RESPONSE TO:

THE FCC's PSHSB SEEKS COMMENT ON THE IMPACTS OF THE MAY 2024 GEOMAGENTIC STORM ON THE U.S. COMMUNICATIONS SECTOR

PS Docket No. 24-161 of 24 May 2024

Response from:

WsprDaemon - a US-led, international group of radio amateurs making, reporting, archiving, interpreting and publishing data and information on radio propagation.

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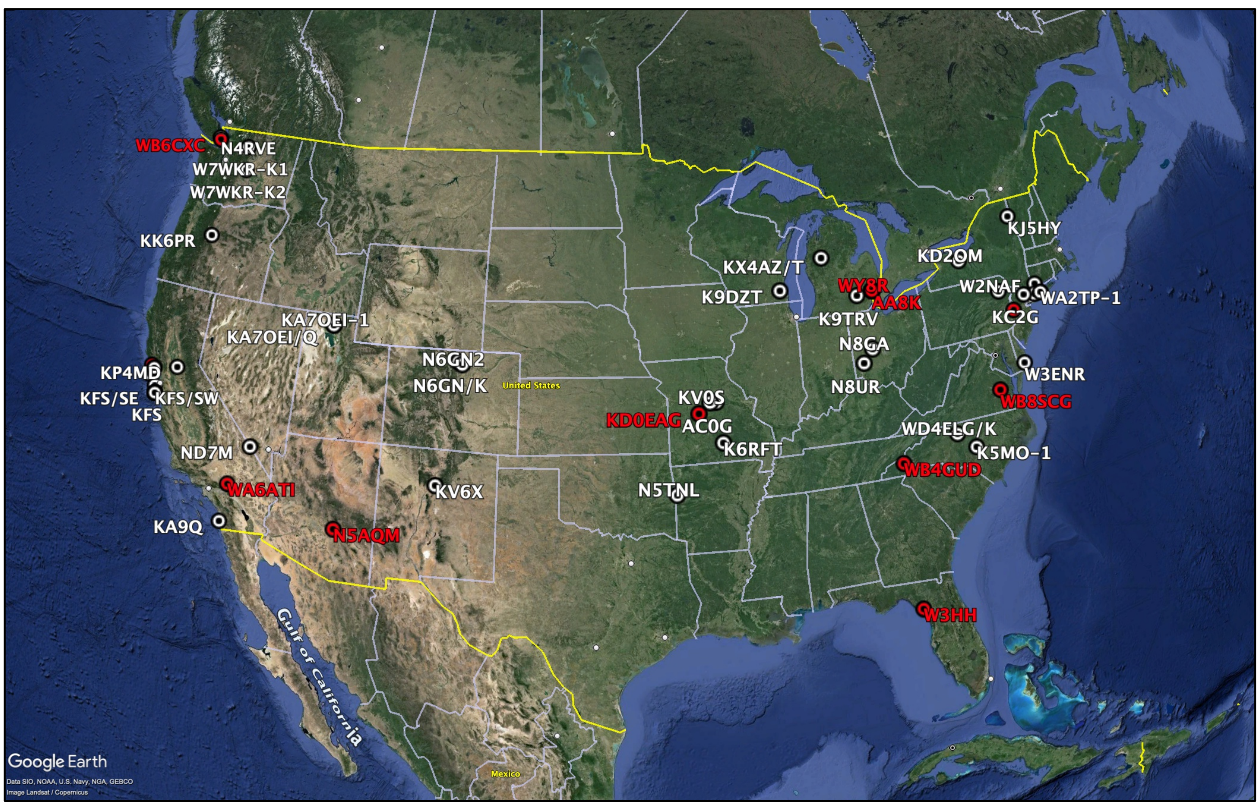
A. Preamble

