The Invisible Highway

Mastering HF Propagation

Presentation to Cabarrus ARS – May 2026

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The ionosphere giveth, and the ionosphere taketh away.

Presentation Goals:

- ✓ Demystify HF propagation
- ✓ Comprehensive – Cover all facets
- ✓ Appropriate technical depth
  - *No, I will not drown you in ionospheric physics equations*
  - *No, this will not be a graduate-level plasma physics lectures*

*** *PDF available for download on CARS-NC.org*

What we will Cover:

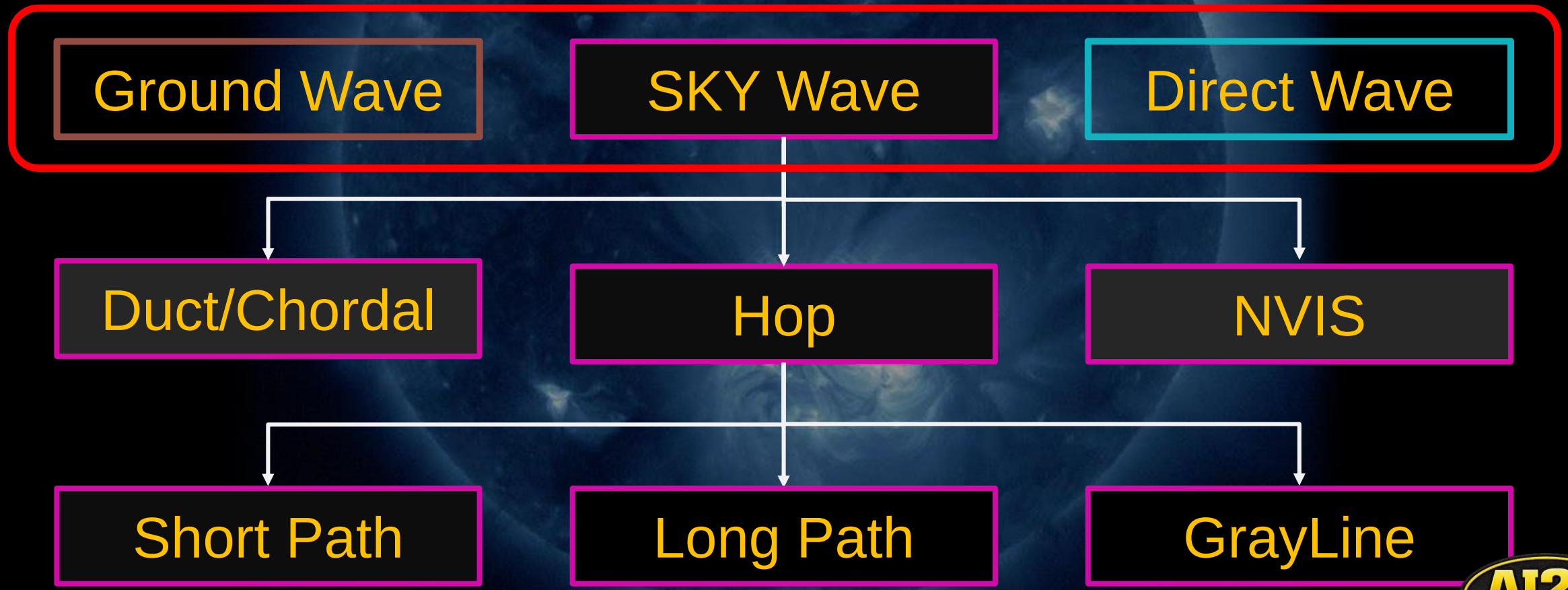
- Ionosphere
- Propagation Foundations
- Understanding the Sun
- Propagation Modes
- Band Specifics
- Tools

Mastering HF propagation is often the deciding factor in whether you land a rare DX contact or find yourself calling into a closed band.

Propagation Modes

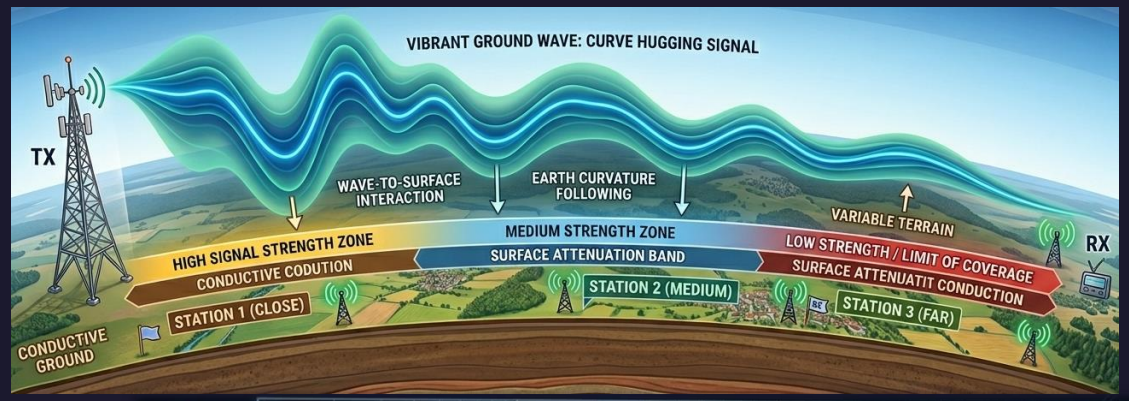
Communications possible over thousands of miles

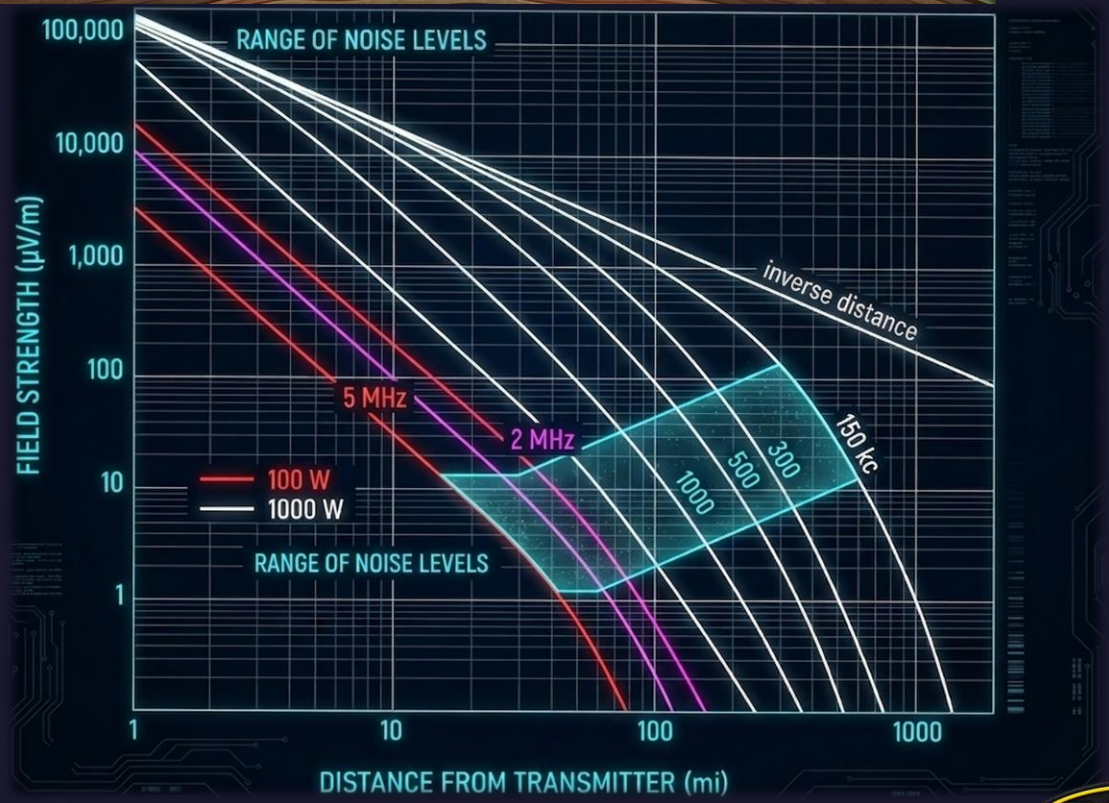
Highly Variable – Daily, Seasonal and Solar 11y Cycles



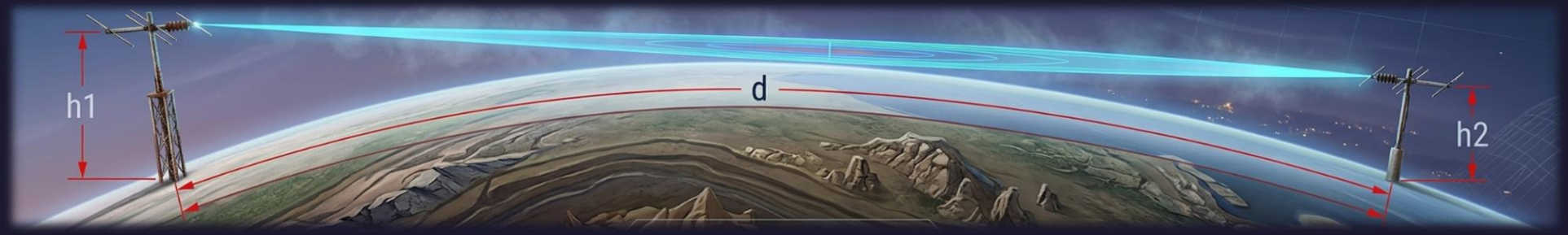
Ground Waves

- Surface wave
- They “hug” the ground
- Think - spilling water on the floor
- Surface conductivity dependent
- Possible on 160m and 80m
- 50 miles max range on 80m
- 5MHz max
- Always vertically polarized!





Direct Waves - i.e. Line of Sight



$$D\ (\text{mi}) \approx 1.415 \cdot (\sqrt{h_1\ (\text{ft})} + \sqrt{h_2\ (\text{ft})})$$

- Both antennas must have low launch angle
- Thus, practically limited to 20m – 10m – think CB
- Any polarization can be used
- Range determined by antenna height and obstacles

Sky Wave – The Long Range Mode

- Made possible by Ionosphere
- Any polarization can be used
- Supports many sub-modes

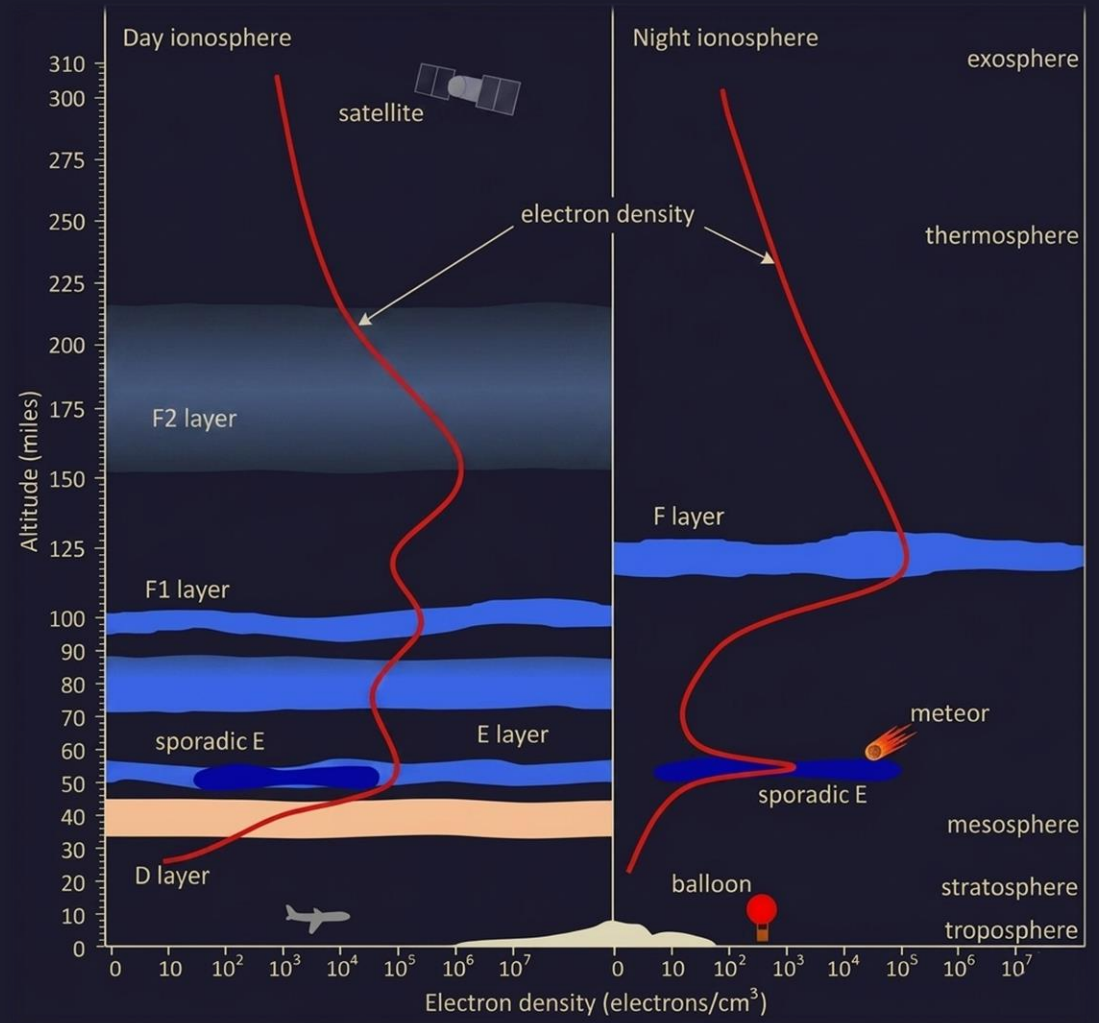
Worldwide communication is achievable across most of the day, provided you know which band to utilize for a given path!

The Ionosphere

- In simple terms, it reflects (more accurately, refracts) the radio waves
- Free Electrons
- Created by ionization by the Sun (EUV)
- Reflects, Bends and Attenuates HF radio waves
- Mostly transparent above VHF

Layer Formations

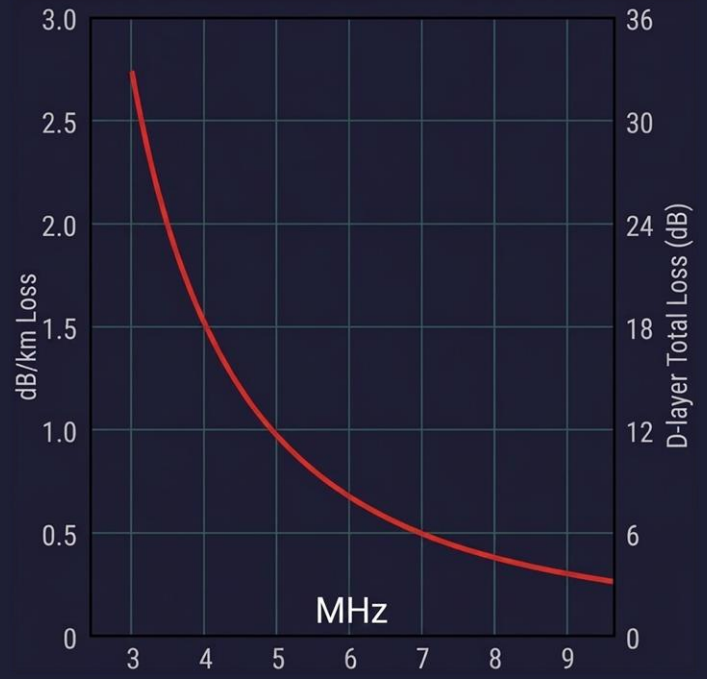
- Created by EUV ionization by the Sun
- Not all layers disappear at night:
  - D and E disappear very quickly
  - F1 and F2 do not disappear, but merge into F layer
  - F layer persists until the dawn

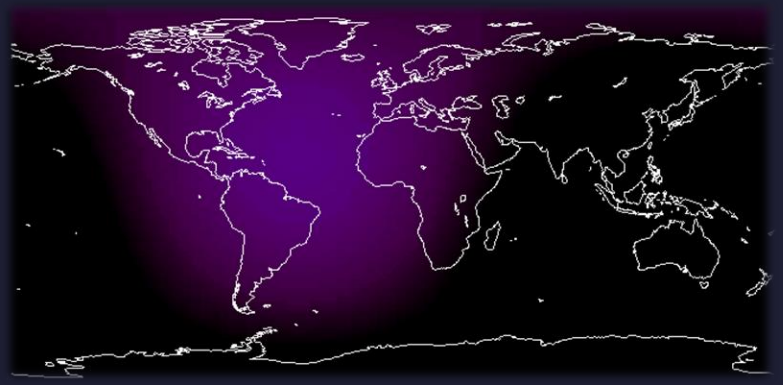


Note: EUV – Extreme UV radiation (10-120nm), ~50-100x more energetic than UVB on the beach

The D-Layer – The Sponge

- Extends from 40 – 55 miles high (15 miles thick)
- e^- density too low to act as a refractor
- Acts as an Attenuator! Negative role in HF
- Frequency dependent
- Created at sunrise by EUV from the Sun
- Maximum effect at noon
- Mostly dissipates immediately after sunset
- X-Rays greatly strengthen it

