# Ionosondes and Ionograms

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What are they and what role do they play?

How do I use them for everyday communications?

How do I interpret ionograms? What is useful and what can I ignore?

Are there secondary data sources?

Underlying mechanisms in the ionosphere

Other related measures

# What are they?

- An ionosonde is a cloud burner antenna with a sweep generator TX that measures the time of flight of vertical incidence waves returned to an broadband RX panadaptor (0.1 to 30MHZ)

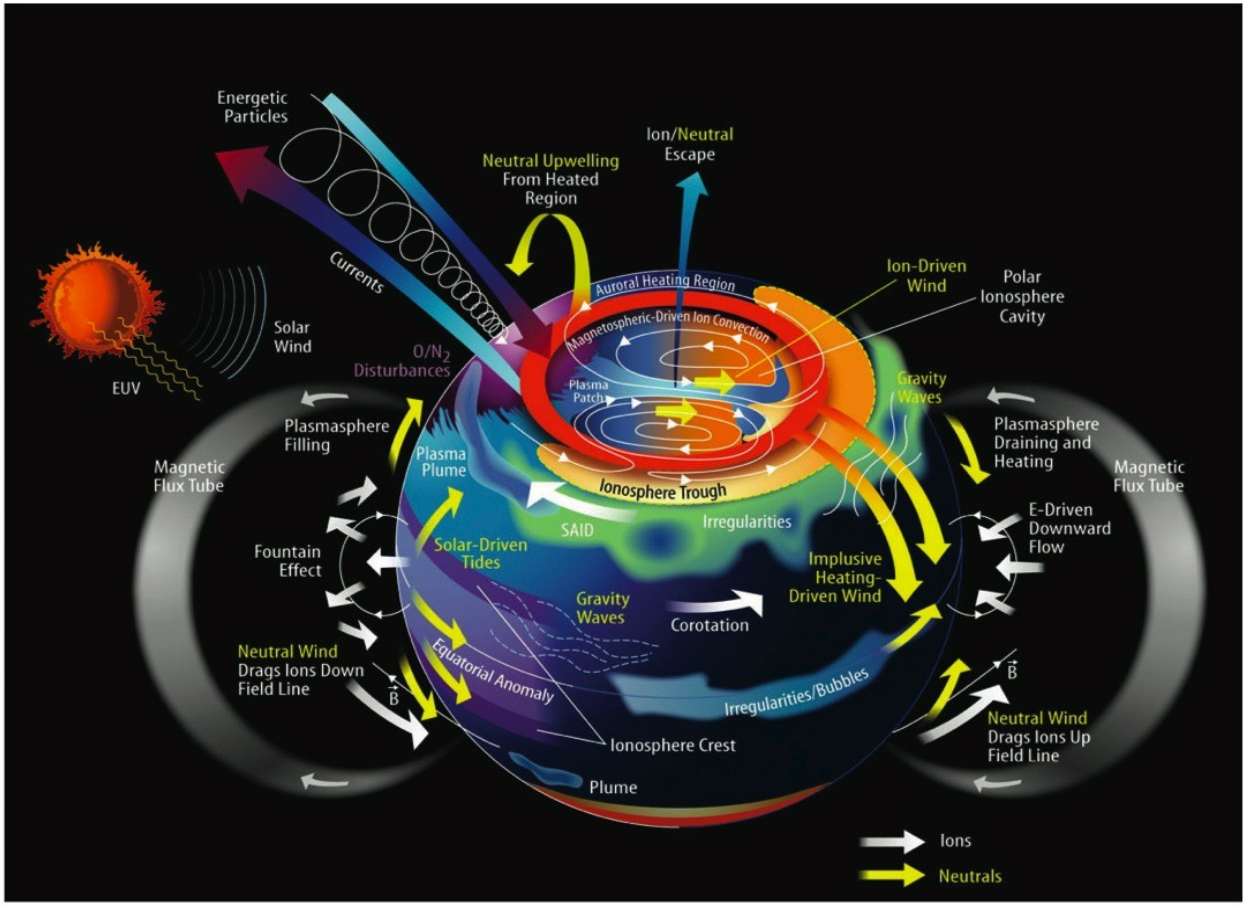
# What role do ionograms play?

- They are the output of ionosondes and they reflect the ‘now’ situation – often updated every 10 mins or so.
- They are REGIONAL in scope
- They are not predictions, they are near real time measurement devices
- operators also provide history and archives
- So, near NOW and PAST data

- Prediction requires modelling- VOACAP;ICEPAC;RE533;HAMCAP;
- Why regional – Ionospheric behaviour differs with latitude. It is generally categorised: Equatorial;Mid latitude;high latitude. The mid to high boundary often seems to be around the English Channel. So, use appropriate sounders.

# More on why regional

- Earth’s magnetic field
- Ionosphere is not homogenous
- Plasma currents
- Ion density varies
- Gives returns from different directions



