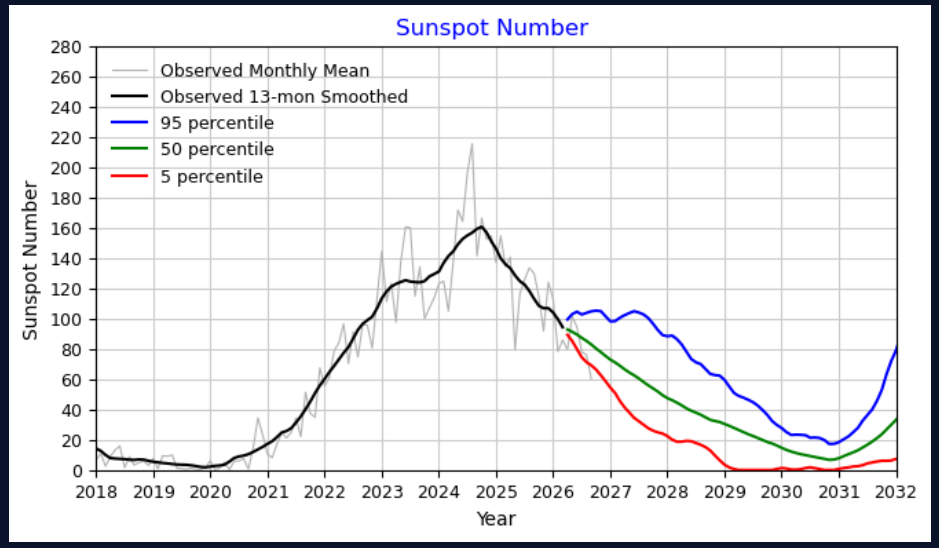
The Sunspot Cycle & Radio Propagation

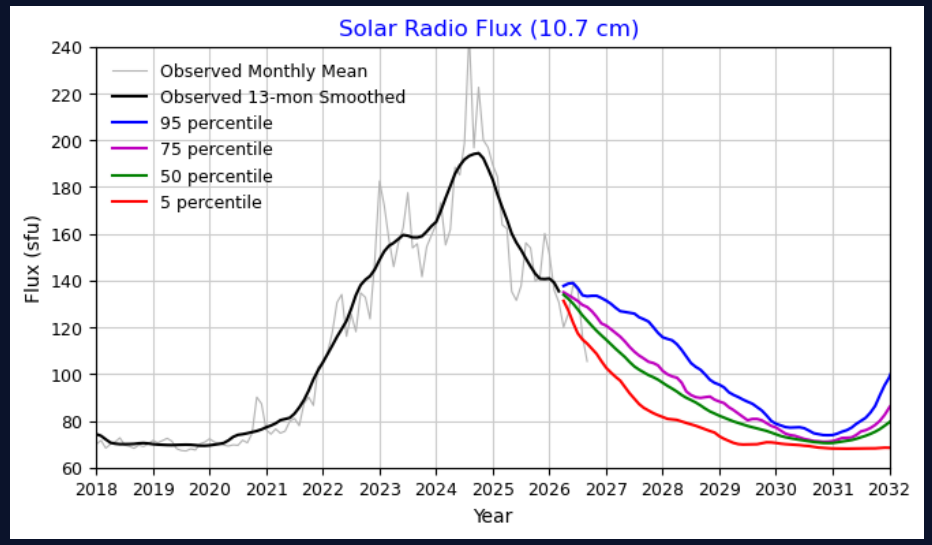
Advanced Technical Data on Ionospheric Indices, MUF Modeling, and Space Weather Impacts

A Guide to Solar Metrics (SFI, K-index, A-index) and Atmospheric Layers

Solar Cycle 25

- **Solar Minimum:** December 2019 marks the official starting boundary of the cycle.
- **The Peak (Solar Maximum):** Achieved an official smoothed sunspot peak of **160.9 in October 2024**, wildly outperforming the initial 2019 NOAA/NASA Panel prediction of a weak 115 peak.
- **Current State (2026 Phase):** Currently entrenched in the **declining phase** heading toward an anticipated next minimum around 2030.
- **Operational Impact:** High HF bands (10m–15m) are increasingly volatile compared to the stable 2024 peak, shifting regular long-distance links down toward mid-tier frequencies.

