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Introduction to Space Weather and Propagation

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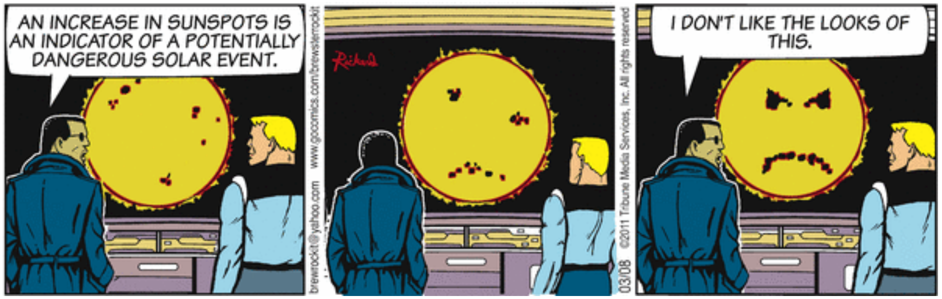
What Is Space Weather?

- Space weather is the quiet Sun
  - Electromagnetic radiation at ionizing wavelengths
- Space weather is disturbances on the Sun
  - CMEs - solar material ejected
  - Coronal holes - fast solar wind
  - Solar flares - protons into polar cap
  - Solar flares - X-rays on dayside

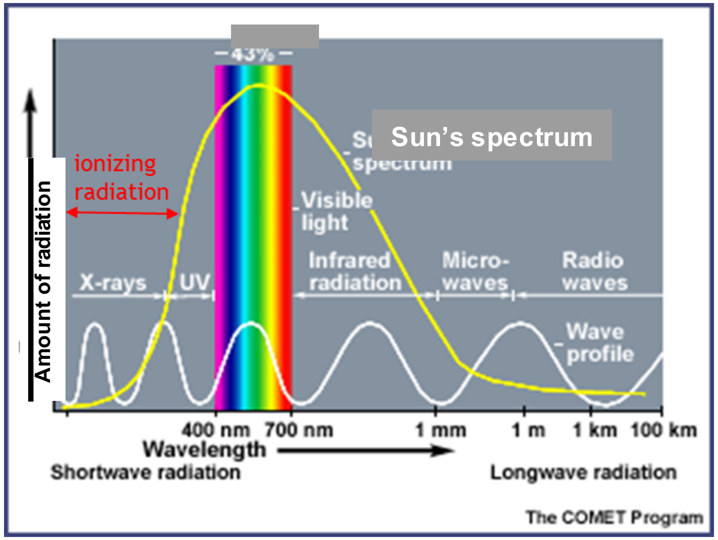


- Space weather is meteors
  - Results in sporadic E propagation
- Space weather is galactic cosmic rays (GCRs)
  - We're seeing an unprecedented amount of GCRs entering our atmosphere – more collisional ionization in the lower ionosphere
- Space weather is gamma ray bursts (GRBs)
  - Their high energy can affect the lower ionosphere
  - Very short duration

