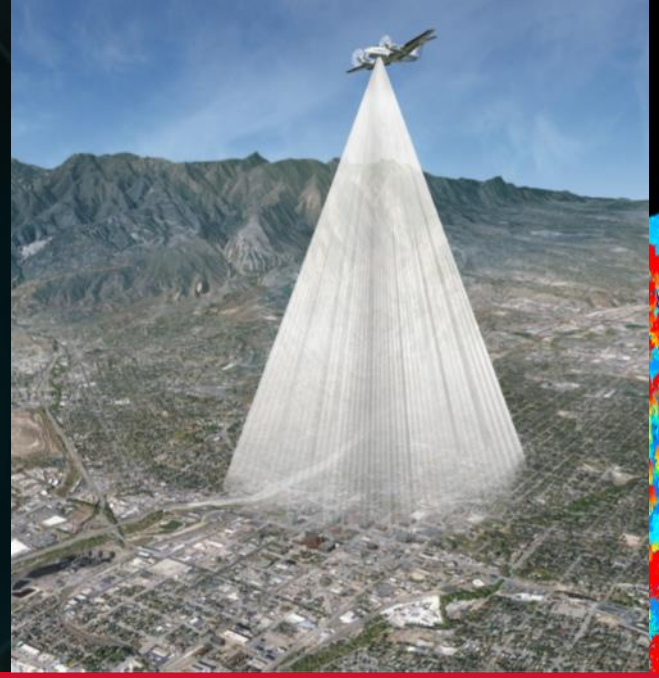
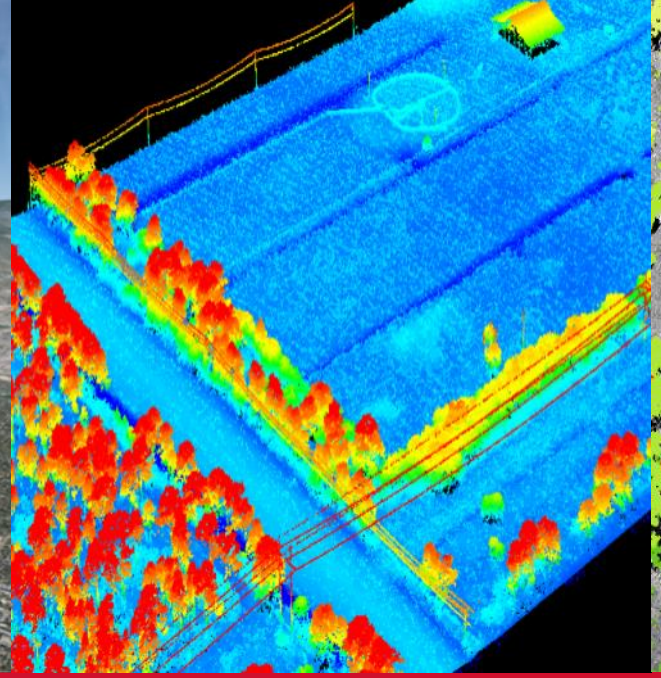
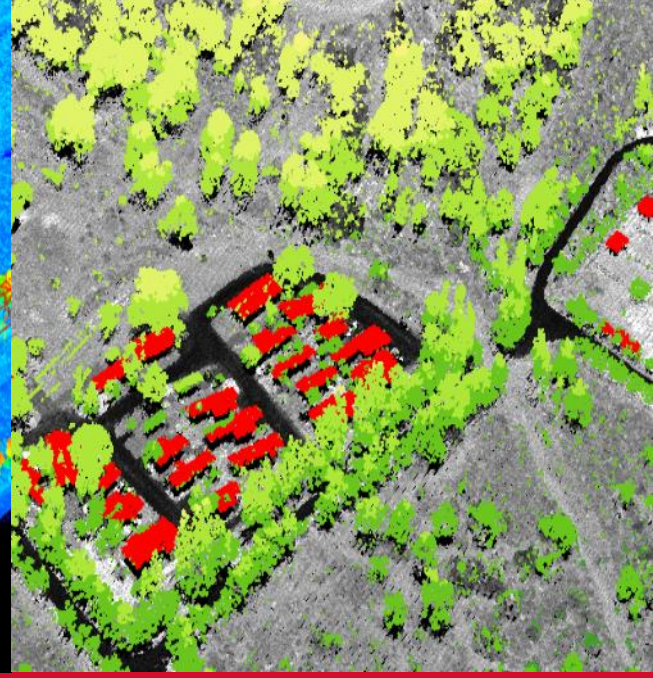

INFORMATION VS. POINTS

TOWARDS A BETTER ASSESSMENT OF PRODUCT INFORMATION AND INTERPRETABILITY

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Product Quality Establishes Fitness for an Application

Helps determine if:

- **Product captures necessary details**
- **Product faithfully represents reality**

May specifically address:

- **Is any data missing?**
- **Can heritage be traced and verified?**
- **Is data relevant to time frame of application?**
- **Do surfaces vary within acceptable tolerances?**
- **Are features placed accurately?**
- **Are features resolved acceptably?**
- **Does data carry sufficient attribution?**

Quality is ultimately determined by a product's ability to be used for a specific purpose.

