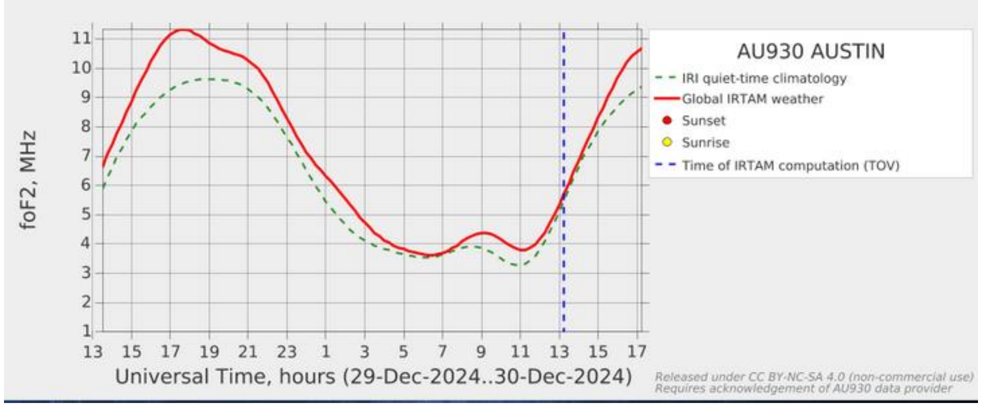


Understanding and Using The GAMBIT Ionosonde Product

W5IFQ

7 JAN 2025

Purpose

- With lose of NOAA Ionosonde support, Learn how to use GAMBIT to obtain foF2 (Critical Frequency) at any location.
- Learn how NVIS (Near Vertical Incident Sky

wave) propagation is dependent on Ionospheric Critical Frequency.

- Learn how Long Range propagation is dependent on the Critical Frequency.

Why Use Ionosondes?

- Ionosondes are one of the very limited means to obtain real-time propagation assessment of the upper Ionosphere. They measure the density of electrons in the F2 layer by direct radio wave reflection unlike other propagation evaluation methods that measure secondary parameters like Solar Flux Index, Sun Spot Number and Planetary Magnetic indices.
- At the present time, adequate scientific modeling of Ionospheric propagation does not work well, so actual measurements of propagation parameters must be done.

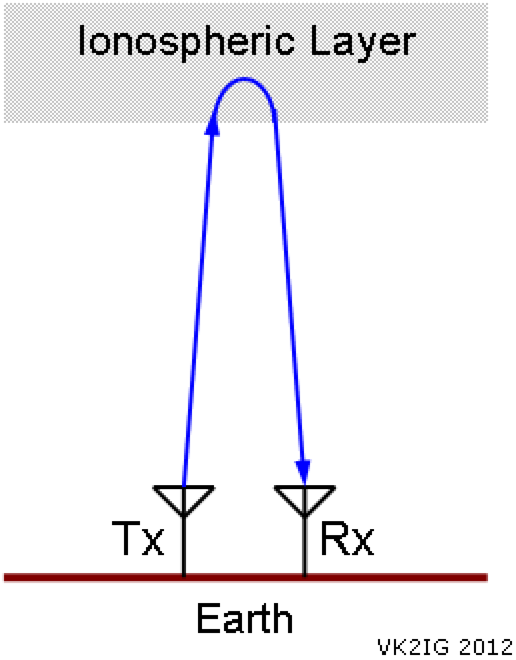
Presentation Outline

- Description of an Ionosonde
- Use of GAMBIT to obtain Ionosonde data
- NVIS Propagation Theory
- Long-Range Propagation Theory
- Anomalies in Ionosonde Data

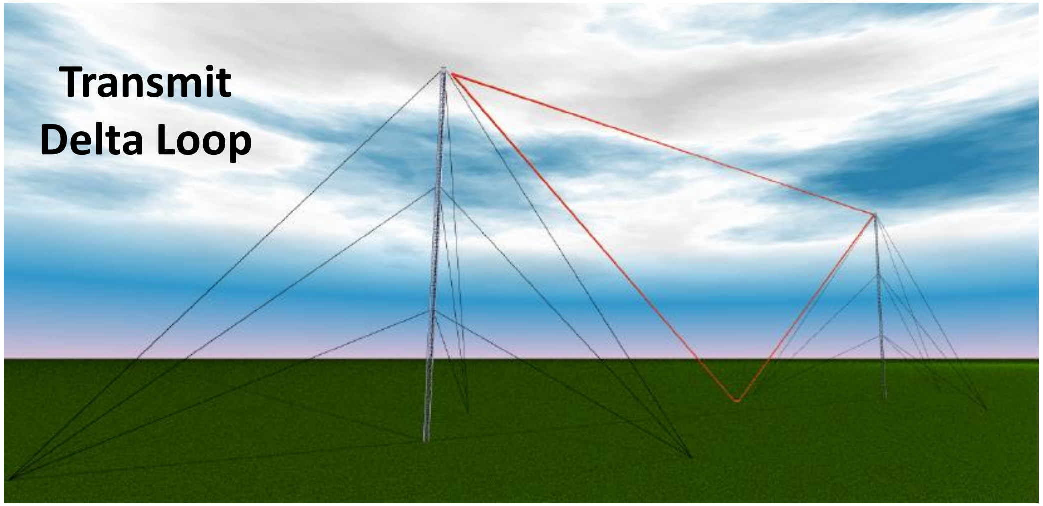
What is an Ionosonde?

- Vertically projecting HF RADAR.
- Transmit frequency is stepped from 1 MHz to 20 MHz in about 100 KHz steps.
- Each transmit frequency consists of a series of narrow pulse-width signals that are averaged by the receiver.
- A circularly polarized receiving array is used to maximize reception and to separate the Ordinary and Extraordinary radio echoes from each other.

Typical Ionosonde - Austin AU930



VK2IG 2012

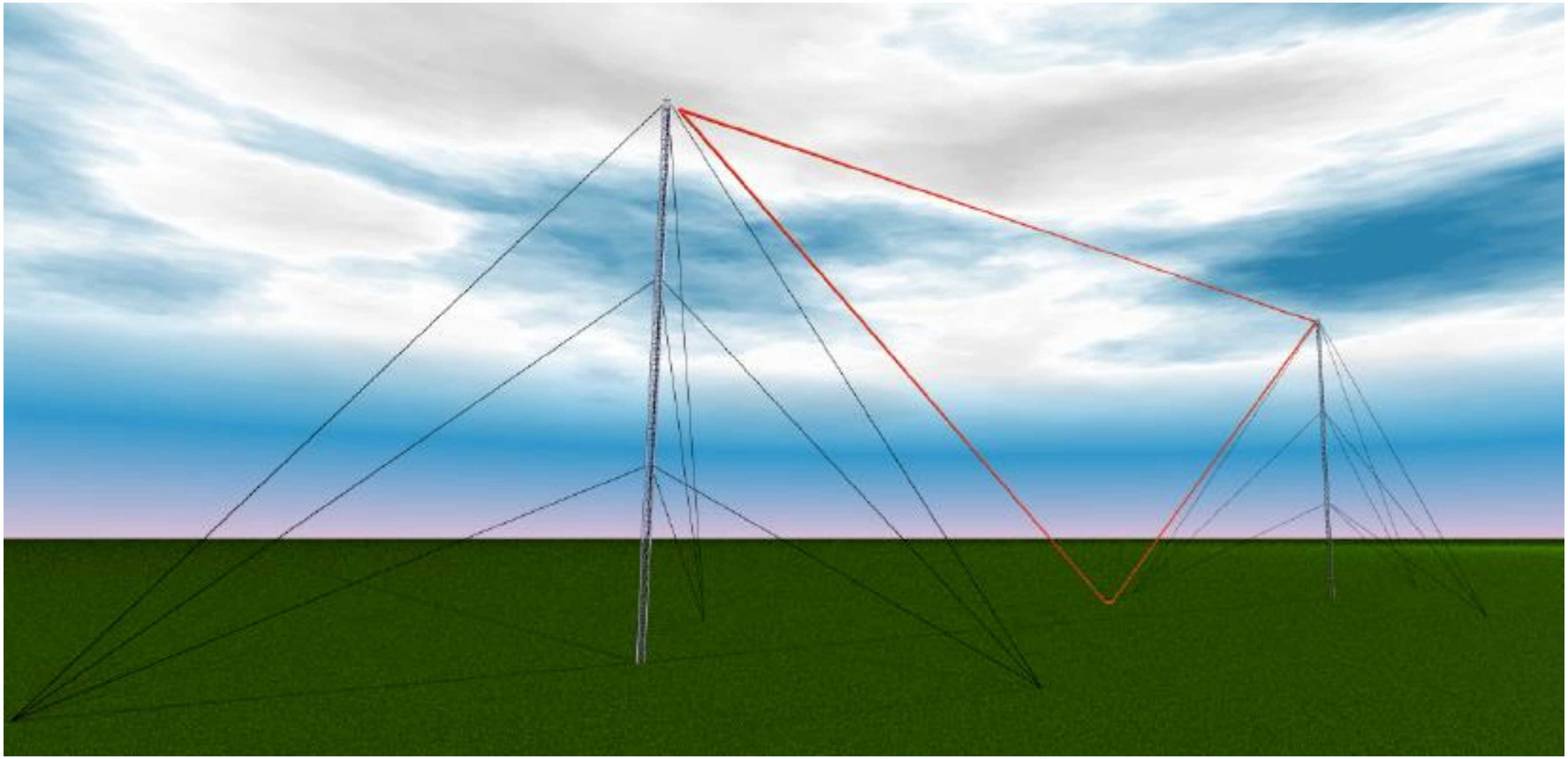

Transmit Delta Loop


Receiving Array Masts

Radio Characteristics of AU930 - Austin

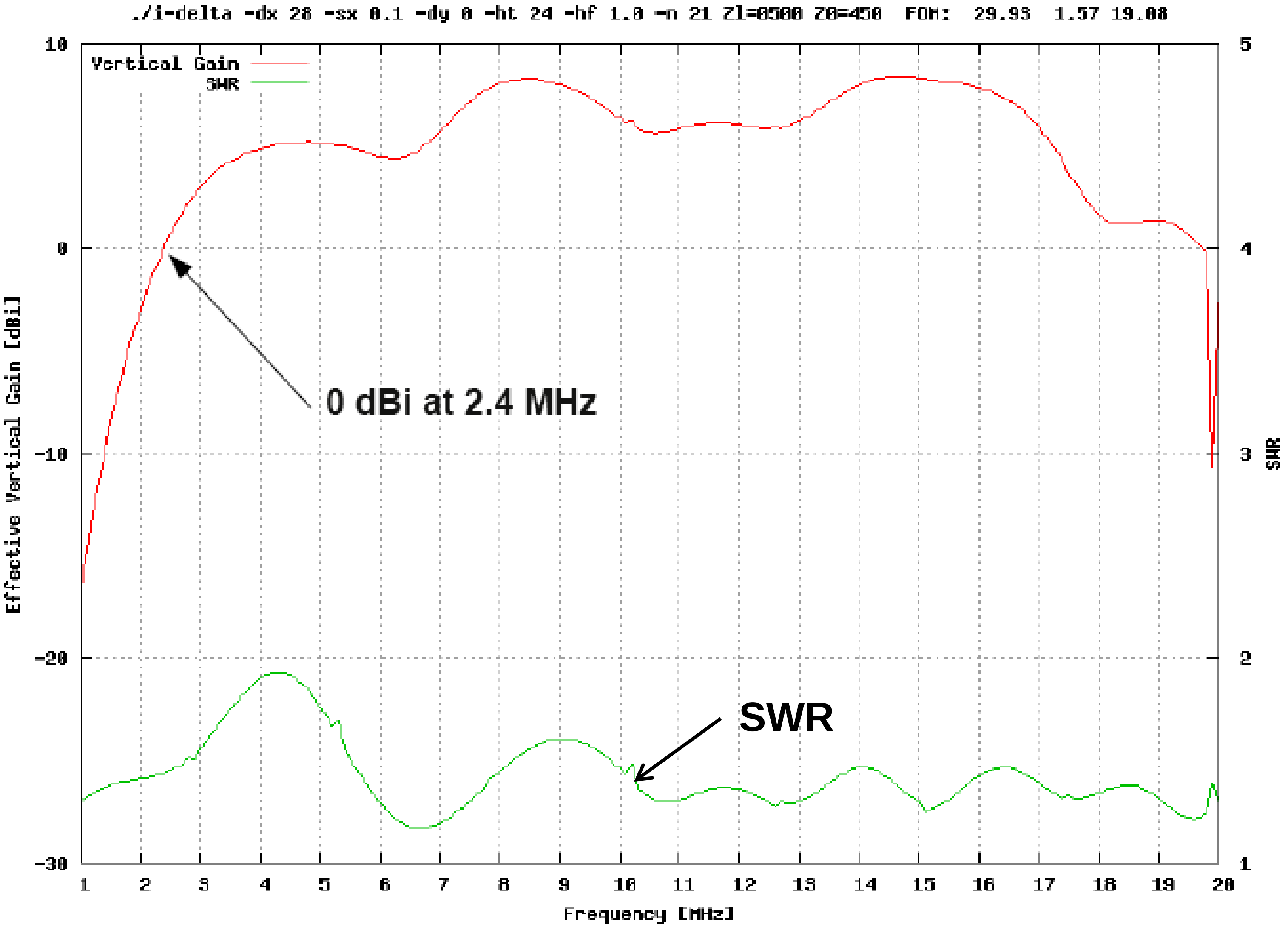
- Sounding Frequency Range – 1 – 20 MHz
- Frequency step – 100 KHz
- Pulse – 70 usec, Gaussian envelope
- Pulses at each frequency – 64
  - 32 pulses for Ordinary wave acquisition
  - 32 pulses for Extraordinary wave acquisition
- Repetition rate – 100 Hz
- Data set sweep time – 3 minutes
- Data collection interval – 5 minutes
- Transmit power – 4 KW PEP
- Display – Power spectrum density versus frequency

Inverted Delta Transmit Antenna



- **+10 dB better than a single tower at only double the cost**
- **Traveling wave antenna**
- **Bottom feed point (balun)**
- **600 ohm termination in center of top section**
- **Two 80 ft Rohn 25G guyed towers (130 mi/hr wind design) spaced 180 ft apart. Guys wires – Phillystran**