Non-terrestrial sources that can affect our ionosphere

The Quiet Sun

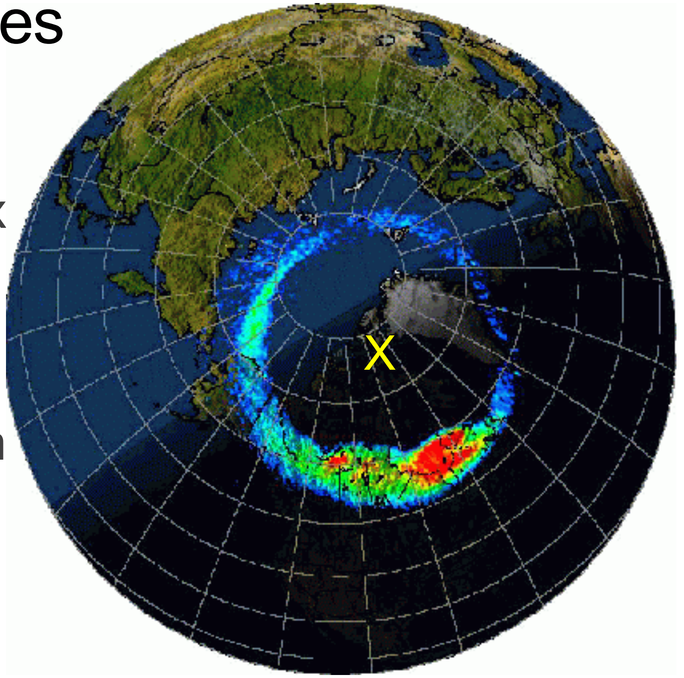
- The Sun radiates at many wavelengths
  - Most amount of radiation (highest flux) is at visible wavelengths: 400-700 nm
- But photons at visible wavelengths do not have enough energy to ionize anything
  - From Planck's Law and ionization potentials of atmospheric constituents
- True ionizing radiation is from 0.1-121.5 nm
  - F2 region 10-100 nm (Extreme UV)
  - F1 region 20-90 nm (EUV)
  - E region 1-10 nm (soft X-rays) and 80-102.5 nm (EUV)
  - D region 0.1-1 nm (hard X-rays) and 121.5 nm (Lyman-α spectral line of hydrogen)
- 10.7 cm solar flux does not have enough energy to ionize anything



10.7 cm solar flux and sunspot numbers are proxies for the true ionizing radiation

Disturbances on the Sun

NOAA defines 3 categories of disturbances



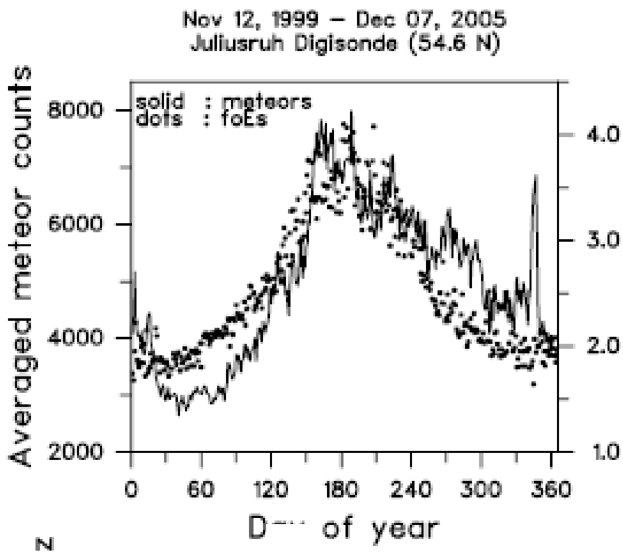
yellow X is north geomagnetic pole

- G = geomagnetic storms
  - CMEs and coronal holes can elevate the K index which modifies the ionosphere
- S = solar radiation storms
  - Big flares can eject energetic protons that funnel into the polar cap(s) to cause increased D region ionization
- R = radio blackouts
  - Big flares can emit X-rays to cause increased D region ionization on the daylight side of Earth
- For details visit
  www.swpc.noaa.gov/sites/default/files/images/NOAAscales.pdf

For the eclipse: August is a quiet month for G, and being near solar minimum reduces chances of S and R

