Cycle 25 and 6m Propagation Topics

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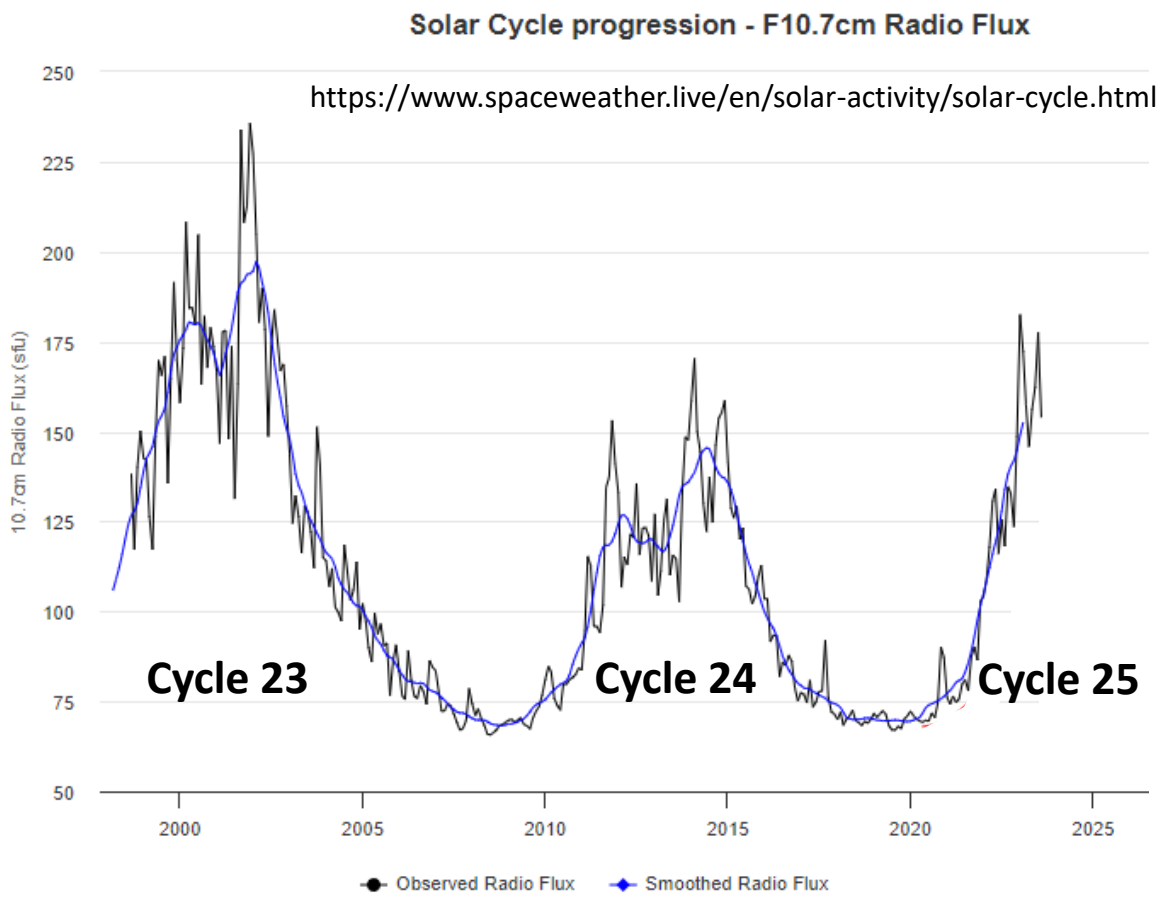
What We'll Cover

- Predicting 6m F_2 propagation
- Previous 24 solar cycles
- Solar cycle predictions
- Latest data on Cycle 25
- What to expect on 6m
- Climate change and the ionosphere

Predicting 6m F_2 Propagation

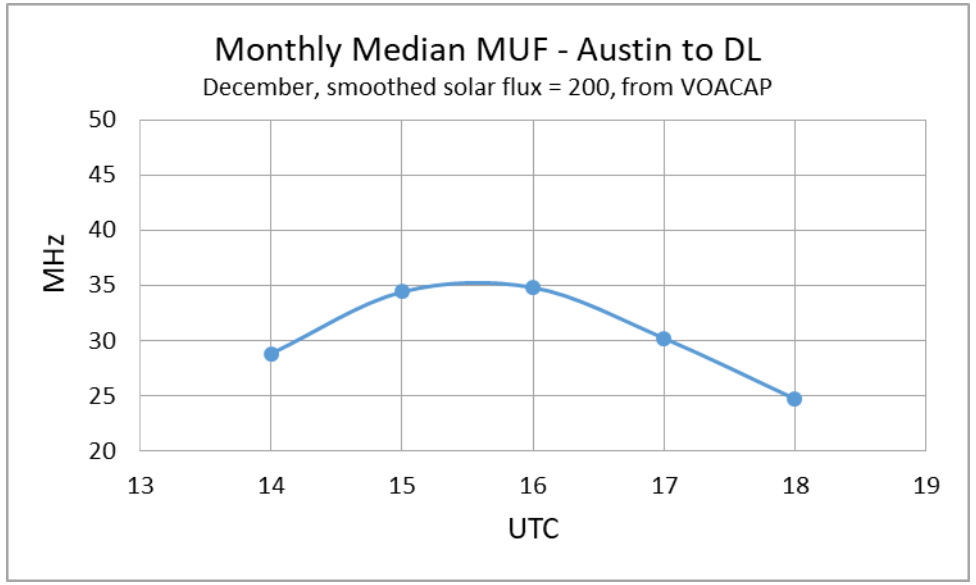
10.7 cm Solar Flux



- How much solar flux do we need for F_2 propagation on 6m?
- The 'accepted' value is around 200
- Should 200 be a smoothed value (blue curve)?
- Should 200 be a monthly mean value (black curve)?
- Could a short-term spike in solar flux to 200 give us a high enough MUF for 6m?
- All this begs the question "How does the ionosphere react to long-term and short-term EUV radiation?"

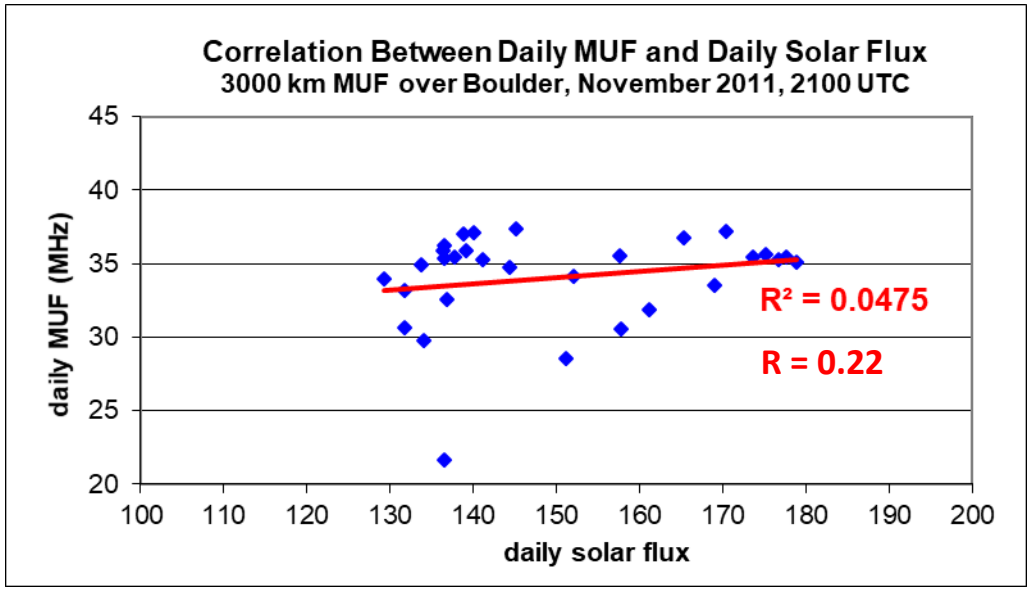
What Does a Smoothed Solar Flux Give Us?

