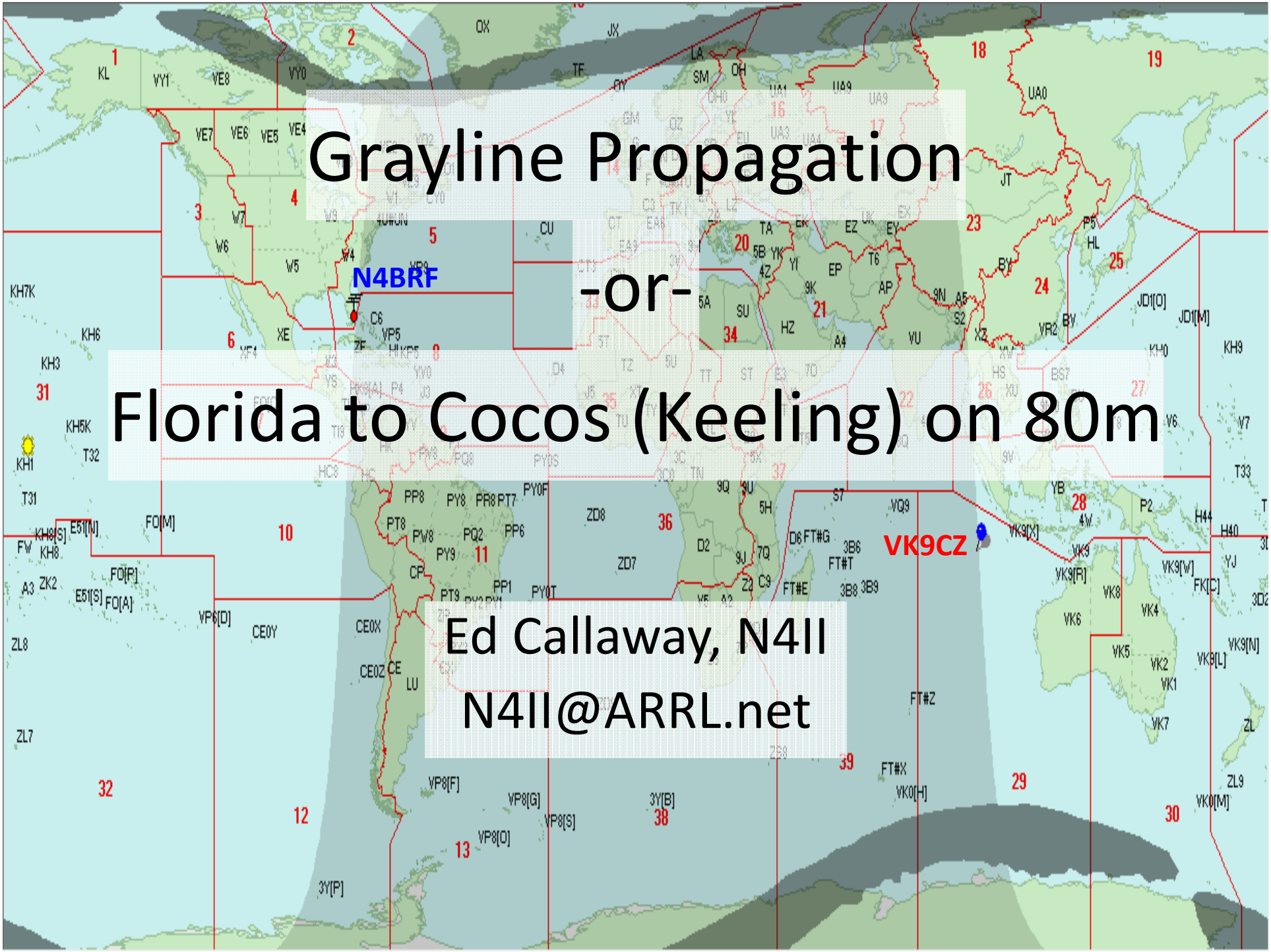


Grayline Propagation

-or-

Florida to Cocos (Keeling) on 80m

Ed Callaway, N4II

N4II@ARRL.net

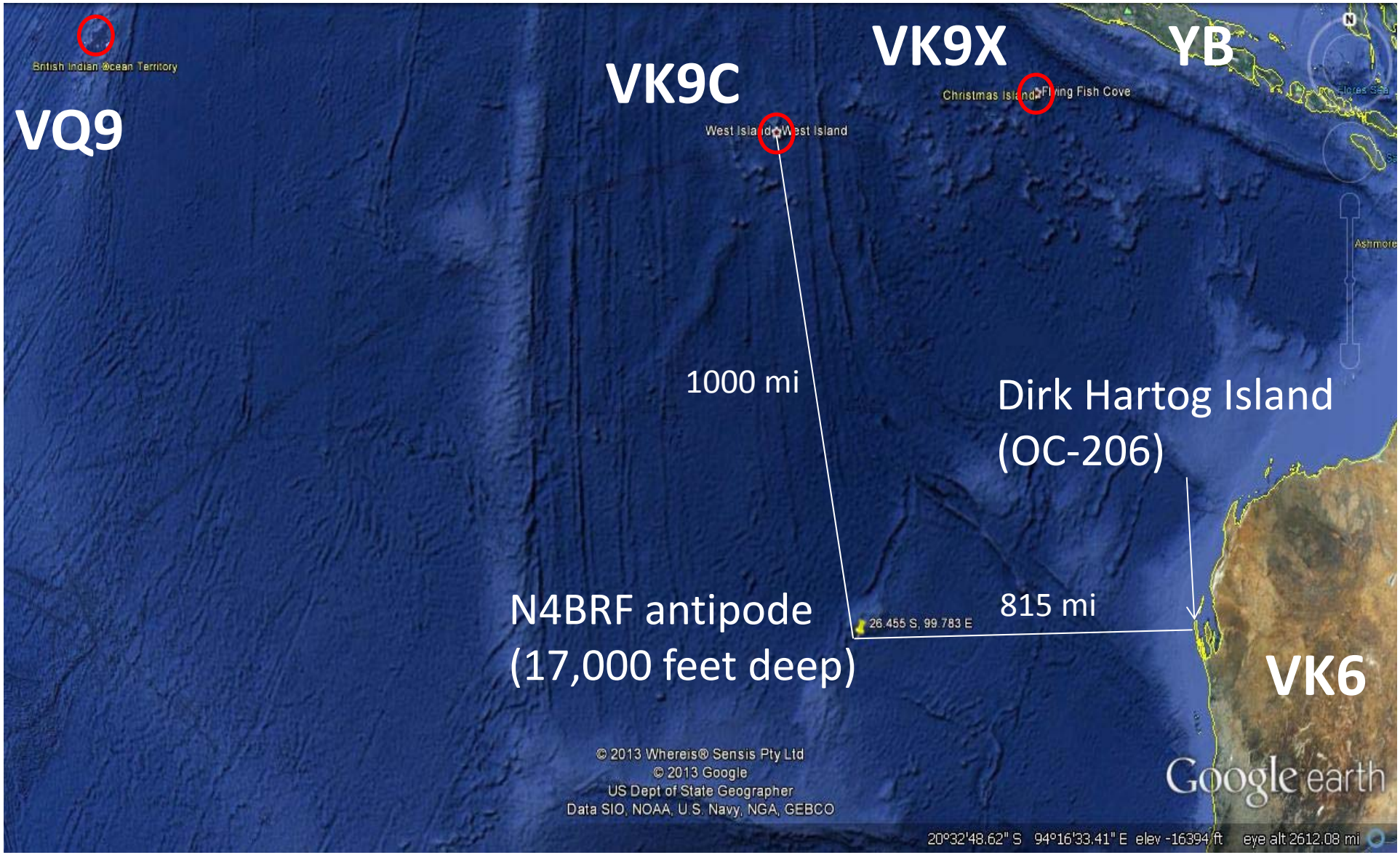
Abstract

The VK9CZ DXpedition to the Cocos (Keeling) Islands made 51 QSOs with US Zone 5 on 80m. 21 of these QSOs – more than 40 percent – were with stations in Florida.

Q: Why were we so fortunate?

A: Grayline propagation – lowband propagation via an unusual path. . . .

The Southeast Indian Ocean



The Cocos (Keeling) Islands

- Farthest DXCC entity from South Florida, at 11,450 mi. (antipode is 12,450 mi.)
- From 30 March to 13 April 2013, GM3WOJ/ZL1CT, Chris, and GM4YXI, Keith, operated as **VK9CZ**
- Ops were great – alternating 80m and 160m every SR and SS, beginning 3 April, and 80m exclusively after 6 April (due to poor production on 160m)

My Plan to Work ‘em on 80m

- Find mutual darkness*
  - On 7 April, midway through the operation:
    - VK9CZ SS = 1132z; N4BRF SR = 1106z
    - VK9CZ SR = 2337z; N4BRF SS = 2340z
  - Conclusion: No mutual darkness, but low bands a possibility at the “gray line” of our SS and VK9CZ SR
- N4BRF the best available station to me
  - SteppIR vertical on 80m, with 60 radials, in a quiet swamp
  - ~500 watt PA
  - Yaesu FT1000MP
  - Disadvantage: No Internet

*http://www.sunrisesunset.com is your friend.

Results, 3 April

- Began monitoring 80m CW at 2300z (40 minutes before SS)
- At 2325z, heard VK9CZ calling CQ on 3507.5
- One guy worked him simplex as I called 1 kHz up
- No pile – worked on first call on freq as N4II
- VK9CZ called CQ again; no pile again; worked again on first call as N4BRF
- VK9CZ called CQ again; no pile again; called him as W4MOT, but he heard “N4MOT”, so no QSO
- Faded at 2345z (5 minutes after SS)

Results, 5 April

- Large thunderstorm sat over N4BRF at SS. Stayed off the air. ☹

Results, 7 April

- Began monitoring 80m CW at 2315z (25 minutes before SS)
- At 2330z, heard VK9CZ calling CQ on 3507.5
- No pile again – worked on first call as W4MOT
- VK9CZ called CQ again; no pile again; worked again on first call as K4FK
- VK9CZ called CQ again; worked several others, but never a true pileup
- Faded at 2350z (10 minutes after SS)

How?!?

- Why no pileup? Why so strong? How could he be worked almost at will, from 11,450 miles away, on 80m? Where was everyone else?
- What kind of propagation made this possible?

AC4G (Taft, Tennessee)

- AC4G wrote in to the 12 April ARRL Propagation Bulletin:
  - "I was so excited to QSO VK9CZ on 80m CW that I had to write in. Our QSO took place on 3 April around 2345Z when VK9CZ and my location in southern Tennessee were in sunlight at the edge of the terminator. This had to be one of my best QSOs ever due to the level of difficulty, the distance, and no darkness at either location (so my terminator map showed).

    "The VK9CZ signal was S5-S7 on my transmit antenna (vertical). The signal was so strong that my separate receive antenna was not required. Since that date, I have not been able to copy their 80m signal. I guess it was one on my luckiest days to be able to make this QSO."
- K7RA replied,
  - "Sounds like fun! At that day and time, I would expect good propagation on 15 and 17 meters! VK9CZ is the Cocos-Keeling DXpedition, and the path was exactly 10,843 miles, or 17,450 km.

    Time given of 2345 UTC was 4 minutes after sunrise at the South Pacific [sic] end, and 21 minutes prior to sunset on the Tennessee end."