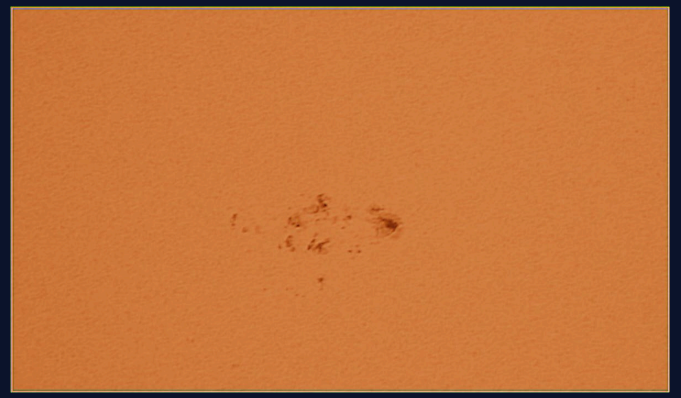




Sun Spots

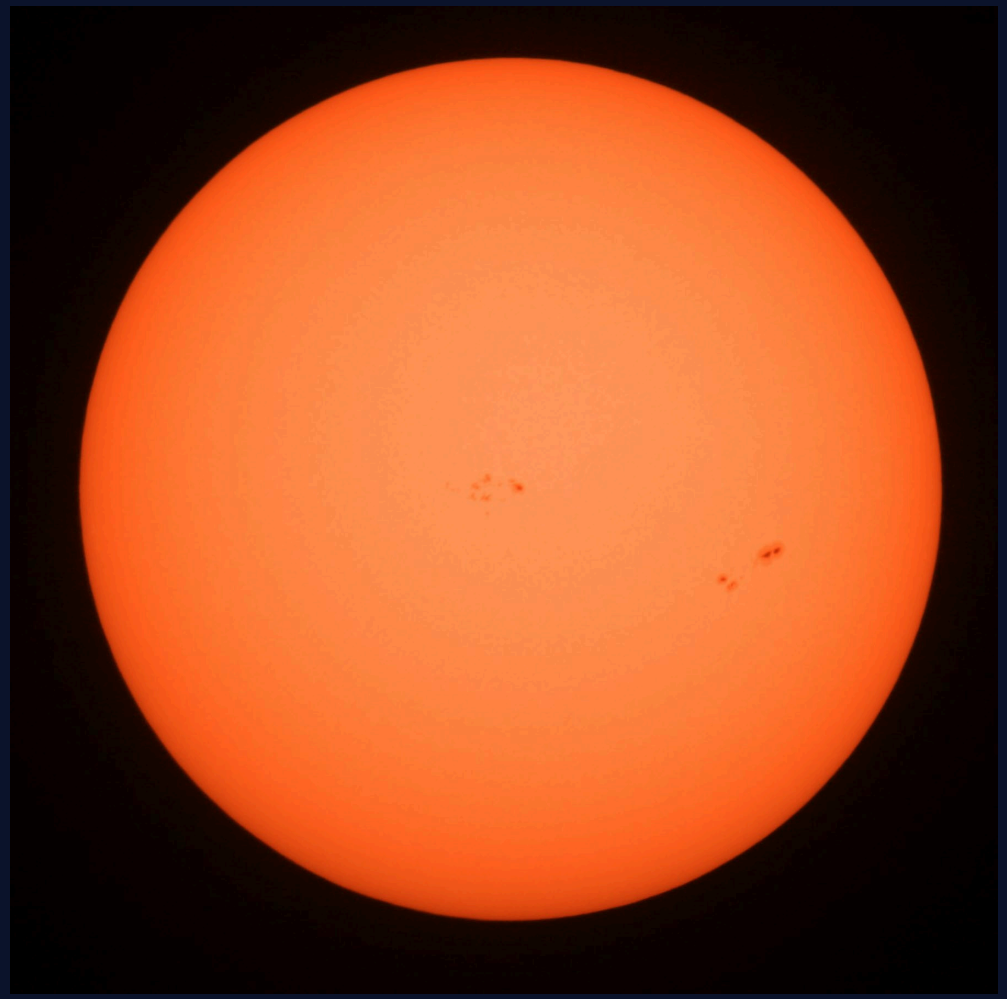
- They are regions of reduced surface temperature (1K to 1.5K °C) caused by concentrations of magnetic flux that inhibit convection. Which results in a darker area, surrounded by a brightened area
- Individual sunspots or groups of sunspots may last anywhere from a few days to a few months
- Sunspot number is correlated with the intensity of solar radiation
- The variation caused by the sunspot cycle to solar output is on the order of 0.1% of the solar constant
- Due to their correlation with other kinds of solar activity, sunspots can be used to help predict space weather, the state of the ionosphere, and conditions relevant to short-wave radio propagation





Stuart’s Telescope





Sun seen on October 17, 2026

Core Space Weather Indices

Solar Flux Index (SFI)

- Measures solar radio emissions at a wavelength of 10.7 cm (2800 MHz).
- Acts as a direct proxy for extreme ultraviolet (EUV) radiation levels.
- Scale range: ~65 (absolute minimum) to over 300 (extreme maximum).
- SFI > 150 provides exceptional ionization for upper HF bands (10m-17m).

Geomagnetic Activity: K & A Indices

- K-Index: A quasi-logarithmic local index updated every 3 hours (scales 0 to 9). Measures geomagnetic field instability.
- Comes in 2 versions, K and Kp (planetary average)

