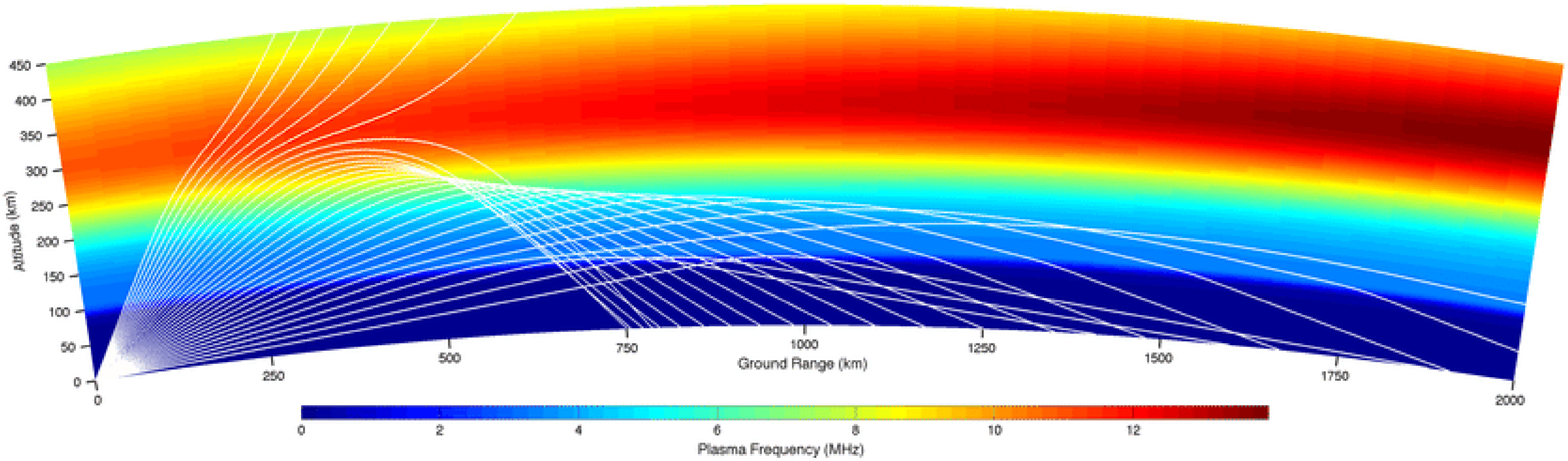
# There is nothing magic about propagation

## In search of MUF isolines





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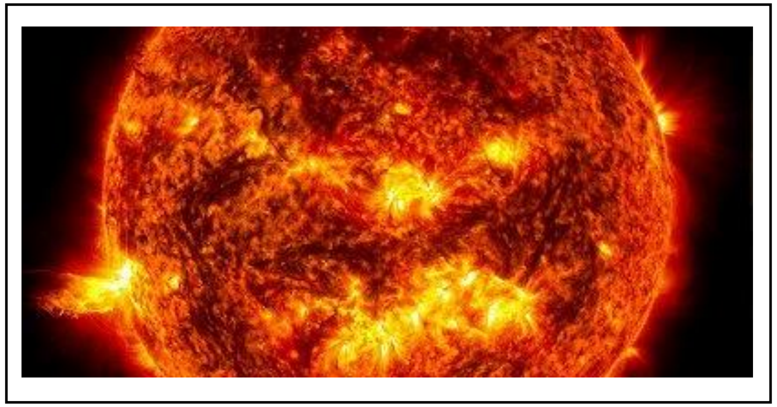
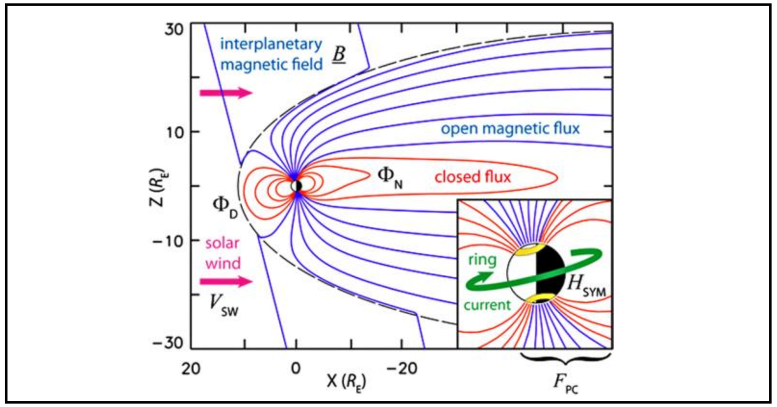
# Sky-wave communication is the consequence of a highly complex solar-terrestrial physics system in constant interaction that impacts propagation

## The Sun



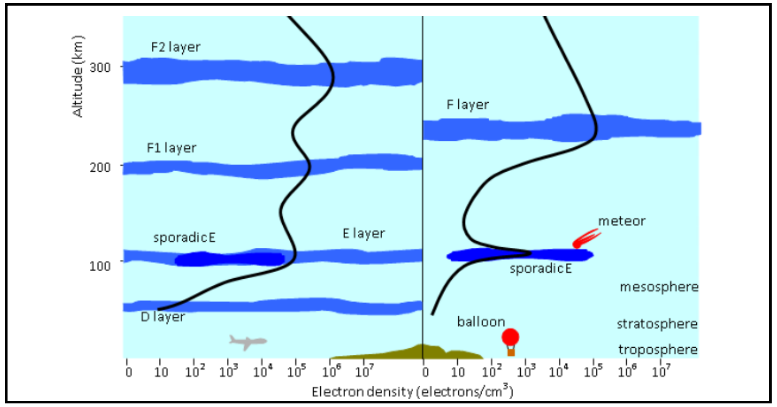
- On the sun (solar cycle; sunspots; Solar flares C, M and X, Coronal holes, CMEs; *Cosmic rays*)
- Coming to earth (particles; X-rays; UV; solar wind; interplanetary magnetic field)
- Impact on earth (ionization of layers; geomagnetic disturbances; Aurora; D layer absorption; polar cap absorption; noise;…)

## The Magnetosphere



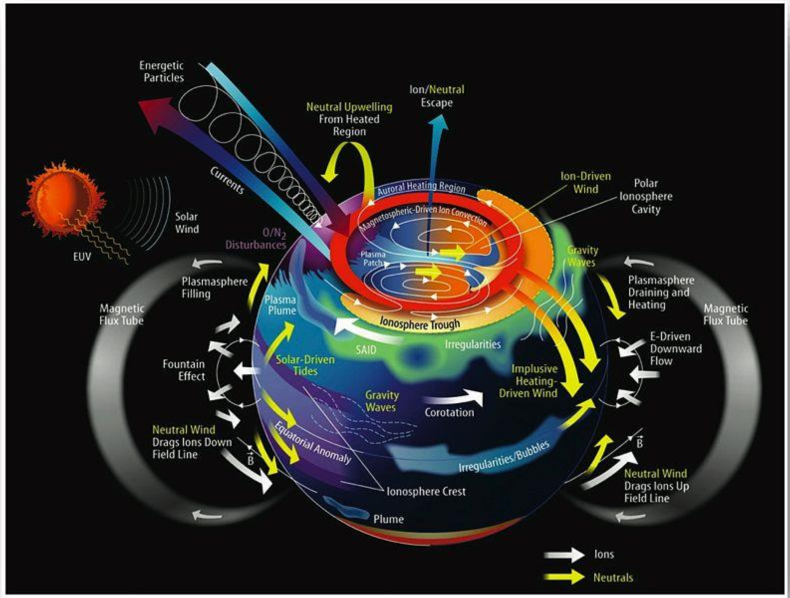

- Van Allen radiation belts
- Solar wind shield
- Coupling of Interplanetary magnetic field with earth magnetic field
- Magnetic reconnection
- Polar cusp
- Auroral oval
- Day and nighttime aurora
- Magnetic latitudes
- …

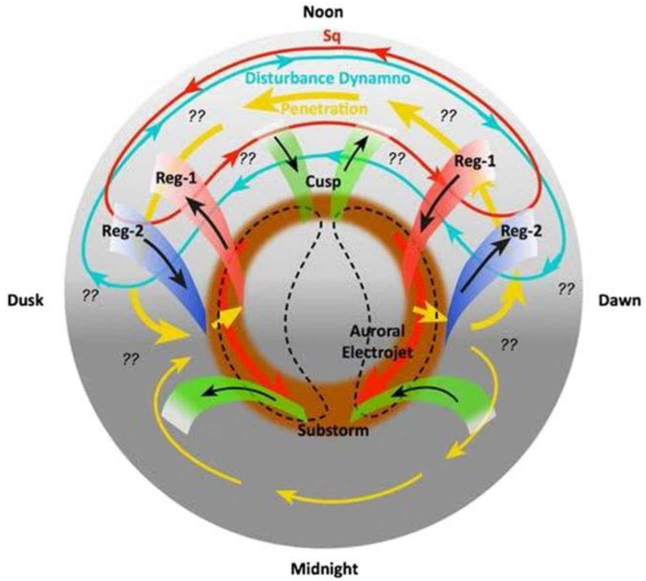
## The Ionosphere

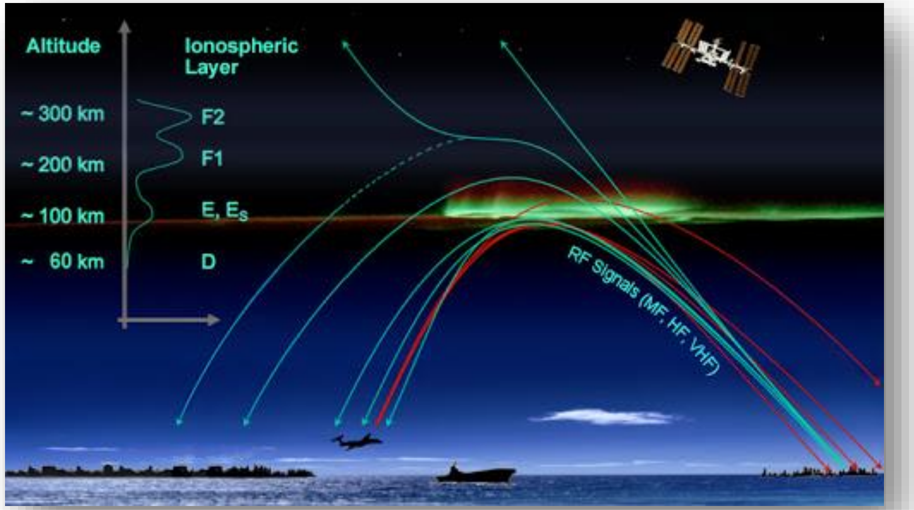


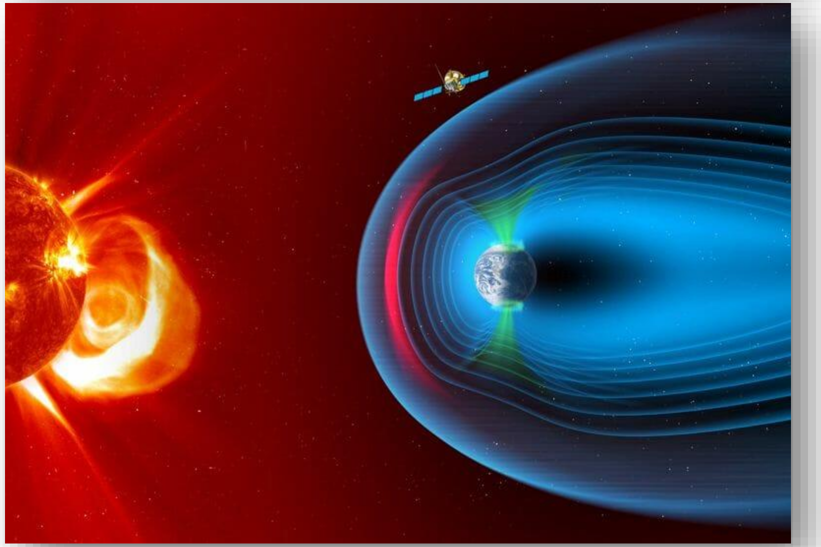

- Ionization and electron density
- Layers D, E, F1, F2
- D layer absorption
- E, F1, F2 layer refraction
- MUF and Critical frequency
- Day, night and season variations
- Angle of sunlight enters atmosphere
- Coupling of planetary, tidal and gravity waves
- …

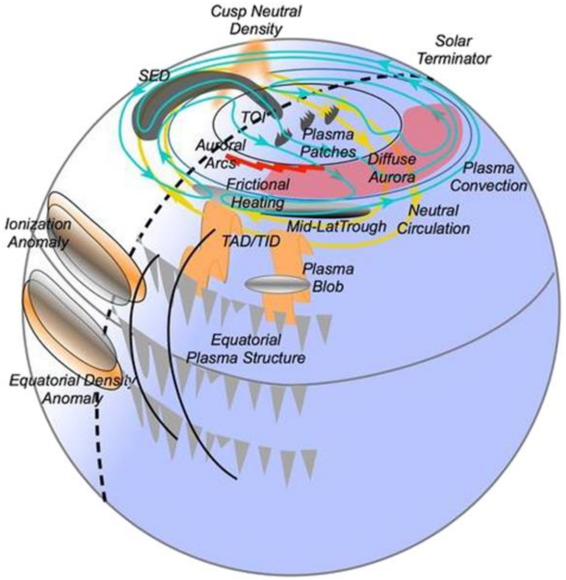
# And what a complex system this is

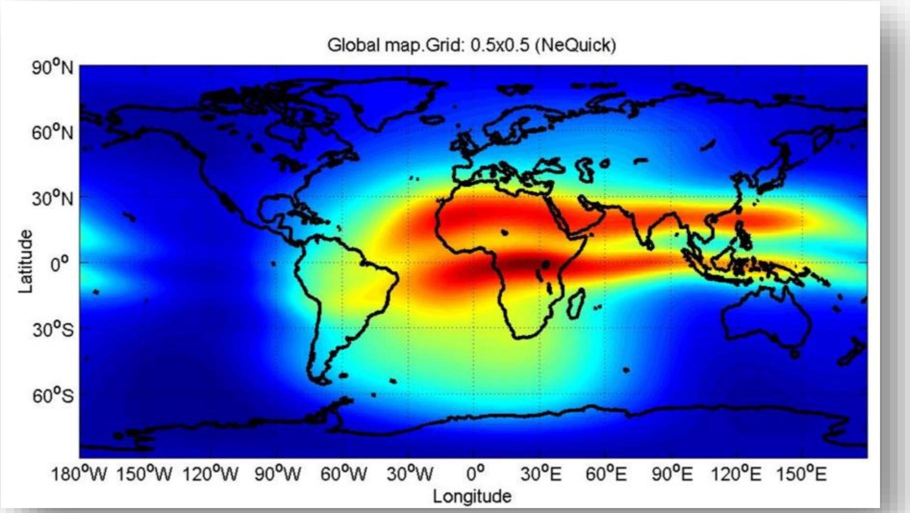


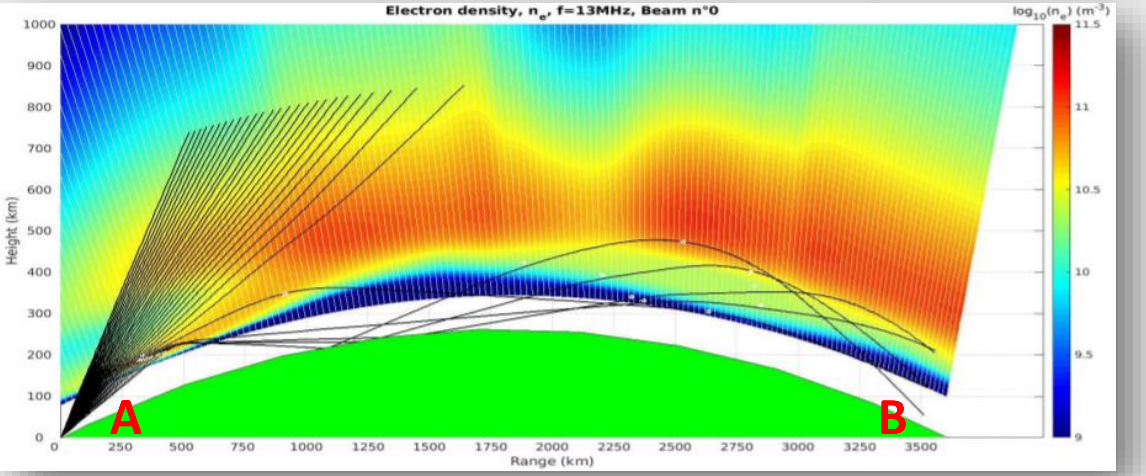





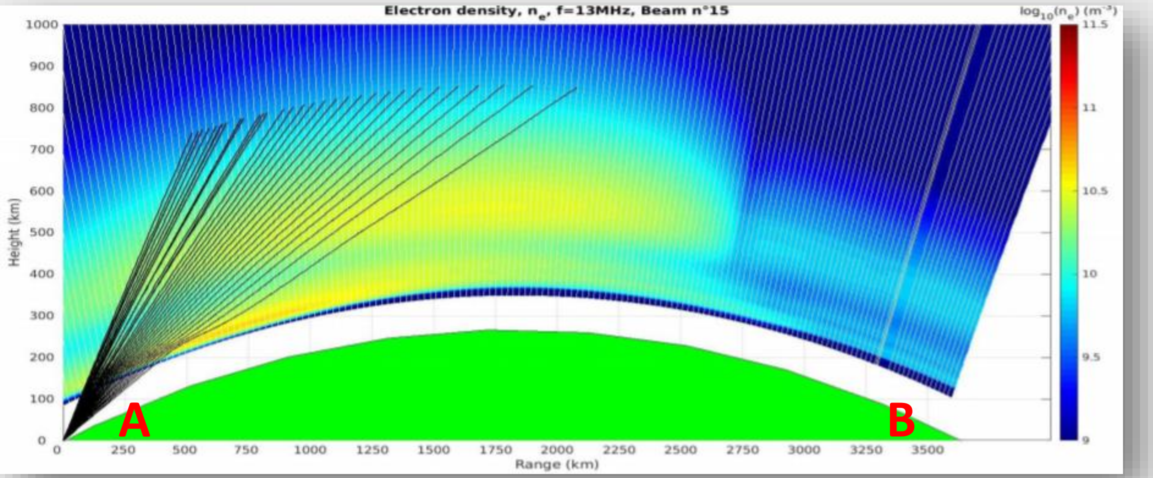



# Sky-wave HF communication from A to B relies ionosphere for refraction, otherwise signal will be lost into space




## Refraction of signal – There is propagation

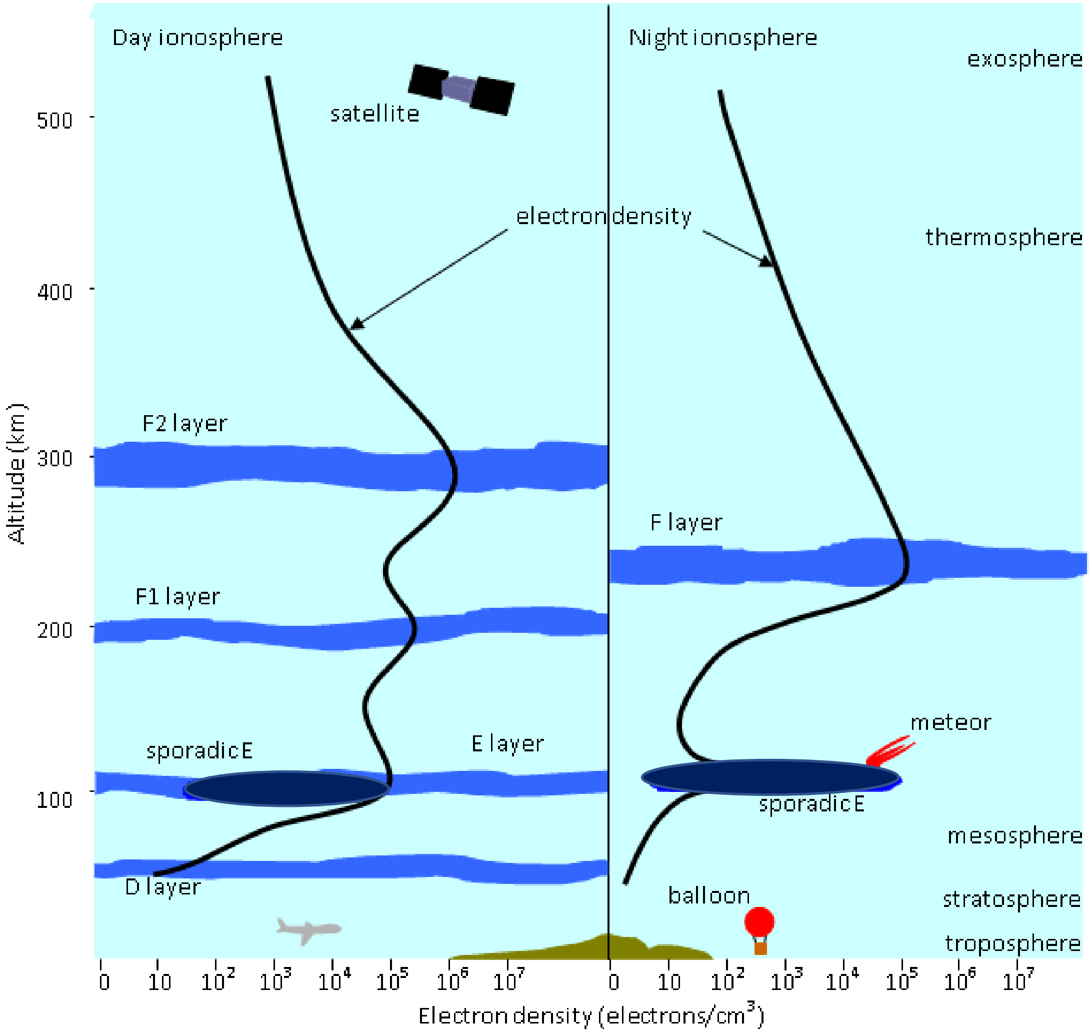
- Electron density of refraction area
- D layer absorption level
- E, F1 an F2 refraction layers
- MUF in refraction area
- Operating frequency below critical frequency in refraction area (or “MUF of ionosphere”)




## No refraction of signal – no propagation

- No refraction in one of the ionospheric layers
- Operating frequency above MUF of E, F1 or F2 layer
- High angle of incidence of RF rays
- Dead band or no propagation to a particular area of the world

# Different Layers of the ionosphere play a pivotal role in absorption and refractions of radio signals together with critical frequency




## Layers

- Layers to refract signals if MUF is higher than operating frequency
- Refractions depends on the density of electrons
- Density depend on ionization from the sun (dominant) and coupling with troposphere
- Electron density with peaks and inflection points (layers)
- The layer with the highest density determines MUF

## D layer

- D layer has no ability to refract signals
- D layer absorbs signals passing through it reducing signal strength
- Absorption levels can vary with season and sun activity (x-rays)
- D layer is not present during the night

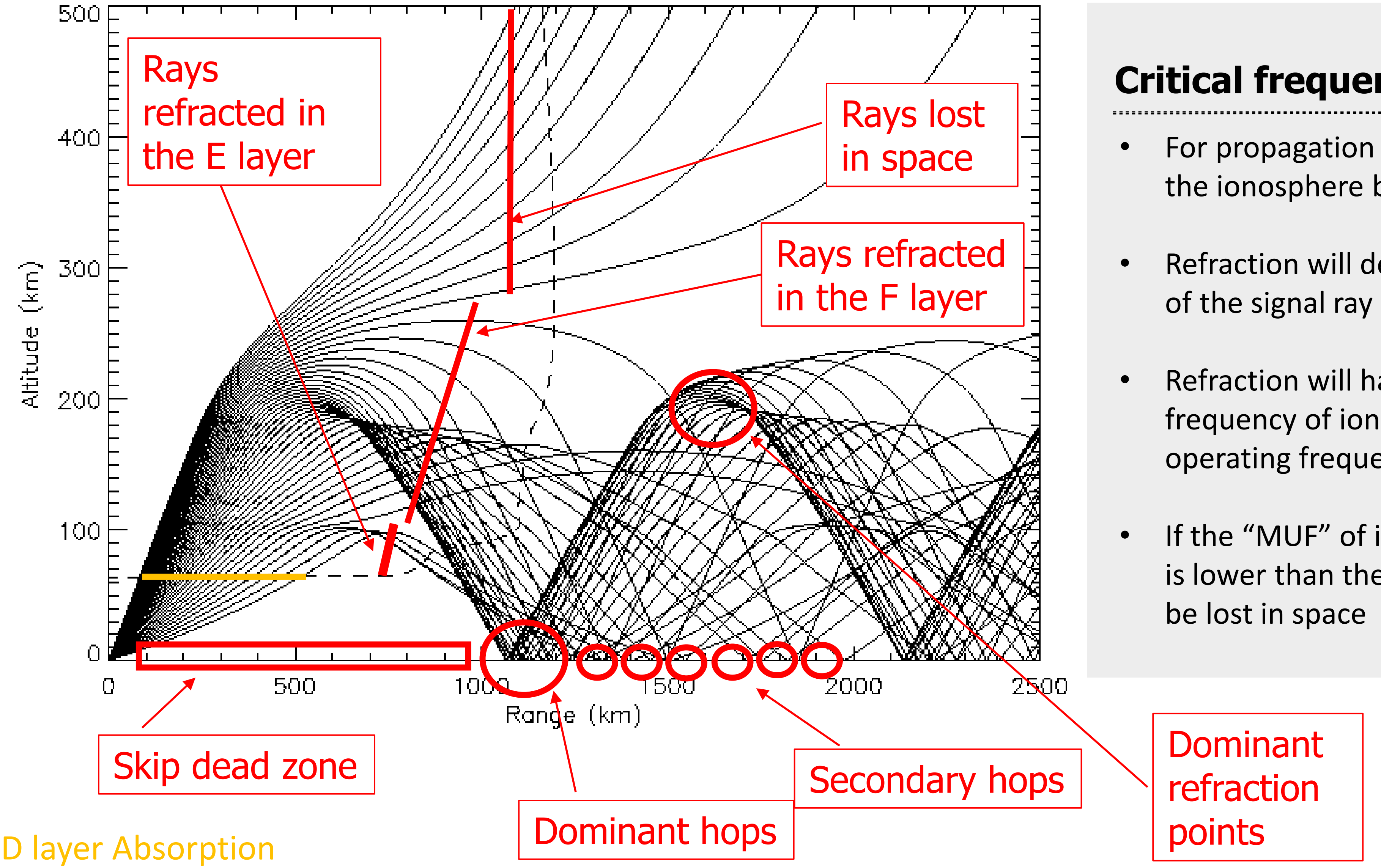
## E layer

- E layer is the first layer capable of refracting signals
- It is present day and night
- Sporadic E occurs with intense electron density
- When E layer has the highest electron density it blankets signals into F layer

## F1, F2 layer

- F2 is the most reliable layer for long distance communications
- At night F1 and F2 layers merge into F
- Being the highest layer, it requires less hops in the refractions
- Usually, the MUF is provided by the F layer

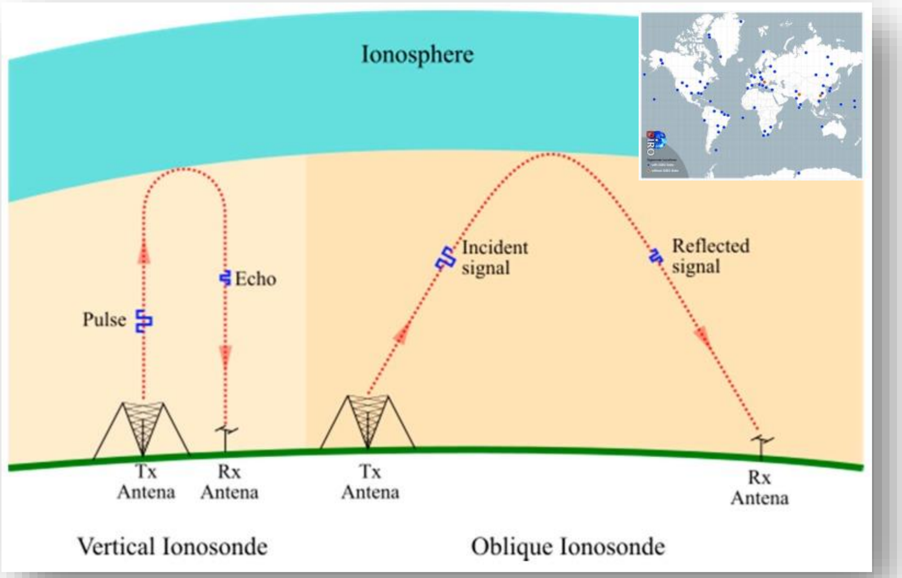
# Understanding signal refraction, skip distance, multi-hop and critical frequency (“MUF of ionosphere”)

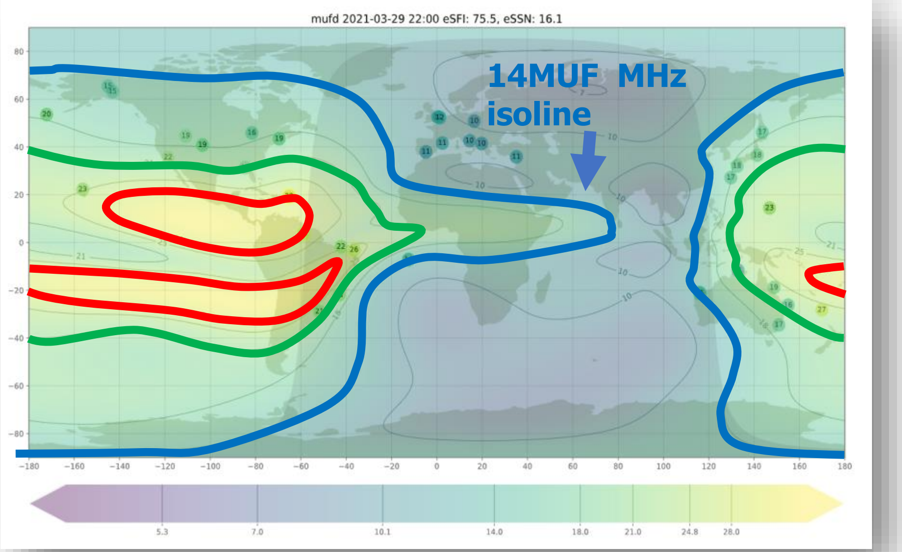



## Critical frequency (MUF of ionosphere)

- For propagation to exist, RF signals must refract in the ionosphere back into earth
- Refraction will depend on the angle of incidence of the signal ray into the ionosphere
- Refraction will happen in ionosphere if the critical frequency of ionosphere is greater than the operating frequency
- If the “MUF” of ionosphere in the refection point is lower than the operating frequency, signal will be lost in space

# Probing the ionosphere with a limited network of Ionosondes enables to model ionosphere real-time conditions




## A worldwide network of ionosondes

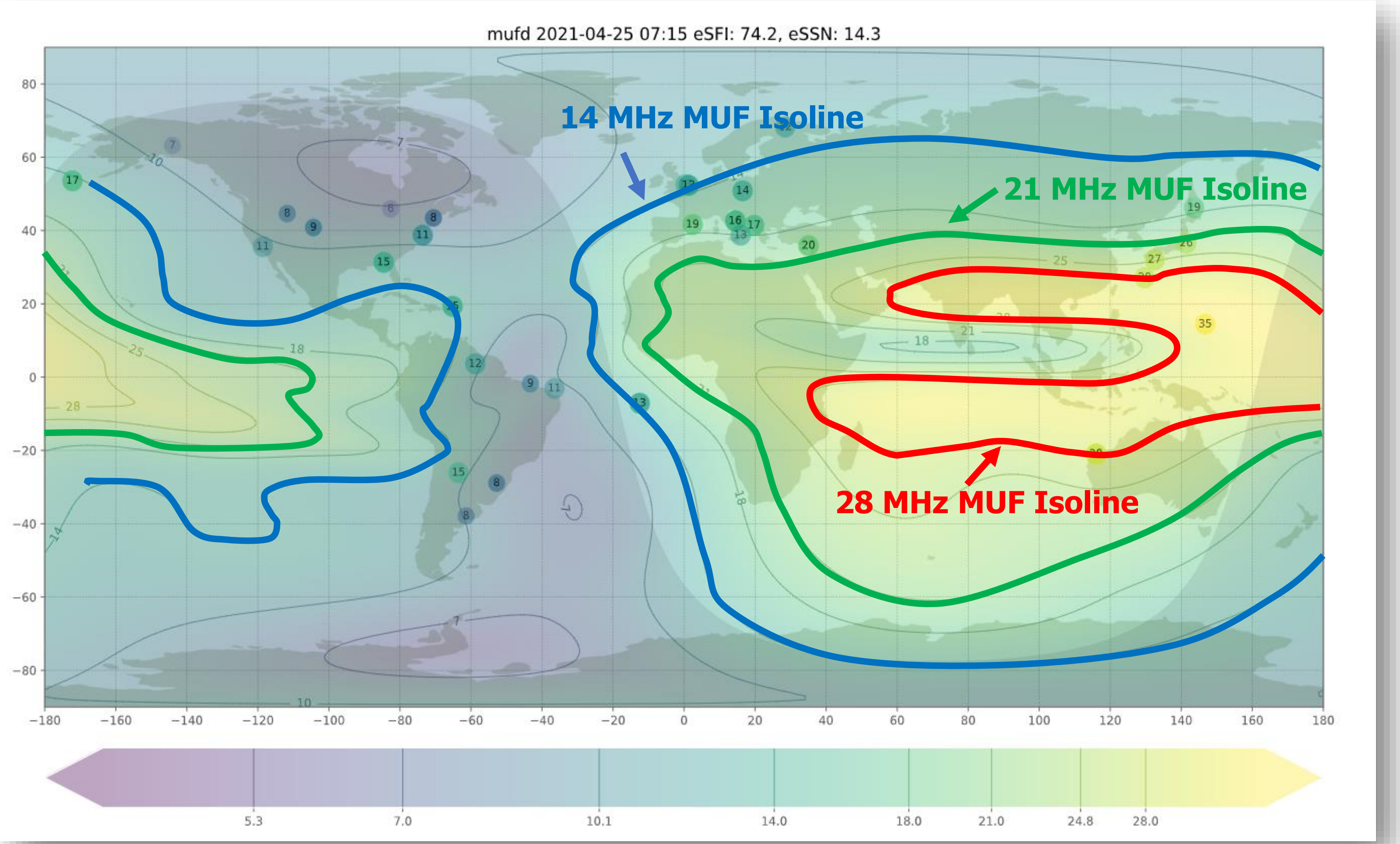
- The ionosonde is used to find the NIVS MUF frequency in the ionosphere immediately above the antenna
- The result of the probe of the ionosonde is an ionogram, depicting ionospheric layers, the height of each layer and the electron density
- A model enables to transform NVIS MUF into MUF for 3000Km
- Oblique ionosonde depicts the true MUF between two points

