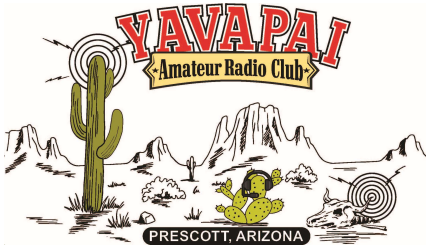

The Sun and HF Propagation

The Basics

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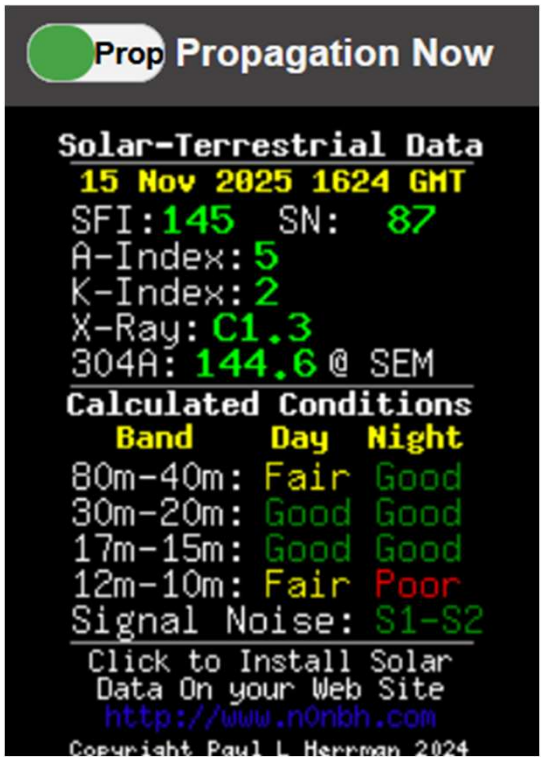
Acknowledgments

Many thanks go to both Rich Amenta KK7NNC and Bud Semon N7CW for reviewing this presentation, providing me with feedback, and making suggestions that improved the quality of the presentation.

What We Will Cover

- The basics of the sun's effect on HF propagation – with an emphasis on the practical.
  - What drives good and not so good HF propagation.
  - Measuring the state of HF propagation.
- Feel free to ask questions at any time.

We Will End Up Demystifying This Chart



Preview of Key Terms

- Solar Flux Index (SFI) – A measurement of atmospheric ionization.
- 304 Angstroms (304A) – Measurement of Solar Extreme Ultra-Violet (EUV) radiation that ionizes the atmosphere.
- K Index –Measurement of geomagnetic disturbances that can disrupt HF propagation.
- X-Ray Classes – Measurement of the intensity of solar X-Ray radiation that can also disrupt HF propagation.

