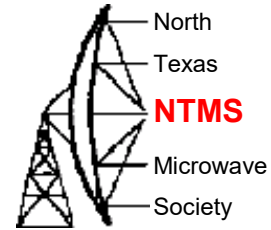


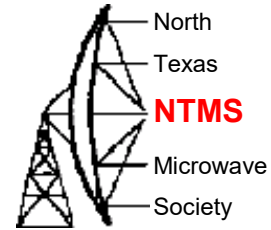
Analysis & Forecasting mm-Wave propagation Part 2

KM5PO & W5ISP – April 11, 2026 NTMS

Significant discoveries



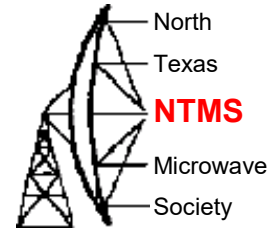
- What started off with simple questions has evolved into a set of useful and enlightening findings and tools.
- In this presentation we will recap the beginnings and the changes that have led to a more complex project.
- The single big boost to the project is the collaboration of multiple team members
 - W5ISP, Graham McIntire
 - An engineer with in-depth experience of back-end server functionality. Owns a WISP with multiple microwave back haul systems.
- N5PYK, Joe Jureka
 - Senior Meteorologist, National Weather Service, Lubbock, Texas
- K6ML, Mike Lavelle
 - Retired engineer (Sun Microsystems)
 - 122 GHz dx world record holder



Recap of Part 1

- What mechanism in the atmosphere enables long over-the-horizon contacts at 47 Ghz. These are not LOS paths.
- First, ask for an analysis of one confirmed two-way contact (successful link closure).
- Evaluate the answer (duct based on various factors / Skew-T)
- Additional confirmed contacts (100+ km) added at 24 and 47 GHz
- Build a predictive tool using everything we know, up til now, and use real time inputs.
- The result: a surface based (ASOS) model with 7 scoring elements with calibration from actual contacts (4).