## Worldwide MUF isoline map model

- Worldwide isoline MUF map shows areas of the world that support a signal to be refracted
- The IRI (International Reference Ionosphere) model uses data from the network of ionosondes around the world, compiled by NOAA and GIRO (Lowell Global Ionospheric Radio Observatory)
- Most ionosondes are clustered around few areas of the world, with large areas away from a probe

https://www.digisonde.com/ https://prop.kc2g.com/

# What is a MUF isoline and why the MUF isoline limits propagation to refraction points inside the MUF isoline



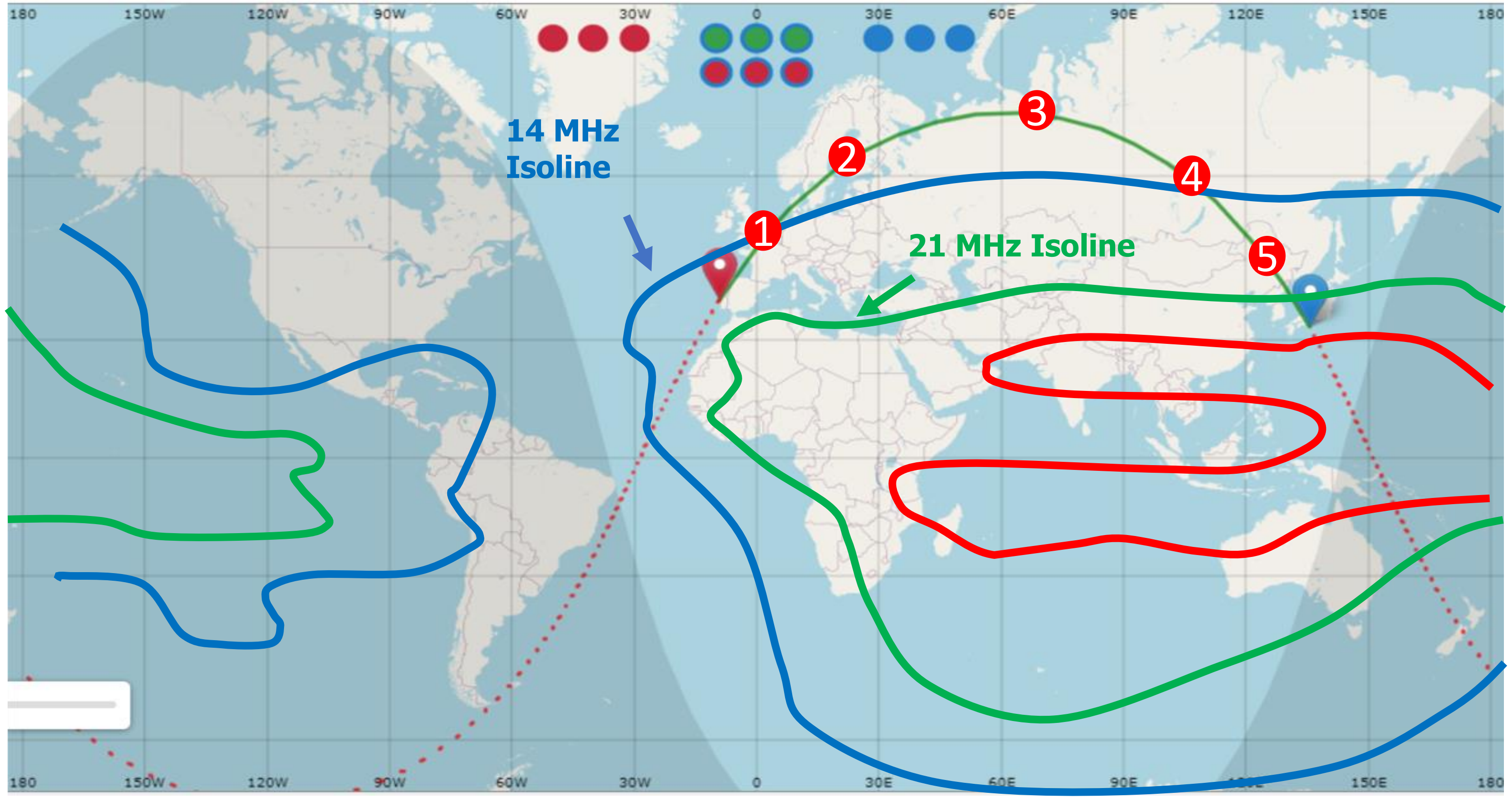

## MUF isoline sets propagation

- A MUF isoline is a contour line where the critical frequency (or ionosphere MUF) is the same all over the word
- Inside the 14 MHz isoline MUF frequency is higher than 14 MHz and outside it is lower

- Propagation on 14 MHz will only be possible if the refraction points in the ionosphere are inside the area of the MUF isoline limit

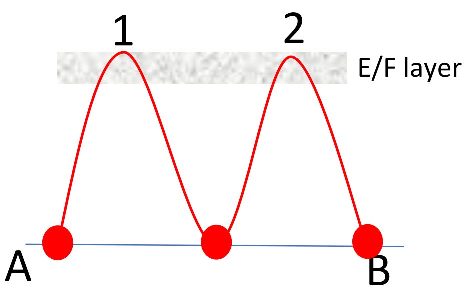
https://prop.kc2g.com/

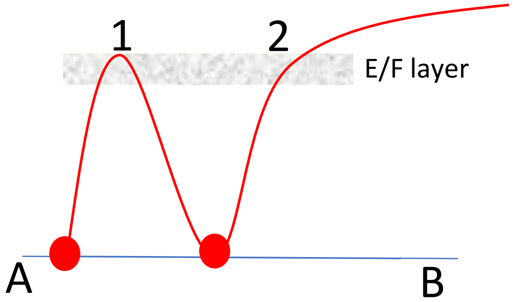
# Paths that have refraction points outside of the MUF isoline will not hold propagation

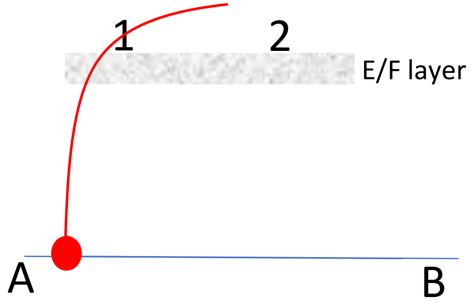



## Portugal into Japan path

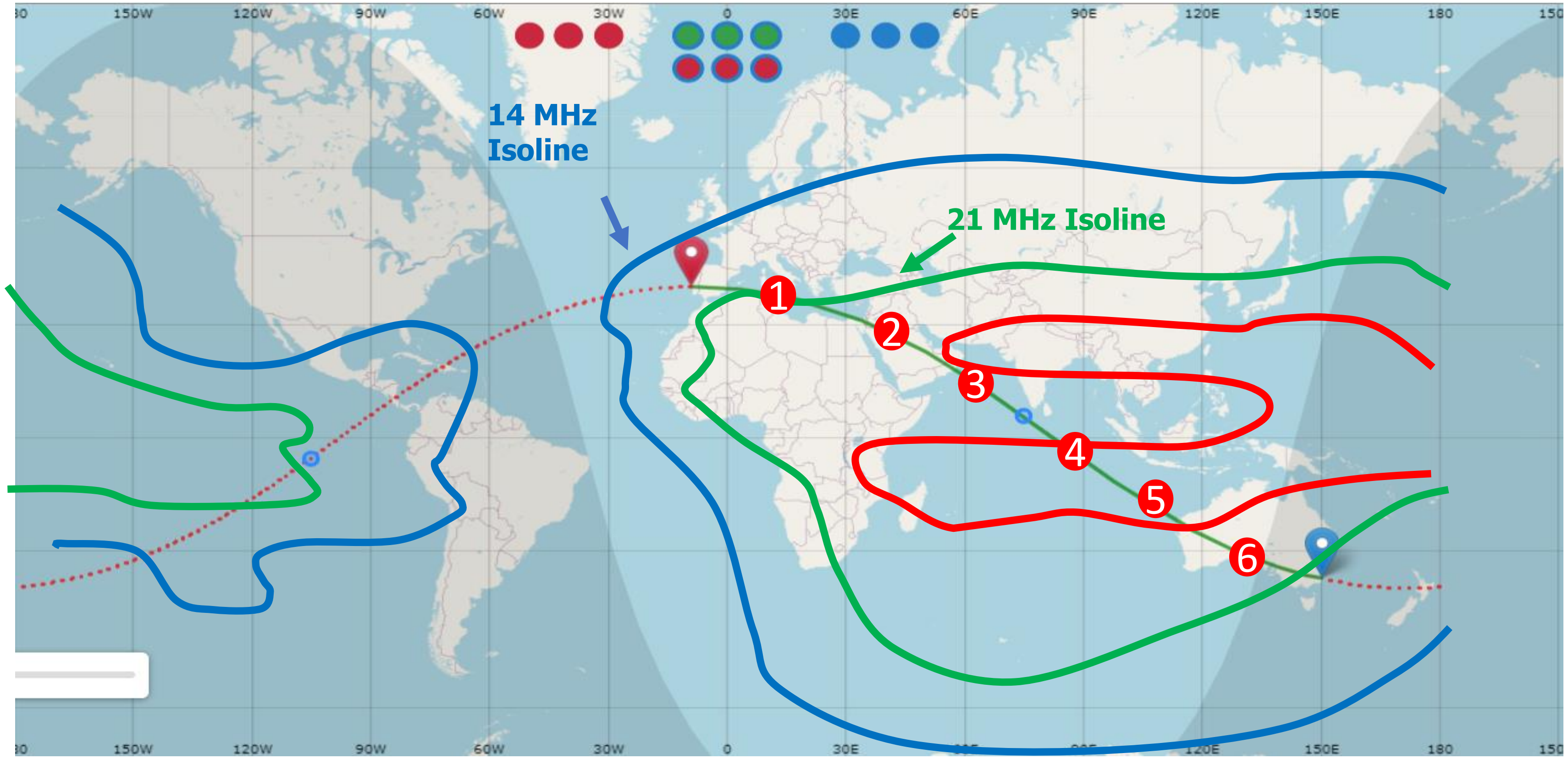
- The path from Portugal into Japan has refraction points outside the MUF limit isoline
- Refraction points 2 and 3 have a MUF frequency lower the operating frequency (14 MHz)



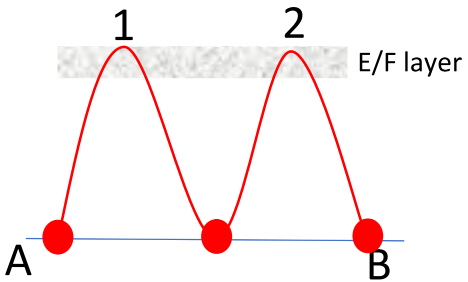



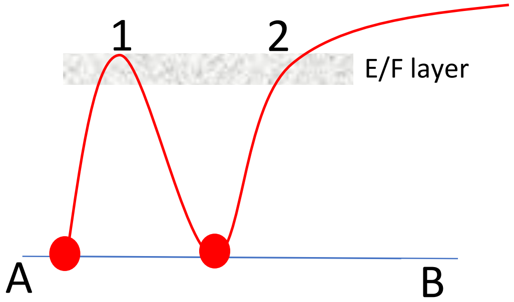
# Paths that have refraction points inside or near the edge of the MUF isoline will hold propagation

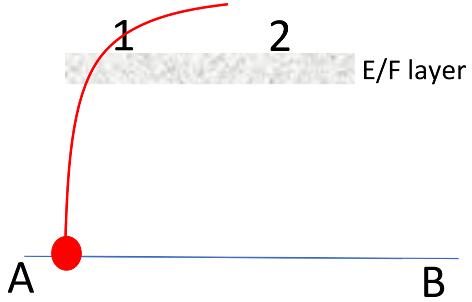



## Portugal into Australia path

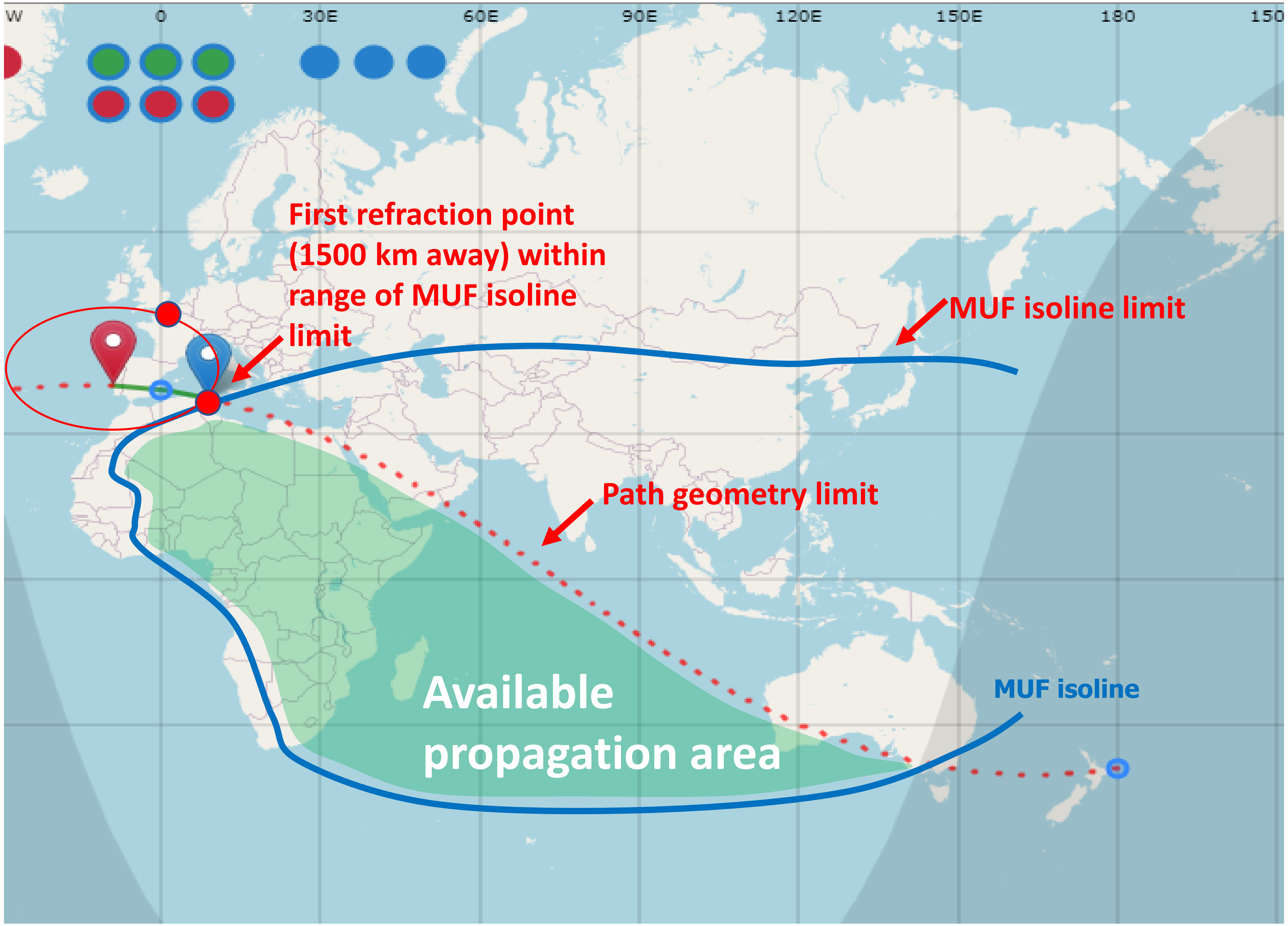
- The path from Portugal into Australia has all refraction points inside the MUF limit isoline for 21 MHz and 14 MHz
- All refraction points will find a MUF frequency above the operating frequency (21 MHz)
- The only limiting factor is power, gain and D layer absorption



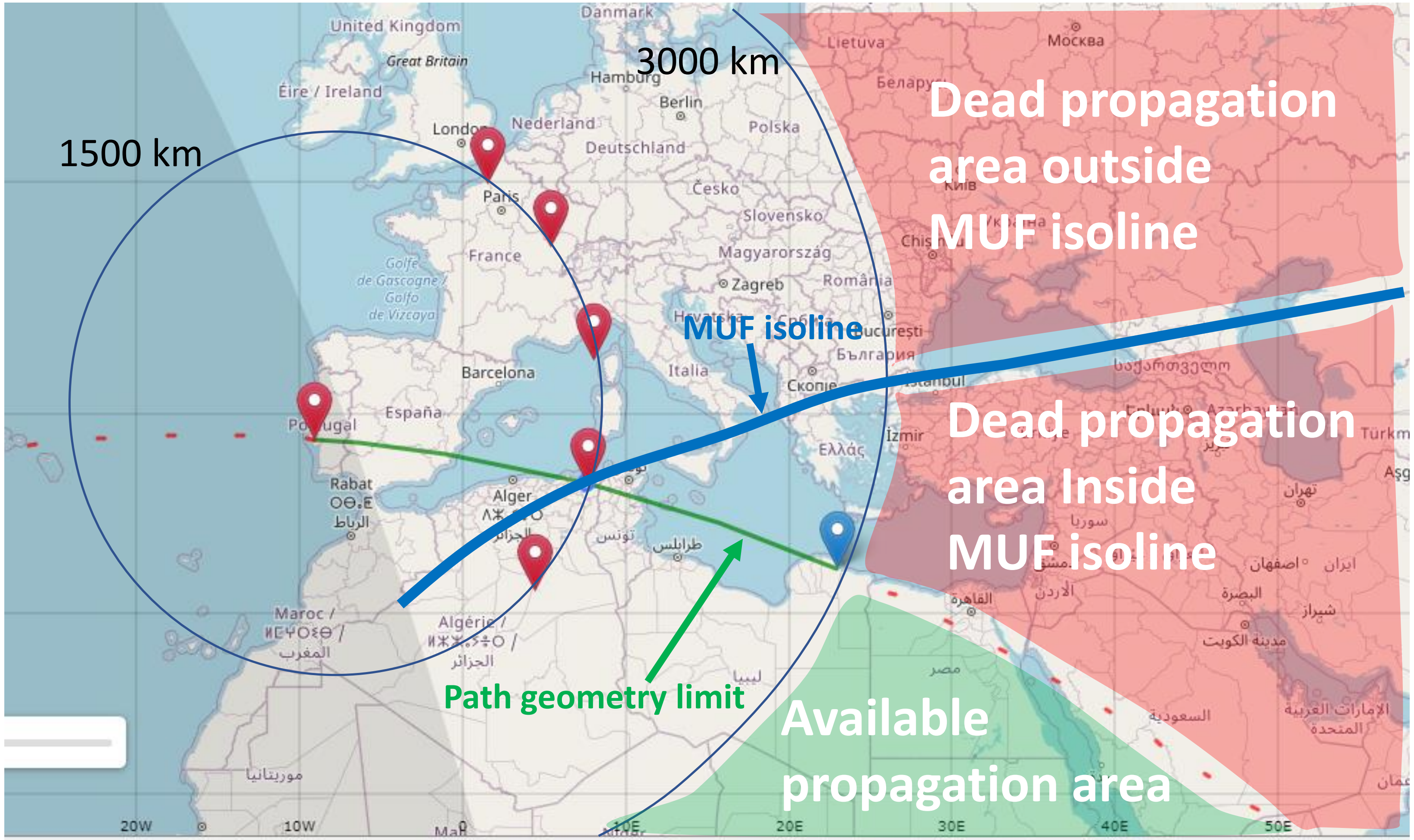
# Combining MUF isolines, path geometry limit and refraction points highlights available propagation inside MUF isoline




## Available propagation area

- When looking for available propagation a combination of MUF isoline and the path geometry limit, where the first refraction point meets the MUF isoline, defines the area of available propagation
- The green shade area is the available propagation
- There are areas inside the MUF isoline with no propagation because of path limit geometry

# Combining first refraction point with MUF isoline to determine path geometry limit inside the isoline

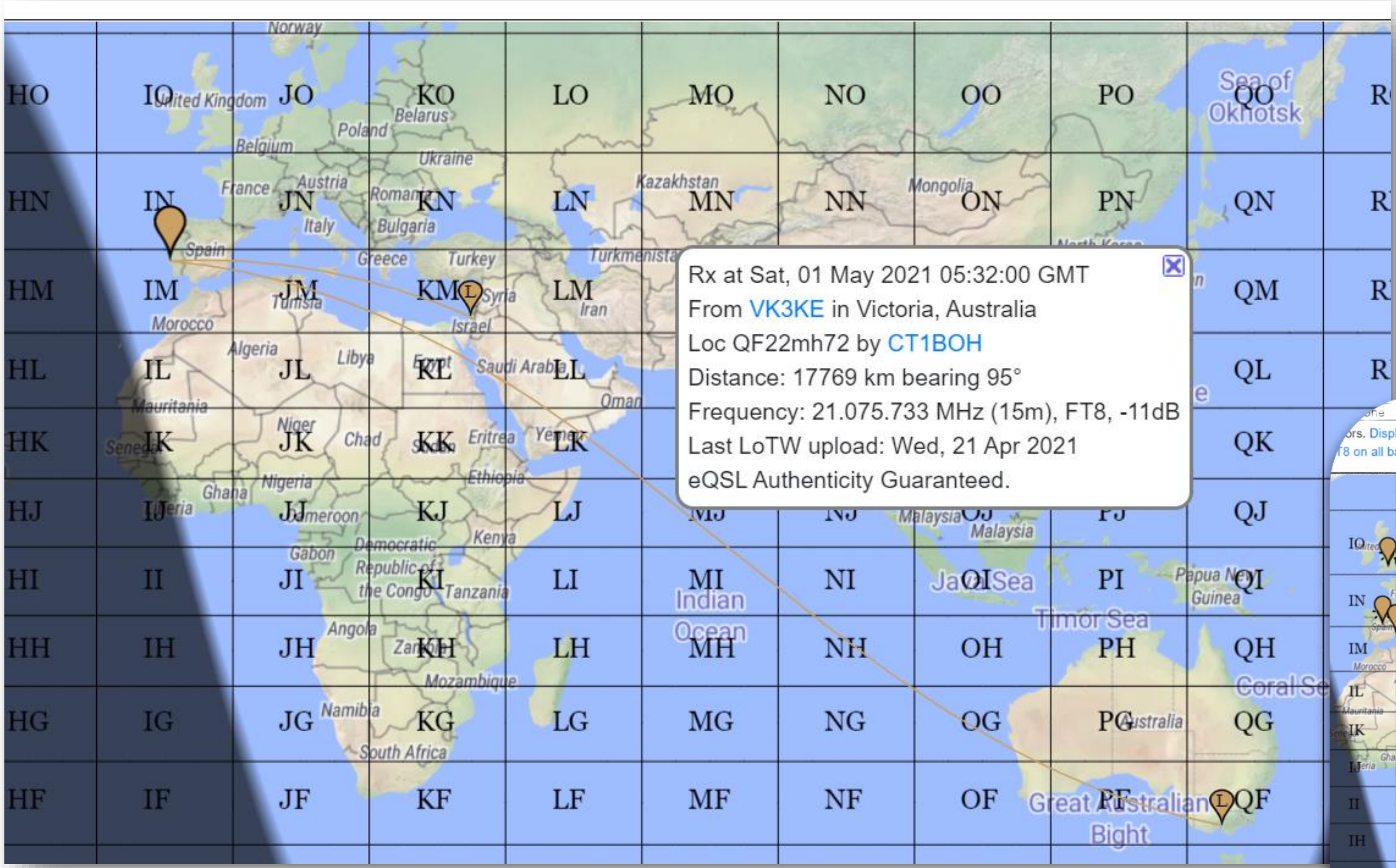



## Available propagation area

- Only refraction points that are on the edge or inside the MUF isoline will be able to refract signals

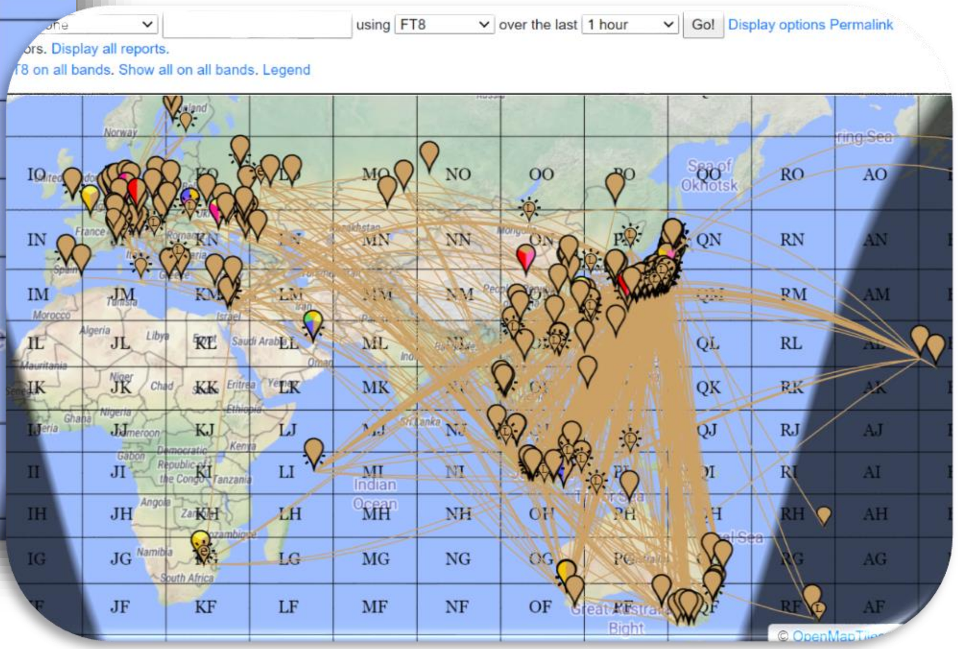
Dead propagation area can be found outside of the MUF isoline and even inside the isoline depending on the intersection of MUF isolines with the first refraction point

# Path geometry limite from CT1BOH FT8 Skimmer – “the only station on the band”

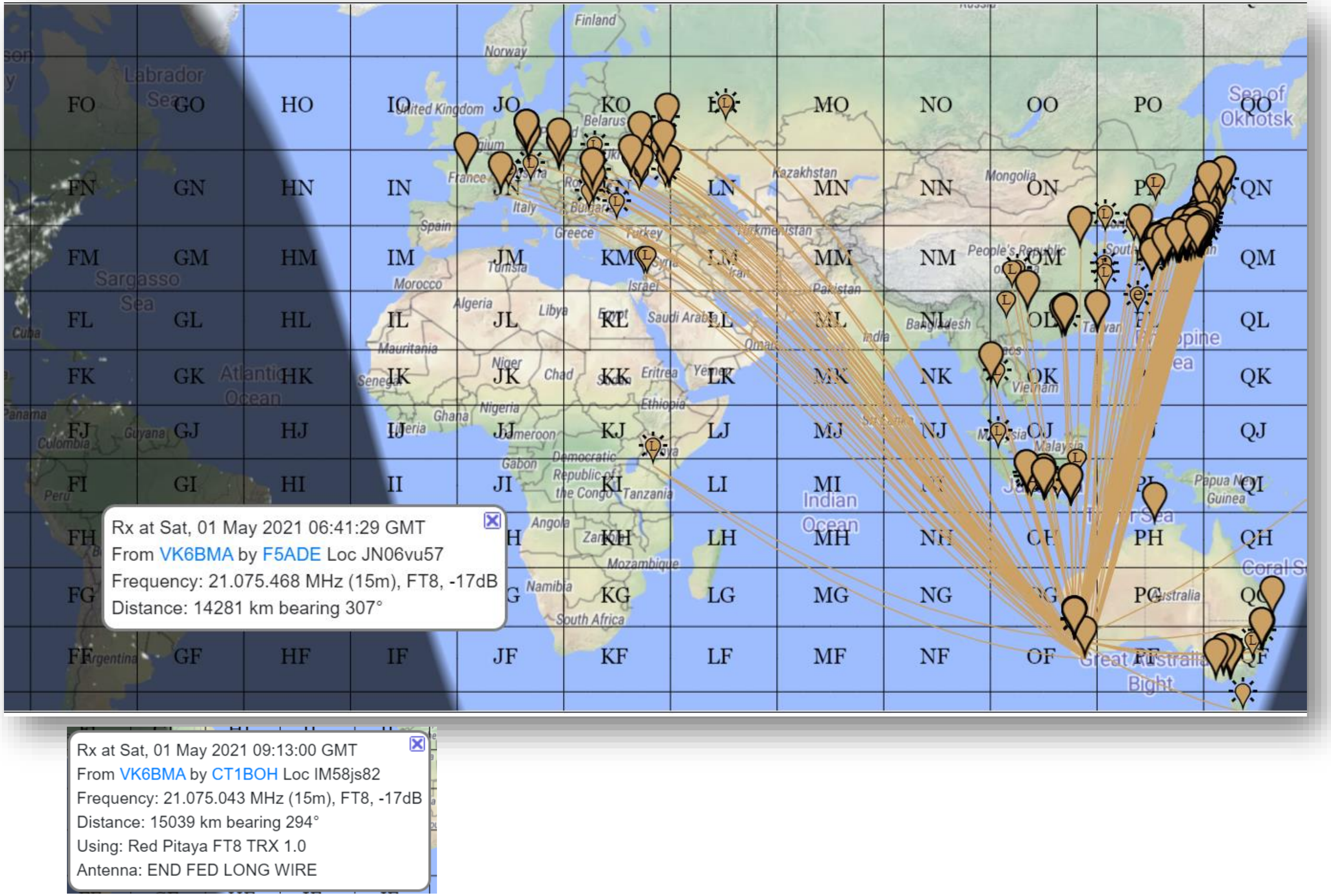



## Only signal on the band

- Many times, a seemingly dead band is just of matter of few station inside the available propagation area



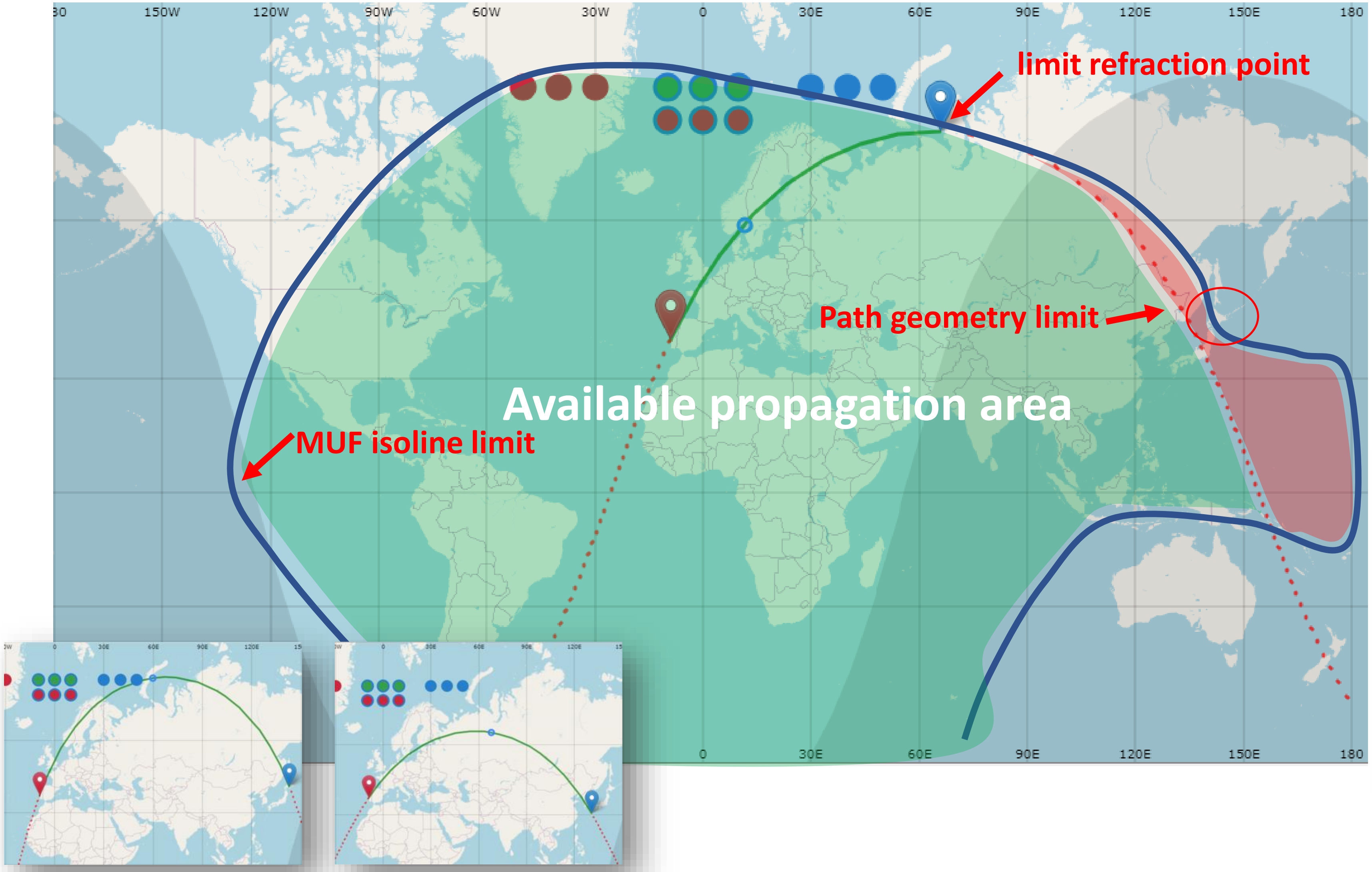
# Why OF grid stations are not being heard by CT1BOH FT8 skimmer?