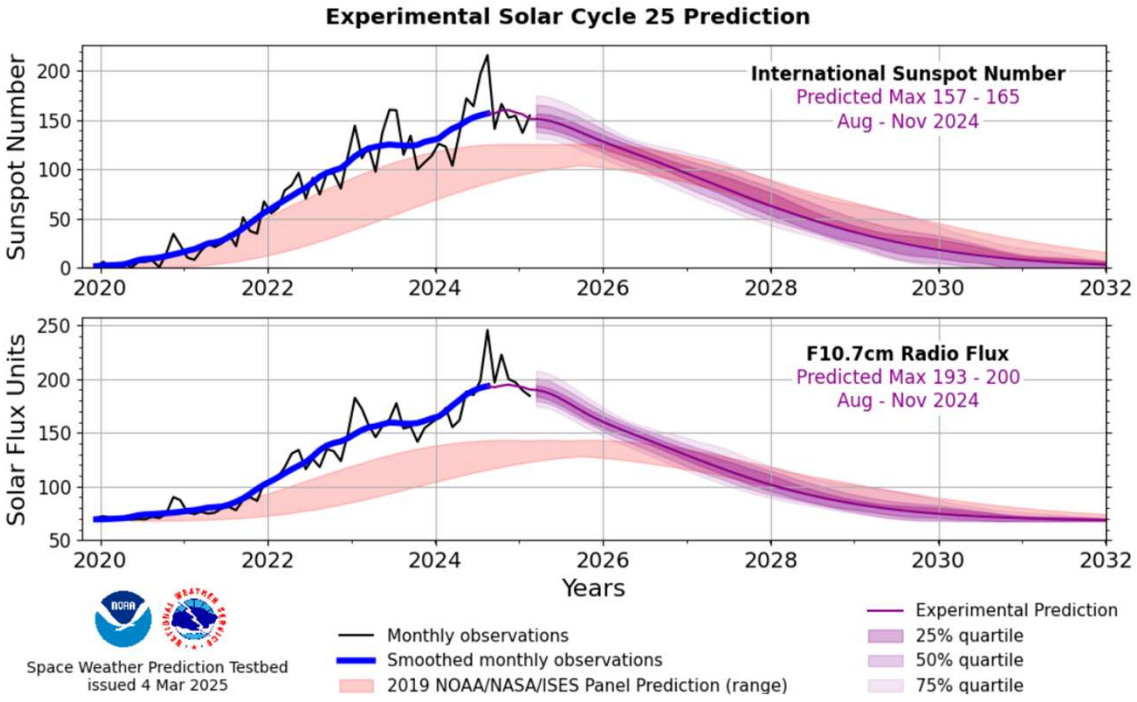
Sunspot Radiation Drives HF Propagation

- HF propagation is mainly driven by the level of radiation from sunspots.
- Electromagnetic radiation, especially in the ultraviolet (UV) wavelengths, emanates from sunspots and ionizes Earth's upper atmosphere.
- Increasing ionization of the Earth's upper atmosphere enables HF propagation.

Solar Cycles

- Solar Cycle Connection - Sunspot numbers follow an approximate 11-year cycle.
  - During solar maximums, HF bands (especially 15M, 12M, 10M, and 6M) come alive with global signals.
  - During cycle minimums, those bands can go quiet.
  - Over time, there will be a number of peaks and dips in a sunspot cycle where the number of sunspots don't follow a smooth curve.

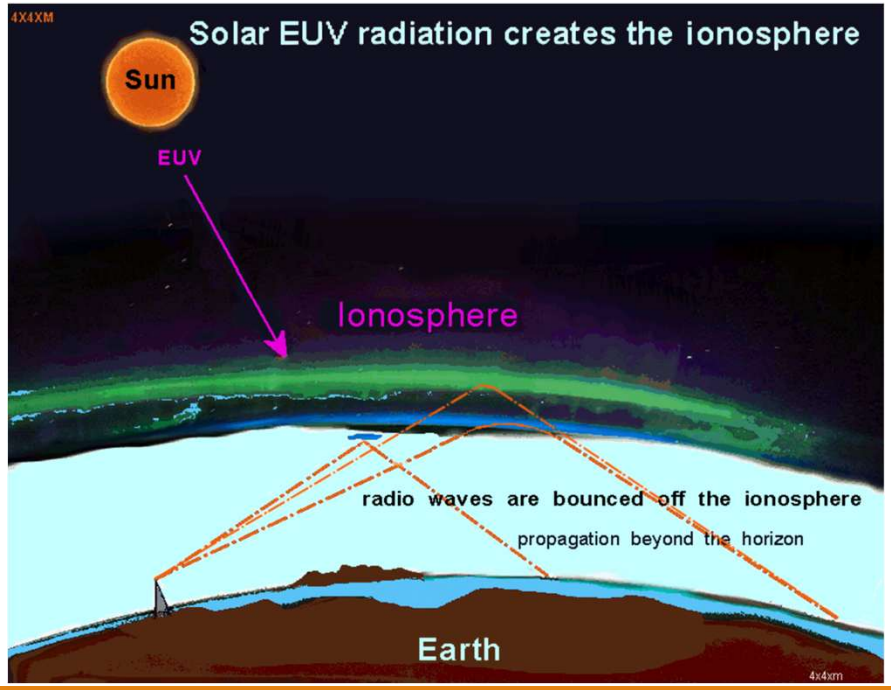
Solar Cycle 25
History and Projection



Solar Extreme Ultra-Violet (EUV) Radiation

Wavelengths From About 10 to 120 Nanometers (NM)

EUV is measured by the strength of 304 Angstrom wavelength (304A), which is 30.4 NM.