Automated Surface Observation Station

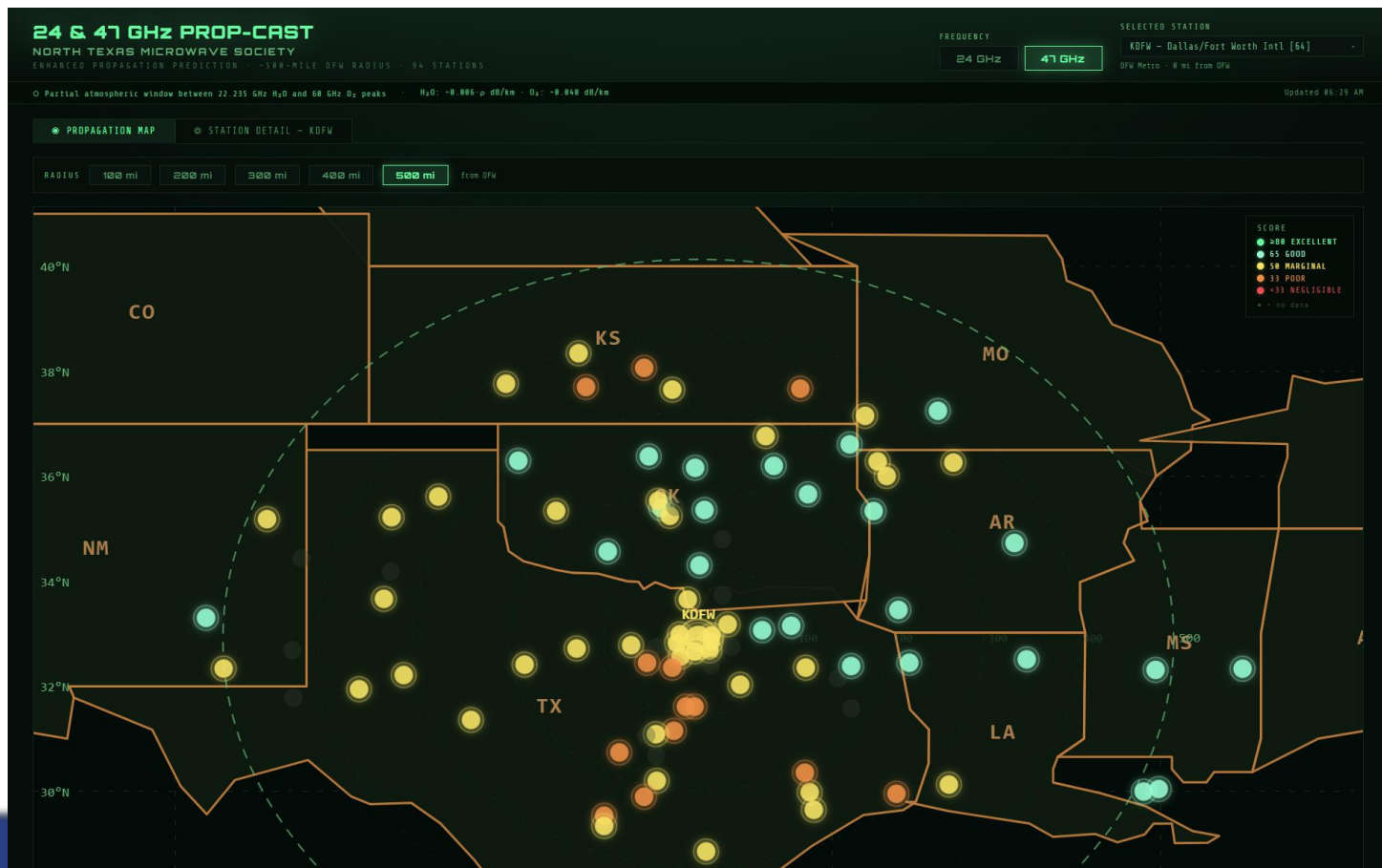


7 scoring factors

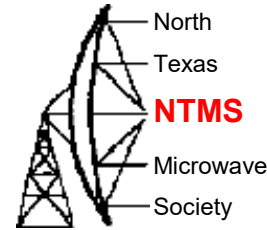
Factor	Weight (%)	Description	Algo Unified (Graham)
Absolute Humidity	26%	Grams of water vapor per cubic meter of air (g/m^3). More moisture = better refractivity for ducting at 24/47 GHz; scored against rho thresholds by frequency.	Flips at 10 GHz
Wind - Calm	18%	Surface wind speed in mph. Calm winds allow nocturnal inversions to build undisturbed. Strong winds create turbulent mixing that destroys duct layers.	Overweighted, drop to 8%
Sky - Radiative Cooling	15%	Cloud cover condition (Clear/Few/Scattered/Broken/Overcast). Clear skies allow the ground to radiate heat at night, building the surface inversion that drives ducting.	
Time of Day	14%	Position relative to local sunrise. Pre-dawn through ~90 min post-sunrise is the peak inversion window. Afternoon convective mixing scores lowest.	
T/Td Depression	11%	Temperature minus dewpoint (F). Larger spread = drier air aloft = more stable layering. Scored differently by frequency - higher bands need drier air.	
Season	9%	Calendar month proxy for long-term moisture regime. Nov-Feb scores highest (cold, dry, strong inversions). July-Aug scores lowest (Gulf moisture, weak inversions).	
Pressure - Subsidence	7%	Barometric pressure trend (rising/falling/steady). Rising pressure indicates post-frontal subsidence and stable air. Falling pressure signals approaching instability.	

