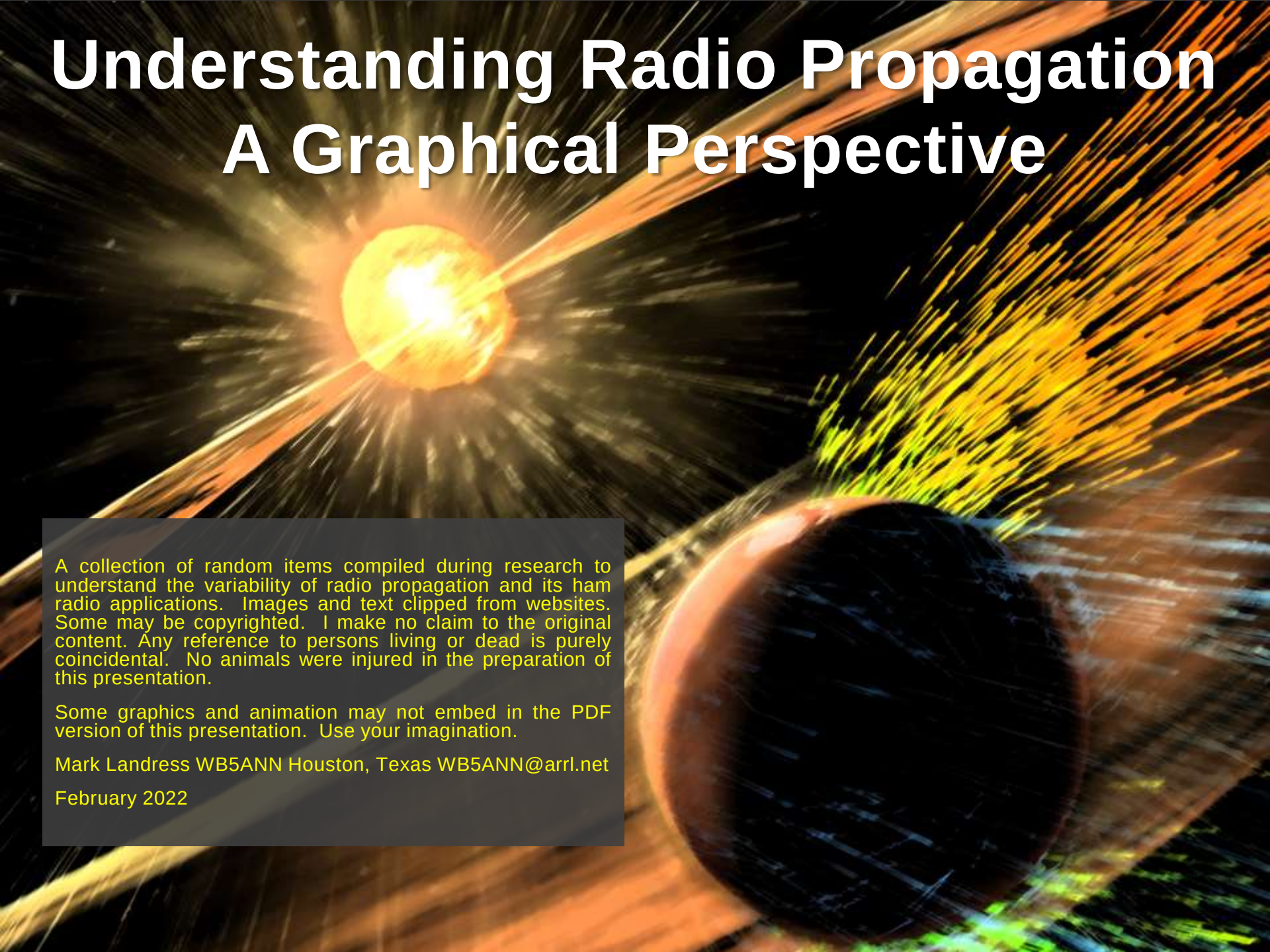
Understanding Radio Propagation
A Graphical Perspective



A collection of random items compiled during research to understand the variability of radio propagation and its ham radio applications. Images and text clipped from websites. Some may be copyrighted. I make no claim to the original content. Any reference to persons living or dead is purely coincidental. No animals were injured in the preparation of this presentation.

Some graphics and animation may not embed in the PDF version of this presentation. Use your imagination.

Mark Landress WB5ANN Houston, Texas WB5ANN@arrl.net

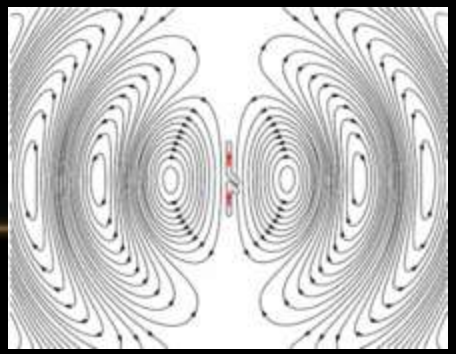
February 2022

What is Propagation?

The behavior of radio waves as they travel, or are propagated, from one point to another or into various parts of the atmosphere.

As a form of electromagnetic radiation, like light waves, radio waves are affected by the phenomena of reflection, refraction, diffraction, absorption, polarization, and scattering.

Propagation of radio waves on the earth is controlled by ionization conditions in the ionosphere.



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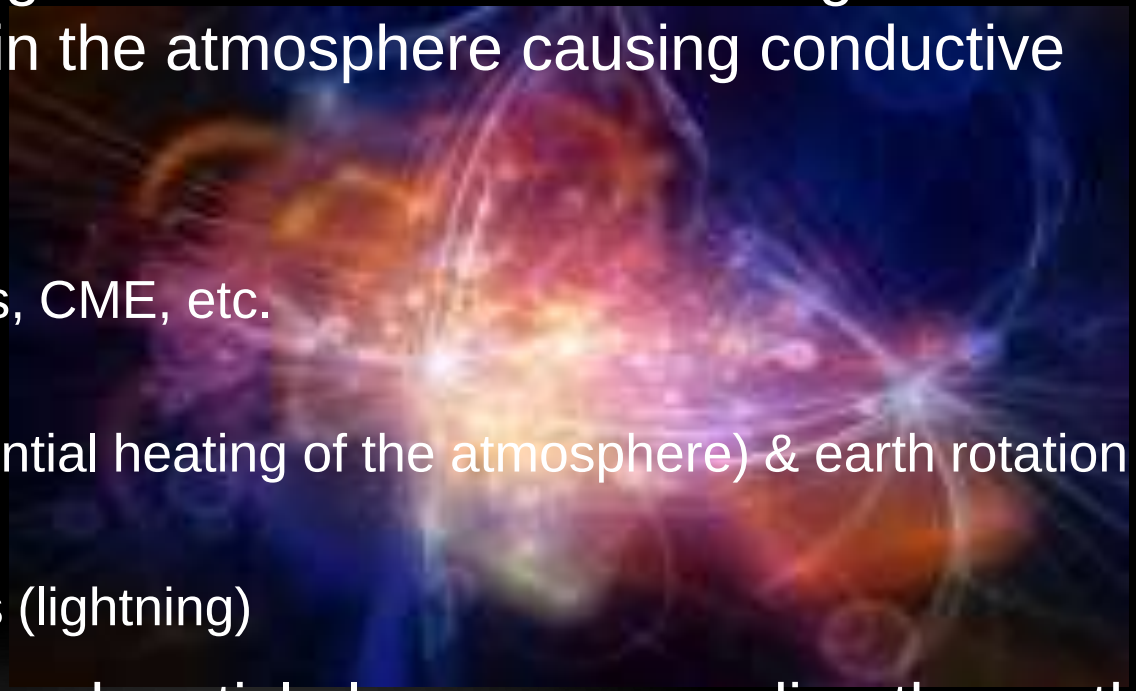
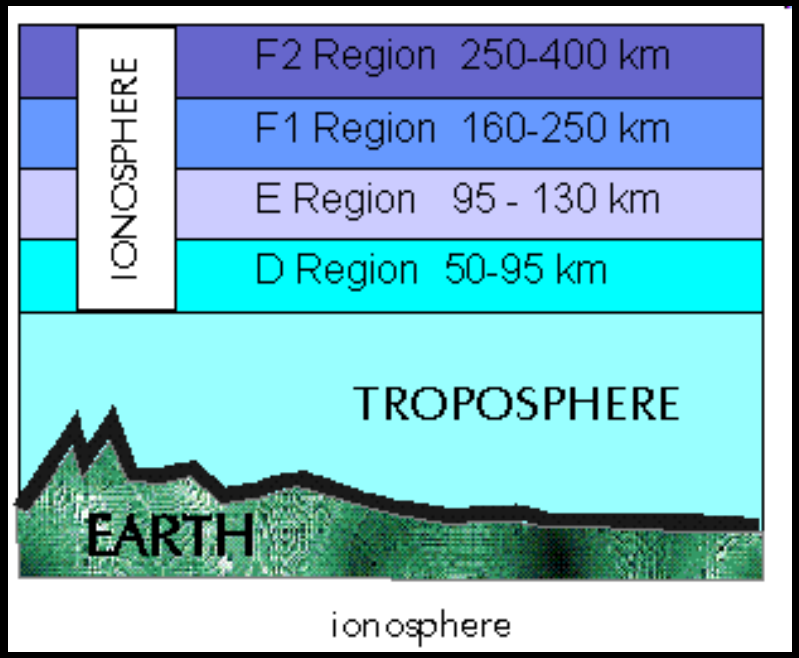
What Causes Ionosphere Ionization?

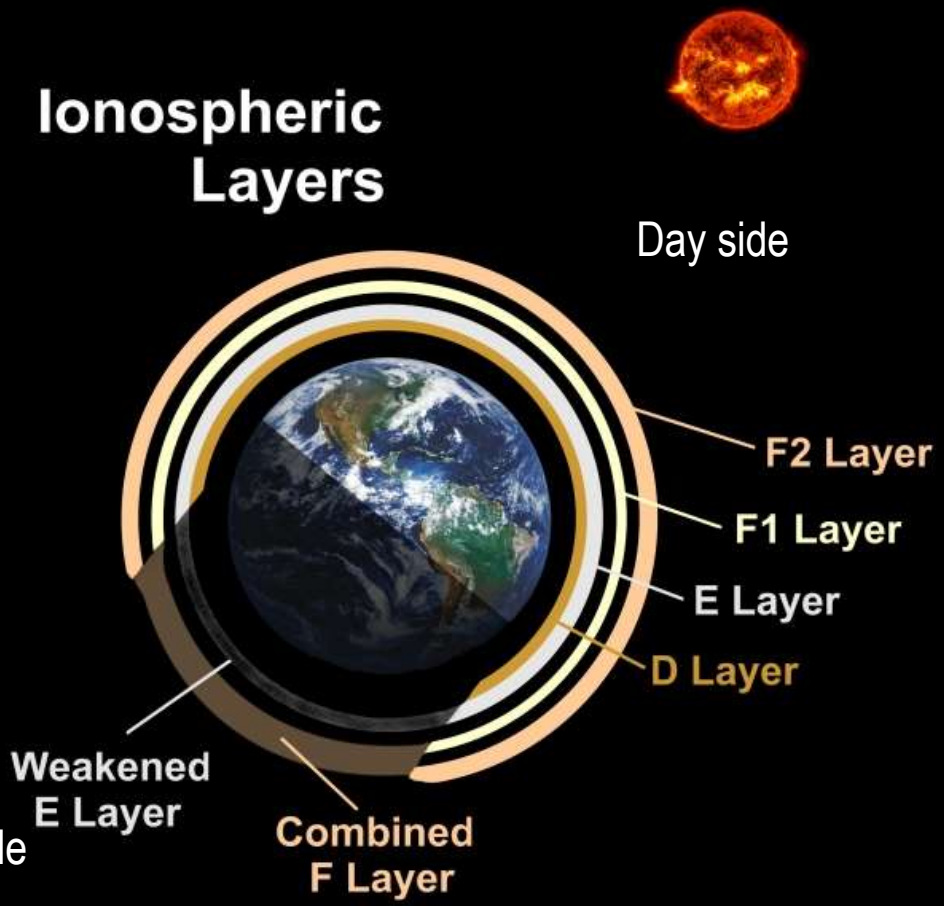
- An ion is a atom or molecule with a unbalanced electric charge
- Caused when UV light knocks electrons off nitrogen and oxygen molecules in the atmosphere causing conductive currents.
- Varies with
  - Solar flux, sunspots, CME, etc.
  - Season
  - Time of day (differential heating of the atmosphere) & earth rotation
  - Atmospheric tides
  - Differential charges (lightning)
- Manifests as charged particle layers surrounding the earth.



Charged Particle Layers

Charged particle layers, solar activity and cosmic effects of space weather control propagation. Conditions of the particle layers are monitored continuously from sites all over the world and compiled to report ionospheric conditions more or less in real time.





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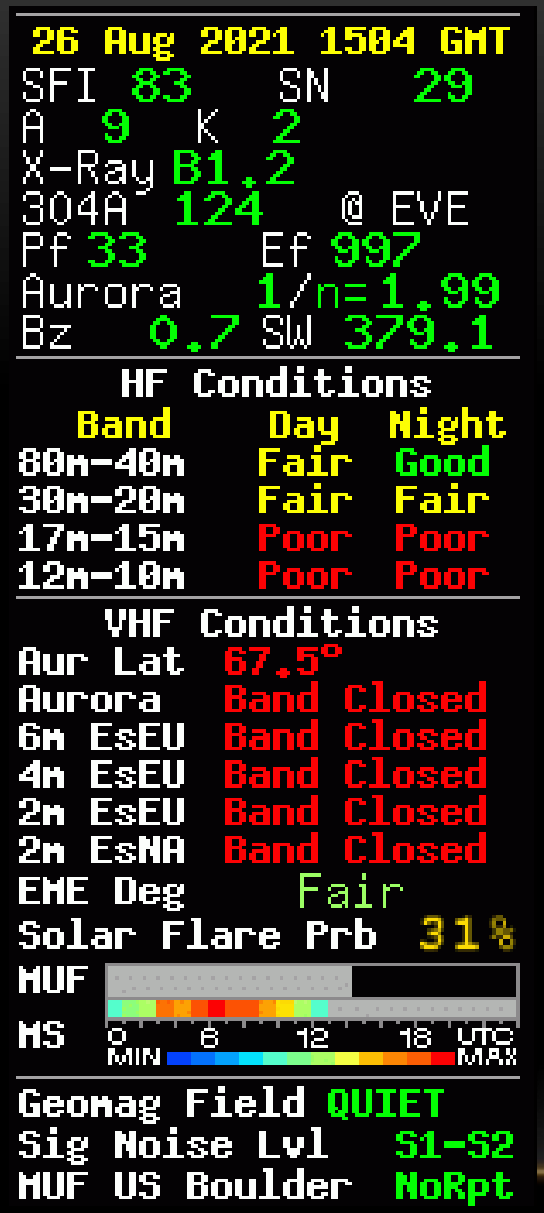
Typical Ham Propagation Dashboard



SFI – Solar Flux Index – 10.7 cm flux. F layer ionization
SN – Sunspot Number – No. of groups on solar disk.
A – A index. Instability of earth magnetic field.
K – K index. Instability of horizontal component of mag field.
X-Ray- Radiation level (D -Layer absorption)
304A – 304 angstrom radiation from ionized helium (F-Layer)
Pf – Proton Flux density in solar wind (E-layer)
Ef – Electron Flux density in solar wind (E-layer)
Aurora - F layer strength in polar region. (1.99 normalization no.)
Bz - Strength of interplanetary mag field. (-) neg => impacts.
SW – Solar wind speed km/sec (>500 affects prop)
HF & VHF Conditions – Good, fair, poor or closed.
Solar flair prb%.
MUF Maximum useable frequency
MS – meteor scatter
Geomagnetic field
Noise

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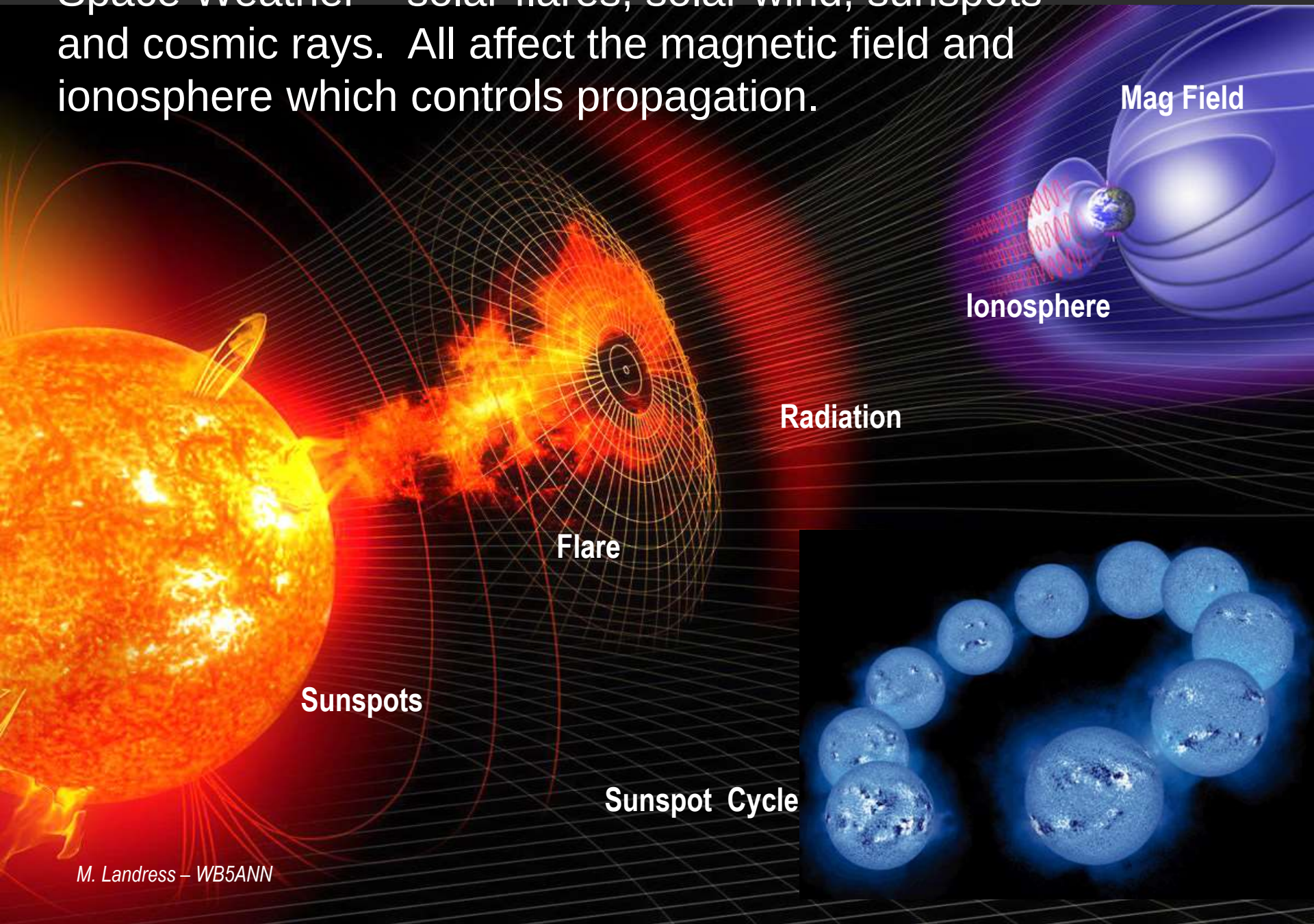
Space Weather – solar flares, solar wind, sunspots and cosmic rays. All affect the magnetic field and ionosphere which controls propagation.



