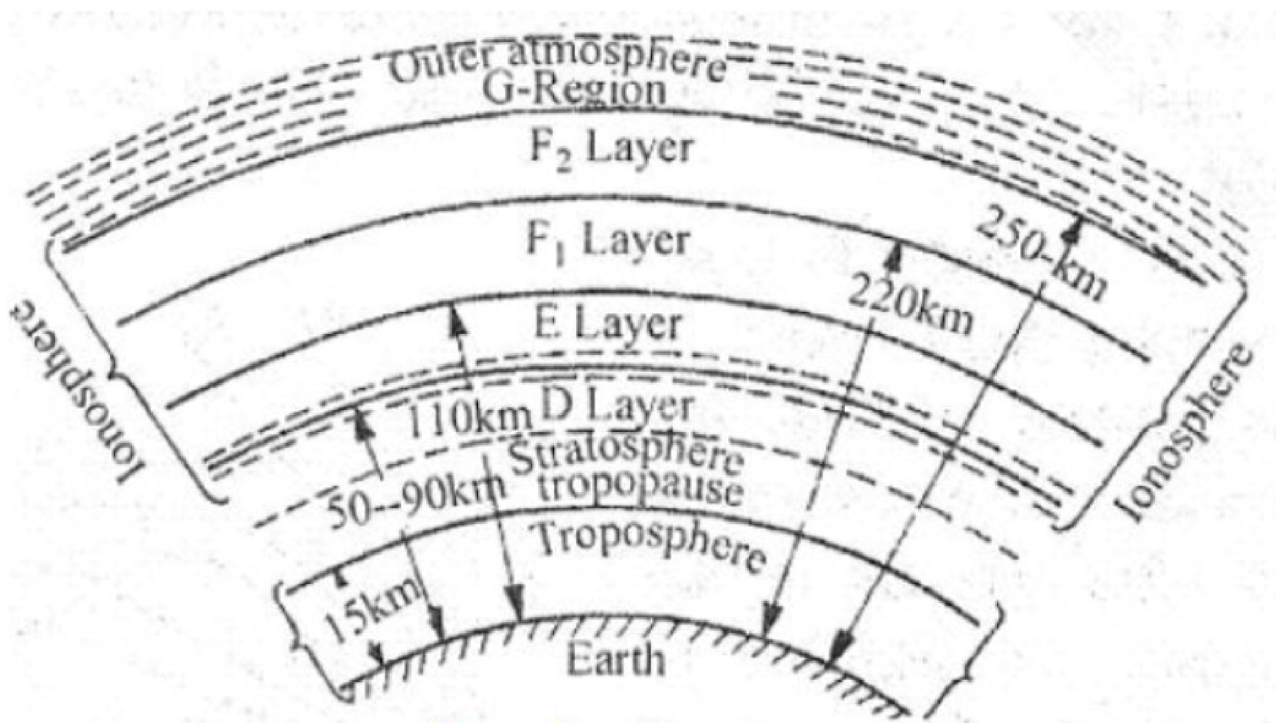
A Systematic Approach to Assessing HF Band Conditions
“A Propagation Primer”



Ionosphere Layers

Anderson Island Amateur Radio Club
WA7AI

Question: What are your operating objecives?

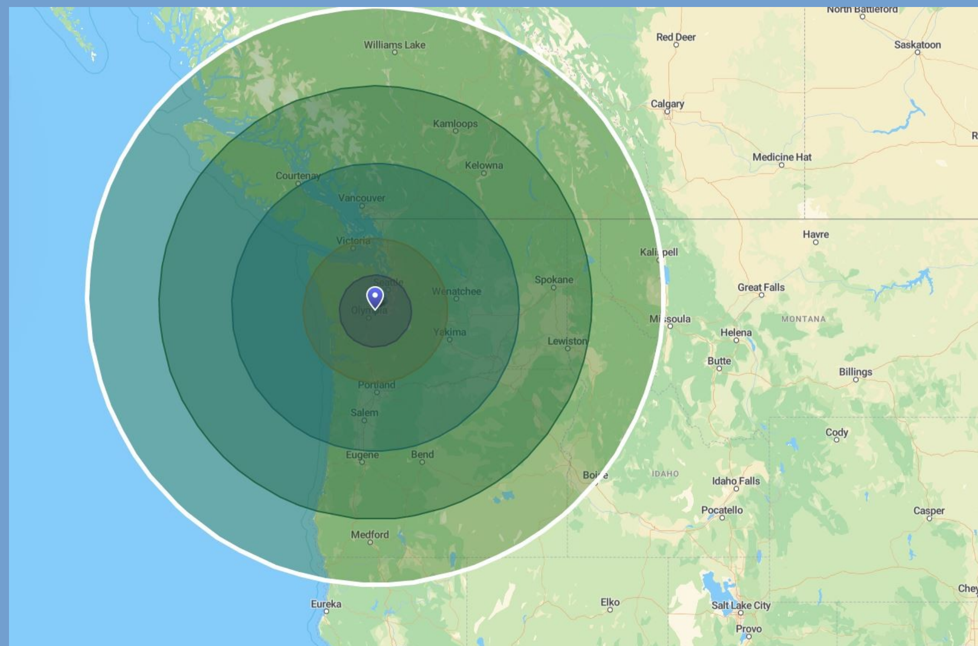
- Emcomm operator: “When the vhf/uhf infrastructure fails, using HF for contacting stations out of the impacted area”

- HF net control operator: For daily, weekly regional HF nets

- QRPer, POTA
  Limited to 5 Watts, quick deploy antenna, local, regional, dx contacts?

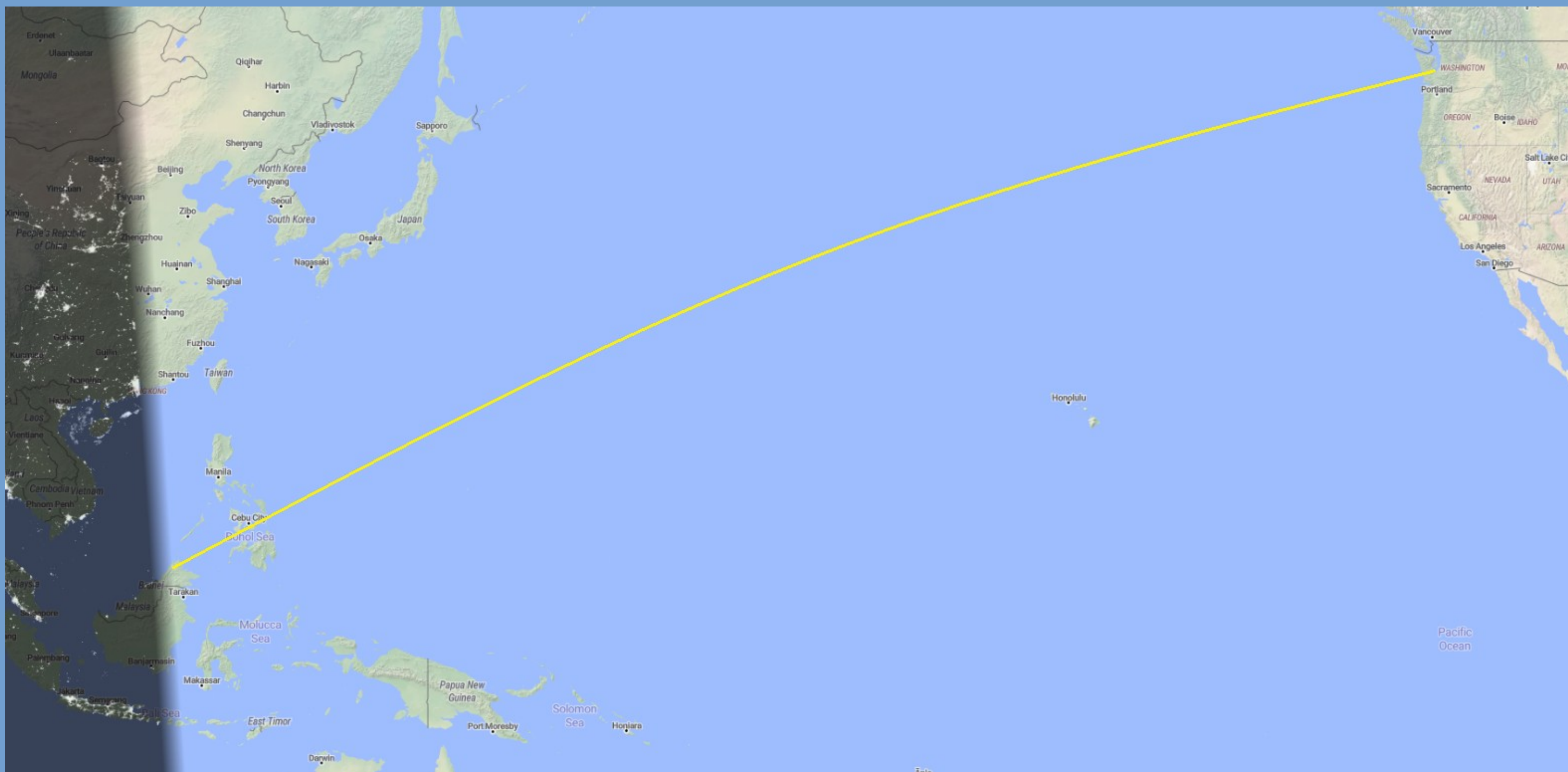
- Dx’er
  Attempting contacts all over the world, Dxpeditions, Contests, WAS, DXCC: Optimal bands/antenna for skip (low angle of radiation). How much power will I need?

