The Geometry of Propagation

Heatherly Takeuchi – N6HKT

Agenda

Introduction

Presentation by José Nunes CT1BOH (48:47)

MUF Isolines

Geometry of Earth

Bringing it together

Introduction

Propagation is a mystery especially when working HF

Is it predictable? More so every day.

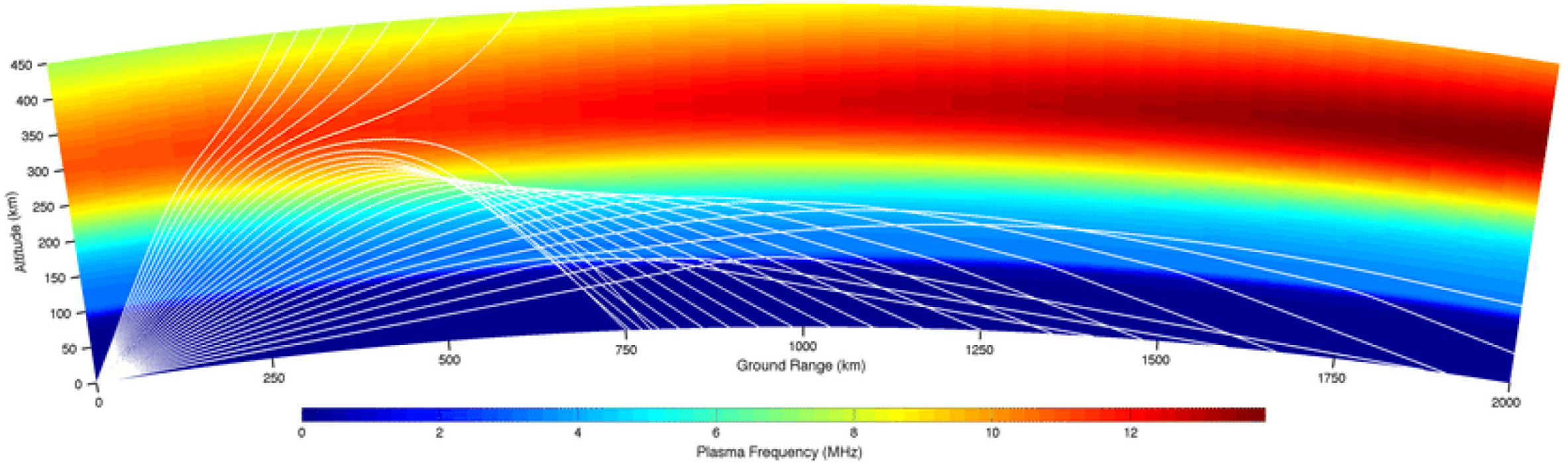
Opening Thoughts

- This is not a talk about the Solar cycle, the magnetosphere, or the ionosphere.
- Just because you can hear them does not mean they can hear you and vice versa.

There is nothing magic about propagation

In search of MUF isolines

Contest University



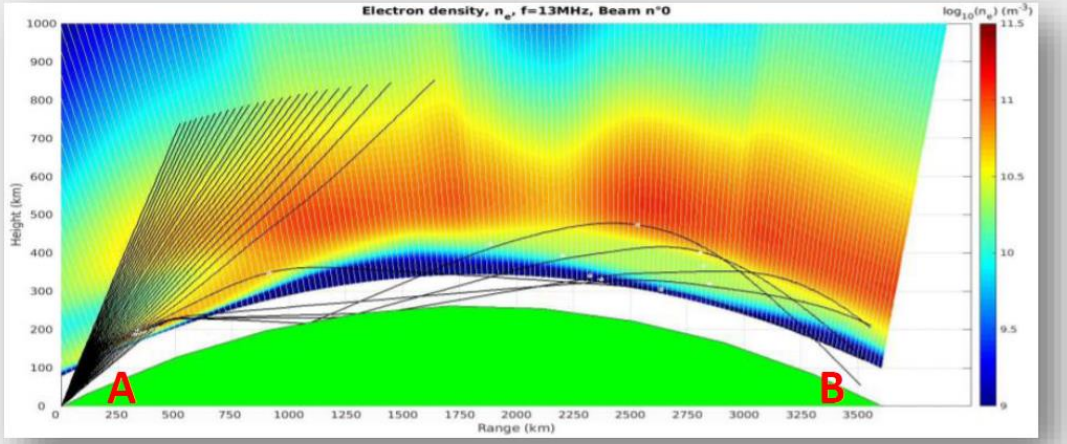
José Nunes – CT1BOH
ct1boh@gmail.com

https://www.youtube.com/watch?v=q-esob7BPtc (5:38 – 6:40)

Maximum Usable Frequency (MUF)

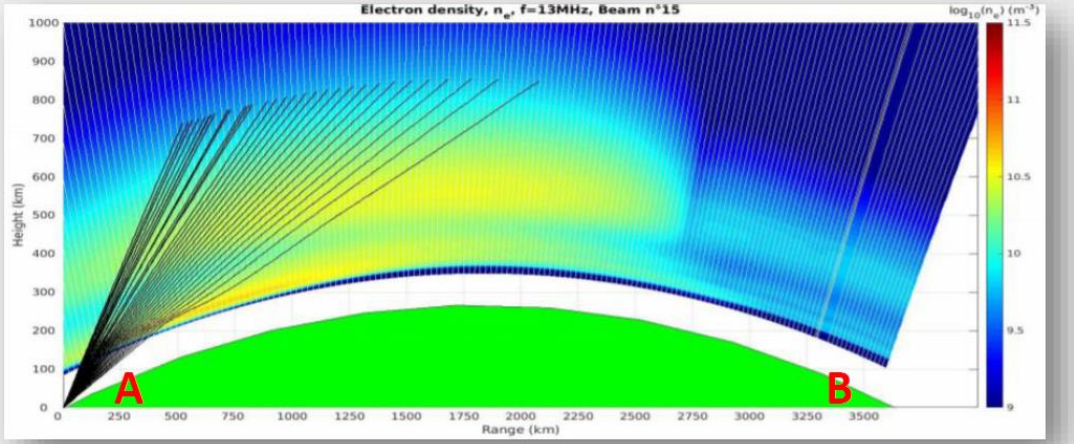
- In radio transmissions, MUF is the highest radio frequency that can be used for transmission between two points via reflection (refraction) from the ionosphere (sky-wave propagation) at a specific time, independent of transmitter power.

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

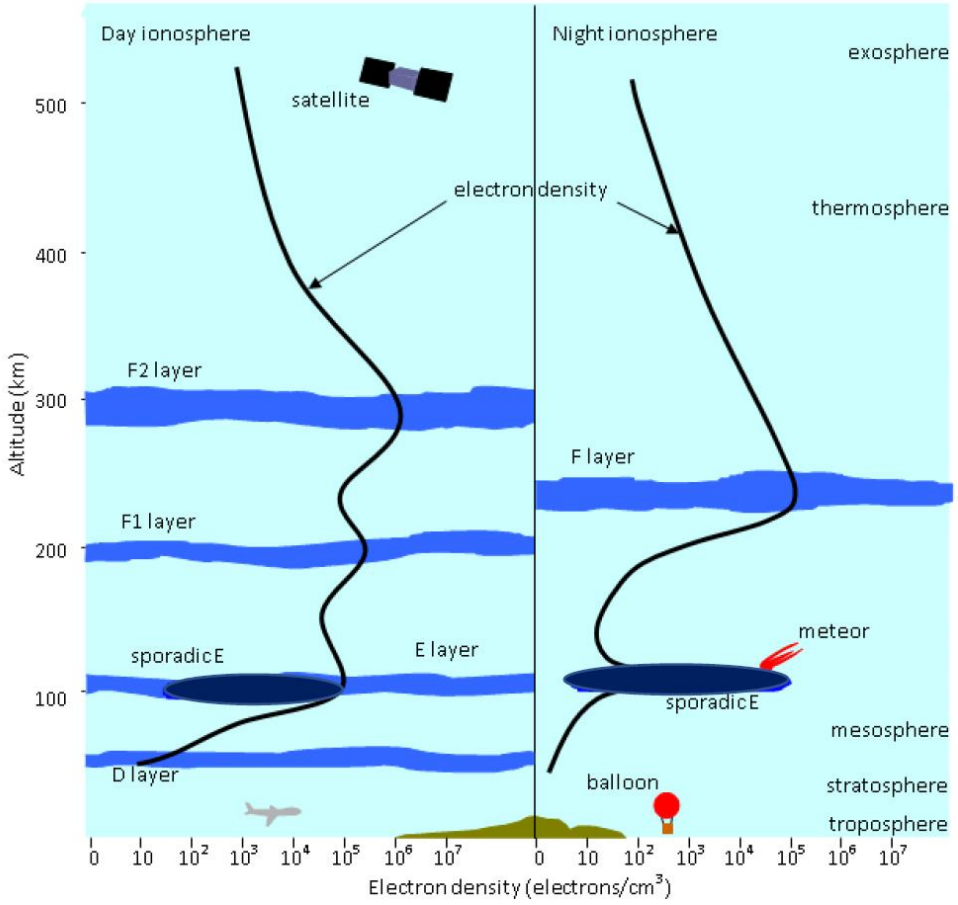
- Electron density of refraction area
- D layer absorption level
- E, F1 an F2 refraction layers
- MUF in refraction area
- Operating frequency below critical frequency in refraction area (or “MUF of ionosphere”)