First map of results

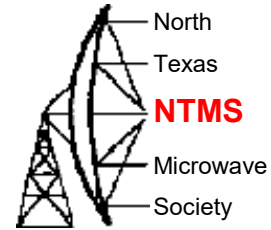
- Selectable ASOS station
- Composite score of 7 factors



Skew-T plots added



- **Min dN/dH gradient** — requires knowing temperature and dewpoint at every pressure level from surface to 200 hPa, not just at ground level. 200 hPa=top of troposphere
- **Inversion layers** — require seeing where temperature *increases* with altitude, invisible from surface obs alone
- **Duct layers (M-profile)** — require computing modified refractivity at each level and finding where it decreases with height
- **BL Depth** — requires seeing where the potential temperature profile departs from the surface value
- **Lifted Index and K-Index** — require 850/700/500 hPa temperature and dewpoint simultaneously



Min dN/dH gradient

Atmosphere Layers (Approximate Heights)

| Layer | Pressure | Height Above Ground | Color Code | Description |

|-----|-----|-----|-----|-----|

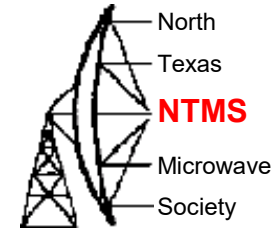
| **Surface** | 1000 hPa | 0 km (0 miles) | ■ Green | Where we live, breathe, and walk. |

| **Lower Atmosphere** | 850–500 hPa | 1–5 km (0.6–3 miles) | ■ Blue | Where most clouds and weather happen. |

| **Mid Atmosphere** | 500–300 hPa | 5–9 km (3–5.5 miles) | ■ Yellow | Around airplane cruising altitude. |

| **Upper Atmosphere** | **200 hPa** | ~12 km (7 miles) | ■ Red | Very thin air, near the top of the troposphere. |

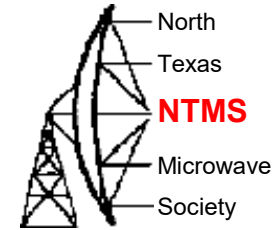
- Looking up from bottom of swimming pool – light is refracted.
- RF in atmosphere does same thing = refractivity index.
- Refractive index of air isn't the same at every altitude.
- When dN/dH exceeds -157 per km, we have ducting.
- The more negative this number, the stronger the duct.



Additional apps created

- Mm-Wave Link Budget Analyzer
- Input two grids, nominal station data

- Predicts closure %
- Skew-T plots now on panel



Additional apps created

- Prop-Analyzer
- Input historical information

PROP-ANALYZER
NORTH TEXAS MICROWAVE SOCIETY
HISTORICAL CONTACT ATMOSPHERIC ANALYZER

335.5 km - 71.8° ENE
87.5h COT - 132.4h
1921 - 88-17

CONTACT PARAMETERS

GRID A (UP TO 10 CHAR) GRID B (UP TO 10 CHAR) DATE TIME UTC - 24 HOUR (ZULU)

EM02HQ49DL EM23A073EV 08/17/2025 12:56

FREQUENCY 10 GHz 24 GHz 47 GHz

EM02HQ → EM23AD 335.46 km 71.8° ENE 10 GHz 12:56Z 07:56 CDT

PATH MAP - 5 WEATHER STATIONS

SURFACE OBS - HISTORICAL AVERAGE

TEMPERATURE	79.7°F	DEWPOINT	72.9°F
FDI DAP	6.8°F	REL HUMIDITY	80%
ABS HUMIDITY	20.02 g/m ³	WIND SPEED	8.5 mph
PRESSURE	1015.5 mb	SKY COVER	BKN

Surface Duct / Inversion 95%

PRE-DAWN INVERSION - inversion layer traps 10 GHz energy near surface, dramatically extending range. Duct enhancement can add 20-40 dB beyond free-space loss.

Tropospheric Scatter 85%

Standard tropo scatter at 10 GHz. Path length 305 km is well within scatter range (~500 km limit). Scatter volume near path midpoint.

Moist Layer Scattering 55%

High absolute humidity (20.02 g/m³) creates elevated moist layer scatter. Humidity gradients in top of BL scatter signal forward.