Emcomm Example: Regional 100 – 350 miles



- Send emergency traffic to Camp Murray EOC that’s been relocated to Yakima, Wa , 100 miles away?
- Send a SITREP via an out of impacted area Winlink HF station 350 miles away in Idaho?

DX Example: 7000 miles



**The thrill of connecting with stations all over the world

**Receiving a QSL!

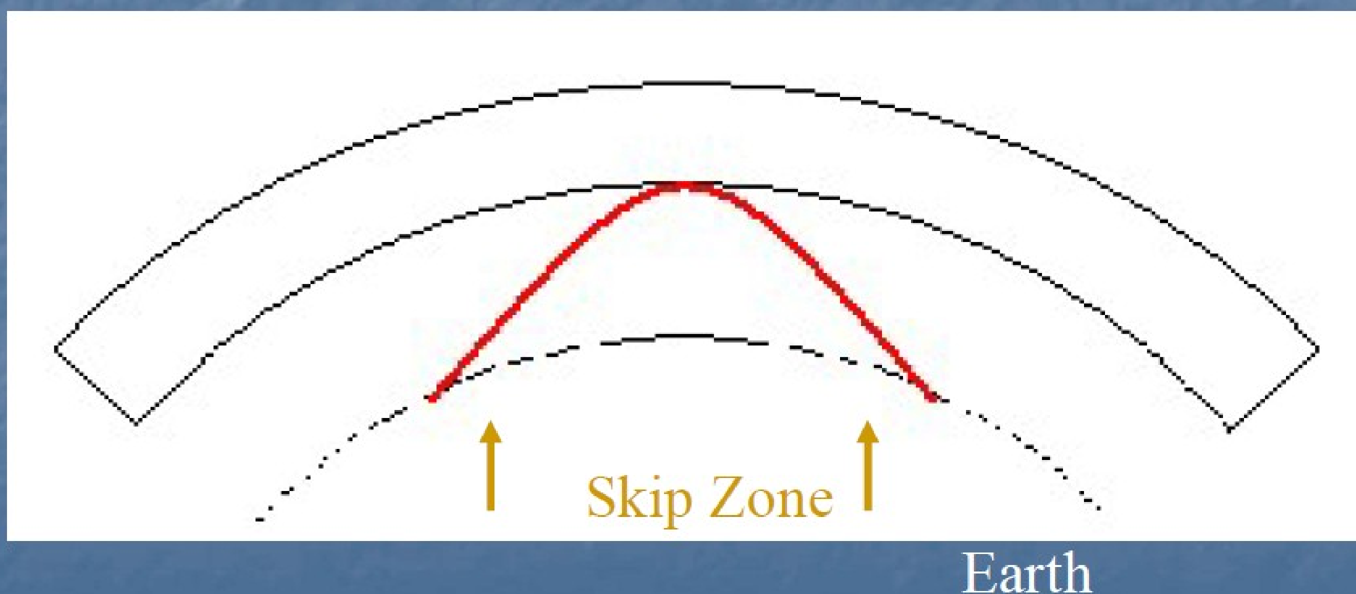

9W6EZ
Jimmy
SABAH
ISLAND OF BORNEO
Loc:OJ85bw ITU:54 CQ:28
IOTA:OC-088 10-10:76936
To: K7RUT This confirms our 2-way JT65 QSO
Date: December 6, 2015 Time: 16:23 UTC
Band: 40M UR Sigs: -22

The ionosphere refracts MF & HF

- Surface and direct waves: 40 to 80 miles at best
- **Sky waves**: can reach anywhere on earth !
- But where on the earth? It depends on the angle at which the wave approaches the ionosphere –the angle of **incidence**