Obviously, More Information Needed

- On 13 April, after the VK9CZ DXpedition ended, I sent a plea to the SFDXA and FCG email reflectors, asking for information from others in Florida
  - 16 Florida QSOs found (eventual VK9CZ log data: 21)
  - Everybody else felt the same way (“Wow!”)
- Also looked at Clublog data
  - 51 QSOs were made with US CQ zone 5
  - . . . So FL QSOs were an unexpectedly large portion
- Sent a request to GM3WOJ for the experience from their side, but got no reply

Interesting Spots [KE4PT]

Date	Time	DX	From	Frequency	Note
3 Apr	2342z	VK9CZ	N4SS	3507.5	QSX 3509.13 Gud signal into Ga.
3 Apr	2343z	VK9CZ	K3TW	3507.5	Amazing 589 in FL! QSX 3508.6
7 Apr	2340z	VK9CZ	N8PR	3507.5	QSX up 1
11 Apr	2335z	VK9CZ	W4SO	3507.5	qsx up 1 great sig tonite
11 Apr	2338z	VK9CZ	W1QS	3507.5	SE 449

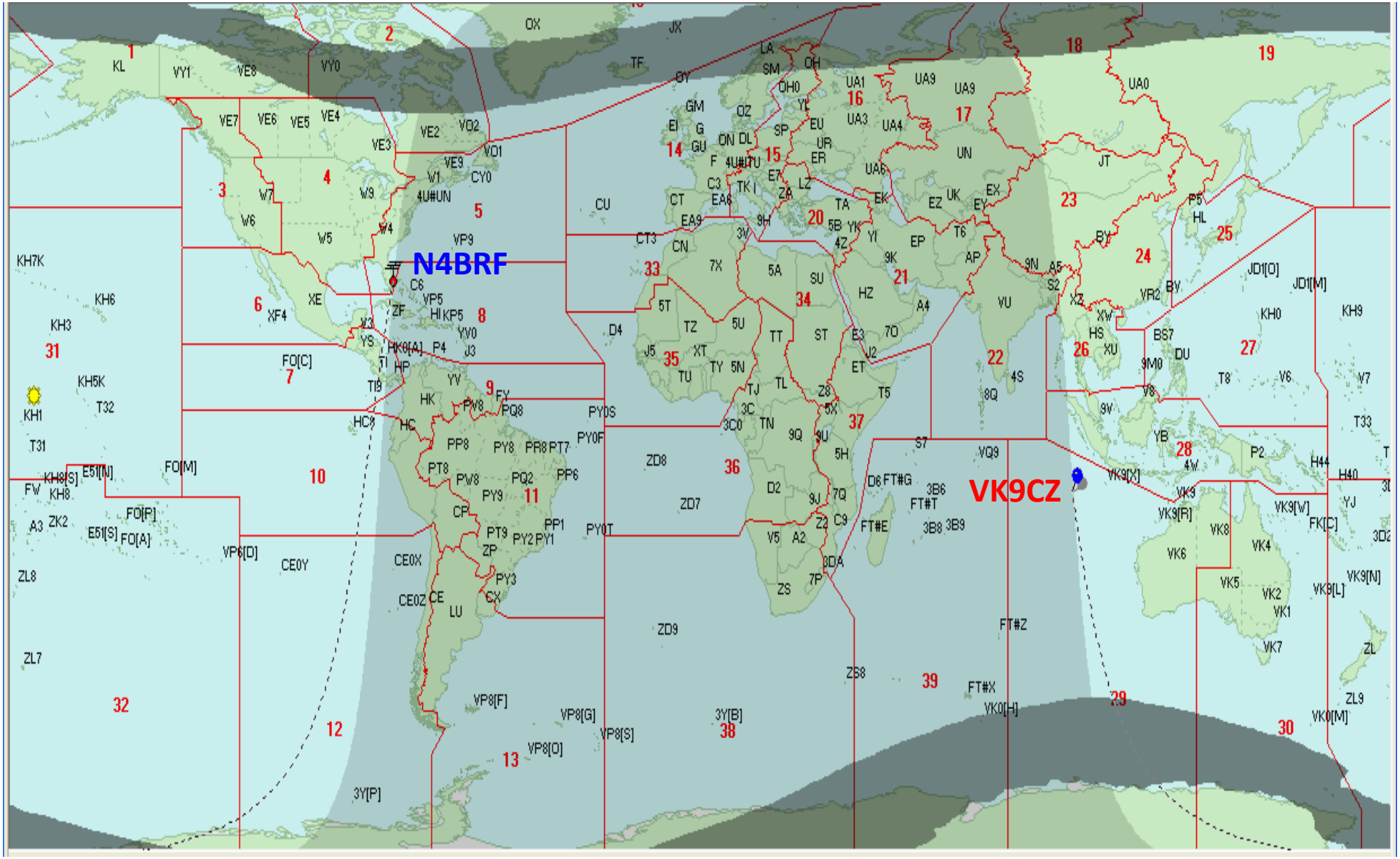
All within an 8-minute window

From the Southeast in ME. Interesting. . .

N8PR

- Of all the email responders, N8PR was the only one with a directional antenna system:
  - "Antenna [was] 4 phased ½-wave sloping dipoles in [a] 4-square phased arrangement and pointed SW when I worked them ... Louder than SE, and better yet on my Waller Flag receive antenna pointed SSW and rotated to the horizontal [polarization] configuration."
- SW? SSW? Into daylight?

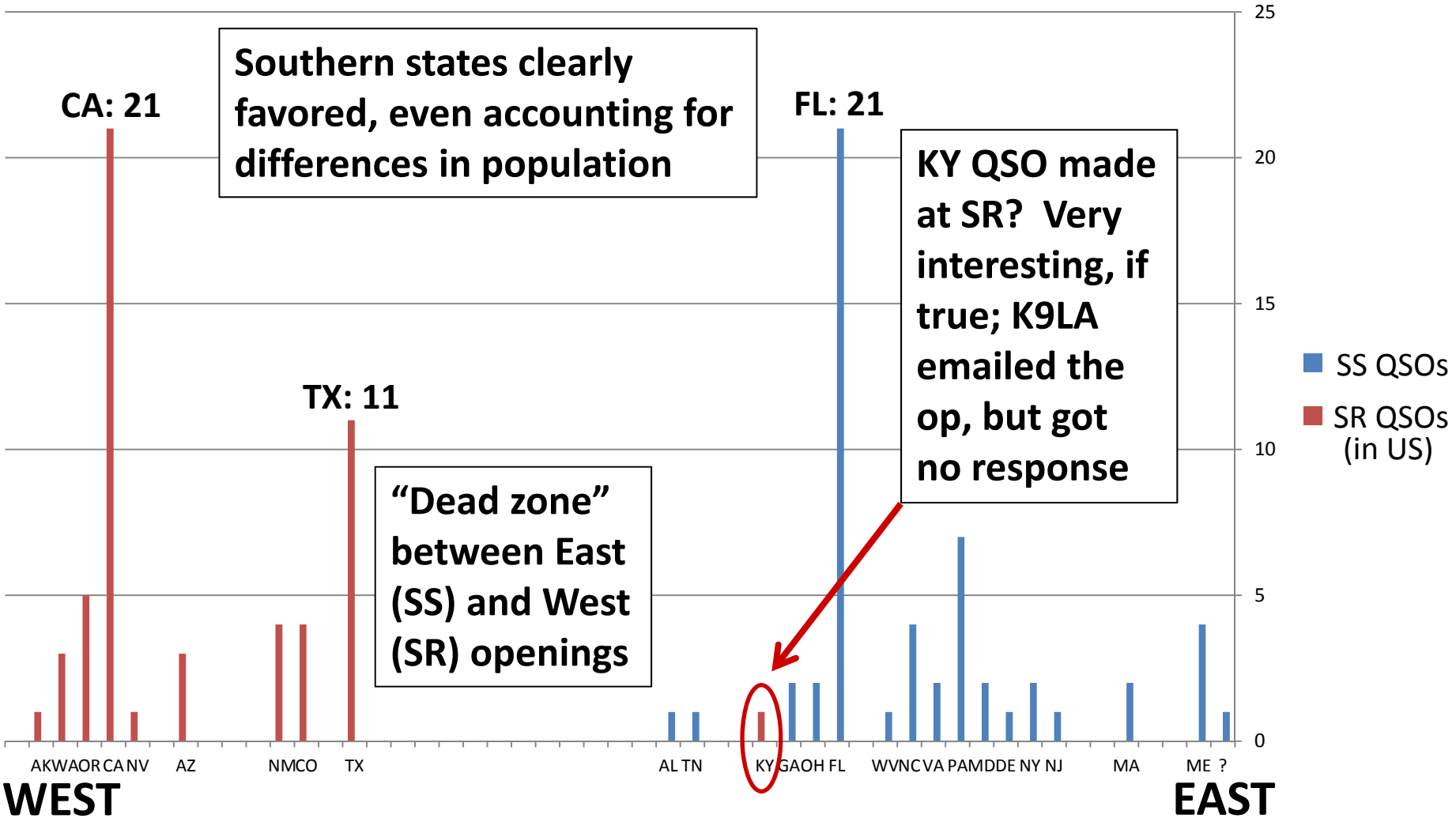
Into Daylight?



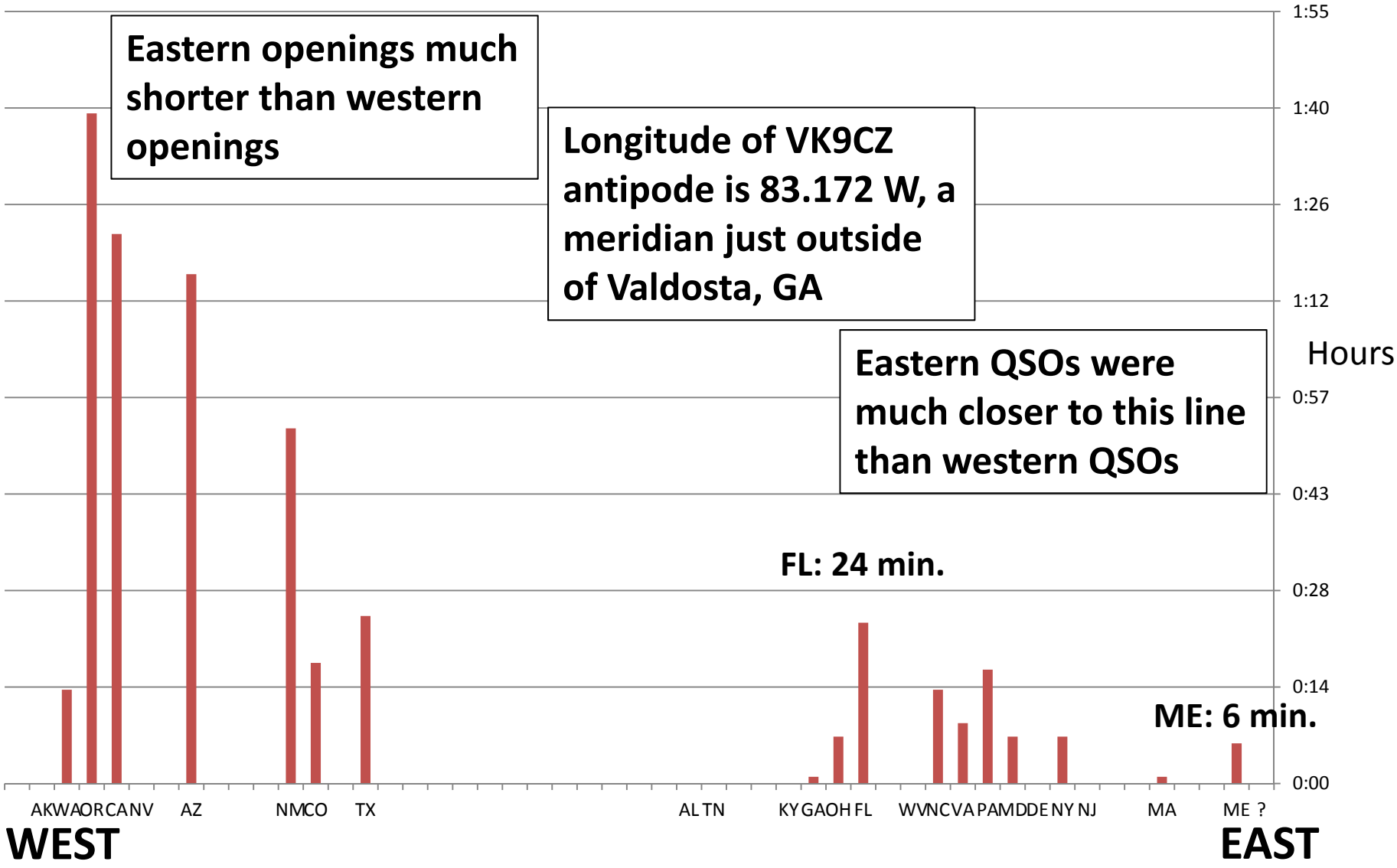
The VK9CZ Side

- Carl Luetzelschwab, K9LA, asked for, and received, the VK9CZ 80m log from GM3WOJ
  - 108 QSOs with W (0 VE)
  - 54 at SR, 54 at SS
- For each QSO, K9LA looked up the US station's QTH, and built a spreadsheet of QSO date, time, and state
- I (N4II) then added some analysis to this anonymized (no call signs) spreadsheet. . .

