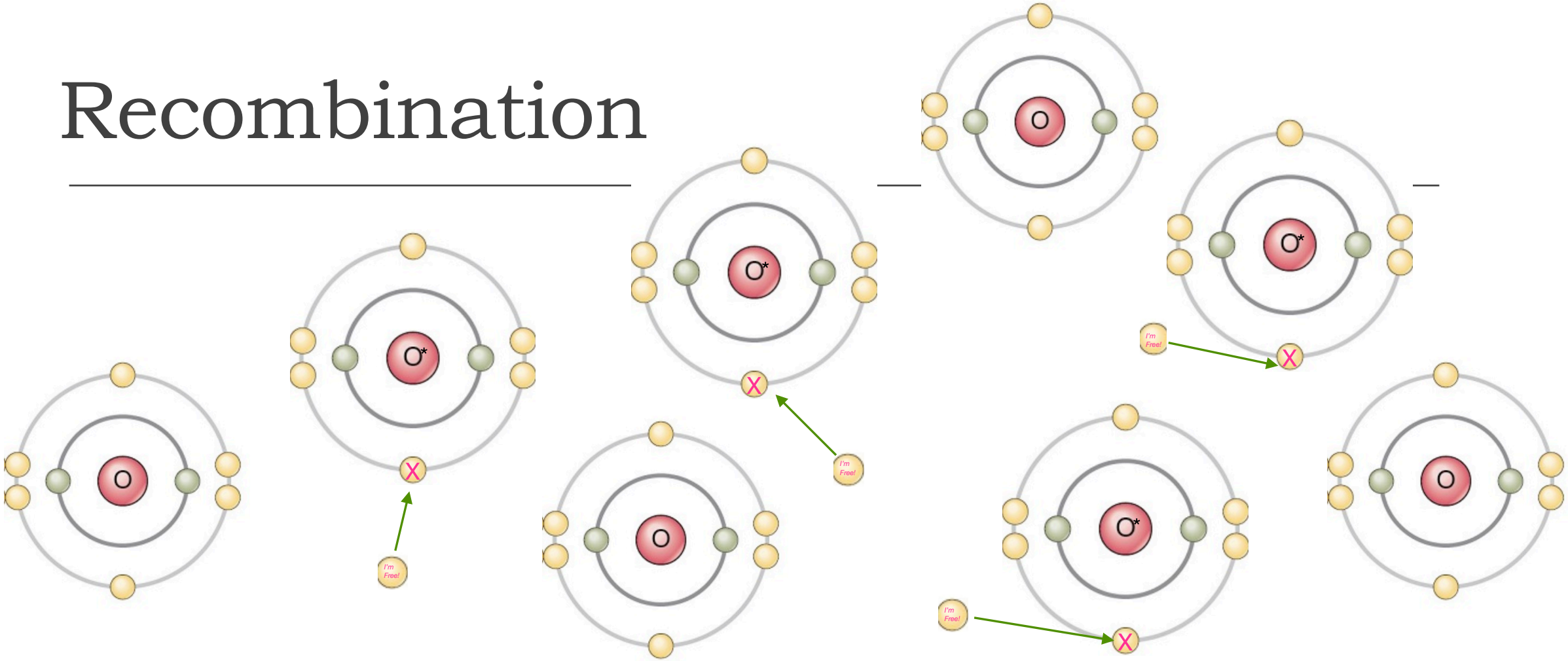
In the ionospheric layers, there exists large numbers of Oxygen atoms

Ionization



UV Radiation from the sun provides these atoms with enough energy to cause them to eject one electron which creates O* ions and free electrons.