HISTORICAL SOUNDING - SKEW-T LOG-P
Fort Worth TX (FWO) - Valid: 2025-08-07T0200Z - matched to contact time

FD0 - Fort Worth TX
Valid: 2025-08-17T12:00Z

DERIVED PROPAGATION PARAMETERS

MIN DN/DH GRADIENT	-220 /km
SUPER-REFRACTIVE @ 403m AGL	
LIFTED INDEX	23.2
Very Stable / Dry - excellent ducting conditions	
K-INDEX	40
High convective potential	
PRECIPITABLE WATER	52.0 mm
BL DEPTH	538 @ AGL
Moderate	
INVERSION LAYERS	2
302-619m, 4036-4039m	
DUCT LAYERS (M-PROFILE)	1
302-619m (ADM-g)	

SOUNDING INTERPRETATION - 10 GHz

- 1 duct layer identified in M-profile - 393-619m AGL. Elevated duct - signal may couple into layer for extended range. Temperature inversion at 393m AGL (+0.8°C). Elevated inversion - potential for wave duct above. Super-refractive layer at 4043m AGL (DN/dh=-220/km). Ducting highly.

ATMOSPHERIC REFRACTIVITY STATE

1.55 (INDEX) 378 (UNITS) ENHANCED REFRACTION (CONDITION) PRE-DAWN INVERSION (TIME OF DAY)

TOD PROPAGATION SCORE 95.0 SEASON SCORE 75.0 SUMMER - HIGH HUMIDITY

ABS HUMIDITY 20.0 g/m³ WIND SPEED 8.5 mph

PATH LOSS BUDGET - 10 GHz

FSPL	162.56 dB
GAS ABSORPTION	4.364 dB
FSPL + GAS	167.33 dB
FREDEL R. (MID)	58.2 m
EARTH BULGE (MID)	1.7 m
λ (WAVELENGTH)	3.00 cm

STATION OBSERVATIONS DETAIL

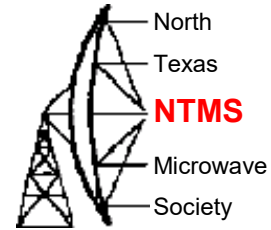
NTMX
Refractivity Normal
T: 7.9°F Td: 7.5°F p: 21.5 k W: 8mph P: 1016mb CLR

HPFW
Sea Level Altitude
T: 8.2°F Td: 7.9°F p: 20.8 k W: 10mph P: 1014mb BKN

HGVI
Sea Level Pressure
T: 7.9°F Td: 7.9°F p: 20.4 k W: 9mph P: 1017mb CLR

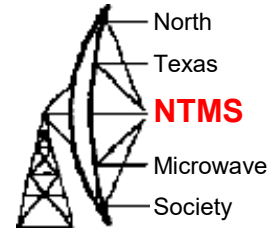
HEKCD
Elevation
T: 8.1°F Td: 7.7°F p: 19.4 k W: 6mph P: 1016mb SCT

Apps are complementary

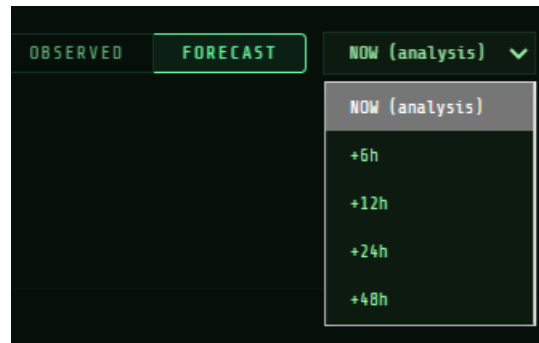


- **The original seven scoring factors** are a *surface weather* model. They answer the question: *"Based on what's happening at the surface right now, how favorable do conditions look?"*
- **The derived propagation parameters** from the addition of Skew-T sounding — either an actual radiosonde balloon launch (Observed mode) or the GFS model forecast (Forecast mode). answer a different question: *"What is the actual vertical structure of the atmosphere doing right now, and is a duct physically present?"*

