K9LA SEA-PAC Workshop

1:00 to 1:45 Solar Topics

2:00 to 2:45 Antenna Topics

3:00 to 3:45 Field Day Topics

4:00 to 4:45 Events That Impact the F2 Region

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SEA-PAC Workshop
Solar Topics

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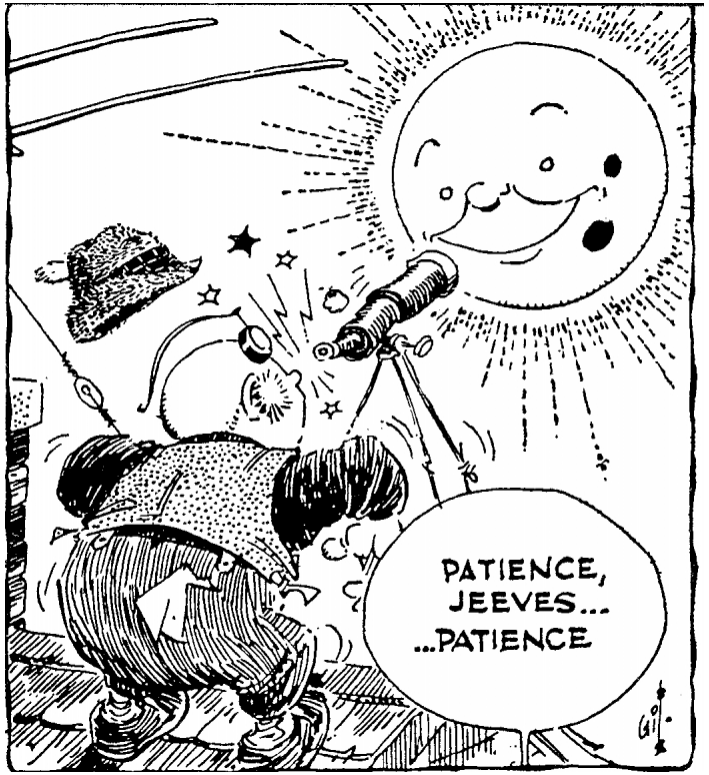
Agenda

- Cycle 25
  - Historical data
  - Predictions
  - Latest data
- Space weather and propagation
  - What should we focus on?
  - Connecting space weather parameters to propagation
  - What's really going on right now?
- Disturbances
  - NOAA categories
  - Big picture
  - K index, Bz, solar wind
  - Examples of disturbances
- General Propagation

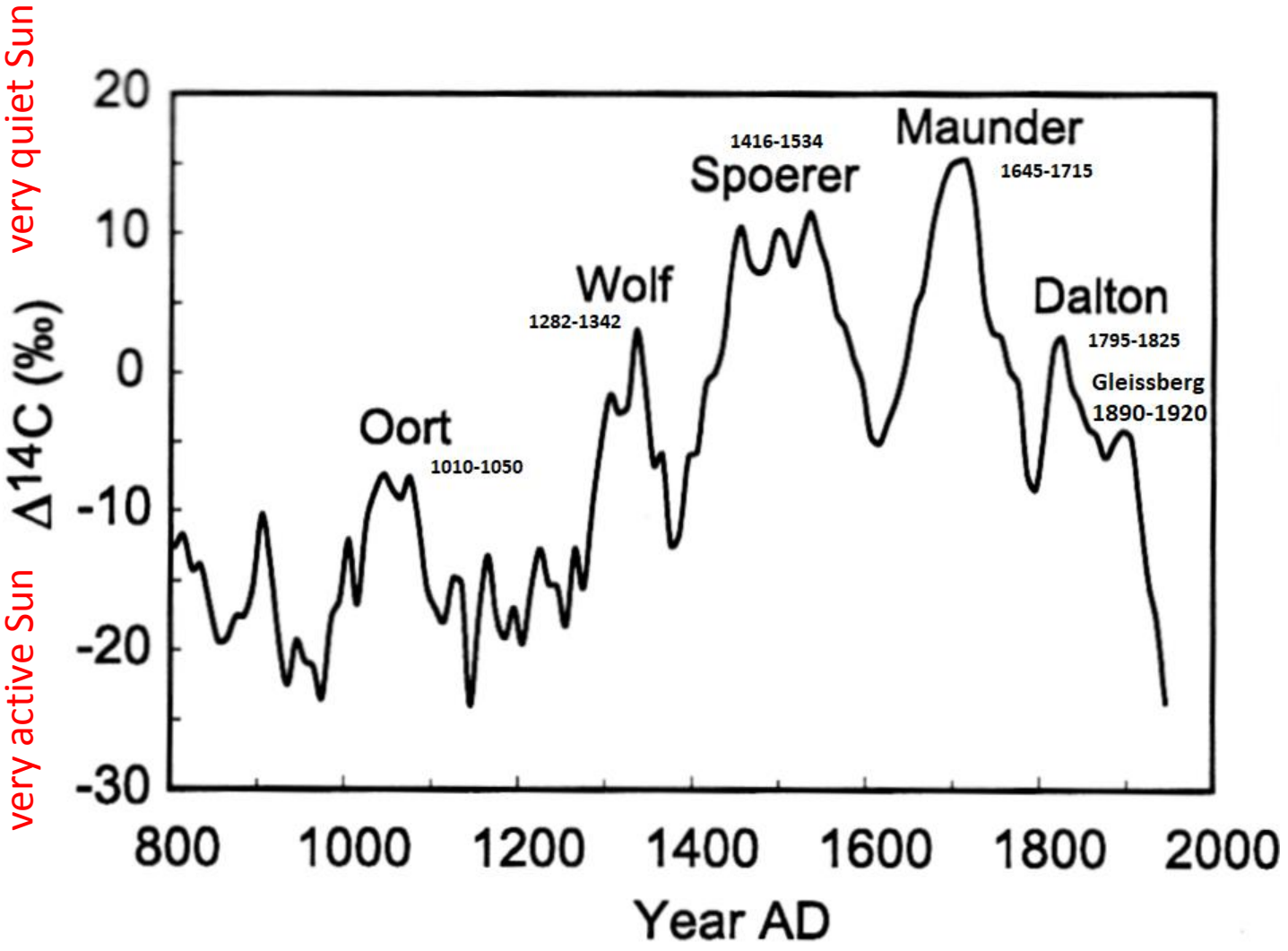
Whew! A lot of stuff!

Cycle 25



from arrl.org

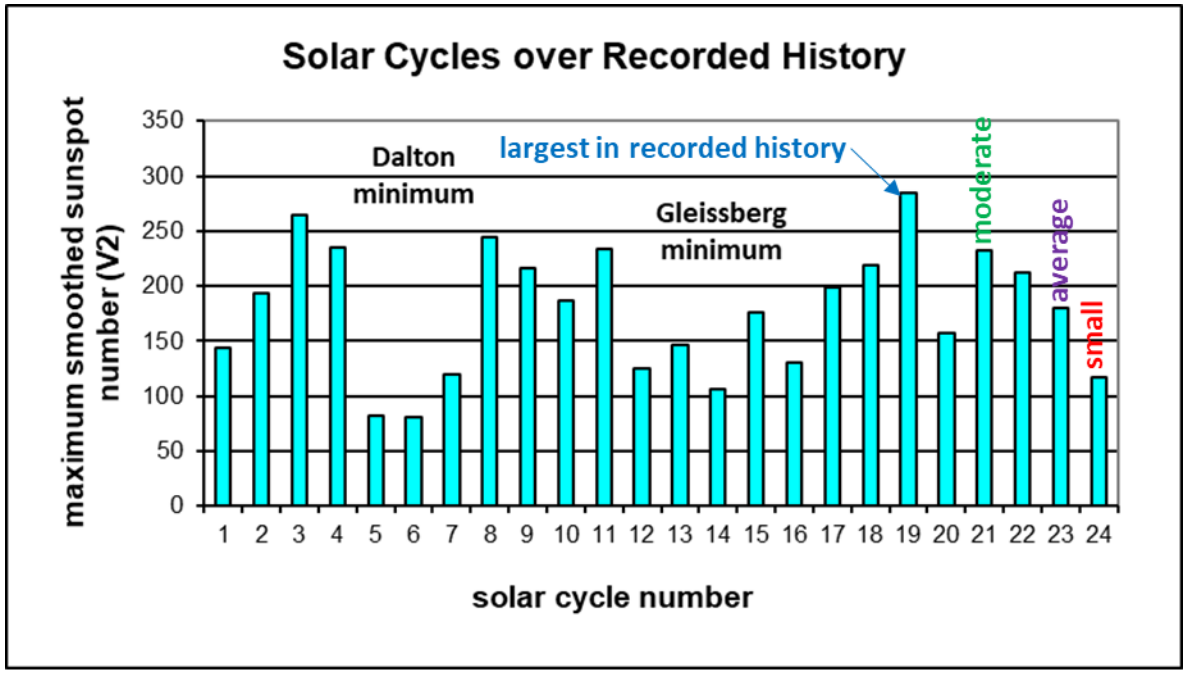
Looking Way Back in Time



- Carbon-14 in tree rings and beryllium-10 in ice cores can be a proxy for long-ago solar activity
- When the Sun is very active, IMF keeps galactic cosmic rays out – not much ^{14}C and ^{10}Be created