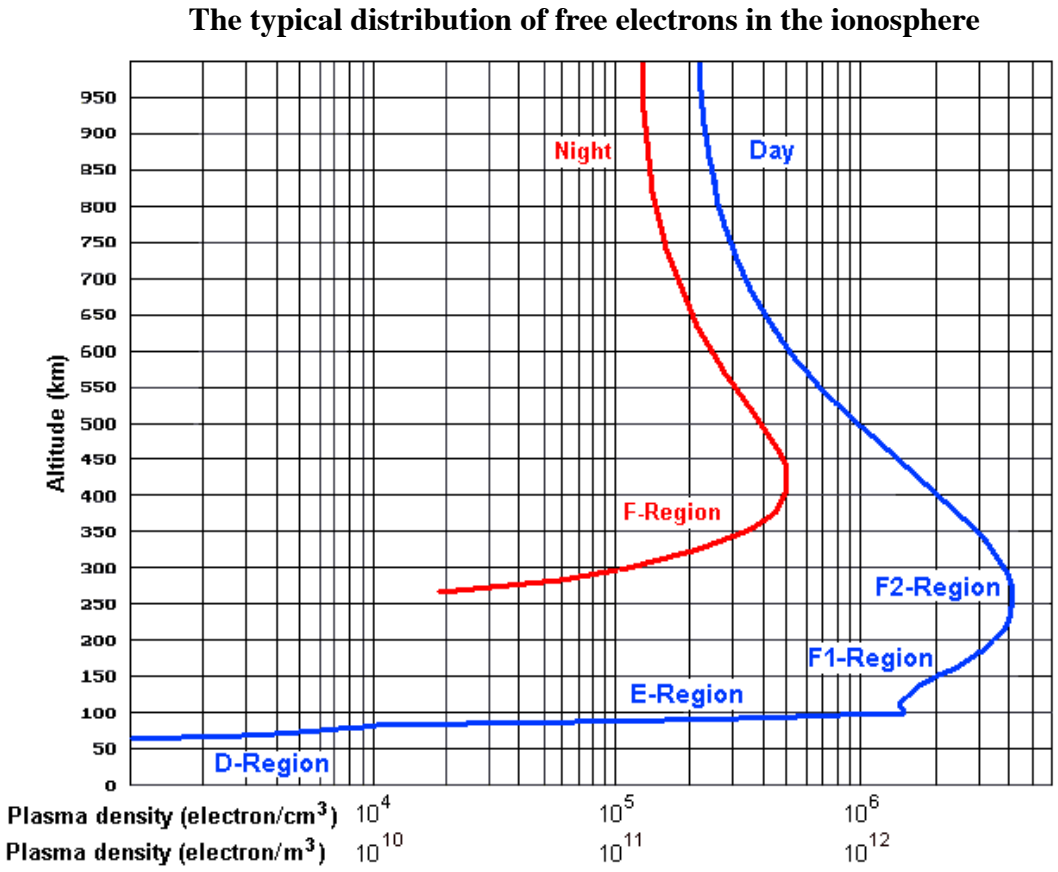
Recombination



These free electrons ‘bounce around’ until they are recaptured by other O* ions.
And this process repeats itself *ad infinitum*…

Continuing

Ionospheric Region	Recombination Time
F1/F2 Layer	Minutes to Hours
E-Layer	**Seconds to Minutes**
D-Layer	Milliseconds to seconds



Typical **recombination** times of Oxygen Ions and Free Electrons.

Ionization - Summary

The ionization of oxygen affects the density of ions and electrons in the ionosphere.