Meteors

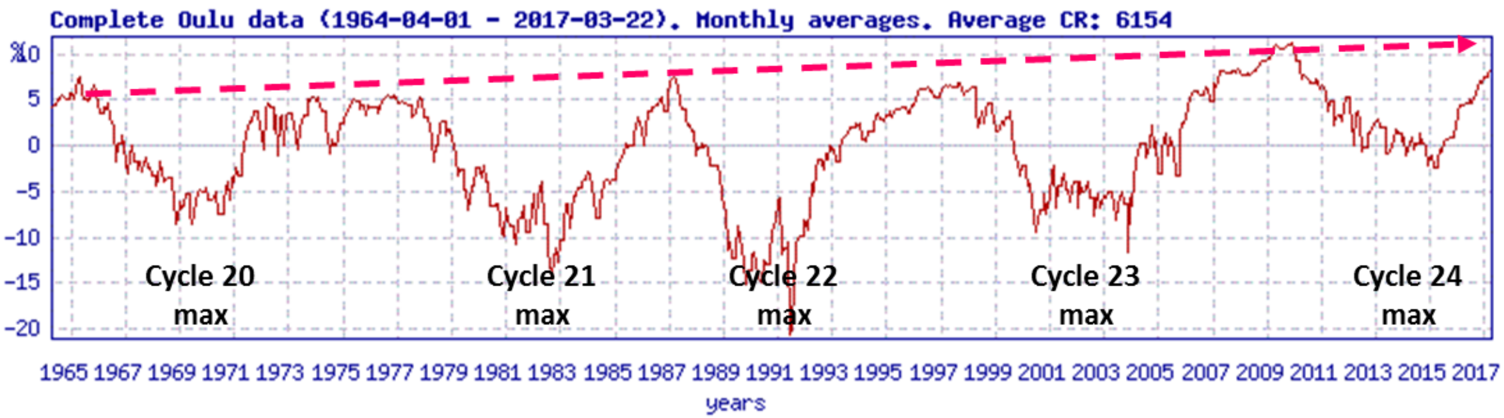
- Annual meteor deposition into the Earth's atmosphere peaks in the summer
- Correlates well with mid-latitude Es peak in summer

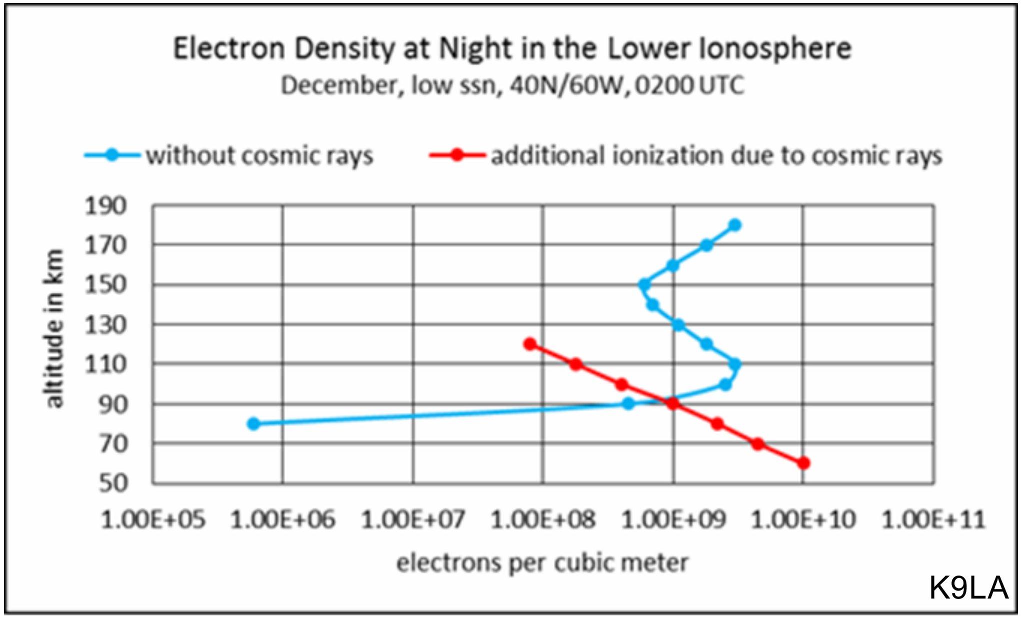


caution – just because two events happen at the same time does not necessarily mean they are connected

- Metallic ions of meteoric origin converge vertically into a thin dense layer (couple km thick)
- Due to thinness of layer, mechanism is reflection