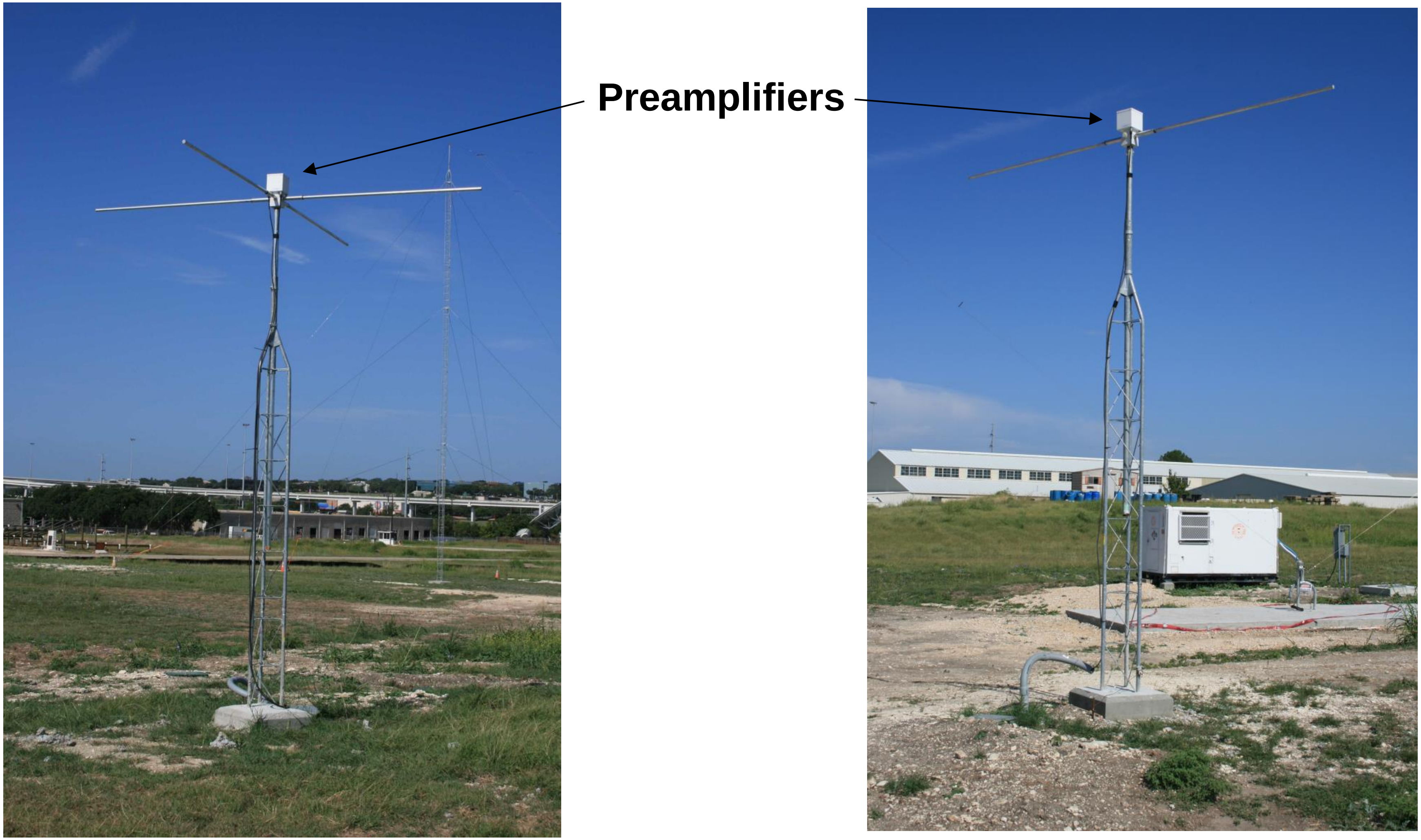
Delta Antenna Performance



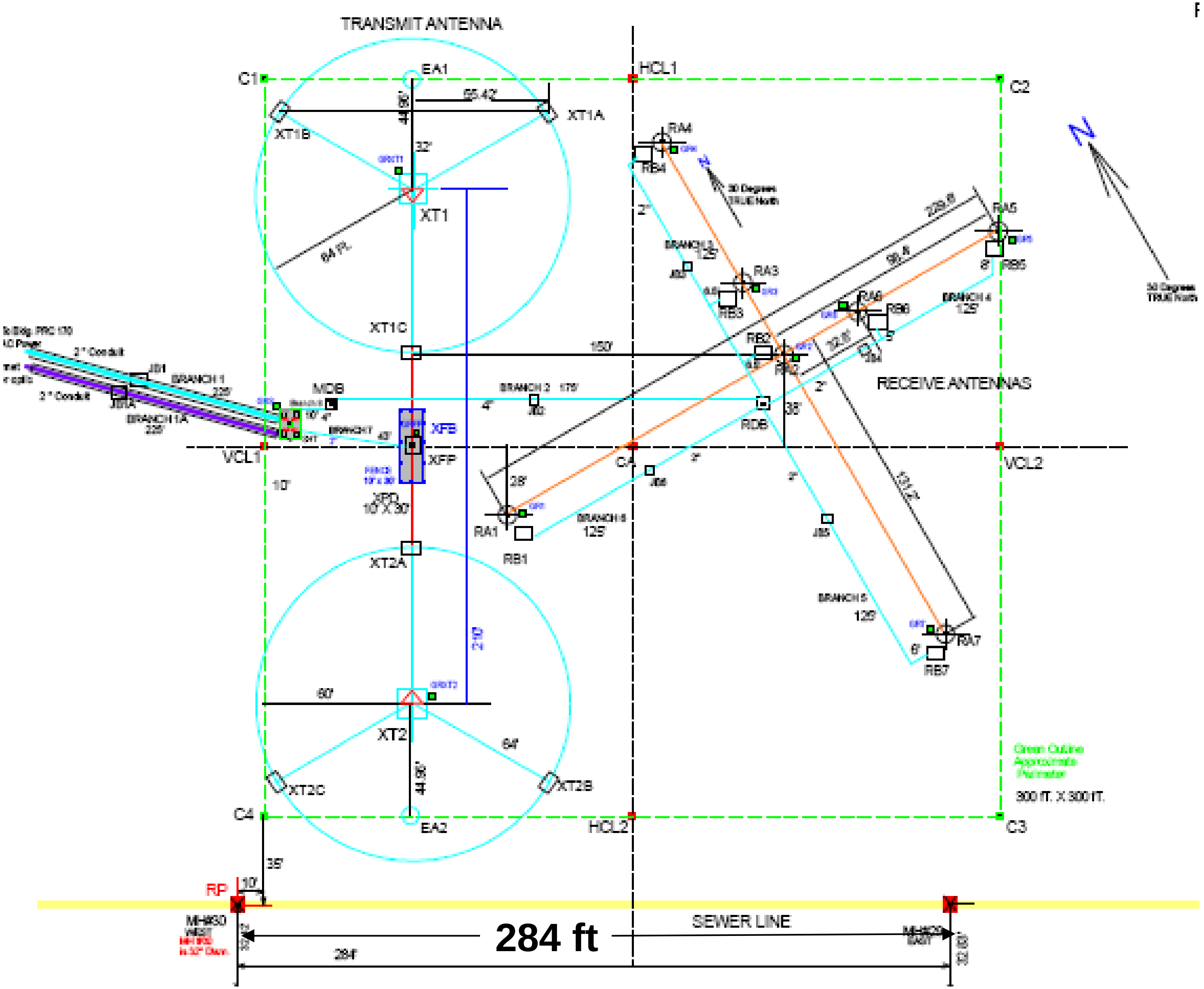
0 dBi at 2.4 MHz

SWR

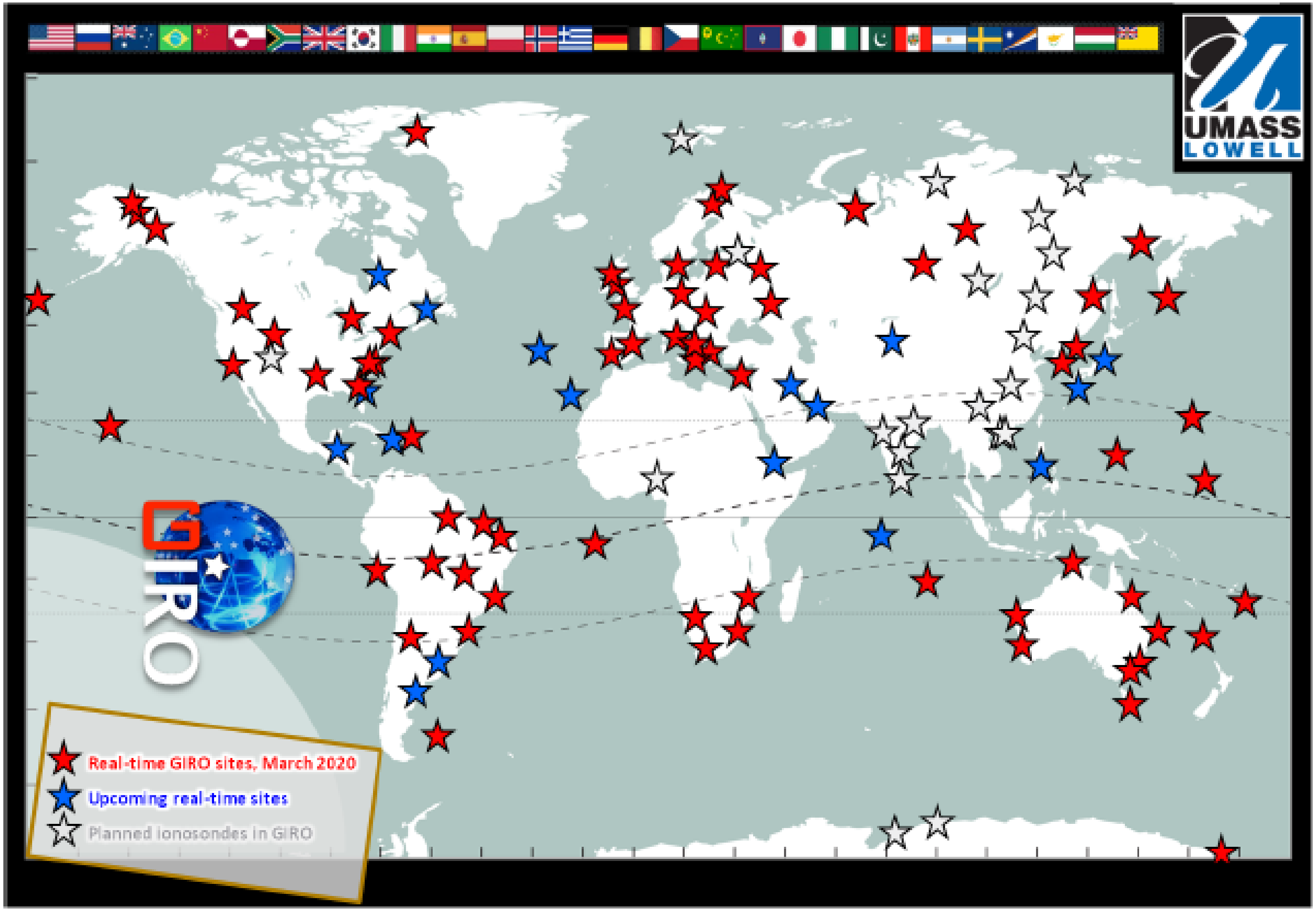
Receive Antennas (7 – 20 ft. towers)



Physical Layout of Ionosonde



Ionosonde Locations Used By GIRO



GAMBIT Ionosonde Data Product

- **NOAA is no longer supporting Ionosonde data distribution**.
- The University of Massachusetts, Lowell's GIRO (global Ionosphere Radio Observatory) Data Center provides a number of useful products that can assist HF radio operators in selecting the best HF operating frequency.
- Their GAMBIT (Global Assimilative Model of Bottomside Ionosphere Timeline) product uses IRTAM (IRI Real Time Assimilative Mapping) model to compute foF2 and other useful products every 15 minutes using **real time data** from their world wide Ionosonde data base.
- For more details on IRTAM, See: https://giro.uml.edu/IRTAM/
- I have compared the Austin Ionosonde (AU930) FTP direct feed Ionograms to GAMBIT plot for AU930 and found very good agreement even though AU930 is not presently part of the GIRO Ionosonde data base.

Use of GAMBIT For foF2 Plots

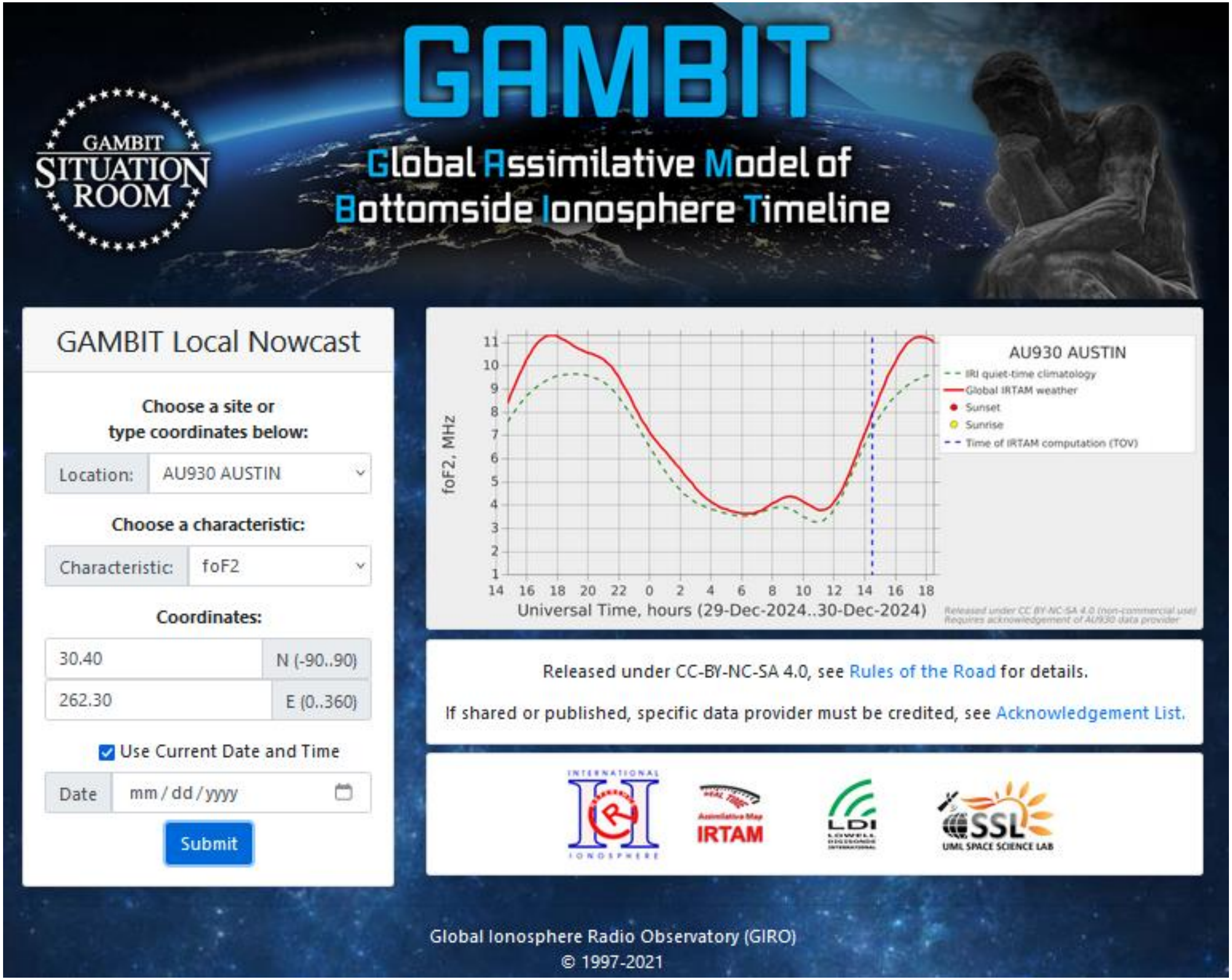
- Go to https://giro.uml.edu/rix/gambit-local-nowcast/ .
- The GAMBIT page can be seen on page 15 with the Austin Ionosonde (AU930) selected for foF2 display. Operation is as follows:
  - ***Location*** – A pull down screen allows the user to select a specific Ionosonde by name. Actual user location can be also be entered in the *Coordinates* fields. Note that North Latitude is positive sign. Longitude is in East notation requiring the user to subtract his West longitude from 360. For example -97.8˚ W = 262.2˚ E. For stations with East Longitude, simple enter East longitude value.
  - ***Characteristic*** *fields available:*
    - ***foF2 -*** **Critical Frequency, MHz**
    - *NmF2* – Electron density in the F2 layer (not important)
    - ***hmF2* – Height of the F2 layer, Km**
    - *B0*, B1 – IRI vertical profiles (not important)

Select *– current date and time (you do not need to enter date and time)*

Click *– Submit*

If the GIRO server is available, the plot on page 15 will be generated. If no result wait and try again later. I would recommend copying this plot for use for the next 24 hours if no severe Ionospheric storms are forecasted. Note that date/time on the horizontal axis is in UTC and can include a change in date.

This plot can be easily copied and printed using *Snipping Tool* or similar graphical capture programs. If you distribute this data please include the source (see rules of the road).



GAMBIT

Global Assimilative Model of Bottomside Ionosphere Timeline

GAMBIT Local Nowcast

Choose a site or type coordinates below:

Location: AU930 AUSTIN

Choose a characteristic:

Characteristic: foF2

Coordinates:

30.40 N (-90..90)

262.30 E (0..360)

☑ Use Current Date and Time

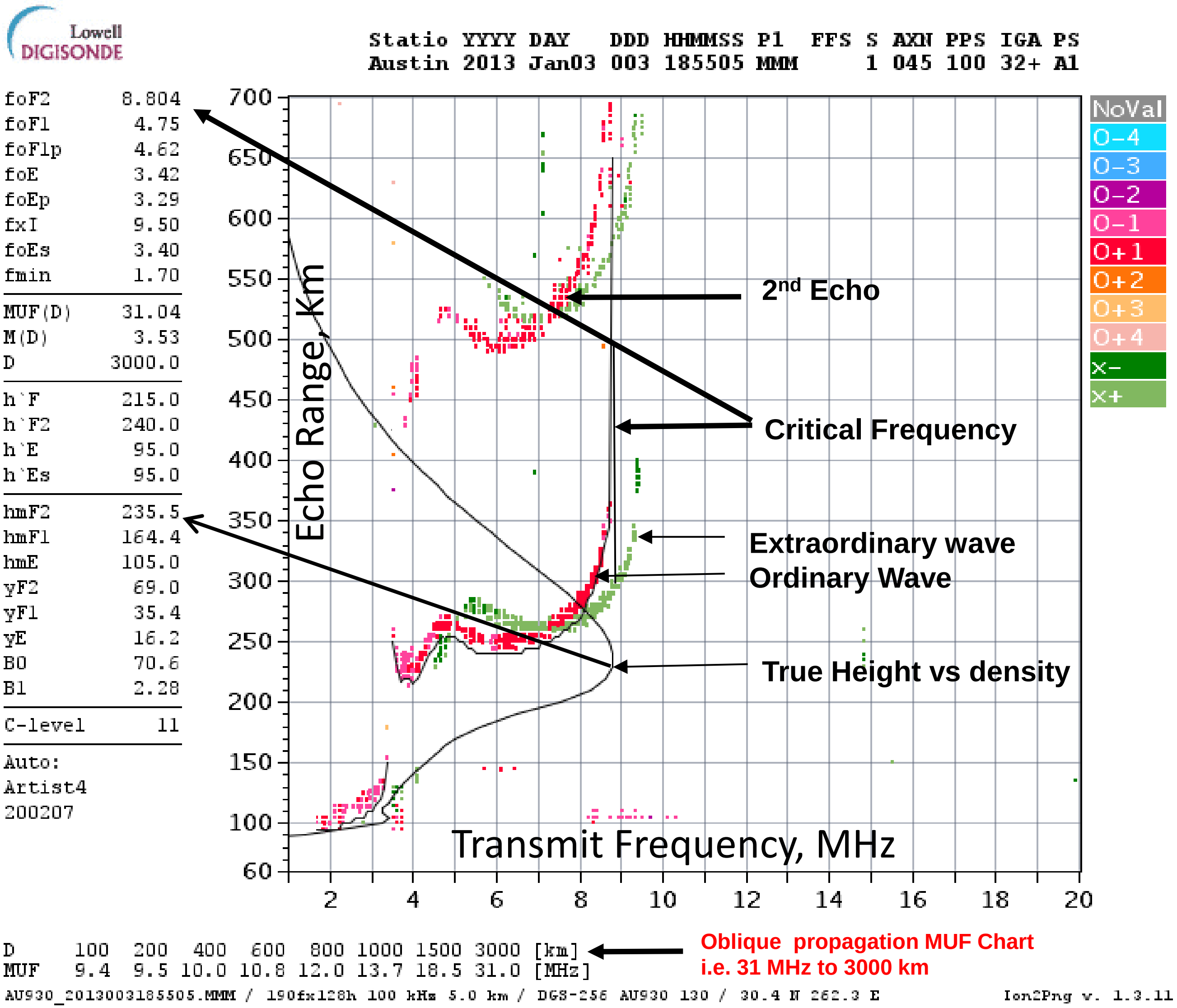
Date mm / dd / yyyy

Released under CC-BY-NC-SA 4.0, see Rules of the Road for details.