Historical Look at All 24 Cycles

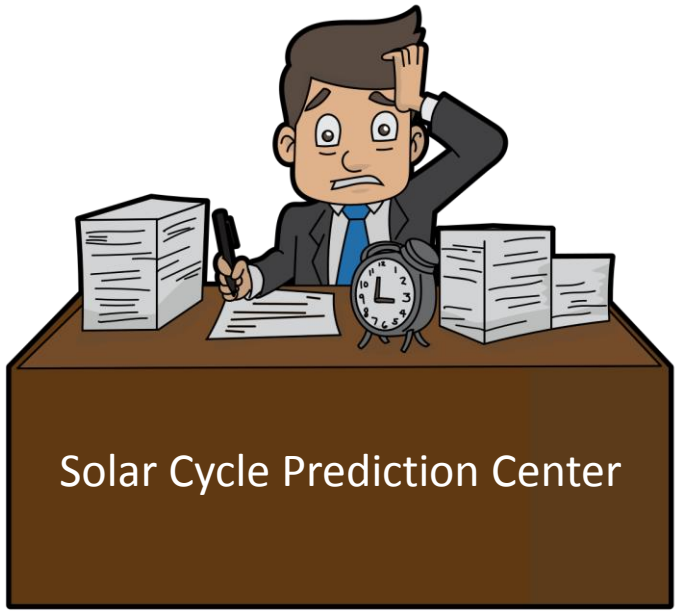
- Cycle 1 began in 1755
  - Maunder Minimum occurred from 1645-1715 with few sunspots
- We've gone through 3 periods of 'big' solar cycles
  - Cycles 1-4, 8-11, 17-23
- We've gone through 2 periods of 'small' solar cycles
  - Cycles 5-7, 12-16
- With Cycle 24, we appear to be in a third period of small solar cycles



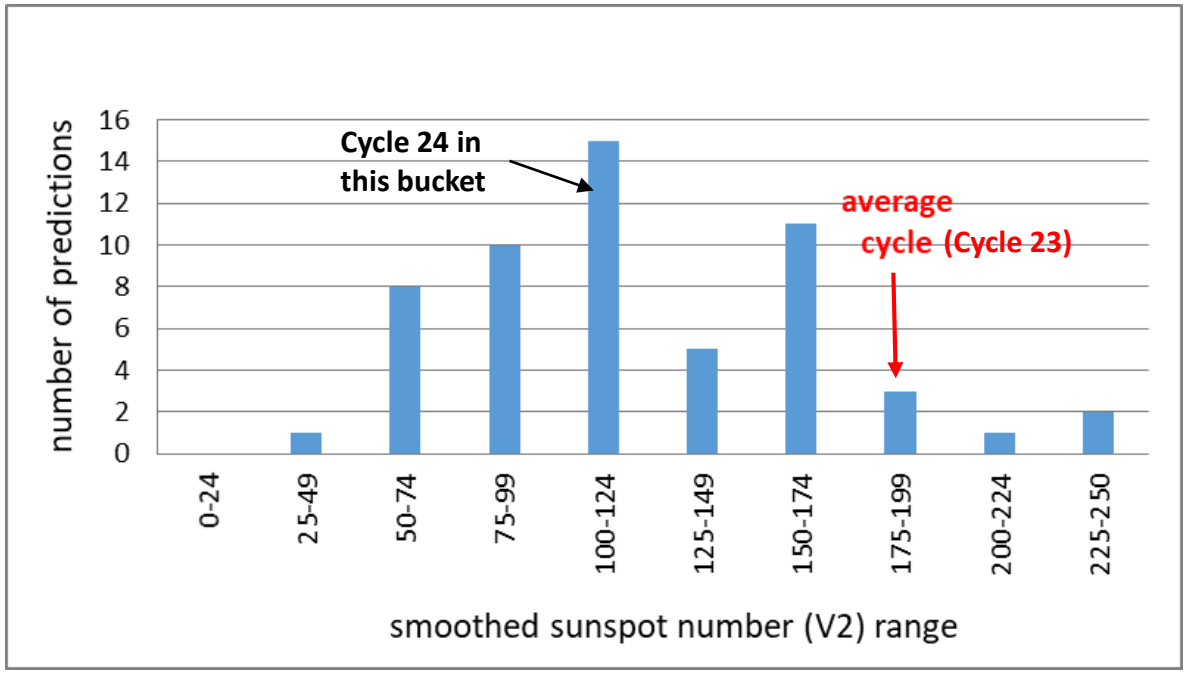
Will Cycle 25 get us out of this third period of small solar cycles?

Cycle 25 Predictions

- I'm aware of 56 predictions for Cycle 25
  - There were over 50 for Cycle 24
- Why so many?
- Because we don't fully understand the sunspot cycle process
  - We know it has to do with how magnetic fields move inside the Sun and how plasma flows inside the Sun – but the nitty-gritty details are not yet fully clear
- Thus many methods are used to make a prediction
  - Precursor, spectral analysis, others



Distribution of the Predictions

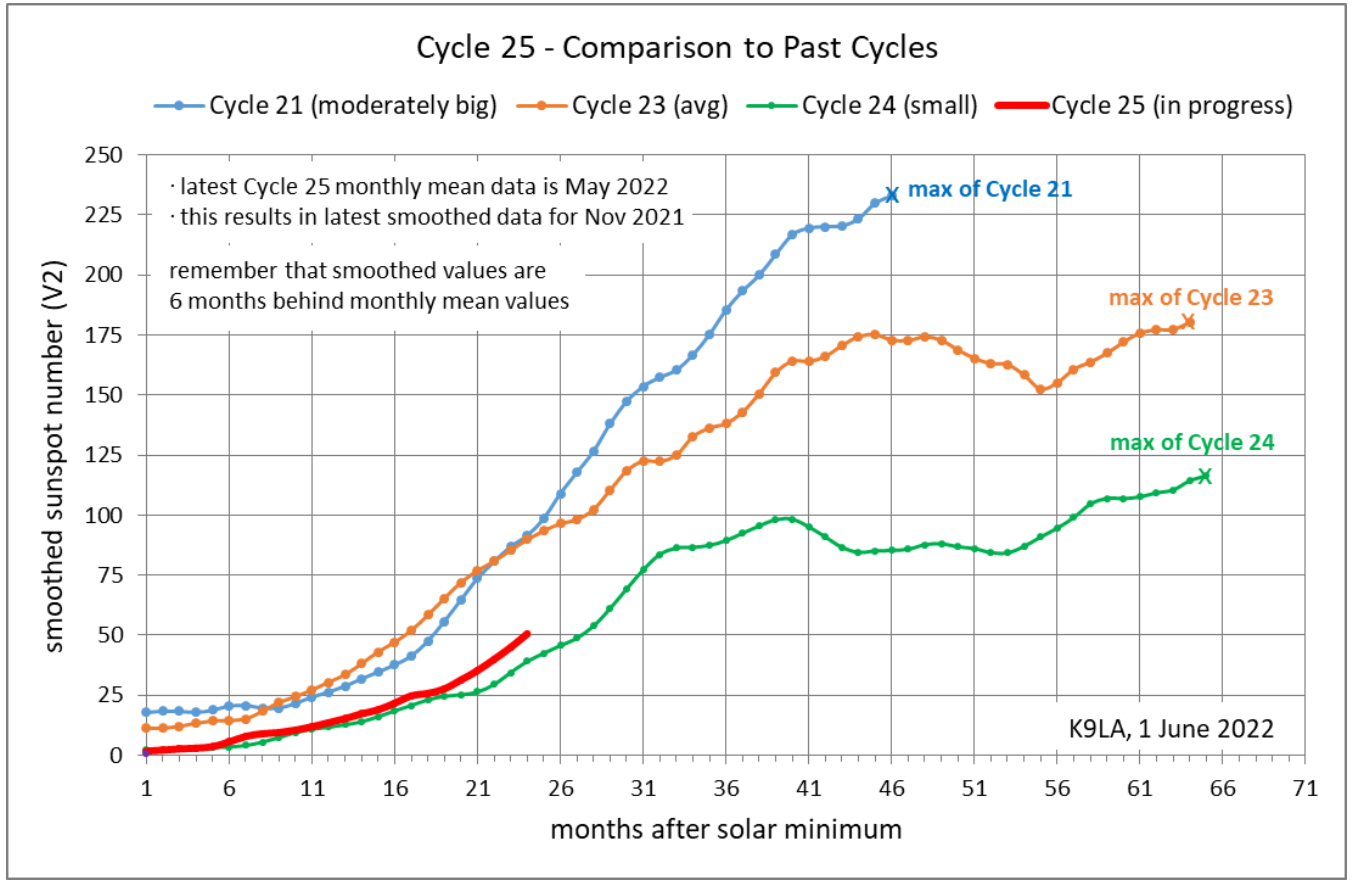


average cycle is 179

- 50 of the 56 predictions (89%) are for a below average cycle
- 3 are for an average cycle (now 4)
- 3 were for a larger-than-average cycle
  - In Aug 2021, the McIntosh (et al) prediction was revised down to an average cycle

