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Radio Propagation on VHF and up with emphasis on Tropospheric modes

What causes band openings?
How can you find them?

Joe Jurecka-N5PYK

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Propagation Mechanisms

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- Line of sight
- Diffraction
- Reflection
- Troposcatter
- E-layer skip
- Tropospheric Ducting

Short range propagation

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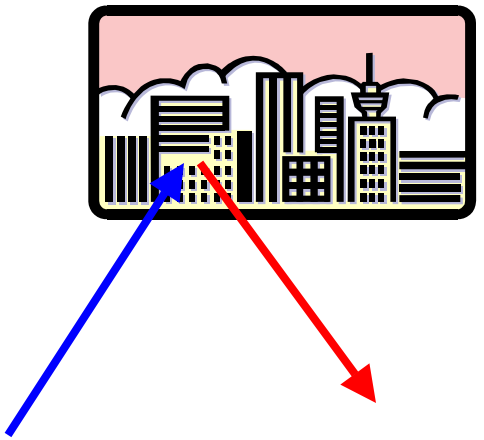
- Line of sight (note, not visual line of sight)
  - Over flat earth, radio travels about 30% further than you can see…on an average day

- Diffraction
  - Radio waves encounter an object and “bend”
- Reflection
  - Especially fun on microwave (water towers…thunderstorms)



Troposcatter

(Very useful and reliable)

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This mode of propagation is what is primarily used in those awful dead-band conditions during contest weekends. An abundance of power is how this mode pushes through where as ducting, in the best conditions, allows good propagation with “low” ERP!

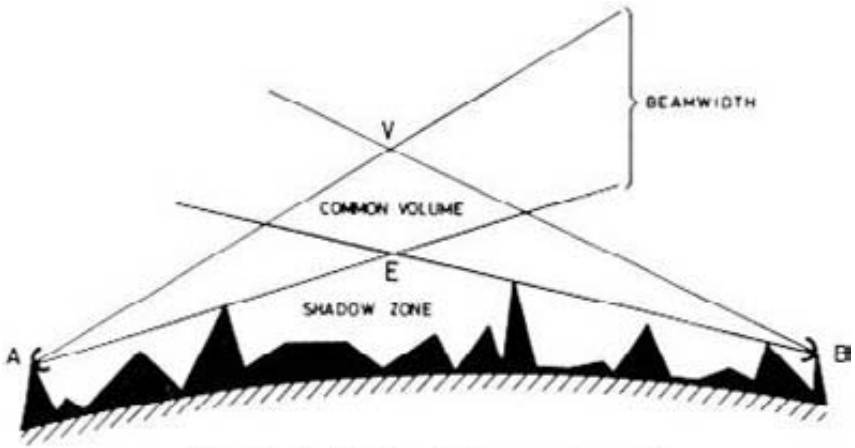
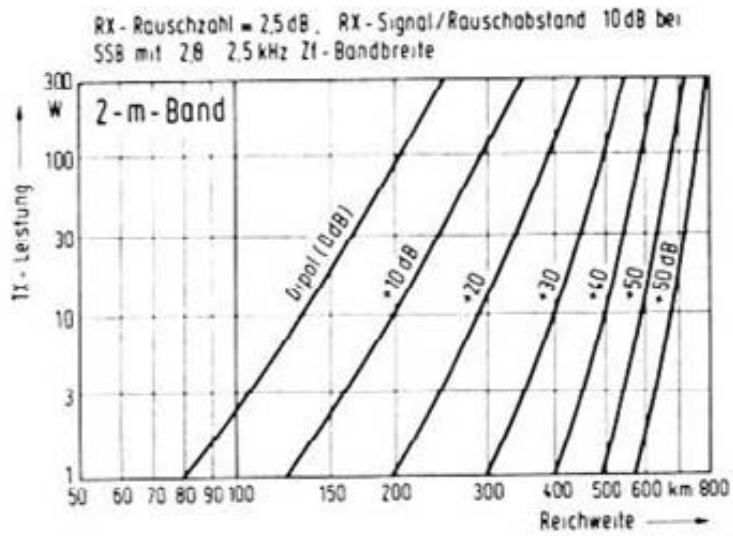


Fig. 4.4 Profile of a typical troposcatter path.

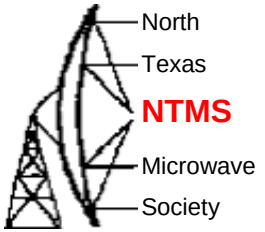
Roda, Troposcatter Links



http://www.qsl.net/oz1rh/troposcatter99/troposcatter99.htm

This mode is why N5PYK in McKinney can work W3XO near Kerrville any time, day or night from EM13qe. Gain antennas plus a little power = DX

Troposcatter and Emergency Comms



- Reliable regional communications with modest antenna setup
- Atmospheric noise (lightning) less influential
- 15-20’ high antenna helps tremendously
- 25-50W all that is required
- Antennas may often be attic mounted!
- Reliable paths include College Station to Austin, Shreveport, San Antonio, Houston, Dallas, Kerrville, etc.
- A little more antenna gain or power enables even greater distance

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Sporadic E-layer Skip

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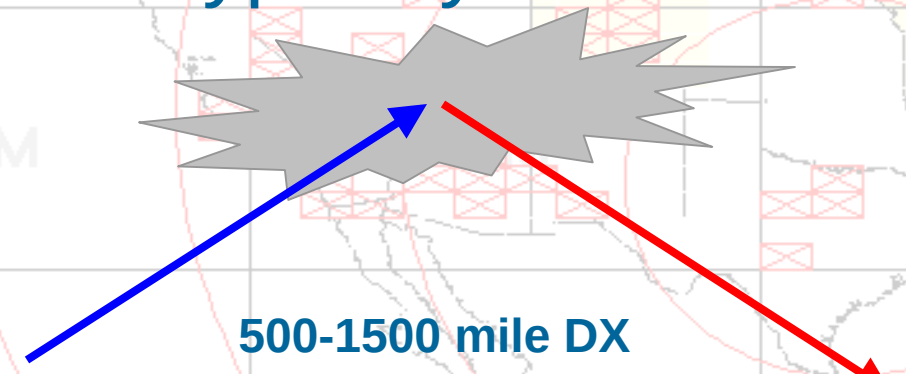
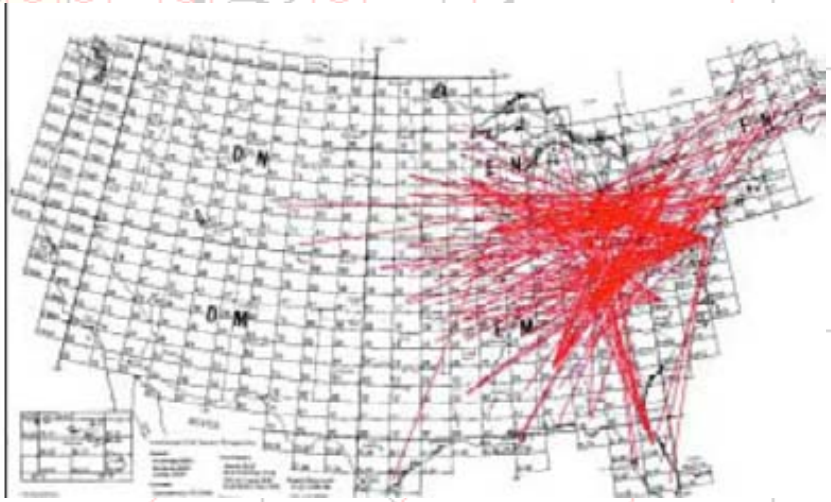
- Similar to HF propagation, signal is reflected of an “E” layer ionization patch
- Most popular May-Jul with secondary peak Dec-Jan, but can happen anytime
- Typically short lived



500-1500 mile DX

Frequent on 6m, somewhat rare on 2m



August 2003 QST. Opening from 2000-2330Z

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My favorite!

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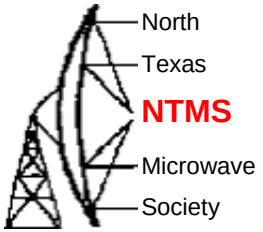
Tropospheric openings

What is a tropo opening?



- Characterized by radio propagation enabling communications at distances significantly beyond line-of-sight.
- Typically affects 50 MHz and up
- Caused by changes in air refractivity with height
- Similar to light in a fiber optic

Local Enhancement (Tropospheric Refraction)

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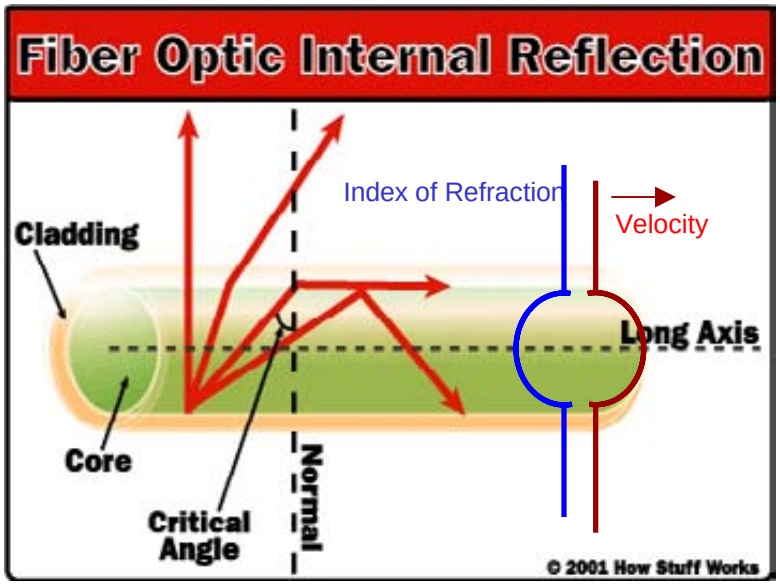
- Present most evenings in eastern Texas
- Accomplished with single hop off inversion layer aloft
- Often a single inversion layer aloft…sometimes very close to the ground



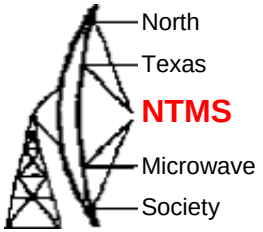
http://electronics.howstuffworks.com/fiber-optic6.htm

10GHz 2001 Contest

Boyd to Weatherford - 10GHz signals peaked at 6 degrees above horizon. Corresponded exactly with location of inversion aloft that evening

Very useful on microwave on spring and summer evenings!

