Introduction to HF Propagation

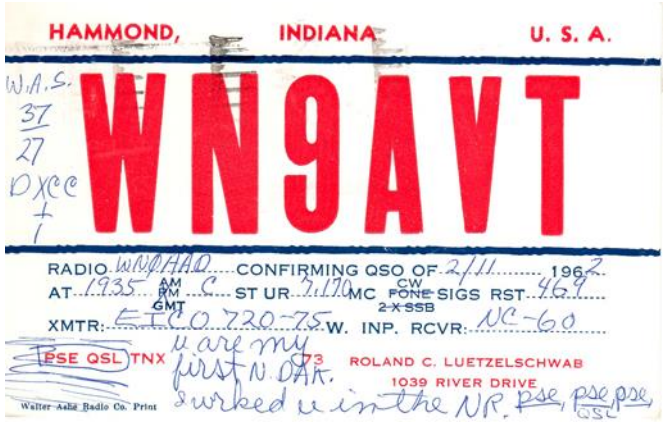
Carl Luetzelschwab K9LA

e-mail: k9la@arrl.net

website: https://k9la.us

Who Is K9LA?

- Novice in October 1961
  - General in May 1962, Extra in 1977
- Enjoy
  - Solar and propagation topics
  - Playing with antennas
  - DXing
  - Contesting (mostly casual now)
  - Fixing and using vintage equipment
  - Traveling to hamfests and conventions
- Purdue graduate (electrical engineer)
- Active duty at Picatinny Arsenal (northern NJ)
- Early days – CFI-AI, owned Cessna 170B (1634D)
- RF design engineer by profession (now retired)
  - Motorola in Schaumburg, IL and Ft Worth, TX
  - Magnavox/Raytheon when we moved back north in 1988
- Wife is Vicky AE9YL (first licensed as KB5EAM in 1987)



Agenda

- The Sun
- The Ionosphere
- HF Propagation
- Solar Cycles
- Space Weather
- Cycle 25

Whew! A lot of stuff!

A Caveat - What We're Trying to Do

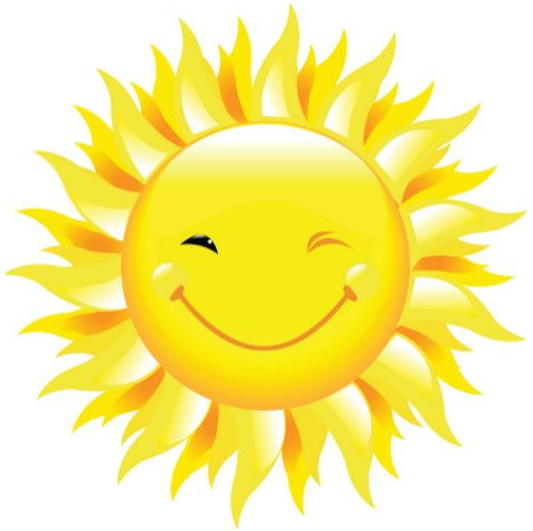
- We're trying to simplify very complicated atmospheric/ionospheric processes into simple statements about HF propagation

- This kind of works most of the time

- Here's what we have trouble with
  - Predicting the day-to-day variability of the ionosphere
    - Our propagation predictions are not daily predictions
  - Predicting even shorter-term enhancements

The Sun

let's look at the Sun first

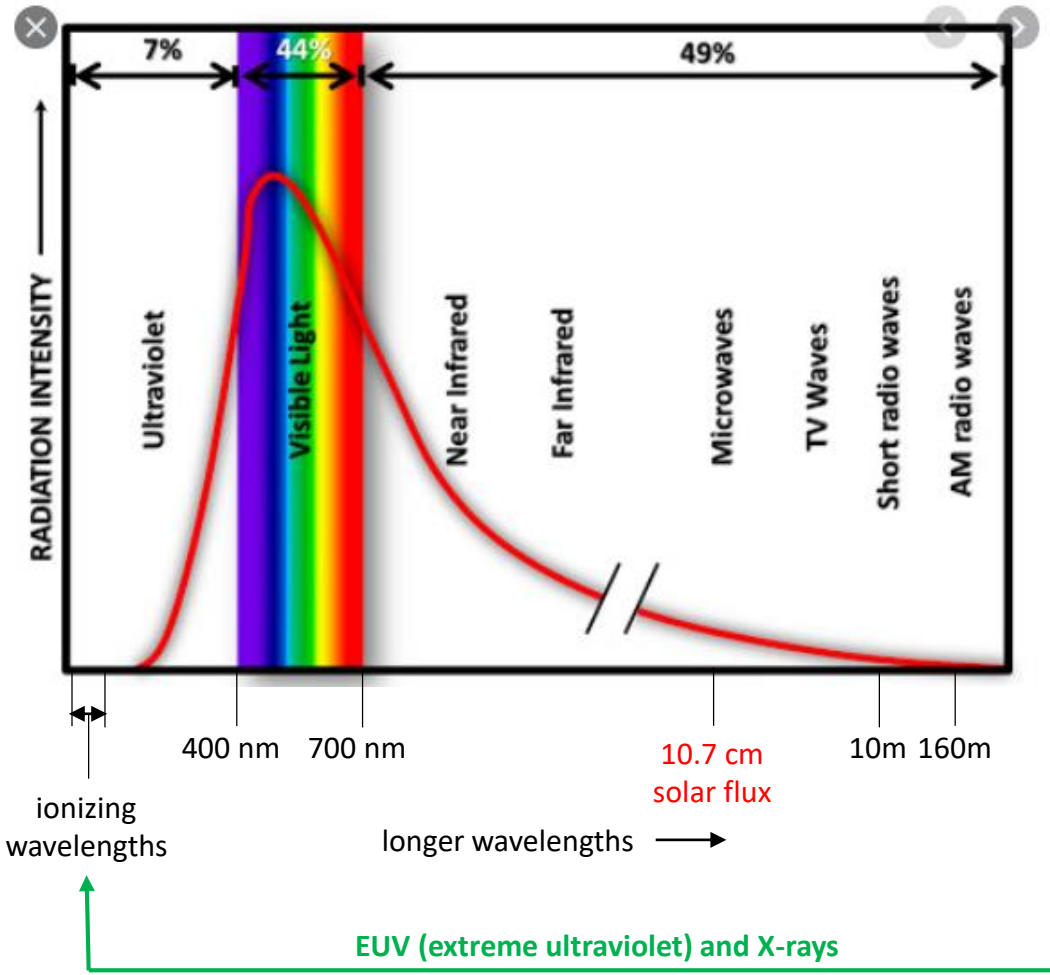


Some Facts About the Sun

the size of the Sun and the planets

- A nearly perfect sphere of hot plasma
  - Plasma = ionized gas
- Nuclear fusion in its core
  - Hydrogen turns into helium
- The sun is about 4.6 billion years old
- It is in the most stable phase of its life cycle
- Will burn out in about 5 billion years

