

Introduction to HF Propagation Part 2

Rick Fletcher, W7YP

FVARC

October 21, 2025

Topics

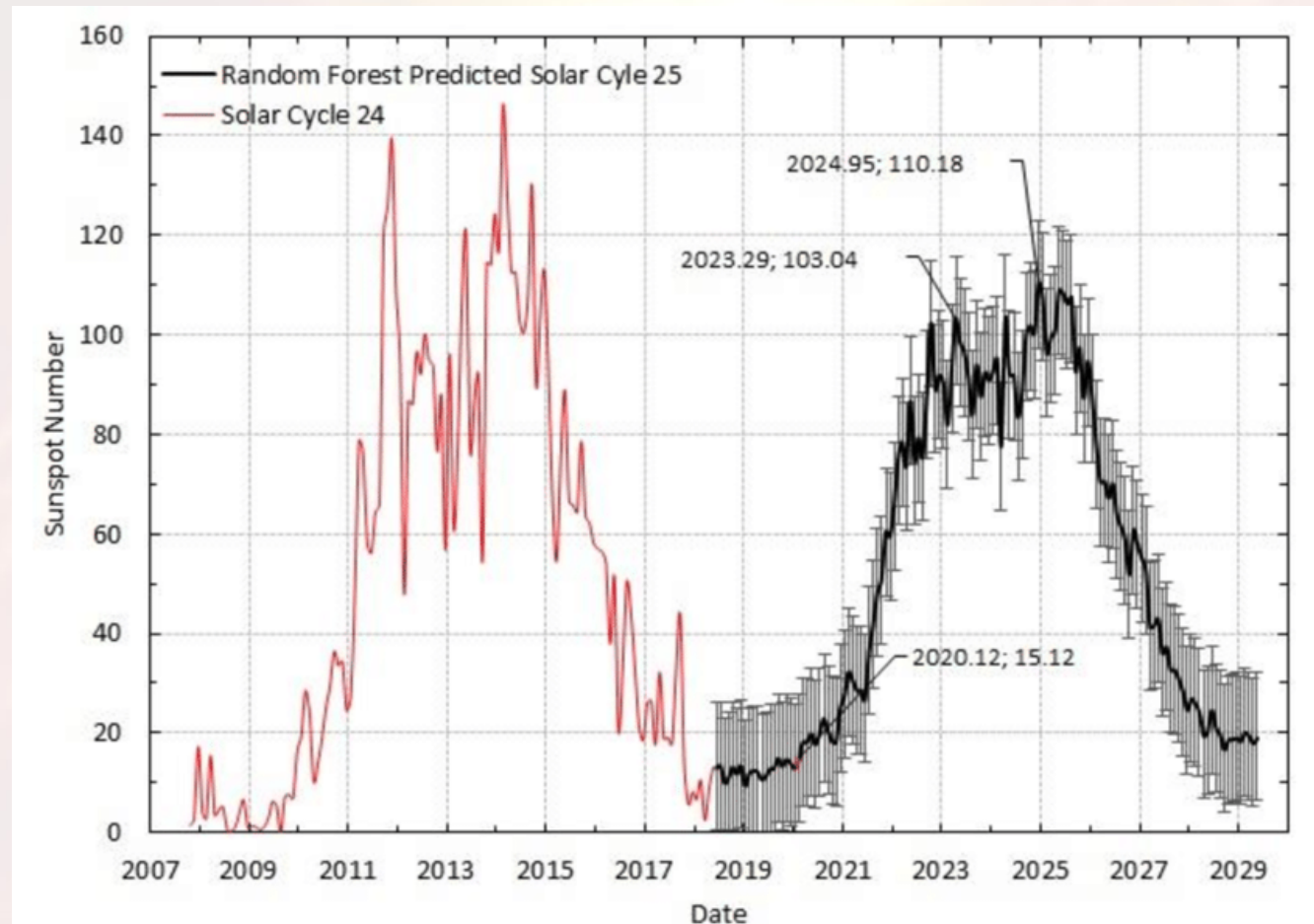
- Current Solar Cycle 25
 - Solar cycle history
- Poor propagation ≠ No propagation
- Checking HF propagation
 - Predictive (HF propagation prediction software)
 - Empirical (beacons, WSPR, PSKREPORTER and operator testing)
- Coping with poor HF propagation
 - Station improvements
 - Modes of operation
 - Times of operation
- Q&A

Solar Cycle 24 => 25

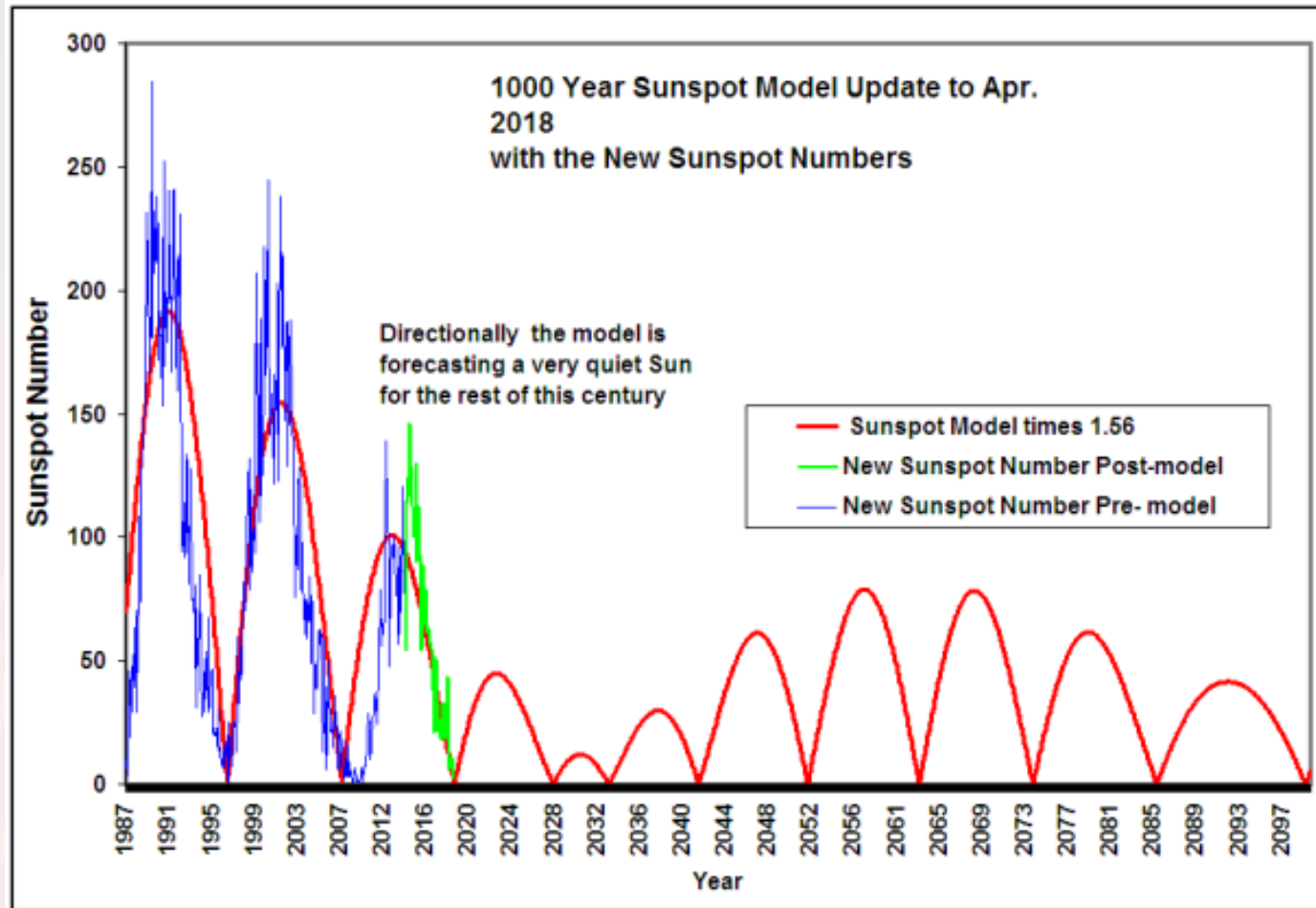
- Cycle 24 had two peaks
 - First peak: Late 2011 to early 2012
 - Driven by sunspot activity in the northern solar hemisphere
 - Second peak: Early to mid-2014
 - Driven by sunspot activity in the southern solar hemisphere
- Double peaks aren't unusual
 - Cycle 21 (1980, 1982)
 - Cycle 22 (1989, 1991)
 - Cycle 23 (2000, 2002)
- Models predict a 50-70% chance of Cycle 25 having two peaks
 - Each hemisphere's magnetic dynamo operates semi-independently
 - One hemisphere often lags the other, finally "catching up"
 - Dip between them is the "Gnevychev Gap"
- Cycle 25 began in December 2019

Solar Cycle 25

- Rising faster and stronger than initially forecast
- First/only peak expected at the end of 2025 or early 2026



Past and Future Solar Cycles:



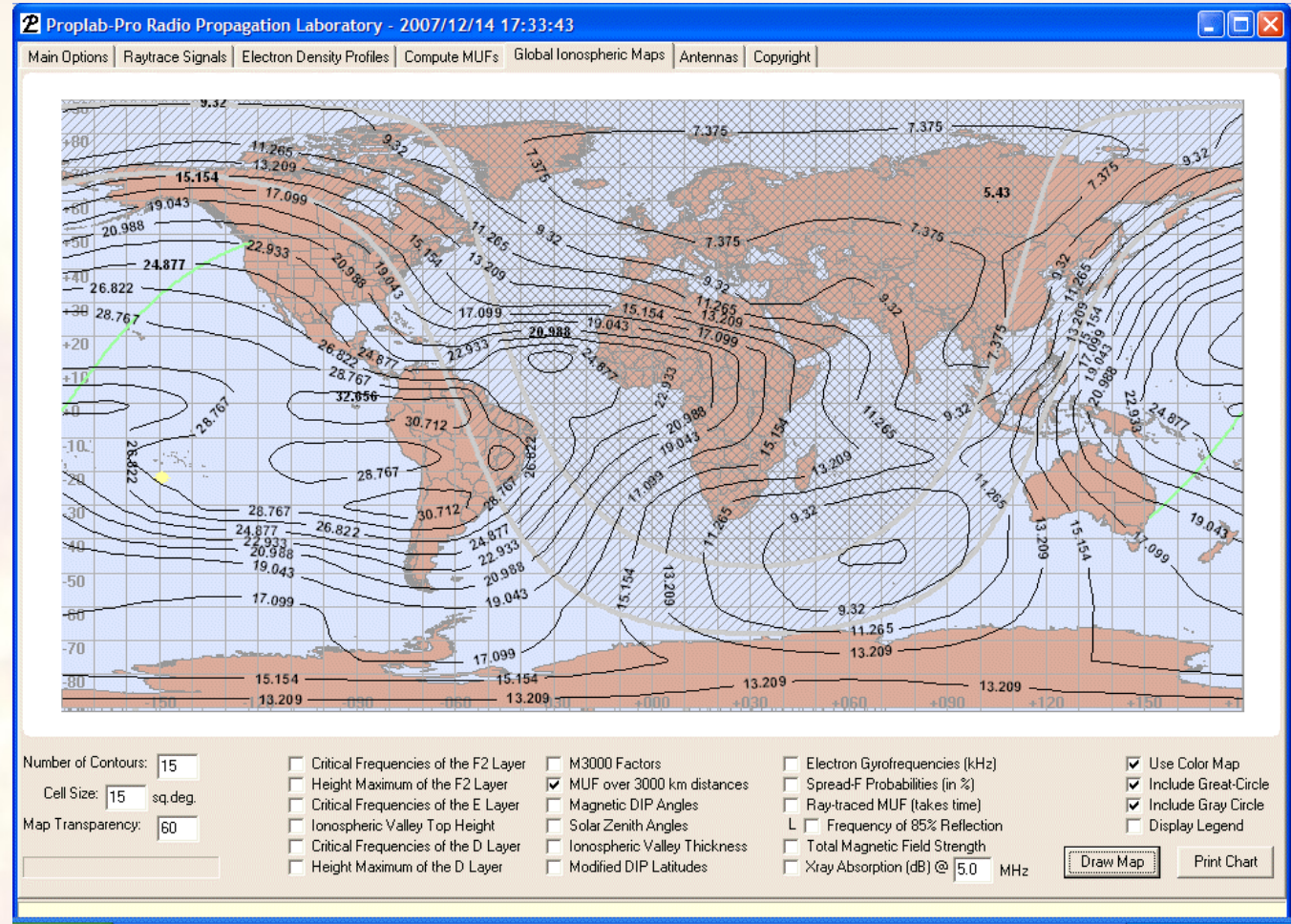
Source: Solar scientist Lief Svalgaard

Poor HF Propagation

- HF won't work as easily, as well and as frequently as it does during peak sun spot cycles
- MUF (Maximum Usable Frequency) is key
 - The maximum HF frequency which can be used for reliable communication between 2 points via ionospheric reflection
 - Critical Frequency is the highest frequency which can be reflected back to Earth when transmitted vertically into the ionosphere
 - MUF is generally roughly 3X the critical frequency
 - Frequency of Optimum Transmission (FOT) is typically 80-90% of the MUF
 - Move to lower frequencies as MUF declines
 - Propagation does occur above the MUF (Refraction and Scatter)
 - Result is low SNR often making voice communication difficult or impossible
 - Shift to CW or digital modes
- Sporadic E on 10m and 12m
 - North-South propagation is often favored between North and South America

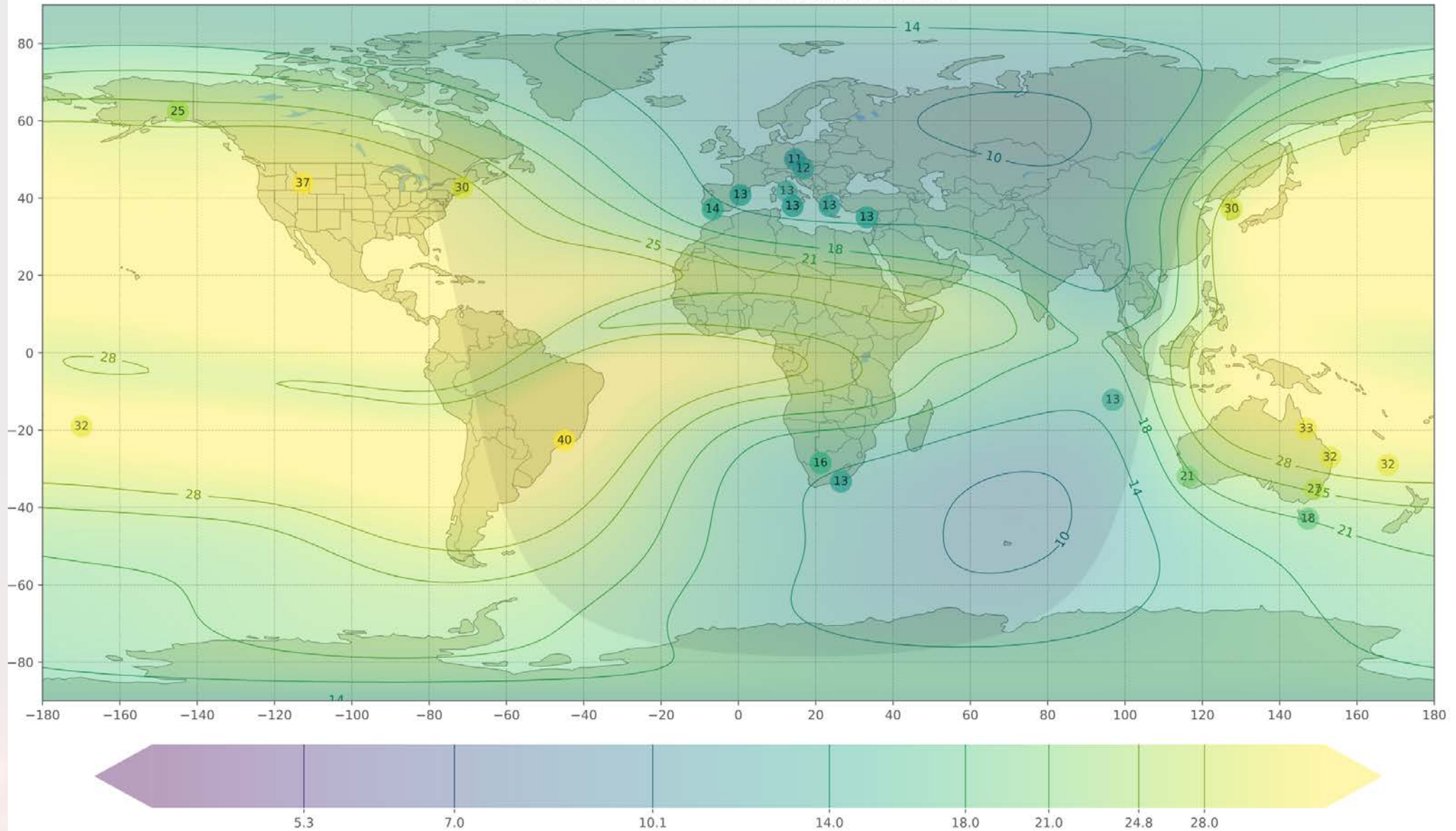
MUF Maps

- Paths (contours) are labeled in MHz
- Grayline also typically shown
- For any 3,000 km path (default distance), find the midpoint of the path and its contour's value
 - For 4,000 km paths, multiply the contour's MUF by 1.1
- For longer paths, divide it into 3,000 km segments and compute the MUFs corresponding to the two midpoints that are 1,500 km from each end of the path
 - Then select the lower of these two MUFs
 - The same approach can be taken using 4,000 km segments