1. The amateur radio service is a user of the HF radio spectrum and observed adverse impacts to communications from the geomagnetic storm of May 8-11, 2024. Adverse effects persisted through 13 May 2024. These impacts were seen in amateur analog voice and digital data communications modes.
2. The amateur radio service has a heritage of contributing to radio science and ionospheric physics, especially through observations. Directly relevant to this Request for Comment are the amateur community's observations via the propagation-reporting modes within the WSJT-X digital communications package devised by Nobel Laureate Dr. Joseph H. Taylor, K1JT, Dr Steven J. Franke, K9AN, and collaborators.
3. The Weak Signal Propagation Reporter (WSPR) mode makes and reports the signal to noise ratio (SNR) of messages from transmitters to receivers typically every ten minutes. WSPR is a very narrow-band mode (~6 Hz) and probability of successful decode is reduced severely when Doppler spread exceeds 1.5 Hz. Typical power output for WSPR at HF ranges from 0.2 W to 5 W.
4. With some 3500 transmitters and 1500 receivers globally some 200,000 propagation path reports are sent to the database at wsprnet.org each hour.
5. The WsprDaemon group (wsprdaemon.org) making this submission designed a database that not only accepts this WSPR data but also has grown a network of receive sites that measure and report HF band noise. Propagated-in noise at quiet sites is affected by space weather: under these circumstances signal to noise ratio may be a compromised proxy for signal level.
6. Furthermore, the WsprDaemon group has pioneered the adoption of FST4W, a specialist mode within the WSJT-X package, to measure frequency spread induced by the ionosphere.
7. The WsprDaemon database is publically accessible. Graphical on-line data visualization tools help users explore datasets. This response provides a commentary on a tiny fraction of the data: this incredibly rich data set merits further analysis. For detailed analysis data is available from a SQL-like database via several tools, with a guide available at: http://wsprdaemon.org/ewExternalFiles/Timescale_wsprdaemon_database_queries_V2-2.pdf
8. In response to this Request for Comment we have customized a sub-set of our visualization dashboards to highlight the impact and disruption to communications of space weather 8-14 May 2024. We go out to 14 May to show how different HF bands and different path distances recovered at different times. The next section is a guide to data access. Subsequent sections describe the space weather impacts on noise and communication paths.

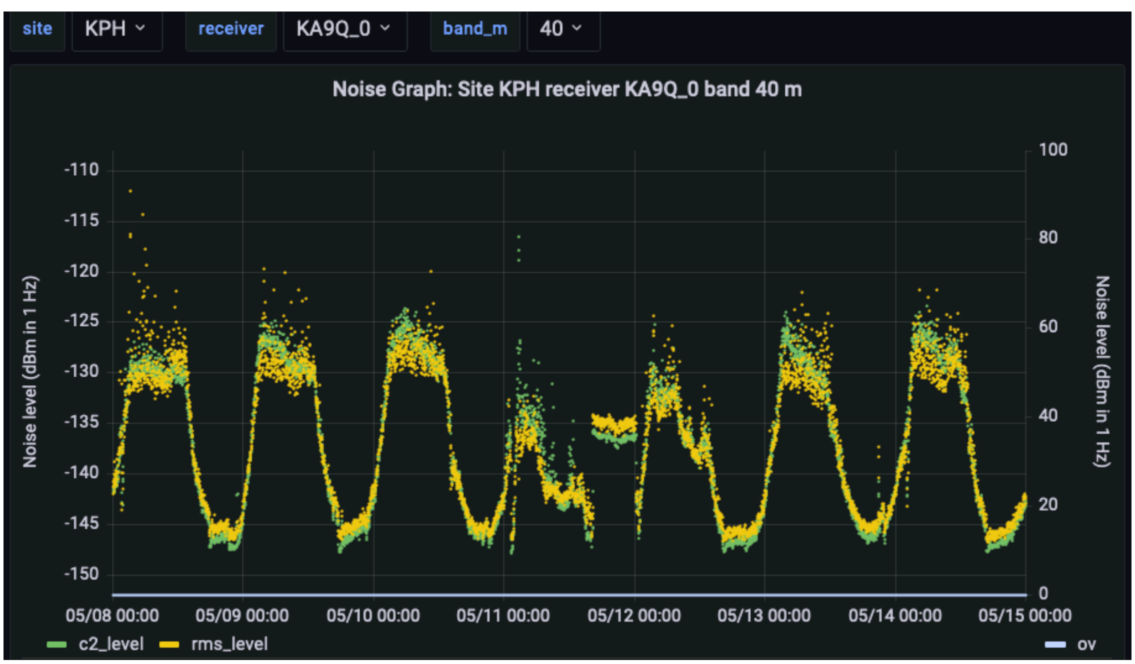
B. Accessing the WsprDaemon FCC dashboards and data coverage