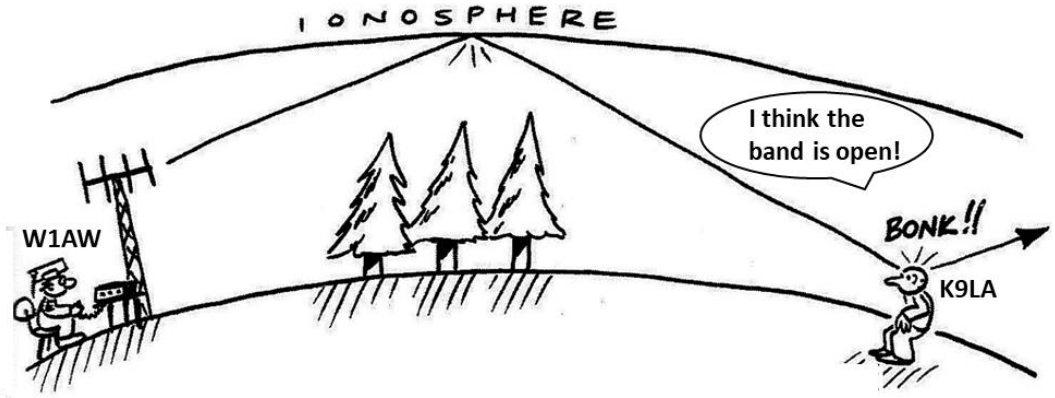
Solar Radiation



- The sun emits electromagnetic radiation at many wavelengths
- Most intense is at visible light wavelengths (400-700 nm)
- Energy of a photon is inversely proportional to its wavelength
  - Shortest wavelengths are highest in energy
- The important range of radiation for our Amateur Radio HF endeavors is very short wavelengths (ionizing wavelengths)

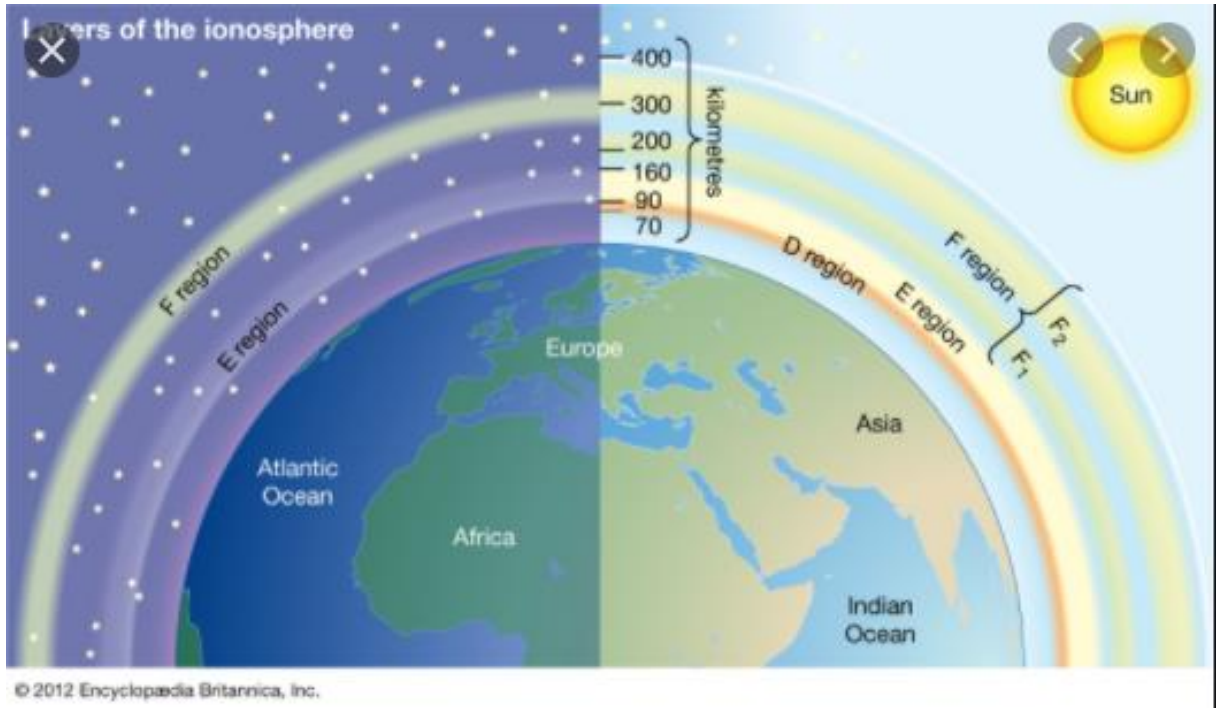
The Ionosphere

what enables skywave propagation



Layers (Regions) of the Ionosphere

- Ionizing radiation creates layers of ionization in the atmosphere
  - Dependent on wavelength of radiation and altitude and number of neutral atmospheric constituents
- EUV (extreme ultraviolet) results in the F_2 region
- Longer X-rays result in the E region
- Shorter X-rays and the Lyman-α spectral line of hydrogen result in the D region



