Area_based_analysis

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2025-01-08

1. Data Loading and Preprocessing

1.1 Edge Data

1.2 Surface Data

1.3 Calibration Wafer Data

2. Surface Area Distribution Analysis

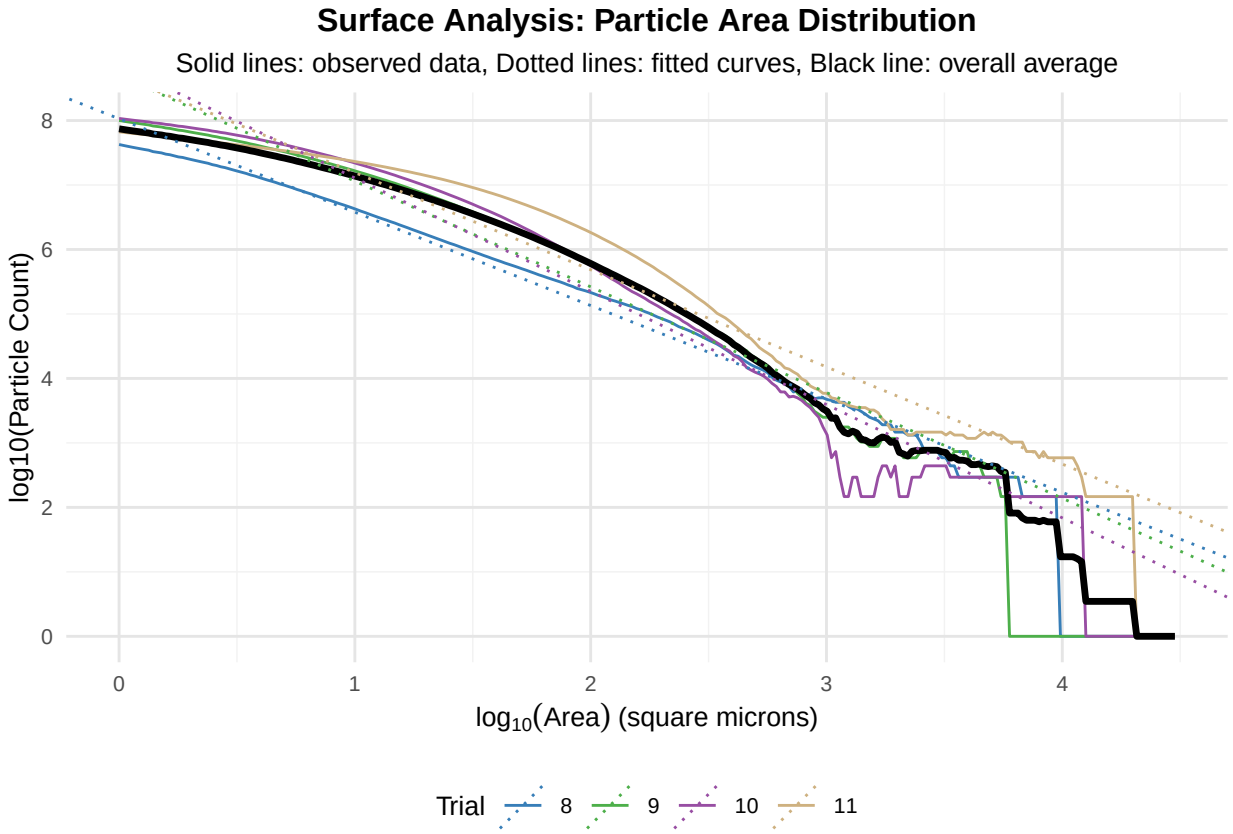
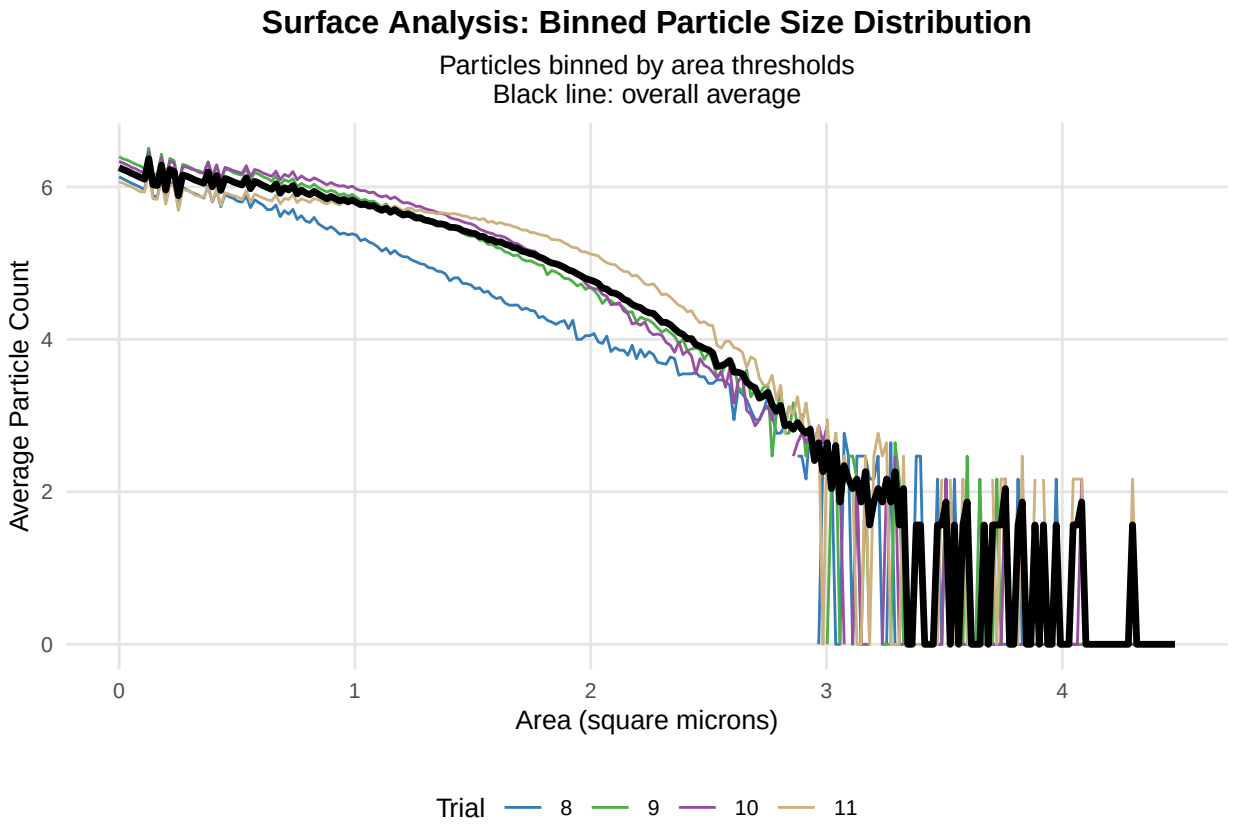


Table 1: PCL and Slope Statistics for Surface Analysis

Trial	slope	intercept	PCL
8	-1.448641	8.027225	347704.0
9	-1.639517	8.699482	202359.9
10	-1.757251	8.866243	111050.4
11	-1.507035	8.699415	592291.9


Surface Analysis: Binned Particle Size Distribution
Particles binned by area thresholds
Black line: overall average
Average Particle Count
0
2
4
6
0
1
2
3
4
Area (square microns)
Trial
8
9
10
11