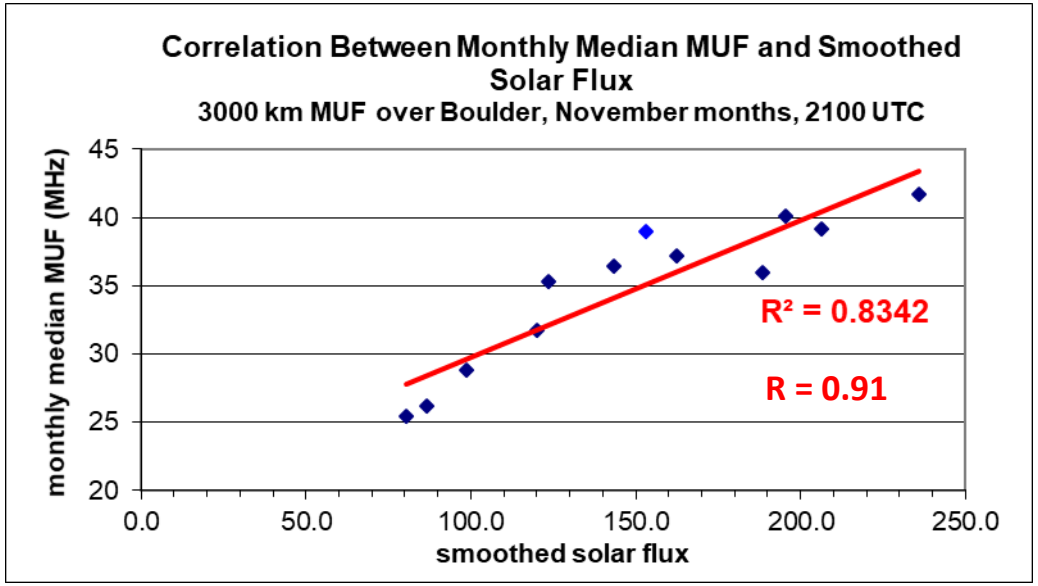
- Our model of the ionosphere is statistical in nature over a month's time fame – we don't have daily predictions
- If the smoothed 10.7 cm solar flux is 200, the monthly median MUF between Austin and DL in a December month will be as shown



- Monthly median = 50% probability = half the days of the month = 35 MHz
- On a couple days of the month, the MUF will be around 40 MHz
- Still not enough – we need to look at enhancements that could allow 6m F2 propagation – see slide 9
- Monthly mean solar flux of 200 or a spike to 200 in solar flux may not be the same as a smoothed 10.7 cm solar flux with respect to what the ionosphere does

