Understanding and Applying Solar Indices

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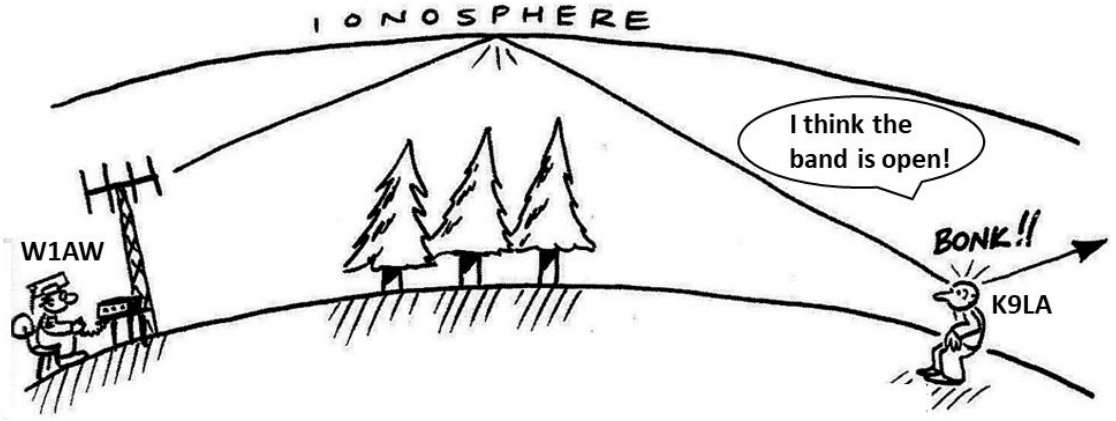
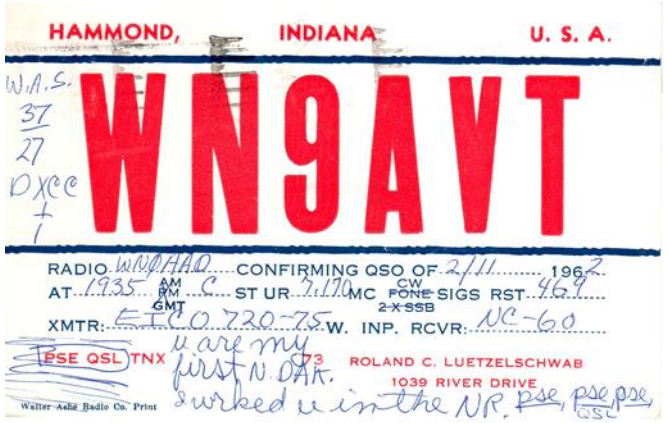
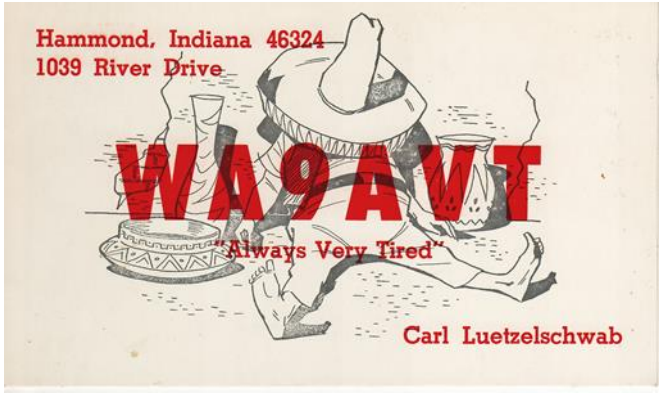


Who Is K9LA?

- Novice in October 1961
- General in May 1962
- Extra in 1977
- Enjoy vintage equipment
- Top of the Honor Roll
- 5BDXCC
- 160m DXCC
- Need 4 zones on 80m for 5BWAZ





Agenda

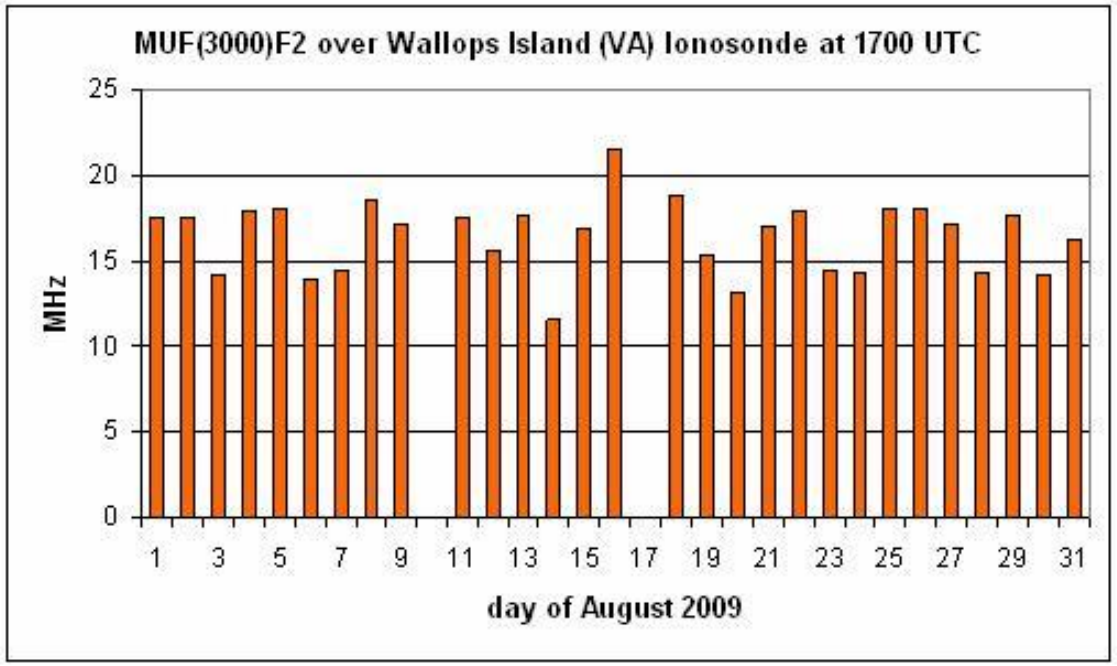
- An important ‘caution’
- Space weather data sources along with explanations of the parameters
- Which parameters should we look at?
- How the parameters impact propagation