3. Edge Area Distribution Analysis

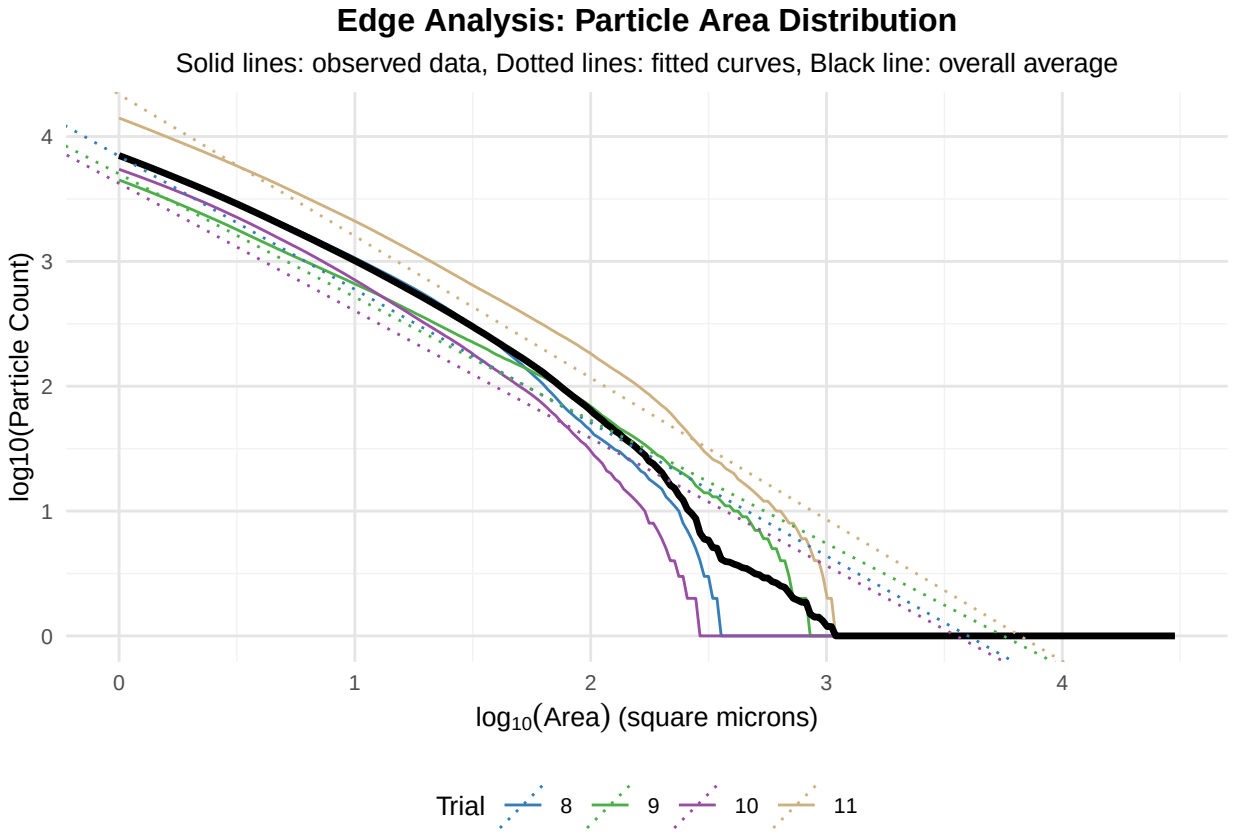
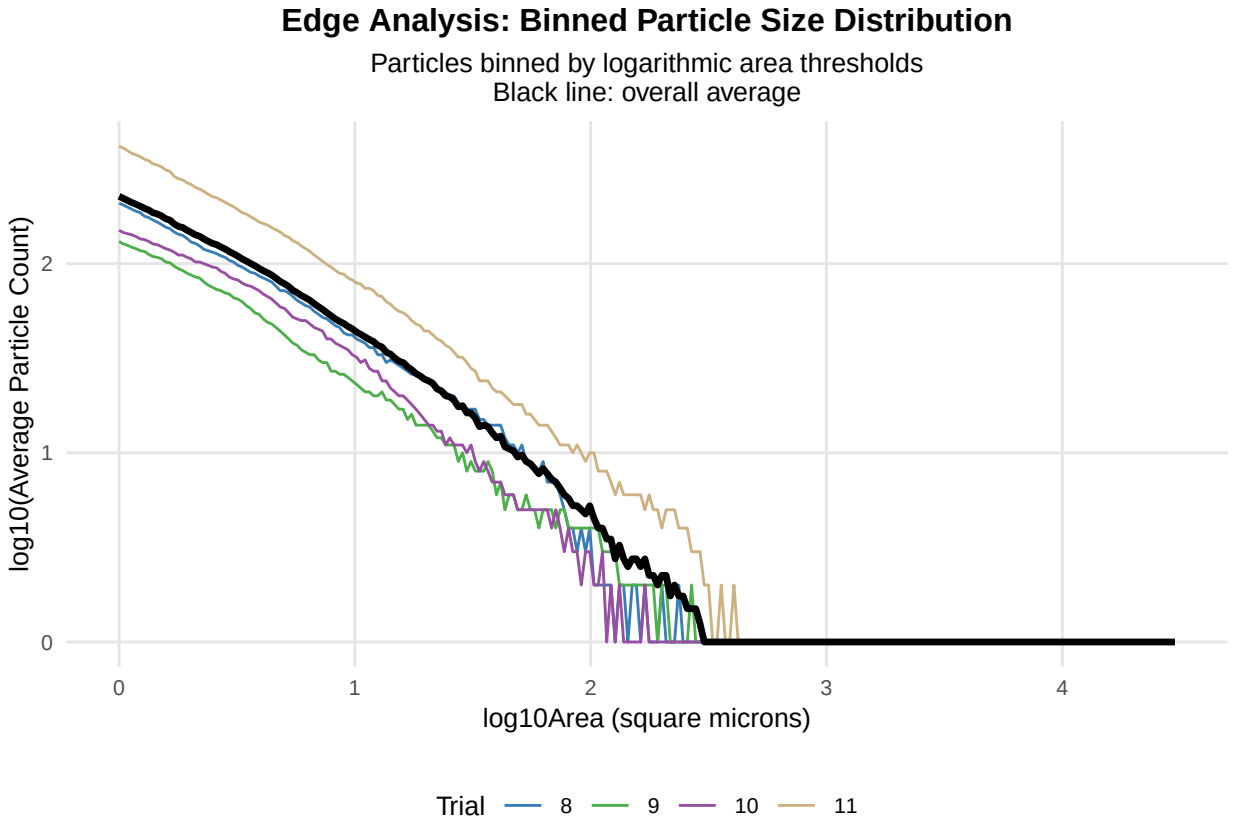


Table 2: Edge Analysis Summary Statistics

Trial	PCL	slope
8	3983.212	-1.0674936
9	5625.376	-0.9868734
10	3554.201	-1.0209514
11	6622.308	-1.1352296


Edge Analysis: Binned Particle Size Distribution
Particles binned by logarithmic area thresholds
Black line: overall average
log10(Average Particle Count)
0
1
2
0
1
2
3
4
log10Area (square microns)
Trial
8
9
10
11

4. Calibration Wafer Analysis

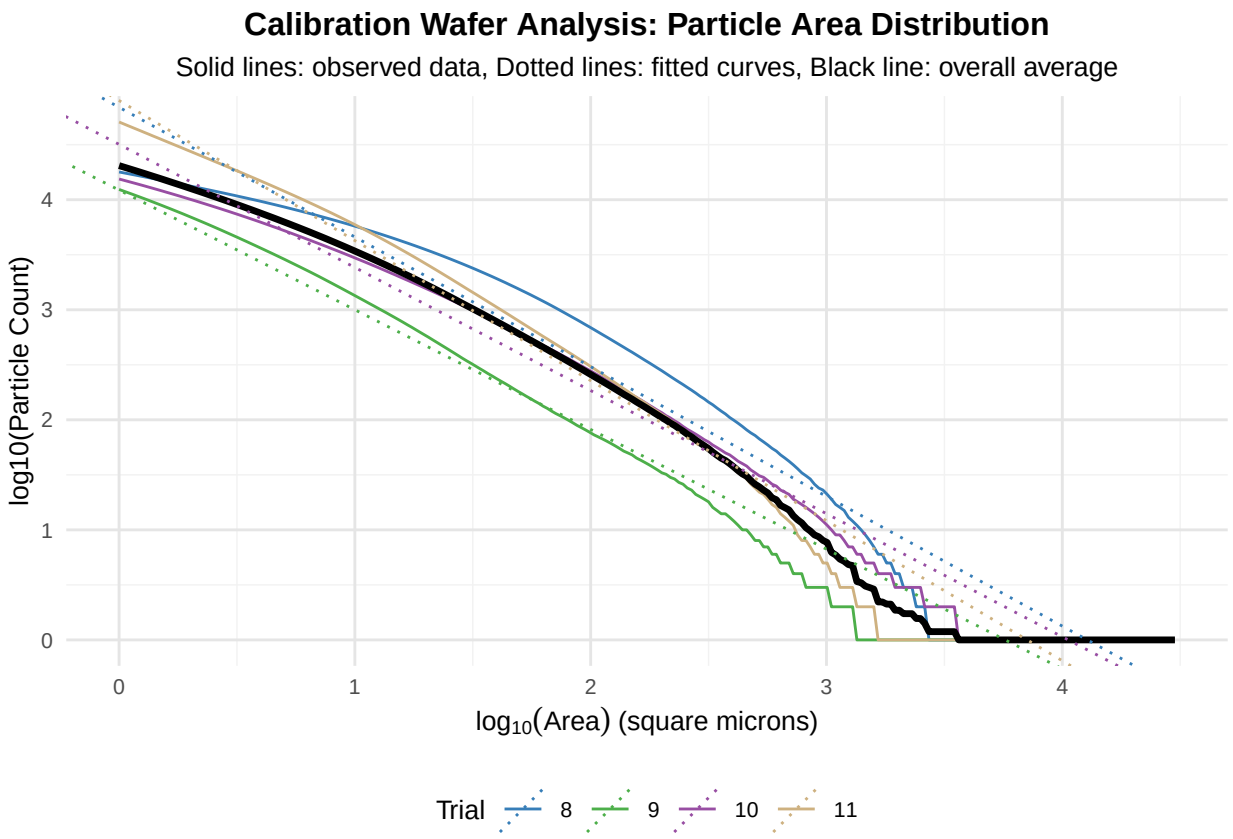
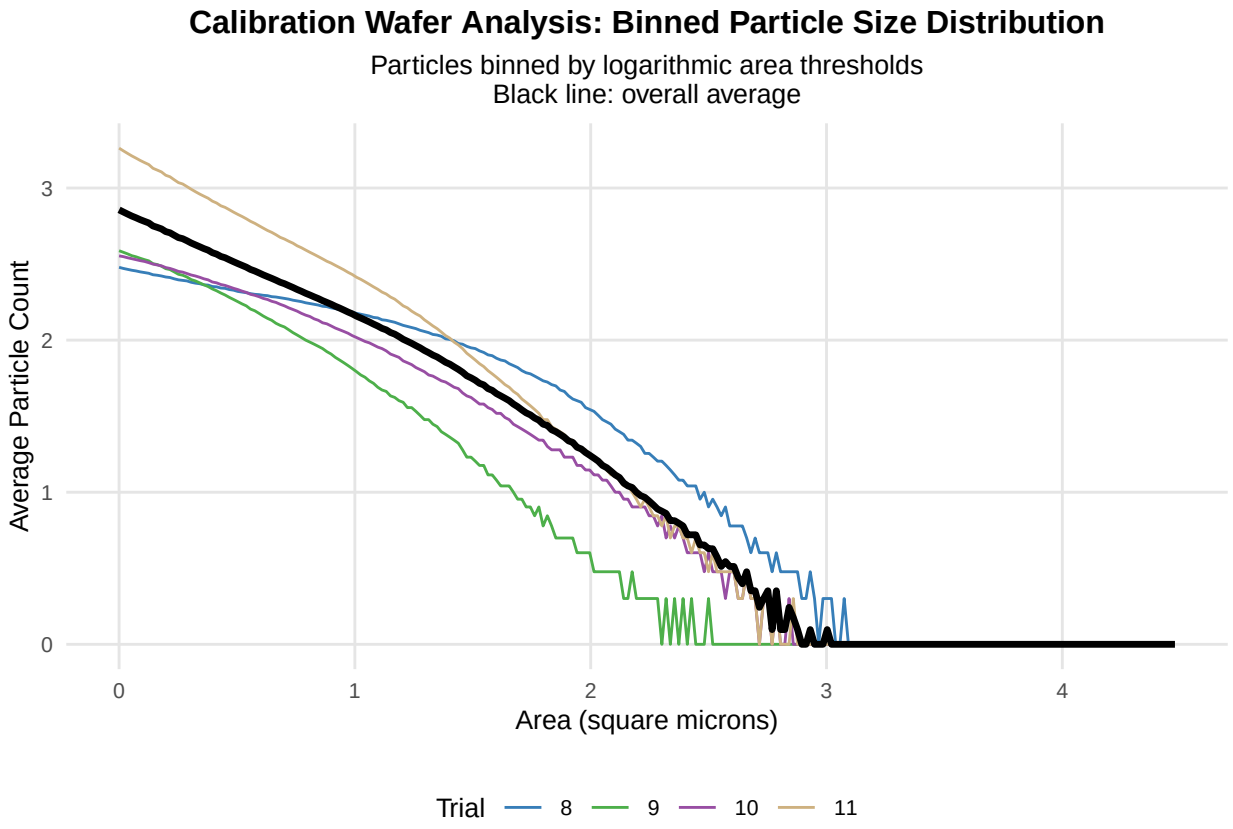


