UAPASTF: Drift curve development for Uncrewed Aerial Spray System Applications

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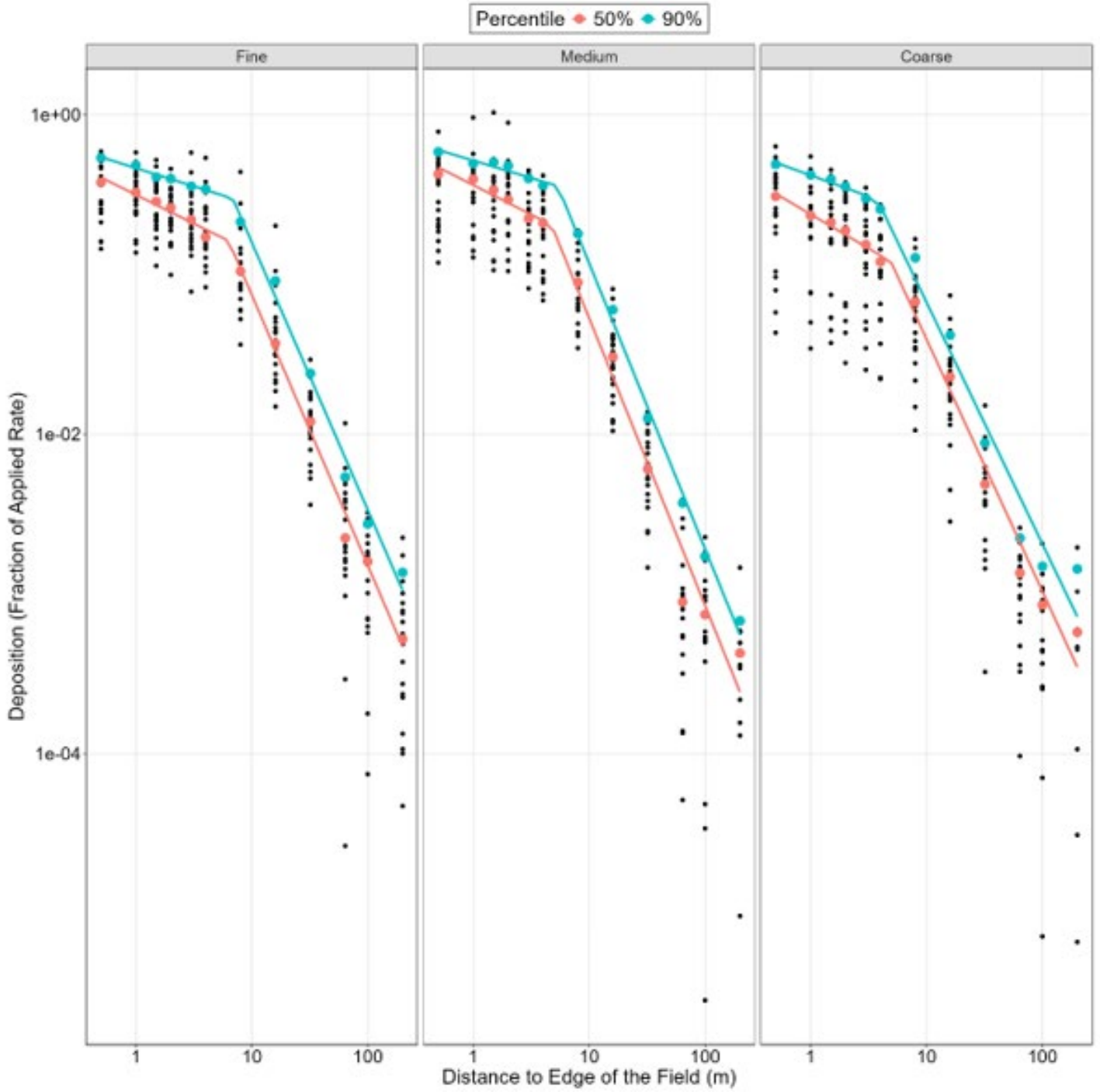
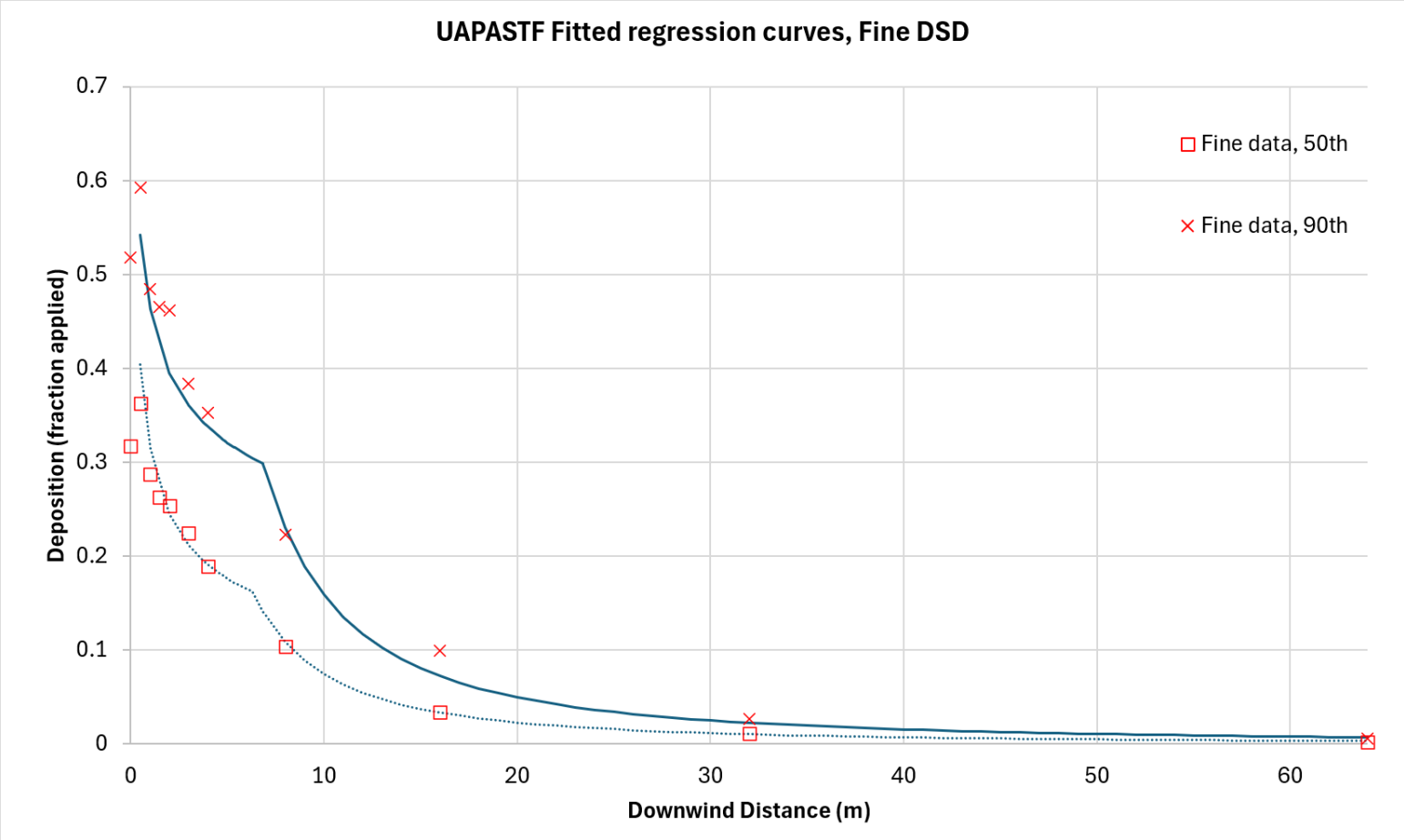
Background