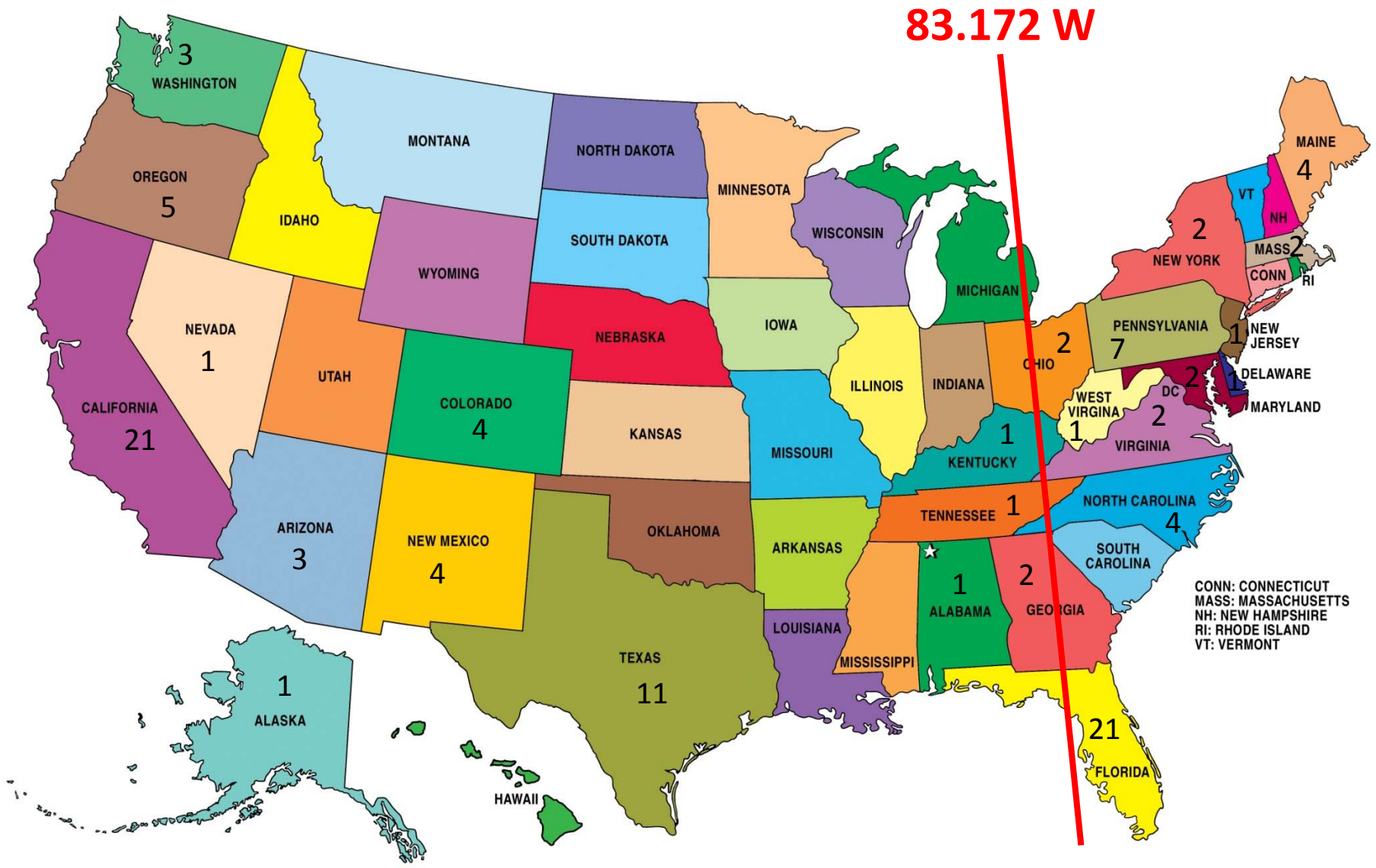
QSOs by State, Ordered West-to-East



Duration of the Opening, by State



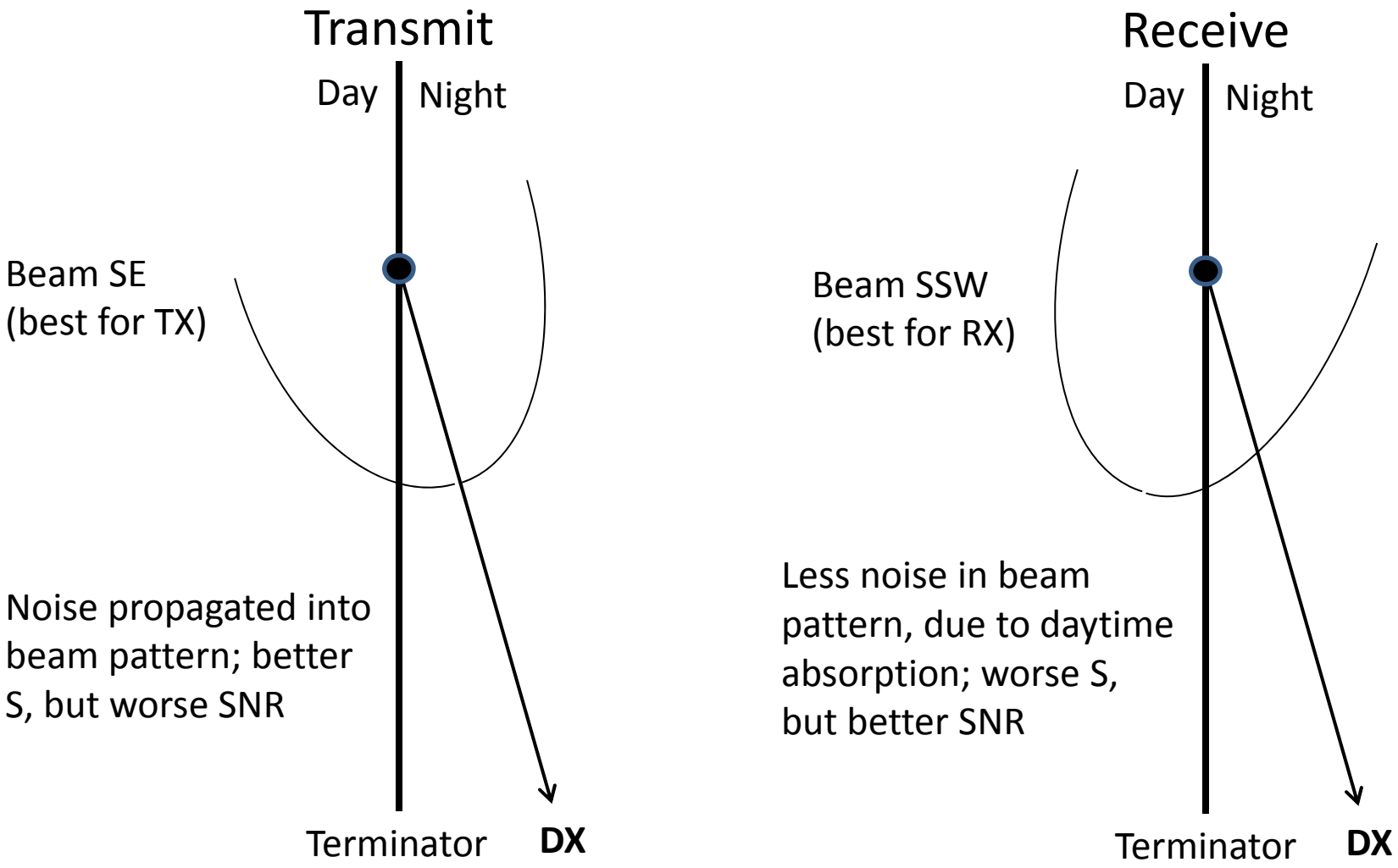
VK9CZ QSOs by State



K9LA

- I asked K9LA for his opinion. He offered several insights:
- Insight 1: Lowband ops using directional receive antennas usually optimize SNR, not S
  - This generates a directional bias towards the sun side of the terminator, since there is less noise propagated from that side
  - In our case, at SS, the signal may be coming from the SSE, while best SNR is found when the Rx antenna is pointed SSW
  - n.b.: Optimum directions for lowband Tx and Rx antennas may be different!

Optimum Beam Headings



Sidebar Advertisement

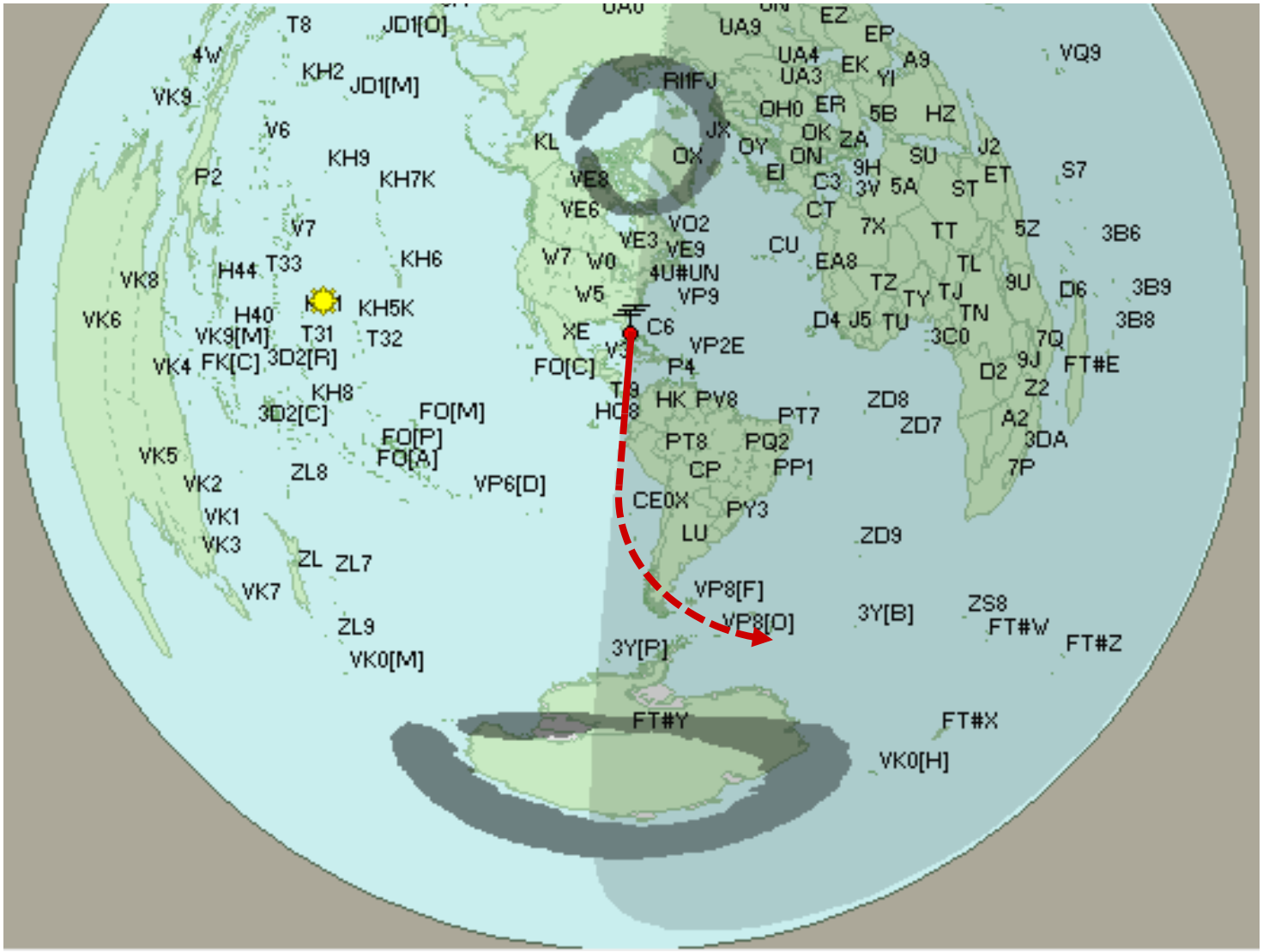
- In 2002, Chris Coleman, VK5AHZ, of the University of Adelaide, wrote a paper* in which he considered optimizing HF antenna patterns for SNR, not just S, taking into account propagated noise from distant thunderstorms, etc.
- This seems to be the next logical extension of HFTA
- Those interested please contact N4II, K9LA and/or KE4PT

*C. J. Coleman, "A direction-sensitive model of atmospheric noise and its application to the analysis of HF receiving antennas" *Radio Science*, v. 37, n. 3, 1031, 2002, pp. 3-1 to 3-10.