Table 3: Calibration Wafer Analysis Summary Statistics

Trial	slope	intercept	PCL
8	-1.178606	4.839839	12776.409
9	-1.087750	4.087671	5726.823
10	-1.118686	4.502859	10595.725
11	-1.272620	4.901119	7099.086


Calibration Wafer Analysis: Binned Particle Size Distribution
Particles binned by logarithmic area thresholds
Black line: overall average
Average Particle Count
0
1
2
3
0
1
2
3
4
Area (square microns)
Trial
8
9
10
11

5. Edge Model Analysis

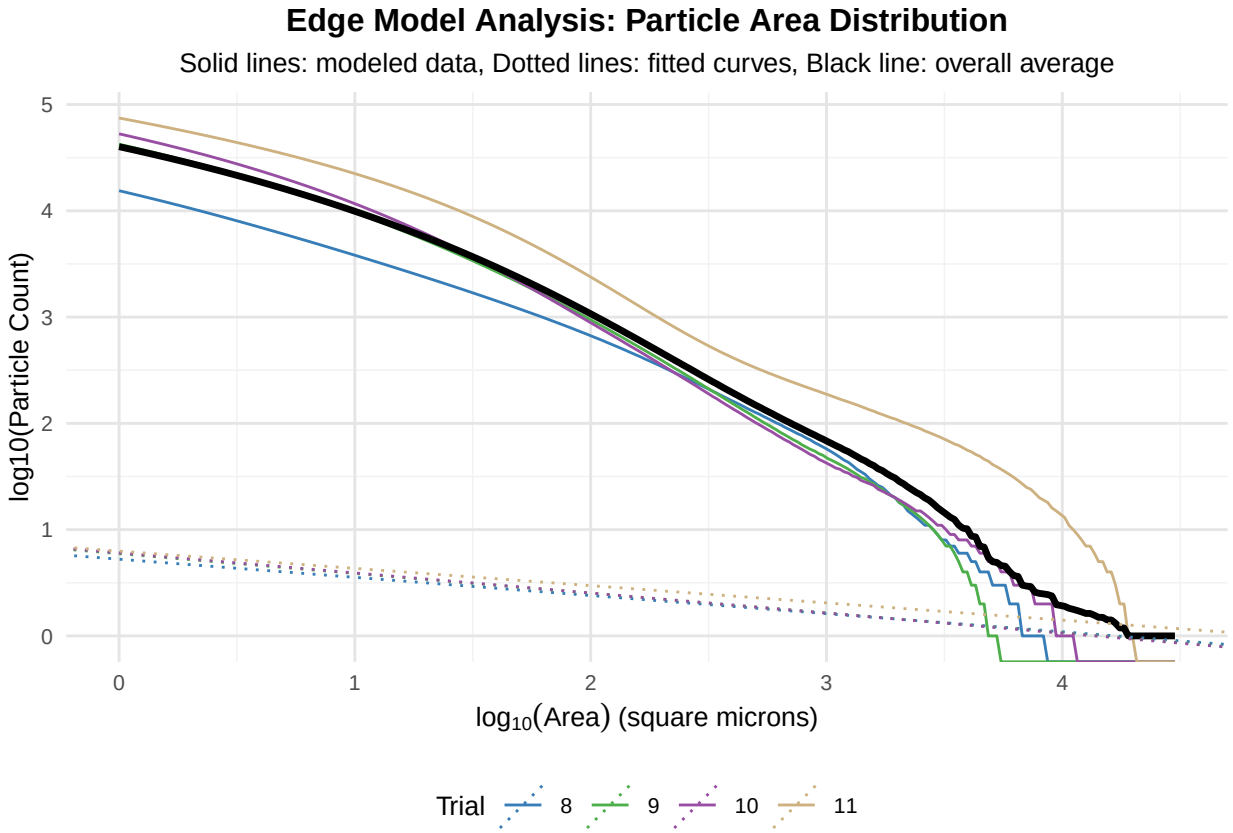
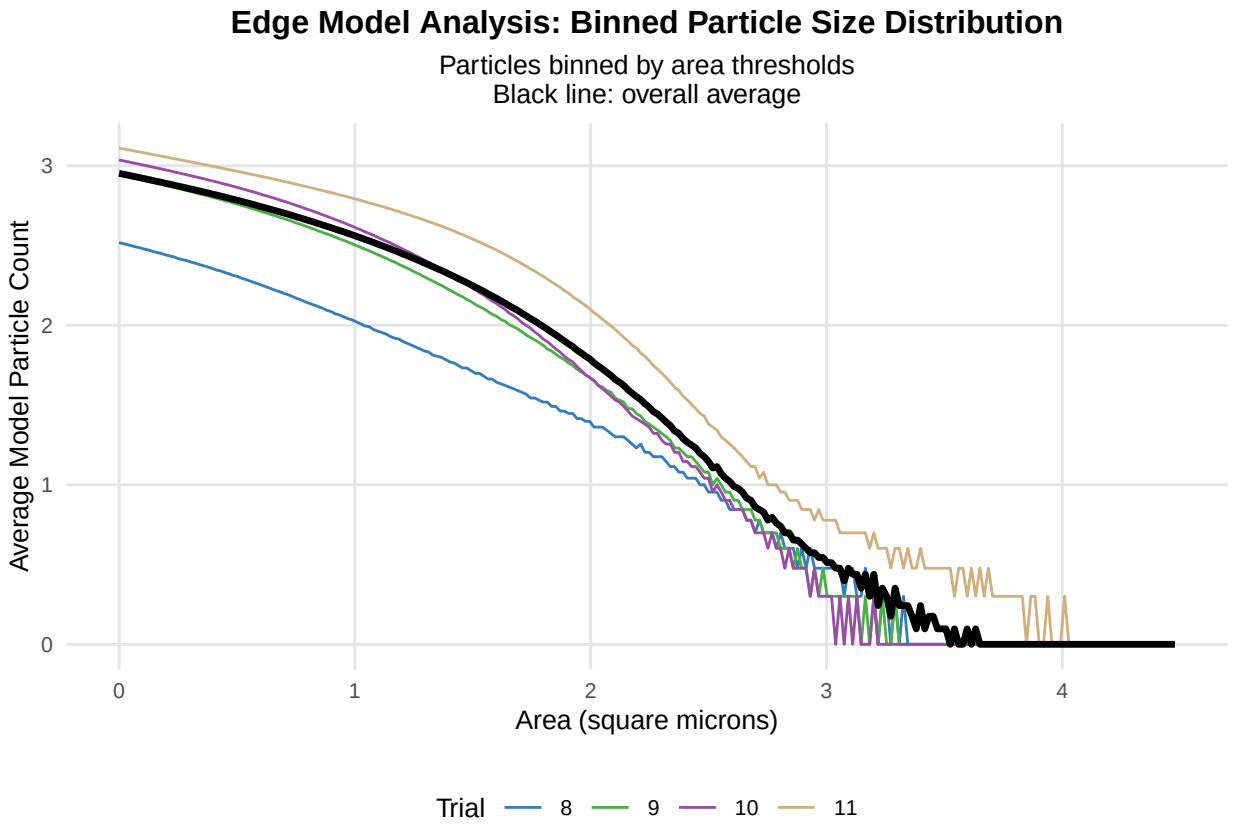
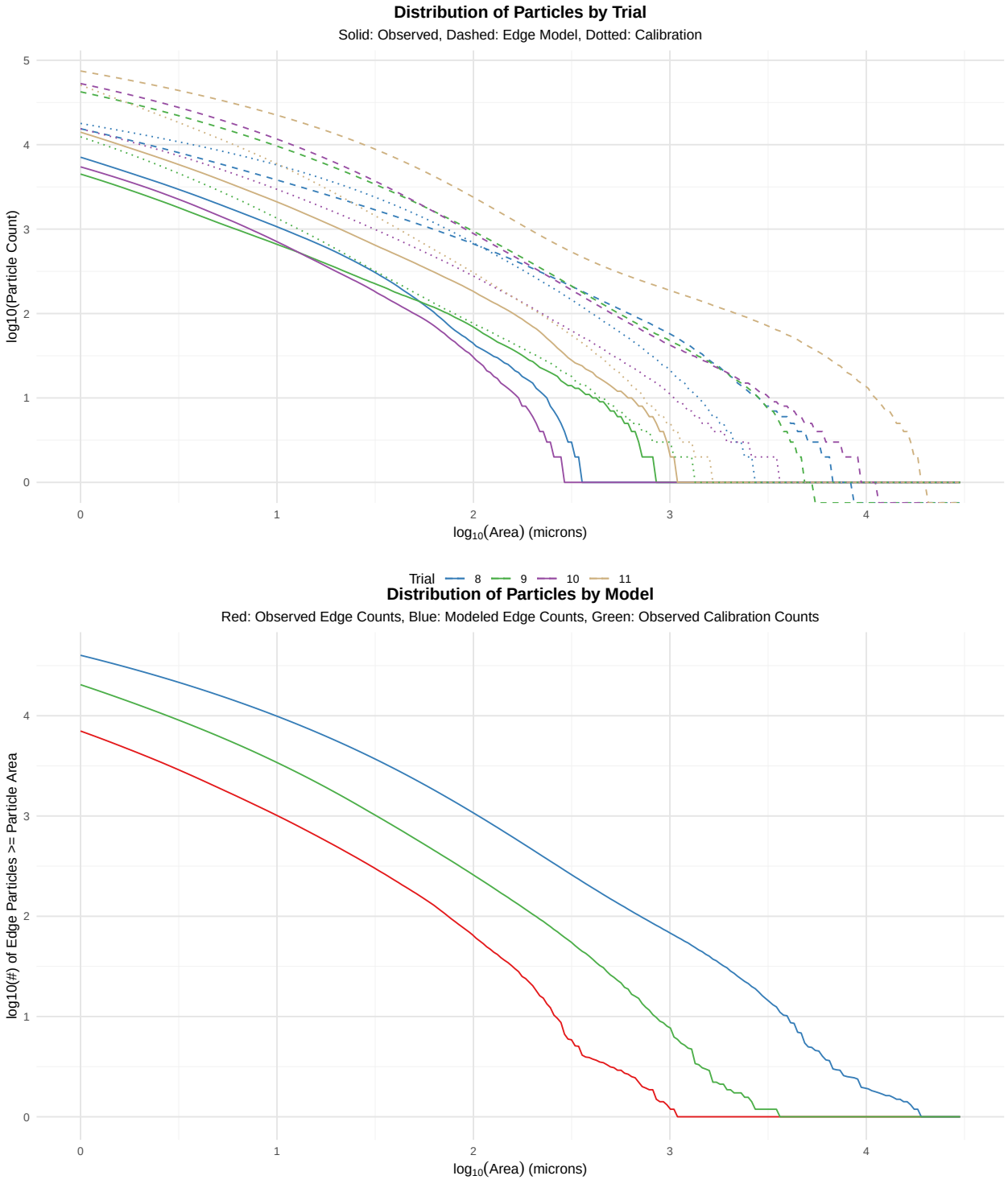