If shared or published, specific data provider must be credited, see Acknowledgement List.

Global Ionosphere Radio Observatory (GIRO)

Ionosonde Ionogram Interpretation



```
Statio YYYY DAY   DDD HHMMSS P1   FFS S AXN PPS IGA PS
Austin 2013 Jan03 003 185505 MMM      1 045 100 32+ A1

foF2      8.804
foF1       4.75
foF1p      4.62
foE        3.42
foEp       3.29
fxI        9.50
foEs       3.40
fmin       1.70
MUF(D)    31.04
M(D)       3.53
D        3000.0
h`F       215.0
h`F2      240.0
h`E        95.0
h`Es       95.0
hmF2      235.5
hmF1      164.4
hmE       105.0
yF2        69.0
yF1        35.4
yE         16.2
B0         70.6
B1         2.28
C-level      11
Auto:
Artist4
200207

D     100  200  400  600  800 1000 1500 3000 [km]
MUF   9.4  9.5 10.0 10.8 12.0 13.7 18.5 31.0 [MHz]
AU930_2013003185505.MMM / 190fx128h 100 kHz 5.0 km / DGS-256 AU930 130 / 30.4 N 262.3 E          Ion2Png v. 1.3.11
```

2nd Echo

Critical Frequency

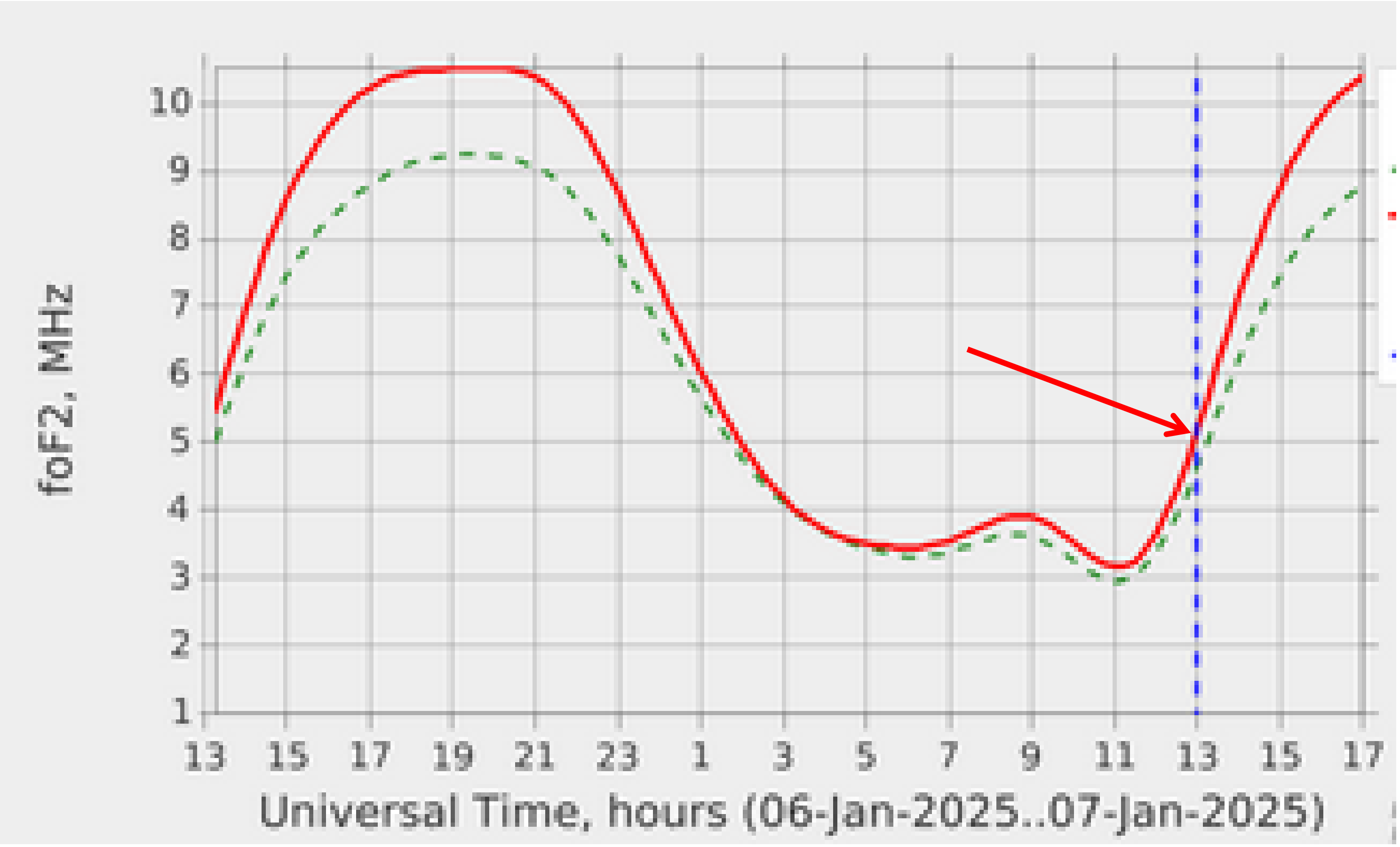
Extraordinary wave

Ordinary Wave

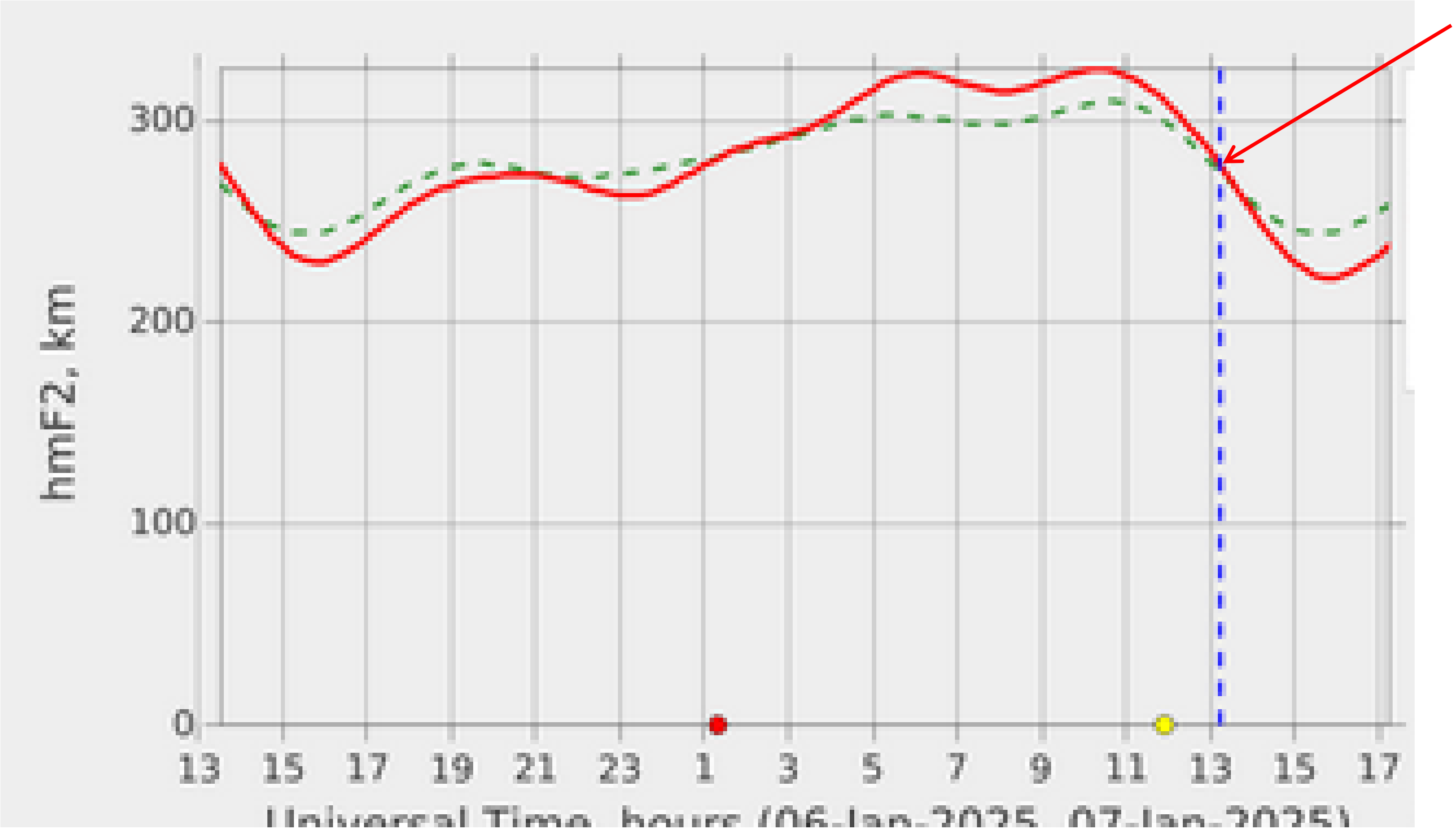
True Height vs density

Oblique propagation MUF Chart
i.e. 31 MHz to 3000 km

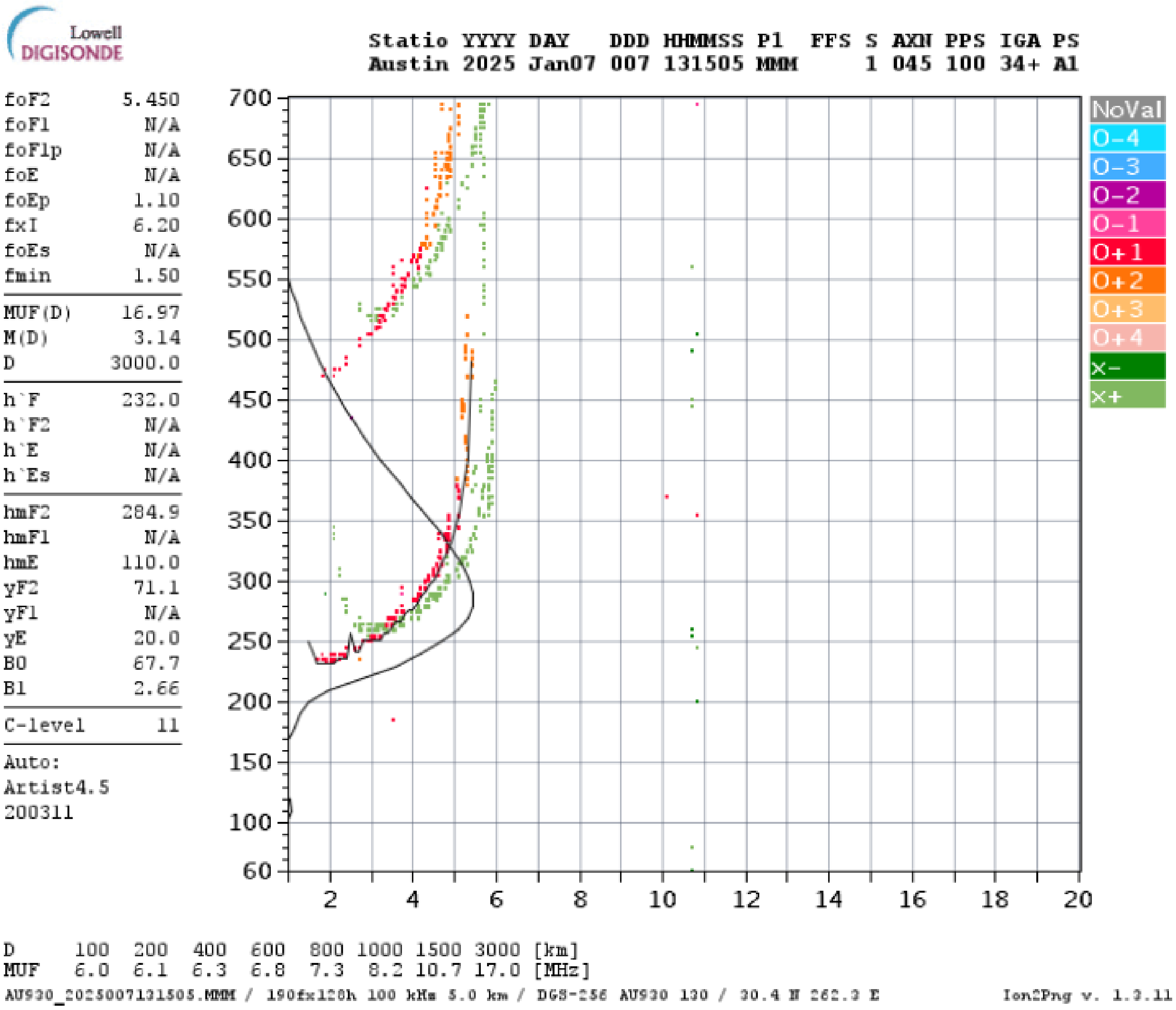
GAMBIT foF2 for Austin Ionosonde



GAMBIT hmF2 for Austin Ionosonde



Ionogram for Austin Ionosonde



```
Statio YYYY DAY   DDD HHMMSS P1   FFS S AXN PPS IGA PS
Austin 2025 Jan07 007 131505 MMM      1 045 100 34+ A1
```

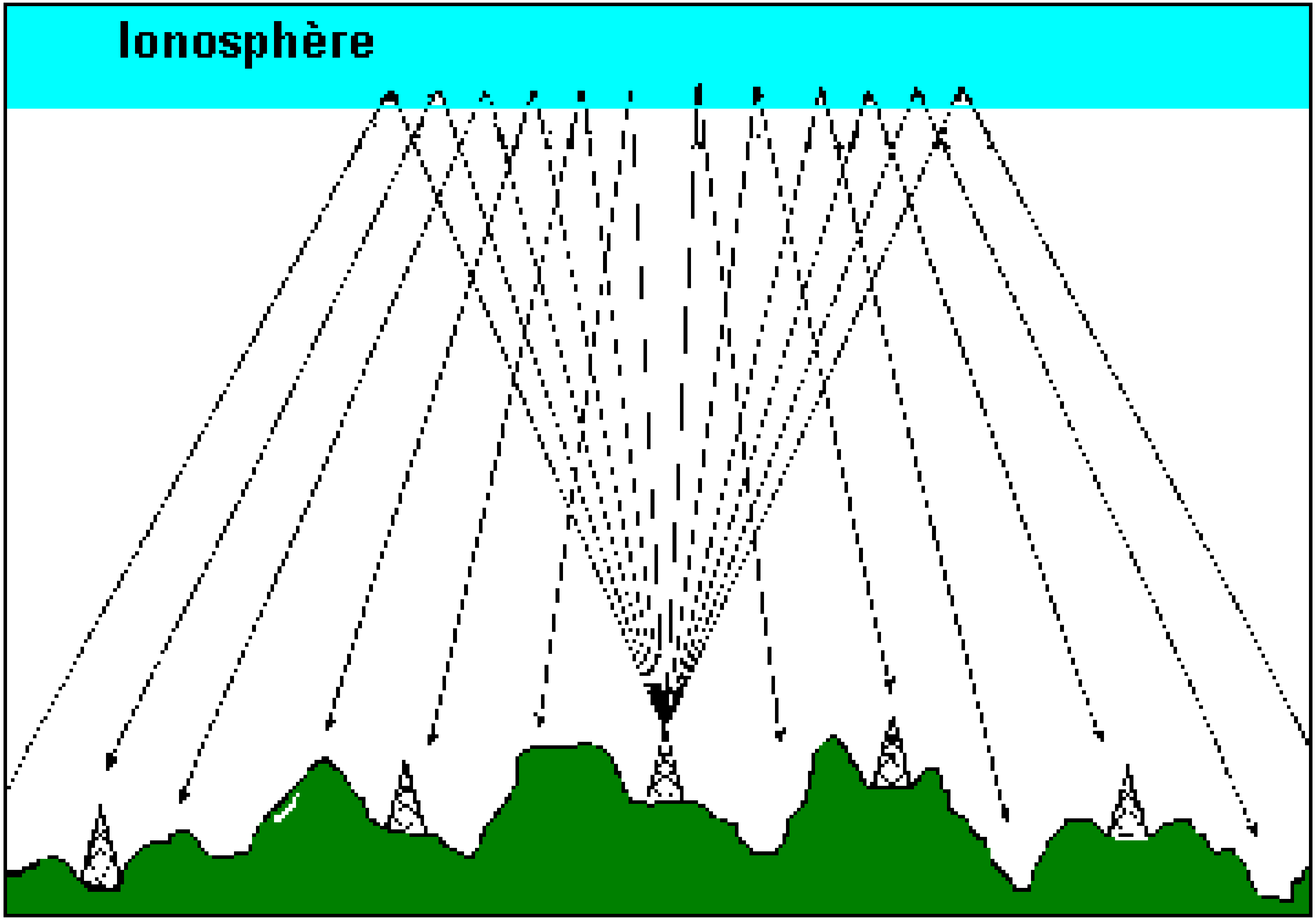
```
foF2       5.450
foF1         N/A
foF1p        N/A
foE          N/A
foEp        1.10
fxI         6.20
foEs         N/A
fmin        1.50
MUF(D)     16.97
M(D)        3.14
D         3000.0
h`F        232.0
h`F2         N/A
h`E          N/A
h`Es         N/A
hmF2       284.9
hmF1         N/A
hmE        110.0
yF2         71.1
yF1          N/A
yE          20.0
B0          67.7
B1          2.66
C-level       11
Auto:
Artist4.5
200311
```

```
D     100  200  400  600  800 1000 1500 3000 [km]
MUF   6.0  6.1  6.3  6.8  7.3  8.2 10.7 17.0 [MHz]
AU930_2025007131505.MMM / 190fx120h 100 kHz 5.0 km / DGS-256 AU930 130 / 30.4 N 262.3 E          Ion2Png v. 1.3.11
```