Current USGS LBS Quality Levels are a Great Launch Point

Quality Level	Aggregate Nominal Pulse Spacing (m)	Aggregate Nominal Pulse Density (pls/m^2)
QL0	≤ 0.35	≥ 8.0
QL1	≤ 0.35	≥ 8.0
QL2	≤ 0.71	≥ 2.0
QL3	≤ 1.41	≥ 0.5

Resolution

Quality Level	Smooth Surface Repeatability, $RMSD_Z$ (m)	Swath Overlap Difference, $RMSD_Z$ (m)
QL0	≤ 0.03	≤ 0.04
QL1	≤ 0.06	≥ 0.08
QL2	≤ 0.06	≥ 0.08
QL3	≤ 0.12	≥ 0.16

Consistency

Quality Level	$RMSE_Z$ (non-vegetated) (m)	NVA 95% C.I. (m)	VVA 95% C.I. (m)
QL0	≤ 0.050	≤ 0.098	≤ 0.150
QL1	≤ 0.100	≤ 0.196	≤ 0.300
QL2	≤ 0.100	≤ 0.196	≤ 0.300
QL3	≤ 0.200	≤ 0.392	≤ 0.600

Accuracy

Need to Evolve for Aggregate, Synthetic and High-Res Products

Resolution

- No ANPD/ANPS assessment approach beyond coarse grid
- Sample-based
- Based on first returns
- Density and spacing relationship based on square raster assumption
- Regularity assessment is coarse w.r.t. density
- Regularity does not flag over-collection

Accuracy

- Only assessed in vertical

Consistency

- Cell sizing results in large point counts for high-res data
- Range is not a robust statistic
- Slope-corrected range may be negative
- Inter-swath assessment is pairwise
- Only assessed in vertical

Completeness

- Void criteria is coarse w.r.t. density
- Based on first returns
- No foliage penetration assessment

Dimension Reduction for ANPS/ANPD Assessment

General

- **Always filter withheld and overage points**
- **ANPS and ANPD are Horizontal assessments**
- **Need to reduce data dimension from 3D to 2.5D**

Multiple Return per Pulse Systems

- **Filter data to only first returns**

Aggregate and Synthetic Systems

- **Compute mean horizontal distance to nearest-neighbor**
- **Perform raster-based stratified sampling with cells sized to $1/\sqrt{2}$x mean nearest-neighbor distance**
  - Top point per cell – similar to first return
  - Closest to Mass-Point – cluster based sampling
  - Closest to Cell-Center – least jitter
  - Random – most jitter

Terrain Recovery Assessment

- **Filter data to only LAS Class 2 ("Ground") points**

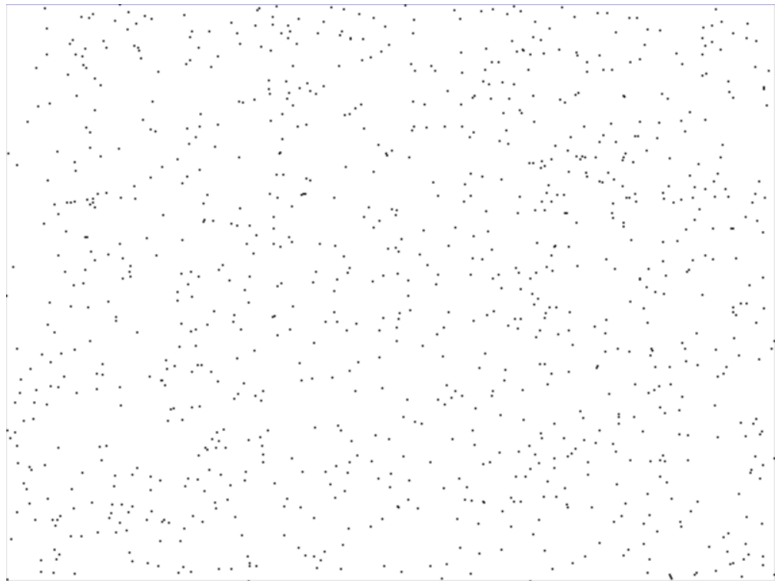
ANPS and ANPD Assessment

Two primary methods currently used:

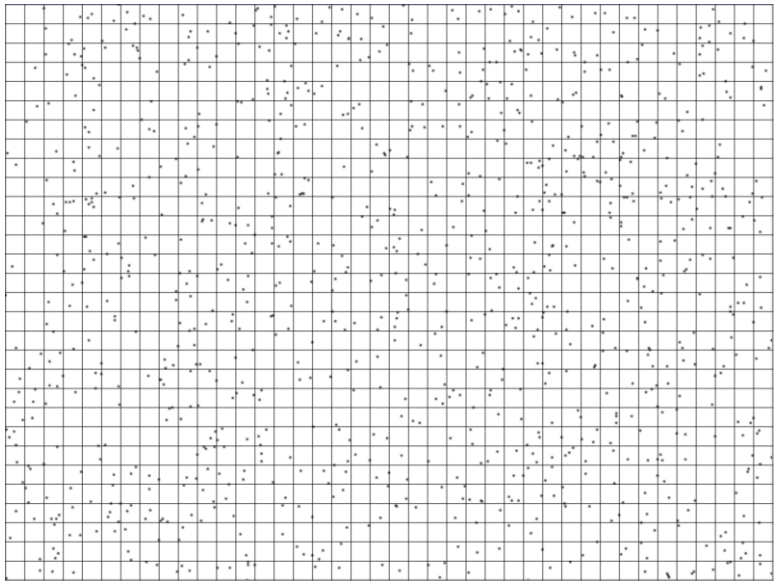
- **Coarse grid - vulnerable to sampling variance**
- **Hit/Miss Raster - vulnerable to aliasing**