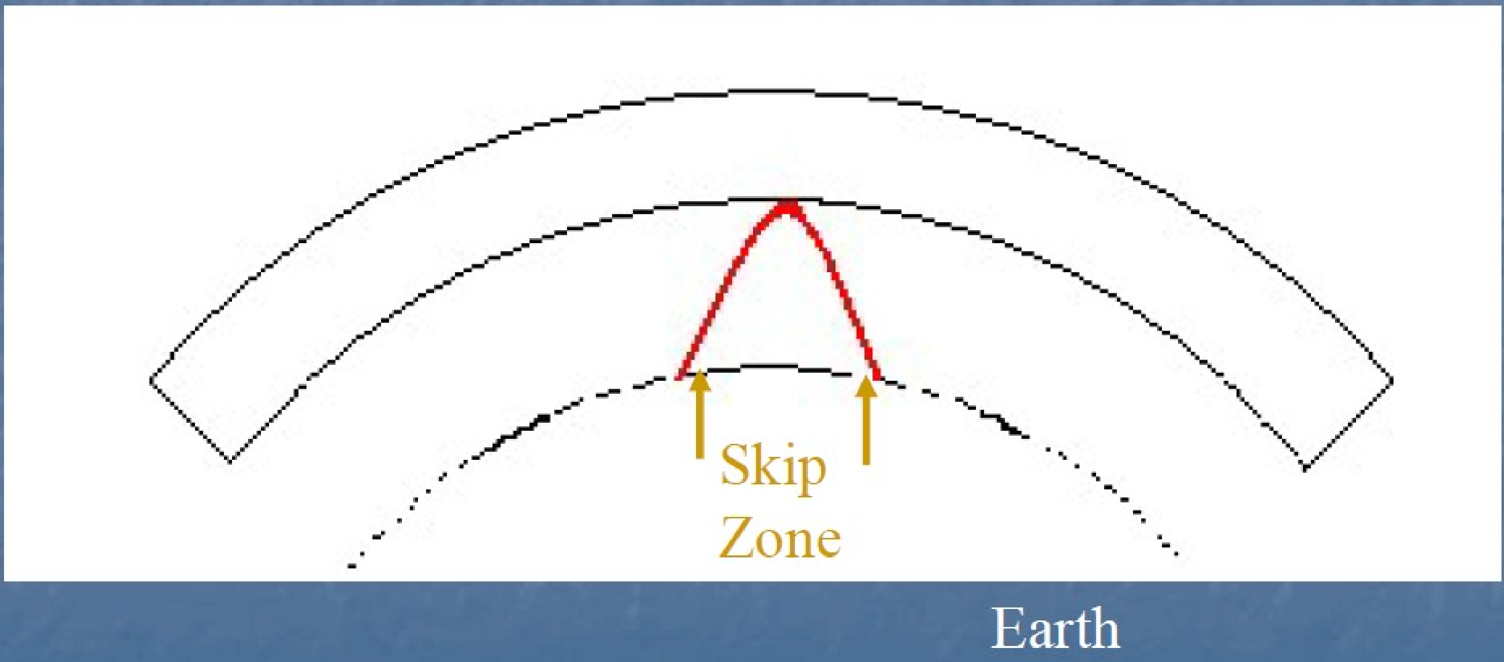
Shallow angle = longer distance

- Low angles can reach over 2,000 miles
- Multiple hops can span the globe
- But . .. There’s a gap: the “skip zone”

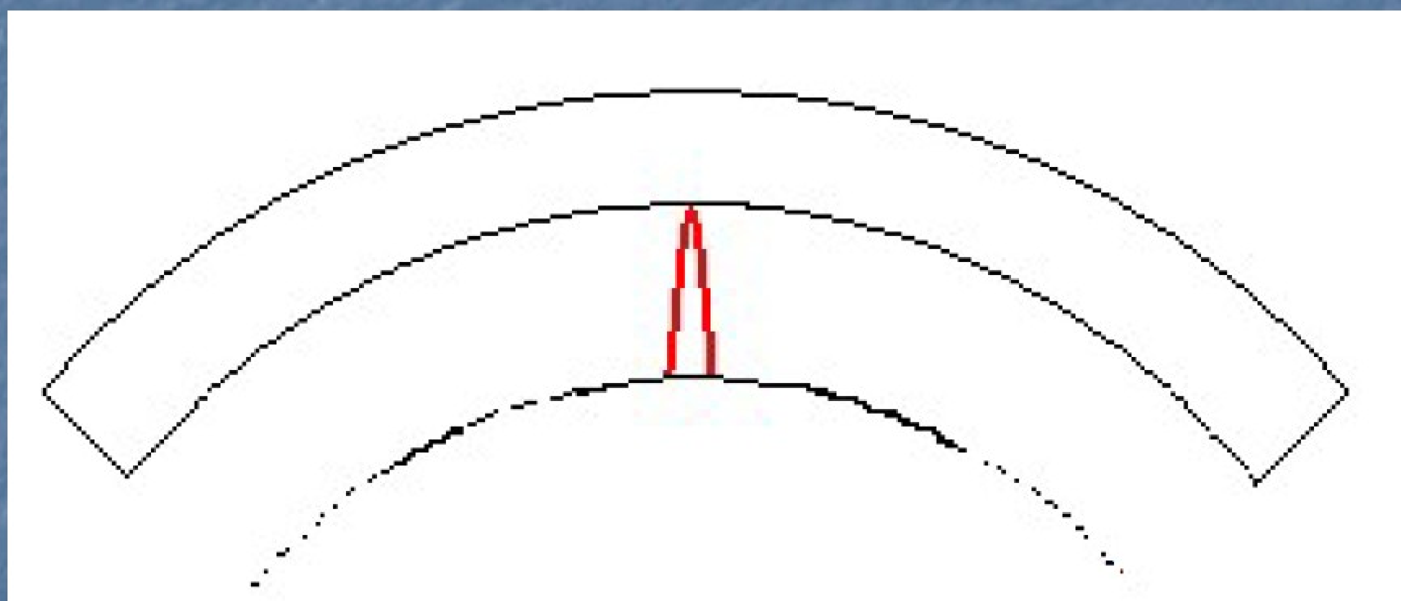


Steeper angle = shorter distance

(The size of the skip zone is reduced)



A **near-vertical** angle eliminates the skip zone entirely!



NVIS for Regional Coverage

- **Near-Vertical Incidence Skywave**
- A method of regional communication that does not rely on infrastructure, is immune to terrain and other obstructions and supports multiple simultaneous, independent users

Critical Angle, Critical Frequency and the MUF

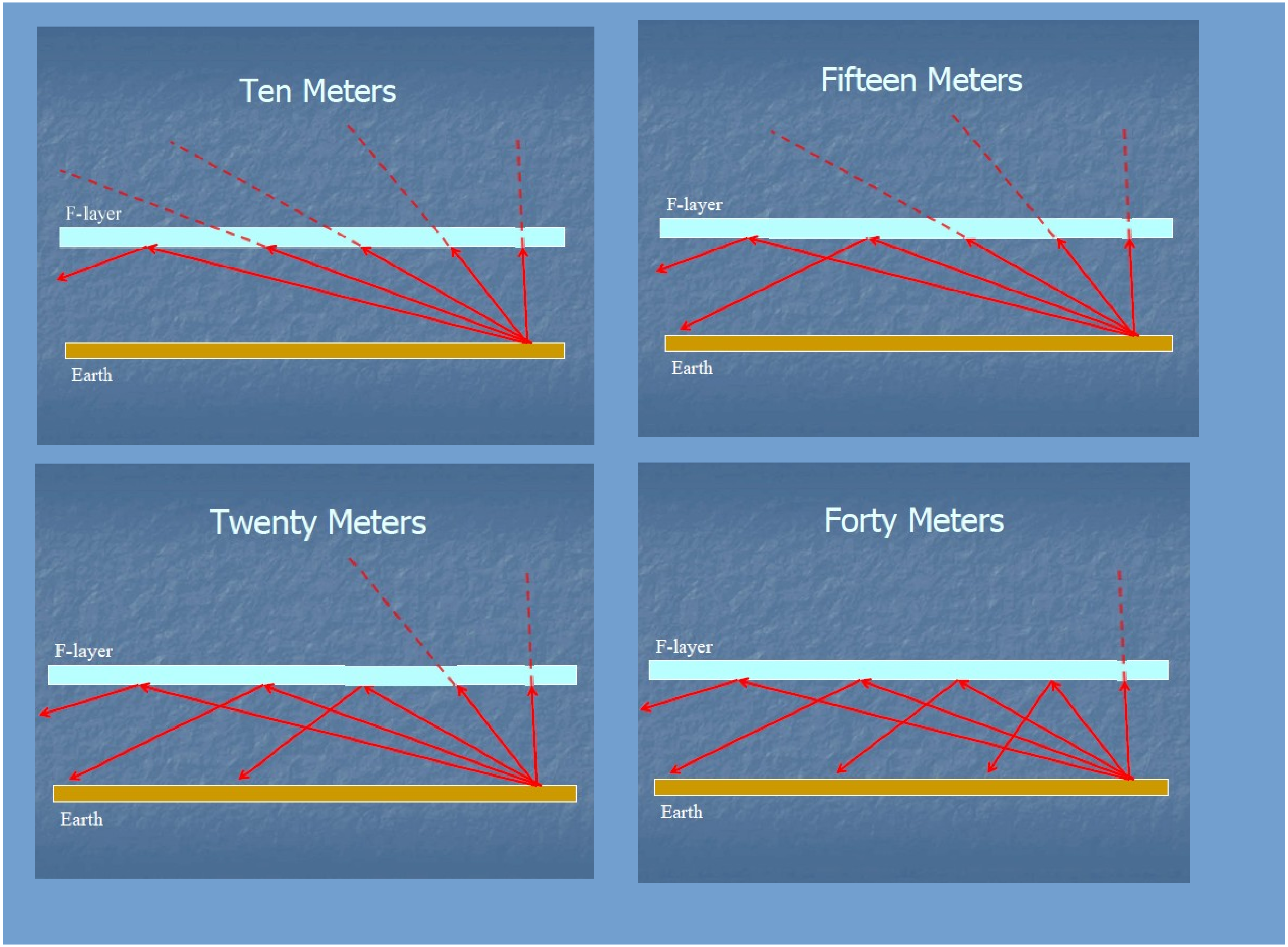
For any given frequency there is a critical angle above which no refraction occurs.