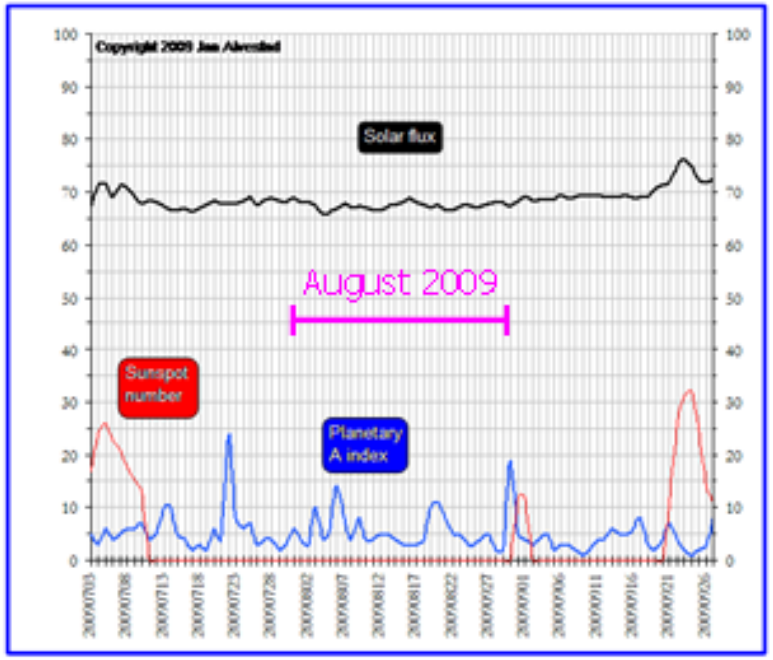
An Important 'Caution'

An Important ‘Caution’

- We try to simplify very complicated atmospheric/ionospheric processes into simple parameters to predict HF propagation
- This is okay for a long-term look at propagation
  - Our propagation predictions give monthly median MUF and signal strength
    - “Median” means 50% probability – thus our predictions are statistical in nature
  - We don’t have daily predictions
- We have trouble predicting propagation in the short-term
  - Day-to-day variability of the ionosphere
  - Enhancements
  - Degradations

Day-to-Day Variability of the Ionosphere





- Zero sunspots and constant 10.7 cm solar flux for entire month
- The Earth's magnetic field was relatively quiet
- MUF varied from 11 MHz (on the 14th) to 22 MHz (on the 16th) – WHY???
- Three parameters determine ionization at a given location at a given time

Enhancements and Degradations

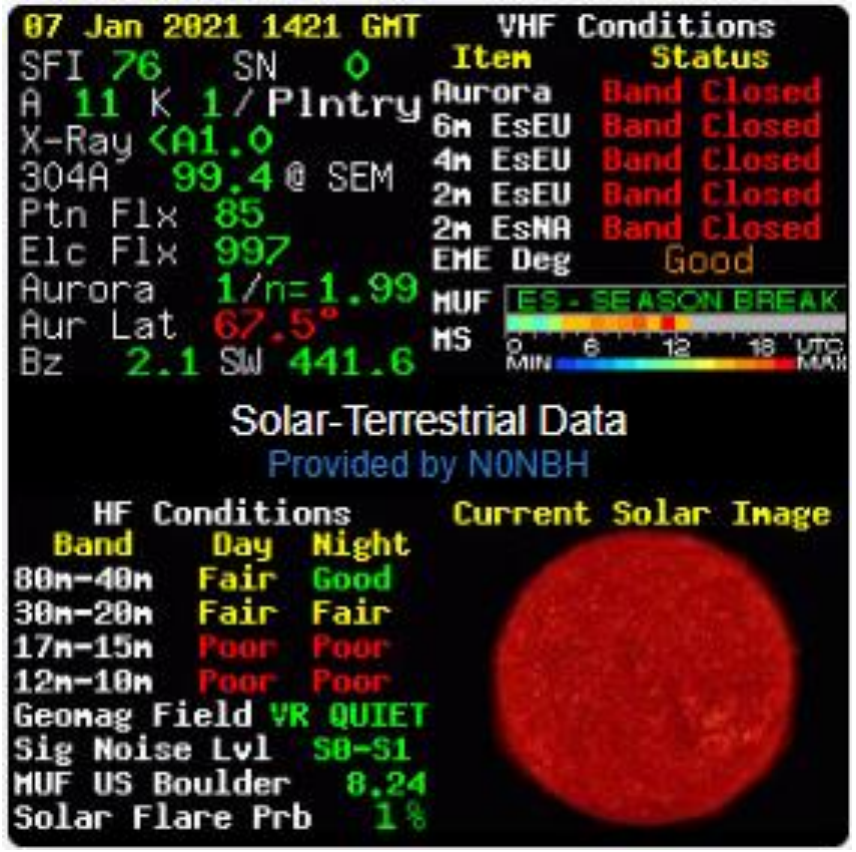
- I have short-term events that I can't explain
- Most are enhancements
  - An unusual band opening
  - Signal strength significantly higher than predicted
- Some are degradations
  - Recent example is K7SS working JD1BMH on 20m via long path (31,825 km)
    - Short path (8,200 km) predicted to be much better but was significantly worse – why?
- Problem is there's just not enough data to see what's going on
  - Not enough ionosonde and TEC data from GPS – especially over the oceans
  - Hardly any ionospheric absorption data – important on the low bands
  - Other data desirable – particle precipitation, electric field, etc