Proposed alternative: TIN/Voronoi Diagram

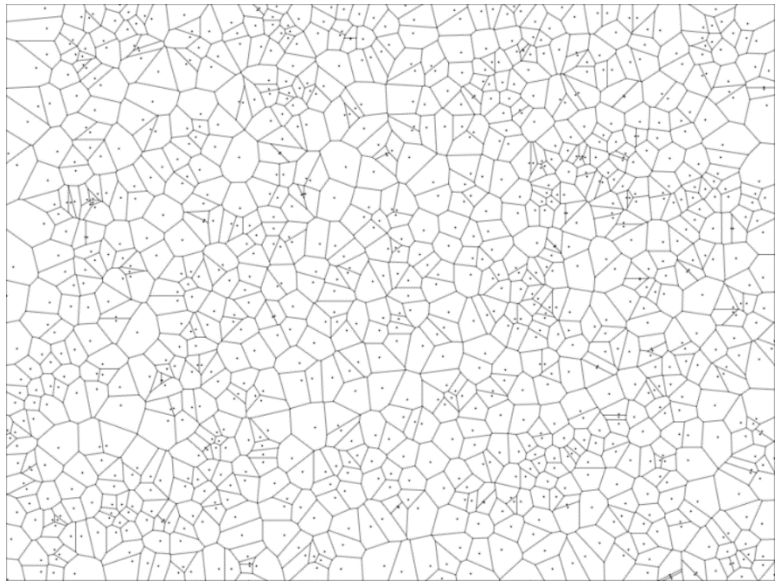
- **Scale, Rotation, and Translation invariant**
- **Directly computes area coverage per point**
- **Set ANPD to 95th Percentile of densities**
- **TIN is dual to Voronoi Diagram**
- **TIN edges are used to establish ANPS**