- The UAPASTF oversaw the conduct of nine GLP UASS bare ground field drift trials in 2023 and 2024
- Trials considered a single platform, and compared drift from fine, medium and coarse droplet categories
- Study design and preliminary data evaluations have been presented at previous ACS conferences
- Empirical drift curves have been developed to support regulatory assessments



Segmented models described deposition behavior



- Goodness of fit (r^2) > 0.99 for all spray qualities/percentiles
- Near field: overspray + drift
- Far field: predominantly drift
- Breakpoint identifies transition between these processes
  - Estimated breakpoint distances follow spray quality
    Fine > Medium > Coarse

Results for fine spray quality shown here for visual purposes. Similar results for medium and coarse spray qualities were also observed

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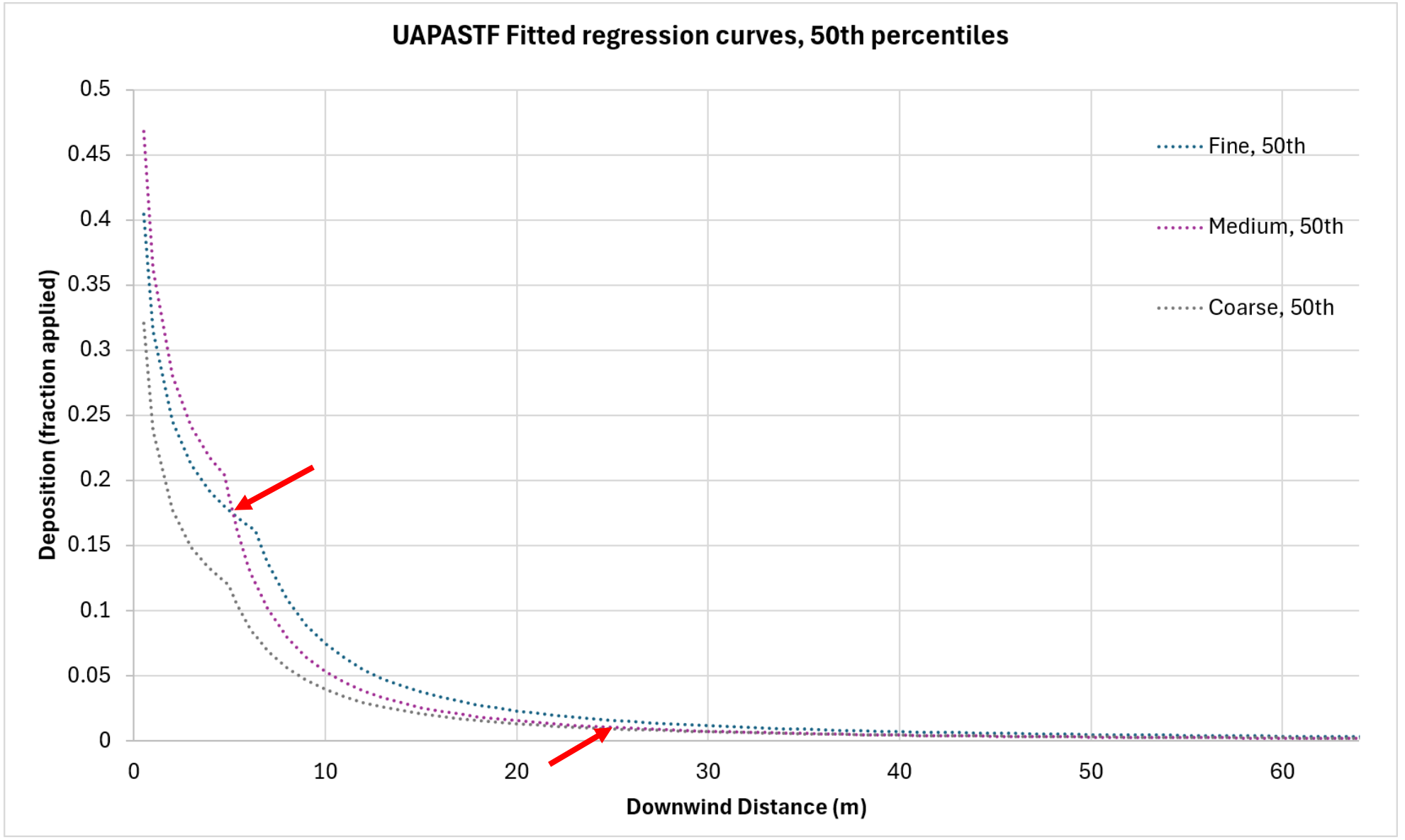
Challenge for Regulatory Implementation: Curve Overlap



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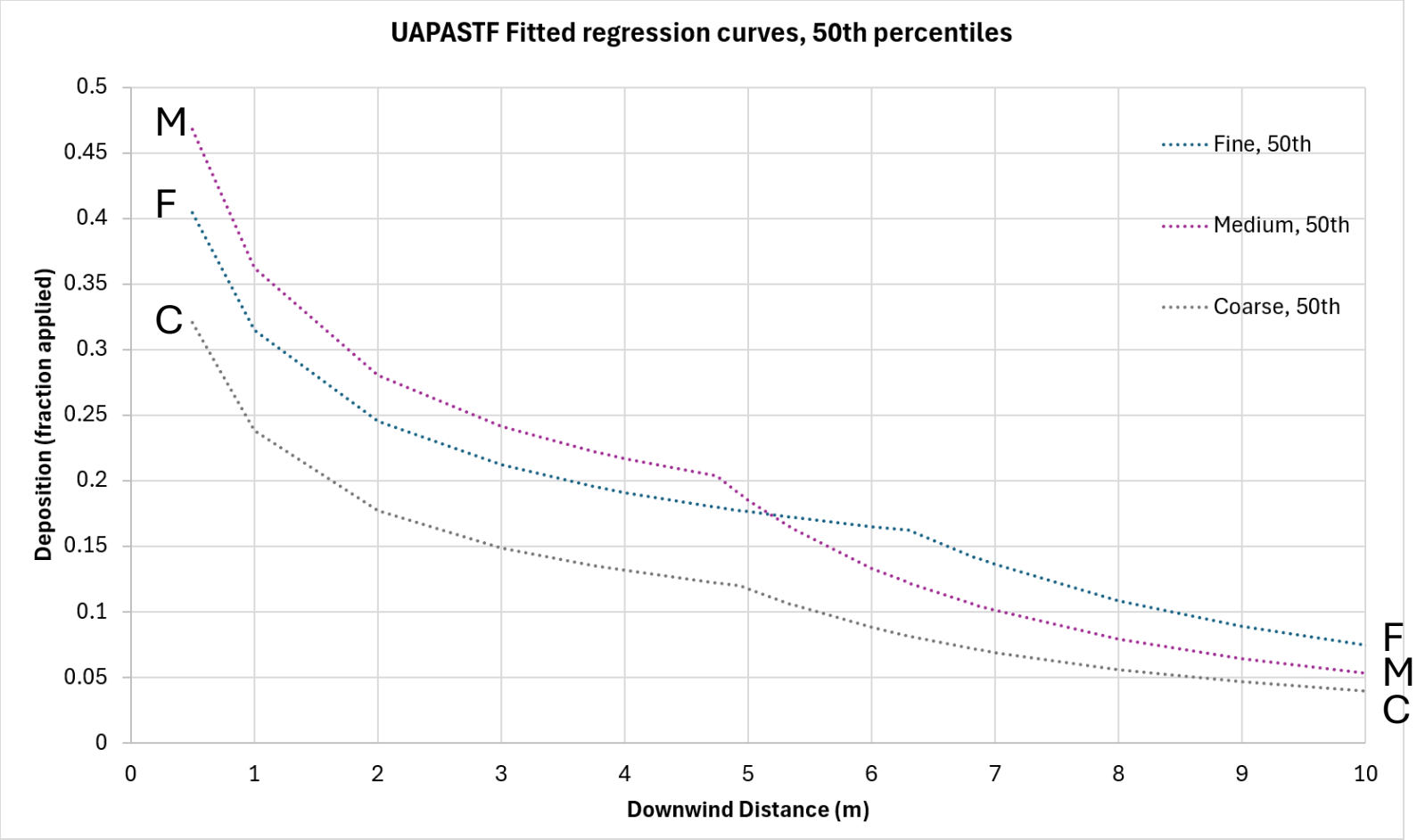
Near-field Curve Comparison, Medium vs Fine