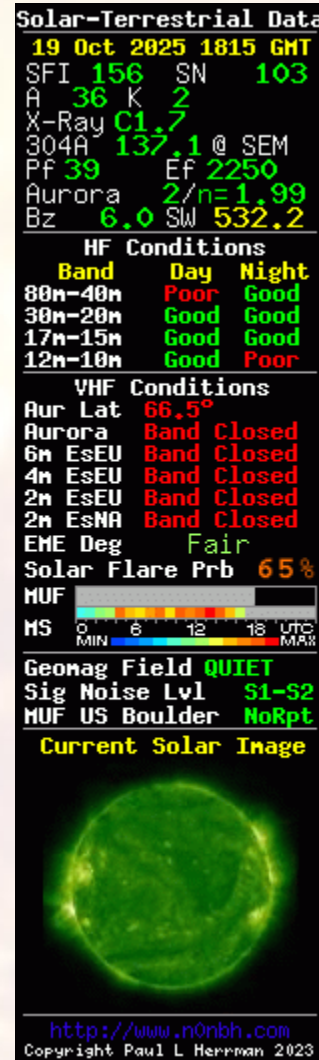
Prop.kc2g.com Near Realtime MUF Maps

mufd 2025-10-20 22:30 eSFI: 134.5, eSSN: 96.0



Relative Predictive Propagation Forecasting

- NONBH's website
 - <http://www.hamqsl.com/solar.html>
 - Offers desktop widgets and banners suitable for inclusion in web sites
 - Supports
 - Windows
 - PC and Phone
 - Mac
 - Linux
 - iPhone
 - Android
- VOACAP software
 - <http://www.voacap.com>



VOACAP's HF Online Propagation Predictions

- Dept. of Commerce: <https://www.voacap.com/hf/>
- Uses a combination of mathematical and statistical models derived from decades of ionospheric data:
 - Smoothed sunspot numbers
 - Time of day and season
 - Frequency band
 - Transmitter/Receiver locations
 - Ionospheric layer parameters (F2, E, D)
- Predicts both MUF and Signal Reliability (%)
- User Manual:
 - https://www.voacap.com/2023/documents/VOACAP_Manual.pdf
- SNR Predictions Using VOACAP Manual:
 - <https://www.greg-hand.com/manuals/VOACAP%20Users%20Guide.pdf>

VOACAP # Ham Radio – 18:01:44 UTC (12:01 PM)

TX: << Select a location >> ▼ or set Grid: MK91vv or Latitude: 11.9000 Longitude: 79.8000
RX: << Select a location >> ▼ or set Grid: IO91jt or Latitude: 51.8000 Longitude: -1.2500

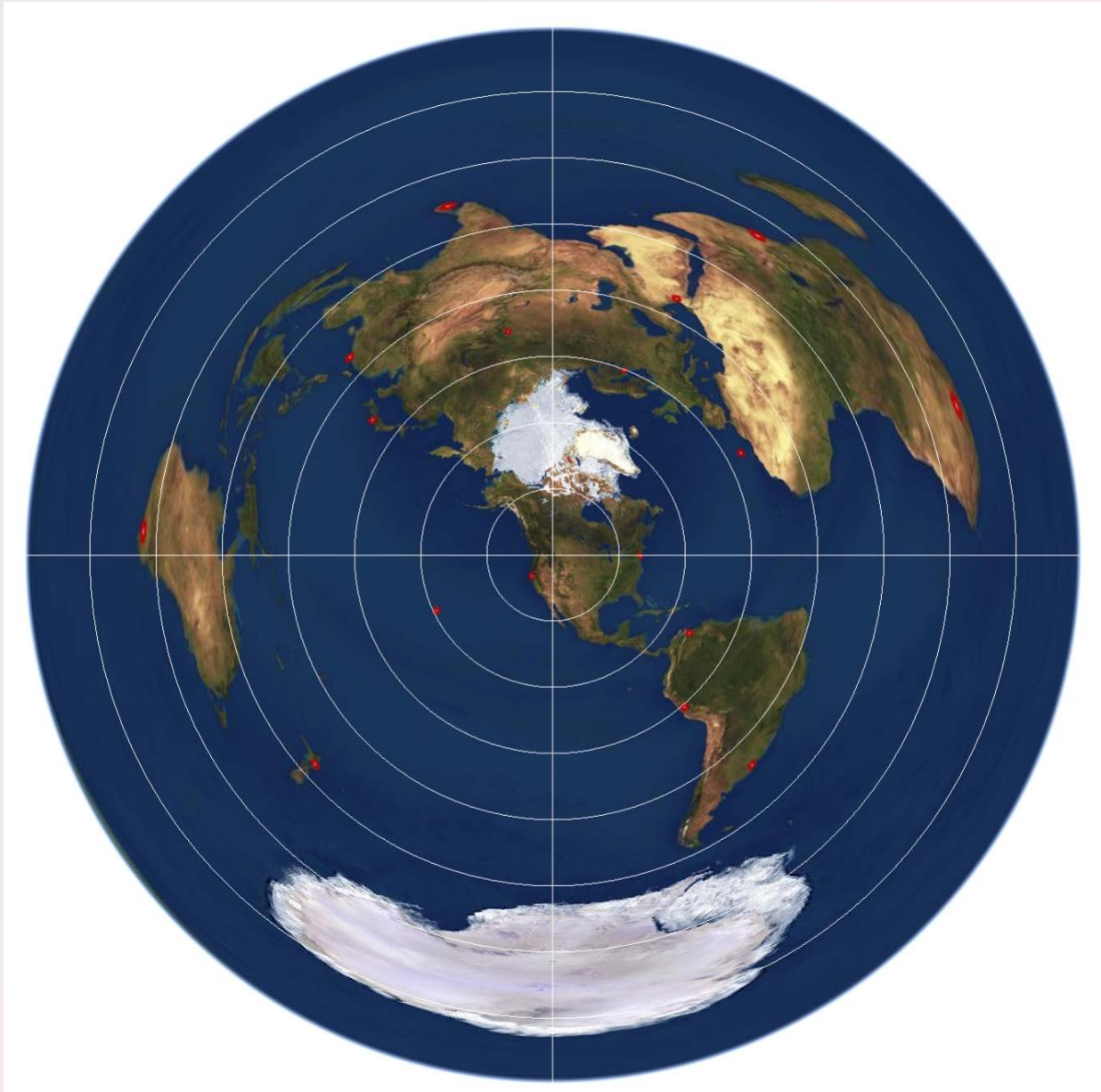


TX: 11.90, 79.80 | RX: 51.80, -1.25 | Short: 8363 km — 5196 mi | 321° — 89° | Mid: 38.8161, 50.1502 | Long: 31645 km — 19663 mi | 141° — 269° | Mid: -38.8161, -129.8498

Empirical Testing With Beacons

- NCDXF/IARU International Beacon Project (www.ncdxf.org)
 - Global network of HF beacons and tracking programs
 - Web-based. Android, iPhone, Windows Mobile, Windows (W95 through Windows 10), Mac, Linux, OS2
 - Beacons and schedule: <http://www.ncdxf.org/beacon/index.html>
 - Each beacon transmits on each band once every three minutes, 24 hours a day
 - A transmission consists of the callsign of the beacon sent at 22 words per minute followed by four one-second dashes
 - The callsign and the first dash are sent at 100 watts. The remaining dashes are sent at 10 watts, 1 watt and 100 milliwatts
 - At the end of each 10 second transmission, the beacon steps to the next higher band and the next beacon in the sequence begins transmitting

NCDXF Azimuthal Map (International Beacon Project)



(<https://www.ncdxf.org/beacon/AzMap/index.html>)

Reverse Beacon Network (RBN)

- RBN is a network of stations listening to the HF bands and reporting what stations they hear, when and how well
 - CW, FT8, FT4 and RTTY
 - Shows a map of active listeners and stations that were detected
 - List presentation is included
 - Signal Comparison tool

REVERSE BEACON NETWORK

Hosted by www.dxwatch.com SSN:103 SFI:140 A:10 K:1 DxWatch Callsign Lookup:

welcome main dx spots nodes FT8 downloads about contact us

630m 160m 80m 60m 40m 30m 20m 17m 15m 12m 10m 6m 4m 2m

Consider supporting the RBN!!! Max rows: 10 Max age: 10 Hours New spots: 10

Donate

Show Elements: map distance mi distance km freq mode type snr speed time seen

Show Spotters CW Speed: Min Max Copy URL to Clipboard

Spotter (dx) Spotted (dx)

callsign

spotter	spotted	distance mi	freq	mode	type	snr	speed	time	seen
KD7EFG	K1OV	2061 mi	14034.0	CW	CQ	21 dB	15 wpm	2257z 20 Oct	now
LU8XW	LU4AA	1473 mi	14100.0	CW	NCDXF	16 dB	23 wpm	2257z 20 Oct	now
K9LC	N7CCD	1435 mi	21041.0	CW	CQ	9 dB	21 wpm	2257z 20 Oct	now
VA2NM	N7CCD	2060 mi	21041.0	CW	CQ	3 dB	21 wpm	2256z 20 Oct	now
W3QA	K7DBN/B	1708 mi	28260.3	CW	BCN	3 dB	15 wpm	2256z 20 Oct	now
TI7W	N4ASF	1945 mi	28019.1	CW	CQ	5 dB	20 wpm	2256z 20 Oct	now
K1RA	W7SWL/B	1903 mi	28232.3	CW	BCN	2 dB	15 wpm	2256z 20 Oct	now
VK6ANC	N4ASF	11668 mi	28019.0	CW	CQ	4 dB	20 wpm	2256z 20 Oct	now
W2NAF	WD5GLO/B	1276 mi	28208.1	CW	BCN	18 dB	14 wpm	2256z 20 Oct	now
NN3RP	K5AB	1316 mi	28280.0	CW	BCN	13 dB	14 wpm	2256z 20 Oct	now