Raw Points: Coarse Grid

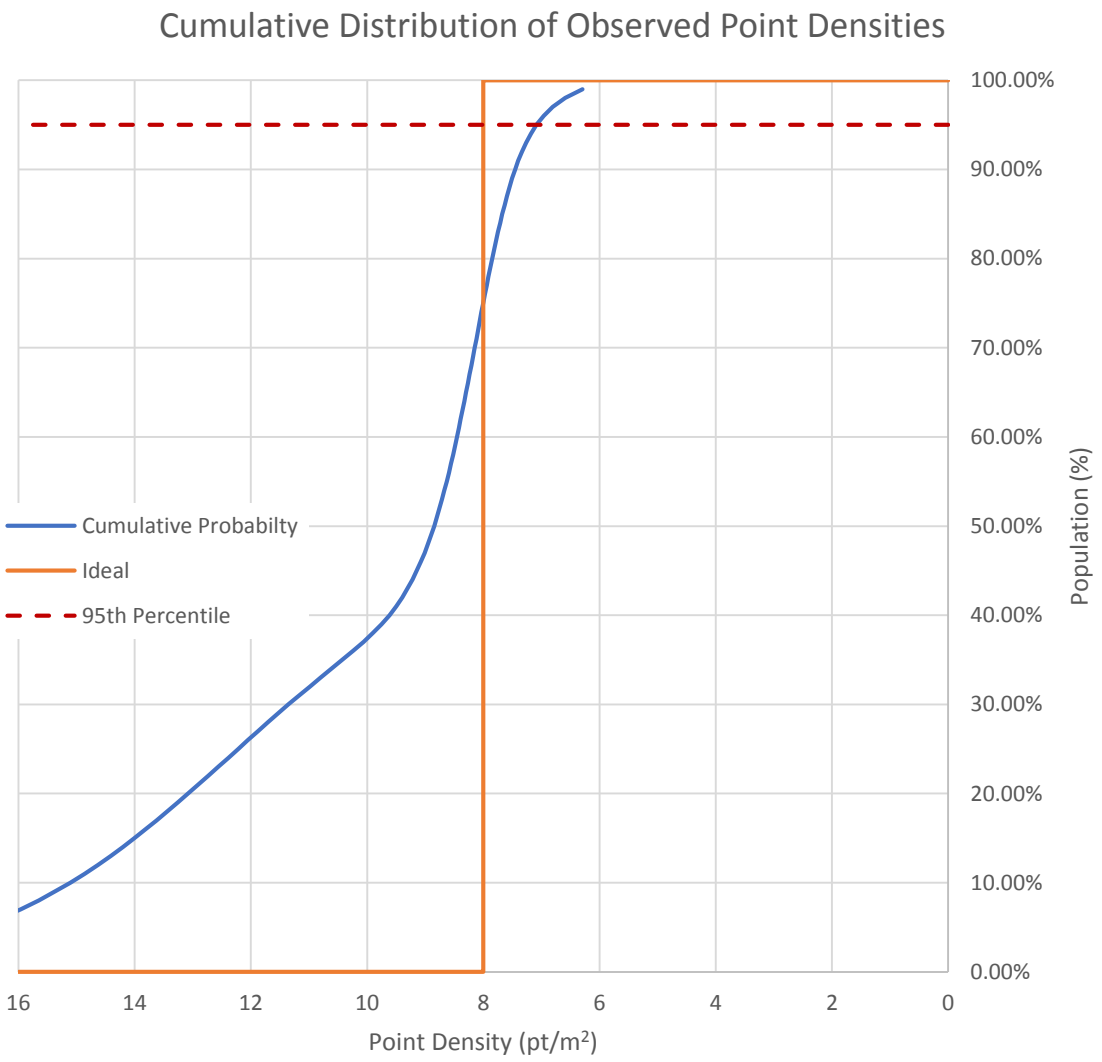


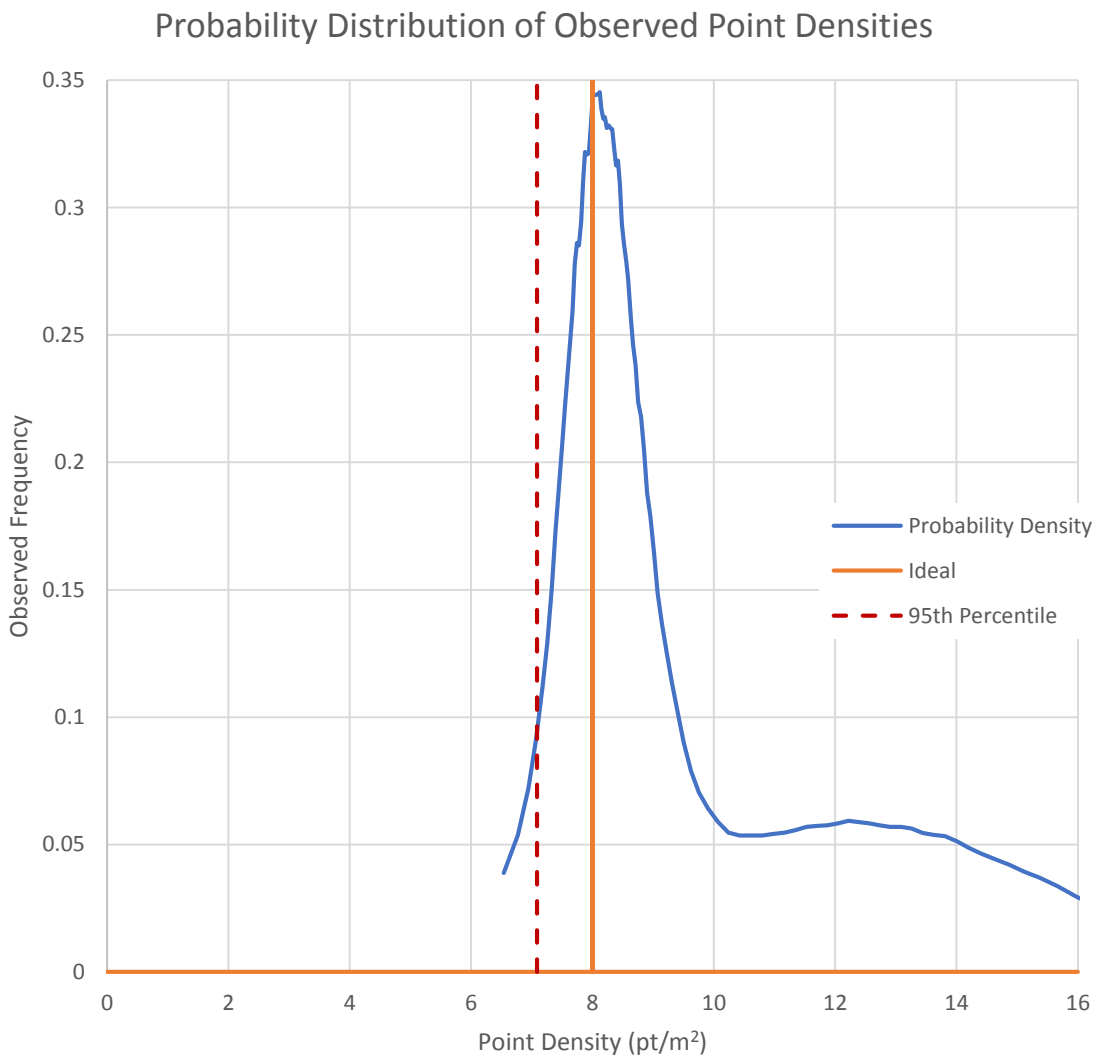
Raster: Hit/Miss, Cell Summary



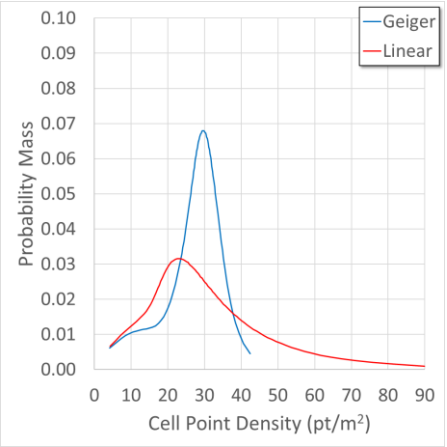
Voronoi Diagram: Cell Summary, 95th Percentile, Mode

Point Density by Voronoi Cells





Ground Classified Point Density by Voronoi Cell



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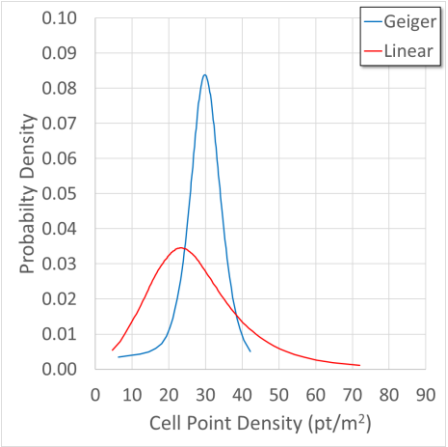

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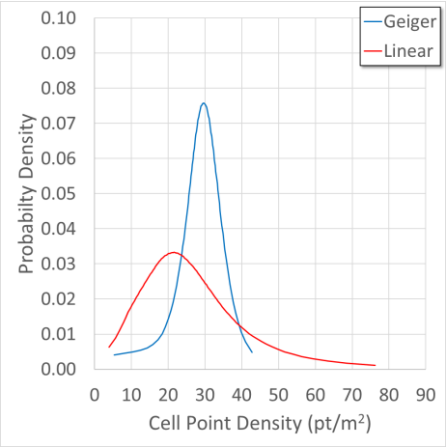