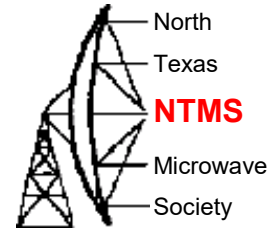
Skew-T to GFS (all apps)



- Skew-T from IEM RAOB (observed soundings).
 - Temperature and dewpoint profiles from real radiosonde balloon launches at 00Z and 12Z.
 - only showed current or recent conditions, only at the nearest radiosonde station and only twice a day.
- GFS forecast soundings from open-meteo.com.
 - Gave us the OBSERVED/FORECAST toggle you see in the panel header, with forecast hours of +0, +6, +12, +24, and +48 hours.



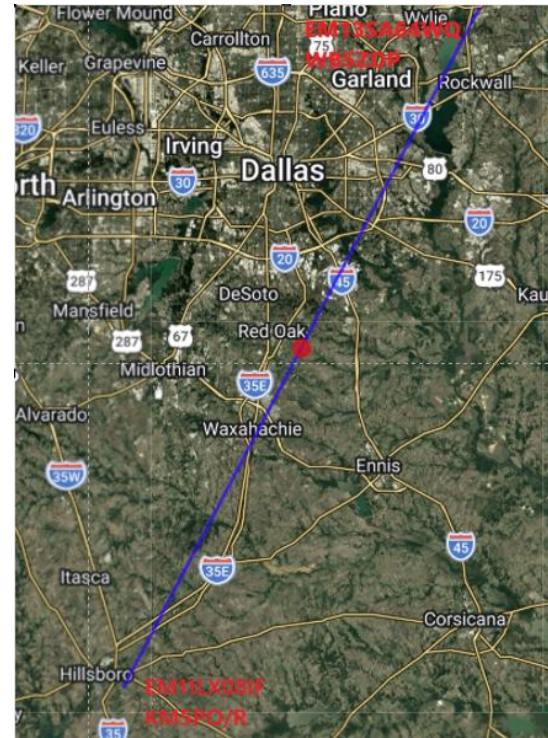
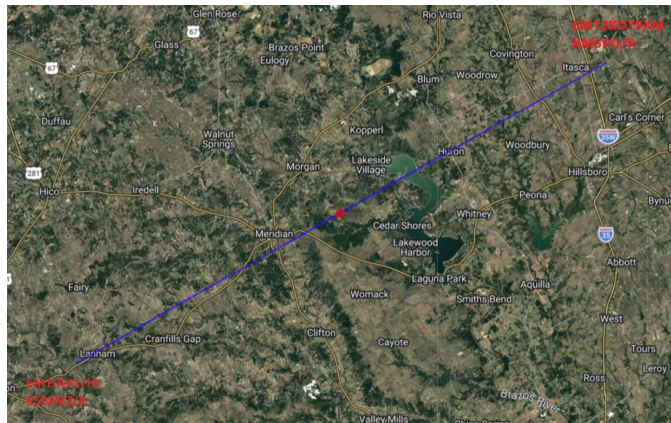
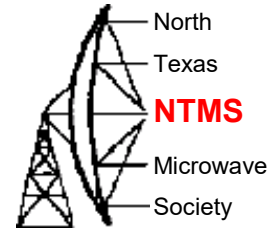
- Moving to prediction (K6ML method with Windy.com)