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

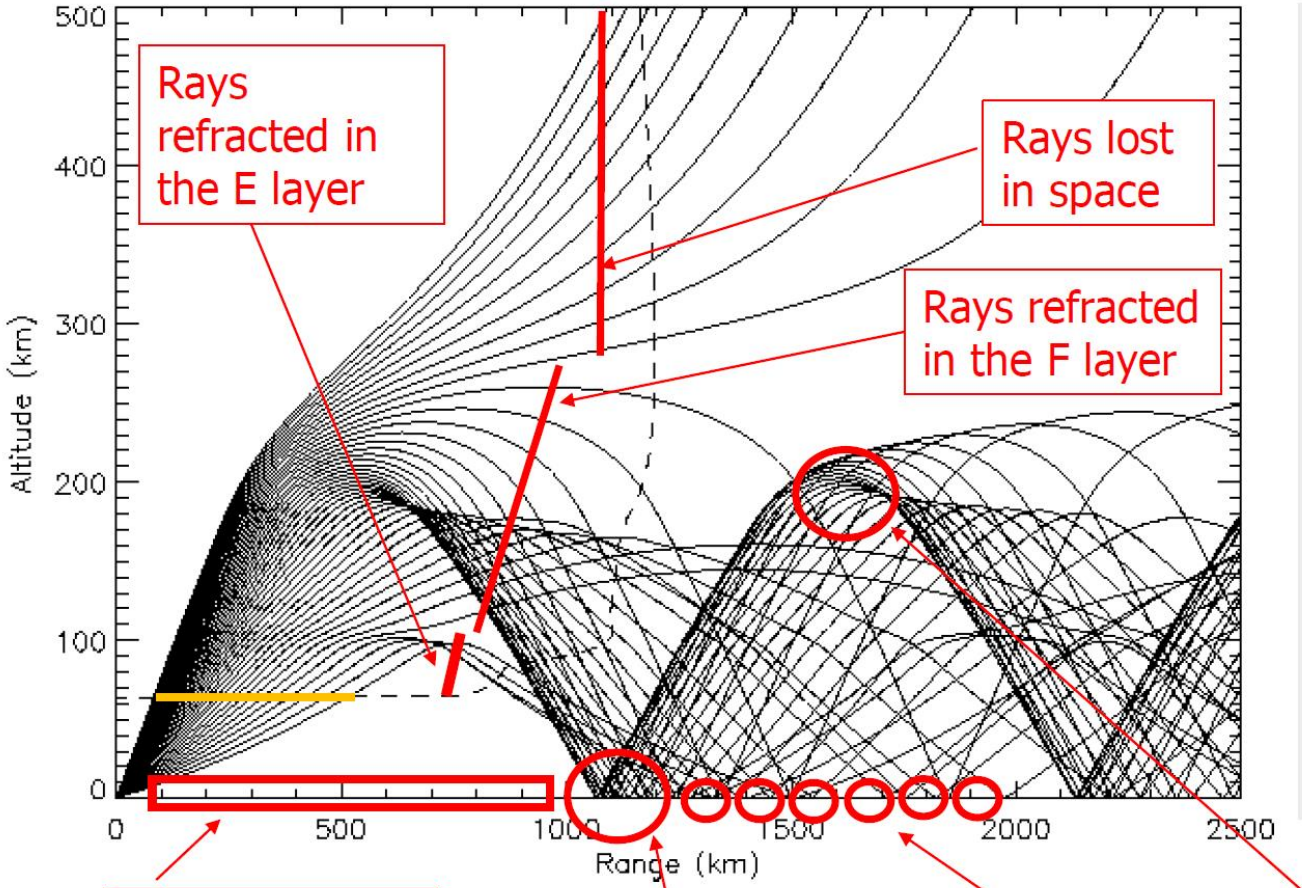
E layer

- 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

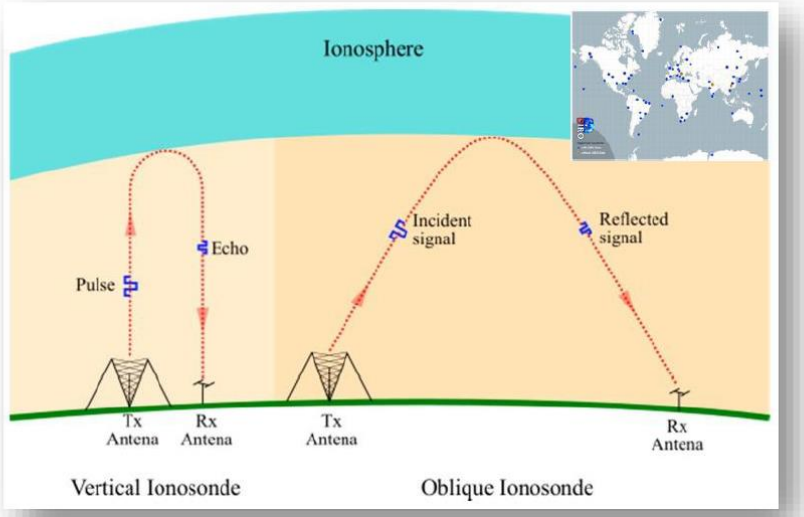
Understanding signal refraction, skip distance, multi-hop and critical frequency ("MUF of ionosphere")

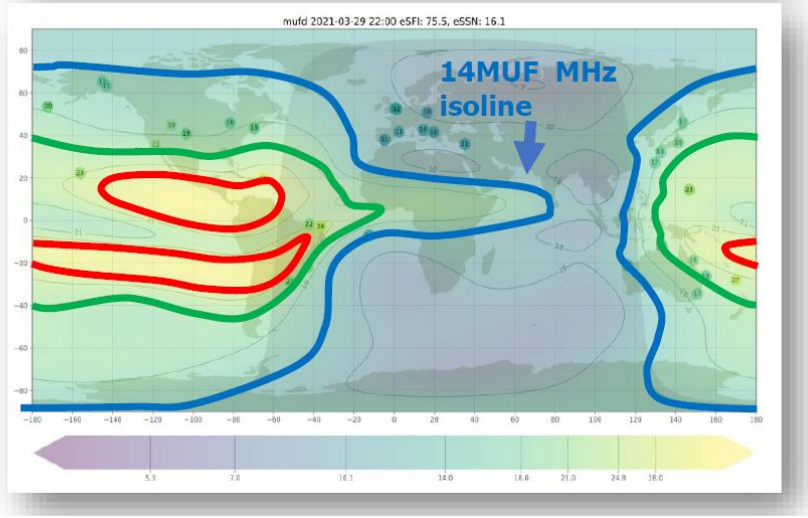


Critical frequency (MUF of ionosphere)

