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Comparison of Spray Deposition from Ground and Unmanned Aerial Vehicle Pesticide Applications in a Multi-Location Field Experiment

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Background

UAPASTF conducted field studies in 2023 and 2024 at 8 locations worldwide

Purpose: Evaluate off-target movement arising from applications using an unmanned aerial vehicle (UAV or drone) and a ground boom sprayer

Statistical analyses conducted to answer the following questions

- How does UAV drift compare to drift from ground applications?
- Is there a need for an in-field buffer for UAV applications due to overspray beyond the targeted downwind edge of the application area?
- Does study location influence ground sprayer and UAV drift deposition?
- Which application practices and environmental conditions best explain the variation observed in spray drift deposition from ground sprayer and UAV applications?

In this presentation, we describe the analyses undertaken to answer the first two questions

Locations and Study Design

Locations

- Brazil — Paraná
- Brazil — Goiás
- Canada — Québec
- Hungary — Bugac
- South Africa — Free State
- South Africa — Limpopo
- Spain — Oropesa
- USA — Texas

Study Design

- Two application methods: ground and UAV
- Three spray qualities: fine, medium, coarse
- 3 replicates/spray quality/application method/location = 18 trials/location
- Drift measured in swath and downwind to 200 m from target edge of field
- 3 mylar cards placed at 12 downwind distances
- Meteorological measurements taken at 10 m upwind and 215 m downwind at two heights: 0.51 and 3 m
- Meteorological variables included: windspeed (mean, min, max, SD), relative humidity (mean, SD), temperature (mean, SD), atmospheric pressure (mean, SD), mean deviation from target wind direction

Analytical Approach

In swath

- Ordinary Least Square (OLS) models, treated area to 4 m downwind of target edge of field (EOF)
- 8 deposition models fitted with various combinations of predictor variables: location, application method, spray quality, distance to EOF, distance to EOF squared

Downwind

- Generalized Linear Mixed Effect Models (GLMEMs), 4 to 200 m from target EOF
- 4 deposition models fitted with various combinations of predictor variables: location, application method, spray quality, distance to EOF, and random intercept (= application event)
- Post hoc contrasts conducted to determine if there were deposition differences between application methods

Regulatory UAV drift curves

- Logistic and segmented models, 50^{th} and 90^{th} percentiles for each spray quality
- Segmented models estimated the transition from slow to rapid decline in deposition

AIC_c used to select most parsimonious models

Two data sets: Unadjusted EOF, EOF adjustment factor

Edge of Field (EOF) Adjustment Factor for UAV Applications

For UAV drift curve analyses, we considered two data sets: unadjusted EOF and adjusted EOF

Calculation of EOF adjustment factor for each application

- Determine effective swath width (ESW) from pattern testing in target spray area
- EOF adjustment factor = CoD + 0.5 × ESW, where CoD = Center of Deposition
- For more information, see Martin et al. (2024, Applied Engineering in Agriculture 40(4):385-399)
- Original Python script partially modified to account for multi-swath applications (n = 3 or 4) rather than single swath applications
- ESW methodology largely unsuccessful
  - EOF adjustment factor was negative for 1/3 of application events
  - Methodology failed for 3 of 73 UAV application events

Spray Quality	N	EOF Adjustment Factor (m)		
		Mean	St. Dev.	Range
Coarse	23	1.3	3.1	-9.0 - 5.9
Medium	24	2.1	2.7	-2.2 - 6.5
Fine	23	2.5	4.3	-5.2 - 13.4
All	70	1.9	3.4	-9.0 - 13.4