Put it to use

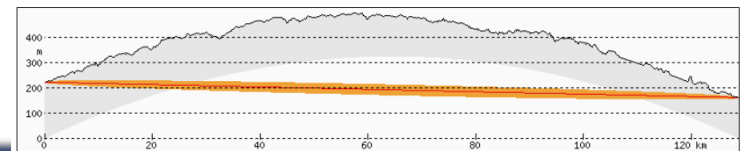
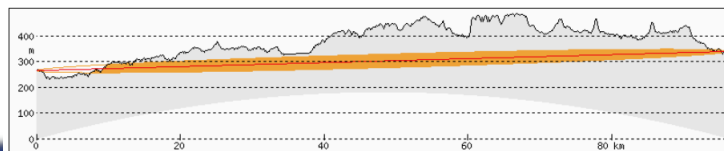
- Start observing app predictions and real time data versus actual conditions.
 - Are empirical beacon reports aligned with propagation tools?
 - How are variances by frequency appearing?
- Anticipate a “truck roll”. What triggers to watch for.
 - Stable weather pattern
 - 24 & 48 hour repeating factors
- Conditions turned favorable after a frontal passage in DFW for Monday/Tuesday 4-6-26 and 4-7-26 (MAD rained out)
- Time to notify partners.

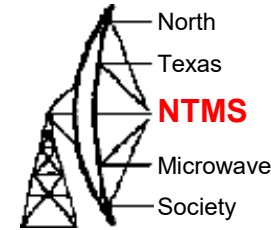
Put it to use



- 10 GHz – 599 signals 100 km

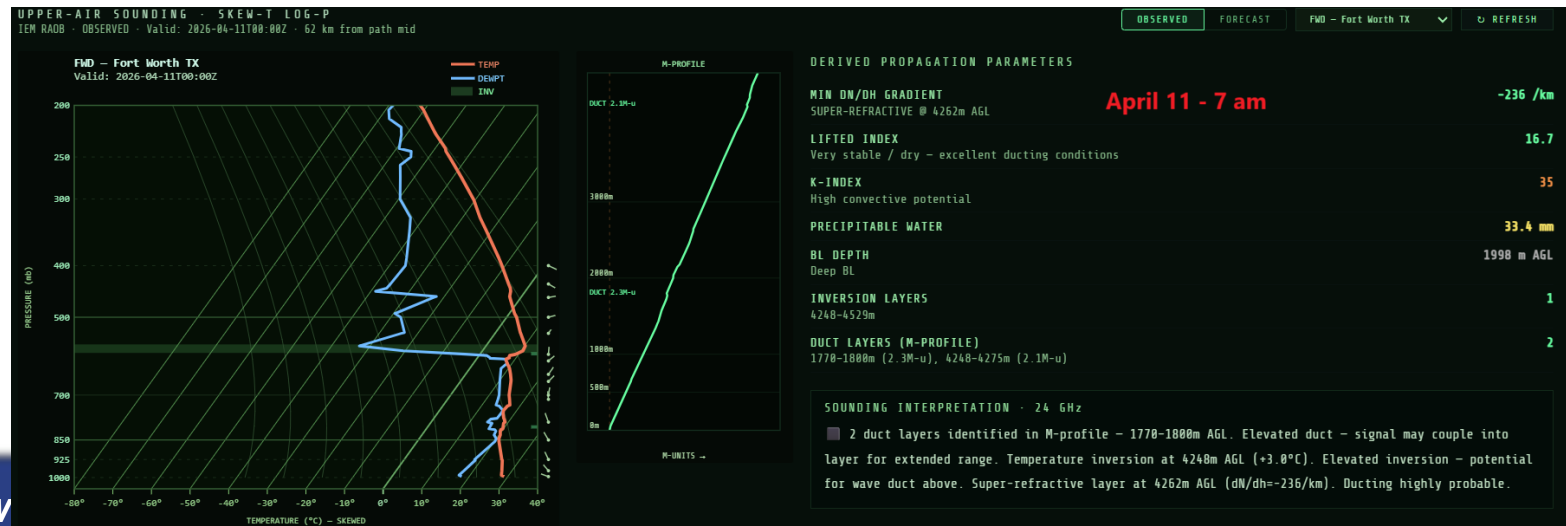
- 24 GHz – strong signals 129 km



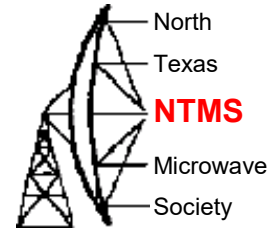


Comparisons

- April 7th 8 am – a 129 km contact at 24 GHz occurred with strong signals

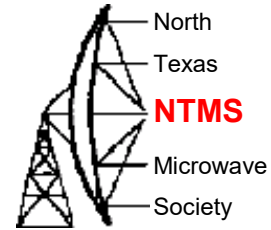


The long Arc (from last presentation 3-14-26)