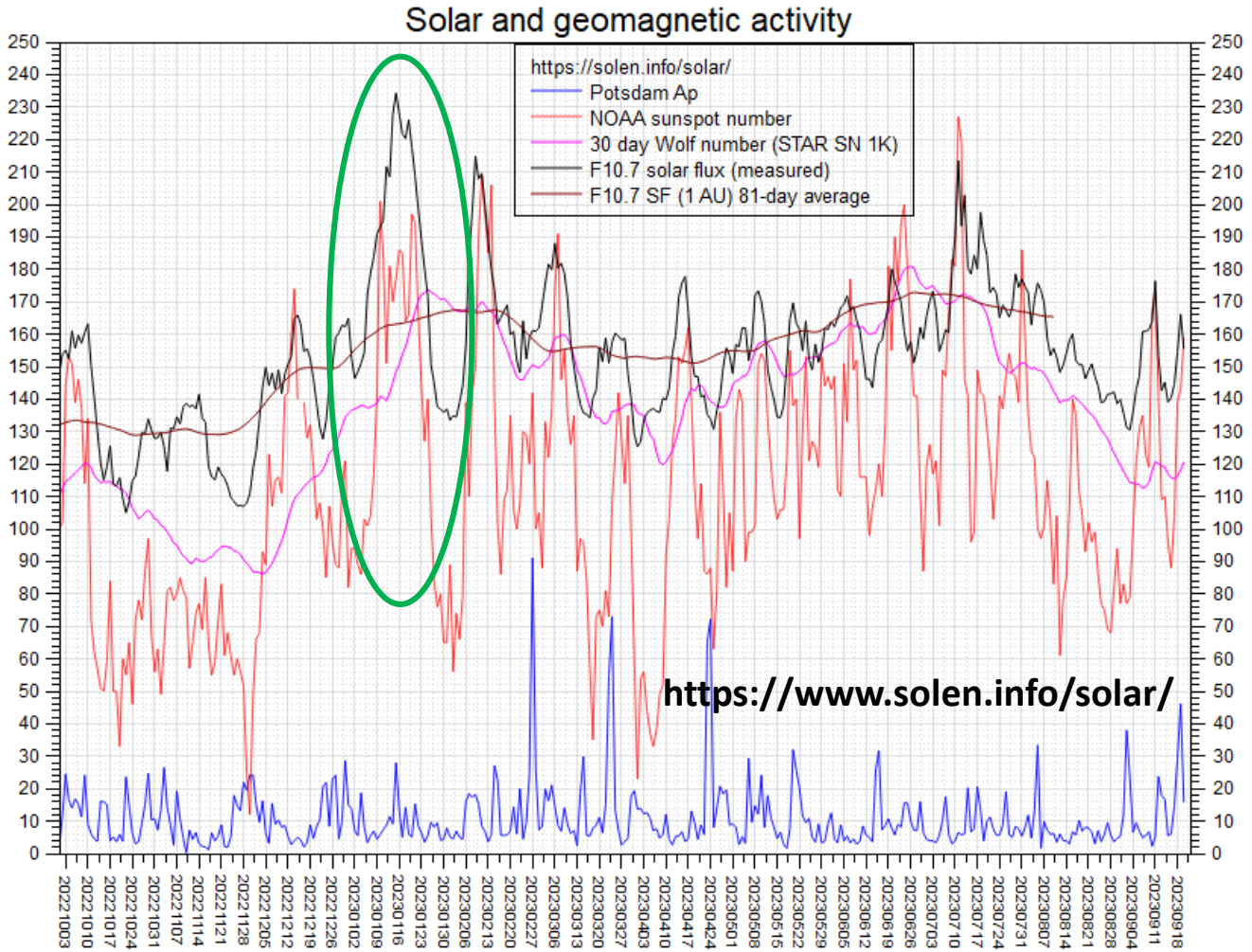
MUF vs 10.7 cm Solar Flux





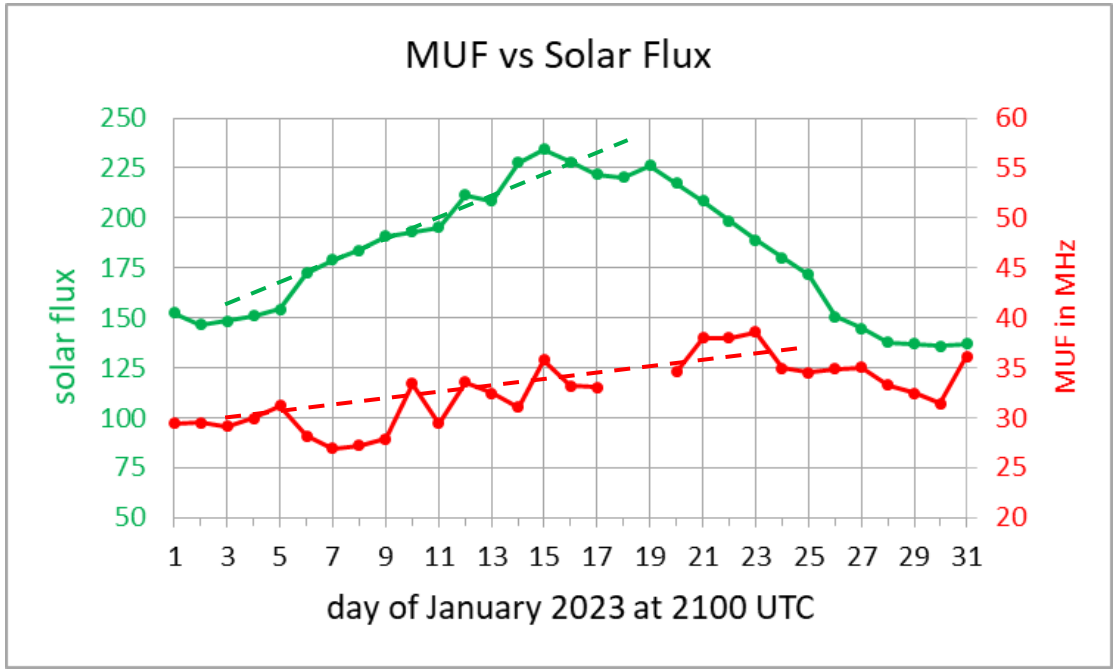
- R = 1.0 is perfect correlation – all data points fall on trend line
- R = 0.0 is no correlation – data points widely scattered about trend line
- Correlation between daily MUF and daily solar flux is poor
- Correlation between monthly median MUF and smoothed solar flux is very good – remember that the monthly median has a distribution about it

A Spike in the Solar Flux



- Let's look at January 2023
- Solar flux peaked at 234 on January 15
  - Sunspot number also peaked at 201 on January 10 and again at 197 on January 20
- A_p index peaked at 28 on January 15
  - Boulder 3-hr K indices were 2 to 4 on the 15th
- What happened to the ionosphere?

Daily MUF vs Daily Solar Flux – January 2023

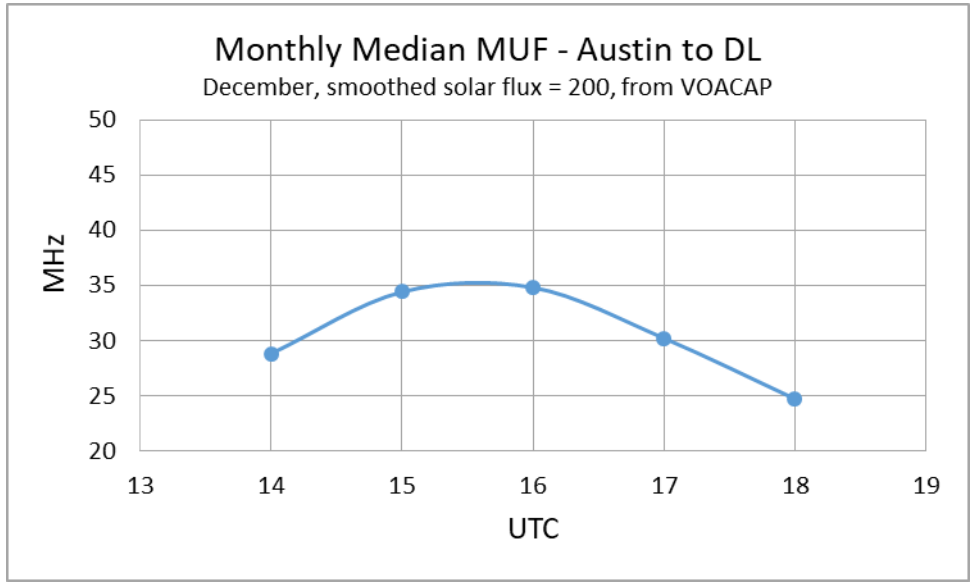


No data from Boulder on the 18th and 19th

- This big spike in the solar flux appears to have caused the 3000 km F_2 region MUF over Boulder to increase from about 30 MHz to 38 MHz in the middle of the month of January 2023
- Not quite as good as a smoothed (long-term) solar flux of 200
- There appears to be a several-day delay in the response in the ionosphere
- A shorter duration and/or smaller peak in solar flux will likely not do as well

the bottom line is we need an enhancement – even if we have a big cycle like Cycle 19

Enhancements to 6m F_2 Propagation



best time is 1500 to 1600 UTC

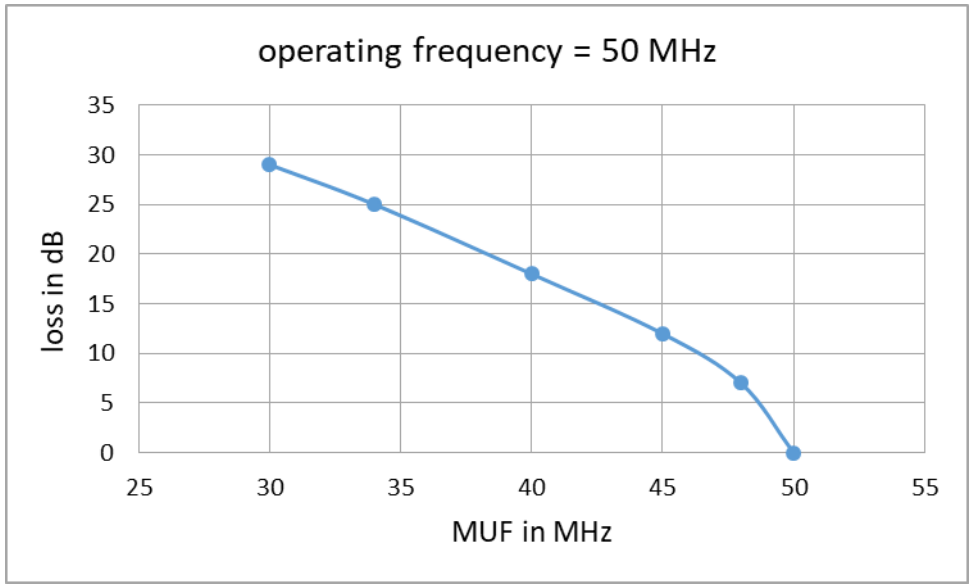
- From slide 5, the monthly median MUF (half the days of the month) is ~35 MHz
  - On a couple days, MUF is ~40 MHz
- Cycle 25 likely will not be big enough to give consistent 6m F_2 openings
- Need enhancements
  - F_2 region scatter mechanism at the expense of more loss
    - Known as above-the-MUF propagation (slide 10)
  - Moderate spike in the K index (slide 11)
  - Solar flares (slide 12)
  - TID (Travelling Ionospheric Disturbances – slide 13)
  - Non-homogeneous F_2 region
    - Spotlight propagation (slide 14)

Above-the-MUF Propagation

- VOACAP has an above-the-MUF algorithm in it based on real-world observations
  - Report ITU-R P.2011 - *Propagation at frequencies above the basic MUF*

