Clutter Modeling: Today's Shortfalls and Tomorrow's Opportunities

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Outline

- Shortfalls
  - Incorrect Model Selection
  - Ignoring Variabilities
  - “Tacking on” Clutter Loss
  - Applying Terrain Diffraction Models to Clutter Predictions
- Opportunities
  - Improved Localization
  - Bridging the Gap to Analyses
  - Machine Learning / Data Science
  - Technical Transparency

Disclaimer

- I’m going to pick on a few models and methods during this talk, some of which are pulled from real experience
- Point is not to disparage, but to demonstrate and motivate improvements
- I’m well aware the “engineering compromises” are perhaps more prevalent than we would prefer to see

Today’s Shortfalls

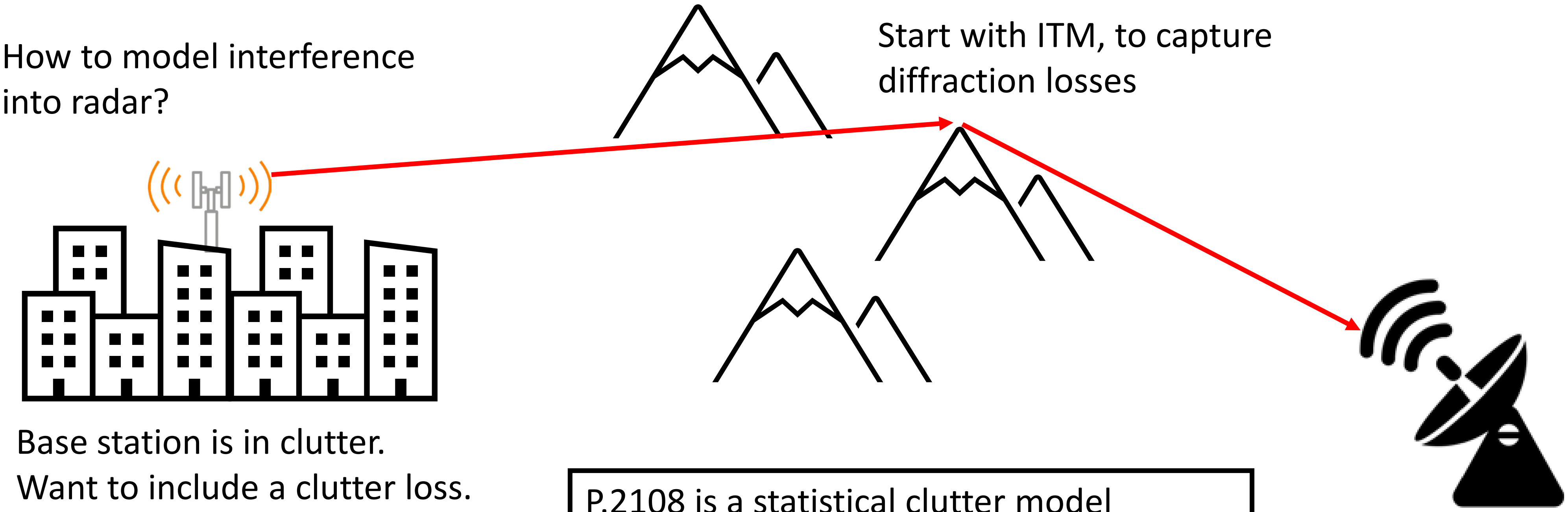
Incorrect Model Selection

- Broadly speaking there are two types of clutter models
- Point-to-point (site-specific) methods
  - Use of location specific information (lidar, etc.)
  - Generally, computationally more expensive
- Point-to-area (site-general) methods
  - Statistical prediction results – generate CDFs of clutter loss
  - Suitable for Monte Carlo simulations
  - Use clutter categories or statistics instead of location specific information
- Model selection **must** align with problem

Incorrect Model Selection (example)

How to model interference into radar?

