Cycle 25
and
Space Weather Effects on Propagation

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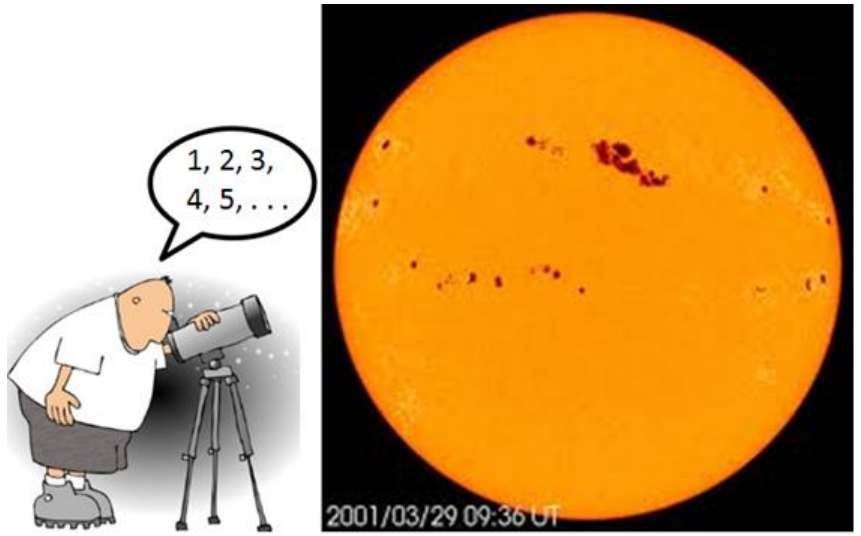
Agenda

- Previous presentations
  - November 2015 – review of the sun, the ionosphere and propagation
  - February 2016 – effect of ground, terrain analysis and elevation angles

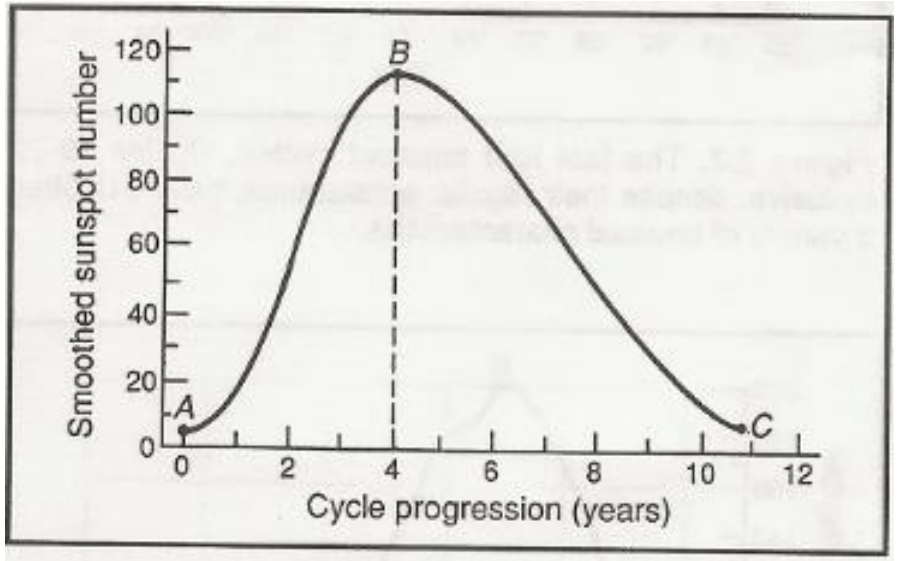
- Tonight
  - Review of solar cycles
  - Propagation at solar minimum
  - Cycle 25
  - Space weather effects on propagation

Review of Solar Cycles



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
  - From 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



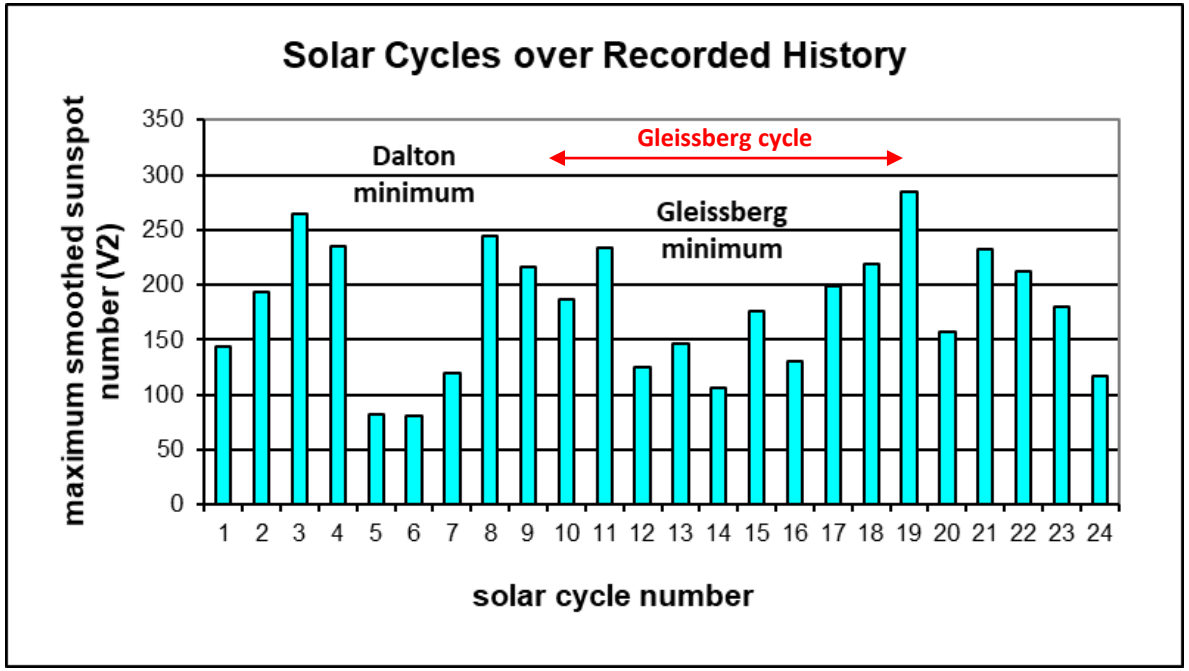
Higher bands (15m, 12m, 10m, 6m) best around solar maximum (B)

Lower bands (160m, 80m, 60m, 40m) best around solar minimum (A and C)

Middle bands (30m, 20m, 17m) good throughout entire solar cycle

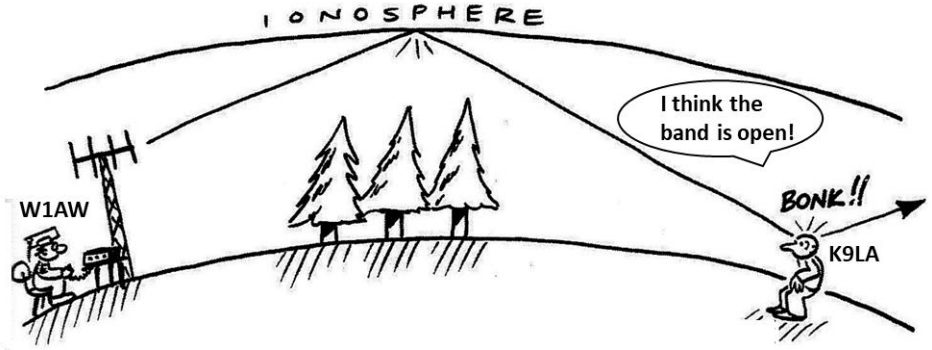
Recorded History

- Cycle 1 began in 1755
  - Maunder Minimum occurred from 1645-1715 with few sunspots
- We've gone through 3 periods of big cycles and 2 periods of small cycles
  - We appear to be in a third period of small cycles