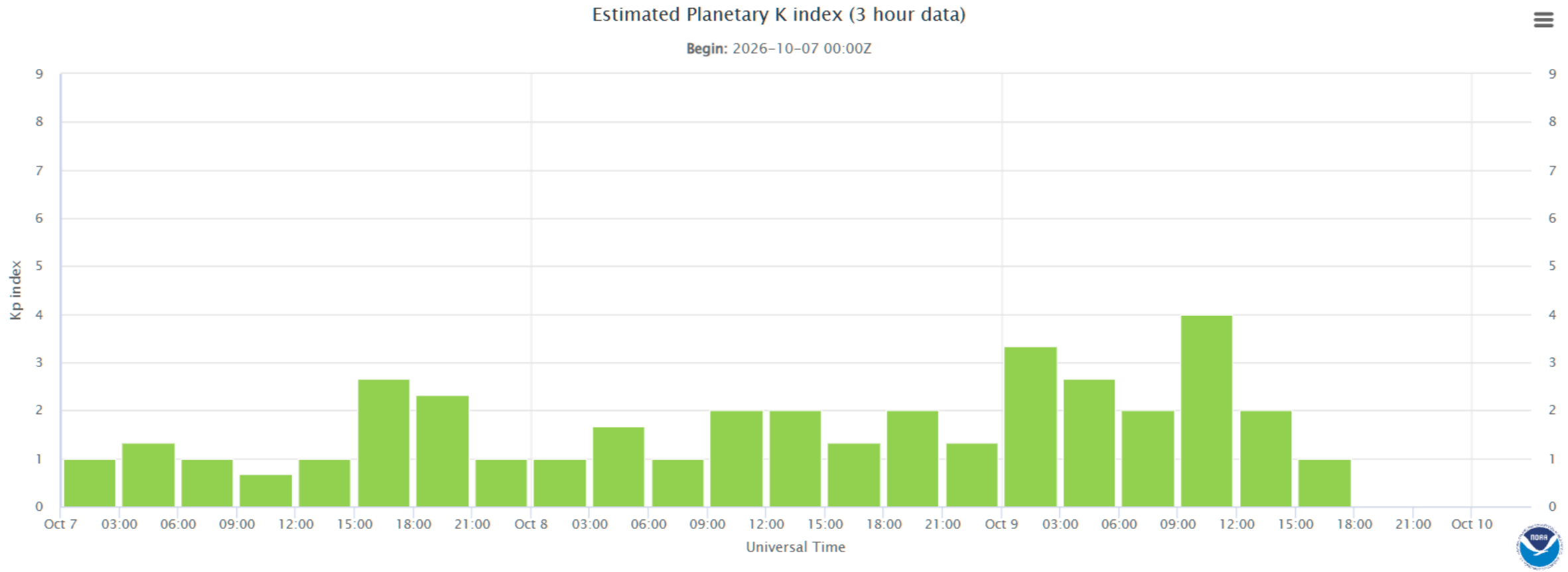
  Sitka, Alaska; Meanook, Canada; Ottawa, Canada; Fredericksburg, Virginia; Hartland, UK; Wingst, Germany; Niemegk, Germany; and Canberra, Australia

- A-Index: A linear daily average derived from the 3-hour K-indices (scales 0 to 400).
- Quiet vs Storm Thresholds: K-indices below 3 imply stable, quiet conditions. K >= 5 indicates a geomagnetic storm, threatening ionospheric stability.

CURRENT SPACE WEATHER CONDITIONS on NOAA Scales

R none | S none | G none

PLANETARY K-INDEX



Updated Time: 2026-10-09 15:00Z

NOAA Scales Geomagnetic Storms

Kp < 5	Kp = 5 (G1)	Kp = 6 (G2)	Kp = 7 (G3)	Kp = 8, 9- (G4)	Kp = 9o (G5)

Ionospheric Stratification & Physics

D-Layer (60–90 km):

Exclusively daytime layer. It possesses high neutral density that acts as an attenuator/absorber for HF signals. Frequencies below 7 MHz suffer heavy daytime attenuation here.

Ionized by hard x-rays(1-10 angstroms, 300 PHz to 3 EHz) (.1 to 1 nanometer)

E-Layer (90–150 km):

Medium density layer. Enables daytime skip up to 2,000 km. Prone to 'Sporadic E' occurrences—intense patches of anomalous cloud ionization that can reflect VHF signals up to 150 MHz.

Ionized by soft X-rays (10-100 angstroms, 30 PHz to 300 PHz)

F-Layer (150–400+ km):

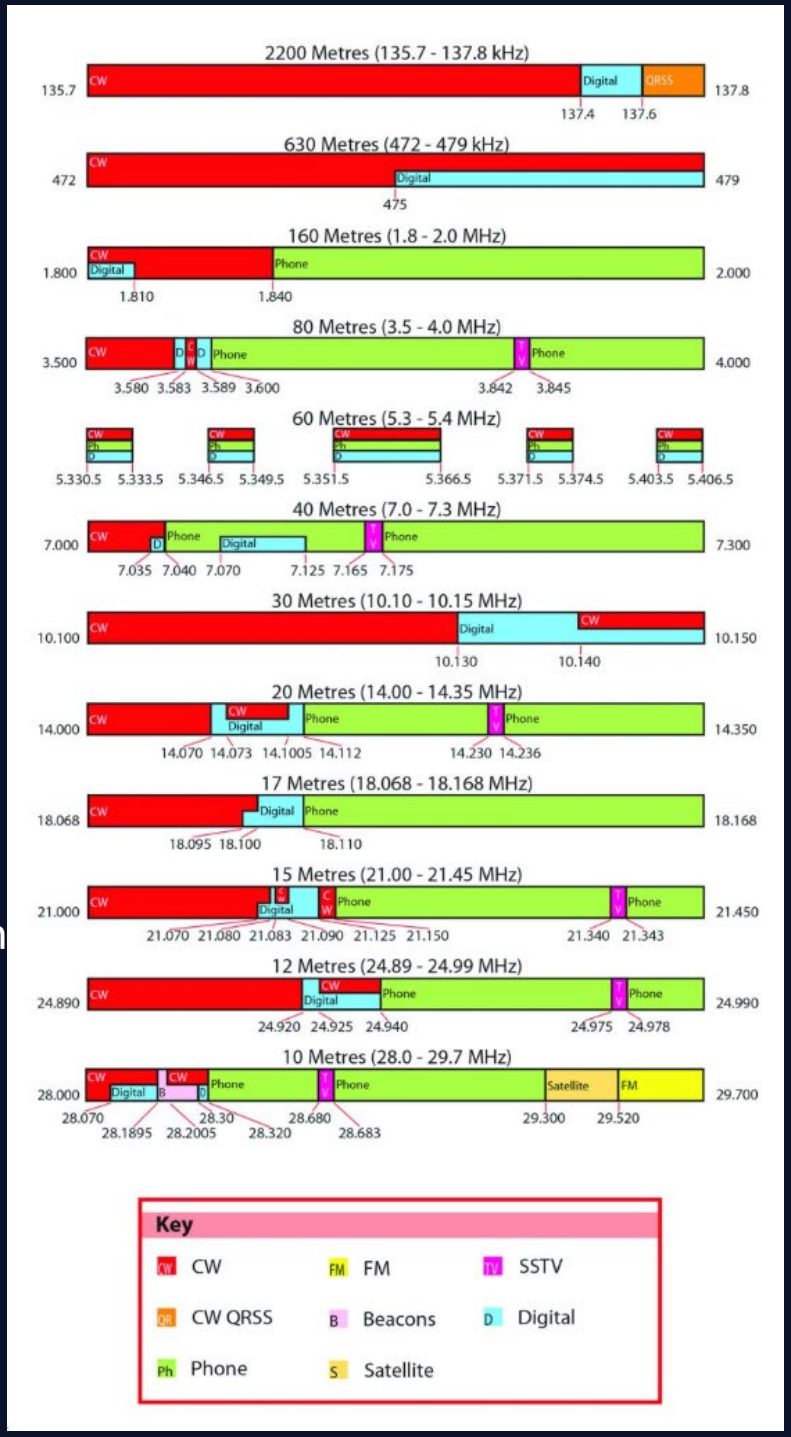
The critical layer for long-haul global communication. Splits during the day into F1 (lower) and F2 (higher, densest layer). Recombines at night into a single F-layer, changing skip behavior.

