Space Weather Parameters and Propagation

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(revised on 1 June 2021 – corrected errors in the table on page 3)

Over the past year I've given many presentations to clubs on the following topics.

1) Cycle 25
2) Simple antennas to get you on 15 meters, 12 meters, 10 meters and 6 meters for when Cycle 25 gets going in earnest
3) Introduction to HF propagation
4) Space weather parameters and their tie to propagation

This month's column puts into words the material that is on the slides of #4 above – space weather parameters and their tie to propagation.

Caution

When talking about how space weather parameters affect HF propagation, we must realize that what we're trying to do is reduce very complicated solar, atmospheric and ionospheric processes into simple statements. This doesn't work all the time. For example, if today's 10.7 cm solar flux is greater than yesterday's 10.7 cm solar flux, does that mean that the higher bands (15m, 12m and 10m) will be better today?

Unfortunately the answer is "not necessarily." The reason is although solar radiation at extreme ultraviolet (EUV) and x-ray wavelengths instigates the ionization process (of which 10.7 cm solar flux is a proxy), geomagnetic field activity and events in the lower atmosphere coupling up to the ionosphere also come into play to determine the amount of ionization at any given point on Earth at any given time.

We have a decent understanding of solar radiation and geomagnetic field activity effects on the ionosphere, but we are lacking in our understanding of events in the lower atmosphere coupling up to the ionosphere. There's much research going on in this latter area. The result of this is that our propagation predictions are not daily predictions – they are monthly median predictions.

Where Do You Get Space Weather Data?

As you're probably aware, there are many sources of space weather data. Here are the ones that I usually mention in my presentations.

a) The NØNBH banner at https://www.qrz.com/ (it shows up in many other places, too)
b) The https://spaceweather.com/ website by Dr. Tony Philips
c) The Space Weather Prediction Center (SWPC) website at https://www.swpc.noaa.gov/
d) VE3EN's website at https://www.solarham.net/
e) WX6SWW videos by Dr. Tamitha Skov at https://www.spaceweatherwoman.com/

I know there are more space weather websites out there. So I apologize if your favorite one is not listed above. What we're going to focus on is the NØNBH banner. It has all the parameters that I think are important for our purposes, and they are included in a single image.

What Parameters Are Important?

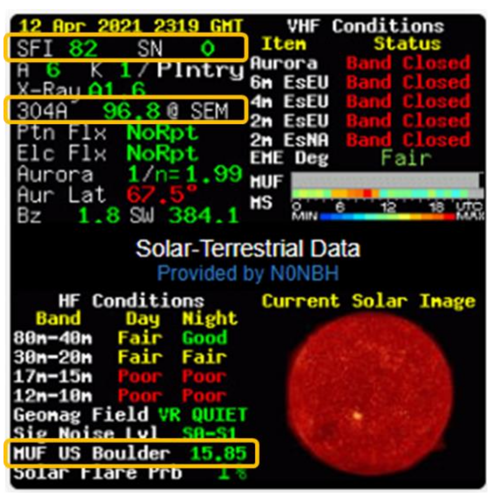
Before identifying which parameters are important, let's take a step back and think about what we're trying to do. We are trying to determine the general state of the ionosphere in relation to the different bands. To do this, we need to know *how ionized the ionosphere could be,* and *if there are any disturbances that could degrade the ionosphere* [note 1]. We'll mainly be interested in the F2 region, as that's the region of the ionosphere that is responsible for most of our medium-distance and long-distance QSOs.

Parameters to Determine How Ionized the Ionosphere Could Be

To start, let's define the baseline condition. When we're in a deep solar minimum period (as we've been in for the last two solar minimums – between Cycles 23 and 24 and now between Cycles 24 and 25), we know that 20 meters can be open worldwide during the day and early evening (and of course the frequencies below 14 MHz should also be open – but they depend more and more on ionospheric absorption as you go lower in frequency). This is true even if the 10.7 cm solar flux is bottomed out between 65 and 70 and there are zero sunspots.

There is still enough solar radiation at EUV wavelengths (the true ionizing radiation for the F2 region – and remember that the 10.7 cm solar flux and sunspots are but proxies for EUV) to result in enough free electrons (what's important for HF propagation) to offer 14 MHz and lower frequency contacts.

Thus EUV, 10.7 cm solar flux and sunspot data can give us an indication of the status of the higher HF bands – 17 meters, 15 meters, 12 meters, 10 meters and 6 meters. These three parameters are found on the NØNBH banner as indicated in the gold boxes in the image below.