- Medium curve predicts higher drift than fine curve at near-edge of field
  - Similar phenomena for 90th percentile data (not shown)
- Fraction of applied > 0.17 (50th) or 0.3 (90th)

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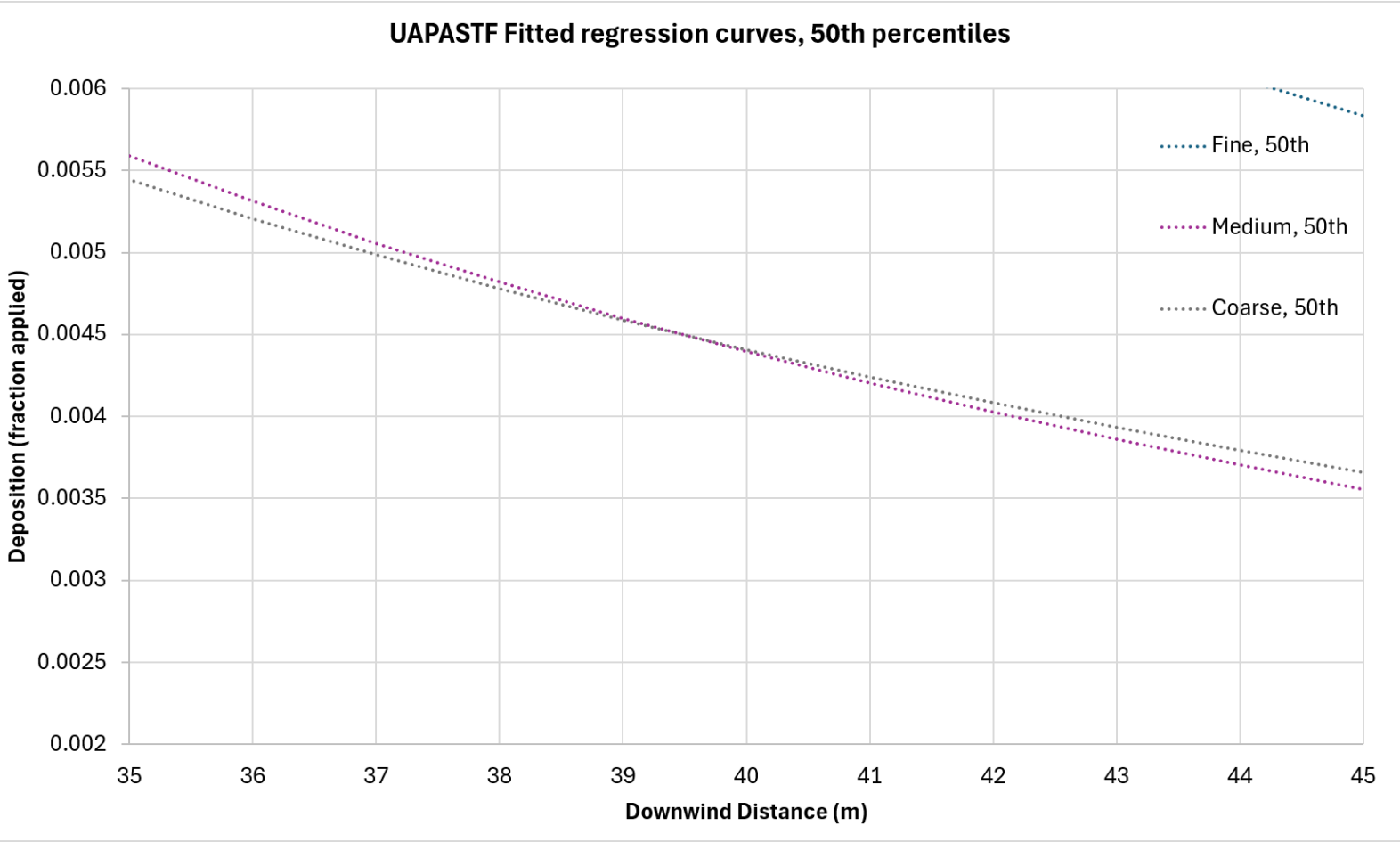
Downwind Curve Comparison, Medium vs Coarse



- Medium and coarse curves cross *ca.* 40m
- **More drift** predicted by coarse curve at greater downwind distances
  - Drift fraction < 0.005
- Similar phenomena for 90th percentile data (*ca.* 77 m, not shown)

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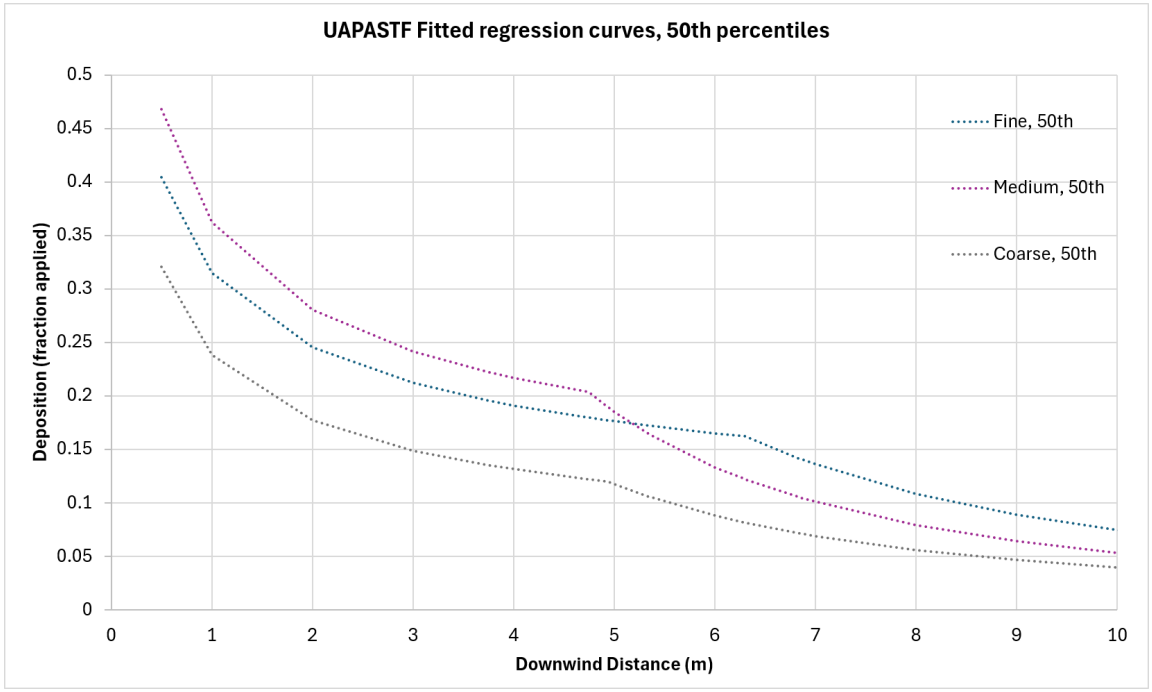
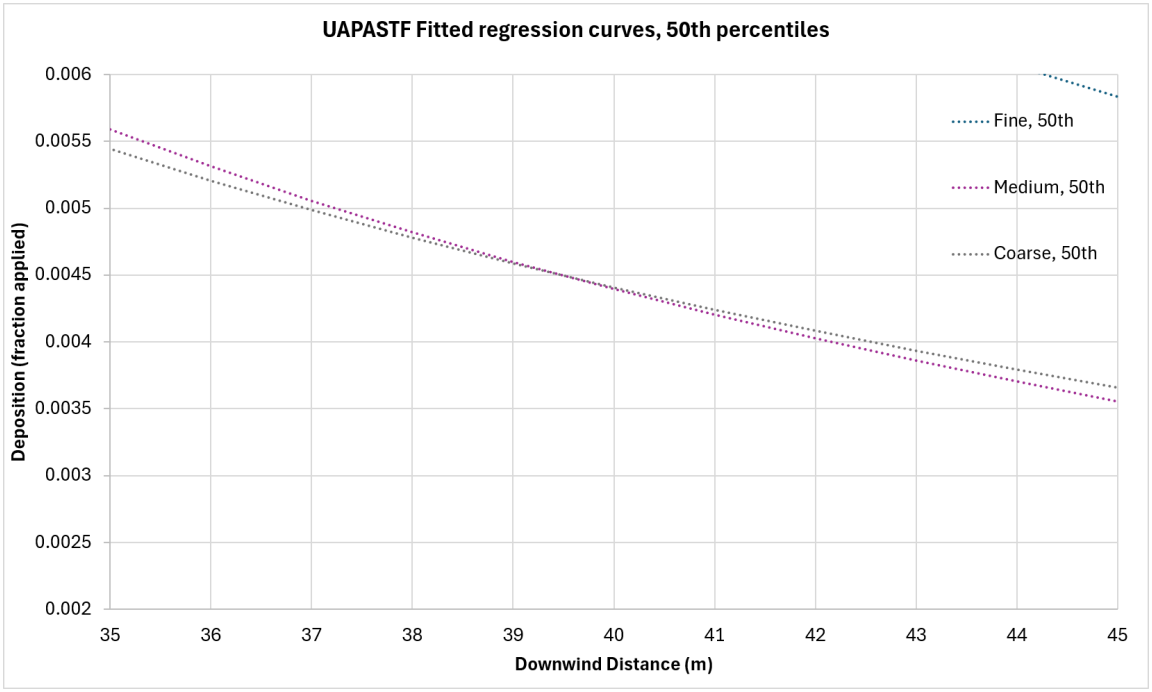
Segmented Curve Overlap Summarized