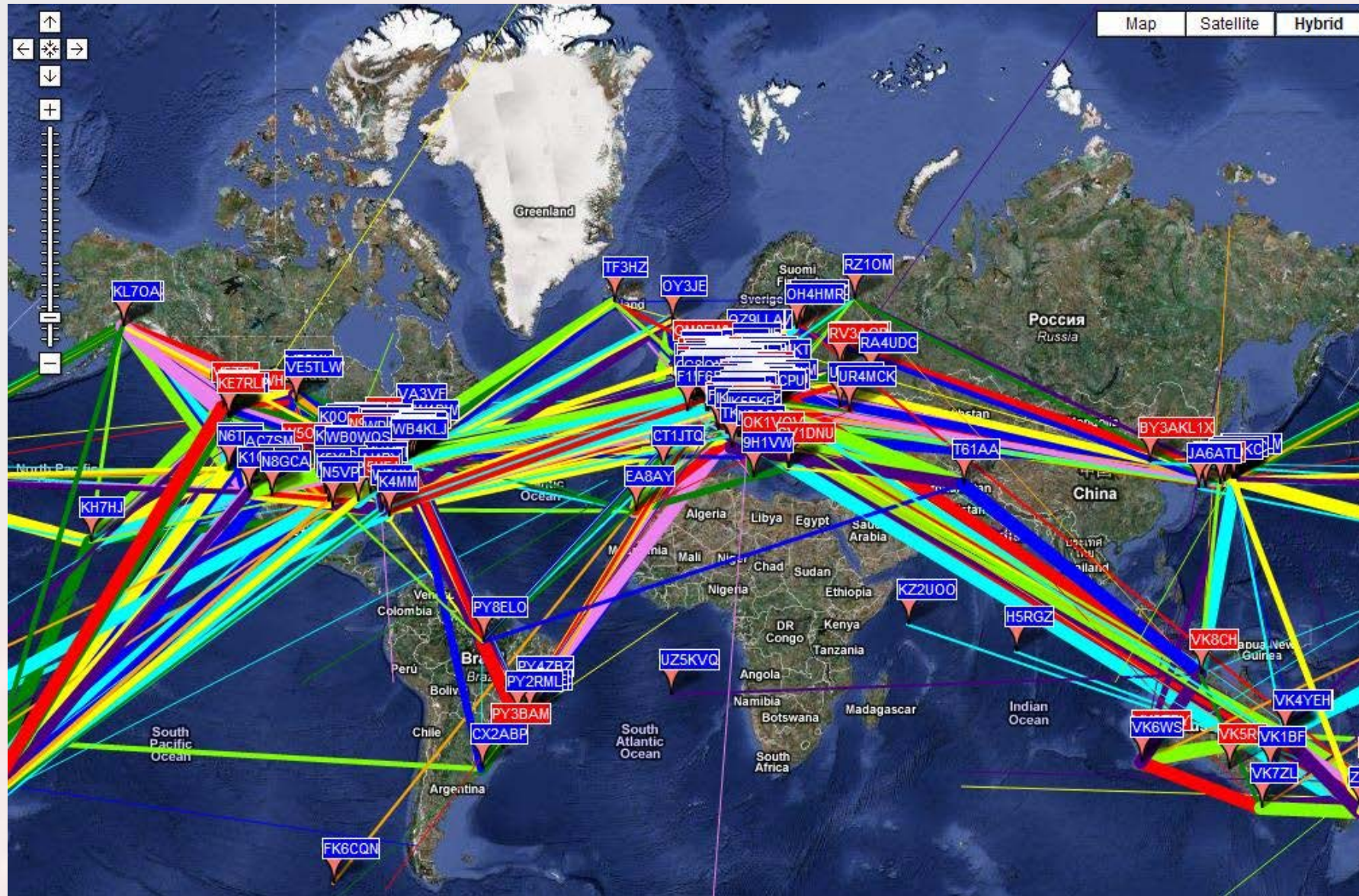
Version: v2.2.6

<https://www.reversebeacon.net/index.php>

WSPR (https://wsjt.sourceforge.io/WSPR_QST_Nov_2010.pdf)

- Written by Joe Taylor, K1JT
- Designed to probe potential HF propagation paths with low power TX
- Originally a standalone application, it is now part of WSJT-X
 - Works with most transceivers
 - Requires an interface to a PC's sound card if the transceiver doesn't have its own Audio CODEC (USB or Ethernet)

WSPRNET (<http://wsprnet.org/drupal/wsprnet/map>)

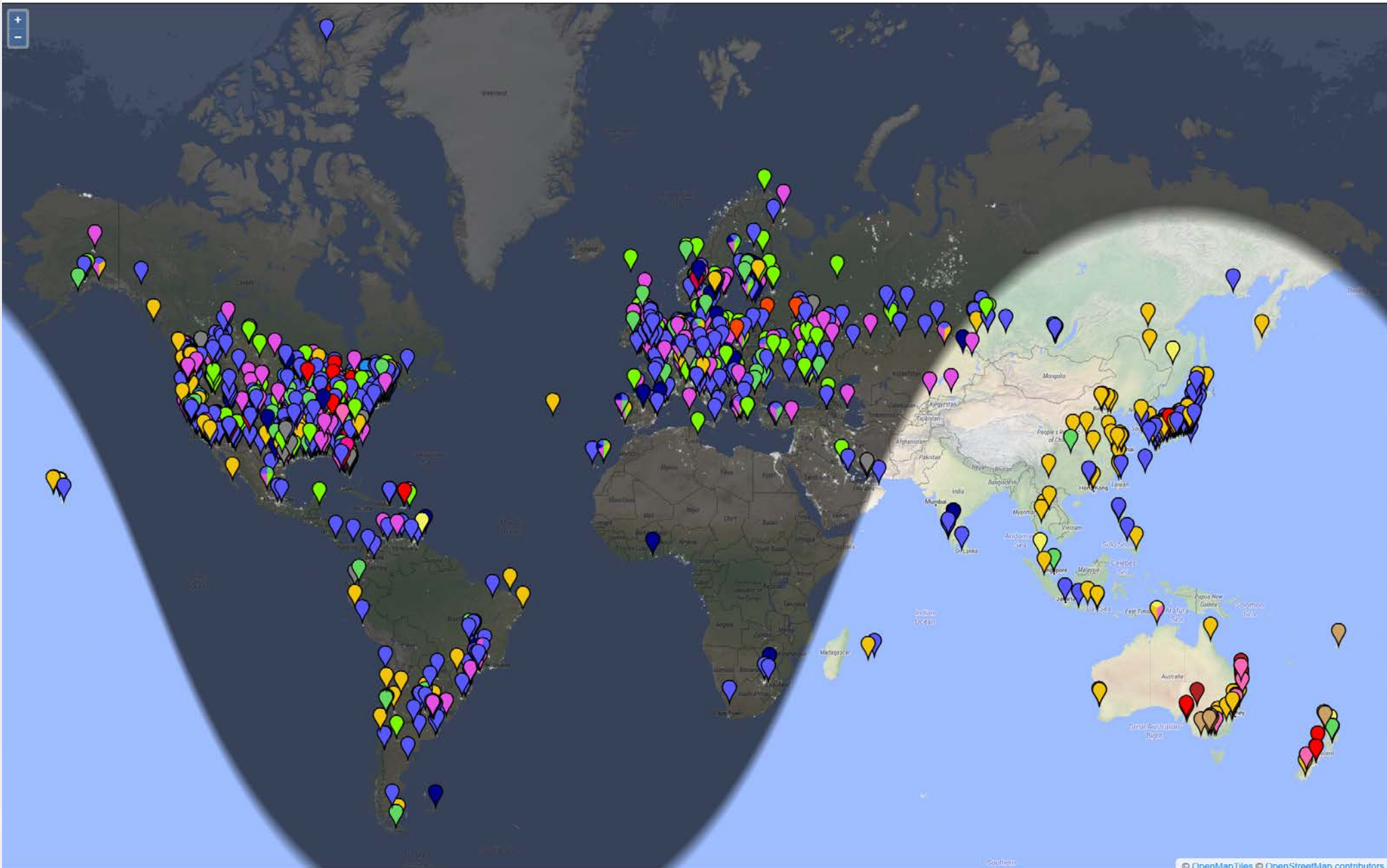


PSK Reporter (<https://pskreporter.info>)

- Tracks Digital traffic reports from individual stations and maps it
 - Originally supported PSK only but now includes JT65 and FT8
 - Software identifies call signs in exchanges
 - Color-coded pins identify bands
 - Unattended software on a PC connected to the transceiver can report all received traffic
 - Typically over 100 stations in North America and Europe are monitoring at any time
 - A node must transmit for its own signal to be reported by stations which see its transmissions
 - Call CQ with the appropriate digital software and watch on the map which stations report seeing your call

Automatic refresh in 4 minutes. Large markers are monitors.

