Outstanding Problems in Radio Propagation

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Who Is Carl K9LA?

- BSEE/MSEE from Purdue University
- RF design engineer by profession (retired 2013)
- Amateur Radio license since 1961
- Great interest in HF propagation

Connecting the Radio Amateur and Radio Science Communities

- Radio Amateurs can make good observations
  - Radio Amateurs take advantage of these observations
  - But Radio Amateurs may not fully understand the physics behind the observations
- Radio Scientists can understand the physics
  - But they may not apply this knowledge to Radio Amateur observations
- When observations match physics, we probably know what's going on
- Good things can happen when Radio Amateurs connect with Radio Scientists

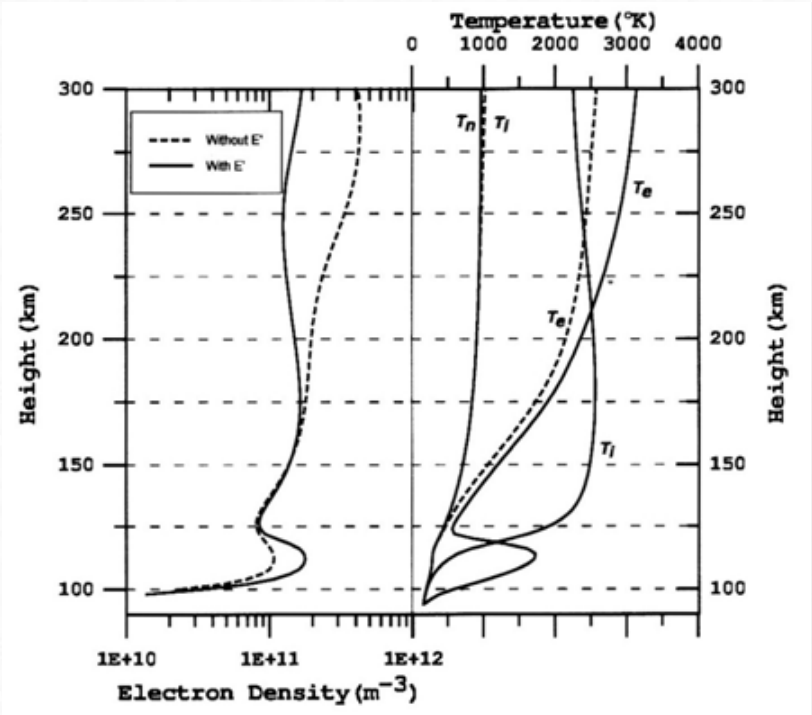
An Example of Radio Amateurs and Radio Scientists Connecting

E-Fields

- Many Radio Amateurs have observed that propagation on our lower bands (160-Meters and 80-Meters) across high latitudes can be enhanced when the K index initially spikes up
  - No explanation offered by Radio Amateurs
- I happened upon "A modeling study of ionospheric conductivities in the high-latitude electrojet regions"
  - JGR, Vol 109 (2004), Zhang/Kamide/Liu/Shinagawa/Iwamasa