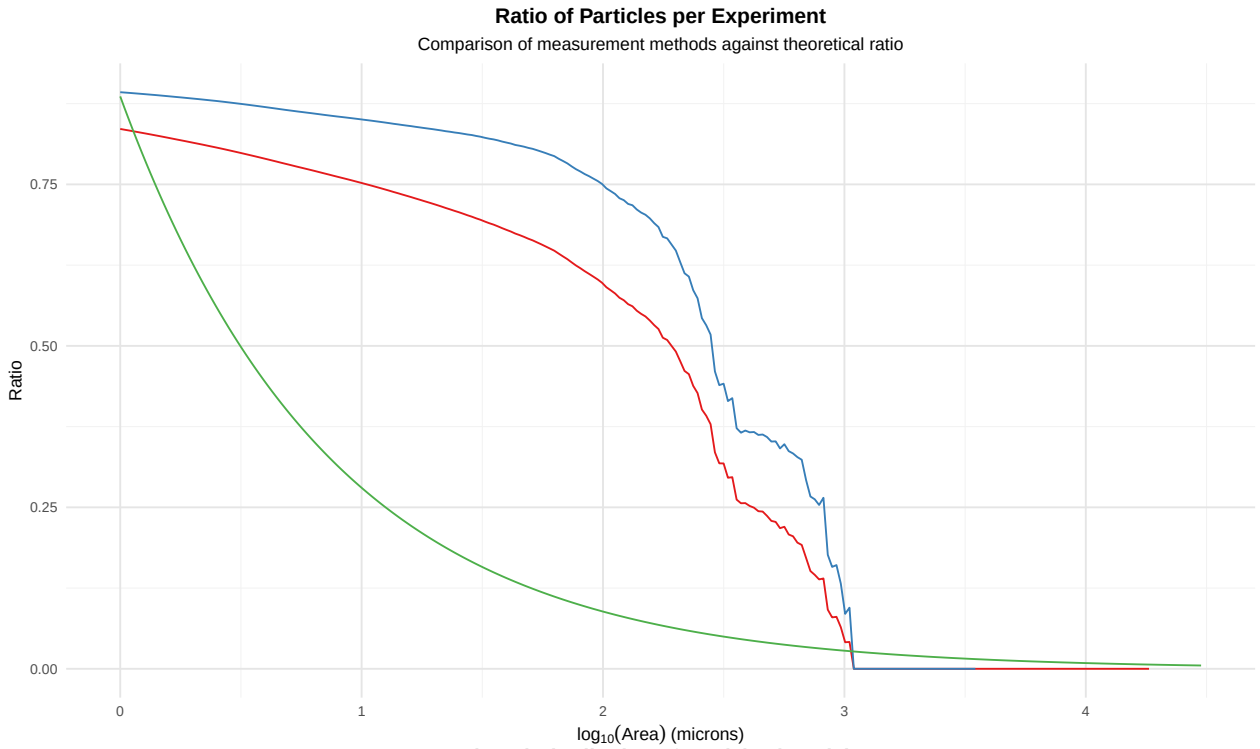
Table 4: Edge Model Analysis Summary Statistics

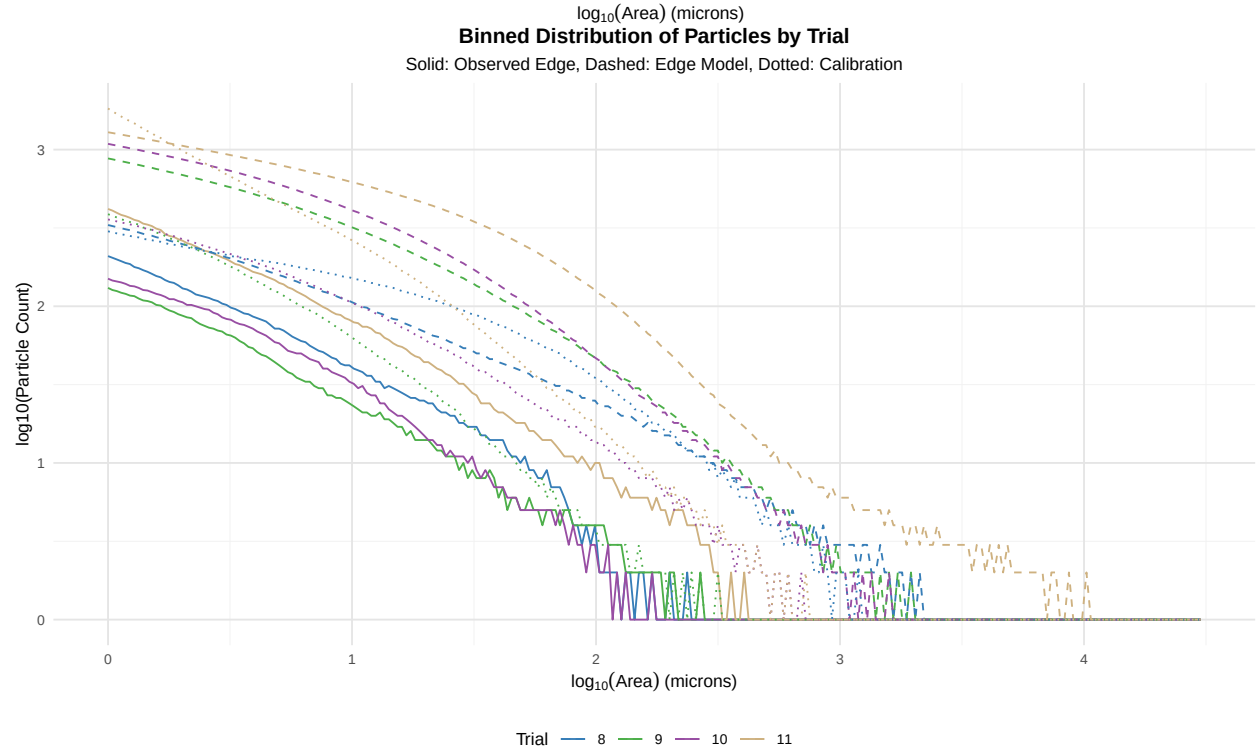
Trial	PCL	slope
8	16841.01	-0.1707850
9	14480.80	-0.1859847
10	13769.60	-0.1888140
11	81903.41	-0.1623550