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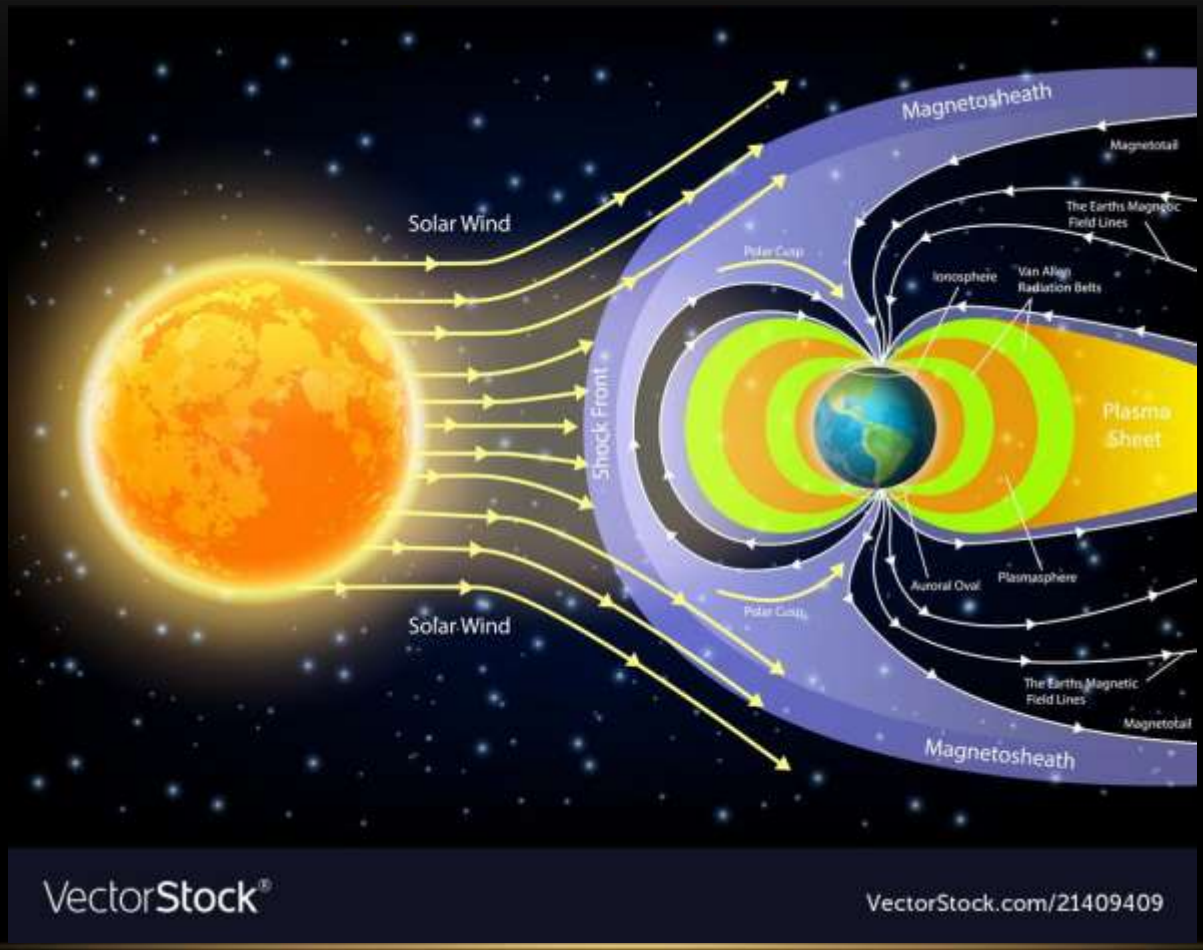
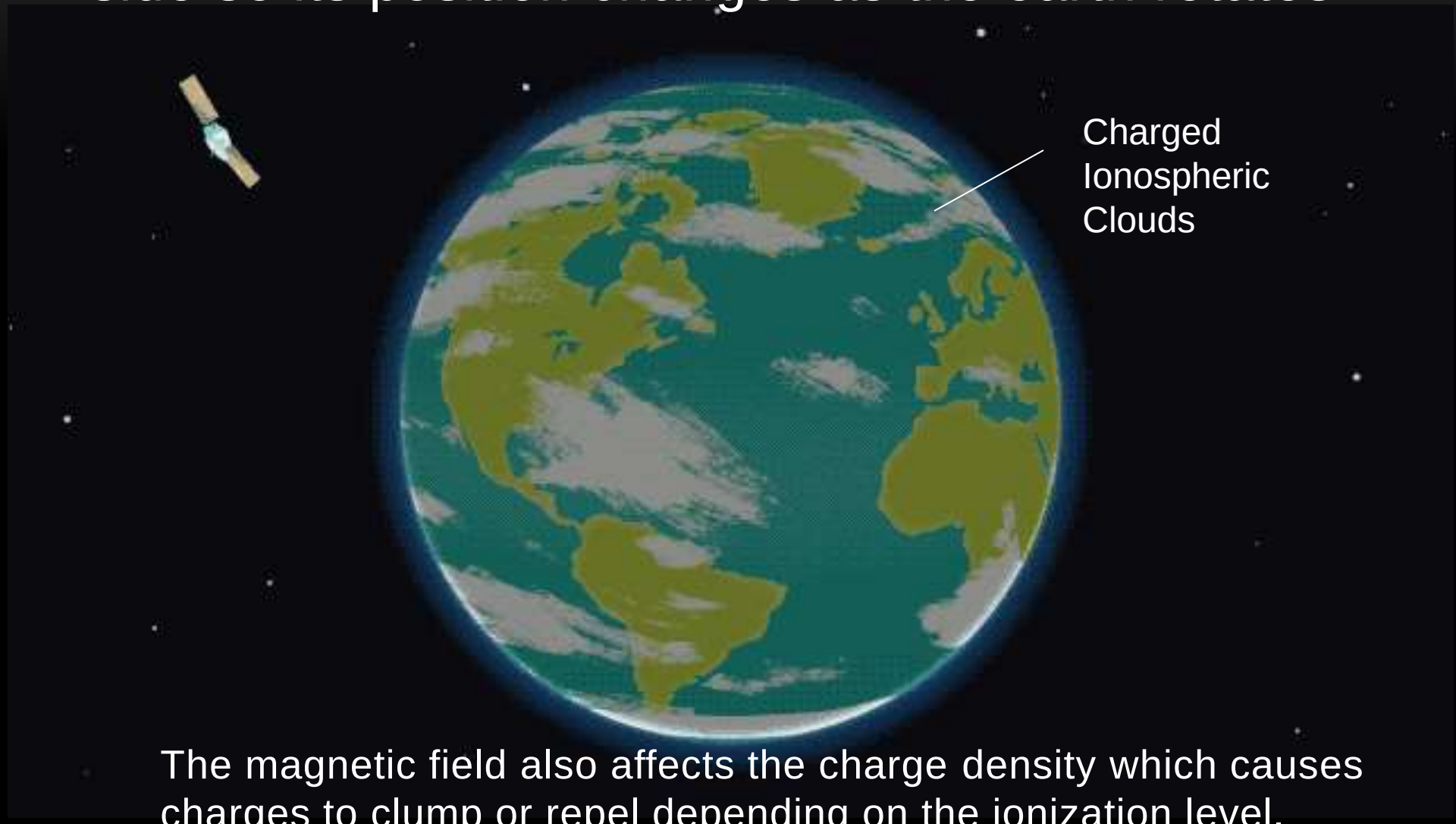
Effects of Solar Wind – Obviously not to scale.

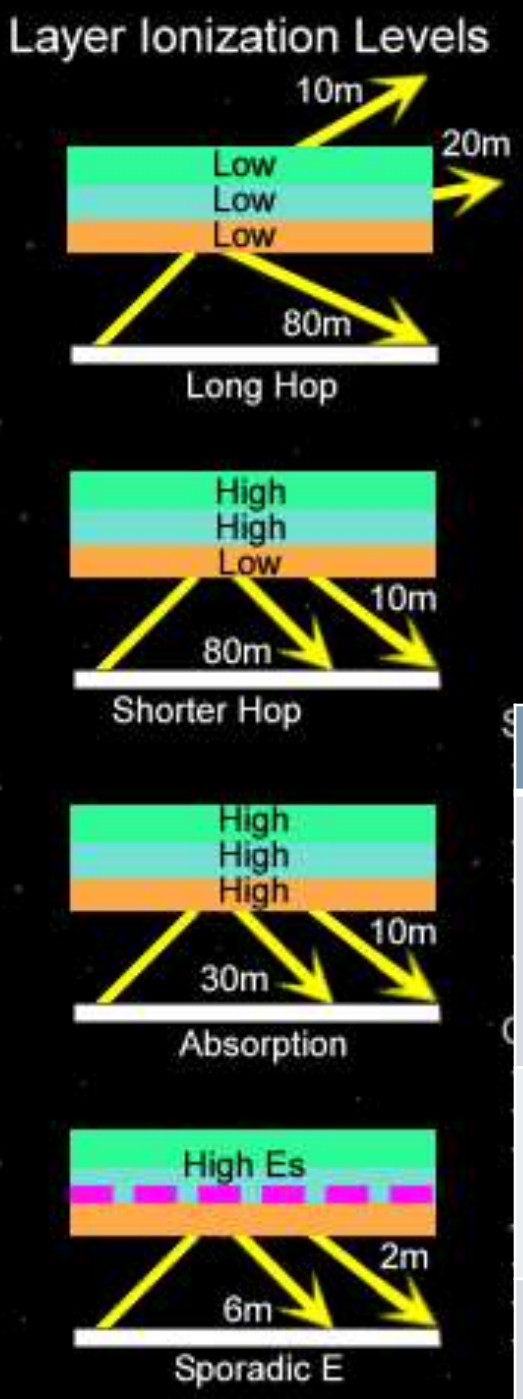


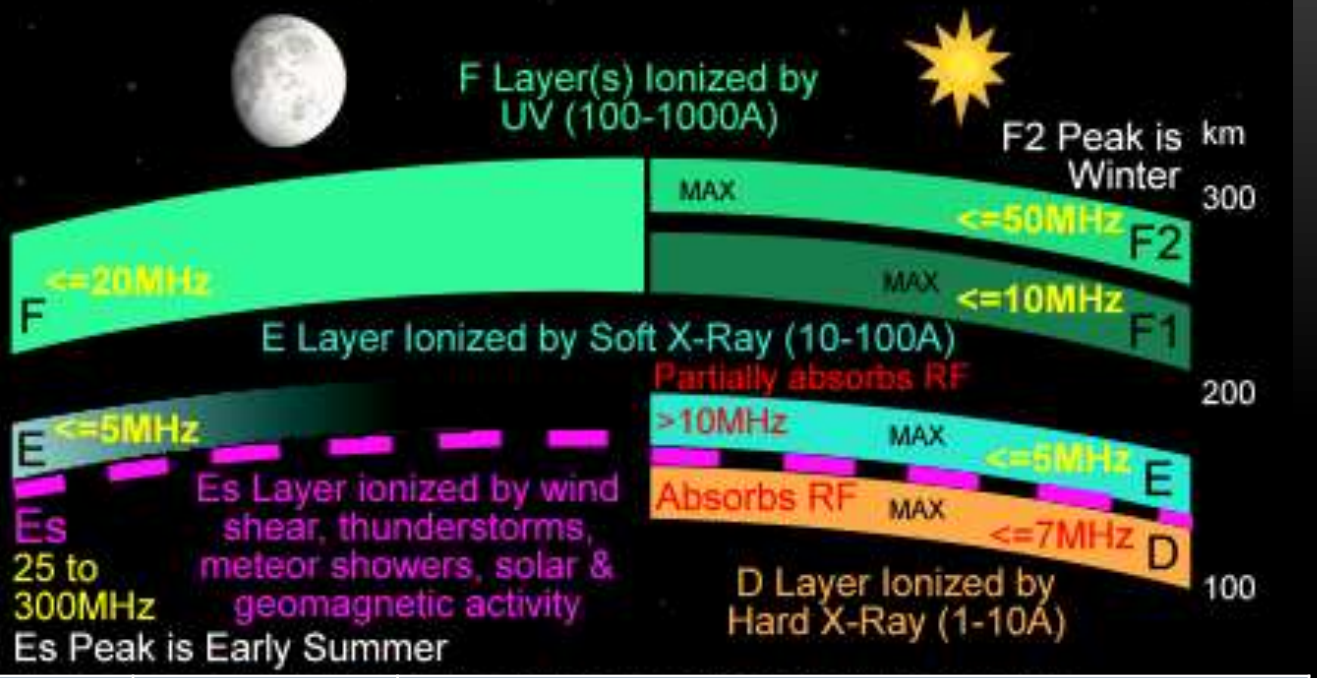
The Ionization is Not Even – Charged particle density varies and causes irregularities in the field that can cause rapid local or regional changes to the propagation

The electron charge density is strongest on the sun side so its position changes as the earth rotates.

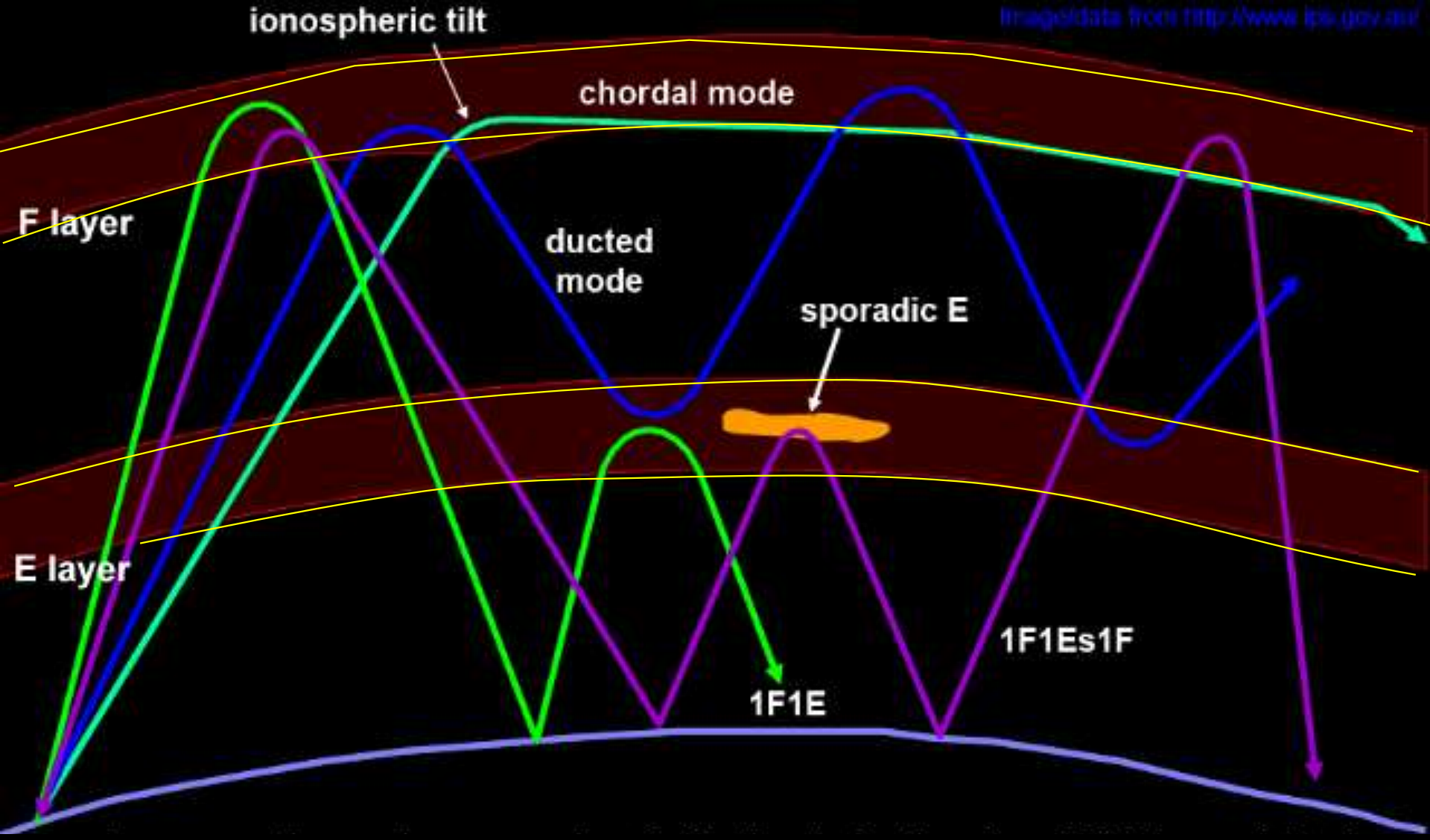


The magnetic field also affects the charge density which causes charges to clump or repel depending on the ionization level.