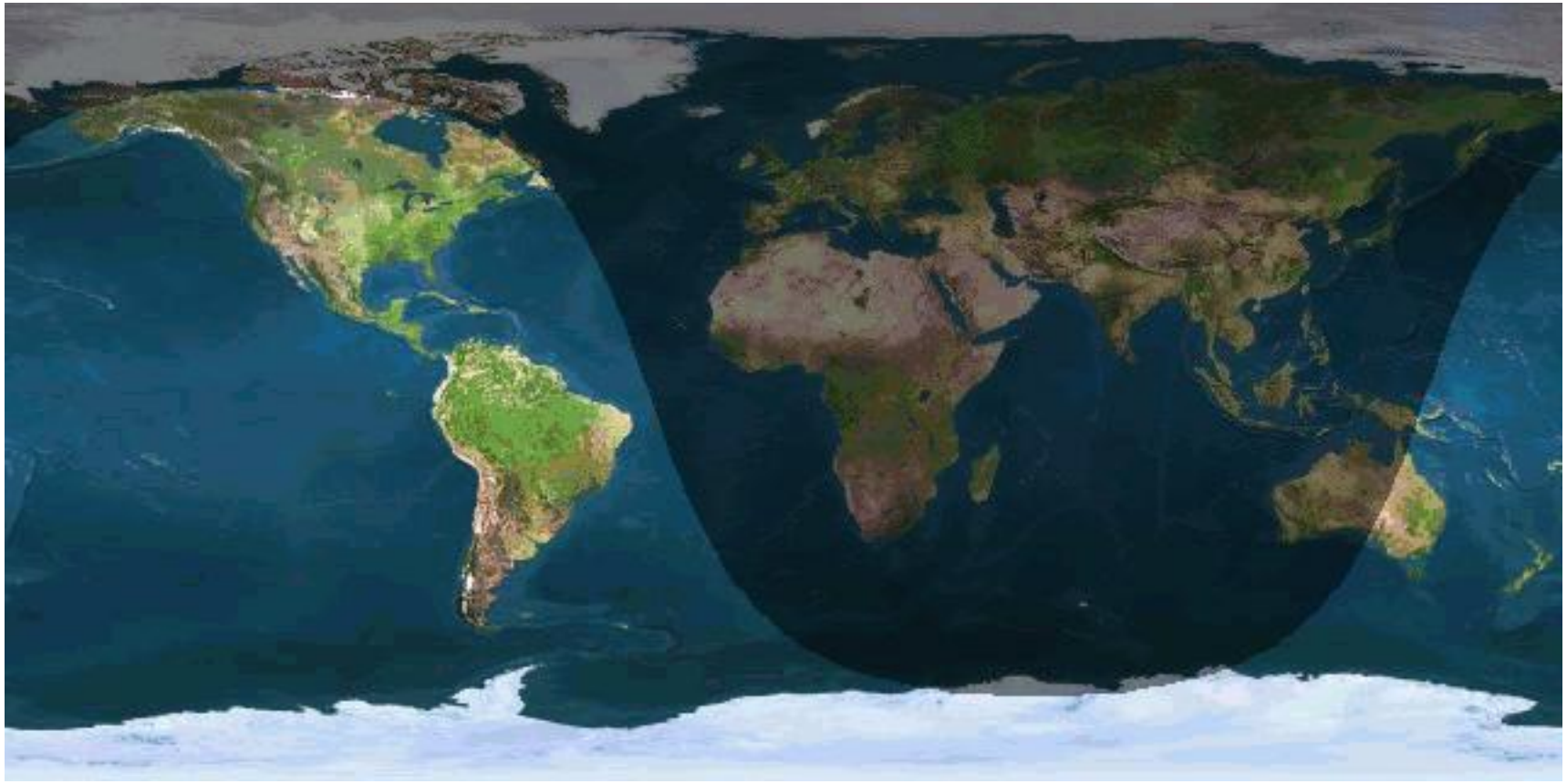
In the lower and middle regions of the ionosphere, particularly in the D and E layers, the concentration of ionized oxygen varies with altitude, solar activity, and time of day.

At Lower altitudes (D layer), oxygen is ionized but the density of ions and free electrons is lower due to rapid recombination processes. At Higher altitudes (F layer), the recombination process is much slower resulting in more ions and electrons remaining in the layer for longer periods of time

The F layer is critical for long-distance radio wave propagation, with ionized oxygen playing major a role in reflecting HF signals back to Earth.

More ionized oxygen present = better reflection of HF signals

Grey Line



RF Signals traveling towards the Grey Line

1. **Enhanced Propagation**:
    - When a signal is transmitted toward the grey line (the area transitioning from day to night), it can take advantage of improved ionospheric conditions. The D layer weakens as the sun sets, allowing for less absorption of HF signals.
2. **Reflection Opportunities**:
    - As the signal approaches the grey line, it is likely to be reflected back to Earth by the ionosphere, particularly by the E and F layers that are more effective during twilight conditions. This can result in longer distances and more reliable communication.
3. **Reduced Skip Distance**:
    - Signals transmitted toward the grey line may achieve shorter skip distances, as they are more likely to reflect effectively off the ionosphere and reach distant receivers.
4. **Higher Frequency Usability**:
    - Frequencies closer to the Maximum Usable Frequency (MUF) can be used as the signal approaches the grey line, enhancing the potential range of communication.