- Cycle 24 is considered to have ended and Cycle 25 is considered to have started in December 2019
  - When the smoothed sunspot number numerically minimized
  - But in reality solar cycles overlap (more on slide 9)

Propagation at Solar Minimum

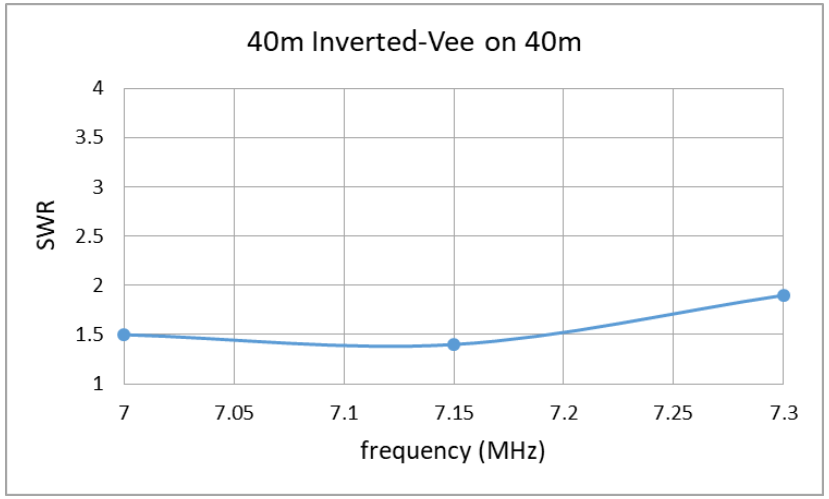


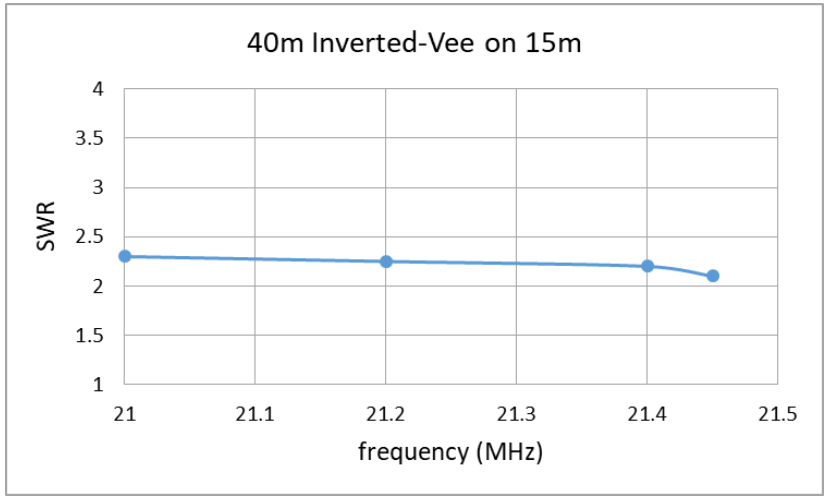
The Bands Right Now

- Solar minimum between Cycles 24 and 25 occurred in December 2019
  - Cycle 25 has started, we're about 1 year past solar minimum
  - About 3 years to solar maximum
- Low Bands
  - 160m, 80m, 60m, 40m best now (except 160m was not good during CQ 160m SSB)
- Middle bands (30m, 20m, 17m) good throughout solar cycle
- Higher bands
  - 15m offers decent worldwide propagation on a few days of the month
  - 12m is kind of quiet – occasional openings to the south and to VK/ZL
  - 10m is mostly noise – very occasional openings to the south and to VK/ZL
- Digital modes offer more opportunities due to their signal-to-noise ratio advantage
  - FT8/FT4 better than CW, CW better than SSB

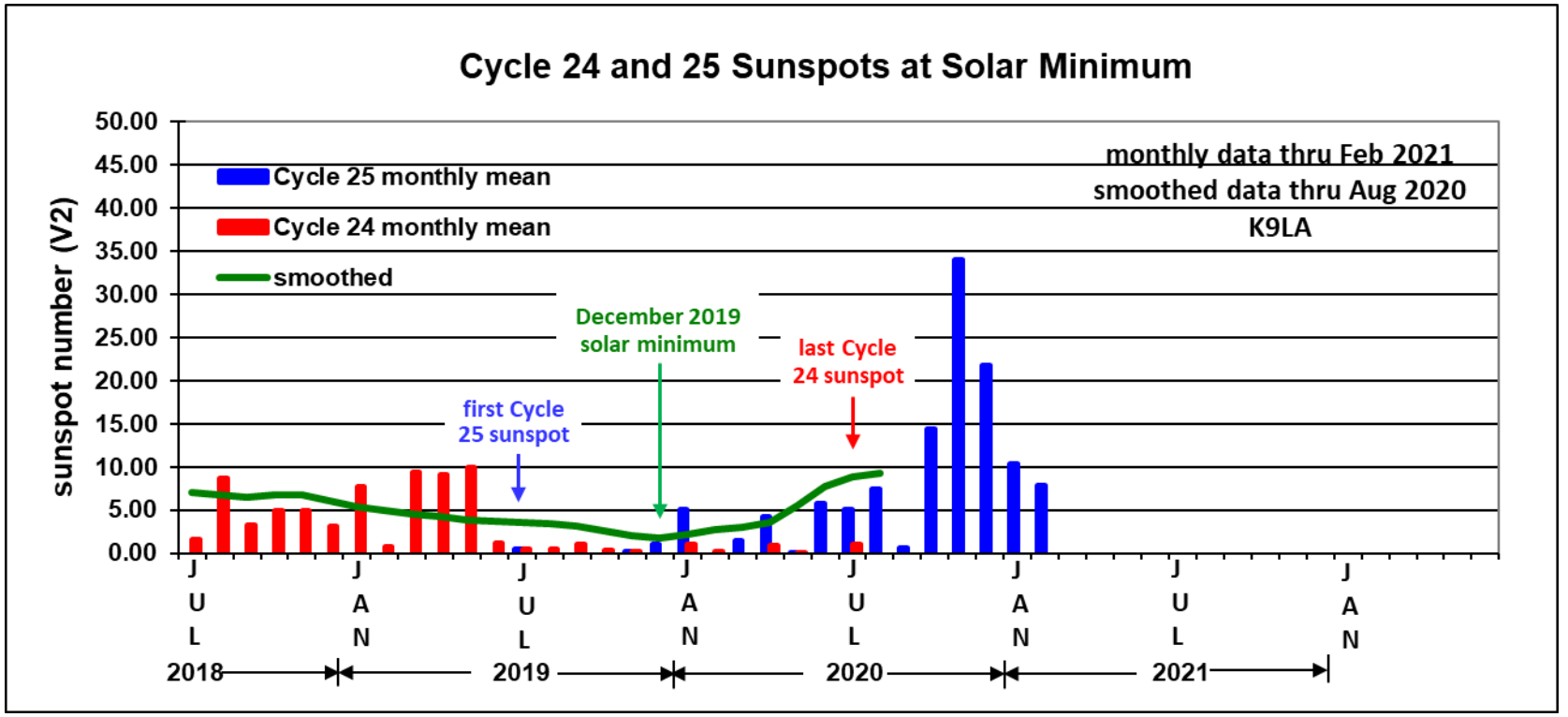
2021 ARRL DX CW Contest

- Last month - solar minimum
- 90 Watts out with my TEN-TEC OMNI VII
- Antennas
  - 80m – wire vertical thanks to a big oak tree
  - 40m – inverted-vee at 40 feet
  - 15m – used 40m inverted-vee
- 54 total countries (48 were on 40m)