Galactic Cosmic Rays

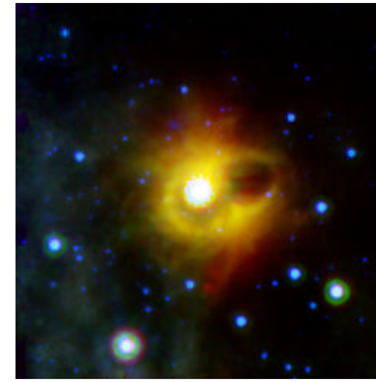


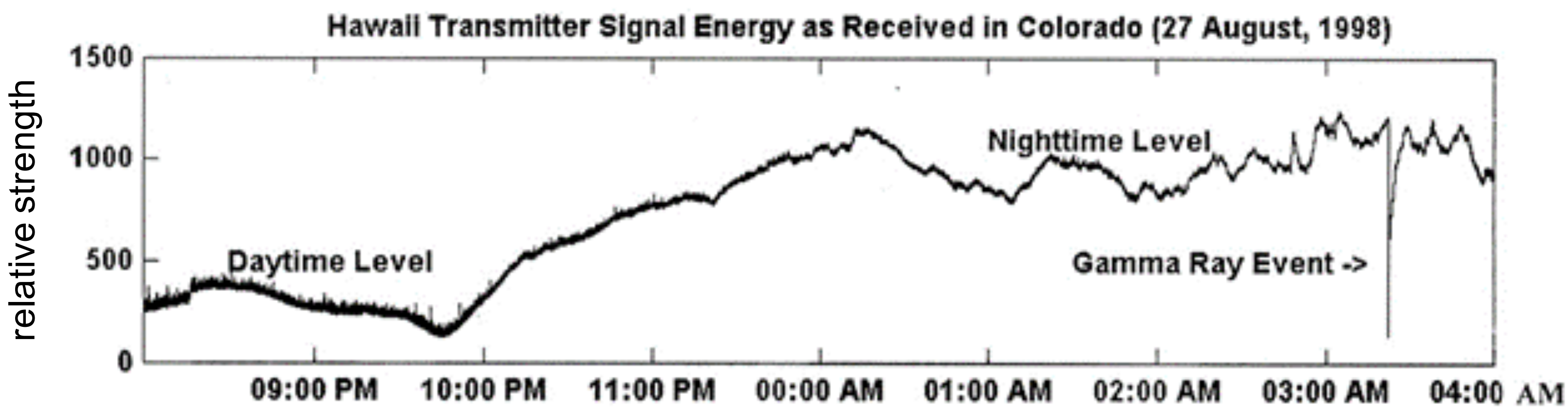


- Sure looks like GCRs result in additional ionization in the lower ionosphere >> more absorption
- Not good for 160-Meters
- Maybe a solar minimum can be <u>too deep</u> for 160-Meters