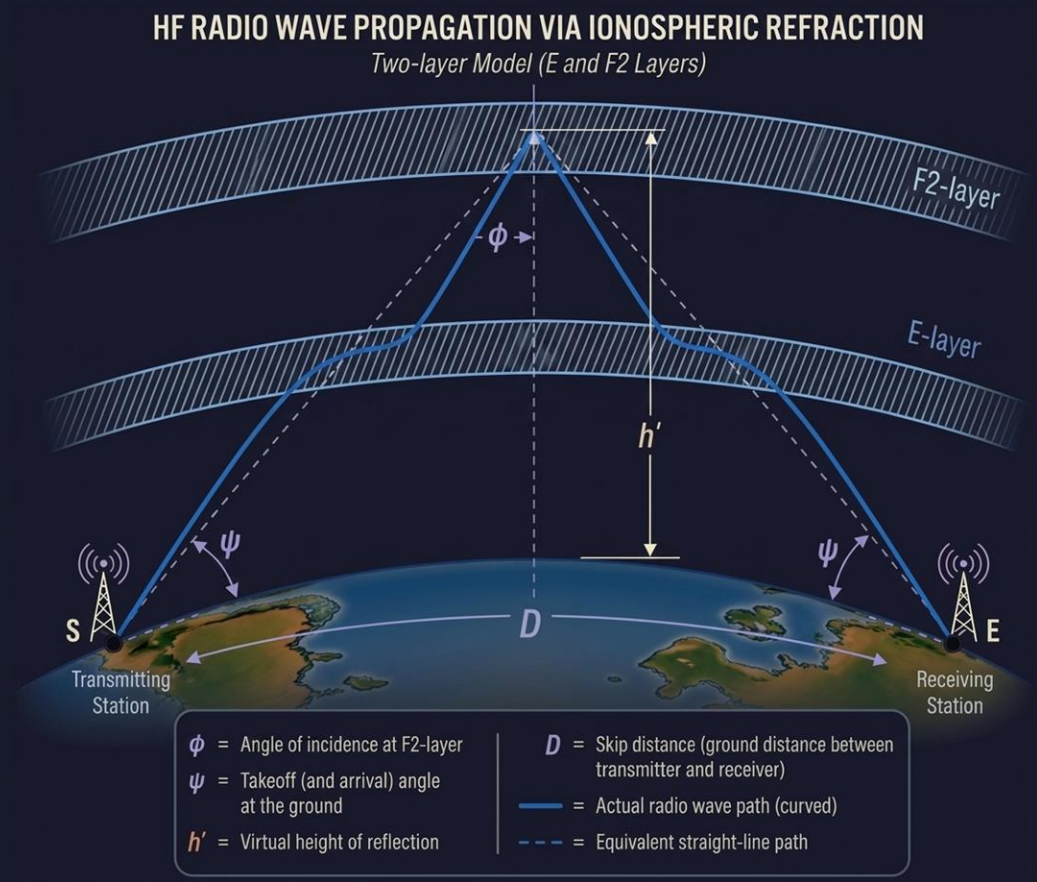




The E-Layer – the Leaky Mirror

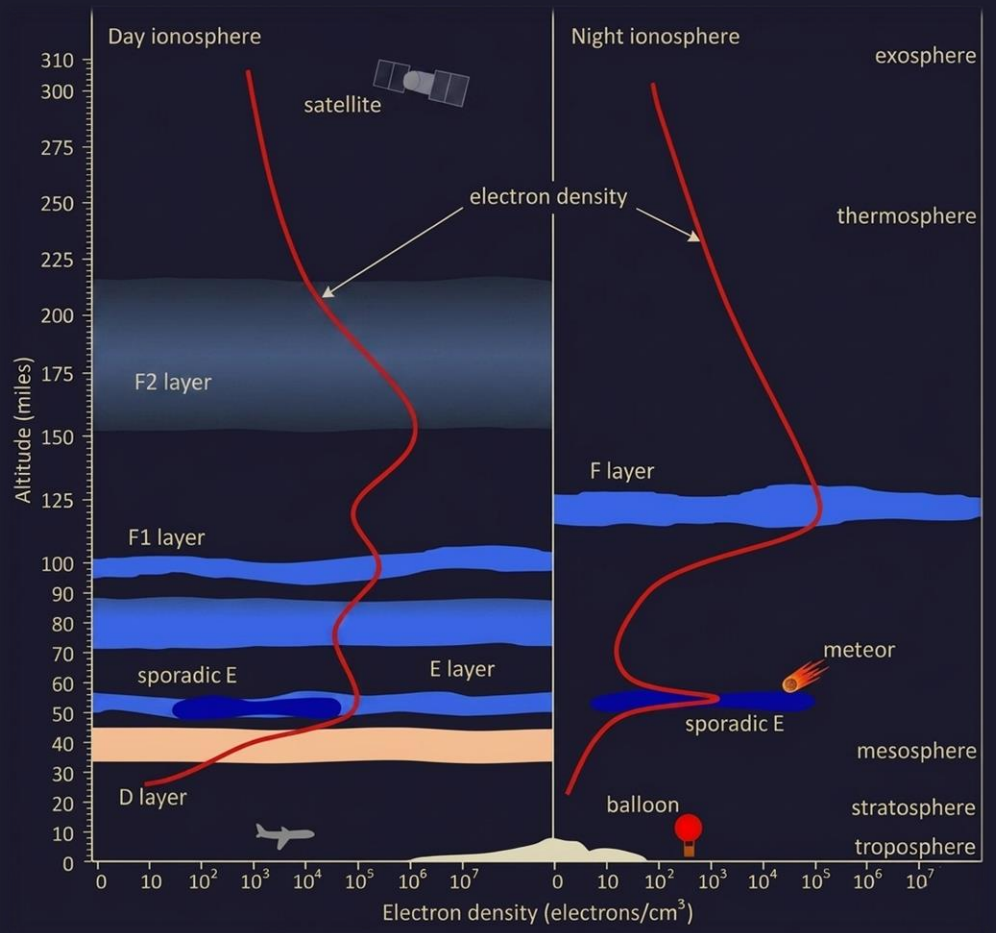
- Extends from 55 – 95 miles high
- Touches D layer - transition between D to E is a gradient. Very different D to E behavior!
- Bends lower frequencies for short hops but lets higher frequencies pass thru to F layer
- E-layer will 'reflect' waves below f_0E (<4MHz)
- E-layer can refract and bend radio waves, most pronounced below 5-10 MHz, with very little attenuation

Mostly used for short range HF communications

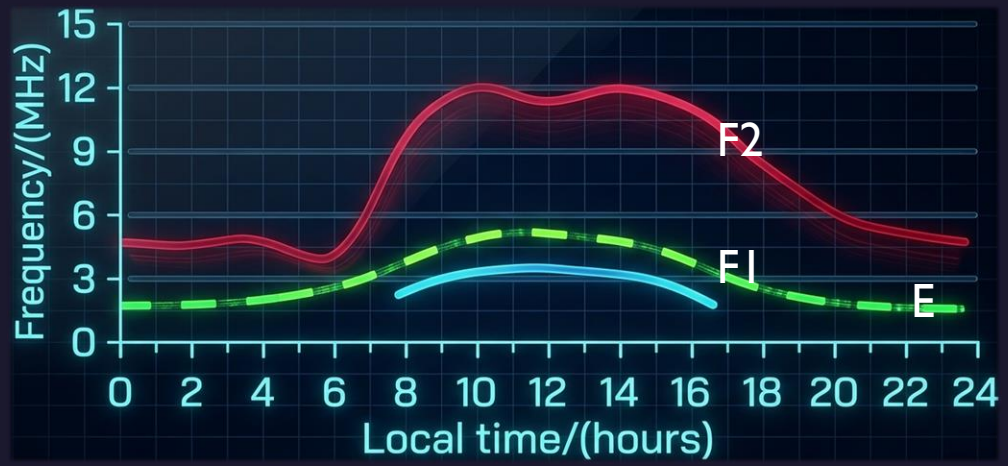


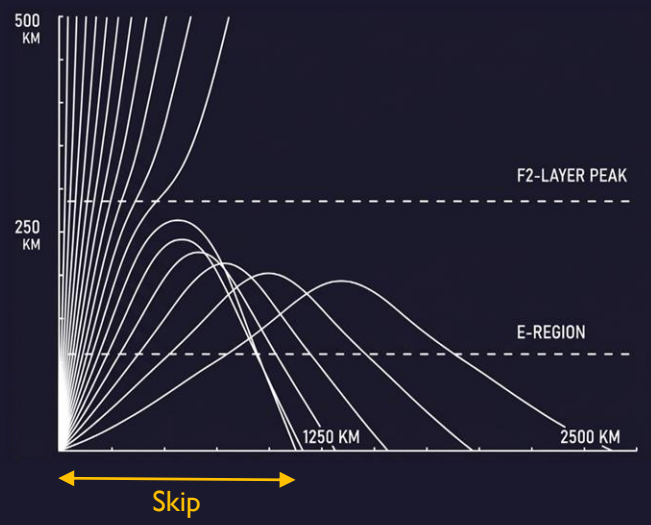
The F-Layer – the DX Mirror

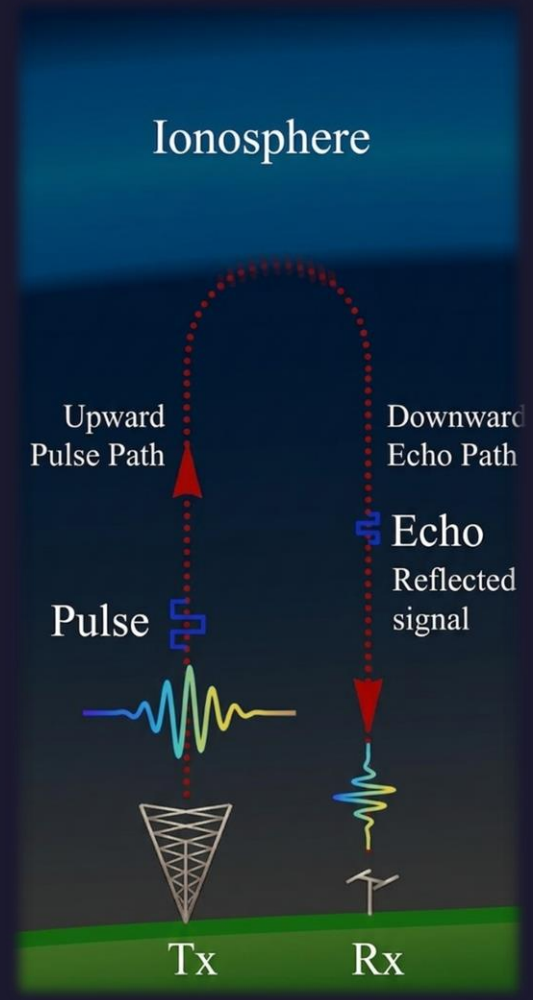
- Most important & highest electron density layer(s)
- Topmost in Ionosphere. Long recombination time!
- Daytime: F1 and F2, at night merge into F
- F1 behaves similarly to E layer
- F2 is a great 'Reflector' – "the DX mirror"
- At night the F layer is:
  - Transparent to top bands, sometimes even 20m
  - Low Band DX Heaven: 160m, 80m, and 40m become your primary DX workhorses
  - About an hour before sunrise, the F layer is at its weakest



Critical Frequency and Angle

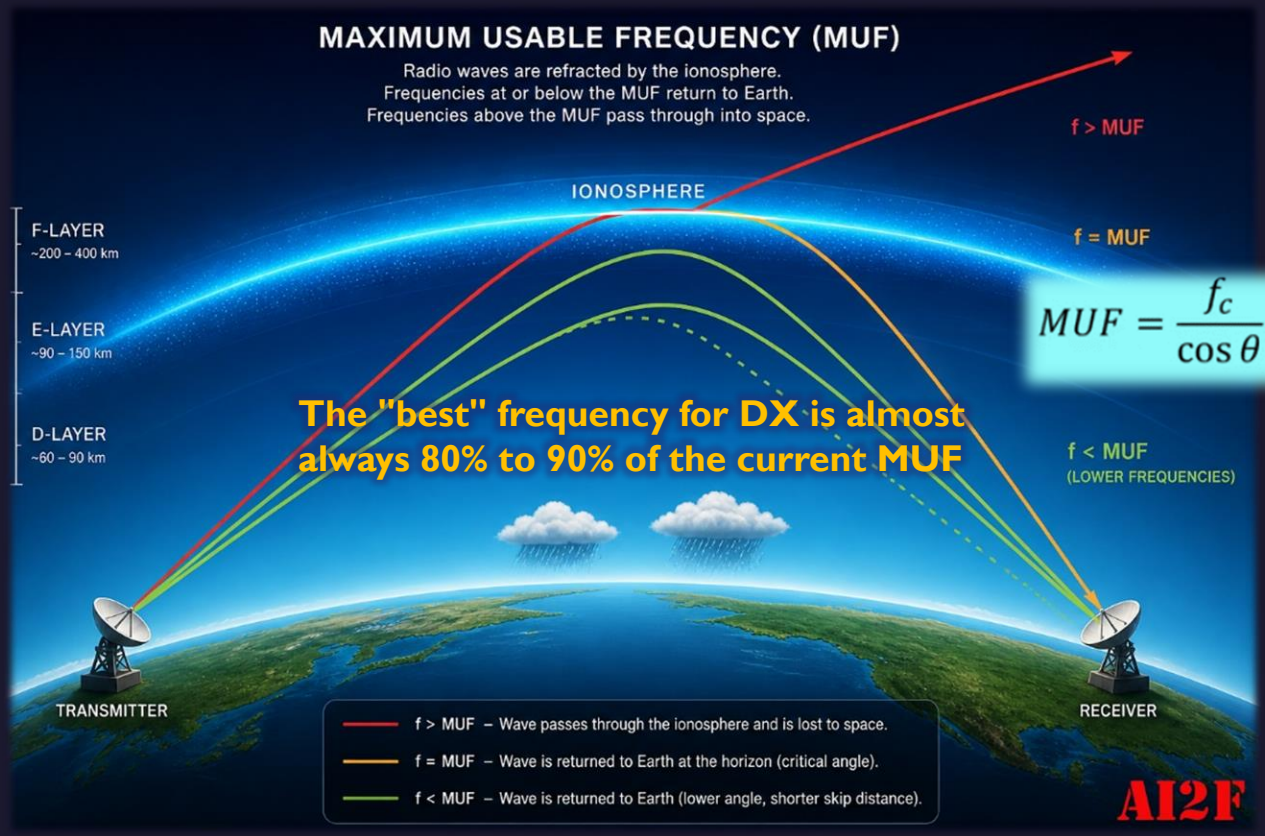






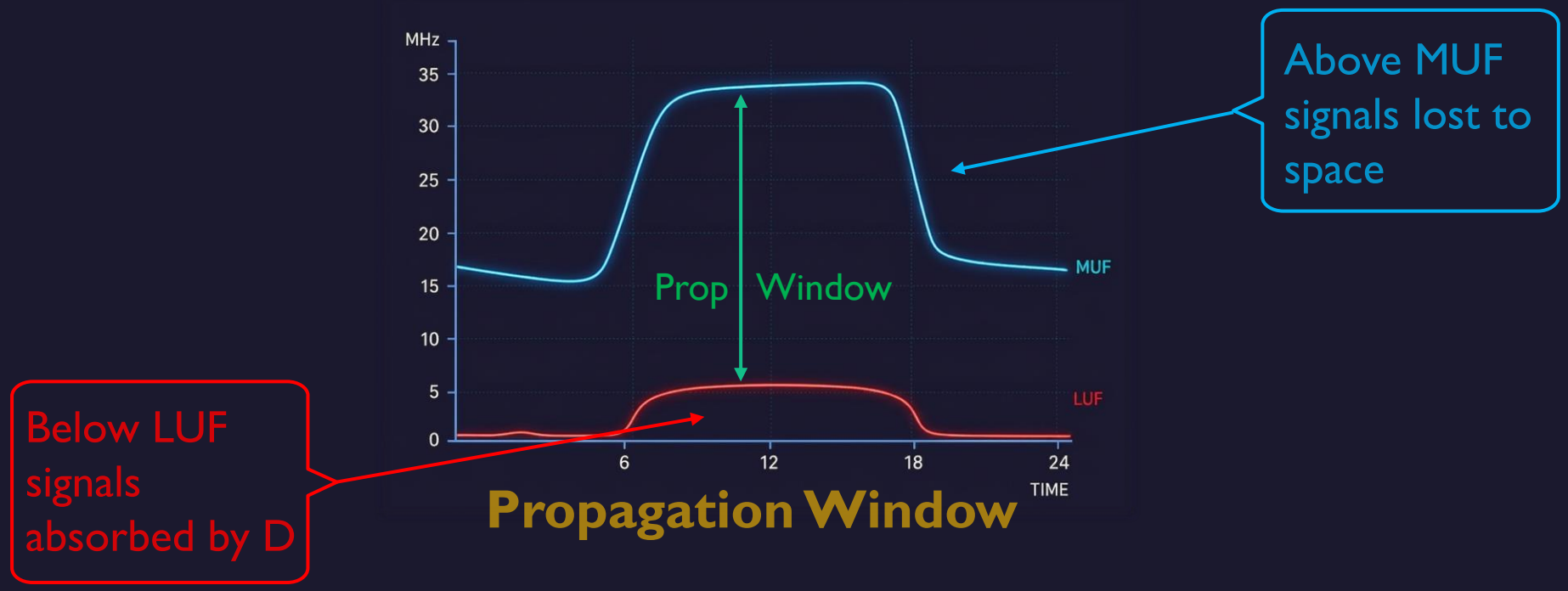
- CF - The highest frequency that will be reflected straight back down
- foF2 = CF for F2 layer, foE for E layer
- CF depends on electron density in the ionosphere, i.e. on the Sun
  - foF2 < 4MHz → only low bands useful
  - foF2: 6-7MHz → 20m solid
  - foF2 > 9MHz → high bands (15m/10m) open
- Decreasing the angle from 90° → Higher Frequency Refracts

MUF – Maximum Usable Frequency



- Upper limit: Highest frequency that will propagate over a path
- MUF is related to foF2 (CF): use ~3x. Ranges 8-35MHz, but even 50MHz is possible
- Angle dependent: Lower takeoff angle → higher MUF → Longer Hop = DX
- Drives band openings: Determines which HF bands are usable