Cycle 24 Transition to Cycle 25

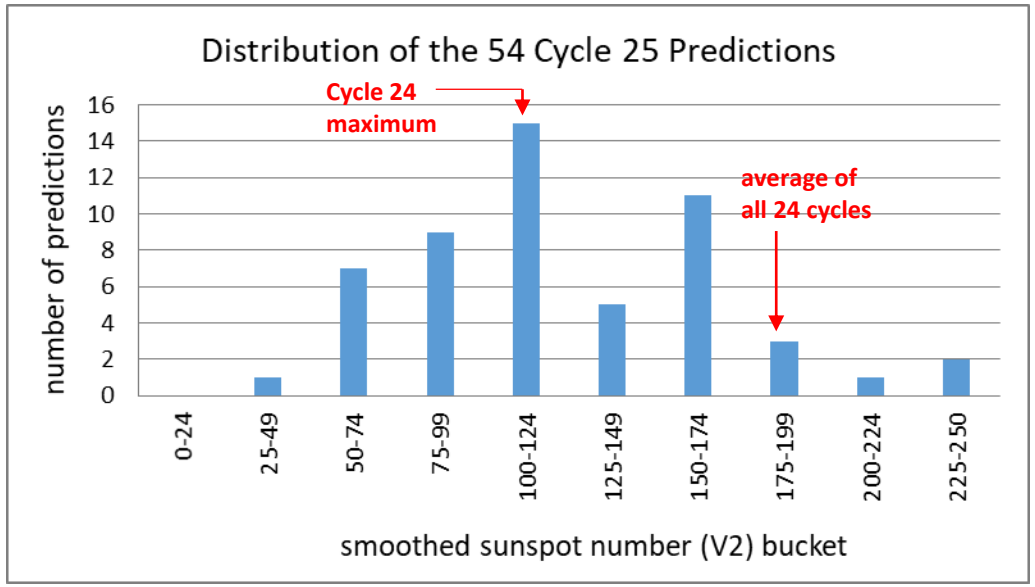


- First Cycle 25 sunspot in July 2019, last Cycle 24 sunspot in July 2020
- We can tell which cycle a sunspot is from by where it emerges on the solar disk and by the polarity of its magnetic field

Cycle 25

Cycle 25 Predictions

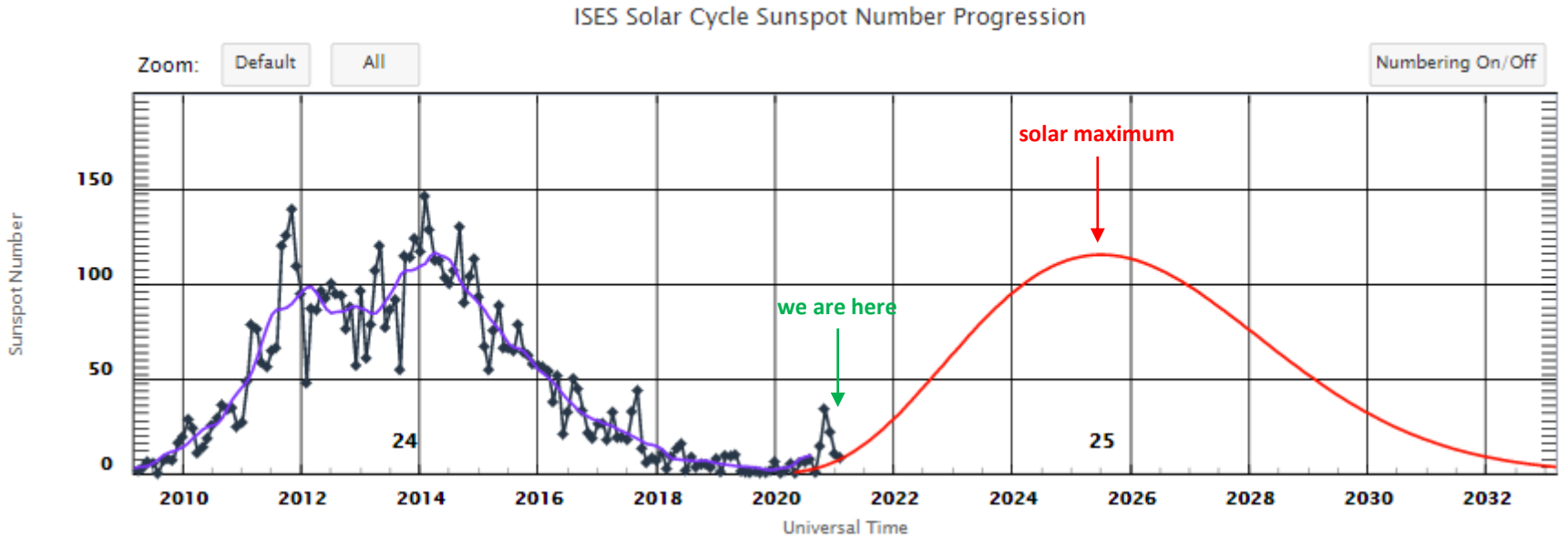
prediction is difficult – especially if it involves the future



- Most forecast Cycle 25 to be similar to Cycle 24
- There are a <u>few</u> for a really big Cycle 25
- We'll just have to wait and see

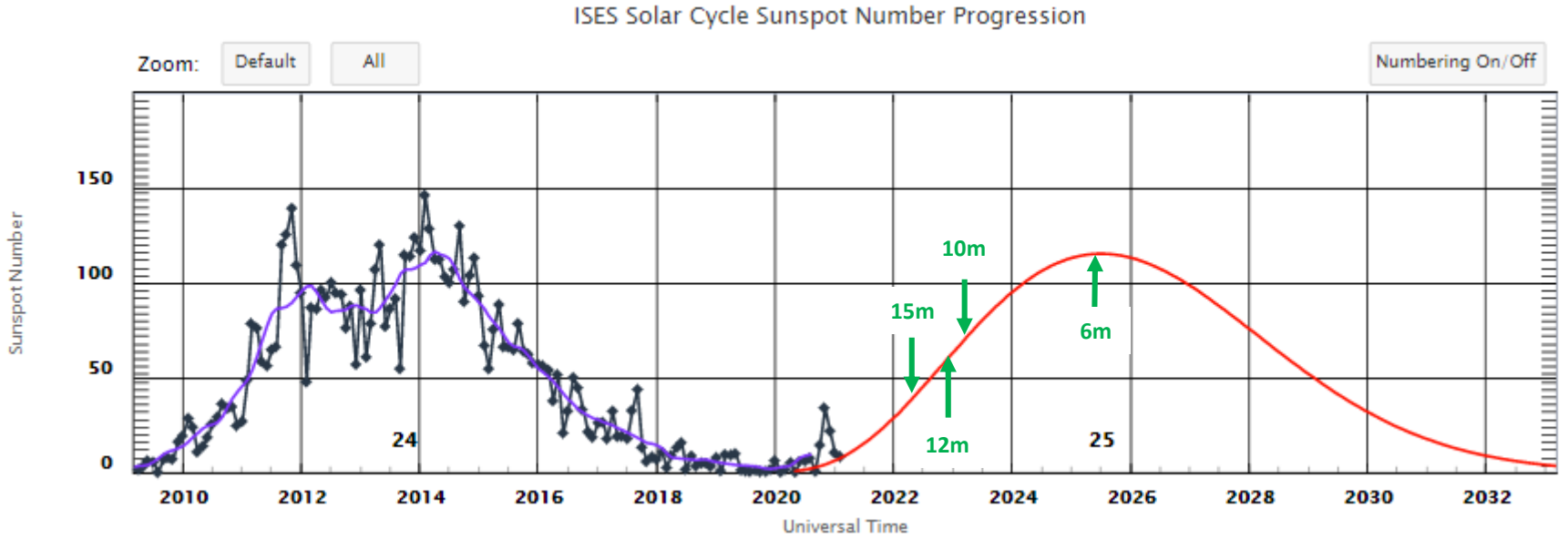
What Will Cycle 25 Do?