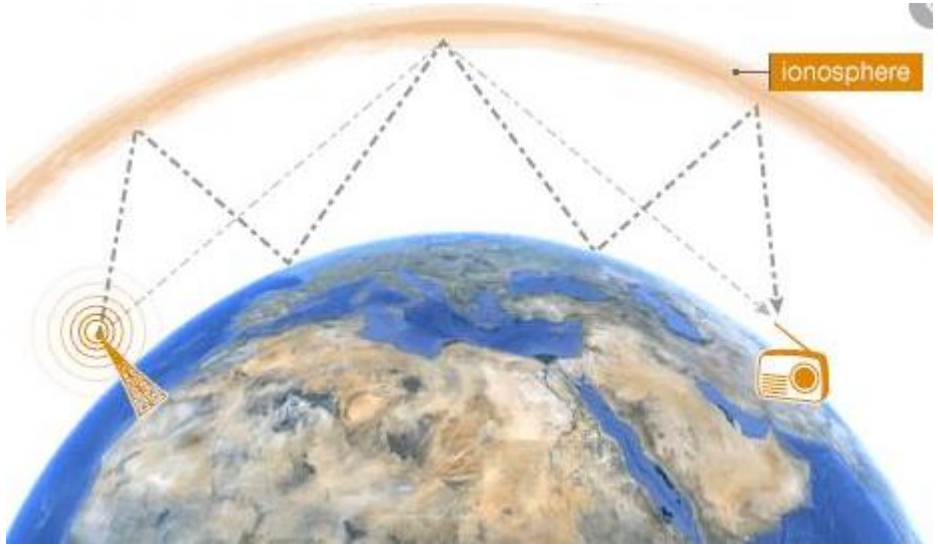
Free electrons (electrons stripped from a neutral atmospheric constituent in the ionization process) are what is important for skywave propagation

General Characteristics of the Regions

- F region (roughly 150-400 km)
  - Highest in altitude – gives the longest hops
  - Highest electron densities – best for the higher bands (15m, 12m, 10m)
  - F_2 region most important for our long distance QSOs
- E region (roughly 90-150 km)
  - Shorter hops due to lower altitude
  - Can block signals from getting to the F region
- D region (roughly 60-90 km)
  - A detriment to propagation due to absorption (loss)

HF Propagation

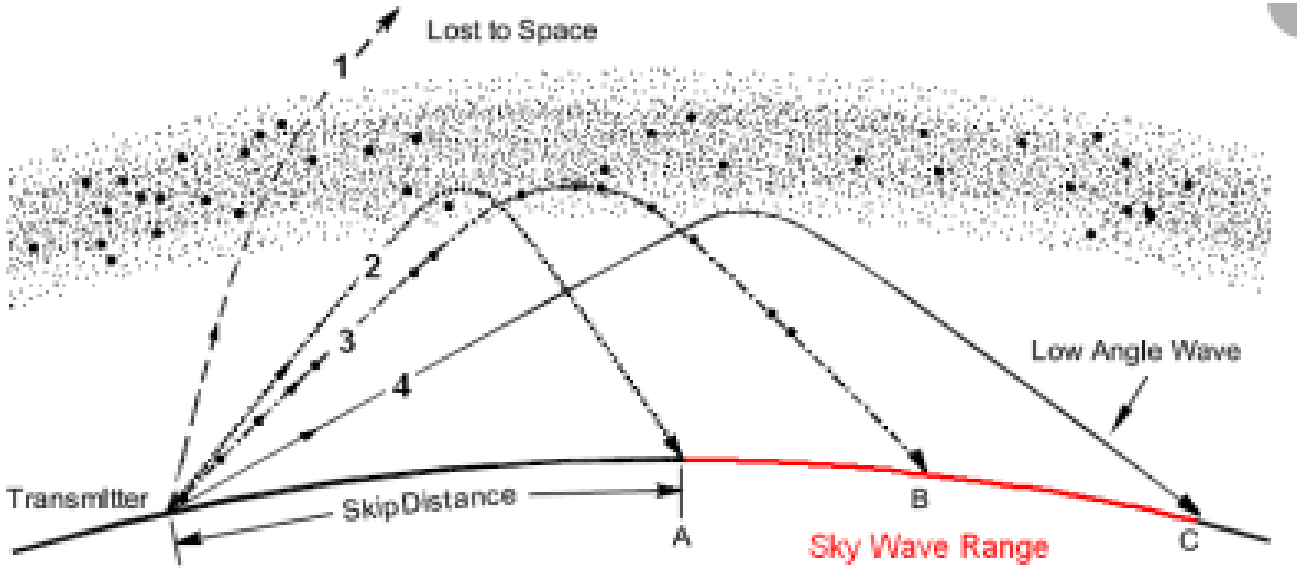
opens up the world



What Does It Take to Make a QSO?

- There must be enough ionization to refract (bend) the signal back to earth
  - The amount of refraction is inversely proportional to the square of the frequency
  - Higher frequencies don't refract as much – need more ionization
- There must be low enough loss to be able to hear the signal
  - Free space path loss – spreading of the wave
    - Depends on frequency and distance
  - Ionospheric absorption in the D region
    - The amount of ionospheric absorption is inversely proportional to the square of the frequency
    - Higher frequencies incur less absorption – signals on 10m are strongest (if there's enough ionization)

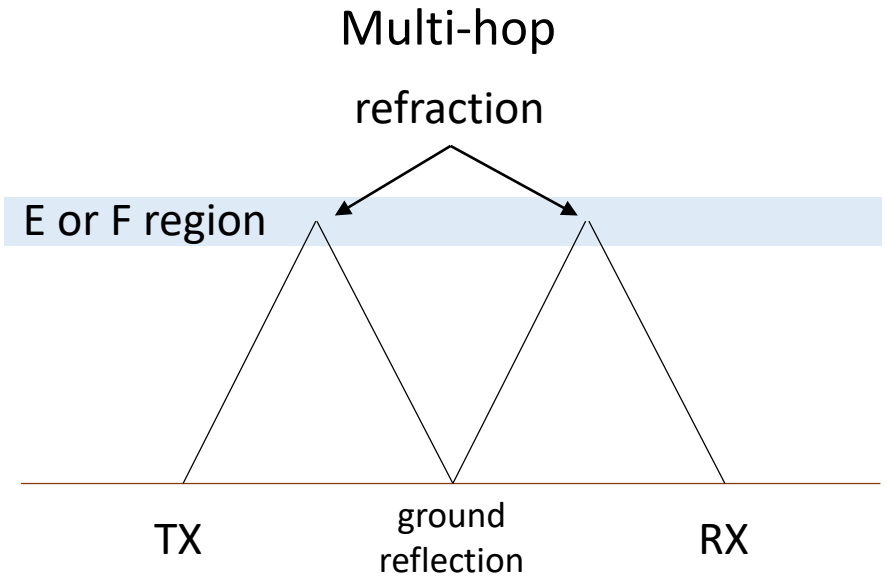
Distance vs Elevation Angle



- If the angle is too high (1), the signal goes through the ionosphere
  - Not enough ionization
- The highest angle that returns to earth (2) determines the skip distance
  - Ground wave can cover some of the skip distance
  - Lower frequencies (NVIS) can shorten the skip distance
- The lower the elevation angle (3 and 4), the farther the distance
  - And the higher the MUF (maximum usable frequency)