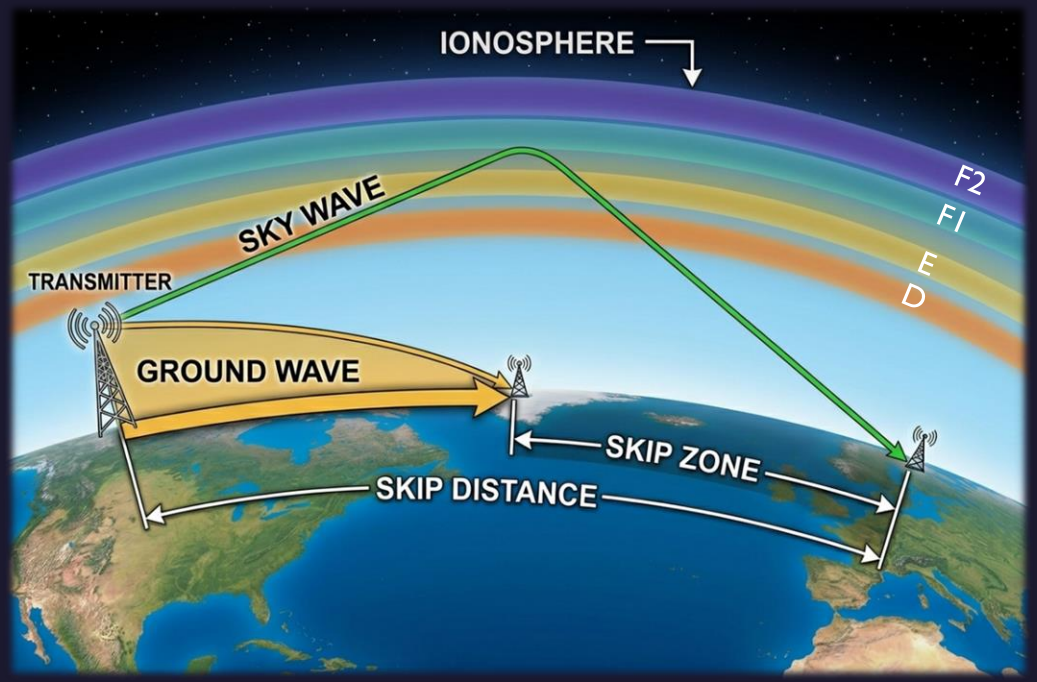
LUF and Propagation Window

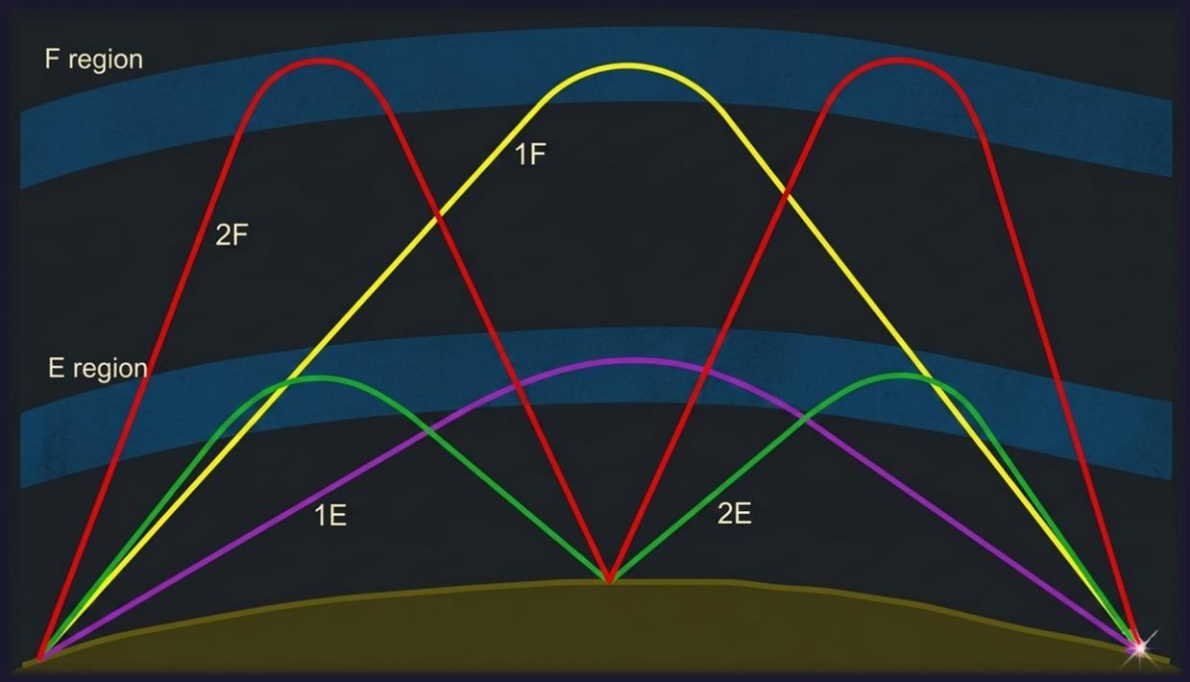


- LUF - Lowest frequency that survives D-layer absorption
- Controlled by D-layer absorption (and QRN)
- Varies with sunlight: Day raises LUF (so no 80m), night lowers it
- Shrinks band window: Works with MUF to define usable HF range

Hop Geometry

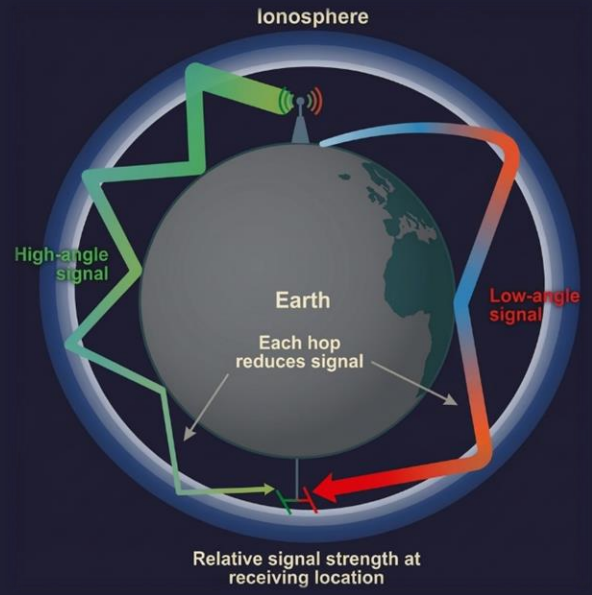
- Longest possible single HOP on HF is ~2500 miles (1F2)
- Longer distances require multiple HOPs





Hop Signal Loss

- Every hop loses signal strength
- Longer distances require multiple HOPs, more loss



Per F-layer bounce:

- **Best case: ~2–5 dB per hop**
- **Average: ~5–10 dB per hop**
- **Disturbed ion: ~10–20+ dB per hop**

Per Ground bounce:

- **Over seawater : ~0.5–2 dB per hop**
- **Good ground : ~2–6 dB per hop**
- **Poor ground : ~6–15+ dB per hop**

Why high antenna works better:

Dipole 0.65 wavelengths high:

- 2 hops × 8 dB = 16 dB loss
- Ground + misc. = 7 dB loss

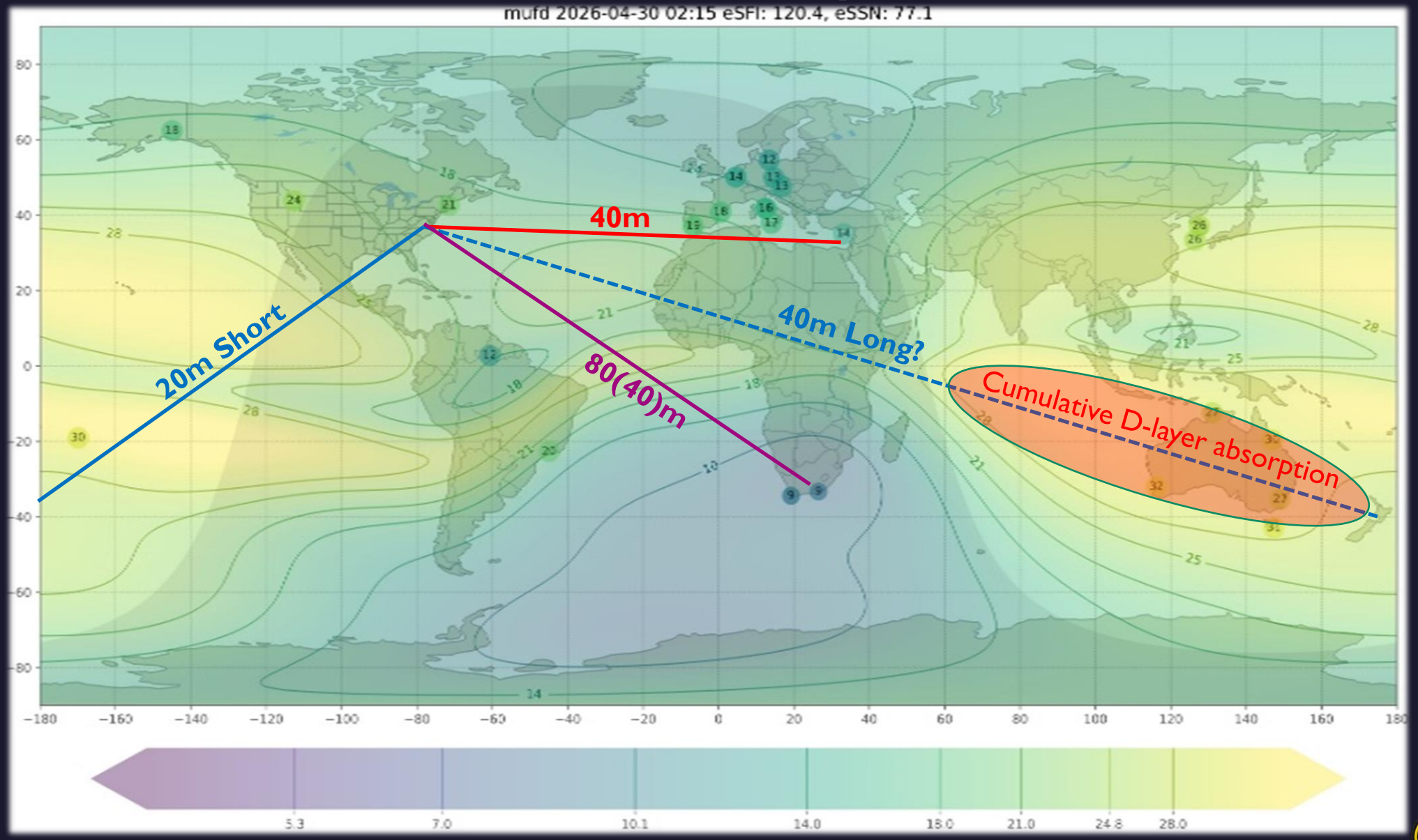
☞ **Total ≈ 23 dB loss**

Dipole 0.20 wavelengths high:

- 4 hops × 8 dB = 32 dB loss
- Ground + misc. = 13 dB loss

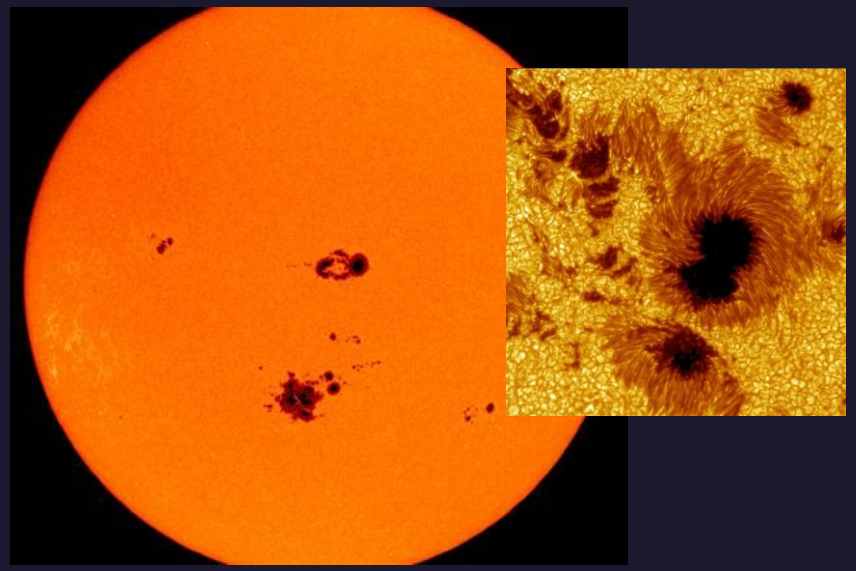
☞ **Total ≈ 45 dB loss** ← **~4 S-units difference**

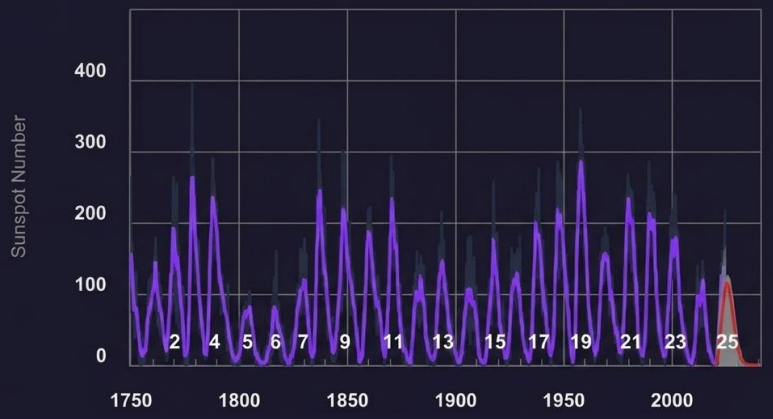
MUF Map

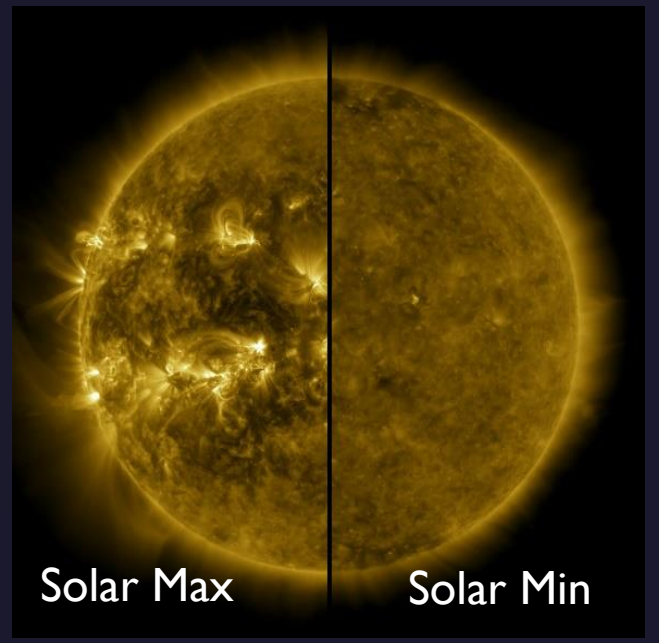


https://prop.kc2g.com/

The Sun – Ionosphere Activator



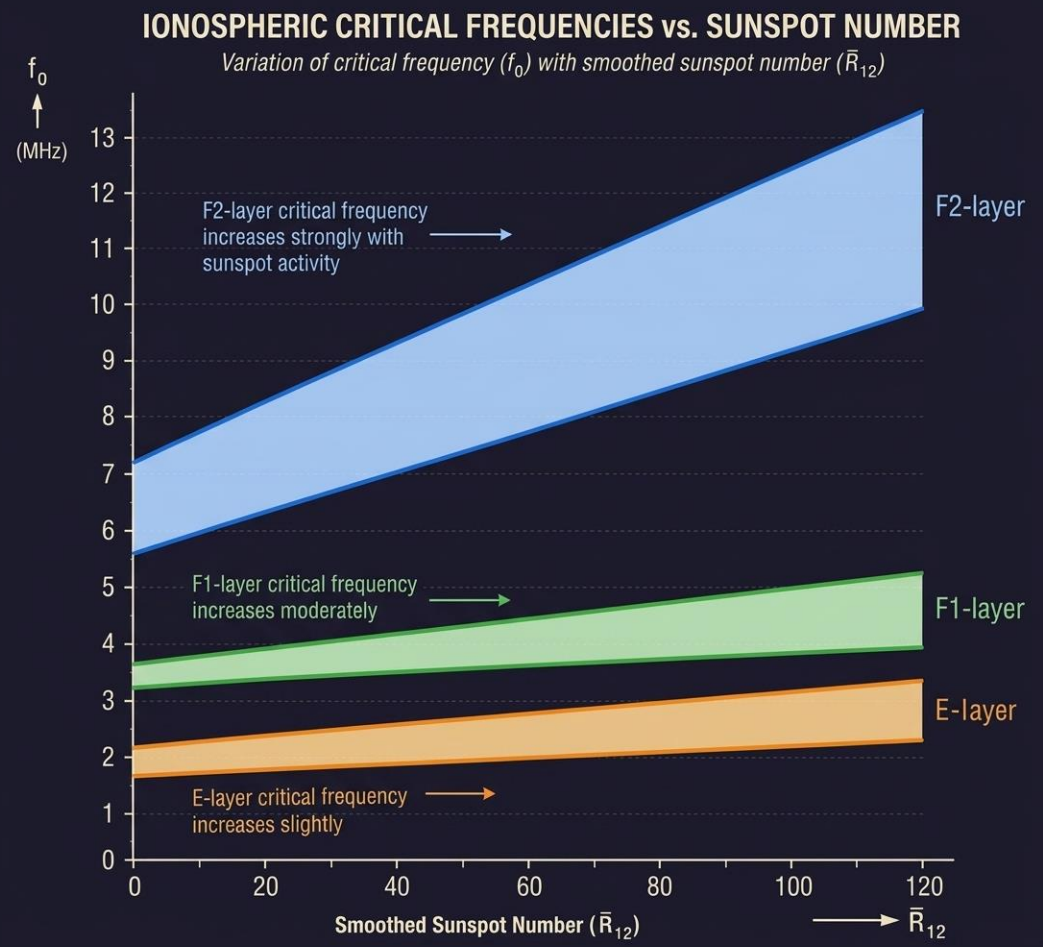




- Solar EUV and X-ray radiation are the primary drivers of ionospheric density
- Increased sunspot activity = Higher Radiation levels = More Refractive Ionosphere
- "The Variable Mirror": Solar output dictates the Maximum Usable Frequency
- 11 year cycle – Solar Minima and Maxima

Sunspots and Critical Frequency

- Sunspots are anchors for massive magnetic fields
- They field immense amounts of EUV and X-rays
- They last few days to few months
- More Spots = More Radiation = Higher CF/MUF
- During solar maximums this opens up high bands
- Predictive Power – SSN and f_0F2 (ionosondes)
- SSN and SFI



Solar Cycle Extremes

SUNSPOT MAXIMUM CONDITIONS

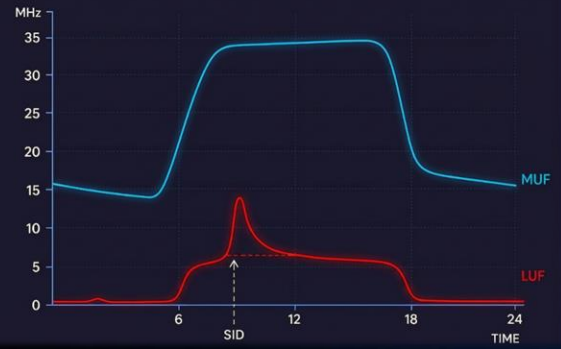
- Highly ionized F2 acts like a mirror
- 20MHz+ reflected with minimum attn.
- 10K mile QSOs with 10W on 15m-10m
- At night MUF stays > 14MHz
- 20m is always open to somewhere