Start with ITM, to capture diffraction losses



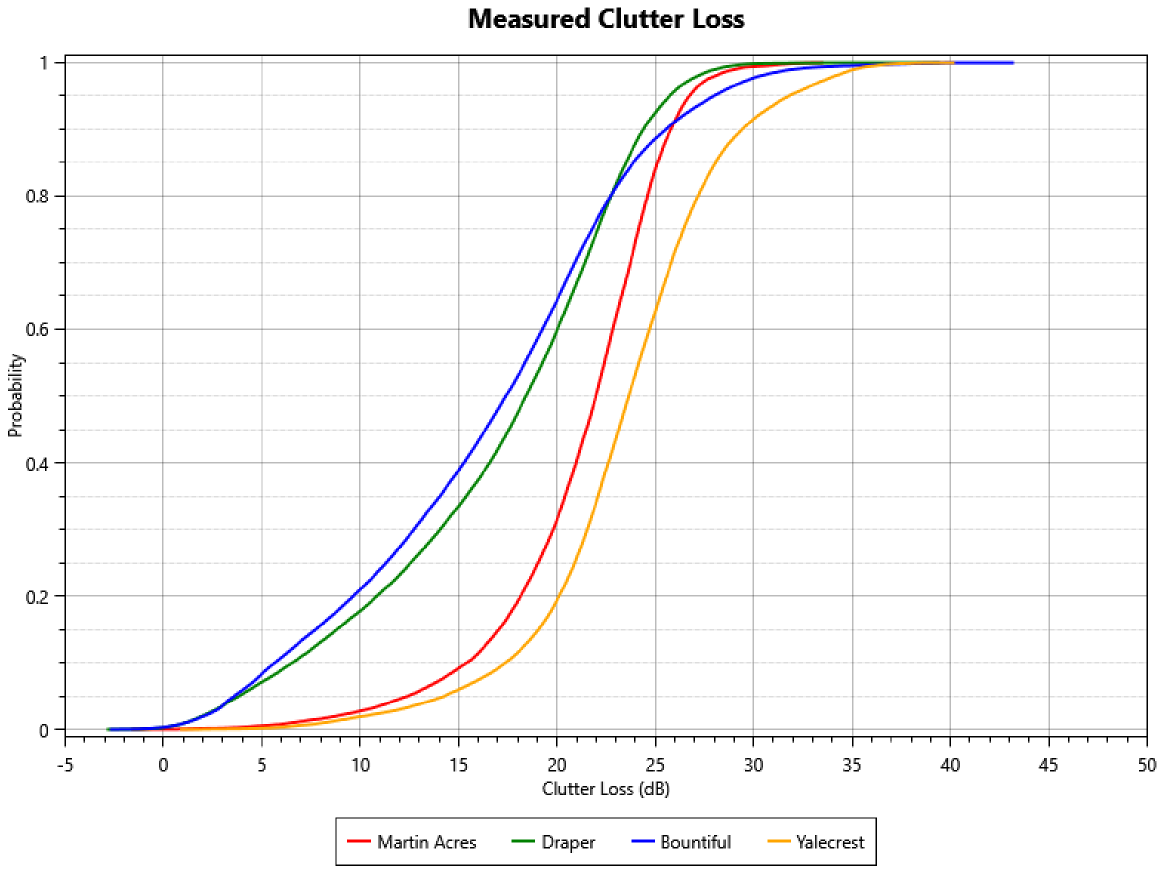
Base station is in clutter.
Want to include a clutter loss.

+ P.2108 Sec 3.2?

P.2108 is a statistical clutter model designed a distribution of locations.
- Base stations are fixed infrastructure
- Base stations not enmeshed in clutter
- A site-specific model is more appropriate

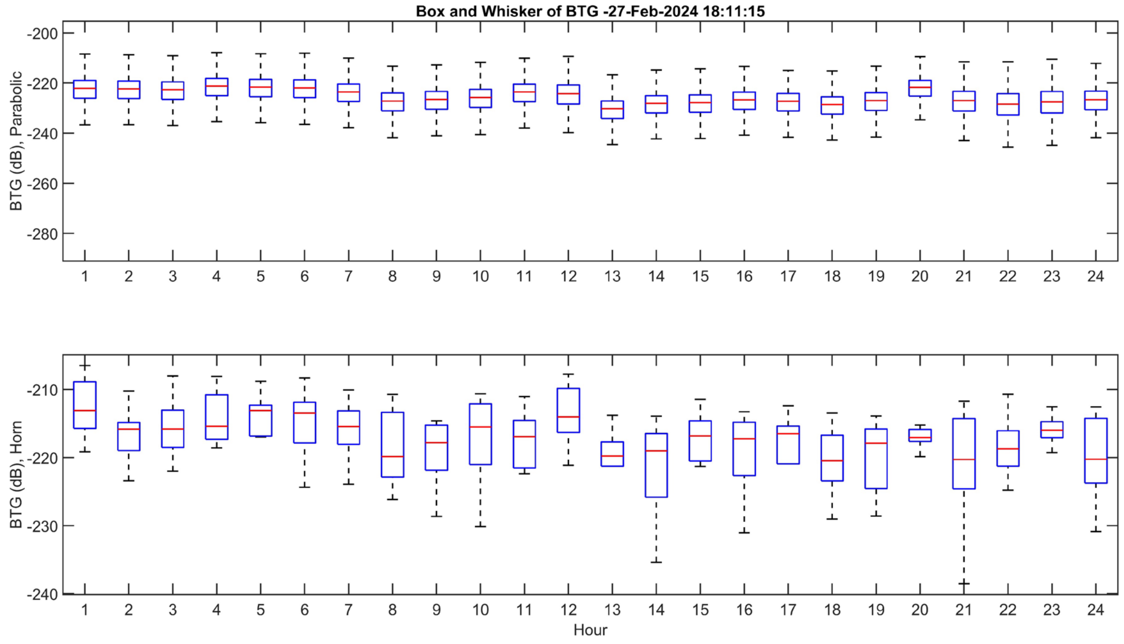
Ignoring Variability

- Propagation modeling is non-deterministic
- Must think in terms of statistics and distributions of loss
- What does location variability of 80% mean?
- What does time variability represent?
- If a system needs to be protected from interference 95% of the time, from a distribution of user equipement, how is that achieved in the analysis?
- Don't correct a perception of "too much margin" by abusing variability distributions