Types of Tropo Openings



- Local Enhancement
  - Enhances signals that would otherwise be weak
  - Nominally a single hop off an inversion layer
- Tropospheric Ducting
  - Regional
    - Openings within an area such as Texas
      - Rio Grande Valley
      - North Texas
  - Wide Area
    - Texas to Florida or Yucatan
    - Texas to Illinois or Virginia…or occasionally, Maine!

N5PYK and openings on 2m

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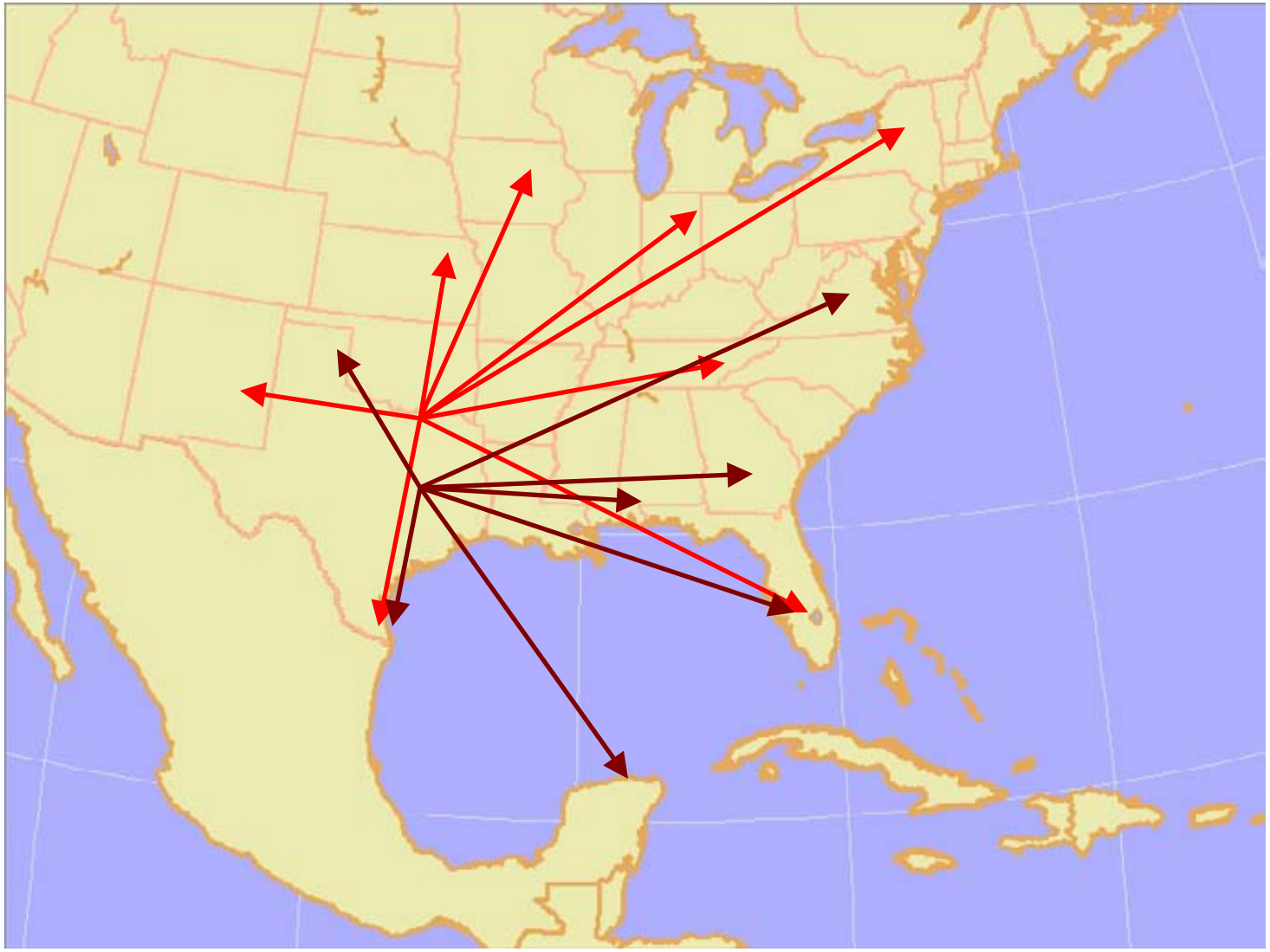

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K=Factor

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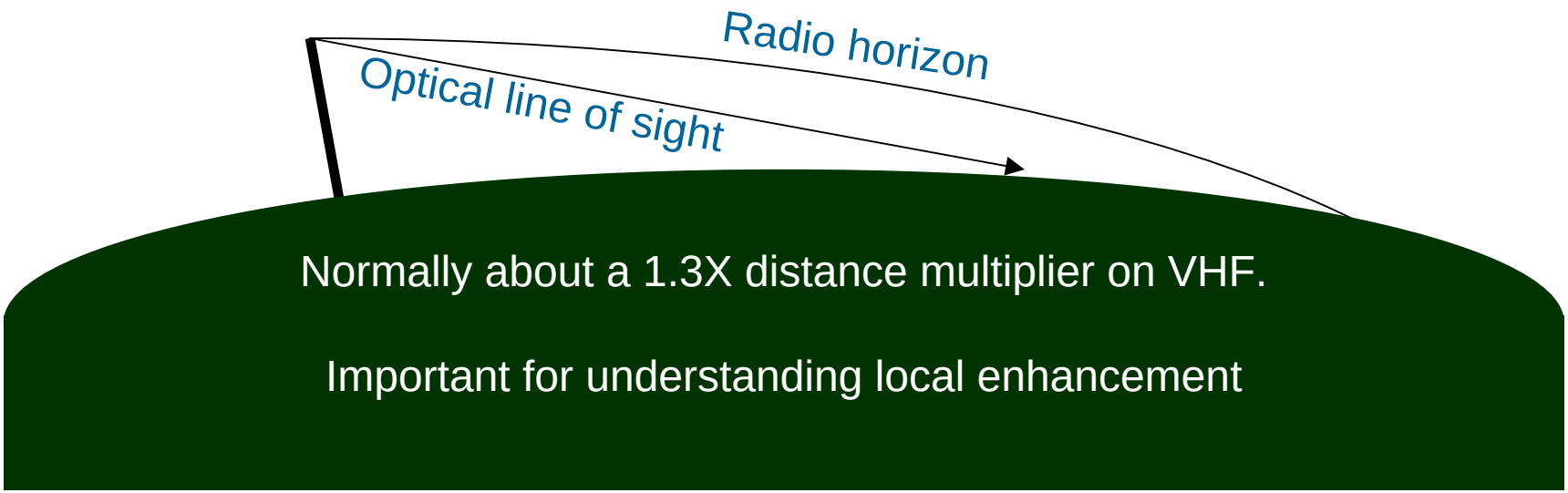
Ratio of effective radius of radio wave ray vs. radius of earth (6370km)

K=r/r0



Normally about a 1.3X distance multiplier on VHF.

Important for understanding local enhancement

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Schematic of Profile (Refraction)

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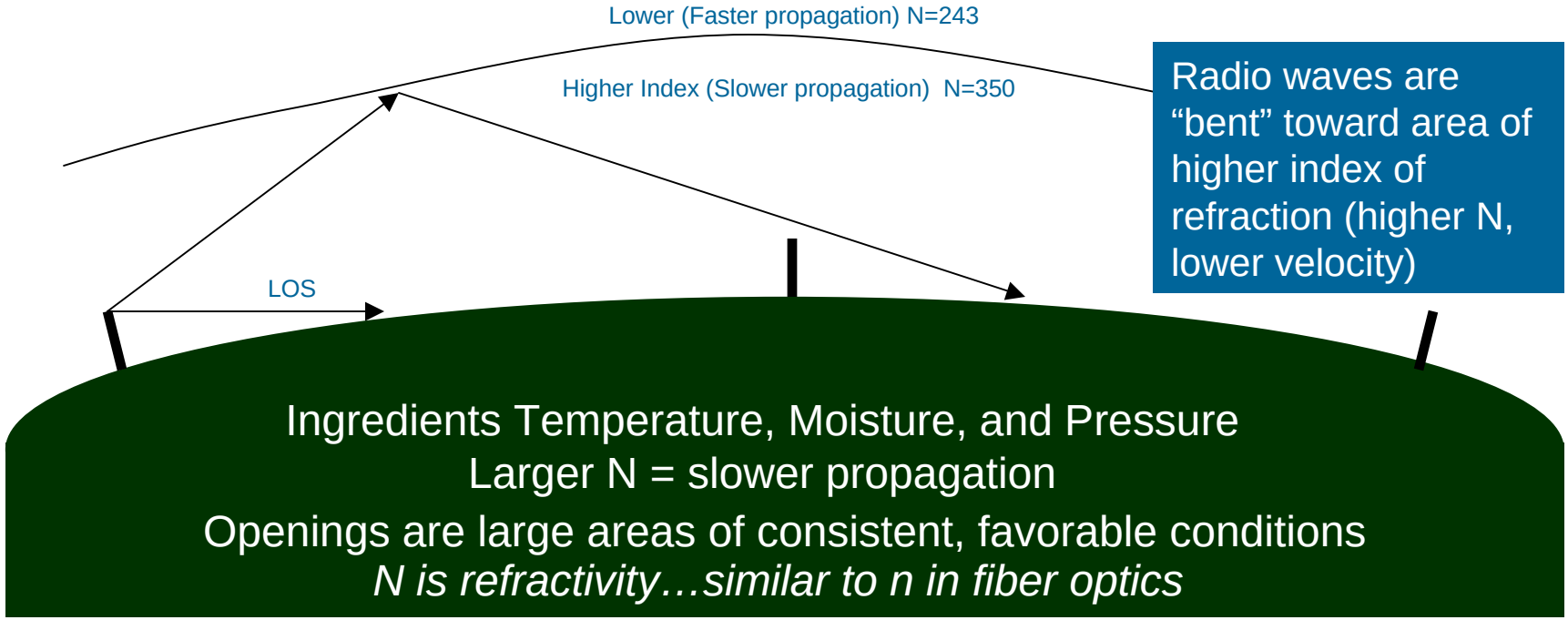
N=77.6/T[P+(4810*Es*(RH))/T) ‡FREEMAN
N=Refractivity
Es=Saturation Water vapor pressure (mB)
RH=Relative Humidity
T=Temperature (Kelvin)
P=Atmospheric pressure (mB)