9. The FCC sub-set of dashboards most relevant to the Request for Comment are accessed via http://logs1.wsprdaemon.org:3000/login
   The username is [redacted]
   the password is [redacted]
10. On login the Home Page has a list of Dashboards on the left.
    For help, contact Gwyn Griffiths, G3ZIL at gwyn "at" autonomousanalytics.com
11. Clicking on a dashboard name will take you to it. From a dashboard, clicking FCC in top left, then FCC_Home from the dashboard list will take you to the home page.
    Sign out is via the icon above the help icon bottom left.
12. Each dashboard has user-selectable options at top left, explained for each dashboard below. Each also has a 'time-picker' top right. This has been set to cover 7-14 May inclusive to show the wider context of the space weather event. All times are UTC.
13. On reloading a dashboard it will return to the default parameters.
14. The map below shows the callsigns and locations of the amateur radio receiving stations contributing to the WsprDaemon database in white, and a small sub-set of transmitting stations in red available to select in the FCC dashboard examples.



C. WsprDaemon visualization of impacts to amateur radio communications: Noise

15. The three user-selectable parameters are: site, receiver, and band, selected from pull-down lists:
    a. **Site** is the callsign of the reporting station.
    The default is KPH, sited at Point Reyes, CA. Maintained by the Maritime Radio Historical Society KPH is at a naturally quiet location and equipment noise has been carefully minimized. On amateur bands up to and including 15 m diurnal variation of propagated-in noise can be identified.
    b. **Receiver** is a designator for one or more receivers at a site. Typically, different receivers are used with different antennas or may differ in their technology. All are software-defined radios (SDRs); most common are the KiwiSDR or the RX888 MKII.
    c. **Band_m** is the amateur band nominal wavelength in meters following customary use, the default is 40 m.
16. **Interpretation with default selections, KPH, KA9Q_0, 40**:
    a. The receiver at KPH is an RX888 Mk II SDR with digital signal processing using ka9q-radio. Details available at: wsprdaemon.org/ewExternalFiles/Hamvention_2024_Rx888_WS8_Presentation.pdf
    b. The antenna at KPH is a TCI530 omnidirectional broadband log-periodic.
    c. The regular pattern of a local daytime minimum due to solar UV-induced ionization, hence absorption in the D and E regions, and a nighttime maximum due to propagated-in noise was disturbed on 11 and 12 May.
    d. The nighttime noise level was lower than normal, likely due to higher-than normal D region non-deviative and E region deviative absorption, and lower F region critical frequency, all factors reducing propagated-in noise.
    e. The sudden rise, plateau, and sudden fall in noise on 11 May, a Saturday, were because KPH was open for visitors and local electrical noise level increased.
    f. The temporary reductions in propagated-in noise at 0141 UTC 8 May and 0123 UTC 11 May were direct impacts of higher absorption due to the UV radiation from the X1 and X5 flares respectively.



17. **KPH, KA9Q_0, 80:**
    a. The picture is similar to 40 m but the recovery to near normal nighttime noise occurred earlier, on the 12 May rather than 13 May.
18. **KPH, KA9Q_0, 20:**
    a. Propagated-in noise on 20 m normally peaks in the evening local time. Noise was lower than normal on 11 and 12 May [ignore the Saturday 11 May local noise event].
19. **WA2TP-1, KA9Q_0, 40:**
    a. WA2TP, Long Island, NY is a more typical suburban amateur radio site but one where the operator has taken great care to minimize local noise. The lower propagated-in noise on 11 and 12 May is perfectly evident.
20. **KF6ZEO, KIWI_0, 40:**
    a. KF6ZEO, San Francisco, CA is in a city environment with higher local noise and there is no conclusive evidence for a change in noise level.
21. **Noise - Summary**
    The 8-11 May solar events resulted in a geomagnetic storm that lowered the propagated-in noise at HF at sites that were not limited by their own local noise.