Ionized by UV light (100-1000 angstroms, 3 PHz to 30 PHz)

There are no A, B, or C layers in the ionosphere; the official layers begin with the **D**, **E**, and **F** regions.
Sir Edward Appleton (who discovered the layers in the 1920s) originally used the letter **E** to stand for the **electric vector** of the down-coming radio waves he was measuring. He left **A, B, C, and D** open on his diagrams in case lower or higher layers were found later. When a lower ionized layer was discovered later, it was named the **D layer**, and the layer above the E layer became the **F layer**.

ITU Radio Frequency Bands

- **ELF (Extremely Low Frequency)**: 3 Hz to 30 Hz (Scientific research)
- **SLF (Super Low Frequency)**: 30 Hz to 300 Hz (Scientific research)
- **ULF (Ultra Low Frequency)**: 300 Hz to 3 kHz (Scientific research)
- **VLF (Very Low Frequency)**: 3 to 30 kHz (Navigation, military communication)
- **LF (Low Frequency)**: 30 to 300 kHz (Navigation, specialty communication)
- **MF (Medium Frequency)**: 300 kHz to 3 MHz (AM radio)
- **HF (High Frequency)**: 3 to 30 MHz (Shortwave radio)
- **VHF (Very High Frequency)**: 30 to 300 MHz (FM radio, short-range communication)
- **UHF (Ultra High Frequency)**: 300 MHz to 3 GHz (Wi-Fi, cellular, commercial communication)
- **SHF (Super High Frequency)**: 3 to 30 GHz (Radar, cellular, satellite communication
- **EHF (Extremely High Frequency)**: 30 to 300 GHz (Cellular, scientific research)
- **THF (Tremendously High Frequency)**: 300 GHz to 3 THz (Scientific research)
- 3 to 30THz
- 30 to 300THz
- 300THz to 3PHz
- 3 to 30PHz (UV Light)



The RF Operating Window: MUF vs. LUF

Critical Frequency (foF2): The highest frequency sent straight up vertically that returns to Earth. Bending capacity scales proportionally with the square root of peak electron density.

Maximum Usable Frequency (MUF): The ceiling for practical oblique-angle propagation paths. Calculated roughly as: MUF = foF2 / cos(theta), where theta is the angle of incidence. Rising sunspot counts dramatically push MUF upward.

Lowest Usable Frequency (LUF): The floor determined by D-layer RF absorption. If solar activity spikes too sharply, the LUF rises and can cross above the MUF, completely shutting down the communication window.

Optimum Working Frequency (OWF / FOT): The sweet spot for communications, generally targeted at 85% of the calculated MUF to provide safety margins against sudden ionospheric fluctuations.

Classifying Solar Disruptions

Solar Flare Classifications: Classified logarithmically by peak X-ray flux (0.1 to 0.8 nm wavelength) near Earth into classes: A, B, C, M, and X. X-class flares unleash extreme energy that immediately triggers Sudden Ionospheric Disturbances (SIDs) and daytime HF blackouts.

Sudden Ionospheric Disturbances (SIDs): Hard X-ray photons strike the D-layer, boosting electron density rapidly. Lower frequencies are absorbed first, creating a rolling HF radio blackout.

Coronal Mass Ejections (CMEs) & Kp Index: Massive plasma eruptions arrive 24 to 72 hours post-flare. They squash Earth's magnetosphere, driving planetary K-indices (Kp) to 7, 8, or 9, leading to auroral flutter, deep signal fading, and polar path blackouts.