- 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

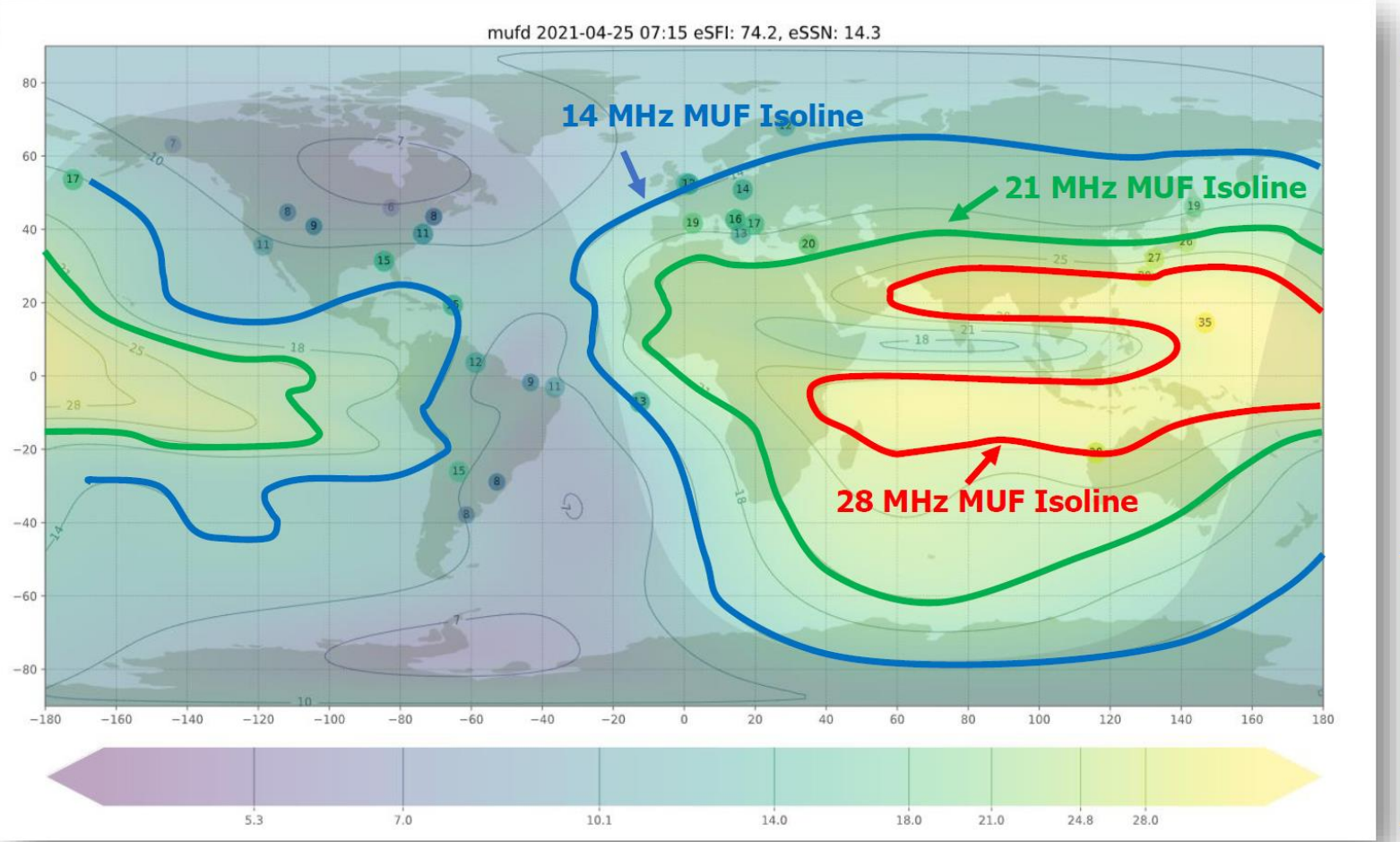
- The ionosonde is used to find the NIVS MUF frequency in the ionosphere immediately above the antenna
- The result of the probe of the ionosonde is an ionogram, depicting ionospheric layers, the height of each layer and the electron density
- A model enables to transform NVIS MUF into MUF for 3000Km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

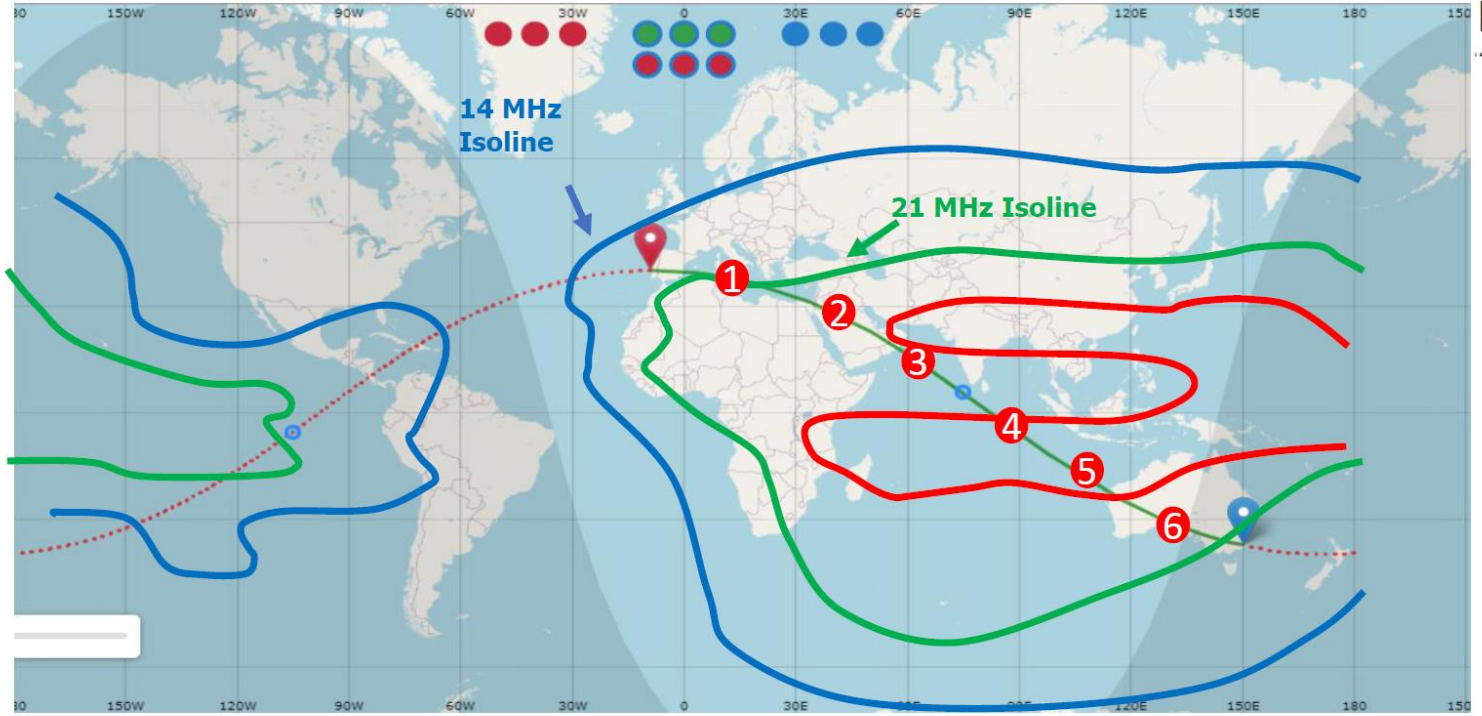


https://prop.kc2g.com/

MUF isoline sets propagation

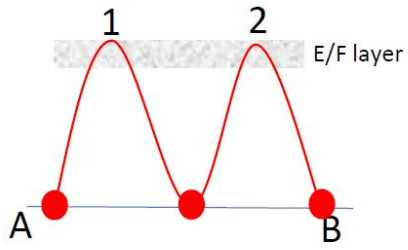
- A MUF isoline is a contour line where the critical frequency (or ionosphere MUF) is the same all over the word
- Inside the 14 MHz isoline MUF frequency is higher than 14 MHz and outside it is lower
- Propagation on 14 MHz will only be possible if the refraction points in the ionosphere are inside the area of the MUF isoline limit

