Interesting Propagation on 6 Meters
What Might Happen in the Future?

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Who Is K9LA?

National NC-60

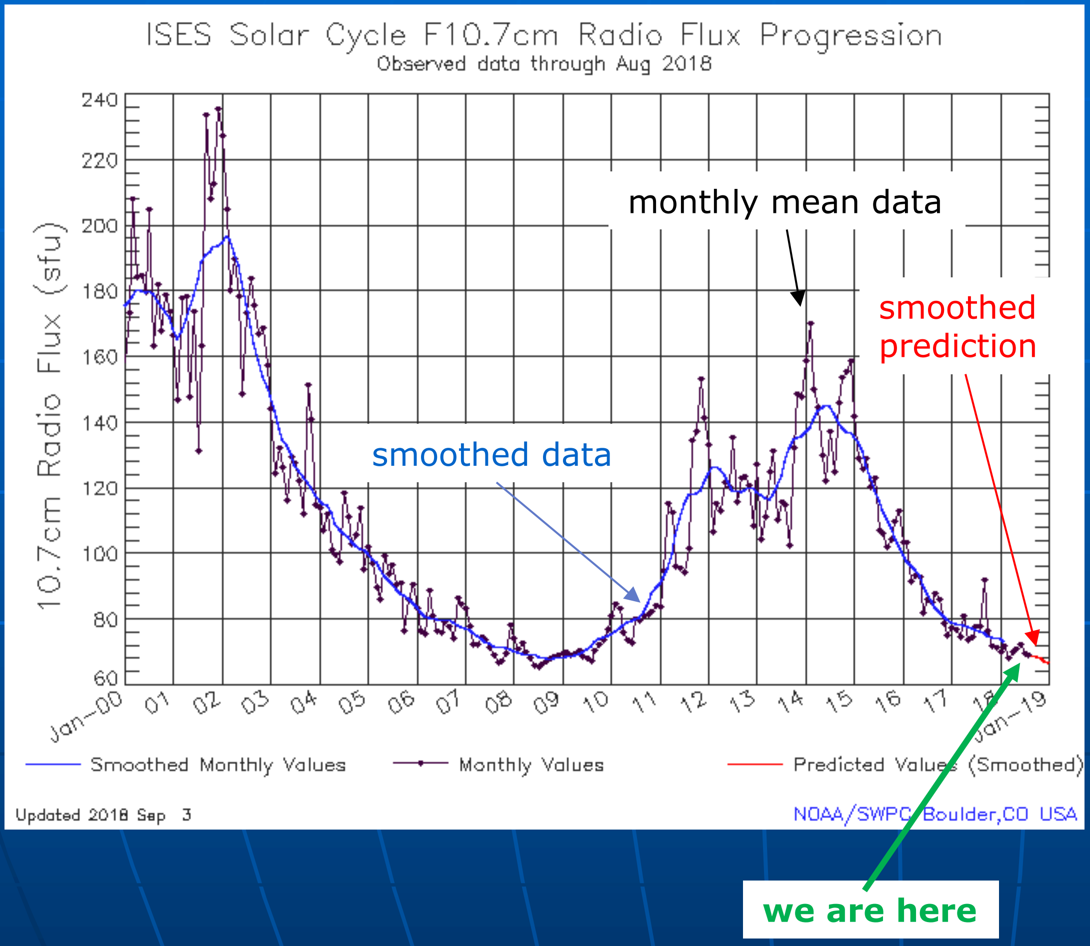
- Started out SWLing in the late 1950's
- Novice 1961, General 1962, Extra 1977
- EE out of Purdue
  - RF design engineer (RF power amplifiers)
    - Motorola (Schaumburg, IL and Ft Worth, TX)
    - Magnavox/Raytheon (Ft Wayne, IN)
  - Retired in October 2013
- Enjoy propagation (MF – 6m), contesting, DXing, antennas, vintage equipment, general aviation
- Wife is Vicky AE9YL
- ARRL Central Division Vice Director

What We'll Cover

- Update on Cycles 24 and 25
- The writings of K6MIO/KH6
- Predicting 6m propagation
- Noctilucent clouds and Es
- FT8 propagation

Update on Cycles 24 and 25

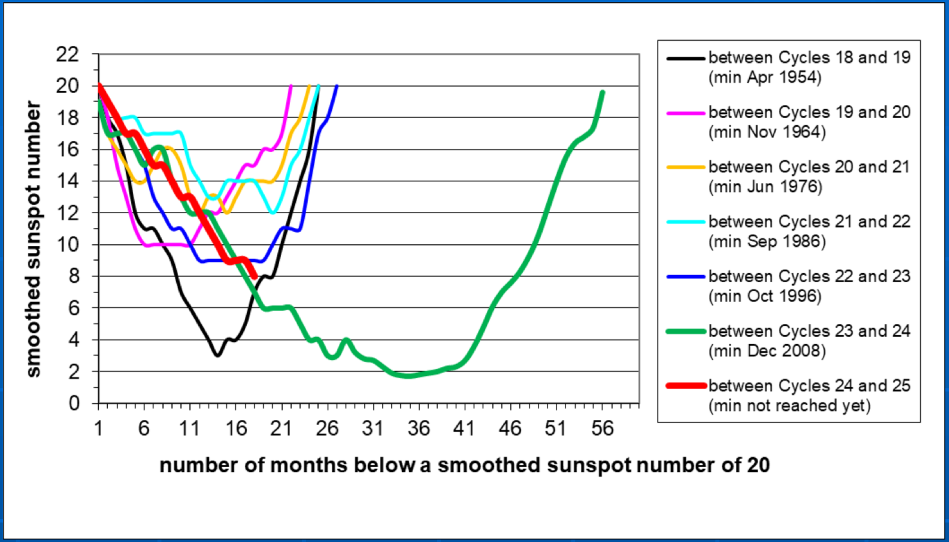
From the SWPC



- Space Weather Prediction Center (NOAA)
- Latest monthly mean data is August 2018
- Latest smoothed data is February 2018
- Solar minimum is near