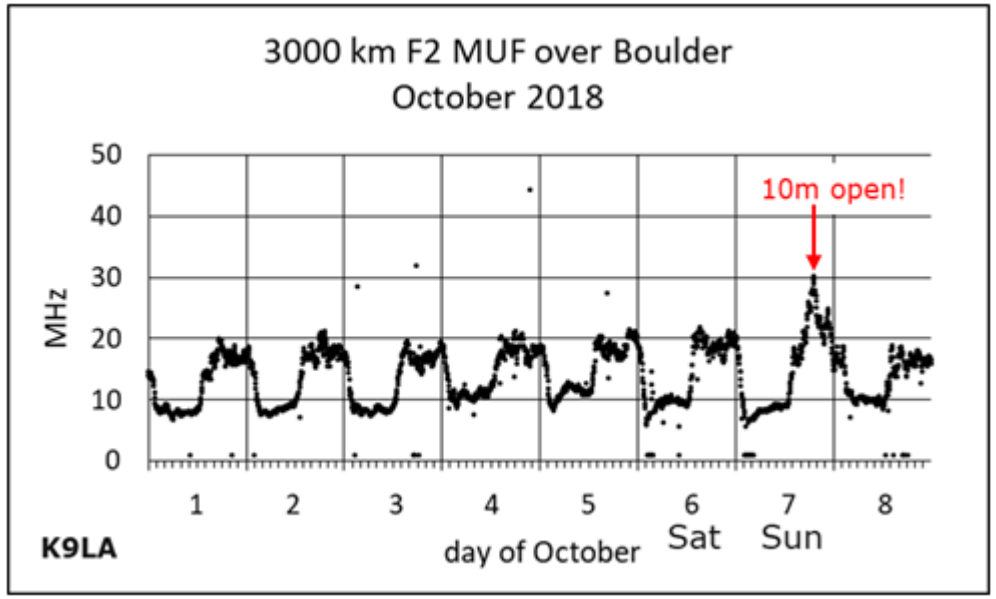
For F2-modes (up to a range of 7 000 km), when $f > f_b$

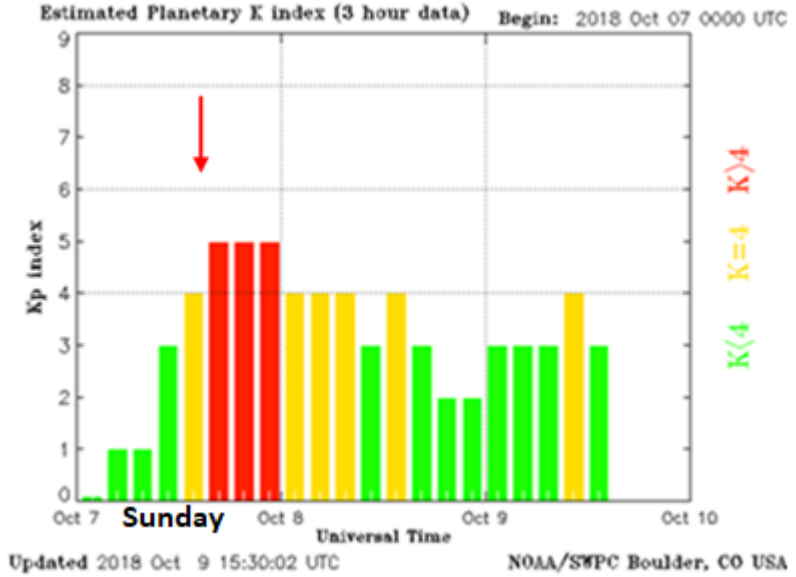
$$L_m = 36\left[\frac{f}{f_b} - 1\right]^{1/2} \text{ dB, or 62 dB whichever is the smaller.}$$



- *It also helps that ionospheric absorption at 50 MHz is minimal*
  - There's also an equation for the E region – thus the E region MUF doesn't have to be 50 MHz for a readable/decodable signal
  - FT8 will give you more opportunities

Moderate Spike in the K Index

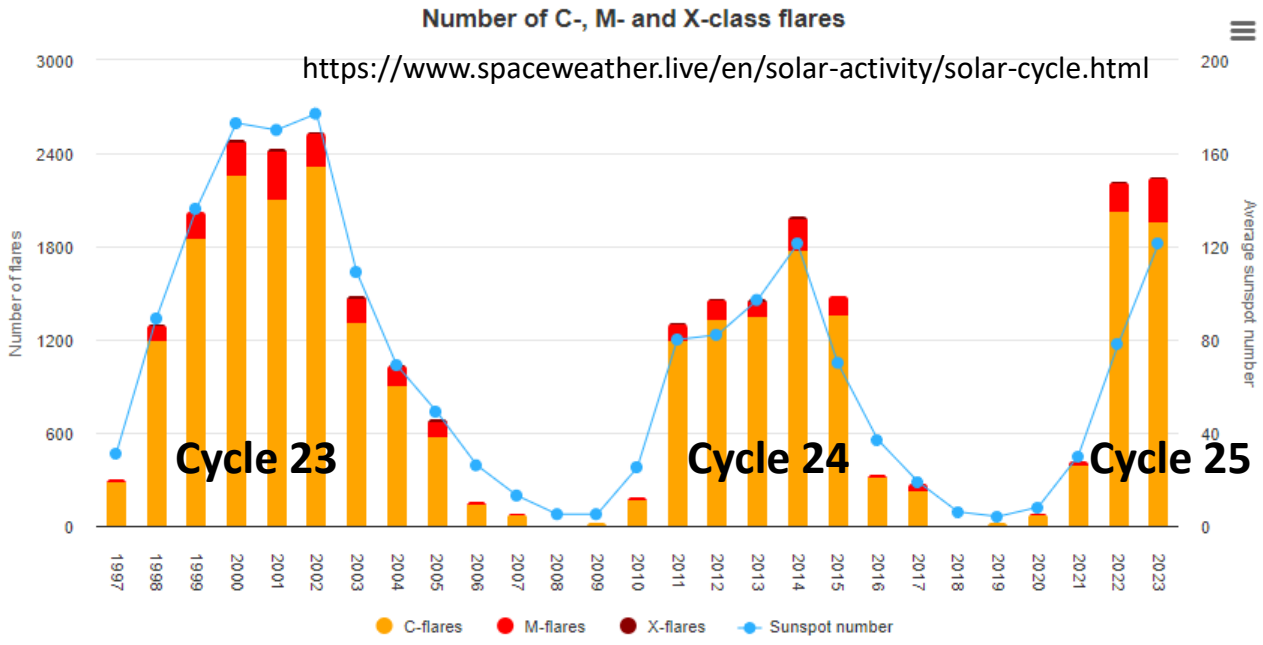


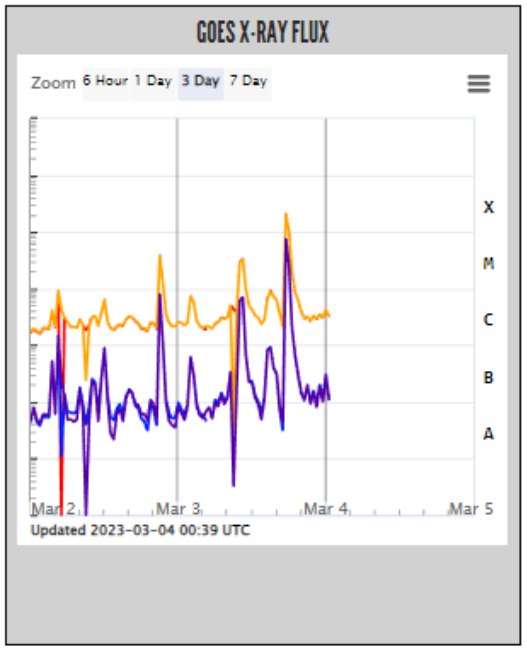


- California QSO party – October 2018
- Boulder ionosonde is about the midpoint of the path from W6 to K9LA
- No W6s on 10m at K9LA on Saturday – MUF only around 20 MHz
- Spike in K index on Sunday resulted in W6s on 10m at K9LA – MUF up to 30 MHz
- MUF increased by 50%