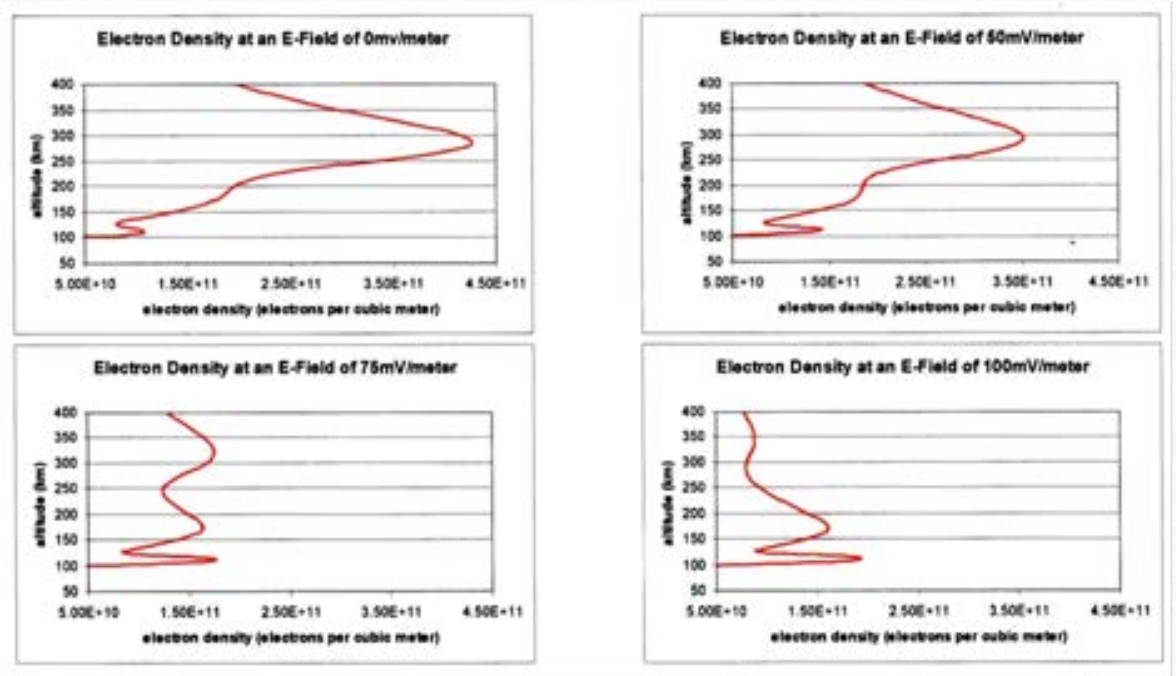
E-Fields – Figure 4 in the JGR Paper

- The figure on the right caught my eye
- The electron density valley above the E region peak was more well formed when the electric field was higher (higher K index)
- Radio Amateurs believe that very long distance contacts on 160-Meters and 80-Meters can be enabled by ducting in this valley
  - Successive refractions between E region peak and higher F region



E-Fields – Further Investigation

- I contacted the lead author and he ran simulations for me
- As the E-field increases (higher K index), the valley is more well formed
- Too high an E-field may result in the valley starting to collapse
- Could this be the answer? Or could it be a skewed path (Warrington, et al)?

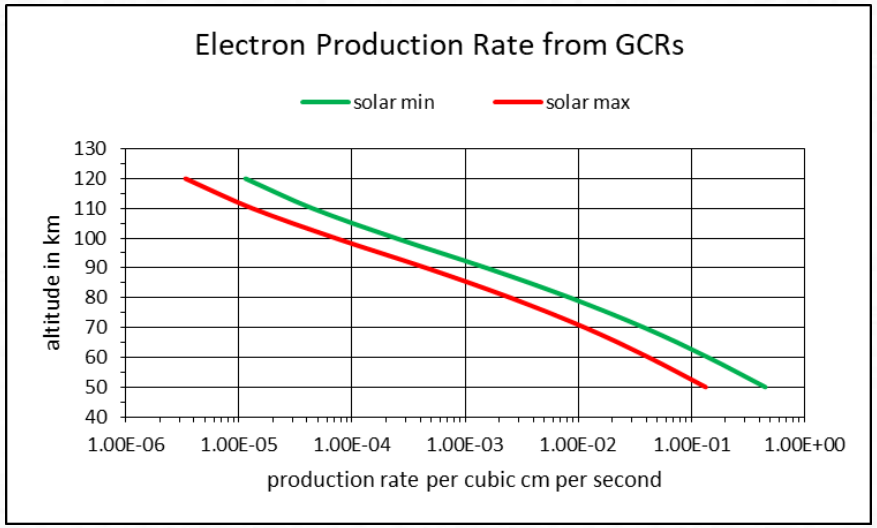


Outstanding Problems in Radio Propagation

- Galactic Cosmic Rays
- Sporadic E
- Propagation Predictions
- There are more!

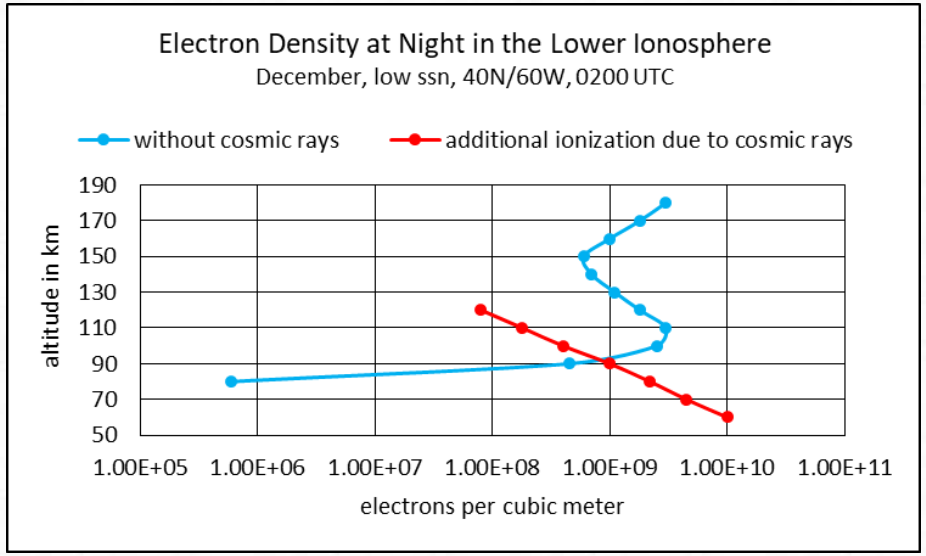
Galactic Cosmic Rays (GCRs)