Solar Minimum

- How near?
  - Best guess: early 2020
- How long?
  - So far we're tracking a <u>long</u> solar min
  - Suggests a small Cycle 25 – consensus among solar scientists, too



- For the next several years, the probability of 6m propagation via the F2 region is extremely low
- Hopefully 6m F2 will be back around Cycle 25 maximum – my best estimate is late 2022

The Writings of K6MIO/KH6

a valuable source of 6m propagation topics

Some of Jim's Papers

- Extreme Multi-Hop 50 MHz Es
  - CSVHFS 2010
- Extreme Range 50 MHz Es: Part 1 – SSSP

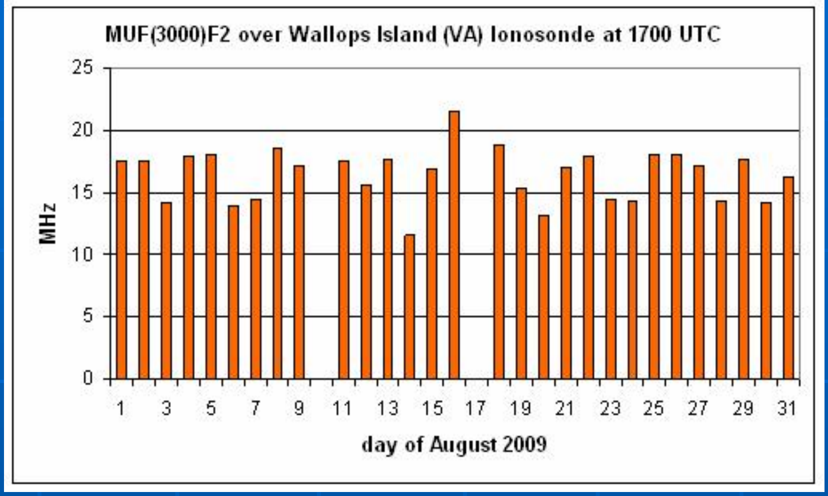
  Short-path Summer Solstice Propagation
  - CSVHFS 2011, with W3ZZ
- Extreme Range 50 MHz Es: Part 2 – TEFE

  Trans-Equatorial with F2 and Es
  - CSVHFS 2011, with W3ZZ
- An Overview of Extreme Es Propagation
  - CSVHFS 2012
- Fields, Winds, Tides, Waves, and Midlatitude Es
  - CSVHFS 2015
- 50 MHz F2 Propagation Mechanisms