RF Signals traveling away from the Grey Line

1. **Increased Losses**:
    - When transmitting away from the grey line, particularly during the day, signals may encounter greater absorption by the D layer, which is fully developed and can significantly weaken the signal.
2. **Higher Skip Distances**:
    - Signals transmitted away from the grey line may experience longer skip distances. This means they may need to travel further to reach the ionosphere and reflect back, leading to less effective communication.
3. **Limited Frequency Options**:
    - Operators may have to use lower frequencies that are less affected by the D layer's absorption, which could limit communication range and effectiveness.
4. **Potential for Fading**:
    - As the signal moves away from the grey line, it may encounter more variability in ionospheric conditions, leading to potential fading and signal degradation.

Things to Know

What are these things called **Planetary Indices**?

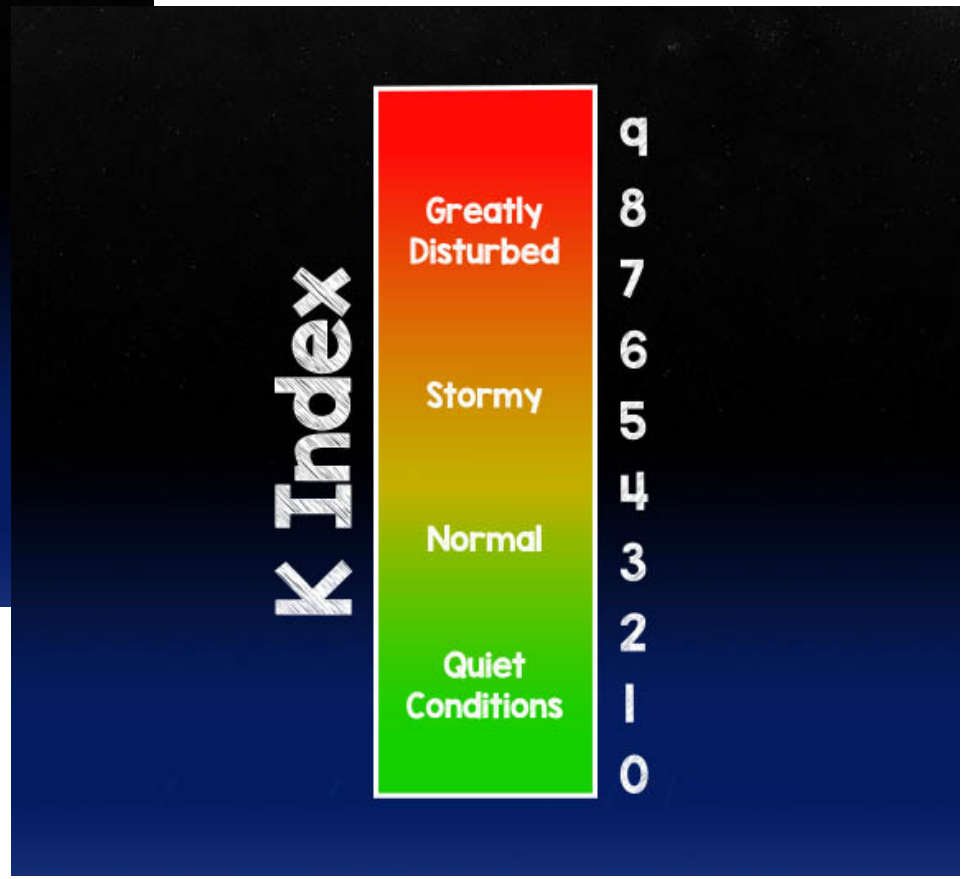
The Ap and Kp indices are a measurement of the behavior of the magnetic field in and around the earth.