K≈[1+(ΔN/Δh)/157]^-1
K=K-factor
N=Refractivity
h=height (km)



Radio waves are "bent" toward area of higher index of refraction (higher N, lower velocity)

Ingredients Temperature, Moisture, and Pressure
Larger N = slower propagation
Openings are large areas of consistent, favorable conditions
N is refractivity…similar to n in fiber optics

N≈(n-1)*10^6 where n=ratio of speed of propagation to speed of light

Es=(1.0003+P*0.00000418)*6.1115*EXP(22.425*DP/(272.55+DP)) If DP >0 C
Es=(1.0007+P*0.00000346)*6.1121*EXP(17.502*DP/(240.9+DP)) If DP <0 C

DP=Dewpoint (Deg C) *Source Honeywell Website

Sounding Stations

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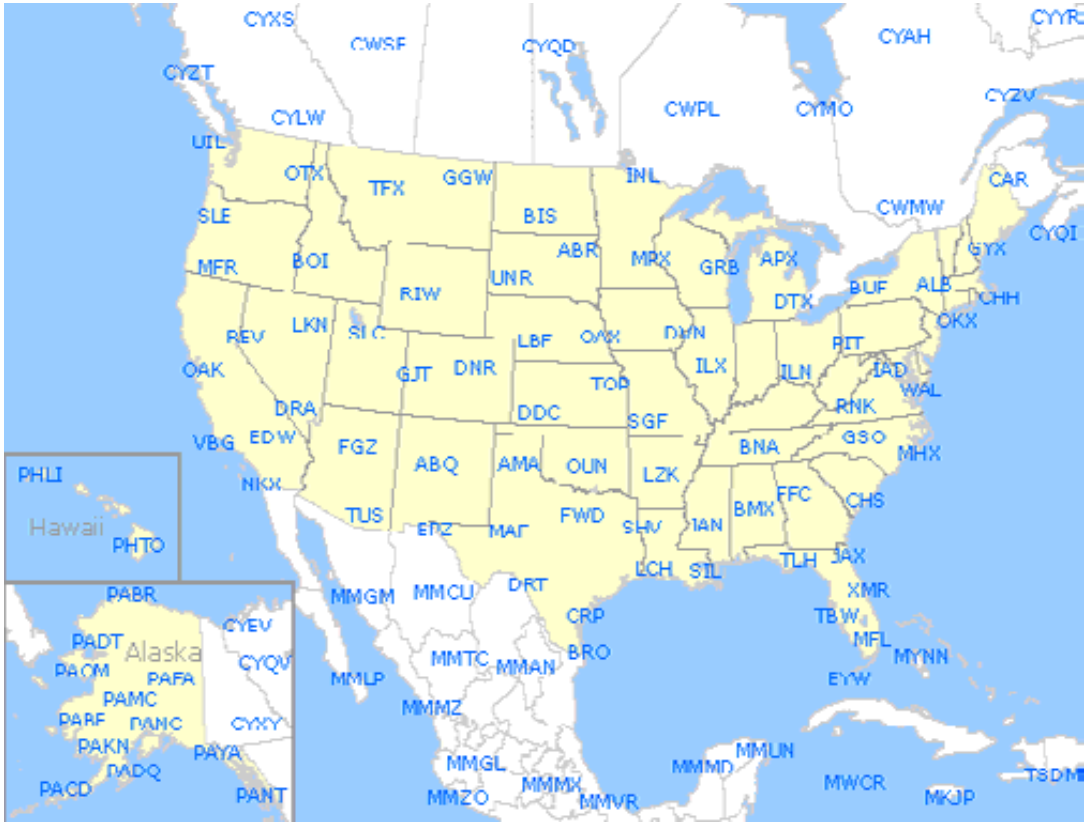

Launch balloons twice a day: 00Z and 12Z

During spring, an 18Z sounding is not uncommon in thunderstorm risk areas

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Upper Air sounding (refraction)

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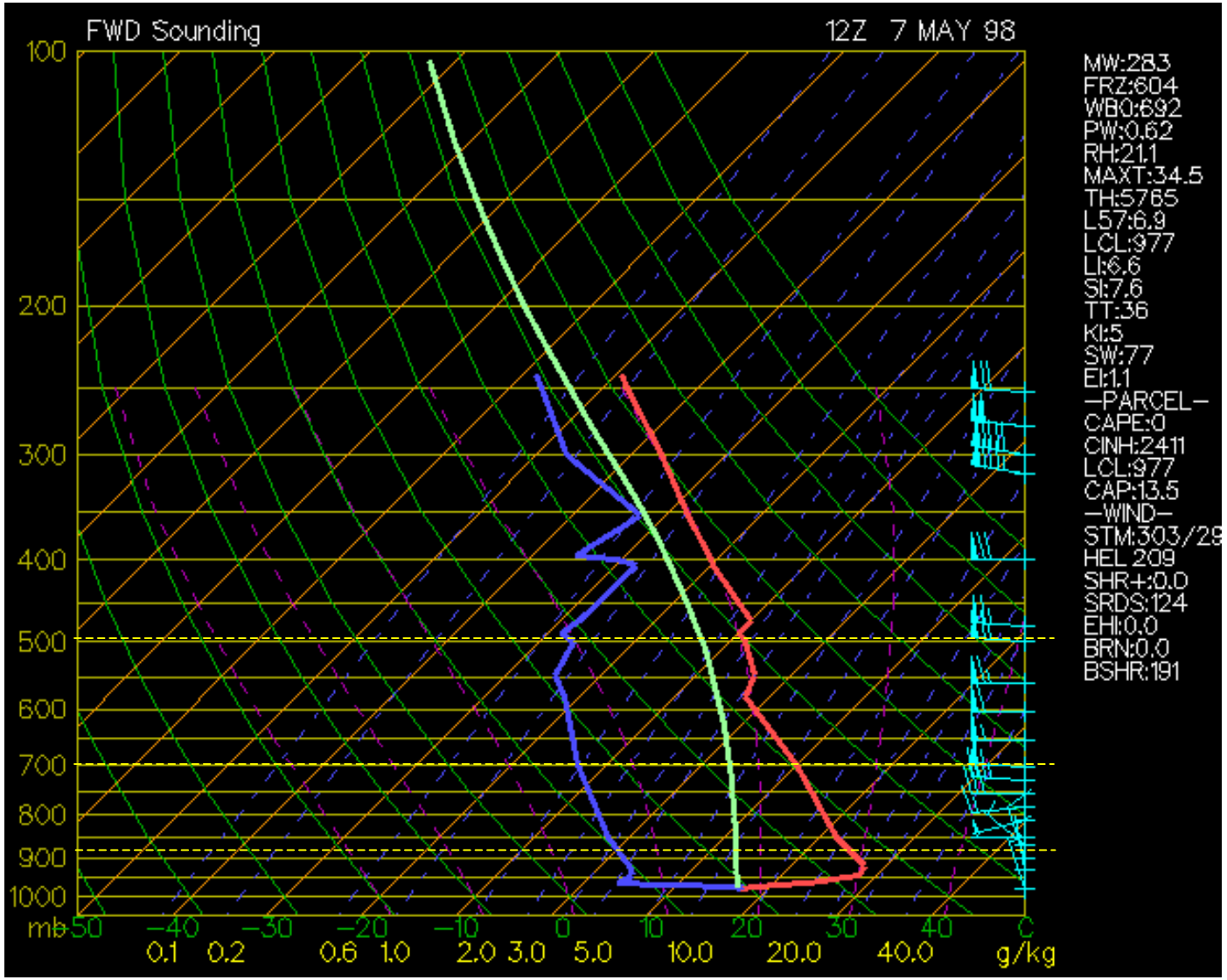
Taken from Opening in Early May 98

@925mB N=243
@975mB N=351

Example of a surface duct right on the deck



18,000’ →

10,000’ →

3,000’ →

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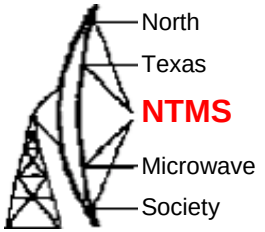
Tropo Ducting



- Can enable contacts over distances of over a thousand miles.
- RF signal is propagated in duct
- Much variance exists on where signal exits the duct
- Signal can pass right over some users such that it is possible to work stations in Florida but not Mississippi

Schematic of Profile (Duct)

N=77.6/T[P+(4810*Es*(RH))/T) ‡FREEMAN
N=Refractivity
Es=Saturation Water vapor pressure (mB)
RH=Relative Humidity
T=Temperature (Kelvin)
P=Atmospheric pressure (mB)