Critical angle varies with frequency: Higher frequency = lower critical angle

Above the critical frequency, high angle signals get no isonospheric refraction; they just pass into space. The critical frequency is referred to as fo/f2

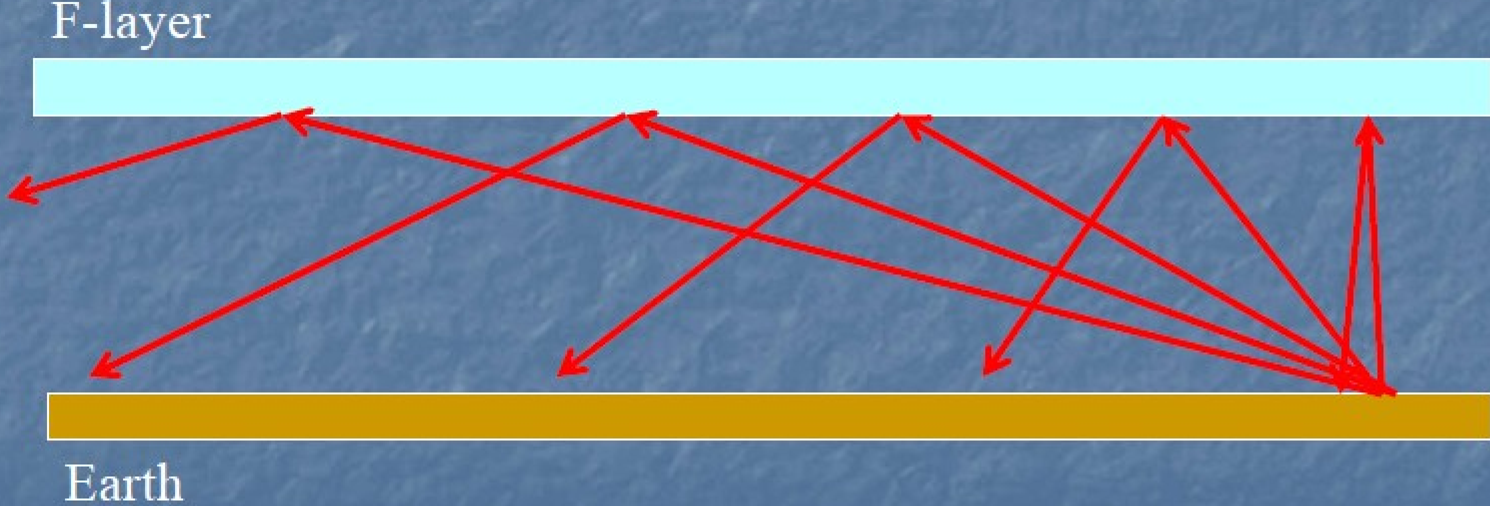
MUF (Maximum Usable Frequency) is the maximum frequency which can be reflected for a given distance of transmission.

MUF is usually 3-4 times fo/f2 and dependent on angle of incidence.



Ten Meters
F-layer
Earth
Fifteen Meters
F-layer
Earth
Twenty Meters
F-layer
Earth
Forty Meters
F-layer
Earth

Eighty Meters



So NVIS is not for the high bands

- 10- and 15-meter signals are refracted at low angles but never at high angles

- 20-meter signals going straight up **might** be refracted, but **only** when sunspots and solar activity are plentiful (many sunspots, daytime)

Even then, 20m is seldom optimal for NVIS

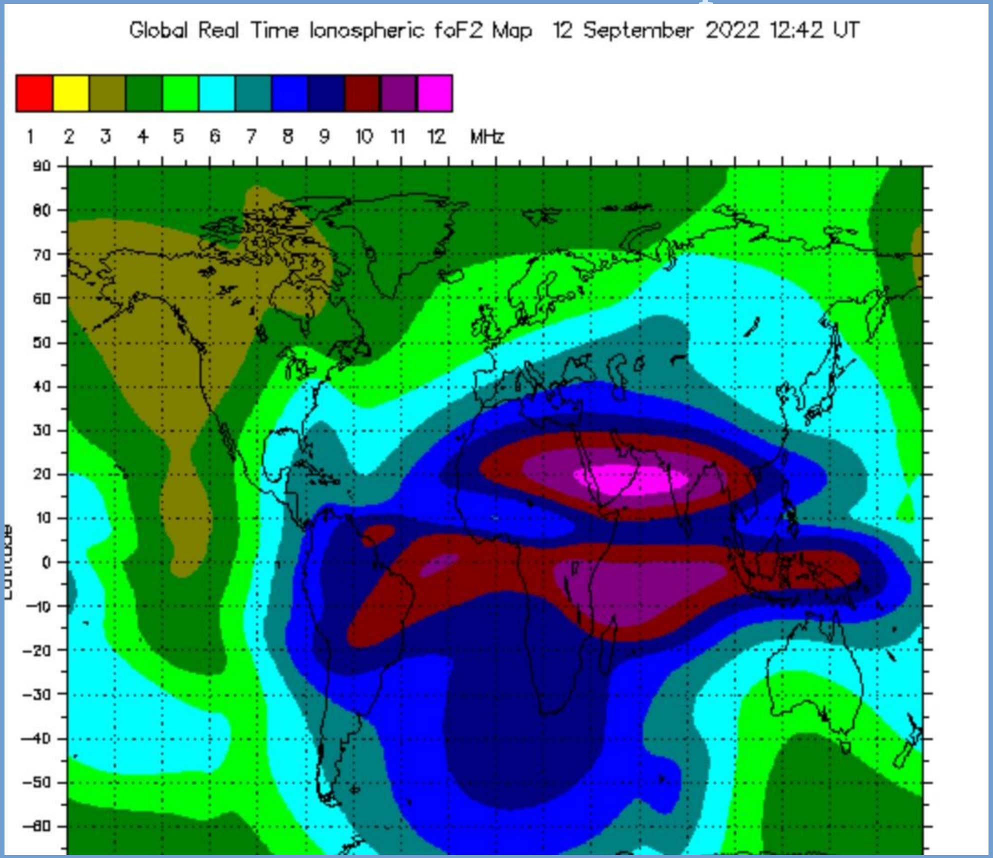
That leaves 160, 80, 60 and 40 meters

- Which band will give the best results?