## Available propagation area

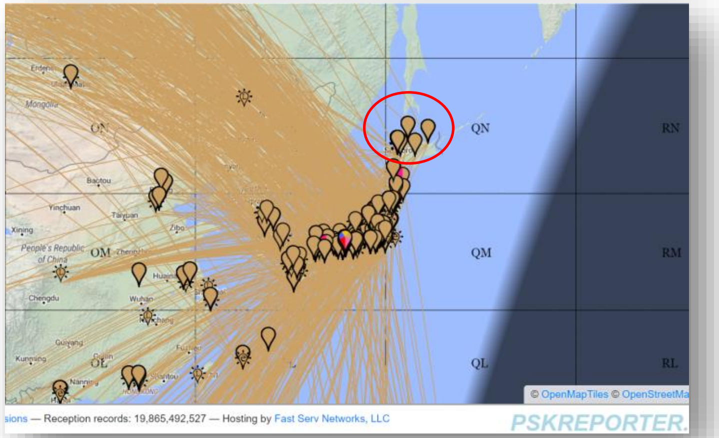
- Australian stations were coming into Europe from grid OF but not into Iberia (Portugal and Spain)
- Signal levels can be checked to determine if propagation is on the edge limits of SNR

# Combining MUF isolines, path geometry and middle refraction points highlights available propagation

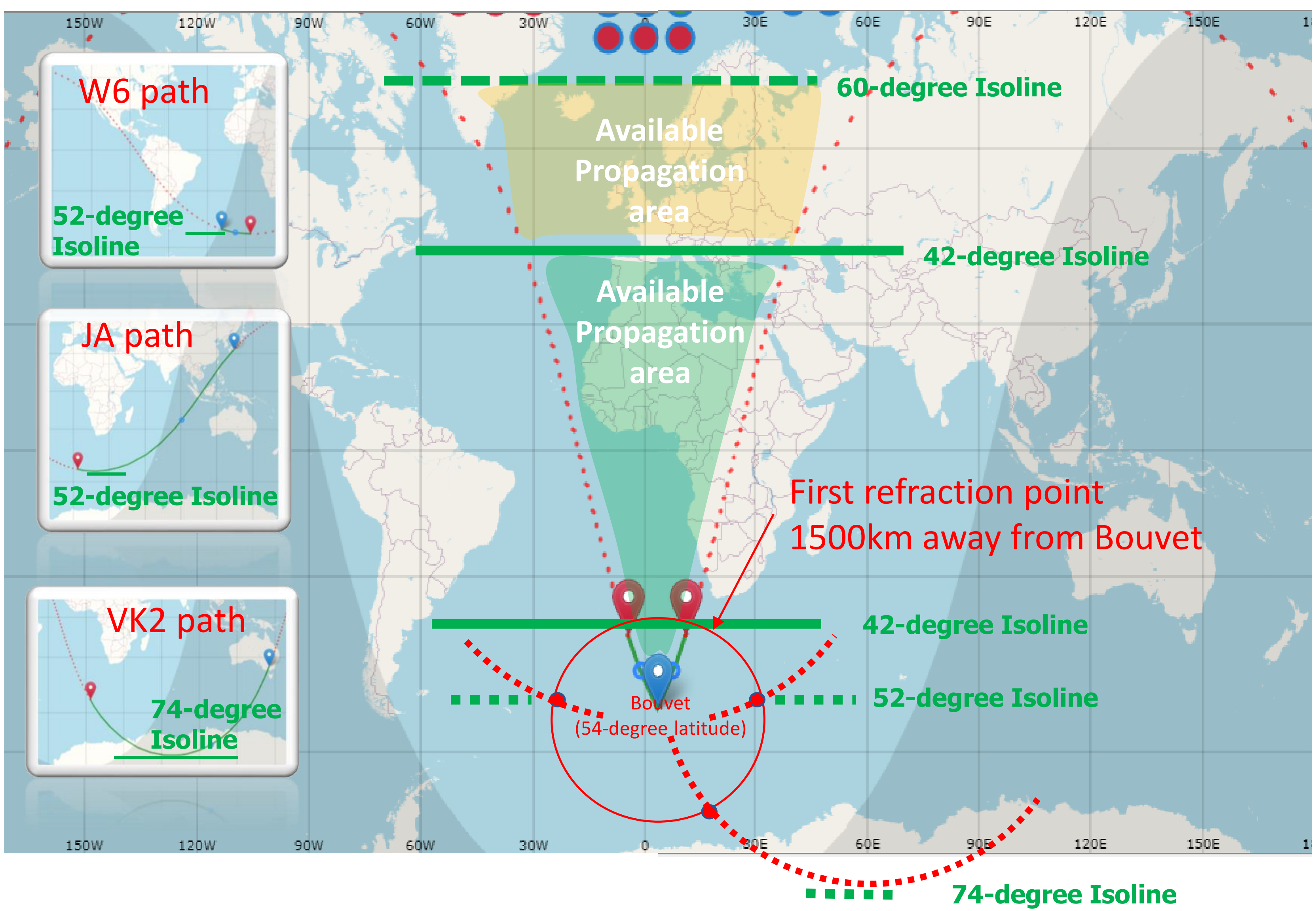



## Available propagation area

- Even with a wide-open band, defined by the size and shape of the MUF isoline, there may be areas inside the isoline that will not hold propagation



# Checking a high latitude location outside the MUF isoline – Bouvet 3Y0



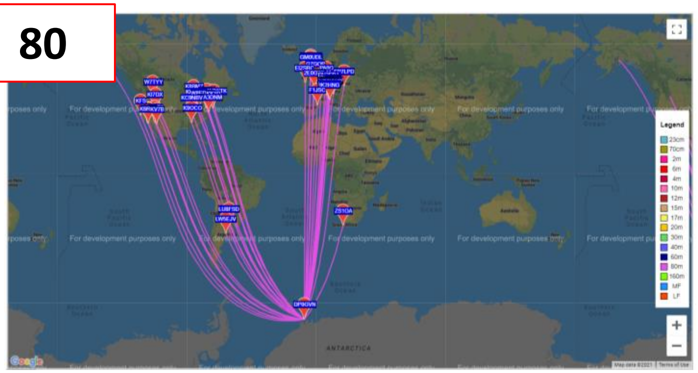

**First refraction point from 3Y0**

- Under the current solar cycle, both 21MHz and 28MHz can face MUF isolines lower than Bouvet latitude
- Propagation will be defined if the MUF isoline is higher or lower than the latitude of the first refraction point
- The available propagation for a symmetrical 42-degree isoline is shown in the green area
- Required isolines for major paths:
  - W6 – 52-degree
  - JA – 52-degree
  - VK2 – 74-degree

# From WSPR to FT8, many sources can be used to determine the position of the MUF isolines

160

80



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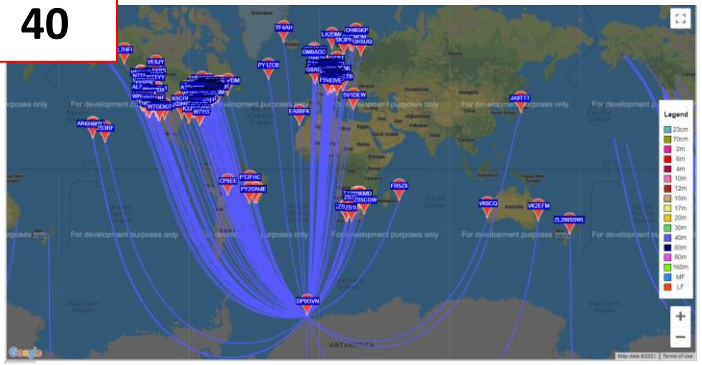

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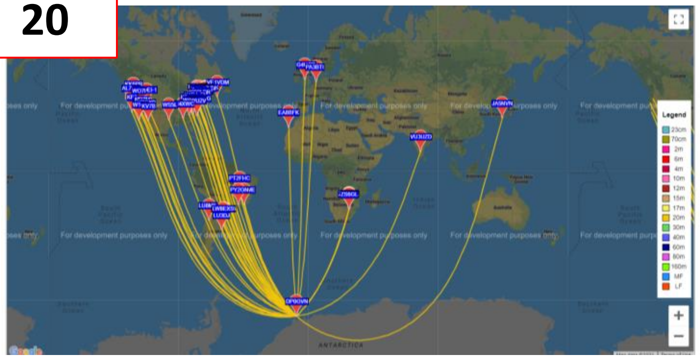

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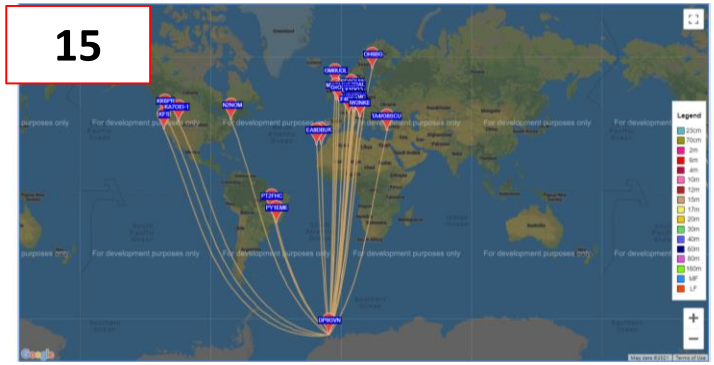

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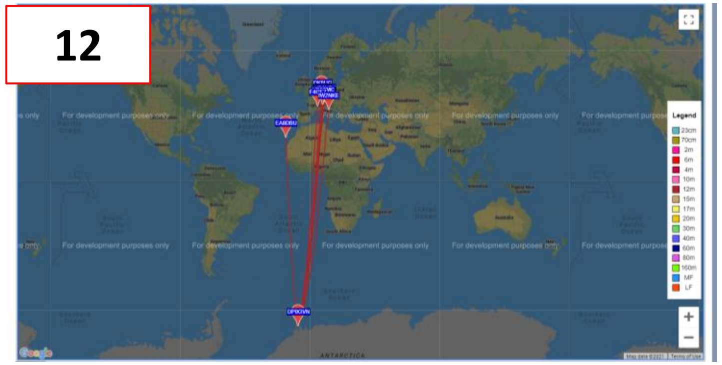
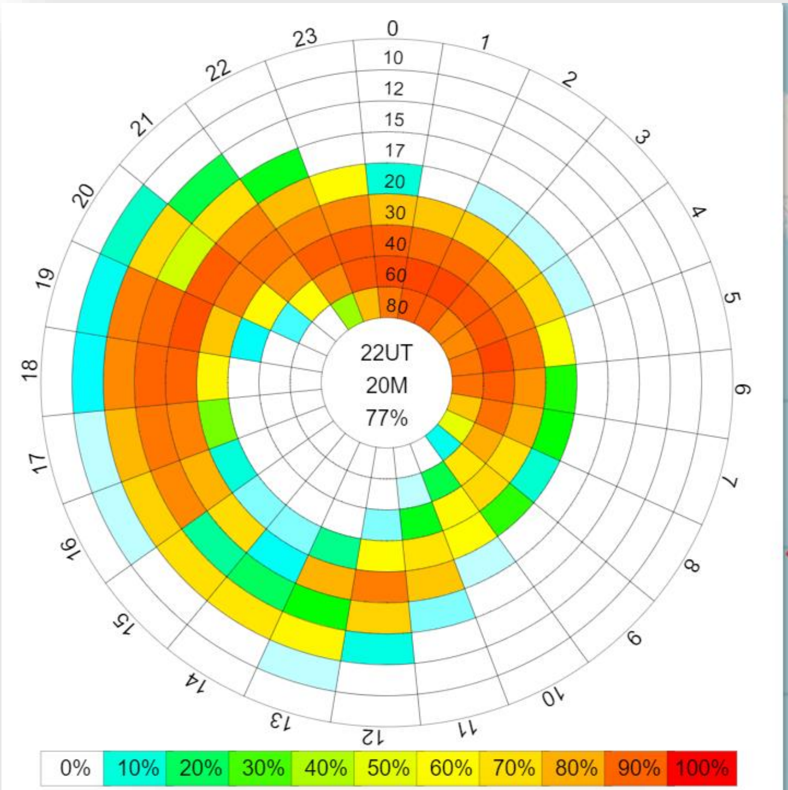
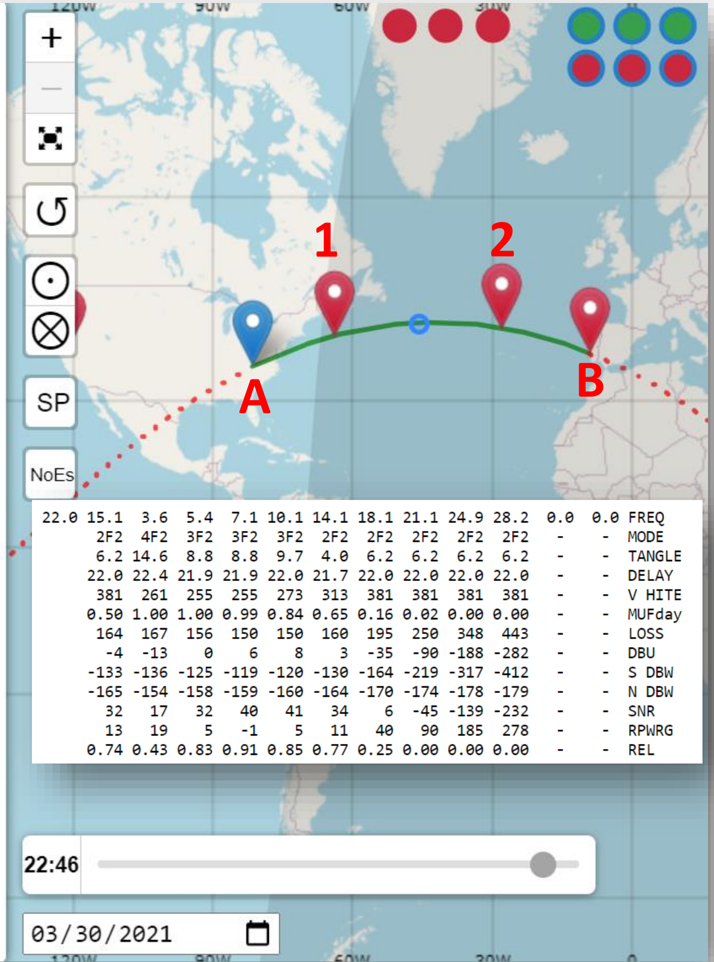


## WSPR and FT8 Sources

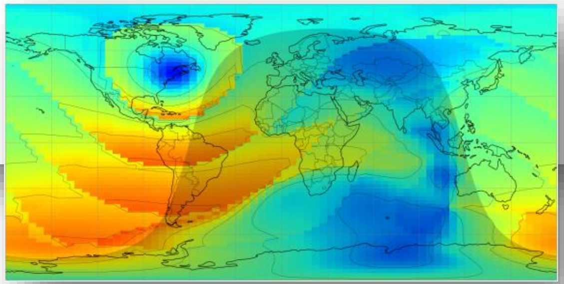
- There are multitude of sources that can be used to determine the MUF isolines
- The advantages of WSPR and FT8 sources is that transmitters and receivers use exact location information (grid locator) enabling to determine correct paths
- Using DP0GVN WSPR reports http://www.wsprnet.org/drupal/wsprnet/map from Antarctica (last 24 hours) illustrates worldwide propagation limits from 160 to 12 (not propagation on 10 at this time)

# Propagation prediction software’s are not able to determine if the path is open or close and deal with variability providing circuit reliability



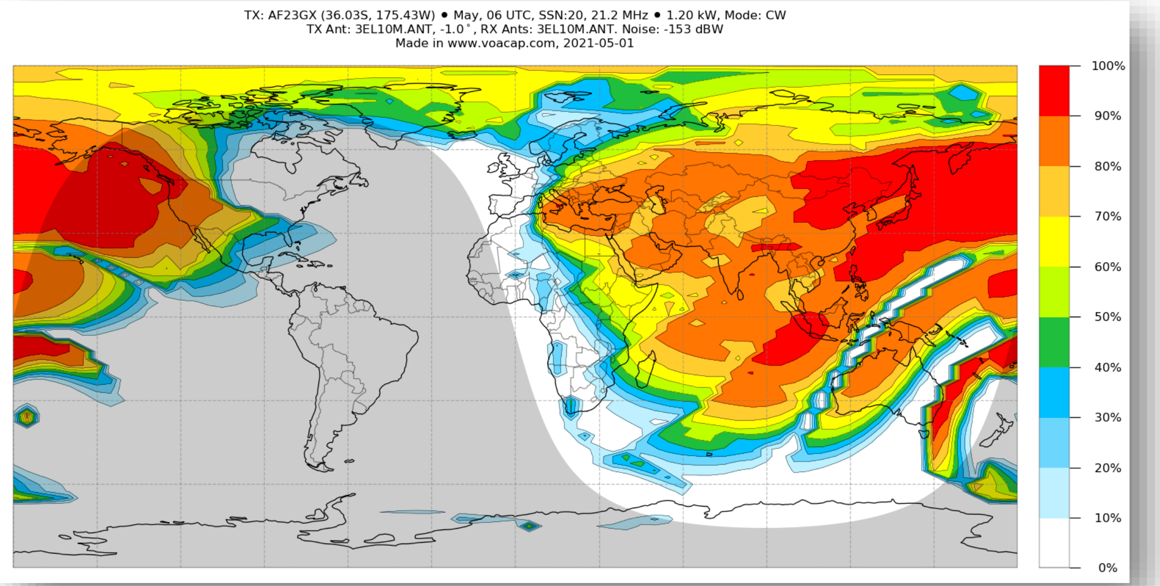

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 22.0 | 15.1 | 3.6 | 5.4 | 7.1 | 10.1 | 14.1 | 18.1 | 21.1 | 24.9 | 28.2 | 0.0 | 0.0 | FREQ |
| | 2F2 | 4F2 | 3F2 | 3F2 | 3F2 | 2F2 | 2F2 | 2F2 | 2F2 | 2F2 | - | - | MODE |
| | 6.2 | 14.6 | 8.8 | 8.8 | 9.7 | 4.0 | 6.2 | 6.2 | 6.2 | 6.2 | - | - | TANGLE |
| | 22.0 | 22.4 | 21.9 | 21.9 | 22.0 | 21.7 | 22.0 | 22.0 | 22.0 | 22.0 | - | - | DELAY |
| | 381 | 261 | 255 | 255 | 273 | 313 | 381 | 381 | 381 | 381 | - | - | V HITE |
| | 0.50 | 1.00 | 1.00 | 0.99 | 0.84 | 0.65 | 0.16 | 0.02 | 0.00 | 0.00 | - | - | MUFday |
| | 164 | 167 | 156 | 150 | 150 | 160 | 195 | 250 | 348 | 443 | - | - | LOSS |
| | -4 | -13 | 0 | 6 | 8 | 3 | -35 | -90 | -188 | -282 | - | - | DBU |
| | -133 | -136 | -125 | -119 | -120 | -130 | -164 | -219 | -317 | -412 | - | - | S DBW |
| | -165 | -154 | -158 | -159 | -160 | -164 | -170 | -174 | -178 | -179 | - | - | N DBW |
| | 32 | 17 | 32 | 40 | 41 | 34 | 6 | -45 | -139 | -232 | - | - | SNR |
| | 13 | 19 | 5 | -1 | 5 | 11 | 40 | 90 | 185 | 278 | - | - | RPWRG |
| | 0.74 | 0.43 | 0.83 | 0.91 | 0.85 | 0.77 | 0.25 | 0.00 | 0.00 | 0.00 | - | - | REL |

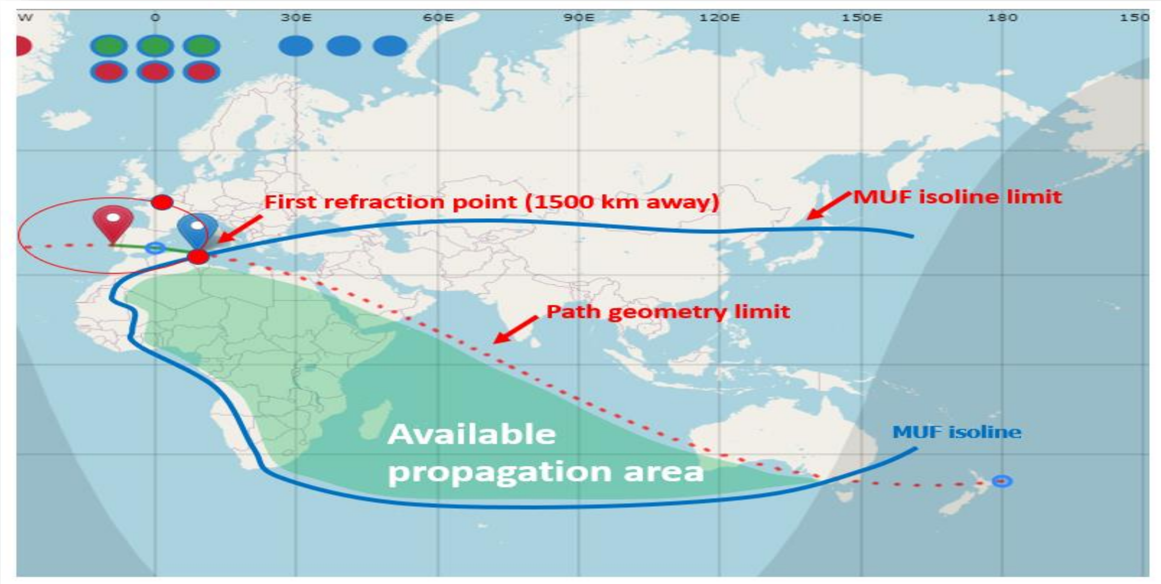


## VOACAP Prediction Software

- Propagation prediction software shows 77% circuit reliability on 14MHz and 23% circuit reliability on 18 MHz
- Prediction is consistent with near-real time ionospheric MUF map
- A 77% reliability circuit reliability tells that in a month, 23 of the days will enable 14 MHz propagation while 7 of the days will not enable 14MHz propagation
- Propagation prediction software's try to account propagation variability into the prediction assigning a circuit reliability

# From reliability into certainty by determining MUF isolines and available propagation area using real time FT8 big data reports from PSK-Reporter database



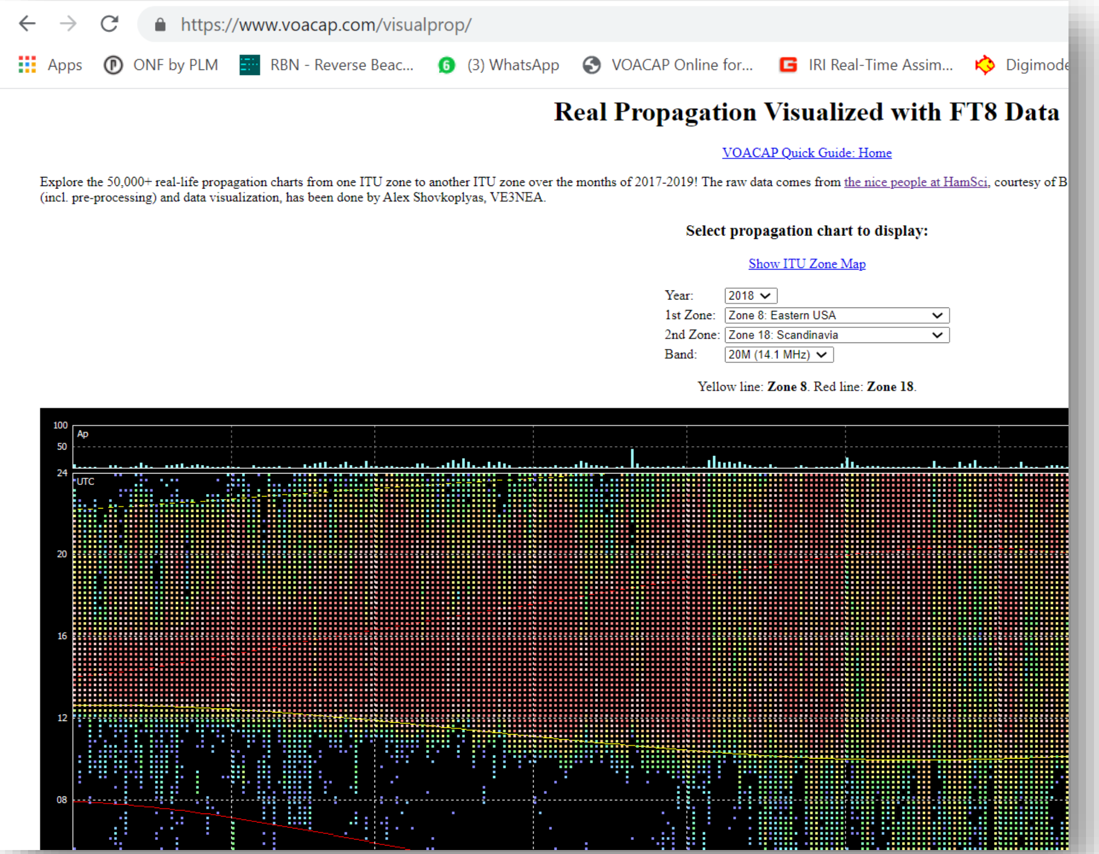

## VOACAP reliability map prediction

- Prediction programs don't have real time position of the isolines, so they provide a probability of occurrence
- According to daily propagation the path may exist or not

## Real time availability propagation area

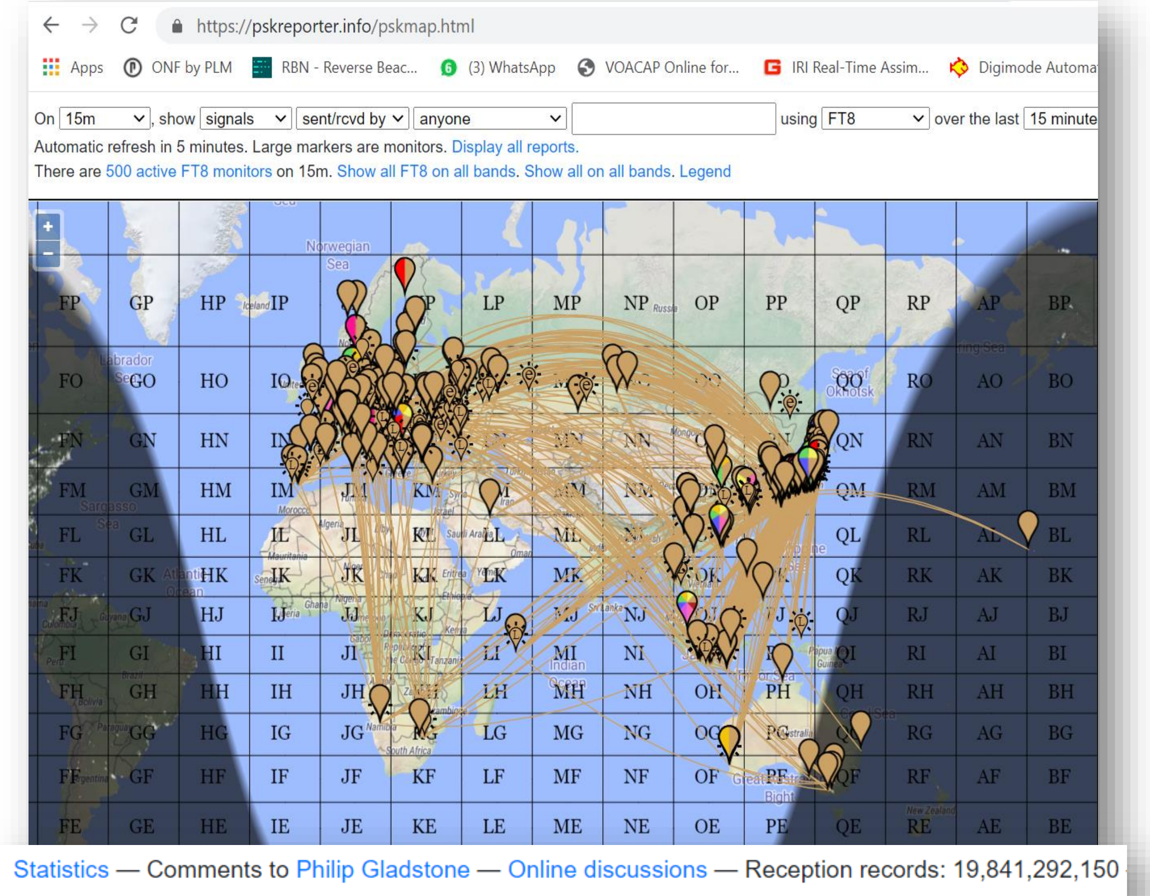
- Real time data from FT8 data can be used to determine with great certainty the contour of the isoline together with path geometry limit - available propagation area can be easily determined

# Moving from propagation prediction programs into real time propagation availability




## Pattern propagation

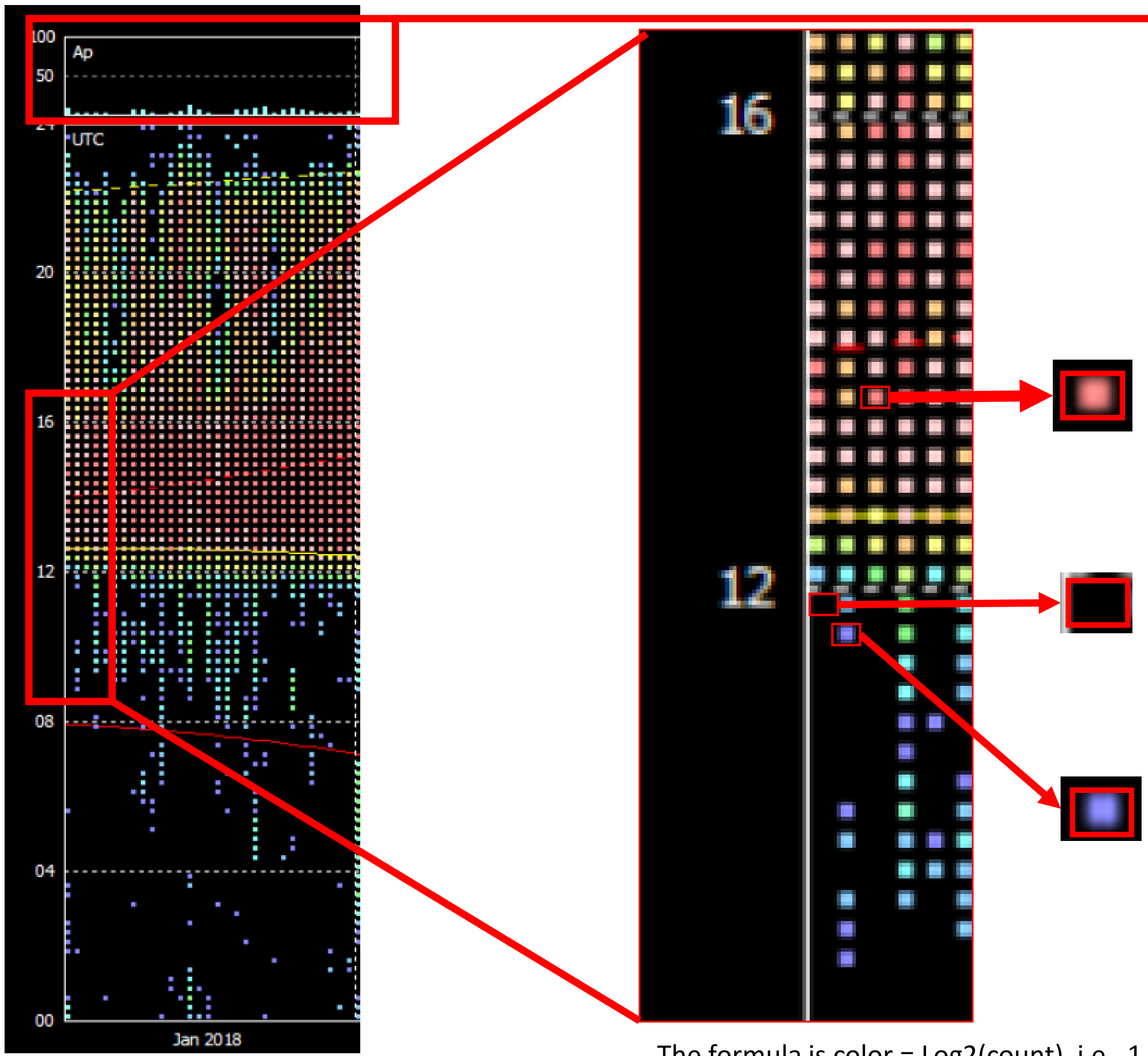
- Historical FT8 real propagation provides accurate propagation pattern profile for Solar Cycle and season

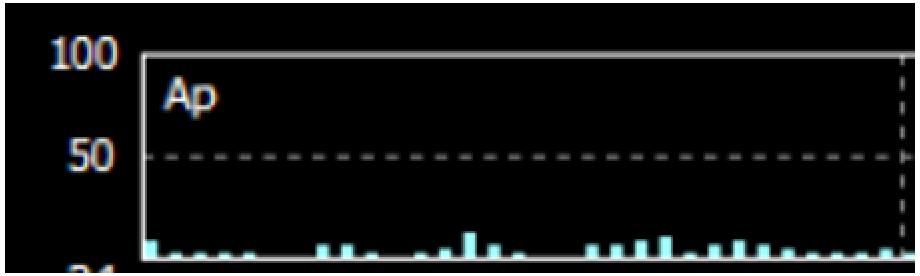



## Real time propagation

- Real time data provides and explains variability in the propagation pattern profile