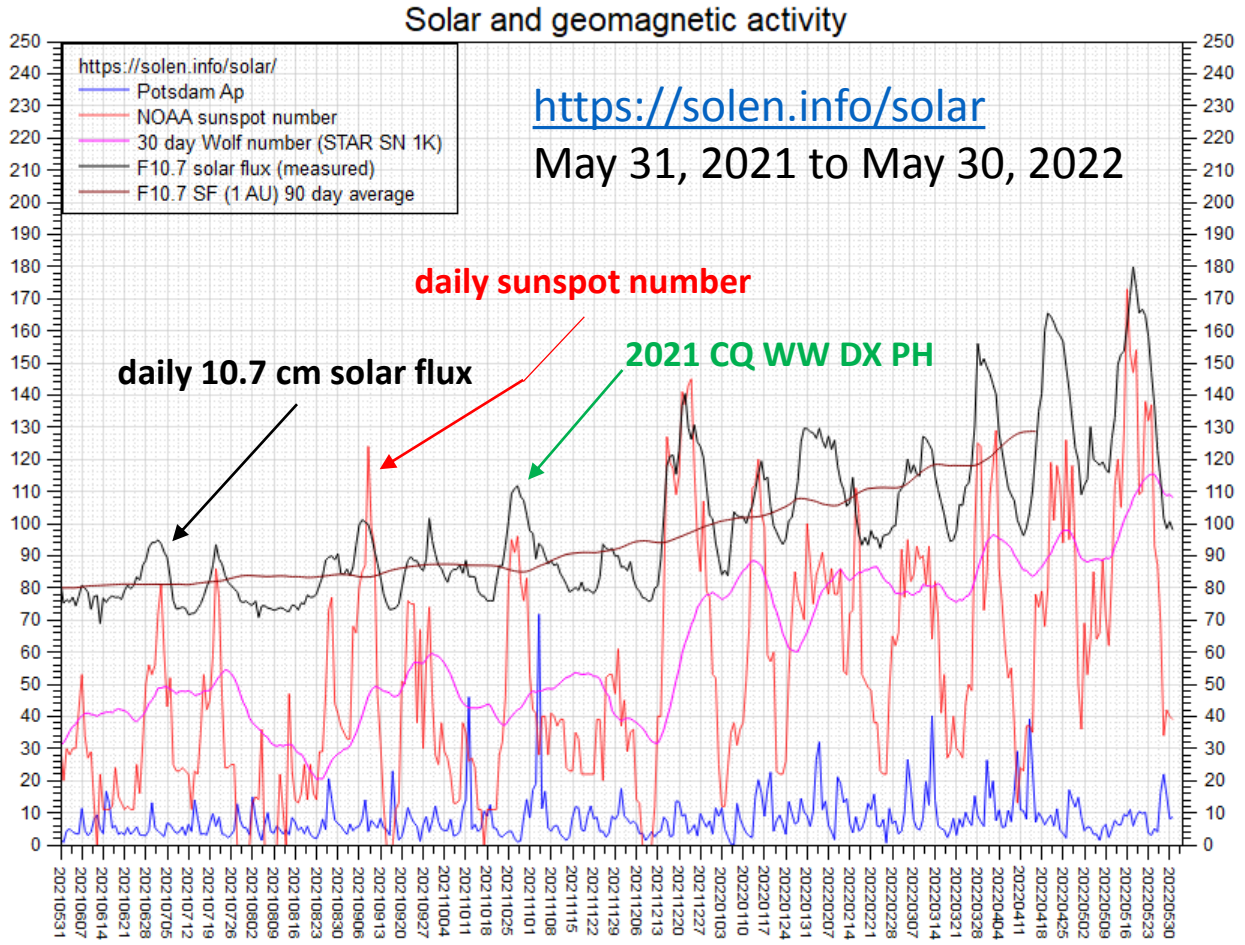
How Is Cycle 25 Doing?

- Solar minimum was in December 2019
- We currently have 24 months of smoothed sunspot number data
- Cycle 25 is doing a bit better than Cycle 24
- Need more sunspots for worldwide 15m, 12m and 10m propagation on a daily basis

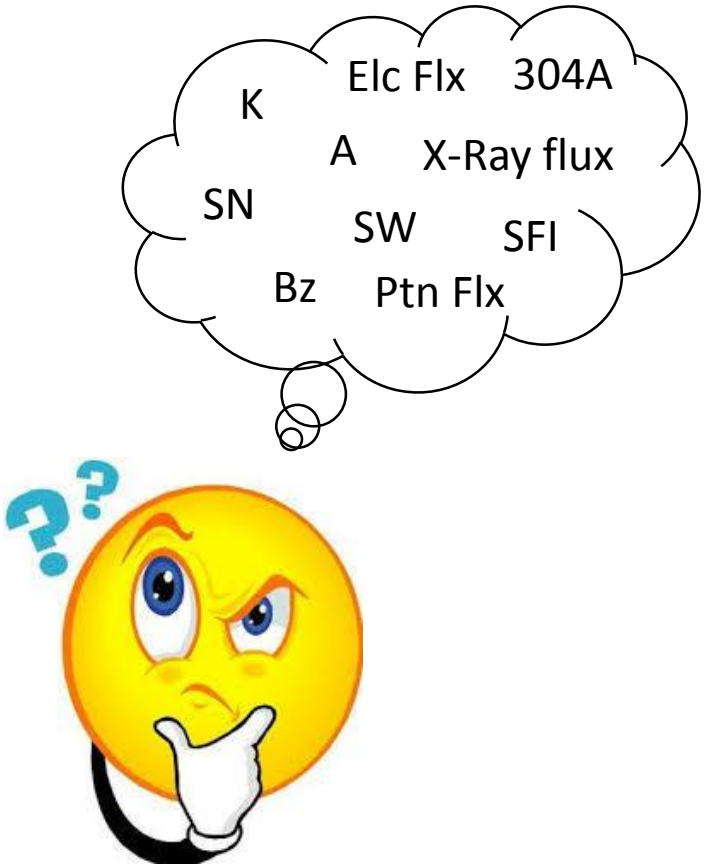


Short-Term Propagation Opportunities

- To reiterate, we still have a way to go before 15m, 12m and 10m will be open worldwide on a daily basis
- Keep an eye on the daily sunspot number and 10.7 cm solar flux
  - Spikes can gives us short-term openings on these higher HF bands



Space Weather and Propagation

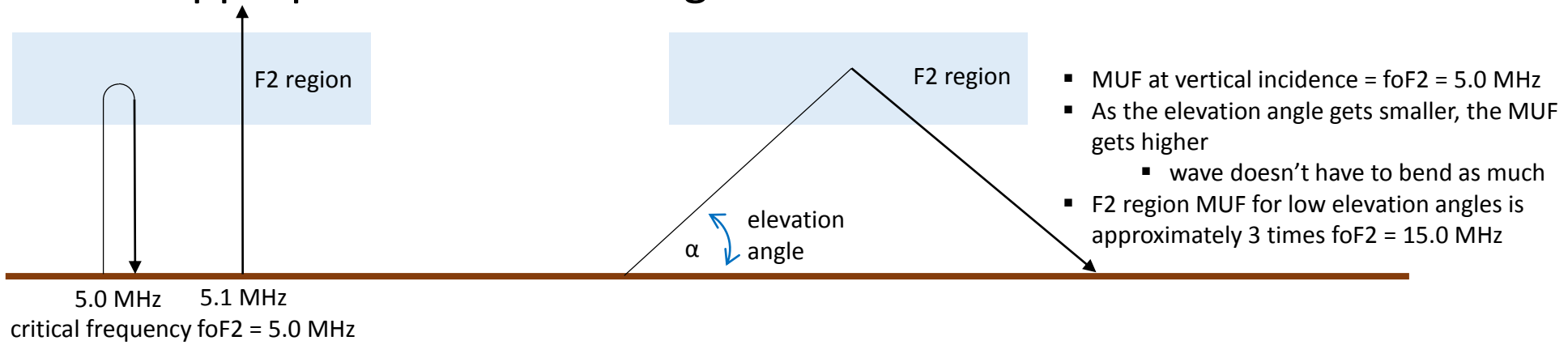


What Parameters Are Important?

- No consistent measurements on the D region and only daytime measurements on the E region
  - Incomplete data set means it's tough to correlate to a parameter
- Thus we'll focus on the F2 region
  - Highest amount of ionization and highest in altitude
  - Gives the longest hops and the highest MUFs (see next slide)
  - Direct measurements day and night by ionosondes
  - All in all, not a bad choice
- Let's look at space weather parameters that suggest how the F2 region is doing
  - Is there enough ionization in the F2 region?
  - Are there any disturbances that can screw up the F2 region?

First, What Is the MUF?