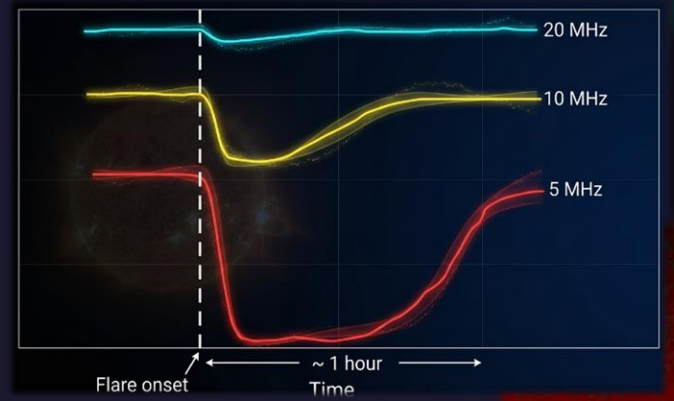
SUNSPOT MINIMUM CONDITIONS

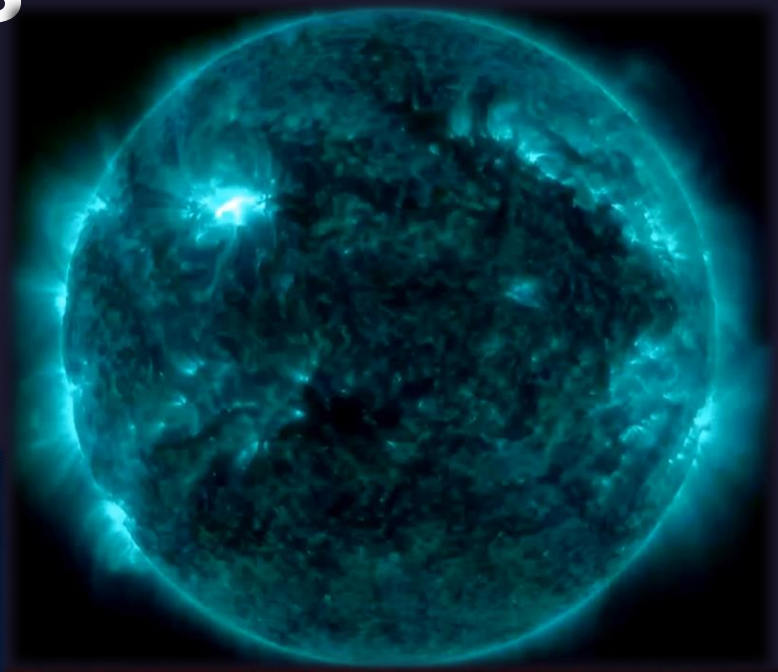
- E and F layers almost transparent to HF
- F2 MUF (f_0F2) rarely rises above 20MHz
- Daytime: use 40-20m bands
- 40m will stay open at least early evening
- Early morning: 160/80m worldwide DX

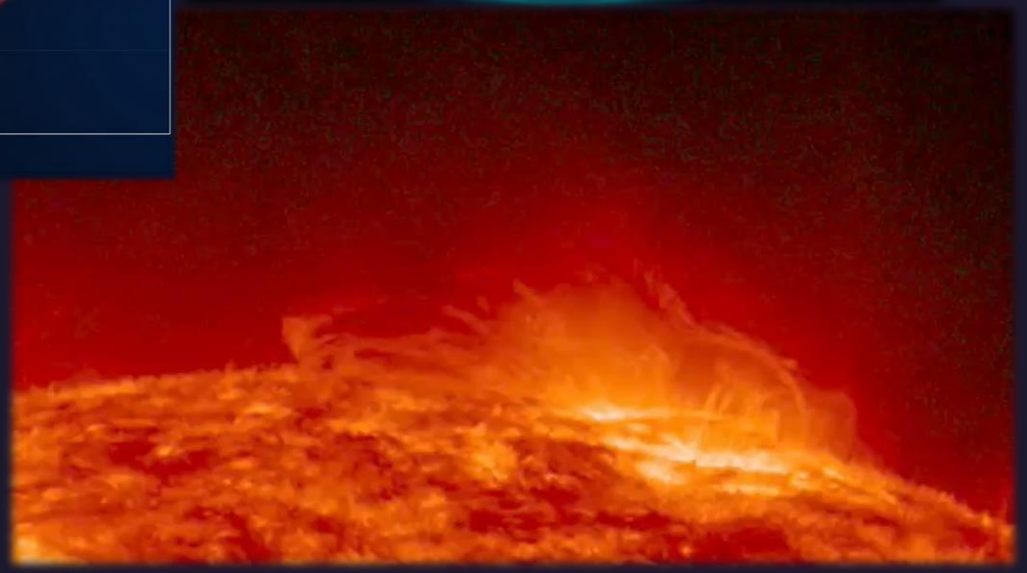
Solar Eruptions & Storms

- Cause Solar Flares and CMEs
- Flare: X-rays and EUV light
  - Travel Time: 8.5 min
  - HF Impact: Instant Blackout
  - Duration: min to hours
- Coronal Mass Ejection
  - Charged particles (pro/el)
  - Travel Time: 1-3 days - Duration Days
  - HF Impact: Geomagnetic (Solar) Storm - Aurora
  - May lead to Ionospheric storm (MUF↓ LUF↑)
- Worst on lower bands. High may work somewhat…

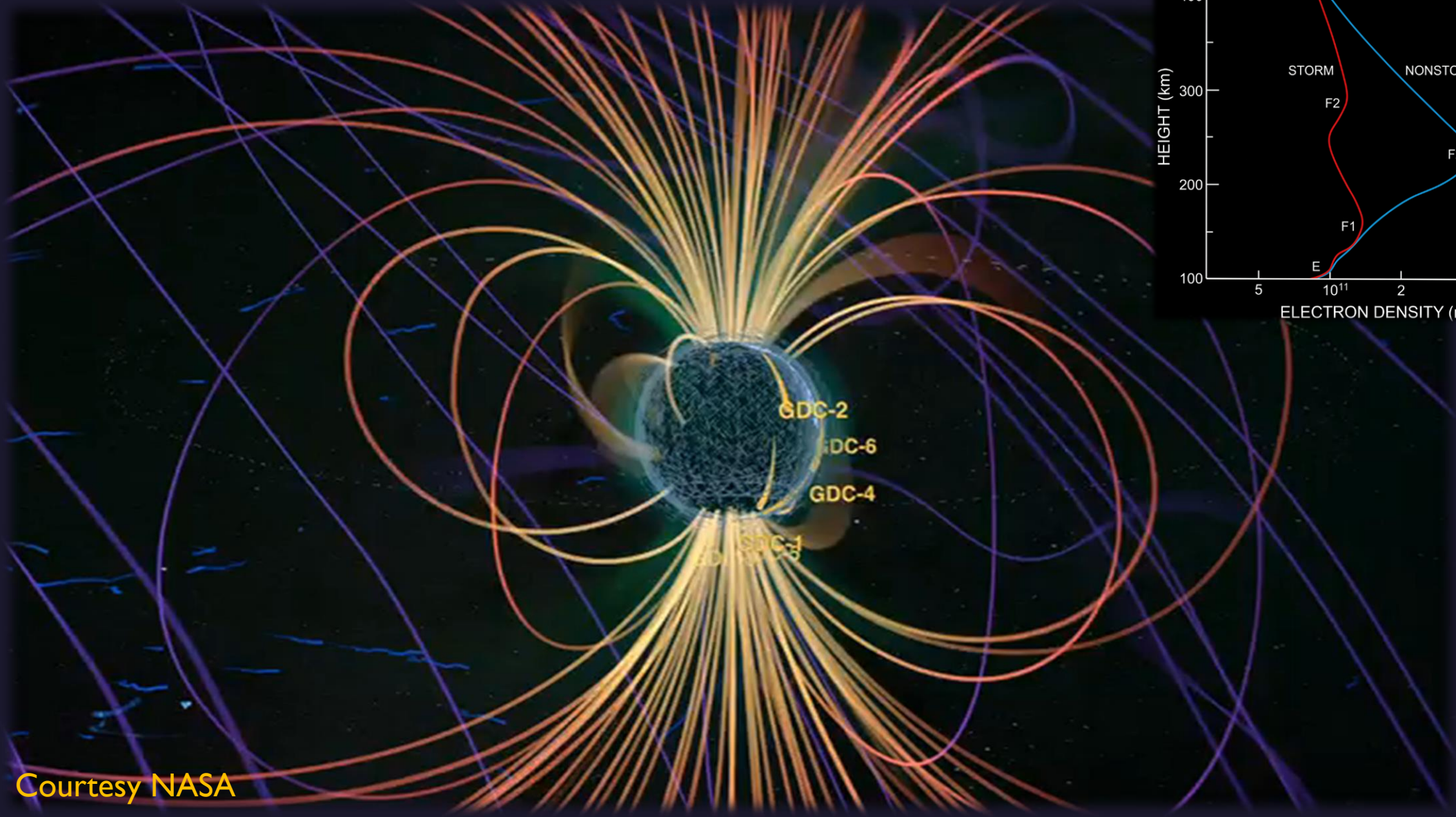








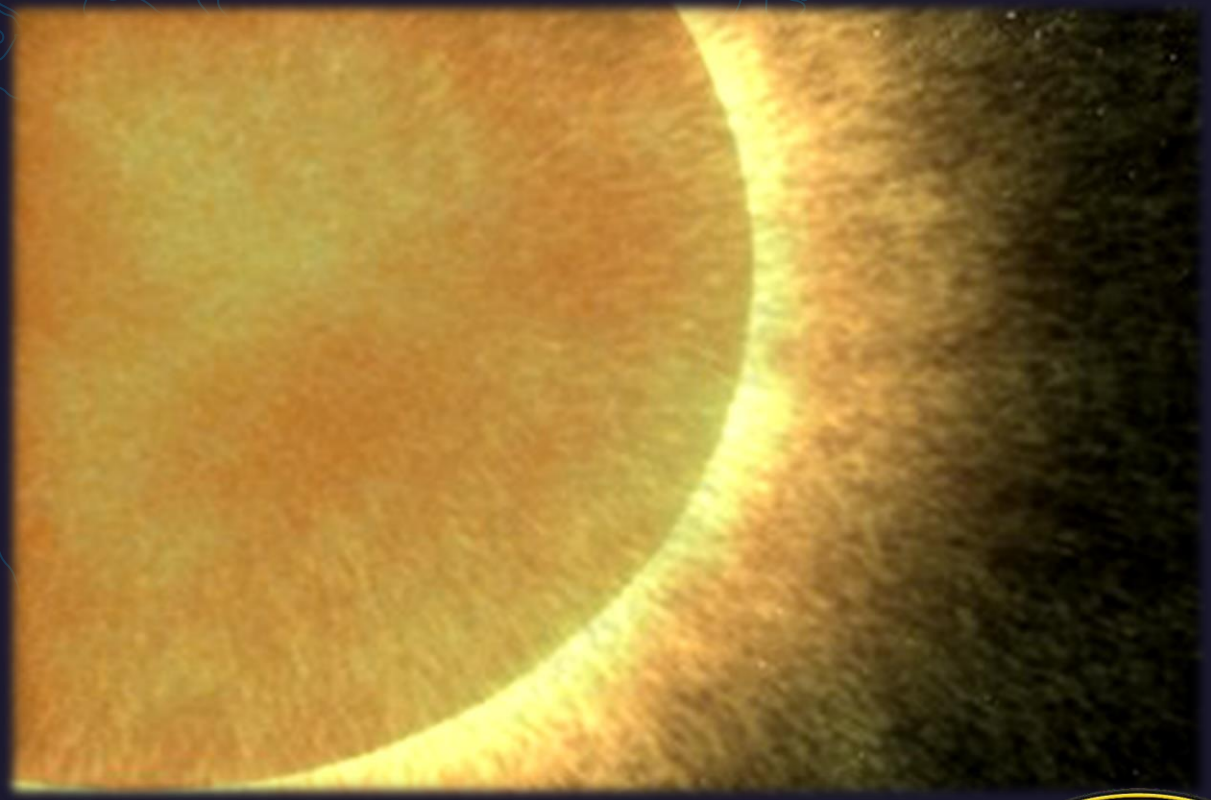
The Bad Sun: Solar Storms



Courtesy NASA

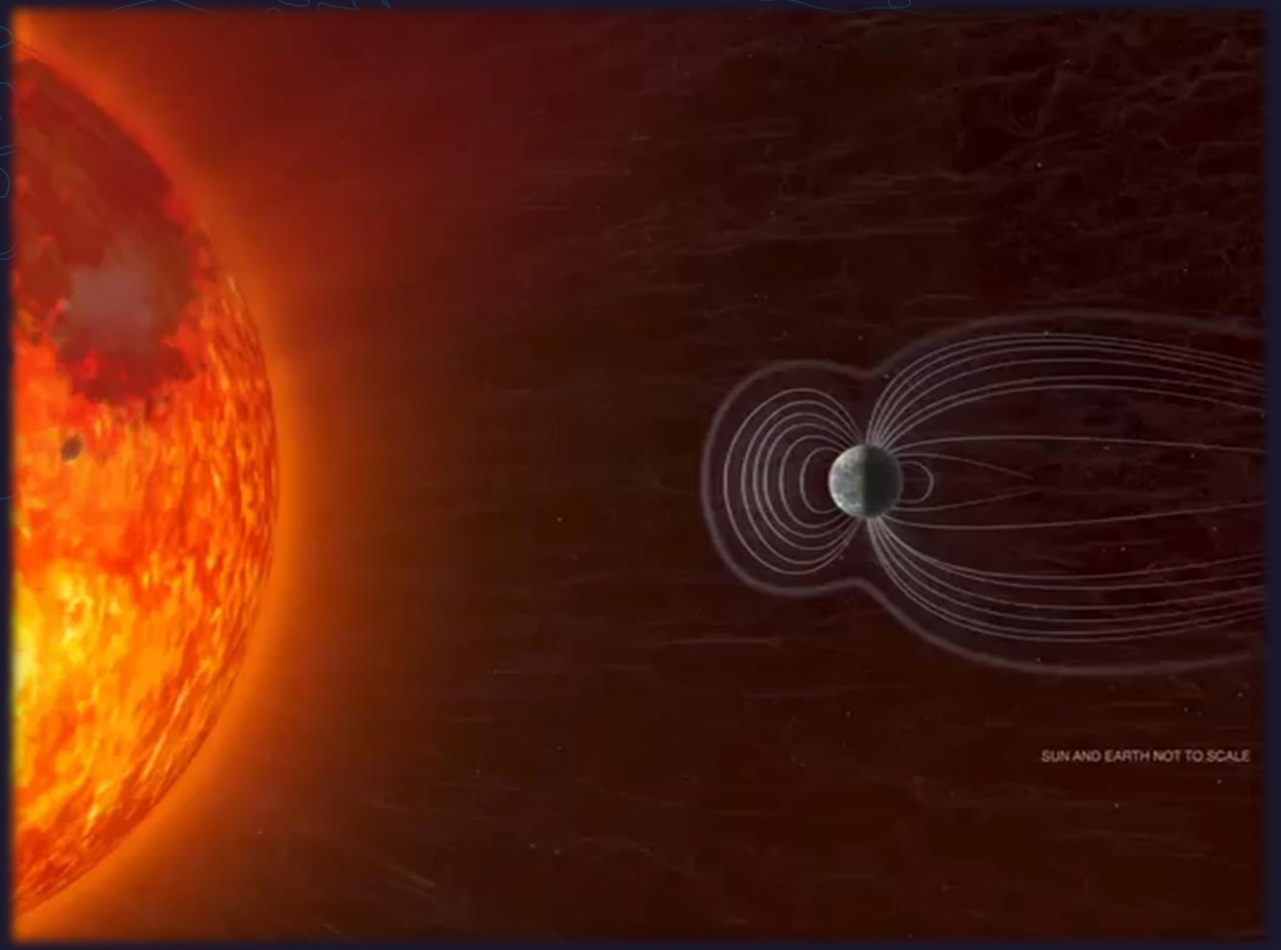
SPE - Solar Proton Events

- Protons accelerated near the speed of light
- Earth's magnetic field guiding them N/S Poles
- Ionize D-layer at high latitudes (poles)
- Big Aurora show
- Total Polar Path Blackout
- Lasts for days

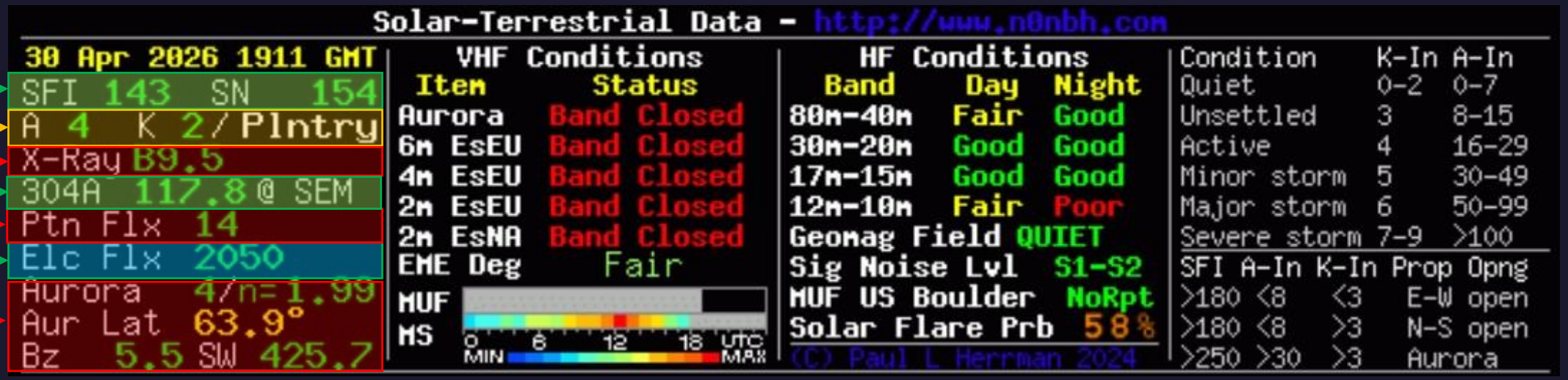


High-Speed Solar Wind - Wind vs. The Storm

- Solar wind is the constant breeze
- Keeps magnetosphere breathing
- When it turns into a gale = Storm
- Three main parameters:
  - Speed, Density, Mag Orientation
    - Fast is Bad
    - Dense is Bad
    - Southward (Bz South) is Bad