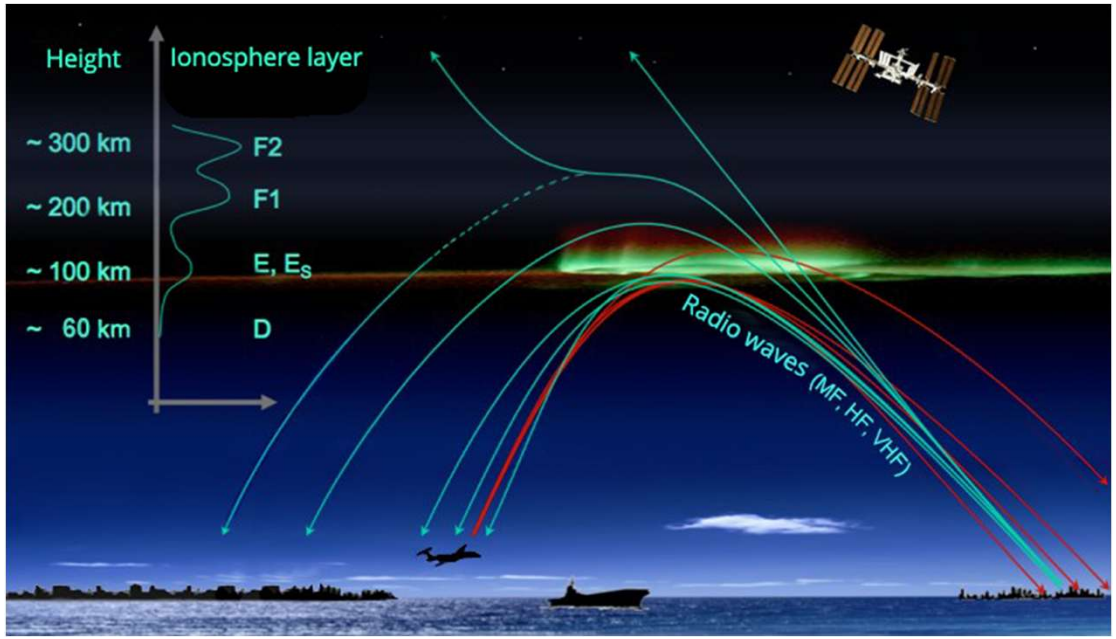


Layers of Ionization

- The ionosphere contains layers (D, E, F1 and F2) of charged particles (ions) that refract HF radio waves back to Earth, enabling long-distance communication.
- More ionization caused by more sunspot energy means:
  - Higher Maximum Usable Frequency (MUF)
  - Better propagation particularly on the 6M, 10M, 12M, 15M, 17M, and 20M bands
  - More reliable skip propagation for DX'ing.

Ionization Layers for HF Propagation

Different layers of the atmosphere get ionized by sunspot radiation. Ionization of the F2 Layer provides the longest skips at the highest HF frequencies. Lower frequencies are refracted by lower layers.



Ionization Factors

- Increased Solar Extreme Ultra-Violet (EUV) radiation can begin having a noticeable effect on ionization after a couple of hours of an EUV intensity change, but it can take up to 24 hours for full ionization to occur.
- Solar Flares, Coronal Mass Ejections (CME), Solar Wind, and increased levels of X-Rays (particularly M and X Classes) increase the ionization of the D Layer, which causes increased absorption of HF signals. This adversely impacts HF propagation.
- Seasonal Differences – With summer, there can be increased absorption of signals by the D Layer of the ionosphere, resulting in degraded HF propagation, particularly for signals below 10 MHz in the daytime.
- HF propagation is generally better in the Fall, Winter, and Spring seasons.

Solar Flux Index (SFI)

- SFI measures the intensity of solar radio emissions, at a wavelength of 10.7 cm (2800 MHz), that cause ionization of the atmosphere.
- SFI is a daily average.

Geomagnetic Disturbances

- Geomagnetic disturbances are caused by Coronal Mass Ejections (CME), Solar Flares, and High-speed Solar Wind.
- Increasing geomagnetic disturbances cause increased atmospheric noise, degradation of signals, fading (QSB) and even blackouts.
- The K and A Indices are key indicators of geomagnetic disturbances, which directly affect radio wave propagartion in the ionosphere.

K Index

The K Index measures short-term geomagnetic disturbances over three-hour intervals.

- The go-to measurement for spotting sudden disturbances.
- Scale is 0 to 9, a quasi-logarithmic measurement.
- Values of 4 + indicate degraded conditions and outages.
  - K Index of 4 and 5 indicate degraded conditions
  - K Index of 6, 7, 8, and 9 indicate increasing levels of disruptions and outages.
- Even a K index of 3 can indicate a good bit of noise.