The Kp index uses a scale from 0 to 9 to measure the change in the horizontal component of the geomagnetic field

The Ap index is a daily value on a scale from 0 to 400 to express the range of disturbance of the geomagnetic field.

Solar flux is a measurement of the intensity of solar radio emissions with a wavelength of 10.7 cm (a frequency of about 2800 MHz)

Ap / Kp Indices



Ap / Kp Indices

Relationship between Kp index and A Index		
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

Solar Flux


Solar Flux Index
Good Conditions
Marginal
Poor Conditions
300
200
100
50

More Things to Know

X-Ray Flux is an early warning system for the earth. X-ray flux intensity is used to classify storm levels. These levels are A, B, C, M, X being the highest.

Solar winds are predictive of solar storms. These storms result in variations in the solar wind that produces major changes in the currents, plasmas, and fields in Earth's magnetosphere. **The largest storms that result from these conditions are associated with solar coronal mass ejections (CMEs) where a billion tons or so of plasma from the sun, with its embedded magnetic field, arrives at Earth.**

Bz indicates the direction of the flow of the magnetic currents induced by the solar winds.

What does it all mean?

When we see a rising **Solar flux,** and a falling **Ap index,** and a **Kp index** of 2 or less we could expect improving DX conditions.

When we see a rapidly rising **x-ray flux** beware that a geomagnetic storm may be on its' way with degrading propagation across the bands and if strong enough, radio blackouts may occur.

The **critical frequency** is indicating the level of **D-layer** formation.

The **MUF** is indicating the best frequency for local NVIS communication at that point in time. When combined with other factors could indicate best frequency for longer communication also.

Gathering this real-time info and plugging it into an available propagation program gives a good opportunity to increase the chances of making contact with a wanted location.