K9LA-2

- Insight 2: Propagation directly along the terminator is very unlikely, and very lossy, even if it did happen
  - Horizontal ionization gradient at terminator (more ionization on the sun side, less on the night side) forces the signal away from the sun side, into the dark ionosphere
  - High ionization levels also lead to increased absorption, compared to the dark ionosphere

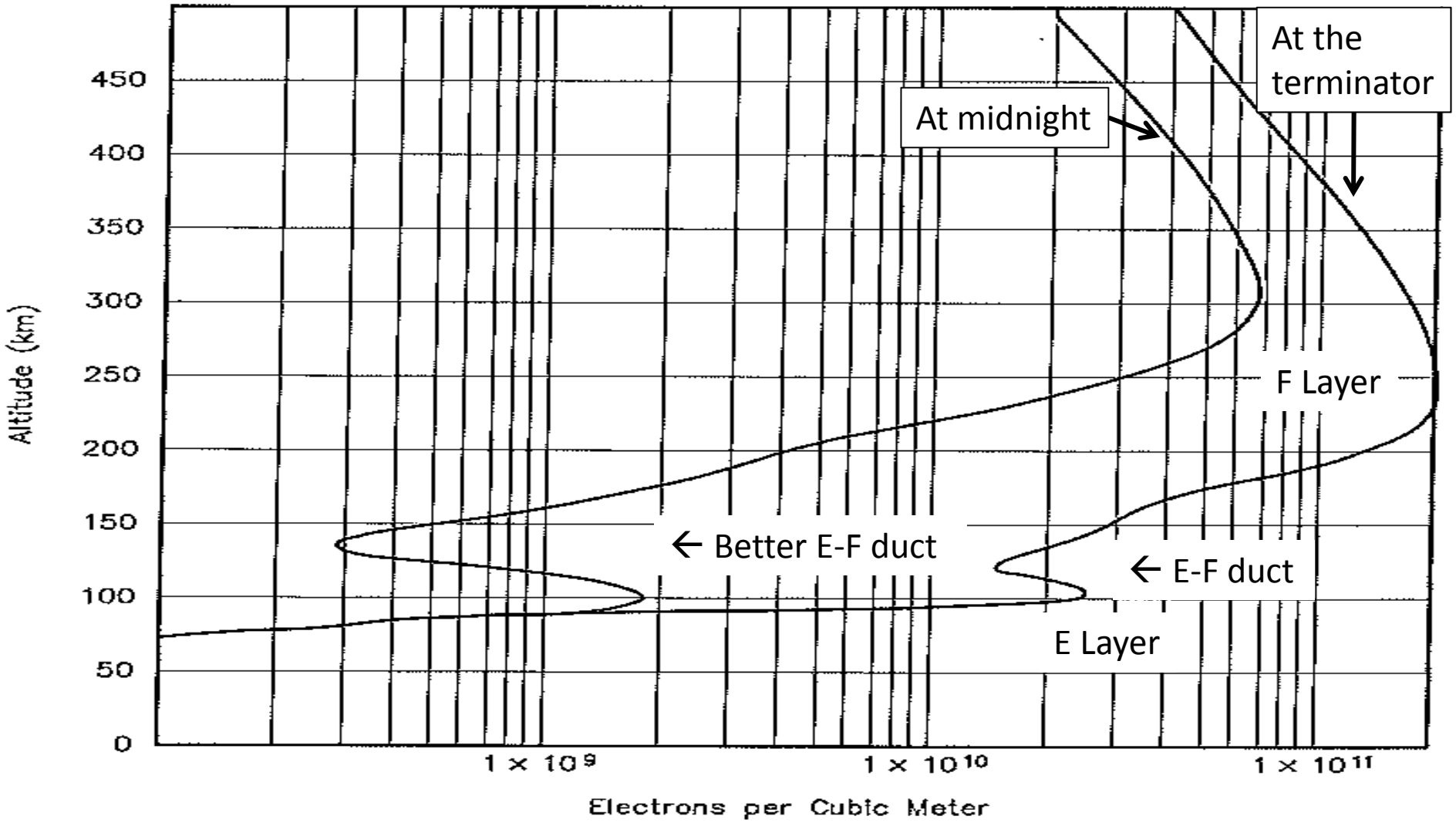
Propagation Along the Terminator



K9LA-3

- Insight 3: Long-distance low-band propagation almost certainly involves the duct between the E and F layers
  - Path via E- or F-layer hops has excessive ground loss and ionospheric absorption for an 11,450-km QSO on 80m
  - Propagation in the duct, though, can be relatively efficient
  - Ionospheric tilt at SR and/or SS enhances duct entry and exit
    - However, signals may exit at almost any location, if a local irregularity (hole) exists in the E layer

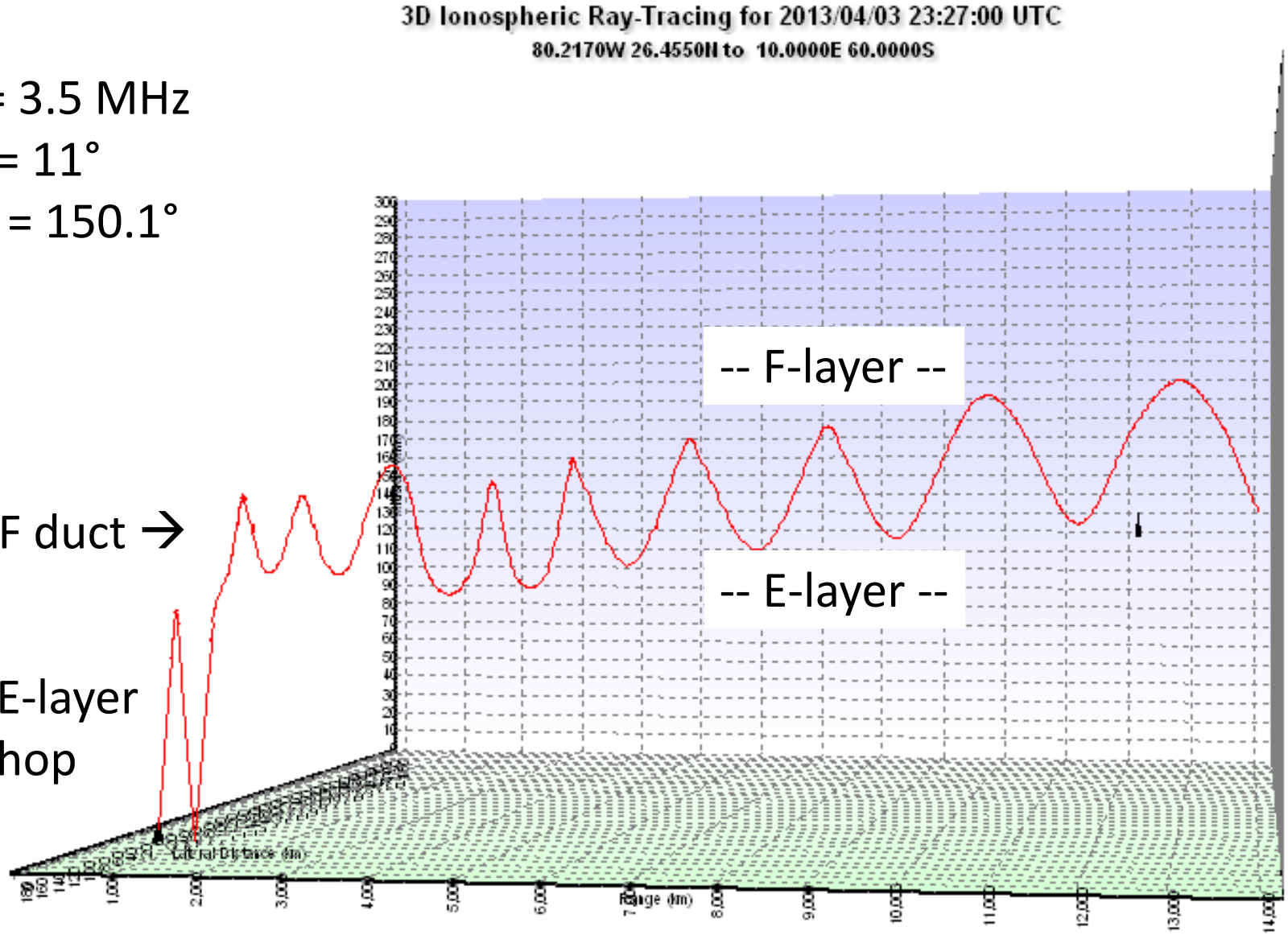
The E-F Duct (a.k.a. the E-Layer Valley)



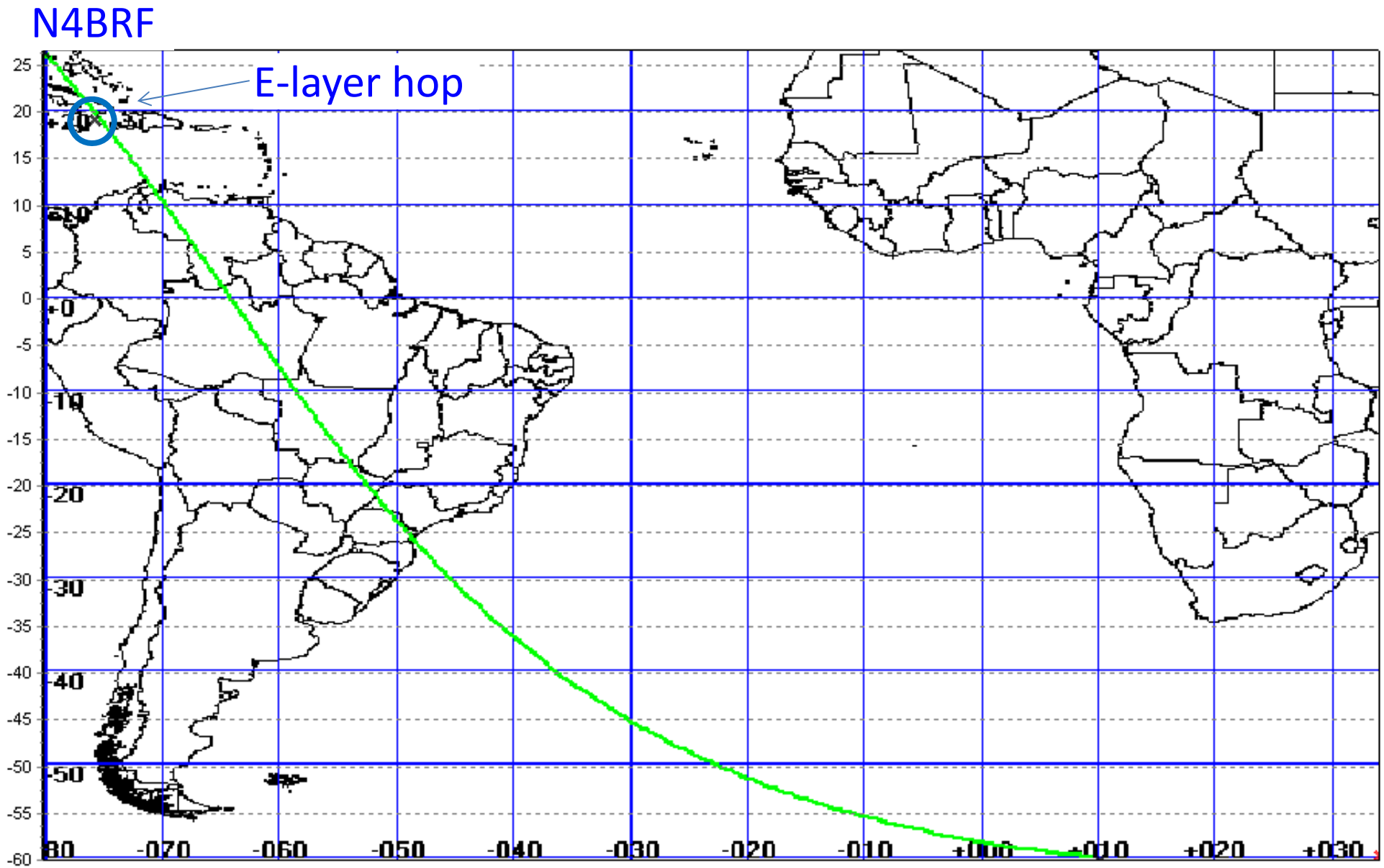
Adapted from: Robert R. Brown, NM7M, "On the SSW Path and 160-Meter Propagation," *QEX*, November/December 2000, pp. 3-9, Figure 1.