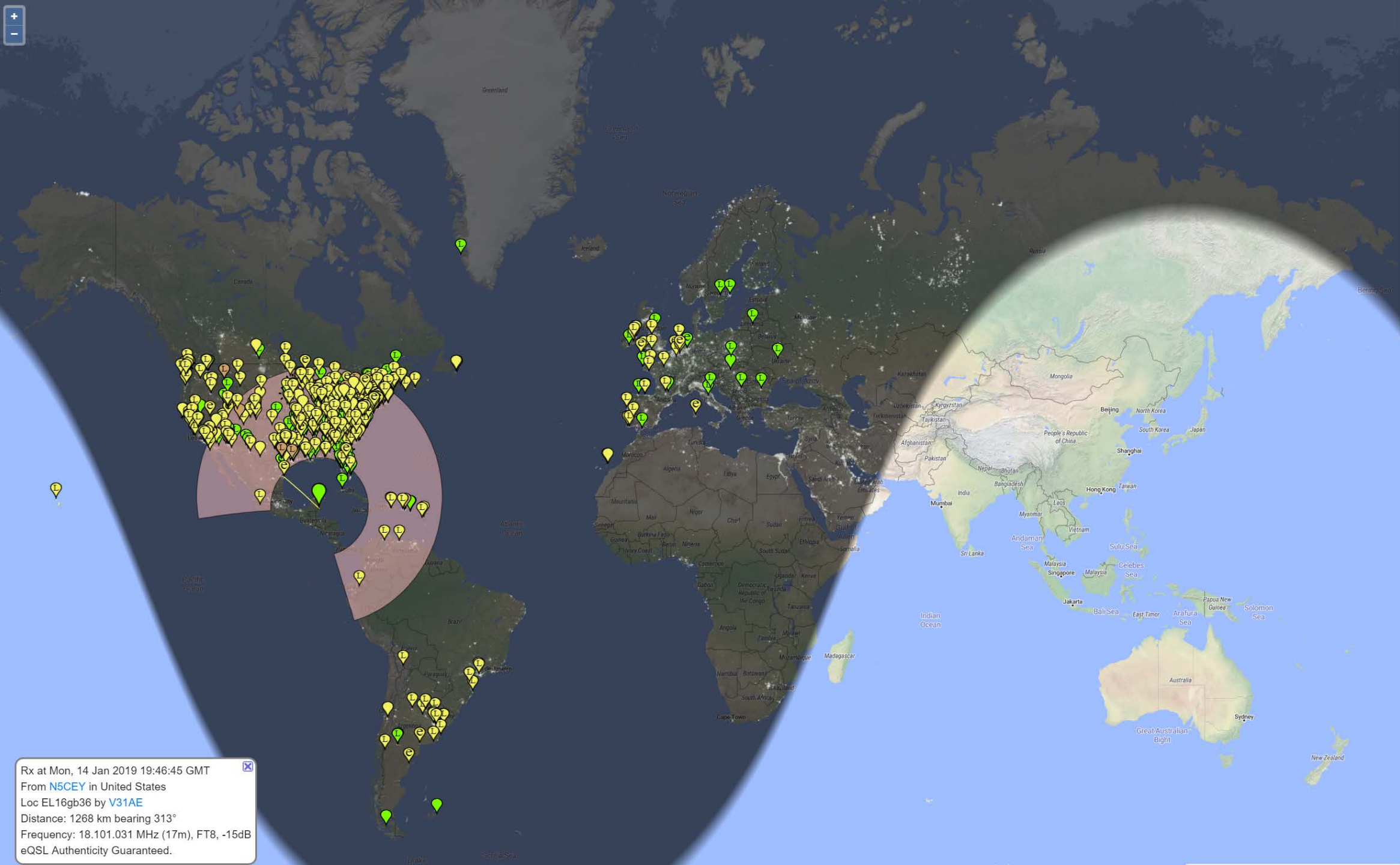
There are 2505 active monitors: 1043 on 40m, 388 on 80m, 310 on 20m, 260 on 160m, 183 on 30m, 104 on 60m, 39 on 6m, 34 on 17m, 30 on 600m, 27 on unknown, 17 on 2m, 15 on 15m, 15 on 10m, 6 on 12m, 3 on 2200m, 1 on 70cm, 1 on 11m, 1 on 4m. [Legend](#)





Monitor: V31AE Loc EK58uk
in Corozal, Belize
Receiving: FT8 on 1.841 MHz (160m)
Using: WSJT-X v2.0.0 784f75
Antenna: 1/4 vertical
[Show all seen by V31AE](#)

Monitor: DU1JIR Loc PJ19ni
in Philippines
Receiving: FT8 on 7.076 MHz (40m)
Using: JTDX v2.0.1-rc123
[Show all seen by DU1JIR](#)



Rx at Mon, 14 Jan 2019 19:46:45 GMT
From **N5CEY** in United States
Loc EL16gb36 by **V31AE**
Distance: 1268 km bearing 313°
Frequency: 18.101.031 MHz (17m), FT8, -15dB
eQSL Authenticity Guaranteed.

Station Improvements

- Better and different antennas
 - Lower MUFs mean operating at lower frequencies
 - If the 20m band is the lowest band your station can handle, your operating windows and modes will be limited
 - 40m and 30m are generally open somewhere
 - Even a compromise antenna and inexpensive tuner can open these bands to you
 - 80m is often good and even usable during the day during times of low solar flux
 - Get a long wire, dipole, horizontal loop, 43' vertical or even a trap vertical
 - DX Engineering MBVE-5-4UP (\$847) 43' vertical with tilt base and UNUN
 - Remote tuners are the best way to feed them
 - Our use a tuner in the shack with ladder line run to a BALUN at the antenna
 - And why not add 160m to the picture?
 - You'd be surprised how well some of these antennas can perform on 160m
 - Use the best antennas you can afford and can have on your lot
 - Directional antennas (e.g., yagi) will make a BIG improvement in operating pleasure

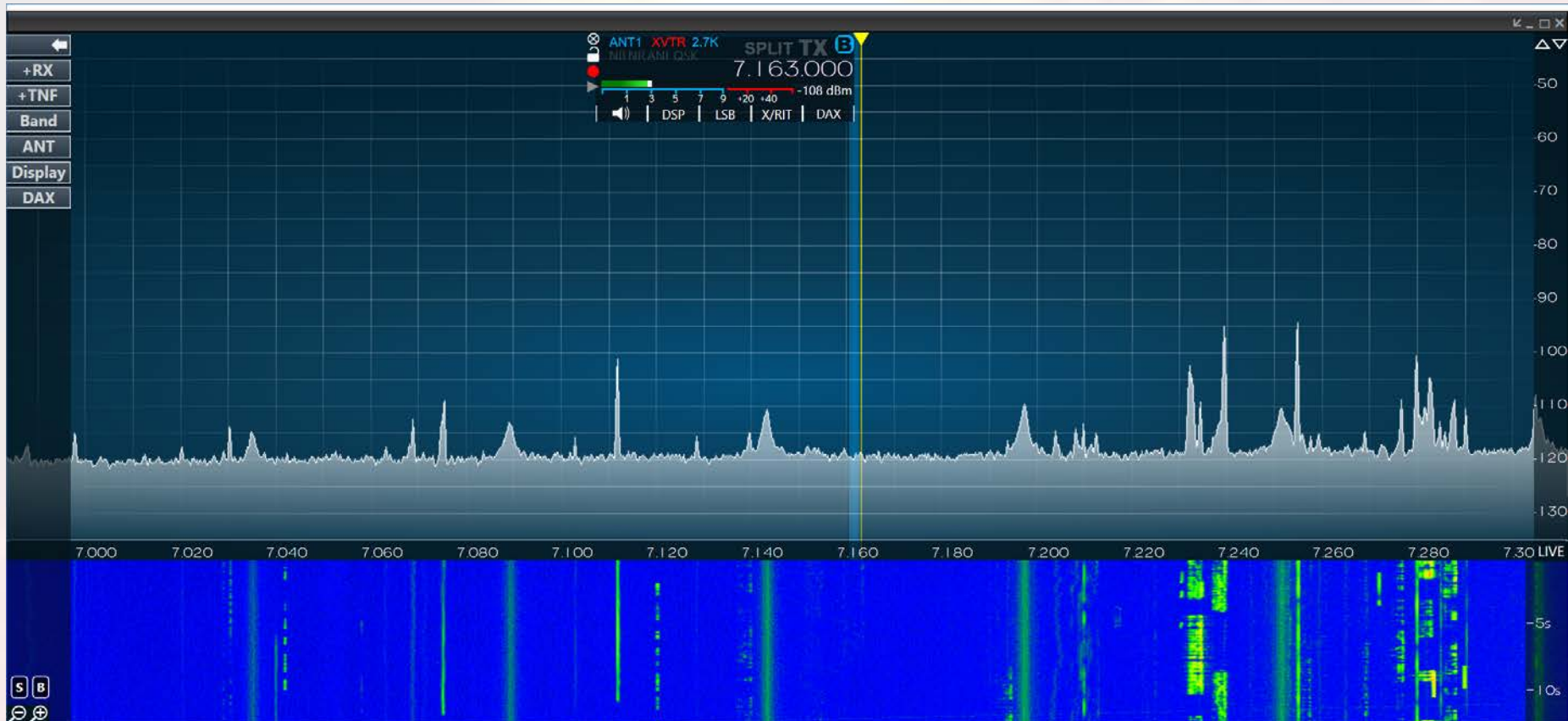
Power Amplifier

- During periods of poor HF propagation, most stations running SSB voice are running power amplifiers
 - You can hear them but they might not be able to hear you unless you also boost your output power
 - Going from 100W to 400W will boost your signal by one S-Unit (6 dB)
 - Going from 100W to 1500W will provide nearly a 2 S-Unit boost (11.76 dB)
- Tube-based amplifiers can be cheaper, but sometimes replacement tubes can be hard to find
- Solid State amplifiers typically require no tuning when switching bands or changing frequencies within a band
 - Ameritron ALS-600 new was \$2600
 - Elecraft solid state KPA500 is \$3350