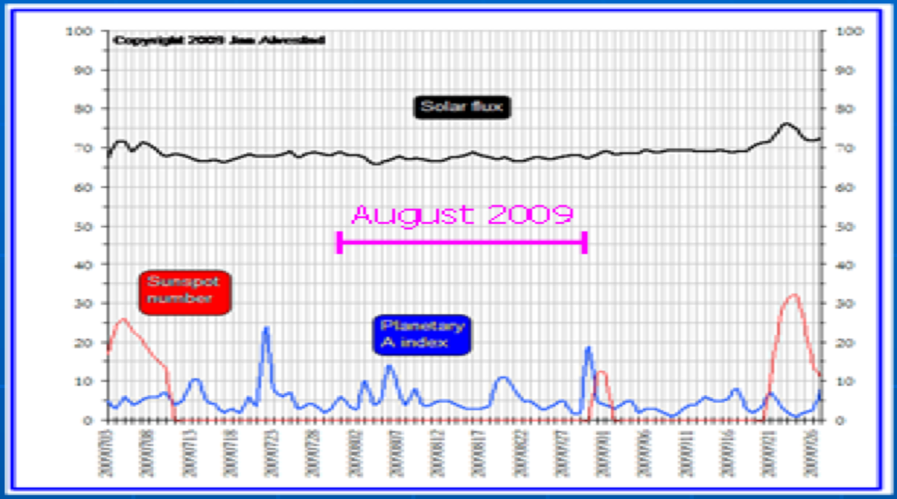
Predicting 6m Propagation

to predict something, it helps to have a model

Your Task – Develop A Model



The F2 MUF varied from a low of 11 MHz to a high of 22 MHz during the month

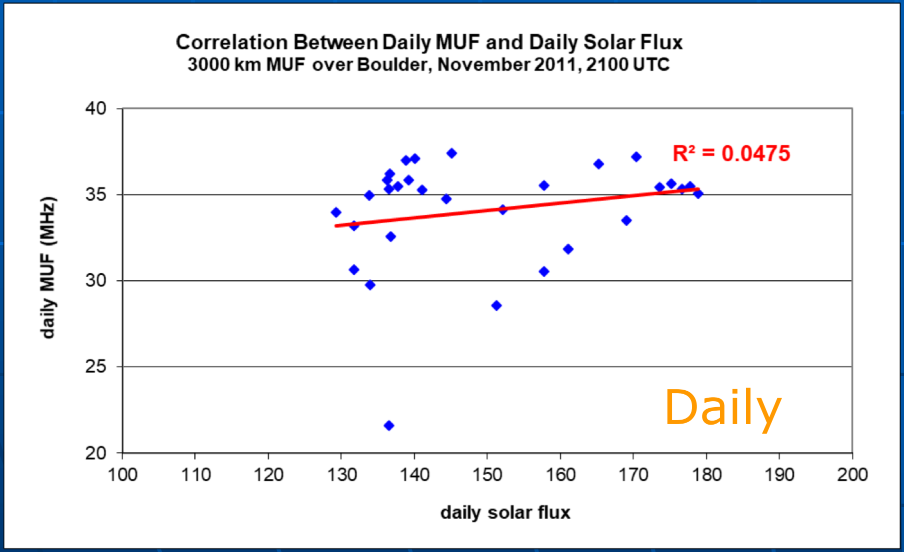


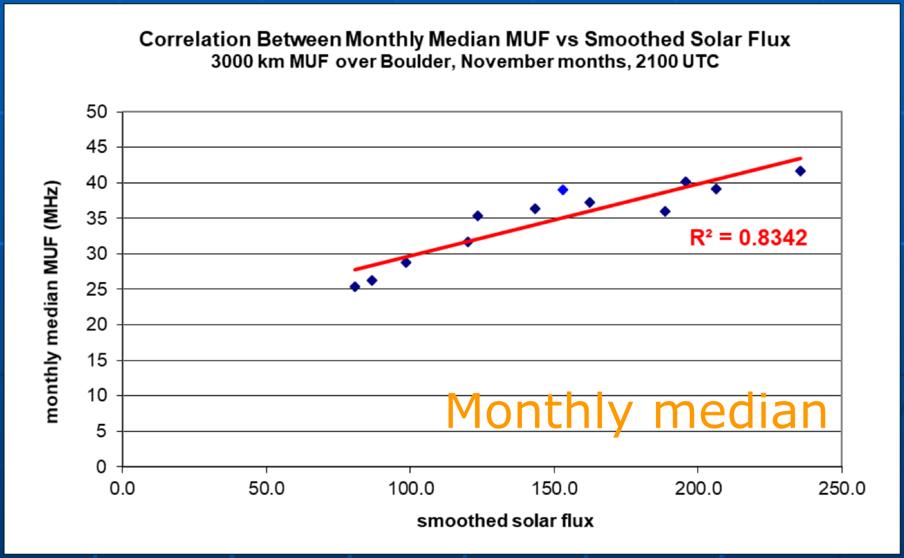
10.7 cm solar flux was constant and the daily sunspot number was zero during the month

- How can a constant solar flux/zero sunspots define the F2 variability?
- It can’t – thus we don’t have daily predictions ☹
- Our model of the ionosphere is a monthly median model
    - Causes of F2 region variability: solar radiation, geomagnetic field activity, events in lower atmosphere coupling up to ionosphere

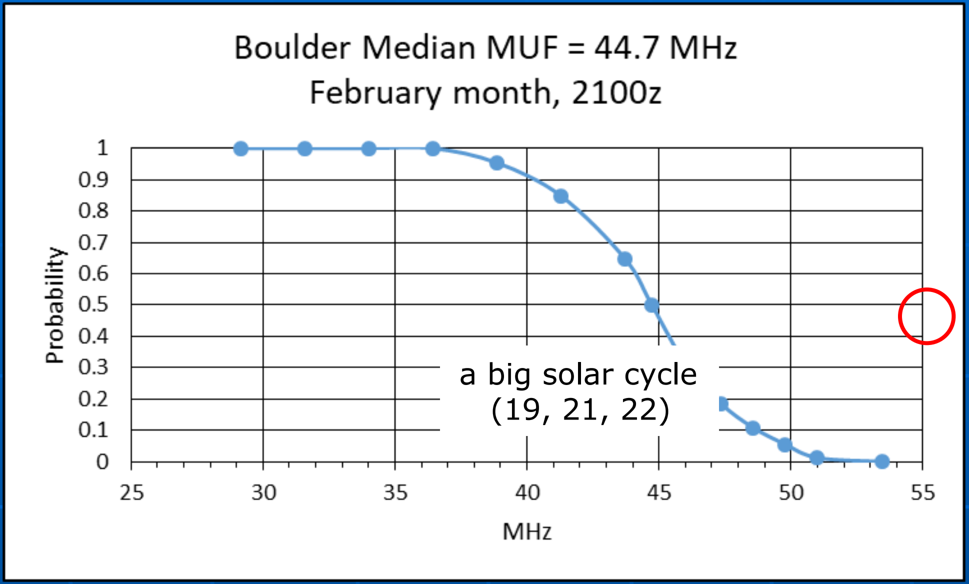
Our Propagation Predictions

- They use a smoothed solar index – 10.7 cm solar flux or sunspots
- Our predictions give us monthly median MUF and signal strength
- Median implies 50% probability
- Our propagation predictions are statistical in nature over a month's time frame





The Median Concept



50 MHz probability = 0.05
.05 times 28 = ~ 1 day

- Let's assume the predicted median MUF for Boulder in a February month is 44.7 MHz (a big solar cycle)
- There's a distribution about the median
- The probabilities are the number of days in the month
- Probabilities are low for 6m – even around a big solar max