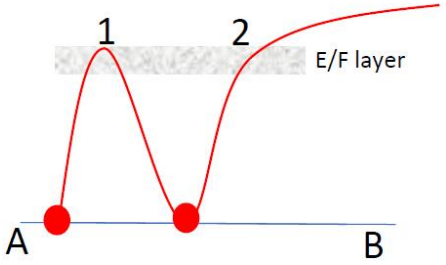
Paths that have refraction points inside or near the edge of the MUF isoline will hold propagation

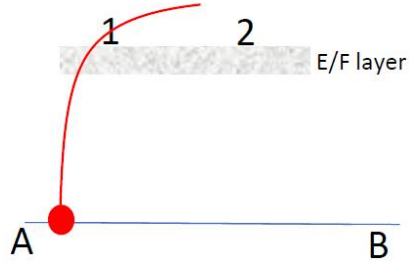


Portugal into Australia path

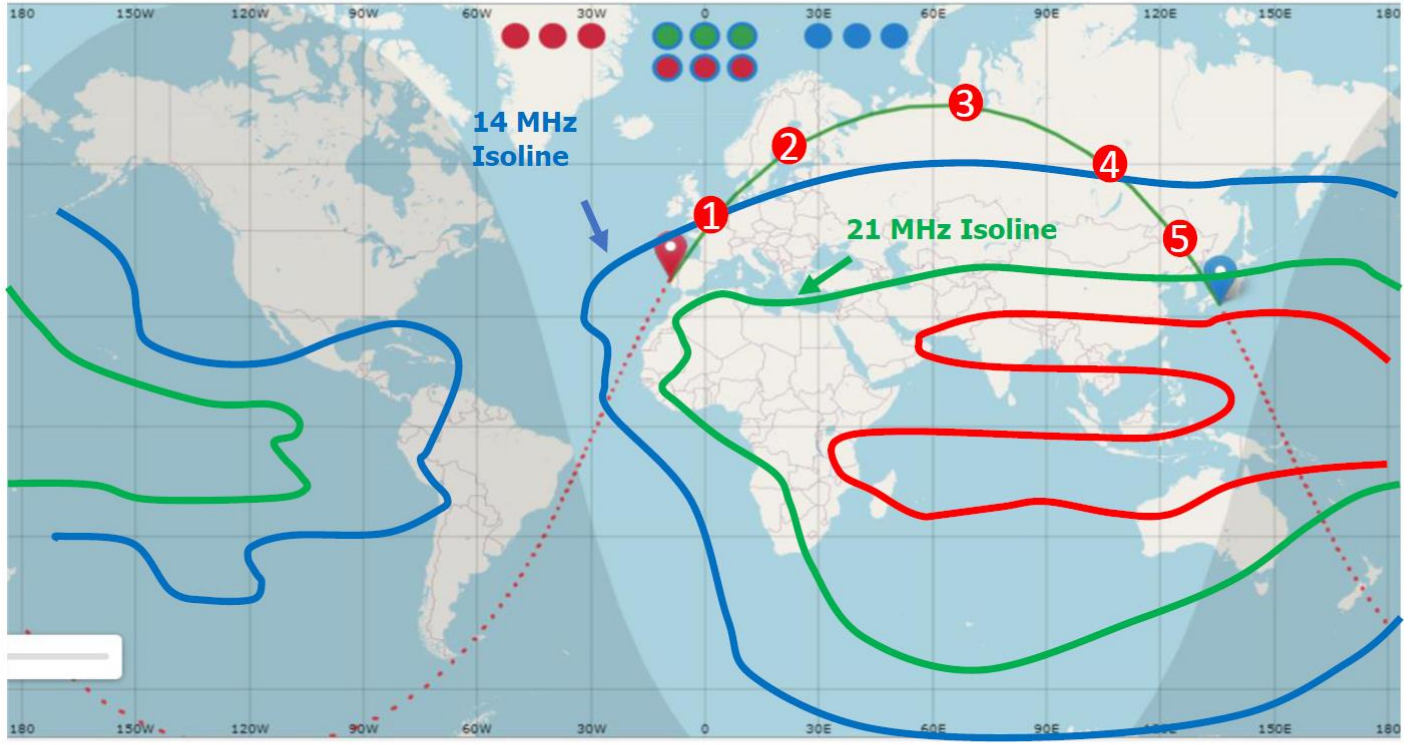
- The path from Portugal into Australia has all refraction points inside the MUF limit isoline for 21 MHz and 14 MHz
- All refraction points will find a MUF frequency above the operating frequency (21 MHz)
- The only limiting factor is power, gain and D layer absorption





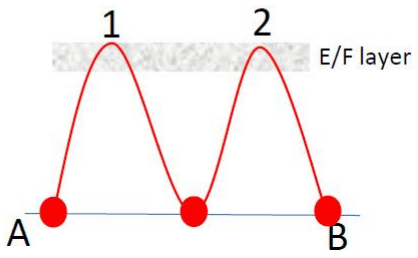


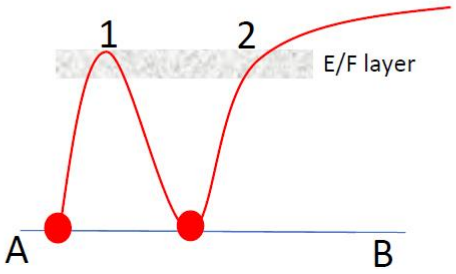
Paths that have refraction points outside of the MUF isoline will not hold propagation