Understanding Solar Data

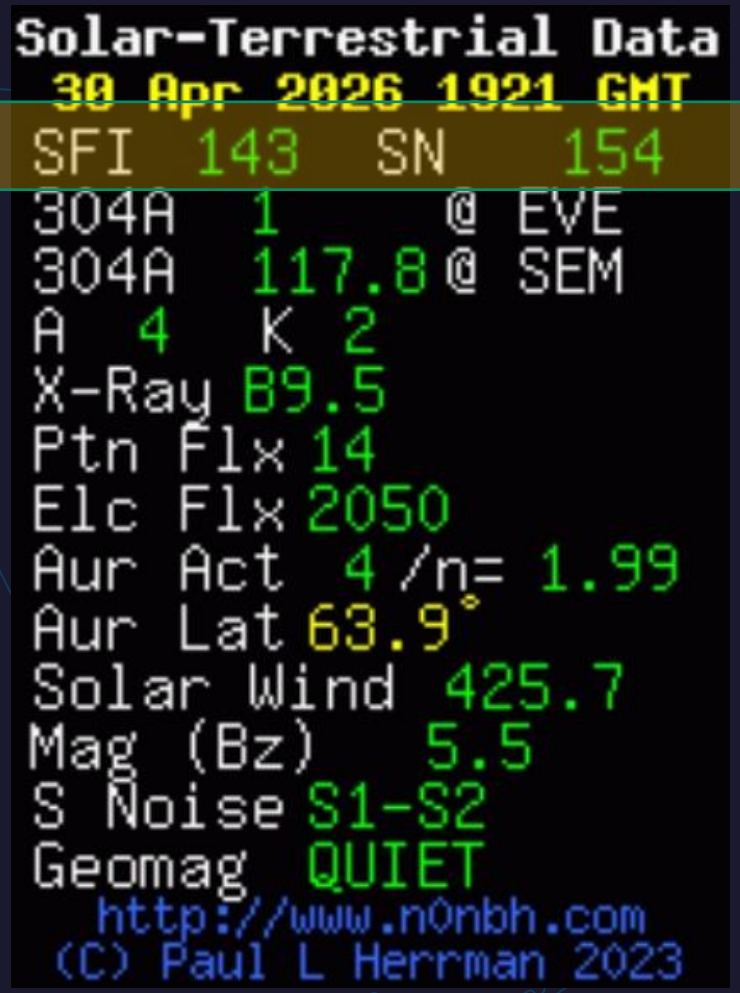


- Assesses real-time band performance
- Gives us a snapshot of the band's health
- Provides real-time condition assessment:

➢The Good, Bad and the Ugly

Good: SSN, SFI

- SSN: A weighted count of dark spots on the Sun
  - More sunspots = more EUV ionization = better HF
- SFI: solar RF output at 10.7 cm (2800 MHz)
  - SFI tracks how much energy is hitting the ionosphere NOW. Directly tied to propagation



- *SFI **60**–70 → Poor, mostly 40m/80m*
- *SFI 70–110 → 20m reliable*
- *SFI 110–130 → 17m/15m open regularly*
- *SFI 130–150 → 12m opens, 10m possible*
- *SFI 150–200+ → 10m wide open, strong DX*

SFI ≈ 73.4 + 0.62 * SSN

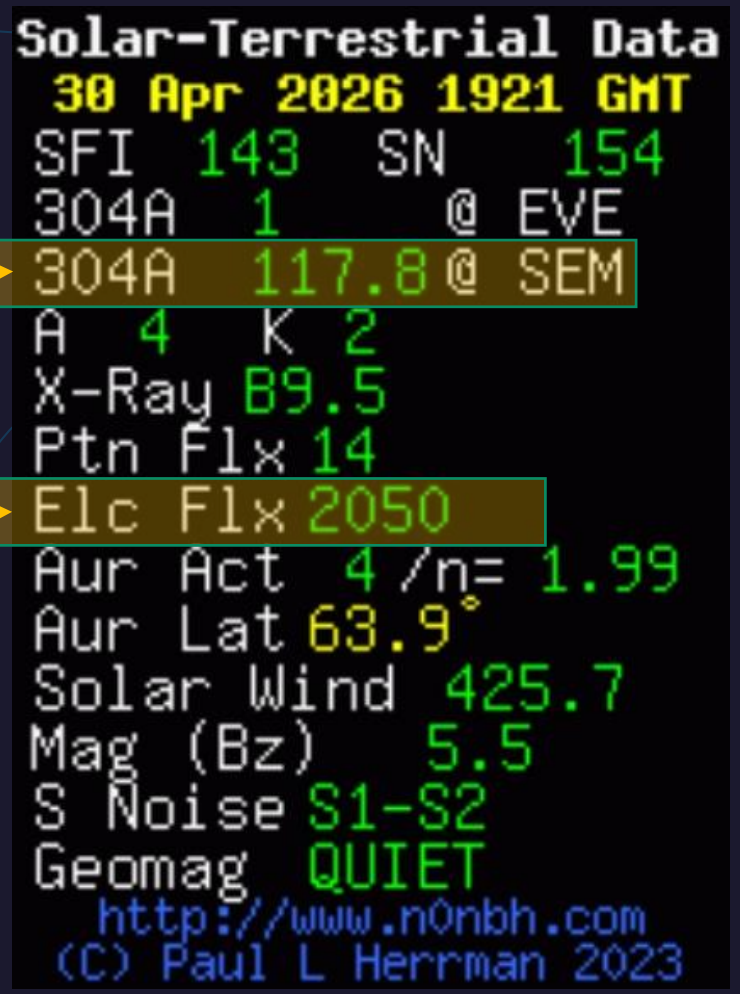
More Good: EUV and Electron Flux

EUV Radiation - 304Å Solar Flux (mW/m^2)

- Ionizes F-layers!!! More is better…
  - 150+ → 10m, 12m, 15m Wide Open
  - 100–150 → 20m (Solid), 15m (Intermittent)
  - Under 100 → 40m, 80m (Night), 20m (Day)

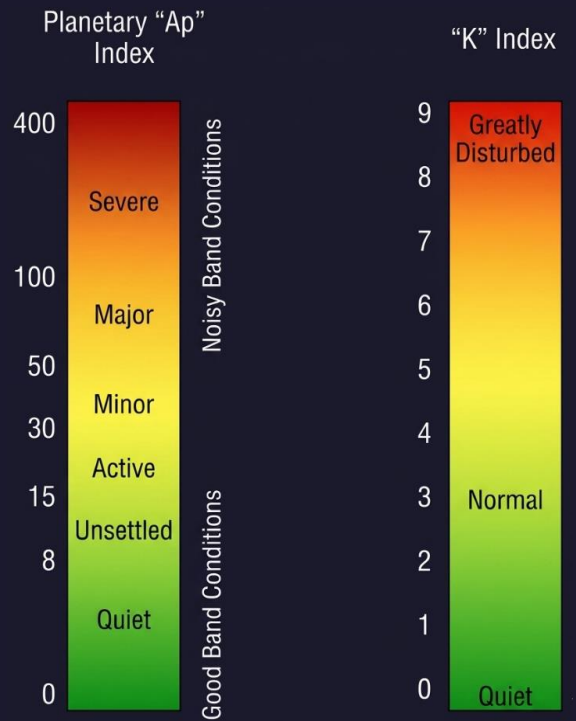
Electron Flux

- Lower-energy electrons in Earth's radiation belts
- Can enhance F2 ionization
- Helps higher bands (15m - 10m) stay open longer
- Moderate to high (1000–10,000) → helps propagation



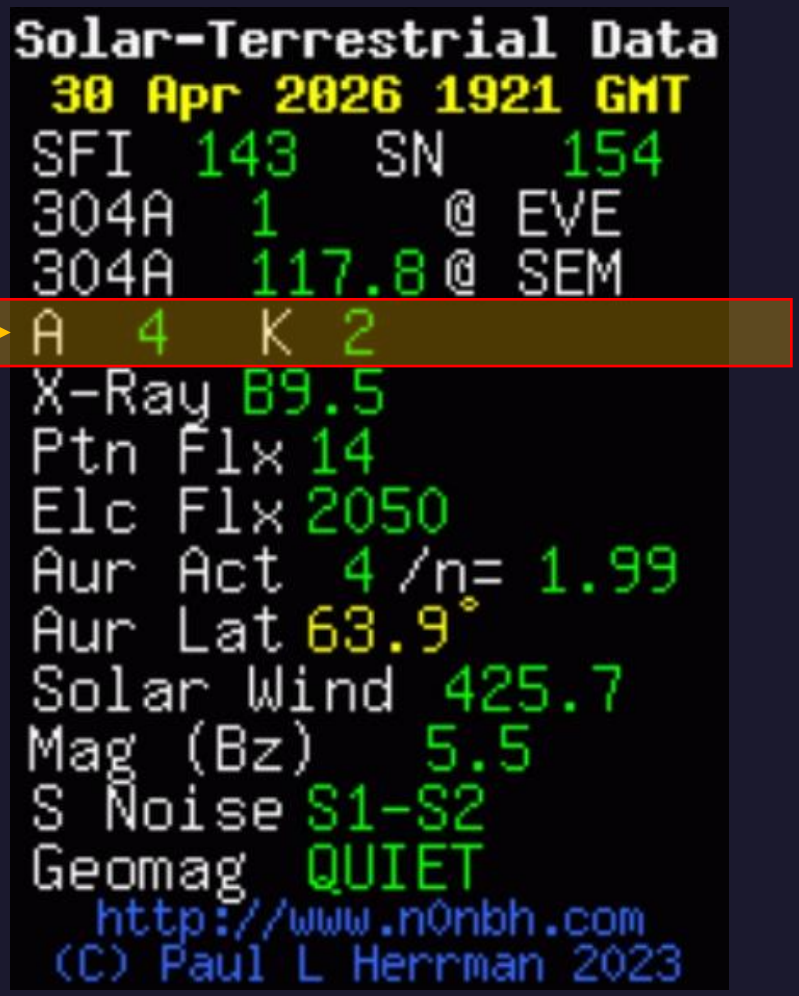
The Bad: Kp (K), Ap (A)

- Kp: 3-hr measure of how disturbed geomagnetic field is
  - Scale: **0 to 9**. Lower is better
- Ap: daily average of geomagnetic activity, from K values
  - Scale: roughly 0 to 400. Updated once per day



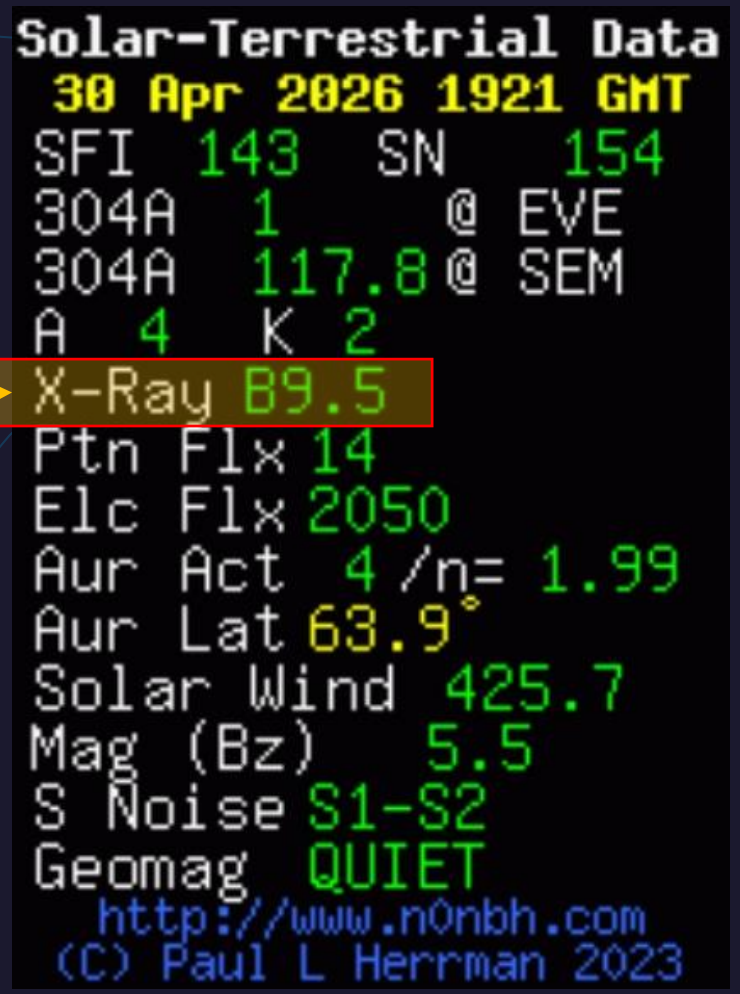
- ❑ Kp indicates current disturbance
- ❑ Ap indicates how long disturbance has been occurring

Think of "A" as ripples of "K" event in the bathtub.



The Ugly: Flux X-rays

- Real-time measurement of Sun X-rays - Flares
- Reported in classes: A, B, C, M, X
- Each step is 10× stronger than the previous one
  - **A-class** → basically nothing
  - **B-class** → very low activity
  - **C-class** → minor flares - won't notice much
  - **M-class** → moderate flare (can affect HF) – HF fadeouts
  - **X-class** → major flare (serious radio impact) – Sunny side HF RIP

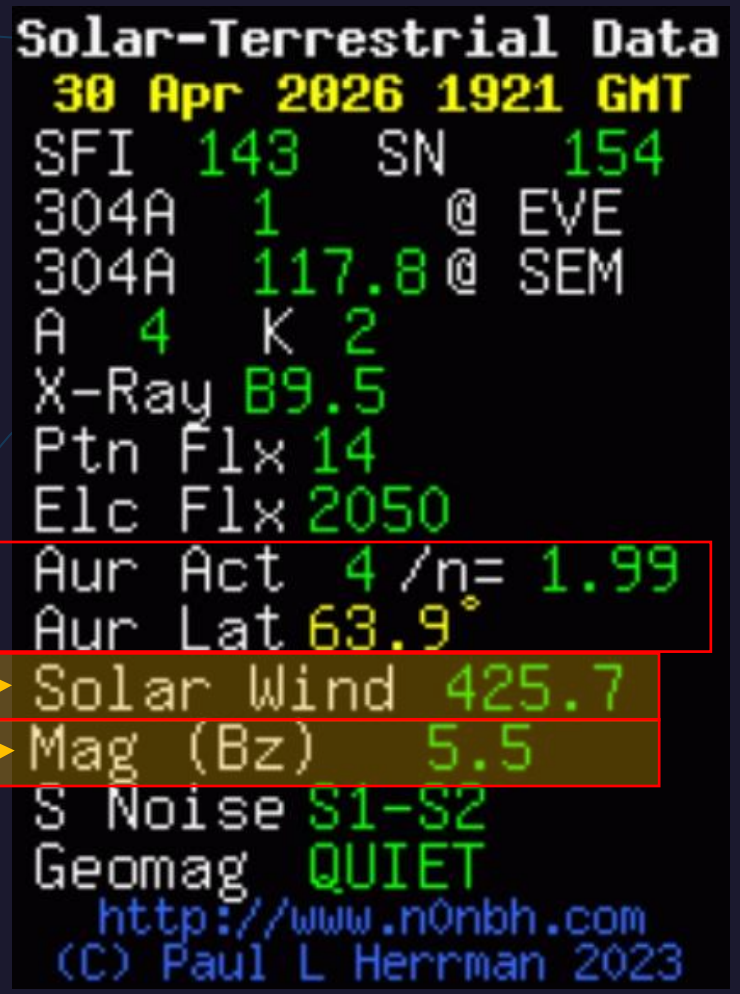


The Ugly: Proton Flux

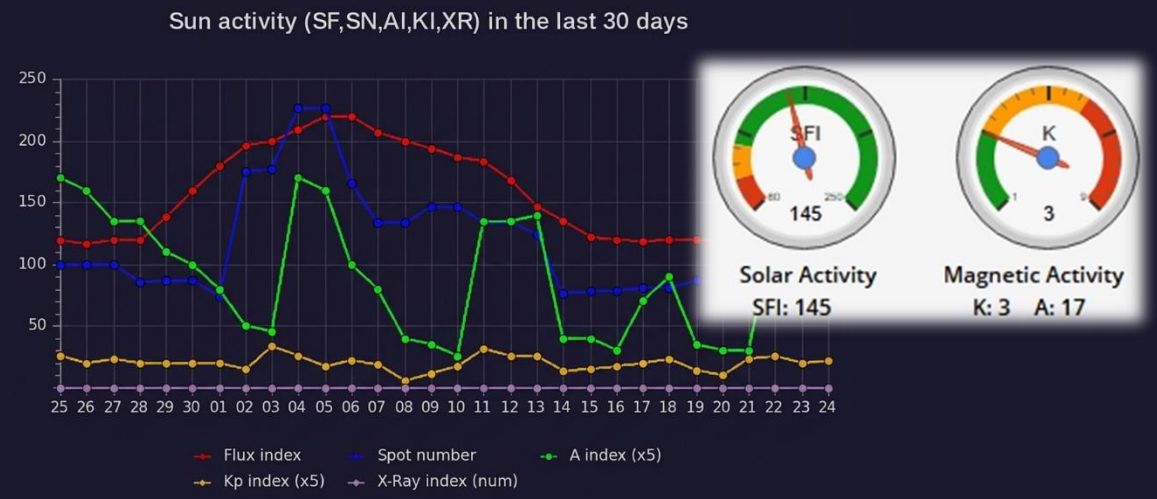
- High-energy protons from solar flares
- Causes D-layer absorption spike
- Kills 20m and below on Polar Paths
  - <10 pfu → Normal (basically zero impact)
  - 10–100 pfu → Minor absorption, mostly polar
  - 100+ pfu → Serious degradation, especially on polar paths
- If proton flux jumps, DX dies fast, even if everything else looks good

The Ugly: Solar Wind - Aurora

- Speed of charged particles hitting magnetosphere
- High solar wind = agitation of the geomagnetic field
- Leads to absorption, fading, and noisy bands
- Polar paths get wrecked first
  - **300–400 km/s** → Quiet, stable bands
  - **400–500 km/s** → Still fine, normal conditions
  - **500–600 km/s** → Starting to stir things up
  - **600+ km/s** → Trouble (geomagnetic disturbances)
- Aurora activity - driven by the interaction of the solar wind with Earth's magnetosphere. Scale: 1-10.
- Positive *Bz* (Northward): The solar wind "slides" off Earth's magnetic field. Negative *Bz* (Southward): BAD!