Low Probability Events

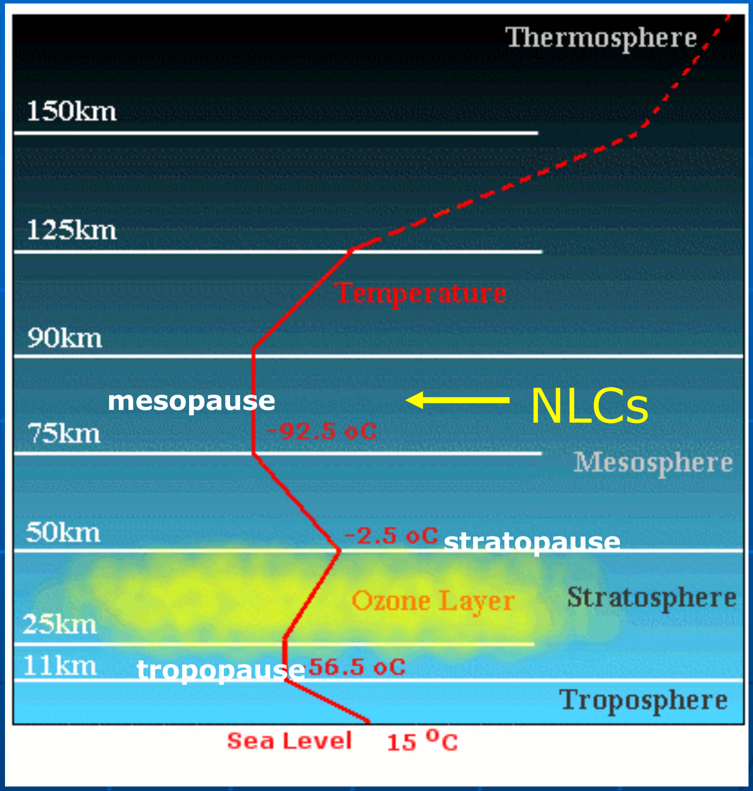
- How do you predict low probability events?
- Sporadic E is a good example
  - We have a general knowledge of the patterns of occurrence
    - Late morning and early evening in summer months
    - Early evening in December
  - We use this determine our operating times
- Similarly, we have a general knowledge of 6m openings
  - F2 in the fall and winter around solar max
  - Es during the summer
  - But it's tough to predict which days will be "good"

Noctilucent Clouds and Es

Noctilucent Clouds

noctilucent = "night shining"

- Noctilucent clouds (NLC) form in the <u>high latitude</u> mesosphere at around 83 km
  - Coldest temperatures in the atmosphere
- Water vapor wraps around meteor smoke particles giving ice crystals
  - Electrons attach to ice crystals
- Usually form in May, intensify in June, and ultimately fade in July and August



But This Year . . .

- NLC did not fade in July
- They continued to persist in August, too
- Unexpected surge in mesospheric water vapor and a bit colder mesosphere

- Reasons for more NLC
  - Upwelling of water vapor
  - Coldest and wettest years appear to be at solar minimum

Prior Work with NLC

- JE1BMJ proposed that these ice crystals (a.k.a. Polar Mesospheric Summer Echoes - PMSE) may play a role in 50 MHz propagation across the high latitudes (e.g., Midwest to JA)
  - September 2006 issue of the Japanese magazine CQ Ham Radio
- He called this SSSP (Short-path Summer Solstice Propagation)
- PMSE has been observed for many years
  - Mostly studied with high-power VHF radars
  - Sometimes PMSE can be seen on ionosondes

NLC Electron Densities

- Radar studies show NLC diurnal pattern
  - 2 AM to 1 PM local
  - 4 PM to 9 PM local
- Kind of similar to Sporadic E
  - Late morning
  - Early evening
- But measured electron densities for NLC are <u>way too low</u> to refract 50 MHz
  - Maybe more this summer?

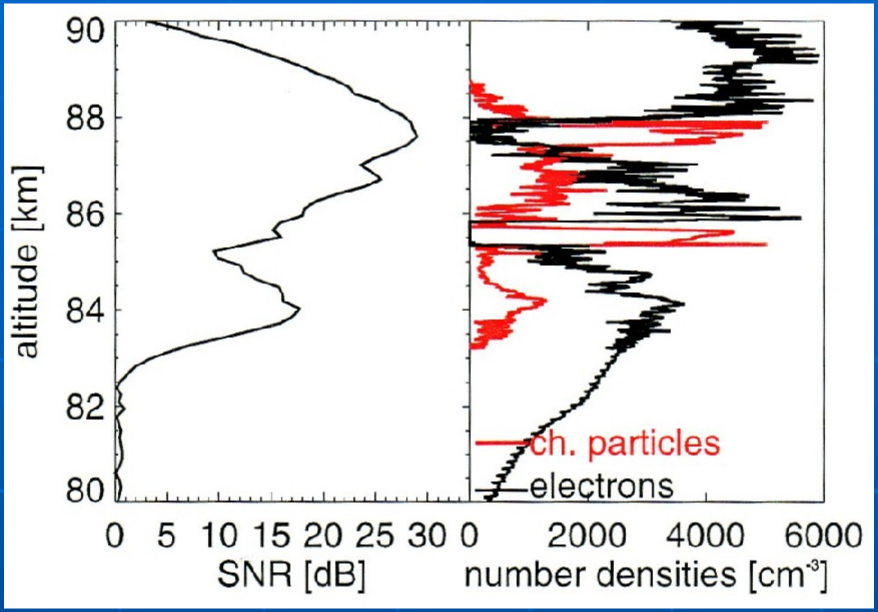
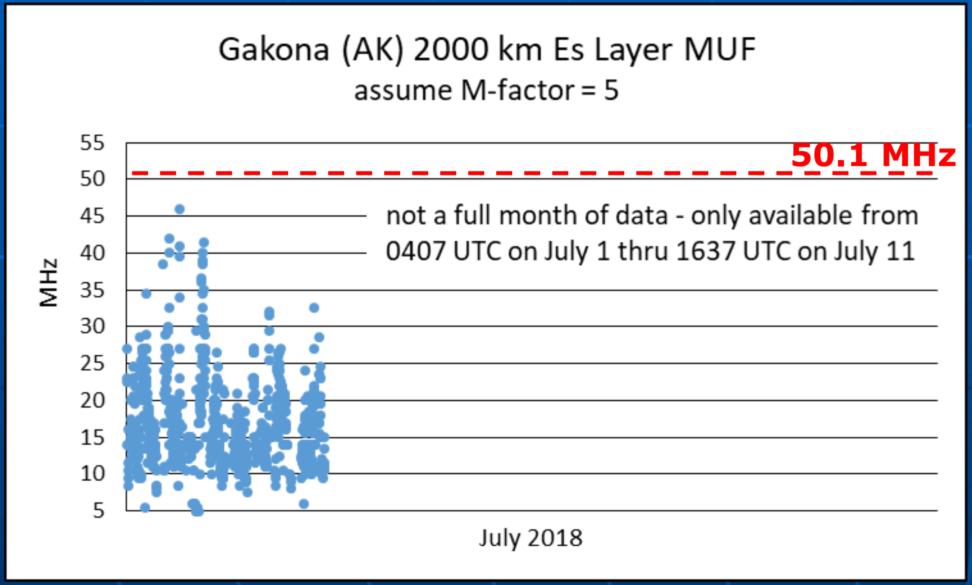