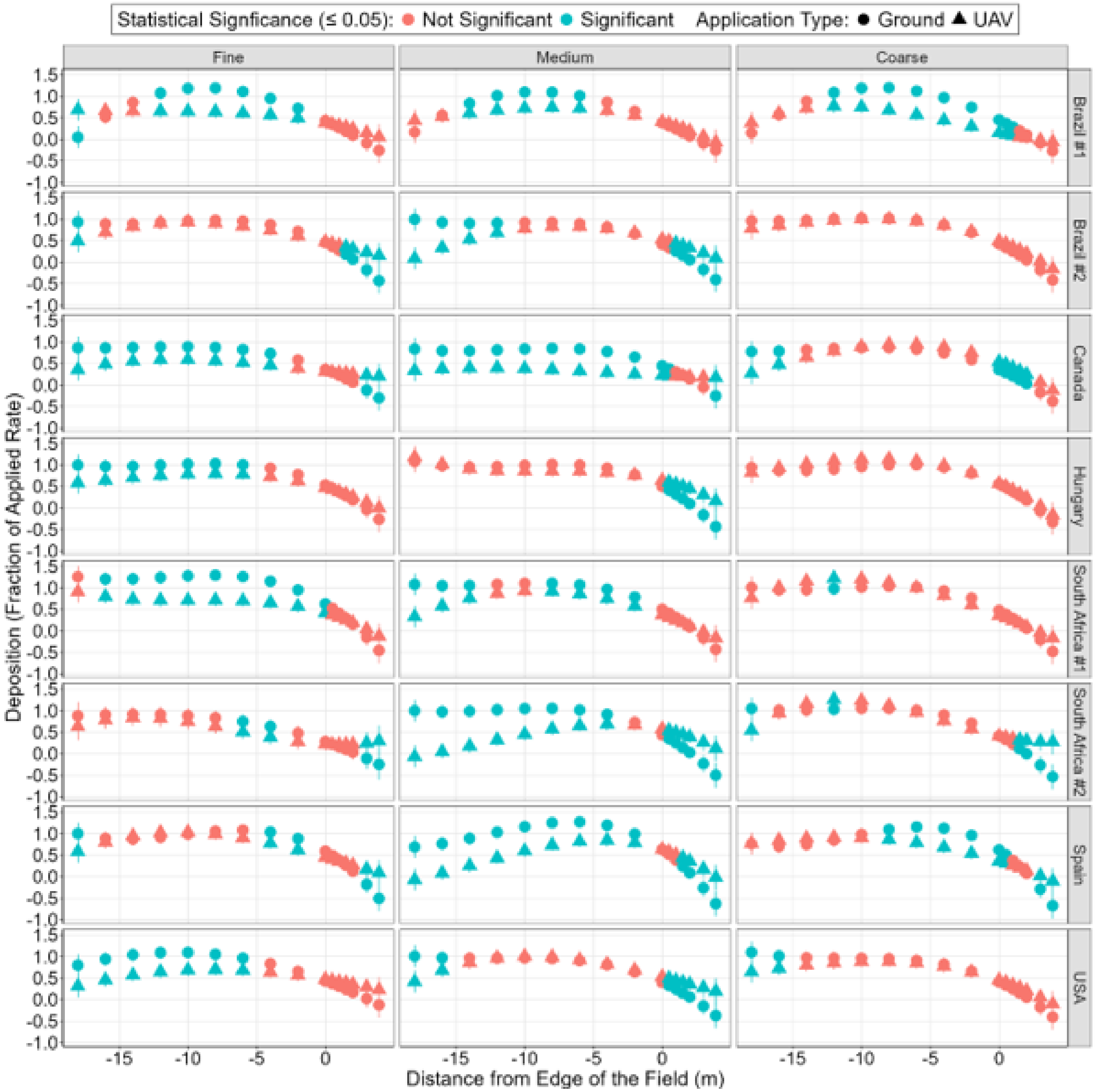
In Swath: Ground Better Matched Target Application Rate

Most parsimonious model (unadjusted EOF)

- Dep = spray quality + location × app method × distance EOF × $(\text{distance EOF})^2$

Post hoc contrasts

- Blue dots and triangles indicate significant differences
- In-swath deposition generally significantly higher ($p < 0.05$) for ground applications
- Particularly evident in upwind and center areas of the treated swath
- In first meters downwind of EOF, deposition from ground applications decreased sharply compared to UAV applications
- Very similar result for data set that incorporated EOF adjustment factor