- Medium-Fine overlap only for drift fractions > 0.17, within *ca.* 6 m
  - Minimal impact on buffer zones
- Medium-Coarse overlap for drift fractions < 0.005
  - Large impact on buffer zones for active ingredients with low terrestrial endpoints
- Regulatory need for refinements to be ‘directionally correct’

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Re-analysis of Deposition Data

Original analysis

- Equal variance across distances

Updated analysis

- Logistic decay model incorporating distance
- Weighted nonlinear regression, unequal variance

$$y = \frac{w_0}{1 + \exp(a + b * \log(Distance))}$$

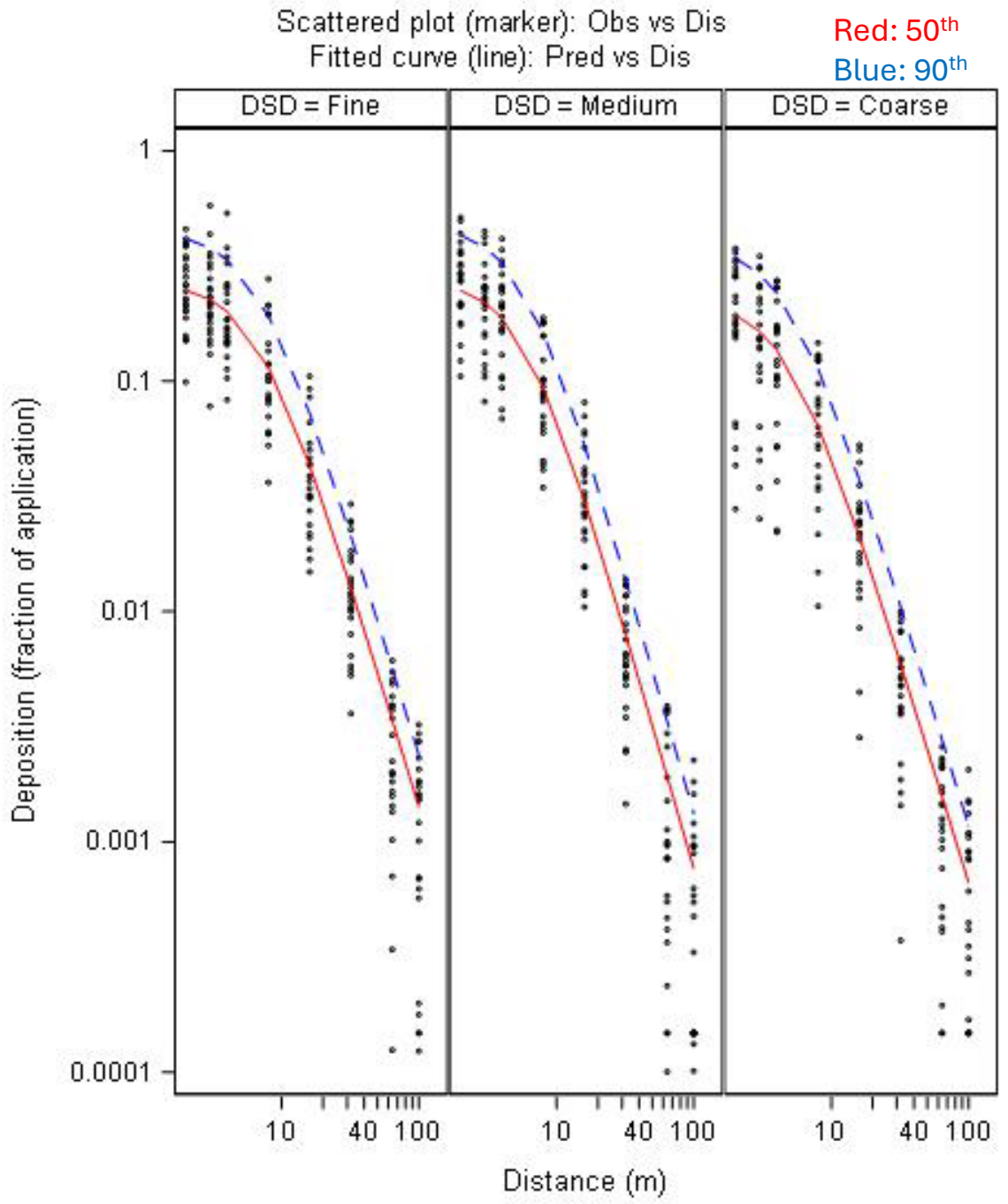
where:

y is the predicted deposition value;