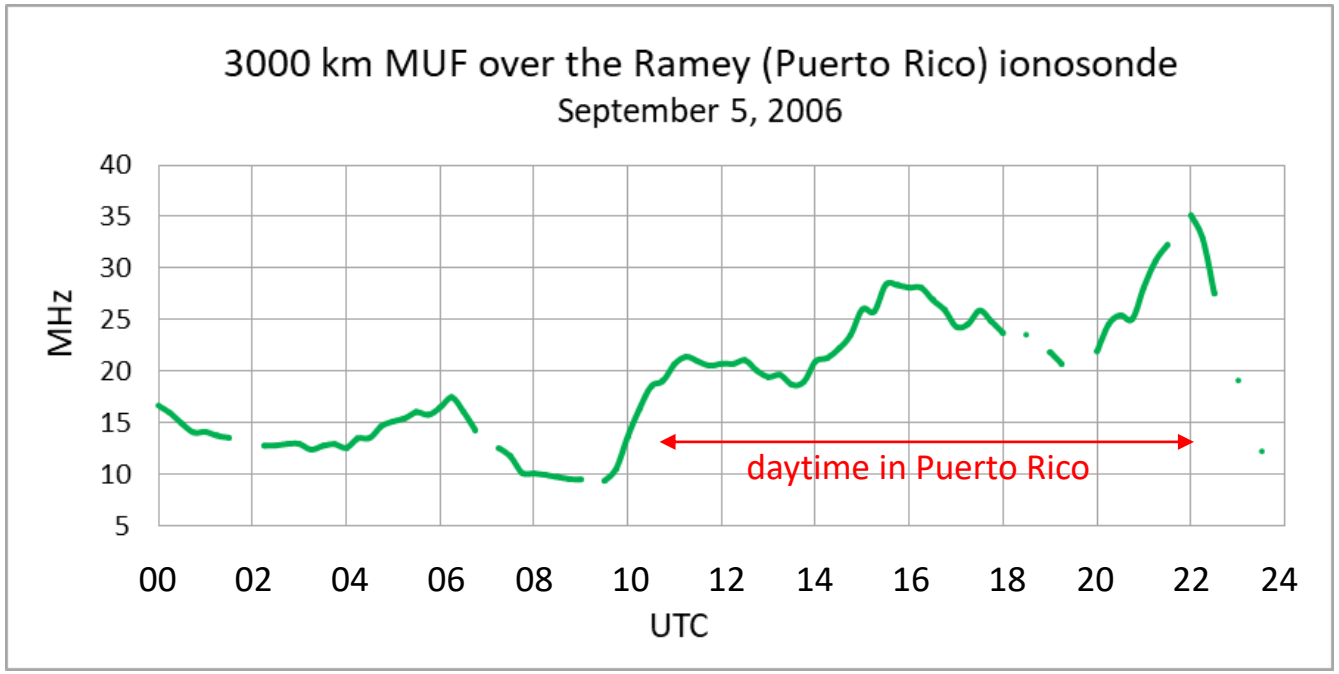
Solar Flares

- Could a short-term EUV spike from a big solar flare increase the MUF?
- If there is help from a big solar flare, it will likely be . . .
  - Near solar maximum and of a very short duration
- Ionosonde data can be iffy due to ionospheric absorption – TEC (Total Electron Content) from GPS measurements may be better – I plan to look at TEC





Travelling Ionospheric Disturbances



- Here's a good example of a TID
- ~ 5 hour period
  - Large scale TID
- There are small scale and medium scale TIDs

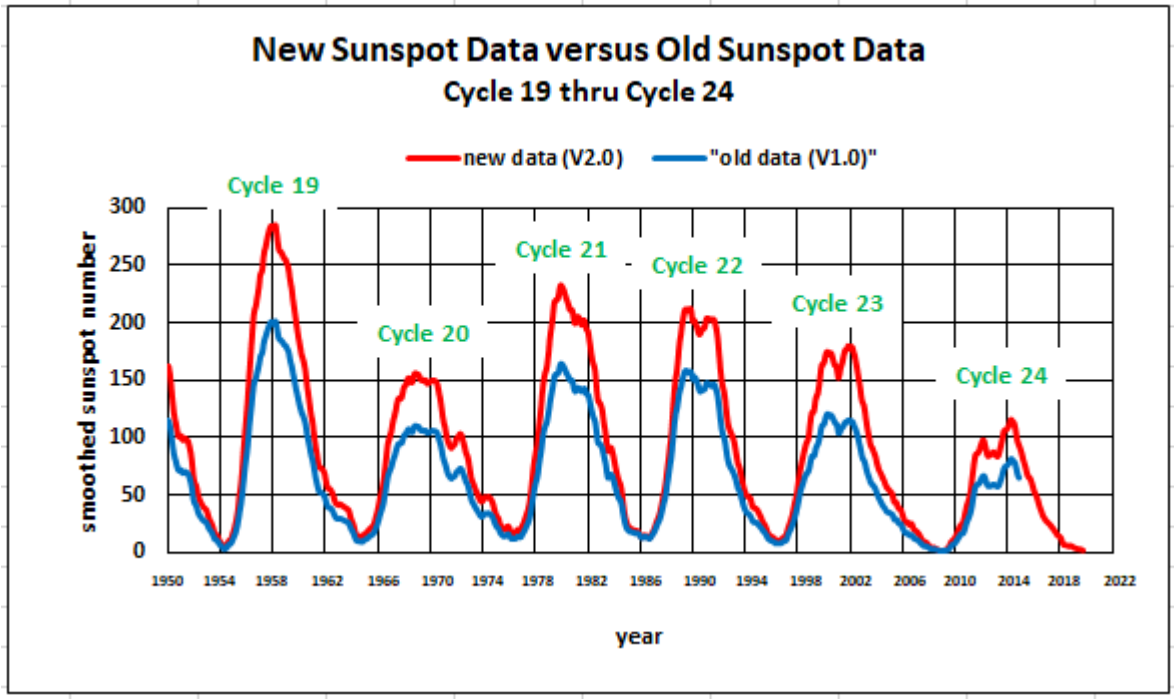
- An event in the lower troposphere (or even at ground level) starts the process
- Creates an atmospheric gravity wave that propagates up to the F_2 region
- Results in a TID – the MUF shows a cyclic pattern
- I believe I experienced a small scale TID at YK9A on 10m in February 2001 – I don't know the source

Non-Homogeneous Ionosphere

- I bet many of us have experienced spotlight propagation on 160m
- No reason why it couldn't happen on 6m
- The ionosphere is lumpy – less ionization in some places and more ionization in other places
  - On 160m, it may also be an absorption issue in the lower ionosphere
- If the 'more ionization' is in the right place, it could enable a 6m path
- Ionosondes tend to show this, but ionosondes are usually not in the right place to confirm what happened along a path

A Comment About Sunspots

- We now have new sunspot numbers as of July 1, 2015
- A series of four workshops (2011, 2012, 2013 and 2014) were held to review old sunspot numbers – concern with old data (V1)