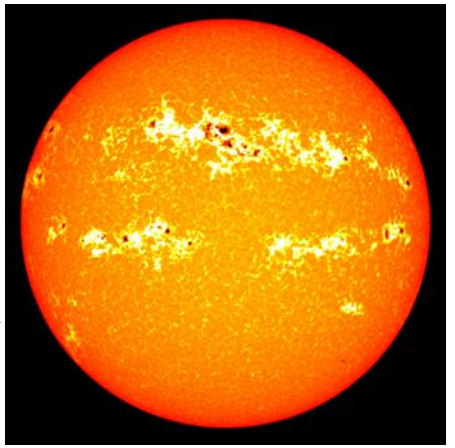
- MUF = maximum usable frequency
- It's the highest frequency that can be used between Point A and B at a given time of day during a given month at the current phase of the solar cycle
- Ionosondes measure the overhead electron density of the regions of the ionosphere
  - Ionosondes are basically stepped-frequency radars looking straight up
  - Results are reported as a critical frequency (vertical incidence)
  - Let's look at the F2 region
- Spherical geometry used to translate critical frequency at vertical incidence to the MUF at an appropriate elevation angle



- MUF at vertical incidence = foF2 = 5.0 MHz
- As the elevation angle gets smaller, the MUF gets higher
  - wave doesn't have to bend as much
- F2 region MUF for low elevation angles is approximately 3 times foF2 = 15.0 MHz

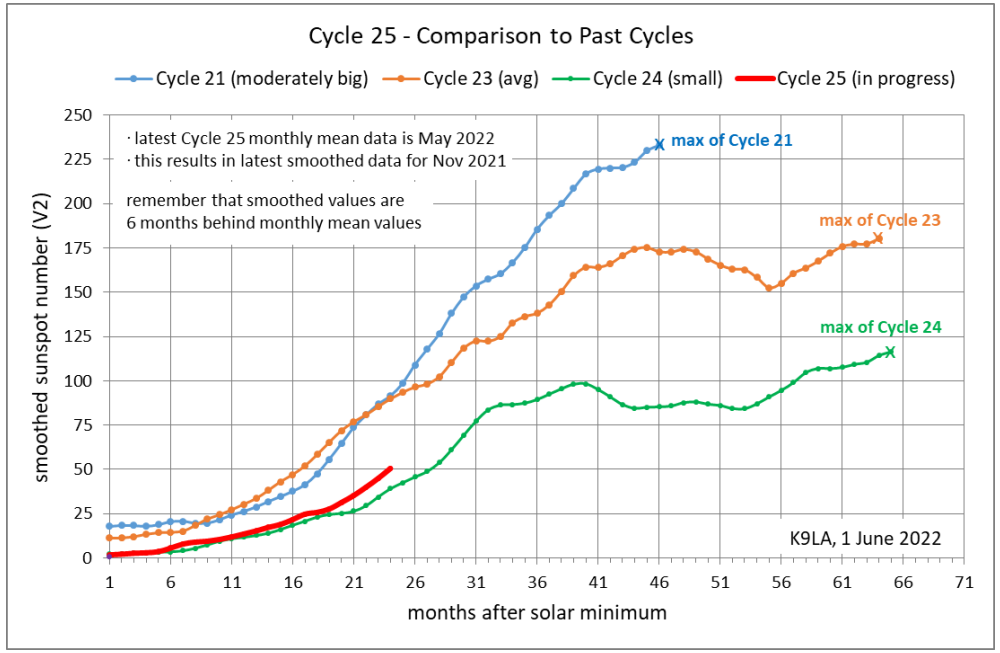
Parameters Relating to Ionization

- Parameters that tell us about the ionization in the F2 region
  - SFI – 10.7 cm solar flux index [daily range is from 65 to 450]
    - Radiation from the Sun at 10.7 cm (2800 MHz)
  - SN – sunspot number [daily range is from 0 to 400]
    - The dark spots on the Sun – they are dark because they are cooler
    - White area (plage) around these dark spots emits EUV
      - EUV is the true ionizing radiation of the F2 region

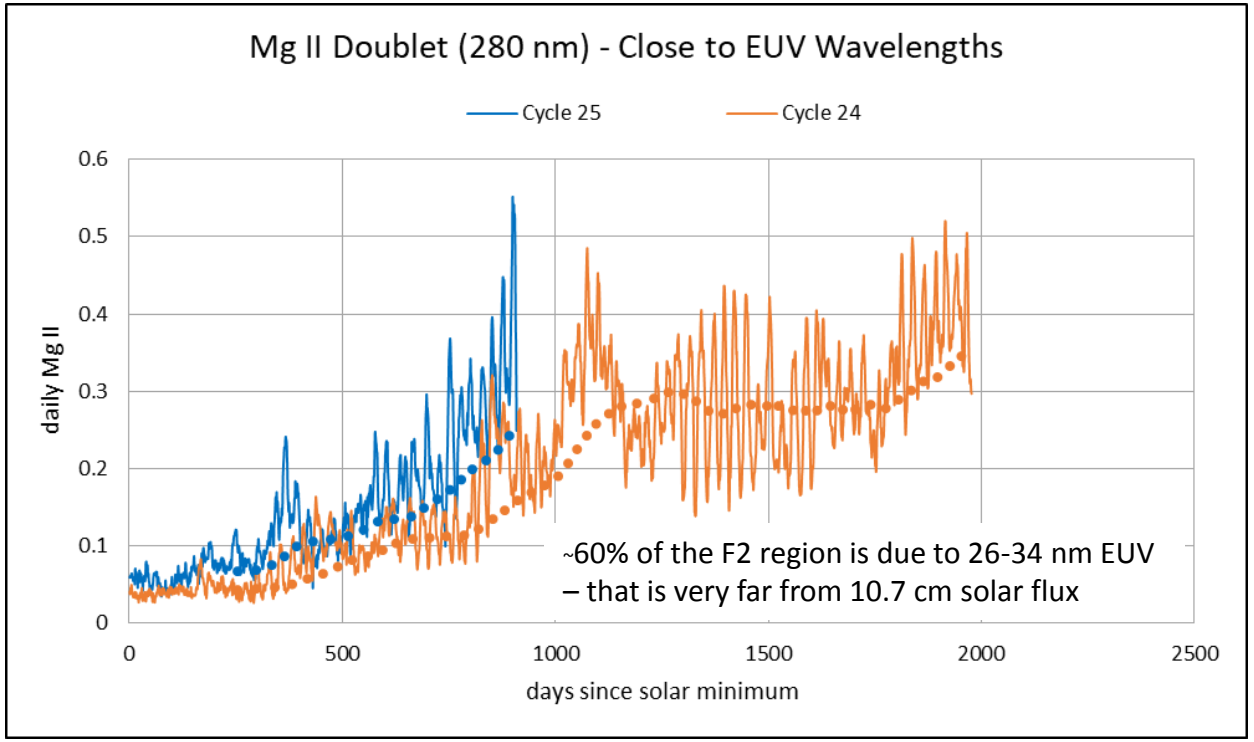


  - 304A – the amount of solar EUV radiation at 304 Angstroms (30.4 nm)
    - EUV is from 10 to 100 nm
  - X-Ray flux – the amount of solar radiation at X-Ray wavelengths
    - Soft X-Rays from 1 to 10 nm – E region – solar zenith angle and solar cycle
    - Hard X-Rays from 0.1 to 1 nm – D region – chemical reactions are important, too

How Is Cycle 25 Doing - Revisited



smoothed sunspot numbers



dots are the running 255-day average of MG II

Cycle 25 certainly looks like it will be bigger than Cycle 24 ☺☺☺

Parameters Related to Disturbances

- Parameters that tell us if there are any disturbances that can screw up the F2 region
  - K – the 3-hour index telling how active the Earth's magnetic field is [0 to 9 – logarithmic index] – the higher it is, the more disturbed the F2 region can be
  - A – the daily index telling how active the Earth's magnetic field is [0 to 400 - linear]
  - Bz – the component of the Sun's magnetic field (IMF) perpendicular to the ecliptic
    - Large positive value to large negative value – the more negative it is, the more disturbed the F2 region can be
  - SW – speed of the solar wind [300 km/sec to 2000 km/sec]
    - Avg about 400 km/sec – the higher it is, the more disturbed the F2 region can be

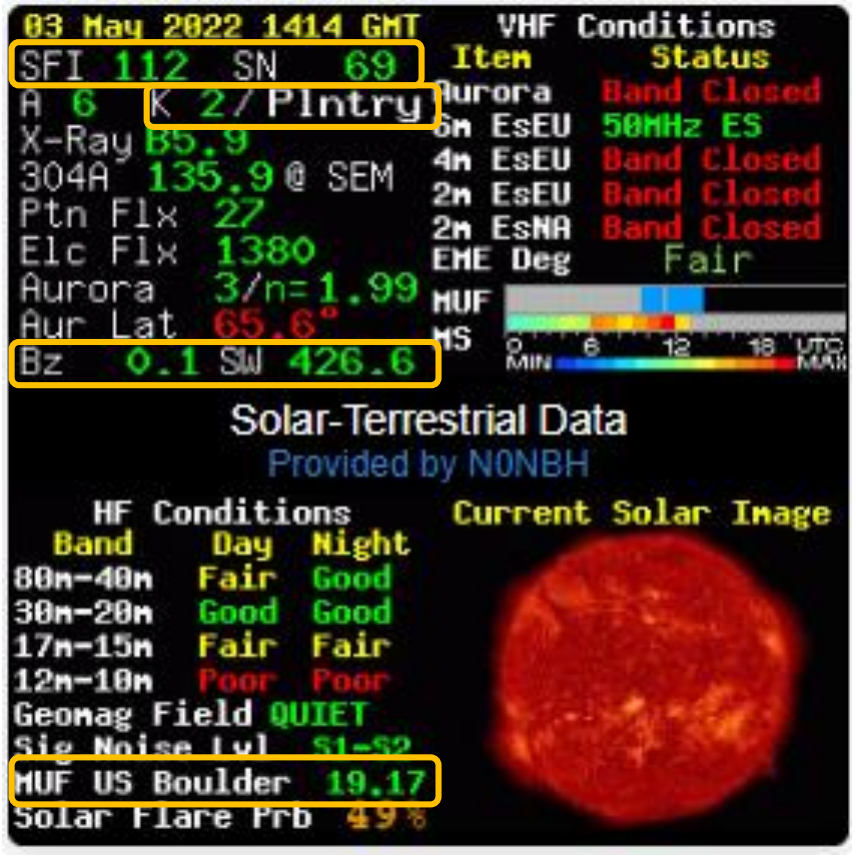
Other Parameters

- What we're not going to pay too much attention to
  - Elc Flx – number of electrons at geostationary altitudes
    - Well above the F2 region
  - Ptn Flx – number of protons at geostationary altitudes
    - Well above the F2 region
  - 304A – values of SFI and SN are just as good
    - SFI and SN are proxies for EUV
  - A – the daily index telling how active the Earth's magnetic field is
    - 0 to 400 [linear index]
    - Average of the eight 3-hour K indices
  - X-Ray flux