Gamma Ray Bursts

- Hawaii transmitter on 21.4 kHz
- Receiver in Boulder





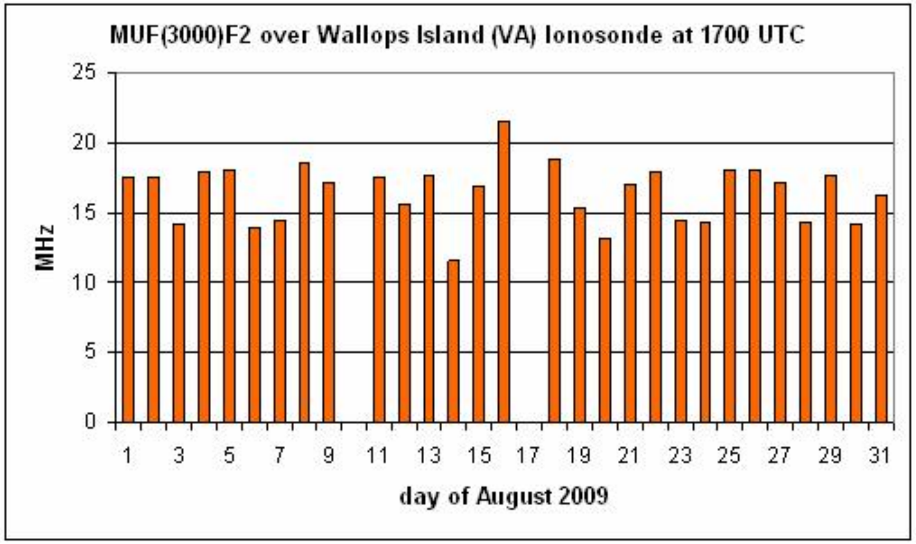
Originated in SGR 1900+14

~ 20,000 light years away !

and you thought the Energizer Bunny had a lot of energy!

Day-to-Day Variation of the Ionosphere

- Three parameters determine the amount of ionization at any given location at any given time
  - Solar radiation – instigates ionization process
  - Geomagnetic field activity – modifies ionization
  - Events in lower atmosphere coupling up to the ionosphere – modifies ionization



- August 2009 had constant 10.7 cm solar flux (~ 66) , zero sunspots and a fairly quiet geomagnetic field – but the MUF varied by a factor of 2 over the month
- This is why we have a monthly median propagation model in our propagation predictions, not a daily model with daily propagation predictions
- Can we get to a daily model?
  - Either develop physical model that includes the three parameters above, or
  - Assimilate real-time data into model – Joshua KD2JAO has NJIT grant to look at doing this with RBN data

Today's solar flux and current K index do not tell us what the ionosphere is doing today. For the eclipse, we need good baseline data prior to the eclipse

Characteristics of the Bands

- Propagation from Point A to Point B depends on three factors
  - MUF – is it high enough to refract the wave back to Earth?
    - Amount of refraction is inversely proportional to the square of the frequency – lower frequencies result in shorter hops
  - Ionospheric absorption – is it low enough for the signal to be readable?
    - Amount of ionospheric absorption is inversely proportional to the square of the frequency – that's why long distance 160m signals are generally near the noise and 10m signals can be S9+
  - Polarization – not too critical on HF, important on 160m
- Lower frequencies
  - Absorption is critical, MUF not too big an issue
- Higher frequencies
  - MUF is critical, absorption not too big an issue

The bands respond differently to a given ionization profile

What to Expect During the Eclipse

- Solar radiation from the quiet Sun will hopefully be the only factor during the eclipse – no disturbances, no Es, no GRBs
- The eclipse will reduce solar radiation impinging on the atmosphere - this will result in less solar-induced ionization in the F region, E region and D region
- Lower bands
  - Strength of signals should increase due to less absorption – but there are other variables involved
- Higher bands
  - Signals will likely disappear due to decreased MUFs – but being near solar minimum in the summer will likely restrict higher band propagation anyway

RBN data should show many interesting events during the Solar Eclipse QSO Party.