D. WsprDaemon One-Station Propagation Path Heatmaps for the HF bands

22. This dashboard shows the normal and disturbed patterns of propagation from one selected transmitter to all WSPR reporting receivers within a specified North America Maidenhead Grid Square (see map below) on HF bands from 3.5 MHz to 28 MHz. The colors represent the count of the number of reception reports in one-hour time intervals. Time is along the X axis and frequency in MHz on the Y axis.

Map courtesy SOTA Maps https://www.sotamaps.org/

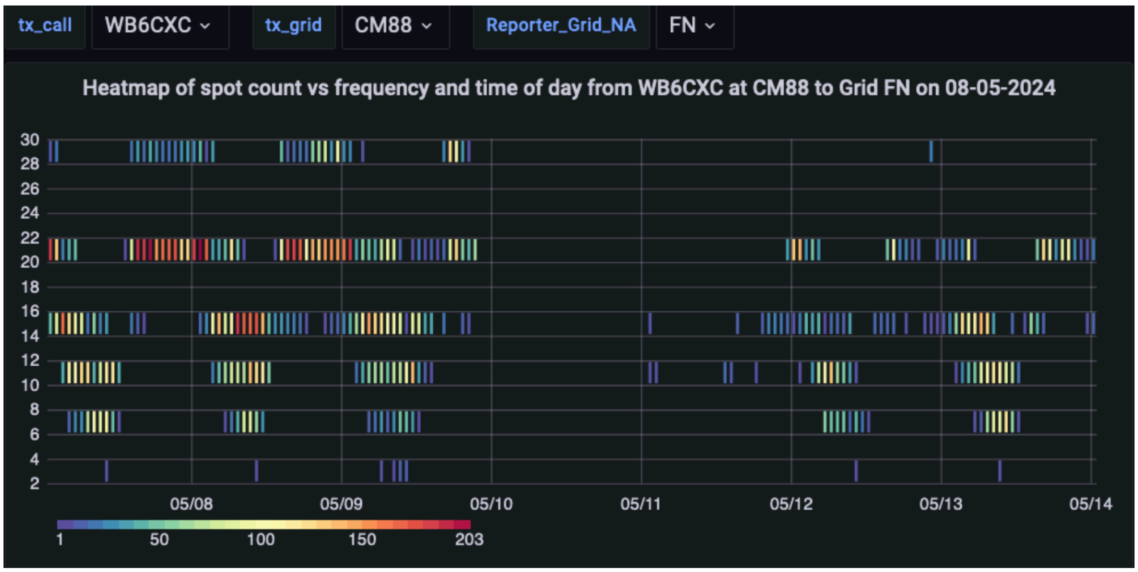
23. **Interpretation with default selections, WB6CXC, CM88, FN**:
    a. In this transcontinental example the transmitter is WB6CXC, Occidental, CA, to receivers in grid FN (see map for extent). WB6CXC uses a WsprSonde transmitter capable of operation on multiple bands. The other selections available in this dashboard are also

WsprSondes as they provide the most complete data over the HF bands. Paths were ~4500 km.

b. No receiver reports at all were received, on any band, between 2100 UTC 10 May and 0000 UTC 12 May. 14 MHz (20 m) was the first to recover, but with far fewer reception reports than normal until 14 May.

c. Reception report counts on 7 MHz and 10 MHz were similar to those on undisturbed days by 13 May.

d. 21 and 28 MHz had still not recovered by 14 May, but as there may have been changes to propagation other than due to the storms attribution is more difficult at several days removed from the core events of 8-11 May.