SDR and Panadapter/Panafall Display

- When there's not a lot of stations to be found, finding them easily becomes more important:



Changing Modes of Operation

- It's all about what kinds of Signal to Noise Ratios (SNR) are possible given current propagation conditions
 - Typical human ear needs about 12-15 dB minimum SNR for voice
 - The trained ear can copy CW down to about a 0 to -6 dB SNR (500 Hz BW)
 - FT8: -21 dB SNR; JT65: -28 dB SNR

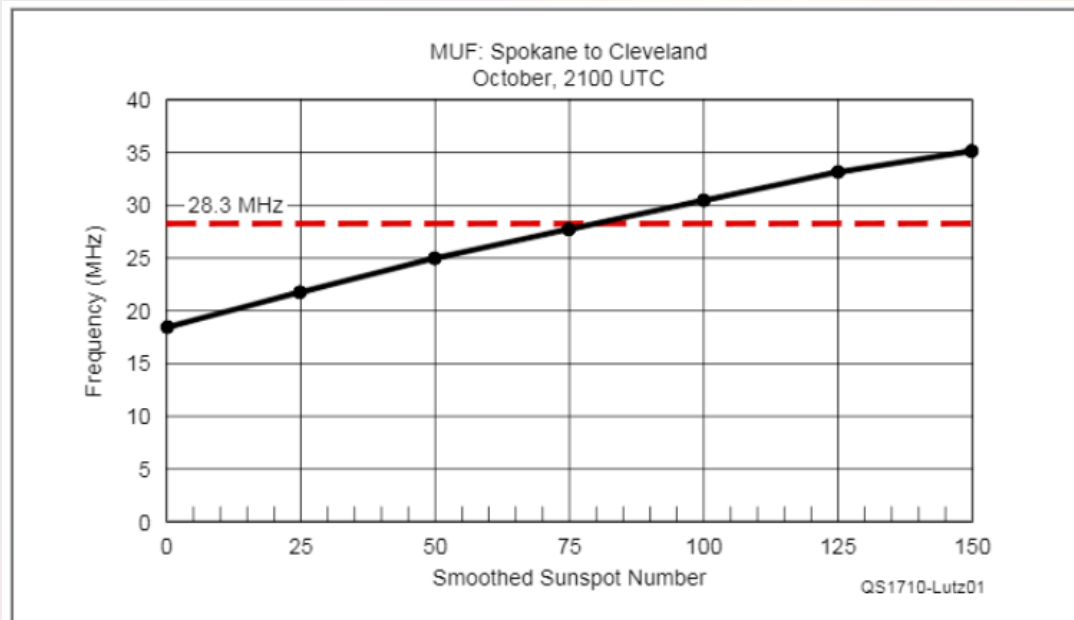


Figure 1 — The predicted MUF (maximum useable frequency) between Spokane and Cleveland at various smoothed sunspot numbers.

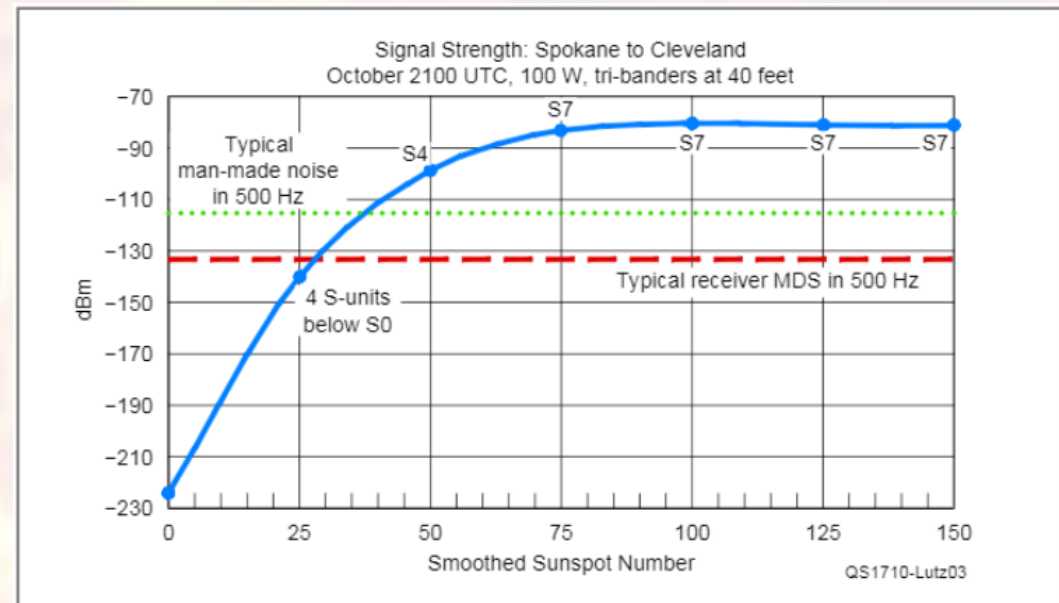


Figure 3 — The predicted signal strength versus the smoothed sunspot number, assuming the use of CW, at 100 W, with Yagi antennas on both ends of the path at 40 feet over average ground, and a residential noise environment in Cleveland.

Digital Modes Easily Beat Even CW

- No need for a power amplifier when using the newer digital modes
 - Just 5-10W is generally adequate
- “Above the MUF” communication is frequently possible
 - Propagation is not abruptly cut off at the MUF
- Great for WAS and WAC

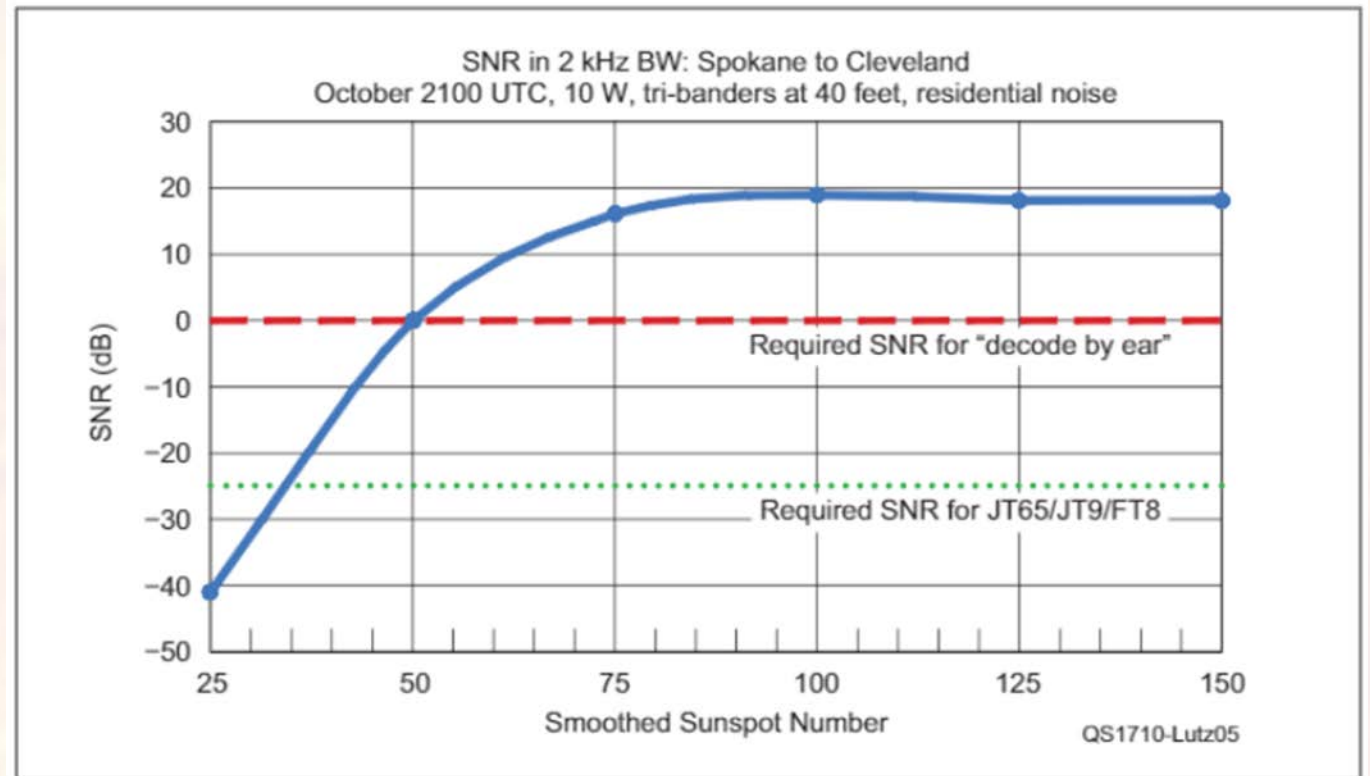


Figure 5 — Re-doing the same analysis shown in Figure 3, but this time at 10 W with a 2 kHz bandwidth. The data point at a smoothed sunspot number of 0 is not plotted to give better resolution to the other data.