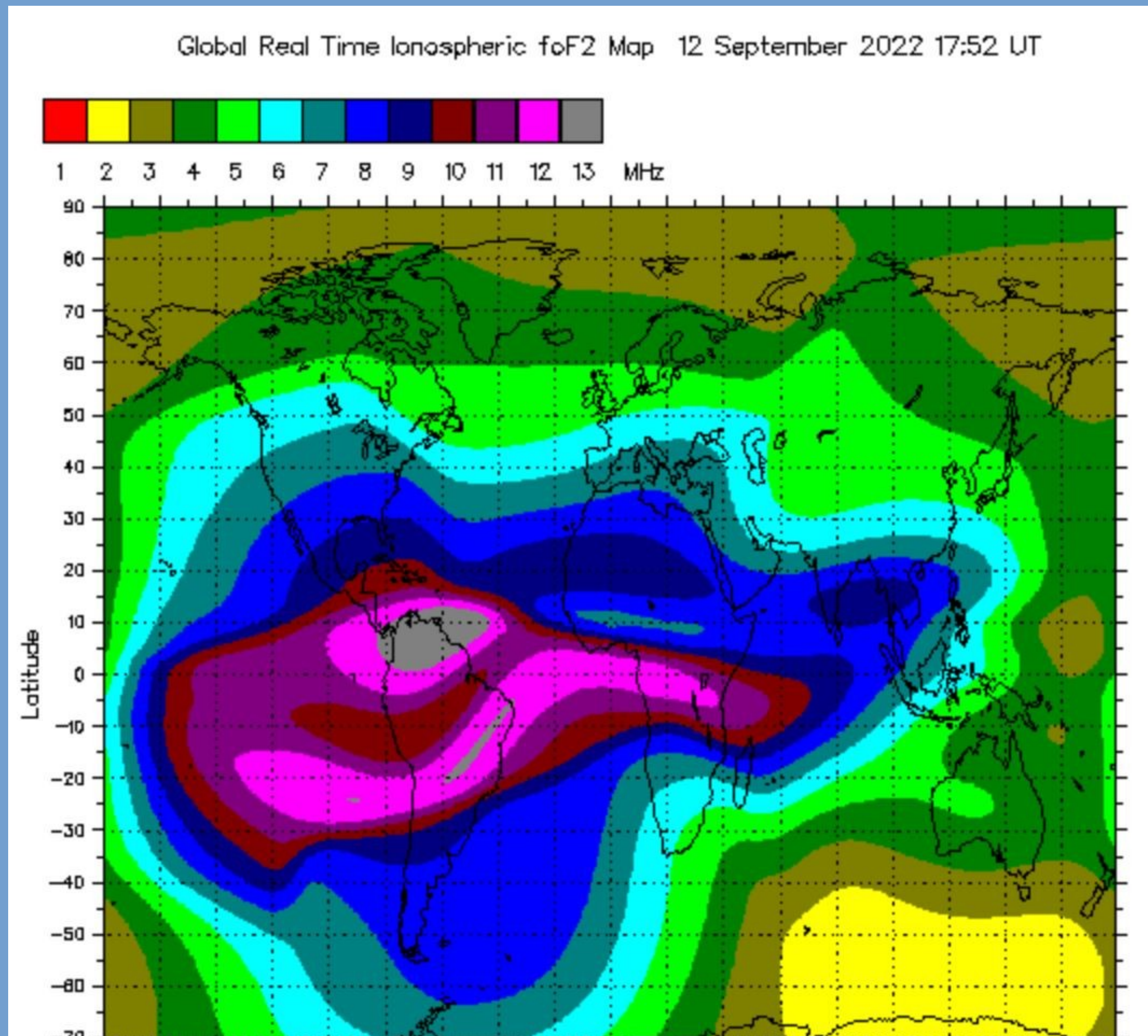
- The optimum frequency varies by
  - time of day
  - time of year
  - where we are in the solar (sunspot) cycle

- Understanding this is the KEY to SUCCESS

Tool #1 foF2 Map



Critical Frequency = 3 Mhz, Use 80M, 160M for NVIS



Critical Frequency = 6-7 Mhz, Move to 40 M

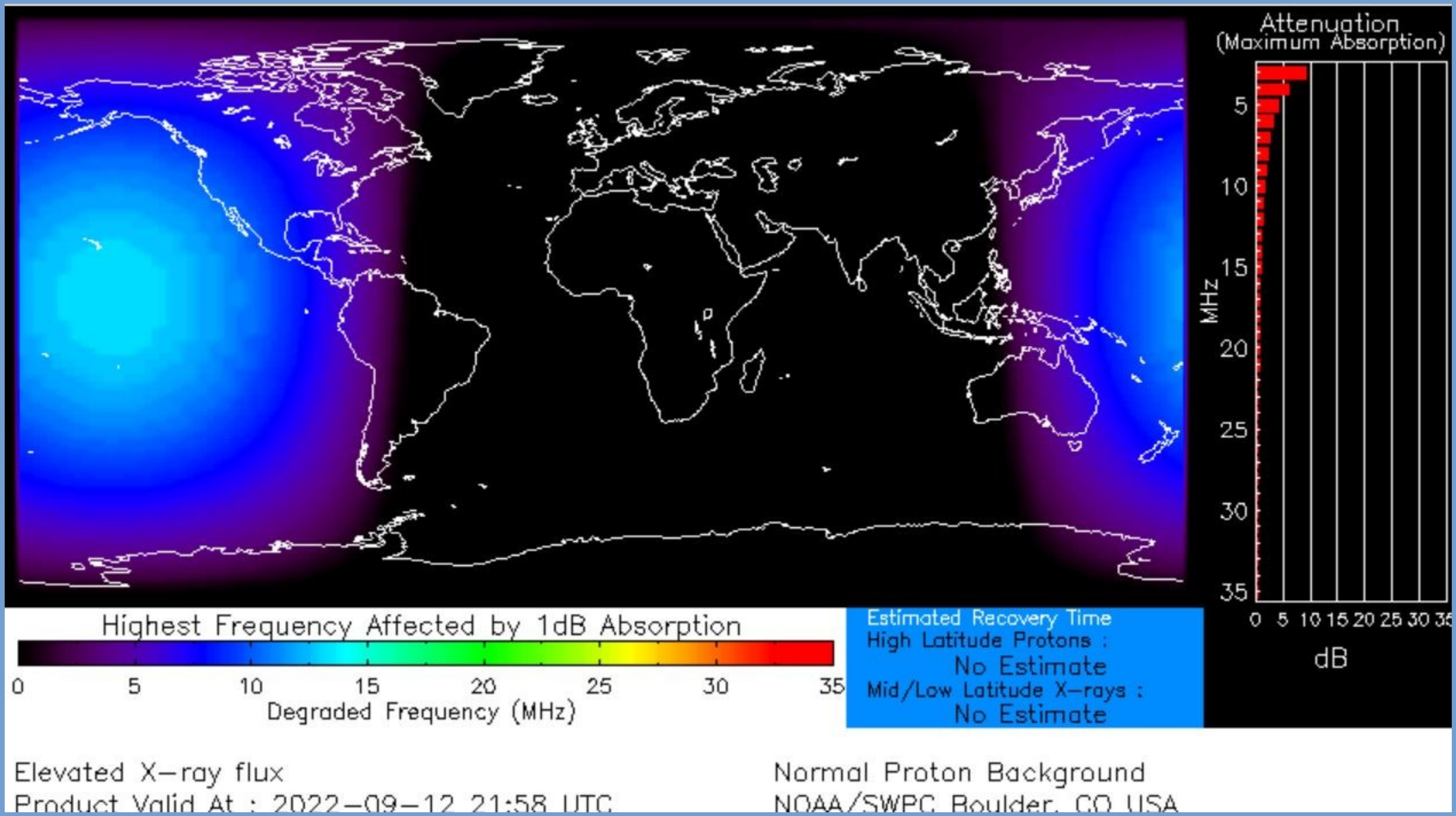
The D-layer: Low-band spoiler during daylight hours

- The D layer lies below the F layer & E layer
- It absorbs RF signals when it's ionized (i.e., during the daytime); **it disappears at night!**

The D-layer: Low-band spoiler during daylight hours

- The lower the operating frequency, the greater the D-layer attenuation (so it's worst at 160m during the daytime)
- A M broadcast band effect