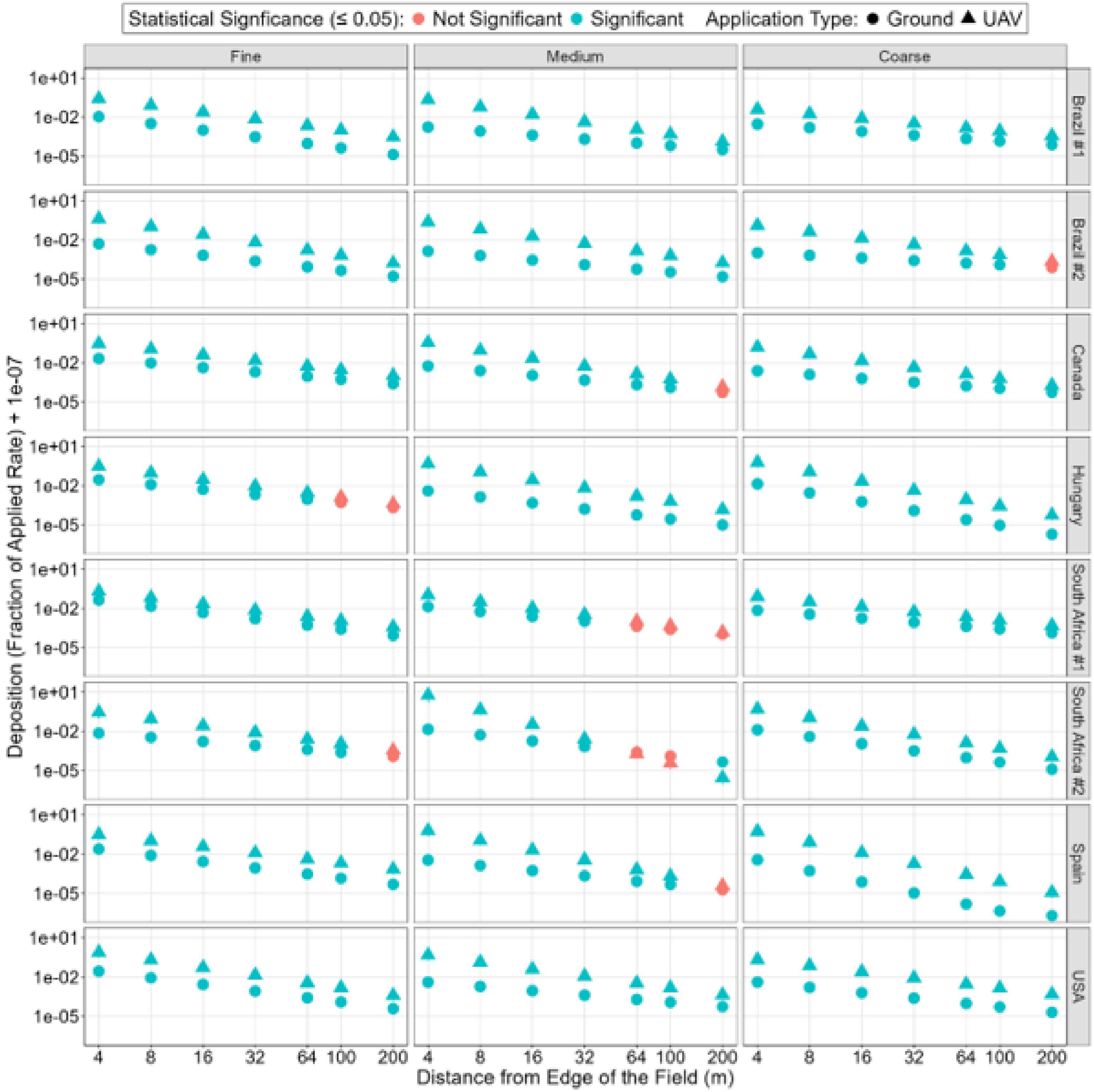
Higher Downwind Drift Deposition With UAV Applications

Most parsimonious model (unadjusted EOF)

- Dep = location × spray quality × app method × log(distance EOF) + 1|application event id
- 1|application_event_id denotes the random intercept included in the model

Post hoc contrasts

- UAV deposition significantly higher at most tested distances
- Some overlap occurred at the far field distances for fine and medium spray qualities
- Model predictions aligned well with downwind field deposition data (not shown), except near the EOF (4 to 10 m)
- Very similar result for data set that incorporated EOF adjustment factor