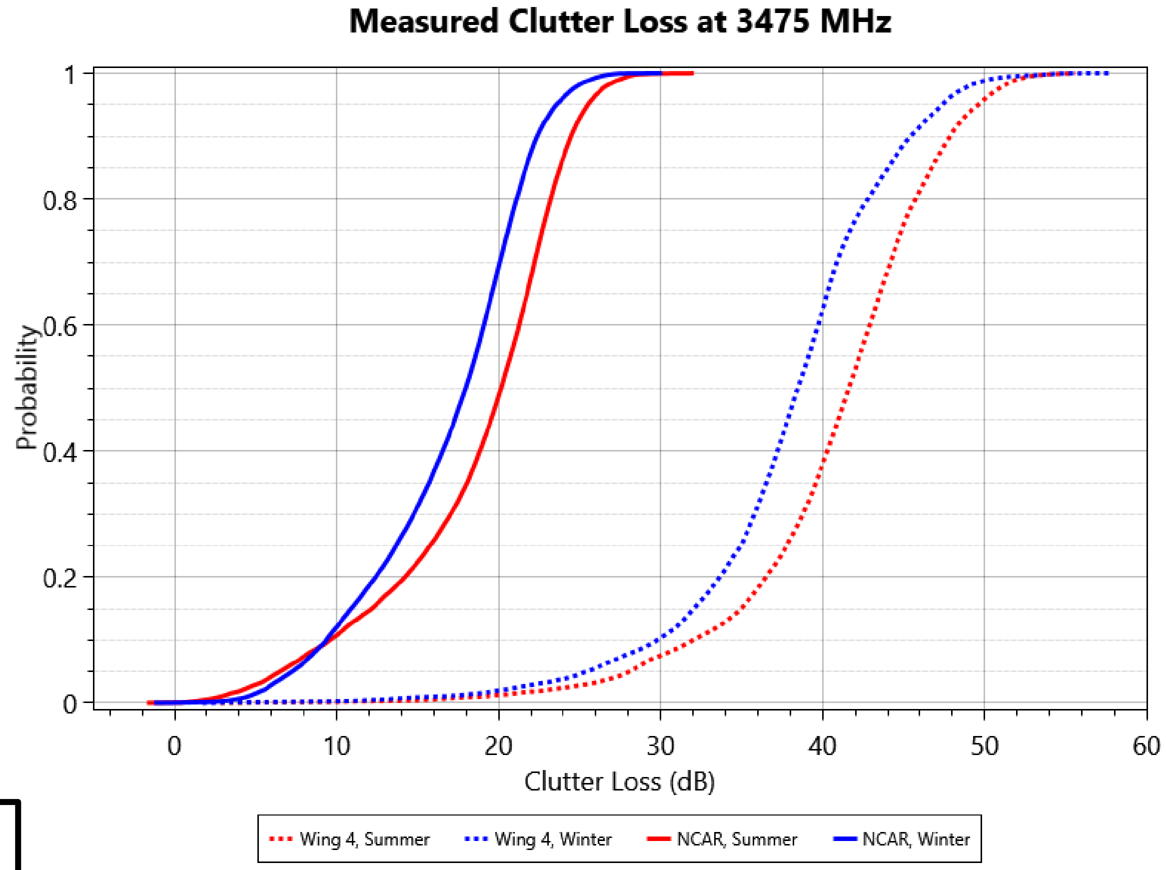
Ignoring Variability (example)

Atmospheric effects can cause significant signal variabilities over time



TIREM? Median basic transmission loss (no clutter)