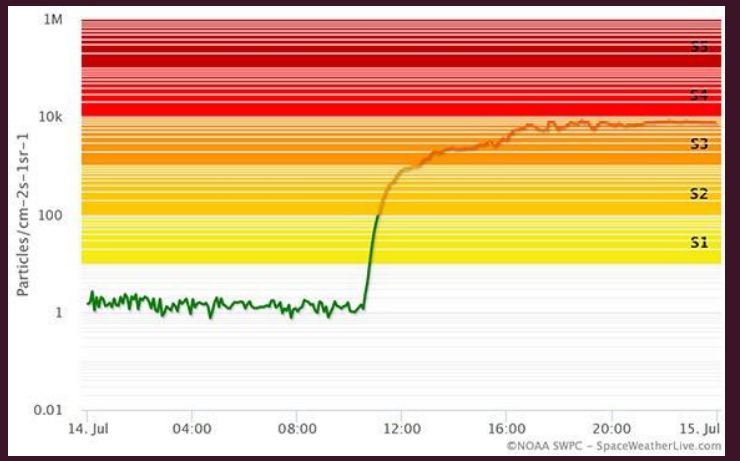
How to Read It All Together



- **Deceptive, bad day:**
  - High SFI of 165 (looks great)
  - BUT:
    - Solar wind: **650**
    - Kp: **7**
      → Bands mostly dead

- **Good DX day:**
  - SFI: 180
  - Kp: **0–2**, Ap: 0-8
  - Solar wind: **<450**
  - Proton flux: **~2**
  - Electron flux: **moderate/high** (1000 - 10000)
  - Noise: **low** (S1)

- **Sudden blackout:**
  - Proton flux spikes → HF just *vanishes*



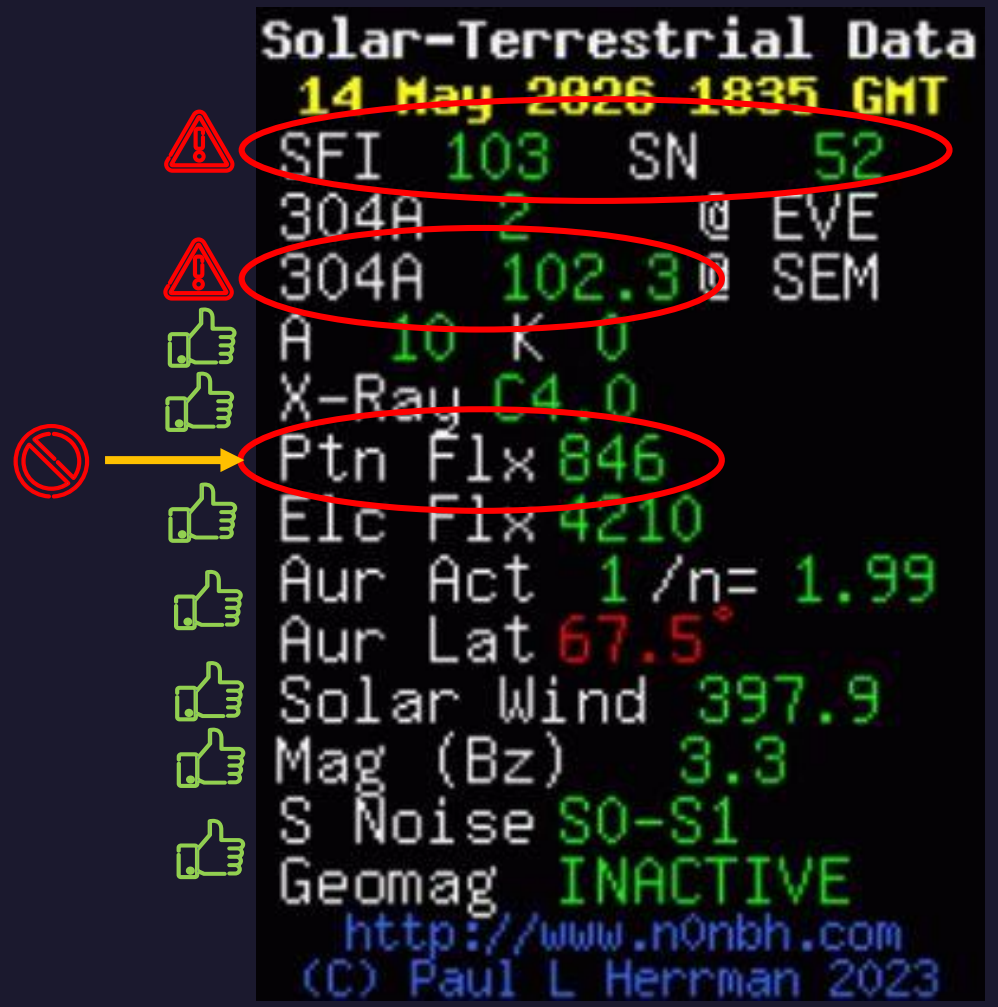
The Bands Have not Been Very Giving Lately… Why?

Snapshot Symptoms:

- 15m and above essentially dead
- 20m: slow, nothing to brag about
- 40m: EU/SA/M. East, but no Asia, no far East…

Analysis:

- Quiet Geomagnetic Field, but…
- Low SFI/SSN and EUV = No high bands!
- High Proton Flux = Polar blackout 20m and below



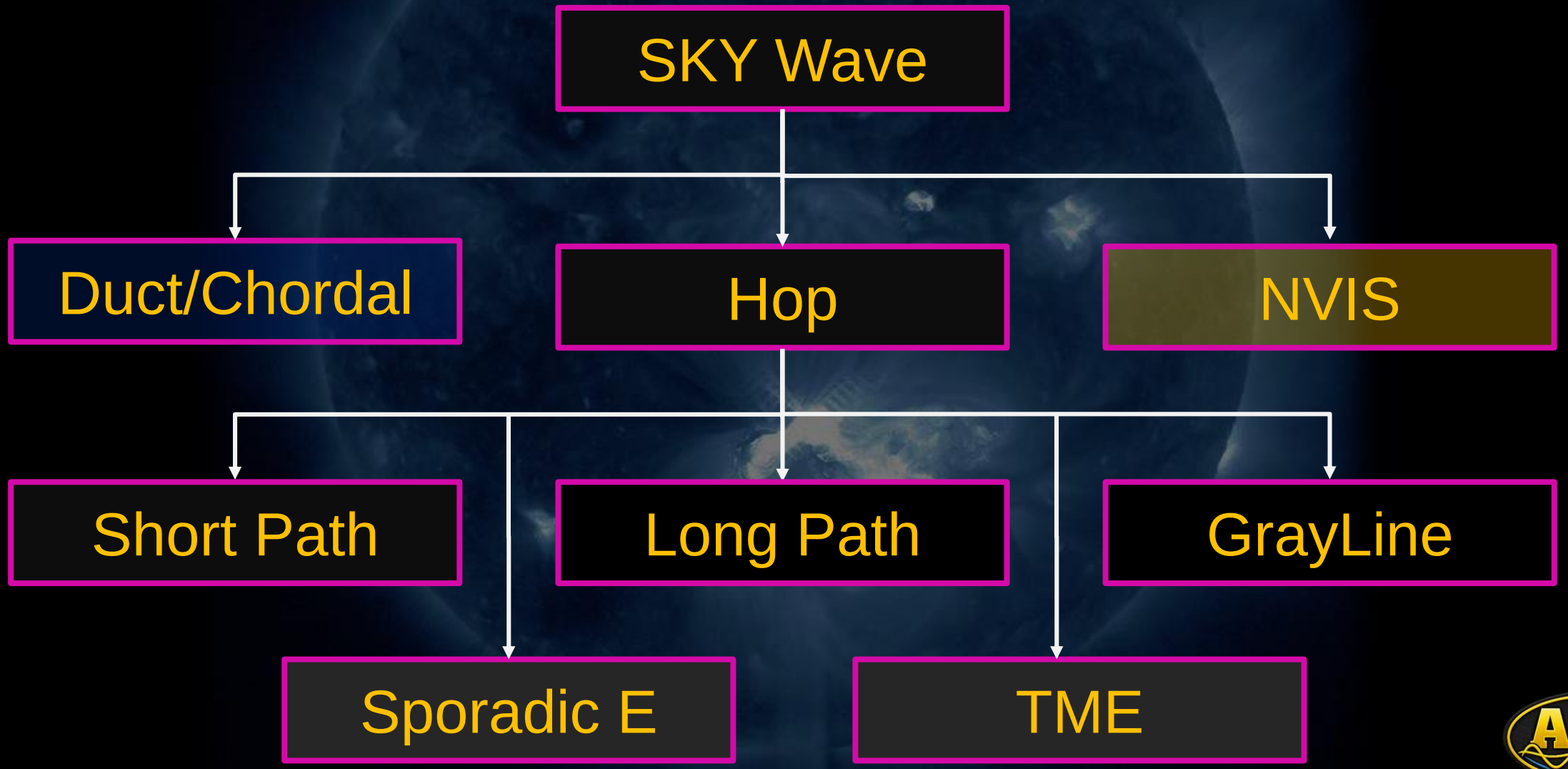
The Bands Will Recover Soon

Short Term Prediction NOAA/SWPC:

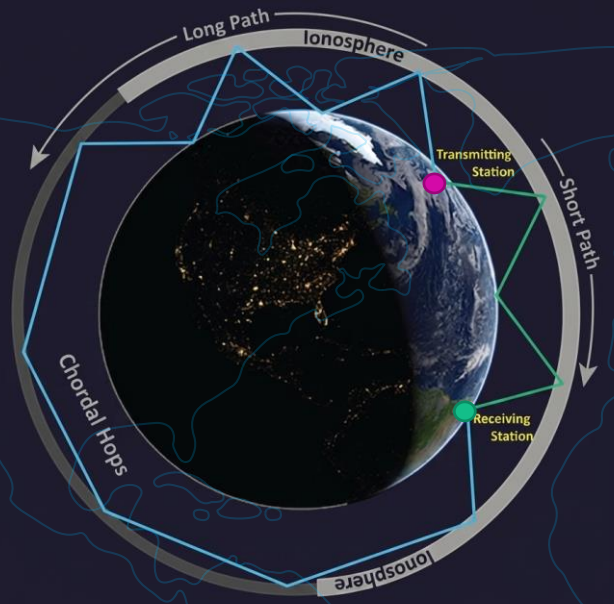
- June 2026: SFI predicted to be between 135 and 145sfu. Hello 15-10m!
- Chance for M-class flares & slight chance for X-class as existing active regions rotate across the disk

2026: 10m - 15m: Should remain viable during the day. Openings will be shorter/less intense than last year

Sky Wave Propagation Modes



Short Path and Long Path



The Direct Route – Most Common

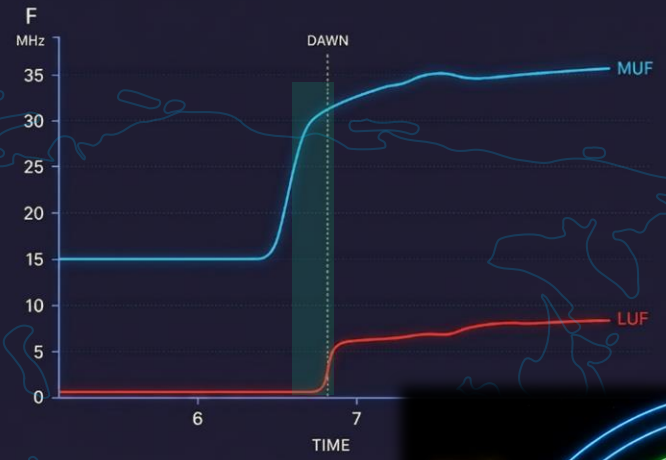
- Short Path (SP): The shortest arc between two stations. Default choice for daily DXing and contest operations.
- Operational Focus: Relies on the direct MUF along the primary heading for maximum signal efficiency.

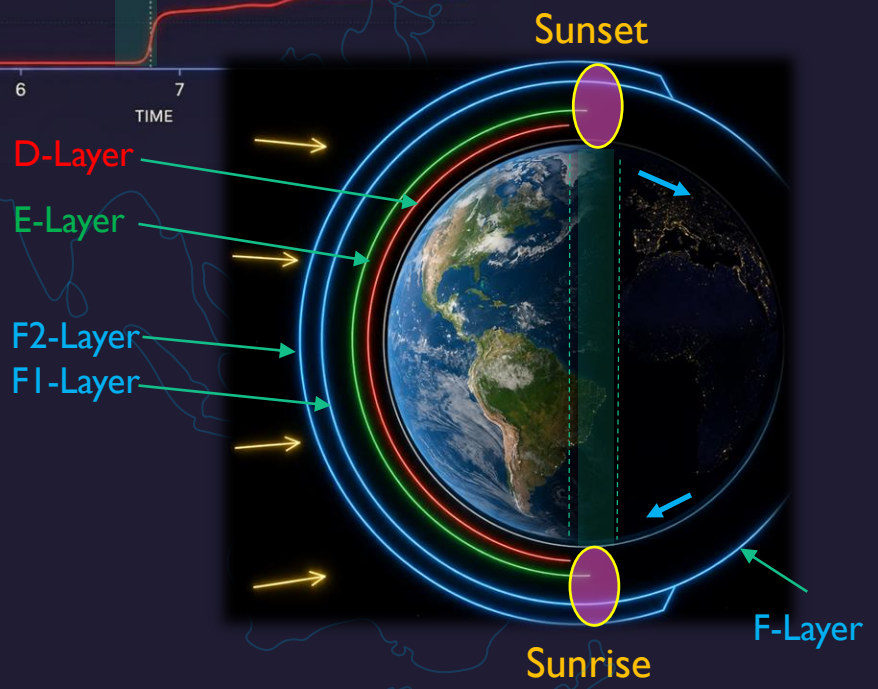
The Backdoor Route

- Long Path (LP): The 180° reciprocal bearing traversing the globe's major arc. Used when the short path is blocked by absorption.
- Frequently, but not always, follows the planet's twilight zone (terminator) for enhanced low-loss propagation.
- *Signals often exhibit a distinct "hollow" or "fluttery" sound.*
- Needs low antenna take-off angles!

Gray Line Propagation Is Real - And Powerful

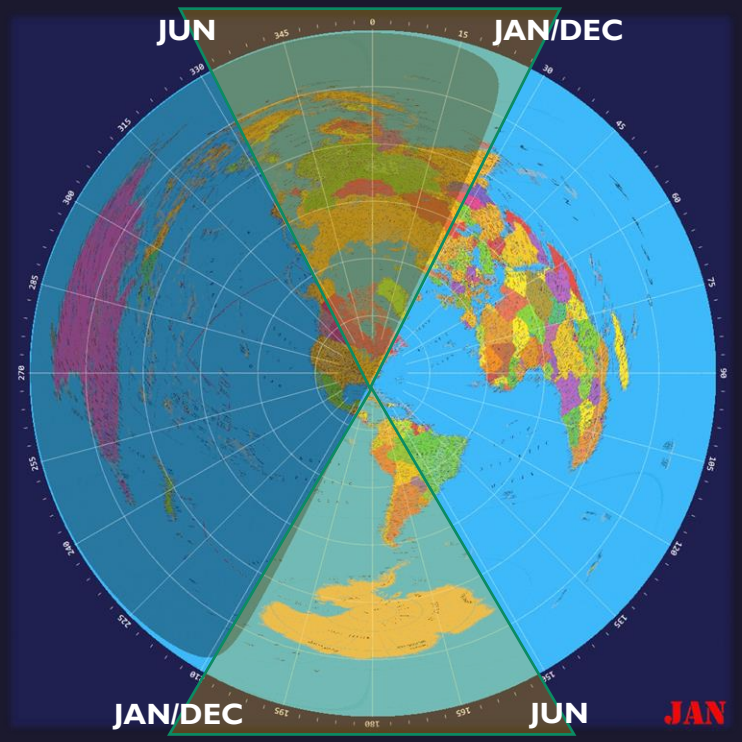
- Sunrise/Sunset line is *Grey-Line or Terminator*
- F2 layer MUF rising rapidly on the sunrise side
- D and E layers very weak – Low LUF
- Forms a tunnel along the terminator – a very low-loss propagation path.
- All bands affected. Lasts minutes to an hour, band dependent. Can be 2 hours on 20m
- Most pronounced on low bands 160m – 40m
- Most exciting paths happen along the *Grey-Line*

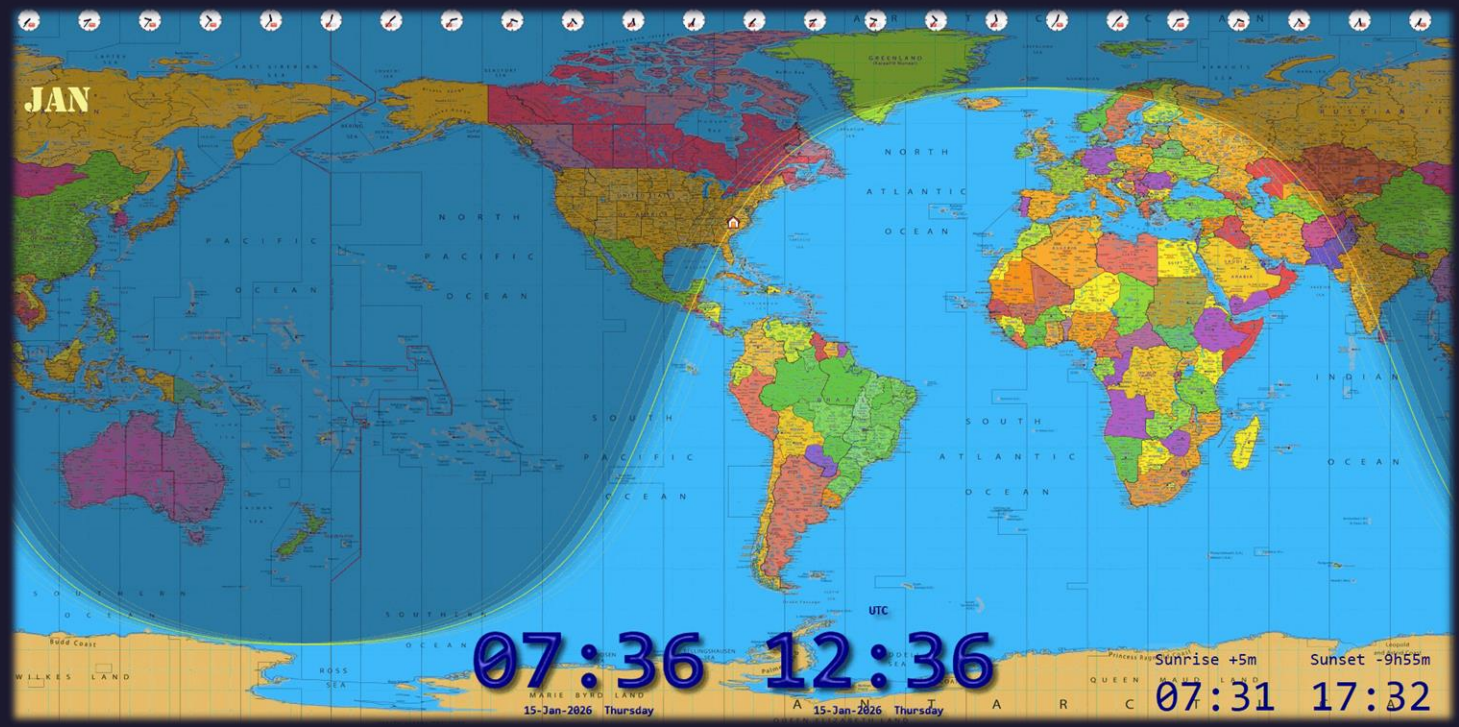




It's the temporary condition where D-layer absorption collapses while the F2-layer supports propagation!