E-F Duct Propagation Example

F = 3.5 MHz
El = 11°
Az = 150.1°



E-F Duct Example – on the Ground



K9LA-4

- Insight 4: Lowest-loss propagation for low-band signals should occur far from the sun, in the dark ionosphere, where absorption is least
- Long-standing problem with this: N4BRF-VK9CZ Great Circle route does not cross the dark ionosphere, but instead is near the terminator
  - A path across the dark ionosphere would require something to skew an N4BRF Great Circle onto a VK9CZ Great Circle
  - But what?

Summary of Path Possibilities

1. “Conventional” short path (or long path)

   Great Circle routes

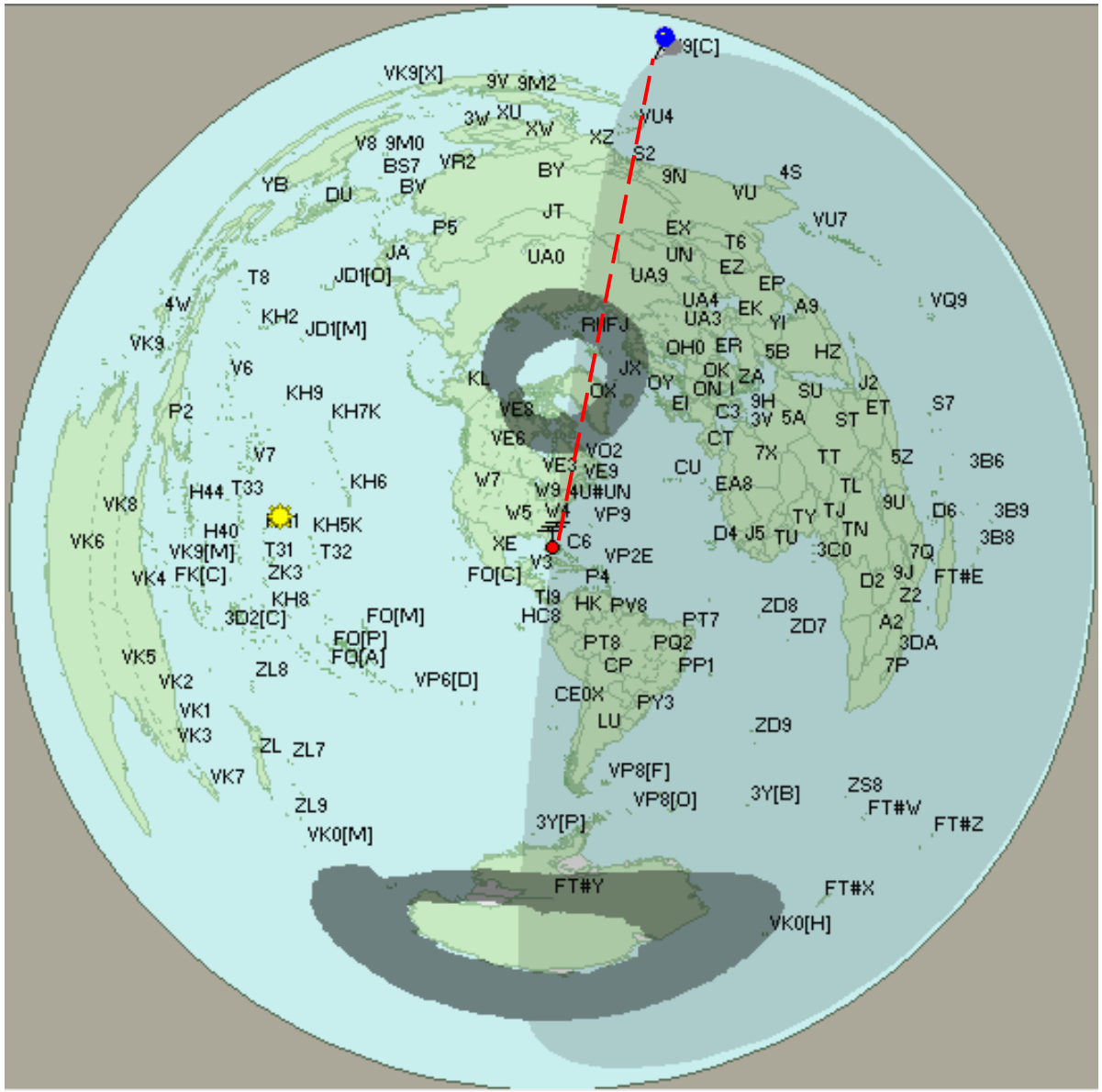
2. Path along the terminator

3. Short path with overfly

4. Path through the “dark ionosphere” ✓✓✓✓

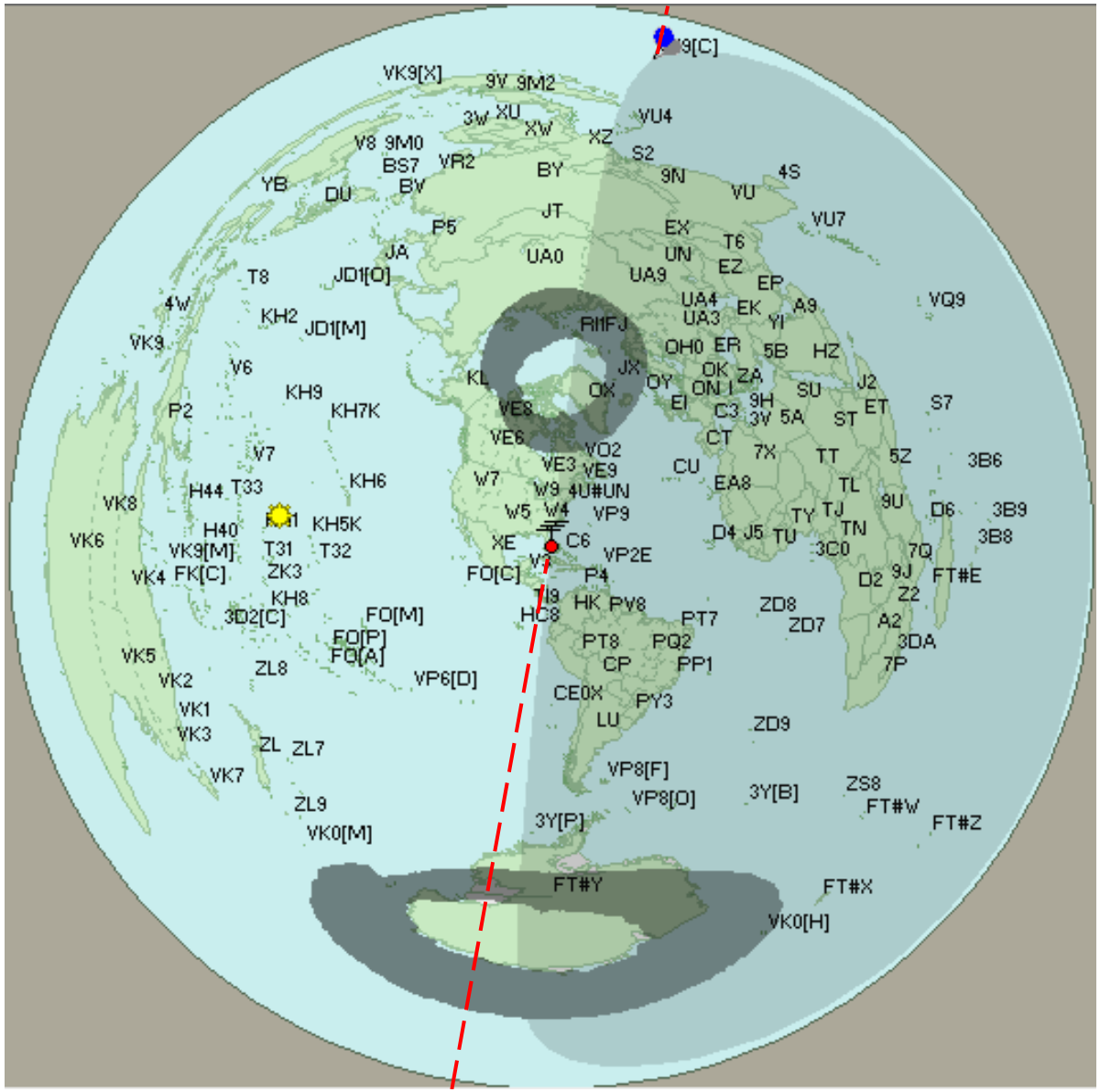
1a. Improbable Short Path (12°)

- Passes through the high attenuation of the northern auroral oval , and . . .
- Disagrees with N8PR's and W1QS's beam headings



1b. Improbable Long Path (192°)

- Passes through the high attenuation of the southern auroral oval, and . . .
- Stays in sunlight the entire way



2. Path Along the Terminator [K9LA]

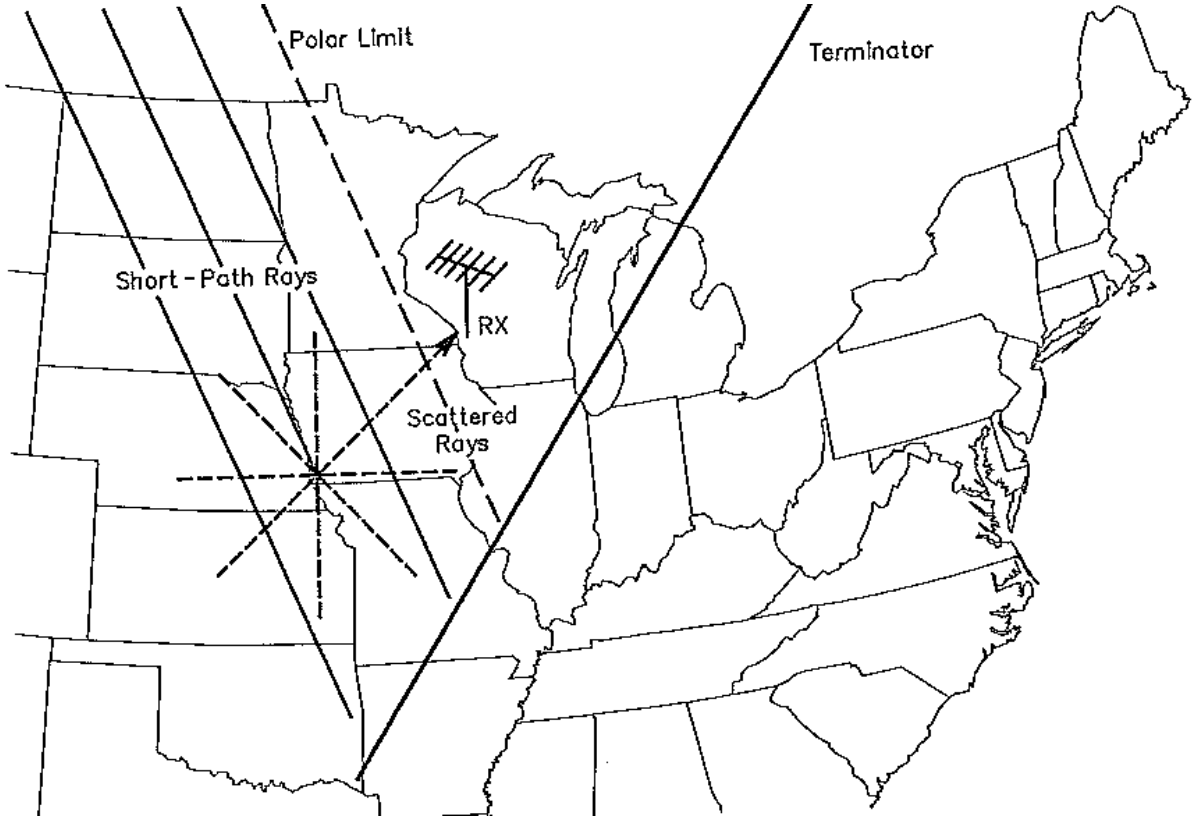
- As mentioned earlier, propagation directly along the terminator is very unlikely, and would be very lossy, even if it did happen
- In addition, the E-F electron density valley is not as well developed along the terminator (i.e., ducting is less likely)

3. Short Path with Overfly [K9LA]

NM7M proposed [1] that a scattering region forms at sunrise, and that short path signals scatter from it and produce a signal coming from the SW.

However, this hypothesis was not widely accepted, for at least two reasons:

1. Scattered signals from other directions should also be heard, at least occasionally
2. Propagation from the SSE at SS is not explained.