Seasonal changes in clutter add additional time variabilities

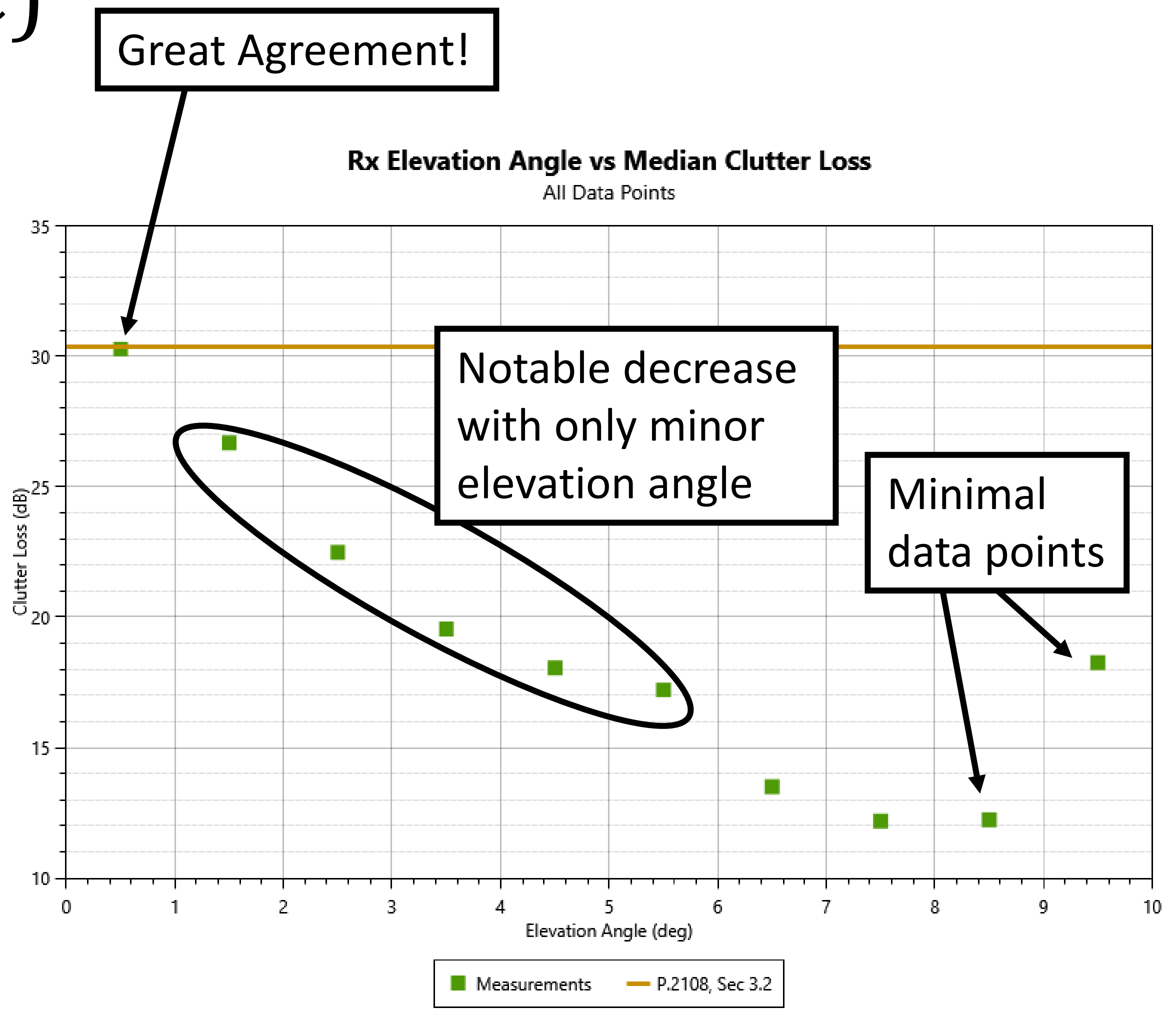


“Tacking on” Clutter

- Clutter loss is treated as independent of other losses (diffraction, troposcatter, etc.)
- Does not imply one can simply take a general-purpose model and simply “tack on” an additive clutter loss component, such as ITM+P.2108
- Clutter loss **is dependent** on path geometry
- Consider:
  - No consideration of terrain geometry is accounted for in the clutter term
  - Handling of variabilities
    - If a general-purpose model considers variabilities, are those statistics being correctly combined with the clutter distribution?
    - In an ITM+P.2108, you have **two** different concepts of location variability, terrain with ITM and clutter with P.2108
  - No consideration of mid-path clutter effects

“Tacking on” Clutter (example)

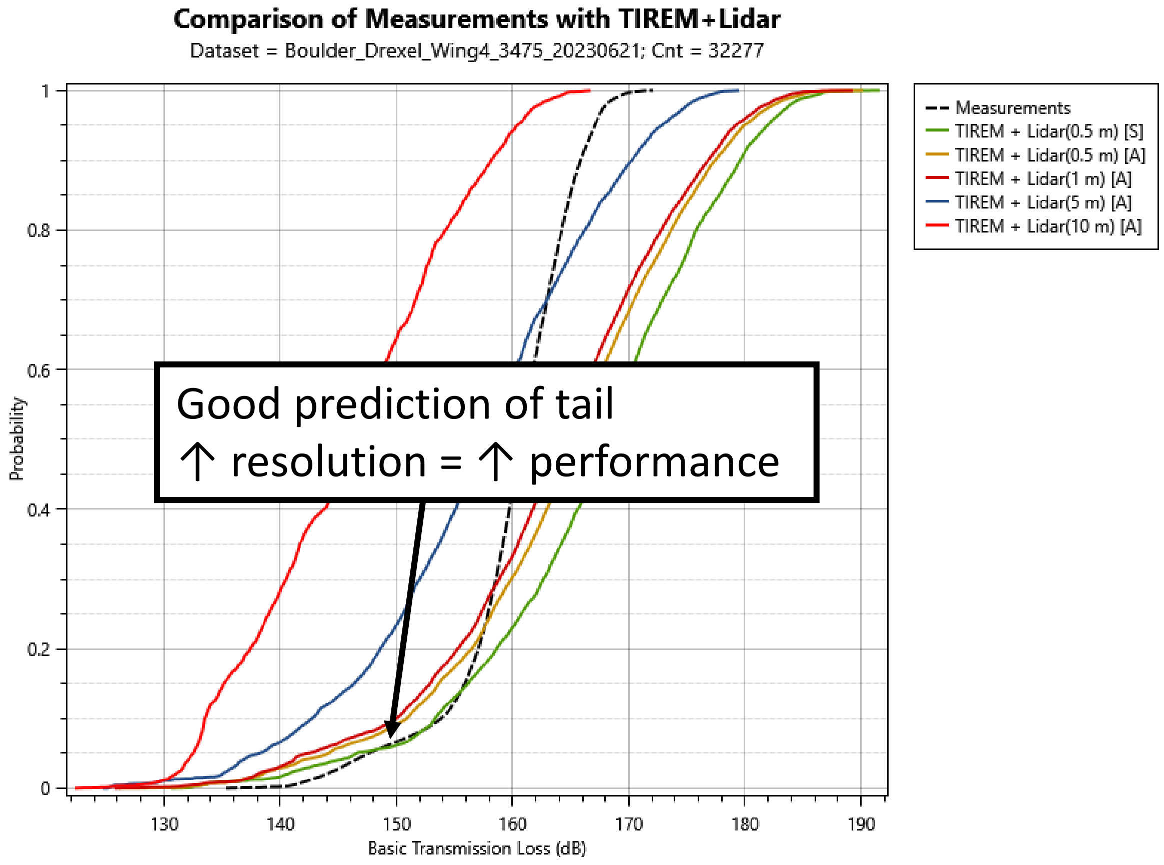
Angle	Count	Median (dB)
[0, 1)	138,830	30.27
[1, 2)	193,857	26.68
[2, 3)	203,722	22.48
[3, 4)	217,757	19.54
[4, 5)	117,722	18.05
[5, 6)	54,347	17.21
[6, 7)	26,438	13.50
[7, 8)	26,932	12.18
[8, 9)	6,539	12.23
[9, 10)	1,052	18.25