Layer	Cause	Feature
F	UV Radiation	Responsible for most propagation.. Forms during day and disappears at night. Sometimes splits into F1 and F2 layer during the day. MUF varies by ionization level.
E	Atmospheric shear and tidal effects	Most common May to July and Dec to Feb. Lasts minutes to hours. 6M and below. VHF less common.
D	UV Radiation	Forms during day. Absorbs lower frequency signals



Layers are not smooth and irregularities caused by streaming particles and mag field affect propagation.

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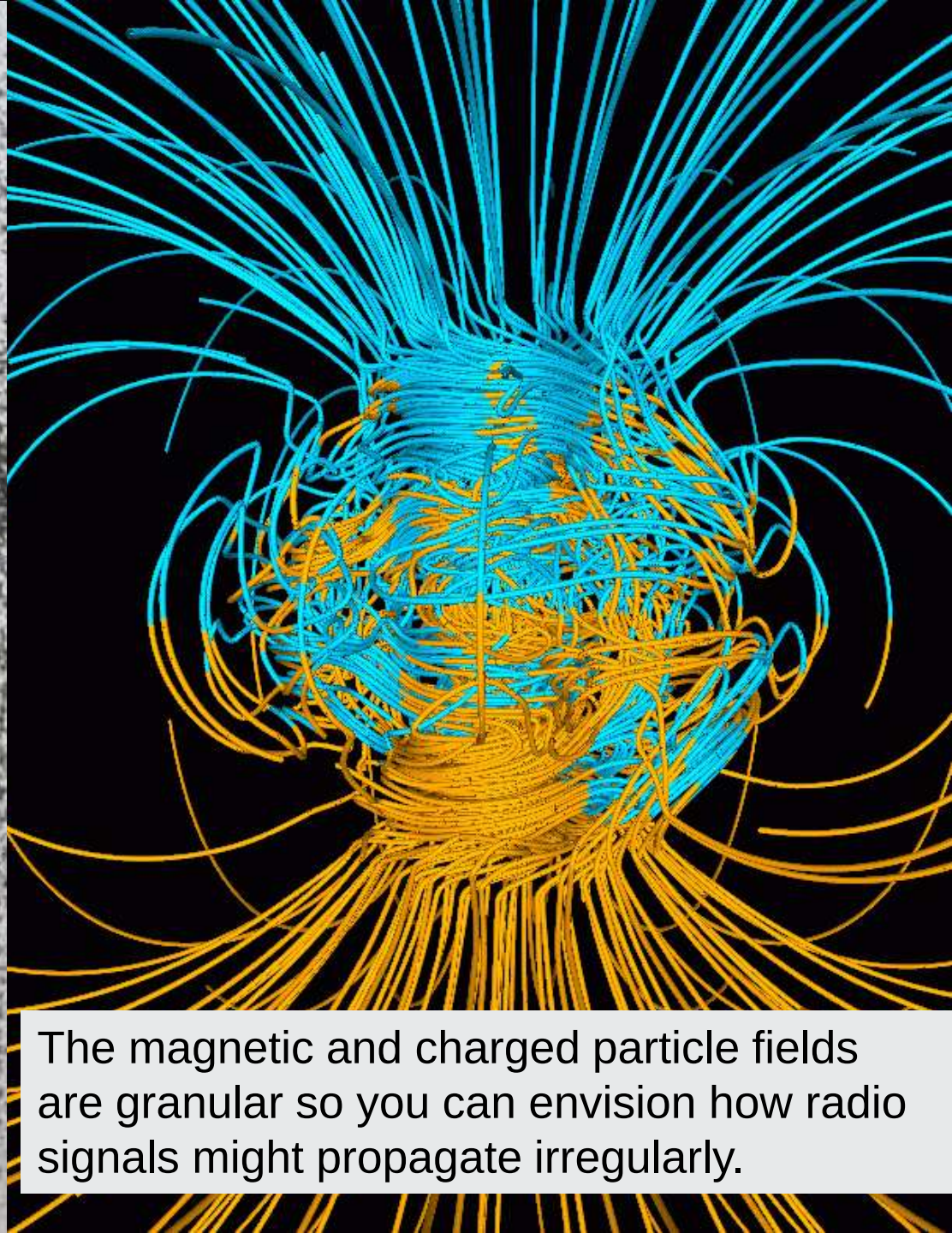

The magnetic and charged particle fields are granular so you can envision how radio signals might propagate irregularly.

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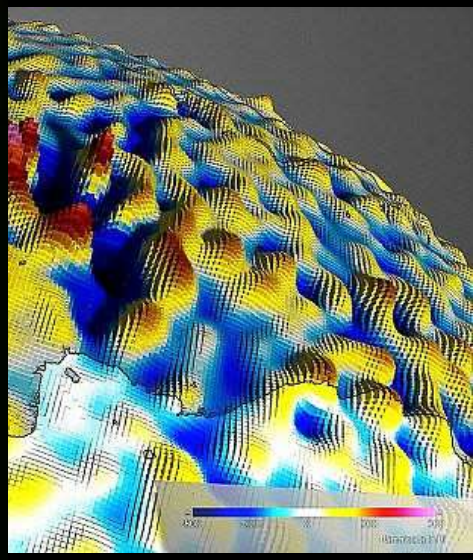
Slide animation of charged particle behavior May not play in all browsers

Surface magnetization is superimposed on the magnetic field. This does not have much to do with propagation but it was a cool picture.



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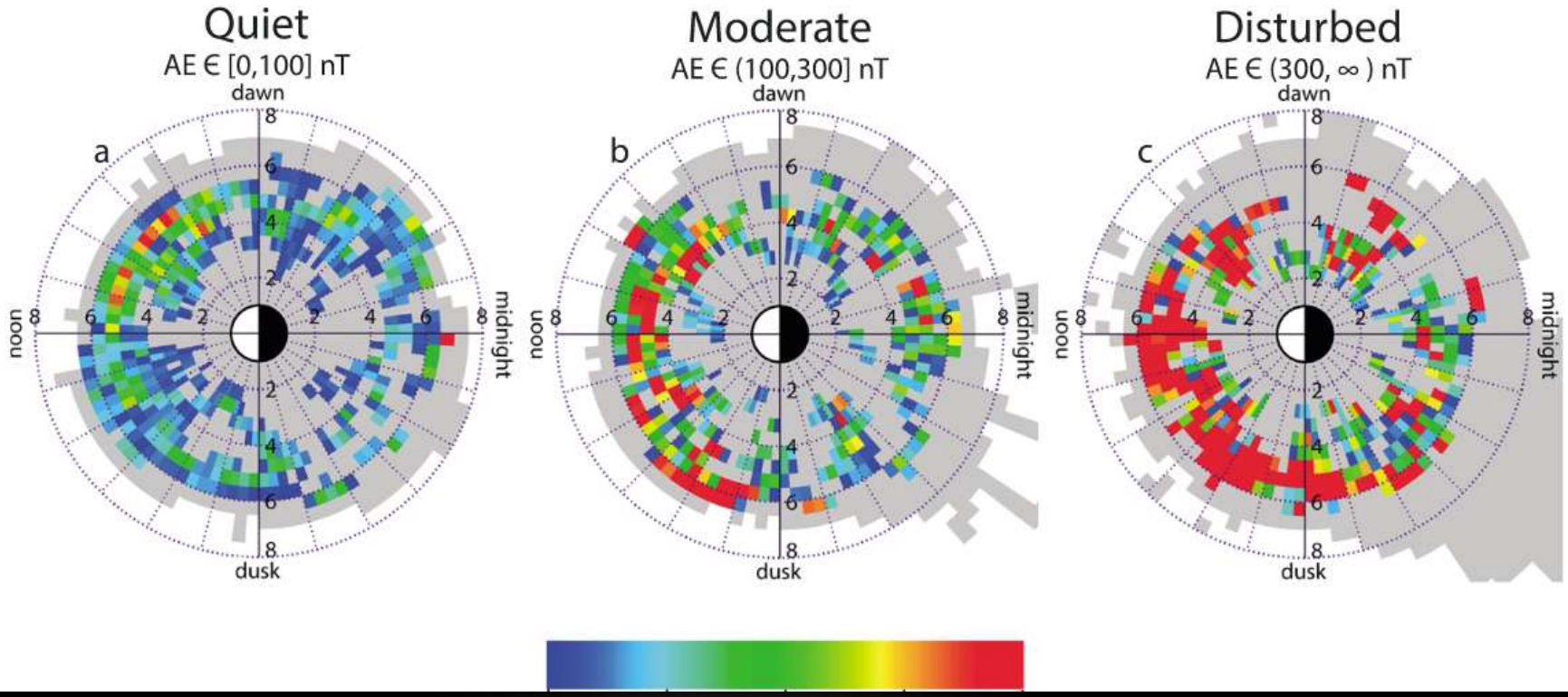
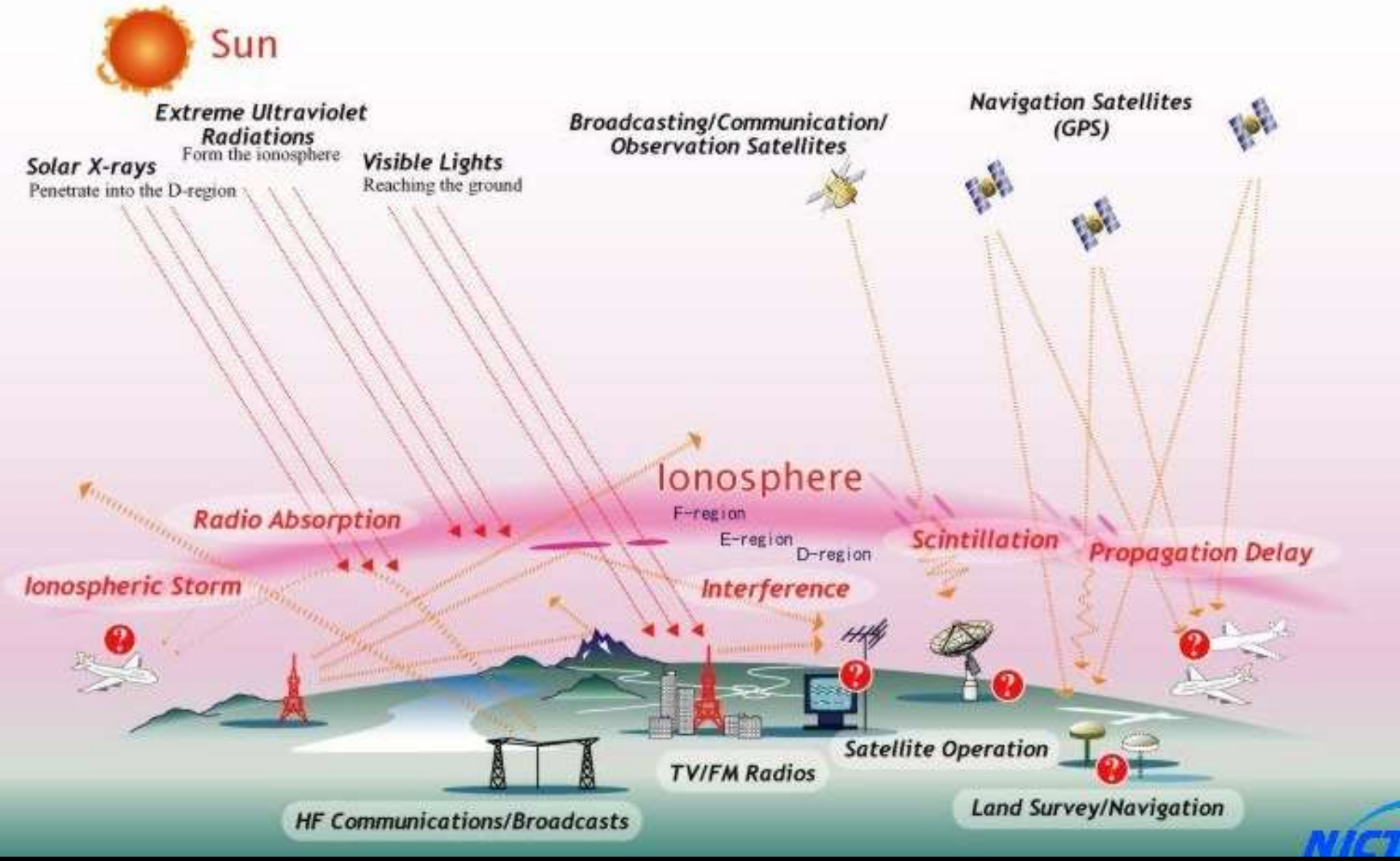
Granularity of the Magnetic Field



The field is more like haze than a shell

Ionospheric Effects on Radio Applications



26 Aug 2021 1504 GMT
SFI 83 SN 29
A 9 K 2
X-Ray B1.2
304A 124 @ EVE
Pf 33 Ef 997
Aurora 1/n=1.99
Bz 0.7 SW 379.1

HF Conditions

Band	Day	Night
80m-40m	Fair	Good
30m-20m	Fair	Fair
17m-15m	Poor	Poor
12m-10m	Poor	Poor

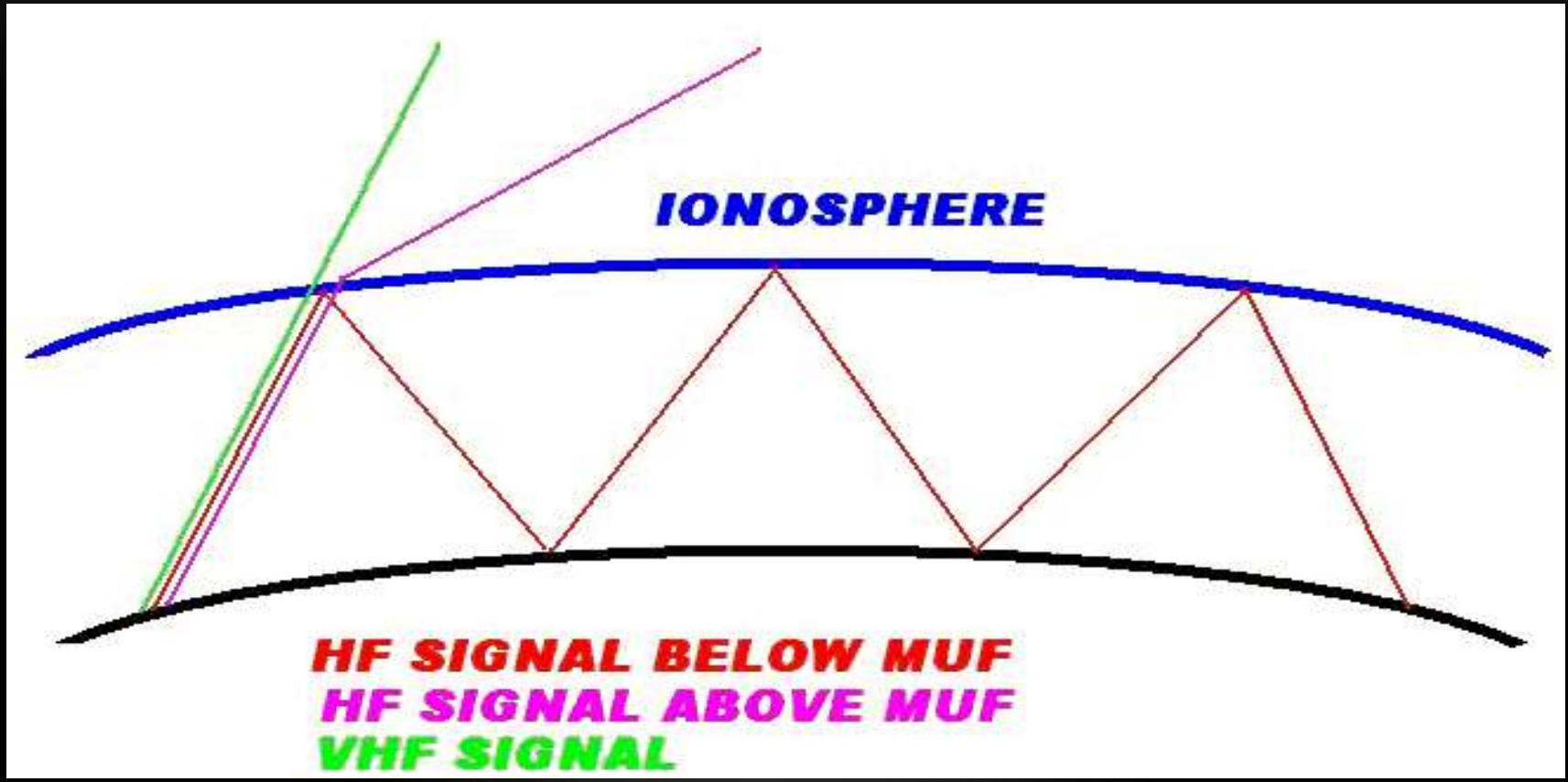
VHF Conditions

Aur Lat	67.5°
Aurora	Band Closed
6m EsEU	Band Closed
4m EsEU	Band Closed
2m EsEU	Band Closed
2m EsNA	Band Closed
EME Deg	Fair
Solar Flare Prb	31%

Geomag Field QUIET
Sig Noise Lvl S1-S2
MUF US Boulder NoRpt

So how do we use all this?