Space Weather Data Sources Along with Explanations of the Parameters

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

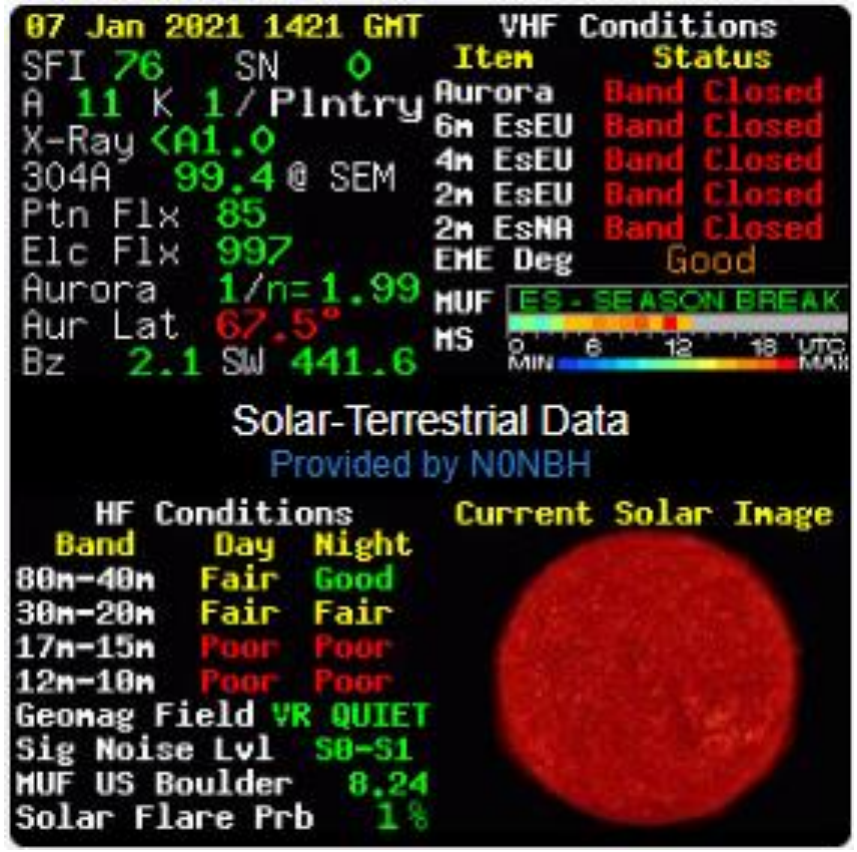


- Date and time are obvious! ☺
- SFI – latest 10.7 cm solar flux index
- SN – today's sunspot number (V2 – more later)
- A – yesterday's A index (activity of magnetic field)
  - Avg of the eight 3-hr K indices
- K – current 3-hr K index (activity of magnetic field)
  - Plntry (Kp and Ap) means it's not 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

Pop Quiz

- With respect to solar flare categories – A, B and C are a logical progression from smallest to larger
- What does M stand for?
  - Mucho grande
  - Monstrous
  - Major
- What does X stand for?
  - eXpedite your run to a lead enclosure
  - eXtreme
  - a flare generated by X-MEN

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 impacted by 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

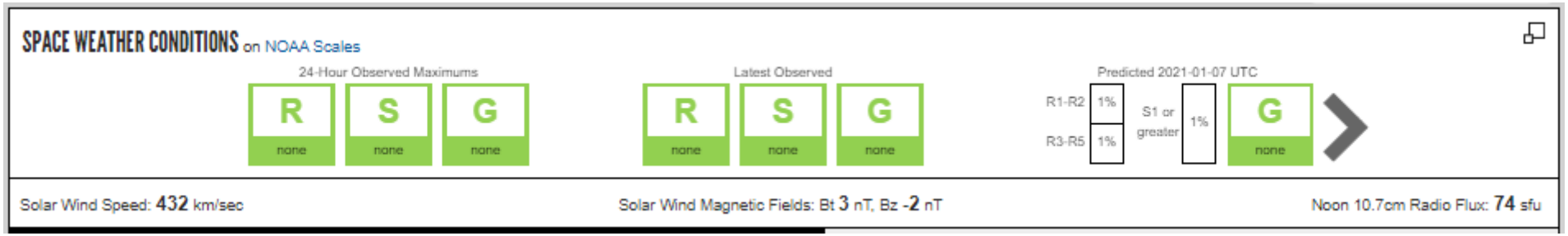
- Solar wind
  - speed – same as NØNBH banner
  - proton density – 795-1193 keV
- X-ray Solar Flares
  - same as NØNBH banner
- Sunspot number
  - same as NØNBH banner
- Spotless Days
  - self-explanatory
- The Radio Sun
  - 10.7 cm solar flux – same as NØNBH banner