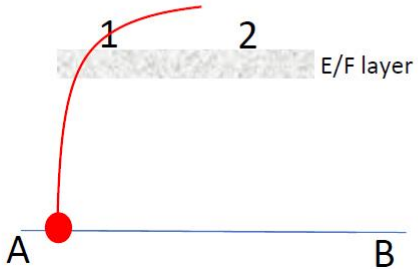


Portugal into Japan path

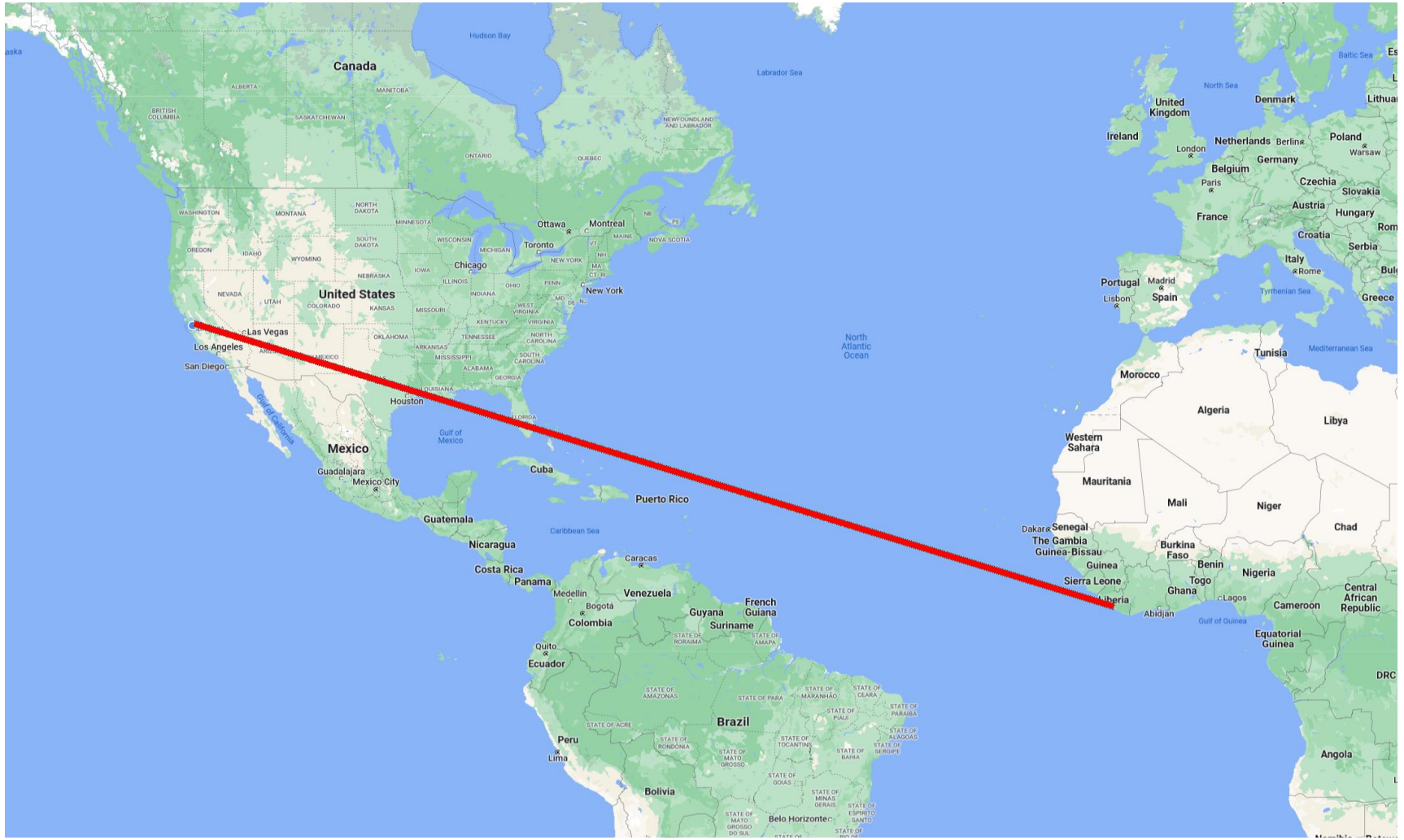
- The path from Portugal into Japan has refraction points outside the MUF limit isoline
- Refraction points 2 and 3 have a MUF frequency lower the operating frequency (14 MHz)







A straight line is the shortest distance…



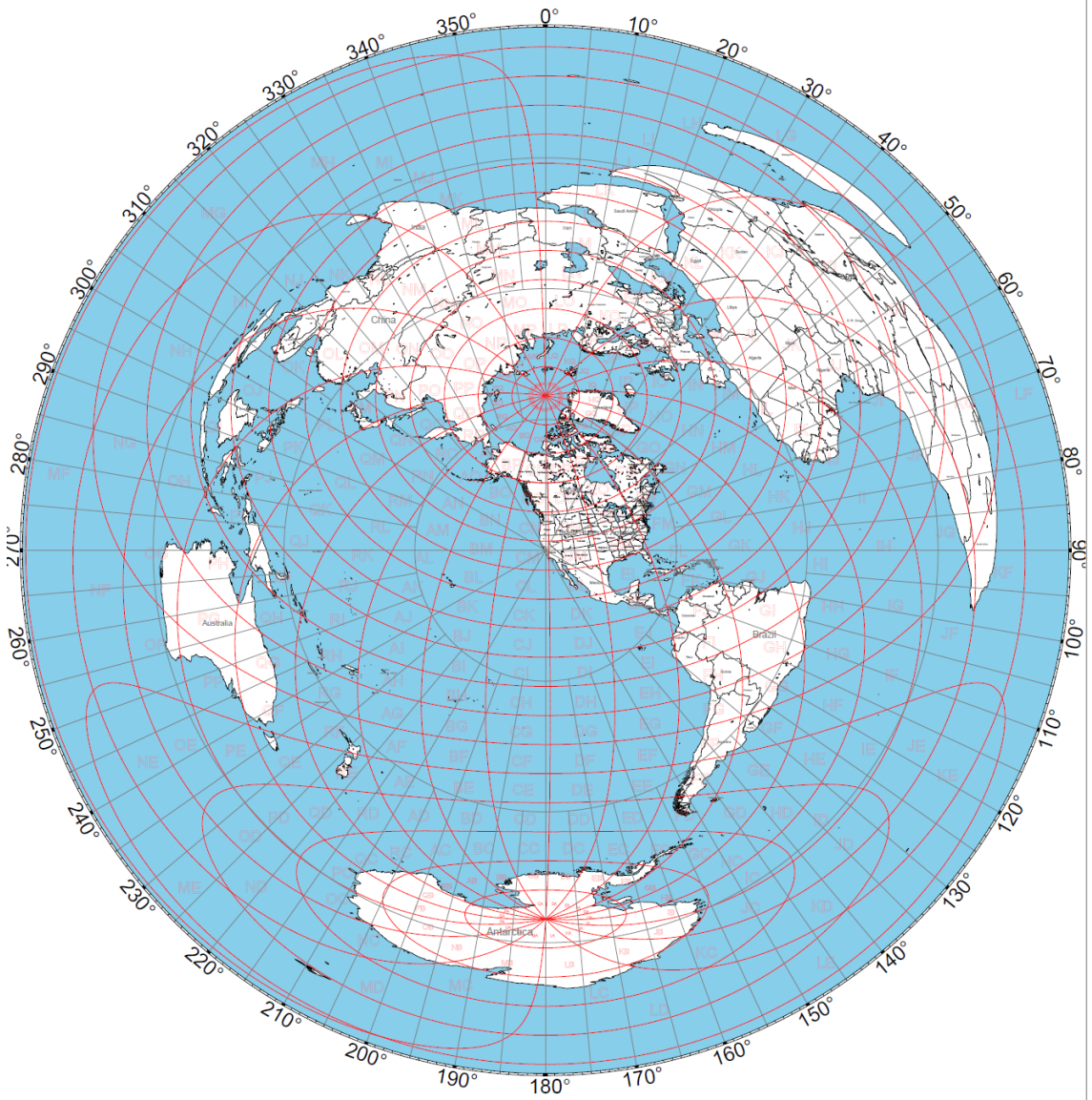
Flat map of Earth

How to See The World for HF

Azimuthal Map

Center: 36°49'59"N 121°25'0"W

Courtesy of Tom (NS6T)