# How to use them

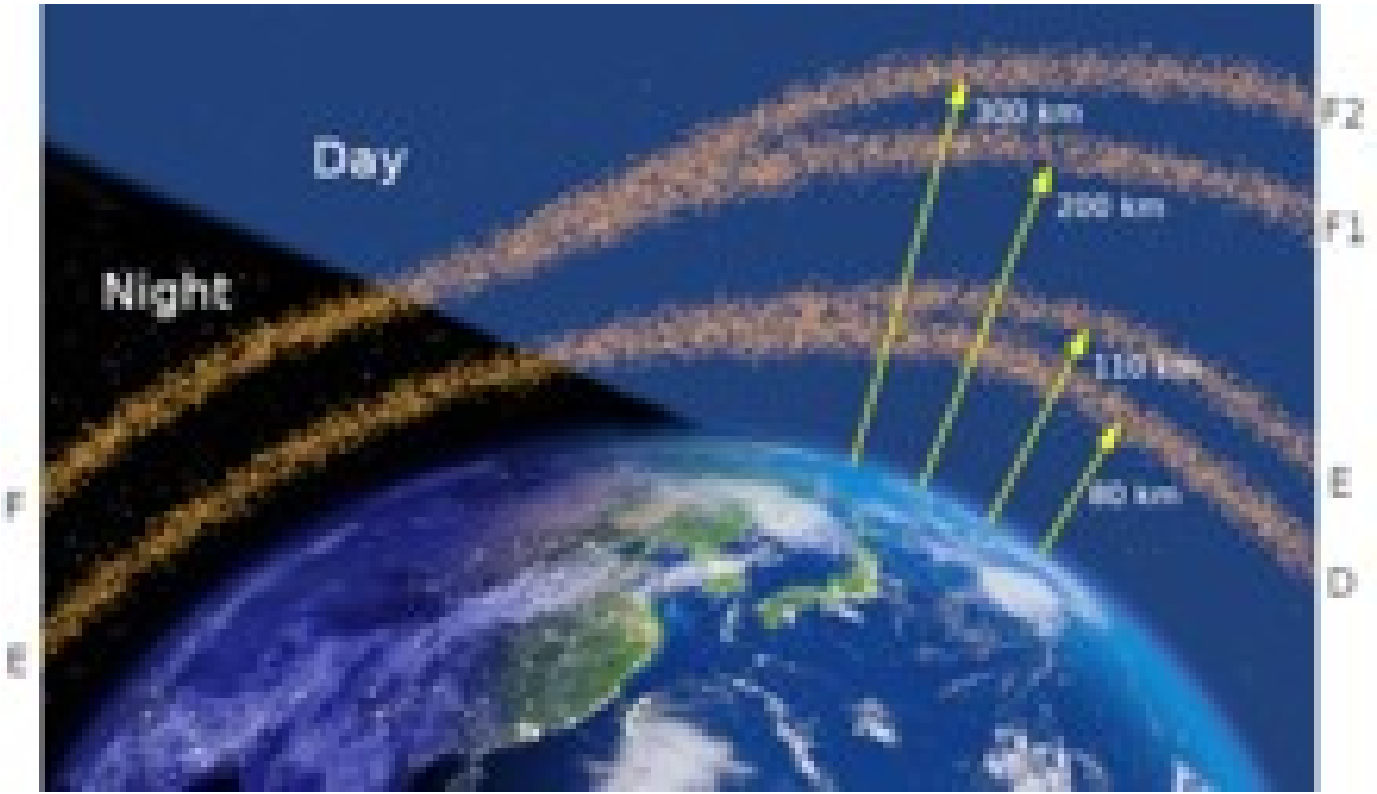
- Know what to ignore and why

  a lot of dry info exists and a notation system that is extensive with all its conventions (126 abbreviations for parameters at the last count!

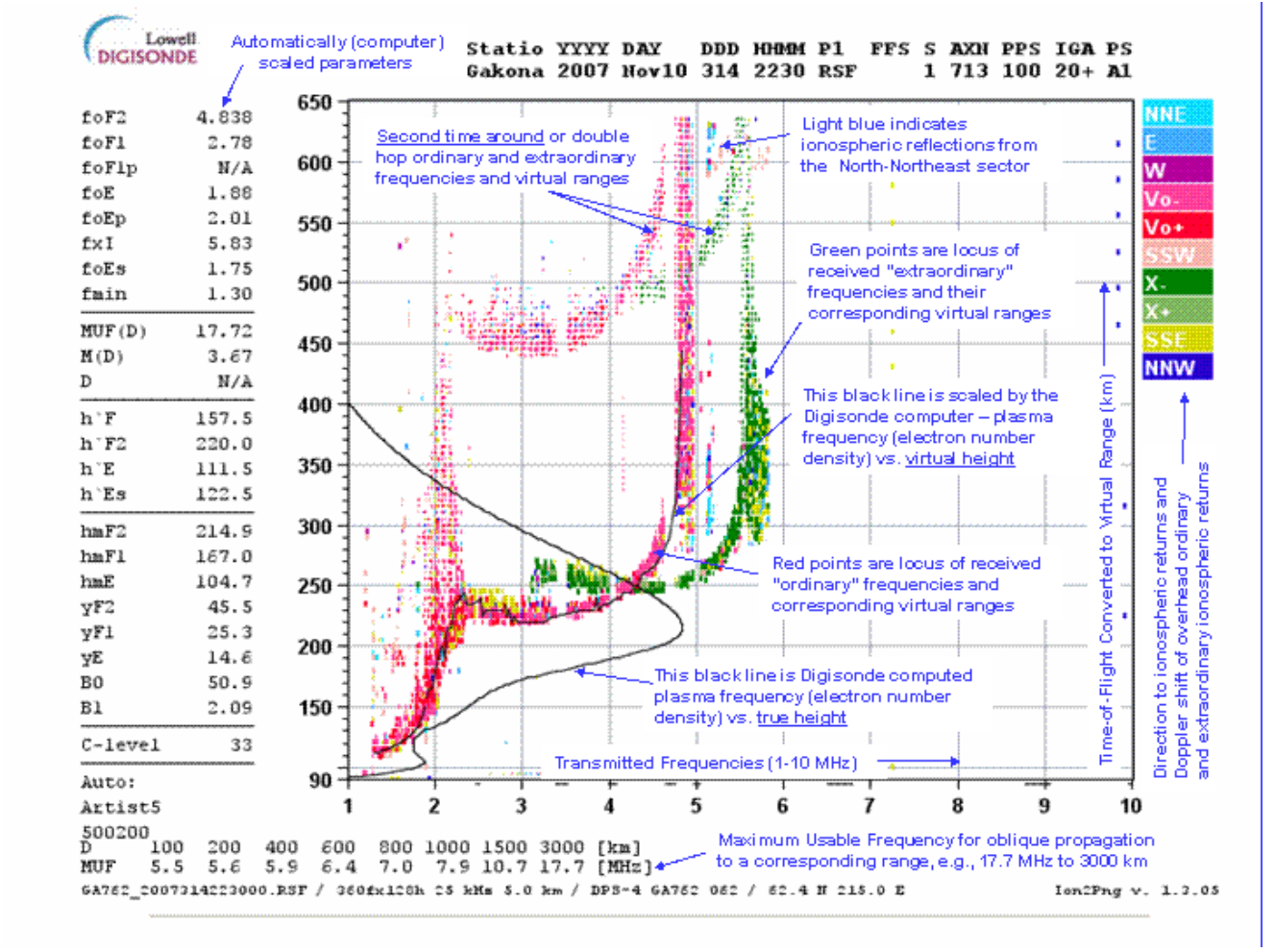
- Know which parameters matter for simple decisions
- Know the graphical appearance for useful and also uninteresting phenomena
- Key Layers
  - D  mainly an absorption layer
  - E  at about 100 km up
  - F  200km up plus  sometimes splits F1 and F2

# Diurnal and cyclic changes

- Day D,E,F1,F2
- Night E,F
- Layers created by different mechanisms
- Layer densities differ
- Usual visualisation is a bit of a ‘fairy story’
- Two actual mechanisms. Refraction and Re-radiation