Data on NØNBH Banner and What We Desire

- SFI
  - > 90 for a long time for daily & worldwide 15m
  - > 120 for a long time for daily & worldwide 10m
- SN
  - > 35 for a long time for daily & worldwide 15m
  - > 70 for a long time for daily & worldwide 10m
- MUF US Boulder
  - As necessary for the band of interest

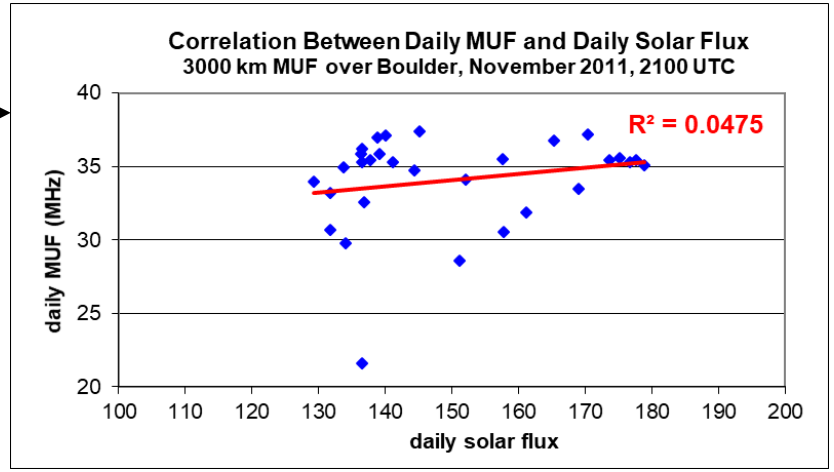
- K ≤ 3
- Bz positive
  - slightly negative (0 to -10) is okay
- SW not too much greater than 400 km/sec



from www.qrz.com

The Big Question

- Do all those parameters tell us what the ionosphere is doing today?
- Unfortunately, the answer is ‘no’
  - Our understanding of the ionosphere is statistical in nature over a month’s time frame
  - A result of this is that we do not have daily propagation predictions (more on this in one of the other sessions
- Why? – there are three sources that contribute to the variation of the ionosphere
  - Solar radiation
  - Geomagnetic field activity
  - Events at ground level and in the lower atmosphere can couple up to the ionosphere
- We understand the first two, but are now learning more about the last one
- The parameters give us a general idea of what the ionosphere is doing

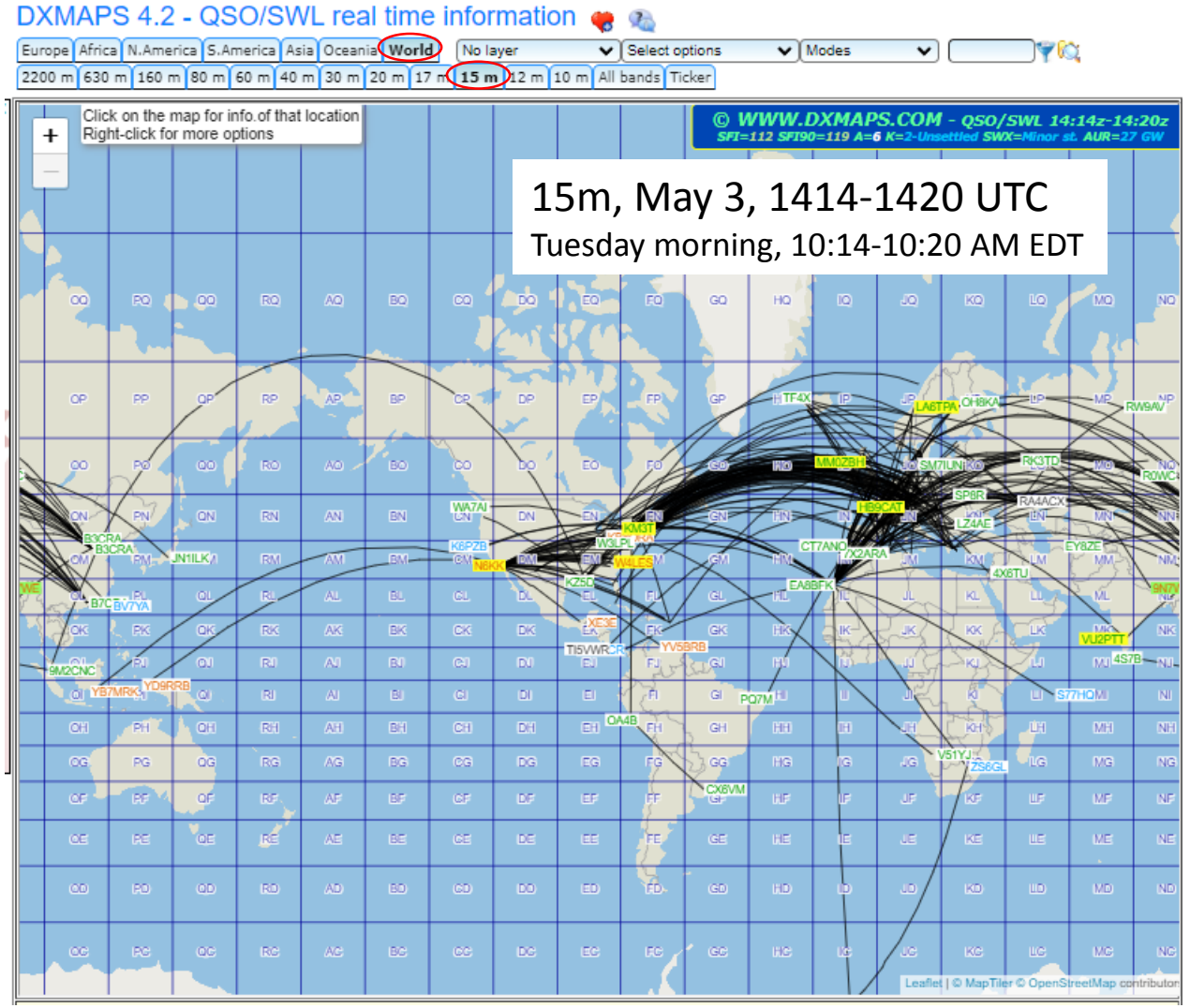


example – daily SFI of 137 gives an MUF anywhere from 22 to 36 MHz

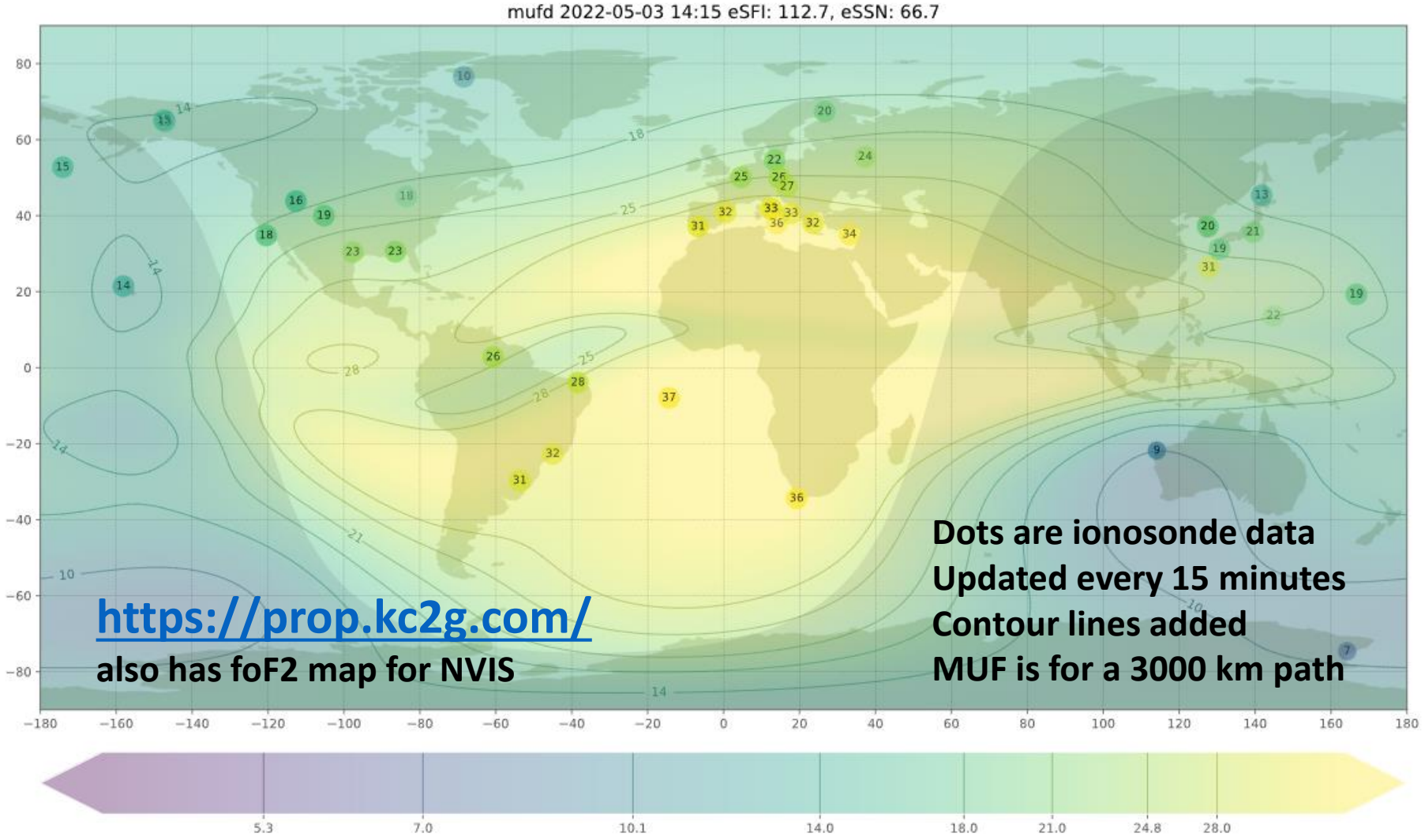
So how do we determine what the ionosphere is doing right now?