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

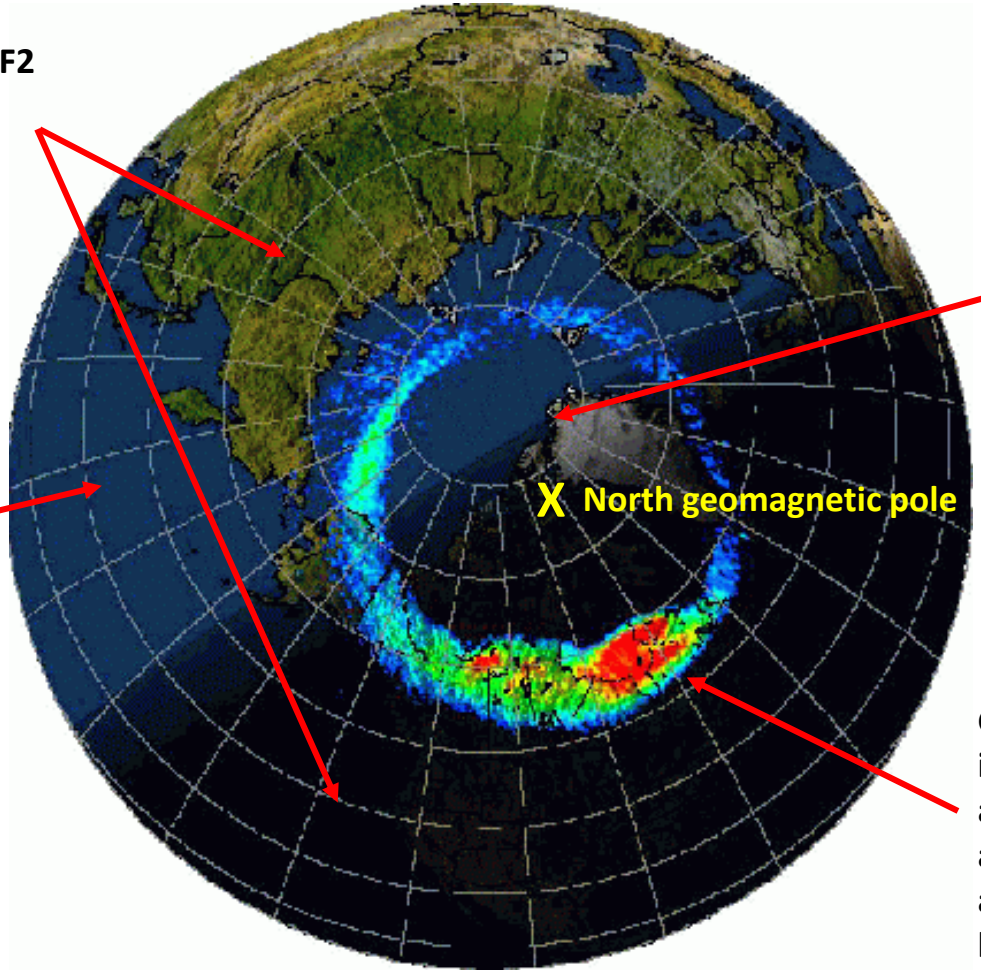


- Disturbances to propagation categorized as G, S and R
  - G is geomagnetic storm – caused by Earth-directed CME or coronal hole
  - S is solar radiation storm – due to energetic protons from big solar flare
  - R is radio blackout – due to X-ray radiation from big solar flare
- Scale is 1 (minor) to 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



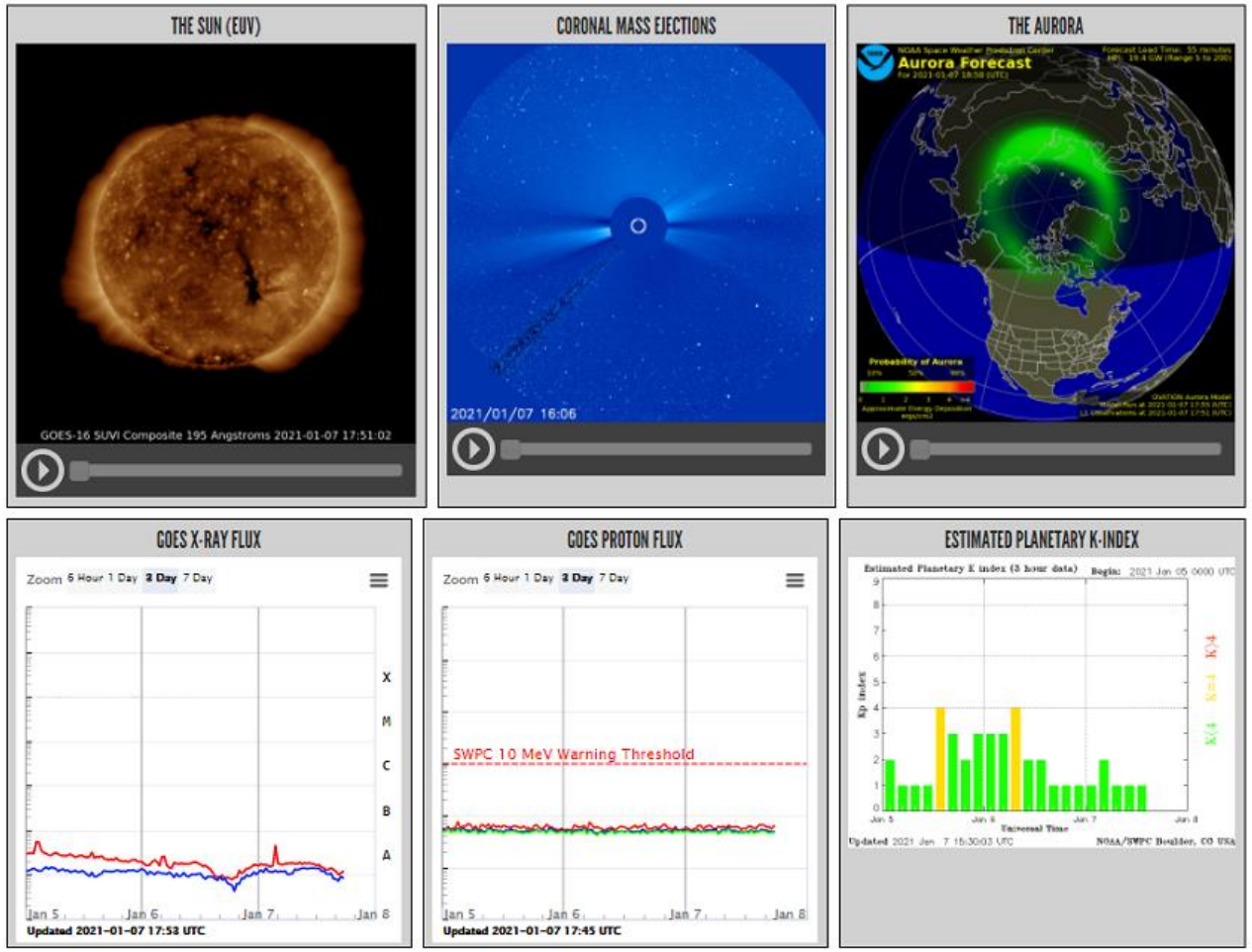
S
Solar radiation storm – increased D region absorption in the polar cap (area within auroral oval)