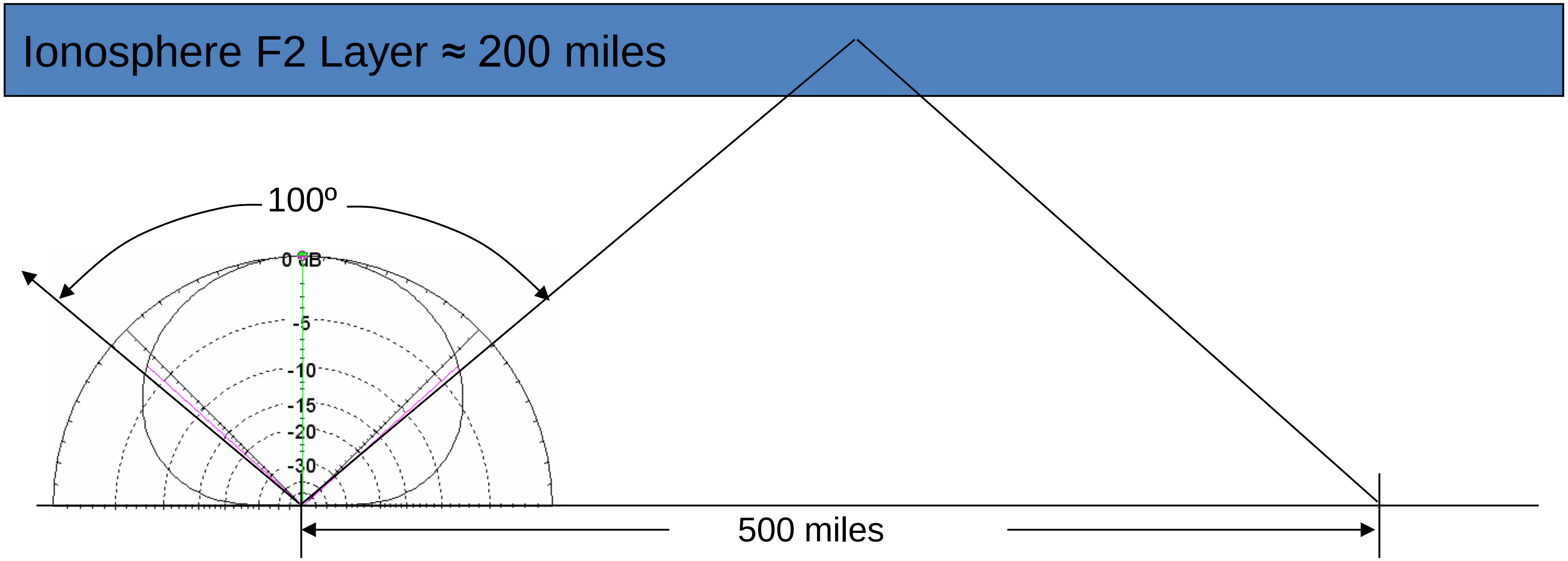
Accuracy Comment

- Note: Very good agreement between GAMBIT and the Austin Ionogram for 1315Z. GAMBIT re-computes every 15 minutes.
- Without major Geomagnetic anomalies, the GAMBIT plot should be good for 24 hours.
- The Austin Ionogram is only valid at a specific time of day and can go down at any time. It is available only at:
- https://www.region6armymars.org/resources/solarweather.php

NVIS Propagation



Antenna Requirement for NVIS Propagation



Ionosphere F2 Layer ≈ 200 miles

100º

500 miles

Only F2 layer propagation can provide necessary range

IONOSPHERE

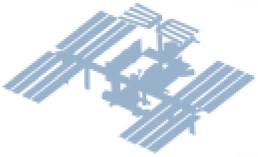
F2 layer

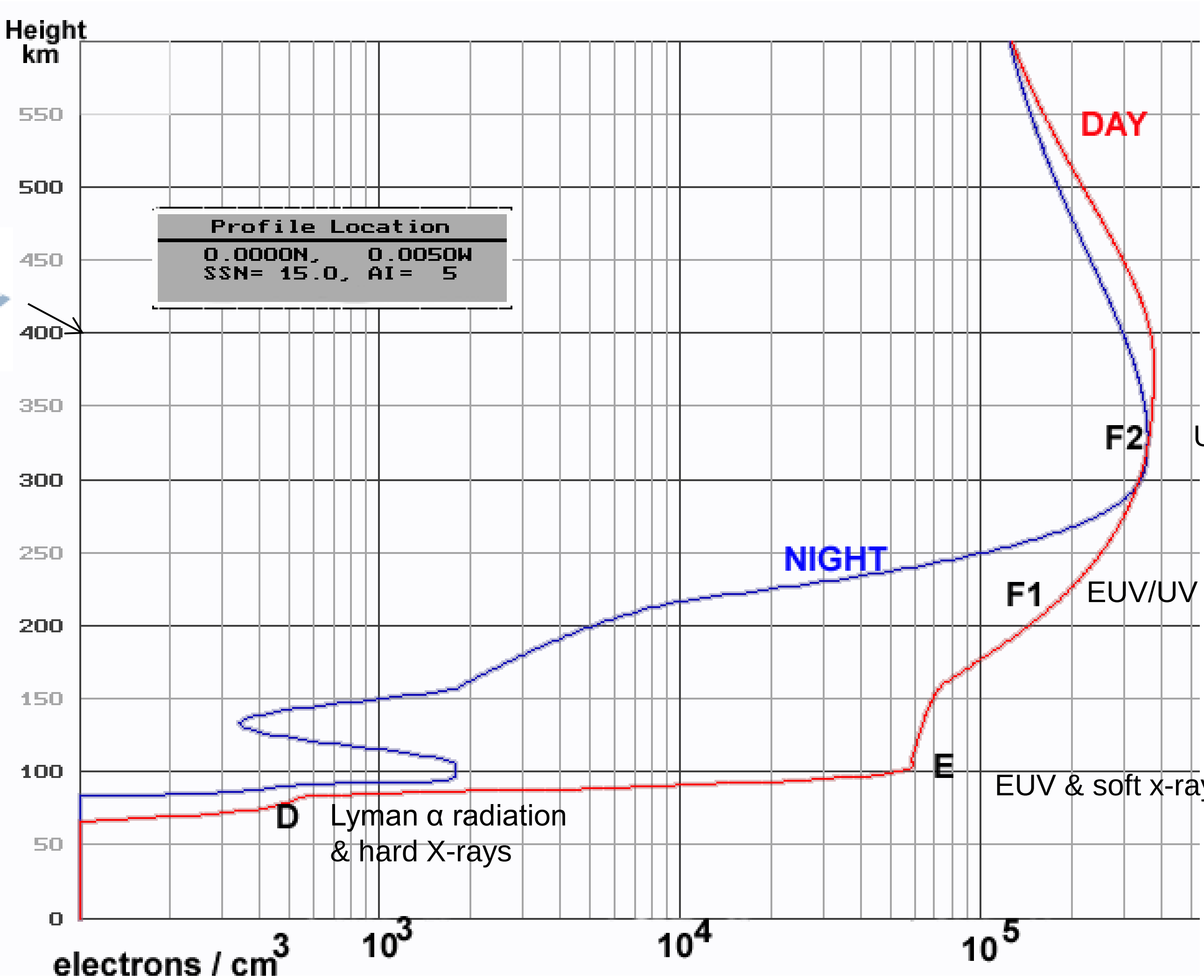
F1 Layer (daytime only)

E Layer

D Layer

Ionosphere Structure





Solar Radiation

Gravity

UV

Monoatomic oxygen

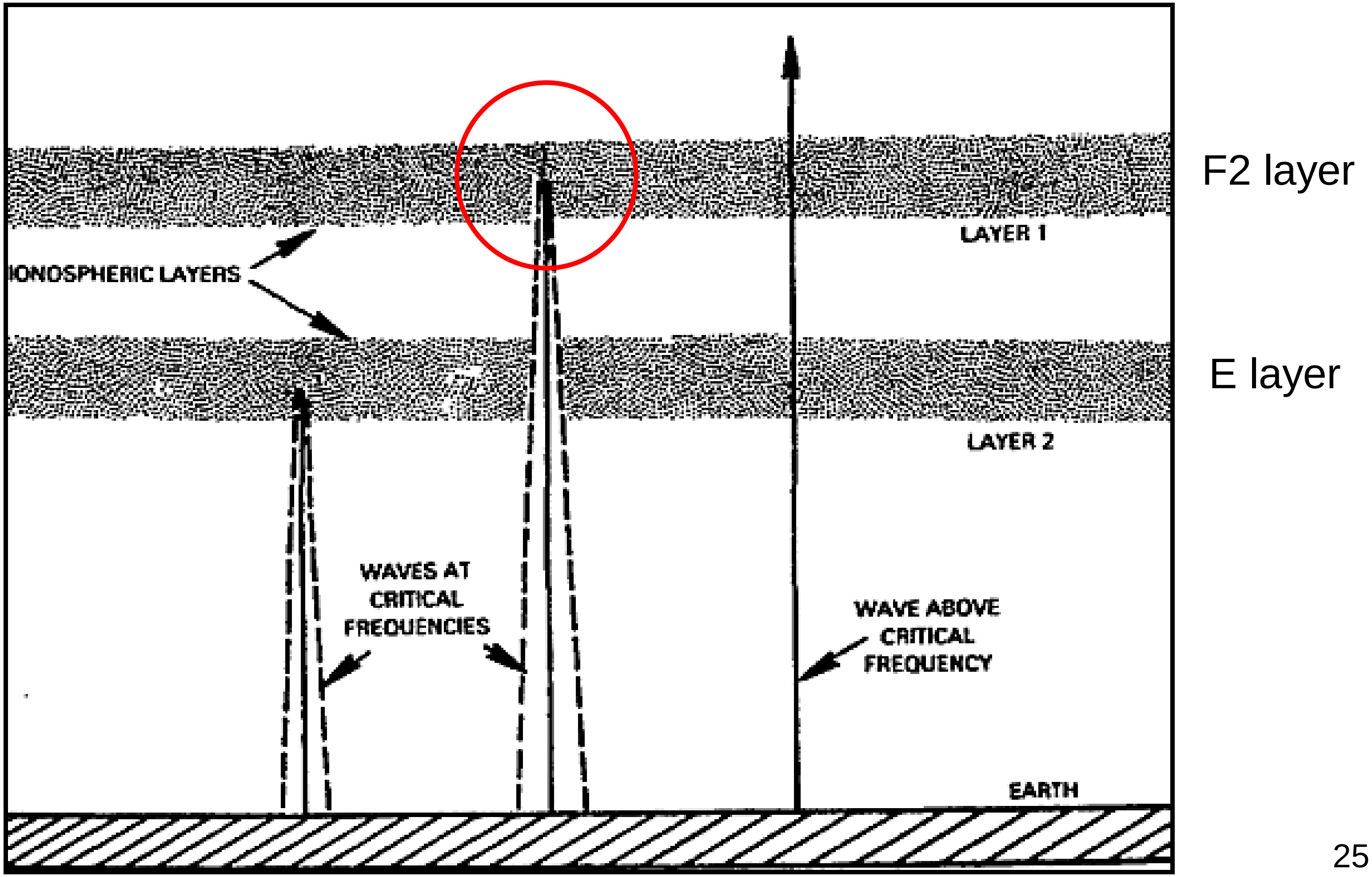
EUV/UV

EUV & soft x-rays

Lyman α radiation
& hard X-rays

NVIS Frequency Selection

- Must operate at or below the local Critical Frequency (CF) in the F2 layer.

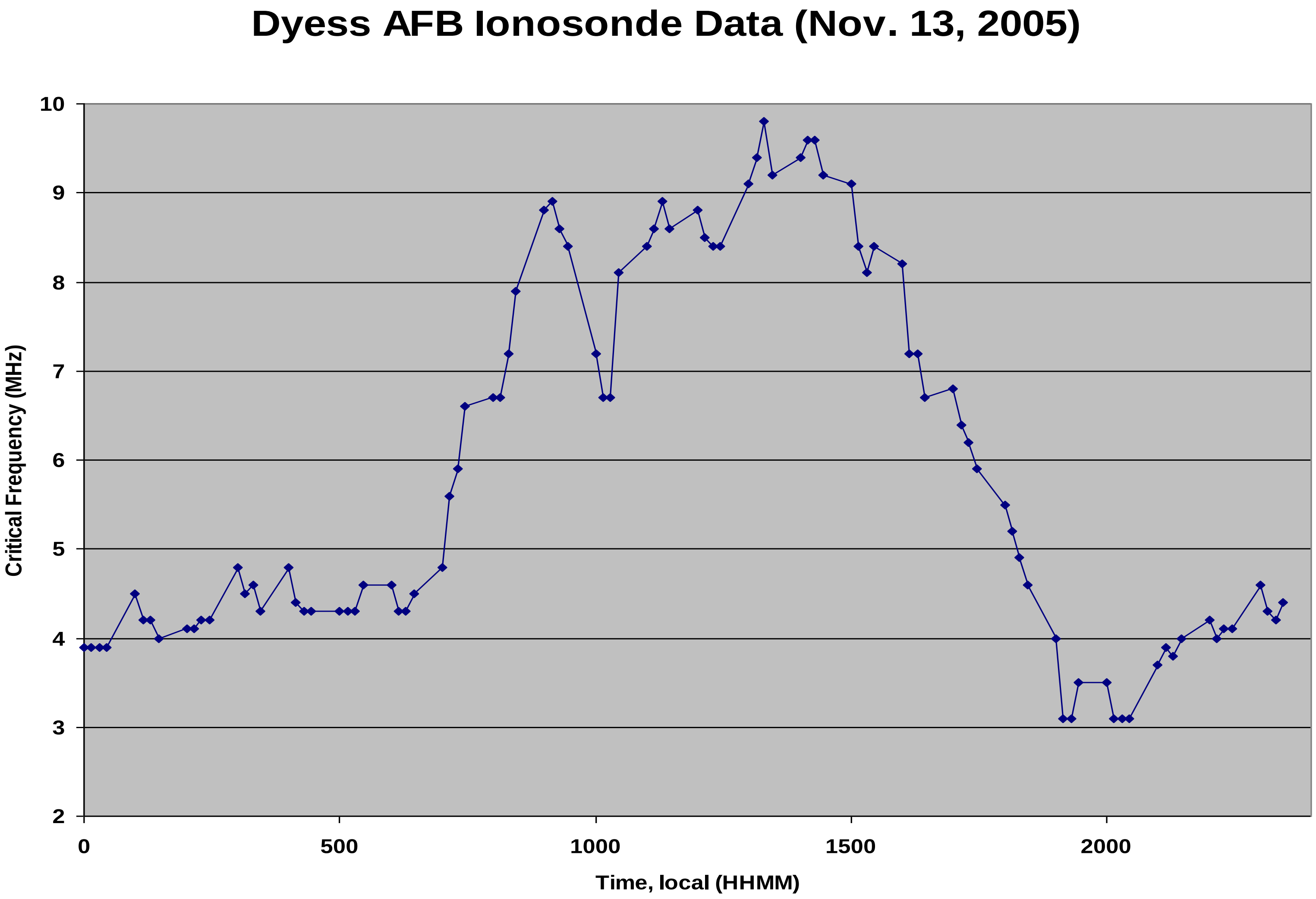


Critical Frequency

- Critical Frequency increases with increased ionization of F-layers
  - Time of day
  - Time of year (Summer Anomaly)
  - Time of the 11-year sun spot cycle
- Other factors
  - Geomagnetic storms (CME and Coronal Holes)
  - Terrestrial heating (summer anomaly)
- NVIS propagation is very sensitive to the correct selection of the Critical Frequency.