- How much do they affect ionospheric absorption on the low bands?
- Ionization rates from "Improved cosmic ray ionization model for the system ionosphere–atmosphere – Calculation of electron production rate profiles"
  - JASTP, Vol 70, 2008, Velinov/Mateev



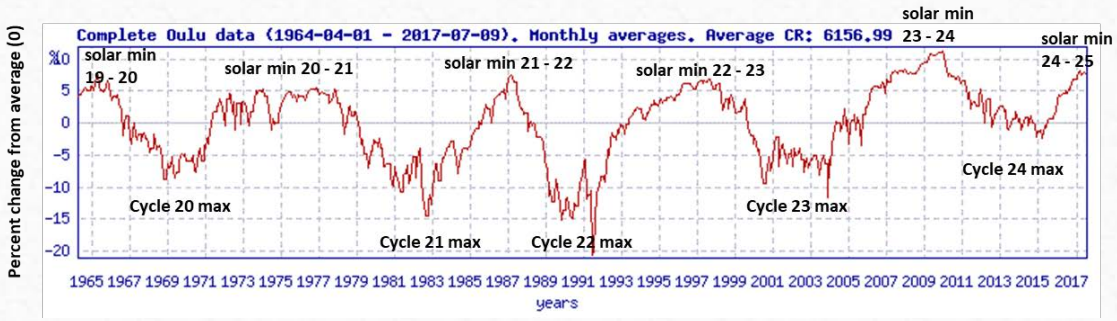
GCRs – Resulting Electron Densities

- GCR ionization rates result in electrons on the order of magnitude of the number of electrons at lower E region altitudes (where absorption occurs at night)
- Can also conceivably fill in the valley to degrade ducting on 160-Meters and 80-Meters
- Are the ionization rates accurate?
- Is my electron density calculation accurate?



GCRs – Neutron Count

- Solar minimum between Cycles 23 and 24 saw the highest neutron counts ever
- Could there be even more electrons in the lower ionosphere?
- What is solar minimum between Cycles 24 and 25 going to do?
- Will propagation on the lower bands be adversely affected even more?



positive percent change (solar min) – more electrons
negative percent change (solar max) – less electrons

Sporadic E

- Will we ever be able to predict sporadic E?
- "Polar mesospheric horizontal divergence and relative vorticity measurements using multiple specular meteor radars"
  - Radio Science, 10.1002/2016RS006225, Chau et al
- Could this shed any light on our understanding of sporadic E at higher altitudes?

"During the summer, the large, swirling vortices that form in the mesosphere reversed their clockwise direction at an altitude of roughly 86 km above Earth and started rotating counterclockwise instead."

this sounds like wind shear

Propagation Predictions

- The model of the F2 region of the ionosphere in our propagation predictions is a monthly median model
  - The smoothed sunspot number (or smoothed 10.7 cm solar flux) is correlated to monthly median ionospheric parameters – median implies 50% probability
  - Thus our predictions are statistical in nature over a month's time frame
- We do not have daily predictions
  - These predictions were never intended to be used on a daily basis
  - Too much day-to-day variability in the F2 region

Propagation Predictions – Why Not Daily?

- The amount of F2 region ionization at any given location at any given time is dependent on three contributors
  - Solar radiation – we understand this one the best thru the sunspot number, solar flux or EUV – smallest contributor to the day-to-day variability
  - Geomagnetic field activity – decent understanding thru the last eleven K indices using the STORM model – large contribution to the day-to-day variability
  - Events in the lower atmosphere coupling up to the ionosphere – we understand this one the least – large contribution to the day-to-day variability

Propagation Predictions - Details

- The previous slide comes from "Patterns of F2-layer variability"
  - JASTP, Vol 61, 2001, Rishbeth/Mendillo
- Much effort in the ionospheric community nowadays to better understand events in the lower atmosphere (ground level, too) coupling up to the ionosphere
  - We need a parameter for it – maybe something in terms of characterizing TIDs (traveling ionospheric disturbances)
- Once we understand all three contributors, we could be on the road to a daily model of the ionosphere

Summary

- There are many more "outstanding problems in radio propagation"
- My list is somewhat biased by my interest in the lower frequencies in the Amateur Radio spectrum
- If Radio Amateurs and Radio Scientists work together, we might be able to understand many of these problems
  - The interest may be there, but the funding may not be there!