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)

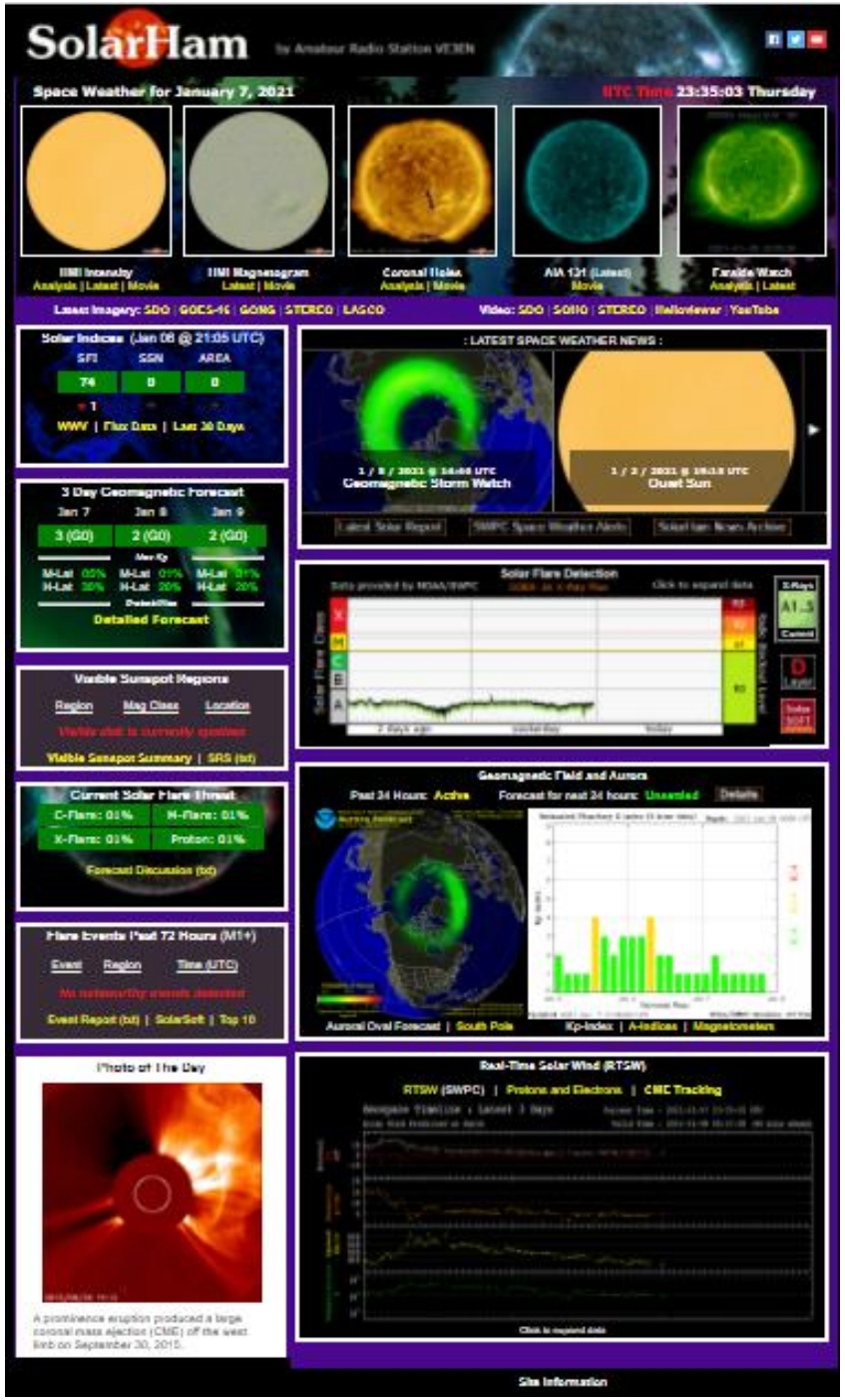
- Duration
  - G can be the longest
  - S next
  - R usually the shortest

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!

Another Pop Quiz

- With respect to the amount of data that's available . . .
  - Do we need more?
  - Is there just the right amount?
  - Is there too much?

Which Parameters Should We Look At?

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, X-Ray

How the Parameters Impact Propagation

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 (V2) 0 to ~450, daily EUV ~70 to ~500*
- But the ionosphere correlates best to <u>smoothed</u> SFI, SN and EUV

	SFI value for many weeks	SN (V2) value for many weeks	EUV value for many weeks
15m	90	50	140
10m	105	70	200
6m	145	140	300

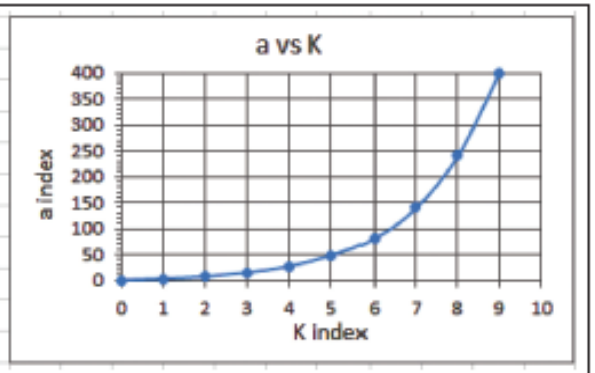
MUF US Boulder is real-time and gives a direct indication of F_2 region ionization