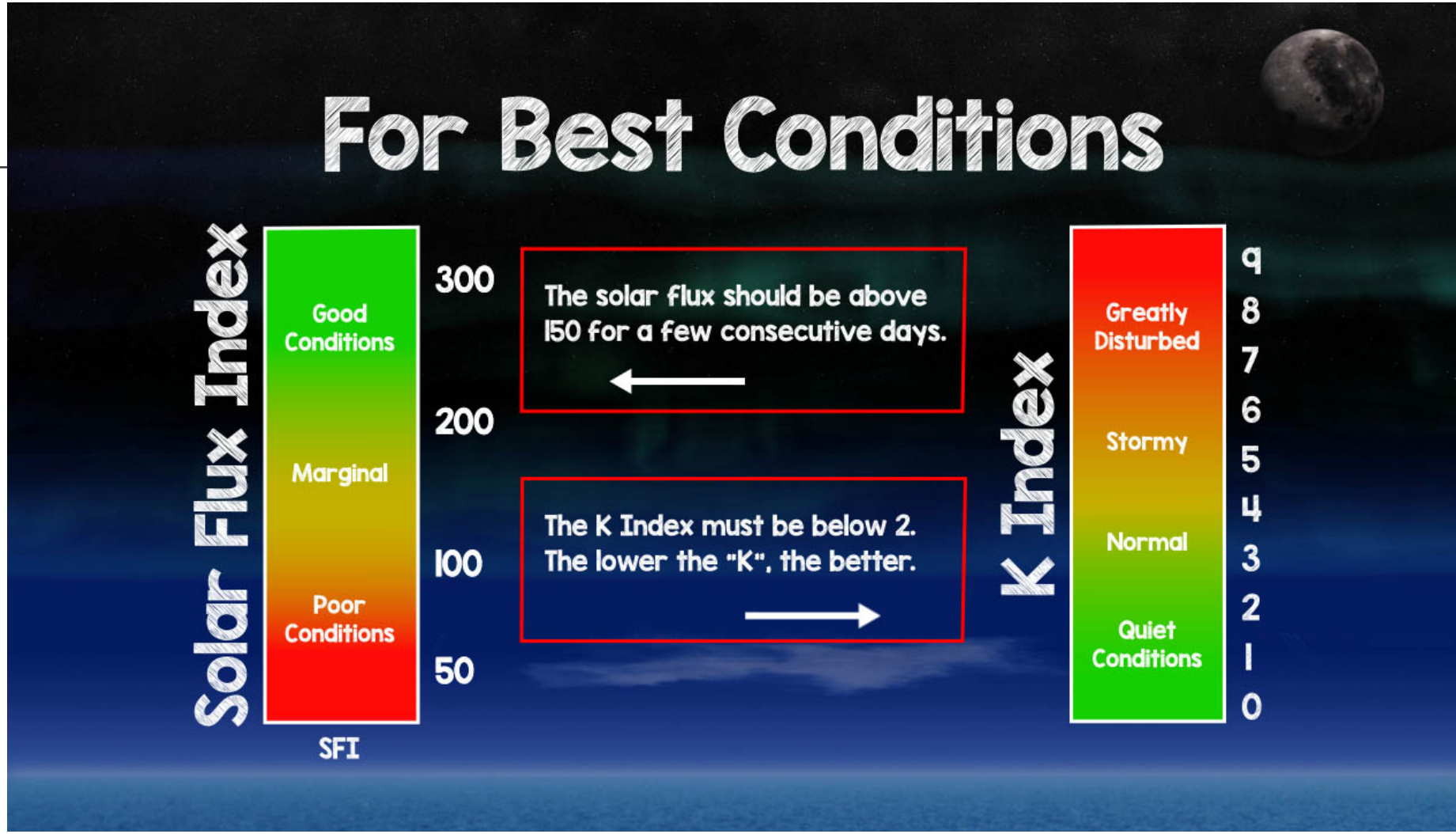
How do I use this information

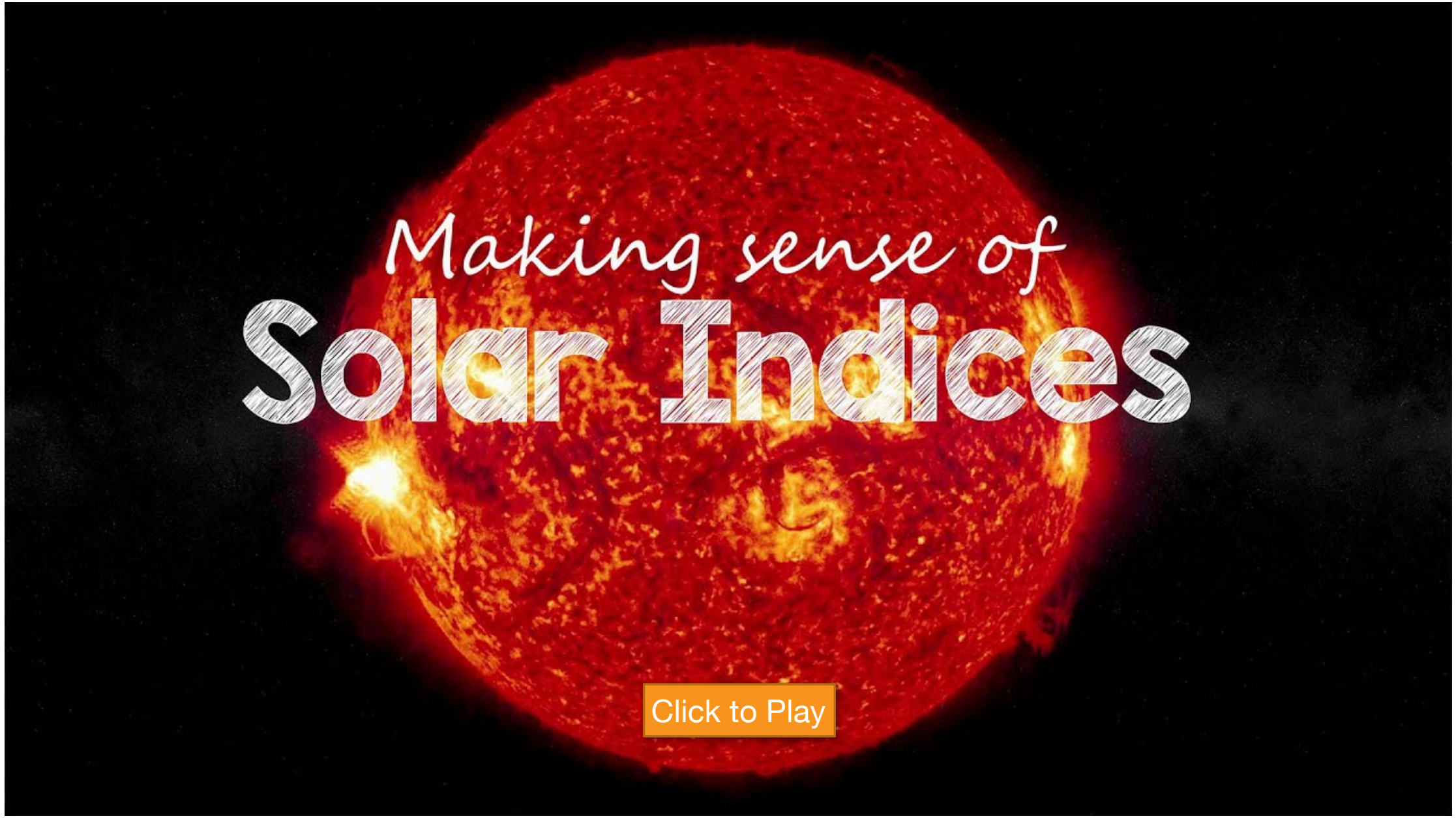
That depends on what you are looking for. Do you want to be a scientist or just want to know if it is worth turning the radio on. Looking for some DX or just some local chat with friends in the USA. It is all in the numbers posted by the scientific community or is it?