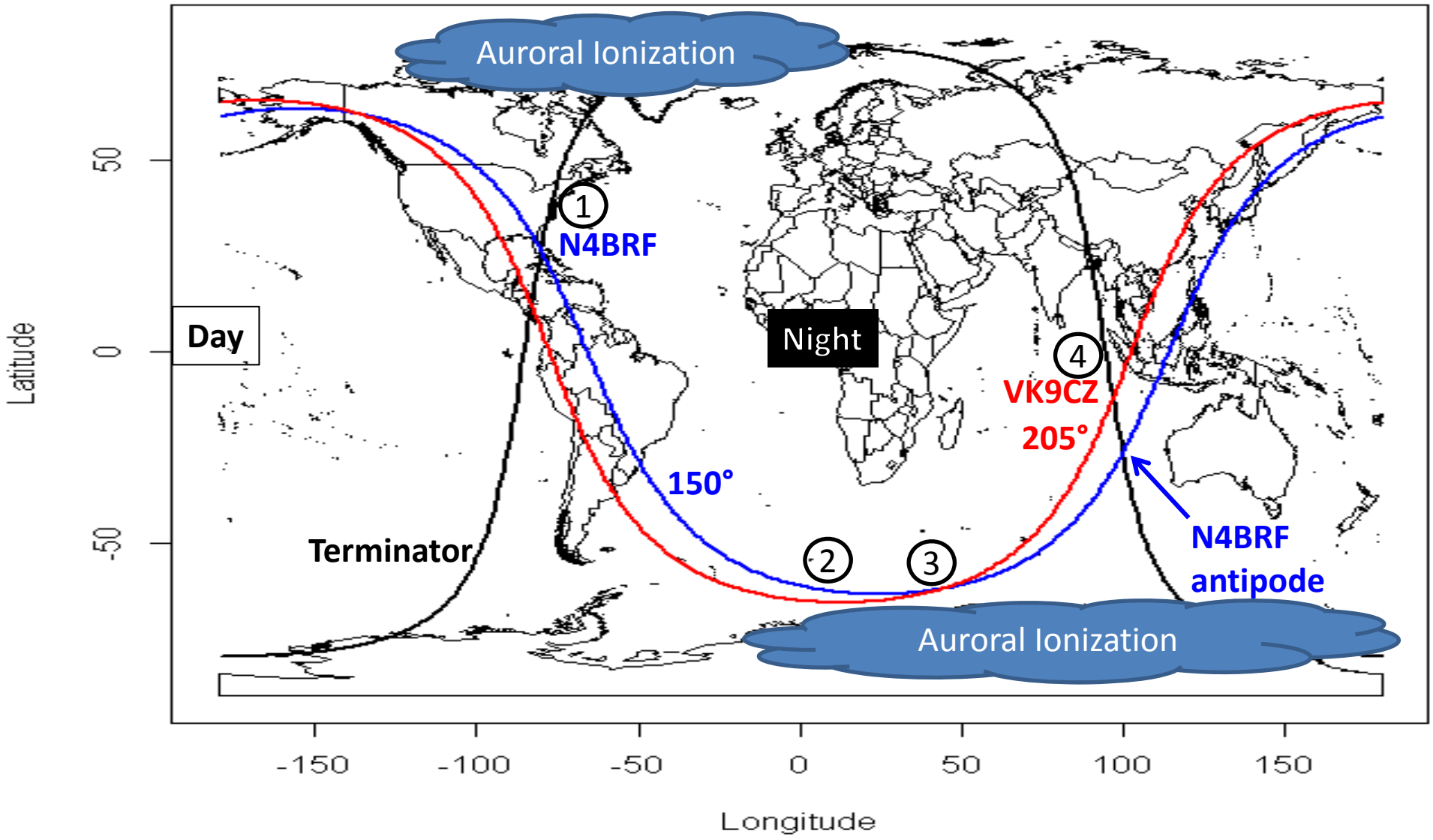
[1] Robert R. Brown, NM7M, "On the SSW Path and 160-Meter Propagation," *QEX*, November/December 2000, pp. 3-9.

✓✓✓✓

4. Path Through the Dark Ionosphere [K9LA]

1. Signal leaves N4BRF at SS, and enters the E-F duct on a Great Circle route to the SSE
2. Signal approaches the southern auroral oval, at a small (almost tangential) angle, where the ionization there closes the E-F duct
3. This ionization refracts the signal onto a new Great Circle route, equator-ward of the previous route, still via the E-F duct
4. Signal exits the E-F duct on a Great Circle route from the SSW, and reaches VK9CZ at SR

4. Path Through the Dark Ionosphere

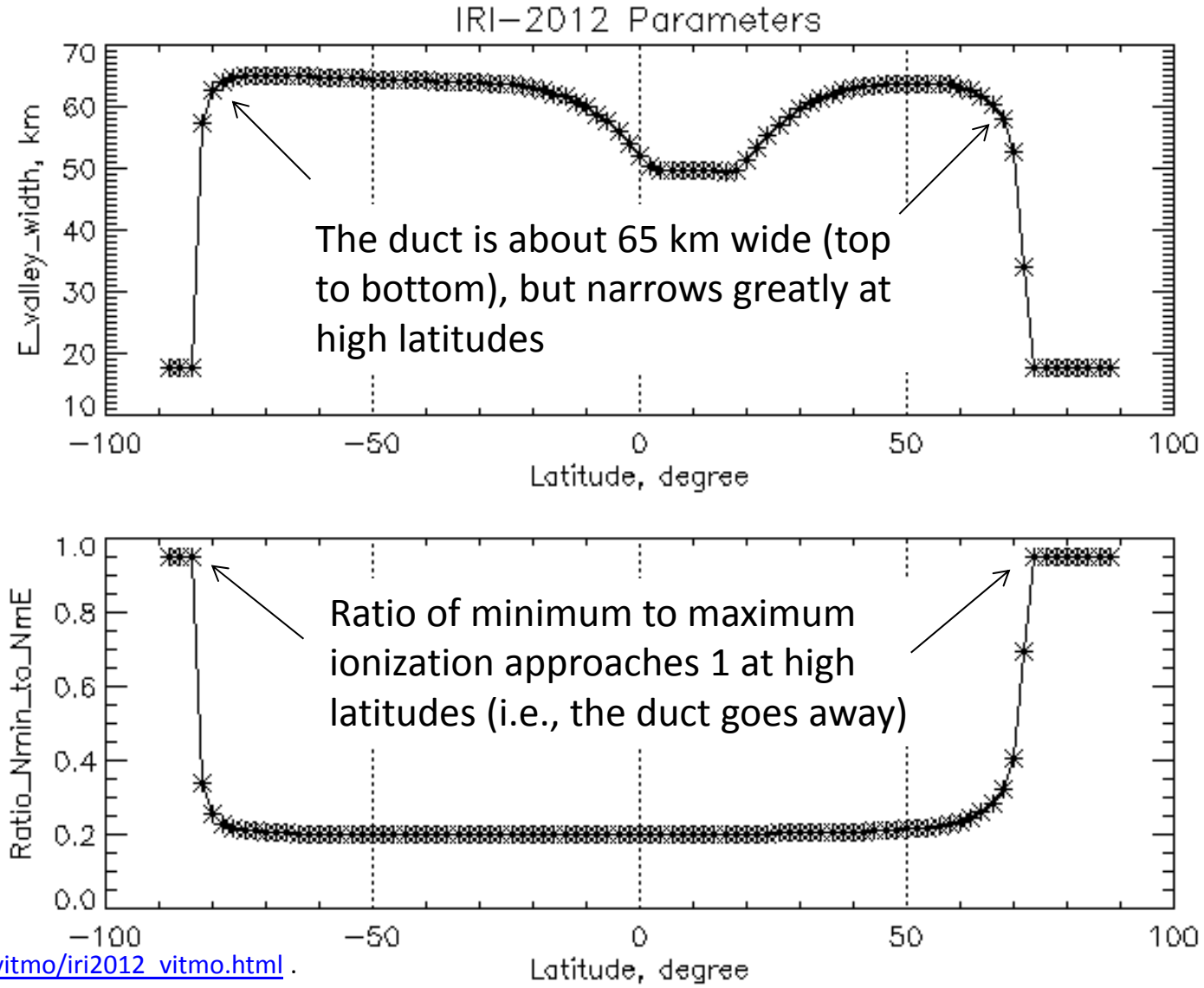


2012 International Reference Ionosphere Model of the Duct

The IRI is an "empirical standard model of the ionosphere, based on all available data sources" (http://iri.gsfc.nasa.gov/)

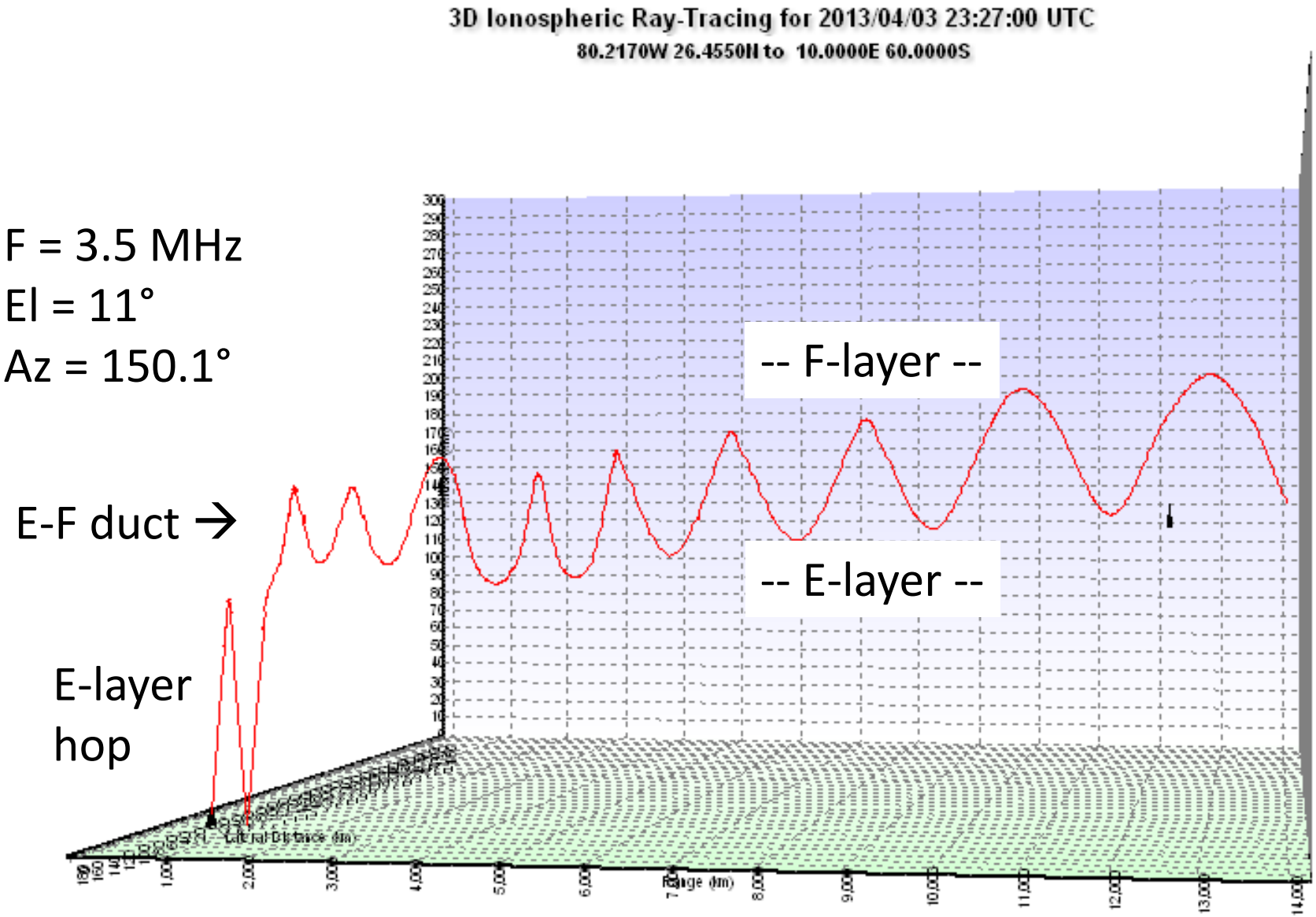
This model simulation is for 3 April 2013, 2330z, along the 20° East Meridian