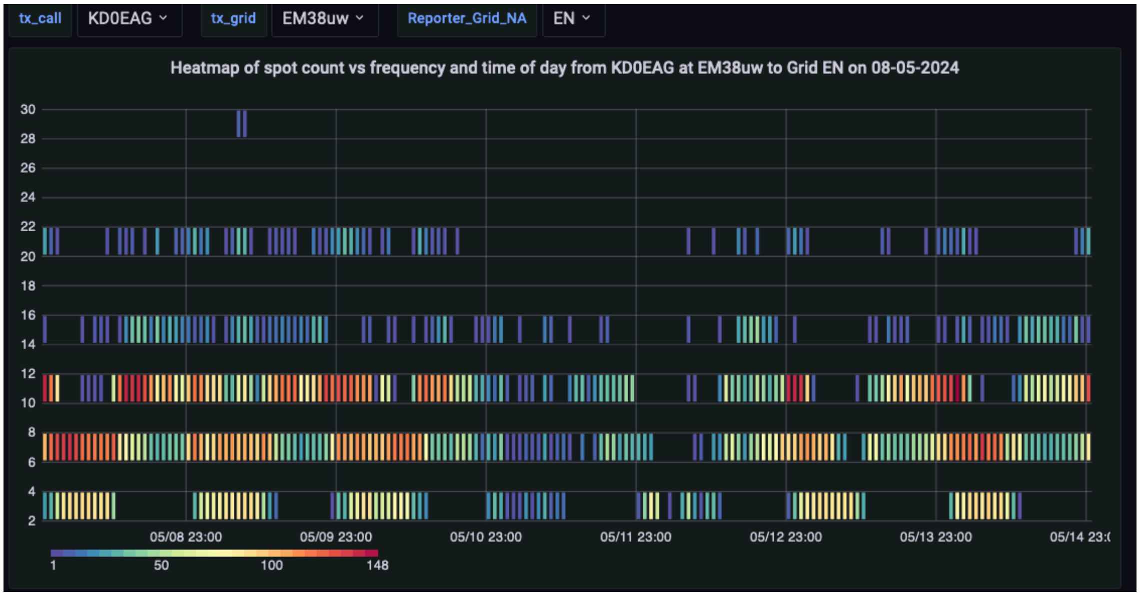
24. **KD0EAG, EM38uw, FN:**

a. Data from transmitter KD0EAG, Columbia, MO, provided propagation impact results for east, west, south and north paths. To grid FN paths are ~1700 km. In contrast to the transcontinental path that closed completely on 11 May a few sporadic reports were received mainly on 10 through 21 MHz on this shorter path.

b. However 3.5 and 7 MHz were both closed on the 11th, with 3.5 MHz recovering on the 12th, but 7 MHz not fully until the 13th.

25. **KD0EAG, EM38uw, EN:**

a. Propagation from KD0EAG to grid EN is over ranges from 200 to 1000 km. On these shorter paths 3.5 through 10 MHz stayed open during 10-11 May, although with fewer reception reports. As expected given the shorter paths, there were few reports at 14 MHz, and none at 21 MHz during the event.