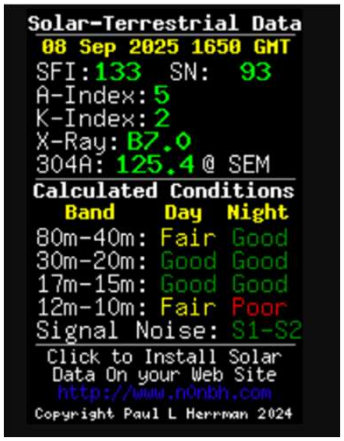
A Index

The A Index measures the daily average of geomagnetic activity (derived from the K Index).

- Smoother, long-term view of conditions that are useful for trend analysis.
- Scale is 0 to 400, a linear measurement.
- Assists in gauging overall geomagnetic stability.
- Lower values (less than 15) suggest quiet conditions and better propagation.

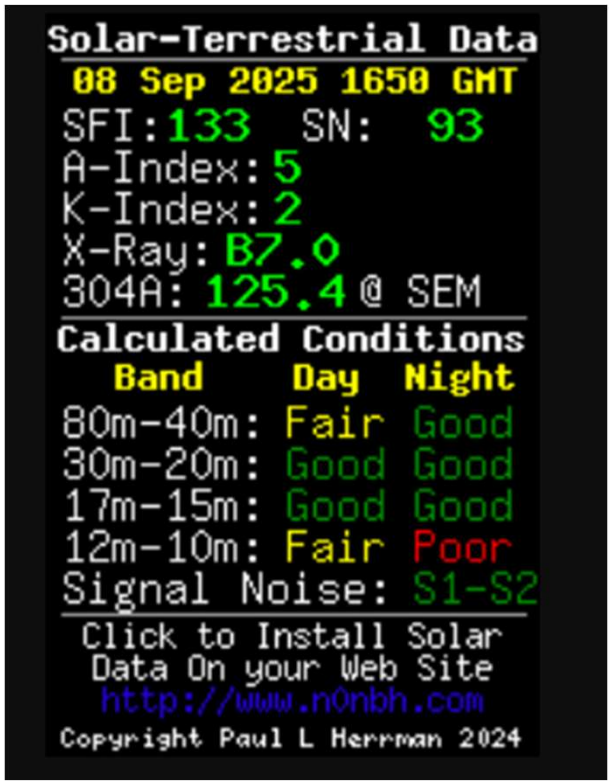
Current Solar Conditions

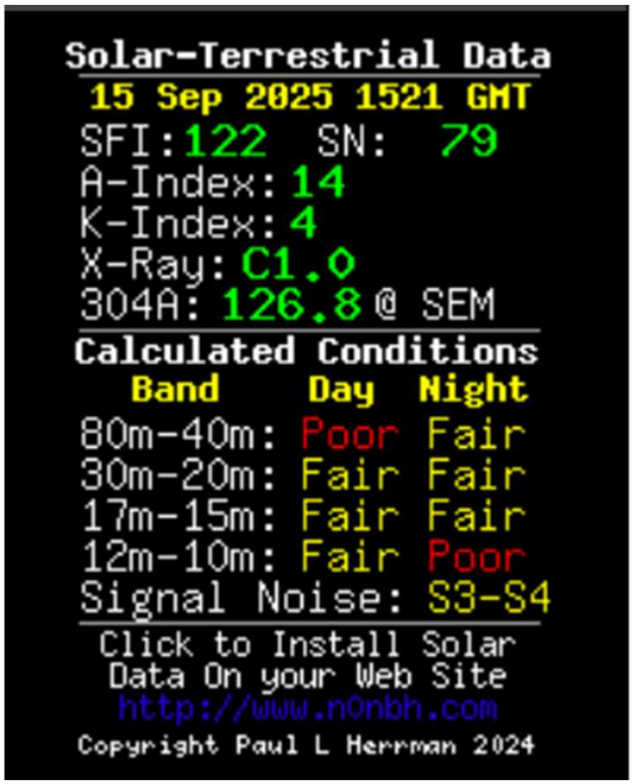
You can find the current solar conditions at the URL below. Key parameters are SFI, K Index, 304A, X-Ray, Calculated Conditions, and Signal Noise. The diagram can also be found embedded in a number of amateur radio websites, such as QRZ.com and DXSummit.fi.