SFI is the daily 10.7 cm solar flux, SN is the daily sunspot number and 304A is the daily EUV radiation at 304 Angstroms (304 Angstroms is equivalent to 30.4 nm). It's important to note that about 60% of the ionization in the F2 region is due to solar radiation between 26 and 34 nm. Thus the 304A parameter is a good direct indication of how well the F2 region could be ionized.

Here are the rough values of SFI, SN and 304A EUV that are needed to open the indicated bands for worldwide propagation on many days of the month (not just for a day or two).

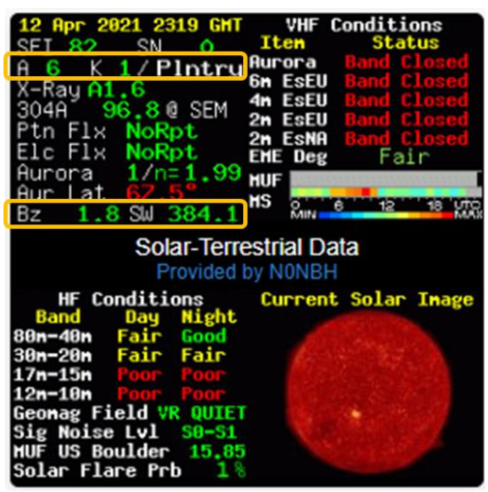
	SFI value for many weeks	SN (V2) value for many weeks	EUV value for many weeks
17m	80	30	105
15m	90	50	140
12m	105	75	195
10m	125	100	250
6m	190	215	400

Note that the values are for many weeks. Ideally they should be long-term smoothed values, but 'many weeks' is a reasonable compromise.

Now you have some ballpark values to assess which of the higher bands could be open on a daily basis. A final comment – the MUF US Boulder parameter is the maximum useable frequency (MUF) in MHz over the Boulder ionosonde assuming it is the midpoint of a 3000 km hop. It is not an assessment of what the ionosphere may be doing – it is an actual measurement of what the ionosphere is doing right now. And it takes into account what we're going to talk about next.

<u>Parameters That Could Degrade the F2 Region</u>

Although the SFI, SN and 304A parameters indicate that the bands may be open, we have to know if there are any disturbances to propagation that may be degrading the F2 region in terms of the amount of ionization (the number of free electrons). The parameters that can help us are those that tell us if the Earth's magnetic field is active (disturbed). These are K, A, Bz and SW in the gold boxes in the image below.



The K index is a 3-hour parameter on a logarithmic scale (0-9). The A index is the daily average of the eight 3-hour K indices and is on a linear scale (0-400). The 'Plntry' annotation is short for 'planetary', indicating that the K and A indices are averages of multiple worldwide observatories. To indicate planetary, a subscript 'p' is appended to K and A – thus the planetary K and A indices are Kp and Ap to distinguish them from observations from a single observatory.

Bz is the strength and magnitude of the interplanetary magnetic field (abbreviated IMF and roughly from -100 to +50 nT). The Bz component is perpendicular to the ecliptic – the plane in which the Earth rotates about the Sun. Thus Bz is essentially the north-south component of the IMF, and Bz tells us how much the IMF is coupling into the Earth's magnetic field.

SW is the solar wind speed in km per second. The quiet time value is around 400 km per second and it can increase to around 2000 km per second when a big Earth-directed coronal mass ejection (CME) or when an Earth-directed coronal hole (CH) high speed stream occurs.

The higher the K and A indices, the more degraded the F2 region of the ionosphere can be. The more negative the Bz component, the more degraded the F2 region can be. And the higher the SW parameter, the more degraded the F2 region can be. Here's a table of what we generally desire in terms of these parameters for an undisturbed F2 region.

parameter	what we desire
K	≤ 3
A	≤ 15
Bz	positive or small negative value
SW	not too much above 400