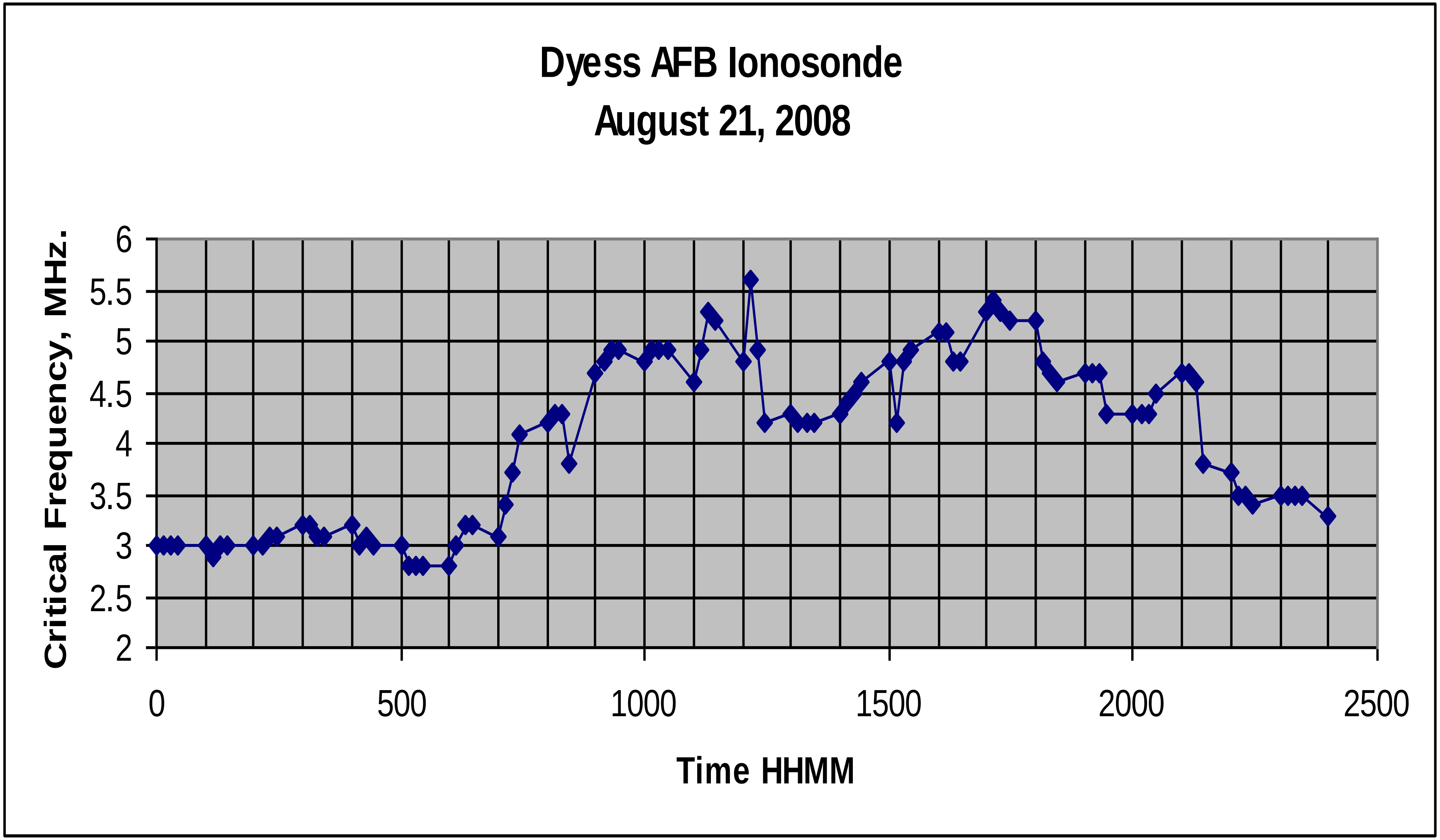
CF Versus Sun Spot Cycle Maximum

(During Sun Spot Cycle 23)



CF Versus Sun Spot Cycle Minimum

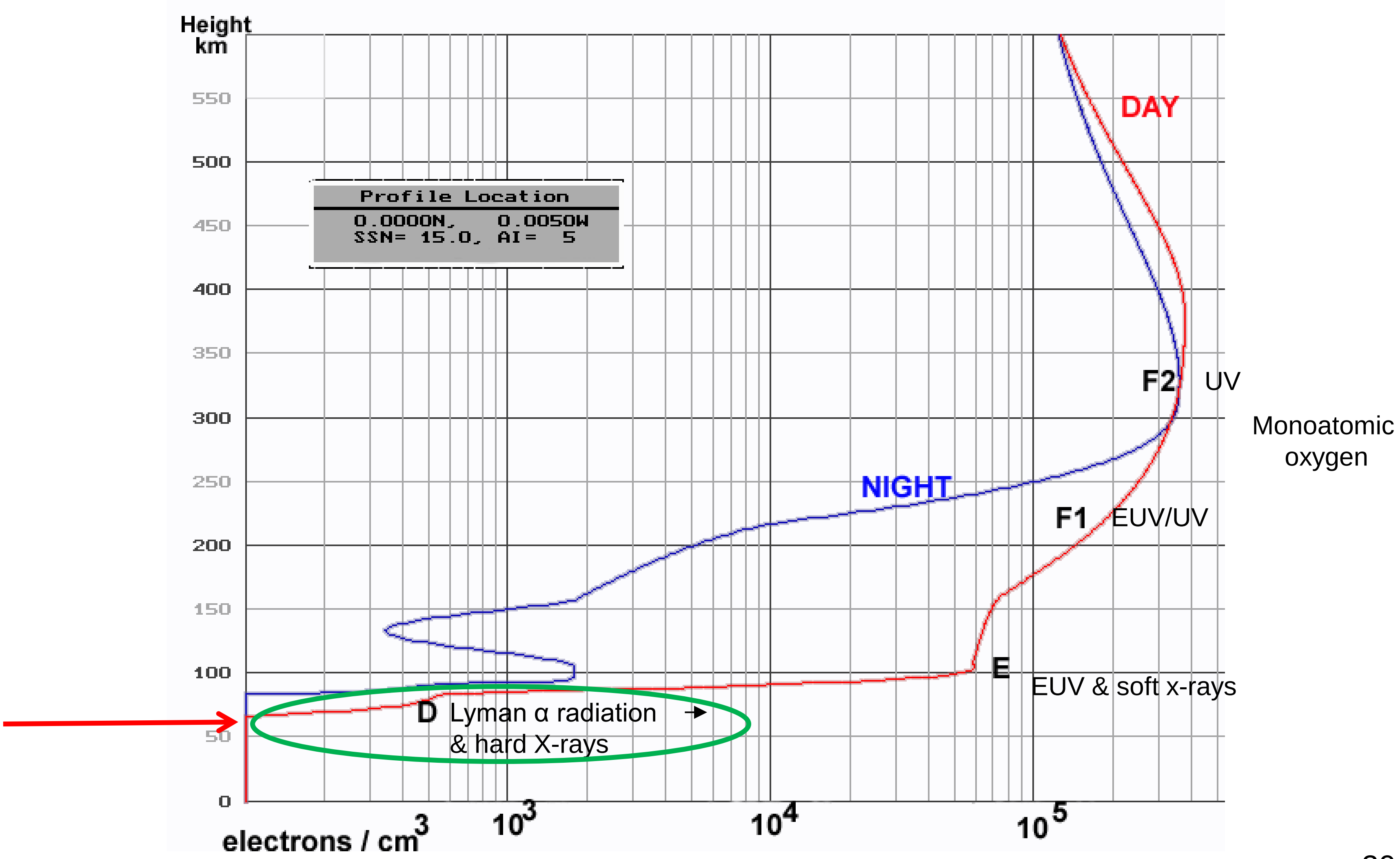
(Between Cycles 23 & 24)



D-Layer Absorption

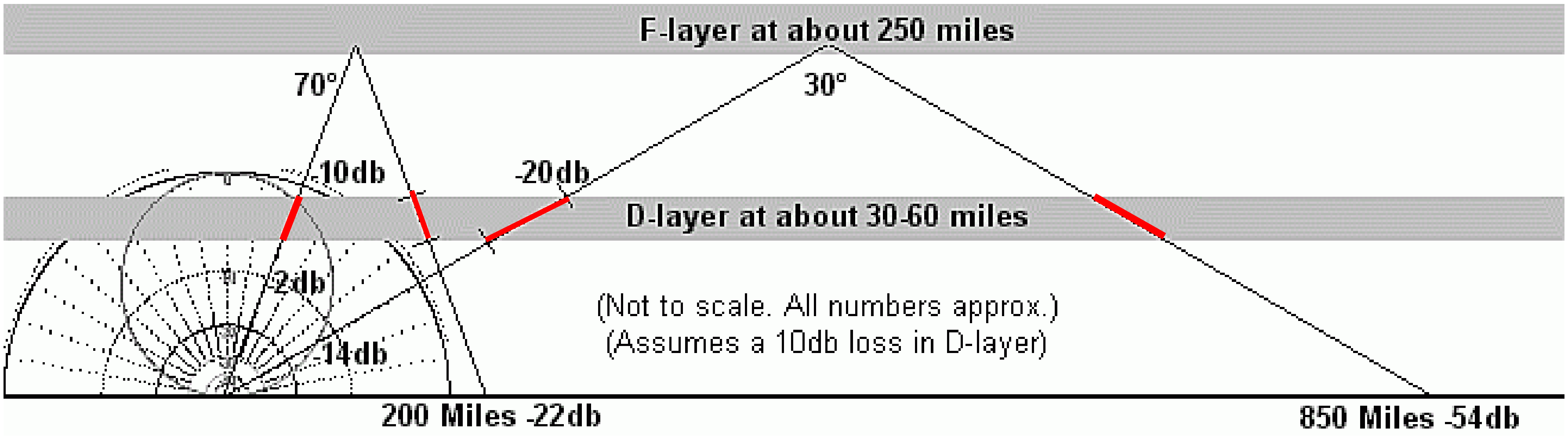
- Why not just operate at a frequency much lower than the CF?
- OK for night-time nets but during day-light hours, D-layer absorption will reduce signal levels dramatically at lower frequencies.

Lowest Useable Frequency (D-Layer Absorption)



Lowest Usable Frequency (LUF)

- Controlled by D-Layer absorption
- Day-time effect
- Function of transmit power and mode of operation
- Absorption is a function of $1/f^2$



NVIS Frequency Selection Rule

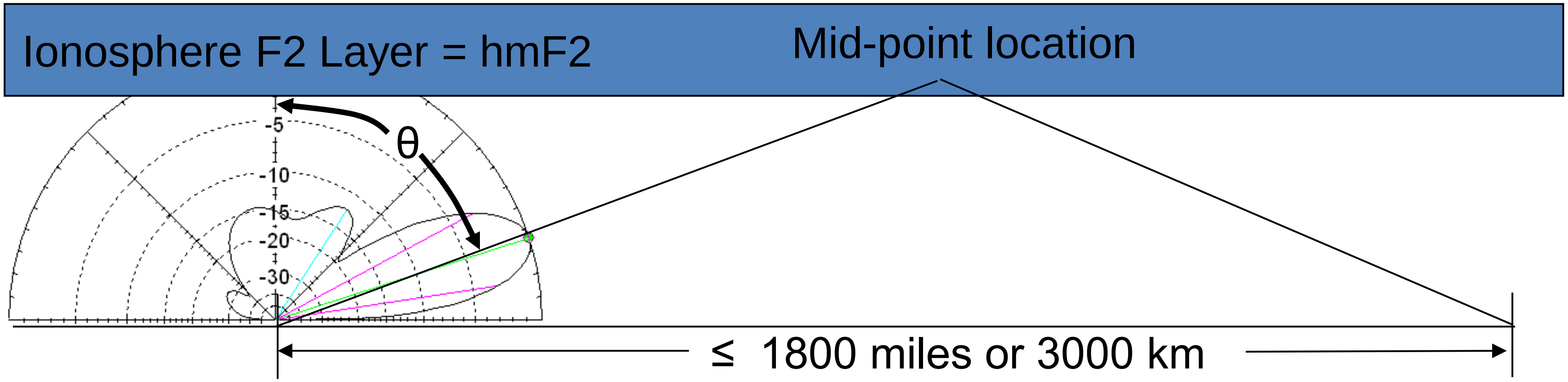
- Day-time: Operate at or just below the Critical Frequency at all times to minimize D-layer absorption.
- Night-time: Operate at or below CF to maintain NVIS propagation as CF drops.
- In both cases, NCS may need to change the net frequency several times during a 30 minute net.

Long-Range Propagation Estimates

- Knowing both the Critical Frequency, foF2, and the F2 layer height, hmF2, at the reflection location can allow an estimate of the optimum frequency, MUF, for a specific, single bounce long-range circuit.
- The MUF calculation and geometry for a long-range circuit is shown on page 34.
- The **reflection location** can be entered into the GAMBIT Coordinates setup screen then both foF2 and hmF2 plots computed at a specific time of day. These values can then be entered into the MUF equation to arrive at the optimum MUF.
- Antenna modeling programs like EZNEC can provide an estimate of the antenna elevation (take-off) angle needed to complete the geometric calculation of the MUF for that specific circuit.
- Propagation programs like VOACAP do similar calculations but must make assumptions about the value of the MUF, since they do not know the actual foF2 and hmF2 at the reflection location. Probabilities of a successful circuit are provided by VOACAP based on the expected range of MUF's for certain solar and ionospheric conditions provided by the user. So using the actual MUF should increase the probability of a successful circuit.

Long-Range Propagation

- MUF (Maximum Useable Frequency) is CF/cosθ, where θ is the angle from the take-off beam to vertical.
- So if you know the CF at the Mid-point of your circuit and Ɵ, then MUF can be calculated.



Ionosphere F2 Layer = hmF2

Mid-point location

≤ 1800 miles or 3000 km

Result For Test Circuit Calculation

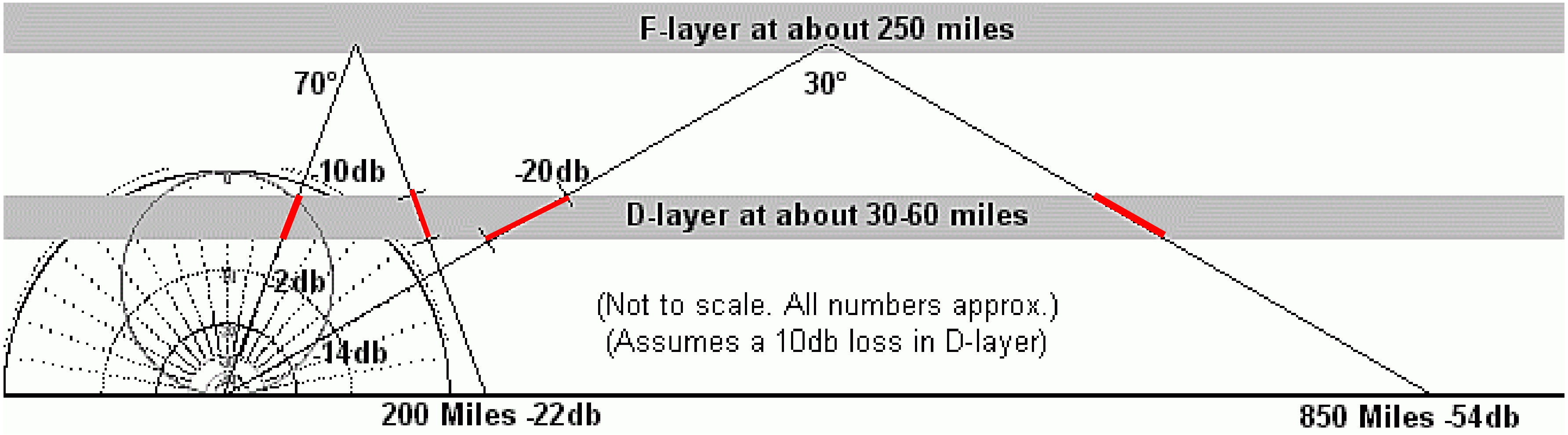
- Circuit – Ft. Huachuca, AZ to Austin, TX
- Both VOACAP and the GAMBIT Ionosonde data arrive at approximately the same MUF of 16 MHz for 2000Z time. Note that VOACAP only uses SSN, date/time and antenna characteristics to calculate the MUF, where the GAMBIT method uses actual real-time Ionosonde data.

Anomalies in Ionosonde Data

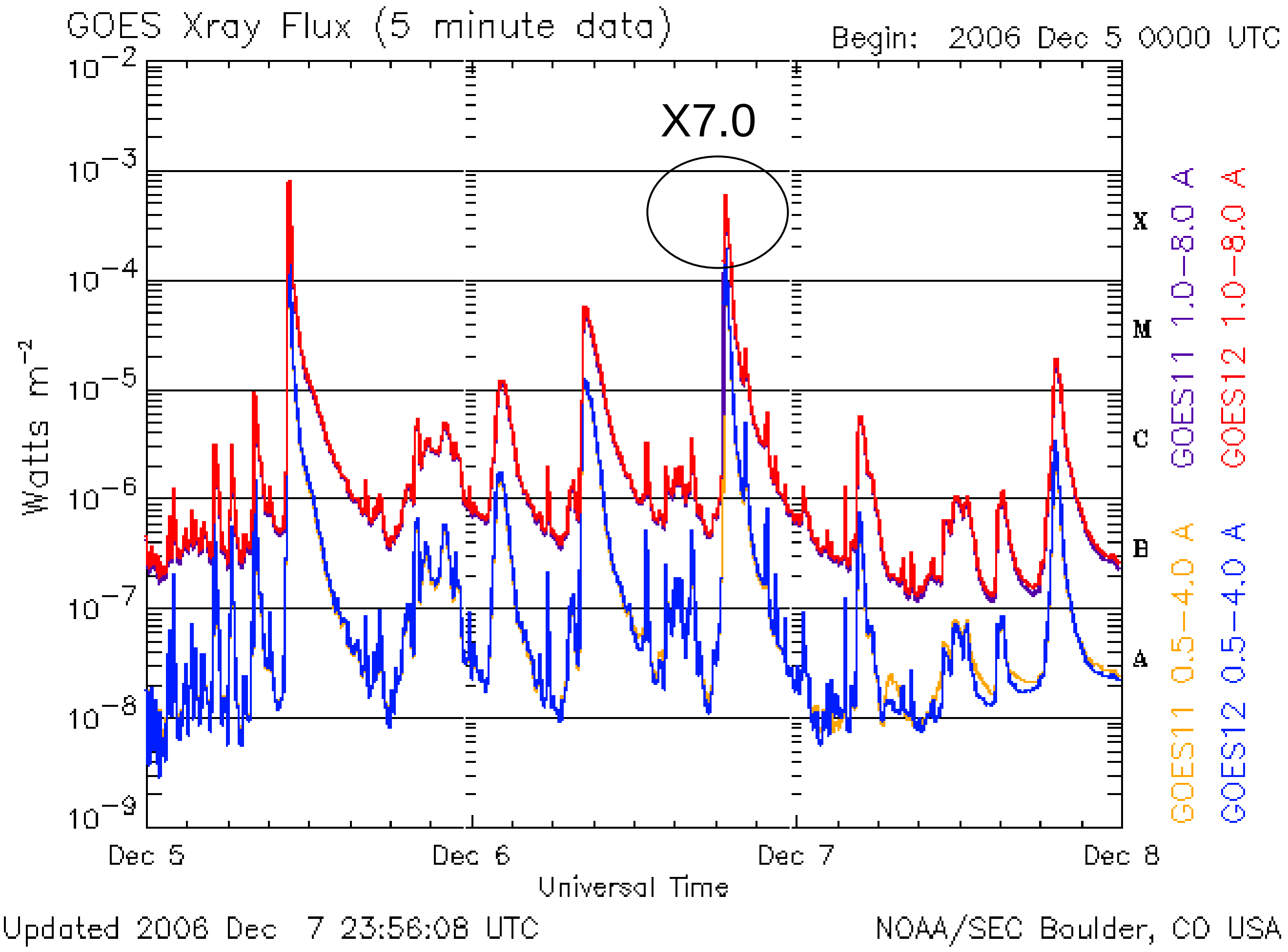
- Solar Flares can cause a Radio Blackout
- Geomagnetic Storms caused by CME, Coronal Holes and EMP
- Sporadic-E