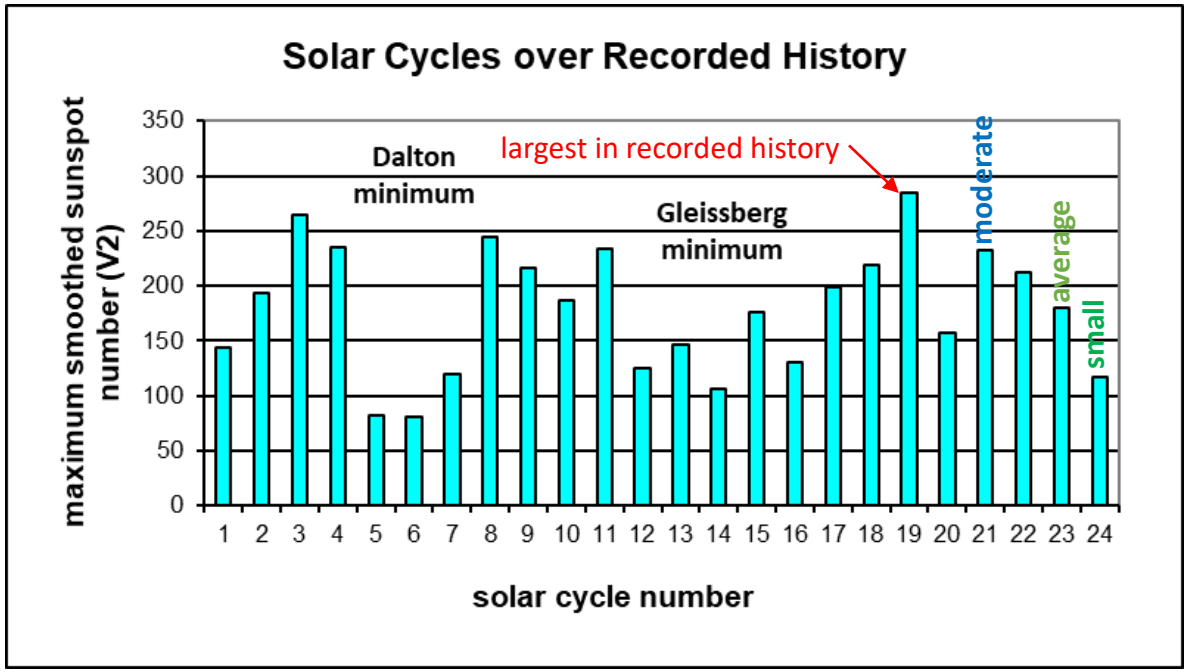


- The new sunspot record (V2) also goes back to 1750
- The model of the ionosphere in our propagation predictions is based on the V1 sunspot record
- V1 sunspot number = V2 sunspot number times 0.7

Previous 24 Solar Cycles

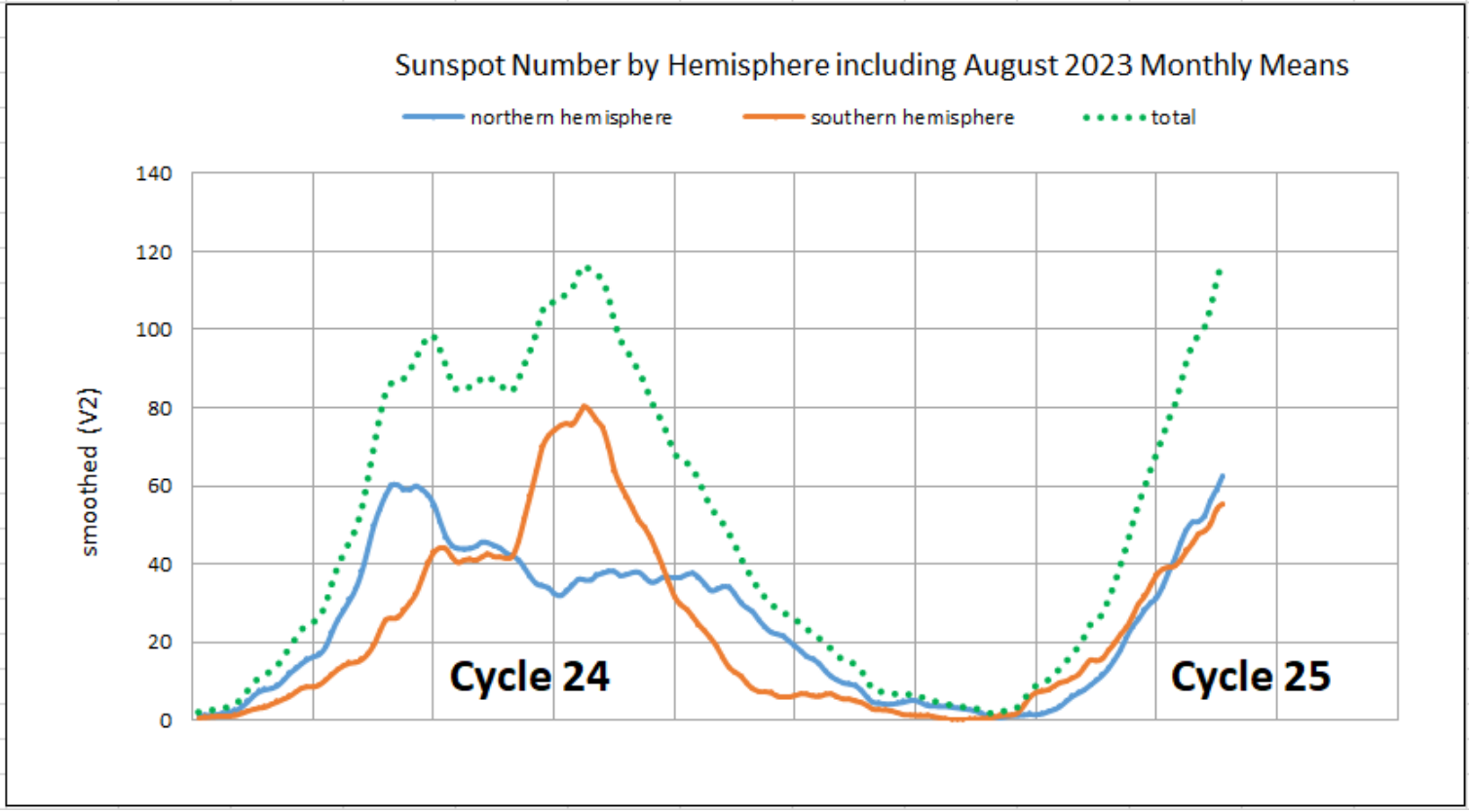
A Look at All Previous Solar Cycles

- Cycle 1 began in 1755
  - Maunder Minimum occurred from 1645-1715 with few sunspots
- We've gone through 3 periods of big solar cycles and 2 periods of small solar cycles
  - We appear to be in a third period of small solar cycles
- Cycle 24 was the smallest in our lifetimes
  - 4th smallest in recorded history



Will Cycle 25 get us out of this third period of small solar cycles?

Cycle 25 – One Peak or Two Peaks?



- Best guess right now is one peak due to the two solar hemispheres working together
- Also tends to confirm that Cycle 25 will be bigger than Cycle 24

Solar Cycle Predictions

Solar Cycle Predictions

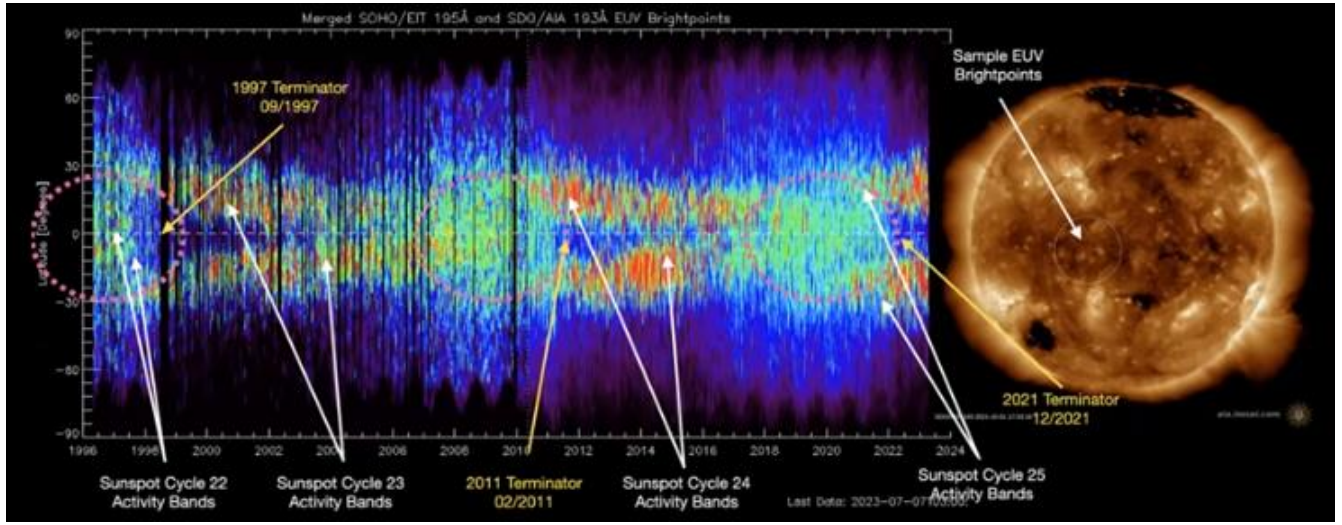
- I’m aware of over 60 predictions for Cycle 25
  - From a small cycle (NOAA/NASA consensus) to a big cycle
  - Why so many?
- Because we don’t fully understand the sunspot cycle process
  - We know it has to do with magnetic fields and plasma inside the Sun – but the nitty-gritty details are not yet fully clear
- Thus many methods are used to make a prediction
  - Example: precursor method