Gray-Line -Terminator Thru the Year





- Because of Earth's ecliptic tilt, Gray-Line is not static!

Gray Line openings often sound unusually quiet because absorption drops and signal strength improves faster than noise levels rise. Thus, excellent readability of weak DX signals.

Monthly Gray-Line Targets: NC

Dawn:

Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cocos Is.	Christmas Is.	Christmas Is.	Christmas Is.	Christmas Is.	Christmas Is.	Christmas Is.	Christmas Is.	Christmas Is.	Cocos Is.	Cocos Is.
Sri Lanka	Cocos Is.	W. Sumatra	W. Sumatra	E. Australia	E. Australia	W. Sumatra	W. Sumatra	Cocos Is.	S. Sumatra	Sri Lanka
India	Sumatra	Java	Java	Java	Java	Java	Java	Sumatra	Andaman Is.	India
Pakistan	Java	Borneo	Borneo	Borneo	Borneo	Borneo	Borneo	Java	Bangladesh	Pakistan
Turkmenistan	Malesia	Sarawak	Sarawak	Sarawak	Sarawak	Sarawak	Sarawak	Malesia	W. India	Turkmenistan
Kazakhstan	Thailand	Brunei	Brunei	Brunei	Brunei	Brunei	Brunei	Thailand	Repal	Kazakhstan
EU Russia	Myanmar	Vietnam	Indonesia	Indonesia	Indonesia	Indonesia	Vietnam	Myanmar	E. China	EU Russia
Easter Is.	Cambodia	E. China	Philippines	S. Korea	S. Korea	Philippines	E. China	Cambodia	Kyrgysstan	Easter Is.
Galapagos	Thailand	E. Asiatic Russia	Korea(s)	Japan	Japan	Korea(s)	E. Asiatic Russia	Thailand	Kazakhstan	Galapagos
Quatemala	Laos	Falkland Is.	E. China	Kamchatka Pen	Kamchatka Pen	E. China	Falkland Is.	Loos	E. Asiatic Russia	Quatomala
Honduras	Cent. China	S. Orkney Is.	Japan	S. Sandwich Is.	S. Sandwich Is.	Japan	S. Orkney Is.	Cent. China	Galapagos	Honduras
Costa Rica	Mongalia	Shetland Is..	E. Asiatic Russia	S. Georgia Is.	S. Georgia Is.	E. Asiatic Russia	Shetiand Is..	Mongolia	Easter Is.	Costa Rica
Easter Is.	Cen. Asiatic Russia	E. South America	S. Georgia Is.	Central S. America	Central S. America	S. Georgia Is.	E. South America	Cen. Asiatic Russia		
	Peru	Caribbeen	Central S. America			Central S. America	Caribbeen	Peru		
	Equator							Equator		
	Colombia							Colombia		
	Panama							Panama		
	Costa Rica							Costa Rica		

Dusk:

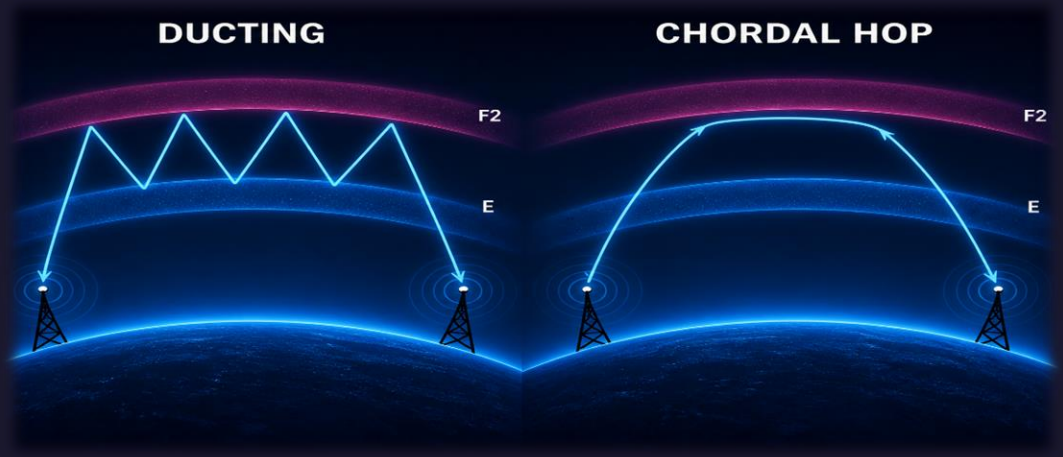
Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Christmas Is.	Christmas Is.	Christmas Is.	Cocos Is.	Cocos Is.	Cocos Is.	Cocos Is.	Christmas Is.	Christmas Is.	Christmas Is.	Christmas Is.
E. Australia	W. Sumatra	Cocos Is.	E. Sumatra	Sri Lanka	Sri Lanka	E. Sumatra	Cocos Is.	W. Sumatra	W. Sumatra	W. Sumatra
Java	Java	Sumatra	Andaman Is.	India	India	Andaman Is.	Sumatra	Java	Java	Java
Borneo	Borneo	Java	Bangladesh	Kakistan	Pakistan	Bangladesh	Java	Borneo	Borneo	Borneo
Sarawak	Sarawak	Malesia	W. India	Turkmenistan	Turkmenistan	W. India	Malesia	Sarawak	Sarawak	Sarawak
Brunei	Brunei	Thailand	Nepal	Kazakhstan	Kazakhstan	Nepal	Thailand	Brunei	Brunei	Brunei
Indonesia	Vietnam	Myanmar	E. China	EU Russia	EU Russia	E. China	Myanmar	Vietnam	Indonesia	Indonesia
S. Korea	E. China	Cambodia	Kyrgyzstan	Easter Is.	Easter Is.	Kyrgyzstan	Cambodia	E. China	Philippines	S. Korea
Japan	E. Asiatic Russia	Thailand	Kazakhstan	Galapagos	Galapagos	Kazakhstan	Thailand	E. Asiatic Russia	Korea(s)	Japan
Kamchatka Pen	Falkland Is.	Laos	E. Asiatic Russia	Guatemala	Guatemala	E. Asiatic Russia	Laos	Falkland is.	E. China	Kamchatka Pen
S. Sandwich Is.	S. Orkney Is.	Cent. China	Galapagos	Honduras	Honduras	Galapagos	Cent. China	S. Orkney Is.	Japan	S. Sandwich Is.
S. Georgia Is.	Shetland Is.	Mongolia	Easter Is.	Costa Rica	Costa Rica	Easter Is.	Mongolia	Shetland Is.	E. Asiatic Russia	S. Georgia Is.
Central S. America	S. South America	Cen. Asiatic Russia					Cen. Asiatic Russia	S. South America	S. Georgia Is.	Central S. America
	Castibean	Peru					Peru	Castibean	Central S. America	
		Equator					Equator			
		Colombia					Colombia			
		Panama					Panama			
		Costa Rica					Costa Rica			

Gray-Line by the Band

- **Gray-Line enhances probability rather than predicting certainty!**
- **It offers a window of opportunity rather than a deterministic target!**

Band	Gray-Line Particulars
160m	Briefest twilight peaks – 5-30min. EU and AF may peak long before sunrise. Unpredictability is the rule on 160.
80m	~30 min openings. Signals from the west strengthen at first light, peak at sunrise. Long path propagation also appears, but with shorter peaks—often just 5–7 minutes. Sometimes you hear DX echo.
40m	The peak lasts about 30 minutes, followed by a slow decline. Best conditions occur ~half an hour after sunrise. Long path openings to central Asia from October through March.
30m+	Grey-line-type effects can still influence higher-frequency signals. The outcome is a higher-frequency counterpart to the classic grey-line enhancement observed on lower bands. **Spills out on sunny side!**
10m	In the eastern U.S., the band typically opens toward the southeast around sunrise, then swings toward Europe and western Asia within 15–20 minutes. The first two hours after sunrise are usually the prime window for central Asia. Spring and fall often bring long path openings toward the Far East and the South China Sea. **Spills out on sunny side!**

Ducting and Chordal Hop

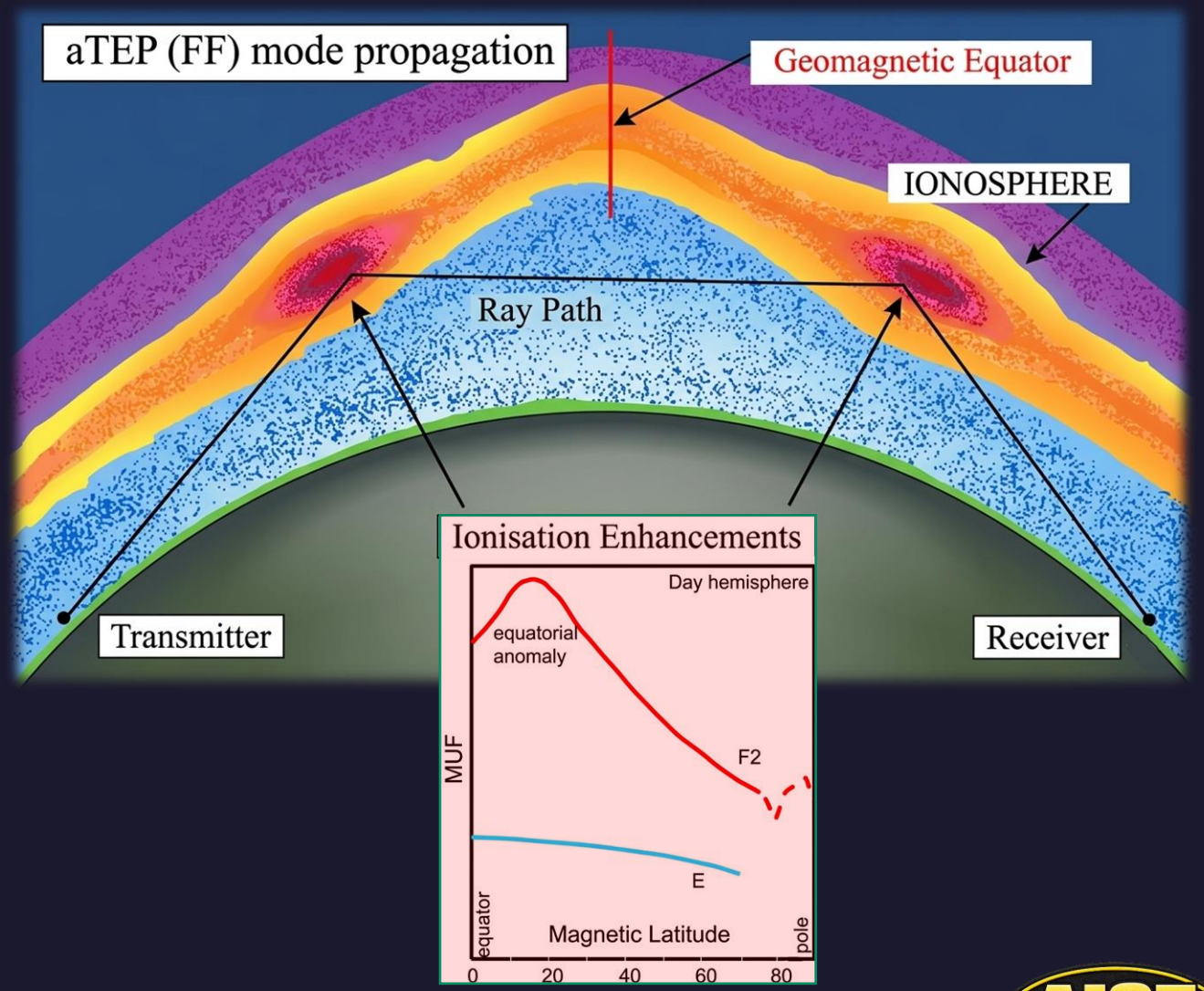


- Radio wave becomes trapped between two layers of the ionosphere
- They do play a significant role on high HF bands
- This is most common on the 10m sometimes as low as 15m
- Avoids the "ground loss" (absorption and scattering)
- Unpredictable and "magical" when they happen

- Wave strikes another part of the ionosphere further along the curve of the planet
- Common near the Geomagnetic Equator (TEP) or the Gray-Line
- Primary suspect for exceptionally clear "Long-Path" communications
- Trans-Equatorial Propagation: example of chordal-adjacent movement

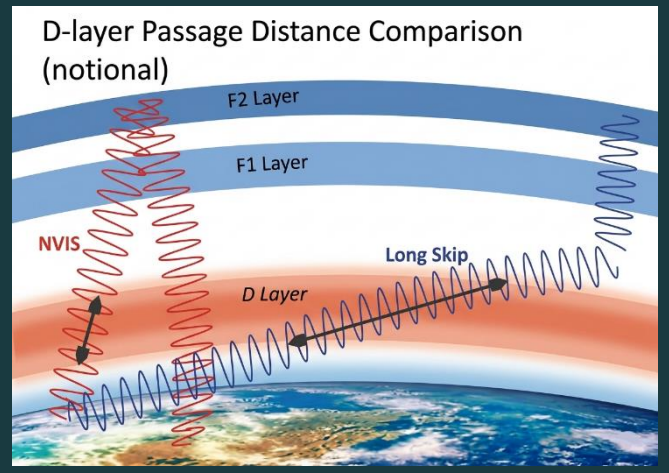
TEP - Trans Equatorial Propagation

- Openings North to South of Equator
- Mag. Equator F2-layer extends upwards
- TEP signal is reflected twice against the ionosphere
- Single TEP HOP routinely > 4000 miles
- On upper HF bands: 12m, 10m… 6m
- TEP usually peaks late afternoon to late evening
- Expect QSB towards the evening

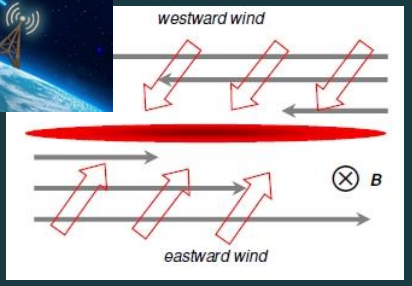


NVIS and Sporadic E Propagation

- Near Vertical Incidence Skywave
- NVIS relies on high-angle radiation (60°–90°)
- Below the current critical frequency (f_0F2), i.e. 160 - 40m
- NVIS eliminates the "skip zone" gap. Range: Few hundred miles
- Antenna 0.1 to 0.25 wavelengths high



- The E-layer produces occasional clouds or patches of ionization.
- Produces unusual propagation effects for 10m, 6m
- 500 – 1,500 miles hop.
- In North America the peak sporadic E occurs in mid to late June and Dec to Jan (Meteor showers)



Daily Propagation Phenomena

PROPAGATION EFFECTS:

DAYTIME

- D-layer absorbs below 5MHz, forget 80m-
- 5 – 10MHz: Short Skip via E or F1 layers
- >10MHz: F2 supports intercontinental QSOs

NIGHTTIME

- 3-15MHz: Intercontinental via F-layer

BAND SELECTION:

DAYTIME

- 20m – 10m bands: Multi Hop DX
- 40m, 30m and 20m: Short Skip (i.e. USA)

NIGHTTIME

- 160m – 30m: Intercontinental DX
- Noise on 160m and 80m makes DX difficult

Seasonal Propagation Phenomena

PROPAGATION EFFECTS:

- Winter is Good for DX!
- During winter atmosphere shrinks (cold)
  - Increased electron density in ionosphere
- During northern hemisphere winter closest to Sun
  - More EUV ionizing ionosphere
- Winter: 5x greater electron density, 2x grater MUF
- Lower QRN as less thunderstorms in the winter

* BAND SELECTION:

WINTER

- 20 - 10m bands: Daytime DX
- 160 - 30m (and possibly 20m) night DX

SUMMER

- 20 - 15m (and possibly 10m) bands: Day DX
- 40m, 30m and 20m DX after dark

* Solar cycle dependent

Band Propagation Personalities

Band Group	Daytime Behavior	Nighttime Behavior	Primary Mechanism
160m - 80m	**D-Layer: DX Sky Wave s**ignals fully absorbed.	**Global DX:** Absorption lifts; long-haul opens.	Nighttime F-Layer.
40m - 30m	**NVIS / Regional:** Best for 0-600 miles.	**Worldwide:** Becomes a global DX engine.	Day NVIS / Night F-Layer.
20m - 17m	**Mainstay DX:** Open global paths daily.	**Twilight Fading:** Diminishes shortly after sunset.	Persistent F-Layers.
15m - 10m	**Variable:** Wide open in Solar Max.	**Closed:** No ionization support at night.	Solar Flux & Sporadic E.

Fading (QSB) Events

Fading: Unwanted Signal Strength Variation

Selective Fading

Most common on HF
Multipath fading
180 deg phase reversals at RX
Short periods (1 – 10sec)

Absorption Fading

D-Layer variations
Long time scales to 30 min
Most pronounced on low bands

Skip Fading

MUF drops below signal freq.
Mostly at sunrise/sunset
Short time scales (seconds)

Auroral Fading

Another multipath fading
Interaction with Aurora
Rapid fluttery distortion
Primarily on paths thru Aurora

Polarization

Changes to the polarization
Short periods (1 – few sec)

Band Identities

Band	The "Personality"	Prime Character
160m	**The Top Band**	Nocturnal, requires massive backyard real estate.
80m	**The Ragchew Band**	Social community hub; noisy in summer, great for night nets. *DX is earned not given*.
40m	**The DX Workhorse**	Best day/night balance; regional daytime, global at night. A workhorse band—*if you can't DX on 40, fix your station*.
30m	**CW Sanctuary**	Stable WARC band; no contests, polite, always open somewhere. Excellent propagation, low noise. *No SSB*.
20m	**King of DX**	The international mainstay; busy, predictable, and global. All-day worldwide DX.
17m	**Gentleman's DX**	Relaxed high-quality DX; solar dependent, *contest-free*. Lower noise, strong signals.
15m	**Daytime Performer**	High speed/energy; massive signals during solar maximums. Lower noise, strong signals.
12m	**The Quiet DXer**	Fast, clean openings; similar to 10m but less crowded. Strong signals, simple antennas.
10m	**High Octane**	Massive skip, tiny antennas, Sporadic E, and high energy. When 10 opens, it really opens.