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Proposed Regulatory Drift Curves for UAV Applications

Standardized drift curves, analogous to US EPA's AgDRIFT curves for ground and aerial applications, are lacking for UAV applications

Multivariate analyses (previous presentation) indicated that meteorological conditions within tight windspeed constraints (2-5 m/sec) have little influence on downwind drift deposition

For UAVs, we derived median (50th %ile) and conservative (90th %ile) drift curves for fine, medium, and coarse spray qualities

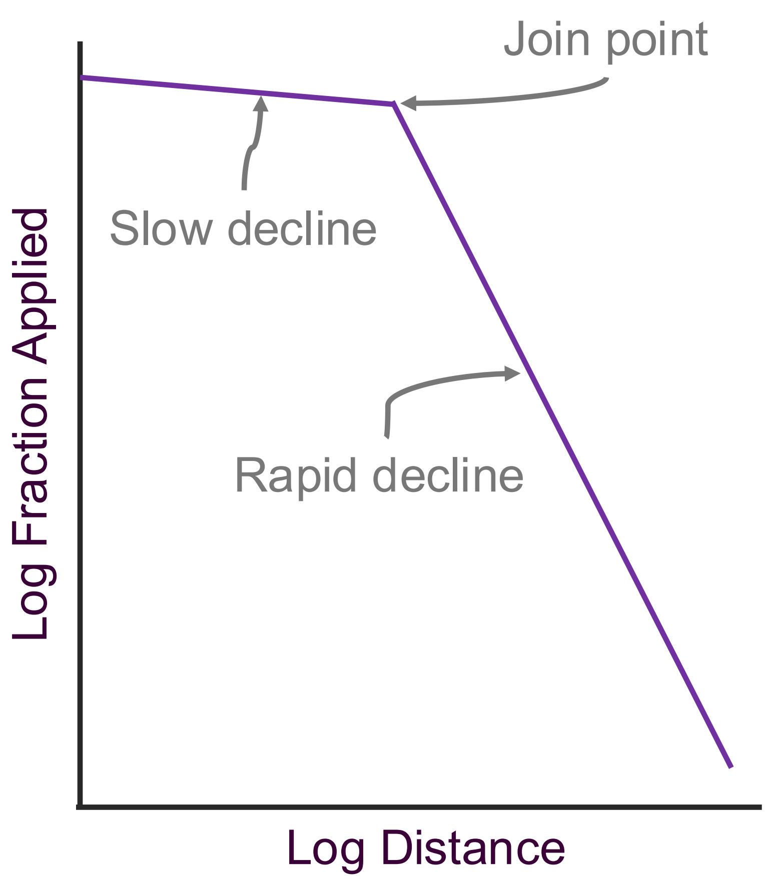
No EOF adjustment factor, non-detects excluded

Two models

- 3 parameter asymptotic logistic
- Segmented

R^2, index of agreement (r index), and mean bias error (d) used to evaluate goodness of fit