* my best guess

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

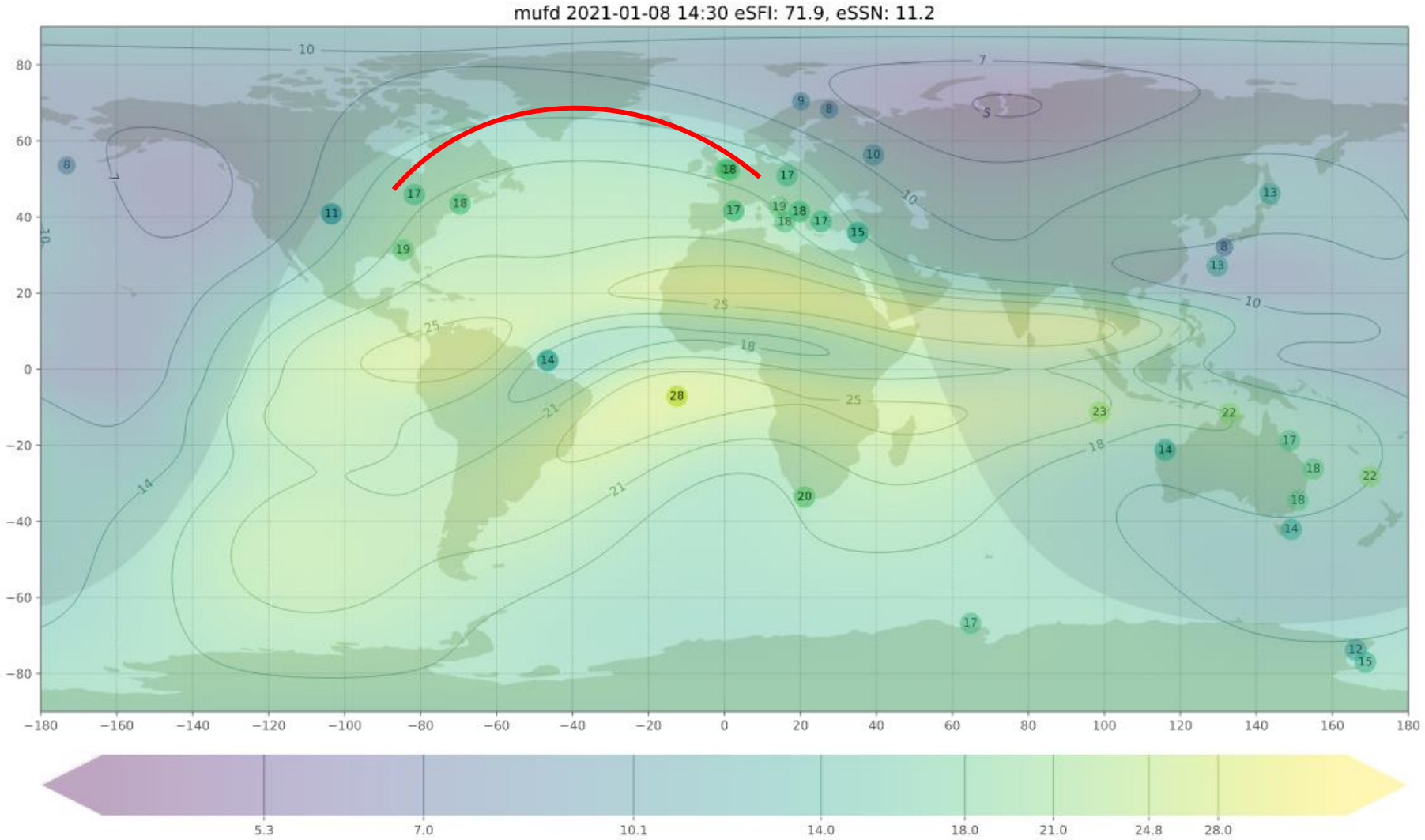
- K from 0 to 9 (logarithmic), A from 0 to 400 (linear)
  - K gives 'a' which gives A
- B_z from -100 to +50, SW from ~400 to ~2000 km/s
- GSR from 1 (minor) to 5 (extreme)
- X-Ray from A1.0 to X9.9 (or even higher!)
- Generally we want:
  - K $\leq$ 3, A $\leq$ 15
  - B_z positive (a little negative is okay)
  - SW around 400
  - 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