- Prediction from the Solar Cycle 25 Prediction Panel



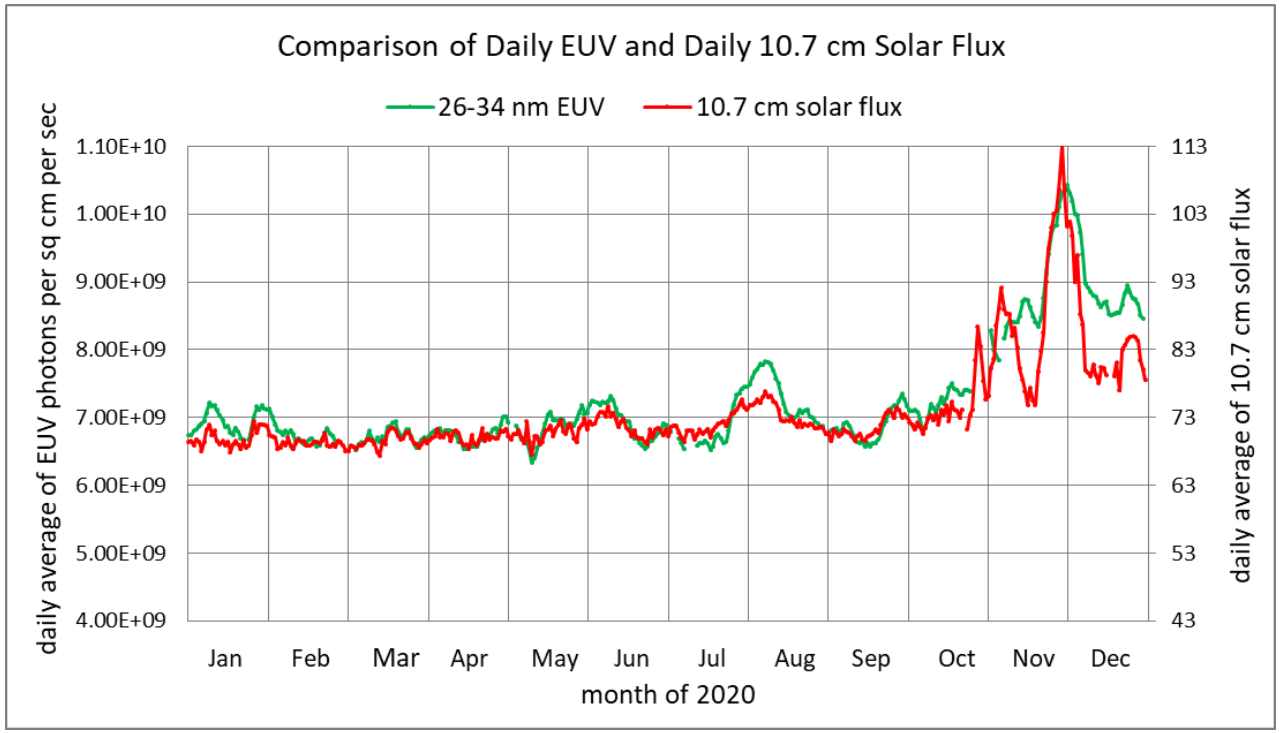
- One of <u>many</u> predictions that forecasts a Cycle 25 similar to or smaller than Cycle 24
- There are a <u>few</u> for a really big Cycle 25 – we'll just have to wait and see

When Will the Higher Bands Be Back?



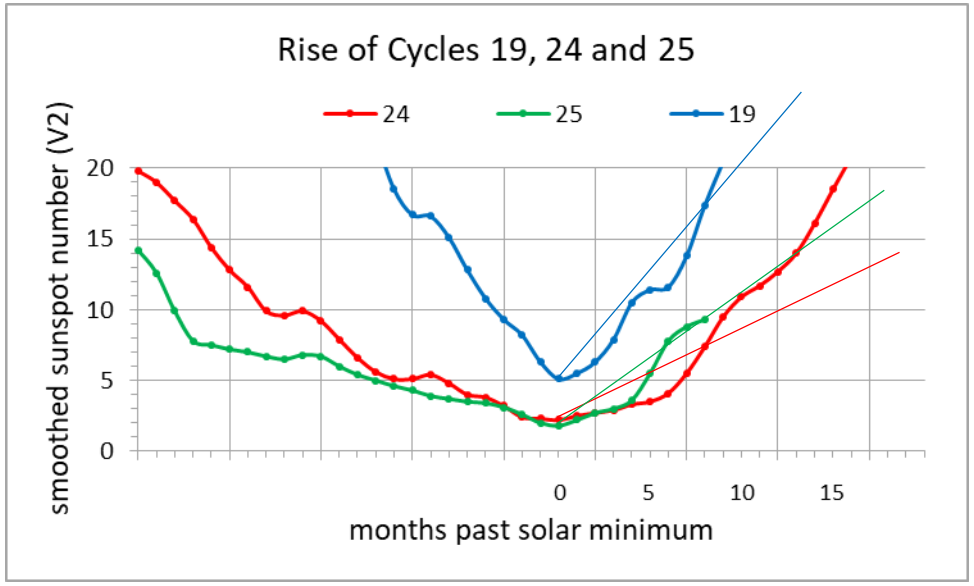
- If Cycle 25 is similar to Cycle 24 . . .
  - 15m should be back around the spring of 2022
  - 12m should be back around the winter of 2022/2023
  - 10m should be back around the spring of 2023
  - 6m should offer F2 propagation around solar maximum
    - Don't forget E_s in the summer – not tied to the solar cycle

When the Sun Hiccups



- The sun hiccupped from late October to mid December of last year
  - Great propagation on 15m and 10m for CQ WW DX and ARRL 10 Meter contests
- Settled back to solar minimum in late December
- Activity picking up again – keep an eye on 10.7 cm solar flux and the sunspot number for propagation on 15m, 12m and 10m

How Is Cycle 25 Doing?



after 8 months of data

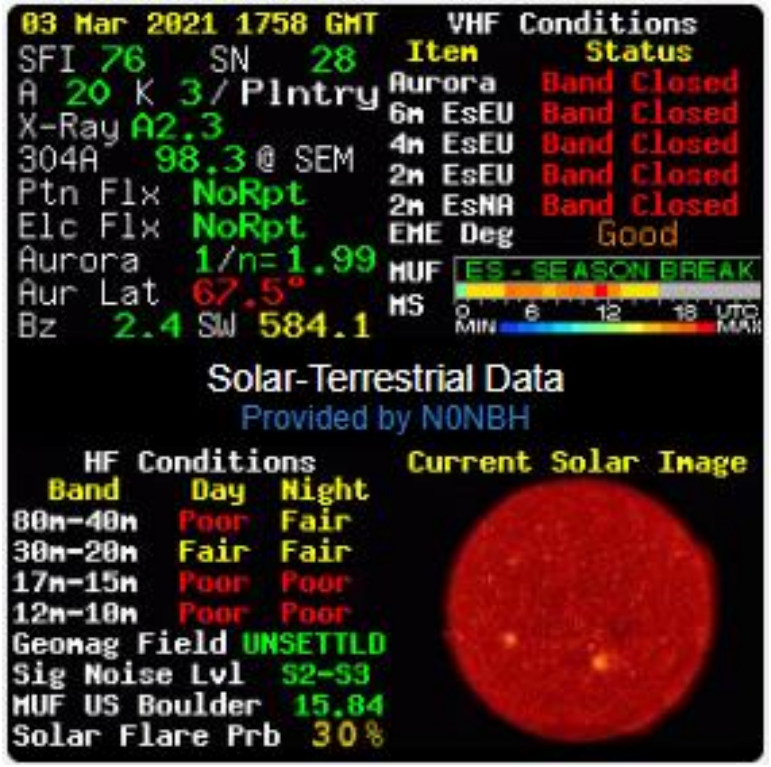
- The faster a cycle rises, in general the bigger it is
- Cycle 25 is off to a decent start – it is rising faster than Cycle 24
- But it's still too early to tell what Cycle 25 will do