HF Propagation Modes

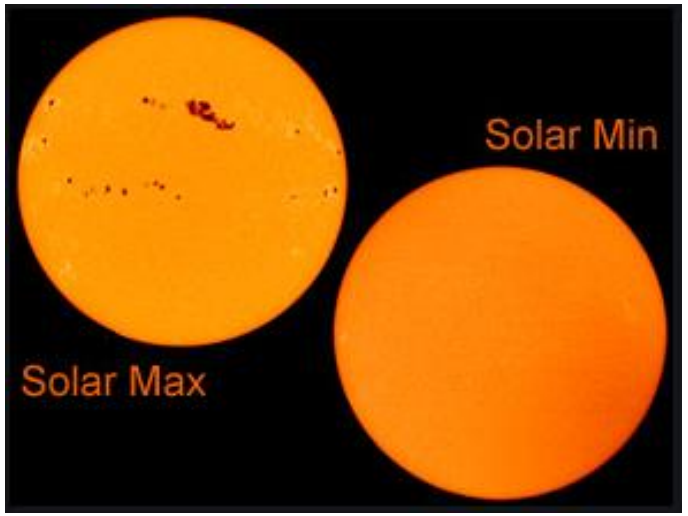
- Many modes – multi-hop, sporadic-E, trans-equatorial (TEP), scatter, ground wave, short path/long path, auroral-E, skewed paths, gray line, propagation across the polar cap, etc
- Multi-hop is the most prevalent mode
  - Occurs from both the E and F regions
- Sporadic-E
  - Great for 6m and 10m
  - Not dependent on a solar cycle
  - Best during the summer months in the late morning and early evening



Solar Cycles

determines which bands are open

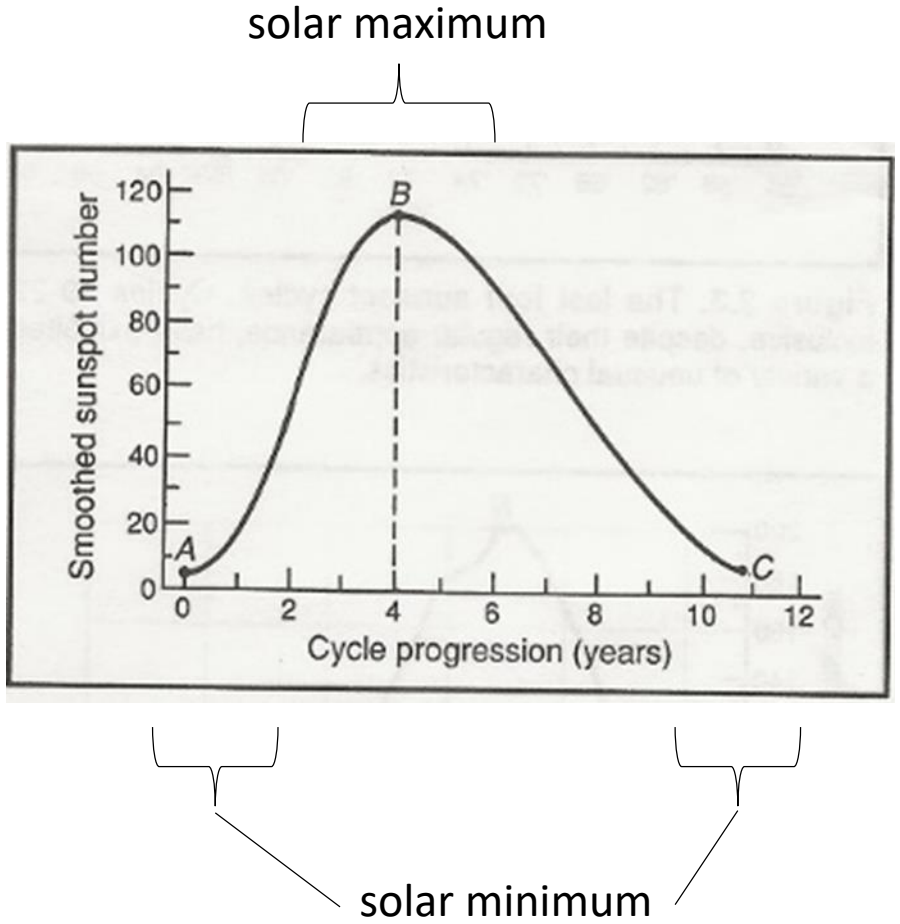
many sunspots



few or no sunspots

What Is a Solar Cycle?

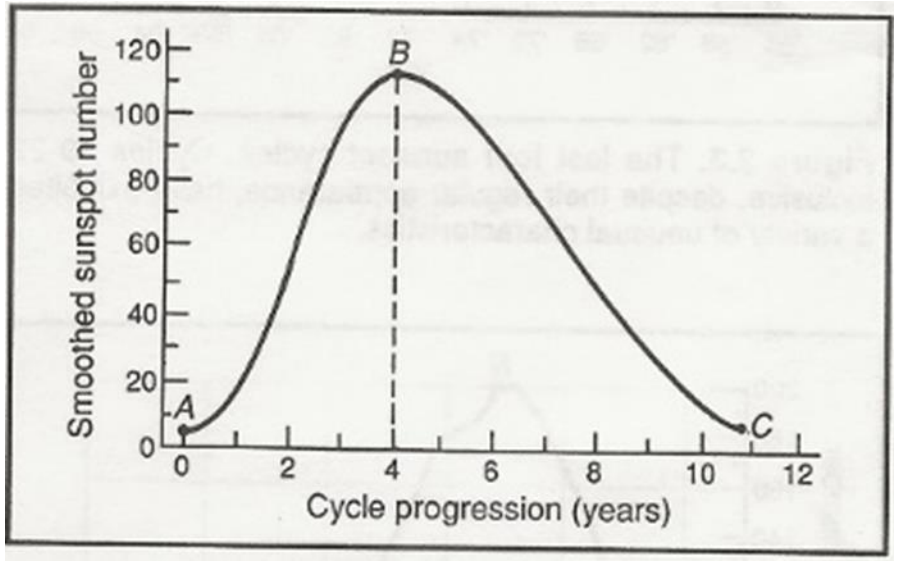
- Also known as a sunspot cycle
- It's the time period from a very low number of sunspots on the sun (solar minimum) through a maximum number of sunspots (solar maximum) and then back down to a very low number of sunspots
  - A to B to C in the plot on the right
- It's an approximate 11 year cycle
- On average
  - Rise time = 4 years
  - Descent time = 7 years



Why Are Solar Cycles Important?