K≈[1+(ΔN/Δh)/157]^-1
K=K-factor
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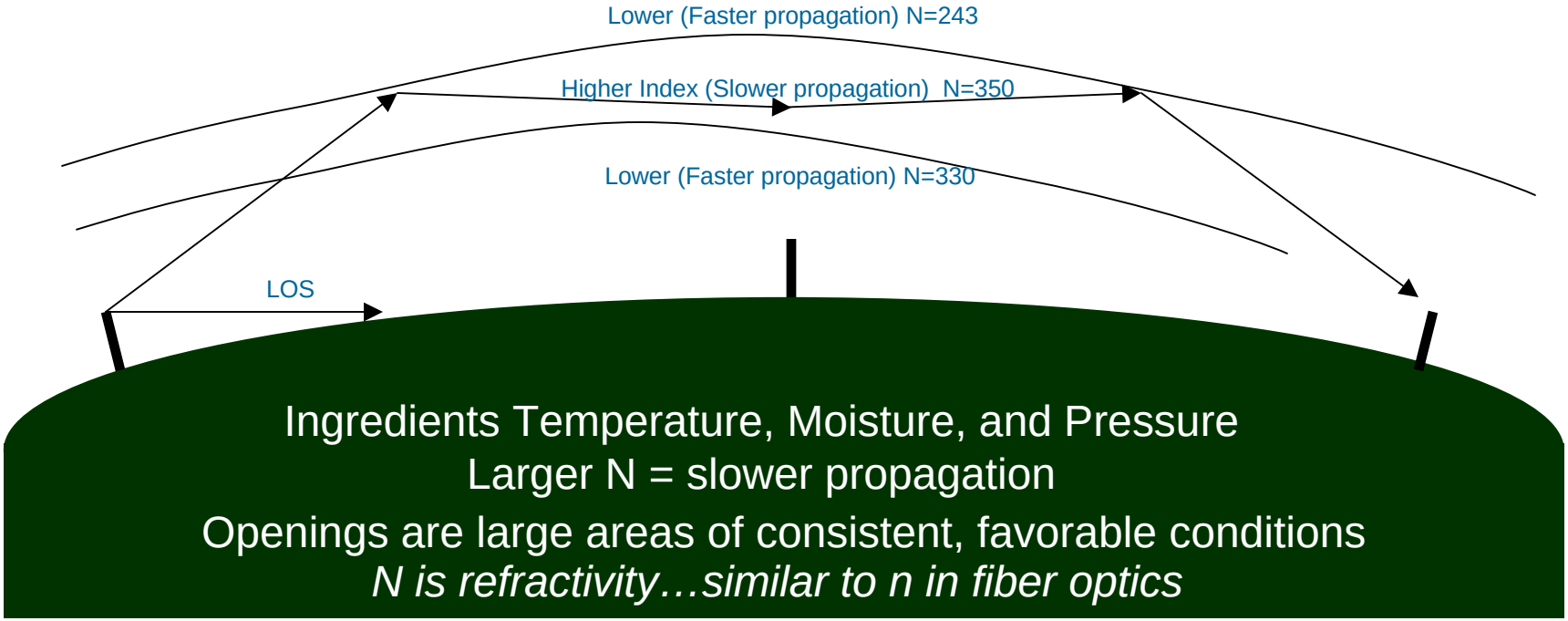

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DP=Dewpoint (Deg C) *Source Honeywell Website

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Upper Air Sounding (Ducting)

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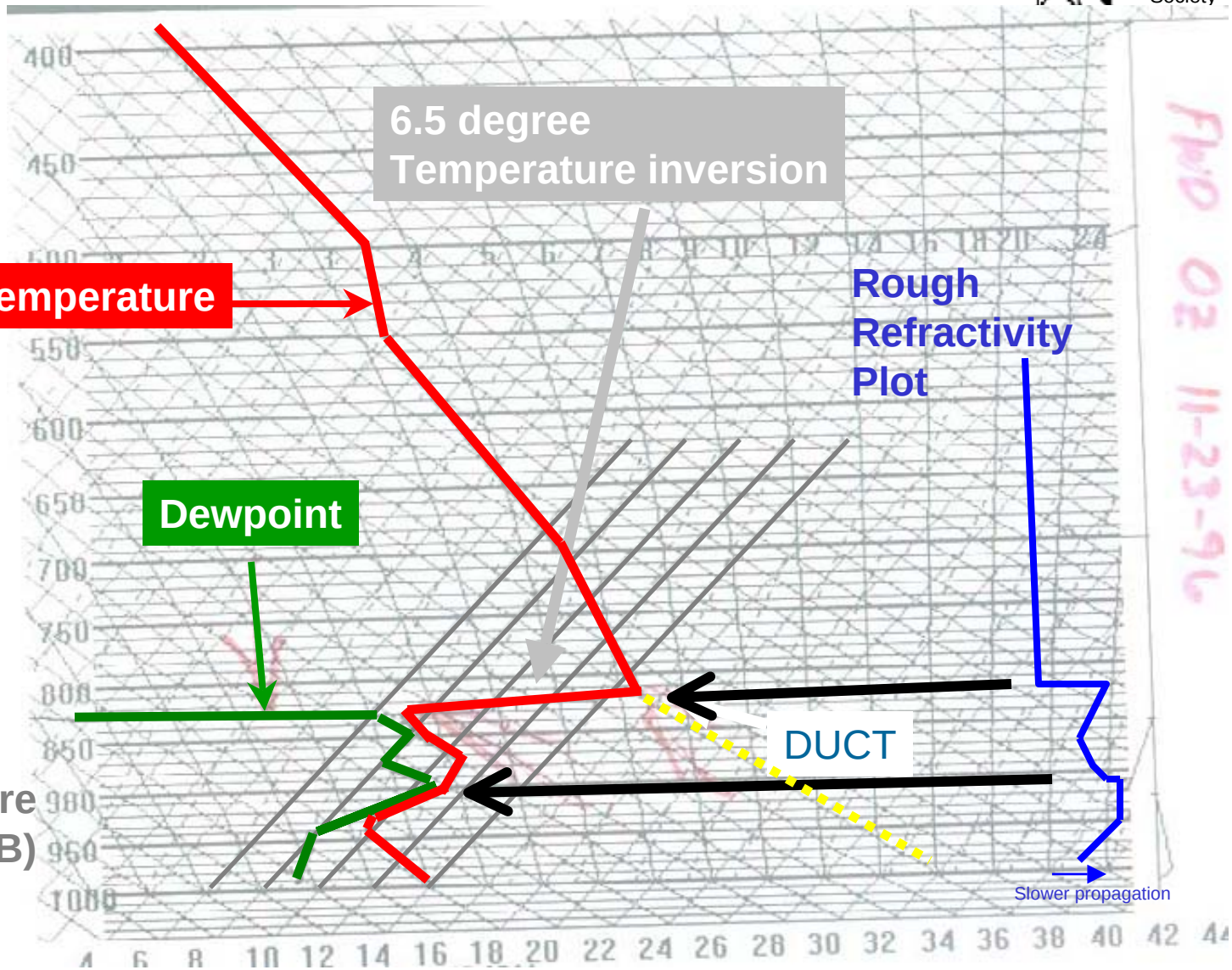
This opening Provided an opening Strong enough to Hear NOAA weather Radio out of Hobbs New Mexico using A 5/8λ whip antenna… Traveling US-75 in Allen



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Duct thickness vs frequency

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Inversion Thickness		LUF	
Feet	*Metres*	*Band*	*M/GHz*
50	15	µW	11.67 GHz
100	30	µW	3.35 GHz
150	46	UHF	1615 MHz
200	61	UHF	962 MHz
300	91	UHF	464 MHz
400	122	VHF	276 MHz
500	152	VHF	185 MHz
600	183	VHF	133 MHz
700	213	VHF	101 MHz
800	244	VHF	79 MHz
900	274	VHF	64 MHz
1000	305	VHF	53 MHz
1100	335	VHF	45 MHz
1200	366	VHF	38 MHz
1300	396	VHF	33 MHz
1400	427	SW	29 MHz
1500	457	SW	26 MHz

From http://www.iprimus.ca/~hepburnw/dx/luf.htm

Unfavorable sounding

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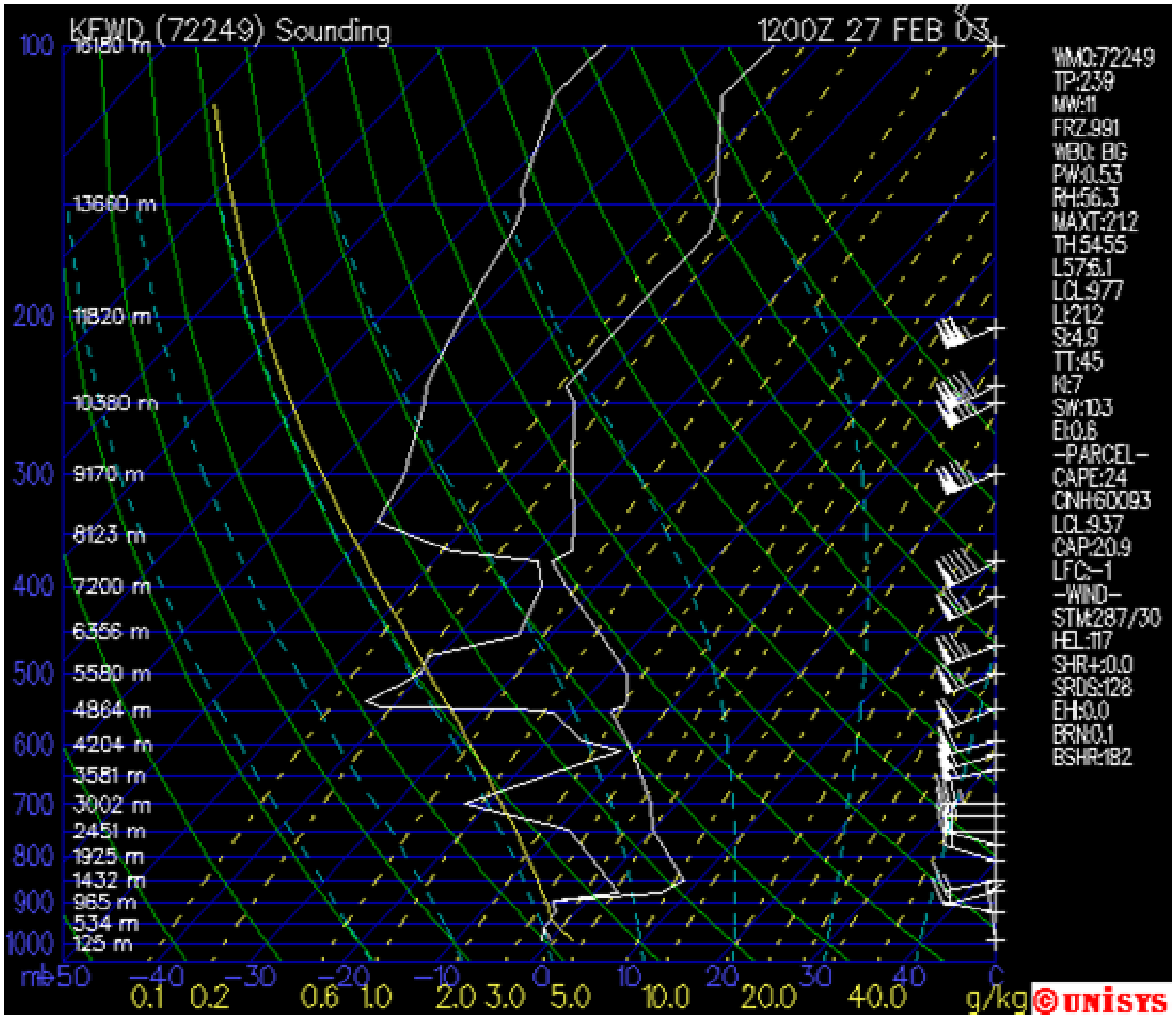

Here, we have an inversion, but…No opening.