Tool #2 1db Absorption, D-Layer



Afternoon, 1 db ABS = 7 mHz

Given Quiet
Solar conditions

Day time

Solar flux ionizes the earth’s ionosphere and creats F1, F2 layers, the sporatic E layer and D layer

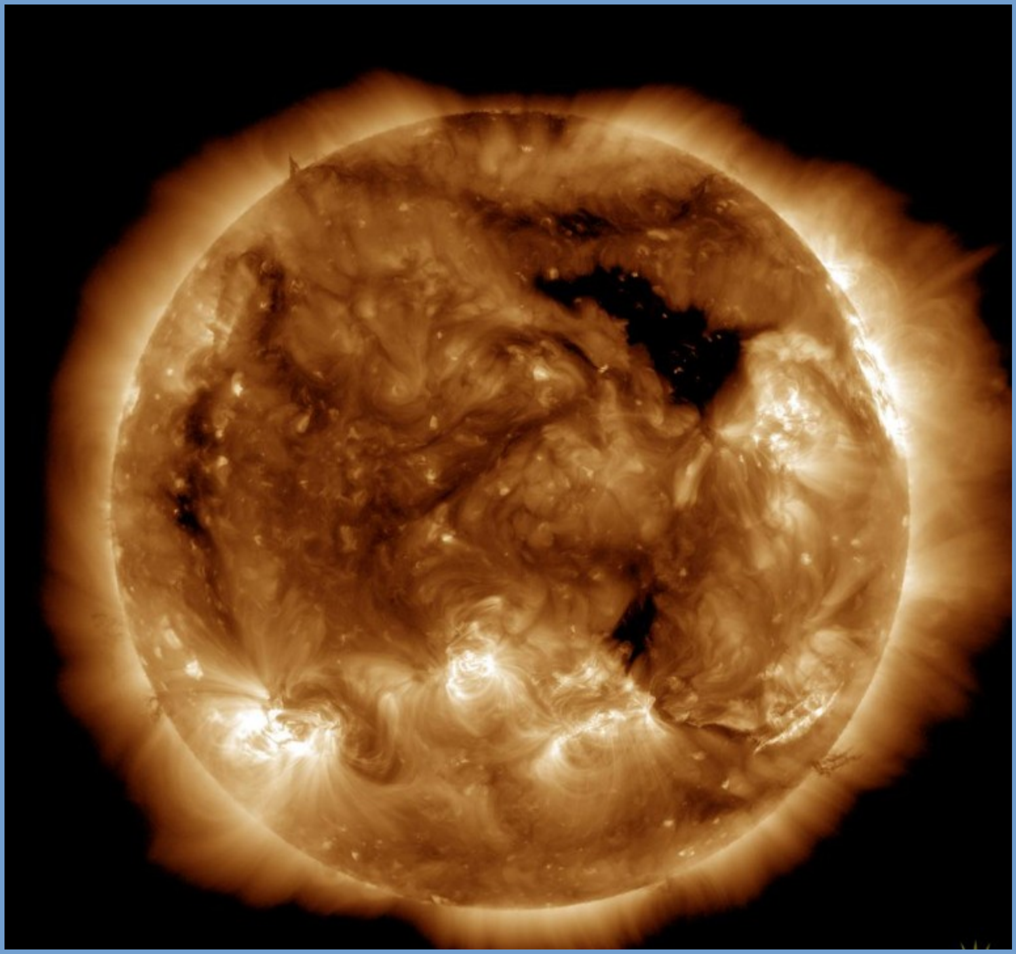
These layers either enhance connumications (Refreaction, F1,F2, E Layers, higher frequencies, MUF) or cause attentuation (D-Layer aborption, lower frequencies).

Night time

D -Layer disappears and with it, absoption of lower frequencies

F1, F2 combine to form a single F layer. Some refraction at high frequencies can still occur later into the night , depending on the level of ionization. MUF decreases.

Now add in a Class M, X solar flare and things get real interesting (and challenging at times)



Sunspots

Sunspots are cooler areas on the the solar surface and are regions with strong magnetic fields categorized as Alpha, Beta and Delta groups.

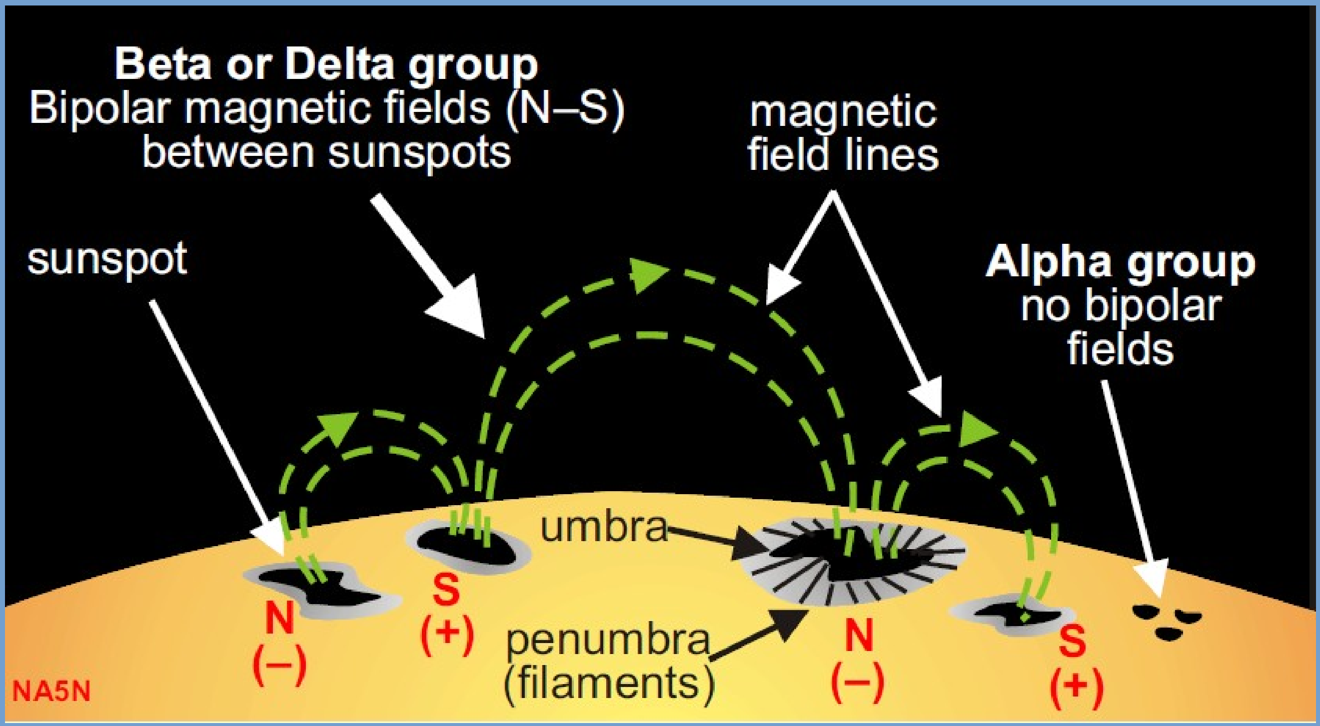
An Alpha group are sunspots with no bipolar magnetic fields, and seldom produce a flare.

When bipolar magnetic fields develop between sunspots, it is called a Beta group.

When a Beta group becomes particularly intense, with strong, bipolar magnetic fields between sunspots its called a Delta group.