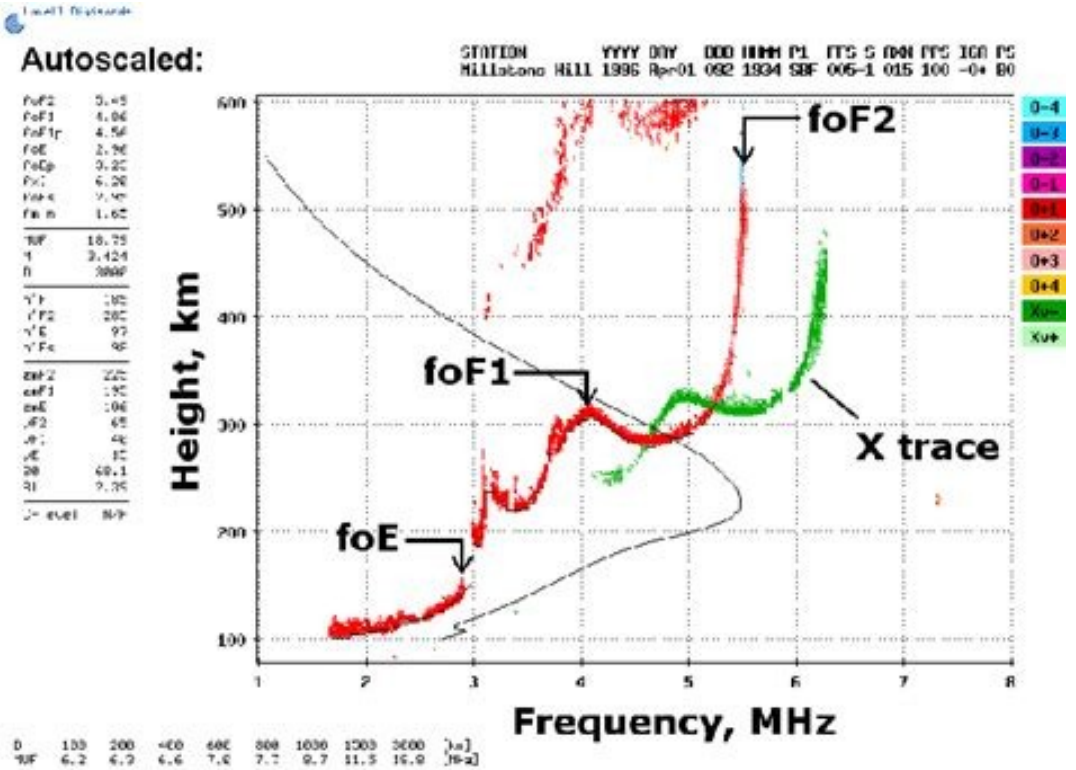


# INTERPRET THE IONOGRAM



# Parameters that matter*

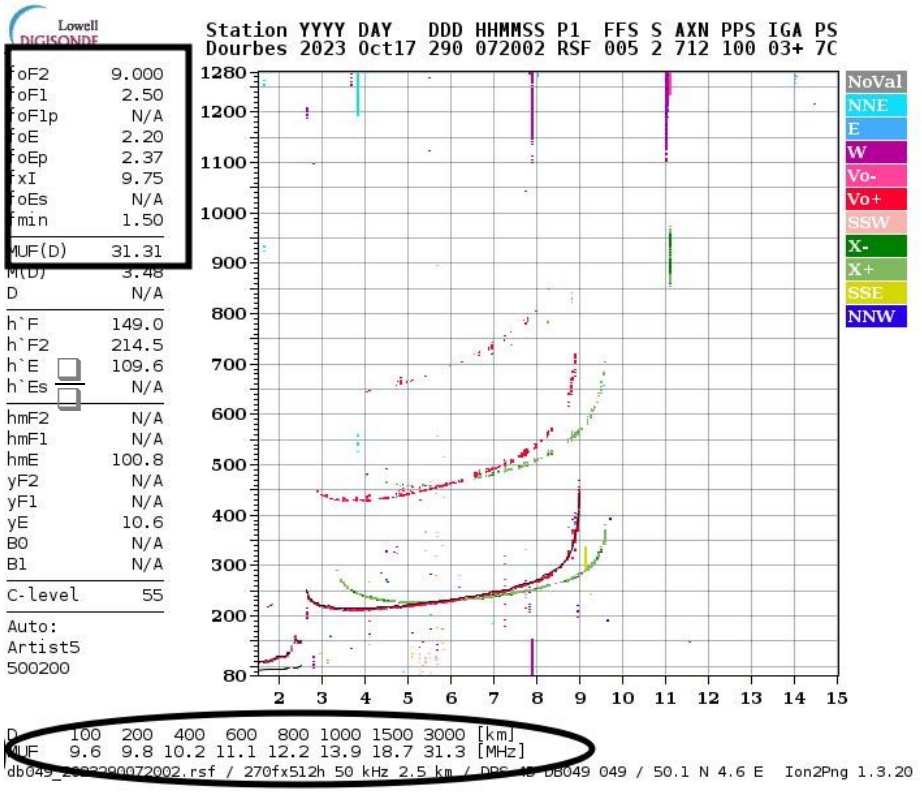
- $f_0$ This is the critical frequency for a given band e.g. $f_0E$ or $f_0F$
  - The highest frequency transmitted with vertical incidence, which, for that band that is not **reflected** back
  - Shows on the ionogram with vertical asymptotes



# Parameters that matter* (2)

- MUF  maximum usable frequency for a given path distance (spherical trig)
- MUF=$f_0$/Cosθ

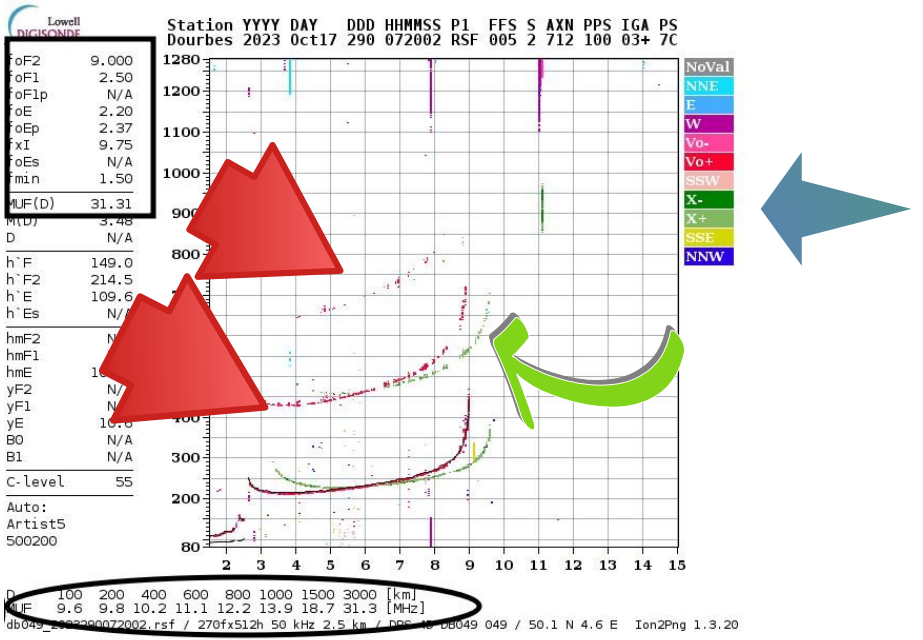
  θ=angle of incidence
- OTF  optimum traffic frequency. 85% MUF (avoids probs caused by ionospheric irregularities)
- Rules of thumb -MUF is often about 3Xcritical frequency, also if $f_0$ is above 9 or 10MHz 10m band likely to be open
- * to us, others matter to science!