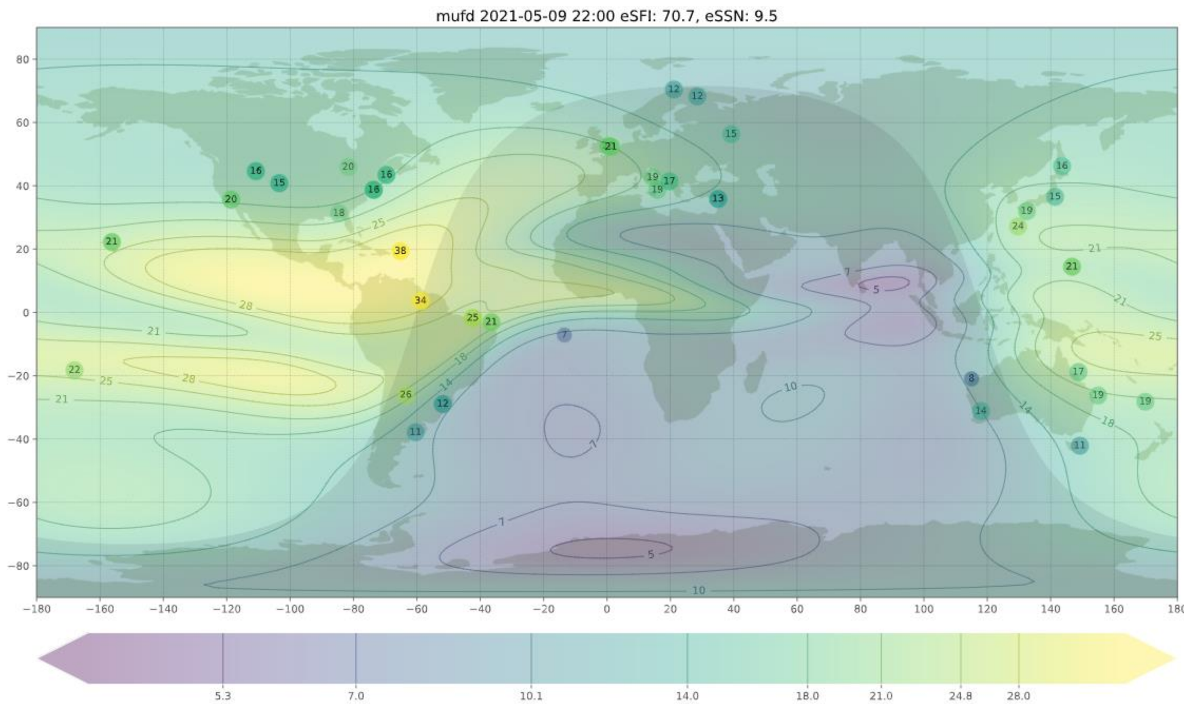
These four parameters can be considered to be bundled into the three categories of disturbances to propagation as defined by NOAA: geomagnetic storms (G), solar radiations storms (S) and radio blackouts (R). The scale for these three disturbances is from 1 (minor) to 5 (extreme). The details are at https://www.swpc.noaa.gov/noaa-scales-explanation. If you see any of the three at greater than 2 (at the top of the home page at https://www.swpc.noaa.gov/, for example), then you can be assured that the F2 region could be disturbed (lower MUFs) and there could be increased D region absorption in the polar cap (from energetic protons caused by a big M- or X-Class solar flare) and/or increased D region absorption on the daylight side of the Earth (from x-ray wavelength radiation caused by a big M- or X-Class solar flare).

Real-Time Assessment of the Ionosphere

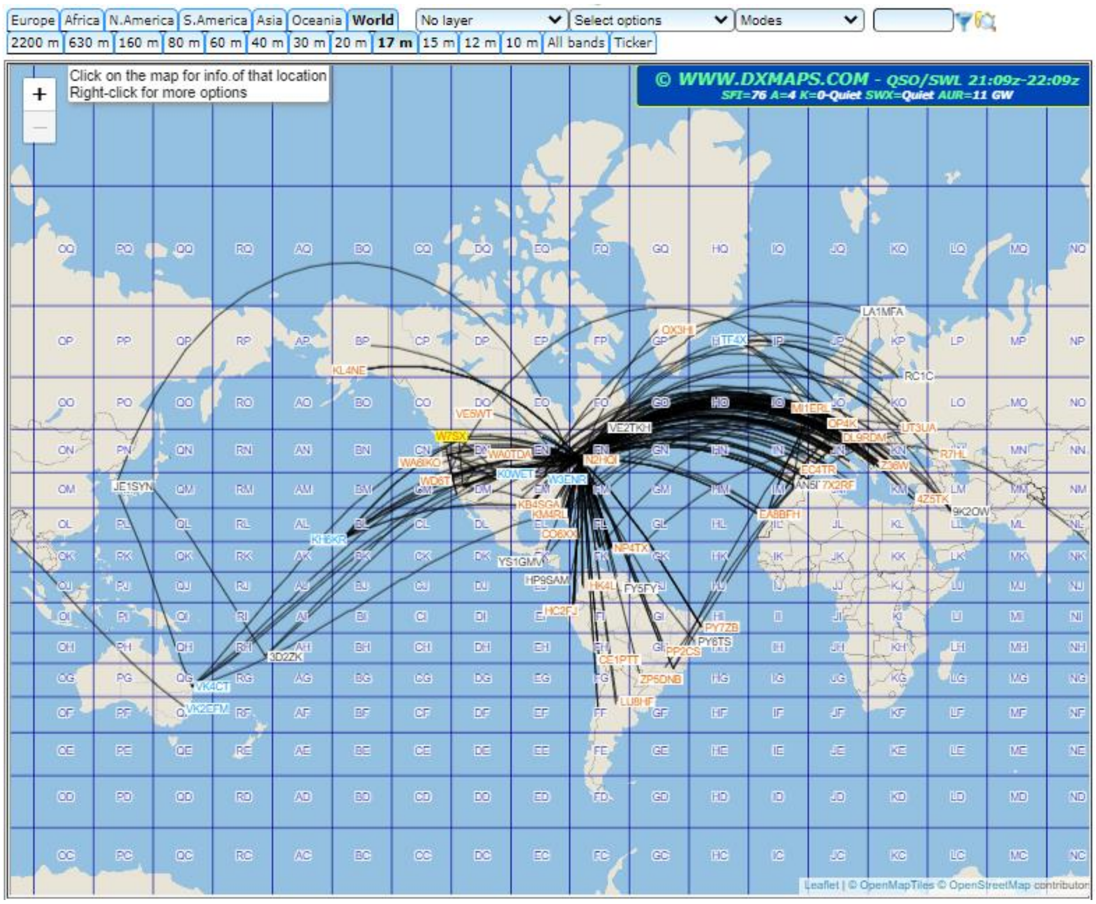
All of these parameters (SFI, SN, 304A, K, A, Bz and SW) allow us to make an assessment of the ionosphere. But remember the caution at the beginning of this column. Sometimes interesting propagation can happen when we think propagation won't be good.