Solar Flare Radio Blackout

- Controlled by D-Layer absorption
- Day-time effect
- Function of transmit power and mode of operation
- Absorption is a function of $1/f^2$

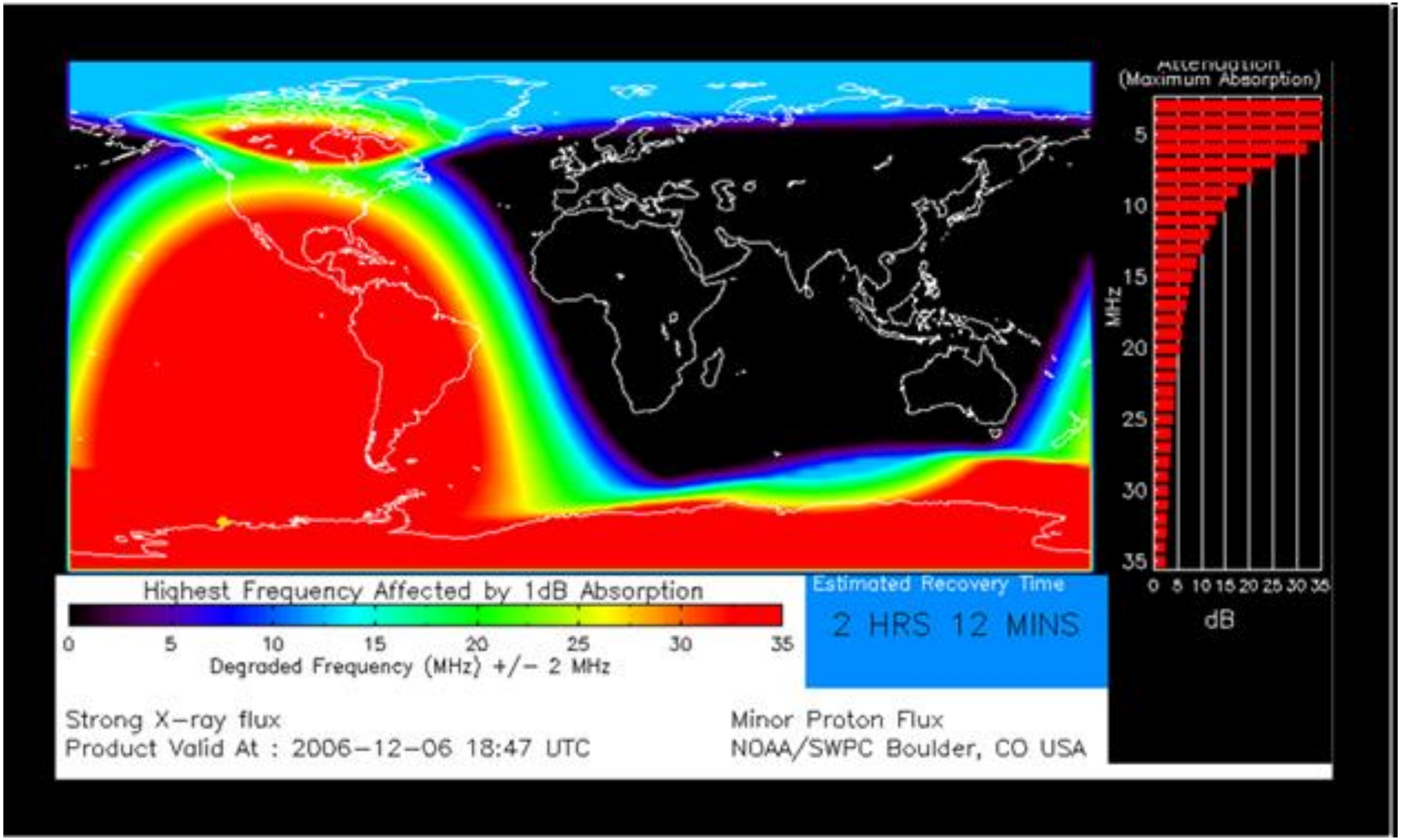


GOES X-Ray Flux
(5-7 DEC 2006)



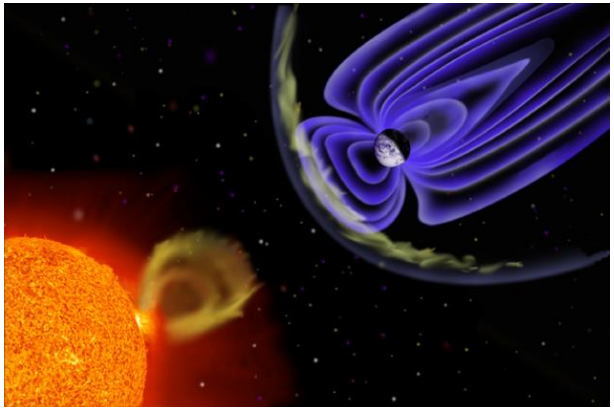
D-Absorption Prediction

(http://www.ngdc.noaa.gov/stp/drap/index.html)
(https://www.region6armymars.org/resources/solarweather.php)

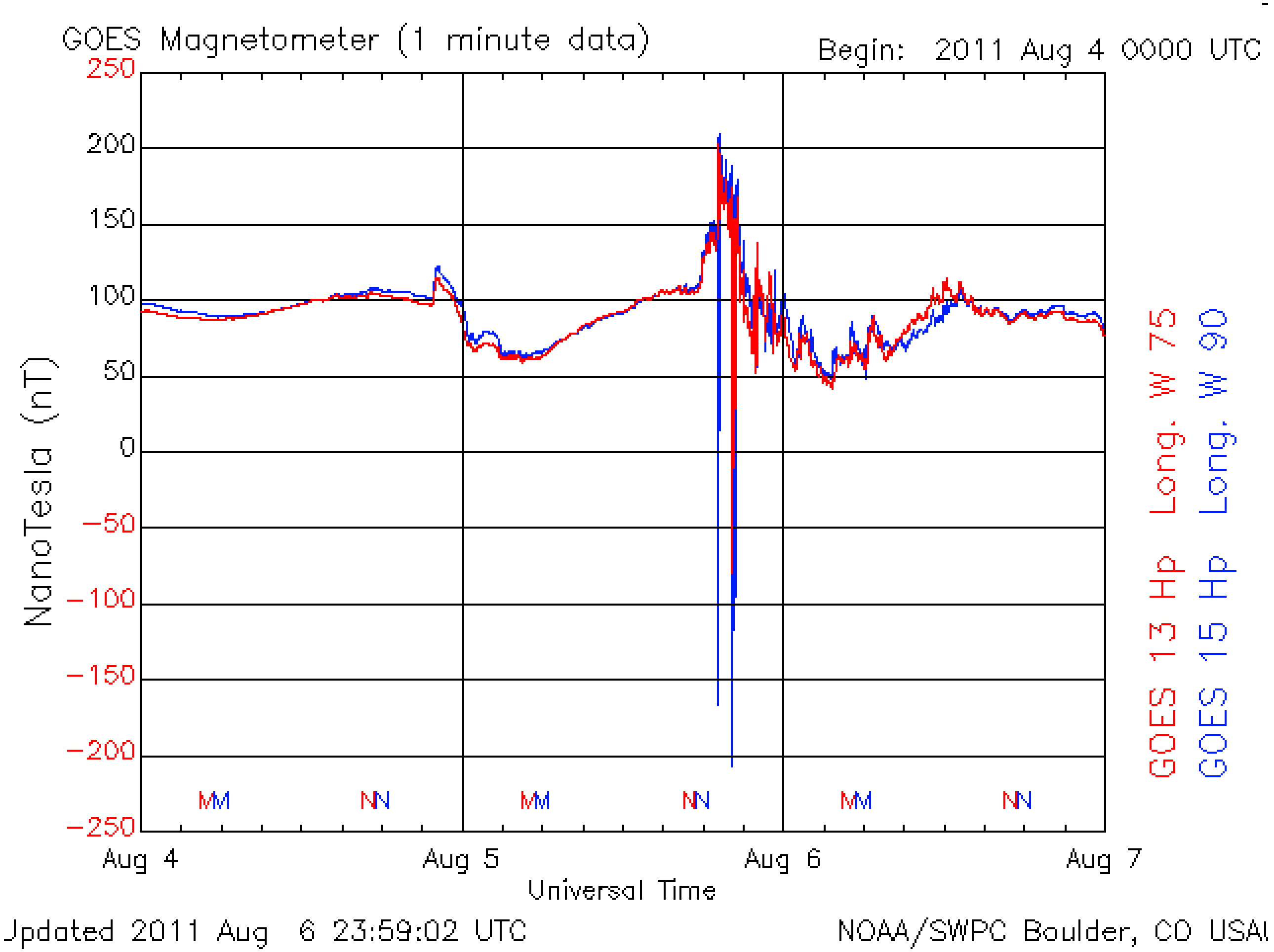


Coronal Mass Ejections

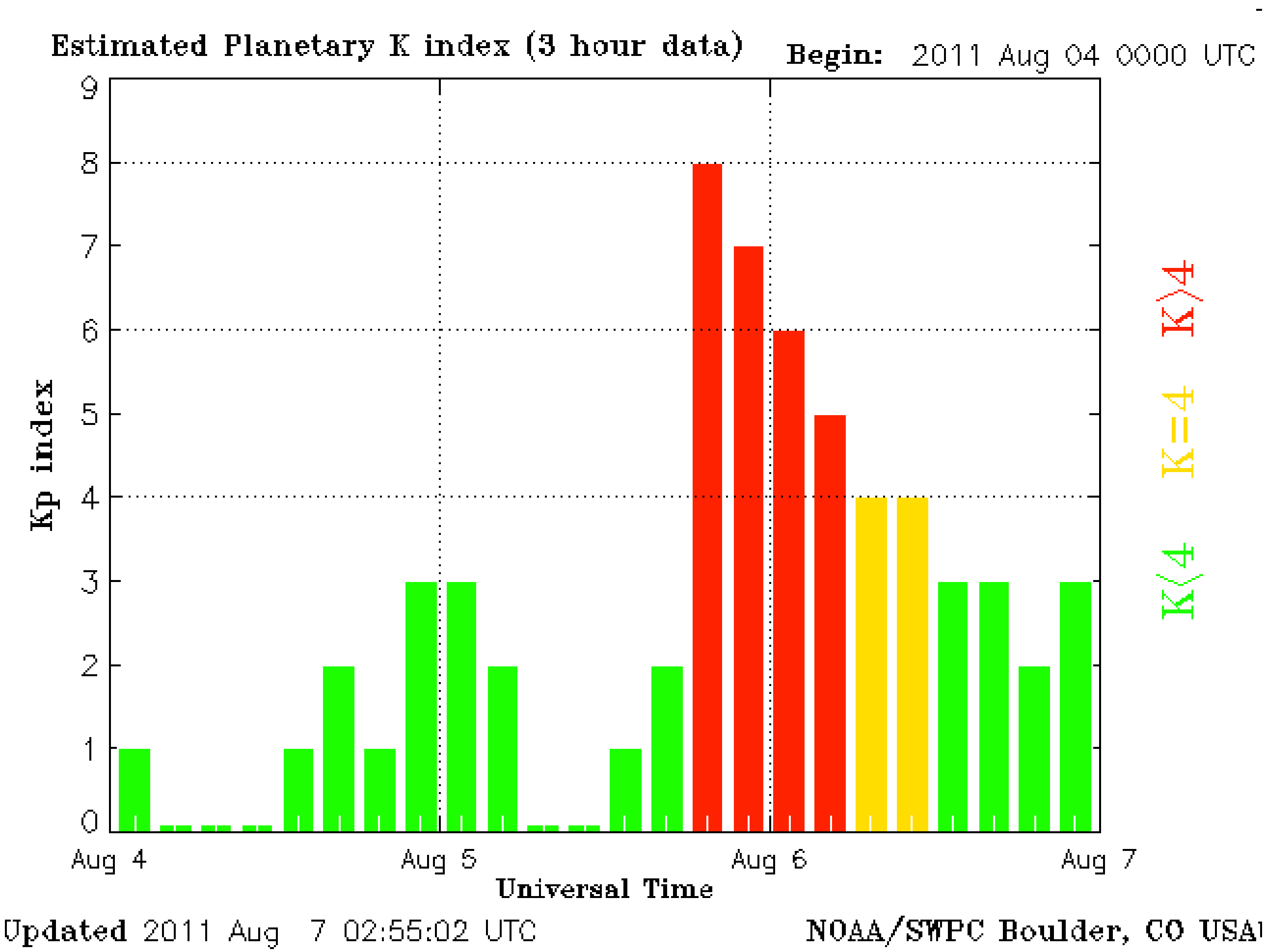
- Geomagnetic Storm caused by CME (Corona Mass Ejection) or Coronal Hole
  - Depressed MUF and increased D absorption
  - Indicated by increased K and A indices
  - Severity of effects are a function of the polarity of Bz
    - Bz South – more severe effects



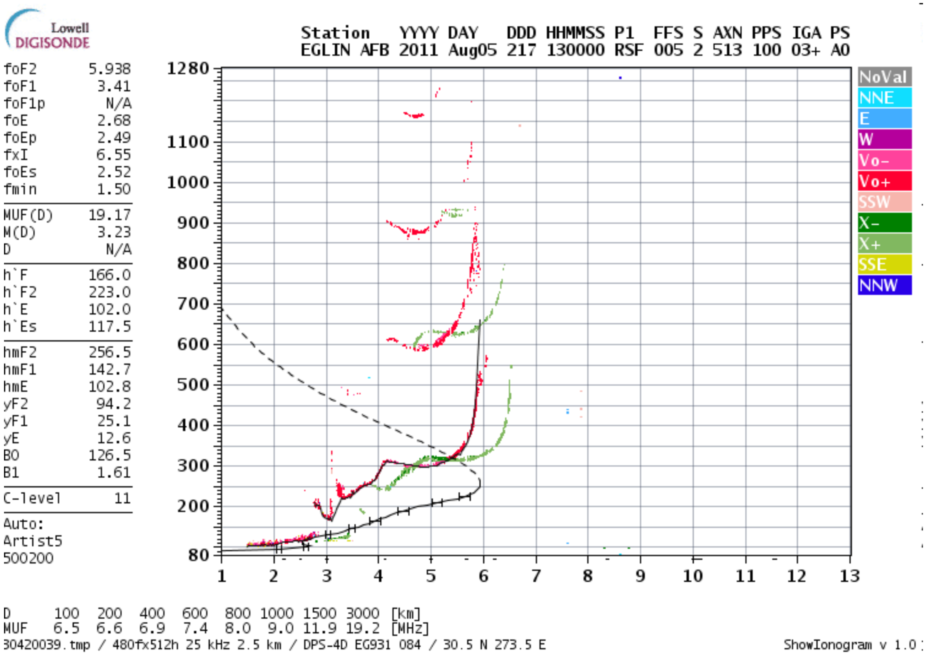
GOES Magnetometer
(Arrival of 2 Aug. CME)



Planetary K Index
(Arrival of 2 Aug CME)



Ionosonde Data – CME Impact (24% drop in CF)



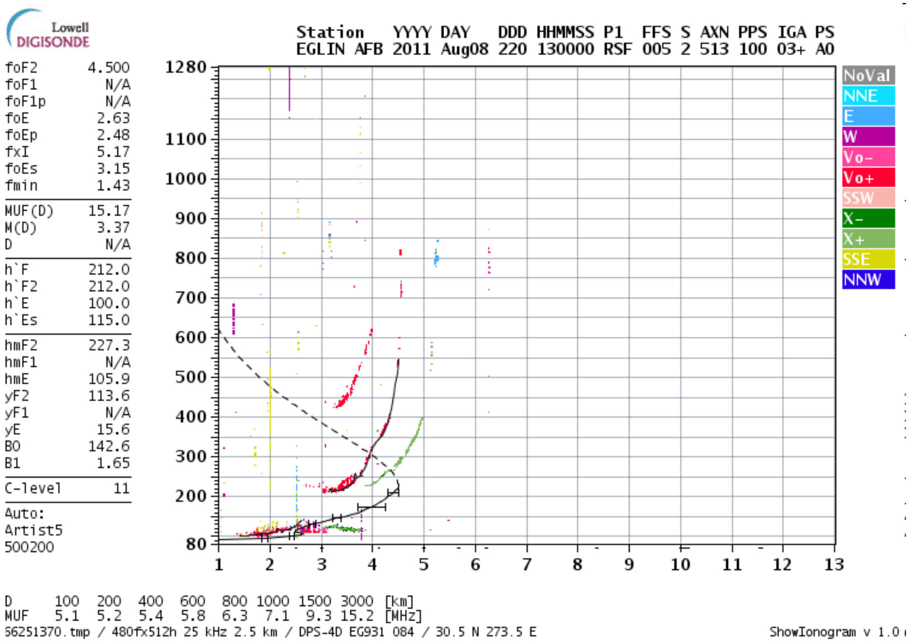
Station	YYYY	DAY	DDD	HHMMSS	P1	FFS	S	AXN	PPS	IGA	PS
EGLIN AFB	2011	Aug05	217	130000	RSF	005	2	513	100	03+	A0

foF2	5.938
foF1	3.41
foF1p	N/A
foE	2.68
foEp	2.49
fxI	6.55
foEs	2.52
fmin	1.50
MUF(D)	19.17
M(D)	3.23
D	N/A
h`F	166.0
h`F2	223.0
h`E	102.0
h`Es	117.5
hmF2	256.5
hmF1	142.7
hmE	102.8
yF2	94.2
yF1	25.1
yE	12.6
B0	126.5
B1	1.61
C-level	11