# Parameters that don’t matter*

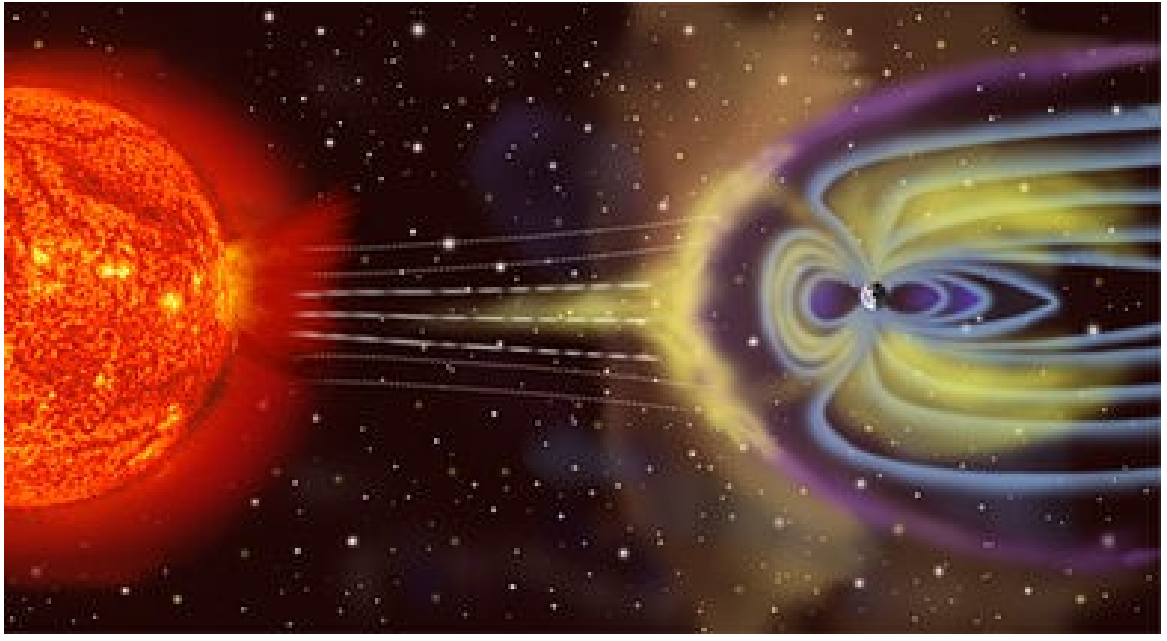
- Green Curves: extraordinary curve for birefringent refraction (x not o!)(green arrow)
- Ghost Curves: Many hop incident waves (red arrows)
- Colourful key (Blue/Grey arrow)

*to us!



# Solar wind and the Magnetosphere

- The ionosphere is affected by the solar wind
- The magnetosphere is affected too
- There is interraction and the solar wind can affect and even disrupt HF communications conditions



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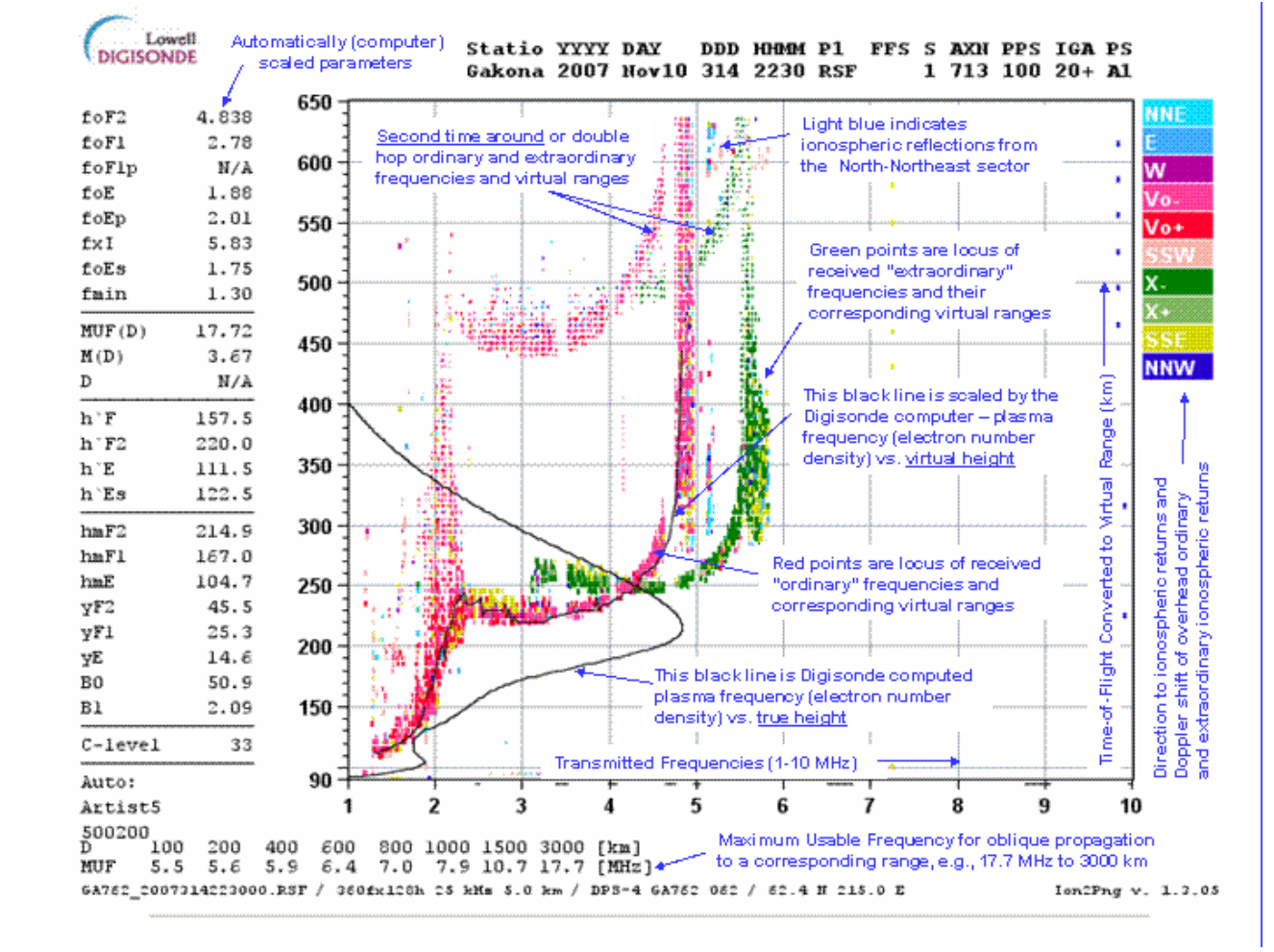
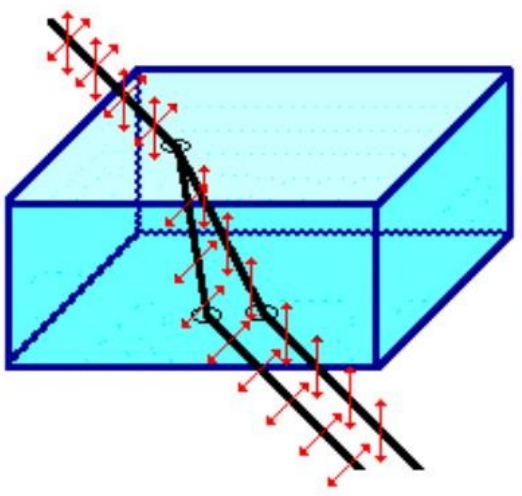