Figure is from *Polar mesosphere summer echoes (PMSE): review of observations and current understanding* by M. Rapp and F.-J. Lübken (**Atmospheric Chemistry and Physics**, 4, 2601-2633, 2004)

NLC and Es

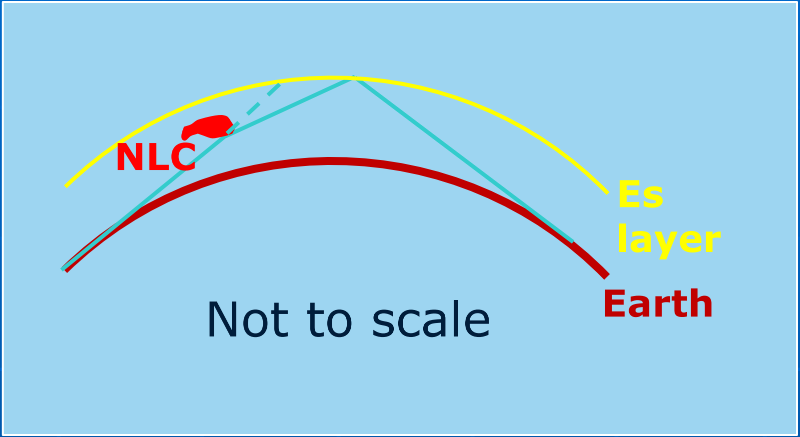
- Although NLC by themselves don't appear to be a mode for 6m propagation, could they help with Es propagation across the high latitudes?
- Let's look at the Gakona ionosonde at 62° N / 145° W
  - Gakona is in Alaska along the path from the Midwest to JA



- MUFs are close to 50 MHz, but still not enough
- Maybe all we need is a bit of help from the underlying NLC electron density
  - Or maybe the normal E layer?

How NLC Could Help Es

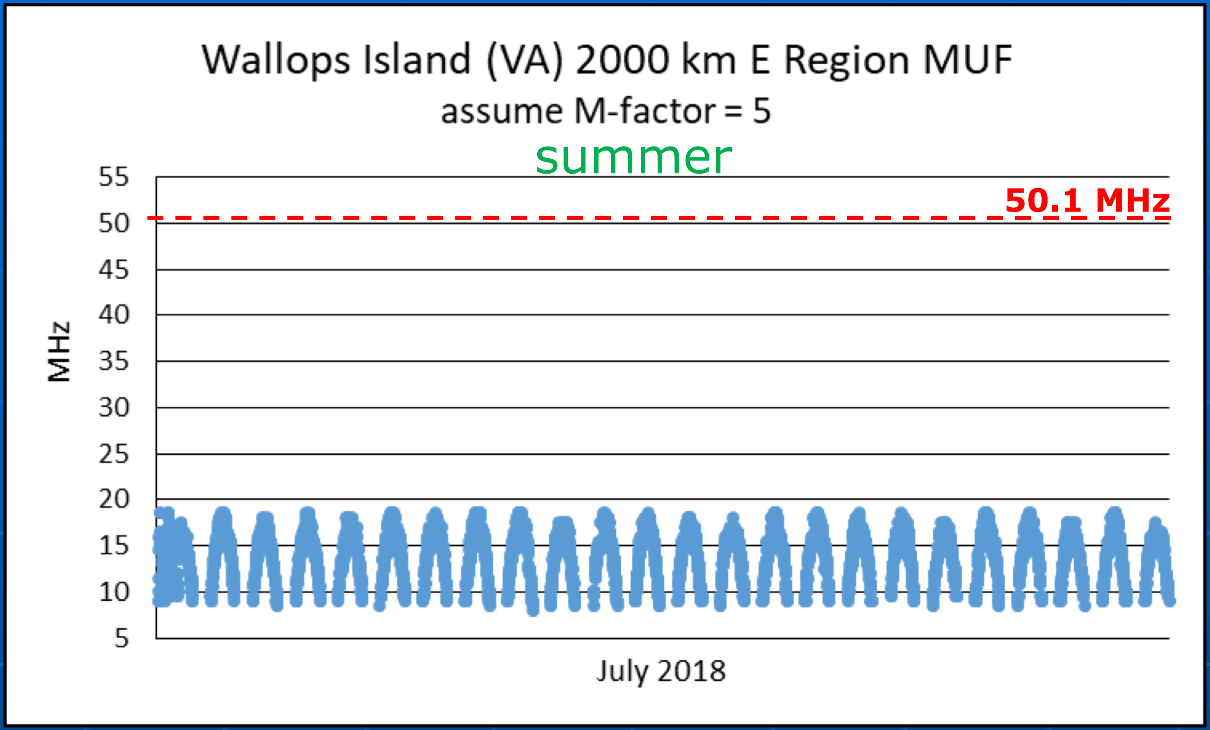
- Perhaps some refraction occurs from NLC such that the Es layer doesn't have to do as much refraction as when there aren't any NLC