Propagation Tools

VOCAP - www.voacap.com/hf/

- Statistical model. Gold standard for quick, reliable HF path planning. It provides "Point-to-Point" and "Area Coverage" maps.

PSKReporter - pskreporter.info/pskmap.html

- The ultimate tool for checking current path viability.

DXMaps - www.dxmaps.com

- Maps spots from Reverse Beacon Network and DX clusters. Global band openings in real-time.

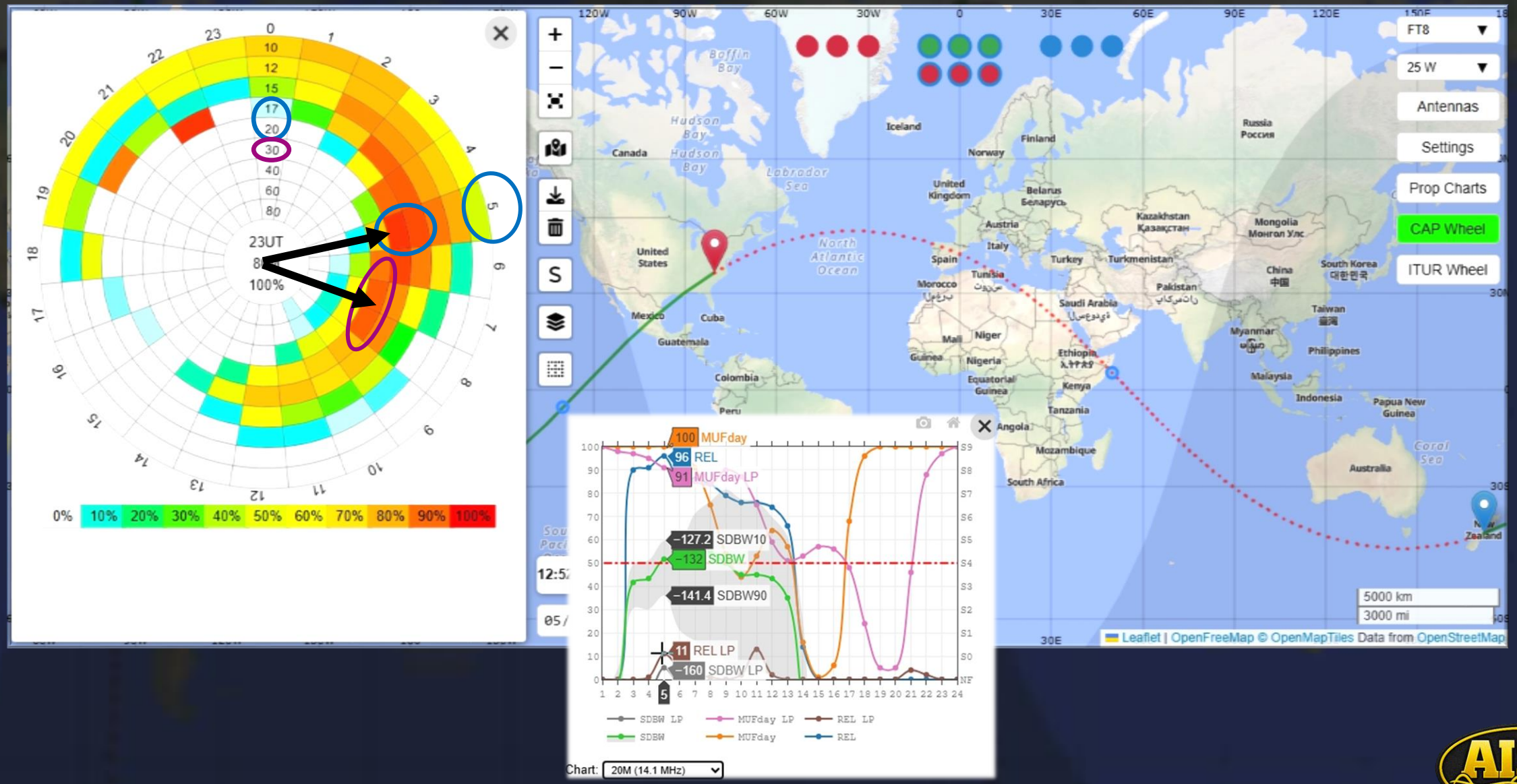
DXHeat - www.dxheat.com/dxc/ (simplest tool)

- DX Cluster Site – with real time prop to regions – useful.

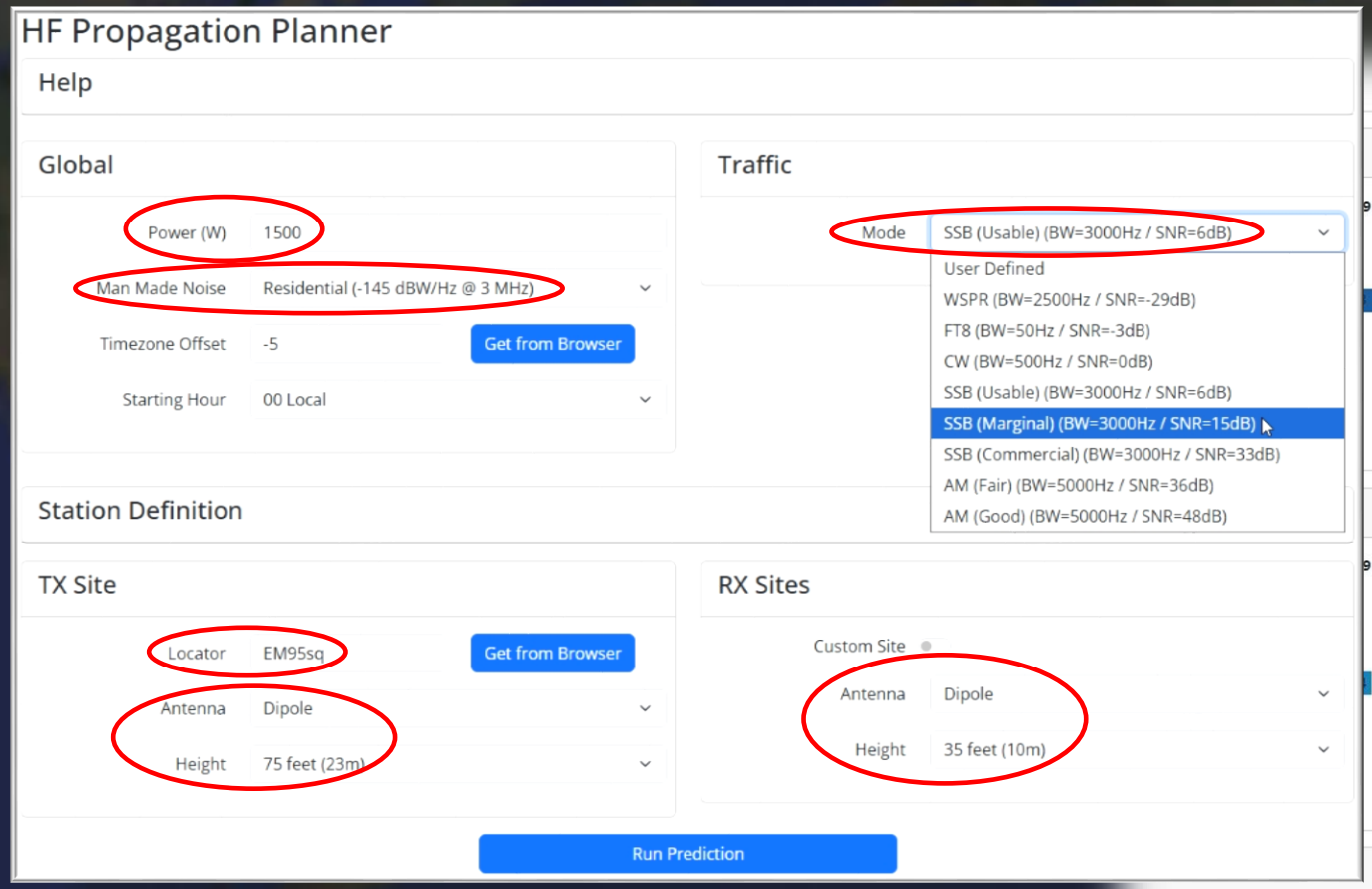
KC2G - prop.kc2g.com/hfprop/planner

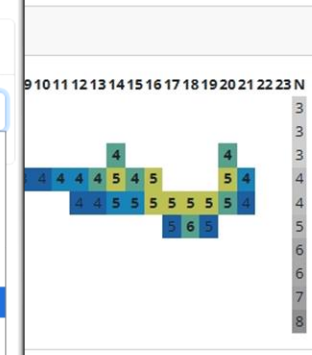
- My favorite! Uses Real-Time Data live data from ionosonde stations. Allows you to personalize the report to your station.

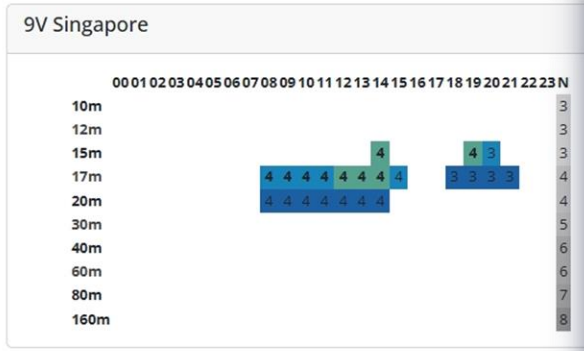
VOACAP Online Propagation Tool

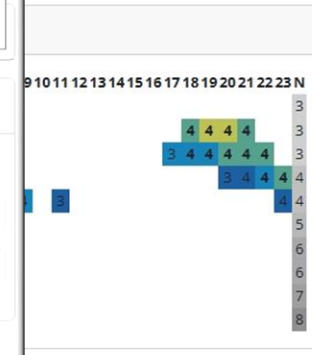


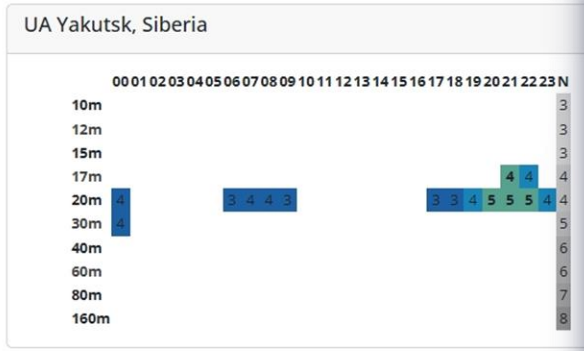
KC2G Propagation Tool – My Favorite

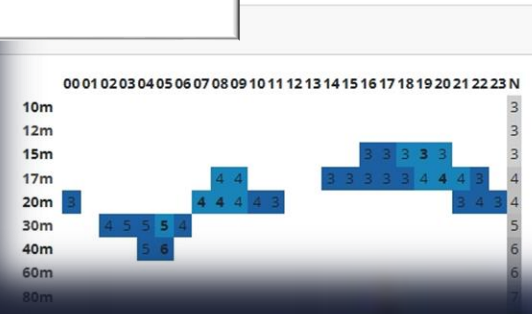


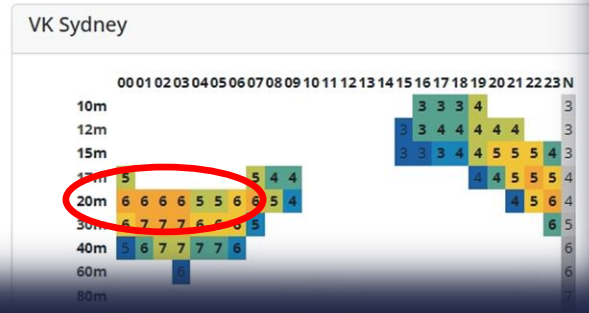












…Sleep DX-ing is Not a Thing…

- Propagation ≠ Contacts
- The path must exist **and** DX must be active
- Many prime paths occur when regions are asleep!
- The best opening is useless if no one is on

HF Band Strategy Table – East Coast US (SSB)

			Africa										
South America			Europe		Asia				Pacific		CONUS		
EST	SA	VP8	UTC	ZS	UAR	India	China	AUS	Fiji	HST	PST	MST	CST
-5	-4	-2	0	2	4	6	8	10	12	-10	-8	-7	-6
08:00	09:00	11:00	13:00	15:00	17:00	*19:00*	21:00	23:00	01:00	03:00	05:00	06:00	07:00
09:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	00:00	02:00	04:00	06:00	07:00	*08:00*
10:00	11:00	13:00	15:00	17:00	19:00	21:00	23:00	01:00	03:00	05:00	07:00	08:00	*09:00*
11:00	12:00	14:00	16:00	18:00	20:00	22:00	00:00	02:00	04:00	06:00	08:00	09:00	*10:00*
12:00	13:00	15:00	17:00	19:00	21:00	23:00	01:00	03:00	05:00	07:00	09:00	10:00	*11:00*
13:00	14:00	16:00	18:00	20:00	22:00	00:00	02:00	04:00	06:00	08:00	10:00	11:00	*12:00*
14:00	15:00	17:00	19:00	21:00	23:00	01:00	03:00	05:00	07:00	09:00	11:00	12:00	*13:00*
15:00	16:00	18:00	20:00	22:00	00:00	02:00	04:00	06:00	08:00	10:00	12:00	13:00	*14:00*
16:00	17:00	19:00	21:00	23:00	01:00	03:00	05:00	07:00	09:00	11:00	13:00	14:00	*15:00*
17:00	18:00	20:00	22:00	00:00	02:00	04:00	06:00	08:00	10:00	12:00	14:00	15:00	*16:00*
18:00	19:00	21:00	23:00	01:00	03:00	05:00	07:00	09:00	11:00	13:00	15:00	16:00	*17:00*
19:00	20:00	22:00	00:00	02:00	04:00	06:00	08:00	10:00	12:00	14:00	16:00	17:00	*18:00*
20:00	21:00	23:00	01:00	03:00	05:00	07:00	09:00	11:00	13:00	15:00	17:00	18:00	*19:00*
21:00	22:00	00:00	02:00	04:00	06:00	08:00	10:00	12:00	14:00	16:00	18:00	19:00	20:00
22:00	23:00	01:00	03:00	05:00	07:00	09:00	11:00	13:00	15:00	17:00	19:00	20:00	21:00
23:00	00:00	02:00	04:00	06:00	08:00	10:00	12:00	14:00	16:00	18:00	20:00	21:00	22:00
00:00	01:00	03:00	05:00	07:00	09:00	11:00	13:00	15:00	17:00	19:00	21:00	22:00	23:00
01:00	02:00	04:00	06:00	08:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	23:00	00:00
02:00	03:00	05:00	07:00	09:00	11:00	13:00	15:00	17:00	19:00	21:00	23:00	00:00	01:00
03:00	04:00	06:00	08:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	00:00	01:00	02:00
04:00	05:00	07:00	09:00	11:00	13:00	15:00	17:00	19:00	21:00	23:00	01:00	02:00	03:00
05:00	06:00	08:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	00:00	02:00	03:00	04:00
06:00	07:00	09:00	11:00	13:00	15:00	17:00	19:00	21:00	23:00	01:00	03:00	04:00	05:00
07:00	08:00	10:00	12:00	14:00	16:00	18:00	20:00	22:00	00:00	02:00	04:00	05:00	06:00

DX Station QRT Time

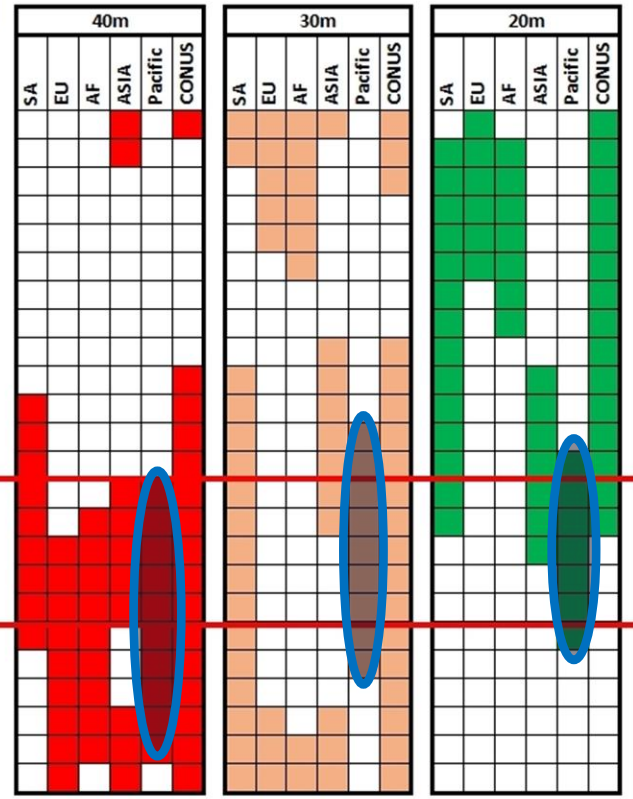
My Normal QRT Time

*FT8 opens and closes 1–2 hours before and after SSB

**The time windows reflect decades of observed patterns by operators.

*** These are operating windows, not predictions. There is no fixed "correct schedule" for propagation.

Propagation Windows



https://cars-nc.org/the_dxer_secret_weapon.html

Finally…

- ✓Propagation prediction is forecasting, not certainty!
- ✓Even great stations cannot overcome bad propagation
- ✓The bands are never dead - just severely misunderstood
- ✓MUF sets the ceiling, LUF sets the floor
- ✓Polar Paths Are Fragile - Auroral activity destroys polar propagation
- ✓Long-path can outperform short-path - Especially near Gray-line
- ✓Morning Often Beats Evening - Operator wisdom
- ✓Be on the air at the *right time*

Thank you

Questions?

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