# Birefringence

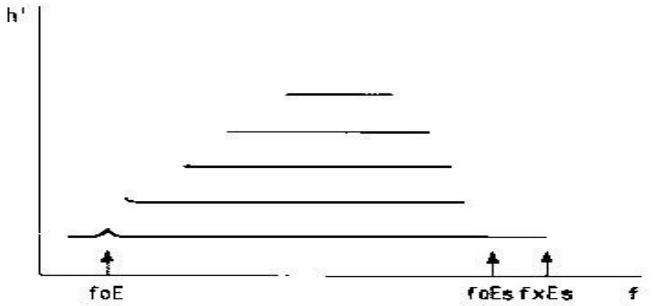
- Incident
  - *split* in
- Show tw
  double r
- Result o
  polarized
  - Due to
    two or
- Two rays
  filters
- → Evidenc



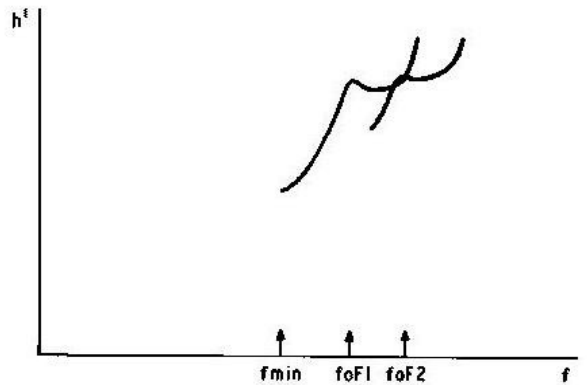
The two refracted rays passing through the Iceland Spar crystal are polarized with perpendicular orientations.

# What other useful things can be spotted?

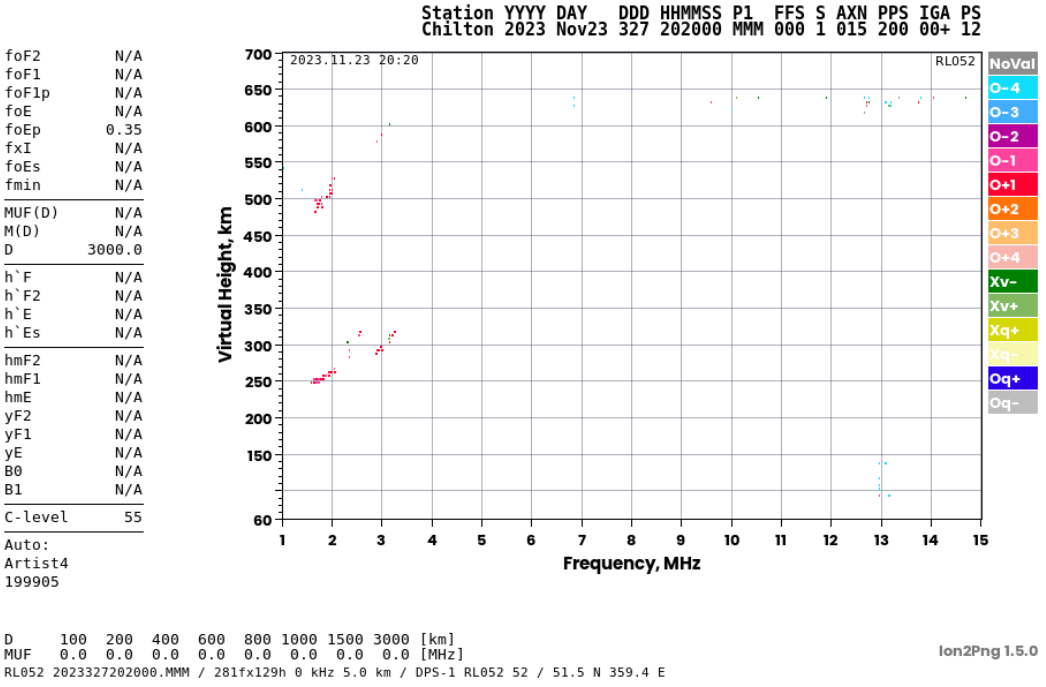
- Blackout or Blanketing




- High Absorption (Day)



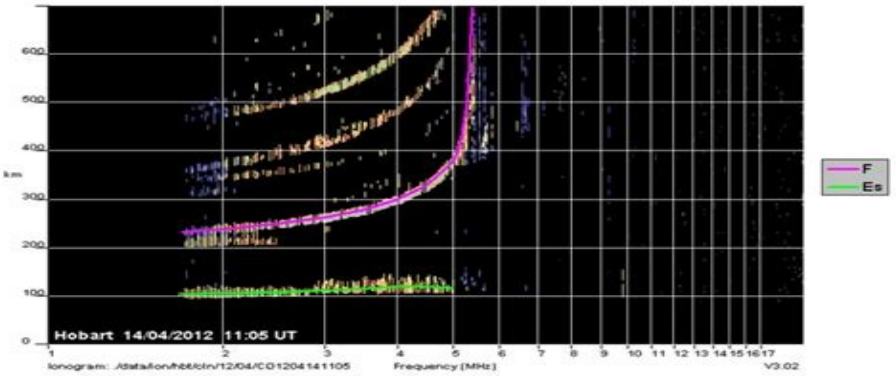
# Classic ‘bad day’ for a contest
# 23/11/23 RSGB Autumn Series CW



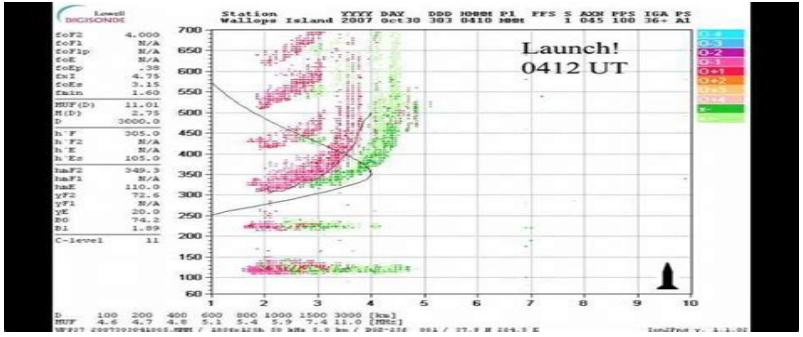
# Useful things (contd)

- Sporadic E – No asymptote!* Intense ionisation, high $E_0$ in 'clouds' floating about – heterogeneous and dynamic