Space Weather Effects on Propagation

Space Weather Data Sources

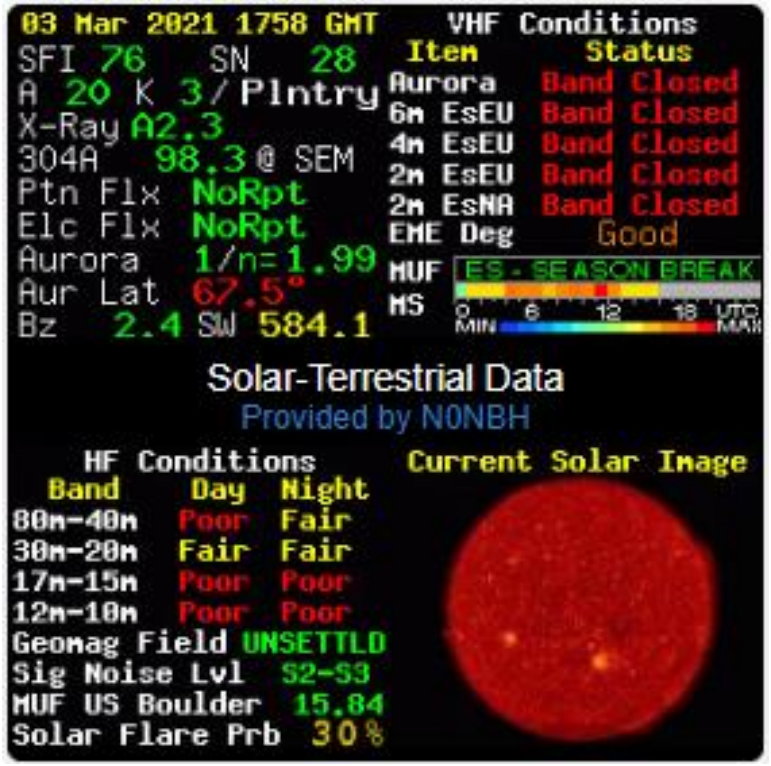
- NØNBH banner (his website is http://www.hamqsl.com/solar.html)
  - at https://www.qrz.com/, for example
- Dr. Tony Phillips
  - at https://spaceweather.com/
- Space Weather Prediction Center (SWPC)
  - at https://www.swpc.noaa.gov/
- VE3EN
  - at https://www.solarham.net/
- Other general websites and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

NØNBH Banner from www.qrz.com



- Date and time are obvious! ☺
- SFI – latest 10.7 cm solar flux index
- SN – today's sunspot number
- A – yesterday's A index (activity of magnetic field)
  - Avg of the eight 3-hr K indices
- K – current 3-hr K index (activity of magnetic field)
  - Plntry (Kp and Ap) means it's not just from 1 station
- X-Ray – background radiation from .1-.8 nm
  - Solar flares classified as A (smallest), B, C, M, X (largest)
- 304A – EUV radiation at 30.4 nm (multiply by 10^8)
  - 26-34 nm responsible for ~60% of the F2 region

NØNBH Banner from www.qrz.com



- Ptn Flx – proton density in solar wind (115-195 keV)
- Elc Flx – electron density in solar wind (38-53 keV)
- Aurora – scaled power (1-10) into auroral oval
  - Loosely correlated to the K index
- Aur Lat – lowest latitude for visible aurora
- B_z – strength and direction (+ or -) of IMF
  - B_z is perpendicular to the ecliptic – pretty much N-S
- SW – solar wind speed in km/sec (quiet time ~400)
- Sig Noise Lvl – in S-units due to magnetic field activity
- MUF US Boulder – MUF in MHz at Boulder
  - For a 3000 km path with Boulder at midpoint
- Solar Flare Prob – self-explanatory

spaceweather.com – Left Vertical Column Data

LEFT COLUMN

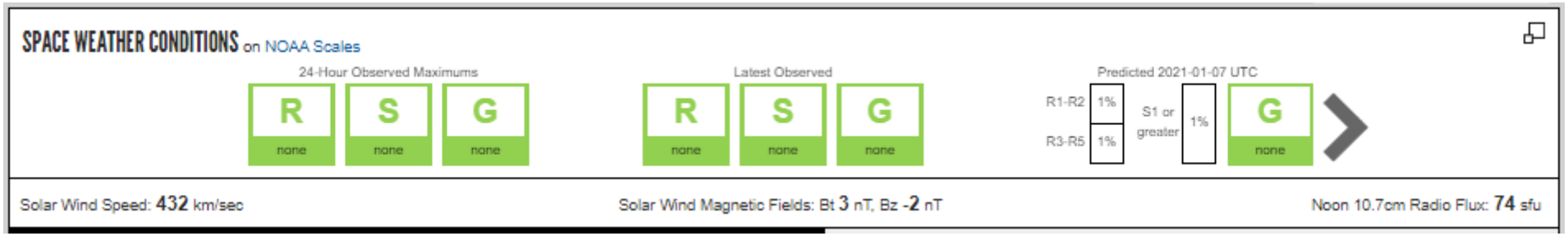
- Solar wind
  - speed – same as NØNBH banner
  - proton density – 795-1193 keV
- X-ray Solar Flares
  - same as NØNBH banner
- Sunspot number
  - same as NØNBH banner
- Spotless Days
  - self-explanatory
- The Radio Sun
  - 10.7 cm solar flux – same as NØNBH banner

MIDDLE COLUMN

- Lots of good discussion and data on a variety of subjects
  - CMEs
  - Aurora
  - Near Earth Asteroids
  - Cosmic Rays
- Many links to specific data