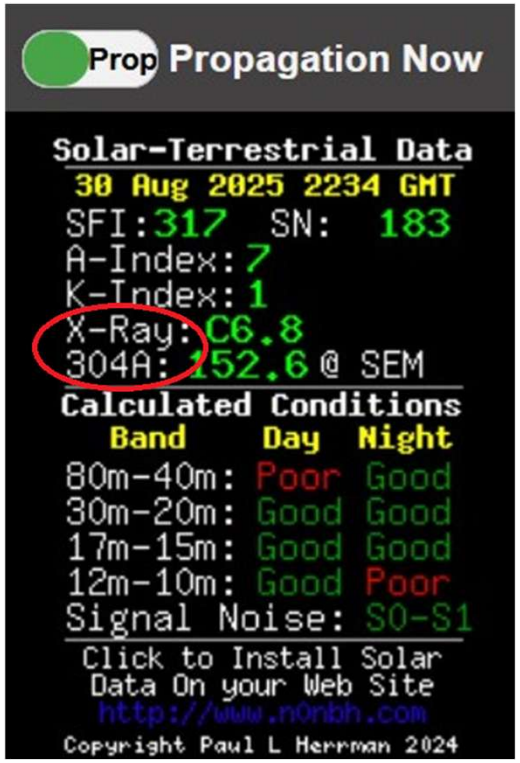
https://www.hamqsl.com/solar.html

Compare two SFIs, K Index Values, Signal Noise Levels, and Calculated Conditions.





304 Angstroms (304A) and X-Rays



304 Angstrom (304A) Values

The 304A value in solar-terrestrial HF propagation data refers to Extreme Ultra-Violet (EUV) radiation measured at the 304 Angstrom wavelength — a key indicator of ionospheric ionization that is measured hourly.

Interpreting the Numbers:

Below 80: Poor ionization — expect weak or closed high-frequency bands.

Around 150: Good ionization — solid conditions for 20 M to 10 M propagation.

Above 200: Excellent ionization — great for DXing and skip propagation.

304A values often correlate with Solar Flux Index (SFI) and Sunspot Number (SN), but 304A gives a more direct and timely measure of the UV energy that affects HF propagation.

X-Rays from Solar Flares

X-Ray values measure the intensity of solar flares, which are bursts of radiation from the sun that can adversely impact radio propagation.

X-Ray Values and Solar Flares

Classification: Solar flares are categorized by their X-ray intensity into five classes:

- **A, B, C, M, X** — from weakest to strongest. The numeric value (e.g. C6.8) indicates the intensity within the X-Ray Class.

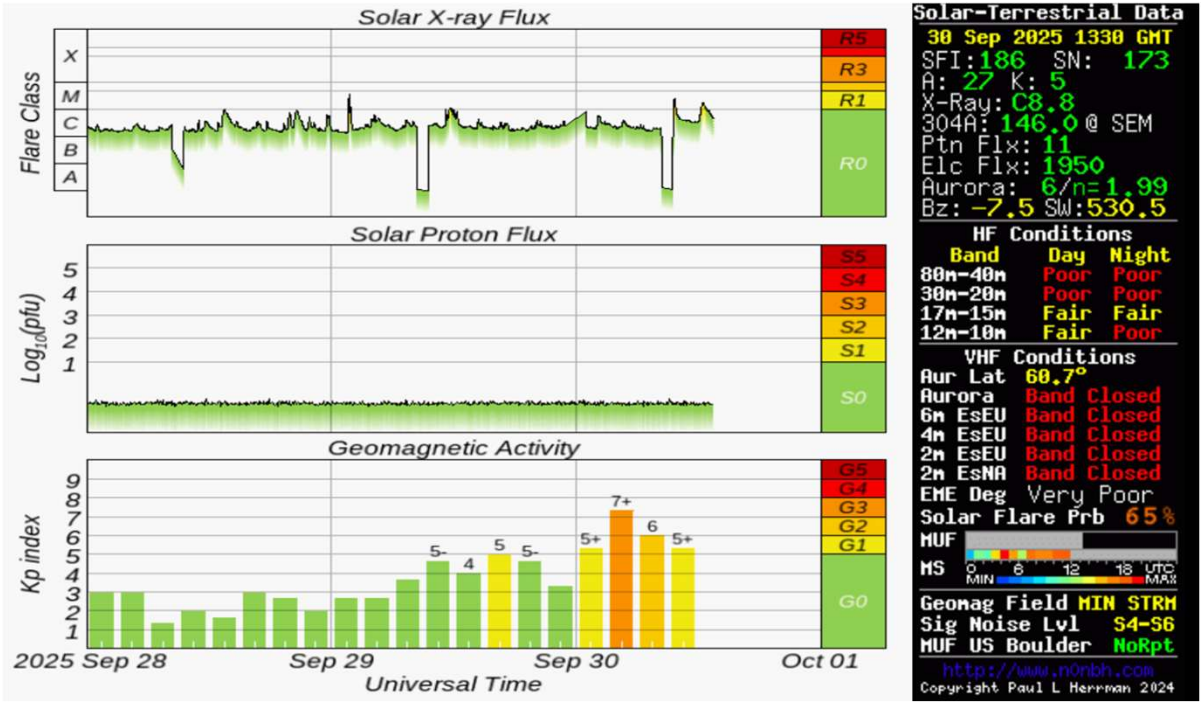
Impact on HF Propagation:

- **C-Class**: Mild impact, usually negligible for HF.
- **M-Class**: Moderate flares that can cause short-term HF blackouts on the sunlit side of Earth.
- **X-Class:** Strong flares that often lead to complete HF signal loss for minutes to hours, especially on lower bands like 80 M and 40 M.

304 Angstroms and X-Ray Summary

- Solar Extreme Ultra Violet (EUV) radiation from sunspots ionize the earth's atmosphere, enabling HF propagation, and is measured by 304 Angstrom (304A).
- X-Rays from Solar Flares, measured as X-Ray Class intensities, increase the ionization of the D-Layer, absorbing HF signals, which is a key reason for blackouts.

X-Ray and K Index Graph



Note: High Solar Proton Flux can degrade HF propagation.

Recap of the Key Solar Measurements

- For better HF Propagation:
  - Look for a high Solar Flux Index (SFI greater than 120).
  - High SFIs will generally not occur near solar cycle minimums.
  - Also look for a high 304 Angstrom (304A) value (150 is a very good value) which measures increasing ionization of the ionosphere, driven by Solar Extreme Ultraviolet (EUV) radiation.
  - Look for a low K Index (K= 0 to 3) for low noise and less signal degradation.
- Beware of X-Ray classes of M and X.
- Increased K Index or X-Ray values can indicate degraded/disrupted HF propagation, resulting in the absorption of HF signals by the D Layer, even though there might be great SFI or 304A measurements.
- Absorption of HF signals by the D Layer, when ionized more by geomagnetic disturbances (K-Index) and solar flares (X-Ray), prevents HF signals from reaching the E, F1, & F2 Layers.

Time Interval of Solar Energy Measurements

- Solar Flux Index (SFI) – Daily Average
- K Index – Every 3 Hours
- A Index – Daily Average
- 304 Angstroms (304A) – Hourly
- X-Ray Flux – Every minute from NASA GOES satellites

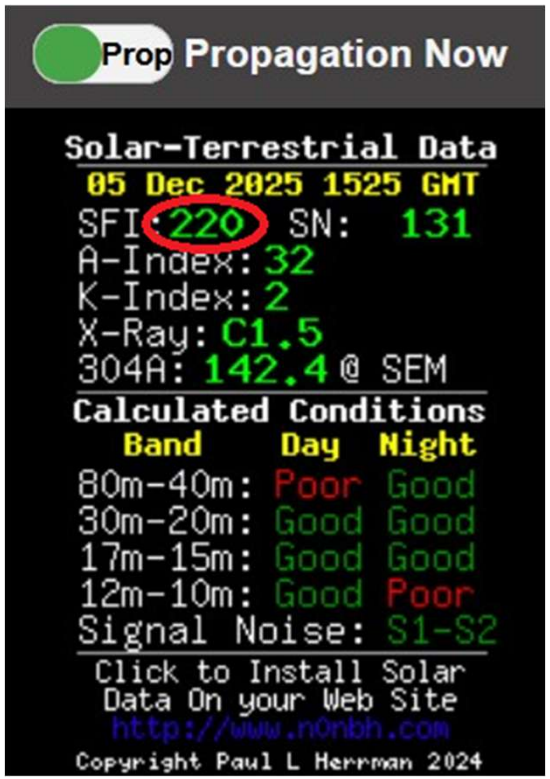
Solar Cycle 25 Maximum

- NASA and NOAA have determined that the peak of Solar Cycle 25 occurred on October 15, 2024
- Cycle 25 has been more active than initially forecasted, exceeding the intensity of Cycle 24
- While the Cycle 25 maximum has been reached, solar activity remains elevated and we can expect months to years of good HF propagation as the cycle gradually declines.
- There could even be an unpredicted second sunspot maximum peak in Cycle 25 coming in 2026.