How to See The World for HF

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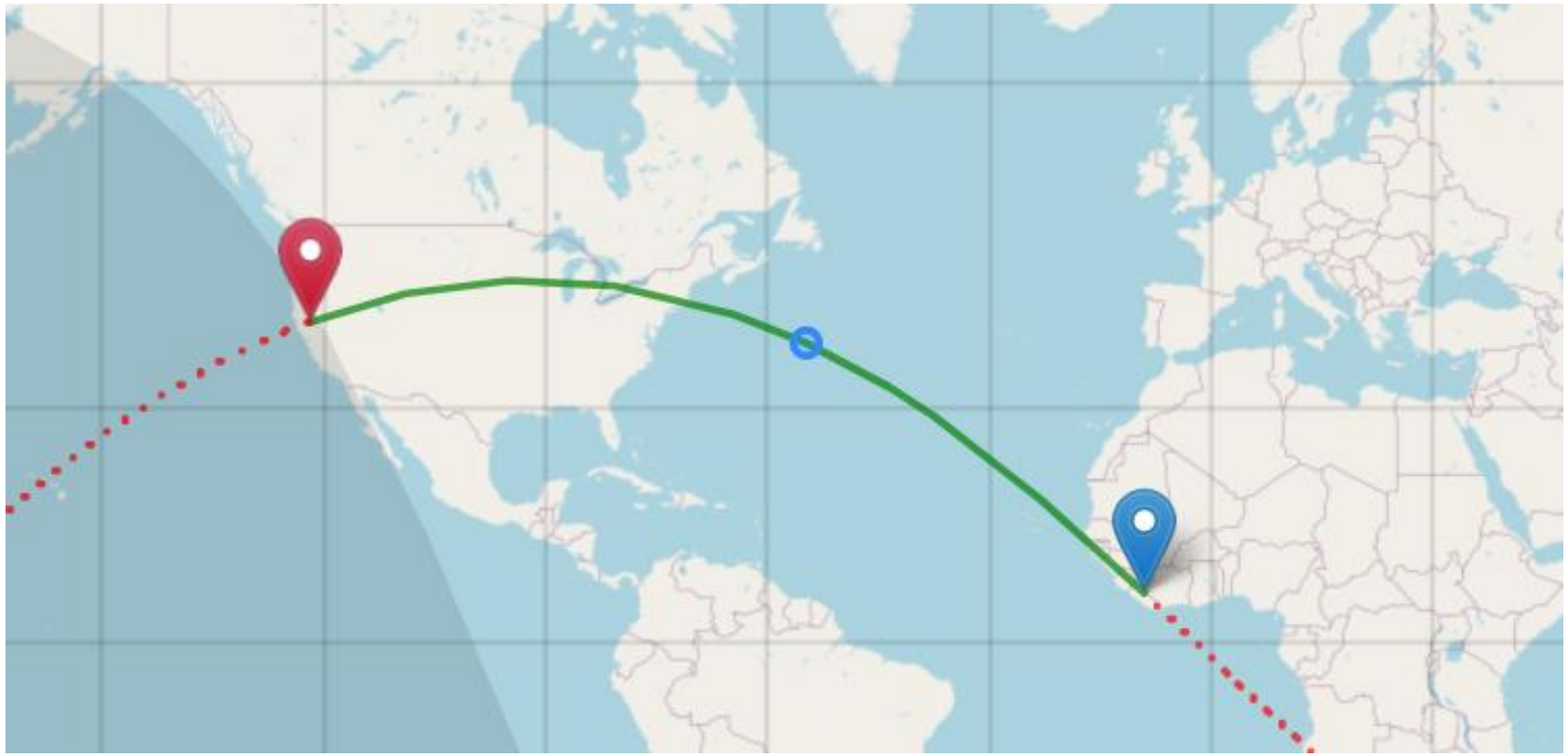
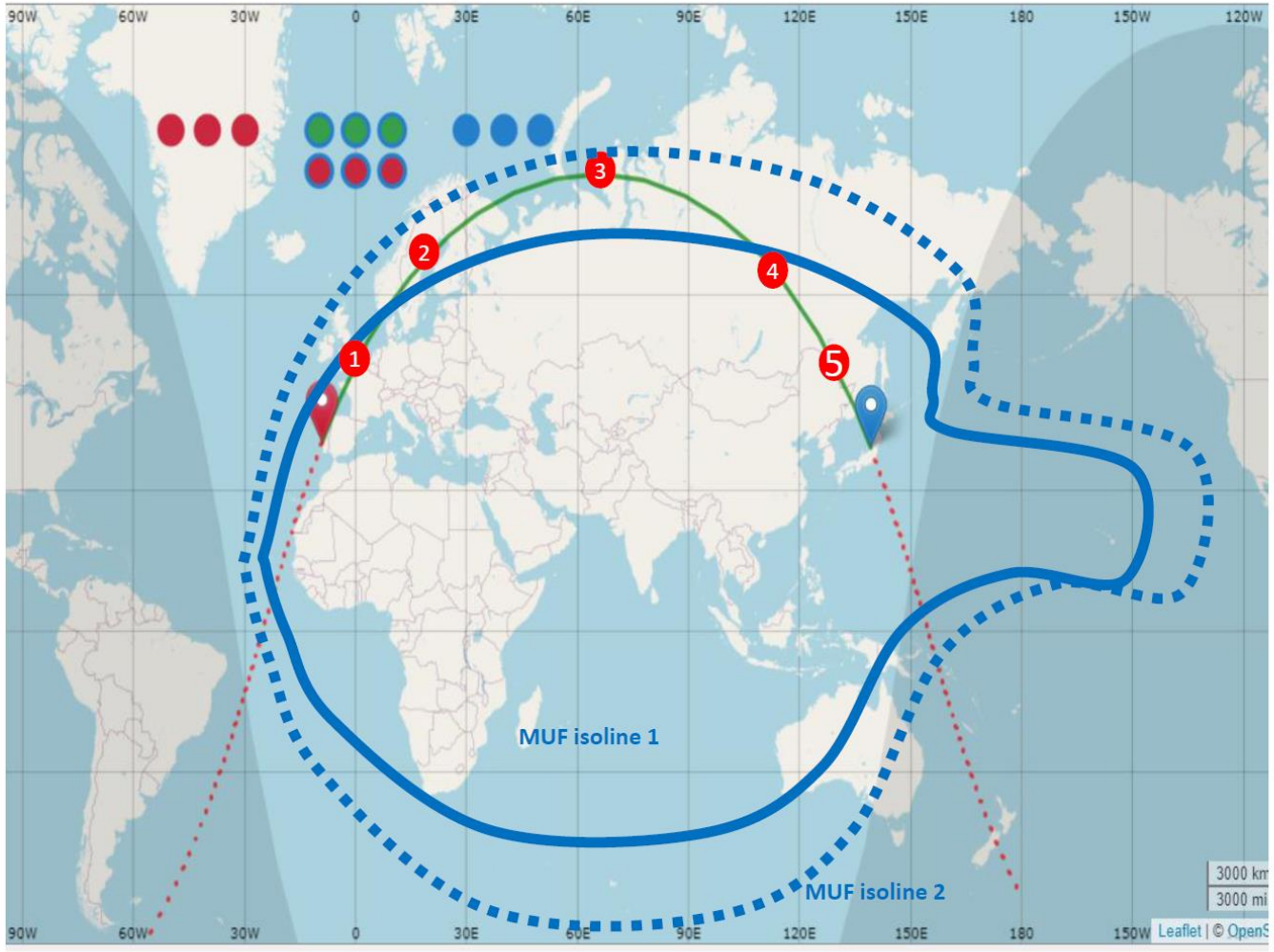