Space Weather Prediction Center

Top of the Home Page

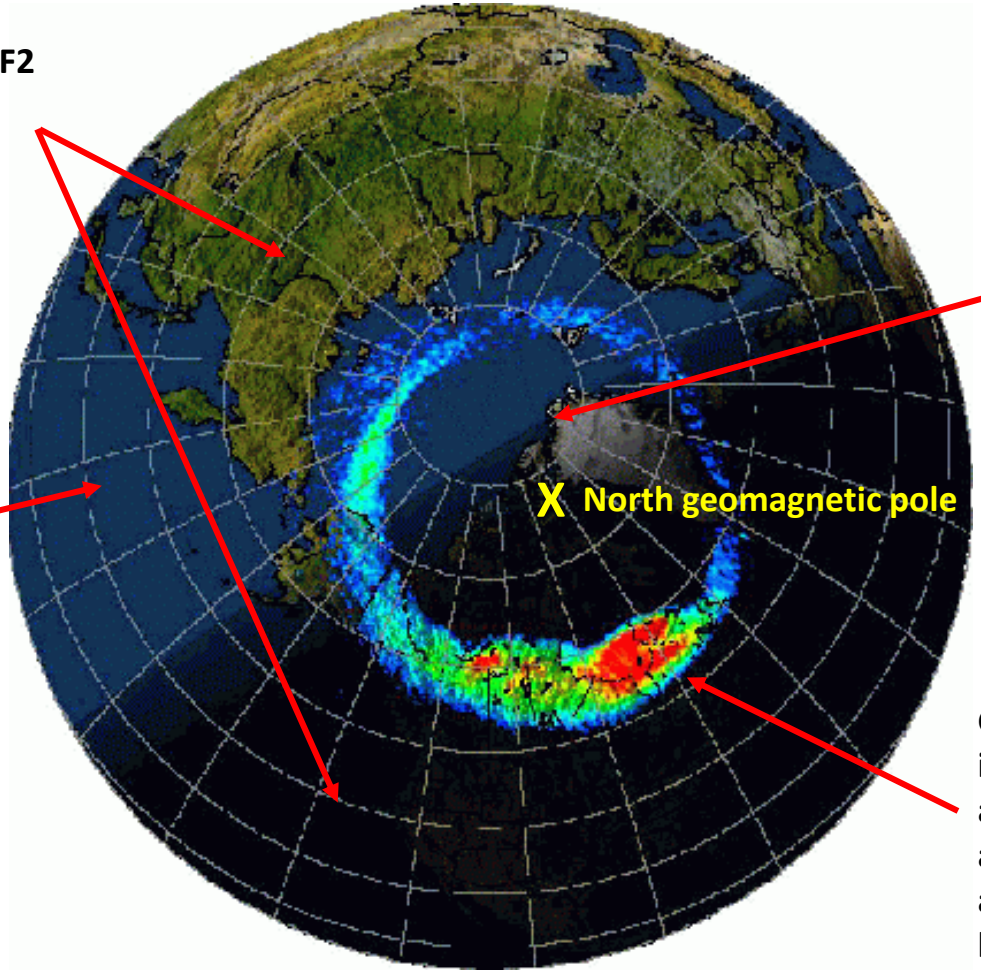


- Disturbances to propagation categorized as G, S and R
  - G is geomagnetic storm – caused by Earth-directed CME or coronal hole
  - S is solar radiation storm – due to energetic protons from big solar flare
  - R is radio blackout – due to X-ray radiation from big solar flare
- Scale is 1 (minor) to 5 (extreme)
  - https://www.swpc.noaa.gov/noaa-scales-explanation

Big Picture for Disturbances to Propagation

G
Geomagnetic storm – decreased F2 region MUFs at high latitudes, possible MUF enhancements at low/mid latitudes, can occur day and night

R
Radio blackout – increased D region absorption on the daylight side of the Earth



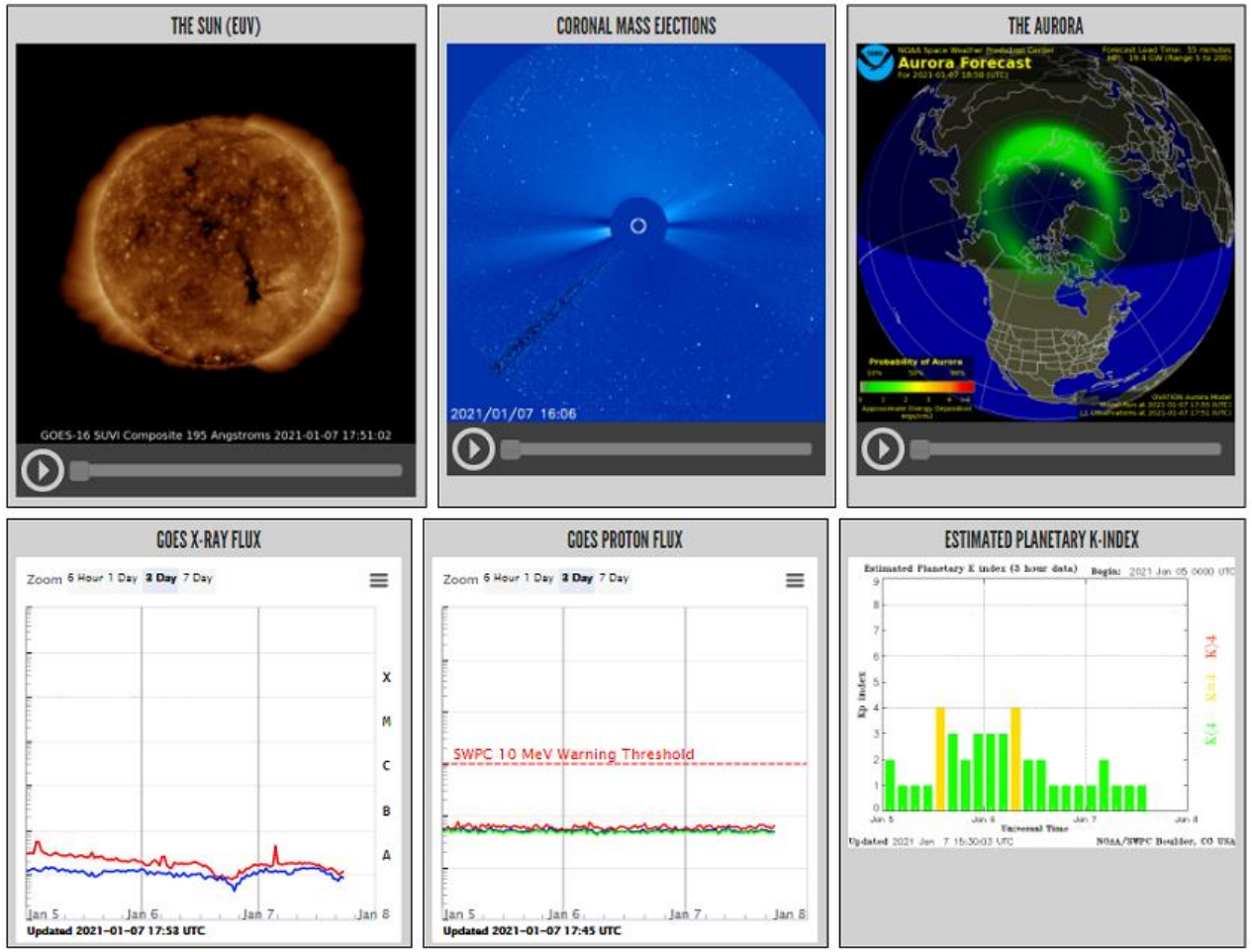
S
Solar radiation storm – increased D region absorption in the polar cap (area within auroral oval)

G
Geomagnetic storm – increased ionization in the auroral oval giving us aurora at VHF, causing more absorption at HF, causing horizontal refraction on the low bands (skewed path)