# Propagation pattern – Using FT8 PSK Reporter real propagation historic data




Bin from 3rd Jan 2018 from 13:45 to 13:59 Color Red, lots of PSK reports

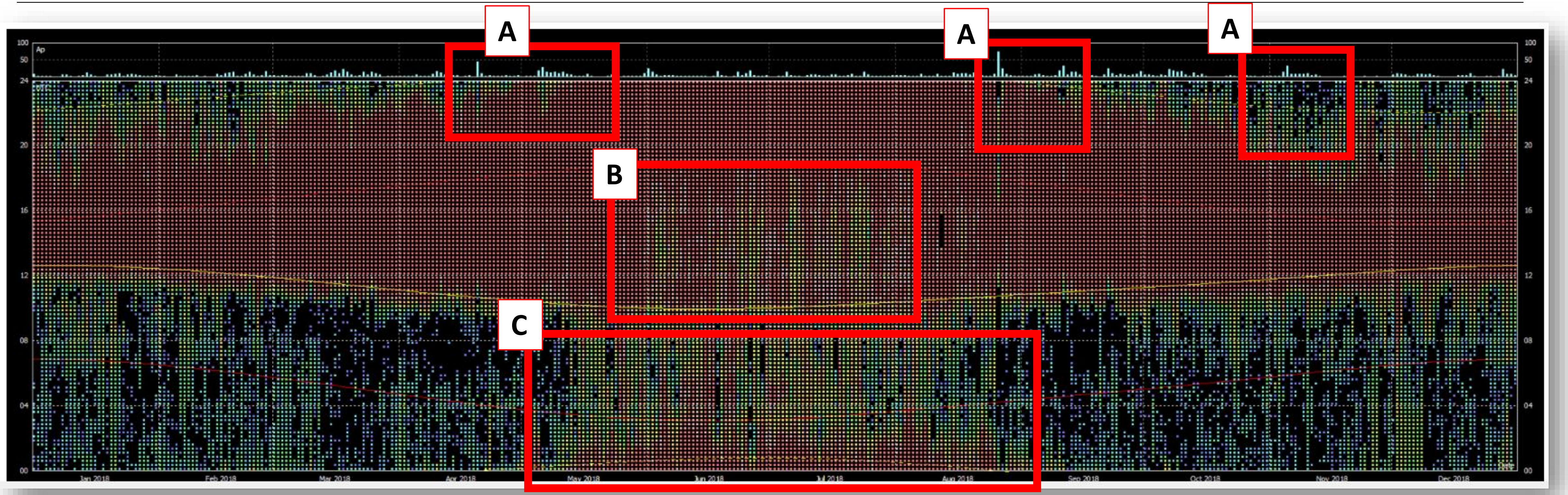
Bin from 1st Jan 2018 from 11:45 to 11:59 Color black, no PSK reports

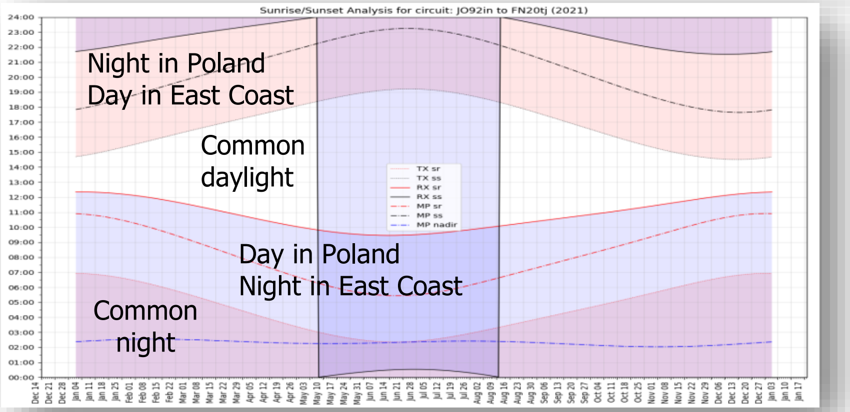
Bin from 2nd Jan 2018 from 11:30 to 11:44 Color blue, few PSK reports

The formula is color = Log2(count), i.e., 1 -> color0, 512 -> color9

https://www.voacap.com/visualprop/

# Propagation pattern – one-year FT8 reported data between ITU zone 8 and 28 on 14MHz

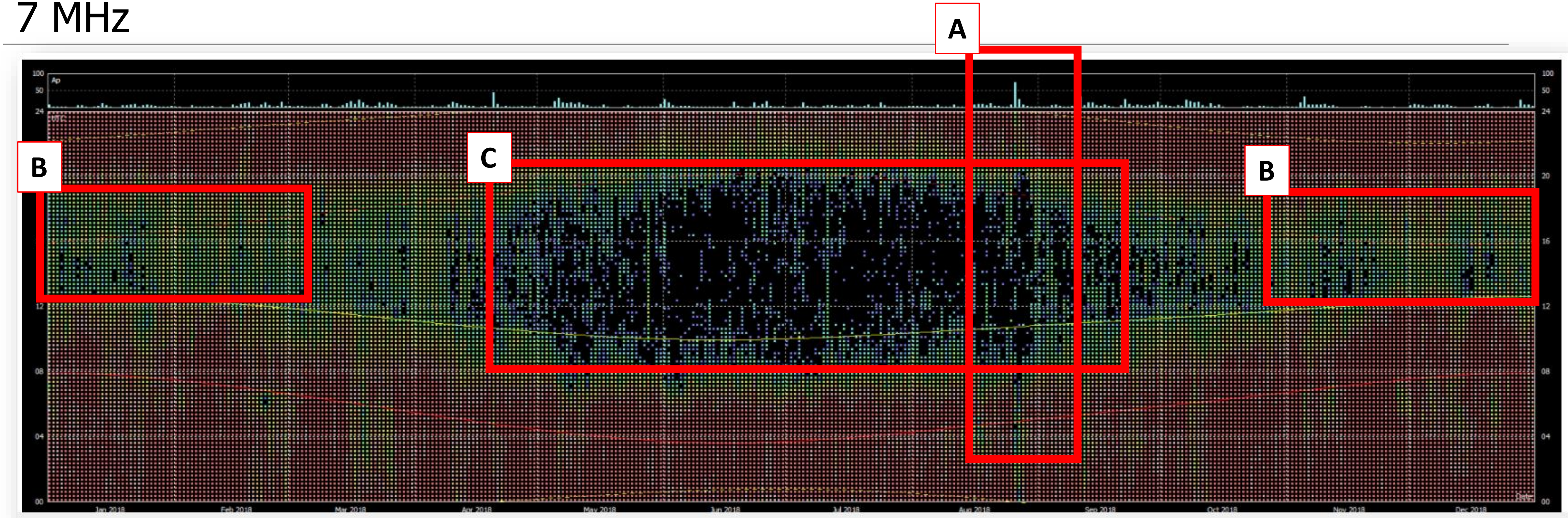


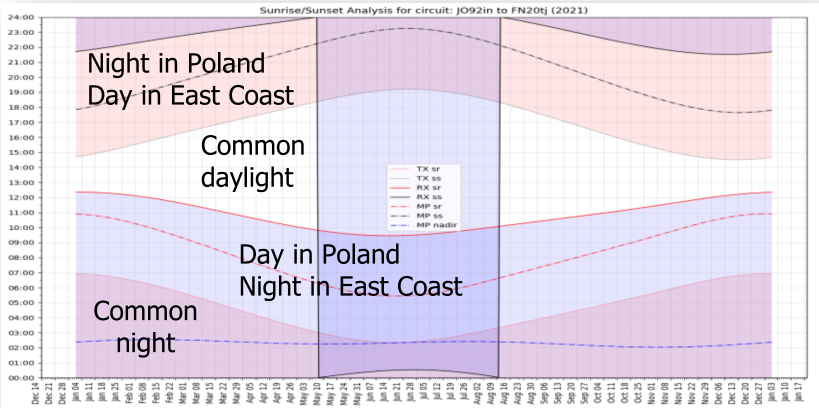




- Sunrise in East Coast opens the path
- Some hours after sunset in Poland closes the path
- Summer, with longer illumination of path keeps band open
- The reliability of this circuit is close to 100%

- **Check in A** – geomagnetic disturbances, with some impact on propagation - the band closes early
- **Check in B** – reduction of signal in the peak of summer – Higher absorption from D layer?
- **Check in C** – nighttime summer propagation because of more illumination of path and higher MUF

# Propagation pattern – one-year FT8 reported data between ITU zone 8 and 28 on 7 MHz

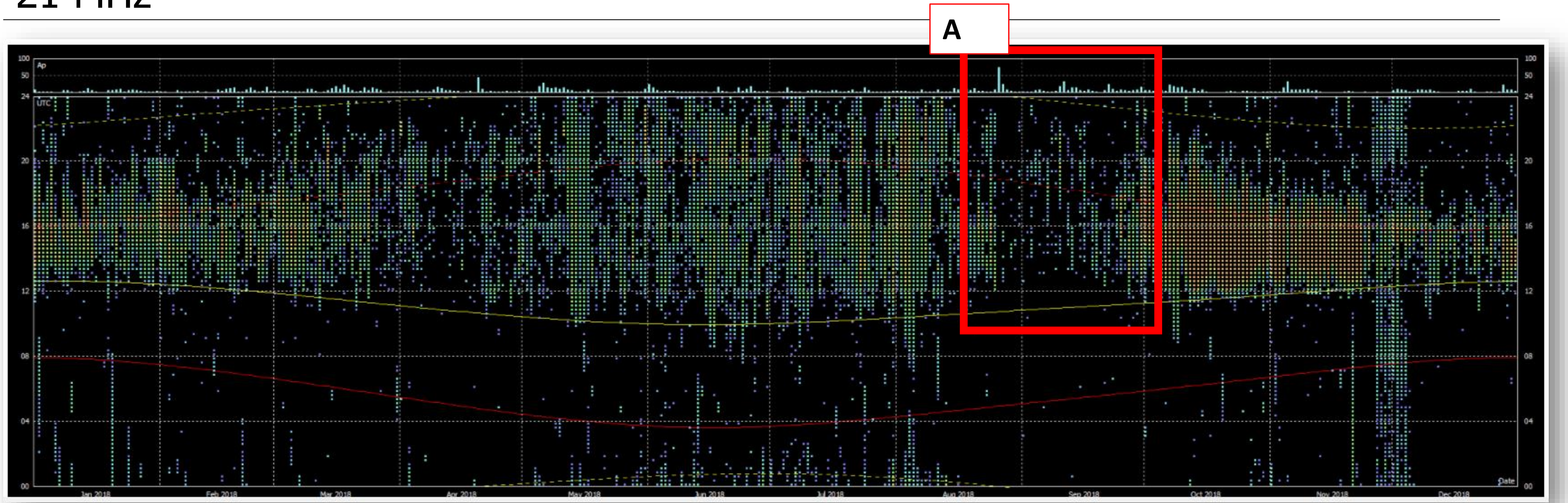


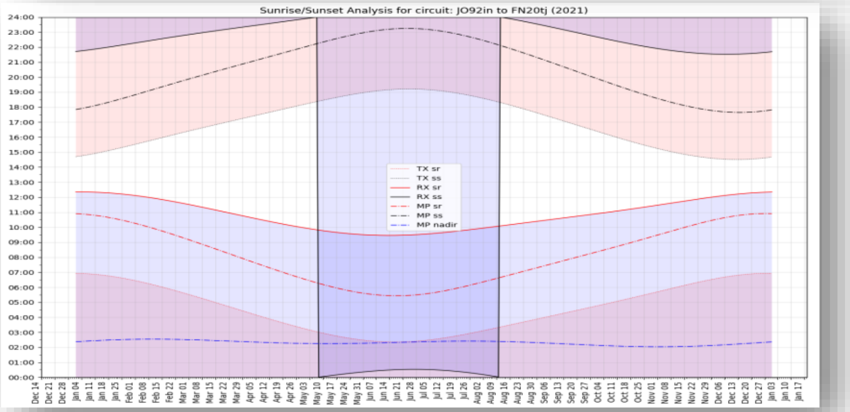




- Propagation is predominant in common nighttime between two locations
- The reliability of this circuit is close to 100%

- **Check in A** – geomagnetic disturbances, without much impact on LF and band seems to recover quickly but noticeable increase in absorption
- **Check in B** – with less sun illumination of path in winter 40 meters extends after sunrise and before sunset
- **Check in C**, no propagation with greater common daytime hours

# Propagation pattern – one-year FT8 reported data between ITU zone 8 and 28 on 21 MHz



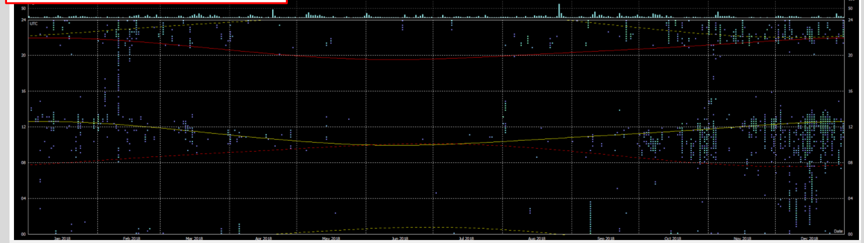




- Propagation is open in the path during common daytime
- Propagation does not last longer than East Coast sunrise
- The reliability of this circuit is not 100% and is very dependent on ionosphere variability

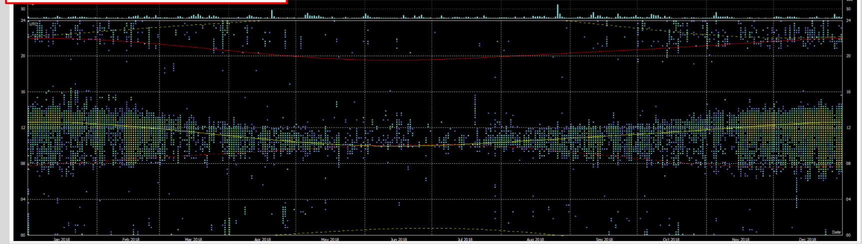
- **Check in A** – geomagnetic disturbances, with great impact on propagation on 21MHz. With higher Kp, Aurora is more intense and at lower altitudes, lowering MUF, and preventing refraction points, signal is then lost in space

# Propagation pattern – 2018 year around FT8 reported data between ITU zone 8 (USA) and 45 (Japan) on 160 through 10

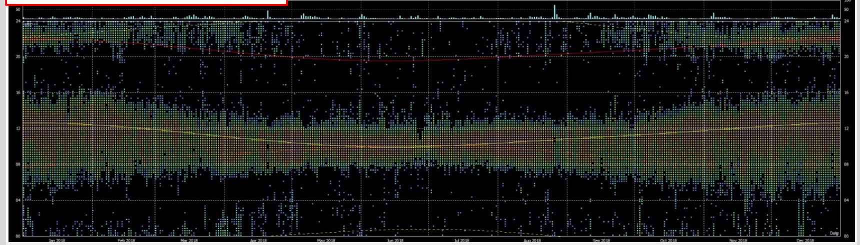
**160 meters**



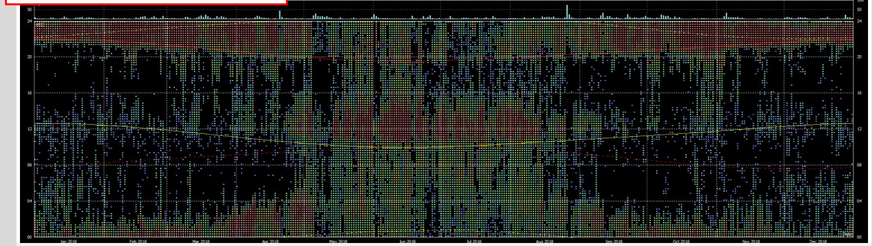
**80 meters**



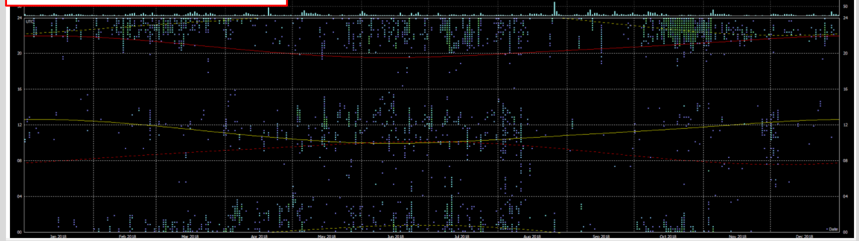
**40 meters**



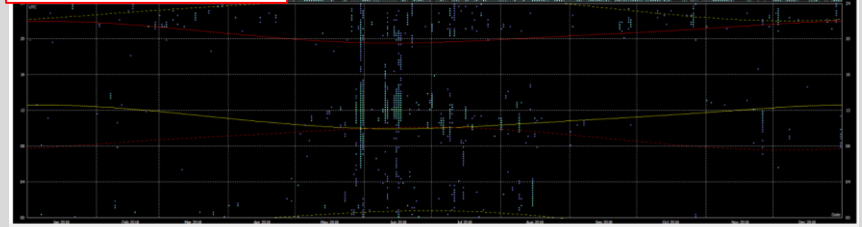
**20 meters**



**15 meters**



**10 meters**

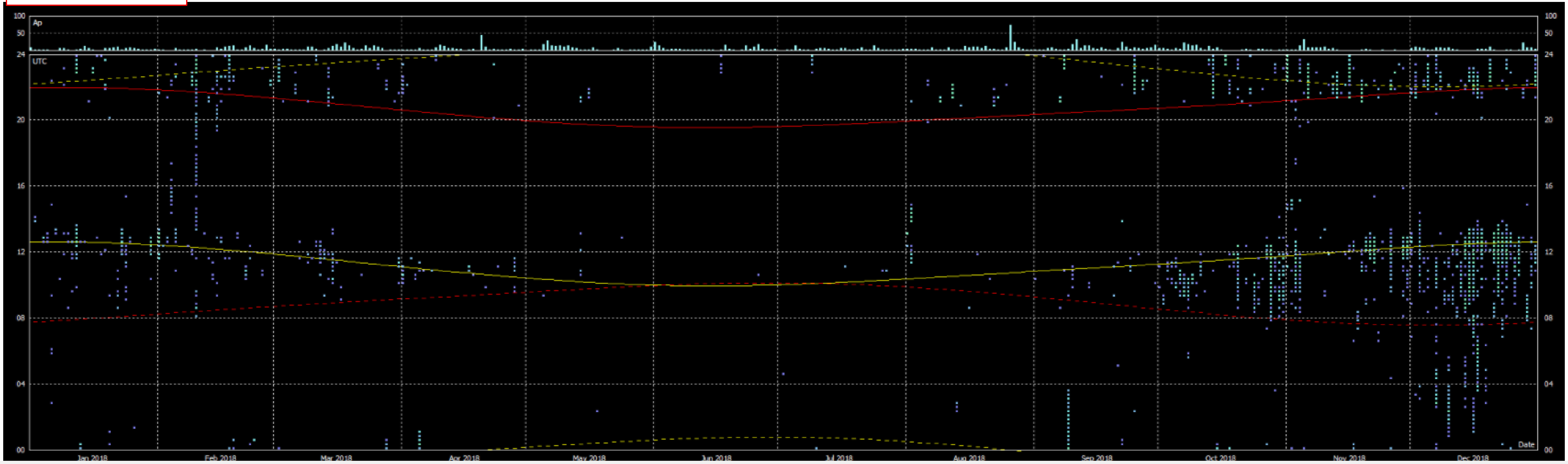


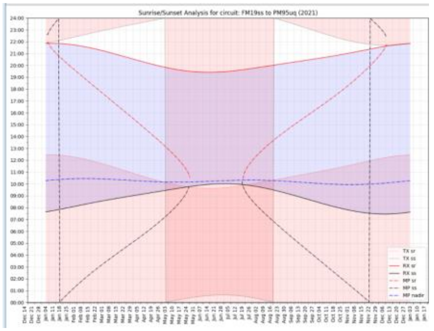
## Variability by band

- FT8 PSK Reporter data, from Jan to December, during the 24 hours of the day, provides the big picture pattern on all the main bands
- Very solid propagation patterns can be found
- 80, 40 and 20 meters, to some extent, have solid and constant behavior
- 160, 15 and 10 meters, although with propagation within expected patterns are the bands susceptible to ionospheric variations

# Propagation pattern – 2018 year around FT8 reported data between ITU zone 8 (USA) and 45 (Japan) on 160 through 10

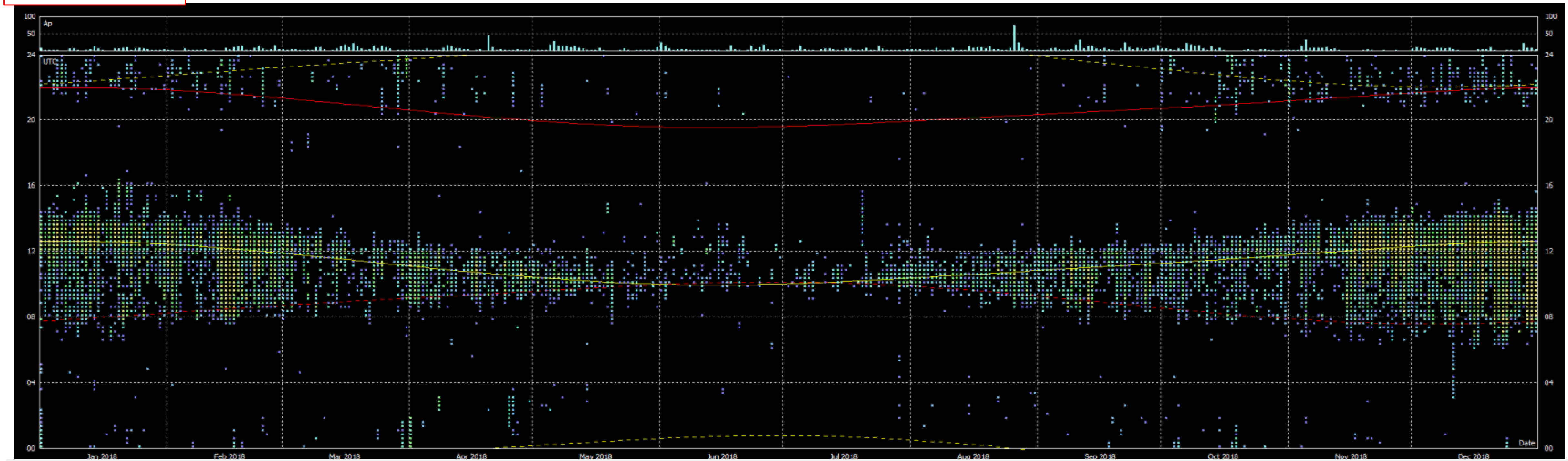
**160 meters**

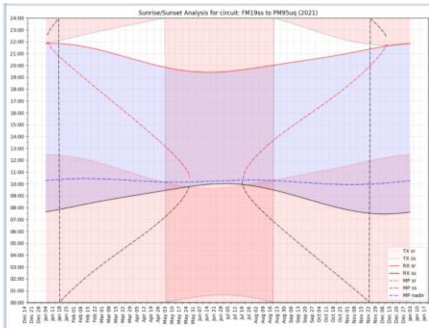


# Propagation pattern – 2018 year around FT8 reported data between ITU zone 8 (USA) and 45 (Japan) on 160 through 10

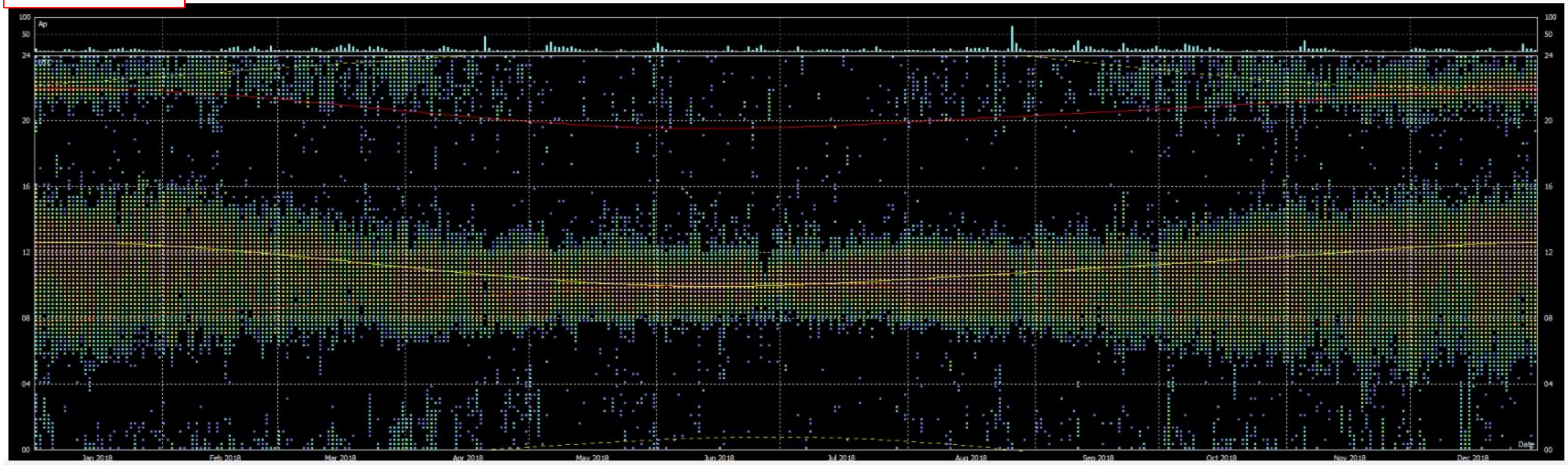
**80 meters**

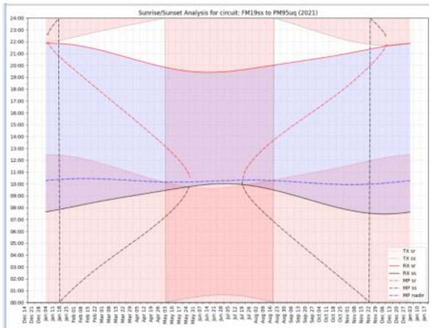


# Propagation pattern – 2018 year around FT8 reported data between ITU zone 8 (USA) and 45 (Japan) on 160 through 10

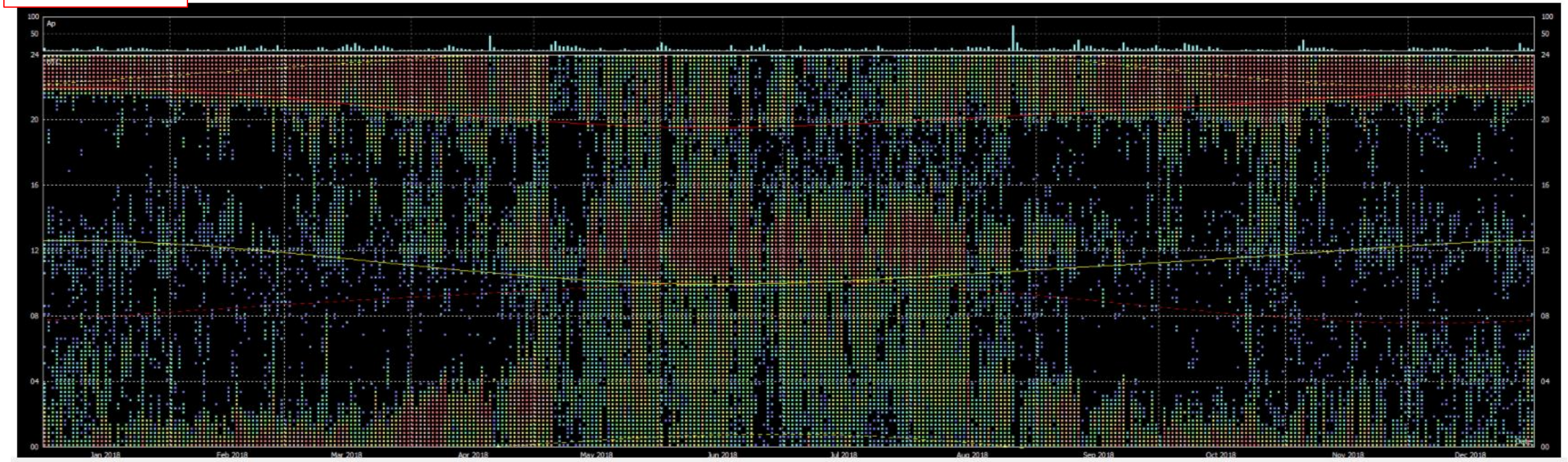
**40 meters**

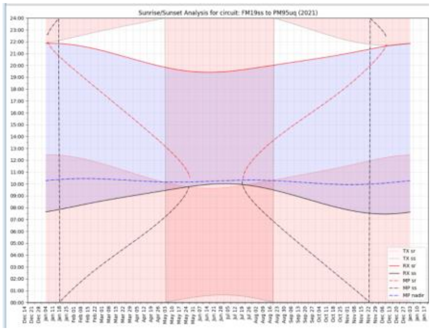


# Propagation pattern – 2018 year around FT8 reported data between ITU zone 8 (USA) and 45 (Japan) on 160 through 10

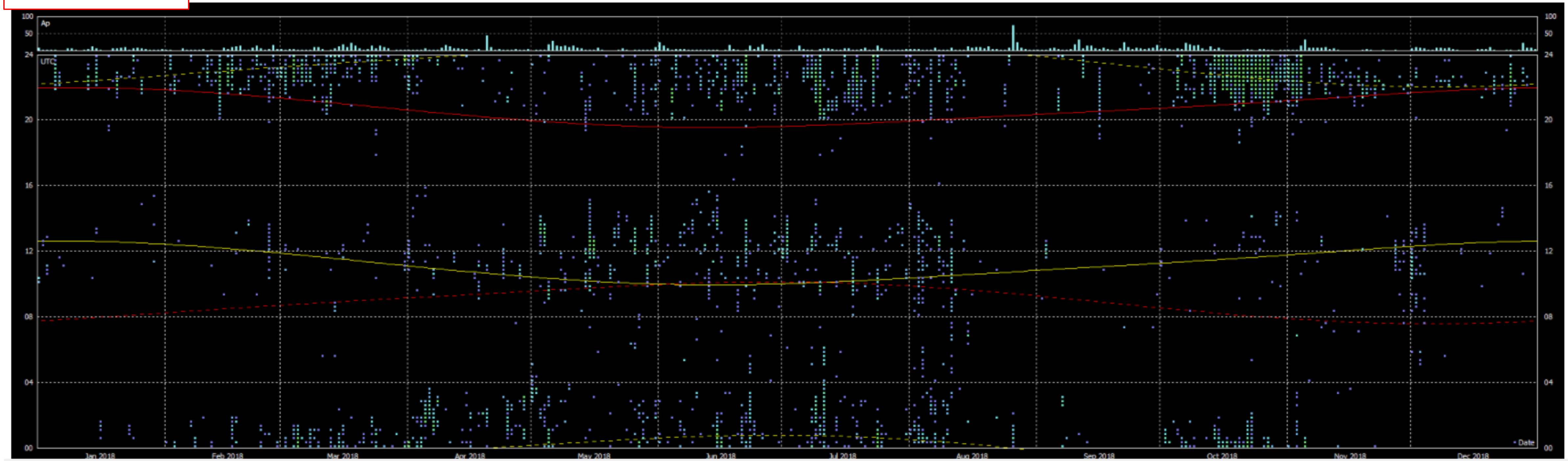
**20 meters**

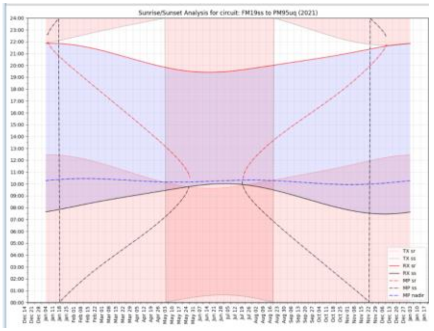


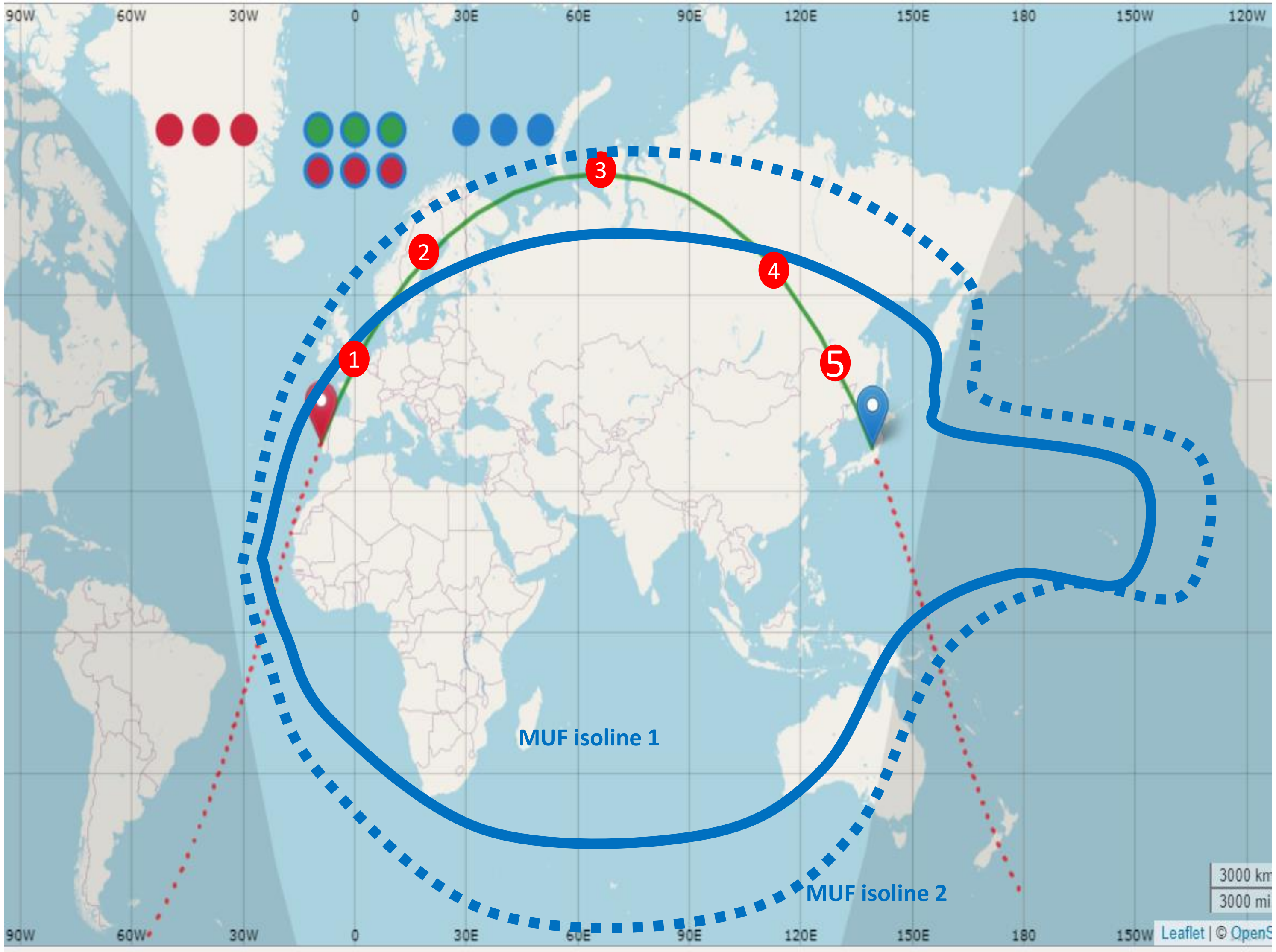
# Propagation pattern – 2018 year around FT8 reported data between ITU zone 8 (USA) and 45 (Japan) on 160 through 10