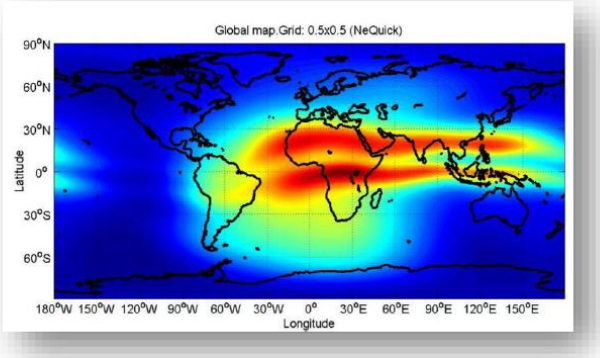
- https://www.voacap.com/hf/

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



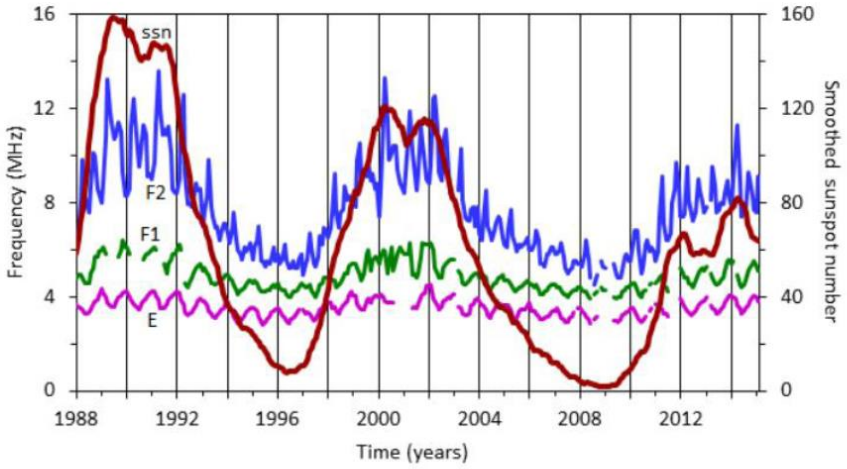
The shape and size of the MUF isoline

- 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



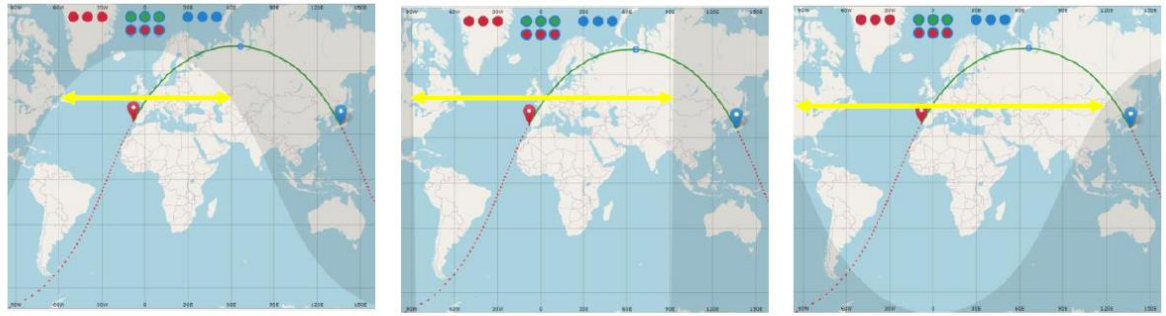
Ionospheric variability – solar cycle and seasonal variations

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

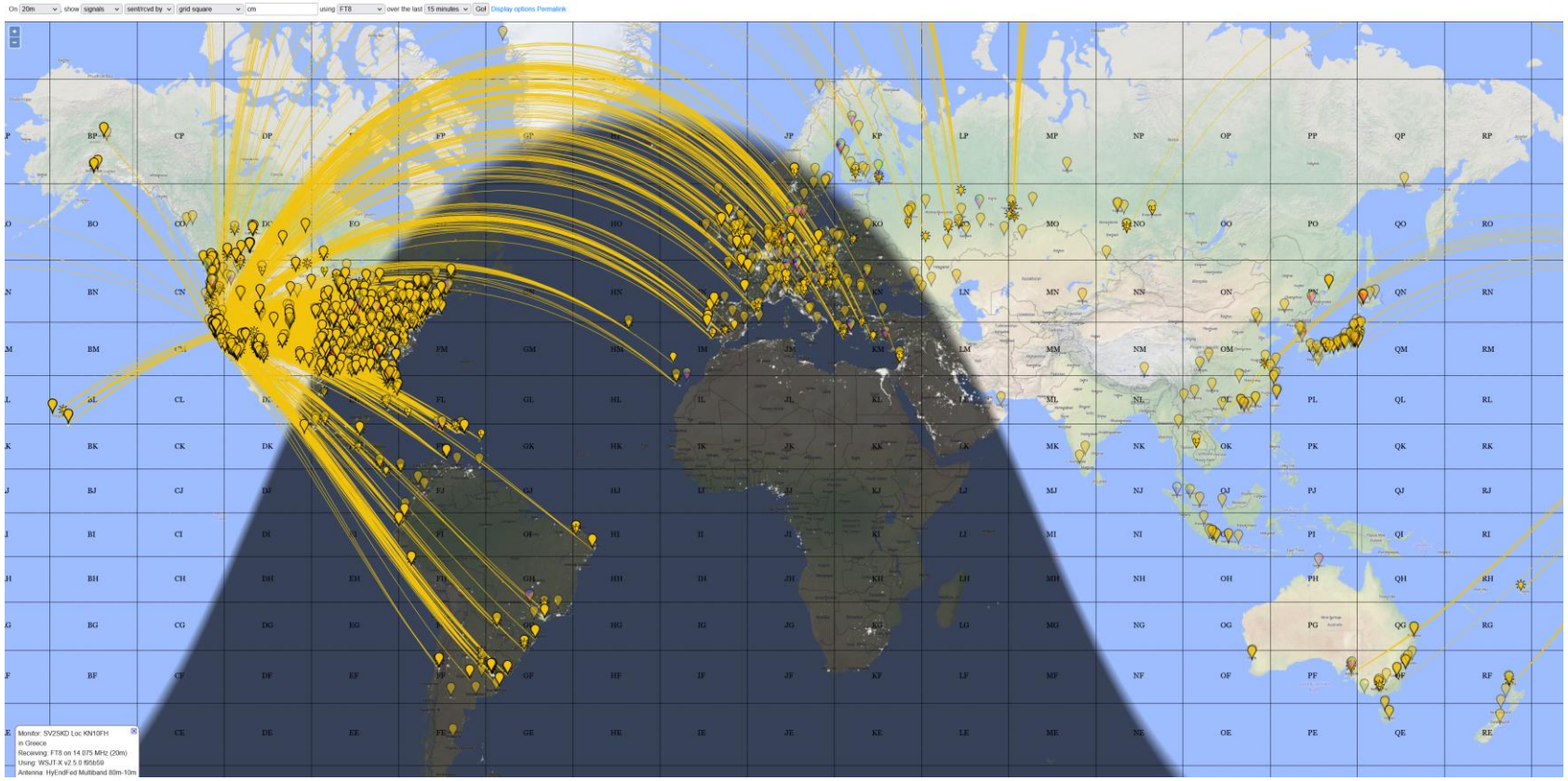


Winter Solstice **Equinox** **Summer Solstice**

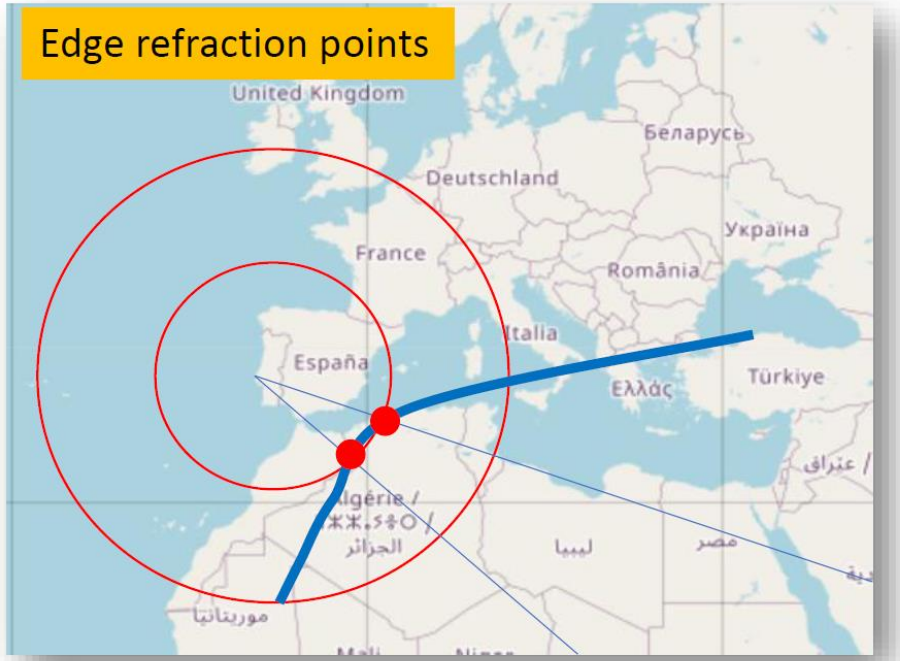
- Seasonal variations have a profound impact in ionization of atmosphere
- Higher or lesser day hours provide different hours of illumination and ionization that impact MUF
- Increased number of refraction points in illuminated atmosphere provide better opportunities between longer paths in HF