E. WsprDaemon Propagation Path 'Telescope' along user-set bearing with user-set beamwidth on three user-set bands.

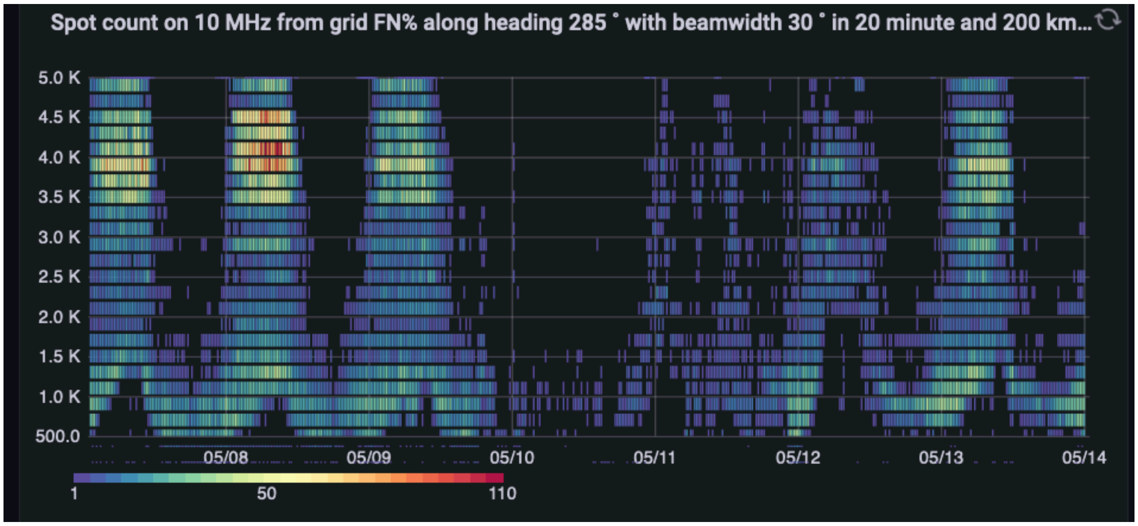
26. This dashboard shows the normal and disturbed pattern of propagation from aggregated data from all WSPR transmitters in a grid square along a heading set by the user, and with a user-set beamwidth. The number of reception reports in twenty-minute intervals in radial range bins 200 km wide represented by color. The minimum range is set to 500 km. The dashboard shows the results on three user-selected frequency bands.

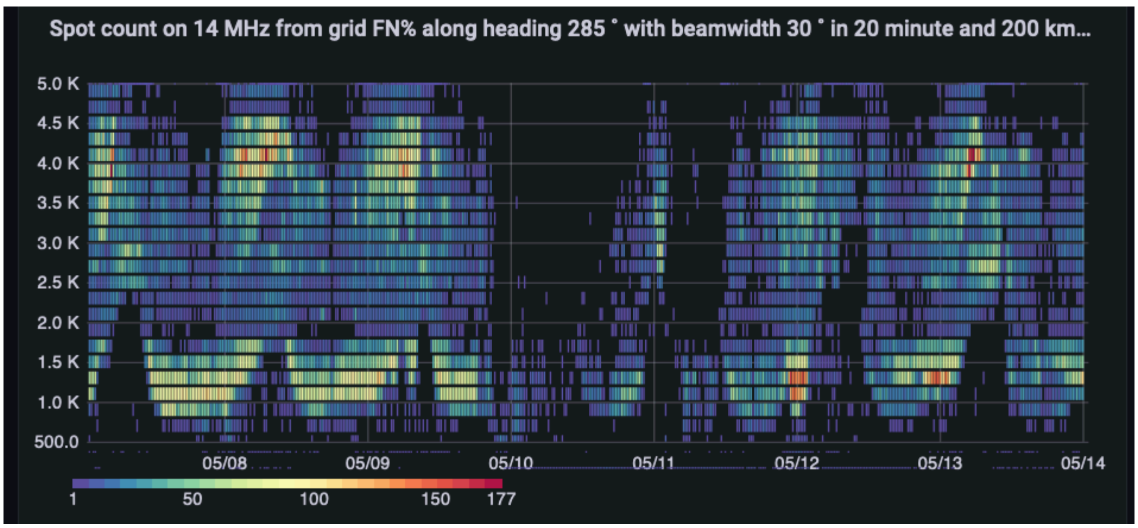
27. Interpretation with default selections, FN, heading 285° with 30° beamwidth on 10, 14 and 21 MHz:

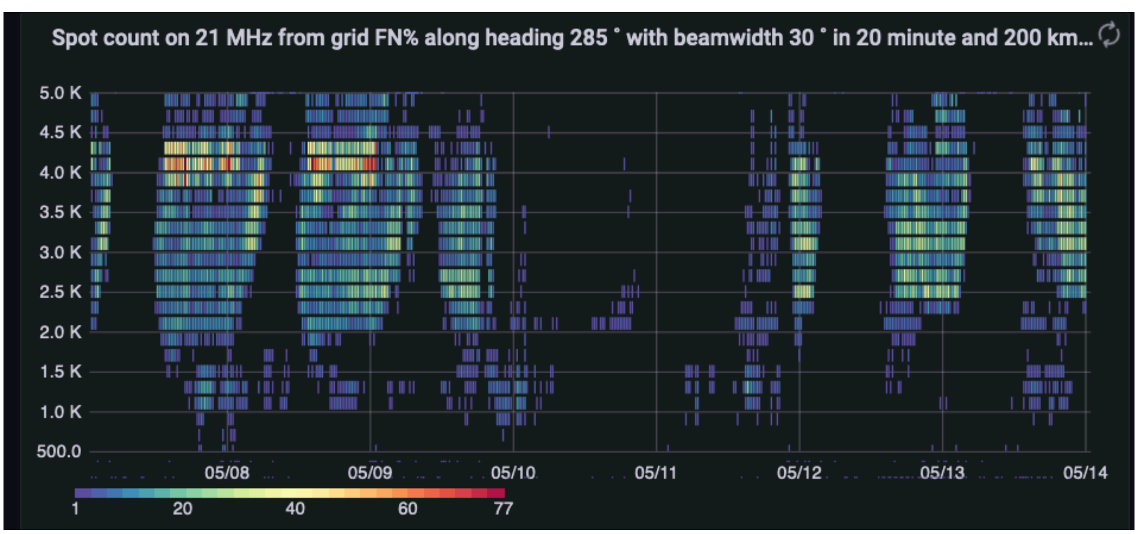
a. With these parameters we see propagation from NY / New England to the west with the 30° 'beam' spanning the sector that spans from San Diego to Vancouver Island at the West Coast. The pre-storm diurnal patterns are clear and distinctively different in detail on the three bands, 10, 14 and 21 MHz. Communications were severely impacted on the 11th on all three bands. There was a partial recovery for ranges of 700-1200 km on 14 MHz around 1900 UTC on the 11th, and a brief opening around 0000 UTC on the 12th at ranges of 2500 to 4000 km.

b. Around 0700 UTC on all three bands a notch exists in the minimum range at distances out to 1000-2000 km on 10 and 14 MHz. Even on the 13th these notches reached out further than pre-storm: to ca. 2000 km on 10 MHz and to ca. 3000 km at 14 MHz. Both bands had recovered by the 14th.

c. On 21 MHz the normal tapering gaps in propagation around 0800 UTC spanned a greater time interval on 13th and 14th, some 12 hours rather than 5 hours at 3000 km range.


Spot count on 10 MHz from grid FN% along heading 285 ° with beamwidth 30 ° in 20 minute and 200 km...
5.0 K
4.5 K
4.0 K
3.5 K
3.0 K
2.5 K
2.0 K
1.5 K
1.0 K
500.0
05/08
05/09
05/10
05/11
05/12
05/13
05/14
1
50
110


Spot count on 14 MHz from grid FN% along heading 285 ° with beamwidth 30 ° in 20 minute and 200 km...
5.0 K
4.5 K
4.0 K
3.5 K
3.0 K
2.5 K
2.0 K
1.5 K
1.0 K
500.0
05/08
05/09
05/10
05/11
05/12
05/13
05/14
1
50
100
150
177