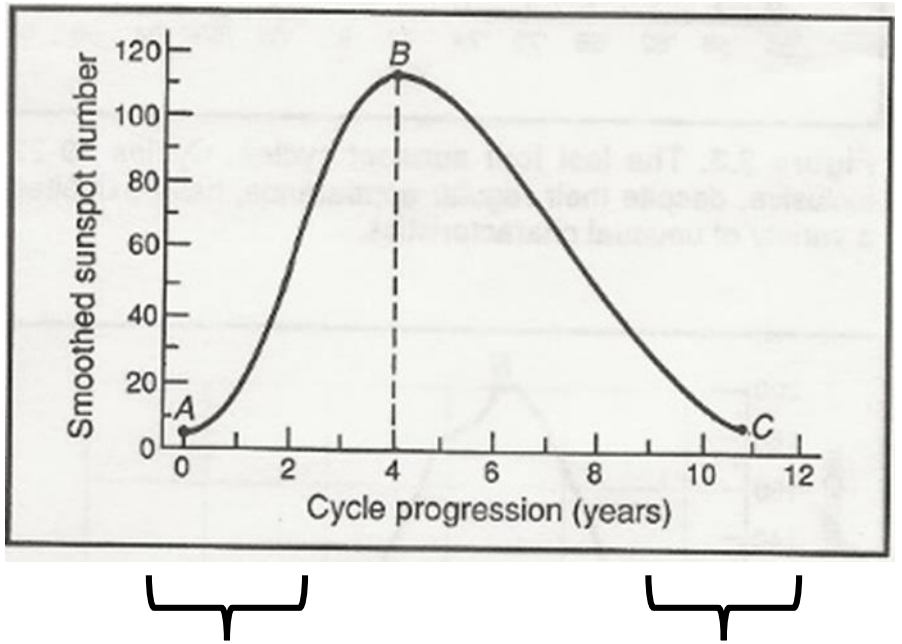
- They are important for the higher HF bands
  - 15m, 12m, 10m (and 6m)
  - The area around sunspots emits EUV (extreme ultraviolet) radiation to ionize the F_2 region
    - To reiterate, the F_2 region is the most important for long-distance contacts on HF
  - More sunspots = more EUV = more ionization = best propagation on the higher HF bands

best propagation on
15m, 12m, 10m, 6m



Why Are Solar Cycles Important?

- They are important for the low bands
  - 160m, 80m, 60m, 40m
  - Less sunspots = less ionospheric absorption and less disturbances to propagation = best propagation on the low bands
- 30m, 20m, 17m are generally good throughout a solar cycle



best propagation on 160m, 80m, 60m, 40m

When Are the Bands Open?

- Lower bands (160m, 80m, 60m, 40m) best at night
  - When ionospheric absorption in the D region minimizes
- Middle bands (30m, 20m, 17m) generally okay day and night
- Higher bands (15m, 12m, 10m) best during the day
  - When the MUF is highest
- 6m propagation via the F_2 region best at solar max in fall/winter
  - Don’t forget sporadic-E in the summer
- The higher bands (15m, 12m, 10m) “follow the sun” during the day
- Digital modes have an advantage over SSB and CW
  - This solar minimum will go down in history as the most active on the higher bands due to the digital modes

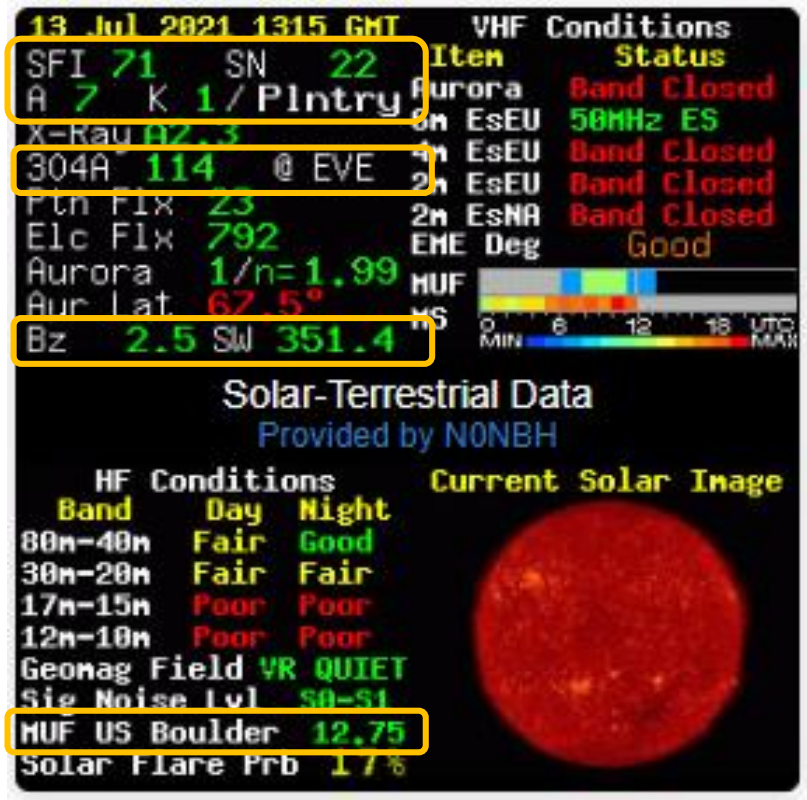
Space Weather

making sense of all those parameters

Lots of Websites With Data

- NØNBH banner (his website is http://www.hamqsl.com/solar.html)
  - at https://www.qrz.com/ and many other places
- Dr. Tony Phillips
  - at https://spaceweather.com/
- Space Weather Prediction Center (SWPC)
  - at https://www.swpc.noaa.gov/
- VE3EN
  - at https://www.solarham.net/
- WX6SWW videos by Dr. Tamitha Skov
  - at https://www.spaceweatherwoman.com/
- Other general websites and many others that are more specific