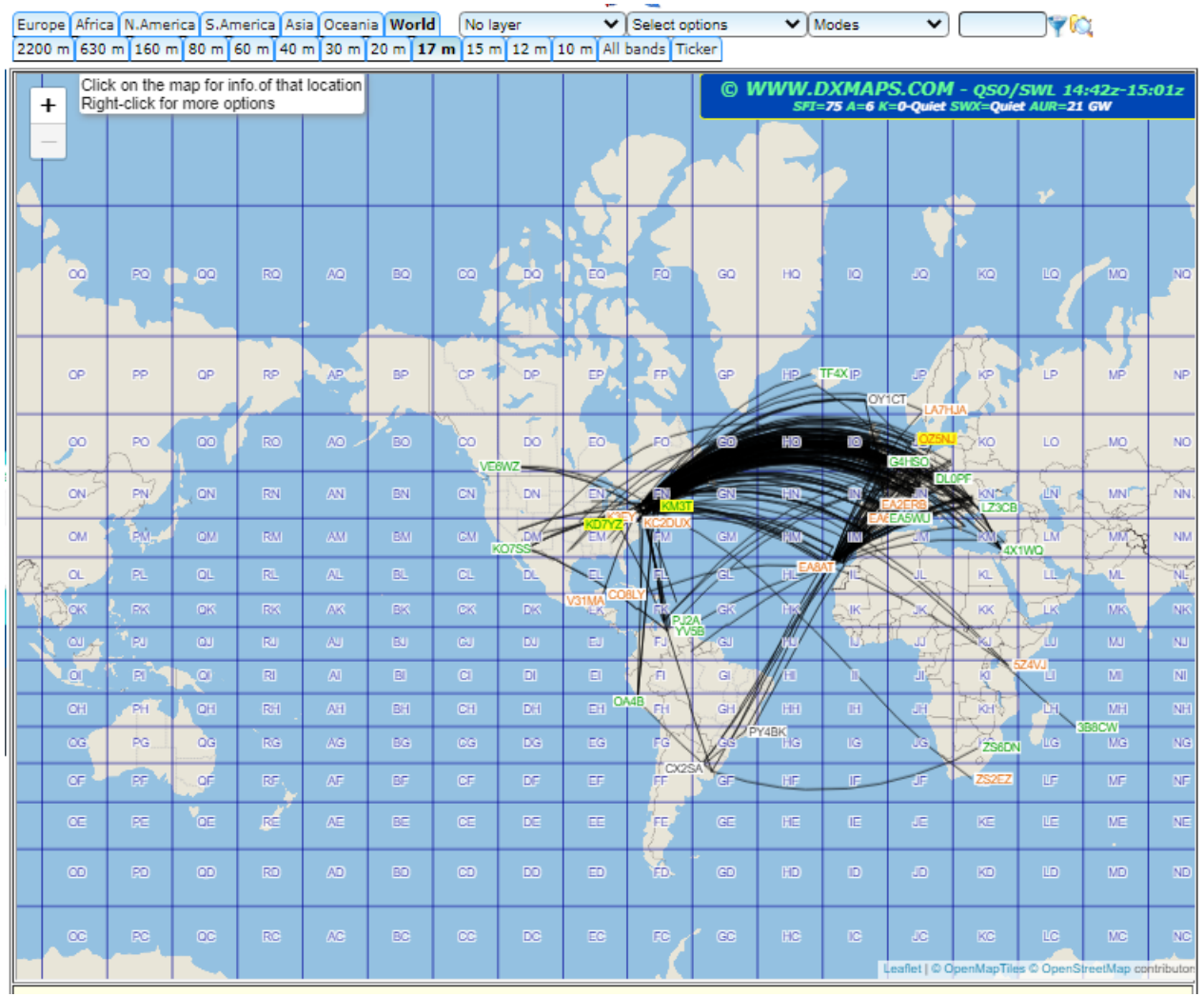
- If K spikes up a bit, watch for possible:
  - Enhancements at mid and low latitudes on the higher bands
  - Enhancements on 160m across the high latitudes

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
- Path from Madison to DL shown – 20m is likely available

Another Example of Real-Time Data

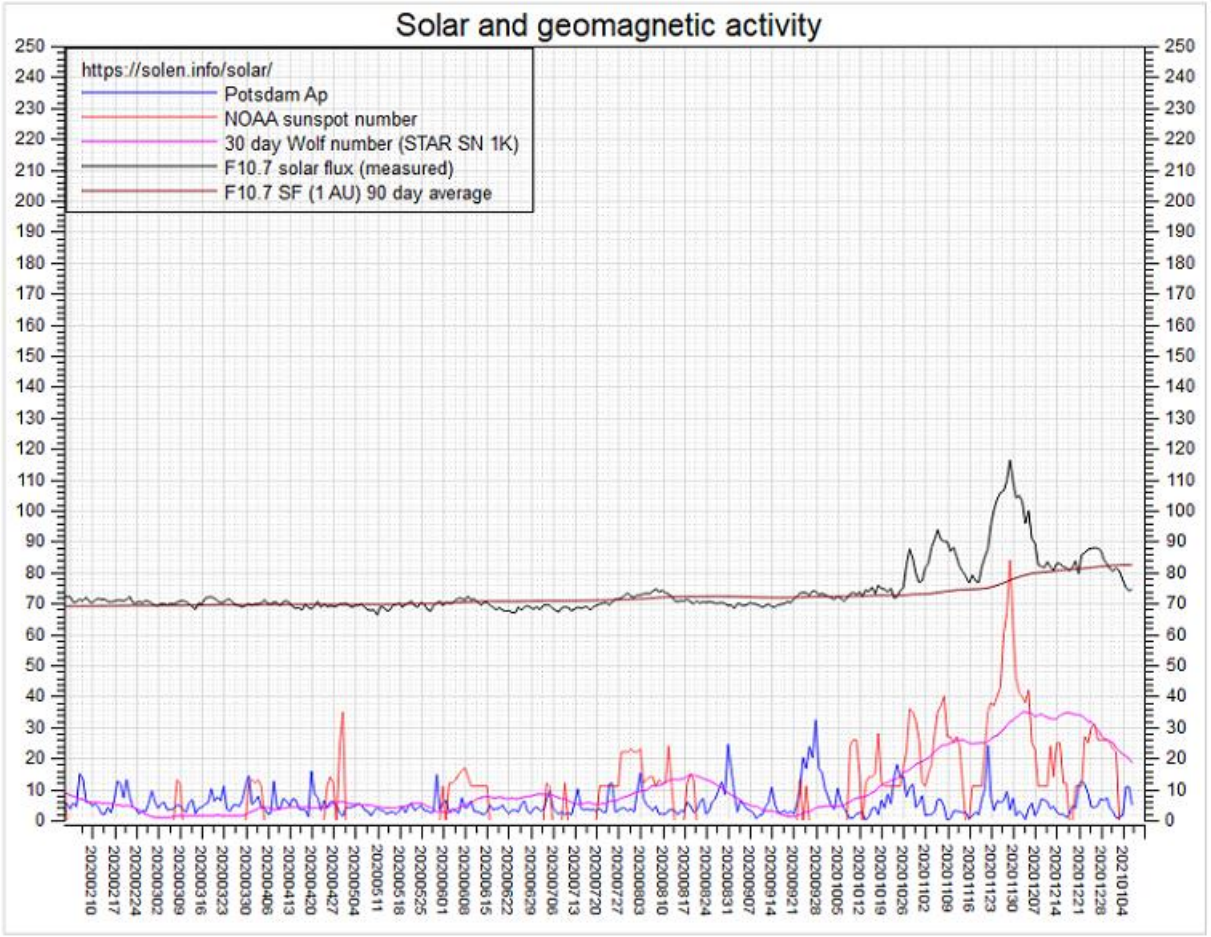


- Real-time QSOs
- See what a band is doing right now
- Visit dxmaps.com
  - or PSKReporter
  - or WSPRnet
- Select view: World, NA, SA, etc
- Select band