It’s Not Too Late

- For the next couple of years, there should still be a number of Cycle 25, upper-HF - even 10 Meter, openings to be taken advantage of.
- It’s not too late, especially for Technician licensees who have 10 Meter voice and FT8 privileges, to enjoy these openings.

Propagation Conditions in December



Interactive Solar Measurement Data

https://solarcdx.com/just-the-grid/

Propagation Evaluation Tools

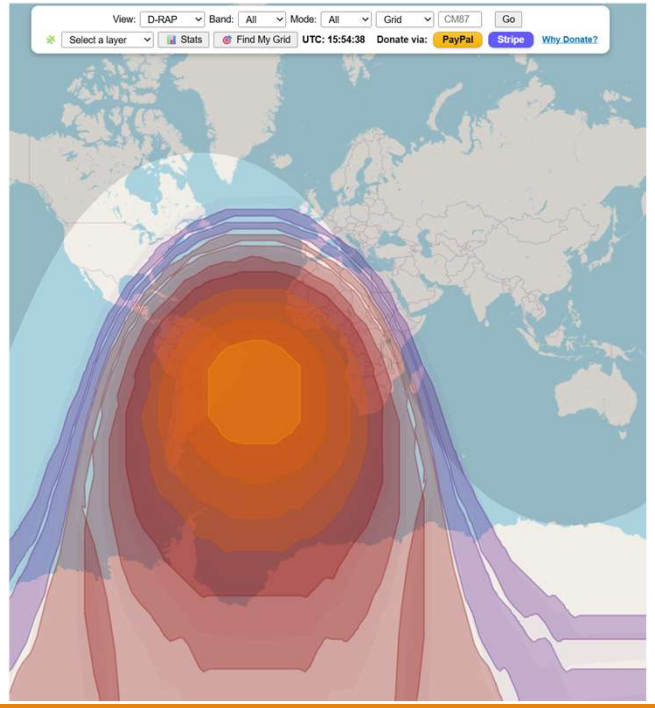
There are a number of tools that can help you evaluate current HF propagation conditions. Locate them by doing an internet search:

- Voice of America Coverage Analysis Program - VOACAP
- Weak Signal Propagation Reporter Network - WSPRnet
- Reverse Beacon Network (RBN) – Global network that spots CQs from CW, RTTY (fewer skimmers available) and FT8 (a separate stream) stations
- PSK Reporter – Digital spotting and mapping
- DXHeat Cluster – propagation maps and band activity visualizations
- WebSDR – listen to HF signals from remote receivers across the world.
- NCDXF/IARU Beacon Network – reporting of HF beacon activity.

HF Absorption Event Prediction Tool

From DXLook - D-Region Absorption Prediction (D-RAP) https://dxlook.com/?view=drapDX

BAND LEGEND



Some Solar Activity References

Space Weather (a wealth of information) - https://hamwaves.com/propagation/en/index.html

NOAA: Space Weather Prediction Center - https://www.swpc.noaa.gov/

NASA: Solar Cycle Progression and Forecast - https://www.nasa.gov/solar-cycle-progression-and-forecast/

Understanding HF Propagation - https://www.youtube.com/watch?v=7Y_RTdPs3NI&t=504s

Dr. Tamith Skov, Space Weather Woman: https://www.youtube.com/@TamithaSkov

ZL4KF: Solar Activity and HF Radio Propagation - https://zl4kf.nz/solar-activity-and-hf-radio-propagation/

D, E, F1, F2 Ionization Layers Explained - https://www.electronics-notes.com/articles/antennas-propagation/ionospheric/ionospheric-layers-regions-d-e-f1-f2.php

Propagation of RF Signals (ARRL) - Propagation of RF Signals

Amateur Radio HF Communications - https://www.sarcnet.org/amateur-radio-hf-communications.html

NOAA 27 Day SFI/K-Index Outlook - https://www.swpc.noaa.gov/products/27-day-outlook-107-cm-radio-flux-and-geomagnetic-indices

Australian Space Weather Forecasting Centre - https://www.sws.bom.gov.au/

Space Weather for Ham Radio

Here are two sites that Steve Stock WA0A recommended:

- Solarham.com
- Go to YouTube.com and search for “SpaceWeatherNews (SO)”

Questions?