Prediction For A Big Cycle

- Dr. Scott McIntosh and colleagues predicted a big cycle in June 2020
  - It ran against the NOAA/NASA consensus of a small cycle like Cycle 24
- This prediction of a big cycle has received much publicity
- Dr. McIntosh has given many updates of their Cycle 25 prediction to the Front Range 6 Meter group
- If the prediction comes true, it would be similar to Cycles 21 and 22
  - Excellent worldwide propagation on the higher HF bands
    - 15m, 12m, 10m
  - Lots of worldwide 6m propagation via the F_2 region around solar maximum, too
- **But . . .**

. . . They Revised Their Prediction

- In August 2021, Dr. McIntosh and colleagues downsized their prediction to a slightly above average cycle
  - The terminator event for Cycle 24 was much later than expected
- New prediction is similar to Cycle 23
  - Still lots of worldwide propagation on the higher HF bands
  - Decent worldwide propagation via the F_2 region on 6m

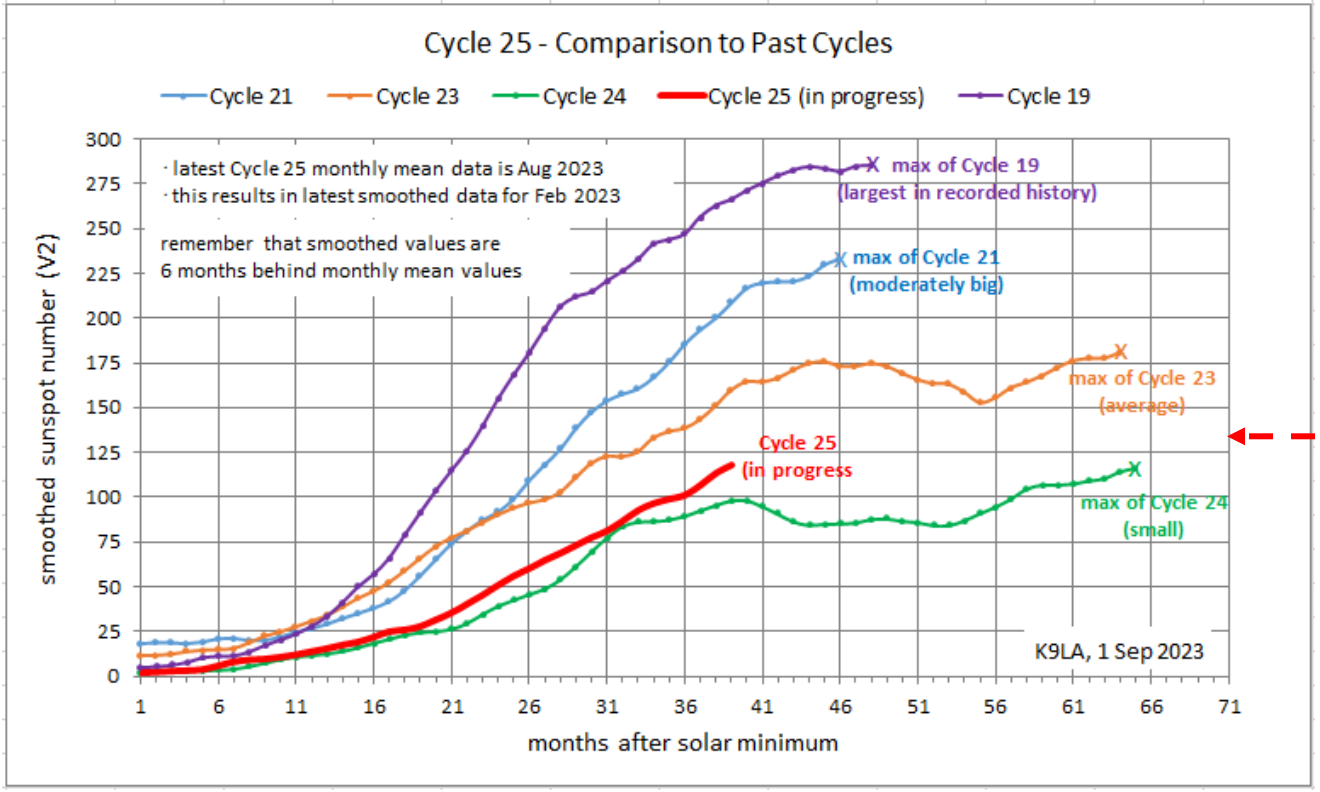


Terminator Cycle 22 – 09/1997
Terminator Cycle 23 – 02/2011 > 13yrs 5mo – small Cycle 24
Terminator Cycle 24 – 12/2021 > 10yrs 10mo – average Cycle 25

We'll gladly take a cycle similar to Cycle 23 than a cycle similar to Cycle 24!

Latest Data on Cycle 25

The Latest Cycle 25 Data



7 Sep 2023 prediction by Upton and Hathaway (134 +/-8)

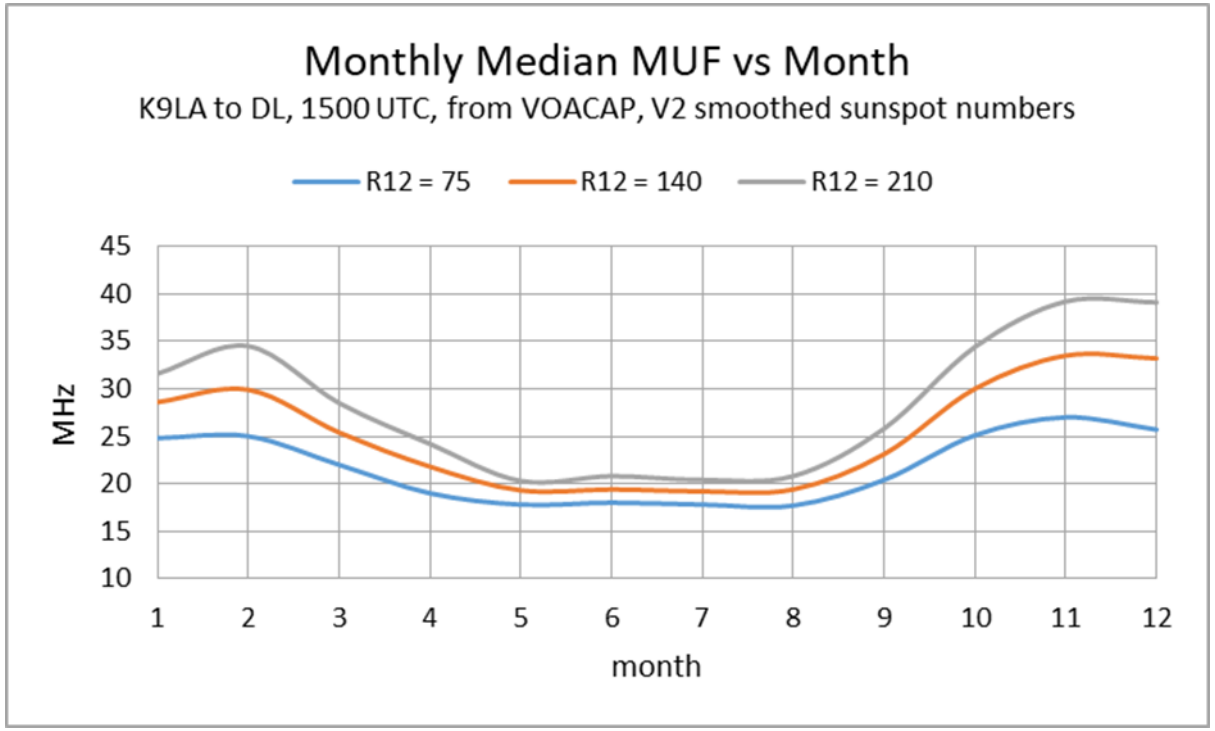
JGR Space Physics
https://doi.org/10.1029/2023JA031681