Its all about **Maximum Useable Frequency**



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The Ionosphere Propagation is measured with an Ionosonde. Essentially this is an ionospheric radar.

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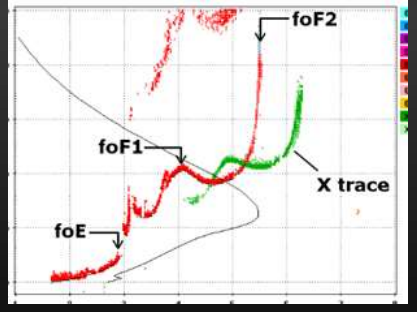
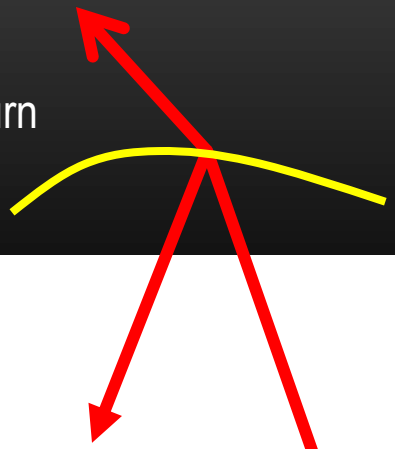
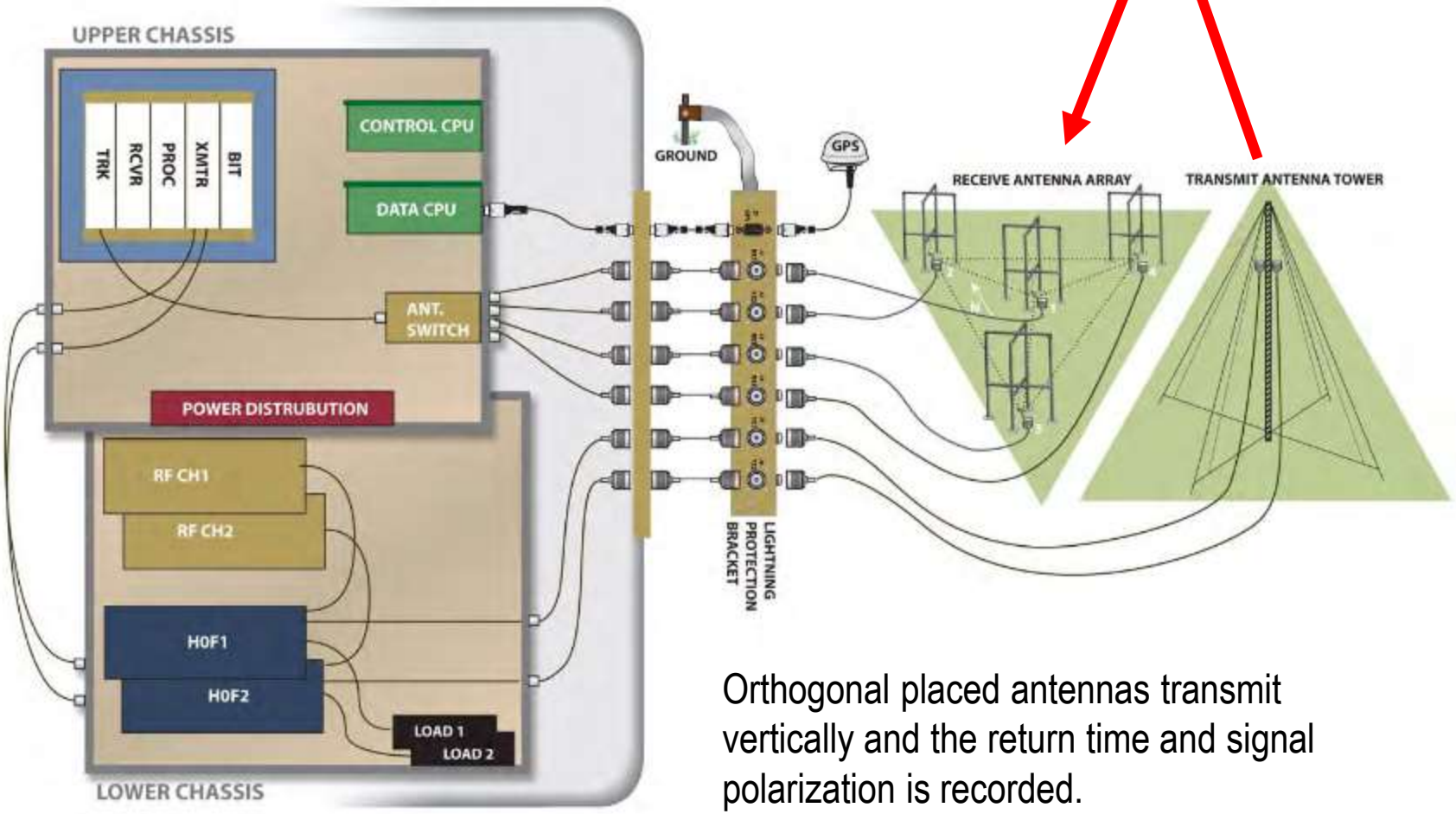


Sweep Frequency and Return

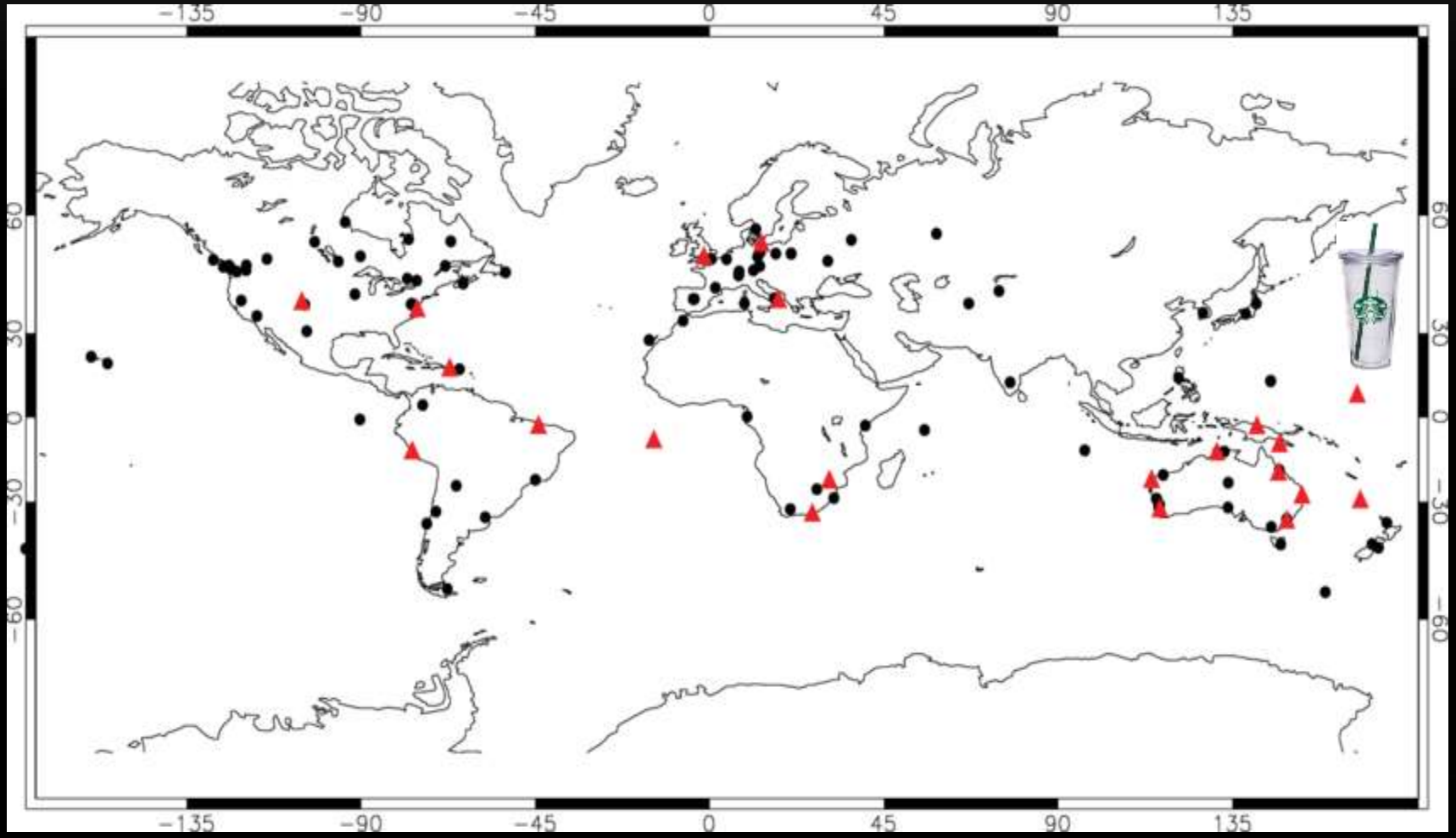




Orthogonal placed antennas transmit vertically and the return time and signal polarization is recorded.

Figure 4-1: Block Diagram of Digisonde-4D

Ionosonde and GPS Receiving Stations Cover the world and are synchronized giving return signals every 15 minutes.



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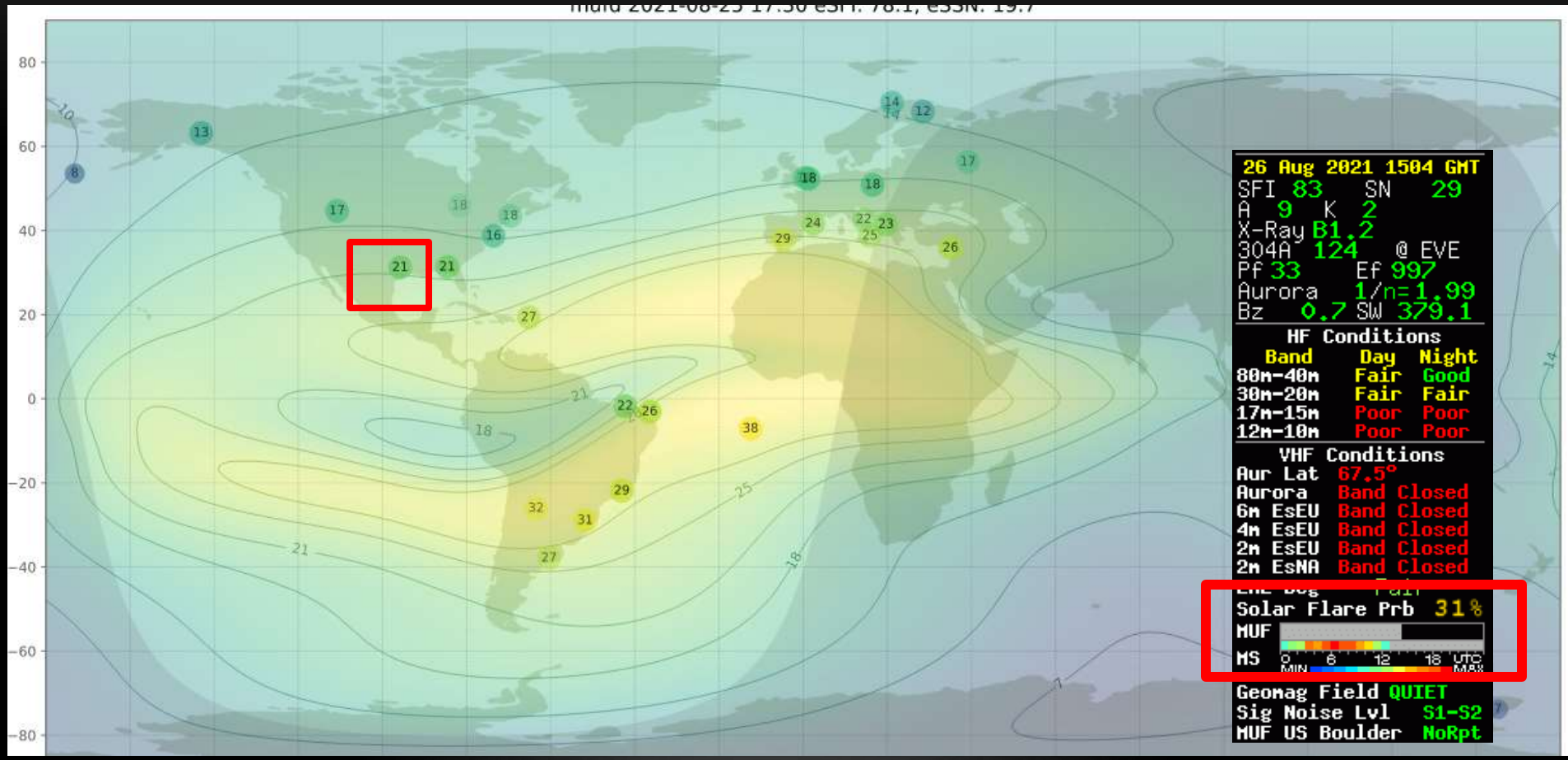
Real-time MUF map derived from ionosonde data. This is the data used to generate propagation summary widgets.



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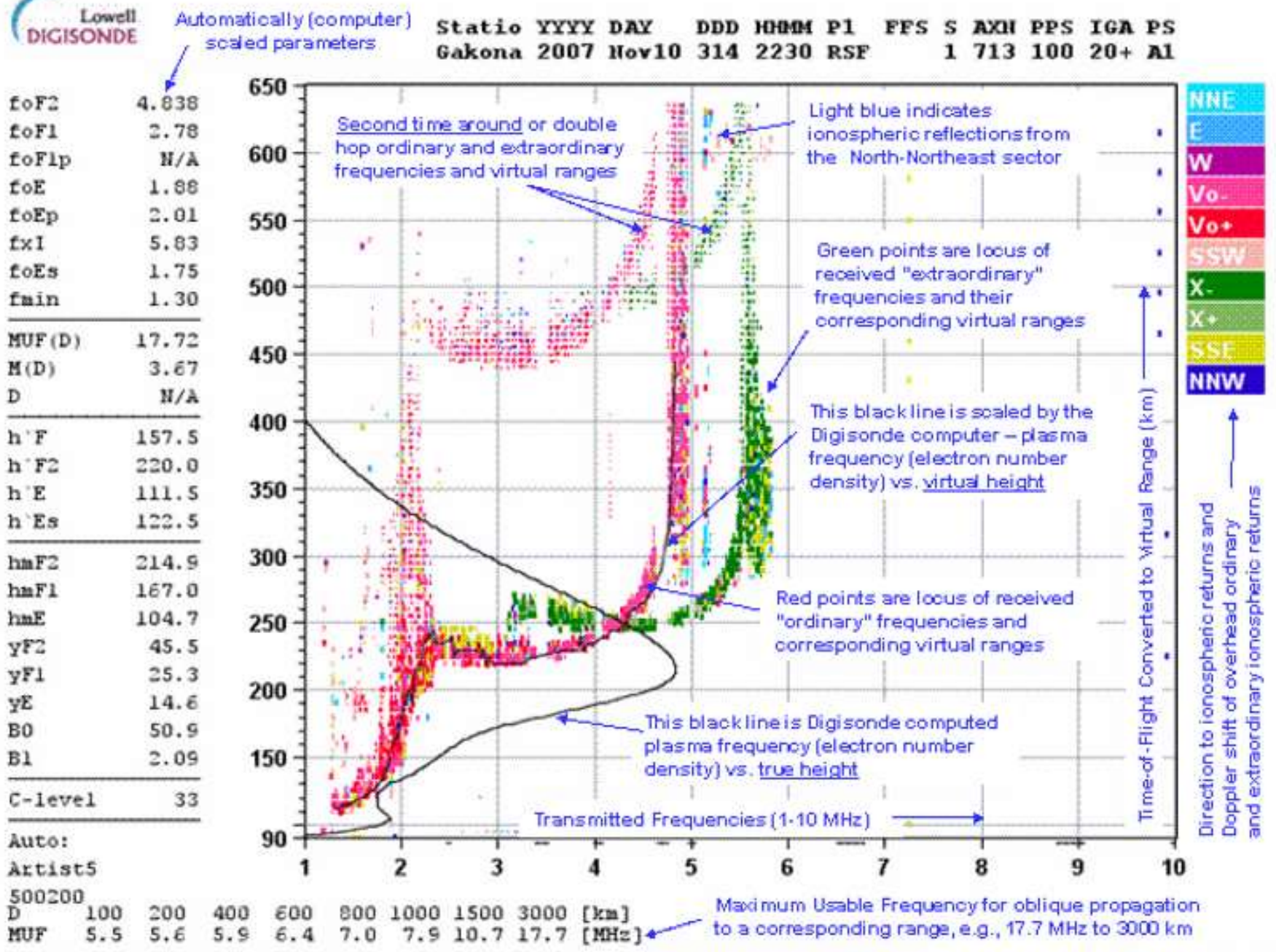