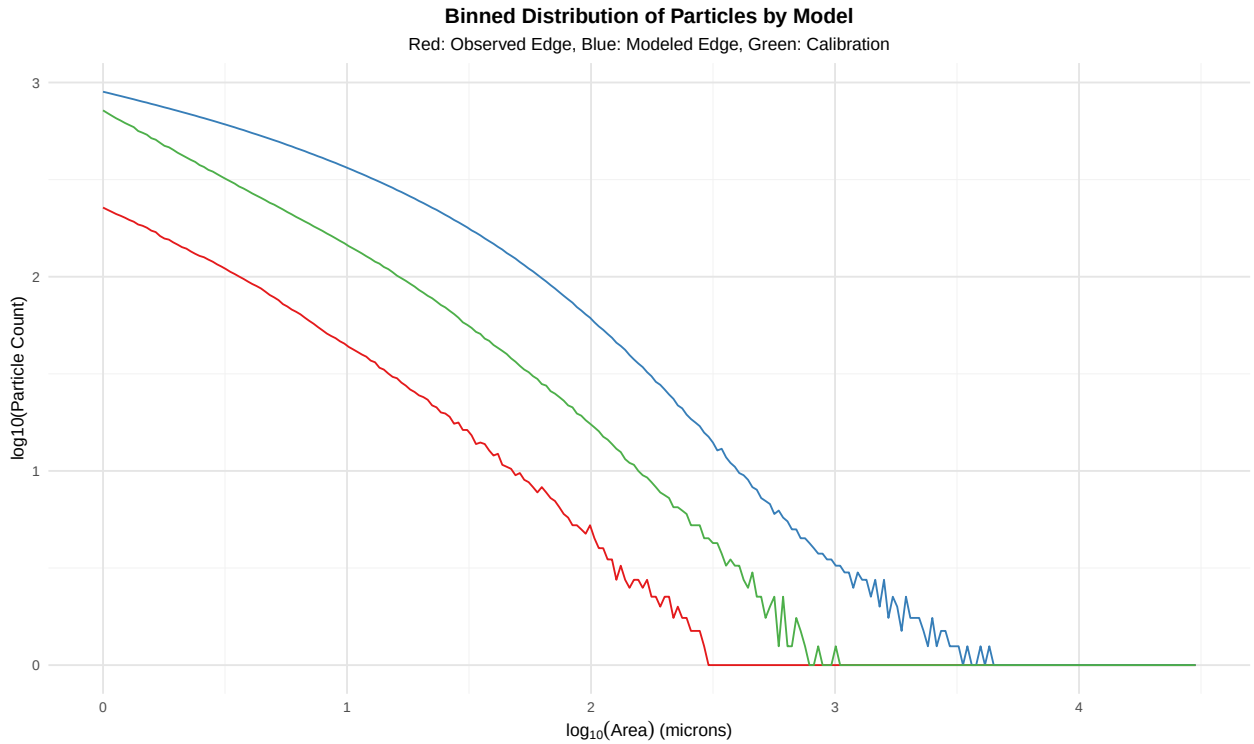

Edge Model Analysis: Binned Particle Size Distribution
Particles binned by area thresholds
Black line: overall average
Average Model Particle Count
0
1
2
3
0
1
2
3
4
Area (square microns)
Trial
8
9
10
11