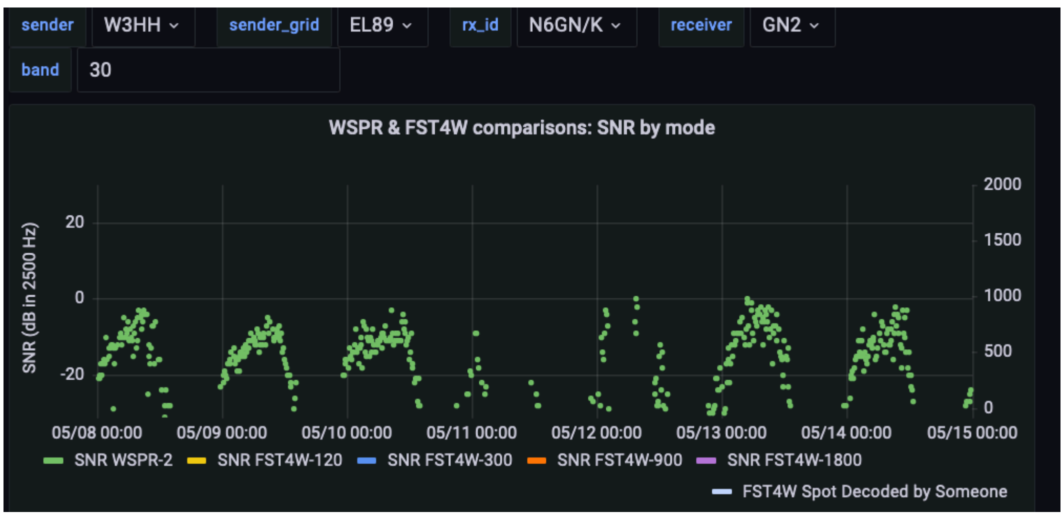

Spot count on 21 MHz from grid FN% along heading 285 ° with beamwidth 30 ° in 20 minute and 200 km...
5.0 K
4.5 K
4.0 K
3.5 K
3.0 K
2.5 K
2.0 K
1.5 K
1.0 K
500.0
05/08
05/09
05/10
05/11
05/12
05/13
05/14
1
20
40
60
77

F. WSPR and FST4W Time series - WsprDaemon Single-Path analysis of SNR, frequency spread, noise level, signal level

28. The WsprDaemon database and visualization tools not only provide 'big picture' aggregate views of the impact of space weather events on communications, as in previous dashboards, it provides detailed time series information for single paths. In this example, signal to noise ratio (SNR), frequency spread, receiver noise level and received signal level are displayed along with summary statistics for a representative sub-set of transmitters and all WsprDaemon reporters.

29. **Interpretation with default selections, W3HH, N6GN/K, 30 meters**:
W3HH, situated in Ocala, FL, used transmitter output of 5 W to a dipole antenna. N6GN/K is a remote solar- and battery-powered receiving site NW of Fort Collins, CO with a KiwiSDR and a hybrid combination of active dipole and Loop on Ground antennas. The path is 2358 km.

30. On the 10th May 30 m failed to open as usual after around 2200 UTC as it had done on days prior to (and after) the storm. However, some 10 WSPR decodes were made between 20:50 UTC and 02:36 UTC 11 May, with 3 decodes later that day. The band started to return to normal on 12 May, but communication until the latter part of the day remained impaired. Signals on 30 m returned to normal on 13th May.



31. **AA8K, EEN82, N6GN/K, 40 meters:**
AA8K, situated in Port Huron, MI, used a WsprSonde multiband digital modes transmitter with 1 W output to an end-fed multiband antenna. The path to N6GN/K is 1855 km. 40 m was essentially closed on 11th May, with only 3 reception reports compared with 286 on 10th May. The band partially recovered on 12th with 88 reports, increasing to 181 on 13th and 234 on 14th.

32. These examples give a mere introduction to the single path data available during the May 2024 storm. There are over 1000 combinations of transmitters, receivers and bands in this subset alone.

G. Conclusion

33. Automated reception reports of Weak Signal Propagation Reporter (WSPR) digital mode transmissions by the amateur radio service has provided multi-faced pictures of the adverse impacts on HF communications of the disturbed space weather on 8-11 May 2024 across the USA.

34. Loss of communication typically began around 22:00 UTC 10 May, some 5 hours after the solar wind shock wave produced a step-change in geomagnetic field at Boulder, CO (at 17:06 UTC).

35. Aggregate data visualization methods provide quick-look summaries of the impact on communications from a single transmitter to a distant region by frequency band, and from transmitters in a region along an arc of azimuth by distance. From such graphics the impact on circuit reliability can be seen.
36. Detailed information on SNR, signal level, frequency spread and noise level on over 1000 individual paths is available on frequencies from 3.5 to 28 MHz from this FCC sub-set.
37. Interactive use of the WsprDaemon database and its visualization tools will yield much more information than can be outlined in this short response.

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19 June 2024