Auto:
Artist5
500200

D	100	200	400	600	800	1000	1500	3000	[km]
MUF	6.5	6.6	6.9	7.4	8.0	9.0	11.9	19.2	[MHz]

30420039.tmp / 480fx512h 25 kHz 2.5 km / DPS-4D EG931 084 / 30.5 N 273.5 E



Station	YYYY	DAY	DDD	HHMMSS	P1	FFS	S	AXN	PPS	IGA	PS
EGLIN AFB	2011	Aug08	220	130000	RSF	005	2	513	100	03+	A0

foF2	4.500
foF1	N/A
foF1p	N/A
foE	2.63
foEp	2.48
fxI	5.17
foEs	3.15
fmin	1.43
MUF(D)	15.17
M(D)	3.37
D	N/A
h`F	212.0
h`F2	212.0
h`E	100.0
h`Es	115.0
hmF2	227.3
hmF1	N/A
hmE	105.9
yF2	113.6
yF1	N/A
yE	15.6
B0	142.6
B1	1.65
C-level	11

Auto:
Artist5
500200

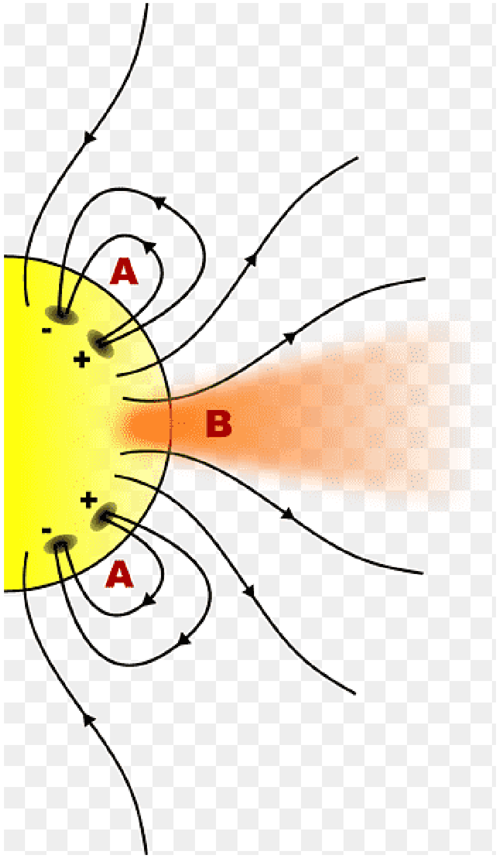
D	100	200	400	600	800	1000	1500	3000	[km]
MUF	5.1	5.2	5.4	5.8	6.3	7.1	9.3	15.2	[MHz]

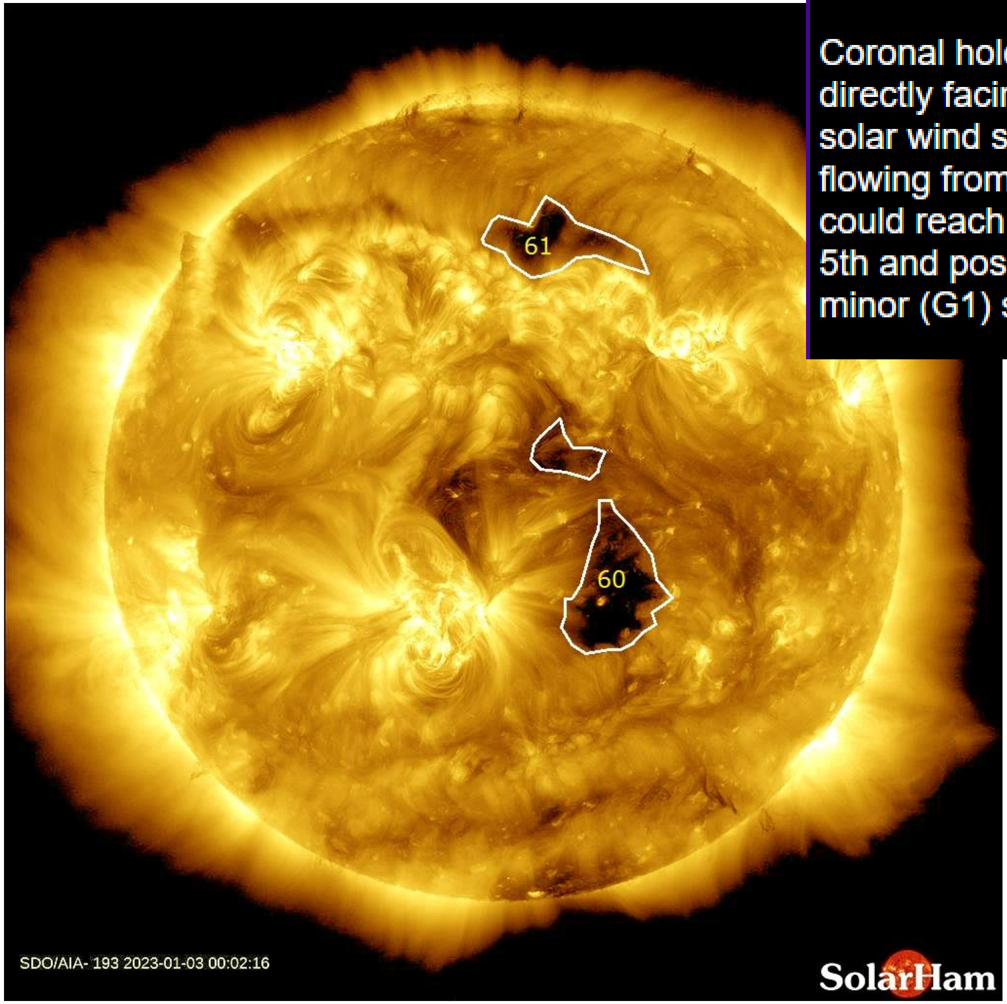
56251370.tmp / 480fx512h 25 kHz 2.5 km / DPS-4D EG931 084 / 30.5 N 273.5 E

5 August 1300Z
(CF = 5.9 MHz - Normal)
(MUF = 19.2 MHz)

8 August 1300Z
(CF = 4.5 MHz)
(MUF = 15.2 MHz)

Coronal Hole Effect



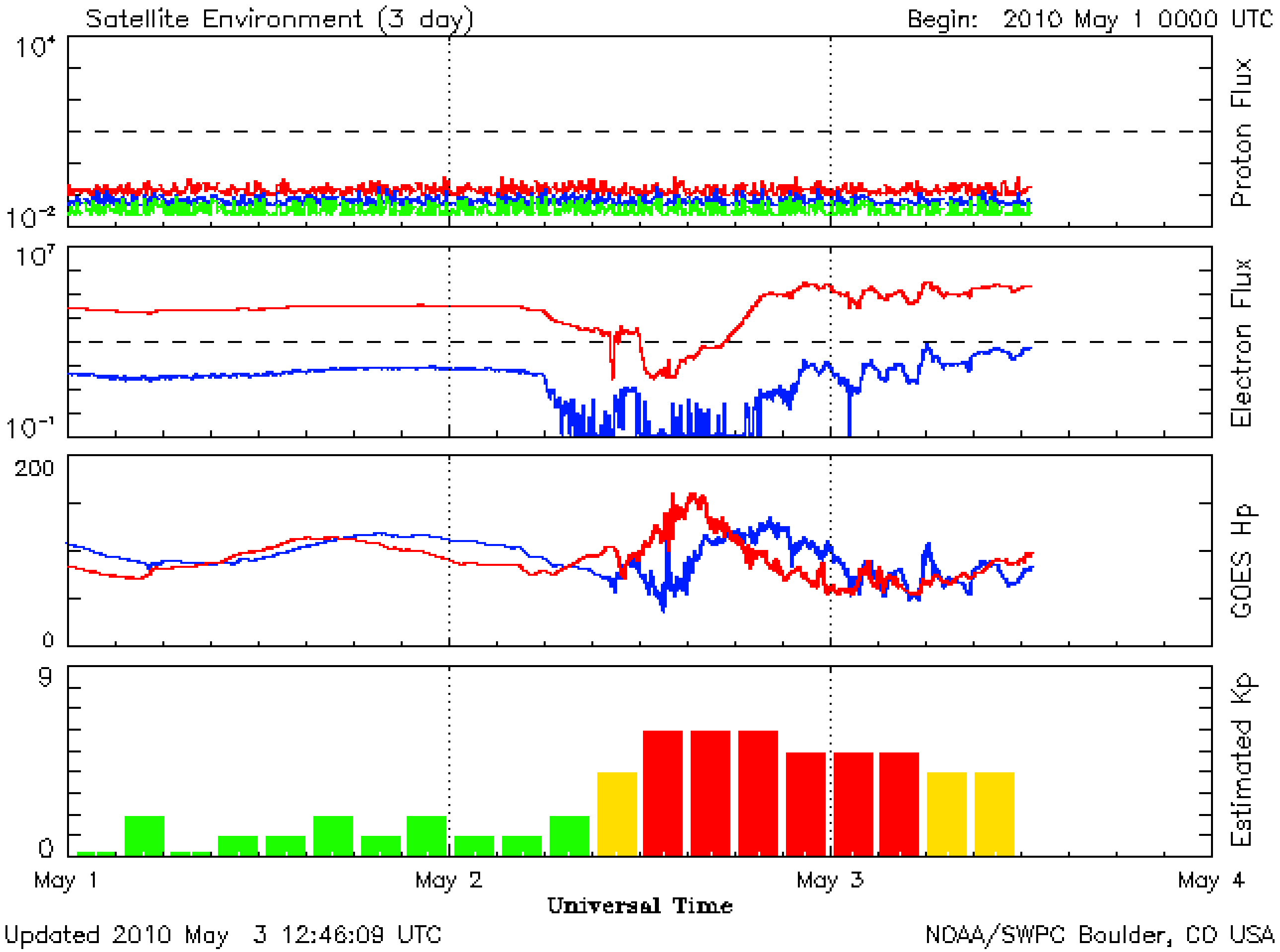


Analysis

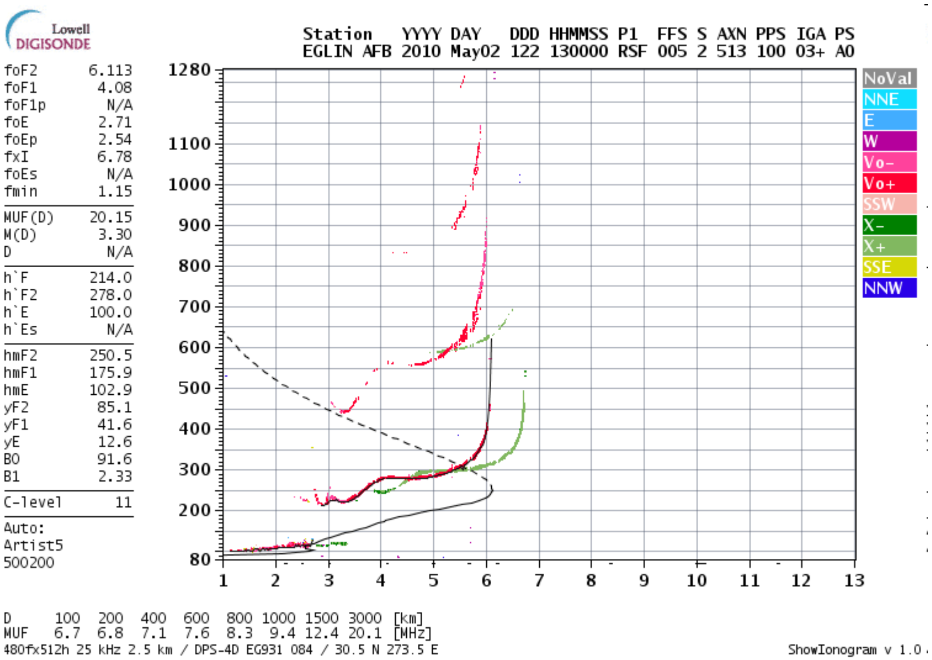
Coronal hole #60 is now directly facing Earth. A solar wind stream flowing from this zone could reach by January 5th and possibly lead to minor (G1) storming.

Solar Weather Environment

(Coronal Hole Event)

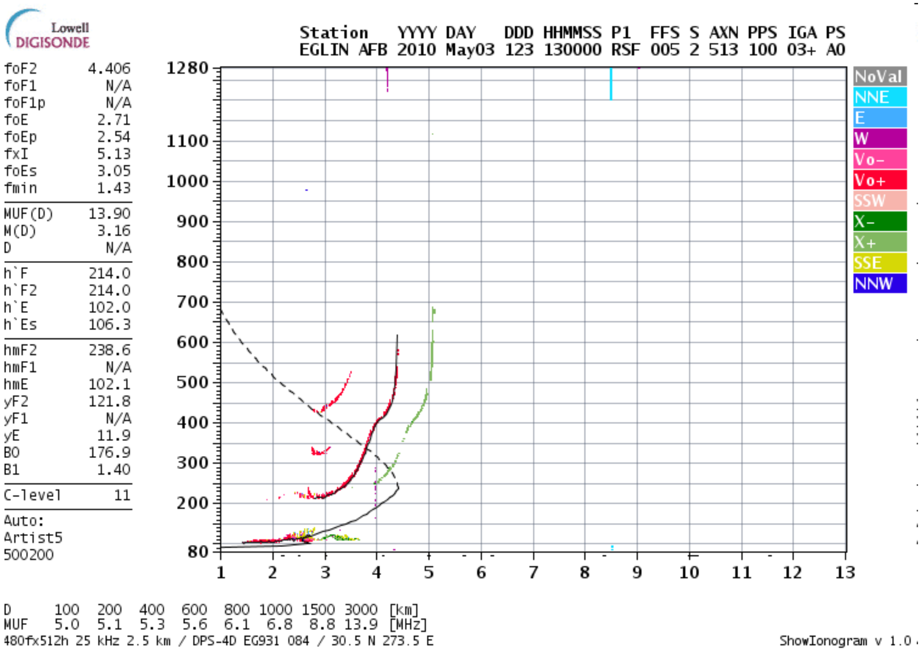


Ionosonde Data – CH Event
(28% drop in CF)



```
Station     YYYY DAY    DDD HHMMSS P1  FFS S AXN PPS IGA PS
EGLIN AFB 2010 May02 122 130000 RSF 005 2 513 100 03+ A0

foF2       6.113
foF1        4.08
foF1p        N/A
foE         2.71
foEp        2.54
fxI         6.78
foEs         N/A
fmin        1.15

MUF(D)     20.15
M(D)        3.30
D            N/A

h`F        214.0
h`F2       278.0
h`E        100.0
h`Es         N/A

hmF2       250.5
hmF1       175.9
hmE        102.9
yF2         85.1
yF1         41.6
yE          12.6
B0          91.6
B1          2.33

C-level       11

Auto:
Artist5
500200

D      100  200  400  600  800 1000 1500 3000 [km]
MUF    6.7  6.8  7.1  7.6  8.3  9.4 12.4 20.1 [MHz]
480fx512h 25 kHz 2.5 km / DPS-4D EG931 084 / 30.5 N 273.5 E
ShowIonogram v 1.0
```