WSJT-X (Joe Taylor) K1JT

- Does FT4, FT8, JT4, JT9, JT65, FST4, FST4W, FT4, FT8, JT4, JT9, JT65, Q65, QRA64, ISCAT, MSK144, WSPR and ECHO (Moon)

WSJT-X v2.0.0 by K1JT

File Configurations View Mode Decode Save Tools Help

Band Activity					Rx Frequency				
UTC	dB	DT	Freq	Message	UTC	dB	DT	Freq	Message
183930	-10	-1.1	695	~ CQ JA4DNC PM64					
183930	5	-1.3	1493	~ W4GRN KB4TOX RR73					
183930	-19	-0.8	2249	~ UK8AEA JA2PTQ PM86					
183930	-11	-1.2	2317	~ CQ W2/F2YS					
----- 40m									
183945	-12	-1.1	1430	~ S57ANA JA3ENN -02					
183945	-1	-1.2	1493	~ KB4TOX W4GRN R-15					
----- 40m									
184000	-5	-1.2	233	~ R7CY JA3FYC -21					
184000	-11	-1.1	695	~ CQ JA4DNC PM64					
184000	-17	-0.8	2249	~ UK8AEA JA2PTQ PM86					
184000	-9	-1.3	2317	~ CQ W2/F2YS					
184000	-17	-1.1	2451	~ R2RBL JR3DRE RR73					
----- 40m									
184015	-8	-1.3	856	~ <...> JA6CNL					
184015	-1	-1.2	1493	~ KB4TOX W4GRN R-15					
----- 40m									
184030	-13	-1.1	695	~ R2RBL JA4DNC -11					
184030	-12	-0.8	2248	~ UK8AEA JA2PTQ PM86					
184030	-12	-1.2	2317	~ CQ W2/F2YS					

CQ only Menus

40m **7.074 000**

Tx even/1st Hold Tx Freq

Tx 1500 Hz

Rx 2102 Hz

Report -15

Auto Seq Call 1st

Generate Std Msgs Next Now Pwr

Tx 1

Tx 2

Tx 3

Tx 4

Tx 5

Tx 6

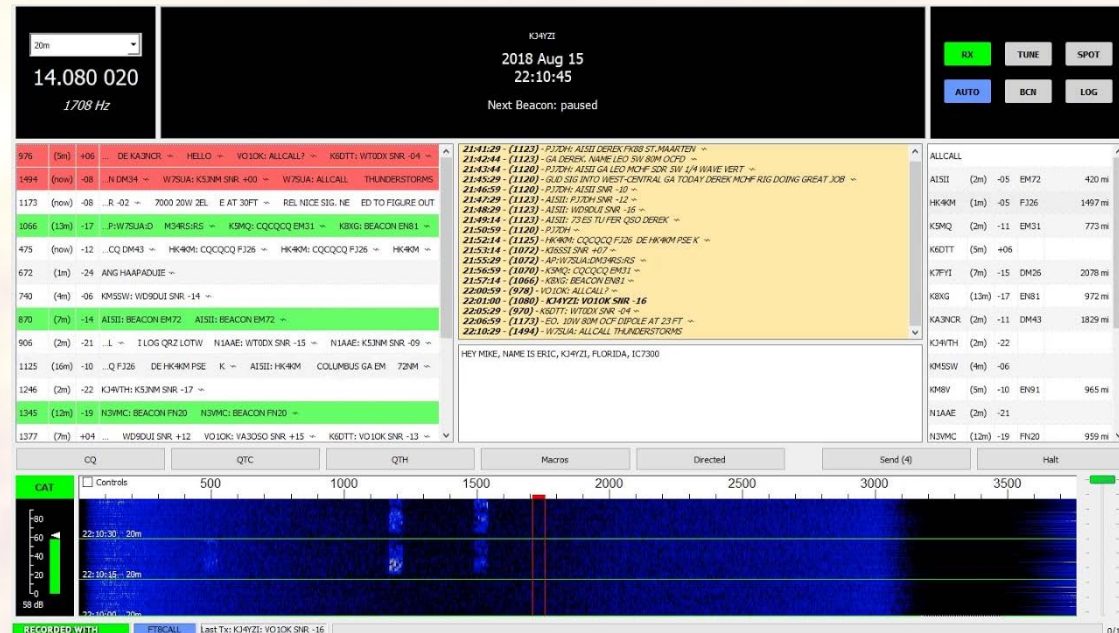
CQ W7YP DN28

Receiving FT8 10/15 WD:4m

Home: <https://wsjt.sourceforge.io/wsjt.html>

JS8Call by KN4CRD

- Uses FT8 modulation
- Allow free text messaging and keyboard chats
- Real time conversations, message forwarding and networked messaging over HF
- Combines FT8's weak-signal robustness with actual communication capability
- Versions for Windows, macOS and Linux
 - https://js8call.com/?utm_source=chatgpt.com



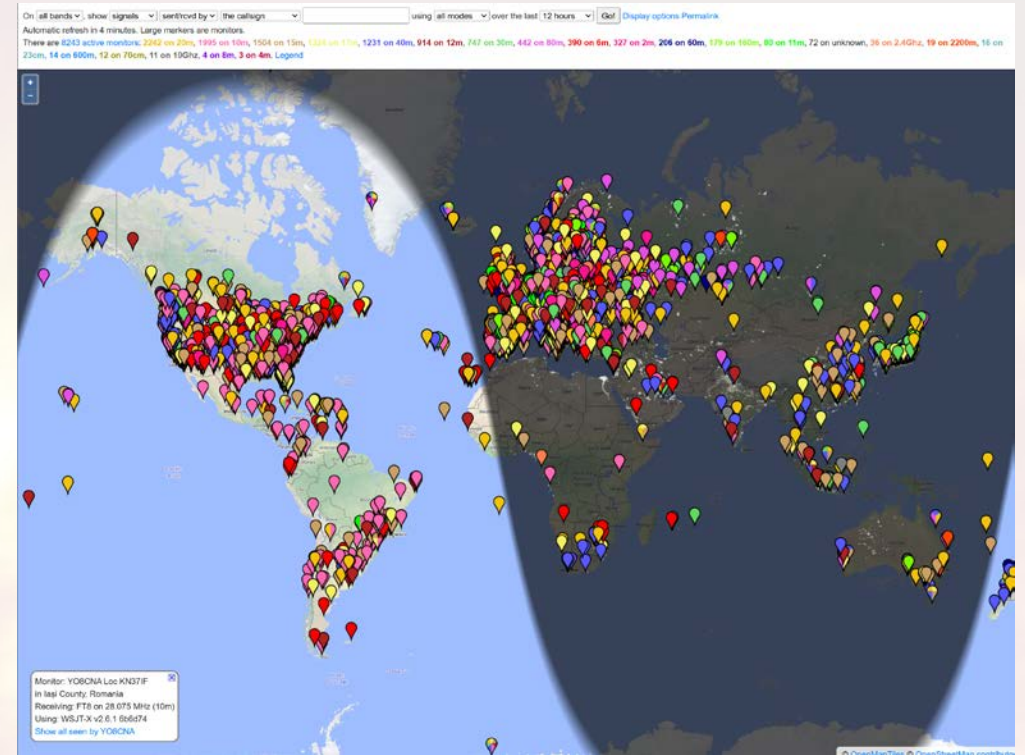
Other Digital Modes

- PSK31 – older, but still used, especially on 20m and 40m
- RTTY
- VARA/ VARA HF/ VARA FM
 - High speed data and email via Winlink
 - Efficient, adaptive mode for digital messaging and emergency comms
- Olivia MFSK
 - Reliable keyboard-to-keyboard chat in poor conditions
 - Very robust, but slow
 - Software: Fldigi, MultiPSK and Ham Radio Deluxe

Snapshot of Mode Usage from PSKReporter:

- 10/20/25 from 0900 to 1100 MDT:

- FT8: 4,102,798
- FT4: 167,494
- WSPR: 145,387
- JS8: 9,947
- PSK31: 141



- FT8 is obviously the de facto standard for weak-signal, high-efficiency automated digital contacts (contest like mode of operation)
- WSPR's number indicates its widespread use primarily for propagation monitoring
- JS8's keyboard chat is significantly less used than FT8's CQ-style mode
 - Popular on 40m in the evenings