**15 meters**



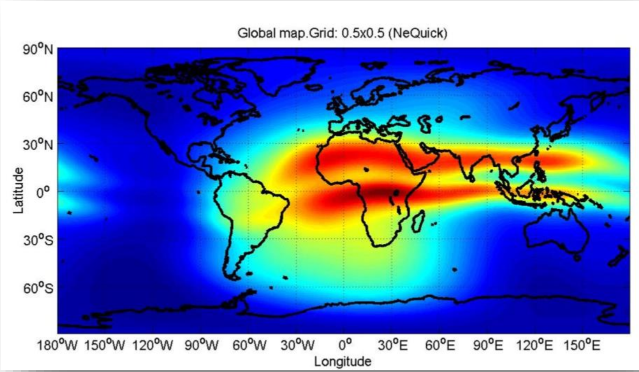



# Variability in propagation can be seen and the increase and decrease of the shape and size of the MUF isoline figure



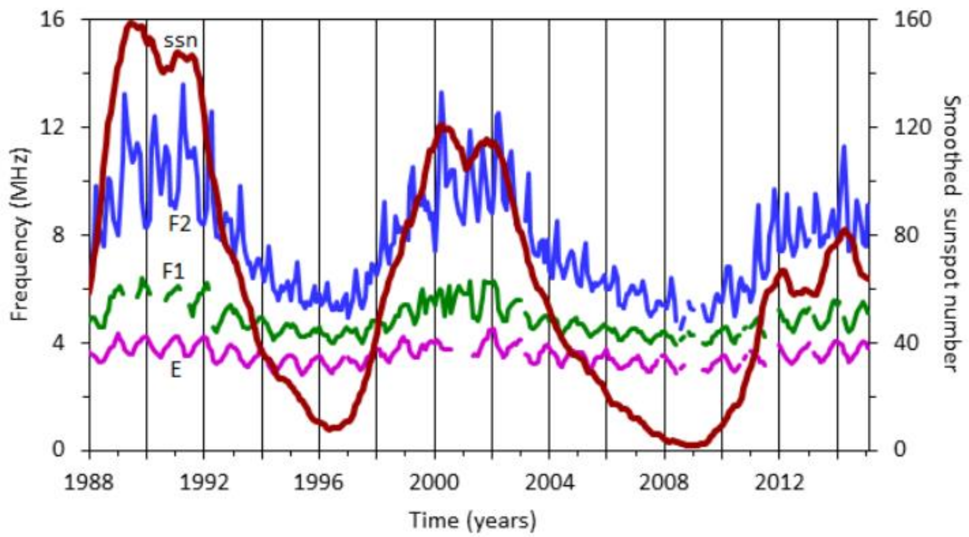

## The shape and size of the MUF isoline

- The shape and size of the MUF isoline determining the quality of propagation is explained by a multitude of factors:
  - Solar Cycle evolution
  - Seasonal variations
  - Latitude variations
  - Diurnal variations
  - Solar and tropospheric events
  - Layer path mode variability
  - Magnetosphere



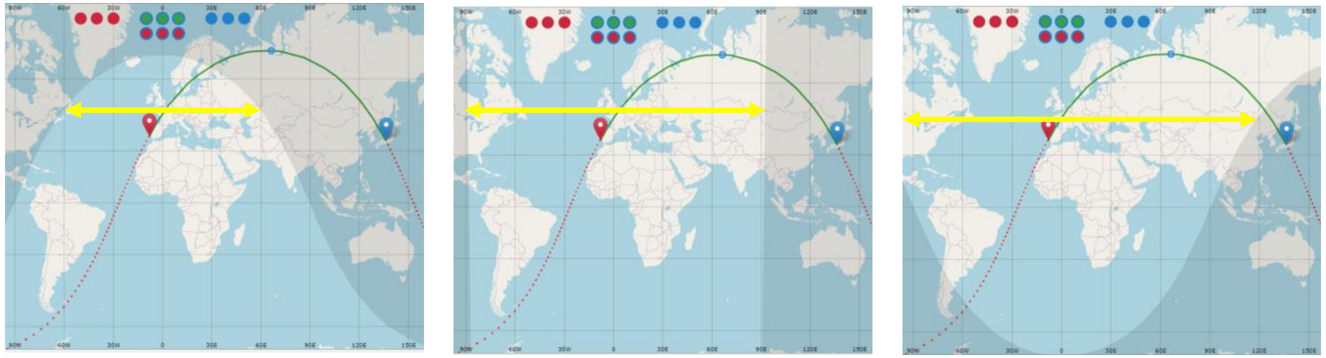
# Ionospheric variability – solar cycle and seasonal variations

## Solar cycle evolution




- Increased radiation during the peak of solar cycle, increases electron density and F2 layer MUF and to a less extend F1 MUF
- Sun radiation does not have a noticeable impact in E layer MUF

## Seasonal variations

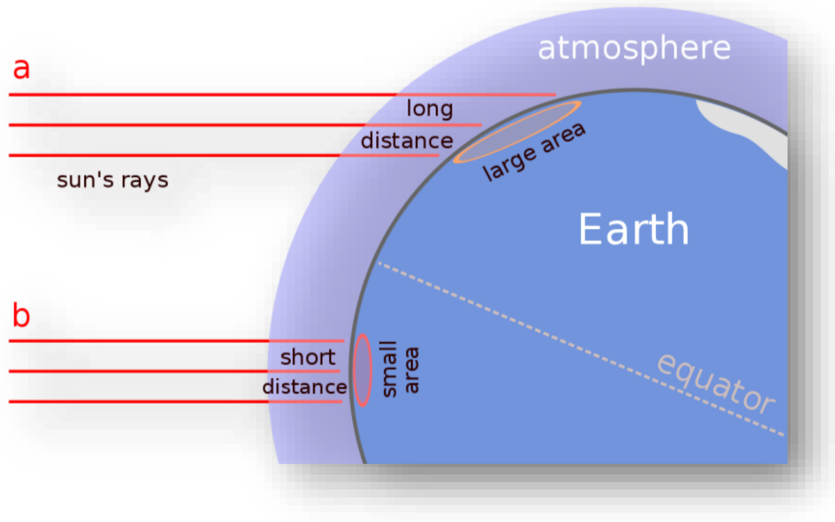


**Winter Solstice** **Equinox** **Summer Solstice**

- Seasonal variations have a profound impact in ionization of atmosphere
- Higher or lesser day hours provide different hours of illumination and ionization that impact MUF
- Increased number of refraction points in illuminated atmosphere provide better opportunities between longer paths in HF

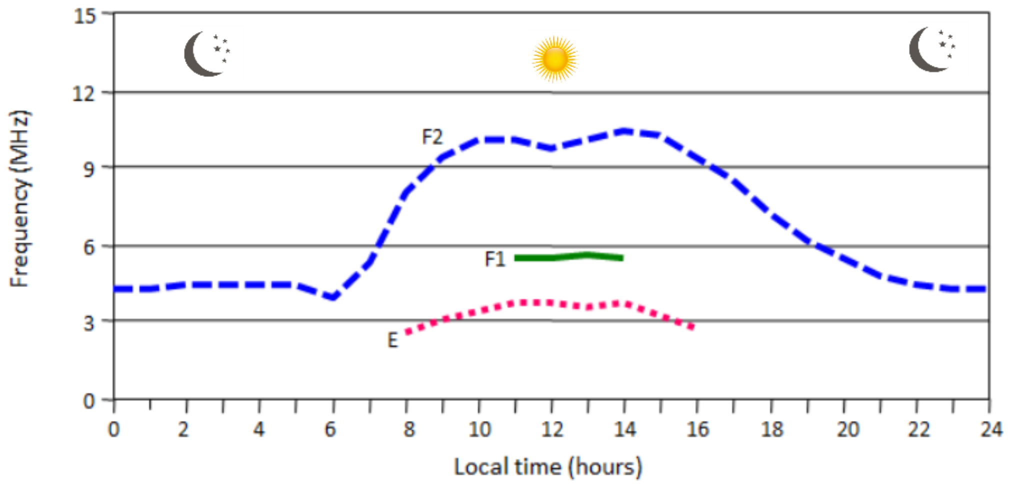
# Ionospheric variability – latitude variations and diurnal variations

## Latitude variations




- MUF is greatest near the equator and decreases with increase of latitude
- Sun incidence angle plays an important part in ionospheric variation due to latitude
- Solar radiation striking the atmosphere in a more oblique way with increased latitude provide less ionization to the atmosphere

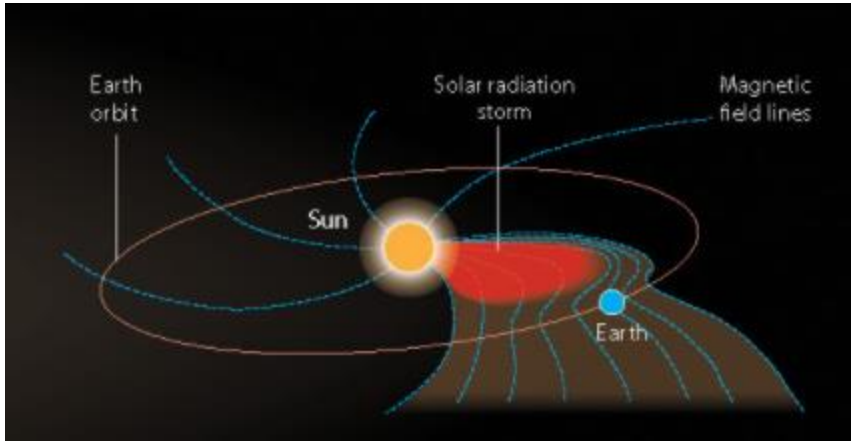
## Diurnal variations




- Local MUF increases quickly with sunrise until noon, when electron density peaks and then slowly decreases thereafter
- After sunrise E and F1 layers have the capability to refract sky waves

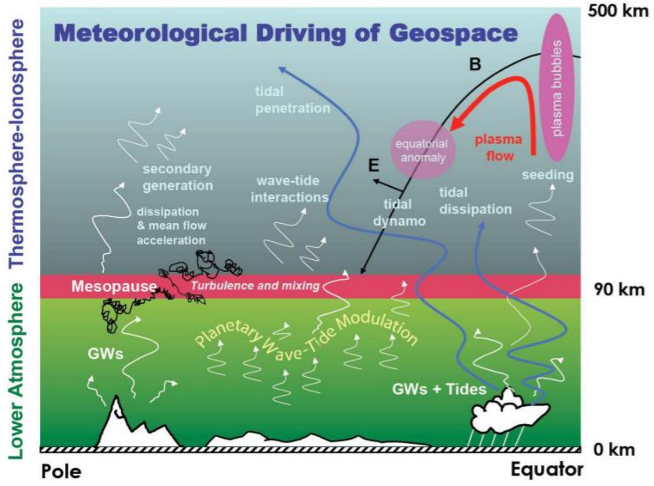
# Ionospheric variability - from above and below, solar and tropospheric events that can either enhance or degrade propagation conditions

## Solar events impacting ionosphere



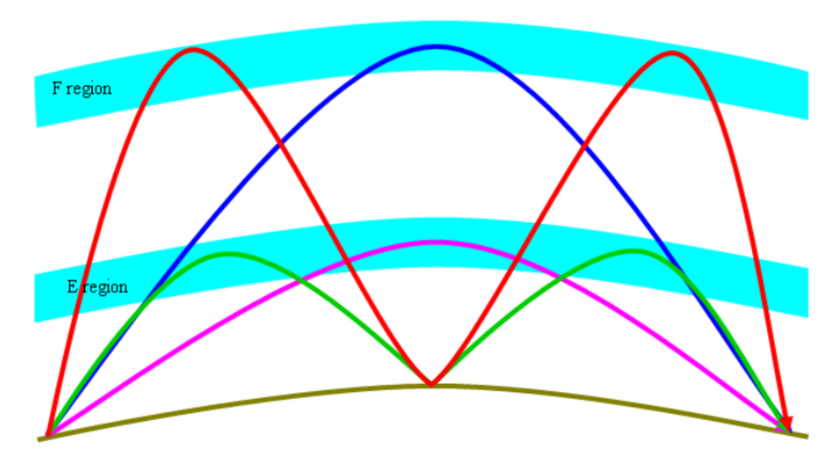

- Sudden Ionization of E and F layers
- Geomagnetic disturbances (Kp index)
- D layer absorption
- Polar cap absorption
- Aurora
- Noise and sounds
- Lightning

## Tropospheric weather impacting ionosphere



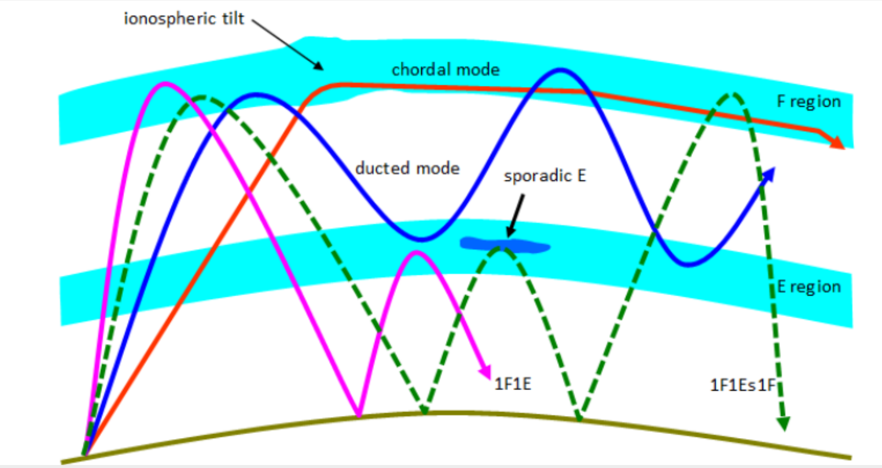

- Waves generated on the lower atmosphere propagate into the thermosphere-ionosphere
- **Planetary waves** (land/sea temperature differences; air flow over mountain ranges), **tidal waves** (heating of water in troposphere; heating of ozone in stratosphere) , **Gravity waves** (weather systems, mountains, tropospheric convection, solar terminator,…) interact with ionosphere

# Path mode variability – Circuit A to B depends on a multitude of factors related to Ionosphere, frequency, antenna take-off angles and gain/power




## Simple path modes

- **F region only** propagation
- **E region** only propagation
- **Sporadic E** only propagation
- Depending on antenna take-off angle the number of hops can be reduced, and with a lower take-off angle, hit a further refraction point with perhaps a better MUF isoline

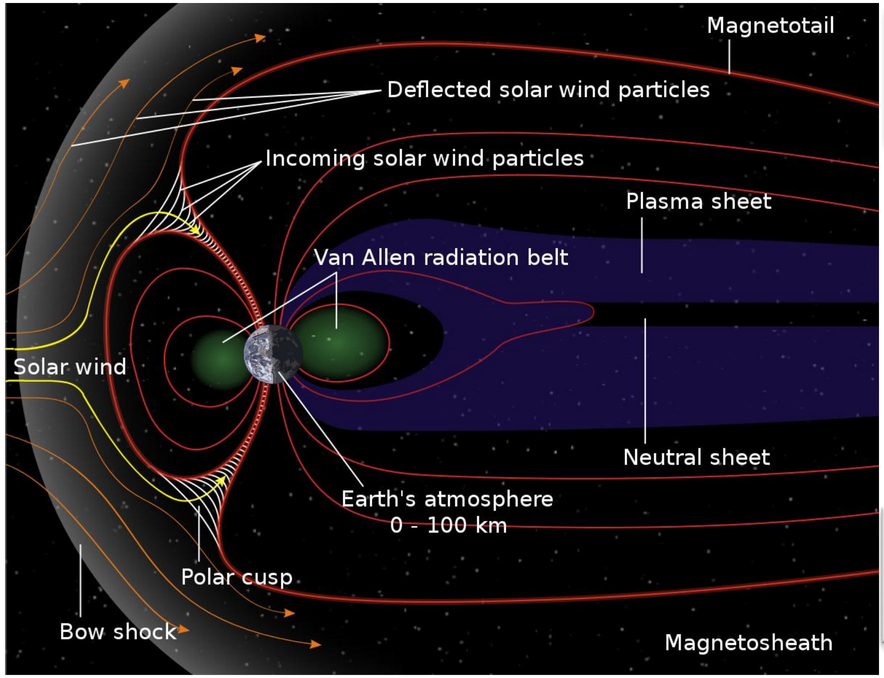


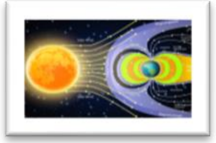

## Complex path modes

- **Combination of refractions** from E and F layers
- **Combination with Sporadic E** mode
- **Ducted mode** with signal trapped between F and E layer
- **Chordal mode** with signal travelling inside F region because of ionospheric tilts (TEP,…)

# Ionospheric variability – the magnetosphere

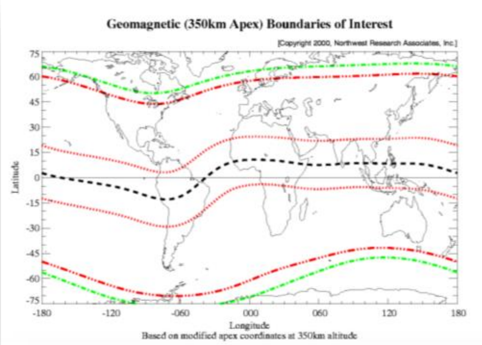
## The polar cusps in the magnetosphere



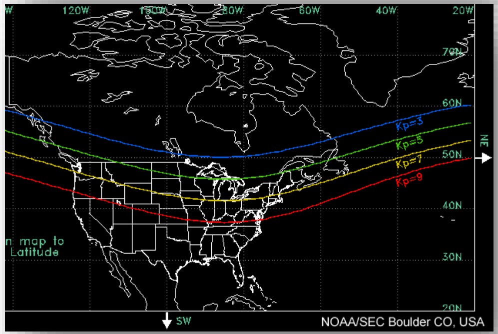



- Magnetosphere shields earth from solar wind
- The polar cusps are two holes in the magnetosphere that funnel solar wind into ionosphere along earth magnetic lines
- Auroras begin with fast moving electrons as they fly through the cusp down to earth

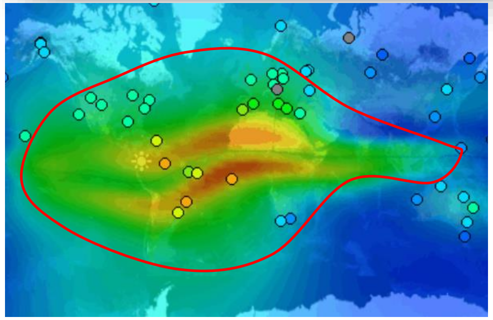
## Geomagnetic latitudes




Geomagnetic maps is not defined to geographic poles, it is defined to the axis of the geomagnetic dipole



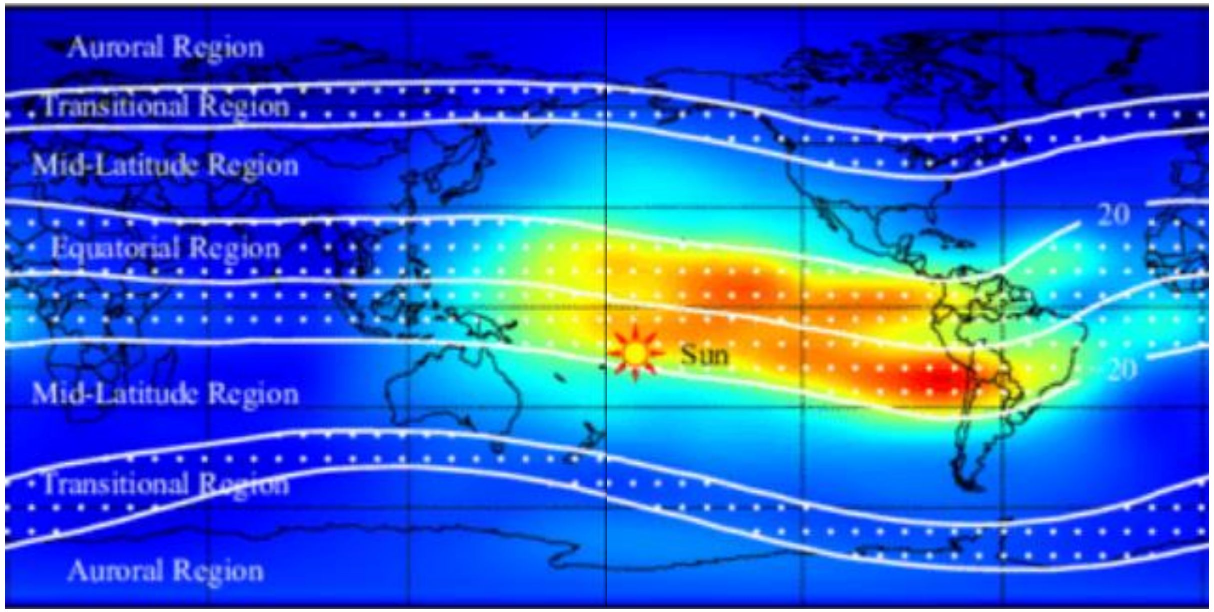

Aurora advances and retracts according to co-ordinates of geomagnetic latitude and longitude



Ionization density follow geomagnetic coordinates as can be seem in the equator dip

https://youtu.be/8vyPtG0NcjA

# A to B path difficulty – Mid, low and high latitudes paths

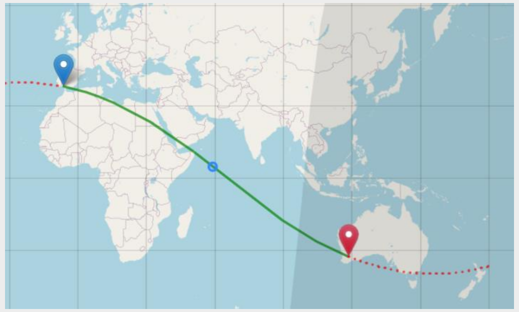



## Magnetic Regions of ionosphere

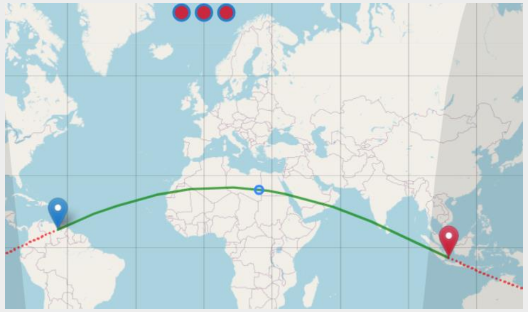
- Earth ionosphere can be divided into three areas, **High latitude** – Auroral Region and transitional region, **Mid-latitude** – in between and **Low latitude** – 20 to 30 degrees around the magnetic equator
- High latitude regions are more volatile where sun energy particles have easier access and susceptible to Aurora and polar cap thus more prone to degradation
- In HF communication distance is not "the" difficulty indicator bur rather the ionosphere regions where refraction point occur

### High latitude path

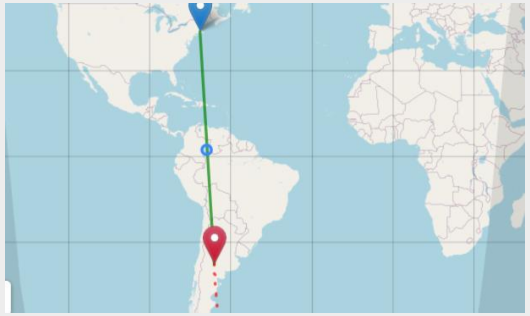
### Mid latitude path



### Low latitude path

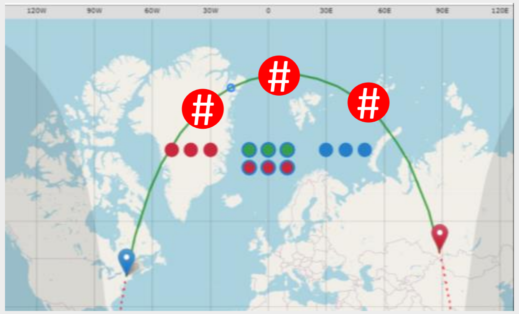


### North South path

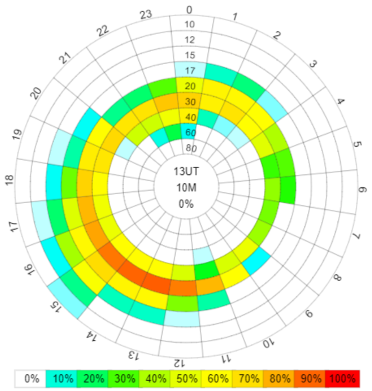


# A to B path difficulty – North South, mid and low latitude paths are very reliable up to 28MHz even at the low of the sunspot cycle

## High latitude path



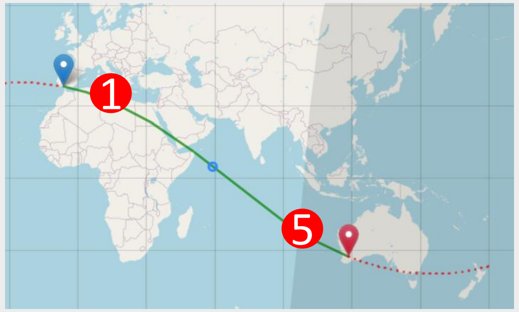

9 500 Km



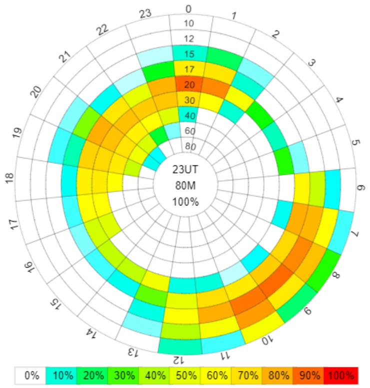

**Propagation reliability**

- 14 MHz – 91%
- 21 MHz – **55%**
- 28 MHz – 1%

## Mid latitude path



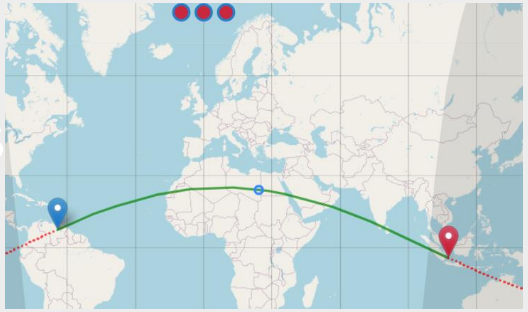

15 000 Km



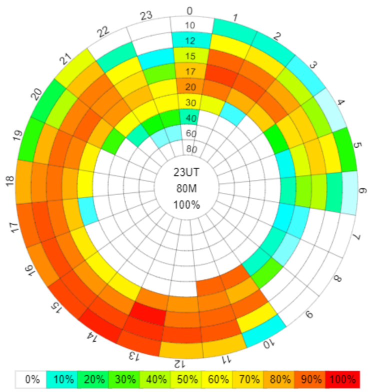

**Propagation reliability**

- 14 MHz – 87%
- 21 MHz – 91%
- 28 MHz – 63%

## Low latitude path



19 300 Km

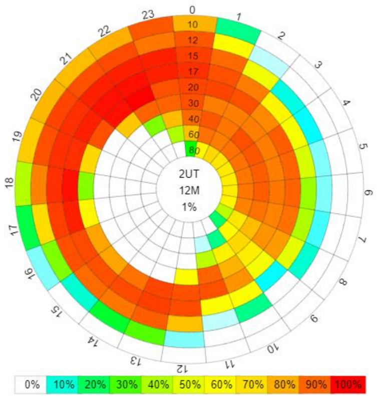



**Propagation reliability**

- 14 MHz – 94%
- 21 MHz – 91%
- 28 MHz – 96%

## North South path

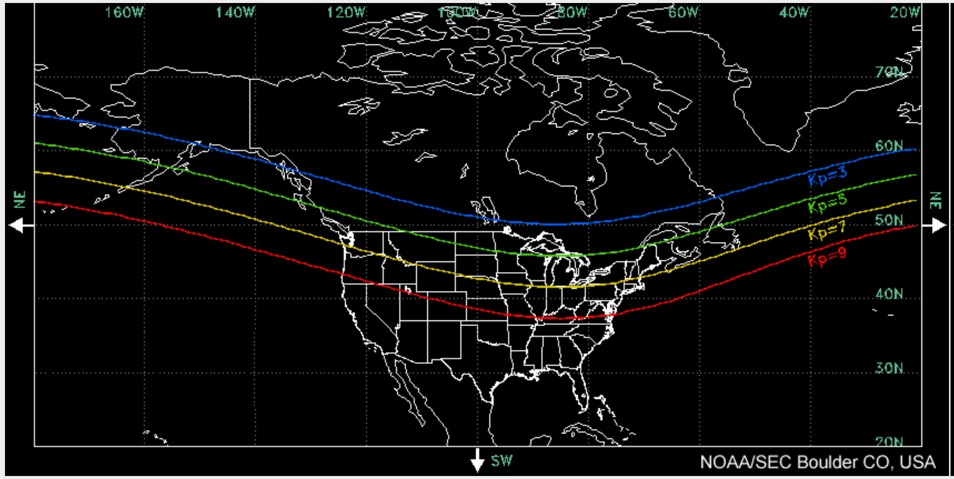

9 000 Km

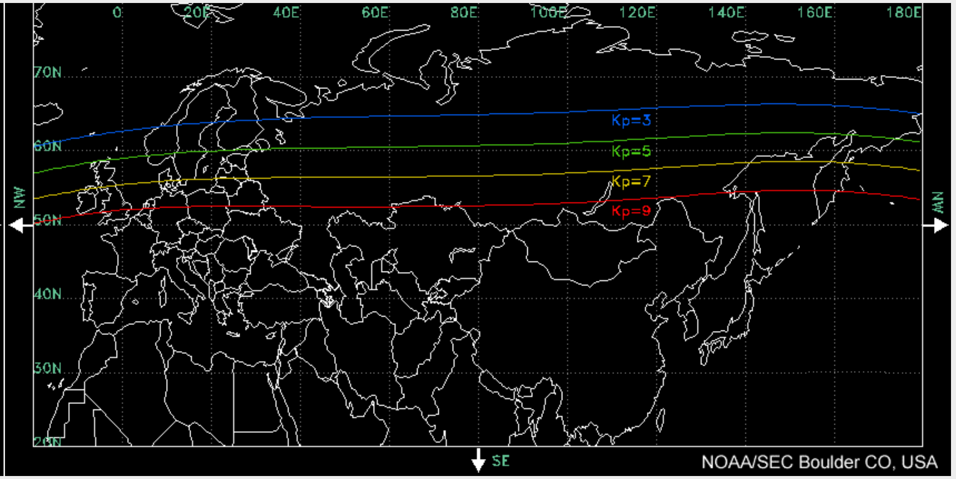



**Propagation reliability**

- 14 MHz – 100%
- 21 MHz – 98%
- 28 MHz – 92%

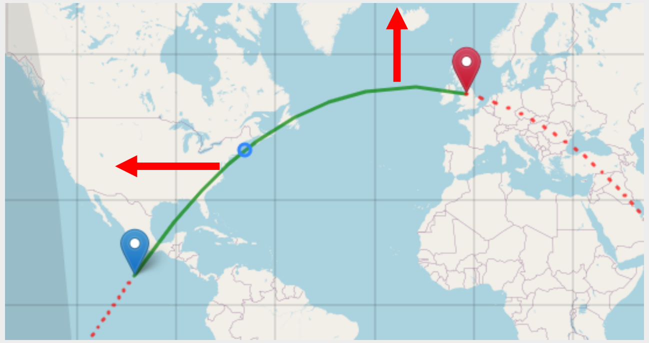
# A to B path difficulty – circuits between major populations areas require refraction points in high latitude areas susceptible to geomagnetic activity




- The Kp map will indicate the limits of Aurora
- Paths that cross the Kp limits can have signal degradation