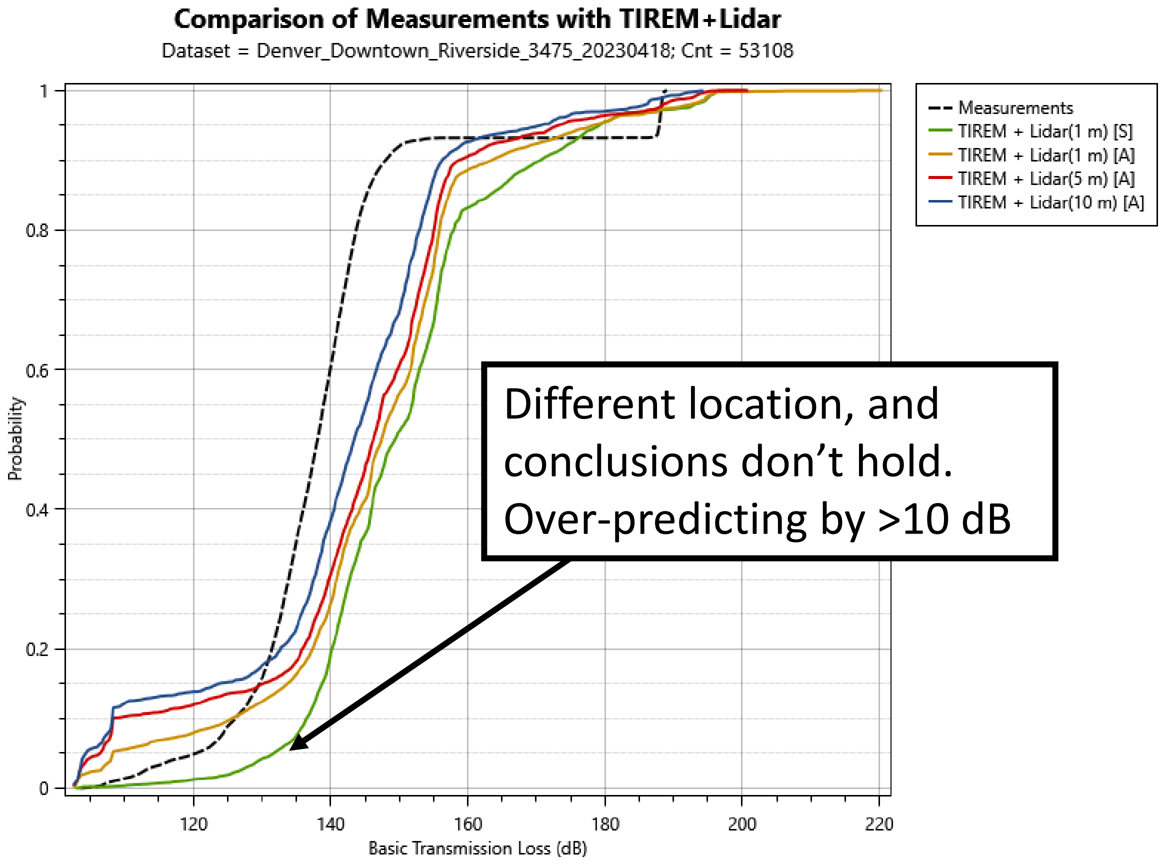


Using DSM Data in a General-Purpose Model

- Idea is to take a general-purpose, site-specific model and replace the terrain profile with a surface profile
  - Underlying physics of the general-purpose model is applied to the clutter surface
  - Ex: TIREM+Clutter
- Assumes that clutter loss is a function of vertical plane knife-edge diffraction
  - No back reflections at terminals
  - No off-axis scattering
  - No negative clutter losses
  - Highly dependent on DSM resolution, in which increased resolution does not always result in increased performance

Using DSM Data in a General-Purpose Model (example)