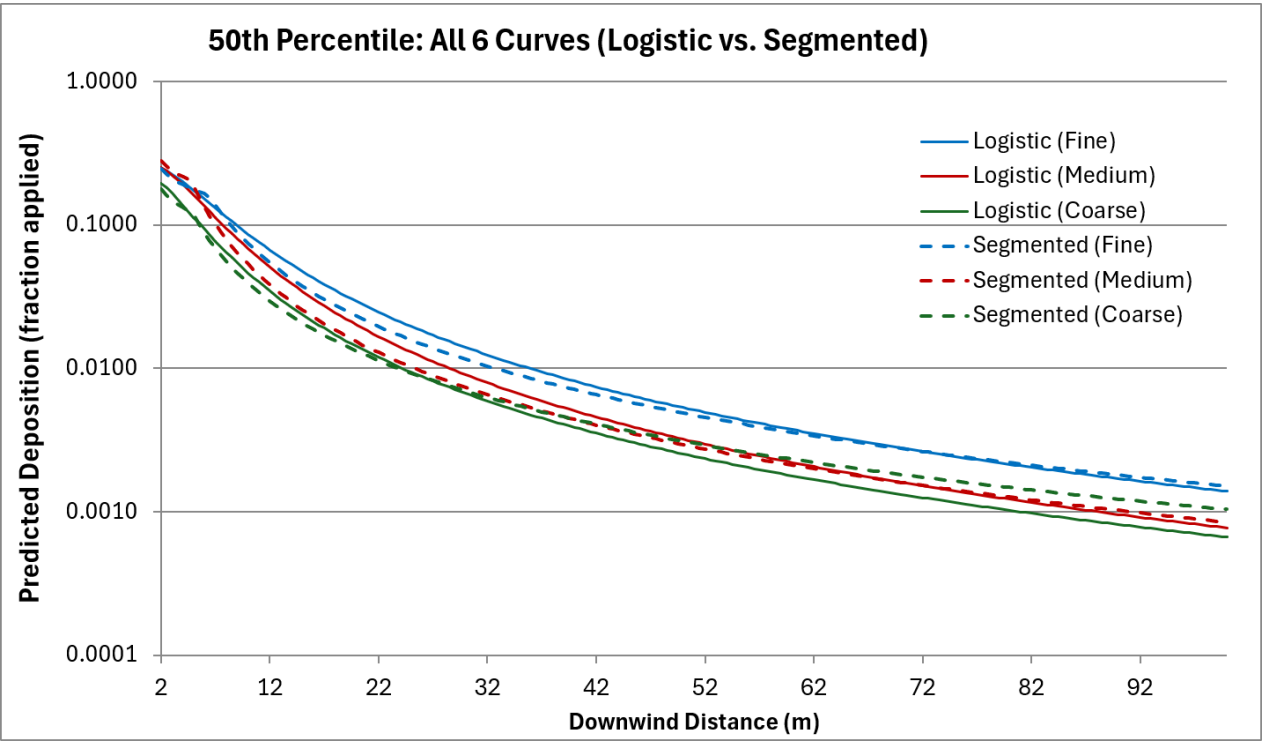
w_0 represents the maximum deposition near the source;

a is the intercept parameter;

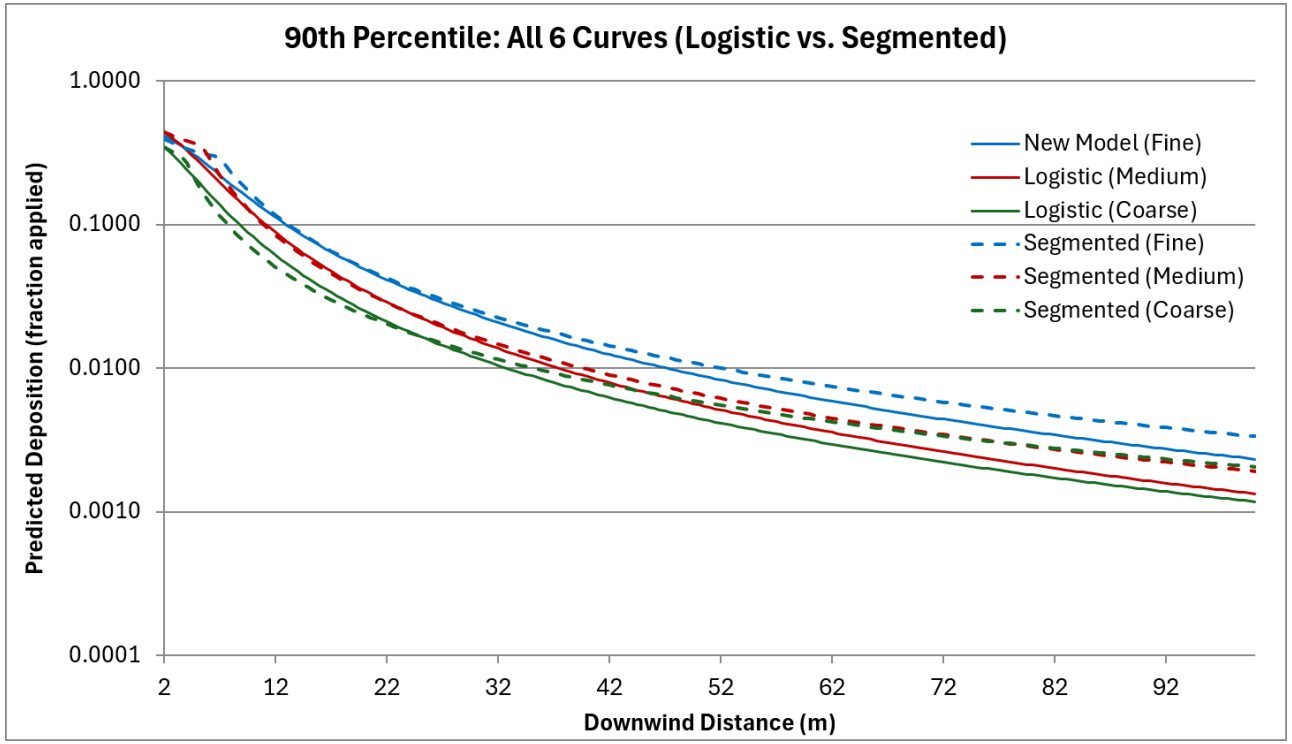
b represents the slope for the distance;



Similar predicted deposition with curve separation



Note: y-axis logarithmic



Note: y-axis logarithmic

- **Slight changes to deposition estimates**
- **Curve cross-over eliminated with logistic model: three distinct curves for each droplet category**