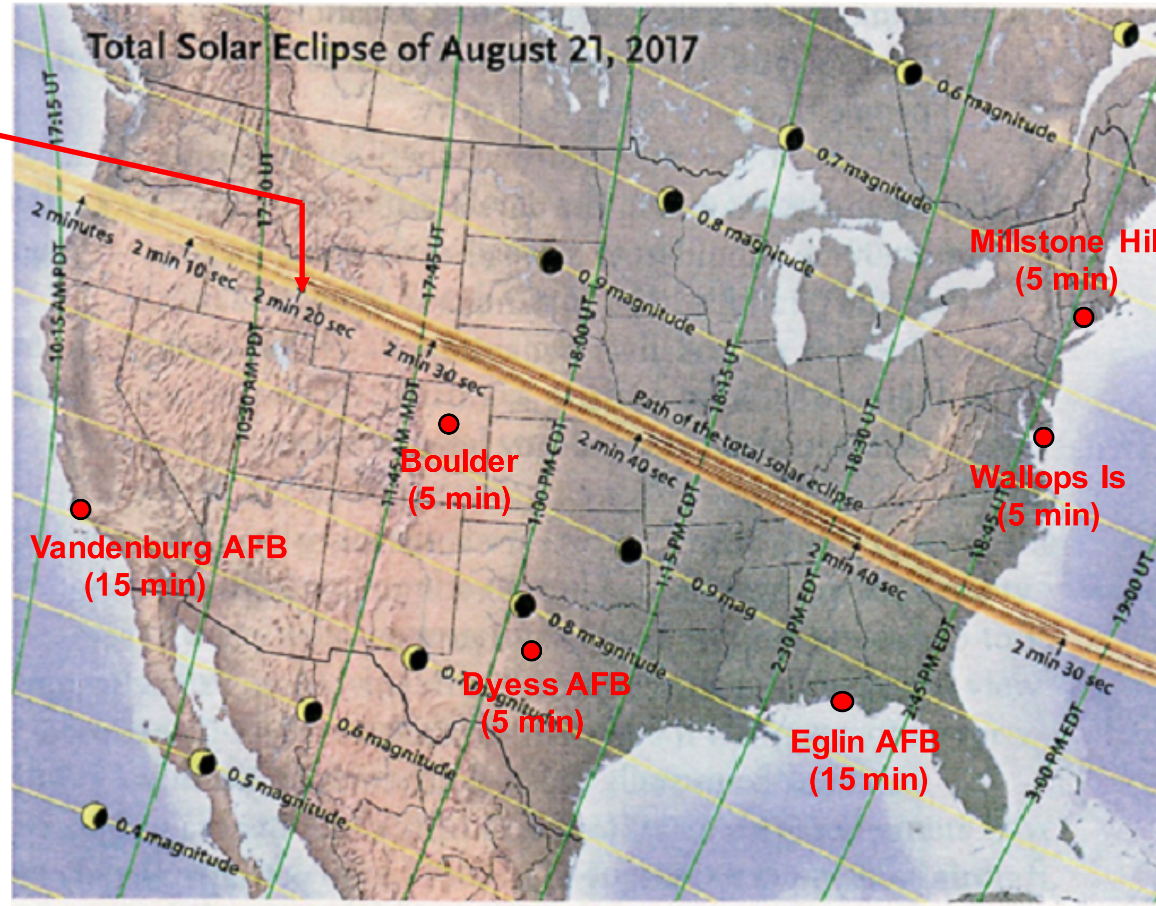
Results of Other Solar Eclipses

- Google "Bamford 1999 UK Total Solar Eclipse"
  - Dr. Ruth Bamford, Rutherford Appleton Laboratory
  - Then download a couple great reports on the UK's total solar eclipse of August 11, 1999
    - Good technical assessments of the ionosphere's response to the eclipse
- Check out the January and July 1979 issues of QST
  - Four articles about the February 26, 1979 eclipse
    - *Effects of a Solar Eclipse on the Ionosphere* by W2HMT
      - Also showed rocket flight measurements in VE4-land of electron densities of the July 20, 1963 eclipse
    - *The Colorado Net* by WBØBAE
    - *The Solar Eclipse Net* by KA7CBV, AC7G and WA7ZWD
    - *An Eclipse Study on 80 Meters* by W7LIX and W7ACP
- And other reports . . .

Lots of good info out there

August 21, 2017 Total Solar Eclipse

- Idaho National Labs ionosonde is right here
  - Currently, it takes data every 15 minutes
  - Bill NQ6Z working with INL to shorten the sweep time (< < 5 min) for the eclipse
- Boulder ionosonde is about 93% totality
- Eglin AFB and Wallops Island ionosondes are about 85% totality
- Several others with less totality



NATIONWIDE EVENT Weather permitting, everyone in North America gets to see at least a partial solar eclipse on August 21, 2017. *Eclipse magnitude* is the fraction of the Sun's diameter covered by the Moon.

Ionosondes have a sensitivity limit