## Circuit USA - Europe

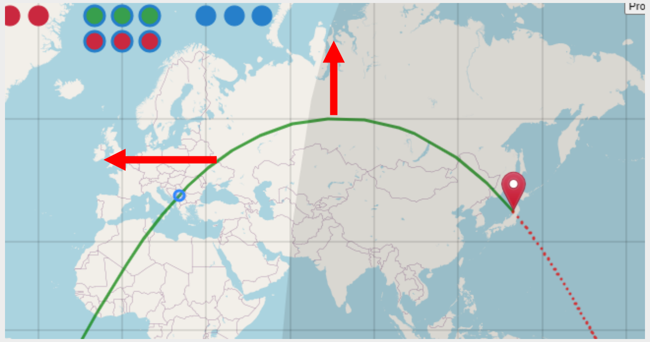


To cover the whole of Europe, only areas in the east cost of the USA can do it without crossing high latitude

## Circuit Japan - USA

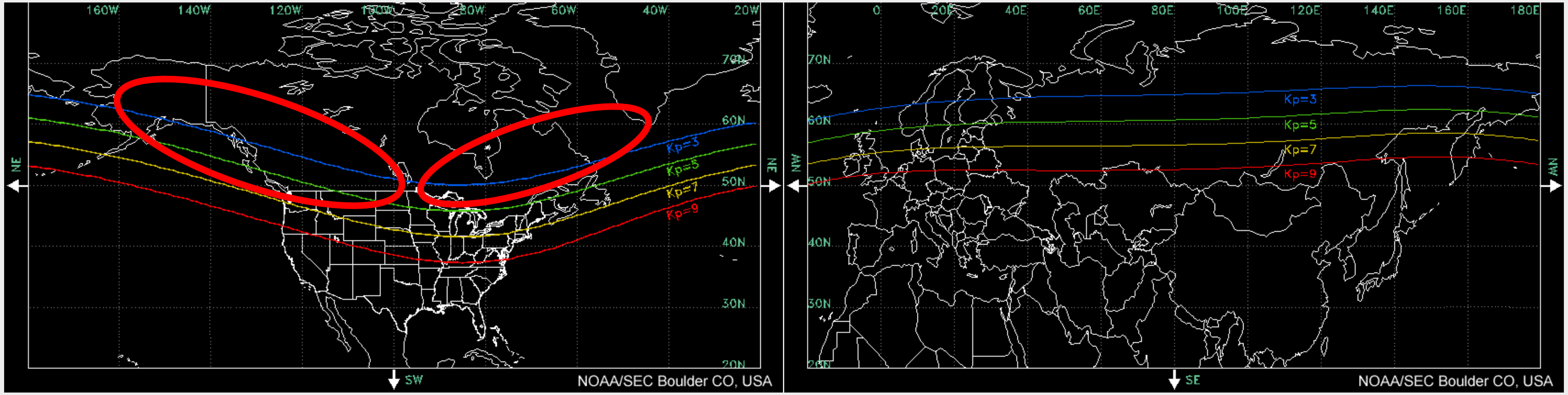
To cover the whole of JA only areas in the west cost of USA can do it without crossing high latitude

## Circuit Europe - Japan



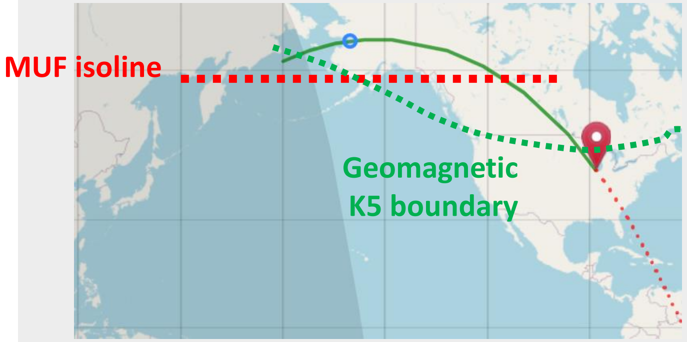
To cover the whole of JA only areas in the eastern part of Europe can do it without crossing the high latitude 60º

# A to B path difficulty – The USA "black-hole" case, facing a double challenge - higher latitude path and the geomagnetic dip



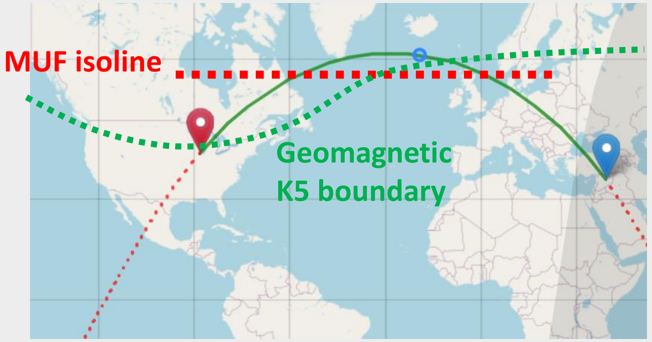

- The Kp map will indicate the limits of Aurora
- Paths that cross the Kp limits can have signal degradation

## Circuit "Black hole" – Japan




To reach Japan, the pass crosses high latitude, going over Alaska

## Circuit USA - Europe

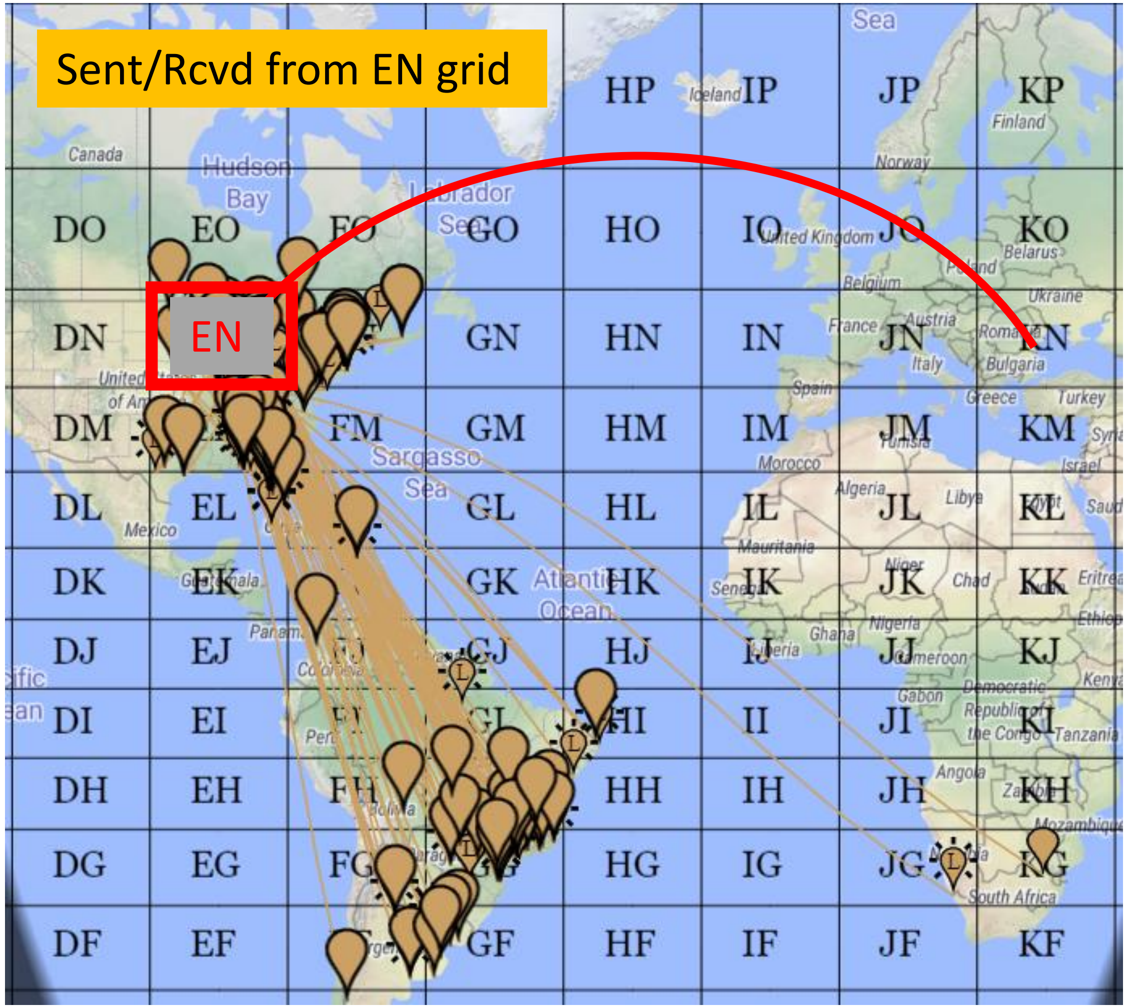


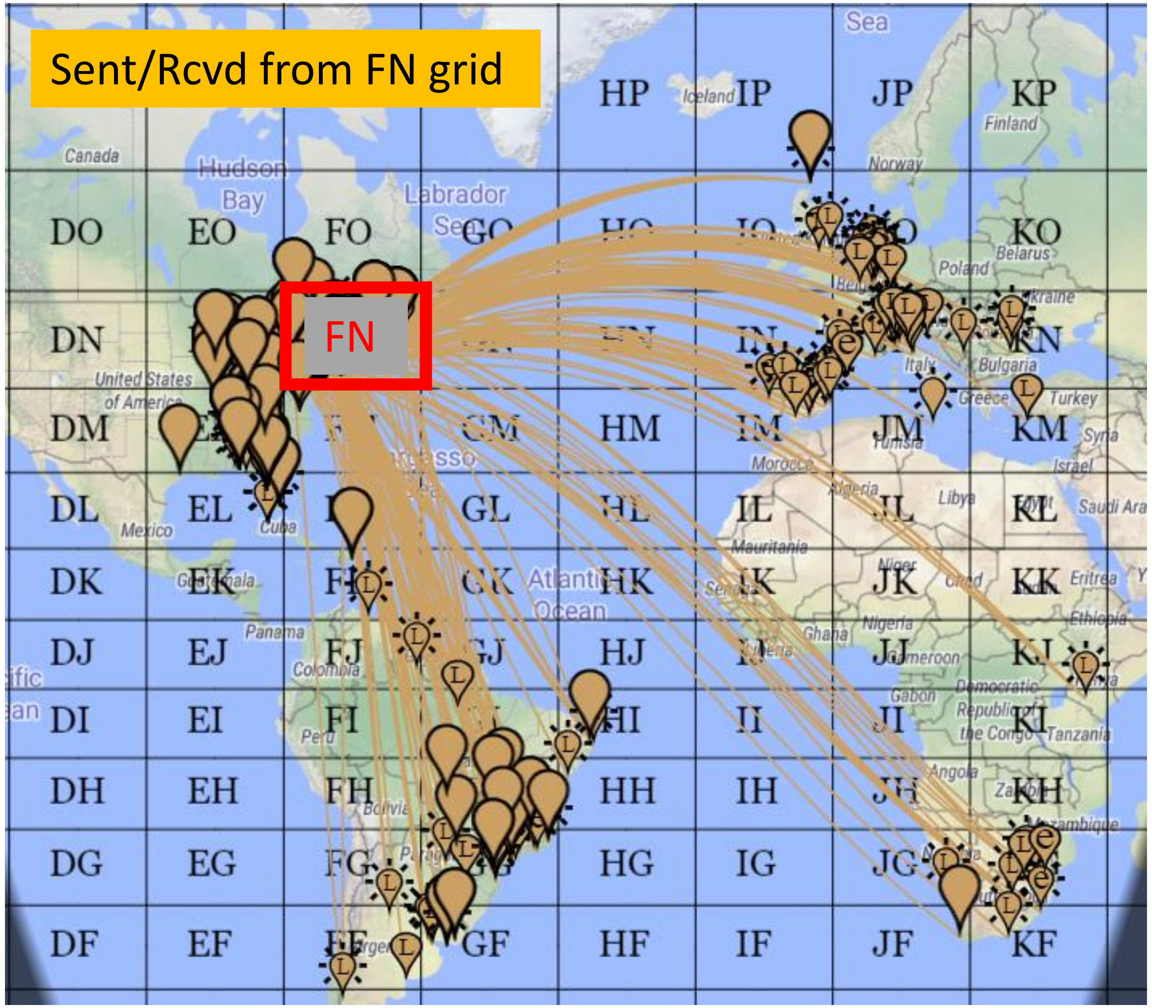

To Europe the path crosses high latitude touching the south tip pf Greenland

## Circuit challenges

- Mid USA stations face double high latitude challenge (above 60 degrees) for both Europe and Japan
- In addition to high latitude paths, they face geomagnetic dip that makes those paths even more susceptible to geomagnetic disturbances
- When conditions are disturbed what it is left is north-south and mid latitudes propagation

# A to B path difficulty – The USA “black-hole” areas face very different propagation from east coast neighbors

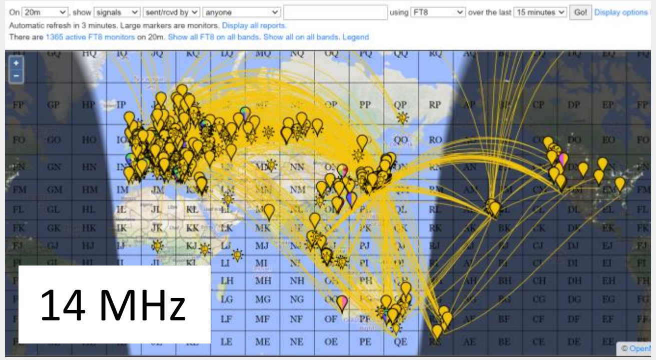


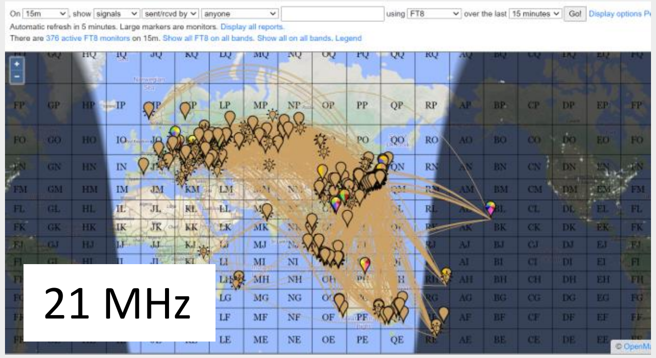



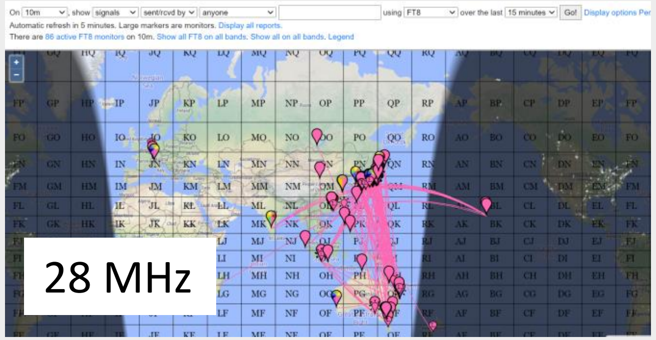

- Stations from grid EN, beaming Europe, will have refractions points in FO grid and crossing the tip of Greenland, locations more susceptible to degradation
- Stations from grid FN, beaming Europe, don’t cross areas as susceptible to propagation degradation when compared to EN grid

# In search of MUF isolines – FT8 PSK Reporter data can be used to immediately assess worldwide conditions and the position of the MUF isolines

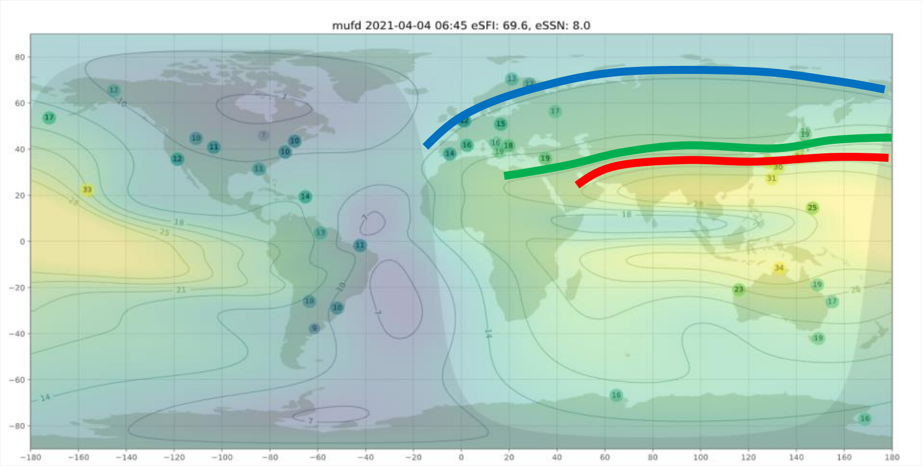
## Worldwide FT8 reports



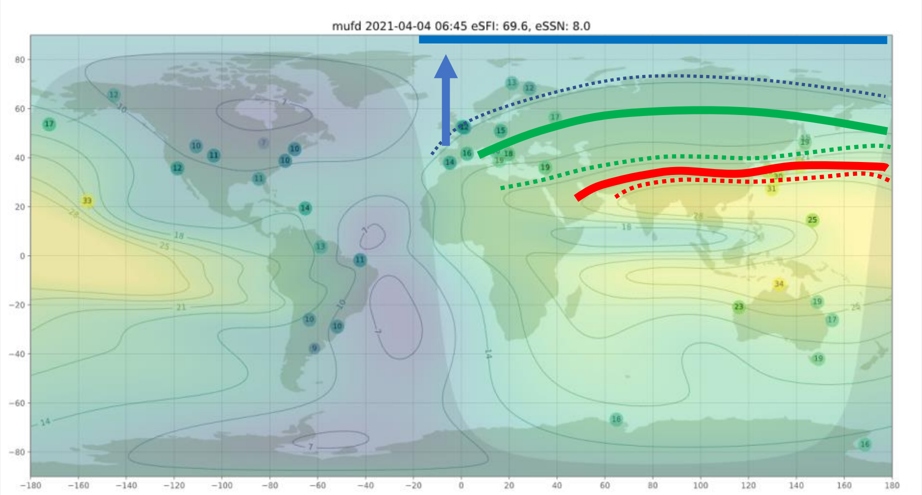




## Model MUF isolines




## Real MUF isolines from FT8 reports

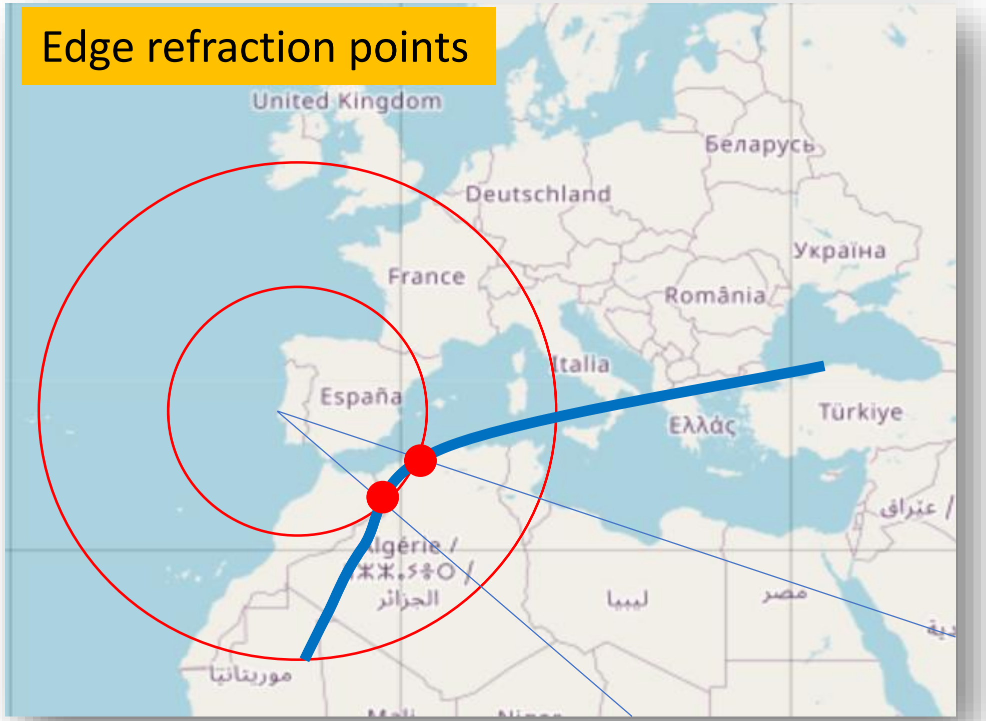



## 19 billions FT8 reports

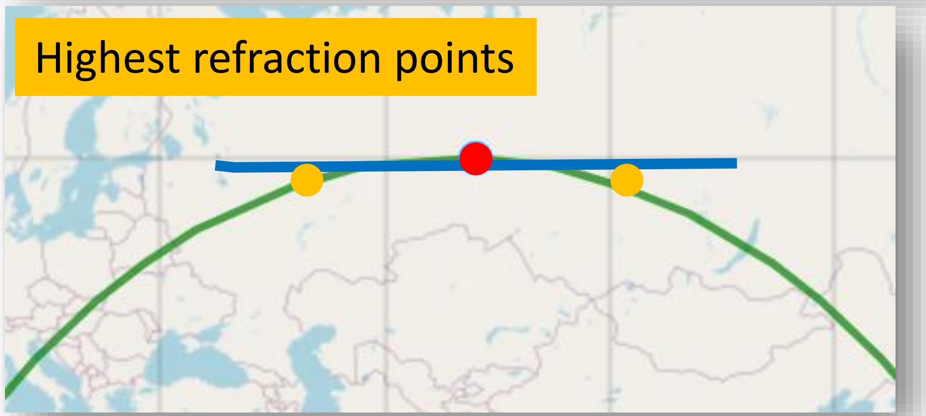
- Although propagation programs and MUF model can predict to a great certainty overall conditions only real time date can present a true image of propagation conditions
- With the profusion of activity from FT8, PSK Reporter big data can give an exact and true representation of ionospheric conditions and overall propagation
- At the time of this presentations there are 19 billion FT8 PSK Reports

# In search of MUF isolines – looking for refraction points in the edges and in the highest latitudes of the path and getting a 24 hour view for propagation pattern

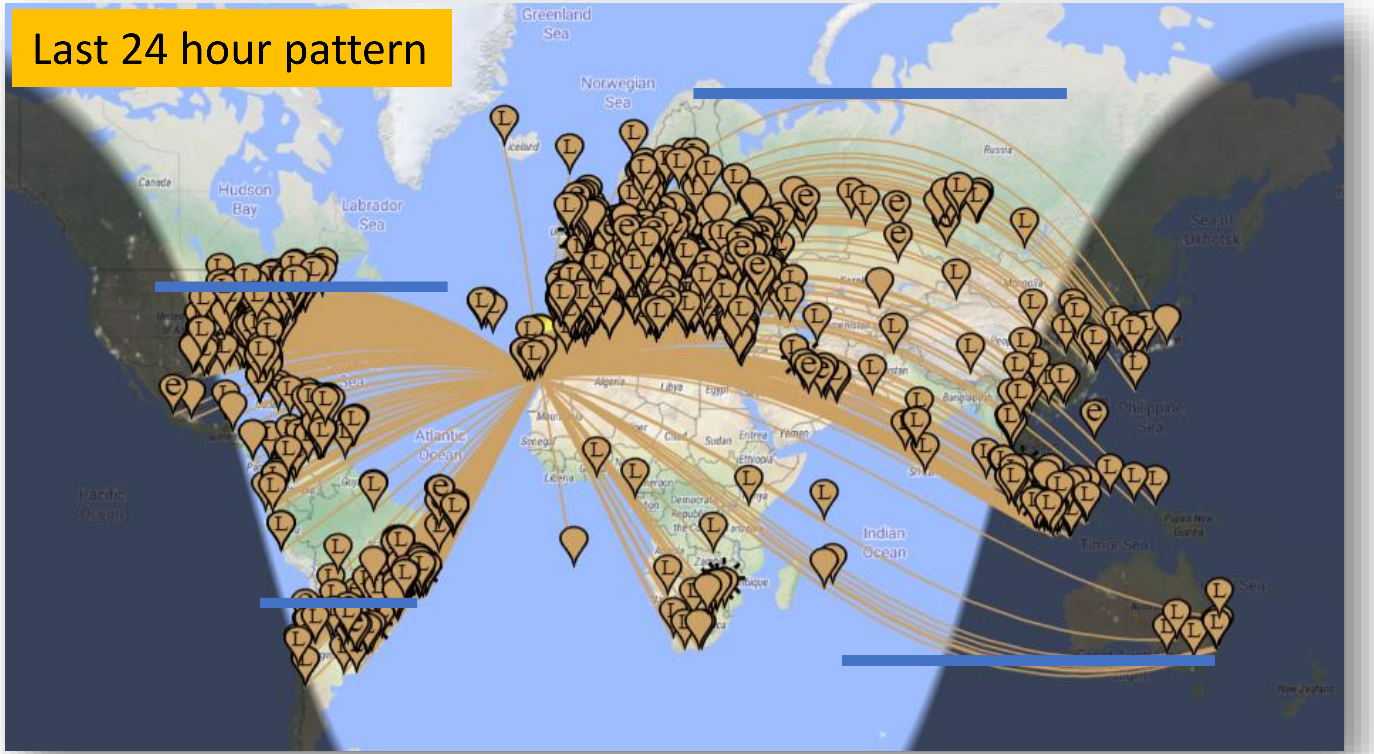
Edge refraction points




Highest refraction points



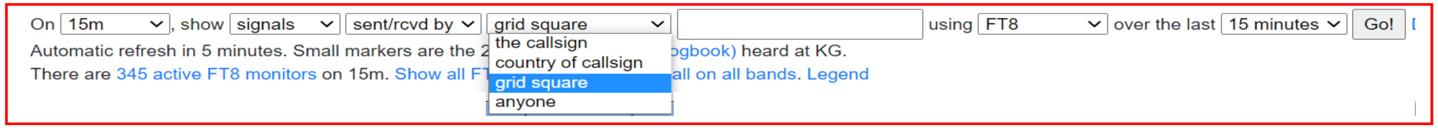
Last 24 hour pattern



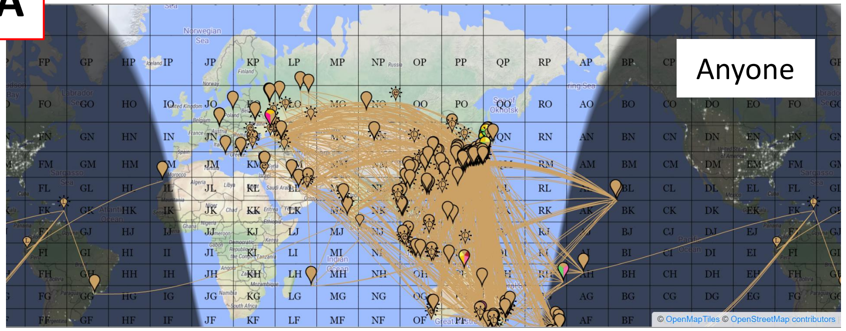

**The exercise of connection the dots…**

- Looking for first refraction points int the edges
- Looking for the highest latitude refraction points
- Getting the MUF isoline size and shape by looking at last 24-hour spots pattern

# In search of MUF isolines? – Checking band conditions using FT8 reports from different grid locators to establish MUF isolines

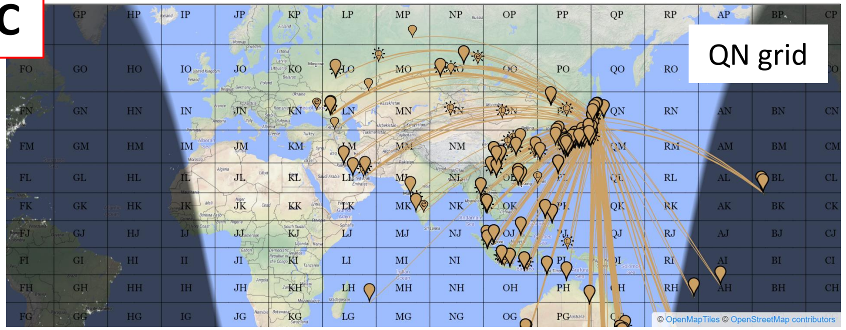



A

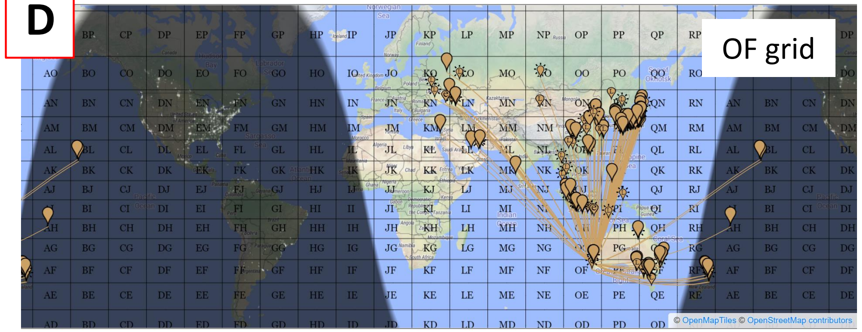



B


C

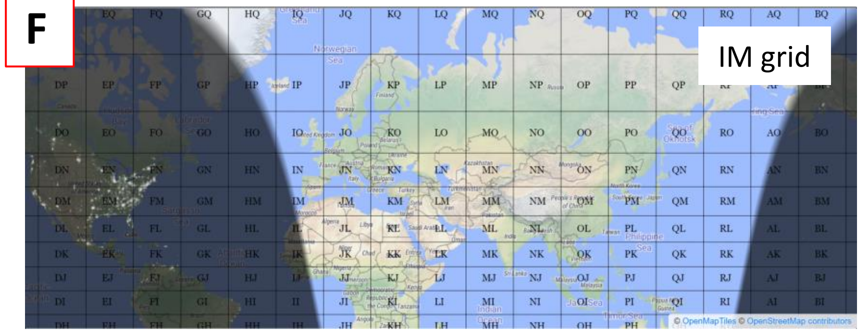



D




E

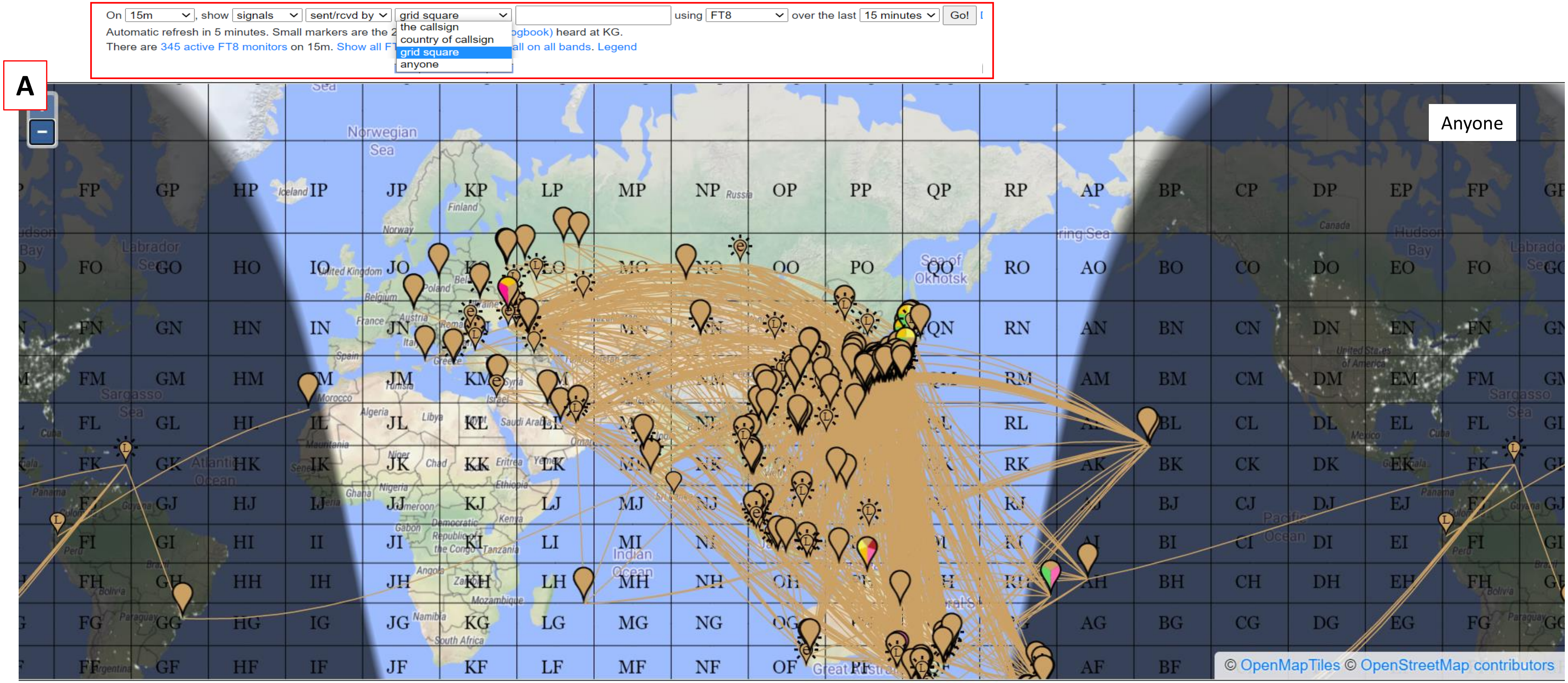

F




## Checking protocol

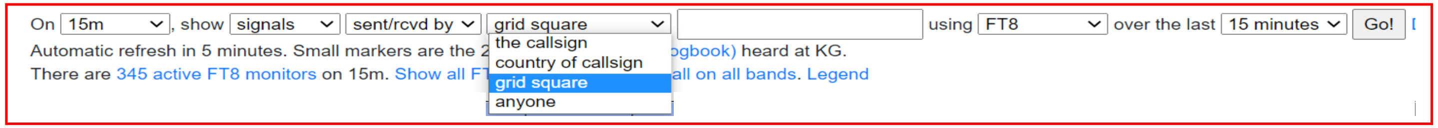
- From figure A, using “anyone” filter pay attention to edges of propagation, latitude limits, band opening and band close
- In figure B using “grid square” filter from “KN” check latitude of east-west path, and how deep mid latitude path goes
- In figure C using “grid square” filter from QN, check north south path to Australia and East west path to Europe
- In figure D using “grid square” filter from OF check latitude limit of paths and how far into Europe
- In figure E check grid KG from south Africa
- In figure F check grid IM for band opening from Iberia (propagation still close at the time of these checks)