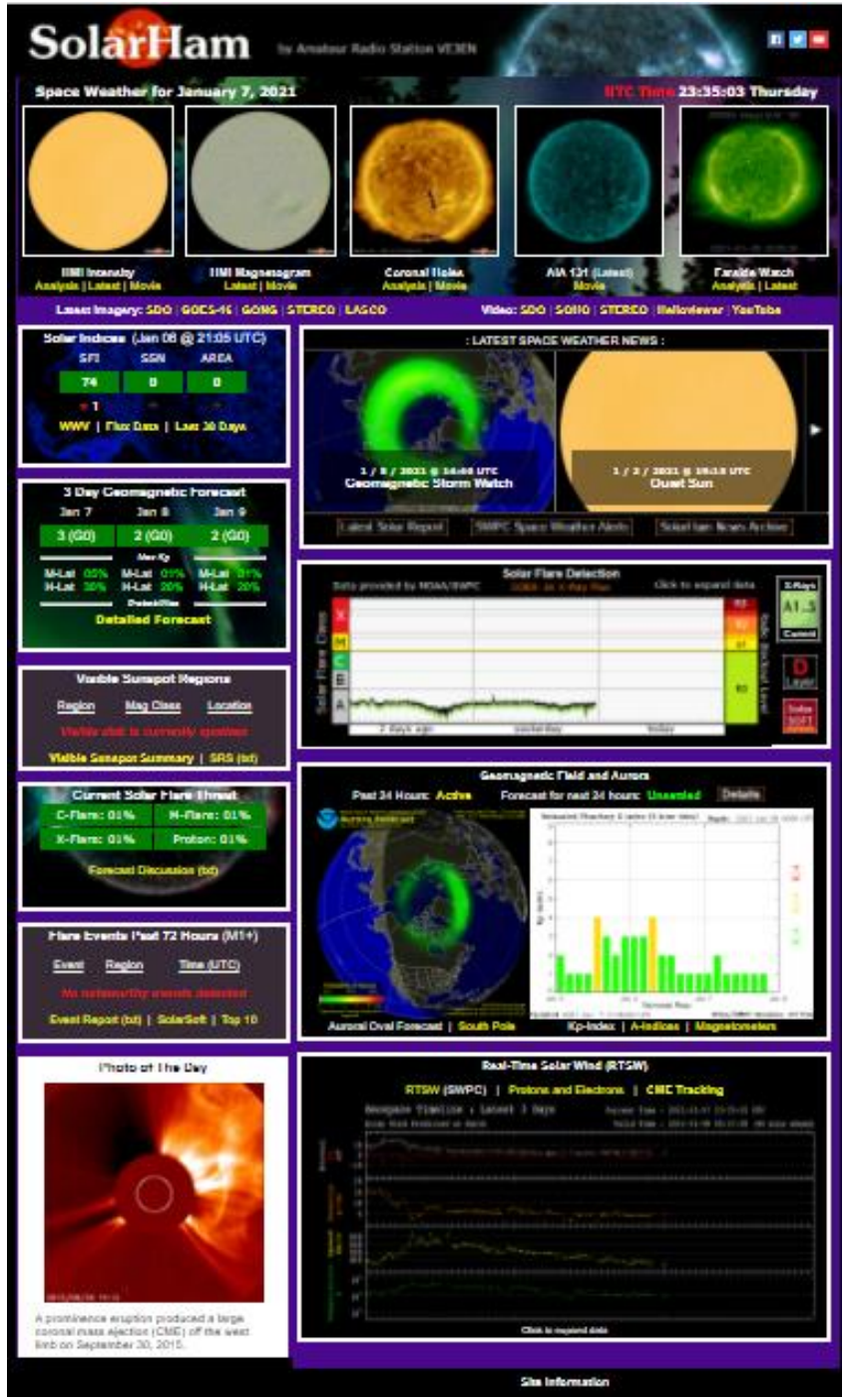
- Duration
  - G can be the longest
  - S next
  - R usually the shortest

Space Weather Prediction Center

Six Panels on the Home Page



- The Sun in EUV at 19.5 nm
  - Not 304A on the NØNBH banner
- Coronal Mass Ejections
- Aurora Forecast
- GOES X-Ray Flux
  - Where X-Ray on the NØNBH banner comes from
- GOES Proton Flux
  - At geosynchronous altitudes
  - Not the NØNBH proton density
- Estimated Planetary K-Index
  - Where K on the NØNBH banner comes from



solarham.net by VE3EN

- Top left-to-right – active regions in visible light, magnetogram (sunspot polarity), coronal holes, atmospheric imaging, far side watch at 19.5 nm
- Left column going down – solar indices, geomagnetic forecast, visible sunspot regions, current solar flare threat, flare events past 72 hours (≥ M1), photo of the day
- Right column going down – geomagnetic storm watch and the Sun in visible light, solar flare detection (X-ray flux), geomagnetic field and aurora (K index), real-time solar wind (B_{total} and B_z, speed, temperature)
- Phew!

I Think There's Too Much Information

but it's very colorful!

- Here's what I think is important
  - SFI and SN
    - They indirectly tell us how much ionizing radiation there is for the F_2 region
    - Related parameters: 304A, MUF US Boulder
  - K and A
    - They tell us how active the Earth's magnetic field is
    - Related parameters: B_z, SW, GSR values, X-Ray

SFI, SN, 304A, MUF US Boulder

- SFI, SN are proxies for true ionizing radiation – EUV for the F_2 region
- At solar min (SFI=65, SN=0), there's still enough EUV to keep 20m open during the day and early evening
- Thus SFI and SN give us an indication of openings on the higher bands
- Daily SFI ~65 to ~350, daily SN 0 to ~450, daily EUV ~70 to ~500*
- But the ionosphere correlates best to smoothed SFI, SN and EUV

	SFI value for many weeks	SN value for many weeks	EUV value for many weeks
15m	90	50	140
10m	105	70	200
6m	145	140	300

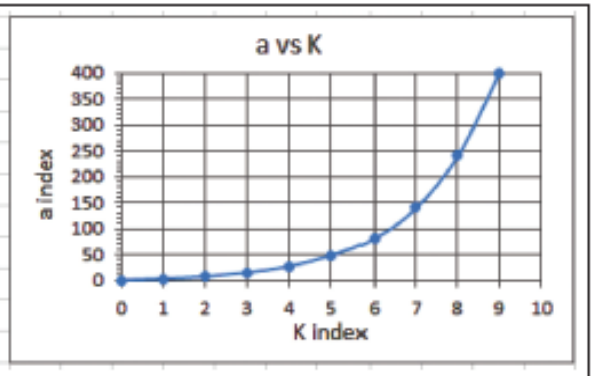
MUF US Boulder is real-time and gives a direct indication of F_2 region ionization