What Are the Bands Doing Right Now?

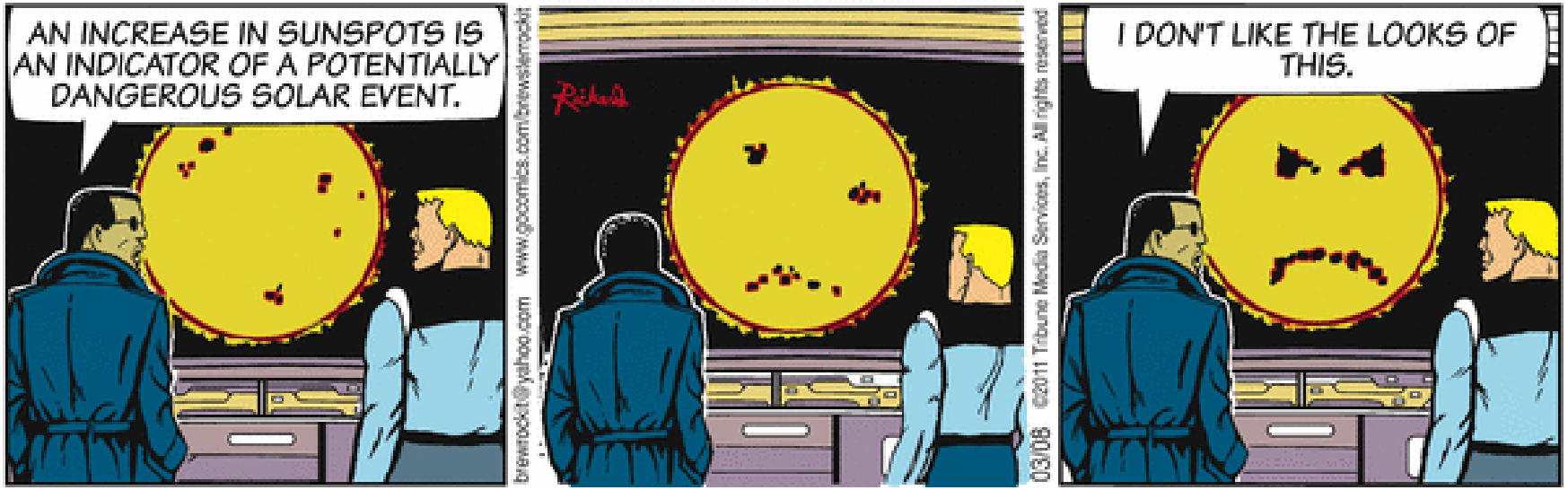
- Go to dxmaps.com
- Select a view
  - World, NA, Europe, . . .
- Select a band
  - 2200m to above 432 MHz
- Other methods
  - KC2G MUF map (next slide)
  - PSKreporter
  - WSPRnet
  - Reverse Beacon Network
  - IARU/NCDXF beacons



What's the MUF Doing Right Now?



Disturbances



https://www.swpc.noaa.gov/noaa-scales-explanation

NOAA Categories

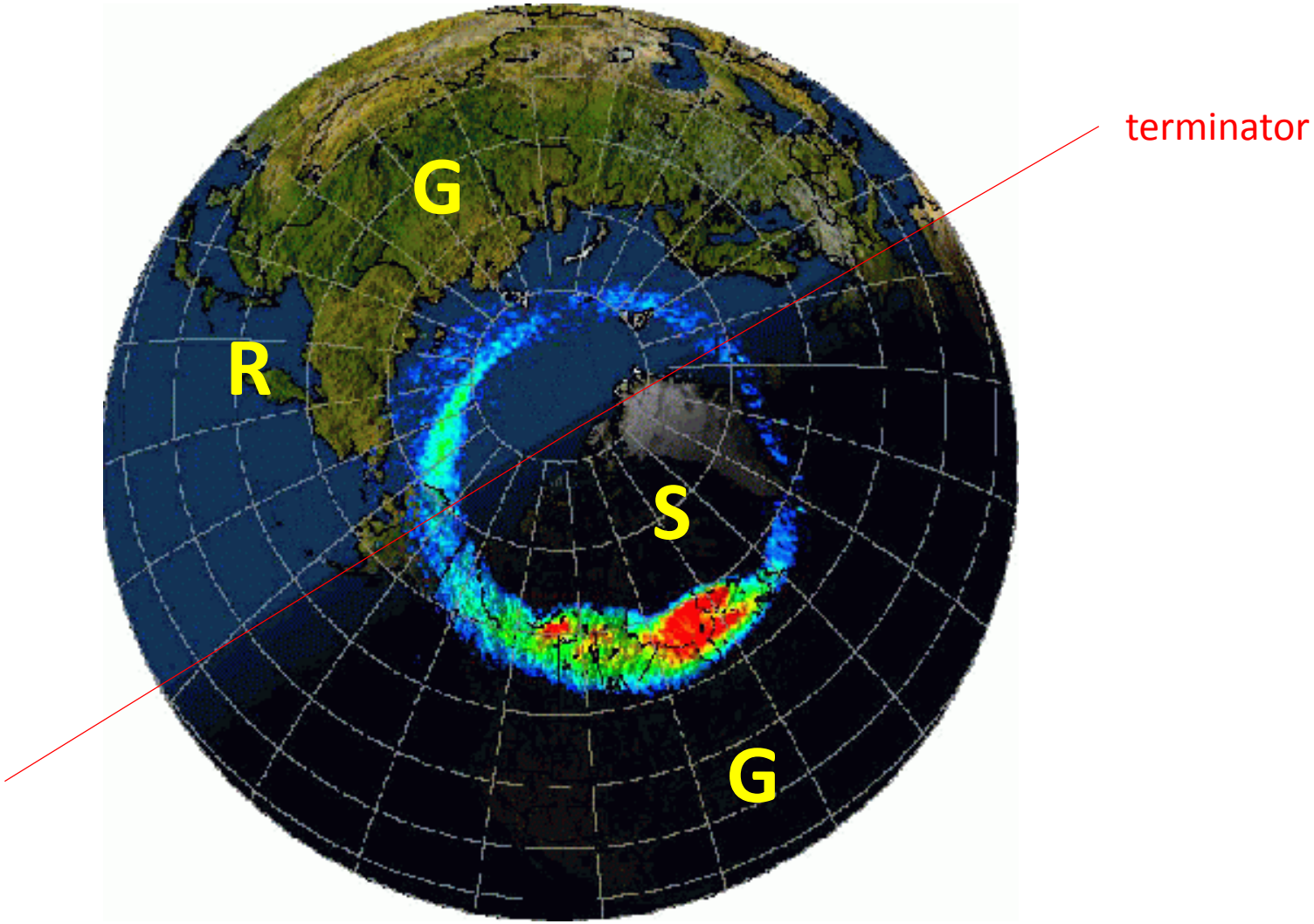
- G – Geomagnetic storm (Coronal Mass Ejection and Coronal Hole)
  - If Earth-directed, may need to move down in frequency due to depleted F2 region
  - Visit https://www.swpc.noaa.gov/products/storm-time-empirical-ionospheric-correction
    - Model of the effect of elevated K indices on the F2 region
- S – Solar radiation storm
  - Energetic protons from big solar flare (M- or X-Class) can funnel into the polar cap causing more absorption
  - Not a big issue for FD since paths are mostly not over-the-pole
- R – Radio Blackout
  - Radiation at X-Ray wavelengths from big solar flare (M- or X-Class) can cause increased absorption on the daylight side of Earth
  - Move to higher frequency if MUF allows (less absorption as freq increases)
  - Visit https://www.swpc.noaa.gov/products/d-region-absorption-predictions-d-rap
    - Model of the effect of a big solar flare on the D region (includes energetic protons, too)