The 2018 California QSO Party was a great example of this. I didn't hear any W6s on 10 meters on Saturday. But the K index spiked up a bit Sunday and then there were many W6s on 10 meters. Looking at the Boulder ionosonde showed MUFs around 20 MHz until the K index spiked up on Sunday. Then the MUF went up to a bit higher than 30 MHz, allowing good propagation between W6 and the Midwest on 10 meters. So pay attention to when the K index initially spikes up a bit – if you're in the right place at the right time, good things could happen. There are also many observations of improved 160 meter propagation across the high latitudes when the K index spikes up a bit [note 2].

With much information on the Internet, it's also possible to bypass all those parameters to get a decent picture of what the ionosphere is doing right now. With respect to the ionosphere, visit http://prop.kc2g.com/. It will show you worldwide MUFs for 3000 km paths. Here's a sample map at 2200 UTC on May 9. It uses ionosonde data (the numbers in circles) and adds contour lines. It's updated every 15 minutes. From this you should be able to estimate what frequencies may be propagating anywhere in the world. Remember this includes all the aforementioned parameters.



To find out who everyone else is working right now, visit dxmaps.com. Select your view (North America, Worldwide, etc.) and the band. Here's a sample display for 17 meters on May 9 between 2109 and 2209 UTC. As you can see, 17 meters was doing very well between North America and VK/ZL, South America and Europe.



PSKreporter, WSPRnet, the Reverse Beacon Network (RBN) and the worldwide IARU/NCDXF beacons on 20m, 17m, 15m, 12m and 10m are similar applications that can tell you what’s going on right now

<u>Summary</u>

I hope I’ve given you some good guidelines to assess propagation. Just remember the caution on page 1.

It’s interesting to think about what the future holds. As mentioned in my September 2020 Monthly Feature titled “The Future of Propagation Predictions,” perhaps someday we’ll have all kinds of real-time propagation information displayed on our SDRs.

Notes:

1) Ionospheric absorption is also important, but there are no regular measurements of the D region (where most absorption occurs). So there isn’t a parameter that we can monitor.

We have riometers (relative ionospheric opacity meters) that measure galactic noise as it passes through the ionosphere, but translating those measurements to absorption is tough. And the D-RAP (D Region Absorption Predictions) measurements (https://www.swpc.noaa.gov/products/d-region-absorption-predictions-d-rap) only tell us about D region absorption in the polar cap or on the daylight side of the Earth when there is a big (M-Class or X-Class) solar flare.

2) And don't forget that the Sun hiccups every once in a while, which might give us great propagation on the higher HF bands. Late last year was a good example. The EUV spiked up significantly, which resulted in great propagation for the CQ WW DX PH Contest in October, the CQ WW DX CW Contest in November and even the ARRL 10 Meter Contest in December. Unfortunately the EUV settled back down to solar minimum levels in early 2021. But it was a good look into the future when Cycle 25 gets going in earnest.