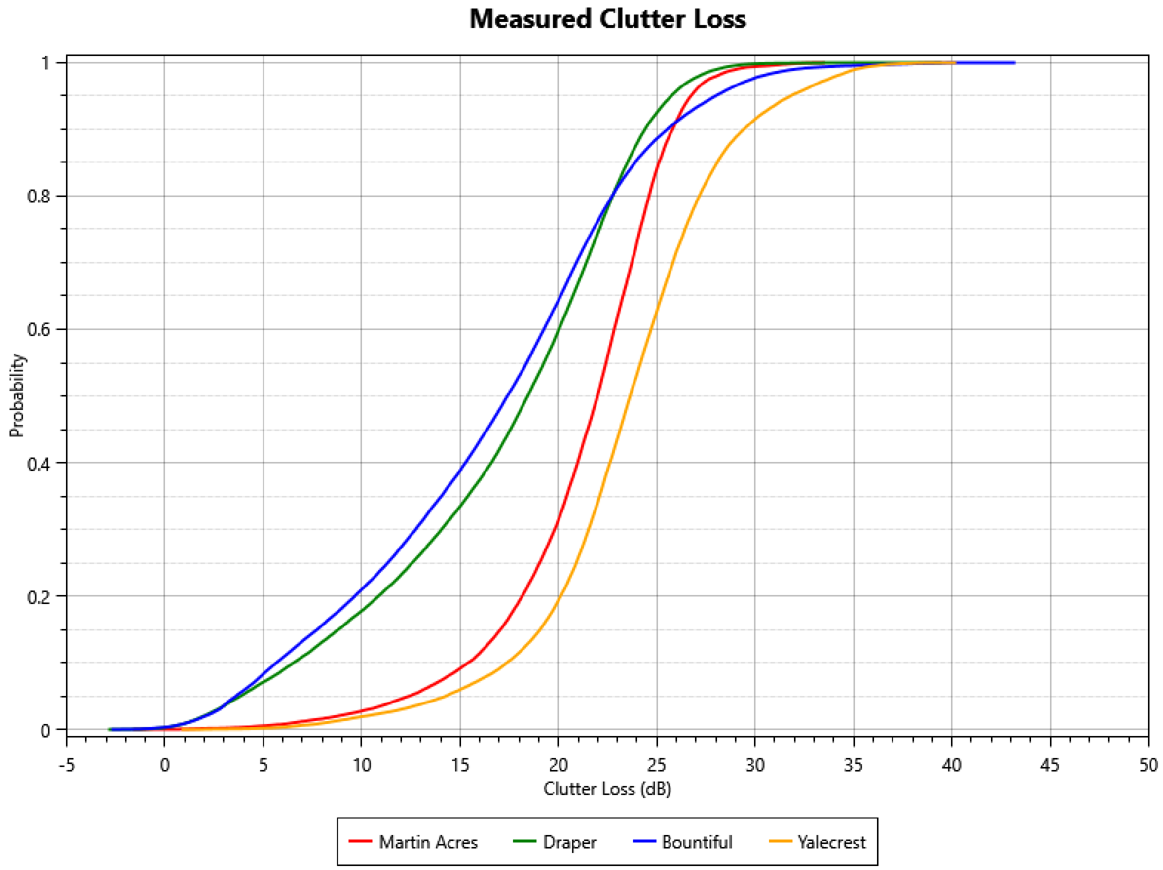


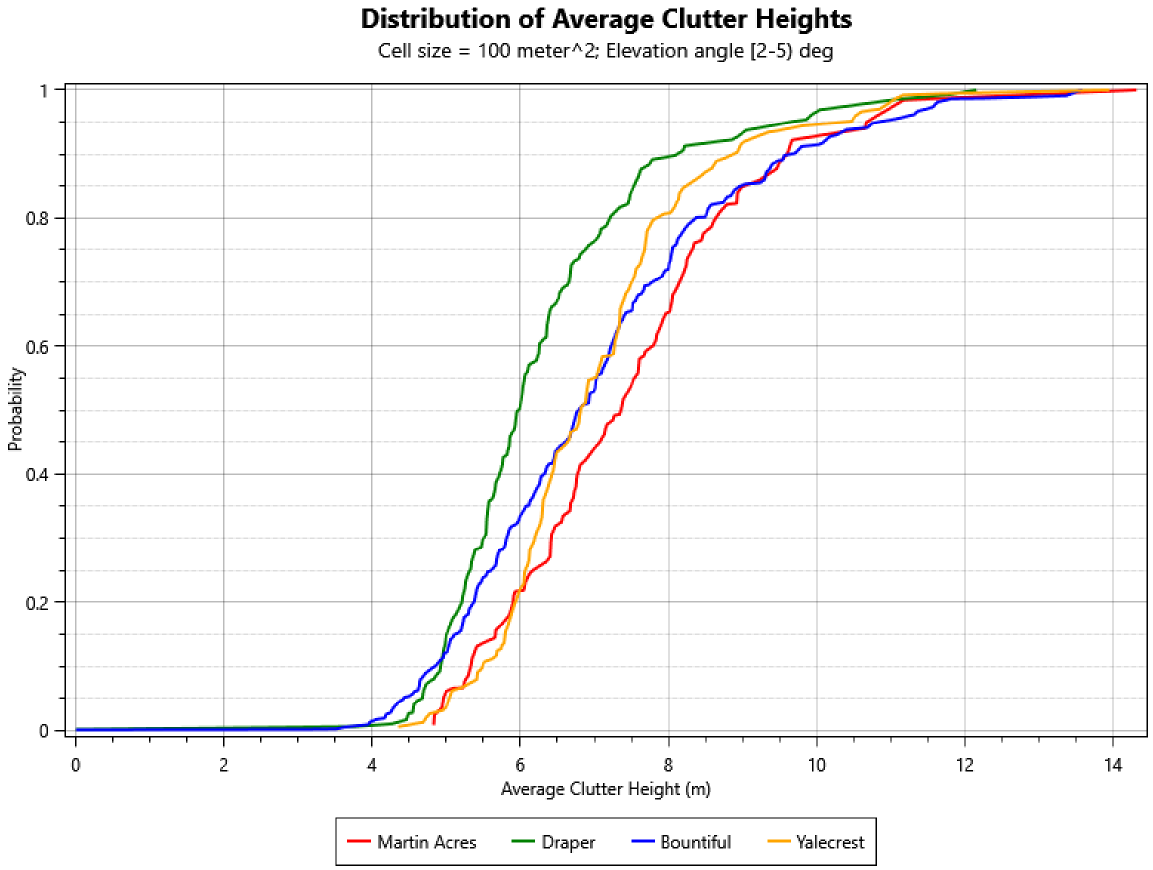
Tomorrow’s Opportunities

Improved Localization

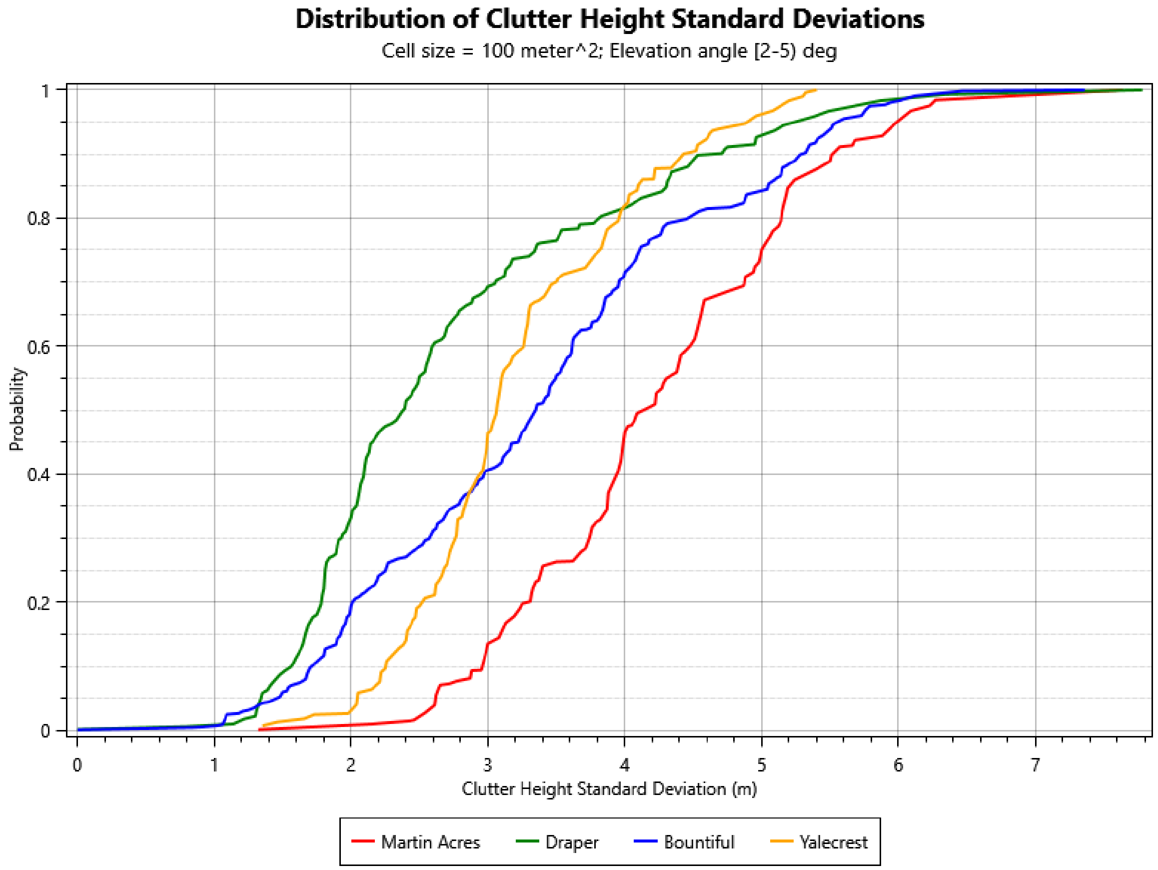
- Clutter categories are useful, but should be the backup option
- Further sub-dividing urban/suburban/rural is not a viable long-term solution
- Models should be tuned via objective metrics