  * no gradual slowing

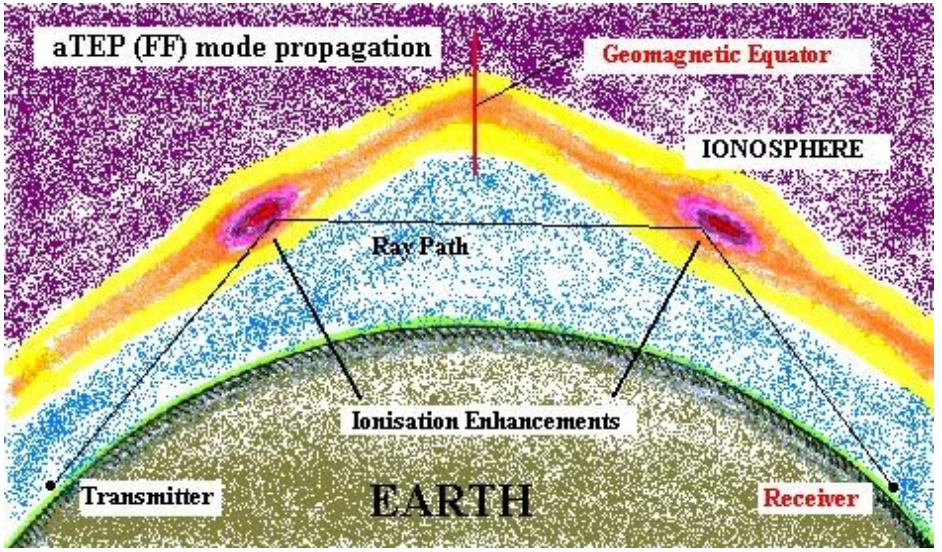



- Spread F – Can be FSF or Range FS -Magnetic and solar energy disturbances – height and frequency spread of ions



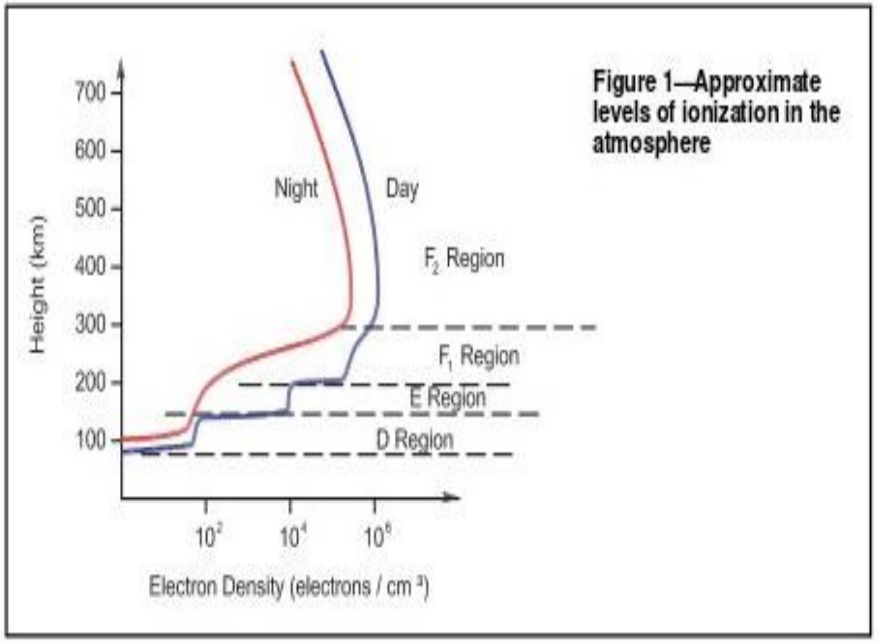
# The Anomolies and underlying mechanisms

- The Dynamic and non-homogenous nature of the layers: are they really like this?
- Gives transequatorial skip for example
- Reflected or refracted? How do vertical incidence waves get returned? Let’s get closer to the facts.
- Plasma and Plasma Frequency-mechanisms above and below



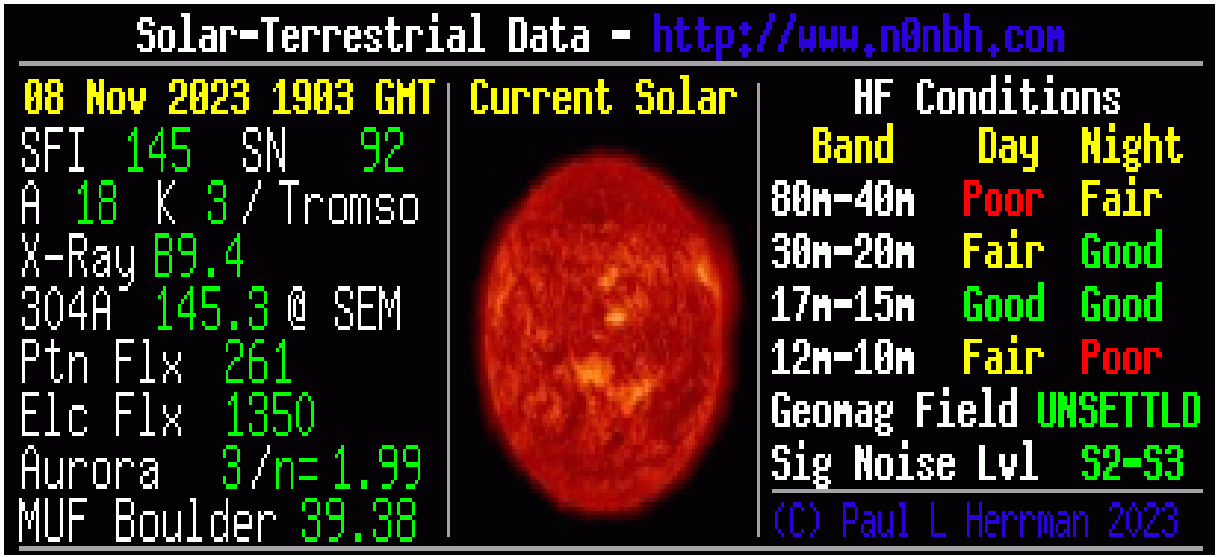
# Secondary sources -Ion Density distribution

- The layers are peaks
- Densities and states are affected by Solar Activity – Mass solar ejections* are bad!
- Sunspot numbers are key
- Densities and behaviour can be affected by Geomagnetic Storms
- Values result from continuous ion creation and recombination



# Related Data except A & K

- SFI - solar flux index – 50-90 is poor, 100-200 is better, Over 220* could be bad
- SN – sunspot number
- X-Ray -hard Xrays , affects mainly D layer
- 304A – Relative strength of solar radiation at 304 Angstroms (gives abut half all ionisation for F layer
- Ptn Flx – Proton Flux in the solar wind , mostly affects the E layer
- Elc Flux – Electron Flux as for above but electrons
- Aurora – Strength of F layer in polar regions affects chances of Auroral activity