Note lack of dewpoint drop at base of inversion layer.

May provide local enhancements to upper bands, but may not be enough for 144MHz.

This profile is typical for cold air intruding at sfc with warm, overrunning conditions aloft. Good for rain…not so much for propagation.
Note: North winds down low

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Side by side comparison

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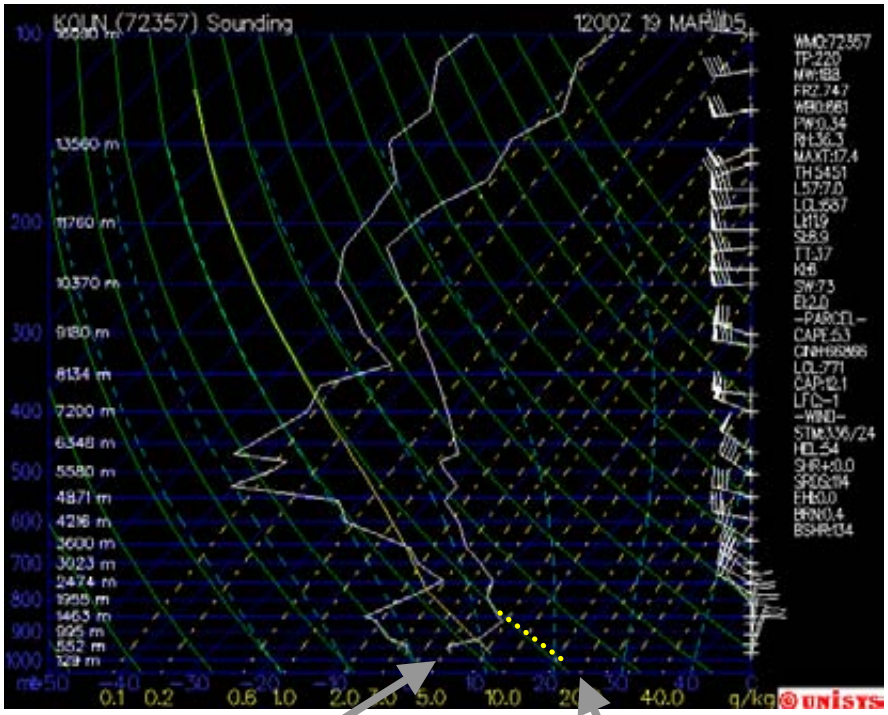
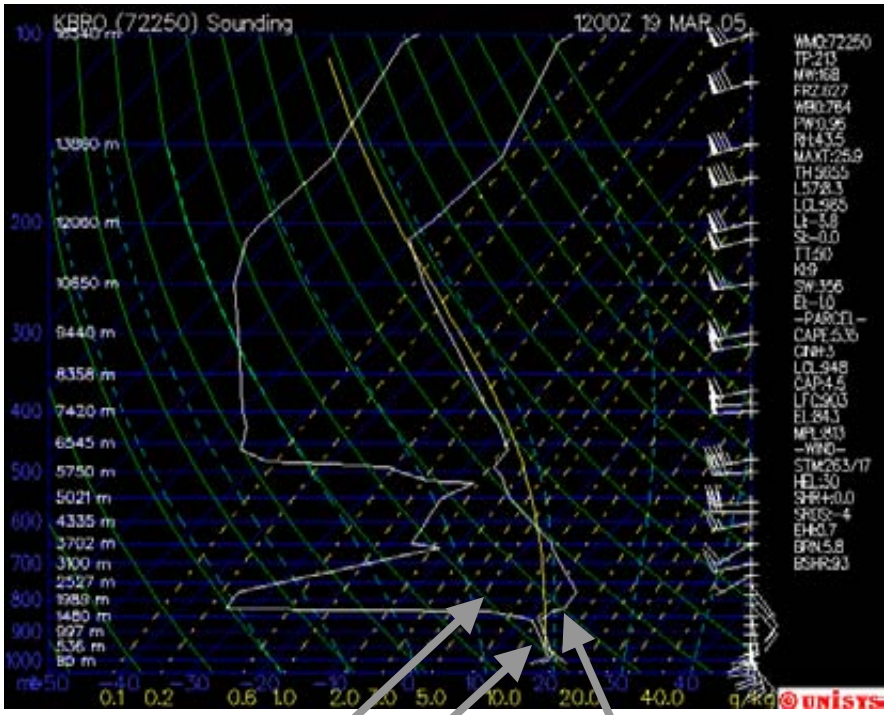
No sharp, vertical gradient



Definitive Vertical Boundary



Moisture lacking at sfc

Evening sounding estimate

Inversion

Near saturation (humid)

Super dry aloft

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The Feb 2, 2003 Opening

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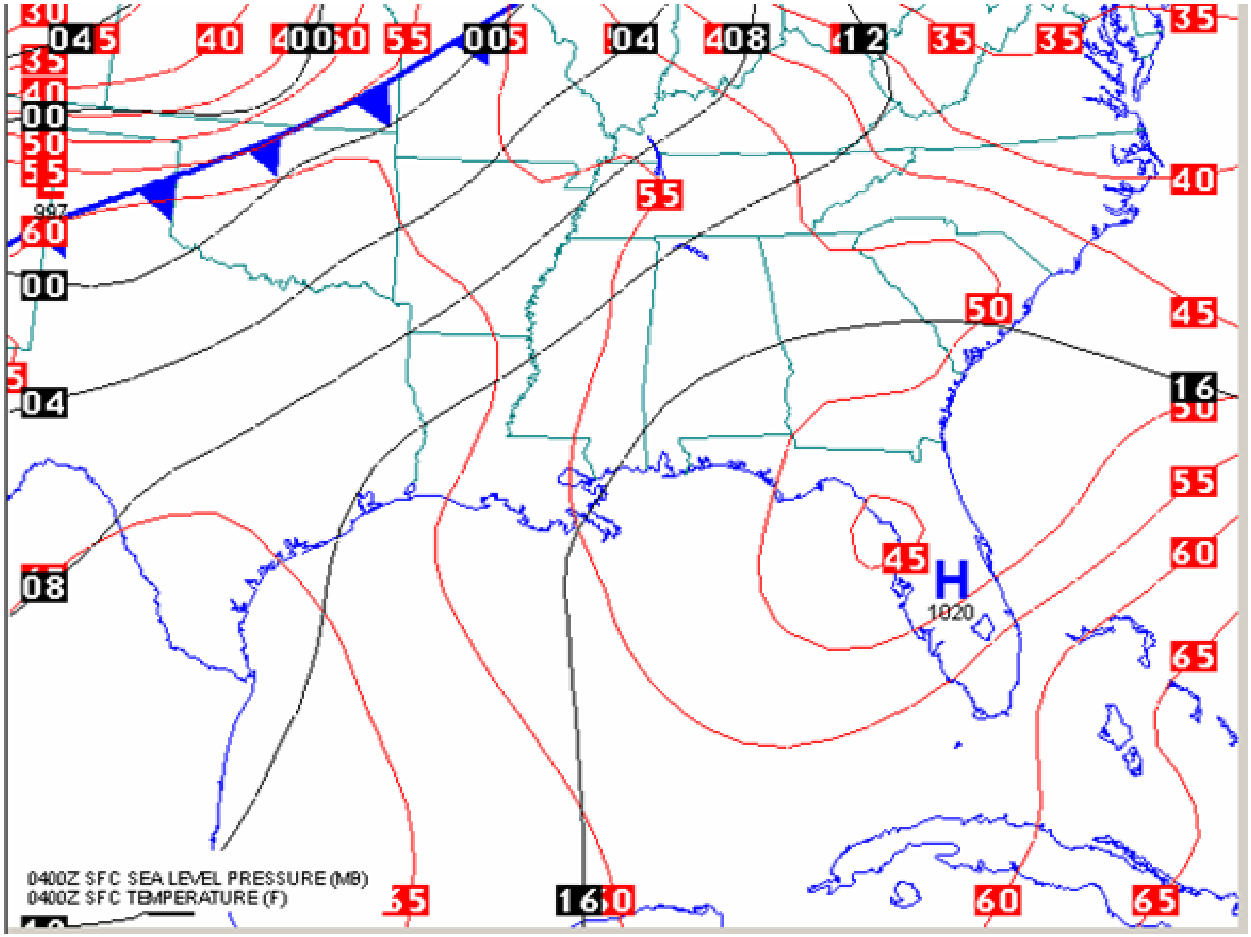
Produced opening From Texas to Florida On 144 - 3456 MHz

Note absence of significant weather features along path.

No pressure discontinuities (fronts) Providing indication of a stable weather pattern. Front approaching from NW is typical for evening for opening.