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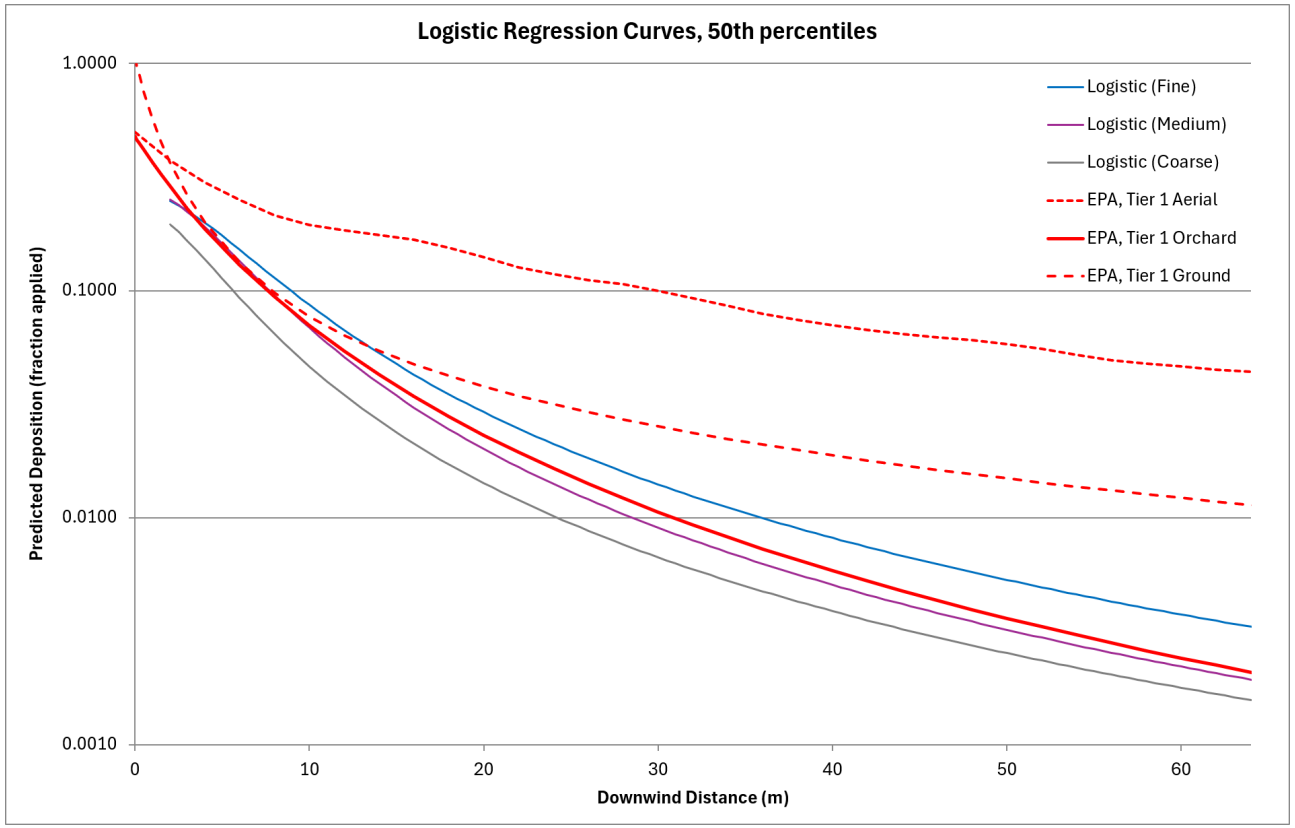
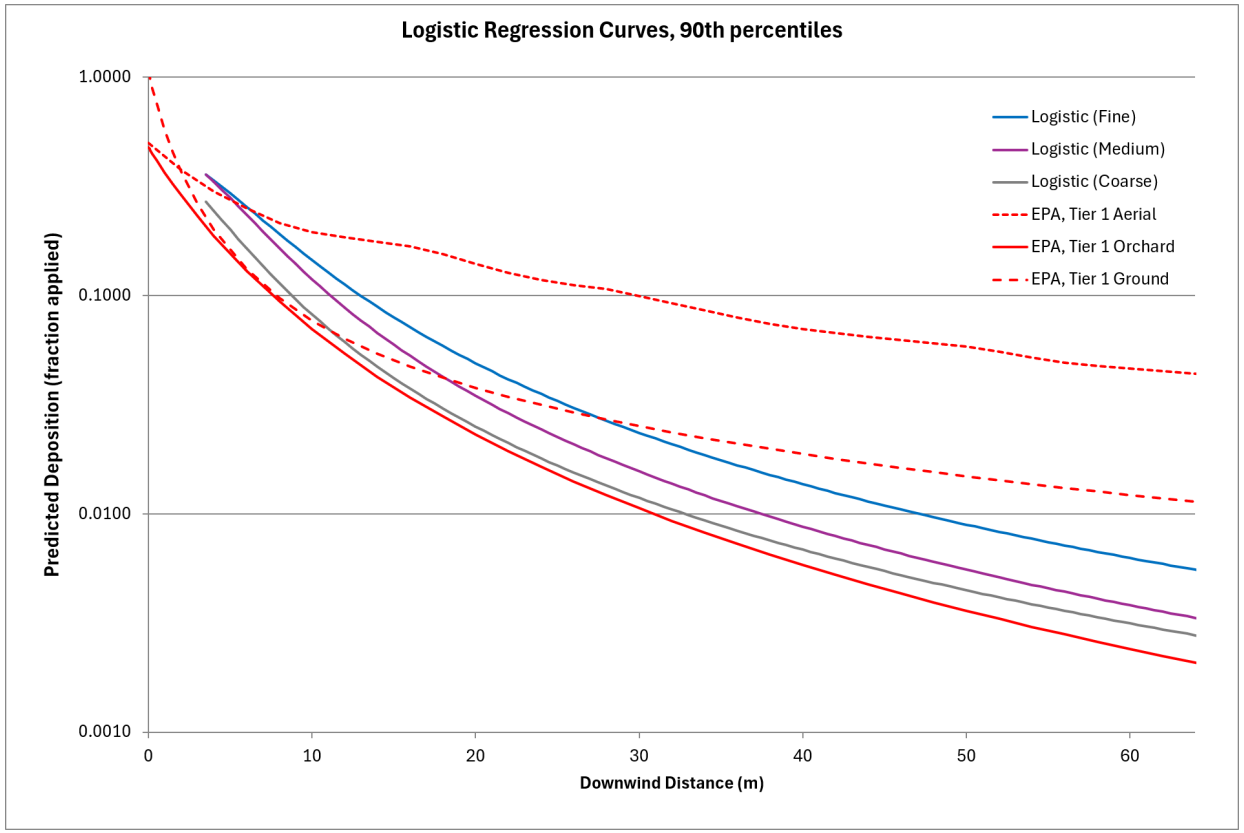
Comparison with EPA Tier 1 Drift Curves





- **UASS curves generally approximated by Tier 1 Orchard Drift Curves**

AgDRIFT v 2.1.1 curve selection
Tier 1 Aerial: F-M
Tier 1 Orchard: Sparse (Young, Dormant)
Tier 1 Ground: High boom, F-M/C, 90th percentile