We'll Focus On the NØNBH Banner



Here are the parameters that I think are important

- SFI, SN, 304A and MUF US Boulder
  - They can indicate which of the higher bands (15m, 12m, 10m) may be open
- K, A, B_z and SW
  - They tell us how disturbed the F2 region may be

Ranges of the Parameters

- SFI – latest 10.7 cm solar flux index: 65 at solar min to 300 at solar max
- SN – today's sunspot number: 0 at solar min to 350 at solar max
- 304A – EUV radiation at 30.4 nm: 90 at solar min to 400 at solar max
- MUF US Boulder – 3000 km MUF in MHz at Boulder

indicates which higher bands (15m, 12m, 10m) may be open

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indicates how disturbed the F_2 region may be

- K – 3-hour index: 0 (quiet) to 9 (very disturbed)
  - Plntry (Kp and Ap) is 'Planetary' and means it's from many stations
- A – average of the eight 3-hr K indices: 0 (quiet) to 400 (very disturbed)
- B_z – strength and direction (+ or -) of IMF: +50 to -100
  - B_z is perpendicular to the ecliptic – pretty much N-S
- SW – solar wind speed: 300 to 2000 km/sec

SFI, SN, EUV vs MUF

this chart indicates which bands may be open

long-term EUV	long-term sunspot number (V2)	long term 10.7 cm solar flux	similar to . . .	monthly median MUF
90	0	65	solar minimum	20 MHz
175	70	100	very small cycle (C6)	28 MHz
215	115	130	small cycle (C24)	33 MHz
285	179	170	average cycle (C23)	38 MHz
325	215	195	moderate cycle (C22)	41 MHz
400	286	245	big cycle (C19)	46 MHz

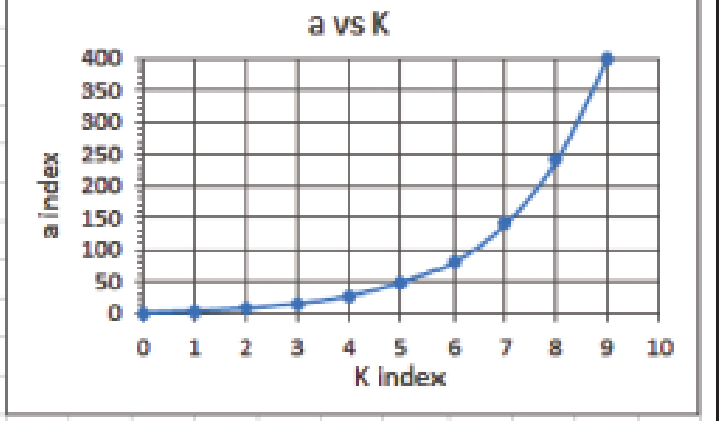
- When SFI = 65 and SN = 0, still enough EUV for 20 meters (and 17m to a lesser degree) to be open during the day and early evening
- Long-term means not for just a couple days (smoothed is best)
- MUFs are for 'normal' F_2 propagation in a fall/winter month in the afternoon on a mid-latitude path

K, A, B_z, SW

- For an undisturbed F_2 region, we desire:
  - K $\leq$ 3
  - A $\leq$ 15
  - B_z positive (a little negative is okay)
  - SW not too much greater than 400

- Although the SFI, SN, 304A parameters may indicate there's enough ionization, the above parameters may say the band is screwed up