HF Spectrum Propagation Profiles

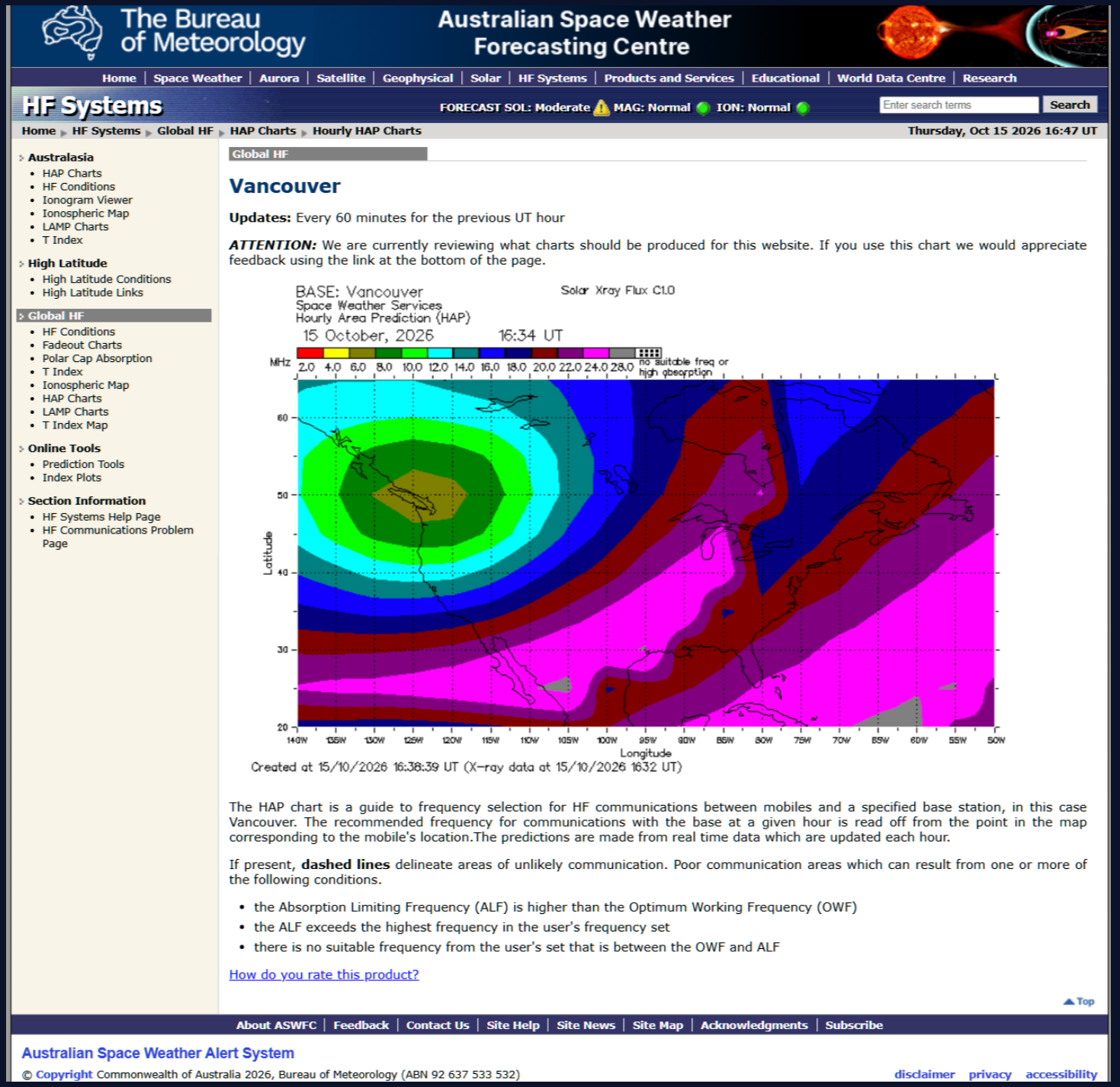
Band Group	Solar Maximum Profile	Solar Minimum Profile	Primary Technical Driver
Low HF (160m - 40m)	High daytime D-layer loss. Excellent long-range nighttime paths.	Reduced daytime absorption. Unrivaled, ultra-quiet nighttime skip.	D-Layer daytime absorption & noise floors.
Mid HF (30m - 20m)	Open 24 hours a day. Global DX capabilities round the clock.	Closes tightly at night. Reliable daylight skip paths remain.	F2 layer critical ionization thresholds.
High HF (15m - 10m)	Consistent worldwide daytime DX. Extreme long-distance skip.	Remains dead or closed for weeks at a time.	Direct SFI correlation (>120 required for 10m).
VHF Crossing (6m / 50 MHz)	F2 layer propagation opens intermittently for global paths.	F2 skip impossible; relies strictly on seasonal Sporadic-E.	Extreme solar ultraviolet radiation spikes.

Summer Doldrums

Primary Causes

- **Increased D-Layer Absorption:** Stronger summer solar radiation increases ionization in the lower D-layer (50 to 90 km altitude). This layer absorbs lower-frequency HF signals (especially below 10 MHz) rather than bending them back to Earth.
- **F-Layer Expansion and Reduced Density:** Intense summer heat causes the F2-layer to expand upward. As it spreads out, its electron density decreases, making it less efficient at refracting radio waves over long distances.
- **F1-Layer and E-Layer Blanketing:** Summer brings an active F1-layer and high E-layer ionization. These lower layers act as a "blanket" that absorbs or reflects higher-angle signals prematurely, blocking them from reaching the higher F2-layer needed for long-haul skip.
- **Higher Atmospheric Noise (QRN):** Increased thunderstorm and lightning activity during summer months drastically raises static noise levels on lower HF bands. [1]
- **Sporadic E (Es) Disruption:** While Sporadic E opens up short-skip contacts on higher bands like 6 meters, dense Es clouds can bounce signals locally and disrupt standard multi-hop HF DX paths.