# In search of MUF isolines? – Checking band conditions using FT8 reports from different grid locators to establish MUF isolines

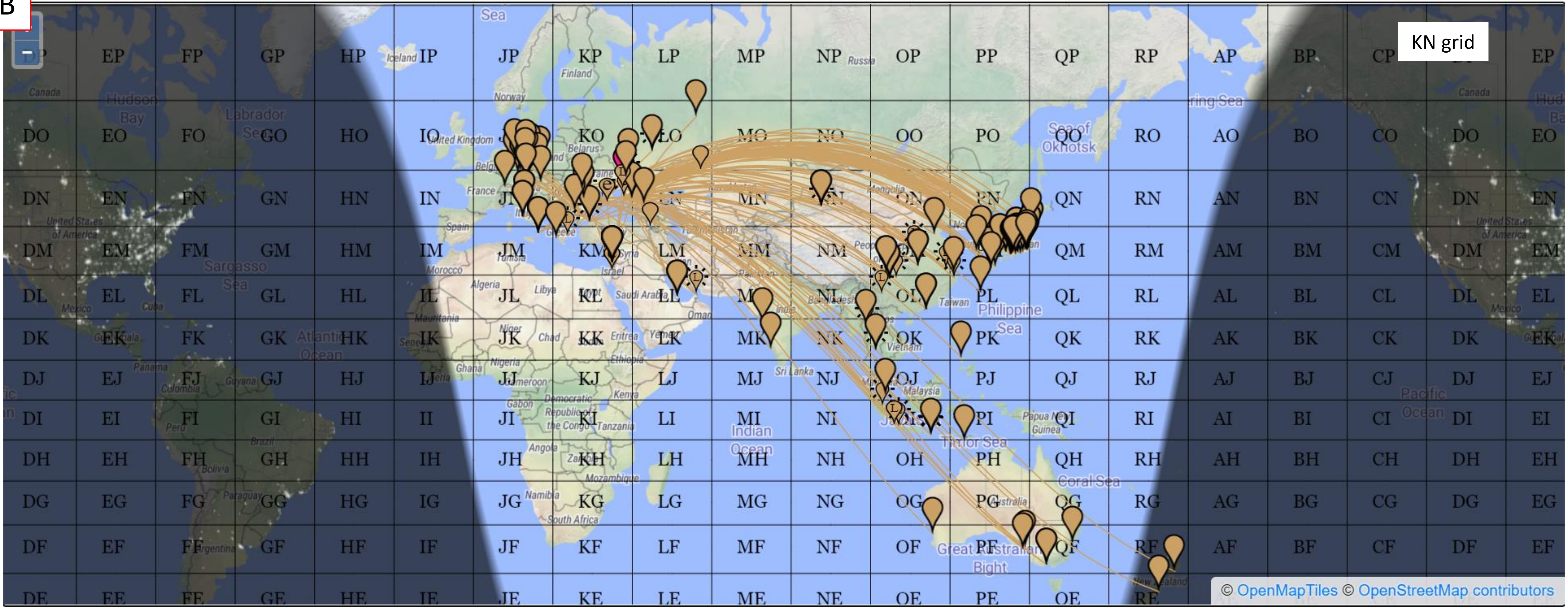



- From figure A, using "anyone" filter, pay attention to edges of propagation, latitude limits, band opening and band close. MUF isoline limit is around 55-degrees

# In search of MUF isolines? – Checking band conditions using FT8 reports from different grid locators to establish MUF isolines

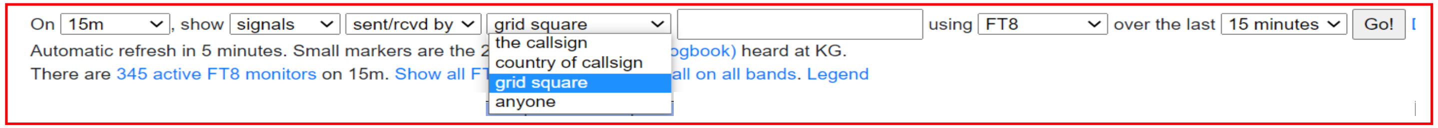



B

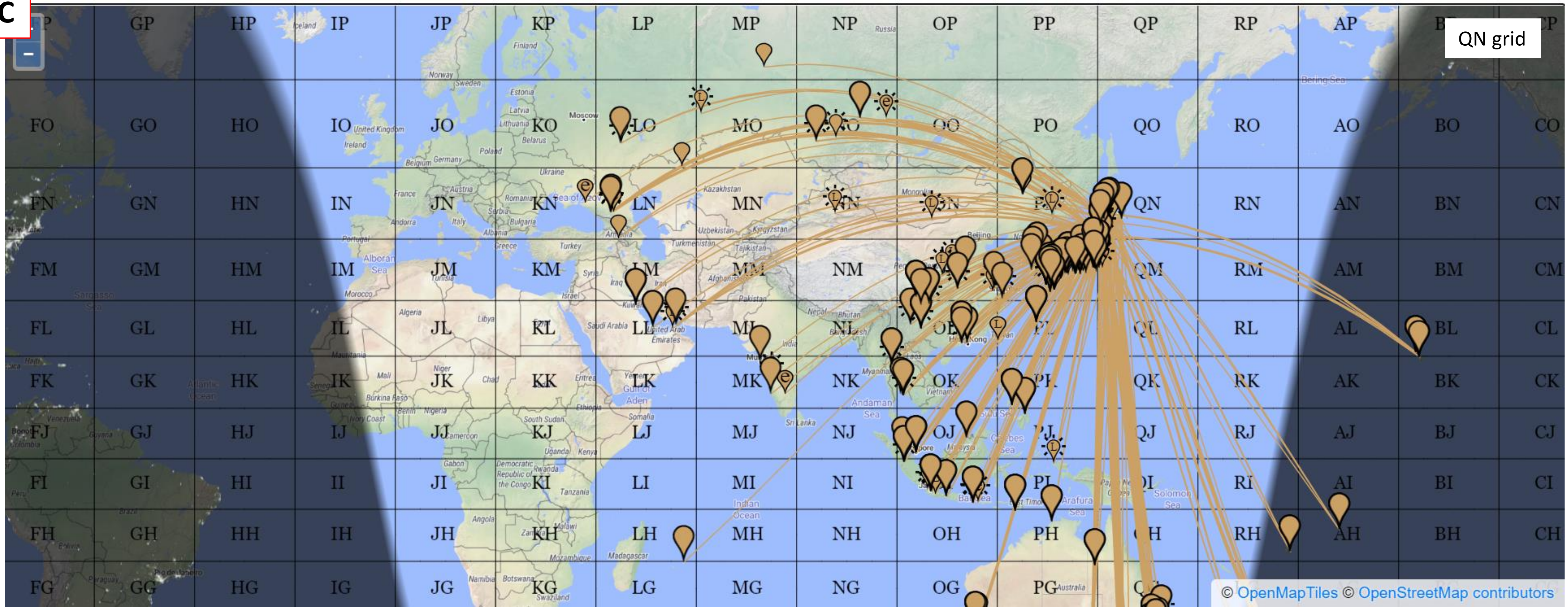



- In figure B using “grid square” filter from “KN” check latitude of east-west path, and how deep mid latitude path goes. The MUF isoline limit is around 55-degrees

# In search of MUF isolines? – Checking band conditions using FT8 reports from different grid locators to establish MUF isolines

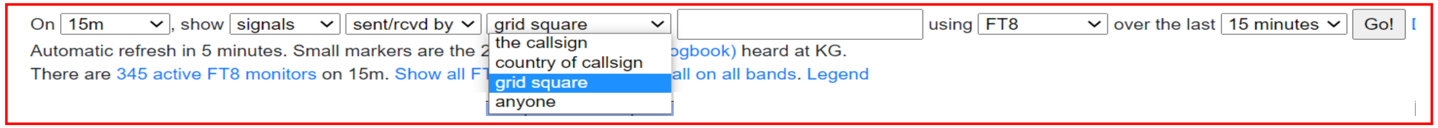



C

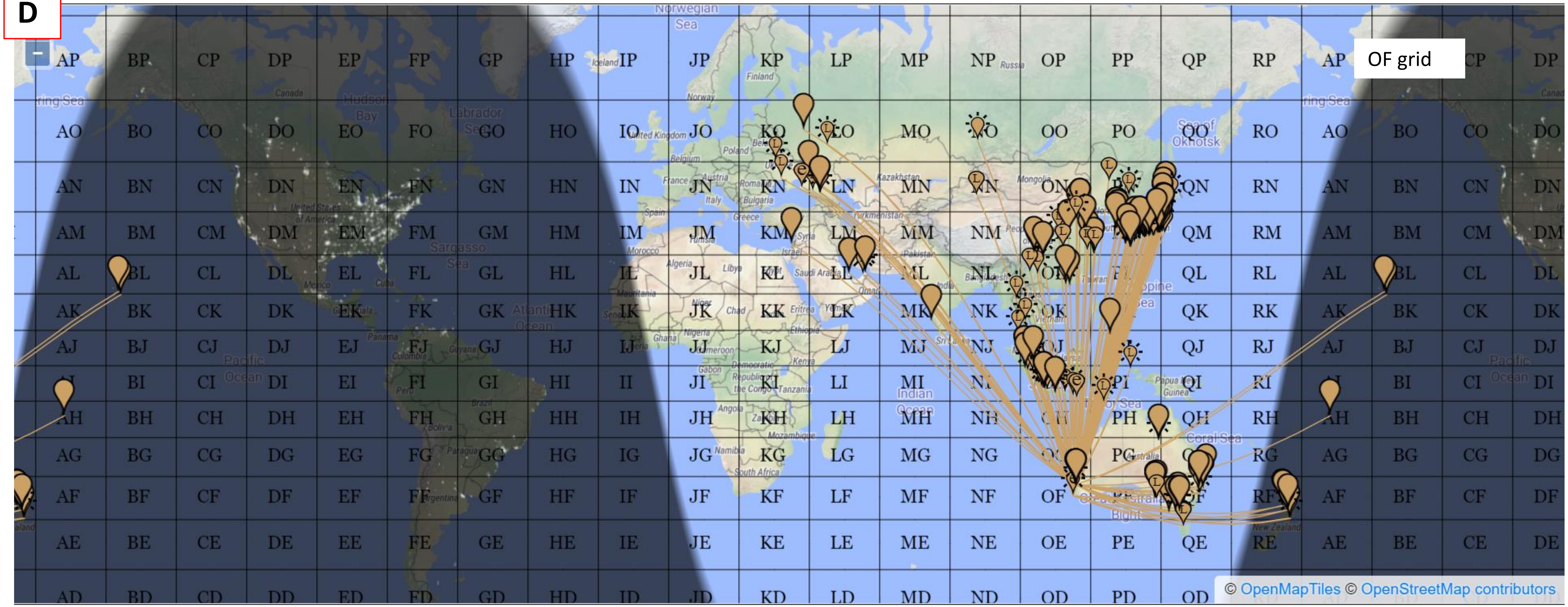



- In figure C using "grid square" filter from PM, check north south path to Australia and East west path to Europe

# In search of MUF isolines? – Checking band conditions using FT8 reports from different grid locators to establish MUF isolines

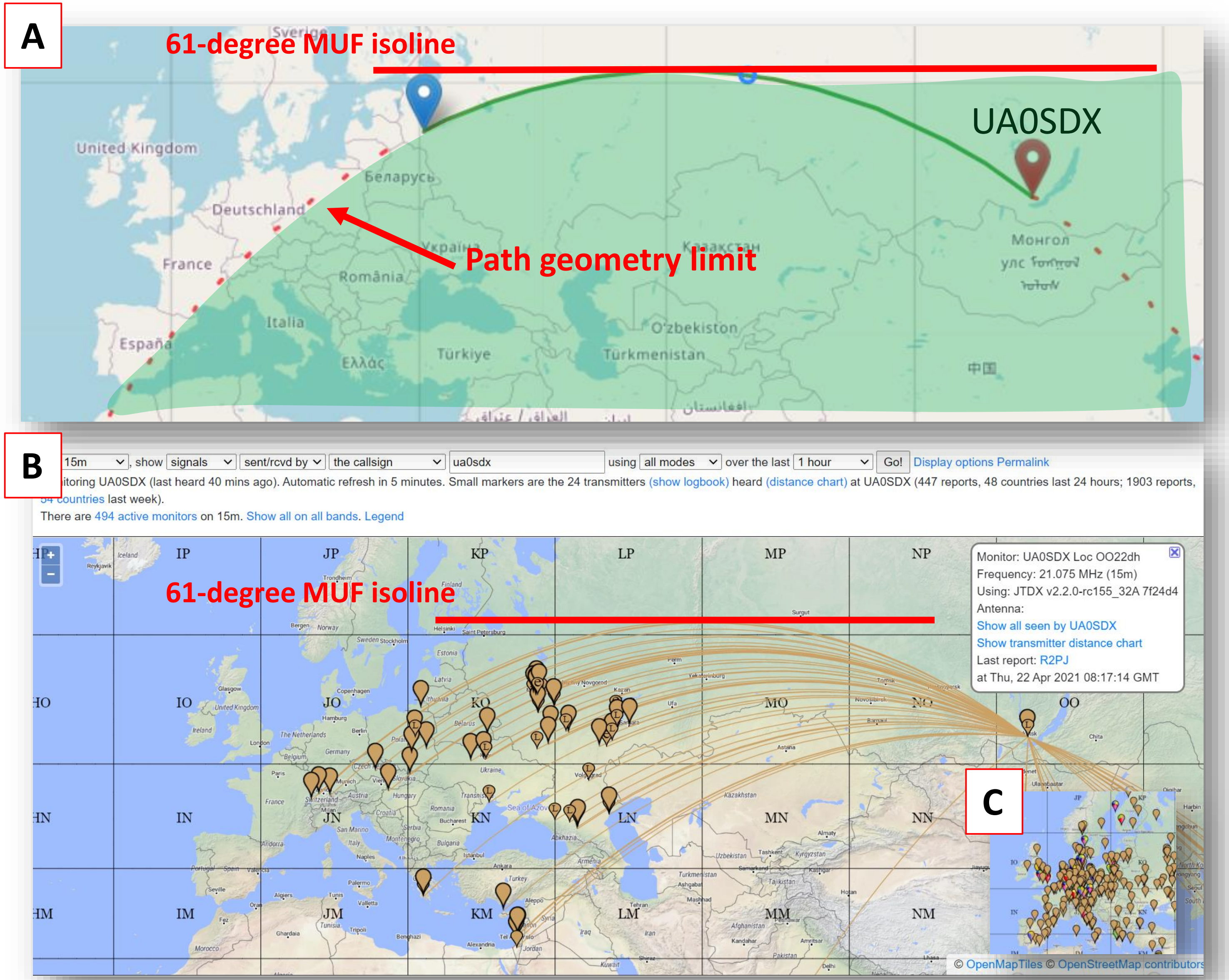



D




- In figure D using "grid square" filter from OF, check north south path into Asia and particularly the stations in higher latitude that can give you the MUF isoline, going back around 1500 km (half one hop) to the last refracting point in ionosphere

# In search of MUF isolines – checking how accurate is the MUF isoline limit and path geometry limit




## Finding the propagation limit

- The MUF isoline is very accurate to define limits of propagation when checking a particular station set-up
- In figure A the path from UA0SDX that peaks at around 61-degree latitude is shown. The MUF isoline will limit propagation to what is inside the highest latitude path. A path from UA0SDX into Portugal would require crossing above 62-degree MUF isoline, with signal going into space in the refraction point
- Green area in figure A shows potential propagation from 61-degree MUF isoline
- In figure B indeed only stations inside the limit path are worked or copied even tough, as seen in figure C, there are many other stations active outside the highest latitude path limit

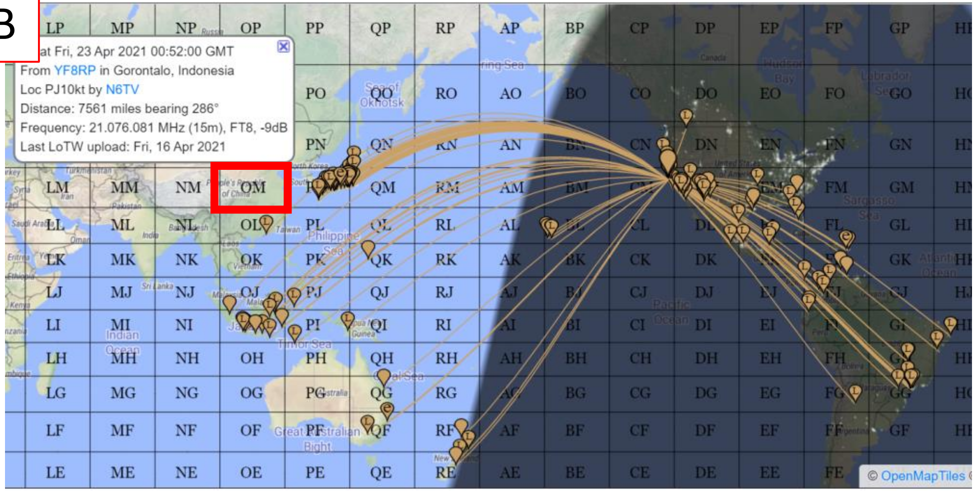
# In search of MUF isolines – checking how accurate is the MUF isoline limit?

A

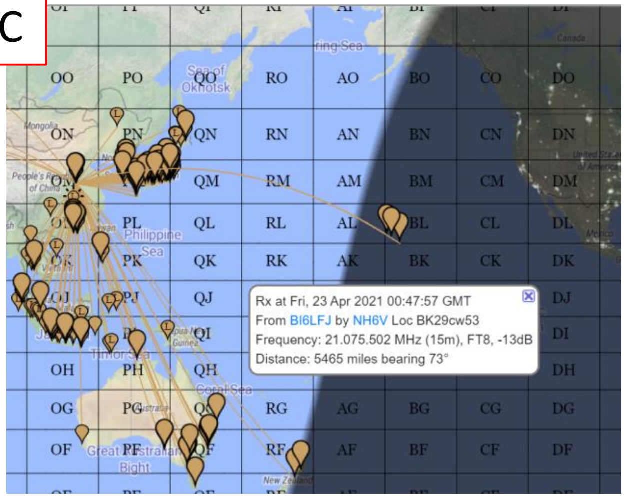

## Checking N6TV path limit

- In figure A, once the 52 MUF isoline limit is found, it is very easy to predict available paths from N6TV location
- Is figure B N6TV cannot copy stations from OM grid that is outside his path limit
- In figure C, BI6LFJ from OM grid works stations inside his path limit (figure D), but short of reaching California, that requires higher latitude path

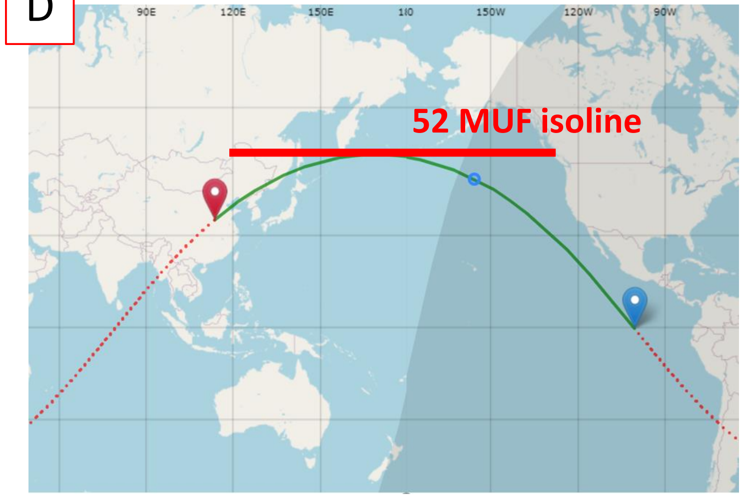
B




C

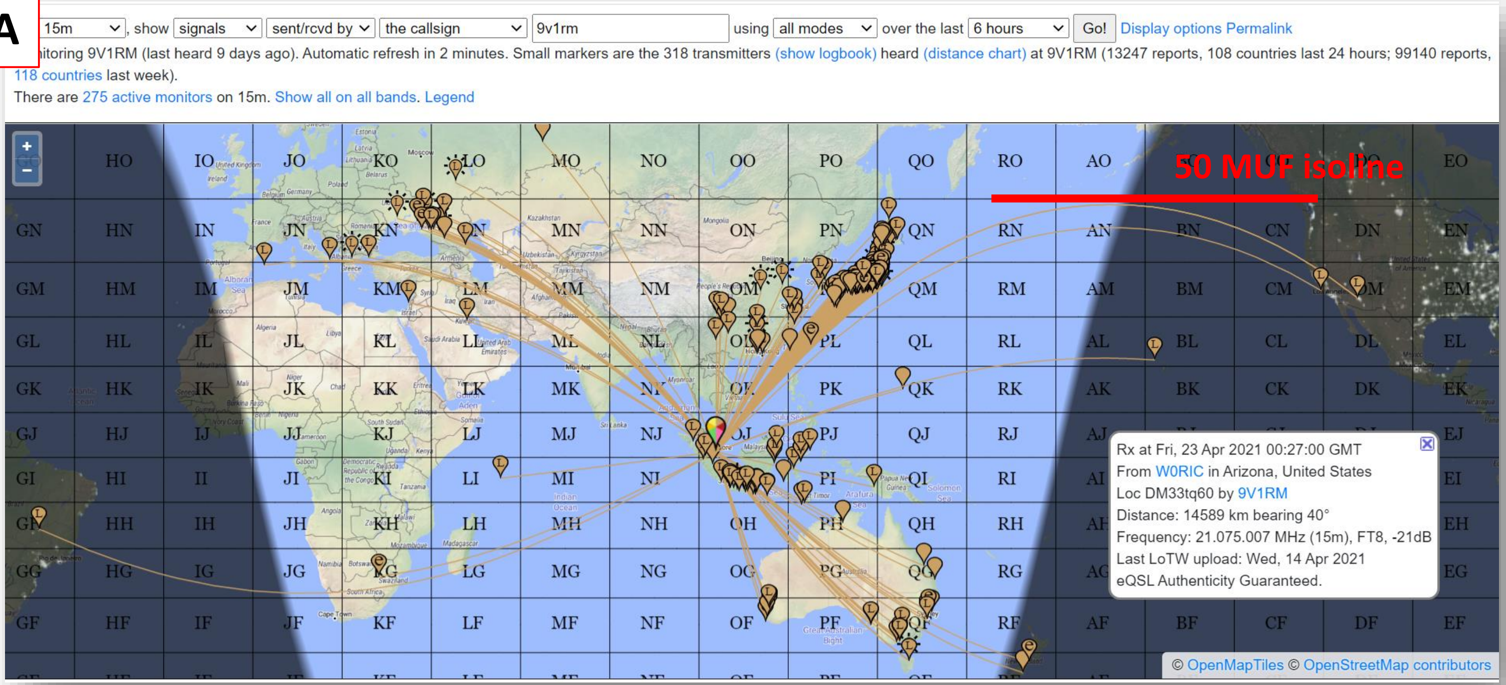



D



# In search of MUF isolines – checking how accurate is the MUF isoline limit?

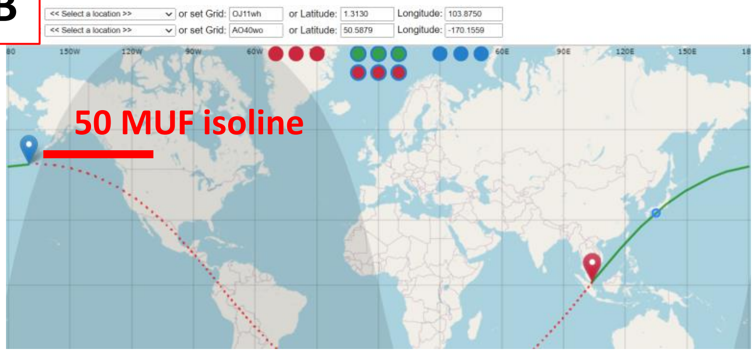
A



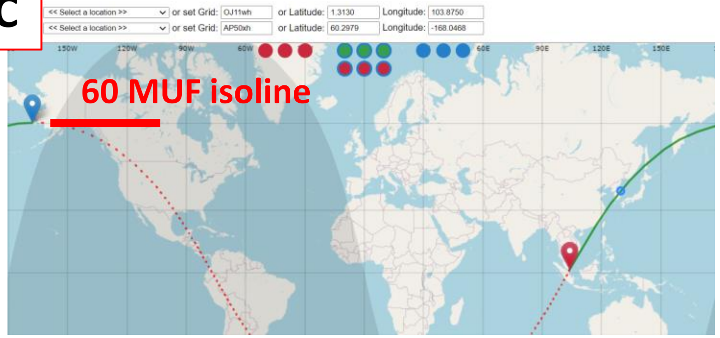

## Checking 9V1RM path limit

- In figure A, 9V1RM FT8 skimmer is excellent to probe MUF isoline position in the Pacific USA area
- In order to reach Southern California a 50-degree isoline (figure B) is needed
- In order to reach Mid West (figure C) a 60-degree MUF isoline is needed
- In order to reach “Black-hole” area (figure D) a 70-degree MUF isoline is needed

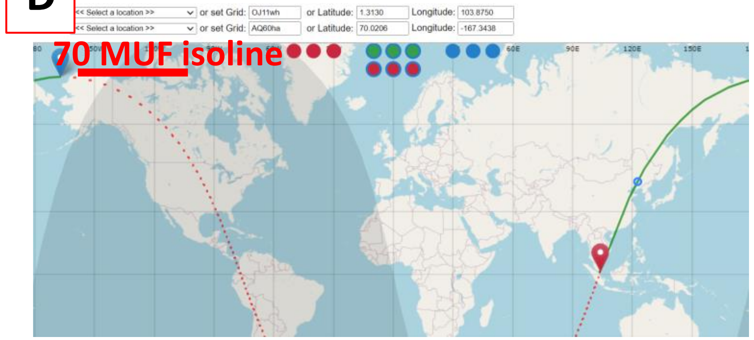
B



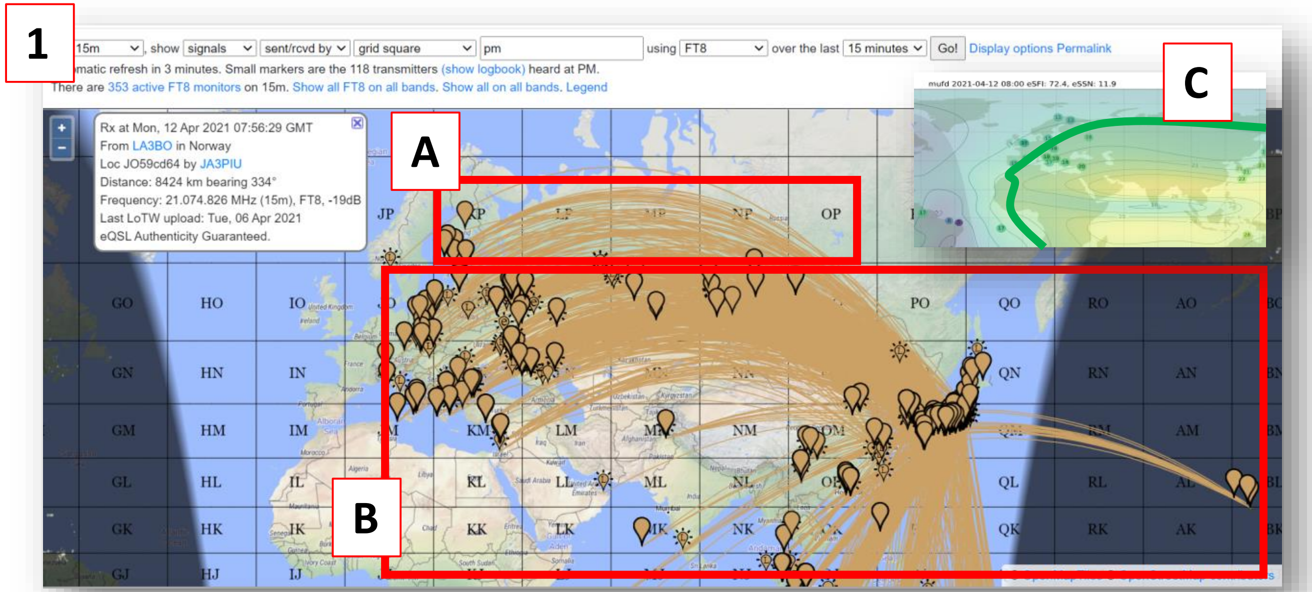

C

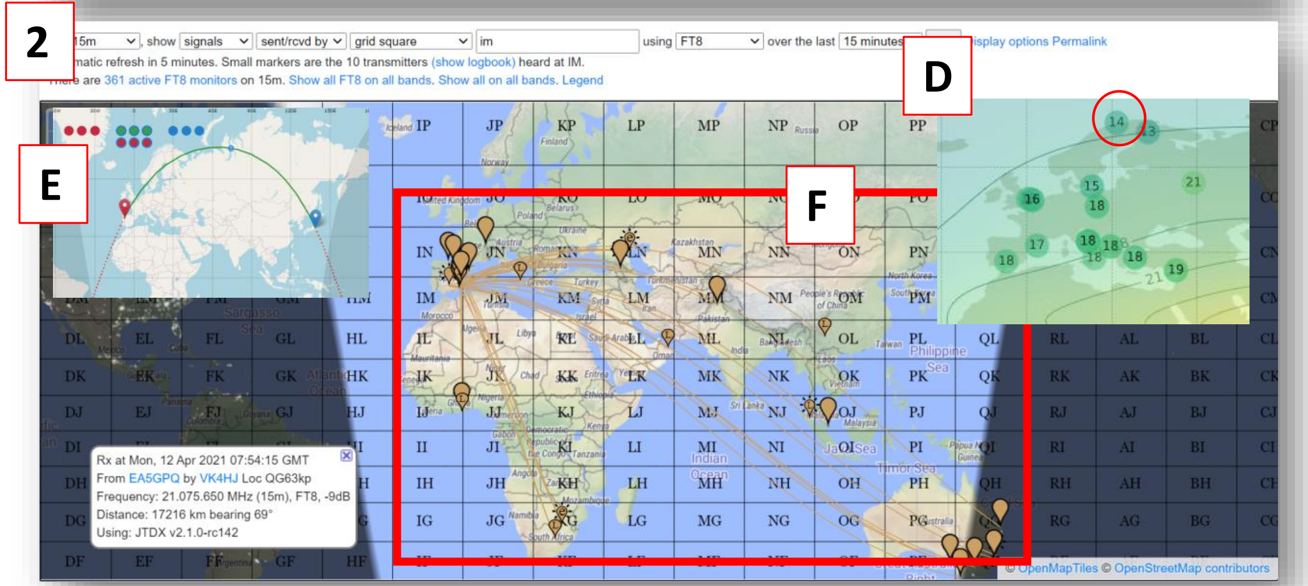



D



# In search of isolines – High latitude MUF on 21 MHz, but band still not open enough for JA into CT/EA path

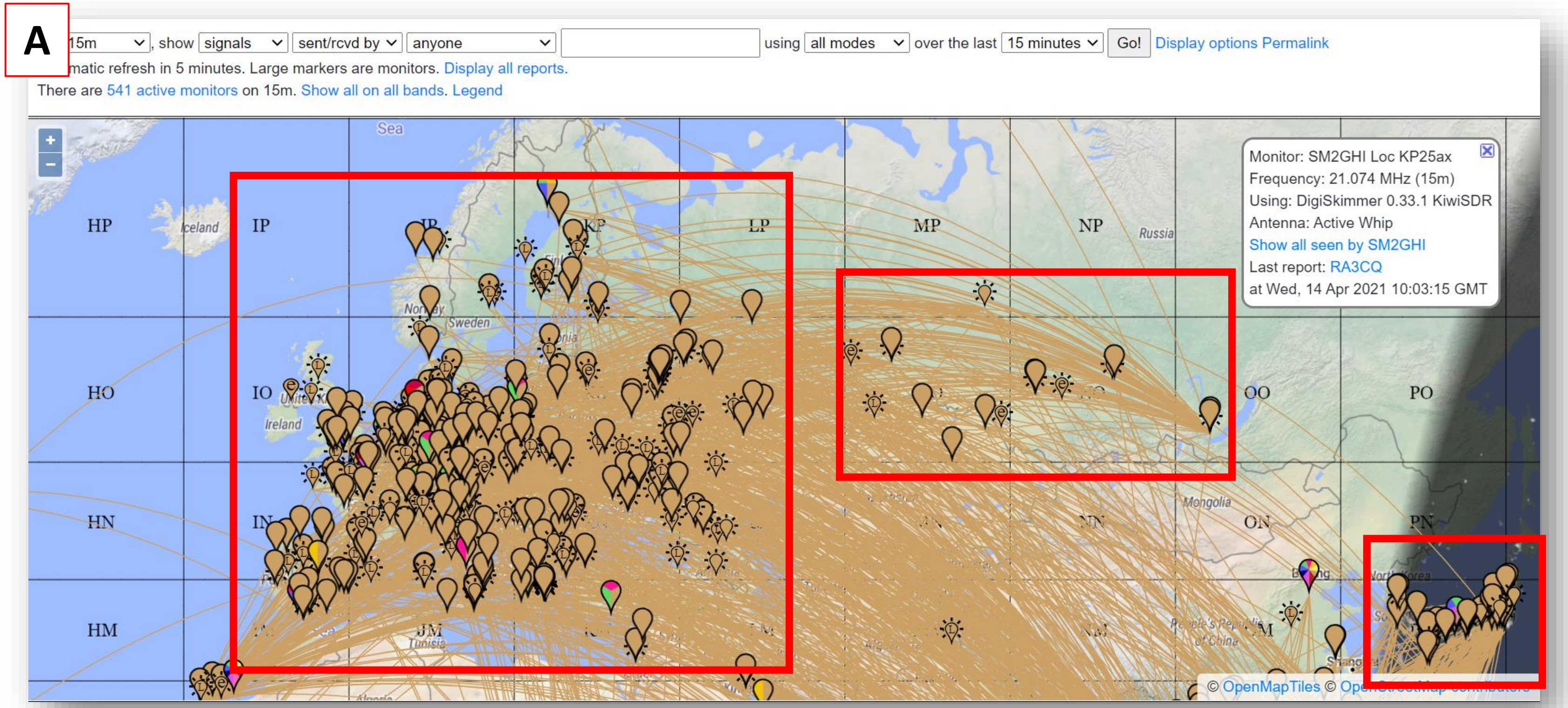


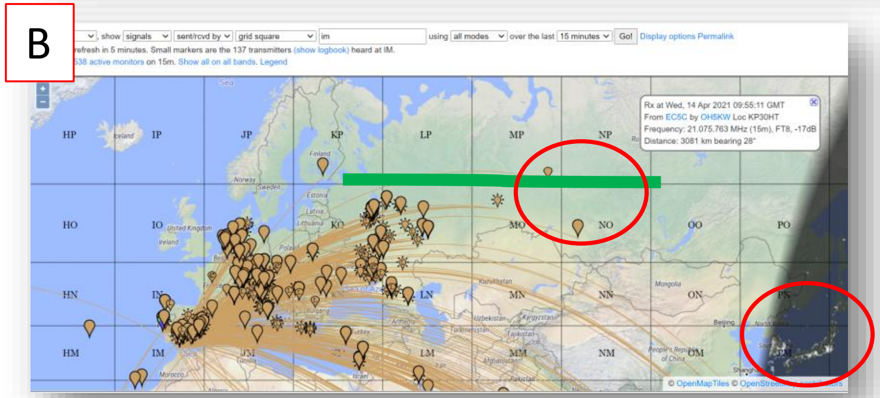



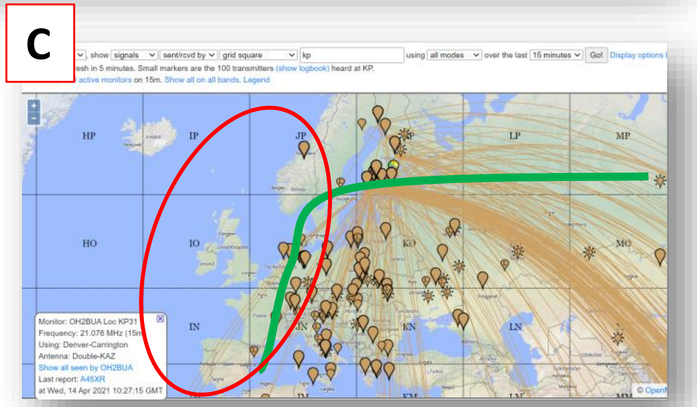

## Checking the CT/EA into JA path

- In figure 1, box A, the path between JA and Europe is open, crossing high latitudes (above 60 degrees)
- In box B from JA east/west, mid latitudes and north south paths are open
- In figure C, looking at signal from figure 1 and figure 2, the 21 MHz isoline can be estimated from real FT8 signals. Notice that the isoline is parallel to latitude lines, except when it becomes closer to the terminator line
- In figure 2 box F there is west/east propagation but limited to 40 degrees, there is long range mid latitude propagation to Australia and there is north/south propagation to Africa
- But the path EA/CT into JA, because it is very high latitude path (figure E), is not open yet. Looking at digisonde from Tromso, MUF is only 14 MHz, putting RF in any refraction point near that location into the space…