Lowell DIGISONDE
Automatically (computer) scaled parameters
Statio YYYY DAY DDD HHMM P1 FFS S AXH PPS IGA PS
Gakona 2007 Nov10 314 2230 RSF 1 713 100 20+ A1
foF2 4.838
foF1 2.78
foF1p N/A
foE 1.88
foEp 2.01
fxI 5.83
foEs 1.75
fmin 1.30
MUF(D) 17.72
M(D) 3.67
D N/A
h'F 157.5
h'F2 220.0
h'E 111.5
h'Es 122.5
hmF2 214.9
hmF1 167.0
hmE 104.7
yF2 45.5
yF1 25.3
yE 14.6
B0 50.9
B1 2.09
C-level 33
Auto:
Artist5
500200
D 100 200 400 600 800 1000 1500 3000 [km]
MUF 5.5 5.6 5.9 6.4 7.0 7.9 10.7 17.7 [MHz]
Second time around or double hop ordinary and extraordinary frequencies and virtual ranges
Light blue indicates ionospheric reflections from the North-Northeast sector
Green points are locus of received "extraordinary" frequencies and their corresponding virtual ranges
This black line is scaled by the Digisonde computer – plasma frequency (electron number density) vs. virtual height
Red points are locus of received "ordinary" frequencies and corresponding virtual ranges
This black line is Digisonde computed plasma frequency (electron number density) vs. true height
Transmitted Frequencies (1-10 MHz)
Time-of-Flight Converted to Virtual Range (km)
650
600
550
500
450
400
350
300
250
200
150
90
1
2
3
4
5
6
7
8
9
10
NNE
E
W
Vo-
Vo+
SSW
X-
X+
SSE
NNW
Direction to ionospheric returns and Doppler shift of overhead ordinary and extraordinary ionospheric returns
Maximum Usable Frequency for oblique propagation to a corresponding range, e.g., 17.7 MHz to 3000 km
GA762_2007314223000.RSF / 360fx120h 25 kMs 5.0 km / DPS-4 GA762 062 / 62.4 N 215.0 E
Ion2Png v. 1.2.05

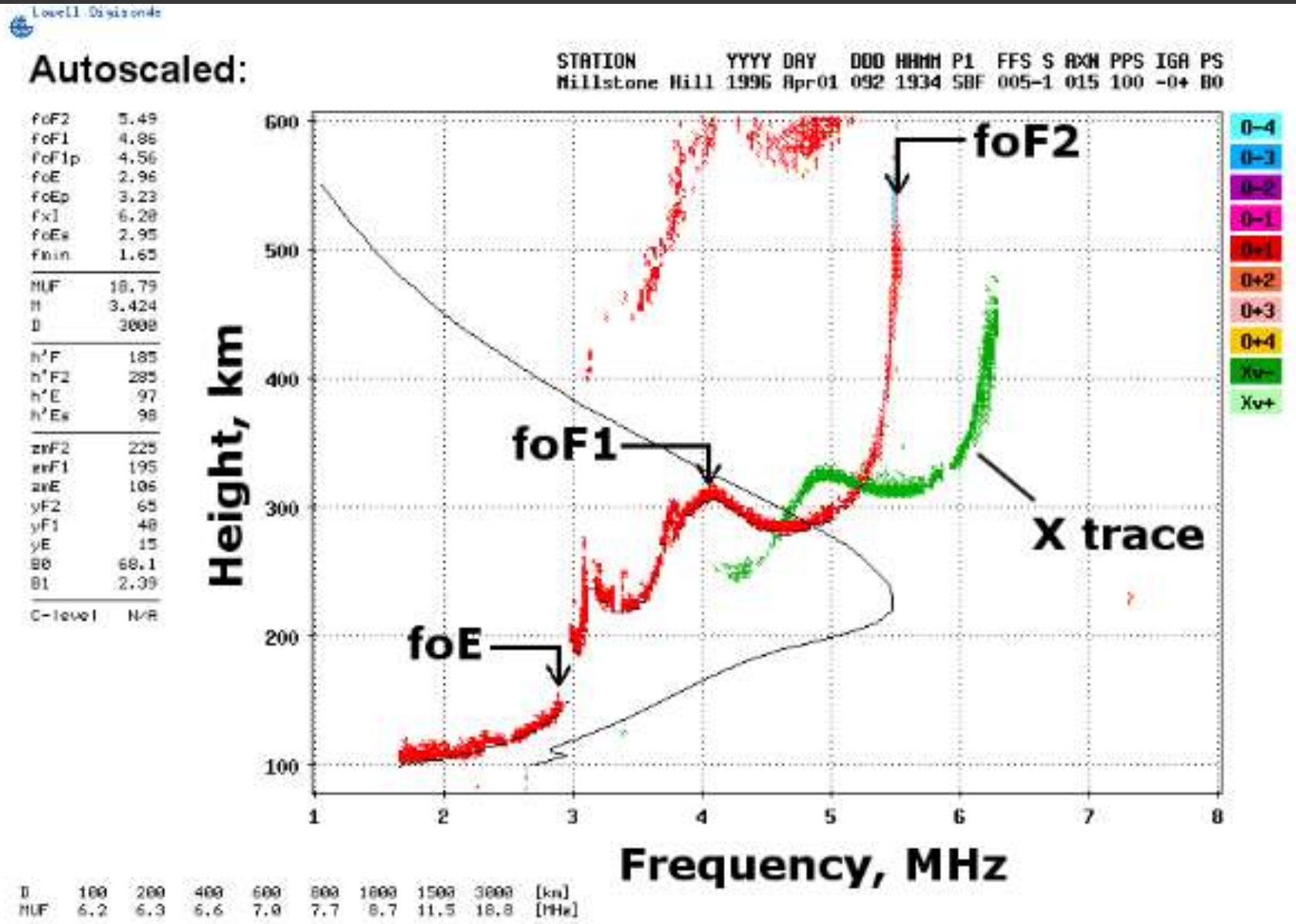
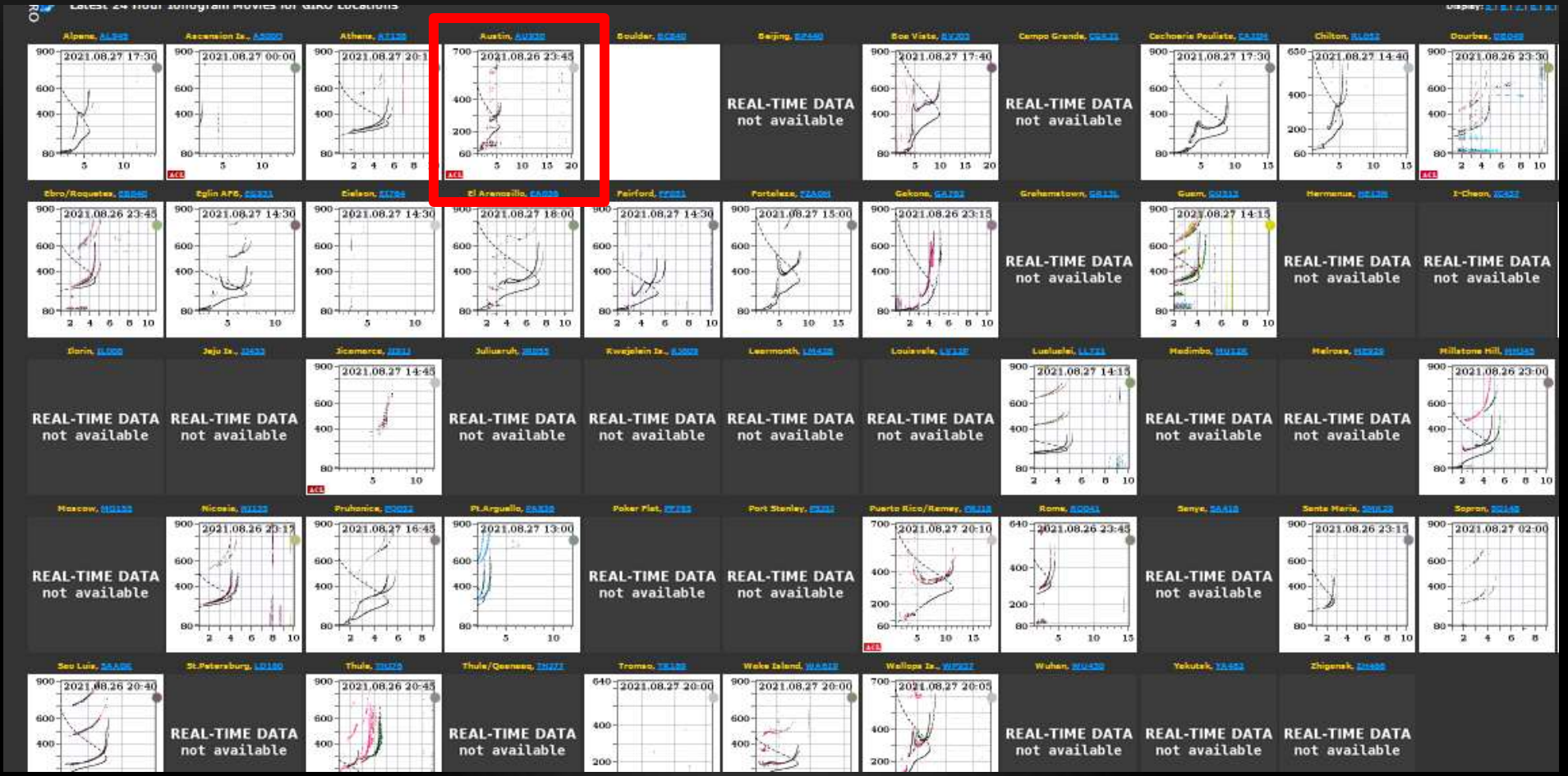


Figure 1-17: Ionogram Consisting of Amplitudes of Maximum Doppler Lines

Ionograms from Around the World are Compiled and Animated into Movies.



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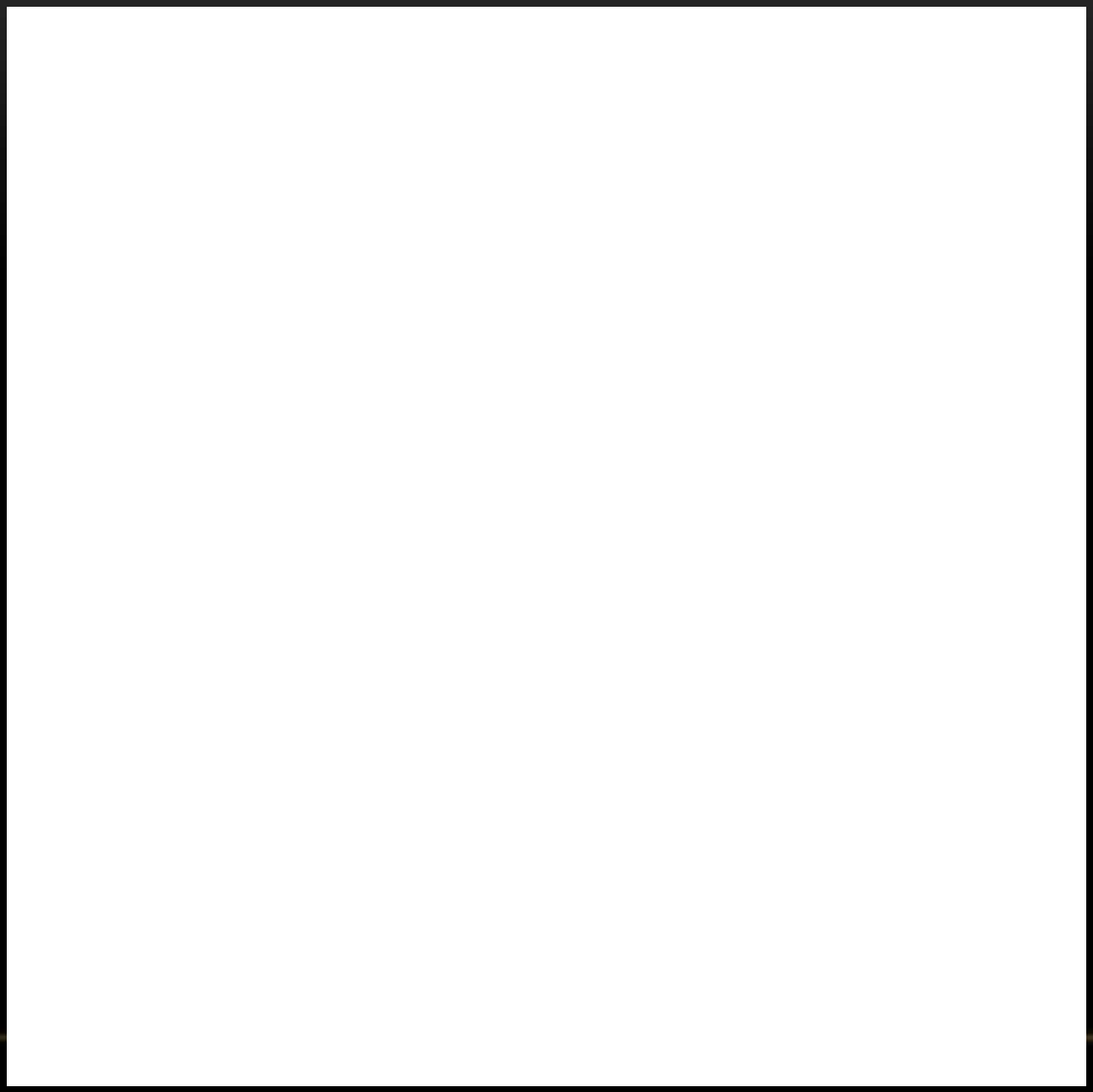
GIRO Compilation

Ionogram Animation at 15 Minute Intervals.