Segmented Model



Asymptotic Logistic Models

50th and 90th percentiles for each distance shown as dots

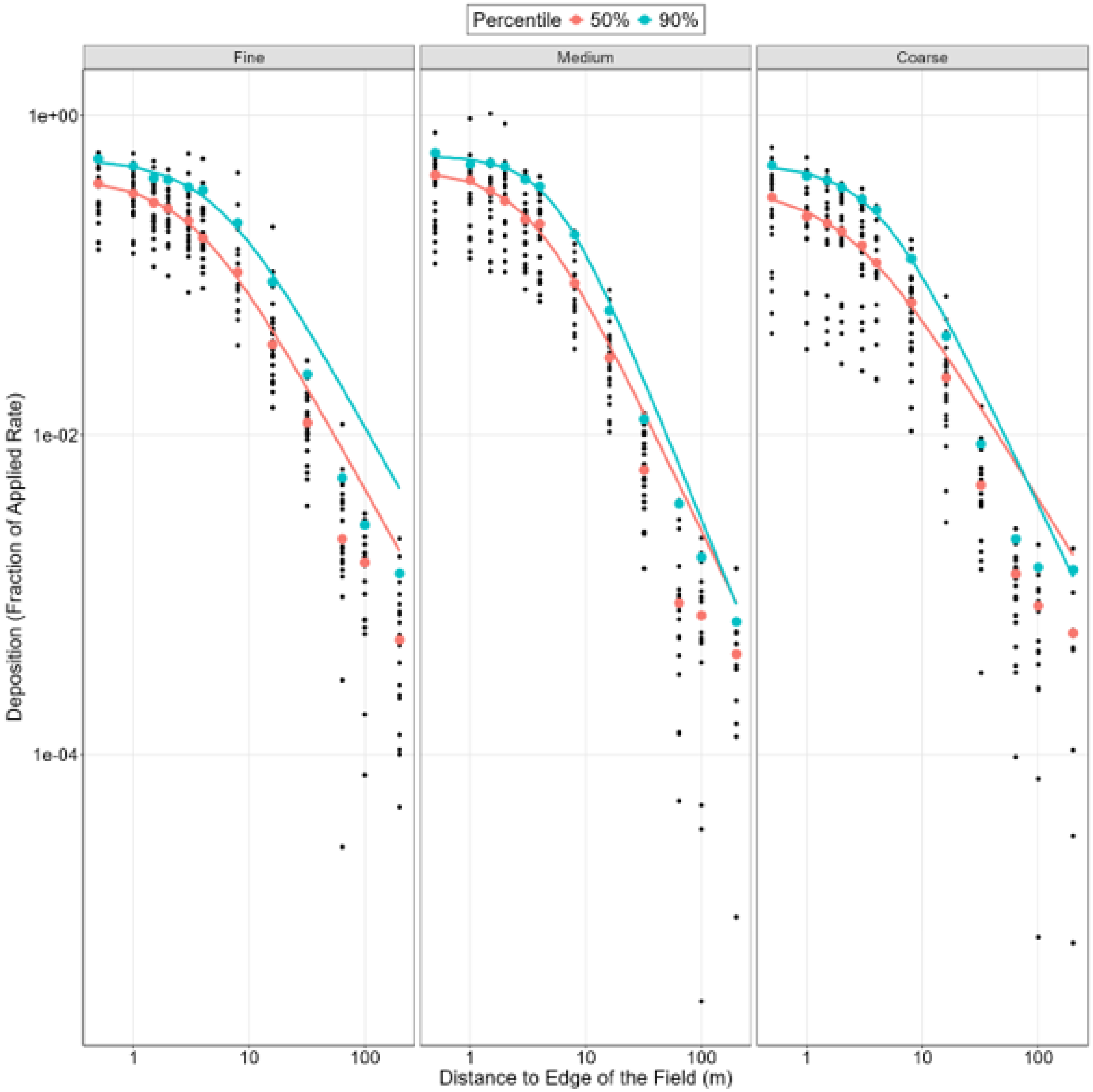
Moderately good fit to the data

- Good fit in the near-field
- General over prediction beyond 10 m

R^2 ranged from 0.888 to 1

r index ranged from 0.871 to 0.999

Mean bias error positive because deposition consistently overestimated in far field