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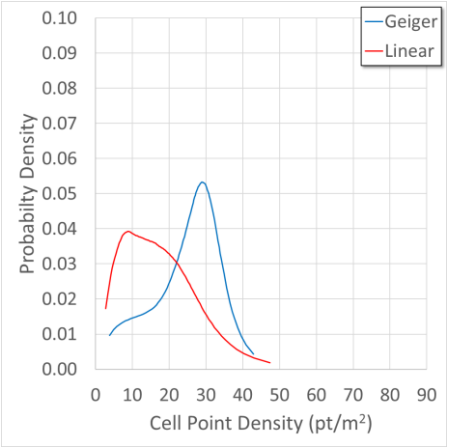

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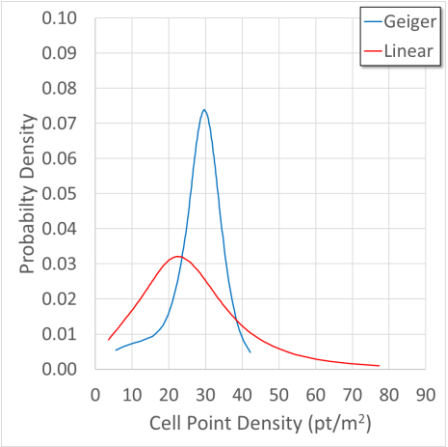

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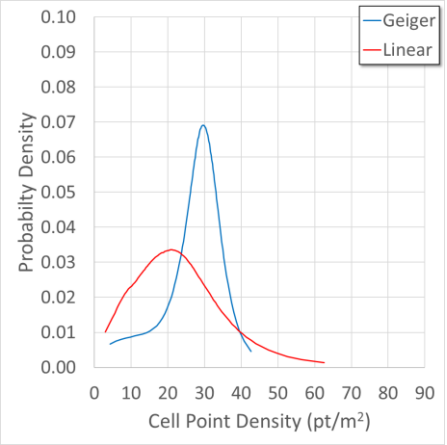

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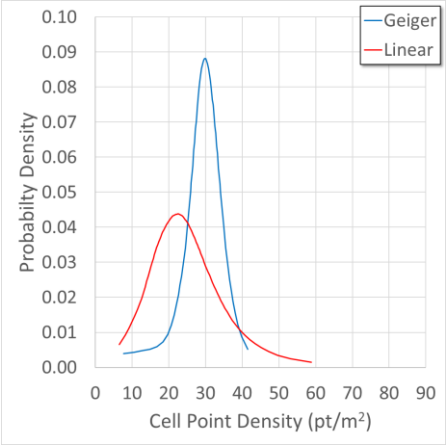

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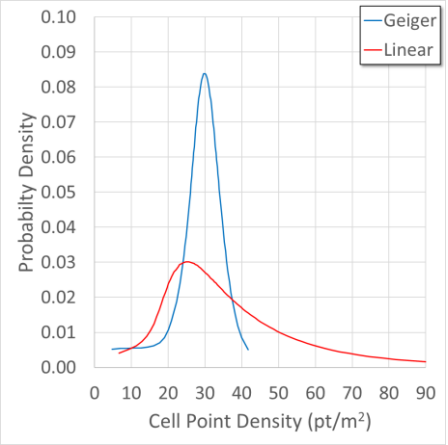

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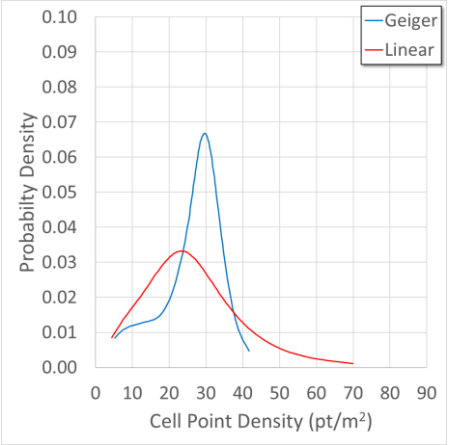

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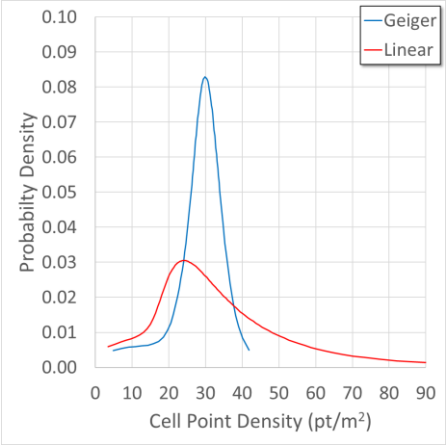


474212

Qualitative Ground Sampling Uniformity Assessment

Approach :