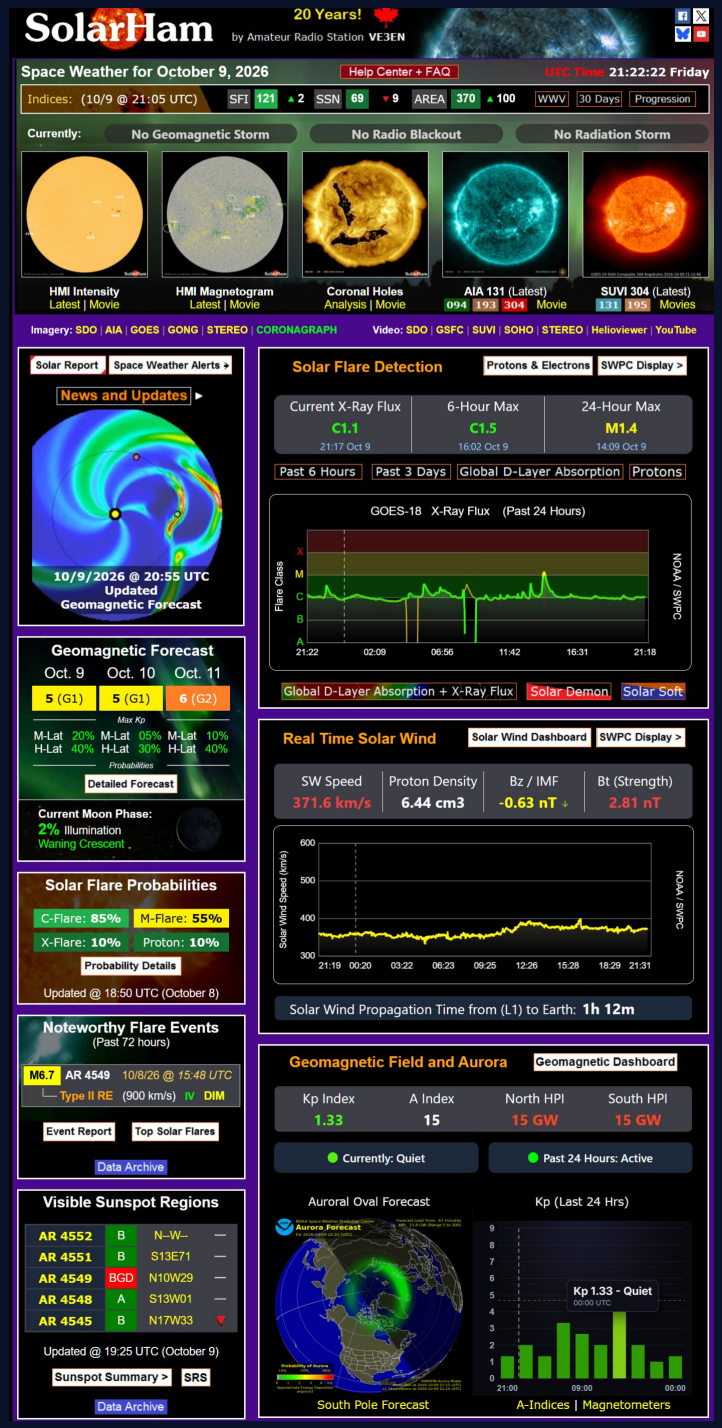
- Overview of best band to use for communications from *Vancouver*
- Selecting *Seattle* will display propagation across the Pacific and Europe



SolarHam Website

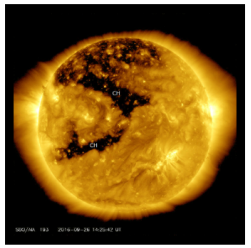
- **Purpose:** Real-time data aggregator built explicitly for amateur radio operators, aviation planners, and emergency communication nets.
- **Solar X-Ray Flux Monitoring:** Tracks live GOES satellite signatures (C, M, X-Class flares) to detect immediate Sudden Ionospheric Disturbances (SIDs).
- **Magnetometer Data Tracking:** Measures real-time planetary geomagnetic stability via live estimated 3-hour Kp-index readings.
- **Solar Region Mapping:** Isolates active sunspot clusters facing Earth to forecast geoeffective solar wind streams. [1]

Practical Application: Operators look at the SolarHam Live Dashboard to determine if an empty radio band is dead due to lack of solar ionization or completely blanked out by a solar flare blackout.



Welcome to the SolarHam Help Center

Below you will find an explanation of frequently used terms regarding space weather used on the SolarHam website.
Please note that this section is currently being built and will contain more information and answers to frequently asked questions soon.



Coronal Hole (CH)

A **coronal hole** is an opening in the Sun's atmosphere associated with open magnetic field lines. High-speed solar winds originate from within these holes which appear as dark zones when viewed at different optical wavelengths. Coronal holes can occur at any time during a solar cycle, but are typically larger and more frequent towards solar maximum.



CME captured by LASCO C2

Coronal Mass Ejection (CME)

A **coronal mass ejection (CME)** is an eruption of material from the solar corona, observed with a white-light coronagraph.

The material consists of plasma made up primarily of electrons and protons (in addition to small quantities of heavier elements such as helium, oxygen, and iron), plus the entrained coronal magnetic field. When the plasma cloud sweeps past the Earth as an ICME (Interplanetary CME), it may disrupt the Earth's magnetosphere, compressing it on the dayside and extending the nightside tail. When the magnetosphere reconnects on the nightside, it creates trillions of watts of power which is directed back towards the Earth's upper atmosphere. This process is responsible for a particularly strong light show known as the aurora borealis or northern lights in the northern hemisphere and the aurora australis or southern lights in the Southern Hemisphere. CME events, along with solar flares, can disrupt radio transmissions, trigger geomagnetic storms that can in rare instances, cause damage to satellites and electrical transmission lines.