Segmented Models

Very good fit to the data

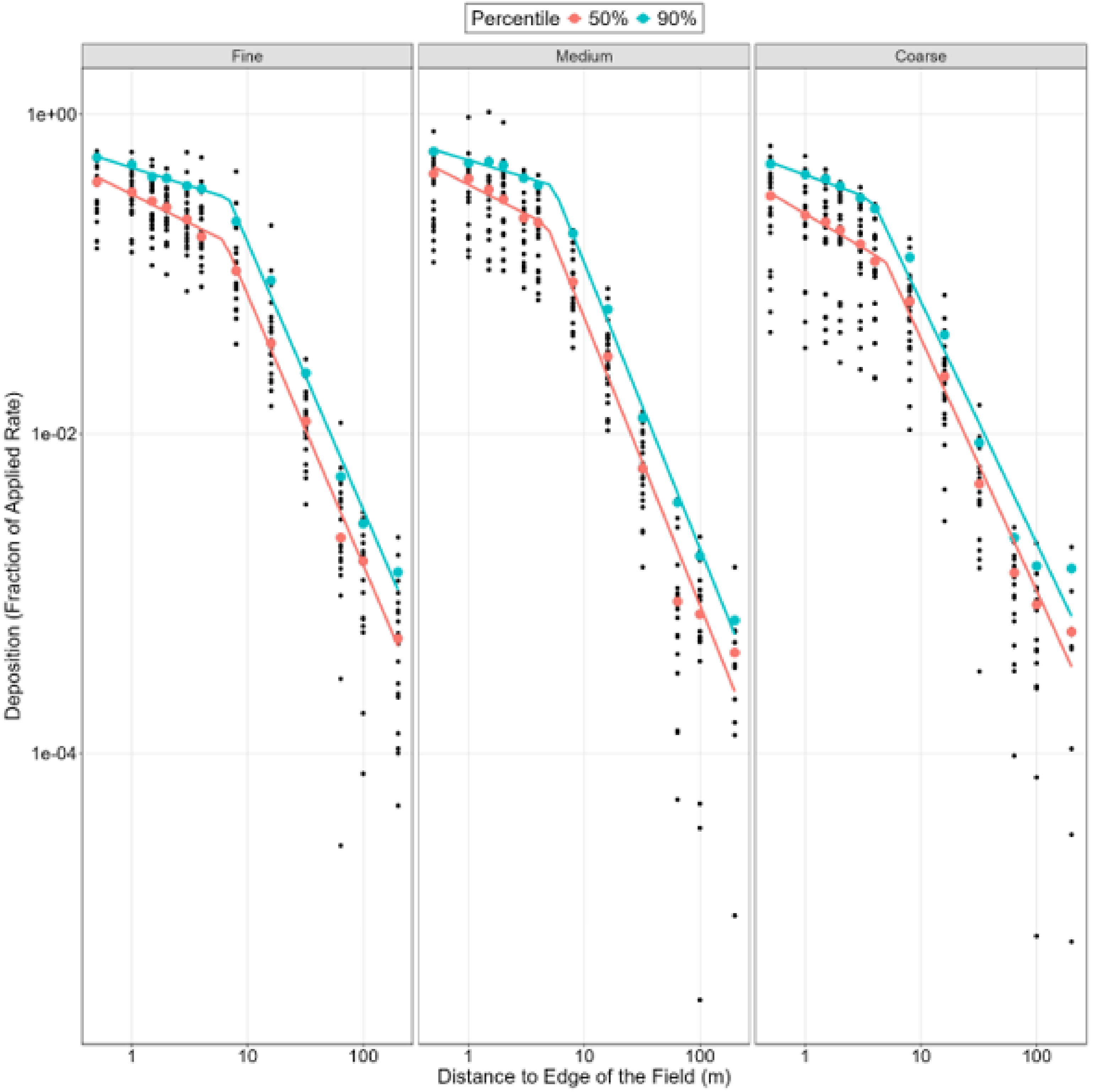
- Considerable improvement beyond 10 m
- High model performance maintained near field

R^2 ranged from 0.997 to 0.999

r index ranged from 0.996 to 0.999

Mean bias error was low for all models

Transition from slow to rapid decline (= join point) ranged from 3.8 m (coarse spray quality) to 6.9 m (fine spray quality)



Conclusions and Recommendations

Off-field downwind spray drift following UAV applications is generally higher than following ground applications

Consistent with previous studies by Bonds et al. (2024) and Goulet-Fortin et al. (2024)

Ground applications more closely achieve in-field target application rates than UAV applications

Segmented models provided best overall fit for downwind drift deposition

- Account for overspray beyond target EOF by incorporating a slow declining component near downwind edge of treated area
- These curves inherently address edge-of-field effects and do not require an EOF adjustment factor
- EOF adjustment factors calculated using the ESW methodology were not reliable, likely because they were originally developed for single-swath UAV applications
- Segmented models without an EOF adjustment factor are recommended as regulatory drift curves for UAV applications

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Thank you.

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