May not play in all browsers See https://giro.uml.edu/IonogramMovies/

Propagation Tools for Monitoring and Forecasting

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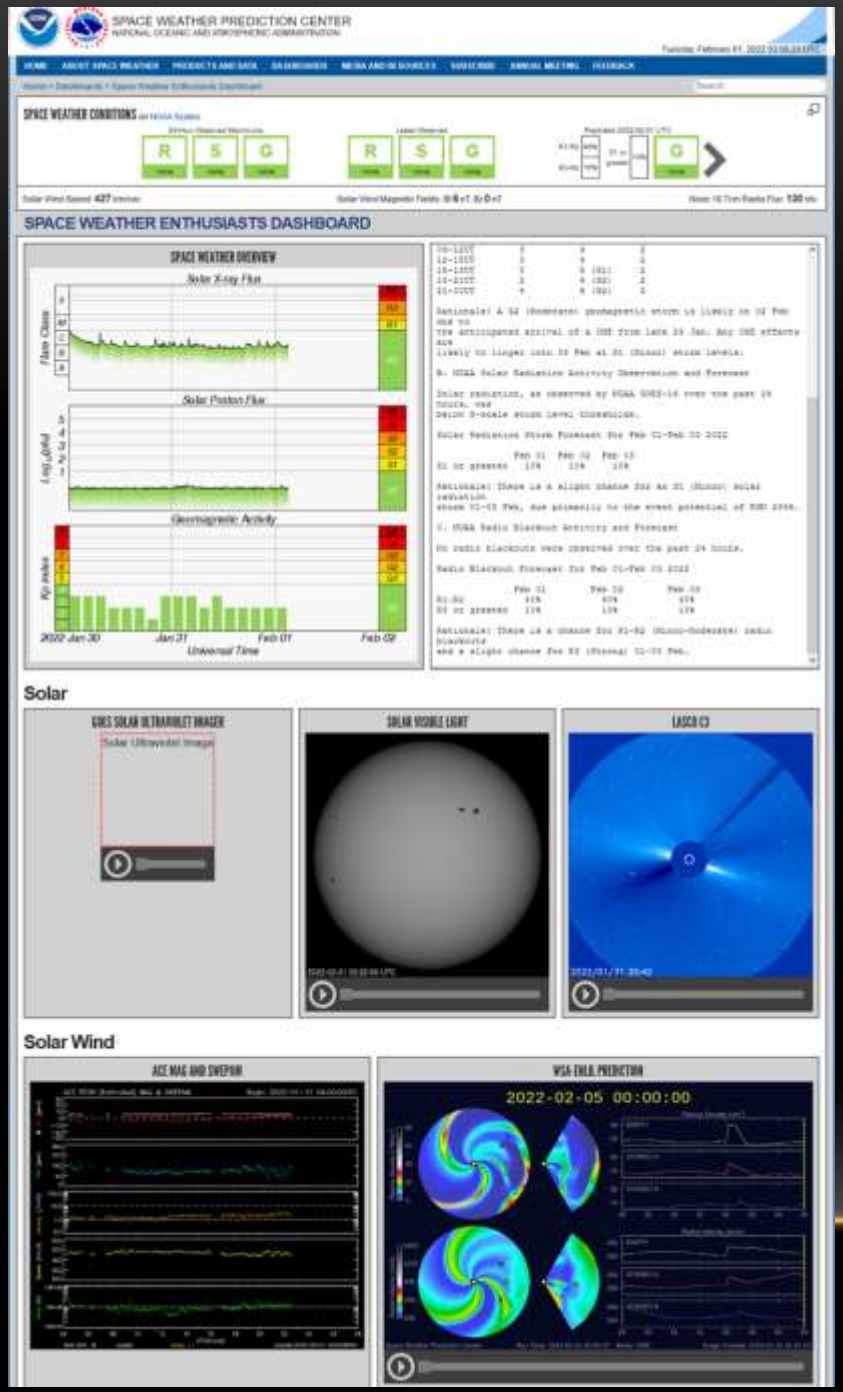
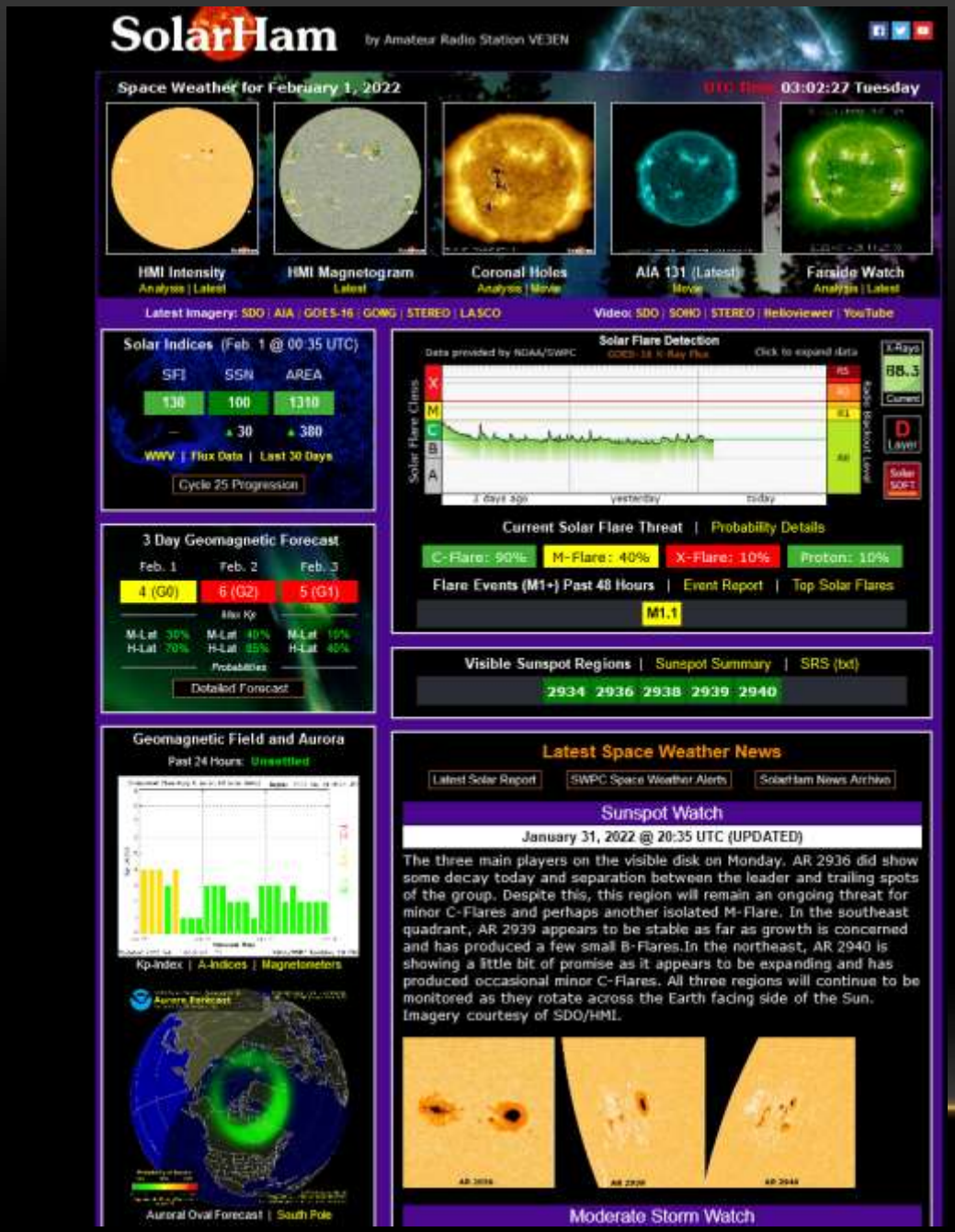


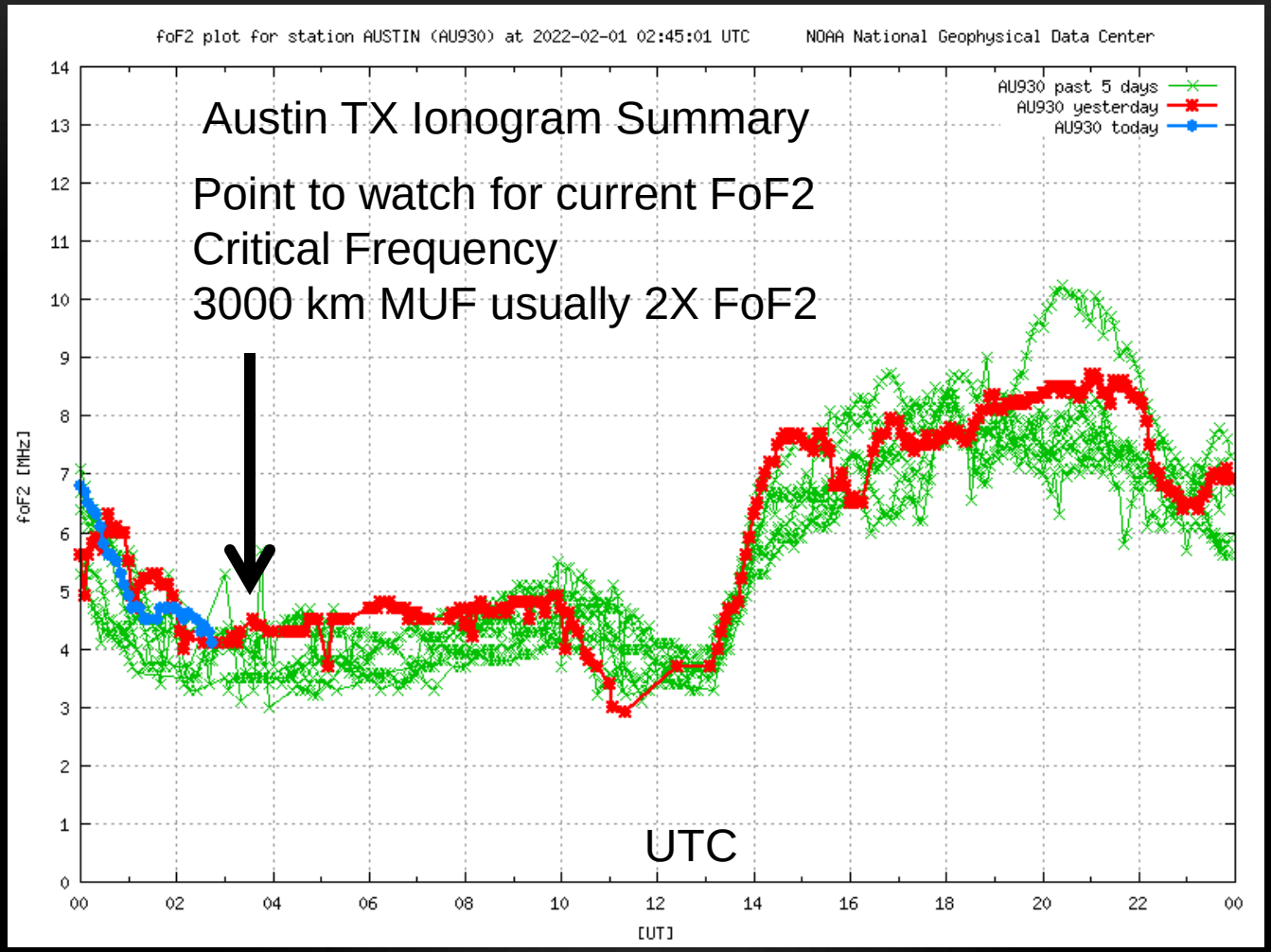
NOAA Space Weather Prediction Center

Aggregator for all data from ground and satellite sensors. Most websites use this information in their dashboards. Lots of information but hard to use unless you are using this site all the time.



Solar Ham –
One stop for most information aggregated into one site. Like the NOAA site, you can get bogged down with data.

Region 6 Army MARS Solar Weather



One of the best quick tools for determining MUF based on nearby real time ionosonde data.

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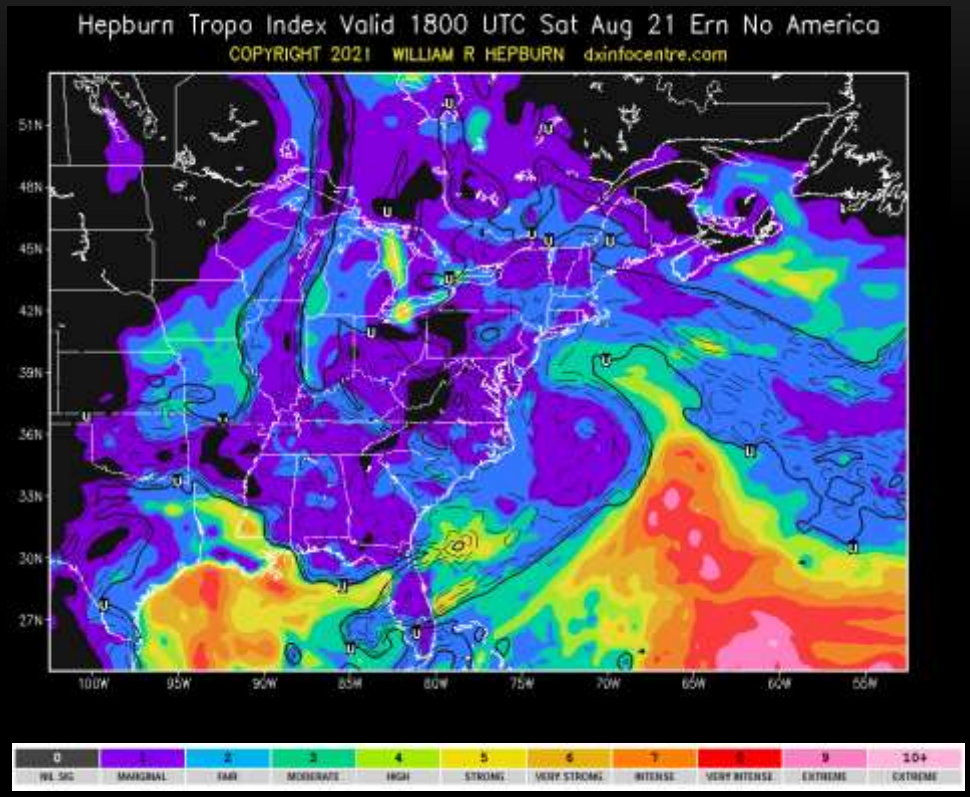
Propagation Tools

Tropospheric Ducting Forecast:

https://www.dxinfocentre.com/tropo_nwe.html

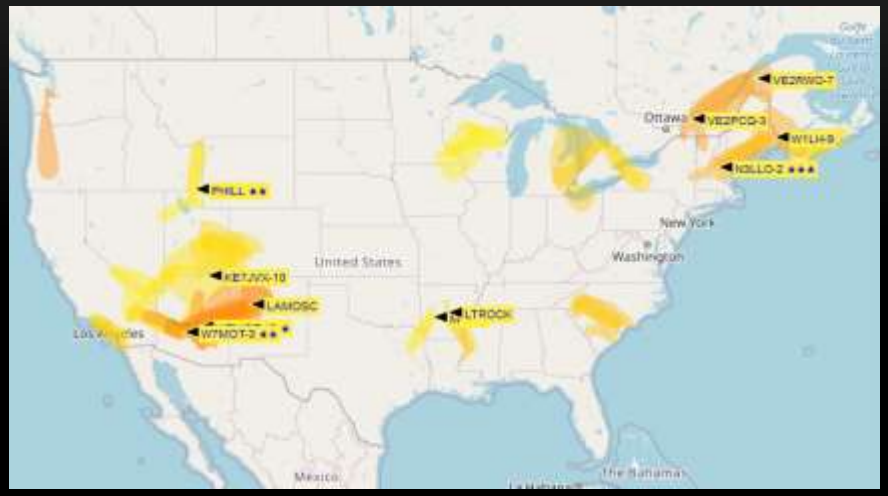
Mainly for VHF and UHF – sometimes 6 and 10 meters

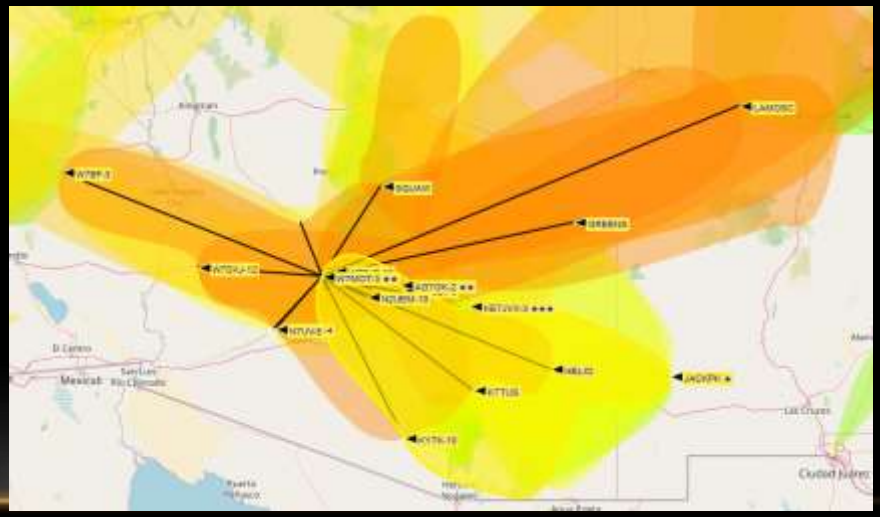


See the Cheat Sheet for the handy propagation tools.

Near Real Time VHF UHF Propagation

Real time propagation based on calculating distance between APRS signals heard on the 2M APRS and packet network. Blobs are the approximate footprint of possible propagation. Distance and bearing are calculated from location of each node.

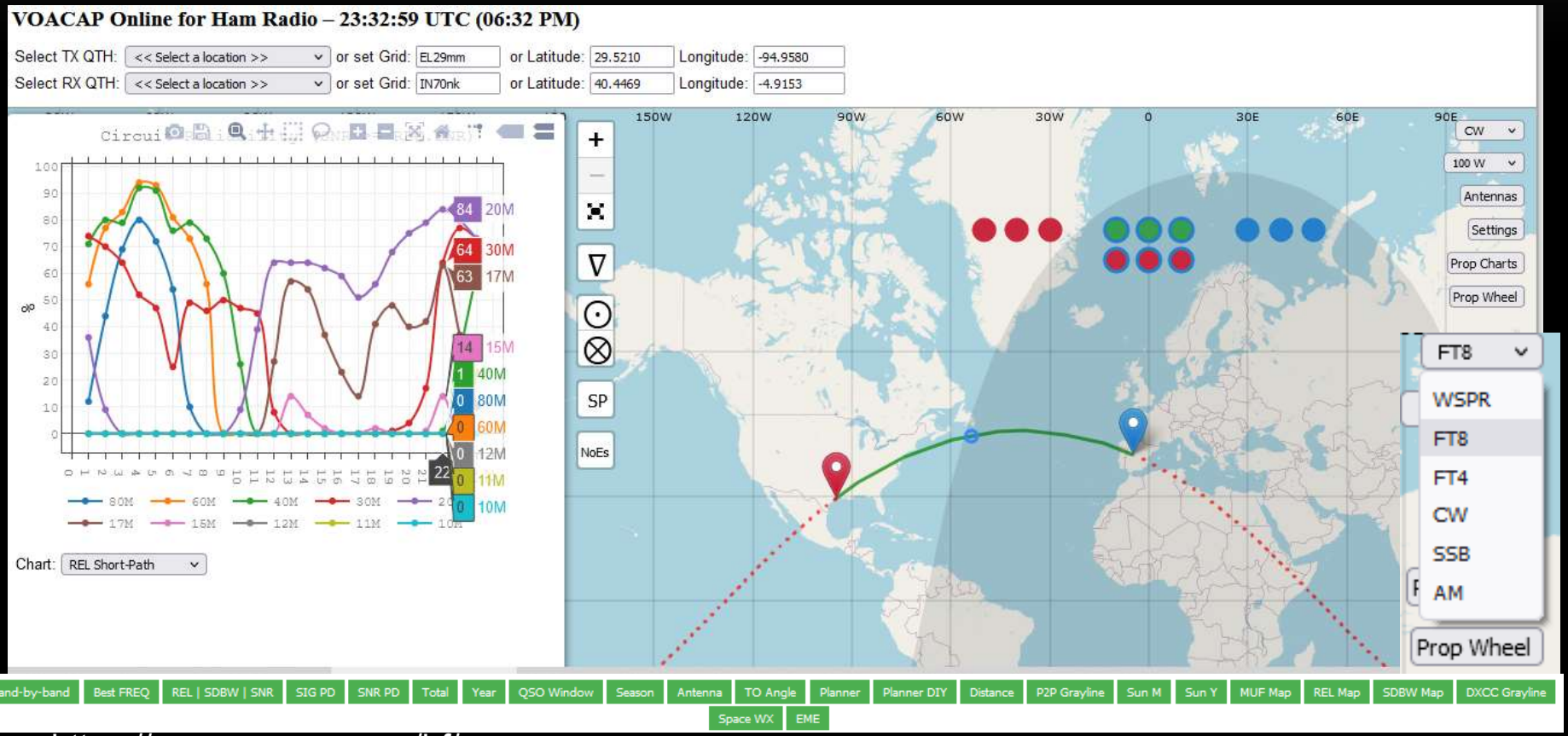




http://aprs.mennolink.org/#

HF Propagation Prediction Tools VOAcap

Predictive tools like VOA CAP are model based propagation tools taking into account MUF and other data from ionosondes.