Animation of band opening

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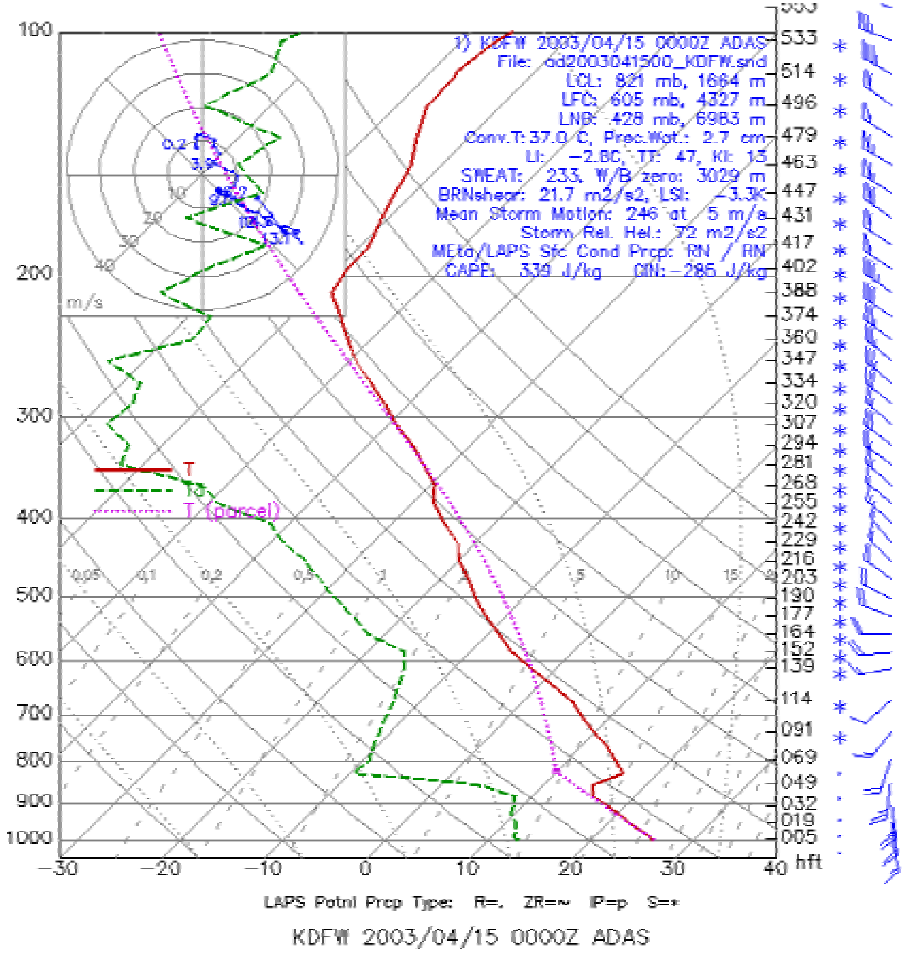
Modified sounding
From model data



Inversion area deepens with time. Propagates lower frequencies

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September 6, 2003 Mega Opening

This opening provided 2m contacts from Texas to Maine!

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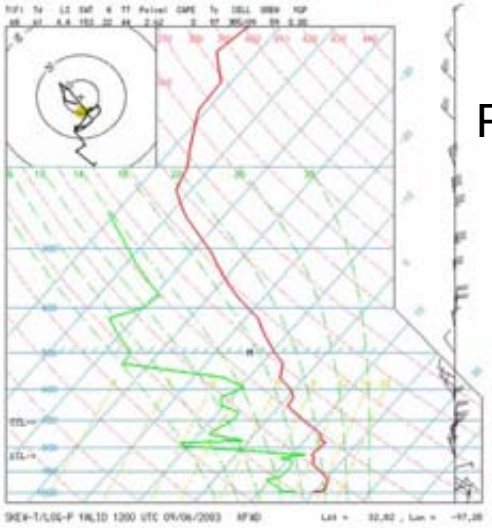
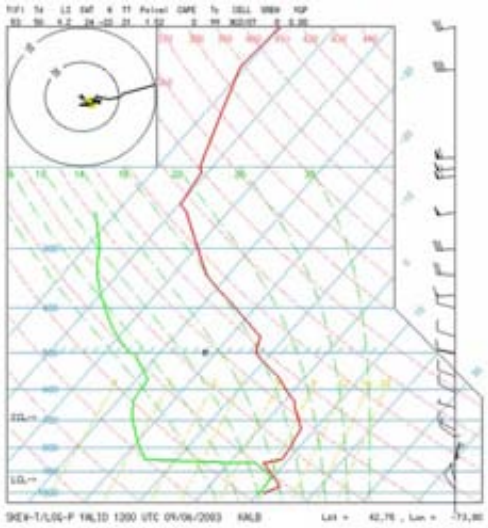


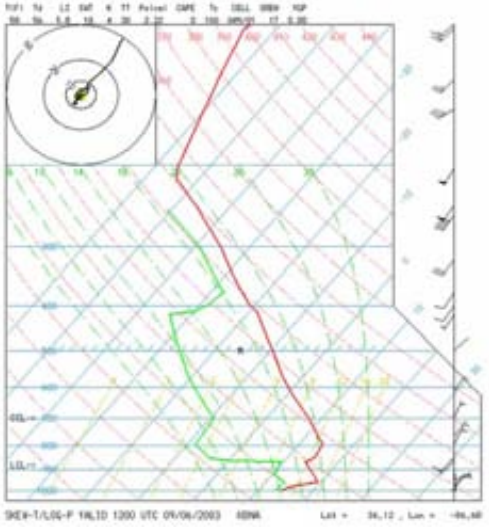
Fort Worth

Interestingly, the higher bands were very poor on this opening

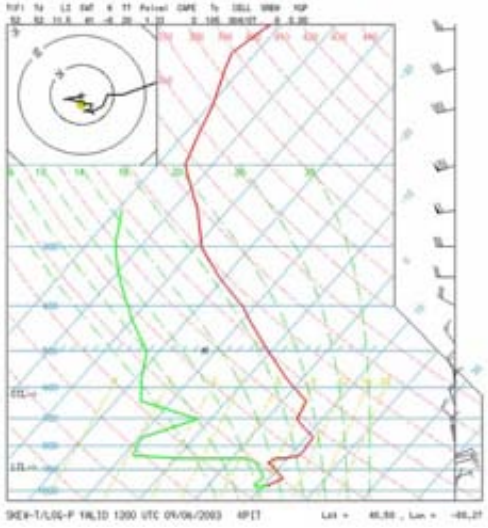


Albany

Nashville



Pittsburgh



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Theory of upper frequency limit for propagation

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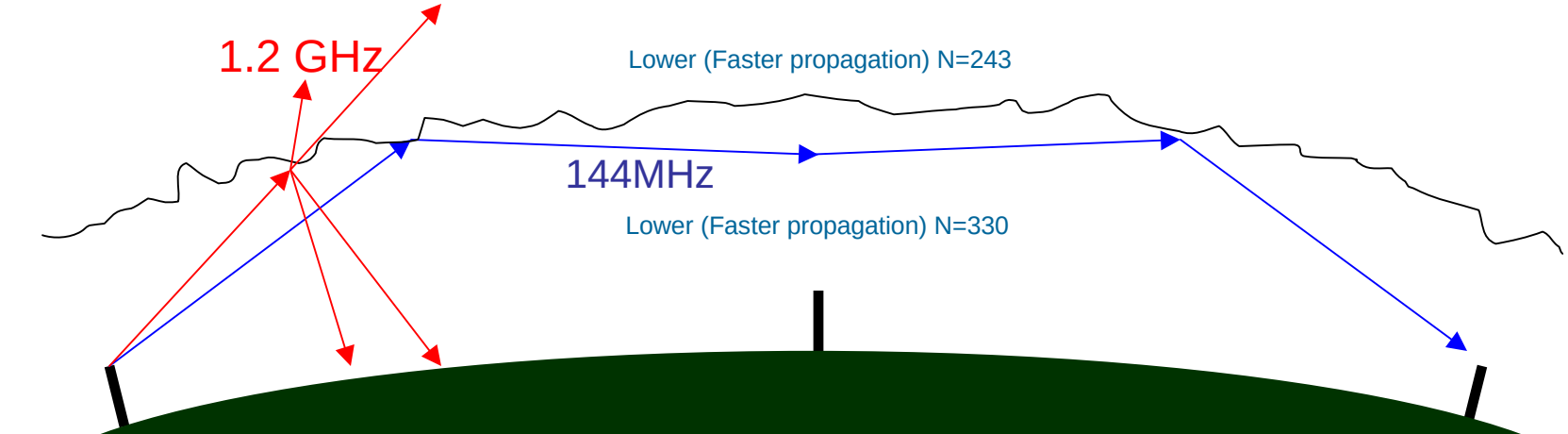
Rough boundary layer prevents a mirror-like image to enable refraction (or reflection)

Concept is similar to looking at a reflection in a mirror, vs aluminum foil, vs paper



This is why the best band openings have a large, homogeneous, stable air mass

Consider that the best smoothness likely occurs when the upper level flow is substantially decoupled from the surface environment. This is generally associated with calm winds at the surface and clear skies. Radiation cooling of the surface helps reinforce the inversion.

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Animation of many stations for the opening of September 6, 2003

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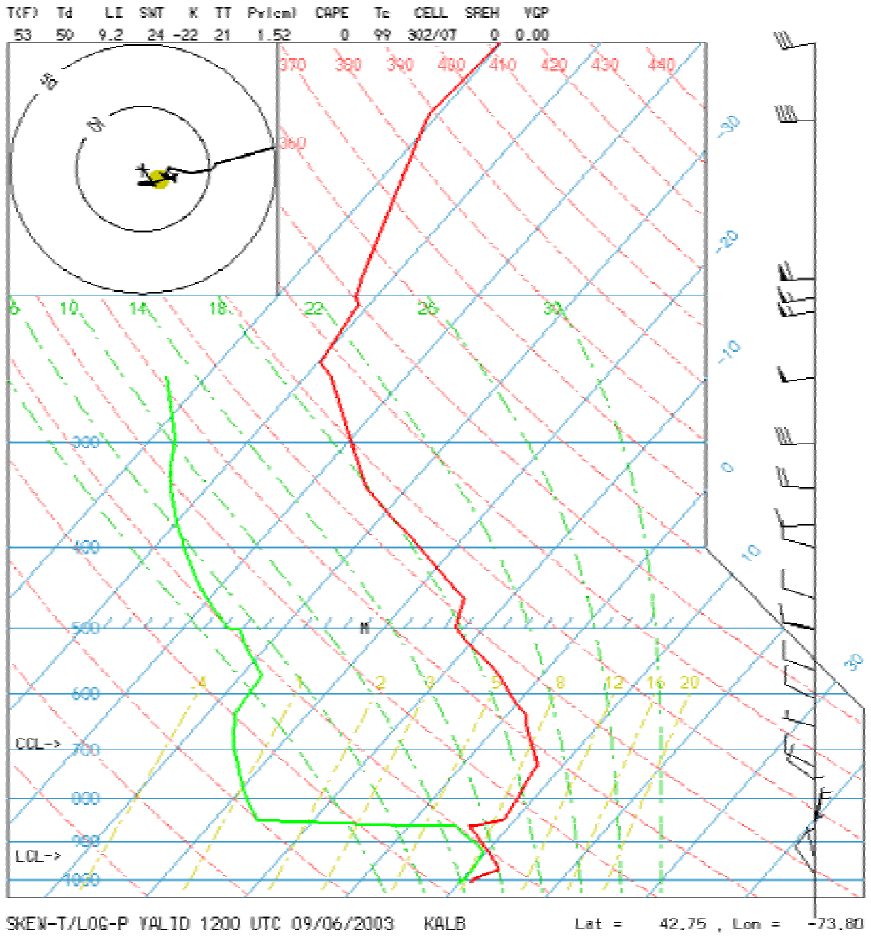
This is a collection of Soundings from many upper air stations from Texas to the northeast