Geomagnetic Storm

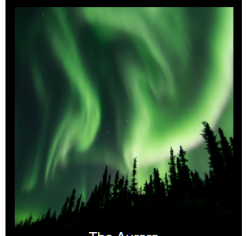
A **geomagnetic storm** is a major disruption of Earth's magnetosphere. When unusually strong surges of solar wind (charged particles from the Sun) sweep past Earth, this effect causes variations in the magnetic field which surrounds the planet. Geomagnetic storms can cause disruptions to high frequency (HF) radio communications through the polar zones, GPS positioning errors, and is also responsible for the northern and southern lights. In extreme cases, voltage control related damage can be inflicted upon power grid transmission lines and lead to power blackouts.

NOAA / SWPC classifies geomagnetic storms on a level ranging between **G1** (minor), **G2** (Moderate), **G3** (Strong), **G4** (Severe) and **G5** (Extreme).

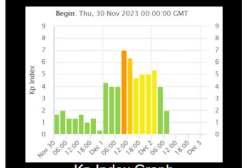
For full impacts, click on the SWPC grid below.

Scale	Description	Effect	Physical measure	Average Frequency (1 cycle = 11 years)
G 5	Extreme	**Power systems:** Widespread voltage control problems and protective system problems can occur, some grid systems may experience complete collapse or blackouts. Transformers may experience damage. **Spacecraft operations:** May experience extensive surface charging, problems with orientation, uplink/downlink and tracking satellites. **Other systems:** Pipeline currents can reach hundreds of amps, HF (high frequency) radio propagation may be impossible in many areas for one to two days, satellite navigation may be degraded for days, low-frequency radio navigation can be out for hours, and aurora has been seen as low as Florida and southern Texas (typically 40° geomagnetic lat.).	Kp = 9	4 per cycle (4 days per cycle)
G 4	Severe	**Power systems:** Possible widespread voltage control problems and some protective systems will mistakenly trip out key assets from the grid. **Spacecraft operations:** May experience surface charging and tracking problems, corrections may be needed for orientation problems. **Other systems:** Induced pipeline currents affect preventive measures, HF radio propagation sporadic, satellite navigation degraded for hours, low-frequency radio navigation disrupted, and aurora has been seen as low as Alabama and northern California (typically 45° geomagnetic lat.).	Kp = 8, including a 9-	100 per cycle (60 days per cycle)
G 3	Strong	**Power systems:** Voltage corrections may be required, false alarms triggered on some protection devices. **Spacecraft operations:** Surface charging may occur on satellite components, drag may increase on low-earth-orbit satellites, and corrections may be needed for orientation problems. **Other systems:** Intermittent satellite navigation and low-frequency radio navigation problems may occur, HF radio may be intermittent, and aurora has been seen as low as Illinois and Oregon (typically 50° geomagnetic lat.).	Kp = 7	200 per cycle (130 days per cycle)
G 2	Moderate	**Power systems:** High-latitude power systems may experience voltage alarms, long-duration storms may cause transformer damage. **Spacecraft operations:** Corrective actions to orientation may be required by ground control; possible changes in drag affect orbit predictions. **Other systems:** HF radio propagation can fade at higher latitudes, and aurora has been seen as low as New York and Idaho (typically 55° geomagnetic lat.).	Kp = 6	600 per cycle (360 days per cycle)
G 1	Minor	**Power systems:** Weak power grid fluctuations can occur. **Spacecraft operations:** Minor impact on satellite operations possible. **Other systems:** Migratory animals are affected at this and higher levels; aurora is commonly visible at high latitudes (northern Michigan and Maine).	Kp = 5	1700 per cycle (900 days per cycle)