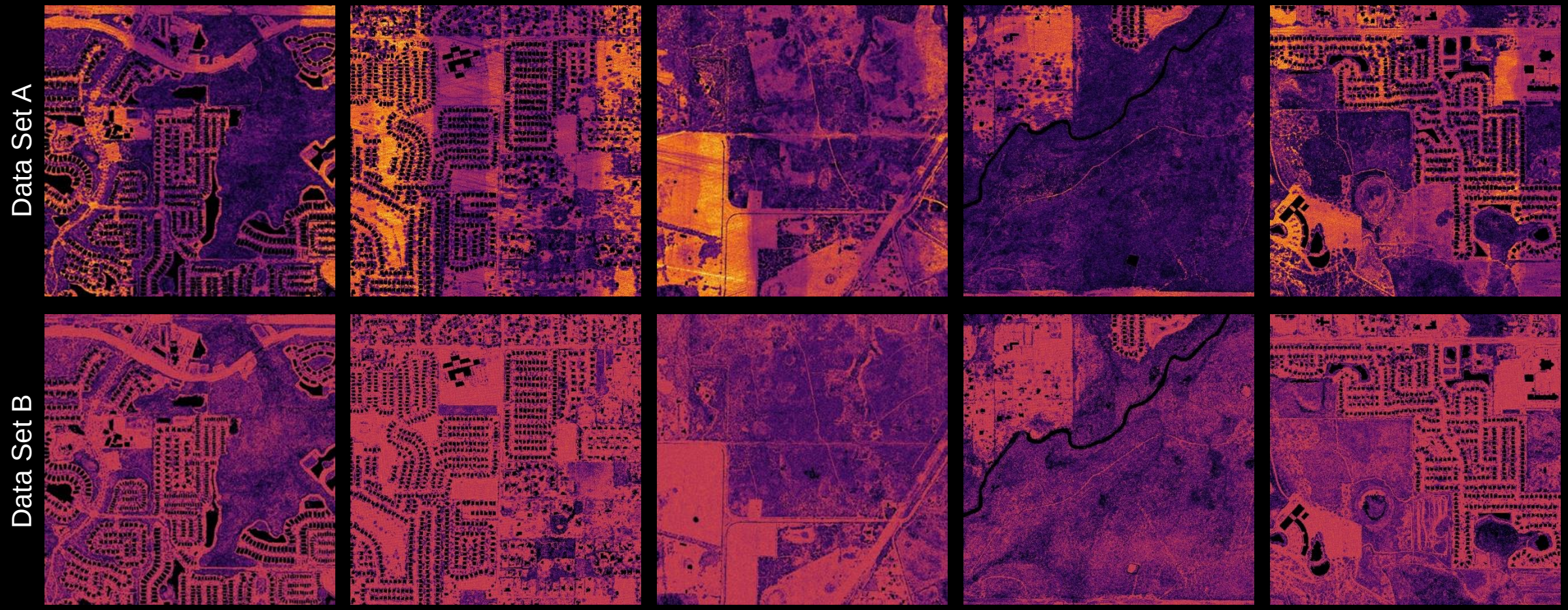
- **Filter data to only non-withheld LAS Class 2 ("Ground") points.**
- **Create a 2D rectangular raster over each tile with $2\sqrt{2}$x ANPS sampling in Easting and Northing.**
- **Compute density vs. ANPD in each raster cell (Num Points/(Cell Area*ANPD)).**

- **Colorize the raster using a heat map gradient (mnemonic – Cool is "Sparse", Hot is "Dense"):**
  - ☐: Extremely Oversampled: 2.0 × Target NPD
  - ☐: Oversampled: 1.5 × Target NPD
  - ☐: Objective: 1.0 × Target NPD
  - ☐: Median: 0.5 × Target NPD
  - ☐: Threshold: 0.2 × Target NPD

- **Any cell below Threshold is considered void (black + transparent).**

Qualitative Sampling Uniformity Comparison

Ground Density Heat Map:
Black: 0 pt/m^2
Yellow: ≥ 60.0 pt/m^2



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Qualitative FOPEN/Terrain Recovery Assessment

Approach :

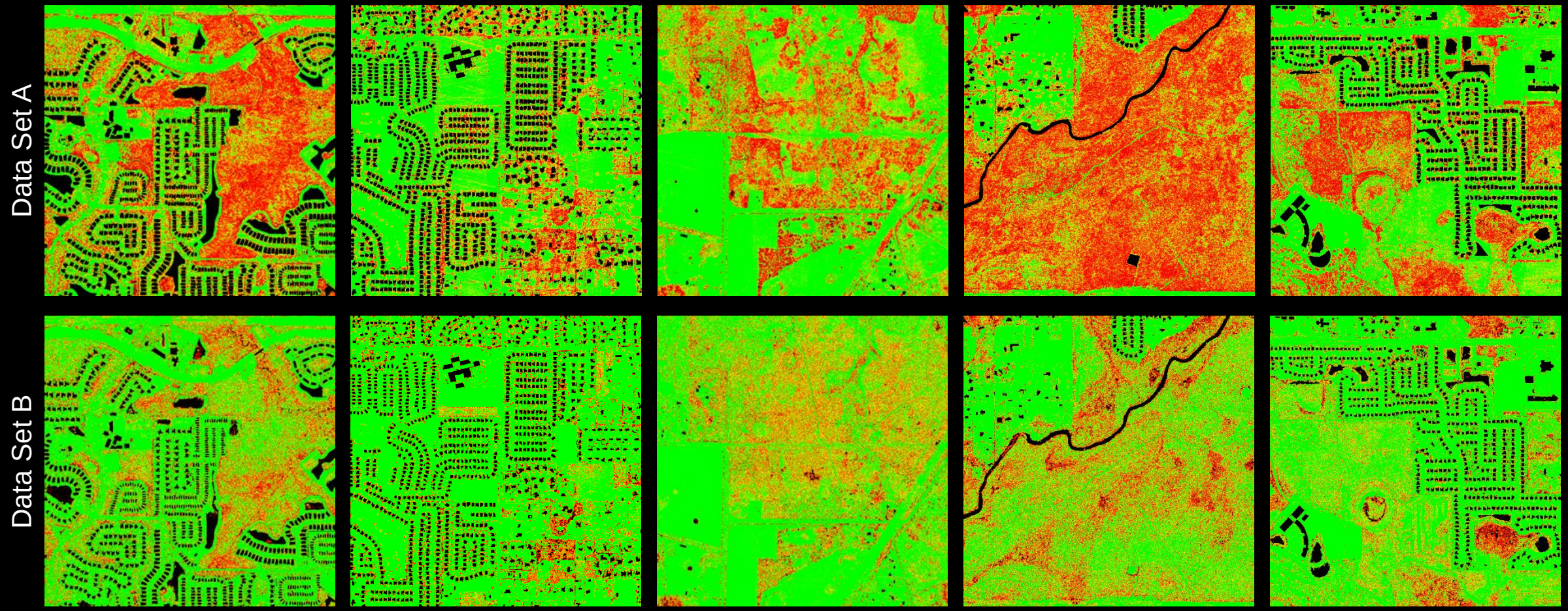
- **Filter data to only non-withheld LAS Class 2 ("Ground") points.**
- **Create a 2D rectangular raster over each tile with $2\sqrt{2}$x ANPS sampling in Easting and Northing.**
- **Compute average density in each raster cell (Num Points/Cell Area).**