* my best guess

K, A, B_z, SW, GSR Values, X-Ray

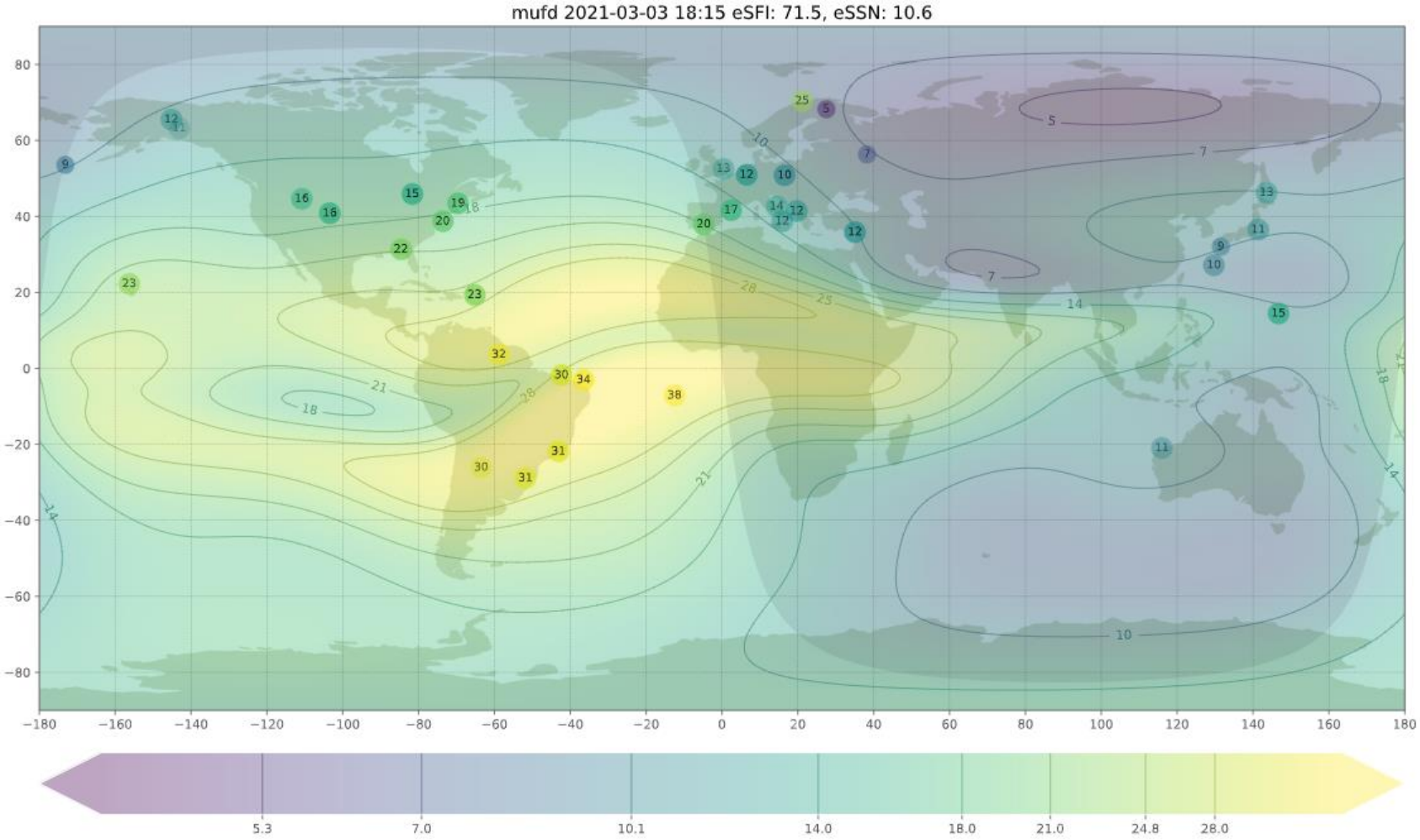
- K from 0 to 9 (logarithmic), A from 0 to 400 (linear)
  - K gives 'a' which gives A
- B_z from -100 to +50, SW from ~400 to ~2000 km/s
- GSR from 1 (minor) to 5 (extreme)
- X-Ray from A1.0 to X9.9 (or even higher!)
- Generally we want:
  - K $\leq$ 3, A $\leq$ 15
  - B_z positive (a little negative is okay)
  - SW around 400 (average)
  - GSR values 1 (or maybe 2)
  - X-Ray at A, B or C (M and X can cause solar radiation storms and radio blackouts)

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



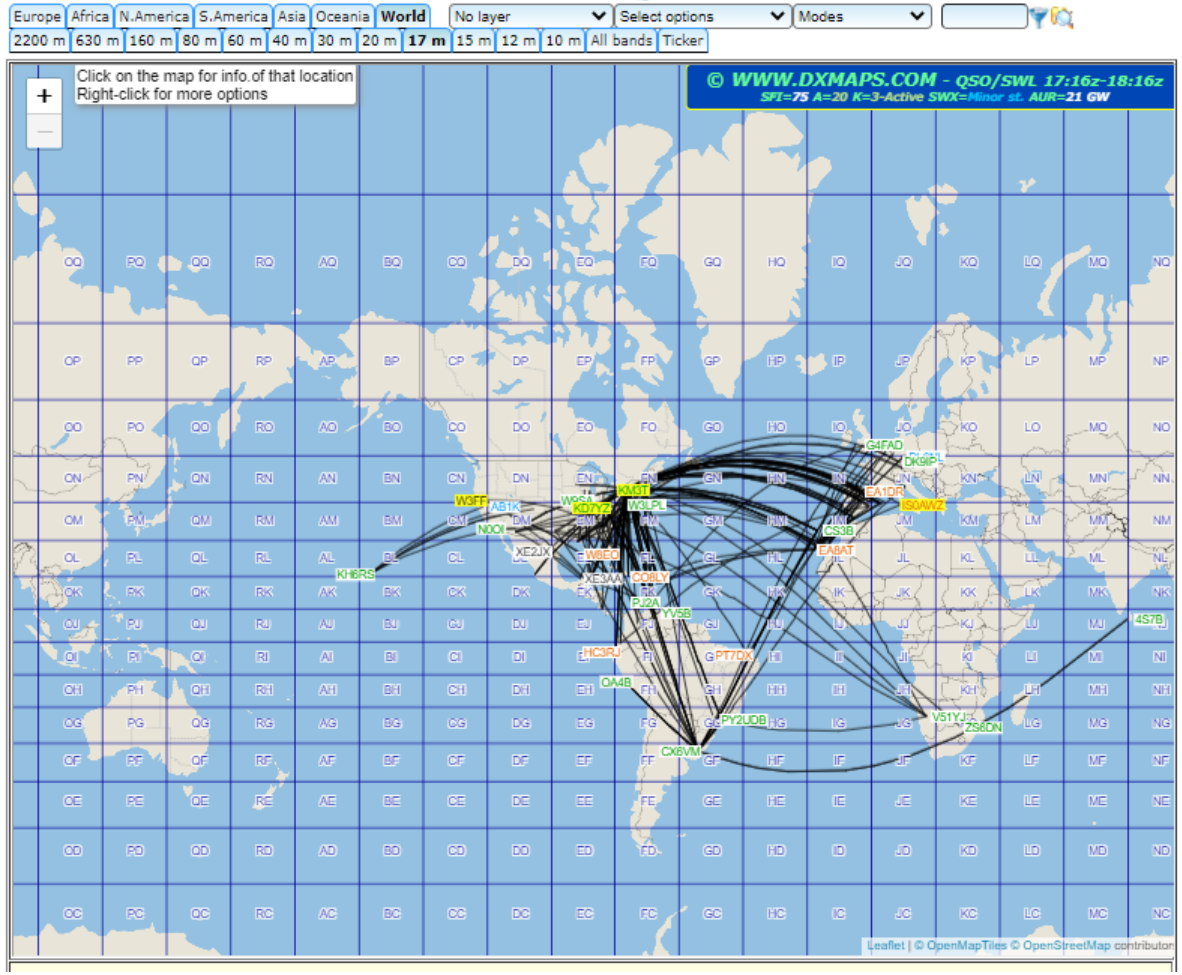
- If K spikes up a bit, watch for possible:
  - Enhancements at mid and low latitudes on the higher bands
  - Enhancements on 160m across the high latitudes

But Do We Really Even Need All That Data?



- Real-time 3000 km MUF
- Visit http://prop.kc2g.com/
  - uses real-time ionosonde data
- Circles with numbers are ionosonde data
- Contours are worldwide from interpolation
- Map shows gray line

Another Example of Real-Time Data



- Real-time QSOs
- See what a band is doing right now
- Visit dxmaps.com
  - or PSKReporter
  - or WSPRnet
- Select view: World, NA, SA, etc
- Select band
- Worldwide 17m QSOs shown
  - 1716-1816 UTC on March 3

Summary

- Cycle 24 is over, Cycle 25 is beginning its ascent
- Most forecast a below average Cycle 25, a few forecast a big Cycle 25
  - All we can do is wait and see what happens
- Solar min is best for the low bands (160m, 80m, 60m, 40m)
- 30m, 20m, 17m are good throughout a solar cycle
- Solar max is best for the higher bands (15m, 12m, 10m, 6m)
  - Lots of things to do with 100 Watts and a wire
- SSB is okay, CW is better, digital modes are even better

Get radio-active on HF!