- For the Midwest to JA path, the Es MUF may not have to be 50 MHz
  - The MUF only has to be close, with NLC supplying the little extra bit of refraction

NLCs are high latitude – now let's look at mid latitude 6m propagation

Wallops, E MUF, Summer 2018

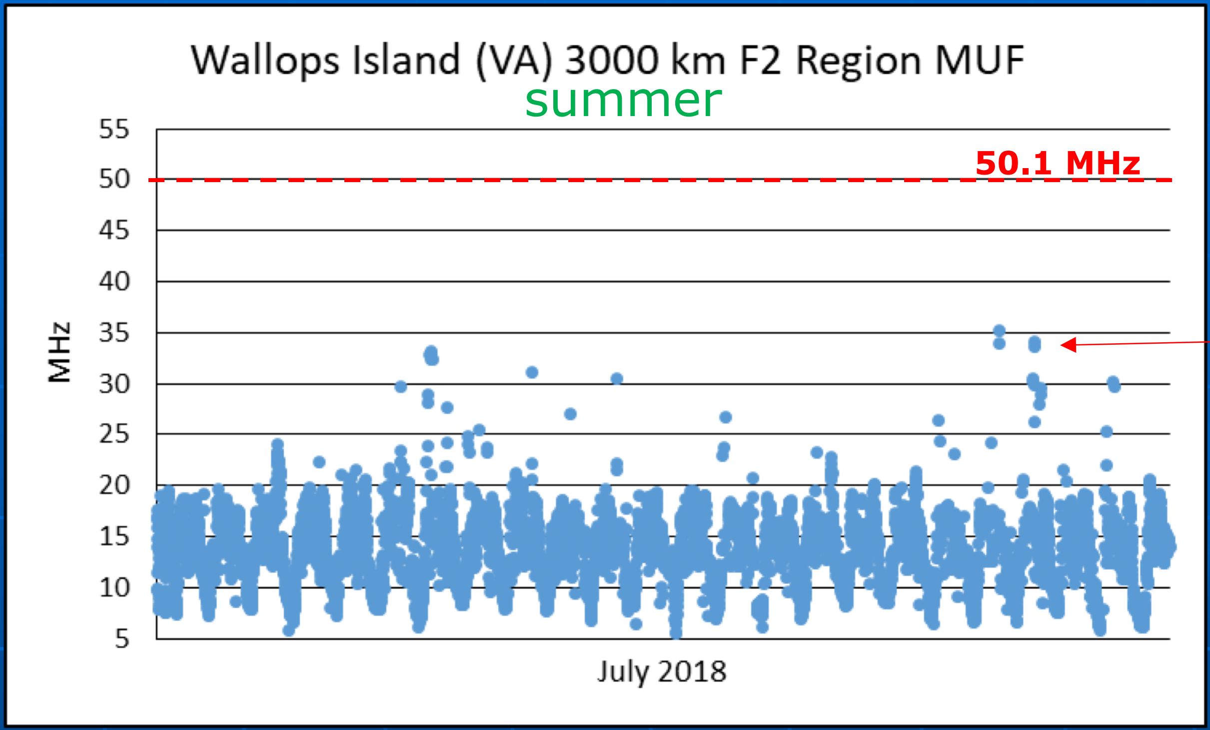


Wallops is at 37º N / 76º W

data around
solar minimum

- This is the typical diurnal variation of the summer E region
- Highest value each day (around noon) says low angle 20m and 17m propagation was via E hops – typical for a mid-latitude summer
- Not enough for 6m openings – somewhat lower E MUFs in winter