- **Colorize the raster using a stoplight gradient (mnemonic – Green is "Good", Red is "Bad"):**
  - ■: Objective Performance: 100.0% × Unobscured ANPD
  - ■: Median Performance: 62.5% × Unobscured ANPD
  - ■: Threshold Performance: 25.0% × Unobscured ANPD

- **Any cell below Threshold Performance is considered void (black + transparent).**

Qualitative FOPEN Comparison

Ground Density Stoplight:
Red: ≤ 6.0 pt/m^2
Green: ≥ 24.0 pt/m^2



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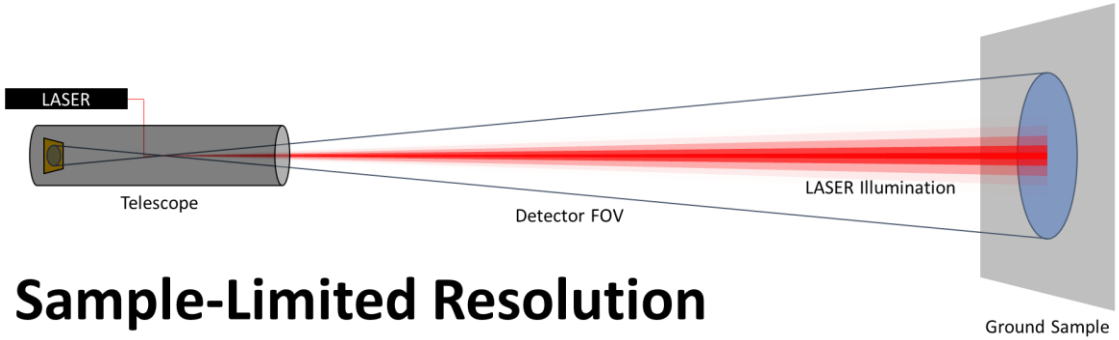
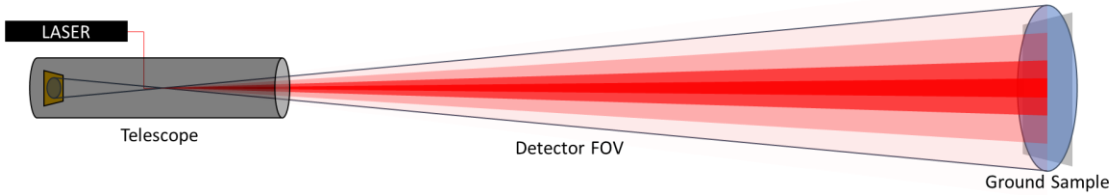
Resolution Should be a Concern for High-Res Products

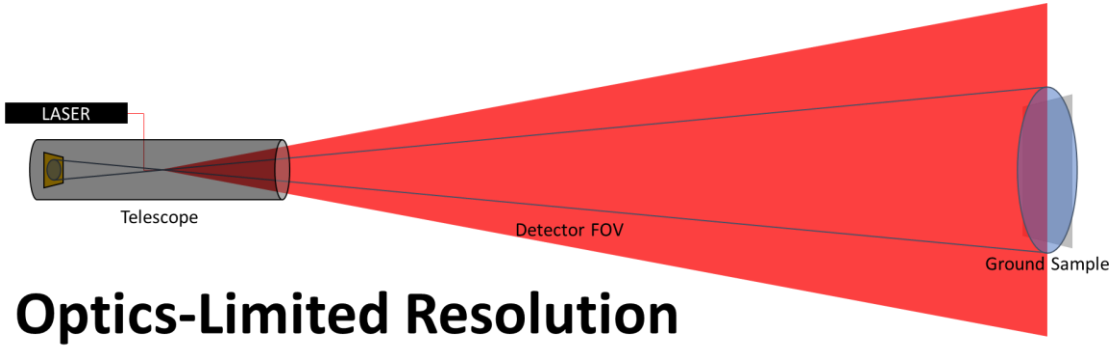
- **Sampling can only limit achievable product resolution.**
- **The maximum product resolution is 2x the ANPS**
  - Assumes that sensor resolution is finer than product sampling
  - Assumes that product is uniformly sampled
- **Resolution depends on several other factors:**
  - LASER Beam Divergence
  - Sensor Optics
  - Diffraction
  - Look Angle
  - Atmosphere



Sample-Limited Resolution



Beam-Limited Resolution



Optics-Limited Resolution

Sampling beyond supported resolution does not improve quality, just data volume.