Note that this is a model, not experimental data

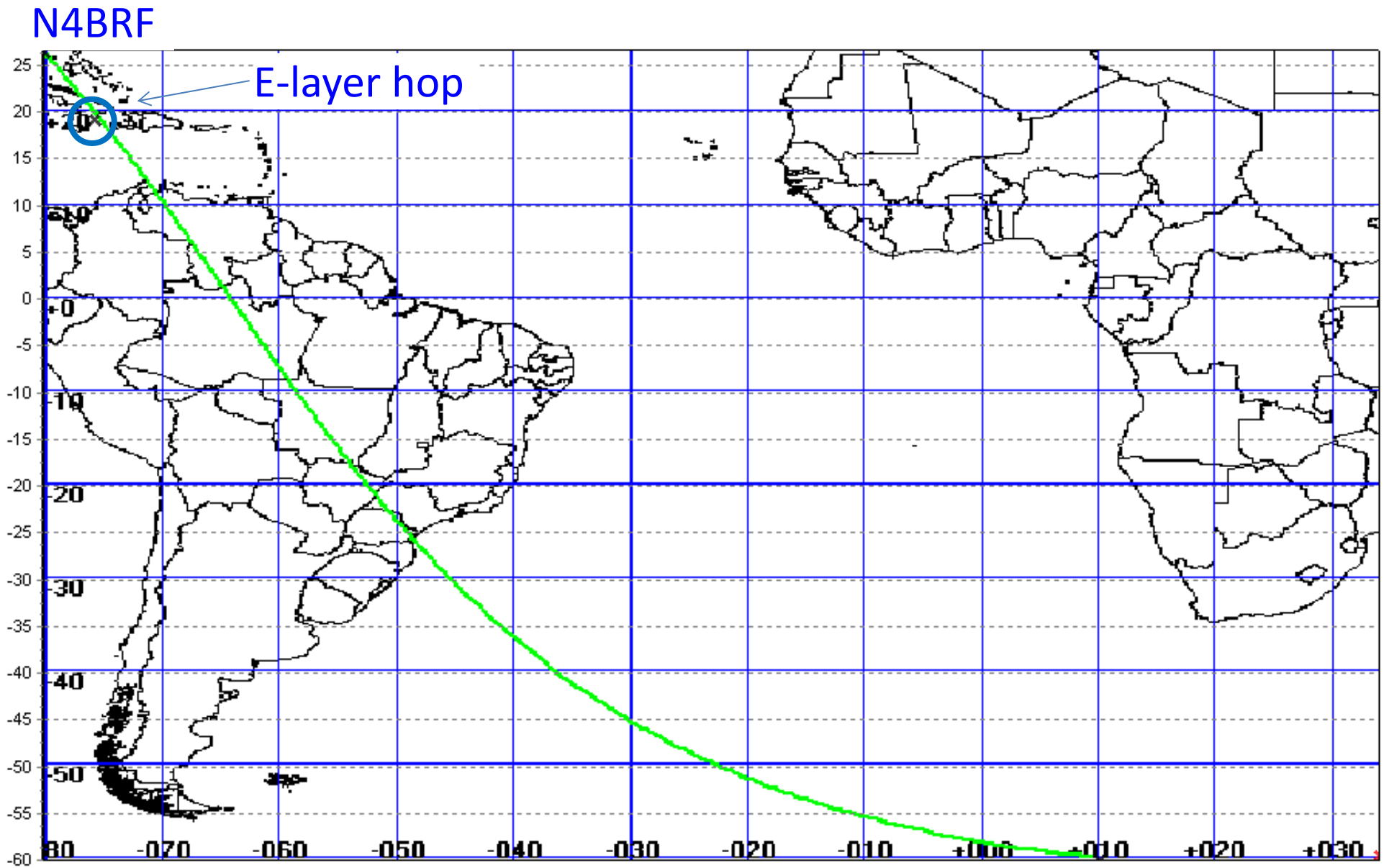


Source: http://omniweb.gsfc.nasa.gov/vitmo/iri2012_vitmo.html .

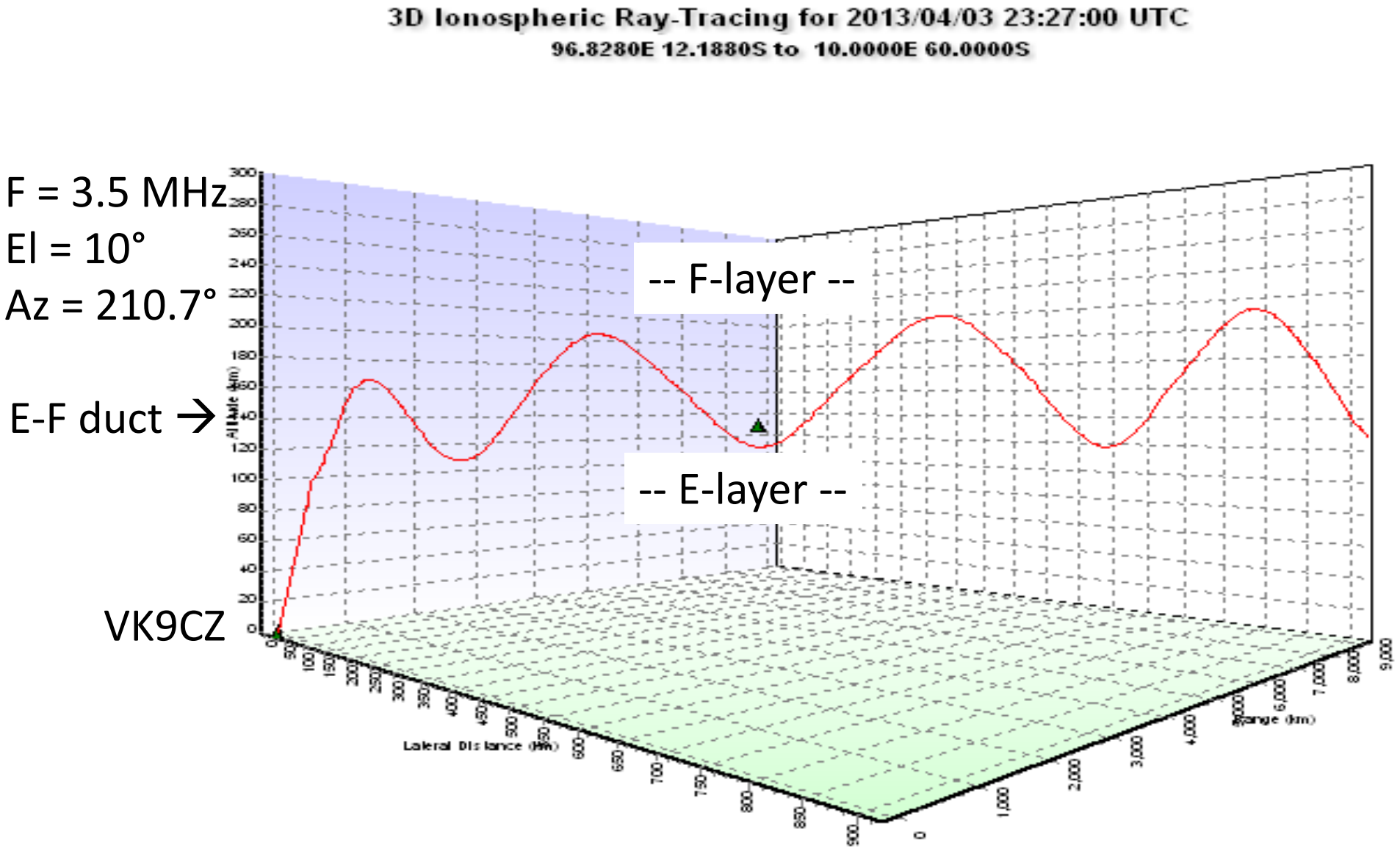
Path from N4BRF to the Southern Auroral Oval