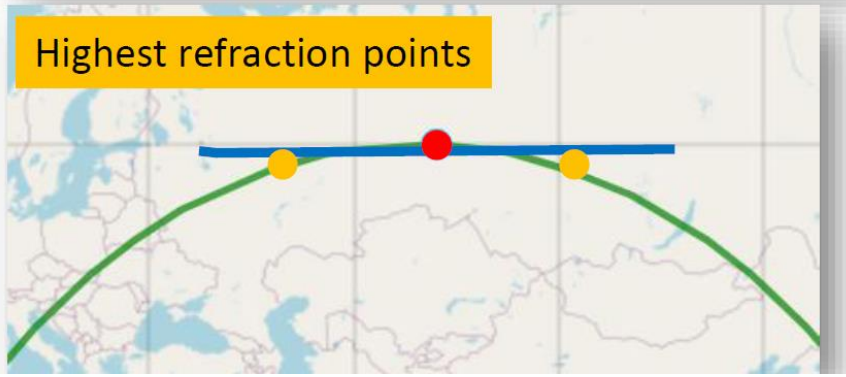
PSKReporter.info

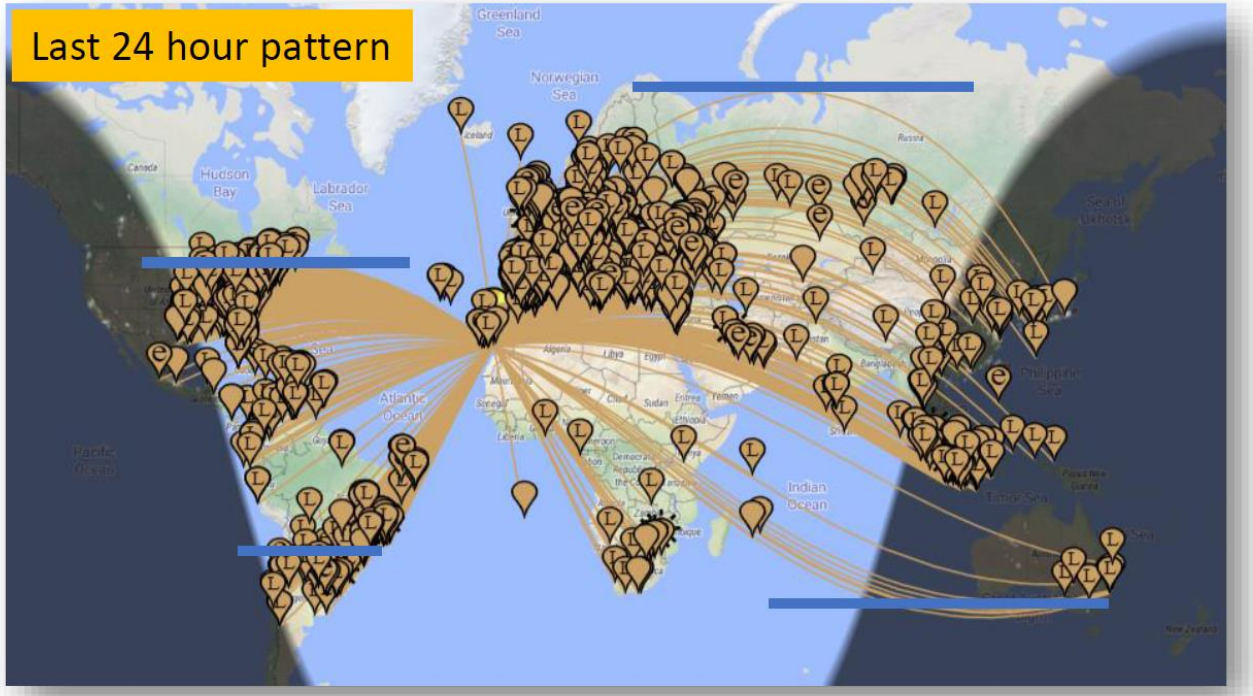
- Go to: https://pskreporter.info/pskmap.html



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





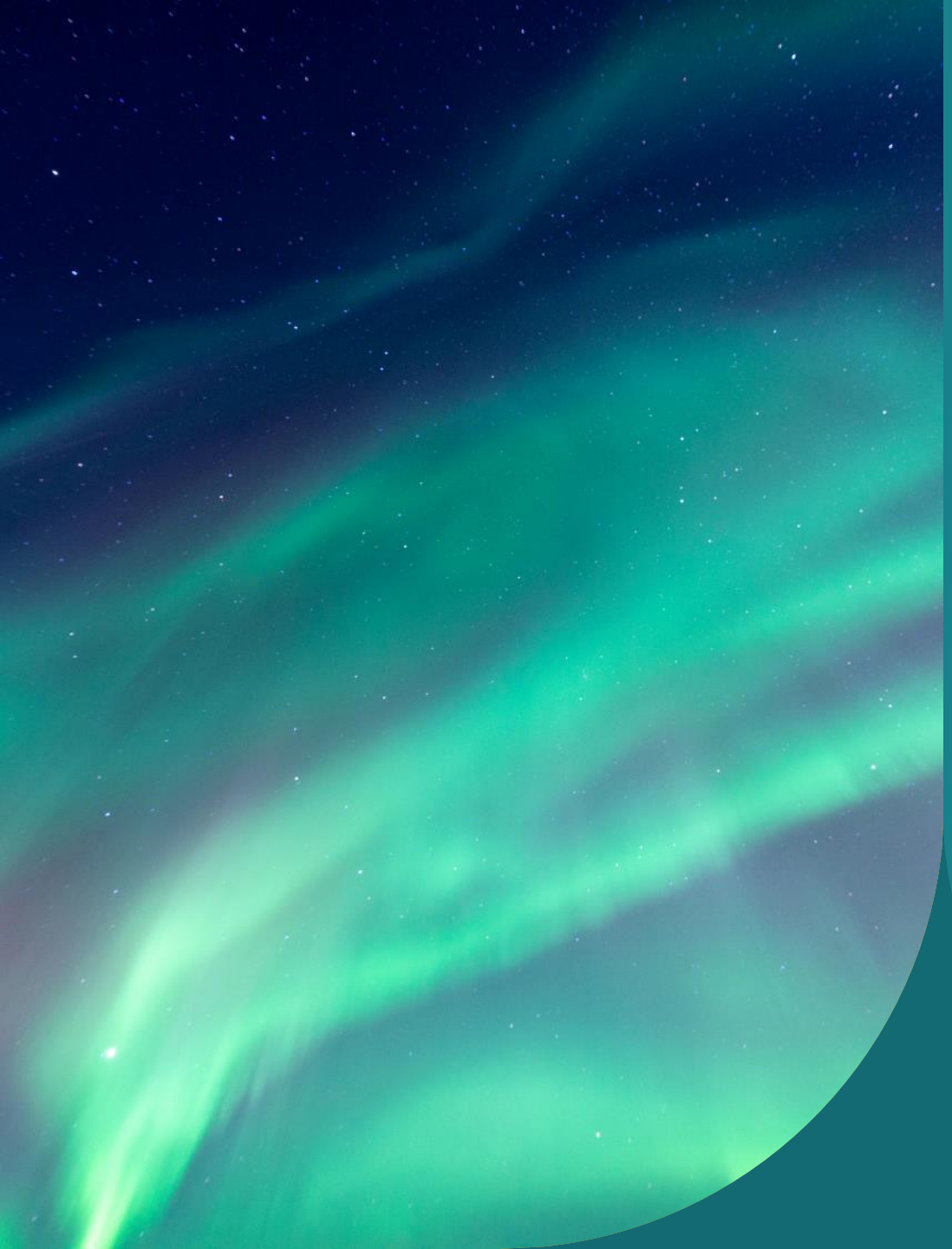


The exercise of connection the dots…

- 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

Closing thoughts for the Geometry of Propagation

- Get an Elmer/Elma
- Use the tools
- Ask questions
- Get on the Air!



Thank You

73,

Heatherly Takeuchi/N6HKT

https://sbcara.org