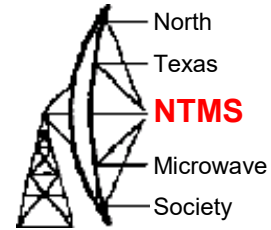
- Right now, we have four data points all in one geographic corridor and one climate regime.
- Two or three years of community submissions across different geographies and seasons could give us enough data to start answering questions that nobody in the amateur microwave world has good answers to yet — things like what the minimum atmospheric signature is that can support a 47 GHz duct contact, or whether there's a seasonal pattern to boundary layer inversion contacts outside of Texas, or how the required duct strength scales with path length.
- Novel empirical work.

A transformation in analysis



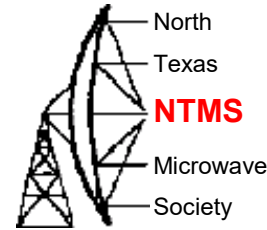
- Graham McIntire shifts the project into high gear.
 - Expands the dataset
- **Algo2 — 58,282 ARRL Contest QSOs (2019–2024)** Six years of microwave contest contacts cross-referenced with actual weather conditions at time of contact. Largest empirical mm-wave propagation dataset assembled for amateur radio.
- **Algo3 — 18,540 Commercial Link Measurements** Graham's own WISP backhaul links at 11, 24, and 68 GHz — continuous 24/7 signal monitoring. Fixed paths, known geometry, real-time calibration data.

A transformation in analysis



- Identifies additional weather data sources and creates interface to them.
 - Upper Air Soundings (RAOB)
 - HRRR Model Data
 - IEMRE Gridded Hourly Weather
 - SRTM Terrain Elevation Data
 - Commercial Link Validation Data
 - Solar Indices

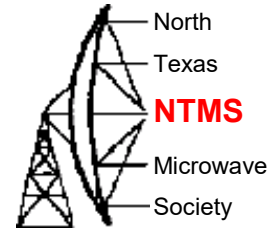
Graham comments?



Several new applications

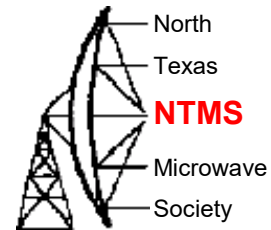
- **Live Scoring Data**
- **Propagation Grid Scores**
- Coverage: CONUS grid at 0.125° resolution
- Update cadence: hourly (HRRR-based via PropagationGridWorker) + 10-minute ASOS adjustments (AsosAdjustmentWorker)
- Per grid point: composite score (0-100), 9 individual factor scores, valid_time
- Bands scored: all configured bands (902 MHz, 1296 MHz, 2304 MHz, 3456 MHz, 5760 MHz, 10, 24, 47, 68, 75, 122, 134, 241 GHz)
- Retention: 2 most recent valid_times kept, older data pruned automatically

Live demo of web pages



- Path
- Map
- Map>Weather Map
- Beacons
- Contact Map
- Contacts
- Submit Contact
- These apps will eclipse the earlier apps although we will leave the previous apps available for now.

"All models are wrong, some are useful." — George Box



- Limitations of Models. All models are simplifications of reality. They cannot capture every detail or nuance of the systems they represent.
- The usefulness of a model should be judged by its ability to provide insights and guide decision-making, rather than its absolute accuracy. A model that is "wrong" in some respects can still be effective if it helps to understand trends or make predictions.
- Prove by testing!

Questions?