Wallops, F2 MUF, Summer 2018

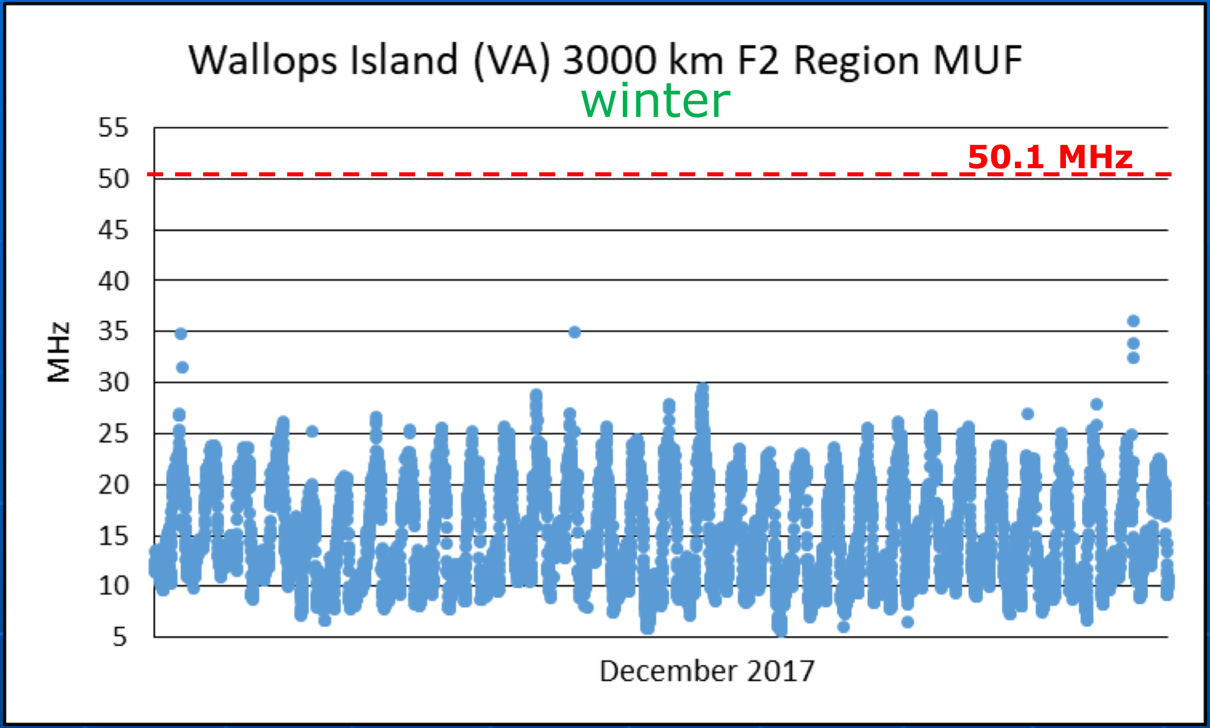


data around
solar minimum

Caution - many of these higher MUF echoes are 2nd up-down Es echoes

- As expected, summer F2 region MUFs are nowhere near 50 MHz
- Not enough for 6m openings

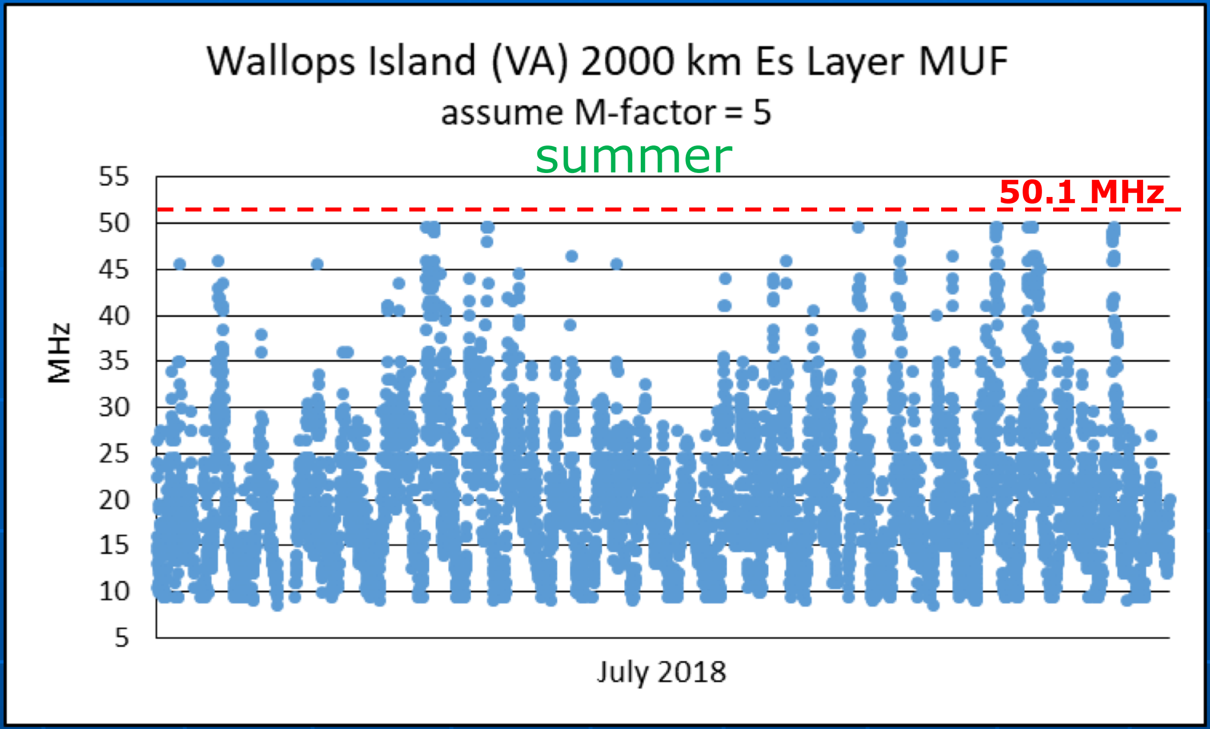
Wallops, F2 MUF, Winter 2017



data around solar minimum

- A bit higher F2 MUFs in the fall/winter – mostly above 24 MHz
- But still not enough for 6m

Wallops, Es MUF, Summer 2018



data around
solar minimum

- Many Es echoes – some approaching an MUF of 50 MHz
- Es echoes at Eglin AFB (FL), Boulder (CO) and INL (ID)