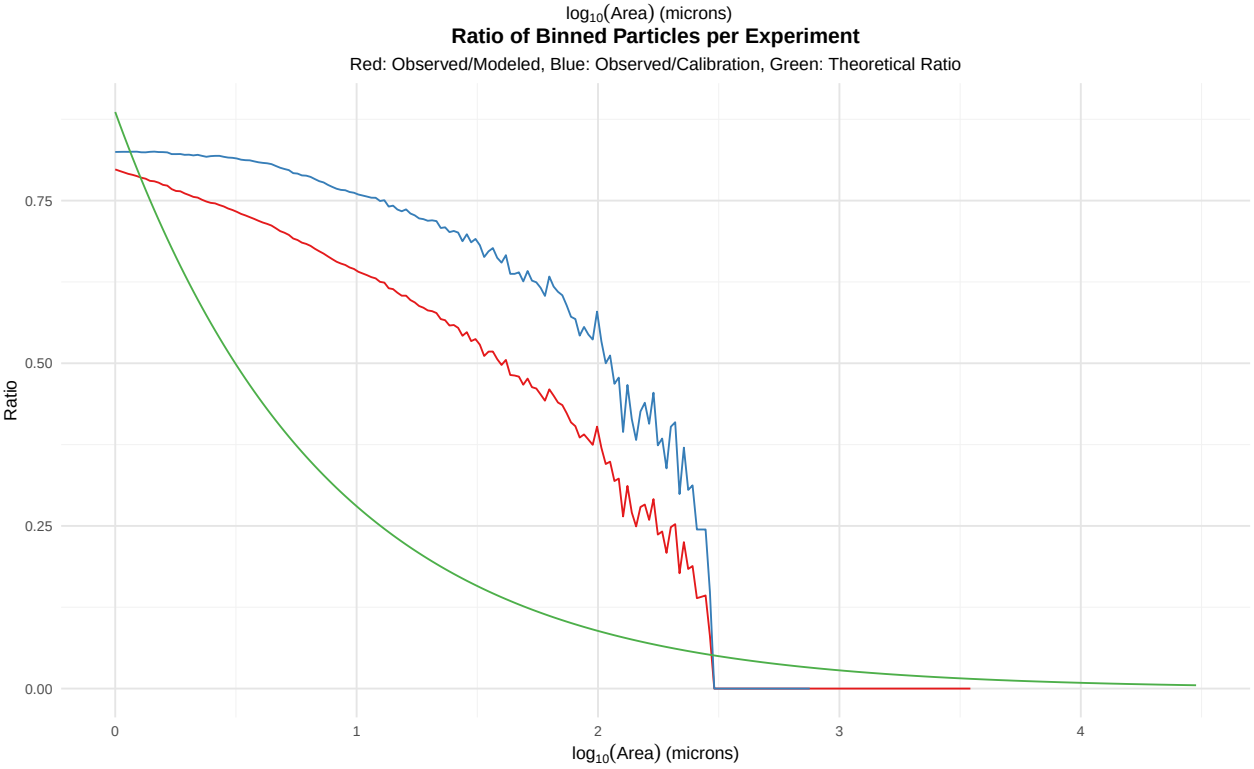
6. Combined Analysis and Comparison

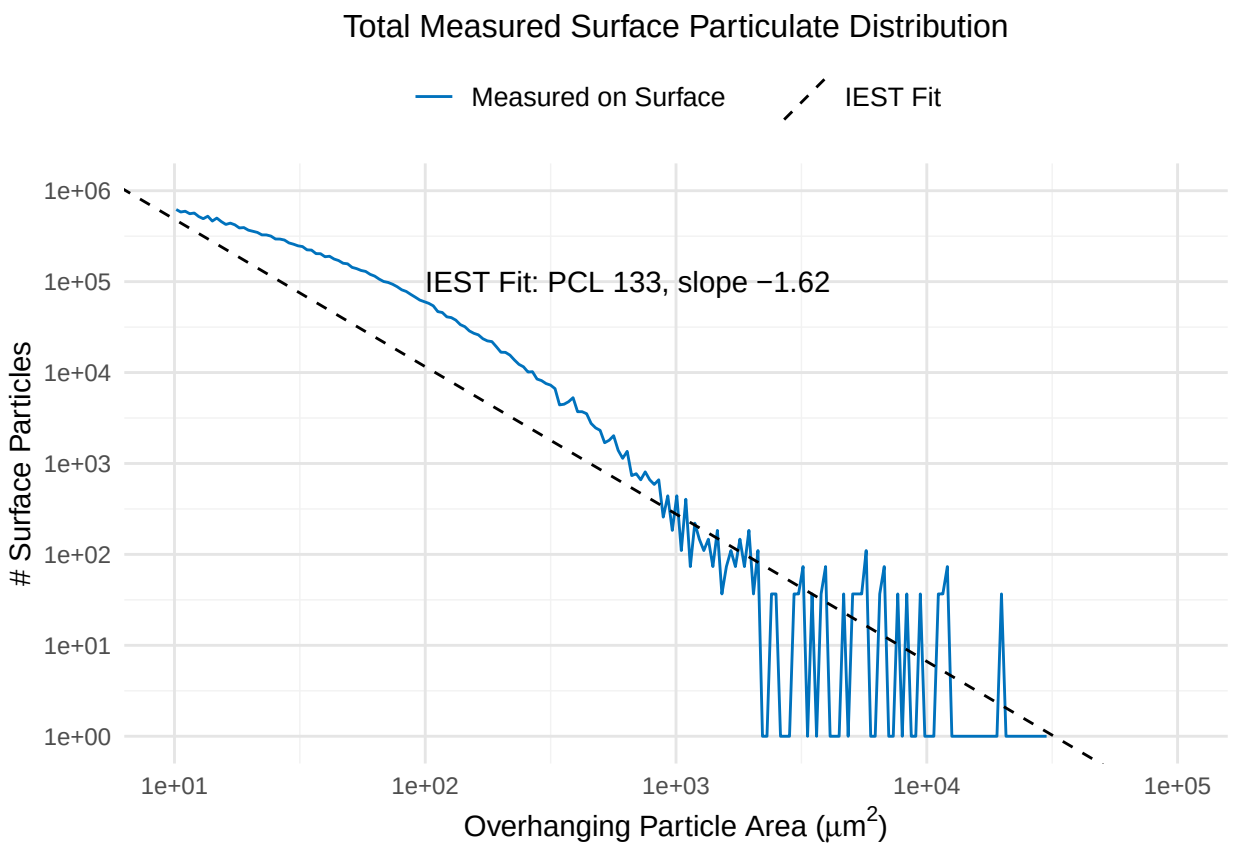


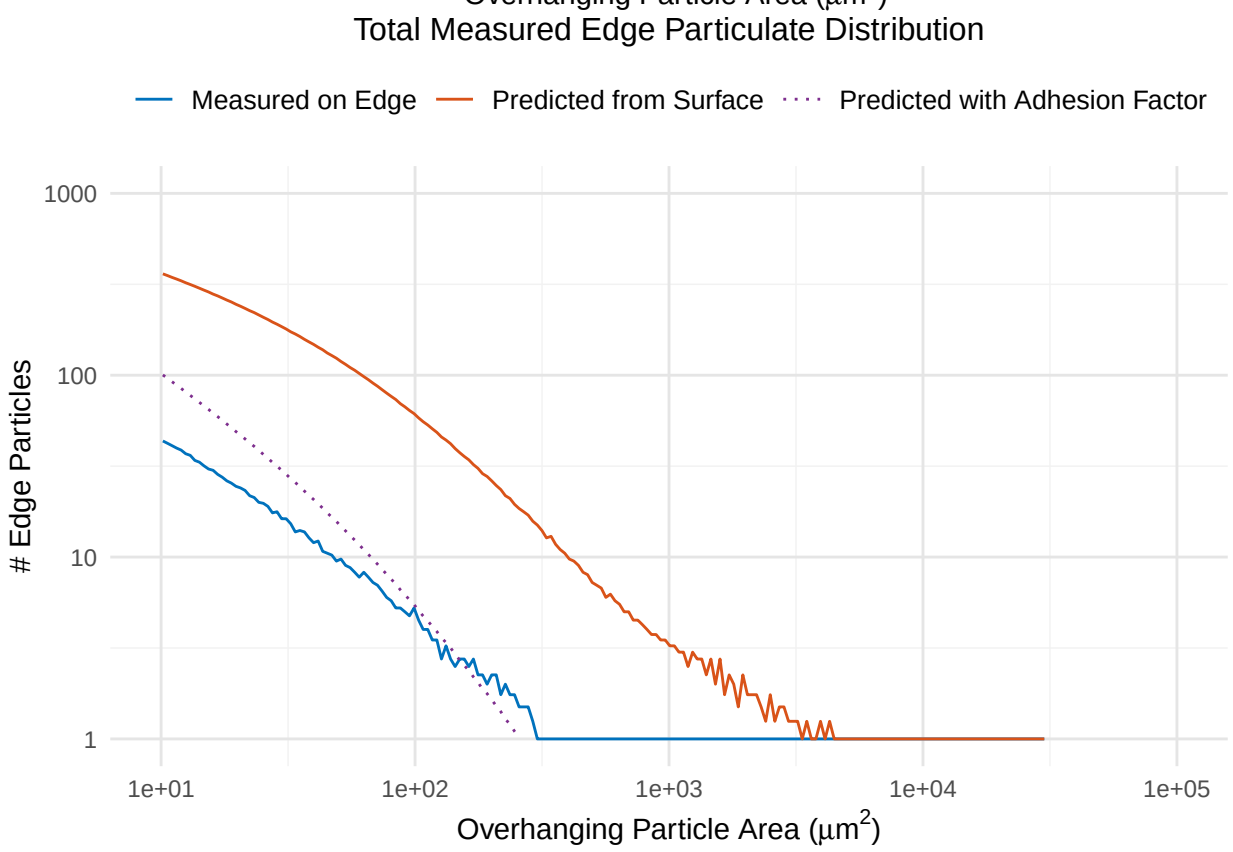

Ratio of Particles per Experiment
Comparison of measurement methods against theoretical ratio
Ratio
0.75
0.50
0.25
0.00
0
1
2
3
4
log10(Area) (microns)

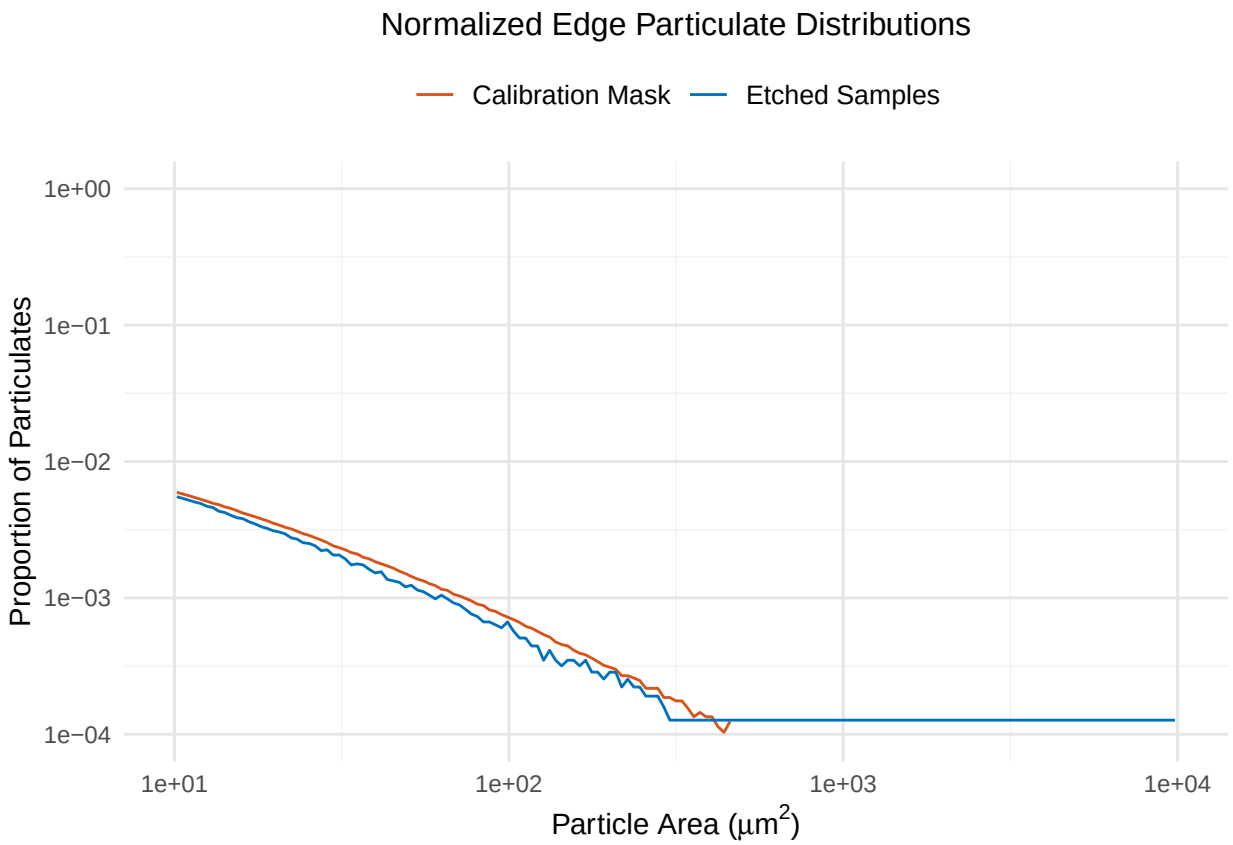

Binned Distribution of Particles by Trial
Solid: Observed Edge, Dashed: Edge Model, Dotted: Calibration
log10(Particle Count)
3
2
1
0
0
1
2
3
4
log10(Area) (microns)
Trial
8
9
10
11


Binned Distribution of Particles by Model
Red: Observed Edge, Blue: Modeled Edge, Green: Calibration
log10(Particle Count)
log10(Area) (microns)


Ratio of Binned Particles per Experiment
Red: Observed/Modeled, Blue: Observed/Calibration, Green: Theoretical Ratio
Ratio
log10(Area) (microns)


Total Measured Surface Particulate Distribution
Measured on Surface
IEST Fit
IEST Fit: PCL 133, slope −1.62
Surface Particles
1e+06
1e+05
1e+04
1e+03
1e+02
1e+01
1e+00
1e+01
1e+02
1e+03
1e+04
1e+05
Overhanging Particle Area (µm2)


Total Measured Edge Particulate Distribution
Measured on Edge
Predicted from Surface
Predicted with Adhesion Factor
Edge Particles
1000
100
10
1
1e+01
1e+02
1e+03
1e+04
1e+05
Overhanging Particle Area (µm2)


Normalized Edge Particulate Distributions
Calibration Mask
Etched Samples
Proportion of Particulates
1e+00
1e−01
1e−02
1e−03
1e−04
1e+01
1e+02
1e+03
1e+04
Particle Area (µm²)

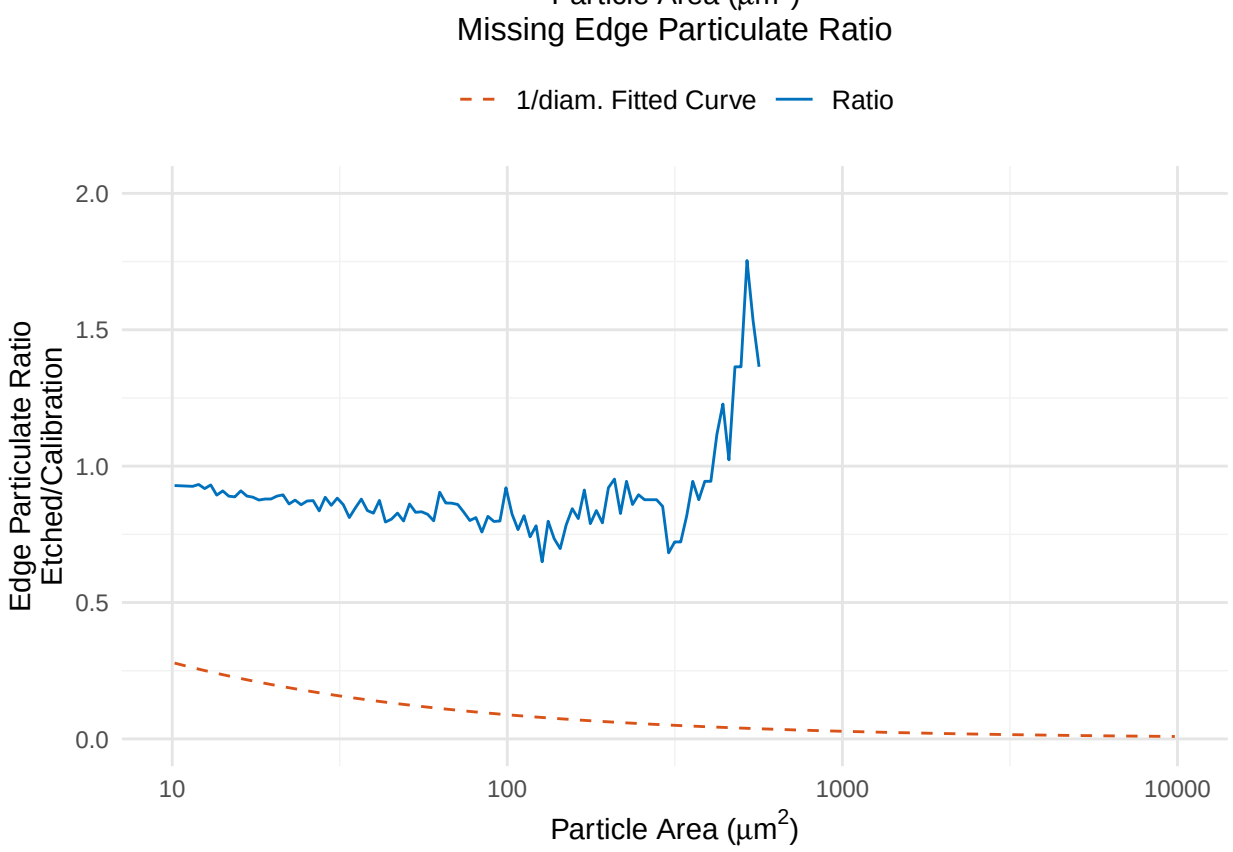

Missing Edge Particulate Ratio
1/diam. Fitted Curve
Ratio
Edge Particulate Ratio
Etched/Calibration
2.0
1.5
1.0
0.5
0.0
10
100
1000
10000
Particle Area (µm²)