  - Numerical and calculable
  - Computable for arbitrary locations, be it a region, an entire city, a neighborhood, or even a select few blocks
  - What makes two environments similar?
- Leverage the modern high-fidelity datasets and tooling we have available

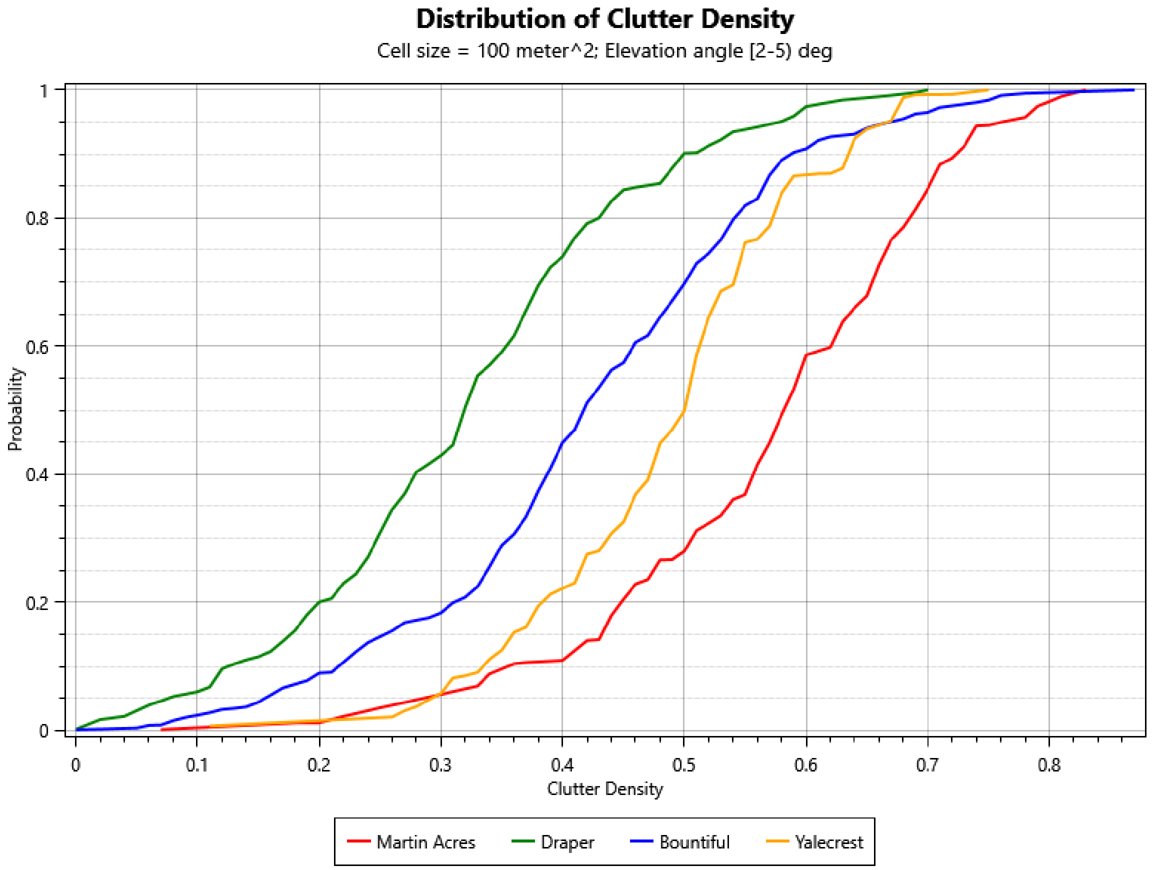
Improved Localization (example)