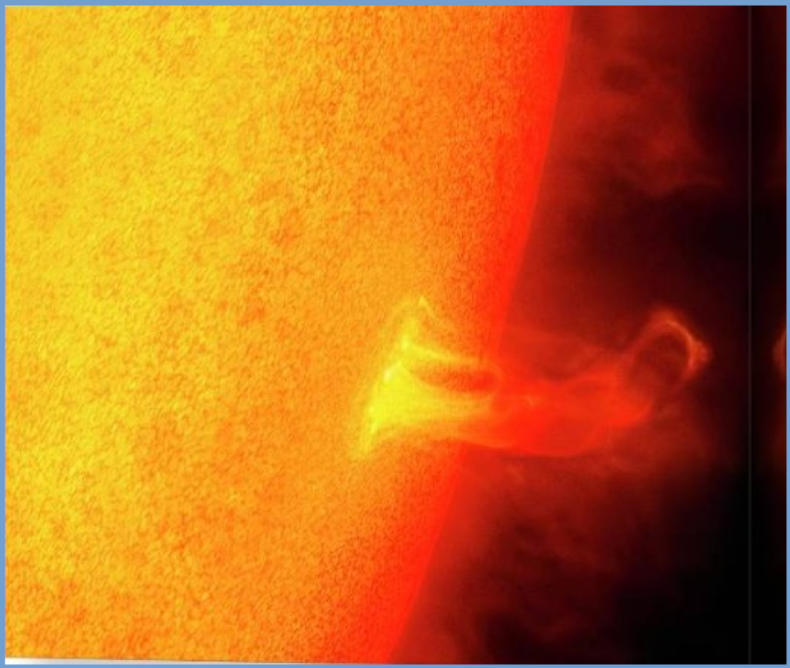
Solar Flare:

When the magnetic field lines emanating from the group Beta or Delta sunspots becomes strong, hot burning gasses from the sun are suddenly sucked out of the interior and carried along the magnetic field lines of the disturbance in a violent explosion.



While the interior of the sun is exposed at the flare site, gamma and x-rays escape.

The explosion creates a shockwave. This shockwave carries some of the burning solar mass out into space. This is called a Coronal Mass Ejection (CME)



A solar flare releases several major forms of energy that can effect the VHF and HF propagation on earth:

1. Ionizing radiation(Gamma and X-rays) arrives at earth immediately and for the duration of the flare event

2. A supersonic shockwave riding along with the solar wind

3. Dense particles behind the shockwave, gas cloud
(#2 and #3 arrives at earth 2-3 days after the flare event)

Radio Emissions from a flare.

The microwave radiation from a solar flare can produce powerful radio energies for several minutes following a flare. This produces "Type" storms as follows

Type 3: Start at 300 MHz and drift down at 20 MHz/sec, Occures first 5 -6 minutes after flare, sound like ignition noise or a buzz. Down to 10 MHz

Type 2: Bursty radio emissions are generaed as the shockwave travels through the sun's magnetic field lines, Down to 10 MHz.

Type 1: A bursty type emission that drifts downward in frequency at about 2 MHz/sec. And sounds like ignition noise from an idling car, to 10Mhz, persists 20-30min.

Behind the shockwave is a gas cloud of particles from the flare, generating wideband noise called a **Type IV Continuum Storm** can persist for hours following the flare and is an overall elevation of noise on HF. Impact down to 10 MHz

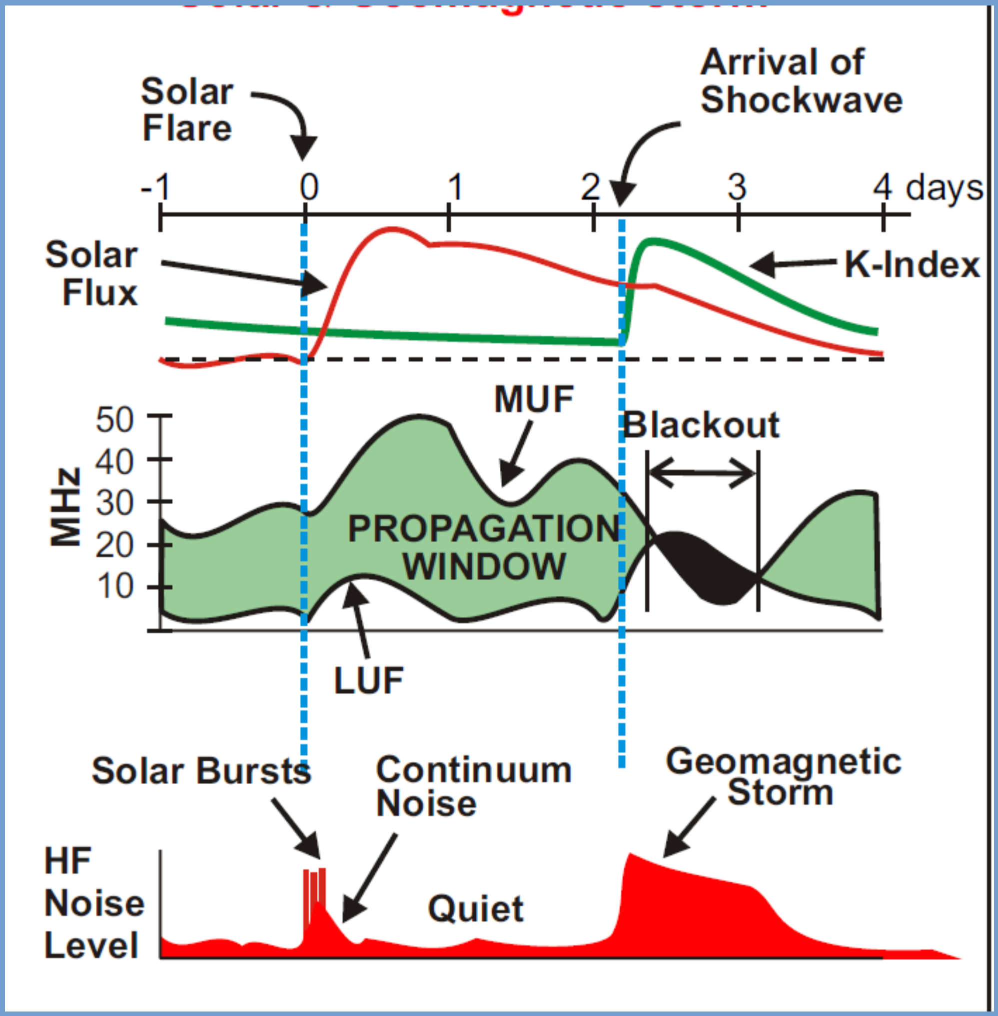
Geomagnetic Storm

Disturbances to the solar wind, from a solar flare or coronal hole, can cause serious disruptions to HF by triggering a geomagnetic storm.

It can often produce strong, bursty noise, or “static crashes.”

As the geomagnetic storm begins to subside, it settles down to an elevated noise level. Impacts 40 M to 160M for 12 to 24 hours

The Solar Flare Propagation Cycle



Primary Solar Indices

Solar Flux Index(SFI)

Solar Flux is the background radiation emitted from the sun

The SFI is used as the basic indicator of solar activity and to determine the level or 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.

It is measured in solar flux units(SFU). It can vary from as low as 50 or so to as high as 300.

Low values indicate that the maximum useable frequency will be low and overall conditions will not be very good.

High values(>200) generally indicate there is sufficient ionization to support long-distance communication at higher than normal frequencies.

It takes a few days of high values for conditions to improve.

Typically values in excess of 200 will be measured during the peak of a sunspot cycle with high values of up to 300.

Geomagnetic Activity

There are two indices that are used to determine the level of geomagnetic activity: the **A index** and the **K index**.

The solar wind is the constant outflow of gasses, electrons, and particles from the sun and travel along the ecliptic plane to the earth.

The solar wind exerts a pressure on the earth’s magnetic field, which distorts the toroidal pattern If this pressure should suddenly change the magnetic field suddenly changes shape in response, causing it to "wiggle".