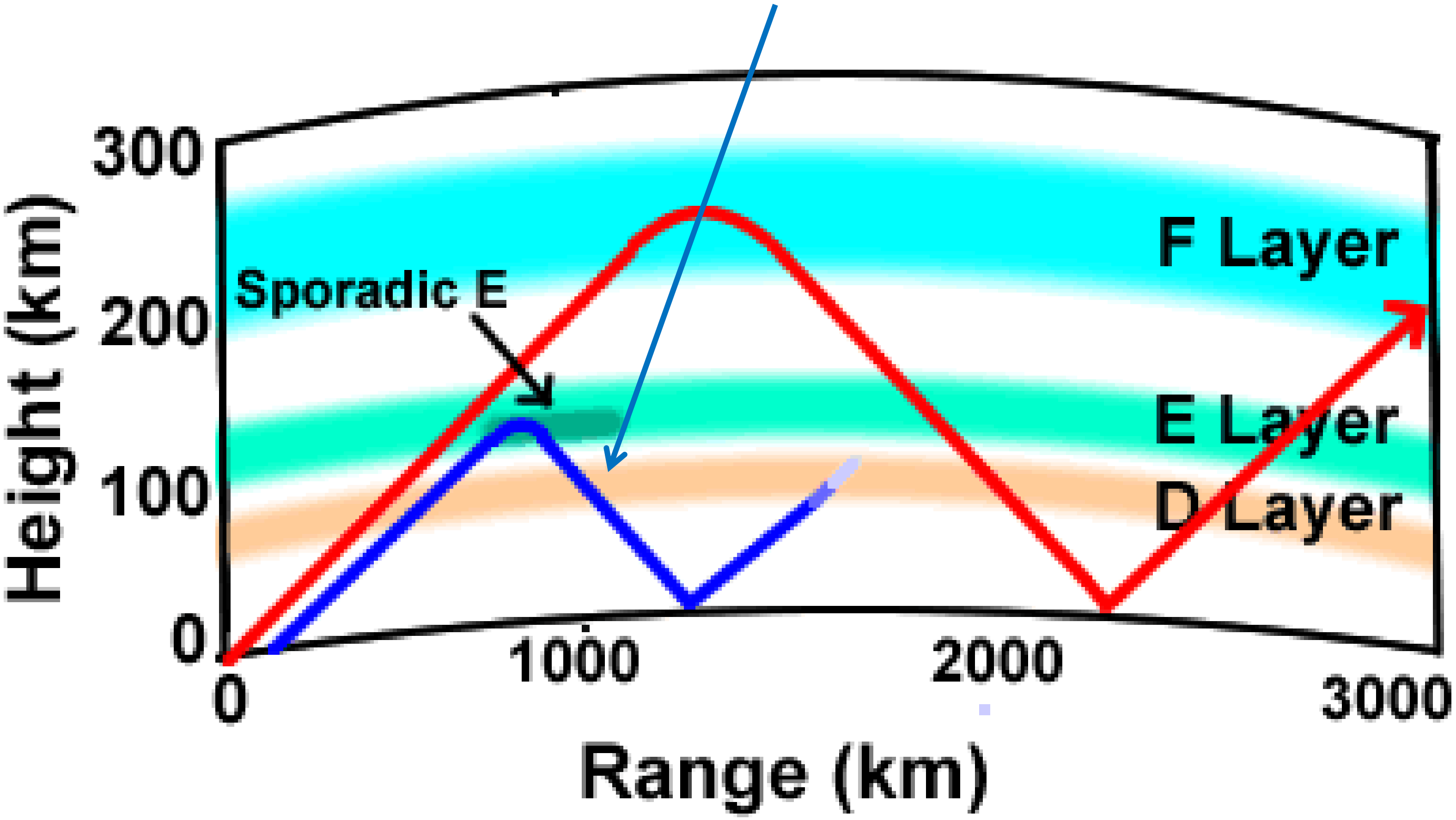
2 May 1300Z
(CF = 6.1 MHz - Normal)
(MUF = 20.1 MHz)



```
Station     YYYY DAY    DDD HHMMSS P1  FFS S AXN PPS IGA PS
EGLIN AFB 2010 May03 123 130000 RSF 005 2 513 100 03+ A0

foF2       4.406
foF1         N/A
foF1p        N/A
foE         2.71
foEp        2.54
fxI         5.13
foEs        3.05
fmin        1.43

MUF(D)     13.90
M(D)        3.16
D            N/A

h`F        214.0
h`F2       214.0
h`E        102.0
h`Es       106.3

hmF2       238.6
hmF1         N/A
hmE        102.1
yF2        121.8
yF1          N/A
yE          11.9
B0         176.9
B1          1.40

C-level       11

Auto:
Artist5
500200

D      100  200  400  600  800 1000 1500 3000 [km]
MUF    5.0  5.1  5.3  5.6  6.1  6.8  8.8 13.9 [MHz]
480fx512h 25 kHz 2.5 km / DPS-4D EG931 084 / 30.5 N 273.5 E
ShowIonogram v 1.0
```

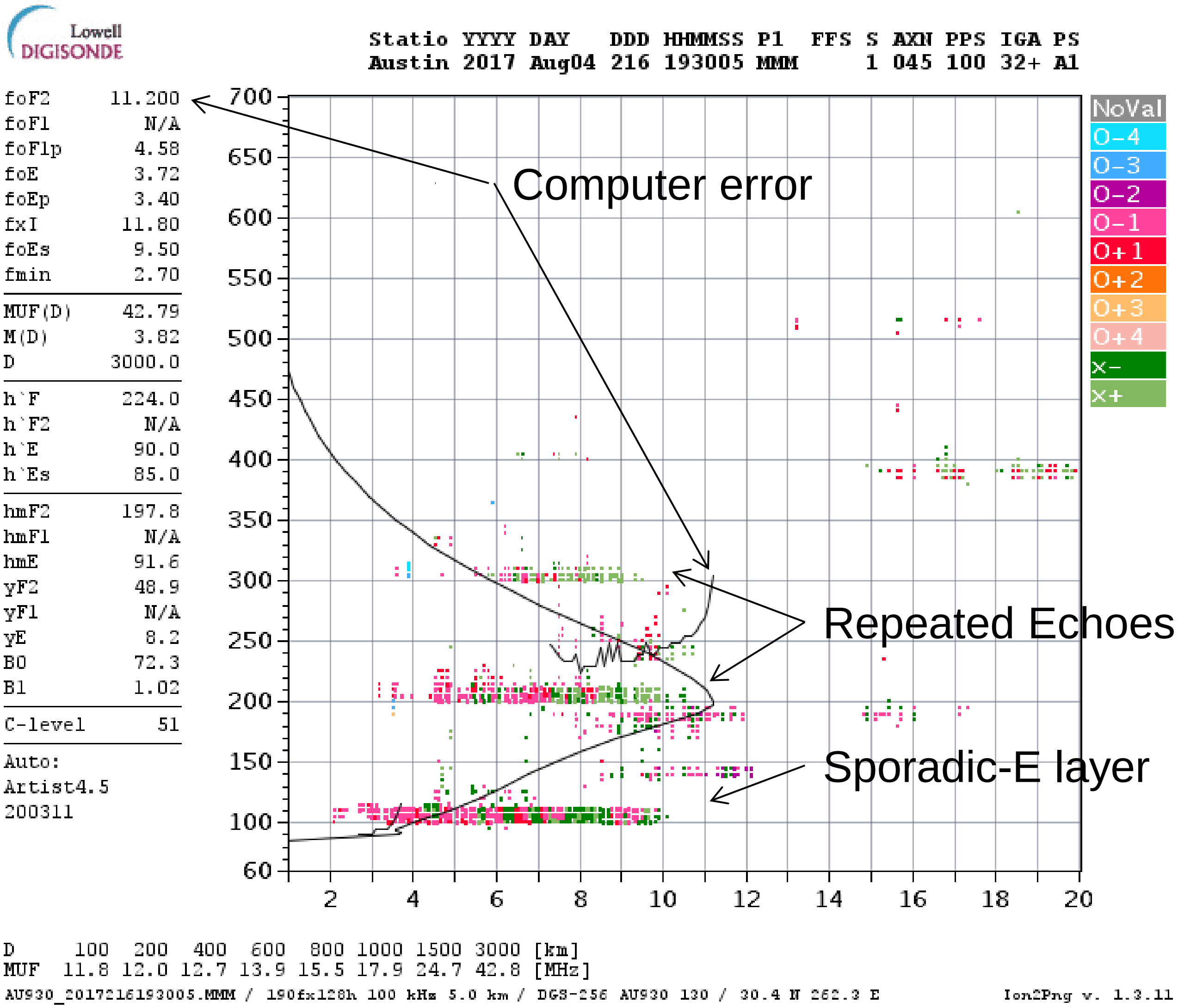
3 May 1300Z
(CF = 4.4 MHz)
(MUF = 13.9 MHz)

Sporadic–E Propagation



MUF = 25 – 150 MHZ

Ionogram During Blanketing Sporadic-E



```
Statio YYYY DAY   DDD HHMMSS P1  FFS S AXN PPS IGA PS
Austin 2017 Aug04 216 193005 MMM     1 045 100 32+ A1
```

```
foF2       11.200
foF1          N/A
foF1p        4.58
foE          3.72
foEp         3.40
fxI         11.80
foEs         9.50
fmin         2.70
MUF(D)      42.79
M(D)         3.82
D          3000.0
h`F         224.0
h`F2          N/A
h`E          90.0
h`Es         85.0
hmF2        197.8
hmF1          N/A
hmE          91.6
yF2          48.9
yF1           N/A
yE            8.2
B0           72.3
B1           1.02
C-level        51
Auto:
Artist4.5
200311
```

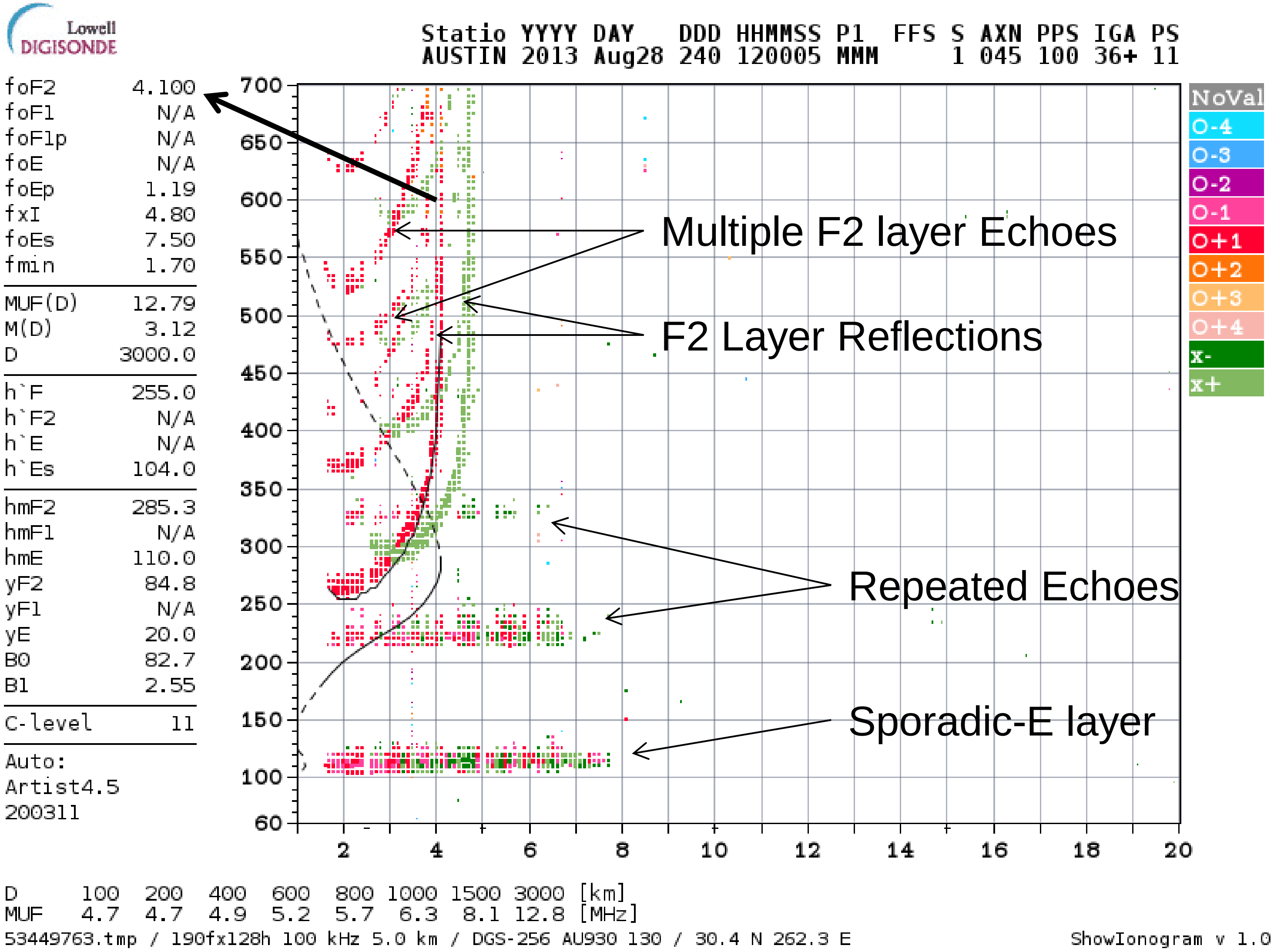
```
D     100  200  400  600  800 1000 1500 3000 [km]
MUF  11.8 12.0 12.7 13.9 15.5 17.9 24.7 42.8 [MHz]
AU930_2017216193005.MMM / 190fx128h 100 kHz 5.0 km / DGS-256 AU930 130 / 30.4 N 262.3 E          Ion2Png v. 1.3.11
```

Computer error

Repeated Echoes

Sporadic-E layer

Return of F2 Layer Reflection



Lowell DIGISONDE

Statio	YYYY	DAY	DDD	HHMMSS	P1	FFS	S	AXN	PPS	IGA	PS
AUSTIN	2013	Aug28	240	120005	MMM		1	045	100	36+	11

foF2	4.100
foF1	N/A
foF1p	N/A
foE	N/A
foEp	1.19
fxI	4.80
foEs	7.50
fmin	1.70
MUF(D)	12.79
M(D)	3.12
D	3000.0
h`F	255.0
h`F2	N/A
h`E	N/A
h`Es	104.0
hmF2	285.3
hmF1	N/A
hmE	110.0
yF2	84.8
yF1	N/A
yE	20.0
B0	82.7
B1	2.55
C-level	11

Auto:
Artist4.5
200311

Multiple F2 layer Echoes

F2 Layer Reflections

Repeated Echoes

Sporadic-E layer

D	100	200	400	600	800	1000	1500	3000	[km]
MUF	4.7	4.7	4.9	5.2	5.7	6.3	8.1	12.8	[MHz]

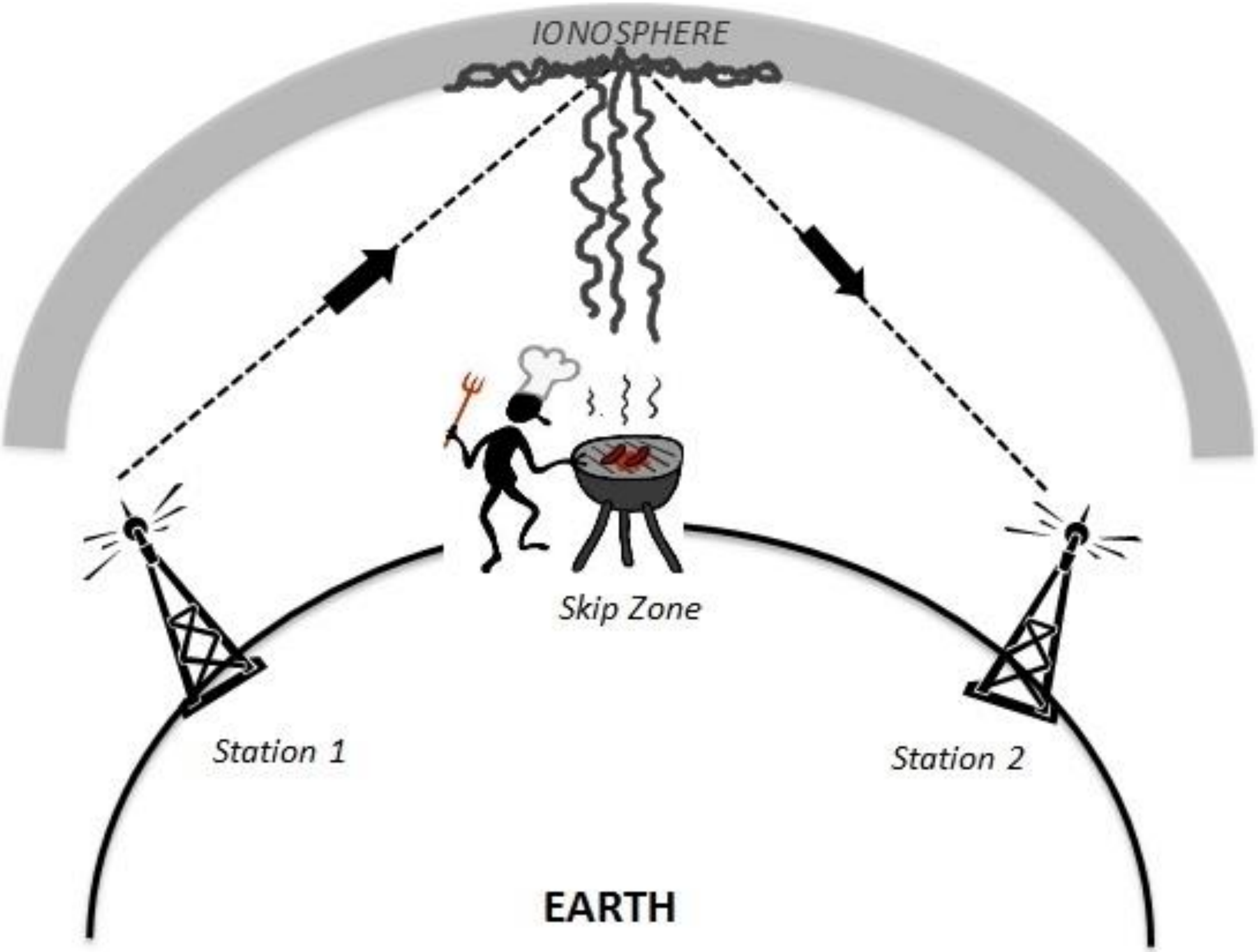
53449763.tmp / 190fx128h 100 kHz 5.0 km / DGS-256 AU930 130 / 30.4 N 262.3 E

ShowIonogram v 1.0

Detection of Sporadic-E

- Since Sporadic-E is a local area phenomena, GAMBIT will only see a small foF2 error from a few Ionosondes located under the SE layer.
- This small error will be smoothed out over all the rest of the world-wide Ionosondes and so will not be detectable.
- Sporadic-E is best detected by observing a local Ionosonde Ionogram or receiving unusually long skip at 6m in a specific direction.

Formation of Sporadic E Propagation



Summary

- The optimum NVIS operating frequency is the local Critical Frequency.
- The Critical Frequency is dependent on a number of highly variable Solar and Geomagnetic conditions.
- Because of this complex dependency, the Critical Frequency is best determined by a physical measurements from Ionosondes.
- The GIRO GAMBIT product can provide local Critical Frequency when a specific Ionosonde is not available.
- The GIRO GAMBIT product can also provide an alternate means to compute the MUF for a specific circuit.

Questions?

Lewis Thompson – W5IFQ

Senior Engineering Scientist (retired)
Applied Research Laboratories,
University of Texas at Austin

Personal Cell – 512-587-9944
Home E-mail: w5ifq@att.net