Ap and Kp index are related and indicate unsettled conditions so higher the numbers the more stormy the conditions which is not good for radio communications

Solar Flux is an indication of solar activity, and to determine the level or amount of radiation being received from the Sun. The solar flux is closely related to the amount of ionization and hence the electron concentration in the **F2 region**. As a result, it gives a very good indication of conditions for long-distance communication.

In One Image:


For Best Conditions
Solar Flux Index
Good Conditions
Marginal
Poor Conditions
300
200
100
50
SFI
The solar flux should be above 150 for a few consecutive days.
The K Index must be below 2. The lower the "K", the better.
K Index
Greatly Disturbed
Stormy
Normal
Quiet Conditions
9
8
7
6
5
4
3
2
1
0


Making sense of
Solar Indices
Click to Play

Putting it to Use

You have looked up the information required to make your own calculations, or you have relied upon trusted sources who have done those calculations for you.

All indications are that conditions will be favorable for your intended purpose and you have determined that it is time to get on the air.

The DX spotting networks, Reverse Beacon network, or PSK Reporter show lots of interesting activity.

It is time to deploy the secret weapon…

Propagation in a Can

Now available in several new formulations, all with *AI Enhanced Ionization* and *Dead-Zone Eliminators:*

- NVIS
- Sporadic Es
- Trans-equatorial skip
- Single or Multi-hop Skywave

Call NOW and get a free can of our *6m Magic Band Aurora Enhancer* at no extra charge*

Operators are standing by…

*(Just pay separate S&H)

The Mark I Human Ear

Continuing

The best predictions in the world are just that: *Predictions*. There is no substitute for your own personal experience in real-time.

Get ON THE AIR and **Listen, Listen, Listen** for a few minutes before calling CQ or returning some else's call: What do you hear? Who do you hear? What is the noise level? Do things track with the predictions or is there something else going on? Your own personal assessment of band conditions at your QTH using your rig and your antenna is what ultimately matters.

Listening is also important as a first step because a band that seems dead/closed may suddenly spring to life when you call CQ — because *someone else* was listening. And that someone else could be you - if you are listening.

Trivia

★What happens to the D-Layer at night?

★What happens to the F-layer during the day?

★Who discovered the F-Layer and won a Nobel Prize in Physics for that and other discoveries?