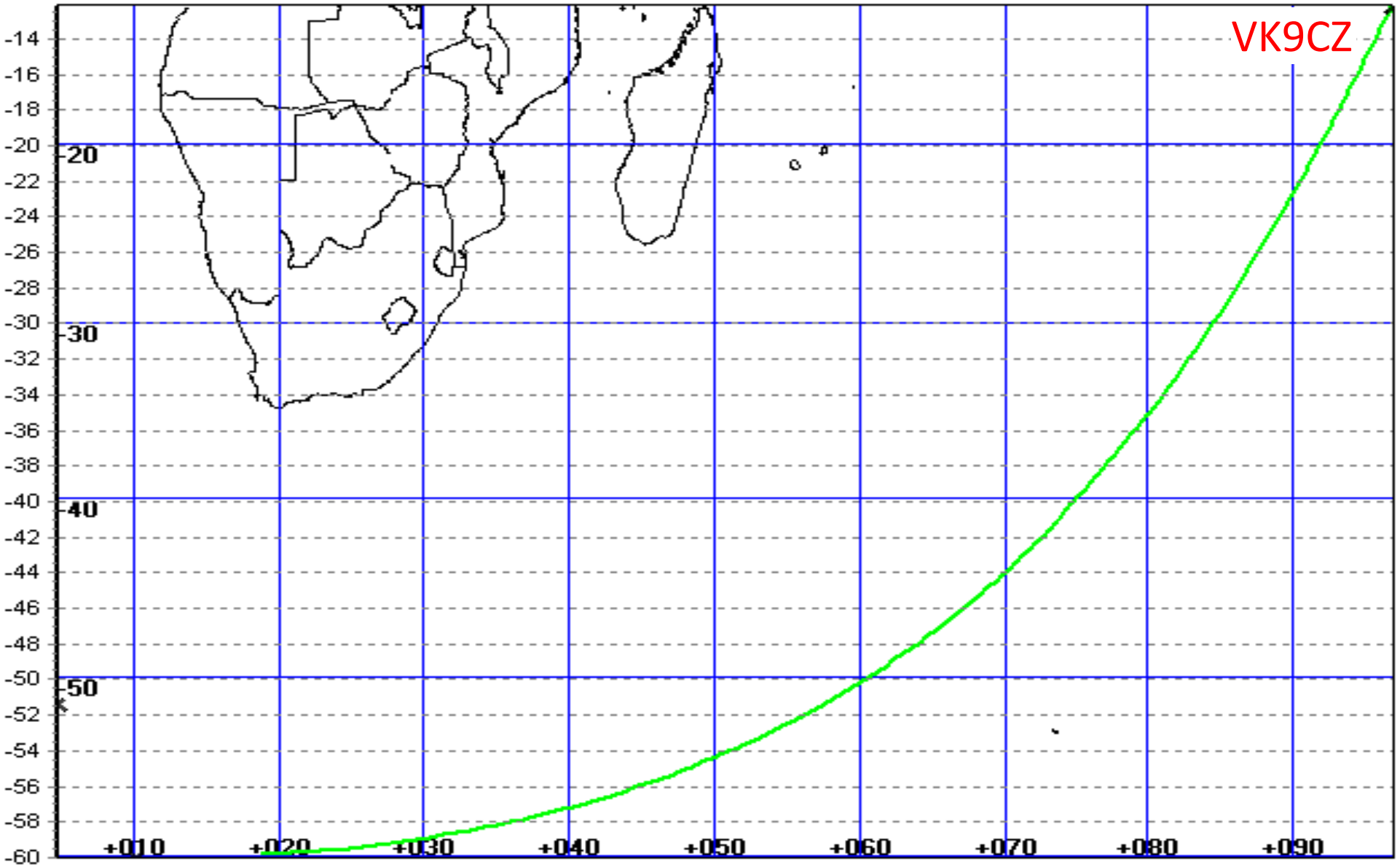
N4BRF to the Southern Auroral Oval



Path from VK9CZ to the Southern Auroral Oval



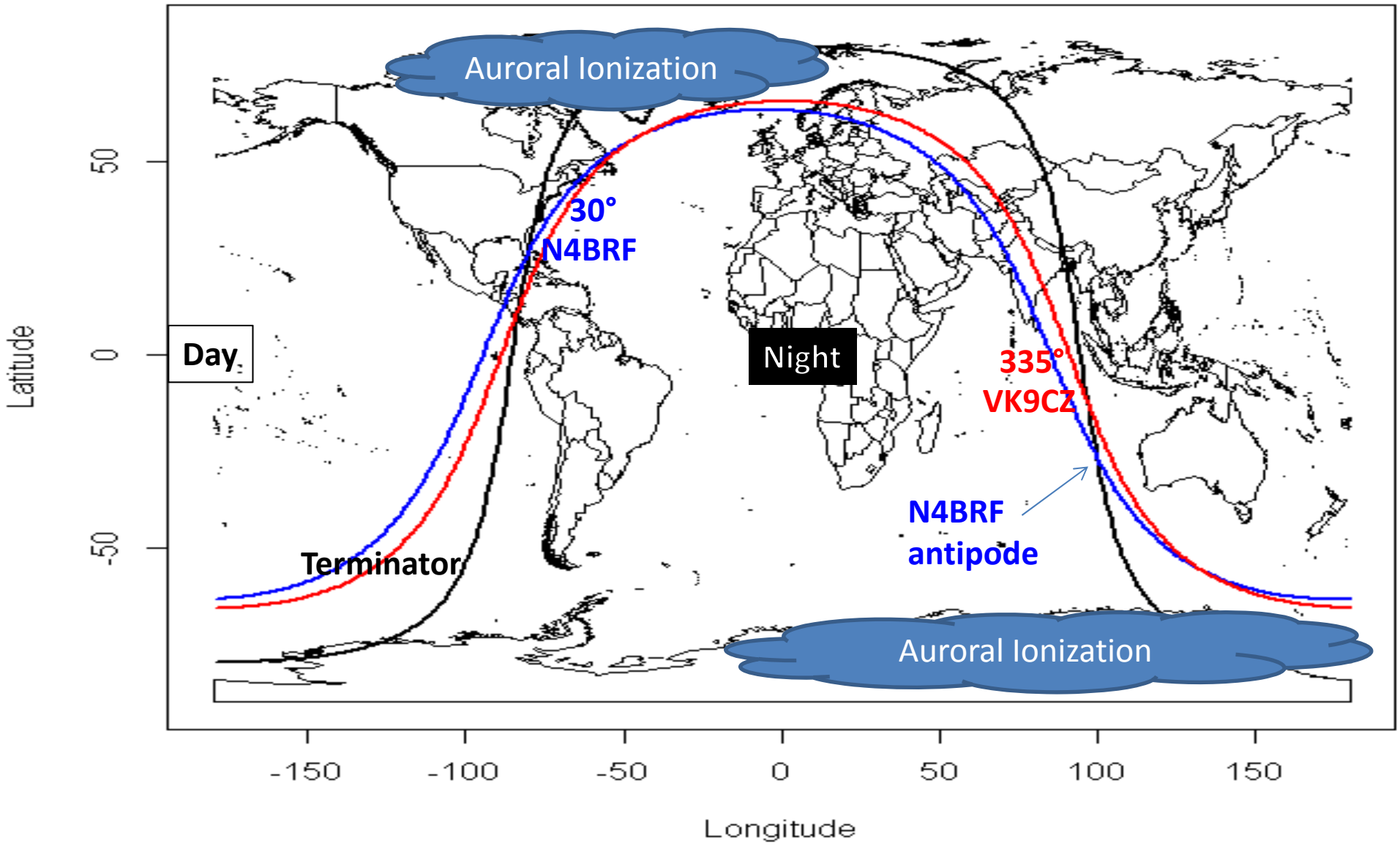
VK9CZ to the Southern Auroral Oval



Why Not to the North?

- Because VK9CZ is north of the N4BRF antipode, a signal on an N4BRF Great Circle to the north must be refracted north (pole-ward) to get on a VK9CZ Great Circle
- However, the horizontal ionization gradient at the auroral oval (higher pole-ward, lower equator-ward) refracts the signal south (equator-ward), sending the N4BRF signal into EU or AF – away from VK9CZ Great Circles

Why Not to the North?-2



Assumptions Made in this Hypothesis

1. Auroral oval ionization is as described, and does close the E-F duct and refract the incoming signal equator-ward
2. Path was to the SSE, not SSW, at N4BRF
3. Path was to the SSW at VK9CZ
   - No data (vertical antenna)
4. E-F duct propagation

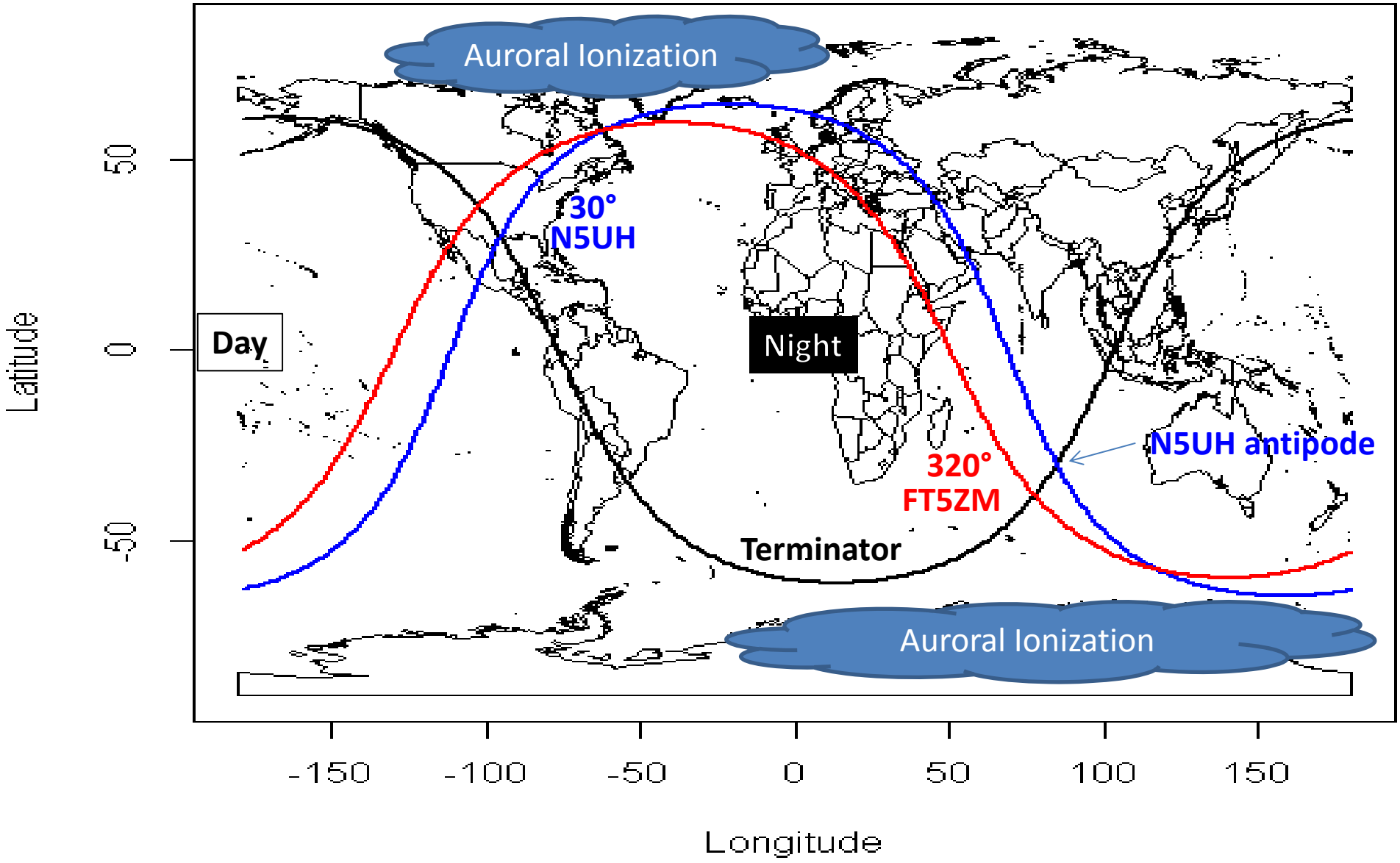
Points in Favor of this Hypothesis

- Explains the “SE at SS, SW at SR” experience of low-band operators for long-distance QSOs
  - Geography: Like VK9CZ, almost all gray line DX is north of the antipode for US operators
- Explains why path to the north is “never” open
- Explains why VK9CZ favored southern stations
- Explains why north-south gray-line paths are “never” experienced
- Can be tested

Possible Tests

- Test 1: Not all DX is north of the US antipode
  - Amsterdam and Heard Islands are south of the southern US antipode
  - For example, the FT5ZM DXpedition to Amsterdam Island (~1 February 2014):
    - N5UH (Univ. of Houston, TX) will have a gray line opening
    - The path should come from the NE at N5UH, and NW at FT5ZM, if hypothesis is true
    - Refraction will come from the northern auroral oval
    - US stations further east, away from the gray line, will see conventional short-path signals coming from the east (NE US) to southeast (SE US), through the dark ionosphere

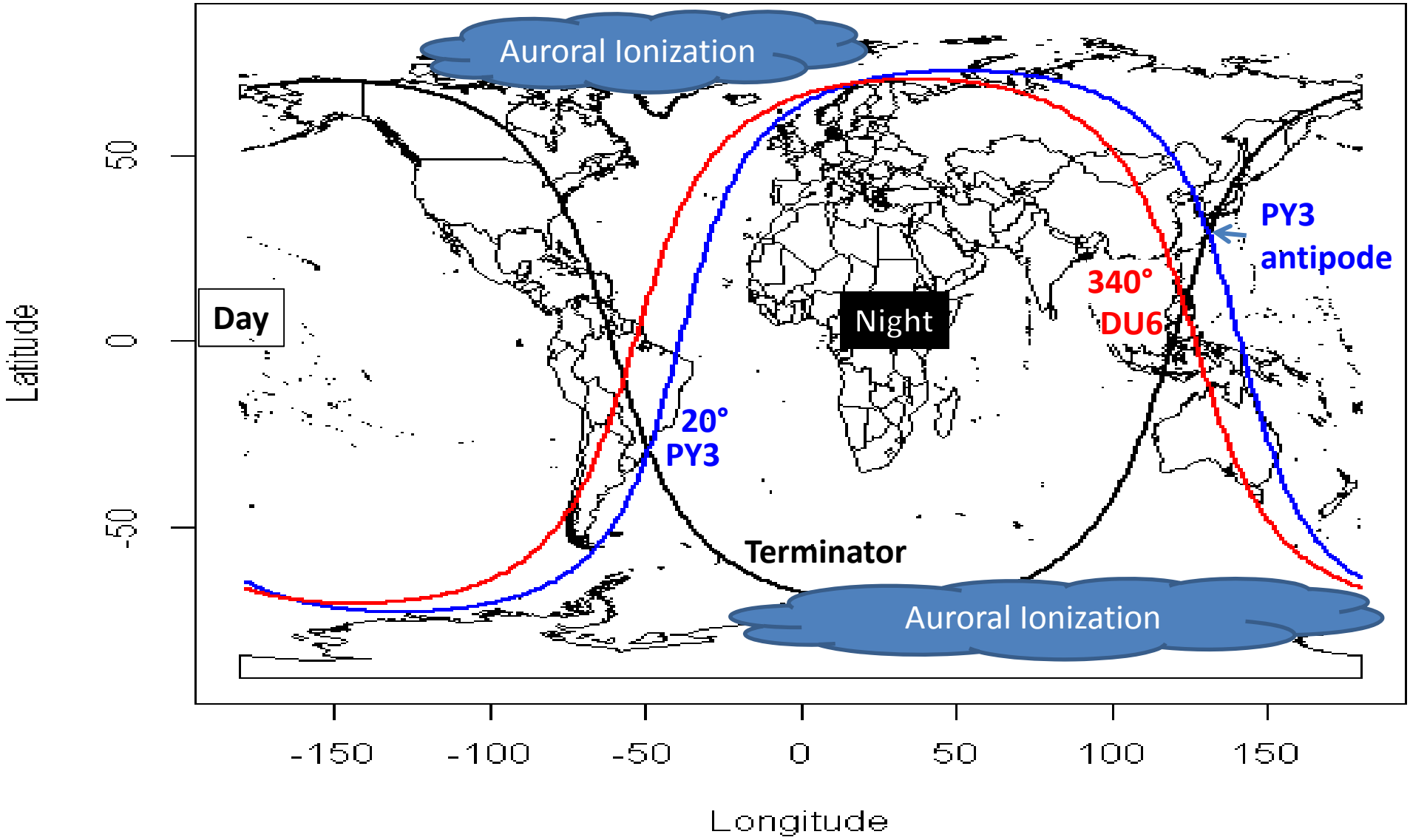
Test #1: Houston, TX – Amsterdam Is.



Possible Test 2

- Test 2: Southern Hemisphere DXers should have a “NE at SS, NW at SR” experience
  - PY3 to DU6, for example
  - Their antipode is north of the DX
  - Refraction will come from the northern auroral oval

Test #2: PY3 – DU6



Thank you!

Ed Callaway, N4II
N4II@ARRL.net