K	a
0	0
1	3
2	7
3	15
4	27
5	48
6	80
7	140
8	240
9	400

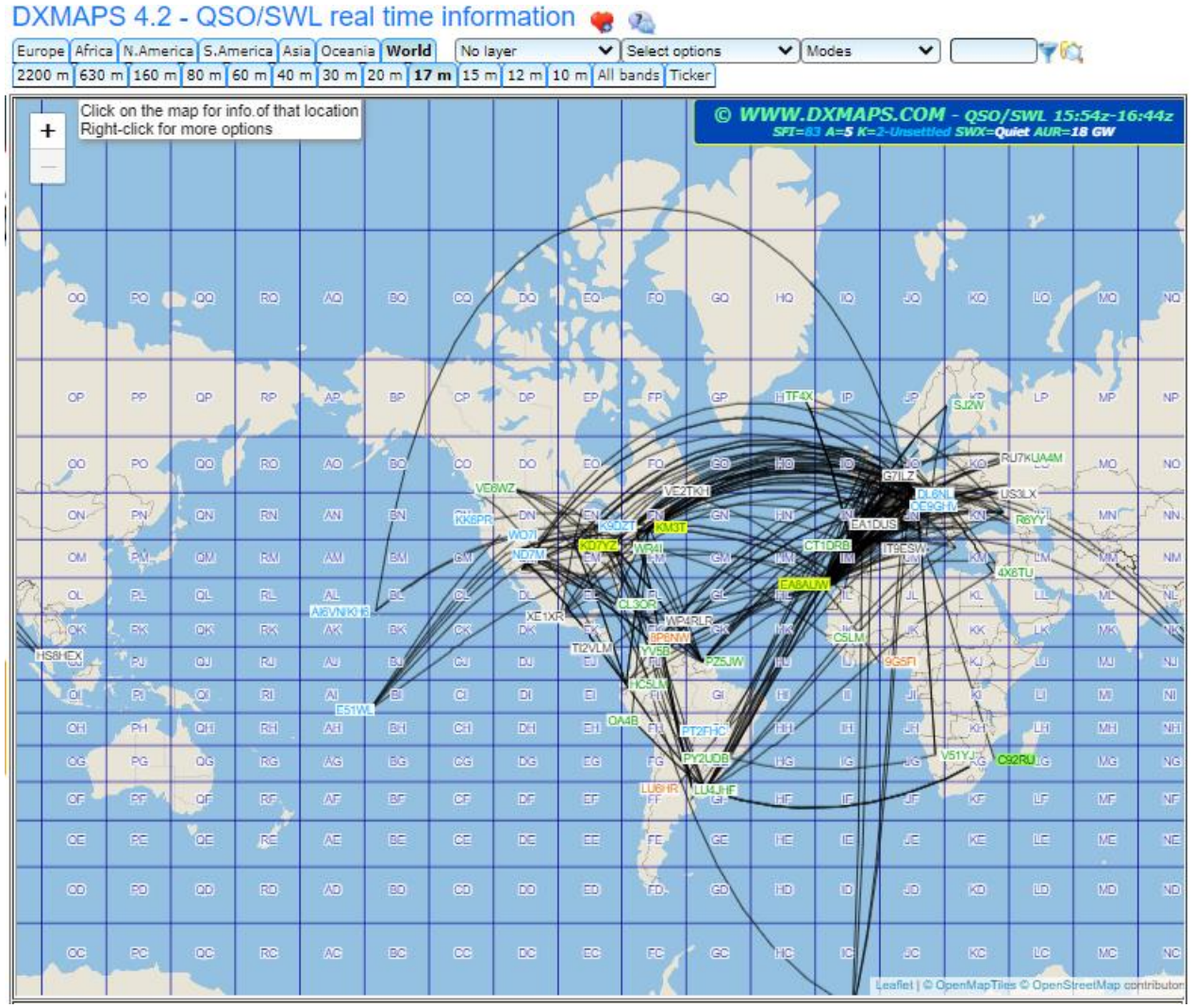


Disturbances to Propagation

in order of severity

- Geomagnetic storms
  - Elevated K indices – disturbed F_2 region
  - Caused by CMEs (coronal mass ejections – mostly around solar maximum) and CHs (coronal holes – declining phase of solar cycle)
- Solar radiation storms
  - Increased proton flux – degraded over-the-pole paths
  - Caused by big solar flares of M and X class (mostly around solar maximum)
- Radio blackouts
  - Increased X-Ray radiation – increased absorption on day side of Earth
  - Caused by big solar flares of M and X class (mostly around solar maximum)

Real-Time QSO Data



- See who others are working
- Visit dxmaps.com
- Select view: World, NA, SA, etc
- Select band
- April 13, 2021 from 1554-1644 UTC on 17m
- Similar info
  - or PSKReporter
  - or WSPRnet
  - or Reverse Beacon Network
  - or IARU/NCDXF beacons

Propagation Right Now

- We're just starting to see Cycle rise
- 160m, 80m – local QSOs during the day, NVIS at night, domestic and worldwide QSOs at night (need good station!)
- 60m, 40m – local QSOs during the day, domestic and worldwide QSOs at night
- 30m, 20m, 17m – worldwide and domestic QSOs during the day and early evening
- 15m, 12m, 10m – occasional north-south QSOs during the day
- Digital modes will provide more opportunities
- Watch for better propagation on the higher bands this fall and winter due to the change in the atmosphere and Cycle 25's rise

Come on, Cycle 25!

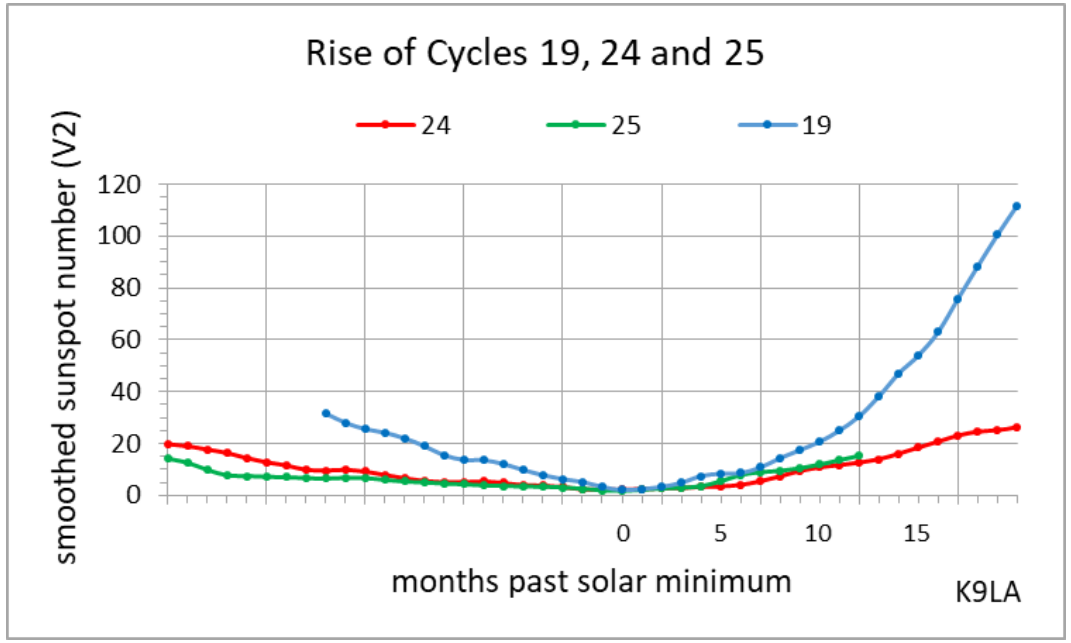
Cycle 25

If you've only been licensed for several years, you may be asking "what's so great about 15m, 12m and 10m?" as most of the time there is only noise and not many signals on those bands

All I can say is "wait a couple years and you'll be amazed what those bands can do around solar maximum with low power and modest antennas"