https://www.voacap.com/hf/

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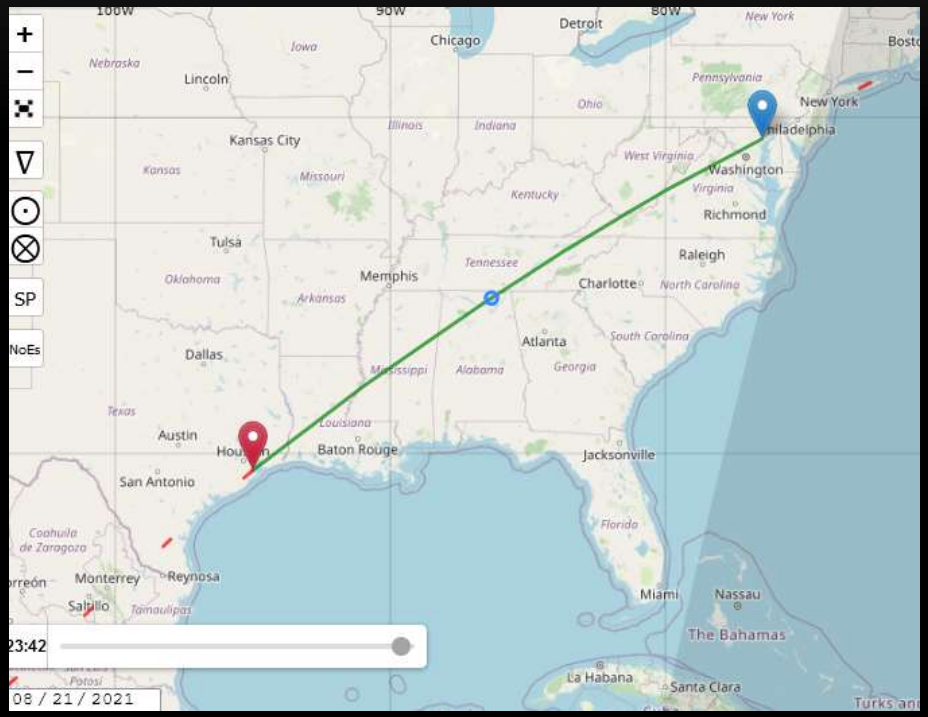
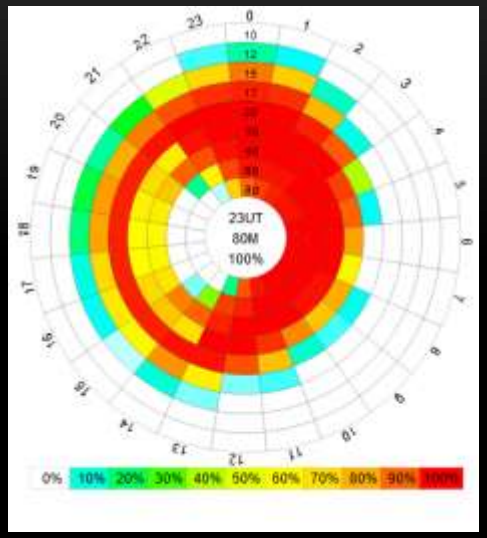
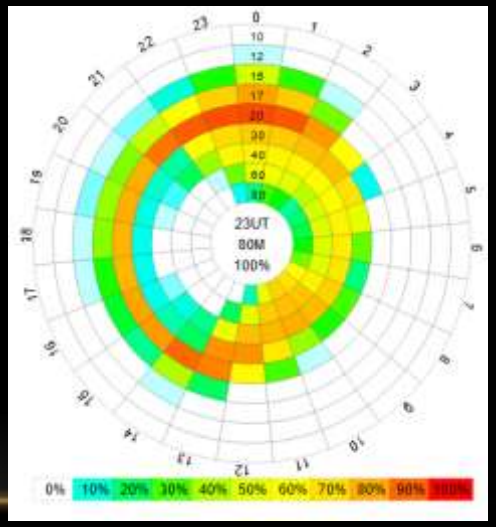
Using VOA Cap Features



FT8



SSB



Point to point time and propagation

Comparing different signal reliability depending on mode.
Better reliability for FT8 contact compared with SSB.

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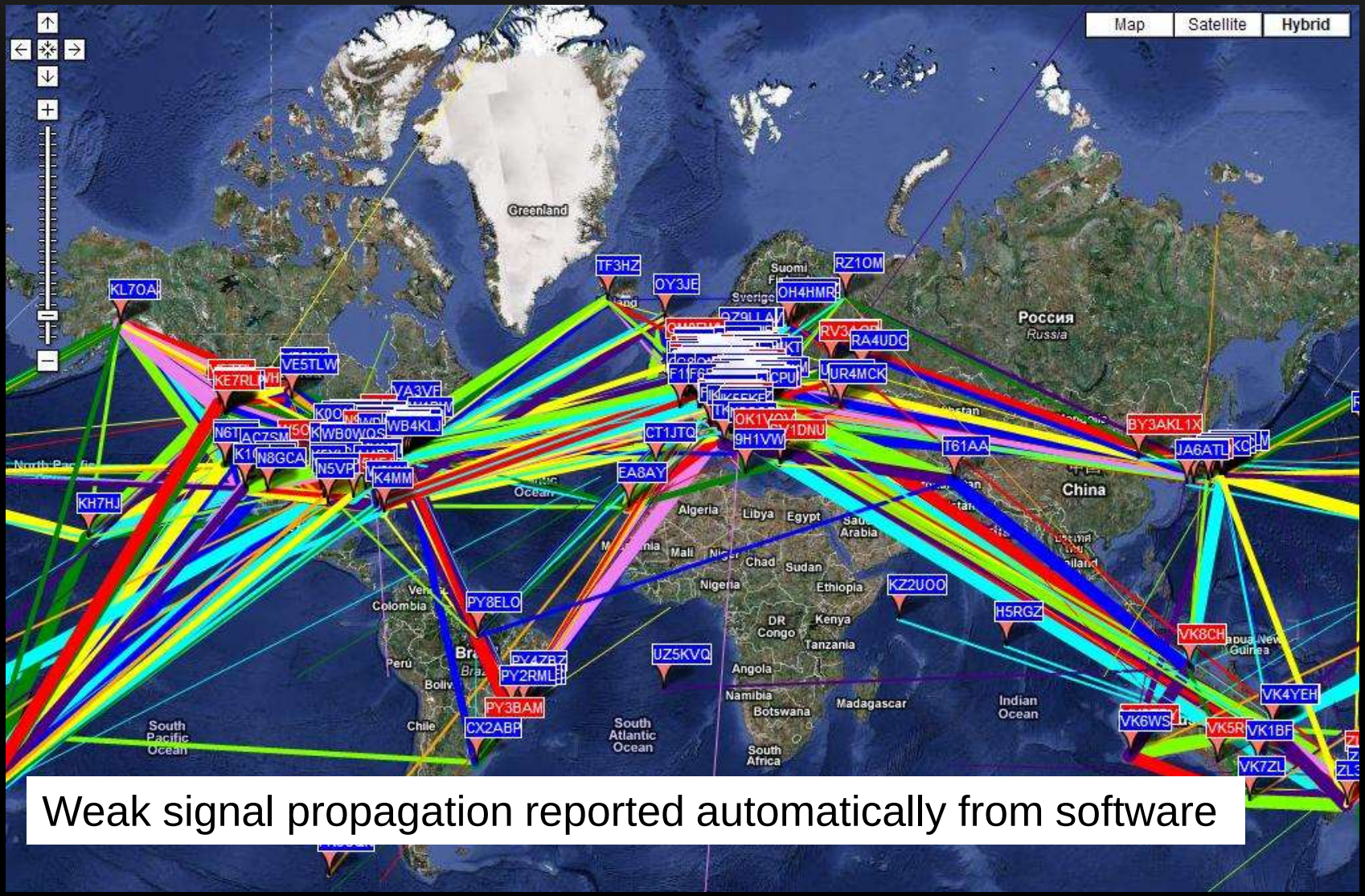
Spot Mapping – WSPR Net Automatic Propagation Reporting



Weak signal propagation reported automatically from software

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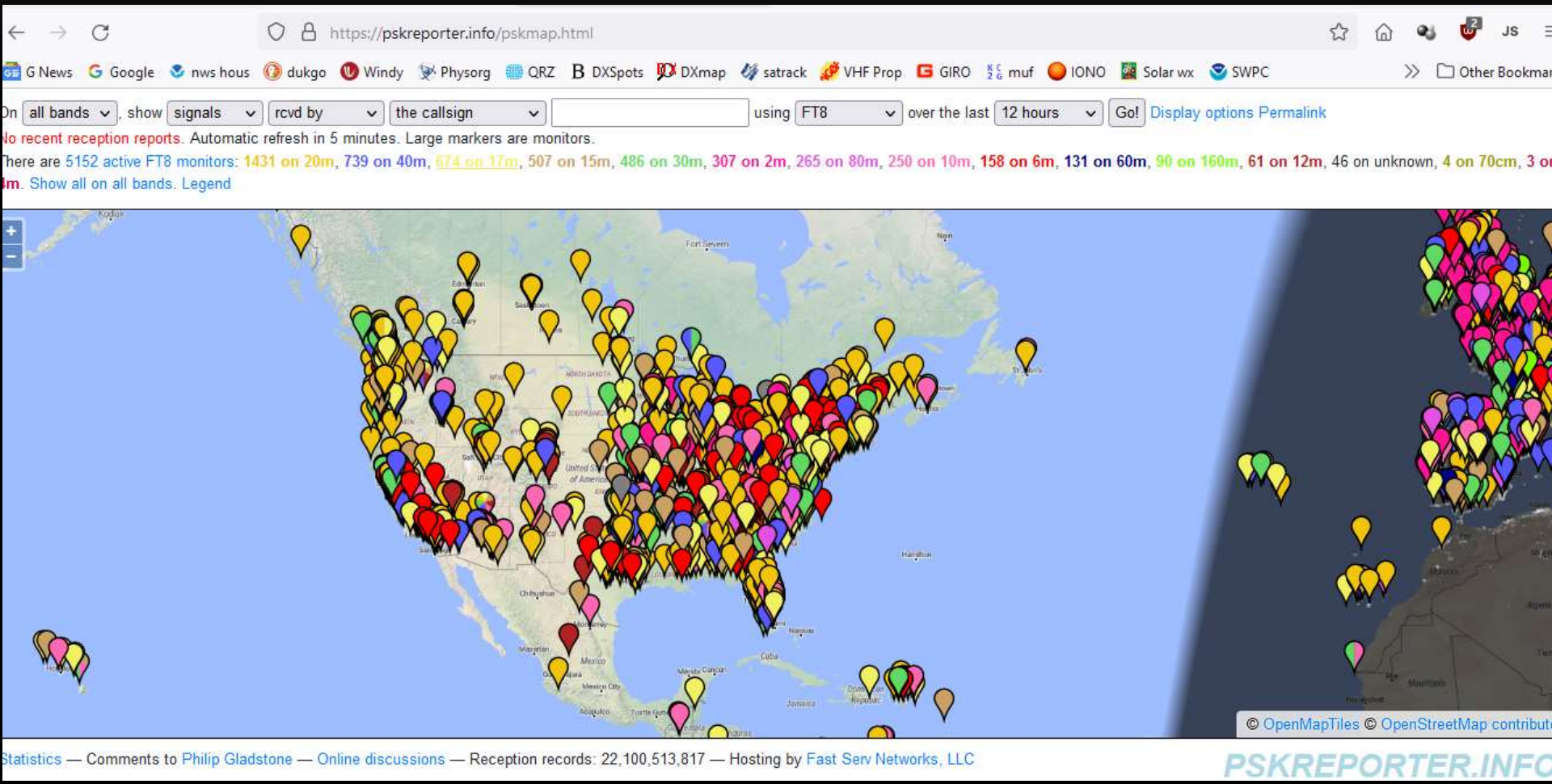
PSK Reporter – Good for digital

Reports received spots automatically from many software packages



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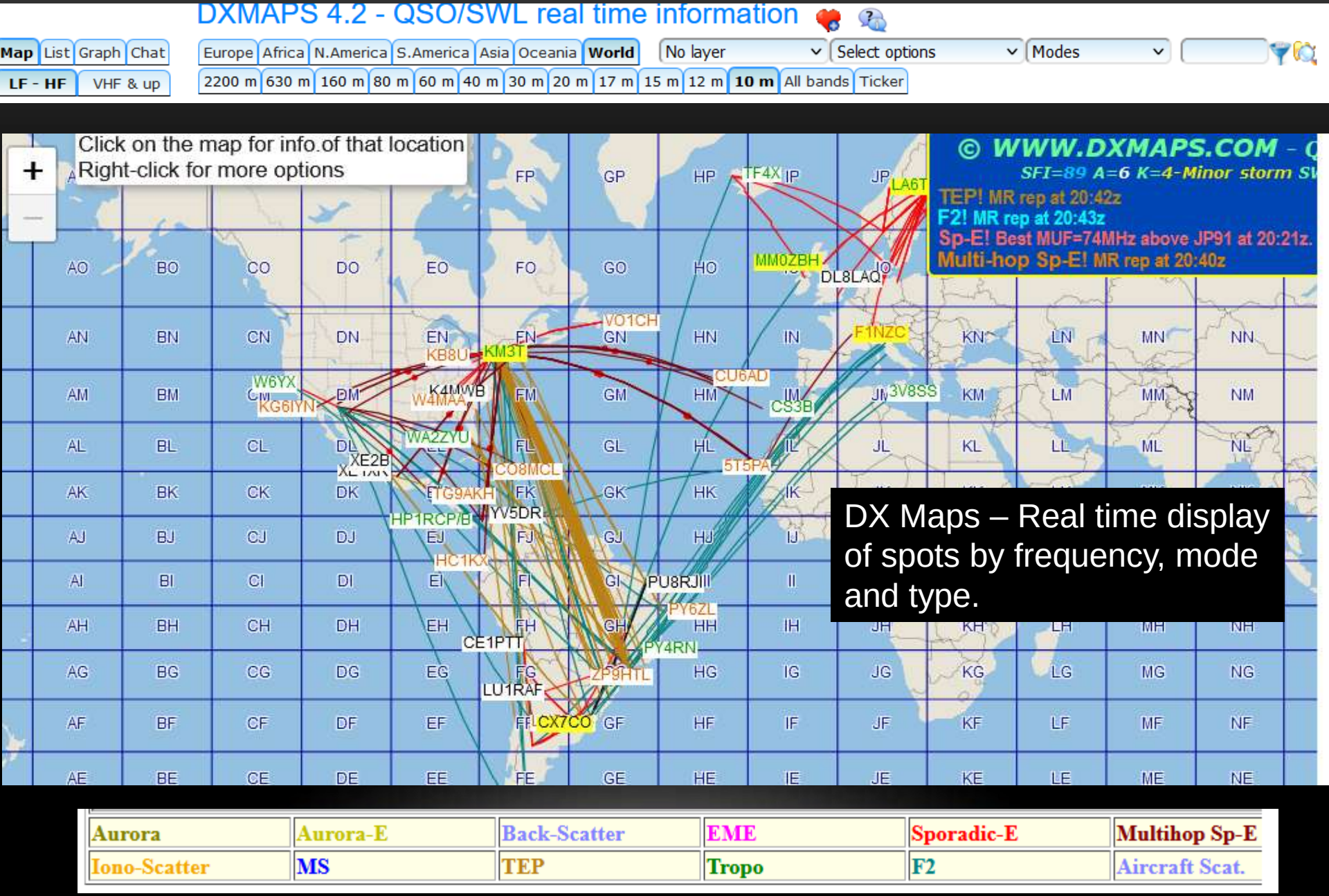
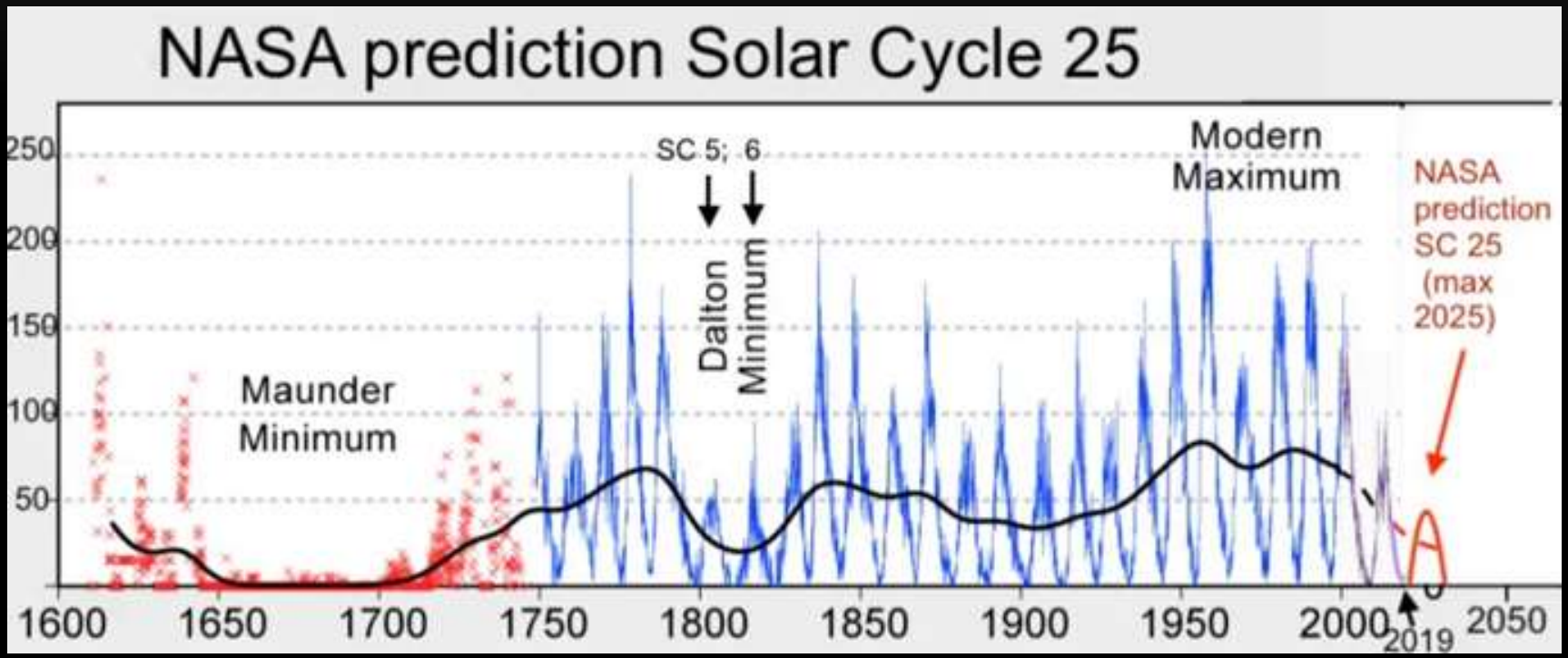
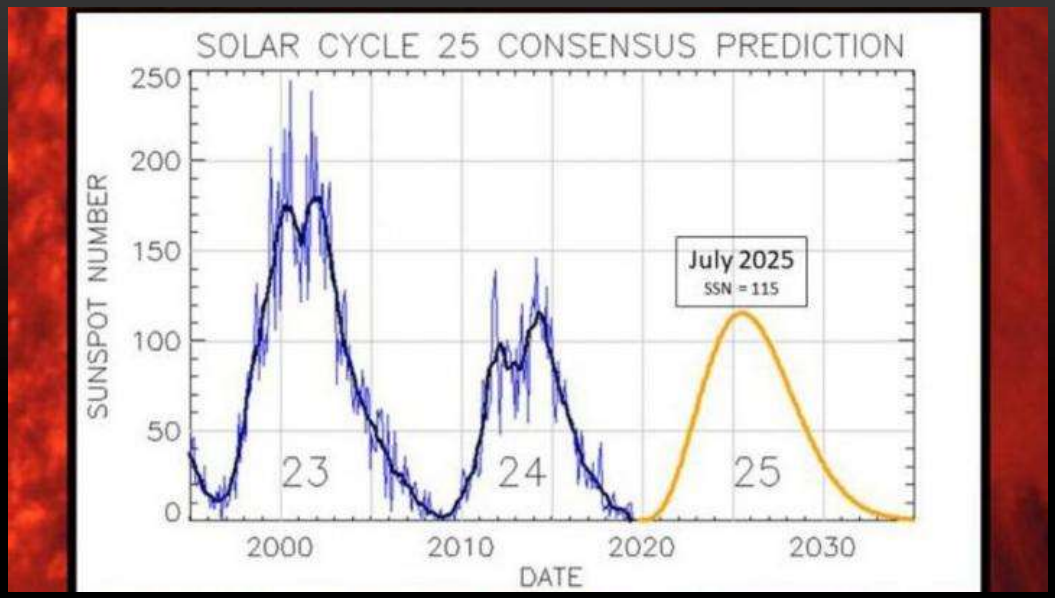
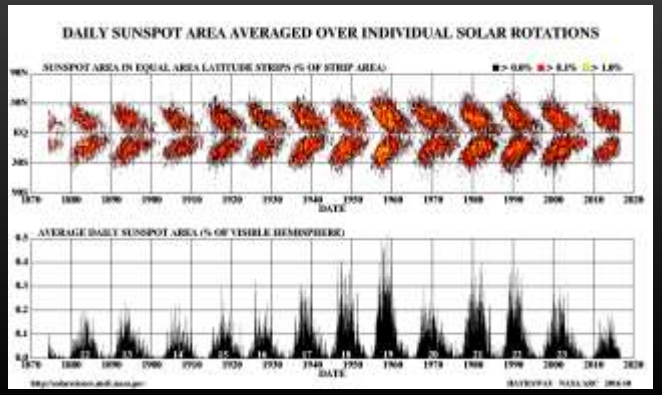