Changing Times of Operation

- Rule of thumb:
 - 20m works to some extent day or night
 - Night openings are rare during periods of low solar flux
 - Lower frequency bands work best at night
 - 30m, 40, and 80m are often open into very late morning during solar minimums
 - 40m is often open all day
 - Higher frequency bands work best during the day
 - Digital modes can often work these bands when nothing else can (“Above the MUF”)
 - Sporadic E can enable communication on 10m and 12m
 - The farther from 20m you get in either direction, the more pronounced these effects are

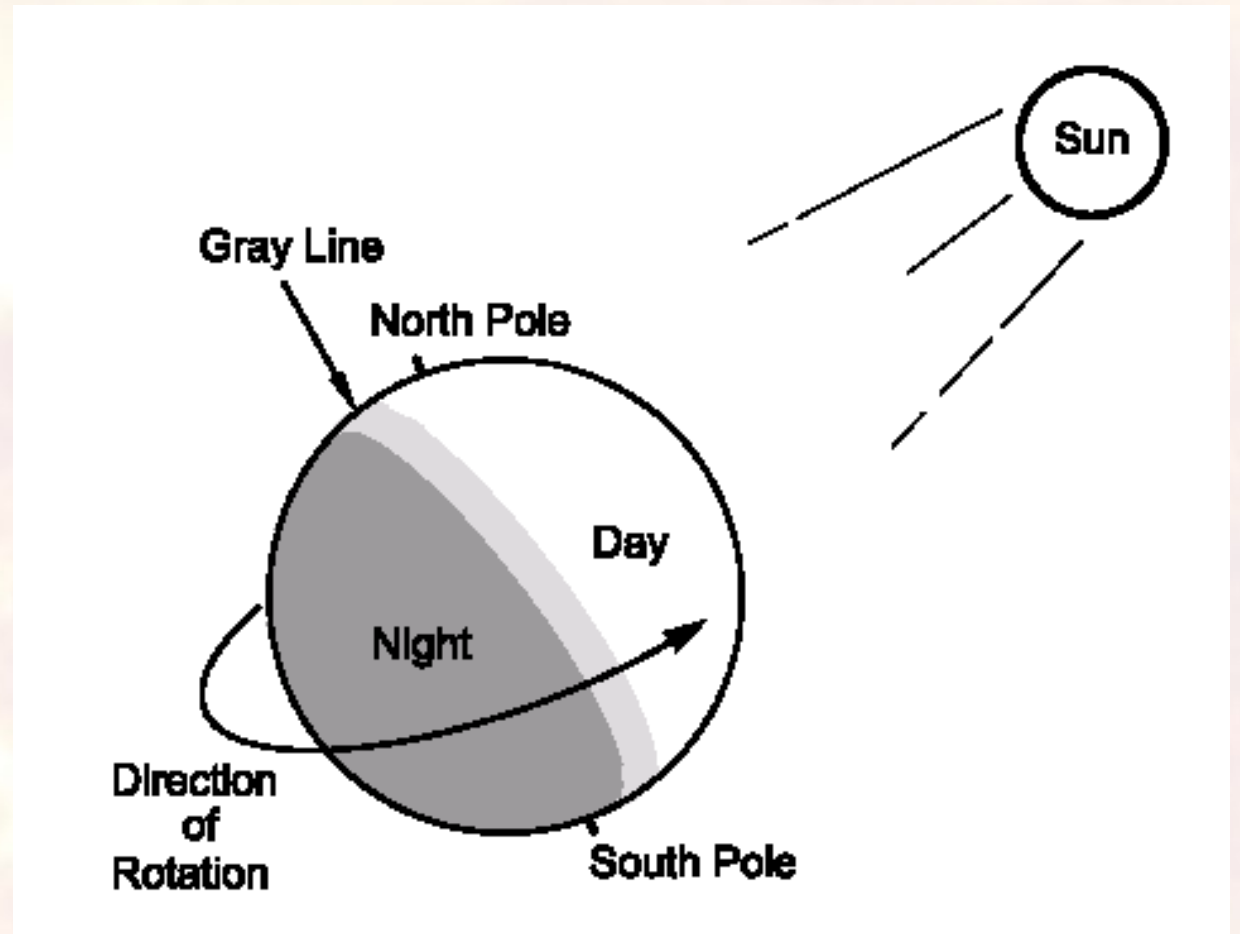
Sporadic E

- “As its name implies, sporadic E is a reflecting layer in the ionosphere which comes and goes sporadically at E-region heights. At mid-latitudes, sporadic E (E s for short) layers are made up of clouds of electrons a few kilometers thick and a few hundred kilometers across, and occur at altitudes between approximately 90 and 130 km. To a radio wave, they often look like rather good quality mirrors.” *
- Strong signals are often enabled over considerable distances
 - Openings are relatively short
 - The causes of sporadic E are still the subject of much research
- VOACAP engine (N6BV) makes propagation predictions
 - Over 240 transmitting locations around the world
 - Detailed predictions show each band over 24 hours by 40 CQ Zones

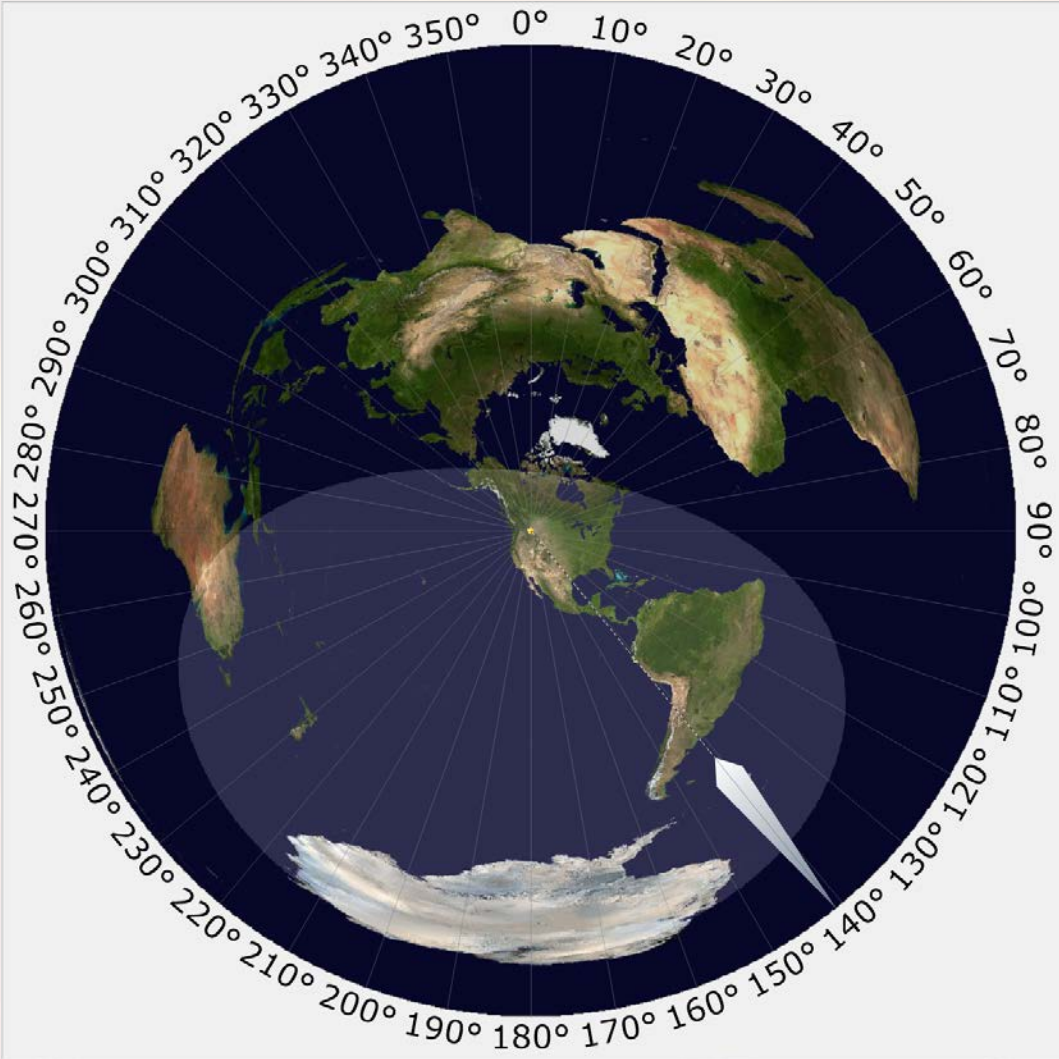
* Leo F. McNamara, in his book “The Ionosphere: Communications, Surveillance, and Direction Finding”

The Gray Line

- The area of transition between daylight and darkness
 - Offers some unique propagation
 - The D Layer, which absorbs HF signals, hasn't built up yet on the sunny side of the line and disappears quickly on the shady side of the line
 - Very long range communication can be possible between points along the gray line



Azimuthal Map of the Gray Line





Q&A