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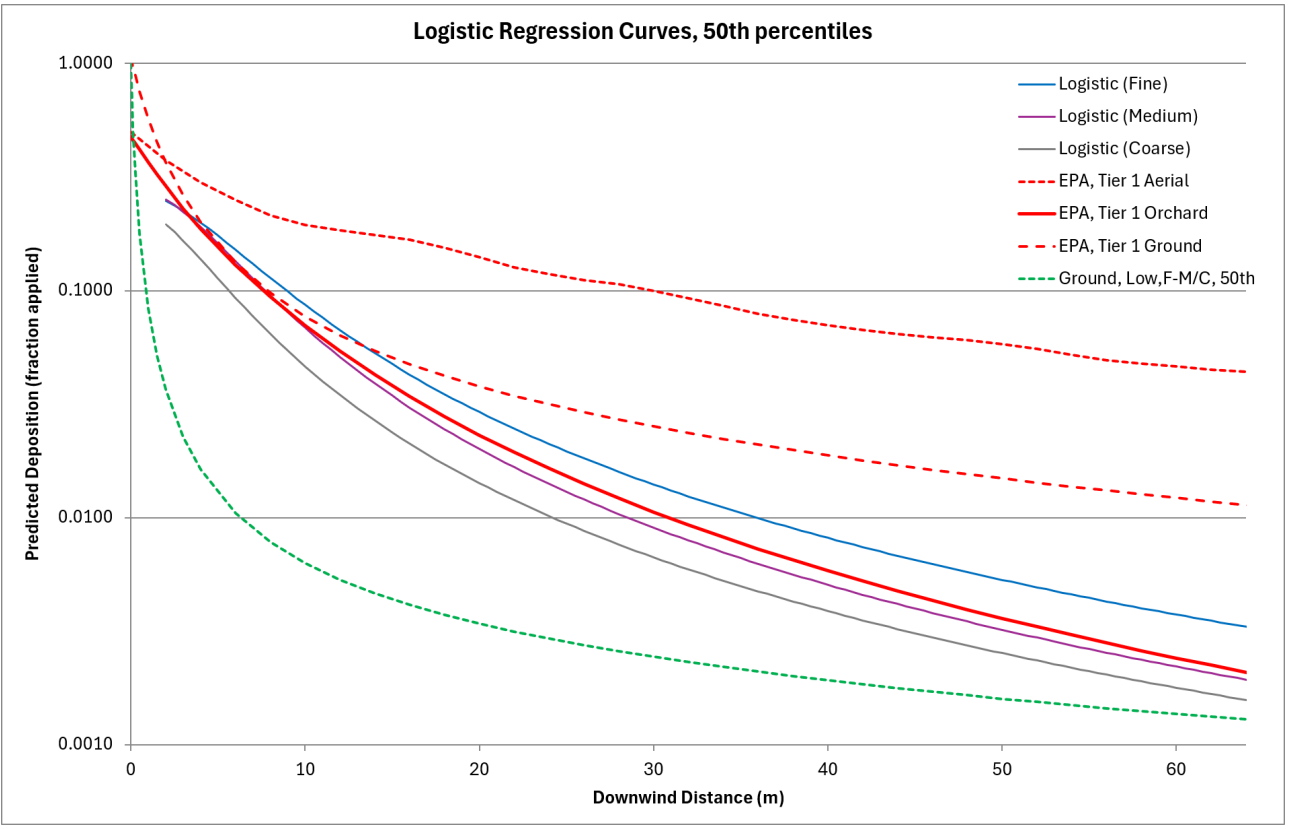
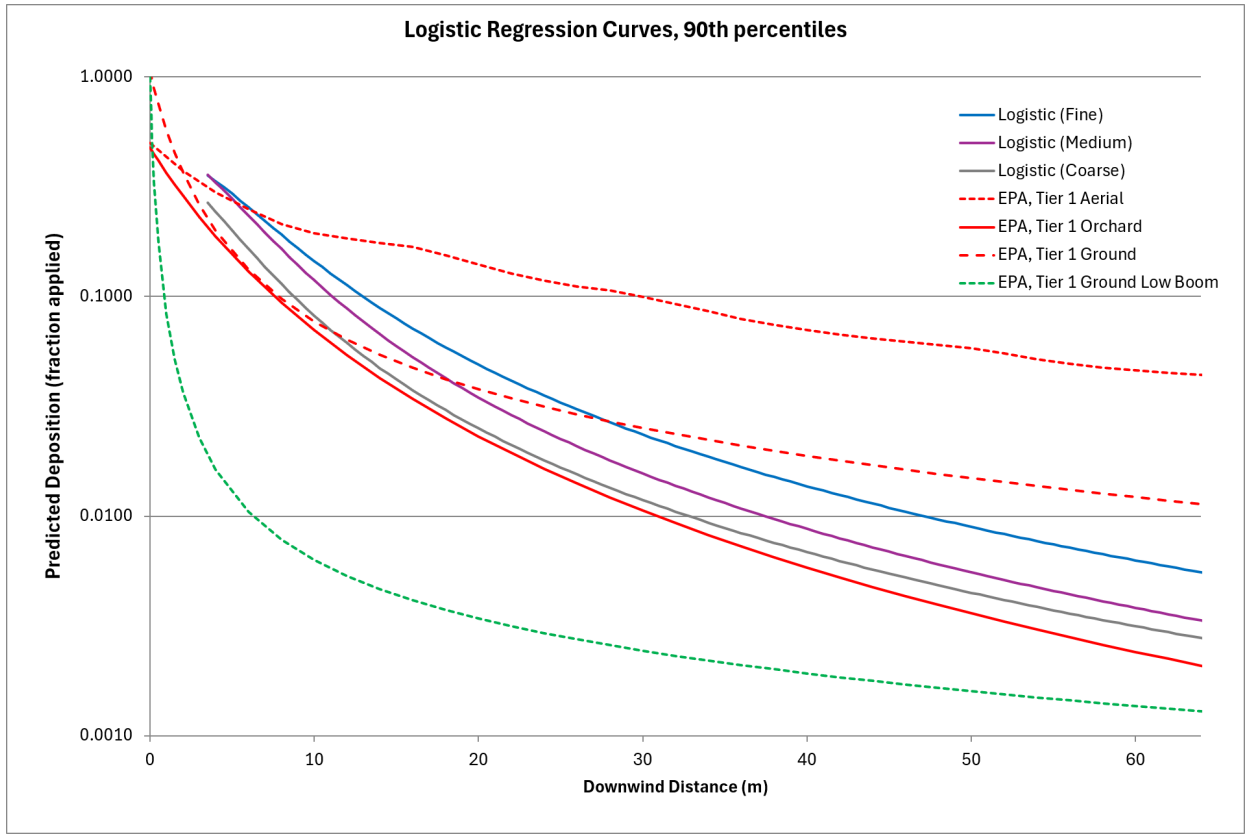
Comparison with EPA Tier 1 Drift Curves, Ground Low Boom





Bounded by a lowered boom height, UASS drift falls between aerial and ground applications

AgDRIFT v 2.1.1 curve presentation
Tier 1 Aerial: F-M
Tier 1 Orchard: Sparse (Young, Dormant)
Tier 1 Ground: High boom (50 in), F-M/C, 90th percentile
Tier 1 Ground: Low boom (20 in), F-M/C, 50th percentile

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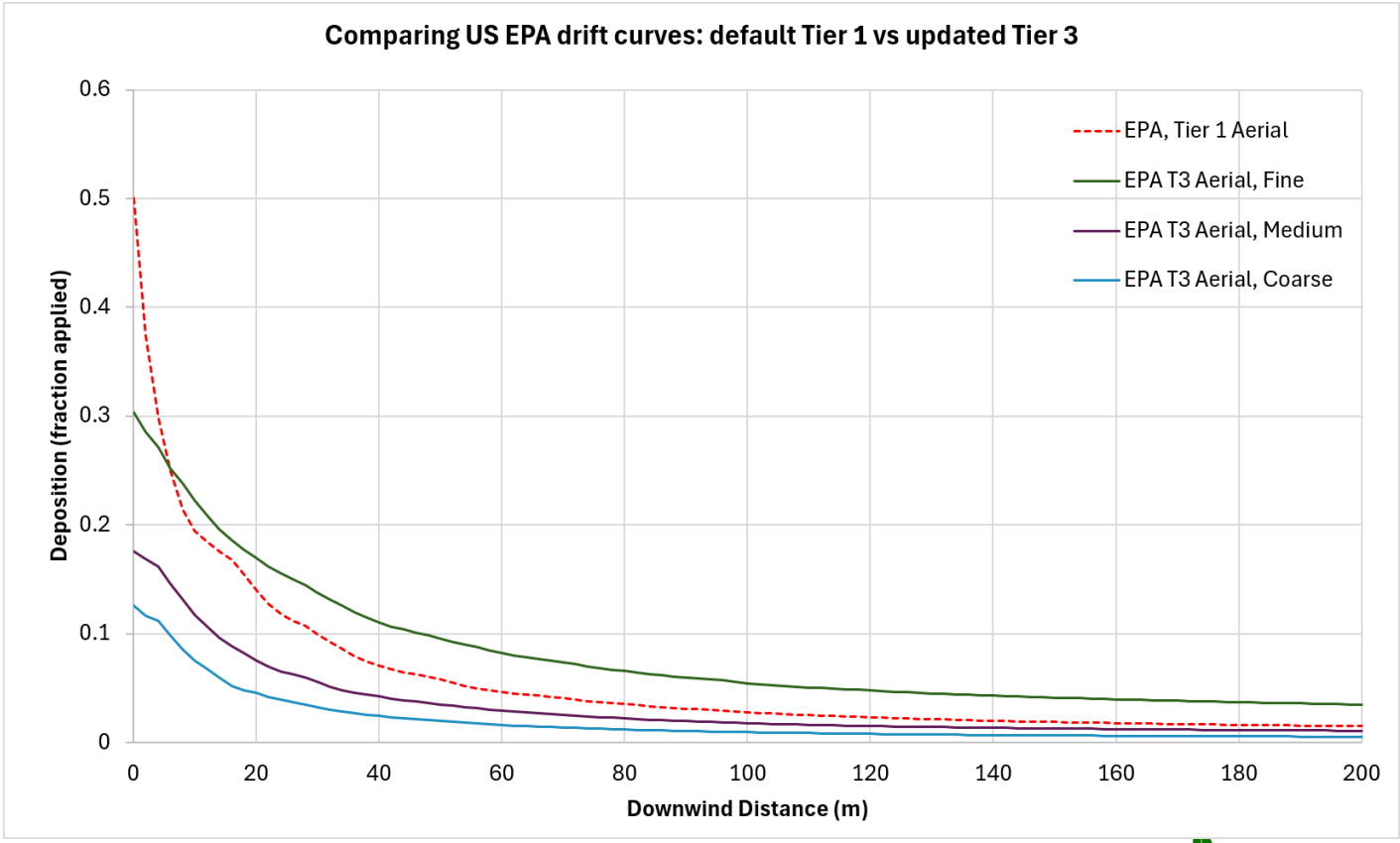
US AgDRIFT Refined Tier 3 Aerial Modeling