# In search of MUF isolines – The importance of the slope of the "sun rise side" of the MUF isoline and the latitude of the isoline to assess quality of propagation



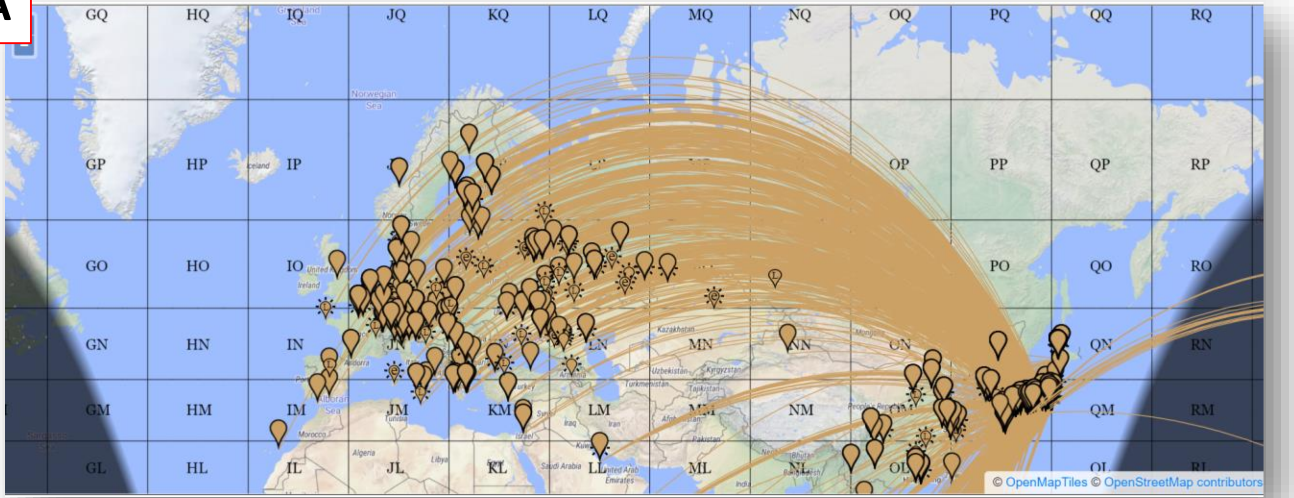




## The missing refraction point

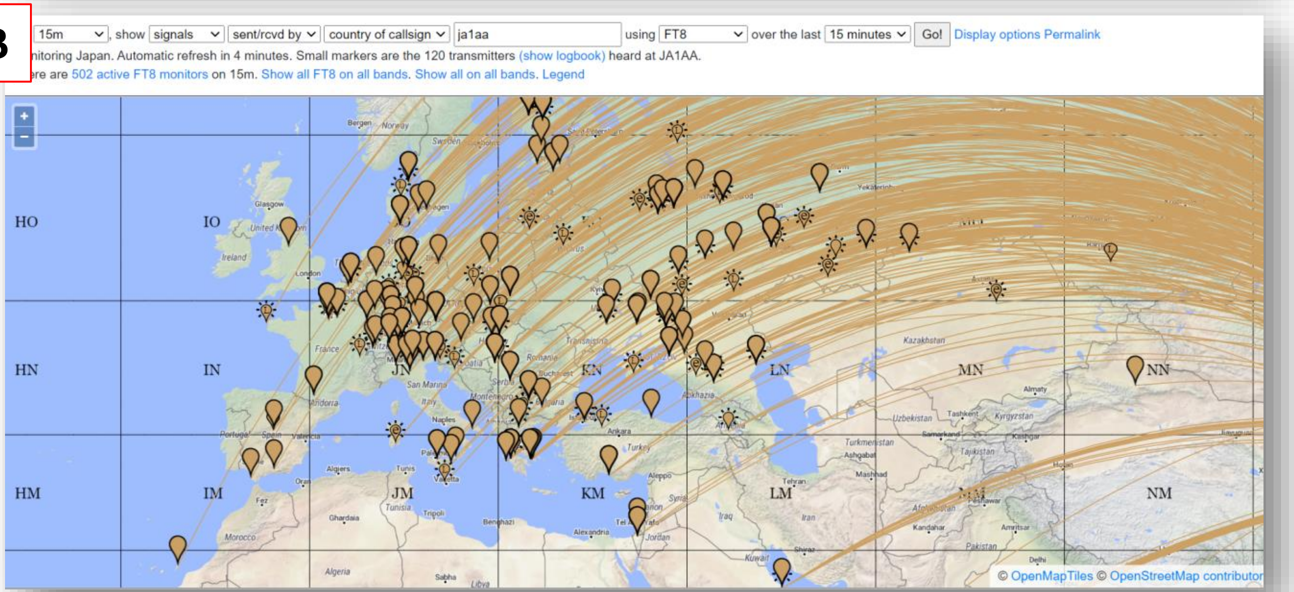
- Figure A shows a very intense activity on 21 MHz with signals from Europe, Russian Asia and Japan
- Figure B shows that stations from Iberia (CT/EA) from grid IM are limited by the 60-degree isolines (green line) and are not able to work Russian Asia nor Japan in the circles
- Figure C shows that even if the isoline was higher in latitude in order to enable Portugal Japan path, the first refraction point, highlighted by the circle would not refract the signal because it is outside of the 21 MHz isoline confirmed by stations from grid KP that are not able to reach Portugal

# In search of MUF isolines – The last refraction point and dominant hops

A




B

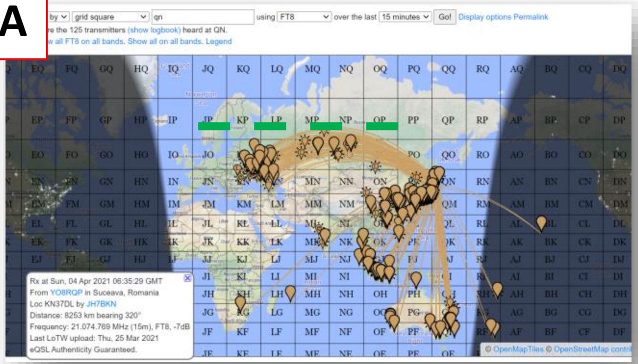



## The last refraction point from Japan

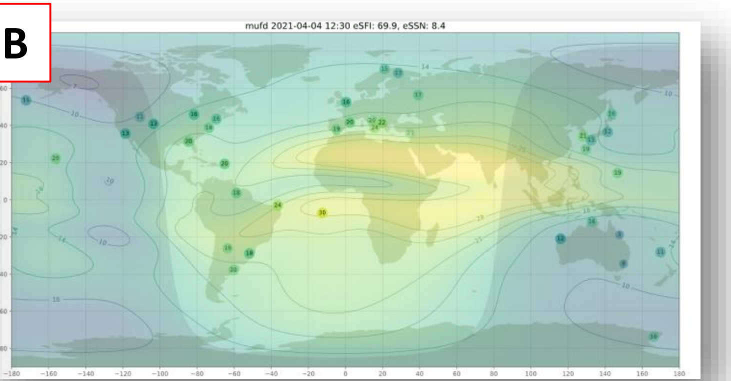
- Figure A condition from Japan into Europe can be checked
- High latitude paths, above  within 70-degrees are available
- Looking closer in figure B, still no stations reported from Portugal
- Looking at the last refraction point (going back 1500 Km for a 3000 Km skip) is a way to find explanations
- Also looking at the dominant hops is a way to find explanations

# In search of MUF isolines – Japan / Iberia path opens late after sunset

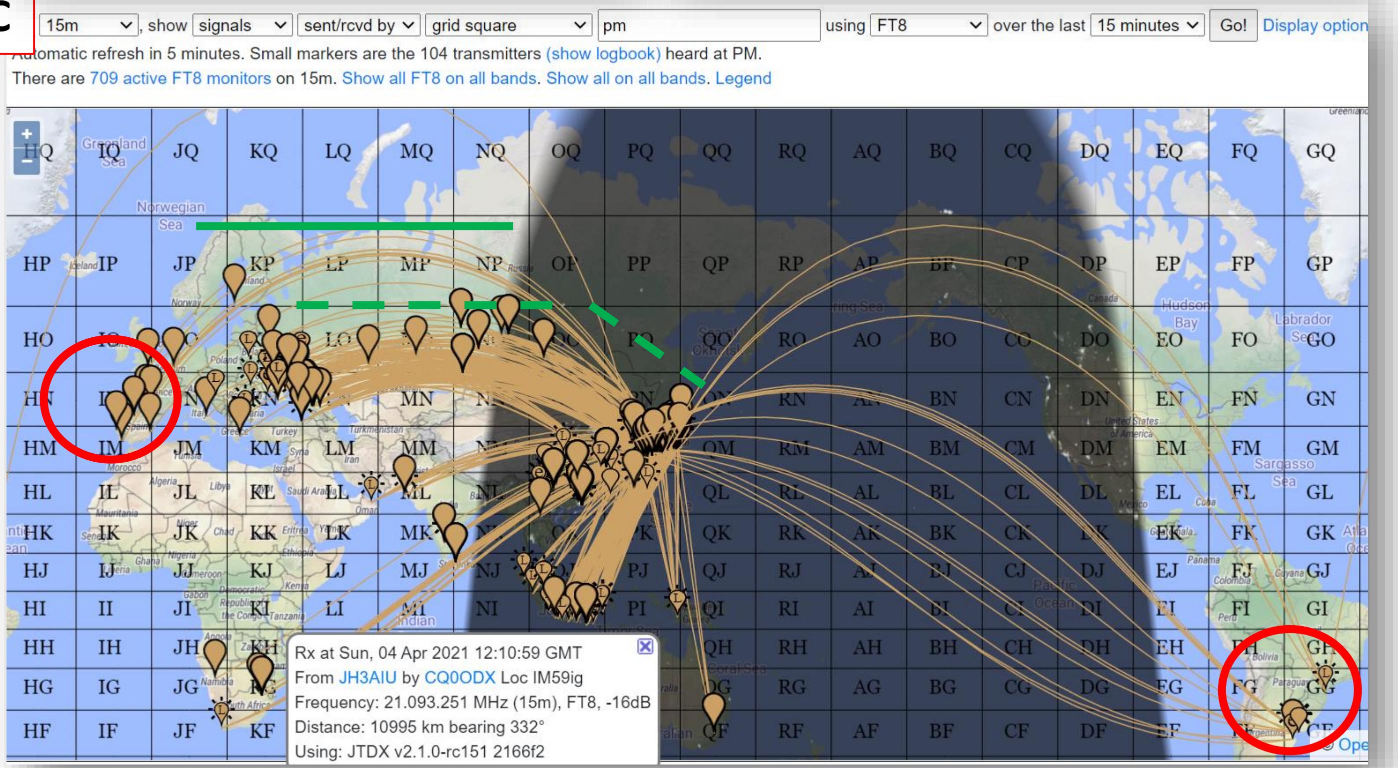
A



B




C

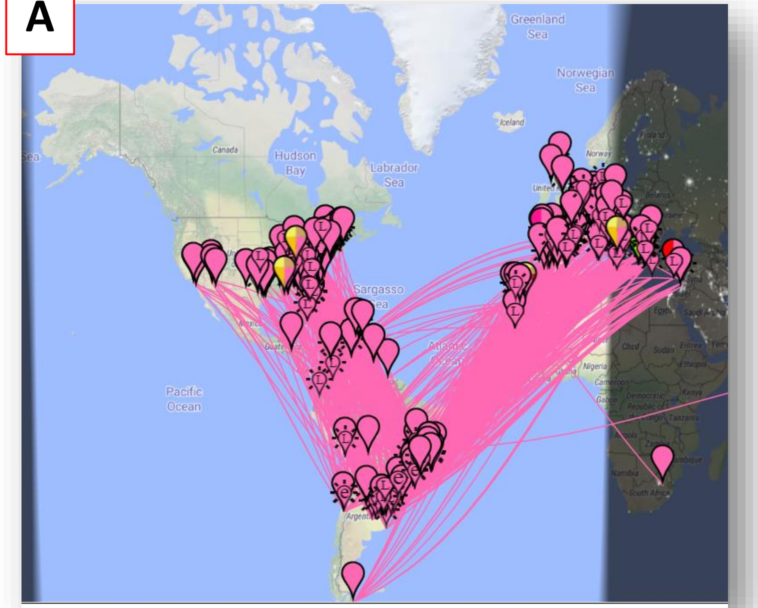



## 21 MHz band open late in JA

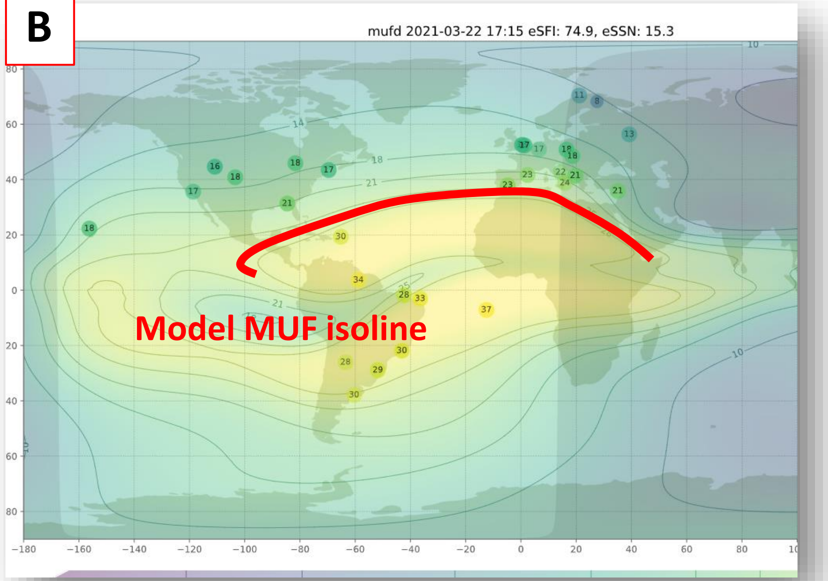
- In figure A and B we can check that the 21MHz isoline was around 60 degrees from sunrise until sunset in Japan and the model world MUF isoline line was consistent with that propagation potential
- A 60-degree isoline does not allow consistent propagation into Iberia (CT1/EA4)
- Suddenly, after sunset in Japan, the path to Iberia opened, requiring a higher MUF Isoline near the 70-degree latitude
- The opening was so good that the Antipodal path into South America also opened. Contrary to what image says, signals are going over the day part of earth where MUF enables refraction points

# In search of MUF isolines – finding the 28 MHz MUF isoline

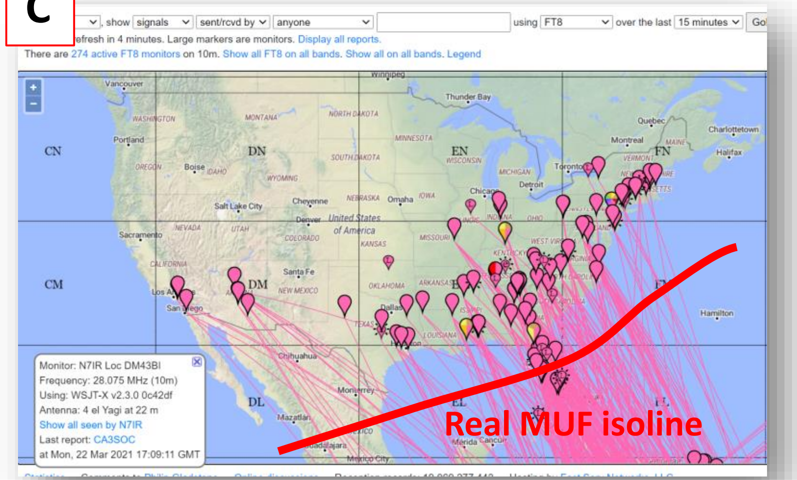
A



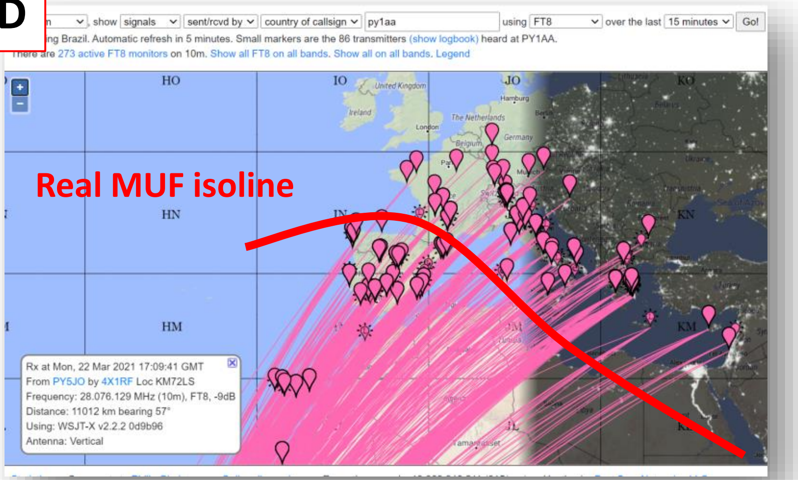
B




C




D

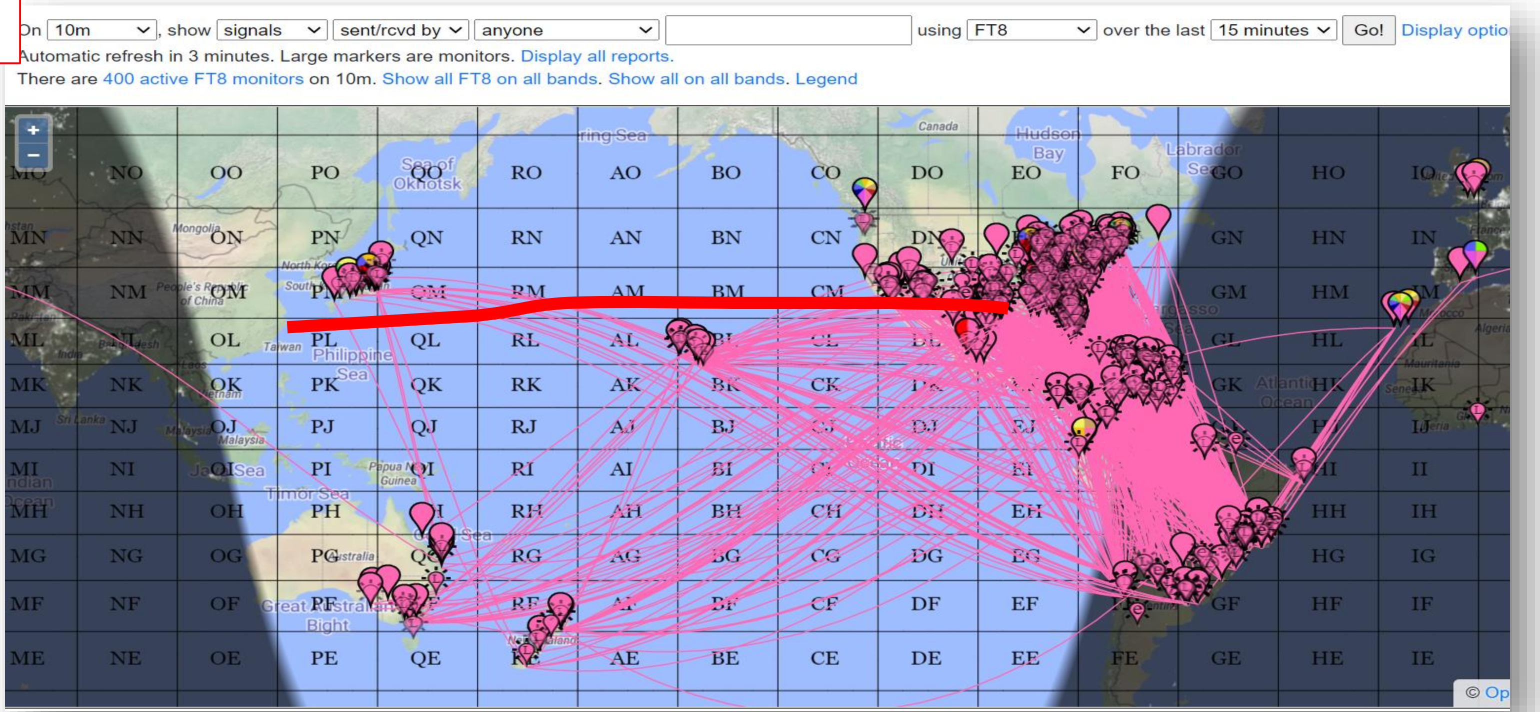



## 28 MHz meters only opens to SA

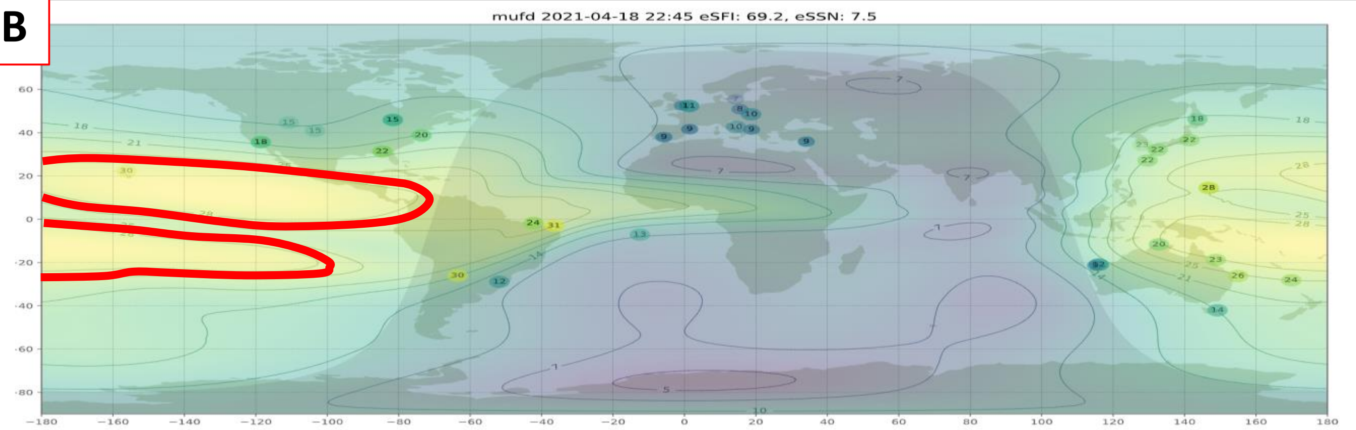
- In figure A we can check that on 28 MHz only north south propagation is open, with the east/west path from Europe to USA closed
- In figure B we can check the location of the 28 MHz MUF isoline according to IRI model and nearby ionosondes
- USA Europe propagation is not possible because refraction points on the north Atlantic will face a MUF lower than 28 MHz putting the signal into space
- Checking closer on figure C and D we can draw the real 28 MHz MUF isoline looking at the location of the reporting stations
- In figure C it can be checked that USA station do not copy each other

# In search of MUF isolines – finding the 28 MHz MUF isoline

A




B

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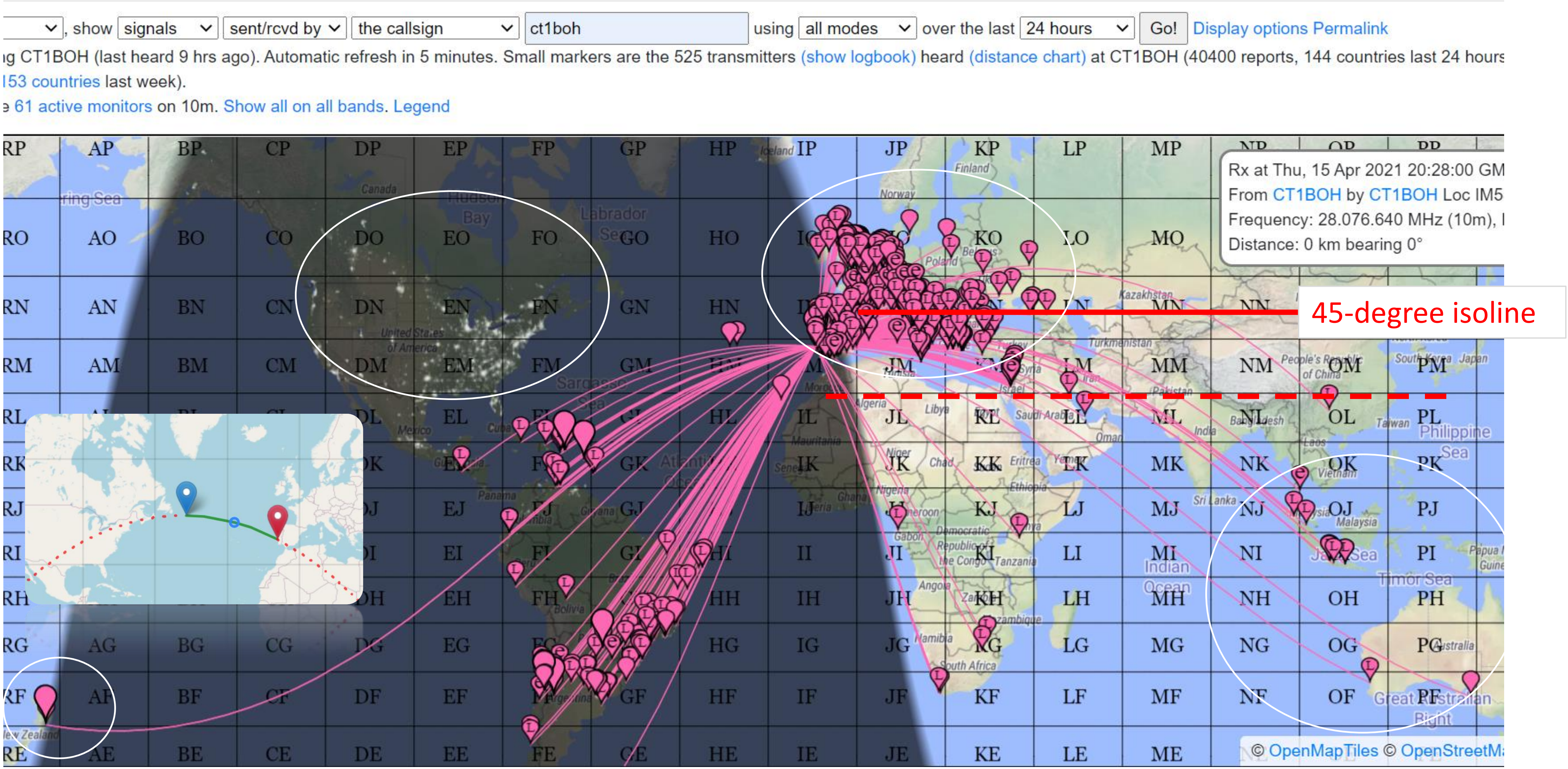
- In figure B we can check the location of the 28 MHz MUF isoline according to IRI model and nearby ionosondes
- USA-Europe propagation is not possible because refraction points on the north Atlantic will face a MUF lower than 28 MHz putting the signal into space

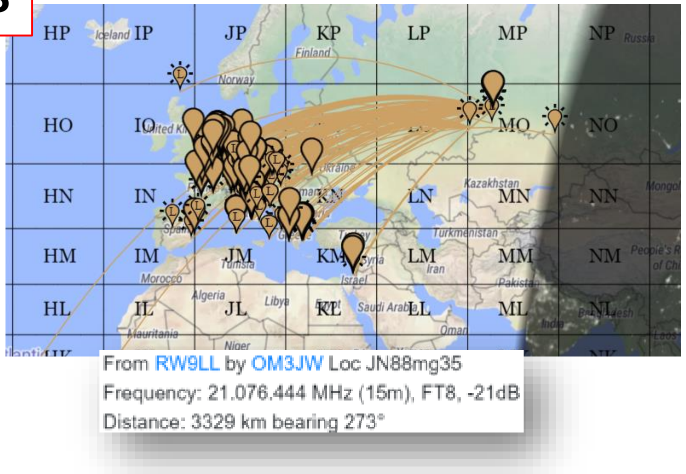
# In search of MUF isolines – 15 degrees increase in 28 MHz isoline from 30 to 45-degrees and 10 meters comes to life but not enough to USA



# Is search of MUF isolines? – Skip mismatch from A to B and B to A

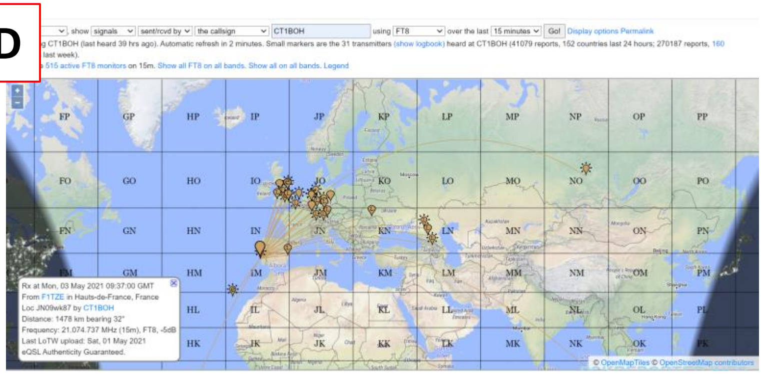
A


B




C

D



## Skip mismatch between circuit points

- Sometimes even tough refracting points are inside the MUF isoline limit, there is no propagation because of skip mismatch between the circuit points
- In figure A, skip distance from CT1BOH into stations due east is around 2600 km
- In figure B, skip distance from RW9LL into station due west is around 3300
- In figure C, JA9IFF is coming into Europe and at a latitude that would enable propagation to Iberia
- In figure D signal from Portugal going into JA direction reaches the first refraction point between France and England, but not additional refractions points

# What next? – Combining HamAlert, PSK Reporter live data, VOACAP and FT8 PSK reported historical data


## Better propagation tools

- Integrate historical FT8 PSK reporter data to update VOACAP reliability values to current propagation
- Determine true global MUF isolines from FT8 PSK reporter data and integrate that into VOACAP program to present not propagation predictions but possible propagation
- Integrate historical and real MUF isolines to determine potential, above potential and below potential propagation presenting a true quality measure for propagation
- Integrate true propagation information into contest logging programs and alert programs