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Mount Scott to Dallas on 10GHz

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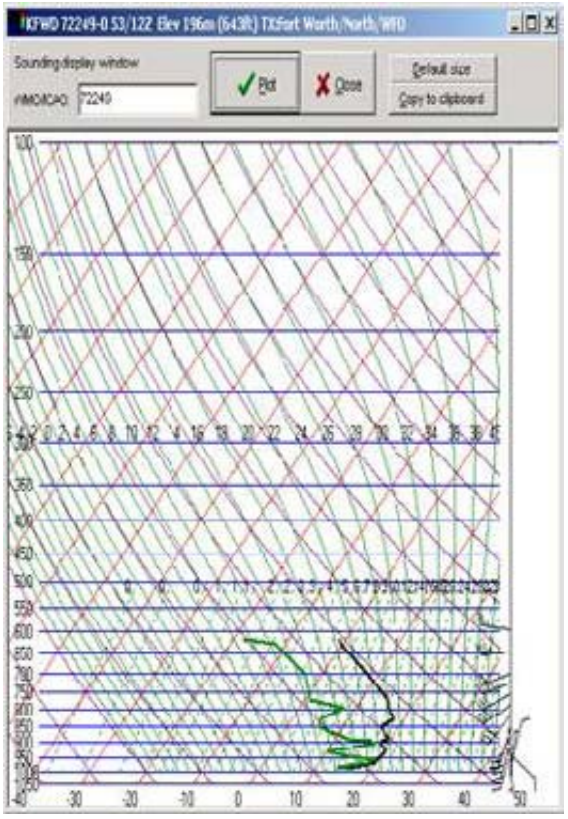

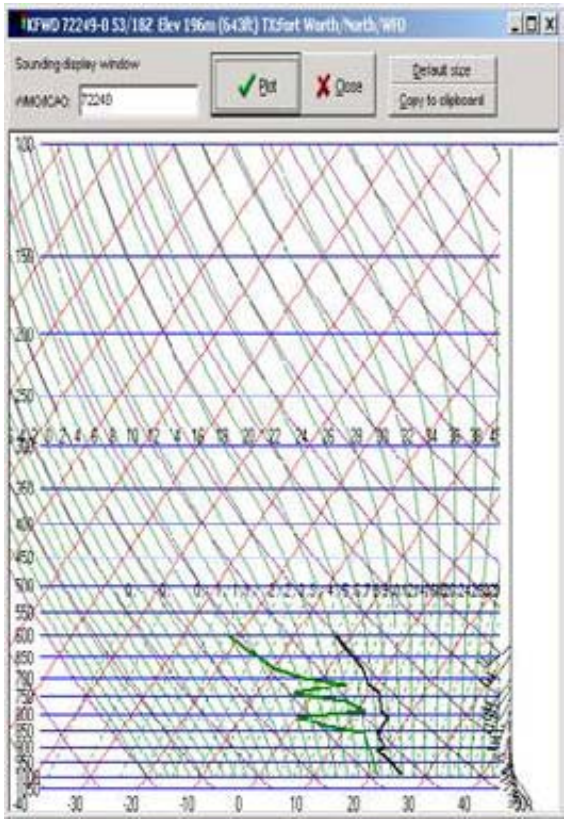

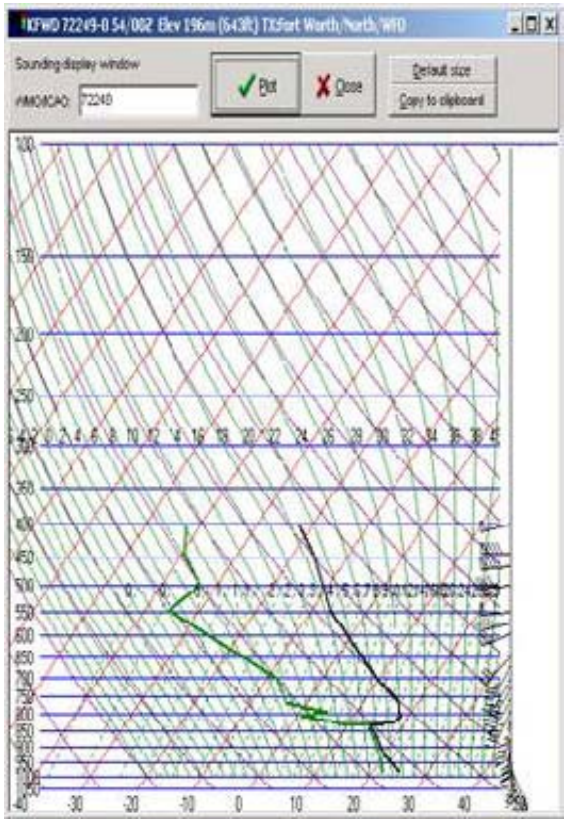

Propagation in the morning was very difficult, but signals came up throughout the day. Notice how the profile becomes more “classic” from 12Z to 18Z to 0Z

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Surface Pattern

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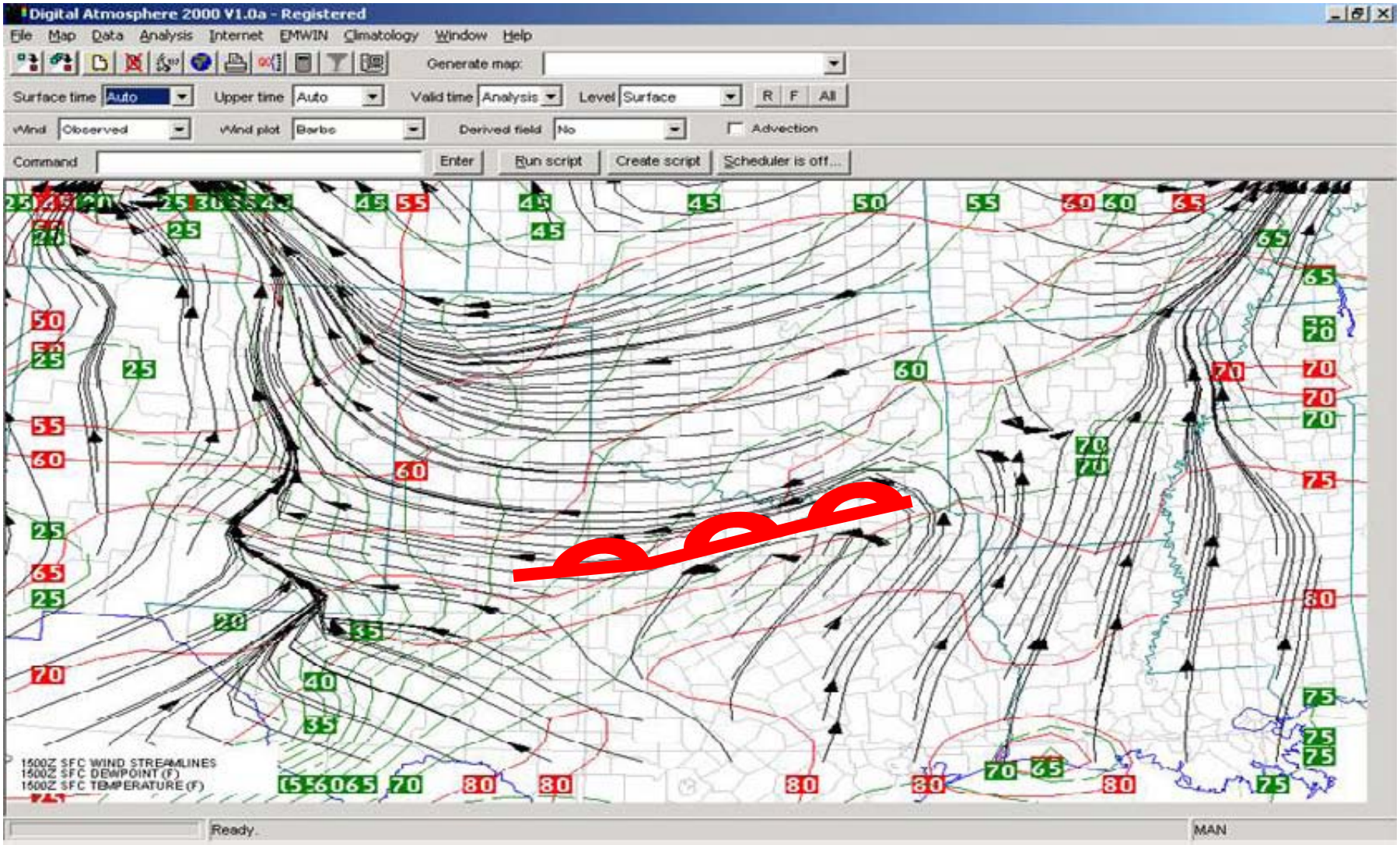

Monitoring for Openings

- TV - Local channels will get interference patterns or a separate set of sync bars

- Listen for UHF TV video carriers (Ch16-KLRT Little Rock, AR 483.25)

Using TV is becoming more difficult with so many digital stations starting service on what used to be clear channels

Monitoring for Openings

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- VHF Aircraft Navigation Aids
  (VOR-very high frequency omnidirectional range)
- 108-117.95 MHz.
- www.airnav.com
- 50-200W ERP
  Horizontal Pol.
- Listen for 30Hz sidebands if listening on USB/LSB (Sounds like a warbling carrier). Tune down / up 1KHz to hear carrier
- Significant co-channel spacing