★Which Layer was discovered first?

Trivia

- ★ What happens to the D-Layer at night?
  It diminishes significantly. When the D-layer is active it is primarily responsible for ABSORBING HF radio signals and negatively impacting the MUF. *(It is NOT our friend…)*
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  It divides into two layers, F-1 and F-2. At night, F2 becomes dominant and becomes the chief ‘mover-and-shaker’ for HF skywave propagation.
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  The discovery of the **E-Layer** begins with early work on radio propagation performed by Marconi in 1901. It was labeled E for 'Electrical layer' by Appleton in the 1920s at which time he also confirmed the presence of layers above and below E, which he labeled D and F to allow for the future discovery of more layers.

Bonus Question

- What is the Carrington Event?

Bonus Question

★ What is the Carrington Event?

A powerful solar storm that occurred in September 1859. It is named after British astronomer Richard Carrington, who observed the solar flare associated with the event.

1. On September 1, 1859, Carrington observed a large solar flare on the sun's surface. This flare was later determined to be associated with a coronal mass ejection (CME), a significant release of plasma and magnetic field from the solar corona.
2. The CME reached Earth just days later, on September 2, 1859. It caused widespread geomagnetic storms, which were particularly intense.
3. Auroras: The geomagnetic storm produced spectacular auroras that were visible at unusually low latitudes, including regions close to the equator. People reported seeing bright, colorful lights in the sky as far south as the Caribbean and even Hawaii.
4. Telegraph Disruptions: The storm caused significant disruptions in telegraph systems. Operators reported sparks and shocks from their equipment, and some systems failed completely. In some cases, telegraph operators were able to continue sending messages even after disconnecting their batteries due to the induced electrical currents.

The Carrington Event is considered one of the most intense solar storms on record. If a similar event were to occur today, it could potentially cause severe disruptions to modern technology, including satellites, power grids, and communication systems. It serves as a critical reminder of the potential impact of solar activity on Earth. It highlights the need for monitoring solar weather and preparing for possible geomagnetic storms, especially in our technology-driven society.

Calculating for Success

Sources of information

WWV/WWVB gives you time and at 18 minutes after the hours solar information at Bolder, CO https://www.swpc.noaa.gov/products/geophysical-alert-wwv-text

https://www.swpc.noaa.gov/ Space Weather Prediction Center at NOAA in Bolder, CO

https://www.spaceweatherlive.com SpaceWeatherLive is an initiative of Parsec vzw, a non-profit organization from Belgium which consists of several websites about astronomy, space, space weather, aurora and related subjects.

https://www.solarham.com/ A mind-blowing collection of Solar data curated by VE3EN

Continuing

Tamitha Skov is a space weather scientist with education programs on U-tube. I have met her in person. She has a lot to offer us to broaden our knowledge base and has weekly solar updates. https://www.youtube.com/c/TamithaSkov

https://hamwaves.com/ This website was developed for Amateur Radio by Serge Stroobandt, ON4AA trying to locate needed information for your station to make predictions in one place.

To look at real-time propagation monitoring. Who other HAMS are contacting. https://www.dxmaps.com/spots/mapg.php

Automatically gather reception records of digimode activity and then make those records available in near realtime to interested parties gives access to propagation of your signal. https://pskreporter.info/

To monitor real-time DX spotting try; https://eham.net/spots

More Tools for Success

Real-Time solar data https://hamwaves.com/propagation/en/index.html

Real-Time ionogram near your location https://hamwaves.com/ionograms/en/index.html

Global Real-Time ionosphere F0F2 mapping https://www.sws.bom.gov.au/Images/HF%20Systems/Global%20HF/Ionospheric%20Map/WorldIMap0.gif

Voice of America (VOA) Coverage Analysis Program (CAP) https://www.voacap.com/hf/ makes quick work of predicting success by entering grid location of contact.

More excellent educational videos from VK3FS. https://www.youtube.com/playlist?list=PLYnYwJakorde9k1qerxCOYv-hSo69NpL_

Discussion

Q&A