Figure 15: Etched Samples Comparison

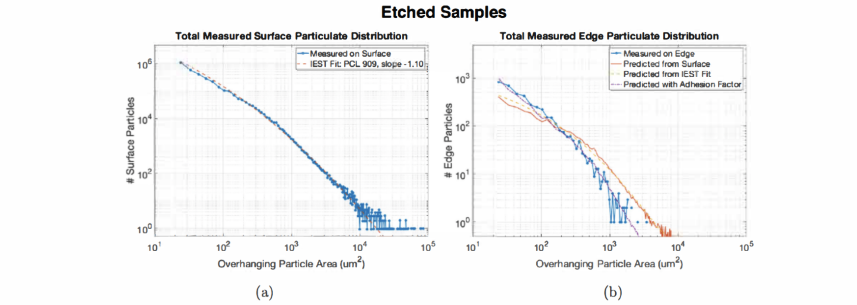


Figure 15. (a) Total surface particulate distribution detected on the etched samples, and a fit to the IEST distribution. (b) Total edge particulate distribution detected on the etched samples, compared to predictions from the surface.

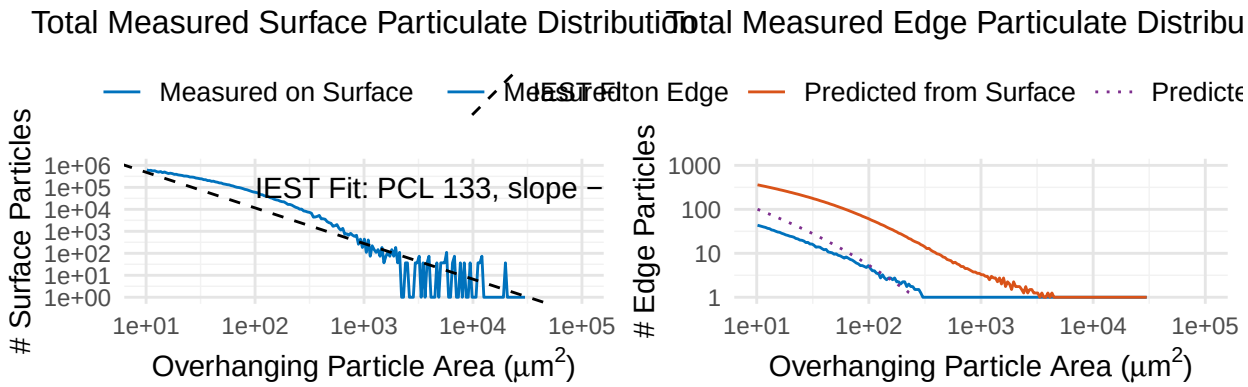


Figure 16: Comparative Analysis Comparison

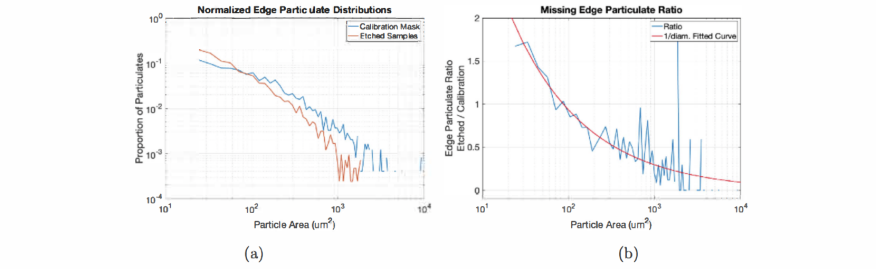
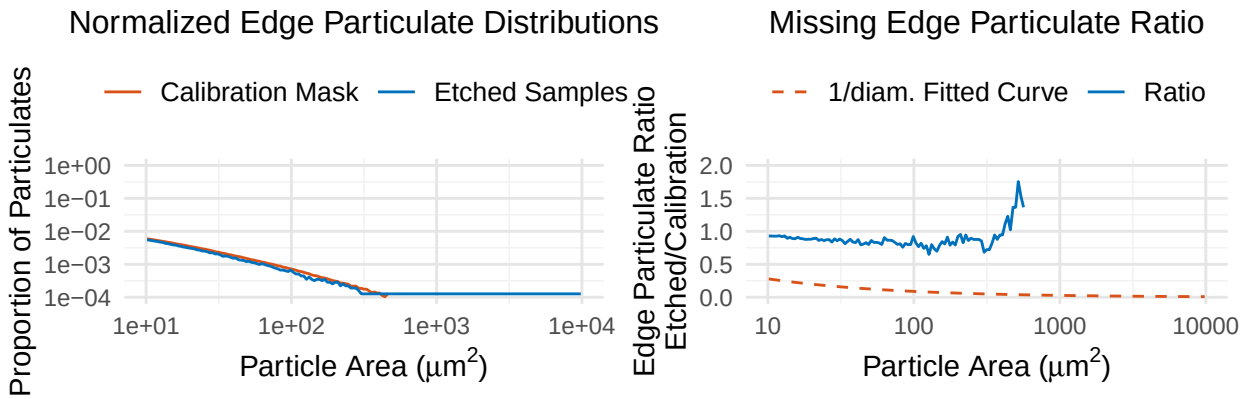


Figure 16. (a) Normalized edge particulate distributions for the calibration mask and the etched samples. Each distribution has been normalized based on the total number of edge particulates. (b) Ratio of the normalized edge distributions, representing the portion of particulates missing from the etched samples. The ratio decreases with particulate size inversely proportional to the particle diameter.



7. Statistical Analysis of Trial Differences

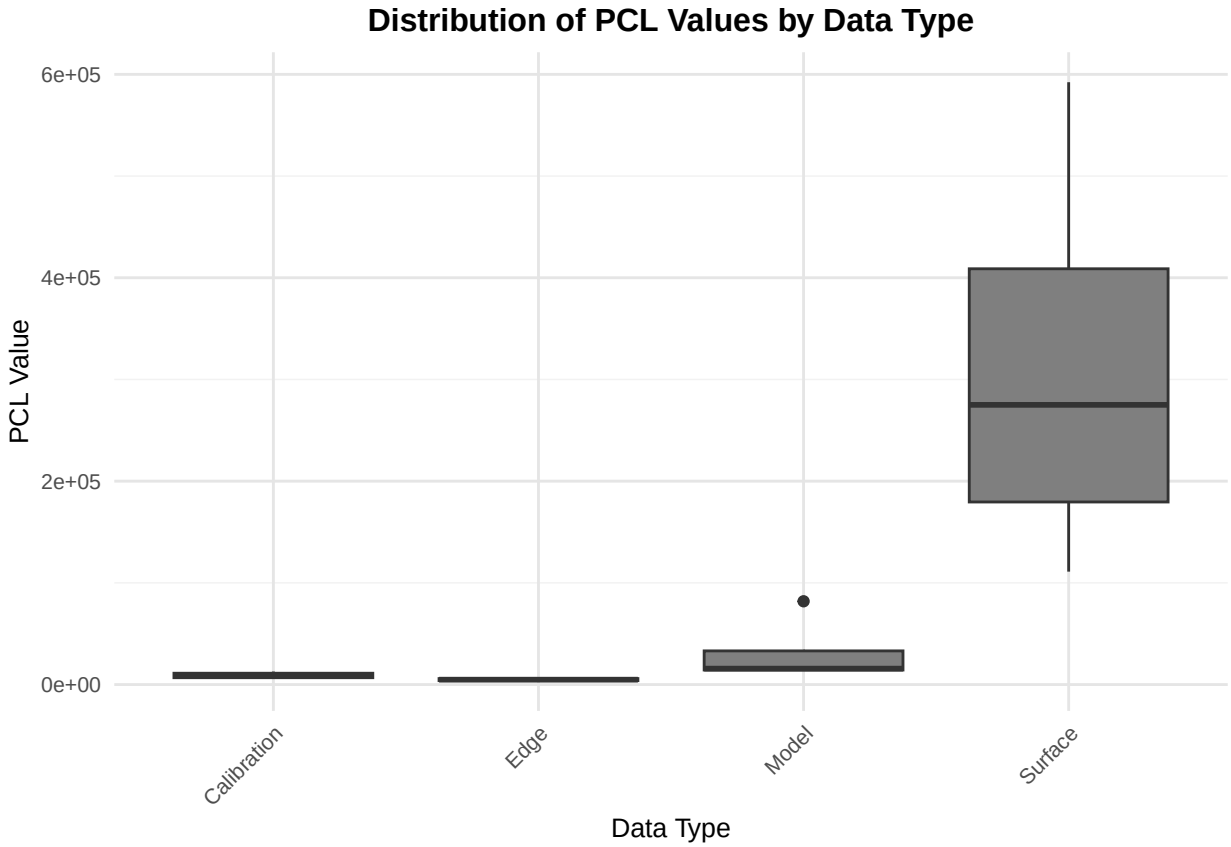
Table 5: Summary Statistics by Data Type