Magnetometers on the earth measure the condition of our magnetic field. The amount of movement is averaged and reported by NOAA as the K-Index every 3 hours.

The K-index is a scale from 0– 9 representing quiet to severe conditions.

The K-indices are averaged over 24-hours to form the A-Index, representing the overall planetary geomagnetic conditions for the UTC day.

The A-index ranges from 0–20 for quiet conditions, up to 400 for extreme conditions.

	K Index	Ap Index	Geomagnetic Conditions	HF Noise	Aurora
NORMAL	0	0–2	Very Quiet	S1–S2	None
	1	3–5	Quiet	S1–S2	None
	2	6–9	Quiet	S1–S2	Very low
	3	12–19	Unsettled	S2–S3	Very low
	4	22–32	Active	S2–S3	Low
STORM	5	39–56	MINOR storm	S4–S6	High
	6	67–94	MAJOR storm	S6–S9	Very high
	7	111–154	SEVERE storm	S9+	Very high
	8	179–236	SEVERE STORM	Blackout	Extreme
	9	300–400	EXTREME storm	Blackout	Extreme

A Coronal Mass Ejection (CME) is an explosive outburst of solar wind plasma from the Sun, usually associated with a solar flare

Arrives 2-3 days after a large flare, impacting ionosphere and noise conditions on HF as low as 2 MHz

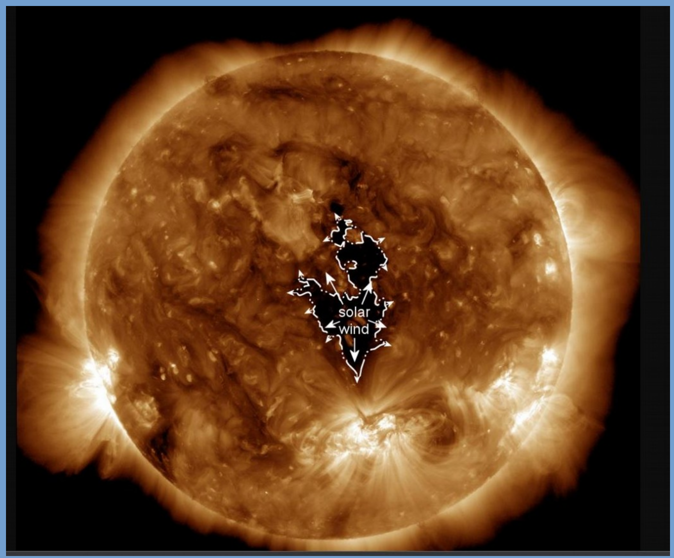
Use solar wind speed (km/sec) and density(1/cm3) to gage arrival and intensity of CME.

Greater than 600 km/sec and 15 part/cm3 indicate a CME is most likely in progress and impacting HF band conditions.

Coronal holes appear as dark areas in the solar corona in extreme ultraviolet (EUV) and soft x-ray solar images.

They appear dark because they are cooler, less dense regions than the surrounding plasma and are regions of open, unipolar magnetic fields.

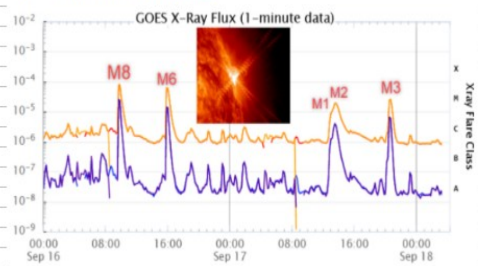
This open structure allows the solar wind to escape more readily into space, resulting in streams of relatively fast solar wind.



Band Conditions Log

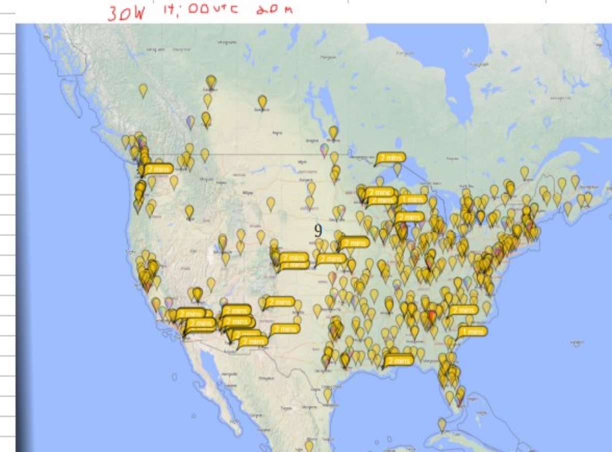
Time (UTC)	SFI	SN	Kp	Ap	Solar Wind	Density	Flare 1 In play	Flare 2 In Play	Flare 3 In Play	Flare 4	Muf	fo/f2	D-Layer Abs	Notes
09/18/2022/1324	132	49	3	5	469/+	11.54	M8/9/16/10:00	M6/09/16/16:00	M2/9/17/13:39	M3/9/17/20:39 In Play	15.85	5.4	5/5db	
09/18/2022/2355	136	51	2	11	530	11.8					23.16	7.6	5/3db	
09/19/2022/1345	136	59	3	11	487	7.95					15.06	4	5/3DB	
09/20/2022/2015	128	70	2	11	474	6.84	X	X			23	7	5/5db	
9/21/2022/1345	137	70	2	8	460	5.127	M1/9/21/0702	X	X	X	15	5	5/5db	

DODGING SOLAR STORMS: How long can Earth keep dodging solar storms? Departing sunspot AR3098 unleashed five M-class solar flares as it was going around the edge of the sun this weekend. One of them (M8 on Sept. 16th) was almost an X-flare:

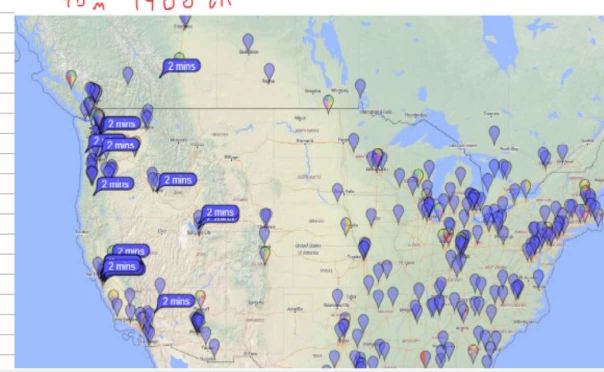


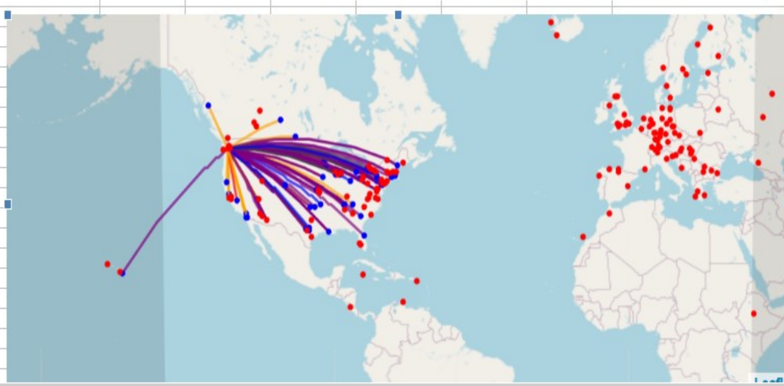
Because AR3098 was not facing Earth, all of the flares were muted in their effect, and none produced an Earth-directed CME. Add them to the list of dozens of misses since August--all produced by departing sunspots.

30W 14:00 UTC 20m



40m 1400 UTC





Links associated with data described in this presentation can be found in the file: **proplinks.pdf**, located in the members area.

Thank you!