DXMAPS 4.2 - QSO/SWL real time information
Map List Graph Chat
LF - HF VHF & up
Europe Africa N.America S.America Asia Oceania World
2200 m 630 m 160 m 80 m 60 m 40 m 30 m 20 m 17 m 15 m 12 m 10 m All bands Ticker
No layer
Select options
Modes
Click on the map for info.of that location
Right-click for more options
© WWW.DXMAPS.COM
SFI=89 A=6 K=4-Minor storm
TEP! MR rep at 20:42z
F2! MR rep at 20:43z
Sp-E! Best MUF=74MHz above JP91 at 20:21z.
Multi-hop Sp-E! MR rep at 20:40z
DX Maps – Real time display of spots by frequency, mode and type.
Aurora
Aurora-E
Back-Scatter
EME
Sporadic-E
Multihop Sp-E
Iono-Scatter
MS
TEP
Tropo
F2
Aircraft Scat.

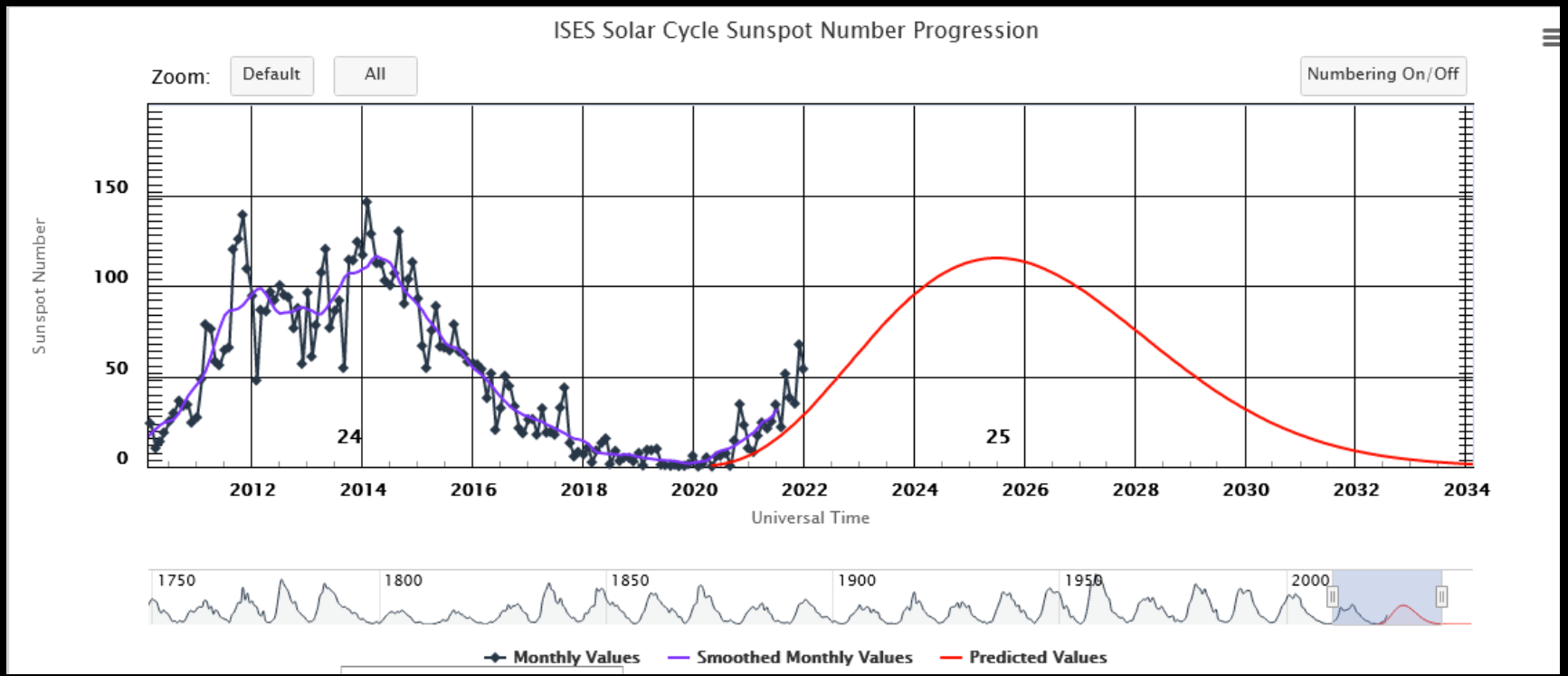
What can we expect in Solar Cycle 25? Depends on who you ask.

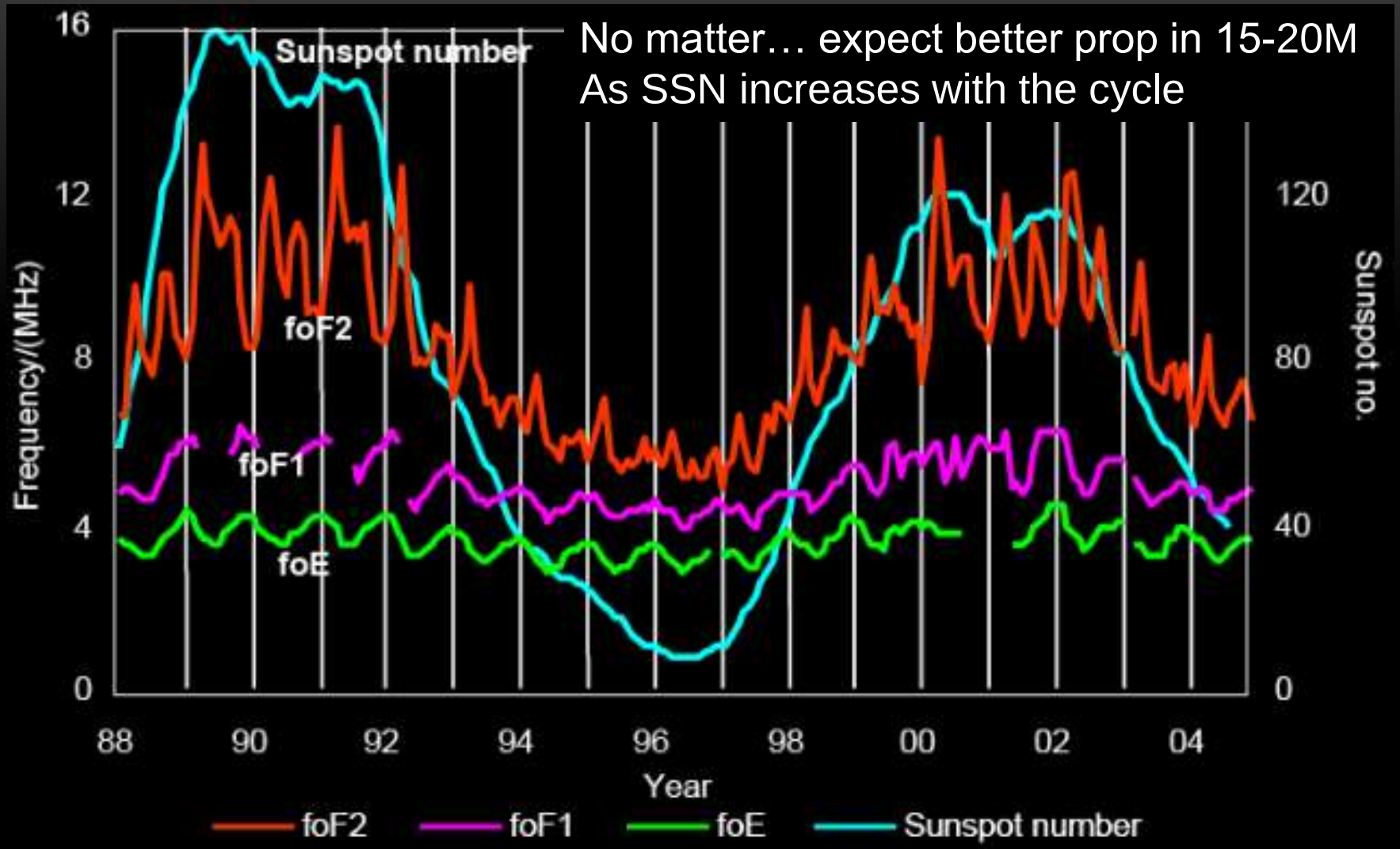






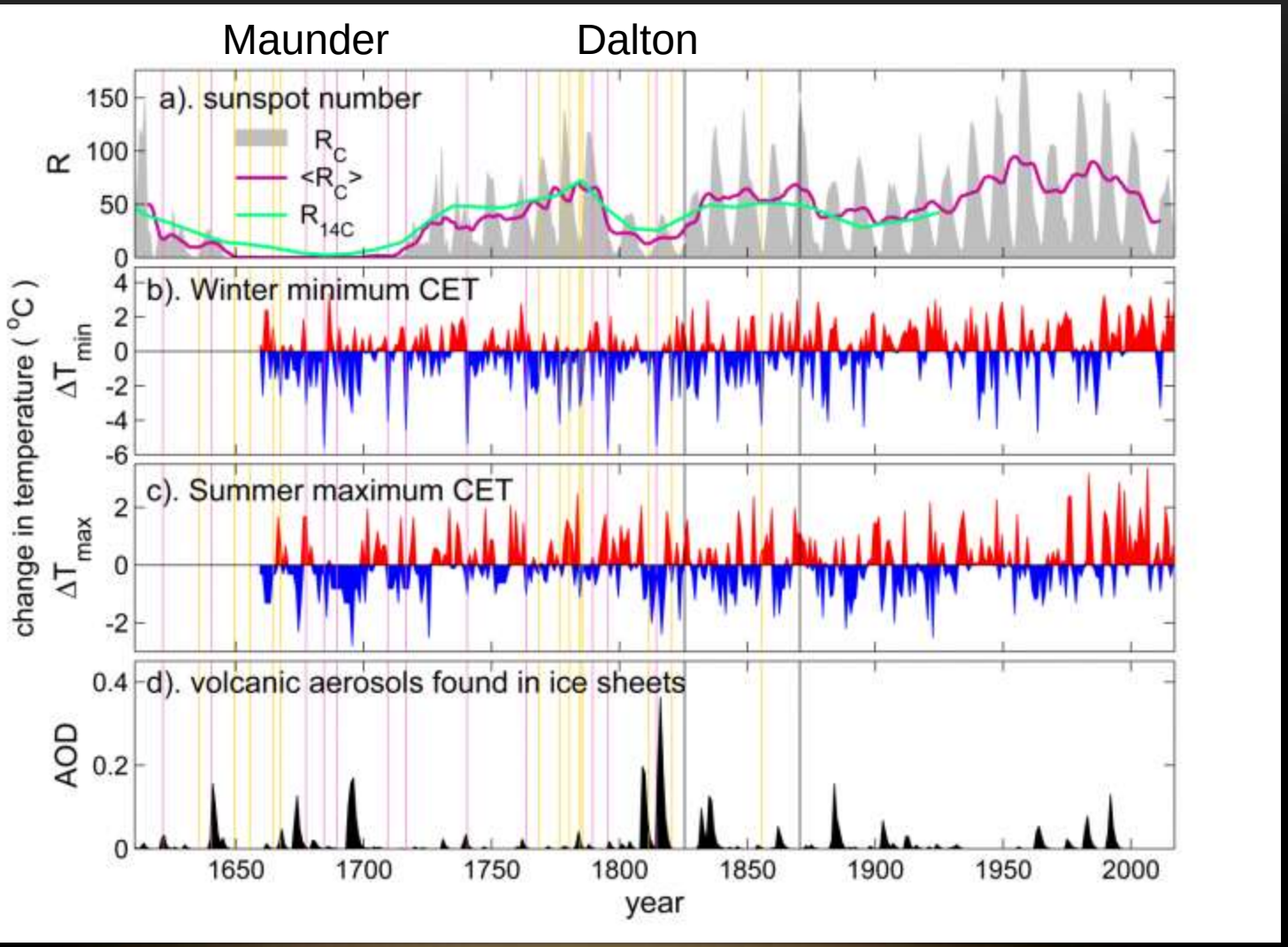
Probably looking at about the same as 24.





Solar Cycle is periodic rise and fall in activity which affects HF communications (9-14 years)
The higher the activity, the more radiation being emitted from the Sun producing more electrons in the ionosphere which allows the use of higher frequencies.
At solar minimum, only the lower frequencies of the HF band will be reflected by ionosphere
At solar maximum the higher frequencies will successfully propagate

What about SSN Number & Weather?



Lot of yapping. "Little Ice Age" at Maunder and Dalton might be an artifact.

Yeehaa… Bands Open!… 5W on 10M to Kasachstan

M. Landress – WB5ANN