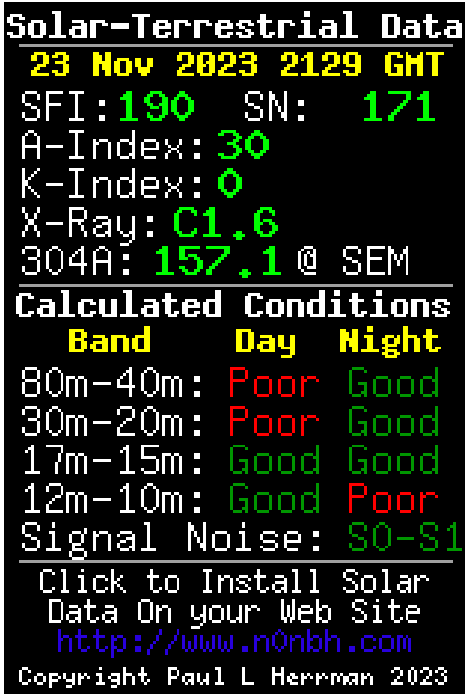
# A&K

- Not agents in Men in Black  but two indices describing the geomagnetic activity – Magnetometer based.
- K – measured over 3 hours (8 times day$^{-1)}$ ) Is a factor that is quasi logarithmic , so can’t be simply averaged. (horizontal component of geomagnetic field and measures disturbance)
- A – uses essence of K to provide an average
  - High A and K indicates Geomagnetic Flux is unstable
  - One high one low- indicates  sudden,abrupt changes and intense but brief comms  failure
  - A is a non-logarithmic term from the defining mathematics

# A&K values

| A | K | Comments |
|---|---|---|
| 0 | 0 | Quiet |
| 2 | 1 | Quiet |
| 3 | 1 | Quiet |
| 4 | 1 | Quiet to unsettled |
| 7 | 2 | Unsettled |
| 15 | 3 | Active |
| 27 | 4 | Active |
| 48 | 5 | Minor storm |
| 80 | 6 | Major storm |
| 132 | 7 | Severe storm |
| 208 | 8 | Very major storm |
| 400 | 9 | Very major storm |

# Solar -Terrestrial data for that ‘bad day’



# Storms are not always bad! Just more often than not!

- Because of the swirling ion densities, some patches can show a higher MUF, Fcrit ( relatively locally, temporarily), whilst other show a lowered MUF. (Fcrit)
- The article in this months RADCOM p.26 ( January ‘24.Vol 100) demonstrates for the storm of November 5/6/7 2023
- n.b. K reached 5,6,7 (Minor;Major;Severe storm)

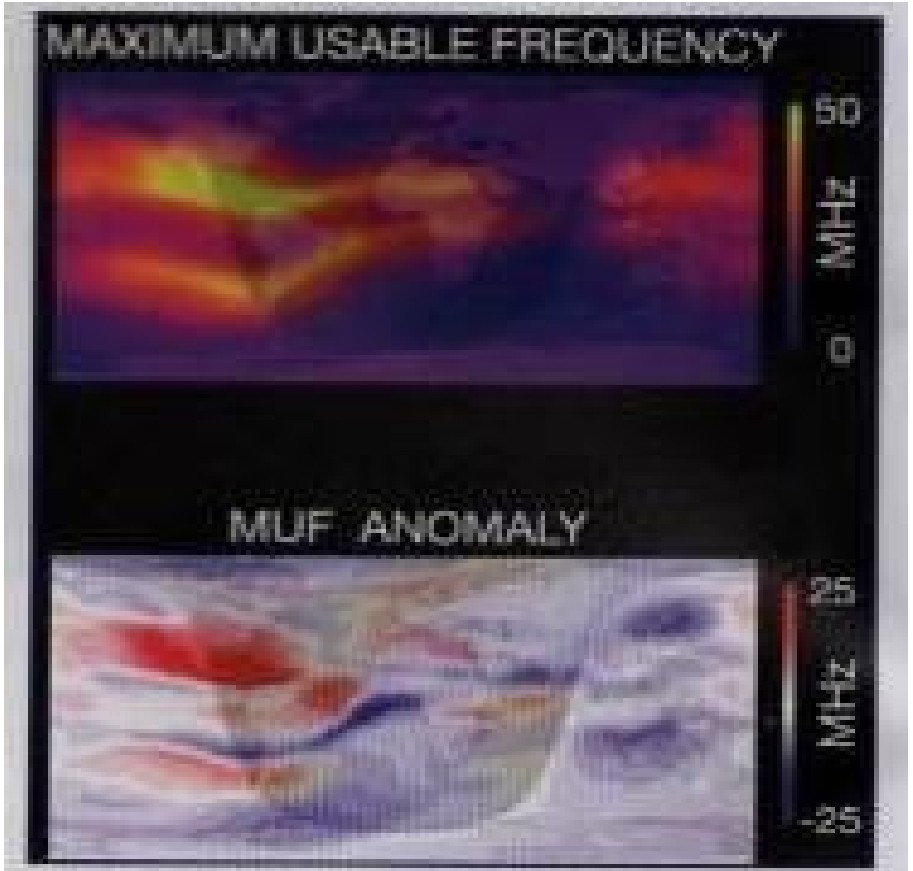



FIGURE 2: Top: Global map of simulated maximum usable frequencies (0-50MHz) at 0000UTC on 6 November. Bottom: Global map of simulated maximum usable frequency anomalies (-25 to +25 MHz) [4].



# MUF and a November storm

**Geomagnetic storms often lower the maximum usable HF frequency. In some cases a major storm can *raise* the frequency limit.**

Carl Leutzelschwab, K9LA points out that the electron density in the F2 region of the ionosphere can be enhanced by a storm in a variety of ways depending on latitude [1]. This temporarily increases the maximum usable frequency (MUF).

For example, a geomagnetic storm that affected MUF around the globe began at 0900UTC on 5 November 2023. **Figure 1** shows the three-hour averaged planetary K index levels, Kp *vs* UTC time [2]. The peak at 1500UTC on 5 November was followed by fluctuating G1-class activity ending at 0600UTC on 7 November. The NOAA severity scale levels at the right side of the figure show that the peak level is Strong (G3). **Table 1** shows the NOAA Space Weather Scale for Geomagnetic Storms [3].

The global maps in **Figure 2** from a NOAA computer simulation show the greatest MUF effects, which are at 0000UTC on 6 November. Color contours in the top map show MUF is 50MHz or higher near the day/night terminator in the Central and North American sectors. The bottom map shows how much the MUF changed: an MUF anomaly (-25MHz to 25MHz) is the difference between MUF and the running ten-day average of MUF measured at the same time of day. Red regions of increased MUF and blue regions of decreased MUF are scattered around the globe.

The maps in Figure 2 are from the NOAA Whole Atmosphere Model (WAM-IPE), a global 3D model with altitude extending from 90km to 10,000km [4]. On the NOAA website you can view animated maps for the previous 24 hours as well as two-day forecasts. The MUF is for single-hop transmissions between stations 3000km apart, and the values are shown at the mid-points between stations. For comparison, MUF for 3000km is three times the critical frequency (foF2) measured with an ionosonde [5].