Resolution is a Key Factor for Establishing Interpretability

- **Resolution is a key factor influencing interpretability**
- **Several criteria criteria exist to relate resolution to fitness (e.g., NIIRS and Johnson Criteria)**
- **Johnson criteria establishes a <u>50%</u> confidence interval for success.**

Example:

- **What does 8 pt/m^2 data support?**

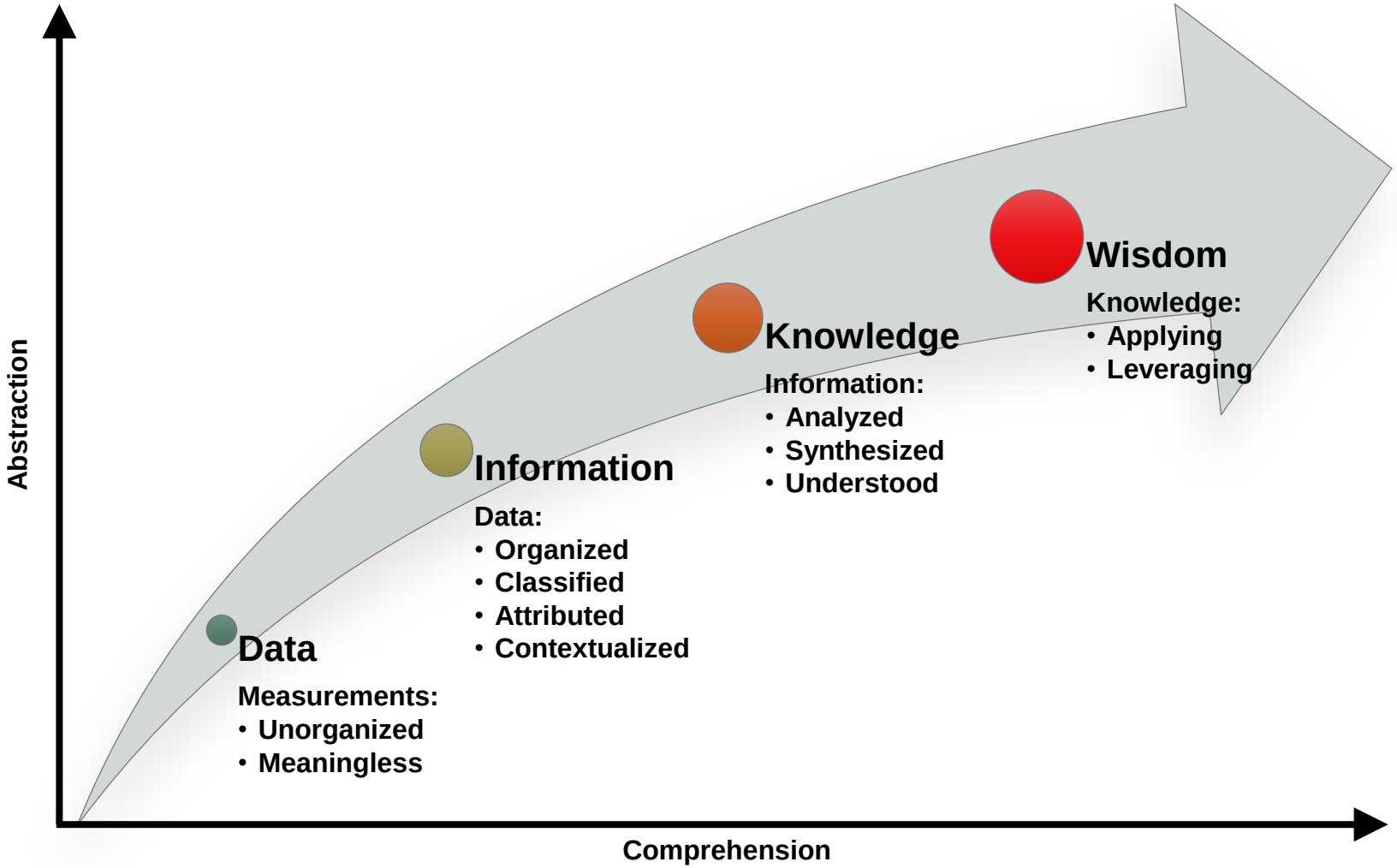
Discrimination Level	Cycles
Detection	1.0 ±0.25
Orientation	1.4 ±0.35
Recognition	4.0 ±0.80
Identification	6.4 ±1.50

Summary of Johnson Criteria

Discrimination Level	Object Dimension (m)
Detection	0.46–0.96
Orientation	0.64–1.34
Recognition	2.03–3.63
Identification	3.03–6.03

Johnson Criteria Applied to 8pt/m^2 Product

Data is Valuable Because of the Information it Provides



We need to continue evolving quality criteria to convey information content and interpretability.

QUESTIONS

Revise Consistency Assessments

Intra- and Inter-swath Assessments

- **Update cell sizing to target consistent cell population regardless of QL:**

$$Cellsize = \sqrt{N/ANPD}$$

Intraswath Assessment

- **Establish best-fit plane for each cell in AOI**
- **Compute point-to-plane distances for each point in the cell**
- **Report deviation of distances summarized for AOI**
- **Optional: Generate qualitative mask from per-cell deviations**

Interswath Assessment – Traditional Product

- **Identify how representative cell value is computed**
- **Modify raster differences to deviations**
- **Report mean deviation summarized for AOI**
- **Optional: Generate qualitative mask from per-cell deviations**

Interswath Assessment – Aggregate Product

- **Identify swaths contributing to point estimates**
- **Compute deviation of look centroids for each point**
- **Report mean deviation for points identifying as "Only" returns**
- **Optional: Generate qualitative mask from per-cell deviations**