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Weather Radar Signatures

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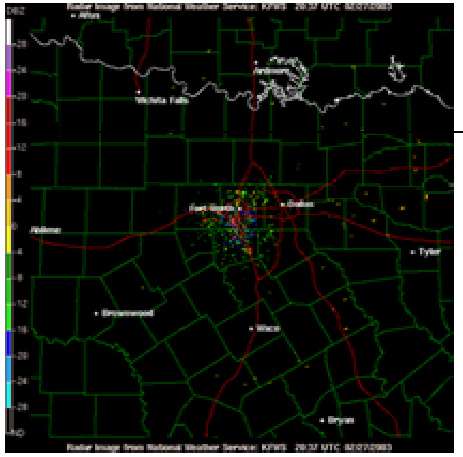
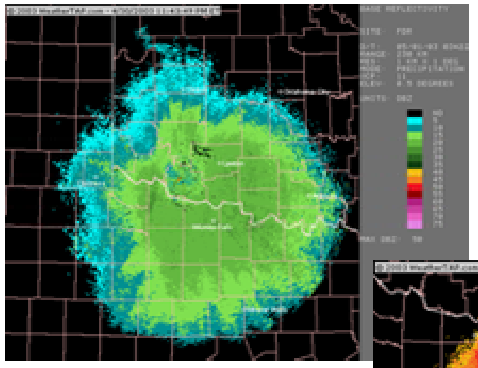
- http://www.srh.noaa.gov/radar/mosaic/DS.p19r0/ar.us.conus.shtml

- Look for ground clutter extending out 50-100 miles from a site (>+10dBz).
- Look at individual sites and note mode of operation
  - Clear Air- most sensitive…will often detect clouds (Scale up to +28dBz)
  - Precipitation Mode: More traditional scaling that users are used to seeing Scale (up to 70dBz)
  - National mosaic is de-cluttered precipitation mode view.
- dBz scale
  - <0 normally clouds, mist or light snow
  - 0-40 rain
  - 40-60 Thunderstorm
  - >60 Potential severe thunderstorm
  - >70 Nasty hail core

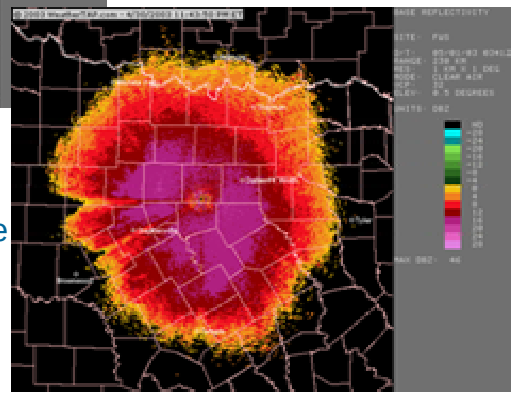


dBz scale

If it looks like this in clear air mode, you might as well work on a project.



Enhancement in precip mode



Enhancement in Clear air mode

Nexrad (WSR-88D) operates around 3 GHz

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Radar View

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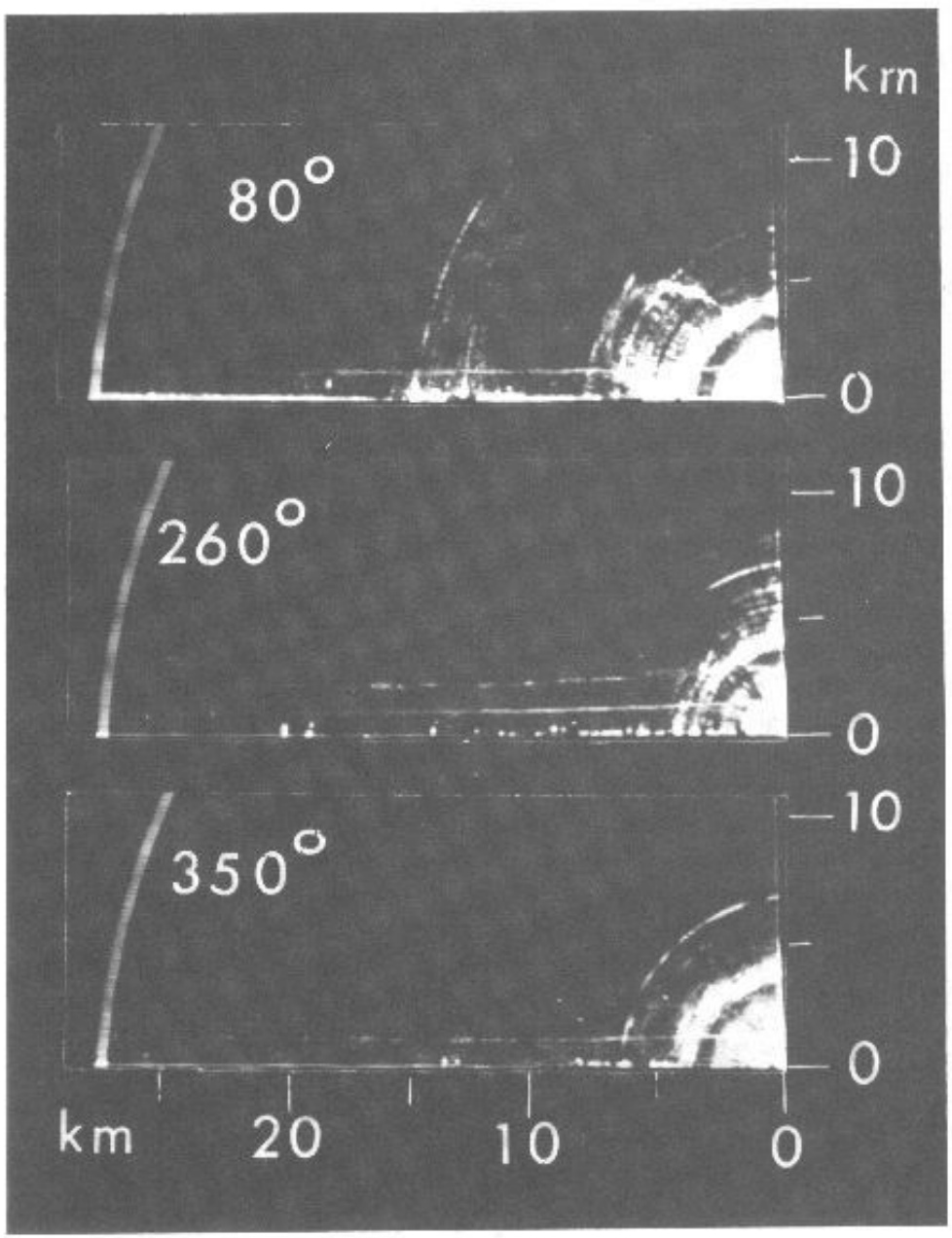


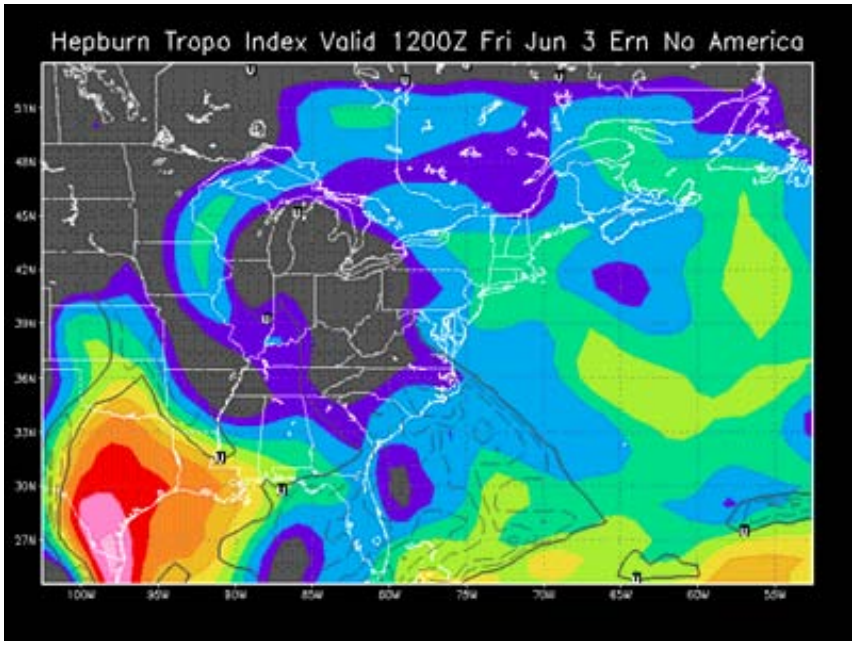
Fig. 12.6. Photographs at three azimuths of the range-height indicators at a wavelength of 10.7 cm at Wallops Island, Va., 0530 EST, 4 September 1965. The sky was perfectly clear at the time of the observation. The layer near 1 km is coincident with a very pronounced inversion. The circumferential arcs at short ranges are ground echoes seen by the side lobes. From Hardy and Glover (1966).

Inversion layer showing up on Range-Height depiction on radar

*Battan

Hepburn Tropo Index

- http://www.iprimus.ca/~hepburnw/tropo_car.html
- Good general indicator of forecasted conditions.
- Not definitive indicator of when and where an opening will occur—This is not an exact science.
- Usually, when there is a lot of yellow, orange, and red, it is wise to at least check conditions more carefully.



Other sources

- NOAA Weather radio 162.4-162.55 http://www.srh.noaa.gov/ftproot/msd/nwr/srnwr.html
- http://dxworld.com/144prop.html
- Monitor 144.200
- Propagation Beacons
  - http://www.ntms.org/Beacons.htm
  - http://www.k5rmg.org/beacons.html
- http://www.rap.ucar.edu/weather/upper/
- http://weather.unisys.com/upper_air/skew/index.html
- Texas DPS 155.460, 159.210, 155.445

References

- Freeman, R.L. *Radio System Design for Telecommunications (1-100 GHz)* John Wiley,1987. ,
- Battan, Louis J., *Radar Observation of the Atmosphere*, University of Chicago Press, Chicago, IL., 1973.

Other good reading

- Preben-Hansen (OZ1RH), “Everyday VHF, UHF, and SHF propagation – 700 km DX anytime using troposcatter” http://www.qsl.net/oz1rh/troposcatter99/troposcatter99.htm

- Microwave activity www.ntms.org

- This presentation found at:

http://n5pyk.no-ip.info/