- For now, Cycle 25 is doing a bit better than the small Cycle 24
- Smoothed sunspot number of 130 (V2) is a smoothed 10.7 cm solar flux of about 140 – far from the 'accepted' value of 200 for 6m F_2

What to Expect on 6m

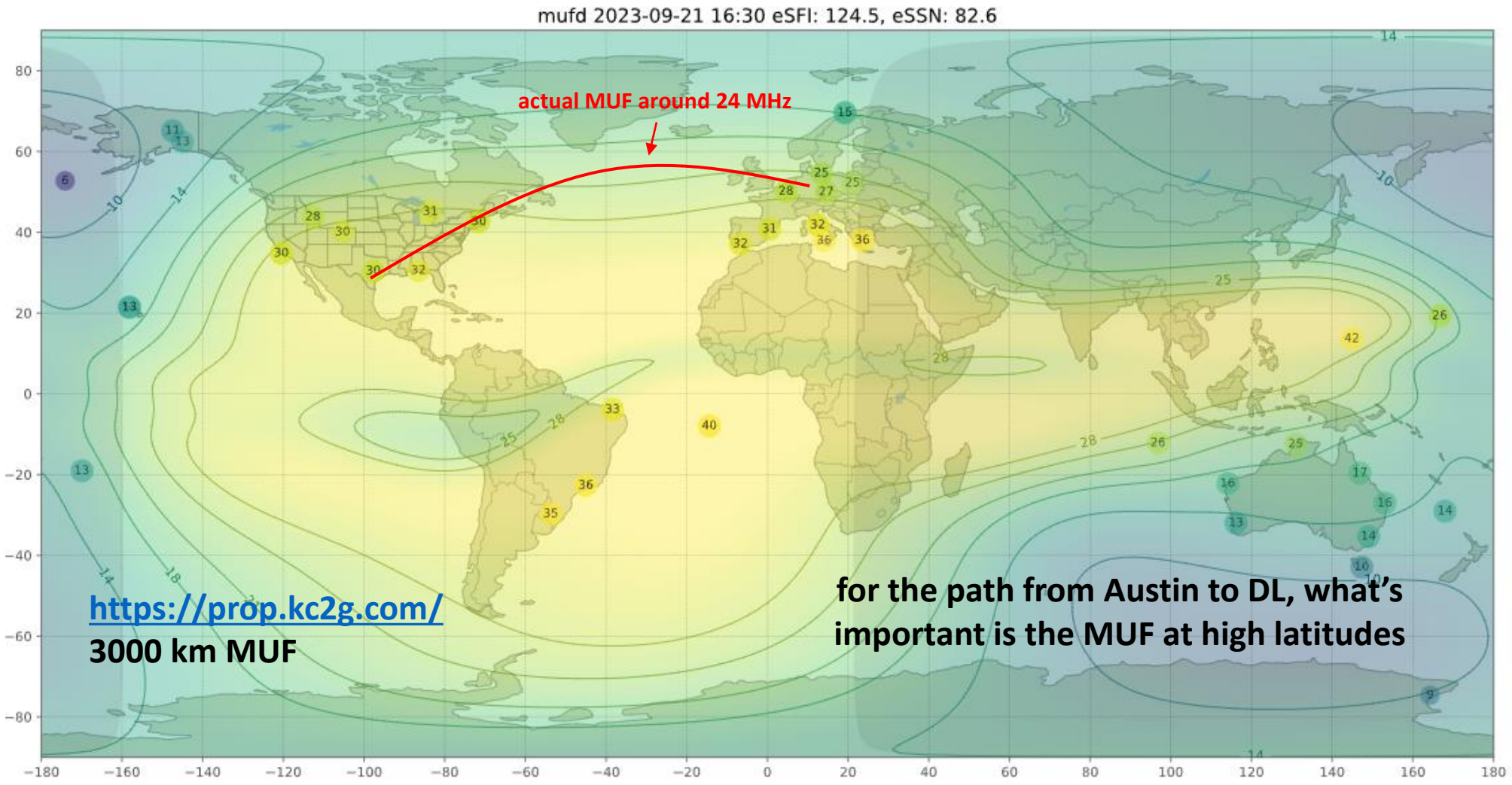
Propagation Right Now

- We're coming out of the F_2 region 'summer slump'
- In the northern hemisphere, lower daytime F_2 region MUFs than in fall/winter
- Caused by a change in the composition of the atmosphere
  - Decreased O/N_2 ratio in the summer
  - Increased O/N_2 ratio in the winter
- Watch for E_s
  - Wasn't much of a season
    - Has the pattern of Es shifted?
  - Major E_s season is close to being over



- Atomic oxygen (O) conducive to F_2 region electron production
- Molecular nitrogen (N_2) conducive to F_2 region electron loss

Worldwide F_2 MUF Data – 9/21/2023



Climate Change and the Ionosphere

Climate Change and the Ionosphere

- Warming is at ground level – results in cooling at ionospheric altitudes
- Many studies done over the years to understand the long-term trends in the ionosphere (long-term = 50 years or so)
- E region trends
  - Height of maximum ionization decreases
  - Amount of ionization increases
- F2 region trends
  - The trends are regionally variable due to neutral atmosphere dynamics (e.g., winds) and electrodynamics (e.g., geomagnetic field activity)

Study of the Effect of CO_2

- Qian, Solomon, Roble, Kane, *Model simulations of global change in the ionosphere*, GRL Vol 35, doi:10.1029/2007GL033156, 2008
- Authors looked at long-term trends in the ionosphere assuming the amount of CO_2 doubled from 2000 to 2100
  - 365 ppmv to 730 ppmv (how accurate is the 730 ppmv assumption?)

	solar min	solar max
height of F2 max	-14 km	-10 km
amount of F2 ionization	-9 %	-4 %
height of E max	-2 km	- 4 km
amount of E ionization	+4 %	+2 %

- Remember this is over a 100-year period
- I believe it would be tough to discern these changes in our ham radio lifetimes

Summary

- Predicting 6m F2 propagation is tough
  - Need short-term enhancements, some of which we don't fully understand yet
- Cycle 25 is ascending – hopefully up to an average cycle
- Some 6m F_2, and excellent worldwide 15m/12m/10m propagation should occur this coming fall/winter

I'm ready with my new 6m rig

☺