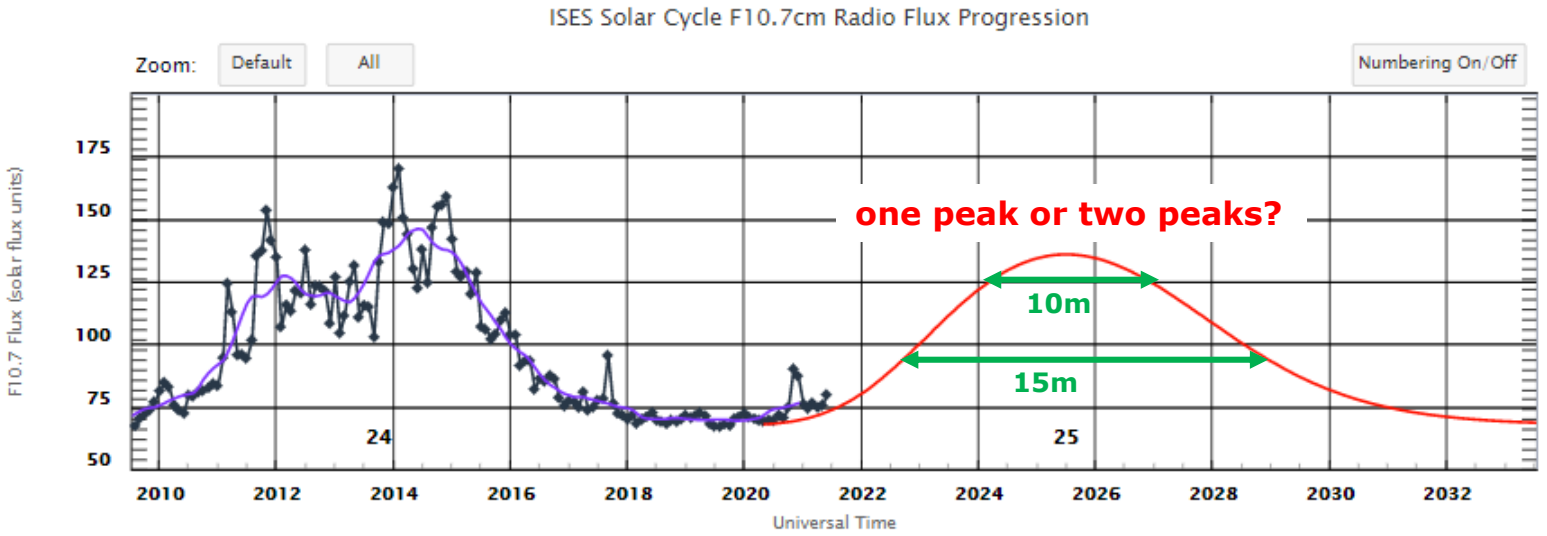
The Rise of Cycle 25

- Historical data says big cycles rise faster than small cycles



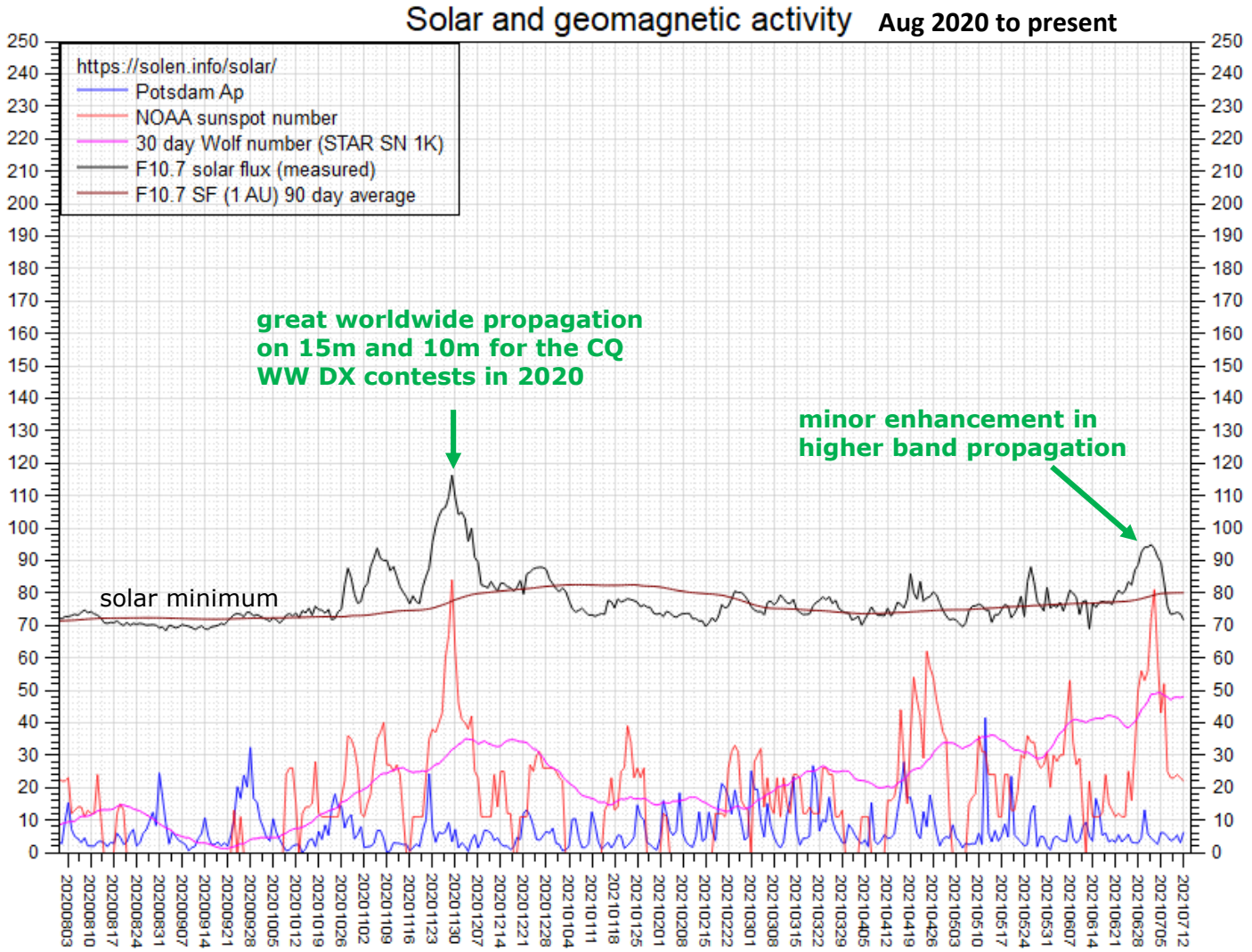
- Cycle 25 is rising a bit faster than Cycle 24 (Cycle 24 was small)
- Suggests Cycle 25 may be a small one – but it's still too early to tell

What to Expect If Cycle 25 Is Similar to Cycle 24



- We still have a way to go before 15m, 12m, and 10m open on a daily basis
- Watch for a big spike in SFI, SN, EUV and for a small spike in K
  - You may be rewarded with an enhanced opening

Spike in 10.7 cm Solar Flux



EUV is true ionizing radiation for the F_2 region

Summary

- Get on the air and operate – experience is a great way to gain knowledge
  - Make QSOs in contests, go after WAS, go after DXCC, go after WAZ
  - Have fun on 15m/12m/10m, especially when Cycle 25 has more sunspots!
- Watch for a big spike in 10.7 cm solar flux and a small spike in the K index
  - May result in enhanced propagation on the higher bands
- Use the digital modes on 15m, 12m, 10m until Cycle 25 really gets going

References

- Propagation chapters of the ARRL Handbook and Antenna Book
- "The Little Pistol's Guide to HF Propagation" by NM7M (SK)
  - Out-of-print but available on my website (15 Mb download)
- "The CQ Shortwave Propagation Handbook – 4th Edition" (very recent update of 1995 Edition)