Be careful with Boulder data – they have an interference problem with a co-located ionosonde

What The Data Suggests

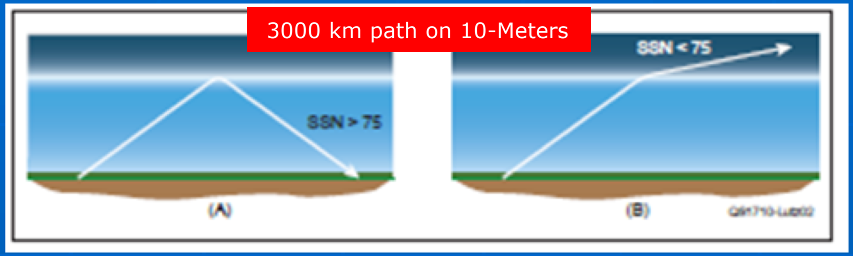
- The MUFs weren't high enough this summer
- Even the Es MUFs didn't appear to be high enough
- So why were there so many 6m FT8 QSOs this summer?
- What is the FT8 advantage?
  - Actually it appears there are two issues

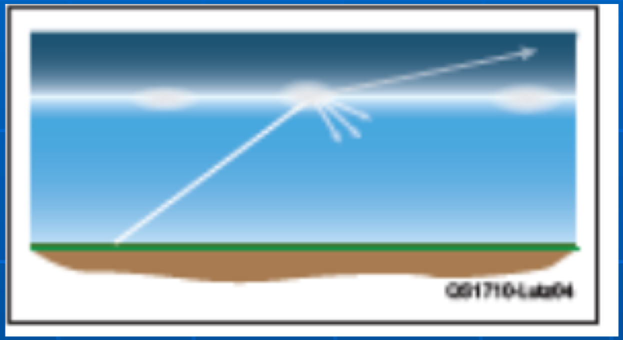
FT8 Propagation

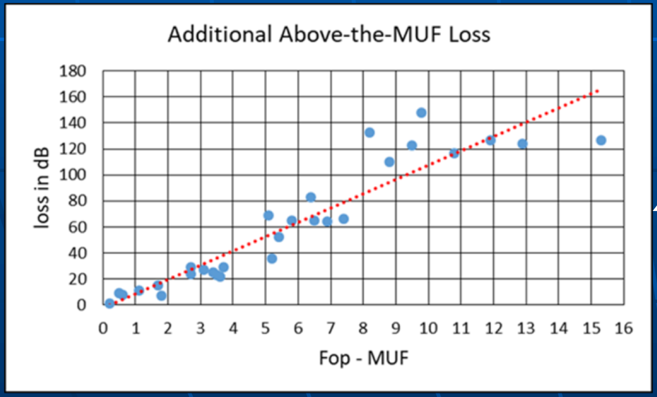
FT8: SNR Advantage

- SNR = Signal-to-Noise ratio
- WSJT documentation says FT8 can decode down to a nominal -19 dB SNR in a 2500 Hz bandwidth
- Using a signal generator and step attenuator with my OMNI-VI, I can decode CW at -2 dB SNR in 250 Hz
  - Is this average? Better than average? Worse than average?
  - Equivalent to -12 dB SNR in 2500 Hz
- FT8 has a nominal 7 dB advantage over me
- I've seen FT8 decode down to -24dB SNR
  - 12 dB advantage
- Why does this matter if the MUF isn't high enough?

Above-the-MUF Mode







- We normally assume refraction – MUF needs to be at or above the operating frequency
- In the real world, the MUF can be slightly below the operating frequency
  - A form of scatter occurs
  - Scatter implies loss
- VOACAP includes this above-the-MUF mode

Ionospheric absorption is minimal on 50 MHz – leaves lots of room for loss due to MUF being less than Fop

FT8: 6-Meters with Es

- Assume one-hop 2000 km path with Es MUF > Fop
  - Ionospheric absorption is 1.5 dB (absorption ~ $1/f^2$)
  - Signal is -75 dBm at 50.1 MHz with 10 Watts and 3-el Yagis
- Man-made noise at 50 MHz is -115 dBm in 2500 Hz
  - From ITU noise document for a residential environment
- Thus the SNR = 40 dB
- FT8 decode capability = -19 dB SNR
- △ = 59 dB
  - MUF for 6-Meter FT8 QSOs can be 6 MHz below 50 MHz (from plot on previous slide)
- Thus the MUF needs to be at least 44 MHz for 6m FT8 propagation
  - We saw that there were many occurrences of the Es MUF at Wallops Island this summer being at and above 44 MHz
- MUF needs to be at least 45.5 MHz for CW (even higher MUF for SSB)

Guidelines at Solar Minimum

- FT8 should be good in the summer via Es
  - CW/SSB might be good if MUF closer to 50 MHz
  - No Es, no FT/CW/SSB
- Nothing consistent for either FT8 or CW/SSB expected in the fall/winter around solar minimum
  - Caution – the ionosphere is very dynamic and we do not capture short-term enhancements very well
- 10m FT8 should benefit greatly from the above-the-MUF mode during this solar minimum
  - The farther south, the better the chances

Summary

- We’re likely to be at solar minimum for a while
- Expect FT8 openings in the summer via Es
- Cycle 25 expected to be another small one
  - There still should be 6m FT8/CW/SSB via F2 around solar max in fall and winter months
- There may be a tie between NLCs and Es across the high latitudes
- I believe the above-the-MUF mode is the enabler for FT8 on 6m (and 10m)