NOAA/SWPC

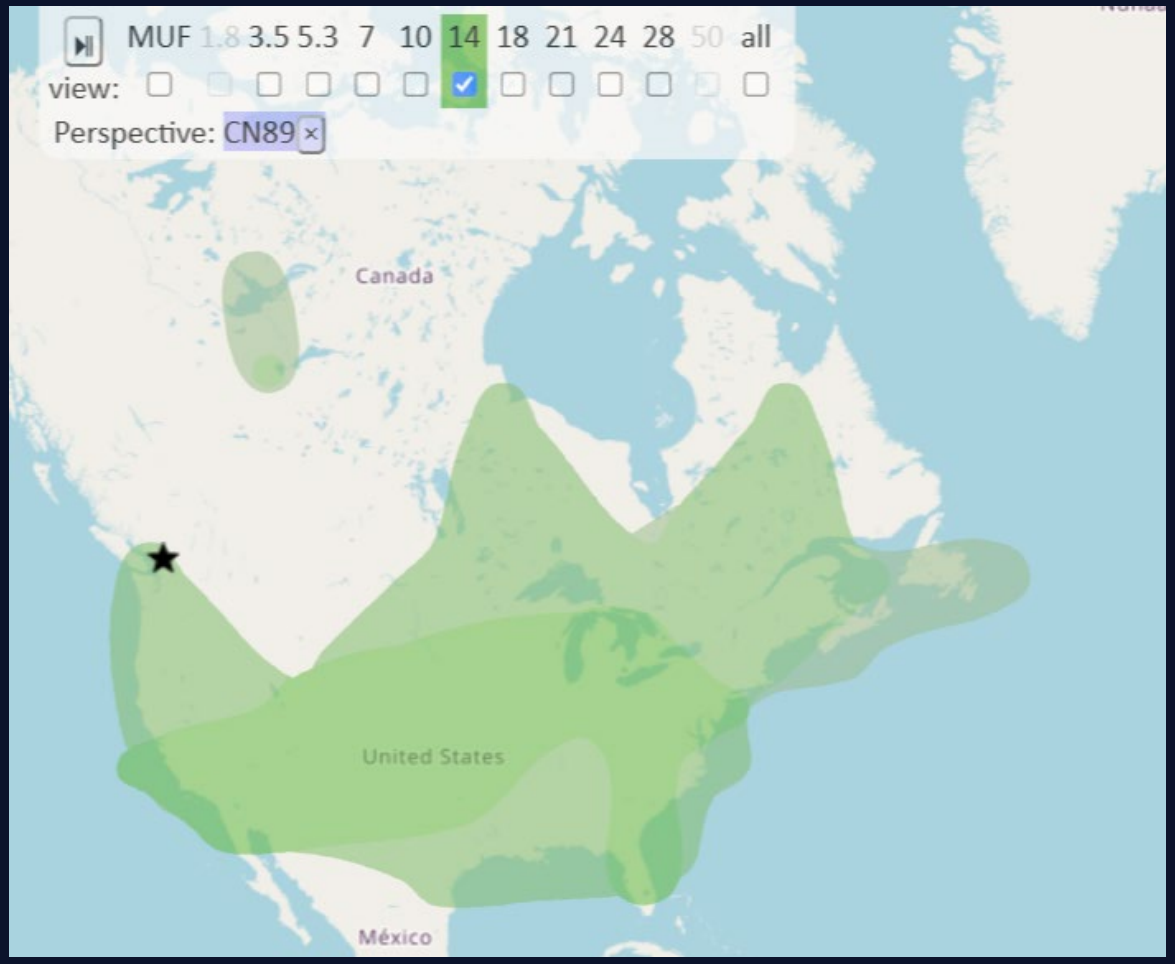


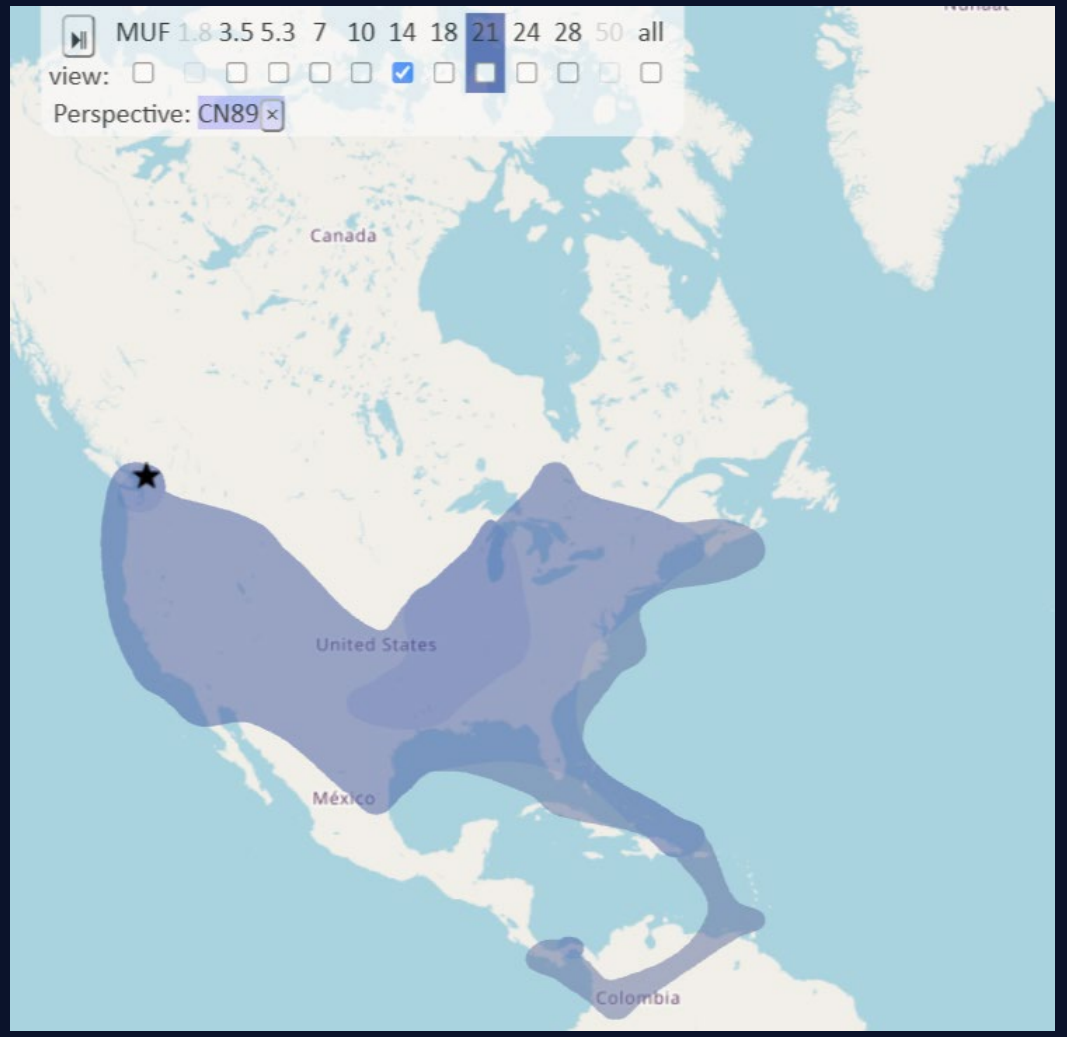
The Aurora



Kp Index Graph

MUF World Map





AI Joke for the Session

- **"Why did the HF radio operator break up with the sun?"**
- **"Because every time things started getting exciting, the sun threw a flare, had a total coronal mass ejection, and completely blacked out the relationship!"**