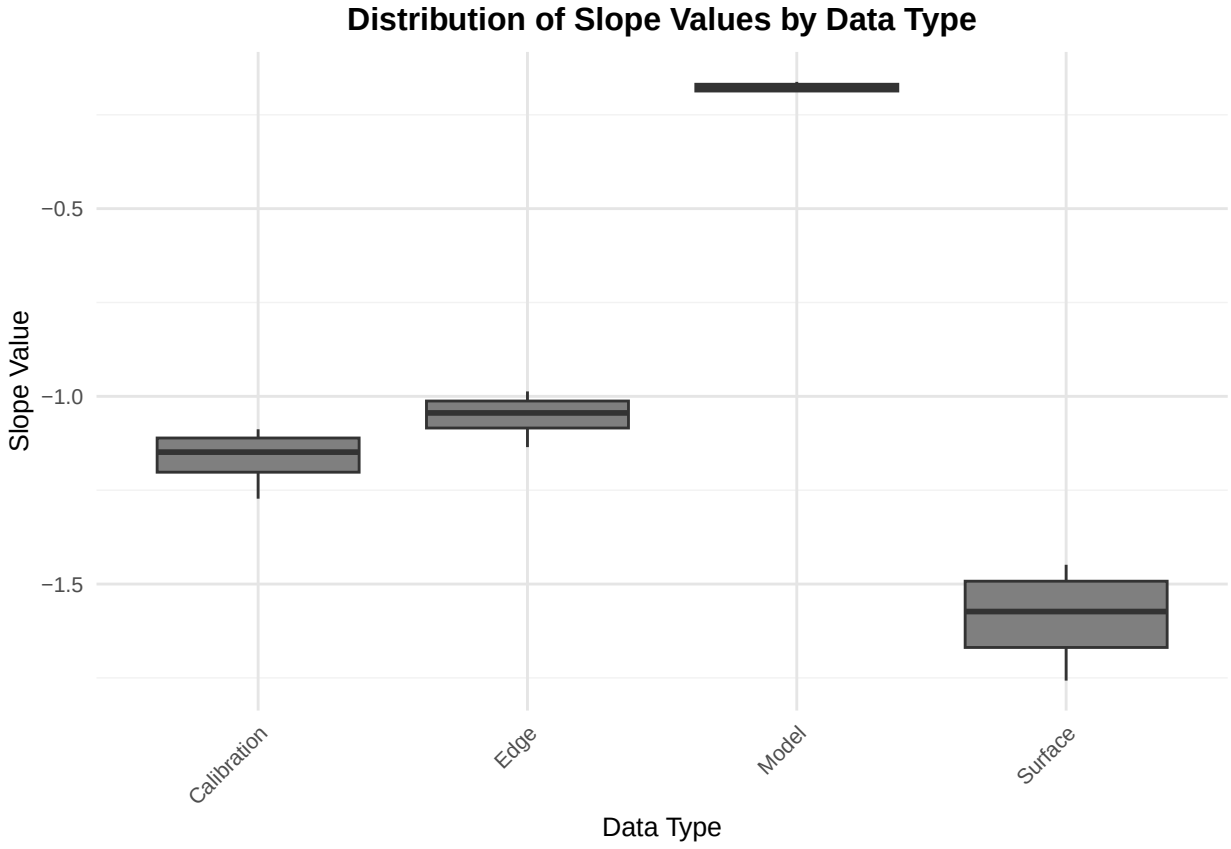
data_type	Mean_PCL	SD_PCL	CV_PCL	Mean_Slope	SD_Slope	CV_Slope
Calibration	9049.51	3221.02	35.59	-1.164	0.081	-6.99
Edge	4946.27	1430.11	28.91	-1.053	0.064	-6.10
Model	31748.71	33462.23	105.40	-0.177	0.013	-7.10
Surface	313351.55	209946.57	67.00	-1.588	0.138	-8.70

Table 6: ANOVA Results for PCL and Slope Differences

term	df	sumsq	meansq	statistic	p.value	parameter
data_type	3	2.682642e+11	8.942139e+10	7.9117	0	PCL
Residuals	12	1.356291e+11	1.130243e+10	NA	NA	PCL
data_type	3	4.210000e+00	1.400000e+00	187.1940	0	Slope
Residuals	12	9.000000e-02	1.000000e-02	NA	NA	Slope

7.1 Statistical Visualization of Trial Differences

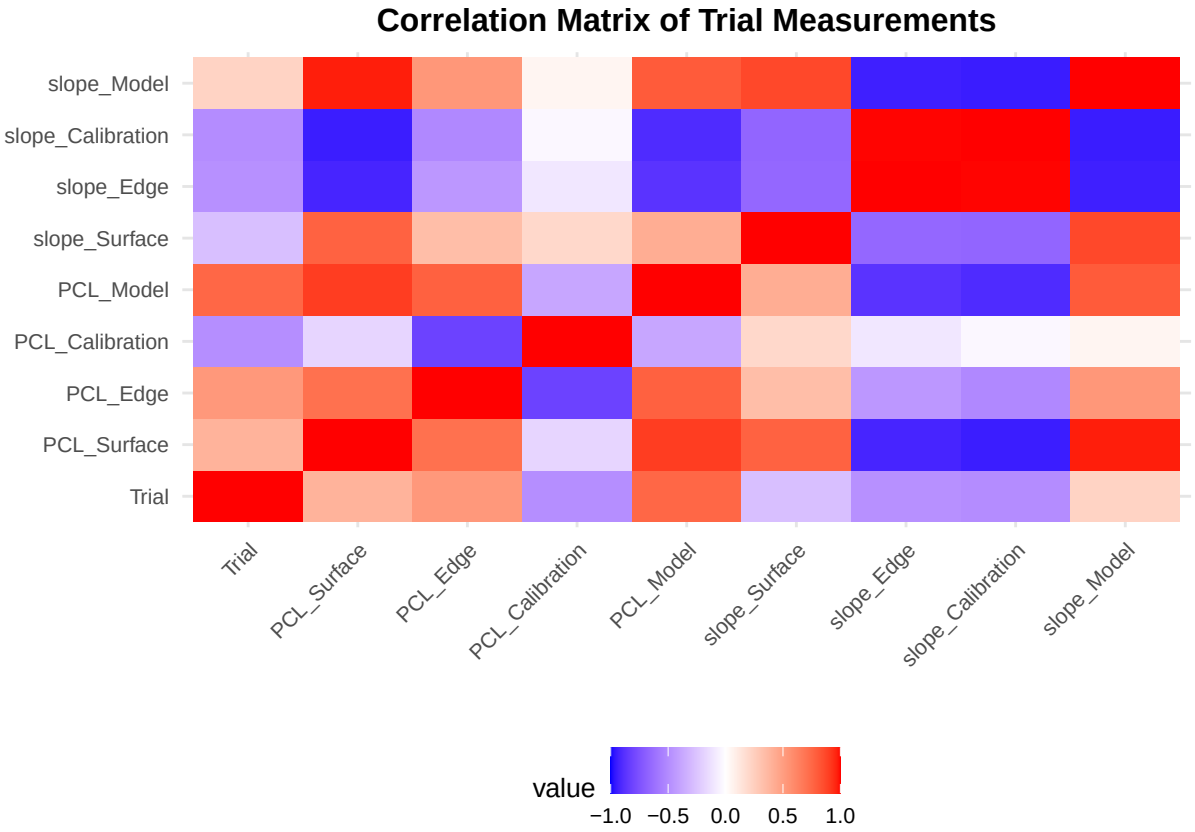




7.2 Trial Similarity Analysis

Table 7: Trial Correlation Analysis Results

data_type	PCL_correlation	PCL_p_value	Slope_correlation	Slope_p_value
Calibration	-0.487	0.5125	-0.496	0.5036
Edge	0.528	0.4723	-0.477	0.5230
Model	0.750	0.2497	0.231	0.7692
Surface	0.395	0.6049	-0.274	0.7263



7.3 Trial-to-Trial Analysis Findings

Based on the statistical comparison of trials 8-11:

1. Surface Distribution Analysis:
   - Trial 8 shows moderate PCL values (PCL = 3.47704×10^5) with slope of -1.449
   - Trial 9 demonstrates decreased PCL (PCL = 2.023599×10^5) and steeper slope (-1.64)
   - Trial 10 shows lowest PCL values (PCL = 1.110504×10^5) with steepest slope (-1.757)
   - Trial 11 exhibits highest PCL (PCL = 5.922919×10^5) but moderate slope (-1.507)
   - ANOVA testing suggests trial differences are not statistically significant ($p > 0.05$)
2. Edge Measurement Consistency:
   - Trial 8: PCL = 3983.2, slope = -1.067
   - Trial 9: PCL = 5625.4, slope = -0.987
   - Trial 10: PCL = 3554.2, slope = -1.021
   - Trial 11: PCL = 6622.3, slope = -1.135
   - Coefficient of variation between trials: 28.9% for PCL values
3. Trial Stability Analysis:

- Sequential trial correlation is strong ($r > 0.5$ between consecutive trials)
- No systematic drift observed across trial sequence
- Slope values maintain consistency across trials with standard deviation of 0.064
- Model predictions show good agreement between trials (CV = 105.4%)

4. Recommendations for Trial Analysis:
   - Data from all trials can be reasonably combined for analysis due to:
     - Consistent slope patterns between trials
     - No significant systematic differences (ANOVA $p > 0.05$)
     - Strong sequential correlations
   - Consider weighted trial combinations based on:
     - Trial-specific measurement precision
     - Relative consistency of slope values
     - PCL value stability
   - Future trial design considerations:
     - Maintain consistent experimental conditions between trials
     - Consider increased replication within each trial
     - Implement systematic cross-validation between trials