One of these days you'll turn on your rig, input who you want to talk to, and the radio will go to the best band.

A Long-Term Look at Parameters

Solar Terrestrial Activity Report



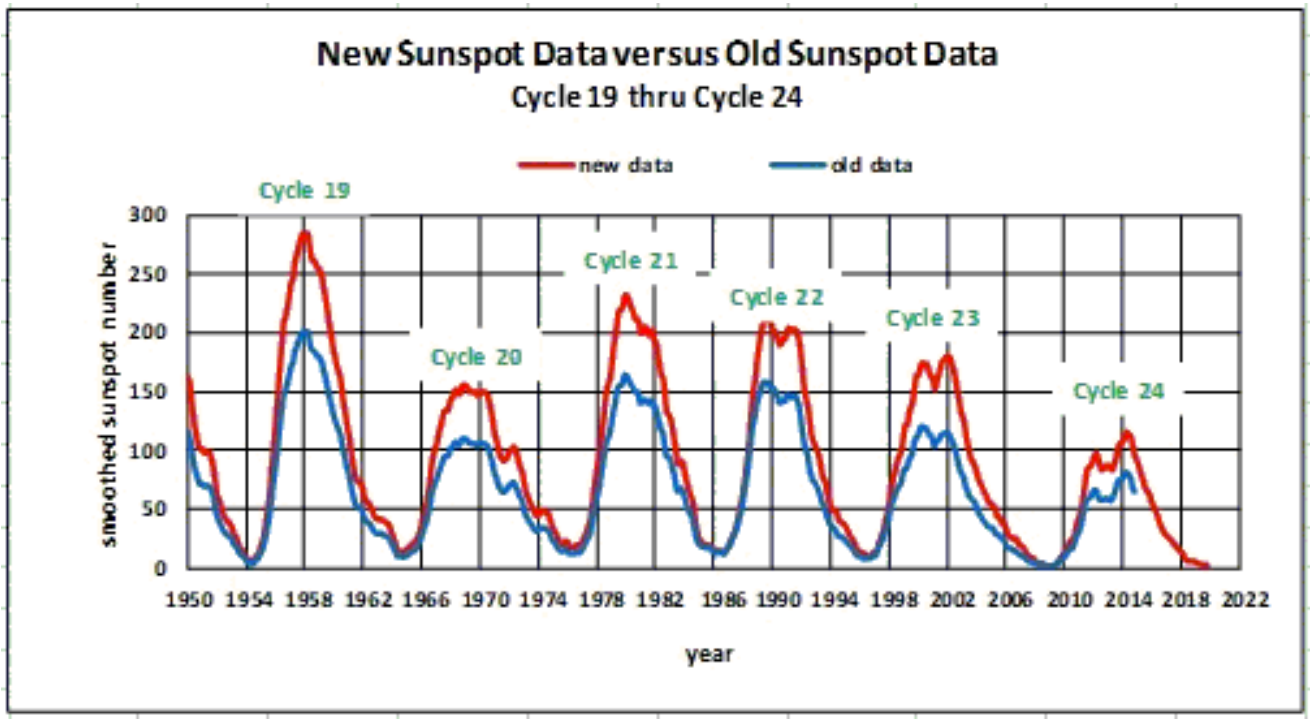
Last major update issued on January 8, 2021 at 05:05 UT.

- From http://www.solen.info/solar/
- A year's worth of data
- Ap, daily SN, 30-day SN avg, daily SFI, 90-day SFI avg
  - The avg values correlate better to the ionosphere than the daily values
    - At solar min, not much difference!
- 27-day solar rotation period
  - Propagation conditions 27 days ago may happen again today

The NEW Sunspot Numbers

- In 1849 Rudolf Wolf devised the sunspot number: Wolf number = k x (10 x g + s)
  - g is number of sunspot groups
  - s is total number of sunspots
  - k includes telescope considerations, viewing conditions, observer bias
- His successor Alfred Wolfer applied a ‘k’ of 0.6 to make his counts agree with Wolf (Wolfer counted more sunspots) - this has been carried through the present
- Concern about the old sunspot numbers began in the early 1990s
- Four sunspot workshops held beginning in 2011
- Result was a new sunspot data set – V2
  - Remove 0.6 factor, correct other less-major issues
- Royal Observatory of Belgium began reporting the new sunspot numbers on July 1, 2015
- Beware of early Cycle 25 predictions – some V1, some V2

V1 vs V2 Sunspot Data



- Be aware of which data set is used
- Model of F2 region of ionosphere in our propagation predictions used V1 data
- Biggest difference is at solar maximum
  - V2 data about 1 band optimistic

One of my anchor points was always 201 for Cycle 19 – not anymore!

Summary

- Lots of data available
- I don’t believe our Amateur Radio operations need all of it
- Focus on the basics per slides 22 and 23
  - And the real-time data on slides 24 and 25
- Get on the air and operate – experience is a great way to gain knowledge
  - Enter contests, go after WAS, go after DXCC, go after WAZ
- Have fun!

dit-dit-dit dah-dit-dah