Improved Localization (example)





Machine Learning / Data Science

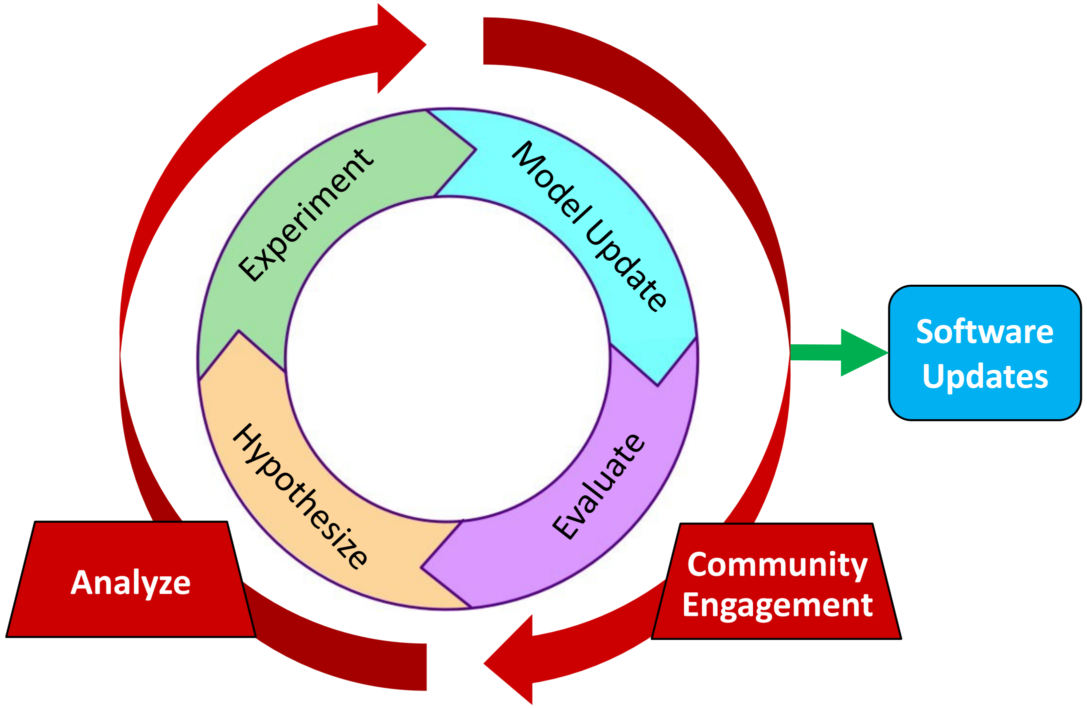
- Must embrace machine learning and data science tools
- Approach ML/DS as a tool to solve a problem, not a magic oracle that grants us answers
  - Analyze environmental and measurement data for key features
  - Extract meaning from data to build a mathematical model
- Attempt to understand why a solutions work
  - Need new methods to evaluate
  - Incorporate known physical relationships and behaviors
- Build trust model behavior
  - Non-technical issue
  - “Comfort level” with physics/mathematics-based models in policy

Bridging the Gap to Analyses

- Must avoid implicit assumptions
  - Folks doing an analysis often were not involved in creation of model
  - Assumptions are necessary to make problems tractable – state them clearly
- Antenna patterns
  - Guidance needs to be considered
  - Simply stating isotropic assumptions is no longer enough
  - Antenna systems continue to become more complex in design and operations
- Model applicability
  - Developed for a particular purpose
  - Design decisions need to be stated

Technical Transparency

- Need to engage the community early in model development
  - Increase buy-in
  - Understand use-cases
  - Encourage collaborative thought
- Requires us to be more transparent in model development, including measurements and data processing
- Three pillars of transparency
  - Publications
  - Software
  - Data



Questions?