The Big Picture

G – day and night side of Earth

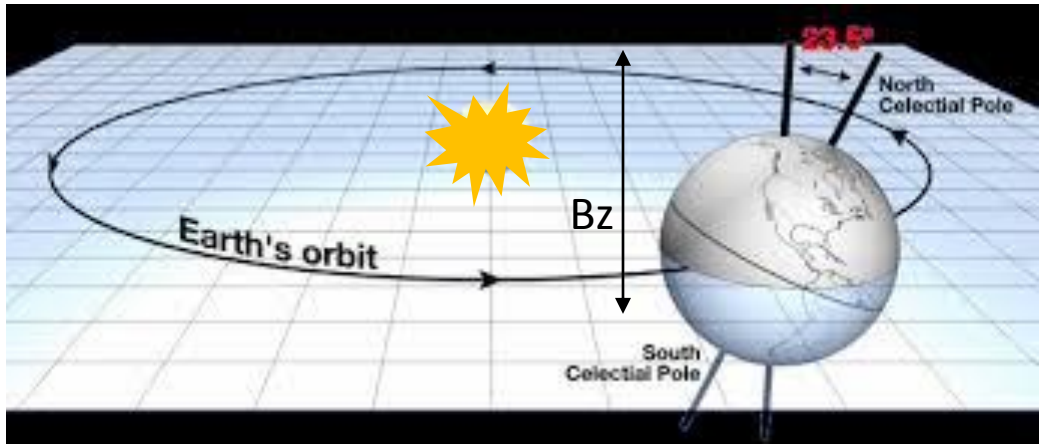
S – in the polar cap

R – day side of Earth



More on K, Bz, SW

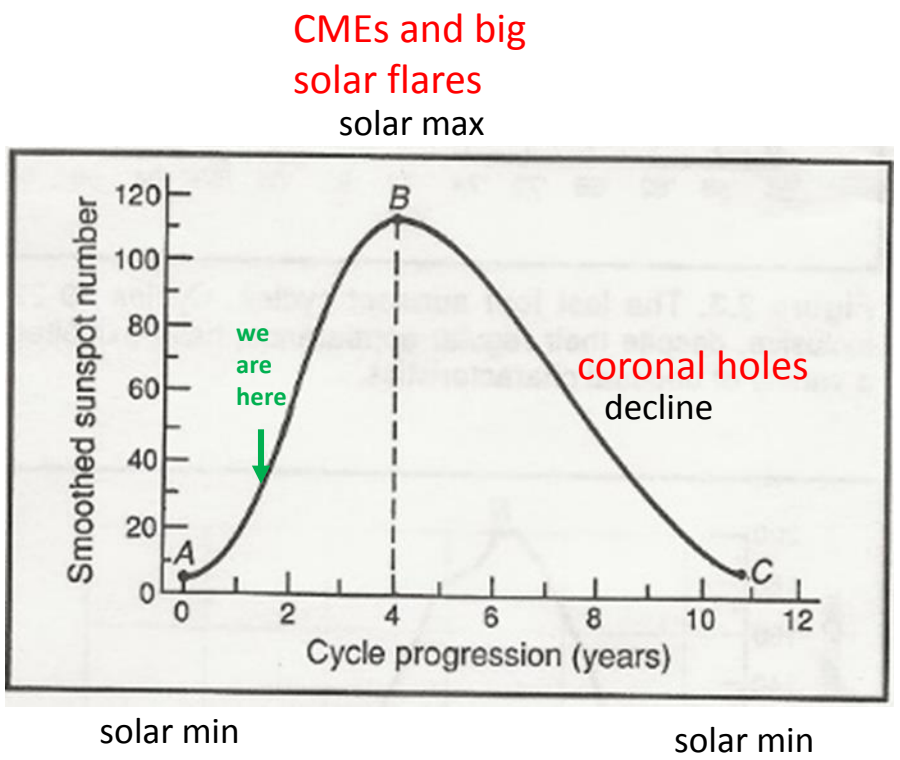
- These three parameters are correlated
  - High K ≈ large negative Bz ≈ high SW
- They tell us if the Earth's magnetic field is disturbed
  - Which can mean the F2 region is disturbed (screwed up)



Bz is perpendicular to the ecliptic

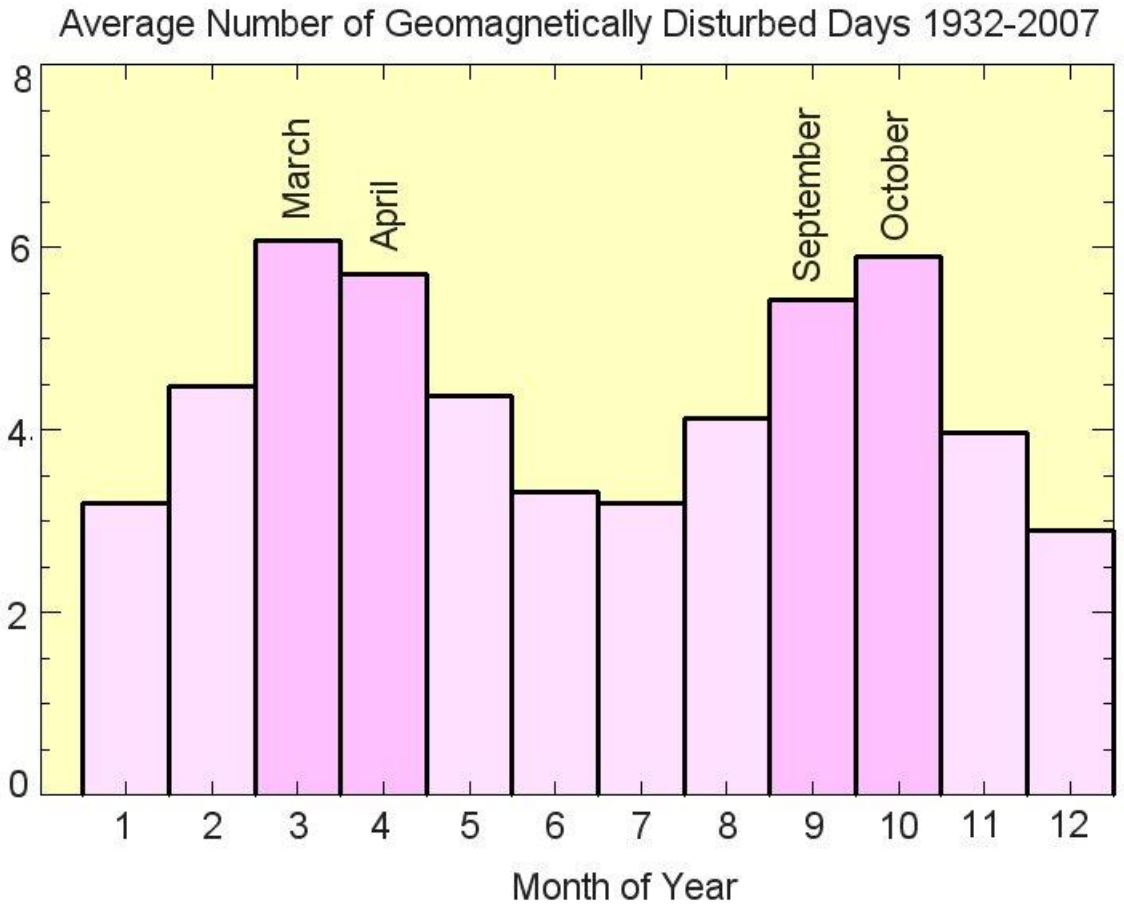
- Ecliptic – plane in which the Earth goes around the Sun
- Bz is perpendicular to the ecliptic
- Bz lines up nicely with the Earth's N-S magnetic field

When Do Disturbances Occur?



- CMEs most prevalent around solar max
  - Geomagnetic storms
- Big solar flares most prevalent around solar max
  - Solar radiation storms and radio blackouts
- Coronal holes most prevalent during the decline of a solar cycle
- Quietest time is during the ascent of a solar cycle