The NOAA model results in Figure 2 show that this storm had no significant effect on MUF in the UK region. Measurements from the Chilton ionosonde confirm this. You can use the online PropQuest application by Jim Bacon, G3YLA, to compare measurements of foF2 during the storm with any previous day [6]. Long range transmissions to and from UK stations may have been affected if there was an MUF anomaly where the signal was refracted.

Storm-related changes in HF propagation depend on latitude, the season of the year, and the local time when a storm begins. A single storm can have both positive (higher MUF) and negative (lower MUF) phases. At middle latitudes, including the UK, storms that mainly lower MUF are more frequent than storms that raise MUF.

From K9LA: "So always keep an ear open during geomagnetic storms. If you're in the right place at the right time, you may be pleasantly surprised" [1].

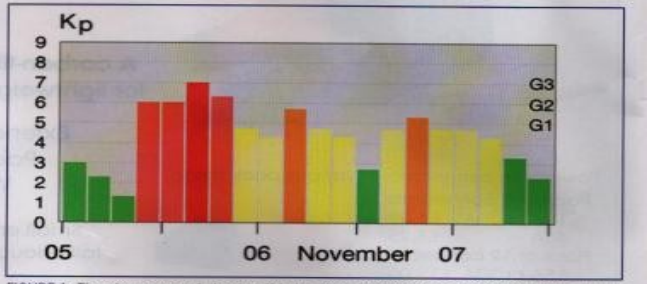



FIGURE 1: Three-hour averaged planetary K-index, Kp vs UTC time for 5-7 November, 2023, storm. Data from [2].

TABLE 1: NOAA Space Weather Scale for Geomagnetic Storms [3].

| Level | | Kp |
|---|---|---|
| G5 | Extreme | 9 |
| G4 | Severe | 8 |
| G3 | Strong | 7 |
| G2 | Moderate | 6 |
| G1 | Minor | 5 |

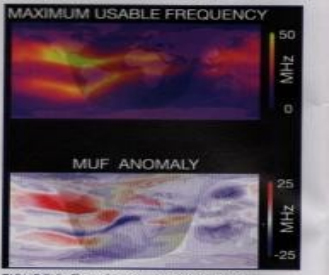



FIGURE 2: Top: Global map of simulated maximum usable frequencies (0-50MHz) at 0000UTC on 6 November. Bottom: Global map of simulated maximum usable frequency anomalies (-25 to +25 MHz) [4].

**References**

[1] Carl Leutzelschwab, K9LA, Electron density changes during geomagnetic storms. https://k9la.us/Jan18_Bonus_-_Electron_Density_Changes_During_Geomagnetic_Storms.pdf
[2] https://swpc.noaa.gov/products/planetary-k-index
[3] https://www.swpc.noaa.gov/noaa-scales-explanation
[4] https://www.swpc.noaa.gov/products/wam-ipe
[5] Steve Nichols, GOKYA, *Radio Propagation Explained*, RSGB.
[6] https://www.propquest.co.uk/graphs.php

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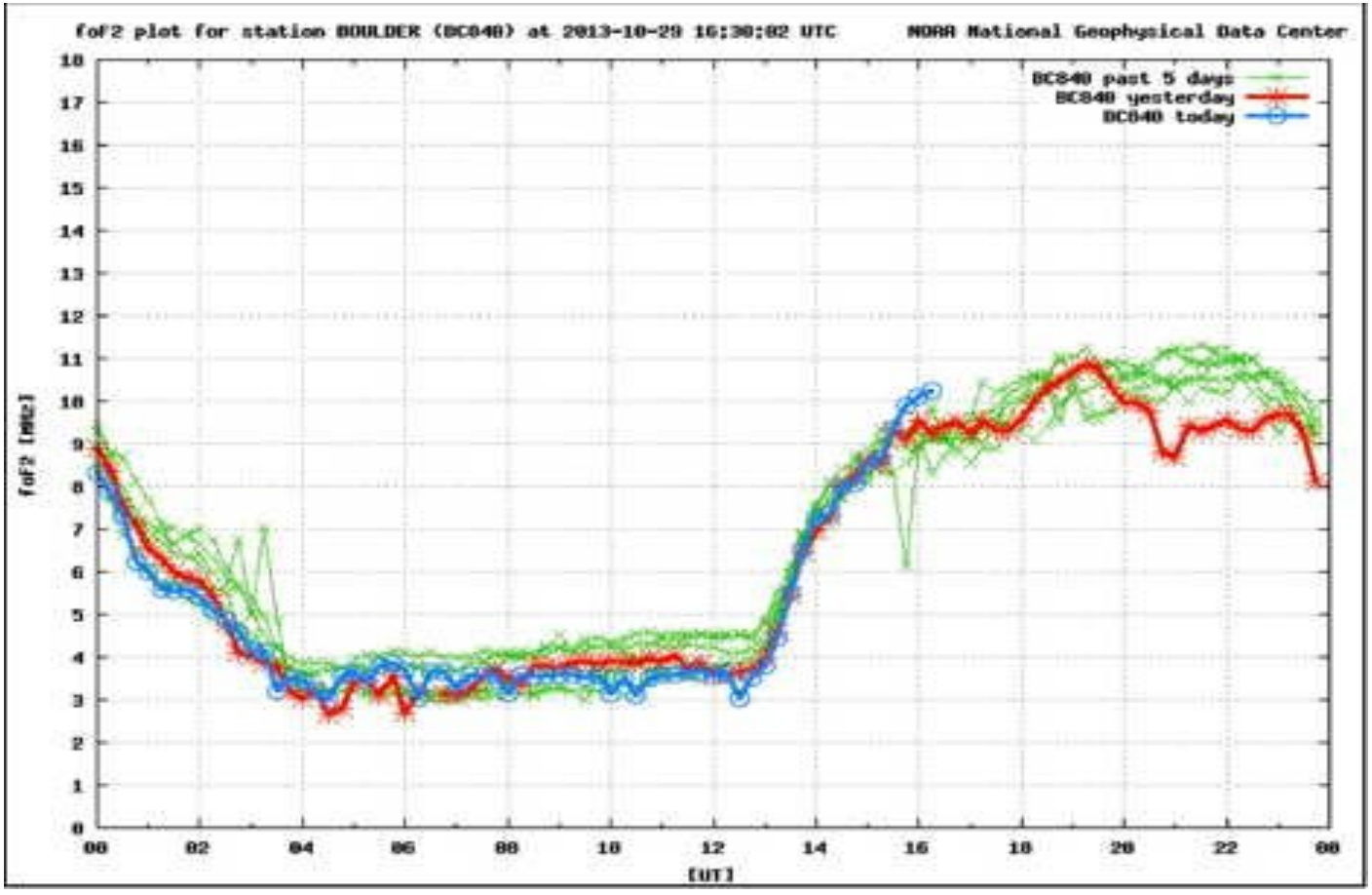
# Other useful data – F2 over time



**Acknowledgements and references:**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**Interpreting digital ionograms G4FKH Radcom May 2009**

**http://hamwaves.com/en, Serge Stroombandt ON4AA**

**MUF and November Storm,Peter De Neef AE7PD Radcom January 2024**