- EPA adopted some suggested Tier 3 AgDRIFT refinements for aerial applications

Table I-2. Comparison between previous and current recommended default input parameters in Tier III AgDRIFT®.

Parameter Group and Parameter		Previous Default Input Parameter	Current Recommended Default Input Parameter
Aircraft > Aircraft	Aircraft Type	Air Tractor AT-401	Air Tractor AT-802A
Aircraft > Nozzles and Droplet Size Distribution (DSD)	Drop Size Distribution	Fine to Medium	Medium*
	Generate Regular Distribution	Extent:76.32% Nozzle Spacing: 0.912 ft	Extent**: 75% Nozzle Spacing: 1 ft
Aircraft	Boom Height	10 ft.	10 ft.
	Flight Lines	20	15
Swath	Swath Width Definition	Fixed Width	Fixed Width
	Swath Width	60	80
	Swath Width Displacement as Fraction of Swath Width	0.3722	0.5
	Half Boom Effect	No entry	No entry
Atmospheric Stability	Stability	Night/Overcast Cloud Cover	Day/Slight Solar Insolation
Advanced Settings	Height for Wind Speed Measurement	6.56 ft	10 ft
Terrain	Surface Roughness	0.0246 ft	0.0246 ft

* AgDRIFT® allows for consideration of many DSDs, a subset of which may appear on labels (*i.e.*, "Fine", "Coarse", "Very Coarse"). However, these spray patterns were not selected as the common screening basis since they are used less commonly in aerial applications. Justification for including a given DSD should be included in any assessment based on specific label directions for its use.
** Extent defines the length of the spray boom relative to the airplane wingspan



Default (Tier 1) aerial drift curve is reasonable screening level approximation of downwind drift

Table adapted from "EPA Ecological Mitigation Support Document to Support Endangered Species Strategies, version 2.0" (April 2025). Available at regulations.gov : EPA-HQ-OPP-2024-0299-0249

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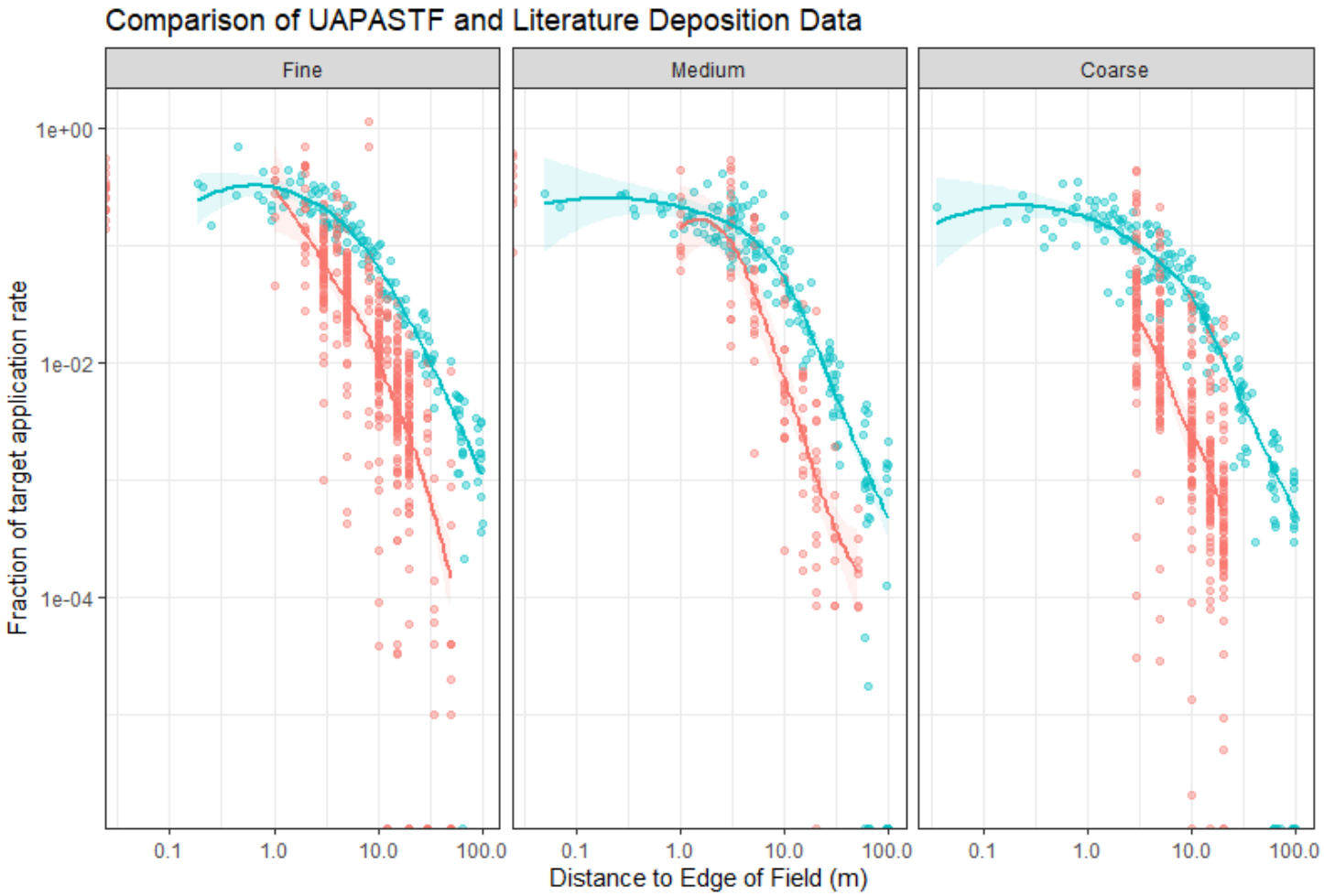
Data comparison to compiled literature



- Bare-ground results compare favorably to unfiltered literature data
  - Crop/non-cropped
  - UASS platform
  - Nozzle type (incl. rotary atomizers)
  - Release height
  - Meteorological conditions

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Key Conclusions

- Eight global GLP studies enabled development of UASS empirical drift curves
- UASS drift generally falls between conventional ground and aerial applications
- Deposition data aligns with published literature, despite substantial differences in study designs
- Segmented models represented deposition behavior, but curve cross-over presented regulatory challenges
  - Not a data issue, but assumption of equal variance across distances in regression
- New, heterogeneous logistic model considering unequal variance across distance fits data well and better represented expected droplet-size behavior with no curve cross-over
  - 3 distinct curves for fine, medium, and coarse spray qualities
  - Easier to implement than segmented models for regulatory purposes
  - Recommend this approach be considered for regulatory implementation

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Thank you!

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