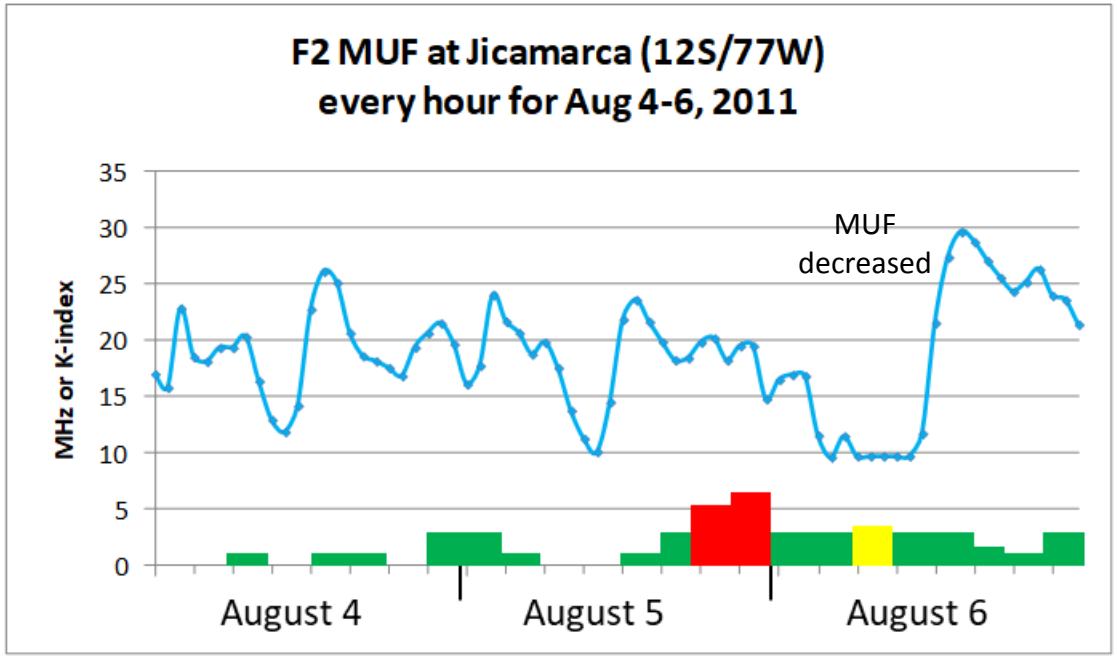
Geomagnetic Storms by Month

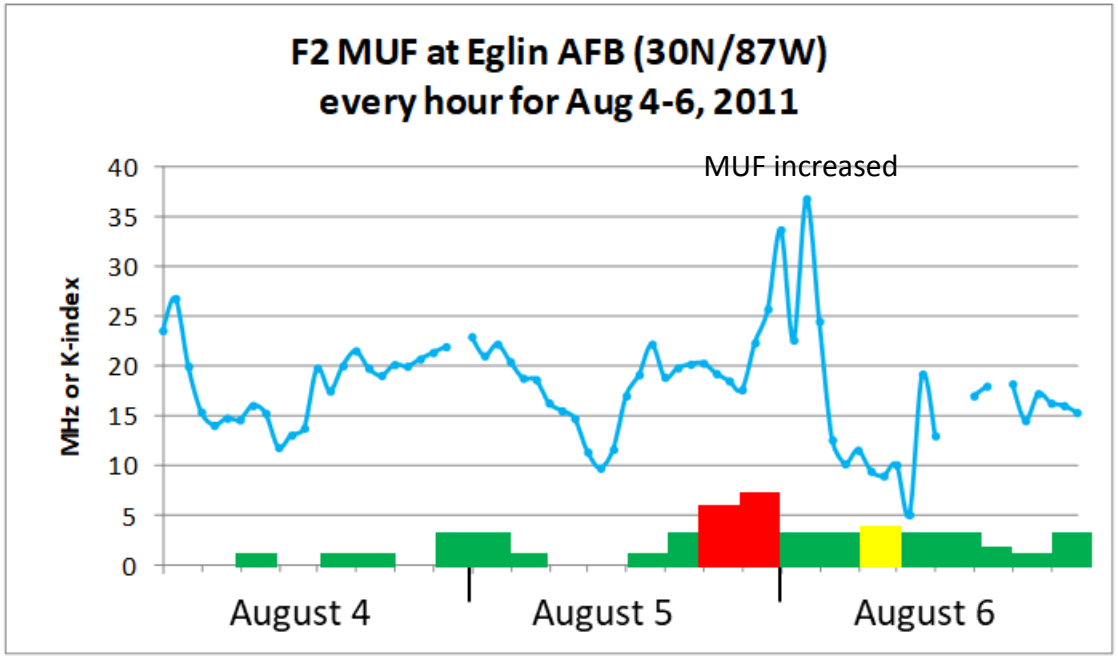


- Equinoxes are the most disturbed
- Winter and summer are the least disturbed
- At the equinoxes, the Earth's magnetic pole tilt aligns us at the peak angle relative to the Sun to “accept” Sun particles

Geomagnetic Storms vs Latitude

Different latitudes can be affected differently by geomagnetic storms

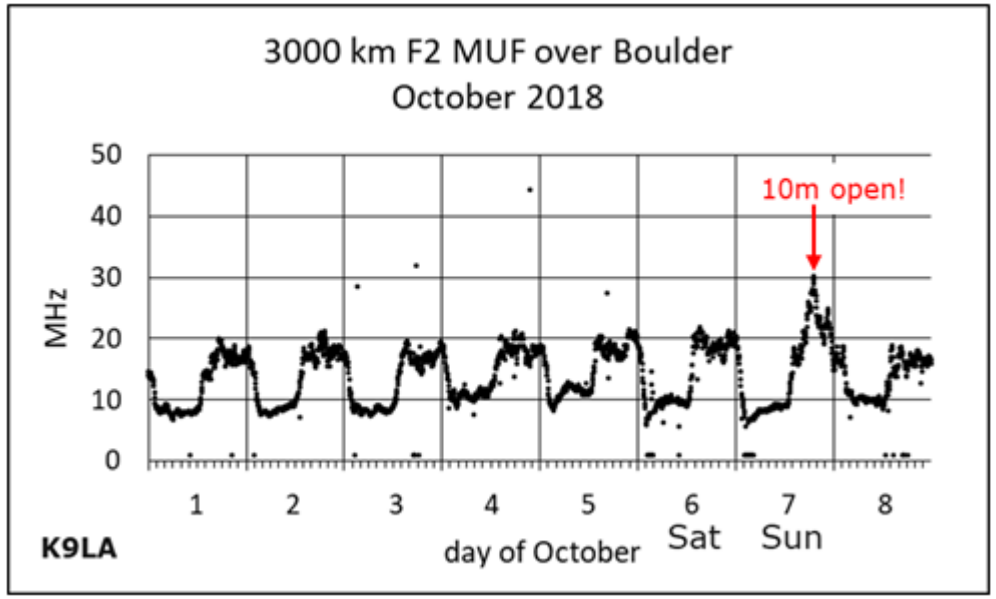


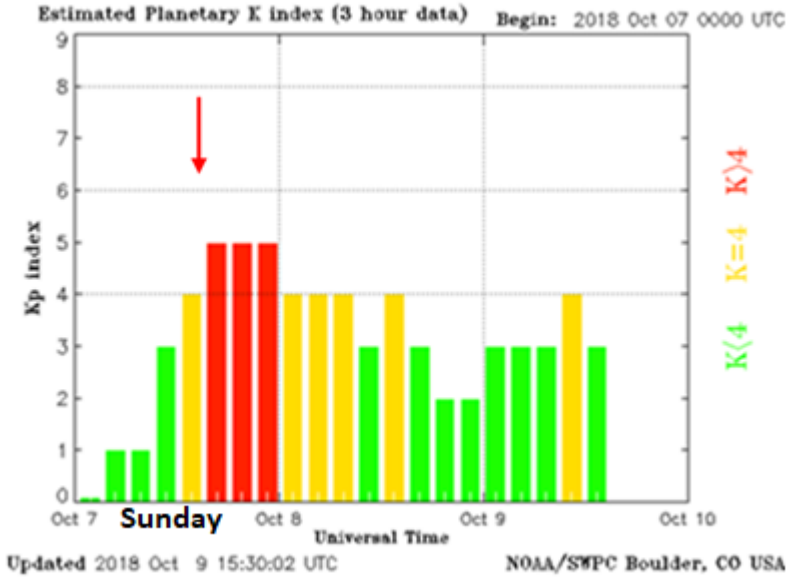


the F2 region is very dynamic

2018 California QSO Party

- Boulder ionosonde about halfway between CA and the Midwest
  - 3000 km path
- Saturday – no W6s heard in Indiana on 10m
- Sunday – many W6s to work on 10m
- Enhanced F2 region propagation on Sunday due to elevated K indices on Sunday





General Propagation

Lower HF Bands – 160m/80m/40m

- Best at night
  - When ionospheric absorption minimizes
- Lower bands should be tougher as Cycle 25 rises
  - More ionospheric absorption
  - More disturbances
    - Mostly geomagnetic storms
  - More people moving to the higher HF bands due to much stronger signals
- But don’t give up at solar maximum
  - W8JI worked over 200 countries and all 40 CQ zones on 160m at Cycle 23 solar maximum

Middle HF Bands – 30m, 20m, 17m

- 30m should still be okay as Cycle 25 rises
  - Ionospheric absorption is inversely proportional to the square of the frequency
- 20m and 17m should be open later in the evening as Cycle 25 rises
- Simple antennas will work very well

Higher HF Bands – 15m/12m/10m

- Should be getting better as Cycle 25 rises
- Right now openings still not worldwide on a daily basis
  - North-South openings most prevalent
- This coming fall/winter should have great worldwide propagation on more and more days of the month
  - Modest power (100W) and modest antennas (dipole/inverted-vee/vertical) should give many opportunities

6m

- There will always be sporadic E during the summer (best) and during December
- Need more sunspots for F2 region propagation
  - But don’t forget that TEP involves F2 region propagation
- Cycle 24 (smallest in our lifetimes and 4th smallest in recorded history) had 6m F2 propagation in the fall and winter months around solar maximum
- We should expect some ‘normal’ F2 propagation for Cycle 25, too

Summary

- Cycle 25 is on the rise
  - It may be like Cycle 23 – an average cycle
  - Next 6-12 months will likely strongly suggest where it's headed
- Keep an eye on real-time methods to see what a band is doing
- Understand disturbances to propagation
- Take advantage of the digital modes

References

- Space weather websites
  - NØNBH banner at www.qrz.com
  - Dr. Tony Phillips – https://spaceweather.com/
  - NOAA – https://www.swpc.noaa.gov/
  - VE3EN – https://www.solarham.net/
  - WX6SWW - https://www.spaceweatherwoman.com/
  - Many other websites out there
- Information about the Sun - https://solarscience.msfc.nasa.gov/
- Propagation and antenna references
  - ARRL Handbook and ARRL Antenna Book
  - The CQ Shortwave Propagation Handbook – 4th Edition (updated 2021)
  - The Little Pistol's Guide to HF Propagation (1996) by NM7M (SK)
    - Out of print but it's on my website (15 Mb file)
  - Many other references out there